Modified Level II Streambed-Scour Analysis for Structure I-69-76-4775 Crossing Salamonie River in Huntington County, Indiana

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

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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

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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-69-76-4775 on Interstate 69 crossing Salamonie River in Huntington County, Indiana, are presented. The site is near the town of Warren in the southeastern part of Huntington 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 13.7 feet for the modeled discharge of 15,800 cubic feet per second and approximately 20.9 feet for the modeled discharge of 26,900 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-69-76-4775.

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 Warren in the southeastern part of Huntington County. The drainage area for the site is approximately 412 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, Salamonie River has a channel-bed slope of approximately 0.0004 ft/ft. The channel-bed material is gravelly sand, and the channel banks consist of sandy silt-clay. At the time of the Level I site visit on June 23, 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 69 crossing of Salamonie River is a 413-ft-long, multi-lane bridge consisting of six 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, 1962) 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-69-76-4775 crossing Salamonie River in Huntington 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 15,800 cubic feet per second							
1	245+83	799	7.5	6.2	13.7	784.5	774.1
2	246+56	788	7.5	6.2	13.7	784.0	774.1
3	247+31	788	7.5	6.2	13.7	776.5	774.1
4	248+06	795	7.5	6.2	13.7	781.5	774.1
5	248+81	797	7.5	6.2	13.7	788.5	774.1
Modeled discharge is 26,900 cubic feet per second							
1	245+83	799	13.9	7.0	20.9	784.5	766.9
2	246+56	788	13.9	7.0	20.9	784.0	766.9
3	247+31	788	13.9	7.0	20.9	776.5	766.9
4	248+06	795	13.9	7.0	20.9	781.5	766.9
5	248+81	797	13.9	7.0	20.9	788.5	766.9

[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, 245+83, represents a point 24,583 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 (787.8 feet).

[5]Coordinated discharge.

SPECIAL CONSIDERATIONS

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

Salamonie Lake is immediately downstream from the I-69-76-4775 bridge. During periods of high flow, back-water effect created by the lake may reduce flow velocities near the bridge and thereby reduce the potential for scouring. The modelling described in this report, however, has been done without consideration of possible back-water effect from the lake.

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, 1962, Bridge plans Interstate Route 69: Bridge File I-69-76-4775.

