Modified Level II Streambed-Scour Analysis for Structure (I-469)-24-02-6953 Crossing Harber Ditch in Allen 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-469)-24-02-6953, an eastbound off ramp to Interstate 469 crossing Harber Ditch in Allen County, Indiana, are presented. The site is near the town of Yoder and is in the southwestern part of Allen 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 3.8 feet for the modeled discharge of 2,080 cubic feet per second and approximately 5.1 feet for the modeled discharge of 2,680 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-469)-24-02-6953.

Background and Scope

Level I scour assessment is a process where a large number of bridges are studied as a group. Assessments usually are made by evaluating a combination of geomorphic, hydrologic, and bridge-characteristic data. The results help investigators determine which bridges appear to be most likely to experience streambed-scour problems and which bridges appear to be relatively immune to problems brought on by streambed scour (for example, bridges built on bedrock).

When applied correctly, Level I scour assessments provide an investigator with information to identify those bridges that appear to be relatively safe and those bridges that fall into higher risk categories.

Level II scour evaluations describe the process for an investigator to apply a model to a bridge site and calculate the potential depth of scour that may result from a given flood event. Level II analyses involve the application of basic hydrologic, hydraulic, and sediment-transport engineering concepts and may include an evaluation of flood history, channel hydraulic conditions (for example, water-surface profile analysis), and basic sediment-transport analyses such as scour calculations (Lagasse and others, 1995).

The methods and model outlined in Hydraulic Engineering Circular (HEC) No. 18 (Richardson and Davis, 1995) formulate the basis for Level II scour evaluations. Methods used in this study for Level II scour evaluations are a modification of the HEC-18 standards. These modifications were made to comply with the methodology requested by INDOT (Merril Dougherty, Indiana Department of Transportation, oral commun., 1996). Descriptions of the specific modifications are given in the "Evaluation Methods" section of this report.

This report presents the methods followed for modeling, special considerations for this study site, and the input for and the output from the Water Surface PROfile (WSPRO) model.

Site Description

The study site is located near the town of Yoder and is in the southwestern part of Allen County. The drainage area for the site is approximately 12.5 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 pasture land.

Within the immediate vicinity of the bridge, Harber Ditch has a channel-bed slope of approximately 0.001 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 June 22, 1993, the banks were observed to have 0 to 25 percent woody vegetative cover; the field report noted that the banks were stable downstream from the bridge and experiencing mass wasting upstream from the bridge.

The Interstate 469 off ramp crossing Harber Ditch is a 120-ft-long, single-lane bridge consisting of three spans supported by concrete and steel piers and sloping riprap-covered spill-through abutments. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.

EVALUATION METHODS

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

To determine drainage area, either published values found in Hoggatt (1975) or 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, 1988) 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-469)-24-02-6953 crossing Harber Ditch in Allen 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 2,080 cubic feet per second							
1	8+49	784	0	3.8	3.8	773.0	776.3
2	8+89	783	0	3.8	3.8	773.0	776.3
Modeled discharge is 2,680 cubic feet per second							
1	8+49	784	1.0	4.1	5.1	773.0	775.0
2	8+89	783	1.0	4.1	5.1	773.0	775.0

[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, 8+49, represents a point 849 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 (780.1 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.

The study bridge is upstream from the I-469 bridge and the westbound on ramp bridge. The study bridge was modeled with the assumption that there was no backwater-effect from the bridges downstream.

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, 1988, Bridge plans Interstate Route 469: Bridge File (I-469)-24-02-6953.

