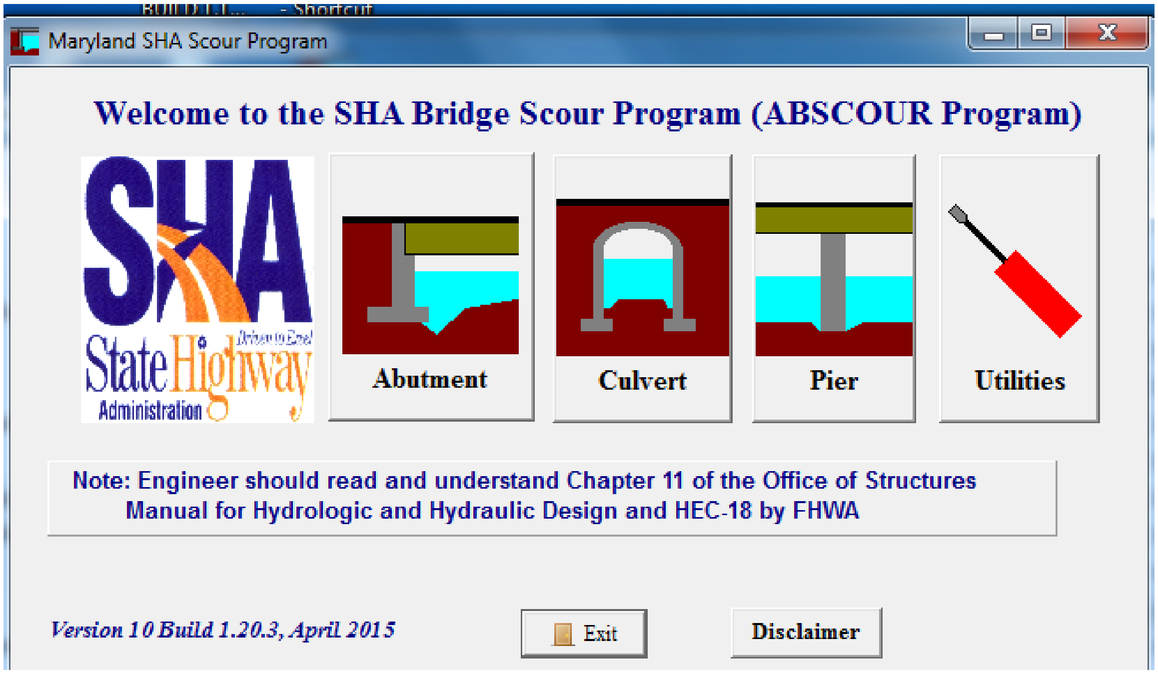
OFFICE OF STRUCTURES
STRUCTURE HYDROLOGY AND HYDRAULICS DIVISION

CHAPTER 11 APPENDIX A

ABSCOUR 10 USERS MANUAL

PART 2

GUIDELINES FOR APPLYING THE ABSCOUR PROGRAM



Welcome to the SHA Bridge Scour Program (ABSCOUR Program)

Note: Engineer should read and understand Chapter 11 of the Office of Structures Manual for Hydrologic and Hydraulic Design and HEC-18 by FHWA

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PART 2: GUIDELINES FOR APPLYING THE ABSCOUR PROGRAM

(See Part 1 for a Table of Contents)

I. INTRODUCTION

Available technology has not developed sufficiently to provide reliable scour estimates at abutments for all possible site conditions. The policies and guidance in the abutment scour program ABSCOUR and in Chapter 11 of the SHA Manual of Hydraulic and Hydrologic Design have been developed with this consideration in mind.

The ABSCOUR program provides for considerable flexibility in the input format and the computations to permit the user to model field conditions. However, the user should make a critical review of all scour computations, using ABSCOUR for sensitivity analyses of input factors, to evaluate whether the answers obtained are reasonable. Part 2 guide has been written to assist the user in this evaluation.

> **The user assumes all responsibility for any decisions or actions taken as a result of the use of this program.**

Please note that definitions used and references cited refer back to the text in Part 1.

The discussion on abutment scour in the FHWA HEC-18 Manual (Reference 1) explains why the early abutment scour equations developed from laboratory flume studies are generally not reliable for predicting scour at abutments. The essence of this discussion is that a rectangular flume with a constant depth and velocity of flow across the width of the flume does not accurately model the field conditions of a channel and its flood plain; consequently, the equations developed from these lab studies generally predict conservative estimates of scour.

In the last several years, various researchers have begun to model “compound channels” to reproduce more accurately the field conditions of a channel and its flood plain. Information from these studies has been used to develop the ABSCOUR software program. The background on the development of the logic and the equations used in the ABSCOUR analysis is presented in Part 1 of this Appendix. The Engineer is encouraged to read and understand this information as well as the information in Part 2, Users Guide, before using the ABSCOUR computer program.

In addition to calibrating the ABSCOUR methodology with information obtained from flume studies conducted by the FHWA, ABSCOUR was calibrated using information from the USGS database of abutment scour measurements of bridges in South Carolina (See the discussion in Part 1 of this Appendix)

The ABSCOUR program is an expanded application of Dr. Emmett Laursen’s live bed contraction scour equation as presented in the FHWA HEC-18 Manual, with certain modifications developed to account for the distribution of flow under the bridge, the bridge geometry and the computation of velocity at the bridge abutments. The ABSCOUR program computes both clear water and live bed scour and selects the appropriate scour type based on the input information. Careful application of the ABSCOUR Program will provide the user with insight into the factors affecting contraction and abutment scour at the bridge site under evaluation. Judgment is needed to modify input information and the ABSCOUR cross-sections so as to best represent actual site conditions during a flood event. *Computed scour depths provided by the ABSCOUR Program require evaluation to determine if the results are reasonable.*

Abutment scour can be viewed as a combination of contraction scour and local scour. The ABSCOUR Program computes the total *scour at the abutment; therefore, the user should not add contraction scour to this value.*
procedure.

The following information is needed to provide the input information for the ABSCOUR program:

1. Hydrologic estimates of Q_{100}, Q_{500}, $Q_{overtopping}$ and Q_{design}
2. topographic map of the stream and its flood plain, the location of the bridge crossing and stream channel cross-sections,
3. information from the geomorphology report regarding estimated channel degradation, the channel lateral movement zone, D50 soil particle sizes in the channel/flood plain and whether the type of scour to be expected is clear-water or live-bed.
4. Surface and subsurface information on channel bed load, flood plain soils, borings, etc.
5. geometric information about the bridge and approach roads
6. HEC-RAS runs for the given hydraulic conditions including:
7. stream channel cross-sections,
8. hydraulic data tables,
9. reliable bridge tailwater elevations,
10. selection of appropriate approach section and flow distribution, and
11. appropriate flow distribution at bridge with regard to channel, flood plain and overtopping flows.

II. DEVELOPMENT OF THE INPUT DATA FOR THE ABSCOUR (ABUTMENT SCOUR) MODEL

SHA has been conducting and reviewing ABSCOUR analyses for a number of years. It is our experience that one of the biggest sources of error in scour computations is an incorrect hydraulic model. It is not an easy task to model a 3-D flow pattern with a 1-D model such as HEC-RAS. In particular, special care needs to be given to the following three primary sources of error in developing the input data:

- Water surface elevation under bridge. The hydraulic model should include a sufficient reach downstream of the bridge to establish a reliable tailwater elevation at the downstream side of the bridge. Guidance on the required length of the downstream reach is provided in Chapter 4 of the H&H Manual.

- Flow distribution for overtopping flow. The Engineer needs to develop a rational flow distribution to account for the flow through the bridge and the flow over the bridge and approach roads. A trial and error approach to the HEC-RAS runs is often used to obtain a balanced flow condition.
- Approach section. Selection of a cross-section and of hydraulic flow parameters that are representative of the flow distribution in the approach section is essential to the scour evaluation. (See Step 3 below).

The guidance below, provided in a step-by-step format, is offered to assist the user in applying the ABSCOUR Program to a specific bridge site. The user is referred to Part 1 for a discussion of definitions and the derivation of equations used for scour calculations.

Help Options

There are two sources of help. Short help is available for most input cells by placing the cursor on the cell and pressing the F-1 key. More detailed help is available from the HELP tab on the Menu Bar at the top of the ABSCOUR screen. It is a good idea to use the short help (F-1 key) to check the text and sketches for clarification of the information to be provided in the cell.

The following guidance provides for a step-by-step explanation of how to input information into the ABSCOUR model. An actual scour evaluation (MD 313 over Marshy Hope Creek) has been used to illustrate the process and to comment on the parameters selected.

A. STEP ONE - HYDRAULIC MODEL

Prior to entering data for the ABSCOUR Model, the user will need to obtain hydraulic data as discussed below:

A.1 Water Surface Profile

Prepare a water surface profile using HEC-RAS or other program to model flow conditions upstream of, through and downstream of the bridge. Discharges selected for evaluation of scour should include the overtopping flow, Q_{100} , Q_{design} *and* Q_{500} *in order to develop the anticipated worst case scour conditions at the bridge.*

Field check Manning's "n" values to obtain the proper flow distribution between the channel and flood plains. Use sufficient downstream cross-sections to establish reliable bridge tailwater elevations.

A.2 Development of ABSCOUR Model Cross-sections

Two cross-sections are required to run the ABSCOUR program:

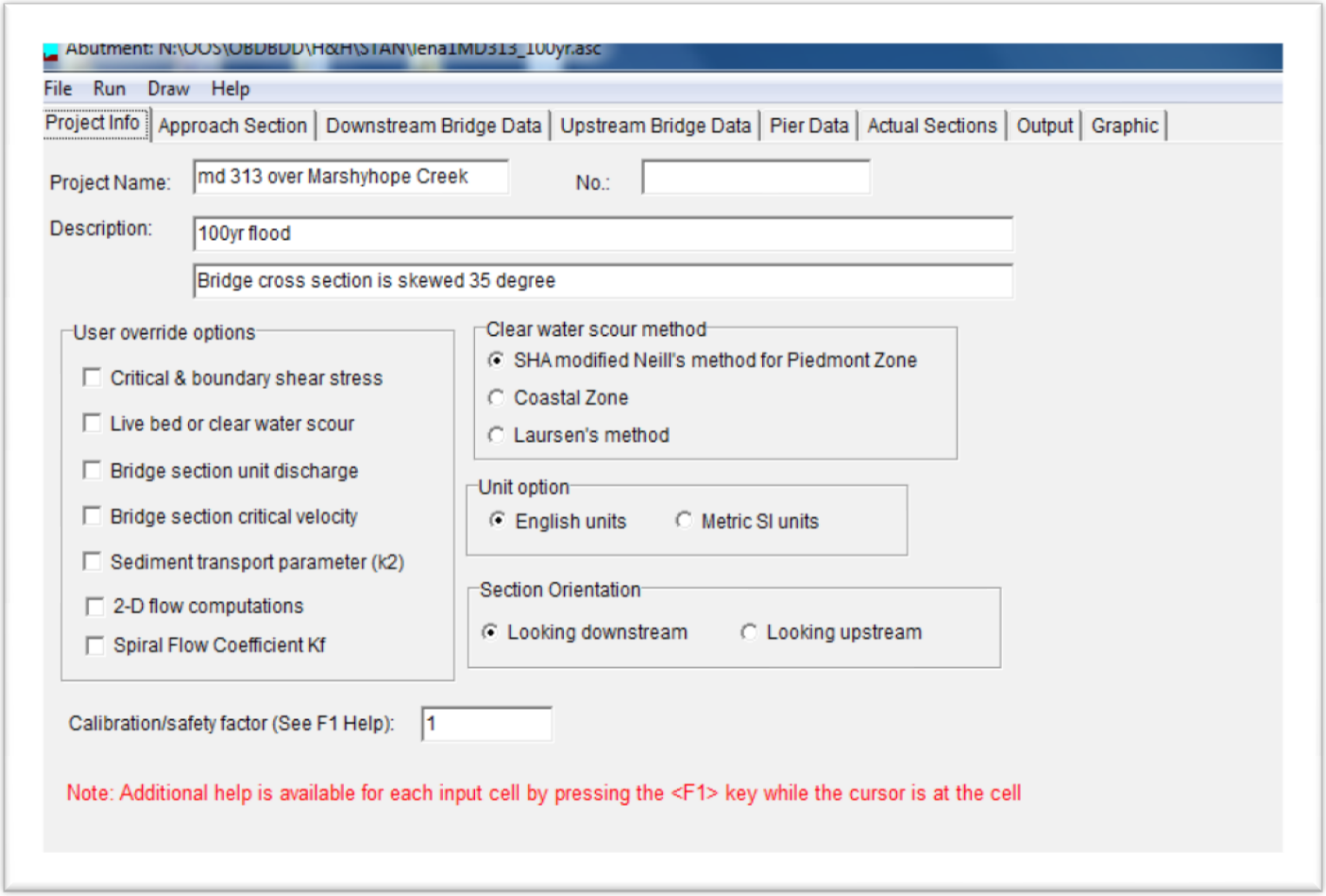
- **Section 1: Upstream approach section**. This section should be upstream of the area of influence of the bridge contraction and should be representative of the approach flow conditions. In some cases, the user may need to modify the actual approach section so that it is representative of actual approach flow conditions. (See Step 3).

- **Section 2: Downstream Bridge Section.** This section is located under the bridge *at the downstream end*.

B. STEP TWO INPUTTING INFORMATION INTO THE ABSCOUR PROGRAM.

PROJECT INFORMATION MENU

Figure 2-1 shows the ABSCOUR Project Information Menu screen. The following section explains each of the input parameters.



Abutment: N:\OOS\OBDBDD\H&H\STAN\lena1MD313_100yr.asc

Project Name: md 313 over Marshyhope Creek

No.:

Description: 100yr flood

Bridge cross section is skewed 35 degree

User override options

☐ Critical & boundary shear stress

☐ Live bed or clear water scour

☐ Bridge section unit discharge

☐ Bridge section critical velocity

☐ Sediment transport parameter (k2)

☐ 2-D flow computations

☐ Spiral Flow Coefficient Kf

Clear water scour method

● SHA modified Neill's method for Piedmont Zone

○ Coastal Zone

○ Laursen's method

Unit option

● English units ○ Metric SI units

Section Orientation

● Looking downstream ○ Looking upstream

Calibration/safety factor (See F1 Help): 1

Note: Additional help is available for each input cell by pressing the <F1> key while the cursor is at the cell

Figure 2-1: ABSCOUR Project Information Screen

Project Name and Description

Use this input to provide information on the project, bridge number, magnitude and frequency of the flood being evaluated, special conditions used in the analysis, etc. Since the user may make several ABSCOUR runs, this section can be used to detail the flood-frequency and magnitude, and any special conditions or modifications used in the analysis. This approach will help to clearly delineate and identify each run.

User Over-Ride Options

The ABSCOUR Program contains various over-ride features to allow the user flexibility in making the scour evaluation. The user is cautioned to use the over-ride features only after giving full consideration to the consequences of this approach. *Problems with the program output or with unrealistic scour estimates can often be traced to improper use of the over-ride functions*. We recommend that none of these features be used on the initial run. They are provided primarily to assist in the evaluation of a bridge with special problems or flow conditions. We suggest that users contact the Office of Structures for guidance on using the over-ride functions. The common overrides include:

- **Critical and Boundary Shear Stress:** For use where these values have been measured and determined to be reasonable.
- **Live Bed/Clear Water:** Use to change the determination made by ABSCOUR regarding the scour condition - live bed scour or clear water scour. A common use for the override is made for the condition on flood plains where there are low flow velocities and depths coupled with heavy vegetative cover, and a clear water scour condition is considered reasonable. Note that the stream morphology report is typically the best source of information regarding the type of scour to be expected.
- **Bridge Section Unit Flow Values:** This over-ride can be useful in conducting sensitivity analyses of complex flow patterns. For example, consideration of higher unit flow values on the outside of a bend.
- **Bridge Section Critical Velocity:** This over-ride should be helpful in evaluating the characteristics of the critical velocity for cohesive soils.
- **Sediment transport parameter:** Not recommended for use unless the engineer has specialized knowledge of the sediment transport characteristics of the stream.
- **Two-Dimensional Flow**: For studies utilizing 2-D flow models, the user can input directly, the velocity of flow measured at the abutment face.
- **Spiral Flow Coefficient k_f:** ABSCOUR 9 has been calibrated using the k_f values computed by the program. A higher kf value override may be justified in certain cases such as an abutment located in a wide wetland where flood plain velocities are low.

Clear water scour method: The SHA has experienced reasonable results in the use of the modified Neill's equation for evaluating clear water scour. In general, Laursen's equations result in much deeper scour estimates for very fine grained, non-cohesive bed material in channels. The user may wish to compare both methods. A (non-tidal) Coastal Zone method is included because of a number of bridges located in the wide wetlands of

South Carolina that were a part of the U.S.G. S calibration study. This method is not recommended at this time.

Unit Option: The user can choose between Metric and English units.

Calibration/Safety Factor: Information from the USGS study of scour at South Carolina bridges was used to modify the recommended calibration factors in earlier versions of ABSCOUR. In general, lower factors are now recommended. Please note that the current scour evaluation process described in Chapter 11 of the Manual recommends the calculation of the potential effect of channel movement and degradation. This calculation serves to decrease the need for reliance on a safety factor to account for lateral channel movement and degradation.

Factors higher than the recommended values should be considered for complex flow conditions.

C. STEP THREE - APPROACH SECTION

Figure 2-2 shows the input screen for the Approach Section. In order to enter the data for this sheet, the actual cross-section must be converted to the ABSCOUR model cross-section for the sub-areas of the left overbank, main channel and right overbank. Refer to Figure 2-3 for a definition sketch of the conversion from the actual cross section to the ABSCOUR cross section. The User has the option of superimposing the actual cross-section on the ABSCOUR cross-section for comparison purposes by using the importing function of ABSCOUR. Represent each sub-area as a rectangle having a width and average depth. Obtain the top width (T) and flow area (A) of each sub area from the HEC-RAS Program. Be careful not to include ineffective flow areas. Compute the average depth of flow or hydraulic depth for each sub-area as $y_{ave} = A/T$.

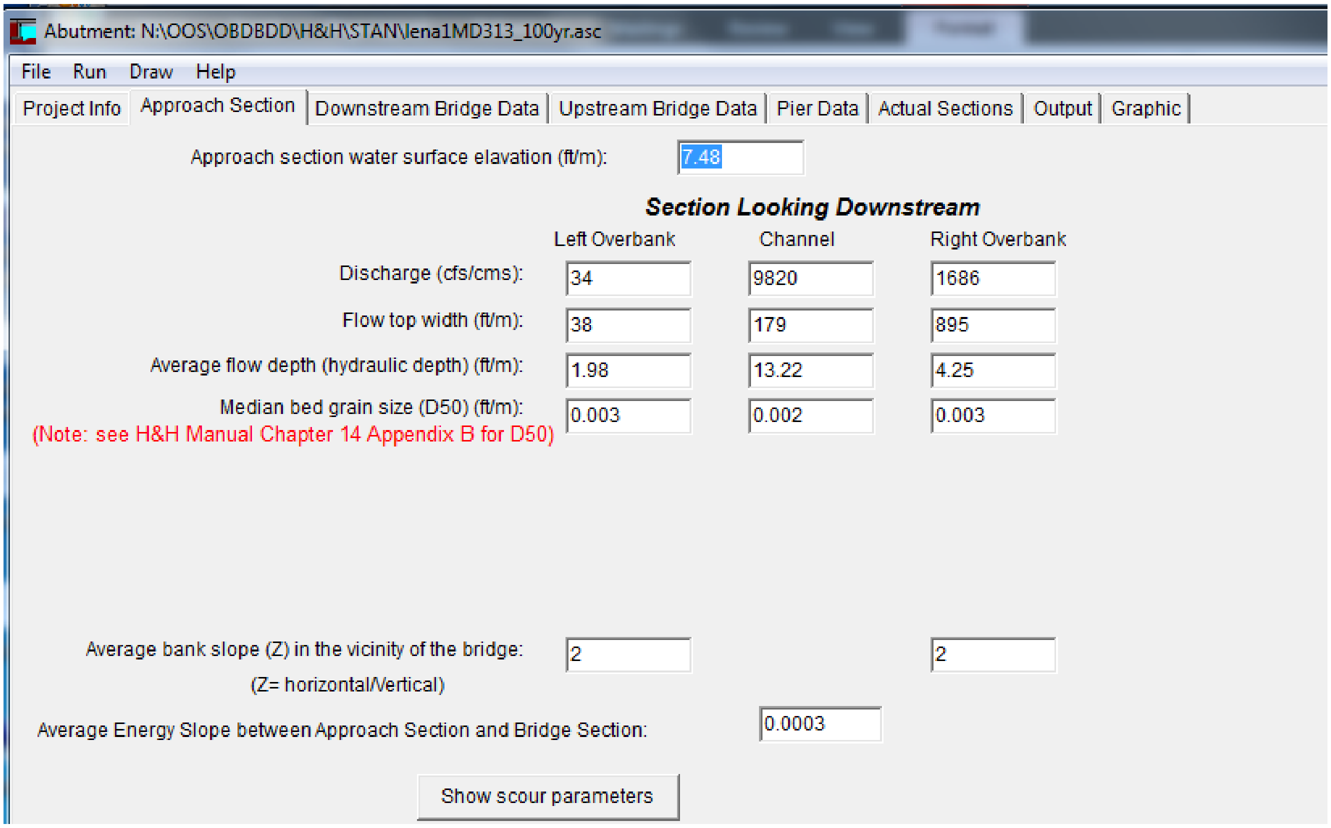
The model assumes an ideal one-dimensional flow pattern with a straight channel. The occurrence of a bend would affect the flow distribution in the reach of the stream under study. Refer to the discussion included under Upstream Bridge Data for ideas on how to modify flow distributions to account for 2-D flow patterns in the reach of the stream upstream of the bridge.

The ABSCOUR program uses Laursen's live bed contraction scour equation to determine scour. This equation serves to compare the unit discharges and scour in the approach section and in the contracted (bridge) section, assuming similar bed materials and hydraulic conditions. The best results will be obtained by selecting an approach section where the flow patterns and bed conditions in the channel are similar to the bridge section, keeping the following considerations in mind:

1. The approach section should be in a relatively straight reach and be representative of the upstream channel and flood plain. (If the bridge is in a bend, the approach section may be selected in an upstream bend with a similar configuration).
2. The cross-section should be perpendicular to the stream tube lines.
3. The approach section should be near the bridge, but far enough upstream (when

practicable) to be out of the influence of the bridge contraction.

4. If upstream conditions are complex, select the approach section one bridge length upstream and reevaluate the ineffective flow areas in the analysis. Refer also to the discussion under Upstream Bridge Data for ideas on complex flow patterns.
5. In many cases, there is no “ideal” approach section. For a complex flow pattern, it may be of help to evaluate scour by comparing the results obtained from two alternative approach sections.



Abutment: N:\OOS\OBDBDD\H&H\STAN\lena1MD313_100yr.asc

Approach section water surface elavation (ft/m): 7.48

Section Looking Downstream

	Left Overbank	Channel	Right Overbank
Discharge (cfs/cms):	34	9820	1686
Flow top width (ft/m):	38	179	895
Average flow depth (hydraulic depth) (ft/m):	1.98	13.22	4.25
Median bed grain size (D50) (ft/m): (Note: see H&H Manual Chapter 14 Appendix B for D50)	0.003	0.002	0.003

Average bank slope (Z) in the vicinity of the bridge: 2 2
(Z= horizontal/Vertical)

Average Energy Slope between Approach Section and Bridge Section: 0.0003

Figure 2-2: ABSCOUR Approach Section input sheet

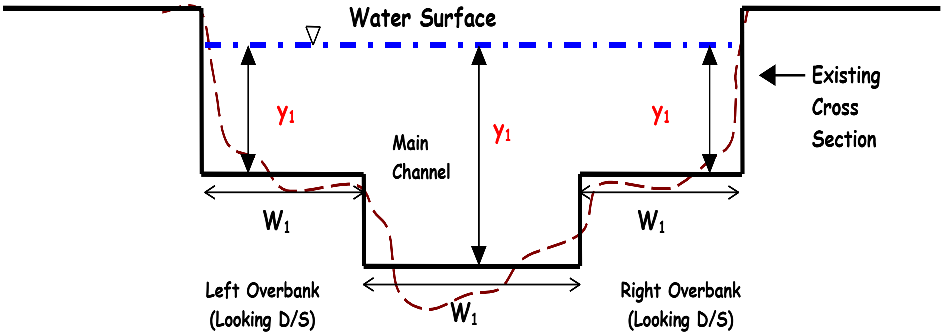


Figure 2-3: Definition Sketch for ABSCOUR Approach Section (Looking Downstream)

(Please note that W and T may be used interchangeably in figures and equations to designate a channel or floodplain width)

C.1 Enter Approach Section Data

The water surface profile models compute flow velocities, depths and discharges for the approach section on the basis of conveyance calculations. Modify these values as necessary to fit the ABSCOUR cross-sections as discussed above.

Verify that values used for y (depth), V (velocity), T (top width), q (discharge per foot of width) and Q (discharge) are consistent ($q = V*y$; $Q= q*T$).

As a general rule, information on each channel and overbank subsection is readily available from the output tables of the water surface profile model. For example, HEC-RAS computes the area of each subsection as the top width times the hydraulic depth. With a known area, hydraulic depth, and discharge provided for each subsection of the approach cross-section, the user can readily obtain the velocity and unit discharge values needed for the program.

3 **Approach Section Water Surface Elevation:** This elevation is used as a datum for importing the HEC-RAS cross-section for the approach section. It is a good idea to compare the ABSCOUR and HEC-RAS cross-sections.

- **Discharge, Q:** Enter the approach section discharge for the left overbank, channel and right overbank in cfs or cms.
- **Flow Top Width, W:** From HEC-RAS, obtain the flow top width for the left overbank, channel and right overbank. Be careful not to include ineffective areas in the top width computations.
- **Average Flow Depth (Hydraulic Depth):** From HEC-RAS, obtain the hydraulic depth for the left overbank, channel and right overbank. Be careful to adjust the hydraulic depth to account for any ineffective flow areas.
- **Median Bed Grain Size, D50:** Determine the D50 median grain size for material on the overbank areas and in the channel from field samples taken at the approach section. (Guidance on collecting samples and measuring D50 is provided in Appendix E of Chapter 11).

Average Bank Slope, Z: Enter the average bank slope of the stream in the vicinity of the bridge. . The program uses this information in evaluating scour when the abutment is close to the channel bank. The average bank slope (Z) of the left side of the channel is the horizontal projection of the slope when vertical is 1. The slope is used to adjust the ground line between the channel and the flood plain. The adjustment modifies the idealized ABSCOUR rectangular sections in order to model a more reasonable geometry for the bank condition. This adjustment provides for a better prediction of the abutment scour depth for abutments with short setbacks. as explained in Attachment 1

The bank slope also determines the relative effect of the channel scour on scour at the abutment for abutments with short setbacks. Steeper slopes such as 1:1 will reduce the effect of channel scour whereas flatter slopes such as 4:1 will increase the effect of channel scour. The bank slope can be used as a variable in sensitivity analyses of factors affecting abutment scour. See Contraction Scour, Adjustment for Short Setback Abutment (Case A).

- **Average Energy Slope:** This value is used in computing the boundary shear stress. Enter the average energy slope of the flow in the stream reach between the approach section (1) and the downstream bridge section (2). Refer to Figure 2-4 for details. The average energy slope is computed as:

  S_{ave} = (Energy Line Elevation Section 1 - Energy Line Elevation Section 2)/ L
  where L = distance between Sections 1 and 2.

  Please note that alternative methods may be more appropriate for some flow conditions, especially for backwater conditions. The computed value should be compared with information obtained from the HEC-RAS runs.

