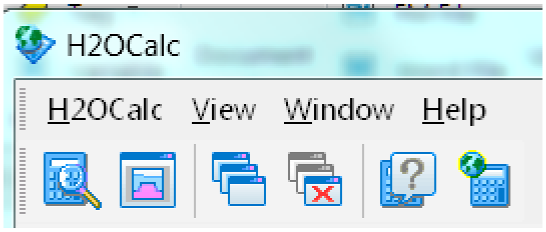

H2OCalc
H2OCalc View Window Help

Introduction

For an overview of the H2OCalc capabilities, you may refer to the overview page.

The H2OCalc is used to and is comprised of the following components.

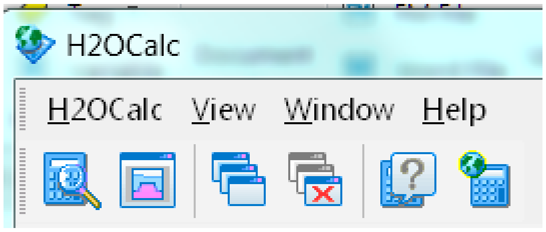
H_2OCalc Calculation Dialog Boxes	Flow Calculator
Gradually Varied Flow	Conservation of Energy
Drainage Structures	Weirs and Orifices
Culverts	Transient Flow
Hydraulic Jump	Discharge from Tank
Pumps	Equivalent Pipe Length
Groundwater Hydrology	Surface Water Hydrology
Unit Converter	H_2OCalc Methodology

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

H_2OCalc Overview

H2OCalc is an easy-to-use, stand-alone program designed as a hydraulic toolbox to assist civil, environmental and water resources engineers with solving complex hydraulic problems quickly and accurately. Its powerful and comprehensive modeling capabilities let engineers streamline the hydraulic analysis and design of pipes, pumps, open channels, weirs, orifices, culverts, and inlets. Calculations for both steady uniform flow and gradually varied flow are supported. The program also performs useful calculations for stormwater runoff and groundwater flow.

H2OCalc can be effectively used to perform pressurized pipe calculations for pipe length, begin and end elevations, roughness coefficient, diameter as well as flow rate and pressure drop using the Hazen-Williams, Darcy-Weisbach, Manning, and Kutter head loss methods. The user can design and analyze channels, ditches, and free surface pipes of various shapes including circular, box, trapezoidal, triangular and irregular channels. Both steady uniform slow and gradually varied flow are supported. Under steady uniform flow, H2OCalc solves for discharge, normal depth, channel dimensions, or slope. Gradually varied flow calculations for flow and depth are carried out using the direct step method and the standard step method.

With H2OCalc, you can design and analyze grate, curb, ditch, slotted, and combination inlets using calculations based on the FHWA Hydraulic Engineering Circular No. 12 and Circular No. 22 methodologies. In sag or on grade conditions with a continuously or locally depressed gutter are supported and water spread and gutter depth for a gutter or pavement section are computed.

You can also size various types of weirs considering discharge, weir coefficients, and crest, headwater and tailwater elevations including rectangular, v-notch, cipolletti, broad crested and generic. Weirs can be free flowing or submerged depending on the depth of tailwater elevation. Three types of orifice are also considered including circular, rectangular and generic.

H2OCalc can perform surface water hydrology calculations for stormwater runoff using both the rational method and the NRCS unit hydrograph method to determine peak discharge; groundwater flow calculations for steady flow in confined and unconfined aquifers; and well hydraulics calculations of confined and unconfined steady flows. Other calculations include transient flow in a pipeline, hydraulic jump, pump characteristic curve, specific speed, torque, power and inertia, parallel and series pump arrangements, discharge from an open or close tank and equivalent pipe length.

The program can also perform complex hydraulic calculations for culverts such as determining the headwater elevation, hydraulic grade line, discharge and size. It uses the U.S. Federal Highway Administration (FHWA) Hydraulic Design of Highway Culverts (HDS-5) methodology for performing both inlet control and outlet control and overtopping calculations. Backwater and drawdown conditions, including hydraulic jumps, are considered. Free-surface, pressurized and transitional flow can be handled. Calculations apply for circular and rectangular culverts as well as for rectangular and trapezoidal stream channels. Simplified culvert equations that classify culverts into various categories depending on headwater and tailwater elevations, slope, size and other characteristics are also supported.

A unit converter is also provided to help you find the equivalent value of inputted parameters in different units. Conversion factors are available for length, area, volume, mass, density, velocity, acceleration, flow rate, temperature, force, pressure, energy and power.

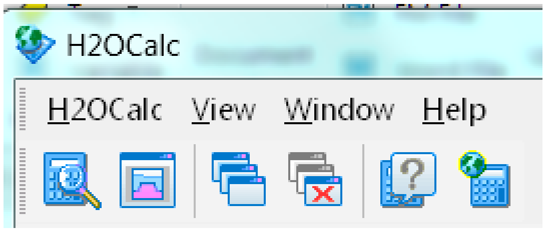
We are happy to bring you an indispensable hydraulic engineering toolbox to help you quickly and accurately analyze and design various hydraulic elements from pipes and open channels to drop inlets, culverts and weirs.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Press Release

MWH Soft Ships Second Generation of H2OCalc,The Indispensable Hydraulic & Hydrology Toolbox for the Water and Wastewater Industries

New Release Features Groundbreaking Advances to Help Engineers Solve Complex Problems Quickly and Easily

Broomfield, Colorado USA, **April 25, 2007**

MWH Soft, a leading global provider of environmental and water resources applications software, today announced the second major release of *H2OCalc*, an advanced version of its professional hydraulic and hydrology calculator for practicing engineers. With the new release, MWH Soft once again moves the water and wastewater industries to the head of the line for key new modeling capabilities.

Powerful, comprehensive and easy to use, *H2OCalc* gives engineers uncomplicated access to scores of advanced hydraulic computational algorithms essential to designing better systems. It enables users to deploy these sophisticated computational abilities to streamline the hydraulic design and analysis of pumps, pipes, ditches, open channels, weirs, orifices, culverts, and inlets without having expertise in this complex field. It also eliminates the need for messy nomographs, cumbersome spreadsheets and homegrown programs, empowering engineers to work more effectively, improve productivity and design better systems.

H2OCalc can be used to solve for any unknown variable or design for any desired characteristic. Users can design and analyze pressurized pipes as well as channels, ditches, and free surface pipes of various shapes, including circular, box, trapezoidal, triangular and irregular channels. They can analyze these carriers under both steady uniform flow and gradually varied flow (direct step and standard step methods), and quickly size various types of weirs. They can also design and analyze grate, curb, ditch, slotted, and combination inlets using rigorous calculations based on U.S. Federal Highway Administration (FHWA) Hydraulic Engineering Circular

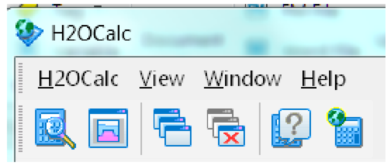
No. 12 and Circular No. 22 methodologies. In-sag and on-grade conditions with continuously or locally depressed gutters are supported, and water spread and gutter depth for a gutter or pavement section can be computed.

The program can also perform complex hydraulic calculations for culverts, including headwater elevation, hydraulic grade line, discharge and size, using FHWA Hydraulic Design of Highway Culverts (HDS-5) methodology for performing inlet control, outlet control and overtopping calculations. Other important functions include surface water hydrology calculations for stormwater runoff using both the rational and NRCS unit hydrograph methods to determine peak discharge, groundwater flow calculations for steady flow in confined and unconfined aquifers, transient flow, and hydraulic jump. Pump characteristic curve, specific speed, torque, power, and inertia; parallel and series pump arrangements; discharge from an open or closed tank or reservoir; and equivalent pipe length computations are also supported. An engineer-friendly unit converter speeds many hydraulic parameter calculations including length, area, volume, mass, density, velocity, acceleration, flow rate, temperature, force, pressure, energy and power.

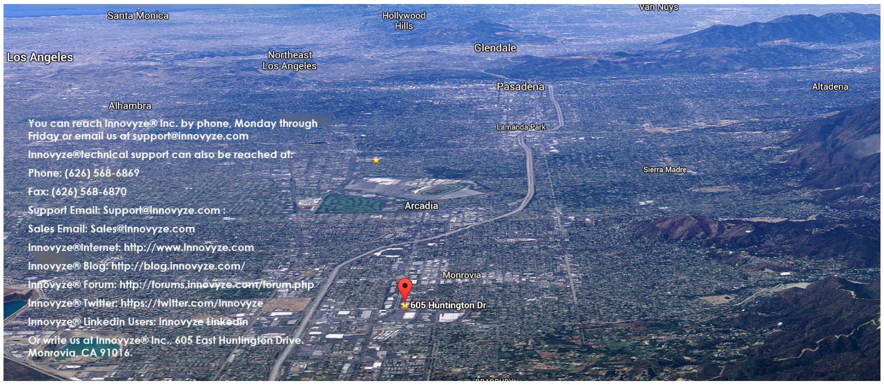
The new version now supports nine additional types of hydrographs: the Colorado Urban Hydrograph Procedure (CUHP), NRCS Dimensionless Unit Hydrograph, NRCS Triangular Unit Hydrograph, Delmarva Unit Hydrograph, Clark Unit Hydrograph, Snyder Unit Hydrograph, Santa Barbara Hydrograph (SBH), Espey Unit Hydrograph, and San Diego Modified Rational Hydrograph (SDMRH). It also computes the head-flow relationship for flow regulating devices.

“I have been using MWH Soft products for ten years, and each release delivers a new level of innovation and power that makes modeling and design easier and more efficient,” said Tony A. Akel, PE, President of Akel Engineering Group, Inc., a specialty engineering firm providing consulting services in water resources infrastructure modeling and master planning. “*H2OCalc* is a must-have toolbox for mainstream design engineers. It gives them convenient access to a comprehensive set of advanced engineering power tools, making it easier than ever to perform accurate hydraulic and hydrology calculations in record time. MWH Soft constantly builds user feedback into each new product to ensure that it meets engineers' needs. We appreciate the company's commitment to continuously improving this critical engineer-friendly tool, because these enhancements add value to our work."

"*H2OCalc* Generation V2 demonstrates our steadfast commitment to listening to our clients and quickly responding to their needs," said Paul F. Boulos, President and Chief Operating Officer of MWH Soft. "The new release extends our time-honored practice of continually adding value to our software and bringing new analysis and design capabilities to the mainstream. I'm particularly proud that we delivered this functionality-rich, yet simple-to-use, release in less than three months — setting a new bar for urban hydrologic modeling in the process."


H2OCalc
H2OCalc View Window Help

Contact Us About H_2OCalc



You can reach **Innovyze® Inc.** by phone, Monday through Friday or email us at support@innovyze.com Innovyze®technical support can also be reached at:

Phone: (626) 568-6869

Fax: (626) 568-6870

Support Email: Support@Innovyze.com :

Sales Email: Sales@Innovyze.com

Innovyze®Internet: http://www.Innovyze.com

Innovyze® Blog: http://blog.innovyze.com/

Innovyze® Forum: http://forums.innovyze.com/forum.php

Innovyze® Twitter: https://twitter.com/Innovyze

Innovyze® Linkedin Users: Innovyze Linkedin

Or write us at **Innovyze® Inc., 605 East Huntington Drive. Monrovia, CA 91016.**

If you contact Innovyze by telephone you will be asked to supply a number of details:

- Your name
- Your company details
- Innovyze product name and version number
- Operating system on which the software is running
- The level of urgency of the problem
- A brief description of the enquiry, fault or problem

If you contact the support team by fax or e-mail, please include all this information. It will help us to deal with your request more quickly.

We will also seriously consider your suggestions for future versions of all Innovyze®Products.

For international support, please contact your local Innovyze®Inc. Certified agent.

We occasionally create interim updates that contain fixes and/or new features or send you an interim dll update.

Please Note: Do not forget to renew the Annual Maintenance Agreement (Subscription Program) to take full advantage of future enhancements, product upgrades and product updates.

Contact Us (New Information)

You can reach Innovyze Technical Support in the following methods

Call us at:

(available Monday through Friday)

Region	Number
Technical Support (USA):	**(626) 568-6869**
Technical Support (UK):	**+44 (0)1491 821 460**
Technical Support (AUS):	**+61 (0)5506 5700**
FAX (US):	**(626) 568-6870**

Email us at:

Contact Type	Email
Technical Support Email:	**support@innovyze.com**
Sales Email:	**sales@innovyze.com**

Write us at:

Region	Address
Innovyze Inc (USA):	**605 East Huntington Drive, Suite 205 Monrovia, CA 91016 United States of America**
Innovyze Ltd (UK):	**Kestrel House Howbery Park Wallingford Oxfordshire, OX10 8BA United Kingdom**
Innovyze Pty Ltd (AUS):	**Suite 38, 75 Wharf St Tweed Heads NSW 2485 Australia**

Visit us on the web:

Site	URL
Innovyze Internet:	http://www.innovyze.com
Innovyze Blog:	http://blog.innovyze.com
Innovyze Forums:	http://forums.innovyze.com
Innovyze Twitter:	https://twitter.com/innovyze
Innovyze Linkedin:	Innovyze Linkedin Users

If you contact Innovyze by telephone, you will be asked to supply a number of details:

- Your name
- Your company
- Innovyze product name and version number
- Operating system on which the software is running
- The level of urgency of the problem
- A brief description of the enquiry, fault, or problem

If you contact Innovyze support team by fax or e-mail, please include all the above information. It will help us to deal with your request more quickly.

We will also seriously consider your suggestions for future versions of all Innovyze Products.

For international support, please contact your local Innovyze certified agent.

Please Note:

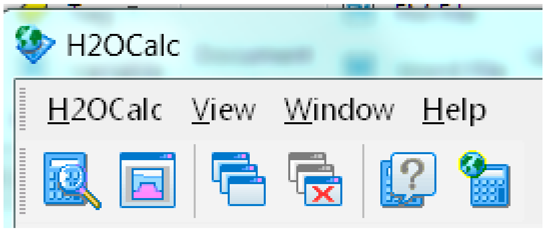
Do not forget to renew the Annual Maintenance Agreement (Subscription Program) to take full advantage of future enhancements, product updates/upgrades.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

Innovyze® H2OCalc™ Modeling Made Easy Innovyze®

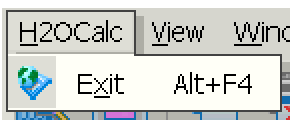

H2OCalc
H2OCalc View Window Help

Menu

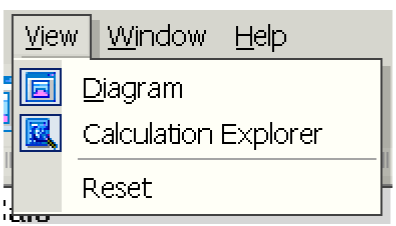
The drop-down menu system allows the user to access H2OCalc's tools and data managers. The menu system consists of the following selections:

- H2OCalc Menu
- View Menu
- Windows Menu
- Help Menu

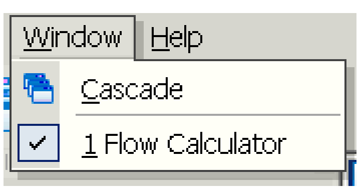
The **H2OCalc Menu** helps to exit H2OCalc.



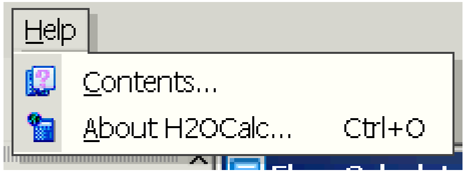
The **View Menu** helps to view either calculation explorer or diagrams and also allows to reset the H2OCalc interface to its original format.



The **Windows Menu** contains commands that allow the user to change the position of the varios dialog boxes within the H2OCalc window.



The **Help menu** provides access to the H2OCalc documentation, where to get technical support, version, license and maintenance/update information, as well as access to online help resources.

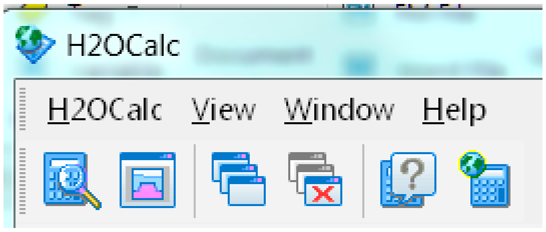


Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

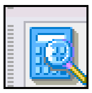
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

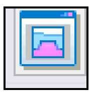

H2OCalc
H2OCalc View Window Help

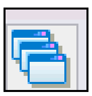
Toolbar

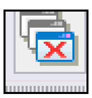
The **H2OCalc Toolbar** consists of six buttons.

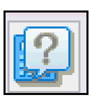
These are;

 **Calculation Explorer** - switches on or off the Calculation Explorer window.

 **Diagram** - switches on or off the Calculation Diagram window.

 **Cascade Window** - causes the worksheet in the Calculation Workspace to overlap one another in an offset way to maintain visibility of all opened Calculation dialog boxes.

 **Close All** - closes all of the Calculation dialog boxes in the Calculation Workspace.

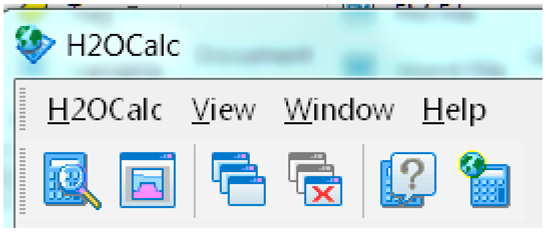
 **Help** - opens the H2OCalc online help.

 **About H2OCalc** - shows the software and license registration information..

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

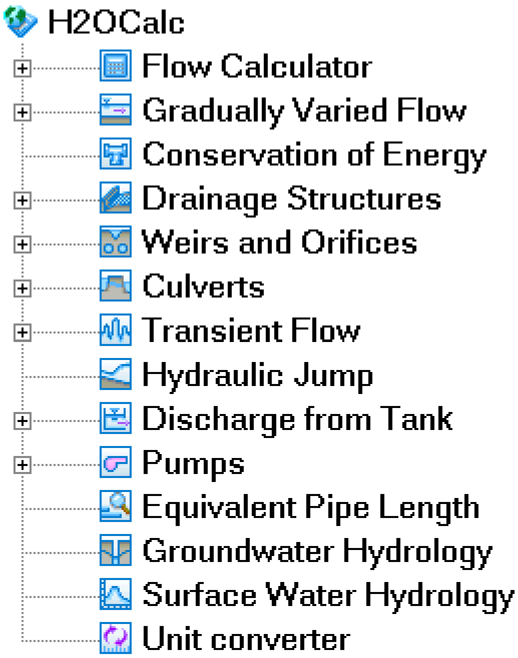
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

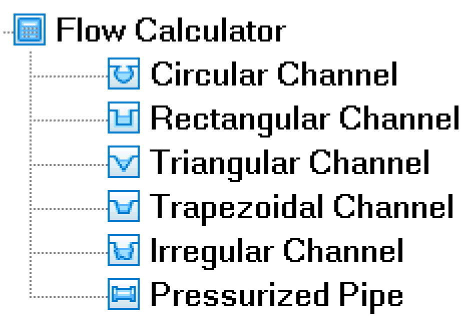
Calculation Explorer

The available calculation categories and associated element types are as follows.

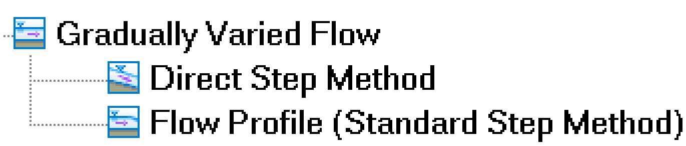


Click on the corresponding link to access description for the individual dialog boxes.

- Flow Calculator



- Gradually Varied Flow



- Conservation of Energy

Conservation of Energy

- Drainage Structures

- Drainage Structures
  - Gutter
  - Inlet
    - Grate Inlets
    - Curb-Opening Inlets
    - Combination Inlets
    - Slotted Inlets
    - Ditch Inlets

- Weirs and Orifices

- Weirs and Orifices
  - Weirs
    - Sharp Crested Rectangular Weir
    - Sharp Crested V-Notch Weir
    - Sharp Crested Cipolletti Weir
    - Generic Weir
    - Broad Crested Weir
  - Orifices
    - Generic Orifice
    - Rectangular Orifice
    - Circular Orifice

- Culverts

- Culverts
  - Simplified Method
  - FHWA HDS-5 Method

- Transient Flow

- Transient Flow
  - Water Hammer
  - Wave Speed
  - Pump Inertia

- [Hydraulic Jump]

Hydraulic Jump

- [Discharge from Tank]

Discharge from Tank
- Discharge from Open Tank
- Discharge from Pressurized Tank

- [Pumps]

Pumps
- Pump Curve
- Affinity Laws
- Pump Power and Torque
- Parallel Arrangement
- Series Arrangement
- System Head Curve

- [Equivalent Pipe Length]

Equivalent Pipe Length

- [Groundwater Hydrology]

Groundwater Hydrology

- [Surface Water Hydrology]

Surface Water Hydrology

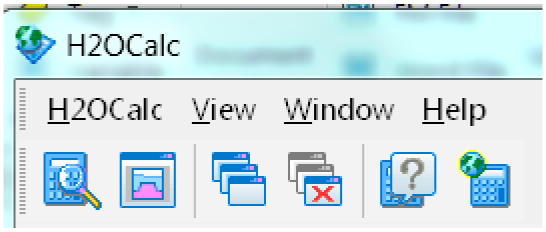
- [Unit Converter]

Unit converter

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Flow Calculator

The Flow Calculator category performs hydraulic calculations for the following elements: Circular Channel, Rectangular Channel, Triangular Channel, Trapezoidal Channel, Irregular Channel, and Pressurized Pipe.

- Circular Channel
- Rectangular Channel
- Triangular Channel
- Trapezoidal Channel
- Irregular Channel
- Pressurized Pipe

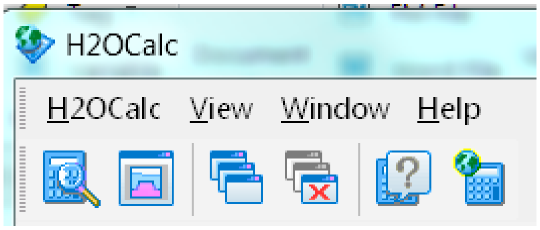
Click the following for more information of Flow Calculator in the methodology.

- Steady Uniform Flow
- The Manning Equation
- The Chezy Equation
- Hazen-Williams Formula
- Darcy-Weisbach (Colebrook-White) Formula
- Moody Friction Factor Calculator

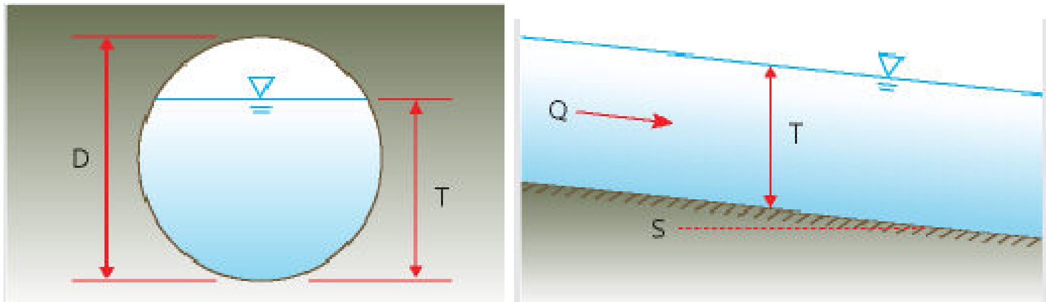
InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

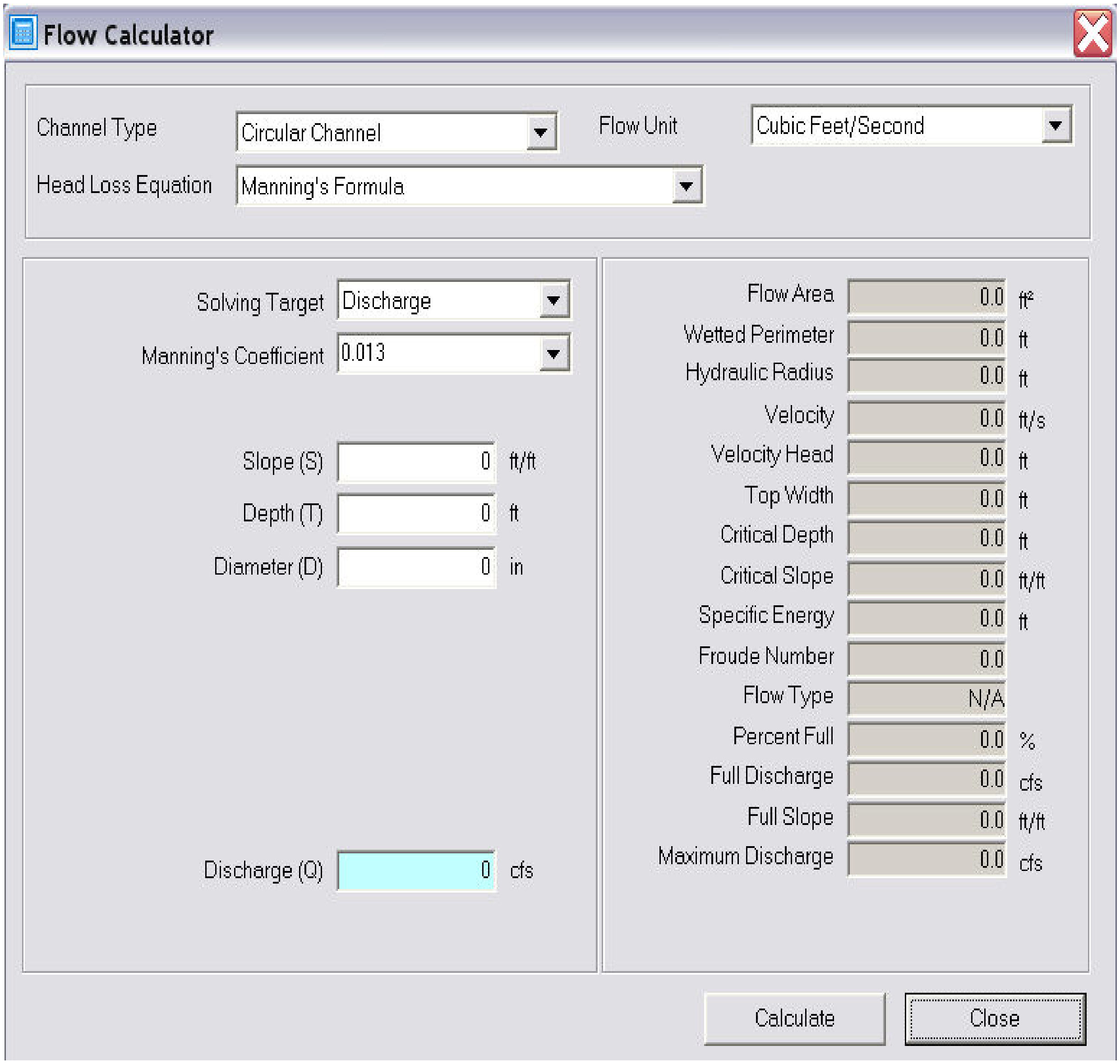
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Circular Channel



The circular channel dialog box is shown below.


Flow Calculator
Channel Type
Circular Channel
Flow Unit
Cubic Feet/Second
Head Loss Equation
Manning's Formula
Solving Target
Discharge
Manning's Coefficient
0.013
Slope (S) 0 ft/ft
Depth (T) 0 ft
Diameter (D) 0 in
Discharge (Q) 0 cfs
Flow Area 0.0 ft²
Wetted Perimeter 0.0 ft
Hydraulic Radius 0.0 ft
Velocity 0.0 ft/s
Velocity Head 0.0 ft
Top Width 0.0 ft
Critical Depth 0.0 ft
Critical Slope 0.0 ft/ft
Specific Energy 0.0 ft
Froude Number 0.0
Flow Type N/A
Percent Full 0.0 %
Full Discharge 0.0 cfs
Full Slope 0.0 ft/ft
Maximum Discharge 0.0 cfs
Calculate
Close

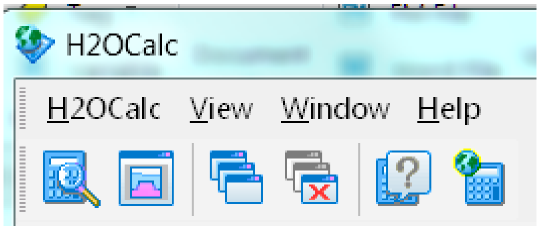
- **Input for circular channel:**
- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.
- **Depth** – Channel normal depth.
- **Diameter** – Circular channel inside diameter.

- Output for circular channel:
- **Flow Area** – Flow cross-sectional area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface (zero for full flow condition).
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
  - **Flow Type** – Subcritical or Supercritical flow characteristics in channel.
- **Percent Full** – Percentage of actual channel flow depth based on full flow.
- **Full Discharge** – Channel flow rate when flowing full.
- **Full Slope** – Channel slope under full flow.
- **Maximum Discharge** – Flow rate when flow depth equals 0.938 times circular channel diameter (applies only to circular channel).
- **Discharge (Q)** – Uniform channel flow rate.

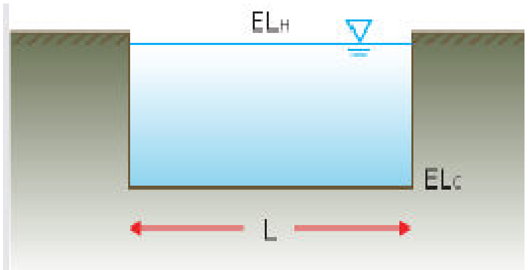
InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

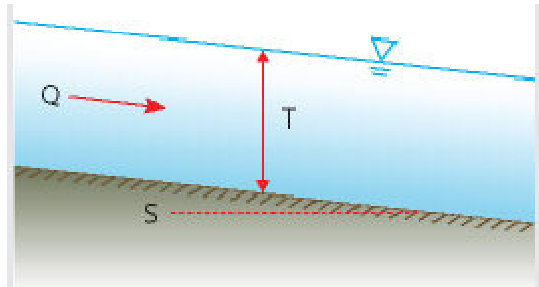
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

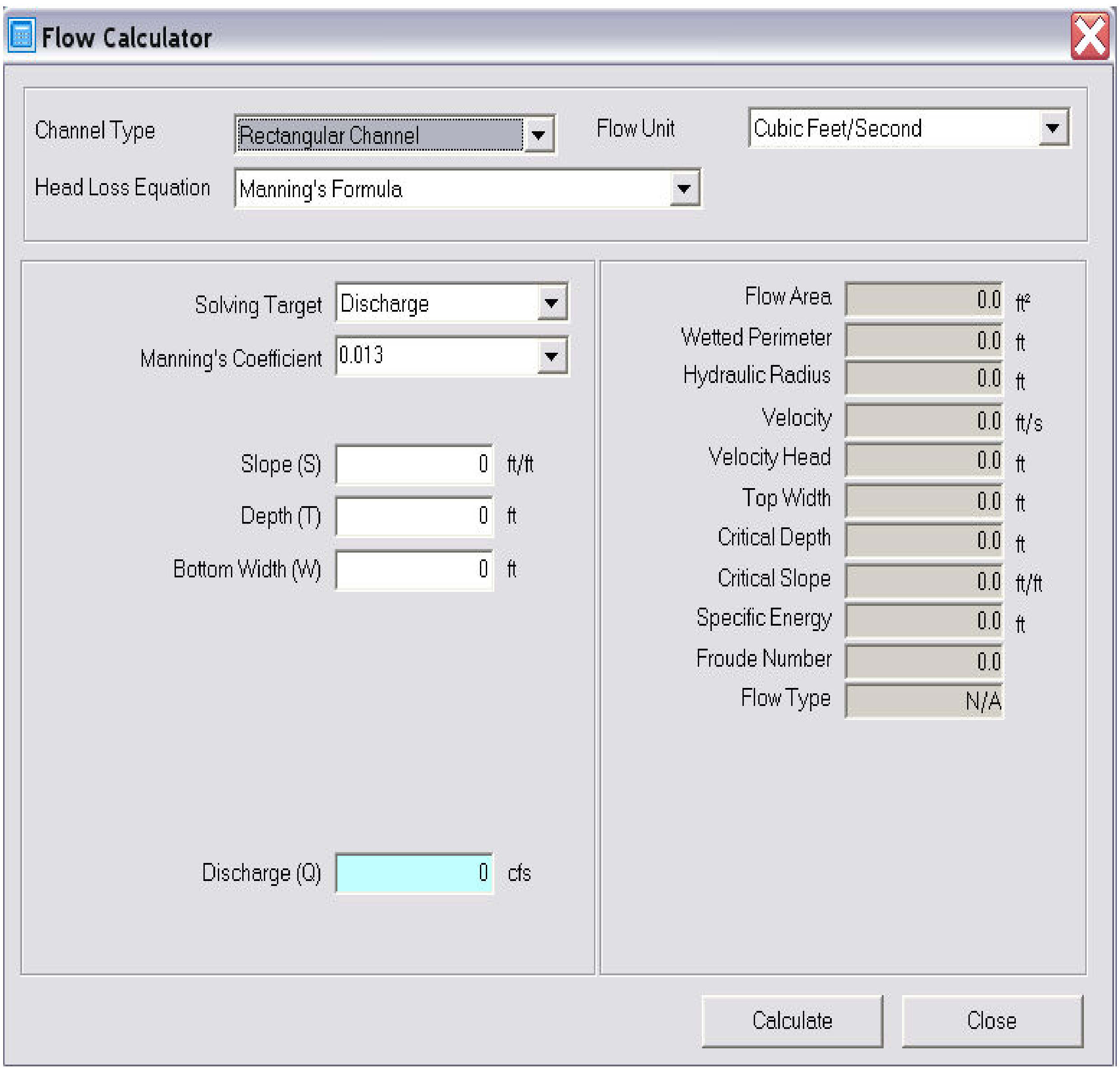

H2OCalc
H2OCalc View Window Help

Rectangular Channel





The rectangular channel dialog box is shown below.



- **Input for rectangular channel:**
- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.
- **Depth** – Channel normal depth.
- **Bottom Width** – Width of the channel.

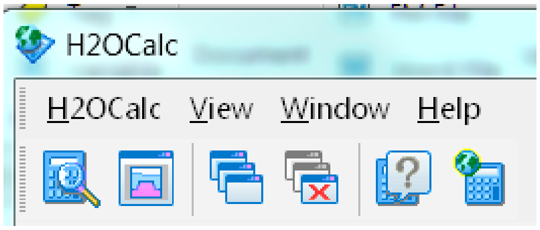
- **Output for rectangular channel:**
- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface (same as bottom width at all depths).
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
- **Flow Type** – Subcritical or Supercritical flow characteristics in channel.
- **Discharge (Q)** – Uniform channel flow rate.

Innovyze®

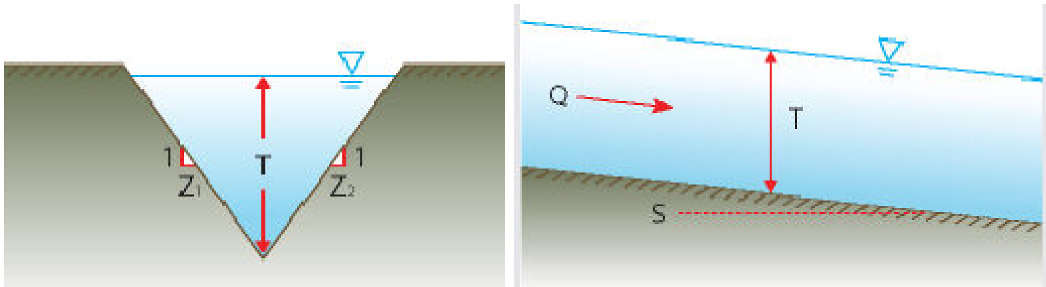
H2OCalc™
Modeling Made Easy

Innovyze®

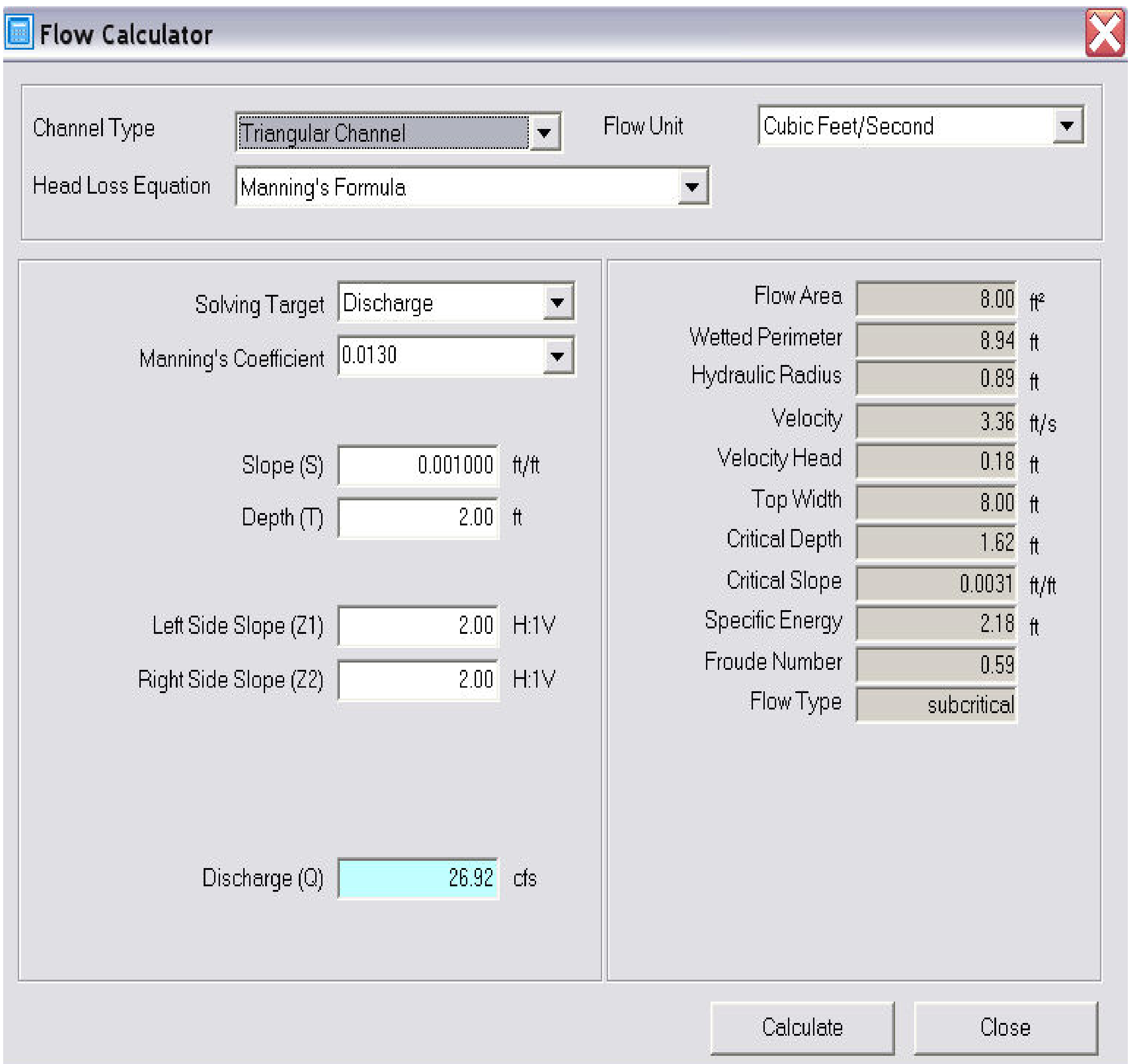
Home > Innovyze H2OCalc Help File and User Guide > Flow Calculator > Triangular Channel



Triangular Channel



The triangular channel dialog box is shown below.



- **Input for triangular channel:**
- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.
- **Depth** – Channel normal depth.
- **Left Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the left side of the channel.
- **Right Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the right side of the channel.

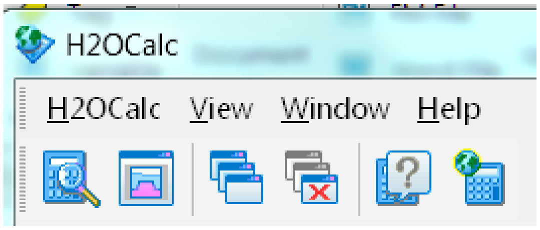
- **Output for triangular channel:**
- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface.
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
- **Flow Type** – Subcritical or Supercritical flow characteristics in channel.
- **Discharge (Q)** – Uniform channel flow rate.

Innovyze®

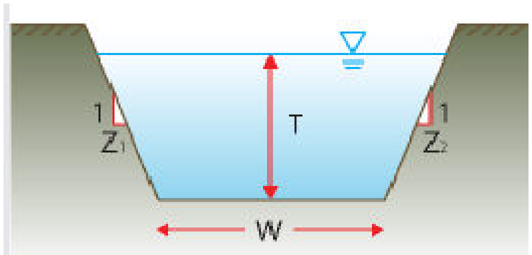
H₂OCalc™

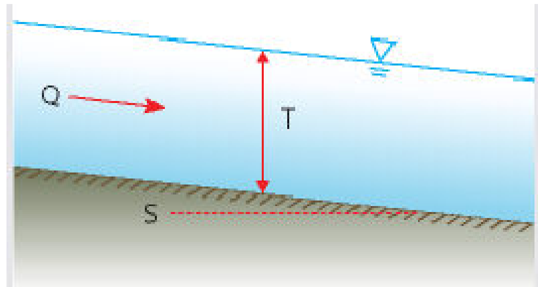
Modeling Made Easy

Innovyze®

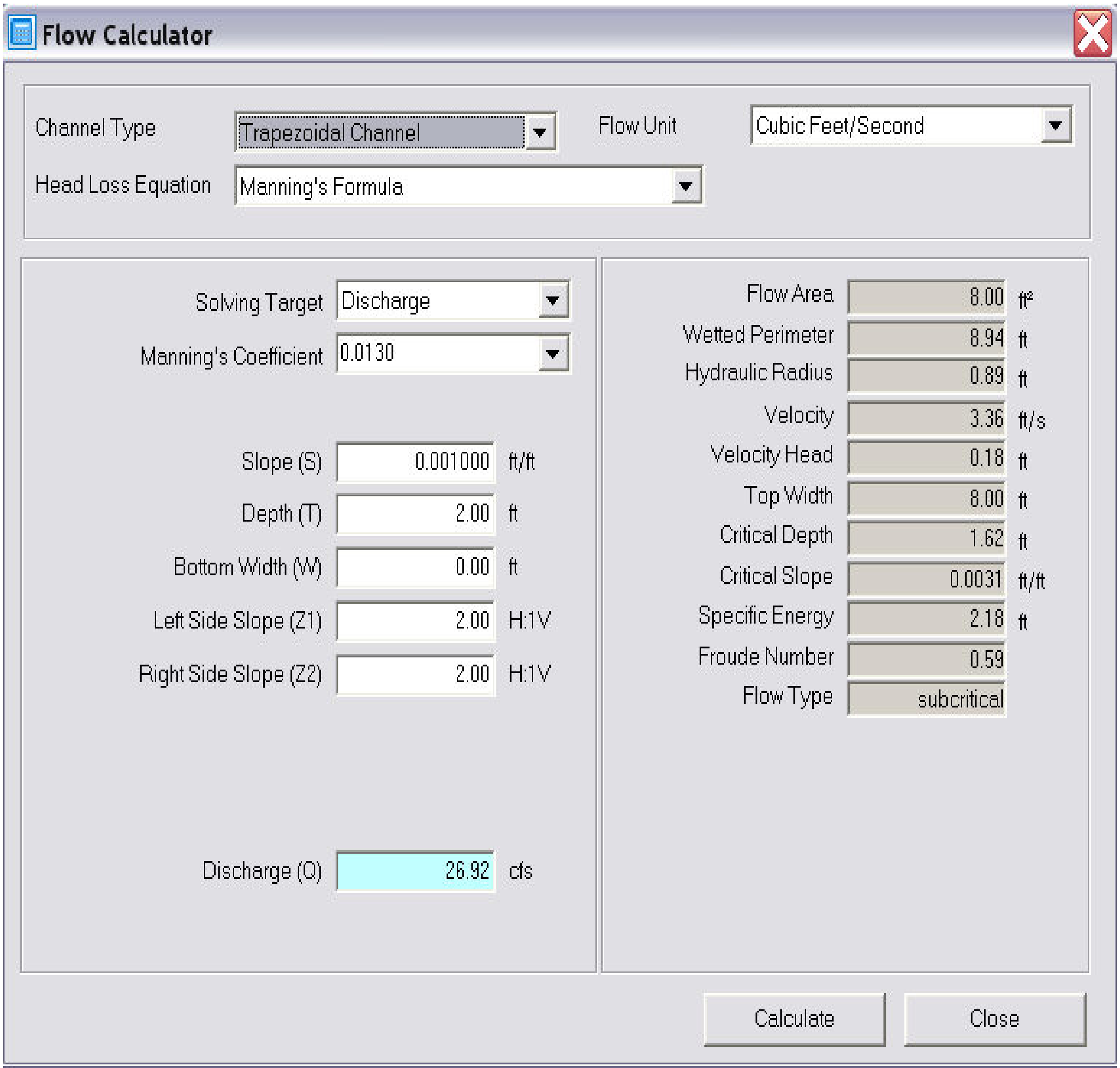

H2OCalc
H2OCalc View Window Help

Trapezoidal Channel





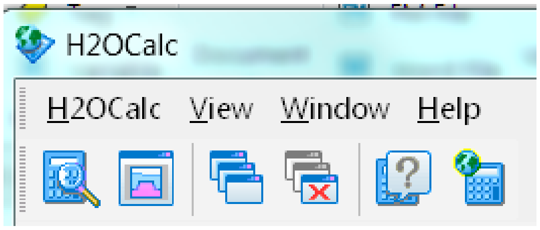
The trapezoidal channel dialog box is shown below.


Flow Calculator
Channel Type
Trapezoidal Channel
Flow Unit
Cubic Feet/Second
Head Loss Equation
Manning's Formula
Solving Target
Discharge
Manning's Coefficient
0.0130
Slope (S)
0.001000
ft/ft
Depth (T)
2.00
ft
Bottom Width (W)
0.00
ft
Left Side Slope (Z1)
2.00
H:1V
Right Side Slope (Z2)
2.00
H:1V
Discharge (Q)
26.92
cfs
Flow Area
8.00
ft²
Wetted Perimeter
8.94
ft
Hydraulic Radius
0.89
ft
Velocity
3.36
ft/s
Velocity Head
0.18
ft
Top Width
8.00
ft
Critical Depth
1.62
ft
Critical Slope
0.0031
ft/ft
Specific Energy
2.18
ft
Froude Number
0.59
Flow Type
subcritical
Calculate
Close

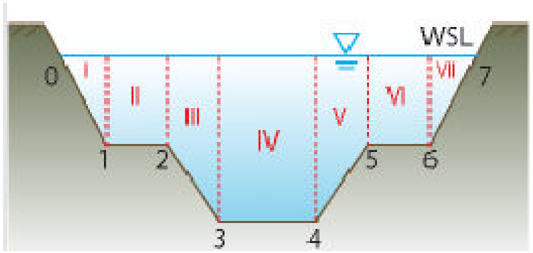
- Input for trapezoidal channel:
- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.
- **Depth** – Channel normal depth.
- **Bottom Width** – Bed width of the channel.
- **Left Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the left side of the channel.
- **Right Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the right side of the channel.

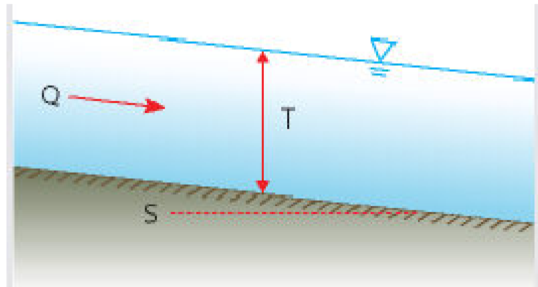
- Output for trapezoidal channel:
- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface.
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
- **Flow Type** – Subcritical or supercritical flow characteristics in channel.
- **Discharge (Q)** – Uniform channel flow rate.

Innovyze® H2OCalc™ Modeling Made Easy Innovyze®

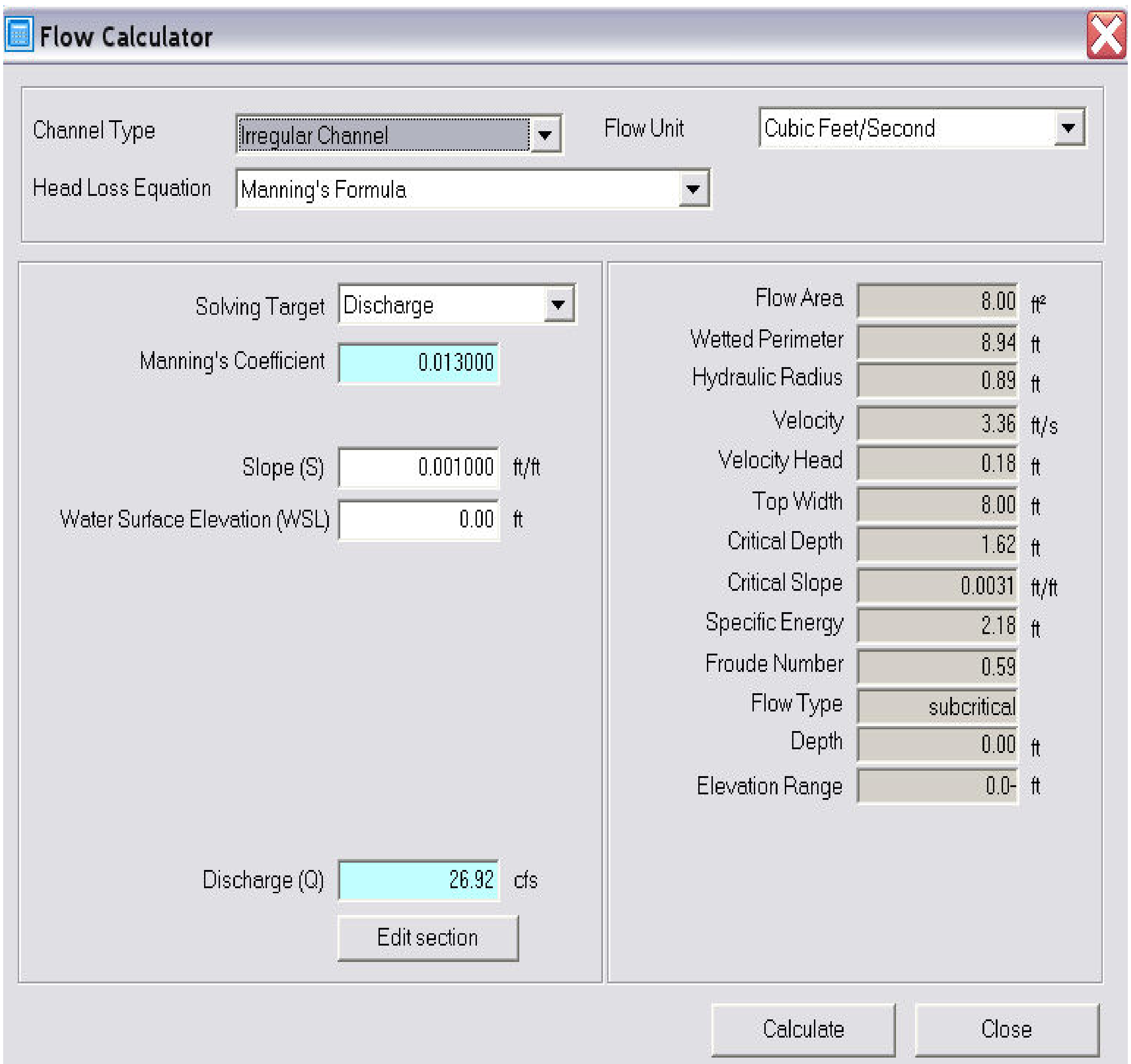

H2OCalc
H2OCalc View Window Help

Irregular Channel



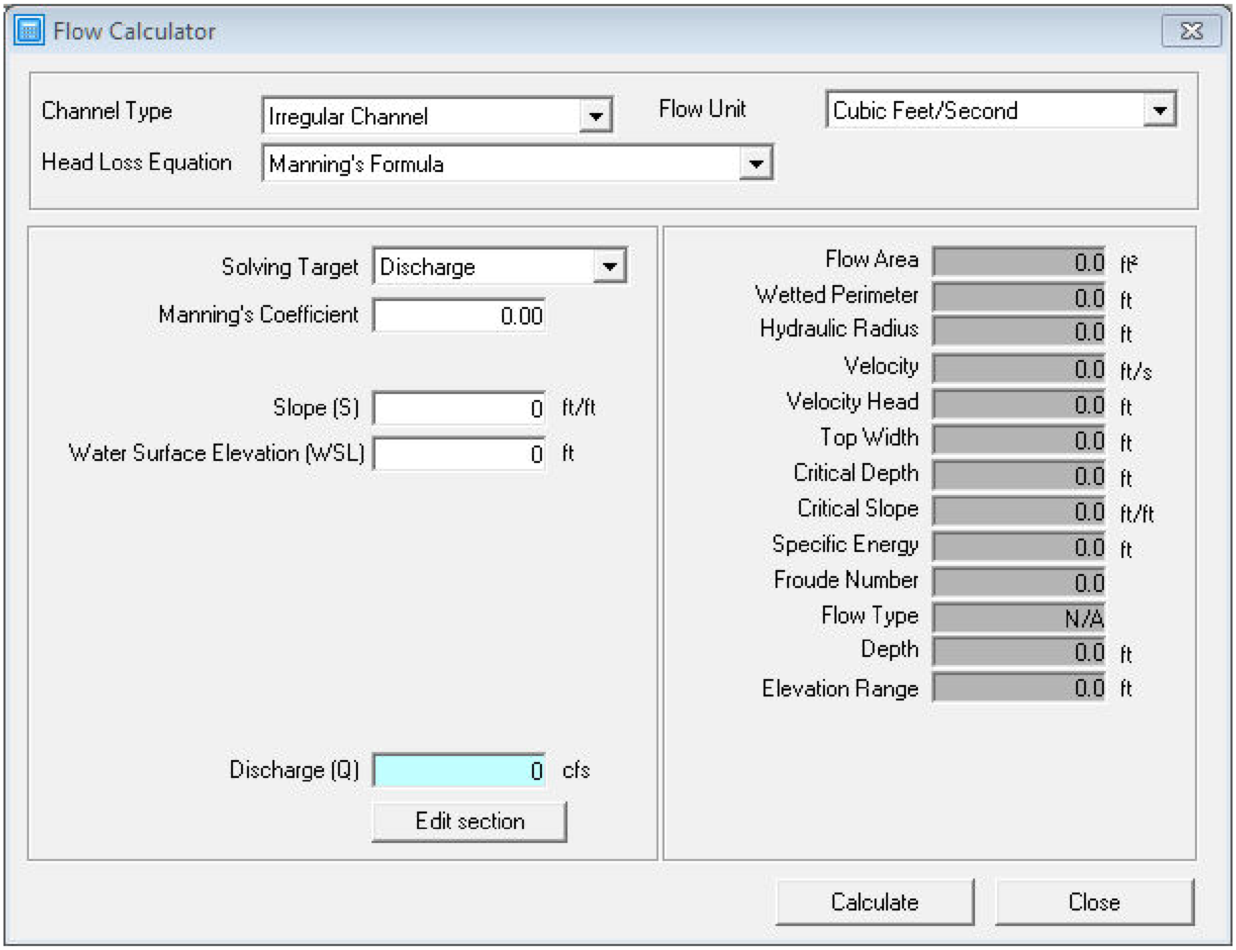


The irregular channel dialog box is shown below.



- **Input for irregular channel:**
- Flow Unit – Select the desired flow unit.
- Head Loss Equation – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- Solving Target – Select the hydraulic parameter to solve for.
- Slope – Channel longitudinal slope.
- Water Surface Elevation – Elevation corresponding to the water depth.
- **Output for irregular channel:**
- Flow Area – Wetted area.
- Wetted Perimeter – Channel wetted perimeter.
- Hydraulic Radius – Flow area divided by the wetted perimeter.
- Velocity – Flow velocity.
- Velocity Head – Energy of flow velocity.
- Top Width – Length of free top water surface.
- Critical Depth – Depth of water under minimum specific energy.
- Critical Slope – Channel slope under critical depth.
- Specific Energy – Velocity head plus pressure head.
- Froude Number – Flow characteristics dimensionless parameter.
- Flow Type – Subcritical or Supercritical flow characteristics in channel.
- Depth – Flow depth.
- Elevation Range – Difference in elevations at the top and at the bottom of the channel.
- Discharge (Q) – Uniform channel flow rate.

The dialog box for irregular channel cross-section editor is shown below. The Edit Section button initiates the irregular channel editor shown below.



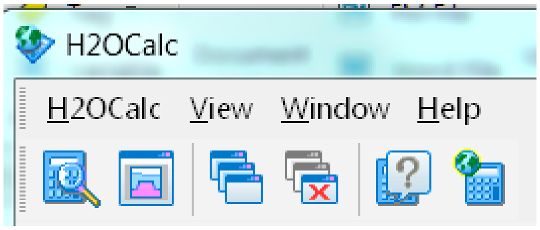
Channel Cross Section – Station vs. Elevation data that represents shape of the channel.

- Left Bank Coefficient – Roughness coefficient for the left bank of the channel.
- Right Bank Coefficient – Roughness coefficient for the right bank of the channel.
- Channel Coefficient – Roughness coefficient for the main (center) channel.
- Main Channel Bank Stations – Stations at which the main channel ends and the banks start from either side of the channel (i.e., left and right).

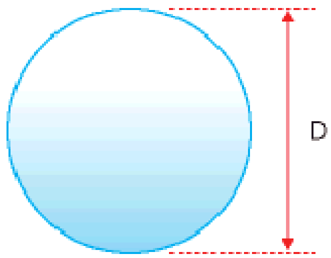
Innovyze Help File Updated September 1, 2017

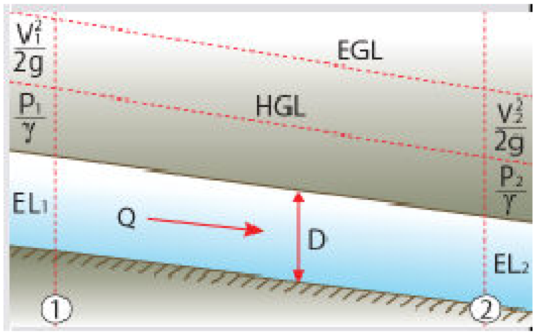
InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

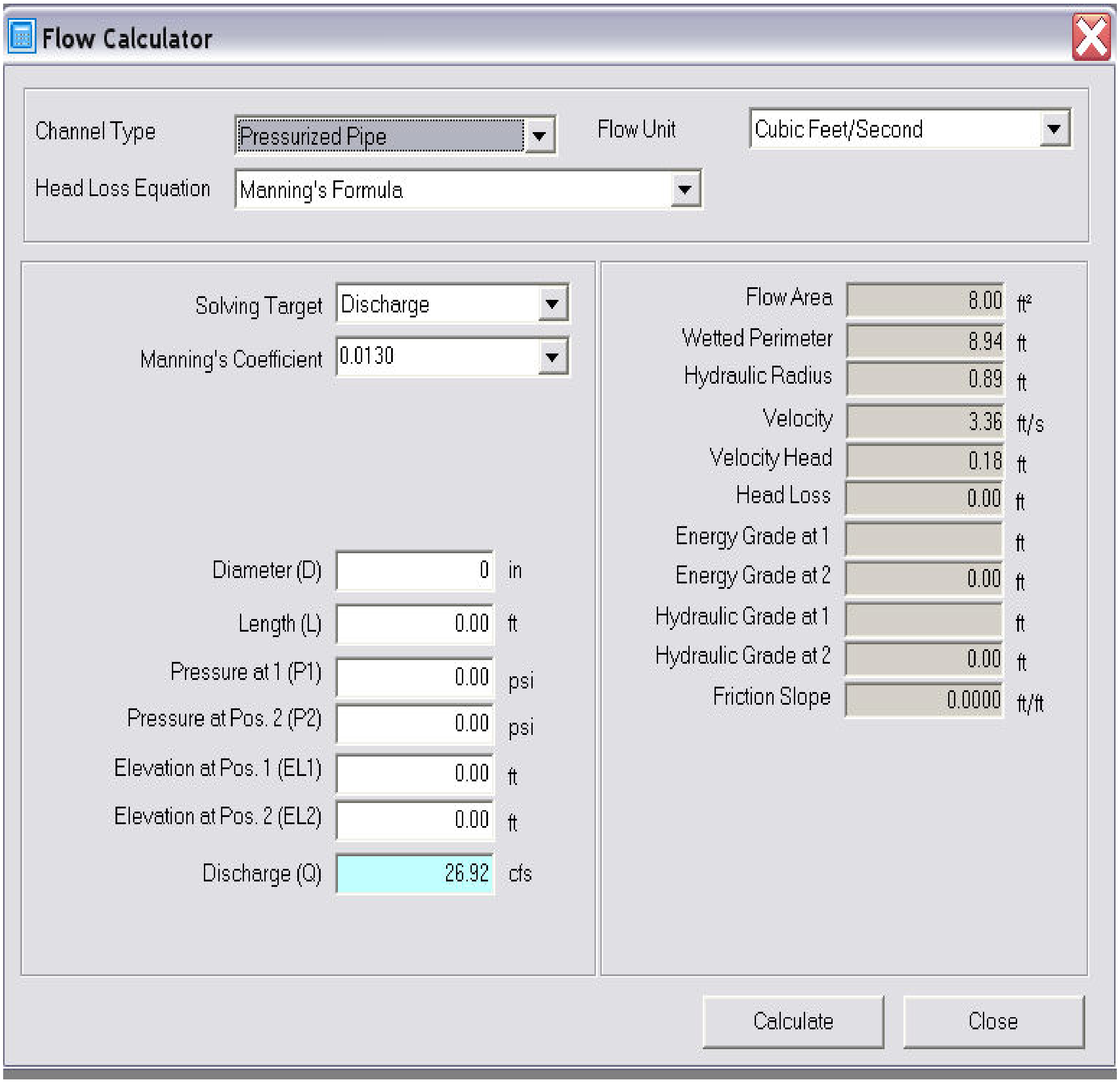

H2OCalc
H2OCalc View Window Help

Pressurized Pipe





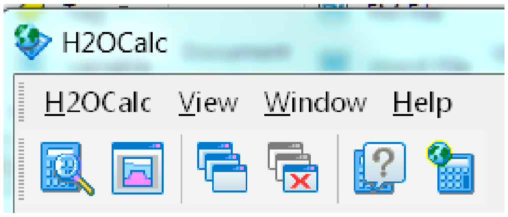
The pressurized pipe calculator applies the energy equation between two points (points 1 and 2) and evaluates the outputs listed below. The pressurized pipe dialog box is shown below.


Flow Calculator
Channel Type
Pressurized Pipe
Flow Unit
Cubic Feet/Second
Head Loss Equation
Manning's Formula
Solving Target
Discharge
Manning's Coefficient
0.0130
Diameter (D)
0
in
Length (L)
0.00
ft
Pressure at 1 (P1)
0.00
psi
Pressure at Pos. 2 (P2)
0.00
psi
Elevation at Pos. 1 (EL1)
0.00
ft
Elevation at Pos. 2 (EL2)
0.00
ft
Discharge (Q)
26.92
cfs
Flow Area
8.00
ft²
Wetted Perimeter
8.94
ft
Hydraulic Radius
0.89
ft
Velocity
3.36
ft/s
Velocity Head
0.18
ft
Head Loss
0.00
ft
Energy Grade at 1
ft
Energy Grade at 2
0.00
ft
Hydraulic Grade at 1
ft
Hydraulic Grade at 2
0.00
ft
Friction Slope
0.0000
ft/ft
Calculate
Close

- **Input for pressurized pipe:**
- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Diameter** – Circular pipe diameter.
- **Length** – Pipe length.
- **Pressure at 1**– Pressure at the upstream end of the pipe.
- **Pressure at 2**– Pressure at the downstream end of the pipe.
- **Elevation at 1**– Elevation at the upstream end of the pipe.
- **Elevation at 2**– Elevation at the downstream end of the pipe.

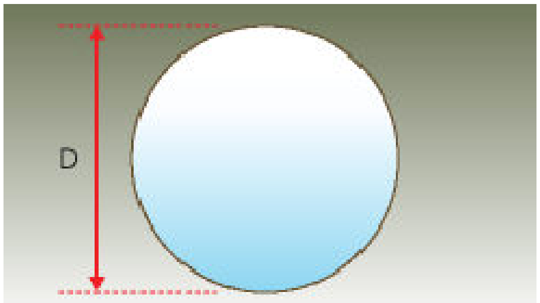
- **Output for pressurized pipe:**
- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Head Loss** – Energy loss due to friction.
- **Energy Grade at 1** – Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the upstream end.
- **Energy Grade at 2** – Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the downstream end.
- **Hydraulic Grade at 1** – Sum of pressure head and elevation head at the upstream end.
- **Hydraulic Grade at 2** – Sum of pressure head and elevation head at the upstream end.
- **Friction Slope** – Slope of the head loss due to friction between sections 1 and 2.
- **Discharge (Q)** – Pipe flow rate.

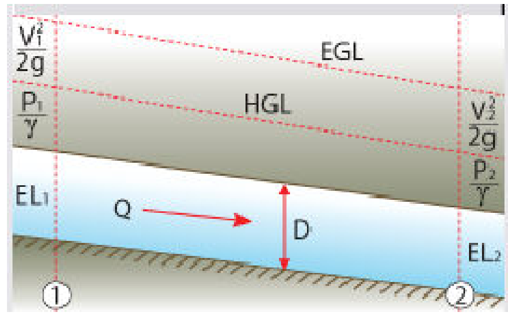
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

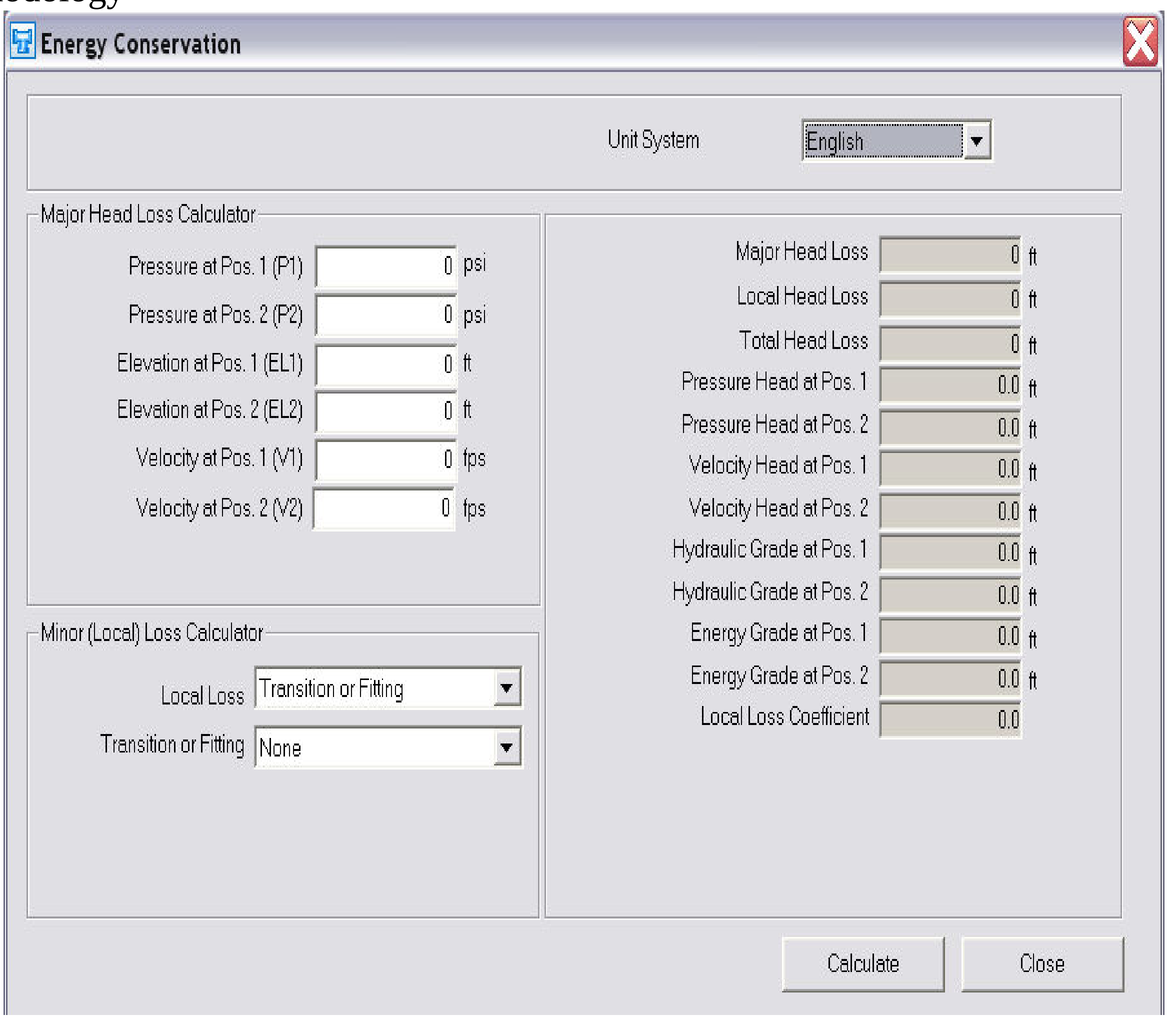
Conservation of Energy

The Conservation of Energy category applies energy equation between two sections of a pressurized pipe and evaluates the outputs listed below.



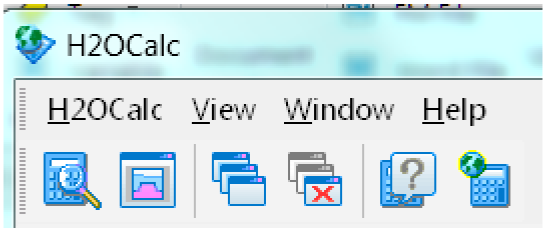


The conservation of energy dialog box is shown below. Click here for the methodology



- **Input for conservation of energy:**
- **Unit System** – English or SI unit.
- **Pressure at 1** – Pressure at the upstream end of the pipe.
- **Pressure at 2** – Pressure at the downstream end of the pipe.
- **Elevation at 1** – Elevation at the upstream end of the pipe.
- **Elevation at 2** – Elevation at the downstream end of the pipe.
- **Velocity at 1** – Flow velocity at the upstream end of the pipe.
- **Velocity at 2** – Flow velocity at the downstream end of the pipe.
- **Local Loss** – Choose the minor loss type from the following options: Minor loss coefficient, transition or fitting, or minor head loss. If minor loss coefficient option is selected, the average velocity ((V1+V2)/2) is used to compute the minor head loss. Depending on the minor loss model selected, additional inputs required for the option should be specified.

- Output for conservation of energy:
- **Major Head Loss** – Head loss due to friction, excluding minor losses.
- **Local Head Loss** – Head loss due to minor losses.
- **Total Head Loss** – Sum of major head loss and local head loss.
- **Pressure Head at 1** – Pressure energy at the upstream section.
- **Pressure Head at 2** – Pressure energy at the downstream section.
- **Velocity Head at 1** – Energy due to flow velocity at the upstream section.
- **Velocity Head at 2** – Energy due to flow velocity at the downstream section.
- **Hydraulic Grade at 1** – Sum of pressure head and elevation head at the upstream end.
- **Hydraulic Grade at 2** – Sum of pressure head and elevation head at the downstream end.
- **Energy Grade at 1** – Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the upstream end.
- **Energy Grade at 2** – Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the downstream end.
- **Local Loss Coefficient** – The (minor) local loss K factor.

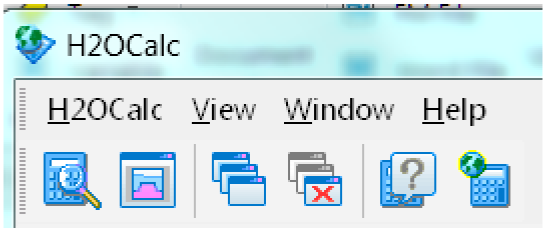

H2OCalc
H2OCalc View Window Help

Gradually Varied Flow

The Gradually Varied Flow category performs flow profile computations for rectangular and trapezoidal channels using the direct step method and the standard step method. It computes water surface elevations and many other outputs at several sections of a reach and plots flow profile for the reach. Manning's equation is used to relate friction slope with flow rate and channel conveyance factor.

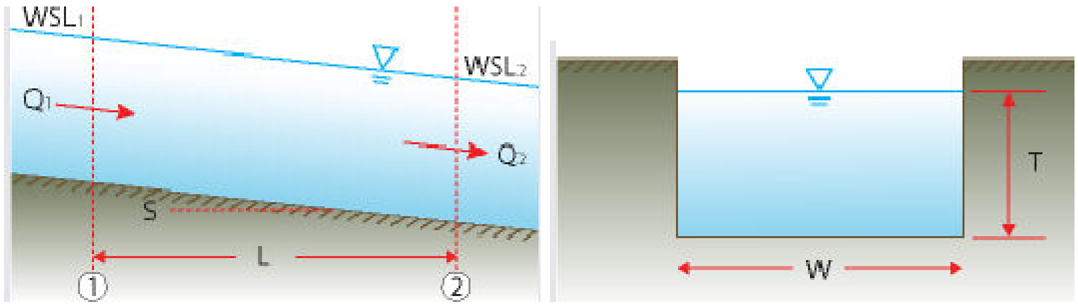
- Direct Step Method
- Flow Profile

Click here for more information of Gradually Varied Flow in the methodology.

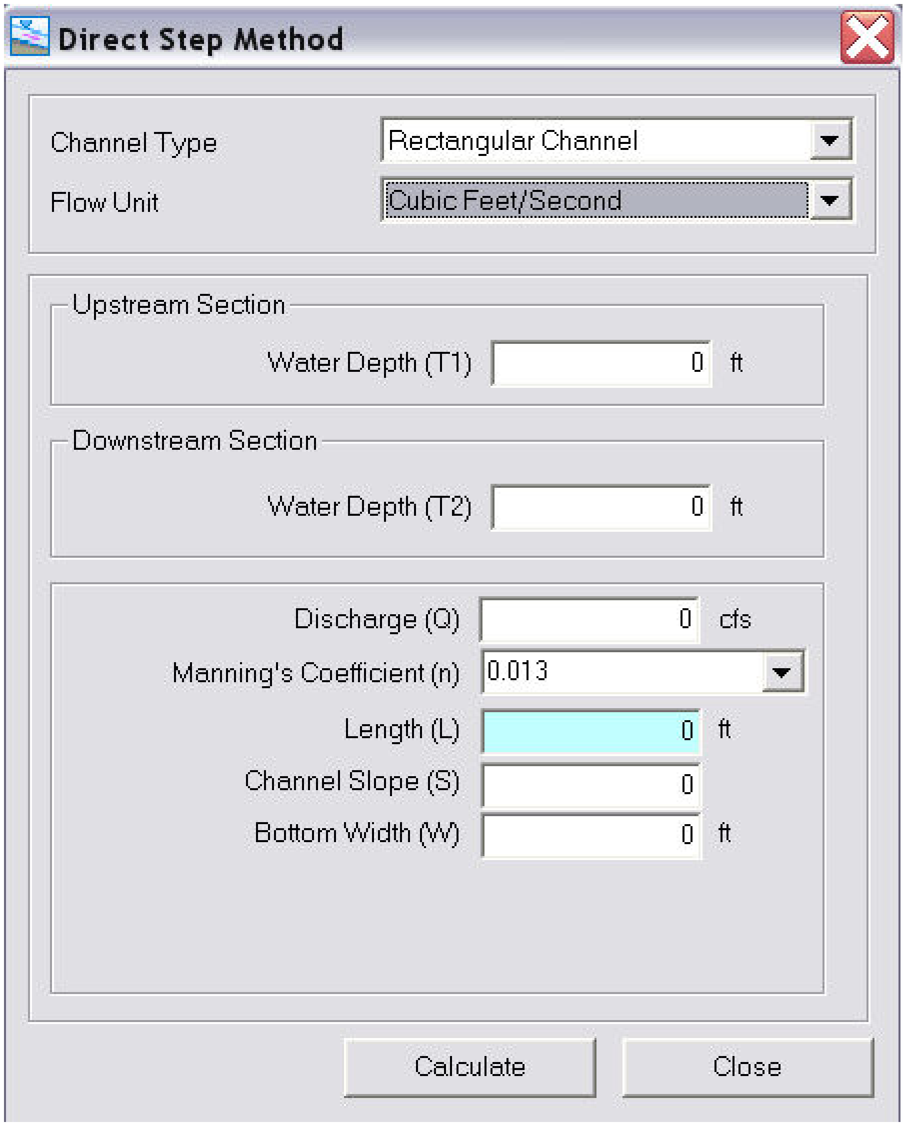

H2OCalc
H2OCalc View Window Help

Direct Step Method

The direct step method uses either the direct step method to determine distance given water depth (direct step) at the end of the reach. Both rectangular channels and trapezoidal channels are supported. It performs only one step calculation, and should be used only for short reaches. For longer reaches, it is advisable to use the flow profile option.

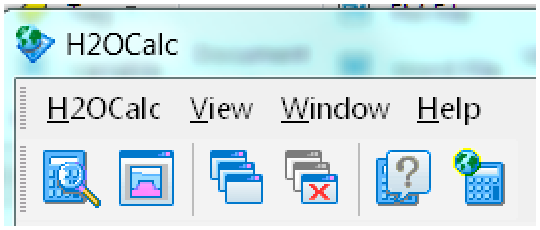


The direct step method dialog box is shown below.


Direct Step Method
Channel Type
Rectangular Channel
Flow Unit
Cubic Feet/Second
Upstream Section
Water Depth (T1)
0
ft
Downstream Section
Water Depth (T2)
0
ft
Discharge (Q)
0
cfs
Manning's Coefficient (n)
0.013
Length (L)
0
ft
Channel Slope (S)
0
Bottom Width (W)
0
ft
Calculate
Close

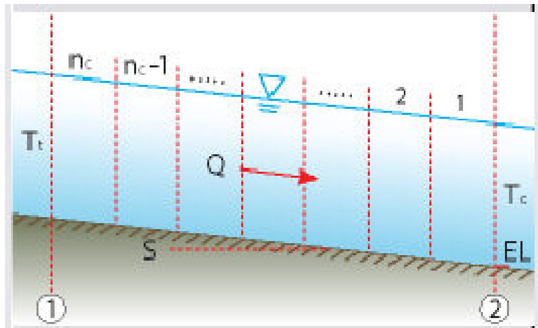
- **Input for direct step method:**
- **Channel Type** – Rectangular or trapezoidal channels.
- **Flow Unit** – Select the desired flow unit.
- **Upstream Water Depth** – Water depth at the upstream end of the reach.
- **Downstream Water Depth** – Water Depth at the downstream end of the reach.
- **Discharge** – Flow rate at the control section.
- **Manning's Coefficient** – Manning's roughness coefficient for both upstream and downstream sections.
- **Length** – Length of the reach between the upstream and the downstream sections. This is required only for standard step method. It is an output for direct step method.
- **Channel Slope** – Longitudinal slope of the channel.
- **Bottom Width** – Channel bottom width for both upstream and downstream sections.

- **Output for direct step method:**
- **Length** – Length between the upstream and the downstream sections will be calculated.

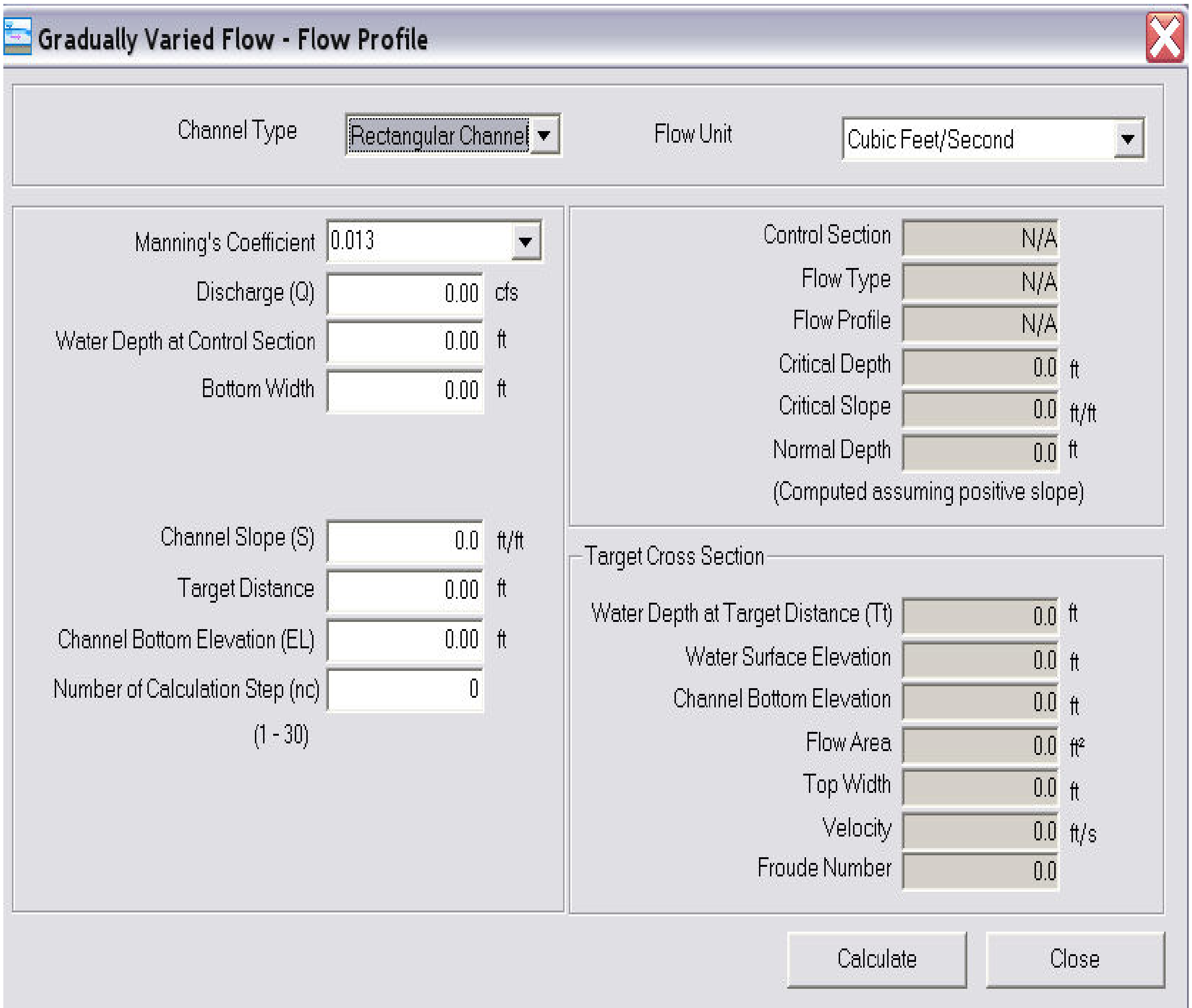

H2OCalc
H2OCalc View Window Help

Flow Profile

The flow profile uses the standard step method to compute water depths at several sections and plots water surface profile for the reach. Both rectangular channel and trapezoidal channel are supported.



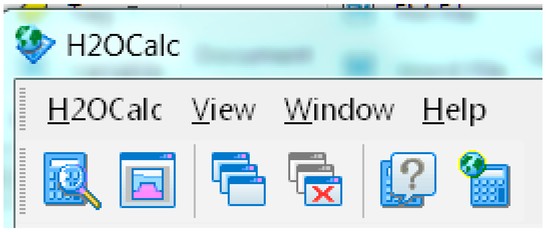
The flow profile dialog box is shown below.


Gradually Varied Flow - Flow Profile
Channel Type
Rectangular Channel
Flow Unit
Cubic Feet/Second
Manning's Coefficient
0.013
Discharge (Q)
0.00
cfs
Water Depth at Control Section
0.00
ft
Bottom Width
0.00
ft
Channel Slope (S)
0.0
ft/ft
Target Distance
0.00
ft
Channel Bottom Elevation (EL)
0.00
ft
Number of Calculation Step (nc)
0
(1 - 30)
Control Section
N/A
Flow Type
N/A
Flow Profile
N/A
Critical Depth
0.0
ft
Critical Slope
0.0
ft/ft
Normal Depth
0.0
ft
(Computed assuming positive slope)
Target Cross Section
Water Depth at Target Distance (Tt)
0.0
ft
Water Surface Elevation
0.0
ft
Channel Bottom Elevation
0.0
ft
Flow Area
0.0
ft²
Top Width
0.0
ft
Velocity
0.0
ft/s
Froude Number
0.0
Calculate
Close

- **Input for flow profile:**
- **Channel Type** – Rectangular or trapezoidal channels.
- **Flow Unit** – Select the desired flow unit.
- **Manning's Coefficient** – Manning's roughness coefficient for the channel.
- **Discharge** – Channel flow rate.
- **Water Depth at Control Section** – Flow depth at the section where profile computation starts.
- **Bottom Width** – Channel bottom width.
- **Left Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the left side of the channel. Valid only for trapezoidal channels.
- **Right Side Slope** - Horizontal increase in channel width per unit increase in depth (H: 1V) for the right side of the channel. Valid only for trapezoidal channels.
- **Channel Slope** – Channel longitudinal slope.
- **Target Distance** – Distance between the sections where the profile computation begins and where it ends.
- **Channel Bottom Elevation** – Elevation corresponding to bed of the channel at the section where profile computation starts.
- **Number of Calculation Steps** – Routing subreaches between the starting and the destination sections. Please note that for short profile types such as S3, H2OCalc computes water depths at 1ft interval to capture the fast transition and generate accurate flow profile. It reports the number of calculation steps used to determine the profile in spite of the calculation steps specified by the user.

- **Output for flow profile:**
- **Control Section** – Upstream or downstream section.
- **Flow Type** – Subcritical, supercritical or critical flow regime.
- **Flow Profile** – Profile type (e.g., M1, S2, C1, etc.)
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Normal Depth** – Uniform flow depth.
- **Water Depth at Target Distance** –Water depth at the end of the reach.
- **Water Surface Elevation** –Water depth plus channel bed elevation at the end of the reach.
- **Channel Bottom Elevation** – Channel bed elevation at the end of the reach.
- **Flow Area** – Wetted area at the end of the reach.
- **Top Width** – Width of the channel at the water surface at the end of the channel.
- **Velocity (Q)** – Flow velocity at the end of the reach.
- **Froude Number** – Flow characteristics dimensionless parameter at the end of the reach.

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Drainage Structures

The Drainage Structure category solves the hydraulics of gutters and storm drain inlets. Storm drain inlets could be either inlets on grade or inlets in sag. Click here for the methodology.

Gutters

Inlets on Grade

- Grate Inlet
- Curb-Opening Inlet
- Combination Inlet
- Slotted Inlet
- Ditch Inlet

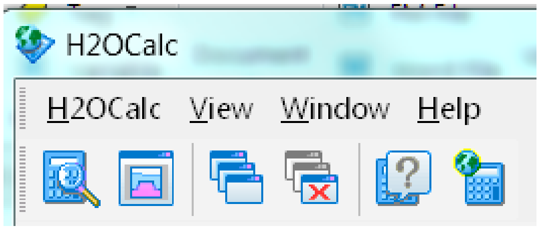
Inlets in Sag

- Grate Inlet
- Curb-Opening Inlet
- Combination Inlet
- Slotted Inlet
- Ditch Inlet

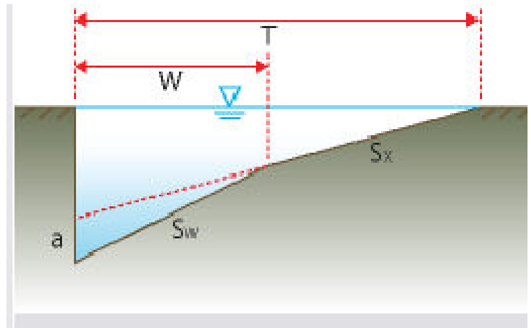
Click the following for more information of Drainage Structures in the methodology.

Drainage Structures

- Gutter Flow
- Drainage Inlet
- Inlets on Grade
- Inlets in Sag

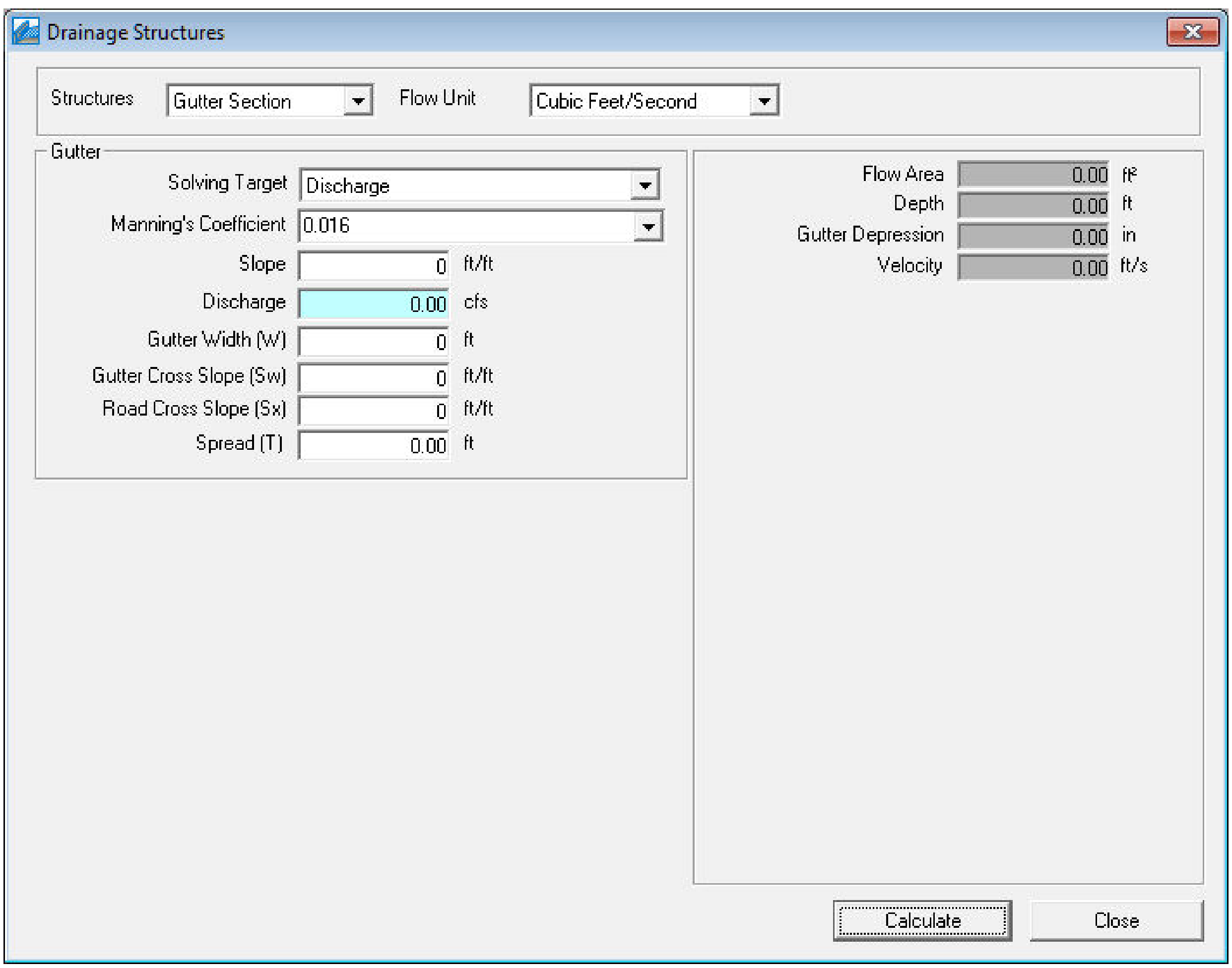

H2OCalc
H2OCalc View Window Help

Gutters



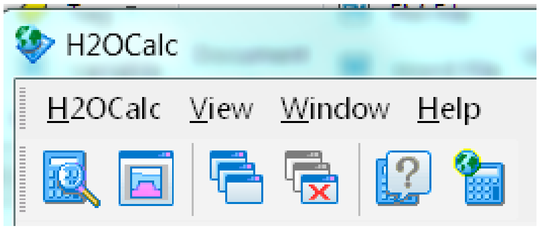
For methodology, please click here

Gutters are triangular shaped channels on both sides of a street that collect stormwater runoff from streets and discharge into storm drain inlets. The gutter dialog box is shown below.

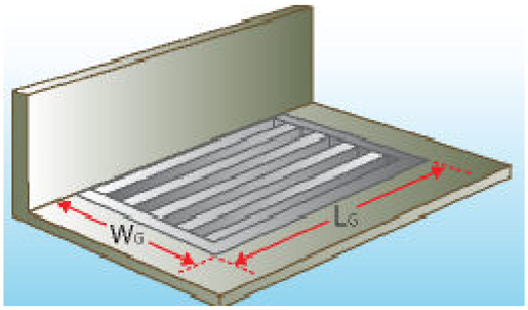


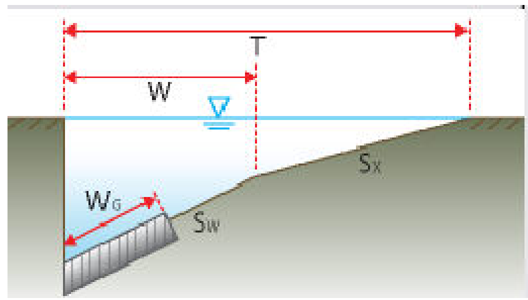
- **Input for gutters:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Width of the gutter at the water surface elevation.

- **Output for gutters:**
- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Discharge** – Flow rate through the gutter. Discharge could be selected as target output.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Like discharge, spread could be selected as a target output.

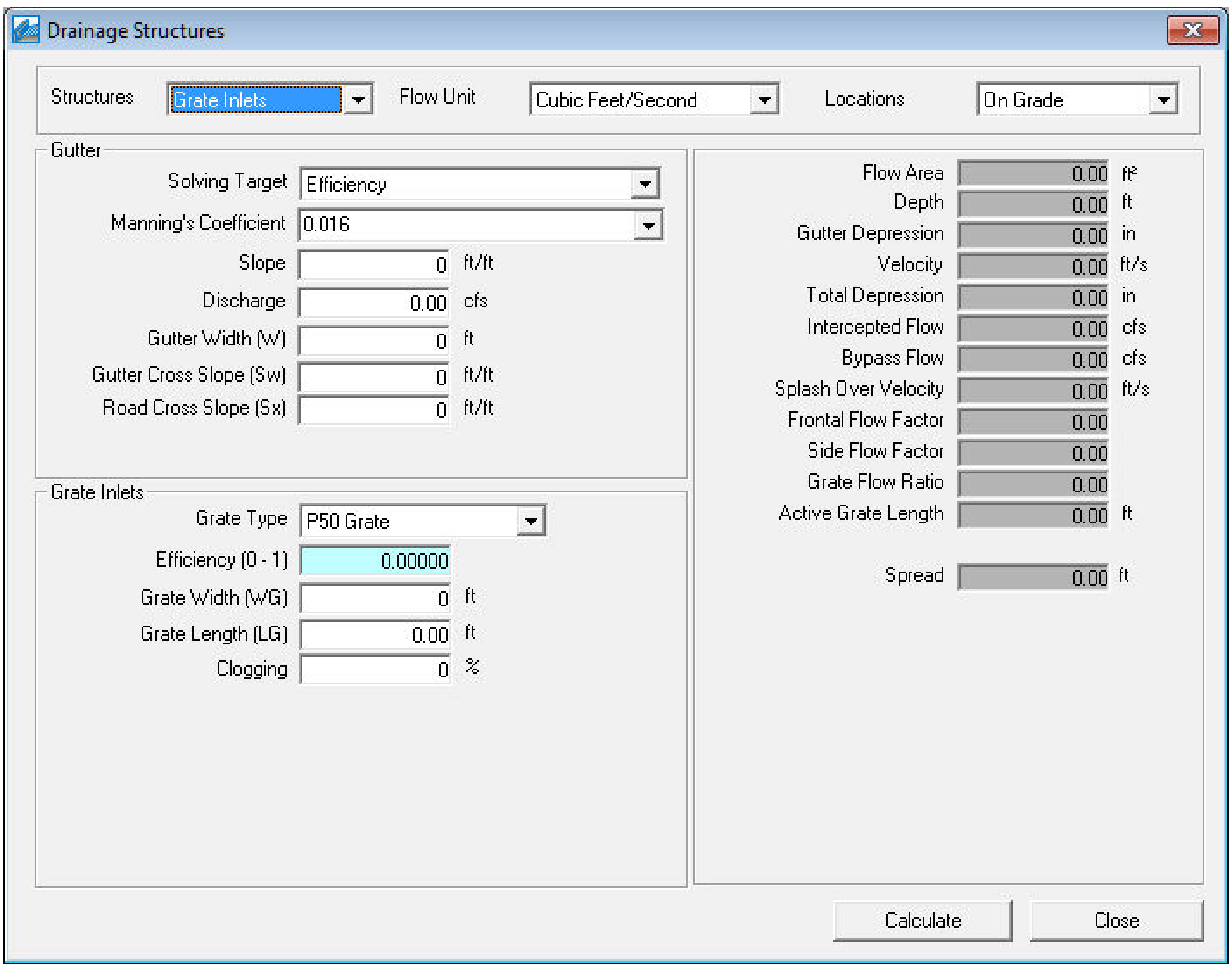

H2OCalc
H2OCalc View Window Help

Grate Inlet on Grade





The dialog box for grate inlet on grade is shown below. For methodology click here.



- **Input for grate inlets on grade:** 

- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Efficiency or length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Grate Type** – Select one of the eight grate types listed.
- **Efficiency** –Interception efficiency of the grate. It represents ratio of intercepted flow to total gutter flow.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.

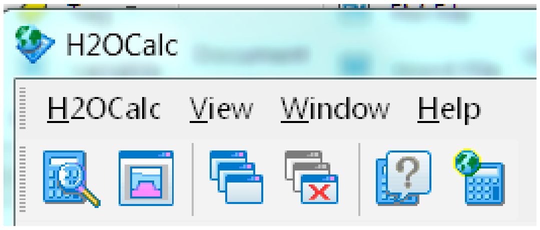
- **Output for grate inlet on grade:**
- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Total Depression** – Sum of the local depression and the gutter depression.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Splash Over Velocity** – Velocity where splash over first occurs. Splash over refers to the fraction of frontal gutter flow that is not intercepted by the inlet.
- **Frontal Flow Factor** – The ratio of intercepted frontal flow to total frontal flow.
- **Side Flow Factor** – The ratio of intercepted side flow to total side flow.
- **Grate Flow Ratio** – The ratio of frontal flow to total gutter flow.
- **Active Grate Length** – Portion of grate length (the side that is parallel to the curb) that is not clogged.
- **Spread** – Top width, or width of the gutter at the water surface elevation.

Innovyze Help File Updated September 1, 2017

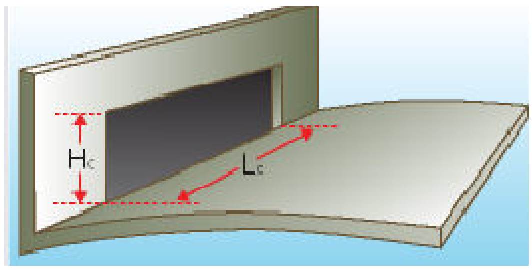
InfoSWMM H$_2$OMap SWMM uses the EPA SWMM 5.1.012 Engine

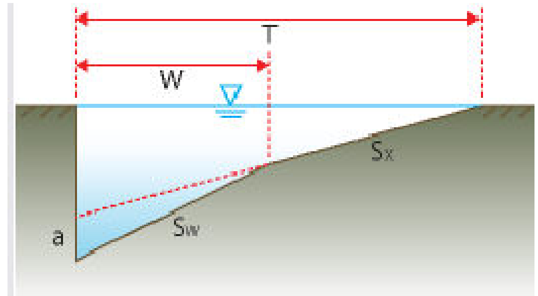
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

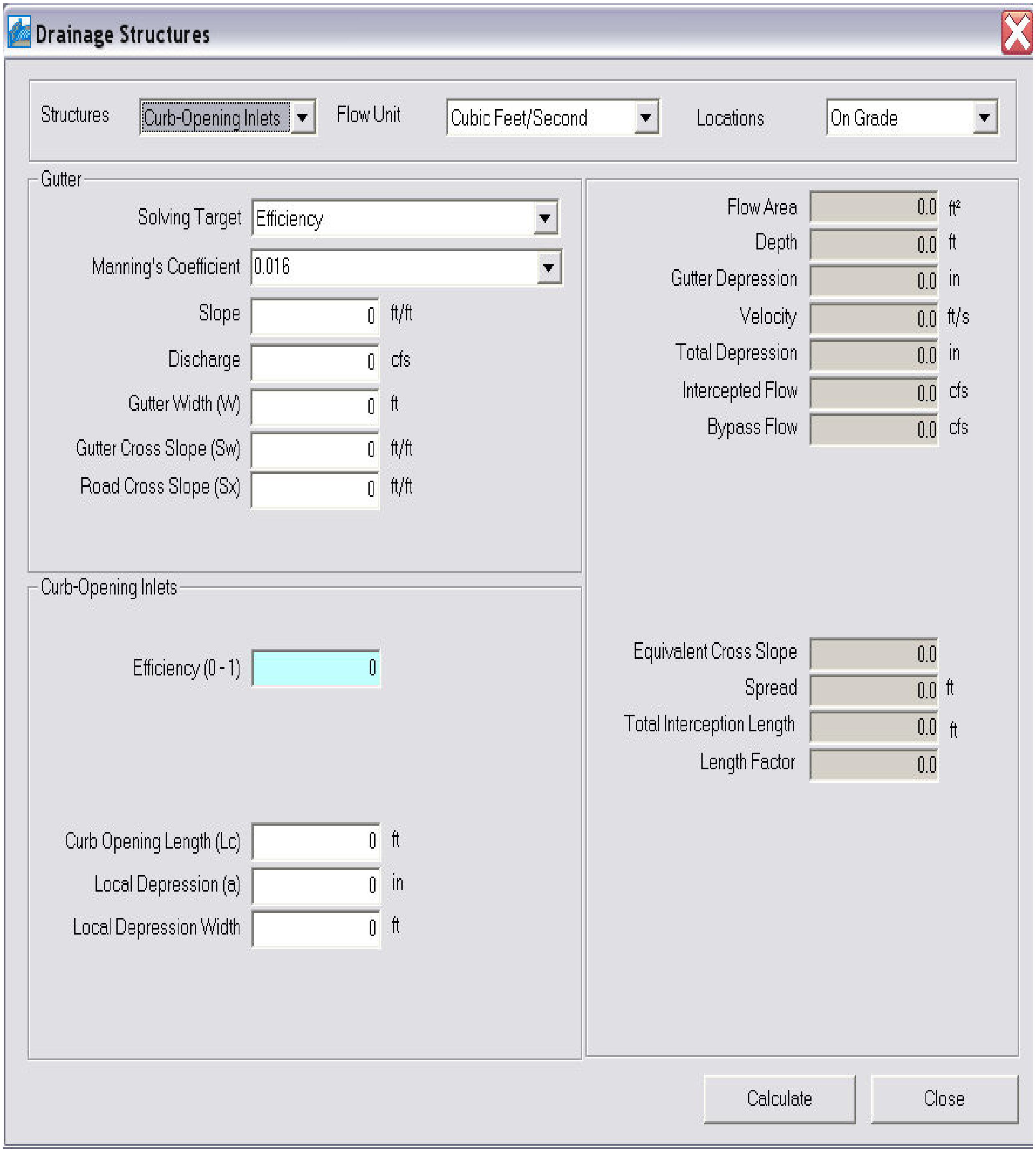

H2OCalc
H2OCalc View Window Help

Curb-Opening Inlet on Grade





The dialog box for curb-opening inlet on grade is shown below. For methodology click here.

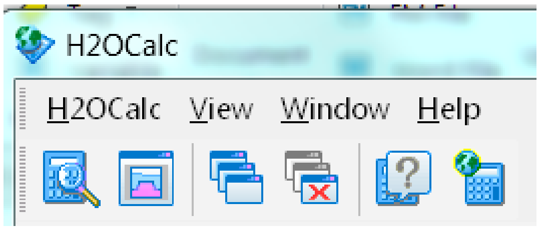

Drainage Structures
Structures
Curb-Opening Inlets
Flow Unit
Cubic Feet/Second
Locations
On Grade
Gutter
Solving Target
Efficiency
Manning's Coefficient
0.016
Slope
0
ft/ft
Discharge
0
cfs
Gutter Width (W)
0
ft
Gutter Cross Slope (Sw)
0
ft/ft
Road Cross Slope (Sx)
0
ft/ft
Curb-Opening Inlets
Efficiency (0 - 1)
0
Curb Opening Length (Lc)
0
ft
Local Depression (a)
0
in
Local Depression Width
0
ft
Flow Area
0.0
ft²
Depth
0.0
ft
Gutter Depression
0.0
in
Velocity
0.0
ft/s
Total Depression
0.0
in
Intercepted Flow
0.0
cfs
Bypass Flow
0.0
cfs
Equivalent Cross Slope
0.0
Spread
0.0
ft
Total Interception Length
0.0
ft
Length Factor
0.0
Calculate
Close

- **Input for curb-opening inlets on grade:**
- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Efficiency or length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Efficiency** –Interception efficiency of the inlet. It represents ratio of intercepted flow to total gutter flow. It is an output if selected as a solving target.
- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.

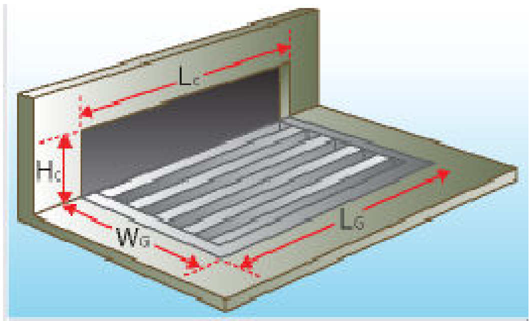
- **Output for curb-opening inlet on grade:**
- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Total Depression** – Sum of the local depression and the gutter depression.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Equivalent Cross Slope** – An equivalent cross-slope that has a conveyance capacity equal to that of the compound cross-slope.
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Total Interception Length** – Length of the curb required to intercept 100% of the gutter flow.
- **Length Factor** – Ratio of actual curb length to total interception length.

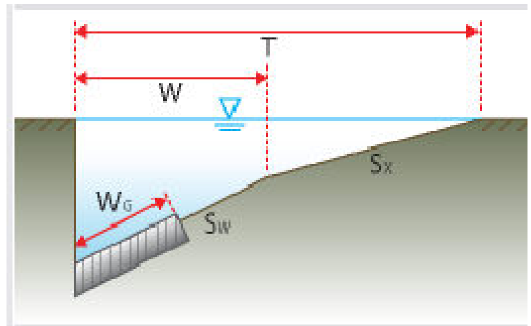
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

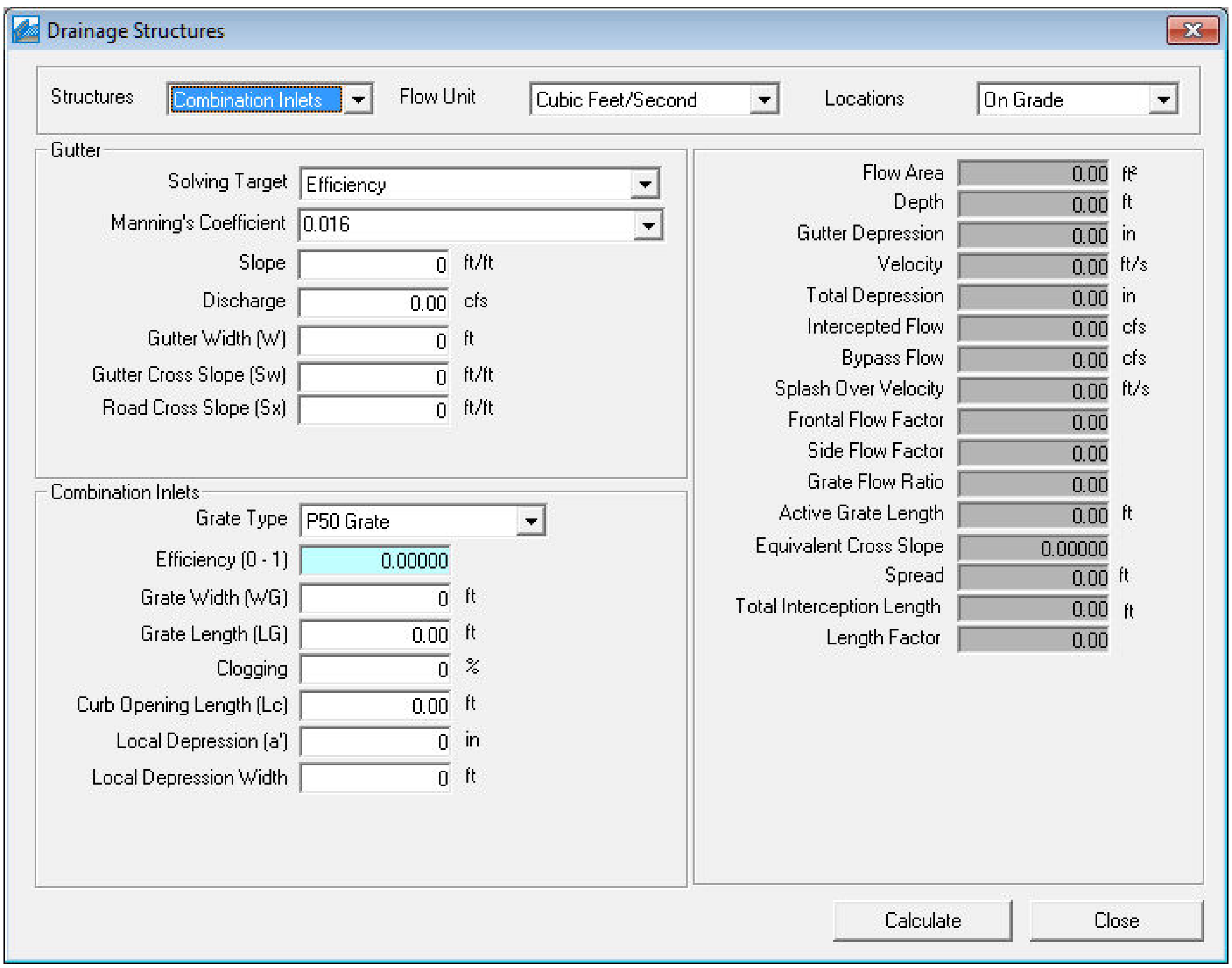

H2OCalc
H2OCalc View Window Help

Combination Inlet on Grade





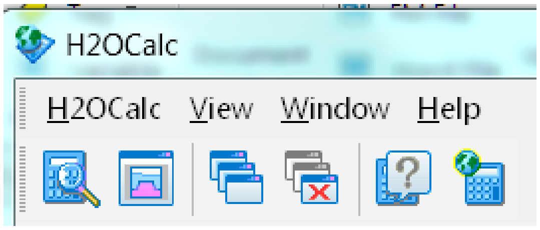
The dialog box for combination inlet on grade is shown below. For methodology click here.



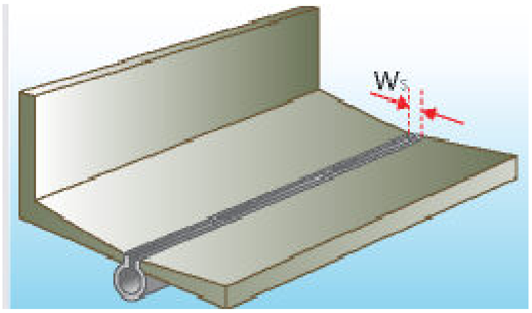
- **Input for combination inlets on grade:**
- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Efficiency, equal opening lengths, or curb opening length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Grate Type** – Select one of the eight grate types listed.
- **Efficiency** –Interception efficiency of the inlet. It represents ratio of intercepted flow to total gutter flow. It is an output if selected as a solving target.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.

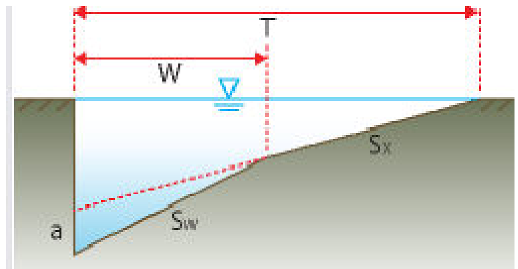
- **Output for combination inlet on grade:**
- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Total Depression** – Sum of the local depression and the gutter depression.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Splash Over Velocity** – Velocity where splash over first occurs. Splash over refers to the fraction of frontal gutter flow that is not intercepted by the inlet.
- **Frontal Flow Factor** – The ratio of intercepted frontal flow to total frontal flow.
- **Side Flow Factor** – The ratio of intercepted side flow to total side flow.
- **Grate Flow Ratio** – The ratio of frontal flow to total gutter flow.
- **Active Grate Length** – Portion of grate length (the side that is parallel to the curb) that is not clogged.
- **Equivalent Cross Slope** – An equivalent cross-slope that has a conveyance capacity equal to that of the compound cross-slope.
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Total Interception Length** – Length of the curb required to intercept 100% of the gutter flow.

- **Length Factor** – Ratio of actual curb length to total interception length.

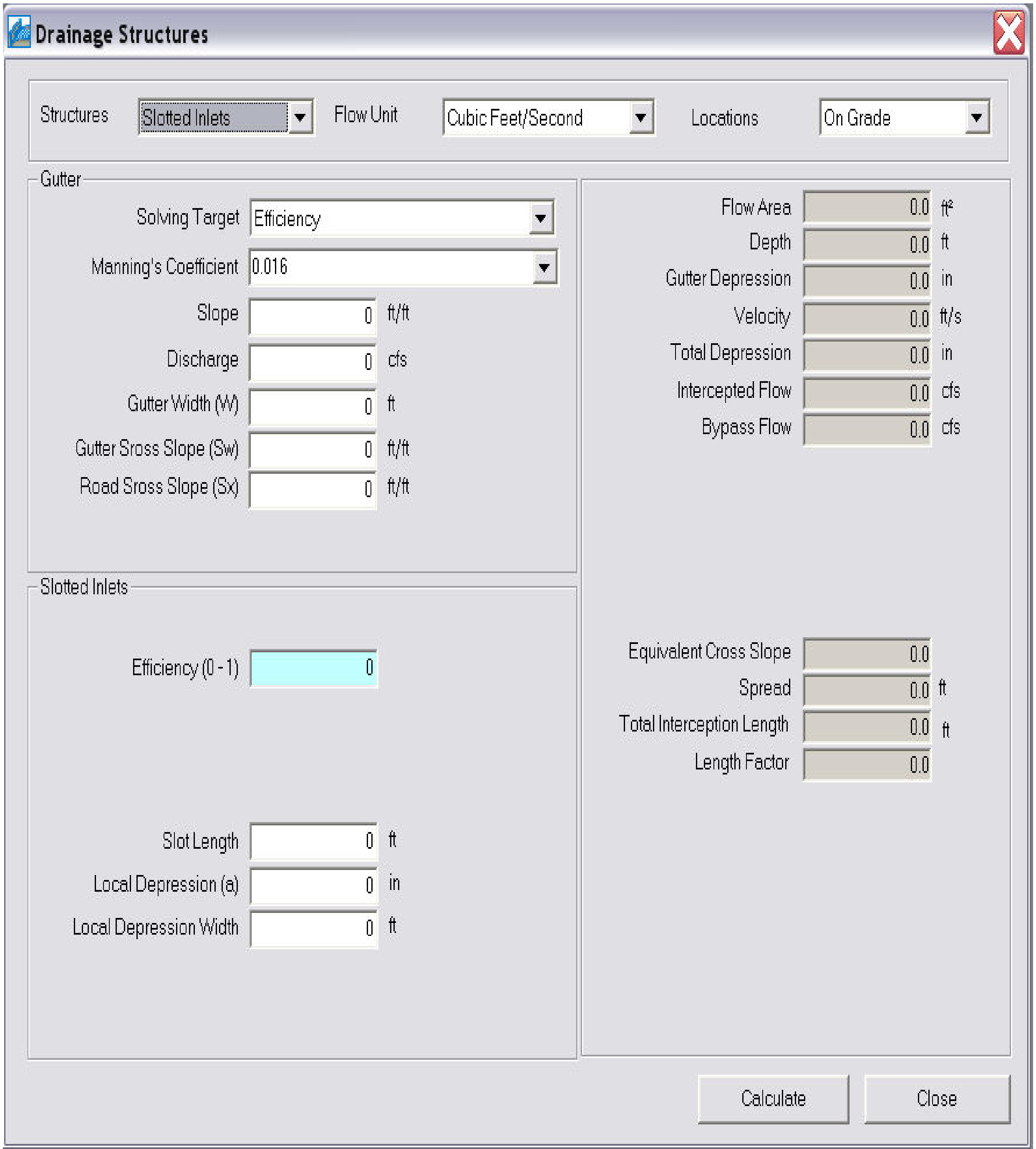

H2OCalc
H2OCalc View Window Help

Slotted Inlet on Grade





The dialog box for slotted inlet on grade is shown below. For methodology click here.

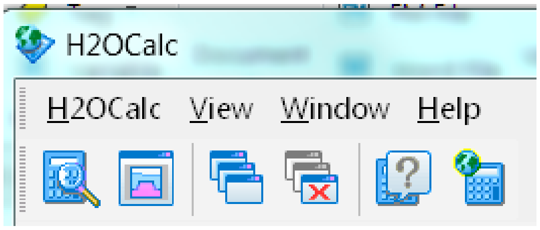

Drainage Structures
Structures
Slotted Inlets
Flow Unit
Cubic Feet/Second
Locations
On Grade
Gutter
Solving Target
Efficiency
Manning's Coefficient
0.016
Slope
0
ft/ft
Discharge
0
cfs
Gutter Width (W)
0
ft
Gutter Sross Slope (Sw)
0
ft/ft
Road Sross Slope (Sx)
0
ft/ft
Slotted Inlets
Efficiency (0 - 1)
0
Slot Length
0
ft
Local Depression (a)
0
in
Local Depression Width
0
ft
Flow Area
0.0
ft²
Depth
0.0
ft
Gutter Depression
0.0
in
Velocity
0.0
ft/s
Total Depression
0.0
in
Intercepted Flow
0.0
cfs
Bypass Flow
0.0
cfs
Equivalent Cross Slope
0.0
Spread
0.0
ft
Total Interception Length
0.0
ft
Length Factor
0.0
Calculate
Close

- **Input for slotted inlets on grade:**
- **Flow Unit** – Select the desired flow unit.
- **Locations** – On grade and in sag.
- **Solving Target** – Efficiency and length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Efficiency** –Interception efficiency of the inlet. It represents ratio of intercepted flow to total gutter flow. It is an output if selected as a solving target.
- **Slot Length** – Length of the inlet.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.

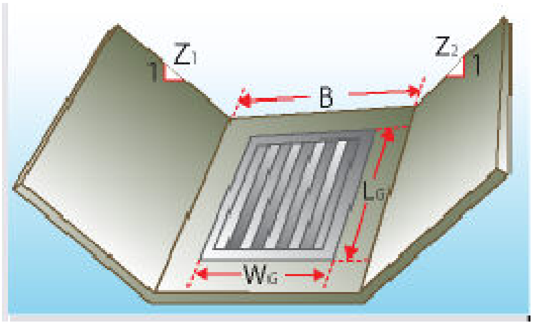
- Output for slotted inlet on grade:
- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Total Depression** – Sum of the local depression and the gutter depression.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Equivalent Cross Slope** – An equivalent cross-slope that has a conveyance capacity equal to that of the compound cross-slope.
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Total Interception Length** – Length of the curb required to intercept 100% of the gutter flow.
- **Length Factor** – Ratio of actual curb length to total interception length.

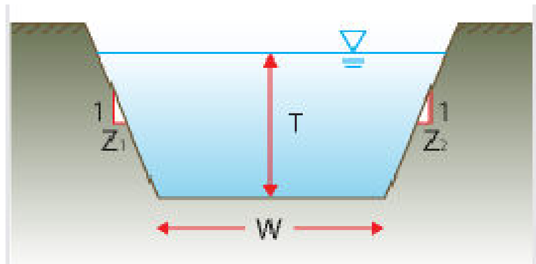
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Ditch Inlet on Grade





The dialog box for ditch inlets on grade is shown below. For methodology click here.


Drainage Structures
Structures
Ditch Inlets
Flow Unit
Cubic Feet/Second
Locations
On Grade
Ditch
Solving Target
Efficiency
Manning's Coefficient
0.016
Slope
0
ft/ft
Discharge
0
cfs
Bottom Width (B)
0
ft
Left Side Slope (Z1)
0
ft/ft
Right Side Slope (Z2)
0
ft/ft
Grate Inlets
Grate Type
P50 Grate
Efficiency (0 - 1)
0
Grate Width (WG)
0
ft
Grate Length (LG)
0
ft
Clogging
0
%
Flow Area
0.0
ft²
Depth
0.0
ft
Velocity
0.0
ft/s
Intercepted Flow
0.0
cfs
Bypass Flow
0.0
cfs
Splash Over Velocity
0.0
ft/s
Frontal Flow Factor
0.0
Side Flow Factor
0.0
Grate Flow Ratio
0.0
Active Grate Length
0.0
ft
Spread
0.0
ft
Velocity Head
0.0
ft
Critical Depth
0.0
ft
Critical Slope
0.0
ft/ft
Specific Energy
0.0
ft
Froude Number
0.0
Flow Type
N/A
Calculate
Close

- **Input for ditch inlets on grade:**
- **Flow Unit** – Select the desired flow unit.
- **Locations** – On grade and in sag.
- **Solving Target** – Efficiency and length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Bottom Width** – Bottom width of the ditch (channel).
- **Left Side Slope** – Left side slope of the ditch.
- **Right Side Slope** – Right side of the ditch.
- **Grate Type** – Select one of the eight grate types listed.
- **Efficiency** –Interception efficiency of the grate. It represents ratio of intercepted flow to total gutter flow.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.

- **Output for ditch inlets on grade:**
- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Velocity** – Flow velocity through the gutter.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Splash Over Velocity** – Velocity where splash over first occurs. Splash over refers to the fraction of frontal gutter flow that is not intercepted by the inlet.
- **Frontal Flow Factor** – The ratio of intercepted frontal flow to total frontal flow.
- **Side Flow Factor** – The ratio of intercepted side flow to total side flow.
- **Grate Flow Ratio** – The ratio of frontal flow to total gutter flow.
- **Active Grate Length** – Portion of grate length (the side that is parallel to the curb) that is not clogged.
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Velocity Head** – Energy head due to velocity.
- **Critical Depth** – Depth corresponding to minimum specific energy of the channel.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Sum of velocity head and pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter for the ditch.

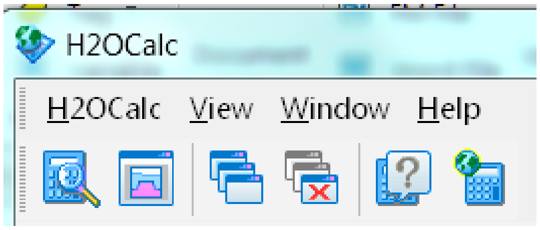
Copyright © Innovyze 2016. All Rights Reserved.

