Modified Level II Streambed-Scour Analysis for Structure I-70-141-4972 Crossing Greens Fork in Wayne County, Indiana

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

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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	United States Geological Survey
WSPRO	Water Surface PROfile model

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

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-70-141-4972 on Interstate 70 crossing Greens Fork in Wayne County, Indiana, are presented. The site is near the town of Jacksonburg in the west-central part of Wayne 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 23.0 feet for the modeled discharge of 8,900 cubic feet per second and approximately 28.1 feet for the modeled discharge of 11,500 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-70-141-4972.

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 Jacksonburg in the west-central part of Wayne County. The drainage area for the site is approximately 73.4 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, Greens Fork has a channel-bed slope of approximately 0.00185 ft/ft. The channel-bed material is silty gravelly sand, and the channel banks consist of silty sand. At the time of the Level I site visit on May 27, 1993, the banks were observed to have 0 to 25 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 70 crossing of Greens Fork is a 280-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, 1987) 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-70-141-4972 crossing Greens Fork in Wayne 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 8,900 cubic feet per second							
1	372+68	961	17.4	5.6	23.0	952	933.0
2	373+28	957	17.4	5.6	23.0	950	933.0
3	373+88	957	17.4	5.6	23.0	950	933.0
4	374+48	961	17.4	5.6	23.0	952	933.0
Modeled discharge is 11,500 cubic feet per second							
1	372+68	961	22.1	6.0	28.1	952	927.9
2	373+28	957	22.1	6.0	28.1	950	927.9
3	373+88	957	22.1	6.0	28.1	950	927.9
4	374+48	961	22.1	6.0	28.1	952	927.9

[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, 372+68, represents a point 37,268 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 (956.0 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, 1987, Bridge plans Interstate Route 70: Bridge File I-70-141-4972.

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 Greens Fork          I70-141-4972
T2        County: Wayne                  Quad: Jacksonburg 115D
T3        10-30-96                       Bret A. Robinson
SI        0
Q         8900 11500
SK        .00185 .00185
XS   EXIT 0 20
GR        34783 1000  35000 990  35187 980  35640 970  36156 960  36438 960
GR        37105 962  37168 961  37234 960  37241 957  37280 956  37317 957
GR        37325 960  37394 961  37395 960  37494 970  39123 980  39302 990
GR        39362 1000
N         .100       .036     .045
SA            37241       37317
XS   FULLV 296 20
GR        34783 1000  35000 990  35187 980  35640 970  36156 960  36438 960
GR        37105 962  37168 961  37234 960  37241 957  37280 956  37317 957
GR        37325 960  37394 961  37395 960  37494 970  39123 980  39302 990
GR        39362 1000
N         .100      .038      .045
SA             37241     37317
BR   BRDGE 296 973.1 20
GR       37204 0973.1  37206 0971.9  37209 0971.8  37211 0971.3  37233 0961.1
GR       37299 0959.9  37306 0956.9  37343 0956.0  37382 0956.9  37389 0959.9
GR       37457 0961.0  37479 0971.4  37482 0971.5  37486 0973.1  37204 0973.1
N         .034
PD        956.8 4 1
PD        960.7 4 2
PD        960.7 8 3
CD        3 128 2 971.8
DC 0 BRDGE 37300 37388 37210 37595 * 8
DP        37204 37486 2 * * 1 1 1.1
DP        37204 37486 2 * * 1 1 1.1
DP        37204 37486 2 * * 1 1 1.1
DP        37204 37486 2 * * 1 1 1.1
XS   APPR 720 20
GR        34574 1000  34787 990  35358 980  35613 970  36969 960  37226 964
GR        37276 961  37343 960  37351 957  37389 956  37427 957  37434 960
GR        37500 961  37516 960  37594 970  39312 980  39473 990  39644 1000
N         .050  .038    .100
SA           37351      37427
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  2:15 pm     Version V050196
          Input File: 4972.dat       Output File: 4972.LST
   *-------------------------------------------------------------*
T1         I-70 OVER GREENS FORK          I70-141-4972
T2         COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
T3         10-30-96                       BRET A. ROBINSON
SI         0
Q          8900 11500

