Modified Level II Streambed-Scour Analysis for Structure I-64-83-5678 Crossing Stinking Fork in Crawford County, Indiana

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

Prepared in cooperation with the
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-64-83-5678 on Interstate 64 crossing Stinking Fork in Crawford County, Indiana, are presented. The site is at the town of West Fork in the southwestern part of Crawford 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 9.1 feet for the modeled discharge of 9,070 cubic feet per second and approximately 10.8 feet for the modeled discharge of 10,950 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-64-83-5678.

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 at the town of West Fork in the southwestern part of Crawford County. The drainage area for the site is approximately 17.5 mi^2 (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is forest; in the immediate vicinity of the bridge, the land is predominantly forest with some agricultural fields nearby.

Within the immediate vicinity of the bridge, Stinking Fork has a channel-bed slope of approximately 0.0038 ft/ft. The channel-bed material is a gravel and cobble mixture. The bridge plans indicate that bedrock is within a few feet of the channel-bed elevation. The channel banks consist of sandy silt-clay. At the time of the Level I site visit on August 1, 1991, the banks were observed to have 50 to 85 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 64 crossing of Stinking Fork is a 301-ft-long, multi-lane bridge consisting of four spans supported by concrete and steel piers and sloping riprap-covered spill-through abutments. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.

EVALUATION METHODS

The methods described in this section apply to a number of bridge sites in Indiana being evaluated for scour and outline the procedures requested by INDOT for these modified Level II scour analyses. The principal modification requested by INDOT was that the input data to the model come from or be estimated from existing data sources; no additional field data were collected. Actual methods used in the scour evaluation at this particular bridge site use the most applicable method possible, given the data available.

To determine drainage area, either published values found in Hoggatt (1975) or 7.5-minute topographic maps with Hoggatt's original drainage-area delineations were used. Where there are no published data, drainage-area segments measured from the maps produced by Hoggatt were either subtracted from downstream sites or added to upstream sites published by Hoggatt (1975).

In Indiana, flood discharges are coordinated by agreement among State and Federal agencies. At sites where flood discharges officially are coordinated among State and Federal agencies in Indiana, the coordinated 100-year discharge (Q100) was modeled. INDOT also provided an additional flood discharge for these coordinated sites in excess of the Q100 to be modeled.

If a flood discharge was not coordinated, the USGS examined Federal Emergency Management Agency (FEMA) studies for Q100 determinations. Where FEMA studies did not produce a Q100, the USGS contacted IDNR for an estimated Q100 in the vicinity of the site being studied. If IDNR did not have a Q100, data from nearby USGS streamflow-gaging stations were analyzed with nearby and similar drainage basins that have been coordinated. At sites having no coordinated discharge data, the two discharges used in the model were 1) the approximated Q100 and 2) a discharge equal to 1.7 times the approximated Q100.

Most of the cross-section and bridge-opening geometry data were taken from the bridge plans (Indiana State Highway Commission, 1969) provided by INDOT. Bridge plans are presumed to be representative of current conditions at the site. To determine the cross-section geometry, a line was drawn on the bridge plans parallel to the bridge stationing and approximately one bridge width from the bridge. For sites where the bridge plans did not extend far enough laterally for collection of all cross-section data required for WSPRO model analysis, additional data were collected from USGS 7.5-minute topographic maps.

The roadway and embankment profile was taken from the bridge and highway plans for those sites where roadway overtopping was expected. The INDOT bridge plans and 7.5-minute topographic maps were used as a guide, based on the water-surface elevations calculated by the WSPRO model, to determine if roadway overtopping might occur.

Roughness values (n-values) for the main channel were estimated by viewing photographs archived from the Level I scour assessments. The n-values for the overbanks were assigned on the basis of the surface-cover data summarized in the Level I data base (Hopkins and Robinson, unpub. data, 1997). From those data, the following roughness values were assigned to the surface-cover categories: urban—0.050, suburban—0.035, row crop—0.045, pasture—0.035, brush—0.120, forest—0.100, and wetland (any area covered by standing water)—0.100. The n-values for the overbanks were adjusted if the Level I photographs provided sufficient detail to warrant an adjustment.

