Modified Level II Streambed-Scour Analysis for Structure I-164-10-6969 Crossing Boesche Ditch in Vanderburgh County, Indiana

By JOHN T. WILSON, 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	U. S. Geological Survey
WSPRO	Water Surface PROfile model

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By John T. Wilson, 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-164-10-6969 on Interstate 164 crossing Boesche Ditch in Vanderburgh County, Indiana, are presented. The site is near the city of Evansville in the southeastern part of Vanderburgh County. Scour depths were computed with the Water Surface PROfile model, version V050196, which incorporates the scour-calculation procedures outlined in Hydraulic Engineering Circular No. 18. Total scour depths at the piers were approximately 6.4 feet for the modeled discharge of 850 cubic feet per second and approximately 8.9 feet for the modeled discharge of 1,190 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-164-10-6969.

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 city of Evansville in the southeastern part of Vanderburgh County. The drainage area for the site is approximately 1.25 mi^2 (Merril Dougherty, Indiana Department of Transportation, written commun., 1997). The predominant land use in the basin is agricultural; in the immediate vicinity of the bridge, the land is predominantly row crop.

Within the immediate vicinity of the bridge, Boesche Ditch has a channel-bed slope of approximately 0.0016 ft/ft. The channel-bed material is silt-clay, and the channel banks consist of silt-clay. At the time of the Level I site visit on December 19, 1991, the banks were observed to have zero percent woody vegetative cover; and the field report noted that the banks were stable.

The Interstate 164 crossing of Boesche Ditch is a 96-ft-long, multi-lane bridge consisting of three spans supported by steel piles 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 USGS 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, 1984) 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-164-10-6969 crossing Boesche Ditch in Vanderburgh 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 850 cubic feet per second							
1	950+69	372	3.1	3.3	6.4	--	359.4
2	951+06	373	3.1	3.3	6.4	--	359.4
Modeled discharge is 1,190 cubic feet per second							
1	950+69	372	5.3	3.6	8.9	--	356.9
2	951+06	373	5.3	3.6	8.9	--	356.9

[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, 950+69, represents a point 95,069 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 (365.8 feet).

[5]Not a coordinated discharge.

SPECIAL CONSIDERATIONS

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

The bases of the piles are protected by the riprap-covered slopewalls. The bridge plans indicate that the piles are driven to bedrock at an unspecified elevation (Indiana State Highway Commission, 1984). The bridge was modeled and scour was computed as if these protective measures did not exist.

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, 1984, Bridge plans Interstate Route 164: Bridge File I-164-10-6969.

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-164 OVER BOESCHE DITCH     I164-10-6969
T2          COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
T3          7-29-97                      JOHN T. WILSON
Q           850      1190
SK          .0016    .0016
XS   EXIT   0
GR         94650 380  95087 372  95090 370  95107 366  95123 370  95136 376
GR         95139 378  95156 380
N          .045        .034
SA               95087
XS   FULLV  93
BR   BRDGE  93   385.0   8
*          ***BRIDGE DECK SKEWED 8 DEGREES (FROM BRIDGE PLANS)***
GR         95041 385.2  95041 384.4  95043 384.4  95080 366.8  95087 365.8
GR         95095 367.5  95100 370.0  95130 384.4  95134 384.4  95134 385.3
GR         95041 385.2
N          .038
PD 1       372.0   1.2   1
PD 1       372.8   1.2   2
PD 1       372.8   2.4   3
PD 1       383.8   5.0   4
CD         3    138    2    388
DC 0 BRDGE  95067  95107  95047  95097  *  2.4
*           ***APPROX. LEW & REW OF Q1 USED FOR DC LIMITS***
*           BXL       BXR       PW    *  *  K1  K2  K3
DP          95041     95134     1.2   *  *  1   1   1.1
DP          95041     95134     1.2   *  *  1   1   1.1
*           ***DP CARDS USE WHOLE BRIDGE OPENING FOR BXL/BXR***
XS   APPR   324
GR         94500 380  94946 372  95047 372  95051 370  95071 366  95084 370
GR         95103 376  95126 376  95142 376  95208 378  95243 380
N          .045        .034        .045
SA               95047       95103
HP 2 BRDGE  373.6  *  373.6   850
HP 2 BRDGE  374.4  *  374.4   1190
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/ 7/97 10:23 am     Version V050196
           Input File: BOESCHE.DAT    Output File: BOESCHE.LST
   *-------------------------------------------------------------*
T1          I-164 OVER BOESCHE DITCH     I164-10-6969
T2          COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
T3          7-29-97                      JOHN T. WILSON
Q           850     1190

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

SK          .0016   .0016

   ************************  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-164 OVER BOESCHE DITCH     I164-10-6969
           COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
              7-29-97                      JOHN T. WILSON

