Modified Level II Streambed-Scour Analysis for Structure I-465-158-4458 Crossing State Ditch in Marion County, Indiana

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

Prepared in cooperation with the
INDIANA DEPARTMENT OF TRANSPORTATION

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Denver, CO 80225

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

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-465-158-4458 on Interstate 465 crossing State Ditch in Marion County, Indiana, are presented. The site is in the city of Indianapolis in the southwestern part of Marion 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 28.9 feet for the modeled discharge of 4,300 cubic feet per second and approximately 38.6 feet for the modeled discharge of 6,450 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-465-158-4458.

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 in the city of Indianapolis in the southwestern part of Marion County. The drainage area for the site is approximately 9.5 mi^2 (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is urban; in the immediate vicinity of the bridge, the land is predominantly suburban with some pasture land nearby.

Within the immediate vicinity of the bridge, State Ditch has a channel-bed slope of approximately 0.004 ft/ft. The channel-bed material is gravelly sandy silt-clay, and the channel banks consist of gravelly sandy silt-clay. At the time of the Level I site visit on May 23, 1995, the banks were observed to have 26 to 75 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 465 crossing of State Ditch is a 116-ft-long, multi-lane bridge consisting of three spans supported by concrete and steel piers and sloping concrete spill-through abutments. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.

EVALUATION METHODS

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

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

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

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

Most of the cross-section and bridge-opening geometry data were taken from the bridge plans (Indiana State Highway Commission, 1959) 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-465-158-4458 crossing State Ditch in Marion 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 4,300 cubic feet per second							
1	182+33	661	15.3	13.6	28.9	655	631.2
2	182+82	661	15.3	13.6	28.9	655	631.2
Modeled discharge is 6,450 cubic feet per second							
1	182+33	661	24.4	14.2	38.6	655	621.5
2	182+82	661	24.4	14.2	38.6	655	621.5

[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, 182+33, represents a point 18,233 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 at the bridge opening (660.1 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.

This site is unique because of the presence of the Thompson Road bridge 45 ft downstream from the I-465-158-4458 bridge structure. The Thompson Road bridge opening is much smaller than the Interstate bridge opening and creates a major constriction in the downstream channel. The site was modeled, starting with a valley section downstream from this constriction.

A composite section was developed to represent the Thompson Road bridge, and the flow was routed through this constriction and the I-465-158-4458 bridge opening. The model calculated initial water-surface elevations based on the valley cross section. From those calculations, it was determined that critical flow occurred at the Thompson Road bridge. The model calculated a drop in water surface of more than 8 ft from the constricted opening of the Thompson Road bridge to the valley cross section. This flow solution does not appear to be unreasonable, based on the channel geometry provided on the bridge plans. Caution should be exercised, however, in using the results of this model because of the complex channel geometry and stream hydraulics in the study reach.

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, 1959, Bridge plans Interstate Route 465: Bridge File I-465-158-4458.

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-465 over State Ditch                  I-465-158-4458
T2          County: Marion                          Quad: Maywood, IND 124A
T3          8-12-97                                 David C Voelker
SI          0
J1          0.05    *    *  *
*           Q-100       Q-500
Q           4300        6450
*           WS                      669.65
*            SLOPE
SK          .004        .004
*           SRD SKEW   (EK)   (CK)   (VSLOPE)
XS    VALL -206
GR          18234 675   18237 674   18242 673   18246 672   18256 671   18276 670
GR          18289 669   18304 668   18361 667   18378 666   18381 665   18384 664
GR          18387 663   18389 662   18390 661   18392 655   18399 654   18405 655
GR          18407 659   18414 660   18416 661   18418 662   18420 663   18422 664
GR          18424 665   18509 680   18556 675   18569 670   18637 665   18733 660
GR          19385 660   19475 665   19644 665   21182 670   21219 675
*           N1            N2            N3
N           .050          .035          .050
*                 SA            SA
SA                18390         18414
XS    EXIT  0
GR          18205 677.4   18254 673   18273 671.6   18284 671.6   18284 657.4
GR          18292 656.6   18303 656.4   18314 657.8   18323 660.0   18323 671.6
GR          18337 671.6   18340 670   18381 677.4
*           N1            N2            N3
N           .050          .035          .050
*                 SA            SA
SA                18283         18323
*            SRD SKEW   (EK)  (CK)  (VSLOPE)
XS    FULLV 45
GR          18205 677.4   18254 673   18273 671.6   18284 671.6   18284 657.4
GR          18292 656.6   18303 656.4   18314 657.8   18323 660.0   18323 671.6
GR          18337 671.6   18340 670   18381 677.4
*           N1            N2            N3
N           .050          .035          .050
*                 SA            SA
SA                18283         18323
*             SRD     LSEL     SKEW    (EK)   (CK)  (USERCD)
BR    BRDGE  45      675.5     15
GR          18202 0675.9   18233 0661.3   18256 0660.2   18281 0661.2   18314 0676.0
GR          18310 0676.0   18306 0675.9   18291 0675.4   18287 0675.0   18285 0674.8
GR          18283 0674.6   18281 0674.5   18279 0674.9   18276 0675.1   18272 0675.4
GR          18268 0675.7   18265 0675.8   18260 0676.0   18257 0676.0   18254 0676.0
GR          18249 0675.9   18245 0675.7   18242 0675.4   18240 0675.2   18237 0674.9
GR          18234 0674.5   18232 0674.5   18230 0674.7   18228 0675.0   18225 0675.2
GR          18222 0675.4   18216 0675.7   18213 0675.8   18208 0675.9   18203 0675.9
GR          18202 0675.9
*                 N1
N                 .036
*   BLANK=
*   PIERS,
*   1=PILES PELV PDDTH
```

WSPRO INPUT FILE