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

SK         .00185 .00185

   ************************  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 GREENS FORK          I70-141-4972
       COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
          10-30-96                       BRET A. ROBINSON

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

XS   EXIT 0 20
GR         34783 1000  35000 990  35187 980  35640 970  36156 960  36438 960
GR         37105 962  37168 961  37234 960  37241 957  37280 956  37317 957
GR         37325 960  37394 961  37395 960  37494 970  39123 980  39302 990
GR         39362 1000
N          .100       .036     .045
SA             37241       37317

 ***   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:  20.0   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
----------  ----------   ----------  ----------   ----------  ----------
 34783.000    1000.000    35000.000     990.000    35187.000     980.000
 35640.000     970.000    36156.000     960.000    36438.000     960.000
 37105.000     962.000    37168.000     961.000    37234.000     960.000
 37241.000     957.000    37280.000     956.000    37317.000     957.000
 37325.000     960.000    37394.000     961.000    37395.000     960.000
 37494.000     970.000    39123.000     980.000    39302.000     990.000
 39362.000    1000.000
----------  ----------   ----------  ----------   ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   34783.000  ( associated Y-Elevation: 1000.000 )
  Maximum X-Station:   39362.000  ( associated Y-Elevation: 1000.000 )
  Minimum Y-Elevation:   956.000  ( associated X-Station:  37280.000 )
  Maximum Y-Elevation:  1000.000  ( associated X-Station:  34783.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
  X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
----------  ----------   ----------  ----------   ----------  ----------
 34783.000   34933.590    35000.000   35137.500    35187.000   35313.220
 35640.000   35738.900    36156.000   36223.790    36438.000   36488.780
 37105.000   37115.550    37168.000   37174.750    37234.000   37236.770
 37241.000   37243.350    37280.000   37280.000    37317.000   37314.770
 37325.000   37322.290    37394.000   37387.130    37395.000   37388.070
 37494.000   37481.090    39123.000   39011.850    39302.000   39180.060
 39362.000   39236.440
----------  ----------   ----------  ----------   ----------  ----------

                    Roughness Data (  3 SubAreas )
                            Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .100        ---
                                ---       ********
                      2         .036        ---
                                ---       ********
                      3         .045        ---
                   -------  -----------  ----------

        *-----------------------------------------------------*
        *      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 GREENS FORK          I70-141-4972
        COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
           10-30-96                       BRET A. ROBINSON

