Modified Level II Streambed-Scour Analysis for Structure I-74-36-4949 Crossing Little Sugar Creek in Montgomery County, Indiana

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

Prepared in cooperation with the
INDIANA DEPARTMENT OF TRANSPORTATION

U.S. GEOLOGICAL SURVEY
Open-File Report 97-325

Indianapolis, Indiana
1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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Tables

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

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-74-36-4949 on Interstate 74 crossing Little Sugar Creek in Montgomery County, Indiana, are presented. The site is near the town of Smartsburg in the east-central part of Montgomery 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 5.1 feet for the modeled discharge of 6,100 cubic feet per second and approximately 5.8 feet for the modeled discharge of 10,400 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-74-36-4949.

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 Smartsburg in the east-central part of Montgomery County. The drainage area for the site is approximately 40.2 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 with some agricultural land nearby.

Within the immediate vicinity of the bridge, Little Sugar Creek has a channel-bed slope of approximately 0.0021 ft/ft. The channel-bed material is sand, and the channel banks consist of silt-clay. At the time of the Level I site visit on June 25, 1991, the banks were observed to have 0 to 60 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 74 crossing of Little Sugar Creek is a 135-ft-long, multi-lane bridge consisting of three spans supported by concrete and steel piers and sloping 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, 1961) 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-74-36-4949 crossing Little Sugar Creek in Montgomery County, Indiana

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 6,100 cubic feet per second							
1	104+29	763.5	0.2	4.9	5.1	758.2	758.4
2	104+74	763.5	.2	4.9	5.1	758.0	758.4
Modeled discharge is 10,400 cubic feet per second							
1	104+29	763.5	0.2	5.6	5.8	758.2	757.7
2	104+74	763.5	.2	5.6	5.8	758.0	757.7

[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, 104+29, represents a point 10,429 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 (763.5 feet).

[5]Not a 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, 1961, Bridge plans Interstate Route 74: Bridge File I-74-36-4949.

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-74 over Little Sugar Creek                    I-74-36-4949
T2        County: Montgomery                              Quad: Darlington
T3        07-24-97                                        D. C. Voelker
SI        0
Q         6100      10400
SK        .0021     .0021
XS   EXIT   0   0
GR        9448 790  9769 790  10000 780  10305 771  10407 770  10467 769.6
GR        10483 763.5  10549 763.5  10562 769.1  10580 769  10610 768
GR        10733 768  10805 769  10809 770  10823 775  10839 780  10855 785
GR        10861 787  11382 790
N            1.0     .034     1.0
SA               10467   10562
XS   FULLV  135  0
GR        9448 790  9769 790  10000 780  10305 771  10407 770  10467 769.6
GR        10483 763.5  10549 763.5  10562 769.1  10580 769  10610 768
GR        10733 768  10805 769  10809 770  10823 775  10839 780  10855 785
GR        10861 787  10932 770  11146 780  11382 790
N            1.0     .034     1.0
SA               10467   10562
BR   BRDGE 135 778.0  0
GR       10380 0778.5  10380 0776.0  10406 0763.5  10497 0763.5  10522 0775.3
GR        10522 0778.0  10380 0778.5
N         .035
PD        763.5  4   2
CD        3   135   2 775
DC 0 BRDGE 10406 10497  10343  10437
DP        10380  10522 2 * * 1.0 1.0 1.1
DP        10380  10522 2 * * 1.0 1.0 1.1
XS   APPR  388   0
GR        9526 800  9900 780  10316 772  10343 771.6  10359 763.5  10426 763.5
GR        10437 768  10486 768  10623 769  10770 770  10775 772  10780 773
GR        10787 776  10802 777  10807 780  10818 785  10822 787
GR        10851 790  11096 790
N            1.0     .034   1.0
SA               10343   10437
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/ 6/97  0:41 pm     Version V050196
          Input File: 4949.dat       Output File: 4949.LST
   *-------------------------------------------------------------*
T1         I-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
T2         COUNTY: MONTGOMERY                        QUAD: DARLINGTON
T3         07-24-97                                  D. C. VOELKER
SI         0
Q          6100     10400

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

SK         .0021    .0021

   ************************  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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
     COUNTY: MONTGOMERY                        QUAD: DARLINGTON
      07-24-97                                  D. C. VOELKER

