InfoSWMM

Introduction to Sustain 4.0

InfoSWMM Sustain

sets a new standard in automated stormwater model calibration of BMP's and Low Impact Development (LID) Controls. Innovyze, a leading global innovator of business analytics software and technologies for smart wet infrastructure released InfoSWMM Sustain at the beginning of March 2015.

Designed in response to the needs of watershed and stormwater engineering professionals, this power tool lets users develop, evaluate, and select optimal best management practice (BMP) combinations at various watershed scales on the basis of cost and effectiveness. The Press Release for the Release of InfoSWMM Sustain can be viewed on **www.innovyze.com**. This is the 3rd major upgrade for InfoSWMM Sustain See **Sustain 2.0** and **Sustain 3.0**

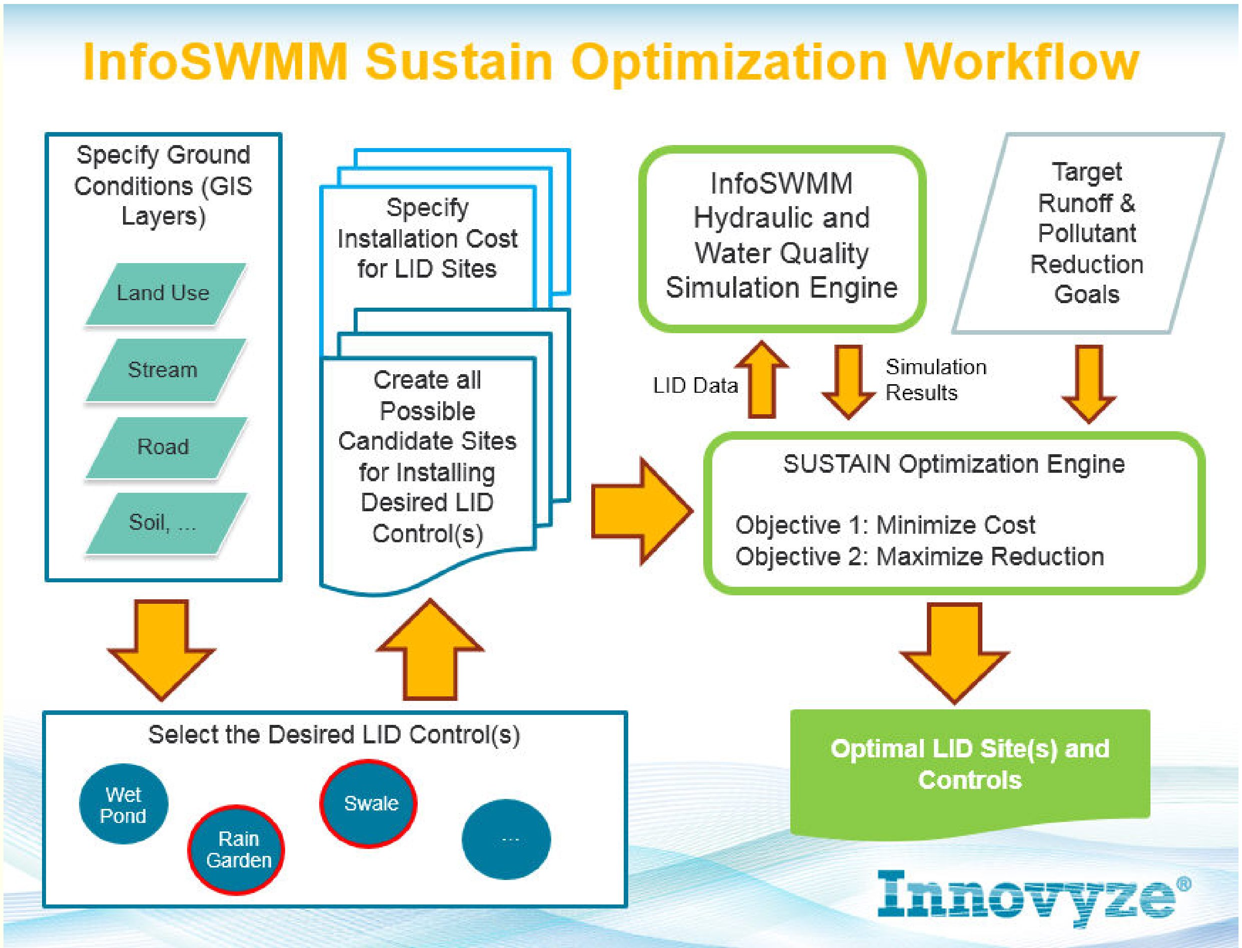
A Deeper Introduction

to infoSWMM Sustain PDF file can be viewed on the

Innovyze Website.

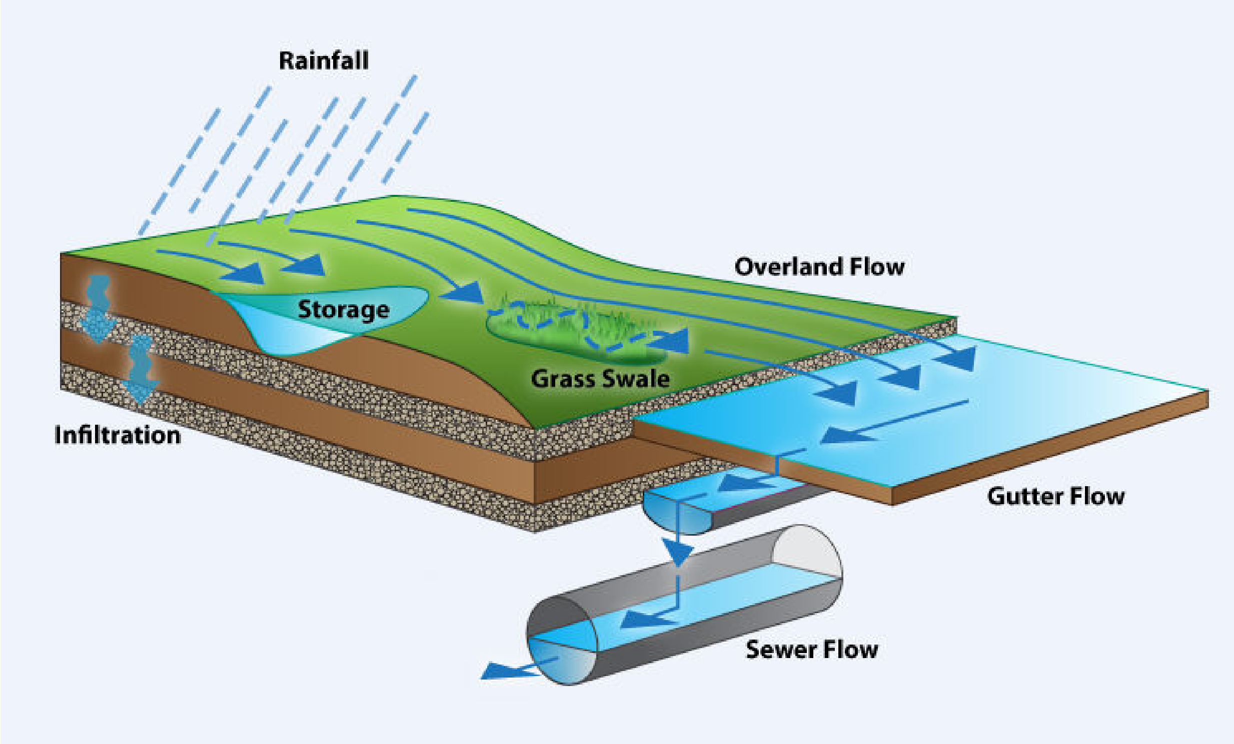
InfoSWMM Sustain is a comprehensive geocentric decision support system created to facilitate optimal selection and placement of BMPs and low impact development (LID) techniques at strategic locations in urban watersheds. It can accurately model any combination of LID controls, such as porous permeable pavement, rain gardens, green roofs, street planters, rain barrels, infiltration trenches, and vegetative swales, to determine their effectiveness in managing stormwater and combined sewer overflows.

Such capabilities can greatly assist users in developing cost-effective and reliable implementation plans for flow and pollution control aimed at protecting source waters and meeting water quality goals. It does so by helping users answer the following questions: How effective are BMPs in reducing runoff and pollutant loadings? What are the most cost-effective solutions for meeting water quality and quantity objectives? And where, what type, and how extensive should BMPs be?



By seamlessly integrating ArcGIS 10.x with SWMM 5.1, InfoSWMM

Sustain greatly expands on the USEPA Sustain software to provide critically needed support to watershed practitioners at all levels in developing stormwater management evaluations and cost optimizations to meet their program needs. The software can automatically import any SWMM5.1,InfoSWMM or InfoWorks ICM model, then evaluate numerous potential combinations of BMPs to determine the optimal combination to meet specified objectives such as runoff volume or pollutant loading reductions. Both kinematic wave and full dynamic wave flow routing models are fully supported. Among its many vital applications, InfoSWMM Sustain can be effectively used in developing TMDL implementation plans, identifying management practices to achieve pollutant reductions under a separate municipal storm sewer system (MS4) stormwater permit, determining optimal green infrastructure strategies for reducing volume and peak flows to combined sewer systems, evaluating the benefits of distributed green infrastructure implementation on water quantity and quality in urban streams, and developing a phased BMP installation plan using cost effectiveness curves.



“With InfoSWMM Sustain 4.0, we are extending our success in the smart network modeling marketplace to address the specific needs of stormwater management professionals and their engineering consultants,”

It performs sophisticated hydrologic and water quality modeling in watersheds and urban streams, and enables users to determine optimal management solutions at multiple-scale watersheds to achieve desired water quality objectives based on cost effectiveness. It also gives users the power tool they need to maximize water quality benefits, minimize stormwater management costs and combined sewer overflows, and protect the environment and public health.”

Colby T. Manwaring, P.E.

Chief Executive Officer, Innovyze Inc.

Portland, Oregon USA January 30, 2019

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InfoSWMM uses the EPA SWMM 5.1.013 Engine

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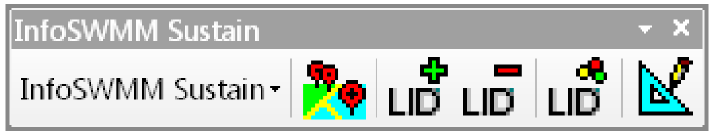
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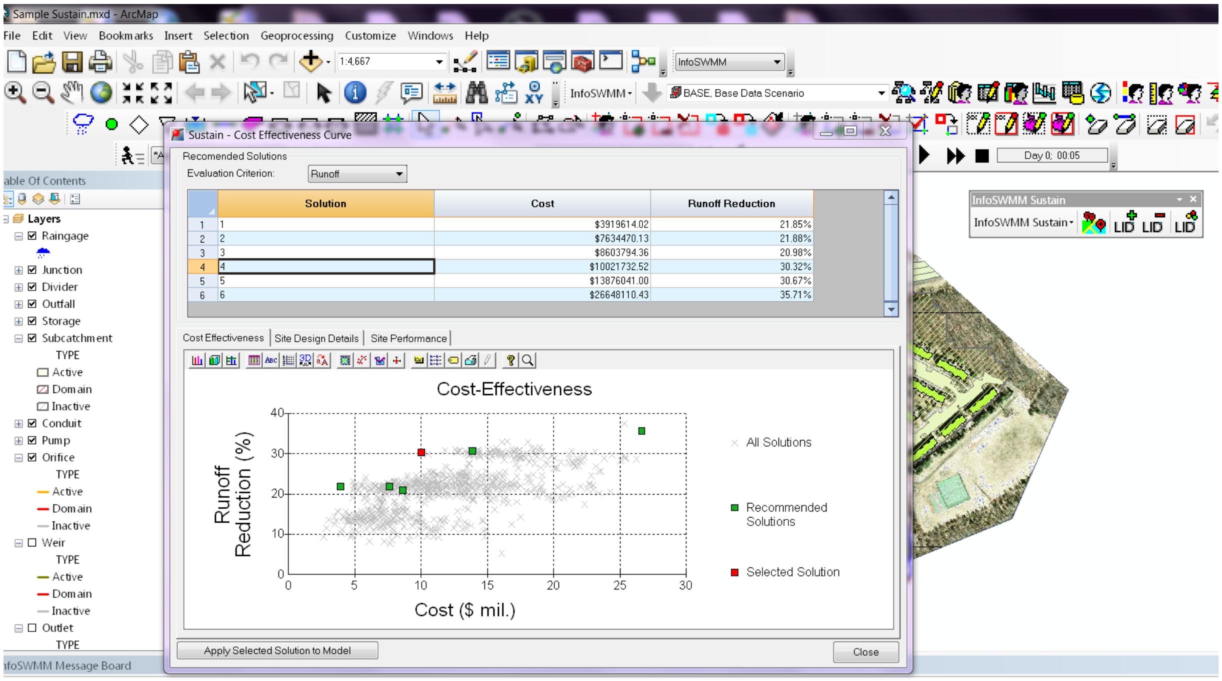
What is the Purpose of Sustain?

The following is from the Innovyze Product Page for Sustain

Designed in response to the needs of watershed and stormwater engineering professionals, InfoSWMM Sustain performs very sophisticated hydrologic and water quality modeling in watersheds and urban streams and enables users to develop, evaluate, and select optimal best management practice (BMP), Low Impact Development (LID) and Sustainable Urban Drainage Systems (SUDS) combinations at various watershed scales on the basis of cost and effectiveness. It can be effectively used to evaluate complex decisions about green infrastructure selection and placement, performance, and costs for meeting flow or water quality targets or both. It also gives users the power tool they need to maximize water quality benefits, minimize stormwater management costs and combined sewer overflows, and protect the environment and public health.

InfoSWMM Sustain is a comprehensive geocentric decision support system created to facilitate optimal selection and placement of BMPs and low impact development (LID) techniques at strategic locations in urban watersheds. It can accurately model any combination of LID controls, such as porous permeable pavement, rain gardens, green roofs, street planters, rain barrels, infiltration trenches, and vegetative swales, to determine their effectiveness in managing stormwater and combined sewer overflows. Such capabilities can greatly assist users in developing cost-effective and reliable implementation plans for flow and pollution control measures aimed at protecting source waters and meeting water quality goals. It does so by helping users answer the following questions:

- How effective are LIDs and BMPs in reducing runoff and pollutant loadings?
- What are the most cost-effective solutions for meeting water quality and quantity objectives?
- And where, what type, and how extensive should the LIDs and BMPs be?



Seamless SWMM5 and ArcGIS Integration

By seamlessly integrating ArcGIS 10.x with SWMM 5.1, InfoSWMM Sustain greatly expands on the USEPA SUSTAIN software to provide critically needed support to watershed practitioners at all levels in developing stormwater management evaluations and cost optimizations to meet their program needs. The software can automatically import any SWMM 5.1, InfoSWMM or InfoWorks ICM model (exported to SWMM 5.1), then evaluate numerous potential combinations of LIDs and BMPs to determine the optimal combination to meet specified objectives such as runoff volume or pollutant loading reductions. Kinematic wave and full dynamic wave flow routing models are fully supported.

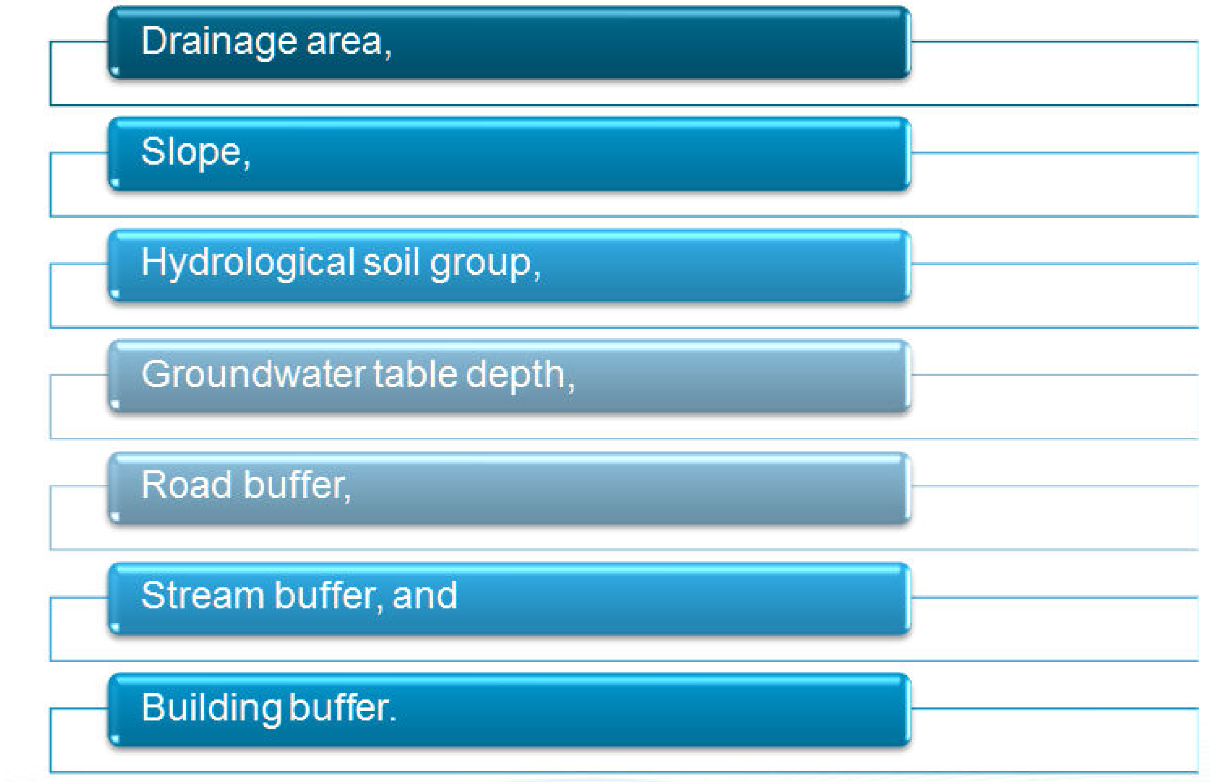


Figure 1. Siting Tool Suitability Criteria

LID/BMP Siting Tool

InfoSWMM Sustain lets users select suitable locations for common structural LIDs/BMPs that meet the defined site suitability criteria, such as:

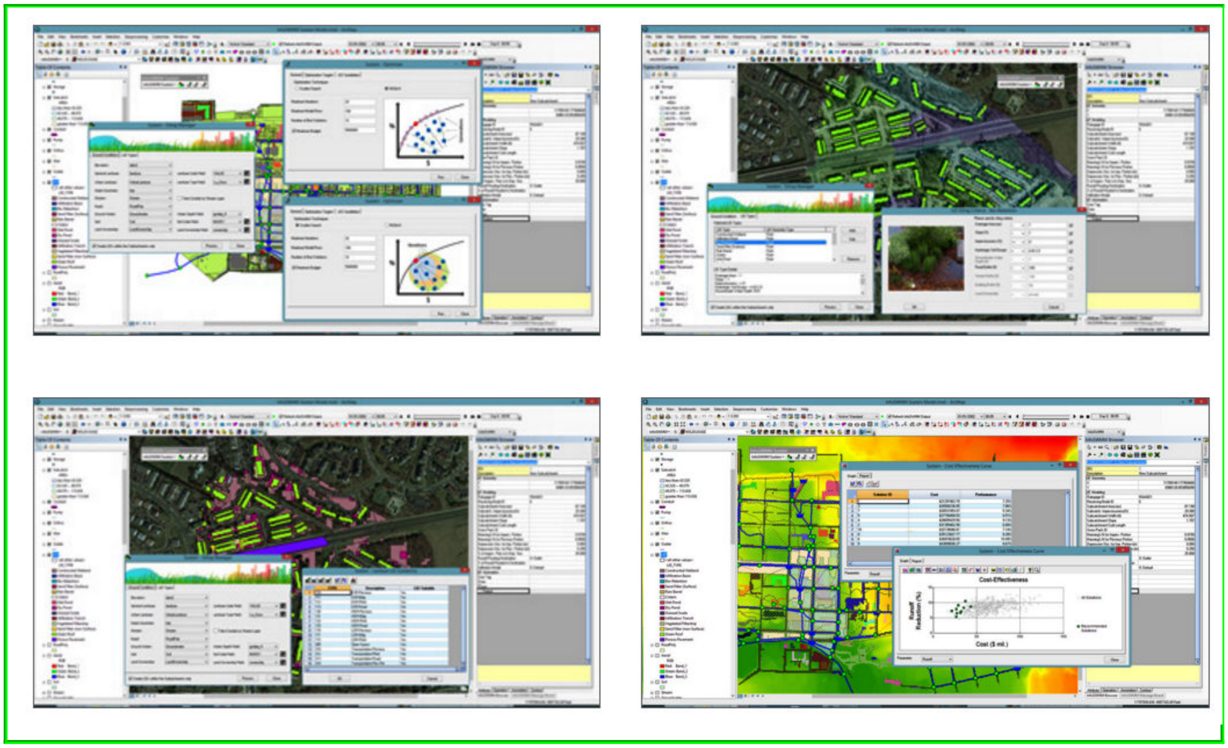
- drainage area,
- slope,
- hydrological soil group,
- groundwater table depth,
- road buffer,
- stream buffer, and
- building buffer.

LIDs/BMPs are classified and conceptualized in InfoSWMM Sustain as scale-based and type-based. The scale-based category classifies LIDs/BMPs according to the size of the application area, such as lot-, community-, and watershed-scales. The type-base category classifies LIDs/BMPs into three types according to the geometric properties:

- Point LIDs/BMPs: practices that capture upstream drainage at a specific location and may use a combination of detention, infiltration, evaporation, settling, and transformation to manage flow and remove pollutants.
- Linear LIDs/BMPs: narrow linear shapes adjacent to stream channels that provide filtration of runoff, nutrient uptake, and ancillary benefits of stream shading, wildlife habitat, and aesthetic value.
- Area LIDs/BMPs: land-based management practices that affect impervious area, land cover, and pollutant input.

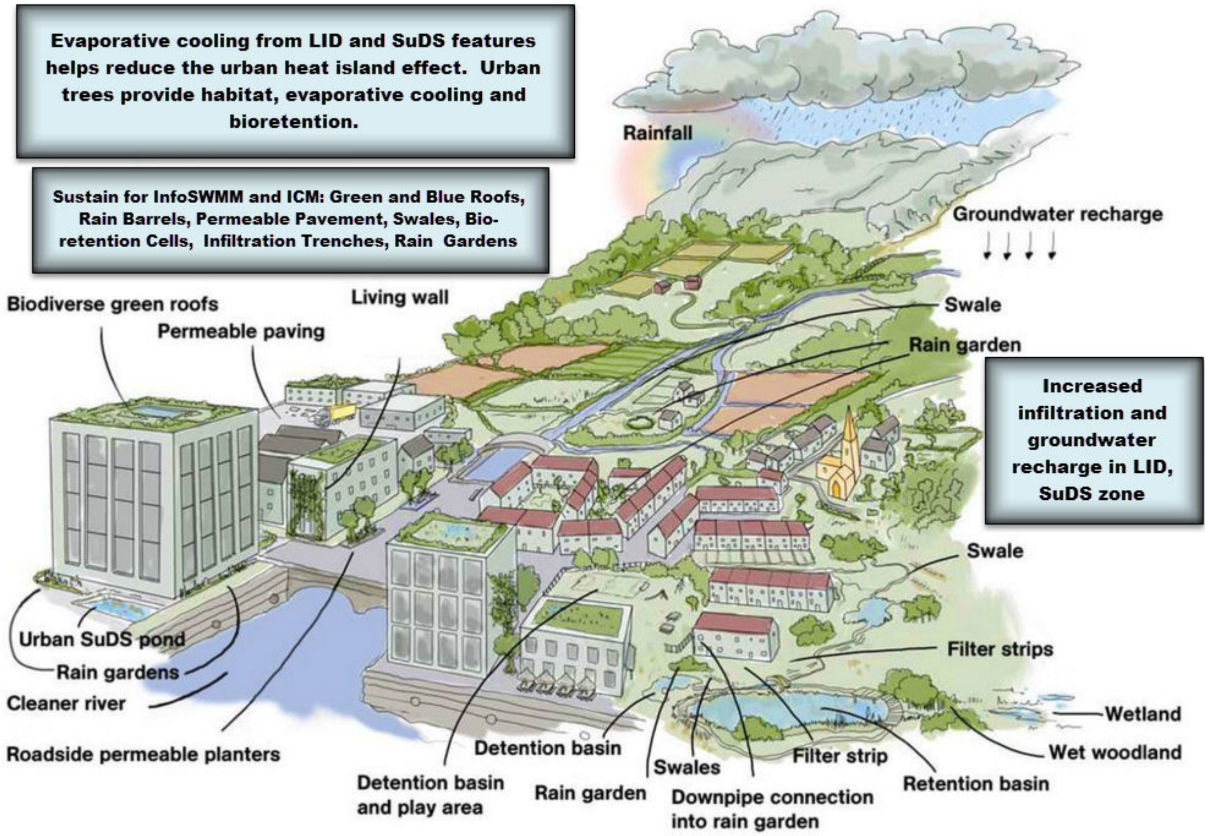
The following structural LID/BMP options are fully supported:

Point LID/BMP	Linear LID/BMP	Area LID/BMP
Constructed Wetland	**Grassed Swale**	**Green Roof**
Infiltration Basin	**Infiltration Trench**	**Porous Pavement**
Bioretention	**Vegetated Filter Strip**	
Sand Filter (surface)	**Sand Filter (non-surface)**	
Rain Barrel		
Cistern		
Wet Pond		
Dry Pond		



Applications

Among its many vital applications, InfoSWMM Sustain can be effectively used by practitioners, municipalities, and watershed groups at the regional and local level in developing TMDL implementation plans, identifying management practices to achieve pollutant reductions under a separate municipal storm sewer system (MS4) stormwater permit, determining optimal green infrastructure strategies for reducing volume and peak flows to combined sewer systems, evaluating the benefits of distributed green infrastructure implementation on water quantity and quality in urban streams, and developing a phased BMP installation plan using cost effectiveness curves.



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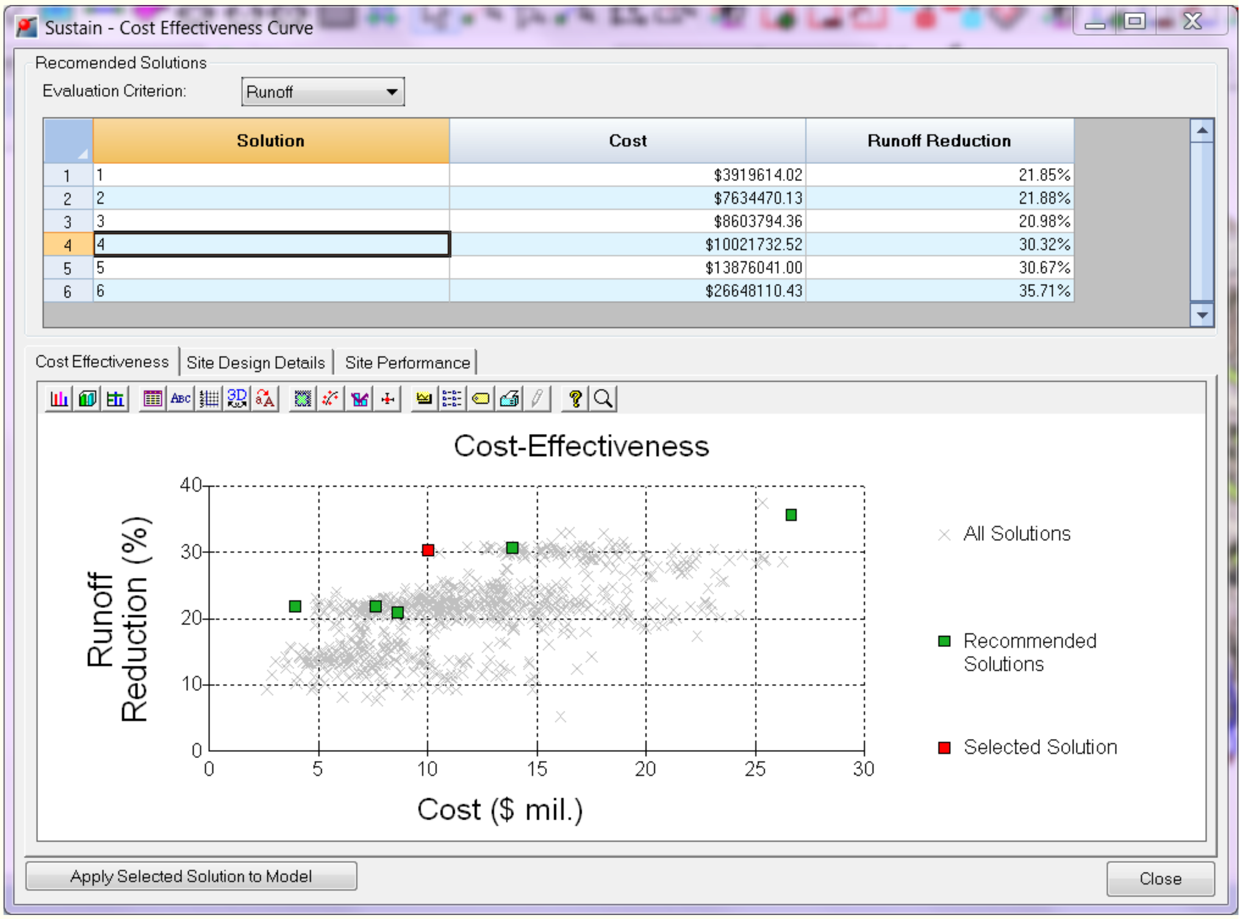
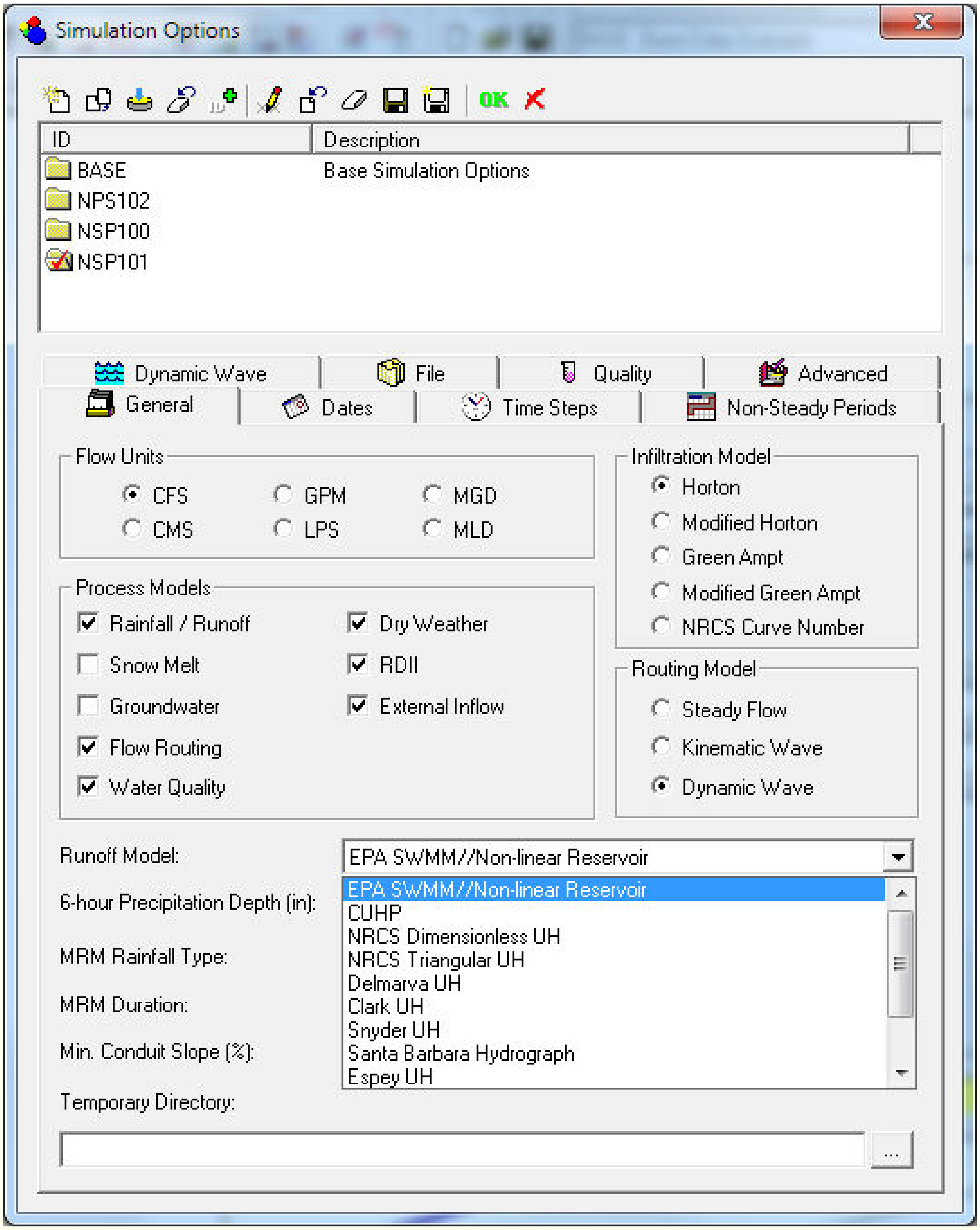
What is New in InfoSWMM Sustain 2.0

New to InfoSWMM 14.5 Update #7 are many new features to the Cost Effectiveness Curve to better integrate the design tables, cost curve and the performance curves. You can now see the recommended designs in RED tied to the Recommended Solutions table. The tab Site Design details will also show you the location of the designed LID on the Arc GIS Map.



New to InfoSWMM 14.5 Update #1-6 is the ability to use Hydrology for ALL InfoSWMM Hydrology options with Groundwater, LID and Sustain Optimization.


Simulation Options
OK
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Description
BASE
Base Simulation Options
NPS102
NSP100
NSP101
Dynamic Wave
File
Quality
Advanced
General
Dates
Time Steps
Non-Steady Periods
Flow Units
CFS
GPM
MGD
CMS
LPS
MLD
Infiltration Model
Horton
Modified Horton
Green Ampt
Modified Green Ampt
NRCS Curve Number
Process Models
Rainfall / Runoff
Dry Weather
Snow Melt
RDII
Groundwater
External Inflow
Flow Routing
Water Quality
Routing Model
Steady Flow
Kinematic Wave
Dynamic Wave
Runoff Model:
EPA SWMM//Non-linear Reservoir
6-hour Precipitation Depth (in):
EPA SWMM//Non-linear Reservoir
CUHP
NRCS Dimensionless UH
NRCS Triangular UH
Delmarva UH
Clark UH
Snyder UH
Santa Barbara Hydrograph
Espey UH
MRM Rainfall Type:
MRM Duration:
Min. Conduit Slope (%):
Temporary Directory:
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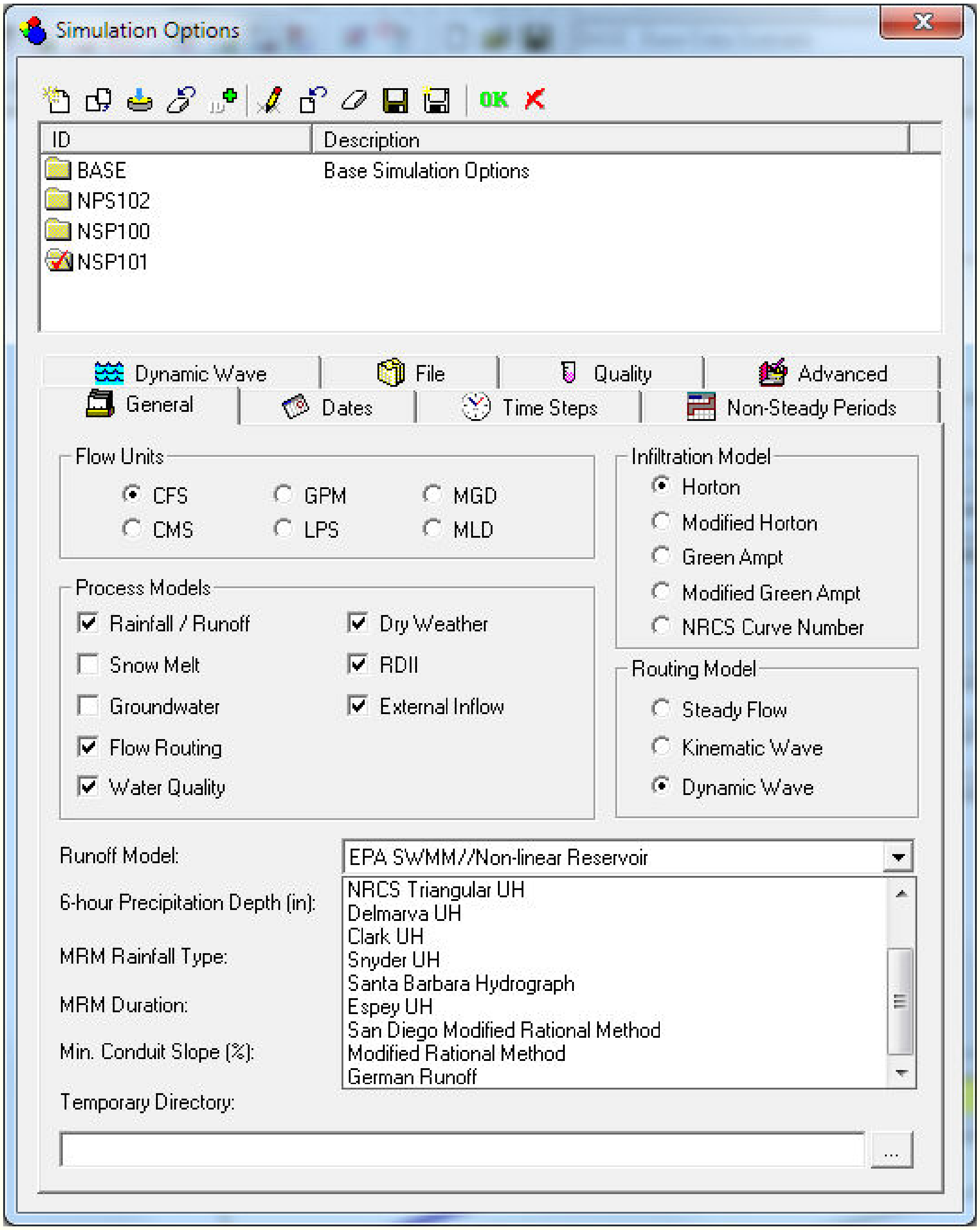
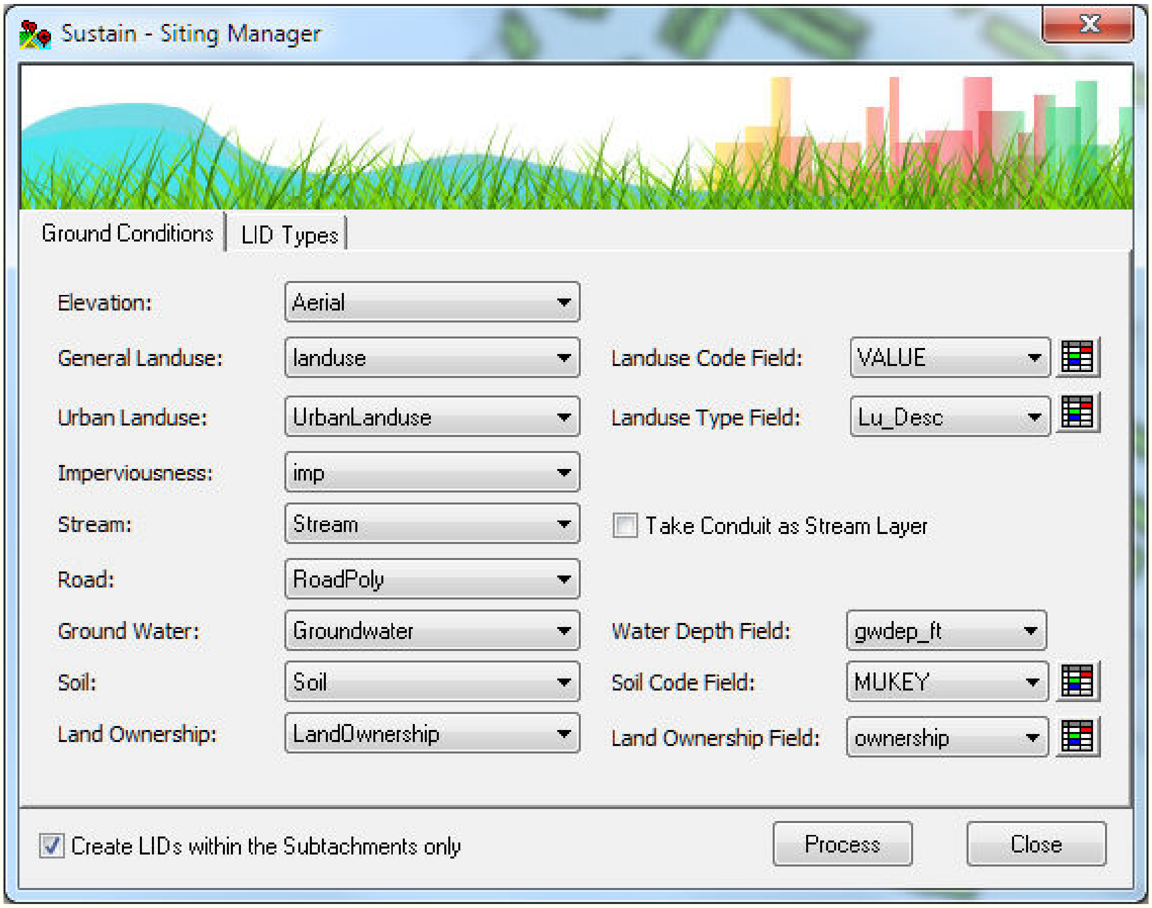


Here is a list of InfoSWMM Sustain 2.0 enhancement and new features:

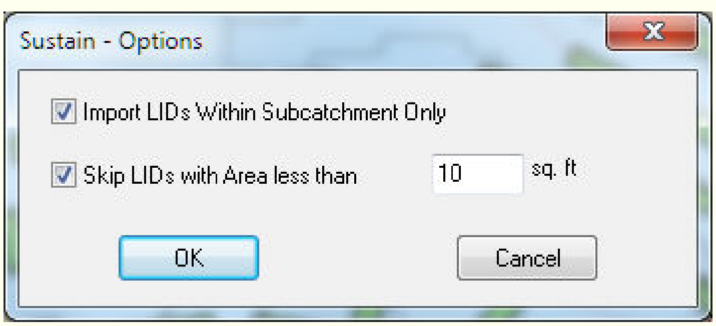
Siting Manager:

1. Allowed users to skip GIS layers on siting manger if they don't have the data.



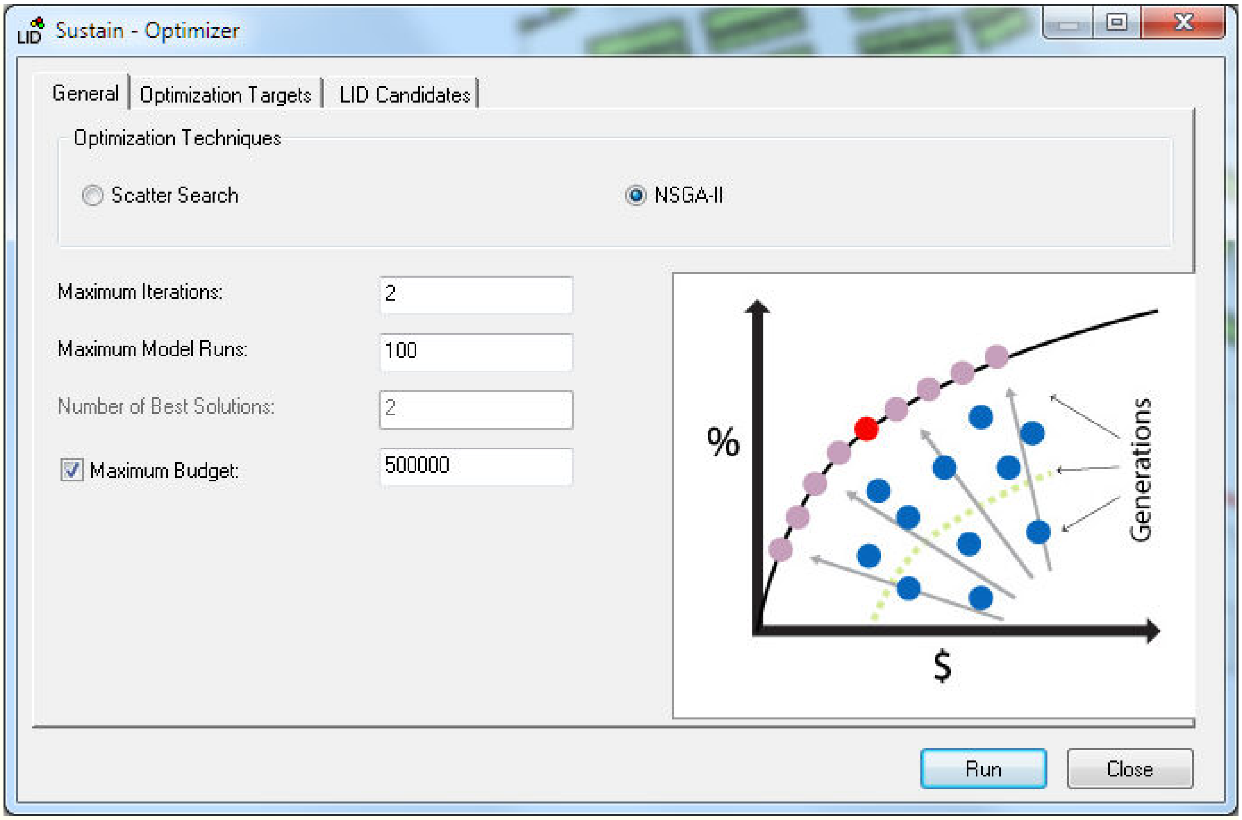
2. Improved speed of intersection, buffering, and cookie-cut geoprocessing on siting manager.

3. Allowed users to ignore LIDs outside the Subcatchments.

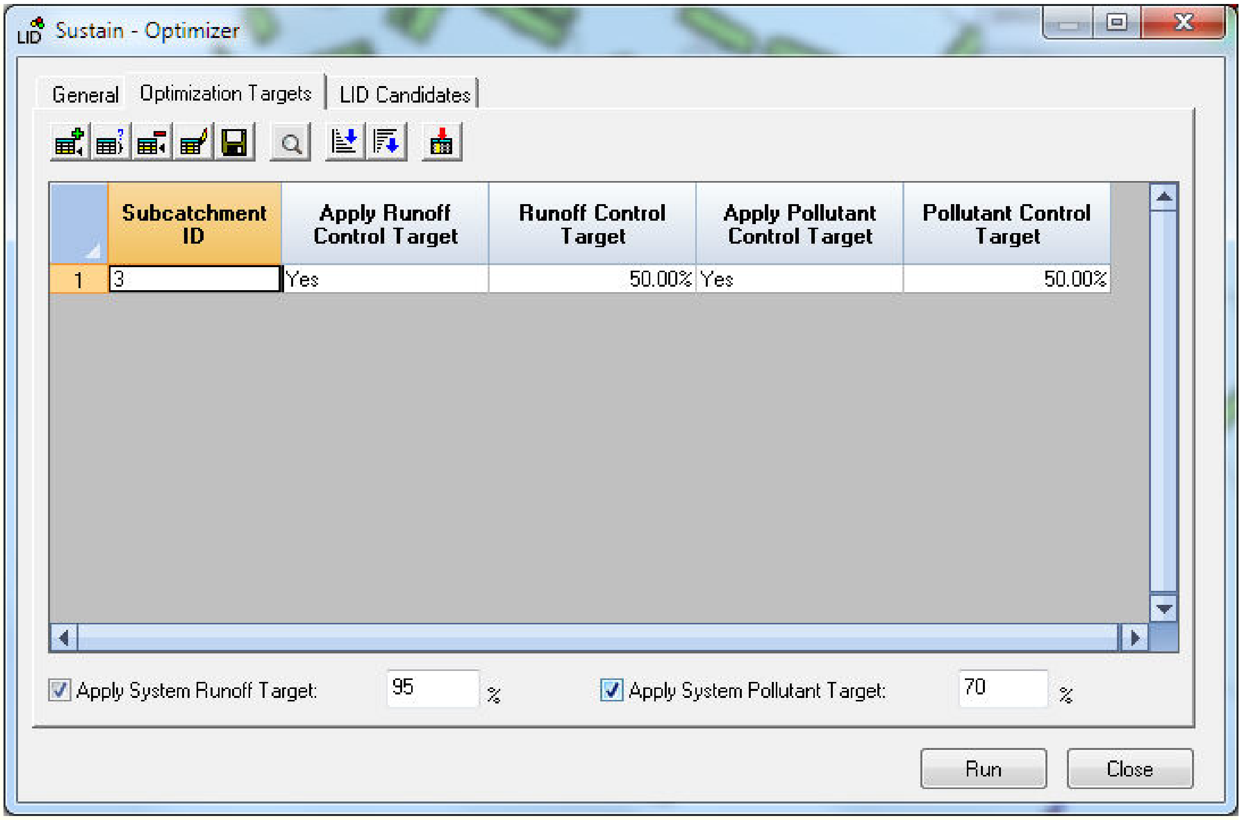


Optimization:

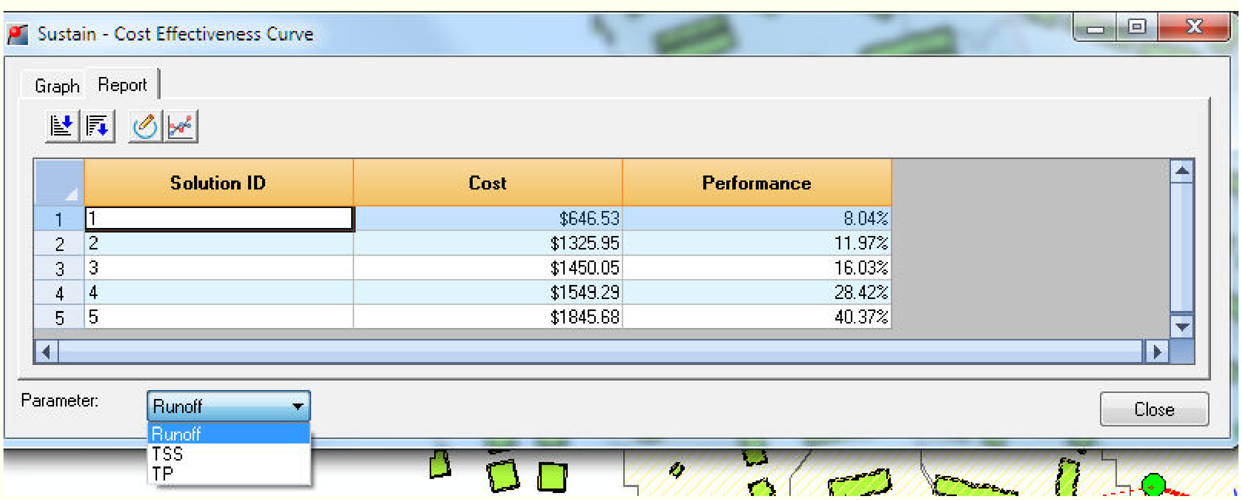
1. Users can choose a system wise budget constraint for the optimization engine(s).