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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
T2          COUNTY: ALLEN                    QUAD: OSSIAN  63A
T3          7-30-97                          JOHN T. WILSON
*           ***STUDY BRIDGE IS UPSTREAM OF I469 AND WB RAMP***
*           ***ASSUME NO BACKWATER EFFECTS FROM THESE BRIDGES***
Q           2080    2680
SK          .001   .001
XS   EXIT   0
*           ***EXIT SECTION IS SHORTENED TO WIDTH OF DS BRIDGE***
GR          858 791   880 790   898 780.1   921 780.1   939 790
GR          962 790.2 962 792
N           .035     .034     .035
SA              880       939
XS   FULLV 117
BR   BRDGE 117    800.0   19
*          ***BASE OF PIERS ARE SET IN RIPRAP SLOPEWALLS***
GR         815 799.2  817 798.3  859 780.2  882 780.1  929 800.3.
GR         932 800.3  932 801.5  815 799.2
N          .034
PD         783.2    2.0    1
PD         784.5    2.0    2
PD         784.5    4.0    3
CD         3    30    2    804
DC 0 BRDGE  835   906   800   857   *  4
*          ***DC LIMITS AT BRIDGE ARE LEW AND REW FOR Q1***
*           BXL      BXR      PW   *  *  K1  K2   K3
DP          815      932      1.5  *  *  1   1.0  1.1
DP          815      932      1.5  *  *  1   1.0  1.1
*           ***DP CARDS USE THE WHOLE BRIDGE OPENING FOR BXL/BXR***
XS   APPR   264
GR          608   795  615   794  623 793  634 792  660 791  732 790   800 790
GR          819 780.1  838 780.1  857 790  933 790  965 791  995 792  1026 793
GR         1054   794
N          .035      .034      .035
SA             800       857
HP 2 BRDGE  790.6  *  790.6   2080
HP 2 BRDGE  791.6  *  791.6   2680
EX
ER
```

WSPRO OUTPUT

```
   ************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
         Run Date & Time:  8/ 5/97  0:19 pm     Version V050196
          Input File: harber.dat     Output File: harber.LST
   *-------------------------------------------------------------*
T1         I-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
T2         COUNTY: ALLEN                    QUAD: OSSIAN  63A
T3         7-30-97                          JOHN T. WILSON
Q          2080    2680

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

SK         .001   .001

   ************************  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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
         COUNTY: ALLEN                   QUAD: OSSIAN  63A
          7-30-97                         JOHN T. WILSON

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

XS   EXIT  0
GR         858 791   880 790   898 780.1   921 780.1   939 790
GR         962 790.2 962 792
N          .035     .034     .035
SA             880       939

  ***   Completed Reading Data Associated With Header Record EXIT    ***
+++072 NOTICE:  X-coordinate # 7 increased to eliminate vertical segment.
  ***  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 ( 7 pairs)
     X          Y          X          Y          X          Y
----------  ----------  ----------  ----------  ----------  ----------
   858.000     791.000     880.000     790.000     898.000     780.100
   921.000     780.100     939.000     790.000     962.000     790.200
   962.100     792.000
----------  ----------  ----------  ----------  ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:      858.000   ( associated Y-Elevation:   791.000 )
  Maximum X-Station:      962.100   ( associated Y-Elevation:   792.000 )
  Minimum Y-Elevation:    780.100   ( associated X-Station:     921.000 )
  Maximum Y-Elevation:    792.000   ( associated X-Station:     962.100 )

                    Roughness Data (  3 SubAreas )
                             Roughness    Horizontal
                   SubArea   Coefficient  Breakpoint
                   -------   ----------   ----------
                      1         .035         ---
                                ---        880.000
                      2         .034         ---
                                ---        939.000
                      3         .035         ---
                   -------   ----------   ----------

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

   ************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
         I-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
         COUNTY: ALLEN                    QUAD: OSSIAN  63A
          7-30-97                          JOHN T. WILSON

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

XS   FULLV 117

 ***   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:      117.   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 ( 7 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
   858.000     791.000      880.000     790.000      898.000     780.100
   921.000     780.100      939.000     790.000      962.000     790.200
   962.100     792.000
----------  ----------   ----------  ----------   ----------  ----------
```

WSPRO OUTPUT

```
                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:     858.000  ( associated Y-Elevation:  791.000 )
  Maximum X-Station:     962.100  ( associated Y-Elevation:  792.000 )
  Minimum Y-Elevation:   780.100  ( associated X-Station:    921.000 )
  Maximum Y-Elevation:   792.000  ( associated X-Station:    962.100 )

