Modified Level II Streambed-Scour Analysis for Structure I-69-16-5324 Crossing Fosters Branch in Madison County, Indiana

By BRENT 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 97-312

Indianapolis, Indiana
1997
CONTENTS

Abstract .................................................................................................................. 1
Introduction ............................................................................................................. 1
  Background and Scope .......................................................................................... 1
  Site Description ................................................................................................... 2
Evaluation Methods ................................................................................................ 3
Special Considerations ............................................................................................. 5
Results .................................................................................................................... 5
References ............................................................................................................... 6
Appendix .................................................................................................................. 7
  Water Surface PROfile Model (WSPRO) Input File ...................................... 8
  Water Surface PROfile Model (WSPRO) Output ........................................... 9

Tables

  1. Cumulative scour depths for the modeled discharges at structure I-69-16-5324
crossing Fosters Branch in Madison County, Indiana ....................................... 5
CONVERSION FACTORS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>inch (in.)</td>
<td>25.4</td>
<td>millimeter</td>
</tr>
<tr>
<td>foot (ft)</td>
<td>0.3048</td>
<td>meter</td>
</tr>
<tr>
<td>square foot (ft²)</td>
<td>929.0</td>
<td>square centimeter</td>
</tr>
<tr>
<td>feet per second (ft/s)</td>
<td>0.3048</td>
<td>meters per second</td>
</tr>
<tr>
<td>cubic foot per second (ft³/s)</td>
<td>0.02832</td>
<td>cubic meter per second</td>
</tr>
<tr>
<td>mile (mi)</td>
<td>1.609</td>
<td>kilometer</td>
</tr>
<tr>
<td>square mile (mi²)</td>
<td>2.590</td>
<td>square kilometer</td>
</tr>
</tbody>
</table>

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
Modified Level II Streambed-Scour Analysis for Structure 1-69-16-5324 Crossing Fosters Branch in Madison 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-69-16-5324 on Interstate 69 crossing Fosters Branch in Madison County, Indiana, are presented. The site is near the town of Ingalls in the southwestern part of Madison 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 8.0 feet for the modeled discharge of 1,600 cubic feet per second and approximately 12.8 feet for the modeled discharge of 2,720 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-69-16-5324.

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 Ingalls in the southwestern part of Madison County. The drainage area for the site is approximately 15.1 mi² (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 agricultural.

Within the immediate vicinity of the bridge, Fosters Branch has a channel-bed slope of approximately 0.0022 ft/ft. The channel-bed material is sandy silt/clay, and the channel banks consist of sandy silt/clay. At the time of the Level I site visit on August 1, 1994, the banks were observed to have 0 to 25 percent woody vegetative cover; and the field report noted that the banks were experiencing some fluvial erosion.

The Interstate 69 crossing of Fosters Branch is a 96-ft-long, multi-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 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, 1964) 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-69-16-5324 crossing Fosters Branch in Madison County, Indiana
[--., no value]

<table>
<thead>
<tr>
<th>Pier number(^1)</th>
<th>Stationing from bridge plans(^2)</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(^3) (feet)</th>
<th>Bottom elevation of pier (feet)</th>
<th>Worst-case bed elevation after scour(^4) (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>933+15</td>
<td>837</td>
<td>3.9</td>
<td>4.1</td>
<td>8.0</td>
<td>829.4</td>
<td>827.4</td>
</tr>
<tr>
<td>2</td>
<td>933+55</td>
<td>837</td>
<td>3.9</td>
<td>4.1</td>
<td>8.0</td>
<td>830.0</td>
<td>827.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modeled discharge(^5) is 1,600 cubic feet per second</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>933+15</td>
<td>837</td>
<td>8.1</td>
<td>4.7</td>
<td>12.8</td>
<td>829.4</td>
<td>822.6</td>
</tr>
<tr>
<td>2</td>
<td>933+55</td>
<td>837</td>
<td>8.1</td>
<td>4.7</td>
<td>12.8</td>
<td>830.0</td>
<td>822.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modeled discharge is 2,720 cubic feet per second</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Pier numbers were assigned from left to right as shown on the bridge plans.
2Stationing is the center line of the pier as determined from the bridge plans. Stationing from bridge plan, 933+15, represents a point 93,315 feet from an arbitrary starting location referenced on the bridge plans.
3Worst-case total-scour depths are generated by summing the calculated contraction-scour depth with the worst case of local scour.
4Worst-case bed elevation is computed by subtracting the worst-case total-scour depth from the lowest initial bed elevation in the bridge opening (835.4 feet).
5Not a coordinated discharge.

