

THE SRICOS-EFA COMPUTER PROGRAM FOR BRIDGE SCOUR

Jean-Louis Briaud¹, H.C. Chen², Kiseok Kwak³, Jun Wang⁴, Jinming Xu⁵,

ABSTRACT

The SRICOS-EFA computer program gives the scour depth as a function of time for pier scour, for contraction scour, and for pier and contraction scour combined. The abutment scour option is in the development stage. The SRICOS-EFA computer program can be downloaded free of charge from the internet at <http://ceprofs.tamu.edu/briaud/sricos-efa.htm>. The help menu of the program gives the user's manual and the research report on which the program algorithm is based. This article describes the input and the output of the program as well as some example runs. The input includes the water (hydrograph or 100 and 500 year flood), the soil (erosion functions from EFA tests), and the geometry (pier size, contraction ratio). The output gives the scour depth as a function of time for the input hydrograph, or the risk level for a chosen scour depth.

INTRODUCTION

Scour takes place as a result of the water eroding the soil over which it passes. This process takes place as a function of time and depends on the velocity of the water among other parameters. The SRICOS-EFA computer program predicts the scour depth as a function of time and follows the evolution of the water velocity as a function of time. It relies on the results of the research developed at Texas A&M University over the last 14 years (Briaud et al., 1999, 2001a and b, 2003). The program is free on the internet and can be found at the address <http://ceprofs.tamu.edu/briaud/sricos-efa.htm>. In order to install the program on your computer, simply follow the instructions on the web site: copy the zipped file on your computer, unzip the file, open the folder SRICOS-EFA, click on the file called SETUP.EXE, and follow the instructions on the screen. When the SRICOS-EFA program is installed, start the program and you should see the screen shown in Fig. 1. The requirements for the computer are as follows: Pentium II 266 processor or higher, hard disk with at least 10 megabytes of free space, minimum of 64 megabytes of RAM, mouse, color VGA monitor, operating system: Windows 95, Windows 98, Windows 2000, Windows NT (Service Pack 4 or later), Windows ME or Windows XP. SRICOS-EFA is a Visual C++ application tied with a calculation engine. The calculation engine was originally developed as a DOS program written in FORTRAN 5.0.

1. Professor and Holder of the Buchanan Chair, Dpt. of Civil Engineering, Texas A&M University, College Station, Texas, 77843-3136, USA, (briaud@tamu.edu).

2. Professor, Dpt. of Civil Engineering, Texas A&M University, College Station, Texas, 77843-3136, USA.

3. Senior Researcher, Geotechnical Eng. Div., Korea Institute of Construction Technology 2311, Daehwa-dong, Ilsan-gu, Koyang-city, Kyonggi-do 411-712, Korea.

