Modified Level II Streambed-Scour Analysis for Structure I-65-120-6016 Crossing Little Eagle Creek and I-65 in Marion County, Indiana

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

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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-65-120-6016, Georgetown Road crossing Little Eagle Creek and I-65 in Marion County, Indiana, are presented. The site is in the city of Indianapolis in the northwestern part of Marion 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 5.2 feet for the modeled discharge of 3,450 cubic feet per second and approximately 5.6 feet for the modeled discharge of 5,210 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-65-120-6016.

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 in the city of Indianapolis in the northwestern part of Marion County. The drainage area for the site is approximately 7.2 mi^2 (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is urban; in the immediate vicinity of the bridge, the land is also urban.

Within the immediate vicinity of the bridge, Little Eagle Creek has a channel-bed slope of approximately 0.0033 ft/ft. The channel-bed material is gravelly sandy silt-clay, and the channel banks consist of gravelly sandy silt-clay. At the time of the Level I site visit on June 17, 1994, the banks were observed to have 25 to 100 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Georgetown Road crossing of Little Eagle Creek and I-65 is a 474-ft-long, multi-lane bridge consisting of five spans supported by concrete and steel piers and sloping concrete 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, 1969) 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-65-120-6016 crossing Little Eagle Creek and I-65 in Marion 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 3,450 cubic feet per second							
1	48+54	775	0	5.2	5.2	762	750.6
2	49+70	770	0	5.2	5.2	766	750.6
3	50+85	767	0	5.2	5.2	760	750.6
4	51+98	759	0	5.2	5.2	752	750.6
Modeled discharge is 5,210 cubic feet per second							
1	48+54	775	0	5.6	5.6	762	750.2
2	49+70	770	0	5.6	5.6	766	750.2
3	50+85	767	0	5.6	5.6	760	750.2
4	51+98	759	0	5.6	5.6	752	750.2

[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, 48+54, represents a point 4,854 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 (755.8 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. The modeling was applied only to the main channel of Little Eagle Creek, and an imaginary abutment was placed at stationing 50+40. The only pier wetted in these model runs was the pier located at stationing 51+98. Therefore, scour was only calculated at this one pier, but the results were applied to all piers (see table 1). Roughness values were estimated from the 7.5-minute topographic map and slope was computed from the elevation data shown on the bridge plans.

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, 1969, Bridge plans Interstate Route 65: Bridge File I-65-120-6016.

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          Coffman Rd. over Little Eagle Creek and I-65 in Marion Co.
T2          County: Marion                          Indianapolis West 111C
T3          05-30-97                                Robert L. Miller
SI          0
Q           3450      5210
SK          .0033     .0033
XS   EXIT    0     40
GR         4939 774  4961 770  4970 765
GR        5007 764  5032 756  5047 755  5087 755  5104 760  5118 765  5128 770
GR         5139 773  5177 773  5238 774  5312 775  5752 775  6593 780
N             .050      .038      050
SA                  5007     5139
XS   FULLV   200 40
GR         4939 774  4961 770  4970 765
GR        5007 764  5032 756  5047 756  5087 756  5104 760  5118 765  5128 770
GR         5139 773  5177 773  5238 774  5312 775  5752 775  6593 780
N             .050      .038      050
SA                  5007     5139
BR   BRDGE  200      785     40
GR         5040 789.9
GR         5041 775.5  5058 773.8  5069 769.6  5075 767.9  5108 765.8
GR         5111 764.6  5136 756.1  5162 755.8  5187 756.0  5215 764.8
GR         5233 773.9  5238 773.8  5276 787.7  5280 787.5  5281 789.2
GR         5040 789.9
N             .050      .038
SA                  5111
PD 1        760    2  2
CD           3      37     2       788
DC   BRDGE     5115 5209 5223 5285 *  2
DP   BRDGE     5040 5281 2 * * 1.0  1.0   1.1
XS   APPR     437
GR           5094 773  5101 772  5113 771  5119 771  5129 772  5136 773
GR           5170 775  5181 774  5192 770  5194 769  5213 768
GR           5217 767  5232 760  5238 757 5253 756.6  5268 757  5279 760
GR           5288 765  5298 770 5309 775  5313 776  5595 780
N            .050   .038
SA               5201
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  3:33 pm      Version V050196
          Input File: 6016.dat        Output File: 6016.LST
   *-------------------------------------------------------------*
T1         COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
T2         COUNTY: MARION                          INDIANAPOLIS WEST 111C
T3         05-30-97                                ROBERT L. MILLER
SI         0
Q          3450     5210