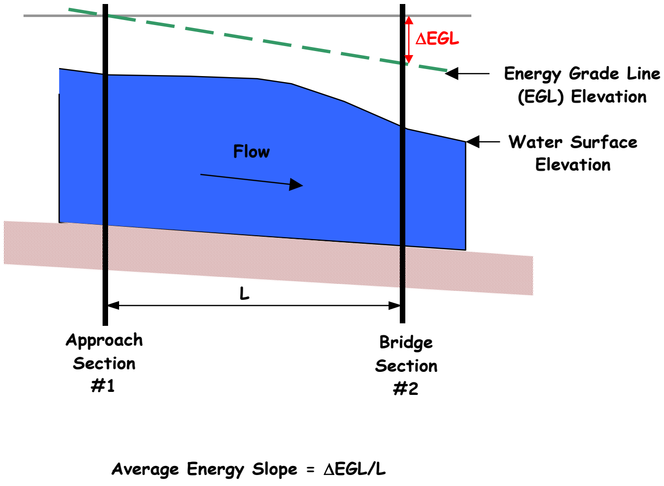
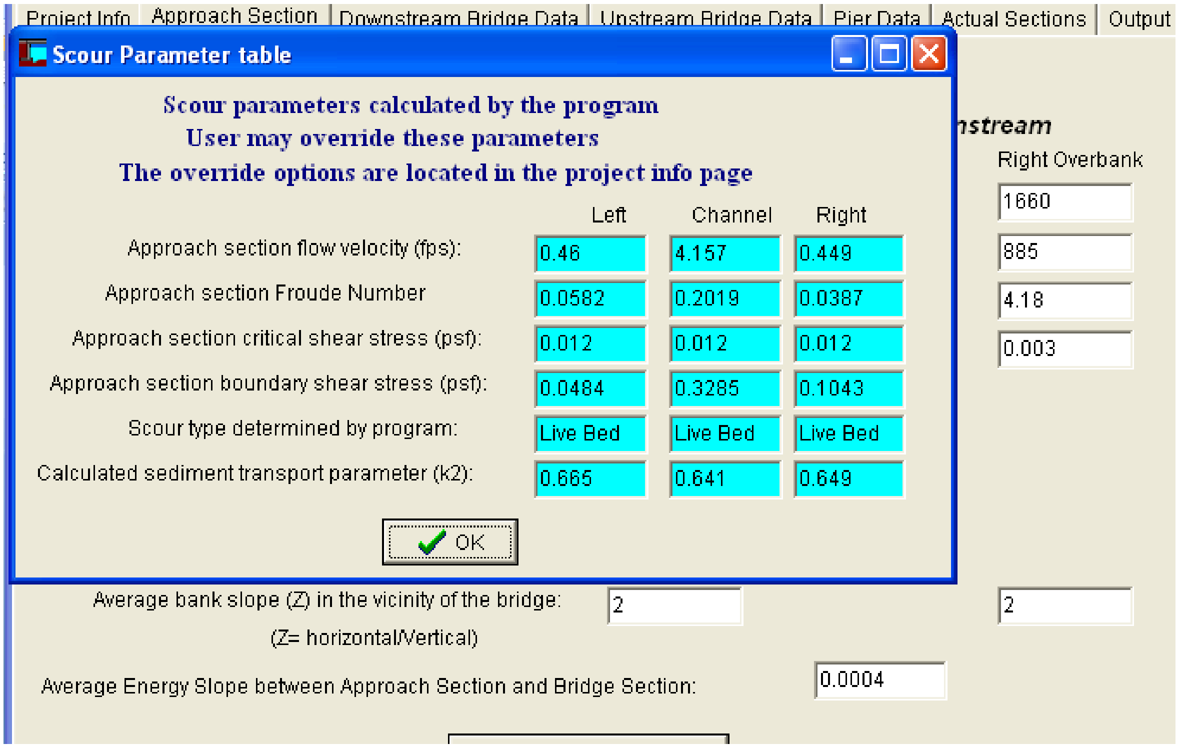


Figure 2-4: Average Energy Slope

- **Scour Parameter Button:** Click on the scour parameter button to view ABSCOUR scour parameters computed from the approach flow conditions. Refer to Figure 2-5. As noted earlier, over-riding any of these values should be undertaken with caution and an understanding of the flow and sediment transport conditions. For example, if the computations indicate live bed scour on the flood plain and the flood plain is covered with heavy vegetation with attendant low velocities, it is likely that clear water scour will actually occur on the flood plain. The scour parameter can be overridden to indicate clear water scour for the flood plain approach flow.



Scour parameters calculated by the program
User may override these parameters
The override options are located in the project info page

	Left	Channel	Right
Approach section flow velocity (fps):	0.46	4.157	0.449
Approach section Froude Number	0.0582	0.2019	0.0387
Approach section critical shear stress (psf):	0.012	0.012	0.012
Approach section boundary shear stress (psf):	0.0484	0.3285	0.1043
Scour type determined by program:	Live Bed	Live Bed	Live Bed
Calculated sediment transport parameter (k2):	0.665	0.641	0.649

nstream

Right Overbank

1660

885

4.18

0.003

Average bank slope (Z) in the vicinity of the bridge: 2 2

(Z= horizontal/Vertical)

Average Energy Slope between Approach Section and Bridge Section: 0.0004

Figure 2-5: Scour Parameter Table

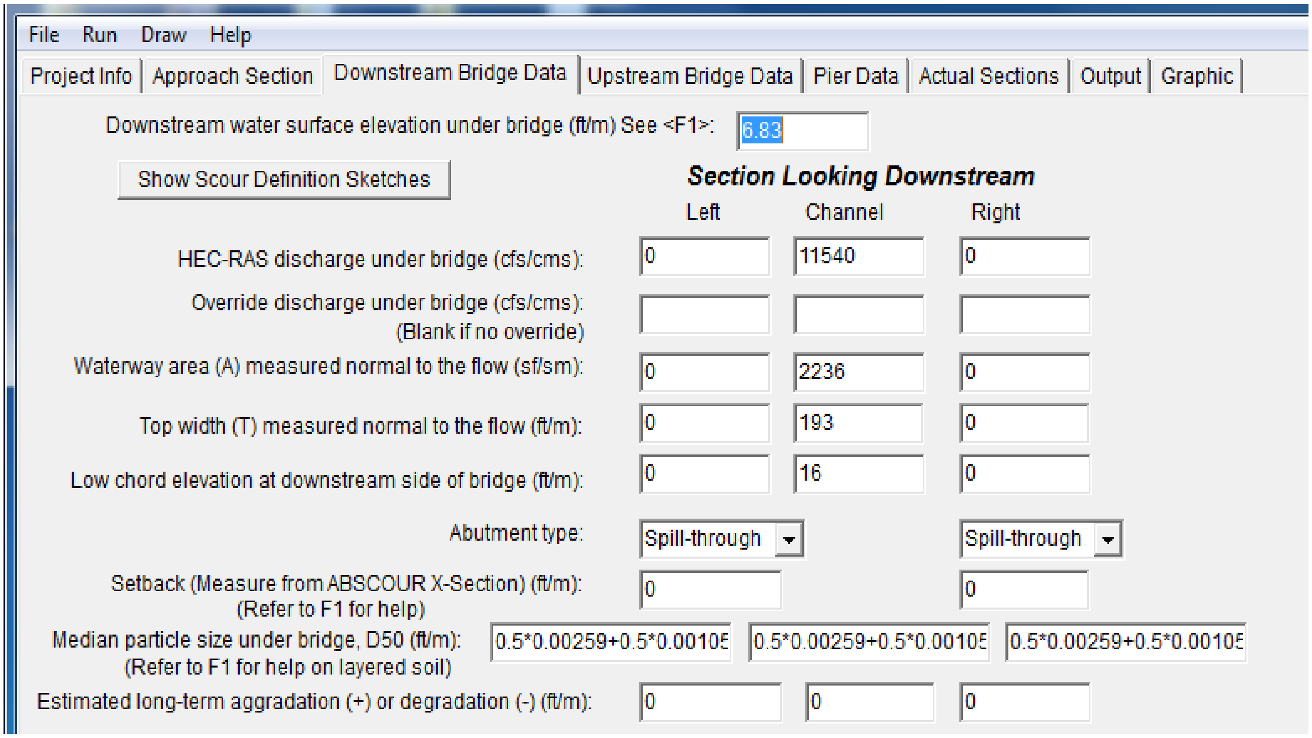
Please be aware that the sediment transport parameter, k_2, represents a complex function. The Level 2 analyses provided by HEC-RAS and ABSCOUR offer a reasonable approach for estimating this function. However, the water surface profile and hydraulic variables are assumed to be fixed for the HEC-RAS/ABSCOUR analysis, remaining constant for changes in the particle size of the bed load. This limitation can be minimized by making small changes to the HEC-RAS runs to account for varying ‘n’ values, but such refinement is normally unnecessary. However, we have observed an unusual and special condition for live bed scour while running sensitivity checks. For certain combinations of hydraulic flow conditions, a slight increase in the D50 particle size will result in an increase in the scour depth. This result, of course is the opposite of what we would expect. The anomaly is typically small and can be modified by the user to obtain a reasonable answer. The user has the option of overriding the calculated values and substituting other values for the critical shear stress and boundary shear stress. A first step in the evaluation of these parameters would be to refine the boundary shear stress as calculated by ABSCOUR ($\tau_1 = \gamma\ RS_{ave}$) at the approach section by obtaining more detailed information about the flow in the channel reach between Section 1 and Section 2.

D. STEP FOUR - DOWNSTREAM BRIDGE DATA

D.1 Enter the Downstream Bridge Data

Figure 2-6 shows the ABSCOUR input screen for the downstream bridge data. Figure 2-

7 shows the definition sketch for the downstream bridge data. Please note that the program is set up to input the flow estimates under the bridge as computed by the HEC-RAS model. However, the user has the option of using the over-ride cells to select a different flow distribution where there is a question regarding the HEC-RAS distribution which is based on conveyance calculations. Examples include a bridge on a bend where the user may expect a larger portion of the flow to move to the outside of the bend, a complex overtopping situation or an upstream confluence. See also the discussion on balancing the flows regarding the Upstream Bridge Data Card.



Downstream water surface elevation under bridge (ft/m) See <F1>: 6.83

Section Looking Downstream

	Left	Channel	Right
HEC-RAS discharge under bridge (cfs/cms):	0	11540	0
Override discharge under bridge (cfs/cms): (Blank if no override)			
Waterway area (A) measured normal to the flow (sf/sm):	0	2236	0
Top width (T) measured normal to the flow (ft/m):	0	193	0
Low chord elevation at downstream side of bridge (ft/m):	0	16	0
Abutment type:	Spill-through		Spill-through
Setback (Measure from ABSCOUR X-Section) (ft/m): (Refer to F1 for help)	0		0
Median particle size under bridge, D50 (ft/m): (Refer to F1 for help on layered soil)	0.5*0.00259+0.5*0.00105	0.5*0.00259+0.5*0.00105	0.5*0.00259+0.5*0.00105
Estimated long-term aggradation (+) or degradation (-) (ft/m):	0	0	0

Figure 2-6: Downstream Bridge Input Screen.

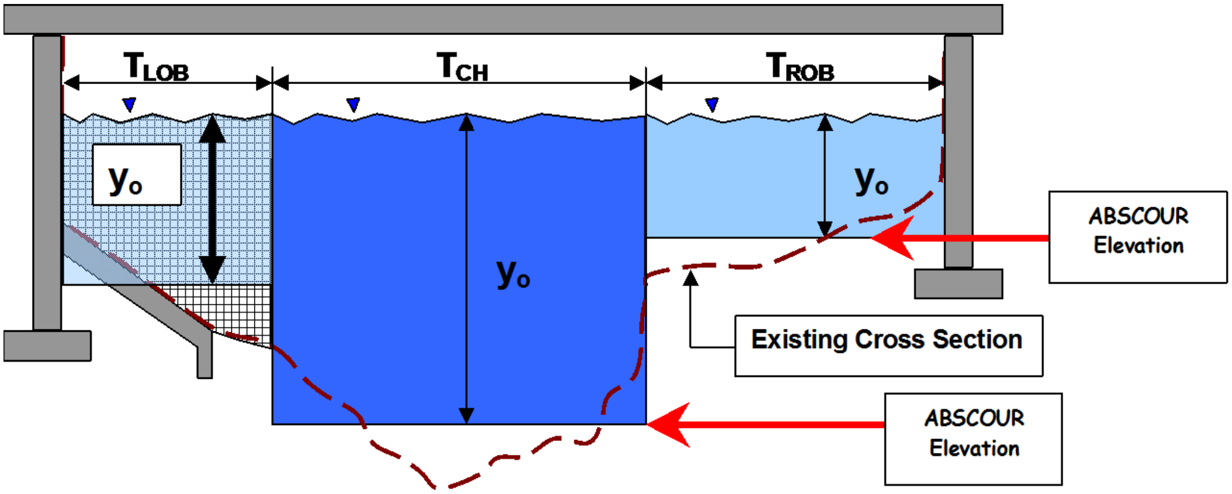


Figure 2-7: Definition sketch for Bridge Section

(Please note that W and T are sometimes used interchangeably in figures and equations to designate a channel or floodplain width)

- **Downstream water surface elevation under bridge:** Enter the information from the hydraulic model. Check that there are enough downstream cross-sections to provide for a reliable estimate of the tailwater elevation. Please note that the measurement is to be made at the downstream side of the bridge and on the inside of the bridge. For pressure flow conditions, enter the water surface elevation immediately downstream from the bridge.
  The downstream water surface elevation serves as the datum for all ABSCOUR computations.
- **Show Scour Parameters Button:** This button provides a quick reference to scour terms when that are used in the program.
- **Waterway Area *(Measured normal to the flow):*** Measure the waterway area bounded by the water surface elevation and the channel cross-section for the right overbank section, channel section and left overbank section. (Typically, this information cannot be directly obtained from the HEC-RAS Tables. The bridge plans or the HEC-RAS cross-sections provide good information for use in measuring the waterway area). Please note that for pressure flow conditions where the water elevation is above the low chord, the top of the waterway area will be defined by the low chord.
- **Top Width, W or T, *(Measured normal to the flow):*** Measure the top width for the channel and the right and left overbank areas under the bridge. Judgment needs to be applied in obtaining this information. In some cases, the left and right overbank top widths may be very small, and it may be more reasonable to model the channel so as to incorporate these small overbank areas as a part of the main channel. If there is a pier within the limits of the ABSCOUR cross-section, the top width and flow area should be adjusted to subtract the pier width/ pier area.

  The program will compute the hydraulic depth for each downstream sub-area (left overbank, channel and right overbank) as $y = A/T$.

- **Low Chord Elevation:** Enter the average low chord (lowest superstructure element) elevation at the downstream side of the bridge for the left overbank section, right overbank section and channel section. Refer to Figure 2-8.

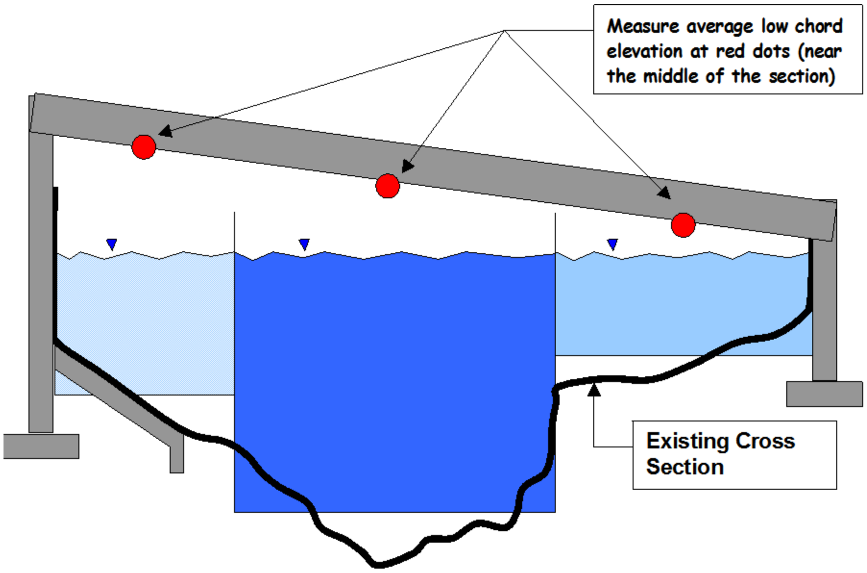


Figure 2-8: Average Low Chord Elevation

- **Abutment Type:** Select the abutment type (Vertical Wall, Wing-wall or Spill-through Slope)
- **Setback:** Setback is the horizontal distance measured from the channel bank or edge of channel to the abutment:
  - For a vertical wall or a wing wall abutment, measure the setback from the channel bank to the face of the abutment.
  - For a bottomless arch culvert, measure the setback from the channel bank to the culvert wall
  - For an abutment on a spill through slope, measure the setback from the channel bank to the point where the ground line intersects the spill-through slope. If the ABSCOUR cross-section is above the existing ground, use the ABSCOUR cross-section to define the ground line. If the ABSCOUR cross-section is below the existing ground, use the existing ground to define the ground line.
  - If there is a pier on the over-bank section, the pier width should not be included in the top width value T. This may result in a condition that the top width as measured from the channel edge will not extend to the abutment, and abutment scour will be computed as zero. For this case, the setback distance needs to be adjusted to equal the top width, T.
  - If the abutment projects into the channel beyond the channel bank, enter the setback as a negative number.

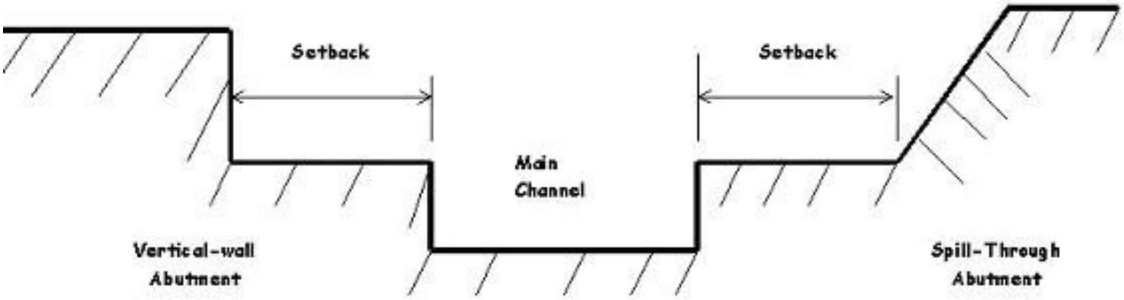


Figure 2-9: Illustration of Setback

- **Median particle size:** This value is important for clear water scour and should represent the particle size at the bottom of the scour hole. The D50 particle size can be entered for up to three soil layers and the program will compute the extent of the scour into each layer (See the F-1 help card)
- **Input the median (D50) particle size in feet (meters) for the material under the bridge/culvert using following format.**
- **For single soil layer, input the D50 in feet/meter.**
- **For two soil layers, input: (top layer thick)*(top layer D50)+(bottom layer D50). For example: 2.5*0.05+0.25**
- **For three soil layers, input: (top layer thick)*(top layer D50)+(2nd layer thick)*(2nd layer D50)+(3rd layer D50). For example: 2.5*0.05+5*0.25+2.5**

- The first layer should be the stream channel in which D50 is obtained by sampling (fine-grained) or by pebble count (coarse grained materials). Subsurface estimates for the D-50 are often available from borings or possibly the stream morphology report. This selection of particle size is often a judgment call due to the lack of good soils data at a distance of 5, 10 or 15 feet below the channel bed. A conservative approach is recommended where there is limited data for selecting a particle size.

- **Cohesive Soils:** A D50 particle size should not be selected for cohesive soils. If the soils are clearly cohesive, the clear water scour condition should be evaluated by using an over-ride feature and estimating the critical velocity of the soil. For particle sizes of about 0.1 mm or less, soils may behave more like a cohesive material and the assumption of a cohesionless bed material used in the ABSCOUR computations becomes less valid. For silt and clay soils, the User is referred to the discussion in Attachment 4. When a critical velocity of such soils can be estimated, select the Bridge Section Critical Velocity override function on the Project Information Screen. This will activate additional cells on the Downstream Bridge Data Screen so that the appropriate critical velocity values can be entered.

- **Armoring:** A complicating factor in selecting a representative particle size for clear water scour is the potential for armoring of the channel bed. A discussion of this consideration is presented in Part 1 of Appendix A; however, a comprehensive treatment of the armoring of channel beds is beyond the scope of this guide, and the user is referenced to the FHWA publication HDS 6, River Engineering for Highway Encroachments or similar texts on river mechanics to evaluate this condition. *In general, great reliance should not be placed on the expectation that armoring of the bed will limit the extent of contraction scour.*

- **Estimated long term bed degradation/aggradation:** The stream morphology report typically addresses the potential for long-term changes in bed elevation at the bridge. If it does not, the Engineer will need to make an evaluation of the stream morphology and utilize available information to determine a best estimate of future conditions. When a value is provided in the input cell, ABSCOUR will include this value in the elevation of the bottom of the scour hole.
- **Safety Factor:** Please refer to the table in Attachment 3 and the accompanying examples for guidance in selecting a safety factor for the abutment scour estimations
- **Over-rides:** Please note that one of the over-ride options on the Project Information Card permits the user to select a unit discharge under the bridge that is different from that computed by the program. An example of the use of this option would be a bridge crossing located in a bend with higher unit discharges on the outside of the bend. If the override is selected, then the input cells are displayed on the Downstream Bridge Data Card. Typically, such over-ride uses might be considered as a part of the sensitivity analyses of the scour evaluation*(Use all over-ride features with caution).*

E. STEP FIVE - UPSTREAM BRIDGE DATA

E.1 Enter the Upstream Bridge Data – See definition sketch Figure 1-6 below

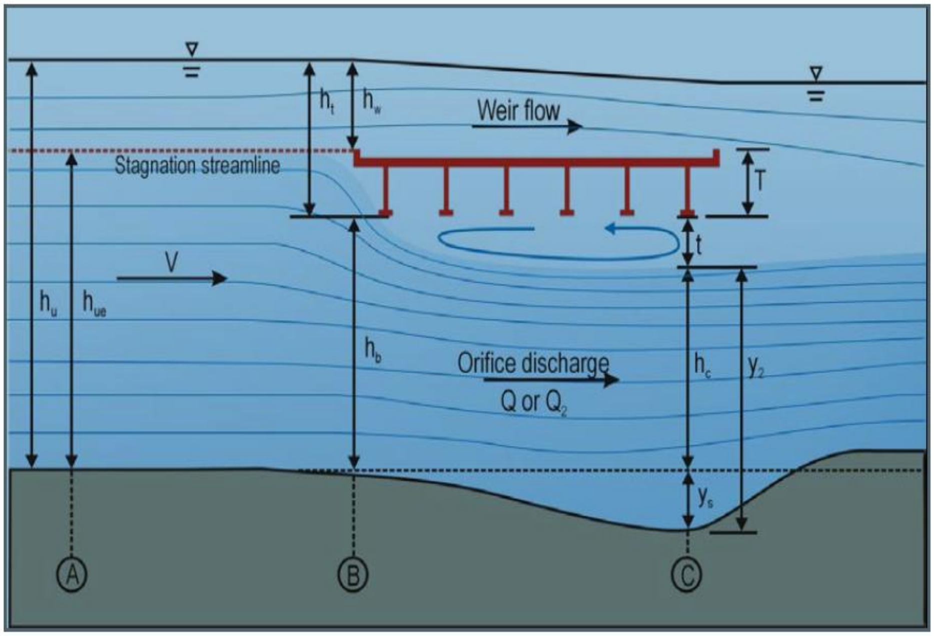
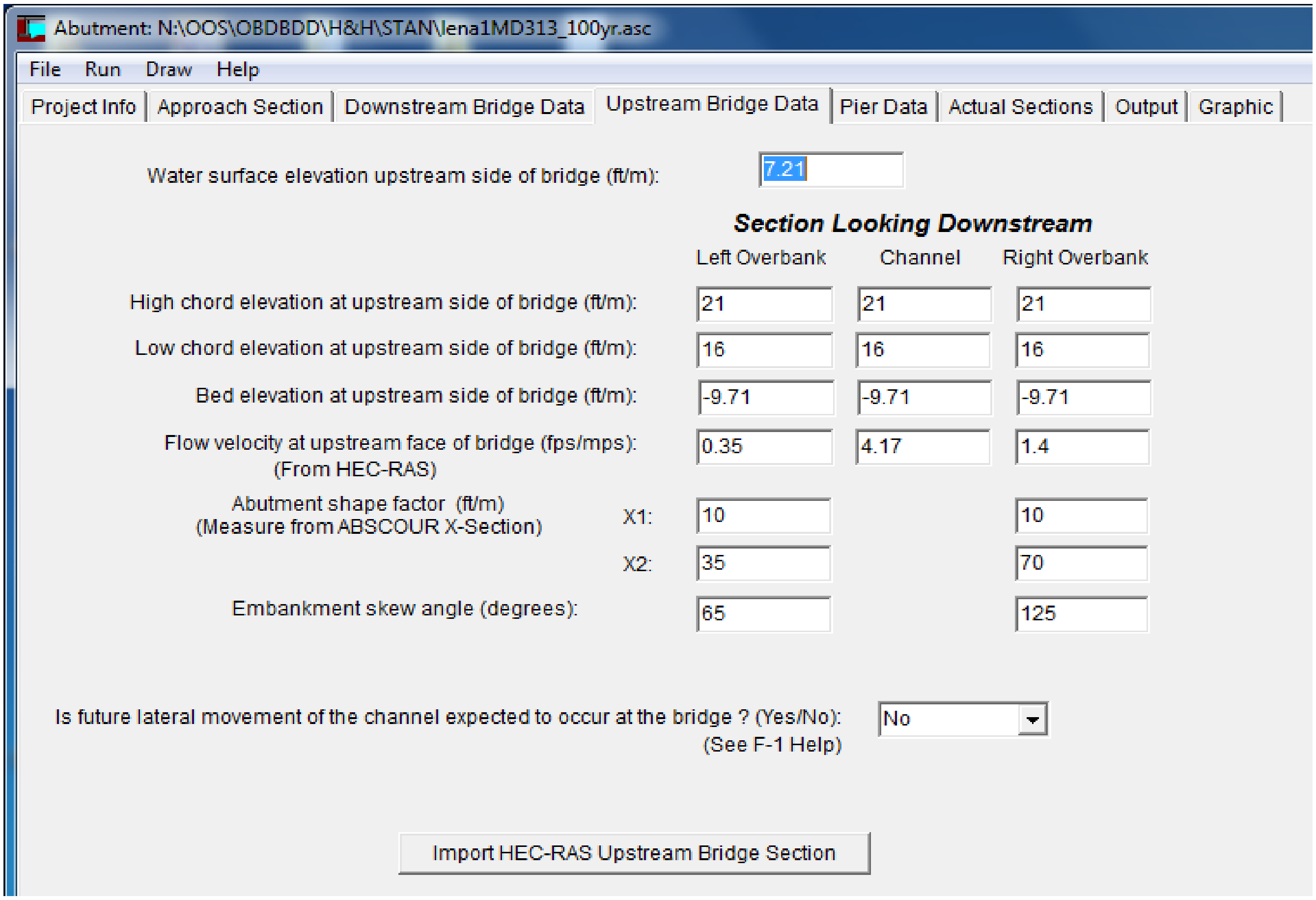


Figure 1-6 Definition Sketch for Upstream Bridge Data
(See Figure 2-10 for the input screen for the upstream bridge data.)