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

XS   FULLV 296 20
GR        34783 1000  35000 990  35187 980  35640 970  36156 960  36438 960
GR        37105 962  37168 961  37234 960  37241 957  37280 956  37317 957
GR        37325 960  37394 961  37395 960  37494 970  39123 980  39302 990
GR        39362 1000
N         .100      .038      .045
SA             37241     37317
```

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:      296.   Cross-Section Skew:  20.0   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
---------  ---------   ---------  ---------   ---------  ---------
34783.000   1000.000    35000.000    990.000    35187.000    980.000
35640.000    970.000    36156.000    960.000    36438.000    960.000
37105.000    962.000    37168.000    961.000    37234.000    960.000
37241.000    957.000    37280.000    956.000    37317.000    957.000
37325.000    960.000    37394.000    961.000    37395.000    960.000
37494.000    970.000    39123.000    980.000    39302.000    990.000
39362.000   1000.000
---------  ---------   ---------  ---------   ---------  ---------

                  Minimum and Maximum X,Y-coordinates
 Minimum X-Station:   34783.000  ( associated Y-Elevation: 1000.000 )
 Maximum X-Station:   39362.000  ( associated Y-Elevation: 1000.000 )
 Minimum Y-Elevation:   956.000  ( associated X-Station:  37280.000 )
 Maximum Y-Elevation:  1000.000  ( associated X-Station:  34783.000 )

     X-coordinates & Horizontal Breakpoints Translated by Skew Angle
 X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
---------  ---------   ---------  ---------   ---------  ---------
34783.000  34933.590    35000.000  35137.500    35187.000  35313.220
35640.000  35738.900    36156.000  36223.790    36438.000  36488.780
37105.000  37115.550    37168.000  37174.750    37234.000  37236.770
37241.000  37243.350    37280.000  37280.000    37317.000  37314.770
37325.000  37322.290    37394.000  37387.130    37395.000  37388.070
37494.000  37481.090    39123.000  39011.850    39302.000  39180.060
39362.000  39236.440
---------  ---------   ---------  ---------   ---------  ---------

                  Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .100        ---
                                        ********
                   2         .038        ---
                                        ********
                   3         .045        ---
                -------  -----------  ----------

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

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-70 OVER GREENS FORK          I70-141-4972
      COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
         10-30-96                      BRET A. ROBINSON

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

  BR   BRDGE 296 973.1 20
  GR        37204 0973.1  37206 0971.9  37209 0971.8  37211 0971.3  37233
0961.1
  GR        37299 0959.9  37306 0956.9  37343 0956.0  37382 0956.9  37389
0959.9
  GR        37457 0961.0  37479 0971.4  37482 0971.5  37486 0973.1  37204
0973.1
  N         .034
  PD        956.8 4 1
  PD        960.7 4 2
  PD        960.7 8 3
  CD        3 128 2 971.8

   ***   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:      296.   Cross-Section Skew:  20.0   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
----------  ----------   ----------  ----------   ----------  ----------
 37204.000     973.100    37206.000     971.900    37209.000     971.800
 37211.000     971.300    37233.000     961.100    37299.000     959.900
 37306.000     956.900    37343.000     956.000    37382.000     956.900
 37389.000     959.900    37457.000     961.000    37479.000     971.400
 37482.000     971.500    37486.000     973.100    37204.000     973.100
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   37204.000  ( associated Y-Elevation:  973.100 )
  Maximum X-Station:   37486.000  ( associated Y-Elevation:  973.100 )
  Minimum Y-Elevation:   956.000  ( associated X-Station:  37343.000 )
  Maximum Y-Elevation:   973.100  ( associated X-Station:  37204.000 )

      X-coordinates & Horizontal Breakpoints Translated by Skew Angle
   X Input    X Skewed      X Input    X Skewed      X Input    X Skewed
----------  ----------   ----------  ----------   ----------  ----------
 37204.000   37212.380    37206.000   37214.260    37209.000   37217.080
```

WSPRO OUTPUT

```
 37211.000   37218.960    37233.000   37239.630    37299.000   37301.650
 37306.000   37308.230    37343.000   37343.000    37382.000   37379.650
 37389.000   37386.230    37457.000   37450.130    37479.000   37470.800
 37482.000   37473.620    37486.000   37477.380    37204.000   37212.380
----------  ----------   ----------  ----------   ----------  ----------

                  Roughness Data (  1 SubAreas )
                            Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .034        ---
                 -------  -----------  ----------

                  Discharge coefficient parameters
              BRType   BRWdth   EMBSS   EMBElv    UserCD
                3      128.000   2.00   971.800 **********

                     Pressure flow elevations
                        AVBCEL     PFElev
                     *********    973.100

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


                  Pier/Pile Data (  3 Group(s) )
                 Code Indicates Bridge Uses Piers
                Group  Elevation  Gross Width  Number
               ------  ---------  -----------  ------
                  1      956.800      4.000       1
                  2      960.700      4.000       2
                  3      960.700      8.000       3
               ------  ---------  -----------  ------

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

  ************************  W S P R O  ***************************
     Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
          Input Units: English  /  Output Units: English
  *-------------------------------------------------------------*
          I-70 OVER GREENS FORK          I70-141-4972
       COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
          10-30-96                       BRET A. ROBINSON
DC 0 BRDGE 37300 37388 37210 37595 * 8
DP        37204 37486 2 * * 1 1 1.1
DP        37204 37486 2 * * 1 1 1.1
DP        37204 37486 2 * * 1 1 1.1
DP        37204 37486 2 * * 1 1 1.1

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

WSPRO OUTPUT

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

XS    APPR 720 20
GR         34574 1000  34787 990  35358 980  35613 970  36969 960  37226 964
GR         37276 961  37343 960  37351 957  37389 956  37427 957  37434 960
GR         37500 961  37516 960  37594 970  39312 980  39473 990  39644 1000
N          .050  .038    .100
SA            37351      37427

 ***   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:       720.   Cross-Section Skew:  20.0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->  Expansion:    .50   Contraction:   .00
```

