OFFICE OF STRUCTURES
STRUCTURE HYDROLOGY AND HYDRAULICS DIVISION

CHAPTER 11 APPENDIX B

TIDEROUT2

USERS MANUAL

MAY 2015

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Preface

TIDEROUT 2, Build 1.22.4 dated April 2015 is the current version of this program and all previous versions should be discarded. The user is advised to check the web site below for any revisions to the program: **http://www.gishydro.eng.umd.edu**

The material presented in this TIDEROUT 2 Users Manual has been carefully researched and evaluated. It is periodically updated and improved to incorporate the results of new research and technology. However, no warranty expressed or implied is made on the contents of this program or the user's manual. The distribution of this information does not constitute responsibility by the Maryland State Highway Administration or any contributors for omissions, errors or possible misinterpretations that may result from the use or interpretation of the materials contained herein.

TIDEROUT 2 is a flood routing program. Its primary purpose is to serve to estimate scour at bridges in tidal waterways. It can be used to route riverine flows from an upland watershed down to the tidal basin and then route the combined riverine/tidal flow through the bridge (and perhaps over the road) down to the sea:

- Basic equation: Inflow – Outflow = Storage
- Bridge flow+roadway overtopping flow = tidal flow + riverine flow

Many newly designed tidal bridges span wetlands and do not constrict tidal flow so as to cause significant contraction scour. Contraction scour may be more of a problem with older structures that do constrict the waterway area.

Please refer to the Introduction to this Appendix for a discussion of the advantages of using both the Tiderout 2 and the HEC-RAS program for determining the worst-case conditions for scour

The advantages of the TIDEROUT program include:

1. Takes into account conditions of unsteady tidal flow
2. Evaluates potential benefits of storage in the tidal basin upstream of structure
3. Provides a means of combining riverine and tidal flow hydrographs to estimate the worst case scour condition
4. The user can very quickly change input parameters to do sensitivity testing of reasonable combinations of storm tides, riverine flow, wind conditions, etc. to find the worst case scour.

The limitations of the TIDEROUT 2 program include:

1. Method does not address other aspects of tidal flow such as littoral drift or movement of sediment through the tidal basin.
2. Method cannot be used for complex tidal currents resulting from flows between islands where wind forces predominate
3. User needs to separately compute contraction and local abutment scour
4. User needs to import TIDEROUT2 output into ABSCOUR to compute pier scour.

Introduction

Chapter 10, Appendix A, Hydraulics of Tidal Bridges, provides a comprehensive discussion of various aspects of the hydraulic design of tidal bridges. The user of the TIDEROUT 2 program is encouraged to become familiar with the guidance in Chapter 10, Appendix A before conducting a tidal analysis at a bridge. The user needs to recognize that unsteady tidal flow is complex, and that TIDEROUT 2 provides for simple hydraulic and scour models to evaluate it. Nevertheless the program can be used effectively in the design of structure foundations to evaluate and determine worst-case scour conditions.

Tide Models

The Office of Structures currently uses TIDEROUT 2 and HEC-RAS to analyze tidal flow at a bridge. Two dimensional flow models are useful for evaluating flow in large estuaries, but are not considered necessary for the typical SHA tidal crossing. The SHA guidance is geared towards tidal areas tributary to the Chesapeake Bay. Special studies may be necessary for estuaries discharging directly to the ocean. The following guidance is provided with regard to selection of a tidal model for Chesapeake Bay estuaries. Most likely, a typical bridge site will not exhibit the clear-cut categories listed below and judgment will be needed to select the most appropriate model. It may be helpful to use both models, compare the results and then select the most appropriate results.

	TIDEROUT 2	HEC-RAS
Tidal crossing in close proximity to the bay (Tide elevations control downstream tailwater elevations)	X	
Tidal crossing at a considerable distance from the outlet to the bay. (Downstream tailwater controlled by normal depth (Manning) considerations		X
Small riverine discharge; tidal flow predominates	X	
Large upland drainage basin, riverine discharge predominates		X

Boundary Conditions for TIDEROUT 2

During a major storm such as a hurricane, there are two different events that need to be considered in evaluating flow through a tidal bridge and the resulting scour at the foundations. One event is the discharge through the bridge caused by the storm tide, and the other related event is the riverine discharge through the bridge caused by the heavy rains on the upland drainage basin. The peak discharges from these two events may or may not occur at the same time .There is no standard or “correct” way of evaluating these flows, since each tidal bridge will present a different set of conditions to consider. However, the Office of Structures recommends that the following procedure be followed as a guide in deciding how to combine the upland riverine flow with the storm tide flow. A preliminary meeting with the Office of Structures is recommended to discuss the tidal conditions. The results of this approach also need to be discussed with the Office of Structures to determine whether the computed discharges are reasonable. If an alternative scenario is determined to offer a better approach, the alternative method should be discussed with the Office of Structures prior to the commencement of the tidal study.

Combining Riverine And Storm Tide Discharges

<u>100 -Year Combined Riverine And Storm Tide Discharges</u>

<u>It has been the experience of the Office of Structures that determining the relative timing of the occurrence of the peak riverine flow with the timing of the peak tidal surge is not subject to a rigorous analysis. Many factors can influence the way in which these two peak flows will develop to form the peak flow conditions at the bridge.. The following guidance is based on previous studies conducted by the office of Structures. However, it may not be appropriate for all tidal crossings..</u>

Estimate the 10-year and 100-year riverine hydrographs from the upland drainage basin. Use the TR-20 dimensionless hydrograph in TIDEROUT 2 for drainage areas under 25 square miles. If the drainage area is over 25 square miles, follow the guidance in Chapter 8 for computing the TR-20 hydrograph. For drainage areas greater than 300 square miles, use the U.S. Geological Survey (USGS) dimensionless hydrograph described in USGS Water-Resources Investigations Report 97-4279. The use of this approach should be discussed with the Office of Structures prior to the commencement of the tidal study.

1. If the drainage area for the 100-year riverine hydrograph is less than 25 square miles, assume that the peak riverine discharge and the peak storm surge elevation occur at the same time (match the peaks of the hydrographs).

2. If the time of concentration of the 100-year riverine hydrograph is more than 24 hours, treat the storm tide and riverine flood as independent events. To evaluate the effects of the 100-year riverine hydrograph separately, use a tidal hydrograph with a tidal period of 24 hours and an average tidal condition having a range between mean lower low water and mean higher high water. (This essentially provides a low tailwater condition for evaluating scour at the bridge.)