```
PD 0       661.6    4.0    1
*          BRTYPE BRWDTH EMBSS EMBELV WWANGL WWWID ENTRND
CD           3      140     2     676
*  X=0 FOR LIVE BED OR 1 FOR CLEARWATER
*              BXL   BXR    AXL    AXR
*                                      X=K1 OR D50
*                                          PW
DC 0 BRDGE   18202    18314   18185   18238   *   4.0
DP   BRDGE   18202    18314    2     *    *    1.0    2.49
DP   BRDGE   18202    18314    2     *    *    1.0    2.49
*            SRD SKEW (EK) (CK) (VSLOPE)
XS   APPR    325
GR         17846 685   17885 680   17939 675   17995 670   18036 667   18046 666
GR         18049 665   18052 664   18084 664   18088 665   18100 666   18109 667
GR         18179 667   18190 660.5  18240 660.5  18254 667   18323 667   18462 666
GR         18686 665   18795 670
N                .035       .06          .036         .06          .035
SA                   18100        18175       18250        18290
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:  8/12/97  2:44 pm     Version V050196
          Input File: 4458.dat       Output File: 4458.LST
   *-------------------------------------------------------------*
T1         I-465 OVER STATE DITCH                 I-465-158-4458
T2         COUNTY: MARION                         QUAD: MAYWOOD, IND 124A
T3         8-12-97                                DAVID C VOELKER
SI         0
J1         0.05   *   *  *

     *-----------------------------------------------------------*
              Computational Control (J1) Parameters
            -----------------------------------------------
            Trial WSE Stepping Increment     (DeltaY):   .05
            Allowable Elevation Tolerance      (yTol):   .02
            Allowable Discharge Tolerance      (qTol):   .02
            Maximum Froude Number Test Value (FNTest):   .80
            Friction-Loss Computation Method (IHFNOJ):   0
     *-----------------------------------------------------------*

Q          4300      6450

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

SK         .004      .004

   ************************  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-465 OVER STATE DITCH                 I-465-158-4458
    COUNTY: MARION                         QUAD: MAYWOOD, IND 124A
        8-12-97                                DAVID C VOELKER

          *-------------------------------------------------*
          *      Starting To Process Header Record VALL     *
          *-------------------------------------------------*

XS   VALL -206
GR         18234 675  18237 674  18242 673  18246 672  18256 671  18276 670
GR         18289 669  18304 668  18361 667  18378 666  18381 665  18384 664
GR         18387 663  18389 662  18390 661  18392 655  18399 654  18405 655
GR         18407 659  18414 660  18416 661  18418 662  18420 663  18422 664
GR         18424 665  18509 680  18556 675  18569 670  18637 665  18733 660
GR         19385 660  19475 665  19644 665  21182 670  21219 675
N           .050        .035       .050
SA               18390      18414

 ***   Completed Reading Data Associated With Header Record VALL    ***
 ***  Storing X-Section Data In Temporary File As Record Number  1  ***
```

WSPRO OUTPUT

