Modified Level II Streambed-Scour Analysis for Structure I-65-34-4240 Crossing a Muscatatuck River Overflow in Scott County, Indiana

By JOHN T. WILSON, 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 97-322

Indianapolis, Indiana
1997

U.S. DEPARTMENT OF THE INTERIOR
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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

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

ABSTRACT

Level II scour evaluations follow a process in which hydrologic, hydraulic, and sediment-transport data are evaluated to calculate the depth of scour that may result when a given discharge is routed through a bridge opening. The results of the modified Level II analysis for structure I-65-34-4240 on Interstate 65 crossing a Muscatatuck River overflow in Scott County, Indiana, are presented. The site is at the town of Austin in the northwestern part of Scott County, approximately 2,500 feet south of the Muscatatuck River. 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 depth at the piers was approximately 66.5 feet for the modeled discharge of 12,600 cubic feet per second. The modeled discharge in the overflow bridge was estimated to be 23 percent of the discharge in the Muscatatuck River.

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-65-34-4240.

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 at the town of Austin in the northwestern part of Scott County. The study site is an overflow bridge for the Interstate 65 crossing of Muscatatuck River (structure I-65-34-4241), located approximately 2,500 ft to the north. The drainage area for the Muscatatuck River is approximately 361 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 forest.

Within the immediate vicinity of the bridge, the channel-bed material is silt-clay, and the channel banks consist of silt-clay. At the time of the Level I site visit on June 22, 1992, the banks were observed to have 0 to 65 percent woody vegetative cover; the field report noted that the banks were stable.

The Interstate 65 crossing of the Muscatatuck River overflow is a 160-ft-long, multi-lane bridge consisting of three spans supported by concrete and steel piers and sloping concrete spill-through abutments. The Interstate 65 crossing of the Muscatatuck River is a 724-ft-long, multi-lane bridge consisting of 10 spans. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.

EVALUATION METHODS

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

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

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

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

Most of the cross-section and bridge-opening geometry data were taken from the bridge plans (Indiana State Highway Commission, 1959) provided by INDOT. Bridge plans are presumed to be representative of current conditions at the site. To determine the cross-section geometry, a line was drawn on the bridge plans parallel to the bridge stationing and approximately one bridge width from the bridge. For sites where the bridge plans did not extend far enough laterally for collection of all cross-section data required for WSPRO model analysis, additional data were collected from 7.5-minute topographic maps.

The roadway and embankment profile was taken from the bridge and highway plans for those sites where roadway overtopping was expected. The INDOT bridge plans and 7.5-minute topographic maps were used as a guide, based on the water-surface elevations calculated by the WSPRO model, to determine if roadway overtopping might occur.

Roughness values (n-values) for the main channel were estimated by viewing photographs archived from the Level I scour assessments. The n-values for the overbanks were assigned on the basis of the surface-cover data summarized in the Level I data base (Hopkins and Robinson, unpub. data, 1997). From those data, the following roughness values were assigned to the surface-cover categories: urban—0.050, suburban—0.035, row crop—0.045, pasture—0.035, brush—0.120, forest—0.100, and wetland (any area covered by standing water)—0.100. The n-values for the overbanks were adjusted if the Level I photographs provided sufficient detail to warrant an adjustment.

WSPRO version V050196 was used to model flow through the study site. Starting water-surface elevation was obtained with a slope-conveyance computation. The channel-bed slope in the immediate vicinity of the bridge was estimated from the 7.5-minute topographic map and was used as the slope of the energy grade line for this computation.

WSPRO version V050196 includes a field that allows the input of up to four scour-adjustment factors (K1 to K4). For this modeling, the default value for K4 (bed armoring) was chosen. For scour-adjustment factors K1 and K2 (pier-nose shape and angle of attack, respectively), input values were determined by evaluating the data archived in the Level I data base (Hopkins and Robinson, unpub. data, 1997). For the K3 factor (bed forms), a value of 1.1 was applied in all cases.

In some cases, piers set on the overbanks are constructed with footings that are higher in elevation than pier footings in the main channel. In these situations, if the channel position changes, the piers that were initially constructed on the overbank may become part of the main channel. Therefore, to evaluate total potential scour, the model results obtained for contraction scour and deepest local scour in the main channel were added and applied to all piers in the bridge opening. This methodology allowed for an evaluation of potential undermining of pier supports in the event that future channel movement placed overbank piers in the main channel.

Where bridge pairs have a continuous abutment or fill between the bridges that does not allow expansion of flow, the bridge pair was modeled as one bridge. Sites with discontinuous abutments, allowing expansion between the bridges, were modeled as two separate bridges. In those cases, a valley cross section was measured between the bridges and used as the approach section for the downstream bridge and as the exit section for the upstream bridge.

At sites with no embankment to function as a weir or at sites where the tailwater drowns out the embankment, a composite bridge and road section was used to compute flow. Those sites were computed with friction-loss equations rather than with a bridge routine.

Total scour is taken as the sum of local scour plus contraction scour. If the model predicted negative contraction scour (aggradation), the contraction-scour value was assumed to be zero in determining the total scour depth (table 1). This assumption was made so that a negative contraction scour would not mask the potentially detrimental effects of local scour at a pier. No abutment scour evaluations were made in this study.

Table 1. Cumulative scour depths for the modeled discharge at structure I-65-34-4240 crossing a Muscatatuck River overflow in Scott 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 12,600 cubic feet per second							
1	1399+25	532	41.3	25.2	66.5	517.0	456.5
2	1399+85	523	41.3	25.2	66.5	513.3	456.5

[1]Pier numbers were assigned from left to right as shown on the bridge plans.

[2]Stationing is the center line of the pier as determined from the bridge plans. Stationing from bridge plan, 1399+25, represents a point 139,925 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 (523.0 feet).

[5]Not a coordinated discharge. The discharge of 12,600 cubic feet per second represents the discharge in the Muscatatuck River that flows through the overflow bridge. The modeled discharge represents approximately 23 percent of 54,000 cubic feet per second.

SPECIAL CONSIDERATIONS

The study site is an overflow bridge for the Muscatatuck River, so the discharge through the bridge will be the flow from the Muscatatuck River that does not pass through the main-channel bridge. The multiple-opening bridge routine of WSPRO (Shearman, 1990) was used to determine the discharge through the overflow bridge and the "stagnation point" on the approach section where flow is split between the bridges.

