6 Input Requirements and Program Output for SAM.hyd

Purpose

SAM.hyd has four main calculation options, with variations within each of these. While some of the input and output are consistent for all options, each calculation option also has specific input data requirements as well as varying output. This chapter will address these specific input data requirements and present an overview of associated output, option by option.

General

SAM.hyd expects an input file designated as *x*.hi, with **no embedded spaces**. SAM.hyd will write a corresponding file *x*.ho, which is the hydraulic calculations output file. All SAM.hyd options except the stable channel calculations also create an *x*.si file, which is an input file to SAM.sed.

SAM.hyd's four calculation options are briefly described below. The first option allows for determination of the unknown variable in the Manning equation, i.e., depth, bottom width in a trapezoidal channel, slope, roughness or discharge. Detailed discussions of the various input requirements follow.

Normal Depth Calculations and Variations offers the user the option of calculating normal depth, bottom width, discharge, energy slope, hydraulic roughness, and flow distribution. Four compositing methods are available. Riprap can be added to most of these calculations.

Stable Channel Dimensions (Copeland Method) will calculate the dependent design variables of width, slope and depth from the independent variables of discharge, sediment inflow and bed material composititon using the analytical approach known as the Copeland Method.

Meander Geometry Calculations will provide both curvilinear and Cartesian coordinates for a meander planform based on the sine-generated curve.

Riprap Size, Known Velocity and Depth, will calculate riprap size according to the procedure in EM 1110-2-1601 (USACE 1991, 1994) for cases when the velocity and depth are given.

Most of the above calculation options have additional options within. These are briefly described below. The input required to trigger these options will be discussed in detail in following sections.

In the uniform flow calculations hydraulic parameters can be calculated by one of four compositing methods: (1) alpha method, (2) equal velocity method, (3) total force method or (4) conveyance method.

Bed-form roughness prediction may be accounted for by using Brownlie's method, which uses velocity, hydraulic radius, slope, particle specific gravity, D_{50} and the geometric standard deviation of the bed sediment mixture.

Regime dimensions using the Blench equation can be calculated when requested with specific input, but this option is not available in SAMwin. (An editor can be used to alter an input file – see Appendix C.) Channel width, depth and slope are calculated as a function of bed-material grain size, channel-forming discharge, bed-material sediment concentration, and bank composition.

Geometry can be simple, as defined by a Channel Template (CT record), or complex, as prescribed by multiple CT records, or with station/elevation data, as in X1/GR-record data sets from HEC-2/HEC-6. In either case the geometry will be transformed into effective hydraulic parameters for sediment transport calculations.

Riprap can be added to most options.

The installation CD contains an example application, and discussion, in the LWV folder. This folder is not copied to the CD during installation, so to review the example application, see the CD.

Program execution

The hydraulic calculations can made in SAMwin by selecting a calculation type from the “Edit” dropdown menu, inputting the data, and selecting “solve,” or from the “Run” dropdown menu, see Figure 6.1. This second option is useful if a ready-to-run data set exists.

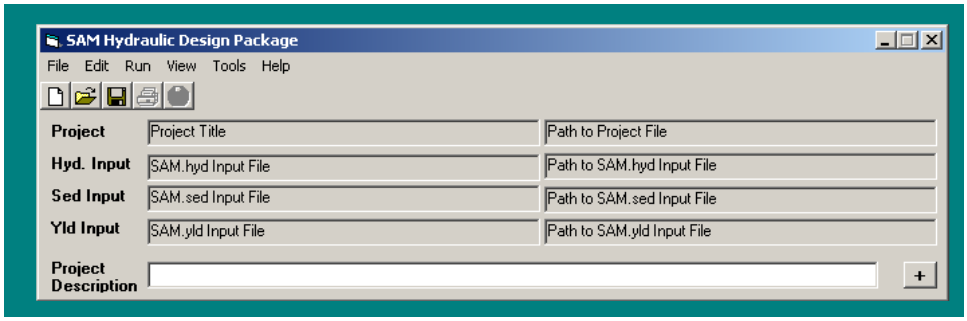


Figure 6.1. Opening window of SAMwin.

Normal Depth Calculations

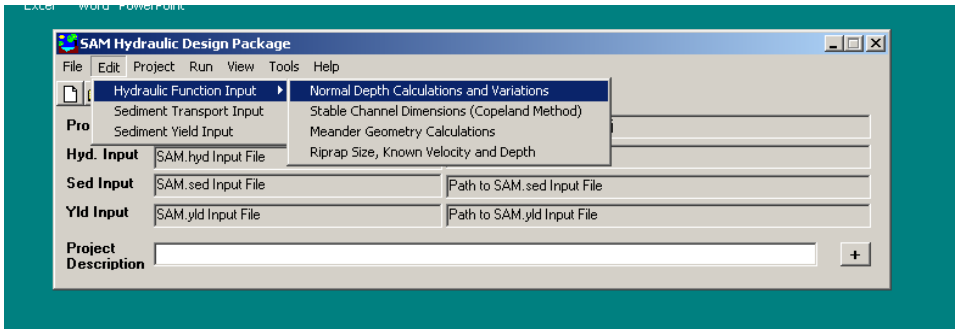


Figure 6.2. Choosing Normal Depth Calculations and Variations.

Input

"Normal Depth Calculations and Variations" selected from within the "Hydraulics Functions Input" menu of the "Edit" drop-down menu is shown in Figure 6.2. This selection will open the screen in Figure 6.3.

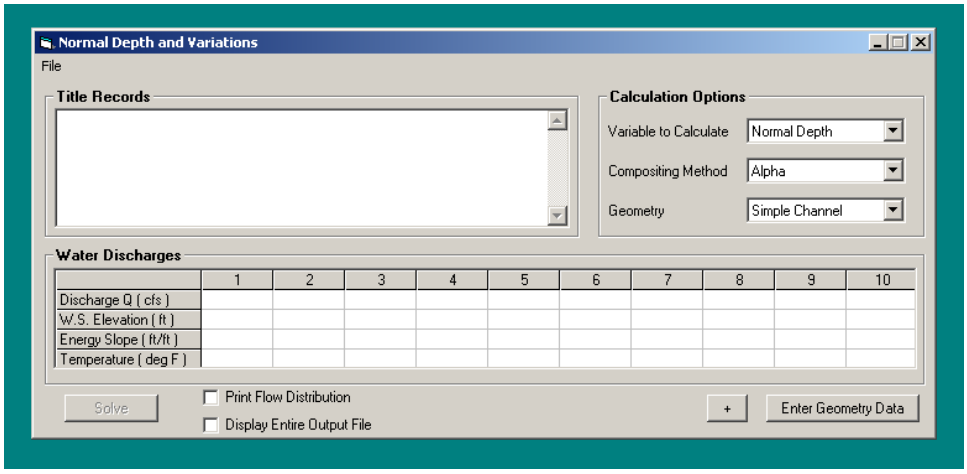


Figure 6.3. Normal Depth and Variations window of SAMwin.

Title Records.

This area allows the user to input descriptive strings, up to about 80 characters long, for use in identifying data sets. Extra characters will be truncated, not wrapped.

Calculation Options.

Variable to Calculate. The dropdown menu allows the user to choose the variable to be calculated without having to leave data blank for that particular variable. Choices are: normal depth, bottom width, energy slope, hydraulic roughness, and water discharge.

Compositing Method. SAM offers four compositing methods: alpha, equal velocity, total force, and conveyance.

Geometry. The three choices here are simple channel (single trapezoidal channel), compound channel (up to three, 'stacked,' trapezoidal channels), and station-elevation.

Flow Data

Water Discharges.

SAM data records accept a maximum of 10 data points per data type. This area allows the user to input discharge (cfs), water surface elevation (ft), energy slope (ft/ft), and temperature (F°)

Enter Geometry Data

This button opens the screen for geometry input according to the choice made in the Calculation Options box. Geometry input will be discussed later.

" + " Box.

This button toggles, opens/closes, a small window which will receive selected output. The output coming to this window cannot be selected by the user.

Print Flow Distribution

When this box is checked, SAM will add the results of the flow distribution calculations to the output file.

Display Entire Output File

When this box is checked the output file will open in its own window (using Notepad) after calculations are complete. If this button is not checked, some input will echo to the screen in an area that will drop down below this entire "Normal Depth and Variations" window. The entire output file can also be viewed by checking the View menu of the SAM main window and selecting "Hydraulic Output File."

Solve

This button causes SAM.hyd to execute. However, SAMwin often "forces" the user to check the geometry. If the Solve button is "greyed out," click on the Geometry button to check the geometry. Be sure to click OK to have the Solve button operational after the Geometry screen closes.

Geometry

The screen that opens here is determined by the Geometry type chosen in the Calculation Options of the screen in Figure 6.3.

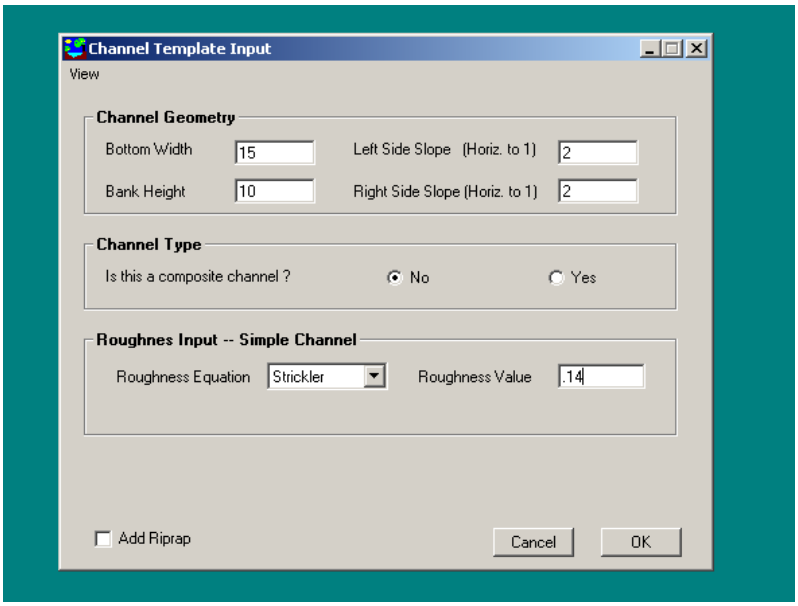


Figure 6-4. Simple Channel screen – showing data for a not composite channel

Simple and Compound Channel. A simple channel is described on either the "Channel Template Input" screen, shown in Figure 6.4, or the "Compound Channel Template" screen, shown in Figure 6.5. The Channel Geometry section of these screens prescribes bottom width, bank height and side slopes for a simple triangular, rectangular, or trapezoidal shape. A plot of the cross-section is

available by clicking the View menu and selecting "Cross Section." The Compound Channel Template can describe up to three, "stacked" shapes in one channel. For example, a low flow channel can be coded on the first tab, followed by a normal flow channel and a high flow berm, as shown in Figure 1A, Chapter 2. **NOTE:** The Compound Channel option requires the discharges to be input in a specific way. See Appendix C, CT Record. Also note that if bottom width calculations are prescribed, the cross section is not sufficiently defined by the input to be plotted by the View menu.

Low Flow Channel Geometry. Bank height must be input even if water surface elevation is being calculated.

Low Flow Channel Type and Low Flow Roughness Input – Simple (or Composite) Channel. These are linked inputs. If the channel described by the geometry in this window has uniform roughness, then that channel is not a composite channel, and only one roughness equation and value are required, as shown in Figure 7.4. However, if the channel and banks either have different roughness values or require different roughness equations, then the channel is a composite channel. Clicking the "yes" button in answer to the "Type" question causes the "Low Flow Roughness" area to change to request the required input, Figure 6.5.

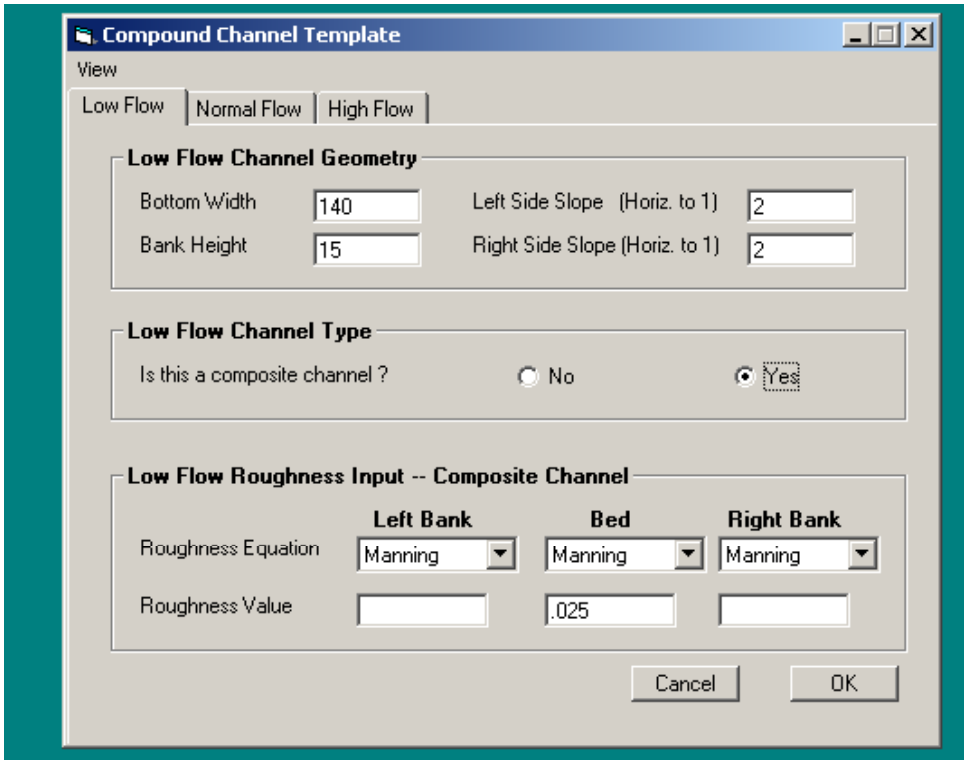


Figure 6.5. Channel template window showing composite channel input.

In addition, if the Limerinos or Brownlie equations are selected, the window further changes to request the "Bed Material Gradation," as shown in Figure 6.6. DMAX is a required input whereas the specific gravity of sediment is optional (the value shown is the default value). The program will accept up to 18 points on the bed material gradation, and they **must** be input from largest grain size to smallest. However, a grain size for 100% finer and for 0% finer is not required.