SPECIAL CONSIDERATIONS

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

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
WSPRO OUTPUT

************************************************************* W S P R O *****************************************************
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Run Date & Time: 8/4/97 0:56 pm    Version V050196
Input File: 5324.dat    Output File: 5324.LST
*************************************************************

T1  I-69 OVER FOSTER BRANCH    I69-16-5324
T2  COUNTY: MADISON    QUAD: INGALLS 112 B
T3  11-18-96    BRET A. ROBINSON
SI  0
Q   1600 2720

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

SK  .0022 .0022

************************************************************* 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-69 OVER FOSTER BRANCH    I69-16-5324
COUNTY: MADISON    QUAD: INGALLS 112 B
11-18-96    BRET A. ROBINSON

'*Starting To Process Header Record EXIT*

XS  EXIT 0 0
GR  92758 870 93006 860 93058 850 93177 840 93215 840 93251 835 93266 834 93280 835 93314 840 93395 840 93526 850 93601 860
GR  94006 870
N   .045 .034 .045
SA  93210 93320

*** 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 (13 pairs)

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>92758.000</td>
<td>870.000</td>
<td>93006.000</td>
<td>860.000</td>
<td>93058.000</td>
<td>850.000</td>
</tr>
<tr>
<td>93177.000</td>
<td>840.000</td>
<td>93215.000</td>
<td>840.000</td>
<td>93251.000</td>
<td>835.000</td>
</tr>
<tr>
<td>93266.000</td>
<td>834.700</td>
<td>93280.000</td>
<td>835.000</td>
<td>93314.000</td>
<td>840.000</td>
</tr>
<tr>
<td>93395.000</td>
<td>840.000</td>
<td>93526.000</td>
<td>850.000</td>
<td>93601.000</td>
<td>860.000</td>
</tr>
<tr>
<td>94006.000</td>
<td>870.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WSPRO OUTPUT

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 92758.000 (associated Y-Elevation: 870.000)
Maximum X-Station: 94006.000 (associated Y-Elevation: 870.000)
Minimum Y-Elevation: 834.700 (associated X-Station: 93266.000)
Maximum Y-Elevation: 870.000 (associated X-Station: 92758.000)

Roughness Data (3 SubAreas)

<table>
<thead>
<tr>
<th>SubArea</th>
<th>Coefficient</th>
<th>Breakpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.045</td>
<td>---</td>
</tr>
<tr>
<td>2</td>
<td>.034</td>
<td>***</td>
</tr>
<tr>
<td>3</td>
<td>.045</td>
<td>---</td>
</tr>
</tbody>
</table>

-------------------------------*                          *-------------------------------*
*                      Finished 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 FOSTER BRANCH I69-16-5324
COUNTY: MADISON QUAD: INGALLS 112 B
11-18-96 BRET A. ROBINSON

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

XS FULLV 100 0
GR 92758 870 93006 860 93058 850 93177 840 93215 840 93251 835
GR 93266 834.7 93280 835 93314 840 93395 840 93526 850 93601
860
GR 94006 870
N .045 .034 .045
SA 93210 93320

*** 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: 100. 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

-10-
Minimum and Maximum X,Y-coordinates
Minimum X-Station: 92758.000  ( associated Y-Elevation: 870.000 )
Maximum X-Station: 94006.000  ( associated Y-Elevation: 870.000 )
Minimum Y-Elevation: 834.700  ( associated X-Station: 93266.000 )
Maximum Y-Elevation: 870.000  ( associated X-Station: 92758.000 )

Roughness Data ( 3 SubAreas )

<table>
<thead>
<tr>
<th>SubArea</th>
<th>Coefficient</th>
<th>Breakpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.045</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>**********</td>
</tr>
<tr>
<td>2</td>
<td>.034</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>**********</td>
</tr>
<tr>
<td>3</td>
<td>.045</td>
<td>---</td>
</tr>
</tbody>
</table>

* Finished Processing Header Record FULLV *

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

I-69 OVER FOSTER BRANCH
COUNTY: MADISON QUAD: INGALLS 112 B
11-18-96 BRET A. ROBINSON

* Starting To Process Header Record BRIDGE *

BR BRIDGE 100 848 0
GR 93292 0848.7 93292 0848.1 93295 0847.8 93325 0835.1 93354
0835.2
GR 93383 0847.6 93385 0847.7 93385 0848.3 93292 0848.7
N .034
PD 837 3 1
CD 3 150 2 846

*** Completed Reading Data Associated With Header Record BRIDGE ***
+++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 ***
WSPRO OUTPUT