The results of the multiple-opening bridge routine indicate that approximately 23 percent of the modeled discharge (54,000 ft^3/s) would flow through the overflow bridge. The stagnation point was estimated to be about 600 ft north of the overflow bridge and about 2,000 feet south of the main bridge.

The overflow discharge of 12,600 ft^3/s was used to compute scour depths, and the exit and approach sections were truncated at the "stagnation point."

Model runs indicate the water-surface elevation at the bridge is above the low-steel elevation for the modeled discharge of 91,800 ft^3/s (1.7 times the approximated Q100), potentially causing pressure flow through the bridge. Therefore, scour depths were computed only for the approximated Q100.

RESULTS

Scour depths were computed with a version of WSPRO (Larry Arneson, Federal Highway Administration, written commun., 1996) modified from Shearman (1990). This version of WSPRO includes scour calculations in the model output. Scour depths were calculated assuming an infinite depth of material that could erode and a homogeneous particle-size distribution. The results of the scour analysis are presented in table 1; a complete input file and output results are presented in the appendix.

REFERENCES

Hoggatt, R.E., 1975, Drainage areas of Indiana streams: U.S. Geological Survey, Water Resources Division, 231 p.

Indiana State Highway Commission, 1959, Bridge plans Interstate Route 65: Bridge File I-65-34-4240.

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-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
T2          COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
T3          8-11-97                            JOHN T. WILSON
Q           54000
SK          .0003
XS    EXIT  0  30   *   *   .0003
GR          37080 550  37210 540  37280 532  39896 532  39903 531  39927 531
GR          39937 532  39942 534  39971 534  39982 533  39989 530  40000 525
GR          40012 523  40021 525  40033 530  40037 531  40046 532  40100 532
GR          40114 531  40141 530  40166 530  40188 531  40211 532  40241 533
GR          40270 534  40294 535  40480 532  42600 532  42737 531  42848 530
GR          42864 529  42897 528  42921 527  42928 526  42932 525  42966 520
GR          42992 515  43041 510  43061 510  43081 512  43095 515  43122 520
GR          43146 525  43156 530  43163 532             43383 532  43431 533
GR          43460 532  43520 532  43565 535  43586 538  43591 540  44480 540
GR          45350 550
N           .100        .034     .100     .034     .100
SA          39982    40037    42921    43163
XS    FULLV  724  30
BR    BRG1  724     545.1
*           ***BRG1 IS MUSCATATUCK OVERFLOW BRIDGE #4240***
GR          39875 545.1  39875 544.0  39877 544.0  39877 543.5  39880 543.5
GR          39905 532.0  39926 532.0  39945 523.0  39984 523.0  40031 543.5
GR          40034 543.5  40034 544.0  40035 544.0  40035 545.1  39875 545.1
N           .040       .034
SA               39926
PW          523 3.0  532 3.0  532 4.9  537 4.0
CD          3    122    2    547
BR    BRG2  724   545.2     45
*           ***BRG2 IS MAIN CHANNEL BRIDGE #4241 AT MUSCATATUCK***
GR          42635  545.2  42635  544.4  42636  544.4  42636  544.1
GR          42639  544.1  42683  532.7  42697  532.7  42772  530.9
GR          42800  530.7  42847  530.7  42900  530.8  42909  530.5
GR          42914  531.0  42922  531.2  42932  531.4  42955  530.2
GR          42966  530.9  42985  529.5  42997  526.6  43001  526.0
GR          43012  521.2  43024  518.8  43032  518.7  43042  514.2
GR          43057  512.2  43072  513.1  43077  513.5  43082  510.5
GR          43091  510.5  43103  511.4  43113  518.0  43123  528.5
GR          43133  532.7  43147  532.1  43160  531.2  43200  532.9
GR          43222  532.4  43252  531.8  43297  532.8  43311  532.8
GR          43355  544.1  43358  544.1  43359  544.4  43359  545.2
GR          42635  545.2
N           .045        .034       .045
SA              42966         43133
PW          513.1 3.0  526.6   3.0  526.6 5.5  531.0 5.5  531.0 11.0
PW          532.0 11.0  532.0 15.4  533.0 15.4  533.0 18.0
CD          3    172    2    547
AS    APPR  1620  30
GR          37750 550  37845 540  37911 532  39834 532
GR          39845 533  39849 534  39852 535  39868 535  39873 534
GR          39886 533  39891 530  39904 525  39911 523  39917 525
GR          39928 530  39934 532  39951 533  39980 533  39997 532
GR          40040 531  40180 531  40244 532  42789 532
GR          42878 531  43025 531  43038 530  43049 525  43063 520
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WSPRO INPUT FILE

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GR          43132 511  43139 512  43146 513  43151 515  43164 520
GR          43170 525  43184 530  43190 532  43215 533  43238 533
GR          43285 532  43292 531  43330 531  43358 532  44345 540
GR          44510 550  44510 560
N           .100      .034       .100       .034       .045
SA          39886      39934    43038       43190
EX
ER
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WSPRO OUTPUT

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V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

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  T3         8-11-97                            JOHN T. WILSON
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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

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         COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
         8-11-97                            JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

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  GR        40270 534  40294 535  40480 532  42600 532  42737 531  42848 530
  GR        42864 529  42897 528  42921 527  42928 526  42932 525  42966 520
  GR        42992 515  43041 510  43061 510  43081 512  43095 515  43122 520
  GR        43146 525  43156 530  43163 532             43383 532  43431 533
  GR        43460 532  43520 532  43565 535  43586 538  43591 540  44480 540
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  40046.0  532.00   40100.0  532.00   40114.0  531.00   40141.0  530.00
  40166.0  530.00   40188.0  531.00   40211.0  532.00   40241.0  533.00
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WSPRO OUTPUT

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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
         COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
         8-11-97                            JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

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  42992.0  515.22   43041.0  510.22   43061.0  510.22   43081.0  512.22
  43095.0  515.22   43122.0  520.22   43146.0  525.22   43156.0  530.22
  43163.0  532.22   43383.0  532.22   43431.0  533.22   43460.0  532.22
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WSPRO OUTPUT

