

FACTSHEET

Cross-Section Hydraulic Analyzer Excel Spreadsheet

1. What is this spreadsheet for?

Given a stream channel cross-section, the spreadsheet provides a rating curve (or data for every half-foot of height) based on uniform flow conditions using the Manning Equation:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

where:

Q is the discharge or flow in cubic feet per second (CFS)

A is cross-sectional area perpendicular to flow in square feet

R is the hydraulic radius in feet, equal to A divided by wetted perimeter

S is the longitudinal or profile slope of the stream in ft horiz./ft vert.

n is Mannings roughness coefficient

After the rating curve is determined, the user may enter any elevation within the cross-section to determine the hydraulic parameters at any given water surface.

2. What information must the user provide?

The user describes a cross-section of a stream channel by entering ground elevations and stations. The elevations, in feet or meters, may be based on a geodetic datum or they may be stages relative to a local datum. The stations, in the same unit system, may start at any number, including a negative number, and must proceed equal to or greater than the previous station.

The resulting cross-section plot is created automatically under a separate tab.

The user must also provide Mannings roughness coefficient, which may be the same for the entire cross-section, or may vary horizontally. In the n-value column, rows may be left blank if the n-value in the previous column still applies. A new value must be entered in a row only when the roughness changes from that point forward in the data. References on how to determine Mannings roughness coefficient are provided on the NRCS website.

The user must also provide left and right bank stations. For many cross-section shapes a better estimate of total section hydraulic parameters is obtained by computing overbanks separately from channel.

Finally, the user may optionally enter the stream longitudinal or profile slope in length horizontal per length vertical. This is required to calculate discharge. But, if not provided, several hydraulic parameters may still be calculated.

3. How does the spreadsheet work?

The spreadsheet employs “macros” which are a set of programmed commands that are activated when the user clicks on one of the two buttons within the spreadsheet. (This Visual Basic for Applications program code may be viewed from the View menu by selecting “Macros”.)

After the user-required info has been entered (item 2 above), the “calculate rating table” button must be clicked first. Hydraulic parameters are calculated, for a water surface elevation at every half-foot of depth for the entire cross-section.

The single water surface calculation uses the same procedure, as follows:

For whichever water surface level is under consideration, the macro must determine the information needed to solve Mannings equation (in item 1 above). Using the ground coordinates, the macro sums coordinate values as needed for the following formula, the area of a polygon:

$$A = \frac{1}{2} \sum_{i=1}^n (x_i y_{i+1} - y_{i+1} x_i)$$

As the macro continues, point to point, from left to right, when it comes to the rating level being computed (or user-specified water surface), it closed the polygon by including the first point, making the water surface the last side of the polygon.

Similarly, the wetted perimeters can be summed by computing the length of each segment using the Pythagorean Theorem:

$$WP = \sum_{i=1}^{n-1} \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

The macro determines top width by keeping track of the coordinates that represent the rating level being considered (or user-specified water surface) and leaving out any intervening ground (islands) that may exist.

The macro also converts Manning roughness coefficient, n , to the Darcy-Weisbach friction factor, f , using the following equation. This may be useful information, but is not needed for Mannings equation.

$$f = \frac{8gRS}{V^2} \quad f = \frac{8gn^2}{(1.486)^2 R^{1/3}} = \frac{116.56n^2}{R^{1/3}}$$

The hydraulic parameter *conveyance* is used in computer programs such as HecRas and contains everything from the Manning equation except slope:

$$K = \frac{1.486}{n} AR^{2/3}$$

If the user has entered the profile slope, discharge or Q is then calculated from Mannings equation. The flow average velocity is then calculated from $V = Q/A$. Finally, the average shear force of the flow is calculated from:

$$\tau_0 = \gamma RS_f$$

where gamma is the unit weight of water or 62.4 lbs per cubic foot, R is the hydraulic radius, and S_f is the profile slope.

While a single value for Mannings roughness coefficient may sometimes be adequate for a channel cross-section, it is often the case that the roughness varies horizontally along the section. For example, the channel may be sand, but the banks have dense vegetation, and the overbanks a forest with underbrush. If the user provides more than one n value for the cross-section the macro computes a single value which is a composite of all the roughnesses (and this for every water surface level). The following equation (6-18 from Chow's Open-Channel Hydraulics) is based on the assumption that the total force resisting the flow is equal to the sum of the forces resisting flow in each of the submerged subsections.

$$n_{total} = \frac{\left(P_1 n_1^2 + P_2 n_2^2 + P_3 n_3^2 + \dots + P_N n_N^2 \right)^{1/2}}{P^2}$$

where subscripted P values are wetted perimeters for each specified roughness.

4. Things to be aware of...

uniform flow versus natural flow

One should understand the difference between "uniform flow" calculations and natural flow in rivers. Mannings equation calculates flow for a uniform channel, one in which the depth does not change along the profile. This is also called "normal depth" because the water surface and streambed profiles are parallel and the depth is normal to (perpendicular to) these profiles.

In natural streams numerous non-uniformities often cause significant differences in roughness or flow resistance along the stream channel profile. The result is that the channel flow will vary from uniform flow. However, Mannings equation may still provide an acceptable approximation.

roughness variation with depth

At very shallow flow depths, such as a hydraulic depth of 1 foot or less, the Mannings roughness coefficient will often diverge significantly from its value for the same channel at a deeper flow. Thus, if the user determines n value from guidance that has not specifically taken into account shallow flow, it should not be assumed to apply to shallow flow within this spreadsheet. (It is probably higher.)

average velocity and shear versus instantaneous point measurements

The average velocity calculation is from the continuity equation, $Q = VA$. If one measures actual river velocities, these instantaneous point measurements may vary markedly from the calculated average. The same is true of average cross-section shear force values.