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

XS   EXIT  0
GR         94650 380  95087 372  95090 370  95107 366  95123 370  95136 376
GR         95139 378  95156 380
N          .045       .034
SA               95087

 ***   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 ( 8 pairs)
    X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 94650.000     380.000    95087.000     372.000    95090.000     370.000
 95107.000     366.000    95123.000     370.000    95136.000     376.000
 95139.000     378.000    95156.000     380.000
----------  ----------   ----------  ----------   ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   94650.000  ( associated Y-Elevation:  380.000 )
  Maximum X-Station:   95156.000  ( associated Y-Elevation:  380.000 )
  Minimum Y-Elevation:   366.000  ( associated X-Station:  95107.000 )
  Maximum Y-Elevation:   380.000  ( associated X-Station:  94650.000 )

                    Roughness Data (  2 SubAreas )
                            Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .045        ---
                                ---       ********
                      2         .034        ---
                   -------  -----------  ----------

          *--------------------------------------------------*
          *      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-164 OVER BOESCHE DITCH    I164-10-6969
           COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
              7-29-97                      JOHN T. WILSON

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

XS   FULLV  93

  ***   Completed Reading Data Associated With Header Record FULLV   ***
  ***   No Roughness Data Input, Propagating From Previous Section   ***
  ***  Storing X-Section Data In Temporary File As Record Number  2  ***

  ***              Data Summary For Header Record FULLV              ***
  SRD Location:       93.   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 ( 8 pairs)
      X          Y          X          Y          X          Y
 ----------  ----------  ----------  ----------  ----------  ----------
  94650.000     380.000    95087.000     372.000    95090.000     370.000
  95107.000     366.000    95123.000     370.000    95136.000     376.000
  95139.000     378.000    95156.000     380.000
 ----------  ----------  ----------  ----------  ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   94650.000  ( associated Y-Elevation:  380.000 )
  Maximum X-Station:   95156.000  ( associated Y-Elevation:  380.000 )
  Minimum Y-Elevation:   366.000  ( associated X-Station:  95107.000 )
  Maximum Y-Elevation:   380.000  ( associated X-Station:  94650.000 )

                   Roughness Data (  2 SubAreas )
                            Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .045        ---
                               ---       ********
                     2         .034        ---
                  -------  -----------  ----------

        *-----------------------------------------------------*
        *      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-164 OVER BOESCHE DITCH    I164-10-6969
          COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
             7-29-97                      JOHN T. WILSON

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

 BR   BRDGE  93    385.0    8
 GR         95041 385.2  95041 384.4  95043 384.4  95080 366.8  95087 365.8
 GR         95095 367.5  95100 370.0  95130 384.4  95134 384.4  95134 385.3
 GR         95041 385.2
 N          .038
 PD 1       372.0    1.2    1
 PD 1       372.8    1.2    2
 PD 1       372.8    2.4    3
 PD 1       383.8    5.0    4
 CD         3     138     2     388

  ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #10 increased to eliminate vertical segment.
  ***   Storing Bridge Data In Temporary File As Record Number  3    ***

  ***              Data Summary For Bridge Record BRDGE             ***
  SRD Location:        93.   Cross-Section Skew:   8.0   Error Code   0
  Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
  Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

WSPRO OUTPUT

X,Y-coordinates (11 pairs)

X	Y	X	Y	X	Y
95041.000	385.200	95041.100	384.400	95043.000	384.400
95080.000	366.800	95087.000	365.800	95095.000	367.500
95100.000	370.000	95130.000	384.400	95134.000	384.400
95134.100	385.300	95041.000	385.200		

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 95041.000 (associated Y-Elevation: 385.200)
Maximum X-Station: 95134.100 (associated Y-Elevation: 385.300)
Minimum Y-Elevation: 365.800 (associated X-Station: 95087.000)
Maximum Y-Elevation: 385.300 (associated X-Station: 95134.100)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
95041.000	95041.450	95041.100	95041.550	95043.000	95043.430
95080.000	95080.070	95087.000	95087.000	95095.000	95094.920
95100.000	95099.880	95130.000	95129.580	95134.000	95133.540
95134.100	95133.640	95041.000	95041.450		

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.038	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	138.000	2.00	388.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	385.000

Abutment Parameters

ABSLPL	ABSLPR	XTOELT	YTOELT	XTOERT	YTOERT
*******	*******	*********	*********	*********	*********

Pier/Pile Data (4 Group(s))

Code Indicates Bridge Uses Piles

Group	Elevation	Gross Width	Number
1	372.000	1.200	1
2	372.800	1.200	2
3	372.800	2.400	3
4	383.800	5.000	4