4. Geotechnical Engineer, Fugro, 6100 Hillcroft Ave., Houston, Texas, 77074, USA.

5. Graduate Student, Dpt. of Mechanical Engineering, Texas A&M University, College Station, Texas, 77843-3136, USA.

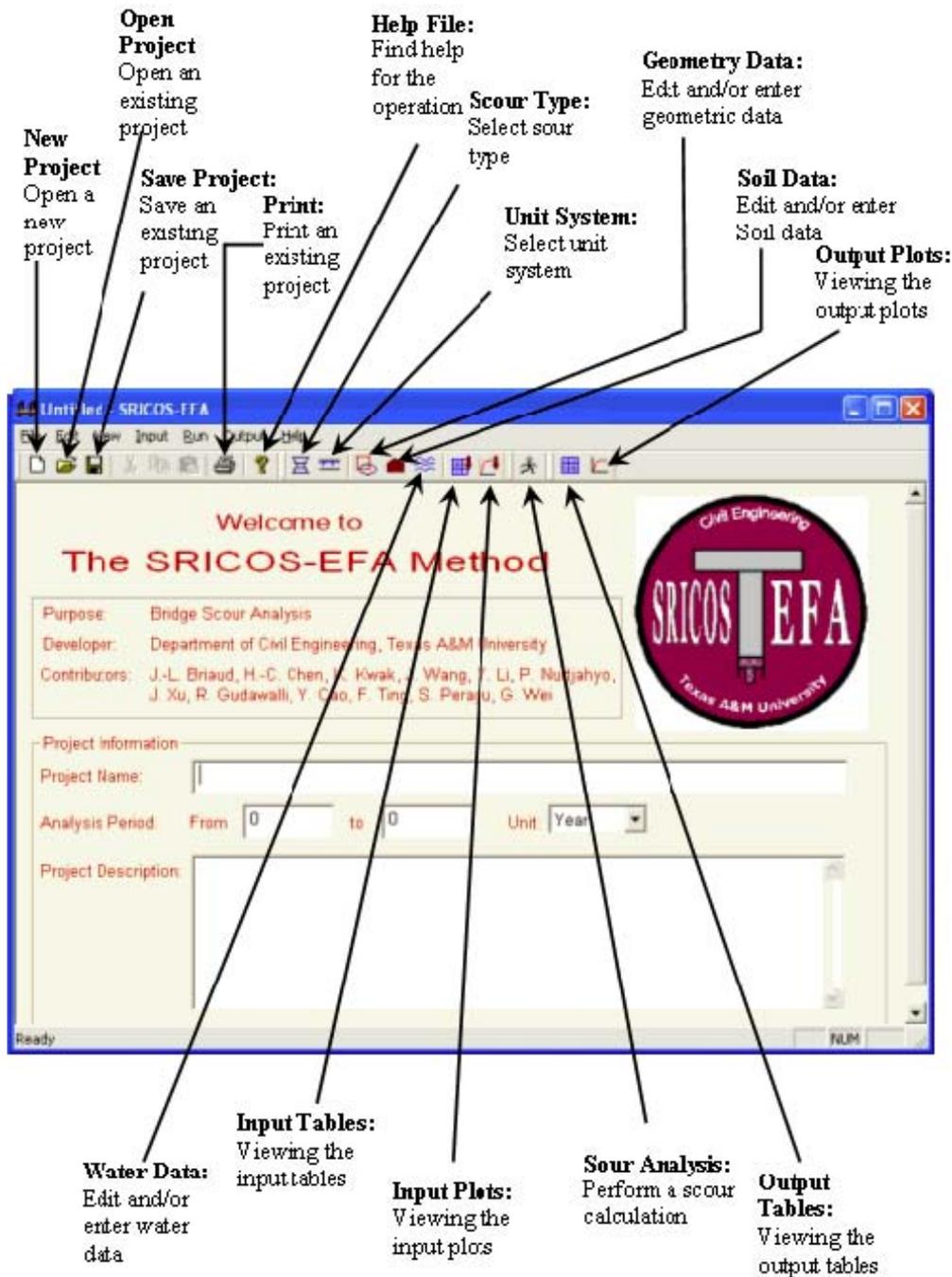


Fig. 1 – Main Screen for the SRICOS-EFA program

UNITS

The units can be SI units (meter, Newton, second) or English customary units (foot, pound, second). The choice (Fig. 2) should be made at the beginning of the input process. If the unit selection is changed during the input process the unit will be changed but the input numbers will not be converted. For example 10 meters would become 10 feet. The units are displayed next to each input number requested.



Fig. 2 – Choice of Units

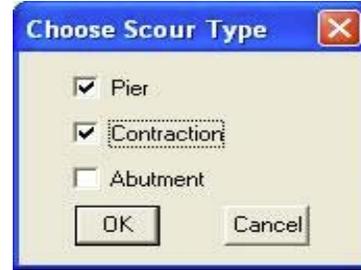


Fig. 3 – Input of scour Type

SCOUR TYPE

The scour type (Fig. 3) that can be solved by the current (2004) version of the SRICOS-EFA program is pier scour alone, contraction scour alone, and pier and contraction scour combined; for this last case, click on both pier and contraction as shown in Fig. 3. In the case of the combined pier and contraction scour, the contraction scour is calculated first using the mean depth velocity in the contracted channel at the location of interest, and then the pier scour is calculated using the critical velocity for the soil. Indeed when the contraction scour is complete, the velocity on the contracted section is reduced to the critical velocity for the soil. This is less conservative than the pure superposition of the two scour types (contraction and pier) using the mean depth velocity in the contracted channel in each case; however, this is often the practice.

INPUTTING THE GEOMETRY

The geometry of the pier scour case (Fig.4) consists of selecting the shape of the piers, the number of piers (row of piers perpendicular to the flow), the length and width of the pier, the channel upstream width, and the angle of attack which is the angle between the direction of the water flow and the main axis of the pier. The geometry of the contraction scour case (Fig. 5) consists of inputting the upstream channel width or un-contracted width,