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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
         COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
         8-11-97                            JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

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  GR         39905 532.0  39926 532.0  39945 523.0  39984 523.0  40031 543.5
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     SKEW      IHFNO     VSLOPE         EK         CK
      0.0         0.     0.0003       0.50       0.00

X-Y COORDINATE PAIRS  (NGP =  15):
       X       Y           X       Y           X       Y           X       Y
  39875.0  545.10    39875.0  544.00    39877.0  544.00    39877.0  543.50
  39880.0  543.50    39905.0  532.00    39926.0  532.00    39945.0  523.00
  39984.0  523.00    40031.0  543.50    40034.0  543.50    40034.0  544.00
  40035.0  544.00    40035.0  545.10    39875.0  545.10

 X-Y MAX-MIN POINTS:
    XMIN       Y          X    YMIN       XMAX       Y          X    YMAX
  39875.0  545.10    39945.0  523.00    40035.0  544.00    39875.0  545.10

SUBAREA BREAKPOINTS (NSA =  2):
      39926.

ROUGHNESS COEFFICIENTS (NSA =  2):
        0.040   0.034
```

WSPRO OUTPUT

```
BRIDGE PARAMETERS:
 BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV  ABSLPL  ABSLPR
    3     122.0   545.10 *******   2.00   547.00 ******* *******

PIER DATA:  NPW =  4    PPCD = 0.
     PELV  PWDTH      PELV  PWDTH      PELV  PWDTH      PELV  PWDTH
   523.00   3.0     532.00   3.0     532.00   4.9     537.00   4.0

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         I-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
         COUNTY: SCOTT                     QUAD: CROTHERSVILLE 163D
         8-11-97                           JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

*** START PROCESSING CROSS SECTION - "BRG2 "
  BR   BRG2  724   545.2     45
  *          ***BRG2 IS MAIN CHANNEL BRIDGE #4241 AT MUSCATATUCK***
  GR         42635  545.2  42635  544.4  42636  544.4  42636  544.1
  GR         42639  544.1  42683  532.7  42697  532.7  42772  530.9
  GR         42800  530.7  42847  530.7  42900  530.8  42909  530.5
  GR         42914  531.0  42922  531.2  42932  531.4  42955  530.2
  GR         42966  530.9  42985  529.5  42997  526.6  43001  526.0
  GR         43012  521.2  43024  518.8  43032  518.7  43042  514.2
  GR         43057  512.2  43072  513.1  43077  513.5  43082  510.5
  GR         43091  510.5  43103  511.4  43113  518.0  43123  528.5
  GR         43133  532.7  43147  532.1  43160  531.2  43200  532.9
  GR         43222  532.4  43252  531.8  43297  532.8  43311  532.8
  GR         43355  544.1  43358  544.1  43359  544.4  43359  545.2
  GR         42635  545.2
  N          .045       .034       .045
  SA             42966        43133
  PW         513.1 3.0  526.6   3.0  526.6 5.5  531.0 5.5  531.0 11.0
  PW         532.0 11.0  532.0 15.4  533.0 15.4  533.0 18.0
  CD         3    172    2    547

*** FINISH PROCESSING CROSS SECTION - "BRG2 "
*** CROSS SECTION "BRG2 " WRITTEN TO DISK, RECORD NO. =  4

--- DATA SUMMARY FOR SECID "BRG2 " AT SRD =    724.  ERR-CODE =      0

     SKEW      IHFNO     VSLOPE         EK         CK
     45.0        0.     0.0003       0.50       0.00

X-Y COORDINATE PAIRS  (NGP =  45):
       X       Y          X       Y          X       Y          X       Y
  42635.0  545.20   42635.0  544.40   42636.0  544.40   42636.0  544.10
  42639.0  544.10   42683.0  532.70   42697.0  532.70   42772.0  530.90
  42800.0  530.70   42847.0  530.70   42900.0  530.80   42909.0  530.50
  42914.0  531.00   42922.0  531.20   42932.0  531.40   42955.0  530.20
  42966.0  530.90   42985.0  529.50   42997.0  526.60   43001.0  526.00
  43012.0  521.20   43024.0  518.80   43032.0  518.70   43042.0  514.20
  43057.0  512.20   43072.0  513.10   43077.0  513.50   43082.0  510.50
```

WSPRO OUTPUT

```
  43091.0  510.50   43103.0  511.40   43113.0  518.00   43123.0  528.50
  43133.0  532.70   43147.0  532.10   43160.0  531.20   43200.0  532.90
  43222.0  532.40   43252.0  531.80   43297.0  532.80   43311.0  532.80
  43355.0  544.10   43358.0  544.10   43359.0  544.40   43359.0  545.20
  42635.0  545.20

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN       XMAX       Y          X    YMAX
  42635.0  545.20   43082.0  510.50   43359.0  544.40   42635.0  545.20

SUBAREA BREAKPOINTS (NSA =  3):
      42966.  43133.

ROUGHNESS COEFFICIENTS (NSA =  3):
        0.045   0.034   0.045

BRIDGE PARAMETERS:
 BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV  ABSLPL  ABSLPR
    3     172.0   545.20 *******   2.00   547.00 ******* *******

PIER DATA:  NPW =  9    PPCD = 0.
     PELV  PWDTH      PELV  PWDTH      PELV  PWDTH      PELV  PWDTH
    513.10   3.0     526.60   3.0     526.60   5.5     531.00   5.5
    531.00  11.0     532.00  11.0     532.00  15.4     533.00  15.4
    533.00  18.0

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         I-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
         COUNTY: SCOTT                     QUAD: CROTHERSVILLE 163D
         8-11-97                           JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

*** START PROCESSING CROSS SECTION - "APPR "
  AS   APPR  1620  30
  GR         37750 550  37845 540  37911 532  39834 532
  GR         39845 533  39849 534  39852 535  39868 535  39873 534
  GR         39886 533  39891 530  39904 525  39911 523  39917 525
  GR         39928 530  39934 532  39951 533  39980 533  39997 532
  GR         40040 531  40180 531  40244 532  42789 532
  GR         42878 531  43025 531  43038 530  43049 525  43063 520
  GR         43079 515  43090 514  43100 513  43110 512  43120 511
  GR         43132 511  43139 512  43146 513  43151 515  43164 520
  GR         43170 525  43184 530  43190 532  43215 533  43238 533
  GR         43285 532  43292 531  43330 531  43358 532  44345 540
  GR         44510 550  44510 560
  N          .100     .034      .100      .034      .045
  SA         39886     39934   43038      43190
  EX