                  Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .035        ---
                              ---        880.000
                    2         .034        ---
                              ---        939.000
                    3         .035        ---
                 -------  -----------  ----------

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

   ************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
       I-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
       COUNTY: ALLEN                    QUAD: OSSIAN  63A
        7-30-97                          JOHN T. WILSON

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

  BR   BRDGE 117    800.0   19
  GR        815 799.2  817 798.3  859 780.2  882 780.1  929 800.3
  GR        932 800.3  932 801.5  815 799.2
  N         .034
  PD        783.2    2.0    1
  PD        784.5    2.0    2
  PD        784.5    4.0    3
  CD        3    30    2    804

   ***   Completed Reading Data Associated With Header Record BRDGE   ***
+++072 NOTICE:  X-coordinate # 7 increased to eliminate vertical segment.
   ***   Storing Bridge Data In Temporary File As Record Number  3    ***

   ***              Data Summary For Bridge Record BRDGE             ***
   SRD Location:      117.   Cross-Section Skew:  19.0   Error Code   0
   Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

WSPRO OUTPUT

X,Y-coordinates (8 pairs)

X	Y	X	Y	X	Y
815.000	799.200	817.000	798.300	859.000	780.200
882.000	780.100	929.000	800.300	932.000	800.300
932.100	801.500	815.000	799.200		

Minimum and Maximum X,Y-coordinates

Minimum X-Station:	815.000	(associated Y-Elevation:	799.200)
Maximum X-Station:	932.100	(associated Y-Elevation:	801.500)
Minimum Y-Elevation:	780.100	(associated X-Station:	882.000)
Maximum Y-Elevation:	801.500	(associated X-Station:	932.100)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
815.000	818.650	817.000	820.541	859.000	860.253
882.000	882.000	929.000	926.439	932.000	929.276
932.100	929.370	815.000	818.650		

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.034	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	30.000	2.00	804.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	800.000

Abutment Parameters

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

Pier/Pile Data (3 Group(s))

Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number
1	783.200	2.000	1
2	784.500	2.000	2
3	784.500	4.000	3

--
* Finished Processing Header Record BRDGE *
--

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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
         COUNTY: ALLEN                    QUAD: OSSIAN  63A
          7-30-97                          JOHN T. WILSON
   DC 0 BRDGE  835   906   800   857   *  4
   DP          815      932      1.5  *  *  1   1.0  1.1
   DP          815      932      1.5  *  *  1   1.0  1.1

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

   XS   APPR   264
   GR          608   795  615   794  623 793  634 792  660 791  732 790   800
790
   GR          819 780.1  838 780.1  857 790  933 790  965 791  995 792  1026
793
   GR         1054   794
   N          .035      .034      .035
   SA              800       857

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

                       X,Y-coordinates (15 pairs)
       X          Y          X          Y          X          Y
   ---------  ---------  ---------  ---------  ---------  ---------
     608.000    795.000    615.000    794.000    623.000    793.000
     634.000    792.000    660.000    791.000    732.000    790.000
     800.000    790.000    819.000    780.100    838.000    780.100
     857.000    790.000    933.000    790.000    965.000    791.000
     995.000    792.000   1026.000    793.000   1054.000    794.000
   ---------  ---------  ---------  ---------  ---------  ---------

                   Minimum and Maximum X,Y-coordinates
     Minimum X-Station:     608.000  ( associated Y-Elevation:  795.000 )
     Maximum X-Station:    1054.000  ( associated Y-Elevation:  794.000 )
     Minimum Y-Elevation:   780.100  ( associated X-Station:    838.000 )
     Maximum Y-Elevation:   795.000  ( associated X-Station:    608.000 )
```

WSPRO OUTPUT

```
                  Roughness Data (  3 SubAreas )
                           Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .035        ---
                              ---        800.000
                    2         .034        ---
                              ---        857.000
                    3         .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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
          COUNTY: ALLEN                    QUAD: OSSIAN  63A
           7-30-97                          JOHN T. WILSON
  HP 2 BRDGE  790.6  *  790.6   2080
  HP 2 BRDGE  791.6  *  791.6   2680
  EX