WSPRO version V050196 was used to model flow through the study site. Starting water-surface elevation was obtained with a slope-conveyance computation. The channel-bed slope in the immediate vicinity of the bridge was estimated from the 7.5-minute topographic map and was used as the slope of the energy grade line for this computation.

WSPRO version V050196 includes a field that allows the input of up to four scour-adjustment factors (K1 to K4). For this modeling, the default value for K4 (bed armoring) was chosen. For scour-adjustment factors K1 and K2 (pier-nose shape and angle of attack, respectively), input values were determined by evaluating the data archived in the Level I data base (Hopkins and Robinson, unpub. data, 1997). For the K3 factor (bed forms), a value of 1.1 was applied in all cases.

In some cases, piers set on the overbanks are constructed with footings that are higher in elevation than pier footings in the main channel. In these situations, if the channel position changes, the piers that were initially constructed on the overbank may become part of the main channel. Therefore, to evaluate total potential scour, the model results obtained for contraction scour and deepest local scour in the main channel were added and applied to all piers in the bridge opening. This methodology allowed for an evaluation of potential undermining of pier supports in the event that future channel movement placed overbank piers in the main channel.

Where bridge pairs have a continuous abutment or fill between the bridges that does not allow expansion of flow, the bridge pair was modeled as one bridge. Sites with discontinuous abutments, allowing expansion between the bridges, were modeled as two separate bridges. In those cases, a valley cross section was measured between the bridges and used as the approach section for the downstream bridge and as the exit section for the upstream bridge.

At sites with no embankment to function as a weir or at sites where the tailwater drowns out the embankment, a composite bridge and road section was used to compute flow. Those sites were computed with friction-loss equations rather than with a bridge routine.

Total scour is taken as the sum of local scour plus contraction scour. If the model predicted negative contraction scour (aggradation), the contraction-scour value was assumed to be zero in determining the total scour depth (table 1). This assumption was made so that a negative contraction scour would not mask the potentially detrimental effects of local scour at a pier. No abutment scour evaluations were made in this study.

Table 1. Cumulative scour depths for the modeled discharges at structure I-64-83-5678 crossing Stinking Fork in Crawford 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 9,070 cubic feet per second							
2	356+37	490	0.7	8.4	9.1	487	480.9
Modeled discharge is 10,950 cubic feet per second							
2	356+37	490	2.0	8.8	10.8	487	479.2

[1]Pier numbers were assigned from left to right as shown on the bridge plans.

[2]Stationing is the center line of the pier as determined from the bridge plans. Stationing from bridge plan, 356+37, represents a point 35,637 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 (490.0 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.

Model runs also indicate that pier one and pier three, as shown on the bridge plans, are high enough in elevation that they are not within the area of flow for the discharges modeled. Therefore, these two piers were not evaluated for scour.

RESULTS

Scour depths were computed with a version of WSPRO (Larry Arneson, Federal Highway Administration, written commun., 1996) modified from Shearman (1990). This version of WSPRO includes scour calculations in the model output. Scour depths were calculated assuming an infinite depth of material that could erode and a homogeneous particle-size distribution. The results of the scour analysis are presented in table 1; a complete input file and output results are presented in the appendix.

REFERENCES

Hoggatt, R.E., 1975, Drainage areas of Indiana streams: U.S. Geological Survey, Water Resources Division, 231 p.

Indiana State Highway Commission, 1969, Bridge plans Interstate Route 64: Bridge File I-64-83-5678.