*** Data Summary For Bridge Record BRDGE ***
SRD Location: 100. Cross-Section Skew: .0 Error Code 0
Valley Slope: ******* Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (9 pairs)

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>93292.000</td>
<td>848.700</td>
<td>93292.100</td>
<td>848.100</td>
<td>93295.000</td>
<td>847.800</td>
</tr>
<tr>
<td>93325.000</td>
<td>835.100</td>
<td>93354.000</td>
<td>835.200</td>
<td>93383.000</td>
<td>847.600</td>
</tr>
<tr>
<td>93385.000</td>
<td>847.700</td>
<td>93385.100</td>
<td>848.300</td>
<td>93292.000</td>
<td>848.700</td>
</tr>
</tbody>
</table>

Minimum and Maximum X,Y-coordinates
Minimum X-Station: 93292.000 (associated Y-Elevation: 848.700)
Maximum X-Station: 93385.100 (associated Y-Elevation: 848.300)
Minimum Y-Elevation: 835.100 (associated X-Station: 93325.000)
Maximum Y-Elevation: 848.700 (associated X-Station: 93292.000)

Roughness Data (1 SubAreas)

<table>
<thead>
<tr>
<th>SubArea</th>
<th>Coefficient</th>
<th>Breakpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.034</td>
<td>---</td>
</tr>
</tbody>
</table>

Discharge coefficient parameters

<table>
<thead>
<tr>
<th>BRType</th>
<th>BRWdth</th>
<th>EMBSS</th>
<th>EMBElv</th>
<th>UserCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>150.000</td>
<td>2.00</td>
<td>846.000</td>
<td>*********</td>
</tr>
</tbody>
</table>

Pressure flow elevations

<table>
<thead>
<tr>
<th>AVBCEL</th>
<th>PFElev</th>
</tr>
</thead>
<tbody>
<tr>
<td>*********</td>
<td>848.000</td>
</tr>
</tbody>
</table>

Abutment Parameters

<table>
<thead>
<tr>
<th>ABSLPL</th>
<th>ABSLPR</th>
<th>XTOELT</th>
<th>YTOELT</th>
<th>XTOERT</th>
<th>YTOERT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pier/Pile Data (1 Group(s))

Code Indicates Bridge Uses Piers

<table>
<thead>
<tr>
<th>Group</th>
<th>Elevation</th>
<th>Gross Width</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>837.000</td>
<td>3.000</td>
<td>1</td>
</tr>
</tbody>
</table>

* Finished Processing Header Record BRDGE *

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

*---------------------*  I-69 OVER FOSTER BRANCH  I69-16-5324  *
COUNTY: MADISON       QUAD: INGALLS 112 B  *
11-18-96               BRET A. ROBINSON  *
DC 0 BRIDGE 93313 93365 93375 93470 * 3  *
DP  93292  93385  1.5 * * 1 1 1.1  *
DP  93292  93385  1.5 * * 1 1 1.1  *

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

XS  APPR  350  0  834.7
GR  92911  870  93222  860  93300  850  93371  840  93406  835  93421  834.7
GR  93434  835  93469  840  93635  840  93659  850  93722  860
GR  94089  870
N  .100  .034  .100
SA  93400  93440

*** 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:  350.  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 (12 pairs)

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>92911.000</td>
<td>870.000</td>
<td>93222.000</td>
<td>860.000</td>
<td>93300.000</td>
<td>850.000</td>
</tr>
<tr>
<td>93371.000</td>
<td>840.000</td>
<td>93406.000</td>
<td>835.000</td>
<td>93421.000</td>
<td>834.700</td>
</tr>
<tr>
<td>93434.000</td>
<td>835.000</td>
<td>93469.000</td>
<td>840.000</td>
<td>93635.000</td>
<td>840.000</td>
</tr>
<tr>
<td>93659.000</td>
<td>850.000</td>
<td>93722.000</td>
<td>860.000</td>
<td>94089.000</td>
<td>870.000</td>
</tr>
</tbody>
</table>

Minimum and Maximum X,Y-coordinates
Minimum X-Station:  92911.000  ( associated Y-Elevation:  870.000  )
Maximum X-Station:  94089.000  ( associated Y-Elevation:  870.000  )
Minimum Y-Elevation:  834.700  ( associated X-Station:  93421.000  )
Maximum Y-Elevation:  870.000  ( associated X-Station:  92911.000  )

Roughness Data ( 3 SubAreas )

<table>
<thead>
<tr>
<th>SubArea</th>
<th>Roughness</th>
<th>Horizontal Breakpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.100</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.034</td>
<td>********</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.100</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-13-
Bridge datum projection(s): XREFLT XREFRT FDSTLT FDSTRT