Water surface elevation upstream side of bridge (ft/m): 7.21

Section Looking Downstream

		Left Overbank	Channel	Right Overbank
High chord elevation at upstream side of bridge (ft/m):		21	21	21
Low chord elevation at upstream side of bridge (ft/m):		16	16	16
Bed elevation at upstream side of bridge (ft/m):		-9.71	-9.71	-9.71
Flow velocity at upstream face of bridge (fps/mps): (From HEC-RAS)		0.35	4.17	1.4
Abutment shape factor (ft/m) (Measure from ABSCOUR X-Section)	X1:	10		10
	X2:	35		70
Embankment skew angle (degrees):		65		125

Is future lateral movement of the channel expected to occur at the bridge ? (Yes/No): (See F-1 Help) No

Figure 2-10: Upstream Bridge Data Input Screen

- **Water surface elevation upstream of the structure:** The water surface elevation just upstream of the structure is determined from the water surface profile (HEC-RAS) model. The ABSCOUR program compares this elevation with the upstream bridge low chord or culvert crown elevations to determine whether pressure flow occurs. If so, a pressure scour factor (t) is computed. (See Figure 1-6)

•

- **High chord elevation at upstream side of bridge:** The average elevation of the high chord (or highest part of the superstructure) on the upstream side of the bridge over the channel and left and right overbank sections. The elevation of the high chord is used by the program to determine whether the bridge will be subject to pressure flow. If pressure flow exists, the program adjusts the predicted scour value to account for pressure flow. (See Figure 1-6).

- **Low chord elevation at upstream side of bridge:** The average elevation of the low chord (or lowest part of the superstructure) on the upstream side of the bridge over the channel and left and right overbank sections. The elevation of the low chord is used by the program to determine whether the bridge will be subject to pressure flow. If pressure flow exists, the program adjusts the predicted scour value to account for pressure flow. (See Figure 1-6).

- **Bed elevation at upstream side of bridge:** This value can be obtained from HEC-RAS. It is also used in the pressure flow computations. (See Figure 1-6).

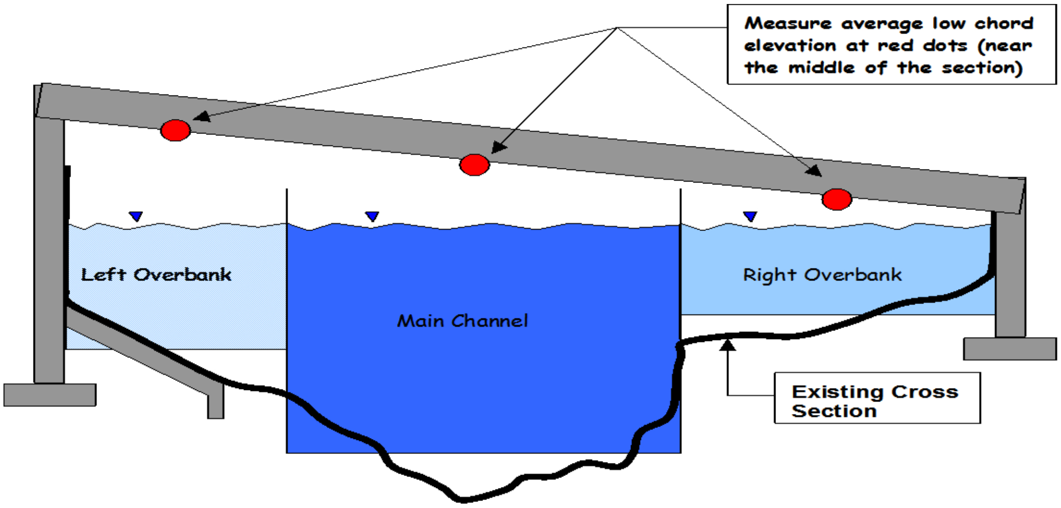


Figure 2-11: Input Values for Low Chord Elevations

- **Flow Velocity at Upstream Side of Bridge Face.** This value can be obtained from HEC-RAS. It is also used in the pressure flow computations. (See Figure 1-6).

Abutment shape factor Left and Right Overbanks: Abutment scour is reduced by a streamlined shape that facilitates a smooth transition of the flow and a corresponding reduction in turbulence. Two common examples of streamlined abutment shapes are vertical wall abutments with flared wing walls and abutments placed on spillthrough slopes. The effectiveness of the abutment shape in reducing scour depends on two factors: (1) the horizontal length, X1, of the streamlined portion of the abutment or spillthrough slope and (2) the total horizontal abutment and approach road length, X2, that is within the effective flow width of the approach flow. Please refer to Figure 2-12 for an illustration of the X1 and X2 values. As indicated in the Figure, measure X1 and X2 on the ABSCOUR cross-section; not on the actual cross-section:

1. The X1 value for a flared wing wall is the horizontal distance perpendicular to the flow from the abutment face to the end of the wing wall
2. The X1 value for a spillthrough slope is the horizontal distance perpendicular to the flow between the abutment toe (on the ABSCOUR cross-section) and the location of the water surface line on the spillthrough slope. (In some cases, the water surface may extend back to the abutment.)
3. A vertical wall abutment without wing walls or with a 90 degree wing wall is not a streamlined shape and has an X1 value of zero.

The shape factor, Kt, is defined as the ratio of X1/X2. Equations 1-29 and 1-30 compute the value of Kt. Kt is used in Equation 1-28 to compute the reduction in scour due to any streamlining of the abutment shape.

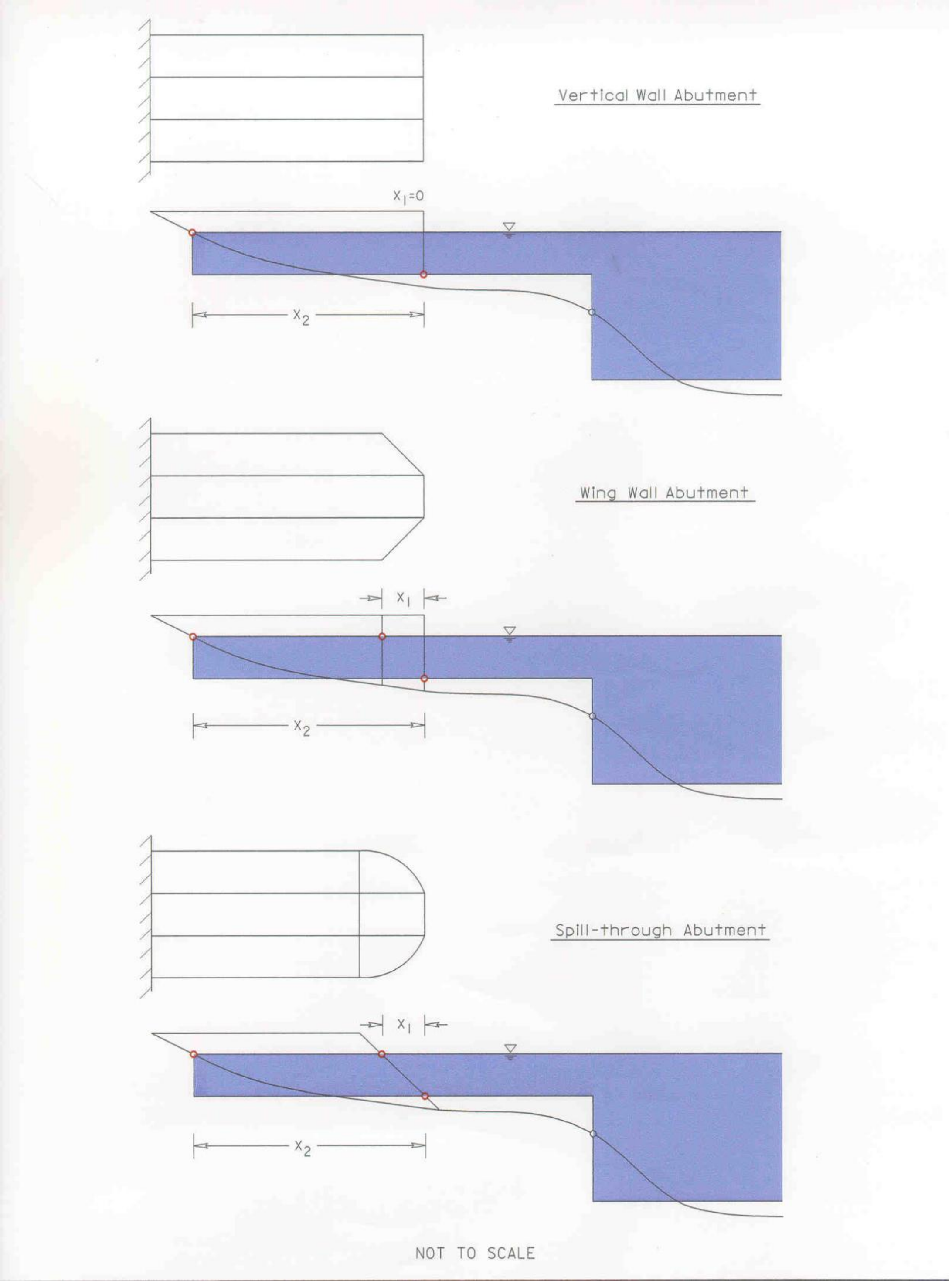


Figure 2-12 Abutment Shape Factor
Selection of X_1 and X_2 Measurements

- **Embankment skew angle:** The angle measured from the flow direction to the centerline of the left or right approach roadway embankment, in degrees. Refer to sketch Figure 2-13. The embankment angle is used to account for the effect of the orientation of the embankment on the contracting approach flow. For an embankment angled downstream, the scour depth is decreased; for an embankment angled upstream, the scour depth is increased. Please note that the embankment skew angle may be different from the abutment skew angle.

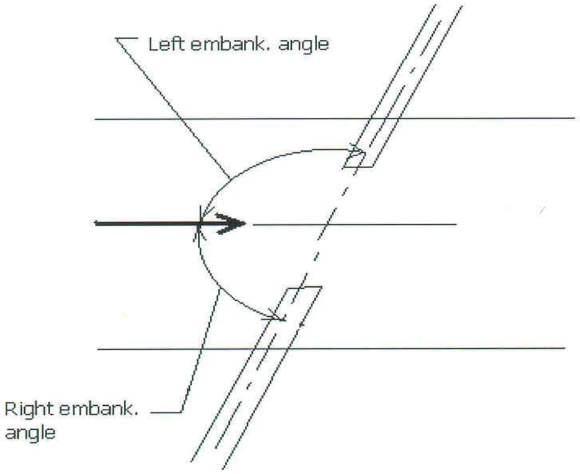


Figure 2-13: Embankment Skew Angle

- **Future lateral movement of the channel:** This input is a yes or no answer. It serves as a reminder to take lateral movement into account. Lateral movement needs to be considered for both bridges and culverts. The structure is fixed, but the channel is free to modify its bed and banks over time. Design considerations for piers and abutments relative to channel movement are presented in the SHA Chapter 11 Scour Manual and in the FHWA publications HEC-18 and HEC-20. The stream morphology study, including the evaluation of the stream location over time, typically provides insight as to future trends of the stream channel and guidance on providing for an adequate abutment setback and scour protection. Please note that the design approach should be made for every bridge foundation element within the channel lateral movement zone to use the thalweg velocity and depth to compute the scour at the bridge foundation element. The Utility Module in ABSCOUR 9 provides a convenient method for computing the effect of channel movement on abutment scour.

F. STEP SIX - PIER DATA

Figure 2-14 depicts the Pier Data Card. It is used to input information on the bridge piers into the ABSCOUR Program so that a complete scour cross-section under the bridge can be generated for the scour report. The User needs to calculate the elevation of total pier scour (contraction scour elevation - local pier scour) before entering information on the Pier Data Card. Use the Pier Local Scour module, Option 4, to calculate total pier scour.

Obtain the contraction scour at the pier from the ABSCOUR output. Once this is done, the following information needs to be supplied on the Pier Data Screen.:

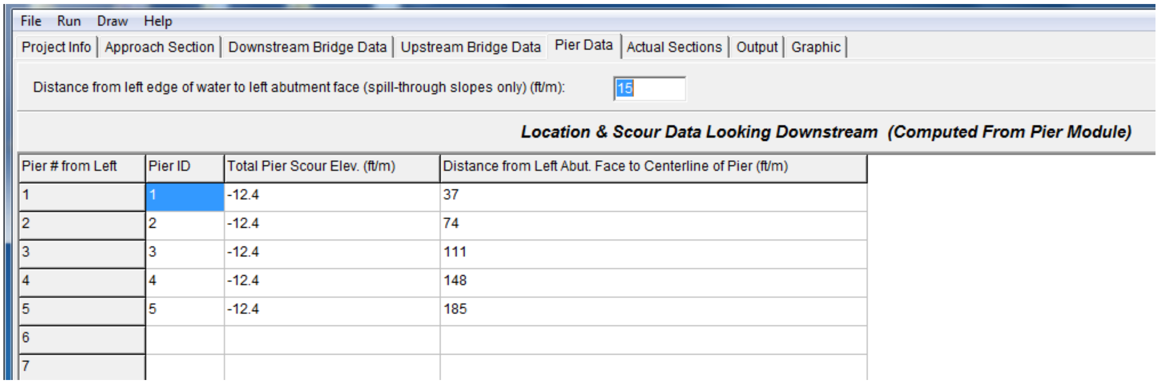
Column 1 - A listing of pier numbers beginning with the pier closest to the left abutment looking downstream (already listed).

Column 2 - The Pier ID number depicted on the plans

Column 3 - The elevation of the bottom of the scour hole at the pier. This needs to be the elevation of the total scour depth - the sum of local scour plus contraction scour + degradation.

Column 4- Distance from the left abutment face to the centerline of the pier.

For the special case of a spill-through slope at which the water edge is at the spill-through slope instead of the abutment face, one more piece of information needs to be input into the cell at the top of the card: Distance from the water's edge to the left abutment face. This step locates the left abutment with regard to the edge of water. All measurements are made from the left abutment face.



Distance from left edge of water to left abutment face (spill-through slopes only) (ft/m): 15

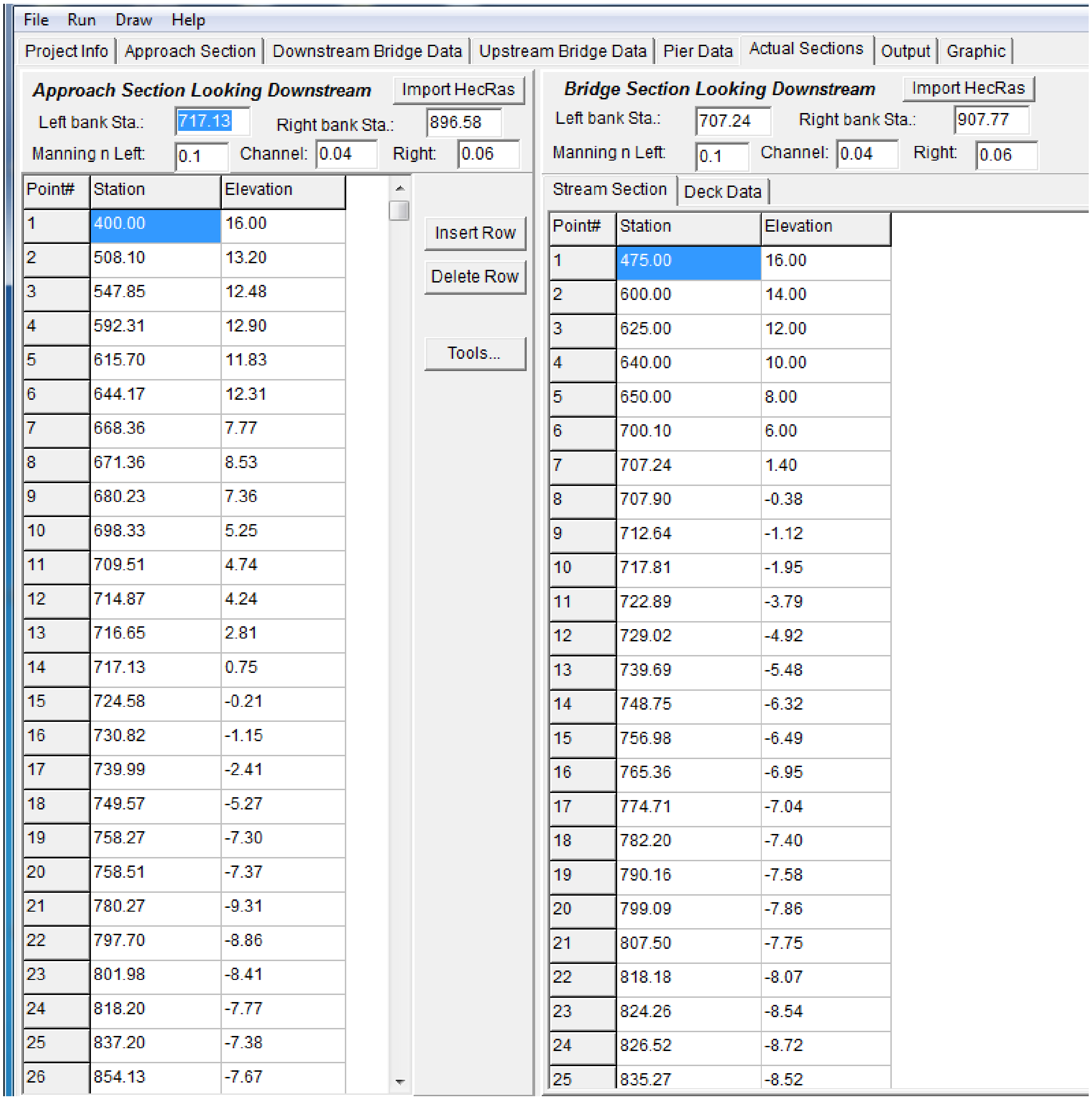
Location & Scour Data Looking Downstream (Computed From Pier Module)

Pier # from Left	Pier ID	Total Pier Scour Elev. (ft/m)	Distance from Left Abut. Face to Centerline of Pier (ft/m)
1	1	-12.4	37
2	2	-12.4	74
3	3	-12.4	111
4	4	-12.4	148
5	5	-12.4	185
6			
7			

Figure 2-14 Pier Data Card

G. STEP 7 ACTUAL SECTIONS

The Actual Sections menu allows the user to import HEC-RAS cross-sections into the ABSCOUR program and to superimpose the HEC-RAS (Actual) Sections on the ABSCOUR (Computed) Sections. This option can be exercised for both the APPROACH SECTION 1 and the BRIDGE SECTION 2. The user can view and compare the fit between the Actual and ABSCOUR sections by accessing the DRAW option on the top MENU bar for the Approach Section, Bridge Section and Scour Section.



Approach Section Looking Downstream

Left bank Sta.: 717.13
Right bank Sta.: 896.58
Manning n Left: 0.1
Channel: 0.04
Right: 0.06

Point#	Station	Elevation
1	400.00	16.00
2	508.10	13.20
3	547.85	12.48
4	592.31	12.90
5	615.70	11.83
6	644.17	12.31
7	668.36	7.77
8	671.36	8.53
9	680.23	7.36
10	698.33	5.25
11	709.51	4.74
12	714.87	4.24
13	716.65	2.81
14	717.13	0.75
15	724.58	-0.21
16	730.82	-1.15
17	739.99	-2.41
18	749.57	-5.27
19	758.27	-7.30
20	758.51	-7.37
21	780.27	-9.31
22	797.70	-8.86
23	801.98	-8.41
24	818.20	-7.77
25	837.20	-7.38
26	854.13	-7.67

Bridge Section Looking Downstream

Left bank Sta.: 707.24
Right bank Sta.: 907.77
Manning n Left: 0.1
Channel: 0.04
Right: 0.06

Point#	Station	Elevation
1	475.00	16.00
2	600.00	14.00
3	625.00	12.00
4	640.00	10.00
5	650.00	8.00
6	700.10	6.00
7	707.24	1.40
8	707.90	-0.38
9	712.64	-1.12
10	717.81	-1.95
11	722.89	-3.79
12	729.02	-4.92
13	739.69	-5.48
14	748.75	-6.32
15	756.98	-6.49
16	765.36	-6.95
17	774.71	-7.04
18	782.20	-7.40
19	790.16	-7.58
20	799.09	-7.86
21	807.50	-7.75
22	818.18	-8.07
23	824.26	-8.54
24	826.52	-8.72
25	835.27	-8.52

Figure 2-15 Actual Sections

The user can use this information to advantage in making an evaluation of the ABSCOUR scour computations:

1 Identify errors in the input data for the ABSCOUR cross-sections
2 Compare how well the ABSCOUR Section fits the Actual Section.
3 Determine if “fine tuning” adjustments in scour elevations should be made in order to match the actual cross-section more closely.

Application

Clicking on the Actual Sections Menu brings up two tables: the “Approach Section Looking Downstream” and the “Bridge Section Looking Downstream.” The top of each table provides cells to input the beginning cross-section station (Left Bank Station) and the ending cross-section station (Right Bank Station). Additional cells are provided to input Manning “n” values for the channel and left and right flood plains.

The body of each table consists of 3 columns: the designated point number, its station and elevation. The information in this table can be filled in manually or imported directly from the appropriate HEC-RAS model. It is useful to run the example problem included with the ABSCOUR program to view the format for the data in a typical table.

Manual Input: Input the data in the same manner as is depicted by the table for the example problem:
Import Cross-section Data Use of the import function is recommended, since it is much easier to do. This function imports the actual cross section of the stream at the approach and at the bridge. At the bridge, the program will also import the bridge deck data from HECRAS. Note, only the geometry file of the last selected plan in HECRAS project will be used.

To import the approach section, select the HECRAS project file in the open file dialog. The program will read the current active plan of HECRAS project and generate a list of available cross sections. The User can then choose the cross section of the desired approach section on the list. The imported data includes the station and elevation of the ground point in the cross section and the left bank and right bank point station.

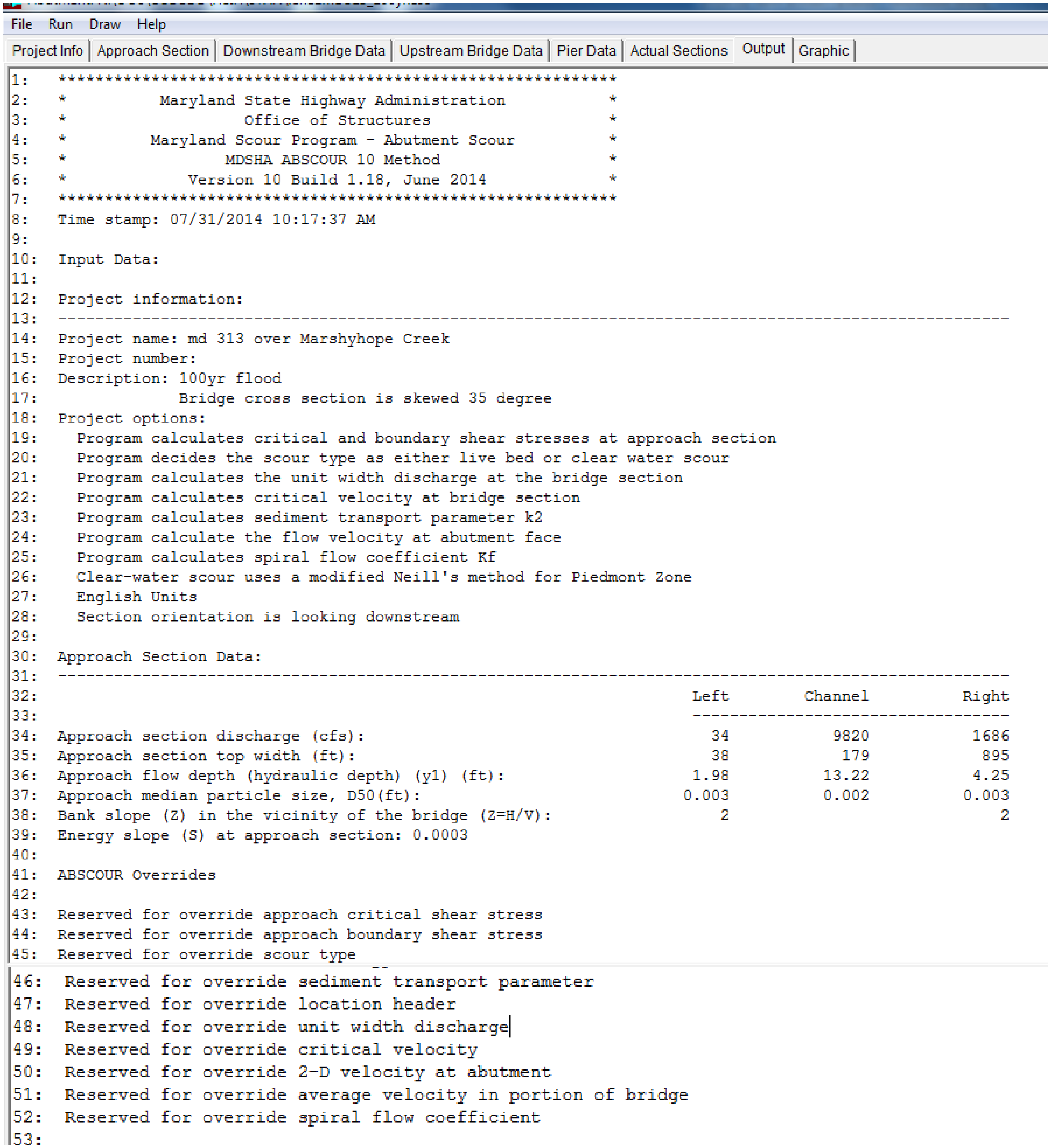
For the bridge section, the program will search through the geometry file of the current active plan of HECRAS project and find the available bridges. If more than one bridge exists, a list of bridges will be generated and the user can select the appropriate bridge. If there is only one bridge, the program will import the bridge data without asking. The bridge data includes the downstream section (or upstream section for the upstream tool) and the bridge deck high chord and low chord elevations. The left bank and right bank point stations are also obtained. If the left bank and right bank stations do not match the ABSCOUR stations used in the scour analysis, the user can make the following adjustment: Change the HEC-RAS stations to match the ABSCOUR section.

III. COMPUTATIONS AND PROGRAM OUTPUT INFORMATION

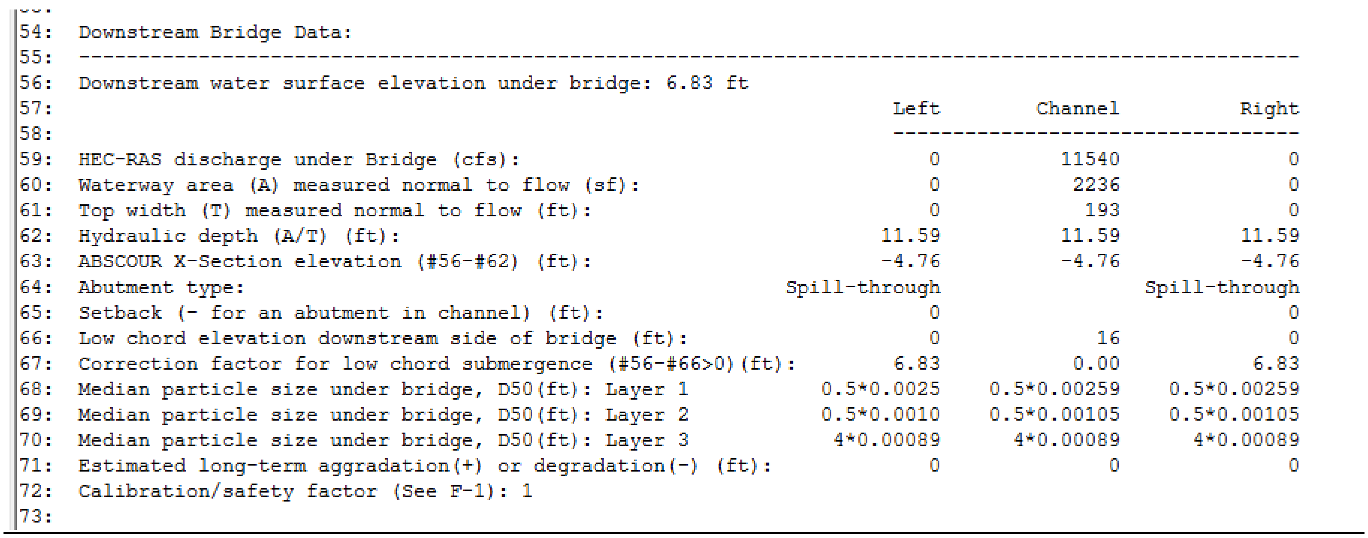
Please note that the ABSCOUR program presents computations with up to three decimal points. However, final scour values used for design should be rounded off to the nearest foot, since the assumption of accuracy of scour estimates to a tenth of a foot is not valid. After entering the data on the input menus as described in Steps 1 through 5, click on the RUN button to compute the scour. If the program inputs are correctly entered, the output file appears. If there are any of the input items are not filled in, an error message will appear prompting the user to correct the input files. All input data and output computations are summarized in the output report.