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

SK         .0033    .0033

   ************************* W S P R O *****************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
     COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
     COUNTY: MARION                          INDIANAPOLIS WEST 111C
        05-30-97                               ROBERT L. MILLER

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

XS   EXIT   0    40
GR         4939 774  4961 770  4970 765
GR         5007 764  5032 756  5047 755  5087 755  5104 760  5118 765
5128 770
GR         5139 773  5177 773  5238 774  5312 775  5752 775  6593 780
N             .050     .038     050
SA                 5007    5139

 ***   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:  40.0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates (16 pairs)
     X          Y          X          Y          X          Y
----------  ----------  ----------  ----------  ----------  ----------
  4939.000    774.000    4961.000    770.000    4970.000    765.000
  5007.000    764.000    5032.000    756.000    5047.000    755.000
  5087.000    755.000    5104.000    760.000    5118.000    765.000
  5128.000    770.000    5139.000    773.000    5177.000    773.000
  5238.000    774.000    5312.000    775.000    5752.000    775.000
  6593.000    780.000
```

WSPRO OUTPUT

```
---------- ---------- ---------- ---------- ---------- ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    4939.000  ( associated Y-Elevation:  774.000 )
  Maximum X-Station:    6593.000  ( associated Y-Elevation:  780.000 )
  Minimum Y-Elevation:   755.000  ( associated X-Station:   5087.000 )
  Maximum Y-Elevation:   780.000  ( associated X-Station:   6593.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
  X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
---------- ----------   ---------- ----------   ---------- ----------
  4939.000    4973.625     4961.000    4990.479     4970.000    4997.373
  5007.000    5025.716     5032.000    5044.868     5047.000    5056.358
  5087.000    5087.000     5104.000    5100.023     5118.000    5110.748
  5128.000    5118.408     5139.000    5126.834     5177.000    5155.944
  5238.000    5202.673     5312.000    5259.360     5752.000    5596.419
  6593.000    6240.663
---------- ----------   ---------- ----------   ---------- ----------

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .050        ---
                                ---        5025.716
                      2         .038        ---
                                ---        5126.834
                      3        *****        ---
                   -------  -----------  ----------

          *-------------------------------------------------*
          *      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
   *-------------------------------------------------------------*
     COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
     COUNTY: MARION                        INDIANAPOLIS WEST 111C
        05-30-97                             ROBERT L. MILLER

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

   XS   FULLV   200 40
   GR         4939 774  4961 770  4970 765
   GR         5007 764  5032 756  5047 756  5087 756  5104 760  5118 765
5128 770
   GR         5139 773  5177 773  5238 774  5312 775  5752 775  6593 780
   N             .050      .038      050
   SA                   5007    5139
```

WSPRO OUTPUT

```
***   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:      200.   Cross-Section Skew:  40.0   Error Code    0
Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

X,Y-coordinates (16 pairs)

X	Y	X	Y	X	Y
4939.000	774.000	4961.000	770.000	4970.000	765.000
5007.000	764.000	5032.000	756.000	5047.000	756.000
5087.000	756.000	5104.000	760.000	5118.000	765.000
5128.000	770.000	5139.000	773.000	5177.000	773.000
5238.000	774.000	5312.000	775.000	5752.000	775.000
6593.000	780.000				

Minimum and Maximum X,Y-coordinates

Minimum X-Station:	4939.000	(associated Y-Elevation:	774.000)
Maximum X-Station:	6593.000	(associated Y-Elevation:	780.000)
Minimum Y-Elevation:	756.000	(associated X-Station:	5087.000)
Maximum Y-Elevation:	780.000	(associated X-Station:	6593.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
4939.000	4973.625	4961.000	4990.479	4970.000	4997.373
5007.000	5025.716	5032.000	5044.868	5047.000	5056.358
5087.000	5087.000	5104.000	5100.023	5118.000	5110.748
5128.000	5118.408	5139.000	5126.834	5177.000	5155.944
5238.000	5202.673	5312.000	5259.360	5752.000	5596.419
6593.000	6240.663				