* Finished Processing Header Record APPR *

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

I-69 OVER FOSTER BRANCH
COUNTY: MADISON
11-18-96

EX

* Summary of Boundary Condition Information *

<table>
<thead>
<tr>
<th>Reach</th>
<th>Water Surface Elevation</th>
<th>Friction Slope</th>
<th>Flow Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td># Discharge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 1600.00</td>
<td>********</td>
<td>.0022</td>
<td>Sub-Critical</td>
</tr>
<tr>
<td>2 2720.00</td>
<td>********</td>
<td>.0022</td>
<td>Sub-Critical</td>
</tr>
</tbody>
</table>

* Beginning 2 Profile Calculation(s) *

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

I-69 OVER FOSTER BRANCH
COUNTY: MADISON
11-18-96

```
 Section: EXIT
 Header Type: XS
 SRD: .000

 WSEL VHD Q AREA SRDL LEW
 840.275 .305 1600.000 385.182 ******** 93173.730
 EGELE HF V K FLEN REW
 CRWS HO FR # SF ALPHA ERR

 Section: FULLV
 Header Type: FV
 SRD: 100.000

 WSEL VHD Q AREA SRDL LEW
 840.517 .250 1600.000 440.307 100.000 93170.850
 EGELE HF V K FLEN REW
 CRWS HO FR # SF ALPHA ERR
```
WSPRO OUTPUT

« The Preceding Data Reflect The "Unconstricted" Profile »

Section: APPR 840.837 .447 1600.000 543.487 250.000 93365.050
Header Type: AS 841.284 .421 2.944 38764.05 250.000 93637.010
SRD: 350.000 838.661 .099 .669 .0017 3.319 -.002

« The Following Data Reflect The "Constricted" Profile »

« Beginning Bridge/Culvert Hydraulic Computations »

Specific Bridge Information
Bridge Type 3 Flow Type 1
Pier/Pile Code 0

« End of Bridge Hydraulics Computations »

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

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

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

.801 .218 49595.2 ******** 842.157

« End of Bridge Hydraulics Computations »
WSPRO OUTPUT

Section: EXIT
Header Type: XS
SRD:

Section: FULLY
Header Type: FV
SRD:

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

Section: APPR
Header Type: AS
SRD:

<< The Following Data Reflect The "Constricted" Profile >>

<< Beginning Bridge/Culvert Hydraulic Computations >>

--- QUESTIONABLE CRITICAL-FLOW SOLUTION AT SECID "BRIDGE".

Q, CRWS:

Section: BRIDGE
Header Type: BR
SRD:

Specific Bridge Information

Pier/Pile Code

Section: APPR
Header Type: AS
SRD:

Approach Flow Contraction Information

<< End of Bridge Hydraulics Computations >>
### Live-Bed Contraction Scour Calculations for Header Record BRDGE

**Constants and Input Variables**

- **Bed Material Transport Mode Factor (k1):** 0.64
- **Total Pier Width Value (Pw):** 3.000

<table>
<thead>
<tr>
<th>#</th>
<th>Depth</th>
<th>Approach Channel Depth</th>
<th>X-Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.941</td>
<td>1600.000</td>
<td>Left:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1395.693</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>49.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>95.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8.148</td>
<td>2720.000</td>
<td>Left:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000.194</td>
<td>Right:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>49.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>95.000</td>
<td></td>
</tr>
</tbody>
</table>

### Pier Scour Calculations for Header Record BRDGE

**Constants and Input Variables**

- **Pier Width:** 1.500

<table>
<thead>
<tr>
<th>#</th>
<th>Depth</th>
<th>Flow WSE</th>
<th>Depth</th>
<th>Velocity Froude</th>
<th>X-Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.08</td>
<td>1600.000</td>
<td>841.131</td>
<td>6.031</td>
<td>7.343</td>
</tr>
</tbody>
</table>
WSPRO OUTPUT

2 4.71 2720.000 842.515 7.415 9.642 .624 93292.000 93385.000

************************** 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-69 OVER FOSTER BRANCH I69-16-5324
COUNTY: MADISON QUAD: INGALLS 112 B
11-18-96 BRET A. ROBINSON

*** Pier Scour Calculations for Header Record BRIDGE ***

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 4.08 1600.000 841.131 6.031 7.343 .527 93292.000 93385.000
2 4.71 2720.000 842.515 7.415 9.642 .624 93292.000 93385.000

ER

************************** Normal end of WSPRO execution. ****************************
************************** Elapsed Time: 0 Minutes 3 Seconds ****************************