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-69 Over Salamonie River          I69-76-4775
T2        County: Huntington                 Quad: Warren 75A
T3        11-08-96                           Bret A. Robinson
SI        0
Q         15800 26900
SK        .0004 .0004
XS   EXIT 0
GR        23963 830  24531 820  24598 810  24604 810  24618 805  24639 800
GR        24678 790  24685 789  24707 788  24847 788  24865 789  24877 797
GR        25648 800  25853 810  26405 820  26663 830
N         .120 .034 .100
SA        24600 24900
XS   FULLV 420
GR        23963 830  24531 820  24598 810  24604 810  24618 805  24639 800
GR        24678 790  24685 789  24707 788  24847 788  24865 789  24877 797
GR        25648 800  25853 810  26405 820  26663 830
N         .120 .034 .100
SA        24600 24900
BR   BRDGE 420 810
GR       24529 0812.6  24529 0811.8  24531 0811.7  24567 0797.1  24588 0796.7
GR        24600 0791.0  24615 0787.8  24700 0787.7  24718 0788.3  24755 0787.6
GR        24801 0788.9  24810 0796.5  24844 0797.4  24901 0796.9  24930 0809.5
GR        24932 0809.5  24932 0810.5  24923 0810.5  24908 0810.0  24895 0809.0
GR        24888 0808.2  24882 0807.5  24876 0809.1  24864 0810.4  24855 0810.9
GR        24844 0811.0  24829 0810.5  24817 0809.4  24810 0808.1  24807 0807.1
GR        24805 0808.2  24798 0809.6  24789 0810.6  24777 0811.3  24763 0811.3
GR        24753 0810.9  24741 0809.7  24735 0808.7  24731 0807.5  24728 0808.7
GR        24716 0810.8  24705 0811.6  24689 0811.8  24676 0811.3  24666 0810.2
GR        24660 0809.0  24657 0807.7  24651 0809.6  24642 0811.0  24628 0811.9
GR        24613 0812.1  24599 0811.4  24589 0810.4  24582 0808.9  24575 0809.8
GR         24557 0811.6  24542 0812.4  24529 0812.6
N         .034
PD        788 3 2
PD        788.1 3 2
PD        788.1 6 3
PD        796 6 3
PD        796 9 4
PD        797 9 4
PD        797 12 5
PD        800 12 5
PD        800 15 1
CD        3 230 2 811
DC 0 BRDGE 24589 24809 24500 24730 * 15
*         LPierEdge RPierEdge PierWdth * * K1 K2 K3(1.1)
DP        24529 24932 3 * * 1 1 1.1
DP        24529 24932 3 * * 1 1 1.1
DP        24529 24932 3 * * 1 1 1.1
DP        24529 24932 3 * * 1 1 1.1
DP        24529 24932 3 * * 1 1 1.1
XS   APPR 1070
GR        23865 830  24128 820  24249 810  24334 800  24501 800  24523 789
GR        24541 788  24712 788  24717 789  24729 797  24877 797  25502 800
GR        25583 810  25752 820  26069 830
N         .100 .034 .035
SA        24500 24725
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  2:43 pm     Version V050196
          Input File: 4775.dat       Output File: 4775.LST
   *-------------------------------------------------------------*
T1        I-69 OVER SALAMONIE RIVER          I69-76-4775
T2        COUNTY: HUNTINGTON                 QUAD: WARREN 75A
T3        11-08-96                           BRET A. ROBINSON
SI        0
Q         15800 26900

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

SK        .0004 .0004

   ************************  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-69 OVER SALAMONIE RIVER          I69-76-4775
        COUNTY: HUNTINGTON                 QUAD: WARREN 75A
        11-08-96                           BRET A. ROBINSON

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

XS   EXIT 0
GR        23963 830  24531 820  24598 810  24604 810  24618 805  24639 800
GR        24678 790  24685 789  24707 788  24847 788  24865 789  24877 797
GR        25648 800  25853 810  26405 820  26663 830
N         .120 .034 .100
SA        24600 24900

 ***   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 (16 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 23963.000     830.000    24531.000     820.000    24598.000     810.000
 24604.000     810.000    24618.000     805.000    24639.000     800.000
 24678.000     790.000    24685.000     789.000    24707.000     788.000
 24847.000     788.000    24865.000     789.000    24877.000     797.000
 25648.000     800.000    25853.000     810.000    26405.000     820.000
 26663.000     830.000
----------  ----------   ----------  ----------   ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   23963.000  ( associated Y-Elevation:  830.000 )
  Maximum X-Station:   26663.000  ( associated Y-Elevation:  830.000 )
  Minimum Y-Elevation:   788.000  ( associated X-Station:  24847.000 )
  Maximum Y-Elevation:   830.000  ( associated X-Station:  23963.000 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .120        ---
                               ---       ********
                     2         .034        ---
                               ---       ********
                     3         .100        ---
                  -------  -----------  ----------

        *-----------------------------------------------------*
        *      Finished Processing Header Record EXIT         *
        *-----------------------------------------------------*

   ************************* W S P R O ****************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
            Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
          I-69 OVER SALAMONIE RIVER          I69-76-4775
        COUNTY: HUNTINGTON                  QUAD: WARREN 75A
        11-08-96                            BRET A. ROBINSON

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

XS   FULLV 420
GR        23963 830  24531 820  24598 810  24604 810  24618 805  24639 800
GR        24678 790  24685 789  24707 788  24847 788  24865 789  24877 797
GR        25648 800  25853 810  26405 820  26663 830
N         .120 .034 .100
SA        24600 24900