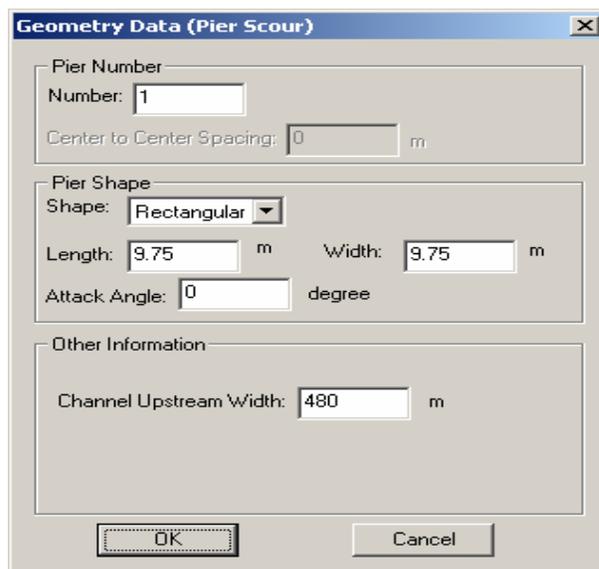


Fig. 4 – Geometry Input for Pier Scour

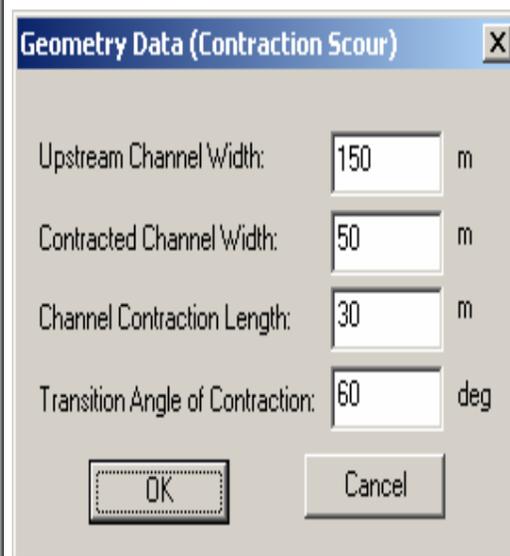


Fig. 5 – Geometry Input for Contraction Scour

the contracted channel width, the length of the contracted section in the direction of the flow, and the angle of the transition between the un-contracted section and the contracted section. For a typical embankment and bridge crossing the river at right angle to the bank, this angle is 90 degrees. Such input for a contraction case requires a certain degree of simplification of the real case and engineering judgment is required to select the best parameters. Current work is aimed at a more complex representation of the contraction scour case where a flood plain and a main channel exist.

INPUTTING THE SOIL PROPERTIES

The soil parameters are input as shown on Fig. 6. They consist of the number of layers, the thickness of each layer, the critical shear stress for each layer, the number of points on the EFA curve and the coordinates of the points on the EFA curve. The EFA is an apparatus used to obtain the erosion function in the laboratory (Briaud et al., 2001a). Note that if the program calculates a scour depth larger than the total thickness of the layers, the program will stop. Ensure that the deeper layer is thick enough to avoid this problem (say 100 meters).

Soil Data (Pier Scour)

Number of Layers: 1

Current Layer: Layer 1

Erodibility Properties (Layer 1)

Layer Thickness: 7.62 m

Critical Shear Stress: 3.9 N / m²

Points on EFA Curve: 7

Point No	Shear Stress (N/m ²)	Scour Rate (mm/hr)
1	2.99	0.02
2	4.36	4.1
3	6.17	20.31
4	11.69	33.09
5	19.56	110.66
6	26.71	575.05
7	45.93	2153.77

OK Cancel

Soil Data (Contraction Scour)

Number of Layers: 2

Current Layer: Layer 2

Erodibility Properties (Layer 2)

Layer Thickness: 20 m

Critical Shear Stress: 10.2 N / m²

Points on EFA Curve: 7

Point No	Shear Stress (N/m ²)	Scour Rate (mm/hr)
1	0.68	0
2	3.98	0.5
3	12.44	4.1
4	19.77	18.21
5	36.71	103.6
6	48.01	425.08
7	58.99	1770.36

OK Cancel

Fig. 6 – Soil Data Input Screen (pier scour and contraction scour)

INPUTTING THE WATER PARAMETERS: HYDROGRAPH APPROACH

With the hydrograph approach, the water data input consists essentially of the water velocity as a function of time over the duration of the chosen hydrograph. This hydrograph is usually a measured hydrograph obtained from a gage station near the bridge considered. The duration of the hydrograph can be tens of years; indeed, the design life of a bridge is 75 years in the USA. For pier scour, the input consists of the time step (usually 24 hours

because that is the usual reading frequency for gauge stations on rivers), the choice between discharge vs. time or velocity vs. time (usually the data comes as discharge vs. time), the choice between a constant velocity (simplest case), a hydrograph, or a risk analysis as discussed in the next paragraph, the hydrograph file (a one column file with the sequence of daily discharges or daily velocities depending on the previous choice), the choice to insert a special flood (Q100 or Q500 for example), the number of points on the discharge vs. velocity curve, the number of points on the discharge vs. water depth curve, and the actual coordinates for the two curves. These curves are usually obtained by using a program like HEC-RAS (1997) which requires the knowledge of the river cross section at the bridge. For contraction scour, additional input is required: the Manning's coefficient, the average river hydraulic radius, and whether the hydrograph gives the upstream velocity or the velocity in the contracted section. If the upstream velocity is input, it is used together with the contraction ratio in the calculations; if the velocity in the contracted section is input, then it is used directly in the calculations. When inserting a special flood, the program will place the flood in the middle of the time scale of the hydrograph. When inserting two floods they are placed at 1/3 and 2/3 of the time scale on the hydrograph.