3. If (1) the drainage area is over 25 square miles, and (2) the time of concentration of the riverine hydrograph is less than 24 hours, then compute the riverine discharge as a constant discharge. The recommended approach for the TIDEROUT 2 analysis is to start the routing procedure for the combined riverine and tidal flows assuming the tidal basin

is full. For this condition, use a constant riverine discharge equal to the 10-year peak discharge (cfs)

500-Year Combined Riverine And Storm Tide Discharges

Estimate the 2-year and 500-year riverine hydrographs from the upland drainage basin. (Also estimate the 10-year hydrograph if not already computed for the 100-year combined riverine and storm tide discharge). Use the SCS dimensionless hydrograph in TIDEROUT 2 for drainage areas under 25 square miles. If the drainage area is over 25 square miles, follow the guidance in Chapter 8 for computing the TR-20 hydrograph. For drainage areas greater than 300 square miles, use the U.S. Geological Survey (USGS) dimensionless hydrograph described in USGS Water-Resources Investigations Report 97-4279. The use of this approach should be discussed with the Office of Structures prior to the commencement of the tidal study.

1. If the drainage area for the 500-year riverine hydrograph is less than 25 square miles, use TIDEROUT 2 to compute the flow of the 500-year tidal storm surge through the bridge. Use a constant discharge value for the riverine flow equal to the 10-year peak discharge.

4. If the time of concentration of the 500-year riverine hydrograph is more than 24 hours treat the storm tide and riverine flood as independent events. To evaluate the 500-year riverine hydrograph separately, use a tidal hydrograph with a tidal period of 24 hours and an average tidal condition having a range between mean lower low water and mean higher high water. This essentially provides a low tailwater condition for evaluating scour at the bridge.)

2. If (1) the drainage area is over 25 square miles, and (2) the time of concentration of the riverine hydrograph is less than 24 hours, then evaluate the 500-year tidal storm surge and compute the riverine discharge as a constant discharge equal in value to the 2-year peak discharge.

Other Considerations

Tidal flow is complex, especially if a combination of riverine and tidal discharges is to be used in the analysis:

- In low-lying tidal basins (particularly on the Eastern shore) the tidal basin boundary elevations may be at four feet or less while the storm tide elevations may be at six feet or more. Careful analysis is needed to decide the proportion of the flows going through the bridge, over the road, and across the drainage divide to other watersheds.

- FEMA maps which are commonly used to define peak storm tide elevations are based on the NGVD datum of 1929 while SHA current project mapping is based on NAVD datum of 1988. The user will need to convert tidal data from the NGVD datum to NAVD datum when using the program (See Chapter 10, Appendix A)

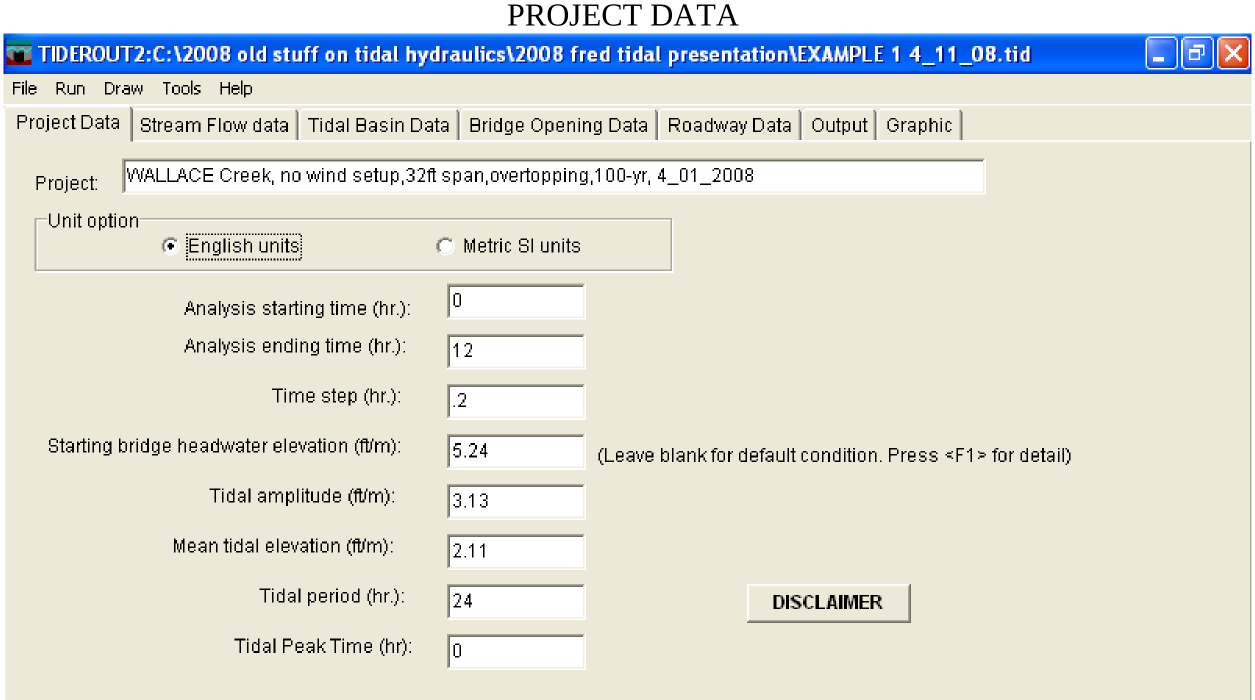
- Various other factors, such as the wind, may influence the flow through the bridge. Please refer to Chapter 10, Appendix A for a discussion of these factors.

- The Office of Structures in currently evaluating the feasibility of constructing a scour module for TIDEROUT 2 that would compute contraction scour on a step by step basis. This approach should add to the accuracy of the estimated scour computed for tidal bridges.

<u>Input Data for TIDEROUT 2</u>

Typical input values are described below. (Tidal elevations for use in the analysis will depend on the location of the structure and other factors.) The user may wish to select other values depending on the issues to be addressed.

PROJECT DATA



TIDEROUT 2 opens to the Project Data Card. This card has the following characteristics:

1. TOOL BAR

- File – File management including accessing and saving TIDEROUT 2 files.
- Run – Run the program
- Draw- Draws a schematic of the output results

- Tools – Utility tools for quick calculations
- Help – Help menus to answer questions about the program
- F-1 (Short Help) – Help for any input window can be obtained by placing the cursor in the input field (window) and clicking on the F1 Key

2. TAB BARS

A. PROJECT DATA

- Project: Describe the highway and the estuary being crossed; include information on particular aspects of the study i.e. flood discharges, referenced tidal station, etc.

