Modified Level II Streambed-Scour Analysis for Structure I-69-87-4781 Crossing Wabash River in Huntington County, Indiana

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

Prepared in cooperation with the INDIANA DEPARTMENT OF TRANSPORTATION

U.S. GEOLOGICAL SURVEY
Open-File Report 97-307

Indianapolis, Indiana
1997
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CONVERSION FACTORS AND ABBREVIATIONS

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<th>To obtain</th>
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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: United States Geological Survey
- WSPRO: Water Surface PROfile model
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By Bret A. Robinson, David C. Voelker, and Robert L. Miller

ABSTRACT

Level II scour evaluations follow a process in which hydrologic, hydraulic, and sediment-transport data are evaluated to calculate the depth of scour that may result when a given discharge is routed through a bridge opening. The results of the modified Level II analysis for structure I-69-87-4781 on Interstate 69 crossing Wabash River in Huntington County, Indiana, are presented. The site is near the town of Markle in the eastern part of Huntington 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 13.1 feet for the modeled discharge of 10,600 cubic feet per second and approximately 14.6 feet for the modeled discharge of 17,000 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-69-87-4781.

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 Markle in the eastern part of Huntington County. The drainage area for the site is approximately 701 mi$^2$ (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is agricultural; in the immediate vicinity of the bridge, the land is predominantly brush covered.

Within the immediate vicinity of the bridge, Wabash River has a channel-bed slope of approximately 0.0016 ft/ft. The channel-bed material is a sand, gravel, and cobble mixture, and the channel banks consist of sandy gravelly silt. At the time of the Level I site visit on June 24, 1993, the banks were observed to have 0 to 25 percent woody vegetative cover; the field report noted that the banks were experiencing fluvial erosion.

The Interstate 69 crossing of Wabash River is a 546-ft-long, multi-lane bridge consisting of six spans supported by concrete and steel piers and sloping riprap-covered spill-through abutments. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.
EVALUATION METHODS

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

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

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

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

Most of the cross-section and bridge-opening geometry data were taken from the bridge plans (Indiana State Highway Commission, 1980) 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 (\(K_1\) to \(K_4\)). For this modeling, the default value for \(K_4\) (bed armoring) was chosen. For scour-adjustment factors \(K_1\) and \(K_2\) (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 \(K_3\) 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-69-87-4781 crossing Wabash River in Huntington County, Indiana

[---, no value]

<table>
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<tr>
<th>Pier number</th>
<th>Stationing from bridge plans</th>
<th>Initial bed-elevation at pier (feet)</th>
<th>Main-channel contraction scour depth (feet)</th>
<th>Local scour depth (feet)</th>
<th>Worst-case total-scour depth (feet)</th>
<th>Bottom elevation of pier (feet)</th>
<th>Worst-case bed elevation after scour (feet)</th>
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<td>13.1</td>
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<td>13.1</td>
<td>13.1</td>
<td>749</td>
<td>740.9</td>
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</tbody>
</table>

Modeled discharge is 10,600 cubic feet per second

Modeled discharge is 17,000 cubic feet per second

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, 739+34, represents a point 73,934 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 (754 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 bridge is within the flood-pool area of Huntington Reservoir. This implies that when the stage of Huntington Reservoir is approaching its flood-pool elevation, this bridge may be in backwater effect from the reservoir. Because this bridge is not always in the area of back-water effect, however, this modeling has been conducted assuming no effect from the downstream reservoir.
The model results indicate negative contraction scour (aggradation). To be consistent with the methodology outlined in the previous section, however, table 1 reports contraction scour depths of zero. This is done so that the total scour depth shown in table 1 does not lead the reader to an overly optimistic margin of safety for this bridge.

Scour calculations for this bridge were completed only at the three center-most piers; piers 1 and 5 were omitted from scour calculations. This was done for two reasons. First, the water surface profile produced from modeling the Q100 was not high enough to reach piers 1 and 5. Secondly, these piers (pier 1 and pier 5) are constructed on the sloping abutments that are protected by riprap. Therefore, it seemed appropriate to exclude these piers from the scour calculations.

