User Assigned Courant Number in TOLER.DAT for Enhanced Model Numerical Stability
Version 2009.06 (Build No. 2010.05.01)

Background

The key to efficient computational flood routing for a finite difference model is that numerical stability criteria limits the timestep to avoid surging and yet allows large enough timesteps to complete the simulation in a reasonable time. FLO-2D has a variable timestep that depends on the numerical stability criteria. The numerical stability criteria are checked for the every grid element and flow direction for every timestep. If any of the numerical stability criteria are exceeded, the timestep is decreased and all the previous hydraulic computations for that timestep are discarded.

Along with two other numerical stability criteria, the Courant Number has always used in the FLO-2D model for numerical stability. The FLO-2D flood routing scheme proceeds on the basis that the timestep is sufficiently small to eliminate or limit numerical surging. The FLO-2D numerical algorithm is an explicit scheme that is subject to the Courant-Friedrich-Lewy (CFL or Courant Number) condition for numerical stability. The Courant Number relates the floodwave movement to the model discretization in time and space. The concept of the Courant Number is that a particle of fluid should not travel more than one spatial increment Δx in one timestep Δt. In the FLO-2D model the Courant number limits the timestep Δt by:

$$\Delta t = C\ \Delta x / (V + c)$$

where:

C is the Courant Number ($C \leq 1.0$)
Δx is the square grid element width
V is the depth averaged velocity
c is the floodwave celerity; $c = (gd)^{0.5}$ where g is gravitation acceleration and d is the flow depth above the thalweg.

While the Courant Number C can vary from 0.3 to 1.0, a value of 1.0 had been employed in the FLO-2D model to allow the model to have the largest possible timestep. When C is set to 1.0, artificial or numerical diffusivity is theoretically zero for a linear convective equation. In previous versions of FLO-2D, the Courant Number was hardwired in the model with value of C = 1.0. Recent testing has shown that the model can run significantly faster with greater stability if the Courant Number is set to values less than 1.0.

Instructions for Using the Courant Number

The Courant Number can now be assigned by the user in the TOLER.DAT file line 2 as follows:

Line 1. 0.1 0.2 1.0 (TOL, DEPTOL, and WAVEMAX values)

Line 2. C 0.6 (Line 2 is optional; where C is a line character identifier and 0.6 is the Courant Number)

Line 2 is optional and if left unassigned, the default Courant Number is 0.6. A typical range of the Courant Number is 0.3 (slower more stable model) to 1.0 (faster less stable model). The default value of 0.6 is recommended as a starting value. For models that appear to be unstable, setting the Courant Number to 0.4 or 0.3 will help to control the numerical surging.

It was found that the Courant Number is more effective in controlling the numerical surging than the combined percent change in depth DEPTOL and WAVEMAX stability parameter for most FLO-2D simulations. The WAVEMAX may still have some value in controlling numerical instability for flow in confluences or split flows. Initially the WAVEMAX value can be set to 1.0 and the DEPTOL = 0.2 (default values). After a simulation is complete and the TIME.OUT file is reviewed, it may be appropriate adjust these values.

Recommendations:

1. Use the default values for the initial simulation: Courant Number C = 0.6
DEPTOL = 0.2
WAVEMAX = 1.0.
2. If the model has no numerical surging or unreasonable maximum velocities (See the Pocket Guide for additional discussion) and it is desired to have the model run faster increase the Courant Number to 0.7 or 0.8.
3. If the model has some numerical instability decrease the Courant Number to 0.4 or 0.3.
4. If the model has some numerical surging in the channel in some unique locations, decrease the WAVEMAX value to 0.5 or 0.25 (this will slow the model down significantly).
5. Review the TIME.OUT file to determine which of the stability criterion is slowing down the model after a flood simulation is complete.
6. It is possible to set DEPTOL = 0. and WAVEMAX = 0. to turn off these stability criteria for the next simulation.
7. It may be necessary to experiment with short duration simulations to determine which combination of the stability criteria results in the fastest stable model.