- Unit option: SHA prefers English units

- Analysis starting time: For the Chesapeake Bay the storm tide period is assumed to be 24 hours. Typically, the worst case scour is expected to occur during the 12 hour ebb tide period starting when the tidal basin is full (high tide) and at the elevation of the design storm tide (time 0 hours) and ending when the basin has emptied (time 12 hours)

- Analysis ending time 12 at low tide

- Time step – See F1

- Starting bridge headwater elevation – High tide elevation of the design storm tide or See F1 guidance

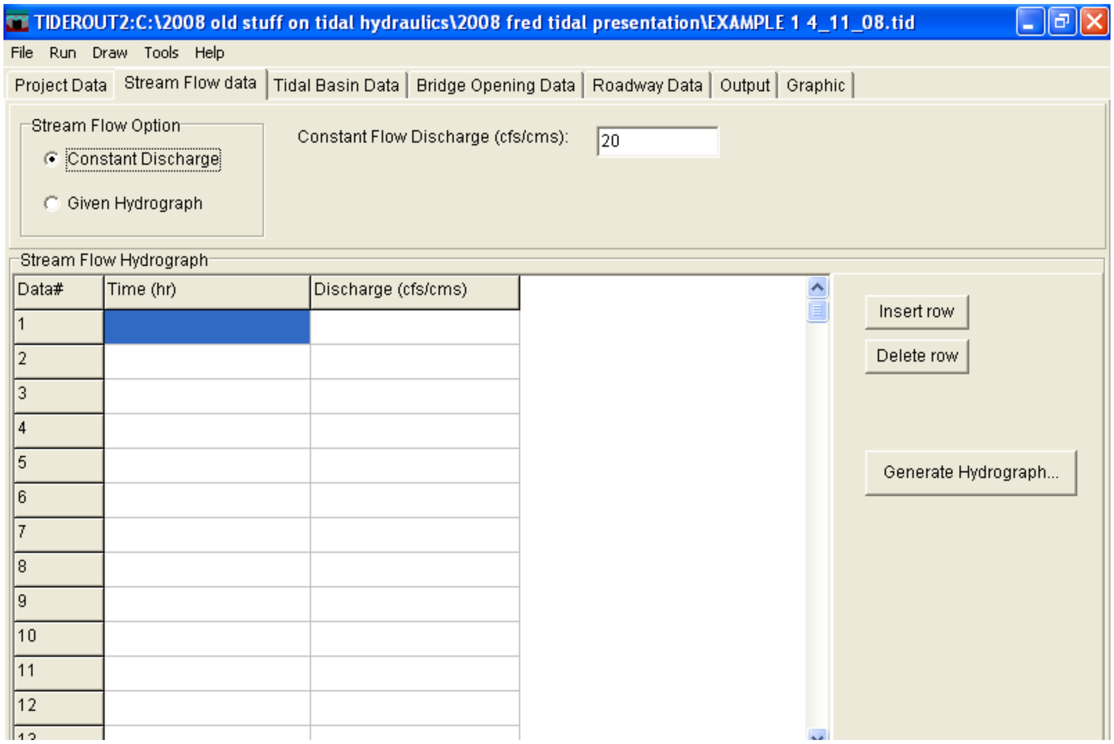
- Tide amplitude – See F1

- Tidal period – Default value is 24 hours

- Tidal peak time (hrs) is Zero

Please click on and read the Disclaimer button

STREAM FLOW DATA



STREAM FLOW OPTION: The User has two options with regard to stream flow data. The objective is to get a conservative, yet reasonable, model combining tidal flow and riverine (stream) flow that includes the peak tidal flow and the peak riverine flow.

- Given Hydrograph: A conservative approach would be to arrange the time of a riverine hydrograph to peak at the same time as the tidal hydrograph peaks (usually time zero). Judgment is needed to decide whether it is reasonable to assume that the time of concentration of the riverine hydrograph will coincide with the peak tidal hydrograph.

- Constant Discharge: A second option is to convert the riverine hydrograph to a hydrograph with a constant discharge. The height (discharge) of this rectangular hydrograph is determined by dividing the total area (runoff volume) under the hydrograph by the length of the hydrograph base. This approach has the advantage of combining tidal and riverine flows when the relative timing of peak flows is problematical.

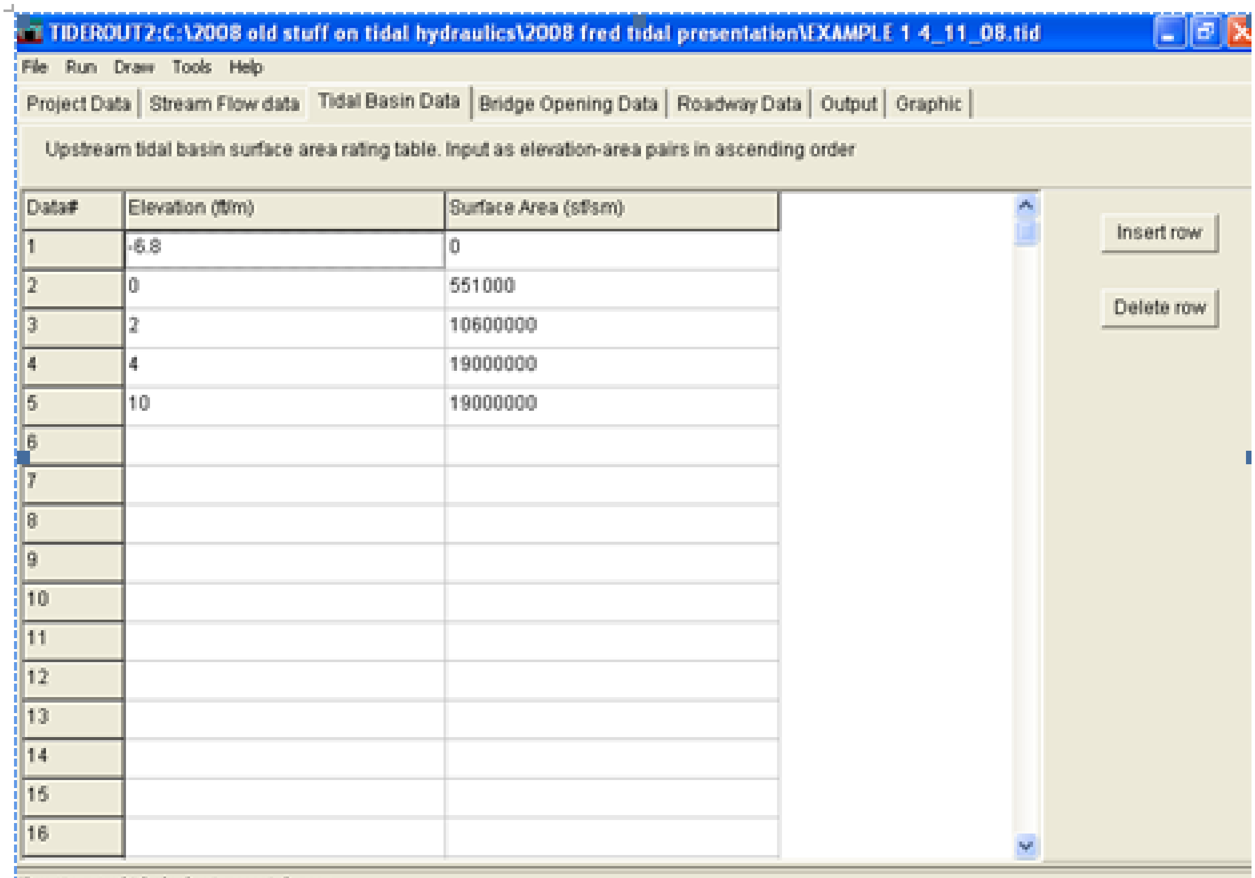
CONSTANT FLOW DISCHARGE: If the constant discharge option is selected, input the value of the computed constant flow discharge; otherwise leave this field blank.
STREAM FLOW HYDROGRAPH:

If the stream flow hydrograph option is selected, there are two ways of inputting the data:

- If a hydrograph has already been developed as a part of a project study, it can be manually input here

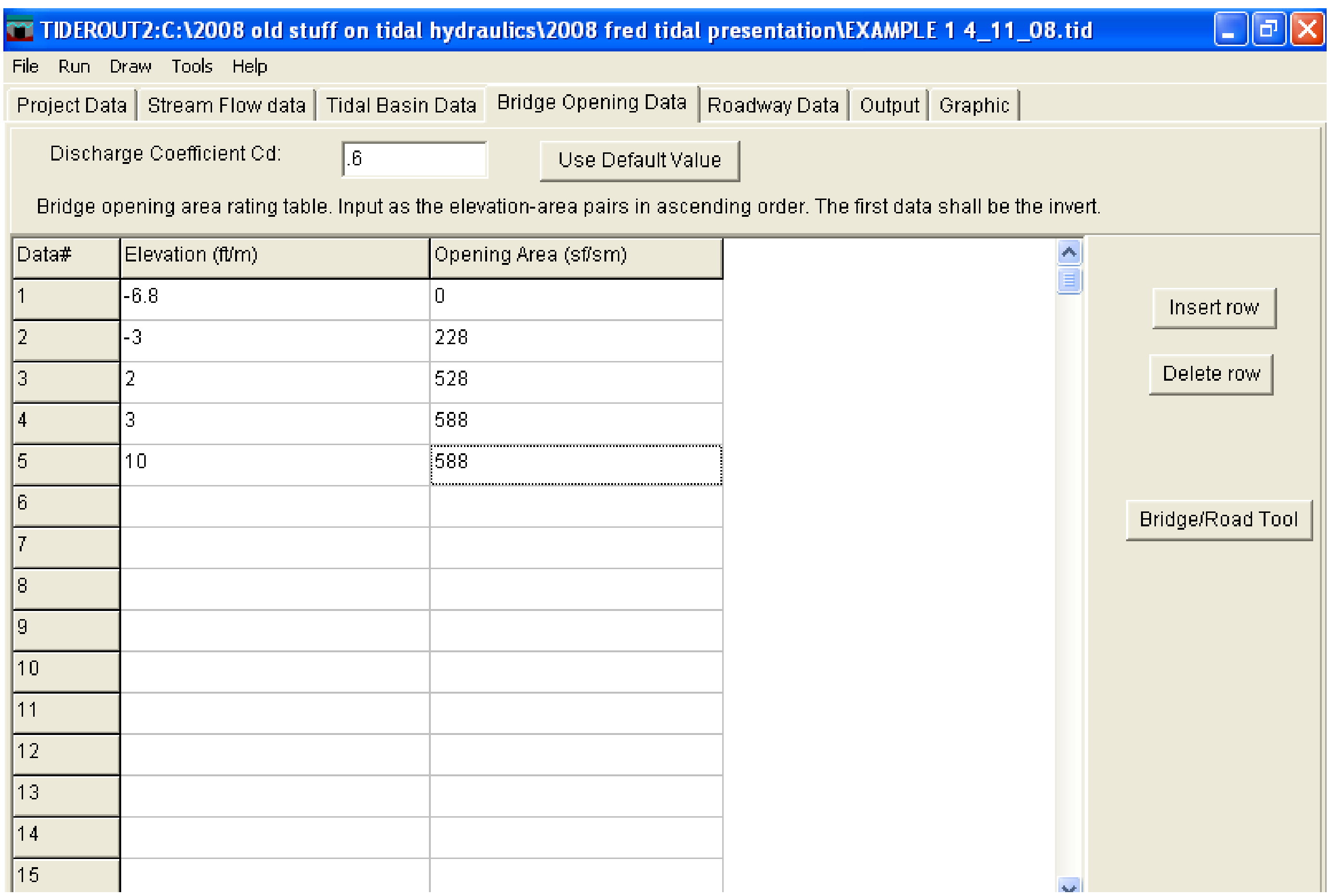
- The user can also click on the generate hydrograph button to obtain a TR-20 single area model. A window is presented to input the hydrograph characteristics. We note that the TR-20 peak factor constant is 484 for all of the physiographic regions in Maryland except for the Eastern Shore which is 284. The time step selected in normally 0.1 to 0.2 hours to be consistent with the tidal hydrograph.
- The user can "shift" the stream inflow hydrograph so that the peak riverine discharge coincides with the peak tidal flow elevation at time zero, or with any other tidal flow elevation or discharge. For example, assume that the time of concentration of the riverine hydrograph peak occurs at time 19 hours and the user desires to shift the hydrograph so that this peak occurs at time zero for the tidal hydrograph. This is accomplished in the following manner: (1) compute the hydrograph and then (2) adjust the hydrograph time/discharge pairs for each time unit to shift the hydrograph peak to the desired time. In the example presented above, the hydrograph would need to start at time -19 hours so that the peak flow would occur at time zero.

TIDE BASIN DATA



The user creates a storage area rating table for the tidal basin upstream of the bridge using the Tidal Basin card. Beginning with the elevation of the channel bottom at the bridge (usually a negative value below zero), the information is provided as a set of elevation-area pairs. The areas corresponding to the elevations can be obtained by measuring the areas between successive contour lines (See F-1 help). The upper limit of the rating table should be selected as an elevation above the design storm tide elevation. The area contained within a given contour line can be measured with a planimeter or can be computed using appropriate software (i.e. GIS Systems, CADD Programs, topographic digital elevation models, etc.)