*** FINISH PROCESSING CROSS SECTION - "APPR "
*** CROSS SECTION "APPR " WRITTEN TO DISK, RECORD NO. =  5
```

WSPRO OUTPUT

```
--- DATA SUMMARY FOR SECID "APPR " AT SRD =   1620.  ERR-CODE =      0

     SKEW      IHFNO     VSLOPE         EK         CK
     30.0        0.     0.0003       0.50       0.00

X-Y COORDINATE PAIRS  (NGP =  50):
       X      Y          X      Y          X      Y          X      Y
  37750.0  550.00   37845.0  540.00   37911.0  532.00   39834.0  532.00
  39845.0  533.00   39849.0  534.00   39852.0  535.00   39868.0  535.00
  39873.0  534.00   39886.0  533.00   39891.0  530.00   39904.0  525.00
  39911.0  523.00   39917.0  525.00   39928.0  530.00   39934.0  532.00
  39951.0  533.00   39980.0  533.00   39997.0  532.00   40040.0  531.00
  40180.0  531.00   40244.0  532.00   42789.0  532.00   42878.0  531.00
  43025.0  531.00   43038.0  530.00   43049.0  525.00   43063.0  520.00
  43079.0  515.00   43090.0  514.00   43100.0  513.00   43110.0  512.00
  43120.0  511.00   43132.0  511.00   43139.0  512.00   43146.0  513.00
  43151.0  515.00   43164.0  520.00   43170.0  525.00   43184.0  530.00
  43190.0  532.00   43215.0  533.00   43238.0  533.00   43285.0  532.00
  43292.0  531.00   43330.0  531.00   43358.0  532.00   44345.0  540.00
  44510.0  550.00   44510.0  560.00

 X-Y MAX-MIN POINTS:
     XMIN       Y         X    YMIN      XMAX       Y         X    YMAX
  37750.0  550.00   43120.0  511.00   44510.0  550.00   44510.0  560.00

SUBAREA BREAKPOINTS (NSA =  5):
      39886.  39934.  43038.  43190.

ROUGHNESS COEFFICIENTS (NSA =  5):
        0.100   0.034   0.100   0.034   0.045

BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                        ******* ******* ******* *******

+++ BEGINNING PROFILE CALCULATIONS --   1

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
         COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
         8-11-97                            JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

 XSID:CODE    SRDL     LEW      AREA   VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

EXIT :XS    ****** 37226.   36962.  0.24 *****  538.38  533.84  54000.  538.14
        0. ****** 43586. 3117420.  7.10 ***** *******    0.26    1.46

FULLV:FV      724. 37226.   37003.  0.23  0.22  538.60 *******  54000.  538.37
       724.   724. 43586. 3121621.  7.09  0.00    0.01    0.26    1.46
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
```

WSPRO OUTPUT

```
APPR :AS      896. 37856.   36432.  0.20  0.30  538.90 *******  54000.  538.70
     1620.    896. 44185. 2822780.  5.75  0.00    0.00    0.24    1.48
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

A3 ---     1254.   4529.

QS ---    11709.  42291.

BOLEW ---    39891.  42661.

BOREW ---    40019.  43333.

STAGLT --- ********  40592.

STAGRT ---    40592.********

AS ---    15955.  20477.  36432.

KS ---  913062.1909755.2822817.

CA3 ---     1098.   3536.   4634.

CJ ---     0.875   0.781

CDF ---     0.670   1.158

CRF ---     2.163   2.388

QS ---    11853.  42147.

CDF ---     0.679   1.154

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

          I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
          COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
          8-11-97                            JOHN T. WILSON
            *** RUN DATE & TIME: 08-14-97  14:51

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K   ALPH     HO      ERR      FR#      VEL

BRG1 :BR       160. 39891.     1290.   1.77  0.48  540.42  534.83  11853.  538.64
      724.     160. 40020.   261252.   1.35  1.55   -0.01    0.60    9.19

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       3.    0.    1.  0.860  0.043  545.10 ****** ****** ******

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K   ALPH     HO      ERR      FR#      VEL
```

WSPRO OUTPUT

```
SLICE:AS     160. 37831.   22541.  0.01  0.98  541.66  523.38  11853.  541.65
     1006.   362. 40592. 1079679.  1.81  0.27   -0.02    0.04    0.53

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.953  0.956   48152. 39316. 39446.   541.63

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPR "     KRATIO =  1.53

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K   ALPH     HO      ERR      FR#      VEL

APPR :XS      614. 37829.   23098.  0.01  0.05  541.71 *******  11853.  541.70
     1620.    614. 40592. 1654942.  1.79  0.00    0.00    0.04    0.51

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K   ALPH     HO      ERR      FR#      VEL

BRG2 :BR      724. 42662.    4480.  2.42  0.67  540.68  536.38  42147.  538.26
      724.    724. 43332.  892762.  1.76  1.46    0.00    0.88    9.41

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   0.754   0.041  545.20 ****** ****** ******

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K   ALPH     HO      ERR      FR#      VEL

SLICE:AS      724. 40592.   29287.  0.13  0.48  541.57  536.38  42147.  541.44
     1620.    857. 44369. 3536701.  4.16  0.41    0.02    0.17    1.44

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.813  0.518 1700431. 42688. 43358.   541.33

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
         COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
         8-11-97                            JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K   ALPH     HO      ERR      FR#      VEL

APPR :XS    ****** 37831.   52229.  0.07 *****  541.59 *******  54000.  541.52
     1620.  ****** 44370. 4712405.  4.07 *****    2.82    0.12    1.03

STAGLT --- ********  40610.
```

WSPRO OUTPUT

```
STAGRT ---   40610.********

AS ---   22815.  29414.  52229.

KS --- 1615183.3097254.4712436.