Figure 2-16 shows the screen that appears after running the ABSCOUR program. The user can scroll down through the output to look at input data, output data and program notes. The output can be sent directly to a printer or it can be saved as a text file so that it can be inserted into an electronic report.

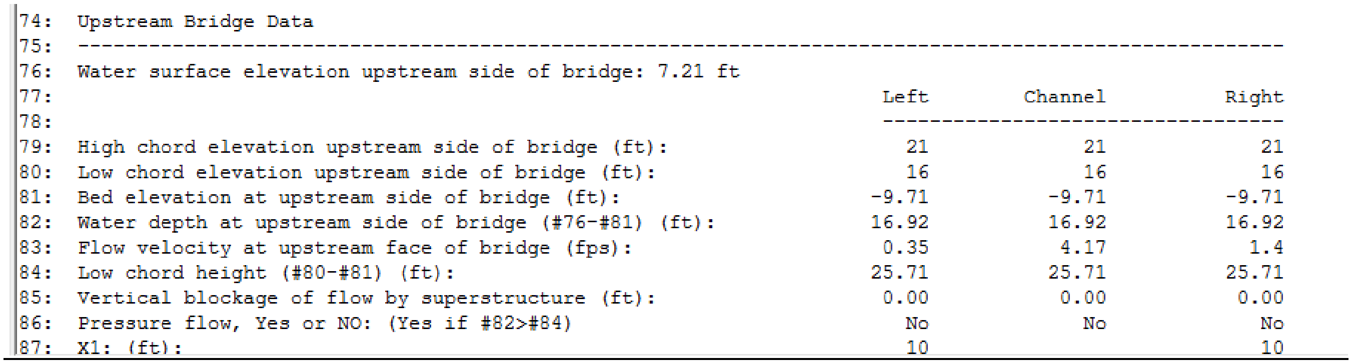
Figure 2-16 ABSCOUR Output Report, MD 313 over Marshy Hope Creek



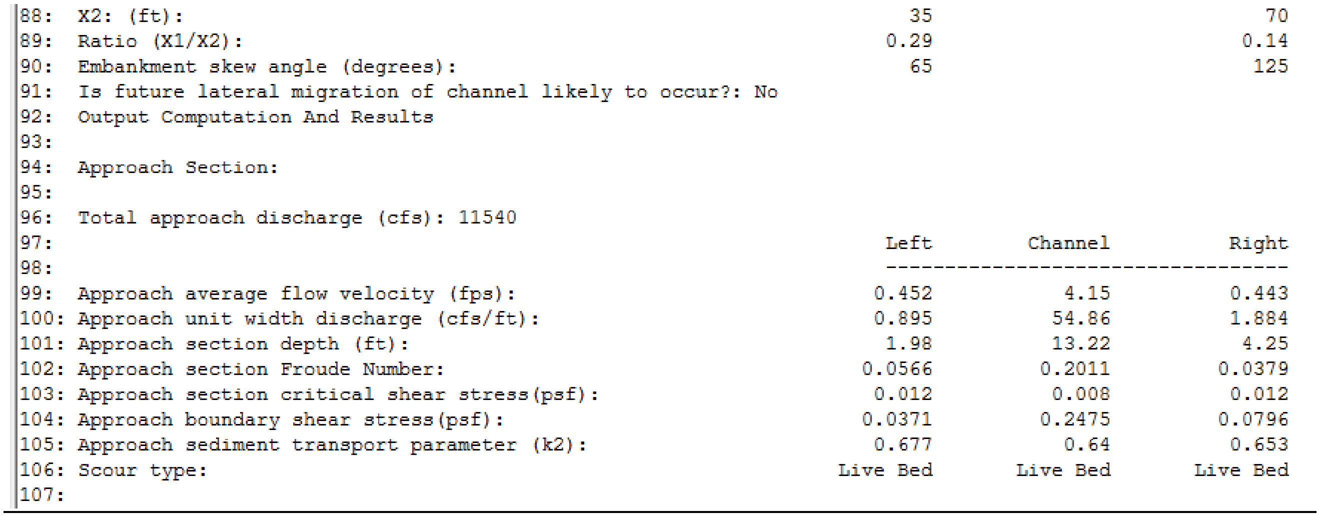
```
************************************************************
*          Maryland State Highway Administration           *
*                   Office of Structures                   *
*         Maryland Scour Program - Abutment Scour          *
*                 MDSHA ABSCOUR 10 Method                  *
*             Version 10 Build 1.18, June 2014             *
************************************************************
Time stamp: 07/31/2014 10:17:37 AM

Input Data:

Project information:
------------------------------------------------------------------------------------------------------
Project name: md 313 over Marshyhope Creek
Project number:
Description: 100yr flood
             Bridge cross section is skewed 35 degree
Project options:
  Program calculates critical and boundary shear stresses at approach section
  Program decides the scour type as either live bed or clear water scour
  Program calculates the unit width discharge at the bridge section
  Program calculates critical velocity at bridge section
  Program calculates sediment transport parameter k2
  Program calculate the flow velocity at abutment face
  Program calculates spiral flow coefficient Kf
  Clear-water scour uses a modified Neill's method for Piedmont Zone
  English Units
  Section orientation is looking downstream

Approach Section Data:
------------------------------------------------------------------------------------------------------
                                                                    Left        Channel          Right
                                                                    ----------------------------------
Approach section discharge (cfs):                                     34           9820           1686
Approach section top width (ft):                                      38            179            895
Approach flow depth (hydraulic depth) (y1) (ft):                    1.98          13.22           4.25
Approach median particle size, D50(ft):                            0.003          0.002          0.003
Bank slope (Z) in the vicinity of the bridge (Z=H/V):                  2                             2
Energy slope (S) at approach section: 0.0003

ABSCOUR Overrides

Reserved for override approach critical shear stress
Reserved for override approach boundary shear stress
Reserved for override scour type
Reserved for override sediment transport parameter
Reserved for override location header
Reserved for override unit width discharge
Reserved for override critical velocity
Reserved for override 2-D velocity at abutment
Reserved for override average velocity in portion of bridge
Reserved for override spiral flow coefficient

```



```
54:  Downstream Bridge Data:
55:  -----------------------------------------------------------------------------------------
56:  Downstream water surface elevation under bridge: 6.83 ft
57:                                                                 Left        Channel         Right
58:                                                                 ------------------------------
59:  HEC-RAS discharge under Bridge (cfs):                             0          11540             0
60:  Waterway area (A) measured normal to flow (sf):                   0           2236             0
61:  Top width (T) measured normal to flow (ft):                       0            193             0
62:  Hydraulic depth (A/T) (ft):                                   11.59          11.59         11.59
63:  ABSCOUR X-Section elevation (#56-#62) (ft):                   -4.76          -4.76         -4.76
64:  Abutment type:                                        Spill-through                Spill-through
65:  Setback (- for an abutment in channel) (ft):                      0                            0
66:  Low chord elevation downstream side of bridge (ft):               0             16             0
67:  Correction factor for low chord submergence (#56-#66>0)(ft):   6.83           0.00          6.83
68:  Median particle size under bridge, D50(ft): Layer 1     0.5*0.0025   0.5*0.00259   0.5*0.00259
69:  Median particle size under bridge, D50(ft): Layer 2     0.5*0.0010   0.5*0.00105   0.5*0.00105
70:  Median particle size under bridge, D50(ft): Layer 3      4*0.00089     4*0.00089     4*0.00089
71:  Estimated long-term aggradation(+) or degradation(-) (ft):        0              0             0
72:  Calibration/safety factor (See F-1): 1
73:
```



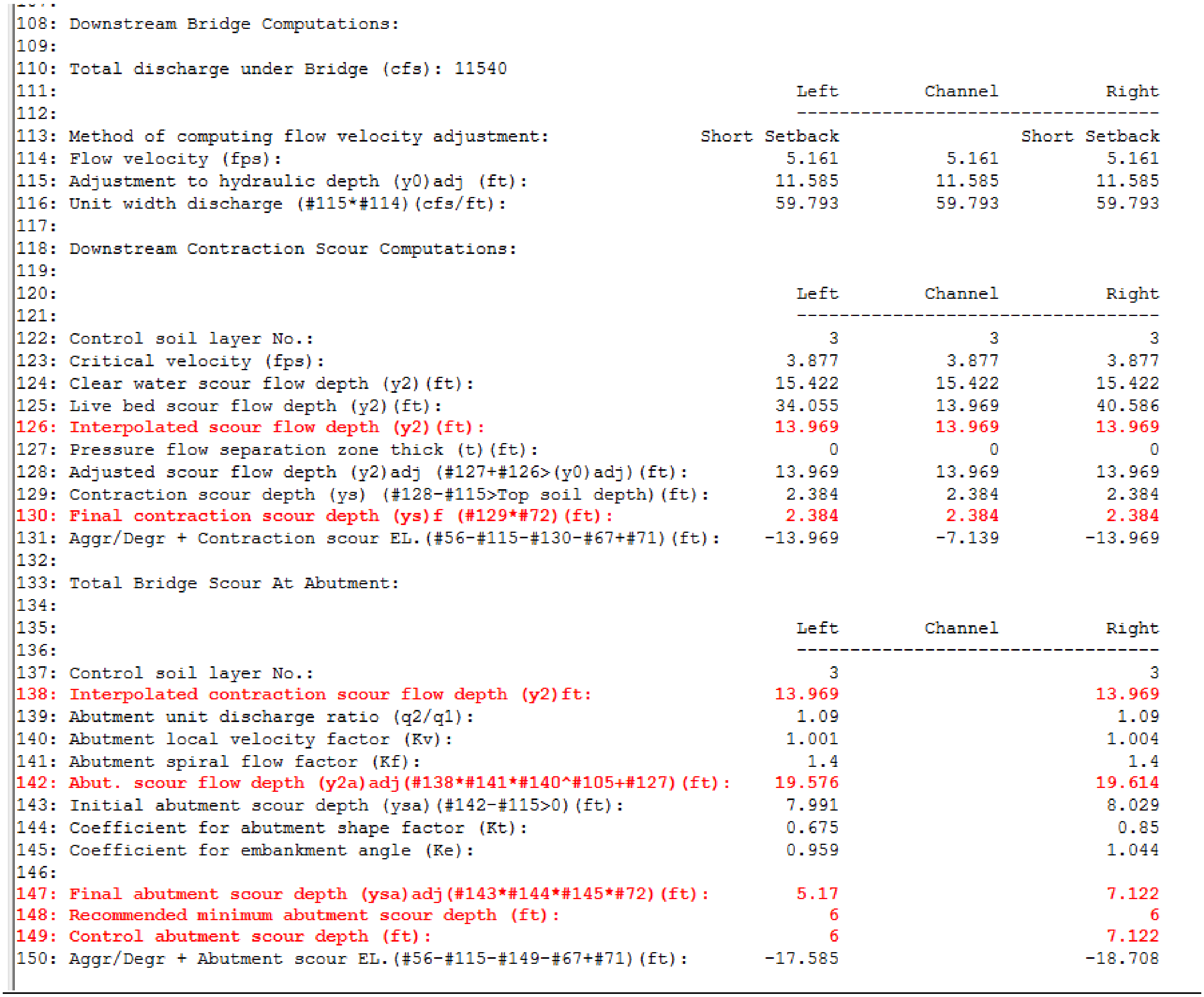
```
74:  Upstream Bridge Data
75:  -----------------------------------------------------------------------------------------
76:  Water surface elevation upstream side of bridge: 7.21 ft
77:                                                                 Left        Channel         Right
78:                                                                 ------------------------------
79:  High chord elevation upstream side of bridge (ft):               21             21            21
80:  Low chord elevation upstream side of bridge (ft):                16             16            16
81:  Bed elevation at upstream side of bridge (ft):                -9.71          -9.71         -9.71
82:  Water depth at upstream side of bridge (#76-#81) (ft):        16.92          16.92         16.92
83:  Flow velocity at upstream face of bridge (fps):                0.35           4.17           1.4
84:  Low chord height (#80-#81) (ft):                              25.71          25.71         25.71
85:  Vertical blockage of flow by superstructure (ft):              0.00           0.00          0.00
86:  Pressure flow, Yes or NO: (Yes if #82>#84)                       No             No            No
87:  X1: (ft):                                                        10                           10
```



```
88:  X2: (ft):                                                        35                           70
89:  Ratio (X1/X2):                                                 0.29                         0.14
90:  Embankment skew angle (degrees):                                 65                          125
91:  Is future lateral migration of channel likely to occur?: No
92:  Output Computation And Results
93:
94:  Approach Section:
95:
96:  Total approach discharge (cfs): 11540
97:                                                                 Left        Channel         Right
98:                                                                 ------------------------------
99:  Approach average flow velocity (fps):                         0.452           4.15         0.443
100: Approach unit width discharge (cfs/ft):                       0.895          54.86         1.884
101: Approach section depth (ft):                                   1.98          13.22          4.25
102: Approach section Froude Number:                              0.0566         0.2011        0.0379
103: Approach section critical shear stress(psf):                  0.012          0.008         0.012
104: Approach boundary shear stress(psf):                         0.0371         0.2475        0.0796
105: Approach sediment transport parameter (k2):                   0.677           0.64         0.653
106: Scour type:                                                Live Bed       Live Bed      Live Bed
107:
```

Figure 2-16 ABSCOUR Output Report, MD 313 over Marshy Hope Creek

Continued



```
108: Downstream Bridge Computations:
109:
110: Total discharge under Bridge (cfs): 11540
111:                                                                     Left        Channel          Right
112:                                                                     ----------------------------------
113: Method of computing flow velocity adjustment:              Short Setback                 Short Setback
114: Flow velocity (fps):                                               5.161          5.161          5.161
115: Adjustment to hydraulic depth (y0)adj (ft):                       11.585         11.585         11.585
116: Unit width discharge (#115*#114)(cfs/ft):                         59.793         59.793         59.793
117:
118: Downstream Contraction Scour Computations:
119:
120:                                                                     Left        Channel          Right
121:                                                                     ----------------------------------
122: Control soil layer No.:                                                3              3              3
123: Critical velocity (fps):                                           3.877          3.877          3.877
124: Clear water scour flow depth (y2)(ft):                            15.422         15.422         15.422
125: Live bed scour flow depth (y2)(ft):                               34.055         13.969         40.586
126: Interpolated scour flow depth (y2)(ft):                           13.969         13.969         13.969
127: Pressure flow separation zone thick (t)(ft):                           0              0              0
128: Adjusted scour flow depth (y2)adj (#127+#126>(y0)adj)(ft):        13.969         13.969         13.969
129: Contraction scour depth (ys) (#128-#115>Top soil depth)(ft):       2.384          2.384          2.384
130: Final contraction scour depth (ys)f (#129*#72)(ft):                2.384          2.384          2.384
131: Aggr/Degr + Contraction scour EL.(#56-#115-#130-#67+#71)(ft):    -13.969         -7.139        -13.969
132:
133: Total Bridge Scour At Abutment:
134:
135:                                                                     Left        Channel          Right
136:                                                                     ----------------------------------
137: Control soil layer No.:                                                3                             3
138: Interpolated contraction scour flow depth (y2)ft:                 13.969                        13.969
139: Abutment unit discharge ratio (q2/q1):                              1.09                          1.09
140: Abutment local velocity factor (Kv):                               1.001                         1.004
141: Abutment spiral flow factor (Kf):                                    1.4                           1.4
142: Abut. scour flow depth (y2a)adj(#138*#141*#140^#105+#127)(ft):    19.576                        19.614
143: Initial abutment scour depth (ysa)(#142-#115>0)(ft):               7.991                         8.029
144: Coefficient for abutment shape factor (Kt):                        0.675                          0.85
145: Coefficient for embankment angle (Ke):                             0.959                         1.044
146:
147: Final abutment scour depth (ysa)adj(#143*#144*#145*#72)(ft):        5.17                         7.122
148: Recommended minimum abutment scour depth (ft):                         6                             6
149: Control abutment scour depth (ft):                                     6                         7.122
150: Aggr/Degr + Abutment scour EL.(#56-#115-#149-#67+#71)(ft):       -17.585                       -18.708
```

Figure 2-16 ABSCOUR Output Report, MD 313 over Marshy Hope Creek

Continued

The ABSCOUR output file contains the scour calculations necessary for inclusion in the scour report. Each line of the output file has an accompanying line number for easy identification. Many of the formulas and the adjustment parameters are shown in the output file reference. The output sheets are labeled in the same manner as the input menu cards. The following is a summary of the sample output sheets included below. Please note that the line numbers and descriptions may vary slightly from run to run, depending on the input data.

INPUT DATA

1. Project information - Lines 1-29
2. Approach Section Data - Lines 30 - 40
3. ABSCOUR Over-rides Lines 41-52
4. Downstream Bridge Data Lines 54- 73
5. Upstream Bridge Data Lines 74 - 93

OUTPUT COMPUTATIONS AND RESULTS

1. Approach Section Lines 94 - 107
2. Downstream Bridge Computations, Lines 107- 117
3. Downstream Contraction Scour Computations, Lines 118 - 132
4. Total Bridge Scour at Abutments, Lines 133 - 150.

ABSCOUR can also generate plots of the approach section, bridge section and the bridge scour cross-section. Figures 2-15, 2-16, and 2-17 show the plots created for the approach section, bridge section and bridge scour section respectively. The plots may be printed directly from the program to a specified scale or the user may export *.dxf files for inclusion in AutoCAD or Microstation. The cursor can be used to determine various elevations and distances depicted on the plots.

If the HEC-RAS Approach Section and Bridge Section have been imported into ABSCOUR, they will be included in the above noted Figures. Comparison of these cross-sections will be helpful in evaluating the answers obtained from the program.

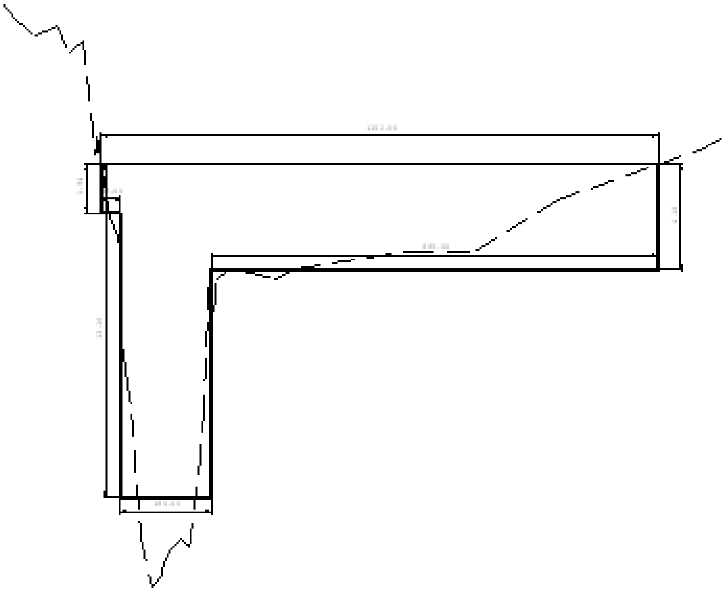


Figure 2-17: Approach Section Plot: MD 313 over Marshy Hope Creek

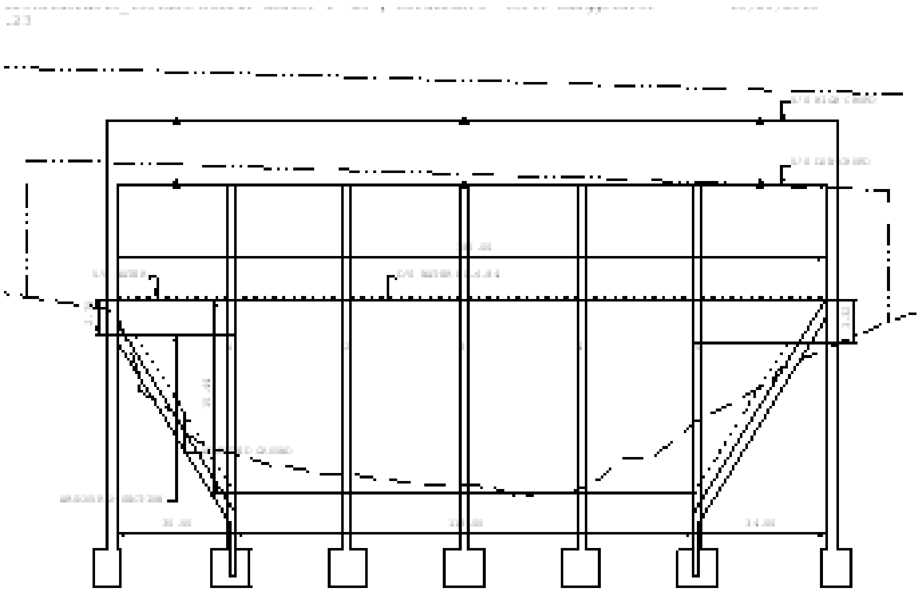


Figure 2-16: Bridge Section Plot: MD 313 over Marshy Hope Creek

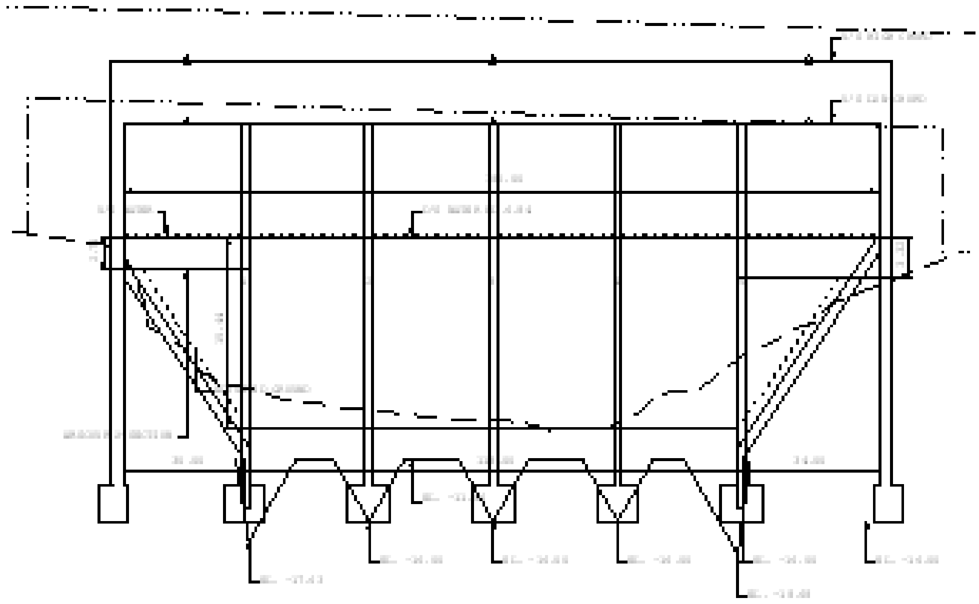


Figure 2-18: Sample Scour Cross-Section Under Bridge

ABUTMENTS SET BACK FROM THE EDGE OF THE CHANNEL

Excerpts from the Office of Structures scour report for the MD Route 313 bridge crossing over Marshy Hope have been presented above. MD 313 a six span steel structure with abutments on spill-through slopes. All foundation elements are on piles. The ABSCOUR abutment module computes the scour cross-section at the bridge across the channel up to the toe of the spill-through slope which, in this case, happens to be a bulkhead. The Pier Scour Module computes the total pier scour, taking into account the effect of contraction scour.

The ABSCOUR program prints out the scour cross-section for the bridge. The procedure for evaluating "worst-case" scour at the abutment piles, set back from the channel, is illustrated below in the sketch of the elevation view of the bridge. The contraction scour elevation is plotted at the toe of the spill-through slope; then the scour profile is continued up the spill-through slope along the estimated angle of repose of the abutment material as illustrated in the blow-up for the bridge sketch for the left abutment. The intersection of the scour line with the piles can be used to evaluate the potential loss of support and the resulting stability of the piles.

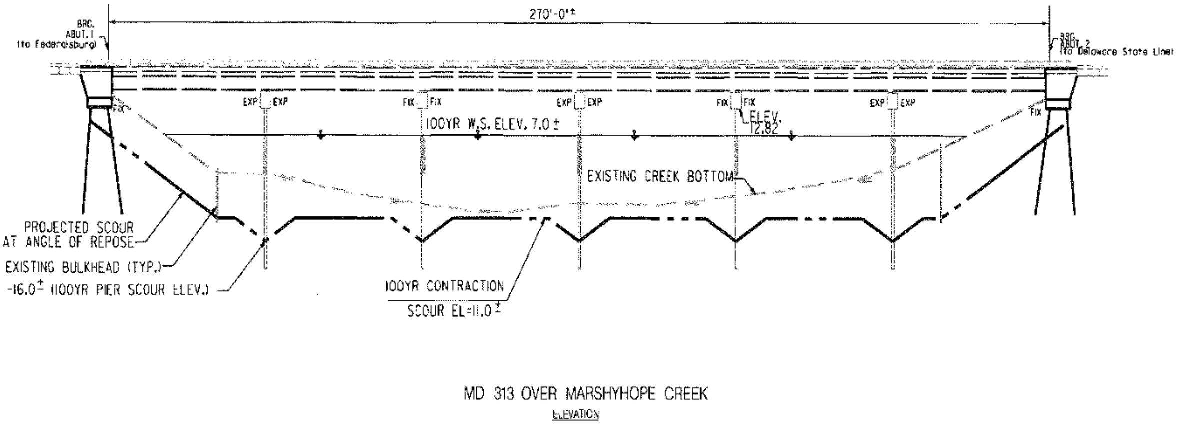


Figure 2-19
CADD Plot of Scour Cross-Section for Marshy Creek Bridge.