 ***   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:      420.   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 (16 pairs)
     X          Y           X          Y           X          Y
----------  ----------  ----------  ----------  ----------  ----------
 23963.000     830.000    24531.000     820.000    24598.000     810.000
```

WSPRO OUTPUT

```
 24604.000     810.000    24618.000     805.000    24639.000     800.000
 24678.000     790.000    24685.000     789.000    24707.000     788.000
 24847.000     788.000    24865.000     789.000    24877.000     797.000
 25648.000     800.000    25853.000     810.000    26405.000     820.000
 26663.000     830.000
---------- ---------- ---------- ---------- ---------- ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   23963.000  ( associated Y-Elevation:  830.000 )
  Maximum X-Station:   26663.000  ( associated Y-Elevation:  830.000 )
  Minimum Y-Elevation:   788.000  ( associated X-Station:  24847.000 )
  Maximum Y-Elevation:   830.000  ( associated X-Station:  23963.000 )

                    Roughness Data (  3 SubAreas )
                           Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .120        ---
                               ---       ********
                     2         .034        ---
                               ---       ********
                     3         .100        ---
                  -------  -----------  ----------

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

     ************************* W S P R O ***************************
        Federal Highway Administration - U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English / Output Units: English
     *-------------------------------------------------------------*
           I-69 OVER SALAMONIE RIVER          I69-76-4775
         COUNTY: HUNTINGTON                  QUAD: WARREN 75A
         11-08-96                            BRET A. ROBINSON

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

   BR   BRDGE 420 810
   GR        24529 0812.6  24529 0811.8  24531 0811.7  24567 0797.1  24588
0796.7
   GR        24600 0791.0  24615 0787.8  24700 0787.7  24718 0788.3  24755
0787.6
   GR        24801 0788.9  24810 0796.5  24844 0797.4  24901 0796.9  24930
0809.5
   GR        24932 0809.5  24932 0810.5  24923 0810.5  24908 0810.0  24895
0809.0
   GR        24888 0808.2  24882 0807.5  24876 0809.1  24864 0810.4  24855
0810.9
   GR        24844 0811.0  24829 0810.5  24817 0809.4  24810 0808.1  24807
0807.1
```

WSPRO OUTPUT

```
   GR         24805 0808.2  24798 0809.6  24789 0810.6  24777 0811.3  24763
0811.3
   GR         24753 0810.9  24741 0809.7  24735 0808.7  24731 0807.5  24728
0808.7
   GR         24716 0810.8  24705 0811.6  24689 0811.8  24676 0811.3  24666
0810.2
   GR         24660 0809.0  24657 0807.7  24651 0809.6  24642 0811.0  24628
0811.9
   GR         24613 0812.1  24599 0811.4  24589 0810.4  24582 0808.9  24575
0809.8
   GR         24557 0811.6  24542 0812.4  24529 0812.6
   N          .034
   PD         788 3 2
   PD         788.1 3 2
   PD         788.1 6 3
   PD         796 6 3
   PD         796 9 4
   PD         797 9 4
   PD         797 12 5
   PD         800 12 5
   PD         800 15 1
   CD         3 230 2 811

    ***   Completed Reading Data Associated With Header Record BRDGE   ***
 +++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
 +++072 NOTICE:  X-coordinate #17 increased to eliminate vertical segment.
    ***   Storing Bridge Data In Temporary File As Record Number  3    ***