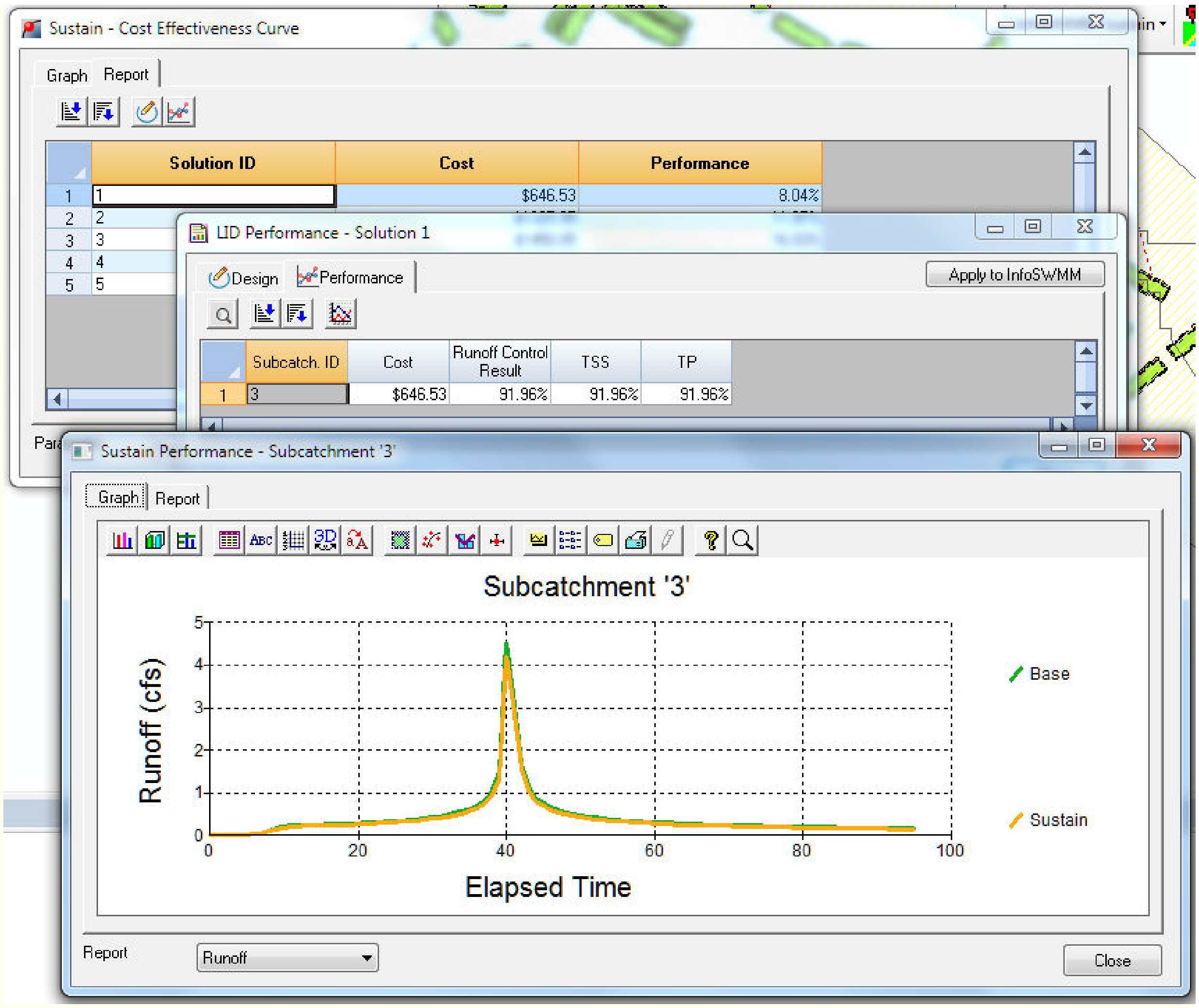
2. Users can set up a system reduction target for runoff and/or pollution.



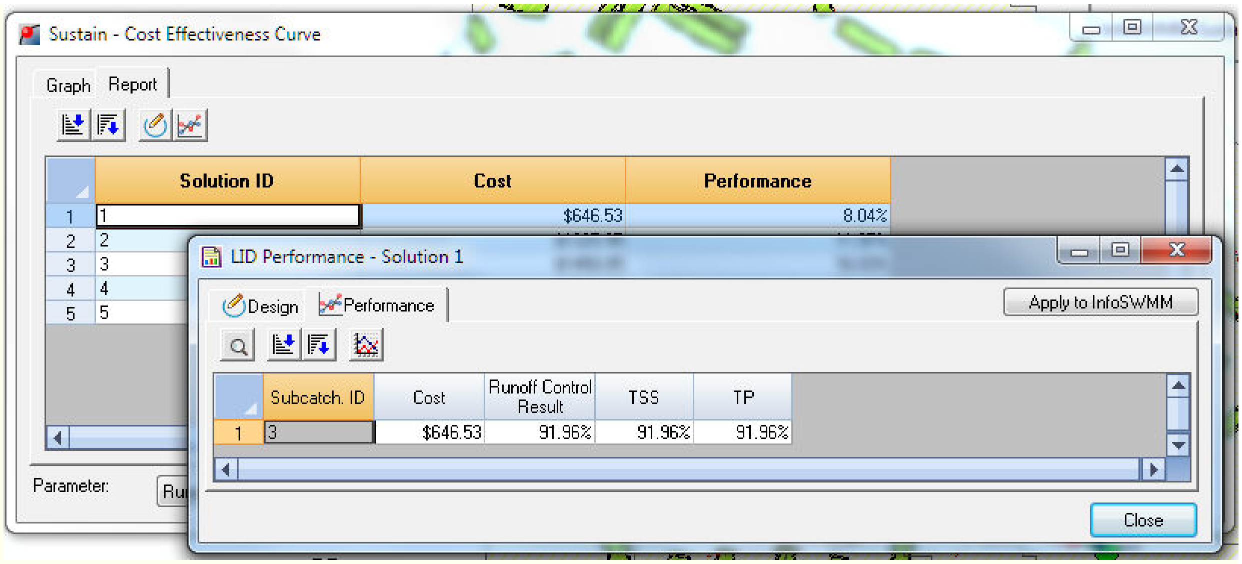
3. Users are able to view LID design and performance report directly from Cost Effective Curve.



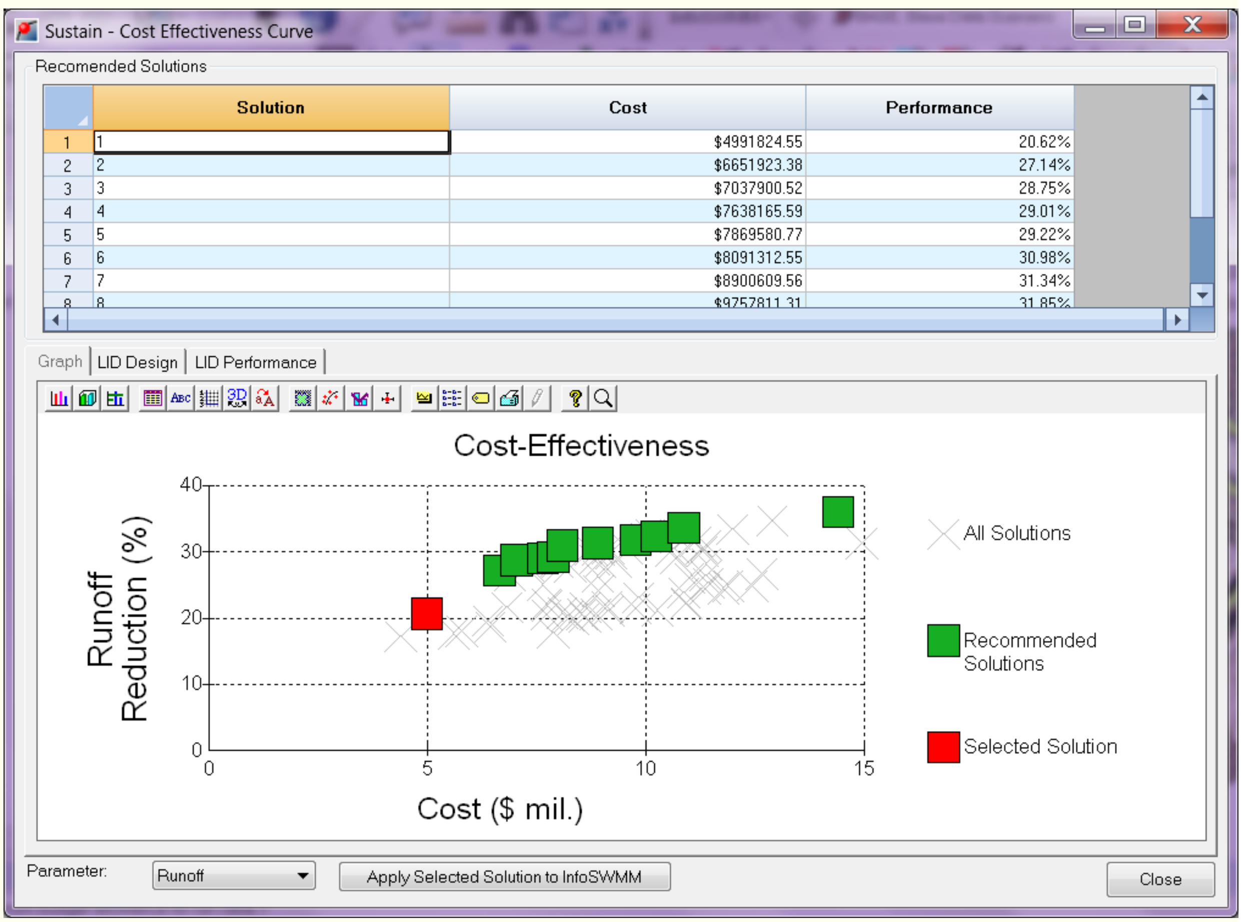
4. Users can compare hydrographs for runoff and pollutant from the solution on Cost Effective Curve.



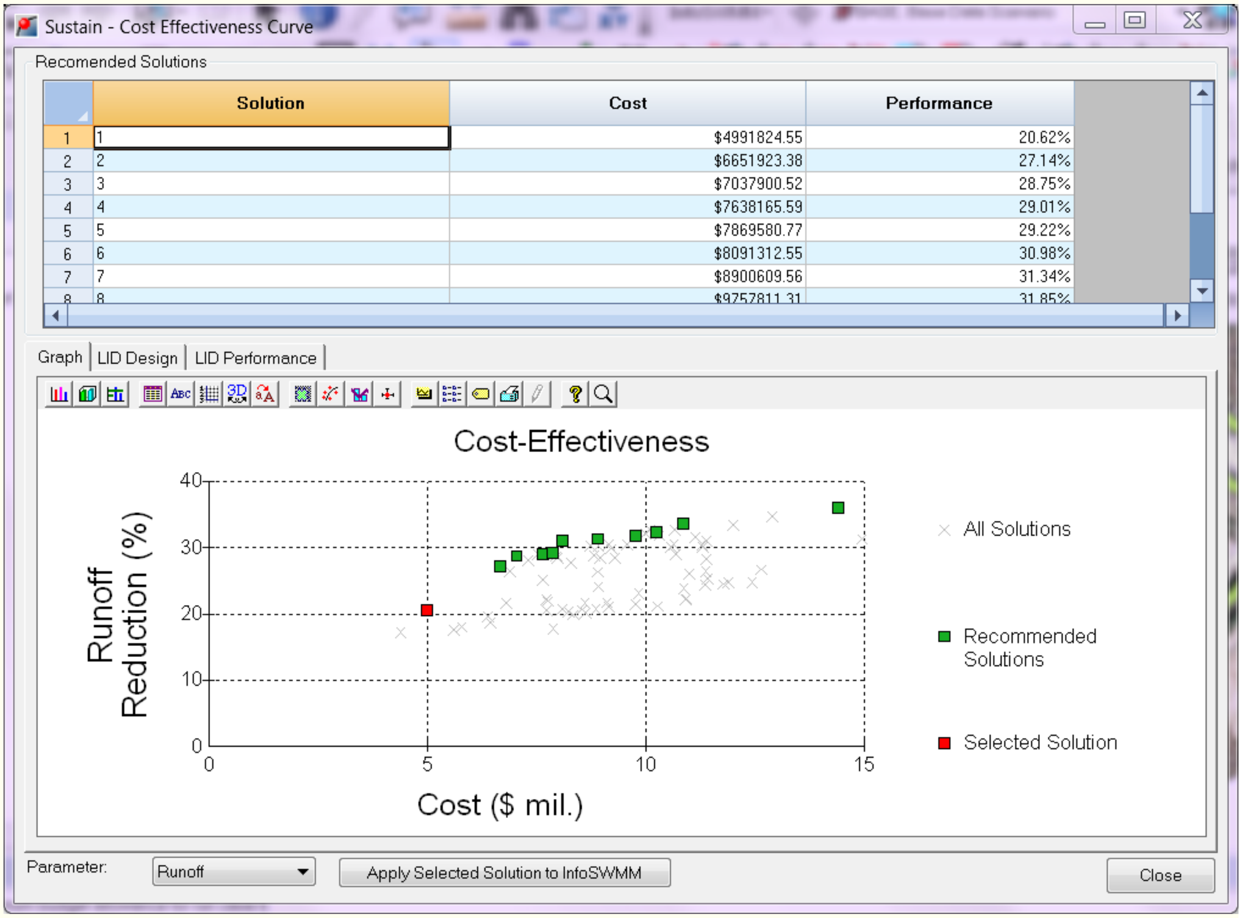
5. Users can select any solution on Cost Effectiveness Curve and apply its LID design to InfoSWMM directly.



6. Cost Effectiveness Curve now can show the whole system runoff/pollutant reduction instead of an individual Subcatchments.



7. Cost Effectiveness curve now includes best design table with cost and performance along with tabs for the design and performance. The Cost Effectiveness curve has All Solutions, Best Solutions and Selected Solution (which the user can click on from the Grid on top of the Cost Effectiveness Curve)



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What is New in InfoSWMM Sustain 3.0 - May, 2017

New to InfoSWMM 14.5 Update #9 is a greatly expanded LID

Installation Cost Manager The icon LID Cost

will show you the cost contribution by category for each of the optimized LID's, SuDS or WSuDs. Greater flexibility has been add to the Cost columns for LID Candidates and Costs for the best solutions. Some of the new features in InfoSWMM Sustain 3.0 are

New LID Installation Plan and Cost Module

- Adopts LID cost database from the US EPA Sustain so users can select LID

  cost based on their local conditions.
- Adds a default installation plan for each LID type so that users can easily view installation procedure and specify the LID cost.
- Allows users to divide LID project cost into different components such as excavation, backfilling, grass, porous paving material, etc so users can manage the LID construction based on different components.
- Allows users to further edit and manage LID installation plan and cost based on local conditions and users knowledge.

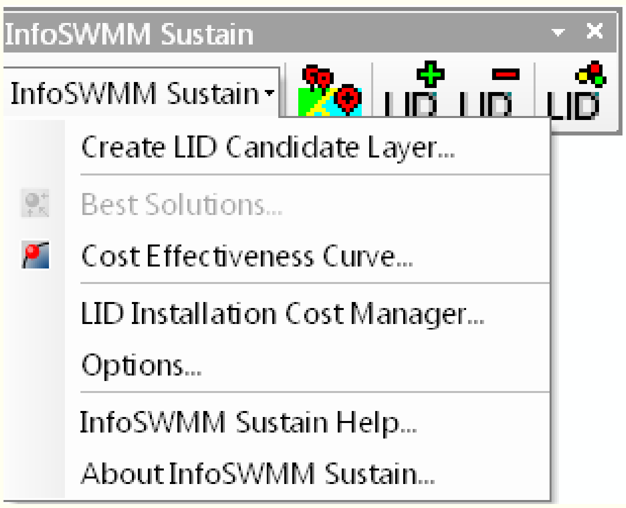
Optimization Manager Enhancement

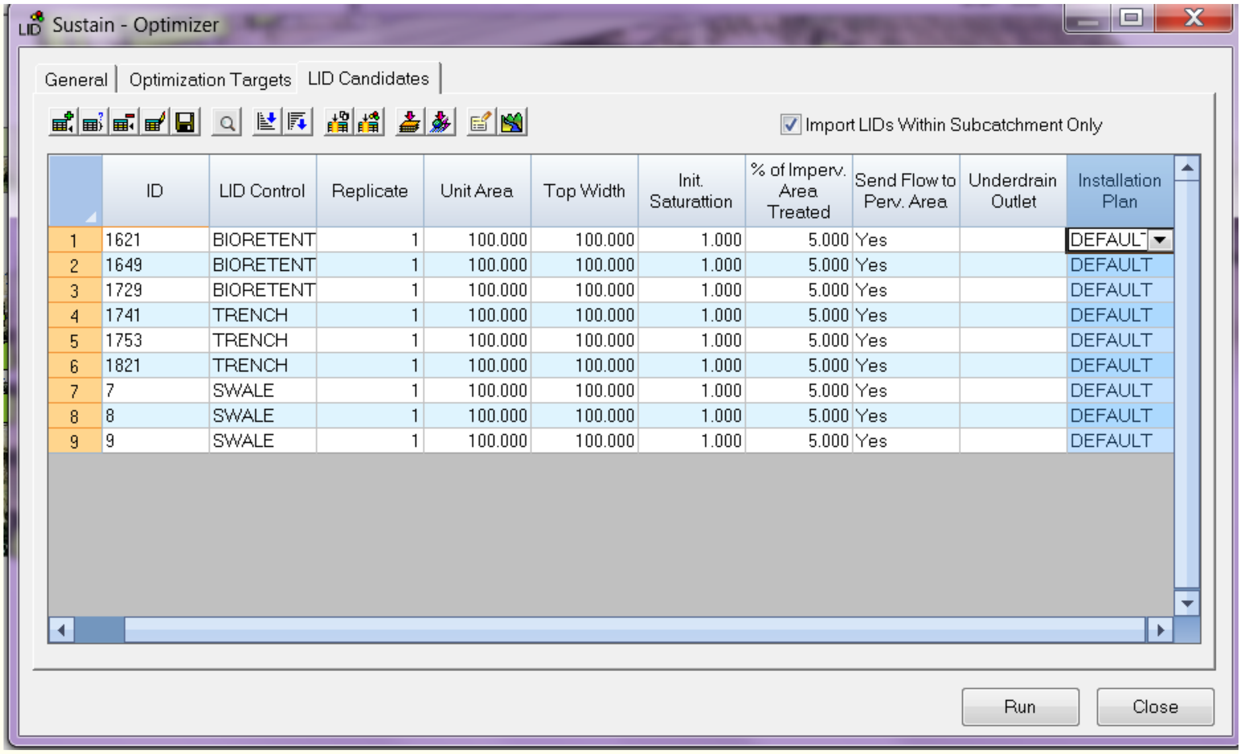
- Allows users to specify runoff and/or pollution reduction targets so users have a clear and explicit goal to design their LID controls.
- Much greater control over the LID Candidate Grid so that less or more information can be optionally shown in the Grid.
- A new property dialog to see all LID Candidate data for one LID in one dialog for easier optimization and better understanding.

Report Enhancement

- Provides breakdown cost report for each LID control.

- Reports more LID control parameters such as total excavation volume, underdrain volume, soil media volume. The cost associated with these parameters will also reported so that users will have better ideas where the money will spend.
- Allows users to select a system recommended solution and highlight it on Cost-Effectiveness Curve directly.
- Allows users to view all of the LID controls for a selected solution and their design details such as area, width, soil thickness, etc. Users can also highlight them and locate them on the map.
- Enhances the reports for Sustain target sites on cost, runoff and pollution reduction using the NSGA-II optimization option. Users can also compare how the hydrograph changes with and without recommended LID controls.




Sustain - Optimizer
General
Optimization Targets
LID Candidates
Import LIDs Within Subcatchment Only
ID
LID Control
Replicate
Unit Area
Top Width
Init. Saturation
% of Imperv. Area Treated
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Underdrain Outlet
Installation Plan
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2 1649 BIORETENT 1 100.000 100.000 1.000 5.000 Yes DEFAULT
3 1729 BIORETENT 1 100.000 100.000 1.000 5.000 Yes DEFAULT
4 1741 TRENCH 1 100.000 100.000 1.000 5.000 Yes DEFAULT
5 1753 TRENCH 1 100.000 100.000 1.000 5.000 Yes DEFAULT
6 1821 TRENCH 1 100.000 100.000 1.000 5.000 Yes DEFAULT
7 7 SWALE 1 100.000 100.000 1.000 5.000 Yes DEFAULT
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9 9 SWALE 1 100.000 100.000 1.000 5.000 Yes DEFAULT
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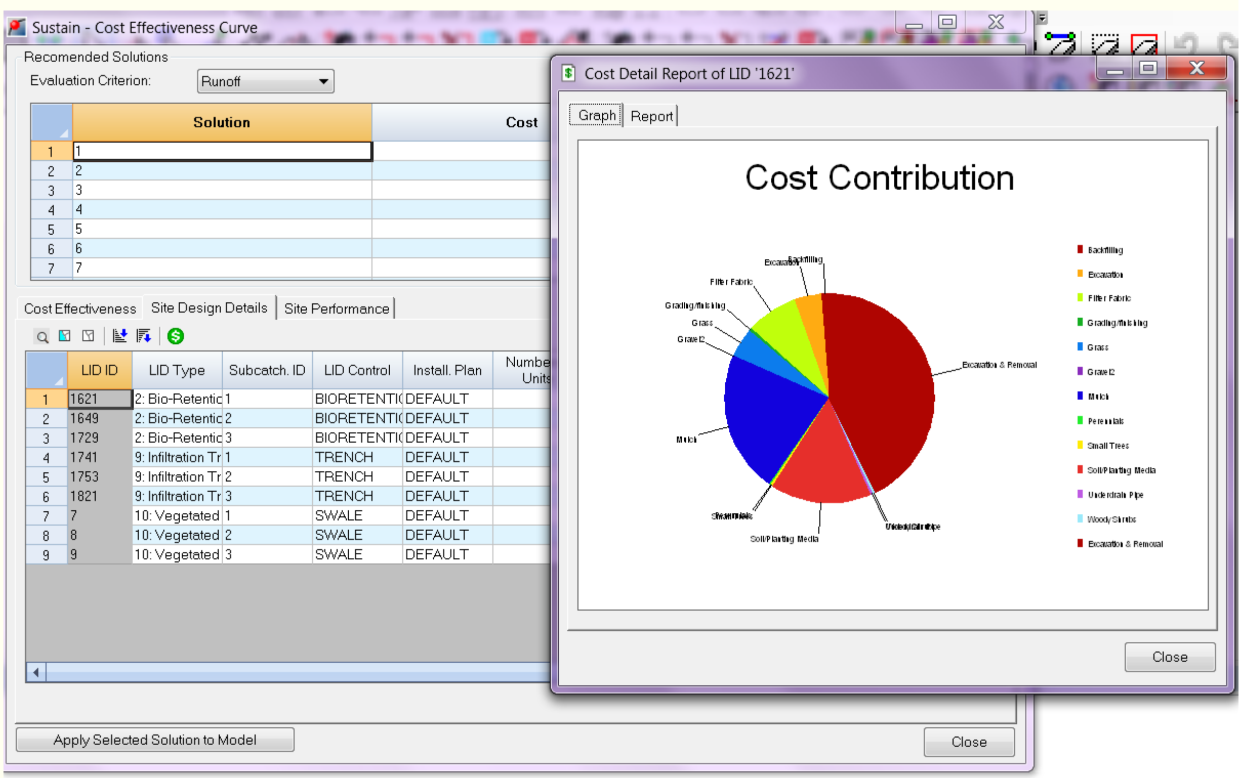
Sustain - Cost Effectiveness Curve
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Evaluation Criterion:
Runoff
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Cost
Cost Effectiveness
Site Design Details
Site Performance
LID ID
LID Type
Subcatch. ID
LID Control
Install. Plan
Number of Units
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2 1649 2: Bio-Retentic 2 BIORETENTI DEFAULT
3 1729 2: Bio-Retentic 3 BIORETENTI DEFAULT
4 1741 9: Infiltration Tr 1 TRENCH DEFAULT
5 1753 9: Infiltration Tr 2 TRENCH DEFAULT
6 1821 9: Infiltration Tr 3 TRENCH DEFAULT
7 7 10: Vegetated 1 SWALE DEFAULT
8 8 10: Vegetated 2 SWALE DEFAULT
9 9 10: Vegetated 3 SWALE DEFAULT
Apply Selected Solution to Model
Close
Cost Detail Report of LID '1621'
Graph
Report
Cost Contribution
Backfilling
Excavation
Filter Fabric
Grading/Mulching
Grass
Gravel2
Mulch
Perennials
Small Trees
Soil/Planting Media
Underdrain Pipe
Woody Shrubs
Excavation & Removal
Close

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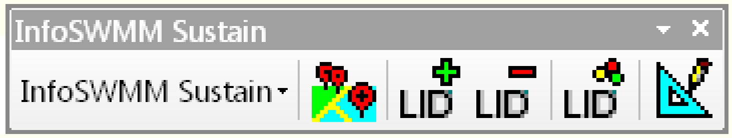
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What are some Example LID's

The Low Impact Development (LID) function was new to SWMM

5.0.019/20/21/22 and SWMM 5.1+ It is integrated within the Subcatchment and allows further refinement of the overflows, infiltration flow and evaporation in Rain barrel, Swales,Permeable paving, Green Roof, Rain Garden, Bioretention and Infiltration trench. The term Low-impact development(Canada/US) is used in Canada and the United States to describe a land planning and engineering design approach to managing stormwater runoff. In recent years many states in the US have adopted LID concepts and standards to enhance their approach to reducing the harmful potential for storm water pollution in new construction projects. LID takes many forms but can generally be thought of as an effort to minimize or prevent concentrated flows of storm water leaving a site. To do this the LID practice suggests that when impervious surfaces (concrete, etc.) are used, they are periodically interrupted by pervious areas which can allow the storm water to infiltrate (soak into the earth)

You can define a variety of sub processes in each LID in SWMM5

such as: Surface, Pavement, Soil, Storage, DrainMat and Drain.

Each type of LID has limitations on the type of sub process allowed by SWMM 5. It has a good report feature and you can have a LID summary report in the rpt file and an external report file in which you can see the surface depth, soil moisture, storage depth, surface inflow, evaporation, surface infiltration, soil percolation, storage infiltration, surface outflow and the LID continuity error. You can have multiple LID's per Subcatchment and we have had no issues having many complicated LID sub networks and processes inside the Subcatchments of SWMM 5 or any continuity issues not solvable by a smaller wet hydrology time step. The types of SWMM 5 LID compartments are: Storage, Underdrain, Surface, Pavement and Soil. A Bio Retention cell has Storage, Underdrain and Surface Compartments.

An Infiltration Trench LID has Storage, Underdrain and Surface Compartments.

A Porous Pavement LID has Storage, Underdrain and Pavement Compartments. A Rain Barrel has only Storage and Underdrain Compartments and a Vegatative Swale LID has a single Surface Compartment. Each type of LID shares different underlying compartment objects in SWMM 5.

New as of July 2013, the EPA's National Stormwater Calculator is a Windows desktop application that estimates the annual amount of rainwater and frequency of runoff from a specific site anywhere in the United States. Estimates are based on local soil conditions, land cover, and historic rainfall records. The Calculator accesses several national databases that provide soil, topography, rainfall, and evaporation information for the chosen site. The user supplies information about the site's land cover and selects the types of low impact development (LID) controls they would like to use on site. The LID Control features in SWMM 5.1.007 include the following among types of Green infrastructure: StreetPlanter: Bio-retention Cells are depressions that contain vegetation grown in an engineered soil mixture placed above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas. Street Planters consist of concrete boxes filled with an engineered soil that supports vegetative growth. Beneath the soil is a gravel bed that provides additional storage. The walls of a planter extend 3 to 12 inches above the soil bed to allow for ponding within the unit. The thickness of the soil growing medium ranges from 6 to 24 inches while gravel beds are 6 to 18 inches in depth. The planter's Capture Ratio is the ratio of its area to the impervious area whose runoff it captures.

Main Street Tree Planter, Miles City (281991376)

Raingarden:Rain Gardens are a type of bio-retention cell consisting of just the engineered soil layer with no gravel bed below it.Rain Gardens are shallow depressions filled with an engineered soil mix that supports vegetative growth. They are usually used on individual home lots to capture roof runoff. Typical soil depths range from 6 to 18 inches. The Capture Ratio is the ratio of the rain garden's area to the impervious area that drains onto it.

Rain garden (2014)

GreenRoof: Green Roofs are another variation of a bio-retention cell that have a soil layer laying atop a special drainage mat material that conveys excess percolated rainfall off of the roof. Green Roofs (also known as

Vegetated Roofs) are bio-retention systems placed on roof surfaces that capture and temporarily store rainwater in a soil growing medium. They consist of a layered system of roofing designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The thickness used for the growing medium typically ranges from 3 to 6 inches.

Intensive extensive green roofs

InfilTrench: Infiltration Trenches are narrow ditches filled with gravel that intercept runoff from upslope impervious areas. They provide storage volume and additional time for captured runoff to infiltrate the native soil below.

Infiltration trench (6438020585)

PermPave or Permeable Pavements Continuous Permeable Pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix. Continuous Permeable Pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix. Modular Block systems are similar except that permeable block pavers are used instead. Normally all rainfall will immediately pass through the pavement into the gravel storage layer below it where it can infiltrate at natural rates into the site's native soil. Pavement layers are usually 4 to 6 inches in height while the gravel storage layer is typically 6 to 18 inches high. The Capture Ratio is the percent of the treated area (street or parking lot) that is replaced with permeable pavement.

Cistern: Rain Barrels (or Cisterns) are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods.

Rain harvesting systems collect runoff from rooftops and convey it to a cistern tank where it can be used for non-potable water uses and on-site infiltration. The harvesting system is assumed to consist of a given number of fixed-sized cisterns per 1000 square feet of rooftop area captured.

The water from each cistern is withdrawn at a constant rate and is assumed to be consumed or infiltrated entirely on-site.

VegSwale: Vegetative Swales are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate the native soil beneath it.Infiltration basins are shallow depressions filled with grass or other natural vegetation that capture runoff from adjoining areas and allow it to infiltrate into the soil.

Wet Ponds are frequently used for water quality improvement, groundwater recharge, flood protection, aesthetic improvement or any combination of these. Sometimes they act as a replacement for the natural absorption of a forest or other natural process that was lost when an area is developed. As such, these structures are designed to blend into neighborhoods and viewed as an amenity.

Dry Ponds temporarily stores water after a storm, but eventually empties out at a controlled rate to a downstream water body.

Sand Filters generally control runoff water quality, providing very limited flow rate control. A typical sand filter system consists of two or three chambers or basins. The first is the sedimentation chamber, which removes floatables and heavy sediments.

The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The third is the discharge chamber. Infiltration trench, is a type of best management practice (BMP) that is used to manage stormwater runoff, prevent flooding and downstream erosion, and improve water quality in an adjacent river, stream, lake or bay. It is a shallow excavated trench filled with gravel or crushed stone that is designed to infiltrate stormwater though permeable soils into the groundwater aquifer.

A Vegatated filter strip is a type of buffer strip that is an area of vegetation, generally narrow and long, that slows the rate of runoff, allowing sediments, organic matter, and other pollutants that are being conveyed by the water to be removed by settling out. Filter strips reduce erosion and the accompanying stream pollution, and can be a best management practice.

Other LID like concepts around the world include Sustainable Drainage System (SUDS). The idea behind SUDS is to try to replicate natural systems that use cost effective solutions with low environmental impact to drain away dirty and surface water run-off through collection, storage, and cleaning before allowing it to be released slowly back into the environment, such as into water courses.

In addition the following features can also be simulated using the features of SWMM 5 (storage ponds, seepage, orifices, Weirs, seepage and evaporation from natural channels): Constructed Wetlands, Wet Ponds, Dry Ponds, Infiltration basin, Non-Surface Sand Filters, Vegetated Filterstrips, Vegetated Filterstrip and Infiltration basin. A WetPark would be a combination of Wet and Dry Ponds and LID features. A WetPark is also considered a Constructed Wetland.

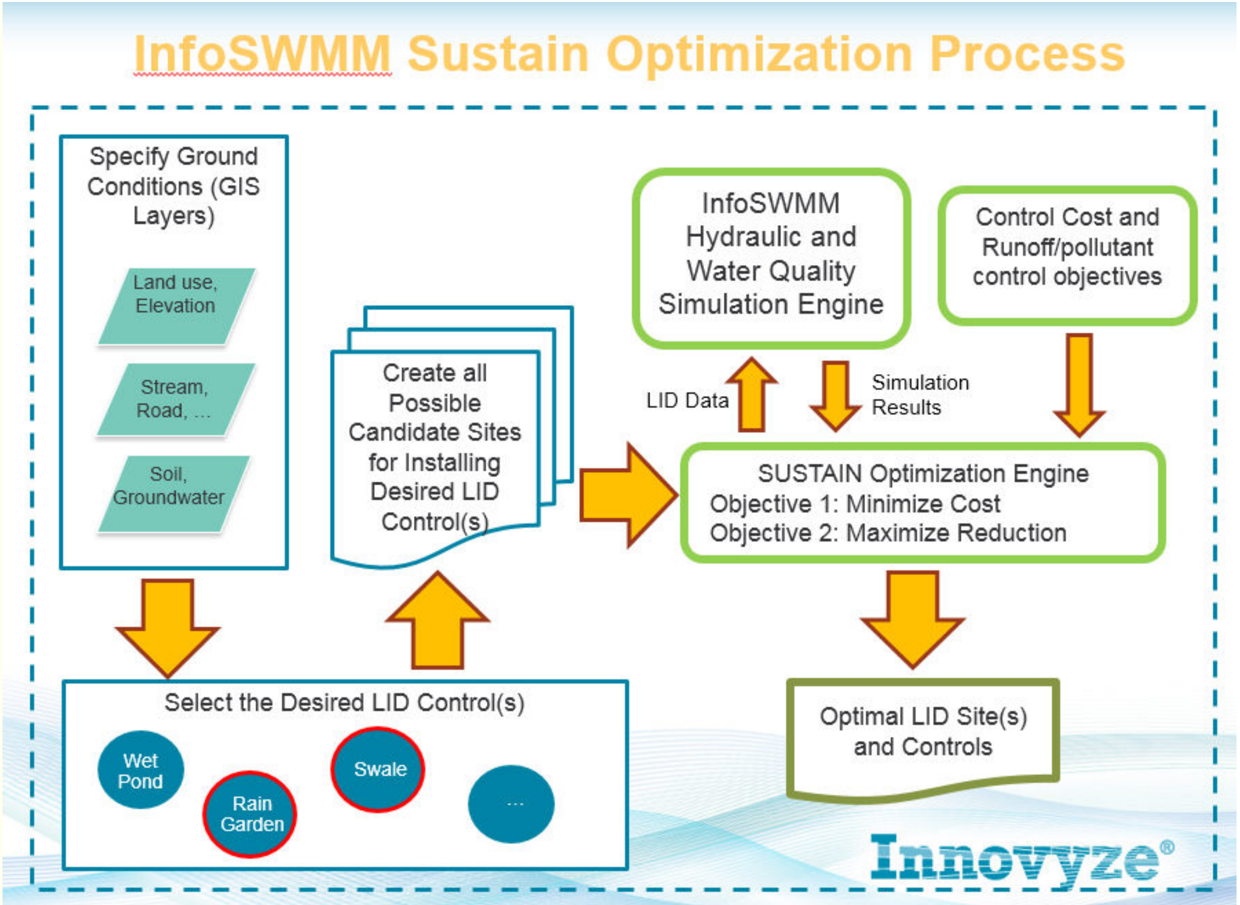
InfoSWMM and InfoSWMM Sustain have LID Types and Process layers for each LID Type. In addition there are storage nodes with evaporation and exfiltration along with link seepage and evaporation as SUDS

like features.

The number of LID controls is unlimited and very flexible. In addition to the 7 main LID controls:

1. Rain Barrel
2. Bio-Retention Cell
3. Infiltration Trench
4. Porous Pavement
5. Vegetative Swale
6. Green Roof
7. Rain Garden
8. Disconnected Rooftops

LID Features in InfoSWMM v14



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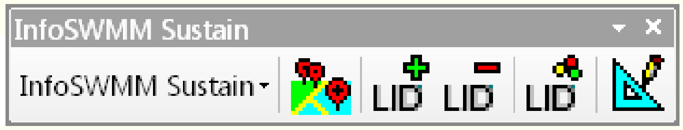
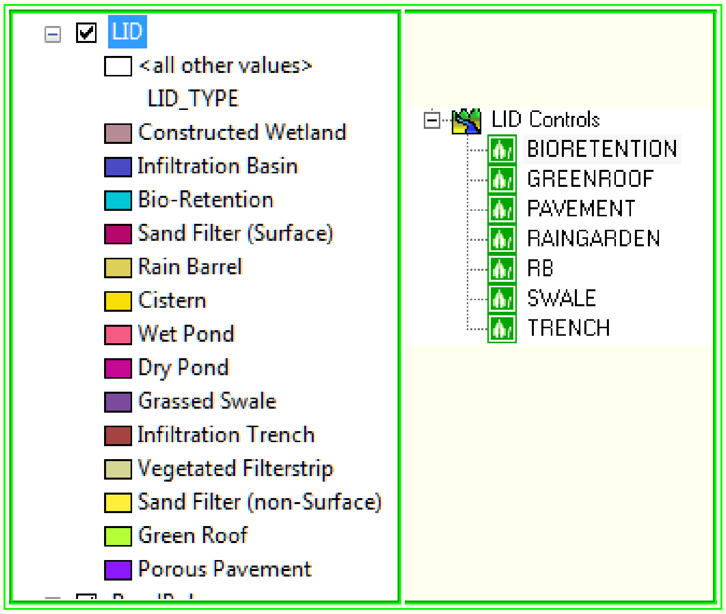

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

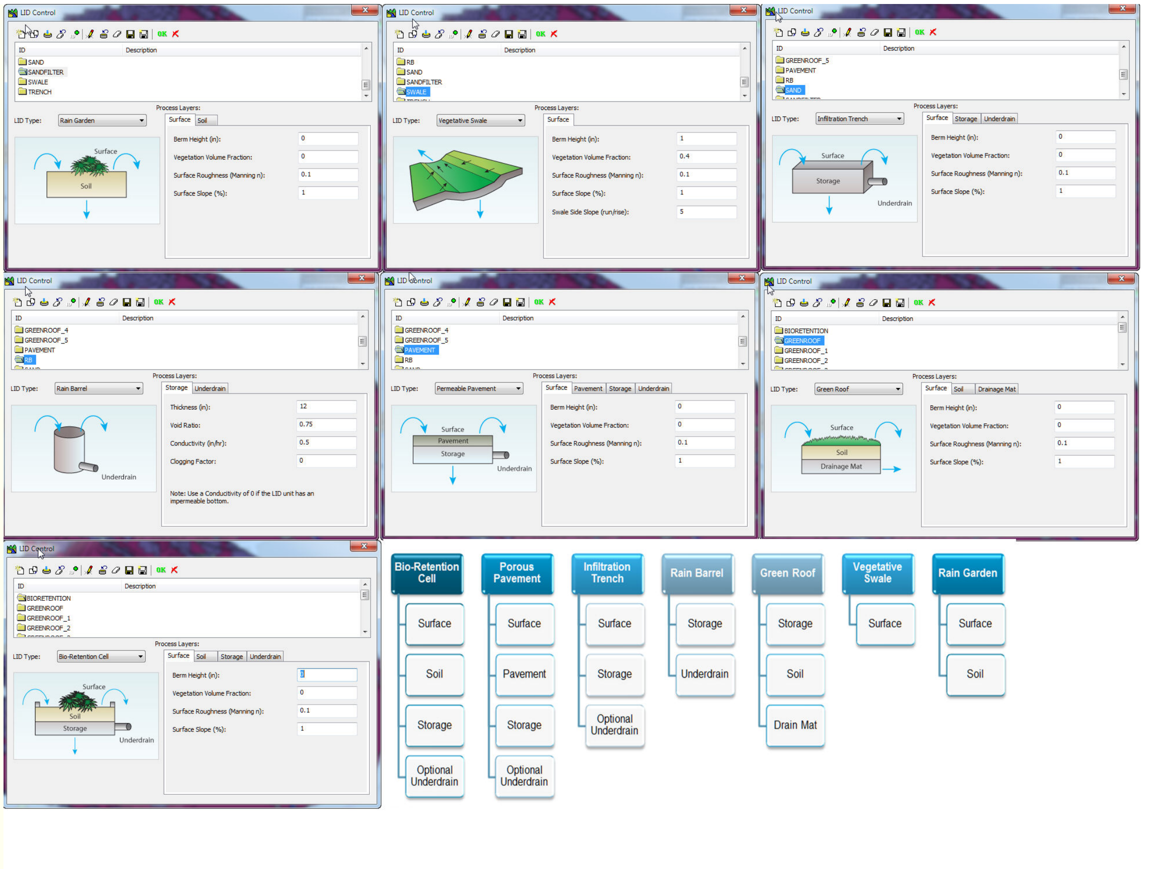
InfoSWMM Sustain BMP's and LID's vs InfoSWMM LID's

There are 14 InfoSWMM Sustain possible Optimized LID's or BMP's versus the seven types of LID Controls in the InfoSWMM v14 SWMM 5 Engine.



An **Collage Image** of the InfoSWMM

LID options and LID Process Layers



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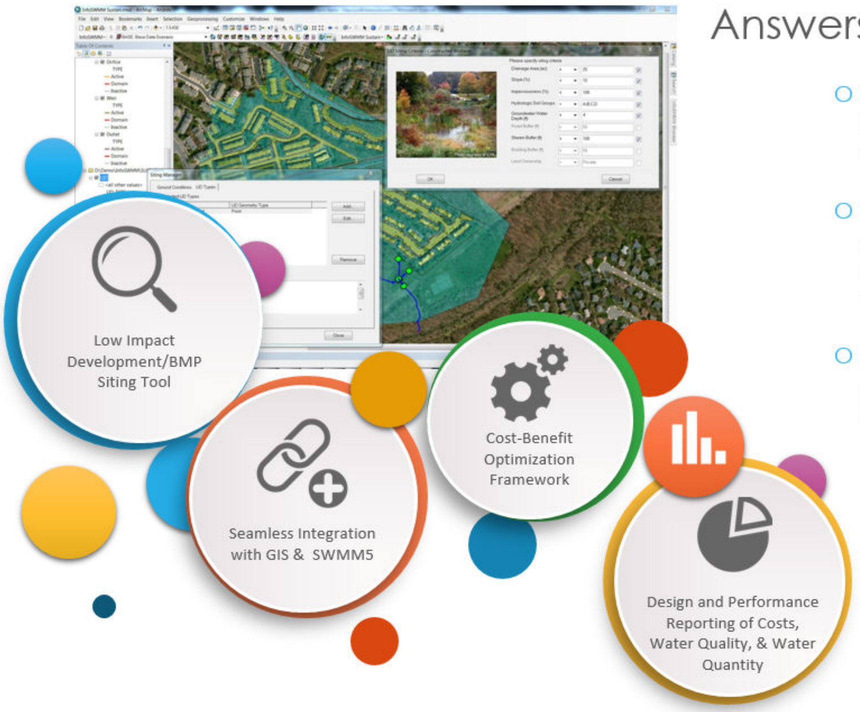
GIF Presentation of LID's

This GIF was originally made in Powerpoint and gifmaker.me

InfoSWMM® Sustain

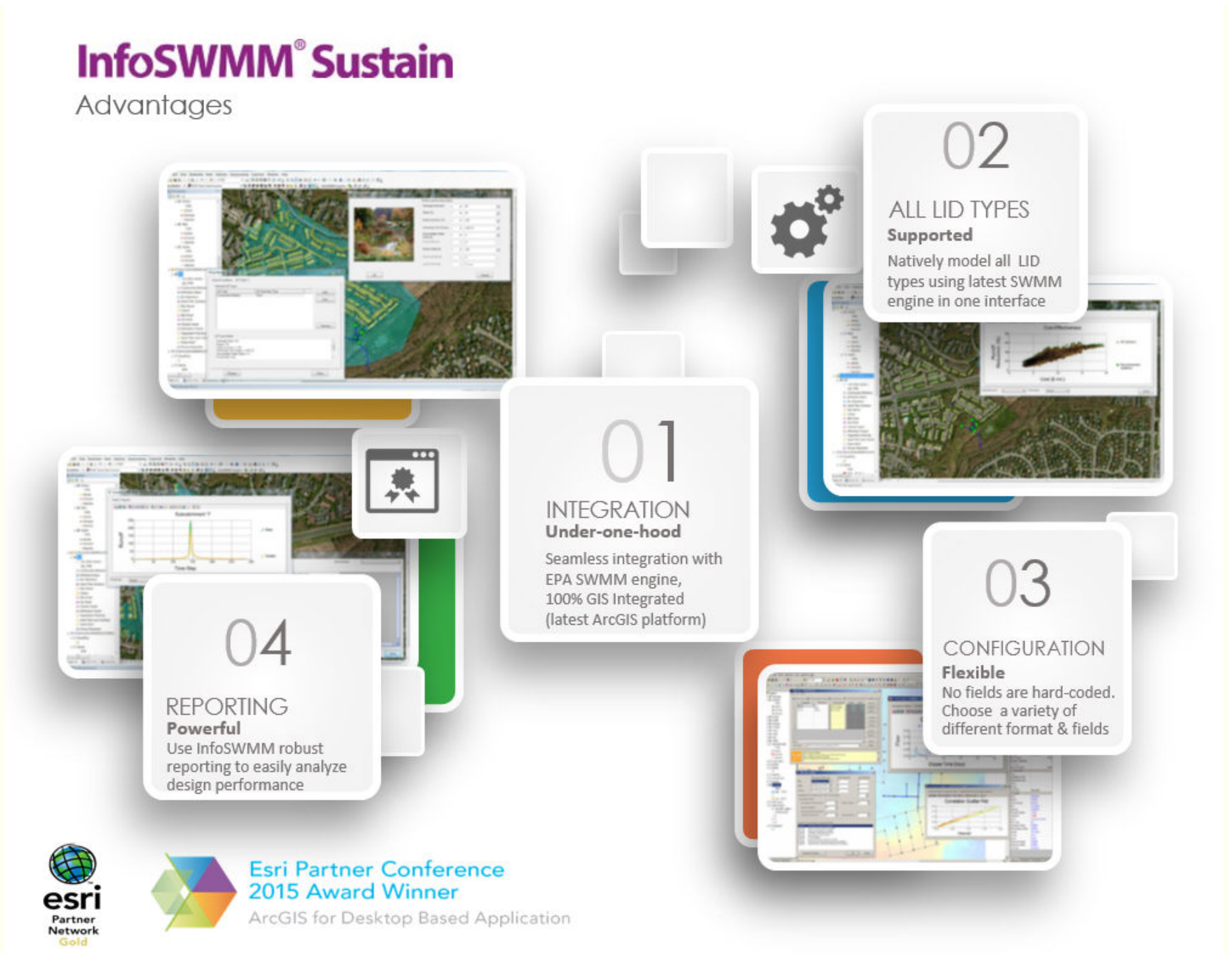
Comprehensive Urban Stormwater Treatment & Analysis Tool

Evaluating BMPs and LIDs for sustainability goals

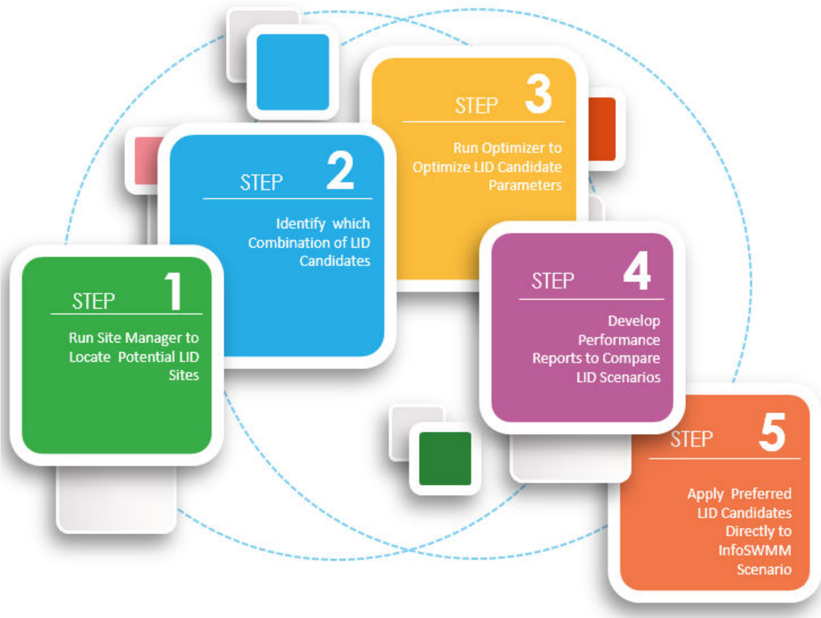


Answers Key Questions:

- How effective are LIDs and BMPs in reducing runoff and pollutant loadings
- What are the most cost-effective solutions for meeting water quality and quantity objectives?
- And where, what type, and how extensive should the LIDs and BMPs be?