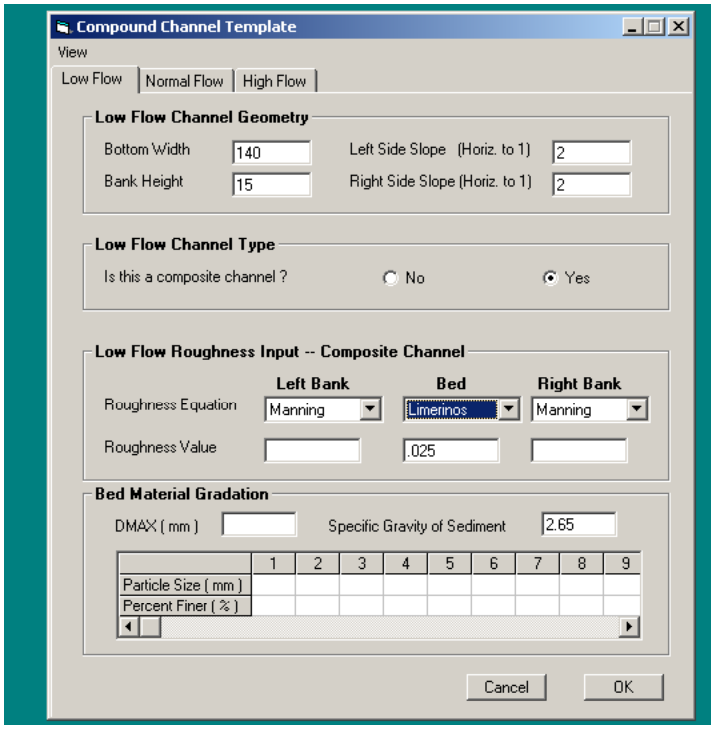


Figure 6.6. Bed Material Gradation input area of the Compound Channel Template.

Station Elevation. Complex channels can be prescribed by station and elevation coordinates. This format is the same as that in HEC-2 and HEC-6. Figure 1B in Chapter 2 shows a typical complex cross section that would be coded in this format. Figure 6.7 shows the input window for this geometry option.

Cross Section Characteristics. River mile is an optional input. The Left and Right bank stations designate the moveable bed and must be points on the cross section, but are also optional in SAM.hyd.

X-Y Coordinates of Channel Cross Section. The user can input up to 100 points. The "Edit" pull down menu offers typical editing functions, including inserting and deleting rows. These edit commands allow the user to cut to or from a columnar spreadsheet, i.e., Microsoft Excel.

Roughness Equations and Roughness Values for Panels. This area will define panels by their station/elevation endpoints and allow the user to input both the roughness equation and value to use for each panel. Roughness equation

choices are listed to the right of the input area. To have hydraulic roughness calculated, put a negative number in the panels involved. Generally a "-1" is used, but the roughness can be prorated by panel. See Appendix C, KS Record, for details of this option.

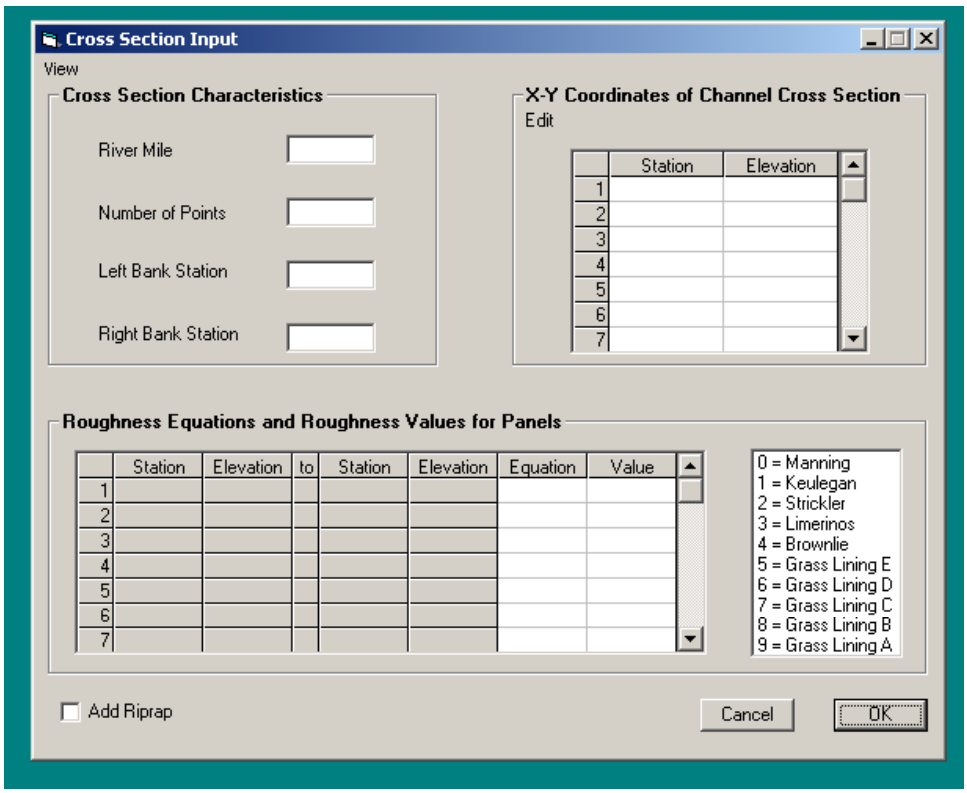


Figure 6.7. Complex geometry input window.

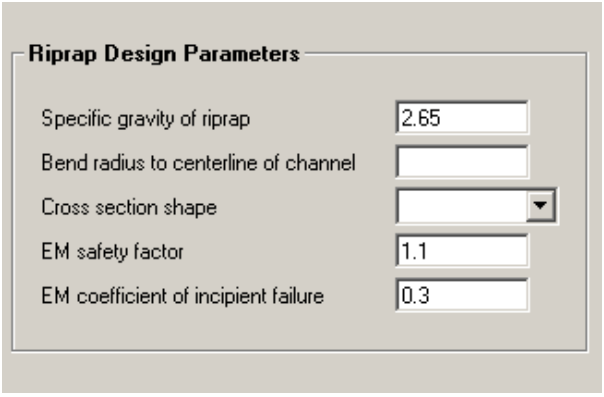


Figure 6.8. Input window added when riprap is requested.

Add Riprap. Checking this box will open the window in Figure 6.8. The numbers already in the input areas are defaults. Cross section shape offers the choice between natural and trapezoidal.

Sample Data Sets

The following examples illustrate input data for normal depth calculations.

```
T1 Test 1A  Calculate normal depth rating curve for Trapezoid
T1           100-ft bottom, 3:1 side slopes, n-value = 0.025, slope = 0.00521, t
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1
CT   100      10       3       3       0    .025
QW   100    1000    5000   10000   20000
ES.00521
WT    50
$$END

T1 Test 1B  same as 1A except using station-elevation geometry
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1
X1     1       4
GR    10     -80       0     -50       0      50      10      80
KN  .025
NE     0
QW  5000
ES.00521
WT    50
$$END


T1 Test 1C  same as 1A except using Brownlie n-value for bed & Strickler for ban
T1     requires bed gradation input;  ask for flow distribution printout
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1       1
CT   100      10       3       3       4               2      .5       2      .5
PF                              1      .8      98     .48      50     .25      16
QW   100    1000    5000   10000   20000
ES.00521
WT    50
SP  2.65
$$END

T1 Test 1D   Calculate normal depth in a Concrete lined, rectangular channel
T1                 Tubeworm roughness below sea level
T1                 Fish rests in center of channel
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     2
X1     1       8
GR    12   -16.5       0   -16.5     -12   -16.5     -12      -2     -12       2
GR   -12    16.5       0    16.5      12    16.5
KN  .007     .10    .007    .035    .007     .10    .007
NE     1
QW  6900
ES.00380
WT    55
$$END
```

Sample Output Data

Selected results are printed to the drop down notebook area of the "Normal Depth and Variations" screen. The user has no control over what prints to this display. The complete output is saved in the appropriate default output file. This file will open upon program execution completion if the "Display Entire Output File" box is checked. Otherwise, the View option on the main screen can be used.

The hydraulic parameters needed for sediment transport calculations are written into the default sediment input file along with the other data needed for calculating sediment transport capacity.

The following output description is from TEST 1C, as given. Note that the Flow Distribution information was requested.

NOTE: The table numbers may change in other output files, depending on the calculation option chosen.

```
*******************************************************************************
*                                                                             *
*      SAMwin   ---   HYDRAULIC DESIGN PACKAGE FOR FLOOD CONTROL CHANNELS     *
*                                                                             *
*                          HYDRAULIC CALCULATIONS                             *
*                                                                             *
*                               Version 1.0                                   *
*                                                                             *
*           A Product of the Flood Control Channels Research Program          *
* Coastal & Hydraulics Laboratory, USAE Engineer Research & Development Center *
*                                                                             *
*                            in cooperation with                              *
*                                                                             *
*               Owen Ayres & Associates, Inc., Ft. Collins, CO                *
*                                                                             *
*******************************************************************************

 Msg 1:  HYD. READING INPUT DATA FROM FILE [  C:\Hold\hydtests.hi  ] THIS
DIRECTORY.
TABLE  1.  LIST INPUT DATA.

 T1 Test 1C  same as 1A except using Brownlie n-value for bed & Strickler for ban
 T1     requires bed gradation input;  ask for flow distribution printout
 TR     1       1
 CT   100      10       3       3       4               2      .5       2      .5
 PF                              1      .8      98     .48      50     .25      16
 QW   100    1000    5000   10000   20000
 ES.00521
 WT    50
 SP  2.65
 $$END

 INPUT IS COMPLETE.

 BED SEDIMENT GRADATION CURVE, PERCENT FINER.
 SIZE, MM=    0.250   0.500   1.000
    %,   =   16.000  53.836 100.000

 D84(mm)=    0.786  D50(mm)=   0.466  D16(mm)=   0.250  Geom Std Dev=   1.8

                        TABLE  2-1.  CROSS SECTION PROPERTIES
  #    STATION     ELEV   ROUGHNESS  N-VALUE :     GROUND     : DELTA Y   RIPRAP
         FT         FT      HEIGHT  EQUATION :SLOPE     ANGLE :    FT    Dmax*[ ]

   1     -80.0     10.00
                        0.5000      STRICKLE    -3.00    -18.4    -10.00     0.0
   2     -50.0      0.00
                        0.1529E-02  BROWNLIE     0.00      0.0      0.00     0.0
   3      50.0      0.00
                        0.5000      STRICKLE     3.00     18.4     10.00     0.0
   4      80.0     10.00

         TOP     MINIMUM     TOTAL
        WIDTH     ELEV       DEPTH
        160.0       0.00     10.00
```

INEFFECTIVE FLOW ELEVATIONS BY STRIP NO.
1 2 3
-9999.0

TABLE 2-2. PHYSICAL PROPERTIES.
ACCELERATION OF GRAVITY = 32.174

TABLE 2-3. PROPERTIES OF THE WATER

#	TEMP DEG F	RHO #-S2/FT4	VISCOSITY *100000 SF/SEC	UNIT WT WATER #/FT3
1	50.	1.940	1.411	62.411
2	50.	1.940	1.411	62.411
3	50.	1.940	1.411	62.411
4	50.	1.940	1.411	62.411
5	50.	1.940	1.411	62.411

TABLE 8-1. CALCULATE NORMAL DEPTH; COMPOSITE PROPERTIES BY ALPHA METHOD.

**** N	Q CFS	WS ELEV FT	TOP WIDTH FT	COMPOSITE R FT	SLOPE ft/ft	COMPOSITE n-Value	VEL FPS	FROUDE NUMBER	SHEAR STRESS #/SF
**** 1	100.	0.36	102.2	0.36	0.005210	0.0199	2.73	0.80	0.12

TABLE 8-2. FLOW DISTRIBUTION. Q = 100.000 ALFA= 1.009

STATION	INC. %Q	area sqft	perm ft	r= a/p	Ks ft	n value	vel fps	taup #/sf	CMT
-80.0									
	0.21	0.2	1.1	0.17	0.5000	0.0305	1.09	0.0188	R S
-50.0									
	99.57	36.2	100.0	0.36	0.8252E-01	0.0198	2.75	0.0710	RTB
50.0									
	0.21	0.2	1.1	0.17	0.5000	0.0305	1.09	0.0188	R S
80.0									
	100.00	36.6	102.3	0.36	0.8433E-01	0.0199	2.73	0.0704	

**** N	Q CFS	WS ELEV FT	TOP WIDTH FT	COMPOSITE R FT	SLOPE ft/ft	COMPOSITE n-Value	VEL FPS	FROUDE NUMBER	SHEAR STRESS #/SF
**** 2	1000.	1.27	107.6	1.26	0.005210	0.0165	7.59	1.20	0.41

TABLE 8-2. FLOW DISTRIBUTION. Q = 1000.00 ALFA= 1.040

STATION	INC. %Q	area sqft	perm ft	r= a/p	Ks ft	n value	vel fps	taup #/sf	CMT
-80.0									
	0.61	2.4	4.0	0.60	0.5000	0.0305	2.51	0.0621	R S
-50.0									
	98.79	126.9	100.0	1.27	0.2412E-01	0.0161	7.79	0.3495	RUB
50.0									
	0.61	2.4	4.0	0.60	0.5000	0.0305	2.51	0.0621	R S
80.0									
	100.00	131.7	108.0	1.26	0.2776E-01	0.0165	7.59	0.3359	

```
**** N     Q       WS     TOP COMPOSITE  SLOPE COMPOSITE VEL  FROUDE  SHEAR
                 ELEV   WIDTH    R             n-Value       NUMBER  STRESS
          CFS     FT     FT      FT     ft/ft           FPS            #/SF

**** 3    5000.    3.42   120.5   3.36 0.005210 0.0181  13.26   1.28   1.09
```

TABLE 8-2. FLOW DISTRIBUTION. Q = 5000.00 ALFA= 1.100

STATION	INC. %Q	area sqft	perm ft	r= a/p	Ks ft	n value	vel fps	taup #/sf	CMT
-80.0									
	1.71	17.5	10.8	1.62	0.5000	0.0305	4.86	0.1680	R S
-50.0									
	96.59	342.0	100.0	3.42	0.3042E-01	0.0172	14.12	0.9019	RUB
50.0									
	1.71	17.5	10.8	1.62	0.5000	0.0305	4.86	0.1680	R S
80.0									
	100.00	377.1	121.6	3.36	0.4422E-01	0.0181	13.26	0.8150	

TABLE 8-4. HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT

Q NO	STRIP NO	STRIP Q CFS	---EFFECTIVE--- WIDTH FT	DEPTH FT	SLOPE FT/FT	n-VALUE	EFF. VEL. FPS	Froude NO	TAU Prime #/SF
1	1	100.	101.3	0.36	0.005210	0.0198	2.74	0.80	0.071
2	1	1000.	104.4	1.25	0.005210	0.0161	7.64	1.20	0.339
3	1	5000.	112.1	3.32	0.005210	0.0172	13.45	1.30	0.834
4	1	10000.	118.6	4.98	0.005210	0.0177	16.94	1.34	1.211
5	1	20000.	128.5	7.38	0.005210	0.0183	21.09	1.37	1.729

TABLE 8-5. EQUIVALENT HYDRAULIC PROPERTIES FOR OVERBANKS AND CHANNEL DISTRIBUTED USING CONVEYANCE

N	STRIP NO	HYDRAULIC RADIUS ft	MANNING n-VALUE	.....SUBSECTION..... DISCHARGE cfs	AREA sqft	VELOCITY fps
1	1	0.36	0.0198	100.00	36.61	2.73
2	1	1.22	0.0161	1000.00	131.71	7.59
3	1	3.10	0.0172	5000.00	377.08	13.26
4	1	4.53	0.0177	10000.00	602.54	16.60
5	1	6.51	0.0183	20000.00	976.11	20.49

```
...END OF JOB...
```

General Tables The banner will reflect the version and date of the particular code being used. Table 1 simply echoes the input. Table 2-1 gives information on the cross-section properties before any calculations are made. Table 2-2 shows the acceleration of gravity. Table 2-3 shows the properties of water as calculated from the specified temperature and assuming sea level elevation.

