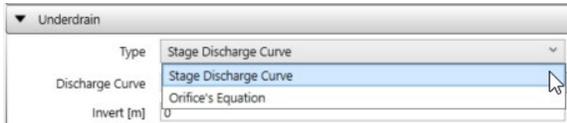


# Orifice Equation for LID Underdrain

Michael Yu, 2020-01-28

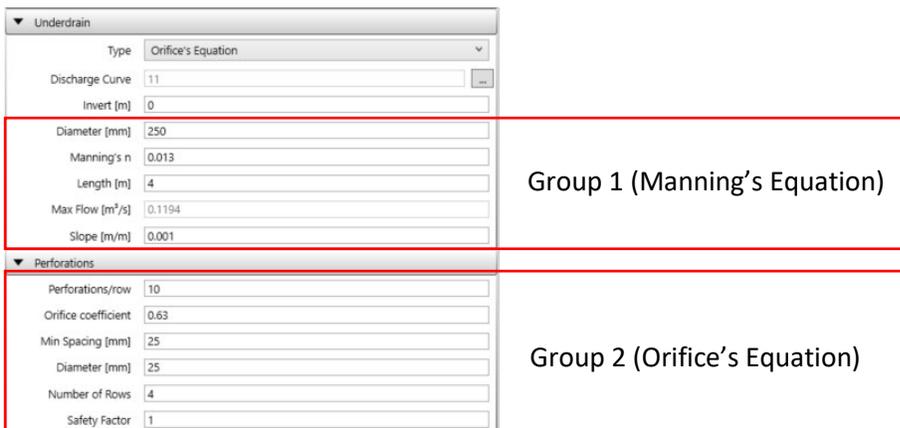
For VO LID commands, there are two ways to specify the outflow capacity of the underdrain: 1) Stage Discharge Curve and 2) Orifice's Equation. With these two options, the stage-discharge curve could be entered directly or calculated with orifice's equation.



## Parameters

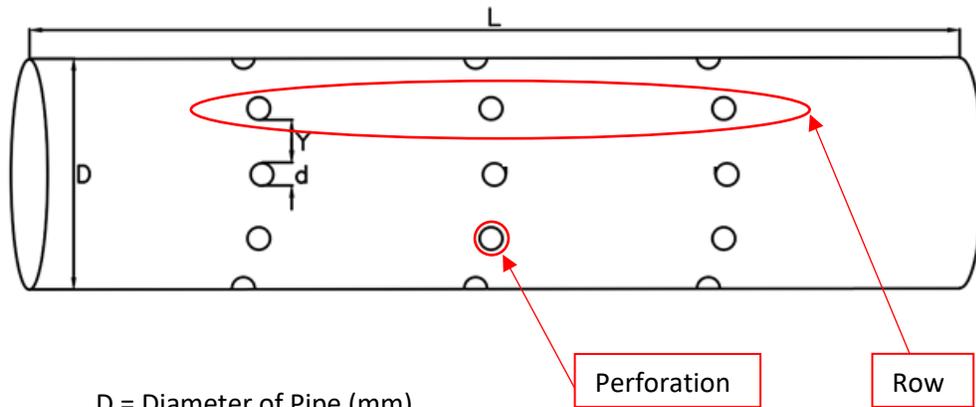
As shown below, there are two groups of parameters for Orifice's Equation option.

1. **Group 1** includes pipe diameter, manning's coefficient and slope, with which the max flow could be calculated using Manning's equation.
2. **Group 2** parameters specify the layout of the perforations so the depth-discharge curve could be calculated with Orifice's equation. The curve then will be checked against the max flow.



## Layout of Perforations

As shown in the diagram below, the perforations are assumed to be placed in horizontal rows and evenly distributed along pipe circumference.



$D$  = Diameter of Pipe (mm)

$L$  = Length of Pipe (m)

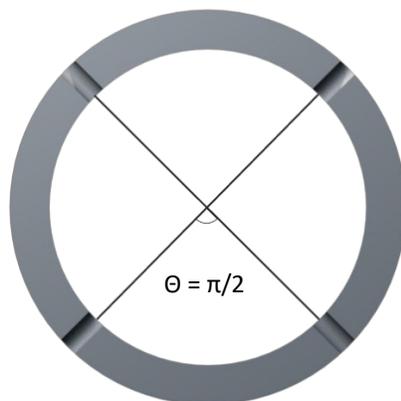
$Y$  = Minimum Space Between Perforations (in both vertical and horizontal direction) (m)

$d$  = Diameter of Perforations (mm)

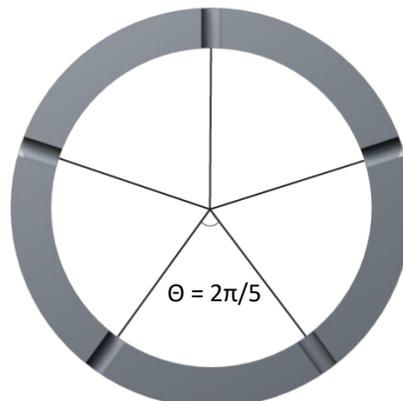
$X1$  = Perforations Per Row

$X2$  = Number of Rows

If the number of rows is even number (e.g.  $X2 = 4$ ), it's assumed the perforations are placed on both sides. If it's odd number (e.g.  $X2 = 5$ ), it's assumed that one of the perforations is on the top and the rest are placed on both sides.



$X2 = 4$



$X2 = 5$

## Max Depth

All layers above the underdrain pipe will be considered in the calculated depth-discharge curve. For example, a bioretention system with 0.2m of ponding, 0.3m of mulch, 1m of engineered soil and 1m of storage will have max depth of 2.5m (0.2 + 0.3 + 1 + 1).

## Calculation

The flow through the perforations is calculated using orifice's equation.

$$Q = C_d A_o \sqrt{2gH} / SF$$

where:

$C_d$  = Orifice Coefficient

$A_o$  = Perforation Area (m<sup>2</sup>)

$g$  = Acceleration from gravity (9.81 m/s<sup>2</sup>)

$H$  = Head (m)

$SF$  = Safety factor.

Note that the head is different for perforations at different level.

## Warnings and Errors

The warnings and errors associated with underdrain parameters are list below.

1. **Error:** Length of pipe shouldn't be longer than the LID  
It indicates that the perforated pipe is longer than length of LID. Consider changing one of them.
2. **Error:** Check (Diameter of Perforations + Minimum Spacing)\*Number of Rows cannot be larger than Pipe Circumference  
This is to check that the total of perforation and spacing along circumference. Decreasing the number of rows or diameter of perforations would remove the warning.
3. **Error:** (Diameter of Perforations \* PerforationsPerRows + Minimum Spacing \* ( PerforationsPerRows + 1 ) ) cannot be larger than the pipe length  
This checks the horizontal dimension setting. Consider decreasing the number of perforations per row or increasing the pipe length.
4. **Warning:** The discharge to underdrain based on orifice equation is larger than maximum flow allowed through underdrain based on Manning's Equation.  
This checks the max discharge in depth-discharge curve against max manning's flow. Consider decreasing the number of perforations or increasing the slope of the pipe.