InfoSWMM® Sustain
Advantages
01
INTEGRATION
Under-one-hood
Seamless integration with EPA SWMM engine, 100% GIS Integrated (latest ArcGIS platform)
02
ALL LID TYPES
Supported
Natively model all LID types using latest SWMM engine in one interface
03
CONFIGURATION
Flexible
No fields are hard-coded. Choose a variety of different format & fields
04
REPORTING
Powerful
Use InfoSWMM robust reporting to easily analyze design performance
esri
Partner Network
Gold
Esri Partner Conference
2015 Award Winner
ArcGIS for Desktop Based Application

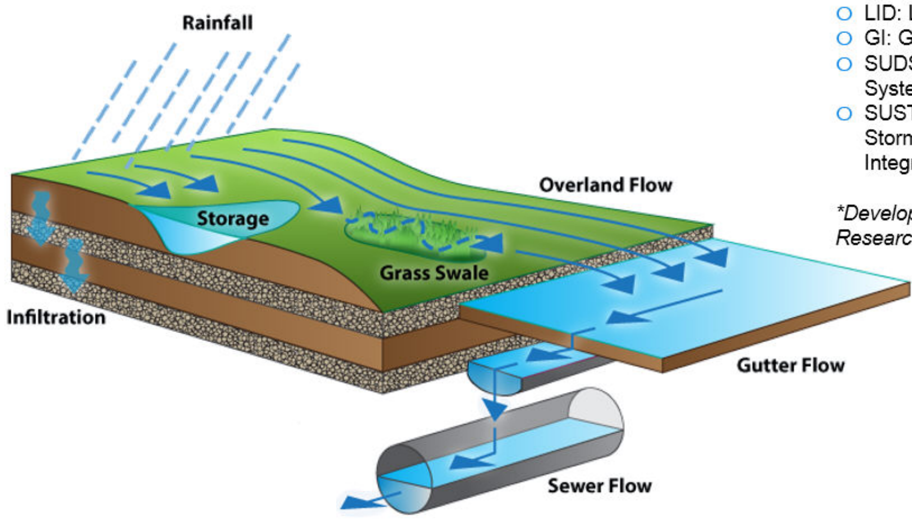
What is the InfoSWMM Sustain Process?



Applications:

- Implement TMDL plans
- Identify pollutant reductions
- Determine optimal green infrastructure (GI) strategies for reducing volume and peak flows to CSOs
- Evaluate benefits of distributed GI on water quantity/quality in streams
- Develop a phased BMP installation plan using cost effectiveness curves

What are BMPS, LIDs, SUDS? What is InfoSWMM Sustain?



Definitions:

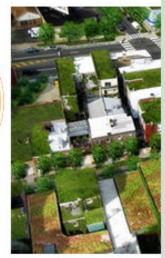
- BMP: Best Management Practice
- LID: Low Impact Development
- GI: Green Infrastructure
- SUDS: Sustainable Urban Drainage Systems
- SUSTAIN*: System for Urban Stormwater Treatment and Analysis Integration

**Developed by EPA's Office of Research and Development (ORD)*

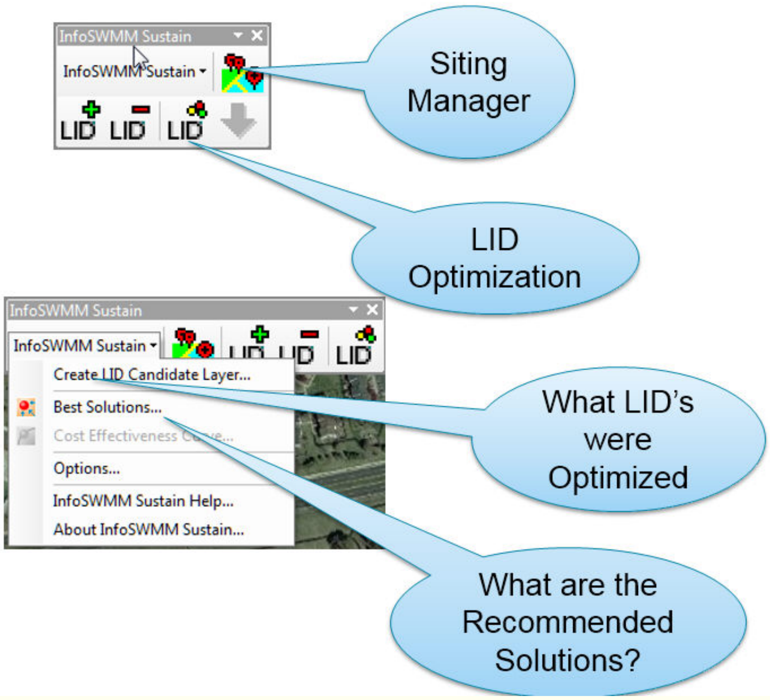
What are LID Control Types in InfoSWMM Sustain?

- There are 8 Types of LID Controls allowed in InfoSWMM
- They are defined in the Attribute Browser under LID Controls
- 1. Rain Garden
- 2. Bio-Retention
- 3. Porous Pavement
- 4. Green Roof
- 5. Rain Barrel
- 6. Rooftop Disconnection
- 7. Vegetative Swale
- 8. Infiltration Trench

- Other BMP's such as Wet and Dry Ponds can be simulated with a Storage Node with Seepage and Evaporation.



What are the Tools in InfoSWMM Sustain?



Tools:

- Siting Manager to find LID's from GIS Data
- Add LID's my Drawing or imported from InfoSWMM
- LID Candidate Selection for 14 Types of LID/BMP's
- Optimization Rules and Goals
- LID Optimization to find best LID Solutions
- Design Report to See Optimized LID's and BMP's
- Performance Report to See Effect of the LID's and BMP's
- Cost Effectiveness Graph for Recommended Solutions
- Export of Best Solution to InfoSWMM

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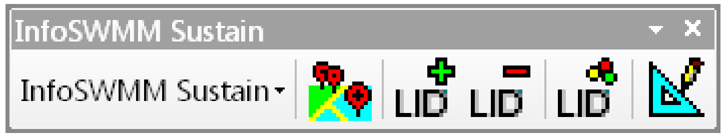
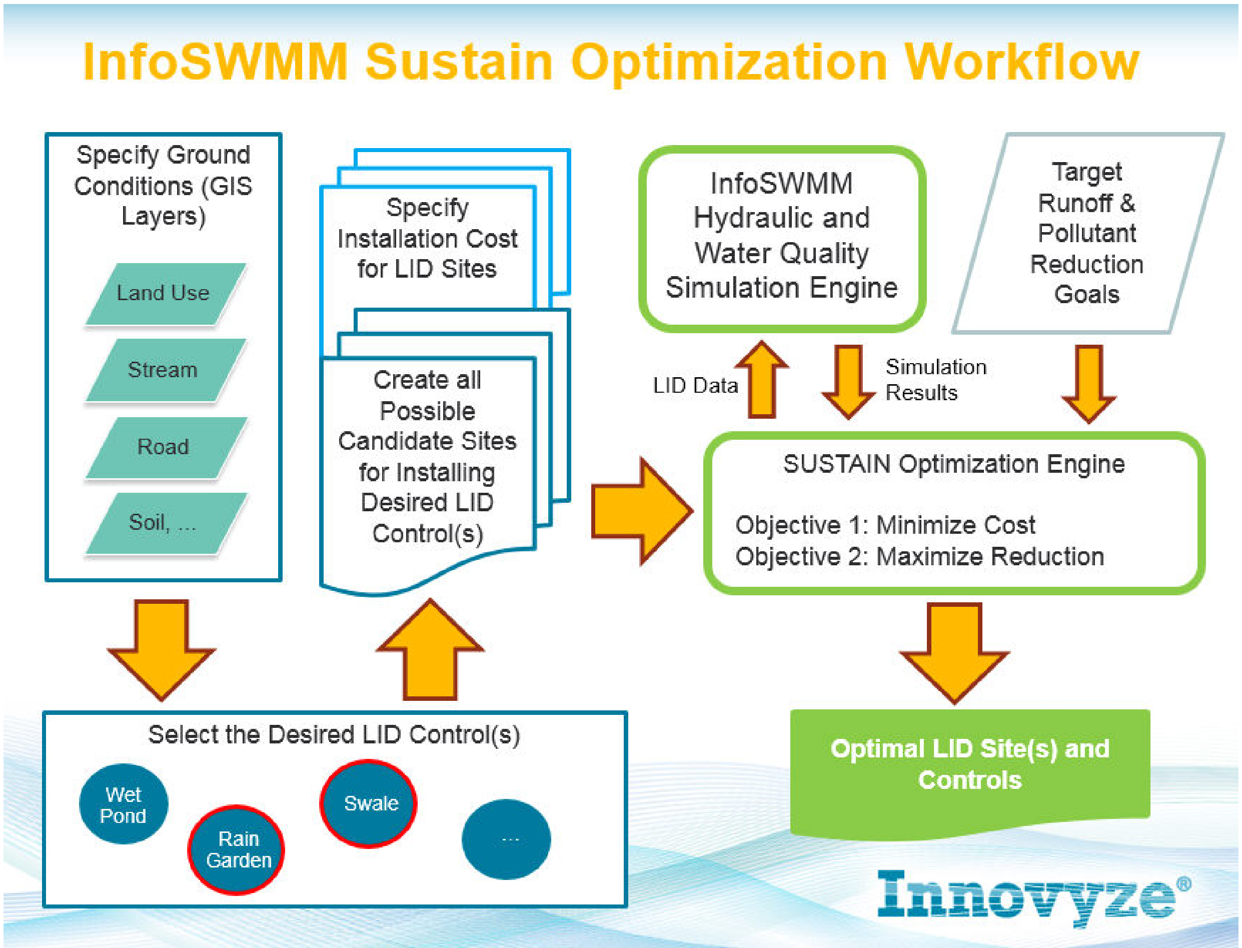
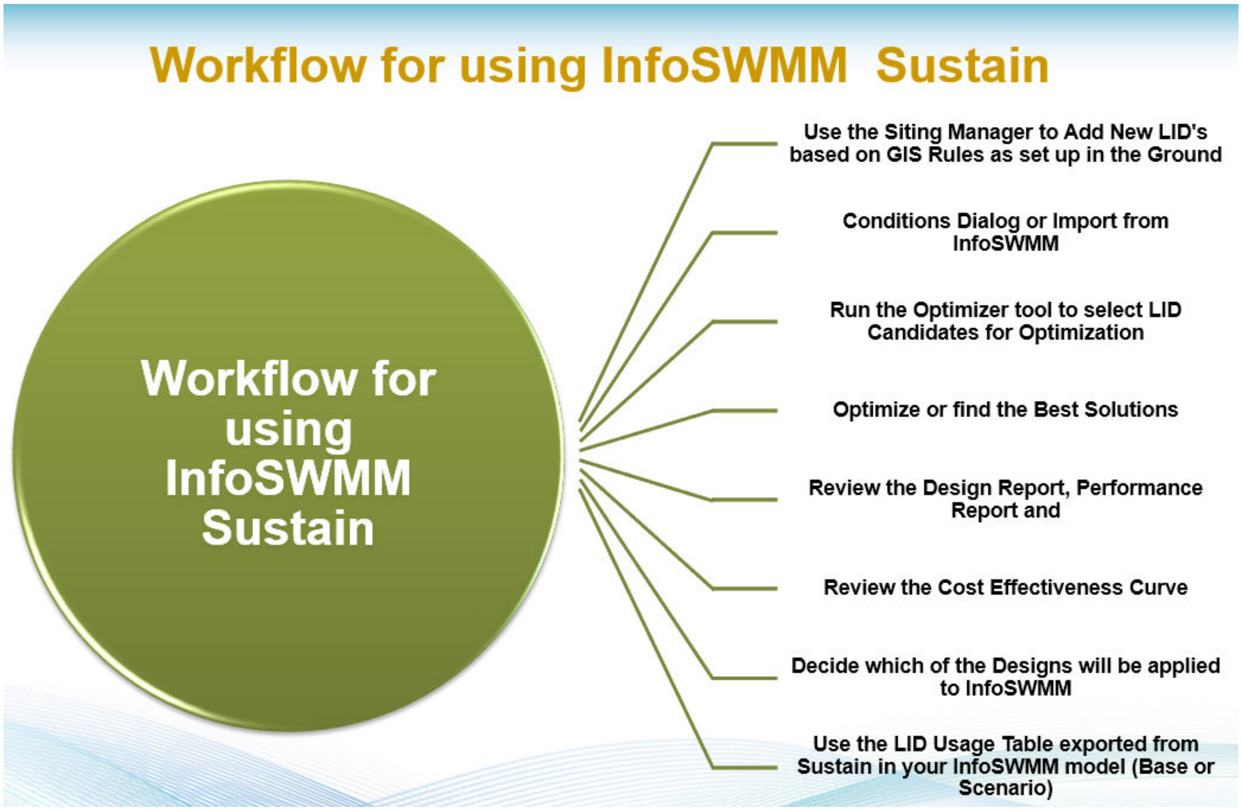

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Work Flow for InfoSWMM Sustain

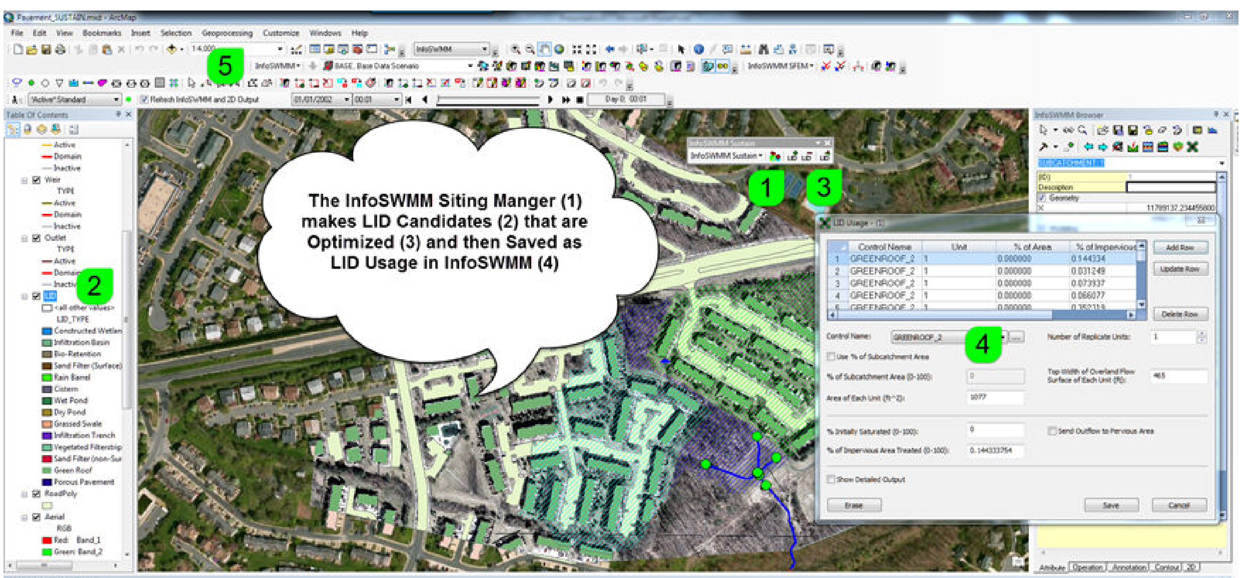
The major tasks in using InfoSWMM Sustain are the following:

- Use the Siting Manager to Add New LID's based on GIS Rules as set up in the Ground Conditions Dialog or Import from InfoSWMM
- Run the Optimizer tool to select LID Candidates for Optimization along with Costs
- Optionally use the LID Designer to calculate local evaporation and rainfall for continuous simulation
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and
- Review the Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model (Base or Scenario)

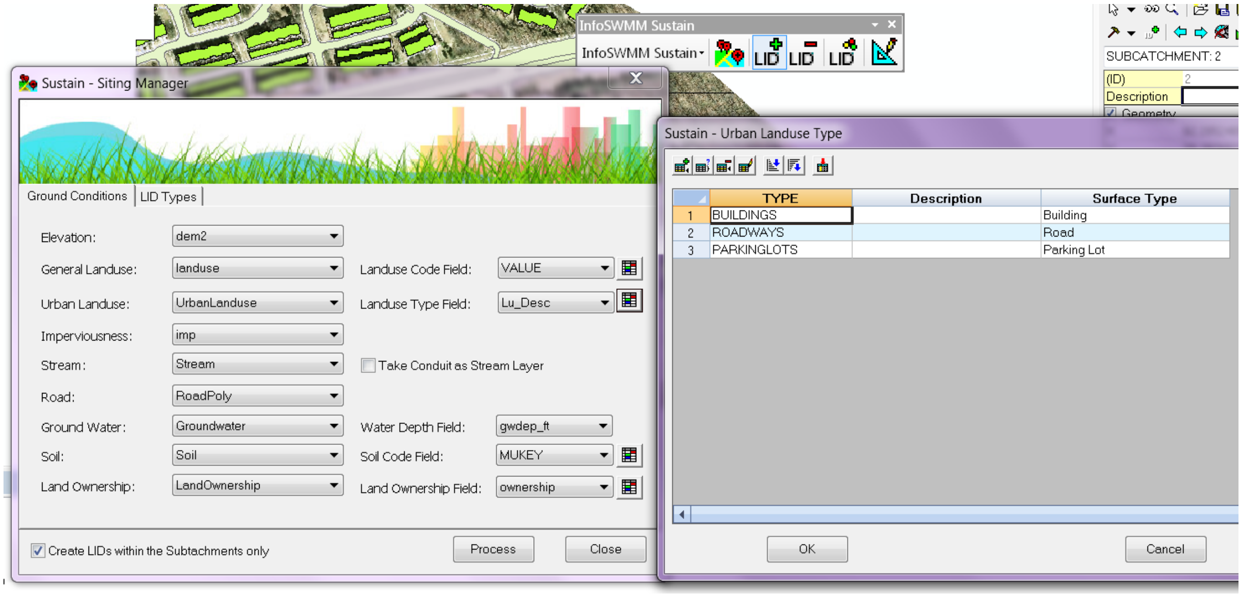

InfoSWMM Sustain Optimization Workflow
Specify Ground Conditions (GIS Layers)
Land Use
Stream
Road
Soil, ...
Specify Installation Cost for LID Sites
Create all Possible Candidate Sites for Installing Desired LID Control(s)
InfoSWMM Hydraulic and Water Quality Simulation Engine
Target Runoff & Pollutant Reduction Goals
LID Data
Simulation Results
SUSTAIN Optimization Engine
Objective 1: Minimize Cost
Objective 2: Maximize Reduction
Select the Desired LID Control(s)
Wet Pond
Rain Garden
Swale
...
Optimal LID Site(s) and Controls
Innovyze®



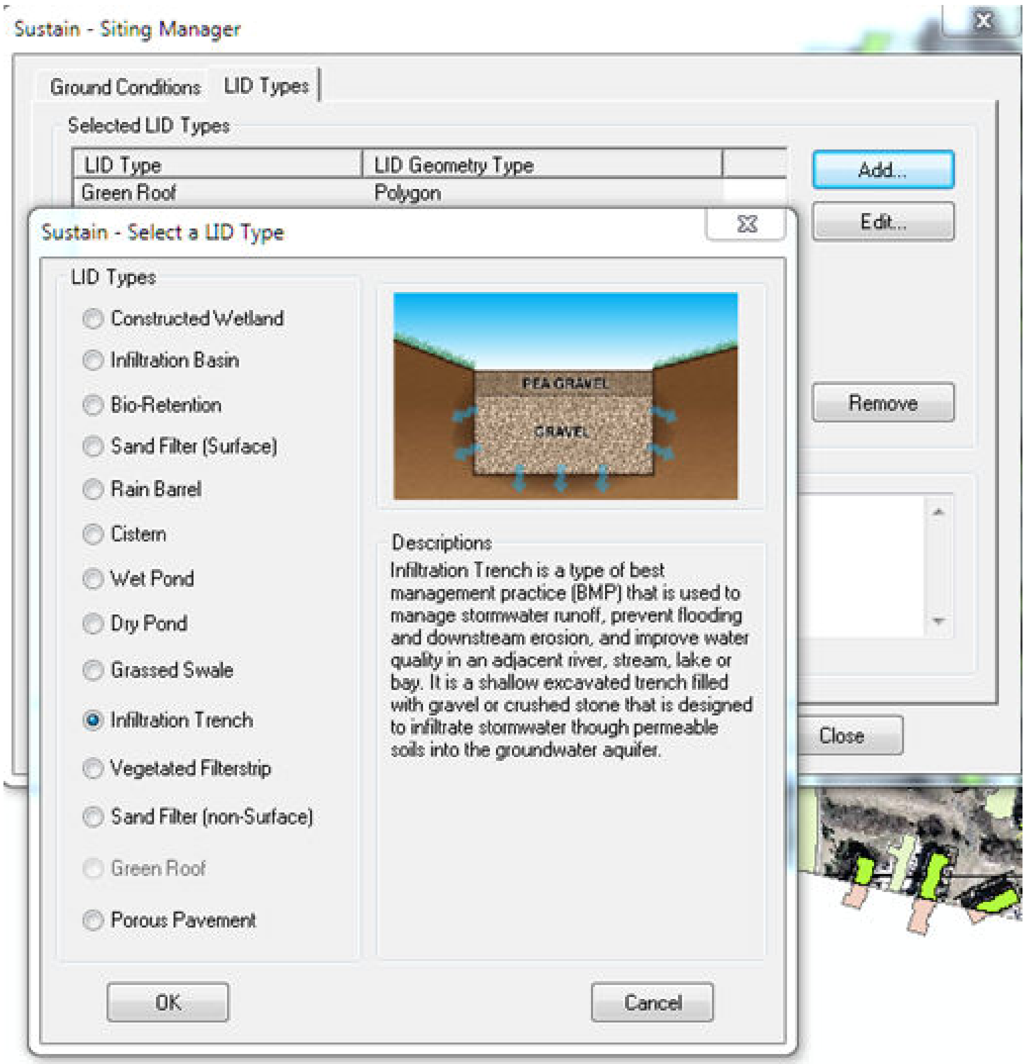
The major tasks in using InfoSWMM Sustain.



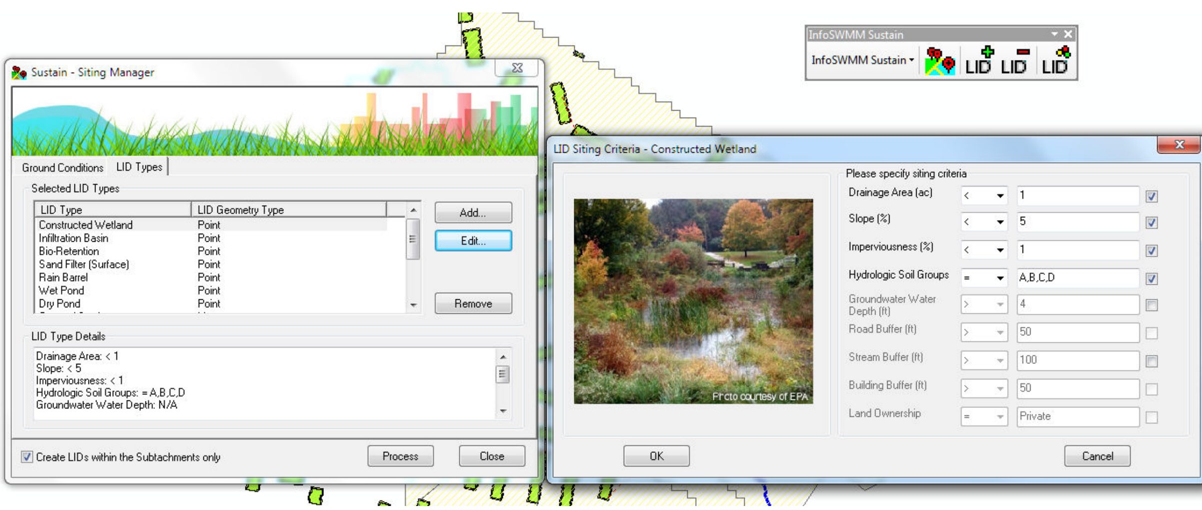
Set up the ground conditions in the Siting Manager.



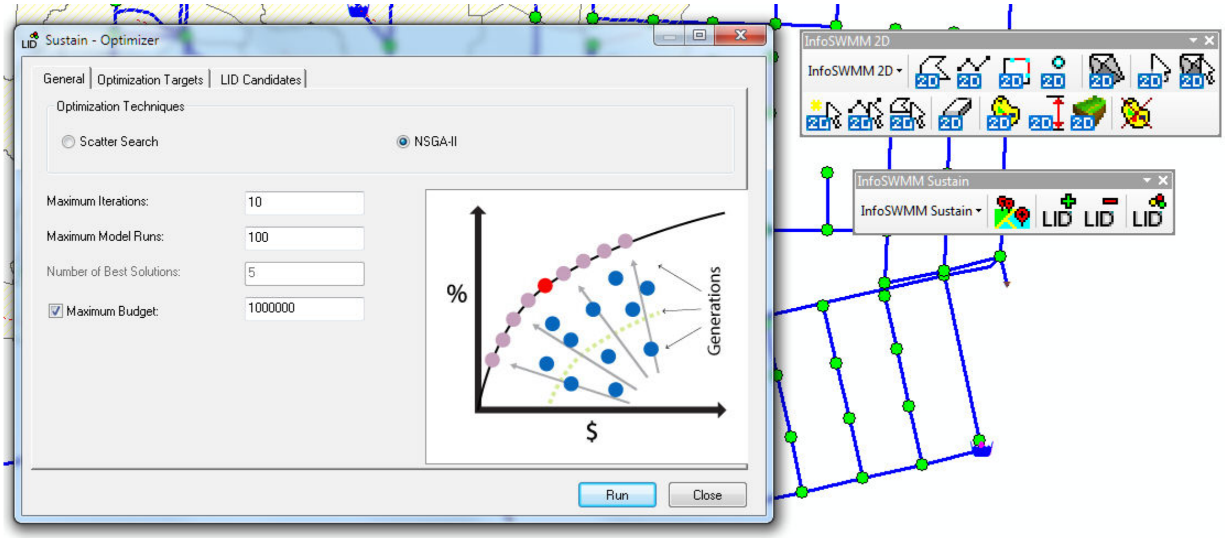
Add LID Types to the LID Candidates Pool using the Siting Manager.



Process the LID Types to the Pool of LID Candidates

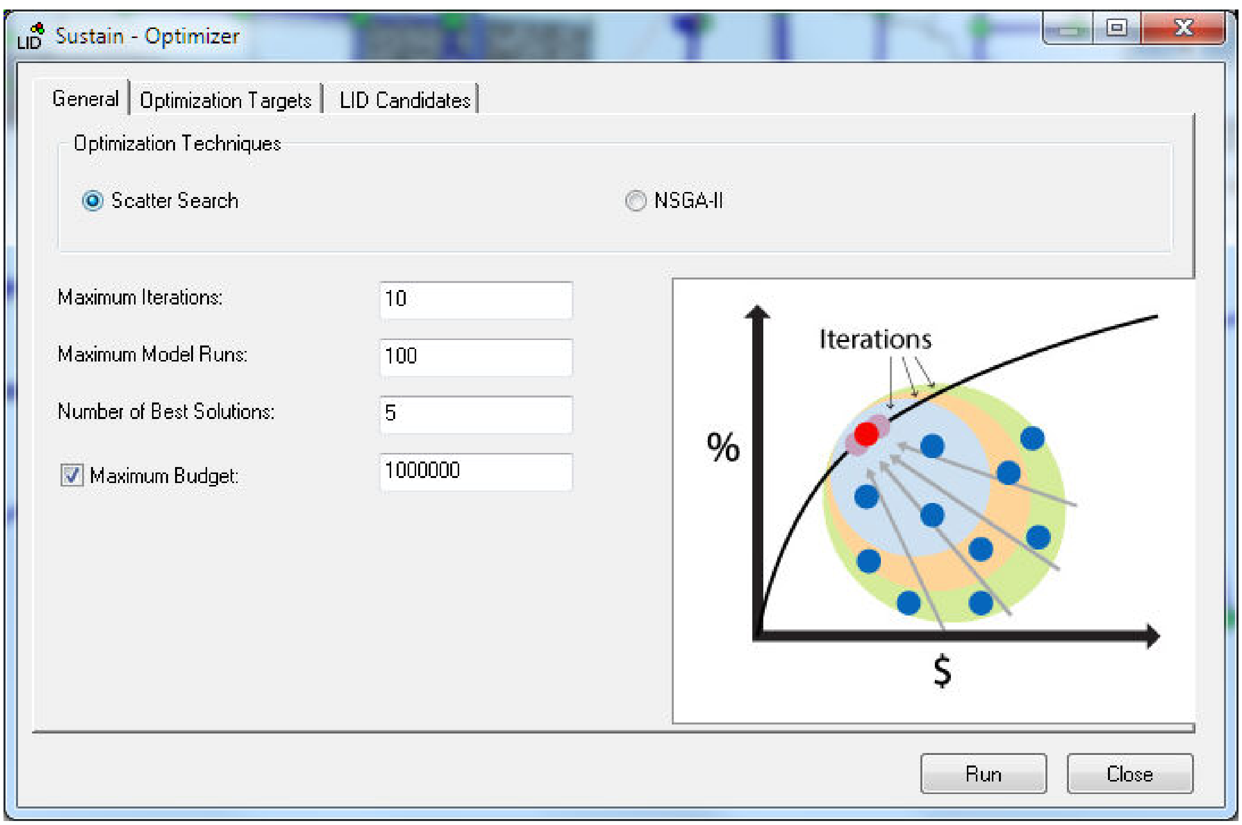


Setup the Optimization Rules and Choose the Final LID Candidates for Optimization.

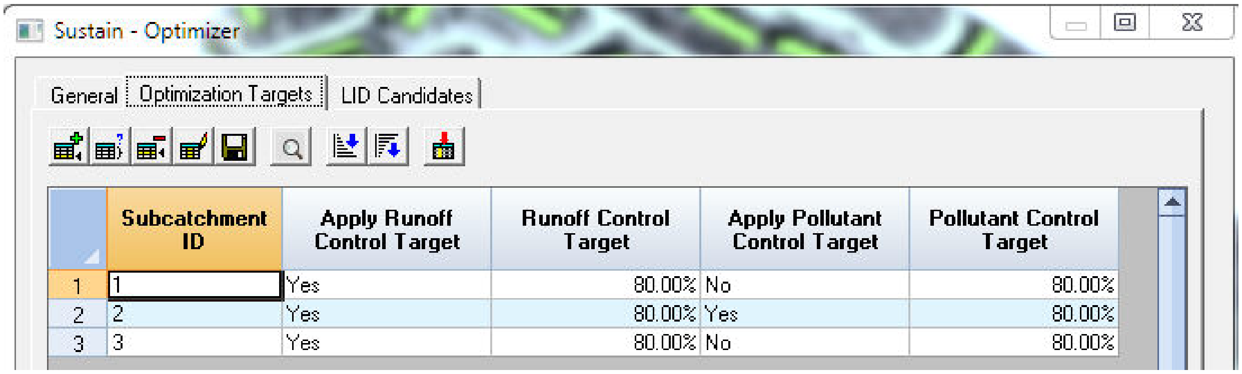


Note: Scatter Search is for the best solution finding and NSGA-II GA is for cost effective curve generation.

Maximum budget is the maximum amount allowed to be spent on the run.

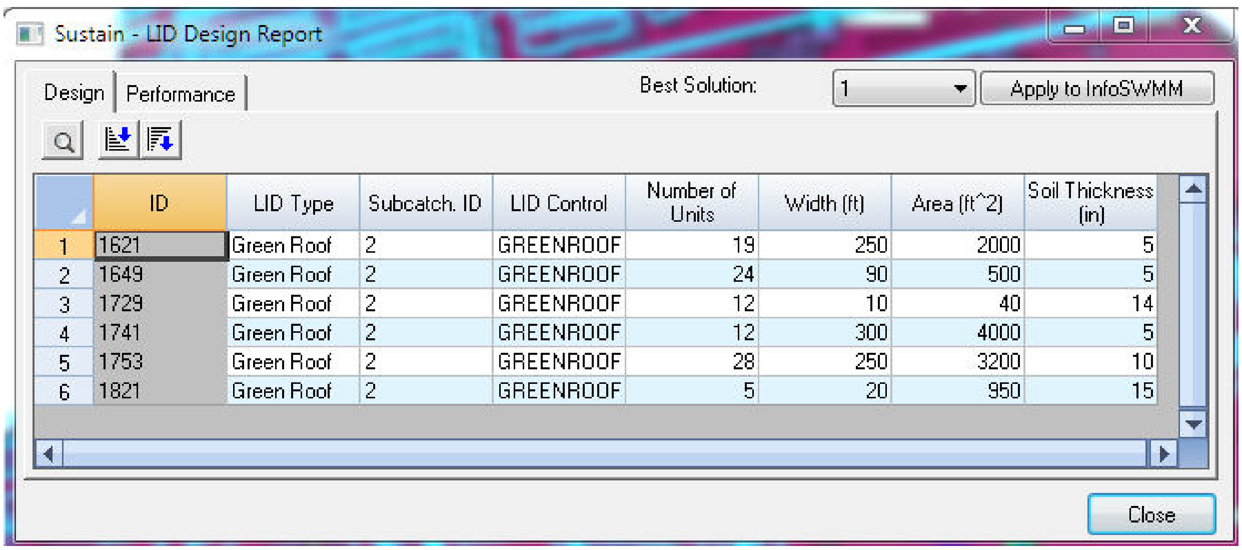


Setup or choose the Optimization Targets.



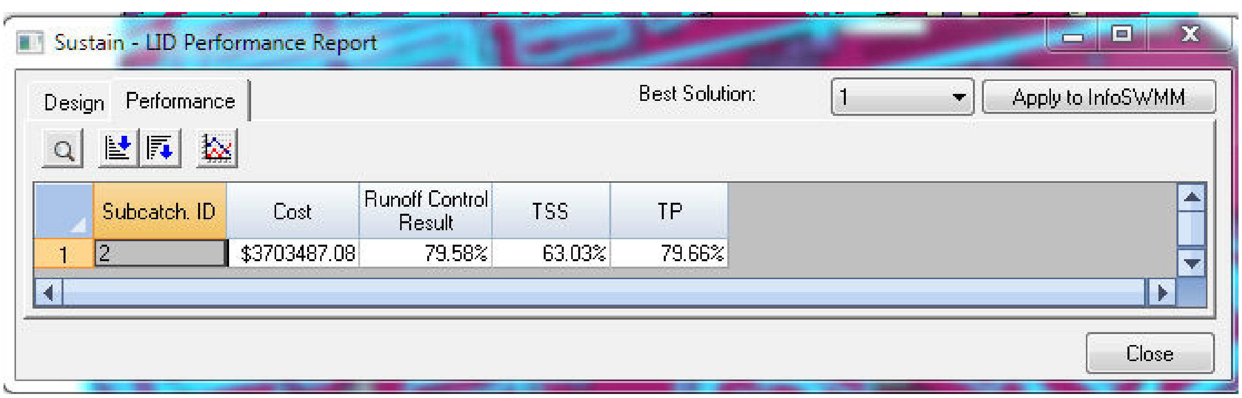
	Subcatchment ID	Apply Runoff Control Target	Runoff Control Target	Apply Pollutant Control Target	Pollutant Control Target
1	1	Yes	80.00%	No	80.00%
2	2	Yes	80.00%	Yes	80.00%
3	3	Yes	80.00%	No	80.00%

Review the Design Report after Optimization.



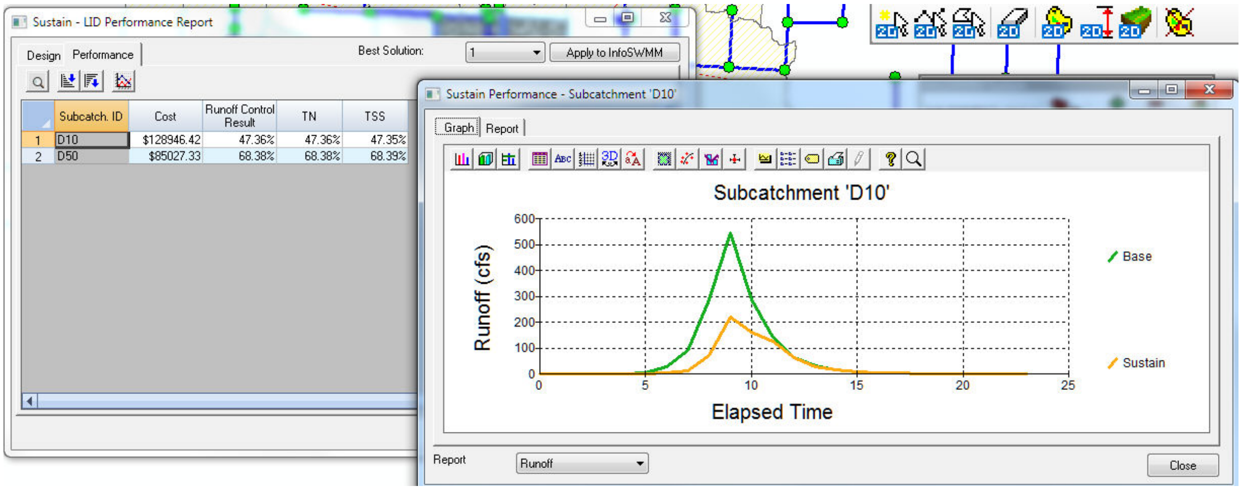
	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness (in)
1	1621	Green Roof	2	GREENROOF	19	250	2000	5
2	1649	Green Roof	2	GREENROOF	24	90	500	5
3	1729	Green Roof	2	GREENROOF	12	10	40	14
4	1741	Green Roof	2	GREENROOF	12	300	4000	5
5	1753	Green Roof	2	GREENROOF	28	250	3200	10
6	1821	Green Roof	2	GREENROOF	5	20	950	15

Review the Performance Report after Optimization.

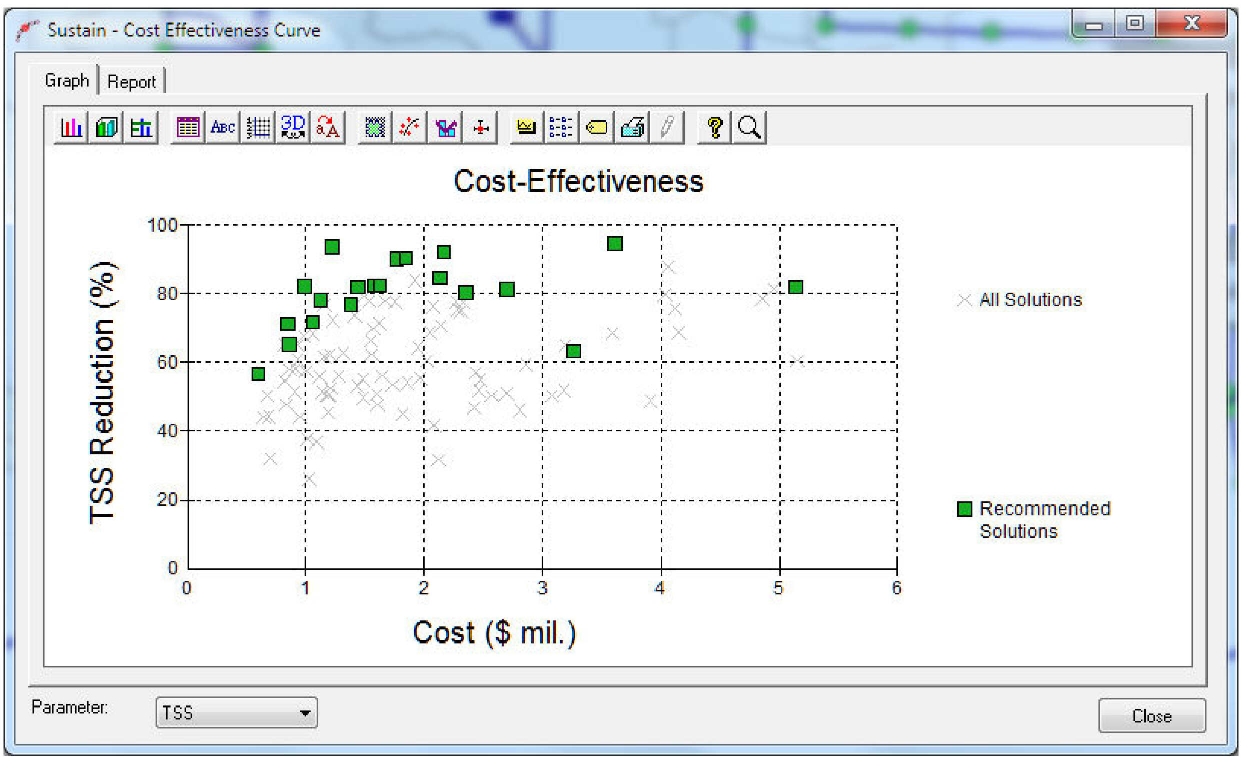


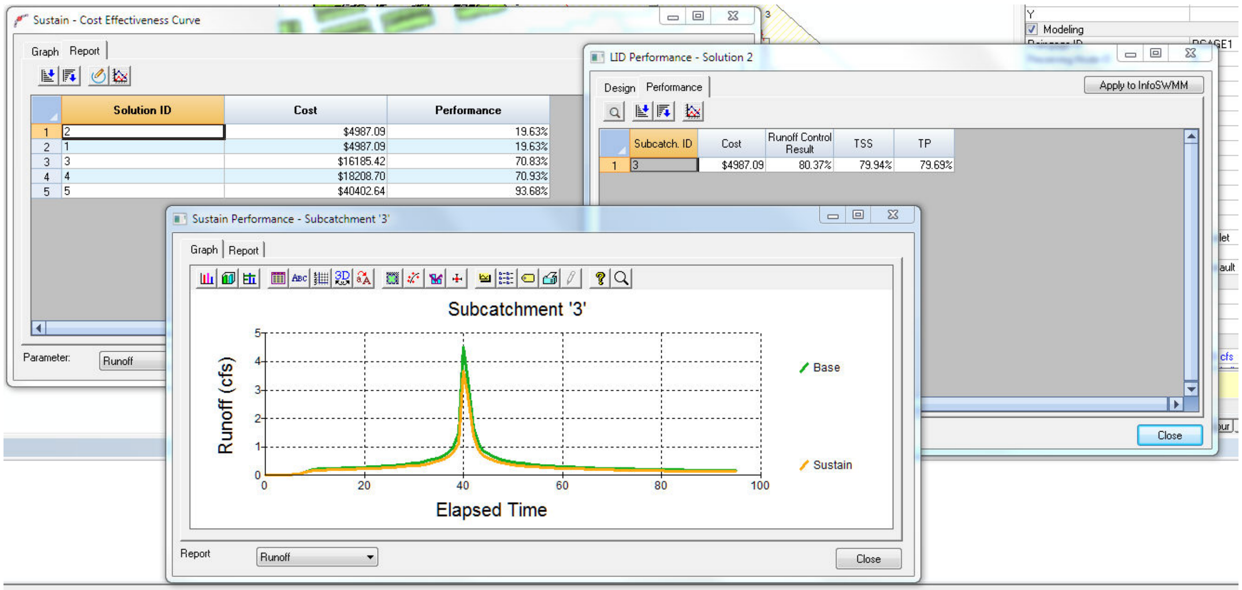
	Subcatch. ID	Cost	Runoff Control Result	TSS	TP
1	2	$3703487.08	79.58%	63.03%	79.66%

Graph the Sustain Performance.

