Modified Level II Streambed-Scour Analysis for Structure I-70-104-5128 Crossing Brandywine Creek in Hancock County, Indiana

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

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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

Modified Level II Streambed-Scour Analysis for Structure I-70-104-5128 Crossing Brandywine Creek in Hancock County, Indiana

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-70-104-5128 on Interstate 70 crossing Brandywine Creek in Hancock County, Indiana, are presented. The site is near the town of Greenfield in the central part of Hancock 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 6.5 feet for the modeled discharge of 6,900 cubic feet per second and approximately 8.0 feet for the modeled discharge of 9,140 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-70-104-5128.

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 Greenfield in the central part of Hancock County. The drainage area for the site is approximately 33.8 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 pasture land nearby.

Within the immediate vicinity of the bridge, Brandywine Creek has a channel-bed slope of approximately 0.000694 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 August 4, 1994, the banks were observed to have 0 to 50 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 70 crossing of Brandywine Creek is a 150-ft-long, multi-lane bridge consisting of three 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, 1988) 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 USGS 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-70-104-5128 crossing Brandywine Creek in Hancock 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 6,900 cubic feet per second							
1	813+08	866	1.1	5.4	6.5	861.5	859.7
2	813+70	866	1.1	5.4	6.5	861.5	859.7
Modeled discharge is 9,140 cubic feet per second							
1	813+08	866	2.0	6.0	8.0	861.5	858.2
2	813+70	866	2.0	6.0	8.0	861.5	858.2

[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, 813+08, represents a point 81,308 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 (866.2 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, 1988, Bridge plans Interstate Route 70: Bridge File I-70-104-5128.

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-70 OVER BRANDYWINE CREEK IN HANCOCK Co.   I70-104-5128
T2          County: Hancock                            Quad: Greenfield 112D
T3          10-18-96                                   Robert Miller
SI          0
Q            6900  9140
SK            .000694    .000694
XS   EXIT    0    25
GR         80807 900  80991 888  81107 880  81195 872  81366 872  81386 871
GR         81391 868  81399 867  81403 867  81418 868  81423 869  81435 870
GR         81470 871  81611 871  82775 880  82895 890  82979 900
N               .035       .032      .035
SA                    81366      81418
XS   FULLV  152   25
GR         80807 900  80991 888  81107 880  81195 872  81366 872  81386 871
GR         81391 868  81399 867  81403 867  81418 868  81423 869  81435 870
GR         81470 871  81611 871  82775 880  82895 890  82979 900
N               .035       .032      .035
SA                    81366      81418
BR   BRDGE  152      877       25
GR         81267 877.9  81302 865.1  81337 864.5  81377 864.7  81406 876.6
GR         81390 876.5  81375 876.1  81367 875.5  81358 876.5  81340 877.4
GR         81323 877.2  81312 876.5  81294 876.8  81278 877.4  81267 877.9
N               .030
PD           865   4  1
CD           3       184   2      876
DC   BRDGE     81275  81402 81285  81360  *  4
DP   BRDGE     81267  81406 2 * * 1.0 1.0 1.1
DP   BRDGE     81267  81406 2 * * 1.0 1.0 1.1
XS   APPR   488
GR         80826 900  80899 890  80966 880  81056 875  81104 874  81153 873
GR         81290 872  81309 871  81311 870  81314 869  81321 868  81325 866
GR         81340 866  81346 867  81358 870  81377 870  81393 871  81515 871
GR         81881 880  82200 880  82484 890  82616 890  82715 900
N               .100     .032    .100
SA                    81285  81360
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  3:51 pm     Version V050196
          Input File: 5128.dat       Output File: 5128.LST
   *-------------------------------------------------------------*
T1          I-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
T2          COUNTY: HANCOCK                            QUAD: GREENFIELD 112D
T3          10-18-96                                   ROBERT MILLER
SI          0
Q            6900  9140