Innovyze Help File Updated September 1, 2017

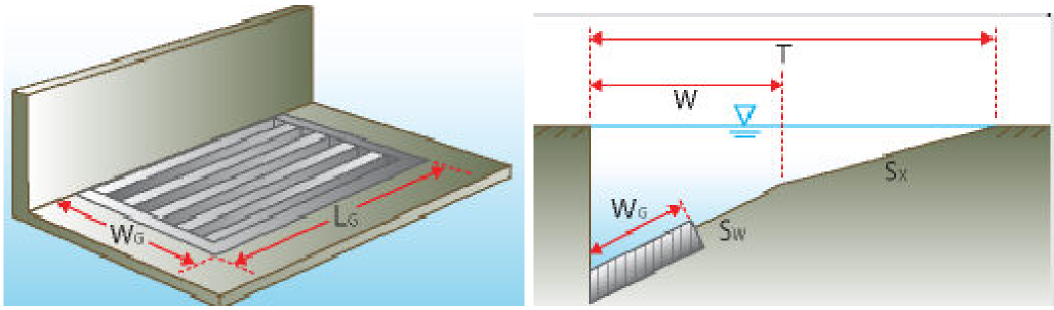
InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

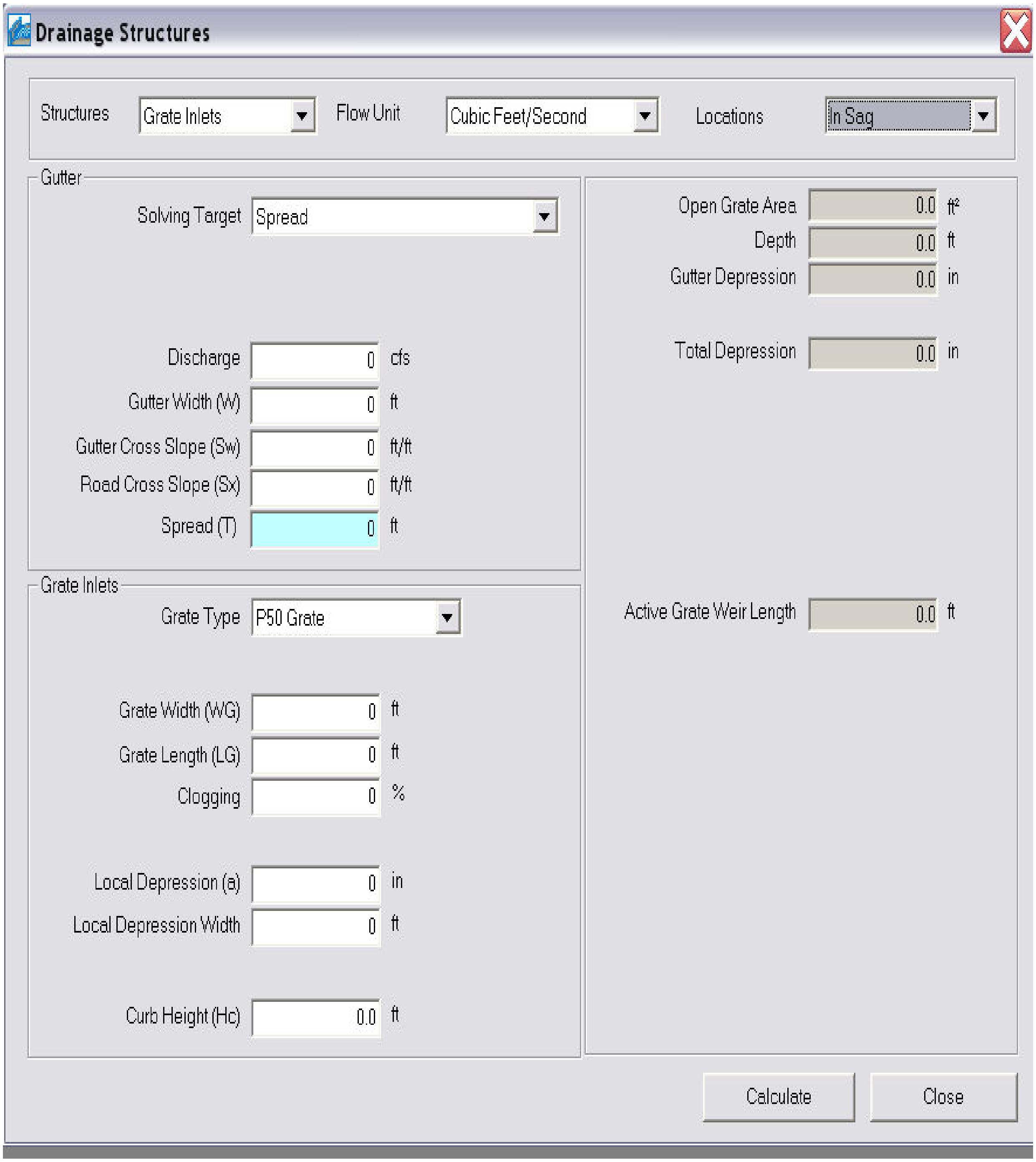
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Grate Inlet In Sag



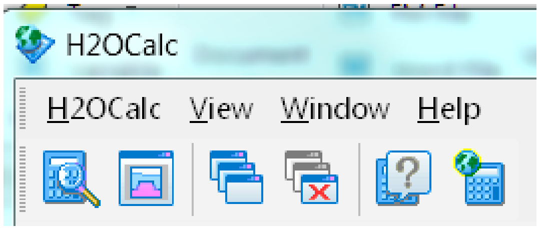
The dialog box for grate inlet in sag is shown below. For methodology click here.


Drainage Structures
Structures
Grate Inlets
Flow Unit
Cubic Feet/Second
Locations
In Sag
Gutter
Solving Target
Spread
Discharge
0
cfs
Gutter Width (W)
0
ft
Gutter Cross Slope (Sw)
0
ft/ft
Road Cross Slope (Sx)
0
ft/ft
Spread (T)
0
ft
Grate Inlets
Grate Type
P50 Grate
Grate Width (WG)
0
ft
Grate Length (LG)
0
ft
Clogging
0
%
Local Depression (a)
0
in
Local Depression Width
0
ft
Curb Height (Hc)
0.0
ft
Open Grate Area
0.0
ft²
Depth
0.0
ft
Gutter Depression
0.0
in
Total Depression
0.0
in
Active Grate Weir Length
0.0
ft
Calculate
Close

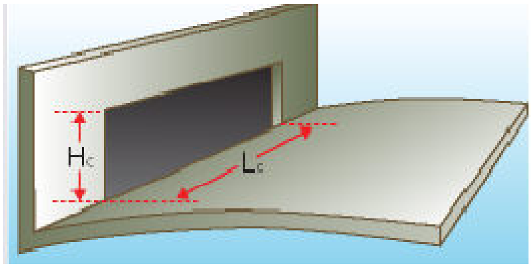
- **Input for grate inlets in sag:**
- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Spread or length.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be output is selected as a solving target.
- **Grate Type** – Select one of the eight grate types listed.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Curb Height** – Height of the curb.

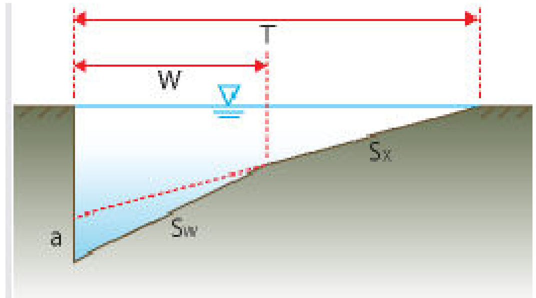
- **Output for grate inlet in sag:**
- **Open Grate Area** – Clear area of the grate accounting for clogging, and area occupied by the bars depending on the grate type. Used when the grate acts as an orifice.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets the curb).
- **Active Grate Weir Length** – Portion of grate length and width that is not clogged and not covered by the bars. Used when the grate acts as a weir.
- **Spread** – Top width, or width of the gutter at the water surface elevation. If selected as solving target, it is an output. Otherwise, it is an input.
- **Grate Length** - Length of the grate. If selected as solving target, it is an output. Otherwise it is an input.

Innovyze® H2OCalc™ Modeling Made Easy Innovyze®

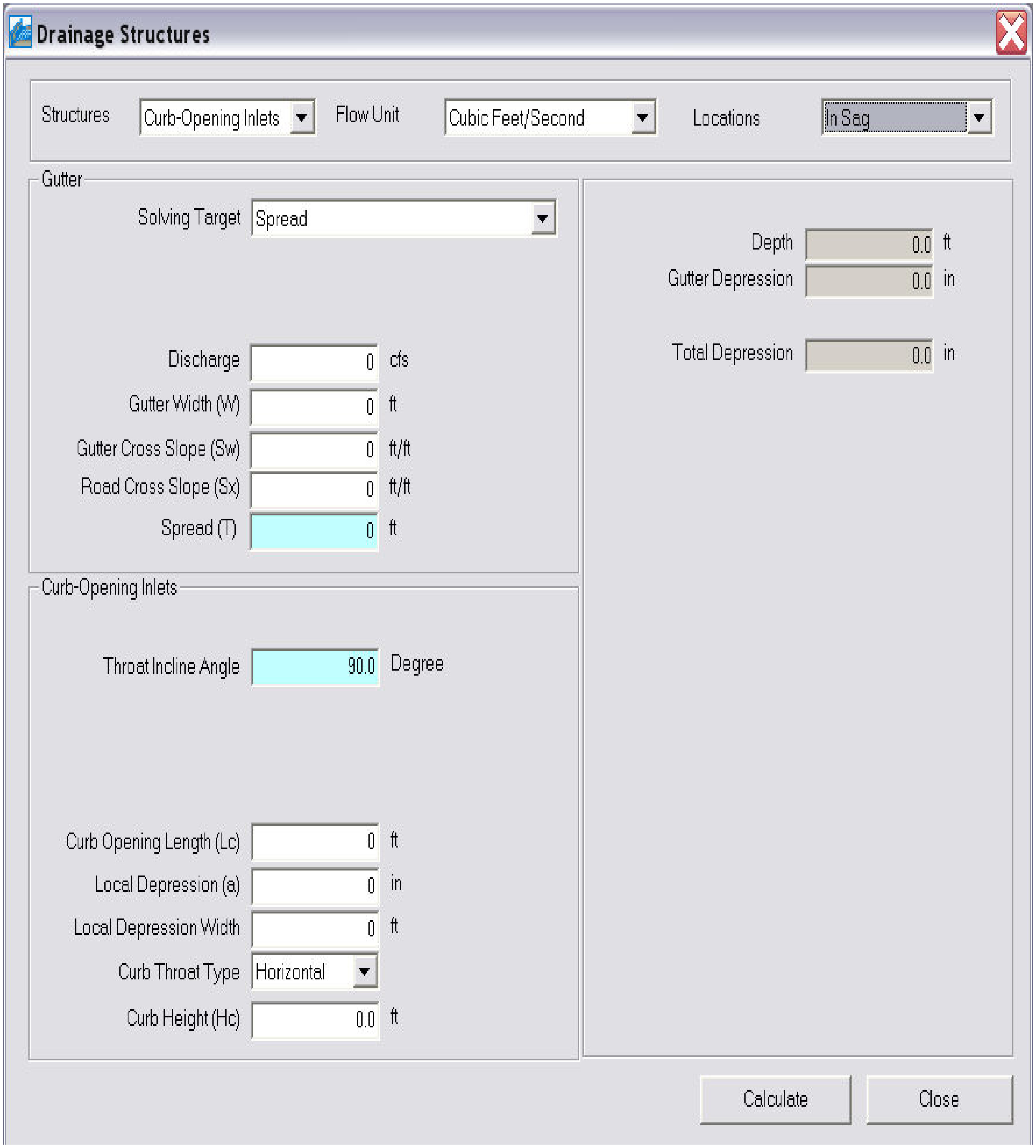

H2OCalc
H2OCalc View Window Help

Curb Opening Inlet in Sag



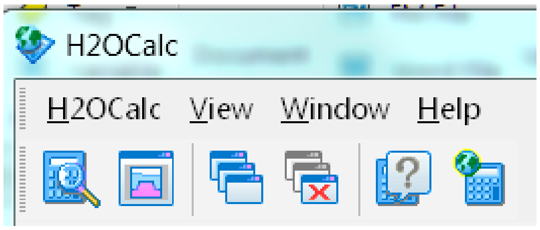


The dialog box for curb-opening inlet in sag is shown below. For methodology click here.

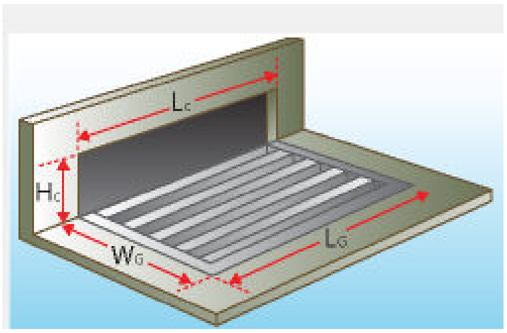

Drainage Structures
Structures
Curb-Opening Inlets
Flow Unit
Cubic Feet/Second
Locations
In Sag
Gutter
Solving Target
Spread
Discharge
0
cfs
Gutter Width (W)
0
ft
Gutter Cross Slope (Sw)
0
ft/ft
Road Cross Slope (Sx)
0
ft/ft
Spread (T)
0
ft
Curb-Opening Inlets
Throat Incline Angle
90.0
Degree
Curb Opening Length (Lc)
0
ft
Local Depression (a)
0
in
Local Depression Width
0
ft
Curb Throat Type
Horizontal
Curb Height (Hc)
0.0
ft
Depth
0.0
ft
Gutter Depression
0.0
in
Total Depression
0.0
in
Calculate
Close

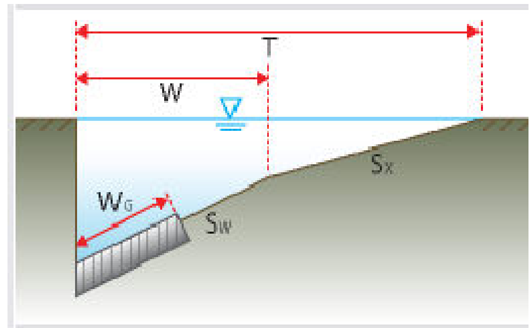
- **Input for curb-opening inlets in sag:**
- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Spread or length.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be an output if selected as a solving target.
- **Throat Incline Angle** – Angle of the curb opening throat.
- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Curb Throat Type** – Horizontal, vertical, or incline.
- **Curb Height** – Height of the curb.

- **Output for curb-opening inlet in sag:**
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets the curb).

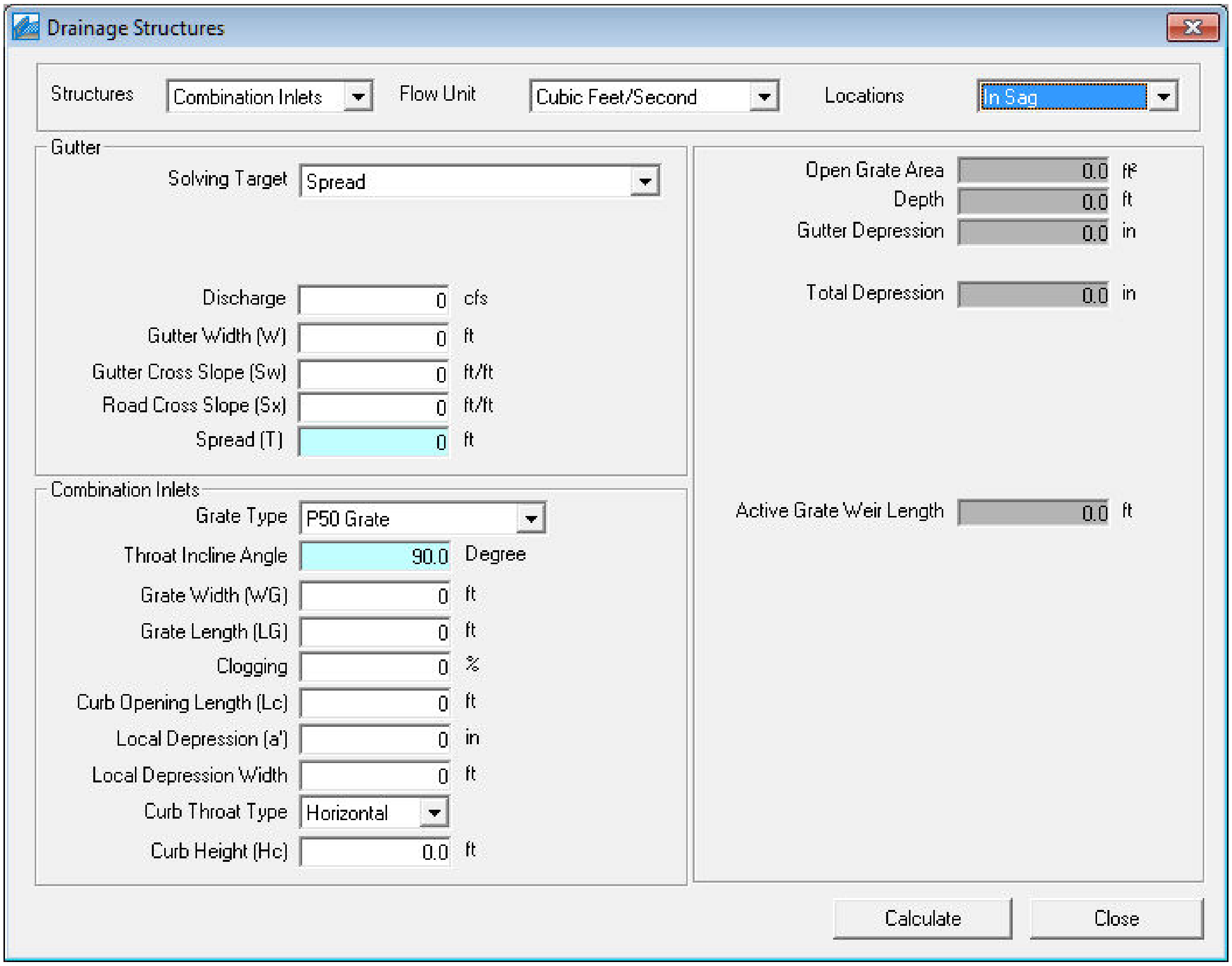

H2OCalc
H2OCalc View Window Help

Combination Inlet in Sag





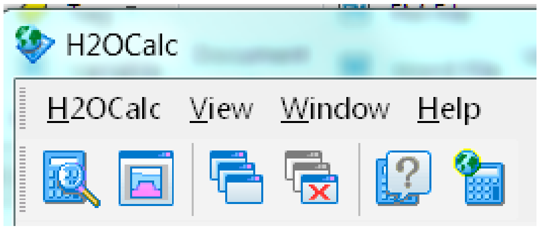
The dialog box for combination inlet in sag is shown below. For methodology click here.



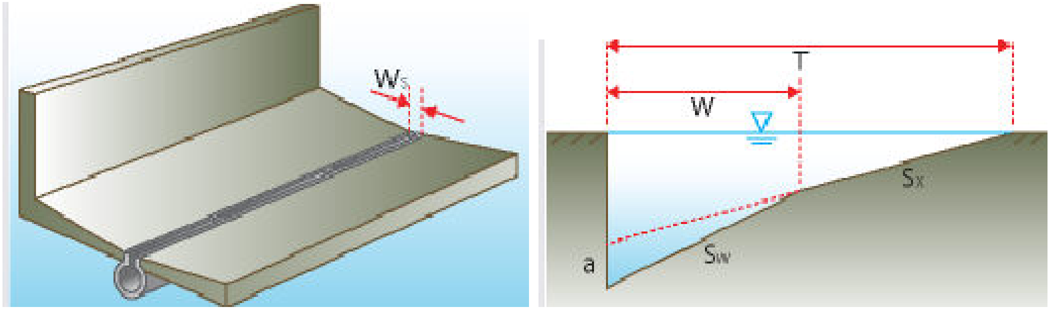
Drainage Structures
Structures
Combination Inlets
Flow Unit
Cubic Feet/Second
Locations
In Sag
Gutter
Solving Target
Spread
Discharge
0
cfs
Gutter Width (W)
0
ft
Gutter Cross Slope (Sw)
0
ft/ft
Road Cross Slope (Sx)
0
ft/ft
Spread (T)
0
ft
Combination Inlets
Grate Type
P50 Grate
Throat Incline Angle
90.0
Degree
Grate Width (WG)
0
ft
Grate Length (LG)
0
ft
Clogging
0
%
Curb Opening Length (Lc)
0
ft
Local Depression (a')
0
in
Local Depression Width
0
ft
Curb Throat Type
Horizontal
Curb Height (Hc)
0.0
ft
Open Grate Area
0.0
ft²
Depth
0.0
ft
Gutter Depression
0.0
in
Total Depression
0.0
in
Active Grate Weir Length
0.0
ft
Calculate
Close

- Input for combination inlets in sag:
- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Efficiency, equal opening lengths, or curb opening length.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be an output if selected as a solving target.
- **Grate Type** – Select one of the eight grate types listed.
- **Throat Incline Angle** – Angle of the curb opening throat.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Curb Throat Type** – Horizontal, vertical, or incline.
- **Curb Height** – Height of the curb.

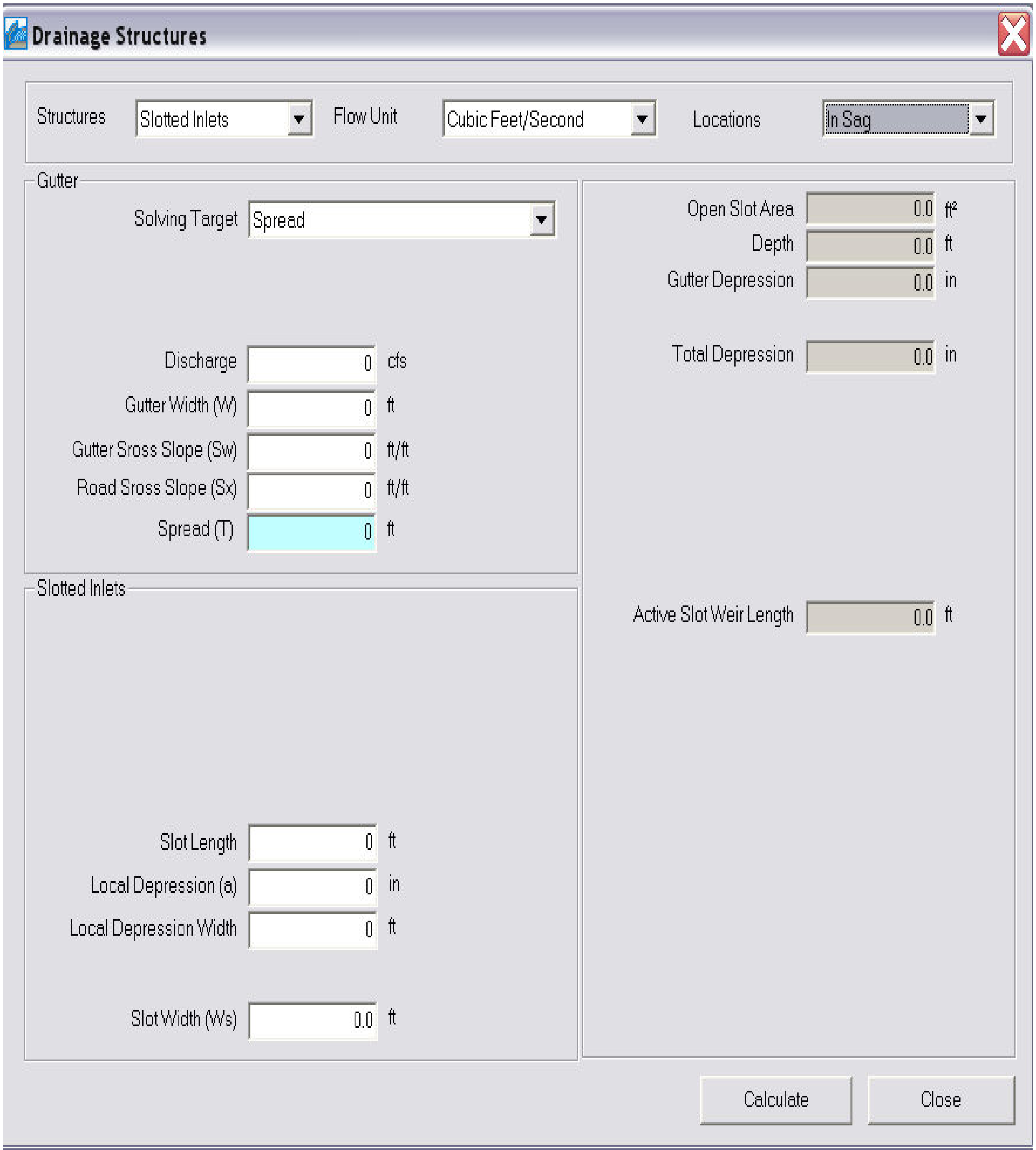
- **Output for combination inlet in sag:**
- **Open Grate Area** – Clear area of the grate accounting for clogging, and area occupied by the bars depending on the grate type. Used when the grate acts as an orifice.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets the curb).
- **Active Grate Weir Length** – Portion of grate length and width that is not clogged and not covered by the bars. Used when the grate acts as a weir.


H2OCalc
H2OCalc View Window Help

Slotted Inlet in Sag

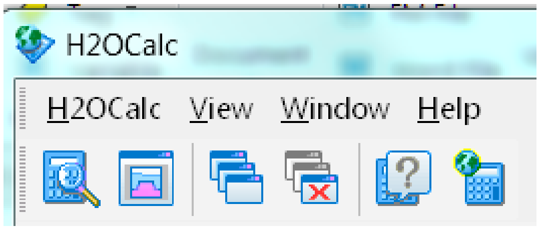


The dialog box for slotted inlet in sag is shown below. For methodology click here.

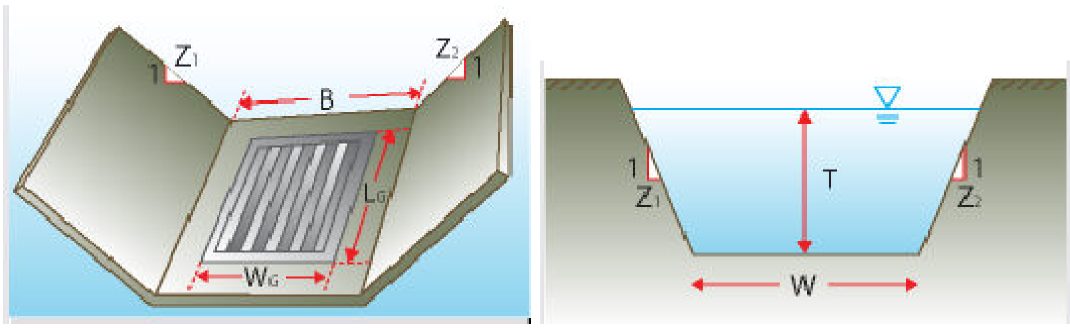

Drainage Structures
Structures
Slotted Inlets
Flow Unit
Cubic Feet/Second
Locations
In Sag
Gutter
Solving Target
Spread
Discharge
0
cfs
Gutter Width (W)
0
ft
Gutter Sross Slope (Sw)
0
ft/ft
Road Sross Slope (Sx)
0
ft/ft
Spread (T)
0
ft
Slotted Inlets
Slot Length
0
ft
Local Depression (a)
0
in
Local Depression Width
0
ft
Slot Width (Ws)
0.0
ft
Open Slot Area
0.0
ft²
Depth
0.0
ft
Gutter Depression
0.0
in
Total Depression
0.0
in
Active Slot Weir Length
0.0
ft
Calculate
Close

- **Input for slotted inlets in sag:**
- **Flow Unit** – Select the flow unit.
- **Locations** – On grade and in sag.
- **Solving Target** – Spread and length.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be an output if selected as a solving target.
- **Slot Length** – Length of the inlet.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Slot Width** – Width of the slot length opening.

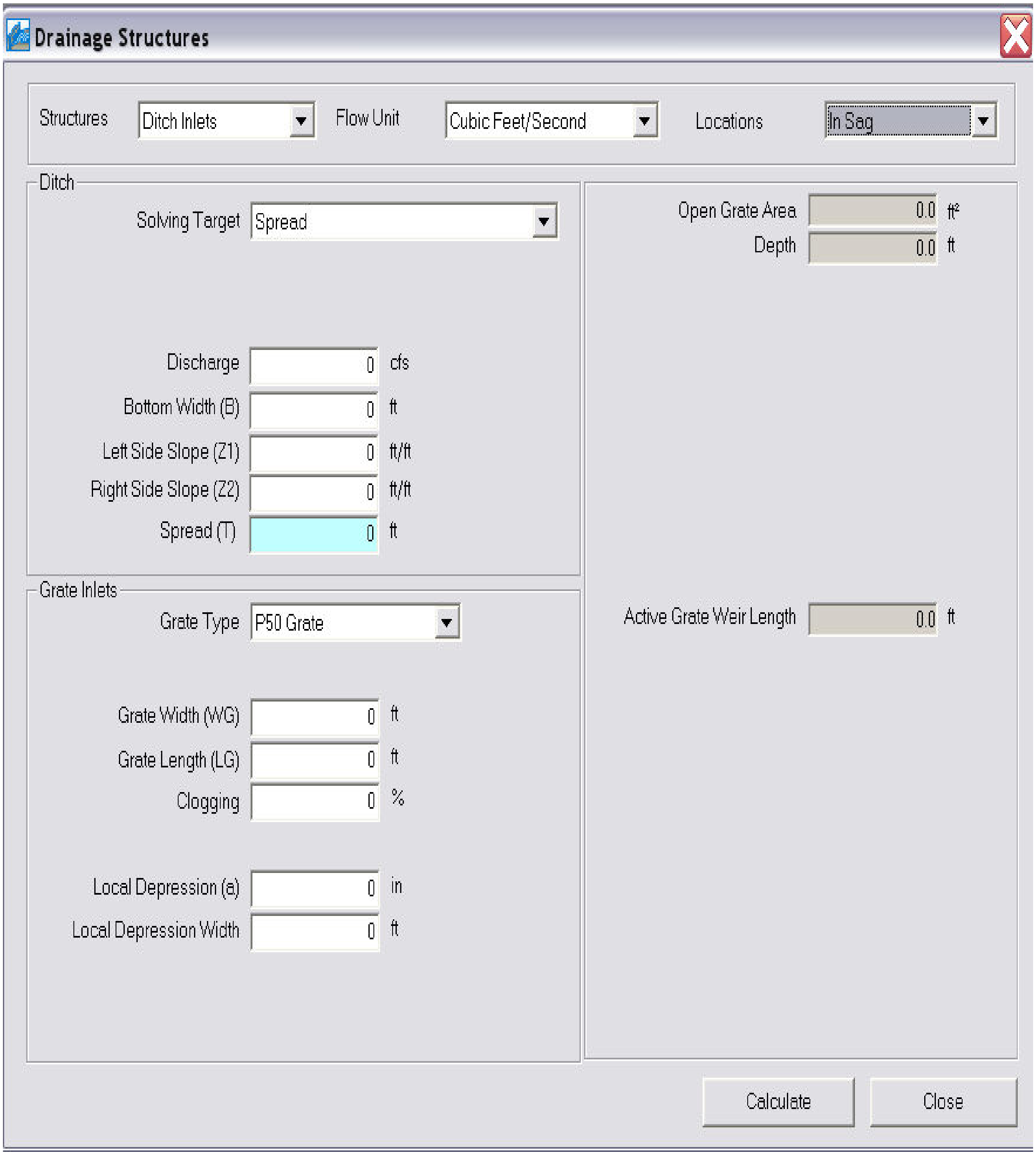
- **Output for slotted inlet in sag:**
- **Open Slot Area** – Area of the slot opening used in the case of orifice opening.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets the curb).
- **Active Slot Weir Length** – Portion of slot length and width that is not clogged and not covered by the bars. Used when the slot acts as a weir.


H2OCalc
H2OCalc View Window Help

Ditch Inlet In Sag

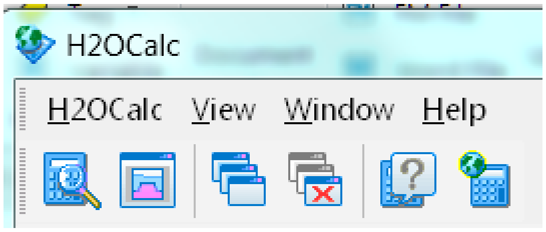


The dialog box for ditch inlets in sag is shown below. For methodology click here.


Drainage Structures
Structures
Ditch Inlets
Flow Unit
Cubic Feet/Second
Locations
In Sag
Ditch
Solving Target
Spread
Discharge
0
cfs
Bottom Width (B)
0
ft
Left Side Slope (Z1)
0
ft/ft
Right Side Slope (Z2)
0
ft/ft
Spread (T)
0
ft
Grate Inlets
Grate Type
P50 Grate
Grate Width (WG)
0
ft
Grate Length (LG)
0
ft
Clogging
0
%
Local Depression (a)
0
in
Local Depression Width
0
ft
Open Grate Area
0.0
ft²
Depth
0.0
ft
Active Grate Weir Length
0.0
ft
Calculate
Close

- **Input for ditch inlets in sag:**
- **Flow Unit** – Select the flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Spread or length.
- **Discharge** – Flow rate through the gutter.
- **Bottom Width** – Bottom width of the ditch (channel).
- **Left Side Slope** – Left side slope of the ditch.
- **Right Side Slope** – Right side of the ditch.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be output is selected as a solving target.
- **Grate Type** – Select one of the eight grate types listed.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.

- **Output for ditch inlets in sag:**
- **Open Grate Area** – Area of the grate accounting for clogging, and area occupied by the bars depending on the grate type. Used when the grate acts as an orifice.
- **Depth** – Flow depth in the gutter.
- **Active Grate Weir Length** – Portion of grate length and width that is not clogged and not covered by the bars. Used when the grate acts as a weir.


H2OCalc
H2OCalc View Window Help

Weirs and Orifices

The Weirs and Orifices category performs hydraulic calculations for various types of weirs and orifices.

Weirs

- Rectangular Weir
- V-notch Weir
- Cipolletti Weir
- Generic Weir
- Broad Crested Weir

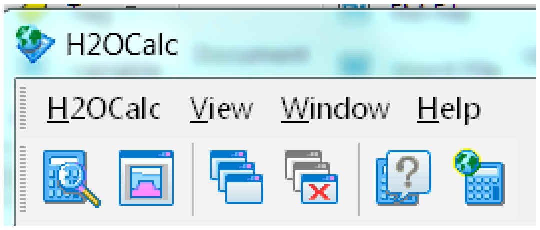
Click the following for more information of Weirs in the methodology.

- Weir
    - Sharp-Crested Weir
        - Rectangular Sharp-Crested Weir
        - Cipolletti Sharp-Crested Weir
        - V-Notch Sharp-Crested Weir
    - Submerged Sharp-Crested Weir
    - Broad-Crested Weir
    - Generic Weir

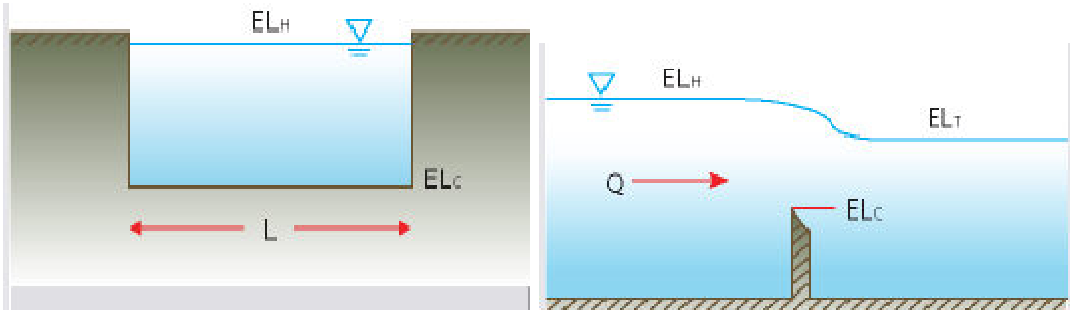
Orifices

- Generic Orifice
- Rectangular Orifice
- Circular Orifice

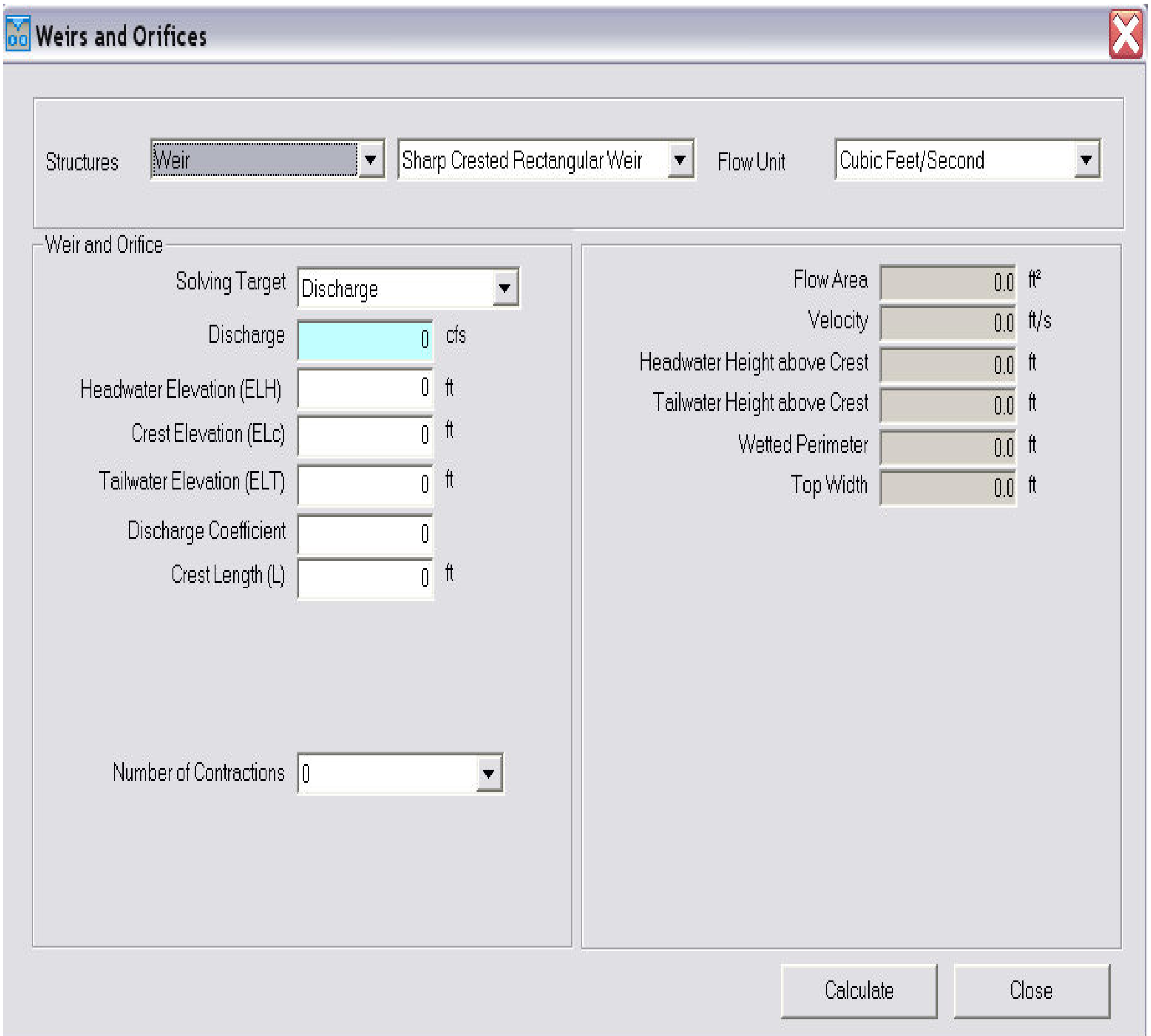
Click here for the methodology of Orifices.


H2OCalc
H2OCalc View Window Help

Rectangular Weir

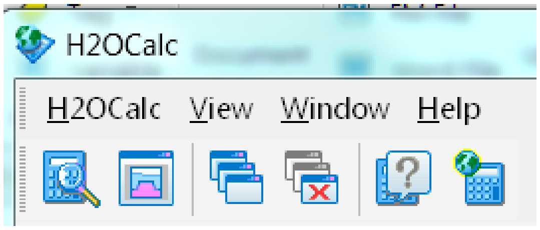


The sharp crested rectangular weir dialog box is shown below. Click here for the methodology.

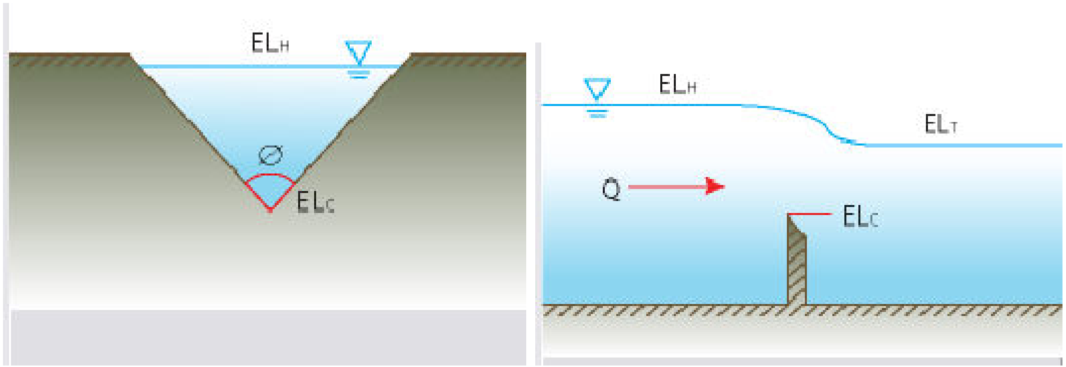

Weirs and Orifices
Structures
Weir
Sharp Crested Rectangular Weir
Flow Unit
Cubic Feet/Second
Weir and Orifice
Solving Target
Discharge
Discharge
0
cfs
Headwater Elevation (ELH)
0
ft
Crest Elevation (ELc)
0
ft
Tailwater Elevation (ELT)
0
ft
Discharge Coefficient
0
Crest Length (L)
0
ft
Number of Contractions
0
Flow Area
0.0
ft²
Velocity
0.0
ft/s
Headwater Height above Crest
0.0
ft
Tailwater Height above Crest
0.0
ft
Wetted Perimeter
0.0
ft
Top Width
0.0
ft
Calculate
Close

- **Input for sharp crested rectangular weir:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation** – Water surface elevation upstream of the weir.
- **Crest Elevation** – Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation**– Water surface elevation downstream of the weir.
- **Discharge Coefficient** – Weir coefficient (cd) used to account for submergence effects.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.
- **Number of Contractions** – Number of end contractions (i.e., one or both sides of the weir).

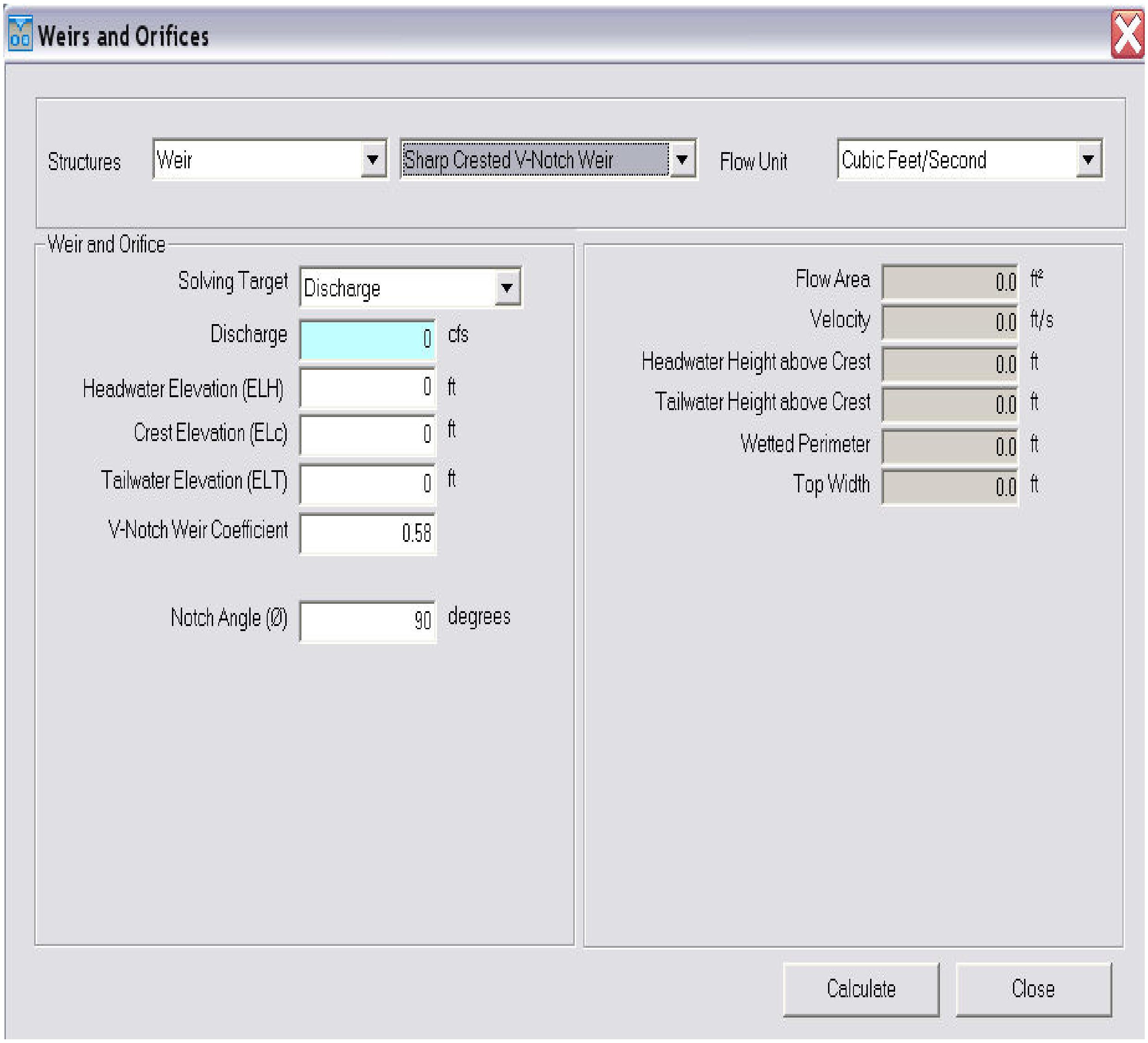
- **Output for sharp crested rectangular weir:**
- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest** – Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest** – Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation. For rectangular channels, it is the same as crest length.


H2OCalc
H2OCalc View Window Help

V-Notch Weir

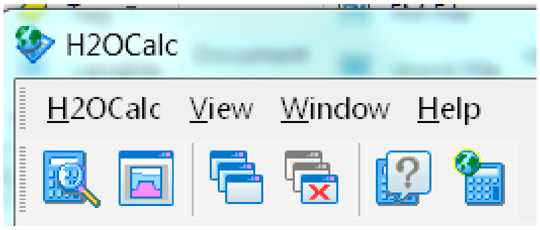


The sharp crested v-notch weir dialog box is shown below. Click here for the methodology.

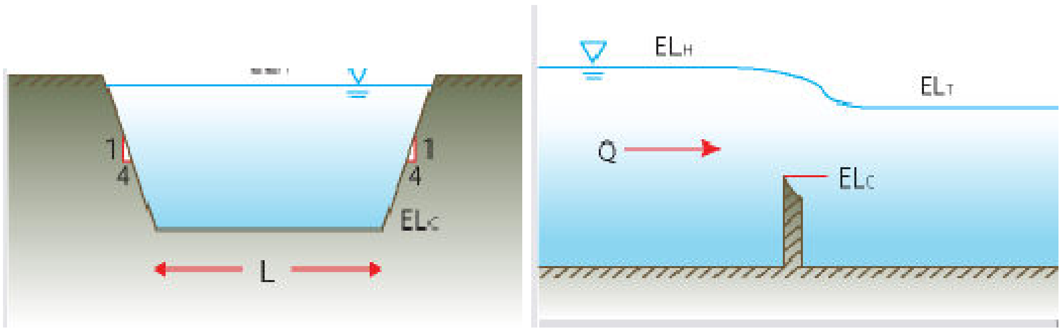

Weirs and Orifices
Structures
Weir
Sharp Crested V-Notch Weir
Flow Unit
Cubic Feet/Second
Weir and Orifice
Solving Target
Discharge
Discharge
0
cfs
Headwater Elevation (ELH)
0
ft
Crest Elevation (ELc)
0
ft
Tailwater Elevation (ELT)
0
ft
V-Notch Weir Coefficient
0.58
Notch Angle (Ø)
90
degrees
Flow Area
0.0
ft²
Velocity
0.0
ft/s
Headwater Height above Crest
0.0
ft
Tailwater Height above Crest
0.0
ft
Wetted Perimeter
0.0
ft
Top Width
0.0
ft
Calculate
Close

- **Input for sharp crested v-notch weir:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation** – Water surface elevation upstream of the weir.
- **Crest Elevation** – Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation -** Water surface elevation downstream of the weir.
- **V-Notch Weir Coefficient** – Weir coefficient (cd) used to account for effects such as submergence and local losses on flow rate through the weir.
- **Notch Angle** – Angle of the triangular weir opening.

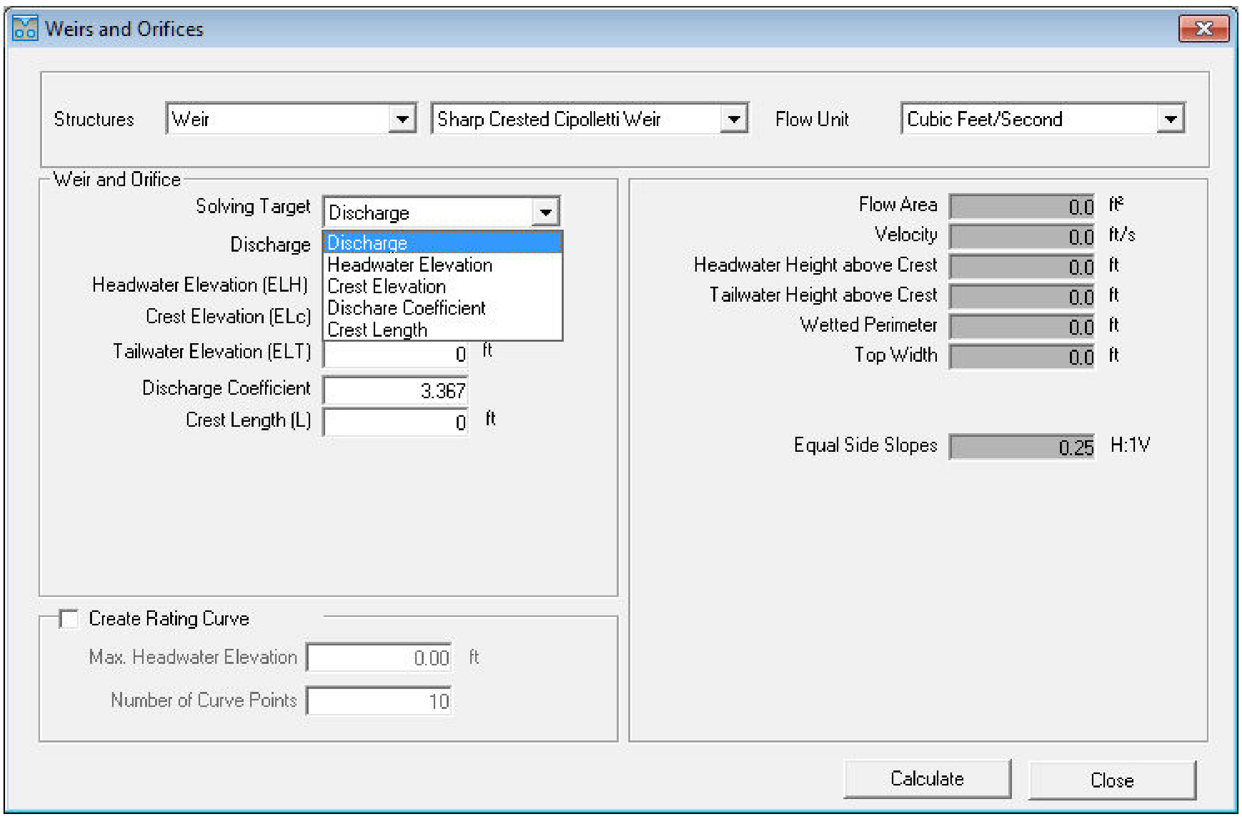
- Output for sharp crested v-notch weir:
- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest** – Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest** – Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.


H2OCalc
H2OCalc View Window Help

Cipolletti Weir

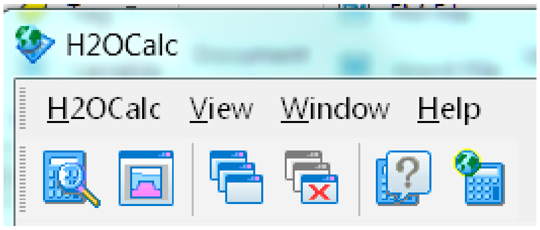


The sharp crested cipolletti weir dialog box is shown below. Click here for the methodology.

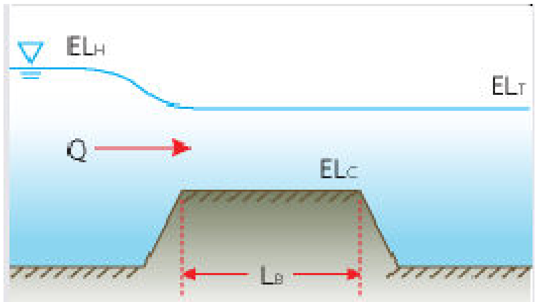


- **Input for sharp crested cipolletti weir:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation** – Water surface elevation upstream of the weir.
- **Crest Elevation** – Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation**– Water surface elevation downstream of the weir.
- **Discharge Coefficient** – Weir coefficient (cd) used to account for submergence effects.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.

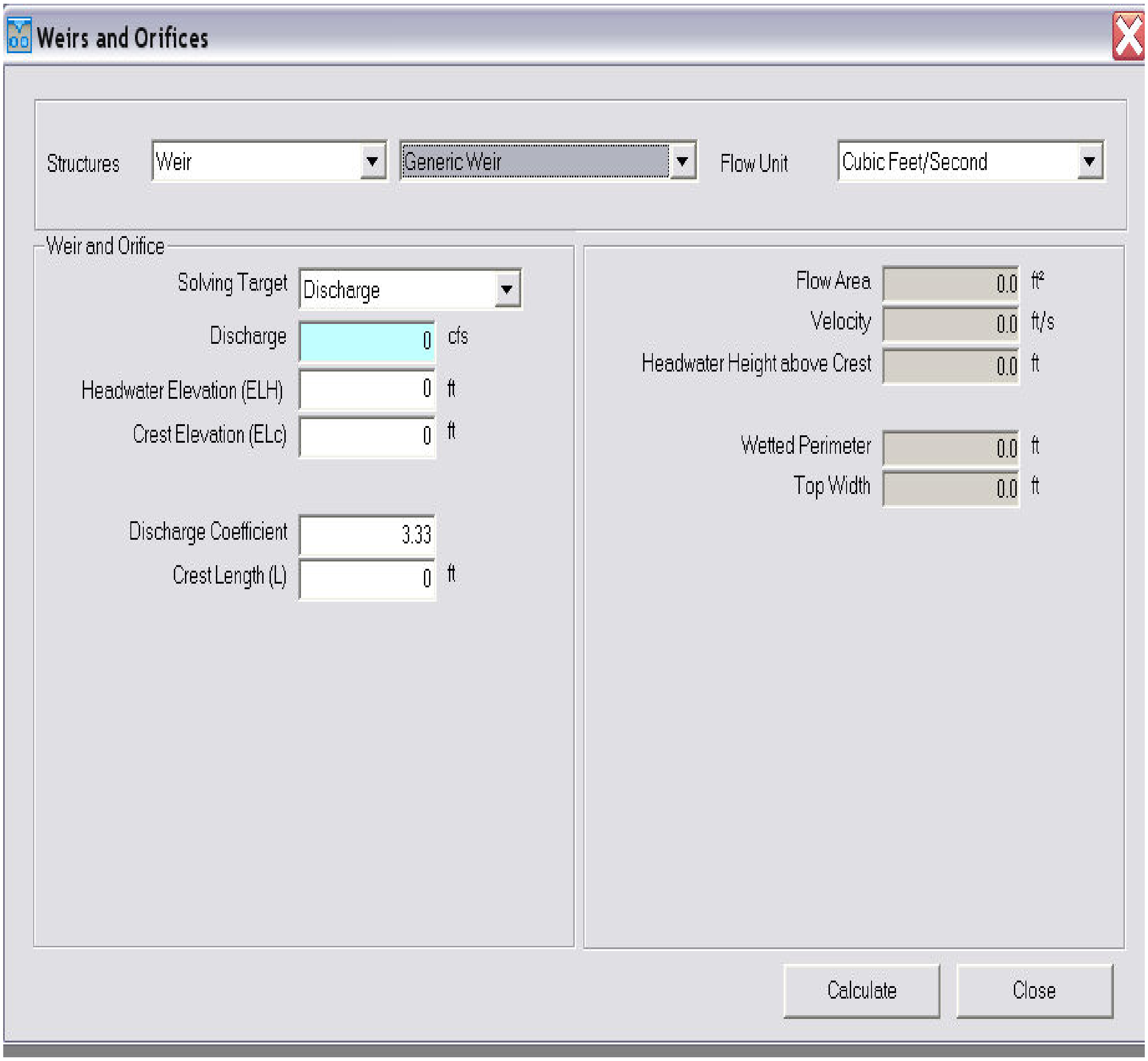
- [Output for sharp crested cipolletti weir:]
- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest** – Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest** – Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.
- **Equal Side Slope** – Side slope for the left and the right side of the cipolletti (trapezoidal) weir. It is assumed identical for both sides of the weir.


H2OCalc
H2OCalc View Window Help

Generic Weir

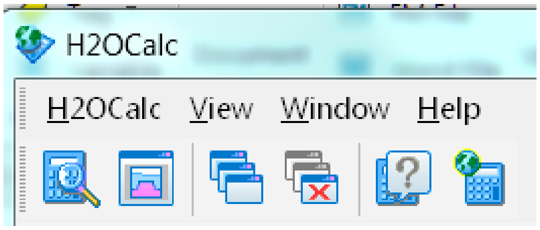


The generic weir dialog box is shown below. Click here for the methodology.

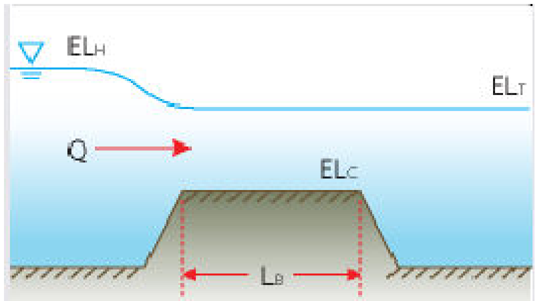

Weirs and Orifices
Structures
Weir
Generic Weir
Flow Unit
Cubic Feet/Second
Weir and Orifice
Solving Target
Discharge
Discharge
0
cfs
Headwater Elevation (ELH)
0
ft
Crest Elevation (ELc)
0
ft
Discharge Coefficient
3.33
Crest Length (L)
0
ft
Flow Area
0.0
ft²
Velocity
0.0
ft/s
Headwater Height above Crest
0.0
ft
Wetted Perimeter
0.0
ft
Top Width
0.0
ft
Calculate
Close

- Input for generic weir:
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation** – Water surface elevation upstream of the weir.
- **Crest Elevation** – Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Discharge Coefficient** – Weir coefficient (cd) used to account for submergence effects.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.

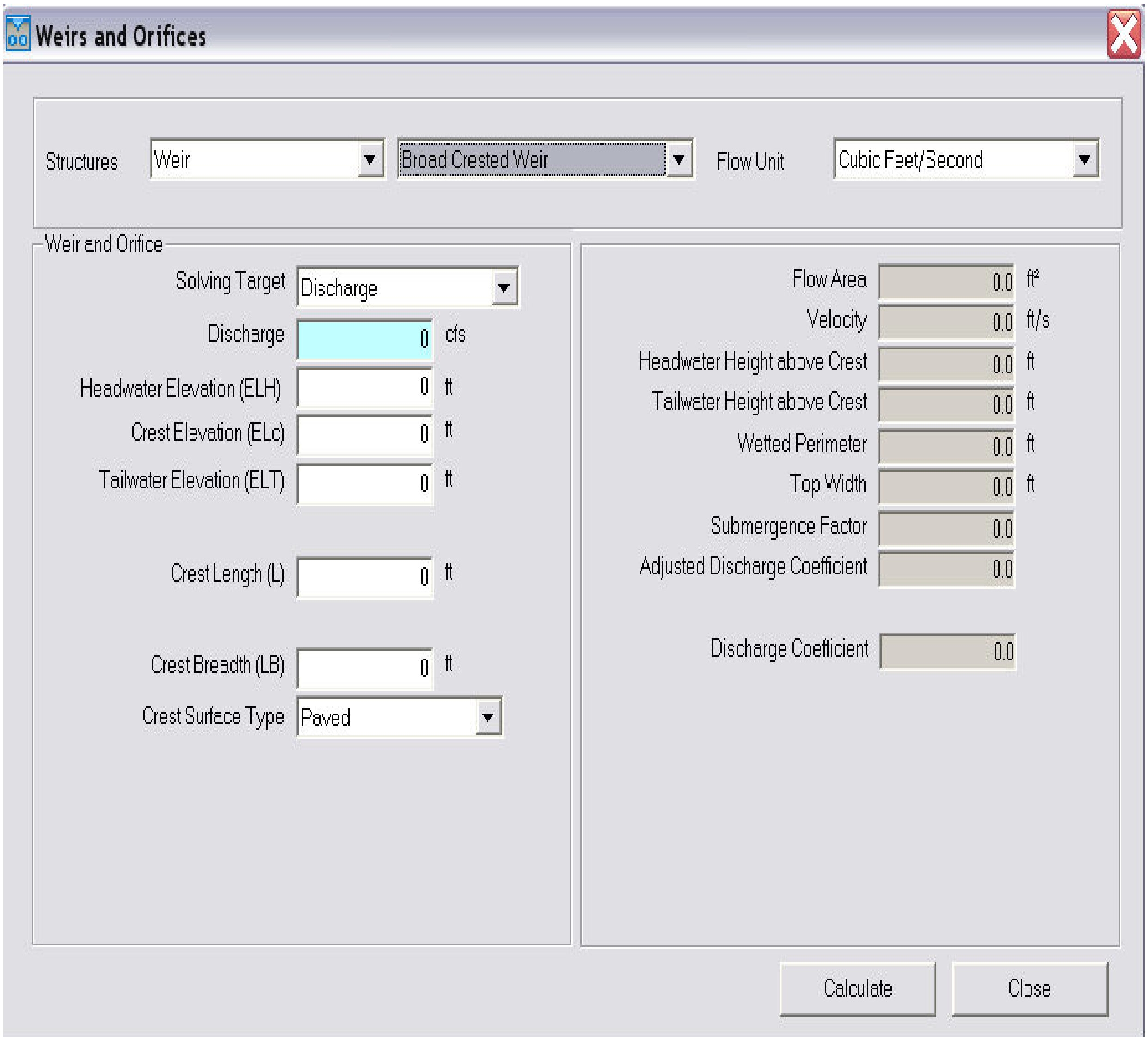
- **Output for generic weir:**
- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest** – Headwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.


H2OCalc
H2OCalc View Window Help

Broad Crested Weir



The broad crested weir dialog box is shown below. Click here for the methodology.


Weirs and Orifices
Structures
Weir
Broad Crested Weir
Flow Unit
Cubic Feet/Second
Weir and Orifice
Solving Target
Discharge
Discharge
0
cfs
Headwater Elevation (ELH)
0
ft
Crest Elevation (ELc)
0
ft
Tailwater Elevation (ELT)
0
ft
Crest Length (L)
0
ft
Crest Breadth (LB)
0
ft
Crest Surface Type
Paved
Flow Area
0.0
ft²
Velocity
0.0
ft/s
Headwater Height above Crest
0.0
ft
Tailwater Height above Crest
0.0
ft
Wetted Perimeter
0.0
ft
Top Width
0.0
ft
Submergence Factor
0.0
Adjusted Discharge Coefficient
0.0
Discharge Coefficient
0.0
Calculate
Close

- **Input for broad crested weir:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation** – Water surface elevation upstream of the weir.
- **Crest Elevation** – Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation**– Water surface elevation downstream of the weir.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.
- **Crest Breadth** – Width of the weir along the flow direction.
- **Crest Surface Type** – Crest surface of the weir (paved or gravel).

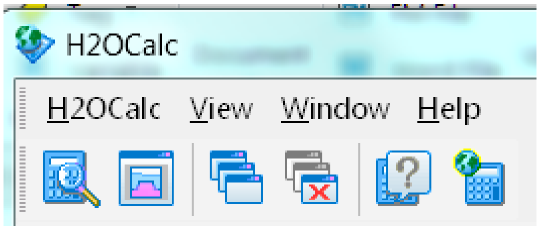
- **Output for broad crested weir:**
- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest** – Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest** – Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.
- **Submergence Factor** –Ratio used to calculate effect of submergence on discharge coefficient.
- **Adjusted Discharge Coefficient** – Discharge coefficient adjusted for submergence effect.
- **Discharge Coefficient** – Weir discharge coefficient. It depends on shape of the weir.

Innovyze®

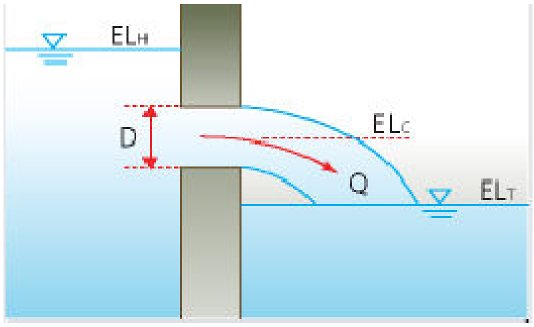
H_2OCalc™

Modeling Made Easy

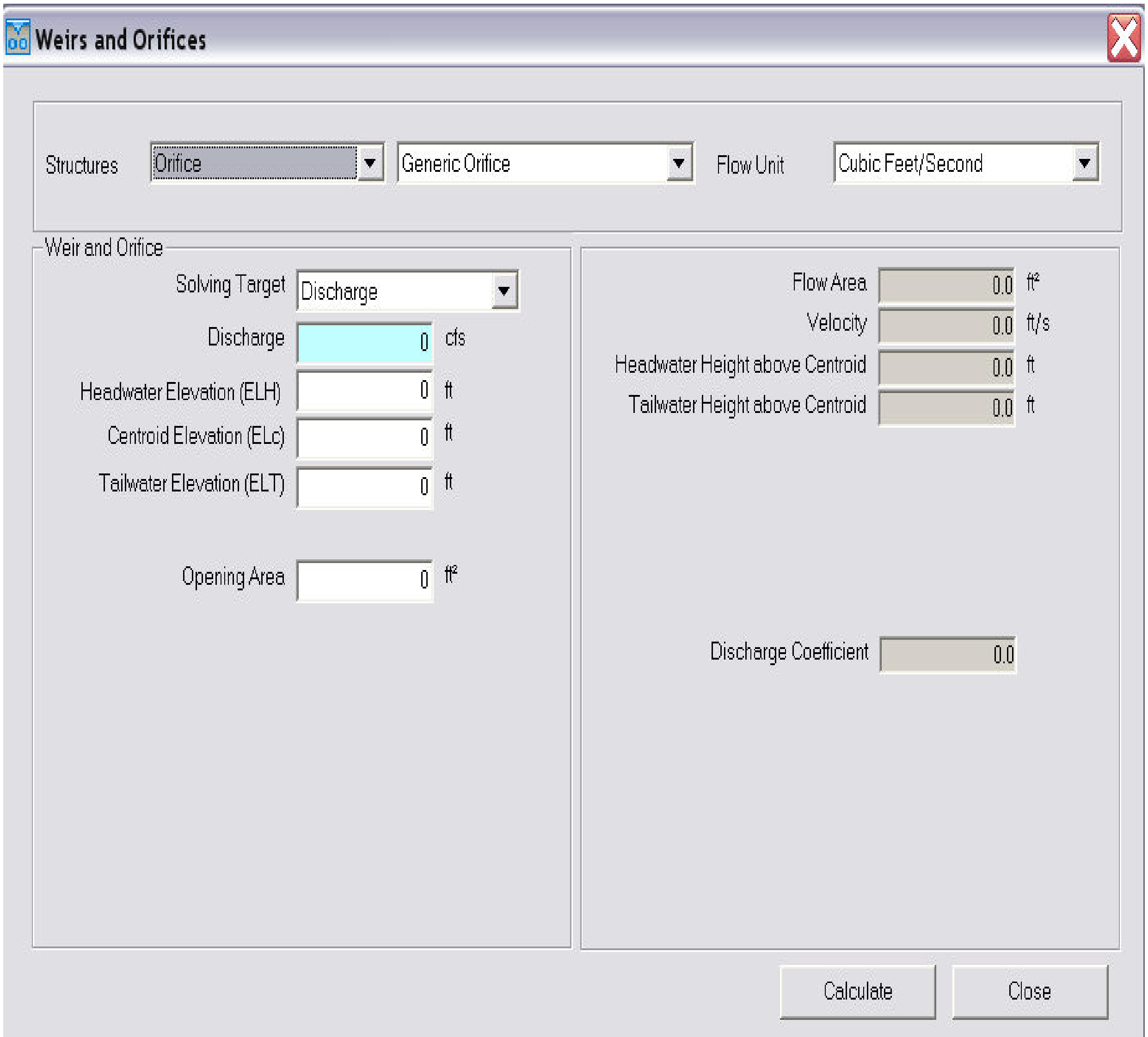
Innovyze®


H2OCalc
H2OCalc View Window Help

Generic Orifice

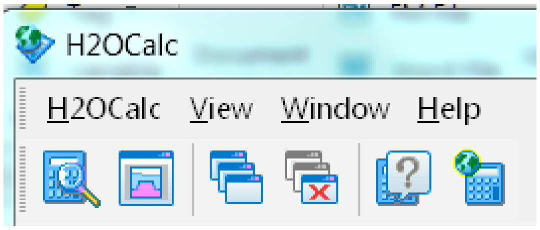


The generic orifice dialog box is shown below. Click here for the methodology.

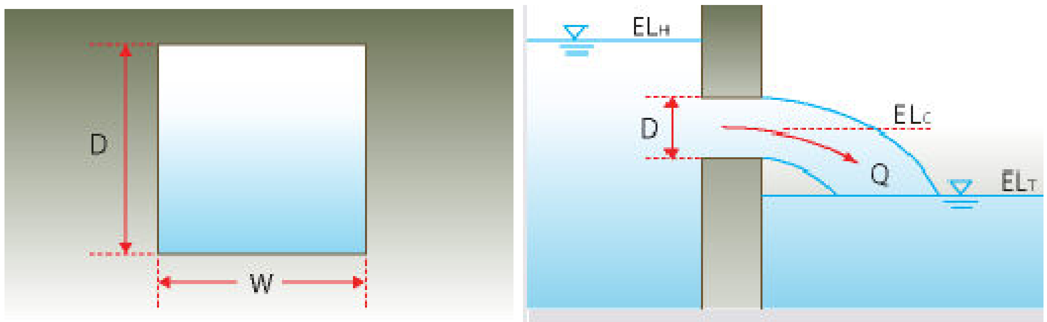

Weirs and Orifices
Structures
Orifice
Generic Orifice
Flow Unit
Cubic Feet/Second
Weir and Orifice
Solving Target
Discharge
Discharge
0
cfs
Headwater Elevation (ELH)
0
ft
Centroid Elevation (ELc)
0
ft
Tailwater Elevation (ELT)
0
ft
Opening Area
0
ft²
Flow Area
0.0
ft²
Velocity
0.0
ft/s
Headwater Height above Centroid
0.0
ft
Tailwater Height above Centroid
0.0
ft
Discharge Coefficient
0.0
Calculate
Close

- **Input for generic orifice:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the orifice.
- **Headwater Elevation** – Water surface elevation upstream of the orifice.
- **Centroid Elevation** – Elevation of the centre cross section of the orifice.
- **Tailwater Elevation**– Water surface elevation downstream of the orifice.
- **Opening Area** – Area of the orifice opening.
- **Discharge Coefficient** – Orifice coefficient used to account for losses, flow area correction, and submergence effects.

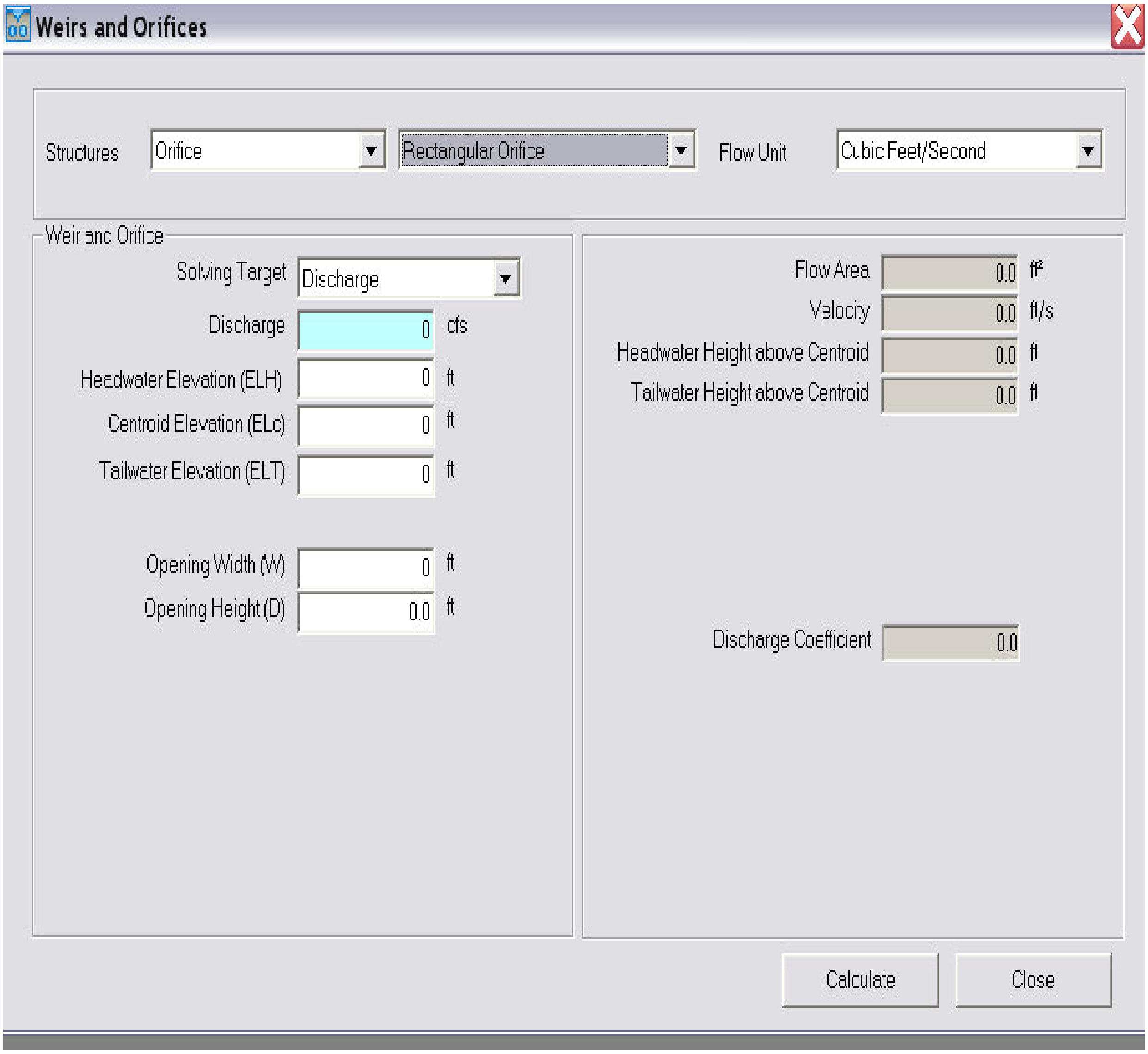
- **Output for generic orifice:**
- **Flow Area** – Cross sectional area of the flow.
- **Velocity** – Flow velocity of the orifice.
- **Headwater Height Above Centroid** – Headwater elevation minus centroid elevation of the orifice.
- **Tailwater Height Above Centroid** – Tailwater elevation minus centroid elevation of the orifice.


H2OCalc
H2OCalc View Window Help

Rectangular Orifice

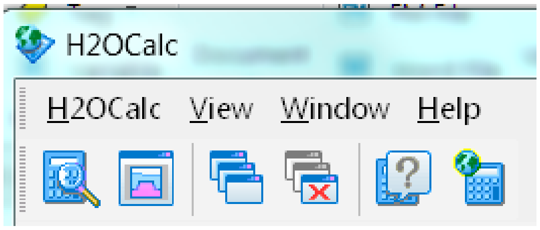


The rectangular orifice dialog box is shown below. Click here for the methodology.

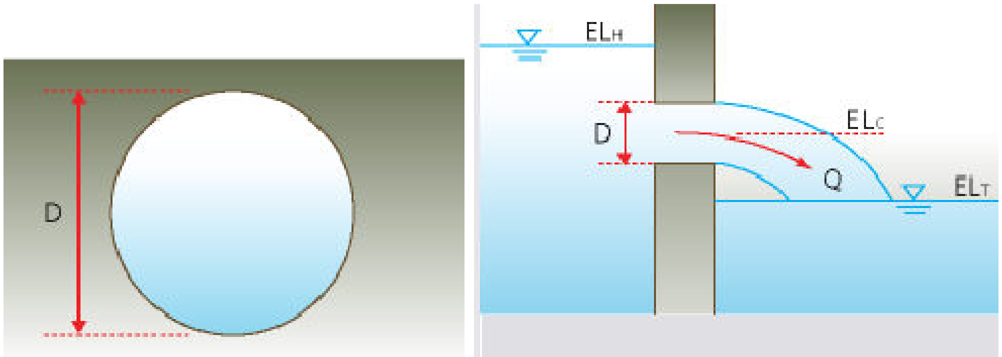

Weirs and Orifices
Structures
Orifice
Rectangular Orifice
Flow Unit
Cubic Feet/Second
Weir and Orifice
Solving Target
Discharge
Discharge
0
cfs
Headwater Elevation (ELH)
0
ft
Centroid Elevation (ELc)
0
ft
Tailwater Elevation (ELT)
0
ft
Opening Width (W)
0
ft
Opening Height (D)
0.0
ft
Flow Area
0.0
ft²
Velocity
0.0
ft/s
Headwater Height above Centroid
0.0
ft
Tailwater Height above Centroid
0.0
ft
Discharge Coefficient
0.0
Calculate
Close

- **Input for rectangular orifice:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the orifice.
- **Headwater Elevation** – Water surface elevation upstream of the orifice.
- **Centroid Elevation** – Elevation of the centre cross section of the orifice.
- **Tailwater Elevation**– Water surface elevation downstream of the orifice.
- **Opening Width** – Width of the orifice opening.
- **Opening Height** – height of the orifice opening.
- **Discharge Coefficient** – Orifice coefficient used to account for losses, flow area correction, and submergence effects.

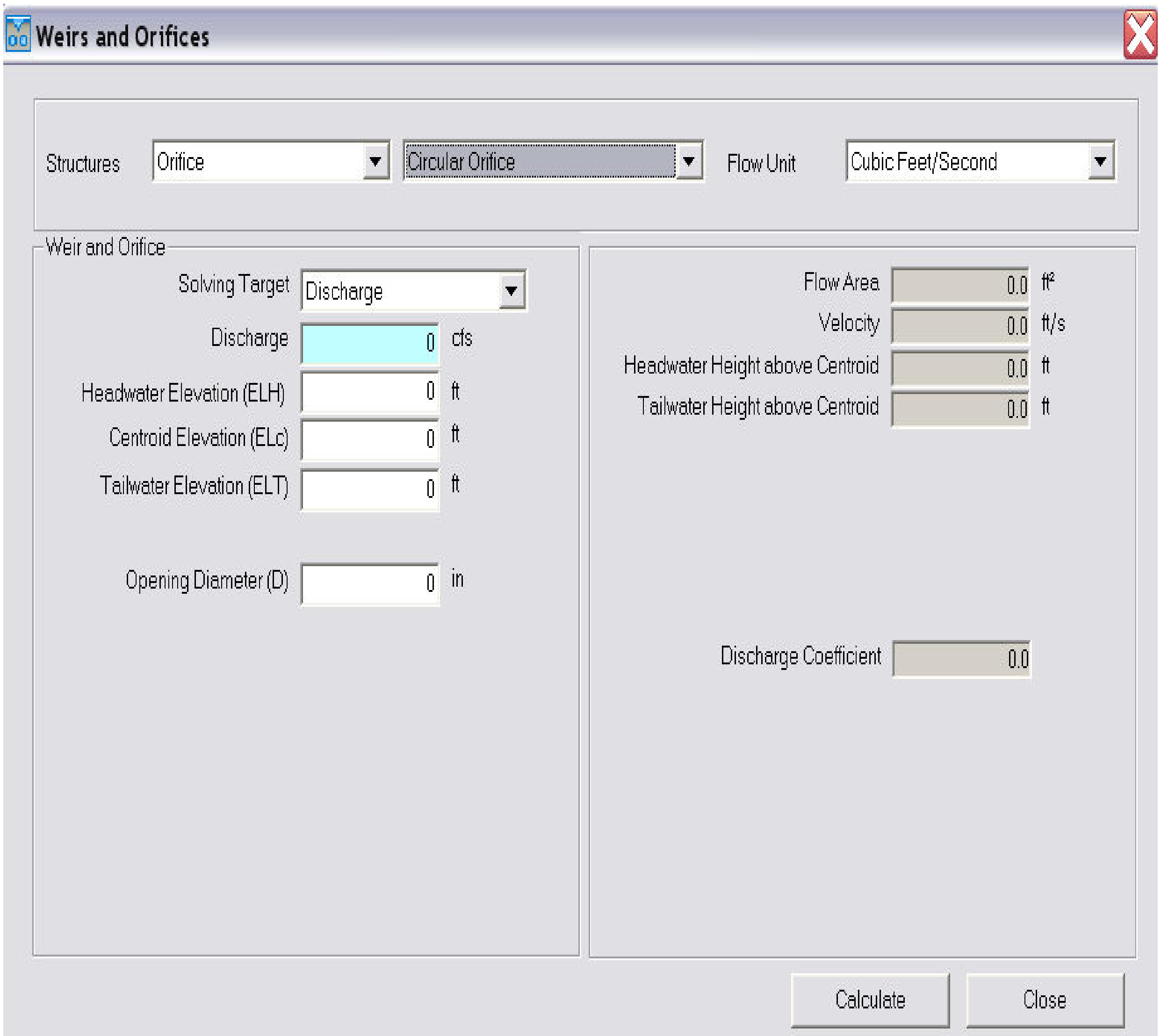
- **Output for rectangular orifice:**
- **Flow Area** – Cross sectional area of the flow.
- **Velocity** – Flow velocity of the orifice.
- **Headwater Height Above Centroid** – Headwater elevation minus centroid elevation of the orifice.
- **Tailwater Height Above Centroid** – Tailwater elevation minus centroid elevation of the orifice.


H2OCalc
H2OCalc View Window Help

Circular Orifice

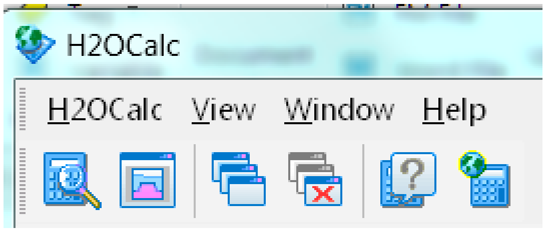


The circular orifice dialog box is shown below. Click here for the methodology.


Weirs and Orifices
Structures
Orifice
Circular Orifice
Flow Unit
Cubic Feet/Second
Weir and Orifice
Solving Target
Discharge
Discharge
0
cfs
Headwater Elevation (ELH)
0
ft
Centroid Elevation (ELc)
0
ft
Tailwater Elevation (ELT)
0
ft
Opening Diameter (D)
0
in
Flow Area
0.0
ft²
Velocity
0.0
ft/s
Headwater Height above Centroid
0.0
ft
Tailwater Height above Centroid
0.0
ft
Discharge Coefficient
0.0
Calculate
Close

- **Input for circular orifice:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the orifice.
- **Headwater Elevation** – Water surface elevation upstream of the orifice.
- **Centroid Elevation** – Elevation of the centre cross section of the orifice.
- **Tailwater Elevation**– Water surface elevation downstream of the orifice.
- **Opening Diameter** – Diameter of the orifice opening.
- **Discharge Coefficient** – Orifice coefficient used to account for losses, flow area correction, and submergence effects.

- **Output for circular orifice:**
- **Flow Area** – Cross sectional area of the flow.
- **Velocity** – Flow velocity of the orifice.
- **Headwater Height Above Centroid** – Headwater elevation minus centroid elevation of the orifice.
- **Tailwater Height Above Centroid** – Tailwater elevation minus centroid elevation of the orifice.

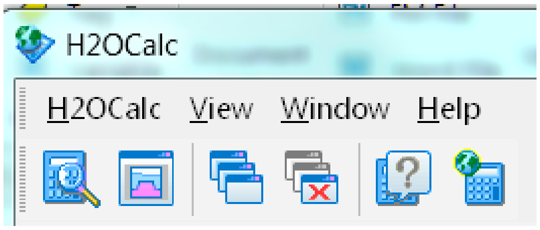

H2OCalc
H2OCalc View Window Help

Culverts

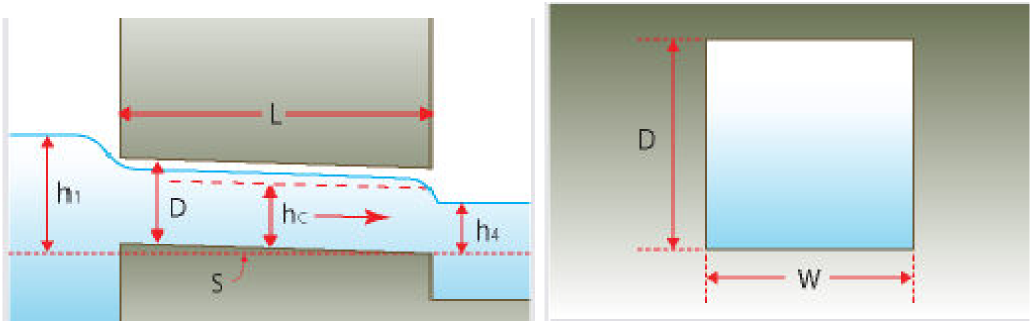
H2OCalc offers both the simplified method and the industry-standard FHWA HDS-5 method for hydraulic calculation of culverts.

- Simplified Method
- FHWA HDS-5 Method

Click here for more information of Culverts in the methodology.

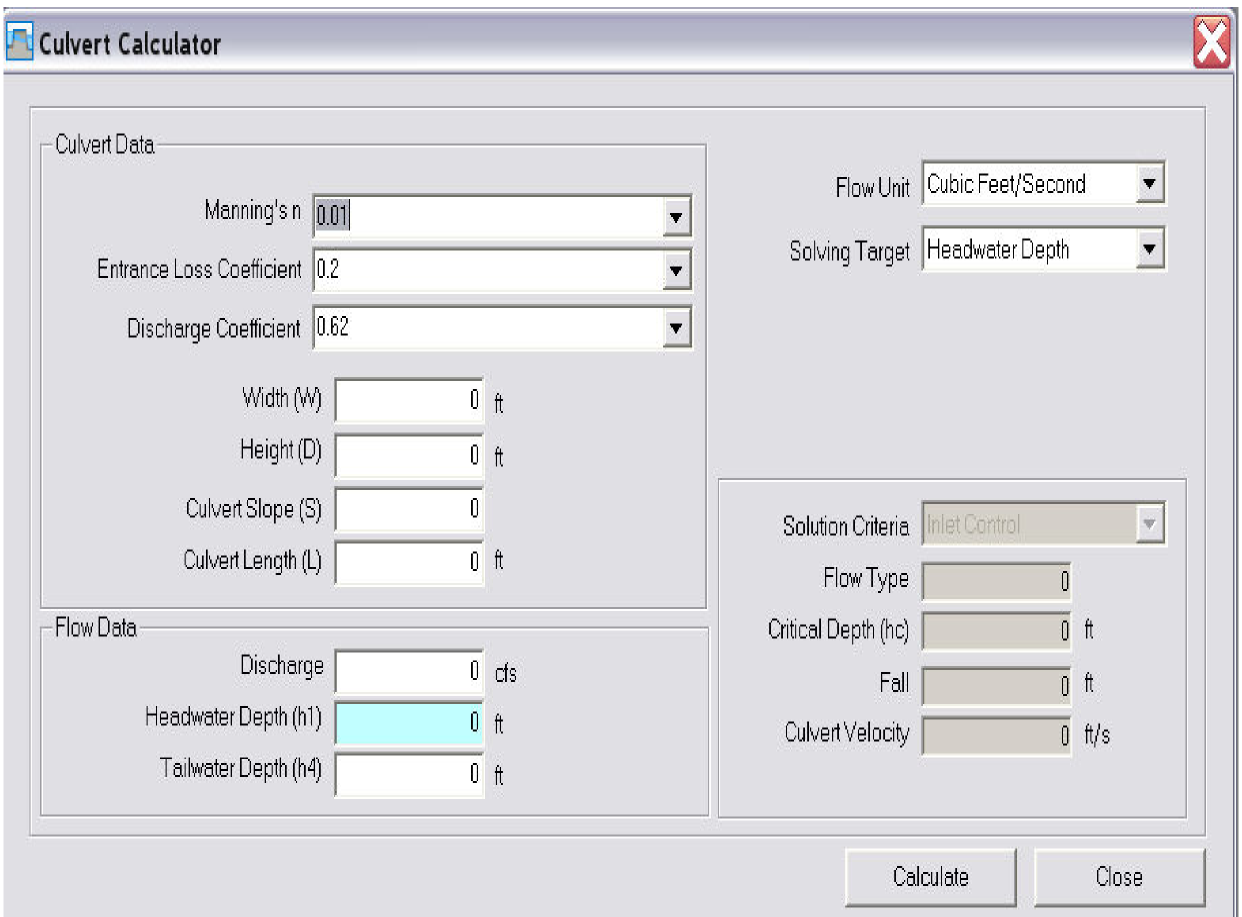

H2OCalc
H2OCalc View Window Help

Simplified Method



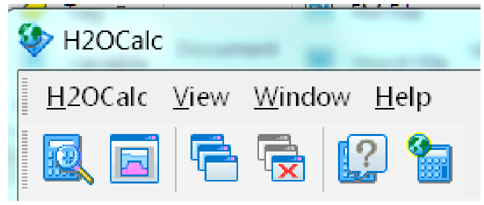
For detail on the methodology used to analyze culverts using the simplified method, click here.

The dialog box for the simplified method for culvert calculation is shown below.

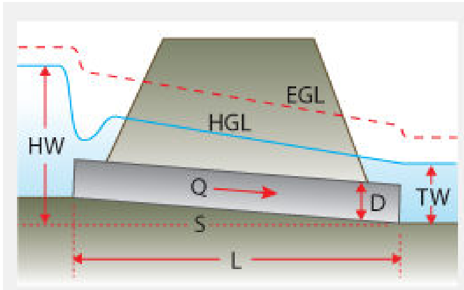


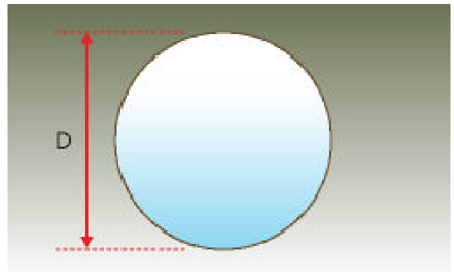
- **Input for the simplified culvert calculation:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Manning's n** – Manning's roughness coefficient.
- **Entrance Loss Coefficient** – Minor loss coefficient (K factor) for entrance to the culvert.
- **Discharge Coefficient** – Discharge coefficient used to account for losses, submergence effect, etc.
- **Width** – Width of the culvert, measured perpendicular to flow direction.
- **Height** – Height of the culvert.
- **Culvert Slope** – Slope of the culvert.
- **Culvert Length** – Length of the culvert.
- **Discharge** – Flow rate through the culvert. If selected as a solving target, it will be an output.
- **Headwater Depth** – Water depth upstream of the culvert measured from upstream invert of the culvert. If selected as a solving target, it will be an output.
- **Tailwater Depth**– Water depth downstream of the culvert measured from downstream invert of the culvert.

- Output for the simplified culvert calculation:
- **Solution Criteria** – Inlet control or outlet control.
- **Flow Type** – Critical, subcritical, or supercritical.
- **Critical Depth** – Flow depth corresponding to minimum specific energy.
- **Fall** – Change in elevation between upstream invert and downstream invert of the culvert.
- **Culvert Velocity** – Flow velocity at the outlet of the culvert.
- **Discharge** – Flow rate through the culvert. If selected as a solving target, it will be an output.
- **Headwater Depth** – Water depth upstream of the culvert measured from upstream invert of the culvert. If selected as a solving target, it will be an output.


H2OCalc
H2OCalc View Window Help

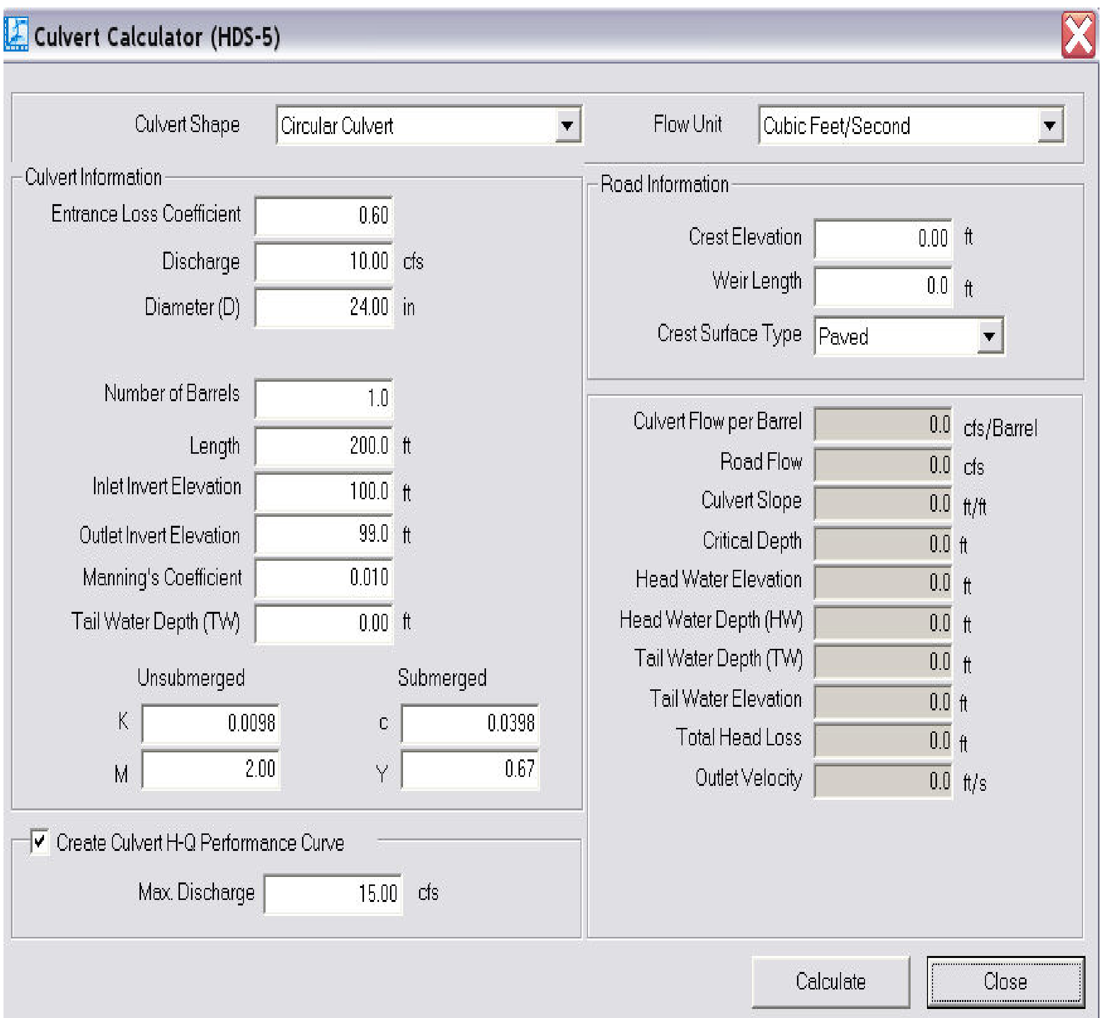
FHWA HDS-5 Method





For detail on the methodology used to analyze culverts using the FHWA method, click [here](#).

The dialog box for the FHWA HDS-5 method is shown below.



- **Input for the FHWA HDS-5 method:**
- **Flow Unit** – Select the desired flow unit.

- Culvert information:
- **Entrance Loss Coefficient –** Minor loss coefficient (K factor) for entrance to the culvert.
- **Discharge –** Flow rate for which the culvert is analyzed or designed.
- **Diameter –** Diameter of the culvert.
- **Number of Barrels –** Number of pipes or culverts used in parallel.
- **Length –** Length of the culvert.
- **Inlet Invert Elevation –** Invert Elevation of the culvert at entrance.
- **Outlet Invert Elevation –** Downstream invert elevation of the culvert.
- **Manning's n –** Manning's roughness coefficient for the culvert.
- **Tailwater Depth –** Water depth downstream of the culvert measured from downstream invert of the culvert.
- **Unsubmerged Flow Constants - K** and **M** represent constants for inlet control design equations under unsubmerged flow conditions. The constants vary with culvert type and material, and inlet edge conditions. See the chart given below for these coefficients.
- **Submerged Flow Constants – c** and **Y** represent constants for inlet control design equations under submerged flow conditions. The constants vary with culvert type and material, and inlet edge conditions. See the chart given below for these coefficients.
- **Create Culvert Performance Curve –** If checked, the program constructs discharge vs headwater depth curve for the culvert.
- **Maximum Discharge –** required only if the "Create Culvert Performance Curve" is checked. Maximum discharge refers to the maximum flow to be considered for constructing the performance curve. The model divides this maximum discharge into ten equal intervals and computes headwater depth for each flow using the FHWA method. Discharge vs headwater depth results for the ten points are reported in the form of graph and table.

- Road information:
- **Crest Elevation** – Crest elevation of the road.
- **Weir Length** – Length of the road parallel to the flow direction.
- **Crest Surface Type** – Paved or gravel.

- **Output for the FHWA HDS-5 method:**
- **Culvert Flow Per Barrel** – Flow rate through an individual barrel of a culvert.
- **Road Flow** – Portion of the discharge that overflows the culvert and flows over the road.
- **Culvert Slope** – Slope of the culvert.
- **Critical Depth** – Depth corresponding to the minimum specific energy.
- **Headwater Elevation –** Water surface elevation at upstream end of the culvert.
- **Headwater Depth** – Water depth upstream of the culvert measured from upstream invert of the culvert.
- **Tailwater Depth** – Water depth downstream of the culvert measured from downstream invert of the culvert.
- **Tailwater Elevation** – Elevation of water surface at downstream.
- **Total Head Loss** – Head loss including minor losses and head loss due to friction in the culvert.
- **Outlet Velocity** – Flow velocity at the outlet of the culvert.
- **Culvert Slope** – Slope of the culvert.
- **Culvert Performance Curve** – If the “Create Culvert Performance Curve” is checked, the model reports the curve in graph and in table form as shown below.

Collection System Modeling	ArcGIS-based Solutions	Stand-Alone Geospatial Solutions	Workgroup Model Management Solutions
Integrated Catchment Modeling Integrated river, sewer and overland flow modeling to accurately represent all flow paths and effectively simulate the water quality impact of polluting runoff and effluent from urban areas.			InfoWorks® ICM
Urban Drainage and Stormwater Modeling Take on the most complex and demanding sewer system with confidence and quickly determine the most cost-effective solution to flooding and pollution management.	InfoSWMM®	H_2OMAP SWMM®	InfoWorks® ICM SE
Urban Stormwater Treatment and Analysis Integrate comprehensive watershed modeling capabilities, best management practice (BMP) process simulation, and BMP cost representation within the context of a cost-benefit optimization framework.	InfoSWMM® Sustain		
Sanitary Sewer Use state-of-the-art tools to cost-effectively plan, design, analyze, rehabilitate and expand your wastewater system in record time.	InfoSewer®	H_2OMAP Sewer®	

Culvert Performance Curve

Graph | Report

	Discharge (cfs)	Head Water Depth (ft)
1	1.50	0.57
2	3.00	0.83
3	4.50	1.04
4	6.00	1.23
5	7.50	1.41
6	9.00	1.58
7	10.50	1.75
8	12.00	1.92
9	13.50	2.09
10	15.00	2.26

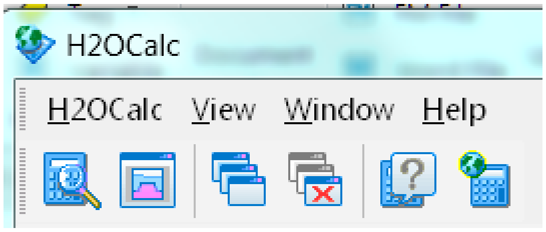
Table 3-5: Constants for Inlet Control Design Equations

Shape and material	Inlet Edge Description	*K*	*M*	*c*	*Y*
Circular Concrete	Square edge w/ headwall	0.0098	2.000	0.0398	0.67
	Groove end w/ headwall	0.0078	2.000	0.0292	0.74
	Groove end projecting	0.0045	2.000	0.0317	0.69
Circular CMP	Headwall	0.0078	2.000	0.0379	0.69
	Mitered to slope	0.0210	1.330	0.0463	0.75
	Projecting	0.0340	1.500	0.0553	0.54
Circular Ring	Beveled ring, 45^0 bevels	0.0018	2.500	0.0300	0.74
	Beveled ring 33.7^0 bevels	0.0018	2.500	0.0243	0.83
Rectangular Box	30^0 - 75^0 wingwall flares	0.0260	1.000	0.0385	0.81
	90^0 and 15^0 wingwall flares	0.0610	0.750	0.0400	0.80
	0^0 wingwall flares	0.0610	0750	0.0423	0.82
Rectangular Box	45^0 wingwall flare	0.5100	0.667	0.0309	0.80
	18^0 - 33.7^0 wingwall flare	0.4860	0.667	0.0249	0.83
Rectangular Box	90^0 headwall w/¾ in chamfers	0.5150	0.667	0.0375	0.79
	90^0 headwall w/ 45^0 bevels	0.7950	0.667	0.0314	0.82
	90^0 headwall w/33.7^0 bevels	0.4860	0.667	0.0252	0.87
Rectangular Box	¾ in chamfers, 45^0 skewed headwall	0.5220	0.667	0.0402	0.73
	¾ in chamfers, 30^0 skewed headwall	0.5330	0.667	0.0425	0.71
	¾ in chamfers, 15^0 skewed headwall	0.5450	0.667	0.0451	0.68
	45^0 bevels, 10-45^0 skewed wall	0.4980	0.667	0.0327	0.75
Rectangular Box, ¾ in. chamfers	45^0 non offset wingwall flares	0.4970	0.667	0.0339	0.80
	18.4^0 non offset wingwall flares	0.4930	0.667	0.0361	0.81
	18.4^0 non offset wingwall flares, 30^0 skewed barrel	0.4930	0.667	0.0386	0.71
Rectangular Box, top bevels	45^0 wingwall flares-offset	0.4970	0.667	0.0302	0.84
	33.7^0 wingwall flares - offset	0.4950	0.667	0.0252	0.88
	18.4^0 wingwall flares - offset	0.4930	0.667	0.0227	0.89
Corrugated Metal Boxes	90^0 headwall	0.0083	2.000	0.0379	0.69
	Thick wall projecting	0.0145	1.750	0.0419	0.64

Adapted from Normann et al. (1985)

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Transient Flow

The Transient Flow category performs basic water hammer calculation, computation of wave speed, and estimation of pump inertia.

- **Water Hammer**
- **Wave Speed**
- **Pump Inertia**

Click the following for more information of Transient Flow in the methodology.

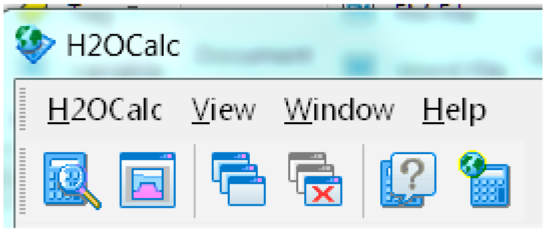
- **Transient Flow**
  - **Joukowski Expression**
  - **Wave Speed**
  - **Inertia of Pumps and Motors**

Innovyze Help File Updated September 1, 2017

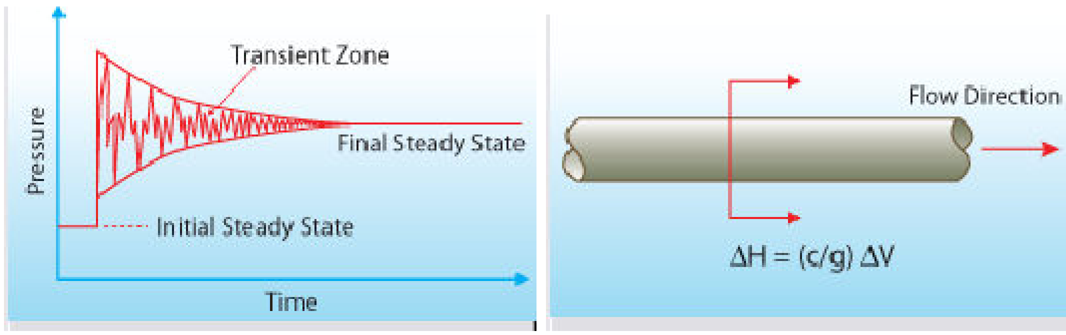
InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

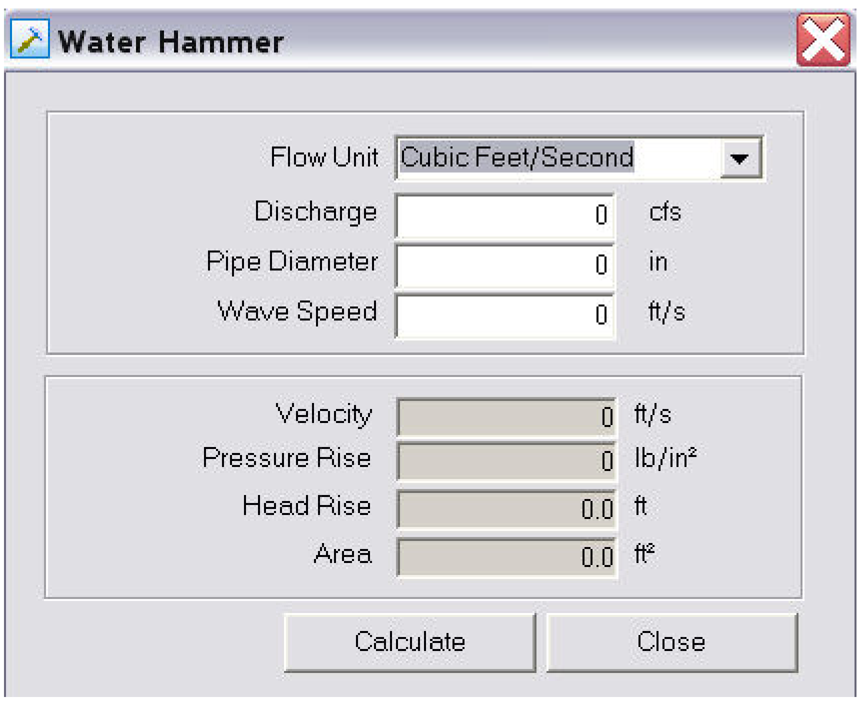
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Water Hammer

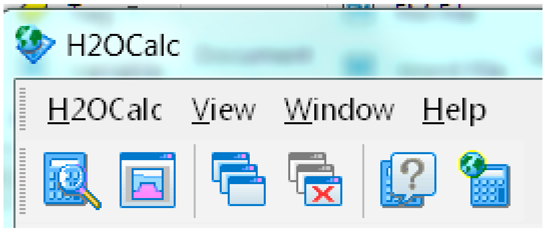


The water hammer dialog box is shown below. Click here for the methodology.

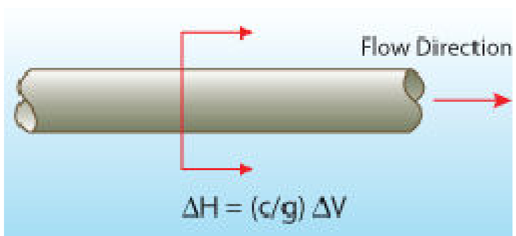


- **Input for water hammer:**
- **Flow Unit** – Select the desired flow unit.
- **Discharge** – Flow rate through the pipe.
- **Pipe Diameter** – Diameter of the pipe.
- **Wave Speed** – Speed of the pressure surge wave. H2OCalc can estimate wave speed depending on pipe material, anchor condition, and the fluid property.

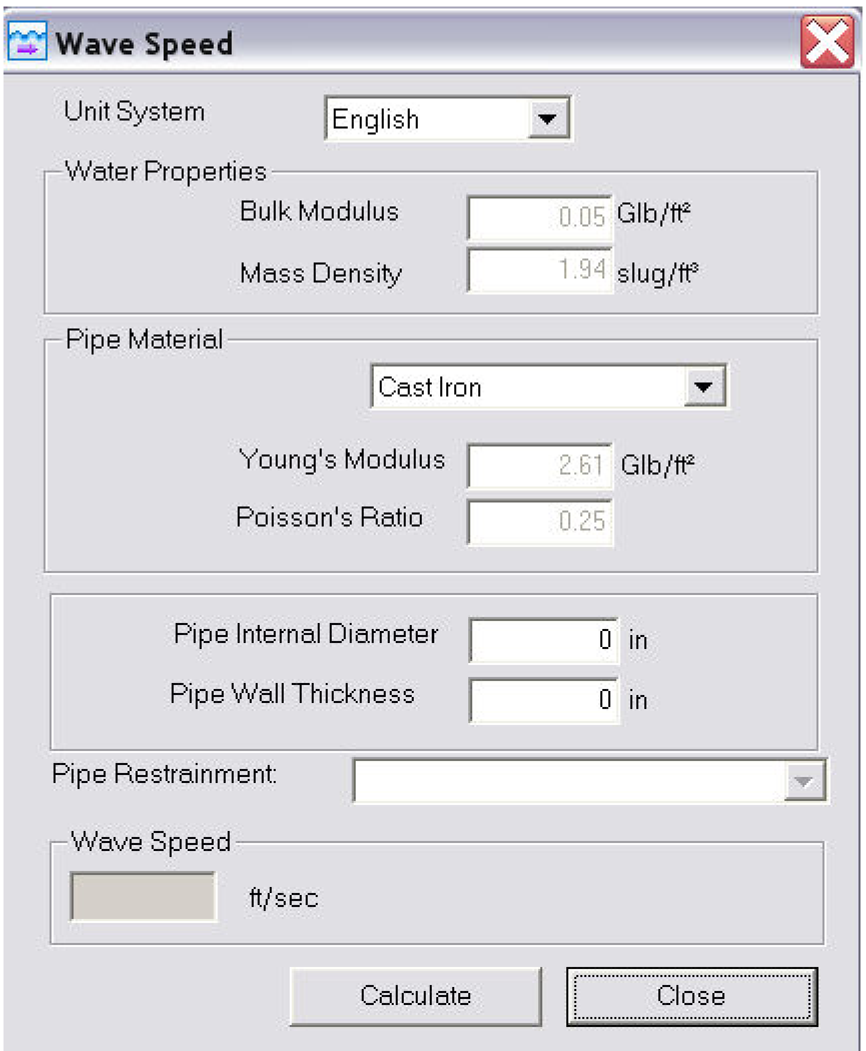
- Output for water hammer:
- **Velocity** – Pipe flow velocity.
- **Pressure Rise** – The amount of pressure increase caused by the surge wave.
- **Head Rise** – Increase in pressure head (pressure rise divided by specific weight of water) caused by the surge wave.
- **Area** – Cross sectional area of the circular pipe.


H2OCalc
H2OCalc View Window Help

Wave Speed

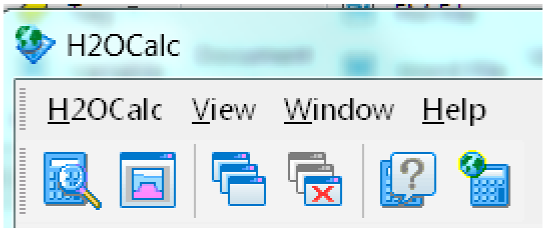


The wave speed dialog box is shown below. Click here for the methodology.



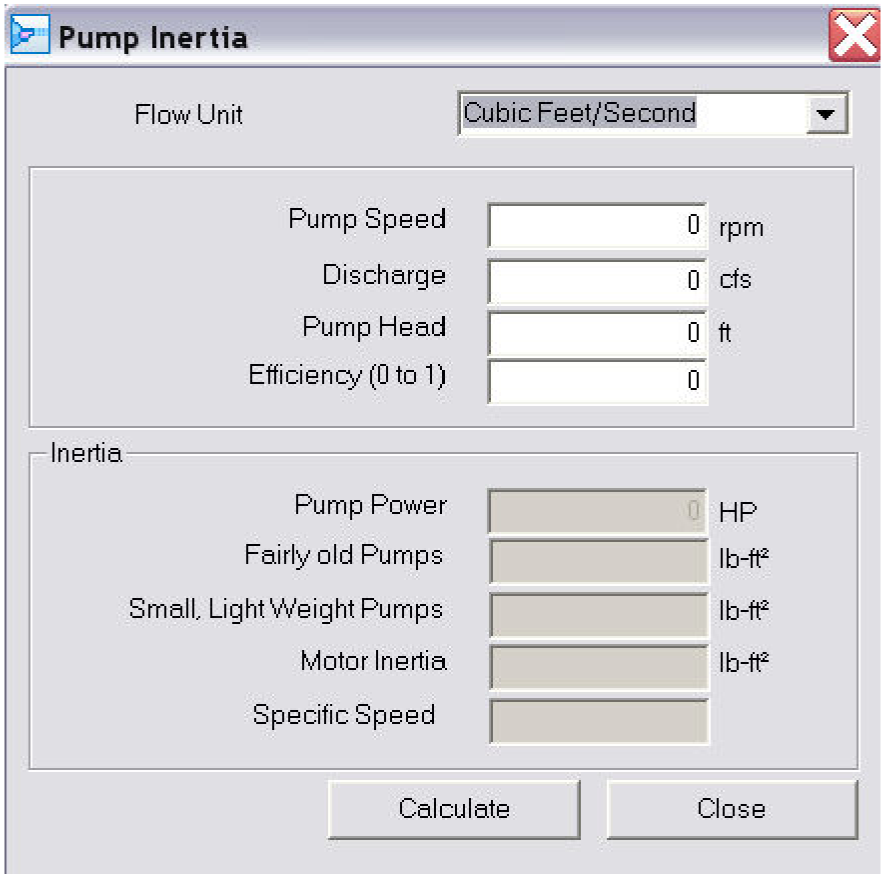
- **Input for wave speed:**
- **Flow Unit** – Select the desired flow unit.
- **Bulk Modulus of Water** – Ratio of incremental change in volume of water per unit increase in pressure. It is a measure of fluid's compressibility. A default value is used.
- **Mass Density of Water** – Mass per unit volume of water. A default value is used.
- **Young's Modulus of the Pipe** – Rate of change of stress with strain. It is a measure of stiffness of the pipe material. A default value is used.
- **Poisson's ratio of the Pipe**– Ratio of the relative transverse strain (normal to the applied load) to the relative longitudinal strain (in the direction of the applied load). A default value is used.
- **Pipe Internal Diameter** – Internal diameter of the pipe (i.e., excluding pipe thickness).
- **Pipe Wall Thickness** – Thickness of the pipe (i.e., external radius minus internal radius).
- **Pipe Restrainment** – Type of support provided for the pipeline against longitudinal movement.

- **Output for wave speed:**
- **Wave Speed** – Speed of the surge wave.


H2OCalc
H2OCalc View Window Help

Pump Inertia

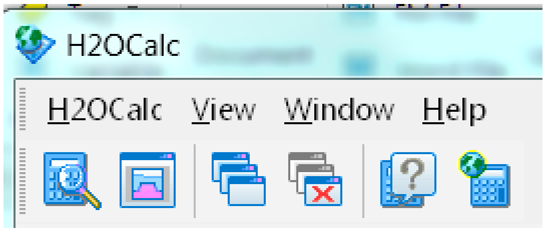
The pump inertia dialog box is shown below. Click here for the methodology.



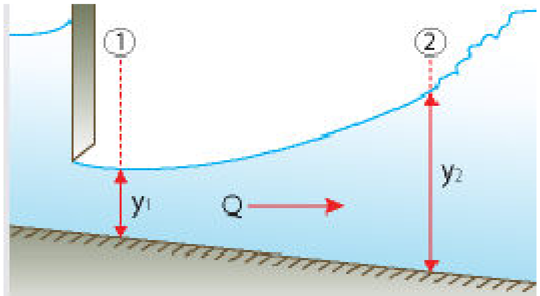
- **Input for pump inertia:**
- **Flow Unit** – Select the desired flow unit.
- **Pump Speed** – Pump speed (number of revolutions per unit time).
- **Discharge** – Rated pump flow rate.
- **Pump Head** – Rated pump head corresponding to the rated pump discharge.
- **Efficiency** – Pump efficiency (ratio of power output to power input).
- **Pump Power** – Power computed from pump head, pump flow and pump efficiency.

- **Output for pump inertia:**
- **Fairly Old Pump** – Pump inertia computed assuming that the pump is fairly old.
- **Small, Light Weigh Pump** – Pump inertial computed assuming that the pump is small and light weight.
- **Motor Inertia** – Inertia of the motor.
- **Specific Speed** – Specific speed of the pump.

Note: The total (or combined) inertia of a pump is the sum of the pump inertia and the motor inertia. The pump inertia is the momentum of inertia of pump impeller and entrained liquid, while the th motor inertia is the momentum of inertia of motor rotor, shaft, and couplings. For transient analysis, the total inertia should be used to properly describe the pump’s resistance to change in momentum. The higher its inertia, the longer it will take the pump to stop spinning after a shutdown. Pump inertia can be increased using a flywheel (may not be effective for very long pipes).


H2OCalc
H2OCalc View Window Help

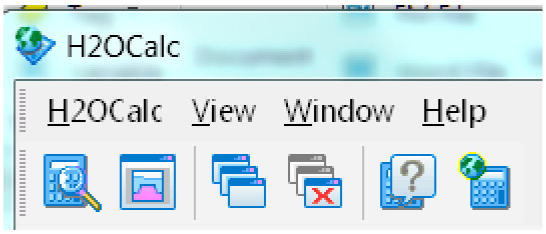
Hydraulic Jump



The hydraulic jump dialog box is shown below. Click here for the methodology.

- **Input for hydraulic jump:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Discharge, upstream depth or downstream depth.
- **Upstream Depth** – Supercritical flow depth at upstream of the jump.
- **Downstream Depth** – Subcritical flow depth at downstream of the jump.
- **Discharge** – Channel flow rate.
- **Channel Bottom Width** – Bed width of the channel.

- **Output for hydraulic jump:**
- **Area (Upstream/Downstream)** – Flow area at upstream section and downstream section of the jump, respectively.
- **Velocity (Upstream/Downstream)** – Flow velocity at upstream section and downstream section of the jump, respectively.
- **Froude Number (Upstream/Downstream)** – Froude number at upstream section and downstream section of the jump, respectively.
- **Critical Depth** – Flow depth corresponding to the minimum specific energy for the flow rate.
- **Head Loss in the Jump** – Difference in specific energy at the upstream end and the downstream end of the jump.

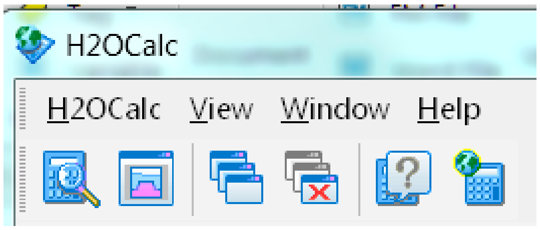

H2OCalc
H2OCalc View Window Help

Discharge from Tank

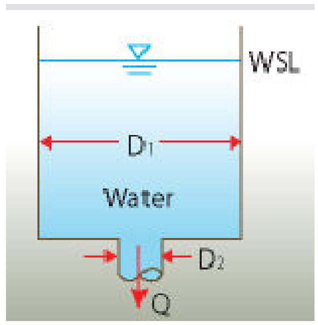
The Discharge from Tank category evaluates the flow discharged from pressurized tanks and open tanks as a function of water level, tank geometry, and outlet (orifice) property.

- Discharge From Open Tanks
- Discharge From Pressurized Tanks

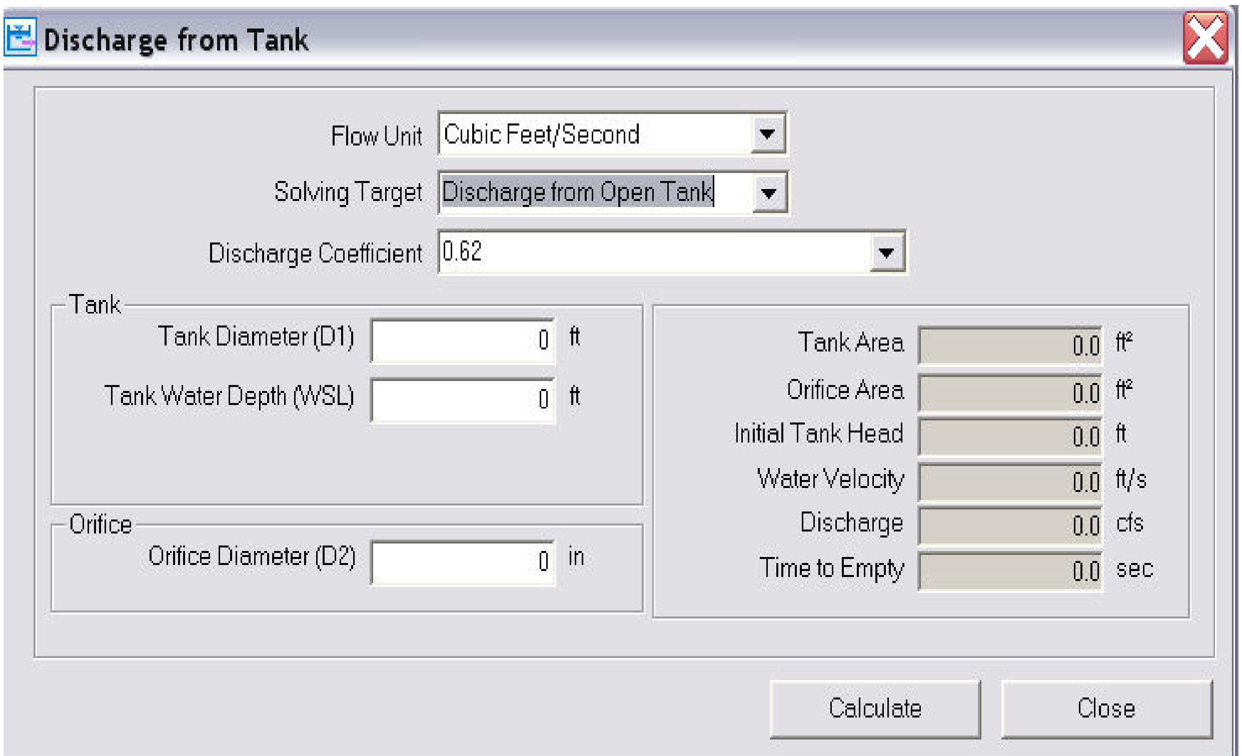
Click here for more information of Discharge from Tank in the methodology.