BRIDGE WATERWAY OPENING DATA



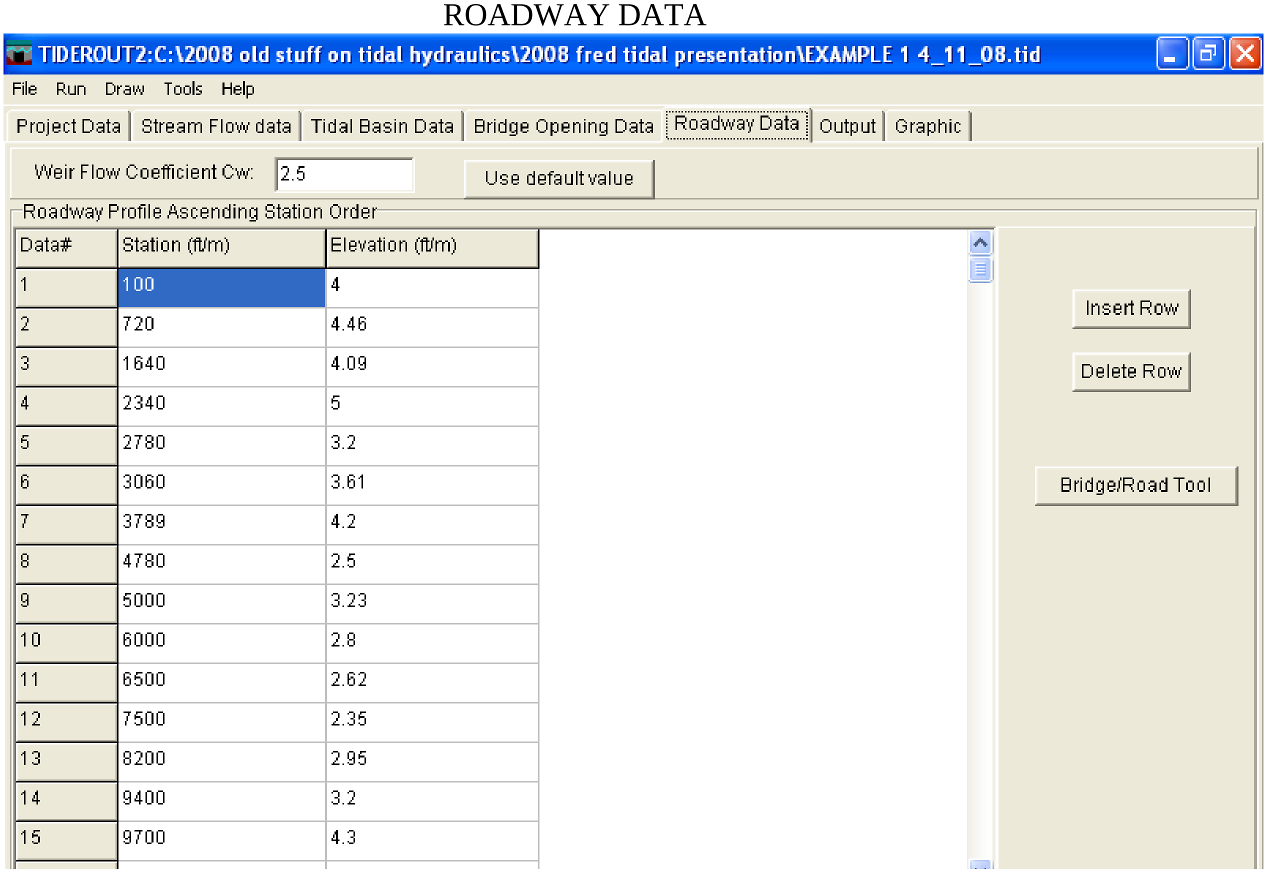
Discharge Coefficient:

Refer to F-1 Help. For l bridges, the default value has been selected as 0.80. For larger bridges, particularly those with streamlined abutments, a higher value may be appropriate.

Bridge Waterway Area Opening Rating Table.

The waterway area rating table is provided by the user as a set of elevation vs. waterway area pairs. See F-1 Help. The waterway area for various water surface elevations can be measured from the bridge plans.

ROADWAY DATA



Data#	Station (ft/m)	Elevation (ft/m)
1	100	4
2	720	4.46
3	1640	4.09
4	2340	5
5	2780	3.2
6	3060	3.61
7	3789	4.2
8	4780	2.5
9	5000	3.23
10	6000	2.8
11	6500	2.62
12	7500	2.35
13	8200	2.95
14	9400	3.2
15	9700	4.3

Weir Flow Coefficient: See F-1 Help

Roadway Profile Ascending Station Order: See F-1 Help.

Boundary Conditions: This roadway data card represents a very important boundary condition for evaluating tidal flow through the bridge. For many Eastern Shore bridges, roadway elevations will be below storm tide elevations, and a large quantity of the tidal prism will flow over the road instead of through the bridge. Similarly, if the watershed boundaries for the tidal basin are lower than the peak storm tide elevations, it may not be possible to estimate the peak tidal flows through the bridge. For this condition the recommended approach is to input an extended roadway length at the watershed overtopping elevation. This will serve to define the flows through the bridge as those flows below the elevation of the watershed divide.

Program Output

The output consists of two parts: (1) a summary of the information input to the program by the user and (2) a time sequence of the changing hydraulic characteristic of the flow during passage of the selected tide and riverine hydrographs.

OUTPUT PRINTOUT
PART 1 – SUMMARY OF USER INPUT

Bridge Opening Data:
Discharge Coefficient: .6
Bridge Opening Area rating Table:

Data#	Elevation (ft)	Area (sf)
1	-6.8	0
2	-3	228
3	2	528
4	3	588
5	10	588

Roadway Data:
Weir Flow Coefficient For Overtopping Flow: 2.5
Roadway Profile:

Data#	Station (ft)	Elevation (ft)
1	100	4
2	720	4.46
3	1640	4.09
4	2340	5
5	2780	3.2
6	3060	3.61
7	3789	4.2
8	4780	2.5
9	5000	3.23
10	6000	2.8
11	6500	2.62
12	7500	2.35
13	8200	2.95
14	9400	3.2
15	9700	4.3

OUTPUT PRINTOUT
PART 2 – TIDEROUT COMPUTATIONS

Note: Remark show critical depth for critical flow, with # indicates fail to converge after 100 cycles