    ***              Data Summary For Bridge Record BRDGE              ***
    SRD Location:      420.   Cross-Section Skew:    .0   Error Code   0
    Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
    Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (58 pairs)
        X          Y              X          Y              X          Y
  ----------  ----------    ----------  ----------    ----------  ----------
   24529.000     812.600     24529.100     811.800     24531.000     811.700
   24567.000     797.100     24588.000     796.700     24600.000     791.000
   24615.000     787.800     24700.000     787.700     24718.000     788.300
   24755.000     787.600     24801.000     788.900     24810.000     796.500
   24844.000     797.400     24901.000     796.900     24930.000     809.500
   24932.000     809.500     24932.100     810.500     24923.000     810.500
   24908.000     810.000     24895.000     809.000     24888.000     808.200
   24882.000     807.500     24876.000     809.100     24864.000     810.400
   24855.000     810.900     24844.000     811.000     24829.000     810.500
   24817.000     809.400     24810.000     808.100     24807.000     807.100
   24805.000     808.200     24798.000     809.600     24789.000     810.600
   24777.000     811.300     24763.000     811.300     24753.000     810.900
   24741.000     809.700     24735.000     808.700     24731.000     807.500
   24728.000     808.700     24716.000     810.800     24705.000     811.600
   24689.000     811.800     24676.000     811.300     24666.000     810.200
   24660.000     809.000     24657.000     807.700     24651.000     809.600
   24642.000     811.000     24628.000     811.900     24613.000     812.100
   24599.000     811.400     24589.000     810.400     24582.000     808.900
```

WSPRO OUTPUT

```
 24575.000     809.800    24557.000     811.600    24542.000     812.400
 24529.000     812.600
----------  ----------  ----------  ----------  ----------  ----------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   24529.000  ( associated Y-Elevation:  812.600 )
  Maximum X-Station:   24932.100  ( associated Y-Elevation:  810.500 )
  Minimum Y-Elevation:   787.600  ( associated X-Station:  24755.000 )
  Maximum Y-Elevation:   812.600  ( associated X-Station:  24529.000 )

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

                    Discharge coefficient parameters
                 BRType   BRWdth    EMBSS    EMBElv    UserCD
                   3      230.000   2.00    811.000 **********

                        Pressure flow elevations
                           AVBCEL     PFElev
                         *********    810.000

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


                    Pier/Pile Data (  9 Group(s) )
                  Code Indicates Bridge Uses Piers
                  Group  Elevation  Gross Width  Number
                 ------  ---------  -----------  ------
                    1      788.000      3.000       2
                    2      788.100      3.000       2
                    3      788.100      6.000       3
                    4      796.000      6.000       3
                    5      796.000      9.000       4
                    6      797.000      9.000       4
                    7      797.000     12.000       5
                    8      800.000     12.000       5
                    9      800.000     15.000       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
  *-----------------------------------------------------------*
```

WSPRO OUTPUT

```
          I-69 OVER SALAMONIE RIVER          I69-76-4775
         COUNTY: HUNTINGTON                  QUAD: WARREN 75A
         11-08-96                            BRET A. ROBINSON
DC 0 BRDGE 24589 24809 24500 24730 * 15
DP         24529 24932 3 * * 1 1 1.1
DP         24529 24932 3 * * 1 1 1.1
DP         24529 24932 3 * * 1 1 1.1
DP         24529 24932 3 * * 1 1 1.1
DP         24529 24932 3 * * 1 1 1.1

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

XS   APPR 1070
GR         23865 830  24128 820  24249 810  24334 800  24501 800  24523 789
GR         24541 788  24712 788  24717 789  24729 797  24877 797  25502 800
GR         25583 810  25752 820  26069 830
N          .100 .034 .035
SA         24500 24725

 ***   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:     1070.   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 (15 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 23865.000     830.000    24128.000     820.000    24249.000     810.000
 24334.000     800.000    24501.000     800.000    24523.000     789.000
 24541.000     788.000    24712.000     788.000    24717.000     789.000
 24729.000     797.000    24877.000     797.000    25502.000     800.000
 25583.000     810.000    25752.000     820.000    26069.000     830.000
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   23865.000  ( associated Y-Elevation:  830.000 )
  Maximum X-Station:   26069.000  ( associated Y-Elevation:  830.000 )
  Minimum Y-Elevation:   788.000  ( associated X-Station:  24712.000 )
  Maximum Y-Elevation:   830.000  ( associated X-Station:  23865.000 )