Normal Depth Table Table 8-1 gives the normal depth calculated using the specified compositing method, which in this example is the alpha method. Also given are composite variables for the entire cross section. Since the alpha method is specified, the composite hydraulic radius, $\overline{R}$, is calculated by a conveyance weighted procedure using the panels between every point defining the cross section. For the conveyance, equal velocity, and total force methods,

the composite hydraulic radius is calculated as the total area divided by the total wetted perimeter.

For the alpha method:

$$\overline{R} = \frac{\sum_{i=1}^{k} R_i C_i A_i \sqrt{R_i}}{\sum_{i=1}^{k} C_i A_i \sqrt{R_i}}$$

For the conveyance, equal velocity, and total force methods:

$$\overline{R} = \frac{\sum_{i=1}^{k} A_i}{\sum_{i=1}^{k} P_i}$$

where:

k = the number of panels
i = the panel number
$\underline{R}$ = the composite hydraulic radius
$\overline{R}_i = A_i / P_i$
C_i = the panel Chezy roughness coefficient
A_i = the panel cross-sectional area
P_i = the wetted perimeter

The composite roughness coefficient, $\overline{n}$, is calculated using the composite R in the Manning equation:

$$\overline{n} = \frac{1.486\ \overline{R}^{\frac{2}{3}}\ S^{\frac{1}{2}} \sum_{i=1}^{k} A_i}{Q}$$

where:

S = energy slope
Q = total discharge

Other results in Table 8-1 are calculated as follows:

$$\overline{V} = \frac{Q}{\sum A_i}$$

$$Froude\ Number = \frac{\overline{V}}{\sqrt{EFD * g}}$$

$$\tau = \gamma \overline{R} S$$

where:

$\underline{V}$ = average velocity
EFD = effective depth
g = acceleration of gravity
τ = bed shear stress
γ = unit weight of water

Flow Distribution Table. Table 8-2 gives the flow distribution for each panel of the cross section. The conveyance weighted discharge percentage for each panel, Q_i , is calculated by the following equation:

$$Q_i = 100\, Q \left(\frac{C_i\, A_i \sqrt{R_i}}{\sum C_i\, A_i \sqrt{R_i}} \right)$$

Area, wetted perimeter, and hydraulic radius are reported for each panel. Panel hydraulic radius, R_i , is defined as A_i/P_i. k_s and *n* are calculated or given for each panel. Velocity, V_i , is defined as Q_i/A_i. If no bed gradation is specified:

$$\tau = \gamma\, D_i\, S$$

where:

D_i = average depth in the panel

If a bed gradation is specified, then τ in the table is the grain shear stress calculated using a combination of the Manning and Limerinos equations, where R' is the hydraulic radius associated with grain roughness and is determined from the following:

$$\frac{V_i}{\sqrt{g\ R'_i\ S}} = 3.28 + 5.75 \log \frac{R'_i}{d_{84}}$$

and the grain shear stress is calculated as:

$$\tau'_i = \gamma\ R'_i\ S$$

The **CMT column** consists of 6 columns of single letter codes. The first 3 columns define the flow type, which is considered to be rough if

$$\frac{\frac{4\ R_i V_i}{\nu} k_{si}}{C_i R_i} \geq 50$$

where:

v = kinematic viscosity

If the flow is rough, an R appears in the third column. Otherwise T/S, standing for transitional to smooth flow, appears in **columns 1 through 3**.

Other nomenclature in **columns 1 through 3** are "V:O", indicating that this panel has a vertical wall, and "DRY", indicating that there is no water in this panel.

The **fourth column** is used to define the flow regime, if the Brownlie equations are specified, or to identify that the SCS grass equations are being used.

U - upper bed regime
T - transitional
L - lower bed regime
G - indicates the equation flagged in column 6 is a grass equation.

The **last column** indicates the roughness equation used for the panel.

B - Brownlie
K - Keulegan
L - Limerinos
M - Strickler (Manning)
A,B,C,D,E - various grass equations if the fourth column was a “G” .

At the bottom of the table are summaries. The numbers below the solid line are totals for the column. The numbers below the dashed line are composite values for the cross-section, calculated the same as in Table 8-1.

In the output for TEST 1C, notice that for Q = 100, the panel between stations 50.0 and 80.0 has a calculated n-value of 0.0305. The comment column for this panel shows "R S", indicating rough flow and that the Strickler method was used. The input data requested Keulegan, but, **NOTE**, SAM will not apply Keulegan if $k_s/R < 3$. It automatically substitutes Strickler.

The Normal depth Table 8-1 and the Flow Distribution Table 8-2 are repeated for every discharge prescribed on the QW-record. The composite hydraulic parameters for each discharge are highlighted between the flow distribution tables, with "****". In the example output included in this chapter, the printout for discharges 4 and 5 have been omitted.

Hydraulic Parameters for Sediment Transport Table The results printed in Table 8-4 are representative hydraulic parameters for making sediment transport calculations. The effective velocity, depth, width and slope are calculated for both overbanks and the channel. EFFECTIVE WIDTH, EFW, and EFFECTIVE DEPTH, EFD are defined by the following equations:

$$EFD = \frac{\Sigma\, d_i \;\; A_i \, d_i^{\,2/3}}{\Sigma\, A_i \;\; d_i^{\,2/3}}$$

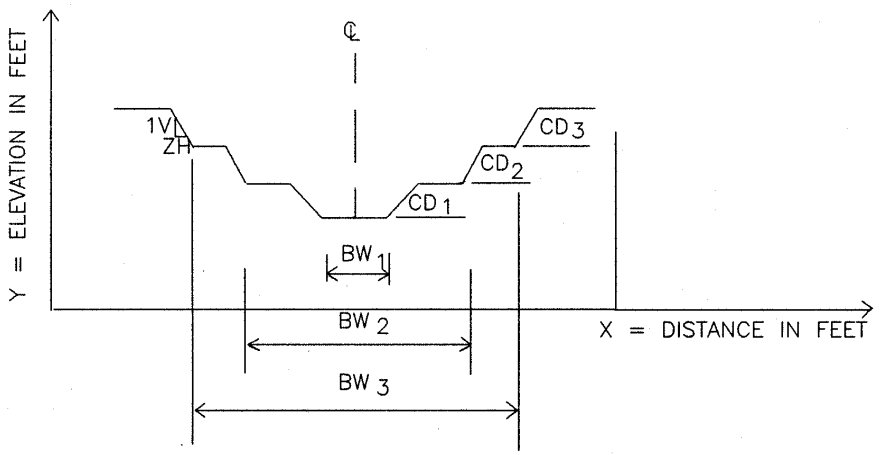
$$EFW = \frac{\Sigma\, A_i \, d_i^{\,2/3}}{EFD^{5/3}}$$

where:

Ai = flow area of each trapezoidal element
di = average water depth of each trapezoidal element

Equivalent Hydraulic Properties for overbanks and channel Flow distribution and conveyance-weighted hydraulic parameters are calculated for the overbanks and channel and listed in Table 8-5. The water-surface elevation that was calculated using the specified compositing method determines channel and overbank subareas and wetted perimeters. Conveyance for each subarea is calculated using the Chezy equation and conveyance weighted discharges determined. Using the area, wetted perimeter, discharge, and slope for the three subareas, a composite n value is calculated for the channel and both overbanks.

Plotting The following hydraulic output plots should be available: stage versus n-value; stage versus average velocity in cross section; stage versus effective velocity; stage versus discharge; stage versus width; stage versus effective width; stage versus hydraulic radius; cross section geometry; and, slope versus width.



1V:ZH -- definition of the side slopes, with the Z as the input parameter
CD1 -- the height of the low flow channel
CD2 -- the incremental height of the normal channel
CD3 -- the incremental height of the high flow channel
BW1 -- the width, toe to toe, of the low flow channel
BW2 -- the width, toe to toe, of the normal channel
BW3 -- the width, toe to toe, of the high flow channel
Note: therefore total depth = CD1+CD2+CD3

Figure 6.9. Definition of input for bottom calculations for compound channels.

Bottom Width Calculations: Input and Output

Bottom width of a simple or compound channel can be determined with this option. Roughness and compositing are handled the same as described for normal depth calculations. Bottom width becomes the dependant variable in the Manning equation:

$$W = f(Q, n, D, z, S)$$

where

W = bottom width
Q = water discharge
n = n-value
D = water depth
z = side slopes of the channel
S = energy slope

Bottom Width must be selected in the "Variable to Calculate" drop down box on the "Normal Depth and Variations" screen, Figure 6-3.

Geometry input

Either the "Simple Channel" or the "Compound Channel" method for inputting geometry is permitted in this calculation; but not the station/elevation method. Note that the water surface elevation, on the "Normal Depth and Variations" screen does not have to be given a value for the bottom width calculations. The bank height input on the "Compound Channel Template" screen sets a limiting depth on the channel.

Simple Channel. To calculate bottom width for a simple channel, put only 1 discharge in the "Flow Data" area, Figure 6-3.

Compound Channel. To calculate bottom width for a compound channel, use the "Compound ChannelTemplate" screen, Figure 6-6. The number of discharges input on the "Flow Data" area **must** match the number of "tabs" filled out. Also, the discharges must be in low-normal-high flow channel order. **NOTE:** The requirements for discharge input in this calculation are different from those for all other hydraulic calculations.

Input for Compound Channel Calculations. The 'bank heights' requested on the "Compound Channel Template" screen are the heights represented by CD1, CD2, and CD3 in Figure 6.9. Each of these heights is *incremental*; each is for its own section of the channel (see Figure 6.9). For example, in Test 2B, below, the maximum depth for the normal channel is 13 ft (3+10); the maximum depth in the high flow channel is 28 ft (3+10+15). The program will increase the calculated bottom width to convey the prescribed discharge rather than increase the depth beyond that 28 ft. The calculated water surface, and depth, is the distance from the low flow channel invert to the water surface. The discharge input is the *total* discharge (input on the "Flow Data" area of the "Normal Depth and Variations" screen).

Sample Input Data

The following example shows input data when calculating bottom width. The difference between this input and that required to calculate normal depth is bottom width, CT record field 1, is left blank by SAMwin. Also note no water surface is prescribed.

```
T1 Test 2A   Calculate bottom width in simple x-section
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1
CT             3       3       3       4              2      .3       2      .3
PF                             1      .8      98     .48      50     .25      16
QW  6000
ES .0050
WT    65
SP  2.65
$$END
```

```
T1   TEST 2B Bottom Width Calculations for Compound channel
T1                     Low Flow, Normal and High Flow channels defined
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
CT             3       3       3       4               2      .3       2      .3
CT            10       3       3       4               2      .3       2      .3
CT            15       3       3       4               2      .3       2      .3
PF                             1      .8      98     .48      50     .25      16
QW   600   12000   85000
ES .0030
WT   65.
$$END
```

Sample Output Data

The following output is taken from the output from Test 2A, above. The general output tables from these calculations are described earlier. However, note that table series "8-*x*" has become "5-*x*". The information contained in the two series of tables is the same, with the title of the "*x*-1" table flagging both the calculation performed and the compositing method used. **NOTE**: The calculated bottom width is shown in Table 5-1 as "Bottom Width" and is not flagged as having been calculated.

```
TABLE  5-1.  CALCULATE BOTTOM WIDTH;  COMPOSITE PROPERTIES BY ALPHA METHOD.

**** N     Q       WS    BOTTOM    R       SLOPE     n       VEL  FROUDE  SHEAR
                 ELEV    WIDTH                    Value          NUMBER  STRESS
         CFS       FT      FT      FT     ft/ft             FPS             #/SF

**** 1    6000.    3.00   153.1   2.97 0.005000 0.0175  12.34   1.27   0.92


    TABLE  5-4.  HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT
     Q STRIP  STRIP        ---EFFECTIVE---     SLOPE    n-     EFF.  Froude
   TAU
    NO   NO      Q            WIDTH   DEPTH            VALUE   VEL.     NO
   Prime
               CFS              FT      FT     FT/FT           FPS
   #/SF
     1   1    6000.           163.6   2.95 0.005000 0.0170  12.45   1.28
   0.729


    TABLE  5-5.  EQUIVALENT HYDRAULIC PROPERTIES FOR OVERBANKS AND CHANNEL
                 DISTRIBUTED USING CONVEYANCE
     N  STRIP  HYDRAULIC   MANNING .........SUBSECTION...........
          NO     RADIUS    n-VALUE DISCHARGE     AREA    VELOCITY
                   ft                 cfs        sqft       fps

     1     1       2.83     0.0170   6000.00     486.35    12.34
```

The following output is from Test 2B, above. Note the "**** 1" lines from the example above and the example below – the bottom widths are very different, because the discharges prescribed are very different and the maximum depth is 3, as prescribed by the bank height input in both. Also note that the "WS ELEV FT" in Table 5-1 is cumulative (the distance from the low flow channel invert to

the water surface), i.e., the 85,000 cfs discharge fills the 28 ft of depth prescribed by the bank heights, causing the high flow channel to gain width. Each bottom width given in Table 5-1 is the width of that channel, from toe of slope to toe of slope, as shown in Figure 6.9.