H2OCalc
H2OCalc View Window Help

Discharge From Open Tank

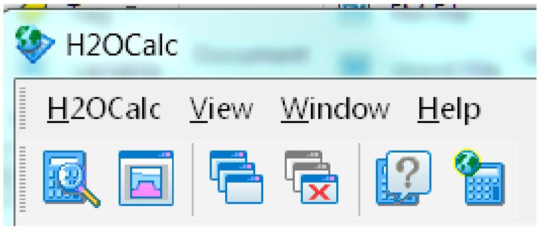


The dialog box for discharge from open tank is shown below.

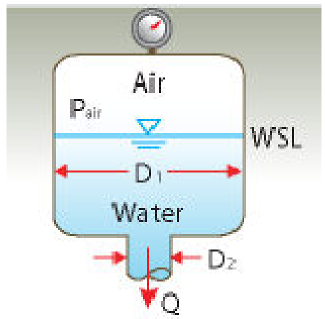


- Input for discharge from open tank:
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Discharge from open tank or discharge from pressurized tank.
- **Discharge Coefficient** – Coefficient of discharge for the orifice.
- **Tank Diameter** – Diameter of the tank.
- **Tank Water Depth** – Depth of water in the tank.
- **Orifice Diameter** – Diameter of the orifice opening.

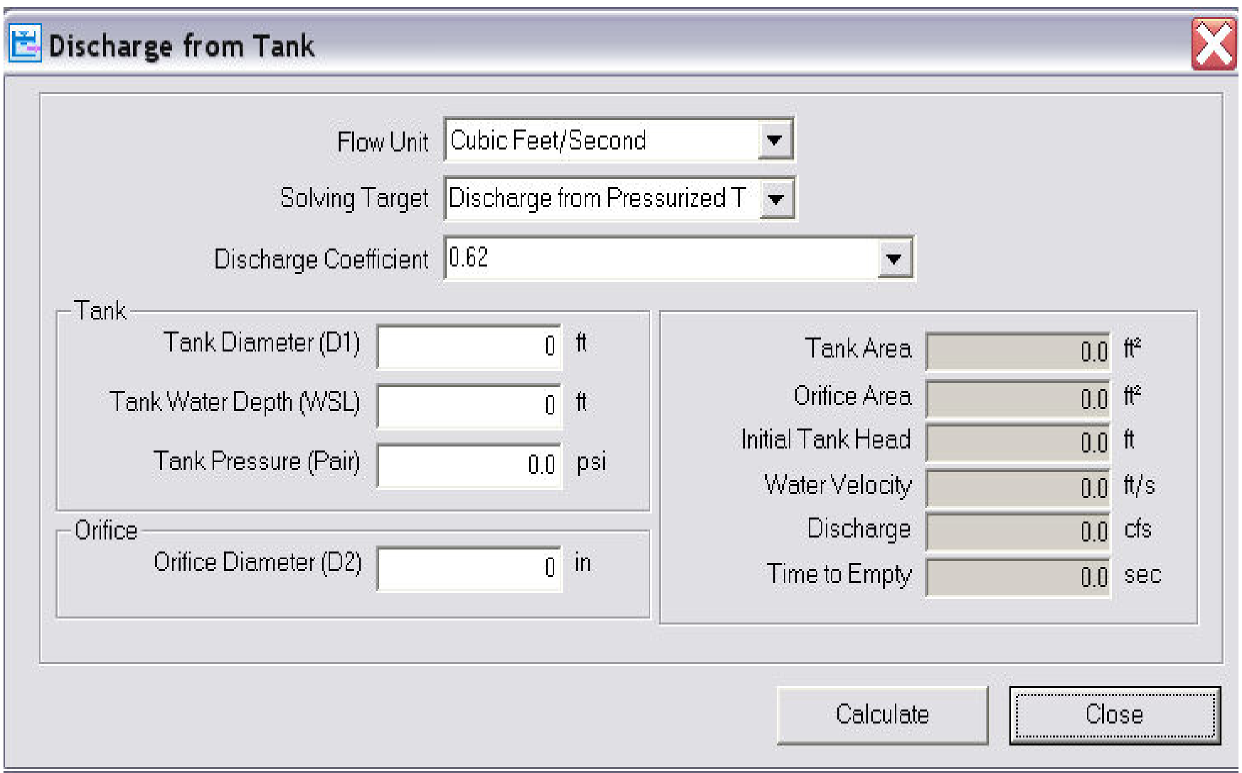
- Output for discharge from open tank:
- **Tank Area** – Cross sectional area (surface area) of the tank.
- **Orifice Area** – Cross sectional area of the orifice.
- **Initial Tank Head** – Head in the tank before the tank started releasing flow.
- **Water Velocity** – The velocity at which water is discharged from the reservoir.
- **Discharge** – Flow rate from the reservoir.
- **Time to Empty** – The time it takes to discharge the entire content of the tank.


H2OCalc
H2OCalc View Window Help

Discharge From Pressurized Tanks

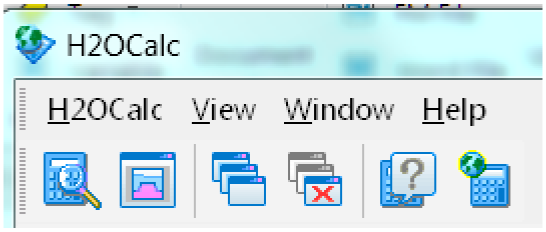


The dialog box for discharge from pressurized tank is shown below.



- **Input for discharge from pressurized tank:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Discharge from open tank or discharge from pressurized tank.
- **Discharge Coefficient** – Coefficient of discharge for the orifice.
- **Tank Diameter** – Diameter of the tank.
- **Tank Water Depth** – Depth of water in the tank.
- **Tank Pressure** – Pressure exerted on the tank (excluding hydrostatic pressure).
- **Orifice Diameter** – Diameter of the orifice opening.

- **Output for discharge from pressurized tank:**
- **Tank Area** – Cross sectional area (surface area) of the tank.
- **Orifice Area** – Cross sectional area of the orifice.
- **Initial Tank Head** – Head in the tank before the tank started releasing flow.
- **Water Velocity** – The velocity at which water is discharged from the reservoir.
- **Discharge** – Flow rate from the reservoir.
- **Time to Empty** – The time it takes to discharge the entire content of the tank.


H2OCalc
H2OCalc View Window Help

Pumps

The Pump category has pump curve, affinity laws, pump power and torque, pumps arranged in parallel, and pumps arranged in series, and system head curve as sub-categories.

- **Pump Curve**
- **Affinity Laws**
- **Pump Power and Torque**
- **Pumps Arranged in Parallel**
- **Pumps Arranged in Series**
- **System Head Curve**

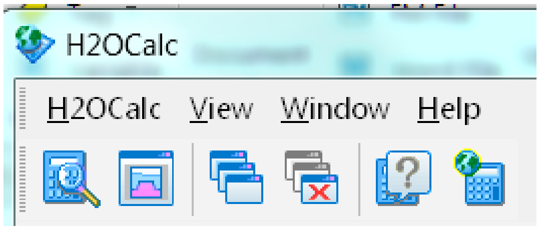
Click the following for the methodology.

- ***Pump Calculation***
    - ***Pump Power***
    - ***Pump Torque***
    - ***Pump Specific Speed***
    - ***Pump Characteristic Curve***
    - ***Pump Affinity Laws***
    - ***System Head Curve***

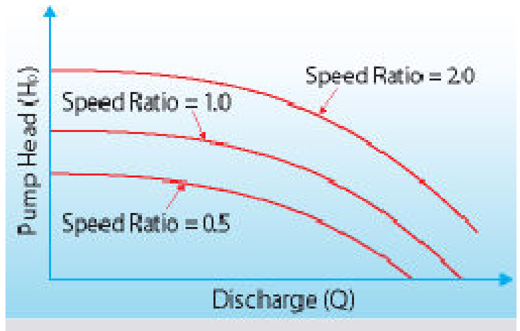
InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

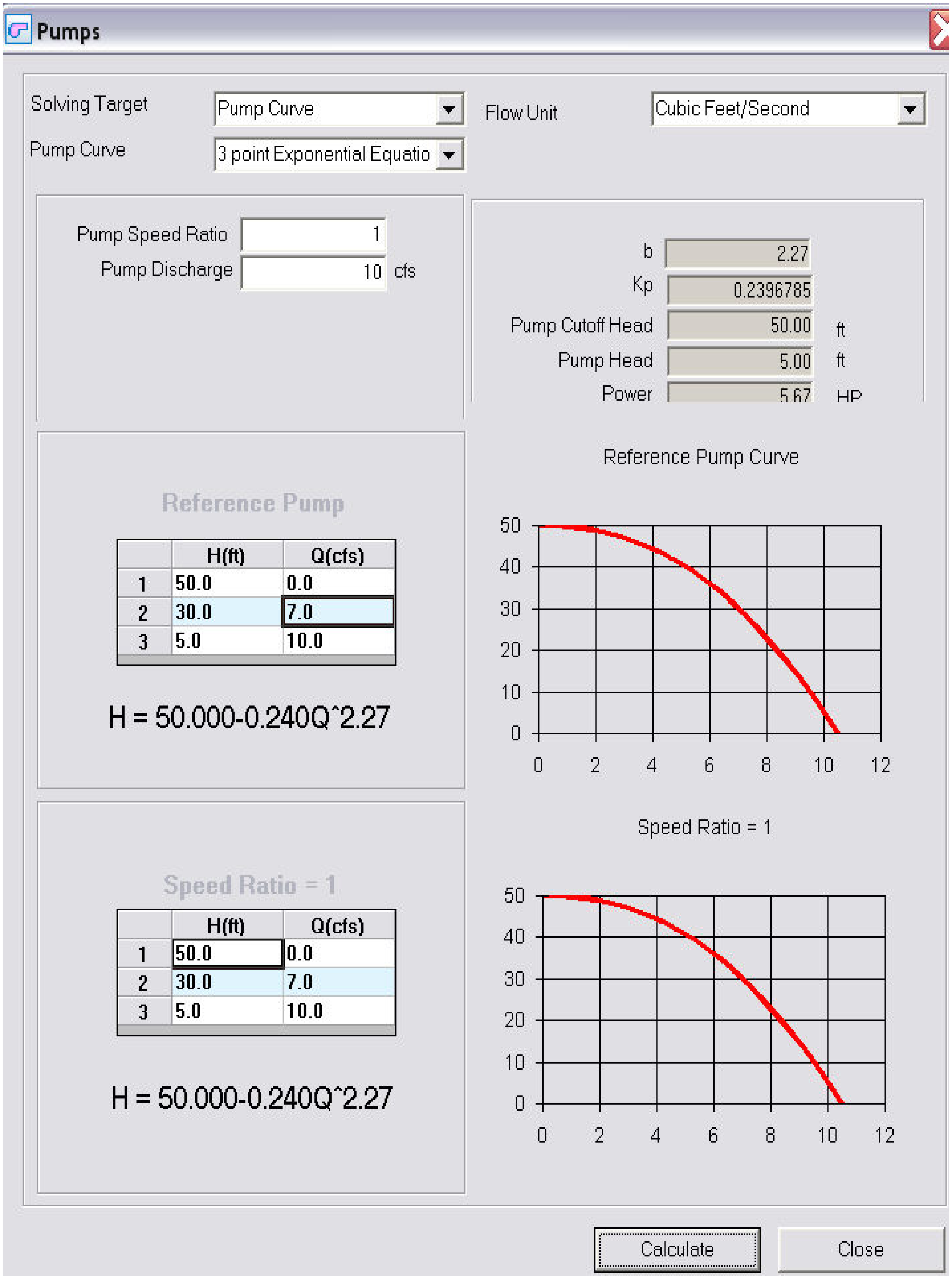
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Pump Curve

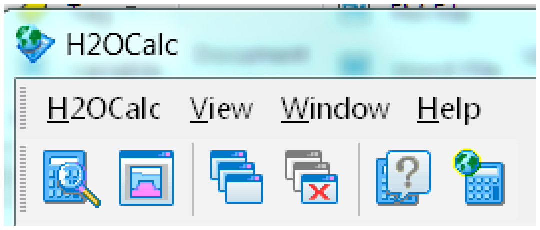


The dialog box for pump curve is shown below. Click here for the methodology of pump curve.

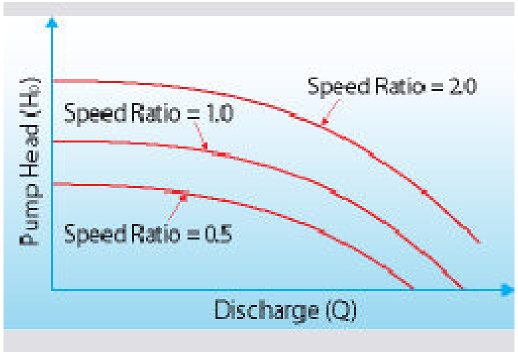

Pumps
Solving Target
Pump Curve
Flow Unit
Cubic Feet/Second
Pump Curve
3 point Exponential Equatio
Pump Speed Ratio
1
Pump Discharge
10
cfs
b
2.27
Kp
0.2396785
Pump Cutoff Head
50.00
ft
Pump Head
5.00
ft
Power
5.67
HP
Reference Pump
H(ft) Q(cfs)
1 50.0 0.0
2 30.0 7.0
3 5.0 10.0
H = 50.000-0.240Q^2.27
Reference Pump Curve
50 40 30 20 10 0
0 2 4 6 8 10 12
Speed Ratio = 1
H(ft) Q(cfs)
1 50.0 0.0
2 30.0 7.0
3 5.0 10.0
H = 50.000-0.240Q^2.27
Speed Ratio = 1
50 40 30 20 10 0
0 2 4 6 8 10 12
Calculate
Close

- **Input for pump curve:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Curve** – Select the pump curve type (single point, 3-point exponential, or 3-point quadratic).
- **Pump Speed Ratio** – The dimensionless pump speed ratio and is defined as the ratio of the actual pump speed to the speed for which the original data is applicable.
- **Pump Discharge** – Pump flow rate.
- **Orifice Diameter** – Diameter of the orifice opening.

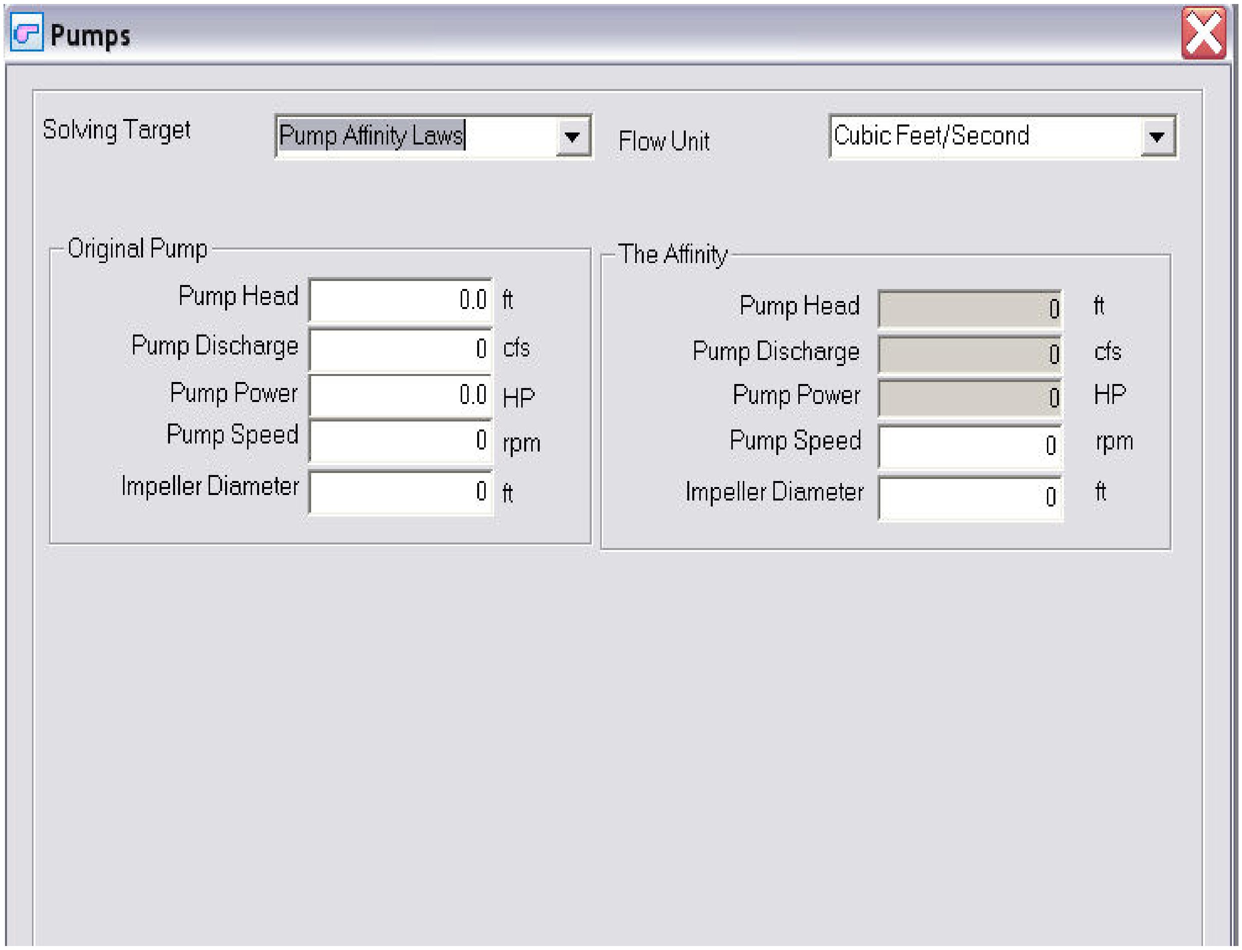
- **Output for pump curve:**
- **a, b, and c** – Pump equation parameters derived from the specified pump curve.
- **Pump Cutoff Head** – Pump head corresponding to zero pump discharge.
- **Pump Head** – Pump head corresponding to the specified pump discharge.
- **Pump Power** – Pump power computed based on pump discharge and pump head.
- **Pump Curve** – Graphical display of pump head vs pump discharge.


H2OCalc
H2OCalc View Window Help

Affinity Laws

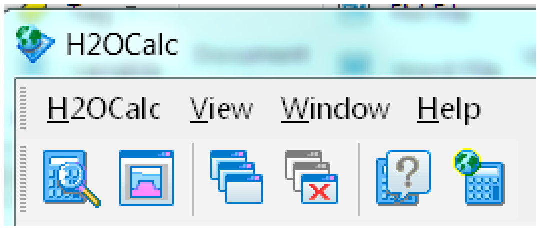


The dialog box for affinity laws is shown below. Click here for the methodology of pump affinity laws.

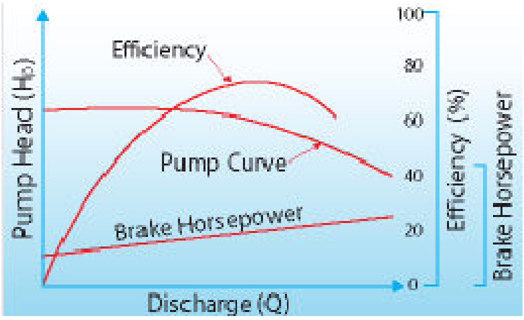


- **Input for affinity laws:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Original Pump Head** – Specified pump head.
- **Original Pump Discharge** – Specified pump flow rate.
- **Original Pump Power** – Specified pump power.
- **Original Pump Speed** – Specified pump speed.
- **Original Impeller Diameter** – Specified impeller diameter.

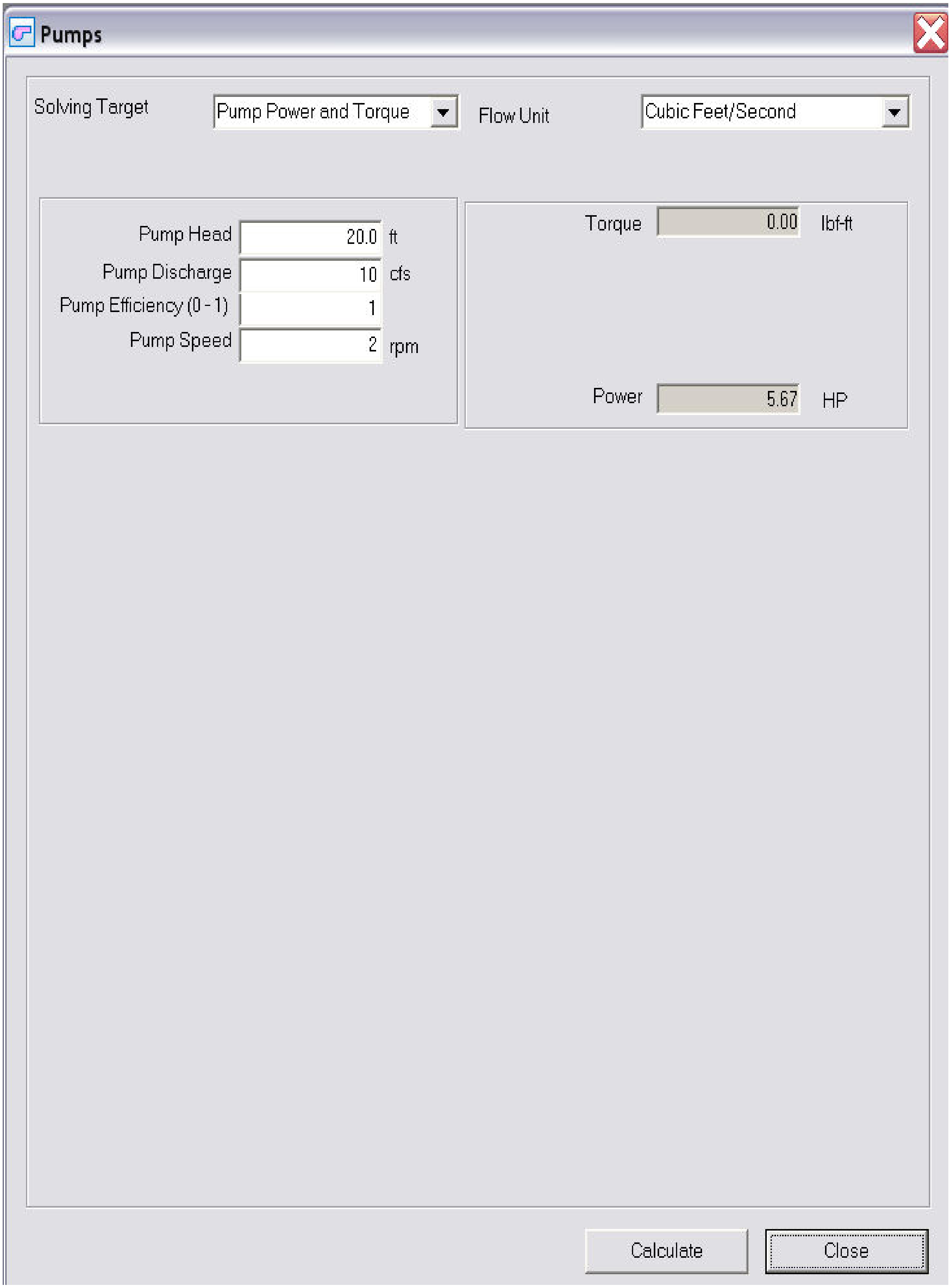
- **Output for affinity laws:**
- **Affinity Pump Head** – Pump head computed from affinity law.
- **Affinity Pump Discharge** – Pump discharge computed from affinity law.
- **Affinity Pump Power** – Pump power computed from affinity law.
- **Affinity Pump Speed** – Pump speed computed from affinity law.
- **Affinity Impeller Diameter** – Impeller diameter computed using affinity law.


H2OCalc
H2OCalc View Window Help

Pump Power and Torque

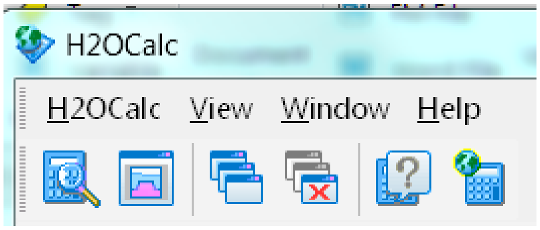


The dialog box for pump power and torque is shown below. Click here for the methodology of pump power and torque.

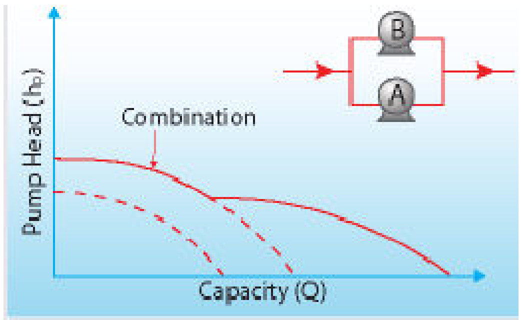

Pumps
Solving Target
Pump Power and Torque
Flow Unit
Cubic Feet/Second
Pump Head
20.0
ft
Pump Discharge
10
cfs
Pump Efficiency (0 - 1)
1
Pump Speed
2
rpm
Torque
0.00
lbf-ft
Power
5.67
HP
Calculate
Close

- **Input for pump power and torque:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Head** – Head supplied by the pump.
- **Pump Discharge** – Pump flow rate.
- **Pump Efficiency** – Efficiency of the pump.
- **Pump Speed** – Desired pump speed.

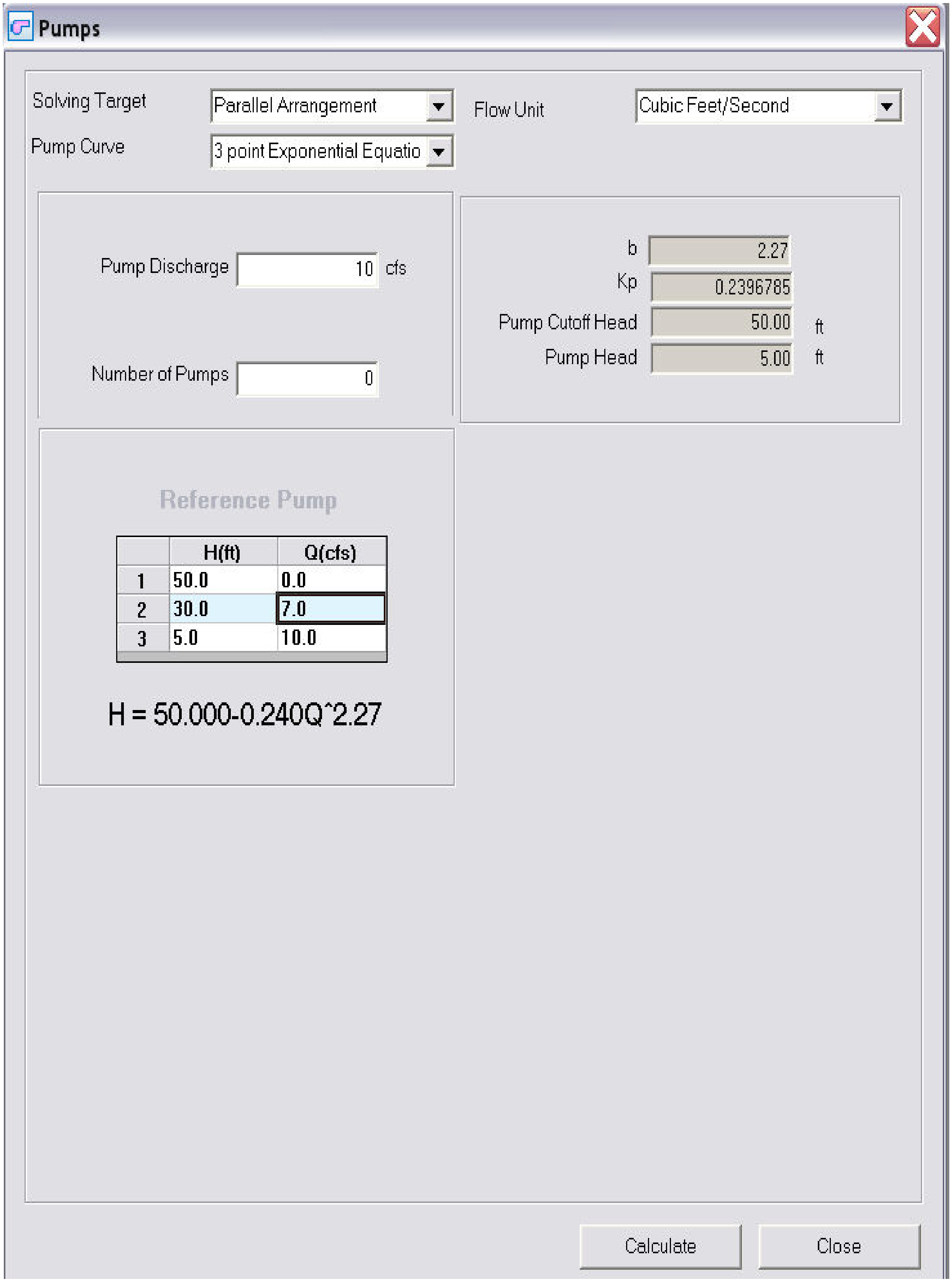
- Output for pump power and torque:
- **Torque** – Torque exerted by the impeller.
- **Pump Power** – Power output from the pump.
- **Affinity Pump Speed** – Pump speed computed from affinity law.


H2OCalc
H2OCalc View Window Help

Pumps Arranged in Parallel

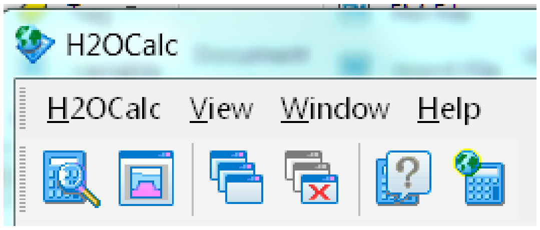


The dialog box for pumps in parallel arrangement is shown below.

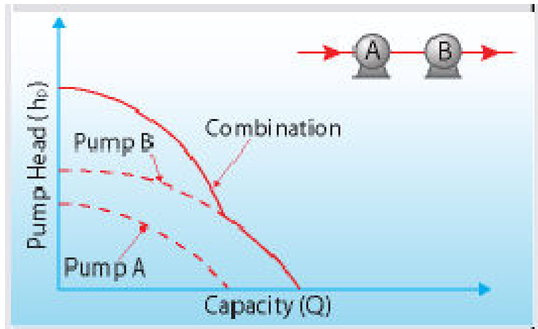

Pumps
Solving Target
Parallel Arrangement
Flow Unit
Cubic Feet/Second
Pump Curve
3 point Exponential Equatio
Pump Discharge
10
cfs
Number of Pumps
0
b
2.27
Kp
0.2396785
Pump Cutoff Head
50.00
ft
Pump Head
5.00
ft
Reference Pump
H(ft)
Q(cfs)
1
50.0
0.0
2
30.0
7.0
3
5.0
10.0
H = 50.000-0.240Q^2.27
Calculate
Close

- <u>**Input for pumps in parallel arrangement:**</u>
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Curve** – Select the pump curve type.
- **Pump Discharge** – Pump flow rate.
- **Rated Q** – Rated discharge for the pump.
- **Rated H** – Rated head for the pump.
- **Number of Pumps** – Number of pumps placed in parallel.

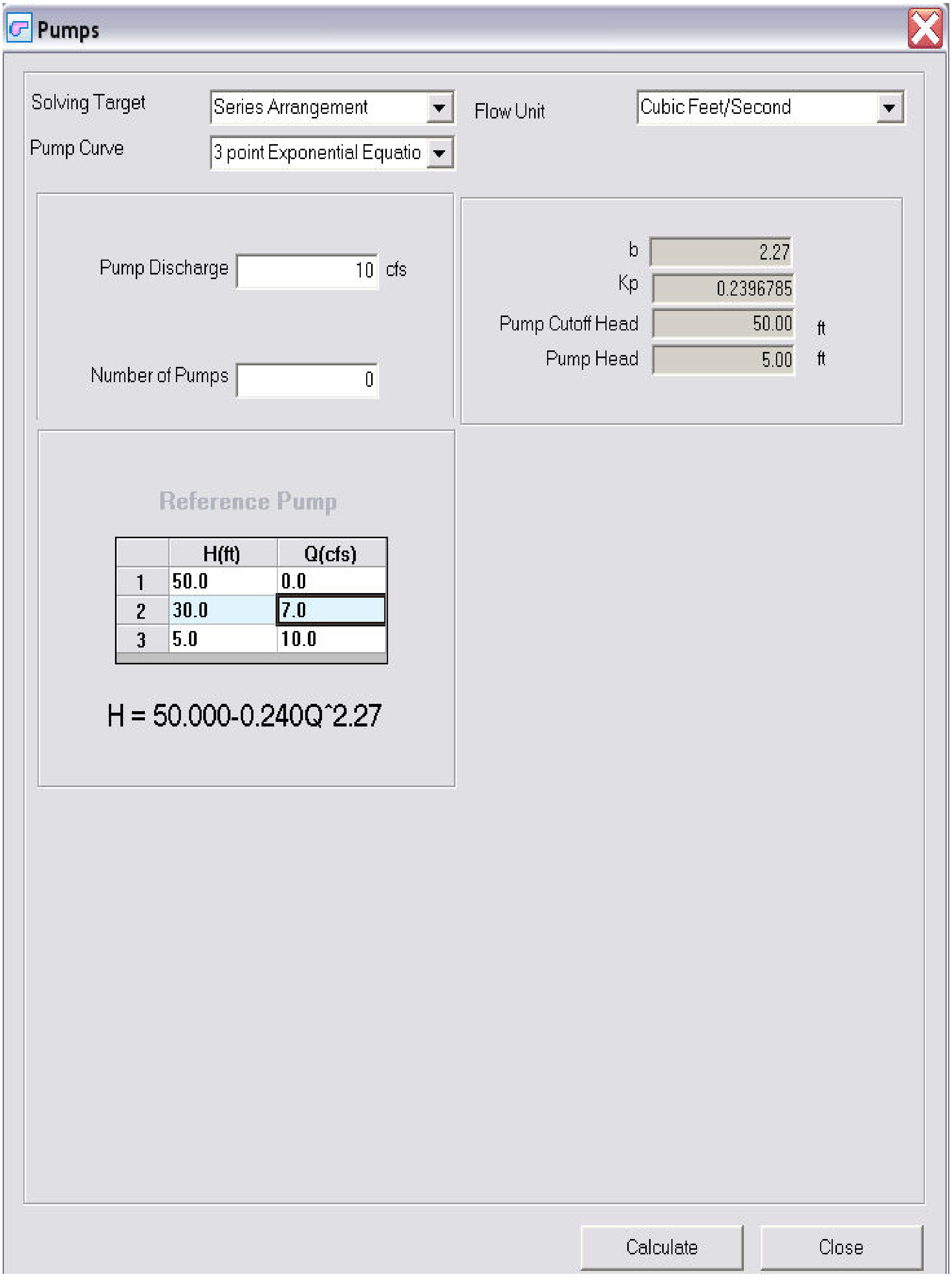
- **Output for pumps in parallel arrangement:**
- **Pump Cutoff Head** – Head corresponding to zero pump discharge. Computed considering all the pumps in parallel.
- **Pump Power** – Head corresponding to pump discharge. Computed considering all the pumps in parallel.


H2OCalc
H2OCalc View Window Help

Pumps Arranged in Series

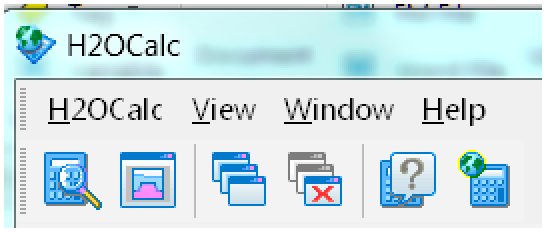


The dialog box for pumps in series arrangement is shown below.

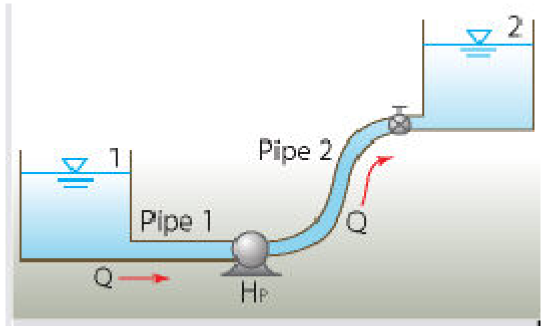

Pumps
Solving Target
Series Arrangement
Flow Unit
Cubic Feet/Second
Pump Curve
3 point Exponential Equatio
Pump Discharge
10
cfs
Number of Pumps
0
b
2.27
Kp
0.2396785
Pump Cutoff Head
50.00
ft
Pump Head
5.00
ft
Reference Pump
H(ft)
Q(cfs)
1
50.0
0.0
2
30.0
7.0
3
5.0
10.0
H = 50.000-0.240Q^2.27
Calculate
Close

- **Input for pump in series arrangement:**
- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Curve** – Select the pump curve type.
- **Pump Discharge** – Pump flow rate.
- **Rated Q** – Rated discharge for the pump.
- **Rated H** – Rated head for the pump.
- **Number of Pumps** – Number of pumps placed in series.

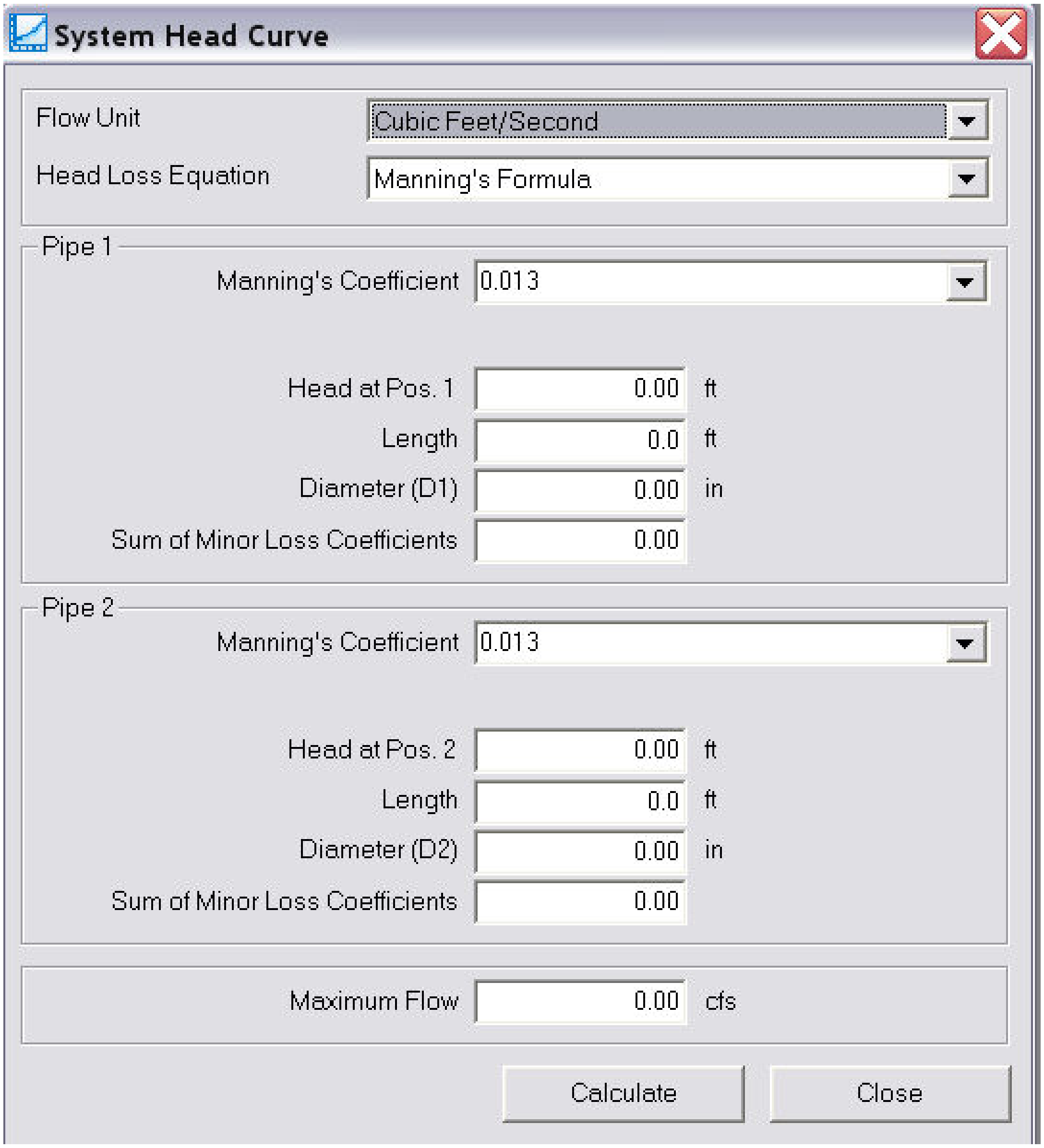
- **Output for pumps in series arrangement:**
- **Pump Cutoff Head** – Head corresponding to zero pump discharge. Computed considering all the pumps in series.
- **Pump Power** – Head corresponding to pump discharge. Computed considering all the pumps in series.


H2OCalc
H2OCalc View Window Help

System Head Curve

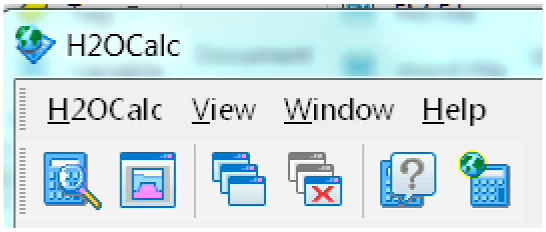


The dialog box for system head curve is shown below. Click here for the methodology of system head curve.


System Head Curve
Flow Unit
Cubic Feet/Second
Head Loss Equation
Manning's Formula
Pipe 1
Manning's Coefficient
0.013
Head at Pos. 1
0.00
ft
Length
0.0
ft
Diameter (D1)
0.00
in
Sum of Minor Loss Coefficients
0.00
Pipe 2
Manning's Coefficient
0.013
Head at Pos. 2
0.00
ft
Length
0.0
ft
Diameter (D2)
0.00
in
Sum of Minor Loss Coefficients
0.00
Maximum Flow
0.00
cfs
Calculate
Close

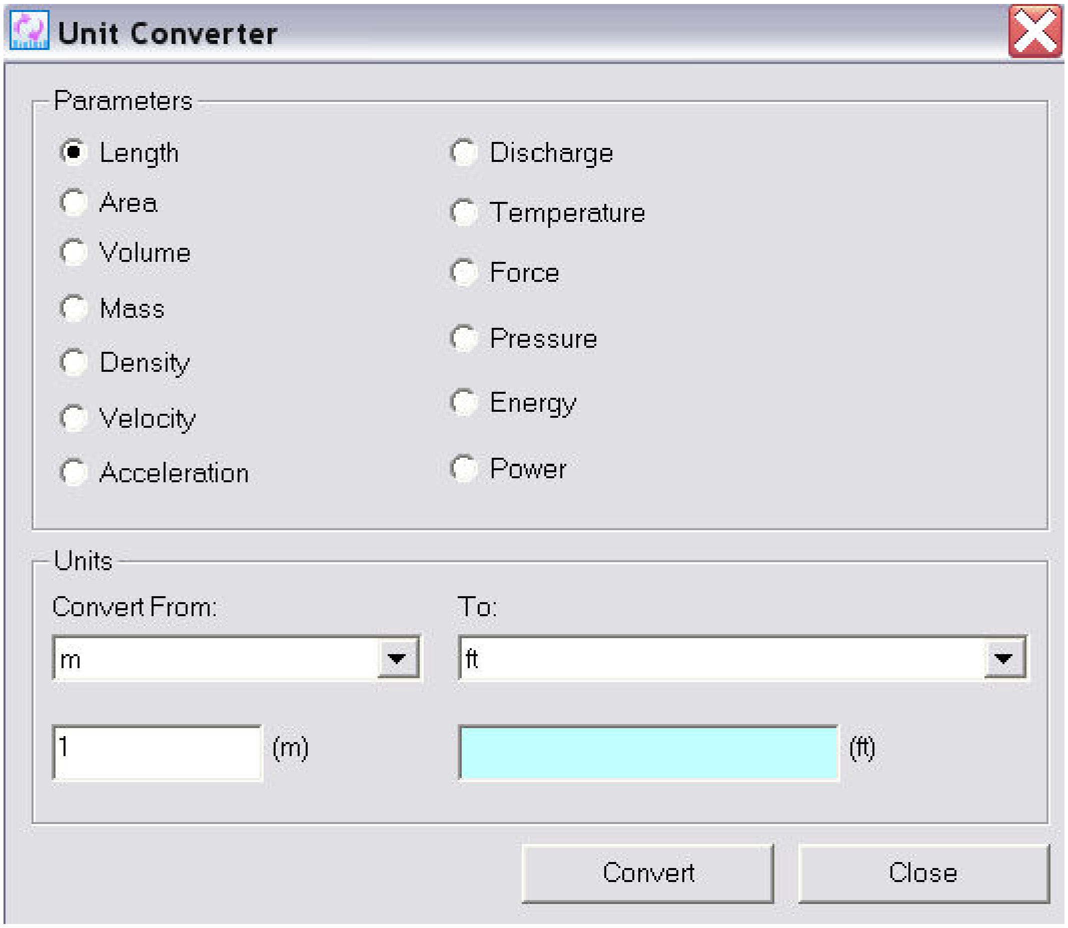
- **Input for system head curve:**
- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Select from Manning, Darcy-Weisbach (Colebrook-White), or Hazen–Williams formula.
- **Pipe 1** – The pipe that connects the upstream reservoir with the pump (i.e., pipe on the suction side of the pump).
- **Pipe 2** – The pipe that connects the pump with the downstream reservoir (i.e., pipe on the discharge side of the pump).
- **Coefficient** – Roughness coefficient.
- **Head at Position 1** – Head at the upstream reservoir.
- **Head at Position 2** – Head at the downstream reservoir.
- **Length** – Length of the pipe (i.e., pipe 1 or pipe 2).
- **Diameter** – Diameter of the pipe (i.e., pipe 1 or pipe 2).
- **Sum of Minor Loss Coefficients** – Sum of minor loss coefficients for the pipe (i.e., pipe 1 or pipe 2).
- **Maximum Flow** – Maximum flow for use in constructing the system head curve. The maximum flow is divided into ten equal intervals and the head corresponding to each of the ten flows is computed to construct the system head curve. Therefore, it is advisable to use a maximum flow that is divisible by ten.

- **Output for system head curve:**
- **Graphical System Curve** – Presents the system head curve graphically.
- **Tabular System Curve** – Presents the system head curve in tabular form.


H2OCalc
H2OCalc View Window Help

Unit Converter

The Unit converter dialog box is shown below. Click here for the methodology.



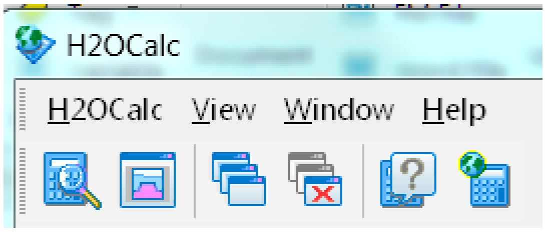
- **Parameters** - Select the physical parameter for which you wish to convert a unit.
- **Convert From** - Select the existing unit from the available list.
- **Convert To** - Select the unit to which you wish to convert.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

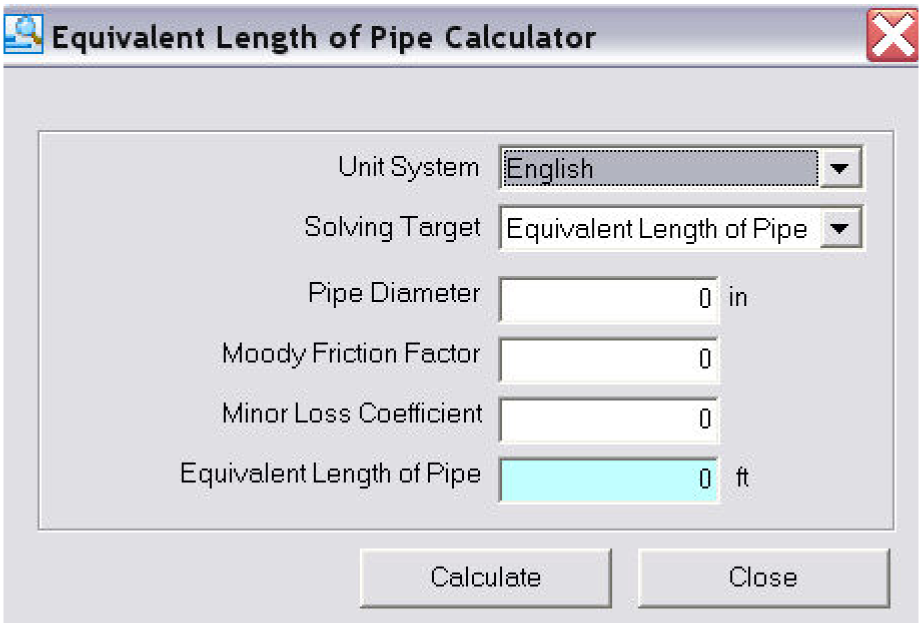
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Equivalent Pipe Length

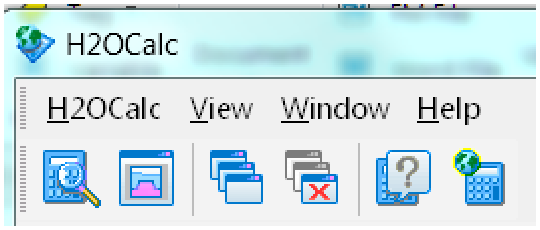
The Equivalent Pipe Length solves for a fictitious pipe that would have the same head loss as a minor loss, and could be replaced for a minor loss while preserving hydraulic equivalency.

The dialog box for equivalent pipe length is shown below. Click here for the methodology.

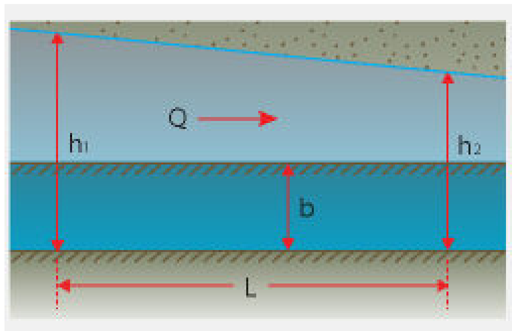


- **Input for equivalent pipe length:**
- **Unit System** – Select SI or English unit.
- **Solving Target** – Equivalent length, Moody friction factor, minor loss coefficient or pipe diameter.
- **Pipe Diameter** – Diameter of the pipe.
- **Moody Friction Factor** – Darcy-Weisbach friction factor from Moody diagram.
- **Minor Loss Coefficient** – Minor loss K factor.
- **Equivalent Length of Pipe** – Pipe length that yields head loss equivalent to minor loss.

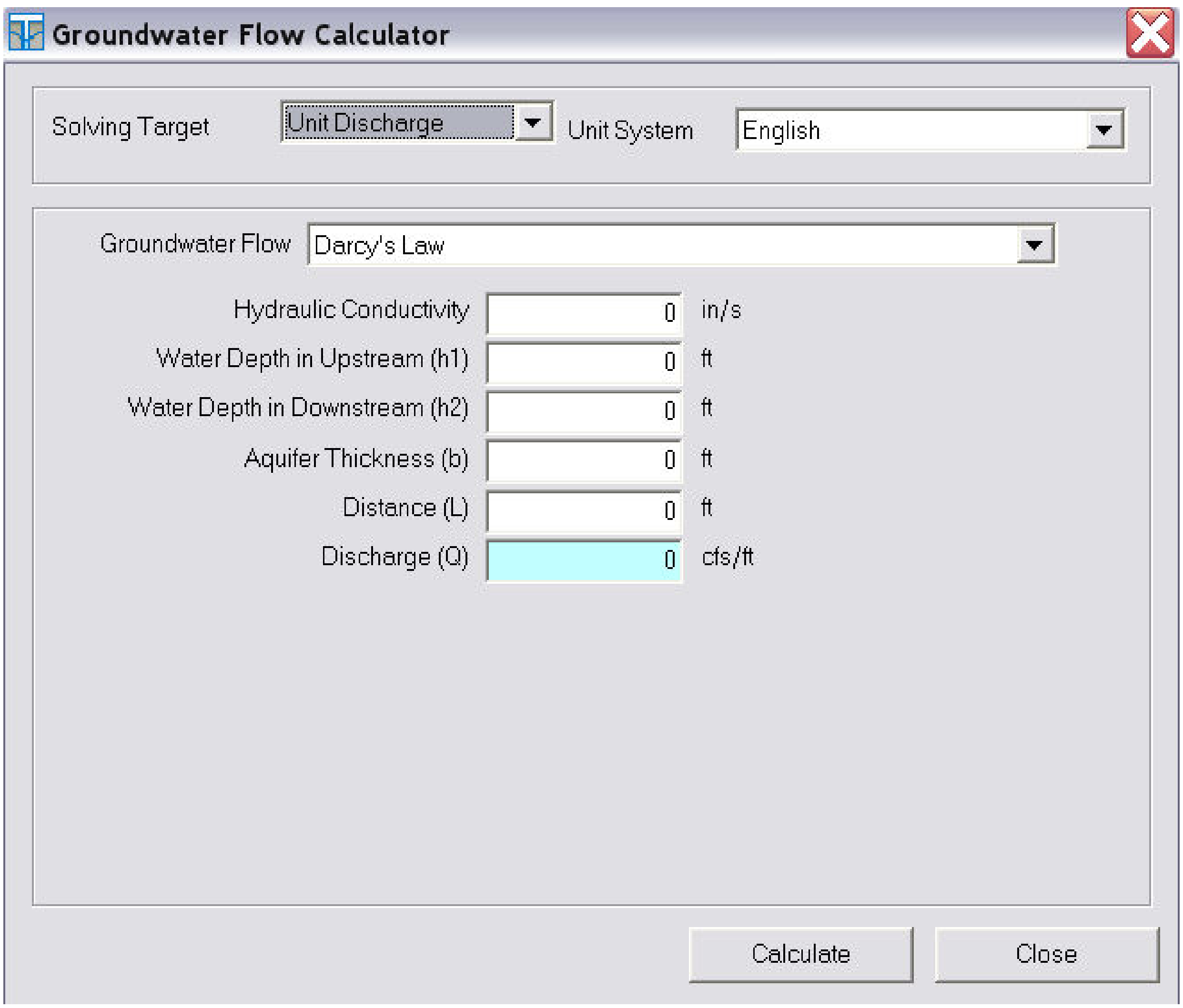
- **Output for equivalent pipe length:**
- **Pipe Diameter** – Would be an output if selected as solving target.
- **Moody Friction Factor** – Would be an output if selected as solving target.
- **Minor Loss Coefficient** – Would be an output if selected as solving target. .
- **Equivalent Length of a Pipe** – Would be an output if selected as solving target.


H2OCalc
H2OCalc View Window Help

Darcy's Equation

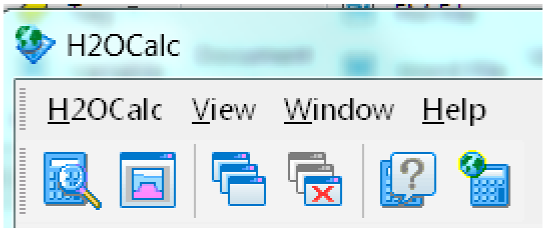


The dialog box for Darcy’s equation is shown below. Click here for the methodology.

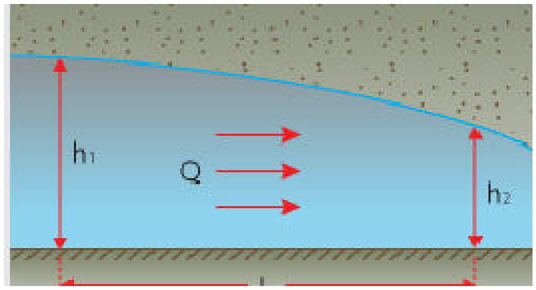


- **Input for Darcy’s equation:**
- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select Darcy’s equation.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Water Depth in Upstream** – Water head at the upstream section of the considered aquifer length.
- **Water Depth in Downstream** – Water head at the downstream section of the considered aquifer length.
- **Aquifer Thickness** – Thickness (depth) of the aquifer.
- **Distance** – Aquifer length between the upstream and the downstream points.
- **Discharge** – Flow rate per unit width of the aquifer.

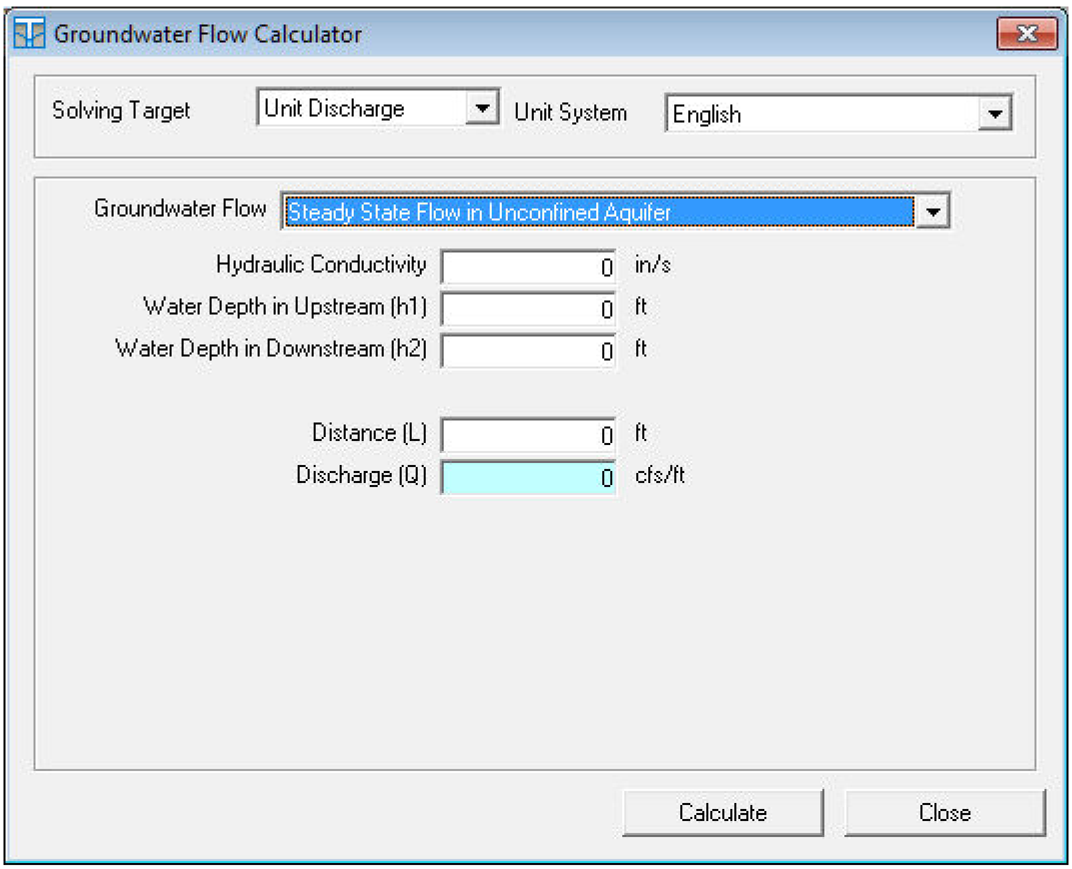
- **Output for Darcy's equation:**
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.


H2OCalc
H2OCalc View Window Help

Steady State Flow in Unconfined Aquifers

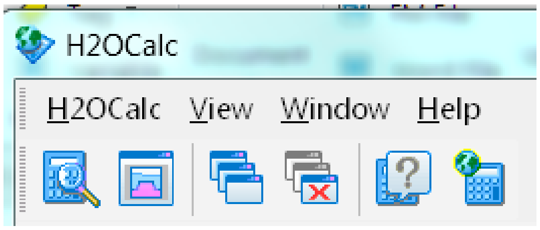


The dialog box for steady state flow in unconfined aquifer is shown below. Click here for the methodology.

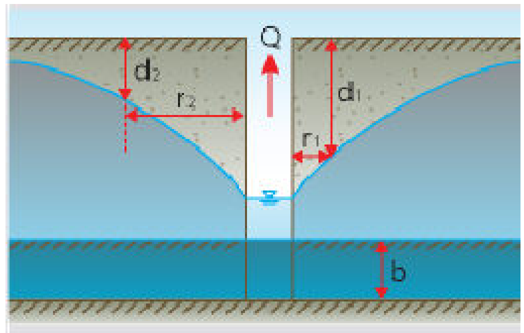


- **Input for steady state flow in unconfined aquifer:**
- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select Dupuit equation.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Water Depth in Upstream** – Water head at the upstream section of the considered aquifer length.
- **Water Depth in Downstream** – Water head at the downstream section of the considered aquifer length.
- **Distance** – Aquifer length between the upstream and the downstream points.
- **Discharge** – Flow rate per unit width of the aquifer.

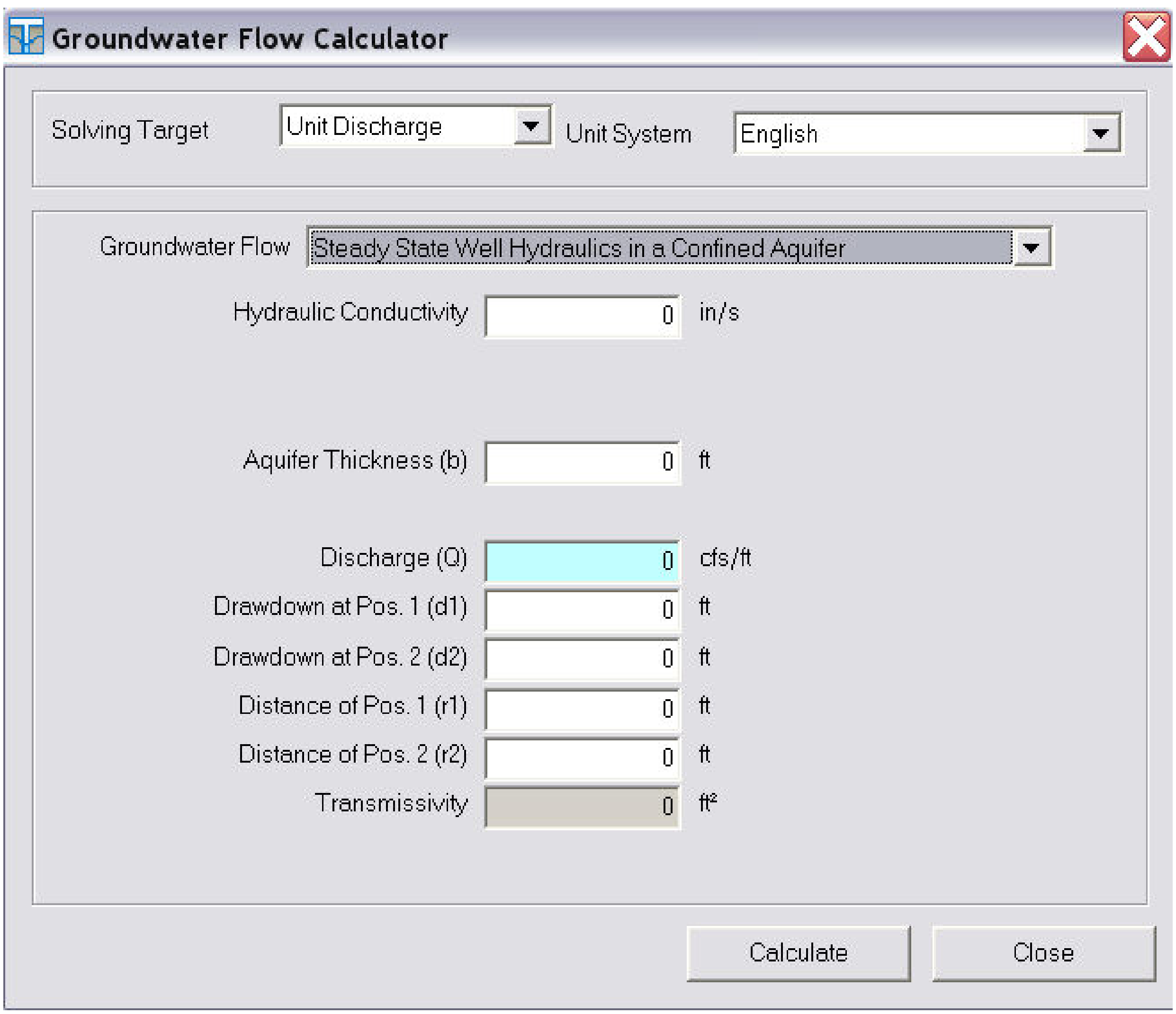
- **Output for steady state flow in unconfined aquifer:**
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.


H2OCalc
H2OCalc View Window Help

Well Hydraulics for Confined Aquifers

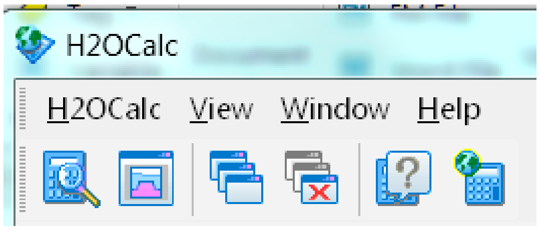


The dialog box for steady state well hydraulics for confided aquifer is shown below. Click here for the methodology.

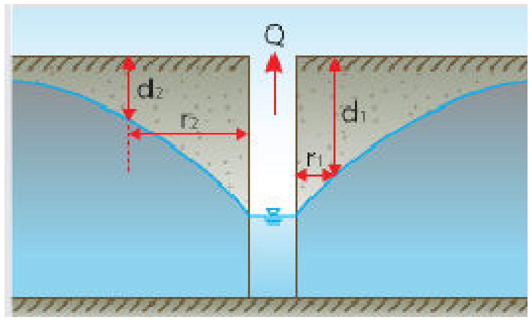


- **Input for steady state well hydraulics for confided aquifer:**
- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select steady state groundwater flow in a confided aquifer.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Aquifer Thickness** – Thickness (depth) of the aquifer.
- **Discharge** – Flow rate per unit width of the aquifer.
- **Drawdown at Position 1** – Groundwater elevation minus water level elevation at point 1.
- **Drawdown at Position 2** – Groundwater elevation minus water level elevation at point 2.
- **Distance of Position 1** – Distance of point 1 from the center of the well.
- **Distance of Position 2** – Distance of point 2 from the center of the well.

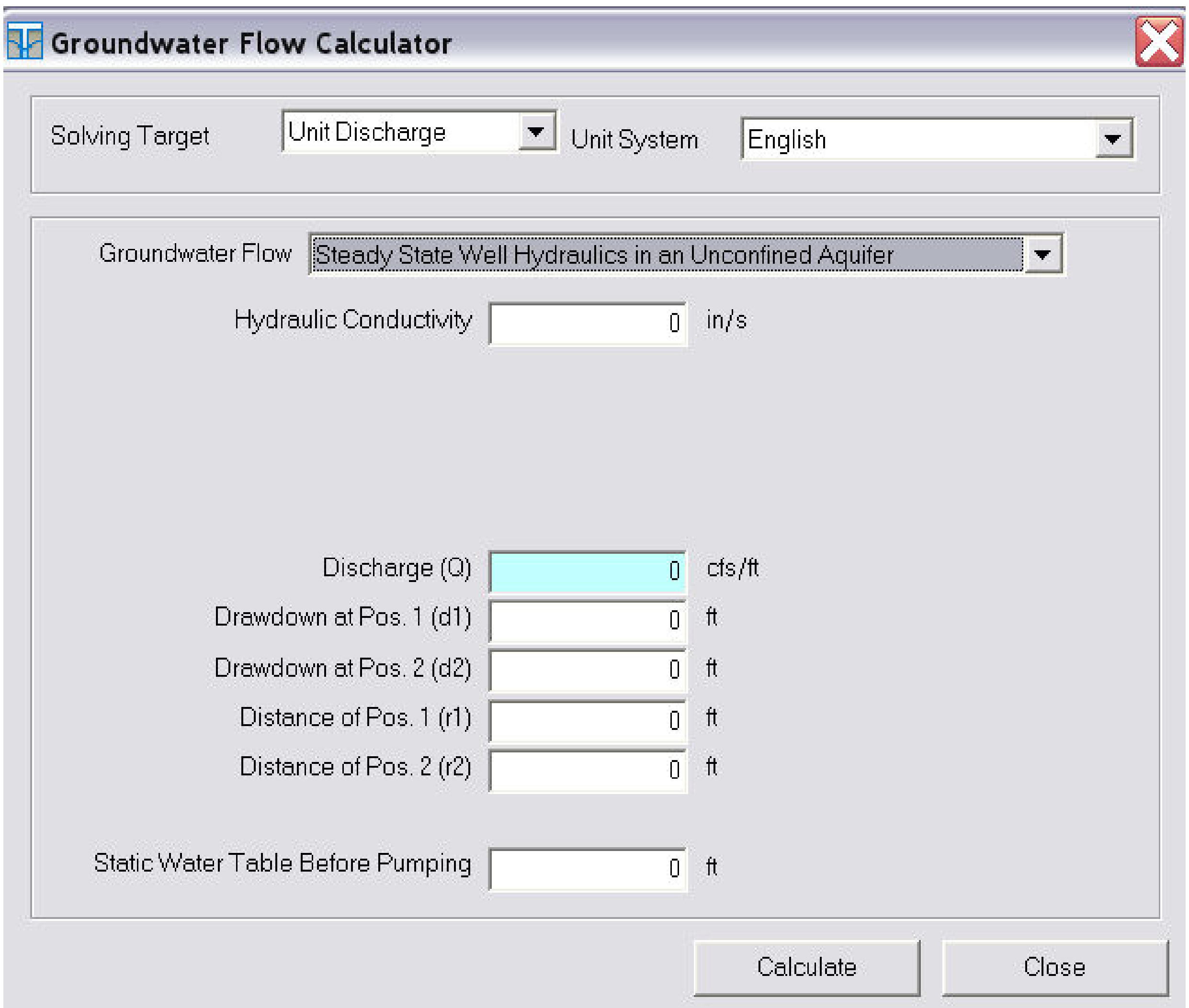
- Output for steady state groundwater flow in a confided aquifer:
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.
- **Transmissivity** – The product of hydraulic conductivity and aquifer thickness. It is the amount of water that can be transmitted horizontally per unit width of the aquifer.


H2OCalc
H2OCalc View Window Help

Well Hydraulics for Unconfined Aquifers

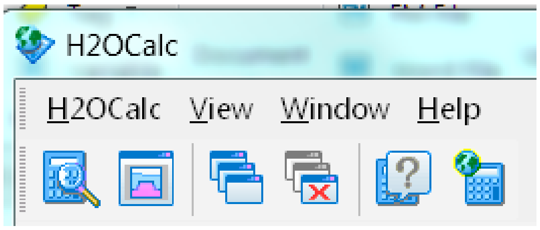


The dialog box for steady state well hydraulics in an unconfined aquifer is shown below. Click here for the methodology.

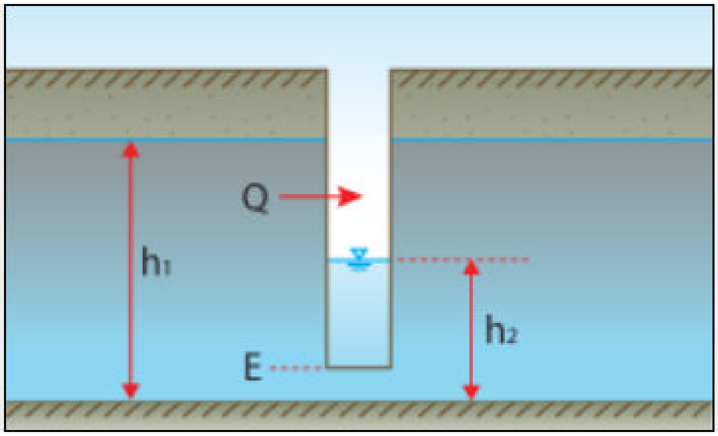


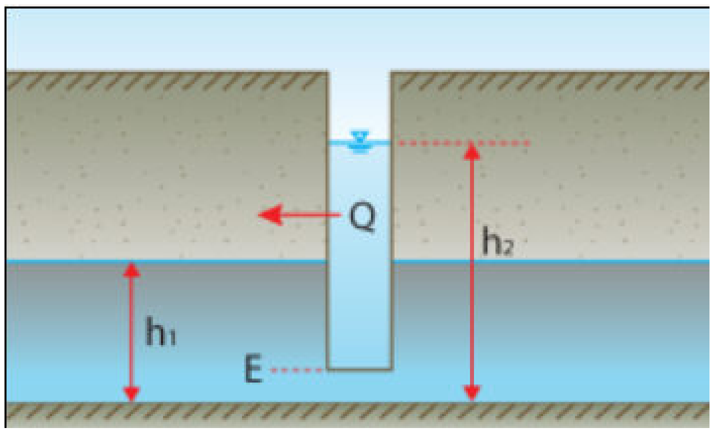
- **Input for steady state well hydraulics in an unconfided aquifer:**
- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select steady state groundwater flow in an unconfined aquifer.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Discharge** – Flow rate per unit width of the aquifer.
- **Drawdown at Position 1** – Groundwater elevation minus water level elevation at point 1.
- **Drawdown at Position 2** – Groundwater elevation minus water level elevation at point 2.
- **Distance of Position 1** – Distance of point 1 from the center of the well.
- **Distance of Position 2** – Distance of point 2 from the center of the well.
- **Static Water Table Before Pumping** – Water table elevation before pumping started.

- **Output for steady state groundwater flow in an unconfined aquifer:**
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.

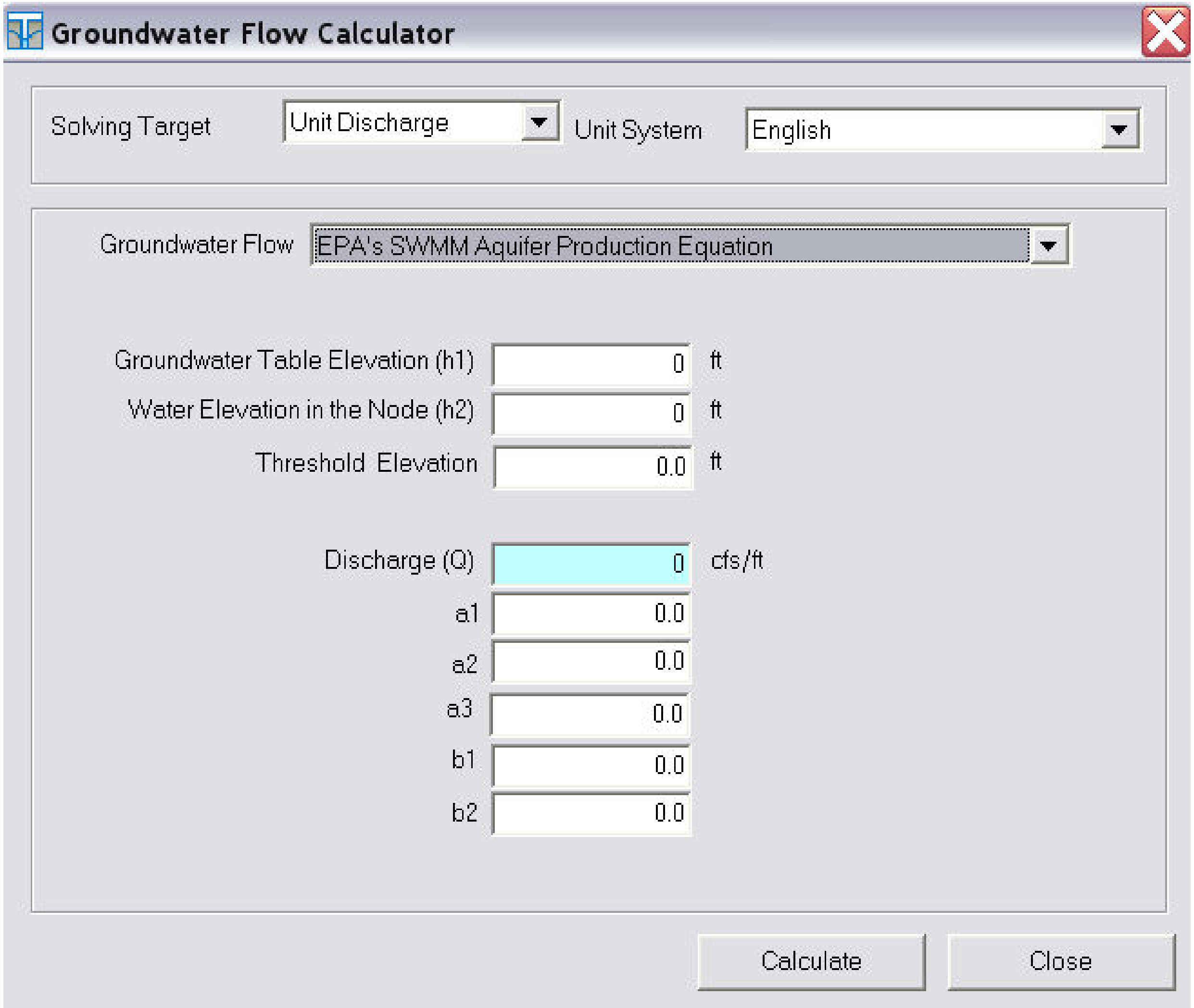

H2OCalc
H2OCalc View Window Help

EPA SWMM's Groundwater Equation





The dialog box for EPA SWMM’s aquifer production equation is shown below.

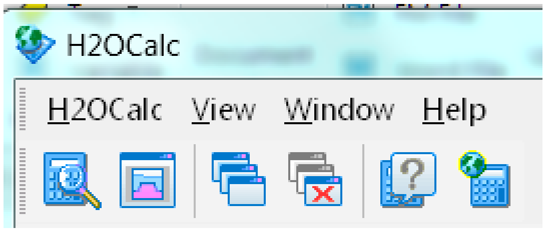

Groundwater Flow Calculator
Solving Target
Unit Discharge
Unit System
English
Groundwater Flow
EPA's SWMM Aquifer Production Equation
Groundwater Table Elevation (h1)
0
ft
Water Elevation in the Node (h2)
0
ft
Threshold Elevation
0.0
ft
Discharge (Q)
0
cfs/ft
a1
0.0
a2
0.0
a3
0.0
b1
0.0
b2
0.0
Calculate
Close

- **Input for EPA SWMM's aquifer production equation:**
- **Groundwater Flow** – Select EPA SWMM's aquifer production equation.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Groundwater Table Elevation** – Elevation of the groundwater table.
- **Water Elevation in the Node** – Elevation of surface water at the receiving node.
- **Threshold Elevation** – Threshold groundwater table elevation or elevation of node invert.
- **a1, a2, b1, b2, and a3** – coefficients that appear in the following equation that computes groundwater flow as a function of groundwater and surface water heads.

$$Q_{gw} = a_1(H_{gw} - E)^{b_1} - a_2(H_{sw} - E)^{b_2} + a_3(H_{gw}H_{SW})$$

- Where: **Qgw** = Groundwater flow (cfs/acre, cms/per hectare)
- **Hgw** = Elevation of groundwater table (ft, m)
- **Hsw** = Elevation of surface water at receiving node (ft, m)
- **E** = Threshold groundwater table elevation or elevation of node invert (ft, m).

- **Output for EPA SWMM's aquifer production equation:**
- **Discharge** – Flow rate per unit width of the aquifer.


H2OCalc
H2OCalc View Window Help

Surface Water Hydrology

The Surface Water Hydrology category estimates peak flow using the rational method and the SCS peak discharge method, the time of concentration using a number of commonly used methods, and runoff hydrograph using nine different method.

Peak Flow Estimation Methods

- Rational Formula
- SCS Peak Discharge Method
- Time of Concentration Estimation Methods
    - Kirpich, California Culverts Practice, Izzard, Federal Aviation Administration
    - Kinematic Wave Formulas, SCS Lag Equation, SCS Average Velocity Charts, Yen and Chow

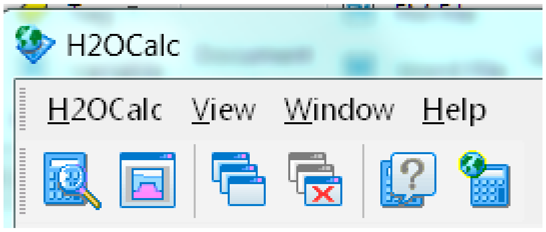
Runoff Hydrograph Generation Methods

- Colorado Urban Hydrograph Procedure
- NRCS Dimensionless Unit Hydrograph
- NRCS Triangular Unit Hydrograph
- Delmarva Unit Hydrograph
- Clark Unit Hydrograph
- Snyder Unit Hydrograph
- Espey Unit Hydrograph
- Santa Barbara Unit Hydrograph
- San Diego Modified Rational Hydrograph

Click the following for the methodology.

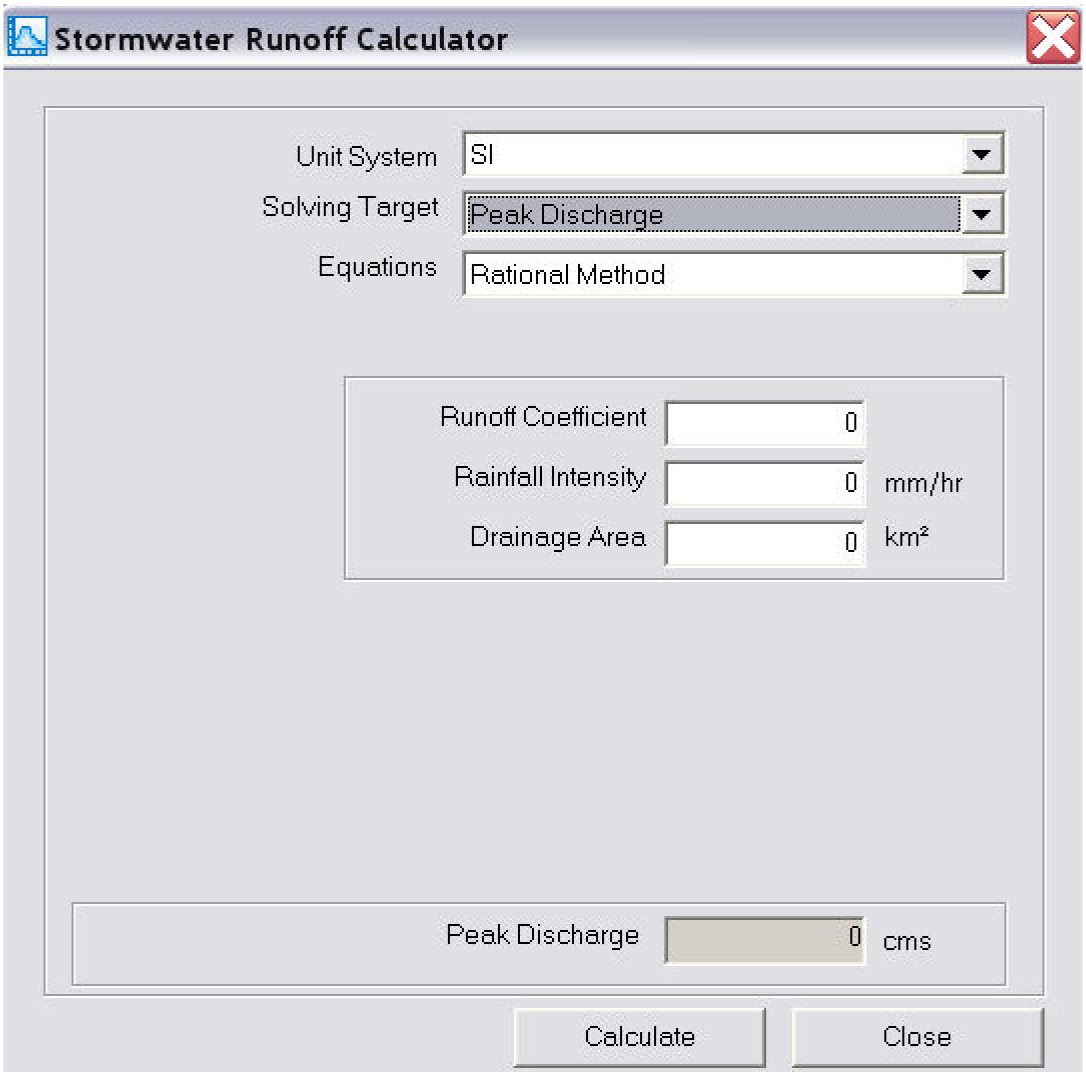
Surface Water Hydrology

- Rational Formula
- NRCS (SCS) Dimensionless Unit Hydrograph Method
- NRCS (SCS) Triangular Unit Hydrograph Method
- Delmarva Unit Hydrograph
- The Colorado Urban Hydrograph Procedure
- Snyder Unit Hydrograph Method
- Clark Unit Hydrograph Method
- Espey Unit Hydrograph Method
- Santa Barbara Urban Hydrograph Method
- San Diego Modified Rational Formula


H2OCalc
H2OCalc View Window Help

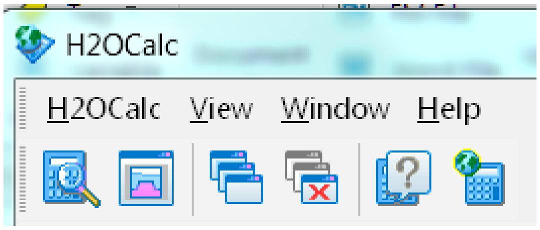
Peak Discharge: Rational Method

The dialog box for the rational method is shown below. Click here for the methodology.



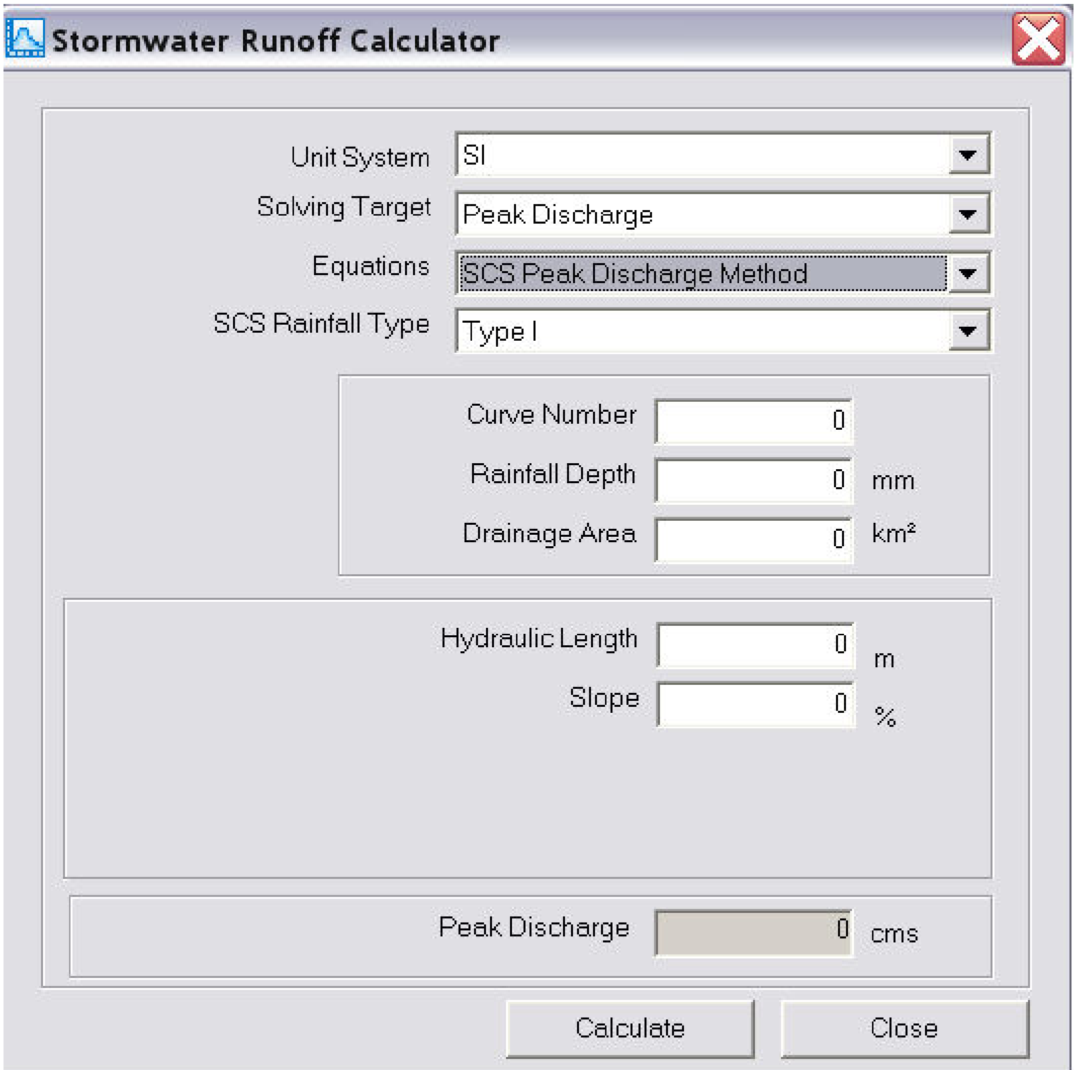
- **Input for the rational method:**
- **Unit System** – English or SI unit.
- **Solving Target** – Peak discharge or time of concentration.
- **Equations** – Rational method or the SCS peak discharge method.
- **Runoff Coefficient** – Ratio of runoff to precipitation. It is a measure of the watershed's runoff generation capability. It is a function of soil, land cover and topography (See Table 3.9).
- **Rainfall Intensity** – Design rainfall intensity derived from IDF curve or equation corresponding to duration of the watershed's time of concentration.
- **Drainage Area** – Area of the total watershed that drains to the location where the peaks flow is determined.

- **Output for the rational method:**
- **Peak Discharge** – Peak flow generated from the watershed.


H2OCalc
H2OCalc View Window Help

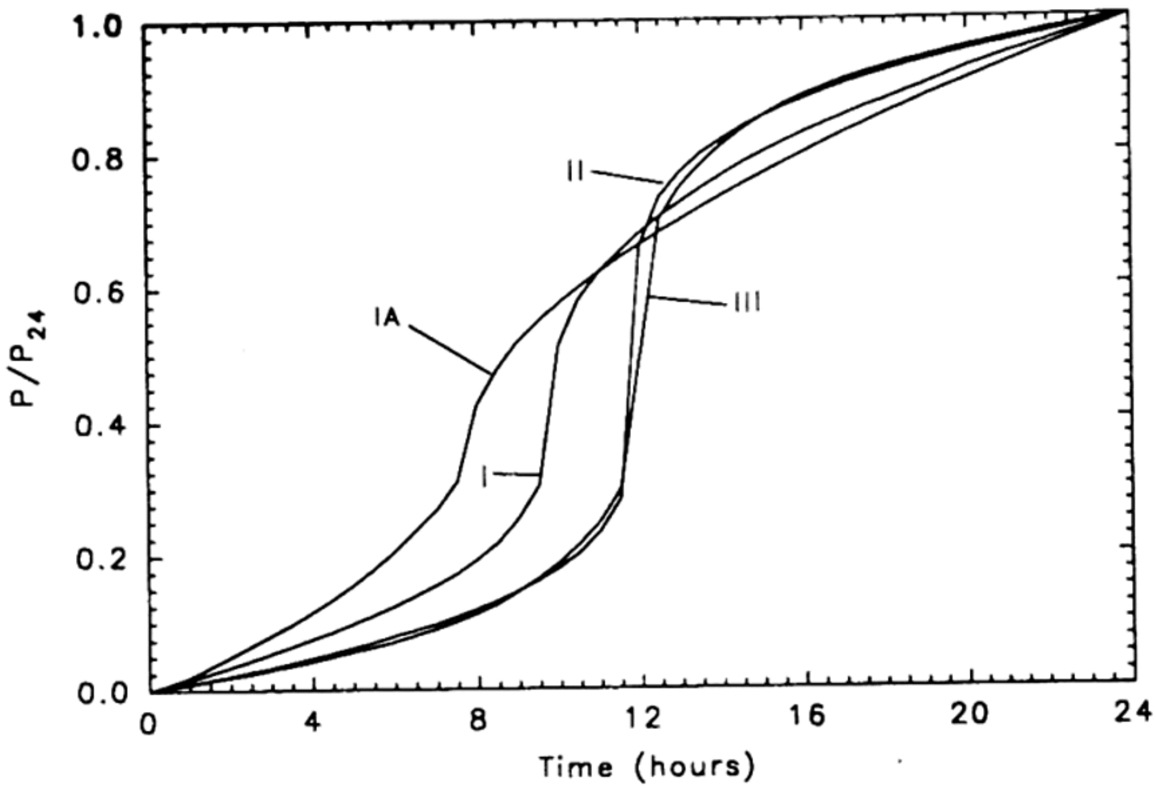
Peak Discharge: SCS Peak Discharge Method

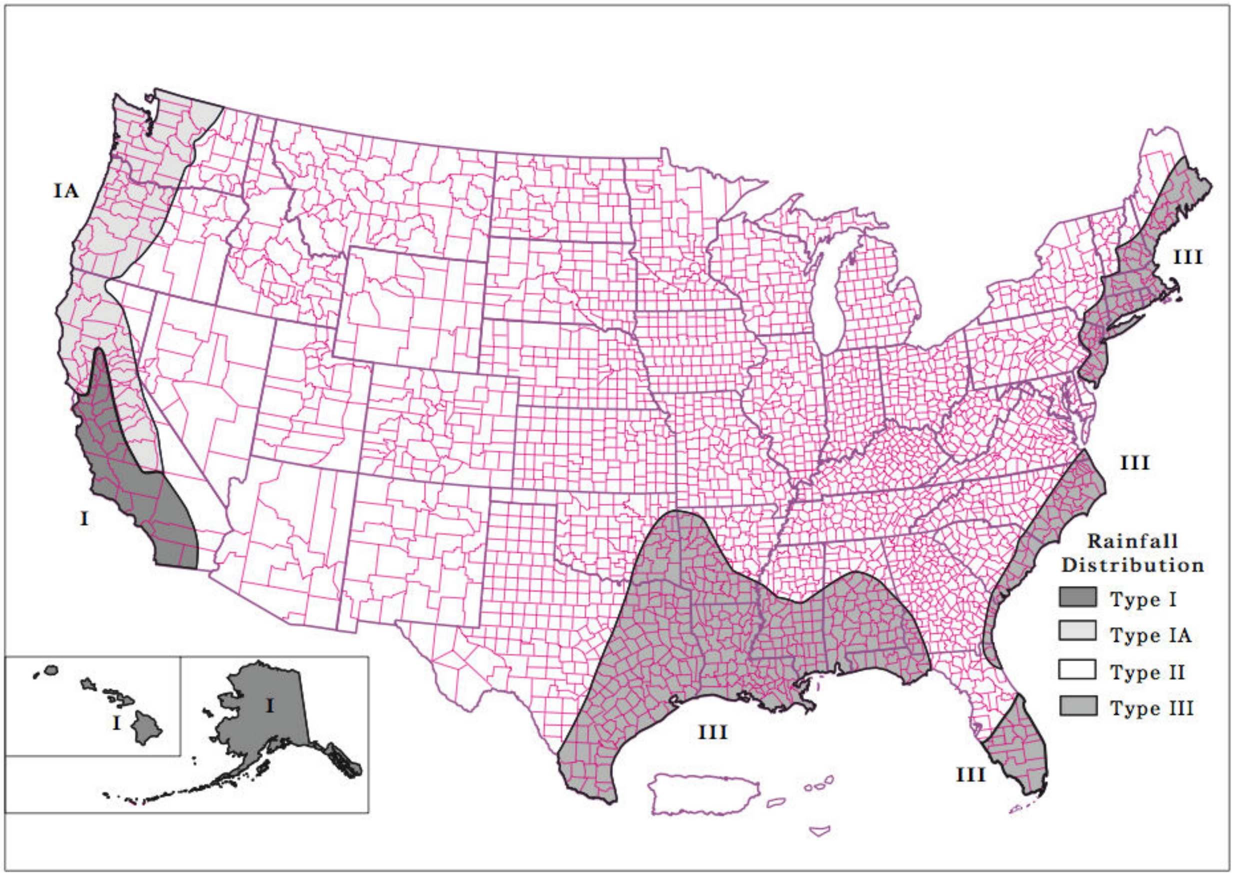
The dialog box for the SCS peak discharge method is shown below. Click here for the methodology.



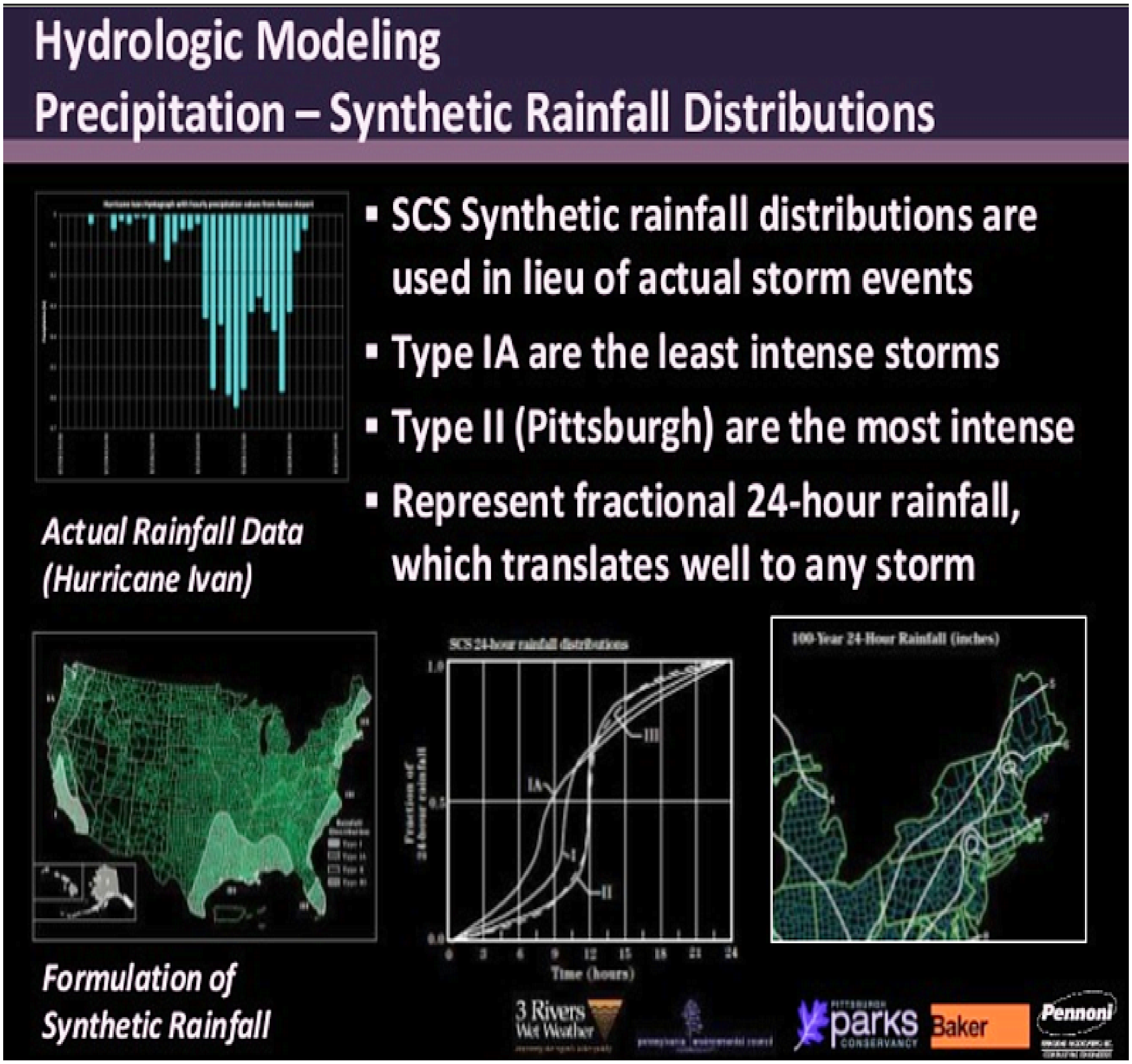
- **Input for the SCS peak discharge method:**
- **Unit System** – English or SI unit.
- **Solving Target** – Peak discharge or time of concentration.
- **Equations** – Rational method or the SCS peak discharge method.
- **SCS Rainfall Type** – Select one of the SCS rainfall types (i.e., Types I, IA, II, or III)
- **Curve Number** – SCS's dimensionless number that is used as a measure of runoff generation capability of a watershed (see Table 3.12). It is a function of soil, land cover and treatment.
- **Rainfall Depth** – 24-hr cumulative design rainfall depth. This rainfall depth will be distributed across the 24-hr duration according to the SCS rainfall type selected.
- **Drainage Area** – Area of the total watershed that drains to the location where the peaks flow is determined.

- **Output for the SCS peak discharge method:**
- **Peak Discharge** – Peak flow generated from the watershed.





Source: http://www.slideshare.net/damonweiss/workshop-on-storm-water-modeling-approaches

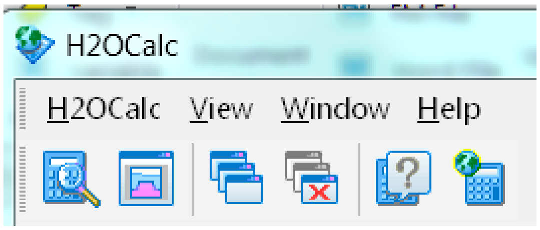


Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

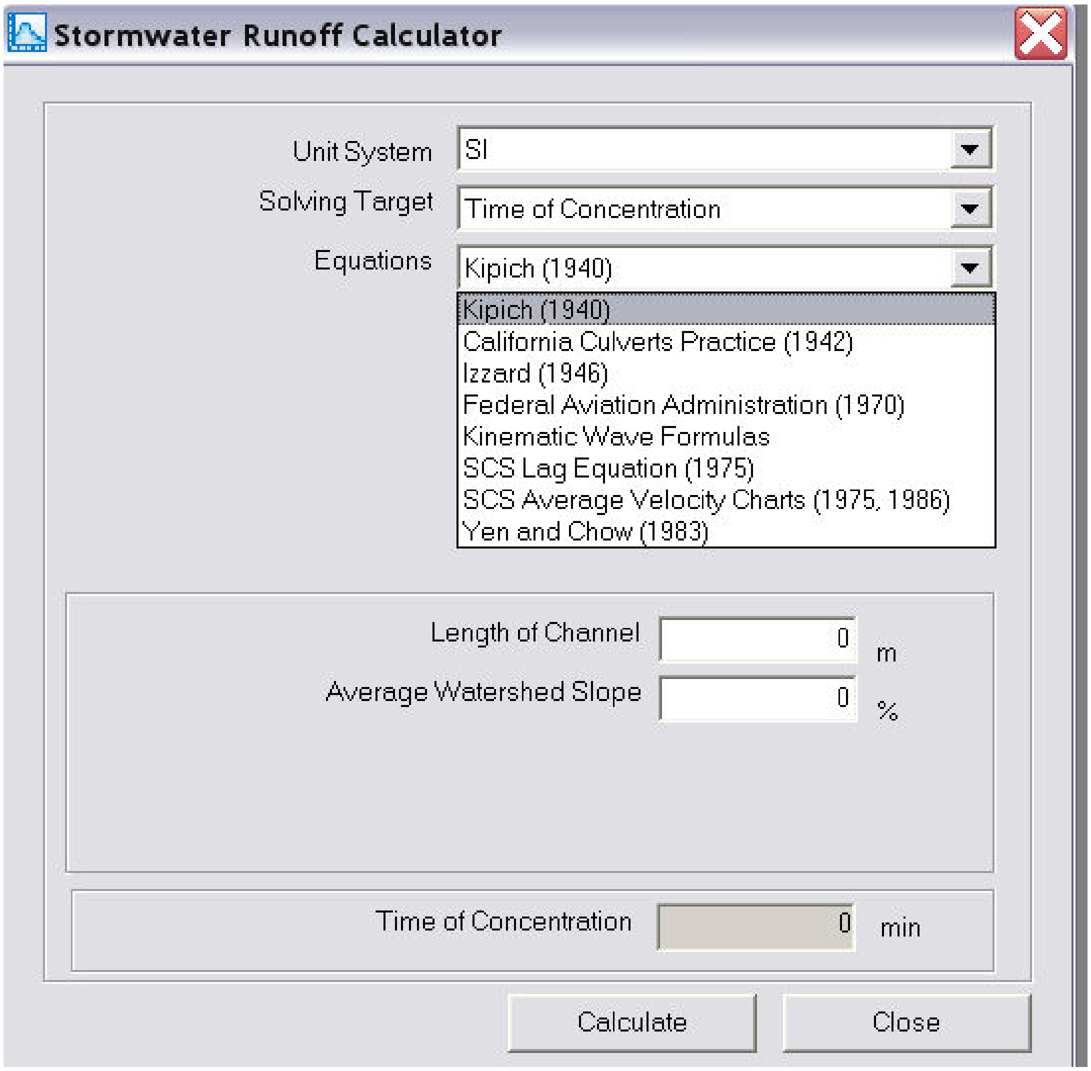
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Time of Concentration

The dialog box for estimating time of concentration using the Kirpich method is shown below.



- **General Input for the time of concentration methods:**
- **Unit System** – English or SI unit.
- **Solving Target** – Choose time of concentration.
- **Equations** – Select one of the eight empirical equations listed in the dialog box shown above.• Unit System – English or SI unit.
- **Solving Target** – Choose time of concentration.
- **Equations** – Select the desired time of concentration estimation equation among the available eight methods. The table given below described these equations in further detail.

- **The inputs required for specific the time of concentration estimation methods (see the following table below for the specific formula)**

- For Kirpich (1940) Equation
- **Length of Channel** – Length of the longest overland flow path for the watershed in feet.
- **Average Watershed Slope** – Average slope for the longest flow channel.

- For California Culverts Practice (1942) Equation
- **Length of Longest Channel** – Length of the longest overland flow path for the watershed in miles.
- **Elevation Difference Between Divide and Outlet** – The difference in elevation (in feet) between the upstream end of the flow path and the outlet of the watershed.

- For Izzard (1946) Method
- **Rainfall Intensity** – Intensity of the design rainfall (in/hr)
- **Length of Flow Path** – Length of the longest overland flow path for the watershed in feet. The product rainfall intensity and the length of flow path should be < 500.
- **Slope of Flow Path** –Average slope for the longest flow channel.
- **Retardance Coefficient** – Coefficient that accounts for friction effect of the channel material. Retardance factor ranges from 0.007 for smooth pavement to 0.012 for concrete and to 0.06 for dense turf. The product rainfall intensity and the length of flow path should be < 500.

- Federal Aviation Administration (1970) Method
- **Runoff Coefficient** – Refers to the runoff coefficient used in rational formula.
- **Length of Overland Flow**– Length of the longest overland flow path for the watershed.
- **Surface Slope** – Average slope of the watershed.

- Kinematic Wave Formula
- **Rainfall Intensity** – Intensity of the design rainfall (in/hr).
- **Length of Overland Flow** – Length of the longest overland flow path for the watershed.
- **Average Overland Slope** - Average slope for the longest flow channel.
- **Manning’s Roughness Coefficient** – Resistance coefficient used in Manning equation.

- **SCS Lag Equation (1975)**
- **Length of Flow Path** – Intensity of the design rainfall (in/hr).
- **Average Watershed Slope** - Average slope for the watershed.
- **Curve Number (CN)** – NRCS curve number used as an index of the watershed's runoff generation potential.

- SCS Average Velocity Charts (1975, 1986)
- **Length vs Velocity Chart** – Specify average flow velocity for various channel lengths.

- **Yen and Chow (1983) Method**
- **Length of Flow** – Length of the longest overland flow path for the watershed in feet.
- **Average Watershed Slope** – Average slope for the watershed..
- **Coefficient Ky** – Coefficient. KY ranges from 1.5 for light rain (intensity <0.8) to 1.1 for moderate rain (0.8 < intensity < 1.2), and to 0.7 for heavy rain (intensity >1.2)
- **Overland Texture Factor** – Overland texture factor. See Table 3.13.

- **Output for the SCS peak discharge method**
- **Time of Concentration** – The time it takes for flow to travel from the hydraulically remotest point in the watershed to reach outlet of the watershed.

Table 3-11: Formulas for Computing Time of Concentration

Method	Formula	
Kirpich (1940)	$t_c = 0.0078L^{0.77}S - 0.385$ L = length of channel (ft) S = average watershed slope (ft/ft)	
California Culverts Practice (1942)	$t_c = 60\left(11.9L^3 / H\right)^{0.385}$ L = length of the longest channel (mi) H = elevation difference between divide and outlet (ft)	
Izzard (1946)	$t_c = \dfrac{41.025(0.0007i + c)L^{1/3}}{S^{1/3} i^{2/3}}$ i = rainfall intensity (in/h) c = retardance coefficient	Retardance factor, c, ranges from 0.007 for smooth pavement to 0.012 for concrete and to 0.06 for dense turf; product i times L should be < 500
Federal Aviation Administration (1970)	$t_c = \dfrac{0.39(1.1 - C)L^{1/2}}{S^{1/3}}$ C = rational method runoff coefficient (see Table 3.9)	
Kinematic wave	$t_c = \dfrac{0.938L^{0.6}n^{0.6}}{i^{0.4}S^{0.3}}$ n = Manning's roughness coefficient	
SCS lag equation	$t_c = \dfrac{100L^{0.8}\left[(1000/CN) - 9\right]^{0.7}}{19000S^{1/2}}$ CN = SCS runoff curve number (see Table 3.10)	
SCS average velocity charts	$t_c = \dfrac{1}{60}\sum_{j=1}^{N}\left(L_j / V_j\right)$ V = average velocity (ft/s)	
Yen and Chow (1983)	$t_c = K_Y\left(\dfrac{NL}{S^{1/2}}\right)^{0.6}$ K_Y = Coefficient N = Overland texture factor (see Table 3.13)	K_Y ranges from 1.5 for light rain (i<0.8) to 1.1 for moderate rain (0.8<i<1.2), and to 0.7 for heavy rain (i>1.2)

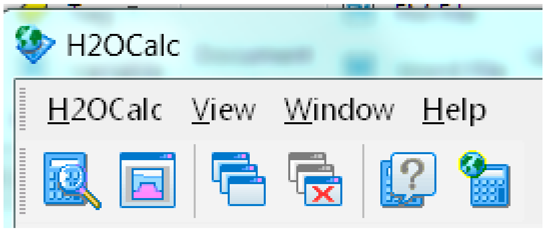
Source: Nicklow et al. (2004)

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

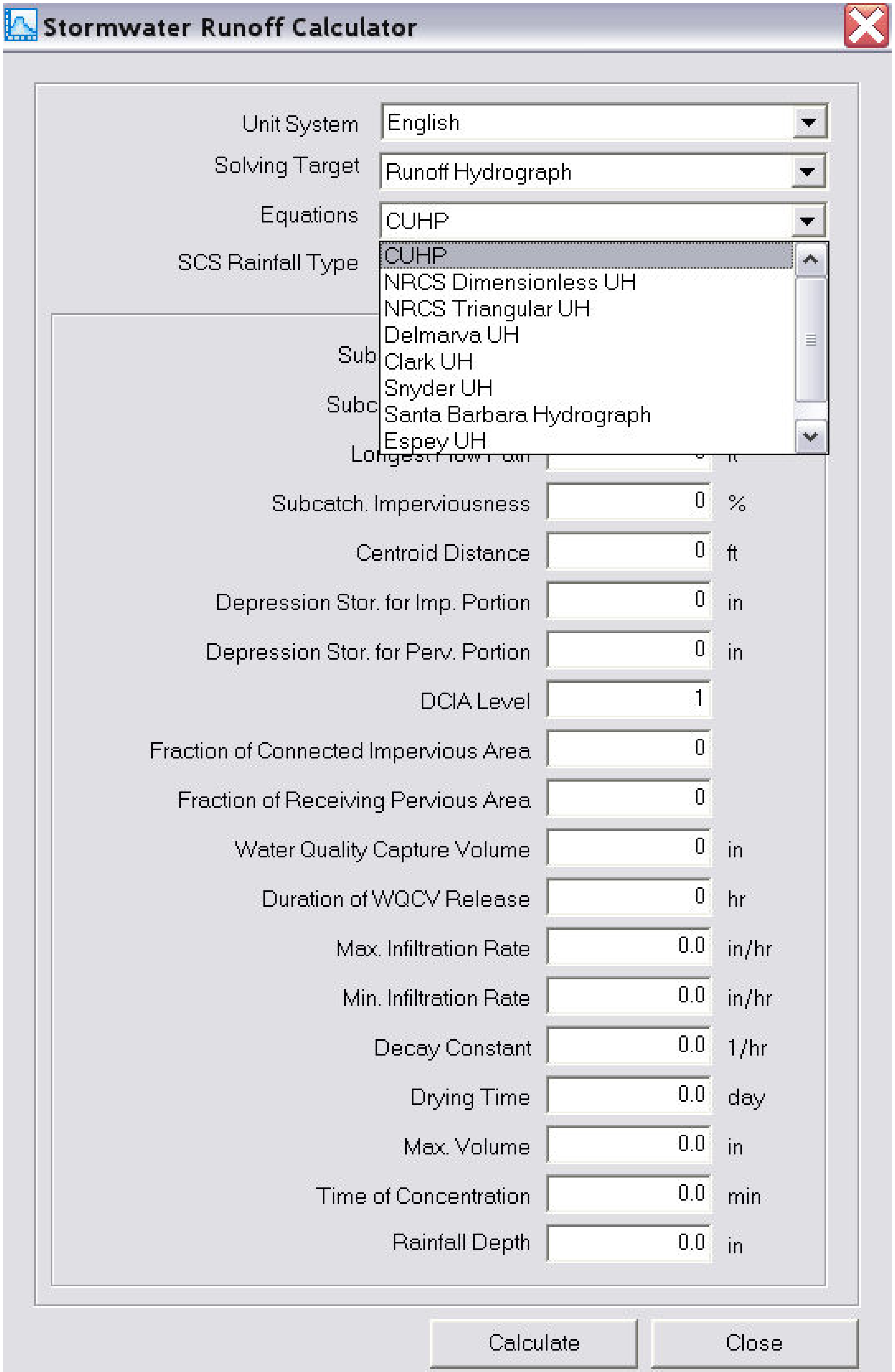
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Runoff Hydrograph

The dialog box for the runoff Hydrograph generation methods is shown below.


Stormwater Runoff Calculator
Unit System
English
Solving Target
Runoff Hydrograph
Equations
CUHP
SCS Rainfall Type
CUHP
NRCS Dimensionless UH
NRCS Triangular UH
Delmarva UH
Clark UH
Snyder UH
Santa Barbara Hydrograph
Espey UH
Subcatch. Imperviousness
0
%
Centroid Distance
0
ft
Depression Stor. for Imp. Portion
0
in
Depression Stor. for Perv. Portion
0
in
DCIA Level
1
Fraction of Connected Impervious Area
0
Fraction of Receiving Pervious Area
0
Water Quality Capture Volume
0
in
Duration of WQCV Release
0
hr
Max. Infiltration Rate
0.0
in/hr
Min. Infiltration Rate
0.0
in/hr
Decay Constant
0.0
1/hr
Drying Time
0.0
day
Max. Volume
0.0
in
Time of Concentration
0.0
min
Rainfall Depth
0.0
in
Calculate
Close

- General inputs required for the runoff hydrograph:
  - **Unit System** – English or SI unit.
  - **Solving Target** – Choose runoff hydrograph.
  - **Equations** – Select one of the nine hydrograph generation options provided.
  - **SCS Rainfall Type** – Select any of the four NRCS rainfall types (i.e., Type I, Type IA, Type II, and Type III).

- **The inputs required for specific runoff hydrograph (Click the following for each methodology):**

- Colorado Urban Hydrograph Procedure (CUHP).
  - **Subcatchment Area** – Drainage area of the watershed.
  - **Subcatchment Slope**– Average slope of the watershed.
  - **Longest Flow Path** – Length of the longest overland flow path for the watershed.
  - **Subcatchment Imperviousness** – Percent imperviousness of the watershed.
  - **Centroid Distance** – Flow length to the centroid of the watershed.
  - **Depression Storage for Impervious Portion** – Depth of depression storage for the impervious portion of the watershed.
  - **Depression Storage for Pervious Portion** – Depth of depression storage for the pervious portion of the watershed
  - **DCIA Level** – Directly connected impervious area practice level. Input should be 1, 2, or 3.
  - **Fraction Of Connected Impervious Area** – Fraction of the impervious portion of the watershed that is directly connected to the watershed outlet.
  - **Fraction of Receiving Pervious Area** – Fraction of the pervious portion of the watershed that receives runoff from the impervious part of the watershed.
  - **Water Quality Capture Volume (WQCV) -** The water quality capture volume to be modeled as detained in swales and/or berms in the watershed.
  - **Duration of Water Quality Release** – Duration over which the WQCV is released in full.
  - **Maximum Infiltration Rate** – Initial (i.e., maximum) infiltration rate for Horton’s equation.
  - **Minimum Infiltration Rate** – Final (i.e., minimum) infiltration rate for Horton’s equation.

- **Decay Constant** – Exponential decay coefficient in Horton’s equation.
- **Drying Time** – The time it takes (in days) for a soil to fully dry and recover its infiltration rate to is initial infiltration rate.
- **Maximum Volume** – Maximum depth of water that can be retained by the soil.
- **Time of Concentration** – The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.
- **Rainfall Depth** – Depth of the design rainfall.

- NRCS Dimensionless UH, NRCS Triangular UH, and Delmarva UH
  - **Subcatchment Area** – Drainage area of the watershed.
  - **Subcatchment Slope**– Average slope of the watershed.
  - **Flow Length** – Length of the longest overland flow path for the watershed.
  - **NRCS Curve Number** – Value of CN for the watershed. See Table 3.11. It is a function of soil type, land use type and quality, and antecedent moisture condition.
  - **Time of Concentration** – The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed. If time of concentration is defined, slope, length, and CN values will not be required.
  - **Rainfall Depth** – Depth of the design rainfall.

- Clark Unit Hydrograph
    - **Subcatchment Area** – Drainage area of the watershed.
    - **Storage Coefficient** - A constant linear reservoir parameter that relates watershed storage to outflow from the watershed. Usually, it is approximated using lag time of the watershed.
    - **Time of Concentration** – The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.
    - **Rainfall Depth** – Depth of the design rainfall.

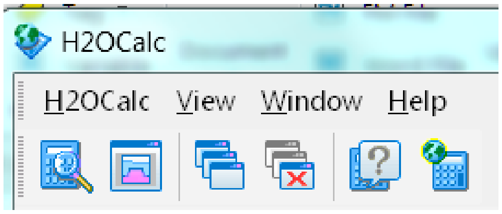
- Snyder Unit Hydrograph
    - **Subcatchment Area** – Drainage area of the watershed.
    - **Storage Coefficient** - An empirical storage coefficient indicated as Ct in the lag time equation (i.e. Equation 108).
    - **Longest Flow Path** – Length of the longest overland flow path for the watershed.
    - **Empirical Coefficient** - An empirical constant indicated as Cp in Equation 112.
    - **Centroid Distance** – Flow length to the centroid of the watershed.
    - **Rainfall Depth** – Depth of the design rainfall.

- Santa Barbara Hydrograph
    - **Subcatchment Area** – Drainage area of the watershed.
    - **Subcatchment Imperviousness** – Percent imperviousness of the subcatchment.
    - **Time of Concentration** – The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.
    - **Rainfall Depth** – Depth of the design rainfall.

- Espey Unit Hydrograph
  - **Subcatchment Area** – Drainage area of the watershed.
  - **Subcatchment Slope** – Average slope of the watershed.
  - **Longest Flow Path** – Length of the longest overland flow path for the watershed.
  - **Subcatchment Imperviousness** – Percent imperviousness of the subcatchment.
  - **Conveyance Factor** – See equation 122.
  - **Rainfall Depth** – Depth of the design rainfall.

- San Diego Modified Rational Hydrograph
  - **Subcatchment Area** – Drainage area of the watershed.
  - **Runoff Coefficient** – Rational formula runoff coefficient (see Table 3.9)
  - **6-hr Precipitation** – Six-hour design rainfall depth.
  - **Time of Concentration** – The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.

H2OCalc™
Modeling Made Easy



3.1 Energy Relation for Closed Conduit Flow

Conservation of energy involves a balance in total energy, expressed as head, between any upstream point of flow and a corresponding downstream point, including head losses caused by friction and the viscous dissipation of turbulence at bends and other appurtenances (i.e., form losses or minor losses). The energy equation states that the incoming energy plus the energy gain (addition) equals the outgoing energy plus the energy loss. The one-dimensional steady flow form of the energy equation is

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_t + h_L$$

where $\frac{P}{\gamma}$ = pressure head (m, ft)

$\frac{V^2}{2g}$ = velocity head (m, ft)

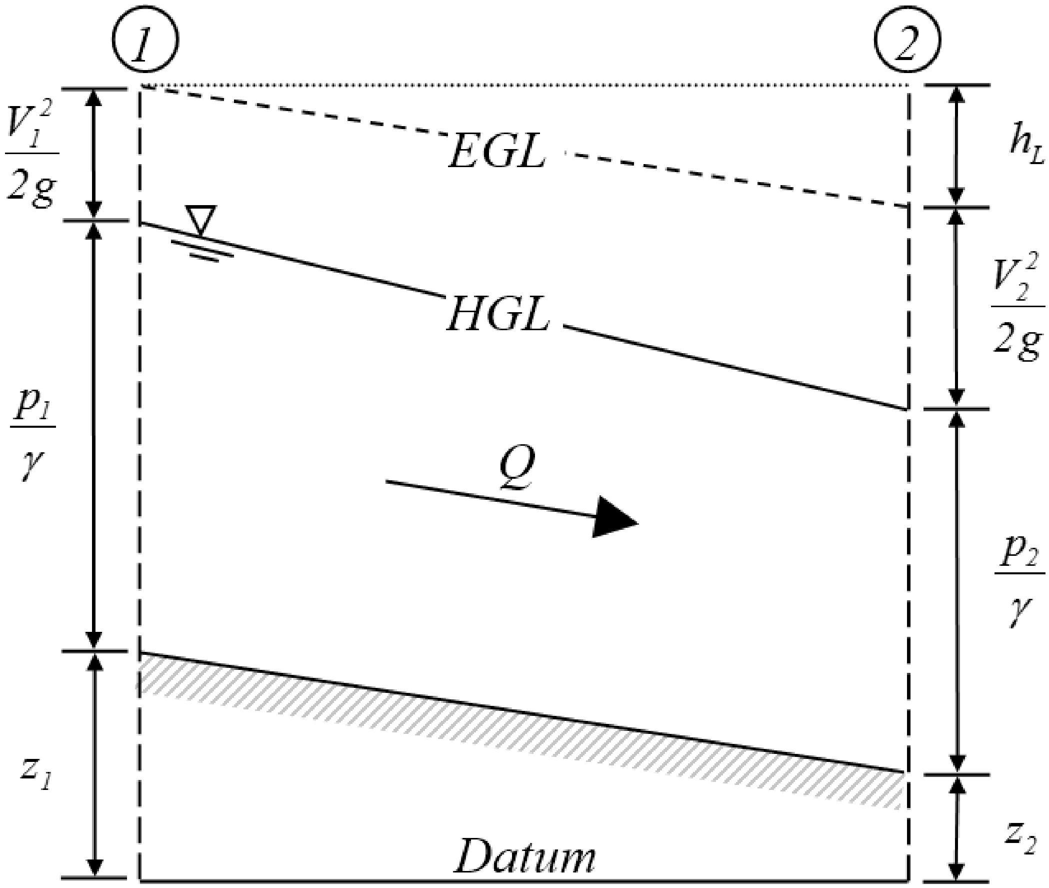
z = elevation (m, ft)

h_p = head supplied by a pump (m, ft)

h_t = head supplied to a turbine (m, ft)

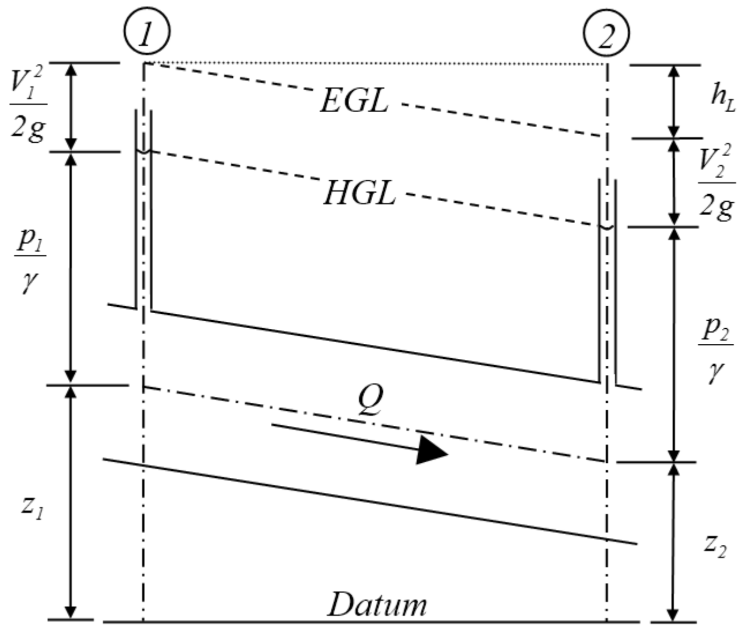
h_L = head loss between section 1 and 2 (m, ft)

A typical graphical representation of the terms in Equation (1) is shown in the following figure.