                   Roughness Data (  3 SubAreas )
                            Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .100        ---
                               ---       ********
                     2         .034        ---
                               ---       ********
                     3         .035        ---
```

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-69 OVER SALAMONIE RIVER          I69-76-4775
         COUNTY: HUNTINGTON                 QUAD: WARREN 75A
         11-08-96                           BRET A. ROBINSON
  EX

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

          Reach       Water Surface   Friction
     #   Discharge      Elevation      Slope          Flow Regime
    --   ---------    ------------   --------   --------------------
     1    15800.00      ********        .0004        Sub-Critical
     2    26900.00      ********        .0004        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-69 OVER SALAMONIE RIVER          I69-76-4775
         COUNTY: HUNTINGTON                 QUAD: WARREN 75A
         11-08-96                           BRET A. ROBINSON

                     WSEL     VHD        Q          AREA       SRDL       LEW
                     EGEL      HF        V            K         FLEN       REW
                     CRWS      HO     FR #           SF        ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: EXIT       802.163   .271  15800.000   5889.287 ********* 24629.920
Header Type: XS     802.434 ******      2.683  789351.80 ********* 25692.340
SRD:       .000     794.173 ******       .313     ******     2.421    ******

Section: FULLV      802.338   .258  15800.000   6075.928   420.000 24629.180
Header Type: FV     802.596   .163      2.600  813401.30   420.000 25695.940
```

WSPRO OUTPUT

```
SRD:    420.000    794.173   .000       .301       .0004      2.451      -.001

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
      KRATIO:  1.44

Section: APPR      802.639   .125  15800.000   7043.511   650.000 24311.570
Header Type: AS    802.765   .170      2.243 1174257.00   650.000 25523.380
SRD:   1070.000    793.922   .000       .208      .0003     1.601      -.001

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

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


                     WSEL     VHD       Q          AREA       SRDL       LEW
                     EGEL      HF       V            K        FLEN       REW
                     CRWS      HO     FR #          SF       ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: BRDGE     802.284   .346  15800.000   3702.867   420.000 24554.220
Header Type: BR    802.630   .182      4.267  757370.40   420.000 24913.390
SRD:    420.000    793.921   .014       .259     ******     1.221      -.002

Specific Bridge Information   C      P/A    PFELEV     BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0             .9051  .034  810.000 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                     WSEL     VHD       Q          AREA       SRDL       LEW
                     EGEL      HF       V            K        FLEN       REW
                     CRWS      HO     FR #          SF       ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: APPR      802.754   .120  15800.000   7182.569   420.000 24310.590
Header Type: AS    802.874   .129      2.200 1203000.00   455.521 25524.310
SRD:   1070.000    793.922   .115       .201      .0003     1.595       .008

            Approach Section APPR  Flow Contraction Information
             M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
            -------- -------- --------- -------- -------- --------
               .703     .259  889476.8 ******** ******** 802.754
            -------- -------- --------- -------- -------- --------

              <<< 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-69 OVER SALAMONIE RIVER          I69-76-4775
         COUNTY: HUNTINGTON                 QUAD: WARREN 75A
```

WSPRO OUTPUT

11-08-96 BRET A. ROBINSON

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	805.645	.324	26900.000	9738.156	*********	24616.190
Header Type: XS	805.969	******	2.762	1344589.00	*********	25763.720
SRD: .000	796.641	******	.276	******	2.732	******
Section: FULLV	805.821	.312	26900.000	9939.874	420.000	24615.700
Header Type: FV	806.133	.164	2.706	1377104.00	420.000	25767.320
SRD: 420.000	796.641	.000	.269	.0004	2.739	-.001

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
KRATIO: 1.61

Section: APPR	806.161	.125	26900.000	11413.640	650.000	24281.630
Header Type: AS	806.286	.154	2.357	2222243.00	650.000	25551.900
SRD: 1070.000	796.346	.000	.167	.0002	1.448	.000

<<< 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	805.646	.664	26900.000	4937.100	420.000	24545.930
Header Type: BR	806.310	.198	5.449	1186017.00	420.000	24921.130
SRD: 420.000	796.351	.143	.318	******	1.439	.000