Time (hrs)	Tide EL. (ft)	Basin EL. (ft)	Bridge Q av.(cfs)	Weir Q av.(cfs)	Bridge V (ft/s)	Basin Area (sf)	Flow Area av.(sf)	Remark/ dcr(ft)
0.00	5.240	5.240	0.00	0.00	0.000	19000000.0	588.00	
0.20	5.236	5.238	84.99	0.65	0.241	19000000.0	588.00	
0.40	5.223	5.231	195.32	7.88	0.554	19000000.0	588.00	
0.60	5.201	5.218	313.22	32.50	0.888	19000000.0	588.00	
0.80	5.172	5.200	424.62	80.96	1.204	19000000.0	588.00	
1.00	5.133	5.175	527.98	155.65	1.497	19000000.0	588.00	
1.20	5.087	5.142	622.54	255.15	1.765	19000000.0	588.00	
1.40	5.032	5.102	708.16	375.58	2.007	19000000.0	588.00	
1.60	4.969	5.053	785.19	511.95	2.226	19000000.0	588.00	
1.80	4.899	4.997	854.45	657.22	2.422	19000000.0	588.00	
2.00	4.821	4.932	916.93	807.70	2.599	19000000.0	588.00	
2.20	4.735	4.860	973.70	957.74	2.760	19000000.0	588.00	
2.40	4.642	4.780	1025.54	1109.41	2.907	19000000.0	588.00	
2.60	4.542	4.692	1073.00	1257.98	3.041	19000000.0	588.00	
2.80	4.436	4.597	1116.71	1403.00	3.165	19000000.0	588.00	
3.00	4.323	4.496	1158.01	1528.75	3.282	19000000.0	588.00	
3.20	4.204	4.391	1200.28	1609.98	3.402	19000000.0	588.00	
3.40	4.080	4.281	1246.07	1671.13	3.532	19000000.0	588.00	
3.60	3.950	4.168	1296.09	1708.24	3.674	19000000.0	588.00	
3.80	3.815	4.050	1347.54	1787.06	3.820	19000000.0	588.00	

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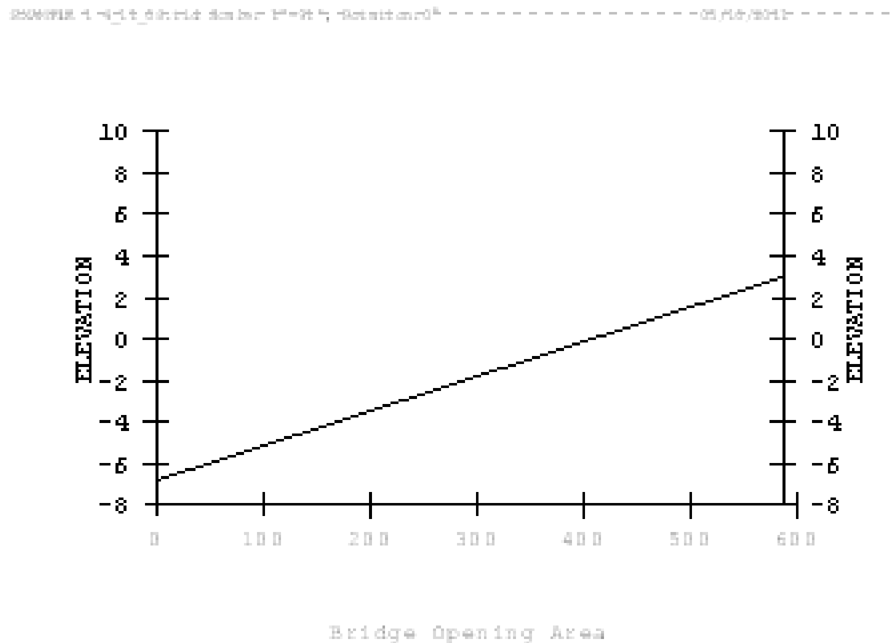
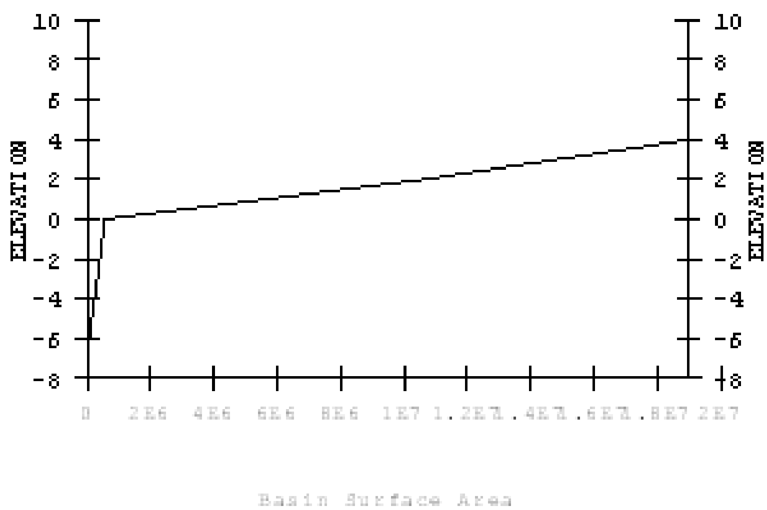
Time (hrs)	Tide EL. (ft)	Basin EL. (ft)	Bridge Q av.(cfs)	Weir Q av.(cfs)	Bridge V (ft/s)	Basin Area (sf)	Flow Area av.(sf)	Remark/ dcr(ft)
4.00	3.675	3.925	1394.72	1882.52	3.953	18686296.2	588.00	
4.20	3.531	3.794	1434.33	1943.29	4.066	18134795.2	588.00	
4.40	3.383	3.656	1465.68	1972.69	4.154	17555526.3	588.00	
4.60	3.232	3.512	1489.67	1973.55	4.222	16952047.7	588.00	
4.80	3.077	3.365	1508.84	1928.10	4.277	16331143.4	588.00	
5.00	2.920	3.221	1528.80	1693.63	4.351	15726982.5	585.60	
5.20	2.761	3.085	1556.27	1381.97	4.484	15155474.9	578.43	
5.40	2.600	2.952	1593.09	1158.37	4.668	14600292.9	568.81	
5.60	2.437	2.825	1638.35	916.68	4.884	14065443.3	559.10	
5.80	2.274	2.708	1695.81	572.10	5.145	13573553.9	549.33	
6.00	2.110	2.600	1765.81	257.25	5.455	13119712.2	539.51	
6.20	1.946	2.494	1836.93	84.84	5.780	12673790.4	529.69	
6.40	1.783	2.384	1897.47	11.47	6.083	12214771.7	519.87	
6.60	1.620	2.269	1941.85	0.00	6.345	11729334.9	510.10	
6.80	1.459	2.147	1969.09	0.00	6.559	11215577.7	500.39	
7.00	1.300	2.018	1980.62	0.00	6.726	10673862.0	490.77	
7.20	1.143	1.881	1977.36	0.00	6.848	10003454.7	481.28	
7.40	0.988	1.736	1959.11	0.00	6.919	9275724.7	471.93	
7.60	0.837	1.582	1925.33	0.00	6.934	8500203.5	462.76	
7.80	0.689	1.417	1875.13	0.00	6.887	7670142.0	453.78	
8.00	0.545	1.239	1806.58	0.00	6.766	6775297.2	445.02	
8.20	0.405	1.045	1715.94	0.00	6.552	5799489.0	436.51	
8.40	0.270	0.829	1595.84	0.00	6.210	4715126.3	428.27	
8.60	0.140	0.581	1430.26	0.00	5.671	3468251.1	420.31	
8.80	0.016	0.272	1173.16	0.00	4.738	1919726.7	412.68	
9.00	-0.103	-0.115	682.75	0.00	2.807	541655.6	405.37	
9.20	-0.216	-0.200	83.44	0.00	0.349	534779.3	398.42	
9.40	-0.322	-0.331	116.03	0.00	0.494	524198.4	391.84	