CA3 ---    1110.   3379.   4488.

CJ ---    0.860   0.754

CDF ---    0.679   1.154

CRF ---    2.191   2.374

QS ---   12564.  41436.

CDF ---    0.679   1.167

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRG1 :BR     160. 39891.    1291.  2.00  0.51  540.65  535.21  12564.  538.65
      724.   160. 40020.  261562.  1.35  1.75    0.00    0.63    9.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        3.   0.   1.  0.859  0.043  545.10 ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     160. 37828.   23382.  0.01  1.00  541.95  523.38  12564.  541.94
     1006.   362. 40610. 1140725.  1.78  0.31    0.01    0.04    0.54

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.953  0.956   50362. 39326. 39456.   541.92

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPR "     KRATIO =  1.53

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPR :XS     614. 37826.   23945.  0.01  0.05  542.00 *******  12564.  541.99
     1620.   614. 40610. 1746146.  1.77  0.00    0.00    0.04    0.52

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
```

WSPRO OUTPUT

```
BRG2 :BR      724. 42662.    4479.  2.34  0.65  540.60  536.27  41436.  538.26
       724.   724. 43332.  892349.  1.76  1.41    0.00    0.70    9.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.755  0.041  545.20 ****** ****** ******

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
         COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
         8-11-97                            JOHN T. WILSON
           *** RUN DATE & TIME: 08-14-97  14:51

 XSID:CODE    SRDL     LEW      AREA   VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

SLICE:AS      724. 40610.   28777.  0.14  0.47  541.46  536.27  41436.  541.33
     1620.    855. 44367. 3504561.  4.21  0.40    0.00    0.18    1.44

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.812  0.513 1704812. 42688. 43359.   541.22

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 XSID:CODE    SRDL     LEW      AREA   VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

APPR :XS    ****** 37830.   52372.  0.07 *****  541.61 *******  54000.  541.55
     1620.  ****** 44371. 4731783.  4.06 *****    0.03    0.12    1.03

STAGLT ---  ********  40611.

STAGRT ---    40611.********

AS ---    22880.  29492.  52372.

KS --- 1622455.3109358.4731813.

CA3 ---     1109.   3380.   4489.

CJ ---     0.859   0.755

CDF ---     0.679   1.167

CRF ---     2.191   2.374

QS ---    12555.  41445.

CDF ---     0.678   1.168
```

WSPRO OUTPUT

```
          <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

BRG1 :BR      160. 39891.     1291.   1.99   0.51   540.64   535.21   12555.   538.65
      724.    160. 40020.   261575.   1.35   1.75     0.00     0.63    9.73

     TYPE PPCD FLOW       C     P/A     LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   0.859   0.043   545.10 ****** ****** ******

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

SLICE:AS      160. 37828.    23383.   0.01   1.00   541.95   523.38   12555.   541.94
     1006.    362. 40611. 1139344.   1.78   0.30     0.01     0.04    0.54

       M(G)   M(K)        KQ    XLKQ    XRKQ     OTEL
      0.954  0.956    50287. 39327. 39456.    541.92

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPR "     KRATIO =  1.53

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

APPR :XS      614. 37826.    23946.   0.01   0.05   542.00  *******   12555.   541.99
     1620.    614. 40611. 1745976.   1.77   0.00     0.00     0.04    0.52

WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

          I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
          COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
          8-11-97                            JOHN T. WILSON
            *** RUN DATE & TIME: 08-14-97  14:51

          <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

BRG2 :BR      724. 42662.     4479.   2.34   0.65   540.60   536.27   41445.   538.26
      724.    724. 43332.   892349.   1.76   1.41     0.00     0.70    9.25

     TYPE PPCD FLOW       C     P/A     LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   0.755   0.041   545.20 ****** ****** ******

 XSID:CODE    SRDL     LEW      AREA    VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL
```

WSPRO OUTPUT

```
SLICE:AS      724. 40611.   28776.  0.14  0.47  541.46  536.27  41445.  541.33
     1620.    855. 44367. 3506360.  4.21  0.40    0.00    0.18    1.44

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      0.812  0.513 1705672. 42688. 43359.   541.22

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 XSID:CODE    SRDL     LEW      AREA   VHD     HF      EGL     CRWS        Q     WSEL
       SRD    FLEN     REW         K  ALPH     HO      ERR      FR#      VEL

APPR :XS    ****** 37830.   52372.  0.07 *****  541.61 *******  54000.  541.55
     1620. ****** 44371. 4731783.  4.06 *****    0.00    0.12    1.03
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