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-64 Over Stinking Fork              I64-83-5678
T2        County: Crawford                     Quad: Branchville 197-B
T3        7-8-97                               Bret A. Robinson
SI        0
Q         9070
Q         10950
SK        .0038  .0038
XS   EXIT 0 0
GR        34821 560  34870 550  34963 510  35502 500  35581 491  35603 490
GR        35624 491  35657 500  35685 500  35749 537  36016 550  36219 570
N         .035
XS   FULLV 301 0
GR        34821 560  34870 550  34963 510  35502 500  35581 491  35603 490
GR        35624 491  35657 500  35685 500  35749 537  36016 550  36192 570
N         .035
BR   BRDGE 301 535.5 0
GR        35488 0535.5  35488 0535.1  35591 0490  35634 0490  35656 0500
GR        35700 0500.0  35788 0537.4  35788 0538.0  35488 0535.5
N         .035
PD        491 3 2
CD        3 184 2 535
*          LXBr RXBr LXApp RXApp * TPierW
DC 0 BRDGE 35505 35795 35520 35680 * 9
*         LPierEdge RPierEdge PierWdth * * K1 K2 K3(1.1)
DP        35488 35788 3 * * 1 1 1.1
XS   APPR 786 0
GR        34678 580  34854 550  34941 510  35063 500  35509 500  35581 490
GR        35603 490  35624 490  35659 500  35684 500  35758 537  35853 550
GR        36356 600
N         .035
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/ 5/97 10:15 am     Version V050196
          Input File: 5678.dat       Output File: 5678.LST
   *-------------------------------------------------------------*
T1         I-64 OVER STINKING FORK            I64-83-5678
T2         COUNTY: CRAWFORD                   QUAD: BRANCHVILLE 197-B
T3         7-8-97                             BRET A. ROBINSON
SI         0
Q          9070
Q          10950

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

SK         .0038  .0038

   ************************  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-64 OVER STINKING FORK           I64-83-5678
    COUNTY: CRAWFORD                  QUAD: BRANCHVILLE 197-B
        7-8-97                            BRET A. ROBINSON

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

XS   EXIT 0 0
GR         34821 560  34870 550  34963 510  35502 500  35581 491  35603 490
GR         35624 491  35657 500  35685 500  35749 537  36016 550  36219 570
N          .035

 ***   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 (12 pairs)
     X          Y           X          Y           X          Y
----------  ----------  ----------  ----------  ----------  ----------
 34821.000     560.000    34870.000     550.000    34963.000     510.000
 35502.000     500.000    35581.000     491.000    35603.000     490.000
 35624.000     491.000    35657.000     500.000    35685.000     500.000
 35749.000     537.000    36016.000     550.000    36219.000     570.000
----------  ----------  ----------  ----------  ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   34821.000  ( associated Y-Elevation:  560.000 )
```

WSPRO OUTPUT

```
 Maximum X-Station:   36219.000  ( associated Y-Elevation:  570.000 )
 Minimum Y-Elevation:   490.000  ( associated X-Station:  35603.000 )
 Maximum Y-Elevation:   570.000  ( associated X-Station:  36219.000 )

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

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

  ************************* W S P R O ***************************
     Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
          Input Units: English  /  Output Units: English
  *-------------------------------------------------------------*
        I-64 OVER STINKING FORK          I64-83-5678
    COUNTY: CRAWFORD                 QUAD: BRANCHVILLE 197-B
        7-8-97                           BRET A. ROBINSON

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

XS   FULLV 301 0
GR        34821 560  34870 550  34963 510  35502 500  35581 491  35603 490
GR        35624 491  35657 500  35685 500  35749 537  36016 550  36192 570
N         .035

 ***   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:      301.   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 (12 pairs)
    X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 34821.000     560.000    34870.000     550.000    34963.000     510.000
 35502.000     500.000    35581.000     491.000    35603.000     490.000
 35624.000     491.000    35657.000     500.000    35685.000     500.000
 35749.000     537.000    36016.000     550.000    36192.000     570.000
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   34821.000  ( associated Y-Elevation:  560.000 )
  Maximum X-Station:   36192.000  ( associated Y-Elevation:  570.000 )
  Minimum Y-Elevation:   490.000  ( associated X-Station:  35603.000 )
```

WSPRO OUTPUT

```
 Maximum Y-Elevation:   570.000  ( associated X-Station:  36192.000 )

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

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

  ************************* W S P R O ***************************
     Federal Highway Administration  -  U. S. Geological Survey
           Model for Water-Surface Profile Computations.
          Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
        I-64 OVER STINKING FORK            I64-83-5678
    COUNTY: CRAWFORD                   QUAD: BRANCHVILLE 197-B
        7-8-97                             BRET A. ROBINSON