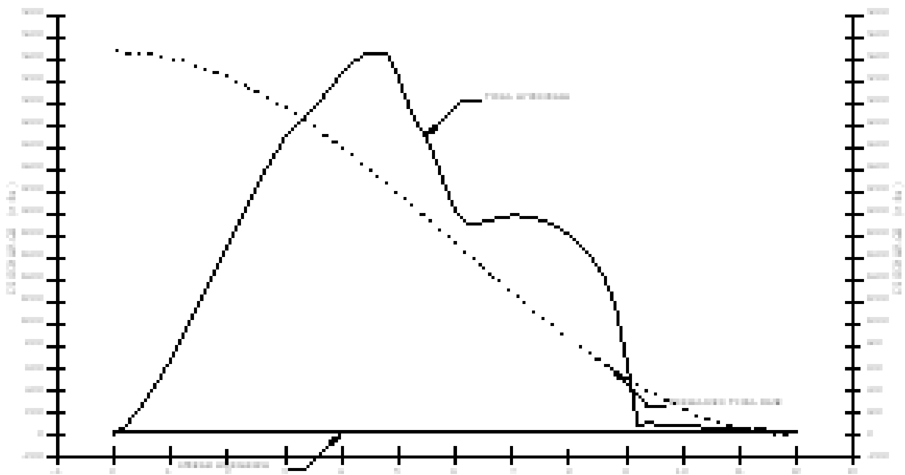
OUTPUT RESULTS – SKETCHES



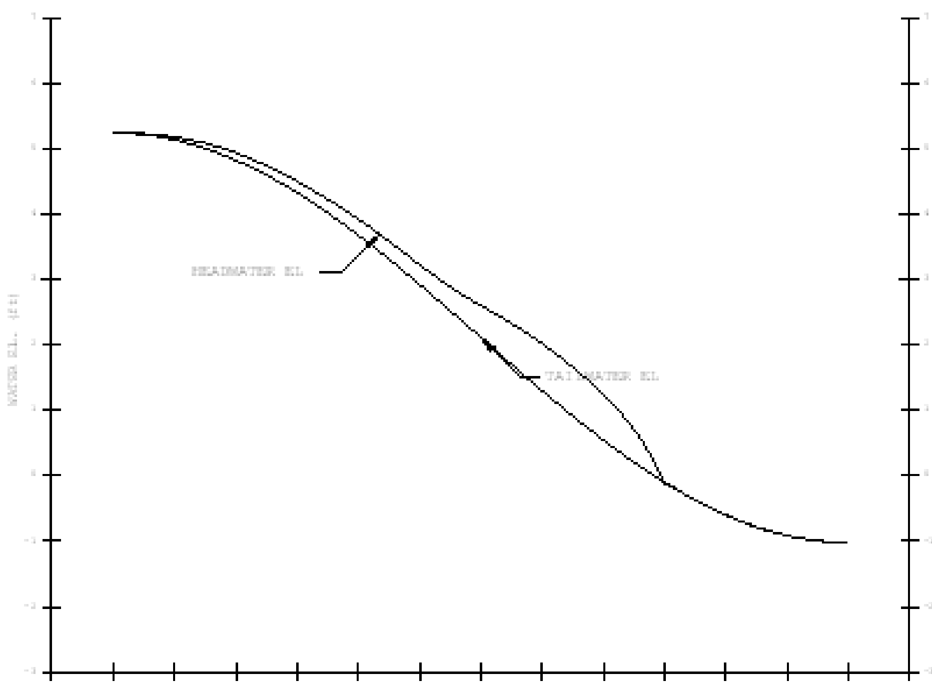
Elevation vs. Bridge Opening Area.



Elevation vs. Basin Surface Area



Tidal and Riverine Hydrographs
(For this case the user selected a riverine hydrograph
with a constant discharge)



Headwater-Tailwater Relationships at Bridge
(Note that the velocity of flow thorough the bridge is highest
When the head differential across the bridge is greatest)

Evaluating Scour Computations At Tidal Bridges

HEC-RAS TIDAL COMPUTATIONS.

Two flow conditions should be checked for each combination of riverine and storm tide discharges to be evaluated:

1. The riverine discharge with low tide elevation.

2. The combination of riverine and maximum storm tide discharges at mid-tide elevation.(Note that the maximum storm tide discharge can be estimated as:

$$Q_{max} = 3.14 \frac{VOL}{T}$$

Where VOL = volume of water in the tidal prism between high and low tides, and T = tidal period (selected as 24 hours for the Chesapeake Bay)