WSPRO INPUT FILE

```
T1          I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
T2          COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
T3          8-11-97                            JOHN T. WILSON
Q           12600
WS          538.32
*           ***Q IS 23 PERCENT OF Q FOR MUSCATATUCK RIVER AT BRIDGE #4241***
*           ***WSEL IS FROM MULTIPLE-OPENING STEP BACKWATER MODEL***
XS   EXIT  0   30
*           ***EXIT WALLED UP AT STAGNATION POINT***
GR          37080 550  37210 540  37280 532  39896 532  39903 531  39927 531
GR          39937 532  39942 534  39971 534  39982 533  39989 530  40000 525
GR          40012 523  40021 525  40033 530  40037 531  40046 532  40100 532
GR          40114 531  40141 530  40166 530  40188 531  40211 532  40241 533
GR          40270 534  40294 535  40480 532  40611 532  40611 550
N           .100       .034       .100
SA               39982      40037
XS   FULLV  160    30
BR   BRG1   160    545.1
*           ***BRG1 IS MUSCATATUCK OVERFLOW BRIDGE #4240***
*           ***PIERS ARE SKEWED TO FLOW 30 DEGREES***
GR          39875 545.1  39875 544.0  39877 544.0  39877 543.5  39880 543.5
GR          39905 532.0  39926 532.0  39945 523.0  39984 523.0  40031 543.5
GR          40034 543.5  40034 544.0  40035 544.0  40035 545.1  39875 545.1
N           .040         .034
SA               39926
PD          523 3.0   1
PD          532 3.0   2
PD          532 4.9   3
PD          537 4.0   4
*           ***PIERS ARE TAPERED FROM 3 TO 2 FEET***
CD          3    122    2    547
DC 0        39891   40019   39791   39833   *   6
*           ***LEW AND REW FOR Q1 USED FOR DC LIMITS IN BRIDGE***
*            BXL     BXR      PW    YB   QB   K1   K2     K3
DP           39891   40019    3.0   *    *    1    2.75   1.1
DP           39891   40019    3.0   *    *    1    2.75   1.1
XS   APPR  442
*           ***APPR WALLED UP AT STAGNATION POINT***
*           ***APPR ADJUSTED FOR 30 DEGREES SKEW***
GR          37941 550  38023 540  38081 532  39746 532  39755 533  39759 534
GR          39762 535  39775 535  39780 534  39791 533  39795 530  39807 525
GR          39813 523  39818 525  39827 530  39833 532  39847 533  39872 533
GR          39887 532  39924 531  40046 531  40101 532  40419 532  40419 550
N           .100       .034       .100
SA               39791      39833
HP 2 BRG1  538.8  *  538.8  12600
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:  8/14/97  1:47 pm     Version V050196
          Input File: MUSCAT1.DAT    Output File: MUSCAT1.LST
   *-------------------------------------------------------------*
T1          I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
T2          COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
T3          8-11-97                            JOHN T. WILSON
Q           12600

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

WS          538.32

   ************************  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-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
     COUNTY: SCOTT                       QUAD: CROTHERSVILLE 163D
          8-11-97                             JOHN T. WILSON

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

XS   EXIT  0   30
GR         37080 550  37210 540  37280 532  39896 532  39903 531  39927 531
GR         39937 532  39942 534  39971 534  39982 533  39989 530  40000 525
GR         40012 523  40021 525  40033 530  40037 531  40046 532  40100 532
GR         40114 531  40141 530  40166 530  40188 531  40211 532  40241 533
GR         40270 534  40294 535  40480 532  40611 532  40611 550
N          .100       .034       .100
SA               39982      40037

   ***   Completed Reading Data Associated With Header Record EXIT    ***
+++072 NOTICE:  X-coordinate #29 increased to eliminate vertical segment.
   ***  Storing X-Section Data In Temporary File As Record Number  1  ***

   ***              Data Summary For Header Record EXIT               ***
   SRD Location:        0.   Cross-Section Skew:  30.0   Error Code   0
   Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
   Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                        X,Y-coordinates (29 pairs)
       X          Y            X          Y            X          Y
  ----------  ----------   ----------  ----------   ----------  ----------
   37080.000     550.000    37210.000     540.000    37280.000     532.000
   39896.000     532.000    39903.000     531.000    39927.000     531.000
   39937.000     532.000    39942.000     534.000    39971.000     534.000
   39982.000     533.000    39989.000     530.000    40000.000     525.000
   40012.000     523.000    40021.000     525.000    40033.000     530.000
```

WSPRO OUTPUT

40037.000	531.000	40046.000	532.000	40100.000	532.000
40114.000	531.000	40141.000	530.000	40166.000	530.000
40188.000	531.000	40211.000	532.000	40241.000	533.000
40270.000	534.000	40294.000	535.000	40480.000	532.000
40611.000	532.000	40611.100	550.000		

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 37080.000 (associated Y-Elevation: 550.000)
Maximum X-Station: 40611.100 (associated Y-Elevation: 550.000)
Minimum Y-Elevation: 523.000 (associated X-Station: 40012.000)
Maximum Y-Elevation: 550.000 (associated X-Station: 37080.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
37080.000	37472.810	37210.000	37585.400	37280.000	37646.020
39896.000	39911.540	39903.000	39917.600	39927.000	39938.390
39937.000	39947.050	39942.000	39951.380	39971.000	39976.490
39982.000	39986.020	39989.000	39992.080	40000.000	40001.610
40012.000	40012.000	40021.000	40019.790	40033.000	40030.190
40037.000	40033.650	40046.000	40041.450	40100.000	40088.210
40114.000	40100.340	40141.000	40123.720	40166.000	40145.370
40188.000	40164.420	40211.000	40184.340	40241.000	40210.320
40270.000	40235.430	40294.000	40256.220	40480.000	40417.300
40611.000	40530.750	40611.100	40530.840		

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.100	---
	---	********
2	.034	---
	---	********
3	.100	---

--
* 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-65 OVER MUSCATATUCK OVERFLOW I65-34-4240
COUNTY: SCOTT QUAD: CROTHERSVILLE 163D
8-11-97 JOHN T. WILSON

WSPRO OUTPUT

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

XS   FULLV  160    30

 ***   Completed Reading Data Associated With Header Record FULLV   ***
 ***   No Roughness Data Input, Propagating From Previous Section   ***
 ***  Storing X-Section Data In Temporary File As Record Number  2  ***

 ***              Data Summary For Header Record FULLV              ***
 SRD Location:      160.   Cross-Section Skew:  30.0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

X,Y-coordinates (29 pairs)

X	Y	X	Y	X	Y
37080.000	550.000	37210.000	540.000	37280.000	532.000
39896.000	532.000	39903.000	531.000	39927.000	531.000
39937.000	532.000	39942.000	534.000	39971.000	534.000
39982.000	533.000	39989.000	530.000	40000.000	525.000
40012.000	523.000	40021.000	525.000	40033.000	530.000
40037.000	531.000	40046.000	532.000	40100.000	532.000
40114.000	531.000	40141.000	530.000	40166.000	530.000
40188.000	531.000	40211.000	532.000	40241.000	533.000
40270.000	534.000	40294.000	535.000	40480.000	532.000
40611.000	532.000	40611.100	550.000		

Minimum and Maximum X,Y-coordinates

Minimum X-Station:	37080.000	(associated Y-Elevation:	550.000)
Maximum X-Station:	40611.100	(associated Y-Elevation:	550.000)
Minimum Y-Elevation:	523.000	(associated X-Station:	40012.000)
Maximum Y-Elevation:	550.000	(associated X-Station:	37080.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
37080.000	37472.810	37210.000	37585.400	37280.000	37646.020
39896.000	39911.540	39903.000	39917.600	39927.000	39938.390
39937.000	39947.050	39942.000	39951.380	39971.000	39976.490
39982.000	39986.020	39989.000	39992.080	40000.000	40001.610
40012.000	40012.000	40021.000	40019.790	40033.000	40030.190
40037.000	40033.650	40046.000	40041.450	40100.000	40088.210
40114.000	40100.340	40141.000	40123.720	40166.000	40145.370
40188.000	40164.420	40211.000	40184.340	40241.000	40210.320
40270.000	40235.430	40294.000	40256.220	40480.000	40417.300
40611.000	40530.750	40611.100	40530.840		