X,Y-coordinates (18 pairs)

X	Y	X	Y	X	Y
34574.000	1000.000	34787.000	990.000	35358.000	980.000
35613.000	970.000	36969.000	960.000	37226.000	964.000
37276.000	961.000	37343.000	960.000	37351.000	957.000
37389.000	956.000	37427.000	957.000	37434.000	960.000
37500.000	961.000	37516.000	960.000	37594.000	970.000
39312.000	980.000	39473.000	990.000	39644.000	1000.000

```
                  Minimum and Maximum X,Y-coordinates
 Minimum X-Station:    34574.000  ( associated Y-Elevation: 1000.000 )
 Maximum X-Station:    39644.000  ( associated Y-Elevation: 1000.000 )
 Minimum Y-Elevation:    956.000  ( associated X-Station:   37389.000 )
 Maximum Y-Elevation:   1000.000  ( associated X-Station:   34574.000 )
```

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
34574.000	34743.770	34787.000	34943.920	35358.000	35480.480
35613.000	35720.110	36969.000	36994.330	37226.000	37235.830
37276.000	37282.820	37343.000	37345.770	37351.000	37353.290
37389.000	37389.000	37427.000	37424.710	37434.000	37431.290
37500.000	37493.300	37516.000	37508.340	37594.000	37581.640
39312.000	39196.030	39473.000	39347.320	39644.000	39508.010

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.050	---
	---	********
2	.038	---
	---	********
3	.100	---

WSPRO OUTPUT

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

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 GREENS FORK          I70-141-4972
         COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
            10-30-96                       BRET A. ROBINSON
 EX

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

        Reach       Water Surface   Friction
     #  Discharge      Elevation      Slope          Flow Regime
    --  ---------    -------------   --------   --------------------
     1    8900.00       ********        .0019        Sub-Critical
     2   11500.00       ********        .0019        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 GREENS FORK          I70-141-4972
         COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
            10-30-96                       BRET A. ROBINSON

                     WSEL     VHD        Q          AREA       SRDL       LEW
                     EGEL      HF        V            K         FLEN       REW
                     CRWS      HO     FR #           SF        ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: EXIT       963.784   .297   8900.000   4310.928 ********* 36040.310
Header Type: XS     964.081 ******      2.065  206862.40 ********* 37423.270
SRD:       .000     962.647 ******       .436     ******     4.481    ******

Section: FULLV      964.348   .179   8900.000   5099.608   296.000 36012.980
Header Type: FV     964.526   .446      1.745  253858.00   296.000 37428.510
```

WSPRO OUTPUT

```
SRD:    296.000    962.607   .000       .315       .0015      3.772      -.001

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

Section: APPR      964.843   .204    8900.000    3670.734    424.000 36377.170
Header Type: AS    965.048   .504       2.425  262297.30    424.000 37543.840
SRD:    720.000    963.045   .013        .360       .0012      2.234       .004

       <<< 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     964.203   1.541   8900.000    1119.479   296.000 37233.340
Header Type: BR    965.744    .830      7.950  142185.60    296.000 37456.490
SRD:    296.000    962.914   .834       .784      ******      1.568       .001

Specific Bridge Information   C      P/A    PFELEV     BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0             .7987  .039  973.100 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                     WSEL     VHD        Q          AREA       SRDL       LEW
                     EGEL      HF        V            K        FLEN       REW
                     CRWS      HO     FR #           SF       ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: APPR      966.665    .063   8900.000    6020.156   296.000 36145.000
Header Type: AS    966.728    .398      1.478  497434.90    340.260 37557.200
SRD:    720.000    963.045   .587       .172       .0012      1.853       .008

          Approach Section APPR  Flow Contraction Information
           M( G )    M( K )      KQ        XLKQ       XRKQ      OTEL
          -------- -------- --------- -------- -------- --------
              .808      .628  184403.8 ******** ********  966.665
          -------- -------- --------- -------- -------- --------