1
2
$\frac{V_1^2}{2g}$
EGL
h_L
HGL
$\frac{V_2^2}{2g}$
$\frac{p_1}{\gamma}$
Q
$\frac{p_2}{\gamma}$
z_1
z_2
Datum

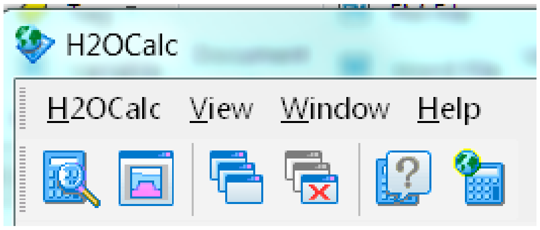
(a)



(b)

Definition Sketch for (a) Open Channel Flow, and (b) Pressurized Pipe Flow

H2OCalc™ Modeling Made Easy



3.2 Steady-Uniform Flow

Uniform flow is exhibited in a channel when there is no change of velocity along the channel. Because the velocity does not change, the velocity head will be constant; therefore, the energy grade line and water surface will have the same slope as the channel bottom. For the flow to be uniform, the channel must be straight and without change in slope or cross section along the length of the channel. Such a channel is called as a prismatic channel. When flow is uniform, the depth in the channel is called normal depth.

The following four equations can be used to compute average velocity based on uniform flow conditions.

- The Manning Equation
- The Chezy Equation
- Hazen-Williams Formula
- Darcy-Weisbach (Colebrook-White) Formula

Once average velocity is known, flow rate can be computed as follows from the Velocity and Cross Sectional Area

$$Q = VA$$

where Q = flow rate (m^3/s, ft^3/s)

V = average velocity (m/s, ft/s)

A = flow area (m^2, ft^2)

Manning Equation

Manning's equation is the most commonly used uniform flow computation method, and is expressed as

$$V = \frac{k}{n} R^{2/3} S^{1/2}$$

$$R = \frac{A}{P}$$

where	k	=	unit conversion factor (1.49 for English, and 1 for SI)
	V	=	mean velocity (m/s, ft/s)
	n	=	Manning's coefficient (see Table 3-1)
	R	=	hydraulic radius (m, ft)
	A	=	area of flow section (m^2, ft^2)
	P	=	wetted perimeter (m, ft)
	S	=	friction slope (m/m, ft/ft)

Table 3-1: Typical Values of Resistance Coefficients

Conduit material	e (Darcy-Weisbach)		C_h (Hazen-Williams)	n (Manning)
	(ft)	(m)		
Cast iron	8.5×10^{-4}	2.5×10^{-4}	130	0.013
Galvanized iron	5×10^{-4}	1.5×10^{-4}	120	0.016
Riveted steel	1.5×10^{-2}	4.5×10^{-3}	110	0.015
Welded steel	2×10^{-4}	6×10^{-5}	120	0.012
Galvanized iron	5×10^{-4}	1.5×10^{-4}	135	0.016
Brass, glass	5×10^{-6}	1.5×10^{-6}	135	0.011
Wood stave	6×10^{-4}	1.8×10^{-4}	120	0.012
Concrete pipe	4×10^{-3}	1.2×10^{-3}	110	0.013
Vitrified clay	6×10^{-3}	1.8×10^{-3}	110	0.013
PVC	5×10^{-6}	1.5×10^{-6}	140	0.009
Asbestos cement	5×10^{-6}	1.5×10^{-6}	140	0.013
Brick	2×10^{-3}	6×10^{-4}	100	0.015
Corrugated metal	1.5×10^{-1}	4.5×10^{-2}	60	0.024
Clay drainage tile	2.5×10^{-3}	7.5×10^{-4}	100	0.013
Smooth earth	-	-	-	0.018
Gravel	-	-	-	0.023
Natural channels	-	-	-	0.025 - 0.08

Source: Nicklow et al. (2004)

Chezy Equation

The Chezy equation is given as

$$V = C\sqrt{SR}$$

where C = Chezy roughness coefficient
R = hydraulic radius (m, ft)
S = friction slope (m/m, ft/ft)

Compared to the Manning Equation, C is given as $C = (k/n) \times R^{1/6}$

Hazen-Williams Formula

The Hazen-Williams formula is a popular method in the United States for uniform flow computation in pressurized flows.

$$V = kC_h R^{0.63} S^{0.54}$$

where	k	=	unit conversion factor (1.32 for English, and 0.85 for SI)
	C_h	=	Hazen-Williams roughness coefficient (see Table 3.1).

Darcy-Weisbach Equation

Darcy-Weisbach equation is given as

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

where	h_f	=	head loss (m, ft)
	f	=	Darcy-friction factor (see Table 3-1)
	L	=	pipe length (m, ft)
	D	=	pipe internal diameter (m, ft)
	V	=	velocity (m/s, ft/s)
	g	=	gravitational acceleration (m/s^2, ft/s^2)

For open channel flows, the diameter D can be replaced by hydraulic radius (R) as follows

$$D = 4R$$

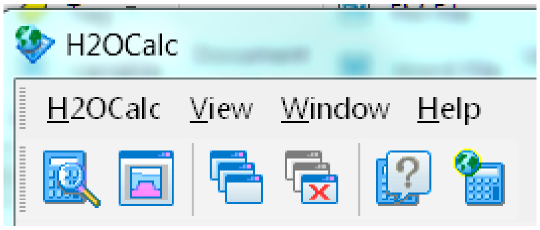
In terms of hydraulic radius and head loss slope ($S = h_f/L$), the Darcy-Weisbach equation can be given as

$$V = \sqrt{\frac{8gRS}{f}}$$

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

H2OCalc™
Modeling Made Easy



3.3 Moody Friction Factor Calculator

Darcy-Weisbach friction factor, *f*, can be evaluated in terms of equivalent sand grain roughness, *e*, and Reynolds number, Re. Reynolds number is a dimensionless ratio of inertial forces to viscous forces acting on flow and is defined for any cross-sectional shape as

$$\mathrm{Re} = \frac{VD}{\nu}$$

where ν = fluid's kinematic viscosity (m^2/s, ft^2/s) (see Table 3-2).

For Re < 2,000, flow is referred to as laminar; if Re > 4,000, flow is generally turbulent. If Re is between 2,000 and 4,000, the flow is in a transitional region.

For laminar flows, the friction factor, *f*, is defined as

$$f = \frac{64}{\mathrm{Re}}$$

Numerous formulas exist to determine the friction factor. The two most popular equations are the Colebrook-White (implicit) and the Swamee-Jain (explicit). The Colebrook-White equation is

$$\frac{1}{\sqrt{f}} = -0.86\ln\left(\frac{e}{3.7D} + \frac{2.51}{R_e\sqrt{f}}\right)$$

which must be solved iteratively. Swamee and Jain (1976) developed an explicit formula of the friction factor, *f*, for $4000 \le \mathrm{Re} \le 10^8$ (turbulent flow region) and $10^{-6} \le e/D \le 10^{-2}$ as

$$f = \frac{1.325}{\left[\ln\left(\frac{e}{3.7D} + \frac{5.74}{\mathrm{Re}^{0.9}}\right)\right]^2}$$

where	Re	=	Reynolds number
	V	=	velocity (m/s, ft/s)
	D	=	pipe diameter (m, ft)
	v	=	kinematic viscosity (m^2/s, ft^2/s) (see Table 3-2)
	e/D	=	relative roughness
	e	=	pipe roughness (m, ft) (see Table 3-1)

A cubic interpolation from the Moody diagram can be applied for the transitional flow range ($2000 \le \mathrm{Re} \le 4000$) as

$$f = X_1 + R\left[X_2 + R(X_3 + X_4)\right]$$

where $R = \mathrm{Re}/2000$

$$X_1 = 7F_A - F_B$$

$$X_2 = 0.128 - 17F_A + 2.5F_B$$

$$X_3 = -0.128 + 13F_A - 2F_B$$

$$X_4 = R(0.032 - 3F_A + 0.5F_B)$$

$$F_A = Y_3^{-2}$$

$$F_B = F_A\left(2 - \frac{0.00514215}{Y_2 Y_3}\right)$$

$$Y_2 = \frac{e}{3.7D} + \frac{5.74}{\mathrm{Re}^{0.9}}$$

$$Y_3 = -0.86859 \ln\left(\frac{e}{3.7D} + \frac{5.74}{4000^{0.9}}\right)$$

Procedure to find friction factor *f*

First, the relative roughness (*e*/*D*) and Reynolds number must be calculated. The Reynolds number is a function of kinematic viscosity of the fluid at the fluid's temperature. Table 3-2 lists the kinematic viscosity for water over a range of temperature. Then, determine relative roughness of the pipe. Table 3-1 can be used as a guide to estimate equivalent sand-grain roughness for various types of pipes. Then, calculate the friction factor using either of the equations described above depending on the flow regime (i.e. laminar, transitional, or turbulent) based on the Reynolds number.

Table 3-2: Kinematic Viscosity of Water

Temperature		SI	English
T(^oC)	T(^oF)	($m^2/s \times 10^{-7}$)	($ft^2/s \times 10^{-5}$)
0	32	17.7	1.91
10	50	13.0	1.40
20	68	10.1	1.09
30	86	8.03	0.86
40	104	6.58	0.71
50	122	5.52	0.59
60	140	4.72	0.51
70	158	4.13	0.44
80	176	3.65	0.39
90	194	3.25	0.35
100	212	2.95	0.32

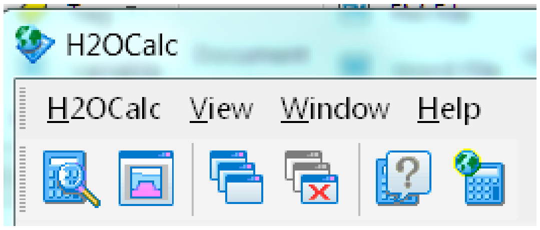
Source: Boulos et al. (2006)

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

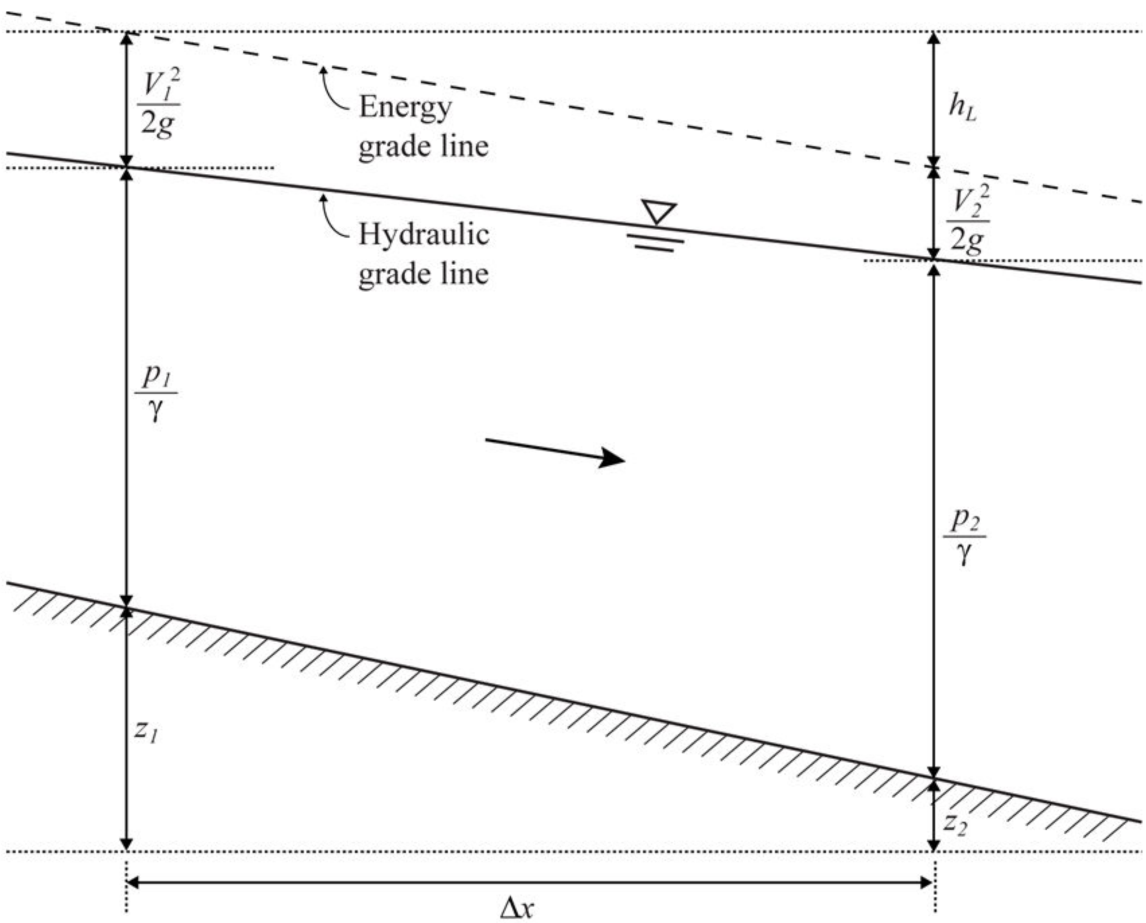
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

3.4 Gradually Varied Flow

Discussions in the previous sections have focused on uniform flow hydraulics where flow depth *y* and flow velocity *V* remain constant along the channel. In this section, we consider gradually varied flow, which is a form of steady nonuniform flow characterized by gradual variations in flow depth and velocity and a free surface that always remains smooth (no abrupt changes).



Definition Sketch for Gradually Varied Flows

The following equation represents the general energy equation for gradually varied flow (see the above figure), for a reach of Δx in length

$$z_1 + y_1 + \frac{V_1^2}{2g} = z_2 + y_2 + \frac{V_2^2}{2g} + h_L$$

where z = elevation head (m, ft)

$(V^2/2g)$ = velocity head (m, ft)

h_L = head loss (m, ft)

The friction slope S_f can be expressed using Manning's equation

$Q = KS_f^{1/2}$ where K is defined as the conveyance factor

$(1/n)AR^{2/3}$ in SI units or

$(1.486/n)AR^{2/3}$ in English units.

Hence

$$S_f = Q^2/\overline{K}^2$$

where

$\overline{K}$ is average of the upstream and the downstream conveyance factors.

Water surface profile for a channel can be generated by solving Equation (13). The channel would be divided into short reaches and computation for water surface elevation would be progressed from one end of the reach to the other end. The two most commonly used techniques for water surface profile computation are the direct step method and the standard step method. In the *direct step method*, depth at the other end of the reach is assumed and the length (Δx) of the reach would be evaluated based on known depth and velocity information at one end of the reach. In the contrary, the computation procedure of the *standard step method* involves determination of the depth based on predetermined reach length (Δx).

Equation 13 can be used to derive the following two alternative forms of the gradually-varied flow equations.

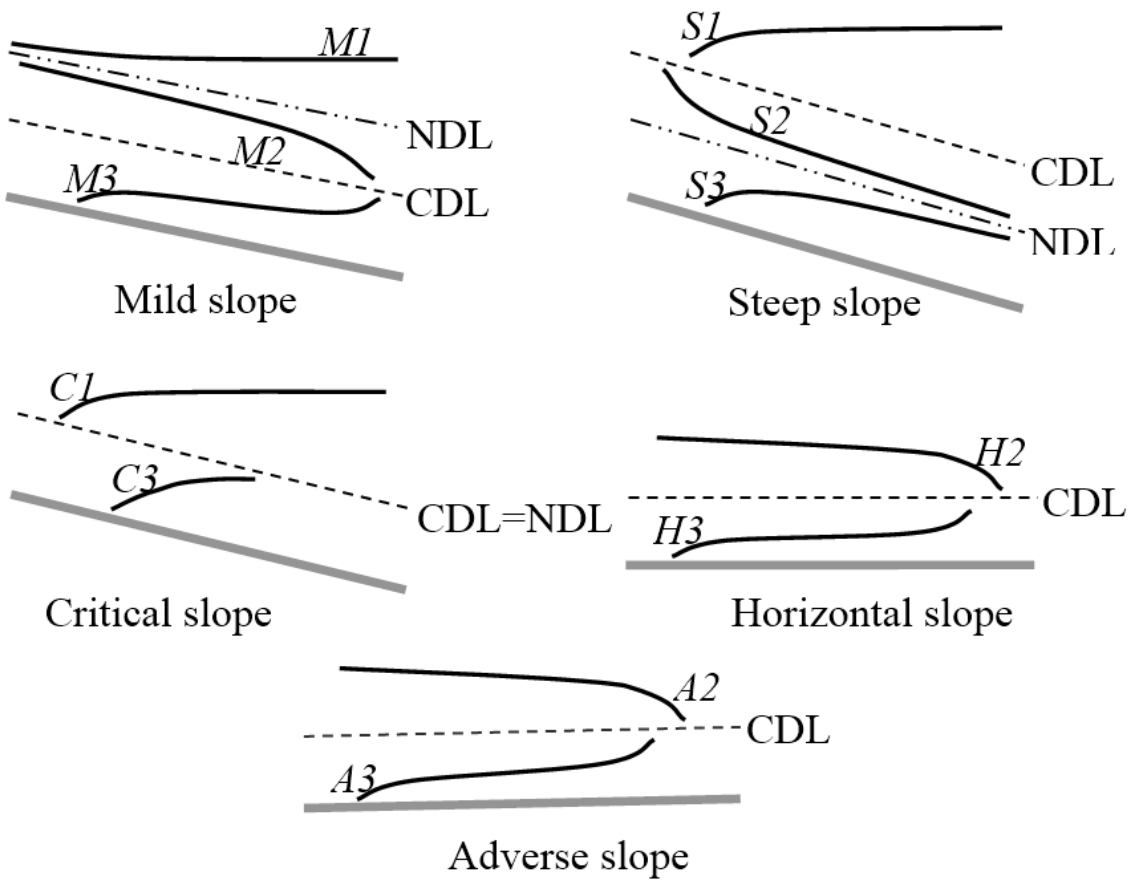
$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - \mathrm{Fr}^2}$$

where	S_0	=	is channel slope given as $(z_1 - z_2)/\Delta x$.
	S_f	=	friction slope
	Fr	=	Froude number ($V / \sqrt{gy_c}$)
	y_c	=	critical depth
	g	=	gravitational acceleration (m/s^2, ft/s^2)
	V	=	velocity (m/s, ft/s)

Equation 14 can be used to qualitatively evaluate gradually varied flow profiles on various channel slopes. The evaluation and subsequent classification of shapes is an important preliminary step to computing associated water surface profiles since it yields information about the location of hydraulic controls, the direction of computation (i.e., upstream for subcritical flow or downstream for supercritical flow), and whether depth is increasing or decreasing. Classification of profiles begins by establishing criteria upon which the water surface depends, namely slope of the channel and depth of flow relative to the critical and normal depths (i.e., y_c and y_n). The criteria are as follows:

- When $y_n > y_c$, the slope is mild and is designated as *M*
- When $y_n < y_c$, the slope is steep and is designated as *S*
- When $y_n = y_c$, the slope is critical and is designated as *C*
- If lines are drawn to represent the normal and critical depths (i.e., *NDL* and *CDL*), three regions of flow are created; Zone 1 is the region of largest depth, Zone 2 lies between the *NDL* and *CDL*, and Zone 3 lies adjacent to the channel bottom.

These criteria can be used to define the water surface profiles shown in the following figure. For example, an M1 profile exists when $y > y_n > y_c$. Under these conditions, Fr < 1 since $y > y_c$, and $S_f < S_o$ since $y > y_n$. Thus, the sign of the numerator and denominator in Equation 14 are both positive, and dy/dx must be positive. The implication is that depth will increase with x, typically referred to as a backwater curve. Flow will also approach the normal depth upstream. Alternatively, for an M2 profile, $y_n > y > y_c$, so that the sign of dy/dx must be negative. In this case, depth decreases with x, which represents a drawdown curve. Similar analyses can be made for other profiles. Note that horizontal and adverse slopes are unique cases in that the normal depth does not exist for either case. In addition, certain theoretical aspects of some profiles do not correlate well with realistic, physical behavior. For example, complete development of an M3 profile is unlikely; upstream flow cannot be zero, and the downstream end of the profile will likely be overcome by a hydraulic jump.

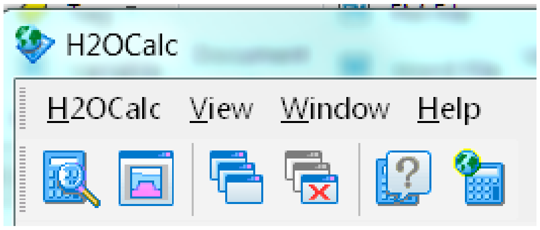


Gradually Varied Flow Classifications (*Adapted from Chow, 1959*)

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

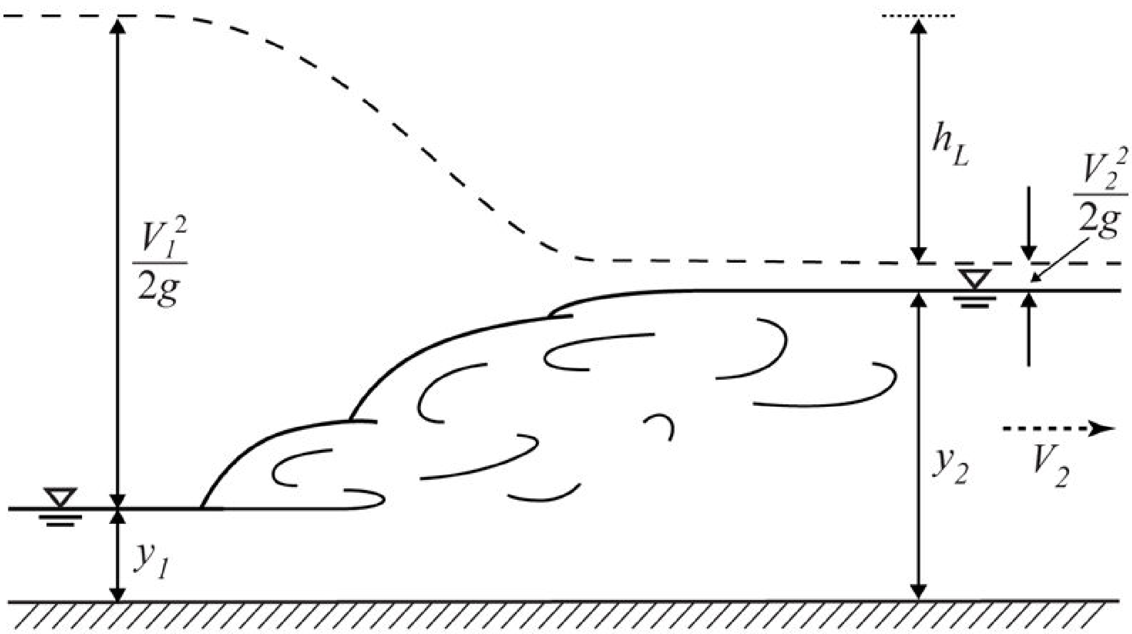
H2OCalc™

Modeling Made Easy



3.5 Hydraulic Jump

When the flow is Supercritical in an upstream section of a channel and is then forced to become subcritical in a downstream section, a rather abrupt change in depth usually occurs and considerable energy loss accompanies the process. This flow phenomenon, known as hydraulic jump, is described in the following figure.



Hydraulic Jump

If a hydraulic jump occurs in a rectangular channel, the depth y_2 (known as conjugate depth) is expressed as a function of y_1 and the Froude number (Fr) as follows:

$$y_2 = \frac{y_1}{2}\left(\sqrt{1+8\mathrm{Fr}_1^2} - 1\right)$$

where y_2 = water depth in the section 2 (m, ft)

y_1 = water depth in the section 1 (m, ft)

Fr_1 = Froude number at the section 1, defined as

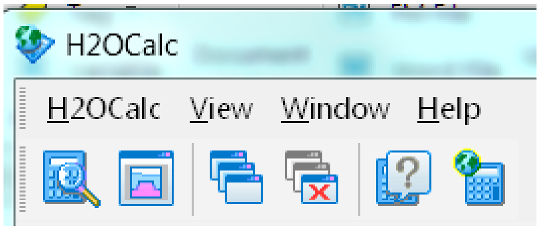
$$Fr_1 = \frac{V_1}{\sqrt{gy_1}}$$

where V_1 = upstream velocity [$V_1 = Q/(y_1 B)$] (m/s, ft/s)

B = channel bottom width (m, ft)

Q = flow (m^3/s, ft^3/s)

H2OCalc™
Modeling Made Easy



3.6 Pump Calculations

A Pump is used to augment head to the system (water distribution systems or waste water collection systems), and helps to lift water from low lying locations to a top of a hill or reservoir so that water could flow by gravity. The following figure shows an example pump configuration along with its corresponding energy and hydraulic grade lines (EGL and HGL).

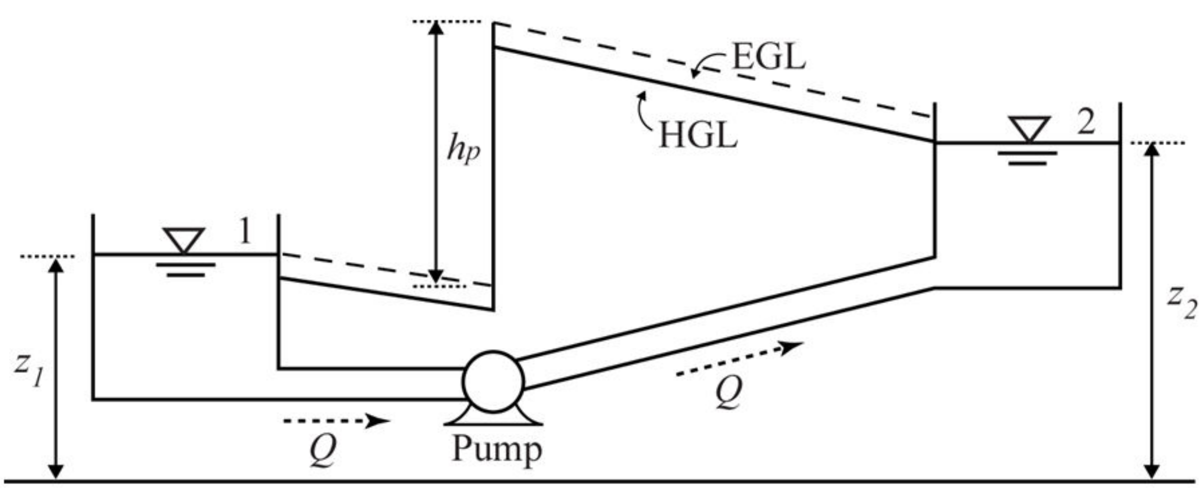
Application of the energy equation between the water surfaces yields

$$h_p = z_2 - z_1 + h_L$$

where h_p = head added by the pump (m, ft)

z = elevation with respect to a specified datum (m, ft)

h_L = total head loss including friction and form losses (m, ft)



Pump System

The term h_p is more widely referred to as the system head, or total dynamic head, that must be overcome before fluid can be lifted by the pump. Since the magnitude of losses is directly proportional with the flow rate, Equation (17) indicates that for a given discharge, a unique system head is needed to maintain flow. The relationship is referred to as the system equation. Following, description of pump power calculation, pump characteristic curve, pump torque calculation and pump affinity laws is given.

Pump Power

The head supplied by a pump to the system can be converted to water power, or output power as follows.

$$P_{water} = \frac{\gamma h_p Q}{K}$$

where *g* = specific weight of water (9810 N/m^3, 62.4 lb/ft^3)

Q = pump discharge (m^3/s, ft^3/s)

h_p = head added by the pump to the system (m, ft), see Equation (17)

P_{water} = water power supplied by pump (KW, hp)

K = unit conversion factor (1000 in SI, 550 in English)

Water power will always be less than the power supplied to the pump shaft, often referred to as the brake power. Brake power is expressed as

$$P_{brake} = \frac{P_{water}}{\eta} = \frac{\gamma h_p Q}{K\eta}$$

where P_{brake} = the power supplied to the pump (KW, hp)

η = the efficiency of the pump motor (the ratio of power supplied to the pump to the energy converted

to actual power in the flow)

Pump Torque

The relationship between the water power supplied by a pump and the torque exerted by the impeller on the water is expressed as

$$T = \frac{P_{brake} K}{\omega}$$

where T = torque (KN-m, lbf-ft)

w = pump speed in RPM

K = constant (9.55 in SI, and 5252 in English)

Pump Specific Speed

Pump specific speed (N_{sp}) is a dimensionless parameter used for preliminary selection of the type of pump that is most appropriate for a given application. The specific speed is defined as

$$N_{sp} = \frac{N\sqrt{Q}}{H^{3/4}}$$

where N = pump speed (rpm)

Q = flow rate (m^3/s, gpm)

H = pump head (m, ft)

Pump Characteristic Curve

Pump characteristic curves are usually presented graphically describing the relationship between pump head, h_p, and the flow rate, Q using either an exponential equation or 3-point quadratic form. The exponential pump characteristic curve is given as

$$h_p = h_c n_R^2 - \frac{K_P}{n_R^{b-2}} Q^b$$

where h_c = the pump cutoff head associated with the zero flow condition (m, ft)

K_p = resistance coefficient

b = flow exponent

n_R = pump speed ratio (the ratio of the actual pump speed to the rated pump

speed); for constant speed pump operation, n_R is equal to 1.

Given three h_p-Q points [h_c, ($h_{p,1}$, Q_1), ($h_{p,2}$, Q_2)], the pump curve can be calculated as

$$b = \log\left(\frac{h_c - h_{p,2}}{h_c - h_{p,1}}\right) \Bigg/ \log\left(\frac{Q_2}{Q_1}\right)$$

$$K_p = (h_c - h_{p,1}) / Q_1^b$$

If a single rated capacity (h_{rated}, Q_{rated}) is given, two more points can be added to the curve by assuming a shutoff head at zero flow equal to 133% of the design head and a maximum flow at zero head equal to twice the design flow. Then, the curve can be treated as a three-point curve.

The 3-point quadratic type of pump characteristic curve is

$$h_p = a_p n_R^2 + b_p n_R Q + c_p Q^2$$

where a_p, b_p, c_p are the coefficients of the quadratic curve.

The coefficients are calculated as

$$a_p = h_c$$

$$b_p = \frac{h_{p,1} - h_c}{Q_1} - c_p Q_1$$

$$c_p = \frac{\dfrac{h_{p,2} - h_{p,1}}{Q_2 - Q_1} - \dfrac{h_{p,1} - h_c}{Q_1}}{Q_2}$$

If pump are constructed from impellers and casings that are geometrically similar (same shape but scale to different size), their pump curves will vary in a predictable manner. Similarly, altering the motor speed that is driving a particular pump will also have a predictable effect. The so-called affinity or similarity laws describe the relationship between the pump flow, head, and motor speed. Knowledge of these relationships will accelerate selecting a pump/motor combination for a particular application.

$$\frac{h_{p,1}}{h_{p,2}} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^2 \left(\frac{D_{p,1}}{D_{p,2}}\right)^2$$

$$\frac{Q_1}{Q_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right) \left(\frac{D_{p,1}}{D_{p,2}}\right)^3$$

$$\frac{P_1}{P_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^3 \left(\frac{D_{p,1}}{D_{p,2}}\right)^5$$

where Q = pump flow (*Length*^{3}/*Time*)

n = pump speed (1/*Time*)

h_p = pump head (*Length*)

D = impeller diameter *Length*)

Using the above equations, variable speed pumps can be directly modeled by fixing the impeller diameter.

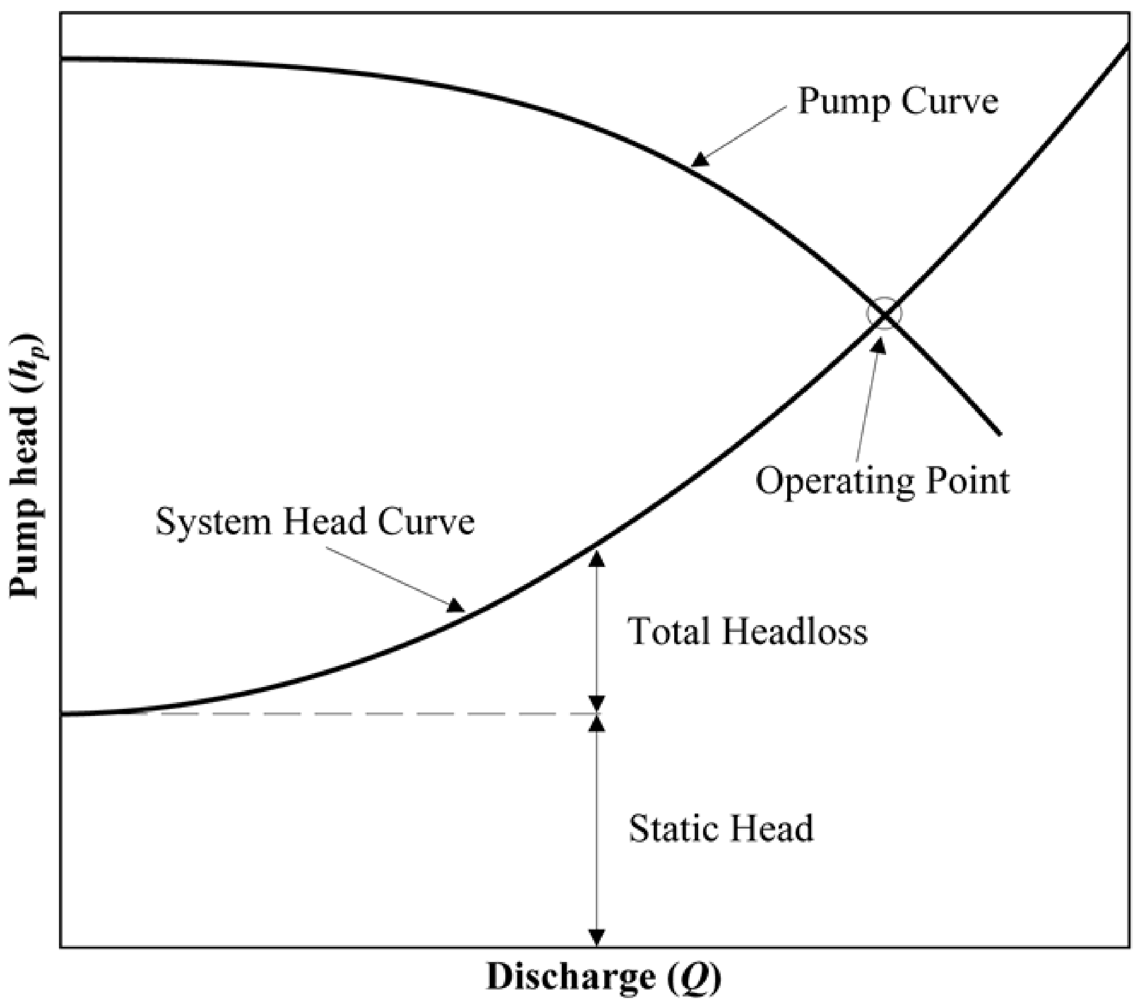
$$\frac{h_{p,1}}{h_{p,2}} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^2$$

$$\frac{Q_1}{Q_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right)$$

$$\frac{P_1}{P_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^3$$

System Head Curve

The ability to determine system head curves (sometimes called head capacity curves) is an essential task in the design of pumping systems. These curves are useful in determining the rating of the pumps and in assessing the number of pumps required and the type of drive to be used. Each curve describes the relationship between system head and capacity under identified conditions. More specifically, the curve represents the variation in total dynamic head against which the pumps will be required to operate under various flow conditions. The intersection of the system head curve (the resistance the pump must overcome) and the pump characteristic curve (head developed by the pump as a function of capacity) defines the point at which the pump will operate (see Figure below).



The solution of the energy equation gives the system curve as:

$$h_p = (H_2 - H_1) + h_{L,1} + h_{L,2} + h_{ML,1} + h_{ML,2}$$

where

$h_{L,1}$ is the head loss in pipe 1,

$h_{L,2}$ is the head loss in pipe 2,

$h_{ML,1}$ is the minor loss in pipe 1, and

$h_{ML,2}$ is the minor loss in pipe 2.

If the Hazen-Williams head loss expression and English units are used, this gives:

$$h_p = (H_2 - H_1) + \frac{4.73 L_1}{C_1^{1.852} D_1^{4.871}} Q^{1.852} + 0.02517 \frac{\sum K_1}{D_1} Q^2 + \frac{4.73 L_2}{C_2^{1.852} D_2^{4.871}} Q^{1.852} + 0.02517 \frac{\sum K_2}{D_2} Q^2$$

where $\sum K_i$

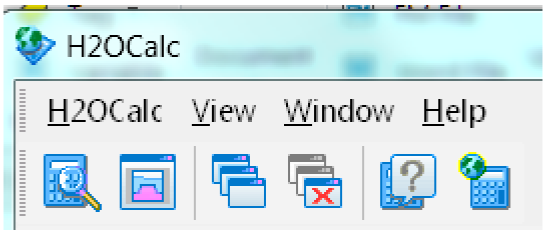
is the sum of the minor loss coefficients in pipe *i*.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Pump Specific Speed

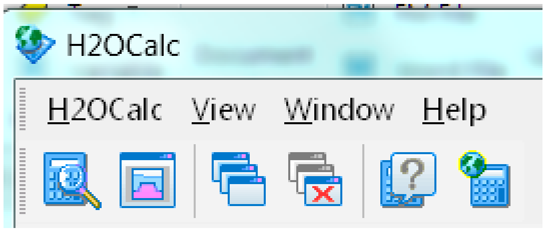
Pump specific speed (N_{sp}) is a dimensionless parameter used for preliminary selection of the type of pump that is most appropriate for a given application. The specific speed is defined as

$$N_{sp} = \frac{N\sqrt{Q}}{H^{3/4}}$$

where N = pump speed (rpm)

Q = flow rate (m^3/s, gpm)

H = pump head (m, ft)


H2OCalc
H2OCalc View Window Help

Pump Characteristic Curve

Pump Characteristic Curve

Pump characteristic curves are usually presented graphically describing the relationship between pump head, h_p, and the flow rate, Q using either an exponential equation or 3-point quadratic form. The exponential pump characteristic curve is given as

$$h_p = h_c n_R^2 - \frac{K_P}{n_R^{b-2}} Q^b$$

where h_c = the pump cutoff head associated with the zero flow condition (m, ft)

K_p = resistance coefficient

b = flow exponent

n_R = pump speed ratio (the ratio of the actual pump speed to the rated pump

speed); for constant speed pump operation, n_R is equal to 1.

Given three h_p-Q points [h_c, ($h_{p,1}$, Q_1), ($h_{p,2}$, Q_2)], the pump curve can be calculated as

$$b = \log\left(\frac{h_c - h_{p,2}}{h_c - h_{p,1}}\right) \Big/ \log\left(\frac{Q_2}{Q_1}\right)$$

$$K_p = (h_c - h_{p,1}) / Q_1^b$$

If a single rated capacity (h_{rated}, Q_{rated}) is given, two more points can be added to the curve by assuming a shutoff head at zero flow equal to 133% of the design head and a maximum flow at zero head equal to twice the design flow. Then, the curve can be treated as a three-point curve.

The 3-point quadratic type of pump characteristic curve is

$$h_p = a_p n_R^2 + b_p n_R Q + c_p Q^2$$

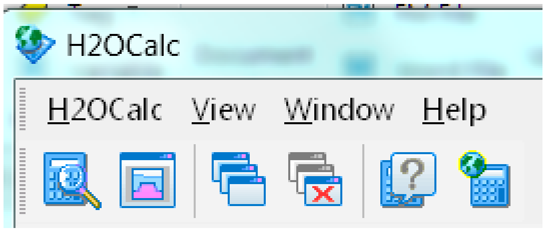
where a_p, b_p, c_p are the coefficients of the quadratic curve.

The coefficients are calculated as

$$a_p = h_c$$

$$b_p = \frac{h_{p,1} - h_c}{Q_1} - c_p Q_1$$

$$c_p = \frac{\dfrac{h_{p,2} - h_{p,1}}{Q_2 - Q_1} - \dfrac{h_{p,1} - h_c}{Q_1}}{Q_2}$$


H2OCalc
H2OCalc View Window Help

Pump Affinity Laws

If pump are constructed from impellers and casings that are geometrically similar (same shape but scale to different size), their pump curves will vary in a predictable manner. Similarly, altering the motor speed that is driving a particular pump will also have a predictable effect. The so-called affinity or similarity laws describe the relationship between the pump flow, head, and motor speed. Knowledge of these relationships will accelerate selecting a pump/motor combination for a particular application.

$$\frac{h_{p,1}}{h_{p,2}} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^2 \left(\frac{D_{p,1}}{D_{p,2}}\right)^2$$

$$\frac{Q_1}{Q_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right) \left(\frac{D_{p,1}}{D_{p,2}}\right)^3$$

$$\frac{P_1}{P_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^3 \left(\frac{D_{p,1}}{D_{p,2}}\right)^5$$

where Q = pump flow ($Length^3/Time$)

n = pump speed ($1/Time$)

h_p = pump head ($Length$)

D = impeller diameter $Length$)

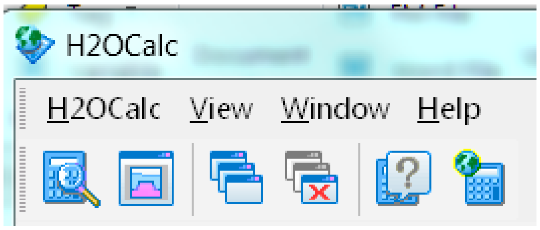
Using the above equations, variable speed pumps can be directly modeled by fixing the impeller diameter.

$$\frac{h_{p,1}}{h_{p,2}} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^2$$

$$\frac{Q_1}{Q_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right)$$

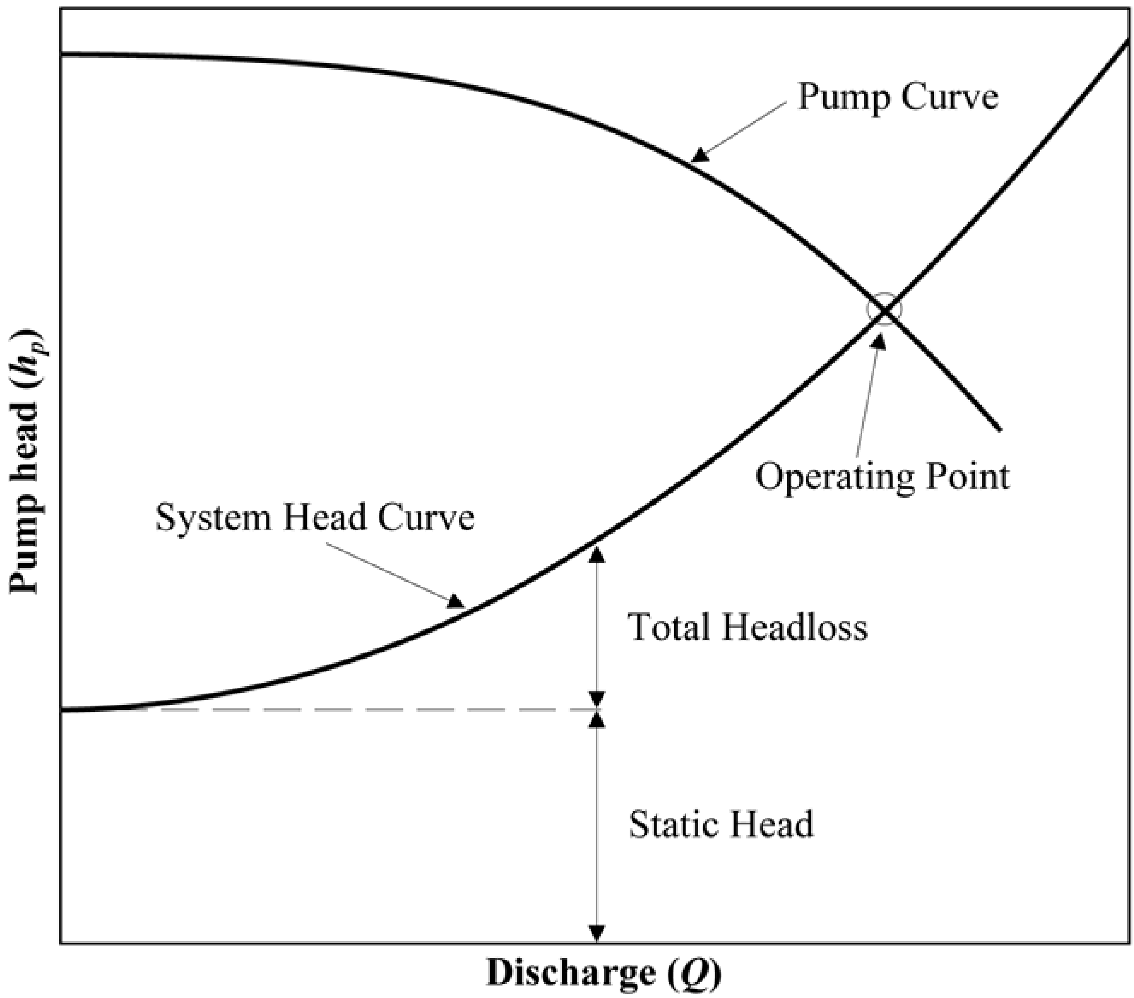
$$\frac{P_1}{P_2} = \left(\frac{n_{p,1}}{n_{p,2}}\right)^3$$

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

System Head Curve

The ability to determine system head curves (sometimes called head capacity curves) is an essential task in the design of pumping systems. These curves are useful in determining the rating of the pumps and in assessing the number of pumps required and the type of drive to be used. Each curve describes the relationship between system head and capacity under identified conditions. More specifically, the curve represents the variation in total dynamic head against which the pumps will be required to operate under various flow conditions. The intersection of the system head curve (the resistance the pump must overcome) and the pump characteristic curve (head developed by the pump as a function of capacity) defines the point at which the pump will operate (see Figure below).



The solution of the energy equation gives the system curve as:

$$h_p = (H_2 - H_1) + h_{L,1} + h_{L,2} + h_{ML,1} + h_{ML,2}$$

where

$h_{L,1}$ is the head loss in pipe 1,

$h_{L,2}$ is the head loss in pipe 2,

$h_{ML,1}$ is the minor loss in pipe 1, and

$h_{ML,2}$ is the minor loss in pipe 2.

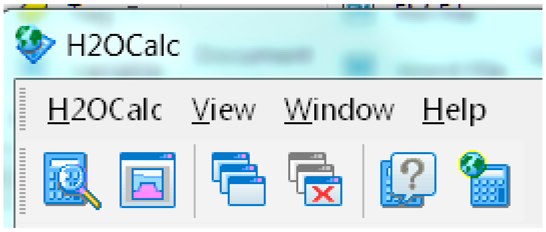
If the Hazen-Williams head loss expression and English units are used, this gives:

$$h_p = (H_2 - H_1) + \frac{4.73 L_1}{C_1^{1.852} D_1^{4.871}} Q^{1.852} + 0.02517 \frac{\sum K_1}{D_1} Q^2 + \frac{4.73 L_2}{C_2^{1.852} D_2^{4.871}} Q^{1.852} + 0.02517 \frac{\sum K_2}{D_2} Q^2$$

where $\sum K_i$

is the sum of the minor loss coefficients in pipe *i*.

H2OCalc™ Modeling Made Easy



3.7 Head loss due to Transitions and Fittings (Local loss)

Whenever flow velocity changes direction or magnitude in a conduit (e.g., at fittings, bends, and other appurtenances) added turbulence is induced. The energy associated with that turbulence is eventually dissipated into heat that produces a minor head loss, or local (or form) loss. The local (minor) loss associated with a particular fitting can be evaluated by

$$h_L = K\frac{V^2}{2g}$$

where V = mean velocity in the conduit (m/s, ft/s)

K = loss coefficient for the particular fitting involved.

The table given below provides the loss coefficients (K) for various transitions and fittings.

Table 3-3: Typical Minor Loss Coefficients

Type of form loss			K
Expansion	Sudden	$D_1 < D_2$	$\left[1-\left(\frac{D_1}{D_2}\right)^2\right]^2$
	Gradual	$D_1/D_2 = 0.8$	0.03
		$D_1/D_2 = 0.5$	0.08

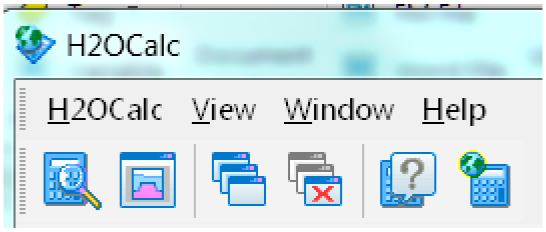
		$D_1/D_2 = 0.2$	0.13
Contraction	Sudden	$D_1 > D_2$	$0.5\left[1-\left(\frac{D_1}{D_2}\right)^2\right]^2$
	Gradual	$D_2/D_1 = 0.8$	0.05
		$D_2/D_1 = 0.5$	0.065
		$D_2/D_1 = 0.2$	0.08
Pipe entrance	Square-edge		0.5
	Rounded		0.25
	Projecting		0.8
Pipe exit	Submerged pipe to still water		1.0
Tee	Flow through run		0.6
	Flow through side outlet		1.8
Orifice	(Pipe diameter /orifice diameter)	$D/d = 4$	4.8
		$D/d = 2$	1.0
		$D/d = 1.33$	0.24

Venturi (long-tube)	(Pipe diameter /throat diameter)	D/d = 3	1.1
		D/d = 2	0.5
		D/d = 1.33	0.2
Bend	90^o miter bend with vanes		0.2
	90^o miter bend without vanes		1.1
	45^o miter bend		0.2
Type of form loss (continued)			*K*
Bend	45^o smooth bend: (bend radius /pipe diameter)	r/D = 1	0.37
		r/D = 2	0.22
		r/D = 4	0.2
	90^o smooth bend	r/D = 1	0.5
		r/D = 2	0.3
		r/D = 4	0.25
	Closed return bend		2.2
Sluice	Submerged port in wall		0.8
	As conduit contraction		0.5
	Without top submergence		0.2

Valve	Globe valve, fully open	10
	Angel valve, fully open	5.0
	Swing check valve, fully open	2.5
	Gate valve, fully open	0.2
	Gate valve, half open	5.6
	Butterfly valve, fully open	1.2
	Ball valve, fully open	0.1

Source: Nicklow and Boulos (2005)

H2OCalc™
Modeling Made Easy



3.8 Equivalent Length of Pipe Calculator

The local loss can be replaced with an equivalent length of pipe, while preserving its hydraulic equivalency. Minor losses can be expressed in terms of the equivalent length (L_{eq}) of pipe that would have the same head loss for the same discharge flow rate. This relationship can be found by equating the Darcy-Weisbach friction equation with the local loss equation.

$$L_{eq} = \frac{KD}{f}$$

where L_{eq} = equivalent length of pipe (m, ft)

D = pipe diameter (m, ft)

F = Darcy-Weisbach friction factor

K = minor loss coefficient

For non-circular conduit, D is replaced by $4R$.

where R = hydraulic radius ($R = A/P$) (m, ft)

A = cross-sectional area of flow section (m^2, ft^2)

P = wetted perimeter (m, ft)

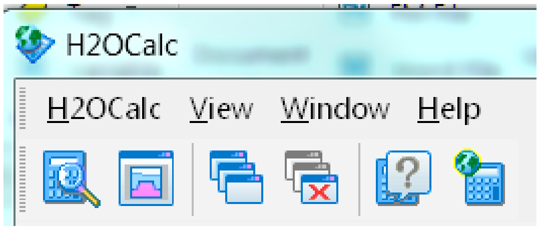
This equivalent length offers considerable benefits in terms of computational performance such as a reduction in model complexity, faster model development, and shorter run times. However, such a model representation should be carefully accessed since hydraulic equivalency is derived solely based on steady state network equilibrium theory. When applied to steady state network analysis, the equivalent length model can generate accurate flow and pressure results. Since the equivalent length modifies the travel time prediction, it should not be applied to water quality calculation and surge analysis.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

9. Orifice

An orifice is a restricted, sharp-edged opening through which fluid flows. In an orifice, flow streamlines converge a short distance downstream of the opening forming a vena contracta. As a result, the flow area at the vena contracta is slightly smaller than that of the orifice opening.

Discharge through an orifice can be expressed as

$$Q = CA\sqrt{2gH}$$

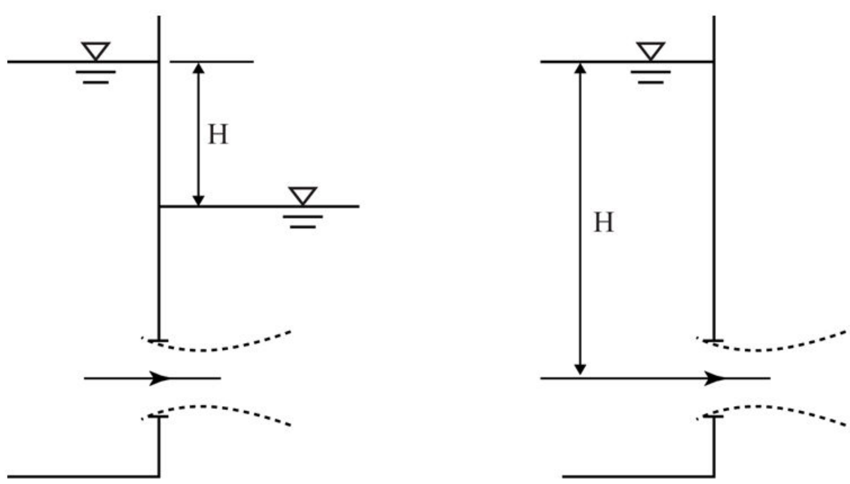
where Q = discharge (m3/s, ft3/s)

C = coefficient of discharge

A = flow area (m^2, ft^2)

g = gravitational acceleration (m/s^2, ft/s^2)

H = head (m, ft) (see the figure below)



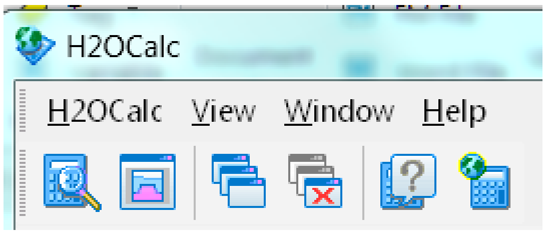
Orifice flow (a) Discharge to Downstream Reservoir; (b) Discharge to Atmosphere

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

10. Discharge from Tanks

Discharge from open tanks and pressurized tanks can be computed using Equation (36) (i.e., orifice equation). For pressurized tanks, the head causing the discharge (i.e., *H*) should incorporate the additional pressure, *p*, imparted on the fluid in the tank, and is computed as.

$$Q = CA\sqrt{2g\left(H + \frac{p}{\gamma}\right)}$$

where γ = specific weight of water (9810 N/m^3, 62.4 lb/ft^3)

p = gage pressure (N/m^2, lb/ft^2)

For a tank with constant cross-sectional area, the time required to empty the tank is

$$t = \frac{2A_t\sqrt{H}}{CA_o\sqrt{2g}}$$

where t = time (sec)

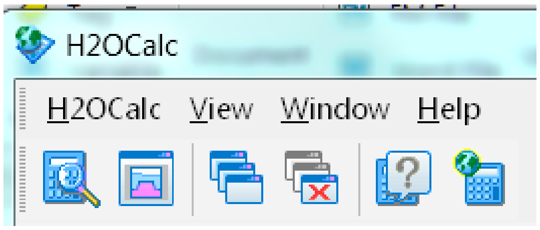
A_t = cross-sectional area of the tank (m^2, ft^2)

H = head (m, ft)

C = coefficient of discharge

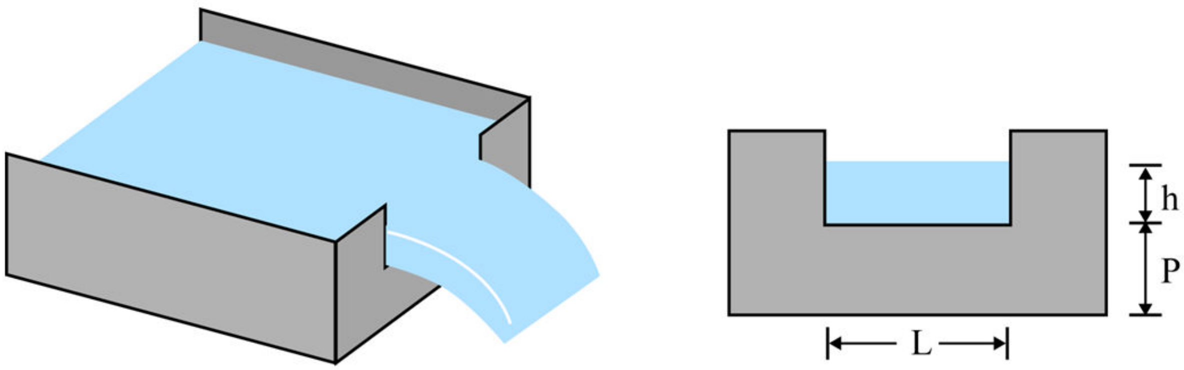
A_o = flow area (m^2, ft^2)

g = gravitational acceleration (m/s^2, ft/s^2)


H2OCalc
H2OCalc View Window Help

Rectangular Sharp-Crested Weir

A vertical thin plate with a straight top edge is referred to as *rectangular weir* since the cross section of the flow over the weir is rectangular (see the following figure).



Rectangular Weir

The discharge equation for a rectangular weir is given as

$$Q = CLh^{3/2}$$

where Q = discharge over the weir (m^3/s, ft^3/s)

h = head (m, ft)

L = weir length (m, ft)

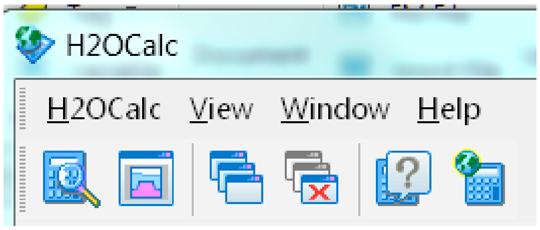
C = weir coefficient

$$[\sqrt{2g}(0.4 + 0.05h/P)]$$

typically given as 1.84 in SI, 3.33 in English.

Flow through the weir may not span the entire width of the channel (L) due to end contractions. Experiments have indicated that the reduction in length is approximately equal to 0.1nh, where n is the number of end contractions (e.g., could be 2 in the contracted rectangular weir), and *h* is head over the crest of the weir as defined above. Therefore, the formula for contracted weir (one with flow contraction due to end walls) is given as

$$Q = C(L - 0.1nh)h^{3/2}$$


H2OCalc
H2OCalc View Window Help

Cipolletti Sharp-Crested Weir

The *Cipolletti* (or trapezoidal) weir has side slopes of 4 vertical to 1 horizontal ratio as shown in the figure below. The discharge equation for a Cipolletti weir is given as

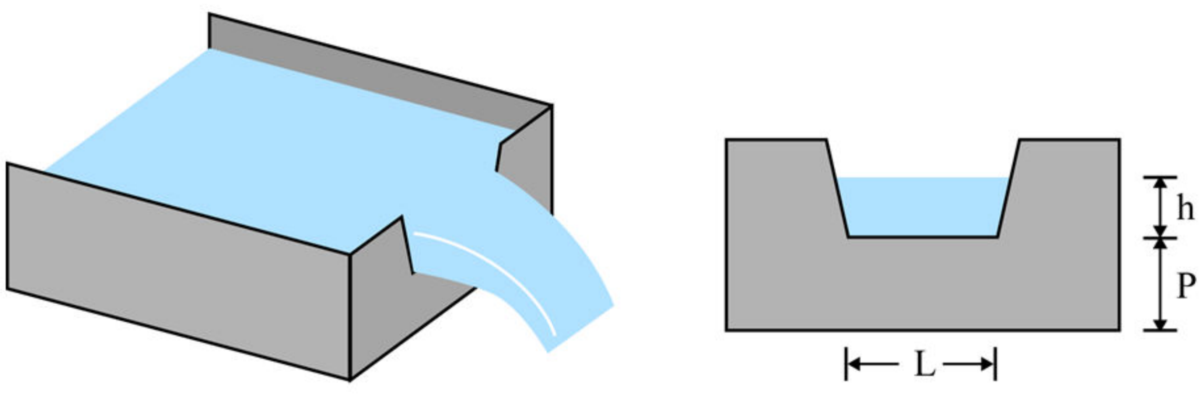
$$Q = CLh^{3/2}$$

where Q = discharge over weir (m^3/s, ft^3/s)

h = head (m, ft)

L = weir bottom length (m, ft)

C = the flow coefficient (1.86 in SI, 3.367 in English)



Cipolletti Weir

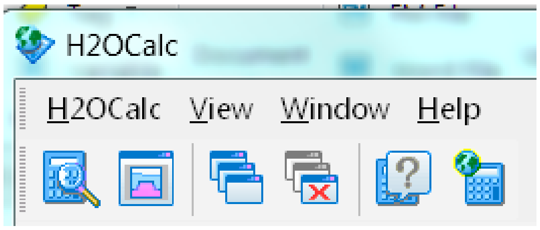
Notice that L is measured along the bottom of the weir (called the crest), not along the water surface.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

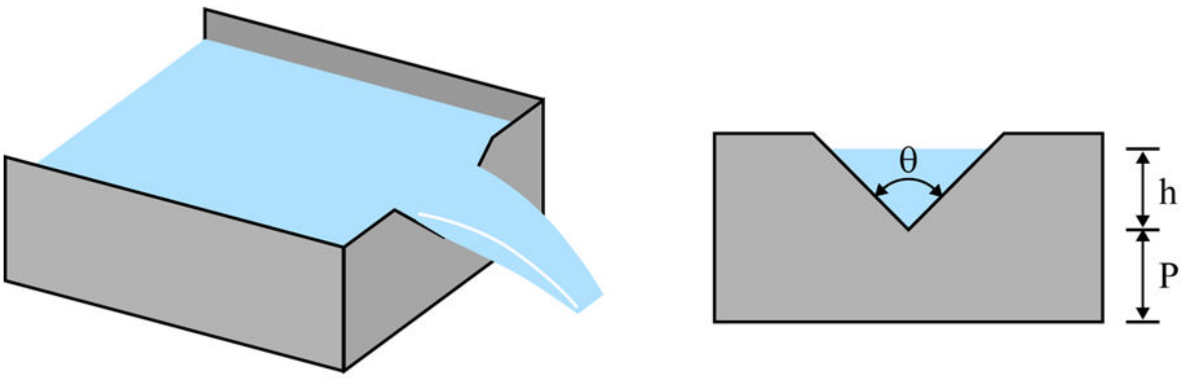
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

V-Notch Sharp-Crested Weir

With low flow rate, it is common to use a V-Notch weir (shown below).



V-Notch Weir

The discharge equation for a V-Notch weir is given as

$$Q = \frac{8}{15} C \sqrt{2g} \tan\left(\frac{\theta}{2}\right) h^{5/2}$$

where Q = discharge over weir (m^3/s, ft^3/s)

h = head (m, ft)

θ = angle of notch (degree)

C = the flow coefficient that typically range between 0.58 and 0.62.

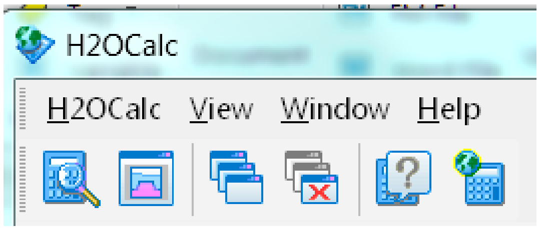
The most commonly used value of the notch angle θ is 90^o; for this case (i.e., θ is 90^o), C is found to be around 0.585.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Submerged Sharp-Crested Weir

The weir equations discussed above assume that the weir is free flowing. However, if the tailwater rises high enough, the weir will be submerged and the weir flow-carrying capacity will be reduced. Therefore, the discharge can be adjusted for submergence using the following equation:

$$Q_s = Q[1.0 - (h_s / h)^n]^{0.385}$$

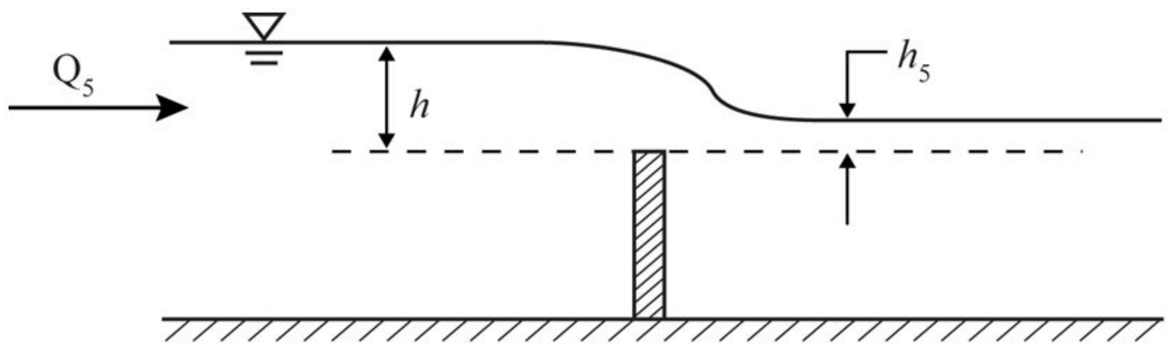
where Q_S = discharge over a submerged weir (m^3/s, ft^3/s)

Q = discharge computed using weir equations (m^3/s, ft^3/s)

h_S = tailwater depth above the weir crest (m, ft)

h = head upstream of the weir (m, ft)

n = exponent, 1.5 for rectangular and Cipolletti weirs, 2.5 for a triangular weir.



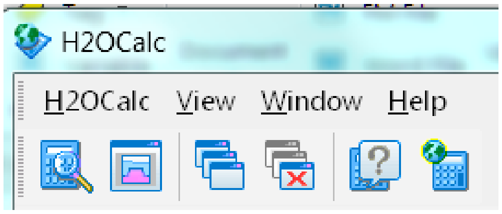
Submerged Weir

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

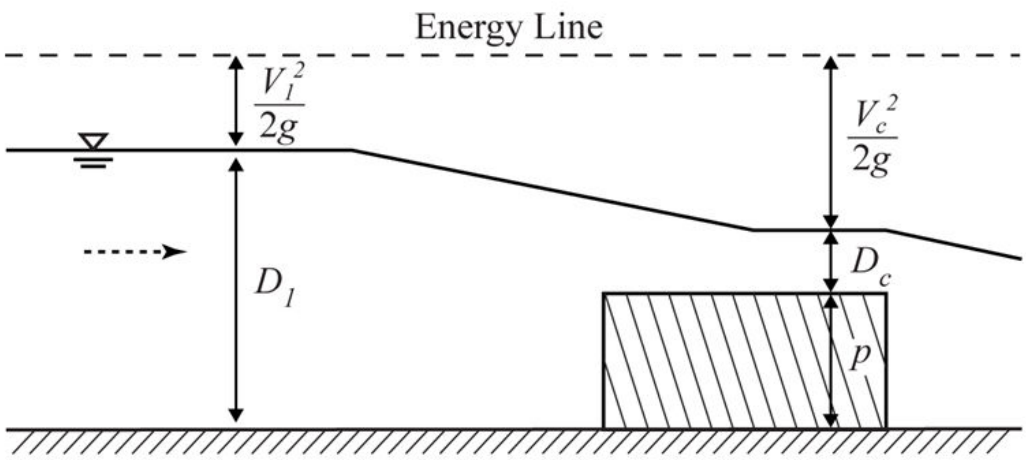
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Broad-Crested Weir

If the weir is long in the direction of flow so that the flow leaves the weir in essentially a horizontal direction, the weir is a broad-crested weir.



Broad-Crested Weir

The discharge equation for a broad crested weir is given as

$$Q = CLh^{3/2}$$

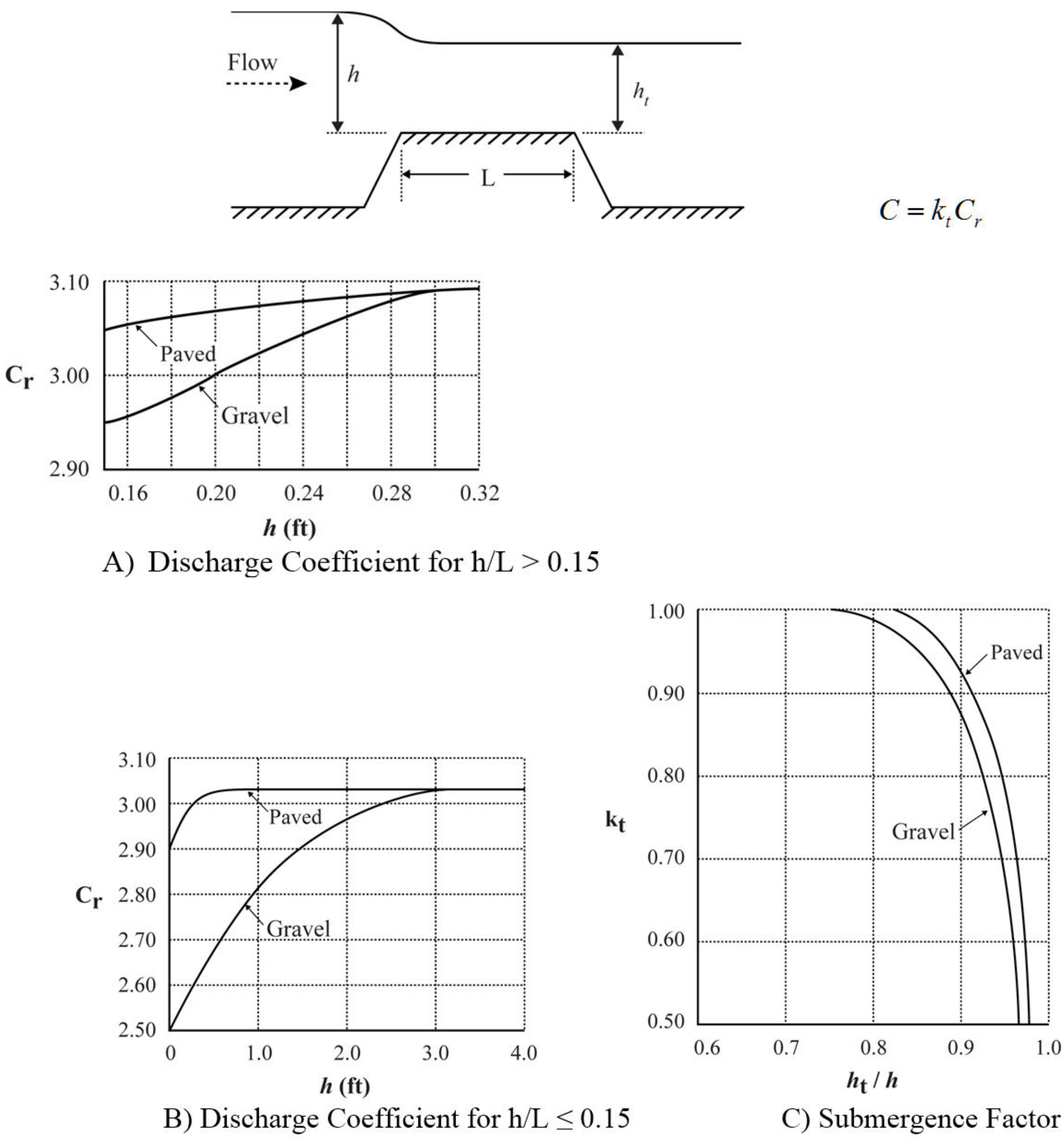
where Q = discharge over weir (m^3/s, ft^3/s)

h = head (m, ft)

L = crest length (m, ft)

C = the flow coefficient that typically range between 2.4 and 3.087.

The flow coefficient C can be obtained from the following figure. Depending on the shape of the weir and head on the weir, the C value may range from 2.4 to 3.1.



Broad-Crested Weir Discharge Coefficients (*Adapted from Normann et al., 1985*)

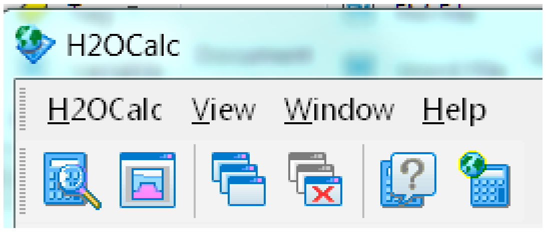
Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

Innovyze H2OCalc™ Modeling Made Easy Innovyze


H2OCalc
H2OCalc View Window Help

Generic Weir

Any other type of weirs can be modeled as generic weir using the following equation.

$$Q = CLh^{3/2}$$

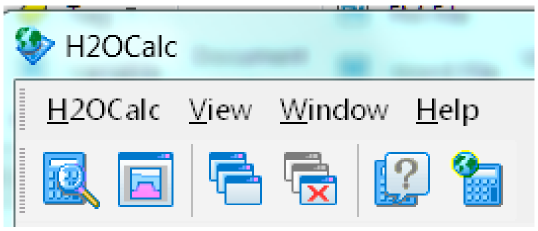
where Q = discharge over weir (m^3/s, ft^3/s)

h = head above weir crest (m, ft)

L = crest length (m, ft)

C = weir coefficient

The weir coefficient value depends on the weir type, and is the function of the head above the weir crest.


H2OCalc
H2OCalc View Window Help

Simplified Method

The simplified method classifies culvert flow into six different types on the basis of the type of control, the steepness of the barrel, the relative tailwater and headwater heights, and in some cases, the relationship between critical depth and culvert size. These parameters are quantified through the use of the ratios in Table 3.4. The six types are illustrated in the following figure.

For culverts flowing full, the friction loss (h_f) can be determined using the Darcy formula. For partial flow, the Manning equation can be used. The friction head loss between sections 1 and 2 (see the figure below), for example, can be calculated from Manning's equation as

$$h_{f,1-2} = \frac{LQ^2}{K_1 K_2}$$

where L = the culvert length

K = Conveyance factor and equals

$$\left(\frac{1.00}{n}\right) R^{2/3} A \text{ (SI)}, \left(\frac{1.49}{n}\right) R^{2/3} A \text{ (English)}$$

R = hydraulic radius (m, ft); $R = A/P$

A = cross-sectional area of flow section (m^2, ft^2)

P = wetted perimeter (m, ft)

N = Manning's coefficient

Table 3-4: Culvert Flow Classification Parameters

Flow type	$(h_1 - z)/D$	h_4/h_c	h_4/D	Culvert slope	Barrel flow	Location of control	Kind of control
1	< 1.5	< 1.0	≤ 1.0	steep	partial	Inlet	critical depth
2	< 1.5	< 1.0	≤ 1.0	mild	partial	outlet	critical depth
3	< 1.5	> 1.0	≤ 1.0	mild	partial	outlet	backwater
4	> 1.0		> 1.0	any	full	outlet	backwater
5	≥ 1.5		≤ 1.0	any	partial	inlet	entrance geometry
6	≥ 1.5		≤ 1.0	any	Full	outlet	entrance geometry

Adapted from Lindeburg (2003)

The total hydraulic head available, *H*, is divided between the velocity head in the culvert, the entrance loss (if considered), and the friction loss as follows

$$H = \frac{v^2}{2g} + k_e\left(\frac{v^2}{2g}\right) + \frac{v^2 n^2 L}{R^{4/3}} \quad \text{(SI)}$$

$$H = \frac{v^2}{2g} + k_e\left(\frac{v^2}{2g}\right) + \frac{v^2 n^2 L}{2.21R^{4/3}} \quad \text{(English)}$$

where k_e is the local loss for entrance.

Re-arranging Equations (46) and (48), velocity through the culvert can be given as

$$v = \sqrt{\frac{H}{\frac{1+k_e}{2g} + \frac{n^2 L}{R^{4/3}}}} \quad \text{(SI)}$$

$$v = \sqrt{\frac{H}{\frac{1+k_e}{2g} + \frac{n^2 L}{2.21 R^{4/3}}}} \quad \text{(English)}$$

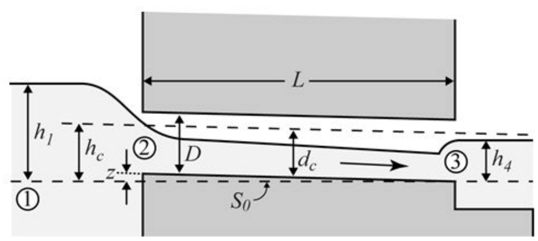
Type 1

Critical depth at inlet

$$\frac{h_1 - z}{D} < 1.5$$

$$\frac{h_4}{h_c} < 1.0$$

$S_0 > S_c$



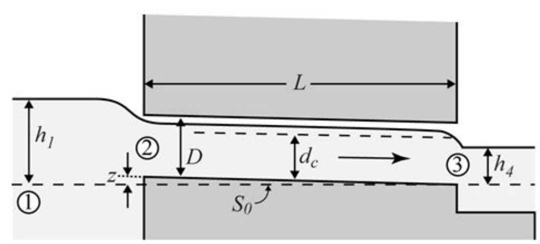
Type 2

Critical depth at outlet

$$\frac{h_1 - z}{D} < 1.5$$

$$\frac{h_4}{h_c} < 1.0$$

$S_0 < S_c$



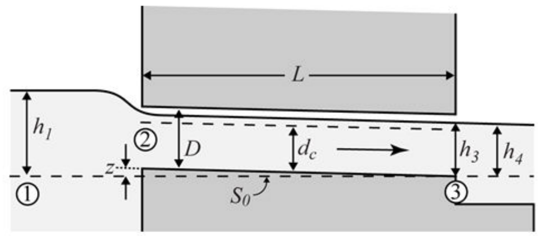
Type 3

Tranquil flow throughout

$$\frac{h_1 - z}{D} < 1.5$$

$$\frac{h_4}{D} \leq 1.0$$

$$\frac{h_4}{h_c} > 1.0$$

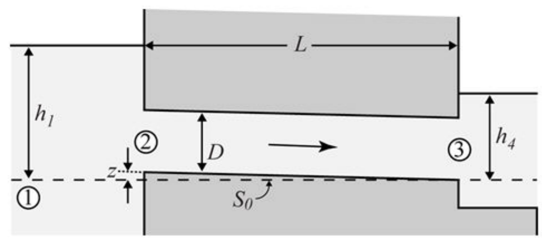


Type 4

Submerged outlet

$$\frac{h_1 - z}{D} > 1.0$$

$$\frac{h_4}{D} > 1.0$$

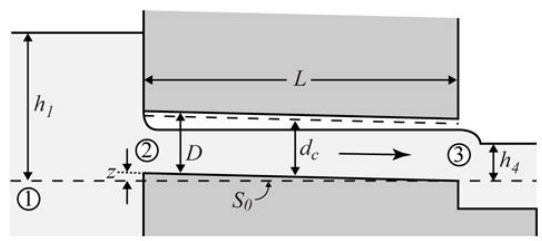


Type 5

Rapid flow at inlet

$$\frac{h_1 - z}{D} \geq 1.5$$

$$\frac{h_4}{D} \leq 1.0$$

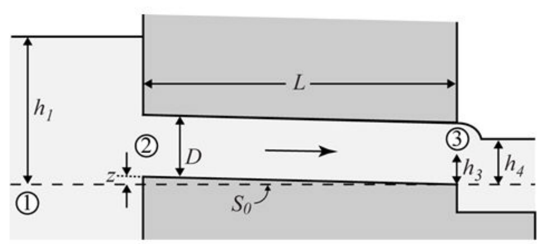


Type 6

Full flow, free outfall

$$\frac{h_1 - z}{D} \geq 1.5$$

$$\frac{h_4}{D} \leq 1.0$$



Culvert Flow Classification (*Adapted from Lindeburg, 2003*)

A. Type-1 Flow

Water passes through the critical depth near the culvert entrance, and the culvert flows partially full. The slope of the culvert barrel is greater than the critical slope, and the tailwater elevation is less than the elevation of the water surface at the control section.

$$Q = C_d A_c \sqrt{2g\left(h_1 - z + \frac{\alpha v_1^2}{2g} - d_c - h_{f,1-2}\right)}$$

where Q = discharge from the culvert (m^3/s, ft^3/s)

C_d = discharge coefficient

v_1 = average velocity of the water approaching the culvert entrance

α = velocity-head coefficient (i.e., assumed as 1.0)

d_c = the critical depth

A_c = flow area at the critical section, not the culvert area

B. Type-2 Flow

As in Type-1 flow, flow passes through the critical depth at the culvert outlet, and the barrel flows partially full. The slope of the culvert is less than critical, and the tailwater elevation does not exceed the elevation of the water surface at the control section.

$$Q = C_d A_c \sqrt{2g\left(h_1 + \frac{\alpha v_1^2}{2g} - d_c - h_{f,1-2} - h_{f,2-3}\right)}$$

C. Type-3 Flow

When backwater is the controlling factor in culvert flow, the critical depth cannot occur. The upstream water surface elevation for a given discharge is a function of the height of the tailwater. For Type-3 flow, flow is subcritical for the entire length of the culvert, with the flow being partial. The outlet is not submerged, but the tailwater elevation does exceed the elevation of critical depth at the terminal section.

$$Q = C_d A_3 \sqrt{2g\left(h_1 + \frac{\alpha v_1^2}{2g} - h_3 - h_{f,1-2} - h_{f,2-3}\right)}$$

where A_3 is the flow area at section 3 (i.e., the exit).

D. Type-4 Flow

As in Type-3 flow, the backwater elevation is the controlling factor in this case. Critical depth cannot occur, and the upstream water surface elevation for a given discharge is a function of the tailwater elevation. Discharge is independent of barrel slope. The culvert is submerged at both the headwater and the tailwater.

$$Q = C_d A_o \sqrt{2g\left(\frac{h_1 - h_4}{1 + \frac{29 C_d^2 n^2 L}{R^{4/3}}}\right)}$$

where A_o is the culvert area. The complicated term in the denominator corrects for friction. For rough estimates and for culverts less than 50 ft long, the friction loss can be ignored.

$$Q = C_d A_o \sqrt{2g(h_1 - h_4)}$$

E. Type-5 Flow

Partially full flow under a high head is classified as Type-5 flow. The flow pattern is similar to the flow downstream from a sluice gate, with rapid flow near the entrance. Usually, Type-5 flow requires a relatively square entrance that causes contraction of the flow area to less than the culvert area. In addition, the barrel length, roughness, and bed slope must be sufficient to keep the velocity high throughout the culvert.

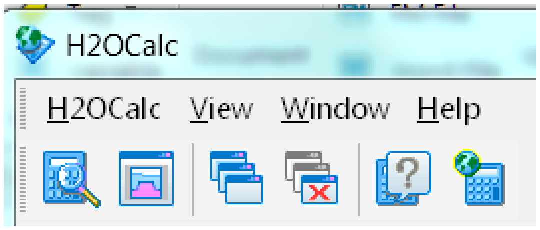
$$Q = C_d A_o \sqrt{2g(h_1 - z)}$$

F. Type-6 Flow

Type-6 flow, like Type-5 flow, is considered a high-head flow. The culvert is full under pressure with free outfall.

$$Q = C_d A_c \sqrt{2g(h_1 - h_3 - h_{f,2-3})}$$

Note that distance $h_3$is undefined. For conservative first approximations, h_3 can be taken as the barrel diameter.


H2OCalc
H2OCalc View Window Help

FHWA Method

The Federal Highway Administration (FHWA) offers equations as well as nomographs that can be used for analysis and design of culverts. Different equations and nomographs are developed for inlet controlled culvert flows and outlet controlled culvert flows. Only equation based analysis and design approaches are described in this section. Readers interested in the FHWA nomographs, for both control types, may refer to Normann et al. (1985).

Culvert design according to FHWA involves analyzing the culvert under both inlet control and outlet control conditions and selecting the control type that yields the worst condition (i.e., larger headwater depth). The design would be acceptable if the governing headwater depth is less than the maximum allowable headwater to avoid flooding of streets and property. Otherwise, the design needs to be revised (e.g., culvert size is increased) to reduce the headwater depth.

Inlet Control

The objective is to determine the headwater depth based on predetermined design discharge and a trial culvert size. The design equation used to determine headwater depth for inlet controlled culvert vary depending on the flow condition at the inlet of the culvert. If the inlet is submerged, the flow type would be orifice flow. Unsubmerged conditions will behave as a weir flow.

If the inlet is submerged (orifice flow), the equation to determine the headwater depth will be

$$\frac{HW_i}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^2 + Y + Z \quad \text{for} \quad \left[\frac{Q}{AD^{0.5}}\right] \geq 4.0$$

where HW_i = headwater depth above the inlet control section invert (ft) D = diameter of the culvert (ft)

Q = discharge (ft^3/s)

A = full cross-sectional area of the culvert (ft^2) c, Y = constant from Table 3.5

Z = culver barrel slope term (ft/ft).

For mitered inlets,

$$Z = 0.7S^2$$

and for all other conditions (i.e., inlet types other than mitered inlets),

$$Z = -0.5S^2$$

The unsubmerged flow (weir flow) condition can be evaluated using one of the following two approaches:

1) Based on specific head (H_c) at critical depth

$$\frac{HW_i}{D} = \frac{H_c}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^M + Z \quad \text{for} \quad \left[\frac{Q}{AD^{0.5}}\right] \leq 3.5$$

$$H_c = d_c + \frac{V_c^2}{2g}$$

where H_c = specific head at critical depth (ft)

K and M = constants from Table 3.5

d_c = critical depth (ft)

V_c = critical velocity (ft/sec)

2) A simpler form that ignores specific head (H_c) at critical depth

$$\frac{HW_i}{D} = \left[\frac{Q}{AD^{0.5}}\right]^M \quad \text{for} \quad \left[\frac{Q}{AD^{0.5}}\right] \leq 3.5$$

Table 3-5: Constants for Inlet Control Design Equations

Shape and material	**Inlet Edge Description**	***K***	***M***	***c***	***Y***
Circular Concrete	Square edge w/ headwall	0.0098	2.000	0.0398	0.67
	Groove end w/ headwall	0.0078	2.000	0.0292	0.74
	Groove end projecting	0.0045	2.000	0.0317	0.69
Circular CMP	Headwall	0.0078	2.000	0.0379	0.69
	Mitered to slope	0.0210	1.330	0.0463	0.75
	Projecting	0.0340	1.500	0.0553	0.54
Circular Ring	Beveled ring, 45^0 bevels	0.0018	2.500	0.0300	0.74
	Beveled ring 33.7^0 bevels	0.0018	2.500	0.0243	0.83
Rectangular Box	30^0 - 75^0 wingwall flares	0.0260	1.000	0.0385	0.81
	90^0 and 15^0 wingwall flares	0.0610	0.750	0.0400	0.80
	0^0 wingwall flares	0.0610	0750	0.0423	0.82

Rectangular Box	45^0 wingwall flare	0.5100	0.667	0.0309	0.80
	18^0 - 33.7^0 wingwall flare	0.4860	0.667	0.0249	0.83
Rectangular Box	90^0 headwall w/¾ in chamfers	0.5150	0.667	0.0375	0.79
	90^0 headwall w/ 45^0 bevels	0.7950	0.667	0.0314	0.82
	90^0 headwall w/33.7^0 bevels	0.4860	0.667	0.0252	0.87
Rectangular Box	¾ in chamfers, 45^0 skewed headwall	0.5220	0.667	0.0402	0.73
	¾ in chamfers, 30^0 skewed headwall	0.5330	0.667	0.0425	0.71
	¾ in chamfers, 15^0 skewed headwall	0.5450	0.667	0.0451	0.68
	45^0 bevels, 10-45^0 skewed wall	0.4980	0.667	0.0327	0.75
Rectangular Box, ¾ in. chamfers	45^0 non offset wingwall flares	0.4970	0.667	0.0339	0.80
	18.4^0 non offset wingwall flares	0.4930	0.667	0.0361	0.81
	18.4^0 non offset wingwall flares, 30^0 skewed barrel	0.4930	0.667	0.0386	0.71

Rectangular Box, top bevels	45^0 wingwall flares-offset	0.4970	0.667	0.0302	0.84
	33.7^0 wingwall flares - offset	0.4950	0.667	0.0252	0.88
	18.4^0 wingwall flares - offset	0.4930	0.667	0.0227	0.89
Corrugated Metal Boxes	90^0 headwall	0.0083	2.000	0.0379	0.69
	Thick wall projecting	0.0145	1.750	0.0419	0.64

Adapted from Normann et al. (1985)

Outlet Control

Headwater for outlet control conditions can be determined using energy equation based on tailwater depth and head loss through the culvert considering entrance loss, exit loss, and friction loss.

$$HW_i = H + h_0$$

$$H = \left(1 + k_e + \frac{29n^2 L}{R^{1.33}}\right)\frac{V^2}{2g} = h_{exit} + h_{entry} + h_f$$

$$h_0 = \max\left[TW, (d_c + D)/2\right]$$

$$d_c = \sqrt[3]{q^2/g}$$

where H = total head loss (ft)

k_e = entrance loss coefficient (see Table 3.6)

h_o = water depth at the outlet of the culvert (ft)

d_c = critical depth (ft)

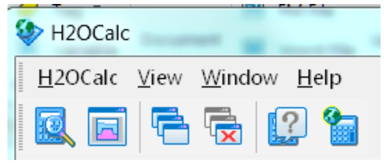
q = unit discharge (discharge per unit width of the culvert) ($ft^3/s/ft$)

Table 3-6: Entrance Loss Coefficients-Outlet Control, Full or Partly Full

Type of Structures and Design of Entrance		Coefficient k_e
Pipe, Concrete	Mitered to conform to fill slope	0.7
	End-section conforming to fill slope	0.5
	Projecting from fill, square cut end	0.5
	Headwall or headwall and wingwalls	
	Square Edge	0.5
	Rounded(radius= 1/12 Culvert Diameter	0.2
	Socket End of Pipe (groove-end)	0.2
	Projecting from fill, socket end (groove-end)	0.2
	Beveled edges, 33.7^0 or 45^0 bevels	0.2
	Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	Projecting from fill (no metal)	0.9
	Mitered to conform to fill slope, paved or unpaved slope	0.7
	Headwall or headwall and wingwalls square-edge	0.5
	End-section conforming to fill slope	0.5
	Beveled edges, 33.7^0 or 45^0 bevels	0.2
	Side- or slope-tapered inlet	0.2

Box, Reinforced Concrete	Wingwalls parallel (extension of sides) Square edge at crown	0.7
	Wingwalls at 10^0-25^0 or 30^0-75^0 to barrel Square-edged at crown	0.5
	Headwall parallel to embankment (no wingwalls) Square-edged on three edges Rounded on three edges to radius of 1/12 barrel dimension, or beveled edges on three sides	0.5 0.2
	Wingwalls at 30^0-75^0 to barrel Crown edge rounded to radius of 1/12 barrel dimension, or beveled to edges	0.2
	Side- or slope-tapered inlet	0.2

Adapted from Normann et al. (1985)

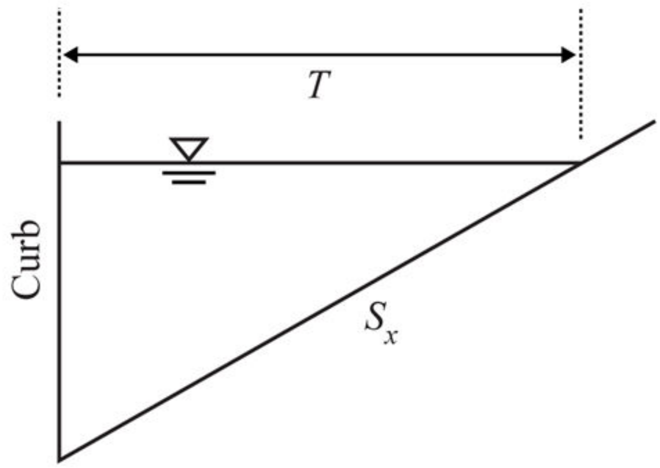

H2OCalc
H2OCalc View Window Help

Gutter Flow

Gutters are the sections of roadway that run adjacent to the curb. Their purpose is to collect and convey surface runoff to drainage inlets and in turn to underground storm sewers. The corresponding spread of water onto the pavement, or top width of flow measured perpendicular to the edge of the roadway, is a primary concern from an analysis perspective. The lateral cross slope of a traffic lane facilitates drainage of incident rainfall to the gutter. Depending on the cross slope, conventional gutters may be grouped as uniform gutter (i.e., has uniform cross slope) or composite gutters (i.e., has multiple cross slopes).

Uniform Gutter Sections

Uniform gutters have a shallow, triangular cross section, with a curb forming the near-vertical leg of the triangle as shown in the following figure.



Uniform Gutter Shapes

The governing equation for uniform gutters is given as

$$Q = \frac{K_c}{n} S_x^{5/3} S^{1/2} T^{8/3}$$

where Q = gutter flow rate (m^3/s, ft^3/s)

K_c = empirical constant (0.376 in SI, 0.56 in English)

n = Manning's roughness coefficient

S_x = gutter cross slope (m/m, ft/ft)

S_L = longitudinal slope of the road way (m/m, ft/ft)

T = spread (m, ft)

Spread T is related to depth at the curb, d, and flow area, A, by

$$d = TS_x$$

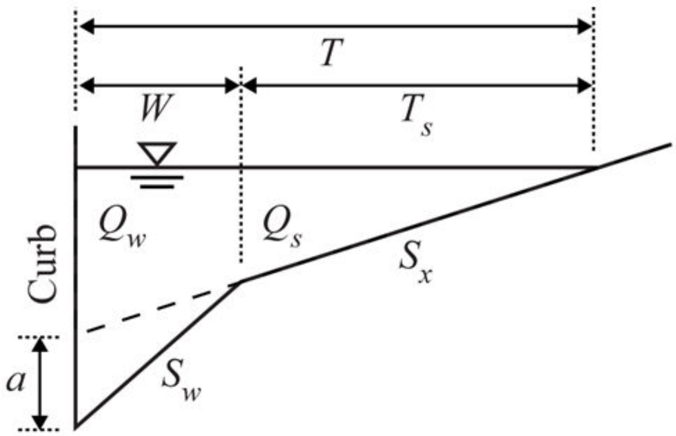
$$A = \frac{S_x T^2}{2}$$

Table 3-7: Manning's n for Street and Pavement Gutters

Type of Gutter or Pavement	Manning's n
Concrete gutter, troweled finish	0.012
Asphalt Pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter-asphalt pavement:	
Smooth	0.013
Rough	0.015
Concrete pavement:	
Float finish	0.014
Broom finish	0.016

Adapted from FHWA (2001)

Composite Gutter Sections



Composite Gutter Shapes

Evaluation of composite gutters requires additional consideration of flow in the depressed section. The depression serves to retain more water above inlet entrances and thus increases gutter flow capacity. The relationship between total discharge, Q, and depressed gutter flow, Q_W, can be expressed as

$$Q = Q_w + Q_s$$

where Q_W *and* Q_S represent portion of the gutter flows for the sections shown in the figure above (m^3/s, ft^3/s).

The relationship between Q and Q_S is given as

$$Q = \frac{Q_s}{(1 - E_o)}$$

where E_O = ratio of Q_W to Q, or

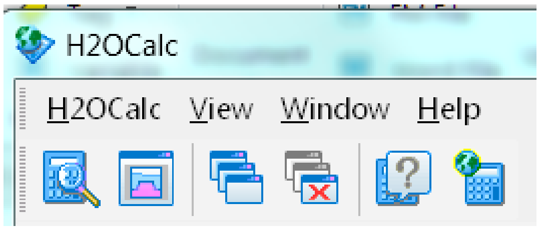
$$E_o = \left[1 + \frac{\left(\dfrac{S_w}{S_x} \right)}{\left(1 + \dfrac{(S_w / S_x)}{(T / W) - 1} \right)^{8/3} - 1} \right]^{-1} \tag{71}$$

where W = width of the depressed section (m, ft)
S_W = cross slope of the depressed section (m/m, ft/ft)

The slope terms and the width of depression are related through depth of the depression, a, as

$$S_w = S_x + \frac{a}{W}$$

where *a* is the gutter depression (m, ft) illustrated in the figure given above.


H2OCalc
H2OCalc View Window Help

Inlets on Grade

Drainage Inlet

As flow accumulates in gutters and spread increases, the risk of traffic accidents and delays increases. To limit this risk, drainage inlets are needed at the edge of the roadway to intercept all or a portion of the runoff and convey it to an underground storm sewer. Although there are many types and sizes of inlets in use, they are generally classified as grate, curb-opening, combination, or slotted-drain inlets. The responsibility of the designer is to determine the type, size, and spacing of inlets that cost-effectively and safely captures runoff.

Key parameters in evaluating inlet flow conditions are capacity, Q_i, and interception efficiency, E. The former refers to flow that is intercepted by a particular drainage inlet. Any gutter flow that is not intercepted is referred to as bypass, or carryover, flow, Q_b. Thus, if Q is total gutter discharge,

$$Q = Q_i + Q_b$$

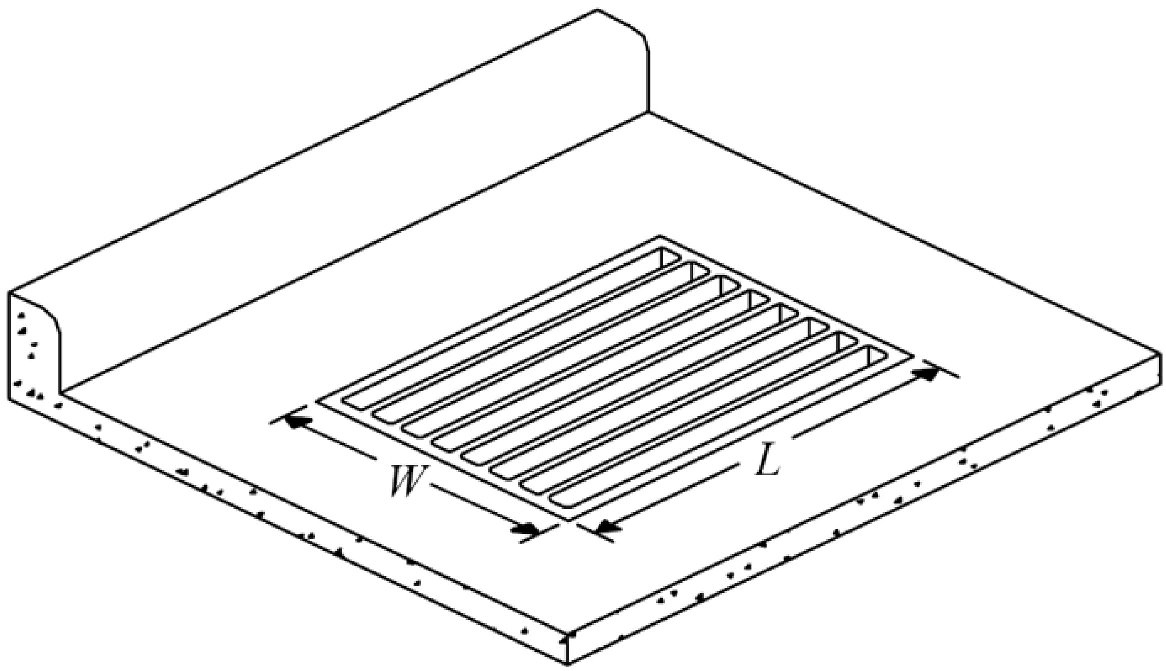
The interception efficiency of the inlet is the fraction of gutter flow that the inlet will capture under a given set of conditions, and is expressed as

$$E = \frac{Q_i}{Q}$$

Inlets on Grade

Grate Inlet

A grate inlet, as shown in the figure below, consists of an opening in the gutter covered by one or more, flush-mounted grates that are placed parallel to gutter flow.



Grate Inlet

E_o, defined as the ratio of frontal flow, Q_W, to total gutter flow, Q, for a uniform gutter can be expressed as

$$E_o = \frac{Q_w}{Q} = 1 - \left(1 - \frac{W}{T}\right)^{8/3}$$

where Q_W = portion of flow that passes directly over the upstream side of the grate

W = width of the grade

The ratio of intercepted frontal flow to total frontal flow, also referred to as frontal flow efficiency, R_f, is defined as

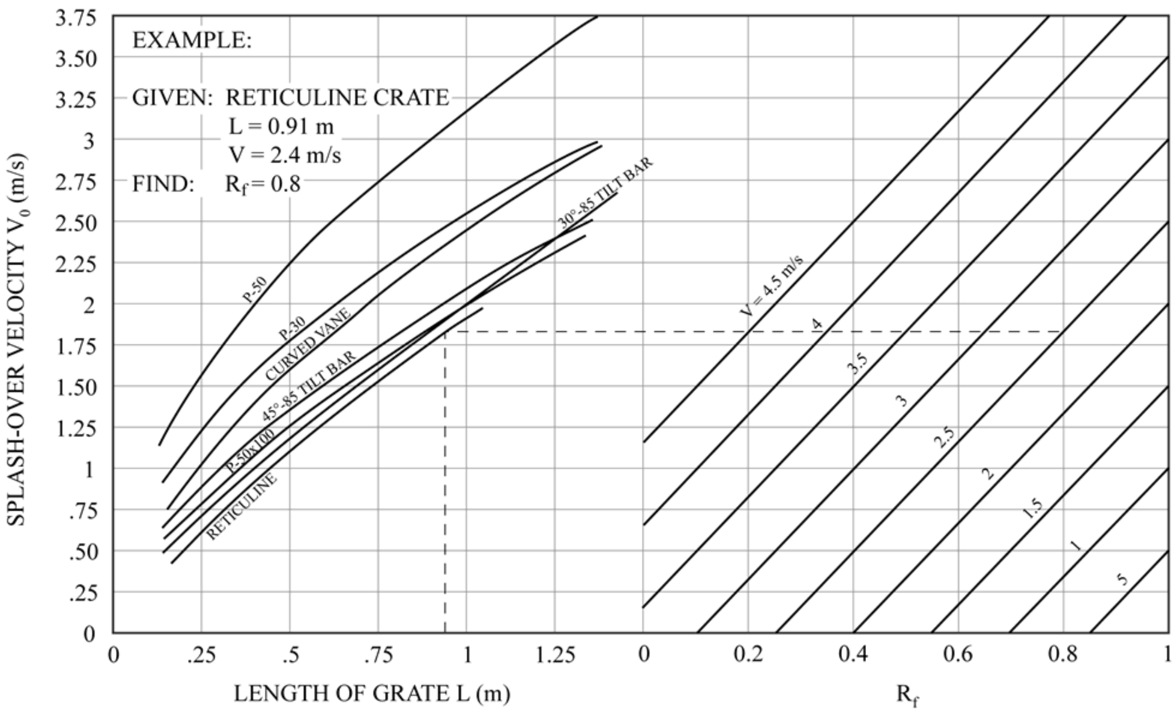
$$R_f = 1 - K_f(V - V_o)$$

where K_f = constant (0.295 in SI, 0.09 in English)

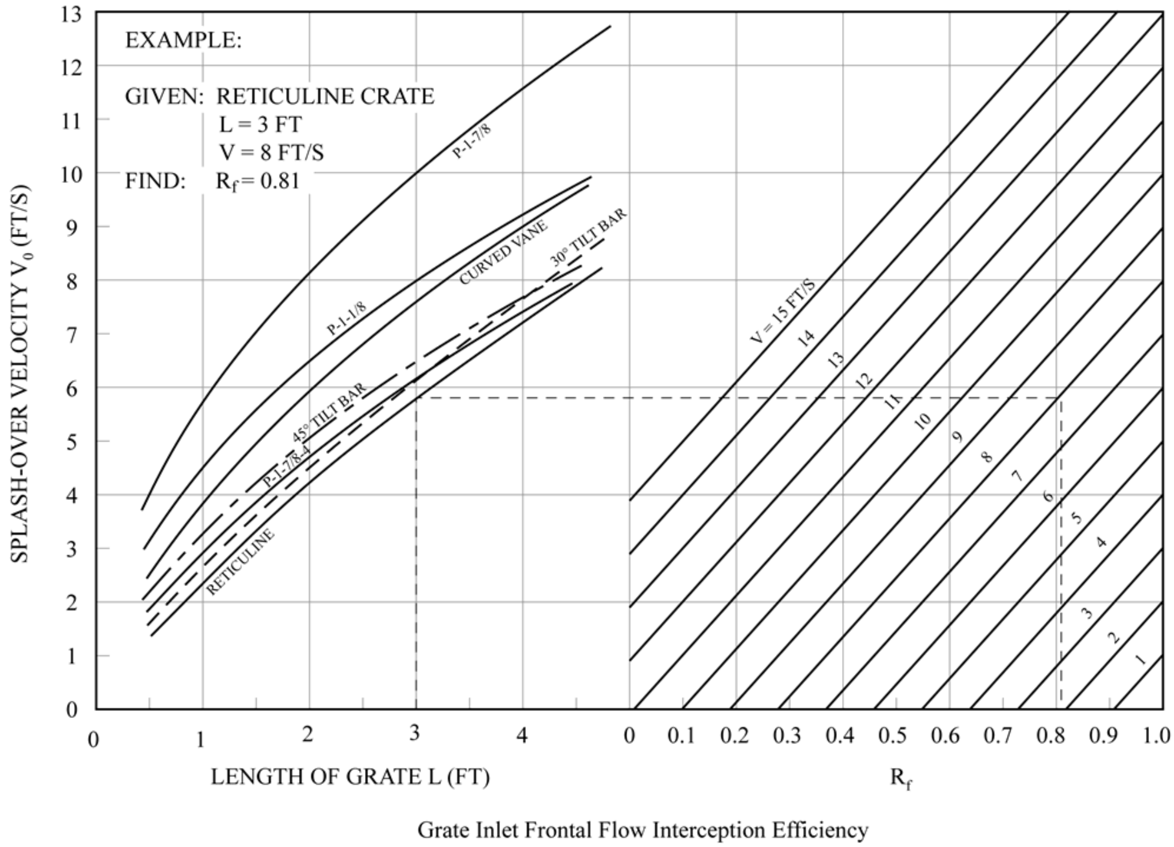
V = gutter flow velocity (m/s, ft/s)

splash-over velocity (velocity where splash-over first occurs) (m/s, ft/s).

The following figure could be used to determine splash-over velocity based on grate type, length of the grate, and gutter flow velocity.



Grate Inlet Frontal Flow Interception Efficiency



Charts to Determine Slash-Over Velocity for Grate Inlets (*Adapted from FHWA, 2001*)

The ratio of side flow to gutter flow is expressed as

$$\frac{Q_s}{Q} = 1 - \left(\frac{Q_w}{Q}\right) = 1 - E_o$$

where Q_S = gutter flow traveling around the perimeter of the grate when spread

exceeds its width (m^3/s, ft^3/s)

The ratio of intercepted side flow to total side flow, referred to as side flow efficiency, R_S, is defined as

$$R_s = \frac{1}{1 + \frac{K_s V^{1.8}}{S_x L^{2.3}}}$$

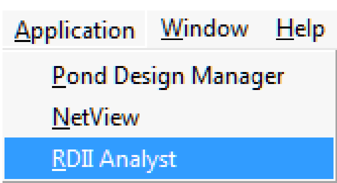
where K_S = empirical constant (0.083 in SI, 0.15 in US)

L = grate length (m, ft) – The range of grate length allowed by H_2OCalc is from 0.5 ft to 4.5 ft as defined in the FHWA Chart 5.

The overall inlet efficiency, E, can be evaluated from the frontal and side flow efficiencies by

$$E = R_f E_o + R_s (1 - E_o)$$

From Equation (74), the capacity of a grate inlet can be obtained by multiplying Equation (79) by the total gutter flow, or



Curb Inlet

A curb-opening inlet is comprised of a vertical opening in the curb that is covered by a concrete slab, as shown in the following figure.

For uniform cross slopes, the length of a curb-opening inlet required to intercept all gutter flow, L_T (m, ft), is defined as

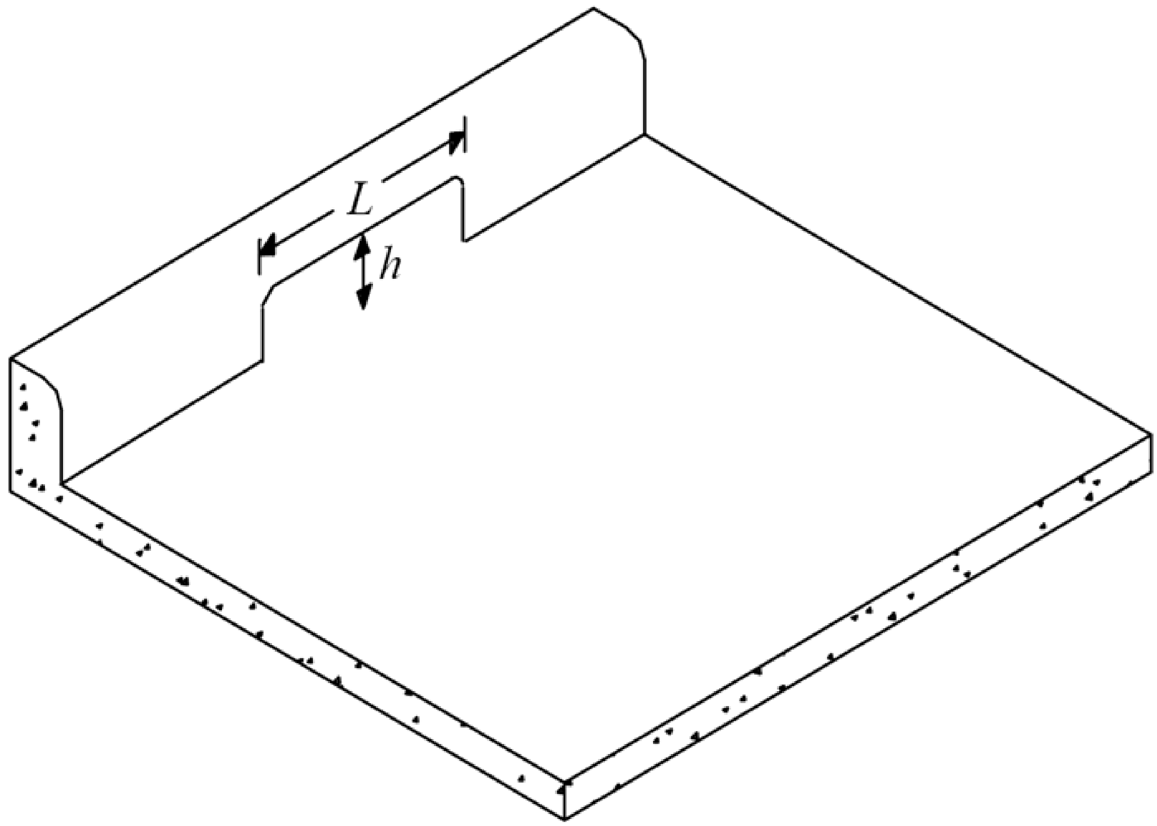
$$L_T = \frac{K_o Q^{0.42} S^{0.3}}{(nS_x)^{0.6}}$$

where K_o = empirical constant (0.817 in SI, 0.6 in English).

The efficiency of shorter-length inlets can be evaluated by

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8}$$

where L = curb-opening length (m, ft).



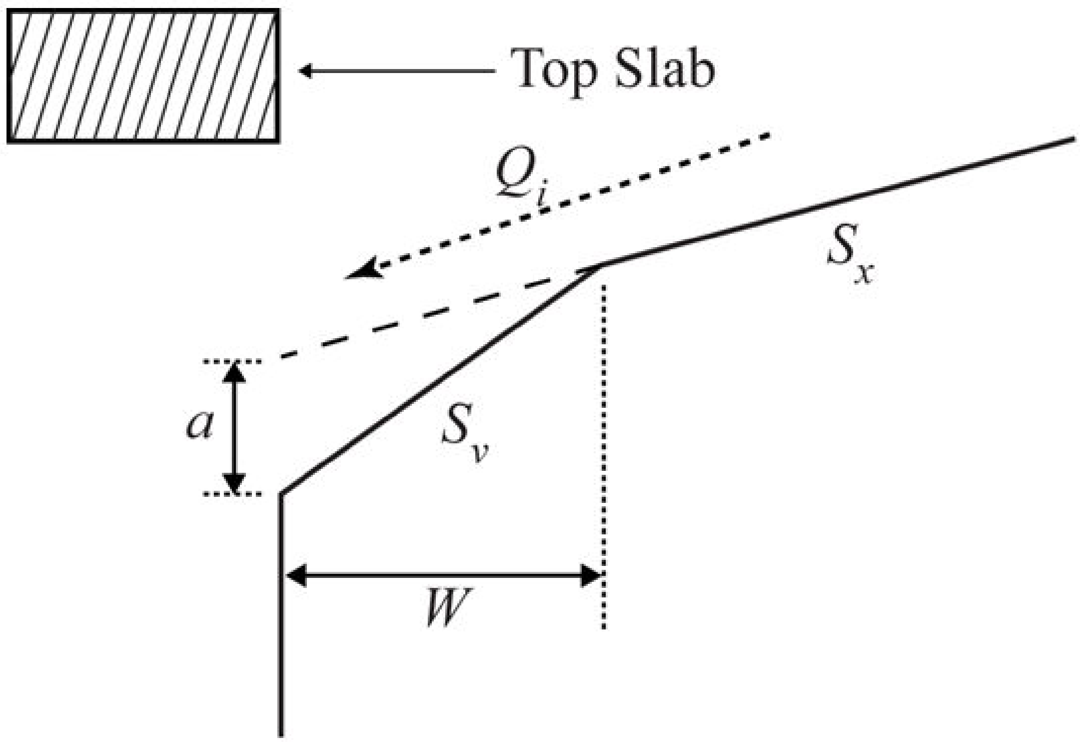
Curb Inlet

For the case where either locally- or continuously-depressed gutter sections are used (see the following figure), Equation (82) can still be used, but an equivalent cross slope, S_e, should be substituted for S_x, where

$$S_e = S_x + S_v E_o$$

where E_o = ratio of Q_w to Q [see Equation (75)]

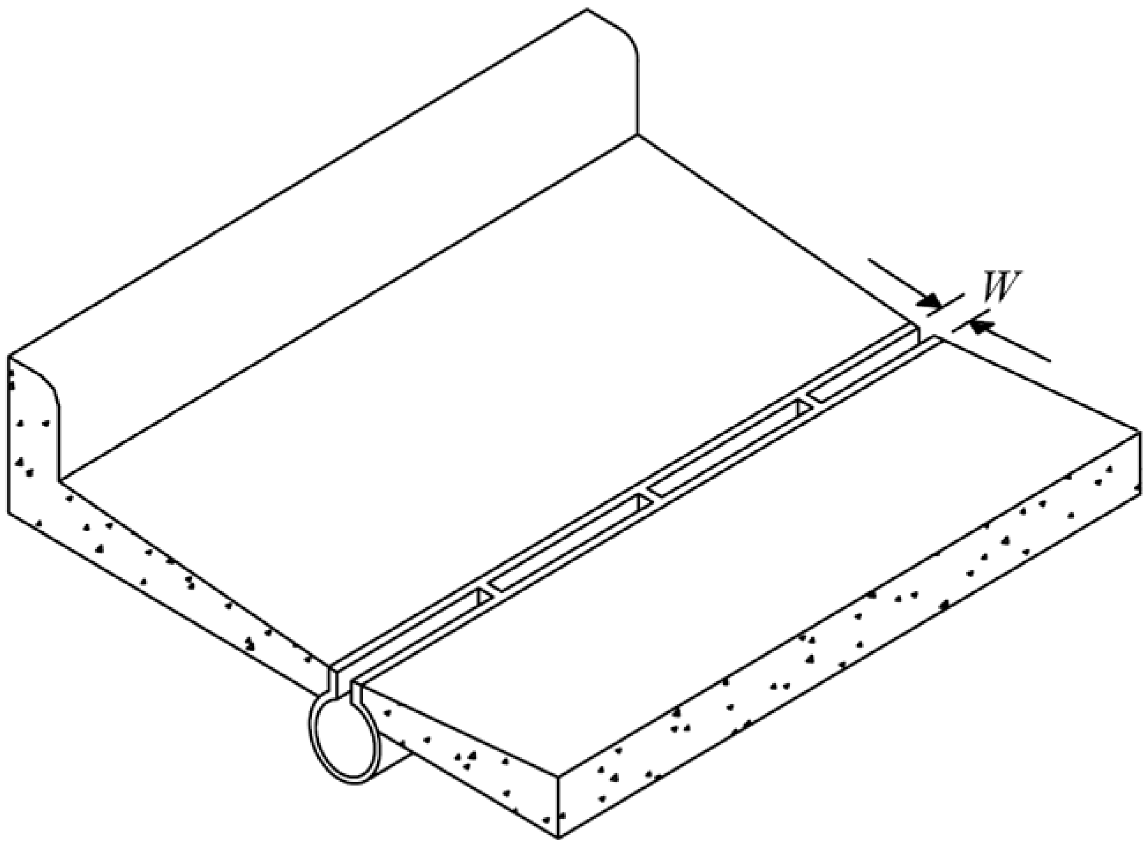
S_v = cross slope of the depressed section, expressed as $S_v = a/W$ (see the following figure).



Depressed Curb-Opening

Slot Inlet

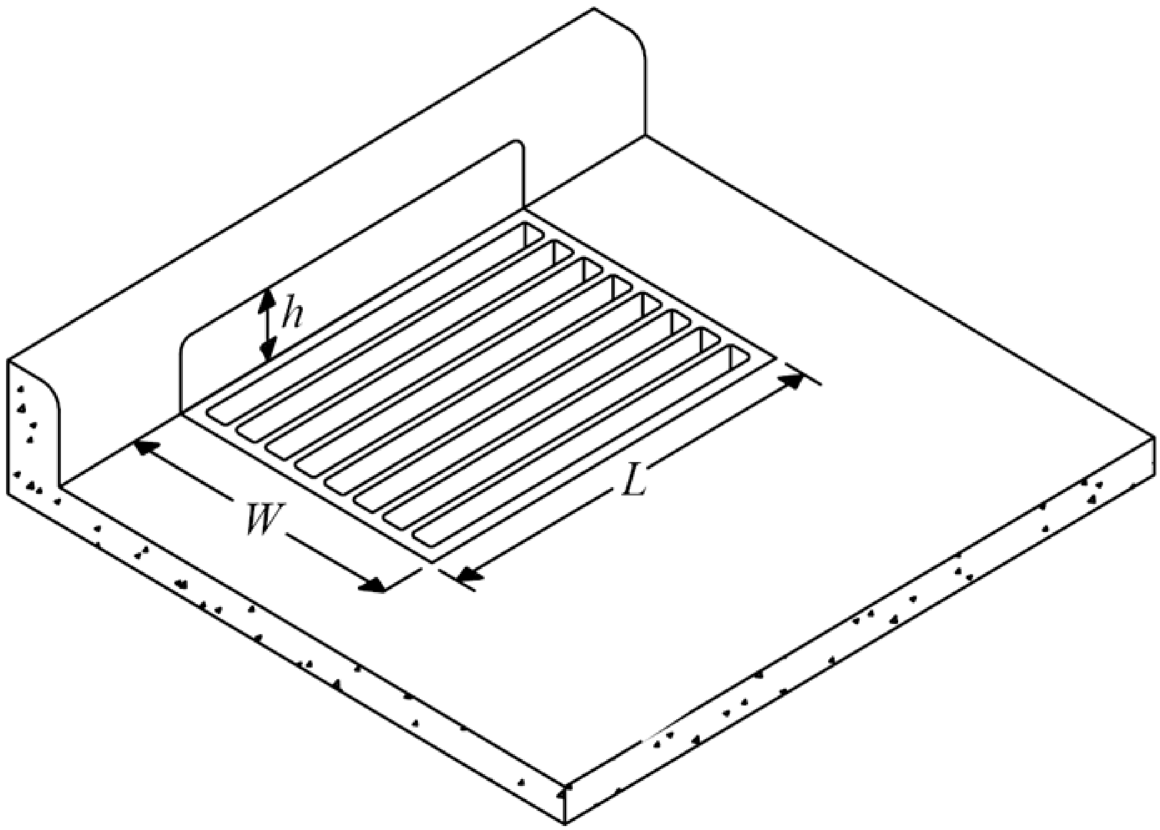
Slotted drain systems, illustrated in the figure given below, are comprised of a pipe that is cut longitudinally along its crown with bars placed perpendicular to support the opening. The hydraulic characteristics of slot inlet are similar to curb opening inlets; thus, Equations (81) and (82) are applicable.



Slot Inlet

Combination Inlet

Combination inlets integrate features of both curb-opening and grate inlets (see the figure below). For equal-length combination inlets, in which the grate and vertical curb opening are of the same length, inlet capacity and interception efficiency is not significantly different from that of the grate alone. Thus, Equations 75 through 80 are generally applicable.



Combination Inlet

Ditch Inlet

Roadside ditches may be drained by drop inlets similar to those used for pavement drainage. The ratio of frontal flow to total flow for trapezoidal ditches (channels) is expressed as

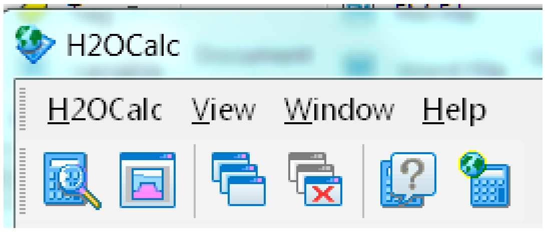
$$E_0 = W / (B + dZ)$$

where W = width of the drop inlet (m, ft)

d = depth of flow in the channel (m, ft) determined using Manning’s equation.