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

XS   EXIT   0   0
GR         9448 790  9769 790  10000 780  10305 771  10407 770  10467 769.6
GR         10483 763.5  10549 763.5  10562 769.1  10580 769  10610 768
GR         10733 768  10805 769  10809 770  10823 775  10839 780  10855 785
GR         10861 787  11382 790
N             1.0    .034    1.0
SA                10467   10562

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

                    X,Y-coordinates (19 pairs)
     X          Y          X          Y          X          Y
----------  ----------  ----------  ----------  ----------  ----------
  9448.000    790.000     9769.000    790.000    10000.000    780.000
 10305.000    771.000    10407.000    770.000    10467.000    769.600
 10483.000    763.500    10549.000    763.500    10562.000    769.100
 10580.000    769.000    10610.000    768.000    10733.000    768.000
 10805.000    769.000    10809.000    770.000    10823.000    775.000
```

WSPRO OUTPUT

```
 10839.000     780.000    10855.000     785.000    10861.000     787.000
 11382.000     790.000
---------- ---------- ---------- ---------- ---------- ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:    9448.000  ( associated Y-Elevation:  790.000 )
  Maximum X-Station:   11382.000  ( associated Y-Elevation:  790.000 )
  Minimum Y-Elevation:   763.500  ( associated X-Station:  10549.000 )
  Maximum Y-Elevation:   790.000  ( associated X-Station:   9448.000 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1        1.000        ---
                                ---       ********
                     2         .034        ---
                                ---       ********
                     3        1.000        ---
                  -------  -----------  ----------

         *-----------------------------------------------------*
         *      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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
     COUNTY: MONTGOMERY                       QUAD: DARLINGTON
      07-24-97                                 D. C. VOELKER

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

XS   FULLV  135  0
GR        9448 790  9769 790  10000 780  10305 771  10407 770  10467 769.6
GR        10483 763.5  10549 763.5  10562 769.1  10580 769  10610 768
GR        10733 768  10805 769  10809 770  10823 775  10839 780  10855 785
GR        10861 787  10932 770  11146 780  11382 790
N            1.0    .034    1.0
SA                10467   10562

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

WSPRO OUTPUT

X,Y-coordinates (21 pairs)

X	Y	X	Y	X	Y
9448.000	790.000	9769.000	790.000	10000.000	780.000
10305.000	771.000	10407.000	770.000	10467.000	769.600
10483.000	763.500	10549.000	763.500	10562.000	769.100
10580.000	769.000	10610.000	768.000	10733.000	768.000
10805.000	769.000	10809.000	770.000	10823.000	775.000
10839.000	780.000	10855.000	785.000	10861.000	787.000
10932.000	770.000	11146.000	780.000	11382.000	790.000

Minimum and Maximum X,Y-coordinates

```
Minimum X-Station:    9448.000  ( associated Y-Elevation:  790.000 )
Maximum X-Station:   11382.000  ( associated Y-Elevation:  790.000 )
Minimum Y-Elevation:   763.500  ( associated X-Station:  10549.000 )
Maximum Y-Elevation:   790.000  ( associated X-Station:   9448.000 )
```

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	1.000	---
	---	********
2	.034	---
	---	********
3	1.000	---

```
        *-----------------------------------------------------*
        *      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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
     COUNTY: MONTGOMERY                       QUAD: DARLINGTON
      07-24-97                                 D. C. VOELKER

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

  BR   BRDGE 135 778.0  0
  GR        10380 0778.5  10380 0776.0  10406 0763.5  10497 0763.5  10522
0775.3
  GR        10522 0778.0  10380 0778.5
  N         .035
  PD        763.5  4   2
  CD        3   135   2 775
```