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

SK             .000694    .000694

   ************************* 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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
  COUNTY: HANCOCK                              QUAD: GREENFIELD 112D
     10-18-96                                     ROBERT MILLER

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

XS   EXIT   0    25
GR        80807 900  80991 888  81107 880  81195 872  81366 872  81386 871
GR        81391 868  81399 867  81403 867  81418 868  81423 869  81435 870
GR        81470 871  81611 871  82775 880  82895 890  82979 900
N              .035       .032      .035
SA                   81366      81418

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

                     X,Y-coordinates (17 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 80807.000     900.000    80991.000     888.000    81107.000     880.000
 81195.000     872.000    81366.000     872.000    81386.000     871.000
 81391.000     868.000    81399.000     867.000    81403.000     867.000
 81418.000     868.000    81423.000     869.000    81435.000     870.000
 81470.000     871.000    81611.000     871.000    82775.000     880.000
 82895.000     890.000    82979.000     900.000
----------  ----------   ----------  ----------   ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   80807.000  ( associated Y-Elevation:  900.000 )
  Maximum X-Station:   82979.000  ( associated Y-Elevation:  900.000 )
  Minimum Y-Elevation:   867.000  ( associated X-Station:  81403.000 )
  Maximum Y-Elevation:   900.000  ( associated X-Station:  80807.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
  X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
----------  ----------   ----------  ----------   ----------  ----------
 80807.000   80862.840    80991.000   81029.600    81107.000   81134.730
 81195.000   81214.480    81366.000   81369.470    81386.000   81387.590
 81391.000   81392.130    81399.000   81399.380    81403.000   81403.000
 81418.000   81416.590    81423.000   81421.130    81435.000   81432.000
 81470.000   81463.720    81611.000   81591.520    82775.000   82646.450
 82895.000   82755.210    82979.000   82831.340
----------  ----------   ----------  ----------   ----------  ----------

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .035        ---
                                ---       ********
                      2         .032        ---
                                ---       ********
                      3         .035        ---
                   -------  -----------  ----------

          *-------------------------------------------------*
          *      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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
  COUNTY: HANCOCK                              QUAD: GREENFIELD 112D
      10-18-96                                     ROBERT MILLER

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

XS   FULLV  152   25
GR        80807 900  80991 888  81107 880  81195 872  81366 872  81386 871
GR        81391 868  81399 867  81403 867  81418 868  81423 869  81435 870
GR        81470 871  81611 871  82775 880  82895 890  82979 900
N              .035       .032       .035
SA                    81366      81418

 ***   Completed Reading Data Associated With Header Record FULLV   ***
```

WSPRO OUTPUT

```
***  Storing X-Section Data In Temporary File As Record Number  2  ***

***                Data Summary For Header Record FULLV                ***
SRD Location:      152.   Cross-Section Skew:  25.0   Error Code   0
Valley Slope:    .00000    Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients ->   Expansion:    .50   Contraction:    .00

                    X,Y-coordinates (17 pairs)
    X          Y            X          Y            X          Y
---------- ---------- ---------- ---------- ---------- ----------
 80807.000    900.000   80991.000    888.000   81107.000    880.000
 81195.000    872.000   81366.000    872.000   81386.000    871.000
 81391.000    868.000   81399.000    867.000   81403.000    867.000
 81418.000    868.000   81423.000    869.000   81435.000    870.000
 81470.000    871.000   81611.000    871.000   82775.000    880.000
 82895.000    890.000   82979.000    900.000
---------- ---------- ---------- ---------- ---------- ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   80807.000  ( associated Y-Elevation:  900.000 )
  Maximum X-Station:   82979.000  ( associated Y-Elevation:  900.000 )
  Minimum Y-Elevation:   867.000  ( associated X-Station:  81403.000 )
  Maximum Y-Elevation:   900.000  ( associated X-Station:  80807.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
  X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
---------- ---------- ---------- ---------- ---------- ----------
 80807.000  80862.840   80991.000  81029.600   81107.000  81134.730
 81195.000  81214.480   81366.000  81369.470   81386.000  81387.590
 81391.000  81392.130   81399.000  81399.380   81403.000  81403.000
 81418.000  81416.590   81423.000  81421.130   81435.000  81432.000
 81470.000  81463.720   81611.000  81591.520   82775.000  82646.450
 82895.000  82755.210   82979.000  82831.340
---------- ---------- ---------- ---------- ---------- ----------