Occassionally the following warning message will appear:

```
ABNORMAL TERMINATION OF WIDTH CALCULATION.
   SUCCESSIVE ITERATIONS ARE NOT IMPROVING THE CONVERGENCE.
```

The program will then print values on the "****" lines anyway. The warning indicates problems encountered when trying to converge on an appropriate width. To check the answer for reasonableness, use the calculated bottom width as input to the water surface elevation calculations. If the water surface then calculated is close to that the bottom width calculations printed, then the answer is reasonable.

TABLE 5-1. CALCULATE BOTTOM WIDTH; COMPOSITE PROPERTIES BY ALPHA METHOD.

**** N	Q	WS ELEV	BOTTOM WIDTH	R	SLOPE	n Value	VEL	FROUDE NUMBER	SHEAR STRESS
	CFS	FT	FT	FT	ft/ft		FPS		#/SF
**** 1	600.	3.00	16.5	2.74	0.003000	0.0203	7.83	0.85	0.51
**** 2	12000.	13.00	41.1	10.46	0.003000	0.0254	15.23	0.84	1.96
**** 3	85000.	28.00	145.2	20.32	0.003000	0.0258	23.34	0.91	3.80

Energy Slope Calculation: Input and Output

Energy slope can be determined with this option, where slope becomes the dependant variable in the Manning equation:

$$S = f\,(W, Q, n, D, z, S)$$

Geometry, roughness, compositing, and plotting are handled the same as described for the normal depth calculations. Choose "Energy Slope" as the "Variable to Calculate."

Sample Input Data

The following example shows input data when calculating energy slope. Notice that it is the same as shown for Normal Depth except that the WS-record is present and the ES-record is missing. The missing ES-record tells SAM to calculate the slope.

```
TI   TEST NO. 4  CALCULATE ENERGY SLOPE
TI     1       2       3       4       5       6       7       8       9     10
F#  345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
CT     100      10       3       3       2     .02       2      .2       2      .2
QW    4050
WS    3.07
WT      55
$$END
```

Sample Output Data

The general output tables from these calculations are described earlier. However, note that table series "8-*x*" has become "6-*x*". The information contained in the two series of tables is the same, with the title of the "*x*-1" table flagging both the calculation performed and the compositing method used. Also note that the calculated slope is shown in Table 6-1 as "Slope" and is not flagged as having been calculated.

TABLE 6-1. CALCULATE ENERGY SLOPE; COMPOSITE PROPERTIES BY ALPHA METHOD.

**** N	Q	WS ELEV	TOP WIDTH	R	SLOPE	n Value	VEL	FROUDE NUMBER	SHEAR STRESS
	CFS	FT	FT	FT	ft/ft		FPS		#/SF
**** 1	4050.	3.07	118.4	3.01	0.005203	0.0185	12.08	1.23	0.98

TABLE 6-4. HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT

Q NO	STRIP NO	STRIP Q	---EFFECTIVE--- WIDTH	DEPTH	SLOPE	n- VALUE	EFF. VEL.	Froude NO	TAU Prime
		CFS	FT	FT	FT/FT		FPS		#/SF
1	1	4050.	110.8	2.99	0.005203	0.0177	12.24	1.25	0.969

Hydraulic Roughness Calculations: Input and Output

In this calculation roughness becomes the dependant variable in the Manning equation, thus calculating that variable:

$$W = f(Q, n, D, z, S)$$

Geometry, compositing and plotting are handled as described for normal depth calculations. This calculation, like the other solutions of the Manning equation which involve compositing, is trial and error. A simple solution of the Manning equation is used to calculate the first trial roughness coefficient. Of the several equations for hydraulic roughness, the Strickler (Manning) equation is the most likely to converge. The Brownlie equation may have trouble converging due to the discontinuity associated with the transition zone.

Sample Input Data

The following example shows input data when calculating k_s. Note the KN record in Test 4B, and field 6 on the CT record in Test 4A. The negative values flag the program to make the hydraulic roughness calculations. The absolute value, i.e., 0.5in Test 4B, tells the program the ratio of roughness in that element to the composite roughness. For example, if the values are -1, as on the KS-record fields 3, 4, 5, and 6, or as on the CT record in field 6 in Test 4A, then the roughness in each of these panels would be calculated as equal proportions of the composite. The program is supposed to supply "missing" values on a record by repeating the data in the previous fields; i.e., on the CT record, the data for fields 7 and 8, and 9 and 10, would be repeated from fields 5 and 6 (see Appendix C). **Note**, however, that currently this does not work *for the KN record*, and *data for all fields should be supplied by the user.*

```
T1 Test 4A  Calculate Ks from Barnes n-value        Simple trapezoidal channel
T1 fld 1    2       3       4       5       6       7       8       9      10
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     2       1
CT   301      10       0       0       1      -1
QW 13900
WS   5.3
ES .0034
WT    50
$$END
```

```
T1 4B Calculate Ks from Barnes, p34
T1           Station-Elevation Geometry
T1 fld 1    2       3       4       5       6       7       8       9      10
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1
X1     1       7
GR    16       0    12.6      40    12.4      65     9.5      80     8.8     200
GR   8.8     290      16     320
KN            -.5      -1      -1      -1      -1
NE     9       2       1
QW 13900
WS  15.6
ES .0034
WT    50
$$END
```

Output Data

The information contained in the output tables is the same as that described in the normal depth calculation output.

Water Discharge Calculations: Input and Output

This option allows water discharge to become the dependant variable in the Manning equation.

$$W = f\ (Q, n, D, z, S)$$

Geometry, roughness, compositing, and plotting are all handled as in the normal depth calculations.

Note, when convergence fails, assume a range of discharges and use the normal depth calculations to arrive at the correct value.

Sample input data

The following example shows input data when calculating Q.

```
T1 Calculate Energy Slope
T1     Simple channel
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1
CT   100      10       3       3       2     .02       2      .2       2      .2
WS  3.07
ES.00052
WT    55
$$END
```

Sample Output

The general output tables from these calculations are described in the normal depth calculation output. However, note that table series "8-*x*" has become "9-*x*". The information contained in the two series of tables is the same, with the title of the "*x*-1" table flagging both the calculation performed and the compositing method used. Also note that the calculated water discharge is shown in Table 9-1, as "Q," and is not flagged as having been calculated.

```
TABLE  9-1.  CALCULATE WATER DISCHARGE;  COMPOSITE PROPERTIES BY ALPHA METHOD.

 **** N     Q       WS     TOP     R      SLOPE    n      VEL  FROUDE  SHEAR
                   ELEV   WIDTH                  Value         NUMBER  STRESS
           CFS      FT     FT      FT     ft/ft            FPS             #/SF


 **** 1    1281.    3.07   118.4   3.01 0.000520 0.0185   3.82   0.39   0.10

 TABLE  9-4.  HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT
  Q STRIP  STRIP        ---EFFECTIVE---    SLOPE    n-    EFF.  Froude   TAU
 NO   NO     Q           WIDTH   DEPTH           VALUE   VEL.    NO    Prime
            CFS            FT      FT     FT/FT          FPS            #/SF
  1   1    1281.           110.8   2.99 0.000520 0.0177   3.87   0.39  0.097


 TABLE  9-5.  EQUIVALENT HYDRAULIC PROPERTIES FOR OVERBANKS AND CHANNEL
              DISTRIBUTED USING CONVEYANCE
  N  STRIP  HYDRAULIC   MANNING .........SUBSECTION...........
       NO     RADIUS    n-VALUE DISCHARGE     AREA    VELOCITY
                ft                 cfs        sqft       fps

  1     1       2.81     0.0177   1281.32     335.35     3.82
```

Riprap Size for a Given Velocity and Depth (RS-Record) Calculations

Input and Output

The input window for these calculations is accessed from the SAMwin main menu – Edit – Hydraulic Function Input – Riprap size, Known Velocity and Depth, Figure 6.10.

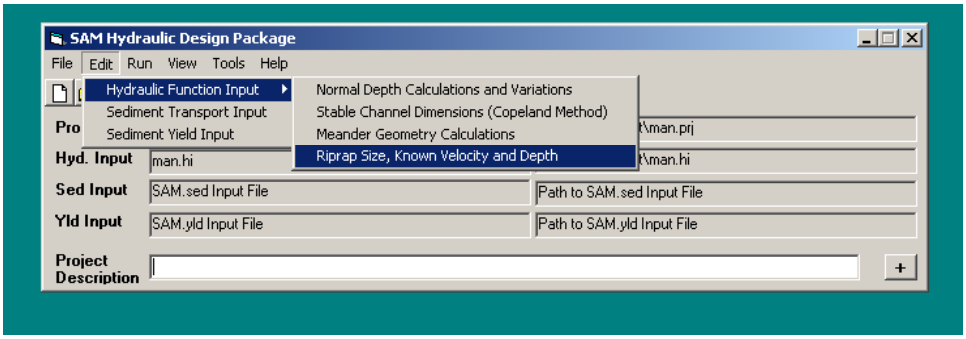


Figure 6.10. Finding the Riprap Calculations input screen.

When flow velocity and depth are known, the riprap size is calculated using the equation described in EM 1110-2-1601 (USACE 1991, 1994). Since the size and specific gravity of available riprap are needed for this calculation, the 13 standard riprap sizes (shown in EM 1110-2-1601 and in Chapter 2) are available in the program by default. The riprap design equation is:

$$d_{30} = S_f \, C_S \, C_V \, C_T \, D \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{0.5} \frac{V_{AVE} \, C_B}{\sqrt{K_1 \, g \, D}} \right]^{2.5}$$

where

d_{30} = characteristic riprap size of which 30 percent is finer by weight
S_f = Safety factor
C_S = Coefficient of incipient failure
C_V = vertical velocity coefficient
C_T = coefficient for riprap thickness
D = local water depth
γ_w = unit weight of water
γ_s = unit weight of riprap
V_{AVE} = average channel velocity
C_B = bend correction for average velocity (V_{SS}/V_{AVE})
K_1 = Correction for side slope steepness
g = Acceleration of gravity

Up to five sizes of quarry run riprap can be specified and will be used in the calculations instead of the default if they appear in the data set. This capability is not available in SAMwin at this time. However, the quarry run riprap data can be input on the RQ record with an editor; see Appendix C. That data set can then be run with the "Run" option of the SAMwin main menu. No plots are available from these calculations.

The safety factor, S_f, accounts for variability and uncertainty in calculated hydrodynamic and non-hydrodynamic imposed forces and/or for uncontrollable physical conditions. The minimum safety factor recommended in EM 1110-2-1601 (USACE 1991, 1994) is 1.1. This is the default value used in SAM. However, a larger value may be specified on the riprap input screen. A discussion of appropriate values for the safety factor is presented in EM 1110-2-1601 (USACE 1991, 1994).

The thickness coefficient, C_T, accounts for the increase in stability that occurs when riprap is placed thicker than the minimum thickness. Minimum thickness is the greater of $d_{100\,MAX}$ and $1.5\,d_{50\,MAX}$. If minimum thickness is desired, then $C_T = 1.0$. EM 1110-2-1601 (USACE 1991, 1994) provides three curves for determining C_T as a function of the ratio d_{85}/d_{15} and the ratio of design thickness to minimum thickness -- T_R/T_{MIN}. Currently, SAM uses the curve that results in the least reduction in design riprap size:

$$C_T = 1.44 - 0.58\frac{T_R}{T_{MIN}} + 0.14\frac{T_R}{T_{MIN}} \qquad 1 \le \frac{T_R}{T_{MIN}} \le 2$$

where:

T_R = riprap thickness
$T_{MIN} = d_{100\,MAX}$ or $1.5\,d_{50\,MAX}$, whichever is greater.

This equation is appropriate when the gradation uniformity coefficient, d_{85}/d_{15}, = 1.7, which corresponds to the gradations recommended in EM 1110-2-1601 (USACE 1991, 1994). Larger gradation uniformity coefficients would result in a smaller value for C_T. In SAM, the default value for T_R/T_{MIN} is 1.0. A different ratio may be prescribed as variable RSEC on the RS record or a variable RT(i) of the RT record. T_R/T_{MIN} ratios usually range between 1.0 and 1.5.

NOTE: THIS DESCRIPTION AND CODING FOR C_T REFLECTS 1991 GUIDANCE.

The stability coefficient for incipient failure, C_S, has been determined to be 0.030 for angular rock, and 0.0375 for rounded stone. These values have been demonstrated for riprap gradations where $1.7 < d_{85}/d_{15} < 5.2$. The default in SAM is for the angular rock. The rounded stone coefficient may be used by specifying a negative thickness ratio, T_R/T_{MIN}, for the variable RSEC on the RS record or for variable RT(L) on the RT record. The stability coefficient for incipient failure may also be changed by changing the variable CIFRRS on the RR record and

using negative values for T_R/T_{MIN} . C_S = 0.30 is multiplied by CIFRSS when T_R/T_{MIN} is negative -- the default for CIFRRS is 1.25 which yields C_S = 0.375.

The vertical velocity distribution coefficient, C_V , varies as a function of the ratio of bend radius, R, to channel width, W. C_V = 1.0 in straight channels, for the inside of bends, and for bends where R/W is ñ 26. The equation for C_V when R/W < 26 is:

$$C_V = 1.283 - 0.2 \log_{10}\left(\frac{R}{W}\right)$$

The maximum value allowed for C_V is 1.283. C_V is determined in SAM using either a calculated water-surface width or a water-surface width prescribed on record RS, and a bend radius prescribed as variable on the RR record.

The side slope correction factor, K_1 , is calculated by SAM from geometric input and the empirical side slope correction graph in EM 1110-2-1601. The side slope steepness angle is calculated for each panel. When the steepness is milder than 1V:3H the side slope correction factor is 1.0. The steepest side slope allowed is 1V:1.5H.

The bend correction factor, C_B , which is the same as V_{SS} / V_{AVE} in EM 1110-2-1601, is determined differently depending on whether the channel is a natural channel or a trapezoidal channel. In SAM, a trapezoidal cross section is identified by setting NTRAP on the RR record equal to 1. If no value is assigned a natural channel is assumed. C_B is calculated in SAM as a function of the R/W ratio. For trapezoidal channels:

$$C_B = 1.71 - 0.78 \log_{10}\left(\frac{R}{W}\right) \qquad 1.48 \le C_B \le 0.82$$

and for natural channels:

$$C_B = 1.74 - 0.52 \log_{10}\left(\frac{R}{W}\right) \qquad 1.58 \le C_B \le 0.90$$

NOTE: THESE DESCRIPTIONS AND CODING FOR CB REFLECT 1991 GUIDANCE.