WSPRO OUTPUT

```
   ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate # 6 increased to eliminate vertical segment.
   ***   Storing Bridge Data In Temporary File As Record Number  3    ***

   ***              Data Summary For Bridge Record BRDGE              ***
   SRD Location:      135.   Cross-Section Skew:    .0   Error Code   0
   Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                     X,Y-coordinates ( 7 pairs)
      X          Y            X          Y            X          Y
 ----------  ----------   ----------  ----------   ----------  ----------
  10380.000     778.500    10380.100     776.000    10406.000     763.500
  10497.000     763.500    10522.000     775.300    10522.100     778.000
  10380.000     778.500
 ----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   10380.000  ( associated Y-Elevation:  778.500 )
  Maximum X-Station:   10522.100  ( associated Y-Elevation:  778.000 )
  Minimum Y-Elevation:   763.500  ( associated X-Station:  10497.000 )
  Maximum Y-Elevation:   778.500  ( associated X-Station:  10380.000 )

                    Roughness Data (  1 SubAreas )
                             Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .035        ---
                   -------  -----------  ----------

                    Discharge coefficient parameters
                 BRType   BRWdth    EMBSS    EMBElv    UserCD
                   3      135.000    2.00    775.000 **********

                        Pressure flow elevations
                           AVBCEL      PFElev
                         *********     778.000

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


                    Pier/Pile Data (  1 Group(s) )
                  Code Indicates Bridge Uses Piers
                  Group  Elevation  Gross Width  Number
                  ------  ---------  -----------  ------
                    1      763.500      4.000       2
                  ------  ---------  -----------  ------

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

WSPRO OUTPUT

```
   ************************* 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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
     COUNTY: MONTGOMERY                        QUAD: DARLINGTON
      07-24-97                                  D. C. VOELKER
  DC 0 BRDGE 10406 10497  10343  10437
  DP        10380  10522 2 * * 1.0 1.0 1.1
  DP        10380  10522 2 * * 1.0 1.0 1.1

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

  XS   APPR  388   0
  GR        9526 800  9900 780  10316 772  10343 771.6  10359 763.5  10426
763.5
  GR        10437 768  10486 768  10623 769  10770 770  10775 772  10780 773
  GR        10787 776  10802 777  10807 780  10818 785  10822 787
  GR        10851 790  11096 790
  N            1.0     .034   1.0
  SA               10343   10437

   ***   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:      388.   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 (19 pairs)
      X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
  9526.000     800.000     9900.000     780.000    10316.000     772.000
 10343.000     771.600    10359.000     763.500    10426.000     763.500
 10437.000     768.000    10486.000     768.000    10623.000     769.000
 10770.000     770.000    10775.000     772.000    10780.000     773.000
 10787.000     776.000    10802.000     777.000    10807.000     780.000
 10818.000     785.000    10822.000     787.000    10851.000     790.000
 11096.000     790.000
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
   Minimum X-Station:    9526.000  ( associated Y-Elevation:  800.000 )
   Maximum X-Station:   11096.000  ( associated Y-Elevation:  790.000 )
   Minimum Y-Elevation:   763.500  ( associated X-Station:  10426.000 )
   Maximum Y-Elevation:   800.000  ( associated X-Station:   9526.000 )

                    Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
```

WSPRO OUTPUT

```
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1        1.000        ---
                              ---        ********
                     2         .034        ---
                              ---        ********
                     3        1.000        ---
                  -------  -----------  ----------

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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
      COUNTY: MONTGOMERY                        QUAD: DARLINGTON
       07-24-97                                  D. C. VOELKER
 EX

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

           Reach      Water Surface   Friction
     #   Discharge      Elevation      Slope         Flow Regime
    --   ---------    -------------   --------   --------------------
     1     6100.00      ********        .0021        Sub-Critical
     2    10400.00      ********        .0021        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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
      COUNTY: MONTGOMERY                        QUAD: DARLINGTON
       07-24-97                                  D. C. VOELKER

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

WSPRO OUTPUT

Section: EXIT	772.315	.923	6100.000	2115.145	*********	10260.430
Header Type: XS	773.238	******	2.884	133053.80	*********	10815.480
SRD: .000	769.506	******	.696	******	7.133	******
Section: FULLV	772.656	.842	6100.000	2396.601	135.000	10248.880
Header Type: FV	773.498	.264	2.545	143079.40	135.000	10988.840
SRD: 135.000	769.506	.000	.668	.0020	8.357	-.004

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

Section: APPR	773.161	.772	6100.000	2334.171	253.000	10255.620
Header Type: AS	773.933	.427	2.613	154162.10	253.000	10780.380
SRD: 388.000	769.463	.000	.589	.0017	7.265	.008

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

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

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDGE	772.958	.535	6100.000	1048.058	135.000	10386.400
Header Type: BR	773.492	.255	5.820	174536.40	135.000	10517.040
SRD: 135.000	768.623	.000	.365	******	1.015	.006