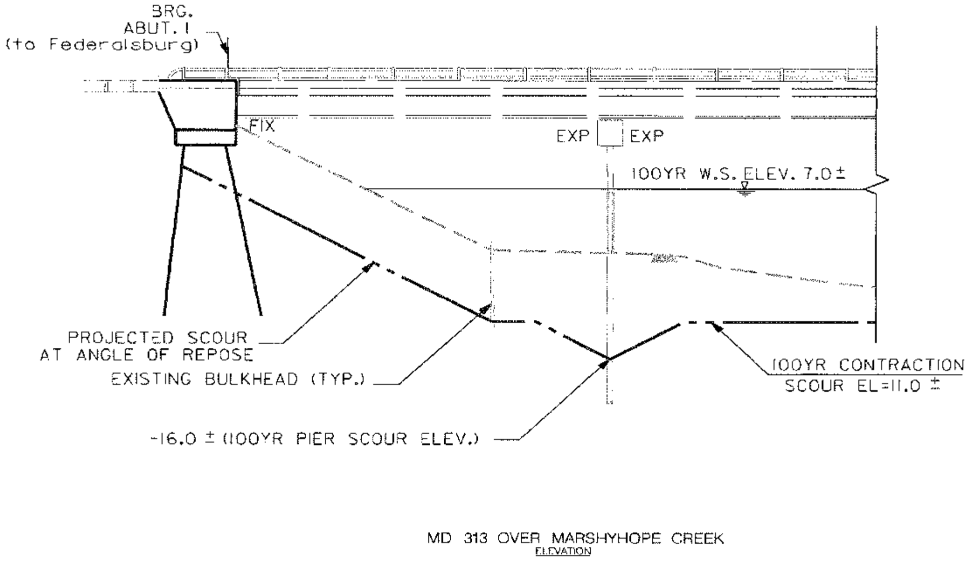


Figure 2-20
Blow-up of the CADD Plot for the Scour Cross-Section for the Marshy Hope Bridge.

The existing bulkhead is at the toe of the spill-through slope. The elevation of the contraction scour is computed at this point. Then the scour cross-section is continued at the angle of repose of the spill-through-slope material back to the abutment piles. The length of the exposed piles are determined to provide a basis for evaluating the stability of the abutment.

DISCUSSION OF THE ABSCOUR REPORT

A. ABSCOUR PROJECT INFORMATION:

- **Project Information:** Use this section to outline the primary factors of interest in the scour evaluation: flood flow, project description and any special conditions to be evaluated (discharge, trial selections for soils, types of scour).
- **Project Options:** This section prints the options used by the program.

B. INPUT DATA:

- **Approach Section Data:** These numbers reflect the information provided by the User for the Approach Section. An important item to check here (Line 101) is whether the flow is live bed or clear water.
- **ABSCOUR Overrides:** This summary should always be reviewed to make sure that the User is aware of any overrides input into the program.
- **Downstream Bridge Data:** This summarizes the information used to construct the ABSCOUR cross-section under the bridge. It computes a correction factor for the case where the downstream water surface is higher than the elevation of the low bridge chord.
- **Upstream Bridge Data:** This is a summary of the information needed to compute the shape factor for the bridge and to determine if pressure flow will occur.

OUTPUT COMPUTATIONS AND RESULTS

- **Approach Section:** This is a summary of the data used to compute the unit discharges at Section 1 and to develop the computations to determine if the flow condition is for live bed or clear water scour.
- **Downstream Bridge Computations:** Based on the abutment setback and channel flow depth, the program computes the flow distribution and velocities as described in Part 1 for short setback, intermediate setback or long setback. There are 16 possible combinations of flood plain geometry and abutment setback distances that are utilized in the ABSCOUR Program to compute the appropriate velocity used in the scour equations. These combinations are presented in Attachment 1.

  For clear water scour, the user has the option to compute the critical velocity from Laursen's equations or the SHA modification of Neill's curves. The ABSCOUR program computes contraction scour depth by setting the average flow velocity equal to the critical velocity (Neill's competent velocity) of the D50 stone size.

  An adjustment is made for the hydraulic depth at the abutment if the abutment is within the limits of the bank slopes line 110.

- **Downstream Contraction Scour Equations:** Line 118 and 119 reflect computed contraction scour for clear water and live bed, respectively, and Line 120 provides for an interpolated scour depth depending on the scour conditions. In the Case C example presented above, there is live bed scour on the overbank and in the channel.

The live bed scour flow depth in the channel (line 119) is 12.4 feet; and on the left overbank at a distance of 5yo (34 feet) it is 5.9 ft. The abutment setback for the left overbank is 169 feet. The program makes a parabolic interpolates between the two scour values to compute the contraction scour flow depth in the left overbank as 12.0 ft. In some cases, the flow width under the bridge for one or more abutments may be less than the abutment setback. When this occurs, the program assumes that there is no water behind the abutment and the abutment scour is calculated as zero. Consequently, the extent of scour at the abutment is limited to the value of the contraction scour. *In general, this case is more likely to be based on user error than on an actual field condition.*

- **Total Bridge Scour at Abutment:** The abutment scour flow depth (y2a) at the abutment (line 134) is computed by multiplying the adjusted contraction scour flow depth determined in line 122 by the kv and kf factors using the procedure explained in line 134 (see also Equation 1-23 or 1-24).

  The computations for final abutment scour depth (Line 139) is explained in Equation 1-28 and also by the accompanying notes on Line 139. Please note that SHA uses a minimum (default) abutment scour depth of 5 feet

COMMENTS ON THE ABSCOUR PROGRAM SCOUR CROSS-SECTION

- **Program Sketches:** After running the program, the user can click on the “DRAW” button on the “Menu Bar at the top of the screen. Three options are presented: Approach Section, Bridge Section and Scour Results. We recommend careful inspection of each of these sketches to check for a reasonable representation of the actual HEC-RAS sections and to view a depiction of the scour cross-section. This exercise is well worthwhile to assure that there are no obvious errors in the input data.

  Please note that the user can input the results of the pier scour modules into the ABSCOUR bridge cross-section (Scour Results) to prepare a complete scour cross-section at the bridge. However, the pier scour elevations apply to the upstream side of the bridge whereas the abutment scour elevations are computed at the downstream side of the bridge. Combining these results provides a simplified and conservative means of evaluating the scour. The user is encouraged to redraw the scour cross-section on the bridge plans to develop a more readable sketch and to account for the issues discussed below.

  1. Perhaps the most common problem encountered with the ABSCOUR bridge section with the irregular HEC-RAS section. In most cases the two sections should be reasonably congruent. However, there are situations where adjustments are needed to refine the scour cross-section:
     - PROBLEM: The area of bridge piers is subtracted from the ABSCOUR waterway area under the bridge; consequently, in some cases the ABSCOUR 9 cross-section area may be smaller than the HEC-RAS section. Consequently the ABSCOUR channel bottom may plot above the HEC-RAS channel bottom.

EXAMPLE SOLUTION: Compute the ABSCOUR contraction scour area and distribute it along the length of the HEC-RAS channel at the elevation of the HEC-RAS channel.

- PROBLEM: For small one-span bridges crossing V-shaped channels, the ABSCOUR contraction scour elevation may plot above the channel thalweg.

  EXAMPLE SOLUTION: It is likely that the channel thalweg may move within the limits of the abutments over the life of the bridge. Subtract the contraction scour depth from the thalweg elevation to compute the elevation of contraction scour for the scour cross-section.

- PROBLEM: A narrow flood plain under bridge; ABSCOUR cross-section divided between the channel and the flood plain does not fit well with the HEC-RAS cross-section. As a basis for comparison, this section will be referred to as Model A

  EXAMPLE SOLUTION: Assume area under bridge is all channel and compute the scour cross-section on this basis. This section will be referred to as Model B; compare the scour cross-sections for Model A and Model B; select the most reasonable answer

- PROBLEM: For a bridge location on a sharp bend, contraction/bend scour may be unequally distributed with most of the scour occurring on the outside of the bend.

  EXAMPLE SOLUTION: (1) use the ABSCOUR program to compute the area of contraction scour. (2) pro-rate more of the scour on the outside of the bend, keeping the scour area constant. .

Other guidance on plotting the scour cross-section on the bridge plans

1. For vertical wall abutments, plot values of y2 and y2a under the bridge, measuring down from the water surface at the downstream side of the bridge.

1 Where the abutment scour is deeper than the channel scour, use an angle of 30 degrees to define the sides of the scour hole. Use a nominal value of 5 feet to determine the width of the bottom of scour hole.

3 Where the abutment scour depths are at a higher elevation than the channel contraction scour, use a smooth curve to define the transition area.

4 The user will need to determine the total scour at each foundation element, taking into account the following factors:

  - Contraction scour

- Abutment scour
- Local pier scour
- Lateral channel movement
- Degradation

The current policy of the Office of Structures is to make a judgment on how to best consider the total effect of these different aspects of scour on a case by case basis as discussed in Chapter 11.

B. ABSCOUR PROGRAM LOGIC

The following discussion is provided for insight into the logic used by the program in computing flow distribution and velocity distribution at the bridge.

A current limitation of the HEC-RAS program used to model flow through a bridge is that it provides for the distribution of flow under the bridge based on conveyance calculations. This approach does not reflect the three dimensional flow patterns actually observed in the field at bridge contractions. To obtain reasonable estimates of scour depth, it is necessary to account for the high local flow velocities and turbulence near the abutments caused by the contracting flow in the overbank areas upstream of the bridge.

Findings from recent laboratory studies of compound channels indicate that the velocity of flow under a bridge tends to be highest at the abutments (due to rapid acceleration and turbulence of the overbank flow entering the bridge contraction) and in the thalweg section of the channel. This phenomenon has been observed in field surveys conducted by the U. S. Geological Survey and is consistent with the theory of potential flow at a contraction. The procedure used by the ABSCOUR Program to determine the flow distribution under the bridge is explained in Part 1 of this guideline.

C. EVALUATION OF THE PROGRAM OUTPUT

C.1 Overrides

A special message indicating that “OVERRIDE IS ACTIVE” is printed when the user over-rides the computer values. *Any over-ride function should be used with caution, and the logic of the over-ride carefully checked in this evaluation phase.* Please be aware that the sediment transport functions and the hydraulic flow conditions must be compatible. If the user imposes unrealistic conditions on the program, the resulting scour estimates will be in error.

C.2 Bridge Section Data

Based on the user’s input data, the program determines the discharge, unit discharge and velocity of flow for each cross-section sub-element under the bridge. As noted earlier, the widths input by the user and the abutment setbacks should be measured normal to the direction of the approach flow.

The method of analysis (Method A, Short Setback, B Long Setback, or Method C, Intermediate or Transition Setback) is determined on the basis of a comparison of the abutment setback with the depth of flow in the main channel at the bridge (Section 2) as previously described. The unit discharges, q, and velocity, V_2 are computed from the equations set forth in Part 1. Attachment 1 provides detailed examples of how the computations are made for various combinations of channel and overbank geometry, and abutment setback.

The critical velocity required for the incipient motion of the D_{50} particle size for flow under the bridge for clear water scour is computed from the particle size of the channel bed or flood plain material and the flow depth using Neill's competent velocity curves, as modified by the Office of Structures. An over-ride table is provided to allow the user to change this value to account for cohesive soils or other factors. This over-ride process is the same as that for the scour parameter table. The user is also given the option of using Laursen's relationship for clear water scour.

C.3 Contraction Scour Table

The value of y_2 in this table is the vertical distance between the water surface and the stream bed after contraction scour has occurred. The program calculates this value using the Equations in Appendix A. The scour depth y_s is the depth of contraction scour:

$$\mathbf{y_s = y_2 - y_o}$$

Where:

y_s = depth of contraction scour
y_2 = vertical distance from the water surface to the stream bed after contraction scour has occurred, and
y_o = depth of flow under bridge before scour occurs (Bridge Section Data)

Please note that the output table will indicate whether or not pressure scour is computed in accordance with the procedure in Part 1.

C.4 Abutment Scour Table

The abutment scour depth, $(ysa)_{adj}$ *represents the total scour, including contraction scour and local scour which is predicted to occur at the abutment. It does not include long term degradation, which the user must account for in the final scour evaluation. The scour depth elevation is the elevation the Engineer should use to evaluate scour.* It reflects all of the adjustments made by the program to account for the various factors affecting abutment scour. These adjustments include the following:

- For a skewed embankment crossing, the ABSCOUR program will adjust the computed scour by a skew coefficient in accordance with the procedure set forth in

FHWA Hydraulic Engineering Circular 18, 2001 Edition. The user must enter the theta angle of the orientation of roadway with respect to the direction of the flow.

- The program increases scour depths where necessary to account for the effects of pressure flow,
- An abutment shape factor is used to evaluate the effect of the abutment shape on the predicted scour.
- A safety factor, input by the user, is applied to increase the calculated scour depth. This safety factor permits the user to apply judgment to the design considerations based on the site conditions, reliability of available data and the risks to the bridge, the transportation system and the traveling public.

C.5 Scour Depth Elevation

The scour depth elevation is used for plotting the scour cross-section and for evaluating the scour.

C.6 Occurrence of Rock

Where rock of varying elevations and resistance to scour is encountered, the user needs to take this into account in the scour cross-section.

C.7 Evaluation of the Computed Scour Values

Use the computed values of scour from the ABSCOUR program *as a guide* in the design of the bridge abutment, keeping the following considerations in mind:

- the SHA policies and procedures set forth in Chapter 11, Bridge Scour,

- the guidance in the FHWA HEC-18 Manual regarding abutment scour (Reference 1).

- the need to provide some form of scour countermeasure to protect the bridge abutment and inhibit the formation of a scour hole. Base the design of the riprap on the anticipated contraction scour depths near the abutment. Use the utility section of the program to compute the minimum D50 size of the riprap for each abutment. These calculations are based on the procedures set forth in the 2001 edition of HEC-23. Use this information to select the appropriate riprap size, typically Class 2 or 3.

There are factors which can affect the extent of contraction scour and abutment scour at a bridge that are not directly computed by the ABSCOUR model. However, various procedures have been suggested in this manual to permit the user to take some of the factors into consideration in the scour evaluation:

- the possible effect of nearby adjacent piers in modifying flow patterns and resultant abutment scour (engineering judgment; model studies)

- effect of bends and upstream tributaries in the distribution of contraction scour (bendway scour) and the effect of a severe angle of attack causing flow to impinge directly on the abutment. These conditions may increase scour at abutments located on the outside of bends. (See Attachment 2 and Reference Numbers 1, 2, and 8).

- effect of ice or debris in clogging a waterway opening, deflecting channel currents and increasing flow velocities and resulting scour (See HEC-18).

- effect of two dimensional flow patterns, especially for wide flood plains, in modifying the flow conditions at a bridge (See Attachment 2; use a 2-D model).

- effect of confluences or other geomorphological features affecting the lateral migration of stream channels (See Attachment 2).

- the method does not directly address critical shear stress or critical velocity for cohesive soils or rock. The user is provided a means of partial evaluation of this condition by use of the over-ride functions.

The engineer also needs to keep in mind the limitations of the ABSCOUR model used to estimate the depth of clear water scour. The concept is that the area under the bridge will scour and thereby increase the flow area while decreasing the flow velocity. This process will continue until the flow velocity is below the critical velocity needed to move the selected D50 particle size under the bridge. The model application is likely to result in high clear water scour depths for high flow velocities in fine-grained non-cohesive soils. The following factors need to be evaluated in this regard:

- Please note that the user can now input the thickness and D50 value of up to three layers of bed material under the bridge on the downstream bridge data card.

- The particle size should be representative of the soil at the elevation of <u>the bottom of the scour hole</u>. Armoring of the stream bed may inhibit the depth of the scour.

- SHA’s experience on Maryland streams is that critical velocities for fine particle sizes are best modeled by the Office of Structures modification to Neill’s curves as discussed in the calibration of ABSCOUR. The user has the option of using Laursen’s method for clear water scour.

- The hydrograph for the worst case scour conditions should be considered. For flashy streams on small watersheds, the time period during which scouring velocities actually occur may be relatively short, especially for overbank areas.

- The conditions for clear water or live bed scour are not always clear cut, and it is possible that both types of scour may occur during different stages of a flood hydrograph. The user is encouraged to evaluate both cases.

As indicated above, a limited flexibility has been built into the ABSCOUR program to allow the engineer to account for some of the above factors. The engineer is encouraged to consider all information obtained from field and office studies, the limitations of the scour model, and to apply judgment in the selection of the appropriate foundation elements. *The user should consider the need for a calibration (safety) factor on the Bridge Data card(consistent with the guidance in Attachment 3 of this Appendix) which reflects the uncertainties of the scour parameters at the site and the importance of the bridge under design.*

The ABSCOUR program requires accurate hydrologic, hydraulic and soils data in order to compute accurate contraction and abutment scour depths. The extent to which the Engineer can obtain accurate data will vary from site to site. In some cases, for example subsurface soils data, it may not be practical to obtain a complete and accurate description of all the input parameters. However, the use of incomplete or inaccurate input data may significantly affect the accuracy of the ABSCOUR output results of predicted scour depths. The Engineer needs to exercise judgment to arrive at a practical solution to this problem.

A big advantage of the ABSCOUR program is the ease of checking the sensitivity of the scour estimate to the different input parameters. Where there is a question about the value of the input parameter, the recommended procedure is to input the best estimate of the value and then check the sensitivity of the scour depths for reasonable maximum and minimum values of the parameter

IV QUESTIONS TO ASK AND FACTORS TO CONSIDER IN REVIEWING THE ABSCOUR OUTPUT

1. Is the ABSCOUR model being used the most up-to-date version? (ABSCOUR 9-BUILD 2.1)

   Check for updates on the web at ***www.gishydro.eng.umd.edu***
2. Are the contraction scour and abutment scour values reasonable? If not, what are the likely sources of error in the input data that are creating what appears to be high or low scour values?
3. Have you checked the performance history of the original structure being replaced or of other nearby bridges? What historical information is available on scour or on bridge failures during previous floods?
4. Does the hydrology study provide for reasonable estimates of flood magnitudes? Follow the latest Maryland Hydrology Panel Recommendations. (Use of TR-20 by itself may overestimate the magnitude of flood discharges and corresponding scour depths).
5. Does the HEC-RAS analysis provide reasonable values for flow distribution

and energy slopes? Are the approach section and bridge section reasonable representations of actual effective flow conditions during a major flood? Do you need to modify the Approach Section or select a different section? How reliable is your estimate of the tailwater elevation at the bridge? Do you have a reasonable flow distribution model for overtopping flow at the bridge?

6. How accurate and complete are the soils data? This is particularly important for clear water scour conditions. Was the appropriate information obtained from the geomorphology report? Do borings and subsurface investigations indicate the presence of rock? Have you consulted a geologist if RQD values are less than 75%? Is the rock erodible or scour resistant? How does the rock affect the scour cross-section under the bridge? If the rock is erodible, have you used Annandale's Erodibility index method or other methods to assess the extent to which it will scour? If the bed conditions indicate cohesive soils, have you selected a critical velocity for cohesive soils to compute clear-water scour?
7. Have you made sensitivity analyses to evaluate the field conditions you are modeling? For example, (a) live bed vs. clear water scour; (b) Maryland SHA modifications to Neill's curves vs. Laursen's curves for clear water scour, etc.

V. COMPUTATION OF PIER SCOUR

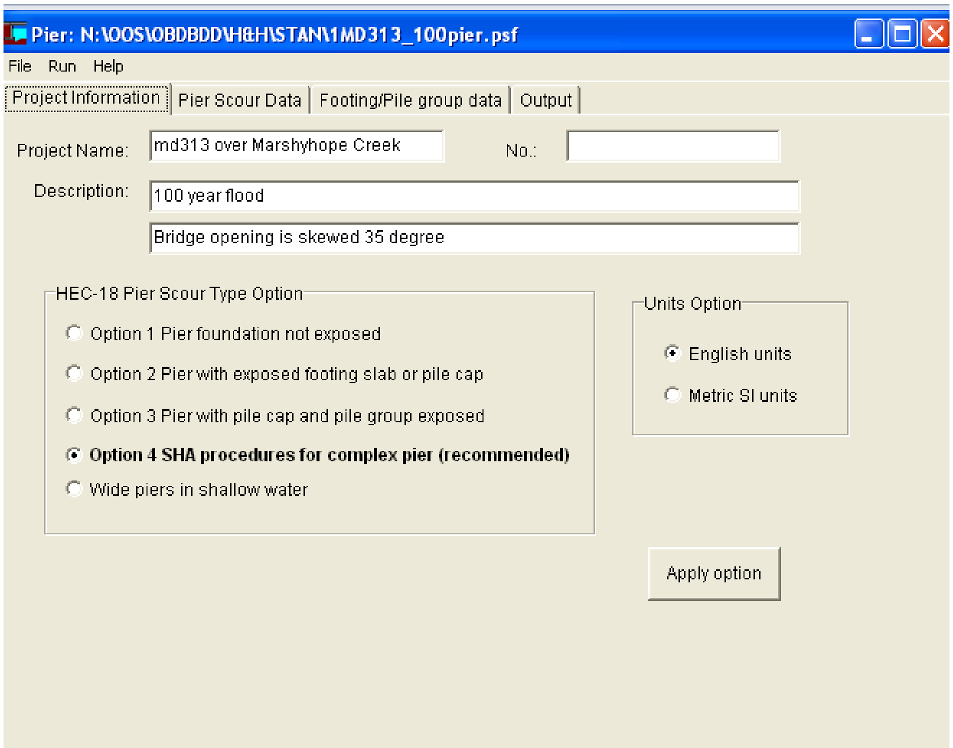
A. Pier Scour Introduction

The computational method in the Pier Local Scour Module of ABSCOUR 9 is based on the research reported by the FHWA in HEC-18, Evaluating Scour at Bridges, May 2001 Edition. The FHWA method and scour equations account for complex pier geometry as well as bed load conditions. The User is encouraged to review HEC-18 for a discussion on the research used to develop the pier scour equations and the implementation method developed for computing pier scour. The Maryland program facilitates the computations required to obtain pier scour depths. To simplify the computations for Pier Scour included in previous ABSCOUR versions, ABSCOUR 9 incorporates Option 4 which automatically makes the pier scour computations and provides a complete output file for the pier.

USING OPTION 4 TO COMPUTE PIER SCOUR

The following example is taken from the MD 313 bridge over Marshy Hope Creek. Since all piers are in the channel, the conditions of highest velocity and deepest depth were used to design all of the piers.

Open the pier scour module and select OPTION 4 on the Project information Menu. Click on the "Apply Option" button. Then click on the Pier Scour Data Tab.



Project Name: md313 over Marshyhope Creek

No.:

Description: 100 year flood

Bridge opening is skewed 35 degree

HEC-18 Pier Scour Type Option

○ Option 1 Pier foundation not exposed

○ Option 2 Pier with exposed footing slab or pile cap

○ Option 3 Pier with pile cap and pile group exposed

● **Option 4 SHA procedures for complex pier (recommended)**

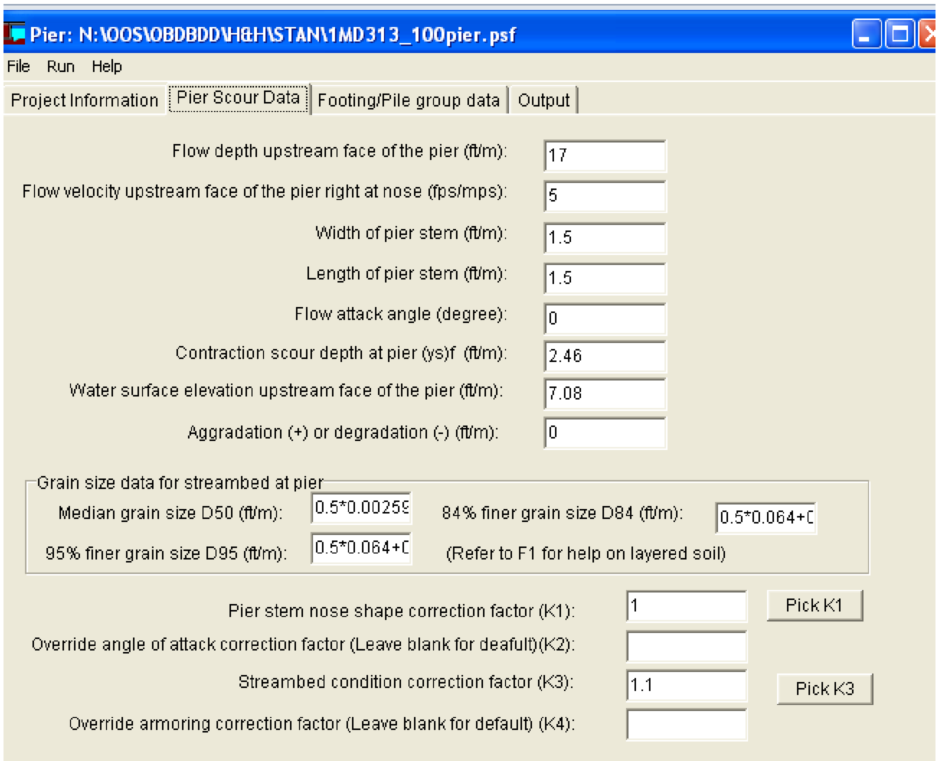
○ Wide piers in shallow water

Units Option

● English units

○ Metric SI units

Project Information Data



Flow depth upstream face of the pier (ft/m): 17
Flow velocity upstream face of the pier right at nose (fps/mps): 5
Width of pier stem (ft/m): 1.5
Length of pier stem (ft/m): 1.5
Flow attack angle (degree): 0
Contraction scour depth at pier (ys)f (ft/m): 2.46
Water surface elevation upstream face of the pier (ft/m): 7.08
Aggradation (+) or degradation (-) (ft/m): 0

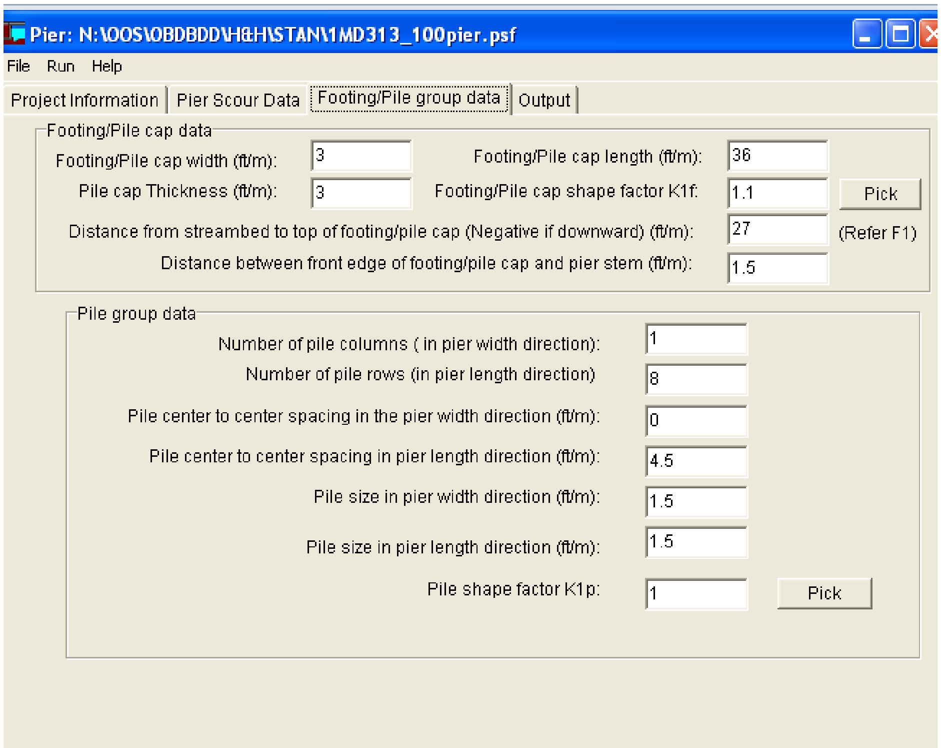
Grain size data for streambed at pier
Median grain size D50 (ft/m): 0.5*0.00259
84% finer grain size D84 (ft/m): 0.5*0.064+
95% finer grain size D95 (ft/m): 0.5*0.064+
(Refer to F1 for help on layered soil)

Pier stem nose shape correction factor (K1): 1
Override angle of attack correction factor (Leave blank for deafult)(K2):
Streambed condition correction factor (K3): 1.1
Override armoring correction factor (Leave blank for default) (K4):

Pier Scour Data

The information for the Pier Scour Data Menu can be obtained from the HEC-RAS run the stream morphology report and the bridge plans.