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

BR   BRDGE 301 535.5 0
GR        35488 0535.5  35488 0535.1  35591 0490  35634 0490  35656 0500
GR        35700 0500.0  35788 0537.4  35788 0538.0  35488 0535.5
N         .035
PD        491 3 2
CD        3 184 2 535

  ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate # 8 increased to eliminate vertical segment.
  ***   Storing Bridge Data In Temporary File As Record Number  3    ***

  ***              Data Summary For Bridge Record BRDGE              ***
  SRD Location:      301.   Cross-Section Skew:    .0   Error Code   0
  Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
  Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates ( 9 pairs)
     X          Y          X          Y          X          Y
 ----------  ----------  ----------  ----------  ----------  ----------
  35488.000     535.500    35488.100     535.100    35591.000     490.000
  35634.000     490.000    35656.000     500.000    35700.000     500.000
  35788.000     537.400    35788.100     538.000    35488.000     535.500
 ----------  ----------  ----------  ----------  ----------  ----------

                   Minimum and Maximum X,Y-coordinates
   Minimum X-Station:   35488.000  ( associated Y-Elevation:  535.500 )
   Maximum X-Station:   35788.100  ( associated Y-Elevation:  538.000 )
```

WSPRO OUTPUT

```
  Minimum Y-Elevation:   490.000  ( associated X-Station:  35634.000 )
  Maximum Y-Elevation:   538.000  ( associated X-Station:  35788.100 )

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

                     Discharge coefficient parameters
                BRType    BRWdth    EMBSS    EMBElv    UserCD
                  3       184.000   2.00    535.000 **********

                        Pressure flow elevations
                           AVBCEL      PFElev
                         *********     535.500

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


                     Pier/Pile Data (  1 Group(s) )
                   Code Indicates Bridge Uses Piers
                  Group  Elevation  Gross Width  Number
                 ------  ---------  -----------  ------
                    1      491.000      3.000       2
                 ------  ---------  -----------  ------

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

    ************************  W S P R O  ****************************
       Federal Highway Administration  -  U. S. Geological Survey
              Model for Water-Surface Profile Computations.
            Input Units: English  /  Output Units: English
    *-------------------------------------------------------------*
           I-64 OVER STINKING FORK            I64-83-5678
      COUNTY: CRAWFORD                  QUAD: BRANCHVILLE 197-B
          7-8-97                            BRET A. ROBINSON
DC 0 BRDGE 35505 35795 35520 35680 * 9
DP         35488 35788 3 * * 1 1 1.1

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

XS   APPR 786 0
GR         34678 580  34854 550  34941 510  35063 500  35509 500  35581 490
GR         35603 490  35624 490  35659 500  35684 500  35758 537  35853 550
GR         36356 600
N          .035
```

WSPRO OUTPUT

```
 ***   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:      786.   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 (13 pairs)
     X          Y             X          Y             X          Y
----------  ----------   ----------  ----------   ----------  ----------
 34678.000     580.000    34854.000     550.000    34941.000     510.000
 35063.000     500.000    35509.000     500.000    35581.000     490.000
 35603.000     490.000    35624.000     490.000    35659.000     500.000
 35684.000     500.000    35758.000     537.000    35853.000     550.000
 36356.000     600.000
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   34678.000  ( associated Y-Elevation:  580.000 )
  Maximum X-Station:   36356.000  ( associated Y-Elevation:  600.000 )
  Minimum Y-Elevation:   490.000  ( associated X-Station:  35624.000 )
  Maximum Y-Elevation:   600.000  ( associated X-Station:  36356.000 )

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

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-64 OVER STINKING FORK            I64-83-5678
      COUNTY: CRAWFORD                  QUAD: BRANCHVILLE 197-B
          7-8-97                            BRET A. ROBINSON
  EX