                  Roughness Data (  3 SubAreas )
                         Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .035        ---
                                       ********
                   2         .032        ---
                                       ********
                   3         .035        ---
                -------  -----------  ----------

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

WSPRO OUTPUT

```
   *-------------------------------------------------------------*
     I-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
  COUNTY: HANCOCK                              QUAD: GREENFIELD 112D
     10-18-96                                     ROBERT MILLER

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

BR   BRDGE  152      877       25
GR         81267 877.9  81302 865.1  81337 864.5  81377 864.7  81406 876.6
GR         81390 876.5  81375 876.1  81367 875.5  81358 876.5  81340 877.4
GR         81323 877.2  81312 876.5  81294 876.8  81278 877.4  81267 877.9
N               .030
PD            865   4  1
CD            3      184   2      876

 ***   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:      152.   Cross-Section Skew:  25.0   Error Code   0
 Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (15 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 81267.000     877.900    81302.000     865.100    81337.000     864.500
 81377.000     864.700    81406.000     876.600    81390.000     876.500
 81375.000     876.100    81367.000     875.500    81358.000     876.500
 81340.000     877.400    81323.000     877.200    81312.000     876.500
 81294.000     876.800    81278.000     877.400    81267.000     877.900
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   81267.000  ( associated Y-Elevation:  877.900 )
  Maximum X-Station:   81406.000  ( associated Y-Elevation:  876.600 )
  Minimum Y-Elevation:   864.500  ( associated X-Station:  81337.000 )
  Maximum Y-Elevation:   877.900  ( associated X-Station:  81267.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
  X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
----------  ----------   ----------  ----------   ----------  ----------
 81267.000   81273.550    81302.000   81305.280    81337.000   81337.000
 81377.000   81373.250    81406.000   81399.540    81390.000   81385.030
 81375.000   81371.440    81367.000   81364.190    81358.000   81356.030
 81340.000   81339.720    81323.000   81324.310    81312.000   81314.340
 81294.000   81298.030    81278.000   81283.530    81267.000   81273.550
----------  ----------   ----------  ----------   ----------  ----------

                  Roughness Data (  1 SubAreas )
                         Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
```

WSPRO OUTPUT

```
-------  ----------  ----------
   1         .030        ---
-------  ----------  ----------

      Discharge coefficient parameters
BRType   BRWdth   EMBSS   EMBElv    UserCD
  3      184.000   2.00   876.000 **********

      Pressure flow elevations
        AVBCEL     PFElev
      *********    877.000

        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      865.000      4.000       1
------  ---------  -----------  ------

 *--------------------------------------------------*
 *      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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
 COUNTY: HANCOCK                          QUAD: GREENFIELD 112D
   10-18-96                                   ROBERT MILLER
DC   BRDGE    81275  81402 81285  81360  *  4
DP   BRDGE    81267  81406 2 * * 1.0 1.0 1.1
DP   BRDGE    81267  81406 2 * * 1.0 1.0 1.1

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

XS   APPR   488
GR        80826 900  80899 890  80966 880  81056 875  81104 874  81153 873
GR        81290 872  81309 871  81311 870  81314 869  81321 868  81325 866
GR        81340 866  81346 867  81358 870  81377 870  81393 871  81515 871
GR        81881 880  82200 880  82484 890  82616 890  82715 900
N             .100    .032   .100
SA                  81285  81360

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

WSPRO OUTPUT

