

Analysis of SWC/Junctions

Muskingum

Muskingum routing is used in xpdrainage to represent channelled flow or filtered flow. It is suitable for drainage systems with significant time of travel between inlet and outlet and some flattening of the hydrograph, either because of long channelled flow, or because flow is filtered slowly. It is available for all SWCs except the Soakaway. The description of the method here is also relevant for the flow routing through Connections. The Muskingum routing method is based on the two following equations.

The equation of continuity of flow is:

$$I - Q = \frac{dS}{dt}$$

The model of storage in the channel/reach/pipe/system is:

$$S = K[\theta I + (1 - \theta)Q]$$

Where:

- I is inflow
- Q is outflow
- S is reach storage
- K represents travel time through the reach
- θ is a weighting coefficient

These can be converted to a routing equation relating outflow to inflow over the timestep Δt from time t_n to time t_{n+1} that can be computed simply as:

$$Q_{n+1} = \frac{-K\theta + 0.5\Delta t}{K(1-\theta) + 0.5\Delta t} I_{n+1} + \frac{K\theta + 0.5\Delta t}{K(1-\theta) + 0.5\Delta t} I_n + \frac{K(1-\theta) - 0.5\Delta t}{K(1-\theta) + 0.5\Delta t} Q_n$$

These simple equations are well suited to represent flow through sustainable drainage systems because of the natural choice of states and parameters (natural in terms of the design process). First of all, maximum storage is either a design aim or can be estimated easily. Similarly, travel time is either a design aim or can be approximated fairly simply using a friction loss equation and length between input and output locations.

The weighting coefficient is more difficult to estimate. 0.5 is the maximum possible value and gives no dispersal of the hydrograph (translation only). Values between 0.2 and 0.4 are recommended for natural channels. 0.4 would be a reasonable default for swales and 0.2 for bioretention systems. Even a value of 0.0 is possible, giving more spread. Note that the spread is symmetrical.

For sustainable drainage systems, the travel time is calculated both along the length of the system and down through the filter layers. This is done as a simple calculation of along + down, where along is along the fastest route through the system (along channel for a swale and through bottom drainage layer for bioretention).

While the Muskingum method gives the output hydrograph value at every timestep, it does not calculate levels. As it is essential for the user to know the levels within the storage system, how full the system is at each timestep, and whether it will overflow or not, xpdrainage calculates the water levels in each structure from the current stored volume, after the volumes have been updated. This allows the software to show the hydraulic grade line.

xpdrainage also offers the following two alternatives to the Muskingum method for the routing through the Stormwater Controls.

Simple Time Delay

While some degree of attenuation is natural with most storage devices and gravity conveyance systems, it is not always clear what should be the degree of flattening of the hydrograph, and the user may prefer to just specify a time delay. The hydrograph is propagated through the structure with a lag but with no attenuation. This is actually calculated as a particular case of the Muskingum method when the weighting coefficient is equal to 0.5.

Note that overall the SWC can still generate some flow attenuation in this case if the outlets restrict the outflow.

No Delay



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Workflow - What's next...?



Connect Inflows to your **Stormwater Control**, specify **Inlets** or **Outlets** or connect to another Stormwater Control or **Junction**.

Alternatively the user can specify the routing to be calculated through the structure without any delay.

Note that overall the SWC can still generate some flow attenuation in this case if the outlets restrict the outflow.