- Use the initial flow velocity immediately upstream of the bridge as determined from HEC-RAS. For small channels compute the velocity as $V_1=q/y_1$ where q is the unit flow in the channel. For larger channels, use the velocity distribution (flow tube) option in HEC-RAS to select the highest velocity in the channel.
- Soils information can be obtained from the Stream Geomorphology Report and borings taken at the pier. Degradation and Contraction Scour values should be consistent with the input used in the ABSCOUR Program. When the input data for this card is complete, click on the Footing/Pile group data tab.



Footing/Pile cap data

Footing/Pile cap width (ft/m): 3
Footing/Pile cap length (ft/m): 36
Pile cap Thickness (ft/m): 3
Footing/Pile cap shape factor K1f: 1.1
Distance from streambed to top of footing/pile cap (Negative if downward) (ft/m): 27 (Refer F1)
Distance between front edge of footing/pile cap and pier stem (ft/m): 1.5

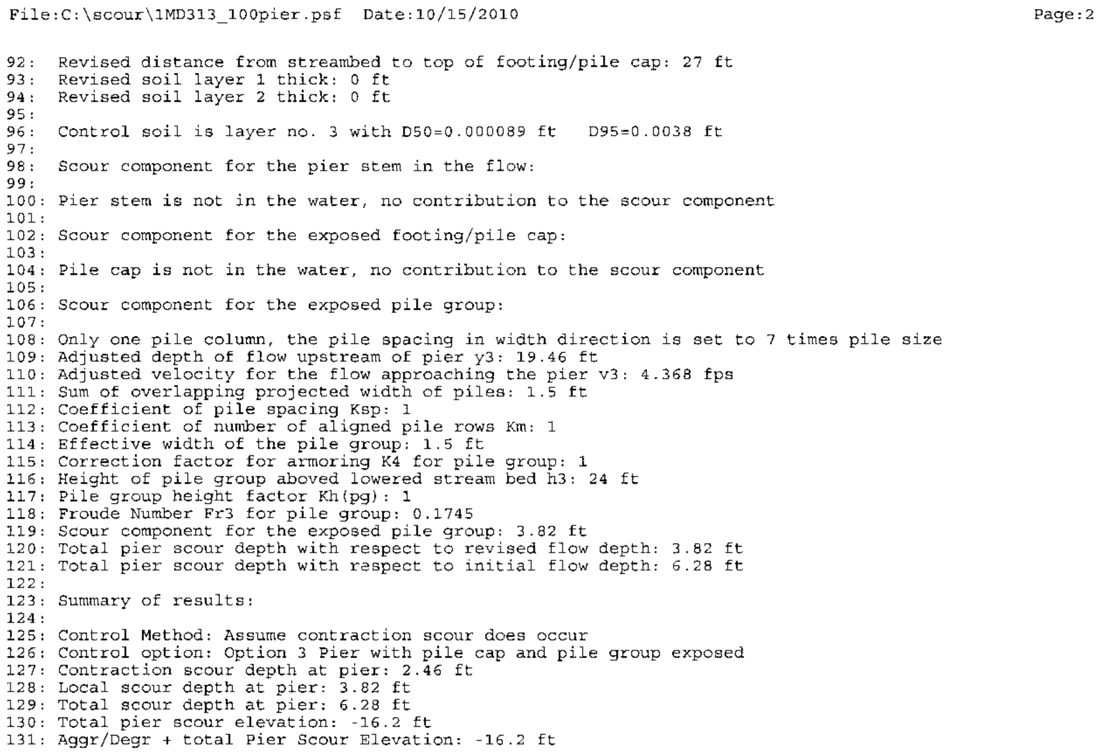
Pile group data

Number of pile columns (in pier width direction): 1
Number of pile rows (in pier length direction) 8
Pile center to center spacing in the pier width direction (ft/m): 0
Pile center to center spacing in pier length direction (ft/m): 4.5
Pile size in pier width direction (ft/m): 1.5
Pile size in pier length direction (ft/m): 1.5
Pile shape factor K1p: 1

Footing/Pile Group Data Menu.

The information for the Footing/Pile Group Data should be available from the bridge plans. When this information is completed, click on “Run” to obtain the program scour calculations. The output results for scour at the MD 313 bridge are presented below:

```
File:C:\scour\1MD313_100pier.psf  Date:10/15/2010                                                    Page:1

***********************************************************
*          Maryland State Hightway Administration         *
*                   Office of Structures                  *
*           Maryland Scour Program - Pier Scour           *
*             Version 9 Build 2, December 2009            *
***********************************************************

Time stamp: 10/15/2010 1:02:17 PM

Input data:

Project information:
----------------------------------------------
Project name: md313 over Marshyhope Creek
Project number:
Description: 100 year flood
             Bridge opening is skewed 35 degree

Pier scour condition: Option 4 Pier with pile group auto solve options 1 thru 3 and contraction conditions
Units used: English Units
Flow depth upstream face of the pier (ft/m): 17 ft
Flow velocity upstream face of the pier right at nose (fps/mps): 5 fps
Width of pier stem (ft/m): 1.5 ft
Length of pier stem (ft/m): 1.5 ft
Flow attack angle (degree): 0 degree
Contraction scour depth at pier (ys)f  (ft/m): 2.46 ft
Water surface elevation upstream face of the pier (ft/m):  7.08 ft
Aggradation (+) or degradation (-) (ft/m):  0 ft
Median grain size D50 (ft/m):  0.5*0.00259+0.5*0.00105+4*0.000089 ft
84% finer grain size D84 (ft/m): 0.5*0.064+0.5*0.0059+4*0.0038 ft
95% finer grain size D95 (ft/m): 0.5*0.064+0.5*0.0059+4*0.0038 ft
Pier stem nose shape correction factor (K1): 1
K2 calculated by the program
Streambed condition correction factor (K3): 1.1
K4 calculated by the program
Footing/Pile cap width (ft/m): 3 ft
Footing/Pile cap length (ft/m): 36 ft
Pile cap Thickness (ft/m): 3 ft
Footing/Pile cap shape factor K1f:  1.1
Distance from streambed to top of footing/pile cap (Negative if downward) (ft/m): 27 ft
Distance between front edge of footing/pile cap and pier stem (ft/m): 1.5 ft
Number of pile columns ( in pier width direction): 1
Number of pile rows (in pier length direction) 8
Pile center to center spacing in the pier width direction (ft/m): 0 ft
Pile center to center spacing in pier length direction (ft/m): 4.5 ft
Pile size in pier width direction (ft/m): 1.5 ft
Pile size in pier length direction (ft/m): 1.5 ft
Pile shape factor K1p: 1

Output Results:


***** Method 1 Option 3 *****

Revised flow depth: 17 ft
Revised flow velocity: 5 fps
Revised distance from streambed to top of footing/pile cap: 27 ft
Revised soil layer 1 thick: 0.5 ft
Revised soil layer 2 thick: 0.5 ft

Control soil is layer no. 3 with D50=0.000089 ft   D95=0.0038 ft

Scour component for the pier stem in the flow:

Pier stem is not in the water, no contribution to the scour component

Scour component for the exposed footing/pile cap:

Pile cap is not in the water, no contribution to the scour component

Scour component for the exposed pile group:

Only one pile column, the pile spacing in width direction is set to 7 times pile size
Adjusted depth of flow upstream of pier y3: 17 ft
Adjusted velocity for the flow approaching the pier v3: 5 fps
Sum of overlapping projected width of piles: 1.5 ft
Coefficient of pile spacing Ksp: 1
Coefficient of number of aligned pile rows Km: 1
Effective width of the pile group: 1.5 ft
Correction factor for armoring K4 for pile group: 1
Height of pile group aboved lowered stream bed h3: 24 ft
Pile group height factor Kh(pg): 1
Froude Number Fr3 for pile group: 0.2137
Scour component for the exposed pile group: 3.975 ft
Total pier scour depth with respect to revised flow depth: 3.975 ft
Total pier scour depth with respect to initial flow depth: 3.975 ft

***** Method 2 Option 3 *****

Revised flow depth: 19.46 ft
Revised flow velocity: 4.3679 fps
```



```
File:C:\scour\1MD313_100pier.psf  Date:10/15/2010                                          Page:2

92:  Revised distance from streambed to top of footing/pile cap: 27 ft
93:  Revised soil layer 1 thick: 0 ft
94:  Revised soil layer 2 thick: 0 ft
95:
96:  Control soil is layer no. 3 with D50=0.000089 ft   D95=0.0038 ft
97:
98:  Scour component for the pier stem in the flow:
99:
100: Pier stem is not in the water, no contribution to the scour component
101:
102: Scour component for the exposed footing/pile cap:
103:
104: Pile cap is not in the water, no contribution to the scour component
105:
106: Scour component for the exposed pile group:
107:
108: Only one pile column, the pile spacing in width direction is set to 7 times pile size
109: Adjusted depth of flow upstream of pier y3: 19.46 ft
110: Adjusted velocity for the flow approaching the pier v3: 4.368 fps
111: Sum of overlapping projected width of piles: 1.5 ft
112: Coefficient of pile spacing Ksp: 1
113: Coefficient of number of aligned pile rows Km: 1
114: Effective width of the pile group: 1.5 ft
115: Correction factor for armoring K4 for pile group: 1
116: Height of pile group aboved lowered stream bed h3: 24 ft
117: Pile group height factor Kh(pg): 1
118: Froude Number Fr3 for pile group: 0.1745
119: Scour component for the exposed pile group: 3.82 ft
120: Total pier scour depth with respect to revised flow depth: 3.82 ft
121: Total pier scour depth with respect to initial flow depth: 6.28 ft
122:
123: Summary of results:
124:
125: Control Method: Assume contraction scour does occur
126: Control option: Option 3 Pier with pile cap and pile group exposed
127: Contraction scour depth at pier: 2.46 ft
128: Local scour depth at pier: 3.82 ft
129: Total scour depth at pier: 6.28 ft
130: Total pier scour elevation: -16.2 ft
131: Aggr/Degr + total Pier Scour Elevation: -16.2 ft
```

BACKGROUND ON THE MARYLAND SHA (HEC-18) PIER SCOUR COMPUTATIONS

The following information is offered only to provide insight into the approach used in ABSCOUR to compute pier scour. **As noted earlier, Option 4 automatically solves the pier scour equations for all the cases discussed below. This is the recommended option to use.**

1. Two alternative methods for evaluating pier scour are described below. The recommended procedure is to compare the scour computed from both Method 1 and Method 2; Select the method which results in the deepest scour elevation. Use this value as the total pier scour value.

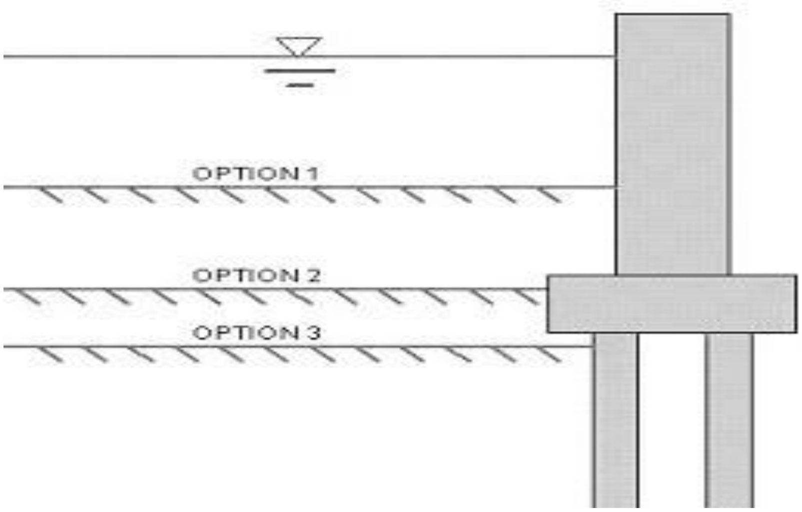
2. **Method 1** Assume contraction scour does not occur. Compute pier scour following the procedure outlined below, using the flow depths and velocities obtained from the water surface model (typically HEC-RAS) and the existing channel bed elevation

3. **Method 2** Assume contraction scour does occur. Compute pier scour following the procedure outlined below using the revised elevation of the channel to account for contraction scour. Also, modify the flow depth and velocity to account for the effect of the contraction scour:

Computing Pier Scour using the ABSCOUR Pier Scour Module.

For both Methods 1 and 2, three options are evaluated (See sketch below):

- Option 1 only the pier stem is contributing to scour
- Option 2 – the pier stem and pile cap/footing is contributing to the scour
- Option 3 – the pier stem, pile cap and piles contribute to the scour



Computing Pier Scour Using Method 1.

Assume contraction scour does not occur. Compute pier scour following the procedure outlined below, using the flow depths and velocities obtained from the water surface model (typically HEC-RAS) and the existing channel bed elevation

- Set the initial channel bed elevation equal to the existing channel bed elevation.
- Set the initial flow depth, y_1, equal to the distance between the water surface and the existing bed elevation.
- Select the initial flow velocity immediately upstream of the bridge as determined from HEC-RAS. For small channels compute the velocity as $V_1=q/y_1$ where q is the unit flow in the channel. For larger channels, use the velocity distribution (flow tube) option in HEC-RAS to select the highest velocity in the channel.
- Proceed to Option 1

Option 1

Option 1 computes local scour for the pier stem only. Fill in the required information, including the initial flow depth, y_1 and the flow velocity V_1 as discussed above. Click the run button.

- If the scour computed by Option 1 is less than the elevation of the top of the footing/pile cap, use this value for the pier scour depth. Then, $y_2 = y_1 + y_s$
- If the scour computed by Option 1 is deeper than the top of the footing/pile cap, continue on to Option 2 below. Note that $ys_{pier} = y_2 - y_1$.

Option 2

1. Fill in the information for the footing/pile cap; use the following revised input values for flow depth and velocity.

2. Set a revised flow depth at an elevation of 1 foot below the top of the footing/pier cap. The total flow depth to this point $= y_2 = y_1 + (ys)$ where ys is the pier scour depth between the channel bottom and the selected elevation one foot below the elevation of the top of the footing/pier cap.

3. Compute a new approach flow velocity as $V_2 = V_1 * y_1 / (y_1 + ys / 2)$

4. Run the program, and note the computed scour depth

   Subtract this computed scour depth from the revised flow depth set in Step 2 above. This determines the scour elevation for Option 2.

5. If the scour elevation from Step 4 is within the limits of the footing/pile cap use this value for the pier scour. If the scour elevation from Step 4 is below the bottom of the footing/pile cap, go to Option 3.

Option 3

Fill in the information regarding the pile group. Use revised input values for flow depth and velocity as described below.

1 Set a revised flow depth y3 at an elevation of one foot below the bottom of the footing: $y3 = y_1 + (ys)$ where ys is the scour depth measured from the existing channel bottom to the point one foot below the bottom of the footing.

2. Compute a new approach flow velocity as $V_3 = V_1 * (y_1) / (y_1 + ys / 2)$

3. Run the program for Option 3 and obtain the scour depth

5. Compute the scour elevation as the elevation of the selected point one foot below the bottom of the footing/pile cap (step 1 above) – scour depth (Step 3)
6. Compare this scour elevation with the scour elevation determined from Method 2. Use the lower scour elevation as the total pier scour elevation.

Computing Pier Scour Using Method 2.

Assume contraction scour does occur. Compute pier scour following the procedure outlined below.

- Set the initial bed elevation equal to the contracted channel bed elevation.
- Set the initial flow depth, y_1, equal to the distance between the water surface and the contracted channel bed elevation.
- Select the initial flow velocity V_1 for Method 2 taking into account the effect of the contracted scour.

  V1(method 2) = V1 (method 1) * (y1) / (y1+ ys)

  where ys = contracted scour depth.

- Proceed to Option 1

Option 1 for Method 2

-

Option 1 computes local scour for the pier stem only. Fill in the required information, including the initial flow depth, y_1 and the flow velocity V_1 as discussed above. Use the contracted scour bed elevation as the initial bed elevation.

Click the run button and note the scour depth computed by Option 1. Subtract this depth from the initial contraction scour bed elevation to obtain the pier scour elevation.

- If the pier scour elevation is less than the elevation of the top of the footing/pile cap, use this value for the pier scour .
- If the scour computed by Option 1 is deeper than the top of the footing/pile cap, continue on to Option 2 below. Note that $ys_{pier} = y_2 - y_1$.

Option 2 for Method 2

1. Fill in the information for the footing/pile cap; use the following revised input values for flow depth and velocity.

2 Set a revised flow depth at an elevation of 1 foot below the top of the footing/pier cap. The total flow depth to this point = $y_2 = y_1 + (ys)$ where y1 is the depth of the contracted scour bed and ys is the pier scour depth between the contracted channel bottom and the selected elevation one foot below the elevation of the top of the footing/pier cap. (Note: If the contracted channel elevation is already below the bottom of the footing/pile cap, proceed to Option 3)

3. Compute a new approach flow velocity as $V_2 = V_1 * (y_1) / (y_1 + ys / 2)$

4. Run the program, and note the computed scour depth

Subtract this computed scour depth from the revised flow depth set in Step 2 above. This determines the scour elevation for Option 2.

5. If the scour elevation from Step 4 is within the limits of the footing/pile cap use this value for the pier scour. If the scour elevation from Step 4 is below the limits of the footing/pile cap, go to Option 3 for Method 2

Option 3 for Method 2

Fill in the information regarding the pile group. Use revised input values for flow depth and velocity as described below.

1 Set a revised flow depth y3 at an elevation of one foot below the bottom of the footing: $y3 = y_1 + (ys)$ where ys is the scour depth measured from the channel bottom to the point one foot below the bottom of the footing.

2. Compute a new approach flow velocity as $V_3 = V_1 * (y_1) / (y_1 + ys/2)$

3. Run the program for Option 3 and obtain the scour depth

4. Compute the scour elevation as the elevation of the selected point one foot below the bottom of the footing/pile cap (step 1 above) – scour depth (Step 3)

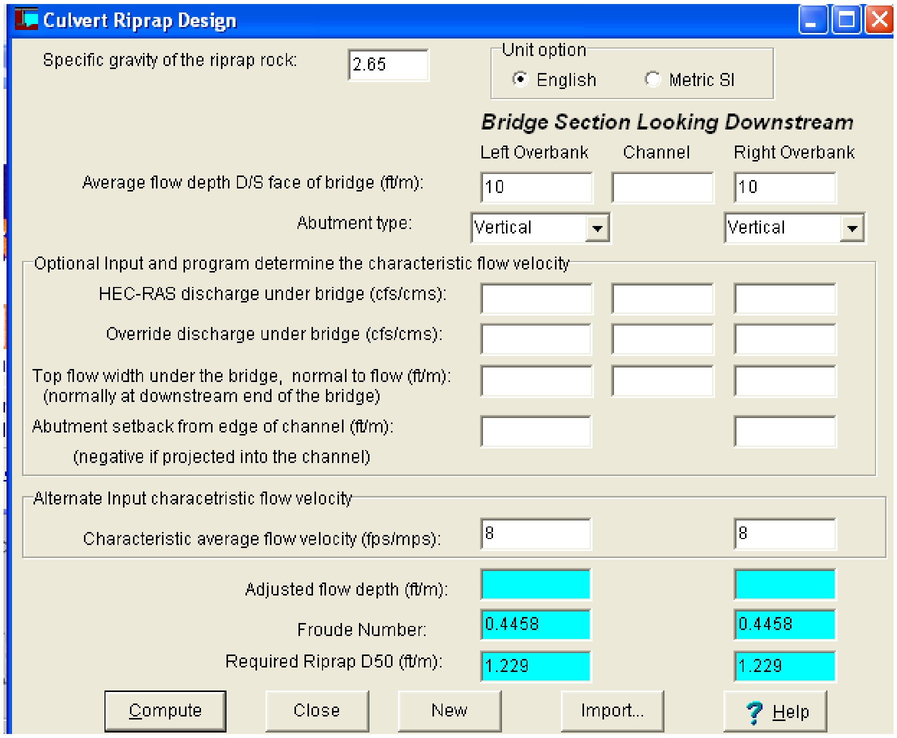
5. Compare this scour elevation with the scour elevation determined from Method 1. Use the lower scour elevation as the total pier scour elevation.

VI. UTILITY MODULE

A. RIPRAP

The Utility module provides a means of selecting the D50 size of riprap for abutments culverts and piers. The computations for the riprap D50 size for piers and abutments use the procedures set forth in the 2001 edition of HEC-23. Use this information to select the appropriate riprap size, typically Class 2 or 3. The computations for the D50 size for bottomless culverts are based on a cooperative FHWA-Maryland SHA research study conducted in the FHWA Hydraulic Laboratory.

The process for using this module is the same as for the other modules previously discussed. The various input cells are to be filled in; then the “COMPUTE” button is clicked to make the calculation



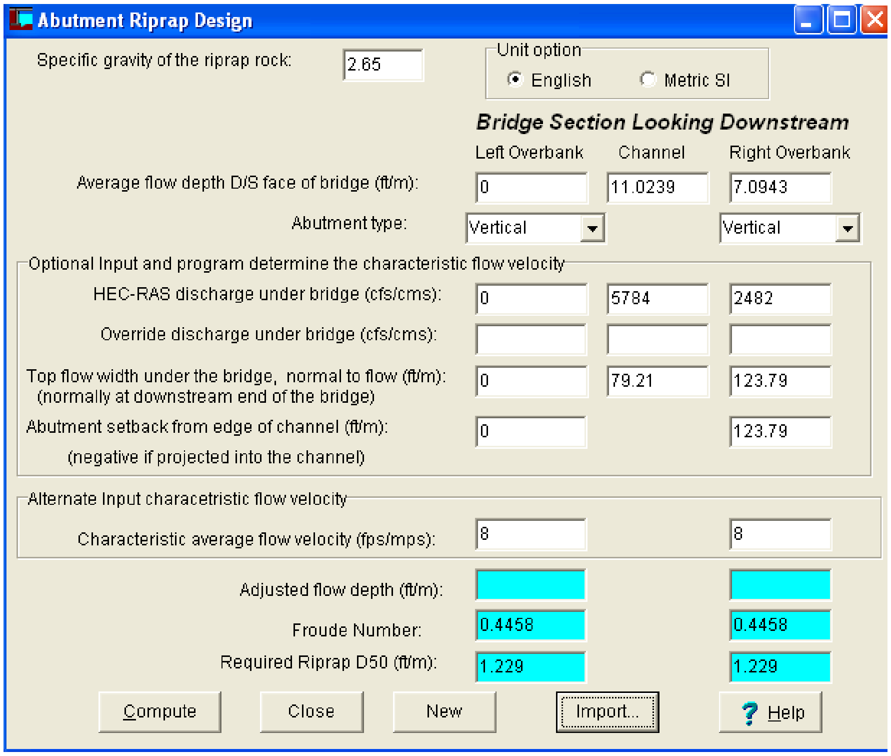
Specific gravity of the riprap rock: 2.65

Unit option: ● English ○ Metric SI

Bridge Section Looking Downstream

	Left Overbank	Channel	Right Overbank
Average flow depth D/S face of bridge (ft/m):	10		10
Abutment type:	Vertical		Vertical
Optional Input and program determine the characteristic flow velocity			
HEC-RAS discharge under bridge (cfs/cms):			
Override discharge under bridge (cfs/cms):			
Top flow width under the bridge, normal to flow (ft/m): (normally at downstream end of the bridge)			
Abutment setback from edge of channel (ft/m): (negative if projected into the channel)			
Alternate Input characetristic flow velocity			
Characteristic average flow velocity (fps/mps):	8		8
Adjusted flow depth (ft/m):			
Froude Number:	0.4458		0.4458
Required Riprap D50 (ft/m):	1.229		1.229

After running the ABSCOUR Program, The utility program can be used in to import the output data from the ABSCOUR run to compute the riprap size required for an abutment or pier. This option is illustrated below



Specific gravity of the riprap rock: 2.65

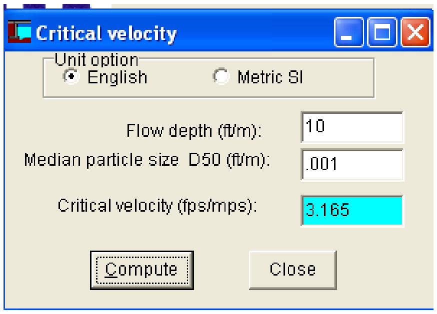
Unit option: ● English ○ Metric SI

Bridge Section Looking Downstream

	Left Overbank	Channel	Right Overbank
Average flow depth D/S face of bridge (ft/m):	0	11.0239	7.0943
Abutment type:	Vertical		Vertical
Optional Input and program determine the characteristic flow velocity			
HEC-RAS discharge under bridge (cfs/cms):	0	5784	2482
Override discharge under bridge (cfs/cms):			
Top flow width under the bridge, normal to flow (ft/m): (normally at downstream end of the bridge)	0	79.21	123.79
Abutment setback from edge of channel (ft/m): (negative if projected into the channel)	0		123.79
Alternate Input characetristic flow velocity			
Characteristic average flow velocity (fps/mps):	8		8
Adjusted flow depth (ft/m):			
Froude Number:	0.4458		0.4458
Required Riprap D50 (ft/m):	1.229		1.229

B. CRITICAL VELOCITY

This is a handy tool for approximating the critical velocity of the soils in a channel bed, given the D50 particle size and the flow depth. Calculations are based on Neill's competent velocity curves (Reference 11). Short Help (F-1 key) and Regular Help are available for this module. A more accurate estimate can be made by using the modified Neill's curves presented later in this appendix



Unit option: ● English ○ Metric SI

Flow depth (ft/m): 10

Median particle size D50 (ft/m): .001

Critical velocity (fps/mps): 3.165

C. SCOUR IN ROCK

The Utility Module provides a methodology for the computation of scour in rock entitled ROCK SCOUR. **However, we currently recommend the use of the SHA Spread sheet in the Software Package of this manual for making the erodibility index computations.** The evaluation of the resistance of rock to scour requires the services of an engineer or geologist who has the specialized training to make such judgments. The Rock Scour Module and the Erodibility Index Spreadsheet are based on the Erodibility

Index Method. The Erodibility Index Method was developed by Dr. George Annandale, currently the President of Engineering and Hydrosystems, Inc. of Littleton Colorado. The Office of Structures recommends that the Erodibility Index Method be used as an additional resource by specialists who have the knowledge to apply the method. **Currently the Rock Scour Module in ABSCOUR 10 is not recommended for use.** The following overview provides background information on the Erodibility Index Method.

C.1 Application of the Erodibility Index Method

The Erodibility Index Method involves the following steps:

1. Calculation of the Erodibility Index of the rock, based on its physical characteristics and orientation with respect to the flow direction of the water.
2. Calculation of the stream power of the flow in the stream or river for the hydraulic conditions under investigation.
3. Calculation of the modified stream power at a pier or abutment due to the effect of the obstruction on the flow. These modified values are calculated by a series of equations developed in the FHWA Hydraulic Laboratory for different types of piers under different flow conditions.

   The piers scour equations are recommended for design when used with caution and the application of engineering judgment.

   <u>The abutment scour equations should not be used for design</u>. The SHA has derived the abutment scour equations from the rectangular pier equations developed by the FHWA lab studies, and there are no data at this time to assure that this approach is valid. However, these equations can be useful of in comparing the estimated scour in rock with the equivalent scour in sand. This information can serve as one factor in making an engineering judgment regarding scour at abutments founded in rock.

Using the empirical relationships presented in the Erodibility Index Method described above, a comparison can be made between stream power and the ability of the rock to resist the hydraulic forces. If the rock at the surface of the stream cannot withstand the hydraulic forces of the water, it will scour and a scour hole will form at the base of the pier or abutment. As the scour hole deepens, the stream power at the bottom of the scour hole diminishes in accordance with the relationships determined by the FHWA studies. At some point, the hydraulic power of the water and the resistance of the rock will achieve a balance, and the scour will end.