```
***                Data Summary For Header Record VALL                  ***
SRD Location:      -206.   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 (35 pairs)
    X          Y           X          Y           X          Y
---------  ---------   ---------  ---------   ---------  ---------
18234.000     675.000   18237.000     674.000   18242.000     673.000
18246.000     672.000   18256.000     671.000   18276.000     670.000
18289.000     669.000   18304.000     668.000   18361.000     667.000
18378.000     666.000   18381.000     665.000   18384.000     664.000
18387.000     663.000   18389.000     662.000   18390.000     661.000
18392.000     655.000   18399.000     654.000   18405.000     655.000
18407.000     659.000   18414.000     660.000   18416.000     661.000
18418.000     662.000   18420.000     663.000   18422.000     664.000
18424.000     665.000   18509.000     680.000   18556.000     675.000
18569.000     670.000   18637.000     665.000   18733.000     660.000
19385.000     660.000   19475.000     665.000   19644.000     665.000
21182.000     670.000   21219.000     675.000
---------  ---------   ---------  ---------   ---------  ---------

                Minimum and Maximum X,Y-coordinates
 Minimum X-Station:   18234.000  ( associated Y-Elevation:  675.000 )
 Maximum X-Station:   21219.000  ( associated Y-Elevation:  675.000 )
 Minimum Y-Elevation:   654.000  ( associated X-Station:  18399.000 )
 Maximum Y-Elevation:   680.000  ( associated X-Station:  18509.000 )

                  Roughness Data (  3 SubAreas )
                         Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .050        ---
                             ---        ********
                   2         .035        ---
                             ---        ********
                   3         .050        ---
                -------  -----------  ----------

       *-------------------------------------------------*
       *      Finished Processing Header Record VALL     *
       *-------------------------------------------------*

  ************************* 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-465 OVER STATE DITCH              I-465-158-4458
   COUNTY: MARION                      QUAD: MAYWOOD, IND 124A
      8-12-97                             DAVID C VOELKER

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

WSPRO OUTPUT

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

  XS   EXIT  0
  GR         18205 677.4  18254 673  18273 671.6  18284 671.6  18284 657.4
  GR         18292 656.6  18303 656.4  18314 657.8  18323 660.0  18323 671.6
  GR         18337 671.6  18340 670  18381 677.4
  N           .050         .035        .050
  SA               18283       18323

   ***   Completed Reading Data Associated With Header Record EXIT     ***
+++072 NOTICE:  X-coordinate # 5 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #10 increased to eliminate vertical segment.
   ***  Storing X-Section Data In Temporary File As Record Number  2  ***

   ***               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 (13 pairs)
      X          Y             X          Y             X          Y
 ----------  ----------    ----------  ----------    ----------  ----------
  18205.000     677.400     18254.000     673.000     18273.000     671.600
  18284.000     671.600     18284.100     657.400     18292.000     656.600
  18303.000     656.400     18314.000     657.800     18323.000     660.000
  18323.100     671.600     18337.000     671.600     18340.000     670.000
  18381.000     677.400
 ----------  ----------    ----------  ----------    ----------  ----------

                  Minimum and Maximum X,Y-coordinates
    Minimum X-Station:    18205.000  ( associated Y-Elevation:  677.400 )
    Maximum X-Station:    18381.000  ( associated Y-Elevation:  677.400 )
    Minimum Y-Elevation:    656.400  ( associated X-Station:  18303.000 )
    Maximum Y-Elevation:    677.400  ( associated X-Station:  18205.000 )

                     Roughness Data (  3 SubAreas )
                              Roughness    Horizontal
                    SubArea  Coefficient  Breakpoint
                    -------  -----------  ----------
                       1         .050         ---
                                  ---       ********
                       2         .035         ---
                                  ---       ********
                       3         .050         ---
                    -------  -----------  ----------