```
***              Data Summary For Header Record APPR                ***
SRD Location:      488.   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 (23 pairs)
    X          Y             X          Y             X          Y
----------  ----------    ----------  ----------    ----------  ----------
80826.000     900.000     80899.000     890.000     80966.000     880.000
81056.000     875.000     81104.000     874.000     81153.000     873.000
81290.000     872.000     81309.000     871.000     81311.000     870.000
81314.000     869.000     81321.000     868.000     81325.000     866.000
81340.000     866.000     81346.000     867.000     81358.000     870.000
81377.000     870.000     81393.000     871.000     81515.000     871.000
81881.000     880.000     82200.000     880.000     82484.000     890.000
82616.000     890.000     82715.000     900.000
----------  ----------    ----------  ----------    ----------  ----------

                 Minimum and Maximum X,Y-coordinates
 Minimum X-Station:   80826.000  ( associated Y-Elevation:  900.000 )
 Maximum X-Station:   82715.000  ( associated Y-Elevation:  900.000 )
 Minimum Y-Elevation:   866.000  ( associated X-Station:  81340.000 )
 Maximum Y-Elevation:   900.000  ( associated X-Station:  80826.000 )

                   Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .100        ---
                              ---        ********
                    2         .032        ---
                              ---        ********
                    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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
     COUNTY: HANCOCK                          QUAD: GREENFIELD 112D
       10-18-96                                   ROBERT MILLER
  EX

          *=================================================*
```

WSPRO OUTPUT

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

        Reach       Water Surface   Friction
 #    Discharge       Elevation       Slope          Flow Regime
--    ---------    -------------   --------   --------------------
 1      6900.00       ********         .0007        Sub-Critical
 2      9140.00       ********         .0007        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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
COUNTY: HANCOCK                          QUAD: GREENFIELD 112D
   10-18-96                                 ROBERT MILLER

                   WSEL     VHD       Q          AREA       SRDL       LEW
                   EGEL      HF       V           K         FLEN       REW
                   CRWS      HO     FR #         SF         ALPHA      ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: EXIT      875.174   .106   6900.000   2889.724 ********* 81160.090
Header Type: XS    875.280 ******      2.388  261822.90 ********* 82150.880
SRD:       .000    873.184 ******       .269     ******     1.194    ******

Section: FULLV     875.282   .098   6900.000   2996.792   152.000 81158.910
Header Type: FV    875.380   .100      2.302  275128.10   152.000 82164.750
SRD:    152.000    873.184   .000       .256      .0007     1.189      -.001

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
      KRATIO:   .47

Section: APPR      875.418   .726   6900.000   2118.759   336.000 81048.480
Header Type: AS    876.144   .454      3.257  128125.00   336.000 81694.660
SRD:    488.000    874.285   .314       .665      .0014     4.402      -.003

       <<< 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
```

WSPRO OUTPUT

```
                    --------- ------ ---------- ---------- --------- ---------
Section: BRDGE       875.031   .803   6900.000   1040.227   152.000 81274.840
Header Type: BR      875.834   .266      6.633  204941.30   152.000 81402.180
SRD:     152.000     870.877   .288       .443     ******     1.173      .006

Specific Bridge Information   C      P/A    PFELEV    BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0             .9233  .039  877.000 ******** ******** ********
------------------------- ------ ----- -------- -------- -------- --------

                      WSEL    VHD       Q         AREA      SRDL      LEW
                      EGEL     HF       V           K       FLEN      REW
                      CRWS     HO      FR #        SF       ALPHA     ERR
                    --------- ------ ---------- ---------- --------- ---------
Section: APPR        876.029   .518   6900.000   2524.626   152.000 81037.480
Header Type: AS      876.547   .484      2.733  157036.80   166.158 81719.520
SRD:     488.000     874.285   .226       .529      .0014     4.458     -.009

          Approach Section APPR  Flow Contraction Information
          M( G )   M( K )     KQ       XLKQ      XRKQ      OTEL
          -------- -------- --------- -------- -------- --------
             .801     .341  103849.6 ******** ******** 876.029
          -------- -------- --------- -------- -------- --------

             <<< 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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
   COUNTY: HANCOCK                              QUAD: GREENFIELD 112D
      10-18-96                                      ROBERT MILLER

                      WSEL    VHD       Q         AREA      SRDL      LEW
                      EGEL     HF       V           K       FLEN      REW
                      CRWS     HO      FR #        SF       ALPHA     ERR
                    --------- ------ ---------- ---------- --------- ---------
Section: EXIT        875.813   .120   9140.000   3551.294 ********* 81153.050
Header Type: XS      875.934 ******      2.574  346689.10 ********* 82233.490
SRD:        .000     873.518 ******       .271     ******     1.169    ******

Section: FULLV       875.926   .112   9140.000   3674.203   152.000 81151.810
Header Type: FV      876.038   .101      2.488  363116.00   152.000 82248.100
SRD:     152.000     873.518   .000       .259      .0007     1.165      .004

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
       KRATIO:   .43

Section: APPR        876.029   .909   9140.000   2524.365   336.000 81037.480
```