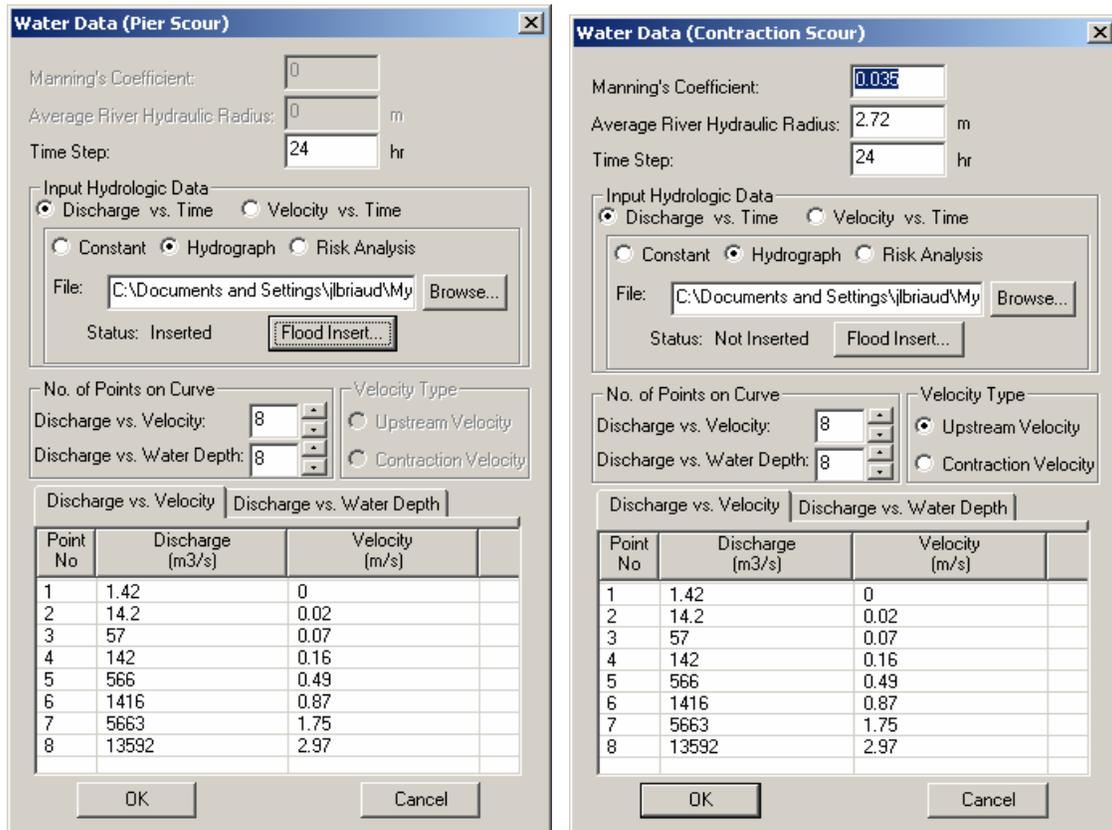


Fig. 7 - Water Data Input Screen for hydrograph (pier scour and contraction scour)

INPUTTING THE WATER PARAMETERS: RISK APPROACH

The risk approach has two options (Fig. 8): the Monte Carlo simulation of hydrographs or the Q100/Q500 approach. In the first case, a measured hydrograph is used to generate a frequency distribution of the discharge, then this distribution is sampled randomly n times

to generate one hydrograph which has the same discharge distribution as the measured hydrograph. The parameter n is equal to the number of days corresponding to the length of the hydrographs. This process is repeated for many such synthetic hydrographs (10,000 synthetic hydrographs generally leads to good results); the computer makes 10,000 times the calculations for one hydrograph which, for example, amounts to 75 years \times 365 days/year = 27375 calculations. The total number of calculations in this example would be 273 million. The time required for such calculations varies with the speed of the processor but may take about 10 minutes on a desk top computer. In the case of the Q100/Q500 approach, a log normal distribution is fitted to the two flood values (Q100 and Q500) and then that distribution is sampled randomly as in the previous approach. This Q100/Q500 approach allows the user to handle scour depth prediction on the basis of the same water input as in the case of cohesionless soils.