WSPRO OUTPUT

```
          *-------------------------------------------------*
          *      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-164 OVER BOESCHE DITCH    I164-10-6969
           COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
              7-29-97                      JOHN T. WILSON
DC 0 BRDGE  95067  95107  95047  95097  *  2.4
DP          95041    95134    1.2  *  *  1   1   1.1
DP          95041    95134    1.2  *  *  1   1   1.1

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

XS   APPR   324
GR         94500 380  94946 372  95047 372  95051 370  95071 366  95084 370
GR         95103 376  95126 376  95142 376  95208 378  95243 380
N          .045       .034       .045
SA               95047      95103

 ***   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:      324.   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 (11 pairs)
    X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 94500.000     380.000    94946.000     372.000    95047.000     372.000
 95051.000     370.000    95071.000     366.000    95084.000     370.000
 95103.000     376.000    95126.000     376.000    95142.000     376.000
 95208.000     378.000    95243.000     380.000
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   94500.000  ( associated Y-Elevation:  380.000 )
  Maximum X-Station:   95243.000  ( associated Y-Elevation:  380.000 )
  Minimum Y-Elevation:   366.000  ( associated X-Station:  95071.000 )
  Maximum Y-Elevation:   380.000  ( associated X-Station:  94500.000 )
```

WSPRO OUTPUT

```
                  Roughness Data (  3 SubAreas )
                           Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .045        ---
                              ---        ********
                    2         .034        ---
                              ---        ********
                    3         .045        ---
                 -------  -----------  ----------

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-164 OVER BOESCHE DITCH    I164-10-6969
           COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
              7-29-97                      JOHN T. WILSON
  HP 2 BRDGE  373.6  *  373.6   850
  HP 2 BRDGE  374.4  *  374.4   1190
  EX

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

            Reach      Water Surface   Friction
     #   Discharge      Elevation       Slope          Flow Regime
    --   ---------    ------------   --------   --------------------
     1     850.00      ********         .0016        Sub-Critical
     2     1190.00     ********         .0016        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-164 OVER BOESCHE DITCH    I164-10-6969
           COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
              7-29-97                      JOHN T. WILSON
```

WSPRO OUTPUT

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	373.072	.302	850.000	215.182	*********	95028.450
Header Type: XS	373.374	******	3.950	21243.54	*********	95129.660
SRD: .000	370.789	******	.533	******	1.244	******
Section: FULLV	373.252	.267	850.000	234.314	93.000	95018.630
Header Type: FV	373.519	.138	3.628	22912.52	93.000	95130.050
SRD: 93.000	370.789	.000	.504	.0015	1.306	.007

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
KRATIO: 1.49

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	373.629	.098	850.000	455.635	231.000	94855.180
Header Type: AS	373.727	.213	1.866	34191.76	231.000	95095.490
SRD: 324.000	370.797	.000	.321	.0009	1.808	-.005

<<< 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	373.197	.361	850.000	176.545	93.000	95066.550
Header Type: BR	373.557	.181	4.815	17668.70	93.000	95106.660
SRD: 93.000	370.612	.003	.405	******	1.000	.000

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1						
Pier/Pile Code 1	1.0000	.011	385.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	373.991	.068	850.000	546.462	93.000	94835.010
Header Type: AS	374.059	.109	1.555	41451.59	108.786	95096.640
SRD: 324.000	370.797	.393	.254	.0009	1.797	.002

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.832	.311	28532.1	********	********	373.991

WSPRO OUTPUT

<<< 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-164 OVER BOESCHE DITCH     I164-10-6969
        COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
           7-29-97                      JOHN T. WILSON
```

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	373.872	.337	1190.000	314.326	*********	94984.750
Header Type: XS	374.208	******	3.786	29724.97	*********	95131.390
SRD: .000	371.487	******	.560	******	1.510	******
Section: FULLV	374.061	.293	1190.000	343.049	93.000	94974.430
Header Type: FV	374.353	.138	3.469	32165.57	93.000	95131.800
SRD: 93.000	371.487	.000	.518	.0015	1.563	.007

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

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===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
      KRATIO:  1.63
```

Section: APPR	374.462	.085	1190.000	676.092	231.000	94808.770
Header Type: AS	374.546	.194	1.760	52435.87	231.000	95098.130
SRD: 324.000	371.507	.000	.269	.0008	1.758	-.001

<<< 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	373.902	.566	1190.000	205.844	93.000	95065.070
Header Type: BR	374.468	.207	5.781	21737.68	93.000	95108.130
SRD: 93.000	371.463	.051	.486	******	1.089	-.002

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 1	.9582	.018	385.000	********	********	********
-------------------------	------	-----	--------	--------	--------	--------

WSPRO OUTPUT

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	375.033	.052	1190.000	851.056	93.000	94776.910
Header Type: AS	375.085	.109	1.398	68255.66	111.578	95099.940
SRD: 324.000	371.507	.509	.198	.0008	1.697	.008

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.849	.460	36714.2	********	********	375.033