WSPRO OUTPUT

```
                Roughness Data (  3 SubAreas )
                         Roughness   Horizontal
               SubArea  Coefficient  Breakpoint
               -------  -----------  ----------
                  1         .100        ---
                            ---        ********
                  2         .034        ---
                            ---        ********
                  3         .100        ---
               -------  -----------  ----------

      *-----------------------------------------------------*
      *      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-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
   COUNTY: SCOTT                       QUAD: CROTHERSVILLE 163D
        8-11-97                             JOHN T. WILSON

      *-----------------------------------------------------*
      *      Starting To Process Header Record BRG1         *
      *-----------------------------------------------------*

BR   BRG1   160    545.1
GR        39875 545.1  39875 544.0  39877 544.0  39877 543.5  39880 543.5
GR        39905 532.0  39926 532.0  39945 523.0  39984 523.0  40031 543.5
GR        40034 543.5  40034 544.0  40035 544.0  40035 545.1  39875 545.1
N         .040         .034
SA              39926
PD        523 3.0   1
PD        532 3.0   2
PD        532 4.9   3
PD        537 4.0   4
CD        3    122    2    547

  ***   Completed Reading Data Associated With Header Record BRG1    ***
+++072 NOTICE:  X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate # 4 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #12 increased to eliminate vertical segment.
+++072 NOTICE:  X-coordinate #14 increased to eliminate vertical segment.
  ***   Storing Bridge Data In Temporary File As Record Number  3    ***

  ***              Data Summary For Bridge Record BRG1              ***
  SRD Location:      160.   Cross-Section Skew:    .0   Error Code   0
  Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
  Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00
```

WSPRO OUTPUT

X,Y-coordinates (15 pairs)

X	Y	X	Y	X	Y
39875.000	545.100	39875.100	544.000	39877.000	544.000
39877.100	543.500	39880.000	543.500	39905.000	532.000
39926.000	532.000	39945.000	523.000	39984.000	523.000
40031.000	543.500	40034.000	543.500	40034.100	544.000
40035.000	544.000	40035.100	545.100	39875.000	545.100

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 39875.000 (associated Y-Elevation: 545.100)
Maximum X-Station: 40035.100 (associated Y-Elevation: 545.100)
Minimum Y-Elevation: 523.000 (associated X-Station: 39984.000)
Maximum Y-Elevation: 545.100 (associated X-Station: 39875.000)

Roughness Data (2 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.040	---
	---	********
2	.034	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	122.000	2.00	547.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	545.100

Abutment Parameters

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

Pier/Pile Data (4 Group(s))

Code Indicates Bridge Uses Piers

Group	Elevation	Gross Width	Number
1	523.000	3.000	1
2	532.000	3.000	2
3	532.000	4.900	3
4	537.000	4.000	4

--
* Finished Processing Header Record BRG1 *
--

WSPRO OUTPUT

```
************************* W S P R O ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
         Input Units: English  /  Output Units: English
*-------------------------------------------------------------*
        I-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
  COUNTY: SCOTT                        QUAD: CROTHERSVILLE 163D
       8-11-97                              JOHN T. WILSON
DC 0     39891   40019   39791   39833   *   6
DP        39891   40019    3.0    *    *    1    2.75   1.1
DP        39891   40019    3.0    *    *    1    2.75   1.1

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

XS   APPR  442
GR        37941 550  38023 540  38081 532  39746 532  39755 533  39759 534
GR        39762 535  39775 535  39780 534  39791 533  39795 530  39807 525
GR        39813 523  39818 525  39827 530  39833 532  39847 533  39872 533
GR        39887 532  39924 531  40046 531  40101 532  40419 532  40419 550
N         .100       .034       .100
SA              39791      39833

  ***   Completed Reading Data Associated With Header Record APPR    ***
+++072 NOTICE:  X-coordinate #24 increased to eliminate vertical segment.
  ***  Storing X-Section Data In Temporary File As Record Number  4  ***

  ***              Data Summary For Header Record APPR               ***
  SRD Location:      442.   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 (24 pairs)
     X          Y            X          Y            X          Y
----------  ----------   ----------  ----------   ----------  ----------
 37941.000     550.000    38023.000     540.000    38081.000     532.000
 39746.000     532.000    39755.000     533.000    39759.000     534.000
 39762.000     535.000    39775.000     535.000    39780.000     534.000
 39791.000     533.000    39795.000     530.000    39807.000     525.000
 39813.000     523.000    39818.000     525.000    39827.000     530.000
 39833.000     532.000    39847.000     533.000    39872.000     533.000
 39887.000     532.000    39924.000     531.000    40046.000     531.000
 40101.000     532.000    40419.000     532.000    40419.100     550.000
----------  ----------   ----------  ----------   ----------  ----------

                  Minimum and Maximum X,Y-coordinates
   Minimum X-Station:   37941.000  ( associated Y-Elevation:  550.000 )
   Maximum X-Station:   40419.100  ( associated Y-Elevation:  550.000 )
   Minimum Y-Elevation:   523.000  ( associated X-Station:  39813.000 )
   Maximum Y-Elevation:   550.000  ( associated X-Station:  37941.000 )
```

WSPRO OUTPUT

```
                  Roughness Data (  3 SubAreas )
                          Roughness   Horizontal
                 SubArea  Coefficient  Breakpoint
                 -------  -----------  ----------
                    1         .100        ---
                              ---        ********
                    2         .034        ---
                              ---        ********
                    3         .100        ---
                 -------  -----------  ----------

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-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
      COUNTY: SCOTT                       QUAD: CROTHERSVILLE 163D
           8-11-97                             JOHN T. WILSON
  HP 2 BRG1  538.8  *  538.8  12600
  EX

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

            Reach      Water Surface   Friction
     #    Discharge      Elevation      Slope         Flow Regime
    --    ---------    -------------   --------   --------------------
     1     12600.00       538.320       ******        Sub-Critical
    --    ---------    -------------   --------   --------------------

          *=================================================*
          *        Beginning  1 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-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
      COUNTY: SCOTT                       QUAD: CROTHERSVILLE 163D
           8-11-97                             JOHN T. WILSON
```