3. The HEC-RAS results can be used as input to ABSCOUR 9 to develop an evaluation of scour at the bridge.

TIDEROUT SCOUR COMPUTATIONS

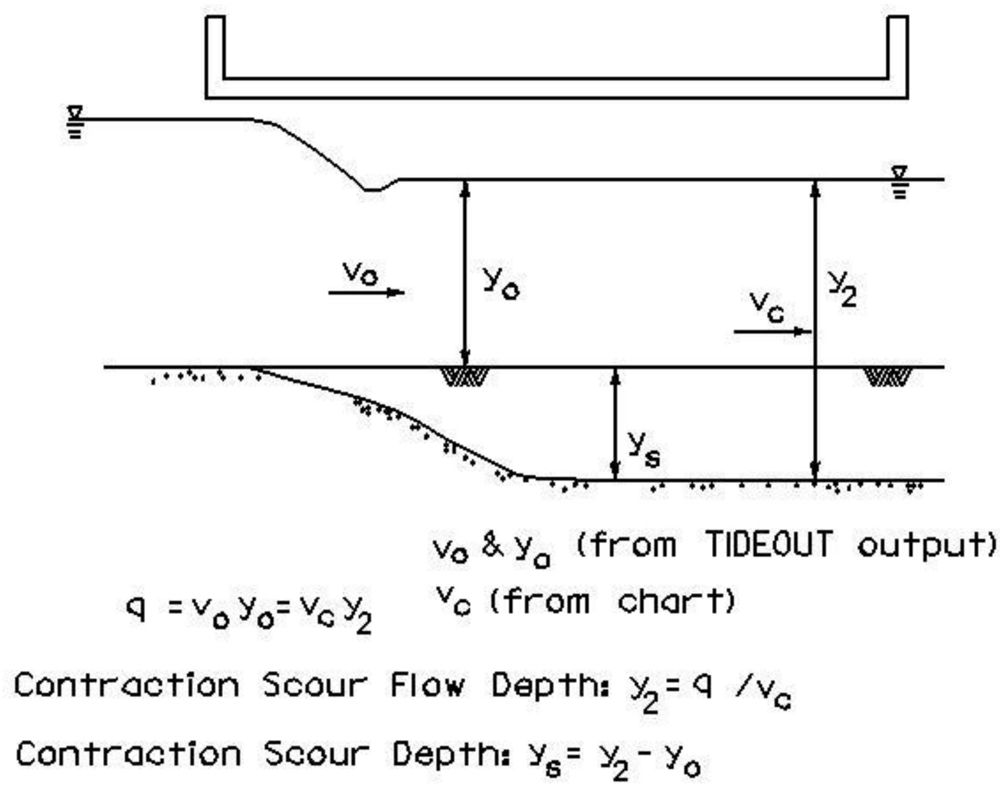
The clear water scour equation (Refer to the ABSCOUR 9 Users Manual in Chapter 11) is used to estimate scour from the TIDEROUT 2 output tables: A portion of the table depicting flow through the bridge vs. time is excerpted below:

----------------------------------Page Break----------------------------------

Time	Tide EL.	Basin EL.	Bridge Q	Weir Q	Bridge V	Basin Area	Flow Area	Remark/
(hrs)	(ft)	(ft)	av.(cfs)	av.(cfs)	(ft/s)	(sf)	av.(sf)	dcr(ft)
4.00	3.675	3.925	1394.72	1882.52	3.953	18686296.2	588.00	
4.20	3.531	3.794	1434.33	1943.29	4.066	18134795.2	588.00	
4.40	3.383	3.656	1465.68	1972.69	4.154	17555526.3	588.00	
4.60	3.232	3.512	1489.67	1973.55	4.222	16952047.7	588.00	
4.80	3.077	3.365	1508.84	1928.10	4.277	16331143.4	588.00	
5.00	2.920	3.221	1528.80	1693.63	4.351	15726982.5	585.60	
5.20	2.761	3.085	1556.27	1381.97	4.484	15155474.9	578.43	
5.40	2.600	2.952	1593.09	1158.37	4.668	14600292.9	568.81	
5.60	2.437	2.825	1638.35	916.68	4.884	14065443.3	559.10	
5.80	2.274	2.708	1695.81	572.10	5.145	13573553.9	549.33	
6.00	2.110	2.600	1765.81	257.25	5.455	13119712.2	539.51	
6.20	1.946	2.494	1836.93	84.84	5.780	12673790.4	529.69	
6.40	1.783	2.384	1897.47	11.47	6.083	12214771.7	519.87	
6.60	1.620	2.269	1941.85	0.00	6.345	11729334.9	510.10	
6.80	1.459	2.147	1969.09	0.00	6.559	11215577.7	500.39	
7.00	1.300	2.018	1980.62	0.00	6.726	10673862.0	490.77	
7.20	1.143	1.881	1977.36	0.00	6.848	10003454.7	481.28	
7.40	0.988	1.736	1959.11	0.00	6.919	9275724.7	471.93	
7.60	0.837	1.582	1925.33	0.00	6.934	8500203.5	462.76	
7.80	0.689	1.417	1875.13	0.00	6.887	7670142.0	453.78	
8.00	0.545	1.239	1806.58	0.00	6.766	6775297.2	445.02	
8.20	0.405	1.045	1715.94	0.00	6.552	5799489.0	436.51	
8.40	0.270	0.829	1595.84	0.00	6.210	4715126.3	428.27	
8.60	0.140	0.581	1430.26	0.00	5.671	3468251.1	420.31	
8.80	0.016	0.272	1173.16	0.00	4.738	1919726.7	412.68	
9.00	-0.103	-0.115	682.75	0.00	2.807	541655.6	405.37	
9.20	-0.216	-0.200	83.44	0.00	0.349	534779.3	398.42	
9.40	-0.322	-0.331	116.03	0.00	0.494	524198.4	391.84	

Please note that the highest flow velocity of 6.9 fps occurs at time 7.6 hours (underlined row above) when the downstream tide elevation is at an elevation of 0.84 feet. The channel bed elevation is at -6.8 feet, so the downstream flow depth is computed as 7.6 feet. Surface and subsurface (boring) samples indicate that the channel bed is comprised of a medium sand with a D50 of 0.0016 feet.

Clear Water Scour Equation



The values of vo (6.9 fps) and yo (7.6 feet) are known values obtained from the TIDEROUT output tables and the value of y_2 is the total scour depth we wish to calculate. This missing variable is Vc, the critical velocity of the sand which can be obtained from the chart below excerpted from the ABSCOUR 9 Users Manual

For a flow depth of 7.6 feet and a particle size of 0.0016, the critical velocity of the sand is estimated as 3.6 fps.

Solve the equation for y2 (total contraction flow depth including flow depth)

- **q = Vo*yo = Vc*y2; then**
- **y2 = q/Vc = (Vo/Vc) *yo = (6.9/ 3.7) * 7.6 = 14.2 ft**

Contraction scour depth ys = y2 – yo= 14.2 – 7.6 = 6.6 (say 7) feet

Total Abutment Scour Depth (y2a)

- **y2a ~ 1.4 * y2 = 1.4 * 14.2 = 19.9 ft**

6 Abutment scour (ysa)
ysa = y2a – yo = 19.9 -7.6 = 12 feet.

The estimates of 7 feet of contraction scour and 12 feet of abutment scour should be evaluated in the context of the Office of Structures policies in Chapter 11 to determine the appropriate design for the bridge abutments.

If the bridge foundations include a pier in the waterway, the above information can be input in the pier module in ABSCOUR 10 to compute the pier scour.