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

WSPRO OUTPUT

```
*-------------------------------------------------------------*
     I-465 OVER STATE DITCH              I-465-158-4458
 COUNTY: MARION                      QUAD: MAYWOOD, IND 124A
     8-12-97                             DAVID C VOELKER

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

XS   FULLV 45
GR        18205 677.4  18254 673  18273 671.6  18284 671.6  18284 657.4
GR        18292 656.6  18303 656.4  18314 657.8  18323 660.0  18323 671.6
GR        18337 671.6  18340 670  18381 677.4
N         .050         .035       .050
SA              18283      18323

  ***   Completed Reading Data Associated With Header Record FULLV   ***
+++072 NOTICE:  X-coordinate # 5 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #10 increased to eliminate vertical segment.
  ***  Storing X-Section Data In Temporary File As Record Number  3  ***

  ***              Data Summary For Header Record FULLV              ***
  SRD Location:       45.   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
----------  ----------   ----------  ----------   ----------  ----------
 18205.000     677.400    18254.000     673.000    18273.000     671.600
 18284.000     671.600    18284.100     657.400    18292.000     656.600
 18303.000     656.400    18314.000     657.800    18323.000     660.000
 18323.100     671.600    18337.000     671.600    18340.000     670.000
 18381.000     677.400
----------  ----------   ----------  ----------   ----------  ----------

                 Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   18205.000  ( associated Y-Elevation:  677.400 )
  Maximum X-Station:   18381.000  ( associated Y-Elevation:  677.400 )
  Minimum Y-Elevation:   656.400  ( associated X-Station:  18303.000 )
  Maximum Y-Elevation:   677.400  ( associated X-Station:  18205.000 )

                   Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                  SubArea Coefficient Breakpoint
                  ------- ----------- ----------
                     1         .050        ---
                               ---       ********
                     2         .035        ---
                               ---       ********
                     3         .050        ---
                  ------- ----------- ----------

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

WSPRO OUTPUT

```
          *      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-465 OVER STATE DITCH                 I-465-158-4458
      COUNTY: MARION                         QUAD: MAYWOOD, IND 124A
          8-12-97                                DAVID C VOELKER

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

   BR   BRDGE  45      675.5     15
   GR         18202 0675.9  18233 0661.3  18256 0660.2  18281 0661.2  18314
0676.0
   GR         18310 0676.0  18306 0675.9  18291 0675.4  18287 0675.0  18285
0674.8
   GR         18283 0674.6  18281 0674.5  18279 0674.9  18276 0675.1  18272
0675.4
   GR         18268 0675.7  18265 0675.8  18260 0676.0  18257 0676.0  18254
0676.0
   GR         18249 0675.9  18245 0675.7  18242 0675.4  18240 0675.2  18237
0674.9
   GR         18234 0674.5  18232 0674.5  18230 0674.7  18228 0675.0  18225
0675.2
   GR         18222 0675.4  18216 0675.7  18213 0675.8  18208 0675.9  18203
0675.9
   GR         18202 0675.9
   N               .036
   PD 0       661.6   4.0   1
   CD           3     140    2      676

    ***   Completed Reading Data Associated With Header Record BRDGE    ***
    ***   Storing Bridge Data In Temporary File As Record Number  4     ***

    ***              Data Summary For Bridge Record BRDGE               ***
    SRD Location:       45.   Cross-Section Skew:  15.0   Error Code    0
    Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
    Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                        X,Y-coordinates (36 pairs)
        X          Y            X          Y            X          Y
   ----------  ----------   ----------  ----------   ----------  ----------
    18202.000     675.900    18233.000     661.300    18256.000     660.200
    18281.000     661.200    18314.000     676.000    18310.000     676.000
    18306.000     675.900    18291.000     675.400    18287.000     675.000
    18285.000     674.800    18283.000     674.600    18281.000     674.500
    18279.000     674.900    18276.000     675.100    18272.000     675.400
    18268.000     675.700    18265.000     675.800    18260.000     676.000
    18257.000     676.000    18254.000     676.000    18249.000     675.900
```

WSPRO OUTPUT

18245.000	675.700	18242.000	675.400	18240.000	675.200
18237.000	674.900	18234.000	674.500	18232.000	674.500
18230.000	674.700	18228.000	675.000	18225.000	675.200
18222.000	675.400	18216.000	675.700	18213.000	675.800
18208.000	675.900	18203.000	675.900	18202.000	675.900

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 18202.000 (associated Y-Elevation: 675.900)
Maximum X-Station: 18314.000 (associated Y-Elevation: 676.000)
Minimum Y-Elevation: 660.200 (associated X-Station: 18256.000)
Maximum Y-Elevation: 676.000 (associated X-Station: 18314.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
18202.000	18203.840	18233.000	18233.780	18256.000	18256.000
18281.000	18280.150	18314.000	18312.020	18310.000	18308.160
18306.000	18304.300	18291.000	18289.810	18287.000	18285.940
18285.000	18284.010	18283.000	18282.080	18281.000	18280.150
18279.000	18278.220	18276.000	18275.320	18272.000	18271.460
18268.000	18267.590	18265.000	18264.690	18260.000	18259.860
18257.000	18256.970	18254.000	18254.070	18249.000	18249.240
18245.000	18245.380	18242.000	18242.480	18240.000	18240.540
18237.000	18237.650	18234.000	18234.750	18232.000	18232.820
18230.000	18230.890	18228.000	18228.950	18225.000	18226.060
18222.000	18223.160	18216.000	18217.360	18213.000	18214.460
18208.000	18209.630	18203.000	18204.810	18202.000	18203.840

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.036	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	140.000	2.00	676.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	675.500

Abutment Parameters

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

Pier/Pile Data (1 Group(s))

Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number

WSPRO OUTPUT