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

            Reach      Water Surface   Friction
     #   Discharge      Elevation       Slope         Flow Regime
    --   ---------    -------------   --------   --------------------
     1     2080.00      ********         .0010        Sub-Critical
     2     2680.00      ********         .0010        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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
          COUNTY: ALLEN                    QUAD: OSSIAN  63A
           7-30-97                          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	790.330	.370	2080.000	431.829	*********	872.748
Header Type: XS	790.700	******	4.817	65755.99	*********	962.007
SRD: .000	785.548	******	.391	******	1.026	******
Section: FULLV	790.461	.355	2080.000	443.776	117.000	869.850
Header Type: FV	790.817	.113	4.687	67883.09	117.000	962.015
SRD: 117.000	785.548	.000	.384	.0010	1.040	.003

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

Section: APPR	790.612	.348	2080.000	518.690	147.000	687.936
Header Type: AS	790.960	.141	4.010	66466.51	147.000	952.584
SRD: 264.000	785.954	.000	.596	.0010	1.391	.002

<<< 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	790.543	.280	2080.000	490.032	117.000	835.000
Header Type: BR	790.823	.119	4.245	74468.43	117.000	906.298
SRD: 117.000	785.431	.005	.285	******	1.000	.006

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1						
Pier/Pile Code 0	1.0000	.055	800.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	790.664	.337	2080.000	532.638	117.000	684.179
Header Type: AS	791.001	.129	3.905	67694.73	129.547	954.254
SRD: 264.000	785.954	.050	.584	.0010	1.420	.004

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.732	.045	64520.7	792.862	864.134	790.664