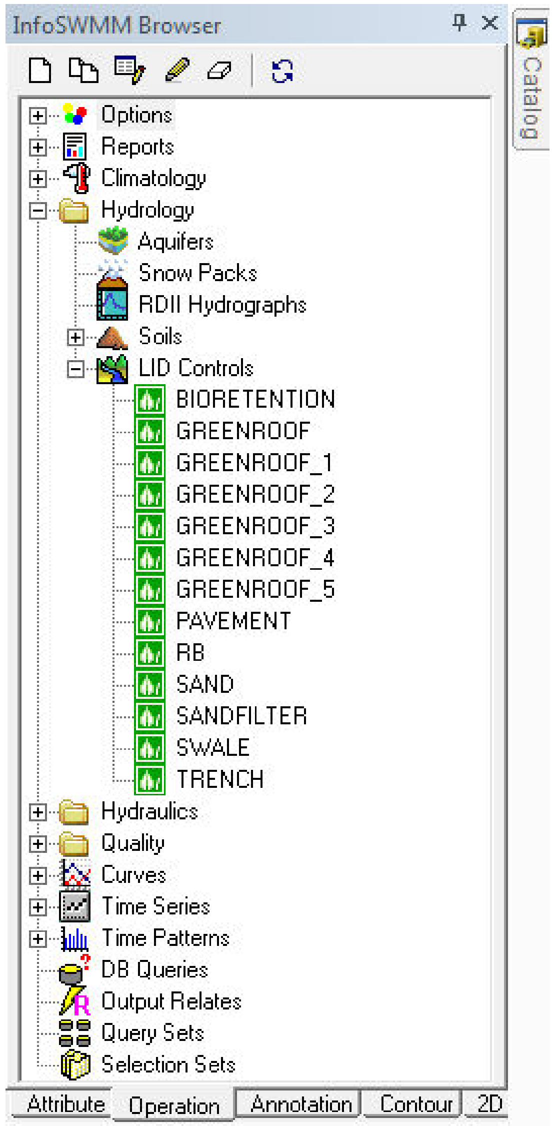


Review the Cost Effectiveness Curve





Export the data back to InfoSWMM to the LID Controls and LID Usage Table



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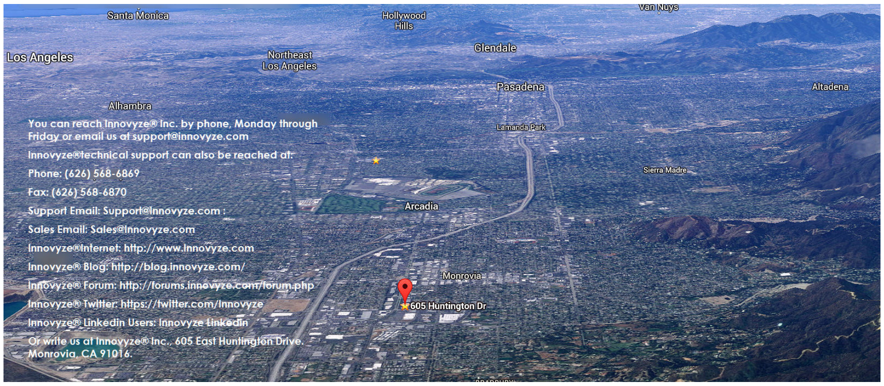

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- The level of urgency of the problem
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Innovyze Ltd (UK):	**Kestrel House Howbery Park Wallingford Oxfordshire, OX10 8BA United Kingdom**
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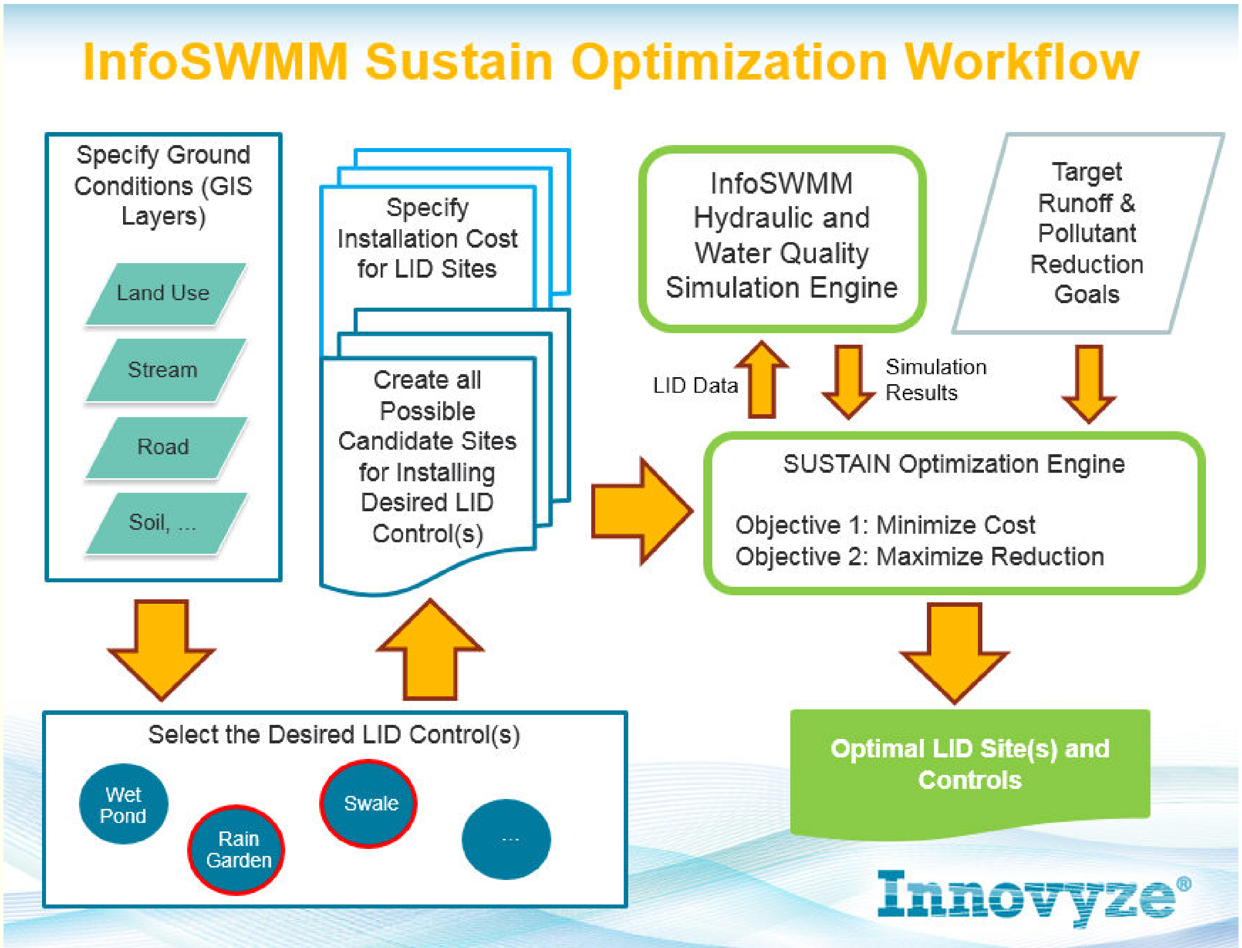
LID
LID

Run Sustain

The major tasks in using InfoSWMM Sustain are the following:

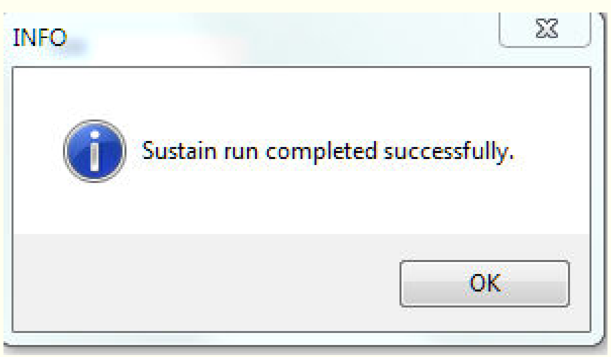
- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

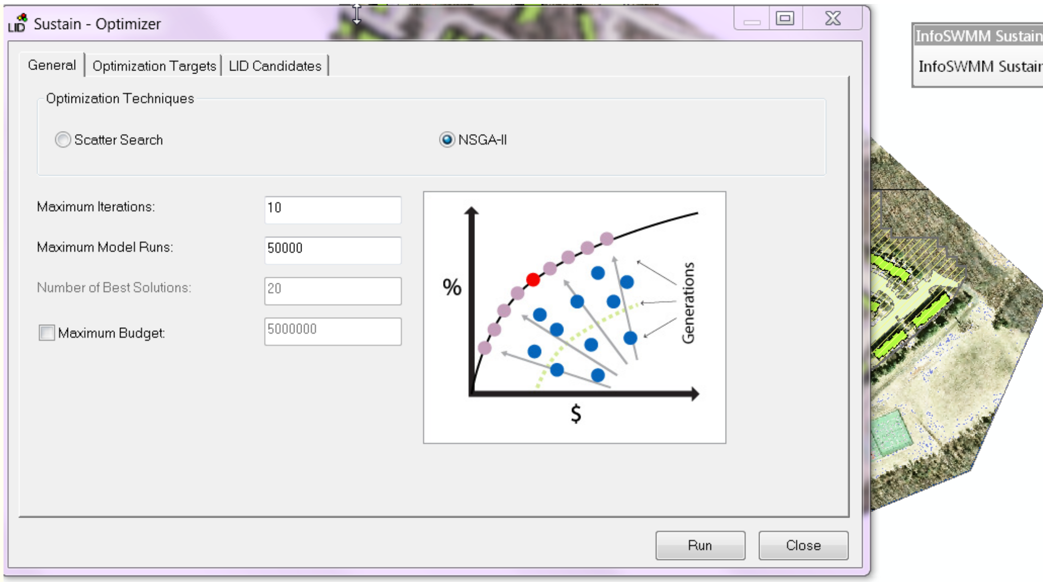
The Optimization takes place after either you create the LID Candidates using the Siting Manager, Createthe LID's yourself on the Map or import the LID's from InfoSWMM. The optimizer as shown in the following image Minimizes Cost and Maximizes the Reduction of Runoff or Pollutants.



The Optimizer runs many InfoSWMM runs to optimize the selected LID Types.

Click on Run and you will see a Blue progress bar at the bottom of the screen and at the end of the Run an Info Dialog Message Box about a successful Run.

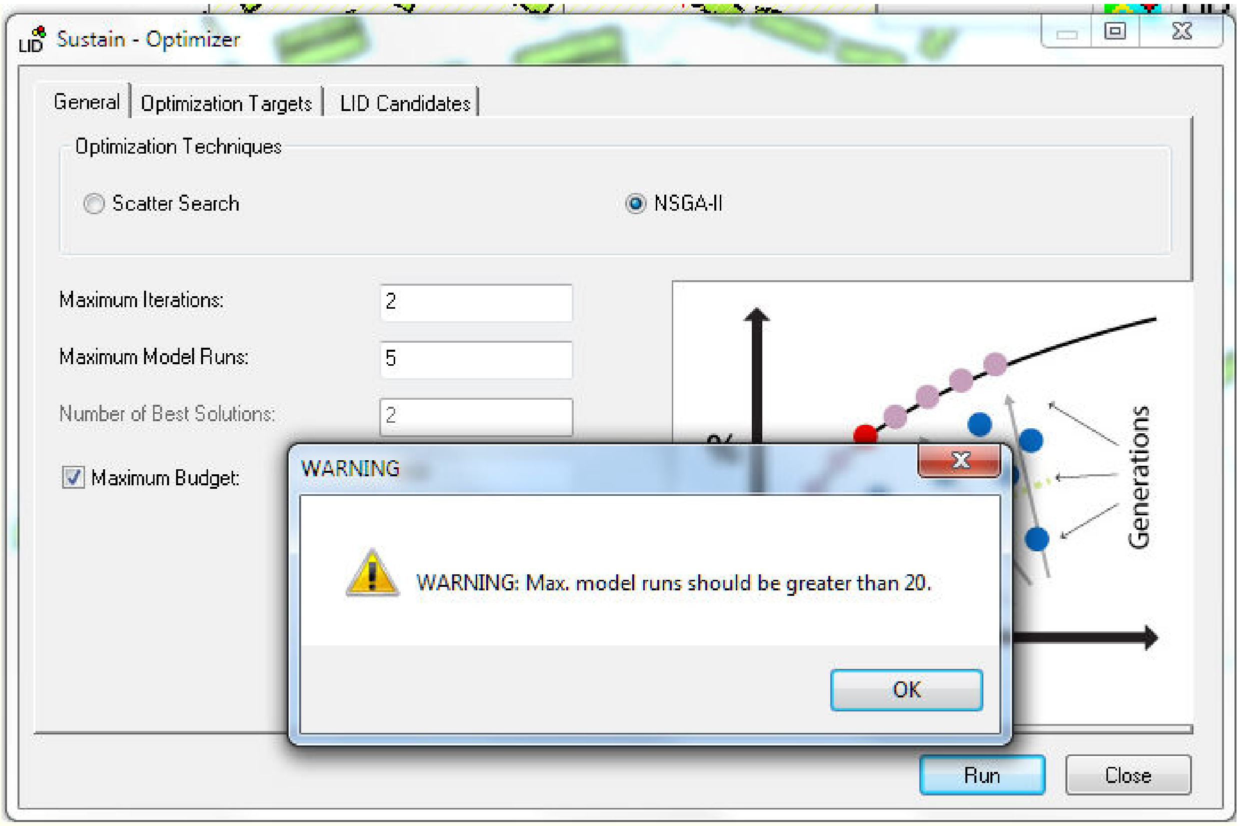


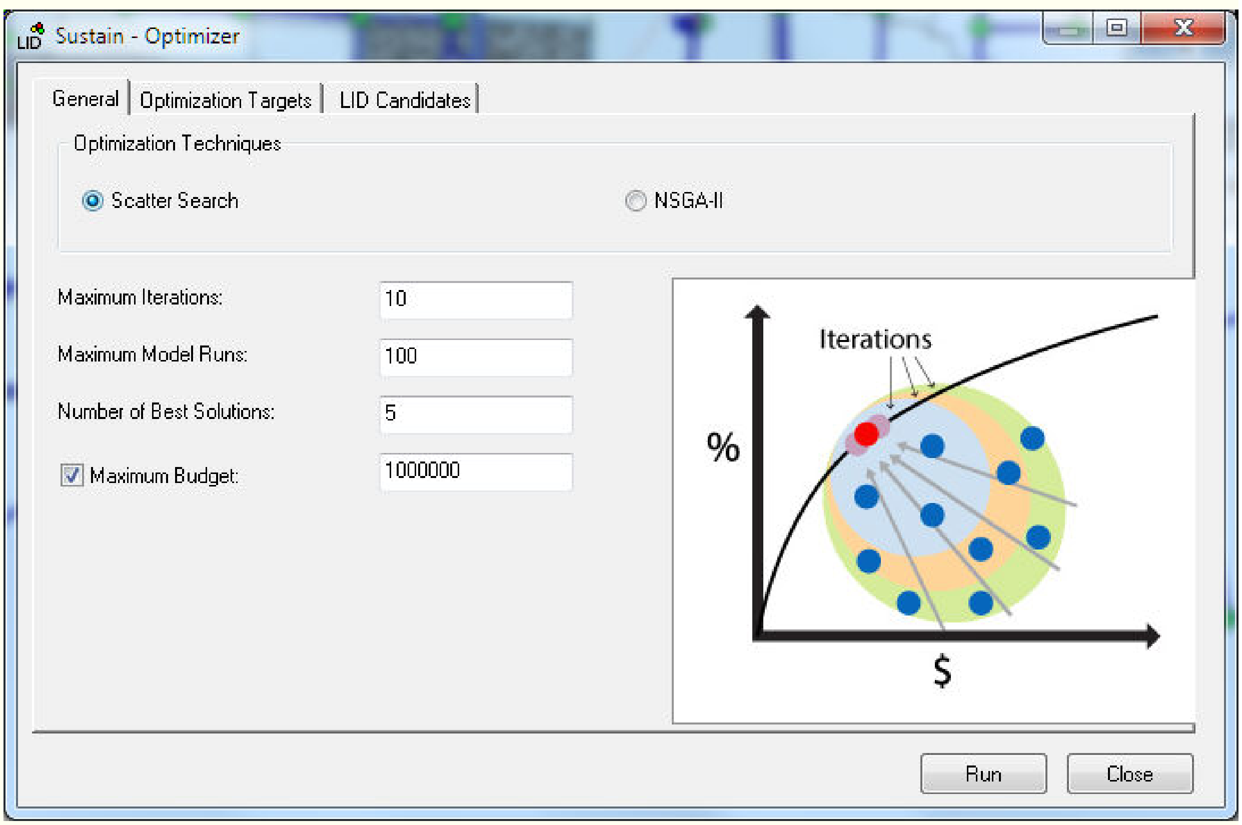


Note: Scatter Search is for the best solution finding and NSGA-II GA is for cost effective curve generation.

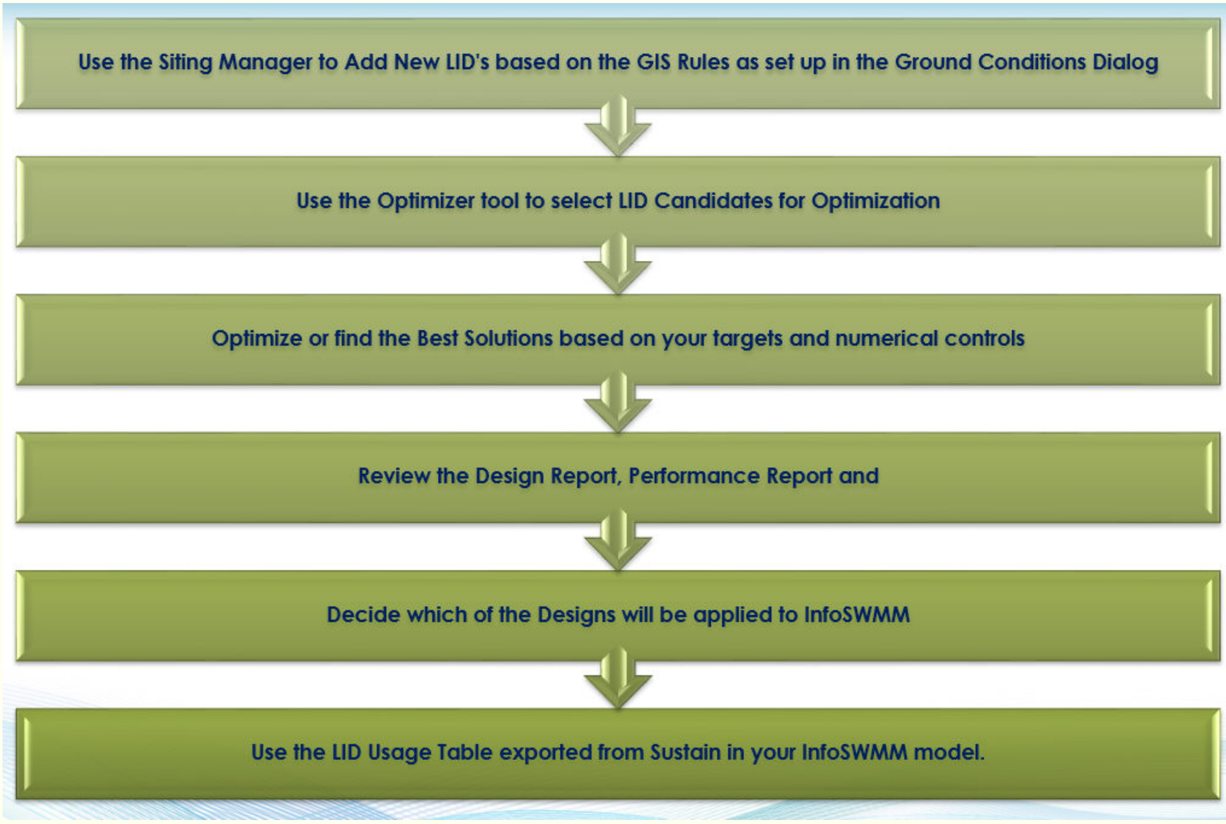
Maximum budget is the maximum amount allowed to be spent on the run.

If there are not enough model runs selected the program will inform you of the needed model runs for your LID targets and LID Candidates.


Sustain - Optimizer
General
Optimization Targets
LID Candidates
Optimization Techniques
Scatter Search
NSGA-II
Maximum Iterations:
2
Maximum Model Runs:
5
Number of Best Solutions:
2
Maximum Budget:
Generations
WARNING
WARNING: Max. model runs should be greater than 20.
OK
Run
Close


Sustain - Optimizer
General
Optimization Targets
LID Candidates
Optimization Techniques
Scatter Search
NSGA-II
Maximum Iterations:
10
Maximum Model Runs:
100
Number of Best Solutions:
5
Maximum Budget:
1000000
Iterations
%
$
Run
Close

A visual view of the major tasks in using InfoSWMM Sustain is shown in the following image.



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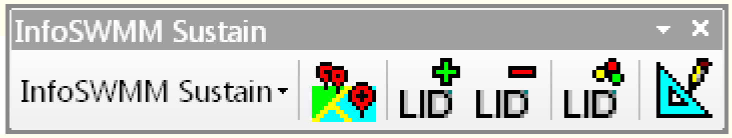
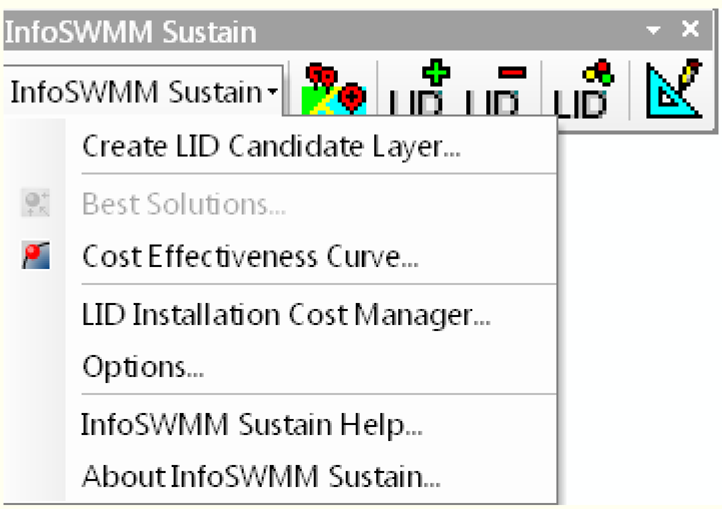

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

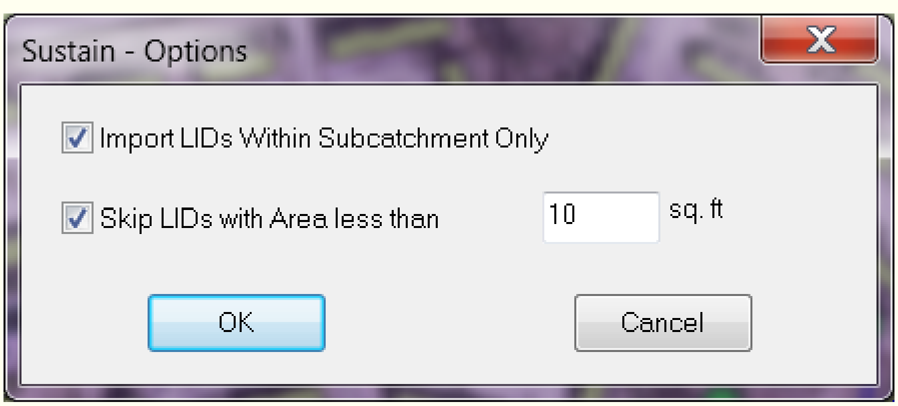
Sustain Options

The dialog Sustain Options are part of the main menu of InfoSWMM Sustain.

It has two options:

- Import only the LID's within Subcatchments in the LID Candidate Dialog
- Do not import LID's with Area's less than 10 square feet or 10 square meters





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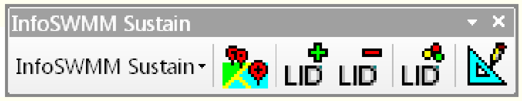
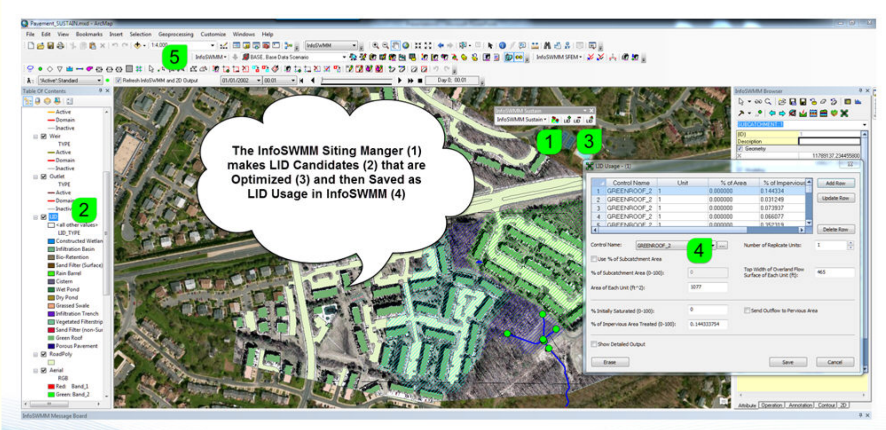

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Siting Manager

The Siting Manager was developed to ass ist users in selecting suitable locations for different types of low impact devel opment (LID) techniques or conventional BMPs. Site suitability is used as the dominant factor in identifying potential site locations (USEPA 1999a). Using GIS analysis and up to eight base data layers, the siting tool helps users identify suitable sites for placement of structural LIDs/BMPs on the basis of suitability criteria including elevation, slope, soil type, urban land use, roads, water table depth, stream location, and rain.

The four main components of InfoSWMM Sustain are:

- Siting Manager
- LID Candidates
- Optimizer
- Save Optimized Controls to InfoSWMM



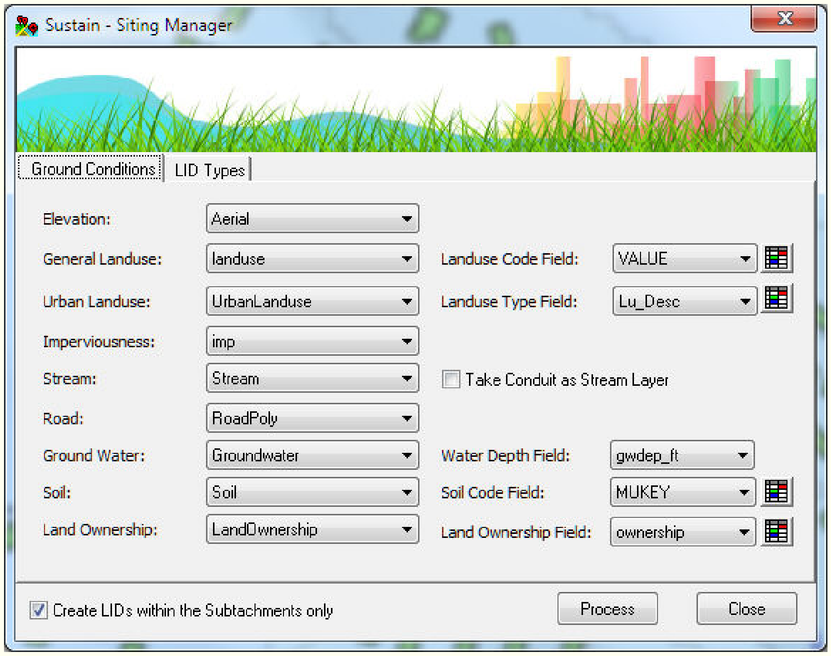
Here is a Youtube Video showing the basics of using the Siting Manager

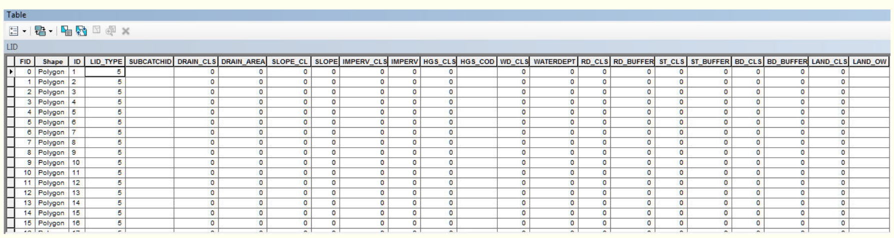
Table 3-3. GIS Data Requirement for BMP Suitability Analysis

GIS Layer	Format	Description
DEM	Raster file	The DEM is used to calculate the drainage slope and drainage area that are used to identify the suitable locations for BMPs.
NLCD Land Use	Raster file	The USGS Multi-Resolution Land Characteristics Consortium NLCD land use grid is used to eliminate the unsuitable areas for BMPs.
Percent Imperviousness	Raster file	The impervious grid is used to identify the suitable locations for BMPs for the given suitability criteria.
Soil	Shape file	The soil data contain the soil properties such as hydrological soil group, which are used to identify suitable locations for BMPs.
Urban Land Use	Shape file	The urban land use data contain the boundaries for the buildings and the impervious areas needed to identify suitable locations for LIDs.
Road	Shape file	The road layer is used to identify suitable locations for some BMPs that must be placed within a specific road buffer area.
Stream	Shape file	The stream layer is used to define a buffer so that certain BMP types can be placed outside the buffer to minimize the impact on streams.
Groundwater Table Depth	Shape file	The groundwater table depth layer is used to identify suitable locations for the infiltration BMPs; derived from monitoring data.

Source: Lai et al. 2007

Elevation	Raster file	
General Landuse	Raster file	
Urban Landuse	Raster file	
Imperviousness	Raster file	
Stream	Shape File	
Road	Shape File	
Ground Water	Shape File	
Soil	Shape File	
Land Ownership	Shape File	





Table

LID

FID	Shape	ID	LID_TYPE	SUBCATCHID	DRAIN_CLS	DRAIN_AREA	SLOPE_CL	SLOPE	IMPERV_CLS	IMPERV	HGS_CLS	HGS_COD	WD_CLS	WATERDEPT	RD_CLS	RD_BUFFER	ST_CLS	ST_BUFFER	BD_CLS	BD_BUFFER	LAND_CLS	LAND_OW
0	Polygon	1	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
1	Polygon	2	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
2	Polygon	3	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
3	Polygon	4	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
4	Polygon	5	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
5	Polygon	6	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
6	Polygon	7	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
7	Polygon	8	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
8	Polygon	9	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
9	Polygon	10	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
10	Polygon	11	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
11	Polygon	12	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
12	Polygon	13	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
13	Polygon	14	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
14	Polygon	15	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	
15	Polygon	16	5		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	

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InfoSWMM Sustain
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LID
LID
LID

InfoSWMM Sustain LID Siting Manager LID Types

InfoSWMM Sustain LID Siting Manager LID Types

- Constructed Wetland
- Infiltration Basin
- Bio-Retention
- Surface Sand Filter
- Rain Barrel
- Cistern
- Wet Pond
- Dry Pond
- Grassed Swale
- Infiltration Trench
- Vegetated Filterstrip
- Non-Surface Sand Filter
- Green Roof
- Porous Pavement

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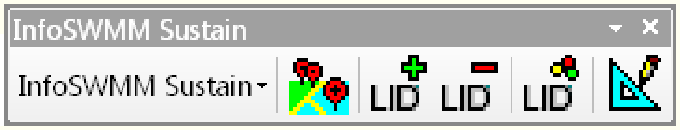
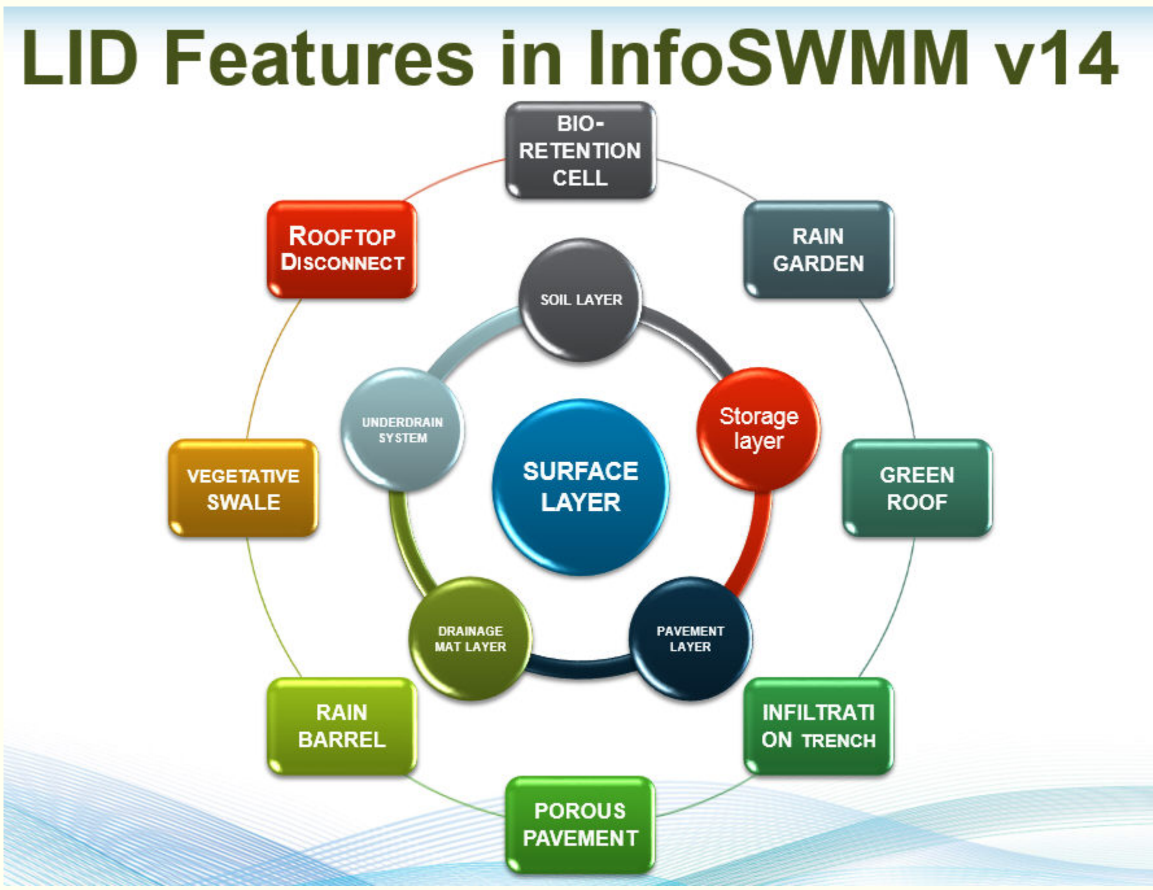
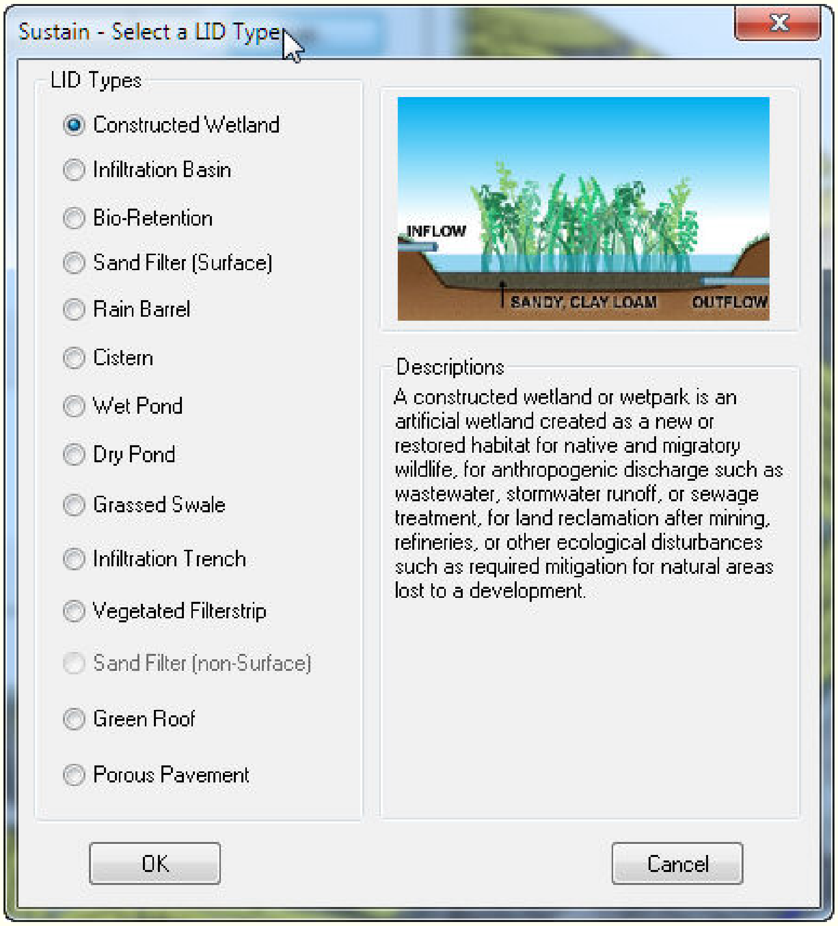

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

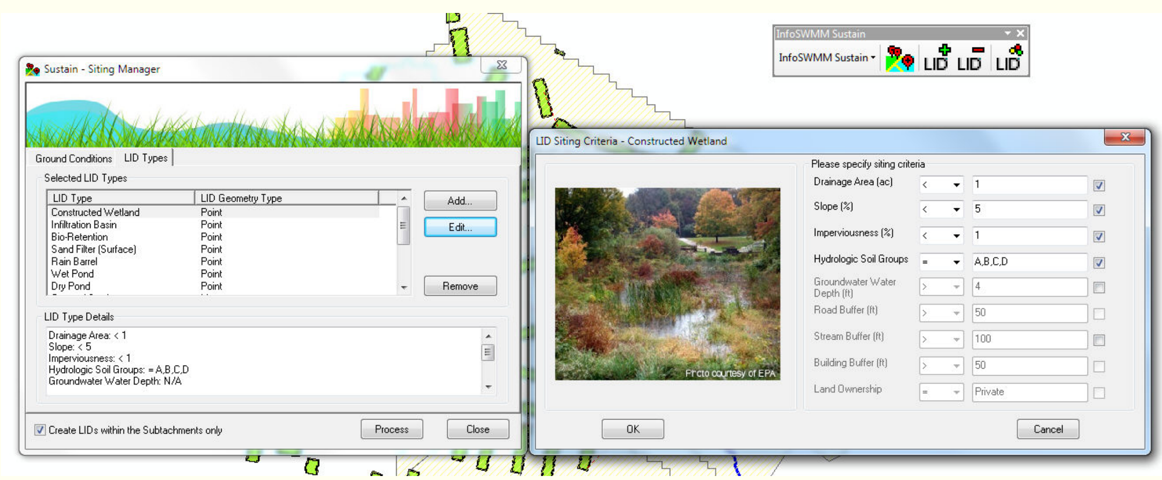
Constructed Wetland

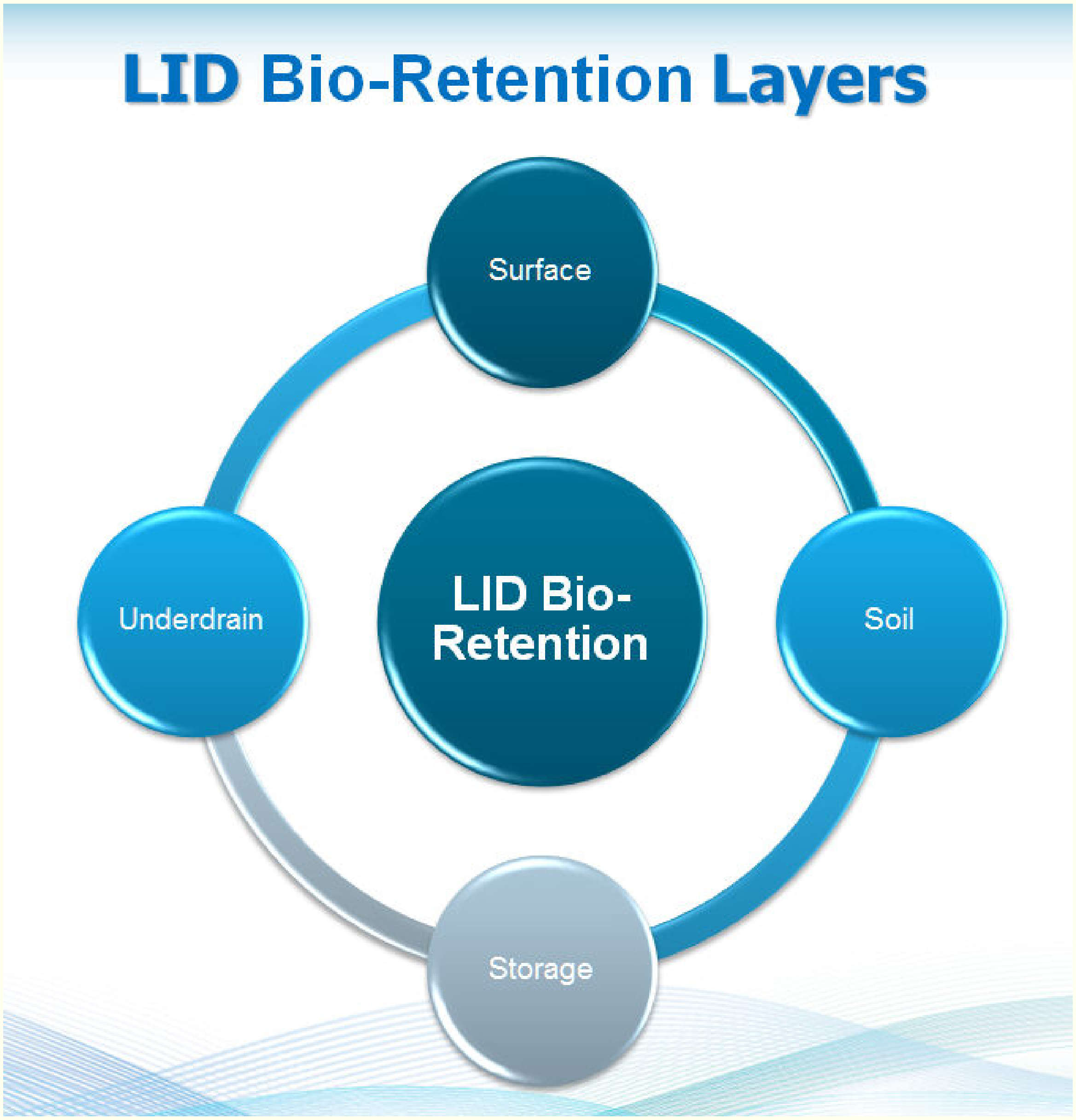
The three steps to selecting a LID Type are:

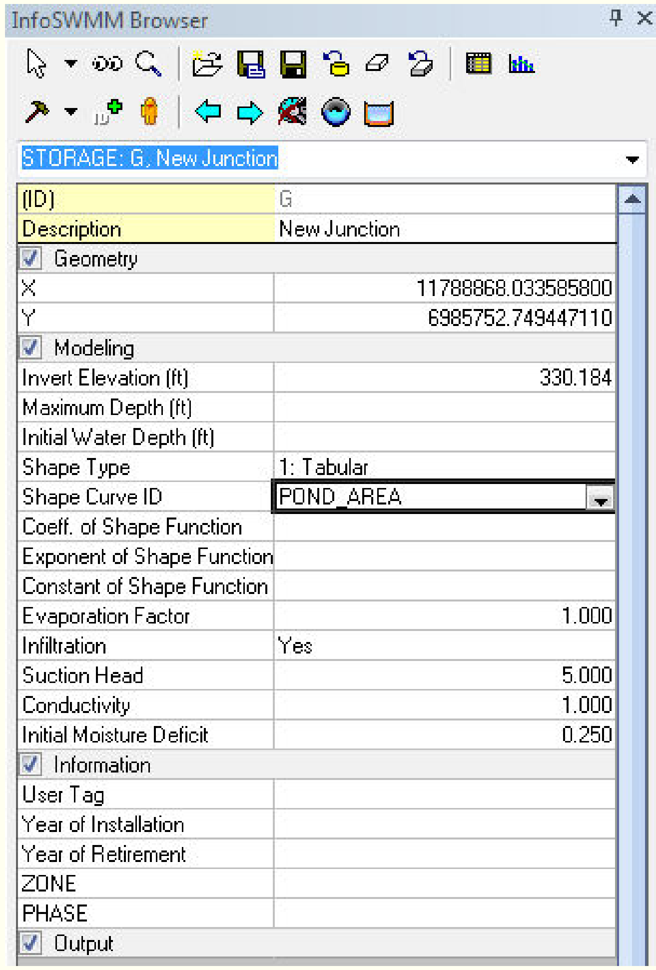
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
  - a. The number of process layers
  - b. The components of each process layer
  - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
  - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

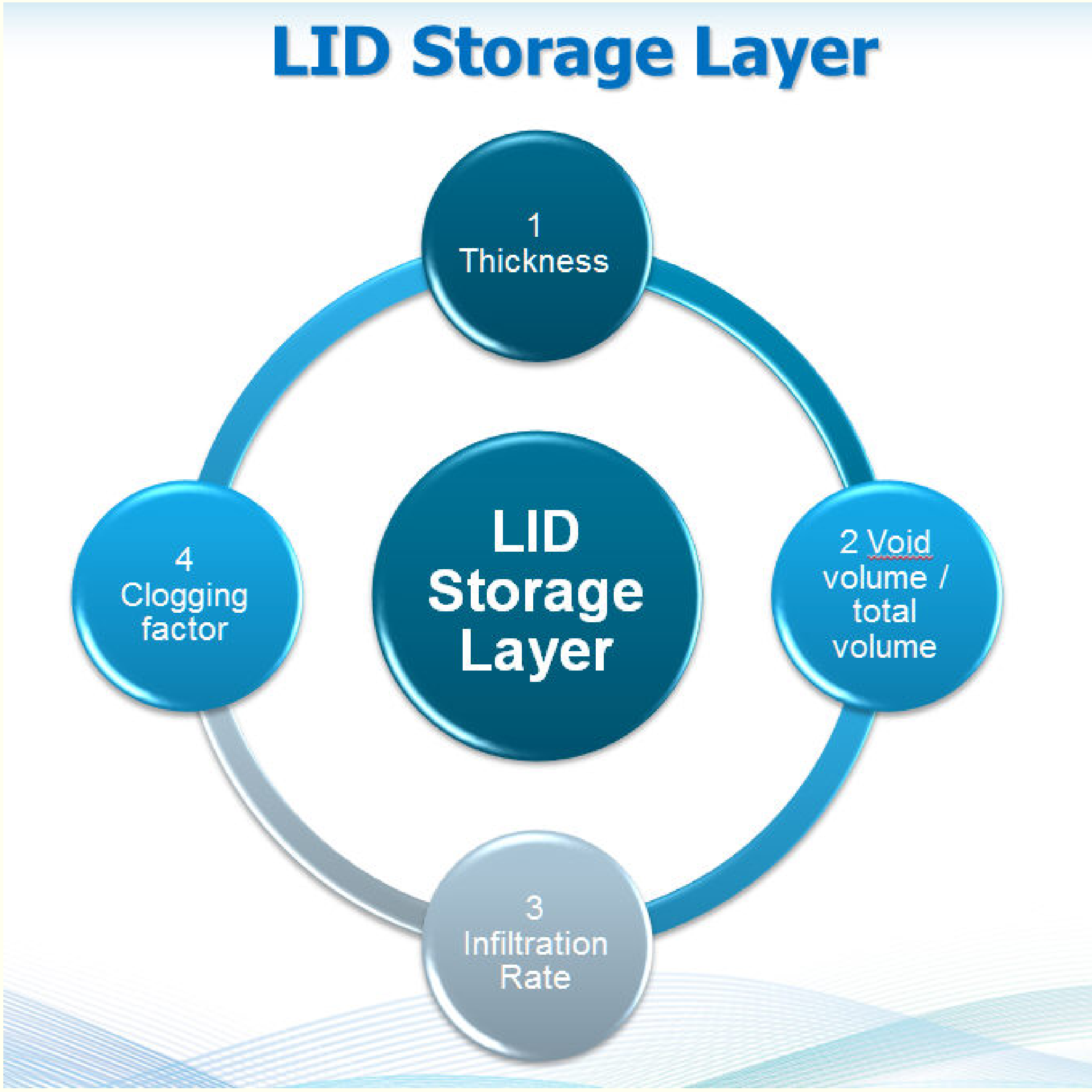


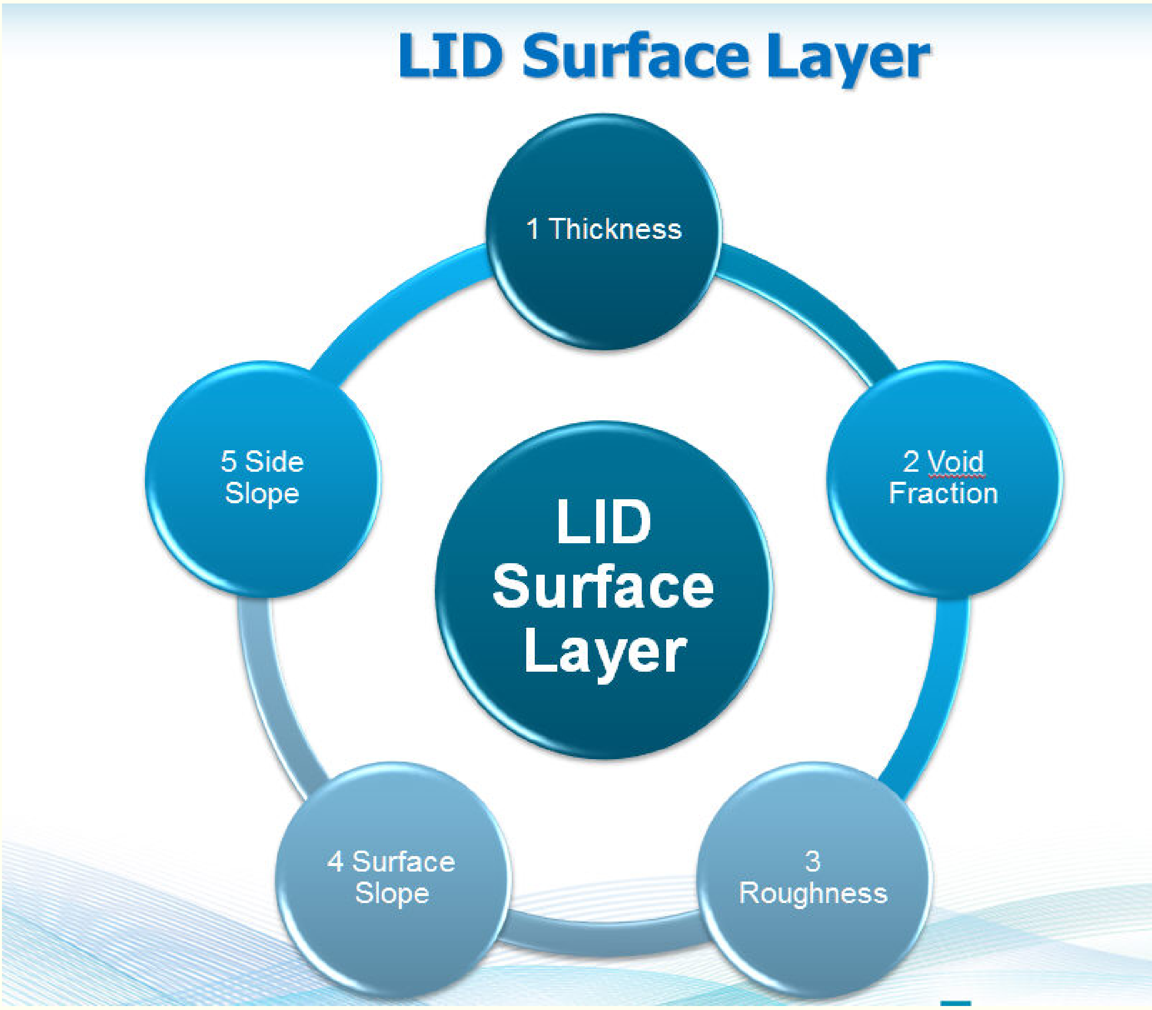

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INFLOW
SANDY, CLAY LOAM
OUTFLOW
Descriptions
A constructed wetland or wetpark is an artificial wetland created as a new or restored habitat for native and migratory wildlife, for anthropogenic discharge such as wastewater, stormwater runoff, or sewage treatment, for land reclamation after mining, refineries, or other ecological disturbances such as required mitigation for natural areas lost to a development.
OK
Cancel