```
                  1      661.600      4.000       1
                ------  ---------  ----------  ------

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

    ************************* W S P R O ***************************
       Federal Highway Administration - U. S. Geological Survey
             Model for Water-Surface Profile Computations.
            Input Units: English  /  Output Units: English
    *-------------------------------------------------------------*
        I-465 OVER STATE DITCH                 I-465-158-4458
     COUNTY: MARION                         QUAD: MAYWOOD, IND 124A
        8-12-97                                 DAVID C VOELKER
   DC 0 BRDGE  18202   18314  18185  18238  *  4.0
   DP   BRDGE  18202   18314   2   *   *   1.0   2.49
   DP   BRDGE  18202   18314   2   *   *   1.0   2.49

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

   XS   APPR   325
   GR        17846 685  17885 680  17939 675  17995 670  18036 667  18046 666
   GR        18049 665  18052 664  18084 664  18088 665  18100 666  18109 667
   GR        18179 667  18190 660.5  18240 660.5  18254 667  18323 667
18462 666
   GR        18686 665  18795 670
   N              .035      .06         .036        .06         .035
   SA                 18100       18175       18250       18290

    ***   Completed Reading Data Associated With Header Record APPR    ***
    ***  Storing X-Section Data In Temporary File As Record Number  5  ***

    ***              Data Summary For Header Record APPR               ***
    SRD Location:      325.   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 (20 pairs)
        X          Y            X          Y            X          Y
   ----------  ----------   ----------  ----------   ----------  ----------
    17846.000     685.000    17885.000     680.000    17939.000     675.000
    17995.000     670.000    18036.000     667.000    18046.000     666.000
    18049.000     665.000    18052.000     664.000    18084.000     664.000
    18088.000     665.000    18100.000     666.000    18109.000     667.000
    18179.000     667.000    18190.000     660.500    18240.000     660.500
    18254.000     667.000    18323.000     667.000    18462.000     666.000
    18686.000     665.000    18795.000     670.000
   ----------  ----------   ----------  ----------   ----------  ----------

                    Minimum and Maximum X,Y-coordinates
     Minimum X-Station:   17846.000  ( associated Y-Elevation:  685.000 )
```

WSPRO OUTPUT

```
Maximum X-Station:   18795.000  ( associated Y-Elevation:  670.000 )
Minimum Y-Elevation:   660.500  ( associated X-Station:  18240.000 )
Maximum Y-Elevation:   685.000  ( associated X-Station:  17846.000 )

                  Roughness Data (  5 SubAreas )
                          Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .035        ---
                             ---        ********
                   2         .060        ---
                             ---        ********
                   3         .036        ---
                             ---        ********
                   4         .060        ---
                             ---        ********
                   5         .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-465 OVER STATE DITCH              I-465-158-4458
     COUNTY: MARION                      QUAD: MAYWOOD, IND 124A
        8-12-97                             DAVID C VOELKER
  EX

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

            Reach       Water Surface   Friction
     #    Discharge       Elevation       Slope          Flow Regime
    --    ---------     ------------    --------   --------------------
     1      4300.00       ********         .0040        Sub-Critical
     2      6450.00       ********         .0040        Sub-Critical
    --    ---------     ------------    --------   --------------------

          *=====================================================*
          *        Beginning  2 Profile Calculation(s)          *
          *=====================================================*


    ************************* W S P R O ****************************
       Federal Highway Administration  -  U. S. Geological Survey
```

WSPRO OUTPUT