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


APPENDIX
WS PRO INPUT FILE

T1  I-69 Over Wabash River  I-69-87-4781
T2  County: Huntington  Quad: Markle 62D
T3  4-11-97  Bret A. Robinson
SI  0
Q  10600
Q  17000
SK  .0016 .0016
XS  EXIT  0  0
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GR  73905  753  73913  754  73933  755  74015  755  74058  755  74121  755
GR  74157  753  74201  753  74209  755  74223  760  74233  765  74288  760
GR  74459  770  74622  780  75327  790  75546  800
N  .120  .034  .120
SA  73800  74300
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GR  73905  753  73913  754  73933  755  74015  755  74058  755  74121  755
GR  74157  753  74201  753  74209  755  74223  760  74233  765  74288  760
GR  74459  770  74622  780  75327  790  75546  800
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PD  757.5  4 2
PD  757.5  6 3
PD  772  6 4
PD  772  10 5
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SA  73725  74200
EX
ER
WS PRO OUTPUT

Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Run Date & Time: 8/4/97 8:24 am Version V050196
Input File: 4781.dat Output File: 4781.LST

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T2  COUNTY: HUNTINGTON QUAD: MARKLE 62D
T3  4-11-97 BRET A. ROBINSON
SI  0
Q  10600
Q  17000

*** Processing Flow Data; Placing Information into Sequence 1 ***
SK  .0016 .0016

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

I-69 OVER WABASH RIVER  I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

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GR  74157 753 74201 753 74209 755 74223 760 74233 765 74288 760
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Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X, Y-coordinates (22 pairs)

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Maximum X-Station: 75546.000 (associated Y-Elevation: 800.000)
Minimum Y-Elevation: 753.000 (associated X-Station: 74201.000)
Maximum Y-Elevation: 800.000 (associated X-Station: 75546.000)

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Roughness Horizontal
SubArea Coefficient Breakpoint
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... *******
2 .034 ---
... *******
3 .120 ---
... ---------

ICIENTED PROCESSING HEADER RECORD EXIT

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

I-69 OVER WABASH RIVER I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

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WSPRO OUTPUT

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Minimum and Maximum X,Y-coordinates

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Maximum X-Station: 75546.000 (associated Y-Elevation: 800.000)
Minimum Y-Elevation: 753.000 (associated X-Station: 74201.000)
Maximum Y-Elevation: 800.000 (associated X-Station: 75546.000)

Roughness Data (3 SubAreas)

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

I-69 OVER WABASH RIVER I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

* Starting To Process Header Record BRDGE *

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Valley Slope: ******* Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)

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<td>797.300</td>
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</tbody>
</table>

Minimum and Maximum X,Y-coordinates
Minimum X-Station: 73762.000 (associated Y-Elevation: 797.300)
Maximum X-Station: 74307.000 (associated Y-Elevation: 798.000)
Minimum Y-Elevation: 753.000 (associated X-Station: 74101.000)
Maximum Y-Elevation: 798.000 (associated X-Station: 74307.000)

Roughness Data (1 SubAreas)
SubArea Coefficient Breakpoint
1  .034 ---

Discharge coefficient parameters
BRTYPE BRWdth EMBSS EMBElv UserCD
3  125.000 3.00 796.000 ********

Pressure flow elevations
AVBCEL PFElev
******* 797.000

Abutment Parameters

Pier/Pile Data (5 Group(s))
WSPRO OUTPUT

Code Indicates Bridge Uses Piers

<table>
<thead>
<tr>
<th>Group</th>
<th>Elevation</th>
<th>Gross Width</th>
<th>Number</th>
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<td>4.000</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>757.500</td>
<td>4.000</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>757.500</td>
<td>6.000</td>
<td>3</td>
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<tr>
<td>4</td>
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<td>6.000</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>772.000</td>
<td>10.000</td>
<td>5</td>
</tr>
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* Finished Processing Header Record BRDGE *

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

I-69 OVER WABASH RIVER  I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

DC 0 BRDGE 73782 74282 73900 74125 * 10
DP 73762 74307 2 * * 1 2.5 1.1
DP 73762 74307 2 * * 1 2.5 1.1
DP 73762 74307 2 * * 1 2.5 1.1