When riprap calculations are made using known velocity and depth, care must be taken in defining the input variables. Depth is the depth of water at the toe of the riprap. SAM will adjust the depth to 0.8 D as prescribed in EM 1110-2-1601 (USACE 1991, 1994). If the local depth averaged velocity at 20 percent up-slope

from the riprap toe is input, then no bend radius should be prescribed. On the other hand, if the average channel velocity upstream of the bend is input, then a bend radius should also be prescribed. The bend radius, R, is defined as the centerline radius of the bend, considering only the main channel. The water-surface width, W, is defined as the main channel water-surface width at the upstream end of the bend.

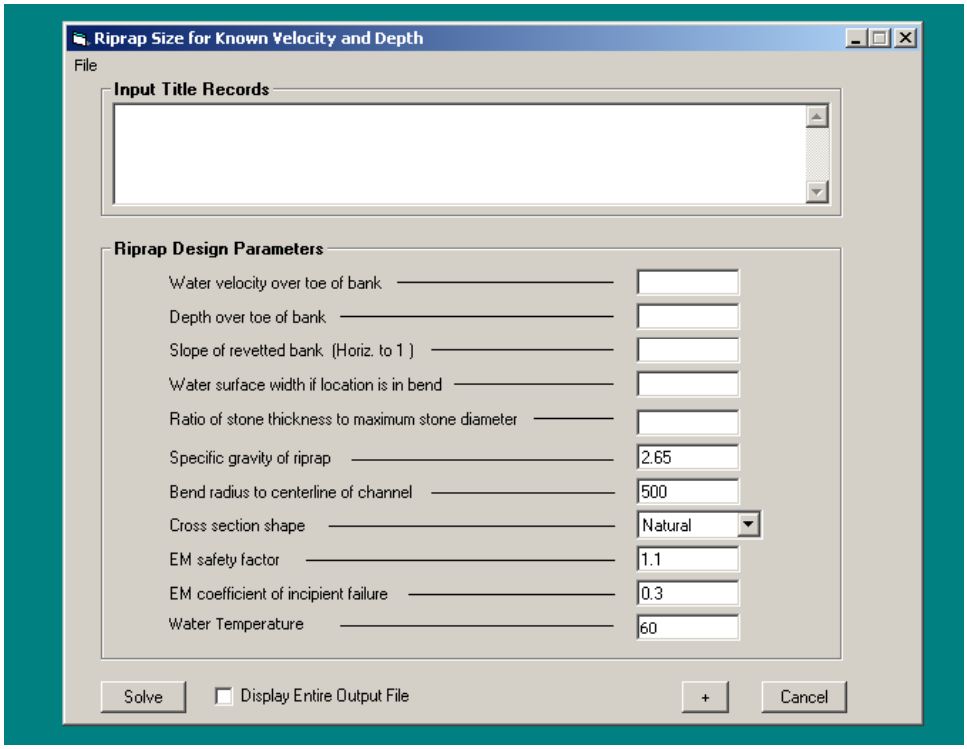


Figure 6.11. Input screen for riprap calculations for known velocity and depth.

Sample Input Data

The required input data for simple riprap calculations are shown in Figure 6.11. Again, if quarry run riprap gradations are to be specified, they must be added to the data set with and editor, and should be entered one size per record, starting with the smallest. This record is currently not available in SAMwin.

Various input data sets are given in the following examples.

```
T1 Test 6A   Simple Riprap design -- given velocity and depth
T1               Problem 1  Appendix H, EM 1110-2-1601
T1               EM 1110-2-1601 gradations
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
RS   7.1      15       2     200
RR  2.65     620              0     1.1     0.3
WT    60
$$END
```

```
T1 Test 6B  Simple Riprap design -- given velocity and depth
T1                with 155 lb stone    Trapezoidal channel
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
RS     8      20       2     500
RR  2.48    1700               1     1.1     0.3
WT    60
$$END

T1 Test 6C Simple Riprap design -- given velocity and depth
T1                with 155 lb stone at 7 fps           Trapezoidal channel
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
RS     7      20       2     500
RR  2.48    1700               1     1.1     0.3
WT    60
$$END

T1 Test 6D Simple Riprap design -- given velocity and depth
T1                with 155 lb stone at 7 fps and 1V:1.5H side slope
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
RS     7      20     1.5     500
RR  2.48    1700               1     1.1     0.3
WT    60
$$END

T1 Test 6E Simple Riprap design -- given velocity and depth
T1        with 155 lb stone at 7 fps and 1V:1.5H side slope, 1.5*DMAX thickness
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
RS     7      20     1.5     500     1.5
RR  2.48    1700               1     1.1     0.3
WT    60
$$END
```

Sample Output Data

The following example is taken from the output from Test 6A. The general tables, Tables 1 and 0-3, are described in the normal depth calculation output. The output shown below is the additional, riprap output. The first line describes the calculation being performed. The next line states the source of the riprap sizes tested. It would have stated "USING QUARRY RUN RIPRAP" had that been prescribed. The first table shown describes the necessary riprap size as determined by the calculations. The second, longer table describes both the riprap and some of its effects as well as some of the factors used in the calculations. The cross section properties are echoed, and there is a table with the "Hydraulic properties with riprap in place." The standard tables, 8-4 and 8-5, are repeated but contain the parameters as calculated with the stated riprap size in place.

```
DETERMINE RIPRAP SIZE FOR A GIVEN WATER DISCHARGE


    USING GRADED RIPRAP TABLES FROM EM 1110-2-1601

 LAYER D30CR DMAXRR   D30   D50   D90   WIDTH   CY/FT TONS/FT   $/FT
  #    FT    IN     FT    FT    FT    FT
  5   0.71  21.00  0.85  1.03  1.23  187.42  12.148   0.622   0.00
```

```
RIPRAP SIZE     = LAYER# 5          DMAX, INCHES      =     21.
 VELOCITY, FT  =     7.90          VSS/VAVG          =    1.354
 BEND RADIUS,FT =     500.          TOP WIDTH, FT     =     175.
 R/W           =    2.861          VERT VEL CORR, Cv =    1.192
 LOCAL DEPTH, FT=    10.60          DESIGN DEPTH      =    8.48
 SAFETY FAC, Sf =     1.10          STABILITY COEF, Cs =    0.300
 THICKNESS, IN  =    21.00          THICKNESS COEF, Cv =    1.750
 SIDE SLOPE     =    2.00           SIDE SLOPE CORR, K1=    1.180
 SP.GR. RIPRAP  =    2.65           POROSITY, %       =    38.00
 CHANNEL TYPE   = TRAPEZOID         COST PER FOOT,$/FT =     0.00


                TABLE  8-1.  CROSS SECTION PROPERTIES
 #   STATION    ELEV  ROUGHNESS  N-VALUE :    GROUND    : DELTA Y   RIPRAP
       FT        FT     HEIGHT  EQUATION :SLOPE    ANGLE :    FT    Dmax*[ ]

 1   -100.0    15.00
                1.230     STRICKLE    -2.00    -26.6    -15.00     1.0
 2    -70.0     0.00
                1.230     STRICKLE     0.00     0.0      0.00     1.0
 3     70.0     0.00
                1.230     STRICKLE     2.00    26.6     15.00     1.0
 4    100.0    15.00
1
HYDRAULIC PROPERTIES WITH RIPRAP IN PLACE.    STRICKLER COEFFICIENT = 0.038

**** N     Q      WS     TOP COMPOSITE  SLOPE COMPOSITE VEL  FROUDE  SHEAR
             ELEV   WIDTH    R           n-Value      NUMBER  STRESS
       CFS     FT     FT      FT     ft/ft         FPS          #/SF

**** 1   13500.   11.26   185.0  10.73 0.001700 0.0404   7.38   0.40   1.14

TABLE  8-4.  HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT
 Q STRIP  STRIP       ---EFFECTIVE---    SLOPE    n-    EFF.  Froude   TAU
NO   NO     Q          WIDTH   DEPTH          VALUE   VEL.    NO    Prime
         CFS           FT      FT     FT/FT         FPS           #/SF
 1   1   13500.          166.8  10.74 0.001700 0.0376   7.53   0.41  1.139


TABLE  8-5.  EQUIVALENT HYDRAULIC PROPERTIES FOR OVERBANKS AND CHANNEL
          DISTRIBUTED USING CONVEYANCE
 N  STRIP  HYDRAULIC   MANNING .....SUBSECTION.....
    NO     RADIUS    n-VALUE DISCHARGE     AREA    VELOCITY
             ft              cfs       sqft       fps

 1    1      9.61     0.0376  13500.00    1830.33     7.38

...END OF JOB...
```

Riprap Size for a Given Discharge and Cross Section Shape: Input and Output

Riprap size calculations are more complicated when the water discharge and cross section are given than when the flow velocity and depth are given because n-value becomes a function of riprap size. The computational procedure is described in detail in Chapter 2. The stone size gradation table is the default for riprap sizes, but quarry run stone can be prescribed, as noted above, although that option is currently not available in SAMwin. Riprap size is determined automatically when the RR-, RT-, and PF-records are included in a data set for normal depth, bottom width, energy slope or water discharge calculations. The

PF record is required for riprap calculations because the program tests bed particles against the Shield's diagram to determine whether or not riprap is needed.

Considerable care must be employed when applying the cross-section shape option because flow conditions may be outside the range of conditions used to develop the riprap equations. When these calculations are made, it is important that the user define the side slope protection as a single panel in the geometry input. SAM will use 0.8 times the maximum depth in the panel for the local flow depth in the riprap equation. When a bend radius is specified, SAM uses the average velocity in the cross section for V_{AVE} in the riprap equation. Therefore, it is important that the input geometry include only channel geometry and discharge. When a bend radius is not specified, SAM uses the calculated panel velocity for V_{AVE} in the riprap equation. This calculation may provide useful information for compound channels in straight river reaches, but it is an extension of the procedure outlined in EM 1110-2-1601 (USACE 1991, 1994). Careful study of the recommendations and guidelines described in that EM are considered essential.

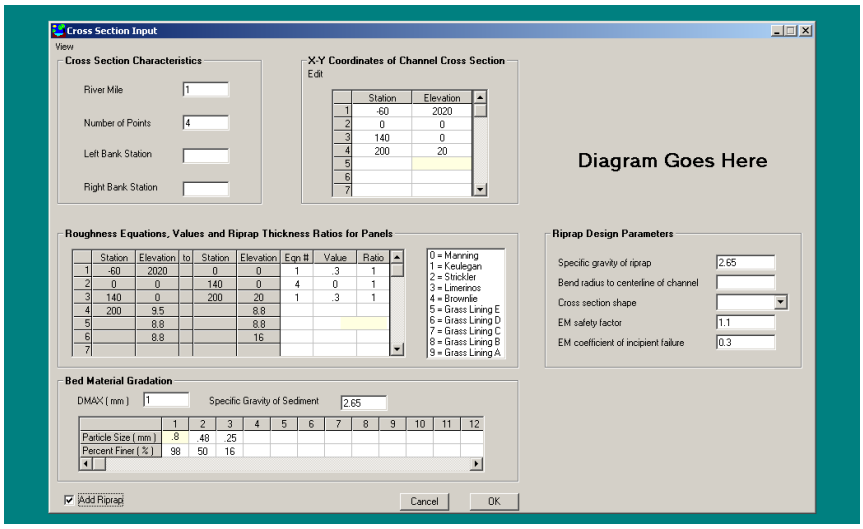


Figure 6-12. Additional input needed when riprap requested on the Station-Elevation normal depth input screen.

Sample Input Data

These calculations can be accessed through the "Normal Depth" input, as described earlier. Figure 6-12 shows some of the required input data for riprap size calculations when station elevation geometry is input. Figure 6-13 shows some of the required input data for riprap size calculations when channel template geometry is input. Other required data are particle size on the channel bed and thickness of the riprap by panel (the RT record). The RT record also tells the calculations in which panel to put riprap. This record is not available in SAMwin at this time and must be manually made and put in the input file. The

other data in this calculation-type file are required to perform the normal depth calculations and produce the water velocity and depth in each panel.

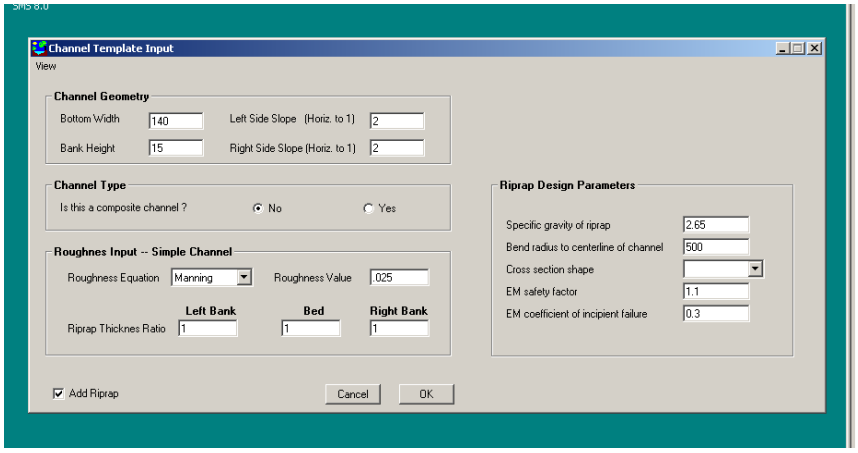


Figure 6-13. Additional input needed when riprap requested on the Channel Template Input screen.

```
T1 7A    Calculate Normal depth, with riprap
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1
X1     1       4
GR    20     -60        0       0       0     140      20     200
KN    .3       0       .3
NE     1       4        1
PF                              1      .8      98     .48      50     .25      16
RR  2.65                        1     1.1     0.3
QW  5000   10000   15000
ES 0.010
WT    65
SP  2.65
$$END


T1 7B    Riprap Design in a Trapezoidal Channel
T1         Problem 2,   Appendix H    EM-1110-2-1601
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR     1
CT   140      15       2       2       0    .025
RT     1       1       1
RR  2.65     500               0     1.1     0.3
QW 13500
ES .0017
$$END
```

Geometry, roughness, compositing and plotting are handled the same as described for normal depth calculations without riprap.

