VICAIRE - MODULE 1B

Engineering Hydrology - Chapter 5

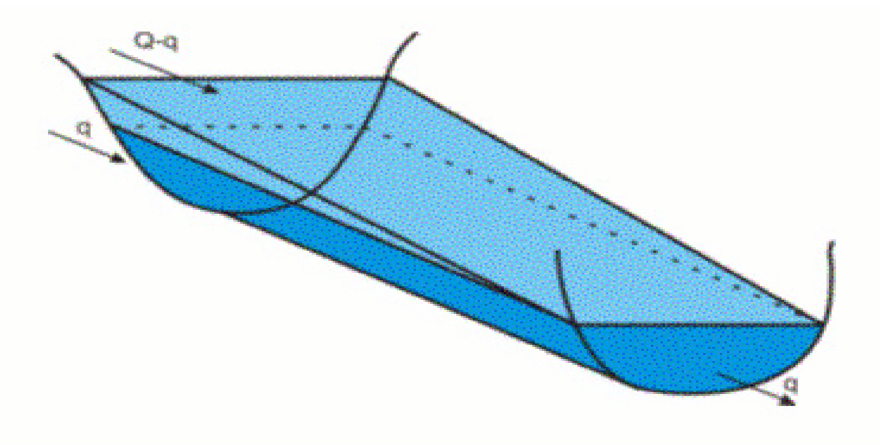
Summary: Routing Function - Hydrologic Approach

The roughness coefficient is bigger in the major bed of the rivers than in the minor bed; because of this, during the floods the movement of the water in the meadow area is slower than in the central part of the river. Therefore, at the downstream end of a reach, the hydrograph is different from the inflow hydrograph, being flattered and with the centroid shifted.

Flood routing is a mathematical procedure for predicting the changing magnitude and shape of a flood wave at one or more points on a watercourse using known or assumed hydrographs at one or more upstream points.

The flood routing can be undertaken using hydrologic models, like Muskingum model, or hydraulic models, based on Saint-Venant equations. The hydrologic routing, known as *lumped* routing, directly allow the computation of the outflow hydrograph from the downstream end of the reach; only two parameters are needed. The hydraulic routing, known as *distributed* routing, requires the computation for every time step of the discharges along the river in an important number of intermediate points; beside the cross sections in these intermediate points, the hydraulic parameters are needed. The hydrologic models lead to approximate results, but due to the fact they need less data and provide results quickly are still largely used in the current practice.

The Muskingum model is based on the equation of continuity, in a discret form, and on an empirical function of storage.



Simplified representation of the storage in a river reach.

The storage in the river reach at the time step *i* is a combination of a prism storage at the lower part and a wedge storage at the upper part.

The prism storage, due to the discharge *q*, is equal to: $V_i^{prism} = q_i \cdot K$, where *K* is expressed in units of time (hours usually) and represents the time needed for the discharge *q* to come from the upstream to the downstream cross section of the reach.

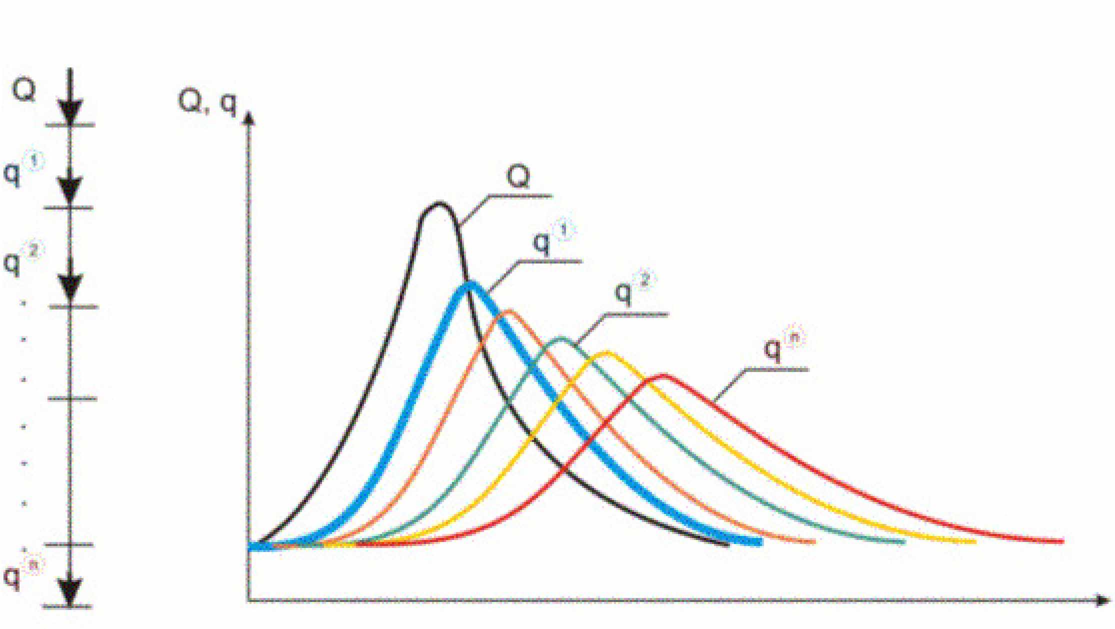
The wedge storage is obtained using a similar relationship; still, because the water table is not a plane a reduction coefficient (or weighting factor) *X* was introduced in the model's formulation: $V_i^{edge} = K \cdot Q_i^{av} = KX\left(Q_i - q_i\right)$

Expressing the storage of the reach between the two successive time steps and grouping the terms, the downstream discharge q_i can be expressed as a linear function of the discharges Q_i, and Q_{i-1} as it follows: $q_i = aQ_i + bQ_{i-1} + cq_{i-1}$

As parameters of the model one can consider or the parameters *K* and *X*, having a physical meaning, or the related parameters *a*, *b* and *c*, functions of *K* and *X*, but with only a mathematical interpretation.

The stability conditions of the Muskingum model are: $2KX \le \Delta t \le 2K\left(1-X\right)$.

If the time step *Δt* is too small, the stability conditions are not satisfied, being necessary to divide the reach into sub-reaches. The Muskingum model is then applied successively on each reach. The computation of the flood propagation is made successively, the output discharge from a sub-reach being the input discharge in the next downstream sub-reach.



Successive routing of the flood wave.

For the parameters identification of the Muskingum model one uses either a graphical method or a mathematical model, which consider the Muskingum relation as a multiple linear correlation.

There are presented also some other models, derived from the Muskingum model: integral form of the Muskingum model, Muskingum model with variable parameters, Muskingum model using a non-linear kernel function, and finally the Muskingum-Cunge method. Cunge (1969) obtained an analytical expression for the *X* parameter; both *X* and *K* are variable in time and along the river.

As in the case of the river routing, the reservoir routing utilizes as basic relationship the continuity equation. Because in this relation there are two unknowns (the storage *V* and the outflow *q*), another relation between these variables is necessary. Empirical formulas for the gates or spillways discharge as a function of the water level or storage in the reservoir are used: $q = q\left(H\right) = q\left(H\left(V\right)\right) = q\left(V\right)$

The obtained system of equations can be solved using an auxiliary function *E(H)* or an iterative process in the frame of each time interval. Different criteria of convergence are presented.