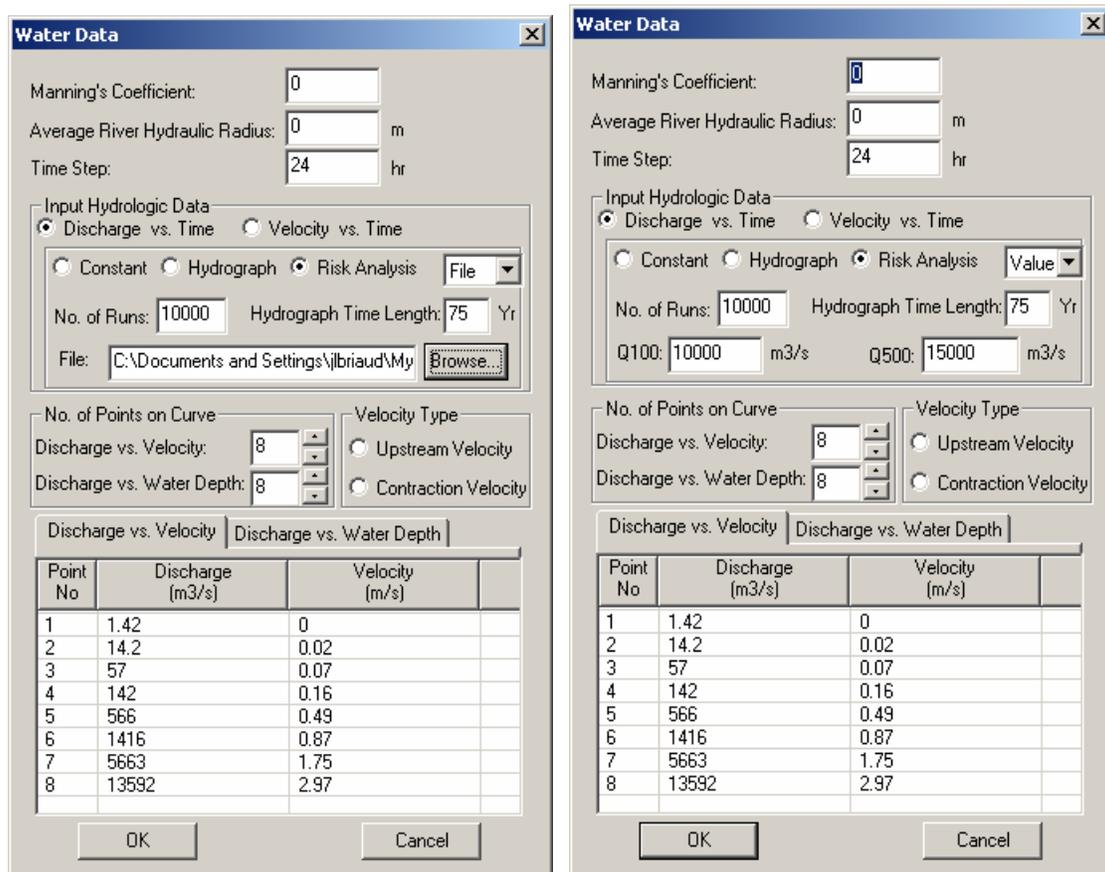


Fig. 8 – Input Screen for the Risk Analysis (hydrograph file and Q100/Q500 approaches)

CHECKING THE INPUT FILE

By clicking on the input tab in the tool bar and then clicking on plots or tables, or by clicking on the icon which shows a table and a plot with a down arrow (for input), the user can check the input prepared. This input is shown in tabular form and in graph form for easy visualization. Fig. 9 shows an example of a measured hydrograph for the Woodrow Wilson bridge over the Potomac River in Washington D.C. spiked with the Q100 at one third of the time (13592 m³/s) and with the Q500 (19822 m³/s) at the two third point. Note

that the maximum discharge occurred in 1972 with 9850 m³/s.

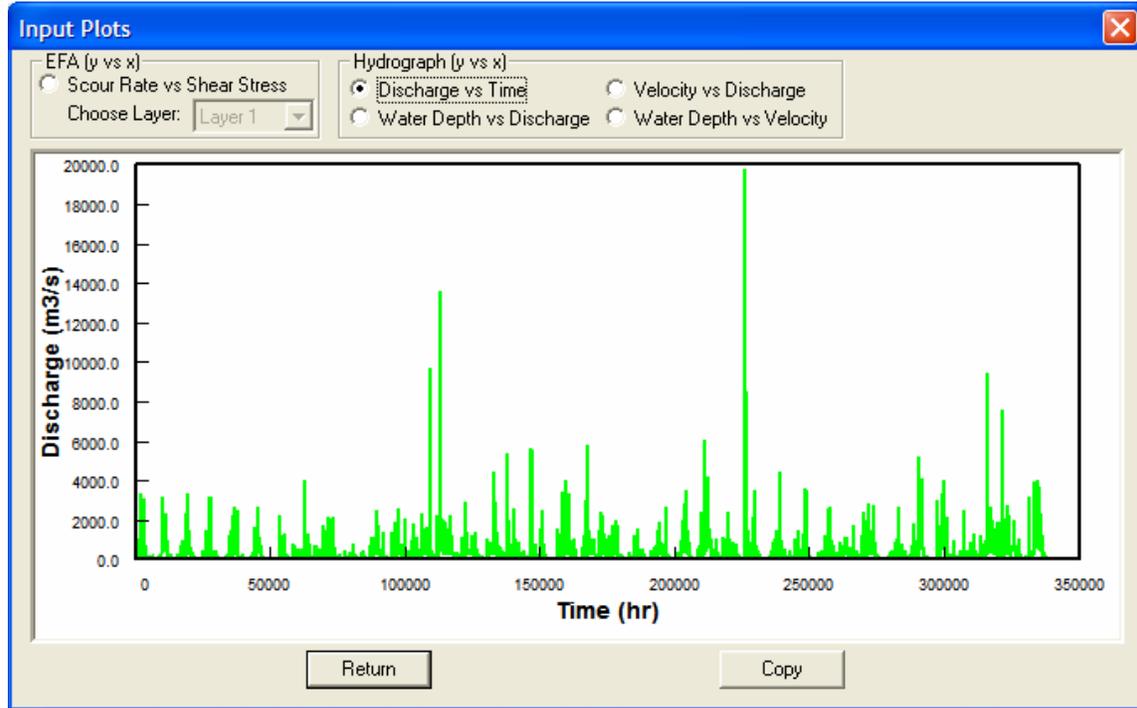


Fig. 9 – Hydrograph spiked with Q100 and Q500 (Woodrow-Wilson Bridge)

RUNNING THE PROGRAM

In order to run the SRICOS-EFA computer program once the input is completed, the user can either click on the run button on the top tool bar or on the icon showing a person running on the second tool bar. The case of one hydrograph takes less than a second and 10,000 hydrographs in the risk analysis mode take about 10 minutes on a recent processor.