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.050	---
	---	5025.716
2	.038	---
	---	5126.834
3	*****	---

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

************************* W S P R O ***************************
   Federal Highway Administration  -  U. S. Geological Survey
```

WSPRO OUTPUT

```
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
     COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
     COUNTY: MARION                        INDIANAPOLIS WEST 111C
        05-30-97                             ROBERT L. MILLER

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

BR   BRDGE  200     785    40
GR         5040 789.9
GR         5041 775.5  5058 773.8  5069 769.6  5075 767.9  5108 765.8
GR         5111 764.6  5136 756.1  5162 755.8  5187 756.0  5215 764.8
GR         5233 773.9  5238 773.8  5276 787.7  5280 787.5  5281 789.2
GR         5040 789.9
N              .050     .038
SA                 5111
PD 1        760   2  2
CD           3     37    2      788

 ***   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:      200.   Cross-Section Skew:  40.0   Error Code    0
 Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (17 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
  5040.000     789.900     5041.000     775.500     5058.000     773.800
  5069.000     769.600     5075.000     767.900     5108.000     765.800
  5111.000     764.600     5136.000     756.100     5162.000     755.800
  5187.000     756.000     5215.000     764.800     5233.000     773.900
  5238.000     773.800     5276.000     787.700     5280.000     787.500
  5281.000     789.200     5040.000     789.900
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    5040.000  ( associated Y-Elevation:  789.900 )
  Maximum X-Station:    5281.000  ( associated Y-Elevation:  789.200 )
  Minimum Y-Elevation:   755.800  ( associated X-Station:   5162.000 )
  Maximum Y-Elevation:   789.900  ( associated X-Station:   5040.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
  X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
----------  ----------   ----------  ----------   ----------  ----------
  5040.000    5068.542     5041.000    5069.309     5058.000    5082.332
  5069.000    5090.758     5075.000    5095.354     5108.000    5120.634
  5111.000    5122.932     5136.000    5142.083     5162.000    5162.000
  5187.000    5181.151     5215.000    5202.601     5233.000    5216.389
```

WSPRO OUTPUT

```
  5238.000    5220.219     5276.000    5249.329     5280.000    5252.393
  5281.000    5253.159     5040.000    5068.542
----------  ----------   ----------  ----------   ----------  ----------

                  Roughness Data (  2 SubAreas )
                           Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .050        ---
                                        5122.932
                   2         .038        ---
                -------  -----------  ----------

                  Discharge coefficient parameters
              BRType   BRWdth   EMBSS   EMBElv    UserCD
                3       37.000   2.00   788.000 **********

                     Pressure flow elevations
                        AVBCEL     PFElev
                     *********    785.000

                       Abutment Parameters
       ABSLPL  ABSLPR   XTOELT    YTOELT    XTOERT    YTOERT
     ******* ******* ********* ********* ********* *********


                  Pier/Pile Data (  1 Group(s) )
                 Code Indicates Bridge Uses Piles
               Group  Elevation  Gross Width  Number
              ------  ---------  -----------  ------
                 1      760.000      2.000       2
              ------  ---------  -----------  ------

        *-------------------------------------------------*
        *      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
   *-----------------------------------------------------------*
    COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
    COUNTY: MARION                      INDIANAPOLIS WEST 111C
       05-30-97                            ROBERT L. MILLER
DC   BRDGE    5115 5209 5223 5285 *  2
DP   BRDGE    5040 5281 2 * * 1.0  1.0   1.1

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

XS   APPR    437
GR          5094 773  5101 772  5113 771  5119 771  5129 772  5136 773
```

WSPRO OUTPUT

```
GR          5170 775  5181 774  5192 770  5194 769  5213 768
GR          5217 767  5232 760  5238 757 5253 756.6  5268 757  5279 760
GR          5288 765  5298 770 5309 775  5313 776  5595 780
N           .050   .038
SA              5201