Sample Output Data

The following example is taken from the output from Test 7C. The general output tables from these calculations are described in the normal depth output

section. However, the output for these calculations is threefold. The first set of normal depth tables show the results of the normal depth, or other, calculations without riprap. The next set of output, starting with "DETERMINE RIPRAP SIZE FOR A GIVEN WATER DISCHARGE," describes the results of the riprap calculations using the hydraulic parameters shown in the first set of tables. The third set of output is a second set of normal depth calculations showing the hydraulic parameters calculated with the given riprap in place. The parameters written to the sediment transport, SAM.sed, input file are taken from this second set of normal depth calculations.

```
TABLE  8-1.  CALCULATE NORMAL DEPTH;  COMPOSITE PROPERTIES BY ALPHA METHOD.

 **** N     Q       WS     TOP COMPOSITE  SLOPE COMPOSITE VEL  FROUDE  SHEAR
                   ELEV   WIDTH    R             n-Value       NUMBER  STRESS
           CFS      FT     FT      FT     ft/ft           FPS            #/SF

 **** 1   13500.    8.68   174.7   8.36 0.001700 0.0255   9.88   0.60   0.89

 TABLE  8-4.  HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT
  Q STRIP  STRIP        ---EFFECTIVE---    SLOPE    n-    EFF.  Froude   TAU
NO   NO     Q            WIDTH   DEPTH           VALUE   VEL.    NO    Prime
           CFS             FT      FT     FT/FT          FPS           #/SF
 1   1   13500.           160.5   8.37 0.001700 0.0241  10.05   0.61  0.887


 TABLE  8-5.  EQUIVALENT HYDRAULIC PROPERTIES FOR OVERBANKS AND CHANNEL
              DISTRIBUTED USING CONVEYANCE
  N  STRIP  HYDRAULIC   MANNING .........SUBSECTION...........
       NO     RADIUS    n-VALUE DISCHARGE     AREA    VELOCITY
                ft                cfs        sqft       fps

 1     1       7.64     0.0241  13500.00    1366.50     9.88

 DETERMINE RIPRAP SIZE FOR A GIVEN WATER DISCHARGE


        USING GRADED RIPRAP TABLES FROM EM 1110-2-1601

  LAYER  D30CR  DMAXRR    D30    D50    D90    WIDTH    CY/FT  TONS/FT    $/FT
    #      FT     IN       FT     FT     FT      FT
     6    0.89   24.00   0.97   1.17   1.40   188.01   13.927    0.714    0.00


 RIPRAP SIZE      = LAYER#  6             DMAX, INCHES       =       24.
   VELOCITY, FT   =       7.79           VSS/VAVG           =     1.503
   BEND RADIUS,FT =       500.           TOP WIDTH, FT      =      175.
   R/W            =      2.861           VERT VEL CORR, Cv  =     1.192
   LOCAL DEPTH, FT=      10.74           DESIGN DEPTH       =      8.59
   SAFETY FAC, Sf =       1.10           STABILITY COEF, Cs =     0.300
   THICKNESS, IN  =      24.00           THICKNESS COEF, Cv =     2.000
   SIDE SLOPE     =       2.00           SIDE SLOPE CORR, K1=     1.180
   SP.GR. RIPRAP  =       2.65           POROSITY, %        =     38.00
   CHANNEL TYPE   =   NATURAL            COST PER FOOT,$/FT =      0.00


                       TABLE  8-1.  CROSS SECTION PROPERTIES
  #    STATION     ELEV   ROUGHNESS  N-VALUE :     GROUND     : DELTA Y   RIPRAP
         FT         FT      HEIGHT  EQUATION :SLOPE     ANGLE :    FT    Dmax*[ ]

   1    -100.0     15.00
                         1.400      STRICKLE    -2.00    -26.6    -15.00     1.0
```

```
  2     -70.0      0.00
                        1.400      STRICKLE     0.00      0.0      0.00     1.0
  3      70.0      0.00
                        1.400      STRICKLE     2.00     26.6     15.00     1.0
  4     100.0     15.00

HYDRAULIC PROPERTIES WITH RIPRAP IN PLACE.    STRICKLER COEFFICIENT = 0.038

**** N     Q       WS     TOP COMPOSITE  SLOPE COMPOSITE VEL  FROUDE  SHEAR
                  ELEV   WIDTH    R             n-Value       NUMBER  STRESS
          CFS      FT     FT      FT     ft/ft            FPS             #/SF

**** 1   13500.   11.40   185.6  10.85 0.001700 0.0413   7.27   0.39   1.15

TABLE  8-4.  HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT
 Q STRIP  STRIP        ---EFFECTIVE---    SLOPE    n-     EFF.  Froude   TAU
NO   NO     Q           WIDTH   DEPTH           VALUE   VEL.    NO    Prime
           CFS             FT      FT     FT/FT          FPS            #/SF
 1   1   13500.           167.1  10.87 0.001700 0.0384   7.43   0.40  1.153


TABLE  8-5.  EQUIVALENT HYDRAULIC PROPERTIES FOR OVERBANKS AND CHANNEL
             DISTRIBUTED USING CONVEYANCE
 N  STRIP  HYDRAULIC   MANNING .........SUBSECTION...........
      NO     RADIUS    n-VALUE DISCHARGE     AREA    VELOCITY
               ft                 cfs        sqft       fps

 1     1       9.72     0.0384  13500.00    1856.17     7.27

...END OF JOB...
```

If there is no RT record in the data set and riprap is required, the following message appears:

```
     DETERMINE RIPRAP SIZE FOR A GIVEN WATER DISCHARGE
          USING GRADED RIPRAP TABLES FROM EM 1110-2-1601

         NO LOCATIONS WERE SPECIFIED FOR RIPRAP.
        N, Q(N), AND WS(N) =    1   6000.    3.00
```

(This message was produced by adding only an RR record to Test 2A. With no RT record SAM had no idea where to put the riprap.)

Blench Regime Equations

Stable channel dimensions may be calculated using the Blench (1970) regime equations. These regime equations are also shown in ASCE Manual 54 (ASCE 1975). The equations were intended for design of canals with sand beds. The basic three channel dimensions, width, depth and slope, are calculated as a function of bed-material grain size, channel-forming discharge, bed-material sediment concentration, and bank composition.

$$W = \left(\frac{F_B \; Q}{F_S} \right)^{0.5}$$

$$F_B = 1.9 \sqrt{d_{50}}$$

$$D = \left(\frac{F_S \; Q}{F_B^2} \right)^{\frac{1}{3}}$$

$$S = \frac{F_B^{0.875}}{\frac{3.63 \; g}{\nu^{0.25}} W^{0.25} d^{0.125} \left(1 + \frac{C}{2{,}330} \right)}$$

where

W = channel width - ft
F_B = bed factor
F_S = side factor
Q = water discharge -cfs
d_{50} = median grain size of bed material - mm
D = depth - ft
S = slope
C = bed-material sediment concentration - in parts per million
g = acceleration of gravity - ft/sec^2
v = kinematic viscosity - ft^2/sec

The results are true regime values only if Q is the channel forming discharge. However, a width, depth and slope will be calculated for any discharge by these equations.

Blench suggests that the following values be used for the side factor:

F_S = 0.10 for friable banks
F_S = 0.20 for silty, clay, loam banks
F_S = 0.30 for tough clay banks

In order to calculate the Blench regime dimensions, the side factor, bed-material sediment concentration, and the bed-material gradation should be input. SAM.hyd sets default values for the Blench variables if none are specified: F_S = 0.20, C = 0.0, and d_{50} = 0.25 mm.

Sample input

The following example is data set 2A with a Blench record, a BL record, added. This record is not currently available in SAMwin and must be put in the input file manually. The side factor is all that has been specified in this example. The BL record can be added to the following calculations: normal depth, bottom width, hydraulic roughness, flow distribution, and the riprap calculations given discharge and depth. Since the Blench equation requires a discharge and a slope, the BL record added to a data set which will calculate discharge, slope, or riprap given velocity and depth will be ignored, usually with a message printed to the output file saying the Blench regime calculations could not be made.

```
TI      TEST BLENCH REGIME EQUATION
TI   1      2       3       4       5       6       7       8       9       10
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
CT             3       3       3       4               2      .3       2      .3
BL   .20
PF                             1      .8      98     .48      50     .25      16
QW  6000
ES .0050
WT   65.
$$END
```

Sample Output

Adding a BL record to a data set only triggers additional output, "Table 3. Blench Regime-Channel Dimensions." It does not change the calculated results for that data set. Shown below is a selection of output from above input file, including Table 3, Table 5-1 and Table 5-4. Tables 5-1 and 5-4 can be compared to the output shown in the bottom width calculations section earlier to see that there is no change in the calculated output specified by the input file without the BL record.

```
TABLE  3.  BLENCH REGIME-CHANNEL DIMENSIONS (ASCE MANUAL 54).
            FB=   0.95  FS=   0.20

     N     Q     REGIME  REGIME   R     REGIME    n      VEL  FROUDE  SHEAR
                 DEPTH   WIDTH          SLOPE  Value         NUMBER  STRESS
          CFS      FT      FT      FT     ft/ft           FPS           #/SF

     1    6000.   11.00   168.8   9.73 0.000098 0.0207   3.23   0.17   0.06


TABLE  5-1.  CALCULATE BOTTOM WIDTH;  COMPOSITE PROPERTIES BY ALPHA METHOD.


**** N     Q       WS   BOTTOM    R      SLOPE    n      VEL  FROUDE  SHEAR
                 ELEV   WIDTH                   Value         NUMBER  STRESS
         CFS       FT      FT      FT     ft/ft           FPS           #/SF

**** 1    6000.    3.00   153.1   2.97 0.005000 0.0175  12.34   1.27   0.92


TABLE  5-4.  HYDRAULIC PARAMETERS FOR SEDIMENT TRANSPORT
 Q STRIP  STRIP        ---EFFECTIVE---    SLOPE    n-    EFF.  Froude   TAU
NO   NO     Q            WIDTH   DEPTH           VALUE   VEL.    NO    Prime
           CFS              FT      FT     FT/FT           FPS           #/SF
 1   1    6000.           163.6   2.95 0.005000 0.0170  12.45   1.28  0.729
```

Stable Channel Dimensions Calculations: Input and Output

These calculations are accessed through the Edit-Hydraulic Function Input-Stable Channel Dimensions (Copeland Method) dropdown menu, as shown in Figure 6.14.

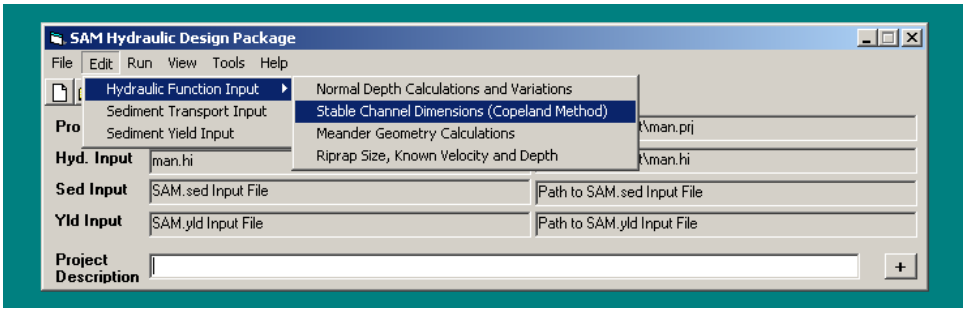


Figure 6.14. Accessing the Stable Channel Method input screens.

General Input Requirements

The input data required, sediment inflow concentration, base width, side slope, bank roughness coefficient, bed material d_{50}, bed material gradation coefficient, valley slope and water discharge, are shown in Figure 6.15.

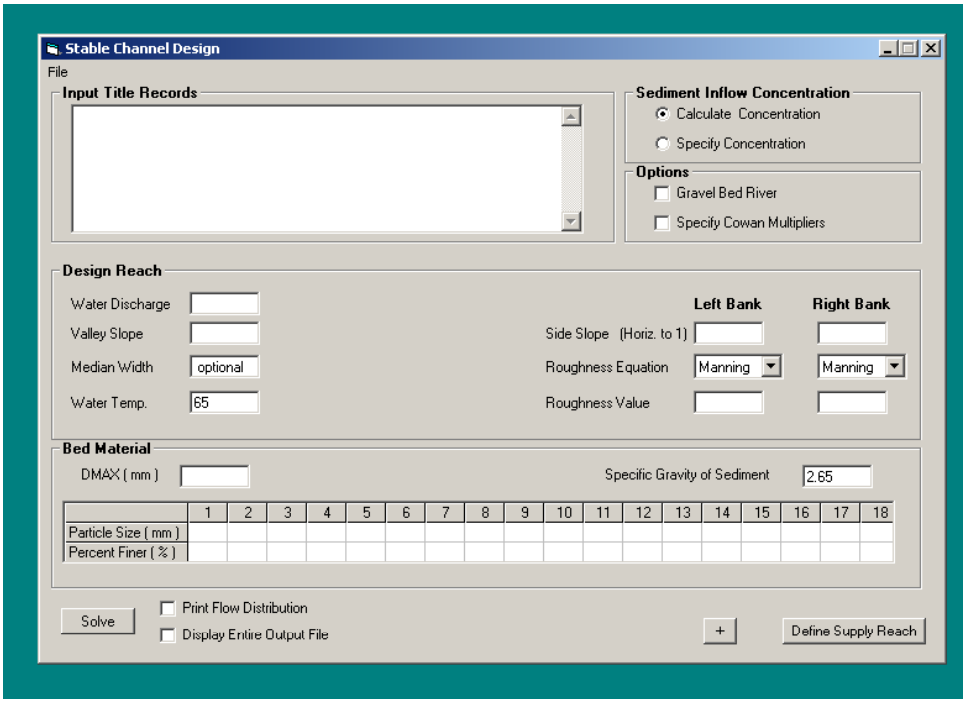


Figure 6.15. Main data input screen for the Stable Channel Dimensions Method.

If sediment inflow is to be calculated, which is the recommended procedure, additional data are required for the supply reach. This screen is accessed by clicking the "Define Supply Reach" button on the lower right, Figure 6.15. The additional input screen, asking for base width, side slope, bank roughness coefficient, bed-material median grain size geometric gradation coefficient, average slope, and discharge, is shown in Figure 6.16.