OUTPUT FOR A HYDROGRAPH APPROACH

By clicking the output button on the top tool bar or the icon showing a table or a plot on the second tool bar, the user can view the output in tabular form or in graph form. The main output consists of the scour depth vs. time curve (Fig. 10). The user also has the option to view in the same window the velocity, the water depth, the shear stress vs. the same time scale. Fig. 11 to 13 show the results obtained for the pier scour at the main pier of the Woodrow Wilson Bridge in Washington D.C.

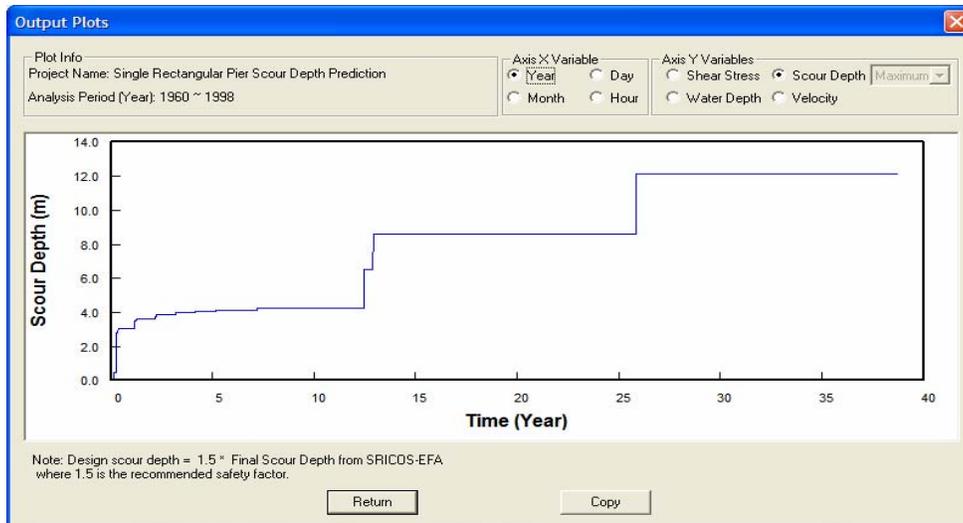


Fig. 10 – Output: Scour Depth vs. Time

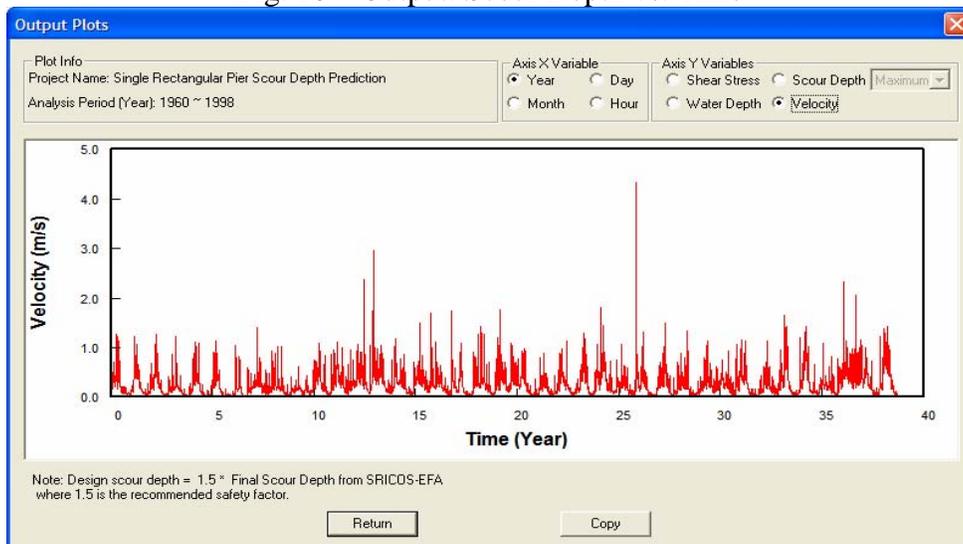


Fig. 11 – Output: Velocity vs. Time

