# Modified Level II Streambed-Scour Analysis for Structure I-465-131-5256 Crossing Williams Creek in Hamilton County, Indiana

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

Prepared in cooperation with the
INDIANA DEPARTMENT OF TRANSPORTATION

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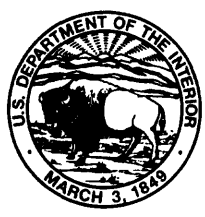


Indianapolis, Indiana
1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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For additional information, write to:
District Chief
U.S. Geological Survey
Water Resources Division
5957 Lakeside Boulevard
Indianapolis, IN 46278-1996

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U.S. Geological Survey
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Box 25286
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Denver, CO 80225

# CONTENTS



## Tables

# 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 |

# Modified Level II Streambed-Scour Analysis for Structure I-465-131-5256 Crossing Williams Creek in Hamilton County, Indiana

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

## ABSTRACT

Level II scour evaluations follow a process in which hydrologic, hydraulic, and sediment-transport data are evaluated to calculate the depth of scour that may result when a given discharge is routed through a bridge opening. The results of the modified Level II analysis for structure I-465-131-5256 on Interstate 465 crossing Williams Creek in Hamilton County, Indiana, are presented. The site is near the city of Indianapolis and is in the southwestern part of Hamilton County. Scour depths were computed with the Water Surface PROfile model, version V050196, which incorporates the scour-calculation procedures outlined in Hydraulic Engineering Circular No. 18. Total scour depths at the piers were approximately 6.5 feet for the modeled discharge of 4,300 cubic feet per second and approximately 9.8 feet for the modeled discharge of 7,310 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-465-131-5256.

### Background and Scope

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

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

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

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

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

## Site Description

The study site is located near the city of Indianapolis and is in the southwestern part of Hamilton County. The drainage area for the site is approximately 16.9 $mi^2$ (Merril Dougherty, Indiana Department of Transportation, written commun., 1997). The predominant land use in the basin is urban; in the immediate vicinity of the bridge, the land is predominantly brush covered with some suburban areas nearby.

Within the immediate vicinity of the bridge, Williams Creek has a channel-bed slope of approximately 0.0025 ft/ft. The channel-bed material is gravelly sandy silt-clay, and the channel banks consist of sandy silt-clay. At the time of the Level I site visit on August 3, 1994, the banks were observed to have 0 to 50 percent woody vegetative cover; the field report noted that the banks were experiencing some fluvial erosion.

The Interstate 465 crossing of Williams Creek is a 111-ft-long, multi-lane bridge consisting of three spans supported by concrete and steel piers and sloping 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, 1965) 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-465-131-5256 crossing Williams Creek in Hamilton 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 | 609+09 | 788 | 0 | 6.5 | 6.5 | 780.3 | 779.1 |
| 2 | 609+51 | 788 | 0 | 6.5 | 6.5 | 780.4 | 779.1 |
| **Modeled discharge is 7,310 cubic feet per second** | | | | | | | |
| 1 | 609+09 | 788 | 2.4 | 7.4 | 9.8 | 780.3 | 775.8 |
| 2 | 609+51 | 788 | 2.4 | 7.4 | 9.8 | 780.4 | 775.8 |

[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, 609+09, represents a point 60,909 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 (785.6 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.

## 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, 1965, Bridge plans Interstate Route 465: Bridge File I-465-131-5256.