* Starting To Process Header Record APPR *

XS APPR 1205 0
GR 72006 780 73553 770 73732 765 73743 760 73751 758 73774 758
GR 73850 759 73901 759 73912 755 73966 753 74110 754 74134 760
GR 74226 765 74277 770 74425 770 74610 780 75024 790 75096 800
N .120 .034 .120
SA 73725 74200

*** 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: 1205. 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 (18 pairs)

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<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
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</thead>
<tbody>
<tr>
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<td>73553.000</td>
<td>770.000</td>
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<td>73743.000</td>
<td>760.000</td>
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<tr>
<td>73850.000</td>
<td>759.000</td>
<td>73901.000</td>
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<td>73912.000</td>
<td>755.000</td>
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<tr>
<td>73966.000</td>
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<td>74110.000</td>
<td>754.000</td>
<td>74134.000</td>
<td>760.000</td>
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<tr>
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<td>74277.000</td>
<td>770.000</td>
<td>74425.000</td>
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</table>
### Minimum and Maximum X,Y-coordinates

- **Minimum X-Station**: 72006.000 (associated Y-Elevation: 780.000)
- **Maximum X-Station**: 75096.000 (associated Y-Elevation: 800.000)
- **Minimum Y-Elevation**: 753.000 (associated X-Station: 73966.000)
- **Maximum Y-Elevation**: 800.000 (associated X-Station: 75096.000)

### Roughness Data (3 SubAreas)

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<tr>
<th>SubArea</th>
<th>Coefficient</th>
<th>Breakpoint</th>
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<td>.120</td>
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### Bridge datum projection(s):

- XREFLT
- XREFRT
- FDSTLT
- FDSTRT

---

*--- Finished Processing Header Record APPR ---*

---

*WSPRO*

Federal Highway Administration - U.S. Geological Survey
Model for Water-Surface Profile Computations.

Input Units: English / Output Units: English

*1-69 OVER WABASH RIVER 1-69-87-4781*
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

*Summary of Boundary Condition Information*

<table>
<thead>
<tr>
<th>Reach</th>
<th>Water Surface Friction</th>
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<tr>
<td></td>
<td>Discharge  Elevation  Slope  Flow Regime</td>
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<td></td>
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<tr>
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<tr>
<td>2</td>
<td>17000.00</td>
</tr>
</tbody>
</table>

*Beginning 2 Profile Calculation(s)*

---

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

<table>
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<tr>
<th>Section</th>
<th>Header Type</th>
<th>3RD:</th>
<th>Flow Type</th>
<th>Pier/Pile Code</th>
<th>Specific Bridge Information</th>
<th>Specific Bridge Information</th>
<th>Approach Section APPR Flow Contraction Information</th>
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<tbody>
<tr>
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<td>XS</td>
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<td>2173.589</td>
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<td>FV</td>
<td>1205.000</td>
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<td>0</td>
<td>540.000</td>
<td>2173.589</td>
<td>665.000</td>
</tr>
<tr>
<td>BRIDGE</td>
<td>BR</td>
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<td>1</td>
<td>0</td>
<td>540.000</td>
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<td>665.000</td>
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<tr>
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<td>AS</td>
<td>1205.000</td>
<td>1</td>
<td>0</td>
<td>540.000</td>
<td>2173.589</td>
<td>665.000</td>
</tr>
</tbody>
</table>