Z = horizontal distance of side slope to a vertical rise of 1 unit (ft, m)

Frontal flow efficiency, side flow efficiency, total efficiency, intercepted flow, and bypass flow are computed using the technique described previously for grate inlets.


H2OCalc
H2OCalc View Window Help

Inlets in Sag

Inlets in vertical curves, or sag locations, operate as weirs at shallow ponding depths and as orifices at larger depths. At intermediate depths, flow is not well defined and may actually fluctuate between weir and orifice control. The depth at which orifice flow begins depends on grate size and bar configuration, curb opening dimensions, or the slot width of an inlet.

Grate Inlets

The capacity under weir conditions is expressed as

$$Q_i = C_w P_i \, d^{3/2}$$

where P_i = perimeter (m, ft) of the grate, not including the side adjacent to the curb, if present C_w = weir coefficient (1.66 in SI, 3.0 in English)

d = depth at the curb (m, ft)

Under orifice conditions,

$$Q_i = C_o A_g \sqrt{2gd}$$

where C_o = orifice coefficient (0.67)

A_g = clear opening, or effective area of the grate

g = gravitational constant (9.81 m/s^2, 32.2 ft/s^2)

Curb inlets

Curb-opening inlets operate as weirs up to a depth (d) that is less than or equal to height (h) of the vertical opening. In this case, inlet capacity can be computed by

$$Q_i = C_w L d^{3/2}$$

where C_w = weir coefficient (1.66 in SI, 3.0 in English)

L = curb-opening length (m, ft)

If the gutter section is depressed, this relationship is modified as

$$Q_i = C_w (L + 1.8W)\ d^{3/2}$$

where C_w = weir coefficient (1.25 in SI, 2.3 in English)

W = lateral width of depression (m, ft)

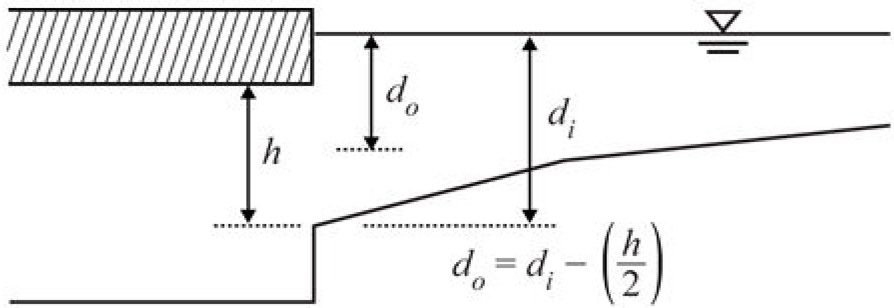
d = throat width (m, ft) measured from the undepressed cross slope

(i.e., $d = TS_x$) At depths of approximately 1.4 times the opening height, curb-opening inlets tend to function as orifices. Under these conditions, capacity can be computed by

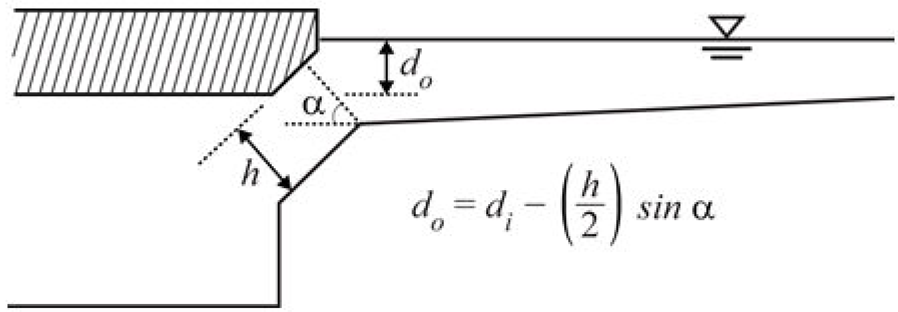
$$Q_i = C_o h L \sqrt{2 g d_o}$$

where d_o = effective head (m, ft) (see the following three figures)

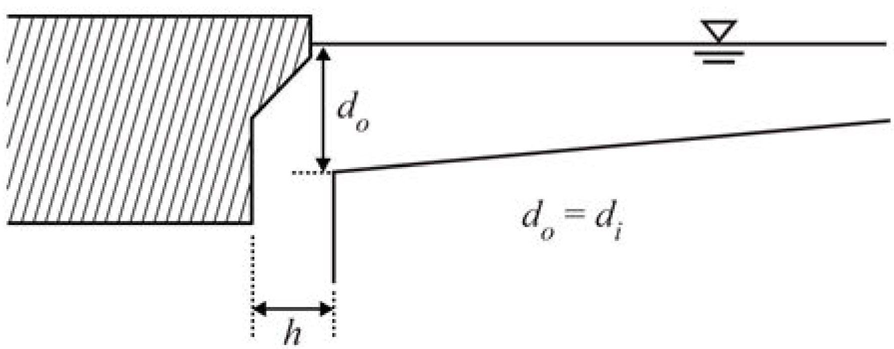
h = throat width (m, ft) (see the following three figures)



(a) Horizontal Throat

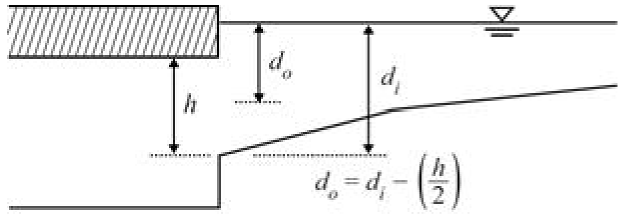


(b) Inclined Throat

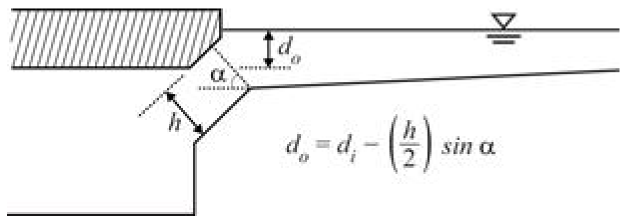


(c) Vertical Throat

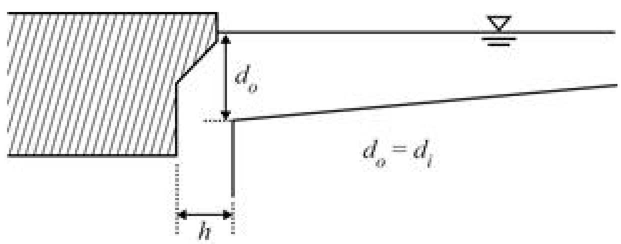
Throat Configuration



(a) Horizontal Throat



(b) Inclined Throat



(c) Vertical Throat

Throat Configuration

Slot Inlets

Due to vulnerability to clogging, slotted drain inlets are not recommended for sag locations. Nevertheless, if they exist, slotted drains operate as weirs when depth at the slot is below approximately 0.2 ft (60 mm) and as orifices for depths greater than 0.4 ft (120 mm). Capacity of a slotted drain operating under weir conditions can be evaluated using Equation (87). The corresponding weir coefficient varies with flow depth and slot length, but a typical value is 1.4 in SI and 2.48 in English. Under orifice conditions, capacity is a function of the slot width, W, and is computed by

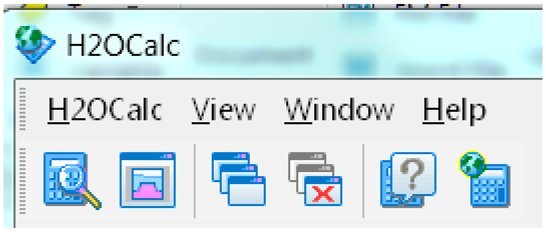
$$Q_i = 0.8LW\sqrt{2gd}$$

Combination Inlets

Combination inlets, especially those of a sweeper configuration, can be effective in sag locations. In this case, the sweeper inlet can extend from both sides of the grate. Similar to on-grade computations, under weir conditions, the inlet capacity of an equal-length combination inlet is essentially equal to that of the grate alone. Under orifice conditions, the capacity increases to the sum of that of the grate (i.e., Equation 86) and that of the curb opening (i.e., Equation 89). For a conservative design, however, it is recommended that combination inlet be designed assuming complete clogging of the grate.

Ditch Inlets

Ditch inlets in sag intercept 100 % of the gutter flow.


H2OCalc
H2OCalc View Window Help

Joukowski Expression

The pressure rise for instantaneous closure is directly proportional to the fluid velocity at cutoff and to the velocity of the predicted surge wave. Thus, the relationship used for analysis is simply the well-known Joukowski expression for sudden closures in frictionless pipes

$$\Delta h = \frac{c}{gA}\Delta Q \text{ or } \Delta h = \frac{c}{g}\Delta V$$

where

Δh = surge pressure (m , ft)

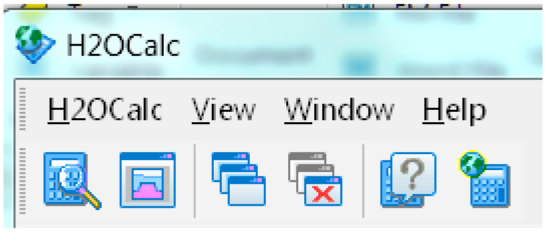
ΔV = velocity change of water in the pipeline (m/s, ft/s)

c = wave speed (m/s, ft/s)

A = cross-sectional area (m^2, ft^2 h)

g = gravitational acceleration (9.81 m/s^2, 32.17 ft/s^2)

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Wave Speed

The wave speed, *c*, is influenced by the elasticity of the pipe wall. For a pipe system with some degree of axial restraint a good approximation for the wave propagation speed is obtained using

$$c = \sqrt{\frac{E_f / \rho}{1 + K_R \dfrac{E_f D}{E_c t}}}$$

where E_f = elastic modulus of the fluid (for water, 2.19 GN/m^2, 0.05 Glb/ft^2)

ρ = density of the fluid (for water, 998 kg/m^3, 1.94 slug/ft^3)

E_c = elastic modulus of the conduit (GN/m^2, Glb/ft^2)

D = pipe diameter (mm, inch)

t = pipe thickness (mm, inch)

K_R = coefficient of restraint for longitudinal pipe movement.

The constant K_R takes into account the type of support provided for the pipeline. Typically, three cases are recognized with K_R defined for each as follows (*m* is the Poisson's ratio for the pipe material):

Case a: The pipeline is anchored at the upstream end only.

$K_R = 1 - m / 2$

Case b: The pipeline is anchored against longitudinal movement.

$K_R = 1 - m^2$

Case c: The pipeline has expansion joints throughout.

$K_R = 1$

The following table provides physical properties of common pipe materials.

Table 3-8: Physical Properties of Common Pipe Materials

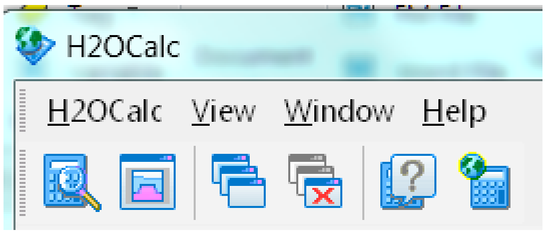
Material	Young's Modulus (Ec)		Poisson's Ratio, μ
	GN/m2	Glb/ft2	
Asbestos Cement	23 - 24	0.53 - 0.55	-
Cast Iron	80 - 170	1.8 - 3.9	0.25 - 0.27
Concrete	14 - 30	0.32 - 0.68	0.1 - 0.15
Reinforced Concrete	30 - 60	0.68 - 1.4	-
Ductile Iron	172	3.93	0.3
PVC	2.4 - 3.5	0.055 - 0.08	0.46
Steel	200 - 207	4.57 - 4.73	0.30

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Inertia of Pumps and Motors

The combined inertia of pumps and motors driving them, including the connecting shafts and couplings, is required for transient analysis associated with the starting and stopping of pumps. The equations provided below are intended to be used as an initial guide to the inertia values that may be used as a reasonable first approximation, when more accurate data is not available. The total inertia for the pump/motor unit is the sum of both pump and motor inertias. The following inertia calculations are based on Thorley (2004).

Pump Inertias

From the linear regression analysis of 300 pump inertia data, two equations were developed for predicting the inertia I of pump impellers, including the entrained water and the shaft on which the impeller is mounted. The first equation represents the upper set of the data, and applies to single- and double-entry impellers, single and multistage, and horizontal and vertical, spindle machines.

$$I = C_1 \left(\frac{P}{(N/1000)^3} \right)^{0.9556}$$

where I = pump inertia (kg m^2, lb ft^2)

C_1 = coefficients (0.03768, 0.6674)

P = power (kW, hp)

N = pump speed (rev/min)

The second equation is for lower set of the data and represents relatively small, single-entry, radial flow impellers of lightweight design. This is applied to relatively small pumps of lightweight design.

$$I = C_2 \left(\frac{P}{(N/1000)^3} \right)^{0.844}$$

where C_2 = coefficients (0.03407 in SI, 0.6244 in English)

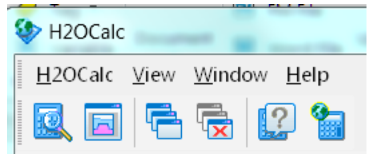
Motor Inertias

Similar to pump inertia, linear regression of the motor inertia data yields the following equations.

$$I = C_3 \left(\frac{P}{(N/1000)^3} \right)^{1.48}$$

where C_3 = coefficients (0.0043 in SI, 0.0648 in English).

H2OCalc™
Modeling Made Easy



Stormwater Runoff and the Rational Method

For storm sewer loading, the focus shifts to hydrologic analysis of excess precipitation and associated runoff. Common techniques for analysis include the rational method and unit hydrograph methods, as well as the use of more advanced hydrologic models.

For small drainage areas, peak runoff is commonly estimated by the rational method. This method is based on the principle that the maximum rate of runoff from a drainage basin occurs when all parts of the watershed contribute to flow and that rainfall is distributed uniformly over the catchment area. Since it neglects temporal and spatial variability in rainfall, and ignores flow routing in the watershed, collection system, and any storage facilities, the rational method should be used with caution only for applications where the assumptions of rational method are valid.

Rational Method

The rational formula is expressed as

$$Q_p = KCiA$$

where Q_p = peak runoff rate (m^3/s, ft^3/s)

C = dimensionless runoff coefficient (see Table 3-9)

I = average rainfall intensity (mm/hr, in/hr) for a duration of the time of concentration (t_c)

A = drainage area (km^2, acres)

K = conversion constant (0.28 in SI, 1 in English)

The time of concentration t_c used in the rational method is the time associated with the peak runoff from the watershed to the point of interest. Runoff from a watershed usually reaches a peak at the time when the entire watershed is contributing; in this case, the time of concentration is the time for a drop of water to flow from the remotest point in the watershed to the point of interest. Time of concentration, t_c (min), for the basin area can be computed using one of the formulas listed in Table 3-10.

Table 3-9: Runoff Coefficients for 2 to 10 Year Return Periods

Description of drainage area		Runoff coefficie
Business	Downtown	0.70-0.95
	Neighborhood	0.50-0.70
Residential	Single-family	0.30-0.50
	Multi-unit detached	0.40-0.60
	Multi-unit attached	0.60-0.75
Suburban		0.25-0.40
Apartment dwelling		0.50-0.70
Industrial	Light	0.50-0.80
	Heavy	0.60-0.90
Parks and cemeteries		0.10-0.25

Railroad yards			0.20-0.35
Unimproved areas			0.10-0.30
Pavement	Asphalt		0.70-0.95
	Concrete		0.80-0.95
	Brick		0.75-0.85
Roofs			0.75-0.95
Lawns	Sandy soils	Flat (2%)	0.05-0.10
		Average (2-7%)	0.10-0.15
		Steep (≥7%)	0.15-0.20
	Heavy soils	Flat (2%)	0.13-0.17
		Average (2-7%)	0.18-0.22
		Steep (≥7%)	0.25-0.35

Source: Nicklow et al. (2006)

Table 3-10: Formulas for Computing Time of Concentration

Method	**Formula**	
Kirpich (1940)	$t_c = 0.0078L^{0.77}S^{-0.385}$ L = length of channel (ft) S = average watershed slope (ft/ft)	
California Culverts Practice (1942)	$t_c = 60\left(11.9L^3 / H\right)^{0.385}$ L = length of the longest channel (mi) H = elevation difference between divide and outlet (ft)	
Izzard (1946)	$t_c = \dfrac{41.025(0.0007i + c)L^{1/3}}{S^{1/3}i^{2/3}}$ i = rainfall intensity (in/h) c = Retardance coefficient	Retardance factor, c, ranges from 0.007 for smooth pavement to 0.012 for concrete and to 0.06 for dense turf; product i times L should be < 500
Federal Aviation Administration (1970)	$t_c = \dfrac{0.39(1.1 - C)L^{1/2}}{S^{1/3}}$ C = rational method runoff coefficient (see Table 3.9)	

Kinematic wave	$$t_c = \frac{0.938 L^{0.6} n^{0.6}}{i^{0.4} S^{0.3}}$$ n = Manning's roughness coefficient	
SCS lag equation	$$t_c = \frac{100 L^{0.8} [(1000/CN) - 9]^{0.7}}{19000 S^{1/2}}$$ CN = SCS runoff curve number (see Table 3.11)	
SCS average velocity charts	$$t_c = \frac{1}{60} \sum_{j=1}^{N} (L_j / V_j)$$ V = average velocity (ft/s)	
Yen and Chow (1983)	$$t_c = K_Y \left(\frac{NL}{S^{1/2}} \right)^{0.6}$$ K_Y = Coefficient N = Overland texture factor (see Table 3.13)	K_Y ranges from 1.5 for light rain (i<0.8) to 1.1 for moderate rain (0.8<i<1.2), and to 0.7 for heavy rain (i>1.2)

Source: Nicklow et al. (2004)

Table 3-11: Runoff Curve Numbers for Urban Land Uses

Land use description	**Soil Group**			
	A	B	C	D
Lawns, open spaces, parks, golf courses:				
Good condition: grass cover on 75% or more area	39	61	74	80
Fair condition: grass cover on 50% to 75% of area	49	69	79	84
Poor condition: grass cover on 50% or less of area	68	79	86	89
Paved parking lots, roofs, driveways, etc	98	98	98	98
Streets and roads:				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Paved with open ditches	83	89	92	93
Commercial and business areas (85% impervious)	89	92	94	95

Industrial districts (72% impervious)	81	88	91	93
Row houses, town houses and residential with lot sizes of 1/8 ac or less (65% impervious)	77	85	90	92
Residential average lot size:				
1/4 ac (38% impervious)	61	75	83	87
1/3 ac (30% impervious)	57	72	81	86
1/2 ac (25% impervious)	54	70	80	85
1 ac (20% impervious)	51	68	79	84
2 ac (12% impervious)	46	65	77	82
Developing urban area (newly graded; no vegetation)	77	86	91	94

Adapted from SCS (1985)

Table 3-12: Description of NRCS Soil Classifications

Group	Description	Min. infiltration (in/hr)
A	Deep sand; deep losses; aggregated silts	0.30-0.45
B	Shallow loess; sandy loam	0.15-0.30
C	Clay loams; shallows sandy loam; soils low in organic content; soils usually high in clay	0.05-0.15
D	Soils that swell significantly	0-0.05

Adapted from SCS (1985)

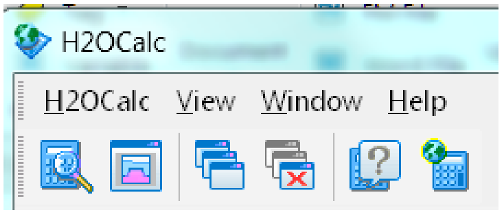
Table 3-13: Overland Texture Factor *N*

Overland flow surface	Low	Medium	High
Smooth asphalt pavement	0.010	0.012	0.015
Smooth impervious surface	0.011	0.013	0.015
Tar and sand pavement	0.012	0.014	0.016
Concrete pavement	0.014	0.017	0.020
Rough impervious surface	0.015	0.019	0.023
Smooth bare packed soil	0.017	0.021	0.025
Moderate bare packed soil	0.025	0.030	0.035
Rough bare packed soil	0.032	0.038	0.045

Gravel soil	0.025	0.032	0.045
Mowed poor grass	0.030	0.038	0.045
Average grass, closely clipped sod	0.040	0.055	0.070
Pasture	0.040	0.055	0.070
Timberland	0.060	0.090	0.120
Dense grass	0.060	0.090	0.120
Shrubs and bushes	0.080	0.120	0.180
Land use	Low	Medium	High
Business	0.014	0.022	0.35
Semi-business	0.022	0.035	0.050
Industrial	0.020	0.035	0.050
Dense residential	0.025	0.040	0.060
Suburban residential	0.030	0.055	0.080
Parks and lawns	0.040	0.075	0.120

Adapted from Yen and Chow (1983)

H2OCalc™ Modeling Made Easy



NRCS (SCS) Dimensionless Unit Hydrograph Method

A unit hydrograph is defined as the direct runoff hydrograph resulting from a unit depth of excess (effective) rainfall produced by a storm of uniform intensity and specified duration. Unit hydrographs could be natural or synthetic. Natural unit hydrographs are derived from observed data, whereas synthetic unit hydrographs are generated following empirical techniques based on watershed parameters and storm characteristics to simulate the natural unit hydrograph. In addition to the rational formula, H2OCalc computes peak flow from a watershed using the NRCS (SCS) dimensionless unit hydrograph.

The NRCS dimensionless unit hydrograph, graphically descried below, is widely used in practice. To generate a t_r-hour unit hydrograph for a watershed, time to peak (T_p) and the peak flow rate (Q_p) are determined using watershed characteristics.

$$T_p = \frac{t_r}{2} + t_l$$

where tr is duration of effective rainfall, and tl is lag time of the watershed. Lag time represents the time from the center of mass of effective rainfall to the time to peak of a unit hydrograph. In other words, lag time is a delay in time, after a brief rain over a watershed, before the runoff reaches its peak. The lag time can either be specified by the user, or can be calculated by the model using the following SCS equation.

$$t_l = L^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7} \Big/ \left(19000 S^{0.5}\right)$$

where **tl** = lag time of the watershed (hr).

L = hydraulic length of the watershed (ft). This refers to travel distance of water from the most upstream location of the watershed to the point where the unit hydrograph is derived.

CN = the SCS curve number. This is a measure of runoff generating capacity of a watershed, and it depends on the soil, the antecedent moisture condition, the cover, and the hydrologic conditions of the watershed. Recommended CN values are given in the following table for urban areas (USDA 1986). The SCS suggests the CN values for the above equation to be within 50 and 95.

S = average slope of the watershed.

The peak flow rate is calculated as:

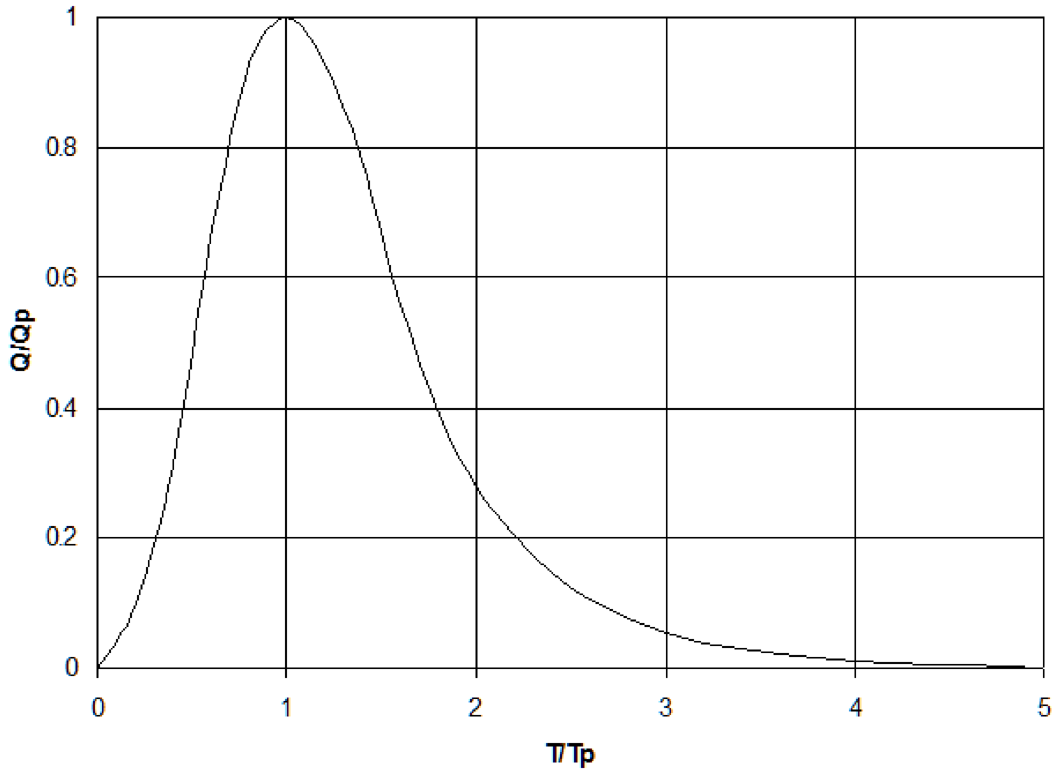
$$Q_p = \frac{484A}{T_p}$$

where Q_p = peak flow rate (ft3/s).

A = area of the watershed, in square miles, draining to the location of the unit hydrograph.

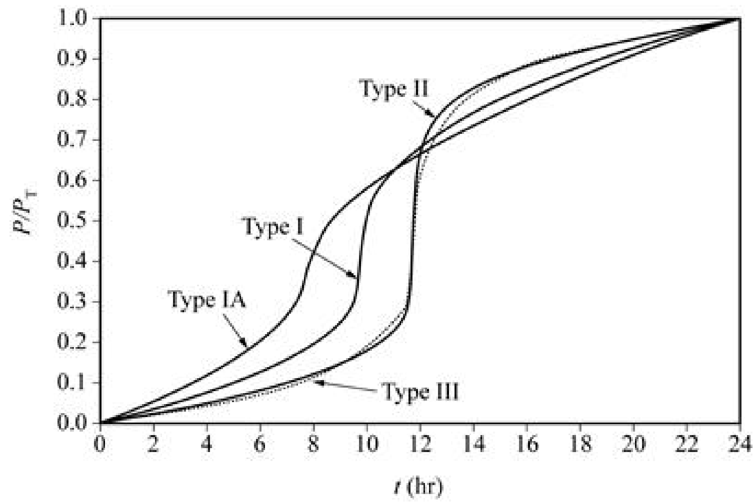
T_p = time to peak of the unit hydrograph in hours.

Once T_p and Q_p are known, actual time and flow rate ordinates of the t_r-hour unit hydrograph are determined by multiplying the dimensionless time (T/Tp) and the dimensionless flow rate ordinates (Q/Qp) by Tp and Qp, respectively.

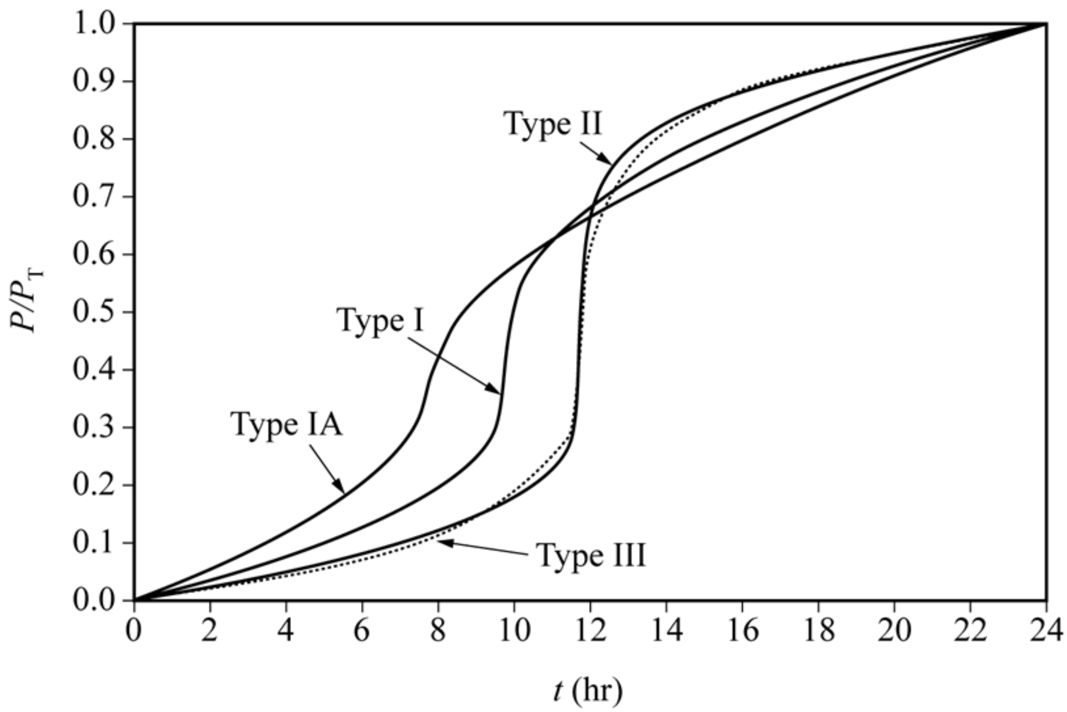


NRCS Dimensionless Unit Hydrograph

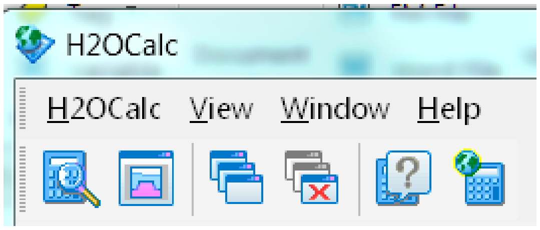
Storm hydrograph could be computed using the unit hydrograph and a given precipitation pattern. The precipitation could be a design precipitation or actual (i.e., historical precipitation). A design precipitation may be specified in the form of rainfall depth over 24-hr duration. Distribution of the rainfall depth across the 24-hour can be estimated using the SCS (NRCS) rainfall types (i.e. Type I, Type IA, Type II and Type III) shown in the following figure.



SCS (NRCS) Rainfall Types (*Source Nicklow et al., 2006*)

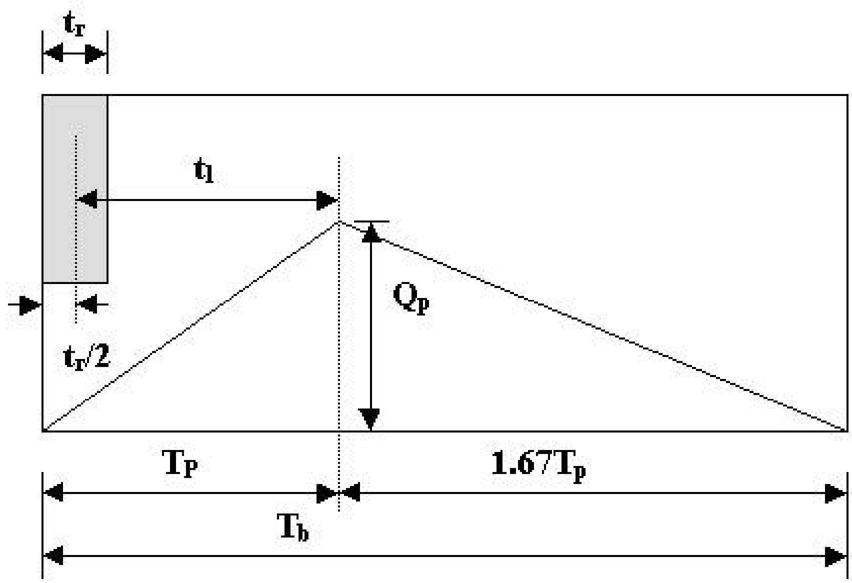


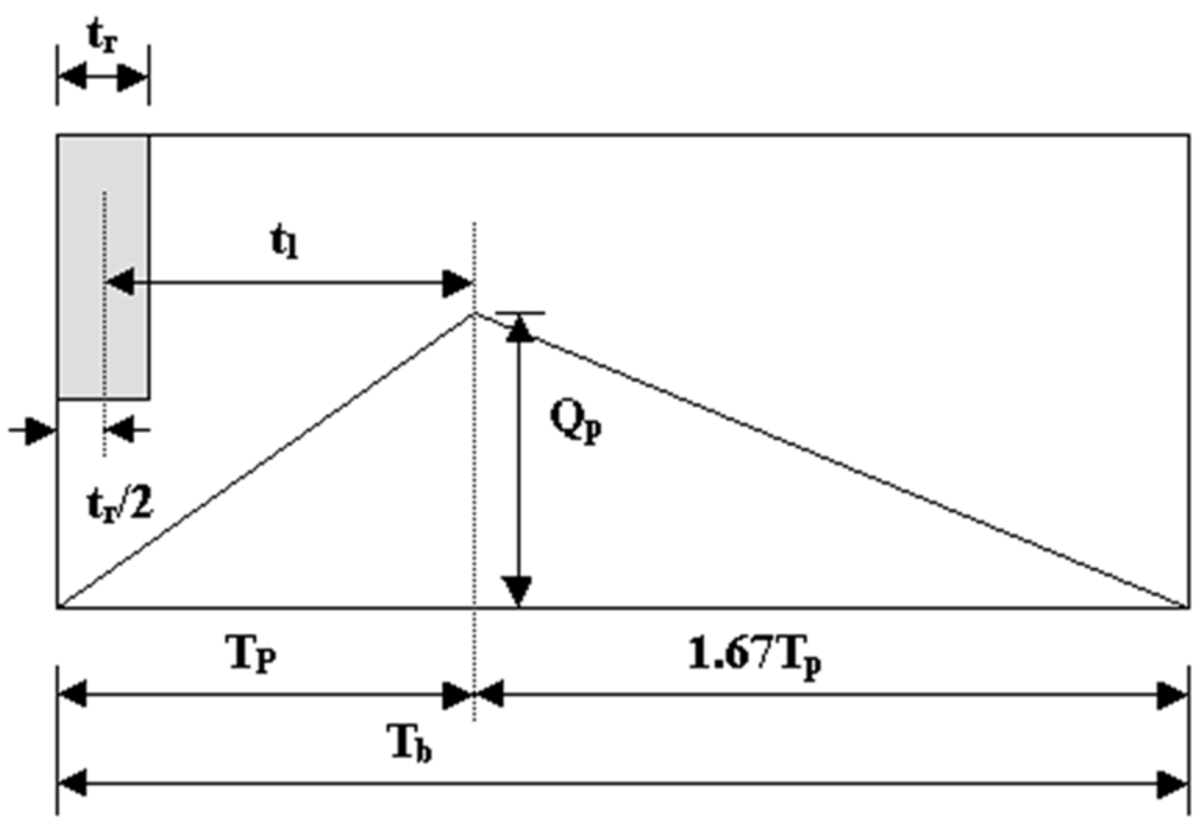
SCS (NRCS) Rainfall Types (*Source Nicklow et al., 2006*)


H2OCalc
H2OCalc View Window Help

NRCS (SCS) Triangular Unit Hydrograph Method

The SCS has also developed a triangular unit hydrograph (USDA 1986) (see figure below) that is an approximation to the dimensionless unit hydrograph described above. The triangular unit hydrograph is entirely defined in terms of three points, Q_p, T_p, and T_b. The lag time, time to peak, and peak flow rate are calculated using the same equations as for the dimensionless unit hydrograph.


t_r
t_l
Q_p
$t_r/2$
T_P
$1.67T_p$
T_b


t_r
t_l
Q_p
$t_r/2$
T_P
$1.67T_p$
T_b

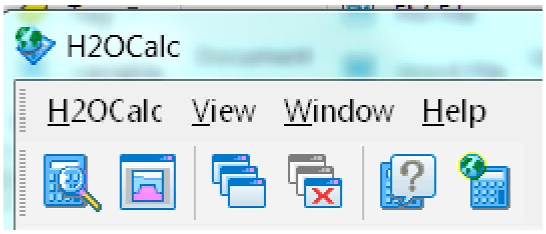
.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Delmarva Unit Hydrograph

As previously described, the NRCS dimensionless unit hydrograph and the NRCS triangular unit hydrograph are extensively used to develop storm Hydrographs for hydrologic evaluation and design of soil and water resources management practices throughout the United States. However, in areas such as the Delmarva Peninsula where the local topography is flat and where considerable surface storage is available, shape of observed storm Hydrographs significantly differ from those generated using the NRCS unit Hydrographs. As a result, a unit hydrograph that is similar with the NRCS dimensionless unit hydrograph, but with modifications to better represent the runoff characteristics of the Delmarva Peninsula has been used by utilities in the states of Delaware, Maryland, Virginia, and some parts of New Jersey. This unit hydrograph is known as the Delmarva unit hydrograph.

The Delmarva unit hydrograph uses the following equation to estimate peak flow rate.

$$Q_p = \frac{284\,A}{T_p}$$

where

Q_p = peak flow rate in cfs.

A = area of the watershed, in square miles, draining to the location of the unit hydrograph.

Tp = time to peak of the unit hydrograph in hour

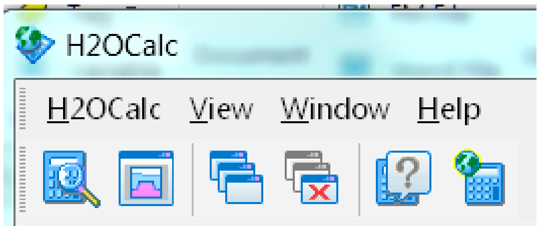
Time to peak, and lag time are calculated according to Equations 97 and 98, respectively. When compared with the NRCS methods, the Delmarva unit hydrograph produces lower peak flow rate but yields the same flow volume.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

The Colorado Urban Hydrograph Procedure

The Colorado Urban Hydrograph Procedure (CUHP) uses the equations and procedures presented in the Urban Drainage Criteria Manual (USDCM) of the Urban Drainage and Flood Control District (UDFCD 2001). Shape of the CUHP synthetic unit hydrograph is determined using the following equations that relate unit hydrograph parameters to catchment properties.

Lag time (t_l) of the watershed (catchment), defined as the time from the center of unit storm duration to the peak of the unit hydrograph, is determined as:

$$t_l = C_t \left(\frac{(L \cdot L_{Ca}}{\sqrt{S}} \right)^{0.48}$$

where t_l = lag time in hours.

L = length along the drainageway path from study point to the most upstream limits of

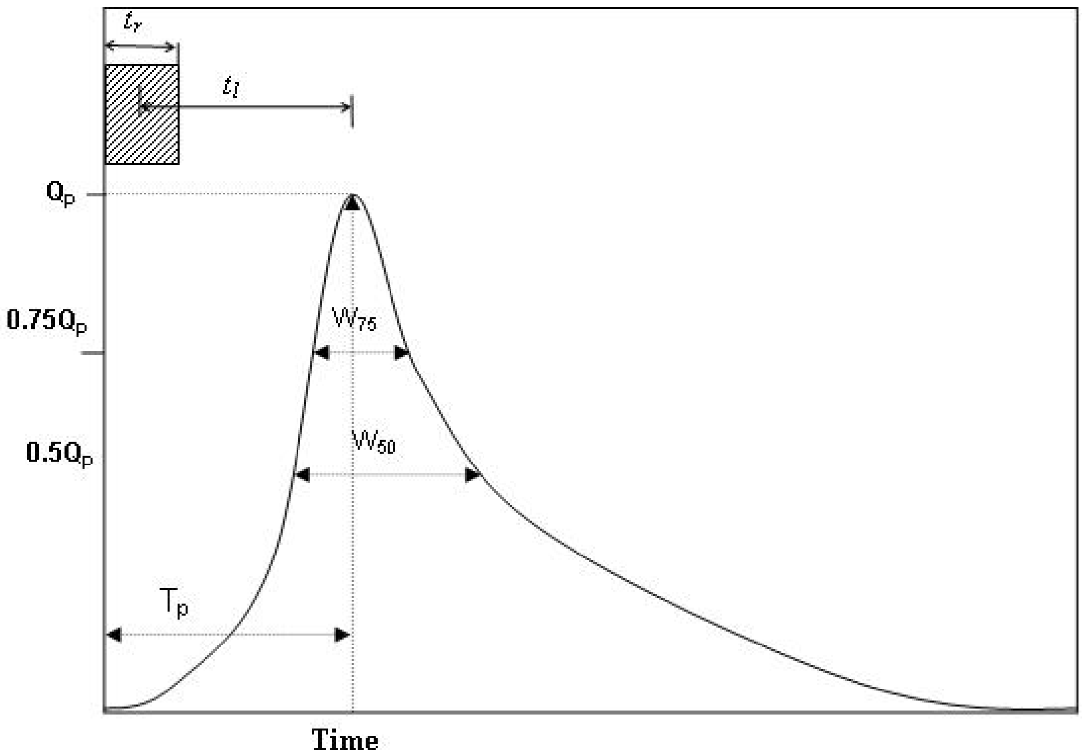
the catchment in miles.

L_{ca} = length along stream from study point to a point along stream adjacent to the centroid

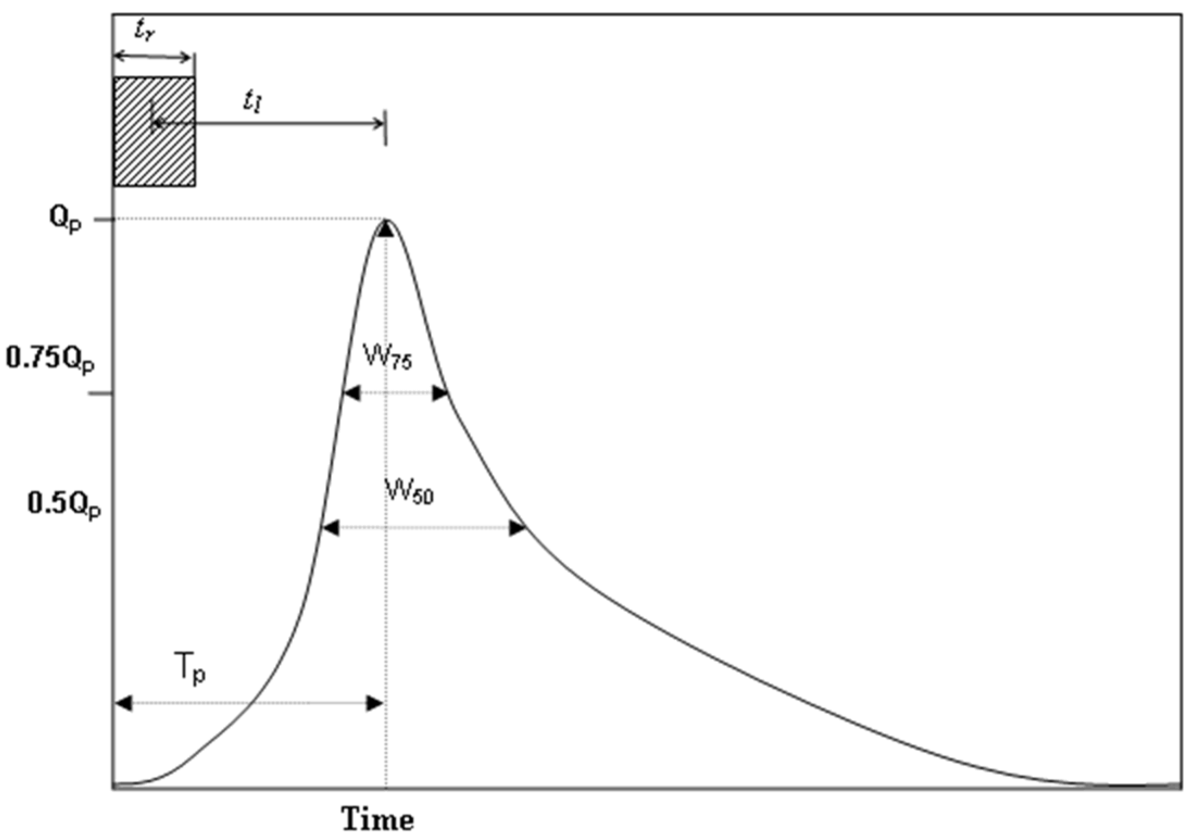
of the catchment in miles.

S = length weighted average slope of catchment along drainageway path to upstream limits of the catchment.

C_t = time to peak coefficient.



t_r
t_l
Q_p
$0.75Q_p$
W_{75}
$0.5Q_p$
W_{50}
T_p
Time



t_r
t_l
Q_p
$0.75Q_p$
W_{75}
$0.5Q_p$
W_{50}
T_p
Time

Once the lag time is known, time to peak (T_p) of the unit hydrograph could be determined by adding $0.5t_r$ to the lag time in consistent units.

Peak flow rate, Q_p, of the unit hydrograph is calculated as:

$$Q_p = \frac{640 C_p A}{T_p}$$

where Q_p = peak flow rate of the unit hydrograph, in cfs.

A = area of the catchment, in square miles.

C_p = unit hydrograph peaking coefficient, and is determined as:

$$C_p = P \cdot C_t \cdot A^{0.15}$$

where P = peaking parameter.

C_t and P are defined in terms of percent impervious (I_a) of the catchment as:

$$C_t = aI_a^2 + bI_a + c$$

$$P = dI_a^2 + eI_a + f$$

The coefficients *a*, *b*, *c*, *d*, *e*, and *f* are defined in terms of I_a in the following table.

IA	***A***	***B***	***C***	***D***	***E***	***F***
***Ia* ≤ 10**	0.0	-0.00371	0.163	0.00245	-0.012	2.16

10 **<** ***Ia*** **≤** **40**	0.000023	-0.00224	0.146	0.00245	-0.012	2.16
Ia **>** **40**	0.0000033	-0.000801	0.120	-0.00091	0.228	-2.06

The widths of the unit hydrograph at 50% and 75% of the peak are estimated as:

$$W_{50} = \frac{500}{\left(\frac{Q_p}{A}\right)}$$

$$W_{75} = \frac{260}{\left(\frac{Q_p}{A}\right)}$$

where W_{50} = width of the unit hydrograph at 50% of the peak, in hours.

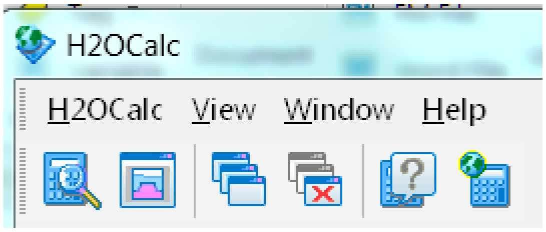
W_{75} = width of the unit hydrograph at 75% of the peak, in hours.

Q_p = peak flow rate, in cfs.

A = catchment area, in square miles.

It is recommended that a unit hydrograph duration of 5-minute be used for studies that apply the CUHP. The maximum recommended drainage area (catchment size) for any single CUHP unit hydrograph is 5 square miles. Whenever a larger watershed is studied, it needs to be subdivided into

Subcatchments of 5-square miles or less. For this synthetic unit hydrograph method, the minimum drainage area should be 90 acres. For catchments smaller than 90 acres, other unit hydrograph generation mechanisms should be used.


H2OCalc
H2OCalc View Window Help

Snyder Unit Hydrograph Method

Snyder's method for unit hydrograph synthesis relates the time from the centroid of the excess rainfall to the peak of the unit hydrograph, also referred to as lag time, to geometric characteristics of the basin in order to derive critical points for interpolating the unit hydrograph. Lag time is evaluated by

$$t_L = C_1 C_t \left(L L_{CA}\right)^{0.3}$$

where t_L is in hrs; C_1 is a constant equal to 1.0 in U.S. customary units and 0.75 in S.I. units; C_t is an empirical watershed storage coefficient, which generally ranges from 1.8 to 2.2; L is the length of the main stream channel in mi or km; and L_{CA} is the length of stream channel from a point nearest the center of the basin to the outlet in mi or km.

The standard duration of excess rainfall is computed empirically by

$$t_r = \frac{t_L}{5.5}$$

Adjusted values of lag time, t_{La}, for other durations of rainfall excess can be obtained by

$$t_{La} = t_L + 0.25\left(t_{ra} - t_r\right)$$

where t_{ra} is the alternative unit hydrograph duration. Time to peak discharge can be computed as a function of lag time and duration of excess rainfall, expressed as

$$t_p = t_{La} + 0.5 t_{ra}$$

The peak discharge, Q_p is defined as

$$Q_p = \frac{C_2 C_p A}{t_{La}}$$

where Q_p is in cfs/in or m^3/s/m; C_2 is a constant equal to 640 in U.S. customary units and 2.75 in S.I. units; A is drainage area in mi^2 or km^2; and C_p is a second empirical constant ranging from approximately 0.5 to 0.7. Coefficients C_t and C_p are regional parameters that should be calibrated or be based on values obtained for similar gaged drainage areas. The ultimate shape of Snyder's unit hydrograph is primarily controlled by two parameters, W_{50} and W_{75}, which represents widths of the unit hydrograph at discharges equal to 50 and 75 percent of the peak discharge, respectively. These shape parameters can be evaluated by

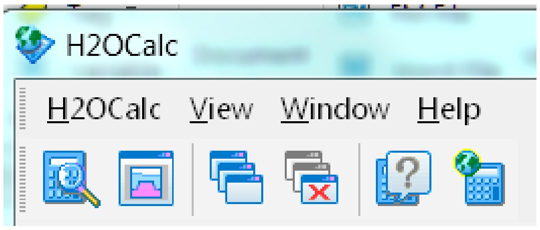
$$W_{50} = C_{50}\left(\frac{A}{Q_p}\right)^{1.08}$$

and

$$W_{75} = C_{75}\left(\frac{A}{Q_p}\right)^{1.08}$$

where C_{50} is a constant equal to 770 in U.S.

where C_{50} is a constant equal to 770 in U.S. customary units and 2.14 in S.I. units; and C_{75} is a constant equal to 440 in U.S. customary units and 1.22 in S.I. units. The location of the end points for W_{50} and W_{75} are often placed such that one-third of both values occur prior to the time to peak discharge and the remaining two-thirds occur after the time to peak. Finally, the base time, or time from beginning to end of direct runoff, should be evaluated such that the unit hydrograph represents 1 in (or 1 cm in S.I. units) of direct runoff volume. With known values of t_p, Q_p, W_{50}, and W_{75}, along with the adjusted base time, one can then locate a total of seven unit hydrograph ordinates.


H2OCalc
H2OCalc View Window Help

Clark Unit Hydrograph Method

Clark's method derives a unit hydrograph by explicitly representing the processes of translation and attenuation, which are the two critical phenomena in transformation of excess rainfall to runoff hydrograph. Translation refers to the movement, without storage, of runoff from its origin to the watershed outlet in response to gravity force, where as attenuation represents the reduction of runoff magnitude due to resistances arising from frictional forces and storage effects of soil, channel, and land surfaces. Clark (1945) noted that the translation of flow through the watershed could be described by a time-area curve (see Figure below), which expresses the curve of the fraction of watershed area contributing runoff to the watershed outlet as a function of travel time since the start of effective precipitation. Each subarea is delineated so that all the precipitation falling on the subarea instantaneously has the same time of travel to the outflow point.

Developing a time-area curve for a watershed could be a time consuming process. For watersheds that lack derived time-area diagram, the HEC-HMS model, which was developed at the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers, uses the following relationship (HEC, 2000)

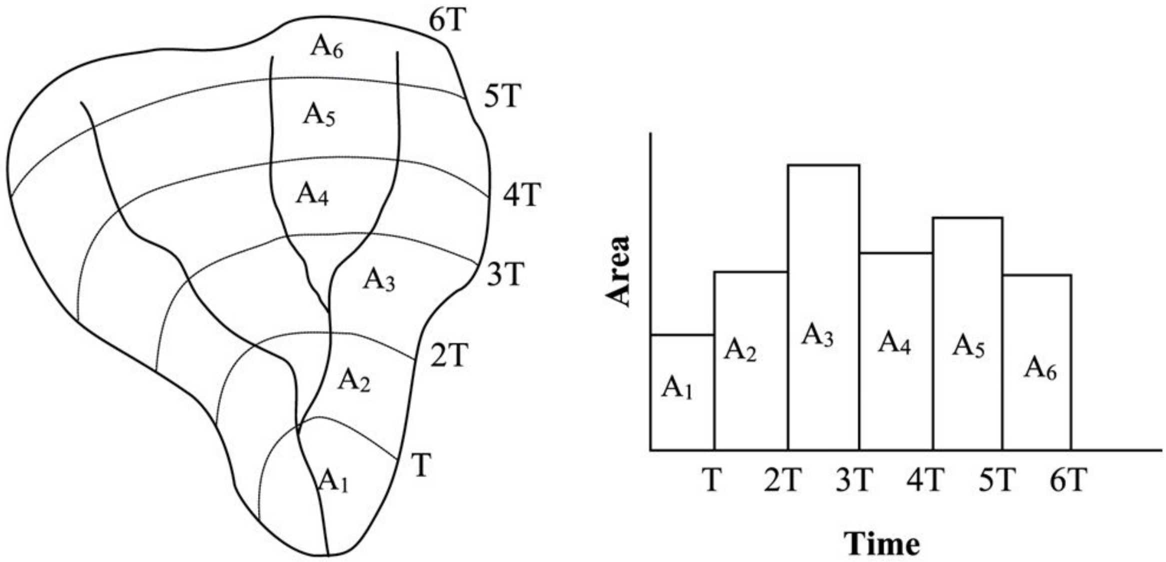
$$\frac{A_{c,t}}{A_T} = \left\{ \begin{array}{ll} 1.414\left(\dfrac{t}{t_c}\right)^{1.5} & for \quad t \leq \dfrac{t_c}{2} \\ 1 - 1.414\left(1 - \dfrac{t}{t_c}\right)^{1.5} & for \quad t \geq \dfrac{t_c}{2} \end{array} \right\}$$

where $A_{c,t}$ is cumulative watershed area contributing at time t; A_T is total watershed area; and t_c is time of concentration of the watershed. If the incremental areas, denoted as A_i in the figure below, are multiplied by a unit depth of excess rainfall and divided by Δt, the computational time step, the result is a translated hydrograph that is considered as an inflow to a conceptual linear reservoir located at the watershed outlet.

To account for storage effects, the attenuation process is modeled by routing the translated hydrograph through a linear reservoir with storage properties similar to those of the watershed. The routing model is based on the mass balance equation

$$\frac{dS}{dt} = I_t - Q_t$$

where ***dS/dt*** is time rate of change of water in storage at time t; I_t is average inflow, obtained from the time-area curve, to storage at time t; and Q_t is outflow from storage at time t.



For linear reservoir model, storage is related to outflow as

$$S_t = RQ_t$$

where R is a constant linear reservoir parameter that represents the storage effect of the watershed. Usually, lag time (t_L) is used as an approximation to R. Combining and solving Equations 116 and 117 using a finite difference approximation provides

$$Q_t = C_1 I_t + C_2 Q_{t-1}$$

where C_1 and C_2 are routing coefficients calculated as

$$C_1 = \frac{\Delta t}{R + 0.5\Delta t}$$

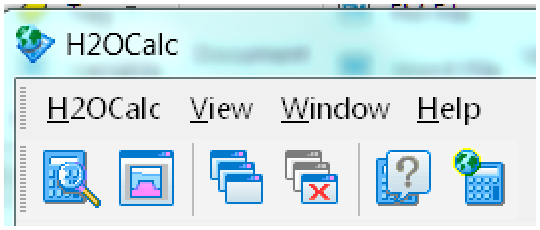
$$C_2 = 1 - C_1$$

The average outflow during period *t* is

$$\bar{Q}_t = \frac{Q_{t-1} + Q_t}{2}$$

If the inflow, I_t, ordinates are runoff from a unit depth of excess rainfall, the average outflows derived by Equation 121 represent Clark’s unit hydrograph ordinates. Clark’s unit hydrograph is, therefore, obtained by routing a unit depth of direct runoff to the channel in proportion to the time-area curve and routing the runoff entering the channel through a linear reservoir. Note that solution of Equations 118 and 121 is a recursive process. As such, average outflow ordinates of the unit hydrograph will theoretically continue for an infinite duration. Therefore, it is customary to truncate the recession limb of the unit hydrograph where the outflow volume exceeds 0.995 inches or mm. Clark’s method is based on the premise that duration of the rainfall excess is infinitesimally small. Because of this, Clark’s unit hydrograph is referred to as an instantaneous unit hydrograph or IUH. In practical applications, it is usually necessary to alter the IUH into a unit hydrograph of specific duration. This can be accomplished by lagging the IUH by the desired duration and averaging the ordinates.

Innovyze® H2OCalc™ Modeling Made Easy Innovyze®


H2OCalc
H2OCalc View Window Help

Espey Unit Hydrograph Method

After analyzing runoff records from 41 urban watersheds located in eight different states in the United States with areas ranging from 9 acres to 15 mi^2 and with percent imperviousness ranging from 2 to 100, Espey and Altman (1978) developed a 10-minute unit hydrograph for urban watersheds. This unit hydrograph is commonly named as Espey 10-minute unit hydrograph, and the following equations are used to determine its ordinates.

$$t_p = \frac{3.1 L^{0.23} \phi^{1.57}}{S^{0.25} IMP^{0.18}}$$

$$Q_p = \frac{31{,}620 A^{0.96}}{t_p^{1.07}}$$

$$t_b = \frac{125{,}890 A}{Q_p^{0.95}}$$

$$W_{50} = \frac{16{,}220 A^{0.93}}{Q_p^{0.92}}$$

$$W_{75} = \frac{3{,}240 A^{0.79}}{Q_p^{0.78}}$$

According to Espey and Altman (1978) method, slope is calculated as:

$$S = \frac{H}{0.8L}$$

where t_p = time to peak in minutes.

Q_p = peak discharge in ft^3/sec.

t_b = total hydrograph base in minutes.

W_{50} = hydrograph widths at 50% of the peak discharge rates in minutes.

W_{75} = hydrograph widths at 75% of the peak discharge rates in minutes.

A = area in mi^2.

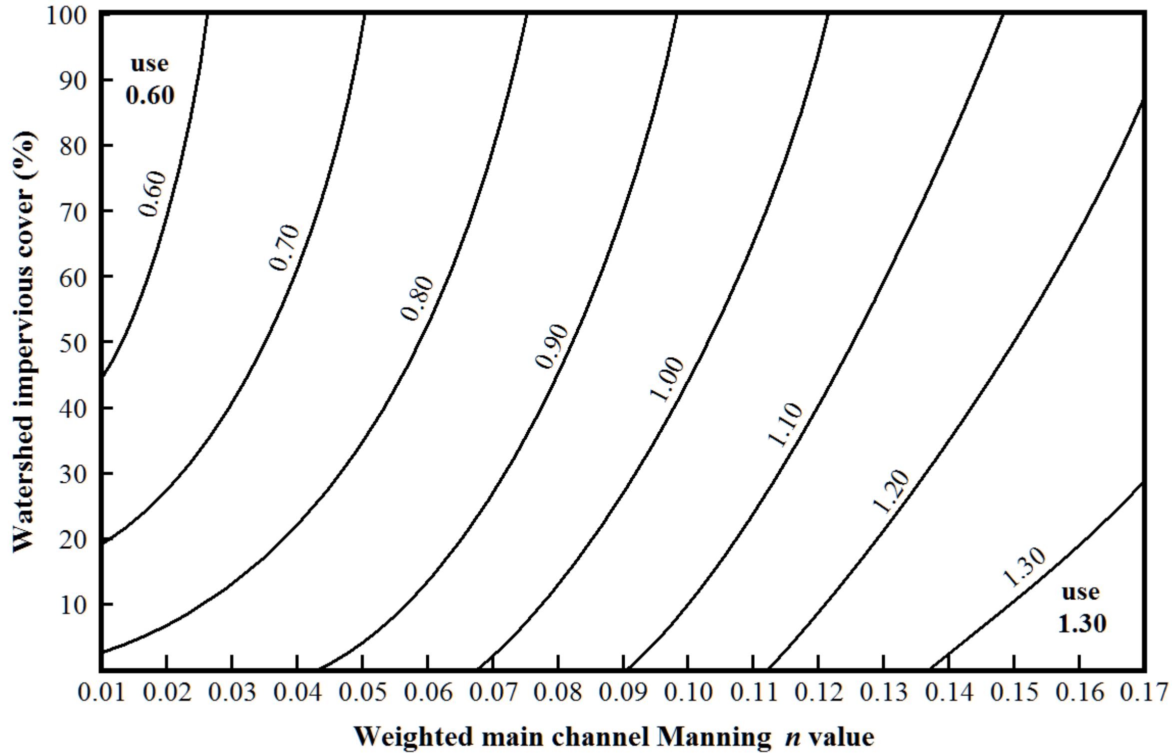
L = length in ft.

S = watershed slope in ft/f.

IMP = roughness and percent imperviousness.

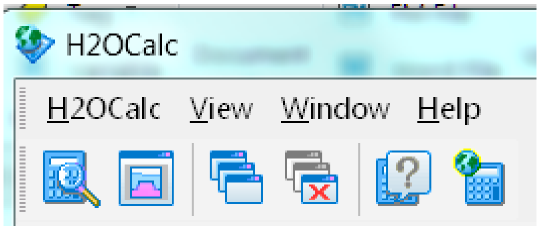
H = is the elevation difference in the channel bottom at design point and 0.8L upstream (ft).

> f = conveyance factor, dimensionless. This factor depends on the percent imperviousness and weighted main channel Manning roughness coefficient is determined graphically from the following figure.



The shape parameters, W_{50} and W_{75}, are to be drawn parallel to the abscissa and are usually located such that one third of the width is located to the left of the time to peak. Once the equations are solved and the seven ordinates that govern the general shape of the 10-minute unit hydrograph are determined, a smooth curve is then fit through these points and adjusted until the volume of direct runoff is equivalent to one inch over the watershed.

Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Espey Unit Hydrograph Method

After analyzing runoff records from 41 urban watersheds located in eight different states in the United States with areas ranging from 9 acres to 15 mi^2 and with percent imperviousness ranging from 2 to 100, Espey and Altman (1978) developed a 10-minute unit hydrograph for urban watersheds. This unit hydrograph is commonly named as Espey 10-minute unit hydrograph, and the following equations are used to determine its ordinates.

$$t_p = \frac{3.1 L^{0.23} \phi^{1.57}}{S^{0.25} IMP^{0.18}}$$

$$Q_p = \frac{31{,}620 A^{0.96}}{t_p^{1.07}}$$

$$t_b = \frac{125{,}890 A}{Q_p^{0.95}}$$

$$W_{50} = \frac{16{,}220 A^{0.93}}{Q_p^{0.92}}$$

$$W_{75} = \frac{3{,}240 A^{0.79}}{Q_p^{0.78}}$$

According to Espey and Altman (1978) method, slope is calculated as:

$$S = \frac{H}{0.8L}$$

where t_p = time to peak in minutes.

Q_p = peak discharge in ft^3/sec.

t_b = total hydrograph base in minutes.

W_{50} = hydrograph widths at 50% of the peak discharge rates in minutes.

W_{75} = hydrograph widths at 75% of the peak discharge rates in minutes.

A = area in mi^2.

L = length in ft.

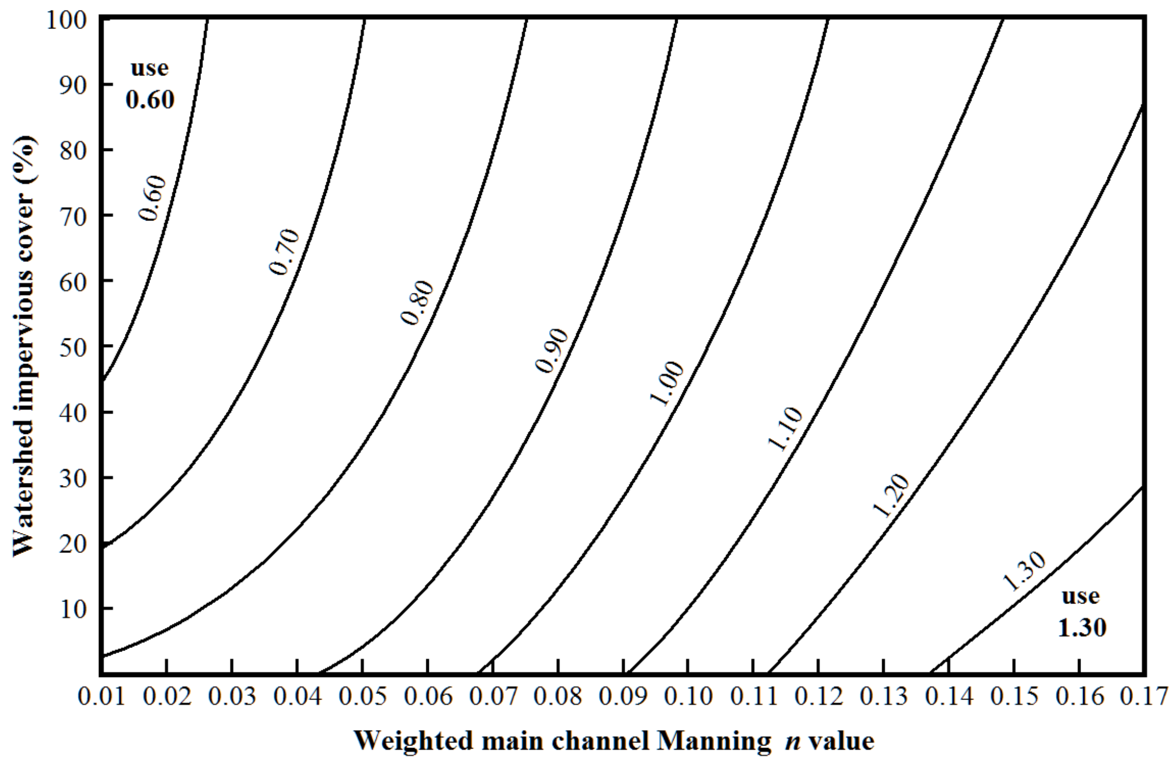
S = watershed slope in ft/f.

IMP = roughness and percent imperviousness.

H = is the elevation difference in the channel bottom at design point and

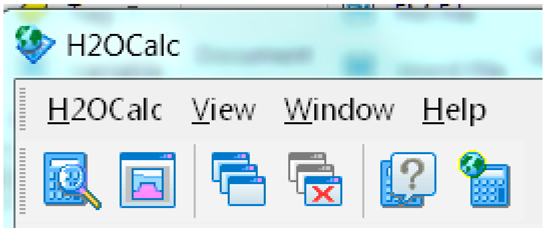
0.8L upstream (ft).

f = conveyance factor, dimensionless. This factor depends on the percent imperviousness and weighted main channel Manning roughness coefficient is determined graphically from the following figure.



The shape parameters, W_{50} and W_{75}, are to be drawn parallel to the abscissa and are usually located such that one third of the width is located to the left of the time to peak. Once the equations are solved and the seven ordinates that govern the general shape of the 10-minute unit hydrograph are determined, a smooth curve is then fit through these points and adjusted until the volume of direct runoff is equivalent to one inch over the watershed.

Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

San Diego Modified Rational Formula

The Rational method is a widely used technique for estimation of peak flows from urban and rural drainage basins (Maidment 1993; Mays 2001). Mathematically, the Rational formula is expressed as:

$$Q = CIA$$

where Q = peak runoff rate (flow unit)

C = runoff coefficient (unitless)

I = rainfall intensity (intensity unit)

A = watershed area (area unit)

Stormwater modeling applications such as the design of detention basins require knowledge of total inflow volume obtained from runoff Hydrographs. For these applications peak flow information alone may not be sufficient. The San Diego modified rational formula is a technique adopted by the San Diego County to generate runoff hydrograph by extending the traditional rational formula.

The San Diego County uses a 6-hour storm event for many Stormwater design applications. Accordingly, for designs that are dependent on total storm volume a hydrograph has to be generated by creating a rainfall distribution consisting of blocks of rain, creating an incremental hydrograph for each block of rain using the modified rational formula, and adding the Hydrographs from each block of rain where each rainfall block lasts for a duration of time of concentration. The rainfall blocks are distributed across the 6-hour duration using the “2/3, 1/3” distribution in which the peak rainfall block is centered at the 4-hour time within the 6-hour rainfall duration, and the additional blocks are distributed in a sequence alternating two blocks to the left and one block to the right of the 4-hour time. The actual rainfall amount for each rainfall block is calculated as:

$$P_N = 0.124P_{6-hr}\left((NT_c)^{0.355} - ((N-1)T_c)^{0.355}\right)$$

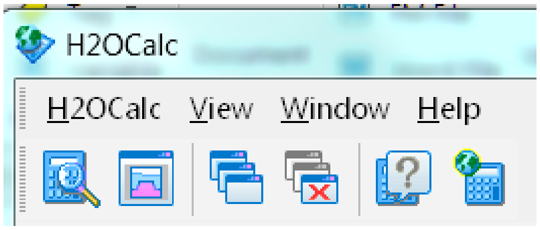
where PN = actual rainfall amount for each rainfall block (inch or mm)

P6-hr = six-hour storm depth (inch or mm)

N = an integer representing position of a given block number of rainfall. N is 1 for the peak rainfall block, and is assigned according to the “2/3, 1/3” distribution rule for other rainfall blocks.

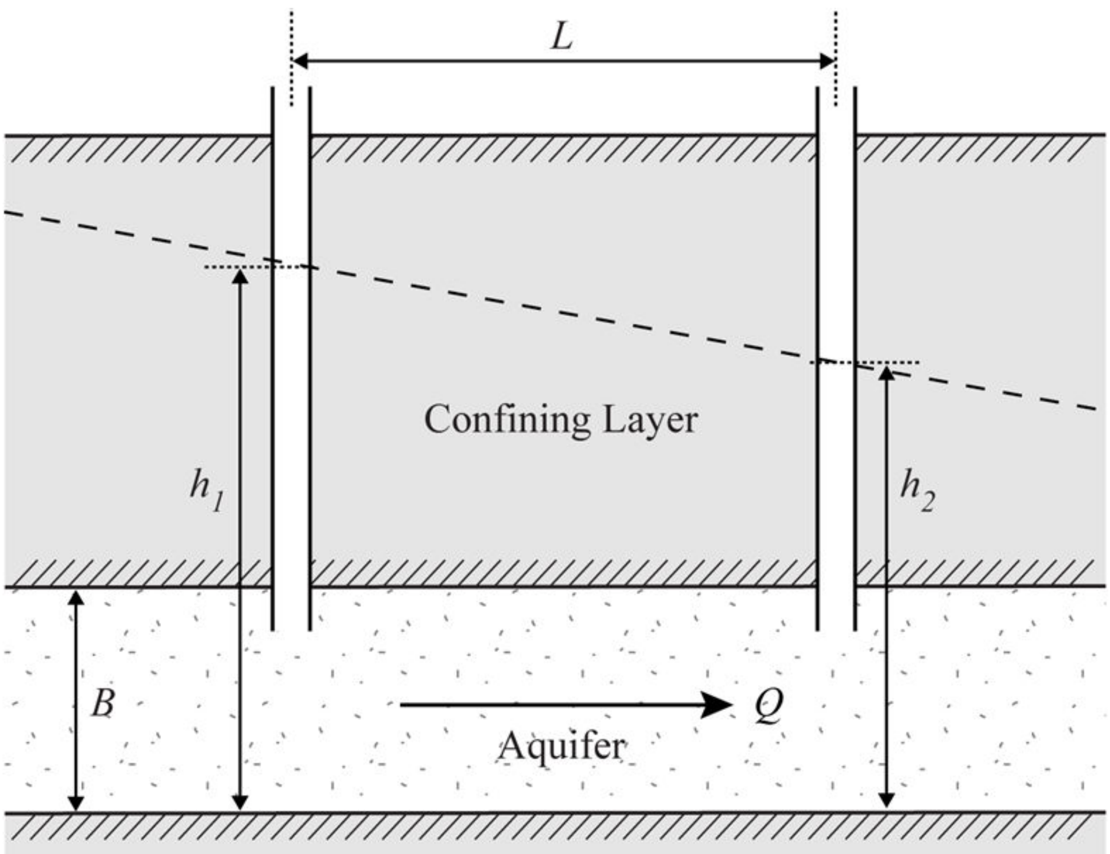
Tc = time of concentration (minutes)

Once rainfall distribution is created, triangular hydrograph is generated for each rainfall block. Peak flow for the triangular hydrograph is computed according to the rational formula. Finally, the overall hydrograph for the 6-hr storm event is determined by adding all the triangular Hydrographs from each block of rain. The final hydrograph has its peak at 4 hours plus ½ of the Tc. The total volume under the hydrograph is the product of runoff coefficient, the six-hour precipitation depth, and area of the Subcatchment.


H2OCalc
H2OCalc View Window Help

Steady Flow in a Confined Aquifer

If there is the steady movement of ground water in a confined aquifer, there will be a gradient or slope to the potentiometric surface of the aquifer. A portion of a confined aquifer of uniform thickness is shown in the following figure. The potentiometric surface has a linear gradient. There are two observation wells where the hydraulic head can be measured.



Steady Flow in a Confined Aquifer

For flow of this type, Darcy’s law may be used directly.

$$q = -KB\frac{dh}{dl} = -KB\frac{h_2 - h_1}{L}$$

where q = flow rate per unit width of aquifer (m^2/d, ft^2/d)

K = hydraulic conductivity of aquifer (m/d, ft/d) (see Table 3-13)

dh/dl = hydraulic gradient

B = aquifer thickness (m, ft)

L = flow length (m, ft)

h_2 = head at length L (m, ft)

h_1 = head at the origin (m, ft)

Table 3-13: Soil Properties

Soil Type	Hydraulic Conductivity, K (cm/s)
Clayey	10^{-9} - 10^{-6}
Silty	10^{-7} - 10^{-3}
Sandy	10^{-5} - 10^{-1}
Gravelly	10^{-1} - 10^{2}

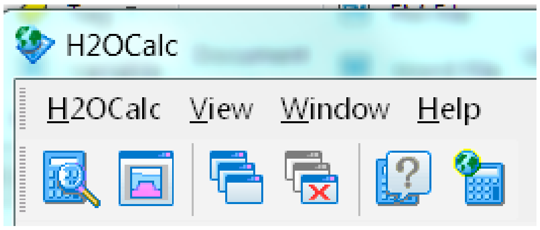
The aquifer transmissivity is defined as a measure of the amount of water that can be transmitted horizontally through a unit width by the fully saturated thickness of the aquifer under a hydraulic gradient of 1. The transmissivity, T, (m^2/d, ft^2/d) is the product of the hydraulic conductivity (K) and the saturated thickness of the aquifer (B) as

$$T = BK$$

Innovyze Help File Updated September 1, 2017

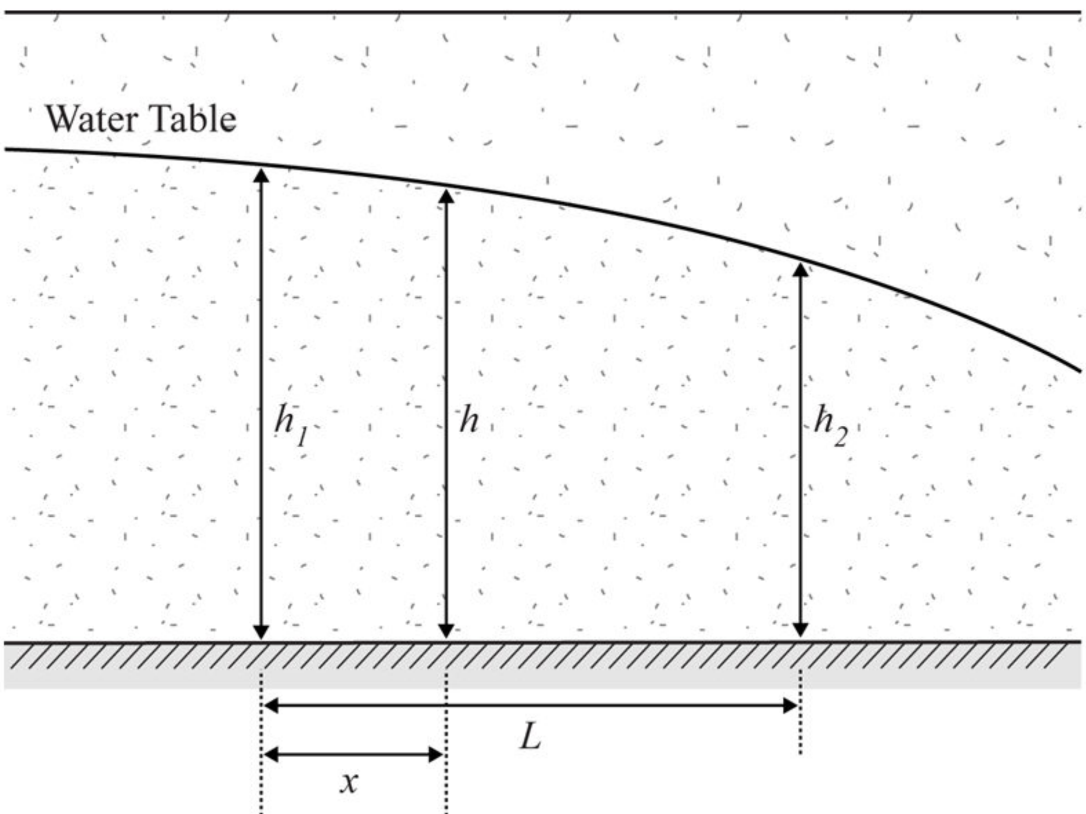
InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Steady Flow in an Unconfined Aquifer

In an unconfined aquifer, the fact that the water table is also the upper boundary of the region of flow complicates flow determinations. This problem was solved by Dupuit who made the following simplifying assumptions: (1) the hydraulic gradient is equal to the slope of the water table and (2) for small water-table gradients, the streamlines are horizontal and the equipotential lines are vertical. Using these assumptions, Depuit developed Equation (102), commonly known as the *Dupuit equation*.



Steady Flow in an Unconfined Aquifer

$$q = \frac{1}{2} K \left(\frac{h_1^2 - h_2^2}{L} \right)$$

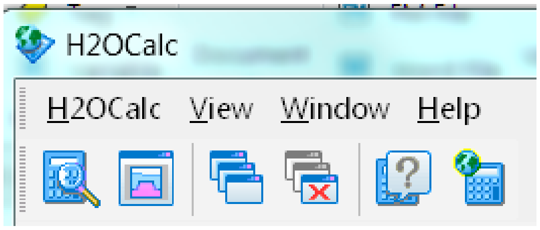
where q = flow rate per unit width of aquifer (m^2/d, ft^2/d)

K = hydraulic conductivity of aquifer (m/d, ft/d) (see Table 3-13)

L = flow length (m, ft)

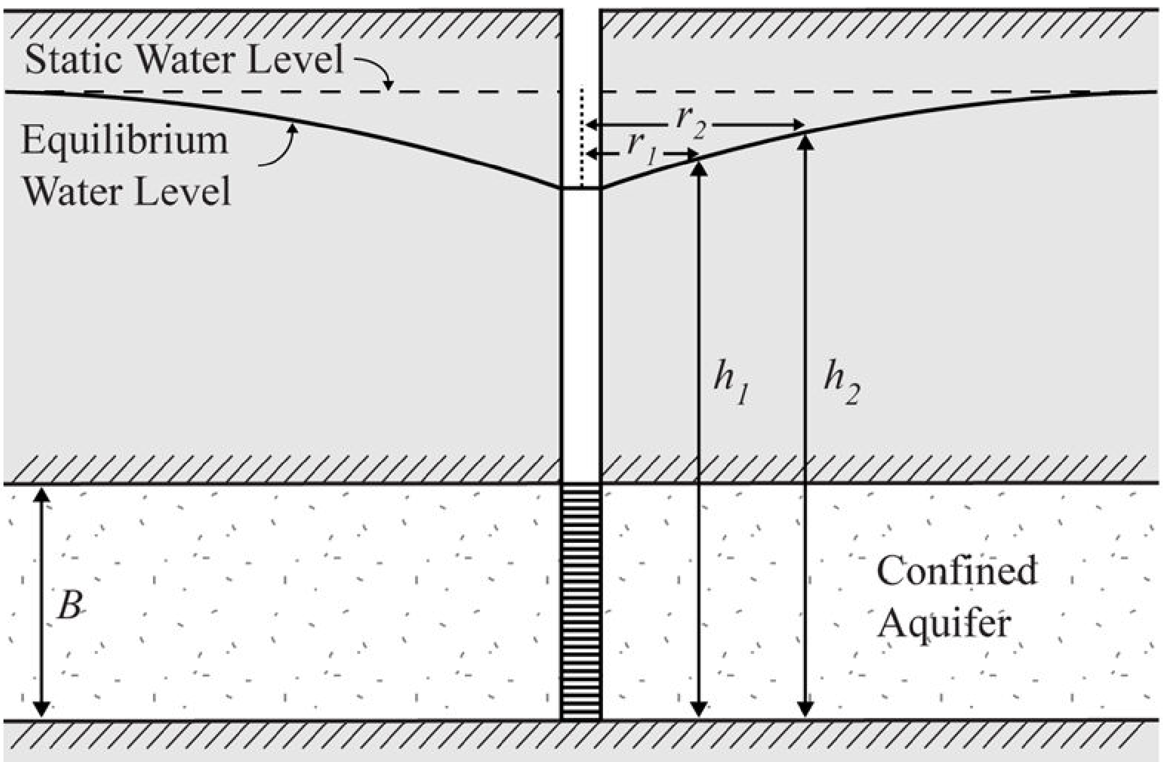
h_2 = head at length L (m, ft)

h_1 = head at the origin (m, ft)


H2OCalc
H2OCalc View Window Help

Well Hydraulics of Confined Steady Flow

Darcy's equation can be used to analyze axially symmetric flow into a well. If a well pumps long enough, the water level may reach a state of equilibrium; that is, there is no further drawdown with time. The following figure illustrates the flow conditions for a well in a confined aquifer.



Steady Flow to a Well in a Confined Aquifer

In the case of steady radial flow in a confined aquifer, the steady pumping rate is

$$Q = 2\pi KB \frac{h_2 - h_1}{\ln(r_2 / r_1)} \quad \text{or} \quad Q = 2\pi T \frac{h_2 - h_1}{\ln(r_2 / r_1)}$$

$$Q = 2\pi KB \frac{d_1 - d_2}{\ln(r_2 / r_1)} \quad \text{or} \quad Q = 2\pi T \frac{d_1 - d_2}{\ln(r_2 / r_1)}$$

where Q = pumping rate (m^3/d, ft^3/d)

K = hydraulic conductivity of aquifer (m/d, ft/d)

B = aquifer thickness (m, ft)

T = hydraulic transmissivity (m^2/d, ft^2/d)

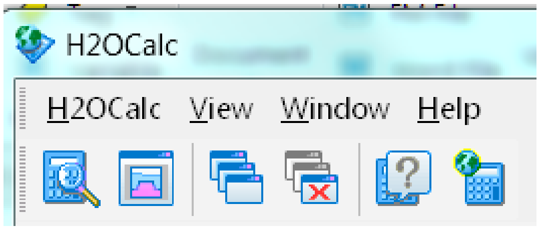
h_2 = head at distance r_2 from the pumping well (m, ft)

h_1 = head at distance r_1 from the pumping well (m, ft)

d_2 = drawdown at distance r_2 from the pumping well (m, ft)

d_1 = drawdown at distance r_1 from the pumping well (m, ft)

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Well Hydraulics of Unconfined Steady Flow

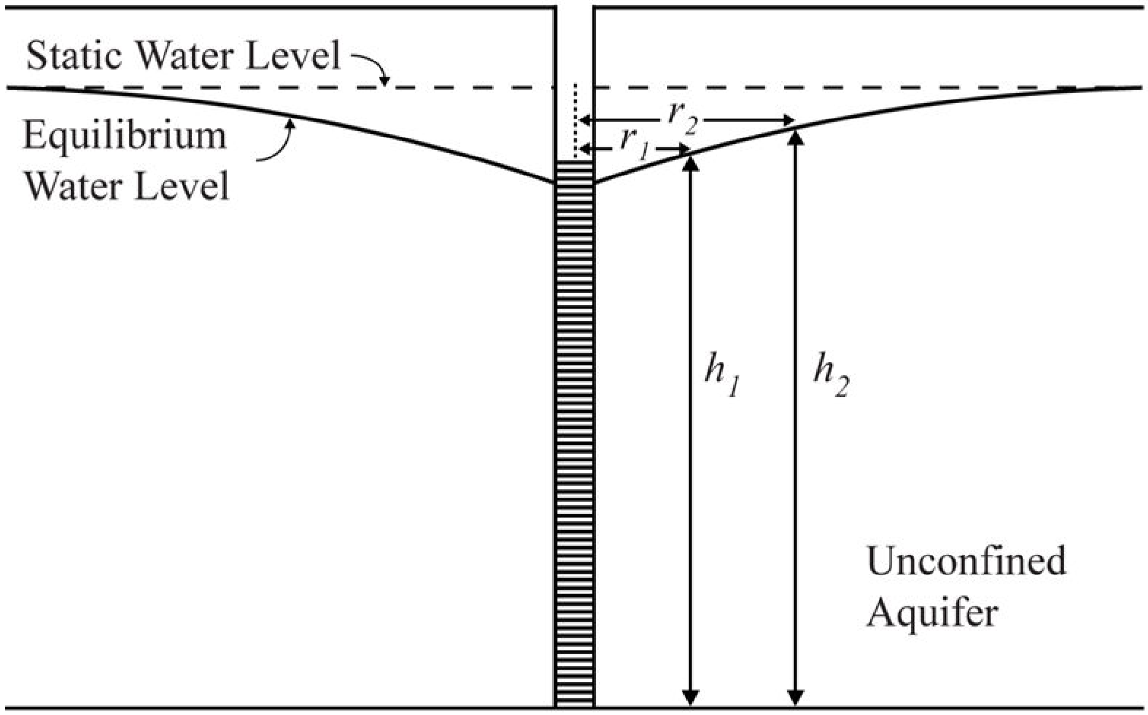
The following figure illustrates the flow conditions for a well in an unconfined aquifer. In the case of steady radial flow in an unconfined aquifer, the steady pumping rate is

$$Q = \pi K \frac{(h_2^2 - h_1^2)}{\ln(r_2 / r_1)}$$

or

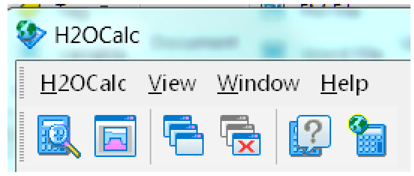
$$Q = \pi K \frac{(d_1^2 - d_2^2)}{\ln(r_2 / r_1)}$$

All the terms are consistent with the definitions given above.



Steady Flow to a Well in an Unconfined Aquifer

H2OCalc™ Modeling Made Easy



3.17 Unit Conversion

Both SI and English units are used throughout this users guide. Tables 13-14 through 13-19 list conversion factors for common units.

Table 13-14: Length Equivalents

Unit	Equivalent					
	Millimeter	Inch	Foot	Meter	Kilometer	Mile
Millimeter	1	0.03937	0.003281	0.001	1´10^{-6}	0.621 ´10^{-6}
Inch	25.4	1	0.0833	0.0254	25.40´10^{-6}	15.78 ´10^{-6}
Foot	304.8	12	1	0.3048	304.8´10^{-6}	189.4 ´10^{-6}
Meter	1,000	39.37	3.281	1	0.0010	621.4 ´10^{-6}
Kilometer	1´10^{6}	39,370	3,281	1,000	1	0.6214
Mile	1.609´10^{6}	63,360	5,280	1,609	1.609	1

Note: Multiply the amount of the given unit by the value shown to obtain the amount in equivalent units (e.g., 1.50 m x 39.37 inch/m = 59.1 inch)

Table 13-15: Area Equivalents

Unit	Equivalent					
	Sq. inch	Sq. foot	Sq. meter	Acre	Hectare	Sq. mile
Sq. inch	1	0.006944	645´10^{-6}	0.16´10^{-6}	64.5´10^{-9}	0.25´10^{-9}
Sq. foot	144	1	0.0929	23´10^{-6}	9.29´10^{-6}	35.9´10^{-9}
Sq. meter	1,550	10.76	1	2471´10^{-6}	0.0001	0.39´10^{-6}
Acre	6.27´10^{6}	43,560	4,047	1	0.4047	0.001563
Hectare	15.5´10^{6}	107,639	10,000	2.471	1	0.003861
Sq. mile	4.01´10^{9}	27.88´10^{6}	2.59´10^{6}	640	259.0	1

Table 3-16: Volume Equivalents

	Equivalent					
Unit	**Cu. inch**	**Liter**	**U.S. gallon**	**Cu. foot**	**Cu. meter**	**Acre-foot**
Cu. inch	1	0.01639	0.004329	578.7´10^{-6}	16.39´10^{-6}	13.29´10^{-9}

Liter	61.02	1	0.2642	0.03531	0.0010	810.6´10^{-9}
U.S. gallon	231.0	3.785	1	0.1337	0.003785	3.068´10^{-6}
Cu. foot	1,728	28.32	7.481	1	0.02832	22.96´10^{-6}
Cu. meter	61,020	1,000	264.2	35.31	1	810.6´10^{-6}
Acre-foot	75.27´10^{6}	1.233´10^{6}	325,900	43,560	1,233	1

Table 3-17: Discharge Equivalents

Unit	Equivalent					
	Gallon/min	Liter/sec	Acre-ft/day	Cu. foot/sec	Million gal/day	Cu. meter/sec
Gallon/min	1	0.06309	0.004419	0.002228	0.001440	63.09´10^{-6}
Liter/sec	15.85	1	0.07005	0.03531	0.02282	0.0010
Acre-ft/day	226.3	14.28	1	0.5042	0.3259	0.01428
Cu. foot/sec	448.8	28.32	1.983	1	0.6463	0.02832
Million gal/day	694.4	43.81	3.069	1.547	1	0.04381
Cu. meter/sec	15,850	1,000	70.04	35.31	22.82	1

Table 3-18: Miscellaneous Conversions

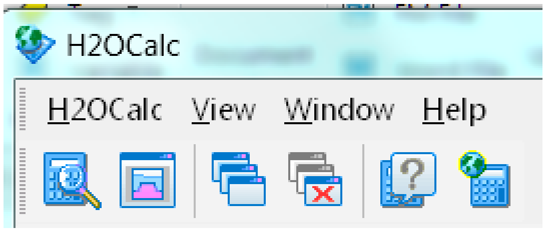
Dimension	SI unit	Multiplier	Equivalent U.S. customary unit
Velocity	Meter/sec	3.281	Feet/second
Mass	Kilogram	0.06852	Slugs
Force	Newton	0.2248	Pound force
Pressure	Pascal	145.0´10^{-6}	Pound force/sq. inch
Pressure	Pascal	0.02089	Pound force/sq. foot
Power	Watt	0.001341	Horsepower
Power	Watt	0.7376	Foot-pound/second
Energy	Joule	0.7376	Foot - pound
Heat Density	Calorie/sq. cm. (i.e., Langley)	3.687	BTU/sq. foot

Note: To covert from U.S. customary units to S.I. units, use the inverse of the listed multiplier (e.g., 2.0 ft/s ´ (1/3.281) = 0.61 m/s)

Table 3-19: Temperature Conversions

Original unit	Conversion formula	Equivalent unit
^{o}F	5 ´ (^{o}F – 32) / 9	^{o}C
^{o}C	32 + (9 ´ ^{o}C / 5)	^{o}F
^{o}C	^{o}C + 273	^{o}K
^{o}F	5 ´ (^{o}F + 460) / 9	^{o}K
^{o}R	5 ´ ^{o}R / 9	^{o}K

Note: oC = degree Celsius; oF = degree Fahrenheit; oR = degree Rankine; and oK = degree Kelvin


H2OCalc
H2OCalc View Window Help

References

- Boulos, P.F., Lansey, K.E., and Karney, B.W. (2006). *Comprehensive Water Distribution Systems Analysis Handbook for Engineers and Planners*. 2nd edition, Innovyze® Inc.. Pasadena, California, USA, 660 p.
- Clark, C.O. (1945). “Storage and the Unit Hydrograph,” *Transaction of the ASCE*, Vol. 110.
- Espey, W.H., D.G. Altman (1978). “Nomographs for 10-minute Unit Hydrographs for Small Urban Watersheds,” U.S. EPA, Report EPA-600/9-78-035.
- Federal Highway Administration (FHWA) (2001). “Urban Drainage Design Manual,” *Hydraulic Engineering Circular NO. 22*, 2nd Edition, Publication No. FHWA-NHI-01-021, Washington, DC, USA
- Hydrologic Engineering Center (HEC) (2000), *Hydrologic Modeling System HEC-HMS – Users Manual*, U.S. Army Corps of Engineers, Davis, CA.
- Lindeburg, M.R. (2003). *Civil Engineering Reference Manual for the PE Exam*. Professional Publications, Inc., Belmont, California, USA.
- Nicklow, J.W. and Boulos, P.F. (2005). *Comprehensive Water and Wastewater Treatment Plant Hydraulics Handbook for Engineers and Operators*. Innovyze® Inc.. Pasadena, California, USA, 234 p.
- Nicklow, J.W., Boulos, P.F., and Muleta, M.K. (2004). *Comprehensive Sewer Collection Systems Analysis Handbook for Engineers and Planners*. Innovyze® Inc.. Pasadena, California, USA, 287 p.
- Nicklow, J.W., Boulos, P.F., and Muleta, M.K. (2006). *Comprehensive Urban Hydrologic Modeling Handbook for Engineers and Planners*. Innovyze® Inc.. Pasadena, California, USA.
- Normann, J.M., Houghtalen, R.J., and Johnson, W.J. (1985). “Hydraulic Design of Highway Culverts,” *HDS No. 5*, Federal

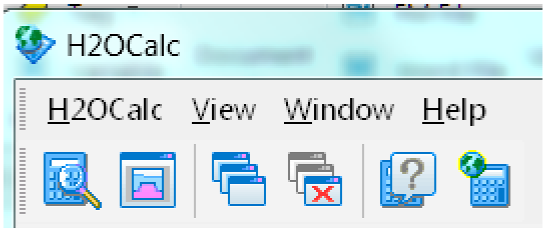
Highway Administration (FHWA), U.S. Department of Transportation, Norfolk, VA

- Soil Conservation Service (SCS) (1985). *National Engineering Handbook*. U.S. Department of Agriculture, Washington D.C., USA.
- Swamee, P.K. and Jain, A.K. (1976). “Explicit Equations for Pipe Flow Problems.” *Journal of Hydraulic Division*, ASCE, 102(5), 657-664.
- Thorley, A.R.D. (2004). *Fluid Transients in Pipeline Systems*. American Society of Mechanical Engineers, New York. USA.
- Urban Drainage and Flood Control District (2001). *Urban Storm Drainage Criteria Manual*
- *Volume 1*. Denver, CO. U.S. Department of Agriculture, Soil Conservation Service (1986). *Urban Hydrology for Small*
- *Watersheds*. Washington, D.C.
- Wood, D.J., Lingireddy, S., and Boulos, P.F. (2005). *Pressure Wave Analysis of Transient Flow in Pipe Distribution Systems*. Innovyze® Inc., Pasadena, California, USA, 213 p.
- Yen, B.C., and Chow, V.T. (1983). “Local Design Storms, Vol. I to III,” Report No. FHWA-RD-82-063 to 065, U.S. Dept. of Transportation, Fed. Highway Administration, Washington, DC, USA.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

H_2OCalc User Guide

Innovyze Contact Information

You can reach Innovyze(R) Inc. by phone, Monday through Friday.

Innovyze(R) technical support can be reached at:

Phone: (626) 568-6869

Fax: (626) 568-6870

Support Email: Support@Innovyze.com :

Sales Email: Sales@Innovyze.com

Innovyze® Internet: http://www.Innovyze.com

Innovyze® Blog: http://blog.innovyze.com/

Innovyze® Forum: http://forums.innovyze.com/forum.php

Innovyze® Twitter: https://twitter.com/Innovyze

Innovyze® Linkedin Users: Innovyze Linkedin

Or write us at Innovyze® Inc., 605 East Huntington Drive. Monrovia, CA 91016.

Software License Agreement

"The current version of Innovyze's Software License Agreement can be found at the following location:

http://www.innovyze.com/licensing/"

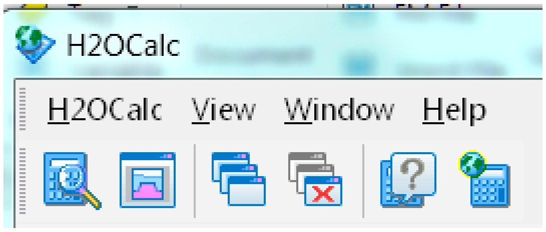
Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

Innovyze® H2OCalc™ Modeling Made Easy Innovyze®


H2OCalc
H2OCalc View Window Help

Introduction

INTRODUCTION

H_2OCalc is an easy-to-use, stand-alone program designed as a hydraulic toolbox to assist civil, environmental and water resources engineers with solving complex hydraulic problems quickly and accurately. Its powerful and comprehensive modeling capabilities let engineers streamline the hydraulic analysis and design of pipes, pumps, open channels, weirs, orifices, culverts, and inlets. Calculations for both steady uniform flow and gradually varied flow are supported. The program also performs useful calculations for stormwater runoff and groundwater flow.

H_2OCalc can be effectively used to perform pressurized pipe calculations for pipe length, begin and end elevations, roughness coefficient, diameter as well as flow rate and pressure drop using the Hazen-Williams, Darcy-Weisbach, Manning, and Kutter head loss methods. The user can design and analyze channels, ditches, and free surface pipes of various shapes including circular, box, trapezoidal, triangular and irregular channels. Both steady uniform slow and gradually varied flow are supported. Under steady uniform flow, *H_2OCalc* solves for discharge, normal depth, channel dimensions, or slope. Gradually varied flow calculations for flow and depth are carried out using the direct step method and the standard step method.

With *H_2OCalc*, you can design and analyze grate, curb, ditch, slotted, and combination inlets using calculations based on the FHWA Hydraulic Engineering Circular No. 12 and Circular No. 22 methodologies. In sag or on grade conditions with a continuously or locally depressed gutter are supported and water spread and gutter depth for a gutter or pavement section are computed.

You can also size various types of weirs considering discharge, weir coefficients, and crest, headwater and tailwater elevations including rectangular, v-notch, cipolletti, broad crested and generic. Weirs can be free flowing or submerged depending on the depth of tailwater elevation. Three types of orifice are also considered including circular, rectangular and generic.

H_2OCalc can perform surface water hydrology calculations for stormwater runoff using both the rational method and the NRCS unit hydrograph method to determine peak discharge; groundwater flow calculations for steady flow in confined and unconfined aquifers; and well hydraulics calculations of confined and unconfined steady flows. Other calculations include transient flow in a pipeline, hydraulic jump, pump characteristic curve, specific speed, torque, power and inertia, parallel and series pump arrangements, discharge from an open or close tank and equivalent pipe length.

The program can also perform complex hydraulic calculations for culverts such as determining the headwater elevation, hydraulic grade line, discharge and size. It uses the U.S. Federal Highway Administration (FHWA) Hydraulic Design of Highway Culverts (HDS-5) methodology for performing both inlet control and outlet control and overtopping calculations. Backwater and drawdown conditions, including hydraulic jumps, are considered. Free-surface, pressurized and transitional flow can be handled. Calculations apply for circular and rectangular culverts as well as for rectangular and trapezoidal stream channels. Simplified culvert equations that classify culverts into various categories depending on headwater and tailwater elevations, slope, size and other characteristics are also supported.

A unit converter is also provided to help you find the equivalent value of inputted parameters in different units. Conversion factors are available for length, area, volume, mass, density, velocity, acceleration, flow rate, temperature, force, pressure, energy and power.

We are happy to bring you an indispensable hydraulic engineering toolbox to help you quickly and accurately analyze and design various hydraulic elements from pipes and open channels to drop inlets, culverts and weirs.

Colby T. Manwaring, P.E.

Chief Executive Officer, Innovyze Inc.

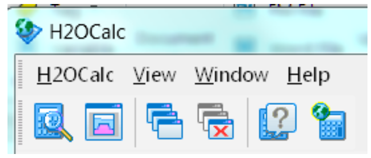
Portland, Oregon USA September 1, 2017

Innovyze Help File Updated September 1, 2017

InfoSWMM H$_2$OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Installation Guide

Recommended Configurations

System Requirements for InfoSWMM w ArcGIS, H2OMap SWMM does not need ArcGIS	
Compatible 32-bit OS:	Windows Server 2008 R2, Windows Server 2012 R2, Windows 7/8/8.1/10 pro or above
Compatible 64-bit OS:	Windows Server 2008 R2, Windows Server 2012 R2, Windows 7/8/8.1/10 pro or above
Compatible ArcGIS:	10.0, 10.1, 10.2 and 10.3 (**Check your PC ability to run ArcGIS**)
Prerequisites:	**Microsoft Visual C++ 2008 Redistributable - x64 v9.0.30729.17**/**Microsoft Visual C++ 2008 Redistributable - x86 v9.0.30729.17**, **Microsoft Visual C++ 2010 Redistributable - x86 v10.0.40219.1**/**Microsoft Visual C++ 2010 Redistributable - x64 v10.0.40219.1** and **Windows Internet Explorer 7 or later**
Hardware Requirements:	CPU Speed: 2.2 GHz minimum or higher; Hyper-threading (HHT) or Multi-core recommended Processor: Intel Pentium 4, Intel Core Duo, or Xeon Processors; SSE2 (or greater) Memory/RAM: 2 GB or higher Screen Resolution: 1024 x 768 recommended or higher at Normal size (96dpi) Disk Space: 500 MB of free space to accommodate a full setup installation and additional disk space - keep as much free disk space available as possible. Its virtual memory system needs additional free disk space when working on large projects Video/Graphics Adapter: 64 MB RAM minimum, 256 MB RAM or higher recommended. NVIDIA, ATI and INTEL chipsets supported Networking Hardware: Simple TCP/IP, Network Card or Microsoft Loopback Adapter is required for the License Manager

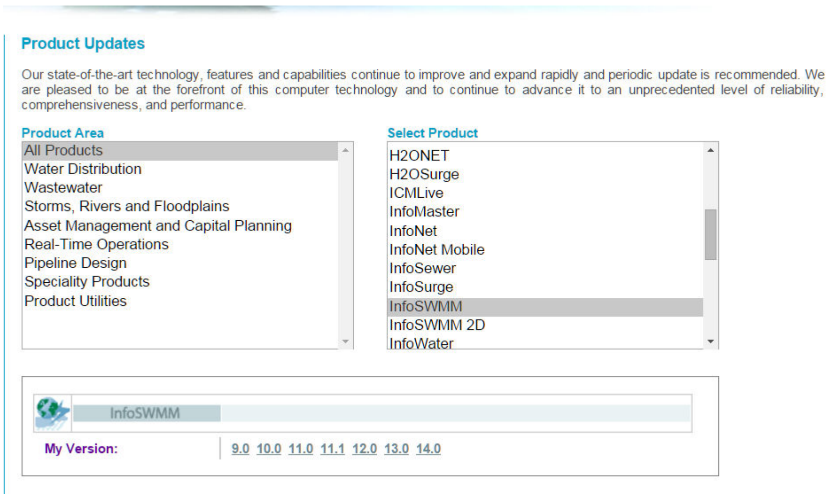
Installing Innovyze Add On's

Innovyze programs can only be installed from our Internet website. To install this program or a single user, perform the following procedure:

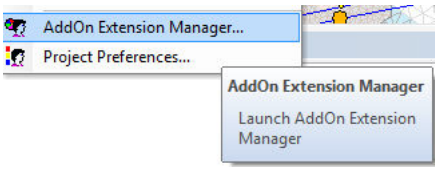
1. Turn on your computer and start Windows. Close any other applications that are currently running.

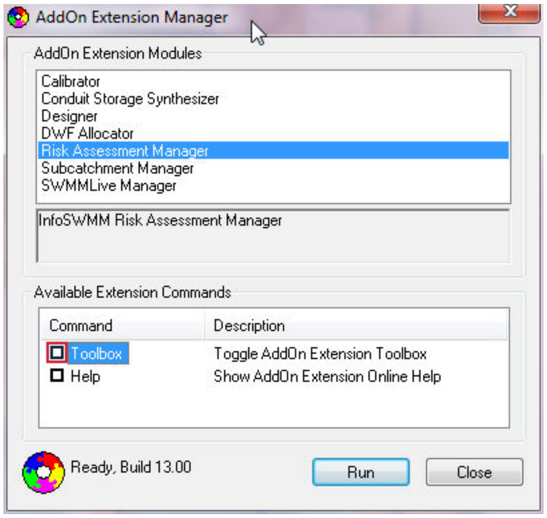
2. Start your Internet Browser software and go to http://www.Innovyze.com. Once on Innovyze® Inc's homepage, please go to http://www.innovyze.com/updates/ Choose the *program* tab and click on the link. This will launch the File Download dialogue box.

3. Choose the *SAVE THIS PROGRAM TO A Directory* option and follow the on-screen instructions. When saved on your hard drive run the Execute (*.exe) file from the folder that was downloaded and follow the on-screen instructions.



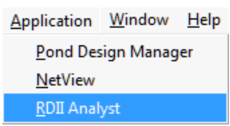
Upon successful installation of the program, the program is initialized from inside H2OMap SWMM InfoSWMM by using the "AddOn Extension Manager" tool. From the Tool Menul, select an Add On as shown below.

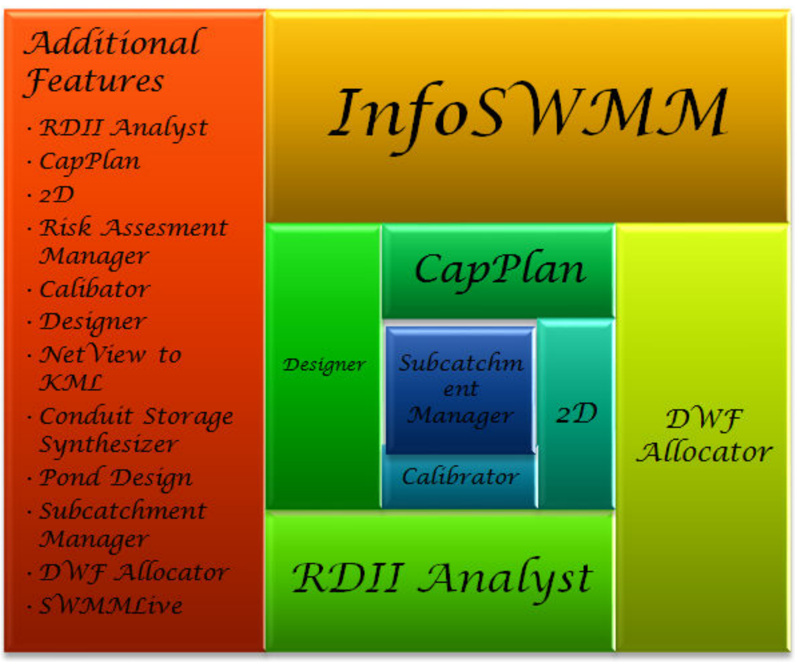




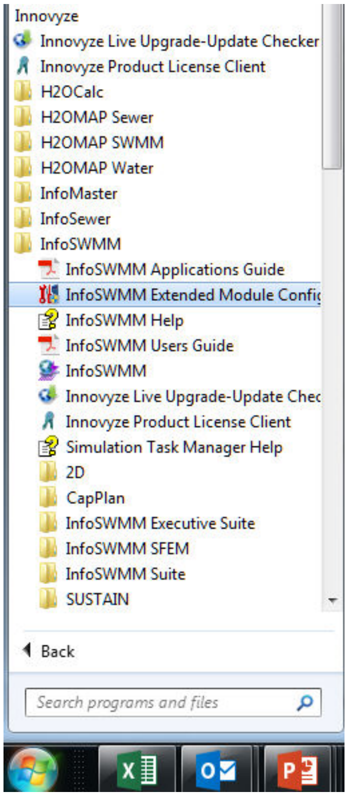
The selected run dialog appears, and it is now available for use. Section 2 discusses each icon and the menu shown below in detail. This program is part of the H2OMap SWMM InfoSWMM Suite.

Or use the Application Window where there are additional AddOns for H2OMap SWMM InfoSWMM





If you do not see the AddON's or Applications for the H2OMap SWMM InfoSWMM Suite version of then you can use the H2OMap SWMM InfoSWMMExtended Module Configuration from Windows Start.


Innovyze
Innovyze Live Upgrade-Update Checker
Innovyze Product License Client
H2OCalc
H2OMAP Sewer
H2OMAP SWMM
H2OMAP Water
InfoMaster
InfoSewer
InfoSWMM
InfoSWMM Applications Guide
InfoSWMM Extended Module Config
InfoSWMM Help
InfoSWMM Users Guide
InfoSWMM
Innovyze Live Upgrade-Update Chec
Innovyze Product License Client
Simulation Task Manager Help
2D
CapPlan
InfoSWMM Executive Suite
InfoSWMM SFEM
InfoSWMM Suite
SUSTAIN
Back
Search programs and files

Using the OnLine Help

Innovyze provides on-line Help with extensive information about modeling features and capabilities. The documentation includes numerous topics, each including narrative descriptions, illustrations, and diagrams describing the features of each program.

The on-line Help offers the ability to search for a desired topic rapidly or to move between related topics in a fast, efficient manner. An extensive index is available allowing you to search on any number of words, phrases, or commands. Innovyze Help includes several major sections, each identified by a magenta book in the Help Contents. Each section contains numerous related topics.

STARTING Innovyze HELP

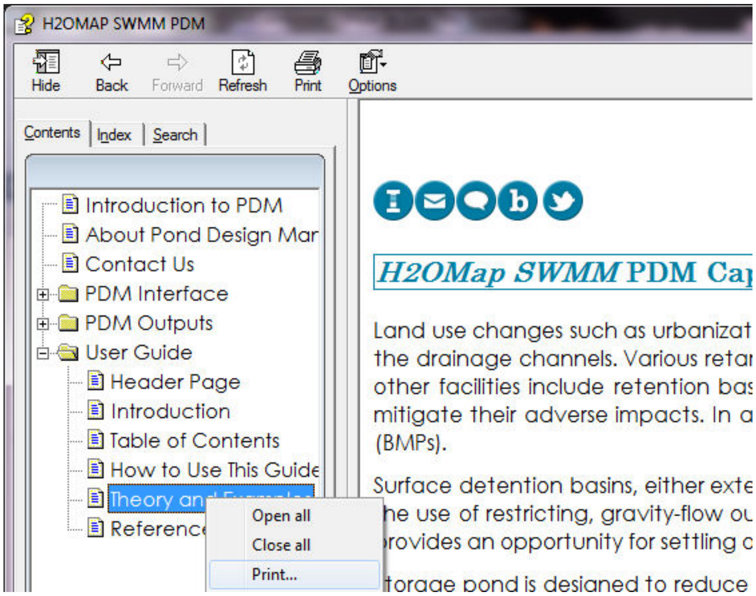
Innovyze Help is available by opening any Innovyze dialog box and pressing the F1 key. You may click on any portion of the dialog box in the help topic for more information.

Navigating the OnLine Help

Use either Innovyze Help Contents or the Index to navigate to the desired topic. Choose the Help Topic button in the upper left-hand corner of the Help window to access the Help contents and index. Embedded in the text of each topic are numerous *links*, identified as underlined blue text, to related topics. Simply click on the desired link text with the mouse to move immediately to the related topic.

Printing the OnLine Help

You may print any Innovyze Help topics you desire. To do so, navigate to the desired Help topic and then choose the Print Topic command from the Help window File menu.



Instructions to Renew the CD and License Keys for the Innovyze (MWH Soft) Floating License Server and the Licenses

Below are instructions to renew the CD and License Keys for the Innovyze (MWH Soft) Floating License Server and the floating licenses to reflect the current expiration date.

1. Open the Innovyze (MWH Soft) Floating License Server.
2. Go to the **Help** -> **About** menu in the upper left corner.
3. Go to the Request License Key On-line for dropdown menu and select Renewal. Press the **Go** button. This will open our On-Line License Registration page.
4. Complete the requested information and press the **Submit** button. This should return to you a new CD Key and License Key.
5. Copy and paste the new keys into the appropriate boxes in the **About** dialog box.
6. Press the **Apply License Changes** button. A new Subscription Expiration Date should appear.
7. Close the **About** box and the Innovyze (MWH Soft) Floating License Server.
8. Download and run the update for the Innovyze (MWH Soft) Floating License Server from the attached link:
   - Innovyze Floating License Server 5.0 Update 020 (22.03 MB), 12/10/2015
9. Open the Innovyze (MWH Soft) Floating License Server.
10. If your FLM is installed on a virtual server, go to the upper left corner and select **Action** -> **Register Virtual Environment …**
11. Select the License Administration tab.
12. Go to the Request License Key On-Line for dropdown menu and select **Renewal**. Press the **Go** button. This will open our On-Line License Registration page.
13. Complete the requested information and press the **Submit** button. This should return to you a new CD Key and License Key.
14. Copy and paste the new keys into the appropriate boxes in the License Administration tab.
15. Press the **Apply** button. A new Expiration Date should appear.

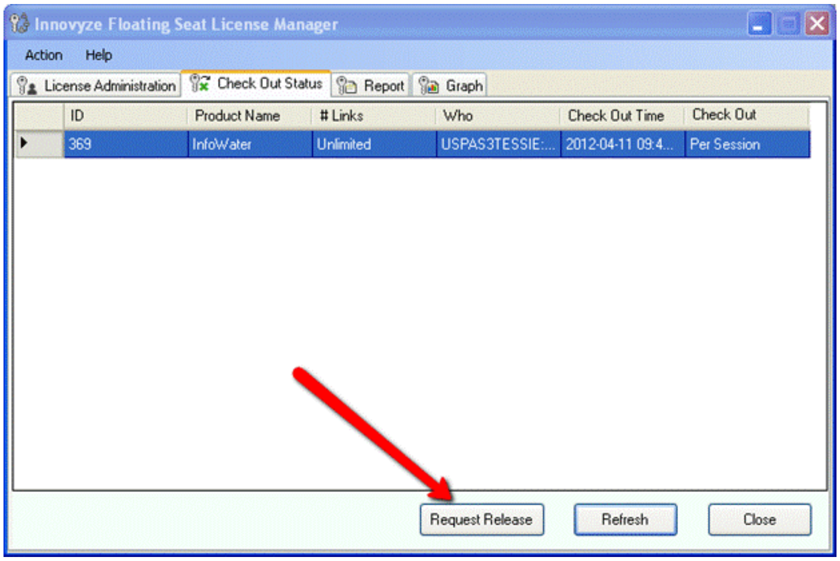
Press the Close button

Please follow the instructions below to request a license release key for a floating license.

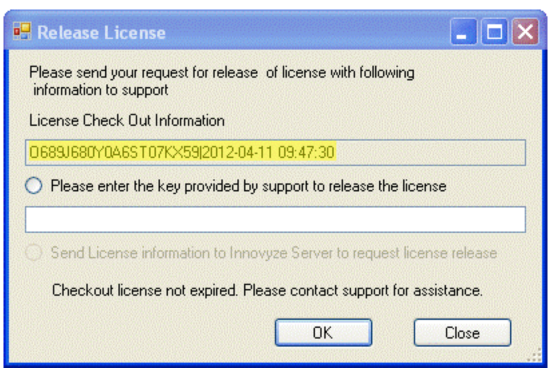
Please follow the instructions below to request a license release key for a floating license. Most likely this will need to be forwarded to someone who has access to the Innovyze Floating Seat License Manager on a server.

Open the Innovyze Floating Seat License Manager and select the Check Out Status tab.

Select the license to release and press the Request Release button.



Copy the License Check Out Information generated and paste into an email to support@innovyze.com



We will return to you a code to enter in to the second field.

Once both fields are populated in the Release License dialog box, press the OK button to release the license.

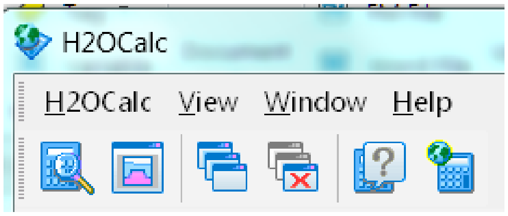
Technical Support On the Web and by Email

See the Help file Topic Contact Us for detailed Innovyze Technical Support information.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

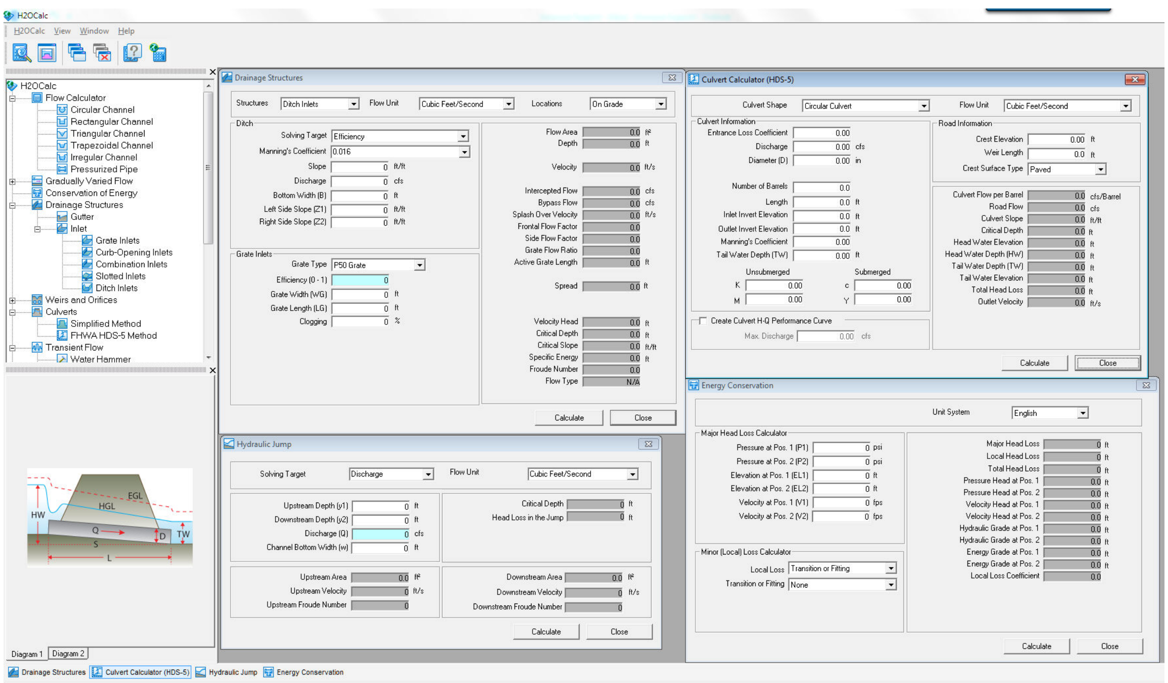
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Section 2 H_2OCalc Interface

H_2OCalc is a hydraulic toolbox to assist civil, environmental and water resources engineers with solving complex hydraulic problems quickly and accurately. Its powerful and comprehensive modeling capabilities let engineers streamline the hydraulic analysis and design of pipes, pumps, open channels, weirs, orifices, culverts, and inlets. Calculations for both steady uniform flow and gradually varied flow are supported. The program also performs unit conversions for various parameter values as well as useful calculations for Stormwater runoff and groundwater flow.

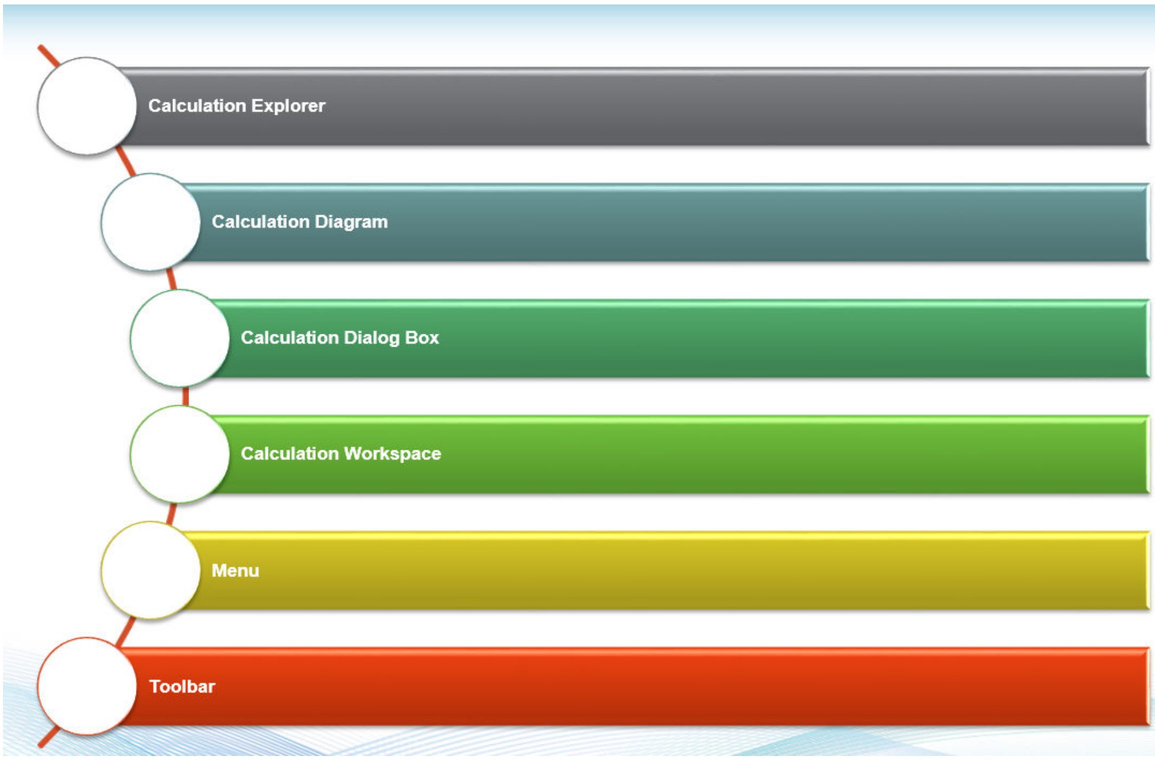
The *H_2OCalc* interface utilizes dockable windows and hydraulic calculation dialog boxes that can be manually positioned. By default, the *H_2OCalc* main dialog box looks like this with cascaded extra windows.



The ***H_2OCalc*** interface consists of six components:

- **Calculation Explorer**
- **Calculation Diagram**

- **Calculation Dialog Box**
- **Calculation Workspace**
- **Menu**
- **Toolbar**

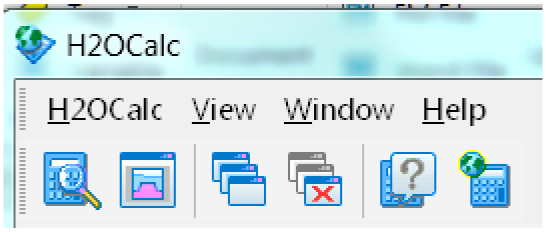


Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

2.1 H_2OCalc Interface Components

Each of these interface components is described below.

The Calculation Explorer window displays the types of calculations available in a hierarchical tree structure. The left pane of the window shows the fourteen calculation categories, and the right pane shows the individual element type under its associated category. The available categories and associated element types are as follows:

- Flow Calculator
    - Circular Channel
    - Rectangular Channel
    - Triangular Channel
    - Trapezoidal Channel
    - Irregular Channel
    - Pressurized Pipe
- Gradually Varied Flow
    - Direct Step Method
    - Standard Step Method
- Conservation of Energy
- Drainage Structures
    - Gutter
    - Inlet
    - Grate Inlet
    - Curb Inlet
    - Combination Inlet
    - Slot Inlet

- Affinity Laws
- Parallel Arrangement
- Series Arrangement
- System Head Curve

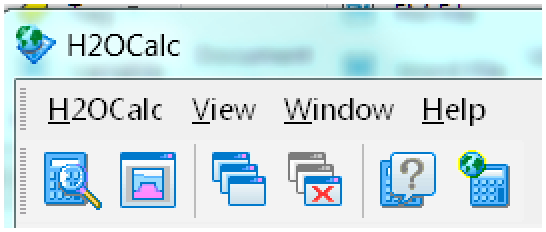
- Equivalent Pipe Length
- Groundwater Hydrology
- Surface Water Hydrology
- Unit Converter

The Calculation Diagram window displays the schematics) associated with the particular category element.