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.9926	.036	778.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	773.120	.780	6100.000	2312.818	118.000	10257.740
Header Type: AS	773.900	.223	2.637	152909.30	135.932	10780.280
SRD: 388.000	769.463	.183	.593	.0017	7.207	-.004

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.753	.033	147999.0	********	********	773.120

<<< End of Bridge Hydraulics Computations >>>

********** W S P R O **********
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.

WSPRO OUTPUT

Input Units: English / Output Units: English

I-74 OVER LITTLE SUGAR CREEK I-74-36-4949
COUNTY: MONTGOMERY QUAD: DARLINGTON
07-24-97 D. C. VOELKER

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	775.147	1.355	10400.000	3833.807	********	10164.470
Header Type: XS	776.502	******	2.713	226788.50	********	10823.470
SRD: .000	771.650	******	.682	******	*****	******
Section: FULLV	775.526	1.248	10400.000	4476.767	135.000	10151.630
Header Type: FV	776.774	.267	2.323	241302.10	135.000	11050.250
SRD: 135.000	771.650	.000	.674	.0020	*****	.005

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

Section: APPR	776.031	1.189	10400.000	4063.949	253.000	10106.390
Header Type: AS	777.220	.448	2.559	253264.40	253.000	10787.460
SRD: 388.000	771.746	.000	.631	.0018	*****	-.002

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

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

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDGE	775.949	.820	10400.000	1457.172	135.000	10380.210
Header Type: BR	776.769	.268	7.137	284285.80	135.000	10522.020
SRD: 135.000	770.675	.000	.399	******	1.035	.010

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.9832	.034	778.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	776.008	1.194	10400.000	4048.315	118.000	10107.580
Header Type: AS	777.202	.236	2.569	252394.30	132.316	10787.120
SRD: 388.000	771.746	.194	.633	.0018	*****	-.006

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL

WSPRO OUTPUT

```
          .793     .051  239796.0 ******** ********  776.008
        -------- -------- --------- -------- --------  --------

              <<< 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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
       COUNTY: MONTGOMERY                        QUAD: DARLINGTON
        07-24-97                                  D. C. VOELKER

  ***  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):  4.000
                  *-----------------------------------------------*

     Scour      -- Flow --          -- Width --         --- X-Limits ---
 #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
--   ------ --------- --------- -------- --------  ------ -------- --------
 1    .221  5711.367  5877.314   87.000   94.000  Left:  ******** ********
    ..... Approach Channel Depth:    8.668 .....  Right: ******** ********
 2    .215  9451.665  9803.486   87.000   94.000  Left:  ******** ********
    ..... Approach Channel Depth:   11.555 .....  Right: ******** ********
--   ------ --------- --------- -------- --------  ------ -------- --------

     ************************* 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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
       COUNTY: MONTGOMERY                        QUAD: DARLINGTON
        07-24-97                                  D. C. VOELKER

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

                        Constants and Input Variables

                             Pier Width:   2.000
                  *-----------------------------------------*
                    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
```

WSPRO OUTPUT

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

     Scour    ---- Localized Hydraulic Properties ----      -- X-Stations --
 #   Depth     Flow       WSE     Depth  Velocity Froude #   Left       Right
--   ----- ---------- -------- ------ -------- -------- --------- ---------
 1    4.93   6100.000  773.140  9.640    6.384     .362  10380.000 10522.000
 2    5.63  10400.000  776.143 12.643    7.973     .395  10380.000 10522.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------


     ************************  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-74 OVER LITTLE SUGAR CREEK              I-74-36-4949
      COUNTY: MONTGOMERY                        QUAD: DARLINGTON
       07-24-97                                  D. C. VOELKER

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

                      Constants and Input Variables

                          Pier Width:   2.000
                    *-----------------------------------------*
                      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    ---- Localized Hydraulic Properties ----      -- X-Stations --
 #   Depth     Flow       WSE     Depth  Velocity Froude #   Left       Right
--   ----- ---------- -------- ------ -------- -------- --------- ---------
 1    4.93   6100.000  773.140  9.640    6.384     .362  10380.000 10522.000
 2    5.63  10400.000  776.143 12.643    7.973     .395  10380.000 10522.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------

  ER

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