A safety factor should be applied to the above scour evaluation, to take into account the limited understanding of and experience with evaluating the resistance of rock to scour. This safety factor should be determined on a case by case basis; however, the current SHA thinking is to use a safety factor in the range of 2 to 5, with a range of 2 to 3 being used for most bridges.

C-2. STREAM POWER CALCULATIONS

The hydraulic calculations are relatively straight-forward and consist of the following:

1. Inputting the velocity, hydraulic radius and energy slope of the flow so that the program can calculate the stream power (Pa): Pa = γVRS.

- For piers, select a section just upstream of the bridge to compute the stream power.
- For abutments, select the downstream section under the bridge (Section 2 as defined in the ABSCOUR Program) to compute the stream power.

2. Selecting the pier type along with the angle of attack of the flow.
3. Calculating the maximum scour in sand for the selected foundation geometry and flow conditions.
    - For piers, select a section just upstream of the bridge to obtain the hydraulic values in the pier scour equation. Use the Pier Scour Module in the ABSCOUR Program to calculate the scour depth in sand.
    - For abutments, select the downstream section under the bridge (Section 2 as defined in the ABSCOUR Program) to compute the maximum scour in sand. Use the ABSCOUR Program to make this computation.

C-3 ERODIBILITY INDEX CALCULATIONS

The recommended approach for computing the Erodibility Index is to use the Spread Sheet developed by the SHA. (See SHA Software Module in the Manual)

Computations of the Erodibility Index of the rock should be made only by engineers or geologists with knowledge and experience in evaluating the properties of rock. It is the practice of the Office of Structures to meet with the SHA geologists for the purpose of:

1. inspection of the rock cores, and
2. selection of appropriate rock characteristics for purposes of computing the erodibility index of the rock.

The steps for computing the Erodibility index are outlined below:

C-4 COMPUTING THE ERODIBILITY INDEX FOR ROCK

Please note that the erodibility index can be expected to vary with the depth of the rock below the channel. Typically it will increase, but this is not necessarily true in all cases.

In conducting studies of scour in rock, it is necessary to compute the erodibility index for the same elevation at which the rock scour will occur. Normally this will involve a trial and error approach using the computer program.

The references below pertain to appropriate tables and pages in Dr. Annandale's manual "Calculation of Pier Scour Using the Erodibility Index Method" The Erodibility Index is computed from the following equation:

$$K = Ms\ Kb\ Kd\ Js \qquad (2\text{-}2)$$

where:

K = erodibility index
Ms = mass strength number
Kb = block size factor
Kd = inter-particle bond shear strength number
Js = relative ground structure number

C-5 DESIGN PROCEDURE

STEP 1 DETERMINE (Ms) THE MASS STRENGTH NUMBER

This value is selected from Table 5, Intact Material Strength Number Ms for Rock, Page 18.

STEP 2 COMPUTE Kb, THE BLOCK SIZE FACTOR:. Kb = RQD/Jn

- RQD = Rock quality designation where RQD > 5. This is obtained by <u>qualified engineers and geologists</u> through an inspection of rock cores taken at the bridge site
- Obtain Jn , the joint set number, from Table 7, page 21

STEP 3 COMPUTE KD, THE INTER-PARTICLE BOND SHEAR STRENGTH NUMBER, Kd = Jr/Ja

- Obtain the joint roughness number, Jr, from Table 8, page 26
- Obtain the joint alteration number, Ja, from Table 9, page 27

STEP 4 COMPUTE Js, THE RELATIVE GROUND STRUCTURE NUMBER,

The information required to obtain Js is obtained from Table 10, the Relative Ground Structure Number Table, page 29.

The value of Js depends upon the appropriate selection of the following rock properties:

- Dip direction in direction of stream flow or dip direction against direction of stream flow (degrees)
- Dip angle of closer spaced joint set (degrees)
- Ratio of joint spacing , r

The SHA spread sheet provides the user with a convenient method to compute and compare the erodibility index and the stream power, and to determine the extent to which the rock will scour for the given conditions. The method allows the user to select an appropriate safety factor to be considered in applying the results of the evaluation.

The following guidance is provided for use in applying the computational method included in the Utility Module. Use the following input menu cards:

PROJECT DATA CARD

1 Project description
2 Pier or Abutment Data

HYDRAULIC DATA

1 Input the data described above in Stream Power Calculations
2 Input the desired safety factor

ROCK DATA

1 Input the data as described in the above section on computing the erodibility index for rock.

After inputting the above noted data, click the run tab, and then the output tab to obtain the scour report. The program will compute the depth of scour in rock along with the computed safety factor.

D. BRIDGE UPSTREAM SECTION.

This Utility can be used to import the cross-section of the upstream face of the bridge from HEC-RAS in order to provide a check on the values that are used to estimate the ground elevation, high chord elevation and low chord elevation.

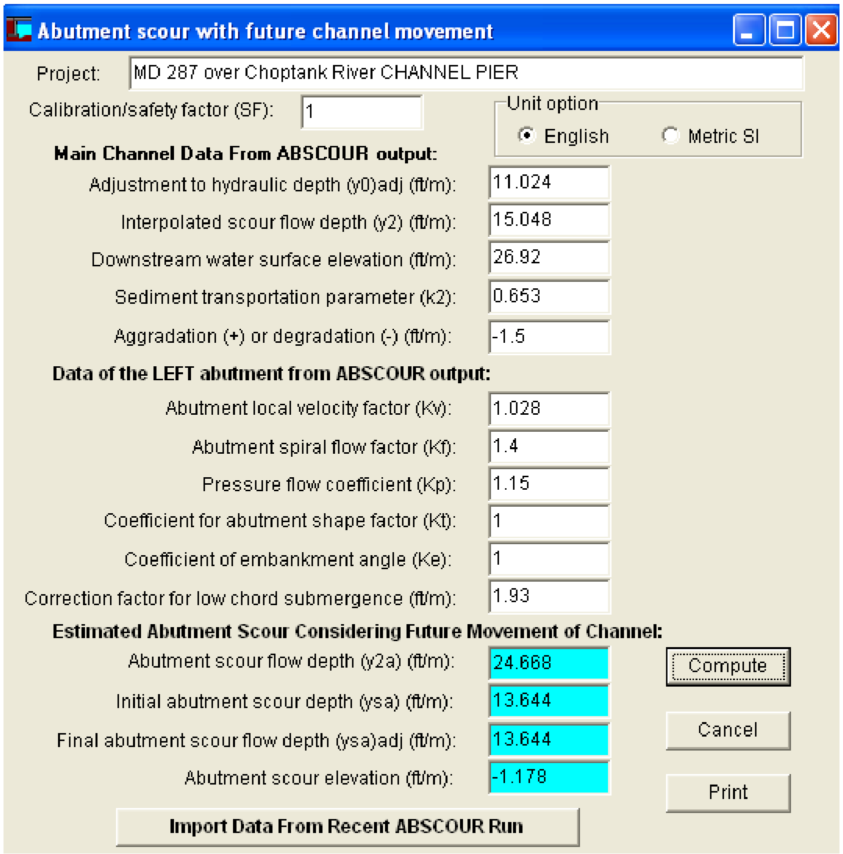
E. ABUTMENT SCOUR CONSIDERING THE FUTURE MOVEMENT OF THE STREAM CHANNEL INTO THE ABUTMENT.

This Utility is a valuable addition to ABSCOUR 9. It is common to find a conclusion in the Stream Morphology Report that one or more of the abutments of a bridge are within the Lateral Channel Movement Zone of the stream being crossed. For this case it is necessary to estimate the scour at the abutment in the event that the channel does move into the abutment. Up to now, such computations have been required to be done manually.

This Utility is used in the following manner:

- Run the ABSCOUR program for the existing conditions
- Open the utility and click on Import Data from Recent ABSCOUR run. In the window which opens up indicate which abutment (left or right) that you wish to evaluate, and then click OK
- The program computes the scour which is expected to occur for main channel flow next to the abutment.

The MD 313 Bridge over Marshy Hope Creek could not be used as an example for this condition, since both abutments are in the channel. Instead, an example was taken from the MD 287 bridge over the Choptank River since the abutment for this bridge is set back a distance from the edge of the channel. The program takes the input information for the main channel flow and the abutment characteristics and the "moves" the main channel to the abutment to compute the abutment scour for this condition.



Project: MD 287 over Choptank River CHANNEL PIER

Calibration/safety factor (SF): 1

Unit option: ● English ○ Metric SI

Main Channel Data From ABSCOUR output:

Adjustment to hydraulic depth (y0)adj (ft/m): 11.024

Interpolated scour flow depth (y2) (ft/m): 15.048

Downstream water surface elevation (ft/m): 26.92

Sediment transportation parameter (k2): 0.653

Aggradation (+) or degradation (-) (ft/m): -1.5

Data of the LEFT abutment from ABSCOUR output:

Abutment local velocity factor (Kv): 1.028

Abutment spiral flow factor (Kf): 1.4

Pressure flow coefficient (Kp): 1.15

Coefficient for abutment shape factor (Kt): 1

Coefficient of embankment angle (Ke): 1

Correction factor for low chord submergence (ft/m): 1.93

Estimated Abutment Scour Considering Future Movement of Channel:

Abutment scour flow depth (y2a) (ft/m): 24.668

Initial abutment scour depth (ysa) (ft/m): 13.644

Final abutment scour flow depth (ysa)adj (ft/m): 13.644

Abutment scour elevation (ft/m): -1.178

ATTACHMENT 1: COMPUTATION OF THE VELOCITY OF FLOW USED IN THE ABUTMENT SCOUR COMPUTATIONS.

I. COMPUTATION OF VELOCITY AND SCOUR

Field observations of flows at bridge crossings in wide streams revealed that the flow in the overbank sections is contracted by the abutment and moves toward the main channel where it mixes with the main channel flow. When the abutment setback from the main channel was less than five times the flow depth in the channel, the flows were well mixed and the flow velocity in the channel and overbank became uniform. If the abutment setback was large, being located near the edge of the flood plain, the flows in the main channel and in the overbank section remained separated as they passed under the bridge. These findings are utilized in computing flow velocity in ABSCOUR program.

Abutment setbacks are classified into three categories: short, intermediate, and long setbacks. The term short setback is used to define the condition where the setback is equal to or less than five times the channel flow depth ($5y_0$). The term long setback is used to define the condition where the setback being is equal or greater than 75% of the overbank width (0.75W). A setback between these two limits is defined as an intermediate setback.

For short setbacks, the velocity (V) is computed as a uniform velocity (V=Q/A) in the waterway area under the bridge(A) where Q is the discharge through the bridge.

For long setbacks, the velocity in the overbank is computed independently from the channel flow. It is based only on the discharge and flow area of the overbank section.

For intermediate setbacks, the velocity is computed by interpolating the velocity of the mixed flow (at a setback distance of $5y_o$ from the channel bank) with the velocity of separate flow (at a setback distance of 0.75W).

In each case above, the unit flow discharge under the bridge is computed by multiplying the velocity and flow depth (q = V* yo). For short setbacks very close to the channel banks and within the limits of the bank slope, the flow depth is adjusted to reflect the actual location within the bank area. Finally, the scoured flow depth, y_2, used to define contraction scour is computed by using the appropriate scour equation:

- Laursen's equations for live-bed contraction scour, or
- The user's choice of Laursen's equation or Neill's competent velocity equation to compute clear-water contraction scour.

When the abutment has no setback (is at the channel bank), the scour at the overbank will be equal to that for channel. When the setback is small, the scour at the overbank will be very close to the scour in the channel. However, due to the idealization of channel and overbank flow into the rectangular shapes for the ABSCOUR cross-section, the calculated overbank scour may be based on clear water scour (as determined from the

Approach Section calculations) whereas it may be subject to live bed scour from the main channel. Some transition is needed between the no setback case and the case where the abutment is set well back on the flood plain.

The limit of the transition zone is defined as five times the flow depth in the downstream channel. When there is no setback, the channel scour flow depth (y2) is used for the contraction scour. When the abutment setback on the flood plain exceeds the limit of the transition zone, separate flow is assumed between the channel and the flood plain and no interpolation is required. When the setback is within this transition zone of from zero to 5yo, the following scheme is used to compute contraction scour:

ABSCOUR separately calculates both clear water scour flow depth and live bed scour flow depth for (1) the channel section and (2) the overbank section

The channel contraction scour flow depth (y2) is the scour when the setback is equal to or less than zero - that is no setback case.

The overbank contraction scour flow depth (y2) is the overbank scour when the setback is located on the flood plain beyond the channel banks a distance equal to 5 times the flow depth in the downstream channel (SB = 5yo)

There are four combination of overbank scour in the transition zone:

1 clear water scour with no setback
2. clear water scour with setback = 5yo
3. live bed scour with no setback
4. live bed scour with setback = 5yo

The computed overbank contraction scour will be interpolated between these four cases, depending on the setback distance and the scour type (live-bed or clear water at overbank and channel). For example:

When the channel is live bed and the overbank is clear water, then the overbank contraction scour for the actual setback (between 0 and 5 times channel flow depth) will be interpolated between case 3 (live bed scour with no setback) and case 2 (clear water scour with setback = 5yo).

The interpolation depends on the distance that the abutment is set back from the channel bank and the scour type at the overbank and channel sections.

A parabolic interpolation is used for the contraction scour flow depth calculation (y2) since this method provides for a smooth transition that approximates the scour depths computed through the application of Laursen’s contraction scour equations. The following parabolic equation is used for interpolation.

y2=(y2)bank + ((y2)channel - (y2)bank)*(1-(setback)/(5*yo))^p

Where: p=4.5-Z and p is limited to the values of 1<=p<=4
Z is the approach section bank slope H/V
(y2)bank is the scour flow depth at setback=5y0
(y2)channel is the scour flow depth with no setback

Please note that the bank slope determines the shape of the parabola and therefore the relative effect of the channel scour on scour at the abutment. Steeper bank slopes such as 1:1 will reduce the effect of channel scour whereas flatter slopes such as 4:1 will increase the effect of channel scour. The bank slope can be used as a variable in sensitivity analyses of factors affecting abutment scour.

The contraction scour flow depth is modified as necessary to take into account the effect of any pressure scour and to apply a safety factor to the design.

Next, the abutment scour flow depth (y2a) is computed directly from the interpolated contraction scour value:

y2a =(kf * (kv)^k2) * (contraction scour)

Abutment scour (ysa) = y2a - (yo)adj , where (yo)adj = flow depth before scour occurs.

The final or adjusted abutment scour value (ysa)adj is determined as

(ysa)adj = Kt * Ke *FS * ysa

Where

Kt = modification for abutment shape

Ke = modification for embankment skew

FS = factor of safety.

ysa = initial abutment scour estimate noted above (ysa = y2 - (yo) adj)

The logic presented above is based on the assumption that the overbank area is wide and that 0.75W > $5y_0$. A special case may exist for a narrow flood plain where 0.75W < $5y_0$. In this instance, no intermediate zone exists and the interpolation scheme for the intermediate setback cannot be applied. If the setback is equal or larger than $5y_0$, the velocity and resulting contraction scour depth is computed assuming that the setback is equal to $5y_0$. If the setback is smaller than $5y_0$, the velocity and scour depth are computed the same as it would be for the short setback case.

Here are some example problems to illustrate the computation of flow velocity and contraction scour for various setback distances from the channel bank.

II. EXAMPLE PROBLEM 1

GIVEN:

	LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
APPROACH SECTION			
- DISCHARGE cfs	600	1600	1200
- TOP FLOW WIDTH ft	80	20	100
- HYDRAULIC DEPTH ft	4.8	9.8	3.8
UNIT DISCHARGE (q1) cfs/ft	7.5	80	12
BRIDGE SECTION			
- DISCHARGE cfs	600	1600	1200
- TOP FLOW WIDTH ft	80	20	100
- HYDRAULIC DEPTH ft	5	10	4

III. COMPUTATION OF CONTRACTION SCOUR:

Computations for the contraction scour flow depths, y_2, for the right overbank section are presented for different abutment setbacks. The left abutment is kept at a fixed location with its setback at a distance of 20 ft from the channel edge. The methods of computation are demonstrated only for the right overbank. Contraction scour of the left overbank for different setbacks can be computed in the same way by keeping the right abutment at the actual fixed location.

A. Short Setback - CASE A in Figure A1-1

Since the channel depth is 10 feet, any setback less than (5 X 10 = 50) feet is a short setback.

Let the setback of the right abutment be 30 ft. Since the left abutment setback is also short, being 20 feet, the velocity is computed as if all flows are mixed. The contraction scour depth then shall be computed by interpolating the contraction scours at the setbacks set at the channel edge and at five times the channel flow depth, $5y_{0.}$

Step 1. Compute flow velocity.

As the setback of the left abutment is short as well as the right abutment, total flow will be mixed.

For right setback of 30 ft:
V2= Q/A = (3400)/(20*5+20*10+30*4)=8.1 ft/s

Step 2. Compute Unit discharges, q2 = V*yo

For setback of 0 ft:
q2=8.1*10=81 cfs/ft

For setback of 50 ft:
q2=8.1*4=32.4 cfs/ft

Step 3. Compute contraction scour depth

The ABSCOUR program will compute two scour depths for each setback for two sediment transport modes (live-bed and clear-water). All together four values will be included on the output sheet. For this example, only the live-bed contraction scour computations for the two setbacks will be presented. The sediment transport coefficient, k2, is computed as 0.638.

For setback 0 ft:
Approach section y1=9.8 ft; q1=1600/20=80 cfs/ft

Bridge section y2 =(to be computed) ; q2=8.1*10=81 cfs/ft

Computation by Lausen's Equation, for a setback equal to zero (at the channel bank):
y2/y1=(81/80)^0.638=1.01
y2=1.01*9.8=9.89 ft

For setback 50 ft:
Approach section: y1=3.8 ft ; q1=12 cfs/ft
Bridge section: y2= value to be computed; q2= 8.1*4=32.4 cfs/ft

y2/y1=(32.4/12)^0.638=1.88
y2=1.88*3.8=7.14 ft

Step 4. The contraction scour for the setback of 30 ft requires interpolation. ABSCOUR will use two appropriate values based on the modes of sediment transport in the channel and the overbank, one at 0 ft setback and another at 50 ft setback. In this example, only the live bed condition is used. The contraction scour for a setback at 30 ft is calculated as:

y2=7.14+(9.89-7.14)*((50-30)/(50-0))^2.5=7.14+0.278=7.42 ft

B. Intermediate Setback of 70 Feet -Wide Overbank Section - CASE B in Figure A1-1

The Intermediate Setback zone exist only for an overbank wider than 6.67 y_0. For this example the channel flow depth is 10 ft and the right overbank at bridge is 100 ft. The intermediate zone exists. The computation of contraction scour depth for the right setback of 70 ft is as follows:

Step 1. Compute flow velocity

For an intermediate setback, the flow is neither mixed nor separate. It will gradually change from mixed flow to separate flow. ABSCOUR first computes the mixed flow velocities at $5y_0$=50 ft setback and separate flow velocity at 0.75W=75 ft setback. Then, the velocity at 70 ft setback will be computed by linear interpolation.

For 50 ft setback:
V2= Q/A = (600+1600+1200)/(20*5+20*10+50*4)=6.8 ft/s

For 75 ft setback:
V2=Q/A = 1200/(75*4)=4 ft/s

For 70 ft setback:
by linear interpolation

V2=4+(6.8-4)*(75-70)/(75-50)=4.56 ft/s

Step 2. Compute unit discharge

q2= V*y0 = 4.56*4=18.27 cfs/ft

Step 3. Compute contraction scour depth

y2/y1=(18.27/12)^0.638=1.31

y2=1.31*3.8=4.98 ft

C. Long Setback CASE C in Figure A1-1

For a long setback, the flow in the overbank is considered independent and not affected by the channel flow. For the setback of 80 ft, the contraction scour will be

Step 1. Compute unit discharge

q2=1200/80=15 cfs/ft

Step 2. Compute contraction scour

y2/y1=((15/12)^0.638=1.15

y2=1.15*3.8=4.37 ft

D. Special Case Intermediate Setback-Narrower Overbank - CASE D in Figure A1-1

When the setback > $5y_0$ in a narrow overbank section (width < $6.67y_{0}$), there is no intermediate flow; consequently, the normal interpolation does not apply. For this case (Figure 1c), ABSCOUR will compute contraction scour assuming that the setback is equal to $5y_0$ for a conservative approximation. For example, the contraction scour for a setback of 60 ft in a 65ft-wide overbank in Figure 1c will be computed the same as that for a setback of 50 ft.

Step 1. Compute flow velocity assuming the setback is at 5y0=50ft

V2=(600+1600+1200)/(20*5+20*10+50*4)=6.8 ft/s

Step 2. Compute unit discharge

q1=1200/65=18.46 cfs/ft

q2=6.8*4=27.2 cfs/ft

Step 3. Compute scour depth

y2/3.8=(27.2/18.46)^0.638=1.28

y2=1.28*3.8=4.87 ft

Figure A1-1 illustrates the four contraction scour examples presented above for varying setback distances. Figure A1-2 illustrates the resulting contraction scour for these cases, although the details of the abutment scour calculations are not presented.

The general procedure to compute the abutment scour flow depth is:

$y_{2a} = kf * (k_v)^{k2} * (\text{contraction scour})$

The final abutment scour depth is computed using the equations presented in Part 1.

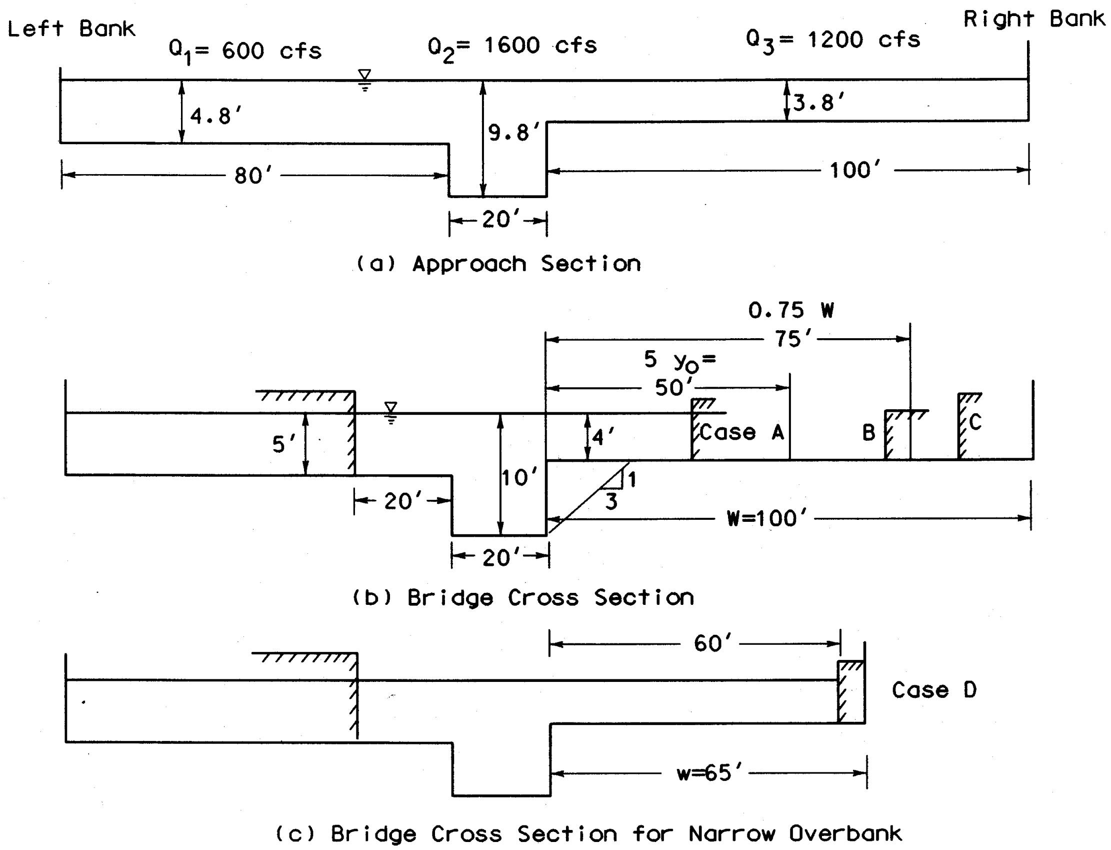


Figure A1-1: Cross Sections of Approach Flow and Under Bridge

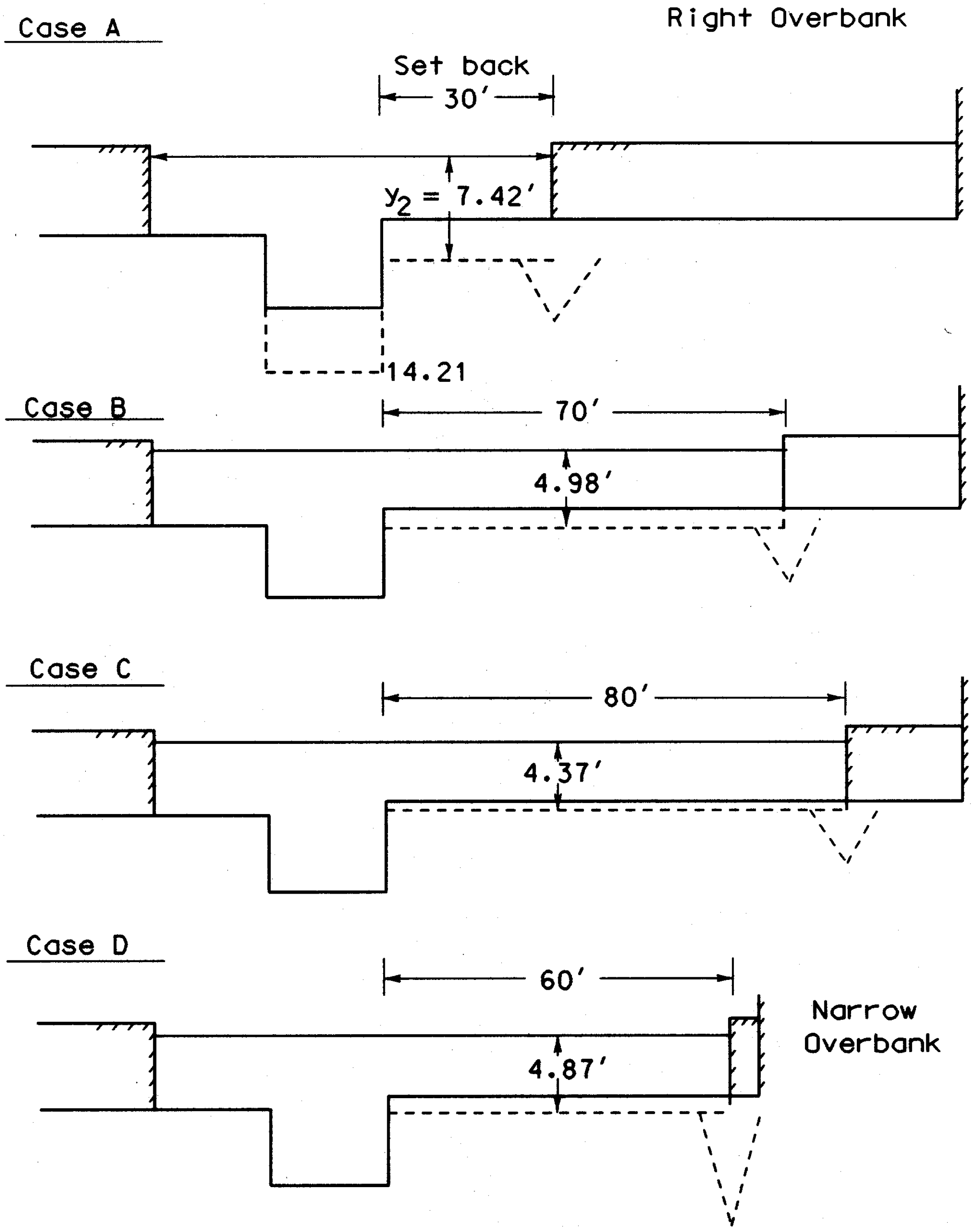


Figure A1-2: Scour Profile of Right Overbank for Different Abutment Setbacks

ATTACHMENT 2: COMPLEX APPROACH FLOW CONDITIONS

The ABSCOUR Program computations are based on rectangular sections for the channel and overbank areas in the approach section and the bridge section with a straight channel reach between the sections. However, the user has considerable flexibility in assigning input values on the ABSCOUR menu cards so that the program can be used to model much more complex flow patterns. Examples of these flow patterns might include:

1. a bridge on a bend in the channel,
2. large overtopping flows on one or both approach roads,
3. the confluence of a tributary stream just upstream of the bridge, and
4. combinations of the above conditions.
5.