WSPRO OUTPUT

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: EXIT	538.320	.014	12600.000	21209.800	*********	37224.700
Header Type: XS	538.334	******	.594	1162826.00	*********	40611.040
SRD: .000	533.746	******	.066	******	2.487	******
Section: FULLV	538.339	.014	12600.000	21275.530	160.000	37224.530
Header Type: FV	538.353	.019	.592	1168556.00	160.000	40611.040
SRD: 160.000	533.746	.000	.066	.0001	2.481	.001

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

Section: APPR	538.380	.023	12600.000	15297.290	282.000	38034.750
Header Type: AS	538.403	.045	.824	845905.60	282.000	40419.040
SRD: 442.000	533.960	.005	.085	.0002	2.201	.000

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

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

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: BRG1	538.396	2.097	12600.000	1257.927	160.000	39891.100
Header Type: BR	540.493	.276	10.016	251835.90	160.000	40019.300
SRD: 160.000	535.209	1.882	.654	******	1.344	-.003

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1						
Pier/Pile Code 0	.8625	.044	545.100	********	********	********

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	541.330	.009	12600.000	22362.470	160.000	38012.100
Header Type: AS	541.339	.482	.563	1555599.00	374.697	40419.050
SRD: 442.000	533.960	.364	.044	.0002	1.819	-.017

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.946	.949	79022.5	********	********	541.330

<<< End of Bridge Hydraulics Computations >>>

WSPRO OUTPUT

```
************************* W S P R O ****************************
   Federal Highway Administration - U. S. Geological Survey
          Model for Water-Surface Profile Computations.
         Input Units: English / Output Units: English
*-------------------------------------------------------------*
        I-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
  COUNTY: SCOTT                      QUAD: CROTHERSVILLE 163D
      8-11-97                             JOHN T. WILSON

***   Beginning Velocity Distribution For Header Record BRG1    ***
      SRD Location:    160.000      Header Record Number  3

    Water Surface Elevation:    538.800            Element # 1
    Flow:   12600.000   Velocity:  9.62  Hydraulic Depth:  10.078
    Cross-Section Area:   1310.12        Conveyance:   266189.30
      Bank Stations ->  Left:  39890.220   Right:  40020.220

X STA.     39890.2    39916.3    39930.1    39936.9    39941.5    39945.2
  A( I )             127.4       97.2       70.9       59.9       56.0
  V( I )              4.95       6.48       8.89      10.52      11.25
  D( I )              4.88       7.08      10.35      13.06      15.02

X STA.     39945.2    39948.5    39951.7    39954.9    39958.1    39961.4
  A( I )              51.8       50.9       50.0       51.2       51.2
  V( I )             12.15      12.39      12.60      12.30      12.30
  D( I )             15.80      15.80      15.80      15.80      15.80

X STA.     39961.4    39964.6    39967.9    39971.2    39974.5    39978.1
  A( I )              50.7       52.3       52.2       52.8       55.6
  V( I )             12.42      12.04      12.08      11.92      11.33
  D( I )             15.80      15.80      15.80      15.80      15.80

X STA.     39978.1    39981.6    39985.5    39990.2    39997.2    40020.2
  A( I )              56.3       60.6       66.8       81.0      115.3
  V( I )             11.19      10.39       9.43       7.78       5.47
  D( I )             15.80      15.67      14.12      11.56       5.01
```

WSPRO OUTPUT

```
************************* W S P R O ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
         Input Units: English  /  Output Units: English
*-------------------------------------------------------------*
        I-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
  COUNTY: SCOTT                       QUAD: CROTHERSVILLE 163D
       8-11-97                             JOHN T. WILSON

***  Live-Bed Contraction Scour Calculations for Header Record BRG1   ***

                    Constants and Input Variables

             *-----------------------------------------------*
              Bed Material Transport Mode Factor (k1):    .64
              Total Pier Width Value             (Pw): 6.000
             *-----------------------------------------------*

    Scour      -- Flow --          -- Width --         --- X-Limits ---
 #  Depth  Contract Approach  Contract Approach  Side   Contract Approach
--  ------ --------- --------- -------- --------  ------ -------- --------
 1  41.342 12600.000  1114.498  122.000   42.000  Left:  ******** ********
    ..... Approach Channel Depth:   13.865 .....  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-65 OVER MUSCATATUCK OVERFLOW    I65-34-4240
  COUNTY: SCOTT                       QUAD: CROTHERSVILLE 163D
       8-11-97                             JOHN T. WILSON

     ***  Pier Scour Calculations for Header Record BRG1   ***

                    Constants and Input Variables

                          Pier Width:   3.000
                *-----------------------------------------*
                  Pier Shape Factor            (K1):   1.00
                  Flow Angle of Attack Factor  (K2):   2.75
                  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  25.24  12600.000  538.760 15.760  12.572     .558  39891.000 40019.000
--  ----- ---------- -------- ------ -------- -------- --------- ---------
```

WSPRO OUTPUT

```
************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
         Input Units: English  /  Output Units: English
*-------------------------------------------------------------*
        I-65 OVER MUSCATATUCK OVERFLOW     I65-34-4240
  COUNTY: SCOTT                        QUAD: CROTHERSVILLE 163D
       8-11-97                              JOHN T. WILSON

    ***  Pier Scour Calculations for Header Record BRG1   ***

                 Constants and Input Variables

                      Pier Width:   3.000
             *-----------------------------------------*
               Pier Shape Factor             (K1):   1.00
               Flow Angle of Attack Factor   (K2):   2.75
               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  25.24  12600.000  538.760 15.760  12.572     .558  39891.000 40019.000
--  ----- ---------- -------- ------ -------- -------- --------- ---------

  ER

  ******************  Normal end of WSPRO execution.  *****************
  ***************  Elapsed Time:   0 Minutes 35 Seconds  **************
```