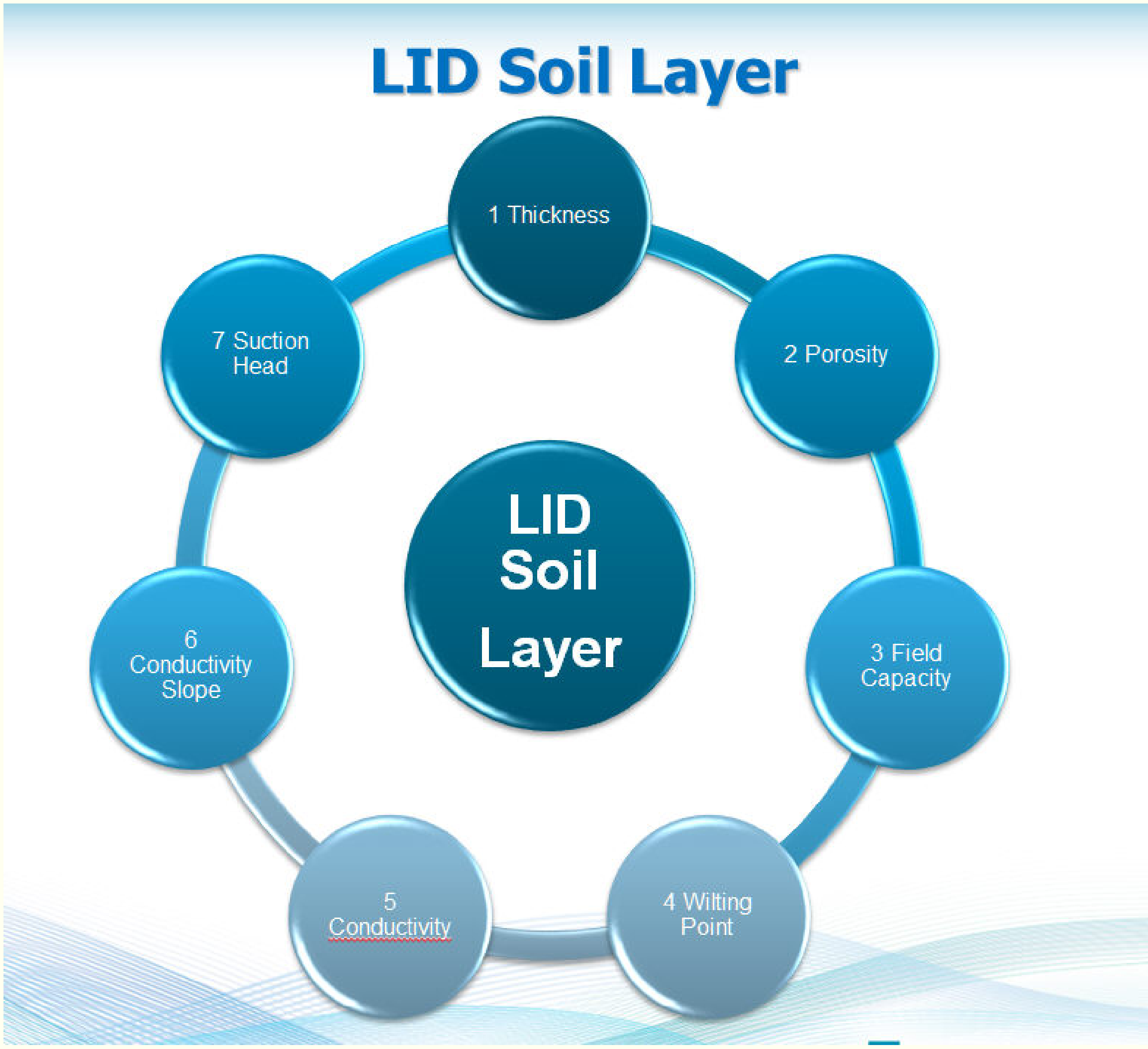

Sustain - Siting Manager
Ground Conditions
LID Types
Selected LID Types
LID Type
LID Geometry Type
Constructed Wetland Point
Infiltration Basin Point
Bio-Retention Point
Sand Filter (Surface) Point
Rain Barrel Point
Wet Pond Point
Dry Pond Point
Add...
Edit...
Remove
LID Type Details
Drainage Area: < 1
Slope: < 5
Imperviousness: < 1
Hydrologic Soil Groups: = A,B,C,D
Groundwater Water Depth: N/A
Create LIDs within the Subtachments only
Process
Close
InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID
LID Siting Criteria - Constructed Wetland
Please specify siting criteria
Photo courtesy of EPA
Drainage Area (ac) < 1
Slope (%) < 5
Imperviousness (%) < 1
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 4
Road Buffer (ft) > 50
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = Private
OK
Cancel

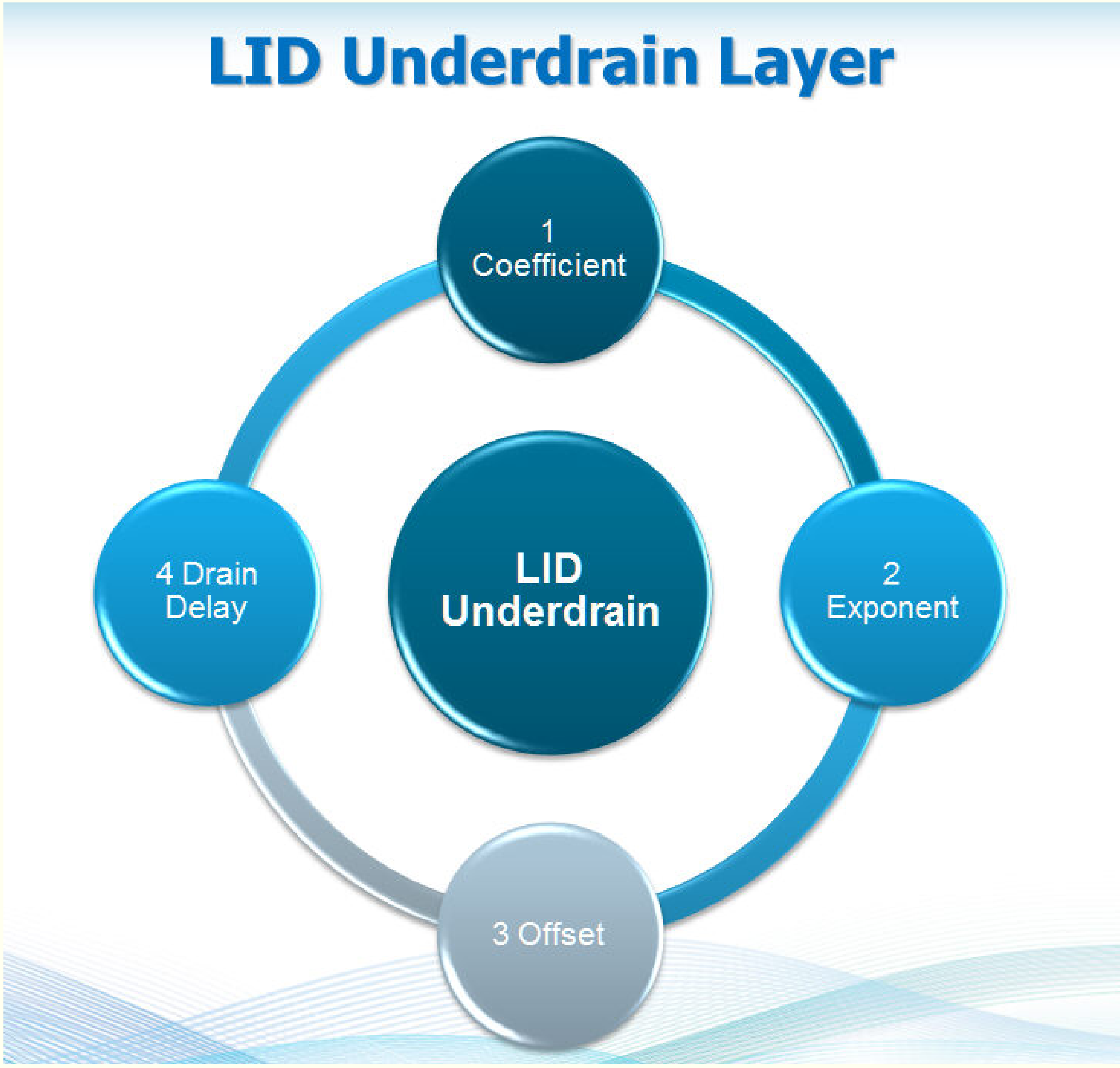

LID Bio-Retention Layers
Surface
LID Bio-Retention
Underdrain
Soil
Storage


InfoSWMM Browser
STORAGE: G, New Junction
(ID) G
Description New Junction
Geometry
X 11788868.033585800
Y 6985752.749447110
Modeling
Invert Elevation (ft) 330.184
Maximum Depth (ft)
Initial Water Depth (ft)
Shape Type 1: Tabular
Shape Curve ID POND_AREA
Coeff. of Shape Function
Exponent of Shape Function
Constant of Shape Function
Evaporation Factor 1.000
Infiltration Yes
Suction Head 5.000
Conductivity 1.000
Initial Moisture Deficit 0.250
Information
User Tag
Year of Installation
Year of Retirement
ZONE
PHASE
Output


LID Storage Layer
1
Thickness
2 Void
volume /
total
volume
3
Infiltration
Rate
4
Clogging
factor
LID
Storage
Layer


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer



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-


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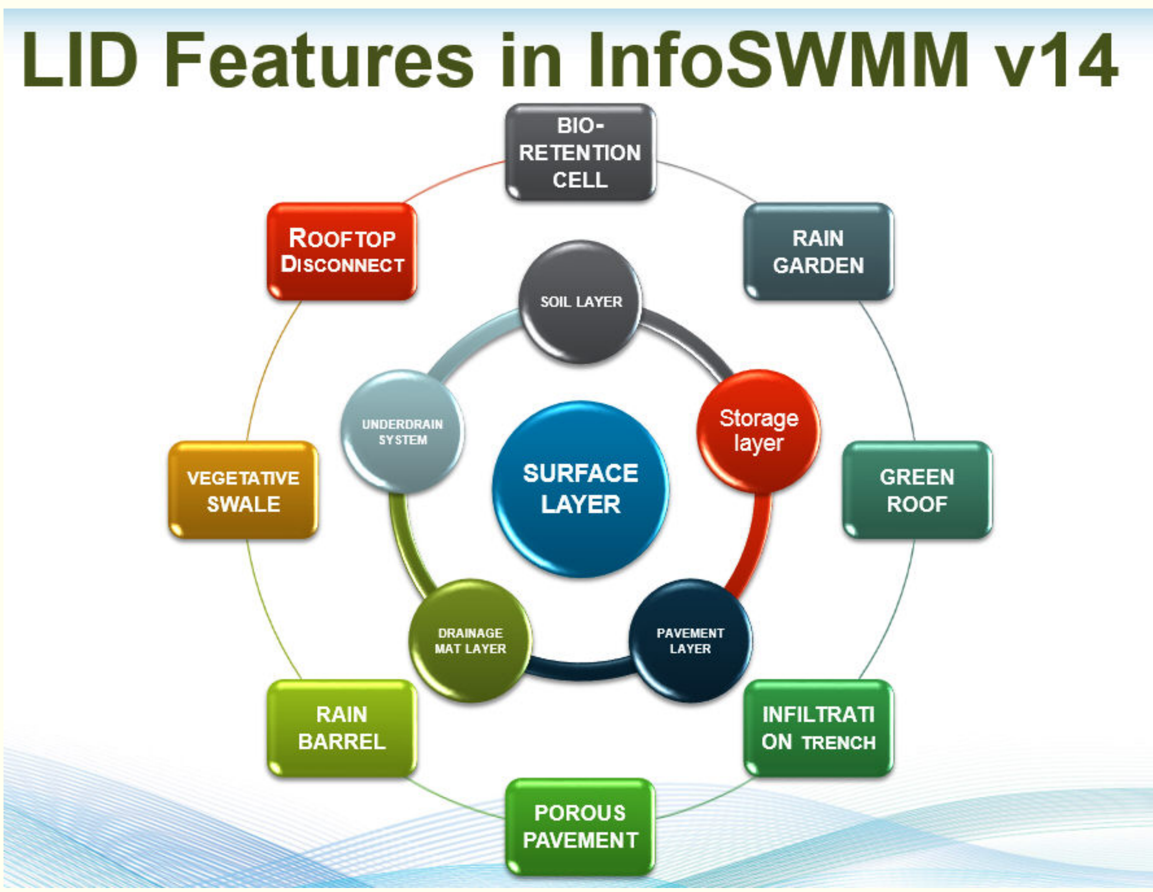
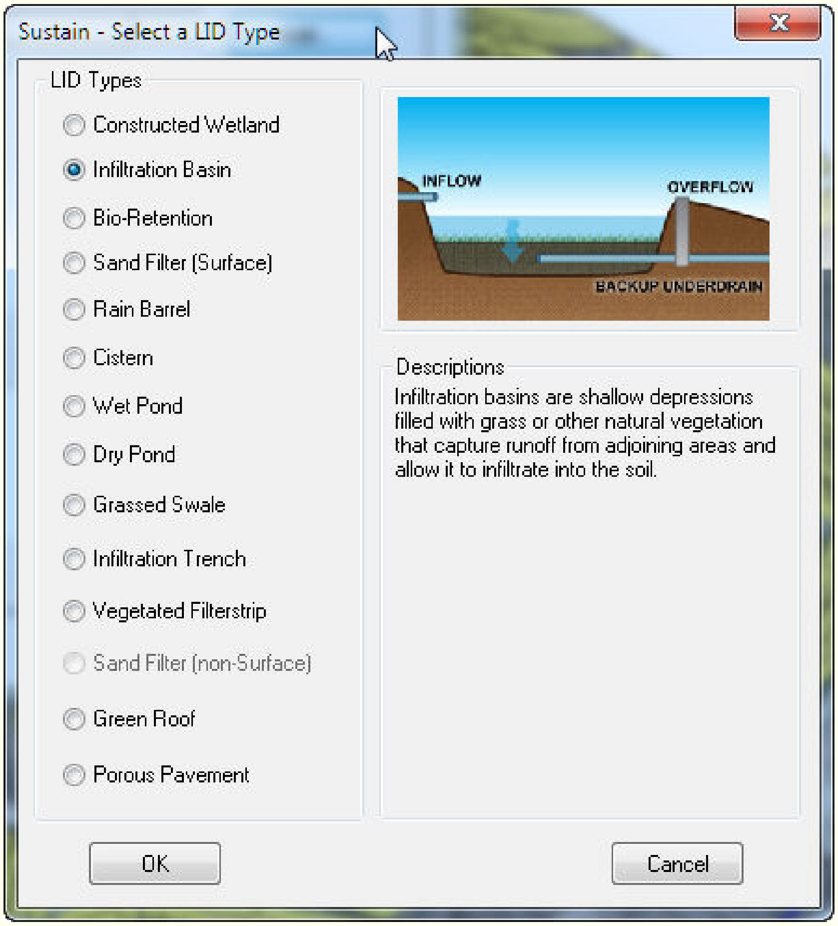
LID
LID
LID

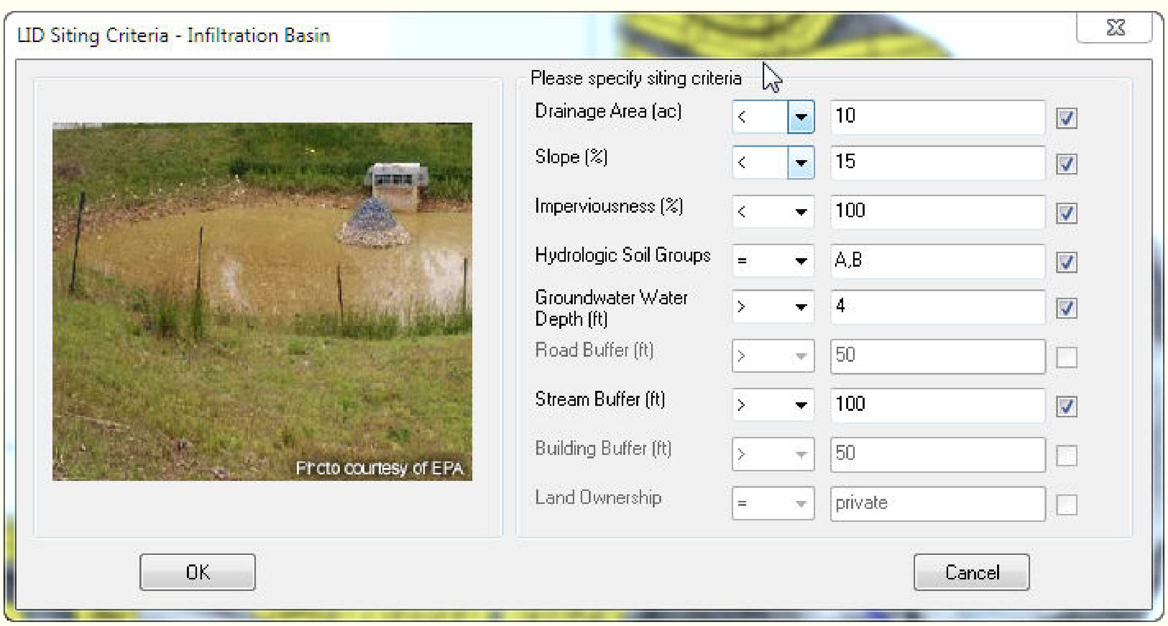
Infiltration Basin

The three steps to selecting a LID Type are:

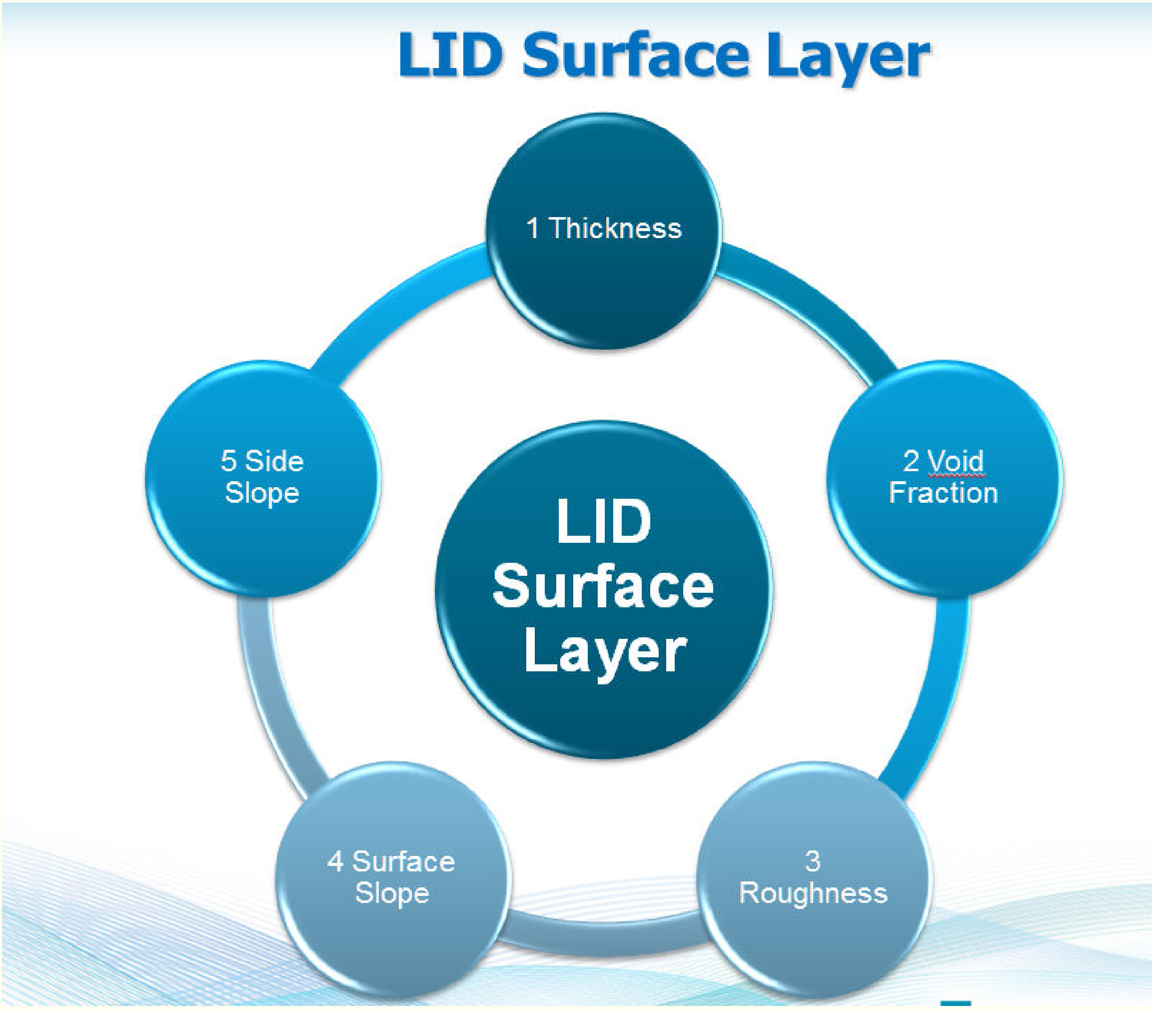
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
  - a. The number of process layers
  - b. The components of each process layer
  - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
  - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

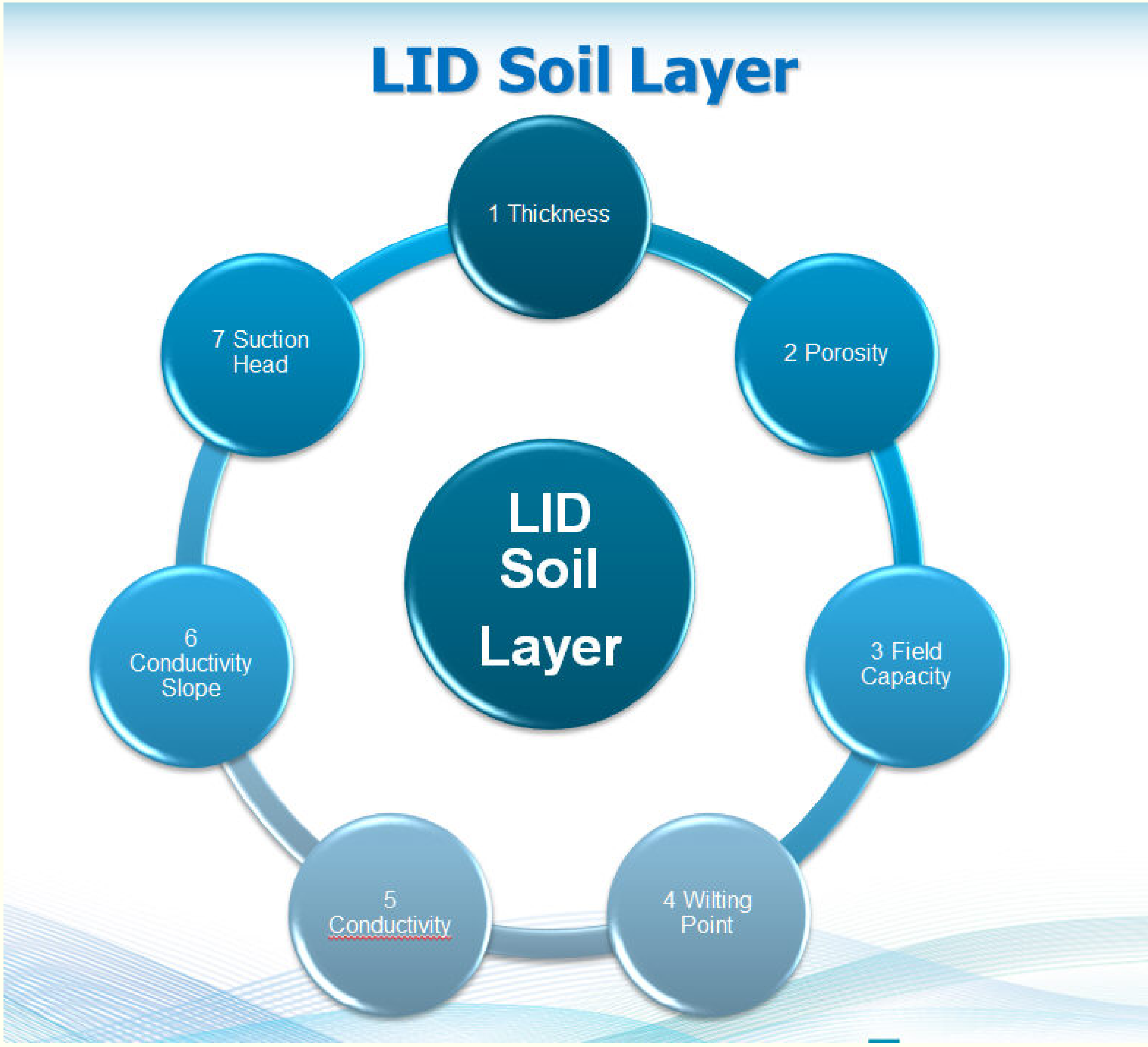



Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INFLOW
OVERFLOW
BACKUP UNDERDRAIN
Descriptions
Infiltration basins are shallow depressions filled with grass or other natural vegetation that capture runoff from adjoining areas and allow it to infiltrate into the soil.
OK
Cancel


LID Siting Criteria - Infiltration Basin
Please specify siting criteria
Drainage Area (ac) < 10
Slope (%) < 15
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B
Groundwater Water Depth (ft) > 4
Road Buffer (ft) > 50
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
Photo courtesy of EPA
OK
Cancel

LID Rain Garden Layers


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer

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InfoSWMM Sustain
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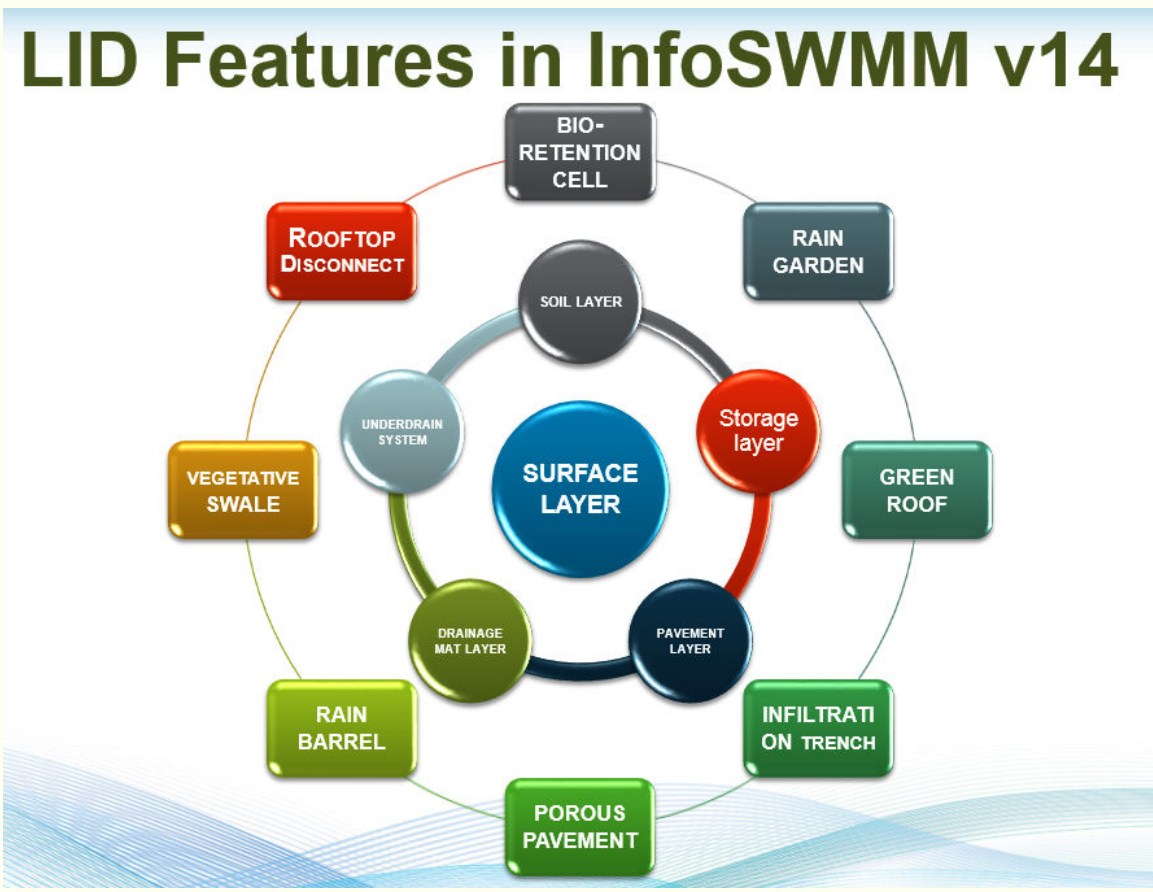
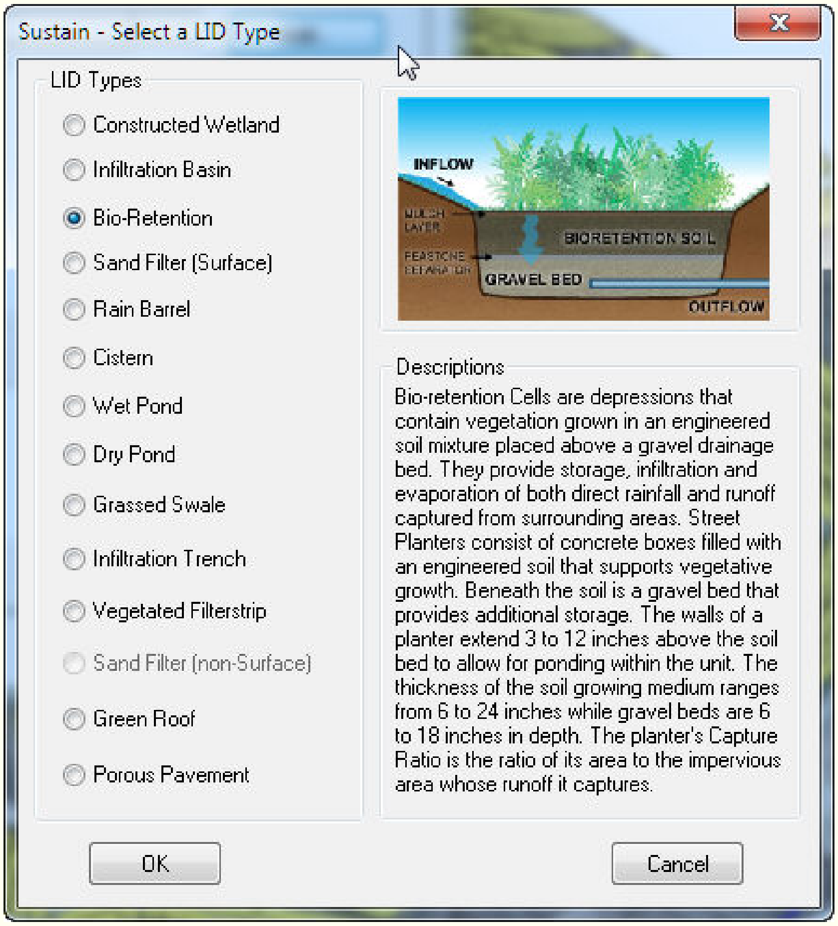
LID
LID
LID

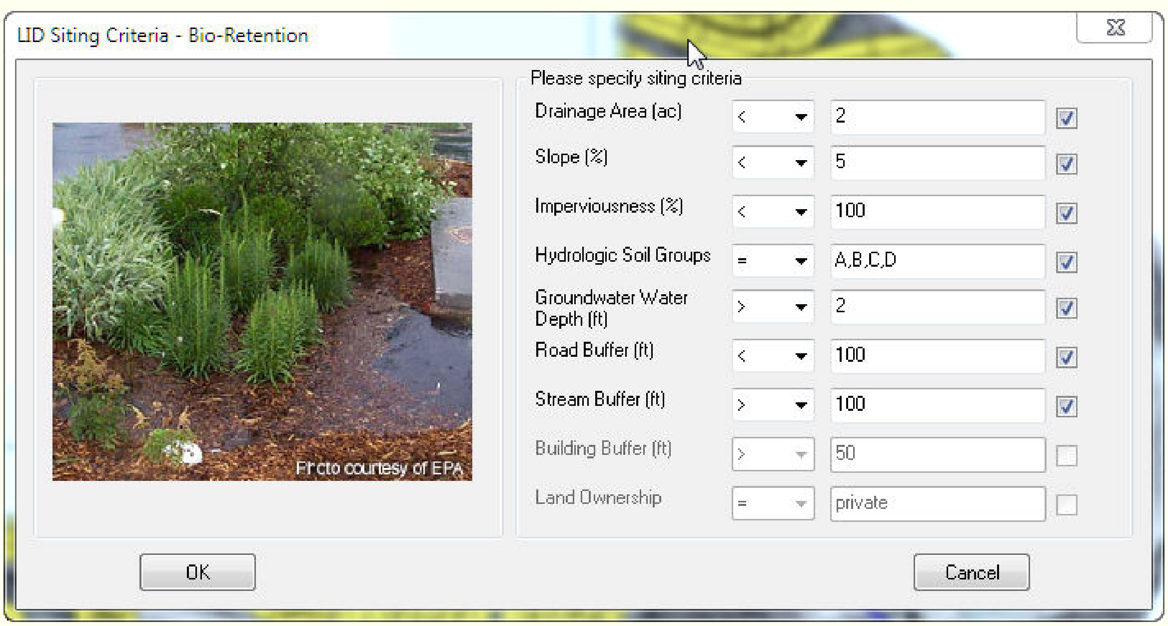
Bio-Retention

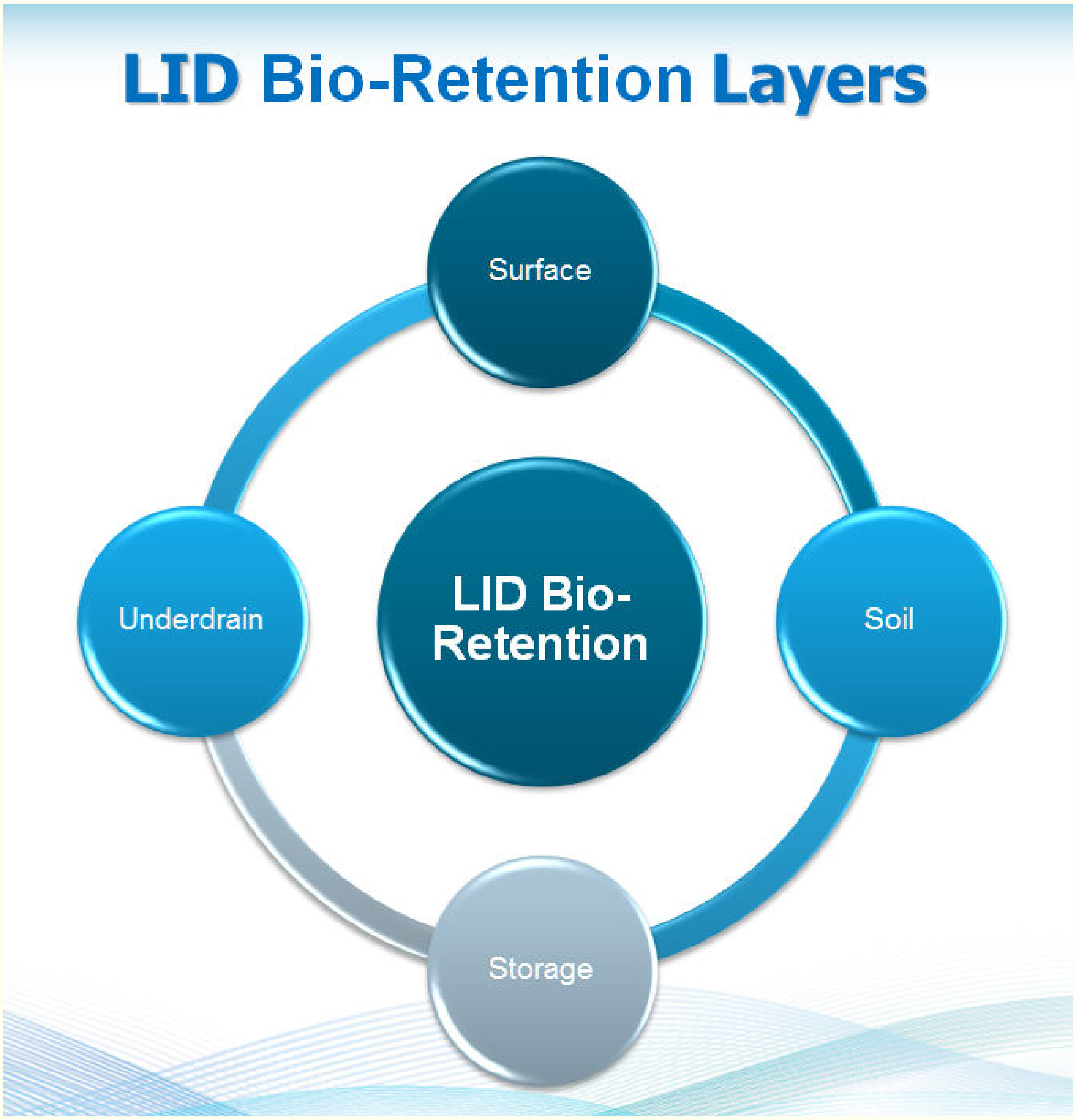
The three steps to selecting a LID Type are:

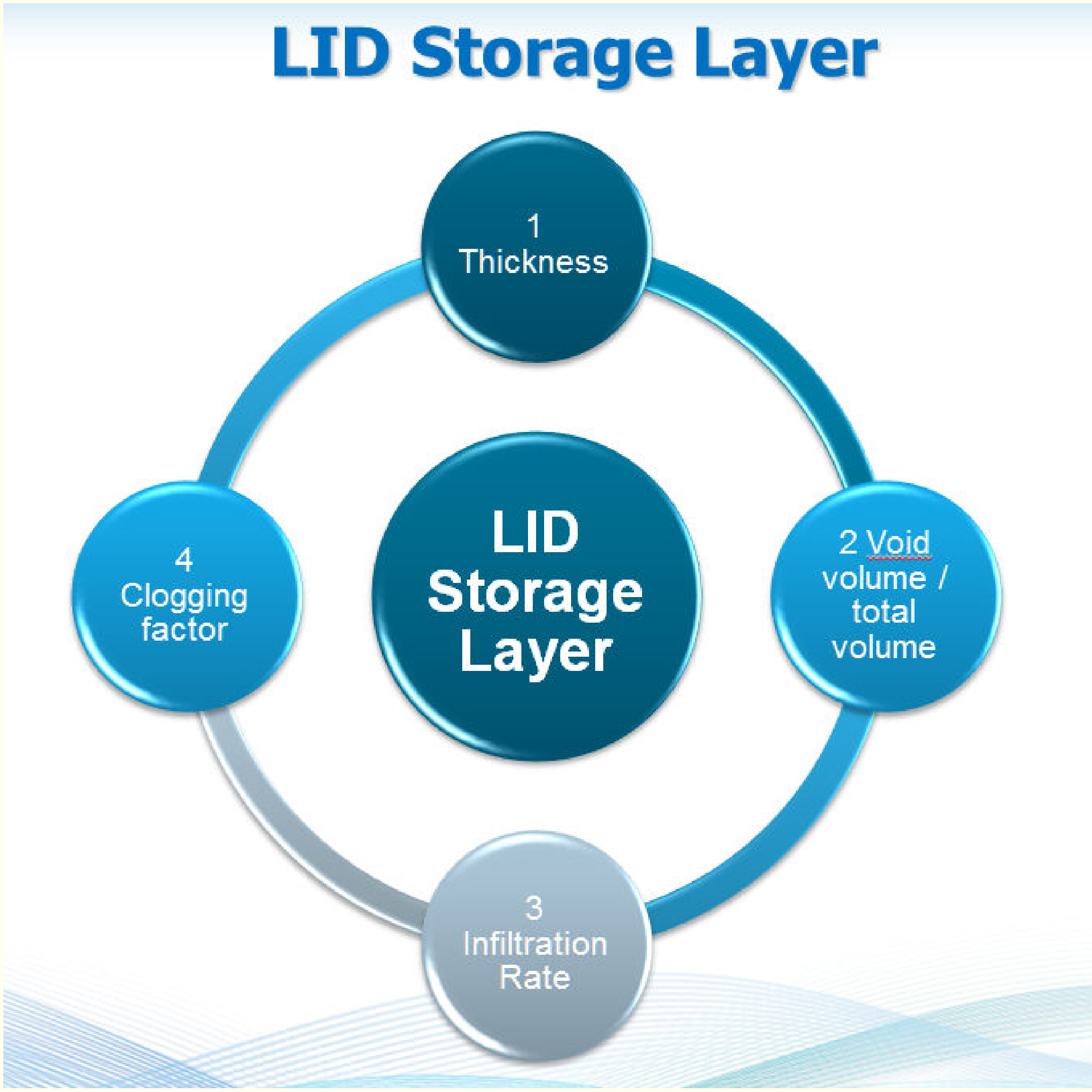
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

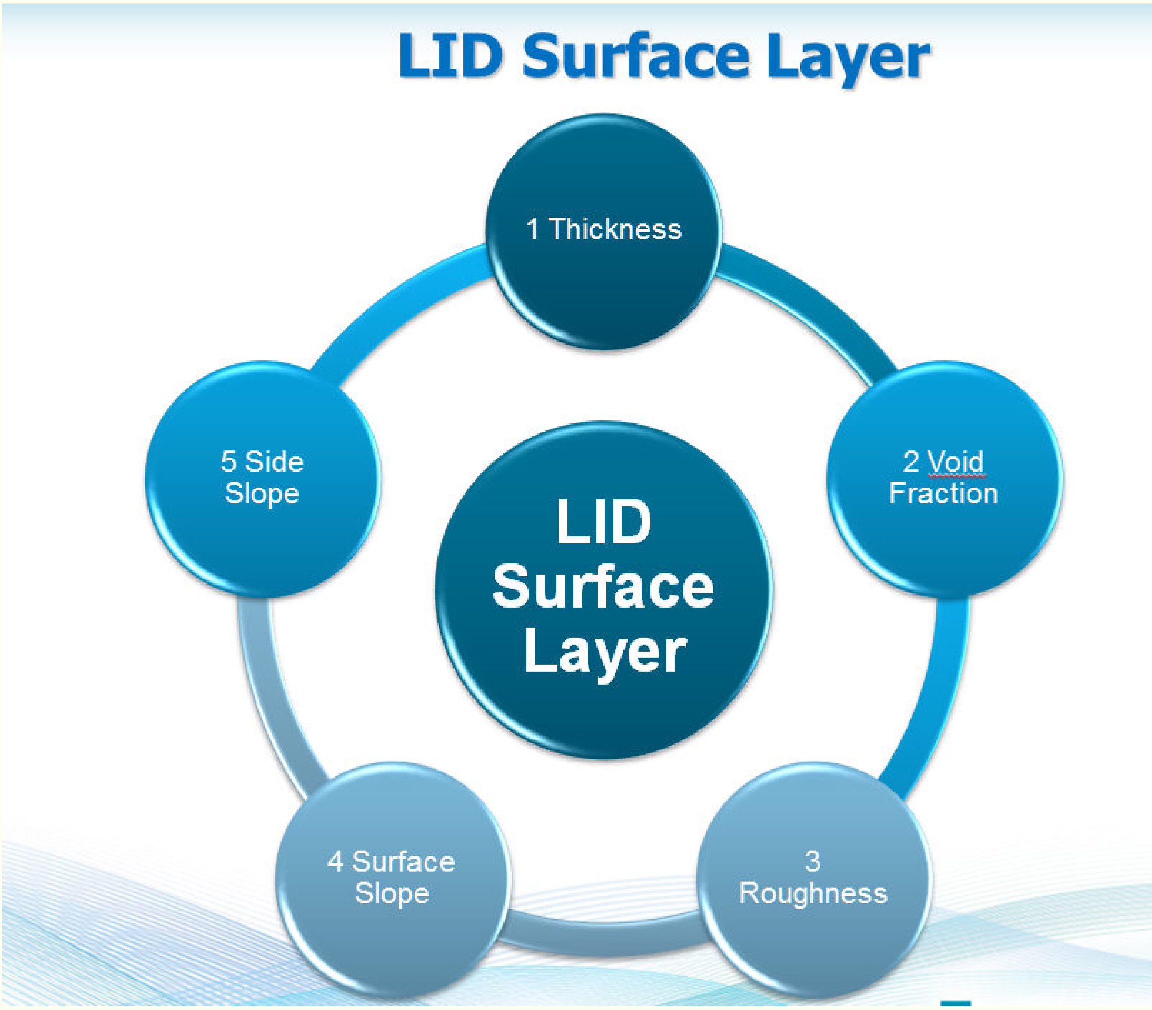


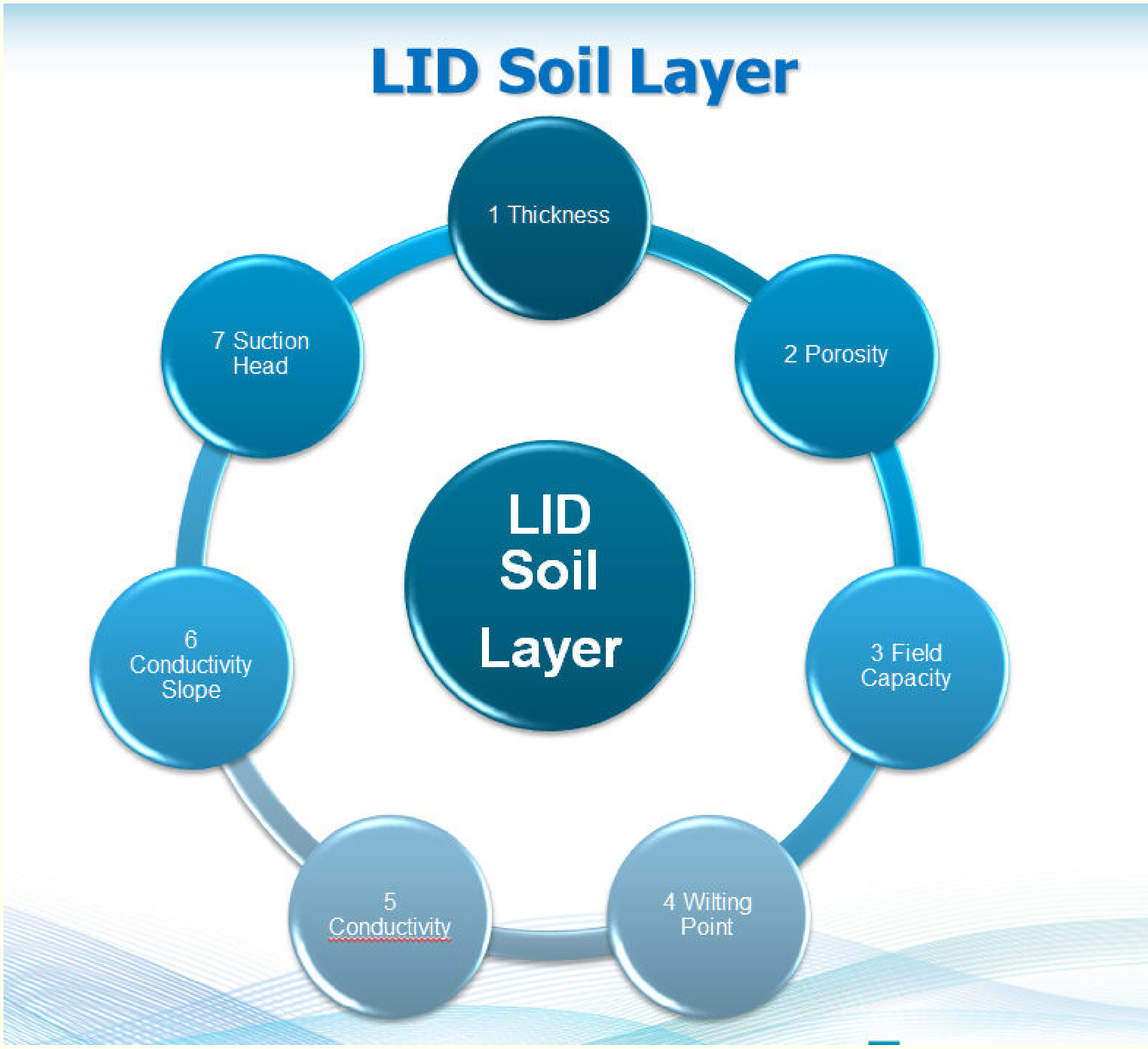

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INFLOW
BIORETENTION SOIL
GRAVEL BED
OUTFLOW
Descriptions
Bio-retention Cells are depressions that contain vegetation grown in an engineered soil mixture placed above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas. Street Planters consist of concrete boxes filled with an engineered soil that supports vegetative growth. Beneath the soil is a gravel bed that provides additional storage. The walls of a planter extend 3 to 12 inches above the soil bed to allow for ponding within the unit. The thickness of the soil growing medium ranges from 6 to 24 inches while gravel beds are 6 to 18 inches in depth. The planter's Capture Ratio is the ratio of its area to the impervious area whose runoff it captures.
OK
Cancel