Please note that any changes to a HEC-RAS model should be made solely for the purpose of sensitivity analysis in assessing scour. A deeper scour elevation may be approved based on the sensitivity analysis, where justified.

In the above noted cases, it is likely that the distribution of flow determined by HEC-RAS (using a 1-D approach based on flow conveyance) may not be truly representative of the actual site conditions. The ABSCOUR program provides for input boxes for both the HEC-RAS analysis and a special analysis provided by the user to explore a worst-case type of condition

The use of flow distributions other than that provided by HEC-RAS is recommended for use only by modelers who have a thorough understanding of the HEC-RAS program. Further, the HEC-RAS distribution should always be tested first in the ABSCOUR program so that there is a basis for comparison for the flow distribution selected by the user. The accuracy of the modeling for such cases will depend on the skill and experience of the user in evaluating flood flows. It requires the user to be able to visualize the flow condition so as to select a reasonable flow distribution at the bridge. In some cases, the momentum equation or other computational methods can be employed to assist with this visualization.

The ABSCOUR computations are illustrated in the table below, with all numbers representing flood flows in cfs:

	LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
APPROACH SECTION	500	2000	250
OVERTOPPING	300	0	0
BRIDGE SECTION	500 - 300 = 200	2000- 0 = 2000	250 - 0 = 250

The user inputs the discharges for the approach section flows and the bridge flows, based on the results obtained from the HEC-RAS runs. As discussed earlier, the HEC-RAS program computes flow on the basis of conveyance. For complex, rapidly changing conditions upstream of the bridge, conveyance calculations may not represent the worst-case scour conditions.

Four examples are presented below to discuss the evaluation of the HEC-RAS flow distribution and to suggest approaches to use in arriving at the worst-case scour condition as a part of the sensitivity assessment of the scour calculations.

I. Example 1: Typical Flow Distribution

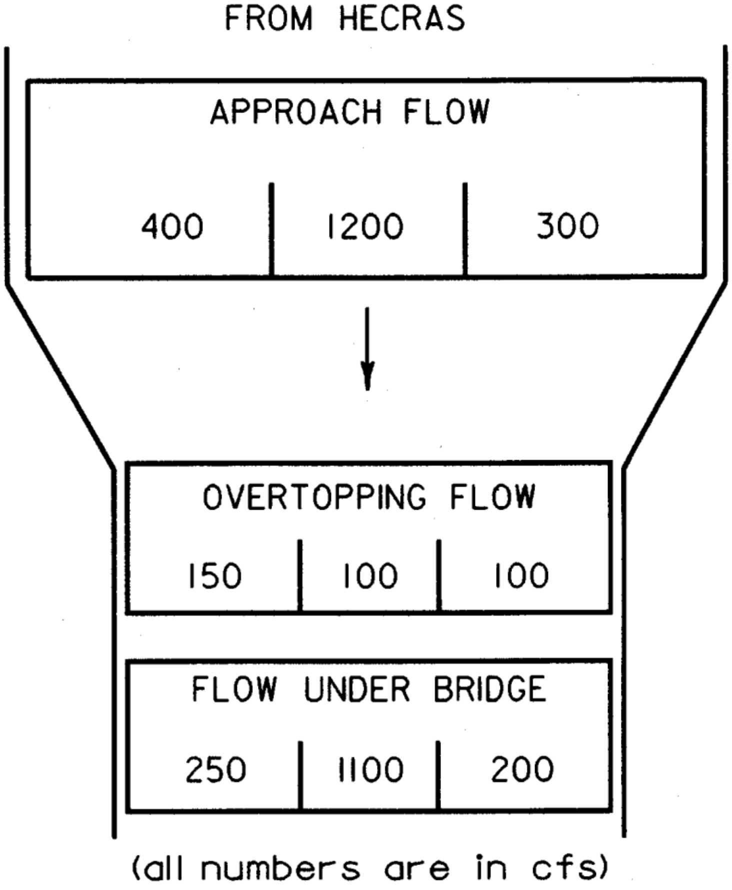


Figure A2-1: Flow re-distribution example

Example 1 presents information obtained from HEC-RAS for a straight reach, depicting the flow distribution at the approach and bridge sections. In the HEC-RAS model, overtopping flow is subtracted from the approach flow to compute the flow through the bridge. This appears to be a reasonable flow distribution at the bridge to use in the ABSCOUR computations

II. Example 2: Unbalanced Flow Condition

The sketch on the left depicts discharge values obtained from HEC-RAS for the approach and bridge sections. Note that there is 300 cfs at the approach on the left overbank section (looking downstream) and 400 cfs of overtopping flow at the left bridge section. HEC-RAS distributes the flow under the bridge according to conveyance, and may underestimate the flow at the right abutment.

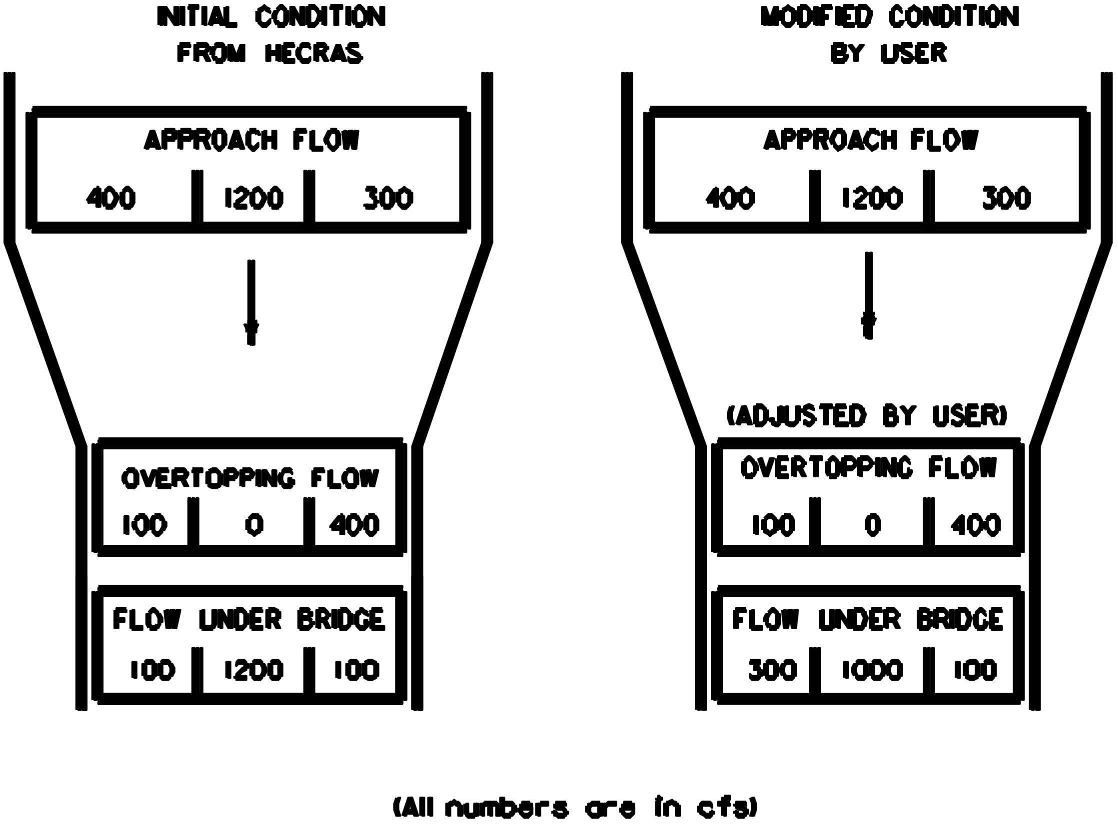


Figure A2-2: Flow re-distribution examples

By inspection, some of the overtopping flow on the left is coming from the main channel and the right overbank section. A rapid shift of the flow from left to right occurs in order to meet the HEC-RAS distribution based on conveyance. This redistribution of flow may not actually occur. Accordingly, the user may wish to consider the consequences of a greater flow on the right overbank section. A trial flow distribution, as depicted on the right sketch, can be selected for a worst case type of analysis. These values may be input instead of the HEC-RAS values to assess worst case scour at the right abutment. The total flow through the bridge remains the same in both cases, as does the total overtopping flow. The difference is that the user can modify the program to provide a different flow distribution under the bridge.

III Example 3: Bend in the River

For a bridge located on a bend in the river, particularly a sharp bend, momentum forces may affect the flow distribution under the bridge. More flow may move to the outside of the bend than is indicated by the HEC-RAS conveyance calculations. This condition can be investigated in the ABSCOUR model by changing the HEC-RAS flow distribution.

IV Example 4 Confluence Upstream of the Bridge

There can be a great deal of uncertainty about the flow distribution at a bridge located just below the confluence of two streams. The location of the confluence is likely to shift over time. Further, the time of concentration of the two streams is likely to vary, affecting the quantity and distribution of flood flows. A worst-case type of scour analysis is recommended for this type of situation. Consider using two or more flow distributions, assuming (1) a worst case condition for the left abutment and then (2) a worst case condition for the right abutment.

ATTACHMENT 3
SAFETY/CALIBRATION FACTORS

In developing the ABSCOUR equations for estimating abutment scour, available information from laboratory studies collected by the consultant firm of GKY and Associates was used as a means of evaluating the model. These laboratory tests were conducted in simple rectangular straight channels (laboratory flumes) with uniform flow. A total of 126 data points were used to develop the envelop equation describing the value of the coefficient for the spiral flow adjustment factor, k_f . These initial studies were augmented by a second set of flume studies conducted by the FHWA in 2004.
Natural rivers are not accurately represented by the simple flow conditions modeled in a laboratory flume. For practical design, use of a safety factor is suggested to take into account the effect of complex flow patterns which can be expected to occur at bridges abutments. However, the ABSCOUR calibration/safety factors have been reassessed on the basis of the USGS comparison study of ABSCOUR computed scour values vs. measured abutment scour at South Carolina Streams. The current recommended factors, based on both the flume and field studies, are presented below.

SELECTION OF BASE CALIBRATION/SAFETY FACTORS

100-YEAR FLOOD PLAIN WIDTH	CHANNELS AND FLOOD PLAINS WITH FINER BEDLOADS	CHANNELS AND FLOOD PLAINS WITH COARSER BEDLOADS
	D50 < 2 MM	D50>2MM
LESS THAN 800 FEET	0.8	1.0
GREATER THAN 800 FEET	1.1	1.0

SELECTION OF INCREMENTAL CALIBRATION/SAFETY FACTORS
BASED ON SITE CONDITONS

Channel Description at Bridge Site	Incremental Safety Factor
Straight channel with uniform flow.	Add 0.0
Moderately meandering upstream channel	Add 0.0
Severely meandering upstream channel	Add 0.1
Channel with complex approach flow conditions (Sharp upstream bend in channel, confluence, unstable reach, lateral migration, etc.)	Add 0.2
Non-tidal river with wide flood plains and complex two dimensional river and flood plain flow patterns that may change with river stage where a 2-D analysis is appropriate but not available	Add 0.1
Tidal river with wide tidal flats or wetlands and complex two dimensional river and flood plain flow patterns that may change with river stage where a 2-D analysis is appropriate but not available	Add 0.1

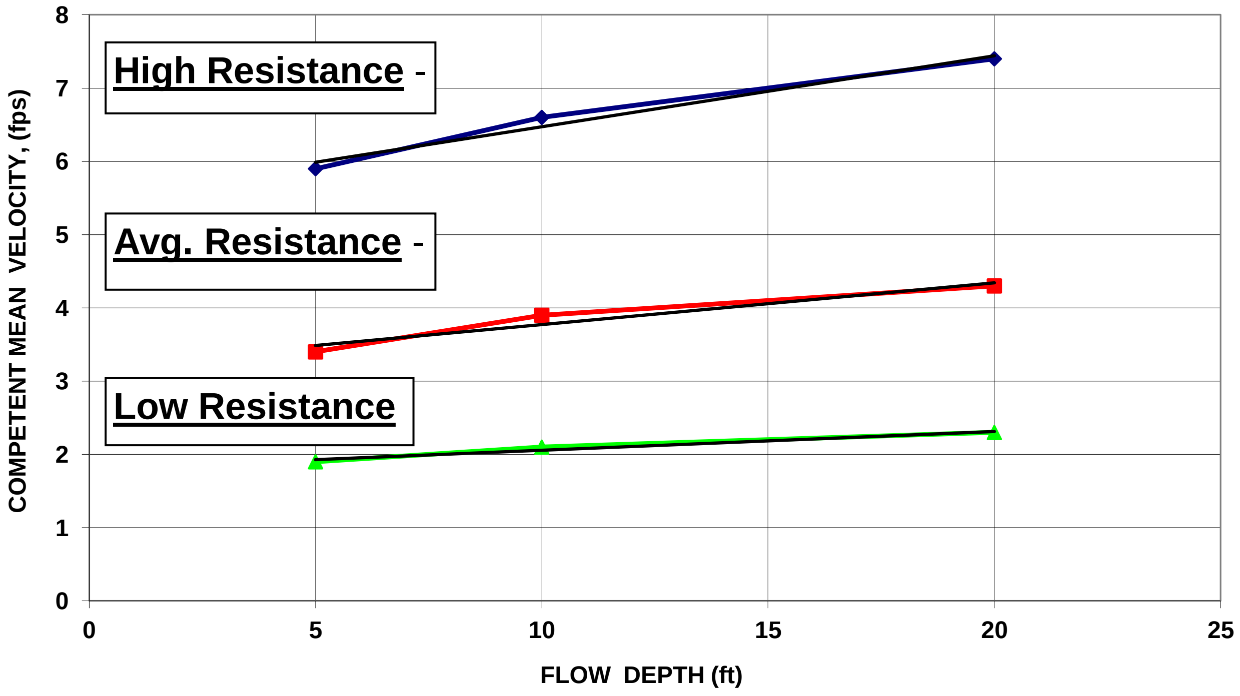
This table is used in the following manner. The user reviews the site conditions or descriptors which are present at the bridge site under consideration, and selects the factor in the table that best describes the crossing site under consideration. The engineer may select a higher safety factor if it is considered necessary to reflect a high risk crossing site.

Please note that the current scour evaluation procedure described in Chapter 11 of the Manual directly calculates the potential effects of both channel migration and degradation. This calculation serves to decrease the need for reliance on a safety factor to account for lateral channel movement and degradation.

ATTACHMENT 4
CRITICAL VELOCITIES IN COHESIVE SOILS

There are no definitive data available for determining critical velocities in cohesive soils. In an unpublished paper (Permissible Shear Stresses/Critical Velocities, 2005) Sterling Jones, Research Engineer, FHWA, has collected and commented on various methods available in the literature regarding this subject. The Office of Structures has conducted limited tests of critical velocities in cohesive soils using the EFA Apparatus in the SHA Soils Lab. On the basis of this existing information, OBD recommends the following:

1. For preliminary guidance on estimates of critical velocities in cohesive soils, use the figure below developed from information in Neill's "Guide to Bridge Hydraulics, Second Edition, June 2001" (Please note that there are two lines drawn close together for the top two curves representing two different soil types. The top line is comprised of straight lines drawn through the data points in Neill's table. The lower line is a curve mathematically fitted to the data points.
2. For more refined estimates of the critical velocity of cohesive soil layers at a bridge site, take Shelby Tube samples of the various soil layers and test them in the EFA Apparatus in the SHA Soils Lab.



ATTACHMENT 5
ESTIMATING CONTRACTION AND ABUTMENT SCOUR AT BRIDGES CROSSING LARGE SWAMPS AND WETLANDS.
(NON-TIDAL COASTAL PLAIN OF SOUTH CAROLINA)

We were unable to get the ABSCOUR program to provide reasonable answers for bridge abutments in the wide swamps and wetlands in the non-tidal coastal plain in South Carolina. Accordingly, an alternative approach to estimating scour for such sites, based on the U.S Geological Survey's studies (Reference 13), is proposed below. We anticipate that such crossing sites will not be common in Maryland. The characteristics of the South Carolina Streams, excerpted from the USGS Report, are depicted below:

TABLE 1 Range of Selected Stream Characteristics for Measurements of Clear-Water Abutment Scour Collected at 129 Bridges in the Piedmont and Coastal Plain of South Carolina

			Properties for Full Cross Section Upstream of Bridge						
Range value	**Drainage area (miles^2)**	**Channel slope (ft/ft)**	**[a]Average cross section velocity (ft/s)**	**[a]Average cross section depth (ft)**	**[a] Cross section top width (ft)**	**[a, b] Unit width flow at bridge (cfs/ft)**	**Median grain size (mm)**	**Observed abutment-scour depth (ft)**	**Observed contraction-scour depth (ft)**
Piedmont (90 abutment and 66 contraction scour measurements)									
Minimum	11	0.00037	0.49	3.4	213	6.7	< 0.062	0.0	0.0
Median	82	0.0012	1.80	7.3	711	29.7	0.091	1.0	0.8
Maximum	677	0.0024	4.38	15.8	2663	72.9	1.19	18.0	4.5
Coastal Plain (104 abutment and 42 contraction scour measurements)									
Minimum	6	0.00007	0.25	2.1	463	3.8	< 0.062	0.0	0.0
Median	54	0.0006	0.47	4.7	2154	17.7	0.19	8.4	2.0
Maximum	8,830	0.0024	0.94	16.3	28952	51.5	0.78	23.6	3.9

[a] Parameter was estimated with the 100-year flow.

[b] Determined by ABSCOUR program.

The significant factor in this table for the Coastal Plain is that, for the most part contraction and abutment scour at bridges crossing these wetlands and swamps is small, with some notable exceptions.

Procedures for Estimating Contraction and Abutment Scour in swamp-wetland areas with characteristic similar to that of the (non-tidal) Coastal Plain of South Carolina (T1)

Design Procedure No. 1: USGS Envelope Curve

Applicability

This procedure is recommended only for bridges crossing wetlands and swamps with characteristics similar to those presented in Table 1 for a (non-tidal) Coastal Plain

The USGS envelope curve depicted above is an empirical method which reports the results of their field investigation of the wetland areas in the South Carolina (Non-tidal) Coastal Zone. The method should be viewed as a tool to assist the engineer in applying engineering judgment.

There is a prescribed method for applying the clear-water abutment-scour envelope curves (See the report section, "Guidance for assessing abutment-scour depth using the envelop curves" on page 91 of Benedict, 2003). In order to properly apply the curves it is important that the engineer develop some understanding of the data and its limitations. To do this, the engineer should become familiar with the content of the USGS reports For the application of clear-water abutment-scour envelope curves the engineer should refer to Benedict (2003) and for the clear-water contraction-scour envelope curves he should refer both Benedict (2003) and Benedict and Caldwell (2006). Both are available on line at the links below:

Benedict, S.T., 2003, Clear-water abutment and contraction scour in the Coastal Plain and Piedmont Provinces of South Carolina, 1996-99: U.S. Geological Survey Water Resources Investigation Report 03-4064, 137p.
http://pubs.usgs.gov/wri/wri034064/

Benedict, S.T. and Caldwell, A.W., 2006, Development and Evaluation of Clear-Water Pier and Contraction Scour Envelope Curves in the Coastal Plain and Piedmont Provinces of South Carolina: U.S. Geological Survey SIR 2005-5289, 112 p.
http://pubs.usgs.gov/sir/2005/5289/

Selection of Scour Parameters

The USGS study will be used to identify those sites where measurements of abutment scour values were high. They key factors in identifying locations with potentially large abutment scour depths are discussed below:

1. Geometric-Contraction Ratio (m), is defined as:

$m = 1- b/B$

Where b = bridge opening width, and B = approach flow width.

As an example, if a bridge opening (b) is 150 feet and the approach flow width is 1500 feet, m = 1- 150/1500 = 0.9; Conversely, if the bridge opening is 1200 feet and the approach flow width is 1500 feet, m = 1-1200/1500 = 0.2. Therefore, if the value of m is large, this is an indication of contracted flow with resulting high velocities and scour. If the value of m is small, this is an indication of little change to velocities at the bridge and resulting low values of scour.

2. Contraction Scour

The maximum contraction scour observed at the 42 measured sites was 3.9 feet. For design purposes, a contraction scour value of 5 feet will be used in this assessment process.

3. ABSCOUR Abutment scour

For streams with low approach velocities, as occurs in wetlands, the ABSCOUR amplification factor is typically 1.4. (The amplification factor is multiplied by the contraction scour to obtain the abutment scour.) For a contraction scour value of 5 feet, the corresponding abutment scour value is: 5ft. x 1.4 = 7 feet. This value will serve as the minimum abutment scour value

4. USGS Envelope Curve of All Abutment Scour Measurements in the Coastal Plain.

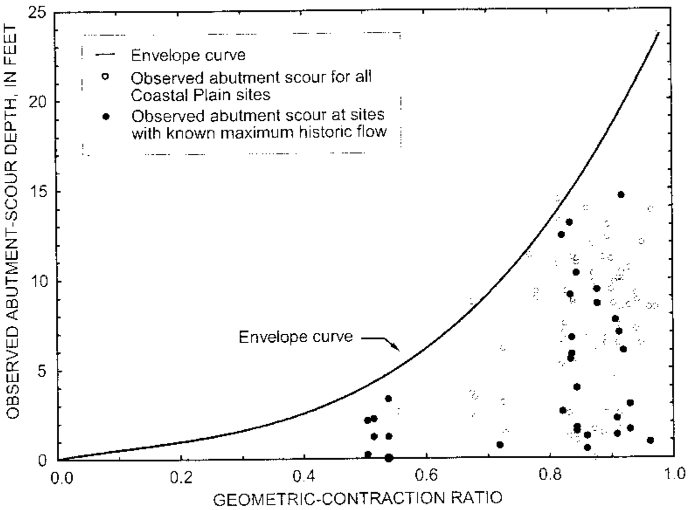


Figure 76. Relation of observed clear-water abutment-scour depth and the 100-year-flow geometric-contraction ratio identifying sites with known maximum historic flows in the Coastal Plain of South Carolina.

The USGS Envelope Curve (Figure 76) plots all of the measured abutment scour depths in the Coastal Plain Vs the geometric-contraction ratio associated with the bridge site where the measurements were taken.

CONTRACTION SCOUR: Use a value of 5 feet

ABUTMENT SCOUR:

1. Measure the geometric- contraction ratio (m) for the bridge site:

m = 1- b/B

Where b = bridge opening width, and B = approach flow width.

Note: for overtopping flows, use only that portion of the approach flow width that actually goes through the bridge.

2. Read the Observed Abutment Scour Depth from the Envelope Curve in Figure 76

- Use a minimum abutment scour depth of 7 feet
- Use a maximum abutment scour depth of 15 feet

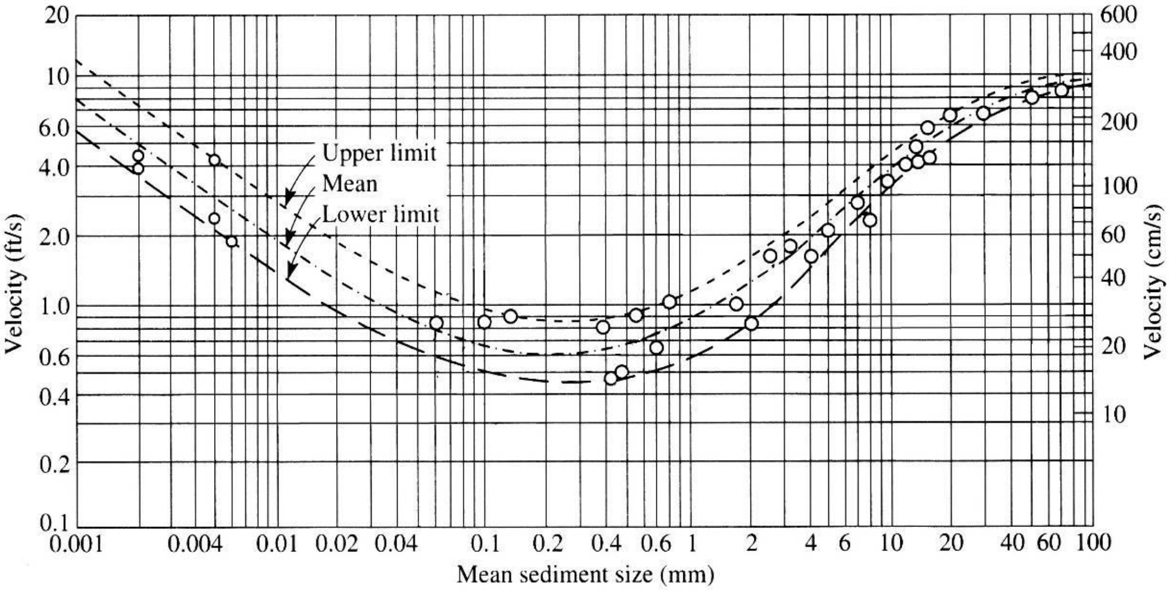
Design Procedure No. 2 – Using the Vanoni Upper Limit Curve for Estimating Threshold (Critical) Velocities for Clear-Water Abutment Scour

The following guidance is excerpted from the studies by Stephen Benedict of clear-water abutment scour at bridges in the (non-tidal) Coastal Plain of South Carolina (Ref. 12): *"For the low gradient streams and sandy soils of the Coastal Plain, the Fortier and Scobey (8), Laursen (9), and Neill (10) methods have a significant number of under predictions particularly with respect to abutment scour. This trend is undesirable for design and assessment purposes, making them a poor method for application at such streams. In contrast, the Vanoni (7) upper limit curve has a significantly lower number of under predictions but with over predictions that are at times excessive. None of these methods perform in an ideal way for the lower gradient streams and sandy soils of the Coastal Plain, but the Vanoni (7) upper curve performs the best with regard to limiting significant under prediction."*

Application:

1. This procedure is recommended only for bridges crossing wetlands and swamps with characteristics similar to those presented in Table 1 for a (non-tidal) Coastal Plain
2. For the abutment under consideration, estimate the D50 particle size of the soil at the expected depth of scour. (This may involve several attempts to correlate the scour depth with the appropriate layer of soil)
3. Select the corresponding value of the critical velocity from the Vanoni upper limit curve in the plot below.
4. Use the over-ride feature in ABSCOUR 9 to enter the critical velocity of the soil at the abutment, and compute the abutment scour for the selected condition.

Discussion: There may be a significant difference between the abutment scour estimates determined from Design Procedures 1 and 2. Use engineering judgment to select the most appropriate scour depth for the given conditions.



Design Procedure No. 2 – Using the Vanoni Upper Limit Curve for Estimating Threshold (Critical) Velocities for Clear-Water Abutment Scour