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 Williams Creek  I-465-131-5256
T2        County: Hamilton           Quad: Carmel 111A
T3        4-11-97                    Bret A. Robinson
SI        0
Q         4300
Q         7310
SK        .0025 .0025
XS   EXIT 0 0
GR        60411 820  60538 805  60614 800  60696 795  60809 790  60893 790
GR       60909 789  60915 785.6  60946 785.6  60953 789  61078 795  61193 800
GR        61225 805  61305 820
N         .12   .032   .12
SA          60890   60950
XS   FULLV110 0
GR        60411 820  60538 805  60614 800  60696 795  60809 790  60893 790
GR       60909 789  60915 785.6  60946 785.6  60953 789  61078 795  61193 800
GR        61225 805  61305 820
N         .12   .032   .12
SA           60890   60950
BR   BRDGE110 801 0
GR       60877 0801.2  60877 0800.8  60885 0800.7  60917 0785.7  60945 0785.7
GR       60976 0801.3  60984 0801.3  60984 0801.8  60955 0801.6  60922 0801.5
GR        60890 0801.3  60877 0801.2
N         .035   .032   .035
SA          60900   60970
PD        789 3 1
CD        3 130 2 800.7
*          LXBr RXBr LXApp RXApp * TPierW
DC 0 BRDGE 60889 60972 60910 60960 * 3
DP        60877 60984 2 * * 1 1 1.1
DP        60877 60984 2 * * 1 1 1.1
XS   APPR 370 0
GR        60518 820  60558 815  60592 810  60636 805  60741 800  60809 795
GR       60908 789  60918 785.6  60943 785.6  60952 789  61144 795  61329 800
GR        61486 820
N         .120   .032   .120
SA           60910  60960
EX
ER
```

# WSPRO OUTPUT

```
   ************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
         Run Date & Time:  8/ 6/97 10:15 am     Version V050196
          Input File: 5256.dat       Output File: 5256.LST
   *-------------------------------------------------------------*
T1        I-465 OVER WILLIAMS CREEK  I-465-131-5256
T2        COUNTY: HAMILTON           QUAD: CARMEL 111A
T3        4-11-97                    BRET A. ROBINSON
SI        0
Q         4300
Q         7310

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

SK        .0025 .0025

   ************************  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 WILLIAMS CREEK  I-465-131-5256
          COUNTY: HAMILTON           QUAD: CARMEL 111A
          4-11-97                    BRET A. ROBINSON

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

XS   EXIT 0 0
GR        60411 820  60538 805  60614 800  60696 795  60809 790  60893 790
GR        60909 789  60915 785.6  60946 785.6  60953 789  61078 795
61193 800
GR        61225 805  61305 820
N         .12   .032   .12
SA          60890   60950

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

 ***              Data Summary For Header Record EXIT              ***
 SRD Location:        0.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (14 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 60411.000     820.000    60538.000     805.000    60614.000     800.000
 60696.000     795.000    60809.000     790.000    60893.000     790.000
 60909.000     789.000    60915.000     785.600    60946.000     785.600
 60953.000     789.000    61078.000     795.000    61193.000     800.000
 61225.000     805.000    61305.000     820.000
```

# WSPRO OUTPUT

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

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   60411.000  ( associated Y-Elevation:  820.000 )
  Maximum X-Station:   61305.000  ( associated Y-Elevation:  820.000 )
  Minimum Y-Elevation:   785.600  ( associated X-Station:  60946.000 )
  Maximum Y-Elevation:   820.000  ( associated X-Station:  60411.000 )

                  Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                SubArea  Coefficient  Breakpoint
                -------  -----------  ----------
                   1         .120        ---
                             ---       ********
                   2         .032        ---
                             ---       ********
                   3         .120        ---
                -------  -----------  ----------

        *-------------------------------------------------*
        *      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-465 OVER WILLIAMS CREEK  I-465-131-5256
           COUNTY: HAMILTON           QUAD: CARMEL 111A
           4-11-97                    BRET A. ROBINSON

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

   XS   FULLV110 0
   GR        60411 820  60538 805  60614 800  60696 795  60809 790  60893 790
   GR        60909 789  60915 785.6  60946 785.6  60953 789  61078 795
61193 800
   GR        61225 805  61305 820
   N         .12   .032   .12
   SA           60890   60950

    ***   Completed Reading Data Associated With Header Record FULLV   ***
    ***  Storing X-Section Data In Temporary File As Record Number  2  ***

    ***              Data Summary For Header Record FULLV             ***
    SRD Location:      110.   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 (14 pairs)
       X          Y            X          Y            X          Y
```