```
          Model for Water-Surface Profile Computations.
        Input Units: English  /  Output Units: English
    *-------------------------------------------------------------*
        I-465 OVER STATE DITCH              I-465-158-4458
     COUNTY: MARION                      QUAD: MAYWOOD, IND 124A
        8-12-97                             DAVID C VOELKER

                     WSEL     VHD       Q         AREA       SRDL       LEW
                     EGEL      HF       V          K         FLEN       REW
                     CRWS      HO     FR #         SF        ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
 Section: VALL      661.825    .246   4300.000   1384.116 ********* 18389.180
 Header Type: XS    662.071 ******       3.107   67948.19 ********* 19417.850
 SRD:   -206.000    661.395 ******        .516     ******     1.642    ******

===110 WSEL NOT FOUND AT SECID "EXIT ":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   664.57     677.40     .03

===115 WSEL NOT FOUND AT SECID "EXIT ":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   664.57     677.40     664.57

===130 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D  !!!!!
       ENERGY EQUATION N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXIT ".
       WSBEG, WSEND, CRWS:   664.57     677.40     664.57

 Section: EXIT      664.566  3.621   4300.000    281.886   206.000 18284.050
 Header Type: XS    668.187 ******      15.254   39790.75   206.000 18323.040
 SRD:       .000    664.566 ******       1.001      .0012     1.001    ******

 Section: FULLV     666.115  2.456   4300.000    342.321    45.000 18284.040
 Header Type: FV    668.572   .389     12.561   53798.84    45.000 18323.050
 SRD:     45.000    664.566   .000       .748      .0086     1.001     -.004

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
       KRATIO:  4.27

 Section: APPR      668.921   .069   4300.000   2398.769   280.000 18009.750
 Header Type: AS    668.990   .418      1.793 229983.90   280.000 18771.480
 SRD:    325.000    666.500   .000       .209      .0015     1.381       .000

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

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

===210 QUESTIONABLE CRITICAL-FLOW SOLUTION AT SECID "BRDGE".
       Q, CRWS:     4300.00     666.84

                     WSEL     VHD       Q         AREA       SRDL       LEW
                     EGEL      HF       V          K         FLEN       REW
                     CRWS      HO     FR #         SF        ALPHA      ERR
```

WSPRO OUTPUT

```
                  --------- ------ ---------- ---------- --------- ---------
Section: BRDGE      666.839  2.626   4300.000     361.520    45.000 18221.240
Header Type: BR     669.465 ******     11.894   42649.25     45.000 18293.570
SRD:     45.000     666.839 ******      1.025     ******      1.194    ******

Specific Bridge Information   C      P/A    PFELEV    BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0             .9153  .058  675.500 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                    WSEL     VHD       Q          AREA       SRDL       LEW
                    EGEL      HF       V            K         FLEN       REW
                    CRWS      HO      FR #         SF         ALPHA      ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: APPR       671.321   .018   4300.000   4308.106   140.000 17980.200
Header Type: AS     671.340   .164       .998  544521.50   192.654 18795.000
SRD:     325.000    666.500  1.711       .083      .0015     1.187      .015

            Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
          -------- -------- --------- -------- -------- --------
              .909     .850   81331.3 ******** ********  671.321
          -------- -------- --------- -------- -------- --------

              <<< 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-465 OVER STATE DITCH                 I-465-158-4458
      COUNTY: MARION                        QUAD: MAYWOOD, IND 124A
         8-12-97                                DAVID C VOELKER

                    WSEL     VHD       Q          AREA       SRDL       LEW
                    EGEL      HF       V            K         FLEN       REW
                    CRWS      HO      FR #         SF         ALPHA      ERR
                  --------- ------ ---------- ---------- --------- ---------
Section: VALL       662.395   .275   6450.000   1817.359 ********* 18388.210
Header Type: XS     662.670 ******      3.549  101948.80 ********* 19428.110
SRD:    -206.000    661.722 ******       .483     ******     1.405    ******

===110 WSEL NOT FOUND AT SECID "EXIT ":  REDUCED DELTAY.
       WSLIM1, WSLIM2, DELTAY:   666.81     677.40      .03

===115 WSEL NOT FOUND AT SECID "EXIT ":  USED WSMIN = CRWS.
       WSLIM1, WSLIM2, CRWS:   666.81     677.40     666.81

===130 CRITICAL WATER-SURFACE ELEVATION A _ S _ S _ U _ M _ E _ D  !!!!!
       ENERGY EQUATION N_O_T  B_A_L_A_N_C_E_D  AT SECID "EXIT ".
       WSBEG, WSEND, CRWS:   666.81     677.40     666.81
```

WSPRO OUTPUT