 ***   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:      437.   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 (22 pairs)
    X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
  5094.000     773.000     5101.000     772.000     5113.000     771.000
  5119.000     771.000     5129.000     772.000     5136.000     773.000
  5170.000     775.000     5181.000     774.000     5192.000     770.000
  5194.000     769.000     5213.000     768.000     5217.000     767.000
  5232.000     760.000     5238.000     757.000     5253.000     756.600
  5268.000     757.000     5279.000     760.000     5288.000     765.000
  5298.000     770.000     5309.000     775.000     5313.000     776.000
  5595.000     780.000
----------  ----------   ----------  ----------   ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    5094.000  ( associated Y-Elevation:  773.000 )
  Maximum X-Station:    5595.000  ( associated Y-Elevation:  780.000 )
  Minimum Y-Elevation:   756.600  ( associated X-Station:   5253.000 )
  Maximum Y-Elevation:   780.000  ( associated X-Station:   5595.000 )

                  Roughness Data (  2 SubAreas )
                          Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .050        ---
                             ---       5201.000
                   2         .038        ---
                -------  -----------  ----------

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
    *-------------------------------------------------------------*
```

WSPRO OUTPUT

```
      COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
      COUNTY: MARION                          INDIANAPOLIS WEST 111C
         05-30-97                               ROBERT L. MILLER
  EX

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

             Reach       Water Surface   Friction
       #   Discharge       Elevation      Slope          Flow Regime
      --   ---------     ------------    --------   --------------------
       1     3450.00       ********        .0033        Sub-Critical
       2     5210.00       ********        .0033        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
      *-------------------------------------------------------------*
       COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
       COUNTY: MARION                          INDIANAPOLIS WEST 111C
          05-30-97                               ROBERT L. MILLER

                        WSEL     VHD        Q          AREA       SRDL       LEW
                        EGEL      HF        V            K         FLEN       REW
                        CRWS      HO       FR #         SF        ALPHA      ERR
                     --------- ------ ---------- ---------- --------- ---------
    Section: EXIT       761.946   .710  3450.000    510.690 *********  5013.417
    Header Type: XS     762.656 ******     6.756   60006.66 *********  5109.450
    SRD:       .000     759.734 ******      .516     ******     1.000     ******

    Section: FULLV      762.636   .679  3450.000    522.294   200.000  5011.264
    Header Type: FV     763.314   .654     6.605   60648.77   200.000  5111.380
    SRD:    200.000     760.452   .000      .510      .0033     1.000      .004

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

   ===125 FR# EXCEEDS FNTEST AT SECID "APPR ":  TRIALS CONTINUED.
          FNTEST, FR#, WSEL, CRWS:   .80     .91     763.34     762.99

   ===110 WSEL NOT FOUND AT SECID "APPR ":  REDUCED DELTAY.
          WSLIM1, WSLIM2, DELTAY:   762.99     780.00     .50

   ===115 WSEL NOT FOUND AT SECID "APPR ":  USED WSMIN = CRWS.
          WSLIM1, WSLIM2, CRWS:   762.99     780.00     762.99

   ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
```

WSPRO OUTPUT

```
      KRATIO:    .55

Section: APPR      763.344  2.047   3450.000    300.717   237.000  5224.834
Header Type: AS    765.391  1.394     11.473   33368.17   237.000  5285.020
SRD:    437.000    762.991   .684       .905      .0059     1.000     -.001

       <<< 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     762.948   .729   3450.000    503.897   200.000  5115.859
Header Type: BR    763.677  1.019      6.847   59744.12   200.000  5209.107
SRD:    200.000    760.671   .000       .519     ******     1.000     -.005

Specific Bridge Information   C      P/A    PFELEV    BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  1           1.0000  .012  785.000 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                    WSEL     VHD       Q          AREA      SRDL      LEW
                    EGEL      HF       V           K        FLEN      REW
                    CRWS      HO     FR #          SF       ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: APPR      763.887  1.660   3450.000    333.969   200.000  5223.671
Header Type: AS    765.547  1.571     10.330   38761.66   200.000  5285.997
SRD:    437.000    762.991   .290       .787      .0059     1.000     -.015

          Approach Section APPR  Flow Contraction Information
           M( G )    M( K )      KQ        XLKQ      XRKQ      OTEL
          -------- -------- --------- -------- -------- --------
              .000     .000   38921.0 5208.419 5301.698  763.887
          -------- -------- --------- -------- -------- --------