<<< 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-164 OVER BOESCHE DITCH I164-10-6969
COUNTY: VANDERBURGH QUAD: DAYLIGHT 194C
7-29-97 JOHN T. WILSON

*** Beginning Velocity Distribution For Header Record BRDGE ***
SRD Location: 93.000 Header Record Number 3

Water Surface Elevation: 373.600 Element # 1
Flow: 850.000 Velocity: 4.40 Hydraulic Depth: 4.619
Cross-Section Area: 193.06 Conveyance: 19936.13
Bank Stations -> Left: 95065.700 Right: 95107.500

X STA.	95065.7	95074.4	95076.9	95078.7	95080.1	95081.3
A(I)		17.8	11.9	10.3	9.3	8.4
V(I)		2.39	3.57	4.14	4.57	5.05
D(I)		2.06	4.71	5.74	6.50	6.90

X STA.	95081.3	95082.5	95083.6	95084.6	95085.6	95086.6
A(I)		8.2	7.9	7.7	7.5	7.6
V(I)		5.20	5.37	5.50	5.64	5.63
D(I)		7.07	7.23	7.38	7.53	7.67

X STA.	95086.6	95087.5	95088.6	95089.6	95090.7	95091.9
A(I)		7.4	7.7	7.6	8.0	8.2
V(I)		5.75	5.52	5.60	5.30	5.20
D(I)		7.75	7.58	7.36	7.13	6.88

X STA.	95091.9	95093.2	95094.7	95096.4	95098.9	95107.5
A(I)		8.6	9.2	10.3	11.9	17.7
V(I)		4.95	4.62	4.14	3.57	2.40
D(I)		6.62	6.33	5.82	4.76	2.06

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-164 OVER BOESCHE DITCH    I164-10-6969
       COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
          7-29-97                      JOHN T. WILSON

***    Beginning Velocity Distribution For Header Record BRDGE    ***
       SRD Location:     93.000       Header Record Number  3

     Water Surface Elevation:    374.400              Element # 1
     Flow:    1190.000   Velocity:  5.22  Hydraulic Depth:   5.047
     Cross-Section Area:    227.82         Conveyance:    24920.60
        Bank Stations ->  Left:  95064.020   Right:  95109.160

X STA.     95064.0    95073.4    95076.2    95078.1    95079.7    95081.0
  A( I )              20.8       14.3       12.2       11.0        9.9
  V( I )              2.86       4.17       4.88       5.41       6.01
  D( I )              2.22       5.11       6.24       7.07       7.63

X STA.     95081.0    95082.2    95083.4    95084.5    95085.6    95086.6
  A( I )               9.7        9.3        9.1        9.0        8.7
  V( I )              6.16       6.39       6.57       6.59       6.81
  D( I )              7.83       8.00       8.16       8.32       8.47

X STA.     95086.6    95087.6    95088.7    95089.8    95091.0    95092.3
  A( I )               8.8        8.9        9.2        9.2        9.8
  V( I )              6.75       6.70       6.47       6.49       6.06
  D( I )              8.55       8.35       8.12       7.88       7.62

X STA.     95092.3    95093.7    95095.2    95097.1    95099.8    95109.2
  A( I )              10.1       10.8       12.2       13.9       21.0
  V( I )              5.87       5.51       4.88       4.29       2.83
  D( I )              7.33       7.02       6.32       5.17       2.25

************************* 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-164 OVER BOESCHE DITCH    I164-10-6969
       COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
          7-29-97                      JOHN T. WILSON
```

WSPRO OUTPUT

*** 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):	2.400

#	Scour Depth	-- Flow -- Contract	Approach	-- Width -- Contract	Approach	--- X-Limits --- Side	Contract	Approach
1	3.139	850.000	577.281	37.600	50.000	Left:	********	********
	..... Approach Channel Depth:	4.698				Right:	********	********
2	5.324	1190.000	681.942	37.600	50.000	Left:	********	********
	..... Approach Channel Depth:	5.739				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-164 OVER BOESCHE DITCH I164-10-6969
COUNTY: VANDERBURGH QUAD: DAYLIGHT 194C
7-29-97 JOHN T. WILSON

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

Constants and Input Variables

Pier Width: 1.200

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	3.29	850.000	373.590	7.790	5.758	.364	95041.000	95134.000
2	3.58	1190.000	374.411	8.611	6.805	.409	95041.000	95134.000

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-164 OVER BOESCHE DITCH     I164-10-6969
       COUNTY: VANDERBURGH          QUAD: DAYLIGHT 194C
          7-29-97                      JOHN T. WILSON

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

                Constants and Input Variables

                    Pier Width:   1.200
            *-----------------------------------------*
              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	3.29	850.000	373.590	7.790	5.758	.364	95041.000	95134.000
2	3.58	1190.000	374.411	8.611	6.805	.409	95041.000	95134.000

```
  ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes 40 Seconds  **************
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