```
Section: EXIT       666.812  4.744   6450.000    369.515   206.000 18284.030
Header Type: XS     671.556 ******    17.455   60517.55   206.000 18323.060
SRD:        .000    666.812 ******     1.001      .0017     1.001    ******

Section: FULLV      668.562  3.380   6450.000    437.816    45.000 18284.020
Header Type: FV     671.942   .395     14.732   78396.63    45.000 18323.070
SRD:      45.000    666.812   .000       .776      .0088     1.001     -.008

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

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
       KRATIO:  8.68

Section: APPR       672.130   .030   6450.000   4970.763   280.000 17971.140
Header Type: AS     672.160   .218      1.298  680215.60   280.000 18795.000
SRD:     325.000    667.261   .000       .100      .0008     1.159       .000

        <<< 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      670.855  1.752   6450.000    687.181    45.000 18212.710
Header Type: BR     672.607   .338      9.386  106793.10    45.000 18302.530
SRD:      45.000    668.512   .722       .677     ******     1.279       .018

Specific Bridge Information   C      P/A    PFELEV     BLEN      XLAB      XRAB
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  0             .8843  .054  675.500 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                     WSEL     VHD       Q          AREA       SRDL       LEW
                     EGEL      HF       V            K        FLEN       REW
                     CRWS      HO      FR #         SF        ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: APPR       673.294   .021   6450.000   5937.574   140.000 17958.100
Header Type: AS     673.315   .103      1.086  898493.10   203.396 18795.000
SRD:     325.000    667.261   .597       .077      .0008     1.135       .001

          Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
          -------- -------- --------- -------- -------- --------
             .903     .898   91636.7 ******** ********  673.294
          -------- -------- --------- -------- -------- --------

            <<< End of Bridge Hydraulics Computations >>>


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

WSPRO OUTPUT

```
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
             Input Units: English  /  Output Units: English
    *-----------------------------------------------------------*
        I-465 OVER STATE DITCH              I-465-158-4458
     COUNTY: MARION                      QUAD: MAYWOOD, IND 124A
        8-12-97                             DAVID C VOELKER

  ***  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):  4.000
               *-----------------------------------------------*

     Scour      -- Flow --          -- Width --        --- X-Limits ---
 #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
--   ------ --------- --------- -------- --------  ------ -------- --------
 1  15.298  4300.000   886.114  108.000   53.000  Left:  ******** ********
    ..... Approach Channel Depth:   10.682 .....  Right: ******** ********
 2  24.408  6450.000  1068.489  108.000   53.000  Left:  ******** ********
    ..... Approach Channel Depth:   12.655 .....  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-465 OVER STATE DITCH              I-465-158-4458
     COUNTY: MARION                      QUAD: MAYWOOD, IND 124A
        8-12-97                             DAVID C VOELKER

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

                      Constants and Input Variables

                           Pier Width:   2.000
                  *-----------------------------------------*
                    Pier Shape Factor            (K1):  1.00
                    Flow Angle of Attack Factor  (K2):  2.49
                    Bed Condition Factor         (K3):  1.00
                    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   13.59   4300.000  668.550  8.350  10.547     .643   18202.000 18314.000
 2   14.20   6450.000  671.452 11.252  10.647     .559   18202.000 18314.000
```

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-465 OVER STATE DITCH                 I-465-158-4458
 COUNTY: MARION                        QUAD: MAYWOOD, IND 124A
    8-12-97                               DAVID C VOELKER

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

                Constants and Input Variables

                    Pier Width:   2.000
              *-----------------------------------------*
                Pier Shape Factor            (K1):   1.00
                Flow Angle of Attack Factor  (K2):   2.49
                Bed Condition Factor         (K3):   1.00
                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  13.59   4300.000  668.550  8.350  10.547      .643  18202.000 18314.000
 2  14.20   6450.000  671.452 11.252  10.647      .559  18202.000 18314.000
--  ----- ---------- -------- ------ -------- -------- --------- ---------

 ER

  ******************  Normal end of WSPRO execution.  *****************
  ***************  Elapsed Time:   0 Minutes 13 Seconds  **************
```