The Calculation Dialog Box window displays the calculation dialog box associated with the selected category and associated element type.

The Calculation Workspace window is the remaining gray area and can be used to open any number of Calculation Dialog boxes for various categories and associated element types.

The Menu system gives access to the *H_2OCalc* on-line help and the graphical interface layout management.


H2OCalc
H2OCalc View Window Help

2.2 *H_2OCalc* Menu and Toolbars

The drop-down menu system allows the user to access *H_2OCalc*'s tools and data managers. The menu system consists of the following selections:

- *H_2OCalc* Menu
- View Menu
- Windows Menu
- Help Menu

The *H_2OCalc* Menu helps to exit *H_2OCalc*.

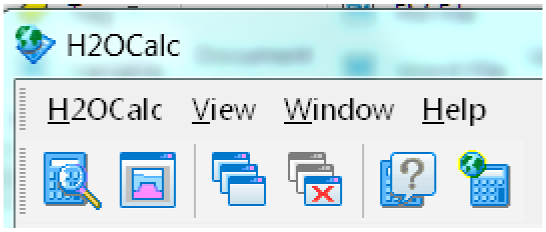
The View Menu helps to view either calculation explorer or diagrams and also allows to reset the *H_2OCalc* interface to its original format.

The Windows Menu contains commands that allow the user to change the position of the various dialog boxes within the *H_2OCalc* window.

The Help menu provides access to the *H_2OCalc* documentation, where to get technical support, version, license and maintenance/update information, as well as access to online help resources.

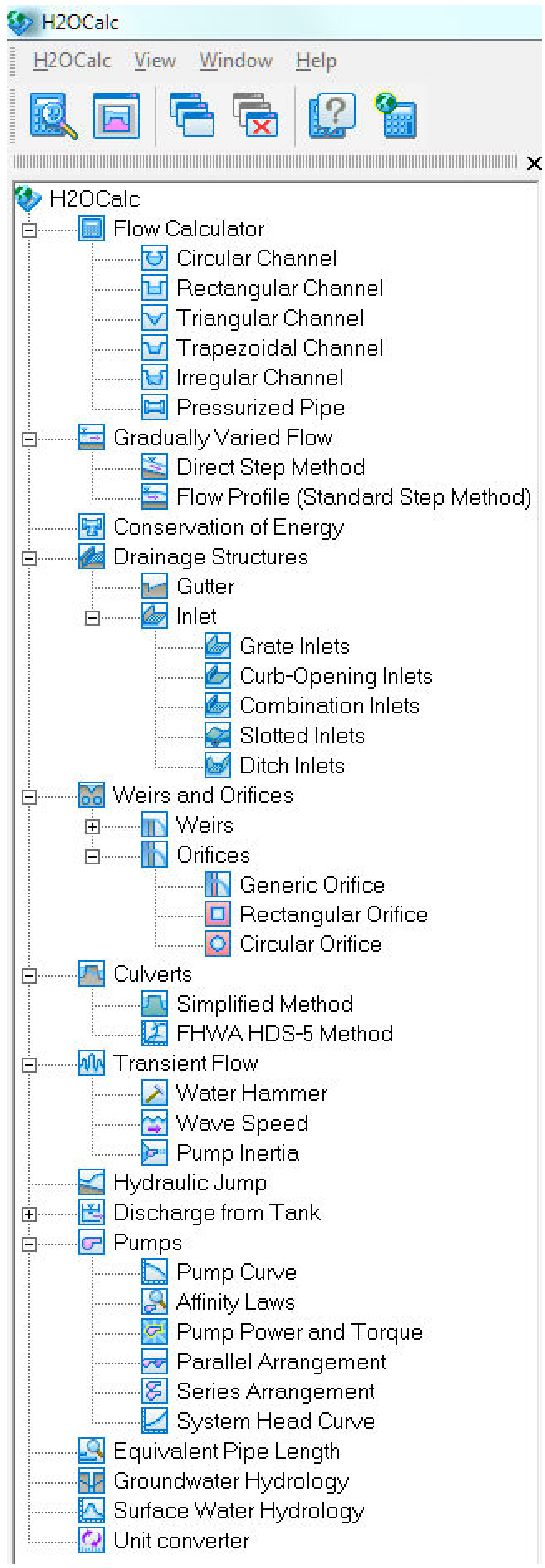
The *H_2OCalc* Toolbar consists of six buttons. These are;

- Calculation Explorer: This command switches on or off the Calculation Explorer window.
- Diagram: This command switches on or off the Calculation Diagram window.
- Cascade Window: This command causes the worksheet in the Calculation Workspace to overlap one another in an offset way to maintain visibility of all opened Calculation dialog boxes.
- Close All: This command closes all of the Calculation dialog boxes in the Calculation Workspace.
- Help: This command opens the *H_2OCalc* online help.
- About *H_2OCalc*: This command shows the software and license registration information.


H2OCalc
H2OCalc View Window Help

2.3 H_2OCalc Calculation Dialog Boxes

H_2OCalc performs hydraulic calculations for fourteen different categories. Each category along with its associated element types is described in this section.

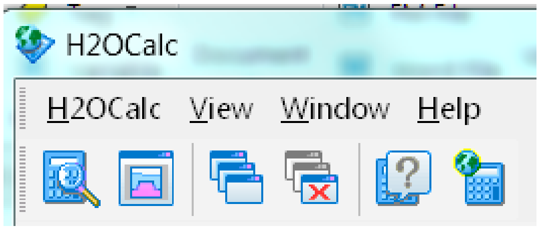

H2OCalc
H2OCalc View Window Help
H2OCalc
Flow Calculator
Circular Channel
Rectangular Channel
Triangular Channel
Trapezoidal Channel
Irregular Channel
Pressurized Pipe
Gradually Varied Flow
Direct Step Method
Flow Profile (Standard Step Method)
Conservation of Energy
Drainage Structures
Gutter
Inlet
Grate Inlets
Curb-Opening Inlets
Combination Inlets
Slotted Inlets
Ditch Inlets
Weirs and Orifices
Weirs
Orifices
Generic Orifice
Rectangular Orifice
Circular Orifice
Culverts
Simplified Method
FHWA HDS-5 Method
Transient Flow
Water Hammer
Wave Speed
Pump Inertia
Hydraulic Jump
Discharge from Tank
Pumps
Pump Curve
Affinity Laws
Pump Power and Torque
Parallel Arrangement
Series Arrangement
System Head Curve
Equivalent Pipe Length
Groundwater Hydrology
Surface Water Hydrology
Unit converter

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

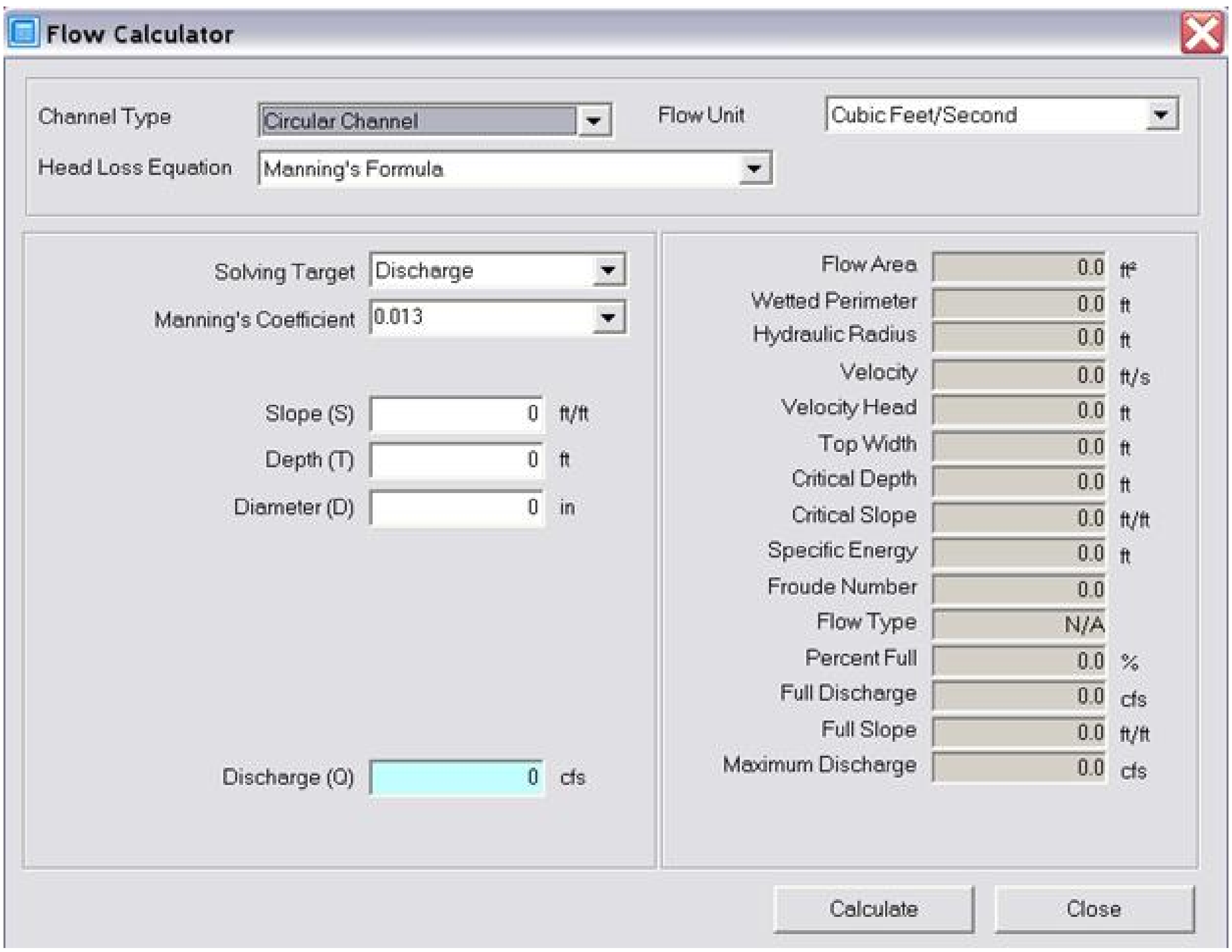

H2OCalc
H2OCalc View Window Help

2.3.1 Flow Calculator

The Flow Calculator category performs hydraulic calculations for the following elements: Circular Channel, Rectangular Channel, Triangular Channel, Trapezoidal Channel, Irregular Channel, and Pressurized Pipe.

Circular Channel

The circular channel dialog box is shown below.



Input for circular channel:

- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.
- **Depth** – Channel normal depth.
- **Diameter** – Circular channel inside diameter.

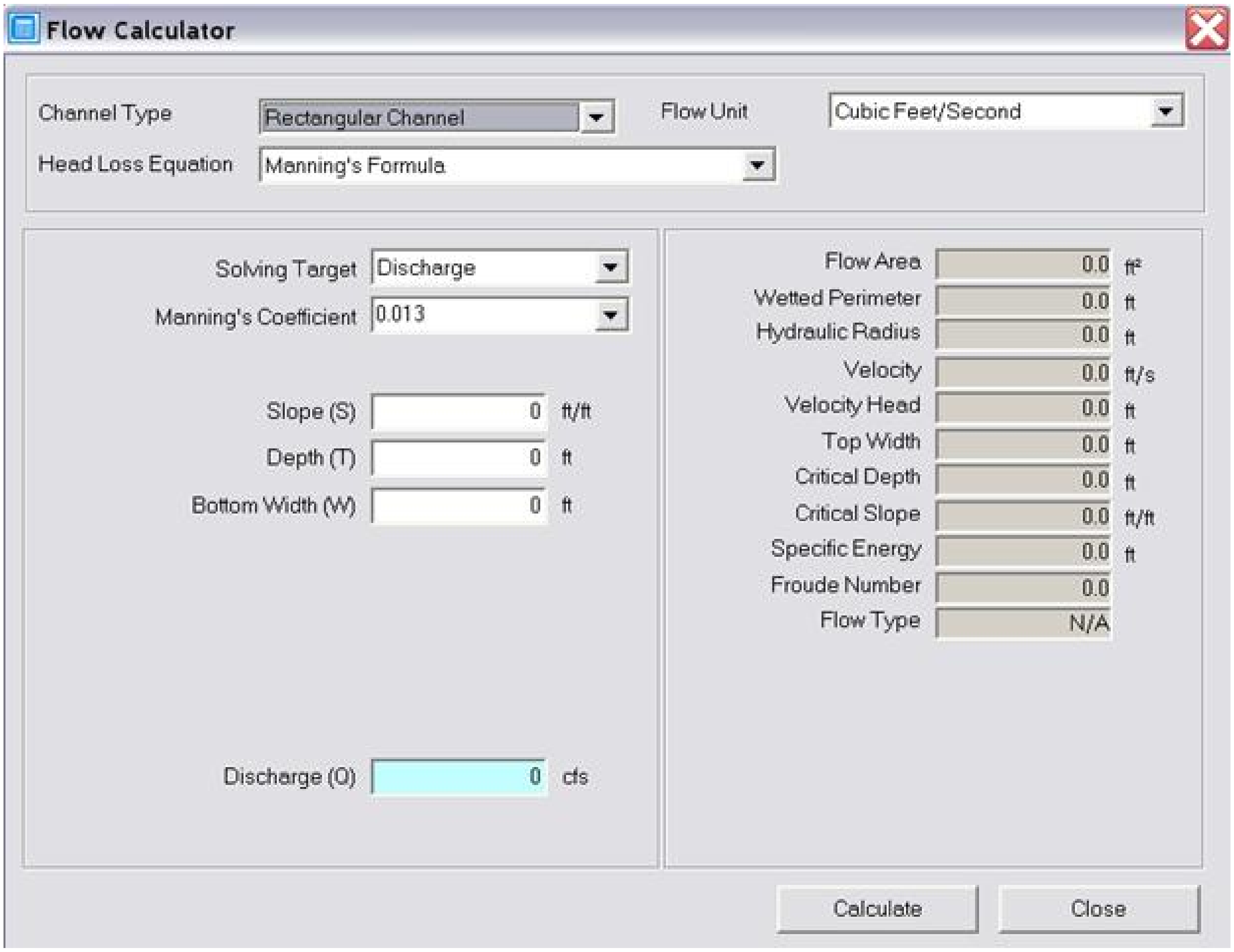
Output for circular channel:

- **Flow Area** – Flow cross-sectional area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface (zero for full flow condition).
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.

- **Flow Type** – Subcritical or supercritical flow characteristics in channel.
- **Percent Full** – Percentage of actual channel flow depth based on full flow.
- **Full Discharge** – Channel flow rate when flowing full.
- **Full Slope** – Channel slope under full flow.
- **Maximum Discharge** – Flow rate when flow depth equals 0.938 times circular channel diameter (applies only to circular channel).
- **Discharge (Q)** – Uniform channel flow rate.

Rectangular Channel

The rectangular channel dialog box is shown below.



Input for rectangular channel:

- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.

- **Depth** – Channel normal depth.
- **Bottom Width** – Width of the channel.

Output for rectangular channel:

- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface (same as bottom width at all depths).
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
- **Flow Type** – Subcritical or supercritical flow characteristics in channel.
- **Discharge (Q)** – Uniform channel flow rate.

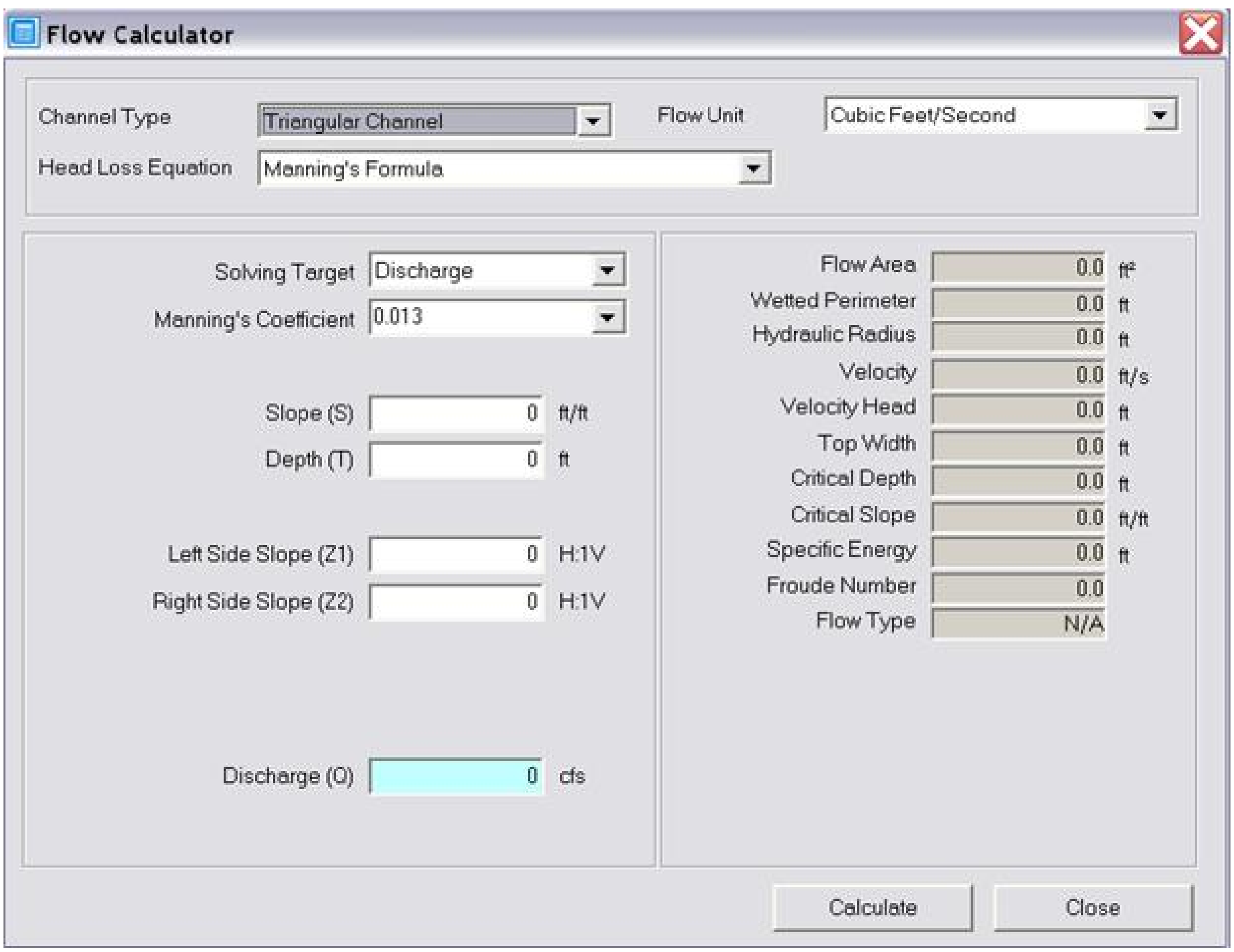
Triangular Channel

The triangular channel dialog box is shown below.

Input for triangular channel:

- **Flow Unit** – Select the desired flow unit.

- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.
- **Depth** – Channel normal depth.
- **Left Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the left side of the channel.
- **Right Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the right side of the channel.

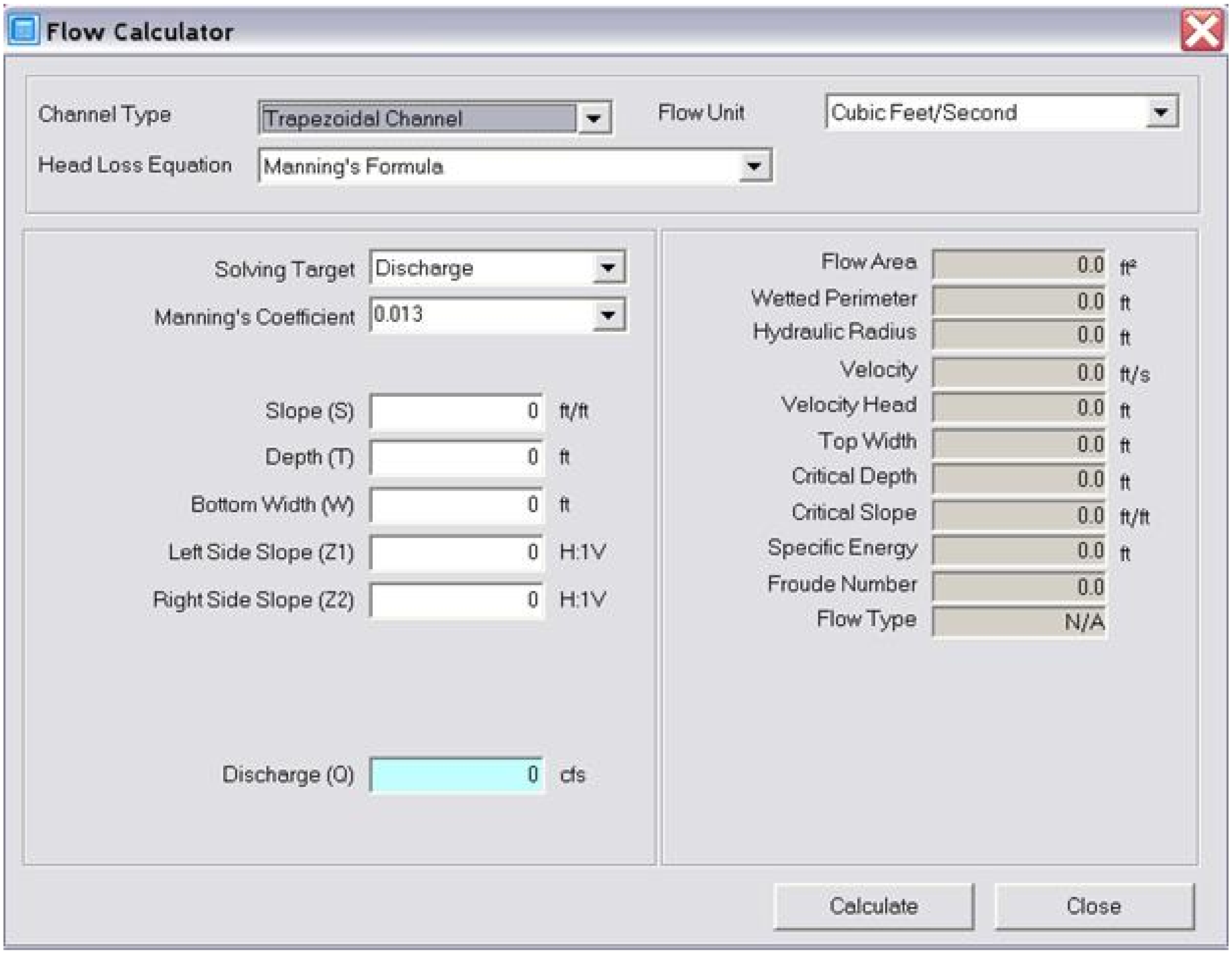


Output for triangular channel:

- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface.
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
- **Flow Type** – Subcritical or supercritical flow characteristics in channel.
- **Discharge (Q)** – Uniform channel flow rate.

Trapezoidal Channel

The trapezoidal channel dialog box is shown below.



Input for trapezoidal channel:

- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Slope** – Channel longitudinal slope.
- **Depth** – Channel normal depth.

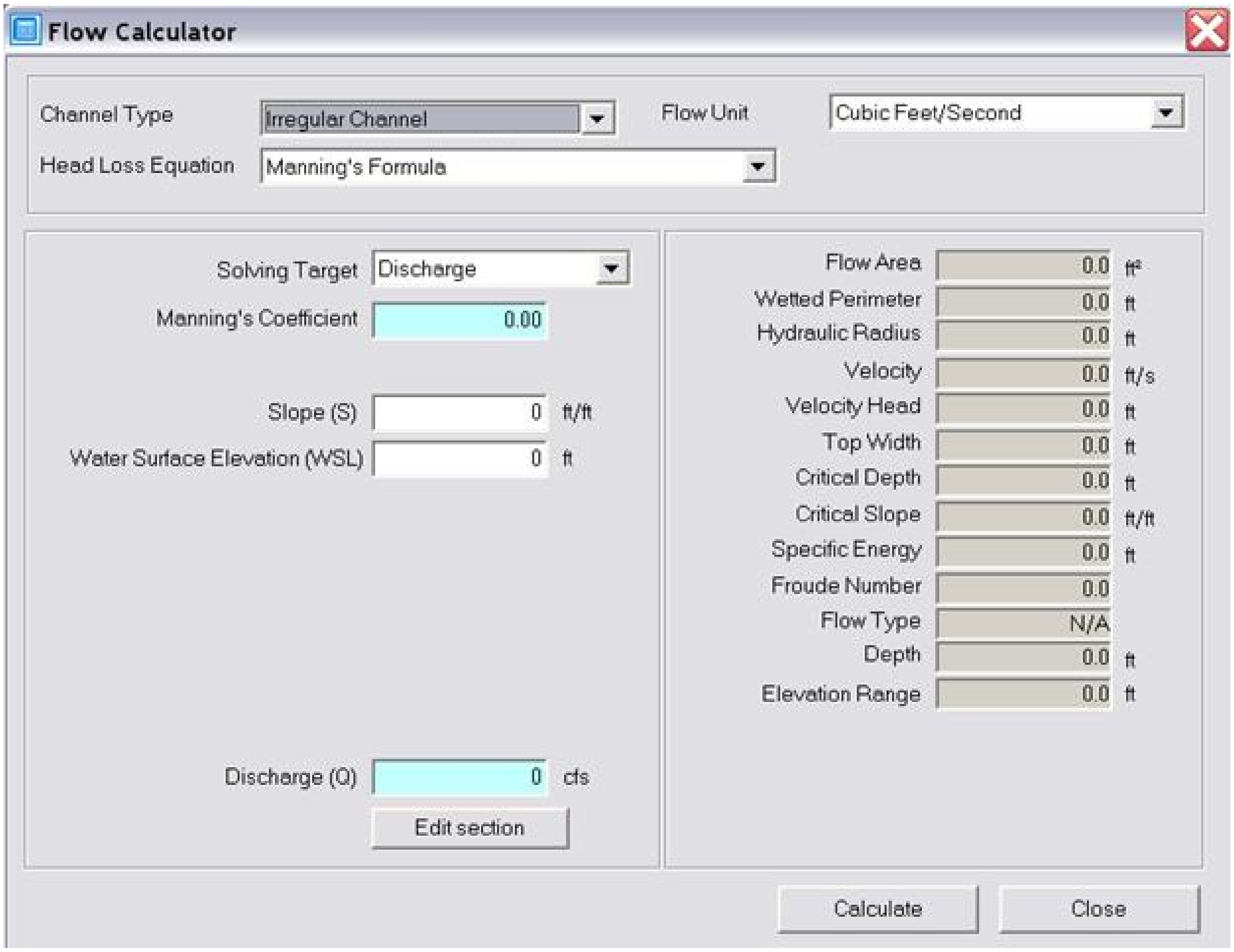
- **Bottom Width** – Bed width of the channel.
- **Left Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the left side of the channel.
- **Right Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the right side of the channel.

Output for trapezoidal channel:

- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface.
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
- **Flow Type** – Subcritical or supercritical flow characteristics in channel.
- **Discharge (Q)** – Uniform channel flow rate.

Irregular Channel

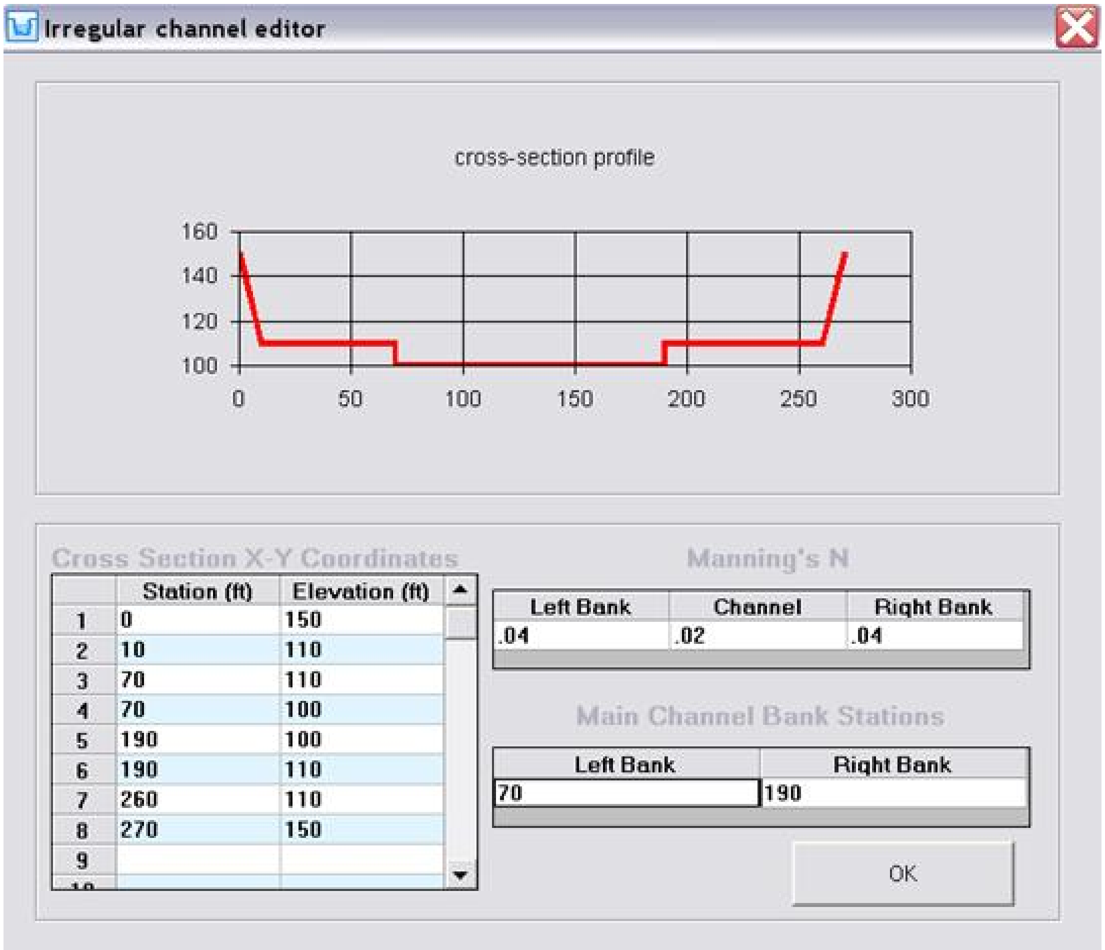
The irregular channel dialog box is shown below.



Input for irregular channel:

- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Slope** – Channel longitudinal slope.
- **Water Surface Elevation** – Elevation corresponding to the water depth.

- **Channel Cross** Section – Station vs. Elevation data that represents shape of the channel. The *Edit Section* button initiates the irregular channel editor shown below.
- **Left Bank Coefficient** – Roughness coefficient for the left bank of the channel.
- **Right Bank Coefficient** – Roughness coefficient for the right bank of the channel.
- **Channel Coefficient** – Roughness coefficient for the main (center) channel.
- **Main Channel Bank Stations** – Stations at which the main channel ends and the banks start from either side of the channel (i.e., left and right).



Output for irregular channel:

- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Top Width** – Length of free top water surface.
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.

- **Specific Energy** – Velocity head plus pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter.
- **Flow Type** – Subcritical or supercritical flow characteristics in channel.
- **Depth** – Flow depth.
- **Elevation Range** – Difference in elevations at the top and at the bottom of the channel.
- **Discharge (Q)** – Uniform channel flow rate.

The dialog box for irregular channel cross-section editor is shown below. The inputs are described above along with the irregular channels inputs.

Pressurized Pipe

The pressurized pipe calculator applies the energy equation between two points (points 1 and 2) and evaluates the outputs listed below. The pressurized pipe dialog box is shown below.

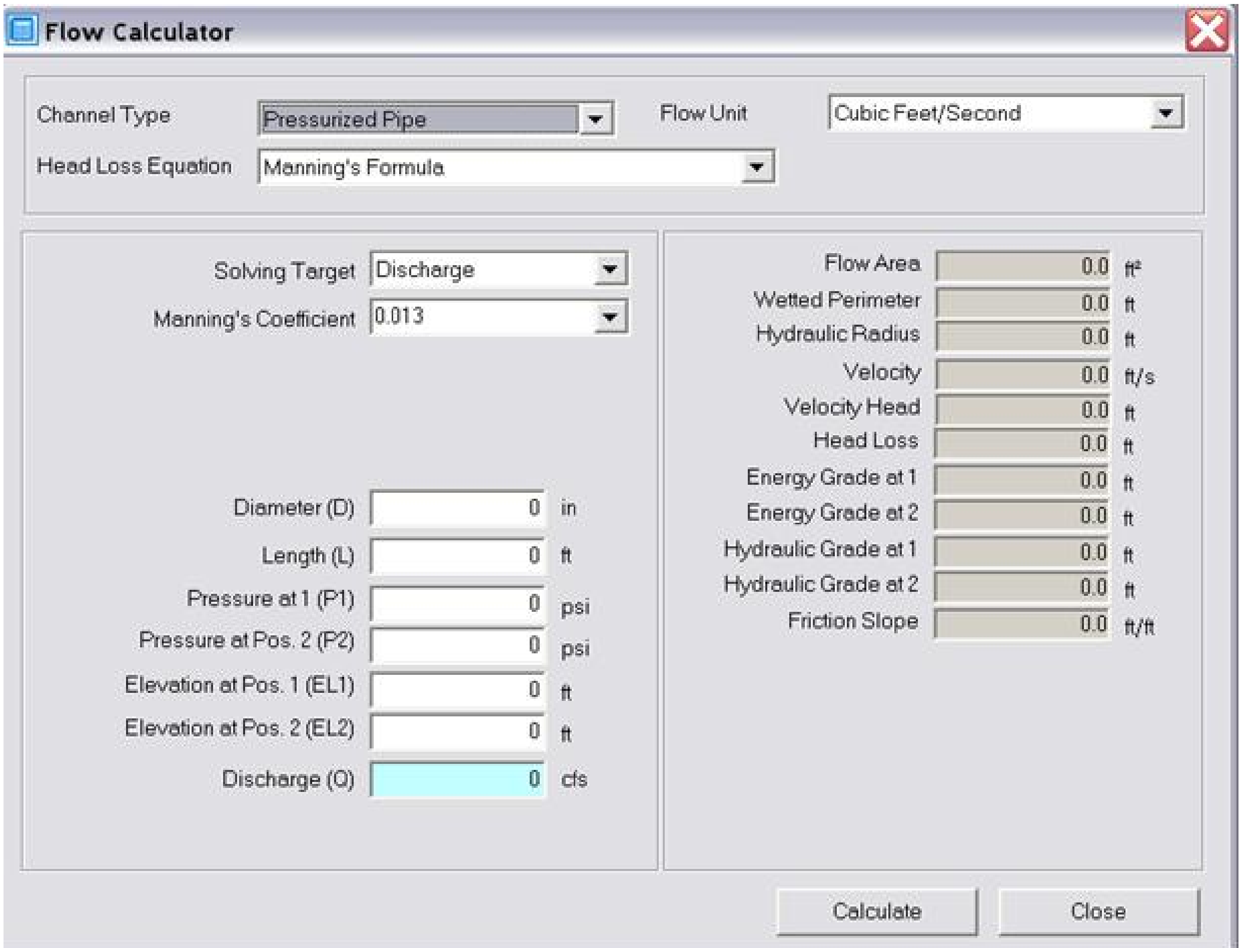
Input for pressurized pipe:

- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Choose between the Manning, Kutter, Darcy-Weisbach (Colebrook-White) and Hazen-Williams friction loss calculation methods.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Coefficient** – The channel roughness coefficient.
- **Diameter** – Circular pipe diameter.
- **Length** – Pipe length.
- **Pressure at 1**– Pressure at the upstream end of the pipe.
- **Pressure at 2**– Pressure at the downstream end of the pipe.

- **Elevation at 1**– Elevation at the upstream end of the pipe.
- **Elevation at 2**– Elevation at the downstream end of the pipe.

Output for pressurized pipe:

- **Flow Area** – Wetted area.
- **Wetted Perimeter** – Channel wetted perimeter.
- **Hydraulic Radius** – Flow area divided by the wetted perimeter.
- **Velocity** – Flow velocity.
- **Velocity Head** – Energy of flow velocity.
- **Head Loss** – Energy loss due to friction.
- **Energy Grade at 1** – Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the upstream end.
- **Energy Grade at 2** – Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the downstream end.
- **Hydraulic Grade at 1** – Sum of pressure head and elevation head at the upstream end.
- **Hydraulic Grade at 2** – Sum of pressure head and elevation head at the upstream end.
- **Friction Slope** – Slope of the head loss due to friction between sections 1 and 2.
- **Discharge (Q)** – Pipe flow rate.



Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

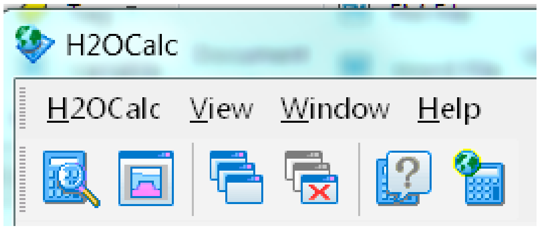
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

Innovyze®

H2OCalc™

Modeling Made Easy

Innovyze®


H2OCalc
H2OCalc View Window Help

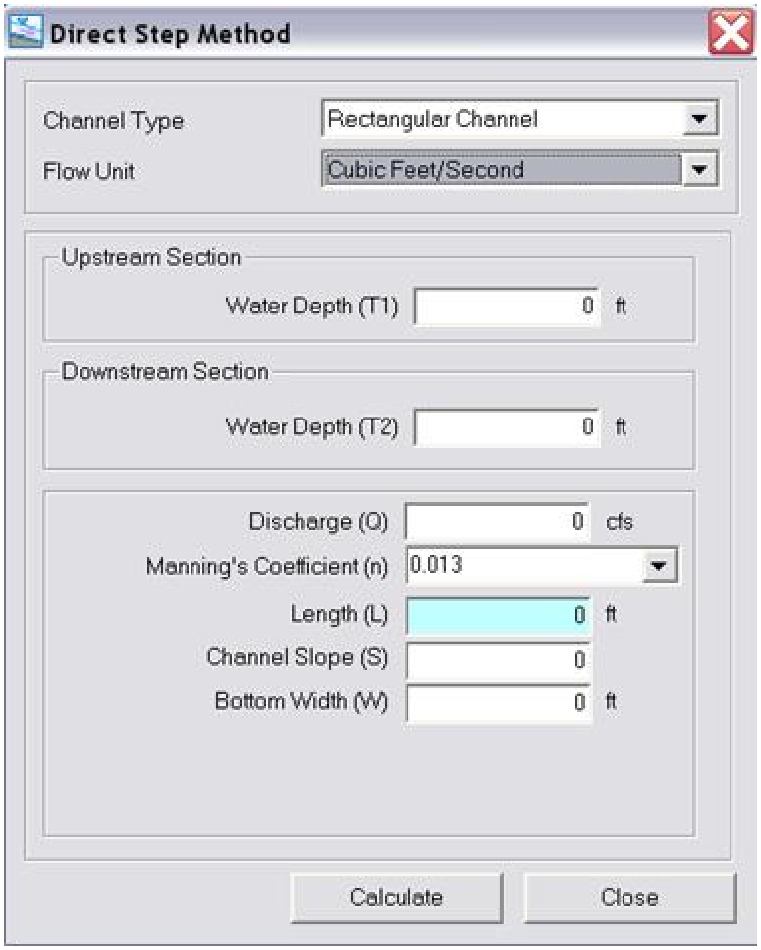
2.3.2 Gradually Varied Flow

The Gradually Varied Flow category performs flow profile computations for rectangular and trapezoidal channels using either the direct step method or the standard step method. It computes water surface elevations and many other outputs at several sections of a reach and plots flow profile for the reach. Manning's equation is used to relate friction slope with flow rate and channel conveyance factor.

Direct Step Method

The direct step method uses the direct step method to determine distance given water depth at the end of the reach. Both rectangular channels and trapezoidal channels are supported. It performs only one step calculation, and should be used only for short reaches. For longer reaches, it is advisable to use the flow profile option described below.

The direct step method dialog box is shown below.



Input for direct step method:

- **Channel Type** – Rectangular or trapezoidal channels.
- **Flow Unit** – Select the desired flow unit.
- **Upstream Water Depth** – Water depth at the upstream end of the reach.
- **Downstream Water Depth –** Water Depth at the downstream end of the reach.
- **Discharge** – Flow rate at the control section.
- **Manning's Coefficient** – Manning's roughness coefficient for both upstream and downstream sections.

- **Length** – Length of the reach between the upstream and the downstream sections. This is required only for standard step method. It is an output for direct step method.
- **Channel Slope** – Longitudinal slope of the channel.
- **Bottom Width** – Channel bottom width for both upstream and downstream sections.

Output for direct step method:

- **Length**– Length between the upstream and the downstream sections will be calculated.

Flow Profile

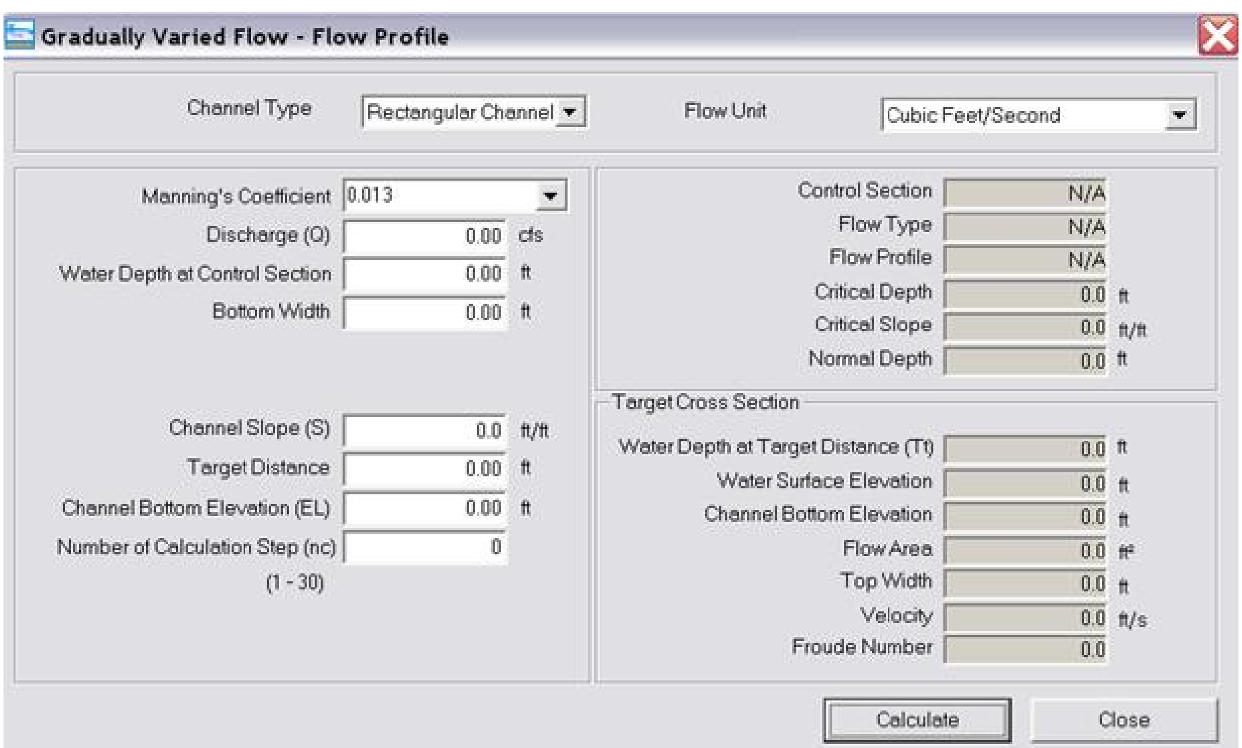
The flow profile uses the standard step method to compute water depths at several sections and plots water surface profile for the reach. Both rectangular channel and trapezoidal channel are supported.

The flow profile dialog box is shown below.

Input for flow profile:

- **Channel Type** – Rectangular or trapezoidal channels.
- **Flow Unit** – Select the desired flow unit.
- **Manning's Coefficient** – Manning's roughness coefficient for the channel.
- **Discharge** – Channel flow rate.

- **Water Depth at Control Section** – Flow depth at the section where profile computation starts.
- **Bottom Width** – Channel bottom width.
- **Left Side Slope** – Horizontal increase in channel width per unit increase in depth (H: 1V) for the left side of the channel. Valid only for trapezoidal channels.
- **Right Side Slope** - Horizontal increase in channel width per unit increase in depth (H: 1V) for the right side of the channel. Valid only for trapezoidal channels.
- **Channel Slope** – Channel longitudinal slope.
- **Target Distance** – Distance between the sections where the profile computation begins and where it ends.
- **Channel Bottom Elevation** – Elevation corresponding to bed of the channel at the section where profile computation starts.
- **Number of Calculation Steps** – Routing subreaches between the starting and the destination sections.



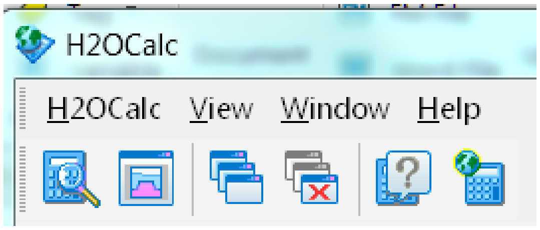
Output for flow profile:

- **Control Section** – Upstream or downstream section.
- **Flow Type** – Subcritical, supercritical or critical flow regime.
- **Flow Profile** – Profile type (e.g., M1, S2, C1, etc.)
- **Critical Depth** – Depth of water under minimum specific energy.
- **Critical Slope** – Channel slope under critical depth.
- **Normal Depth** – Uniform flow depth.
- **Water Depth at Target Distance** –Water depth at the end of the reach.
- **Water Surface Elevation** –Water depth plus channel bed elevation at the end of the reach.
- **Channel Bottom Elevation** – Channel bed elevation at the end of the reach.
- **Flow Area** – Wetted area at the end of the reach.
- **Top Width**– Width of the channel at the water surface at the end of the channel.
- **Velocity (Q)** – Flow velocity at the end of the reach.
- **Froude Number** – Flow characteristics dimensionless parameter at the end of the reach.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

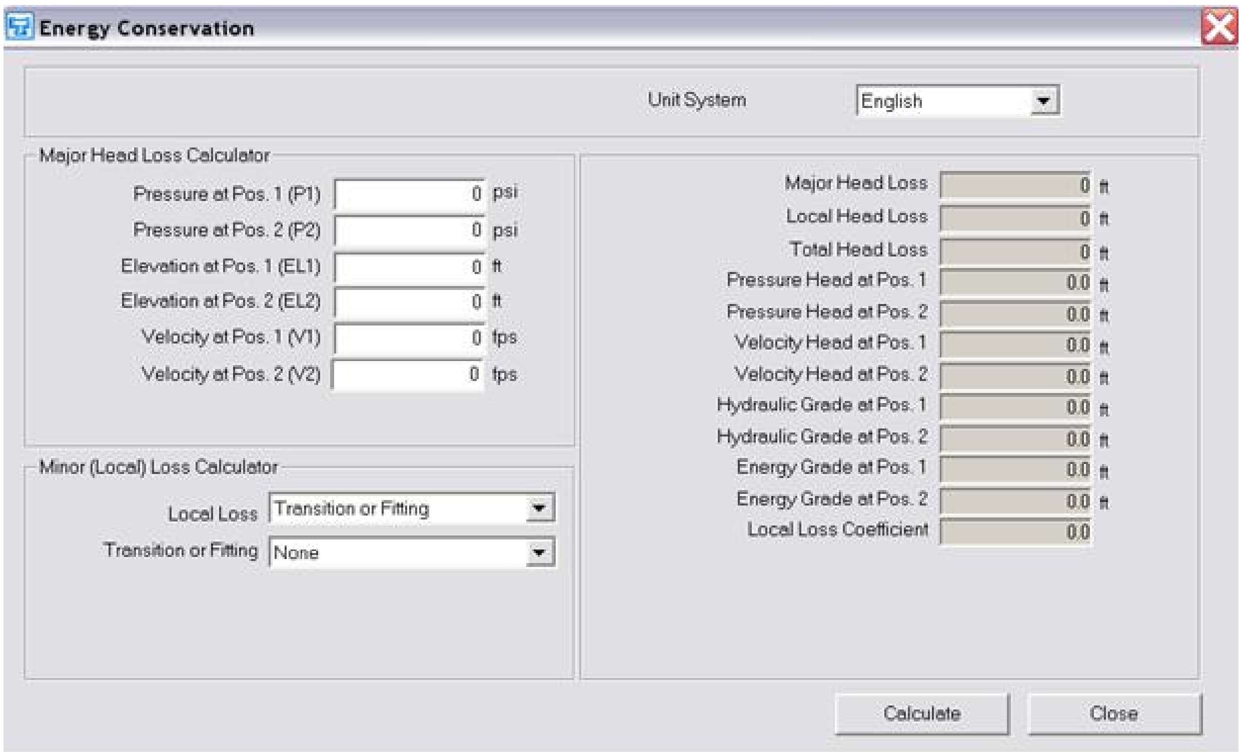
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

2.3.3 Conservation of Energy

The Conservation of Energy category applies energy equation between two sections of a pressurized pipe and evaluates the outputs listed below.

The conservation of energy dialog box is shown below.



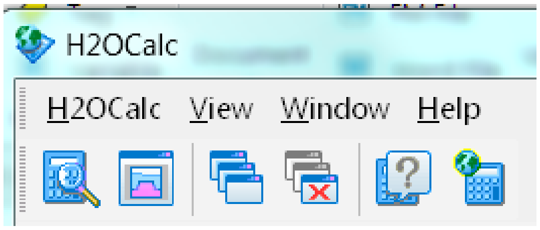
Input for conservation of energy:

- **Unit System** – English or SI unit.
- **Pressure at 1**– Pressure at the upstream end of the pipe.
- **Pressure at 2**– Pressure at the downstream end of the pipe.
- **Elevation at 1**– Elevation at the upstream end of the pipe.

- **Elevation at 2**– Elevation at the downstream end of the pipe.
- **Velocity at 1**– Flow velocity at the upstream end of the pipe.
- **Velocity at 2**– Flow velocity at the downstream end of the pipe.
- **Local Loss**– Choose the minor loss type from the following options: Minor loss coefficient, transition or fitting, or minor head loss. If minor loss coefficient option is selected, the average velocity $((V_1+V_2)/2)$ is used to compute the minor head loss. Depending on the minor loss model selected, additional inputs required for the option should be specified.

Output for conservation of energy:

- **Major Head Loss** – Head loss due to friction, excluding minor losses.
- **Local Head Loss** – Head loss due to minor losses.
- **Total Head Loss** – Sum of major head loss and local head loss.
- **Pressure Head at 1** – Pressure energy at the upstream section.
- **Pressure Head at 2** – Pressure energy at the downstream section.
- **Velocity Head at 1** – Energy due to flow velocity at the upstream section.
- **Velocity Head at 2 –** Energy due to flow velocity at the downstream section.
- **Hydraulic Grade at 1 –** Sum of pressure head and elevation head at the upstream end.
- **Hydraulic Grade at 2 –** Sum of pressure head and elevation head at the downstream end.
- **Energy Grade at 1 –** Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the upstream end.
- **Energy Grade at 2 –** Total energy head (i.e., sum of pressure head, velocity head, and elevation head) at the downstream end.
- **Local Loss Coefficient –** The (minor) local loss *K* factor.


H2OCalc
H2OCalc View Window Help

2.3.4 Drainage Structures

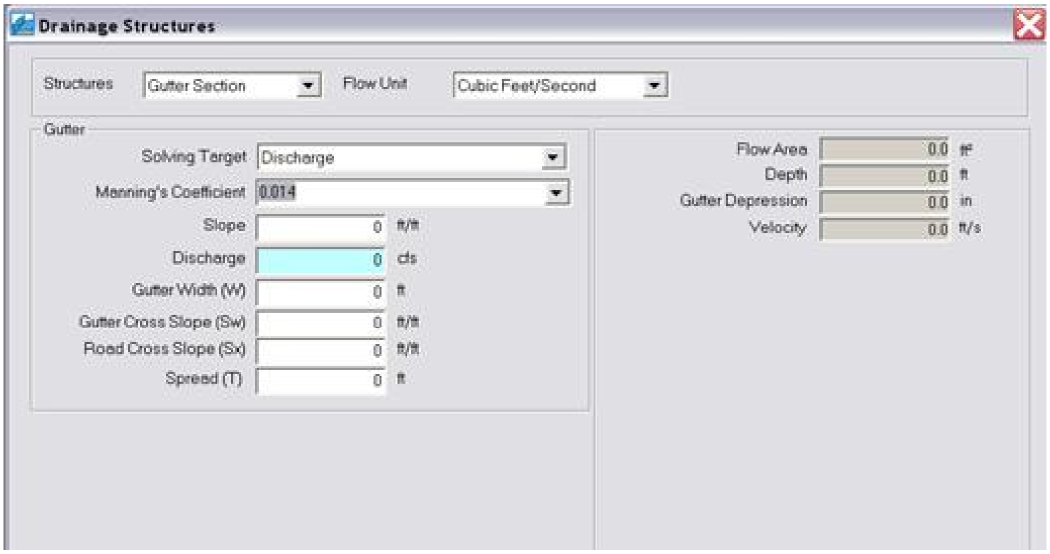
The Drainage Structure category solves the hydraulics of gutters and storm drain inlets.

Gutters

Gutters are triangular shaped channels on both sides of a street that collect stormwater runoff from streets and discharge into storm drain inlets. The gutter dialog box is shown below.

Input for gutters:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Width of the gutter at the water surface elevation.



Output for gutters:

- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Discharge** – Flow rate through the gutter. Discharge could be selected as target output.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Like discharge, spread could be selected as a target output.

Inlets

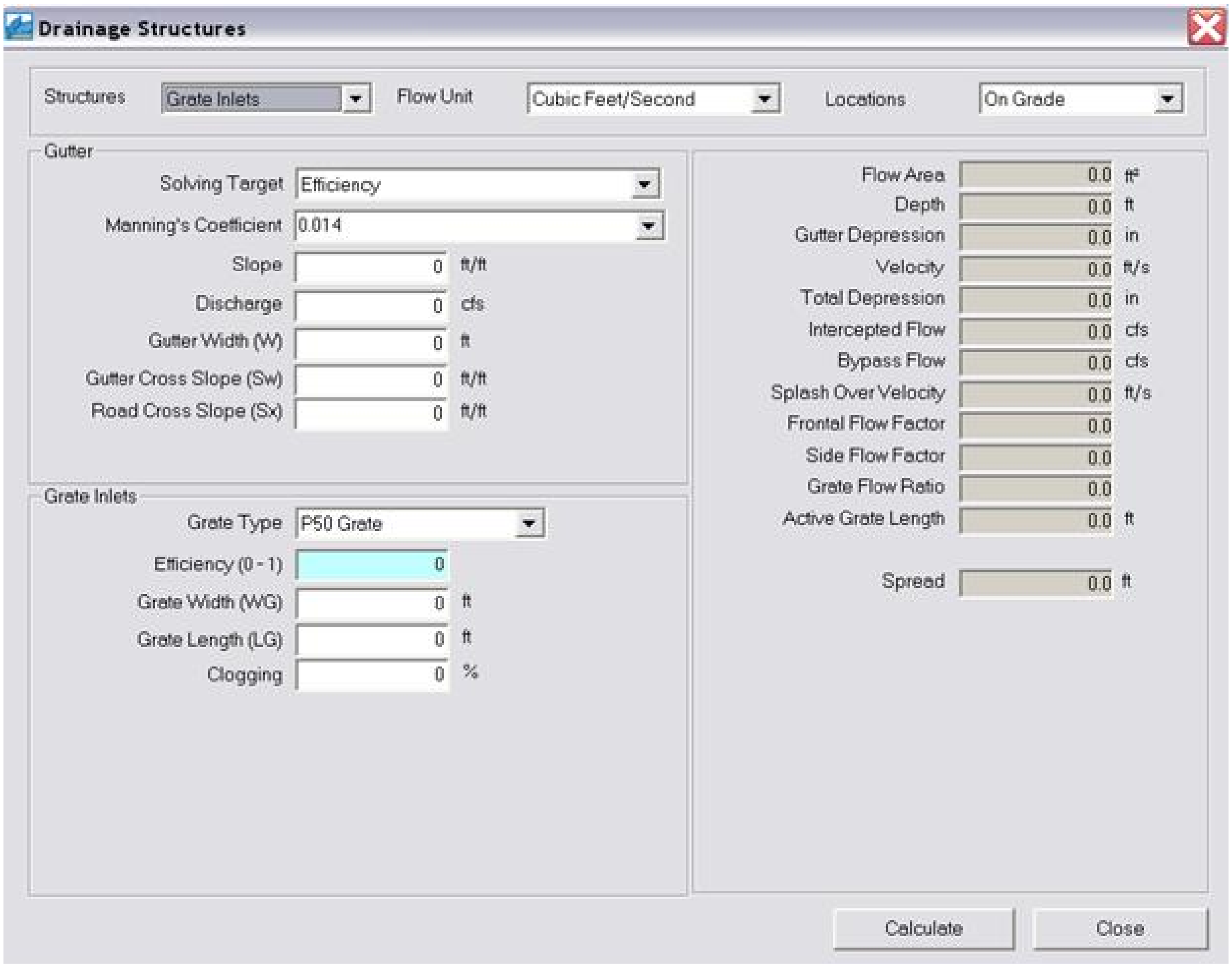
H_2OCalc performs hydraulic calculation for grate inlet, curb-opening inlet, combination inlet, slot inlet, and ditch inlets. Each of these inlet types can be either on grade or in sag. The different inlet types are described below.

Grate Inlet

Input for grate inlets on grade:

- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Efficiency or length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Grate Type** – Select one of the eight grate types listed.
- **Efficiency** –Interception efficiency of the grate. It represents ratio of intercepted flow to total gutter flow.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.

The dialog box for grate inlet on grade is shown below.

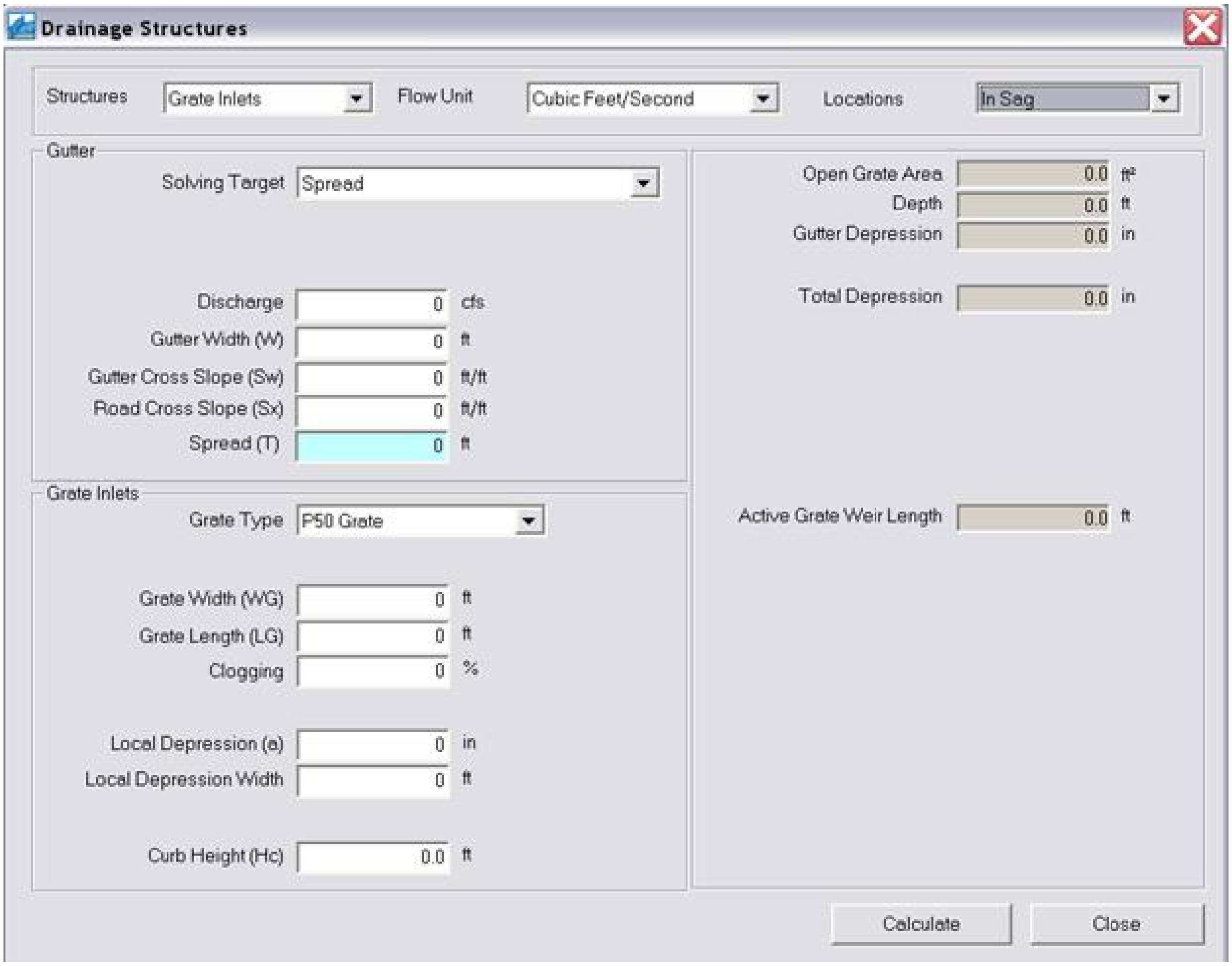


Output for grate inlet on grade:

- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Total Depression** – Sum of the local depression and the gutter depression.

- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Splash Over Velocity** – Velocity where splash over first occurs. Splash over refers to the fraction of frontal gutter flow that is not intercepted by the inlet.
- **Frontal Flow Factor** – The ratio of intercepted frontal flow to total frontal flow.
- **Side Flow factor** – The ratio of intercepted side flow to total side flow.
- **Grate Flow Ratio** – The ratio of frontal flow to total gutter flow.
- **Active Grate Length** – Portion of grate length (the side that is parallel to the curb) that is not clogged.
- **Spread** – Top width, or width of the gutter at the water surface elevation.

The dialog box for grate inlet in sag is shown below.



Input for grate inlets in sag:

- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Spread or length.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.

- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be output is selected as a solving target.
- **Grate Type** – Select one of the eight grate types listed.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Curb Height** – Height of the curb.

Output for grate inlet in sag:

- **Open Grate Area** – Clear area of the grate accounting for clogging, and area occupied by the bars depending on the grate type. Used when the grate acts as an orifice.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets the curb).
- **Active Grate Weir Length** – Portion of grate length and width that is not clogged and not covered by the bars. Used when the grate acts as a

weir.

- **Spread** – Top width, or width of the gutter at the water surface elevation. If selected as solving target, it is an output. Otherwise, it is an input.
- **Grate Length -** Length of the grate. If selected as solving target, it is an output. Otherwise it is an input.

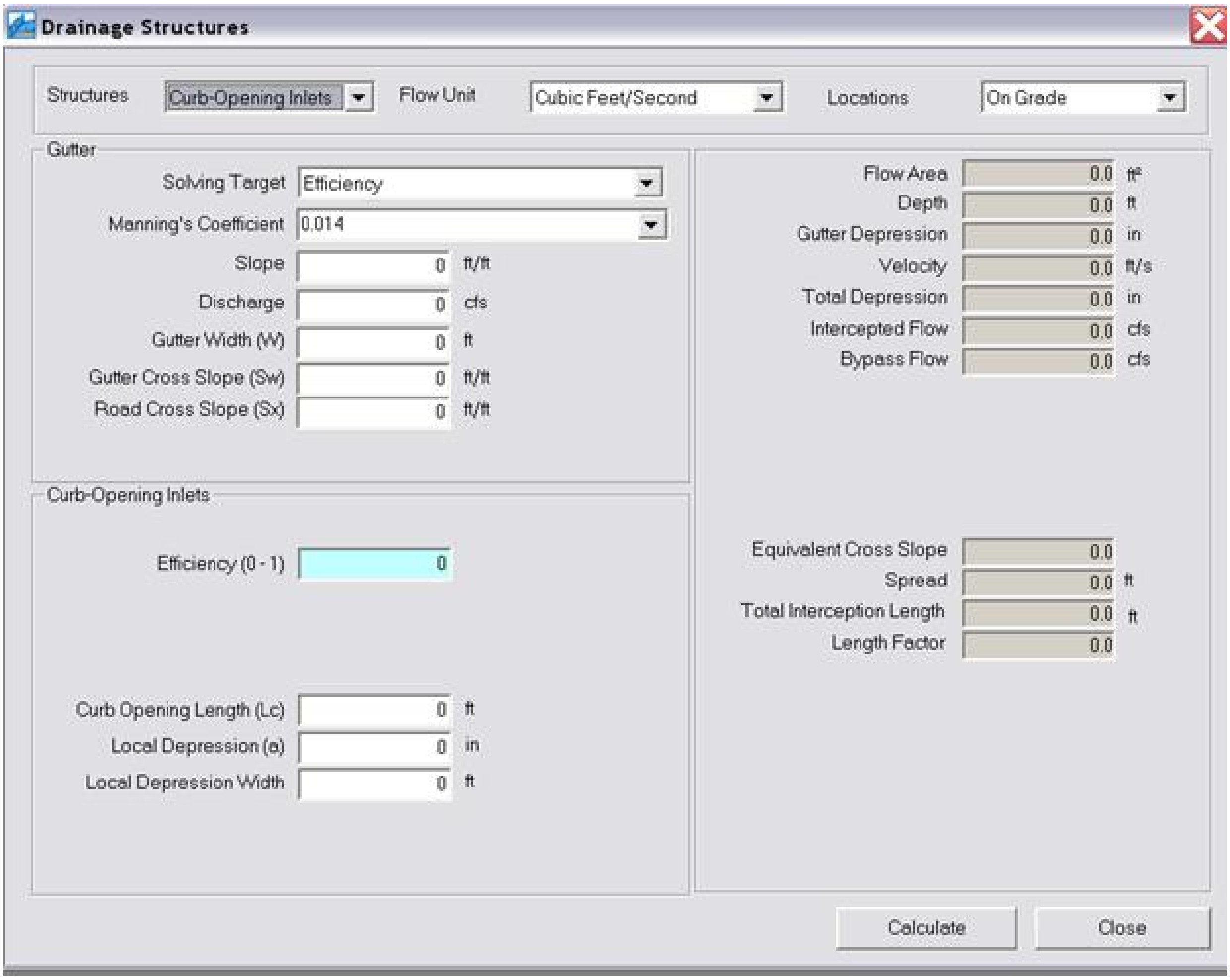
Curb-Opening Inlet

The dialog box for curb-opening inlet on grade is shown below.

Input for curb-opening inlets on grade:

- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Efficiency or length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Efficiency** –Interception efficiency of the inlet. It represents ratio of intercepted flow to total gutter flow. It is an output if selected as a solving target.

- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.

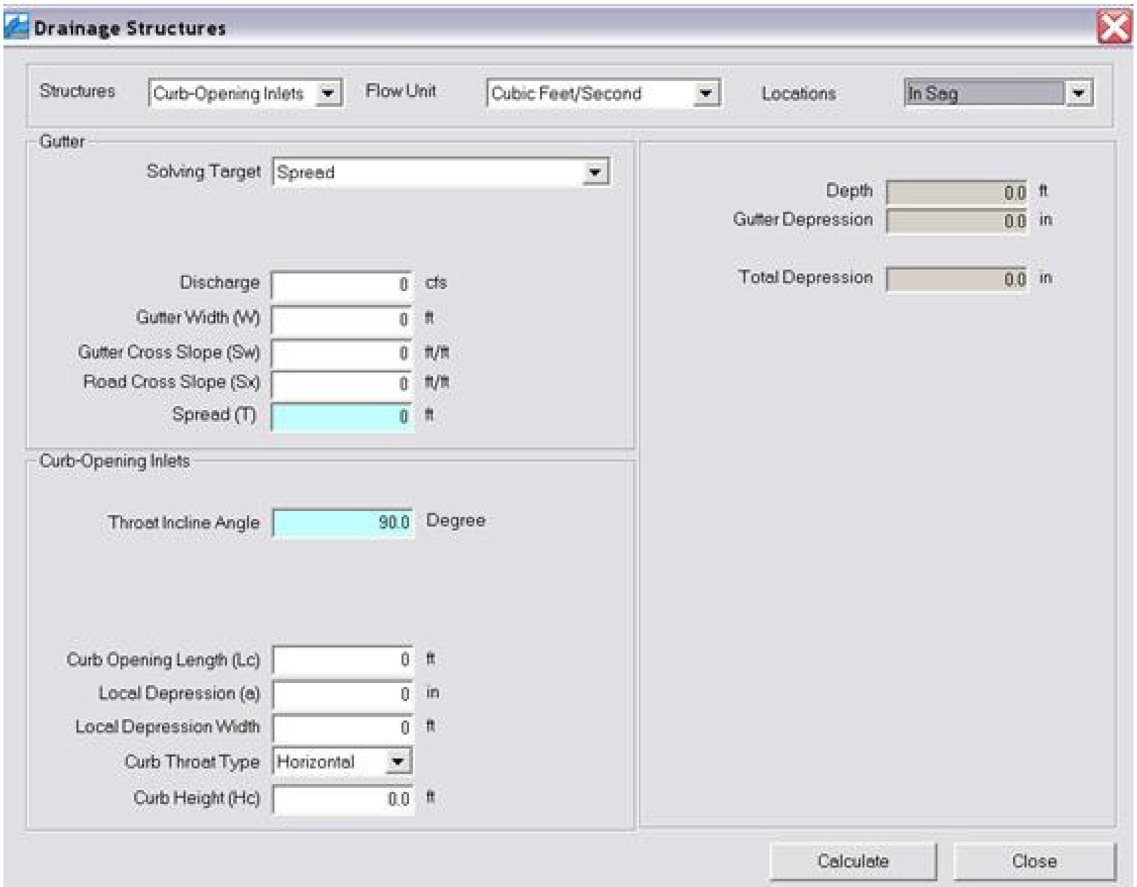


Output for curb-opening inlet on grade:

- **Flow Area** – Wetted area of the gutter.

- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Total Depression** – Sum of the local depression and the gutter depression.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Equivalent Cross Slope** – An equivalent cross-slope that has a conveyance capacity equal to that of the compound cross-slope.
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Total Interception Length** – Length of the curb required to intercept 100% of the gutter flow.
- **Length Factor** – Ratio of actual curb length to total interception length.

The dialog box for curb-opening inlet in sag is shown below.



Input for curb-opening inlets in sag:

- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Spread or length.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.

- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be an output if selected as a solving target.
- **Throat Incline Angle** – Angle of the curb opening throat.
- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Curb Throat Type** – Horizontal, vertical, or incline.
- **Curb Height** – Height of the curb.

Output for curb-opening inlet in sag:

- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets the curb).

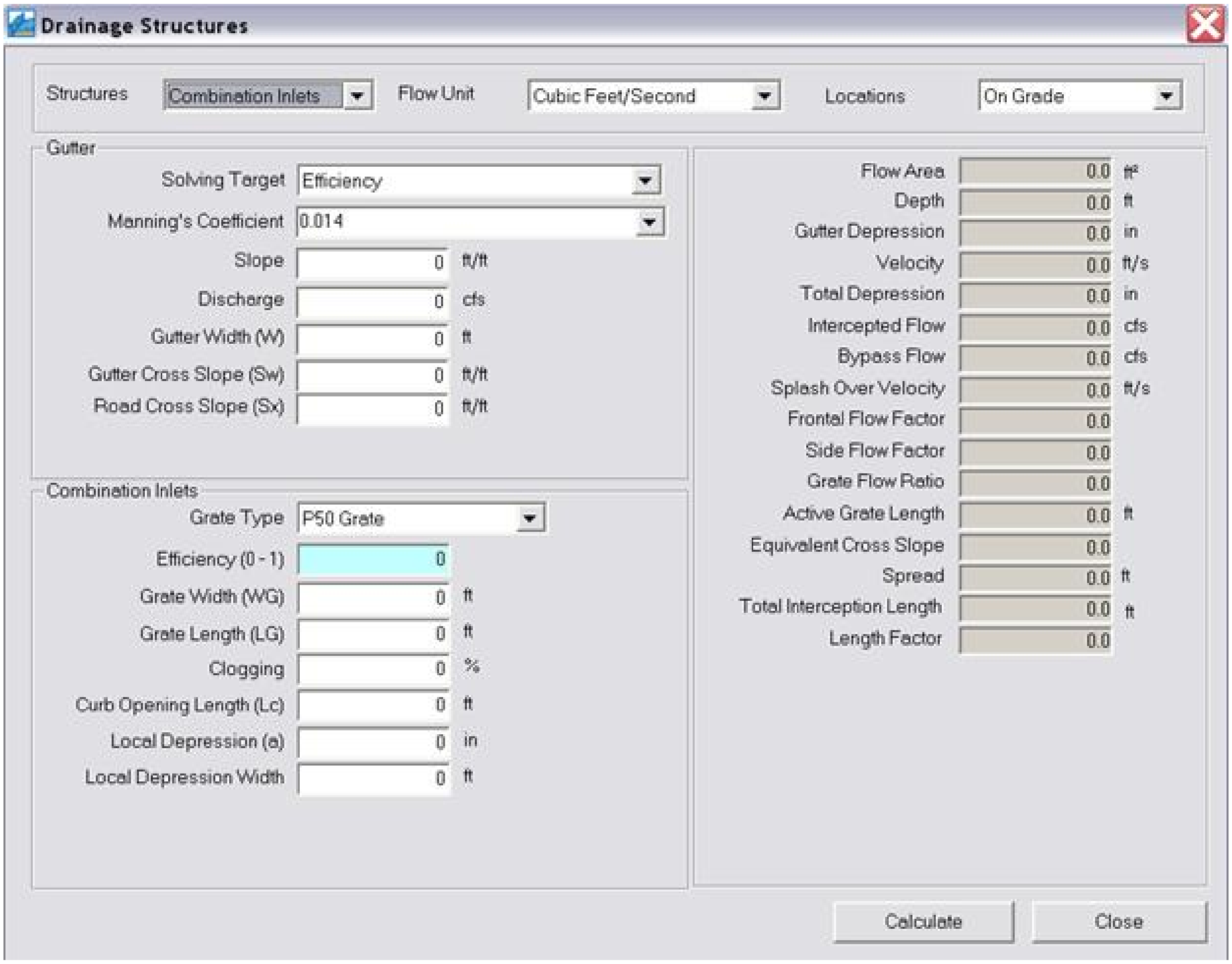
Combination Inlet

The dialog box for combination inlet on grade is shown below.

Input for combination inlets on grade:

- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.

- **Solving Target** – Efficiency, equal opening lengths, or curb opening length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Grate Type** – Select one of the eight grate types listed.
- **Efficiency** –Interception efficiency of the inlet. It represents ratio of intercepted flow to total gutter flow. It is an output if selected as a solving target.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.



Output for combination inlet on grade:

- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.
- **Total Depression** – Sum of the local depression and the gutter depression.

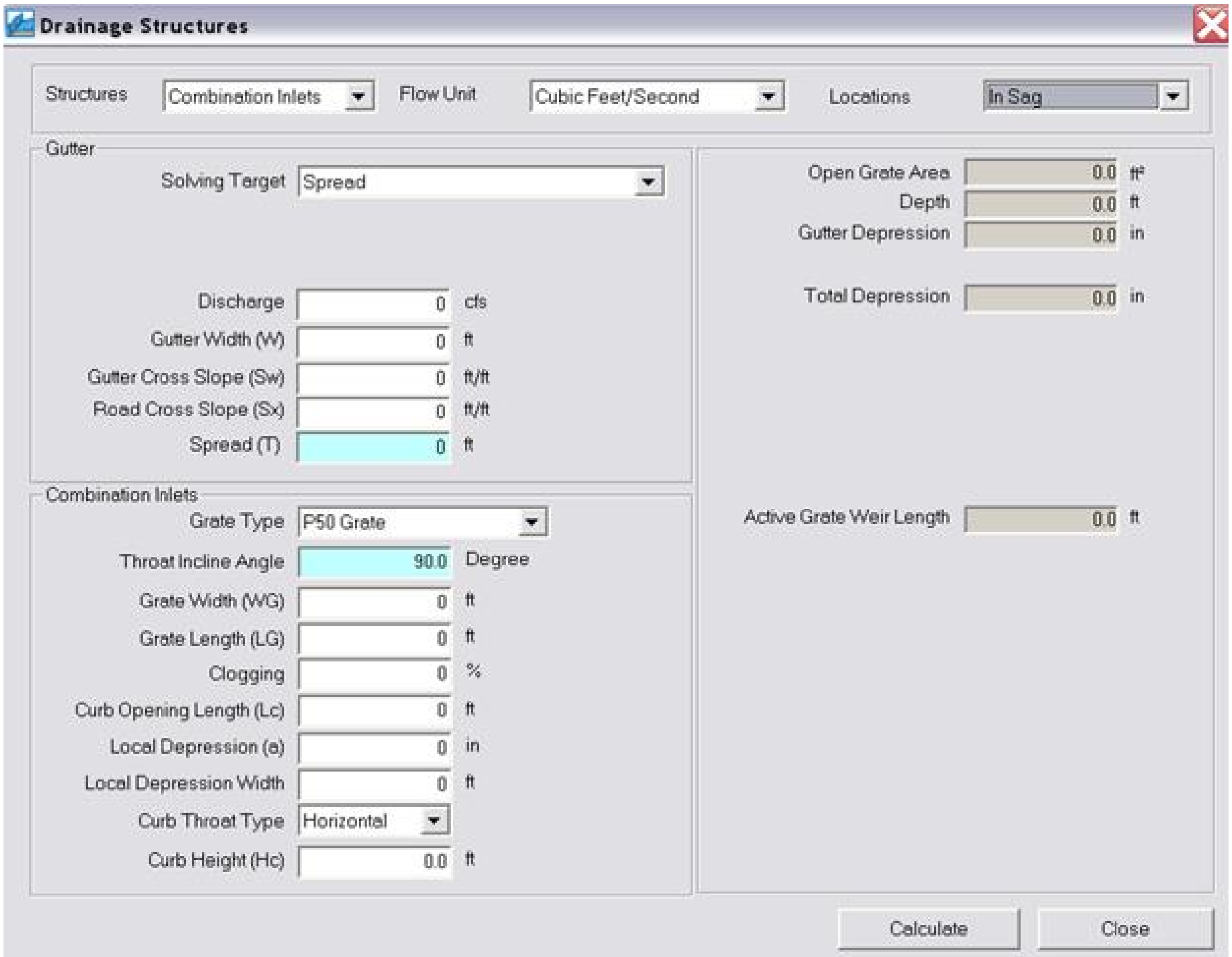
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Splash Over Velocity** – Velocity where splash over first occurs. Splash over refers to the fraction of frontal gutter flow that is not intercepted by the inlet.
- **Frontal Flow Factor** – The ratio of intercepted frontal flow to total frontal flow.
- **Side Flow Factor** – The ratio of intercepted side flow to total side flow.
- **Grate Flow Ratio** – The ratio of frontal flow to total gutter flow.
- **Active Grate Length** – Portion of grate length (the side that is parallel to the curb) that is not clogged.
- **Equivalent Cross Slope** – An equivalent cross-slope that has a conveyance capacity equal to that of the compound cross-slope.
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Total Interception Length** – Length of the curb required to intercept 100% of the gutter flow.
- **Length Factor** – Ratio of actual curb length to total interception length.

The dialog box for combination inlet in sag is shown below.

Input for combination inlets in sag:

- **Flow Unit** – Select the desired flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Efficiency, equal opening lengths, or curb opening length.

- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be an output if selected as a solving target.
- **Grate Type** – Select one of the eight grate types listed.
- **Throat Incline Angle** – Angle of the curb opening throat.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Curb Opening Length** – Length of the curb-opening inlet (i.e., length parallel to the curb).
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Curb Throat Type** – Horizontal, vertical, or incline.
- **Curb Height** – Height of the curb.



Output for combination inlet in sag:

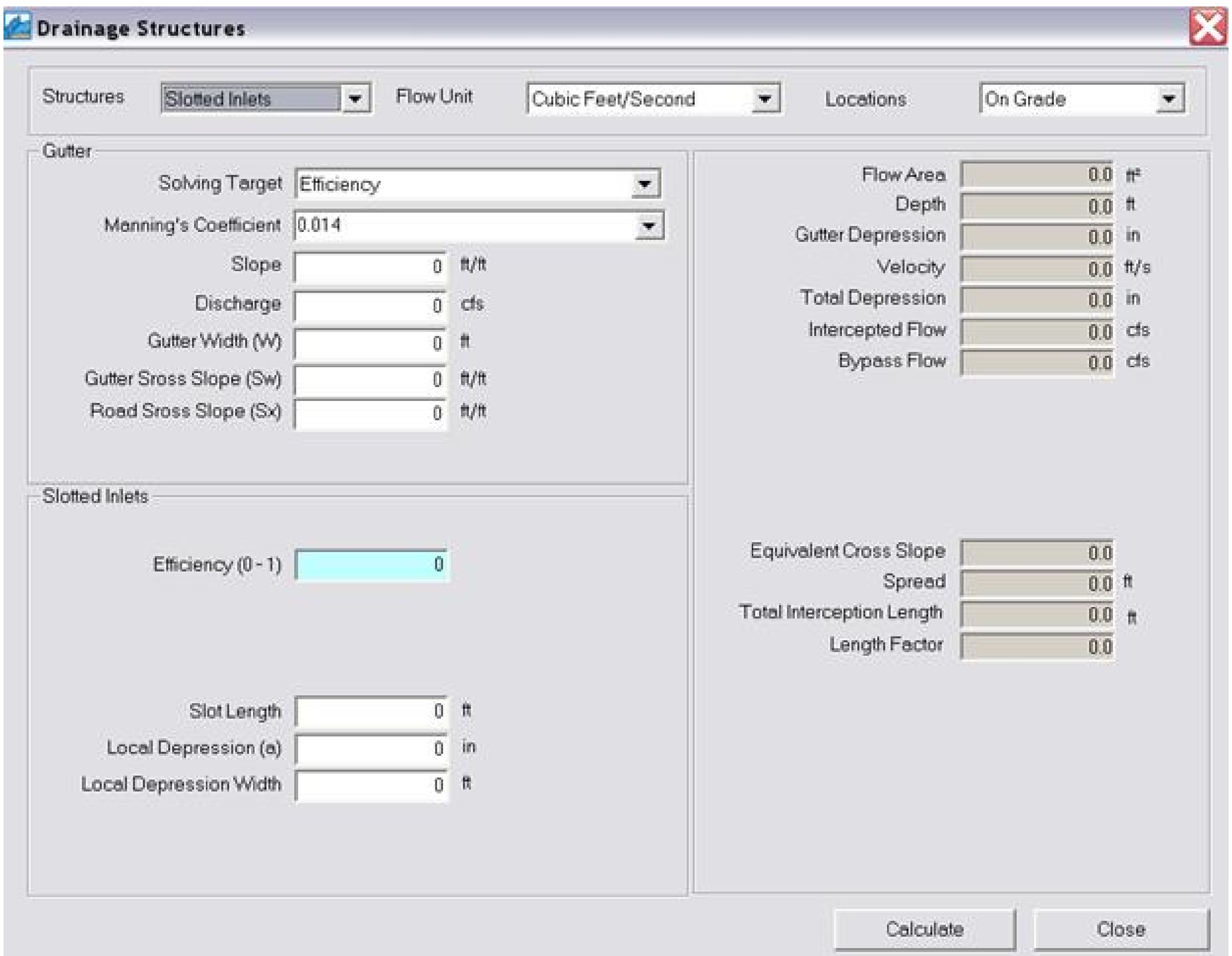
- **Open Grate Area** – Clear area of the grate accounting for clogging, and area occupied by the bars depending on the grate type. Used when the grate acts as an orifice.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets

the curb).

- **Active Grate Weir Length** – Portion of grate length and width that is not clogged and not covered by the bars. Used when the grate acts as a weir.

Slotted Inlet

The dialog box for slotted inlet on grade is shown below.



Input for slotted inlets on grade:

- **Flow Unit** – Select the desired flow unit.
- **Locations** – On grade and in sag.
- **Solving Target** – Efficiency and length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** –Width of the gutter measured from the curb.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.
- **Efficiency** –Interception efficiency of the inlet. It represents ratio of intercepted flow to total gutter flow. It is an output if selected as a solving target.
- **Slot length** – Length of the inlet.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.

Output for slotted inlet on grade:

- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Velocity** – Flow velocity through the gutter.

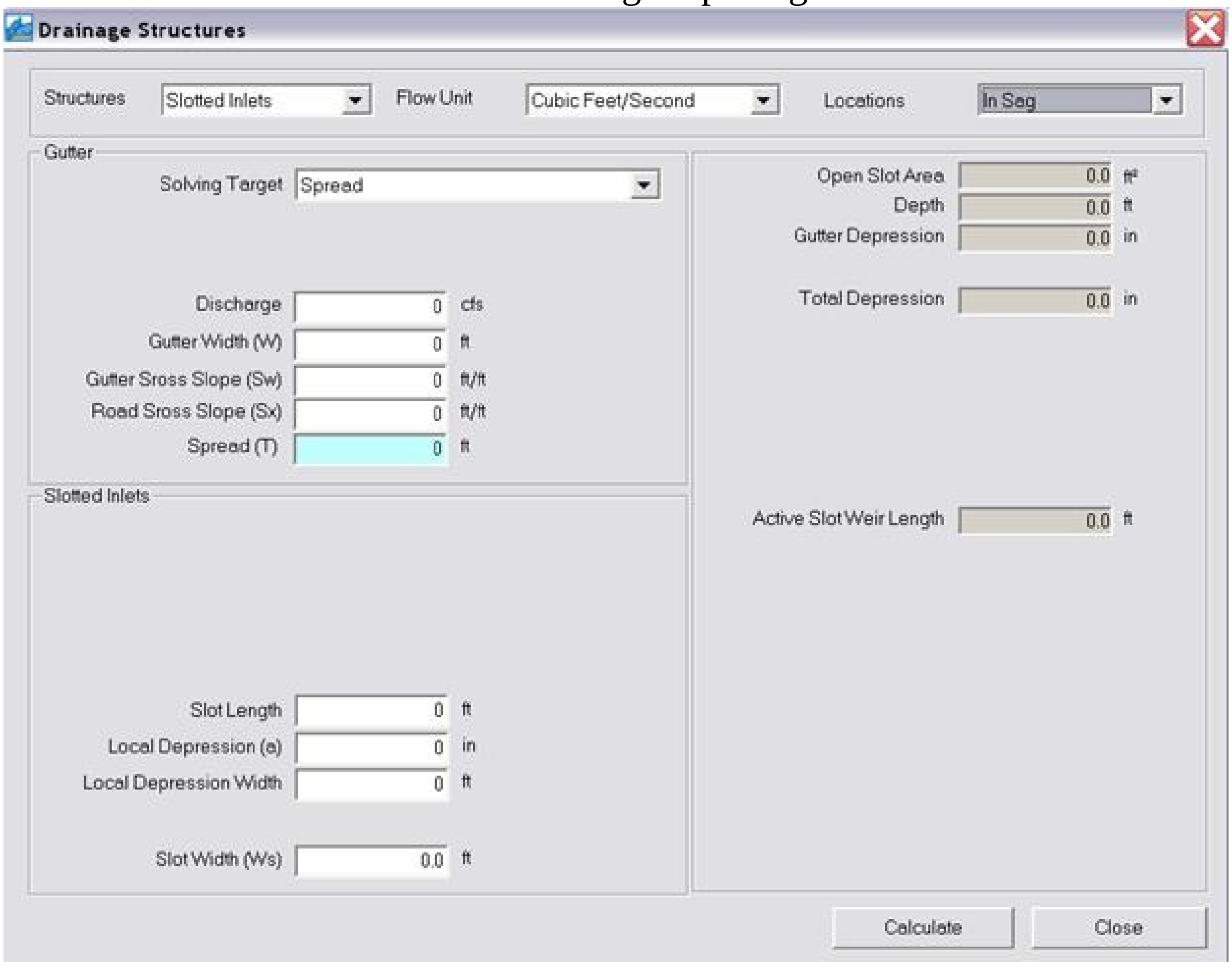
- **Total Depression** – Sum of the local depression and the gutter depression.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Equivalent Cross Slope** – An equivalent cross-slope that has a conveyance capacity equal to that of the compound cross-slope.
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Total Interception Length** – Length of the curb required to intercept 100% of the gutter flow.
- **Length Factor** – Ratio of actual curb length to total interception length.

The dialog box for slotted inlet in sag is shown below.

Input for slotted inlets in sag:

- **Flow Unit** – Select the flow unit.
- **Locations** – On grade and in sag.
- **Solving Target** – Spread and length.
- **Discharge** – Flow rate through the gutter.
- **Gutter Width** – Width of the gutter measured from the curb to the break in slope of the street.
- **Gutter Cross Slope** – Slope of the gutter measured perpendicular to centerline of the street.
- **Road Cross Slope** –Slope of the street perpendicular to the longitudinal direction.

- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be an output if selected as a solving target.
- **Slot Length** – Length of the inlet.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.
- **Slot Width** – Width of the slot length opening.



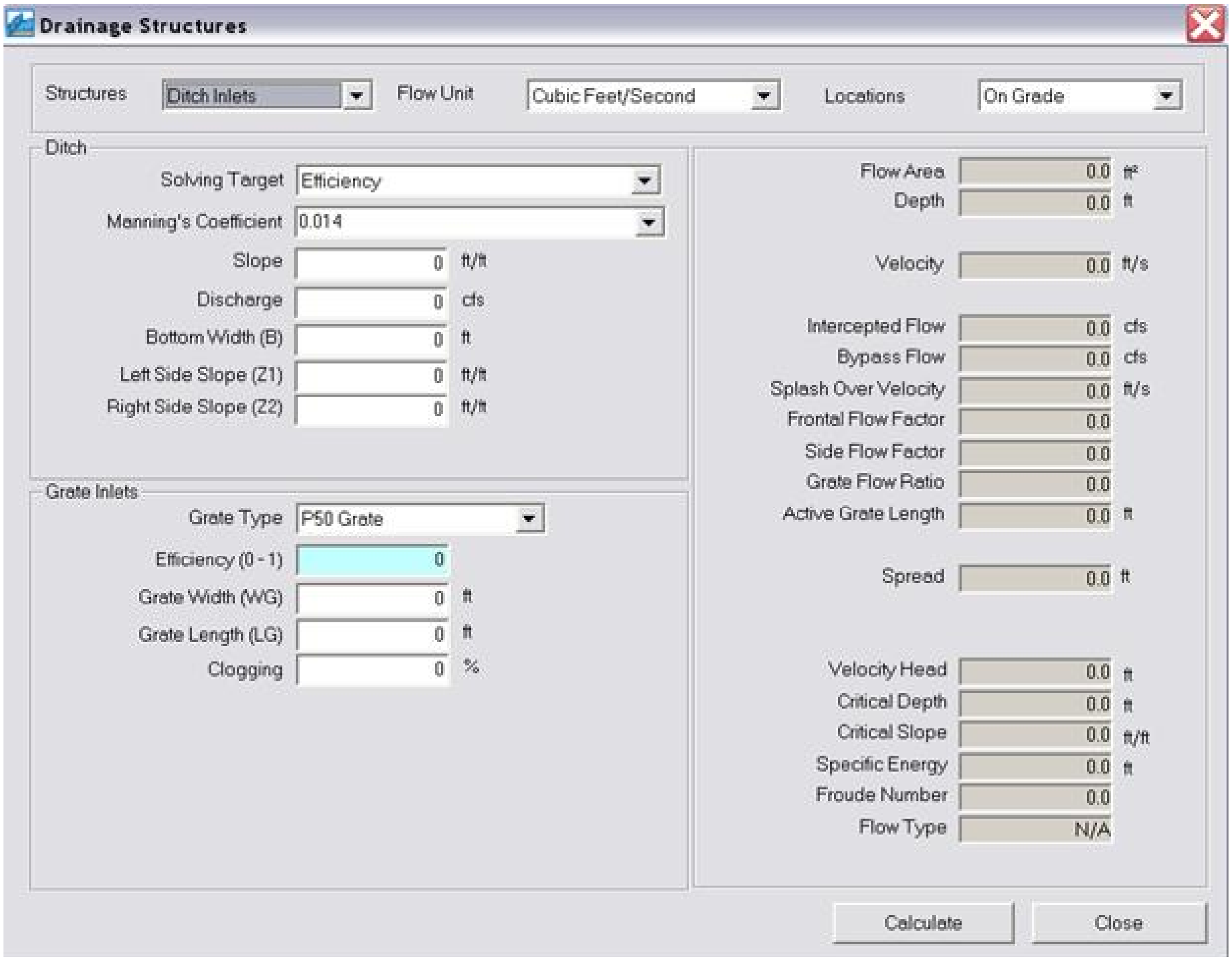
Output for slotted inlet in sag:

- **Open Slot Area** – Area of the slot opening used in the case of orifice opening.

- **Depth** – Flow depth in the gutter.
- **Gutter Depression** – Local depression of the gutter measured from the point the cross slope line intersects with the curb.
- **Total Depression** – Sum of the local depression and the gutter depression (measured from the point where the street cross slope meets the curb).
- **Active Slot Weir Length** – Portion of slot length and width that is not clogged and not covered by the bars. Used when the slot acts as a weir.

Ditch Inlet

The dialog box for ditch inlets on grade is shown below.



Input for ditch inlets on grade:

- **Flow Unit** – Select the desired flow unit.
- **Locations** – On grade and in sag.
- **Solving Target** – Efficiency and length.
- **Manning's Coefficient** – Manning's roughness coefficient for the gutter.
- **Slope** – Longitudinal slope of the street.
- **Discharge** – Flow rate through the gutter.
- **Bottom Width** – Bottom width of the ditch (channel).

- **Left Side Slope** – Left side slope of the ditch.
- **Right Side Slope** – Right side of the ditch.
- **Grate Type** – Select one of the eight grate types listed.
- **Efficiency** –Interception efficiency of the grate. It represents ratio of intercepted flow to total gutter flow.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.

Output for ditch inlets on grade:

- **Flow Area** – Wetted area of the gutter.
- **Depth** – Flow depth in the gutter.
- **Velocity** – Flow velocity through the gutter.
- **Intercepted Flow** – The portion of gutter flow that entered the inlet.
- **Bypass Flow** – The portion of the gutter flow that is not intercepted by the inlet. It is total gutter flow less the intercepted flow.
- **Splash Over Velocity** – Velocity where splash over first occurs. Splash over refers to the fraction of frontal gutter flow that is not intercepted by the inlet.
- **Frontal Flow Factor** – The ratio of intercepted frontal flow to total frontal flow.
- **Side Flow factor** – The ratio of intercepted side flow to total side flow.
- **Grate Flow Ratio** – The ratio of frontal flow to total gutter flow.
- **Active Grate Length** – Portion of grate length (the side that is parallel to the curb) that is not clogged.

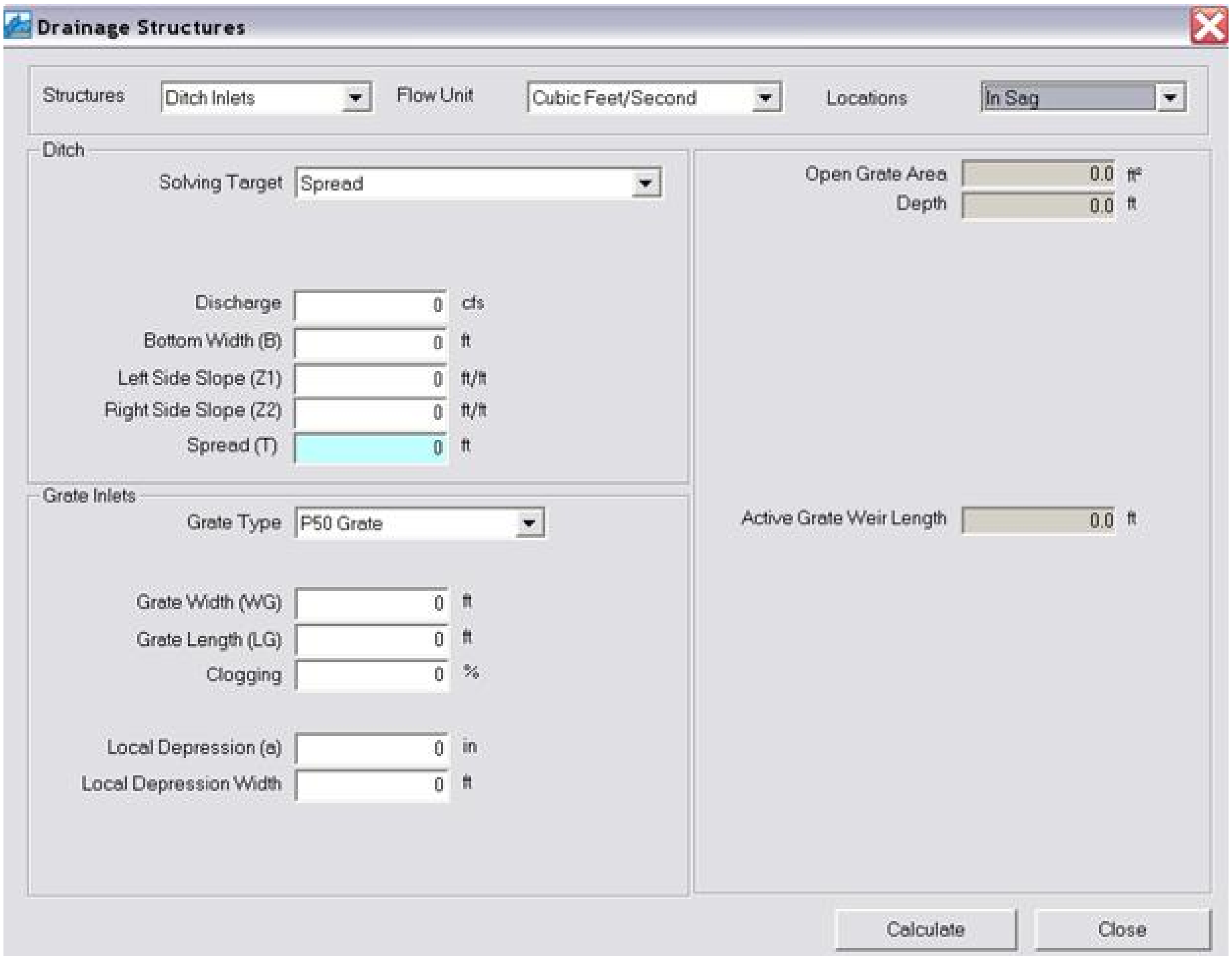
- **Spread** – Top width, or width of the gutter at the water surface elevation.
- **Velocity Head** – Energy head due to velocity.
- **Critical Depth** – Depth corresponding to minimum specific energy of the channel.
- **Critical Slope** – Channel slope under critical depth.
- **Specific Energy** – Sum of velocity head and pressure head.
- **Froude Number** – Flow characteristics dimensionless parameter for the ditch.

The dialog box for ditch inlets in sag is shown below.

Input for ditch inlets in sag:

- **Flow Unit** – Select the flow unit.
- **Location** – On grade and in sag.
- **Solving Target** – Spread or length.
- **Discharge** – Flow rate through the gutter.
- **Bottom Width** – Bottom width of the ditch (channel).
- **Left Side Slope** – Left side slope of the ditch.
- **Right Side Slope** – Right side of the ditch.
- **Spread** – Top width, or width of the gutter at the water surface elevation. Could be output is selected as a solving target.
- **Grate Type** – Select one of the eight grate types listed.
- **Grate Width** – Width of the grate.
- **Grate Length** – Length of the grate.

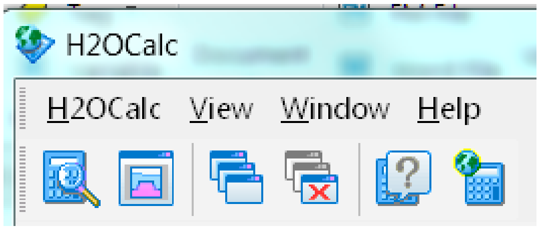
- **Clogging** – Percentage of the grate opening that is clogged by debris, leaves, etc, and is not available to intercept flow.
- **Local Depression** – Depth of local depression of the gutter measured from the point where the cross slope line intersects with the curb.
- **Local Depression Width** – Width of the local depression.



Output for ditch inlets in sag:

- **Open Grate Area** – Area of the grate accounting for clogging, and area occupied by the bars depending on the grate type. Used when the grate acts as an orifice.

- **Depth** – Flow depth in the gutter.
- **Active Grate Weir Length** – Portion of grate length and width that is not clogged and not covered by the bars. Used when the grate acts as a weir.


H2OCalc
H2OCalc View Window Help

2.3.5 Weirs and Orifices

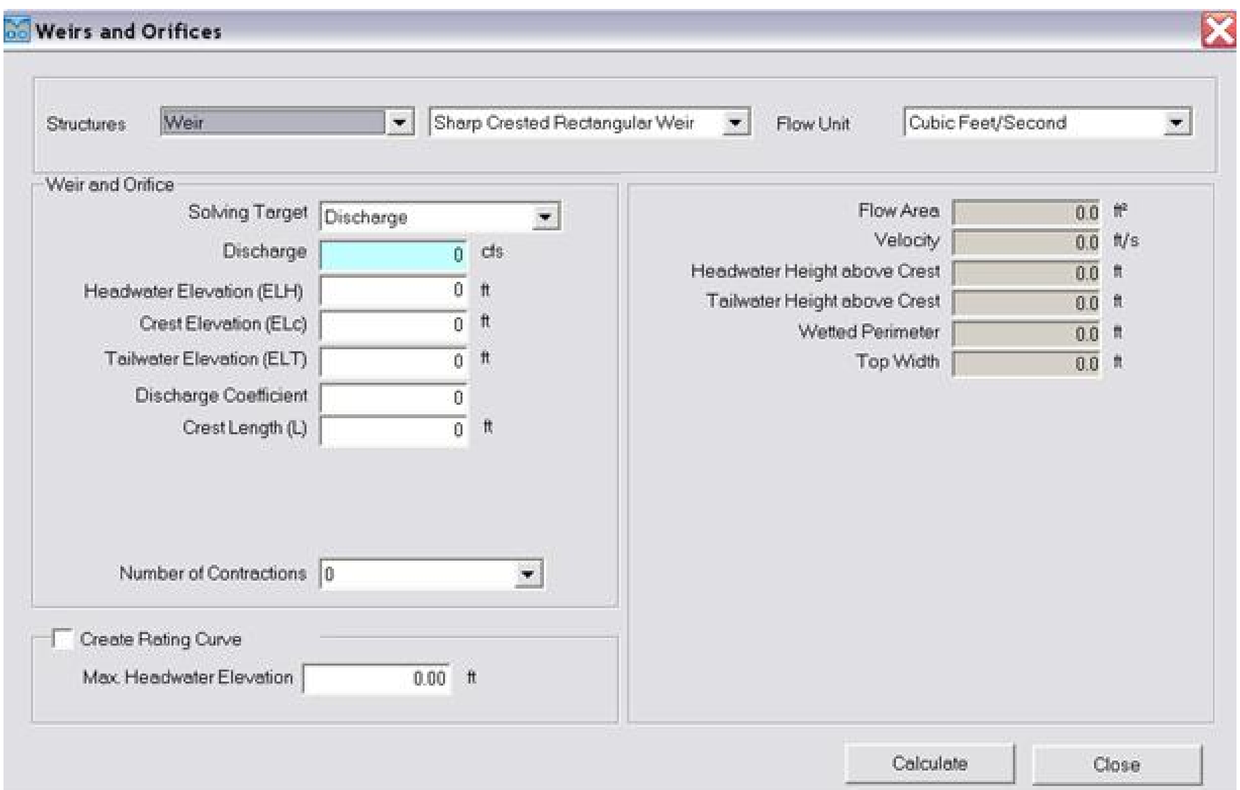
The Weirs and Orifices category performs hydraulic calculations for various types of weirs and orifices.

Weirs

Sharp crested rectangular weir, sharp crested V-notch weir, sharp crested cipolletti weir, generic weir, and broad crested weir are supported.

Sharp Crested Rectangular Weir

The sharp crested rectangular weir dialog box is shown below.



Input for sharp crested rectangular weir:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation –** Water surface elevation upstream of the weir.
- **Crest Elevation –** Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation–** Water surface elevation downstream of the weir.
- **Discharge Coefficient** – Weir coefficient (c_d) used to account for submergence effects.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.
- **Number of Contractions** – Number of end contractions (i.e., one or both sides of the weir).
- **Create rating curve** - check the option if you wish to construct a rating curve (headwater elevation vs discharge) curve for the weir.
- **Max. Headwater Elevation** (HWel) - maximum head water elevation to be considered to construct the rating curve. The rating curve would be constructed from ten (HWel,Q) points where the head values considered range from the lowest crest elevation to the maximum headwater elevation.

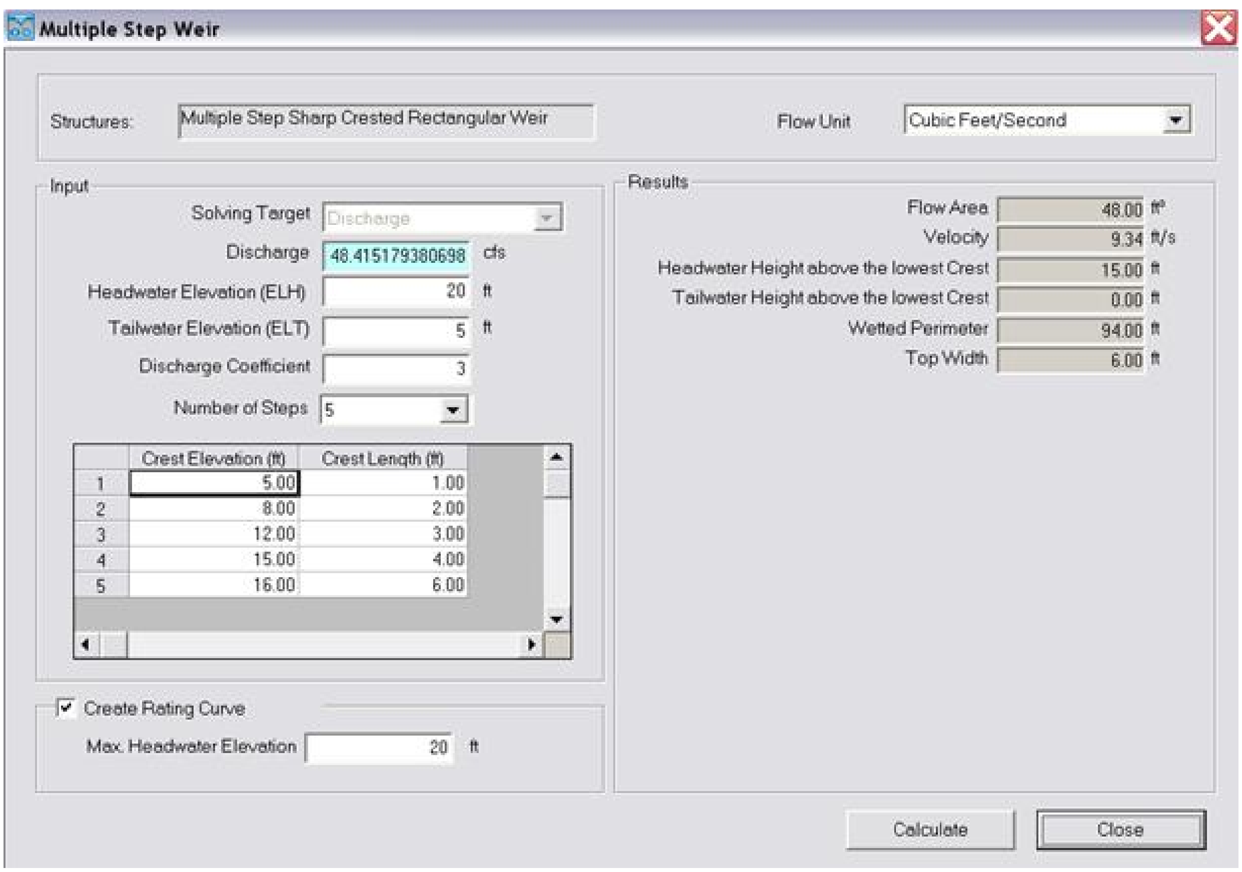
Output for sharp crested rectangular weir:

- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest –** Headwater elevation minus crest elevation of the weir.

- **Tailwater Height Above Crest –** Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation. For rectangular channels, it is the same as crest length.
- **Rating Curve** – if the rating curve option is on, the headwater elevation vs discharge values would be presented in graph and report form.

Multiple Step Sharp Crested Rectangular Weir

The multi-step sharp crested rectangular weir dialog box is shown below.



Input for multi-step sharp crested rectangular weir are:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation –** Water surface elevation upstream of the weir.
- **Tailwater Elevation–** Water surface elevation downstream of the weir.
- **Discharge Coefficient** – Weir coefficient (c_d) used to account for submergence effects.
- **Number of Contractions** – Number of end contractions (i.e., one or both sides of the weir).
- **Crest Elevation** – Elevation of the weir crest (i.e., bottom elevation of the weir) at various steps along the weir height.
- **Crest Length** – Length of the weir perpendicular to the flow direction measured at the corresponding crest of the weir.
- **Number of Steps** - Number of times that the weir changes length along its height.
- **Create rating curve** - check the option if you wish to construct a rating curve (headwater elevation vs discharge) curve for the weir.
- **Max. Headwater Elevation** (HWel) - maximum head water elevation to be considered to construct the rating curve. The rating curve would be constructed from ten (HWel,Q) points where the head values considered range from the lowest crest elevation to the maximum headwater elevation.

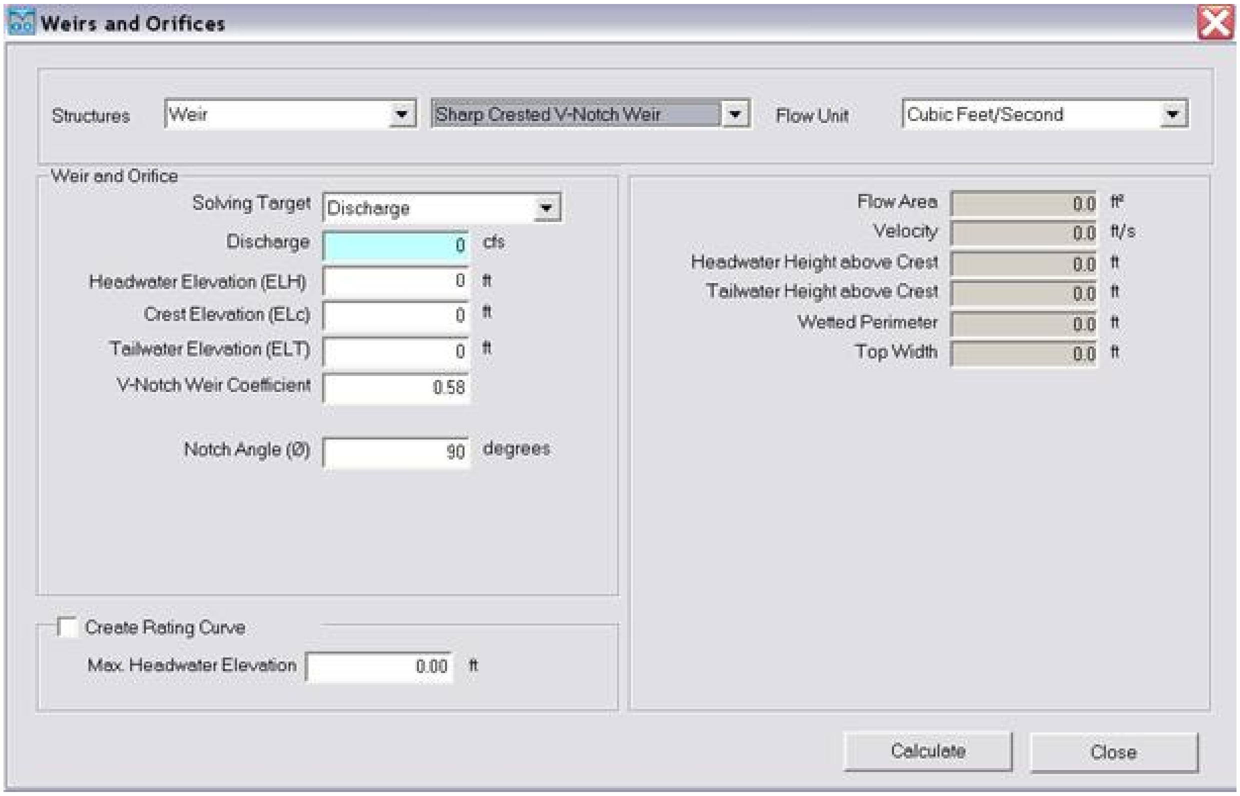
Output for multi-step sharp crested rectangular weir:

- **Flow Area** – Wetted area of the weir.

- **Velocity** – Flow velocity.
- **Headwater Height Above Crest –** Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest –** Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation. For rectangular channels, it is the same as crest length.
- **Rating Curve** – if the rating curve option is on, the headwater elevation vs discharge values would be presented in graph and report form.

Sharp Crested V-notch Weir

The sharp crested v-notch weir dialog box is shown below.



Input for sharp crested V-notch weir:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation –** Water surface elevation upstream of the weir.
- **Crest Elevation –** Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation–** Water surface elevation downstream of the weir.
- **V-Notch Weir Coefficient** – Weir coefficient (c_d) used to account for effects such as submergence and local losses on flow rate through the weir.

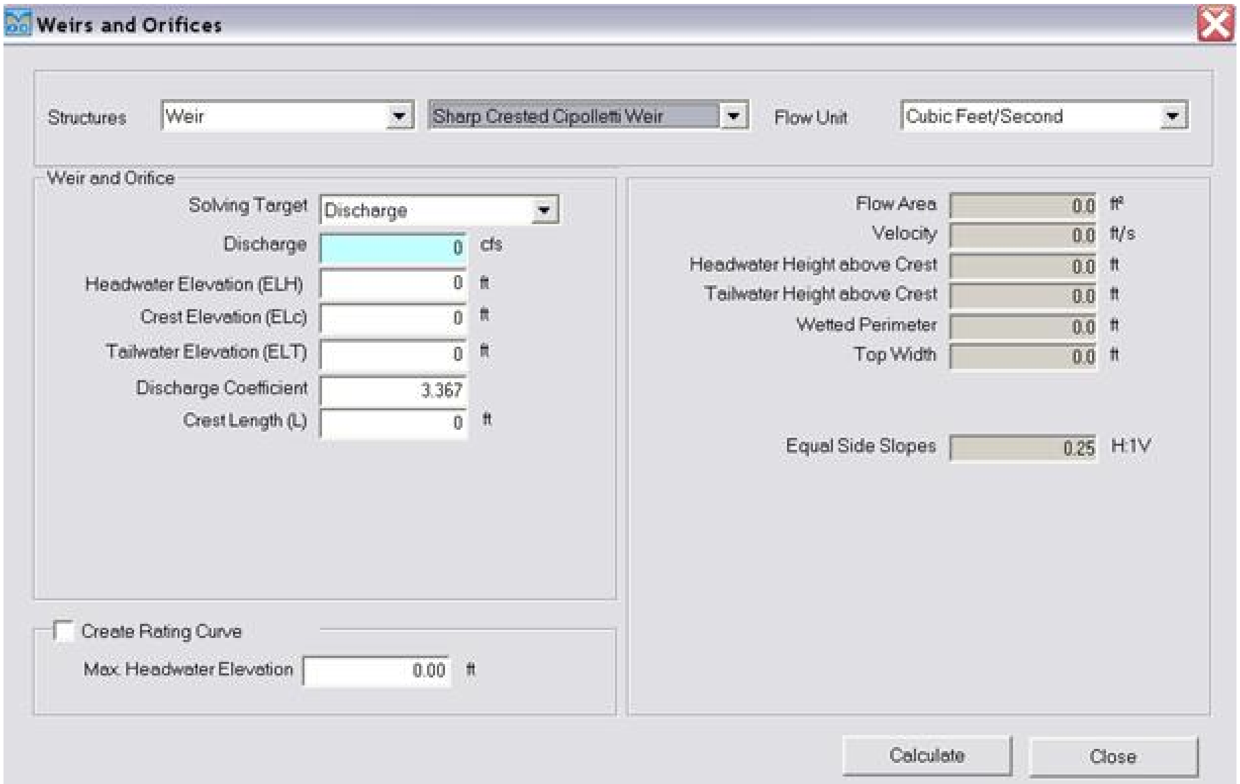
- **Notch Angle** – Angle of the triangular weir opening.
- **Create rating curve** - check the option if you wish to construct a rating curve (headwater elevation vs discharge) curve for the weir.
- **Max. Headwater Elevation** (HWel) - maximum head water elevation to be considered to construct the rating curve. The rating curve would be constructed from ten (HWel,Q) points where the head values considered range from the lowest crest elevation to the maximum headwater elevation.

Output for sharp crested v-notch weir:

- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest –** Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest –** Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.
- **Rating Curve** – if the rating curve option is on, the headwater elevation vs discharge values would be presented in graph and report form.

Sharp Crested Cipolletti Weir

The sharp crested cipolletti weir dialog box is shown below.



Input for sharp crested cipolletti weir:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation –** Water surface elevation upstream of the weir.
- **Crest Elevation –** Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation–** Water surface elevation downstream of the weir.
- **Discharge Coefficient** – Weir coefficient (c_d) used to account for submergence effects.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.

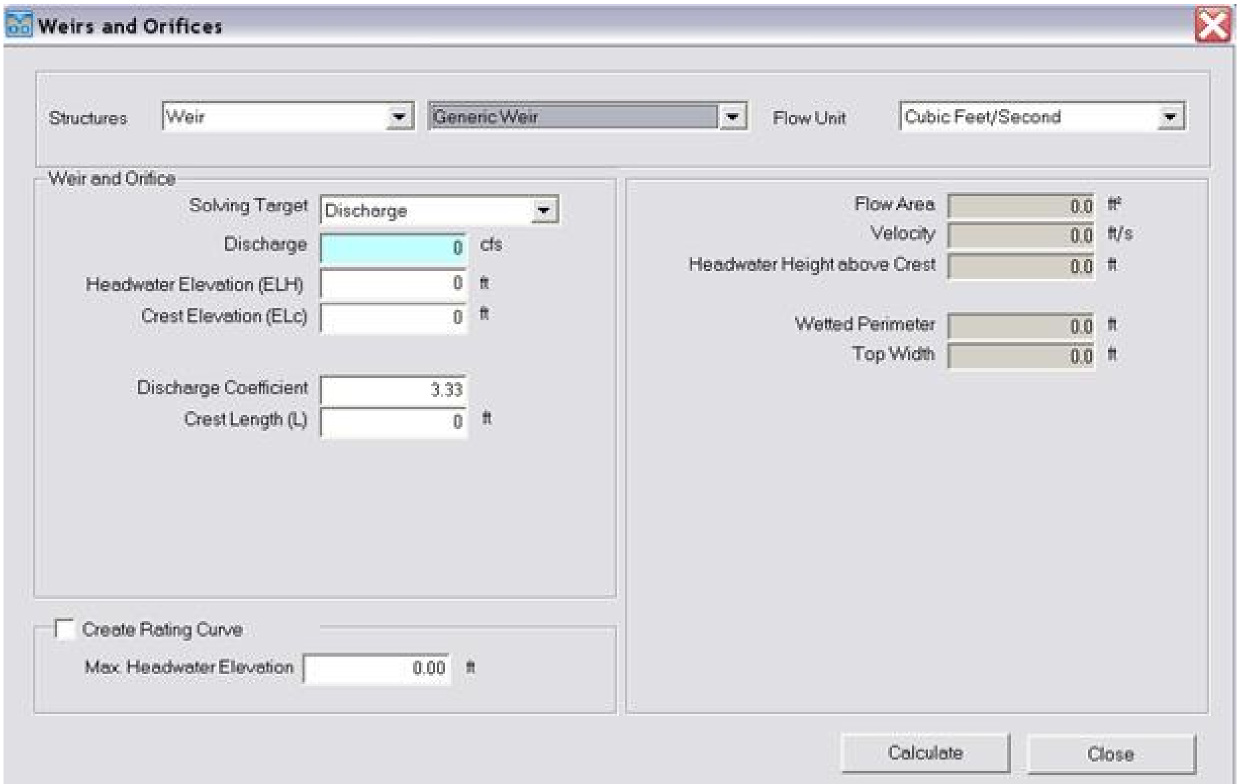
- **Create rating curve** - check the option if you wish to construct a rating curve (headwater elevation vs discharge) curve for the weir.
- **Max. Headwater Elevation** (HWel) - maximum head water elevation to be considered to construct the rating curve. The rating curve would be constructed from ten (HWel,Q) points where the head values considered range from the lowest crest elevation to the maximum headwater elevation.

Output for sharp crested cipolletti weir:

- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest –** Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest –** Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.
- **Equal Side Slope** – Side slope for the left and the right side of the cipolletti (trapezoidal) weir. It is assumed identical for both sides of the weir.
- **Rating Curve** – if the rating curve option is on, the headwater elevation vs discharge values would be presented in graph and report form.

Generic Weir

The generic weir dialog box is shown below.



Input for generic weir:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation –** Water surface elevation upstream of the weir.
- **Crest Elevation –** Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Discharge Coefficient** – Weir coefficient (c_d) used to account for submergence effects.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.

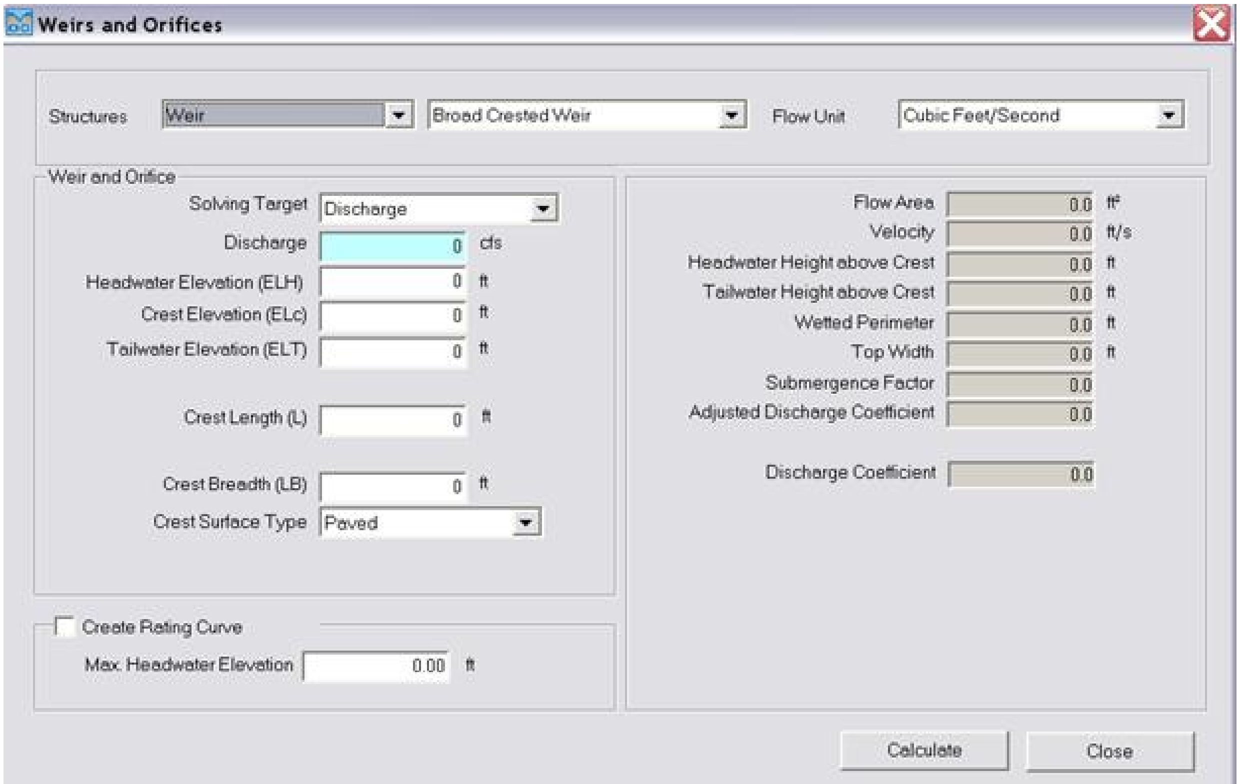
- **Create rating curve** - check the option if you wish to construct a rating curve (headwater elevation vs discharge) curve for the weir.
- **Max. Headwater Elevation** (HWel) - maximum head water elevation to be considered to construct the rating curve. The rating curve would be constructed from ten (HWel,Q) points where the head values considered range from the lowest crest elevation to the maximum headwater elevation.