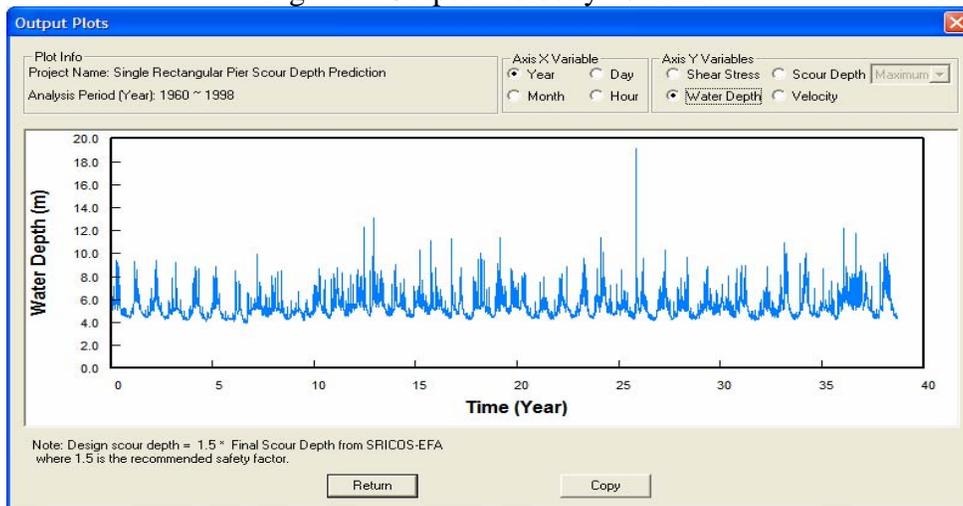


Fig. 12 – Output: Water Depth vs. Time

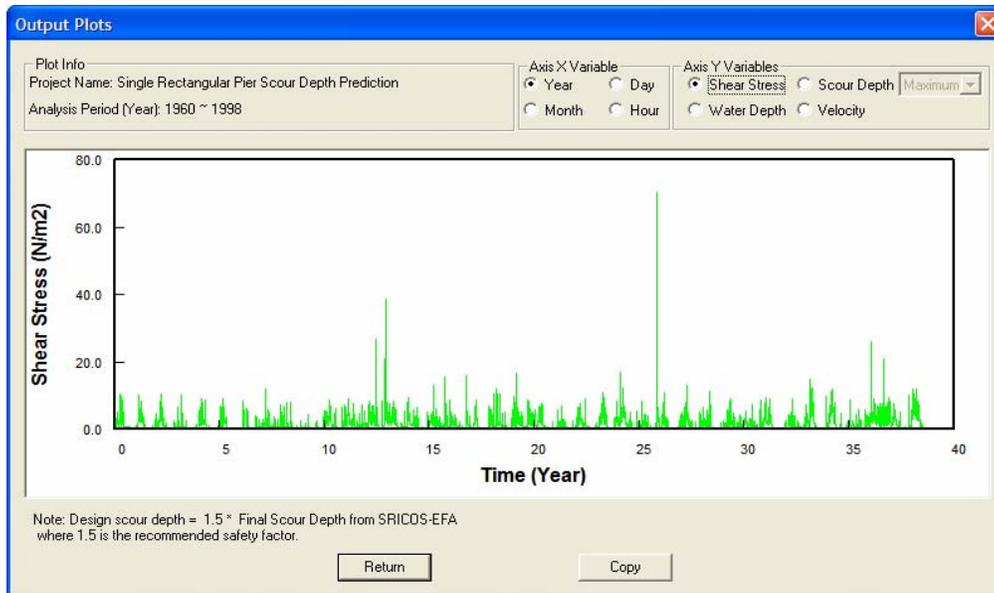


Fig. 13 – Output: Shear Stress vs. Time

OUTPUT FOR A RISK ANALYSIS APPROACH

In the case of a risk analysis approach, the output consists of the frequency of occurrence vs. scour depth (Fig. 14) and the probability of exceedance or risk vs. scour depth (Fig. 15). This output is obtained whether the user chooses the hydrograph approach or the Q100/Q500 approach. A plot like the one of Figure 15 can be used by the engineer to make a decision as to what risk should be used and then read the scour depth corresponding to that risk.