WSPRO OUTPUT

```
Header Type: AS    876.938   .492      3.621  157017.20   336.000 81719.500
SRD:    488.000    875.029   .398       .701      .0015     4.458      .009

       <<< 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      875.581  1.266   9140.000   1110.890   152.000 81273.340
Header Type: BR     876.846   .274      8.228  223191.40   152.000 81403.520
SRD:    152.000     872.039   .640       .548     ******     1.202      .004

Specific Bridge Information   C      P/A    PFELEV    BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0            .9120  .038  877.000 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                     WSEL     VHD       Q          AREA       SRDL       LEW
                     EGEL      HF       V            K        FLEN       REW
                     CRWS      HO     FR #          SF       ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: APPR       877.131   .533   9140.000   3311.528   152.000 81017.650
Header Type: AS     877.663   .483      2.760  217140.70   167.607 81764.310
SRD:    488.000     875.029   .334       .490      .0015     4.495      .005

          Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ      XRKQ      OTEL
          -------- -------- --------- -------- -------- --------
              .807     .384  133576.7 ******** ******** 877.131
          -------- -------- --------- -------- -------- --------

             <<< 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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
  COUNTY: HANCOCK                            QUAD: GREENFIELD 112D
     10-18-96                                    ROBERT MILLER

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

                    Constants and Input Variables

            *---------------------------------------------*
             Bed Material Transport Mode Factor (k1):    .64
```

WSPRO OUTPUT

```
                Total Pier Width Value              (Pw):  4.000
               *-----------------------------------------------*

     Scour      -- Flow --          -- Width --         --- X-Limits ---
 #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
--   ------ --------- --------- -------- --------  ------ -------- --------
 1   1.131  6900.000  4002.209  123.000   75.000  Left:  ******** ********
     ..... Approach Channel Depth:    7.141 .....  Right: ******** ********
 2   2.021  9140.000  4869.604  123.000   75.000  Left:  ******** ********
     ..... Approach Channel Depth:    8.243 .....  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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
      COUNTY: HANCOCK                              QUAD: GREENFIELD 112D
         10-18-96                                     ROBERT MILLER

          ***  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    5.37   6900.000  875.257 10.757   7.524      .404  81267.000 81406.000
 2    6.01   9140.000  875.914 11.414   9.592      .500  81267.000 81406.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------


      ************************* 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-70 OVER BRANDYWINE CREEK IN HANCOCK CO.   I70-104-5128
      COUNTY: HANCOCK                              QUAD: GREENFIELD 112D
         10-18-96                                     ROBERT MILLER

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

WSPRO OUTPUT

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	5.37	6900.000	875.257	10.757	7.524	.404	81267.000	81406.000
2	6.01	9140.000	875.914	11.414	9.592	.500	81267.000	81406.000

ER

********** Normal end of WSPRO execution. **********
********** Elapsed Time: 0 Minutes 4 Seconds **********