Output for generic weir:

- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest –** Headwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.
- **Rating Curve** – if the rating curve option is on, the headwater elevation vs discharge values would be presented in graph and report form.

Broad Crested Weir

The broad crested weir dialog box is shown below.



Input for broad crested weir:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the weir.
- **Headwater Elevation –** Water surface elevation upstream of the weir.
- **Crest Elevation –** Elevation of the weir crest (i.e., bottom elevation of the weir).
- **Tailwater Elevation–** Water surface elevation downstream of the weir.
- **Crest Length** – Length of the weir perpendicular to the flow direction, measured at the crest of the weir.
- **Crest Breadth –** Width of the weir along the flow direction.
- **Crest Surface Type –** Crest surface of the weir (paved or gravel).

- **Create rating curve** - check the option if you wish to construct a rating curve (headwater elevation vs discharge) curve for the weir.
- **Max. Headwater Elevation** (HWel) - maximum head water elevation to be considered to construct the rating curve. The rating curve would be constructed from ten (HWel,Q) points where the head values considered range from the lowest crest elevation to the maximum headwater elevation.

Output for broad crested weir:

- **Flow Area** – Wetted area of the weir.
- **Velocity** – Flow velocity.
- **Headwater Height Above Crest –** Headwater elevation minus crest elevation of the weir.
- **Tailwater Height Above Crest –** Tailwater elevation minus crest elevation of the weir.
- **Wetted Perimeter** – Wetted perimeter of the weir.
- **Top Width** – Width of the weir at the water surface elevation.
- **Submergence Factor** –Ratio used to calculate effect of submergence on discharge coefficient.
- **Adjusted Discharge Coefficient** – Discharge coefficient adjusted for submergence effect.
- **Discharge Coefficient** – Weir discharge coefficient. It depends on shape of the weir.
- **Rating Curve** – if the rating curve option is on, the headwater elevation vs discharge values would be presented in graph and report form.

Orifice

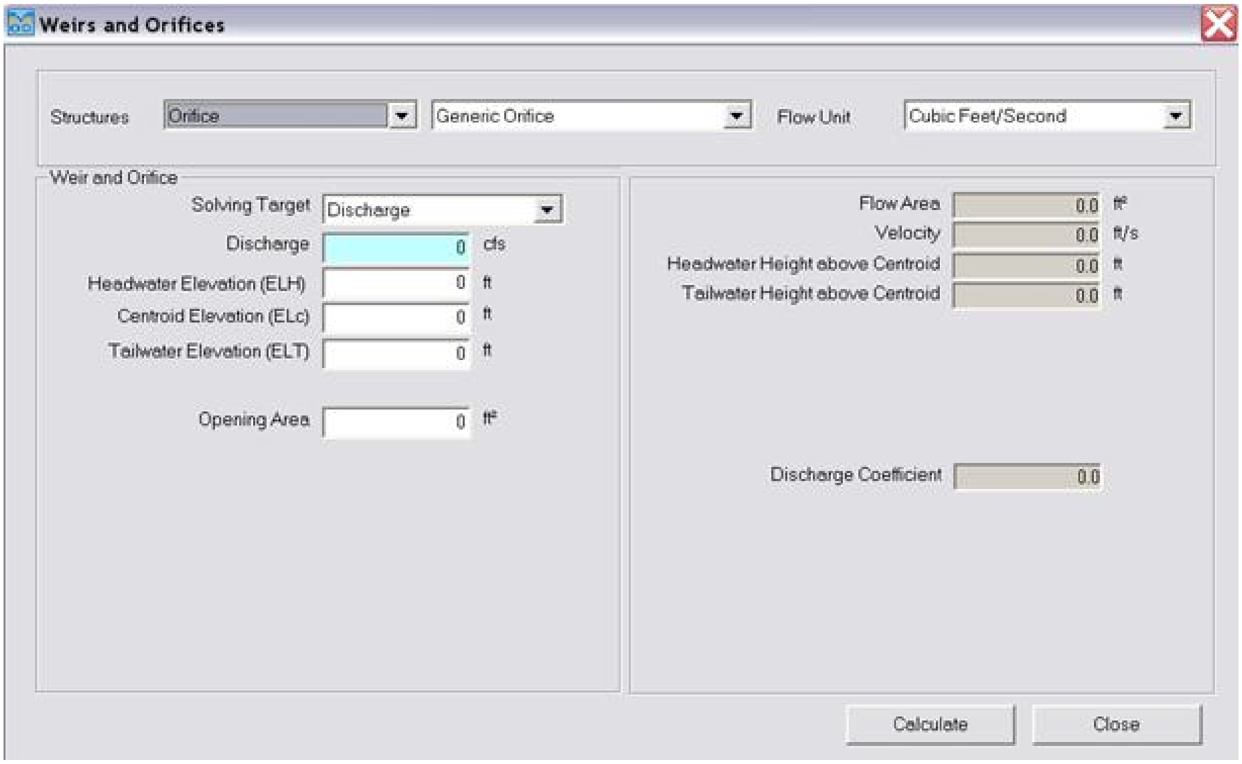
Generic orifice, rectangular orifice, and circular orifice are supported.

Generic Orifice

The generic orifice dialog box is shown below.

Input for generic orifice:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the orifice.
- **Headwater Elevation –** Water surface elevation upstream of the orifice.
- **Centroid Elevation –** Elevation of the centre cross section of the orifice.
- **Tailwater Elevation–** Water surface elevation downstream of the orifice.
- **Opening Area** – Area of the orifice opening.
- **Discharge Coefficient** – Orifice coefficient used to account for losses, flow area correction, and submergence effects.



Output for generic orifice:

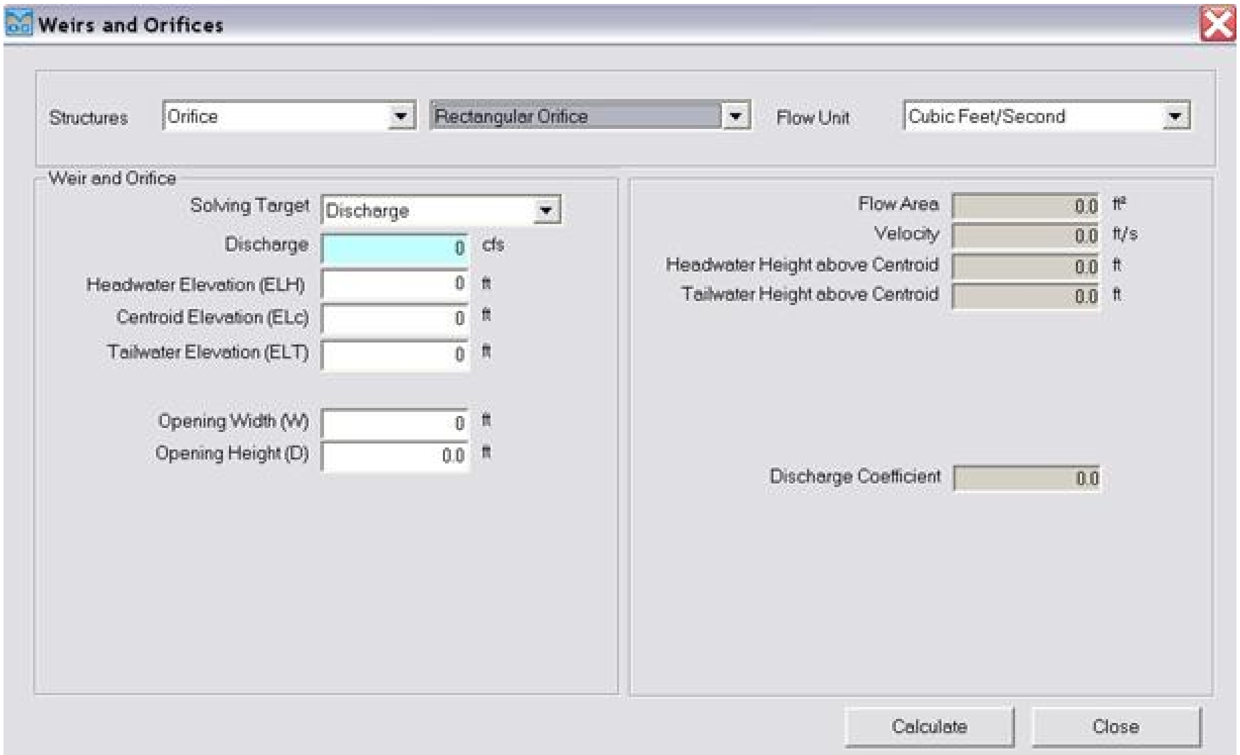
- **Flow Area** – Cross sectional area of the flow.
- **Velocity** – Flow velocity of the orifice.
- **Headwater Height Above Centroid –** Headwater elevation minus centroid elevation of the orifice.
- **Tailwater Height Above Centroid –** Tailwater elevation minus centroid elevation of the orifice.

Rectangular Orifice

The rectangular orifice dialog box is shown below.

Input for rectangular orifice:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the orifice.
- **Headwater Elevation –** Water surface elevation upstream of the orifice.
- **Centroid Elevation –** Elevation of the centre cross section of the orifice.
- **Tailwater Elevation–** Water surface elevation downstream of the orifice.
- **Opening Width** – Width of the orifice opening.
- **Opening Height** – height of the orifice opening.
- **Discharge Coefficient** – Orifice coefficient used to account for losses, flow area correction, and submergence effects.



Output for rectangular orifice:

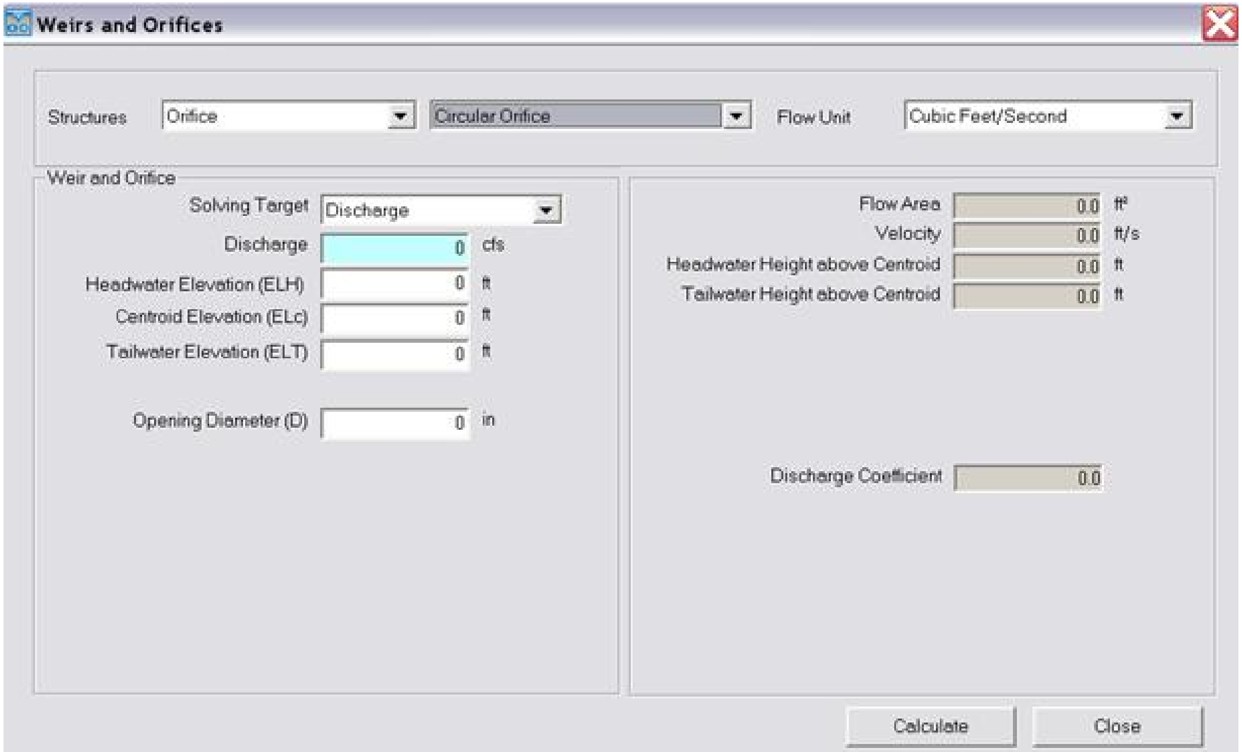
- **Flow Area** – Cross sectional area of the flow.
- **Velocity** – Flow velocity of the orifice.
- **Headwater Height Above Centroid –** Headwater elevation minus centroid elevation of the orifice.
- **Tailwater Height Above Centroid –** Tailwater elevation minus centroid elevation of the orifice.

Circular Orifice

The circular orifice dialog box is shown below.

Input for circular orifice:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Discharge** – Flow rate over the orifice.
- **Headwater Elevation –** Water surface elevation upstream of the orifice.
- **Centroid Elevation –** Elevation of the centre cross section of the orifice.
- **Tailwater Elevation–** Water surface elevation downstream of the orifice.
- **Opening Diameter** – Diameter of the orifice opening.
- **Discharge Coefficient** – Orifice coefficient used to account for losses, flow area correction, and submergence effects.

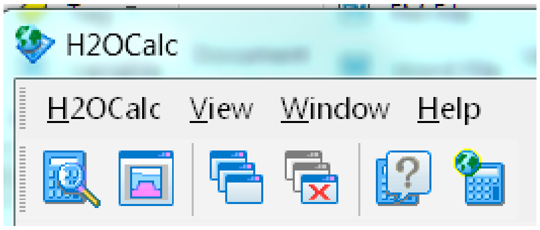


Output for circular orifice:

- **Flow Area** – Cross sectional area of the flow.
- **Velocity** – Flow velocity of the orifice.
- **Headwater Height Above Centroid –** Headwater elevation minus centroid elevation of the orifice.
- **Tailwater Height Above Centroid –** Tailwater elevation minus centroid elevation of the orifice.

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

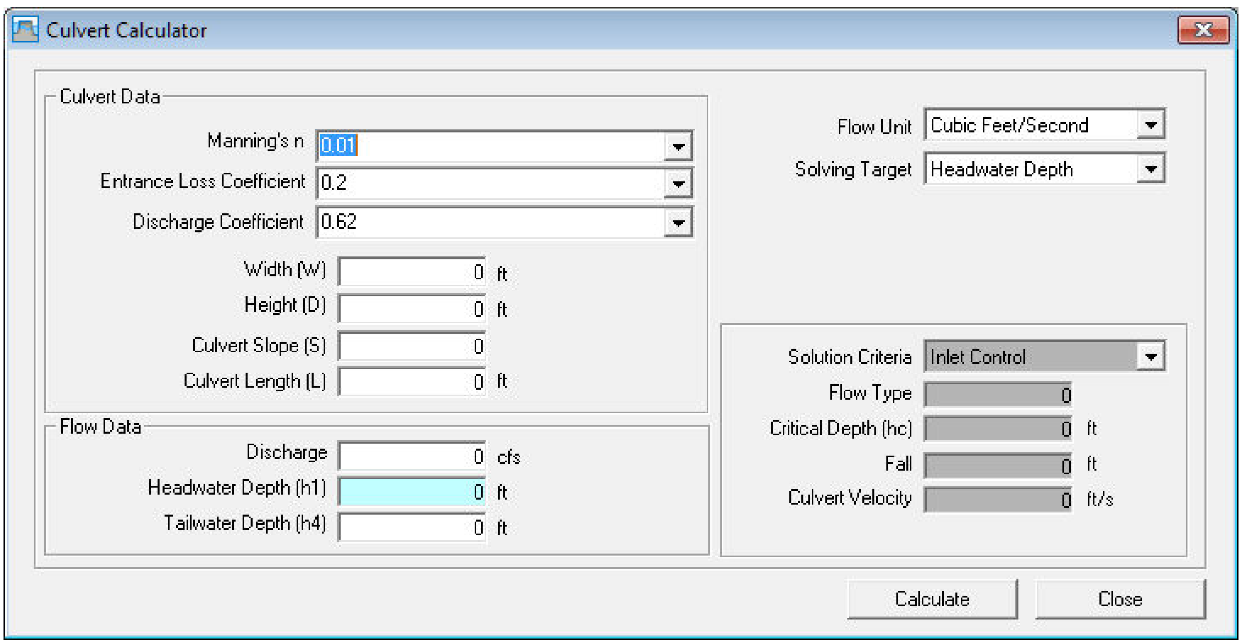

H2OCalc
H2OCalc View Window Help

2.3.6 Culverts

H_2OCalc offers both the simplified method and the industry-standard FHWA HDS-5 method for hydraulic calculation of culverts.

Simplified Method

The dialog box for the simplified method for culvert calculation is shown below.



Input for the simplified culvert calculation:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the hydraulic parameter to solve for.
- **Solution Criteria** – Inlet control or outlet control.

- **Manning's n** – Manning's roughness coefficient.
- **Entrance Loss Coefficient** – Minor loss coefficient (*K* factor) for entrance to the culvert.
- **Discharge Coefficient** – Discharge coefficient used to account for losses, submergence effect, etc.
- **Width –** Width of the culvert, measured perpendicular to flow direction.
- **Height –** Height of the culvert.
- **Culvert Slope** – Slope of the culvert.
- **Culvert Length** – Length of the culvert.
- **Channel Width** – Width of the channel.
- **Discharge** – Flow rate through the culvert. If selected as a solving target, it will be an output.
- **Headwater Depth –** Water depth upstream of the culvert measured from upstream invert of the culvert. If selected as a solving target, it will be an output.
- **Tailwater Depth–** Water depth downstream of the culvert measured from downstream invert of the culvert.

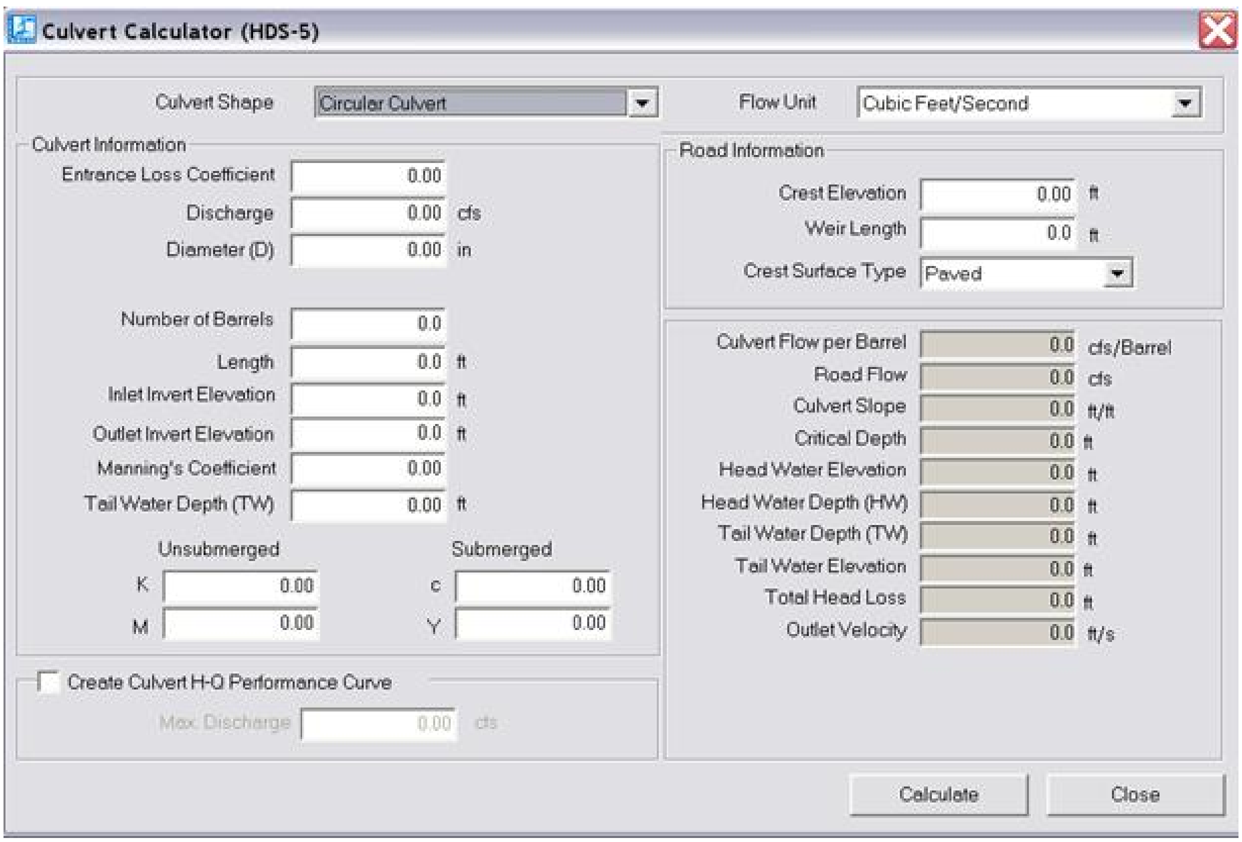
Output for the simplified culvert calculation:

- **Solution Criteria** – Inlet control or outlet control.
- **Flow Type** – Critical, subcritical, or supercritical.
- **Critical Depth** – Flow depth corresponding to minimum specific energy.
- **Fall** – Change in elevation between upstream invert and downstream invert of the culvert.
- **Culvert Velocity –** Flow velocity at the outlet of the culvert.

- **Discharge** – Flow rate through the culvert. If selected as a solving target, it will be an output.
- **Headwater Depth –** Water depth upstream of the culvert measured from upstream invert of the culvert. If selected as a solving target, it will be an output.

FHWA HDS-5 Method

The dialog box for the FHWA HDS-5 method is shown below.



Input for the FHWA HDS-5 method:

- **Flow Unit** – Select the desired flow unit.

Culvert information:

- **Entrance Loss Coefficient** – Minor loss coefficient (*K* factor) for entrance to the culvert.
- **Discharge –** Flow rate for which the culvert is analyzed or designed.
- **Diameter –** Diameter of the culvert.
- **Number of Barrels –** Number of culverts used in parallel.
- **Length** – Length of the culvert.
- **Inlet Invert Elevation –** Invert Elevation of the culvert at entrance.
- **Outlet Invert Elevation** – Downstream invert elevation of the culvert.
- **Manning's n –** Manning's roughness coefficient for the culvert.
- **Tailwater Depth –** Water depth downstream of the culvert measured from downstream invert of the culvert.
- **Unsubmerged Flow Constants-** K and M represent constants for inlet control design equations under unsubmerged flow conditions. The constants vary with culvert type and material, and inlet edge conditions.
- **Submerged Flow Constants –** c and Y represent constants for inlet control design equations under submerged flow conditions. The constants vary with culvert type and material, and inlet edge conditions.
- **Create Culvert Performance Curve –** If checked, the program constructs discharge vs headwater depth curve for the culvert.
- **Maximum Discharge –** required only if the "Create Culvert Performance Curve" is checked. Maximum discharge refers to the maximum flow to be considered for constructing the performance curve. The model divides this maximum discharge into ten equal intervals and computes headwater depth for each flow using the FHWA method. Discharge vs

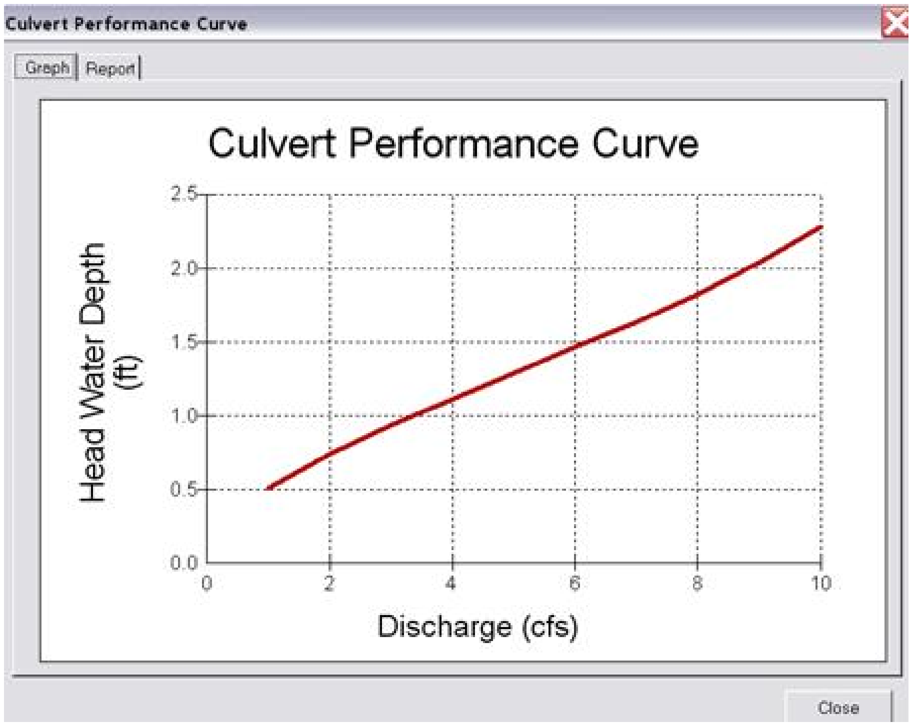
headwater depth results for the ten points are reported in the form of graph and table.

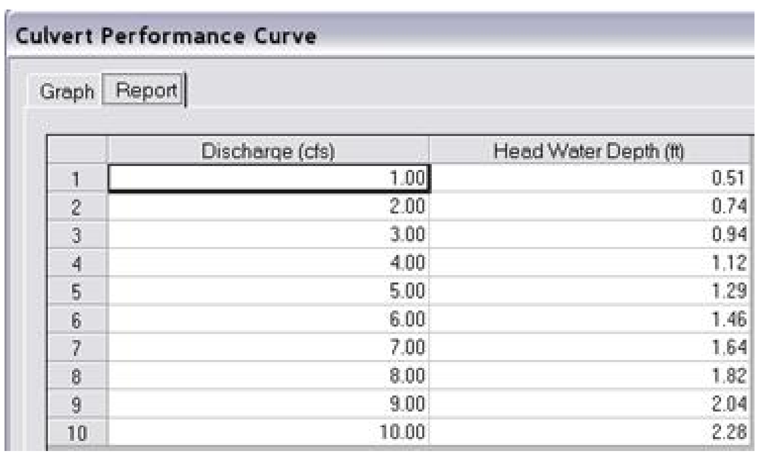
Road information:

- **Crest Elevation** – Crest elevation of the road.
- **Weir Length** – Length of the road parallel to the flow direction.
- **Crest Surface Type –** Paved or gravel.

Output for the FHWA HDS-5 method:

- **Culvert Flow Per Barrel –** Flow rate through an individual barrel of a culvert.
- **Road Flow –** Portion of the discharge that overflows the culvert and flows over the road.
- **Culvert Slope** – Slope of the culvert.
- **Critical Depth** – Depth corresponding to the minimum specific energy.
- **Headwater Elevation –** Water surface elevation at upstream end of the culvert.
- **Headwater Depth –** Water depth upstream of the culvert measured from upstream invert of the culvert.
- **Tailwater Depth –** Water depth downstream of the culvert measured from downstream invert of the culvert.
- **Tailwater Elevation –** Elevation of water surface at downstream.
- **Total Head Loss –** Head loss including minor losses and head loss due to friction in the culvert.
- **Outlet Velocity –** Flow velocity at the outlet of the culvert.
- **Culvert Slope –** Slope of the culvert.
- **Culvert Performance Curve –** If the “Create Culvert Performance Curve” is checked, the model reports the curve in graph and in table form as shown below.





Culvert Performance Curve

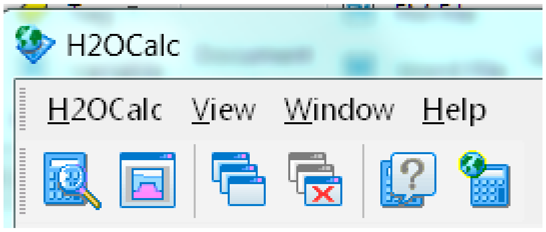
Graph | Report

	Discharge (cfs)	Head Water Depth (ft)
1	1.00	0.51
2	2.00	0.74
3	3.00	0.94
4	4.00	1.12
5	5.00	1.29
6	6.00	1.46
7	7.00	1.64
8	8.00	1.82
9	9.00	2.04
10	10.00	2.28

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

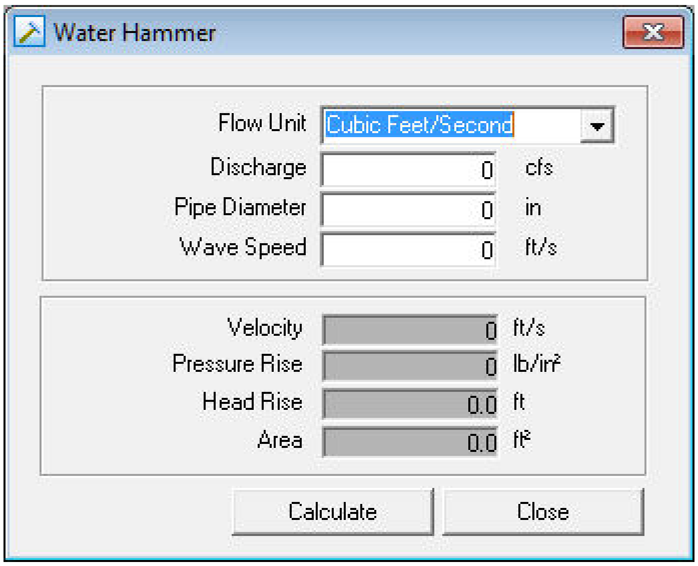

H2OCalc
H2OCalc View Window Help

2.3.7 Transient Flow

The Transient Flow category performs basic water hammer calculation, computation of wave speed, and estimation of pump inertia. Each of these calculations is described below.

Water Hammer

The water hammer dialog box is shown below.



Input for water hammer:

- **Flow Unit** – Select the desired flow unit.
- **Discharge** – Flow rate through the pipe.
- **Pipe Diameter** – Diameter of the pipe.
- **Wave Speed** – Speed of the pressure surge wave. *H_2OCalc* can estimate wave speed depending on pipe material, anchor condition, and the fluid property.

Output for water hammer:

- **Velocity** – Pipe flow velocity.
- **Pressure Rise** – The amount of pressure increase caused by the surge wave.
- **Head Rise** – Increase in pressure head (pressure rise divided by specific weight of water) caused by the surge wave.
- **Area** – Cross sectional area of the circular pipe.

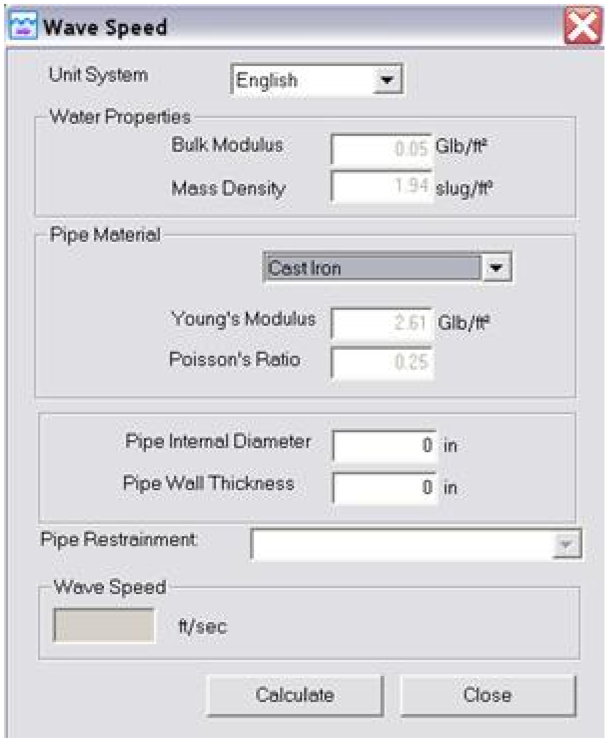
Wave Speed

The wave speed dialog box is shown below.

Input for wave speed:

- **Flow Unit** – Select the desired flow unit.
- **Bulk Modulus of Water** – Ratio of incremental change in volume of water per unit increase in pressure. It is a measure of fluid's compressibility. A default value is used.
- **Mass Density of Water** – Mass per unit volume of water. A default value is used.
- **Young's Modulus of the Pipe** – Rate of change of stress with strain. It is a measure of stiffness of the pipe material. A default value is used.
- **Poisson's ratio of the Pipe**– Ratio of the relative transverse strain (normal to the applied load) to the relative longitudinal strain (in the direction of the applied load). A default value is used.
- **Pipe Internal Diameter** – Internal diameter of the pipe (i.e., excluding pipe thickness).

- **Pipe Wall Thickness** – Thickness of the pipe (i.e., external radius minus internal radius).
- **Pipe Restrainment** – Type of support provided for the pipeline against longitudinal movement.



Output for wave speed:

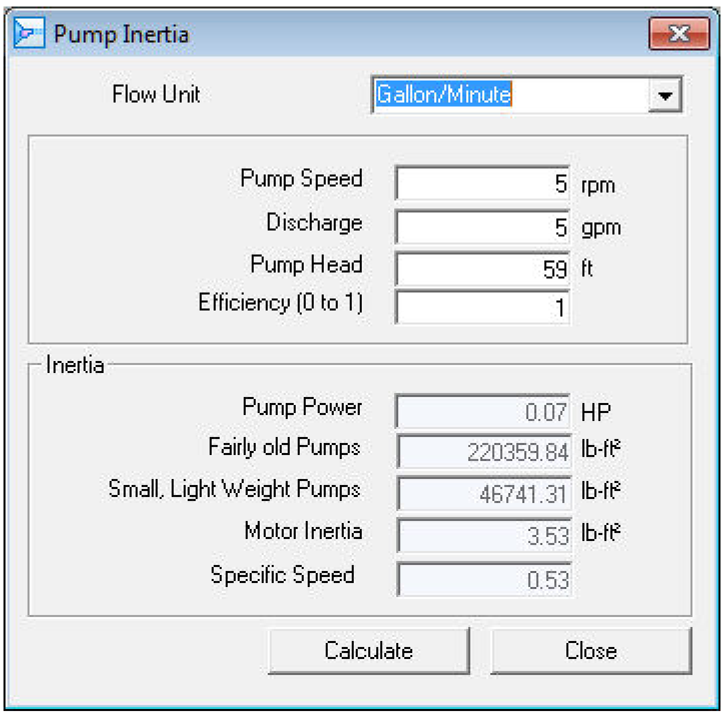
- **Wave Speed** – Speed of the surge wave.

Pump Inertia

The pump inertia dialog box is shown below.

Input for pump inertia:

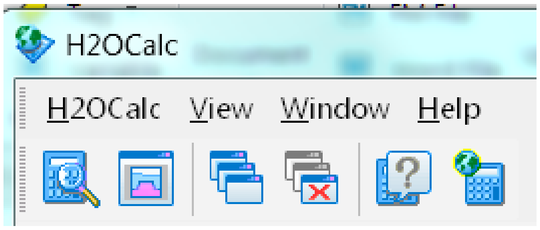
- **Flow Unit** – Select the desired flow unit.
- **Pump Speed** – Pump speed (number of revolutions per unit time).
- **Discharge** – Rated pump flow rate.
- **Pump Head** – Rated pump head corresponding to the rated pump discharge.
- **Efficiency** – Pump efficiency (ratio of power output to power input).
- **Pump Power** – Power computed from pump head, pump flow and pump efficiency.



Output for pump inertia:

- **Fairly Old Pump** – Pump inertia computed assuming that the pump is fairly old.
- **Small, Light Weigh Pump** – Pump inertial computed assuming that the pump is small and light weight.

- **Motor Inertia** – Inertia of the motor.
- **Specific Speed** – Specific speed of the pump.

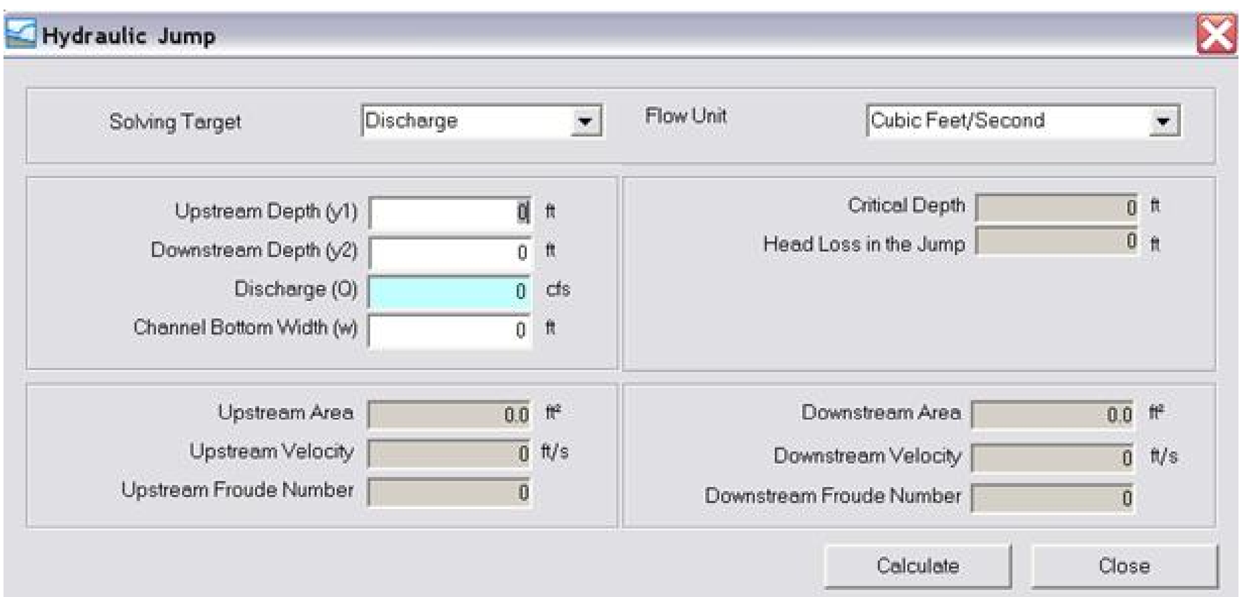

H2OCalc
H2OCalc View Window Help

2.3.8 Hydraulic Jump

The hydraulic jump dialog box is shown below.

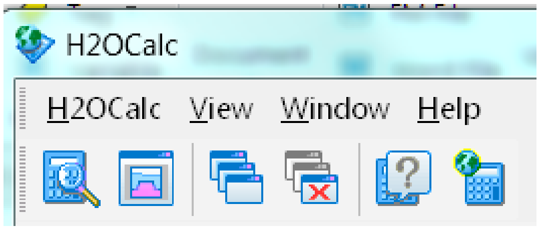
Input for hydraulic jump:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Discharge, upstream depth or downstream depth.
- **Upstream Depth** – Supercritical flow depth at upstream of the jump.
- **Downstream Depth** – Subcritical flow depth at downstream of the jump.
- **Discharge** – Channel flow rate.
- **Channel Bottom Width** – Bed width of the channel.



Output for hydraulic jump:

- **Area (Upstream/Downstream)** – Flow area at upstream section and downstream section of the jump, respectively.
- **Velocity (Upstream/Downstream)** – Flow velocity at upstream section and downstream section of the jump, respectively.
- **Froude Number (Upstream/Downstream)** – Froude number at upstream section and downstream section of the jump, respectively.
- **Critical Depth** – Flow depth corresponding to the minimum specific energy for the flow rate.
- **Head Loss in the Jump** – Difference in specific energy at the upstream end and the downstream end of the jump.


H2OCalc
H2OCalc View Window Help

2.3.9 Discharge From Tank

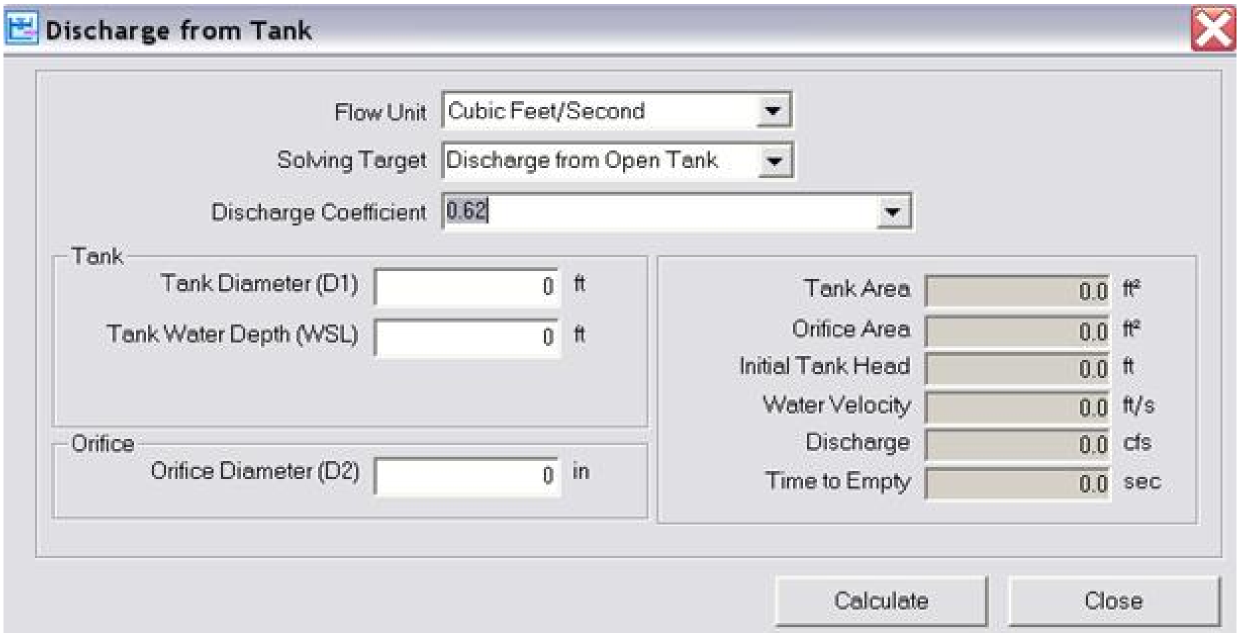
The Discharge from Tank category evaluates the flow discharged from pressurized tanks and open tanks as a function of water level, tank geometry, and outlet (orifice) property.

Discharge from Open Tank

The dialog box for discharge from open tank is shown below.

Input for discharge from open tank:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Discharge from open tank or discharge from pressurized tank.
- **Discharge Coefficient** – Coefficient of discharge for the orifice.
- **Tank Diameter** – Diameter of the tank.
- **Tank Water Depth** – Depth of water in the tank.
- **Orifice Diameter** – Diameter of the orifice opening.



Output for discharge from open tank:

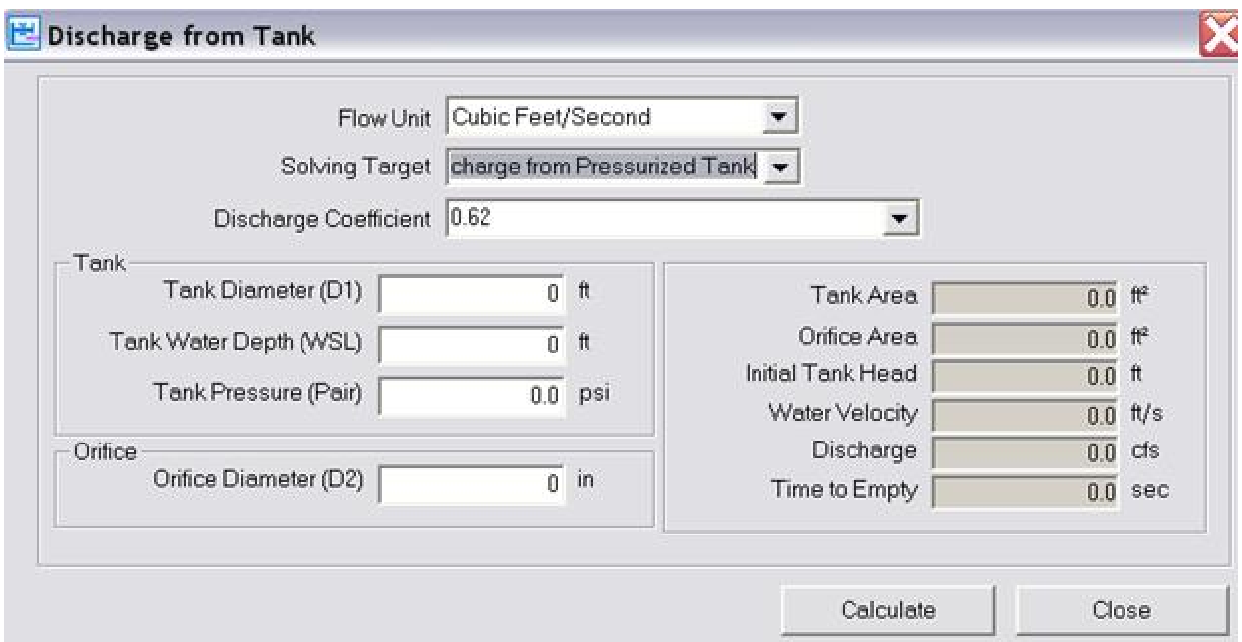
- **Tank Area** – Cross sectional area (surface area) of the tank.
- **Orifice Area** – Cross sectional area of the orifice.
- **Initial Tank Head** – Head in the tank before the tank started releasing flow.
- **Water Velocity** – The velocity at which water is discharged from the reservoir.
- **Discharge** – Flow rate from the reservoir.
- **Time to Empty** – The time it takes to discharge the entire content of the tank.

Discharge from Pressurized Tank

The dialog box for discharge from pressurized tank is shown below.

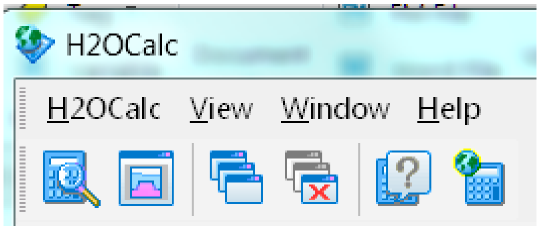
Input for discharge from pressurized tank:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Discharge from open tank or discharge from pressurized tank.
- **Discharge Coefficient** – Coefficient of discharge for the orifice.
- **Tank Diameter** – Diameter of the tank.
- **Tank Water Depth** – Depth of water in the tank.
- **Tank Pressure –** Pressure exerted on the tank (excluding hydrostatic pressure).
- **Orifice Diameter** – Diameter of the orifice opening.



Output for discharge from pressurized tank:

- **Tank Area** – Cross sectional area (surface area) of the tank.
- **Orifice Area** – Cross sectional area of the orifice.
- **Initial Tank Head** – Head in the tank before the tank started releasing flow.
- **Water Velocity** – The velocity at which water is discharged from the reservoir.
- **Discharge** – Flow rate from the reservoir.
- **Time to Empty** – The time it takes to discharge the entire content of the tank.


H2OCalc
H2OCalc View Window Help

2.3.10 Pumps

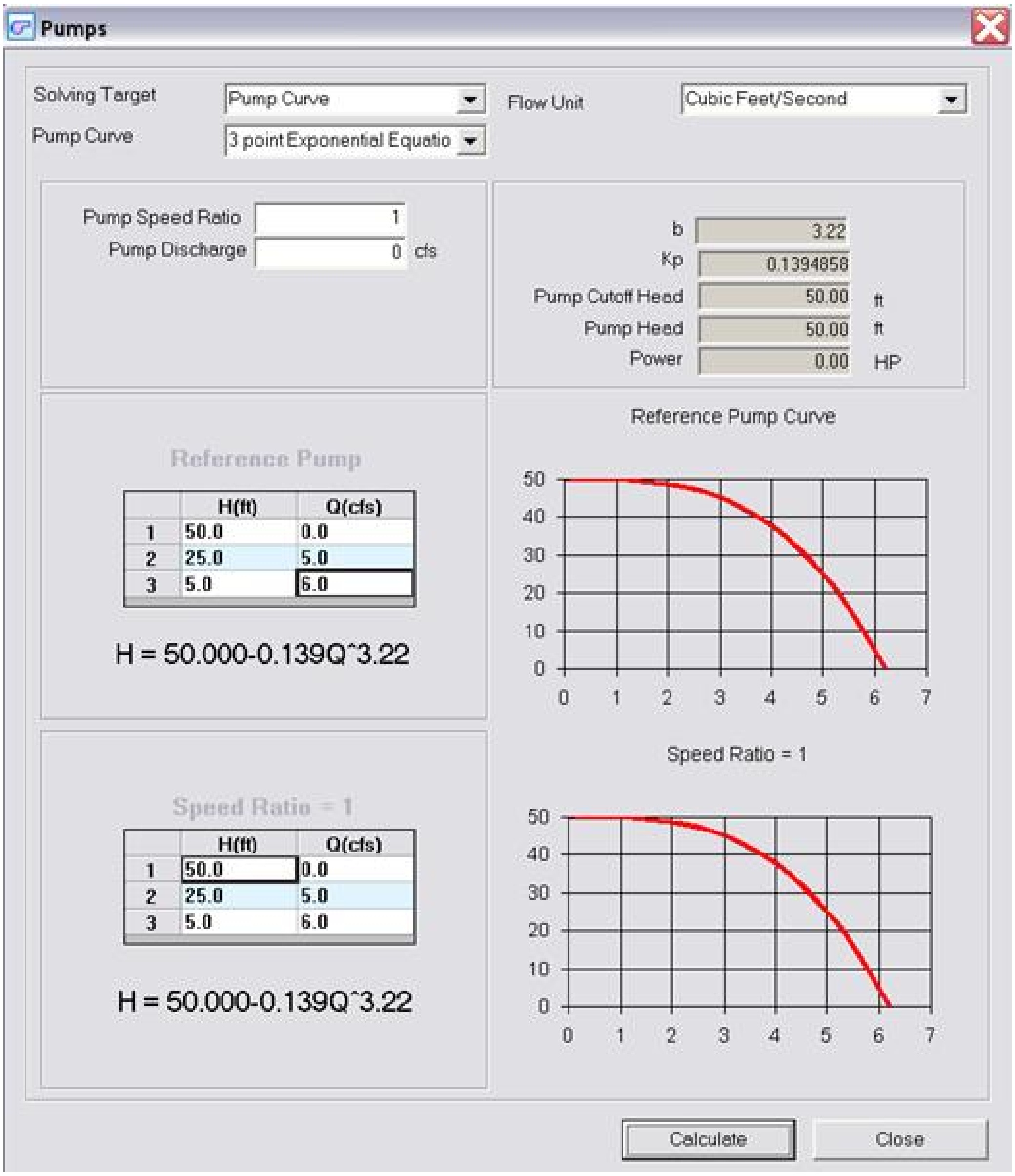
The Pump category has pump curve, affinity laws, pump power and torque, pumps arranged in parallel, and pumps arranged in series, and system head curve as sub-categories.

Pump Curve

The dialog box for pump curve is shown below.

Input for pump curve:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Curve** – Select the pump curve type (single point, 3-point exponential, or 3-point quadratic).
- **Pump Speed Ratio** – The dimensionless pump speed ratio and is defined as the ratio of the actual pump speed to the speed for which the original data is applicable.
- **Pump Discharge** – Pump flow rate.
- **Orifice Diameter** – Diameter of the orifice opening.



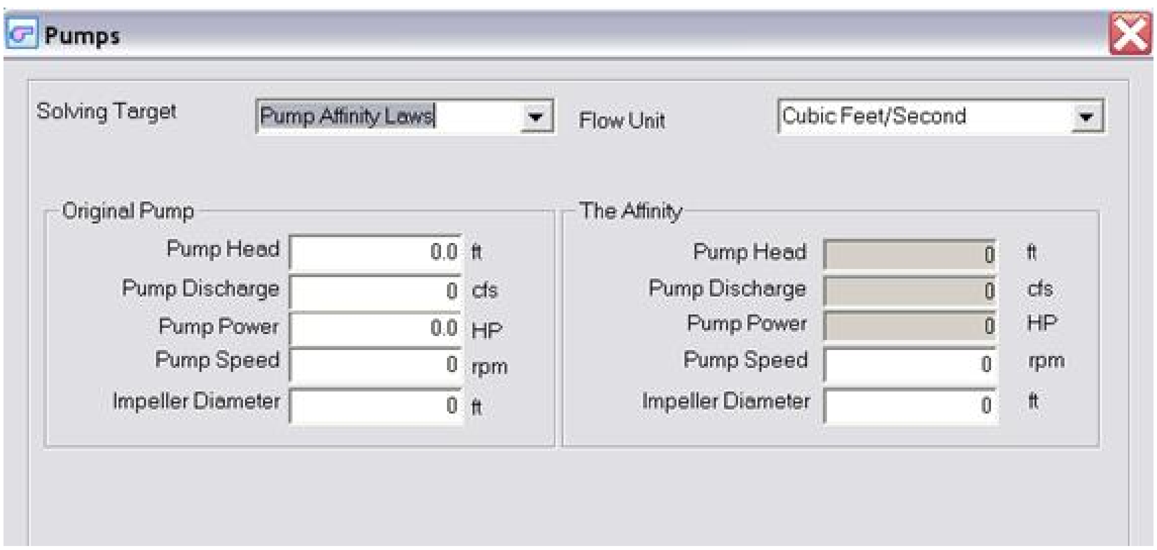
Output for pump curve:

- **a, b, and c** – Pump equation parameters derived from the specified pump curve.
- **Pump Cutoff Head** – Pump head corresponding to zero pump discharge.

- **Pump Head** – Pump head corresponding to the specified pump discharge.
- **Pump Power** – Pump power computed based on pump discharge and pump head.
- **Pump Curve** – Graphical display of pump head vs pump discharge.

Affinity Laws

The dialog box for affinity laws is shown below.



Input for affinity laws:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Original Pump Head** – Specified pump head.
- **Original Pump Discharge** – Specified pump flow rate.

- **Original Pump Power** – Specified pump power.
- **Original Pump Speed** – Specified pump speed.
- **Original Impeller Diameter** – Specified impeller diameter.

Output for affinity laws:

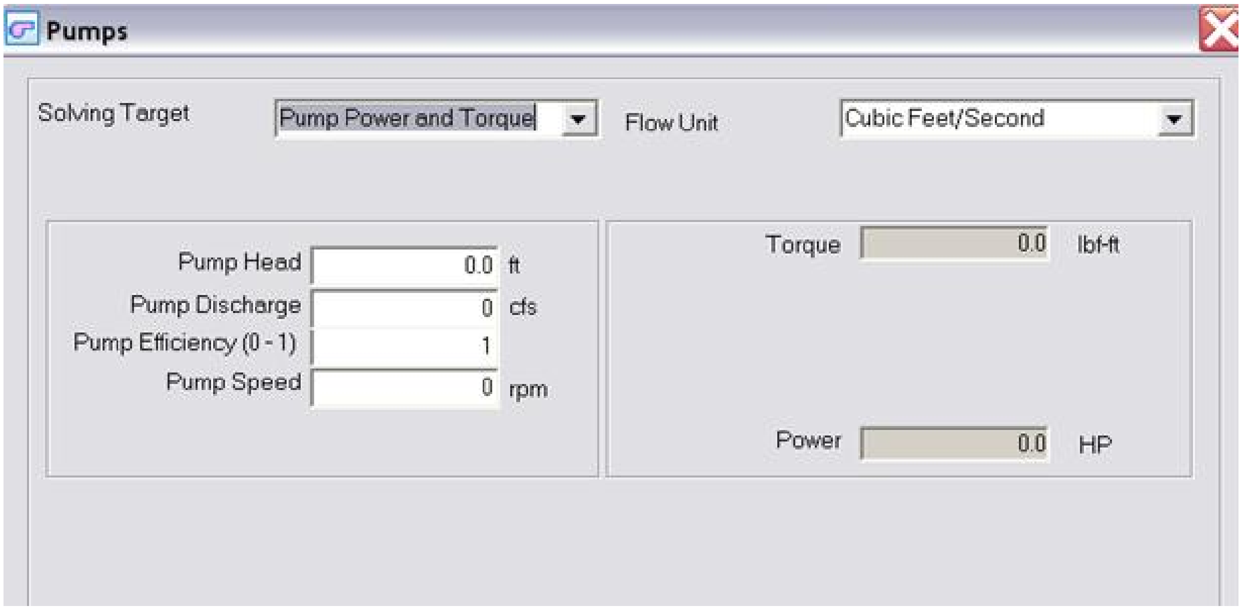
- **Affinity Pump Head** – Pump head computed from affinity law.
- **Affinity Pump Discharge** – Pump discharge computed from affinity law.
- **Affinity Pump Power** – Pump power computed from affinity law.
- **Affinity Pump Speed** – Pump speed computed from affinity law.
- **Affinity Impeller Diameter** – Impeller diameter computed using affinity law.

Pump Power and Torque

The dialog box for pump power and torque is shown below.

Input for pump power and torque:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Head** – Head supplied by the pump.
- **Pump Discharge** – Pump flow rate.
- **Pump Efficiency** – Efficiency of the pump.
- **Pump Speed** – Desired pump speed.



Output for pump power and torque:

- **Torque** – Torque exerted by the impeller.
- **Pump Power** – Power output from the pump.
- **Affinity Pump Speed** – Pump speed computed from affinity law.

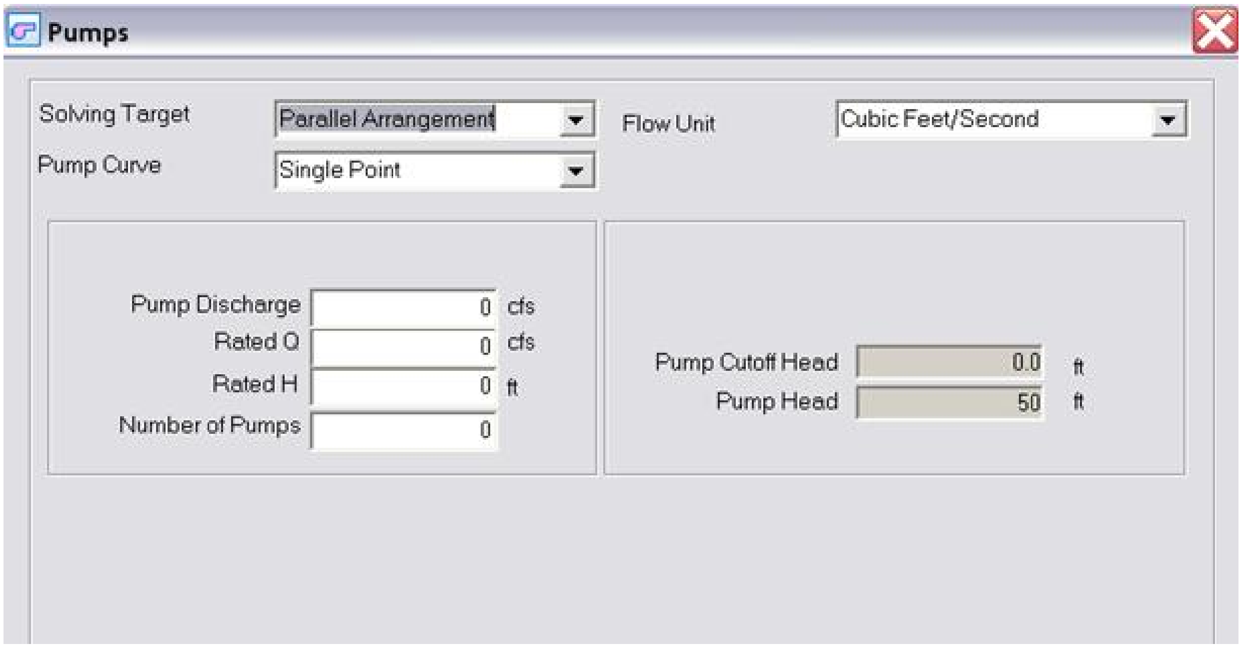
Parallel Arrangement

The dialog box for pumps in parallel arrangement is shown below.

Input for pumps in parallel arrangement:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Curve** – Select the pump curve type.

- **Pump Discharge** – Pump flow rate.
- **Rated Q** – Rated discharge for the pump.
- **Rated H** – Rated head for the pump.
- **Number of Pumps** – Number of pumps placed in parallel.

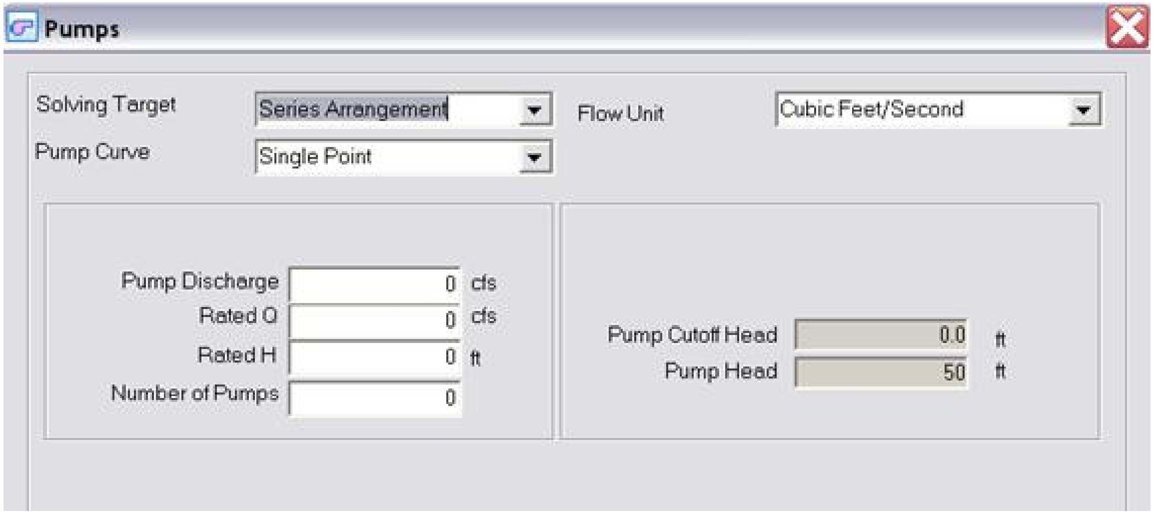


Output for pumps in parallel arrangement:

- **Pump Cutoff Head** – Head corresponding to zero pump discharge. Computed considering all the pumps in parallel.
- **Pump Power** – Head corresponding to pump discharge. Computed considering all the pumps in parallel.

Series Arrangement

The dialog box for pumps in series arrangement is shown below.



Input for pump in series arrangement:

- **Flow Unit** – Select the desired flow unit.
- **Solving Target** – Select the desired pump analysis type.
- **Pump Curve** – Select the pump curve type.
- **Pump Discharge** – Pump flow rate.
- **Rated Q** – Rated discharge for the pump.
- **Rated H** – Rated head for the pump.
- **Number of Pumps** – Number of pumps placed in series.

Output for pumps in series arrangement:

- **Pump Cutoff Head** – Head corresponding to zero pump discharge. Computed considering all the pumps in series.

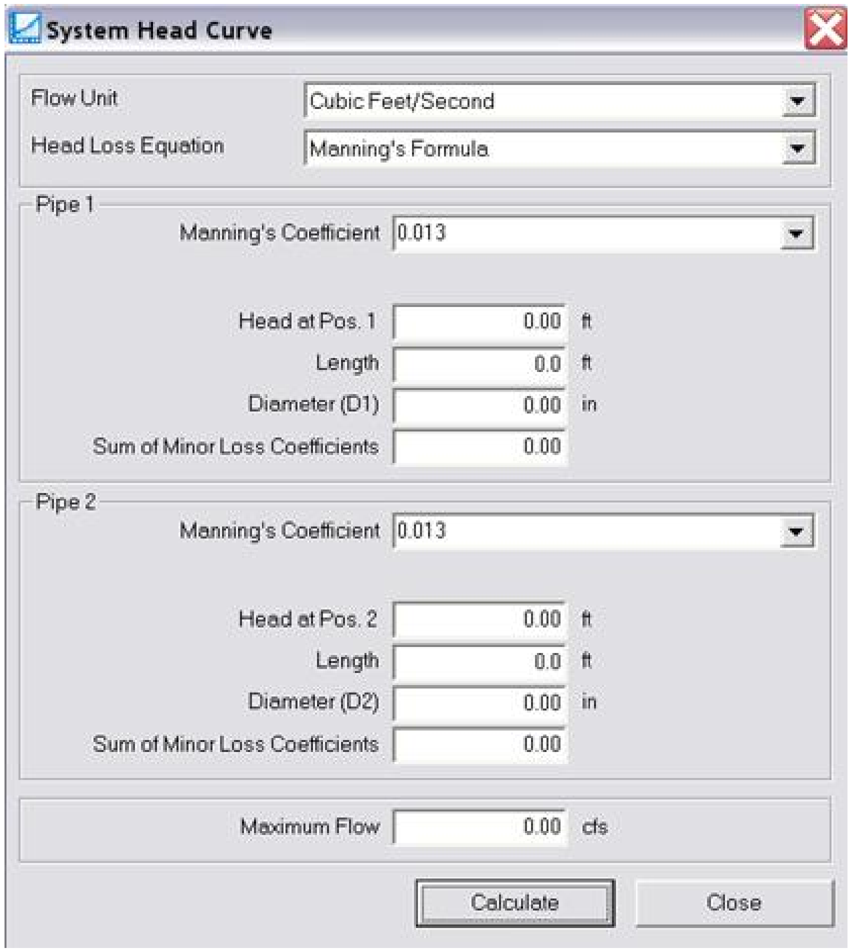
- **Pump Power** – Head corresponding to pump discharge. Computed considering all the pumps in series.

System Head Curve

The dialog box for system head curve is shown below.

Input for system head curve:

- **Flow Unit** – Select the desired flow unit.
- **Head Loss Equation** – Select from Manning, Darcy-Weisbach (Colebrook-White), or Hazen–Williams formula.
- **Pipe 1** – The pipe that connects the upstream reservoir with the pump (i.e., pipe on the suction side of the pump).
- **Pipe 2** – The pipe that connects the pump with the downstream reservoir (i.e., pipe on the discharge side of the pump).
- **Coefficient** – Roughness coefficient.
- **Head at Position** 1 – Head at the upstream reservoir.
- **Head at Position 2** – Head at the downstream reservoir.
- **Length** – Length of the pipe (i.e., pipe 1 or pipe 2).
- **Diameter** – Diameter of the pipe (i.e., pipe 1 or pipe 2).
- **Sum of Minor Loss Coefficients** – Sum of minor loss coefficients for the pipe (i.e., pipe 1 or pipe 2).
- **Maximum Flow** – Maximum flow for use in constructing the system head curve. The maximum flow is divided into ten equal intervals and the head corresponding to each of the ten flows is computed to construct the system head curve. Therefore, it is advisable to use a maximum flow that is divisible by ten.



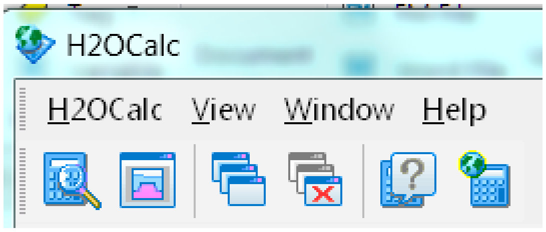
Output for system head curve:

- **Graphical system curve** – Presents the system head curve graphically.
- **Tabular system curve** – Presents the system head curve in tabular form.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

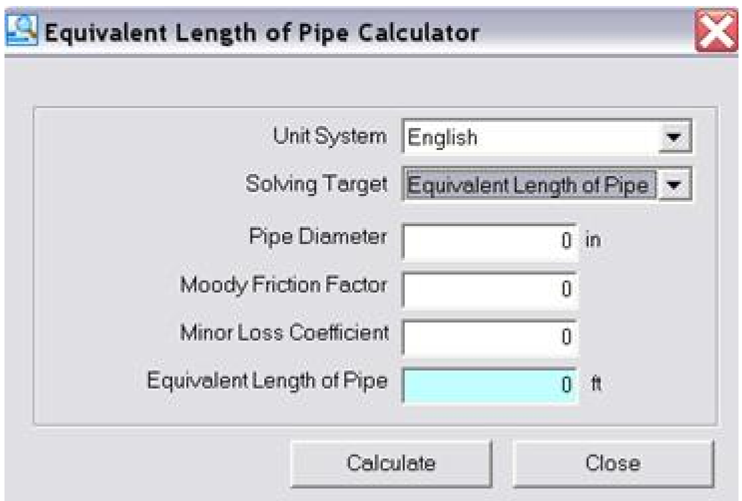
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

2.3.11 Equivalent Pipe Length

The Equivalent Pipe Length solves for a fictitious pipe that would have the same head loss as a minor loss, and could be replaced for a minor loss while preserving hydraulic equivalency.

The dialog box for equivalent pipe length is shown below.



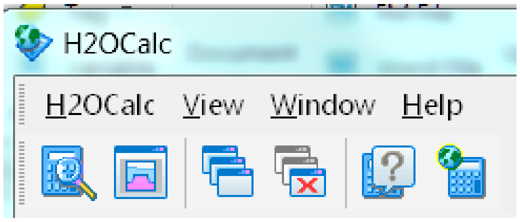
Input for equivalent pipe length:

- **Unit System** – Select SI or English unit.
- **Solving Target** – Equivalent length, Moody friction factor, minor loss coefficient or pipe diameter.
- **Pipe Diameter** – Diameter of the pipe.
- **Moody friction factor** – Darcy-Weisbach friction factor from Moody diagram.
- **Minor Loss Coefficient** – Minor loss *K* factor.

- **Equivalent Length of Pipe** – Pipe length that yields head loss equivalent to minor loss.

Output for equivalent pipe length:

- **Pipe Diameter** – Would be an output if selected as solving target.
- **Moody friction factor** – Would be an output if selected as solving target.
- **Minor Loss Coefficient** – Would be an output if selected as solving target. .
- **Equivalent length of a pipe** – Would be an output if selected as solving target.

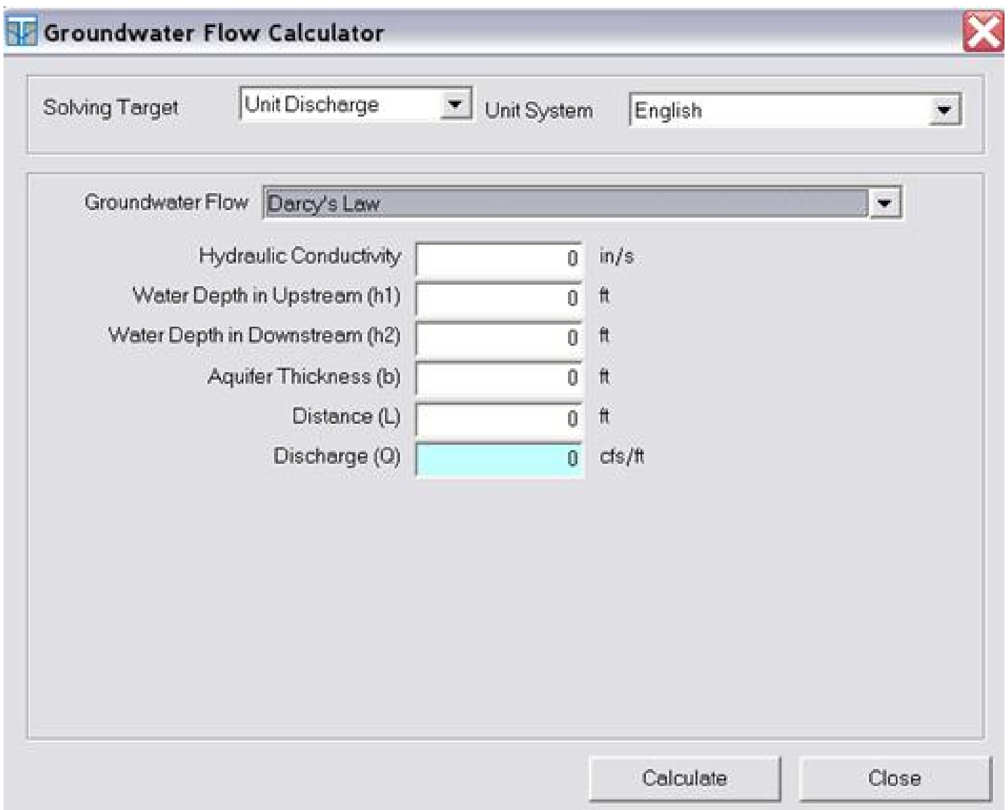

H2OCalc
H2OCalc View Window Help

2.3.12 Groundwater Hydrology

The Groundwater Flow Hydrology category solves Darcy's equation, Dupuit equation (steady state groundwater flow for unconfined aquifers), well hydraulics for confined and unconfined aquifers, and EPA SWMM's aquifer production equation.

Darcy's Equation

The dialog box for Darcy's equation is shown below.



Input for Darcy's equation:

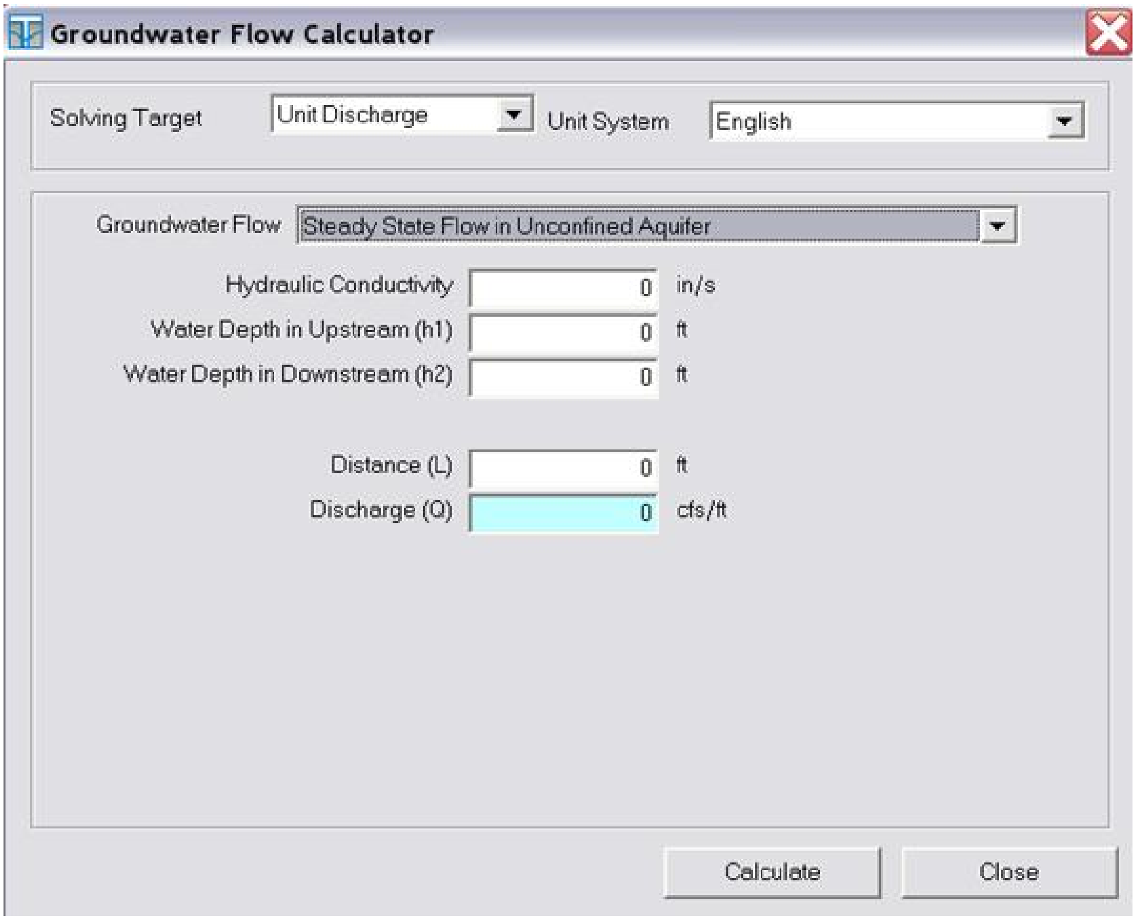
- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select Darcy’s equation.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Water Depth in Upstream** – Water head at the upstream section of the considered aquifer length.
- **Water Depth in Downstream** – Water head at the downstream section of the considered aquifer length.
- **Aquifer Thickness** – Thickness (depth) of the aquifer.
- **Distance** – Aquifer length between the upstream and the downstream points.
- **Discharge** – Flow rate per unit width of the aquifer.

Output for Darcy’s equation:

- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.

Steady State Flow in Unconfined Aquifer

The dialog box for steady state flow in unconfined aquifer is shown below.



Input for steady state flow in unconfined aquifer:

- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select Dupuit equation.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Water Depth in Upstream** – Water head at the upstream section of the considered aquifer length.
- **Water Depth in Downstream** – Water head at the downstream section of the considered aquifer length.

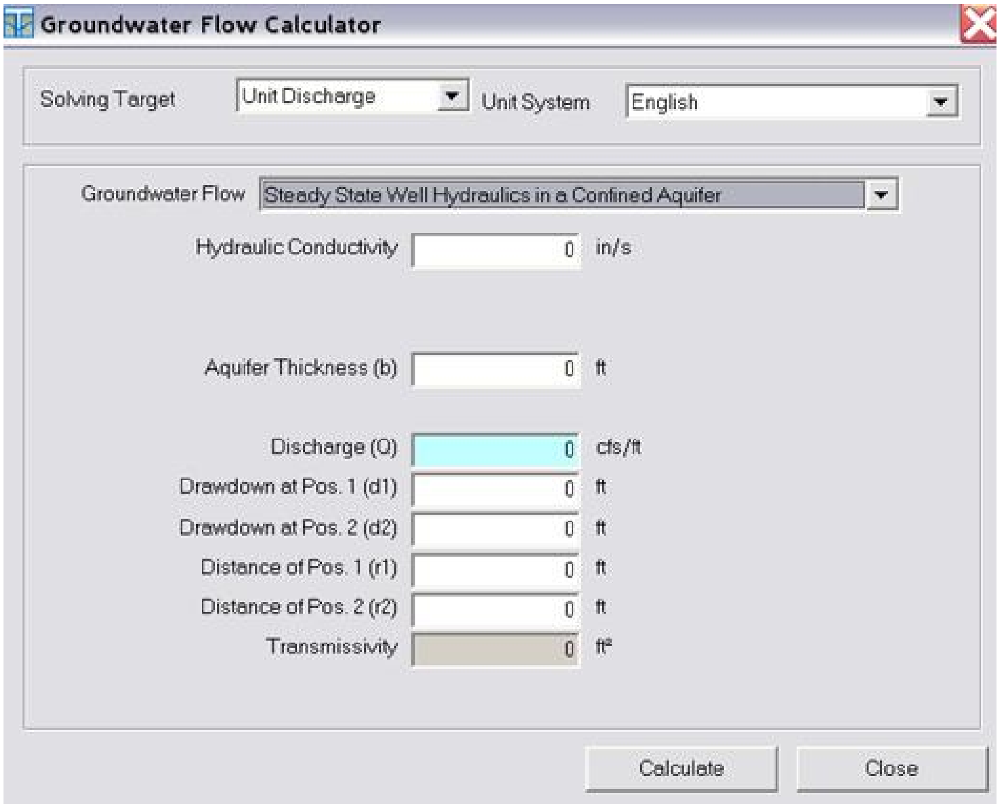
- **Distance** – Aquifer length between the upstream and the downstream points.
- **Discharge** – Flow rate per unit width of the aquifer.

Output for steady state flow in unconfined aquifer:

- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.

Steady State Well Hydraulics for Confined Aquifer

The dialog box for steady state well hydraulics for confided aquifer is shown below.



Input for steady state well hydraulics for confided aquifer:

- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select steady state groundwater flow in a confided aquifer.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Aquifer Thickness** – Thickness (depth) of the aquifer.
- **Discharge** – Flow rate per unit width of the aquifer.
- **Drawdown at Position 1** – Groundwater elevation minus water level elevation at point 1.

- **Drawdown at Position 2** – Groundwater elevation minus water level elevation at point 2.
- **Distance of Position 1** – Distance of point 1 from the center of the well.
- **Distance of Position 2** – Distance of point 2 from the center of the well.

Output for steady state groundwater flow in a confided aquifer:

- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.
- **Transmissivity** – The product of hydraulic conductivity and aquifer thickness. It is the amount of water that can be transmitted horizontally per unit width of the aquifer.

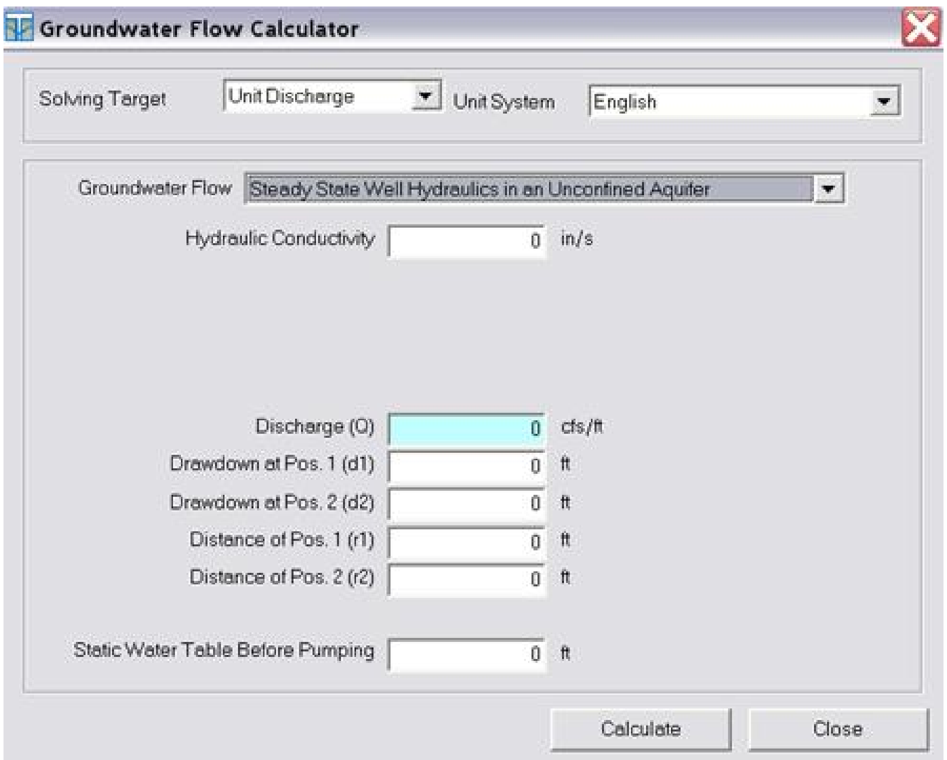
Steady State Well Hydraulics in an Unconfined Aquifer

The dialog box for steady state well hydraulics in an unconfined aquifer is shown below.

Input for steady state well hydraulics in an unconfined aquifer:

- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge or hydraulic conductivity.
- **Groundwater Flow** – Select steady state groundwater flow in an unconfined aquifer.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer.
- **Discharge** – Flow rate per unit width of the aquifer.

- **Drawdown at Position 1** – Groundwater elevation minus water level elevation at point 1.
- **Drawdown at Position 2** – Groundwater elevation minus water level elevation at point 2.
- **Distance of Position 1** – Distance of point 1 from the center of the well.
- **Distance of Position 2** – Distance of point 2 from the center of the well.
- **Static Water Table Before Pumping** – Water table elevation before pumping started.



Output for steady state groundwater flow in an unconfined aquifer:

- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.

- **Discharge** – Flow rate per unit width of the aquifer. It is an output if selected as a solving target.

EPA SWMM's Aquifer Production Equation

The dialog box for EPA SWMM's aquifer production equation is shown below.

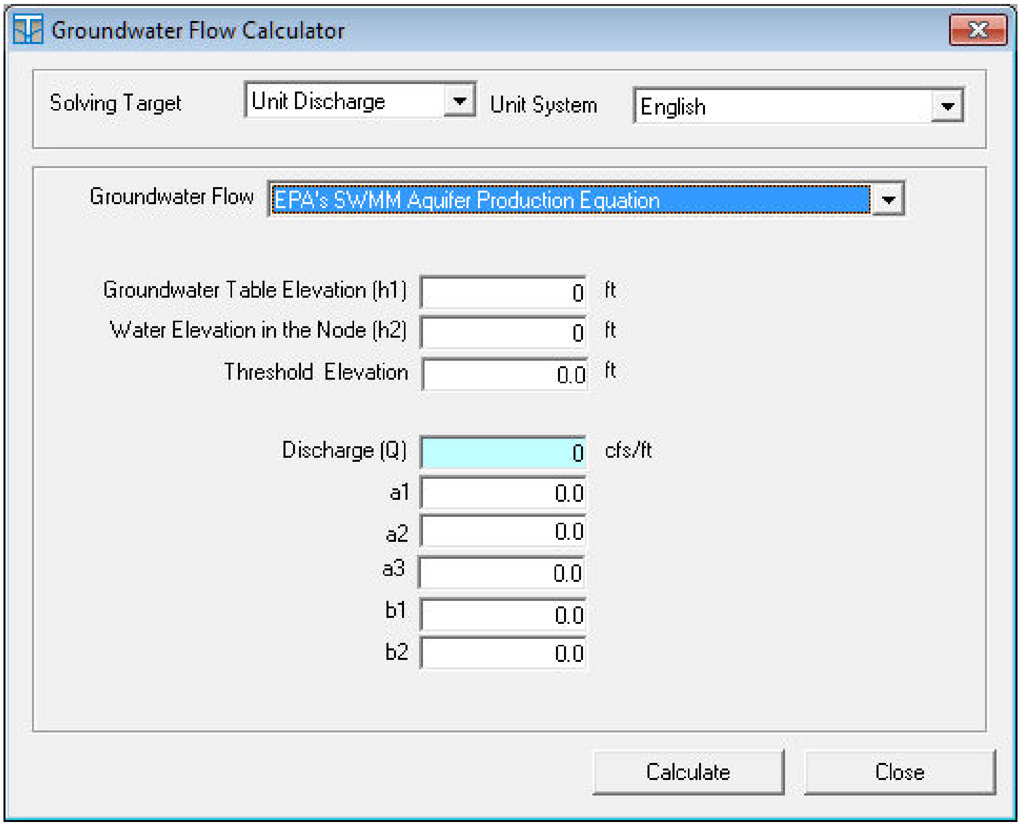
Input for EPA SWMM's aquifer production equation:

- **Unit System** – English or SI unit.
- **Solving Target** – Unit discharge.
- **Groundwater Flow** – Select EPA SWMM's aquifer production equation.
- **Hydraulic Conductivity** – A proportionality constant that describes the ease with which water can move through pore spaces of the aquifer. It is an output if selected as a solving target.
- **Groundwater Table Elevation** – Elevation of the groundwater table.
- **Water Elevation in the Node** – Elevation of surface water at the receiving node.
- **Threshold Elevation** – Threshold groundwater table elevation or elevation of node invert.
- **a1, a2, b1, b2, and a3** – coefficients that appear in the following equation that computes groundwater flow as a function of groundwater and surface water heads.

$$Q_{gw} = a_1(H_{gw} - E)^{b_1} - a_2(H_{sw} - E)^{b_2} + a_3(H_{gw}H_{SW})$$

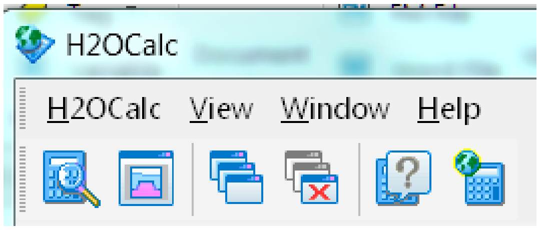
where Q_{gw} = Groundwater flow (cfs/acre, cms/per hectare)

H_{gw} = Elevation of groundwater table (ft, m)
H_{sw} = Elevation of surface water at receiving node (ft, m)
E = Threshold groundwater table elevation or elevation of node invert (ft, m).



Output for EPA SWMM's aquifer production equation:

- **Discharge** – Flow rate per unit width of the aquifer.

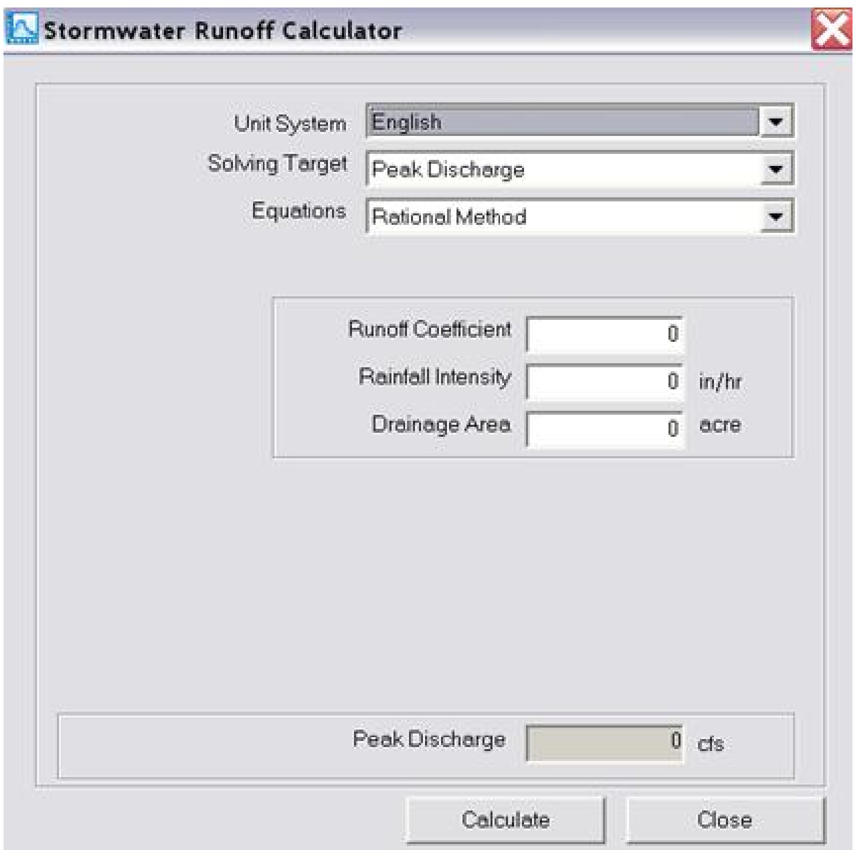

H2OCalc
H2OCalc
View
Window
Help

2.3.13 Surface Water Hydrology

The Surface Water Hydrology category serves three purposes: it estimates peak flow using the rational method and the SCS peak discharge method, it determines runoff hydrograph using 9 different rainfall- runoff models (mostly unit hydrographs), and it estimates time of concentration using a number of commonly used methods.

Rational Method

The dialog box for the rational method is shown below.



Input for the rational method:

- **Unit System** – English or SI unit.

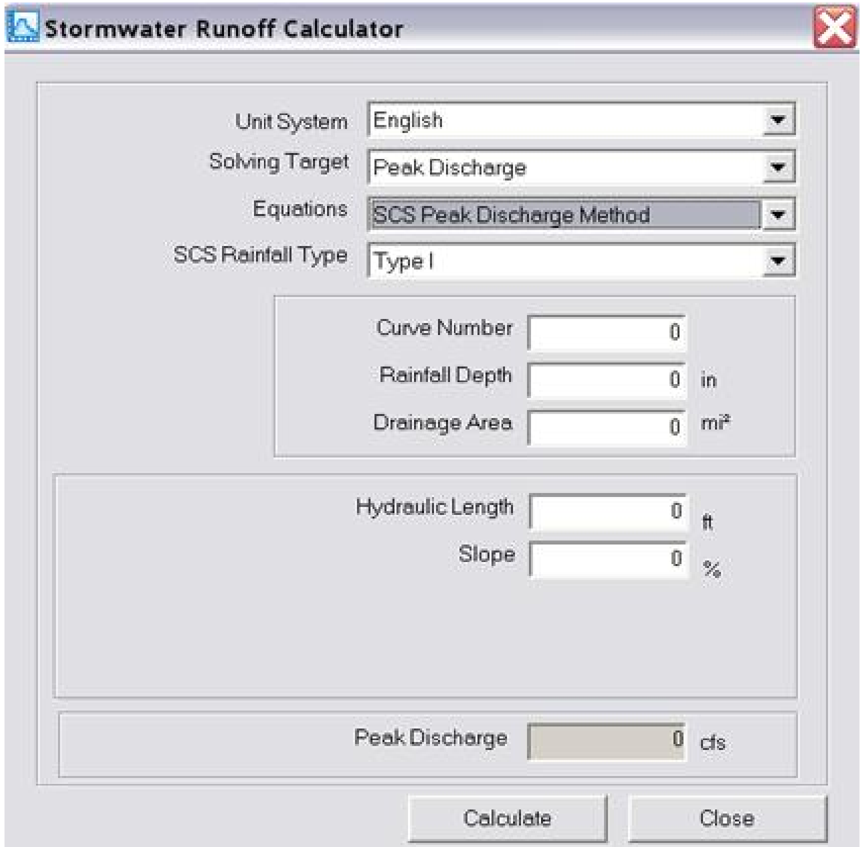
- **Solving Target** – Peak discharge or time of concentration.
- **Equations** – Rational method or the SCS peak discharge method.
- **Runoff Coefficient** – Ratio of runoff to precipitation. It is a measure of the watershed's runoff generation capability. It is a function of soil, land cover and topography (see Table3.9).
- **Rainfall Intensity** – Design rainfall intensity derived from IDF curve or equation corresponding to duration of the watershed's time of concentration.
- **Drainage Area** – Area of the total watershed that drains to the location where the peaks flow is determined.

Output for the rational method:

- **Peak Discharge** – Peak flow generated from the watershed.

SCS Peak Discharge Method

The dialog box for the SCS peak discharge method is shown below.



Input for the SCS peak discharge method:

- **Unit System** – English or SI unit.
- **Solving Target** – Peak discharge or time of concentration.
- **Equations** – Rational method or the SCS peak discharge method.
- **SCS Rainfall Type** – Select one of the SCS rainfall types (i.e., Types I, IA, II, or III)
- **Curve Number** – NRCS dimensionless number that is used as a measure of runoff generation potential of a watershed (see Table 3.12). It is a function of soil, land cover and quality, and antecedent moisture condition of the soil.
- **Rainfall Depth** – 24-hr cumulative design rainfall depth. This rainfall depth will be distributed across the 24-hr duration according to the SCS rainfall type selected.

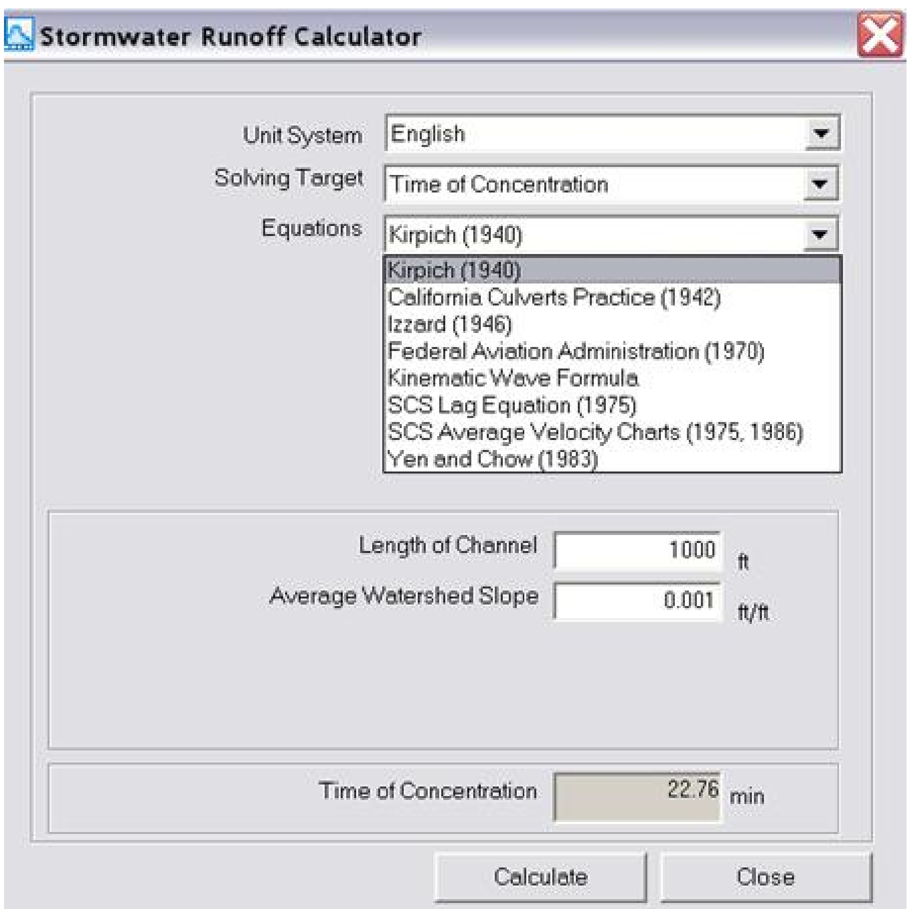
- **Drainage Area** – Area of the total watershed that drains to the location where the peak flow is determined.

Output for the SCS peak discharge method:

- **Peak Discharge** – Peak flow generated from the watershed.

Time of Concentration

The dialog box for the time of concentration estimation methods is shown below.



Input for the time of concentration methods depend on the time of concentration estimation approach selected.

- **Unit System** – English or SI unit.
- **Solving Target** – Choose time of concentration.
- **Equations** – Select one of the eight empirical equations listed in the dialog box shown above.

The inputs required for the time of concentration estimation methods supported by H2OCALC are described below.

For Kirpich (1940) Equation:

- **Length of Channel** – Length of the longest overland flow path for the watershed in feet.
- **Average Watershed Slope** – Average slope for the longest flow channel.

For California Culverts Practice (1942) Equation:

- **Length of Longest Channel** – Length of the longest overland flow path for the watershed in miles.
- **Elevation Difference Between Divide and Outlet** – The difference in elevation (in feet) between the upstream end of the flow path and the outlet of the watershed.

For Izzard (1946) Method

- **Rainfall Intensity** – Intensity of the design rainfall (in/hr)
- **Length of Flow Path** – Length of the longest overland flow path for the watershed in feet. The product rainfall intensity and the length of flow path should be < 500.
- **Slope of Flow Path** –Average slope for the longest flow channel.
- **Retardance Coefficient** – Coefficient that accounts for friction effect of the channel material. Retardance factor ranges from 0.007 for smooth pavement to 0.012 for concrete and to 0.06 for dense turf. The product rainfall intensity and the length of flow path should be < 500.

Federal Aviation Administration (1970) Method

- **Runoff Coefficient** – Refers to the runoff coefficient used in rational formula.
- **Length of Overland Flow**– Length of the longest overland flow path for the watershed.
- **Surface Slope** – Average slope of the watershed.

Kinematic Wave Formula

- **Rainfall Intensity** – Intensity of the design rainfall (in/hr).
- **Length of Overland Flow** – Length of the longest overland flow path for the watershed.
- **Average Overland Slope -** Average slope for the longest flow channel.
- **Manning's Roughness Coefficient** – Resistance coefficient used in Manning equation.

SCS Lag Equation (1975)

- **Length of Flow Path** – Intensity of the design rainfall (in/hr).
- **Average Watershed Slope -** Average slope for the watershed.
- **Curve Number (**CN**)** – NRCS curve number used as an index of the watershed's runoff generation potential.

SCS Average Velocity Charts (1975, 1986)

- **Length vs Velocity Chart** – Specify average flow velocity for various channel lengths.

Yen and Chow (1983) Method

- **Length of Flow** – Length of the longest overland flow path for the watershed in feet.
- **Average Watershed Slope** – Average slope for the watershed..
- **Coefficient Ky** – Coefficient. K_Y ranges from 1.5 for light rain (intensity <0.8) to 1.1 for moderate rain (0.8 < intensity < 1.2), and to 0.7 for heavy rain (intensity >1.2)
- **Overland Texture Factor** – Overland texture factor. See Table 3.13.

Output for the SCS peak discharge method:

- **Time of Concentration** – The time it takes for flow to travel from the hydraulically remotest point in the watershed to reach outlet of the watershed.

Runoff Hydrograph

The dialog box for the runoff hydrograph generation methods is shown below.

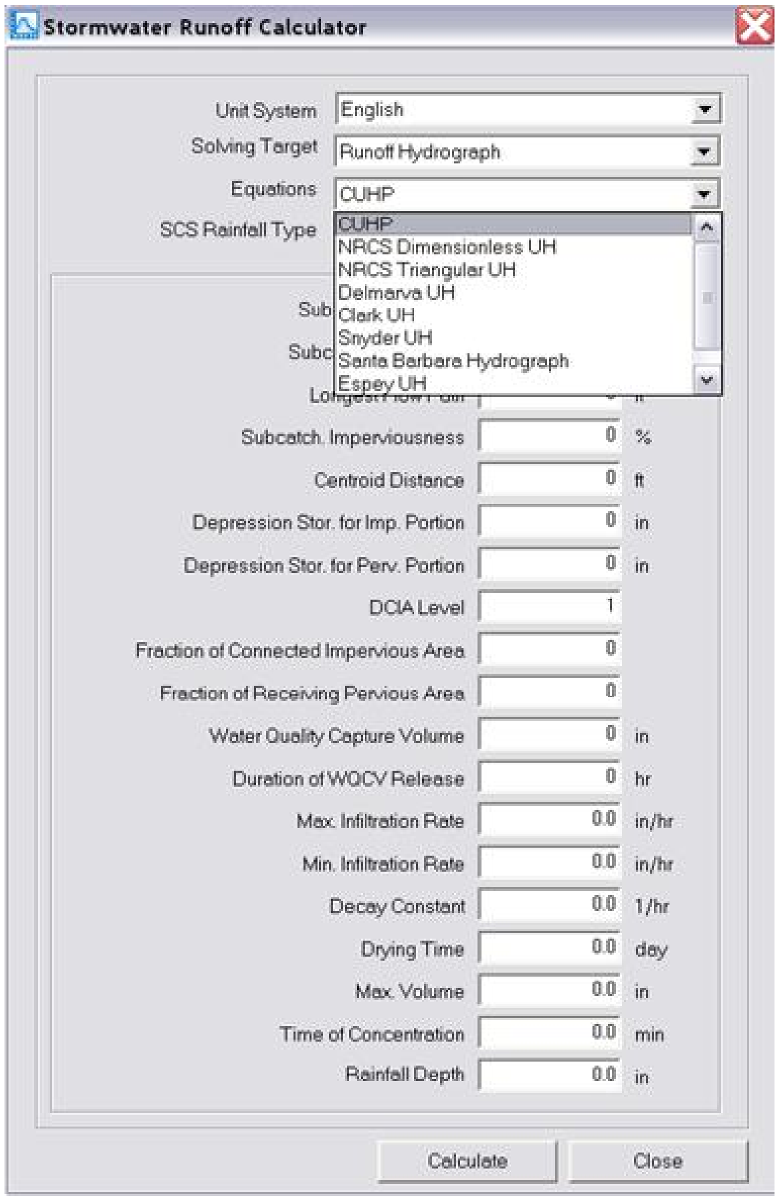
General inputs required for the runoff hydrograph option are as follows.

- **Unit System** – English or SI unit.
- **Solving Target** – Choose runoff hydrograph.
- **Equations** – Select one of the nine hydrograph generation options provided.
- **SCS Rainfall Type** – Select any of the four NRCS rainfall types (i.e., Type I, Type IA, Type II, and Type III).

The inputs required for the runoff hydrograph generation methods supported by H2OCALC are described below.

Colorado Urban Hydrograph Procedure (CUHP)

- **Subcatchment Area** – Drainage area of the watershed.
- **Subcatchment Slope**– Average slope of the watershed.
- **Longest Flow Path** – Length of the longest overland flow path for the watershed.
- **Subcatchment Imperviousness** – Percent imperviousness of the watershed.
- **Centroid Distance –** Flow length to the centroid of the watershed.
- **Depression Storage for Impervious Portion –** Depth of depression storage for the impervious portion of the watershed.
- **Depression Storage for Pervious Portion –** Depth of depression storage for the pervious portion of the watershed



- **DCIA Level –** Directly connected impervious area practice level. Input should be 1, 2, or 3.
- **Fraction Of Connected Impervious Area –** Fraction of the impervious portion of the watershed that is directly connected to the watershed outlet.
- **Fraction of Receiving Pervious Area –** Fraction of the pervious portion of the watershed that receives runoff from the impervious part of the watershed.

- **Water Quality Capture Volume (WQCV) -** The water quality capture volume to be modeled as detained in swales and/or berms in the watershed.
- **Duration of Water Quality Release –** Duration over which the WQCV is released in full.
- **Maximum Infiltration Rate –** Initial (i.e., maximum) infiltration rate for Horton's equation.
- **Minimum Infiltration Rate –** Final (i.e., minimum) infiltration rate for Horton's equation.
- **Decay Constant –** Exponential decay coefficient in Horton's equation.
- **Drying Time –** The time it takes for a soil to fully dry and recover its infiltration rate to the initial rate.
- **Maximum Volume –** Maximum depth of water that can be retained by the soil**.**
- **Time of Concentration –** The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.
- **Rainfall Depth –** Depth of the design rainfall.

NRCS Dimensionless UH, NRCS Triangular UH, and Delmarva UH

- **Subcatchment Area** – Drainage area of the watershed.
- **Subcatchment Slope**– Average slope of the watershed.
- **Flow Length** – Length of the longest overland flow path for the watershed.
- **NRCS Curve Number** – Value of CN for the watershed. See Table 3.11. It is a function of soil type, land use type and quality, and antecedent moisture condition.
- **Time of Concentration –** The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the

watershed. If time of concentration is defined, slope, length, and CN values will not be required.

- **Rainfall Depth –** Depth of the design rainfall.

Clark Unit Hydrograph

- **Subcatchment Area** – Drainage area of the watershed.
- **Storage Coefficient** - A constant linear reservoir parameter that relates watershed storage to outflow from the watershed. Usually, it is approximated using lag time of the watershed.
- **Time of Concentration –** The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.
- **Rainfall Depth –** Depth of the design rainfall.

Snyder Unit Hydrograph

- **Subcatchment Area** – Drainage area of the watershed.
- **Storage Coefficient** - An empirical storage coefficient indicated as C_t in the lag time equation (i.e. Equation 108).
- **Longest Flow Path** – Length of the longest overland flow path for the watershed.
- **Empirical Coefficient** - An empirical constant indicated as C_p in Equation 112.
- **Centroid Distance –** Flow length to the centroid of the watershed.
- **Rainfall Depth –** Depth of the design rainfall.

Santa Barbara Hydrograph

- **Subcatchment Area** – Drainage area of the watershed.

- **Subcatchment Imperviousness** – Percent imperviousness of the subcatchment.
- **Time of Concentration –** The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.
- **Rainfall Depth –** Depth of the design rainfall.

Espey Unit Hydrograph

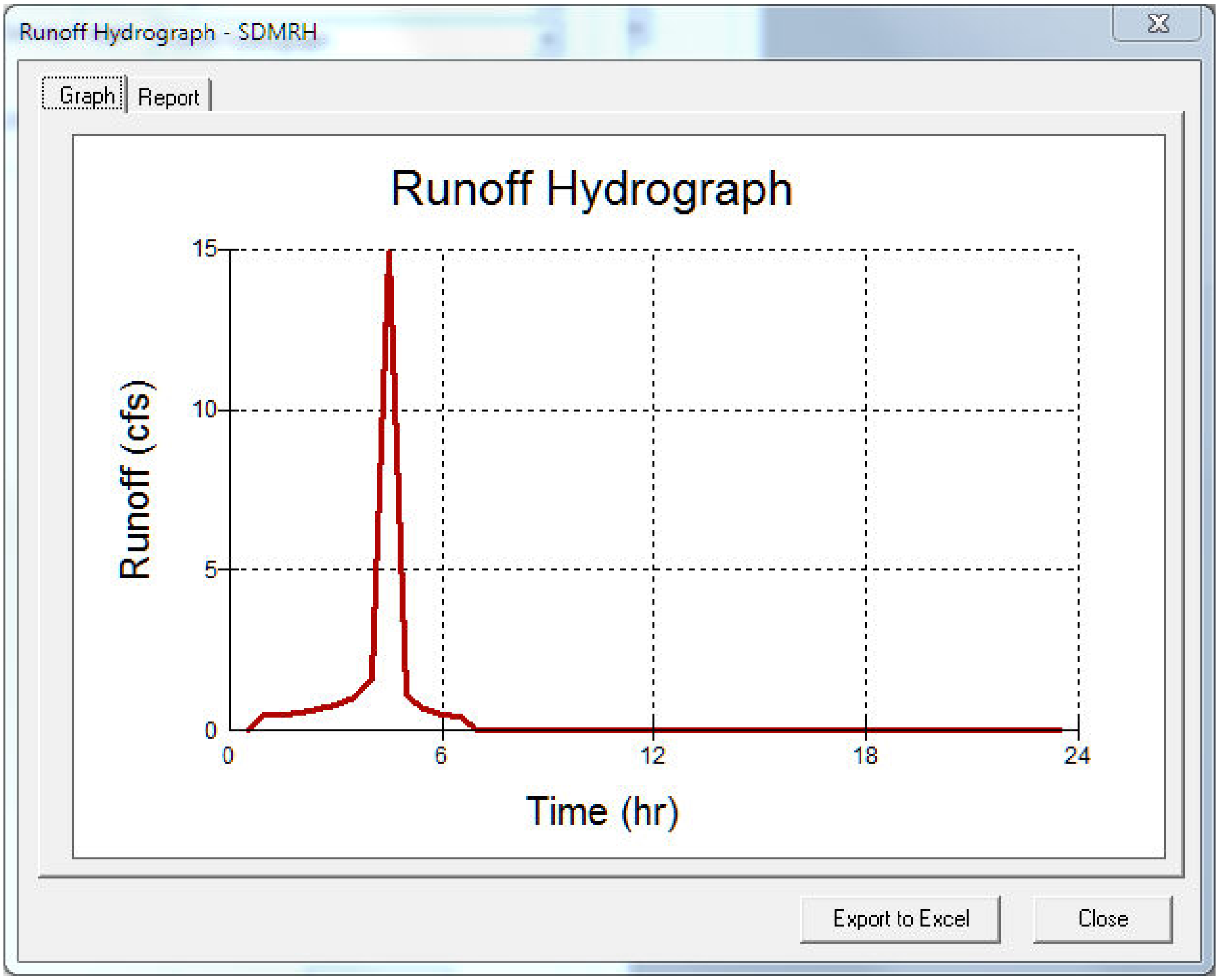
- **Subcatchment Area** – Drainage area of the watershed.
- **Subcatchment Slope** – Average slope of the watershed.
- **Longest Flow Path** – Length of the longest overland flow path for the watershed.
- **Subcatchment Imperviousness** – Percent imperviousness of the subcatchment.
- **Conveyance Factor** – See equation 122.
- **Rainfall Depth –** Depth of the design rainfall.

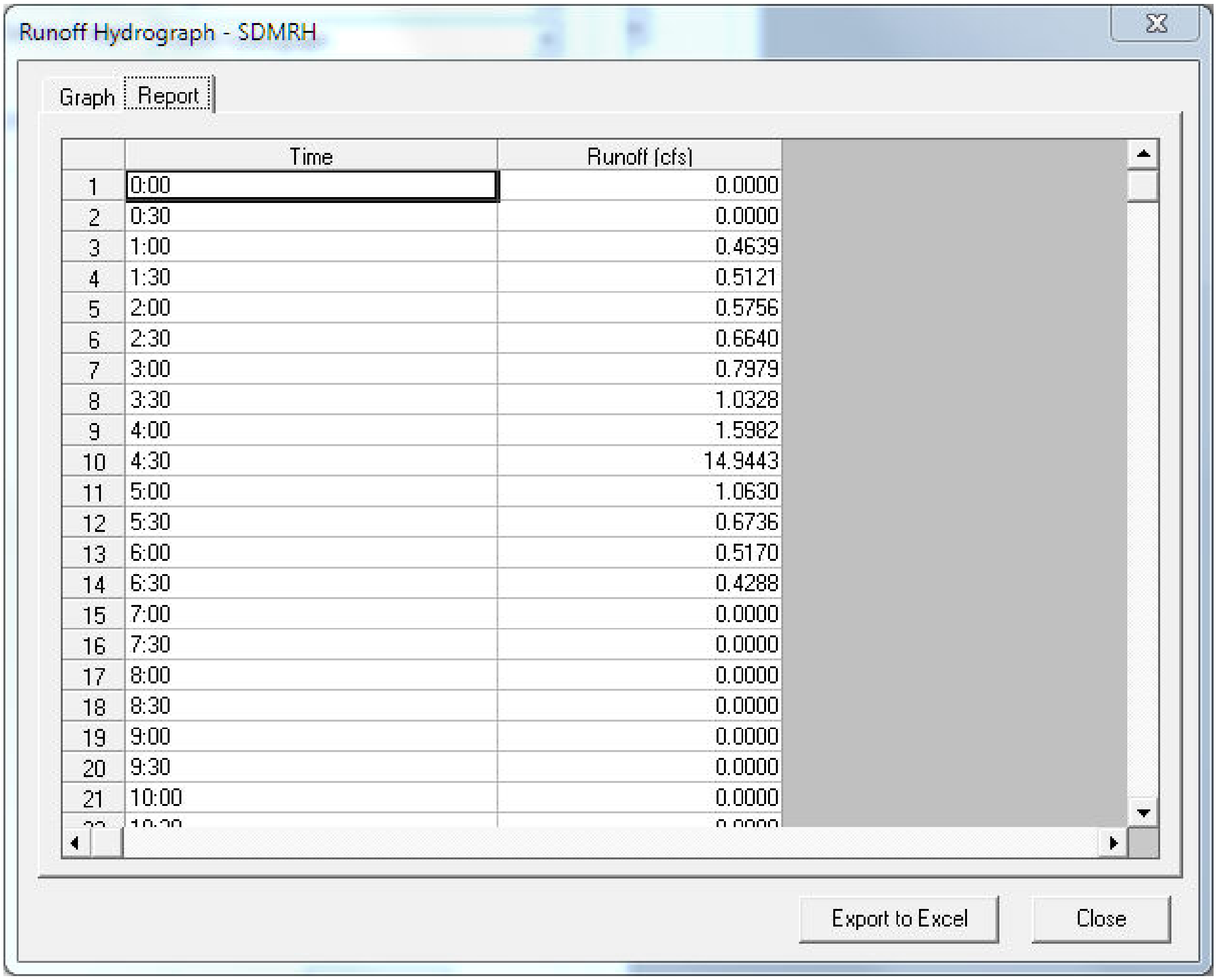
San Diego Modified Rational Hydrograph

- **Subcatchment Area** – Drainage area of the watershed.
- **Runoff Coefficient** – Rational formula runoff coefficient (see Table 3.9)
- **6-hr Precipitation** – Six-hour design rainfall depth.
- **Time of Concentration –** The time it takes for flow to travel from the hydraulically remotest point in the watershed to get to outlet of the watershed.

Output for Runoff Hydrograph

The output is a runoff hydrograph given graphically as well as in tabular form.





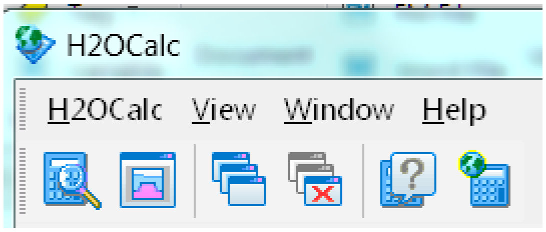
	Time	Runoff (cfs)
1	0:00	0.0000
2	0:30	0.0000
3	1:00	0.4639
4	1:30	0.5121
5	2:00	0.5756
6	2:30	0.6640
7	3:00	0.7979
8	3:30	1.0328
9	4:00	1.5982
10	4:30	14.9443
11	5:00	1.0630
12	5:30	0.6736
13	6:00	0.5170
14	6:30	0.4288
15	7:00	0.0000
16	7:30	0.0000
17	8:00	0.0000
18	8:30	0.0000
19	9:00	0.0000
20	9:30	0.0000
21	10:00	0.0000

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

H_2OCalc Methodology Introduction

H_2OCalc is an extremely powerful, comprehensive and easy-to-use modeling software that lets users streamline the hydraulic design and analysis of pipes, pumps, open channels, weirs, orifices, culverts, and inlets by allowing them to take advantage of advanced hydraulic computational algorithms without having expertise in this complex field. It also eliminates the need for messy nomographs, cumbersome spreadsheets and homegrown programs, empowering engineers to work more effectively, improve productivity and design better systems.

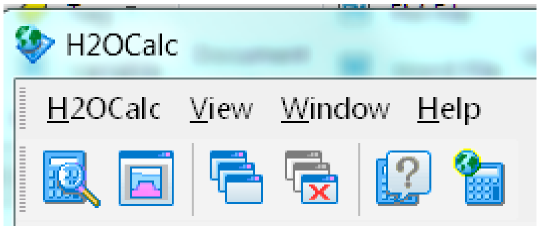
This section provides the comprehensive methodologies applied in H_2OCalc as follows:

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

3.9 Orifice

An orifice is a restricted, sharp-edged opening through which fluid flows. In an orifice, flow streamlines converge a short distance downstream of the opening forming a vena contracta. As a result, the flow area at the vena contracta is slightly smaller than that of the orifice opening.

Discharge through an orifice can be expressed as

$$Q = CA\sqrt{2gH}$$

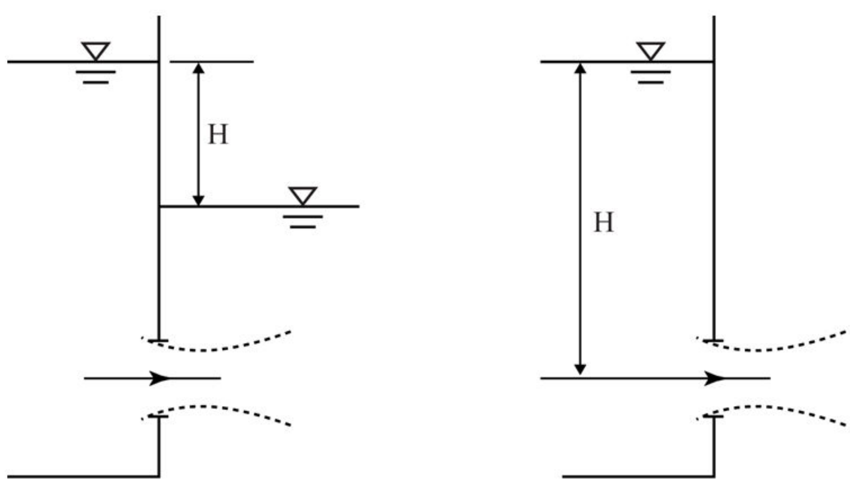
where Q = discharge (m3/s, ft3/s)

C = coefficient of discharge

A = flow area (m^2, ft^2)

g = gravitational acceleration (m/s^2, ft/s^2)

H = head (m, ft) (see the figure below)



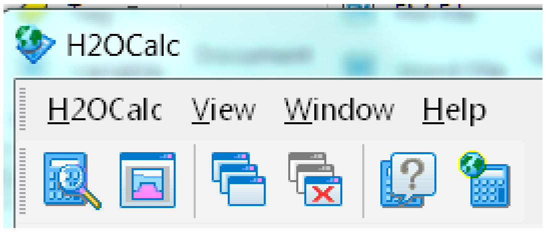
Orifice flow (a) Discharge to Downstream Reservoir; (b) Discharge to Atmosphere

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

3.10 Discharge from tanks

Discharge from open tanks and pressurized tanks can be computed using Equation (36) (i.e., orifice equation). For pressurized tanks, the head causing the discharge (i.e., *H*) should incorporate the additional pressure, *p*, imparted on the fluid in the tank, and is computed as.

$$Q = CA\sqrt{2g\left(H + \frac{p}{\gamma}\right)}$$

where γ = specific weight of water (9810 N/m^3, 62.4 lb/ft^3)

p = gage pressure (N/m^2, lb/ft^2)

For a tank with constant cross-sectional area, the time required to empty the tank is

$$t = \frac{2A_t\sqrt{H}}{CA_o\sqrt{2g}}$$

where t = time (sec)

A_t = cross-sectional area of the tank (m^2, ft^2)

H = head (m, ft)

C = coefficient of discharge

A_o = flow area (m^2, ft^2)

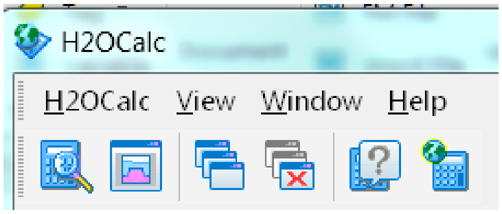
g = gravitational acceleration (m/s^2, ft/s^2)

Innovyze Help File Updated September 1, 2017

InfoSWMM H$_2$OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

3.11 Weir

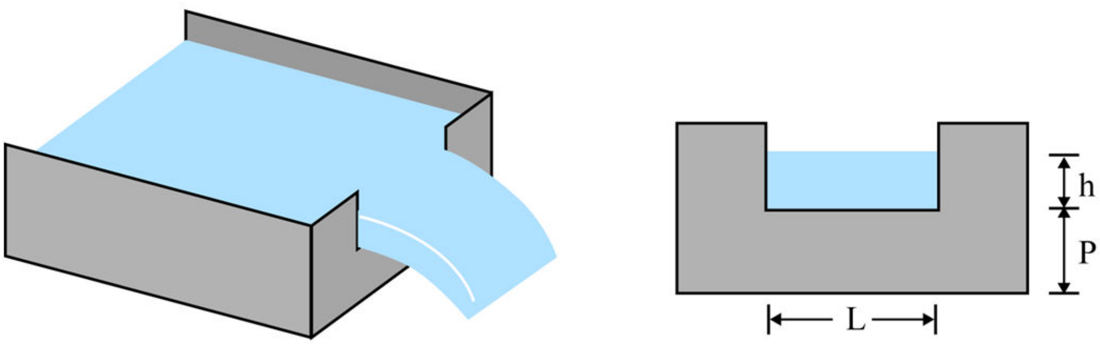
Discharge in channels and small streams can be conveniently measured by using a weir. Weirs can be categorized in to two: sharp crested and broad crested.

Sharp-Crested Weir

A sharp-crested weir is a vertical plate placed in a channel that forces the liquid to flow through an opening to measure the flow rate. The type of the weir is characterized by the shape of opening.

Rectangular Sharp-Crested Weir

A vertical thin plate with a straight top edge is referred to as *rectangular weir* since the cross section of the flow over the weir is rectangular (see the following figure).