# WSPRO OUTPUT

```
---------  ---------  ---------  ---------  ---------  ---------
 60411.000    820.000   60538.000    805.000   60614.000    800.000
 60696.000    795.000   60809.000    790.000   60893.000    790.000
 60909.000    789.000   60915.000    785.600   60946.000    785.600
 60953.000    789.000   61078.000    795.000   61193.000    800.000
 61225.000    805.000   61305.000    820.000
---------  ---------  ---------  ---------  ---------  ---------

                Minimum and Maximum X,Y-coordinates
  Minimum X-Station:   60411.000  ( associated Y-Elevation:  820.000 )
  Maximum X-Station:   61305.000  ( associated Y-Elevation:  820.000 )
  Minimum Y-Elevation:   785.600  ( associated X-Station:  60946.000 )
  Maximum Y-Elevation:   820.000  ( associated X-Station:  60411.000 )

                    Roughness Data (  3 SubAreas )
                            Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .120        ---
                               ---       ********
                     2         .032        ---
                               ---       ********
                     3         .120        ---
                  -------  -----------  ----------

        *-------------------------------------------------*
        *      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 WILLIAMS CREEK  I-465-131-5256
           COUNTY: HAMILTON           QUAD: CARMEL 111A
           4-11-97                    BRET A. ROBINSON

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

   BR   BRDGE110 801 0
   GR        60877 0801.2  60877 0800.8  60885 0800.7  60917 0785.7  60945
0785.7
   GR        60976 0801.3  60984 0801.3  60984 0801.8  60955 0801.6  60922
0801.5
   GR        60890 0801.3  60877 0801.2
   N         .035   .032   .035
   SA          60900   60970
   PD        789 3 1
   CD        3 130 2 800.7

    ***   Completed Reading Data Associated With Header Record BRDGE   ***
```

# WSPRO OUTPUT

```
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate # 8 increased to eliminate vertical segment.
   ***   Storing Bridge Data In Temporary File As Record Number  3    ***

   ***              Data Summary For Bridge Record BRDGE              ***
   SRD Location:      110.   Cross-Section Skew:    .0   Error Code   0
   Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                      X,Y-coordinates (12 pairs)
      X          Y            X          Y            X          Y
 ----------  ----------   ----------  ----------   ----------  ----------
  60877.000     801.200    60877.100     800.800    60885.000     800.700
  60917.000     785.700    60945.000     785.700    60976.000     801.300
  60984.000     801.300    60984.100     801.800    60955.000     801.600
  60922.000     801.500    60890.000     801.300    60877.000     801.200
 ----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
   Minimum X-Station:   60877.000  ( associated Y-Elevation:  801.200 )
   Maximum X-Station:   60984.100  ( associated Y-Elevation:  801.800 )
   Minimum Y-Elevation:   785.700  ( associated X-Station:  60945.000 )
   Maximum Y-Elevation:   801.800  ( associated X-Station:  60984.100 )

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .035        ---
                               ---       ********
                     2         .032        ---
                               ---       ********
                     3         .035        ---
                  -------  -----------  ----------

                    Discharge coefficient parameters
                BRType   BRWdth   EMBSS   EMBElv    UserCD
                  3      130.000   2.00   800.700 **********

                      Pressure flow elevations
                         AVBCEL     PFElev
                        *********    801.000

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


                      Pier/Pile Data (  1 Group(s) )
                    Code Indicates Bridge Uses Piers
                   Group  Elevation  Gross Width  Number
                  ------  ---------  -----------  ------
                     1      789.000      3.000       1
                  ------  ---------  -----------  ------
```