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.8337	.036	810.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	806.455	.117	26900.000	11787.880	420.000	24279.130
Header Type: AS	806.571	.129	2.282	2324444.00	473.748	25554.280
SRD: 1070.000	796.346	.132	.159	.0002	1.439	.001

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.704	.425	1336569.0	********	********	806.455

WSPRO INPUT FILE

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

          <<< 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-69 OVER SALAMONIE RIVER          I69-76-4775
     COUNTY: HUNTINGTON                 QUAD: WARREN 75A
     11-08-96                           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): 15.000
            *-----------------------------------------------*

    Scour      -- Flow --          -- Width --        --- X-Limits ---
 #  Depth  Contract Approach  Contract Approach  Side   Contract Approach
--  ------ --------- --------- -------- --------  ------ -------- --------
 1  7.499 15745.760 10289.150  205.000  230.000  Left:  ******** ********
    ..... Approach Channel Depth:   13.730 .....  Right: ******** ********
 2 13.906 24615.050 13473.330  205.000  230.000  Left:  ******** ********
    ..... Approach Channel Depth:   17.431 .....  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-69 OVER SALAMONIE RIVER          I69-76-4775
     COUNTY: HUNTINGTON                 QUAD: WARREN 75A
     11-08-96                           BRET A. ROBINSON

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

                    Constants and Input Variables

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

#	Scour Depth	Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	X-Stations Right
1	6.21	15800.000	802.399	14.799	5.175	.237	24529.000	24932.000
2	7.04	26900.000	805.778	18.178	6.492	.268	24529.000	24932.000

```
************************  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-69 OVER SALAMONIE RIVER          I69-76-4775
     COUNTY: HUNTINGTON                  QUAD: WARREN 75A
     11-08-96                            BRET A. ROBINSON

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

                Constants and Input Variables

                     Pier Width:   3.000
            *-----------------------------------------*
              Pier Shape Factor            (K1):   1.00
              Flow Angle of Attack Factor  (K2):   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	6.21	15800.000	802.399	14.799	5.175	.237	24529.000	24932.000
2	7.04	26900.000	805.778	18.178	6.492	.268	24529.000	24932.000

```
************************  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-69 OVER SALAMONIE RIVER          I69-76-4775
     COUNTY: HUNTINGTON                  QUAD: WARREN 75A
     11-08-96                            BRET A. ROBINSON

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

                Constants and Input Variables

                     Pier Width:   3.000
```

WSPRO INPUT FILE

```
                *-----------------------------------------*
                  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    6.21  15800.000  802.399 14.799    5.175     .237  24529.000 24932.000
 2    7.04  26900.000  805.778 18.178    6.492     .268  24529.000 24932.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------


     ************************  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-69 OVER SALAMONIE RIVER          I69-76-4775
          COUNTY: HUNTINGTON                  QUAD: WARREN 75A
          11-08-96                            BRET A. ROBINSON

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

                       Constants and Input Variables

                           Pier Width:   3.000
                *-----------------------------------------*
                  Pier Shape Factor            (K1):   1.00
                  Flow Angle of Attack Factor  (K2):   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    6.21  15800.000  802.399 14.799    5.175     .237  24529.000 24932.000
 2    7.04  26900.000  805.778 18.178    6.492     .268  24529.000 24932.000
--   ----- ---------- -------- ------ -------- -------- --------- ---------


     ************************  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-69 OVER SALAMONIE RIVER          I69-76-4775
```

WSPRO INPUT FILE

COUNTY: HUNTINGTON QUAD: WARREN 75A
11-08-96 BRET A. ROBINSON

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

Constants and Input Variables

Pier Width: 3.000

Pier Shape Factor	(K1):	1.00
Flow Angle of Attack Factor	(K2):	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	6.21	15800.000	802.399	14.799	5.175	.237	24529.000	24932.000
2	7.04	26900.000	805.778	18.178	6.492	.268	24529.000	24932.000

ER

********** Normal end of WSPRO execution. **********
********** Elapsed Time: 0 Minutes 10 Seconds **********