Rectangular Weir

The discharge equation for a rectangular weir is given as

$$Q = CLh^{3/2}$$

where Q = discharge over the weir (m^3/s, ft^3/s)

h = head (m, ft)

L = weir length (m, ft)

C = weir coefficient

$$[\sqrt{2g}(0.4+0.05h/P)]$$

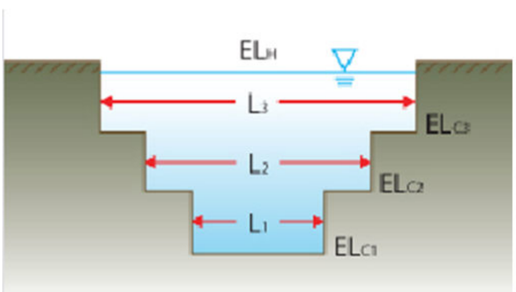
typically given as 1.84 in SI, 3.33 in English.

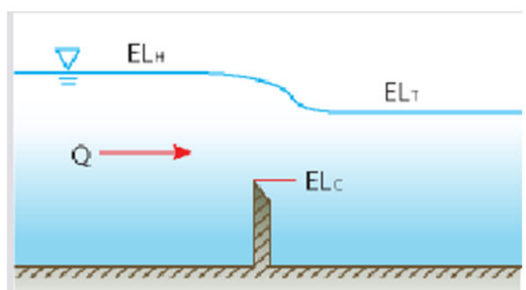
Flow through the weir may not span the entire width of the channel (L) due to end contractions. Experiments have indicated that the reduction in length is approximately equal to $0.1nh$, where n is the number of end contractions (e.g., could be 2 in the contracted rectangular weir), and h is head over the crest of the weir as defined above. Therefore, the formula for contracted weir (one with flow contraction due to end walls) is given as

$$Q = C(L-0.1nh)h^{3/2}$$

Multiple-Step Sharp Crested Rectangular Weir

A multiple step weir is a rectangular weir with stepwise increase in length along the weir height. It helps to maintain low velocity across the weir during low flows and may be ecologically friendly as it allows fish freely pass across the weir.





The discharge equation for multi-step weirs is given as:

$$Q = C\left(L_1 h_1^{\,3/2} + (L_2 - L_1)h_2^{3/2} + \ldots + (L_n - L_{n-1})h_n^{\,3/2}\right)$$

where Q = discharge over weir (m^3/s, ft^3/s)

h_i = head over the crest of the weir at step i (m, ft)

L_i = length of the weir at step i (m, ft)

C = the flow coefficient (1.86 in SI, 3.367 in English)

Cipolletti Sharp-Crested Weir

The *Cipolletti* (or trapezoidal) weir has side slopes of 4 vertical to 1 horizontal ratio as shown in the figure below. The discharge equation for a Cipolletti weir is given as

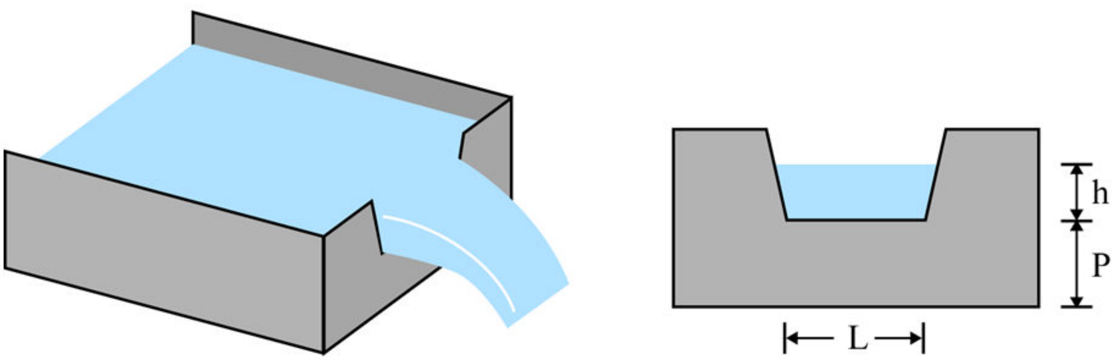
$$Q = CLh^{3/2}$$

where Q = discharge over weir (m^3/s, ft^3/s)

h = head (m, ft)

L = weir bottom length (m, ft)

C = the flow coefficient (1.86 in SI, 3.367 in English)

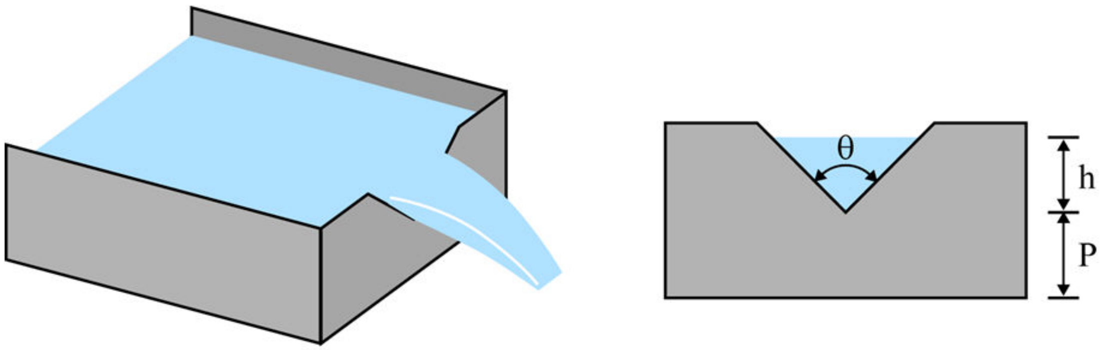


Cipolletti Weir

Notice that L is measured along the bottom of the weir (called the crest), not along the water surface.

V-Notch Sharp-Crested Weir

With low flow rate, it is common to use a V-Notch weir (shown below).



V-Notch Weir

The discharge equation for a V-Notch weir is given as

$$Q = \frac{8}{15} C \sqrt{2g} \tan\left(\frac{\theta}{2}\right) h^{5/2}$$

where Q = discharge over weir (m^3/s, ft^3/s)

h = head (m, ft)

θ = angle of notch (degree)

C = the flow coefficient that typically range between 0.58 and 0.62.

The most commonly used value of the notch angle θ is 90^o; for this case (i.e., θ is 90^o), C is found to be around 0.585.

Submerged Sharp-Crested Weir

The weir equations discussed above assume that the weir is free flowing. However, if the tailwater rises high enough, the weir will be submerged and the weir flow-carrying capacity will be reduced. Therefore, the discharge can be adjusted for submergence using the following equation:

$$Q_s = Q[1.0 - (h_s / h)^n]^{0.385}$$

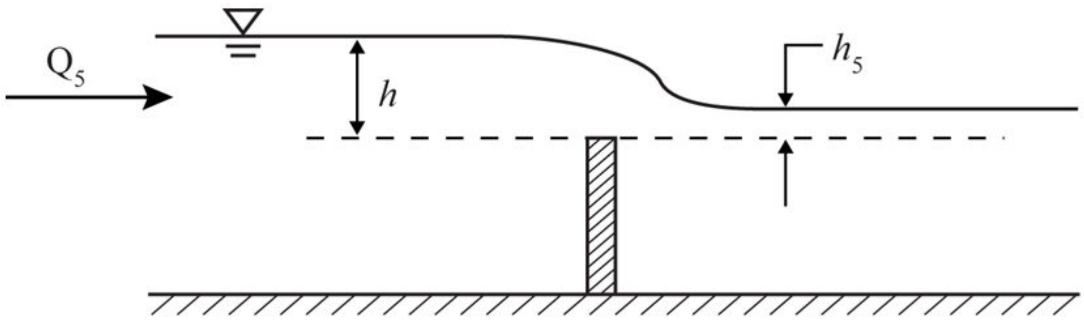
where Q_S = discharge over a submerged weir (m^3/s, ft^3/s)

Q = discharge computed using weir equations (m^3/s, ft^3/s)

h_S = tailwater depth above the weir crest (m, ft)

h = head upstream of the weir (m, ft)

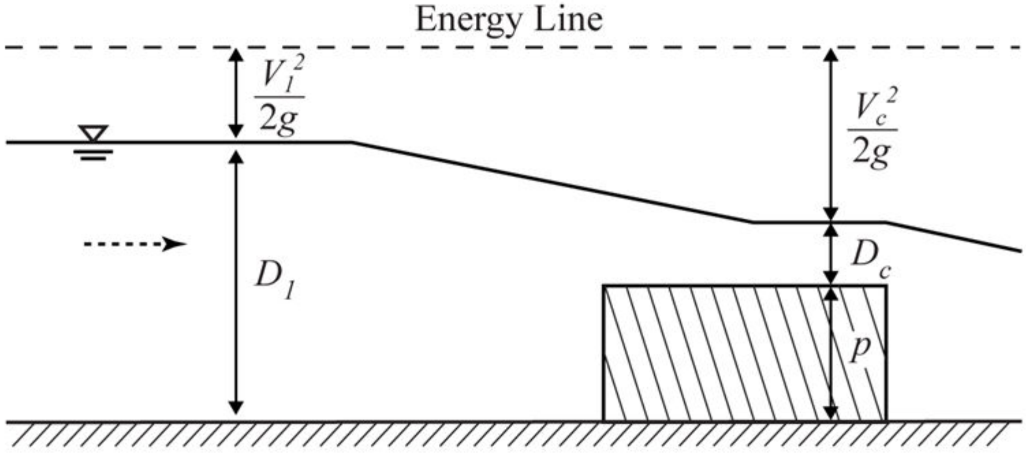
n = exponent, 1.5 for rectangular and Cipolletti weirs, 2.5 for a triangular weir.



Submerged Weir

Broad-Crested Weir

If the weir is long in the direction of flow so that the flow leaves the weir in essentially a horizontal direction, the weir is a broad-crested weir.



Broad-Crested Weir

The discharge equation for a broad crested weir is given as

$$Q = CLh^{3/2}$$

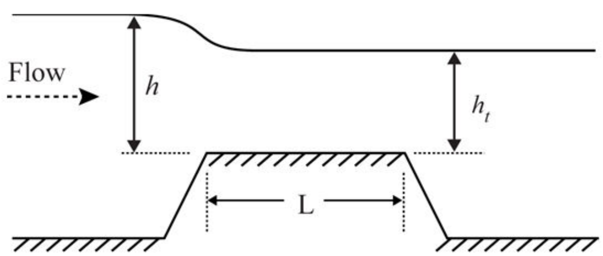
where Q = discharge over weir (m^3/s, ft^3/s)

h = head (m, ft)

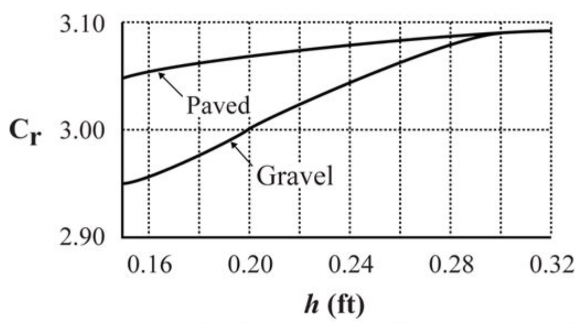
L = crest length (m, ft)

C = the flow coefficient that typically range between 2.4 and 3.087.

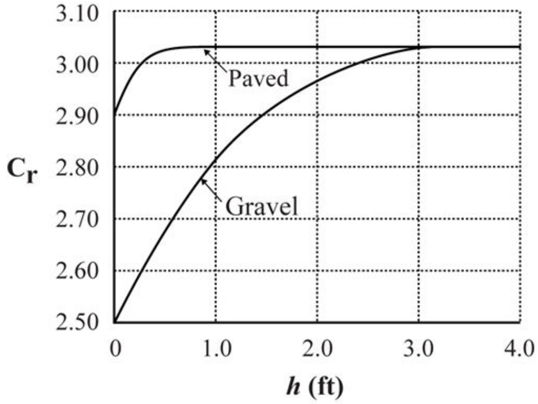
The flow coefficient C can be obtained from the following figure. Depending on the shape of the weir and head on the weir, the C value may range from 2.4 to 3.1.



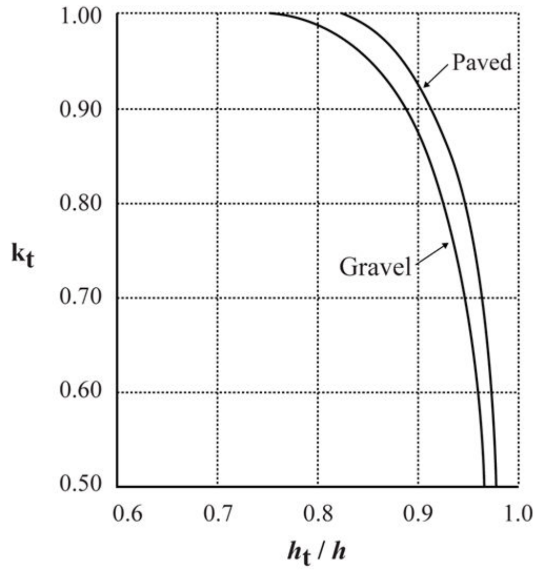
$$C = k_t C_r$$



A) Discharge Coefficient for h/L > 0.15



B) Discharge Coefficient for h/L ≤ 0.15



C) Submergence Factor

Broad-Crested Weir Discharge Coefficients (*Adapted from Normann et al., 1985*)

Generic Weir

Any other type of weirs can be modeled as generic weir using the following equation.

$$Q = CLh^{3/2}$$

where Q = discharge over weir (m^3/s, ft^3/s)

h = head above weir crest (m, ft)

L = crest length (m, ft)

C = weir coefficient

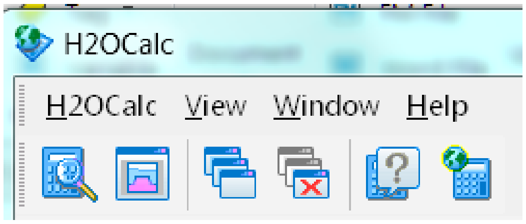
The weir coefficient value depends on the weir type, and is the function of the head above the weir crest.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

3.12 Culvert

A culvert is a pipe that carries water under or through some feature (usually a road or highway) that would otherwise block the flow of water. The culvert acts as an open channel as long as the flow is partly full. The characteristics of the flow are very complicated because the flow is controlled by many variables, including the inlet geometry, slope, size, roughness, approach and tailwater conditions, etc. Therefore, an adequate determination of the flow through a culvert is generally made by laboratory or field investigation.

Culverts are classified according to which of their ends controls the discharge capacity: inlet control or outlet control. If water can flow through and out of the culvert faster than it can enter, the culvert is under inlet control. If water can flow into the culvert faster than it can flow through and out, the culvert is under outlet control. Culverts under inlet control will always flow partially full. Culverts under outlet control can flow either partially full or full. H2OCalc analyzes culverts using two different approaches: a simplified culvert analysis method and the Federal Highway Administration's (FHWA) HDS No. 5 method (Normann et al, 1985). Both techniques are described below.

Simplified Method

The simplified method classifies culvert flow into six different types on the basis of the type of control, the steepness of the barrel, the relative tailwater and headwater heights, and in some cases, the relationship between critical depth and culvert size. These parameters are quantified through the use of the ratios in Table 3.4. The six types are illustrated in the following figure.

For culverts flowing full, the friction loss (h_f) can be determined using the Darcy formula. For partial flow, the Manning equation can be used. The friction head loss between sections 1 and 2 (see the figure below), for example, can be calculated from Manning's equation as

$$h_{f,1-2} = \frac{LQ^2}{K_1 K_2}$$

where L = the culvert length

K = Conveyance factor and equals

$$\left(\frac{1.00}{n}\right) R^{2/3} A \text{ (SI)}, \left(\frac{1.49}{n}\right) R^{2/3} A \text{ (English)}$$

R = hydraulic radius (m, ft); $R = A/P$

A = cross-sectional area of flow section (m^2, ft^2) P = wetted perimeter (m, ft)

N = Manning's coefficient

Table 3-4: Culvert Flow Classification Parameters

Flow type	**$(h_1 - z)/D$**	**h_4/h_c**	**h_4/D**	**Culvert slope**	**Barrel flow**	**Location of control**	**Kind of control**
1	< 1.5	< 1.0	≤ 1.0	steep	partial	Inlet	critical depth
2	< 1.5	< 1.0	≤ 1.0	mild	partial	outlet	critical depth
3	< 1.5	> 1.0	≤ 1.0	mild	partial	outlet	backwater
4	> 1.0		> 1.0	any	full	outlet	backwater
5	≥ 1.5		≤ 1.0	any	partial	inlet	entrance geometry

6	≥ 1.5		≤ 1.0	any	Full	outlet	entrance geometry

Adapted from Lindeburg (2003)

The total hydraulic head available, *H*, is divided between the velocity head in the culvert, the entrance loss (if considered), and the friction loss as follows

$$H = \frac{v^2}{2g} + k_e\left(\frac{v^2}{2g}\right) + \frac{v^2 n^2 L}{R^{4/3}} \quad \text{(SI)}$$

$$H = \frac{v^2}{2g} + k_e\left(\frac{v^2}{2g}\right) + \frac{v^2 n^2 L}{2.21 R^{4/3}} \quad \text{(English)}$$

where k_e is the local loss for entrance.

Re-arranging Equations (46) and (48), velocity through the culvert can be given as

$$v = \sqrt{\frac{H}{\frac{1+k_e}{2g} + \frac{n^2 L}{R^{4/3}}}} \text{ (SI)}$$

$$v = \sqrt{\frac{H}{\frac{1+k_e}{2g} + \frac{n^2 L}{2.21 R^{4/3}}}} \text{ (English)}$$

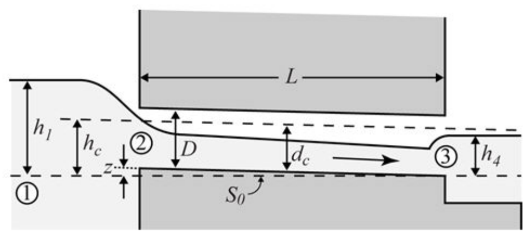
Type 1

Critical depth at inlet

$$\frac{h_1 - z}{D} < 1.5$$

$$\frac{h_4}{h_c} < 1.0$$

$S_0 > S_c$



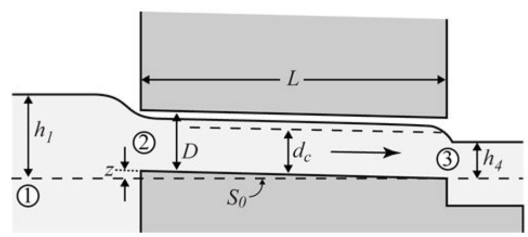
Type 2

Critical depth at outlet

$$\frac{h_1 - z}{D} < 1.5$$

$$\frac{h_4}{h_c} < 1.0$$

$S_0 < S_c$

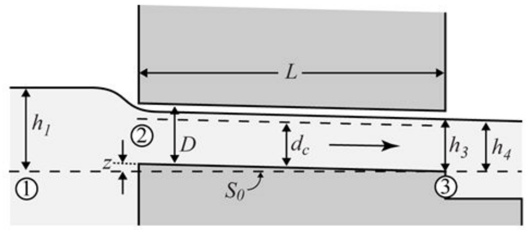


Type 3
Tranquil flow throughout

$$\frac{h_1 - z}{D} < 1.5$$

$$\frac{h_4}{D} \leq 1.0$$

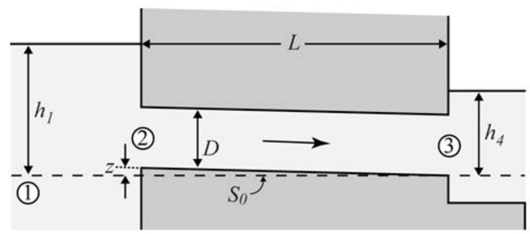
$$\frac{h_4}{h_c} > 1.0$$



Type 4
Submerged outlet

$$\frac{h_1 - z}{D} > 1.0$$

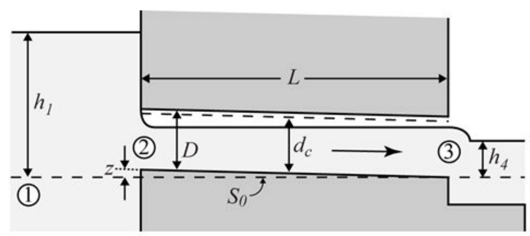
$$\frac{h_4}{D} > 1.0$$



Type 5
Rapid flow at inlet

$$\frac{h_1 - z}{D} \geq 1.5$$

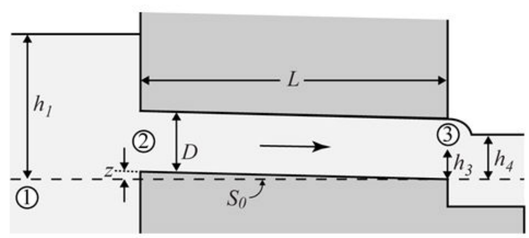
$$\frac{h_4}{D} \leq 1.0$$



Type 6
Full flow, free outfall

$$\frac{h_1 - z}{D} \geq 1.5$$

$$\frac{h_4}{D} \leq 1.0$$



Culvert Flow Classification (*Adapted from Lindeburg, 2003*)

A. Type-1 Flow

Water passes through the critical depth near the culvert entrance, and the culvert flows partially full. The slope of the culvert barrel is greater than the critical slope, and the tailwater elevation is less than the elevation of the water surface at the control section.

$$Q = C_d A_c \sqrt{2g\left(h_1 - z + \frac{\alpha v_1^2}{2g} - d_c - h_{f,1-2}\right)}$$

where Q = discharge from the culvert (m^3/s, ft^3/s)

C_d = discharge coefficient

v_1 = average velocity of the water approaching the culvert entrance

α = velocity-head coefficient (i.e., assumed as 1.0)

d_c = the critical depth

A_c = flow area at the critical section, not the culvert area

B. Type-2 Flow

As in Type-1 flow, flow passes through the critical depth at the culvert outlet, and the barrel flows partially full. The slope of the culvert is less than critical, and the tailwater elevation does not exceed the elevation of the water surface at the control section.

$$Q = C_d A_c \sqrt{2g\left(h_1 + \frac{\alpha v_1^2}{2g} - d_c - h_{f,1-2} - h_{f,2-3}\right)}$$

C. Type-3 Flow

When backwater is the controlling factor in culvert flow, the critical depth cannot occur. The upstream water surface elevation for a given discharge is a function of the height of the tailwater. For Type-3 flow, flow is subcritical for the entire length of the culvert, with the flow being partial. The outlet is not submerged, but the tailwater elevation does exceed the elevation of critical depth at the terminal section.

$$Q = C_d A_3 \sqrt{2g\left(h_1 + \frac{\alpha v_1^2}{2g} - h_3 - h_{f,1-2} - h_{f,2-3}\right)}$$

where A_3 is the flow area at section 3 (i.e., the exit).

D. Type-4 Flow

As in Type-3 flow, the backwater elevation is the controlling factor in this case. Critical depth cannot occur, and the upstream water surface elevation for a given discharge is a function of the tailwater elevation. Discharge is independent of barrel slope. The culvert is submerged at both the headwater and the tailwater.

$$Q = C_d A_o \sqrt{2g\left(\frac{h_1 - h_4}{1 + \frac{29 C_d^2 n^2 L}{R^{4/3}}}\right)}$$

where A_o is the culvert area. The complicated term in the denominator corrects for friction. For rough estimates and for culverts less than 50 ft long, the friction loss can be ignored.

$$Q = C_d A_o \sqrt{2g(h_1 - h_4)}$$

E. Type-5 Flow

Partially full flow under a high head is classified as Type-5 flow. The flow pattern is similar to the flow downstream from a sluice gate, with rapid flow near the entrance. Usually, Type-5 flow requires a relatively square entrance that causes contraction of the flow area to less than the culvert area. In addition, the barrel length, roughness, and bed slope must be sufficient to keep the velocity high throughout the culvert.

$$Q = C_d A_o \sqrt{2g(h_1 - z)}$$

F. Type-6 Flow

Type-6 flow, like Type-5 flow, is considered a high-head flow. The culvert is full under pressure with free outfall.

$$Q = C_d A_c \sqrt{2g(h_1 - h_3 - h_{f,2-3})}$$

Note that distance $h_3$is undefined. For conservative first approximations, h_3 can be taken as the barrel diameter.

The FHWA Method

The Federal Highway Administration (FHWA) offers equations as well as nomographs that can be used for analysis and design of culverts. Different equations and nomographs are developed for inlet controlled culvert flows and outlet controlled culvert flows. Only equation based analysis and design approaches are described in this section. Readers interested in the FHWA nomographs, for both control types, may refer to Normann et al. (1985).

Culvert design according to FHWA involves analyzing the culvert under both inlet control and outlet control conditions and selecting the control type that yields the worst condition (i.e., larger headwater depth). The design would be acceptable if the governing headwater depth is less than the maximum allowable headwater to avoid flooding of streets and property. Otherwise, the design needs to be revised (e.g., culvert size is increased) to reduce the headwater depth.

Inlet Control

The objective is to determine the headwater depth based on predetermined design discharge and a trial culvert size. The design equation used to determine headwater depth for inlet controlled culvert vary depending on the flow condition at the inlet of the culvert. If the inlet is submerged, the flow type would be orifice flow. Unsubmerged conditions will behave as a weir flow.

If the inlet is submerged (orifice flow), the equation to determine the headwater depth will be

$$\frac{HW_i}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^2 + Y + Z \text{ for } \left[\frac{Q}{AD^{0.5}}\right] \geq 4.0$$

where HW_i = headwater depth above the inlet control section invert (ft) D = diameter of the culvert (ft)

Q = discharge (ft^3/s)

A = full cross-sectional area of the culvert (ft^2) c, Y = constant from Table 3.5

Z = culver barrel slope term (ft/ft).

For mitered inlets,

$$Z = 0.7S^2$$

and for all other conditions (i.e., inlet types other than mitered inlets),

$$Z = -0.5S^2$$

The unsubmerged flow (weir flow) condition can be evaluated using one of the following two approaches:

1) Based on specific head (H_c) at critical depth

$$\frac{HW_i}{D} = \frac{H_c}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^M + Z \quad \text{for} \quad \left[\frac{Q}{AD^{0.5}}\right] \leq 3.5$$

$$H_c = d_c + \frac{V_c^2}{2g}$$

where H_c = specific head at critical depth (ft)

K and M = constants from Table 3.5

d_c = critical depth (ft)

V_c = critical velocity (ft/sec)

2) A simpler form that ignores specific head (H_c) at critical depth

$$\frac{HW_i}{D} = \left[\frac{Q}{AD^{0.5}}\right]^M \quad \text{for} \quad \left[\frac{Q}{AD^{0.5}}\right] \leq 3.5$$

Table 3-5: Constants for Inlet Control Design Equations

Shape and material	**Inlet Edge Description**	***K***	***M***	***c***	***Y***
Circular Concrete	Square edge w/ headwall	0.0098	2.000	0.0398	0.67
	Groove end w/ headwall	0.0078	2.000	0.0292	0.74
	Groove end projecting	0.0045	2.000	0.0317	0.69

Circular CMP	Headwall	0.0078	2.000	0.0379	0.69
	Mitered to slope	0.0210	1.330	0.0463	0.75
	Projecting	0.0340	1.500	0.0553	0.54
Circular Ring	Beveled ring, 45^0 bevels	0.0018	2.500	0.0300	0.74
	Beveled ring 33.7^0 bevels	0.0018	2.500	0.0243	0.83
Rectangular Box	30^0 - 75^0 wingwall flares	0.0260	1.000	0.0385	0.81
	90^0 and 15^0 wingwall flares	0.0610	0.750	0.0400	0.80
	0^0 wingwall flares	0.0610	0750	0.0423	0.82
Rectangular Box	45^0 wingwall flare	0.5100	0.667	0.0309	0.80
	18^0 - 33.7^0 wingwall flare	0.4860	0.667	0.0249	0.83
Rectangular Box	90^0 headwall w/¾ in chamfers	0.5150	0.667	0.0375	0.79
	90^0 headwall w/ 45^0 bevels	0.7950	0.667	0.0314	0.82
	90^0 headwall w/33.7^0 bevels	0.4860	0.667	0.0252	0.87
Rectangular Box	¾ in chamfers, 45^0 skewed headwall	0.5220	0.667	0.0402	0.73
	¾ in chamfers, 30^0 skewed headwall	0.5330	0.667	0.0425	0.71

	¾ in chamfers, 15^0 skewed headwall	0.5450	0.667	0.0451	0.68
	45^0 bevels, 10-45^0 skewed wall	0.4980	0.667	0.0327	0.75
Rectangular Box, ¾ in. chamfers	45^0 non offset wingwall flares	0.4970	0.667	0.0339	0.80
	18.4^0 non offset wingwall flares	0.4930	0.667	0.0361	0.81
	18.4^0 non offset wingwall flares, 30^0 skewed barrel	0.4930	0.667	0.0386	0.71
Rectangular Box, top bevels	45^0 wingwall flares- offset	0.4970	0.667	0.0302	0.84
	33.7^0 wingwall flares - offset	0.4950	0.667	0.0252	0.88
	18.4^0 wingwall flares - offset	0.4930	0.667	0.0227	0.89
Corrugated Metal Boxes	90^0 headwall	0.0083	2.000	0.0379	0.69
	Thick wall projecting	0.0145	1.750	0.0419	0.64

Adapted from Normann et al. (1985)

Outlet Control

Headwater for outlet control conditions can be determined using energy equation based on tailwater depth and head loss through the culvert considering entrance loss, exit loss, and friction loss.

$$HW_i = H + h_0$$

$$H = \left(1 + k_e + \frac{29n^2L}{R^{1.33}}\right)\frac{V^2}{2g} = h_{exit} + h_{entry} + h_f$$

$$h_0 = \max\left[TW, (d_c + D)/2\right]$$

$$d_c = \sqrt[3]{q^2/g}$$

where H = total head loss (ft)

k_e = entrance loss coefficient (see Table 3.6)

h_o = water depth at the outlet of the culvert (ft)

d_c = critical depth (ft)

q = unit discharge (discharge per unit width of the culvert) (ft^3/s/ft)

Table 3-6: Entrance Loss Coefficients-Outlet Control, Full or Partly Full

Type of Structures and Design of Entrance		Coefficient k_e
Pipe, Concrete	Mitered to conform to fill slope	0.7
	End-section conforming to fill slope	0.5
	Projecting from fill, square cut end	0.5
	Headwall or headwall and wingwalls	
	Square Edge	0.5
	Rounded(radius= 1/12 Culvert Diameter	0.2
	Socket End of Pipe (groove-end)	0.2
	Projecting from fill, socket end (groove-end)	0.2

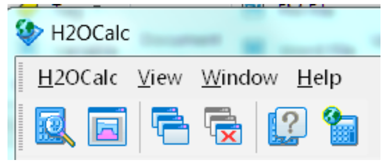
	Beveled edges, 33.7^{0} or 45^{0} bevels	0.2
	Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	Projecting from fill (no metal)	0.9
	Mitered to conform to fill slope, paved or unpaved slope	0.7
	Headwall or headwall and wingwalls square-edge	0.5
	End-section conforming to fill slope	0.5
	Beveled edges, 33.7^{0} or 45^{0} bevels	0.2
	Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	Wingwalls parallel (extension of sides) Square edge at crown	0.7
	Wingwalls at 10^{0}-25^{0} or 30^{0}-75^{0} to barrel Square-edged at crown	0.5
	Headwall parallel to embankment (no wingwalls) Square-edged on three edges Rounded on three edges to radius of 1/12 barrel dimension, or beveled edges on three sides	0.5 0.2
	Wingwalls at 30^{0}-75^{0} to barrel Crown edge rounded to radius of 1/12 barrel dimension, or beveled to edges	0.2
	Side- or slope-tapered inlet	0.2

Adapted from Normann et al. (1985)

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

3.13 Urban Drainage Structures

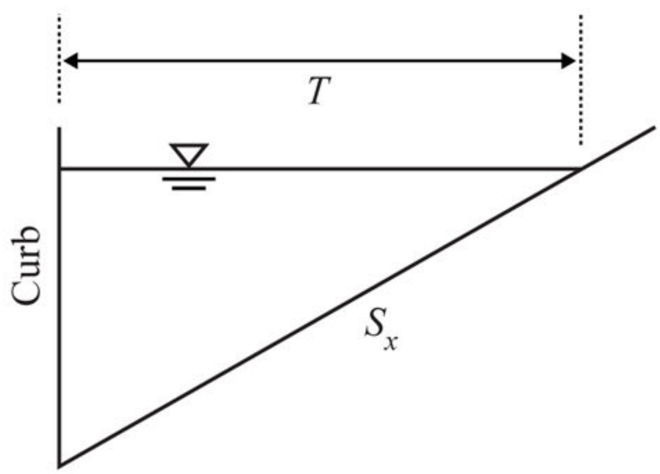
The methodology presented here for analysis and design of the drainage structures described in this section is based on HEC-22 manual (FHWA, 2001)

Gutter Flow

Gutters are the sections of roadway that run adjacent to the curb. Their purpose is to collect and convey surface runoff to drainage inlets and in turn to underground storm sewers. The corresponding spread of water onto the pavement, or top width of flow measured perpendicular to the edge of the roadway, is a primary concern from an analysis perspective. The lateral cross slope of a traffic lane facilitates drainage of incident rainfall to the gutter. Depending on the cross slope, conventional gutters may be grouped as uniform gutter (i.e., has uniform cross slope) or composite gutters (i.e., has multiple cross slopes).

Uniform Gutter Sections

Uniform gutters have a shallow, triangular cross section, with a curb forming the near-vertical leg of the triangle as shown in the following figure.



Uniform Gutter Shapes

The governing equation for uniform gutters is given as

$$Q = \frac{K_c}{n} S_x^{5/3} S^{1/2} T^{8/3}$$

where Q = gutter flow rate (m^3/s, ft^3/s)

K_c = empirical constant (0.376 in SI, 0.56 in English)

n = Manning's roughness coefficient

S_X = gutter cross slope (m/m, ft/ft)

S_L = longitudinal slope of the road way (m/m, ft/ft)

T = spread (m, ft)

Spread T is related to depth at the curb, d, and flow area, A, by

$$d = TS_x$$

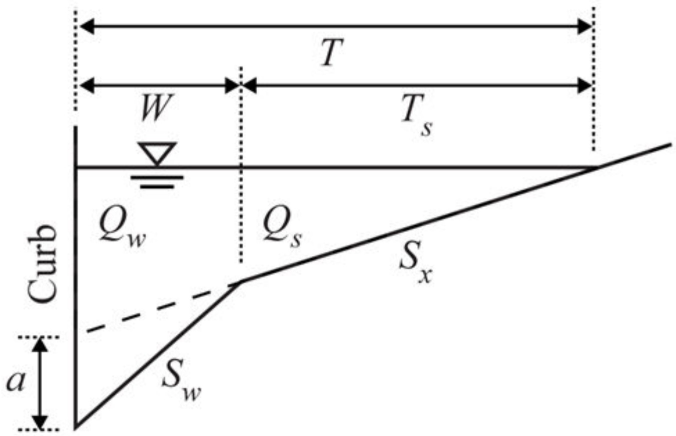
$$A = \frac{S_x T^2}{2}$$

Table 3-7: Manning's n for Street and Pavement Gutters

Type of Gutter or Pavement	Manning's n
Concrete gutter, troweled finish	0.012
Asphalt Pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter-asphalt pavement:	
Smooth	0.013
Rough	0.015
Concrete pavement:	
Float finish	0.014
Broom finish	0.016

Adapted from FHWA (2001)

Composite Gutter Sections



Composite Gutter Shapes

Evaluation of composite gutters requires additional consideration of flow in the depressed section. The depression serves to retain more water above inlet entrances and thus increases gutter flow capacity. The relationship between total discharge, Q, and depressed gutter flow, Q_W, can be expressed as

$$Q = Q_w + Q_s$$

where Q_W *and* Q_S represent portion of the gutter flows for the sections shown in the figure above (m^3/s, ft^3/s).

The relationship between Q and Q_S is given as

$$Q = \frac{Q_s}{(1 - E_o)}$$

where E_O = ratio of Q_W to Q, or

$$E_o = \left[1 + \frac{\left(\frac{S_w}{S_x} \right)}{\left(1 + \frac{(S_w / S_x)}{(T / W) - 1} \right)^{8/3} - 1} \right]^{-1} \tag{71}$$

where W = width of the depressed section (m, ft)
S_W = cross slope of the depressed section (m/m, ft/ft)

The slope terms and the width of depression are related through depth of the depression, a, as

$$S_w = S_x + \frac{a}{W}$$

where *a* is the gutter depression (m, ft) illustrated in the figure given above.

Drainage Inlet

As flow accumulates in gutters and spread increases, the risk of traffic accidents and delays increases. To limit this risk, drainage inlets are needed at the edge of the roadway to intercept all or a portion of the runoff and convey it to an underground storm sewer. Although there are many types and sizes of inlets in use, they are generally classified as grate, curb-opening, combination, or slotted-drain inlets. The responsibility of the designer is to determine the type, size, and spacing of inlets that cost-effectively and safely captures runoff.

Key parameters in evaluating inlet flow conditions are capacity, Q_i, and interception efficiency, E. The former refers to flow that is intercepted by a particular drainage inlet. Any gutter flow that is not intercepted is referred to as bypass, or carryover, flow, Q_b. Thus, if Q is total gutter discharge,

$$Q = Q_i + Q_b$$

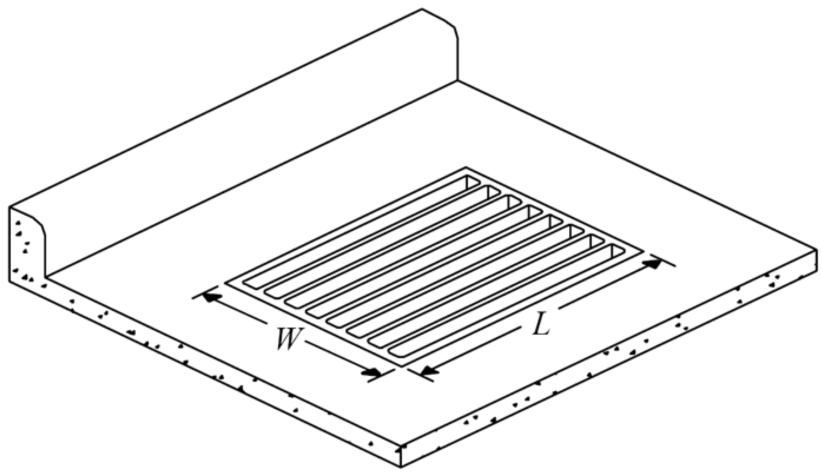
The interception efficiency of the inlet is the fraction of gutter flow that the inlet will capture under a given set of conditions, and is expressed as

$$E = \frac{Q_i}{Q}$$

Inlets on Grade

Grate Inlet

A grate inlet, as shown in the figure below, consists of an opening in the gutter covered by one or more, flush-mounted grates that are placed parallel to gutter flow.



Grate Inlet

E_o, defined as the ratio of frontal flow, Q_w, to total gutter flow, Q, for a uniform gutter can be expressed as

$$E_o = \frac{Q_w}{Q} = 1 - \left(1 - \frac{W}{T}\right)^{8/3}$$

where Q_w = portion of flow that passes directly over the upstream side of the grate

W = width of the grade

The ratio of intercepted frontal flow to total frontal flow, also referred to as frontal flow efficiency, R_f, is defined as

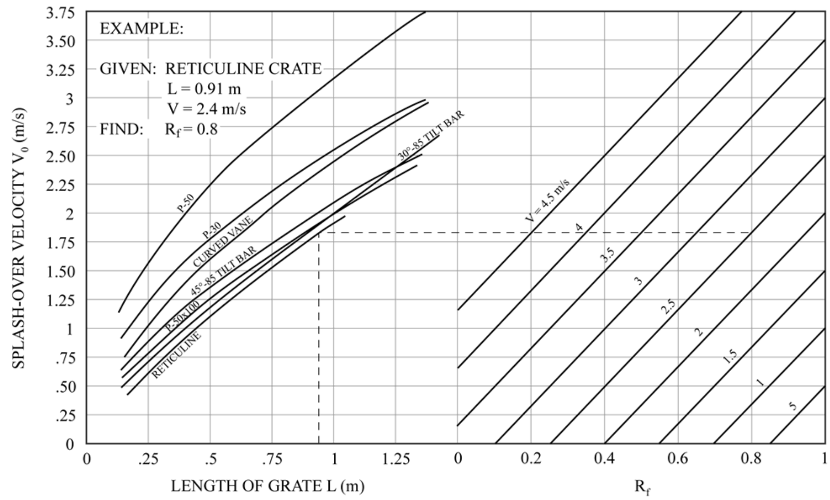
$$R_f = 1 - K_f(V - V_o)$$

where K_f = constant (0.295 in SI, 0.09 in English)

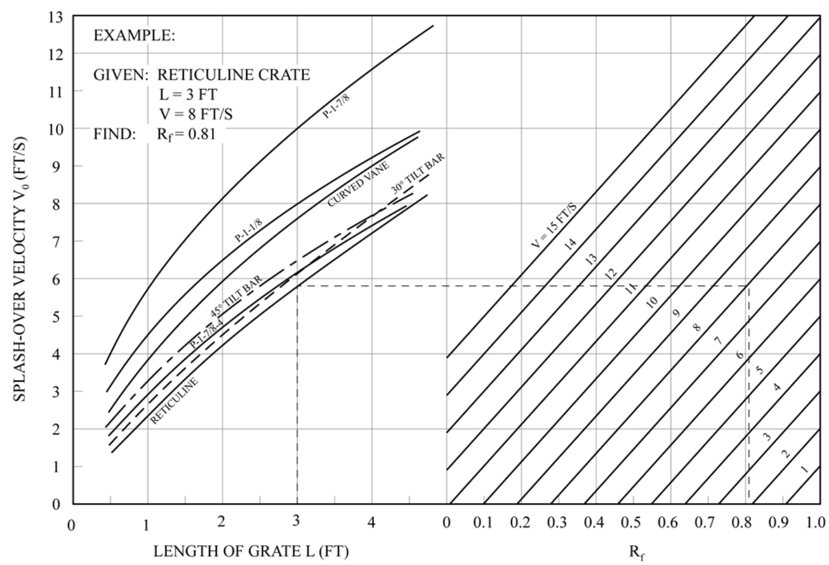
V = gutter flow velocity (m/s, ft/s)

splash-over velocity (velocity where splash-over first occurs) (m/s, ft/s).

The following figure could be used to determine splash-over velocity based on grate type, length of the grate, and gutter flow velocity.



Grate Inlet Frontal Flow Interception Efficiency



Grate Inlet Frontal Flow Interception Efficiency

Charts to Determine Slash-Over Velocity for Grate Inlets (*Adapted from FHWA, 2001*)

The ratio of side flow to gutter flow is expressed as

$$\frac{Q_s}{Q} = 1 - \left(\frac{Q_w}{Q}\right) = 1 - E_o$$

where Q_S = gutter flow traveling around the perimeter of the grate when spread exceeds its width (m^3/s, ft^3/s)

The ratio of intercepted side flow to total side flow, referred to as side flow efficiency, R_S, is defined as

$$R_s = \frac{1}{1 + \dfrac{K_s V^{1.8}}{S_x L^{2.3}}}$$

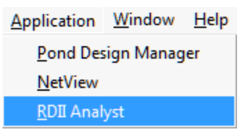
where K_S = empirical constant (0.083 in SI, 0.15 in US)

L = grate length (m, ft) – The range of grate length allowed by H_2OCalc is from 0.5 ft to 4.5 ft as defined in the FHWA Chart 5.

The overall inlet efficiency, E, can be evaluated from the frontal and side flow efficiencies by

$$E = R_f E_o + R_s (1 - E_o)$$

From Equation (74), the capacity of a grate inlet can be obtained by multiplying Equation (79) by the total gutter flow, or



[Curb Inlet](#)

A curb-opening inlet is comprised of a vertical opening in the curb that is covered by a concrete slab, as shown in the following figure.

For uniform cross slopes, the length of a curb-opening inlet required to intercept all gutter flow, L_T (m, ft), is defined as

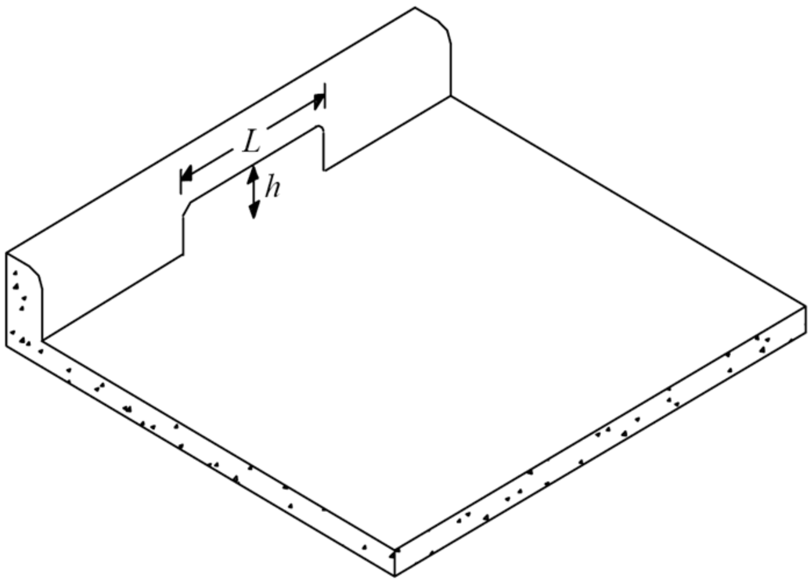
$$L_T = \frac{K_o Q^{0.42} S^{0.3}}{(n S_x)^{0.6}}$$

where K_O = empirical constant (0.817 in SI, 0.6 in English).

The efficiency of shorter-length inlets can be evaluated by

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8}$$

where L = curb-opening length (m, ft).



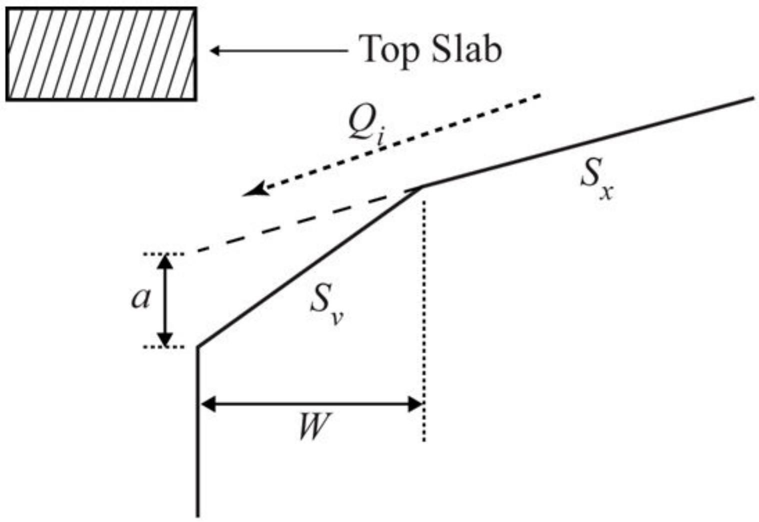
Curb Inlet

For the case where either locally- or continuously-depressed gutter sections are used (see the following figure), Equation (82) can still be used, but an equivalent cross slope, S_e, should be substituted for S_x, where

$$S_e = S_x + S_v E_o$$

where E_o = ratio of Q_w to Q [see Equation (75)]

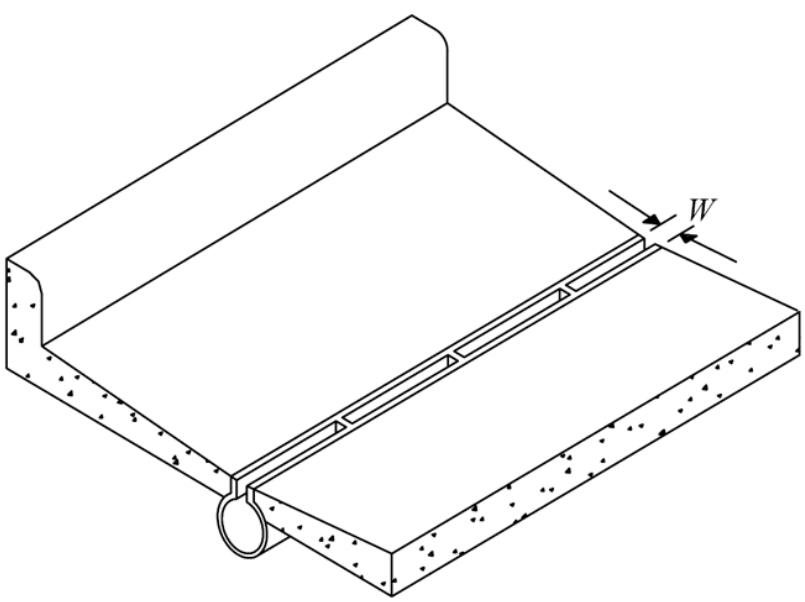
S_v = cross slope of the depressed section, expressed as $S_v = a/W$ (see the following figure).



Depressed Curb-Opening

Slot Inlet

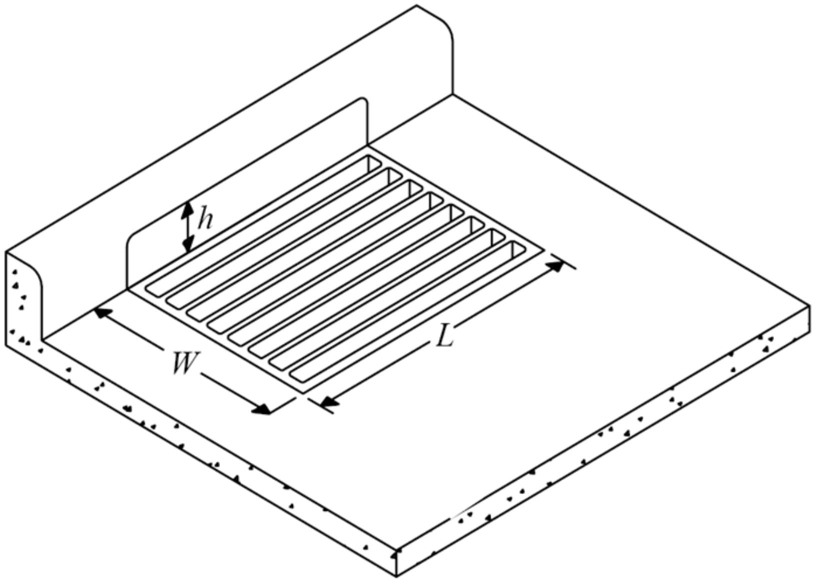
Slotted drain systems, illustrated in the figure given below, are comprised of a pipe that is cut longitudinally along its crown with bars placed perpendicular to support the opening. The hydraulic characteristics of slot inlet are similar to curb opening inlets; thus, Equations (81) and (82) are applicable.



Slot Inlet

Combination Inlet

Combination inlets integrate features of both curb-opening and grate inlets (see the figure below). For equal-length combination inlets, in which the grate and vertical curb opening are of the same length, inlet capacity and interception efficiency is not significantly different from that of the grate alone. Thus, Equations 75 through 80 are generally applicable.



Combination Inlet

Ditch Inlet

Roadside ditches may be drained by drop inlets similar to those used for pavement drainage. The ratio of frontal flow to total flow for trapezoidal ditches (channels) is expressed as

$$E_0 = W/(B + dZ)$$

where W = width of the drop inlet (m, ft)

d = depth of flow in the channel (m, ft) determined using Manning's equation.

Z = horizontal distance of side slope to a vertical rise of 1 unit (ft, m)

Frontal flow efficiency, side flow efficiency, total efficiency, intercepted flow, and bypass flow are computed using the technique described previously for grate inlets.

Inlets in Sag

Inlets in vertical curves, or sag locations, operate as weirs at shallow ponding depths and as orifices at larger depths. At intermediate depths, flow is not well defined and may actually fluctuate between weir and orifice control. The depth at which orifice flow begins depends on grate size and bar configuration, curb opening dimensions, or the slot width of an inlet.

Grate Inlets

The capacity under weir conditions is expressed as

$$Q_i = C_w P_i \, d^{3/2}$$

where P_i = perimeter (m, ft) of the grate, not including the side adjacent to the curb, if present C_w = weir coefficient (1.66 in SI, 3.0 in English)

d = depth at the curb (m, ft)

Under orifice conditions,

$$Q_i = C_o A_g \sqrt{2gd}$$

where C_o = orifice coefficient (0.67)

A_g = clear opening, or effective area of the grate

g = gravitational constant (9.81 m/s^2, 32.2 ft/s^2)

Curb inlets

Curb-opening inlets operate as weirs up to a depth (d) that is less than or equal to height (h) of the vertical opening. In this case, inlet capacity can be computed by

$$Q_i = C_w L d^{3/2}$$

where C_w = weir coefficient (1.66 in SI, 3.0 in English)

L = curb-opening length (m, ft)

If the gutter section is depressed, this relationship is modified as

$$Q_i = C_w (L + 1.8W) \, d^{3/2}$$

where C_w = weir coefficient (1.25 in SI, 2.3 in English)

W = lateral width of depression (m, ft)

d = throat width (m, ft) measured from the undepressed cross slope

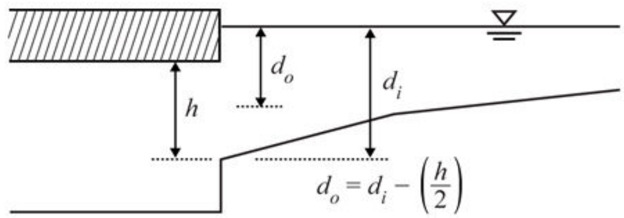
(i.e., $d = TS_x$)

At depths of approximately 1.4 times the opening height, curb-opening inlets tend to function as orifices. Under these conditions, capacity can be computed by

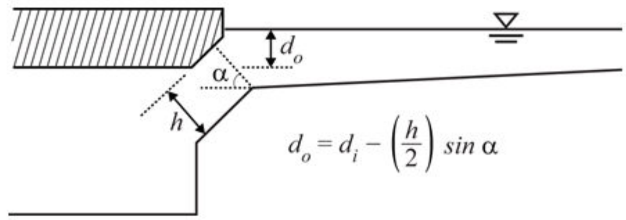
$$Q_i = C_o h L \sqrt{2gd_o}$$

where d_o = effective head (m, ft) (see the following three figures)

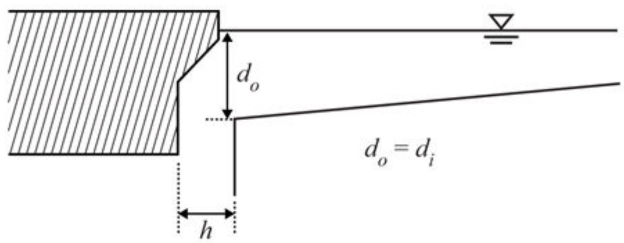
h = throat width (m, ft) (see the following three figures)



(a) Horizontal Throat

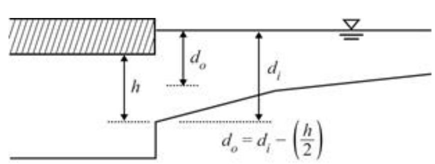


(b) Inclined Throat

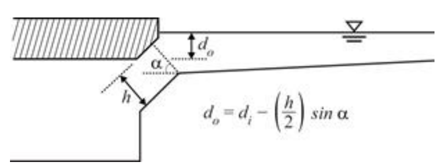


(c) Vertical Throat

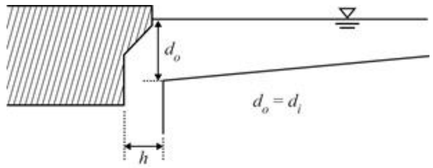
Throat Configuration



(a) Horizontal Throat



(b) Inclined Throat



(c) Vertical Throat

Throat Configuration

Slot Inlets

Due to vulnerability to clogging, slotted drain inlets are not recommended for sag locations. Nevertheless, if they exist, slotted drains operate as weirs when depth at the slot is below approximately 0.2 ft (60 mm) and as orifices for depths greater than 0.4 ft (120 mm). Capacity of a slotted drain operating under weir conditions can be evaluated using Equation (87). The corresponding weir coefficient varies with flow depth and slot length, but a typical value is 1.4 in SI and 2.48 in English. Under orifice conditions, capacity is a function of the slot width, W, and is computed by

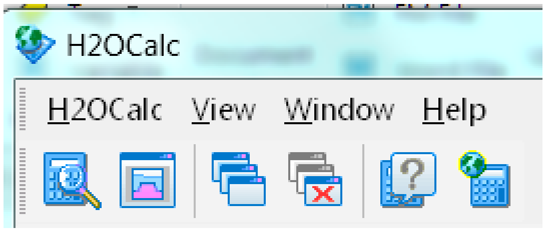
$$Q_i = 0.8LW\sqrt{2gd}$$

Combination Inlets

Combination inlets, especially those of a sweeper configuration, can be effective in sag locations. In this case, the sweeper inlet can extend from both sides of the grate. Similar to on-grade computations, under weir conditions, the inlet capacity of an equal-length combination inlet is essentially equal to that of the grate alone. Under orifice conditions, the capacity increases to the sum of that of the grate (i.e., Equation 86) and that of the curb opening (i.e., Equation 89). For a conservative design, however, it is recommended that combination inlet be designed assuming complete clogging of the grate.

Ditch Inlets

Ditch inlets in sag intercept 100 % of the gutter flow.


H2OCalc
H2OCalc View Window Help

3.14 Water Hammer

Surge analysis is important to estimate the worst-case events in the Water Distribution Systems (WDS). Transient regimes in WDS are inevitable and will normally occur as a result of action at pump stations and control valves. Regions that are particularly susceptible to transients are high elevation areas, locations with either low or high static pressures, and regions far removed from overhead storage. They are generally characterized by fluctuating pressures and velocities and are critical precisely because pressure variations can be of high magnitude, possibly large enough to break or damage pipes or other equipment, or to greatly disrupt delivery conditions.

This section presents the calculation of potential surge using Joukowski equation, which is widely applied as a simplified surge analysis, and wave speed calculation. In the end, it provides the calculation of the inertia of pumps and motors, which are important for transients caused by pump failure.

Joukowski Expression

The pressure rise for instantaneous closure is directly proportional to the fluid velocity at cutoff and to the velocity of the predicted surge wave. Thus, the relationship used for analysis is simply the well-known Joukowski expression for sudden closures in frictionless pipes

$$\Delta h = \frac{c}{gA}\Delta Q \text{ or } \Delta h = \frac{c}{g}\Delta V$$

where

Δh = surge pressure (m , ft)

ΔV = velocity change of water in the pipeline (m/s, ft/s)

c = wave speed (m/s, ft/s)

A = cross-sectional area (m^2, ft^2 h)

g = gravitational acceleration (9.81 m/s^2, 32.17 ft/s^2)

Wave Speed

The wave speed, c, is influenced by the elasticity of the pipe wall. For a pipe system with some degree of axial restraint a good approximation for the wave propagation speed is obtained using

$$c = \sqrt{\frac{E_f / \rho}{1 + K_R \dfrac{E_f D}{E_c t}}}$$

where E_f = elastic modulus of the fluid (for water, 2.19 GN/m^2, 0.05 Glb/ft^2)

ρ = density of the fluid (for water, 998 kg/m^3, 1.94 slug/ft^3)

E_c = elastic modulus of the conduit (GN/m^2, Glb/ft^2)

D = pipe diameter (mm, inch)

t = pipe thickness (mm, inch)

K_R = coefficient of restraint for longitudinal pipe movement.

The constant K_R takes into account the type of support provided for the pipeline. Typically, three cases are recognized with K_R defined for each as follows (m is the Poisson's ratio for the pipe material):

Case a: The pipeline is anchored at the upstream end only.

$K_R = 1 - m / 2$

Case b: The pipeline is anchored against longitudinal movement.

$K_R = 1 - m^2$

Case c: The pipeline has expansion joints throughout.

$K_R = 1$

The following table provides physical properties of common pipe materials.

Table 3-8: Physical Properties of Common Pipe Materials

Material	Young's Modulus (E_C)		Poisson's Ratio, μ
	GN/m^2	Glb/ft^2	
Asbestos Cement	23 - 24	0.53 - 0.55	-
Cast Iron	80 - 170	1.8 - 3.9	0.25 - 0.27
Concrete	14 - 30	0.32 - 0.68	0.1 - 0.15
Reinforced Concrete	30 - 60	0.68 - 1.4	-

Ductile Iron	172	3.93	0.3
PVC	2.4 - 3.5	0.055 - 0.08	0.46
Steel	200 - 207	4.57 - 4.73	0.30

Inertia of Pumps and Motors

The combined inertia of pumps and motors driving them, including the connecting shafts and couplings, is required for transient analysis associated with the starting and stopping of pumps. The equations provided below are intended to be used as an initial guide to the inertia values that may be used as a reasonable first approximation, when more accurate data is not available. The total inertia for the pump/motor unit is the sum of both pump and motor inertias. The following inertia calculations are based on Thorley (2004).

Pump Inertias

From the linear regression analysis of 300 pump inertia data, two equations were developed for predicting the inertia I of pump impellers, including the entrained water and the shaft on which the impeller is mounted. The first equation represents the upper set of the data, and applies to single- and double-entry impellers, single and multistage, and horizontal and vertical, spindle machines.

$$I = C_1\left(\frac{P}{(N/1000)^3}\right)^{0.9556}$$

where I = pump inertia (kg m^2, lb ft^2)

C_1 = coefficients (0.03768, 0.6674)

P = power (kW, hp)

N = pump speed (rev/min)

The second equation is for lower set of the data and represents relatively small, single-entry, radial flow impellers of lightweight design. This is applied to relatively small pumps of lightweight design.

$$I = C_2\left(\frac{P}{(N/1000)^3}\right)^{0.844}$$

where C_2 = coefficients (0.03407 in SI, 0.6244 in English)

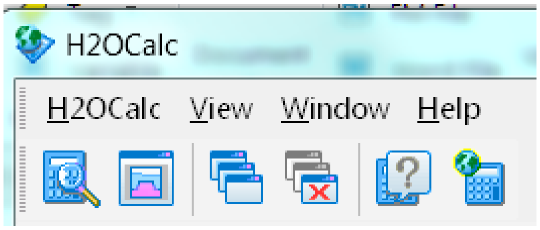
Motor Inertias

Similar to pump inertia, linear regression of the motor inertia data yields the following equations.

$$I = C_3\left(\frac{P}{(N/1000)^3}\right)^{1.48}$$

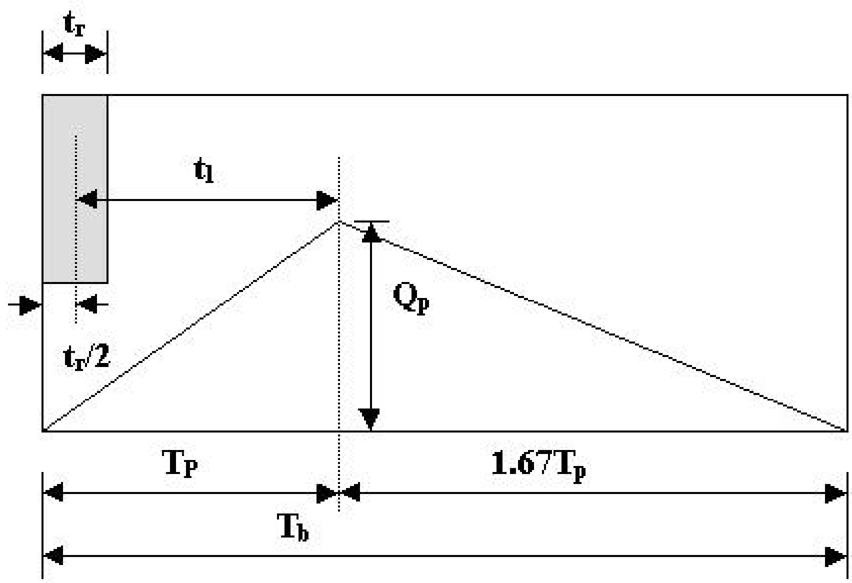
where C_3 = coefficients (0.0043 in SI, 0.0648 in English).

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

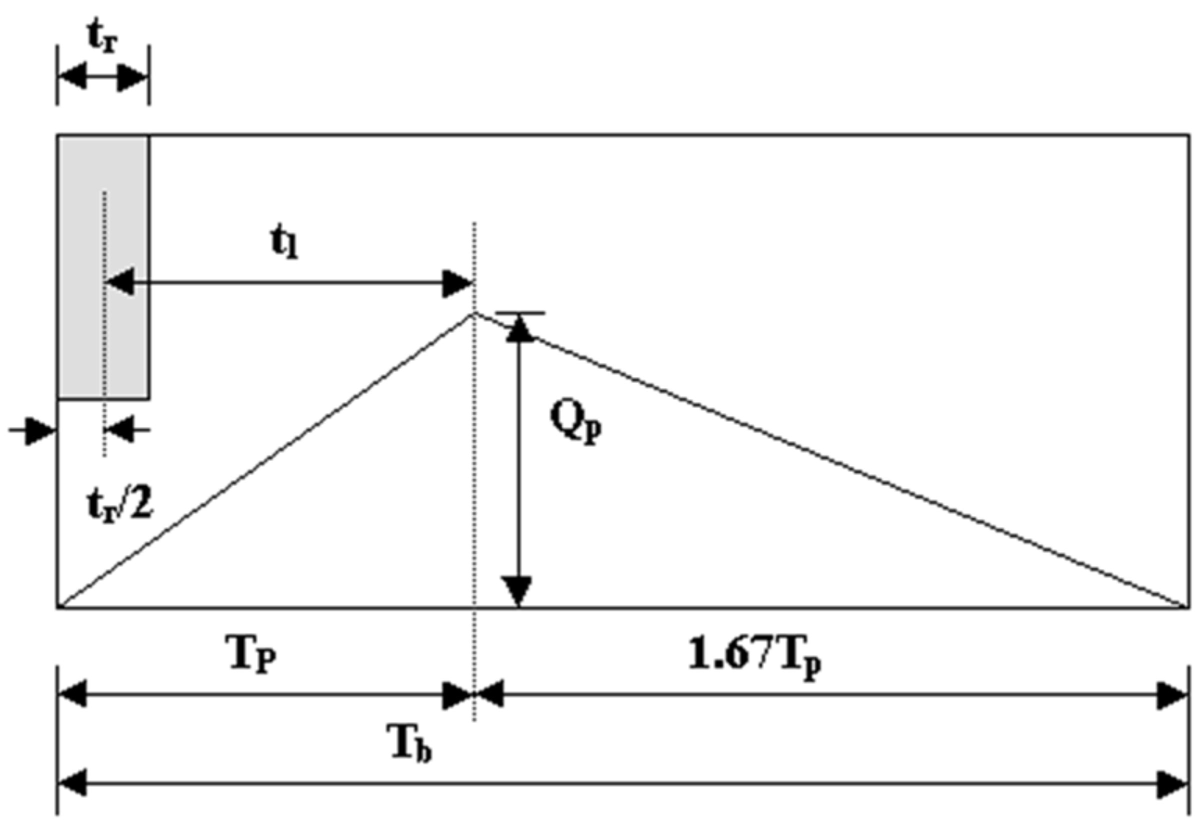

H2OCalc
H2OCalc View Window Help

NRCS (SCS) Triangular Unit Hydrograph Method

The SCS has also developed a triangular unit hydrograph (USDA 1986) (see figure below) that is an approximation to the dimensionless unit hydrograph described above. The triangular unit hydrograph is entirely defined in terms of three points, Q_p, T_p, and T_b. The lag time, time to peak, and peak flow rate are calculated using the same equations as for the dimensionless unit hydrograph.



t_r
t_l
Q_p
$t_r/2$
T_P
$1.67T_p$
T_b



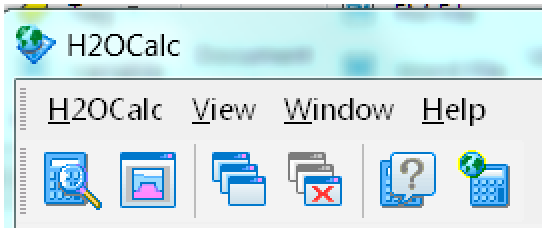
t_r
t_l
Q_p
$t_r/2$
T_P
$1.67T_p$
T_b

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

Delmarva Unit Hydrograph

As previously described, the NRCS dimensionless unit hydrograph and the NRCS triangular unit hydrograph are extensively used to develop storm Hydrographs for hydrologic evaluation and design of soil and water resources management practices throughout the United States. However, in areas such as the Delmarva Peninsula where the local topography is flat and where considerable surface storage is available, shape of observed storm Hydrographs significantly differ from those generated using the NRCS unit Hydrographs. As a result, a unit hydrograph that is similar with the NRCS dimensionless unit hydrograph, but with modifications to better represent the runoff characteristics of the Delmarva Peninsula has been used by utilities in the states of Delaware, Maryland, Virginia, and some parts of New Jersey. This unit hydrograph is known as the Delmarva unit hydrograph.

The Delmarva unit hydrograph uses the following equation to estimate peak flow rate.

$$Q_p = \frac{284A}{T_p}$$

where

Q_p = peak flow rate in cfs.

A = area of the watershed, in square miles, draining to the location of the unit hydrograph.

Tp = time to peak of the unit hydrograph in hour

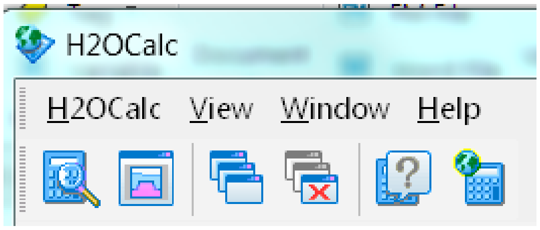
Time to peak, and lag time are calculated according to Equations 97 and 98, respectively. When compared with the NRCS methods, the Delmarva unit hydrograph produces lower peak flow rate but yields the same flow volume.

Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

The Colorado Urban Hydrograph Procedure

The Colorado Urban Hydrograph Procedure (CUHP) uses the equations and procedures presented in the Urban Drainage Criteria Manual (USDCM) of the Urban Drainage and Flood Control District (UDFCD 2001). Shape of the CUHP synthetic unit hydrograph is determined using the following equations that relate unit hydrograph parameters to catchment properties.

Lag time (t_l) of the watershed (catchment), defined as the time from the center of unit storm duration to the peak of the unit hydrograph, is determined as:

$$t_l = C_t \left(\frac{(L \cdot L_{Ca}}{\sqrt{S}} \right)^{0.48}$$

where t_l = lag time in hours.

L = length along the drainageway path from study point to the most upstream limits of

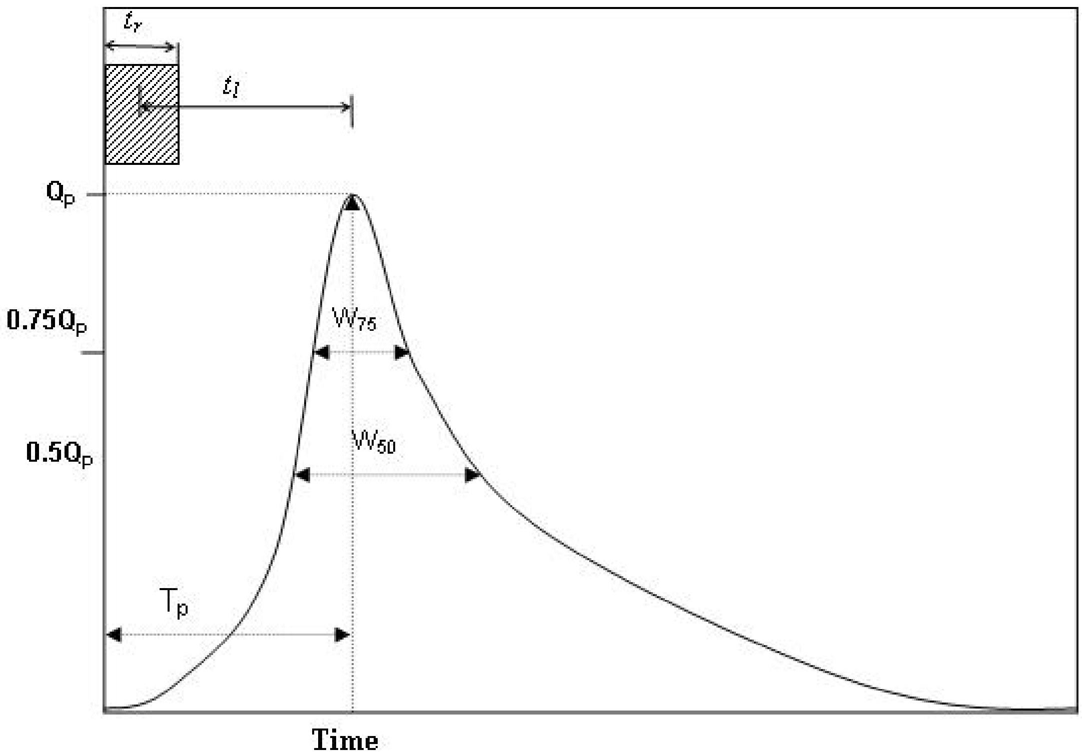
the catchment in miles.

L_{ca} = length along stream from study point to a point along stream adjacent to the centroid

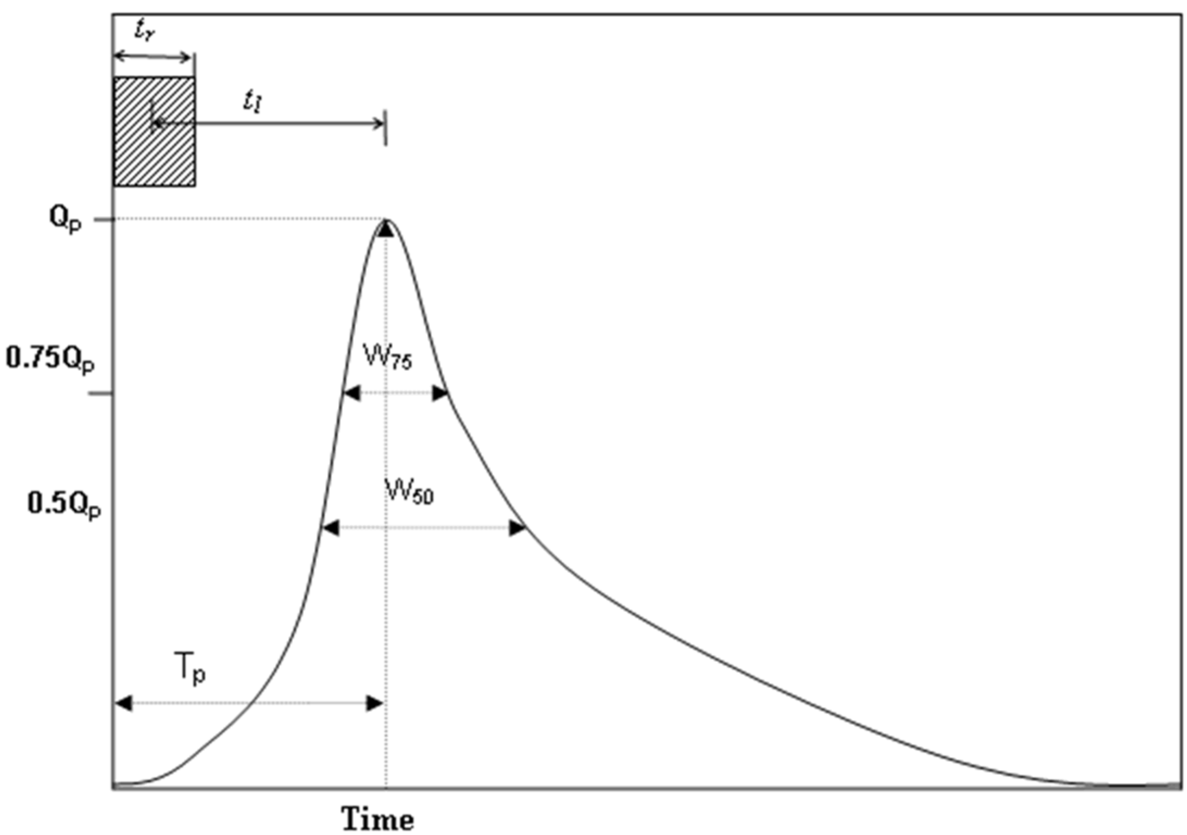
of the catchment in miles.

S = length weighted average slope of catchment along drainageway path to upstream limits of the catchment.

C_t = time to peak coefficient.



t_r
t_l
Q_p
$0.75Q_p$
W_{75}
$0.5Q_p$
W_{50}
T_p
Time



t_r
t_l
Q_p
$0.75Q_p$
W_{75}
$0.5Q_p$
W_{50}
T_p
Time

Once the lag time is known, time to peak (T_p) of the unit hydrograph could be determined by adding $0.5t_r$ to the lag time in consistent units.

Peak flow rate, Q_p, of the unit hydrograph is calculated as:

$$Q_p = \frac{640 C_p A}{T_p}$$

where Q_p = peak flow rate of the unit hydrograph, in cfs.

A = area of the catchment, in square miles.

C_p = unit hydrograph peaking coefficient, and is determined as:

$$C_p = P \cdot C_t \cdot A^{0.15}$$

where P = peaking parameter.

C_t and P are defined in terms of percent impervious (I_a) of the catchment as:

$$C_t = aI_a^2 + bI_a + c$$

$$P = dI_a^2 + eI_a + f$$

The coefficients *a*, *b*, *c*, *d*, *e*, and *f* are defined in terms of I_a in the following table.

IA	***A***	***B***	***C***	***D***	***E***	***F***
***Ia* ≤ 10**	0.0	-0.00371	0.163	0.00245	-0.012	2.16

10 < Ia ≤ 40	0.000023	-0.00224	0.146	0.00245	-0.012	2.16
***Ia* > 40**	0.0000033	-0.000801	0.120	-0.00091	0.228	-2.06

The widths of the unit hydrograph at 50% and 75% of the peak are estimated as:

$$W_{50} = \frac{500}{\left(\dfrac{Q_p}{A}\right)}$$

$$W_{75} = \frac{260}{\left(\dfrac{Q_p}{A}\right)}$$

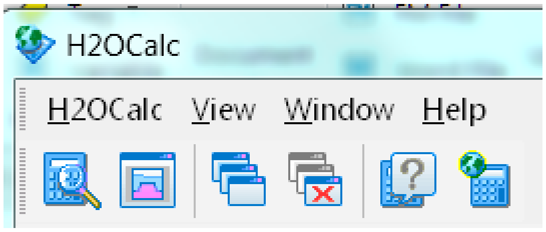
where W_{50} = width of the unit hydrograph at 50% of the peak, in hours.

W_{75} = width of the unit hydrograph at 75% of the peak, in hours.

Q_p = peak flow rate, in cfs.

A = catchment area, in square miles.

It is recommended that a unit hydrograph duration of 5-minute be used for studies that apply the CUHP. The maximum recommended drainage area (catchment size) for any single CUHP unit hydrograph is 5 square miles. Whenever a larger watershed is studied, it needs to be subdivided into Subcatchments of 5-square miles or less. For this synthetic unit hydrograph method, the minimum drainage area should be 90 acres. For catchments smaller than 90 acres, other unit hydrograph generation mechanisms should be used.


H2OCalc
H2OCalc View Window Help

Snyder Unit Hydrograph Method

Snyder's method for unit hydrograph synthesis relates the time from the centroid of the excess rainfall to the peak of the unit hydrograph, also referred to as lag time, to geometric characteristics of the basin in order to derive critical points for interpolating the unit hydrograph. Lag time is evaluated by

$$t_L = C_1 C_t (L L_{CA})^{0.3}$$

where t_L is in hrs; C_1 is a constant equal to 1.0 in U.S. customary units and 0.75 in S.I. units; C_t is an empirical watershed storage coefficient, which generally ranges from 1.8 to 2.2; L is the length of the main stream channel in mi or km; and L_{CA} is the length of stream channel from a point nearest the center of the basin to the outlet in mi or km.

The standard duration of excess rainfall is computed empirically by

$$t_r = \frac{t_L}{5.5}$$

Adjusted values of lag time, t_{La}, for other durations of rainfall excess can be obtained by

$$t_{La} = t_L + 0.25(t_{ra} - t_r)$$

where t_{ra} is the alternative unit hydrograph duration. Time to peak discharge can be computed as a function of lag time and duration of excess rainfall, expressed as

$$t_p = t_{La} + 0.5 t_{ra}$$

The peak discharge, Q_p is defined as

$$Q_p = \frac{C_2 C_p A}{t_{La}}$$

where Q_p is in cfs/in or m^3/s/m; C_2 is a constant equal to 640 in U.S. customary units and 2.75 in S.I. units; A is drainage area in mi^2 or km^2; and C_p is a second empirical constant ranging from approximately 0.5 to 0.7. Coefficients C_t and C_p are regional parameters that should be calibrated or be based on values obtained for similar gaged drainage areas. The ultimate shape of Snyder's unit hydrograph is primarily controlled by two parameters, W_{50} and W_{75}, which represents widths of the unit hydrograph at discharges equal to 50 and 75 percent of the peak discharge, respectively. These shape parameters can be evaluated by

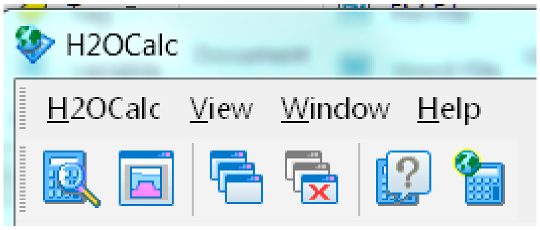
$$W_{50} = C_{50}\left(\frac{A}{Q_p}\right)^{1.08}$$

and

$$W_{75} = C_{75}\left(\frac{A}{Q_p}\right)^{1.08}$$

where C_{50} is a constant equal to 770 in U.S.

where C_{50} is a constant equal to 770 in U.S. customary units and 2.14 in S.I. units; and C_{75} is a constant equal to 440 in U.S. customary units and 1.22 in S.I. units. The location of the end points for W_{50} and W_{75} are often placed such that one-third of both values occur prior to the time to peak discharge and the remaining two-thirds occur after the time to peak. Finally, the base time, or time from beginning to end of direct runoff, should be evaluated such that the unit hydrograph represents 1 in (or 1 cm in S.I. units) of direct runoff volume. With known values of t_p, Q_p, W_{50}, and W_{75}, along with the adjusted base time, one can then locate a total of seven unit hydrograph ordinates.


H2OCalc
H2OCalc View Window Help

Clark Unit Hydrograph Method

Clark's method derives a unit hydrograph by explicitly representing the processes of translation and attenuation, which are the two critical phenomena in transformation of excess rainfall to runoff hydrograph. Translation refers to the movement, without storage, of runoff from its origin to the watershed outlet in response to gravity force, where as attenuation represents the reduction of runoff magnitude due to resistances arising from frictional forces and storage effects of soil, channel, and land surfaces. Clark (1945) noted that the translation of flow through the watershed could be described by a time-area curve (see Figure below), which expresses the curve of the fraction of watershed area contributing runoff to the watershed outlet as a function of travel time since the start of effective precipitation. Each subarea is delineated so that all the precipitation falling on the subarea instantaneously has the same time of travel to the outflow point.

Developing a time-area curve for a watershed could be a time consuming process. For watersheds that lack derived time-area diagram, the HEC-HMS model, which was developed at the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers, uses the following relationship (HEC, 2000)

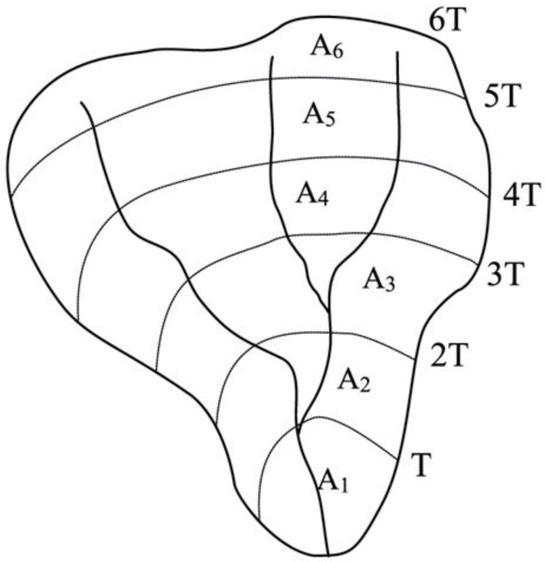
$$\frac{A_{c,t}}{A_T} = \begin{cases} 1.414\left(\dfrac{t}{t_c}\right)^{1.5} & \text{for} \quad t \le \dfrac{t_c}{2} \\ 1 - 1.414\left(1 - \dfrac{t}{t_c}\right)^{1.5} & \text{for} \quad t \ge \dfrac{t_c}{2} \end{cases}$$

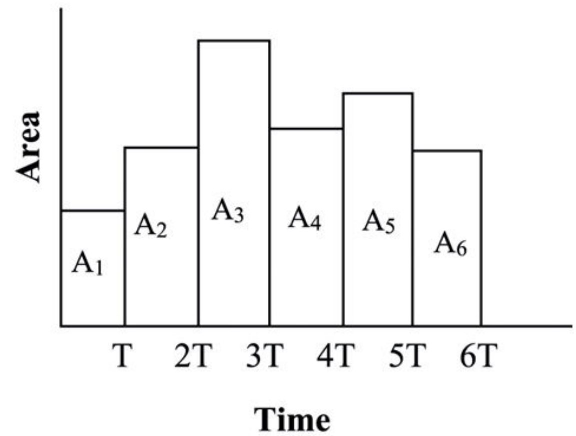
where $A_{c,t}$ is cumulative watershed area contributing at time t; A_T is total watershed area; and t_c is time of concentration of the watershed. If the incremental areas, denoted as A_i in the figure below, are multiplied by a unit depth of excess rainfall and divided by Δt, the computational time step, the result is a translated hydrograph that is considered as an inflow to a conceptual linear reservoir located at the watershed outlet.

To account for storage effects, the attenuation process is modeled by routing the translated hydrograph through a linear reservoir with storage properties similar to those of the watershed. The routing model is based on the mass balance equation

$$\frac{dS}{dt} = I_t - Q_t$$

where ***dS/dt*** is time rate of change of water in storage at time *t*; I_t is average inflow, obtained from the time-area curve, to storage at time *t*; and Q_t is outflow from storage at time *t*.





For linear reservoir model, storage is related to outflow as

$$S_t = RQ_t$$

where *R* is a constant linear reservoir parameter that represents the storage effect of the watershed. Usually, lag time (t_L) is used as an approximation to *R*. Combining and solving Equations 116 and 117 using a finite difference approximation provides

$$Q_t = C_1 I_t + C_2 Q_{t-1}$$

where C_1 and C_2 are routing coefficients calculated as

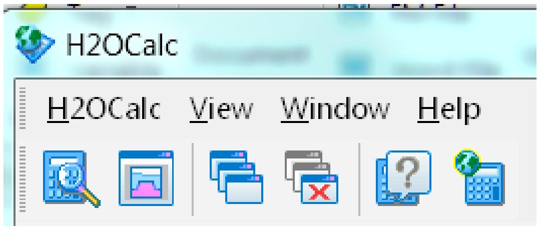
$$C_1 = \frac{\Delta t}{R + 0.5\Delta t}$$

$$C_2 = 1 - C_1$$

The average outflow during period *t* is

$$\bar{Q}_t = \frac{Q_{t-1} + Q_t}{2}$$

If the inflow, I_t, ordinates are runoff from a unit depth of excess rainfall, the average outflows derived by Equation 121 represent Clark's unit hydrograph ordinates. Clark's unit hydrograph is, therefore, obtained by routing a unit depth of direct runoff to the channel in proportion to the time-area curve and routing the runoff entering the channel through a linear reservoir. Note that solution of Equations 118 and 121 is a recursive process. As such, average outflow ordinates of the unit hydrograph will theoretically continue for an infinite duration. Therefore, it is customary to truncate the recession limb of the unit hydrograph where the outflow volume exceeds 0.995 inches or mm. Clark's method is based on the premise that duration of the rainfall excess is infinitesimally small. Because of this, Clark's unit hydrograph is referred to as an instantaneous unit hydrograph or IUH. In practical applications, it is usually necessary to alter the IUH into a unit hydrograph of specific duration. This can be accomplished by lagging the IUH by the desired duration and averaging the ordinates.


H2OCalc
H2OCalc View Window Help

Espey Unit Hydrograph Method

After analyzing runoff records from 41 urban watersheds located in eight different states in the United States with areas ranging from 9 acres to 15 mi^2 and with percent imperviousness ranging from 2 to 100, Espey and Altman (1978) developed a 10-minute unit hydrograph for urban watersheds. This unit hydrograph is commonly named as Espey 10-minute unit hydrograph, and the following equations are used to determine its ordinates.

$$t_p = \frac{3.1 L^{0.23} \phi^{1.57}}{S^{0.25} IMP^{0.18}}$$

$$Q_p = \frac{31{,}620 A^{0.96}}{t_p^{1.07}}$$

$$t_b = \frac{125{,}890 A}{Q_p^{0.95}}$$

$$W_{50} = \frac{16{,}220 A^{0.93}}{Q_p^{0.92}}$$

$$W_{75} = \frac{3{,}240 A^{0.79}}{Q_p^{0.78}}$$

According to Espey and Altman (1978) method, slope is calculated as:

$$S = \frac{H}{0.8L}$$

where t_p = time to peak in minutes.

Q_p = peak discharge in ft^3/sec.

t_b = total hydrograph base in minutes.

W_{50} = hydrograph widths at 50% of the peak discharge rates in minutes.

W_{75} = hydrograph widths at 75% of the peak discharge rates in minutes.

A = area in mi^2.

L = length in ft.

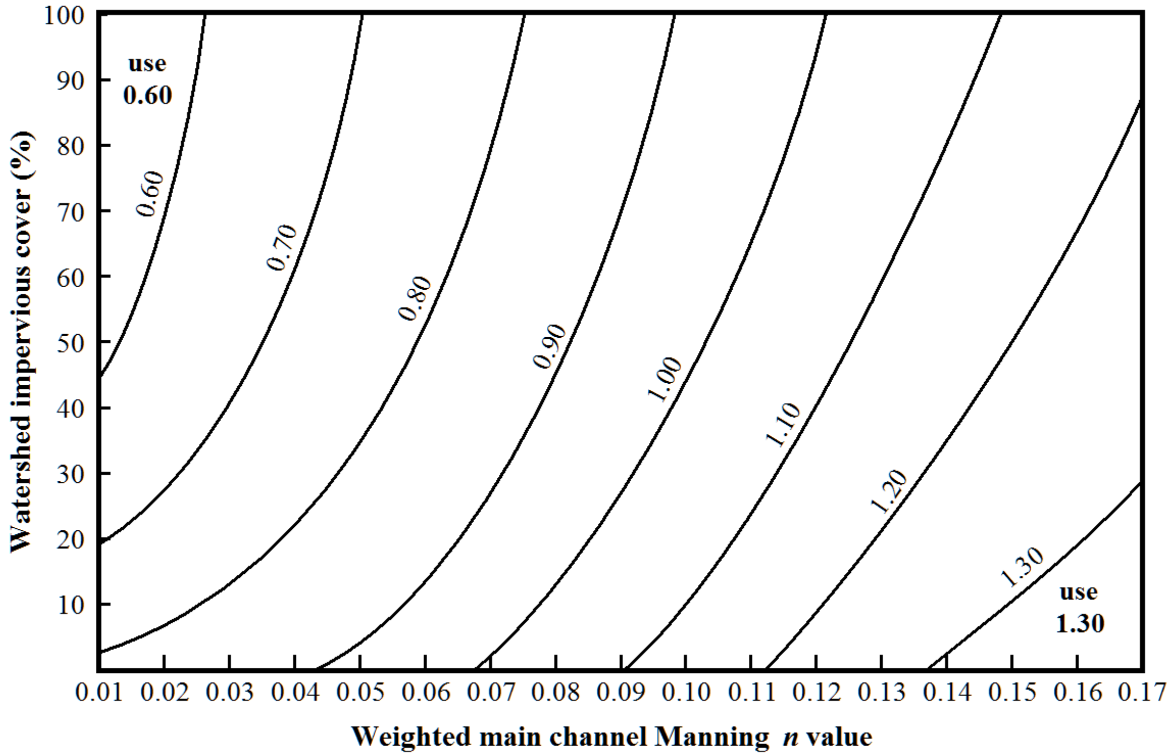
S = watershed slope in ft/f.

IMP = roughness and percent imperviousness.

H = is the elevation difference in the channel bottom at design point and

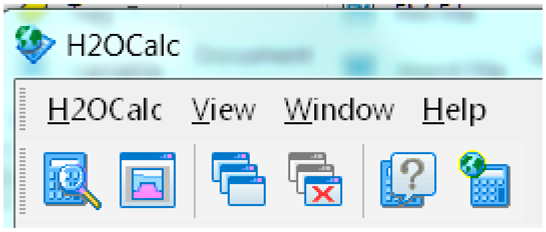
$0.8L$ upstream (ft).

f = conveyance factor, dimensionless. This factor depends on the percent imperviousness and weighted main channel Manning roughness coefficient is determined graphically from the following figure.



The shape parameters, W_{50} and W_{75}, are to be drawn parallel to the abscissa and are usually located such that one third of the width is located to the left of the time to peak. Once the equations are solved and the seven ordinates that govern the general shape of the 10-minute unit hydrograph are determined, a smooth curve is then fit through these points and adjusted until the volume of direct runoff is equivalent to one inch over the watershed.

Searching the Internet for #INFOSWMM


H2OCalc
H2OCalc View Window Help

San Diego Modified Rational Formula

The Rational method is a widely used technique for estimation of peak flows from urban and rural drainage basins (Maidment 1993; Mays 2001). Mathematically, the Rational formula is expressed as:

$$Q = CIA$$

where Q = peak runoff rate (flow unit)

C = runoff coefficient (unitless)

I = rainfall intensity (intensity unit)

A = watershed area (area unit)

Stormwater modeling applications such as the design of detention basins require knowledge of total inflow volume obtained from runoff Hydrographs. For these applications peak flow information alone may not be sufficient. The San Diego modified rational formula is a technique adopted by the San Diego County to generate runoff hydrograph by extending the traditional rational formula.

The San Diego County uses a 6-hour storm event for many Stormwater design applications. Accordingly, for designs that are dependent on total storm volume a hydrograph has to be generated by creating a rainfall distribution consisting of blocks of rain, creating an incremental hydrograph for each block of rain using the modified rational formula, and adding the Hydrographs from each block of rain where each rainfall block lasts for a duration of time of concentration. The rainfall blocks are distributed across the 6-hour duration using the “2/3, 1/3” distribution in which the peak rainfall block is centered at the 4-hour time within the 6-hour rainfall duration, and the additional blocks are distributed in a sequence alternating two blocks to the left and one block to the right of the 4-hour time. The actual rainfall amount for each rainfall block is calculated as:

$$P_N = 0.124 P_{6-hr}\left((NT_c)^{0.355} - ((N-1)T_c)^{0.355}\right)$$

where PN = actual rainfall amount for each rainfall block (inch or mm)

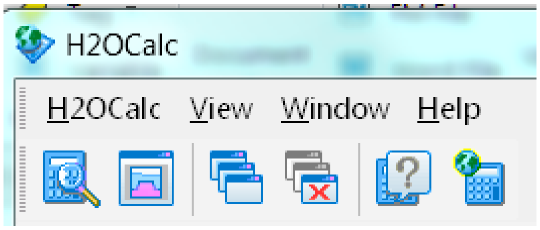
P6-hr = six-hour storm depth (inch or mm)

N = an integer representing position of a given block number of rainfall. N is 1 for the peak rainfall block, and is assigned according to the "2/3, 1/3" distribution rule for other rainfall blocks.

Tc = time of concentration (minutes)

Once rainfall distribution is created, triangular hydrograph is generated for each rainfall block. Peak flow for the triangular hydrograph is computed according to the rational formula. Finally, the overall hydrograph for the 6-hr storm event is determined by adding all the triangular Hydrographs from each block of rain. The final hydrograph has its peak at 4 hours plus ½ of the Tc. The total volume under the hydrograph is the product of runoff coefficient, the six-hour precipitation depth, and area of the Subcatchment.

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

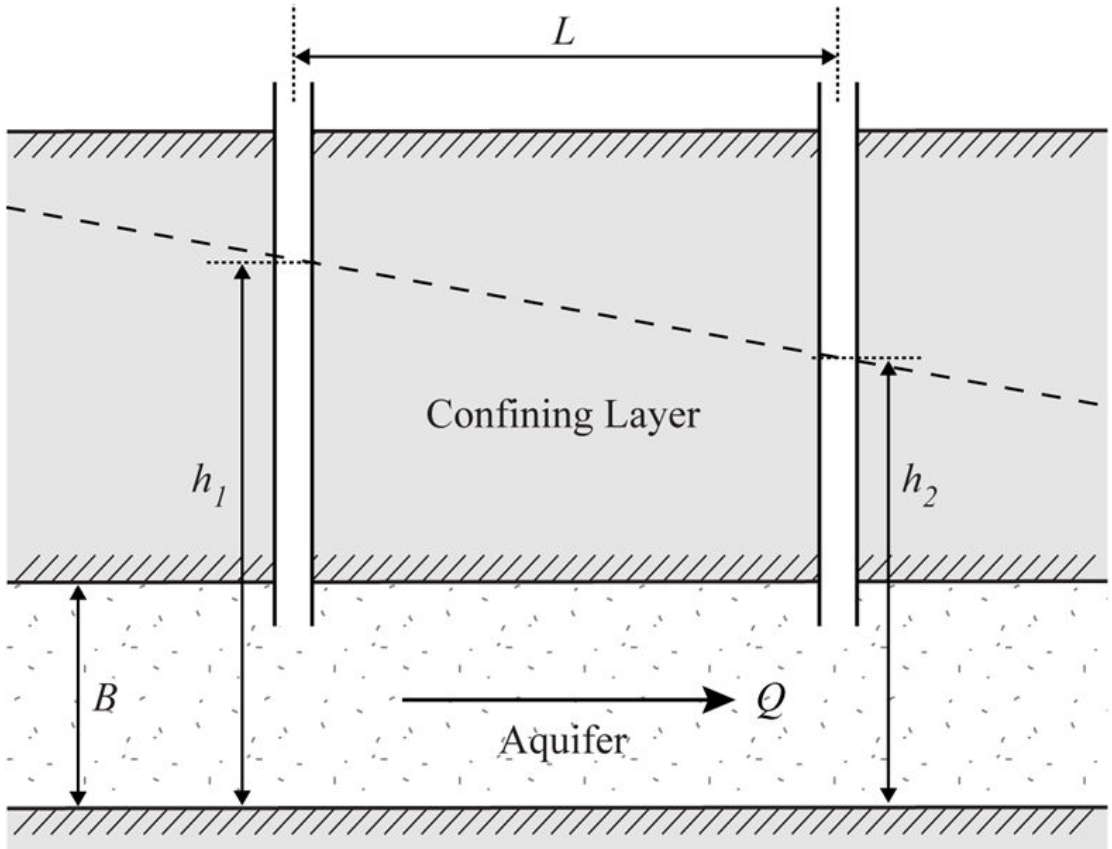

H2OCalc
H2OCalc View Window Help

3.16 Groundwater Flow

Groundwater has always been one of the most important sources of water supply. Virtually all parts of the earth are underlain by water, and wells have been constructed to provide a water supply when surface water was not readily available. Groundwater-bearing formations which are sufficiently permeable to yield usable quantities of water are called aquifers. When an aquifer is not overlain by an impermeable layer it is said to be unconfined. Confined aquifers consist of a water-bearing layer contained between two less permeable layers. This section presents the calculation of the steady flow in the confined or unconfined aquifers. It also presents the well hydraulics in confined or unconfined steady flow.

Steady Flow in a Confined Aquifer

If there is the steady movement of ground water in a confined aquifer, there will be a gradient or slope to the potentiometric surface of the aquifer. A portion of a confined aquifer of uniform thickness is shown in the following figure. The potentiometric surface has a linear gradient. There are two observation wells where the hydraulic head can be measured.



Steady Flow in a Confined Aquifer

For flow of this type, Darcy's law may be used directly.

$$q = -KB\frac{dh}{dl} = -KB\frac{h_2 - h_1}{L}$$

where q = flow rate per unit width of aquifer (m^2/d, ft^2/d)

K = hydraulic conductivity of aquifer (m/d, ft/d) (see Table 3-13)

dh/dl = hydraulic gradient

B = aquifer thickness (m, ft)

L = flow length (m, ft)

h_2 = head at length L (m, ft)

h_1 = head at the origin (m, ft)

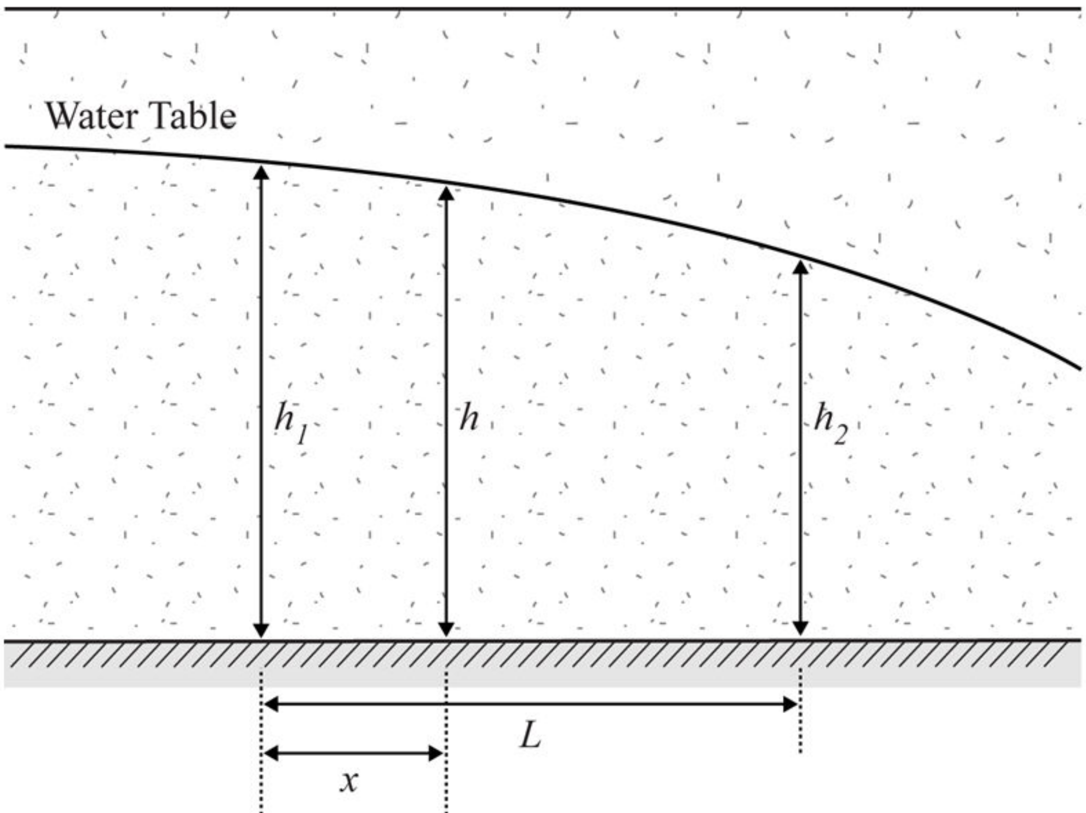
Table 3-13: Soil Properties

Soil Type	Hydraulic Conductivity, K (cm/s)
Clayey	10^{-9} - 10^{-6}
Silty	10^{-7} - 10^{-3}
Sandy	10^{-5} - 10^{-1}
Gravelly	10^{-1} - 10^{2}

The aquifer transmissivity is defined as a measure of the amount of water that can be transmitted horizontally through a unit width by the fully saturated thickness of the aquifer under a hydraulic gradient of 1. The transmissivity, T, (m^2/d, ft^2/d) is the product of the hydraulic conductivity (K) and the saturated thickness of the aquifer (B) as

$$T = BK$$

Steady Flow in an Unconfined Aquifer



Steady Flow in an Unconfined Aquifer

In an unconfined aquifer, the fact that the water table is also the upper boundary of the region of flow complicates flow determinations. This problem was solved by Dupuit who made the following simplifying assumptions: (1) the hydraulic gradient is equal to the slope of the water table and (2) for small water-table gradients, the streamlines are horizontal and the equipotential lines are vertical. Using these assumptions, Depuit developed Equation (102), commonly known as the *Dupuit equation*.

$$q = \frac{1}{2} K \left(\frac{h_1^2 - h_2^2}{L} \right)$$

where q = flow rate per unit width of aquifer (m^2/d, ft^2/d)

K = hydraulic conductivity of aquifer (m/d, ft/d) (see Table 3-13)

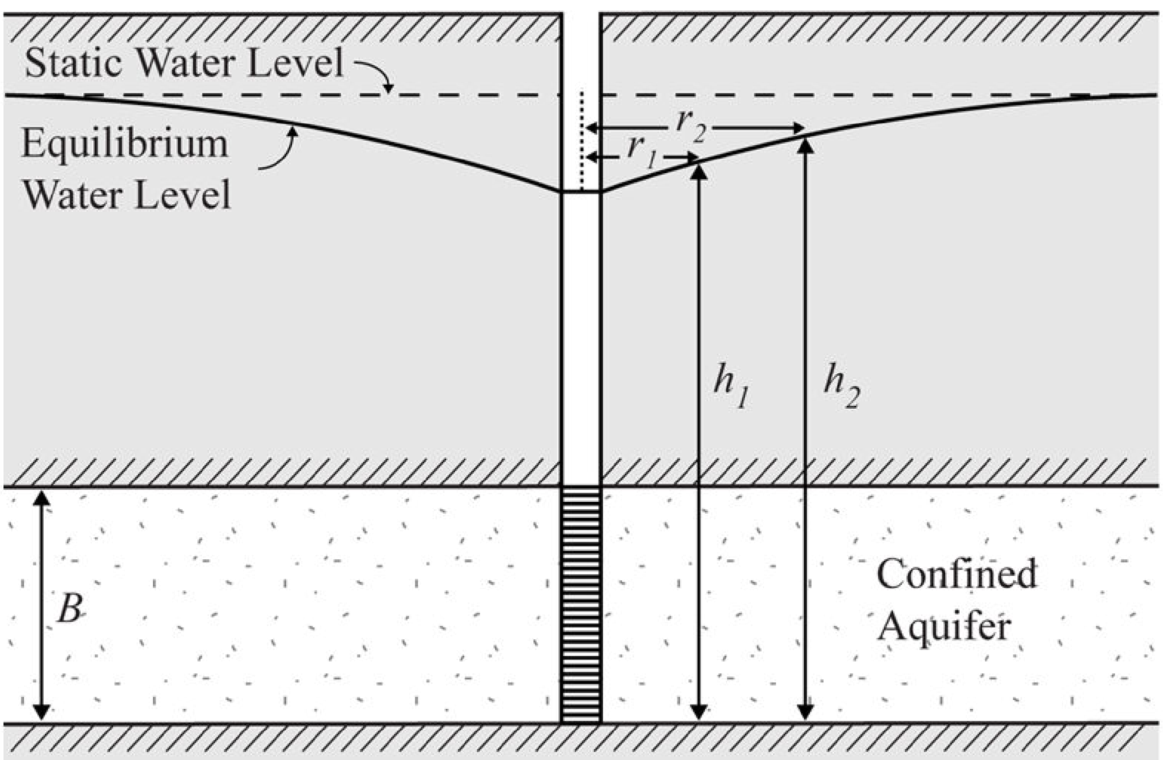
L = flow length (m, ft)

h_2 = head at length L (m, ft)

h_1 = head at the origin (m, ft)

Well Hydraulics of Confined Steady Flow

Darcy’s equation can be used to analyze axially symmetric flow into a well. If a well pumps long enough, the water level may reach a state of equilibrium; that is, there is no further drawdown with time. The following figure illustrates the flow conditions for a well in a confined aquifer.



Steady Flow to a Well in a Confined Aquifer

In the case of steady radial flow in a confined aquifer, the steady pumping rate is

$$Q = 2\pi KB \frac{h_2 - h_1}{\ln(r_2 / r_1)} \quad \text{or} \quad Q = 2\pi T \frac{h_2 - h_1}{\ln(r_2 / r_1)}$$

$$Q = 2\pi KB \frac{d_1 - d_2}{\ln(r_2 / r_1)} \quad \text{or} \quad Q = 2\pi T \frac{d_1 - d_2}{\ln(r_2 / r_1)}$$

where Q = pumping rate (m^3/d, ft^3/d)

K = hydraulic conductivity of aquifer (m/d, ft/d)

B = aquifer thickness (m, ft)

T = hydraulic transmissivity (m^2/d, ft^2/d)

h_2 = head at distance r_2 from the pumping well (m, ft) h_1 = head at distance r_1 from the pumping well (m, ft) d_2 = drawdown at distance r_2 from the pumping well (m, ft) d_1 = drawdown at distance r_1 from the pumping well (m, ft)

Well Hydraulics of Unconfined Steady Flow

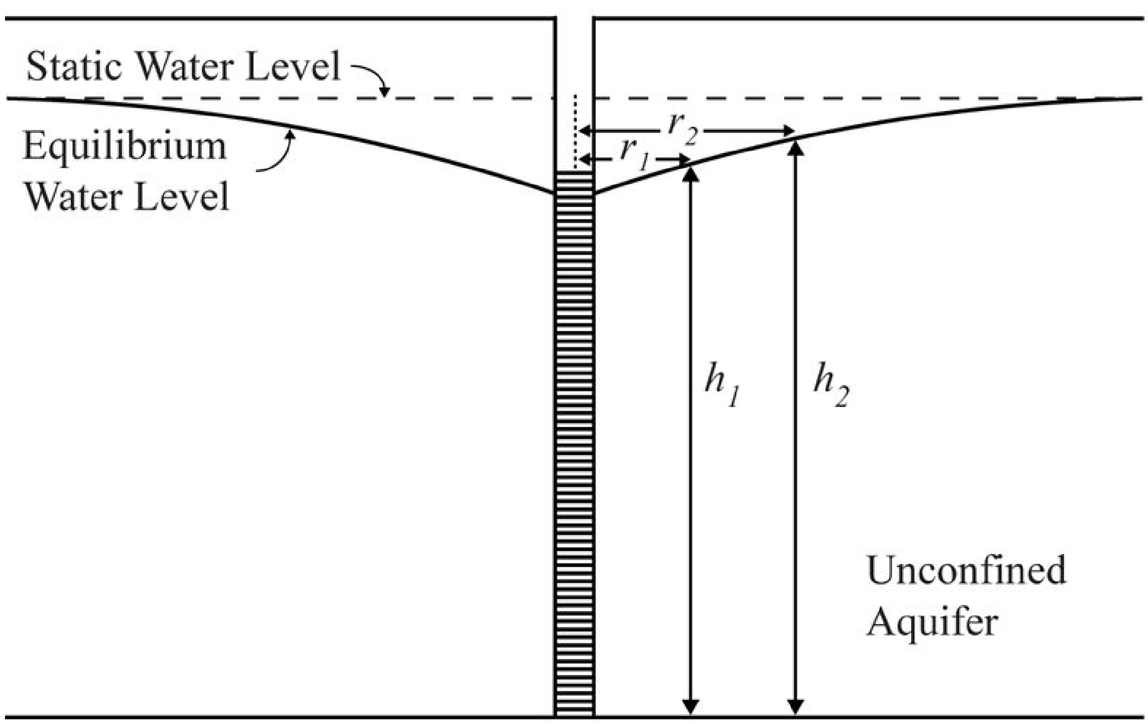
The following figure illustrates the flow conditions for a well in an unconfined aquifer. In the case of steady radial flow in an unconfined aquifer, the steady pumping rate is

$$Q = \pi K \frac{(h_2^2 - h_1^2)}{\ln(r_2 / r_1)}$$

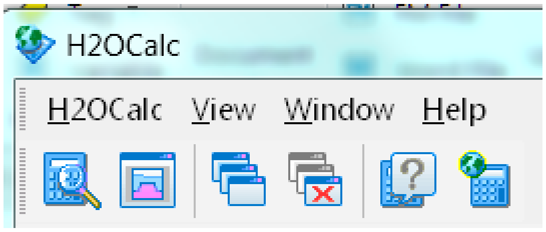
or

$$Q = \pi K \frac{(d_1^2 - d_2^2)}{\ln(r_2 / r_1)}$$

All the terms are consistent with the definitions given above.



Steady Flow to a Well in an Unconfined Aquifer

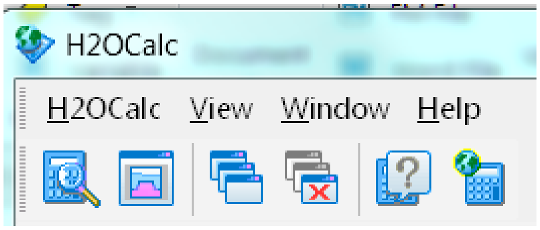

H2OCalc
H2OCalc View Window Help

Groundwater Hydrology

The Groundwater Flow Hydrology category solves Darcy’s equation, Dupuit equation (steady state groundwater flow for unconfined aquifers), well hydraulics for confined and unconfined aquifers, and EPA SWMM’s aquifer production equation. Click here for the methodology.

- Darcy's Equation
- Steady State Flow in Unconfined Aquifers (Dupuit Equation)
- Well Hydraulics for Confined Aquifers
- Well Hydraulics for Unconfined Aquifers
- EPA SWMM's Aquifer Production Equation

Innovyze® H2OCalc™ Modeling Made Easy Innovyze®


H2OCalc
H2OCalc View Window Help

Rational Formula

For small drainage areas, peak runoff is commonly estimated by the rational method. This method is based on the principle that the maximum rate of runoff from a drainage basin occurs when all parts of the watershed contribute to flow and that rainfall is distributed uniformly over the catchment area. Since it neglects temporal and spatial variability in rainfall, and ignores flow routing in the watershed, collection system, and any storage facilities, the rational method should be used with caution only for applications where the assumptions of rational method are valid.

The rational formula is expressed as

$$Q_p = KCiA \tag{96}$$

where Q_p = peak runoff rate (m3/s, ft3/s)

C = dimensionless runoff coefficient (see Table 3-9)

I = average rainfall intensity (mm/hr, in/hr) for a duration of the time of concentration (tc)

A = drainage area (km2, acres)

K = conversion constant (0.28 in SI, 1 in English)

The time of concentration tc used in the rational method is the time associated with the peak runoff from the watershed to the point of interest. Runoff from a watershed usually reaches a peak at the time when the entire watershed is contributing; in this case, the time of concentration is the time for a drop of water to flow from the remotest point in the watershed to the point of interest. Time of concentration, tc (min), for the basin area can be computed using one of the formulas listed in Table 3-11.

Table 3-9: Runoff Coefficients for 2 to 10 Year Return Periods

Description of drainage area			Runoff coefficient
Business	Downtown		0.70-0.95
	Neighborhood		0.50-0.70
Residential	Single-family		0.30-0.50
	Multi-unit detached		0.40-0.60
	Multi-unit attached		0.60-0.75
Suburban			0.25-0.40
Apartment dwelling			0.50-0.70
Industrial	Light		0.50-0.80
	Heavy		0.60-0.90
Parks and cemeteries			0.10-0.25
Railroad yards			0.20-0.35
Unimproved areas			0.10-0.30
Pavement	Asphalt		0.70-0.95
	Concrete		0.80-0.95
	Brick		0.75-0.85
Roofs			0.75-0.95
Lawns	Sandy soils	Flat (2%)	0.05-0.10
		Average (2-7%)	0.10-0.15
		Steep (≥7%)	0.15-0.20
	Heavy soils	Flat (2%)	0.13-0.17
		Average (2-7%)	0.18-0.22
		Steep (≥7%)	0.25-0.35

Source: Nicklow et al. (2006)

Table 3-10: Formulas for Computing Time of Concentration

Method	Formula	
Kirpich (1940)	$t_c = 0.0078L^{0.77}S - 0.385$ L = length of channel (ft) S = average watershed slope (ft/ft)	
California Culverts Practice (1942)	$t_c = 60\left(11.9L^3 / H\right)^{0.385}$ L = length of the longest channel (mi) H = elevation difference between divide and outlet (ft)	
Izzard (1946)	$t_c = \dfrac{41.025(0.0007i + c)L^{1/3}}{S^{1/3}i^{2/3}}$ i = rainfall intensity (in/h) c = retardance coefficient	Retardance factor, c, ranges from 0.007 for smooth pavement to 0.012 for concrete and to 0.06 for dense turf; product i times L should be < 500
Federal Aviation Administration (1970)	$t_c = \dfrac{0.39(1.1 - C)L^{1/2}}{S^{1/3}}$ C = rational method runoff coefficient (see Table 3.9)	
Kinematic wave	$t_c = \dfrac{0.938L^{0.6}n^{0.6}}{i^{0.4}S^{0.3}}$ n = Manning's roughness coefficient	
SCS lag equation	$t_c = \dfrac{100L^{0.8}\left[(1000/CN) - 9\right]^{0.7}}{19000S^{1/2}}$ CN = SCS runoff curve number (see Table 3.11)	
SCS average velocity charts	$t_c = \dfrac{1}{60}\sum_{j=1}^{N}\left(L_j / V_j\right)$ V = average velocity (ft/s)	
Yen and Chow (1983)	$t_c = K_Y\left(\dfrac{NL}{S^{1/2}}\right)^{0.6}$ K_Y = Coefficient N = Overland texture factor (see Table 3.12)	K_Y ranges from 1.5 for light rain (i<0.8) to 1.1 for moderate rain (0.8<i<1.2), and to 0.7 for heavy rain (i>1.2)

Source: Nicklow et al. (2004)

Table 3-11: Runoff Curve Numbers for Urban Land Uses

Land use description	Soil Group			
	A	B	C	D
Lawns, open spaces, parks, golf courses:				
Good condition: grass cover on 75% or more area	39	61	74	80
Fair condition: grass cover on 50% to 75% of area	49	69	79	84
Poor condition: grass cover on 50% or less of area	68	79	86	89
Paved parking lots, roofs, driveways, etc	98	98	98	98
Streets and roads:				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Paved with open ditches	83	89	92	93
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Row houses, town houses and residential with lot sizes of 1/8 ac or less (65% impervious)	77	85	90	92
Residential average lot size:				
1/4 ac (38% impervious)	61	75	83	87
1/3 ac (30% impervious)	57	72	81	86
1/2 ac (25% impervious)	54	70	80	85
1 ac (20% impervious)	51	68	79	84
2 ac (12% impervious)	46	65	77	82
Developing urban area (newly graded; no vegetation)	77	86	91	94

Adapted from SCS (1985)

Table 3-12: Description of NRCS Soil Classifications

Group	Description	Min. infiltration (in/hr)
A	Deep sand; deep losses; aggregated silts	0.30-0.45
B	Shallow loess; sandy loam	0.15-0.30
C	Clay loams; shallows sandy loam; soils low in organic content; soils usually high in clay	0.05-0.15
D	Soils that swell significantly	0-0.05

Adapted from SCS (1985)

Table 3-13: Overland Texture Factor N

Overland flow surface	Low	Medium	High
Smooth asphalt pavement	0.010	0.012	0.015
Smooth impervious surface	0.011	0.013	0.015
Tar and sand pavement	0.012	0.014	0.016
Concrete pavement	0.014	0.017	0.020
Rough impervious surface	0.015	0.019	0.023
Smooth bare packed soil	0.017	0.021	0.025
Moderate bare packed soil	0.025	0.030	0.035
Rough bare packed soil	0.032	0.038	0.045
Gravel soil	0.025	0.032	0.045
Mowed poor grass	0.030	0.038	0.045
Average grass, closely clipped sod	0.040	0.055	0.070
Pasture	0.040	0.055	0.070
Timberland	0.060	0.090	0.120
Dense grass	0.060	0.090	0.120
Shrubs and bushes	0.080	0.120	0.180
Land use	**Low**	**Medium**	**High**
Business	0.014	0.022	0.35
Semi-business	0.022	0.035	0.050
Industrial	0.020	0.035	0.050
Dense residential	0.025	0.040	0.060
Suburban residential	0.030	0.055	0.080
Parks and lawns	0.040	0.075	0.120

Adapted from Yen and Chow (1983)

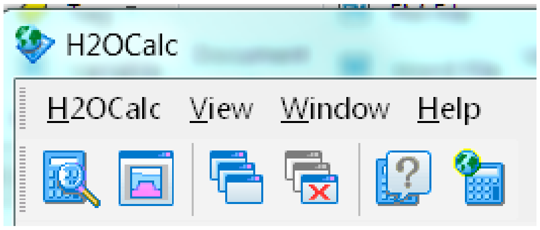
Innovyze Help File Updated September 1, 2017

InfoSWMM H_2OMap SWMM uses the EPA SWMM 5.1.012 Engine

More Questions? Further Help Can be Found by Emailing Support@Innovyze.com

or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

H2OCalc™
Modeling Made Easy



Santa Barbara Urban Hydrograph Method

As the name implies, this method was first developed for the Santa Barbara County Flood Control and Water Conservation District in 1975. However, its usage is not limited to Santa Barbara; it can be used at other places as well. The method is well suited for urban applications since it explicitly models impervious areas and pervious areas in a watershed.

The Santa Barbara Urban Hydrograph method generates the actual runoff hydrograph, not a unit hydrograph. According to this method losses from rainfall such as infiltration losses are neglected for the impervious areas, and are considered for pervious areas. Horton's method is used to determine infiltration losses from pervious areas for the method implemented in InfoSWMM. Once effective rainfall (i.e. rainfall excess) from the impervious and pervious portions of the watershed is known, an instantaneous hydrograph is determined according to the following equation:

$$I(t) = \left[i(t) \times IMP + i_{eff}(t)(1 - IMP) \right] A$$

where $I(t)$ = ordinate of the instantaneous hydrograph at time t in cfs.

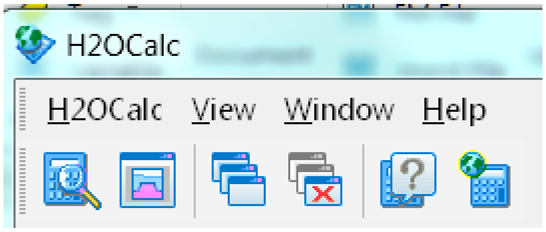
$i(t)$ = rate of rainfall at time t in in/hr.
$i_{eff}(t)$ = rate of rainfall excess for pervious area in in/hr
IMP = impervious area as a fraction of total area.
A = total drainage area in acres

One can see from the above equation that the instantaneous hydrograph is calculated based on the assumption that the rainfall excess is produced at the outlet of the subbasin. To account for the time actually needed to transport the effective rainfall to the subbasin outlet, the instantaneous hydrograph is routed through an imaginary linear reservoir according to the following equations to cause a time delay equal to the time of concentration of the subbasin.

$$Q(t) = Q(t-\Delta t) + C_r(I(t-\Delta t) + I(t) - 2Q(t-\Delta t))$$

$$C_r = \frac{\Delta t}{2T_c + \Delta t}$$

where Q = runoff hydrograph ordinate at the subbasin outlet in cfs.
T_c = time of concentration for the subbasin in time unit.
Δt = computational time interval in the time unit used for T_c.


H2OCalc
H2OCalc View Window Help

16. Groundwater Flow

Groundwater has always been one of the most important sources of water supply. Virtually all parts of the earth are underlain by water, and wells have been constructed to provide a water supply when surface water was not readily available. Groundwater-bearing formations which are sufficiently permeable to yield usable quantities of water are called aquifers. When an aquifer is not overlain by an impermeable layer it is said to be unconfined. Confined aquifers consist of a water-bearing layer contained between two less permeable layers. This section presents the calculation of the steady flow in the confined or unconfined aquifers. It also presents the well hydraulics in confined or unconfined steady flow.