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

            Reach      Water Surface   Friction
```

WSPRO OUTPUT

#	Discharge	Elevation	Slope	Flow Regime
1	9070.00	********	.0038	Sub-Critical
2	10950.00	********	.0038	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-64 OVER STINKING FORK            I64-83-5678
  COUNTY: CRAWFORD                   QUAD: BRANCHVILLE 197-B
     7-8-97                              BRET A. ROBINSON
```

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	501.474	.828	9070.000	1242.769	*********	35422.530
Header Type: XS	502.303	******	7.298	147024.20	*********	35687.550
SRD: .000	498.571	******	.594	******	1.000	******
Section: FULLV	502.674	.499	9070.000	1600.656	301.000	35357.880
Header Type: FV	503.173	.872	5.666	193080.30	301.000	35689.630
SRD: 301.000	498.571	.000	.455	.0029	1.000	-.002

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
      KRATIO:  2.07
```

Section: APPR	503.579	.119	9070.000	3278.630	485.000	35019.330
Header Type: AS	503.698	.518	2.766	399278.60	485.000	35691.160
SRD: 786.000	498.029	.000	.221	.0011	1.000	.008

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

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

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDGE	502.198	1.423	9070.000	954.948	301.000	35563.170
Header Type: BR	503.620	1.236	9.498	141050.40	301.000	35705.170
SRD: 301.000	500.529	.079	.650	******	1.014	-.006

WSPRO OUTPUT

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.9930	.035	535.500	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	504.990	.071	9070.000	4240.547	301.000	35002.120
Header Type: AS	505.061	.362	2.139	600981.80	360.112	35693.980
SRD: 786.000	498.029	1.081	.152	.0011	1.000	.008

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.785	.396	362462.1	********	********	504.990

<<< 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-64 OVER STINKING FORK I64-83-5678

COUNTY: CRAWFORD QUAD: BRANCHVILLE 197-B

7-8-97 BRET A. ROBINSON

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	502.312	.846	10950.000	1484.349	*********	35377.370
Header Type: XS	503.159	******	7.377	177499.00	*********	35689.000
SRD: .000	499.369	******	.596	******	1.000	******
Section: FULLV	503.504	.519	10950.000	1895.234	301.000	35313.140
Header Type: FV	504.023	.867	5.778	234620.40	301.000	35691.060
SRD: 301.000	499.369	.000	.455	.0029	1.000	-.002

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
KRATIO: 2.18

Section: APPR	504.386	.127	10950.000	3825.403	485.000	35009.490
Header Type: AS	504.514	.486	2.862	510445.70	485.000	35692.770
SRD: 786.000	498.856	.000	.213	.0010	1.000	.005

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

WSPRO OUTPUT

<<< 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	502.847	1.780	10950.000	1048.146	301.000	35561.690
Header Type: BR	504.627	1.296	10.447	162329.20	301.000	35706.700
SRD: 301.000	501.274	.171	.702	******	1.048	-.002

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.9766	.034	535.500	********	********	********

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	506.090	.074	10950.000	5010.500	301.000	34988.700
Header Type: AS	506.165	.361	2.185	781751.30	368.397	35696.180
SRD: 786.000	498.856	1.178	.145	.0010	1.000	.008

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.783	.464	417980.2	********	********	506.090

<<< 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-64 OVER STINKING FORK I64-83-5678
COUNTY: CRAWFORD QUAD: BRANCHVILLE 197-B
7-8-97 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): 9.000

Scour	-- Flow --	-- Width --	--- X-Limits ---

WSPRO OUTPUT

#	Depth	Contract	Approach	Contract	Approach	Side	Contract	Approach
1	.729	9070.000	5506.029	281.000	160.000	Left:	********	********
	..... Approach Channel Depth:		10.969			Right:	********	********
2	1.989	10950.000	5992.945	281.000	160.000	Left:	********	********
	..... Approach Channel Depth:		12.069			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-64 OVER STINKING FORK            I64-83-5678
  COUNTY: CRAWFORD                  QUAD: BRANCHVILLE 197-B
      7-8-97                            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	8.45	9070.000	503.279	13.279	10.943	.529	35488.000	35788.000
2	8.81	10950.000	504.025	14.025	11.869	.558	35488.000	35788.000

```
  ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes  2 Seconds  **************
```