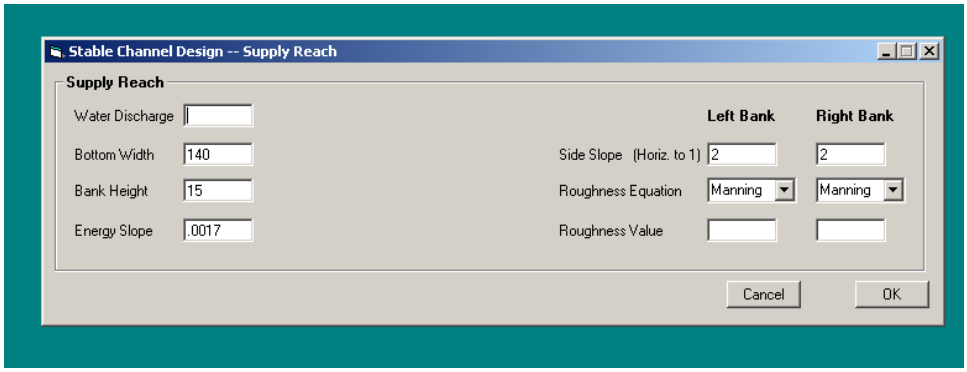


Figure 6.16. Input screen for the Supply Reach for Stable Channel Design Method Calculations.

For both these sub-data sets, it is important that the base width is representative of the total movable-bed width of the channel. The bank roughness should serve as a composite of all additional roughness factors, i.e., channel irregularities, variations of channel cross-section shape, relative effect of obstructions, vegetation, and sinuosity. Only flow that is vertical above the bed is considered capable of transporting the bed material sediment load.

Specific Input Requirements

Water Discharge The design discharge is critical in determining appropriate dimensions for the channel. Investigators have proposed different methods for estimating that design discharge. The 2-year frequency flood is sometimes used for perennial streams. For ephemeral streams the 10-year frequency is some times used. The "bankfull" discharge is sometimes suggested. Others prefer using the "effective" discharge. Currently, there is no generally accepted method for determining the channel-forming discharge. It is recommended that a range of discharges be used in the analysis to test sensitivity of the solution. However, currently SAMwin will calculate for only one discharge at a time.

Inflowing Sediment Discharge This is the concentration of the inflowing bed material load. It is best if SAM.hyd is allowed to calculate the sediment concentration based on hydraulic conditions in the sediment supply reach. The bed-material composition is defined by the median grain size and the gradation coefficient.

Valley Slope Valley slope is the maximum possible slope for the channel invert. This value is used in the test for sediment deposition. If the required slope exceeds the prescribed valley slope, the following message is printed:

```
>>>>MINIMUM SLOPE IS GREATER THAN VALLEY SLOPE - THIS IS A SEDIMENT TRAP <<<<
```

Bank Slopes and Roughness The analytical method assumes all bed material transport occurs over the bed of the cross section and that none occurs above the side slopes. Therefore, the portion of water conveyed above the side slopes expends energy but does not transport sediment, making "Flow Distribution" an extremely important calculation. The input parameters for flow distribution are bank angle and bank roughness. The recommended procedure to use for this is that discussed in Chapter 5 of EM 1110-2-1601 (USACE 1991, 1994). Any roughness input for the bed will be disregarded by the calculations as bed roughness is calculated using the Brownlie equations. Also, only the Manning and Strickler equations are available for roughness calculations in this option. For maximum transport of sediment, use the steepest bank angle allowed by bank stability requirements

Bottom Width Again, it is important that the base width is representative of the total movable-bed width of the channel.

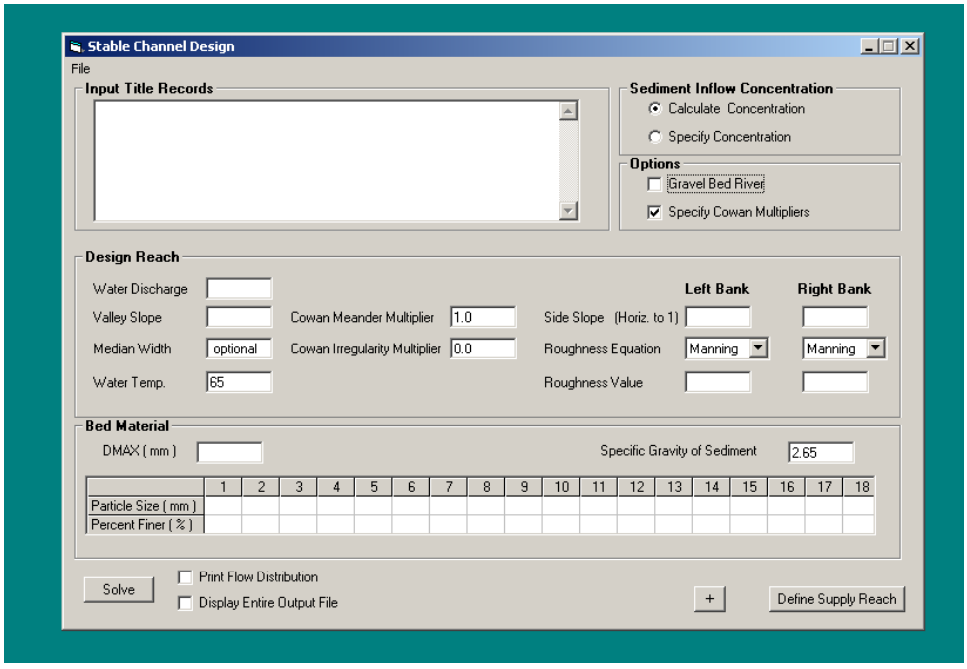


Figure 6.17. Cowan Multipliers input turned on – Stable Channel Methods screen.

Gravel Bed River Option

In this option SAM uses the Limerinos (1970) equation to calculate grain roughness on the bed, the Manning equation to calculate roughness on the channel side slope, and the Meyer-Peter and Muller (1948) equation to calculate sediment transport.

To access this option the "Gravel Bed River" box in the Options area must be checked. No extra input is required; the checkbox simply sends flag to the program to make the gravel bed calculations.

Cowan Multiplier Option

This option is currently available **only** for gravel bed streams. To access this option, the "Specify Cowan Multipliers" box in Options area of the Stable Channel Design screen must be checked see Figure 6.17. It allows the user to provide additional bed roughness that may be added to the grain bed roughness using the Cowan (1956) method. The additional roughness may be added to account for factors such as surface irregularities, variability in channel shape, obstructions, vegetation and meandering.

$$n_{total} = m\left(n_{base} + n_{additional}\right)$$

where

n_{base} = the base n-value, input for the bed and channel side slopes (input elsewhere on the screens)

$n_{additional}$ = the addition for surface irregularities +
the addition for variation in channel cross section +
the addition for obstructions +
the addition for vegetation.

Suggested values for these additions can be found in Cowan (1956) and Chow (1959).

Meandering is accounted for with a meandering coefficient, m; for a straight channel the meandering coefficient is 1.0. Appropriate values for the meandering coefficient and additions to the grain roughness n-value can be found in Cowan (1956) and Chow (1959).

The n-value additions and the meandering coefficient can be input for the design reach and/or the supply reach. See Appendix C, GB record.

Example input data

Test 8A is a data set that provides the parameters for calculating the stable channel dimension, i.e., the GC and PF records, and asks SAM.hyd to calculate

the inflowing sediment concentration by providing information about the supply reach, i.e., the CT record. Note that when field 2 of the GC record is either blank, a zero or a –1, the program will calculate the design sediment concentration for the design water discharge; that is, all concentrations will be calculated from the supply reach parameters. However, if a negative value other than 1 is coded, it is interpreted as the water discharge to use for calculating the design sediment concentration, i.e., the water discharge for the approach reach. (See Appendix C, GC record.) Also note that the channel geometry, (CT record), channel slope (ES record) and bed sediment gradation (PF record) must be supplied for the approach channel when concentrations are to be calculated.

Test 8B contains two GC records which will allow SAM.hyd to calculate two sets of stable channel dimensions with the only difference between the two being the water discharge. This means of running is not currently available in SAMwin, but may be accomplished by manually editing the input file. Test 8C provides the sediment inflow concentration on the GC record, so is complete without any supply reach information records.

```
T1 Test 8A   Calculate stable channel geometry
T1 Calculate Design sediment concentration using a reference reach
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR
CT    15      10       2       2       4               1       1       1       1
PF                             1      .8      98     .48      50     .25      16
ES.00016
WT    60
GC  2680   -2680 .000162       3       3       1      .7       1      .7
SP  2.65
$$END

TI   TEST NO. 8B  CALCULATE GEOMETRY USING COPELAND'S PROCEDURE
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
CT    15      10    1.65     3.0       4               1       2       1       2
PF                             1      .8      98     .48      50     .25      16
ES162E-6
GC  3680         .000162       3       3       2      .7       2      .7
GC  6530         .000162       3       3       0     .05       0     .05
WT    60
$$END

TI   TEST NO. 8C  CALCULATE GEOMETRY USING COPELAND'S PROCEDURE
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
GC  3680     100 .000162       3       3       2      .7       2      .7
PF                             1      .8      98     .48      50     .25      16
WT    60
$$END

T1 8D    Stable Channel Design,  Gravel Bed river option
T1             Cowan multiplier used for both design and supply reach
F#345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678 2345678
TR
CT   140      15       2       2       4               0               0
PF                            16       8      98       4      65       2      45
PFC    1      20      .5      10
ES0.0017
WT    50
GC  2680   -2680 .000162       3       3       1      .7       1      .7
SP  2.65
GB    10    1.15   0.025  1.0000  0.0150
$$END
```

Output description

The general output tables are the same as those generated in the normal depth calculations and are described in that section. The following output is from Test 8A. The calculations being made are stated, and then the results of the inflowing sediment concentration calculations are listed. The rest of the parameters used for the stable channel dimension calculations are listed. Table 4-1 provides the results of these calculations. Note that included in this output, at the end of the file, is a key to the regime abbreviations in the right-most column. Also notice that the line starting "Table 4-1" also lists the discharge, concentration and d_{50}. If gravel bed calculations had been made, as for Test 8D, the statement

USING MEYER-PETER-MULLER & LIMERINOS EQUATIONS

would have appeared on the line after

CALCULATE STABLE CHANNEL DIMENSIONS.