# WSPRO OUTPUT

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

   ************************* W S P R O ***************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
            I-465 OVER WILLIAMS CREEK  I-465-131-5256
           COUNTY: HAMILTON           QUAD: CARMEL 111A
           4-11-97                    BRET A. ROBINSON
  DC 0 BRDGE 60889 60972 60910 60960 * 3
  DP         60877 60984 2 * * 1 1 1.1
  DP         60877 60984 2 * * 1 1 1.1

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

  XS   APPR 370 0
  GR         60518 820  60558 815  60592 810  60636 805  60741 800  60809 795
  GR         60908 789  60918 785.6  60943 785.6  60952 789  61144 795
61329 800
  GR         61486 820
  N          .120   .032   .120
  SA            60910  60960

   ***   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:      370.   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
 ----------  ----------   ----------  ----------   ----------  ----------
  60518.000     820.000    60558.000     815.000    60592.000     810.000
  60636.000     805.000    60741.000     800.000    60809.000     795.000
  60908.000     789.000    60918.000     785.600    60943.000     785.600
  60952.000     789.000    61144.000     795.000    61329.000     800.000
  61486.000     820.000
 ----------  ----------   ----------  ----------   ----------  ----------

                   Minimum and Maximum X,Y-coordinates
    Minimum X-Station:   60518.000  ( associated Y-Elevation:  820.000 )
    Maximum X-Station:   61486.000  ( associated Y-Elevation:  820.000 )
    Minimum Y-Elevation:   785.600  ( associated X-Station:  60943.000 )
    Maximum Y-Elevation:   820.000  ( associated X-Station:  60518.000 )

                      Roughness Data (  3 SubAreas )
```

# WSPRO OUTPUT

```
                          Roughness   Horizontal
                SubArea   Coefficient  Breakpoint
                -------   -----------  ----------
                   1         .120         ---
                             ---         ********
                   2         .032         ---
                             ---         ********
                   3         .120         ---
                -------   -----------  ----------

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 WILLIAMS CREEK  I-465-131-5256
            COUNTY: HAMILTON           QUAD: CARMEL 111A
            4-11-97                    BRET A. ROBINSON
  EX

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

           Reach       Water Surface   Friction
     #   Discharge       Elevation       Slope          Flow Regime
    --   ---------     -------------   --------   --------------------
     1     4300.00       ********         .0025        Sub-Critical
     2     7310.00       ********         .0025        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-465 OVER WILLIAMS CREEK  I-465-131-5256
            COUNTY: HAMILTON           QUAD: CARMEL 111A
            4-11-97                    BRET A. ROBINSON