Approach Section APPR Flow Contraction Information
WSPRO OUTPUT

```plaintext
M(G)  M(K)  KQ  XLKQ  XRKQ  OTEL
-------  ------  -----  ------  ------  -------
   .299    .061  410179.8  ********  ********  763.129

<<< End of Bridge Hydraulics Computations >>>

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

I-69 OVER WABASH RIVER I-69-87-4781
COUNTY: HUNTINGTON QUAD: MARKLE 62D
4-11-97 BRET A. ROBINSON

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

Section: EXIT  761.679  .546  17000.000  2895.391  ********  73764.300
Header Type: XS  762.226  *****  5.871  424851.20  ********  74316.720
SRD:  .000  758.502  *****  .438  *****    1.019  ****

Section: FULLV  762.502  .424  17000.000  3334.519  540.000  73740.430
Header Type: FV  762.926  .712  5.098  515591.10  540.000  74330.790
SRD:  540.000  758.502  .000  .377  .0013  1.049  -.012

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

Section: APPR  763.288  .506  17000.000  2980.945  665.000  73735.770
Header Type: AS  763.794  .825  5.703  452023.50  665.000  74194.500
SRD:  1205.000  759.833  .041  .394  .0012  1.000  .002

<<< 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: BRIDGE  762.487  1.192  17000.000  1941.629  540.000  73865.800
Header Type: BR  763.679  1.325  8.756  283751.00  540.000  74181.970
SRD:  540.000  760.757  .129  .623  *****    1.000  .000

Specific Bridge Information  C  P/A  PFELEV  BLEN  XLAB  XRAB
Bridge Type 3  Flow Type 1  ********  ********  ******  ******  ********
Pier/Pile Code  0  1.0000  .023  797.000  ********  ********  ******
```
Section: APPR 765.065  .310  17000.000  3828.824  540.000  73729.660
Header Type: AS 765.375  .877  4.440  668726.60  562.513  74226.660
SRD: 1205.000  759.833  .818  .283  .0012  1.010  .006

Approach Section APPR  Flow Contraction Information
M( G )  M( K )  KQ  XLKQ  XRKQ  OTEL

.310  .095  604322.0  ******  ******  765.065

<< End of Bridge Hydraulics Computations >>

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

Constants and Input Variables

Bed Material Transport Mode Factor (kl): .64
Total Pier Width Value (Pw): 10.000

- Negative Scour Depth Encountered - Check If Variables Are Reasonable -
**WSPRO OUTPUT**

4-11-97

BRET A. ROBINSON

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

Constants and Input Variables

Pier Width: 2.000

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier Shape Factor (K1)</td>
<td>1.00</td>
</tr>
<tr>
<td>Flow Angle of Attack Factor (K2)</td>
<td>2.50</td>
</tr>
<tr>
<td>Bed Condition Factor (K3)</td>
<td>1.10</td>
</tr>
<tr>
<td>Bed Material Factor (K4)</td>
<td>1.00</td>
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<tr>
<td>Velocity Multiplier (VM)</td>
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</tr>
<tr>
<td>Depth Multiplier (YM)</td>
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</table>

Scour ---- Localized Hydraulic Properties ---- -- X-Stations --

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<th>Flow</th>
<th>WSE Depth</th>
<th>Velocity</th>
<th>Froude</th>
<th># Left</th>
<th>Right</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>761.648</td>
<td>8.648</td>
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<tr>
<td>2</td>
<td>14.57</td>
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<td>10.306</td>
<td>9.216</td>
<td>0.506</td>
<td>73762.000 74307.000</td>
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</tbody>
</table>

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Federal Highway Administration - U. S. Geological Survey

Model for Water-Surface Profile Computations.

Input Units: English / Output Units: English

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

Constants and Input Variables

Pier Width: 2.000

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Pier Shape Factor (K1)</td>
<td>1.00</td>
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<tr>
<td>Flow Angle of Attack Factor (K2)</td>
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<td>Bed Condition Factor (K3)</td>
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<td>Bed Material Factor (K4)</td>
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<tr>
<td>Velocity Multiplier (VM)</td>
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<td>Depth Multiplier (YM)</td>
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Scour ---- Localized Hydraulic Properties ---- -- X-Stations --

<table>
<thead>
<tr>
<th></th>
<th>Depth</th>
<th>Flow</th>
<th>WSE Depth</th>
<th>Velocity</th>
<th>Froude</th>
<th># Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>10600.000</td>
<td>761.648</td>
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<td>10.306</td>
<td>9.216</td>
<td>0.506</td>
<td>73762.000 74307.000</td>
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</table>
*** 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): 2.50  
Bed Condition Factor (K3): 1.10  
Bed Material Factor (K4): 1.00  
Velocity Multiplier (VM): 1.00  
Depth Multiplier (YM): 1.00

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<th>#</th>
<th>X-Stations</th>
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<th>Right</th>
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<td>74307.000</td>
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<td>9.216</td>
<td>.506</td>
<td>73762.000</td>
<td>74307.000</td>
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</tbody>
</table>

ER

******************* Normal end of WSPRO execution. *******************

******************* Elapsed Time: 0 Minutes 4 Seconds *******************