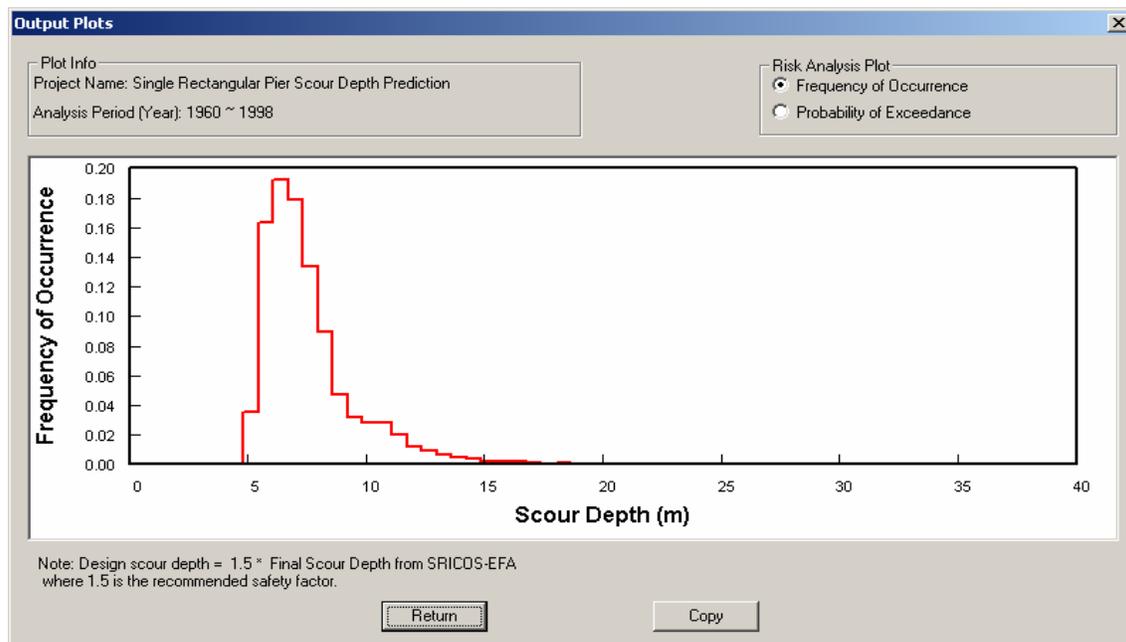


Fig. 13 – Output: Frequency of Occurrence vs. Scour Depth

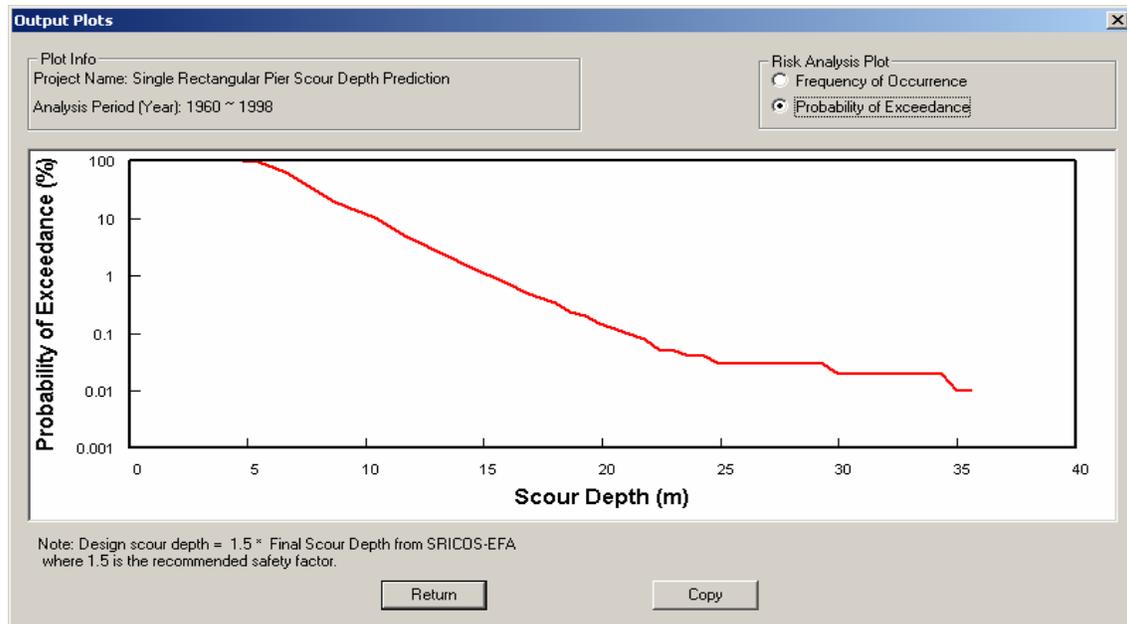


Fig. 13 – Output: Risk vs. Scour Depth

CONCLUSION

The SRICOS-EFA computer program can be downloaded free of charge on the internet at <http://ceprofs.tamu.edu/briaud/sricos-efa.htm>. The program predicts the scour depth for a pier, for several piers in a row perpendicular to the flow, for a contraction in a channel, and for a combination of pier and contraction scour. The input required includes the geometry of the pier or the contraction, the hydrograph describing the water velocity as a function of time, and the erosion function of the soil layers as measured in the Erosion Function Apparatus. The output is the scour depth vs. time curve or the risk associated with choosing a certain scour depth. The module solving the problem of abutment scour is being developed.

ACKNOWLEDGEMENTS

This computer program is the result of 14 years of research and many people have contributed to parts of the process. They are too numerous to list but are thanked for their work. The sponsors include the Texas Department of Transportation and the National Cooperative Highway Research Program.

REFERENCES:

1. **BRIAUD J.-L., TING F. C. K., CHEN H. C., GUDAVALLI R., PERUGU S., WEI G.**, 1999, "SRICOS: Prediction of Scour Rate in Cohesive Soils at Bridge Piers," *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 125, No.4, pp. 237-246, April 1999, ASCE, Reston, Virginia.
2. **BRIAUD J.-L., TING F., CHEN H.C., CAO Y., HAN S.-W., KWAK K.**, 2001a, "Erosion Function Apparatus for Scour Rate Predictions", *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 127, No.2, pp. 105-113, Feb. 2001, ASCE,

- Reston, Virginia.
3. **BRIAUD J.-L., CHEN H.-C., KWAK K., HAN S., TING F.**, 2001b, “Multiflood and Multilayer Method for Scour Rate Prediction at Bridge Piers”, *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 127, No.2, pp. 114-125, Feb. 2001, ASCE, Reston, Virginia.
 4. **BRIAUD J.-L., CHEN H.-C., LI Y., NURTJAHYO P., WANG J.**, 2003, “Complex Pier Scour and Contraction Scour in Cohesive Soils ”, NCHRP Report 24-15, Transportation Research Board, National Research Council, Washington D.C., USA, pp. 266.
 5. **HEC-RAS** River Analysis System, (1997), *User’s Manual, Version 2.0*, Hydrologic Engineering Center, U.S. Army Corps of Engineering, Davis, CA.