                    WSEL     VHD        Q          AREA       SRDL       LEW
                    EGEL      HF        V           K         FLEN       REW
```

# WSPRO OUTPUT

| | CRWS | HO | FR # | SF | ALPHA | ERR |
|---|---|---|---|---|---|---|
| Section: EXIT | 793.921 | .831 | 4300.000 | 1170.048 | ********* | 60720.390 |
| Header Type: XS | 794.752 | ****** | 3.675 | 85978.46 | ********* | 61055.520 |
| SRD: .000 | 792.407 | ****** | .690 | ****** | 3.958 | ****** |
| Section: FULLV | 794.300 | .702 | 4300.000 | 1300.384 | 110.000 | 60711.810 |
| Header Type: FV | 795.003 | .246 | 3.307 | 96044.64 | 110.000 | 61063.430 |
| SRD: 110.000 | 792.407 | .000 | .616 | .0022 | 4.129 | .004 |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| Section: APPR | 794.737 | .902 | 4300.000 | 1167.780 | 260.000 | 60813.340 |
| Header Type: AS | 795.639 | .539 | 3.682 | 92877.37 | 260.000 | 61135.570 |
| SRD: 370.000 | 792.857 | .100 | .705 | .0021 | 4.279 | -.003 |

<<< 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 | 793.773 | 2.283 | 4300.000 | 360.323 | 110.000 | 60899.780 |
| Header Type: BR | 796.056 | .468 | 11.934 | 52550.45 | 110.000 | 60961.040 |
| SRD: 110.000 | 793.289 | .833 | .881 | ****** | 1.031 | -.003 |

| Specific Bridge Information | C | P/A | PFELEV | BLEN | XLAB | XRAB |
|---|---|---|---|---|---|---|
| Bridge Type 3 Flow Type 1 | ------ | ----- | -------- | -------- | -------- | -------- |
| Pier/Pile Code 0 | .9850 | .040 | 801.000 | ******** | ******** | ******** |

| | WSEL / EGEL / CRWS | VHD / HF / HO | Q / V / FR # | AREA / K / SF | SRDL / FLEN / ALPHA | LEW / REW / ERR |
|---|---|---|---|---|---|---|
| Section: APPR | 796.974 | .388 | 4300.000 | 2014.247 | 130.000 | 60782.150 |
| Header Type: AS | 797.362 | .314 | 2.135 | 157406.60 | 134.585 | 61217.040 |
| SRD: 370.000 | 792.857 | .997 | .409 | .0021 | 5.479 | .018 |

Approach Section APPR Flow Contraction Information

| M( G ) | M( K ) | KQ | XLKQ | XRKQ | OTEL |
|---|---|---|---|---|---|
| .803 | .264 | 115326.0 | ******** | ******** | 796.974 |

<<< End of Bridge Hydraulics Computations >>>

********** 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 WILLIAMS CREEK  I-465-131-5256
          COUNTY: HAMILTON           QUAD: CARMEL 111A
          4-11-97                    BRET A. ROBINSON
```

| | WSEL<br>EGEL<br>CRWS | VHD<br>HF<br>HO | Q<br>V<br>FR # | AREA<br>K<br>SF | SRDL<br>FLEN<br>ALPHA | LEW<br>REW<br>ERR |
|---|---|---|---|---|---|---|
| Section: EXIT | 795.913 | 1.060 | 7310.000 | 1922.222 | ********* | 60681.020 |
| Header Type: XS | 796.973 | ****** | 3.803 | 146110.30 | ********* | 61099.000 |
| SRD: .000 | 794.088 | ****** | .679 | ****** | 4.713 | ****** |
| Section: FULLV | 796.292 | .923 | 7310.000 | 2083.619 | 110.000 | 60674.800 |
| Header Type: FV | 797.216 | .252 | 3.508 | 159631.80 | 110.000 | 61107.730 |
| SRD: 110.000 | 794.088 | .000 | .619 | .0023 | 4.822 | -.010 |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| Section: APPR | 796.721 | 1.227 | 7310.000 | 1905.638 | 260.000 | 60785.600 |
| Header Type: AS | 797.948 | .584 | 3.836 | 149006.90 | 260.000 | 61207.660 |
| SRD: 370.000 | 794.869 | .152 | .737 | .0022 | 5.362 | -.004 |

<<< 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:     7310.00     795.87
```

| | WSEL<br>EGEL<br>CRWS | VHD<br>HF<br>HO | Q<br>V<br>FR # | AREA<br>K<br>SF | SRDL<br>FLEN<br>ALPHA | LEW<br>REW<br>ERR |
|---|---|---|---|---|---|---|
| Section: BRDGE | 795.869 | 3.921 | 7310.000 | 497.749 | 110.000 | 60895.310 |
| Header Type: BR | 799.789 | ****** | 14.686 | 84705.07 | 110.000 | 60965.210 |
| SRD: 110.000 | 795.869 | ****** | 1.049 | ****** | 1.169 | ****** |

| Specific Bridge Information | C | P/A | PFELEV | BLEN | XLAB | XRAB |
|---|---|---|---|---|---|---|
| Bridge Type 3 Flow Type 1 | ------ | ----- | -------- | -------- | -------- | -------- |
| Pier/Pile Code 0 | .9250 | .041 | 801.000 | ******** | ******** | ******** |

| | WSEL<br>EGEL<br>CRWS | VHD<br>HF<br>HO | Q<br>V<br>FR # | AREA<br>K<br>SF | SRDL<br>FLEN<br>ALPHA | LEW<br>REW<br>ERR |
|---|---|---|---|---|---|---|
| Section: APPR | 800.786 | .336 | 7310.000 | 4032.697 | 130.000 | 60724.500 |
| Header Type: AS | 801.122 | .279 | 1.813 | 323338.70 | 137.181 | 61335.170 |
| SRD: 370.000 | 794.869 | 1.054 | .319 | .0022 | 6.576 | .004 |

# WSPRO OUTPUT