That statement in the output is the only one that flags that output file as having used the gravel bed calculations.

```
CALCULATE CHANNEL WIDTH, DEPTH AND SLOPE BY COPELAND METHOD.  GC-RECORD # 1

 CALCULATE INFLOWING SEDIMENT CONCENTRATION, PPM.

 INFLOWING WATER DISCHARGE, CFS        =   2680.000
 BASE WIDTH                            =   15.00000
 CHANNEL SLOPE, FT/FT                  = 0.00016000

                                         LEFT BANK  RIGHT BANK
 SIDE SLOPE                            =      2.000       2.000
 Ks, FT                                =  1.000       1.000
 n-VALUE                               =    0.03420     0.03420

 CALCULATE STABLE CHANNEL DIMENSIONS.

        USING  BROWNLIES RESISTANCE & TRANSPORT EQUATIONS

 MEDIAN BED SIZE ON BED, MM            =    0.46607
 GRADATION COEFFICIENT                 =      1.776
 VALLEY SLOPE                          = 0.00016200

                                         LEFT BANK  RIGHT BANK
 SIDE SLOPE                            =      3.000       3.000
 Ks, FT                                = 0.7000      0.7000
 n-VALUE                               =    0.03223     0.03223

 TABLE  4-1.  STABLE CHANNELS FOR Q=     2680.0 C,mgl=  22.69     D50=    0.466
  K: BOTTOM : DEPTH :  ENERGY :CMPOSIT:   HYD :   VEL : FROUDE:  SHEAR:   BED *
   :  WIDTH :       :   SLOPE :n-Value: RADIUS:       : NUMBER: STRESS:B-REGIME
   :   FT   :   FT  :   FT/FT :       :   FT  :   FPS :       :  #/SF:

  1      10.   16.0  0.000220  0.0317    8.38    2.86    0.13    0.22      LO
  2      21.   15.5  0.000158  0.0312    8.80    2.56    0.11    0.15      LO
  3      31.   14.7  0.000133  0.0306    8.93    2.41    0.11    0.12      LO
  4      42.   13.9  0.000120  0.0301    8.92    2.33    0.11    0.10      LO
  5      52.   13.0  0.000111  0.0295    8.81    2.27    0.11    0.09      LO
  6      62.   12.2  0.000106  0.0290    8.65    2.22    0.11    0.08      LO
  7      73.   11.5  0.000102  0.0286    8.45    2.18    0.11    0.07      LO
  8      83.   10.8  0.000100  0.0282    8.23    2.15    0.12    0.07      LO
  9      94.   10.2  0.000099  0.0278    8.00    2.12    0.12    0.06      LO
 10     104.    9.6  0.000098  0.0275    7.75    2.10    0.12    0.06      LO
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11      114.    9.1  0.000098  0.0271    7.51    2.07    0.12    0.06      LO
12      125.    8.7  0.000098  0.0269    7.27    2.05    0.12    0.05      LO
13      135.    8.3  0.000098  0.0266    7.04    2.03    0.12    0.05      LO
14      146.    7.9  0.000098  0.0264    6.82    2.01    0.13    0.05      LO
15      156.    7.5  0.000099  0.0262    6.61    1.99    0.13    0.05      LO
16      166.    7.2  0.000100  0.0260    6.40    1.97    0.13    0.05      LO
17      177.    6.9  0.000101  0.0258    6.21    1.96    0.13    0.04      LO
18      187.    6.7  0.000102  0.0256    6.02    1.94    0.13    0.04      LO
19      198.    6.4  0.000103  0.0255    5.84    1.93    0.13    0.04      LO
20      208.    6.2  0.000105  0.0253    5.68    1.91    0.14    0.04      LO

          RESULTS AT MINIMUM STREAM POWER
21      118.    9.0  0.000098  0.0270    7.43    2.07    0.12    0.05      LO

* REGIMES:  LO=LOWER, TL=TRANSITIONAL-LOWER, TU=TRANSITIONAL-UPPER, UP=UPPER.

...END OF JOB...
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Table 4-1 contains the family of widths, depths, and slopes which satisfies the sediment transport and resistance equations for the given conditions. It is important to consider river morphology when interpreting these calculated values. That is, each line in the table satisfies the governing equations, but natural rivers tend toward a regime width. Consequently, the calculations start with the regime width as determined by the following equation:

$$B = 2.0\,Q^{0.5}$$

For the water discharge in this example, the equation gives a regime width of 120 feet. This regime width is then divided by 10 to provide a starting value for the table, 12 ft in this case. The rest of the table is produced by adding the 12 ft increment to each successive width and repeating the depth, slope, n-value calculations. Note the last column in the table, "Flow Regime." Four conditions are possible:

LO = Lower regime
(i.e. ripples and dunes)
TL = Transition zone, Lower regime selected
(bed forms tend towards ripples and dunes.)
TU = Transition zone, Upper regime selected
(Bed forms tend toward plain bed.)
UP = Upper regime selected
(Plain bed and antidunes)

Channel dimensions corresponding to minimum stream power, Q*S , (which also corresponds to minimum slope), are presented at the bottom of the table. In this example the energy slope reaches a minimum value at about the regime width. However, that is not always the case. Much depends on the bank roughness.

These calculations will provide the information to plot the stable channel dimension curve,

Range of Solutions

Stable channel dimensions are calculated for a range of widths. For each combination of slope and base width, a unique value of depth is calculated. This can be used to evaluate stability in an existing channel or in a proposed design channel. It is important to consider river morphology when interpreting these calculated values. It is important to be consistent in the selection of channel dimensions. That is, once a width is selected, the depth and slope are fixed. This allows the designer to select specific project constraints, such as right-of-way, bank height or minimum bed slope, and then arrive at a consistent set of channel dimensions.

If the calculations indicate that the slope of the project channel needs to be less than the natural terrain, the slopes in the table can be used to aid in spacing drop structures or introducing sinuosity into the project alignment.

An example of a family of slope-width solutions that satisfy the resistance and sediment transport equations for the design discharge is illustrated by Figure 6.18. Any combination of slope and base width from this curve will be stable for the prescribed channel design discharge.

NOTE: Combinations of width and slope that plot above the stability curve will result in degradation, and combinations below the curve will result in aggradation. The greater the distance from the curve, the more severe the instability.

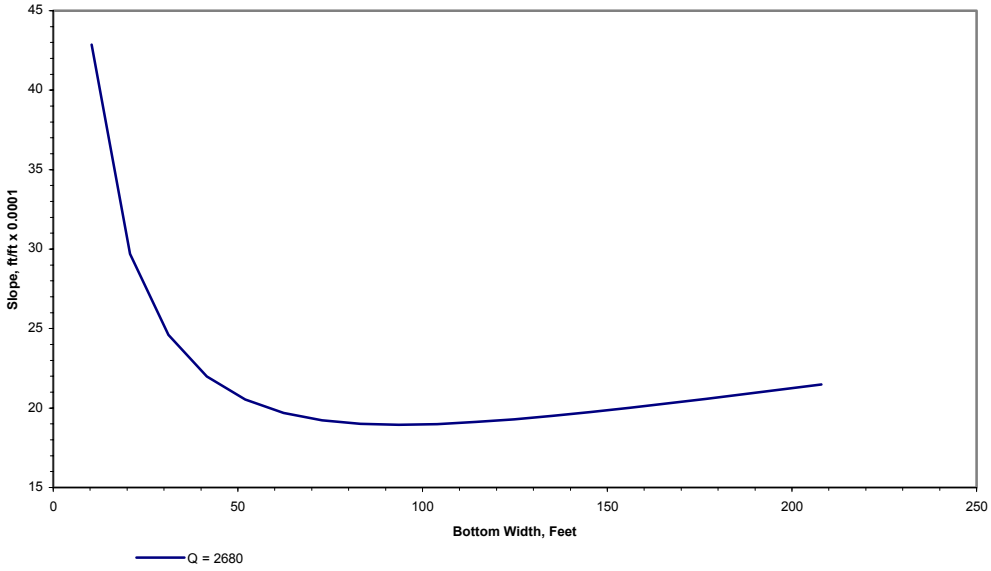

Figure 6.18. Example slope-width graph from the stable channel dimensions calculations.

Constraints on this wide range of solutions may result from a maximum possible slope, or a width constraint due to right-of-way. Maximum allowable

depth could also be a constraint. Depth is not plotted in Figure 6.18, but it is calculated for each slope and width combination determined. With constraints, the range of solutions is reduced, see Figure 6.19.

Different water and sediment discharges will produce different stability curves. First, the stable channel solution is obtained for the channel-forming discharge. Then, stability curves are calculated for a range of discharges to determine how sensitive the channel dimensions are to variations in water and sediment inflow events.

The stable channel dimensions are calculated for a range of widths on either side of a prescribed median value. (A median value can be prescribed, manually, on the GC record, but not in SAMwin.) If no median value is prescribed, the program assigns a value based on the following hydraulic geometry equation, proposed in EM 1110-2-1418 (USACE 1994).

$$B = 2.0\,Q^{0.5}$$

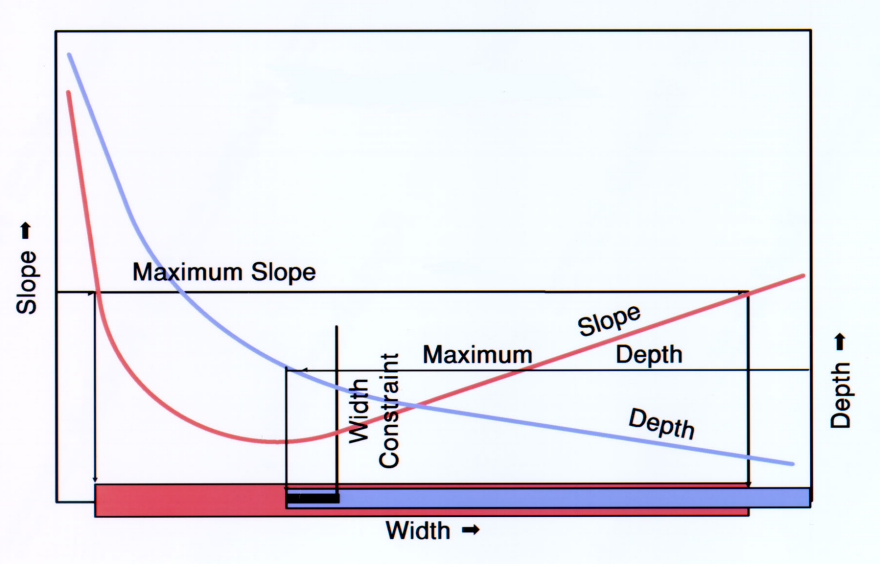

Figure 6.19. Slope-width graph showing the effect of constraints on the range of solutions.

The SAM program assigns 20 base widths for the calculation, each with an increment of 0.1B. Calculations for these conditions are displayed as output. Stability curves can then be plotted from these data.

A solution for minimum stream power is also calculated by the model. This solution represents the minimum slope that will transport the incoming sediment load. Solution for minimum slope is obtained by using a second-order Lagrangian interpolation scheme. Opinions are divided regarding the use of

minimum stream power to uniquely define channel stability. An optional use of the analytical method is to assign a value for slope, thereby obtaining unique solutions for width and depth. Typically there will be two solutions for each slope.

Meander Geometry

Input

The purpose of the meander calculations is to provide both curvilinear and Cartesian coordinates for a meander planform based on the sine-generated curve. The sine-generated curve has been shown to effectively replicate meander patterns in a wide variety of natural rivers. (Langbein and Leopold, 1966)

Required input are the meander arc length and the meander wavelength, as shown in Figure 6.20. Title records are optional. The Meander arc length is the actual length of the channel, whereas the wavelength is the length, along the valley, of one full meander.

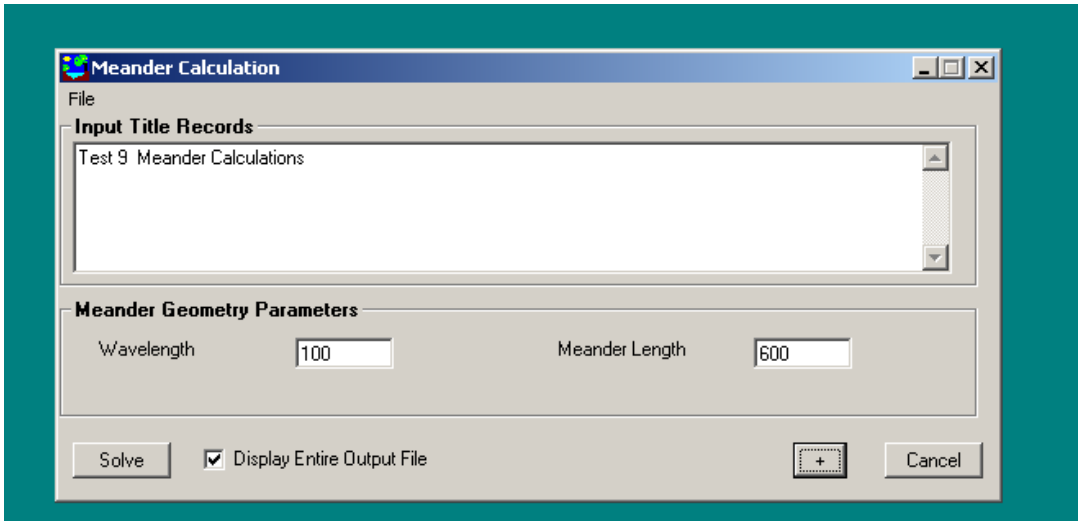

Figure 6.20. The Meander Calculation screen, with input.

Output

The output file first displays the SAM.hyd banner and echoes the input. An internal banner stresses that these calculations are appropriate for sand-be streams. The input wavelength and meander length are then printed along with the sinuosity, maximum deflection angle (in degrees), and the amplitude. Then a table of "Coordinates along one meander wavelength" is printed, giving the distance along the channel, deflection angle in degrees, the Y perpendicular to the valley slope, and the X along the valley slope.

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  *                                                      *
  *   PLANFORM GEOMETRY FOR A MEANDERING SAND-BED STREAM   *
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WAVE LENGTH	MEANDER LENGTH	SINUOSITY	MAXIMUM DEFLECTION ANGLE-DEG	AMPLITUDE
100.00	600.00	6.00	120.371	236.90

COORDINATES ALONG ONE MEANDER WAVELENGTH

ALONG THE CHANNEL	DEFLECTION ANGLE DEGREES	PERPENDICULAR TO VALLEY SLOPE	ALONG THE VALLEY SLOPE
S	THETA	Y	X
0.00	120.37	0.00	0.00
6.00	120.13	5.20	-3.03
12.00	119.42	10.43	-6.02
18.00	118.24	15.70	-8.93
24.00	116.59	21.04	-11.70
30.00	114.48	26.47	-14.29
36.00	111.92	32.01	-16.66
42.00	108.92	37.65	-18.76
48.00	105.48	43.39	-20.54
54.00	101.63	49.24	-21.95
60.00	97.38	55.18	-22.95
66.00	92.75	61.17	-23.48
72.00	87.75	67.18	-23.50
78.00	82.40	73.17	-22.99
84.00	76.73	79.09	-21.90
90.00	70.75	84.86	-20.21
96.00	64.50	90.42	-17.93
102.00	57.99	95.69	-15.03
108.00	51.25	100.59	-11.55
114.00	44.31	105.04	-7.52
120.00	37.20	108.96	-2.96
126.00	29.94	112.28	2.04
132.00	22.56	114.94	7.43
138.00	15.09	116.87	13.12
144.00	7.56	118.05	19.01
150.00	0.00	118.45	25.00
156.00	-7.56	118.05	30.99
162.00	-15.09	116.87	36.88
168.00	-22.56	114.94	42.57
174.00	-29.94	112.28	47.96
180.00	-37.20	108.96	52.96
186.00	-44.31	105.03	57.52
192.00	-51.25	100.58	61.55
198.00	-57.99	95.68	65.03
204.00	-64.50	90.42	67.93
210.00	-70.75	84.86	70.21
216.00	-76.73	79.09	71.90
222.00	-82.40	73.17	72.99
228.00	-87.75	67.18	73.50
234.00	-92.75	61.17	73.48
240.00	-97.38	55.18	72.95
246.00	-101.63	49.24	71.95
252.00	-105.48	43.39	70.54
258.00	-108.92	37.65	68.76
264.00	-111.92	32.01	66.66
270.00	-114.48	26.47	64.29
276.00	-116.59	21.04	61.70
282.00	-118.24	15.70	58.93
288.00	-119.42	10.43	56.02

294.00	-120.13	5.20	53.03
300.00	-120.37	0.00	50.00
306.00	-120.13	-5.20	46.97
312.00	-119.42	-10.43	43.98
318.00	-118.24	-15.70	41.07
324.00	-116.59	-21.04	38.30
330.00	-114.48	-26.47	35.71
336.00	-111.92	-32.01	33.34
342.00	-108.92	-37.65	31.24
348.00	-105.48	-43.39	29.46
354.00	-101.63	-49.24	28.05
360.00	-97.38	-55.18	27.05
366.00	-92.75	-61.17	26.52
372.00	-87.75	-67.18	26.50
378.00	-82.40	-73.17	27.01
384.00	-76.73	-79.09	28.10
390.00	-70.75	-84.86	29.79
396.00	-64.50	-90.42	32.07
402.00	-57.99	-95.68	34.97
408.00	-51.25	-100.58	38.45
414.00	-44.31	-105.03	42.48
420.00	-37.20	-108.96	47.03
426.00	-29.94	-112.28	52.04
432.00	-22.56	-114.94	57.43
438.00	-15.09	-116.87	63.12
444.00	-7.56	-118.05	69.01
450.00	0.00	-118.45	75.00
456.00	7.56	-118.05	80.99
462.00	15.09	-116.87	86.88
468.00	22.55	-114.94	92.57
474.00	29.93	-112.28	97.96
480.00	37.20	-108.96	102.96
486.00	44.31	-105.04	107.52
492.00	51.25	-100.59	111.55
498.00	57.99	-95.69	115.03
504.00	64.50	-90.42	117.92
510.00	70.75	-84.86	120.21
516.00	76.73	-79.09	121.90
522.00	82.40	-73.17	122.99
528.00	87.75	-67.18	123.50
534.00	92.75	-61.17	123.48
540.00	97.38	-55.18	122.95
546.00	101.63	-49.24	121.95
552.00	105.48	-43.39	120.54
558.00	108.91	-37.65	118.76
564.00	111.92	-32.01	116.66
570.00	114.48	-26.47	114.29
576.00	116.59	-21.04	111.70
582.00	118.24	-15.70	108.93
588.00	119.42	-10.43	106.02
594.00	120.13	-5.20	103.03
600.00	120.37	0.00	100.00

This calculation has no plotting capability, but the table of coordinates could be copied into a spreadsheet for plotting.