             <<< 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
   *-----------------------------------------------------------------*
     COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
     COUNTY: MARION                        INDIANAPOLIS WEST 111C
        05-30-97                              ROBERT L. MILLER

                    WSEL     VHD       Q          AREA      SRDL      LEW
                    EGEL      HF       V           K        FLEN      REW
                    CRWS      HO     FR #          SF       ALPHA     ERR
```

WSPRO OUTPUT

```
                  --------- ------ ---------- ---------- --------- ---------
 Section: EXIT      763.637   .909   5210.000    681.562 *********  5008.133
 Header Type: XS    764.546 ******      7.644   90667.70 *********  5114.185
 SRD:       .000    761.023 ******       .532     ******     1.000     ******

 Section: FULLV     764.349   .855   5210.000    704.546   200.000  4994.098
 Header Type: FV    765.204   .640      7.395   93608.65   200.000  5116.176
 SRD:    200.000    761.694   .000       .544      .0032     1.006      .018

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

===125 FR# EXCEEDS FNTEST AT SECID "APPR ":  TRIALS CONTINUED.
       FNTEST, FR#, WSEL, CRWS:   .80     .96     764.81     764.61

===110 WSEL NOT FOUND AT SECID "APPR ":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   764.61     780.00     .50

===115 WSEL NOT FOUND AT SECID "APPR ":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   764.61     780.00     764.61

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
       KRATIO:   .52

 Section: APPR      764.816  2.725   5210.000    393.560   237.000  5221.681
 Header Type: AS    767.541  1.405     13.238   48930.52   237.000  5287.668
 SRD:    437.000    764.615   .935       .956      .0059     1.000     -.002

        <<< 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     764.700   .922   5210.000    676.641   200.000  5110.751
 Header Type: BR    765.622  1.077      7.700   90809.19   200.000  5214.681
 SRD:    200.000    762.027   .000       .532     ******     1.000      .006

 Specific Bridge Information   C      P/A   PFELEV    BLEN     XLAB     XRAB
 Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
 Pier/Pile Code  1           1.0000  .014  785.000 ******** ******** ********
 ------------------------- ------ ----- -------- -------- -------- --------

                    WSEL    VHD       Q         AREA      SRDL      LEW
                    EGEL     HF       V           K       FLEN      REW
                    CRWS     HO     FR #         SF      ALPHA     ERR
                  --------- ------ ---------- ---------- --------- ---------
 Section: APPR      765.387  2.263   5210.000    431.920   200.000  5220.456
 Header Type: AS    767.650  1.757     12.062   55753.34   200.000  5288.774
 SRD:    437.000    764.615   .279       .846      .0059     1.000      .014
```

WSPRO OUTPUT

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.000	.000	55586.8	5203.419	5307.313	765.387

<<< 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

COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
COUNTY: MARION INDIANAPOLIS WEST 111C
05-30-97 ROBERT L. 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): 2.000

#	Scour Depth	Flow Contract	Flow Approach	Width Contract	Width Approach	X-Limits Side	X-Limits Contract	X-Limits Approach
1	-1.201	3450.000	3450.000	92.000	62.000	Left:	5115.000	5223.000
	..... Approach Channel Depth:		5.382			Right:	5209.000	5285.000
*	Negative Scour Depth Encountered - Check If Variables Are Reasonable							*
2	-1.536	5210.000	5210.000	92.000	62.000	Left:	5115.000	5223.000
	..... Approach Channel Depth:		6.881			Right:	5209.000	5285.000
*	Negative Scour Depth Encountered - Check If Variables Are Reasonable							*

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

COFFMAN RD. OVER LITTLE EAGLE CREEK AND I-65 IN MARION CO.
COUNTY: MARION INDIANAPOLIS WEST 111C
05-30-97 ROBERT L. MILLER

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

Constants and Input Variables

Pier Width: 2.000

WSPRO OUTPUT

```
                  Pier Shape Factor            (K1):   1.00
                  Flow Angle of Attack Factor  (K2):   1.00
                  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	5.15	3450.000	763.238	7.438	7.652	.494	5040.000	5281.000
2	5.62	5210.000	764.979	9.179	8.778	.511	5040.000	5281.000

```
  ER

   ****************** Normal end of WSPRO execution. ******************
   *************** Elapsed Time:   0 Minutes  3 Seconds ***************
```