```
          Approach Section APPR  Flow Contraction Information
         M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
        -------- -------- --------- -------- -------- --------
            .830     .373  202662.2 ******** ********  800.786
        -------- -------- --------- -------- -------- --------

            <<< 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 WILLIAMS CREEK  I-465-131-5256
            COUNTY: HAMILTON           QUAD: CARMEL 111A
            4-11-97                    BRET A. ROBINSON

  ***  Live-Bed Contraction Scour Calculations for Header Record BRDGE  ***

                      Constants and Input Variables

              *-----------------------------------------------*
               Bed Material Transport Mode Factor (k1):    .64
               Total Pier Width Value             (Pw):  3.000
              *-----------------------------------------------*

     Scour      -- Flow --          -- Width --         --- X-Limits ---
 #   Depth  Contract Approach  Contract Approach  Side   Contract Approach
--   ------ --------- --------- -------- --------  ------ -------- --------
 1   -.066  4300.000  3042.667   80.000   50.000  Left:  ******** ********
    ..... Approach Channel Depth:   10.287 .....  Right: ******** ********
*  Negative Scour Depth Encountered - Check If Variables Are Reasonable  *

 2   2.432  7310.000  4258.095   80.000   50.000  Left:  ******** ********
    ..... Approach Channel Depth:   14.098 .....  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 WILLIAMS CREEK  I-465-131-5256
            COUNTY: HAMILTON           QUAD: CARMEL 111A
            4-11-97                    BRET A. ROBINSON

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

                      Constants and Input Variables

                          Pier Width:   2.000
              *-----------------------------------------*
```

# WSPRO OUTPUT

```
                  Pier Shape Factor            (K1):   1.00
                  Flow Angle of Attack Factor  (K2):   1.00
                  Bed Condition Factor         (K3):   1.10
                  Bed Material Factor          (K4):   1.00
                  Velocity Multiplier          (VM):   1.00
                  Depth Multiplier             (YM):   1.00
                *-----------------------------------------*
```

| # | Scour Depth | Flow | WSE | Depth | Velocity | Froude # | Left | Right |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.49 | 4300.000 | 794.770 | 9.070 | 12.334 | .722 | 60877.000 | 60984.000 |
| 2 | 7.39 | 7310.000 | 796.922 | 11.222 | 15.614 | .821 | 60877.000 | 60984.000 |

```
     ************************* 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-465 OVER WILLIAMS CREEK  I-465-131-5256
             COUNTY: HAMILTON           QUAD: CARMEL 111A
             4-11-97                    BRET A. ROBINSON

         ***  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):   1.00
                  Bed Condition Factor         (K3):   1.10
                  Bed Material Factor          (K4):   1.00
                  Velocity Multiplier          (VM):   1.00
                  Depth Multiplier             (YM):   1.00
                *-----------------------------------------*
```

| # | Scour Depth | Flow | WSE | Depth | Velocity | Froude # | Left | Right |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.49 | 4300.000 | 794.770 | 9.070 | 12.334 | .722 | 60877.000 | 60984.000 |
| 2 | 7.39 | 7310.000 | 796.922 | 11.222 | 15.614 | .821 | 60877.000 | 60984.000 |

```
  ER

   ****************** Normal end of WSPRO execution. *****************
   *************** Elapsed Time:   0 Minutes  4 Seconds **************
```