             <<< 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 GREENS FORK          I70-141-4972
        COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
           10-30-96                       BRET A. ROBINSON

                     WSEL     VHD        Q          AREA       SRDL       LEW
```

WSPRO OUTPUT

	EGEL CRWS	HF HO	V FR #	K SF	FLEN ALPHA	REW ERR
Section: EXIT	964.437	.306	11500.000	5226.145	*********	36008.650
Header Type: XS	964.743	******	2.200	267367.00	*********	37429.340
SRD: .000	963.005	******	.408	******	4.061	******
Section: FULLV	965.004	.195	11500.000	6041.754	296.000	35981.130
Header Type: FV	965.199	.457	1.903	320385.00	296.000	37434.620
SRD: 296.000	962.958	.000	.306	.0015	3.462	.000

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

Section: APPR	965.503	.212	11500.000	4469.818	424.000	36293.100
Header Type: AS	965.716	.518	2.573	337566.40	424.000	37548.680
SRD: 720.000	963.503	.009	.345	.0012	2.064	-.011

<<< 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	964.963	2.036	11500.000	1290.319	296.000	37231.800
Header Type: BR	966.999	1.062	8.913	178370.30	296.000	37458.000
SRD: 296.000	963.650	1.190	.845	******	1.648	-.006

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.7790	.039	973.100	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	968.003	.054	11500.000	8029.395	296.000	35974.580
Header Type: AS	968.057	.454	1.432	726923.60	345.674	37567.000
SRD: 720.000	963.503	.608	.146	.0012	1.696	-.018

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.820	.811	137847.2	********	********	968.003

<<< End of Bridge Hydraulics Computations >>>

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

WSPRO OUTPUT

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

I-70 OVER GREENS FORK I70-141-4972
COUNTY: WAYNE QUAD: JACKSONBURG 115D
10-30-96 BRET A. ROBINSON

*** 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):	8.000

#	Scour Depth	Flow Contract	Flow Approach	Width Contract	Width Approach	X-Limits Side	X-Limits Contract	X-Limits Approach
1	17.397	6587.570	4051.800	80.000	385.000	Left:	********	********
	..... Approach Channel Depth:	5.551				Right:	********	********
2	22.122	7999.088	4742.114	80.000	385.000	Left:	********	********
	..... Approach Channel Depth:	6.774				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 GREENS FORK I70-141-4972
COUNTY: WAYNE QUAD: JACKSONBURG 115D
10-30-96 BRET A. ROBINSON

*** 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 Depth	Localized Hydraulic Properties: Flow	WSE	Depth	Velocity	Froude #	X-Stations: Left	Right
1	5.63	8900.000	964.790	8.790	8.930	.531	37204.000	37486.000
2	5.97	11500.000	965.571	9.571	9.993	.569	37204.000	37486.000

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-70 OVER GREENS FORK          I70-141-4972
     COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
        10-30-96                       BRET A. ROBINSON

    ***  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   5.63   8900.000  964.790  8.790    8.930     .531  37204.000 37486.000
 2   5.97  11500.000  965.571  9.571    9.993     .569  37204.000 37486.000
--  ----- ---------- -------- ------ -------- -------- --------- ---------


**************************  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 GREENS FORK          I70-141-4972
     COUNTY: WAYNE                  QUAD: JACKSONBURG 115D
        10-30-96                       BRET A. ROBINSON

    ***  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 Depth	Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	X-Stations Right
1	5.63	8900.000	964.790	8.790	8.930	.531	37204.000	37486.000
2	5.97	11500.000	965.571	9.571	9.993	.569	37204.000	37486.000

********** 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 GREENS FORK I70-141-4972
COUNTY: WAYNE QUAD: JACKSONBURG 115D
10-30-96 BRET A. ROBINSON

*** 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 Depth	Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	X-Stations Right
1	5.63	8900.000	964.790	8.790	8.930	.531	37204.000	37486.000
2	5.97	11500.000	965.571	9.571	9.993	.569	37204.000	37486.000

ER

********** Normal end of WSPRO execution. **********
********** Elapsed Time: 0 Minutes 5 Seconds **********