<<< End of Bridge Hydraulics Computations >>>

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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
      COUNTY: ALLEN                    QUAD: OSSIAN  63A
       7-30-97                          JOHN T. WILSON
```

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: EXIT	791.390	.434	2680.000	537.190	*********	858.000
Header Type: XS	791.824	******	4.989	84741.55	*********	962.066
SRD: .000	786.411	******	.410	******	1.122	******
Section: FULLV	791.521	.415	2680.000	550.833	117.000	858.000
Header Type: FV	791.936	.113	4.865	87378.75	117.000	962.073
SRD: 117.000	786.411	.000	.396	.0010	1.129	-.001

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

Section: APPR	791.807	.244	2680.000	893.693	147.000	639.008
Header Type: AS	792.051	.116	2.999	104175.30	147.000	989.221
SRD: 264.000	786.856	.000	.437	.0008	1.742	-.002

<<< 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	791.582	.358	2680.000	566.630	117.000	832.588
Header Type: BR	791.940	.116	4.730	90704.46	117.000	908.716
SRD: 117.000	786.301	.000	.310	******	1.030	.002

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1	------	-----	--------	--------	--------	--------
Pier/Pile Code 0	.9854	.055	800.000	********	********	********

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	791.863	.234	2680.000	913.245	117.000	637.564
Header Type: AS	792.097	.104	2.935	106393.90	130.424	990.887
SRD: 264.000	786.856	.053	.425	.0008	1.745	.003

WSPRO OUTPUT

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.783	.199	85145.5	790.078	866.196	791.863

<<< 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-469 EB RAMP OVER HARBER DITCH (I469)24-02-6953
COUNTY: ALLEN QUAD: OSSIAN 63A
7-30-97 JOHN T. WILSON

*** Beginning Velocity Distribution For Header Record BRDGE ***
SRD Location: 117.000 Header Record Number 3

Water Surface Elevation: 790.600 Element # 1
Flow: 2080.000 Velocity: 4.21 Hydraulic Depth: 6.904
Cross-Section Area: 494.10 Conveyance: 75310.02
Bank Stations -> Left: 834.867 Right: 906.431

X STA.	834.9	849.3	853.5	856.5	858.9	861.0
A(I)		44.7	30.3	25.5	24.0	21.5
V(I)		2.33	3.43	4.07	4.34	4.84
D(I)		3.10	7.12	8.67	9.83	10.40

X STA.	861.0	863.0	864.9	866.8	868.8	870.6
A(I)		21.3	19.9	20.1	20.2	19.6
V(I)		4.89	5.23	5.18	5.16	5.32
D(I)		10.41	10.42	10.43	10.44	10.45

X STA.	870.6	872.6	874.5	876.3	878.3	880.3
A(I)		20.0	20.0	19.5	20.7	20.5
V(I)		5.21	5.20	5.32	5.02	5.08
D(I)		10.45	10.46	10.47	10.48	10.49

X STA.	880.3	882.4	884.7	887.7	891.9	906.4
A(I)		22.1	23.3	26.1	29.6	45.4
V(I)		4.71	4.47	3.99	3.51	2.29
D(I)		10.48	9.83	8.68	7.14	3.12

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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
      COUNTY: ALLEN                    QUAD: OSSIAN  63A
       7-30-97                          JOHN T. WILSON

***    Beginning Velocity Distribution For Header Record BRDGE    ***
       SRD Location:    117.000       Header Record Number  3

     Water Surface Elevation:    791.600              Element # 1
     Flow:    2680.000   Velocity:  4.72  Hydraulic Depth:   7.453
     Cross-Section Area:    567.99         Conveyance:    90998.84
        Bank Stations ->  Left:    832.547   Right:    908.757

X STA.      832.5      848.0      852.6      855.8      858.3      860.6
  A( I )             51.6       35.2       29.6       27.0       25.1
  V( I )             2.60       3.81       4.53       4.96       5.33
  D( I )             3.34       7.66       9.33      10.57      11.36

X STA.      860.6      862.6      864.7      866.7      868.7      870.7
  A( I )             23.8       23.6       22.8       22.6       22.6
  V( I )             5.62       5.69       5.87       5.94       5.93
  D( I )            11.41      11.42      11.43      11.44      11.45

X STA.      870.7      872.6      874.6      876.6      878.7      880.7
  A( I )             22.6       22.6       22.9       23.7       23.4
  V( I )             5.93       5.92       5.85       5.65       5.71
  D( I )            11.45      11.46      11.47      11.48      11.49

X STA.      880.7      882.9      885.4      888.7      893.3      908.8
  A( I )             25.1       26.9       30.2       35.1       51.5
  V( I )             5.33       4.99       4.44       3.82       2.60
  D( I )            11.42      10.57       9.32       7.64       3.33

************************* 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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
      COUNTY: ALLEN                    QUAD: OSSIAN  63A
       7-30-97                          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):	4.000

#	Scour Depth	-- Flow -- Contract	Approach	-- Width -- Contract	Approach	--- X-Limits --- Side	Contract	Approach
1	-.419	2080.000	1975.152	67.000	57.000	Left:	835.000	800.000
	..... Approach Channel Depth:	7.264				Right:	906.000	857.000
* Negative Scour Depth Encountered - Check If Variables Are Reasonable *								
2	.972	2680.000	2088.651	67.000	57.000	Left:	835.000	800.000
	..... Approach Channel Depth:	8.463				Right:	906.000	857.000

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

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

I-469 EB RAMP OVER HARBER DITCH (I469)24-02-6953
COUNTY: ALLEN QUAD: OSSIAN 63A
7-30-97 JOHN T. WILSON

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

Constants and Input Variables

Pier Width: 1.500

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	3.82	2080.000	790.593	10.493	5.291	.288	815.000	932.000
2	4.06	2680.000	791.635	11.535	5.925	.307	815.000	932.000

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-469 EB RAMP OVER HARBER DITCH  (I469)24-02-6953
      COUNTY: ALLEN                    QUAD: OSSIAN  63A
       7-30-97                          JOHN T. WILSON

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

                  Constants and Input Variables

                       Pier Width:   1.500
             *-----------------------------------------*
               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	3.82	2080.000	790.593	10.493	5.291	.288	815.000	932.000
2	4.06	2680.000	791.635	11.535	5.925	.307	815.000	932.000

```
  ER

   ******************  Normal end of WSPRO execution.  *****************
   ***************  Elapsed Time:   0 Minutes 39 Seconds  **************
```