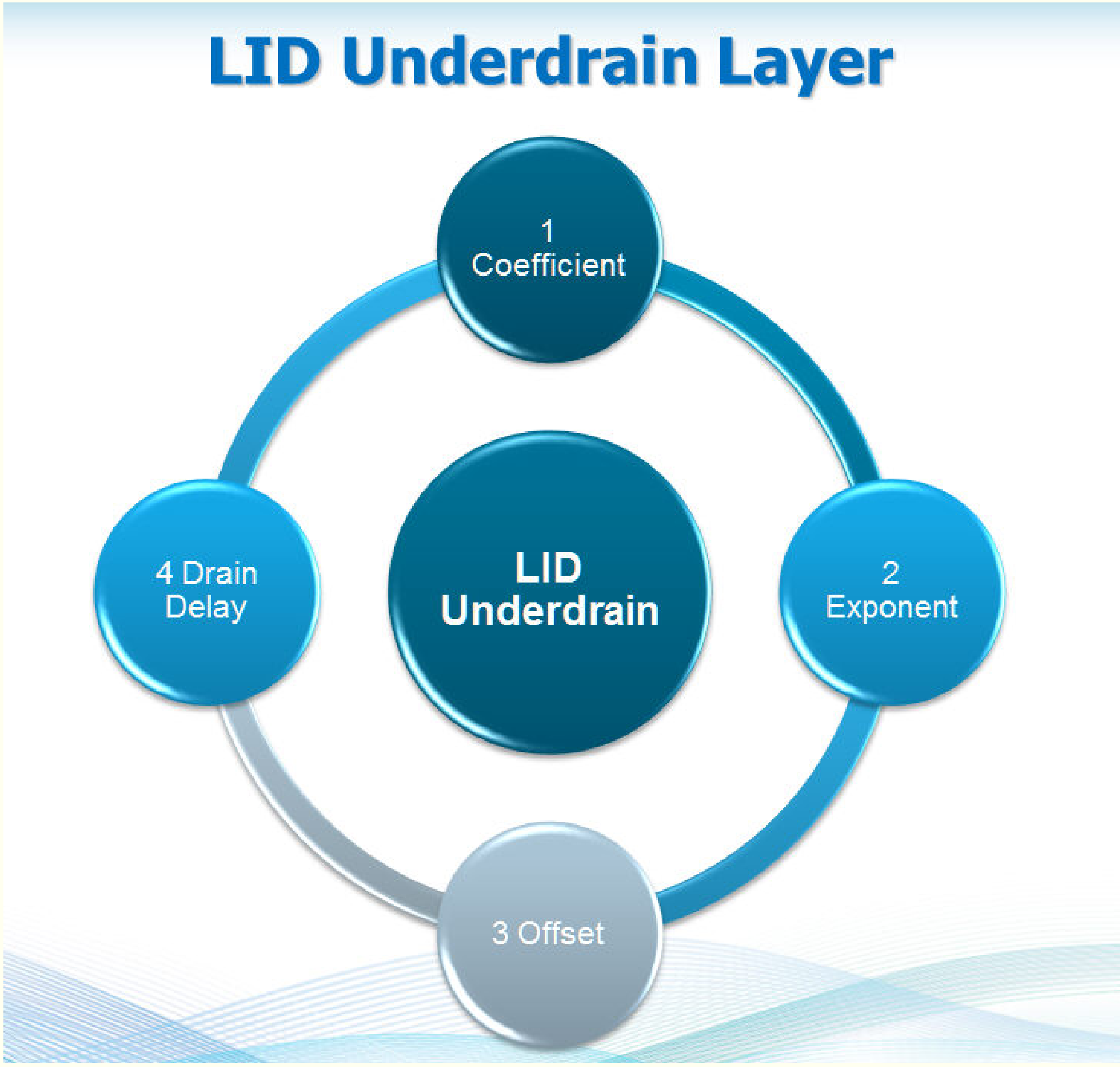

LID Siting Criteria - Bio-Retention
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 2
Slope (%) < 5
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel


LID Bio-Retention Layers
Surface
Underdrain
LID Bio-Retention
Soil
Storage


LID Storage Layer
1
Thickness
2 Void
volume /
total
volume
3
Infiltration
Rate
4
Clogging
factor
LID
Storage
Layer


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer



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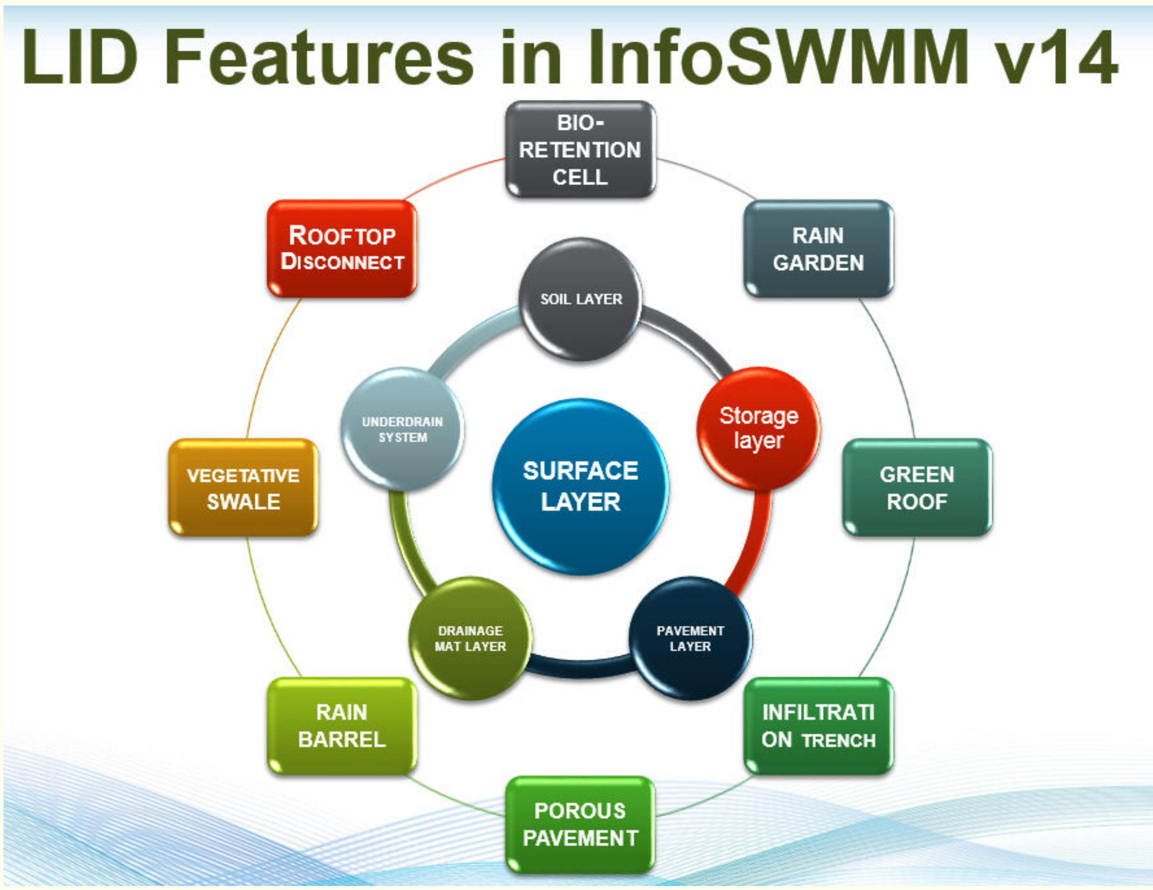
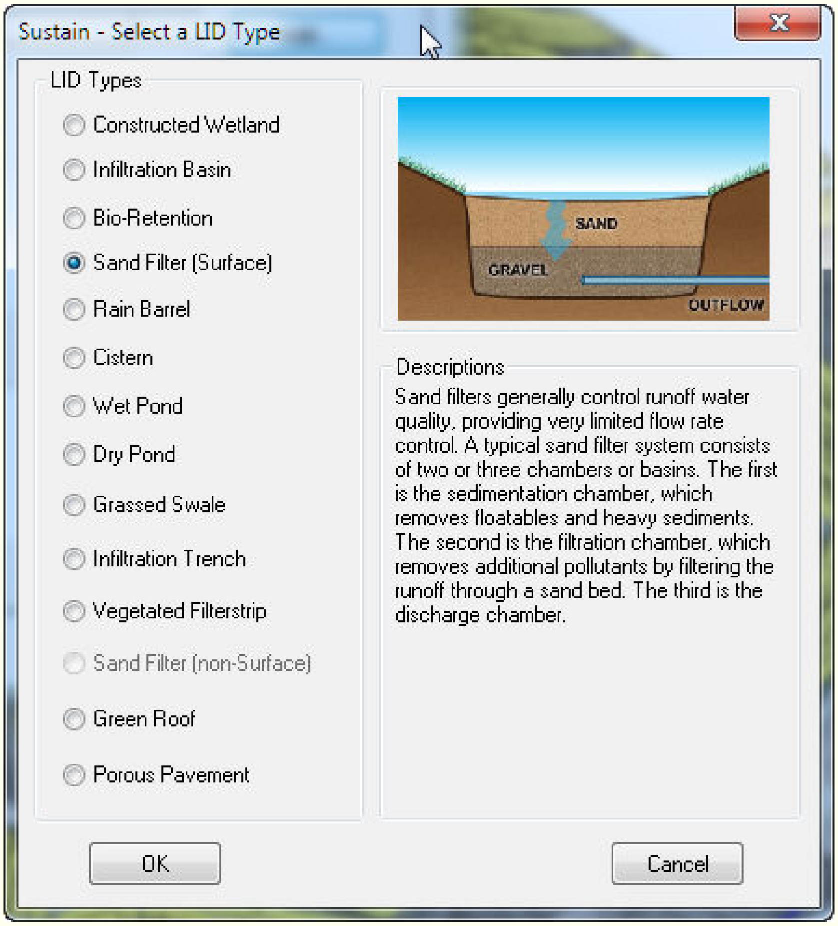
LID
LID

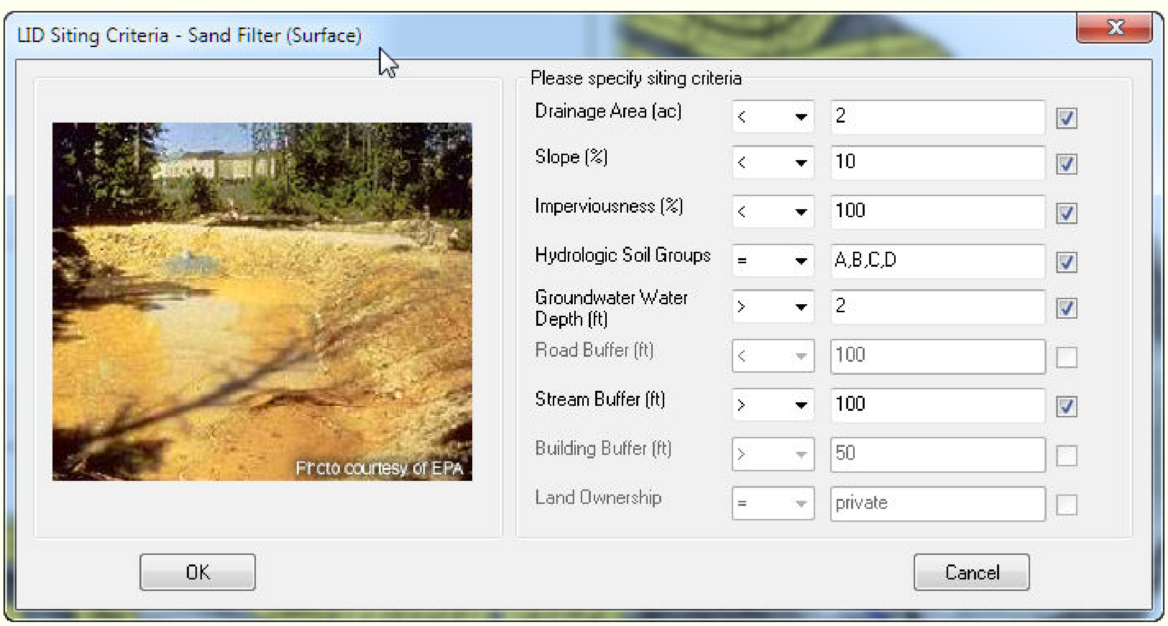
Surface Sand Filter

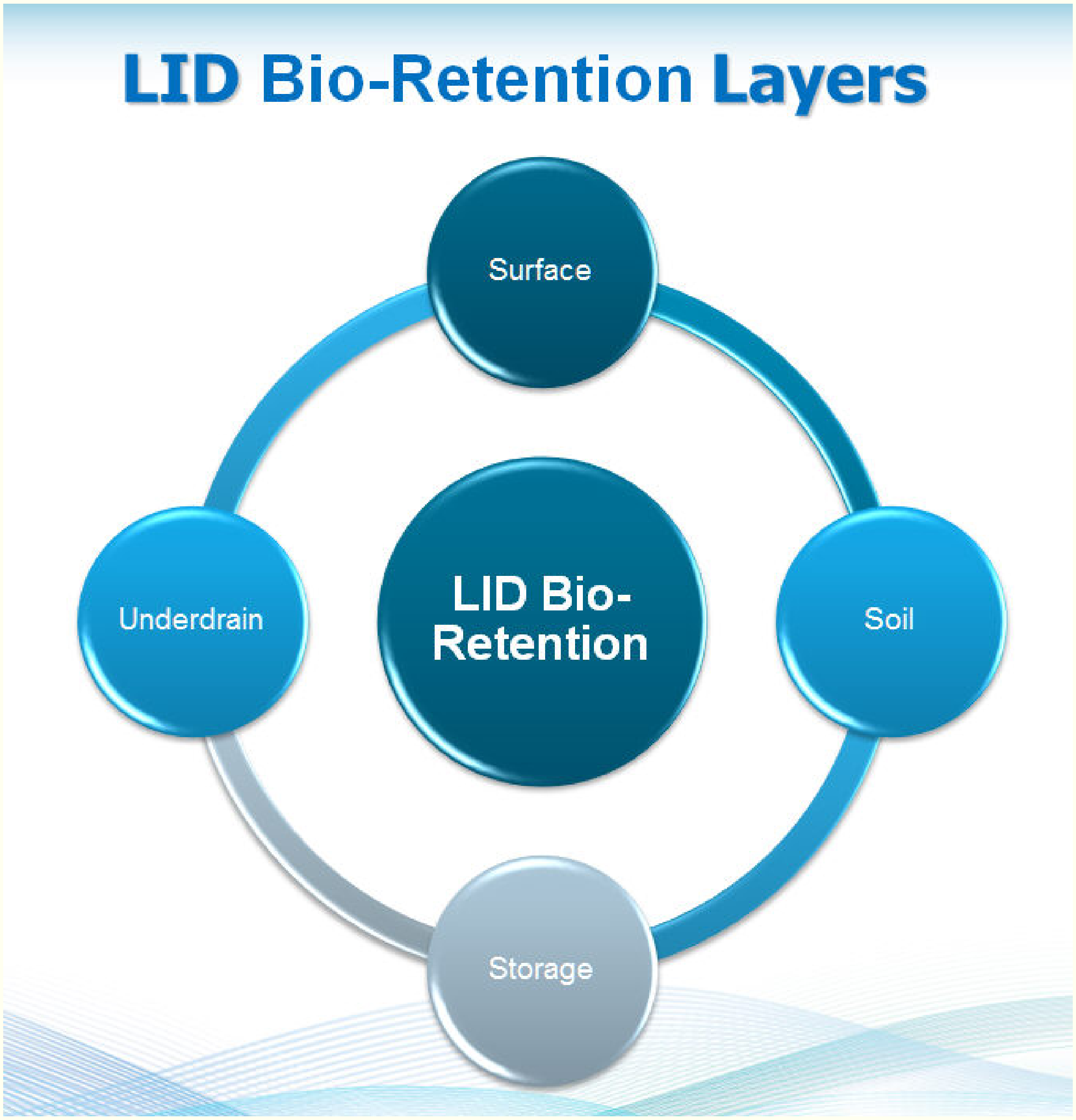
The three steps to selecting a LID Type are:

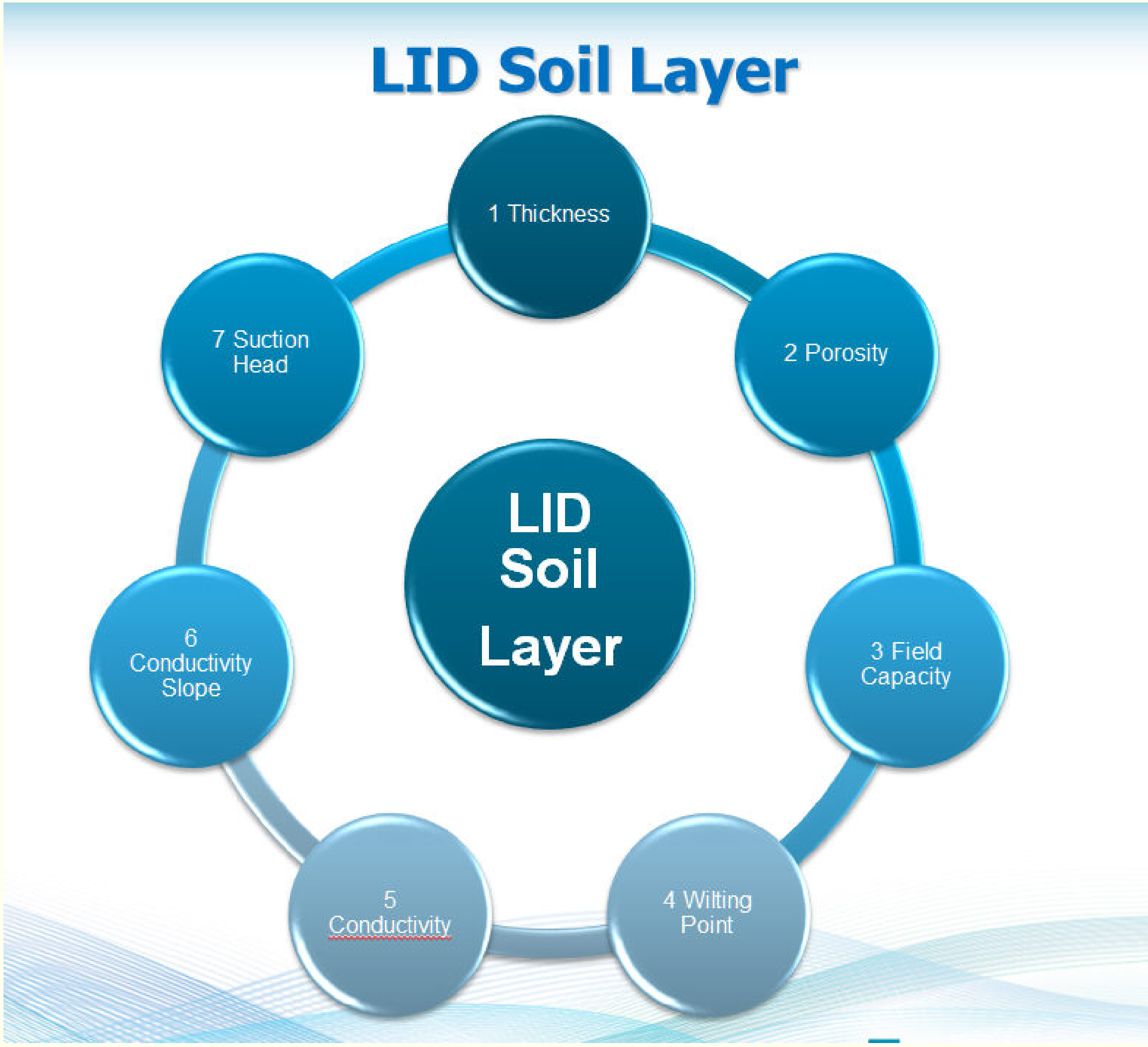
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration




Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
SAND
GRAVEL
OUTFLOW
Descriptions
Sand filters generally control runoff water quality, providing very limited flow rate control. A typical sand filter system consists of two or three chambers or basins. The first is the sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The third is the discharge chamber.
OK
Cancel


LID Siting Criteria - Sand Filter (Surface)
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 2
Slope (%) < 10
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel


LID Bio-Retention Layers
Surface
Underdrain
LID Bio-Retention
Soil
Storage



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InfoSWMM Sustain
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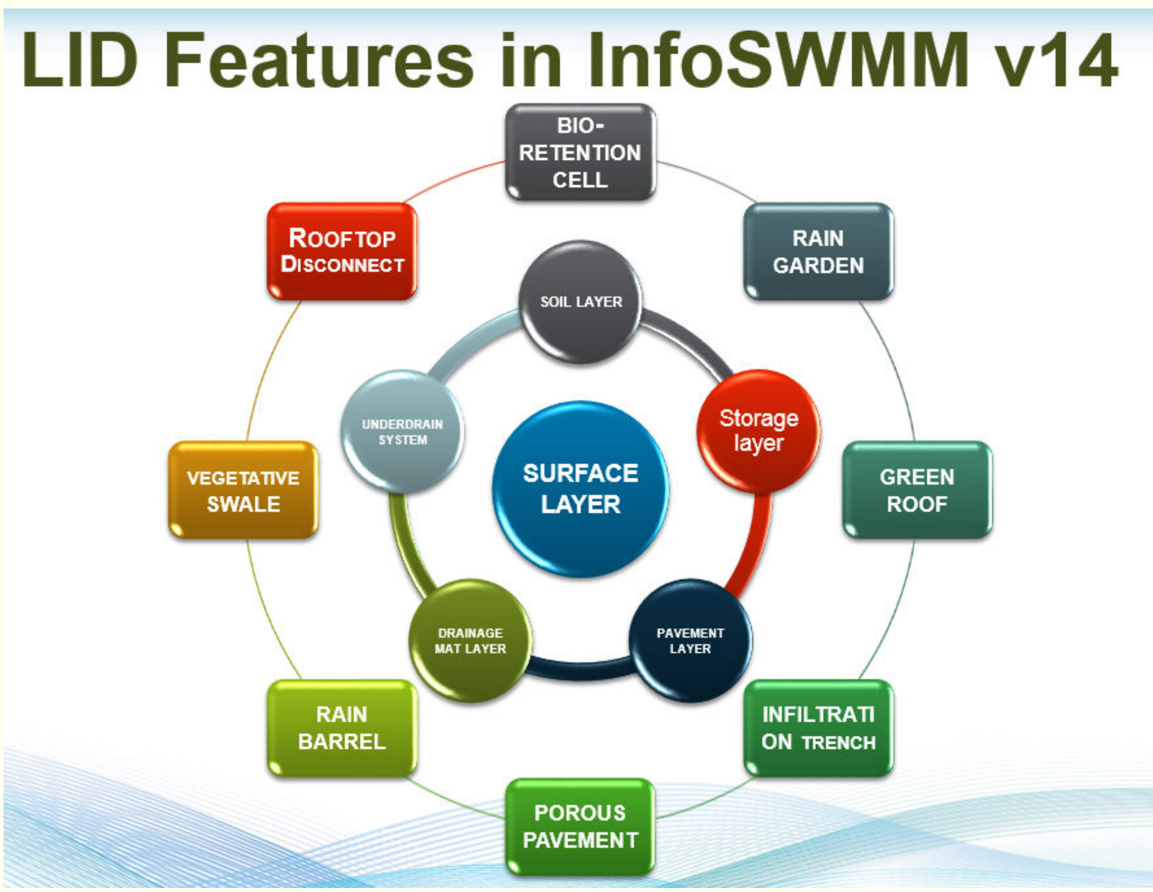
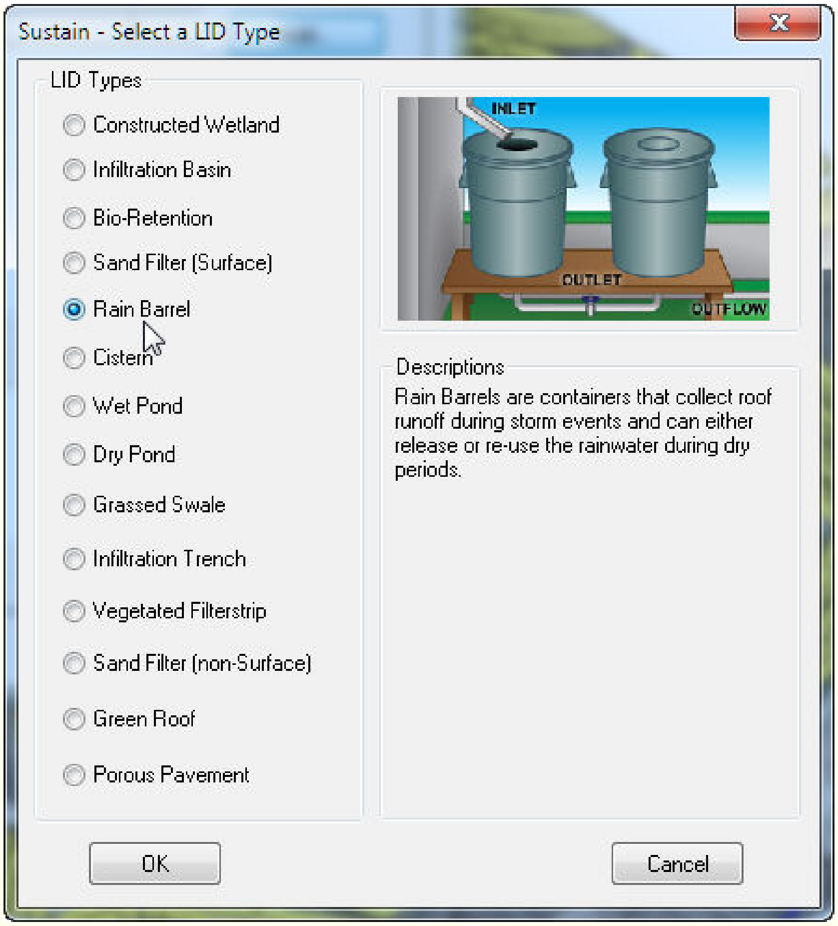
LID
LID
LID

Rain Barrel

The three steps to selecting a LID Type are:

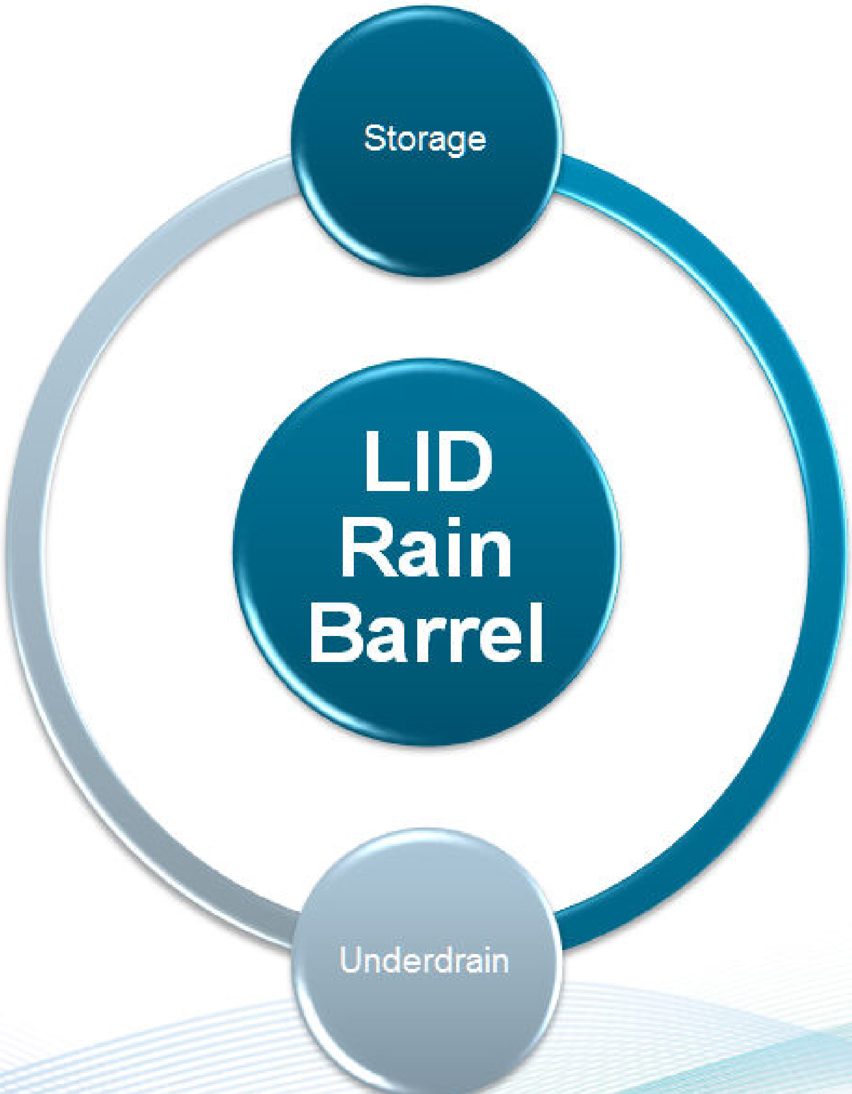
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

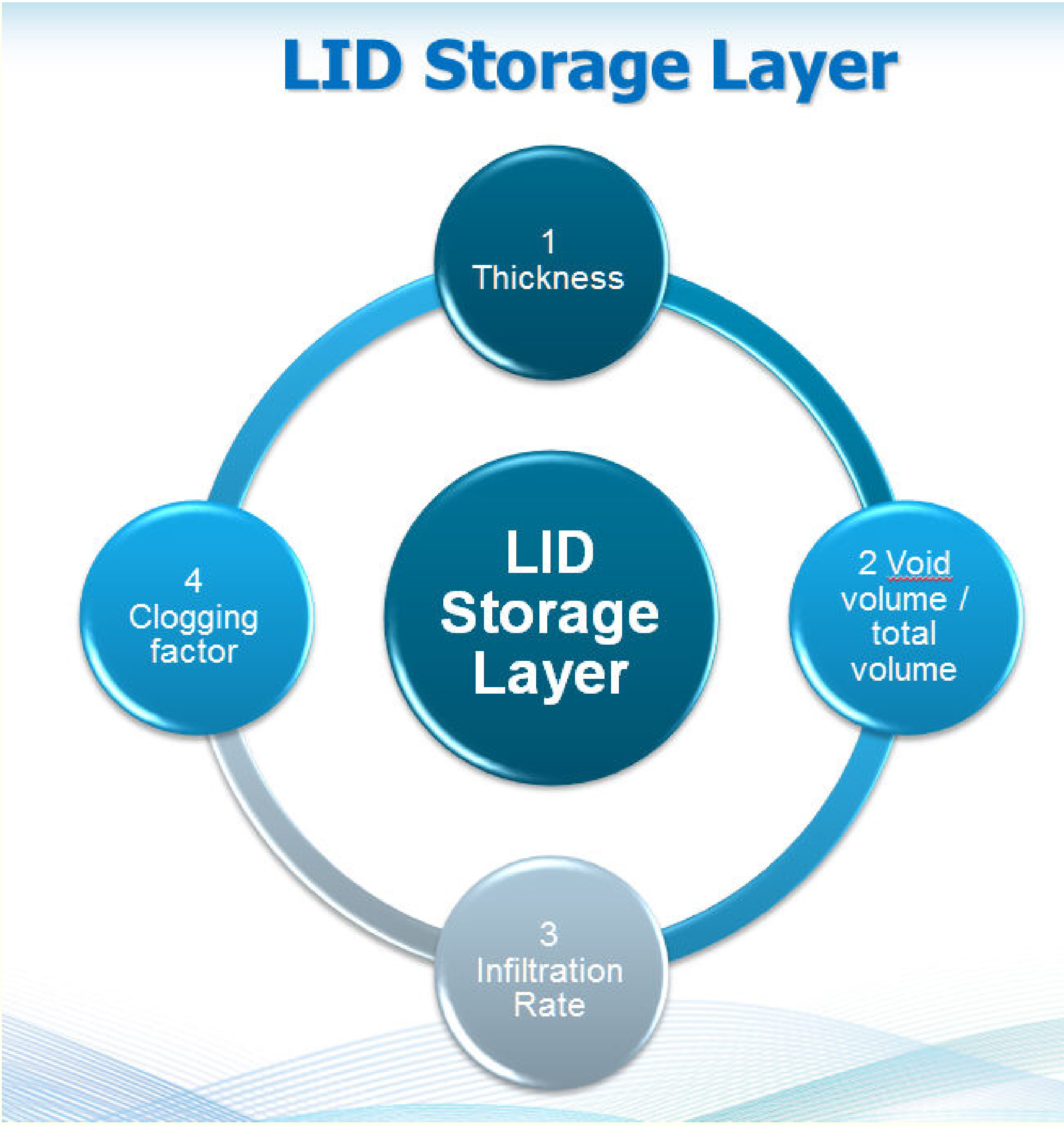


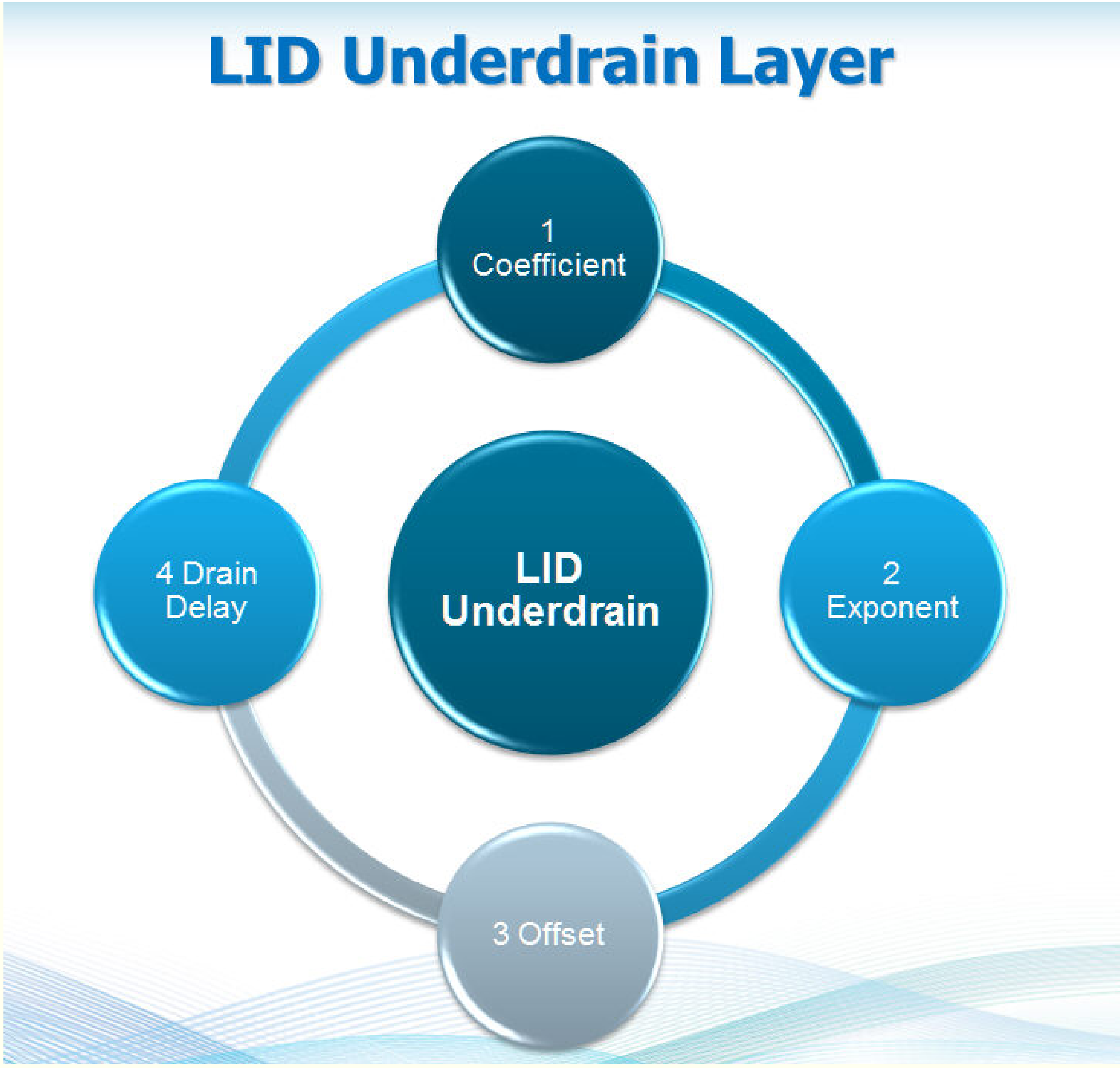

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INLET
OUTLET
OUTFLOW
Descriptions
Rain Barrels are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods.
OK
Cancel

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®	

LID Rain Barrel Layers




LID Storage Layer
1 Thickness
LID Storage Layer
2 Void volume / total volume
4 Clogging factor
3 Infiltration Rate



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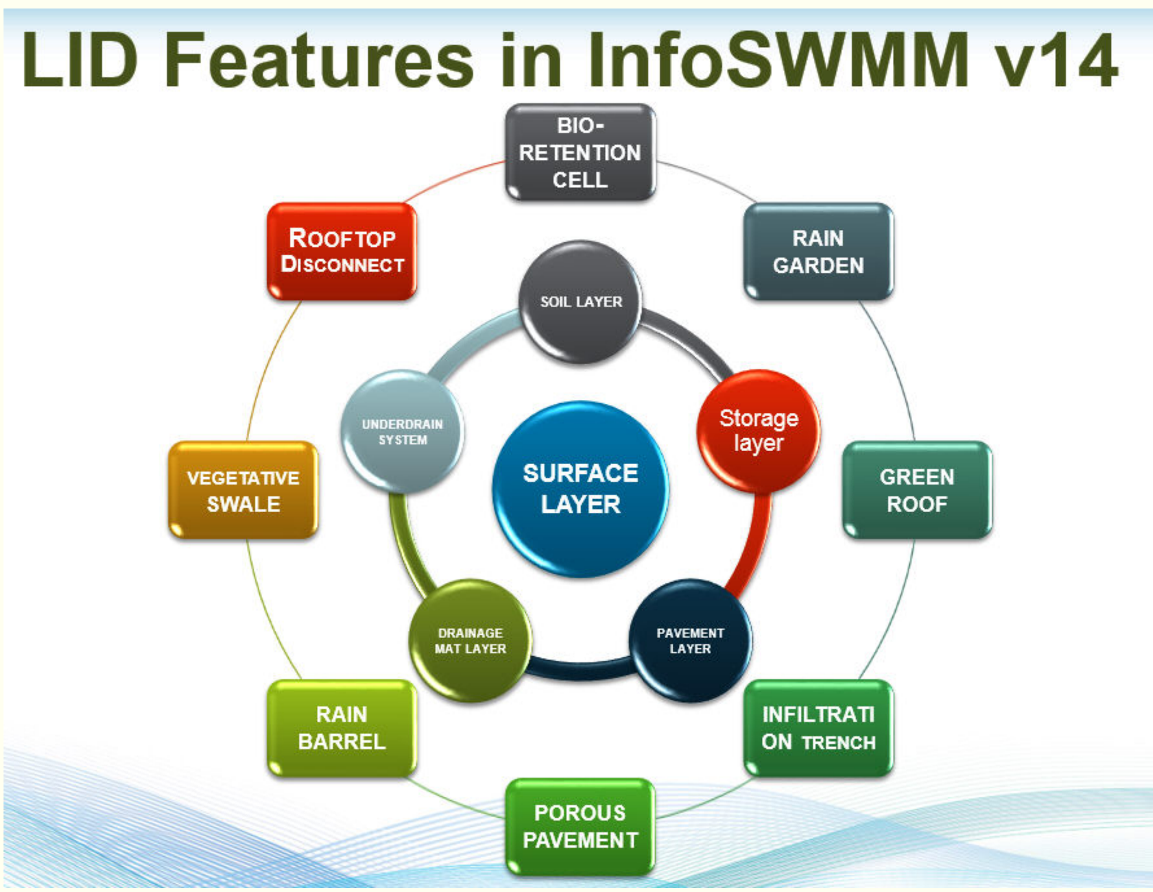
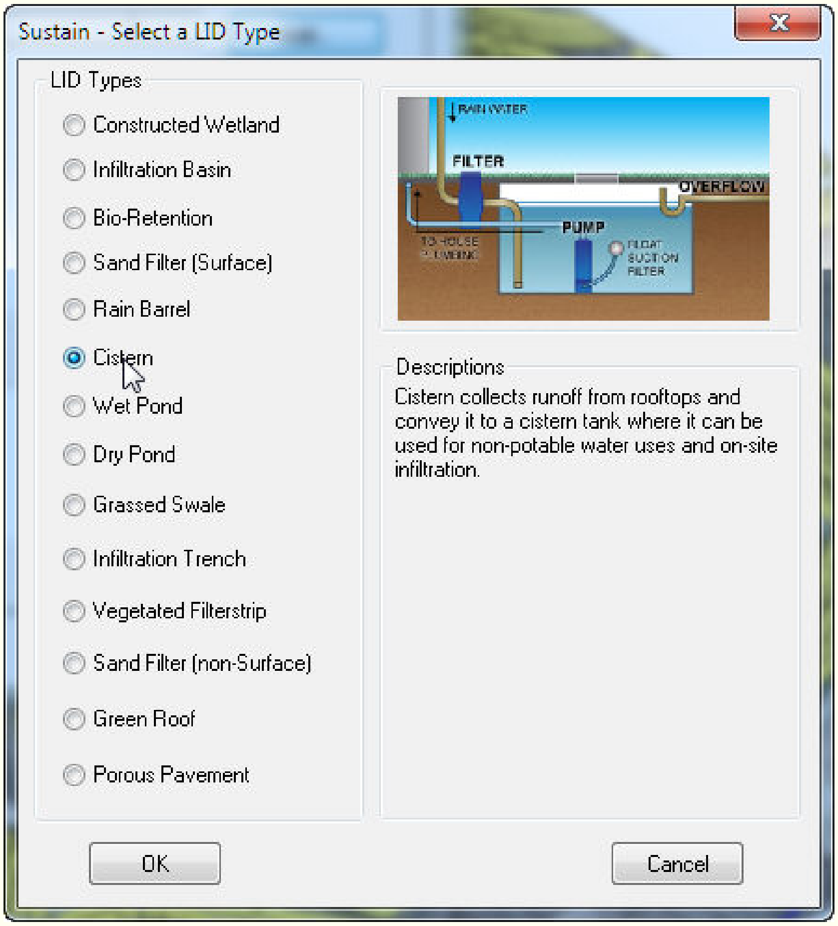
LID
LID
LID

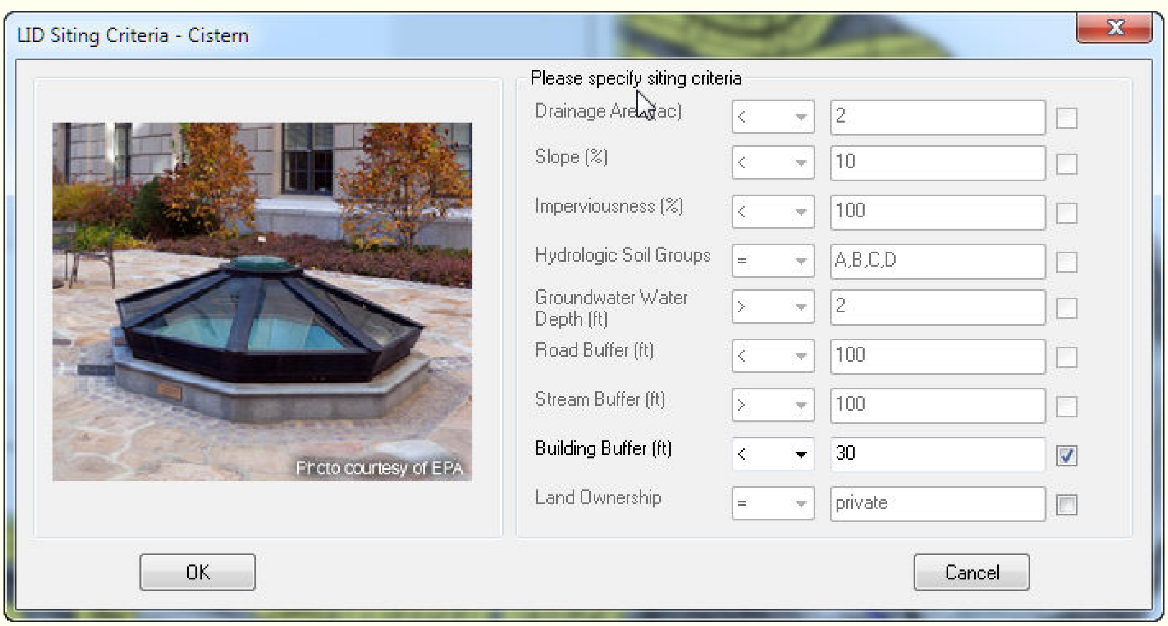
Cistern

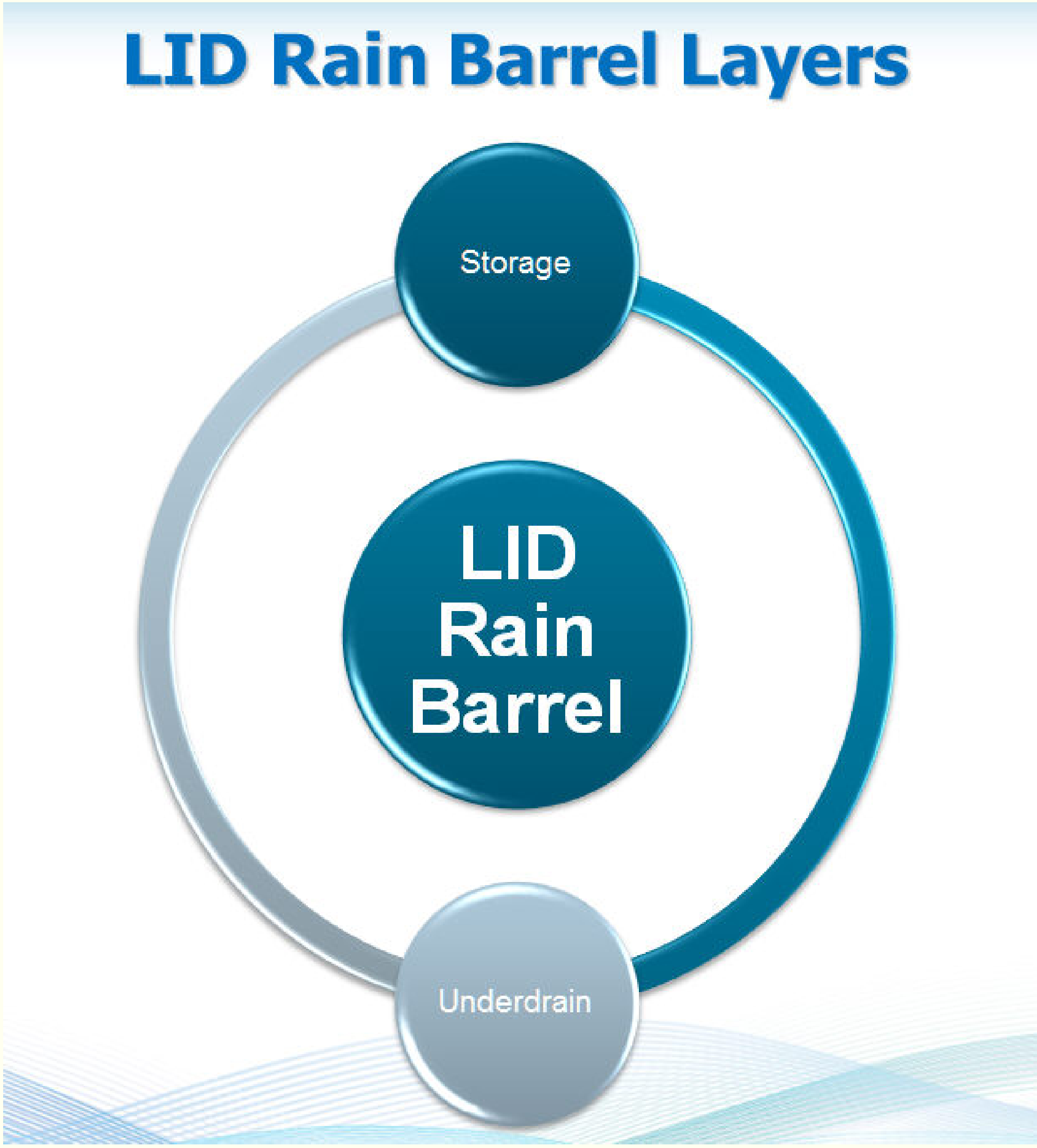
The three steps to selecting a LID Type are:

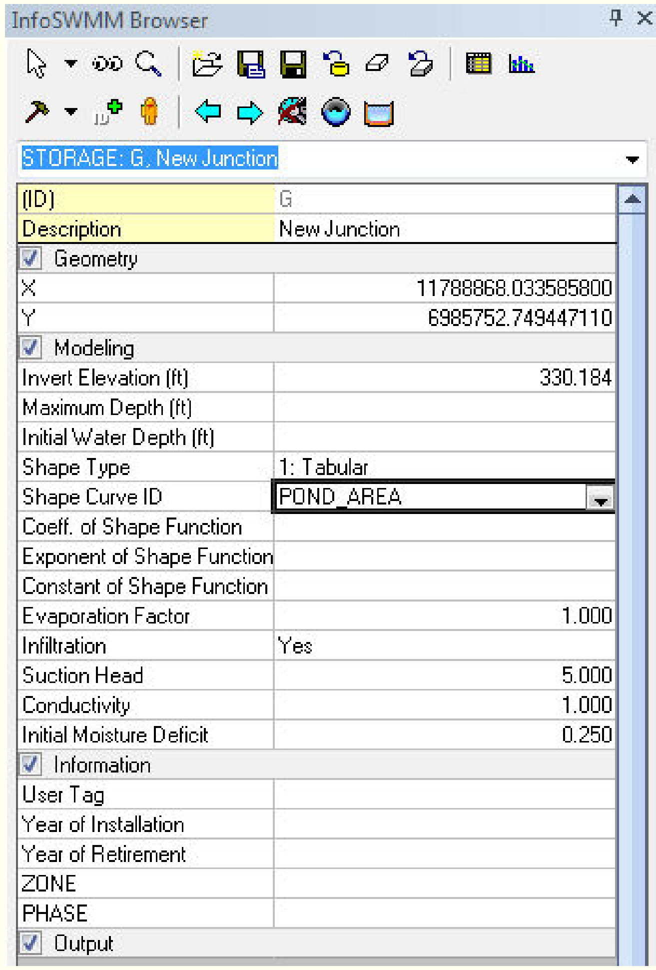
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

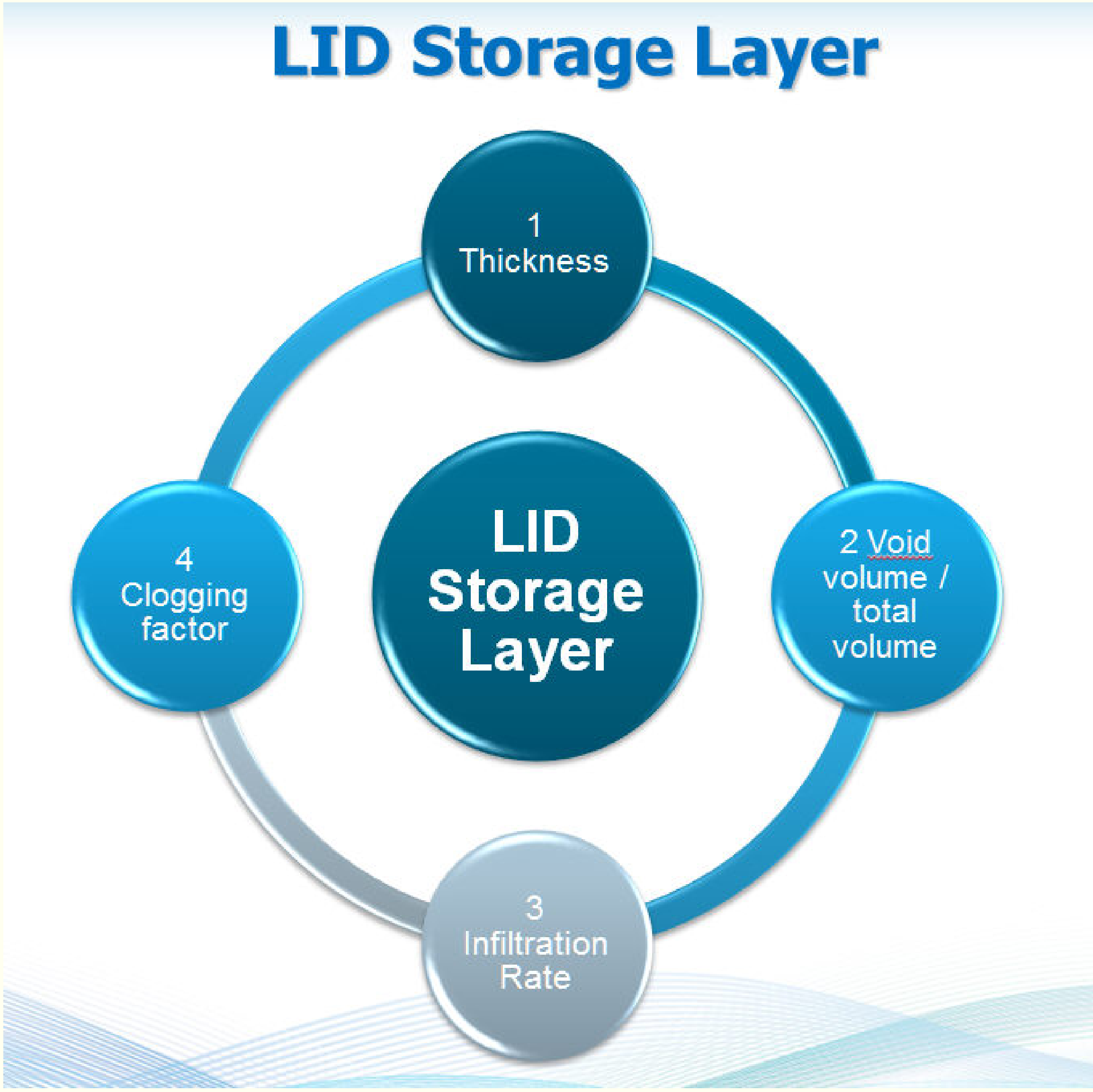



Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
FILTER
OVERFLOW
PUMP
Descriptions
Cistern collects runoff from rooftops and convey it to a cistern tank where it can be used for non-potable water uses and on-site infiltration.
OK
Cancel


LID Siting Criteria - Cistern
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 2
Slope (%) < 10
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) < 30
Land Ownership = private
OK
Cancel


LID Rain Barrel Layers
Storage
LID
Rain
Barrel
Underdrain


InfoSWMM Browser
STORAGE: G, New Junction
(ID)
G
Description
New Junction
Geometry
X
11788868.033585800
Y
6985752.749447110
Modeling
Invert Elevation (ft)
330.184
Maximum Depth (ft)
Initial Water Depth (ft)
Shape Type
1: Tabular
Shape Curve ID
POND_AREA
Coeff. of Shape Function
Exponent of Shape Function
Constant of Shape Function
Evaporation Factor
1.000
Infiltration
Yes
Suction Head
5.000
Conductivity
1.000
Initial Moisture Deficit
0.250
Information
User Tag
Year of Installation
Year of Retirement
ZONE
PHASE
Output



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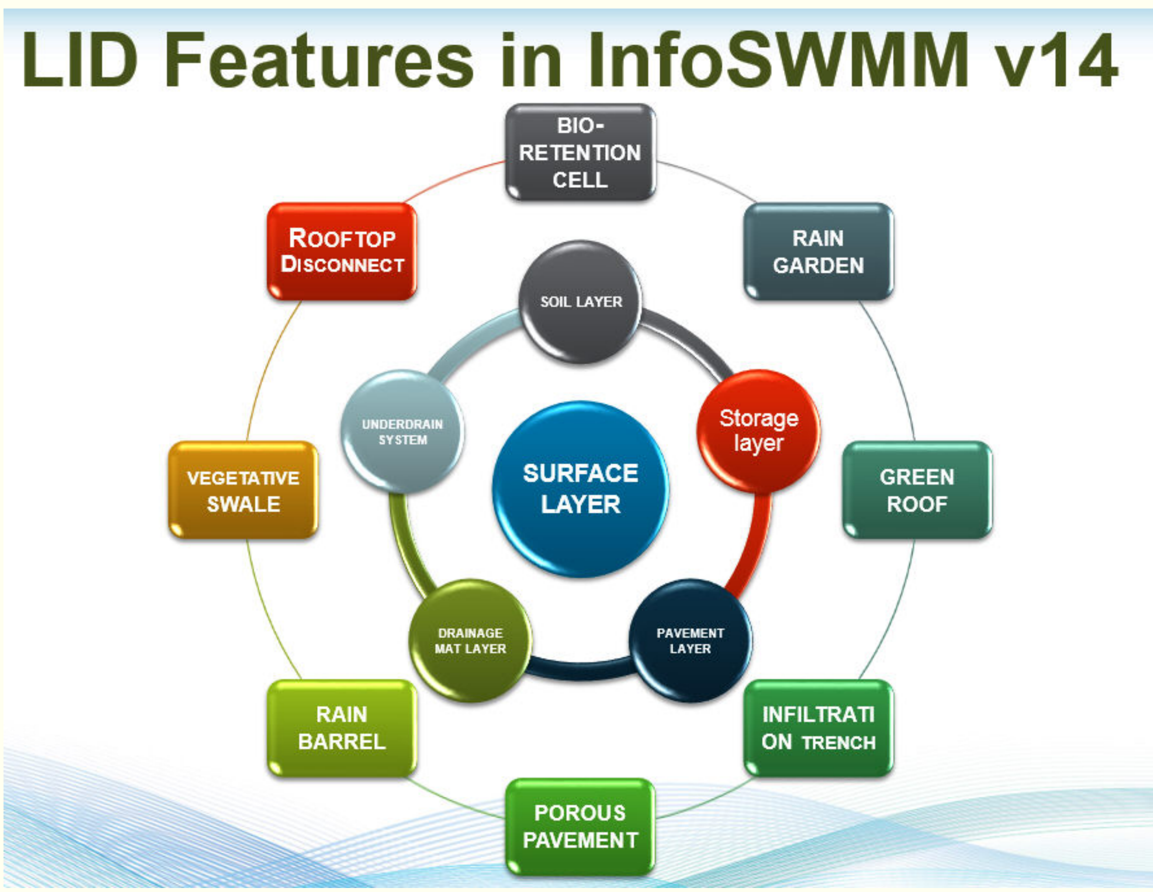
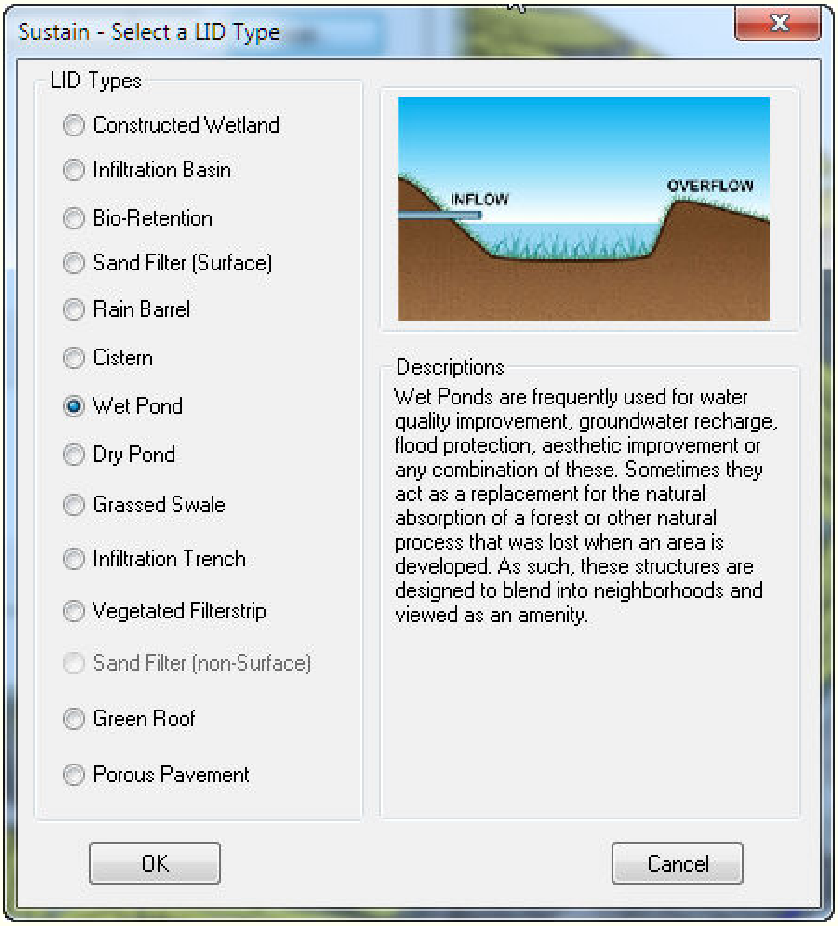
LID

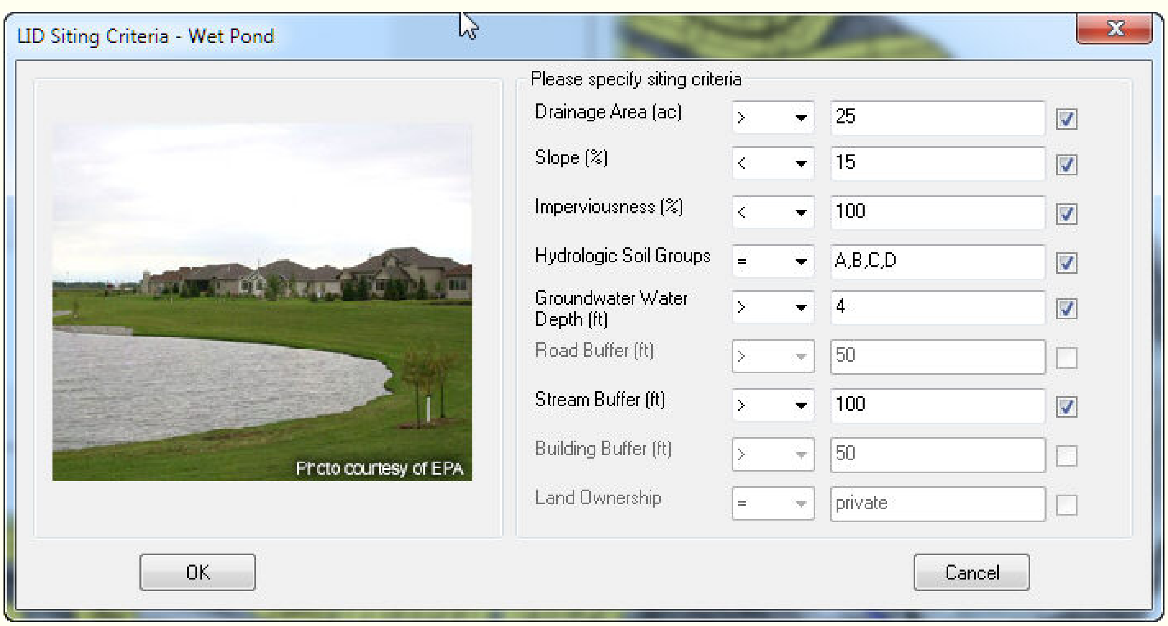
Wet Pond

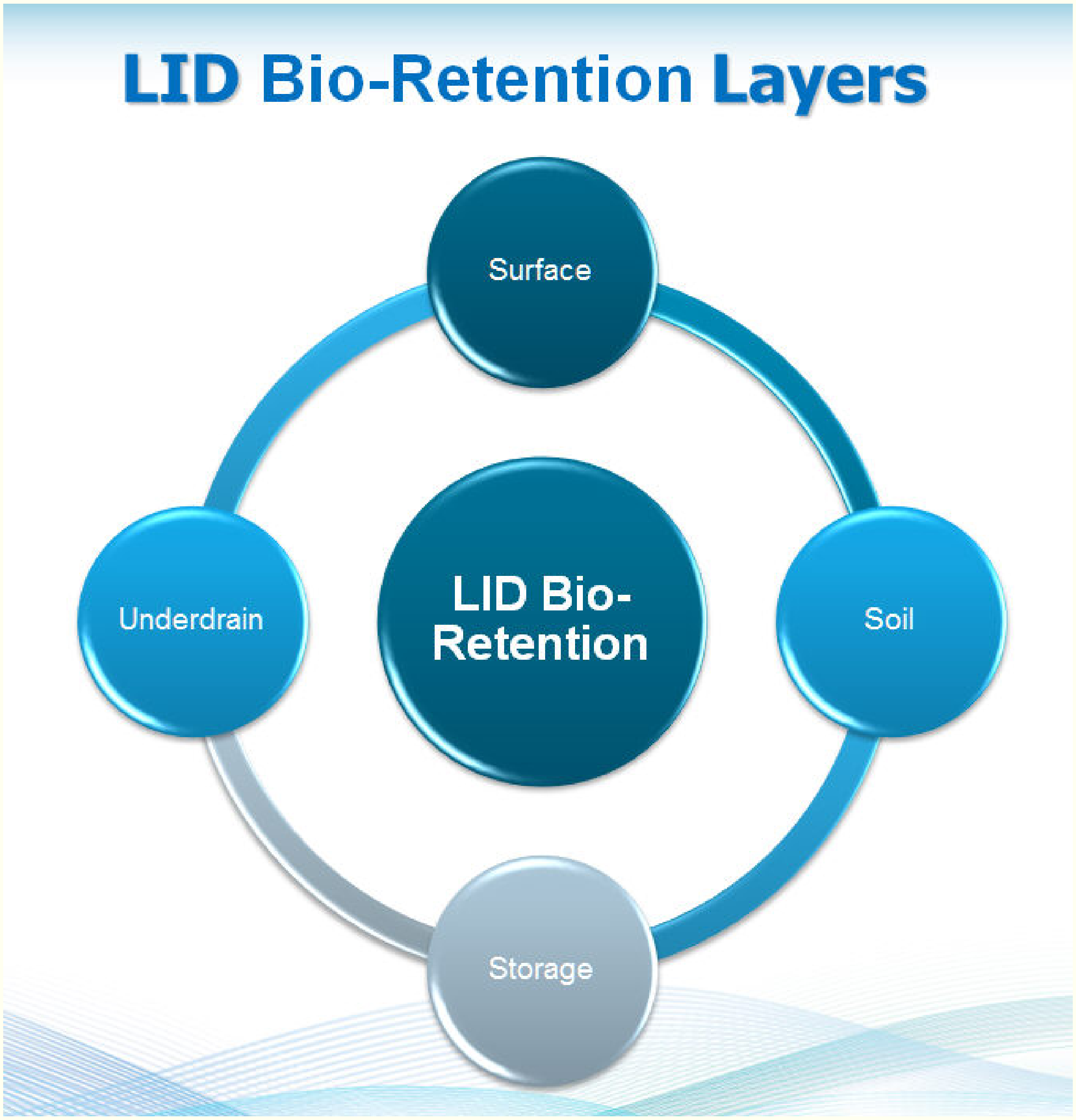
The three steps to selecting a LID Type are:

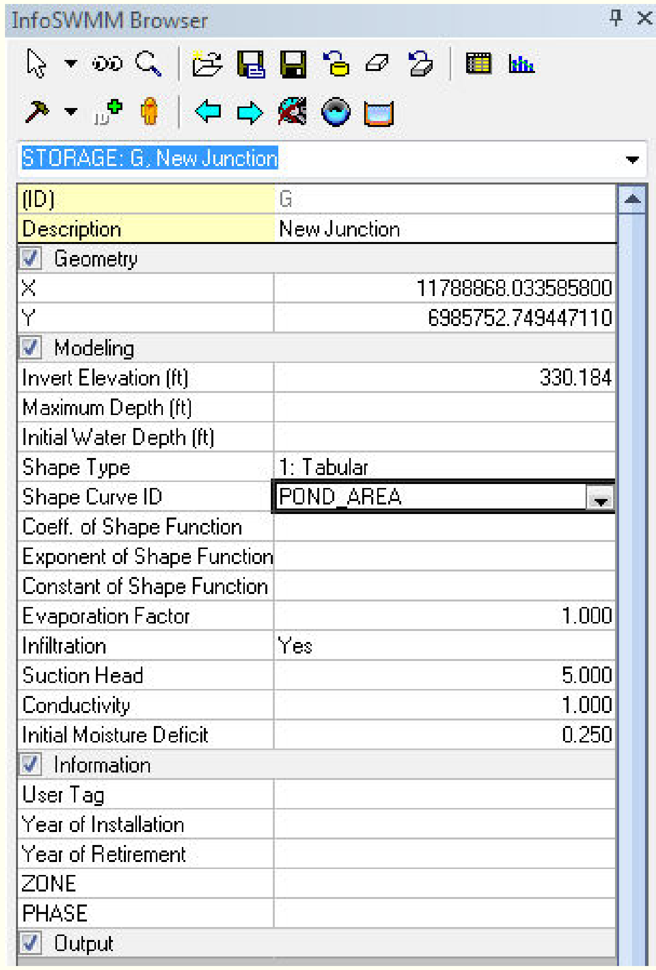
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

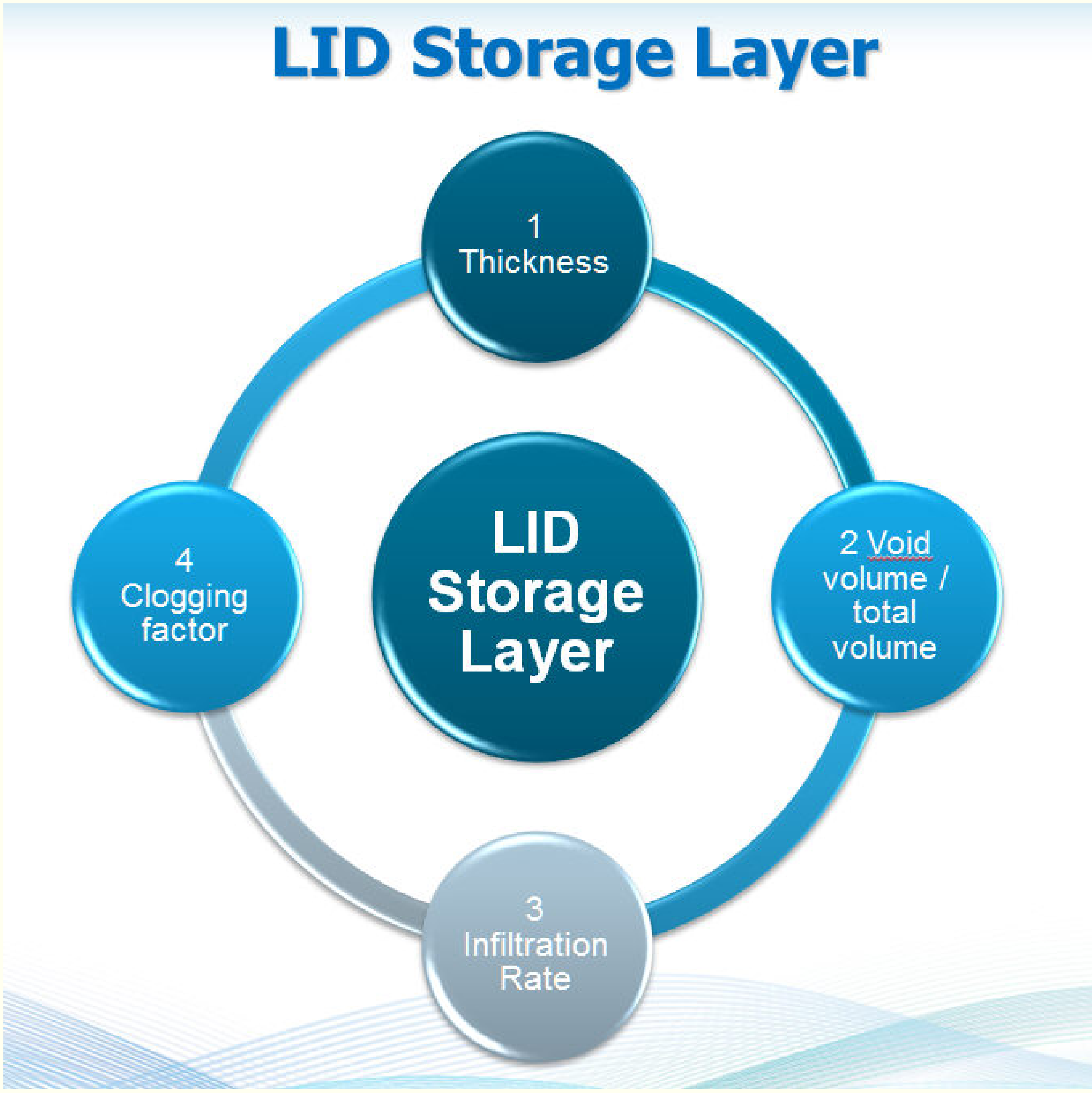


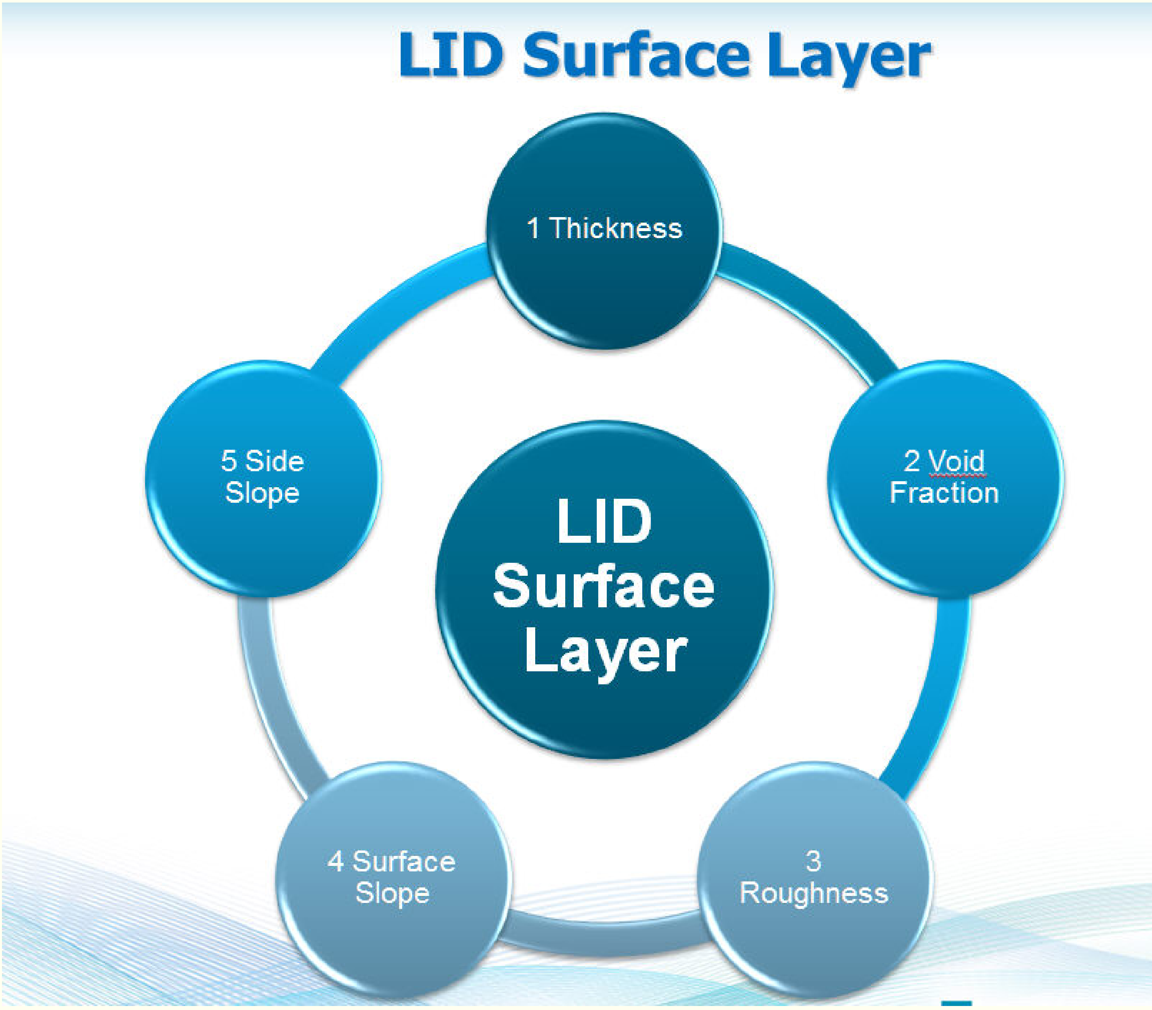

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INFLOW
OVERFLOW
Descriptions
Wet Ponds are frequently used for water quality improvement, groundwater recharge, flood protection, aesthetic improvement or any combination of these. Sometimes they act as a replacement for the natural absorption of a forest or other natural process that was lost when an area is developed. As such, these structures are designed to blend into neighborhoods and viewed as an amenity.
OK
Cancel

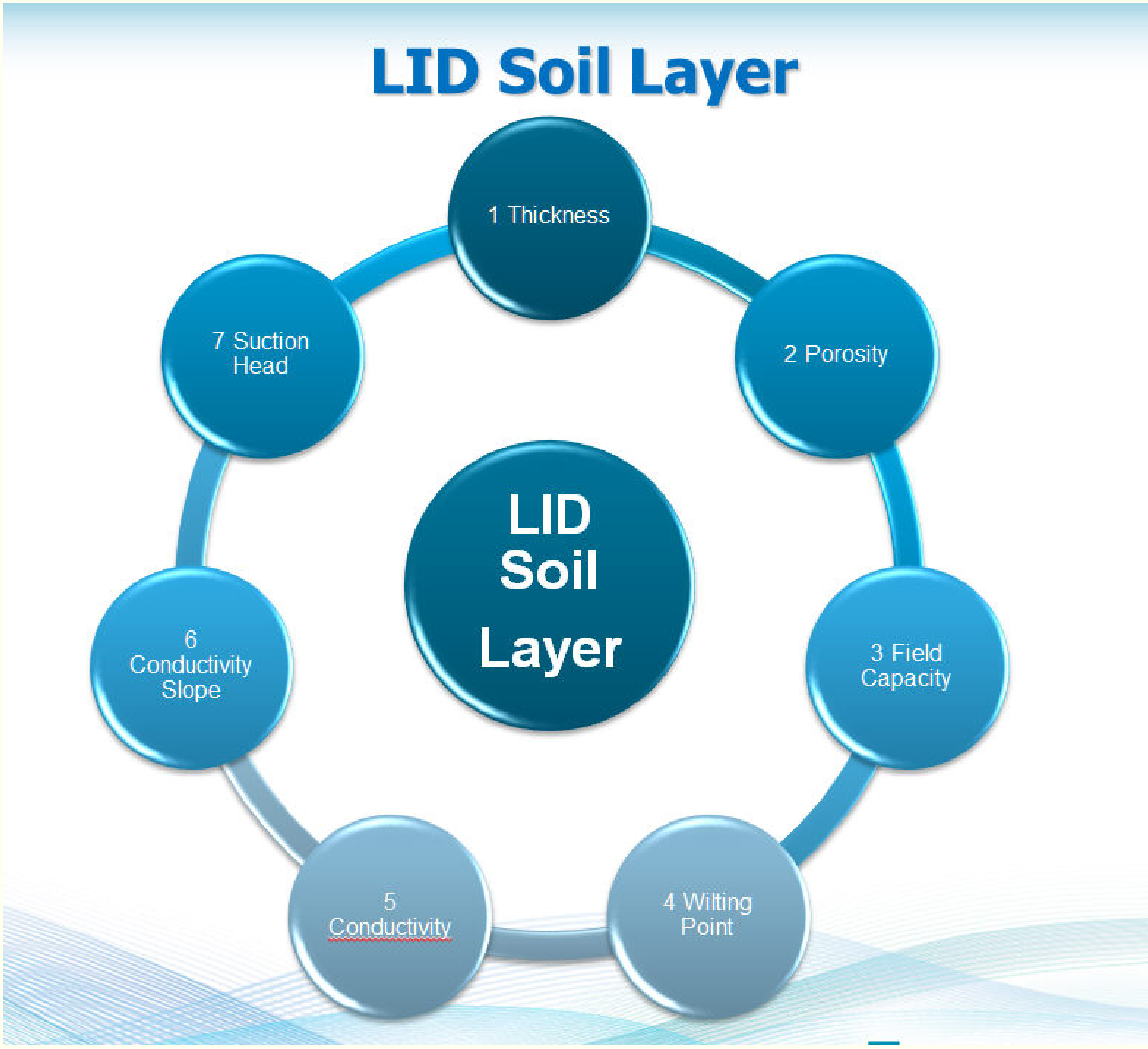

LID Siting Criteria - Wet Pond
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) > 25
Slope (%) < 15
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 4
Road Buffer (ft) > 50
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel

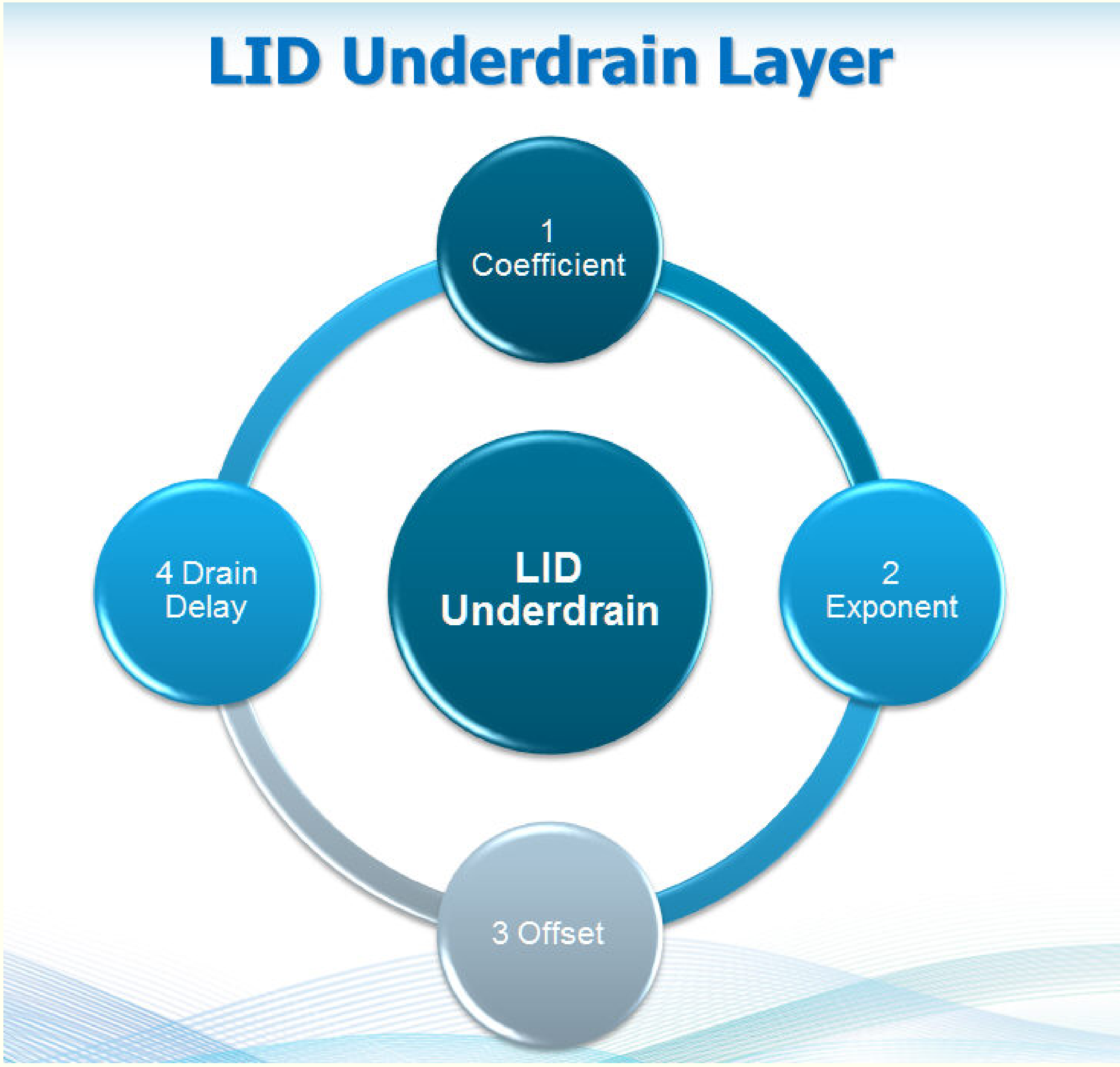

LID Bio-Retention Layers
Surface
Underdrain
LID Bio-Retention
Soil
Storage


InfoSWMM Browser
STORAGE: G, New Junction
(ID) G
Description New Junction
Geometry
X 11788868.033585800
Y 6985752.749447110
Modeling
Invert Elevation (ft) 330.184
Maximum Depth (ft)
Initial Water Depth (ft)
Shape Type 1: Tabular
Shape Curve ID POND_AREA
Coeff. of Shape Function
Exponent of Shape Function
Constant of Shape Function
Evaporation Factor 1.000
Infiltration Yes
Suction Head 5.000
Conductivity 1.000
Initial Moisture Deficit 0.250
Information
User Tag
Year of Installation
Year of Retirement
ZONE
PHASE
Output


LID Storage Layer
1
Thickness
4
Clogging
factor
LID
Storage
Layer
2 Void
volume /
total
volume
3
Infiltration
Rate


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer



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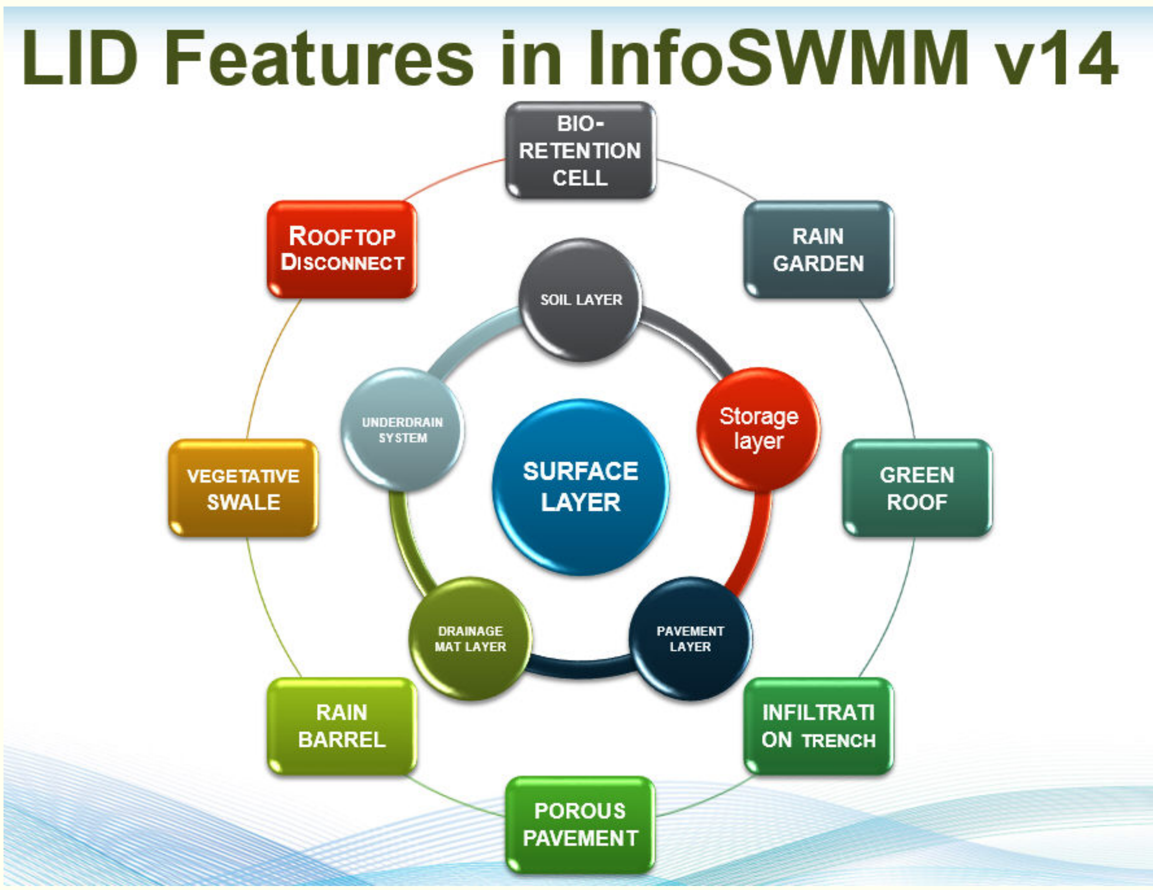
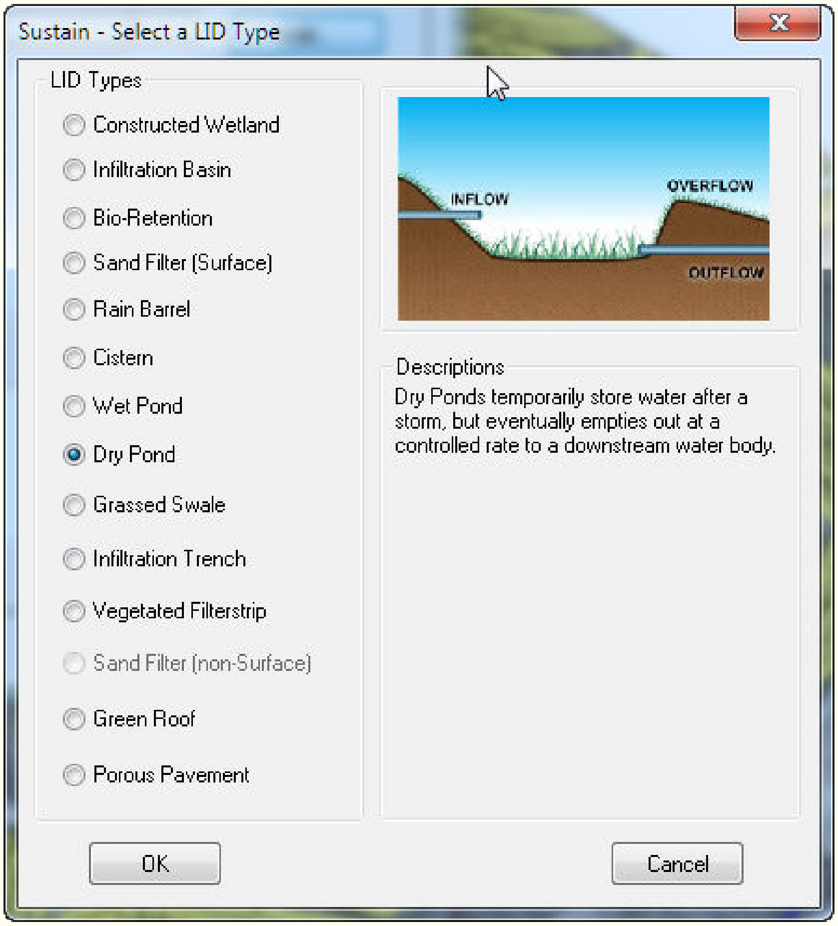
LID
LID
LID

Dry Pond

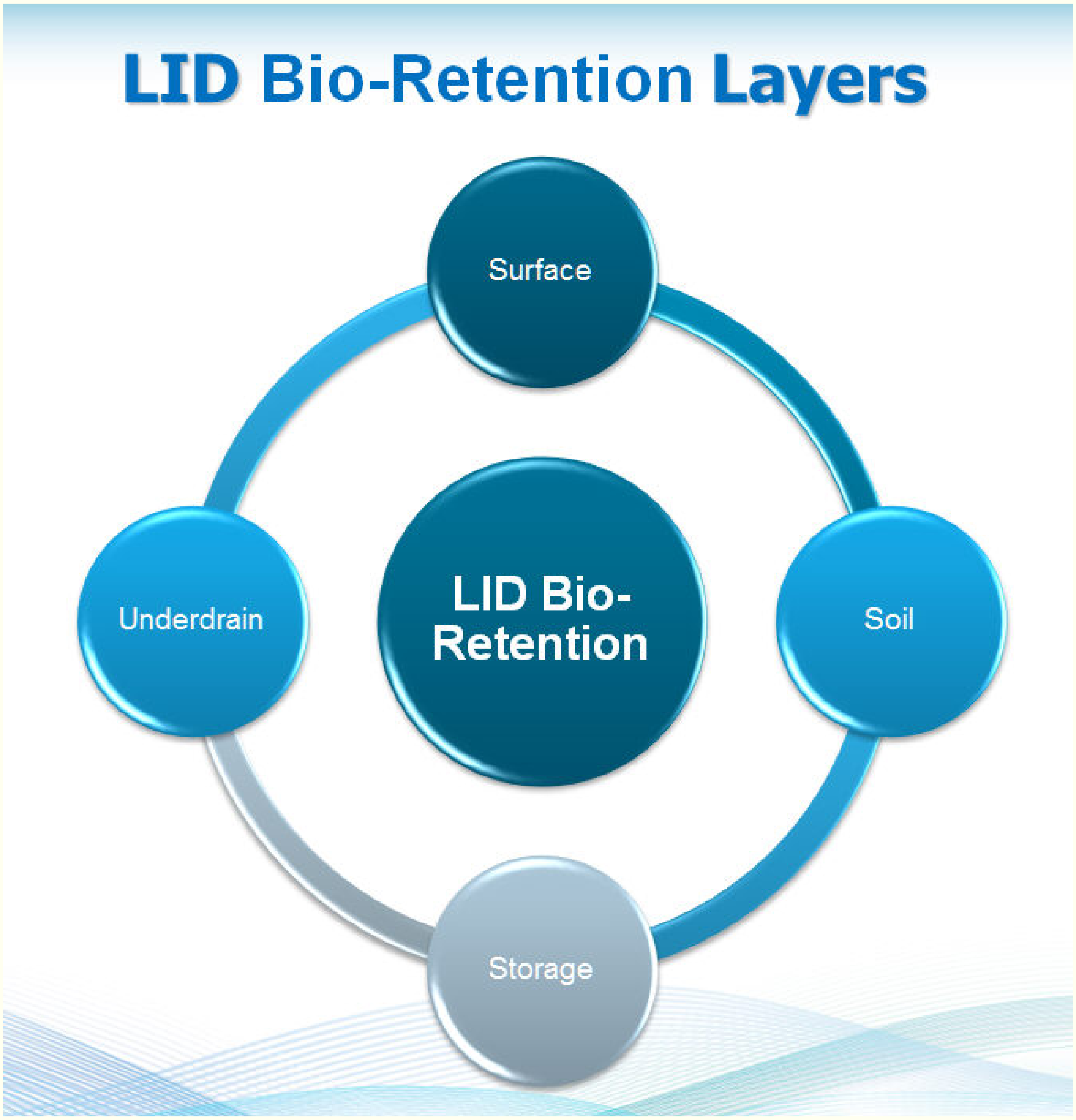
The three steps to selecting a LID Type are:

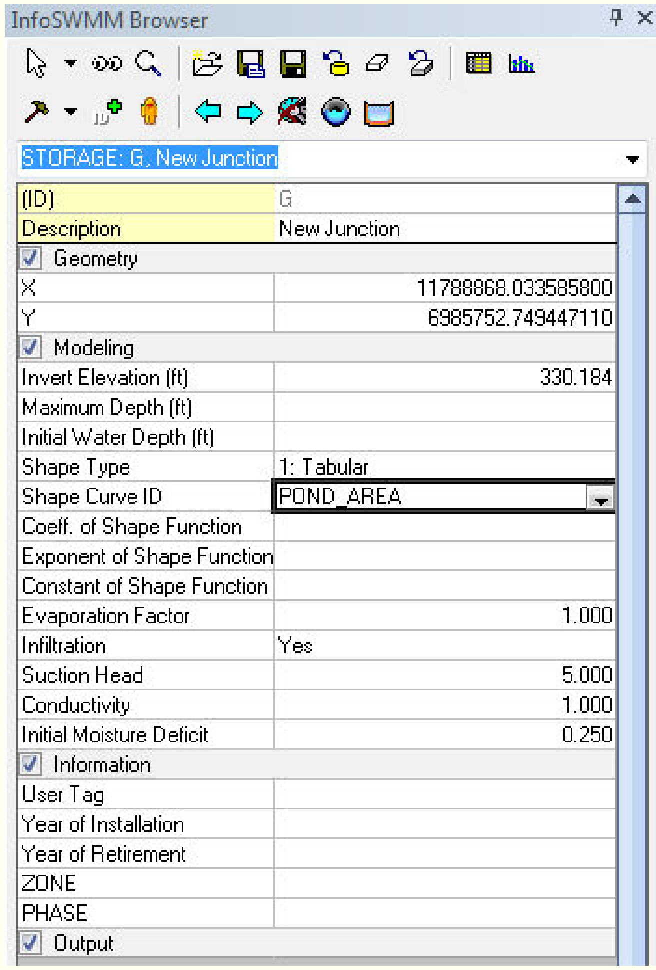
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

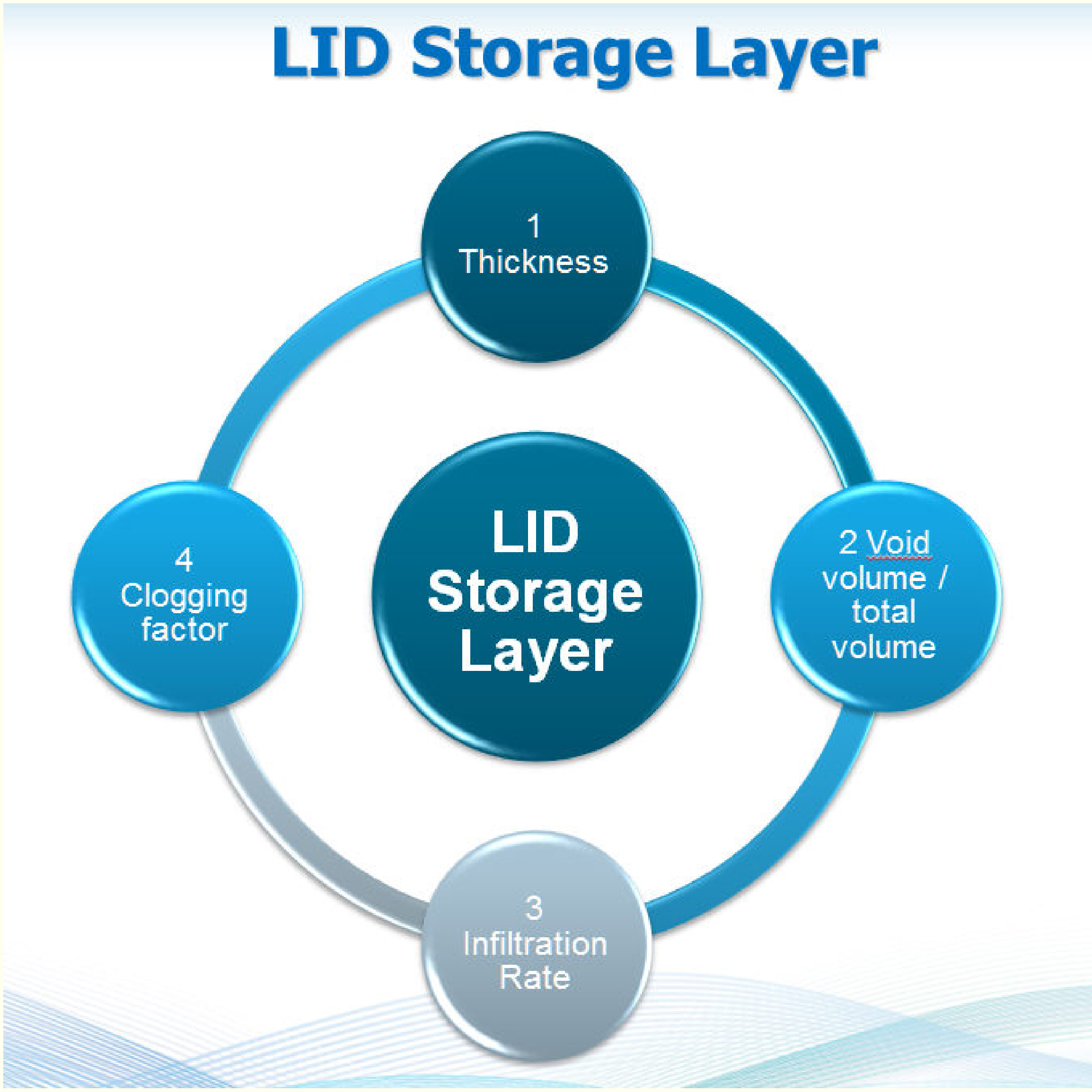


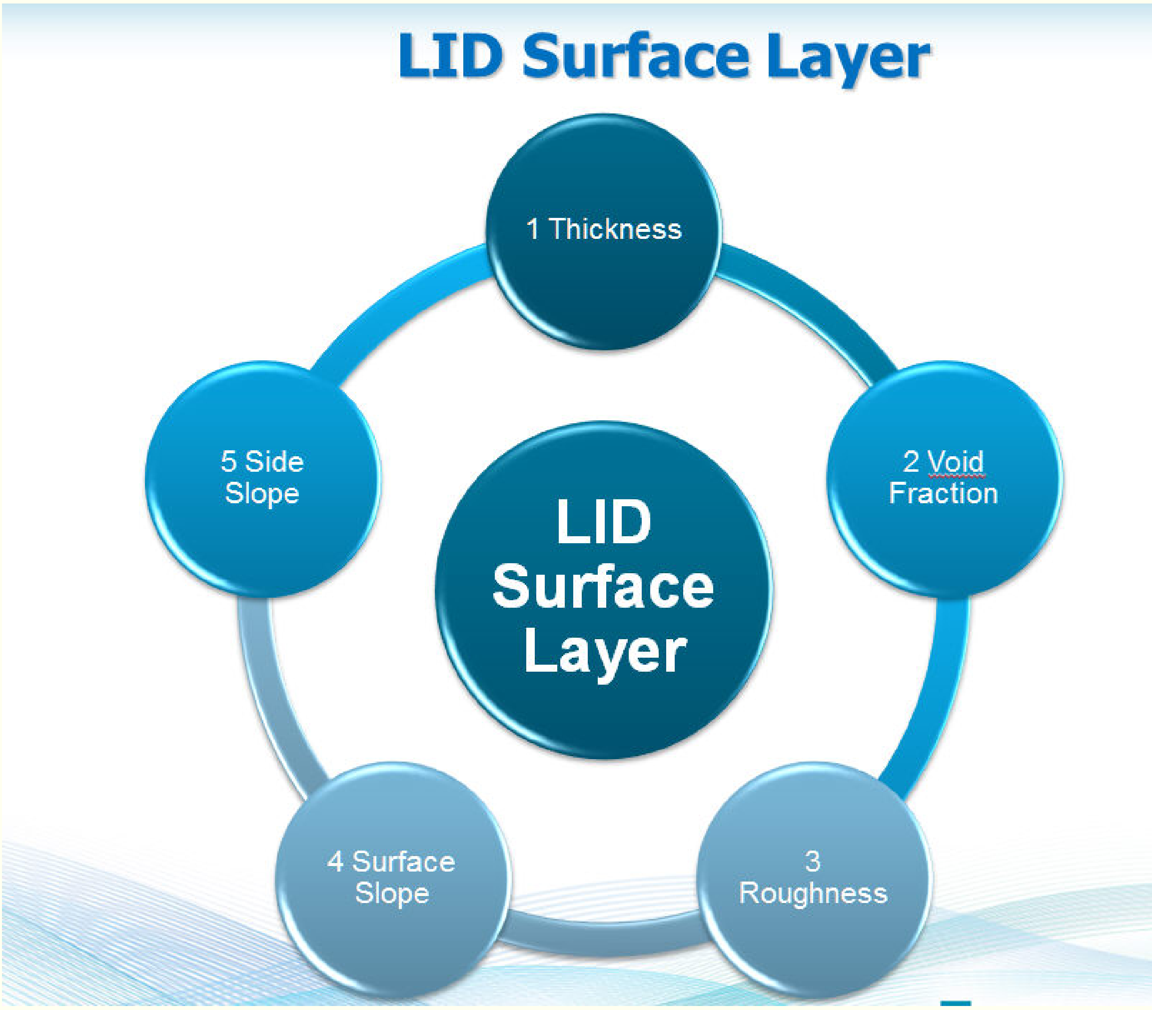

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INFLOW
OVERFLOW
OUTFLOW
Descriptions
Dry Ponds temporarily store water after a storm, but eventually empties out at a controlled rate to a downstream water body.
OK
Cancel

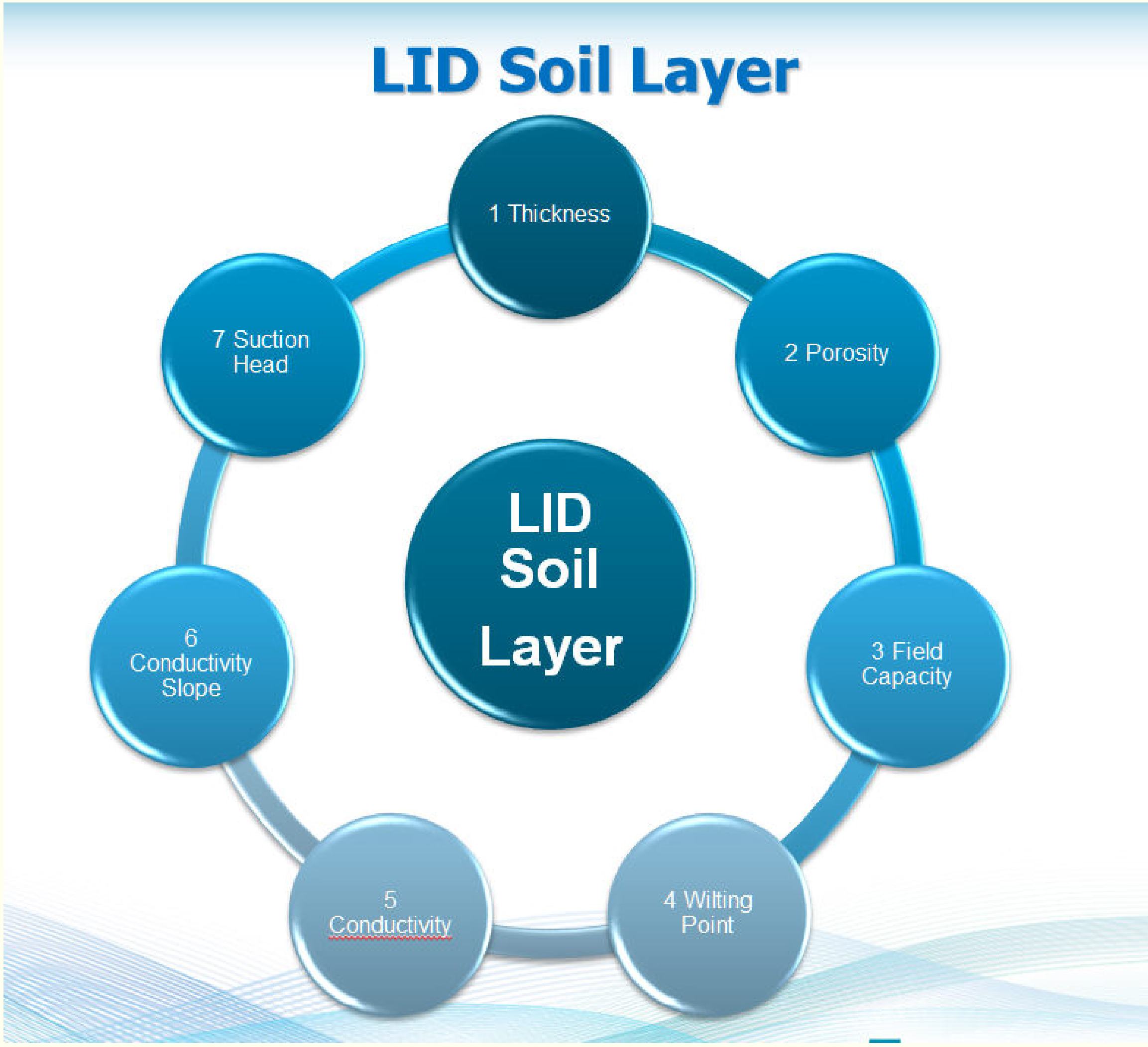

LID Siting Criteria - Dry Pond
Please specify siting criteria
Drainage Area (ac) > 25
Slope (%) < 15
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 4
Road Buffer (ft) > 50
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
Photo courtesy of EPA
OK
Cancel

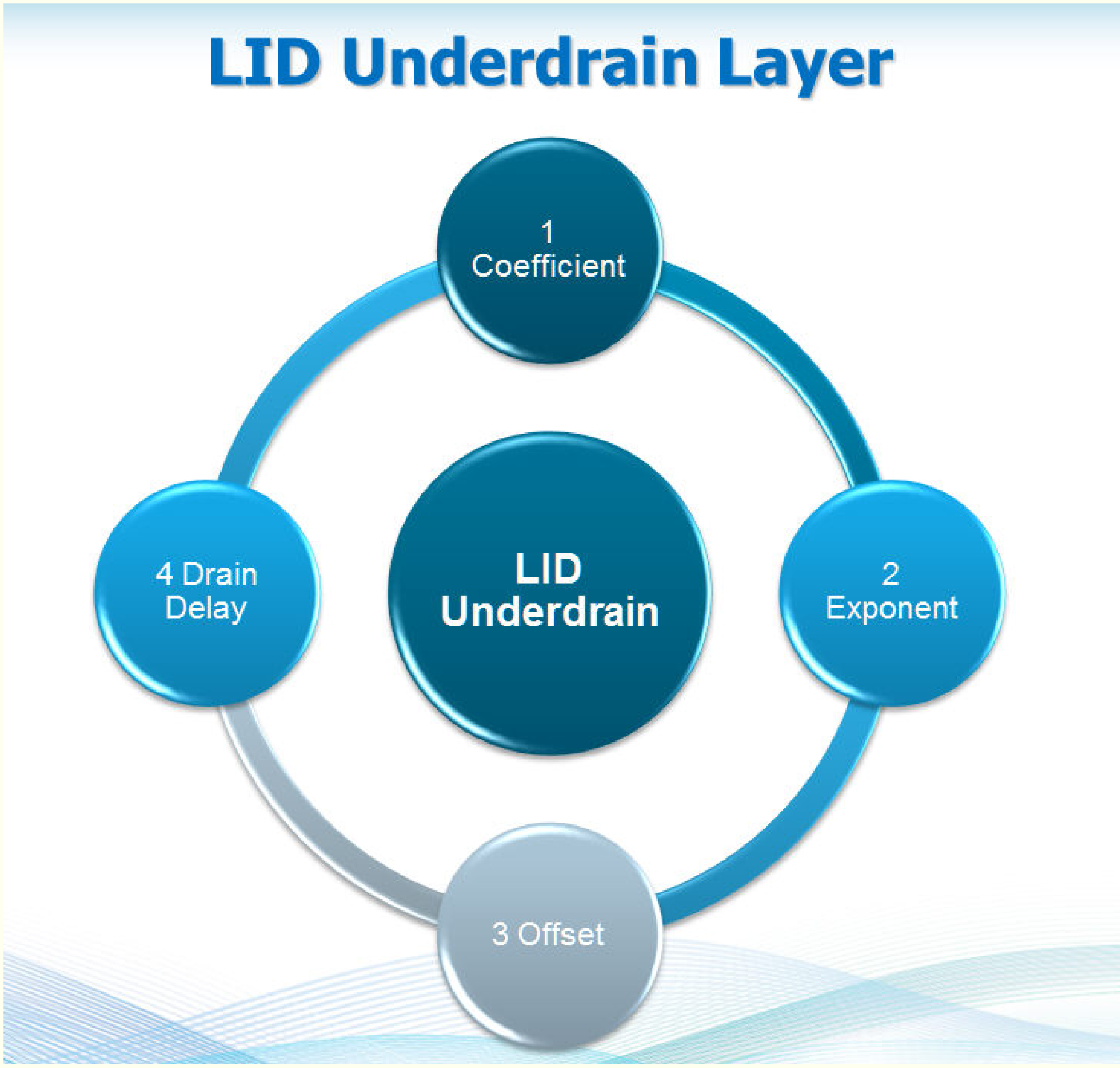

LID Bio-Retention Layers
Surface
Underdrain
LID Bio-Retention
Soil
Storage


InfoSWMM Browser
STORAGE: G, New Junction
(ID) G
Description New Junction
Geometry
X 11788868.033585800
Y 6985752.749447110
Modeling
Invert Elevation (ft) 330.184
Maximum Depth (ft)
Initial Water Depth (ft)
Shape Type 1: Tabular
Shape Curve ID POND_AREA
Coeff. of Shape Function
Exponent of Shape Function
Constant of Shape Function
Evaporation Factor 1.000
Infiltration Yes
Suction Head 5.000
Conductivity 1.000
Initial Moisture Deficit 0.250
Information
User Tag
Year of Installation
Year of Retirement
ZONE
PHASE
Output


LID Storage Layer
1
Thickness
2 Void
volume /
total
volume
3
Infiltration
Rate
4
Clogging
factor
LID
Storage
Layer


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer



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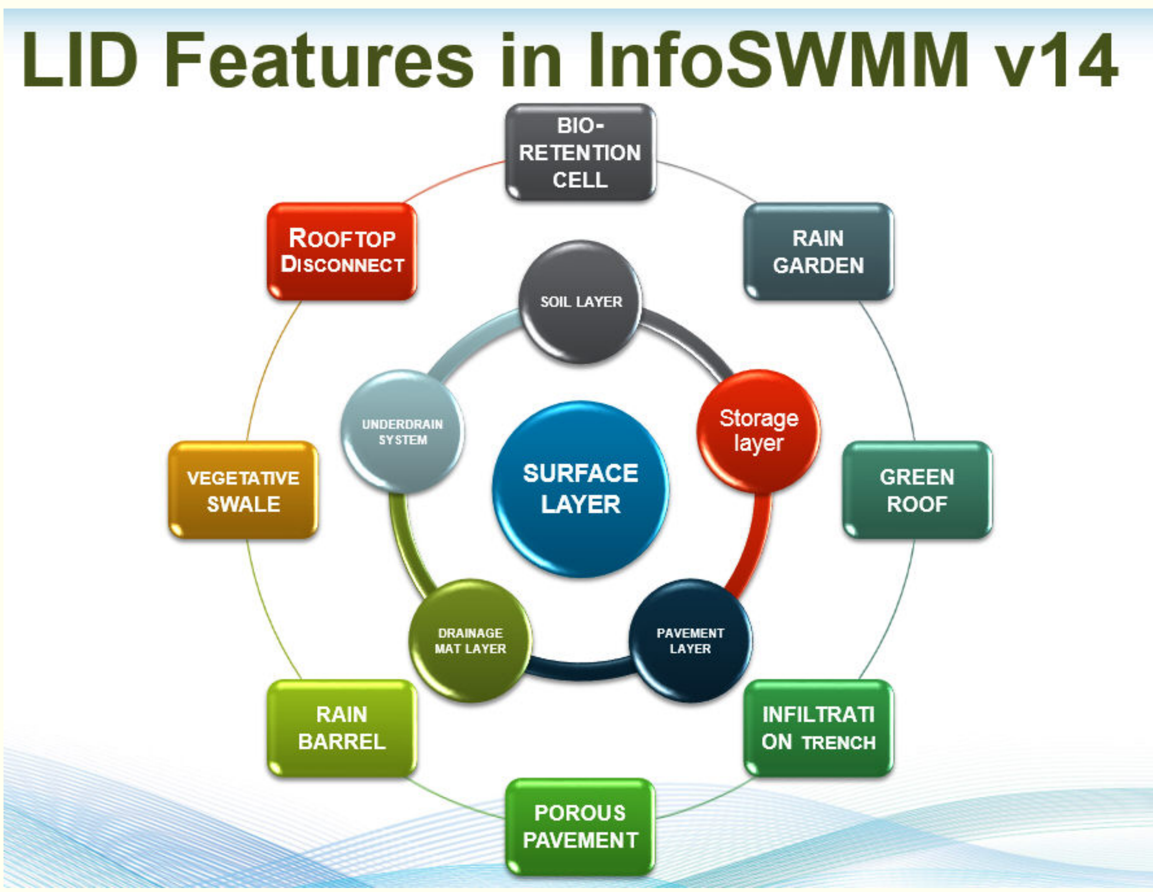
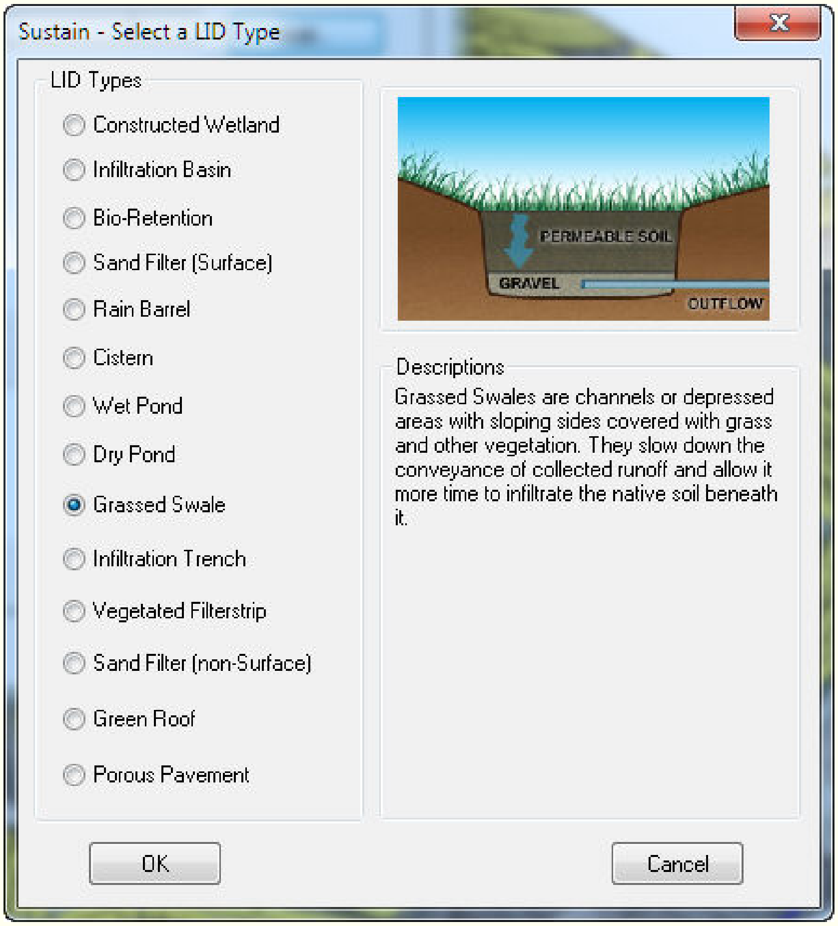
LID
LID
LID

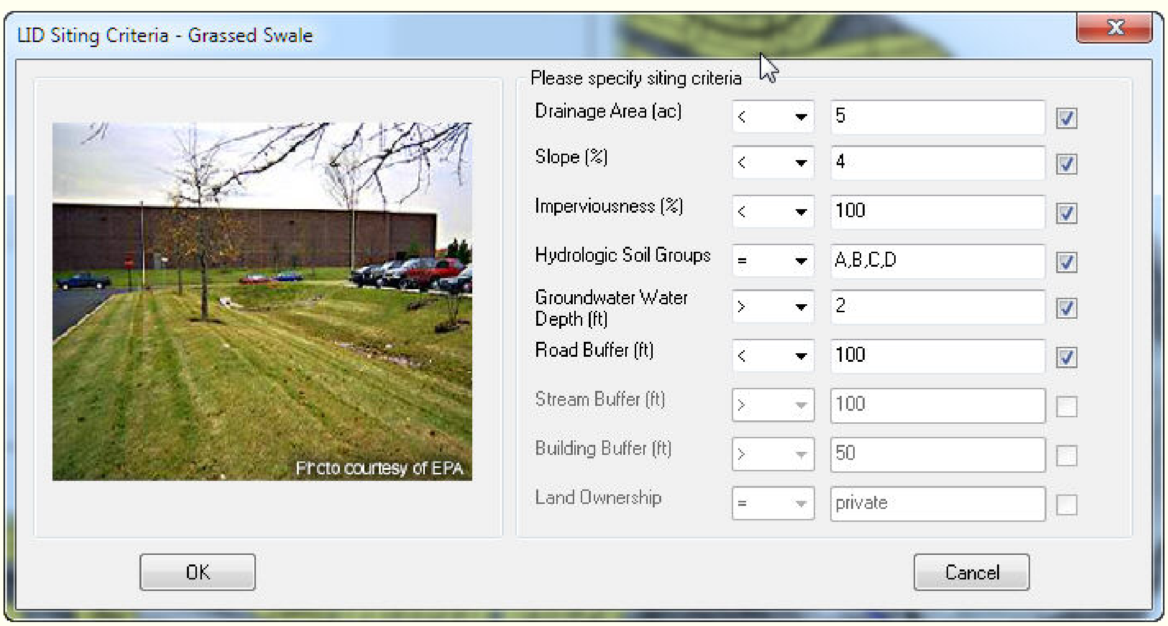
Grassed Swale

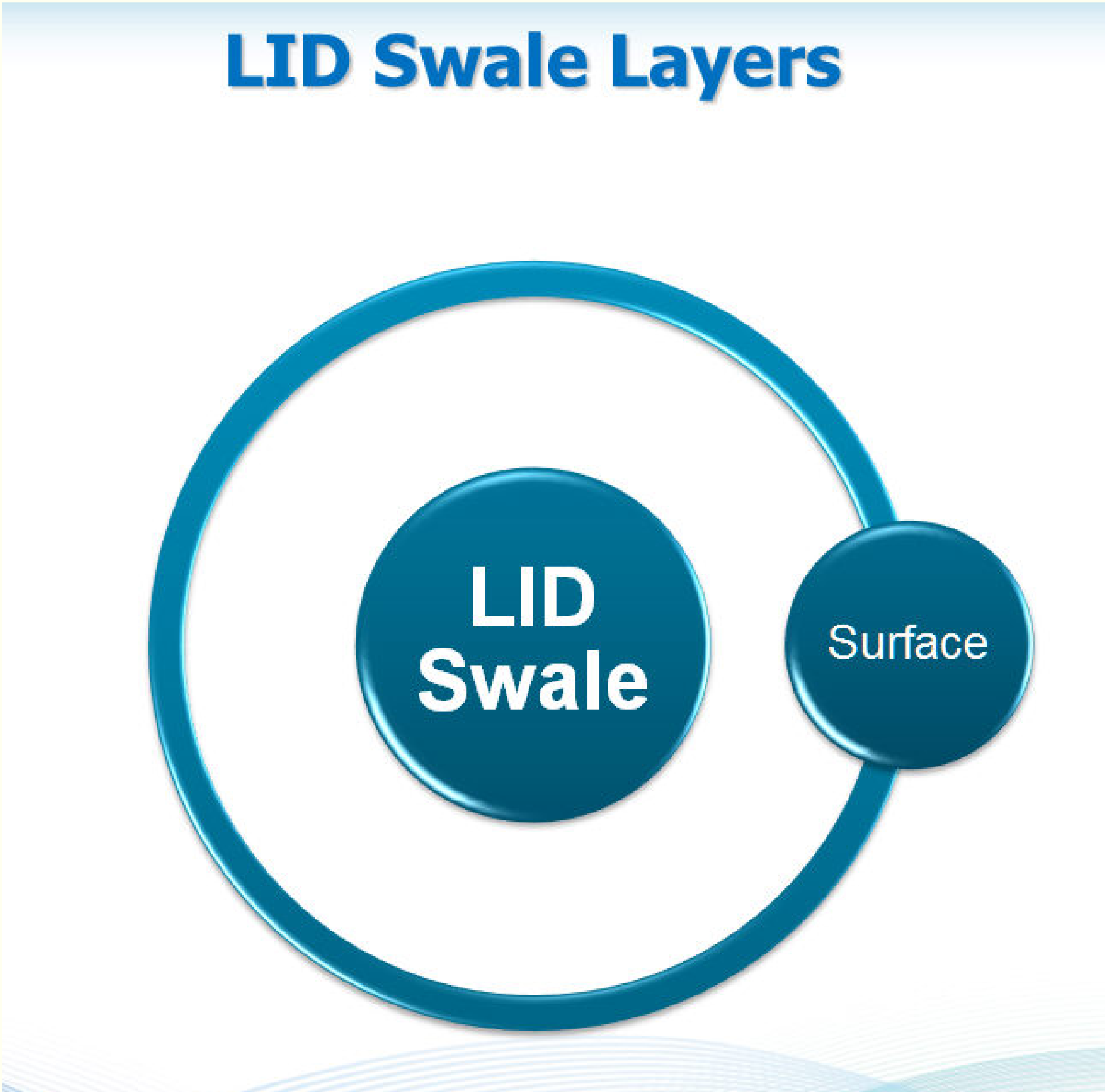
The three steps to selecting a LID Type are:

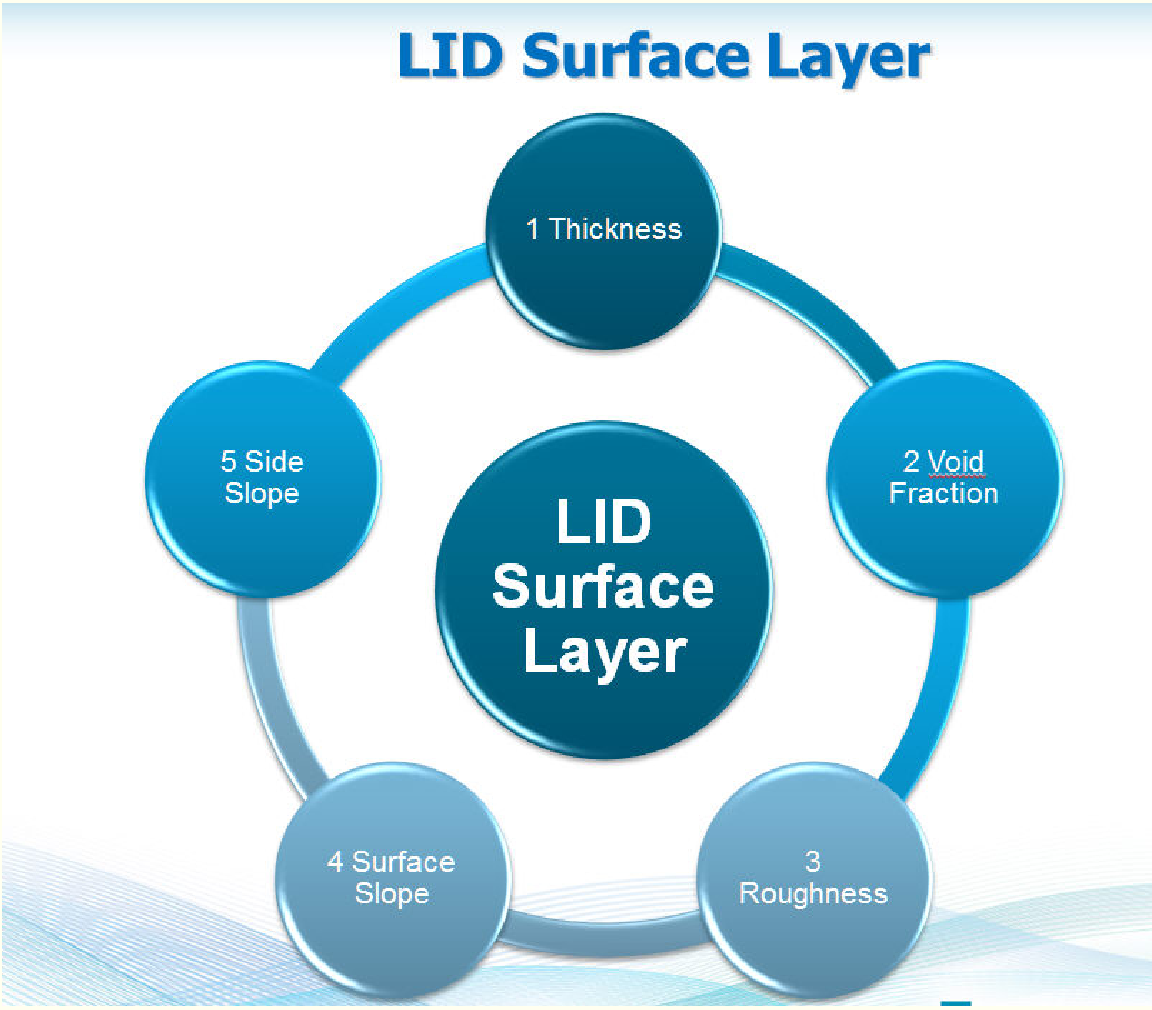
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
  - a. The number of process layers
  - b. The components of each process layer
  - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
  - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration




Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
PERMEABLE SOIL
GRAVEL
OUTFLOW
Descriptions
Grassed Swales are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate the native soil beneath it.
OK
Cancel


LID Siting Criteria - Grassed Swale
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 5
Slope (%) < 4
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel


LID Swale Layers
LID
Swale
Surface



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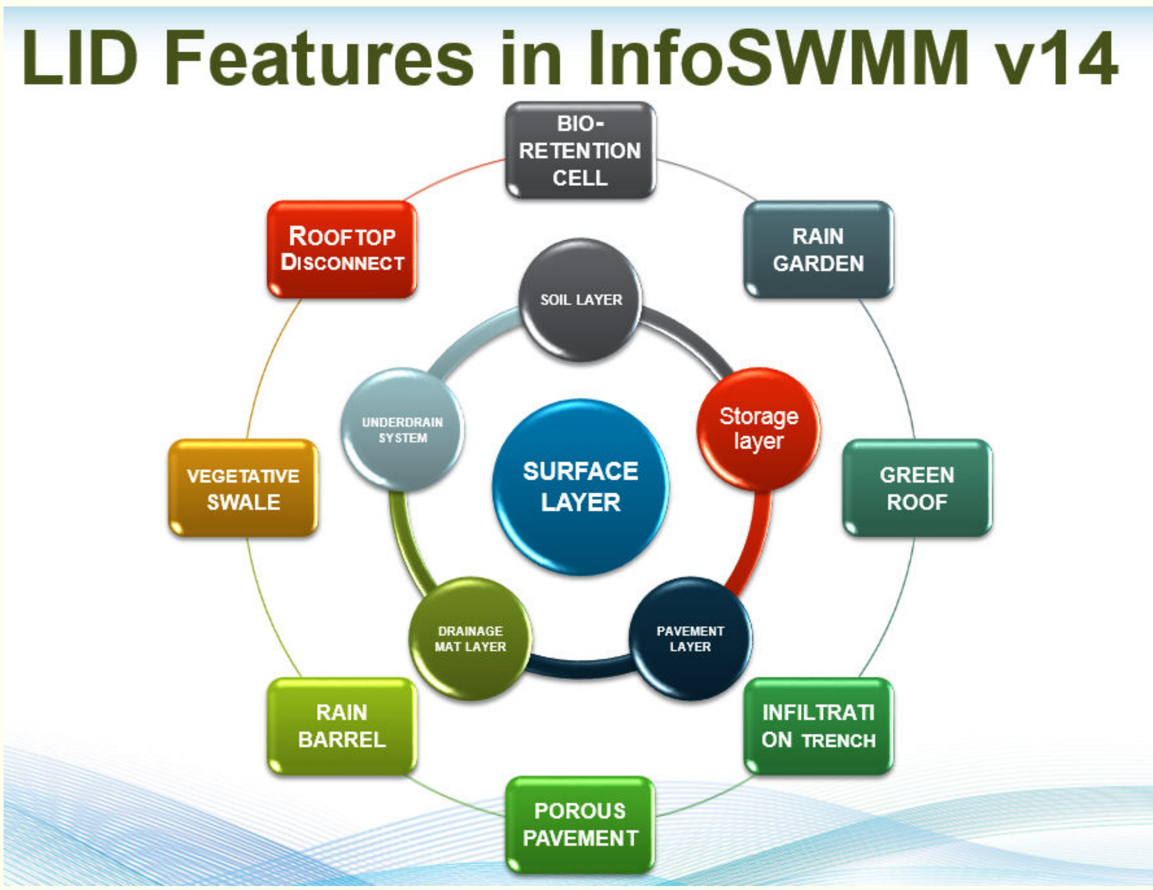
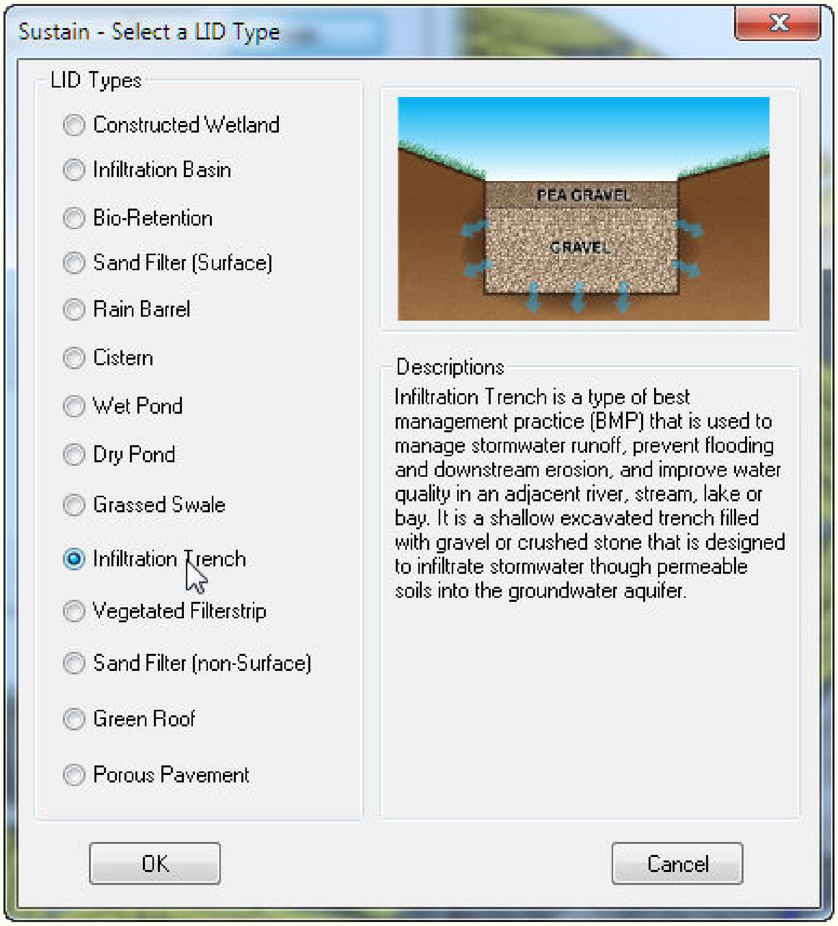
LID
LID
LID

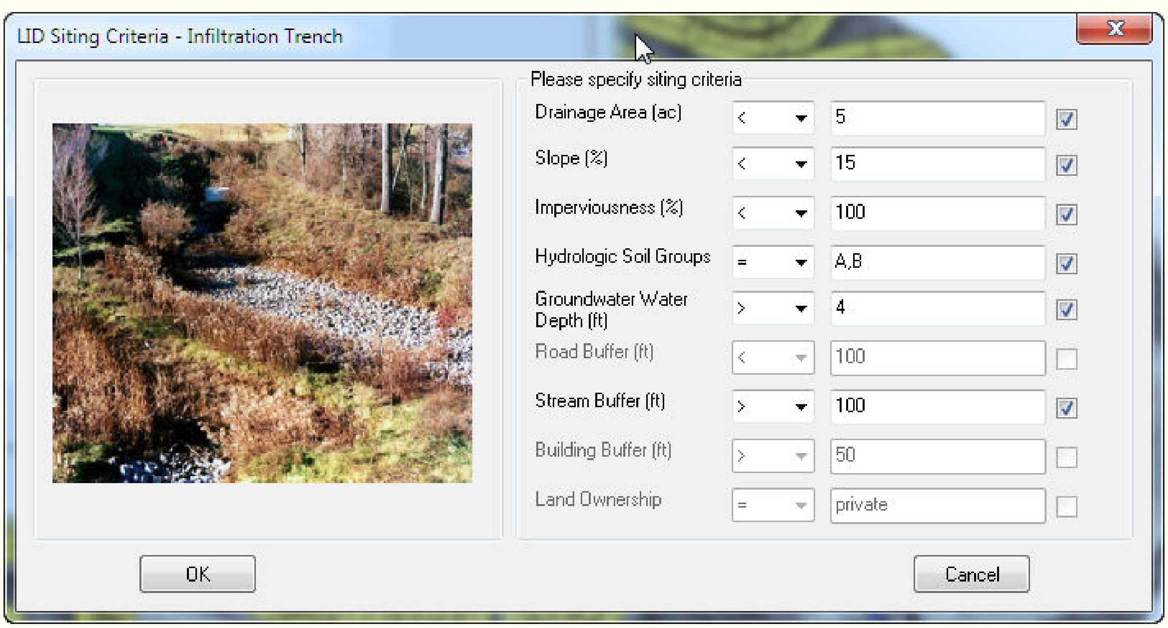
Infiltration Trench

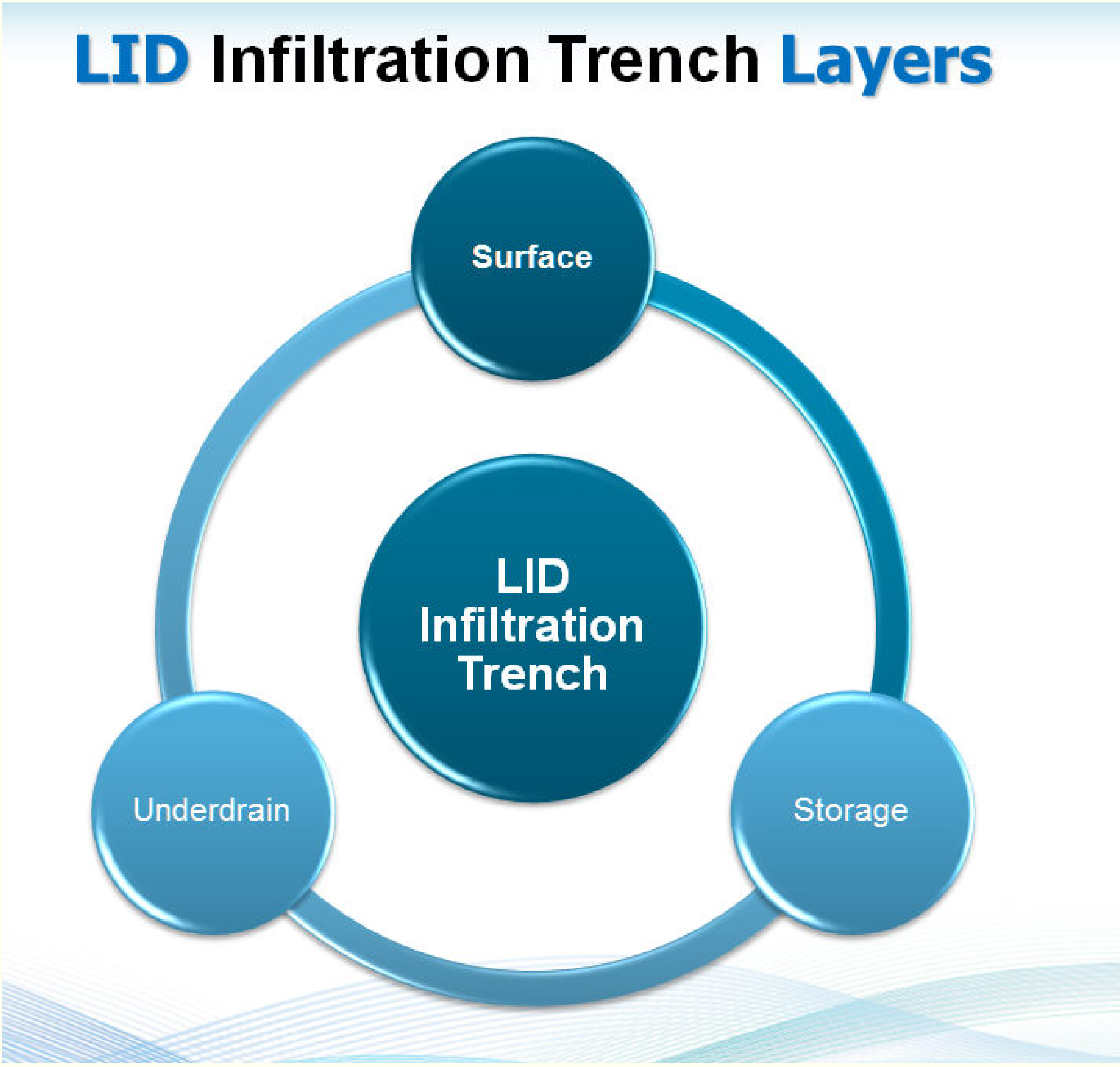
The three steps to selecting a LID Type are:

- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
  - a. The number of process layers
  - b. The components of each process layer
  - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
  - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

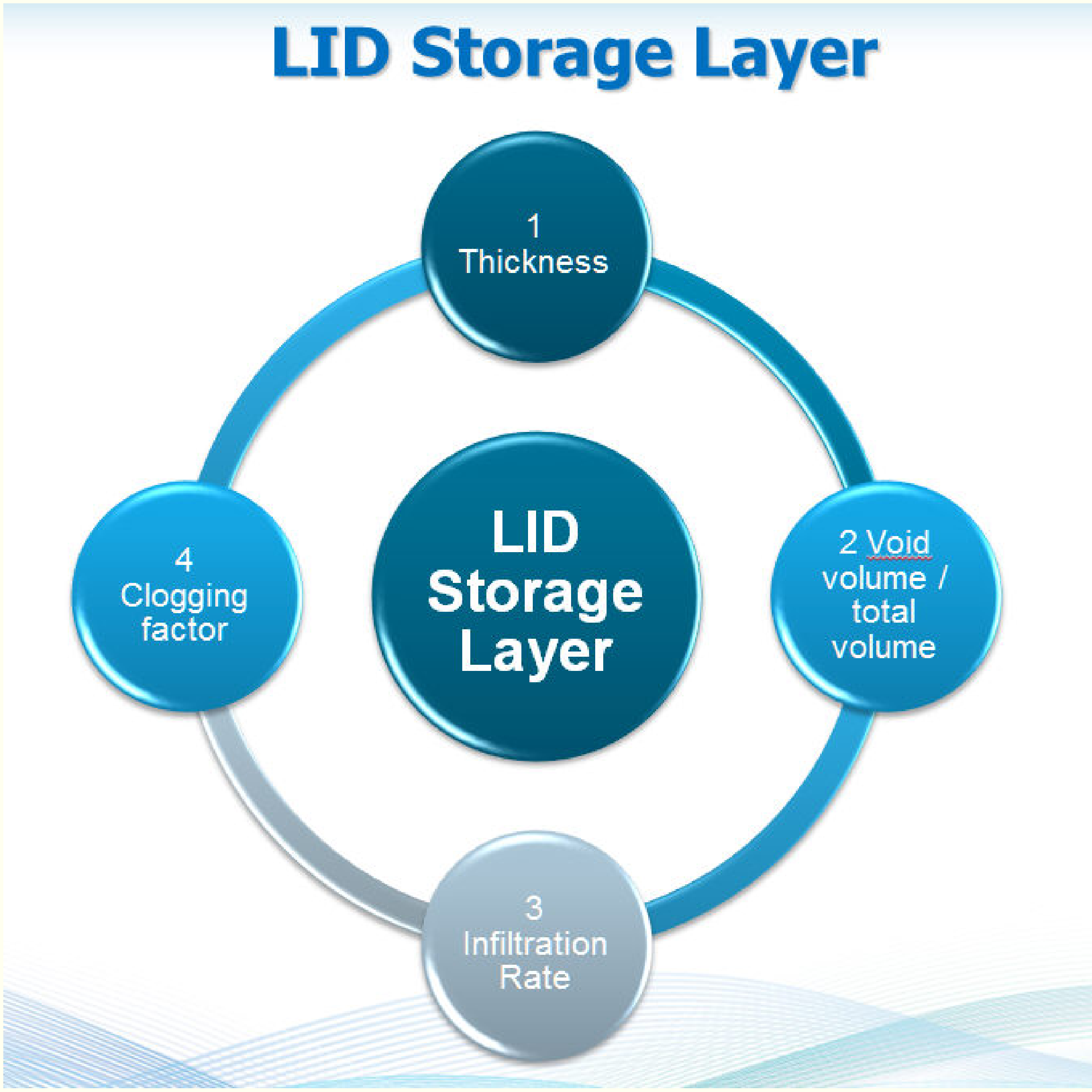


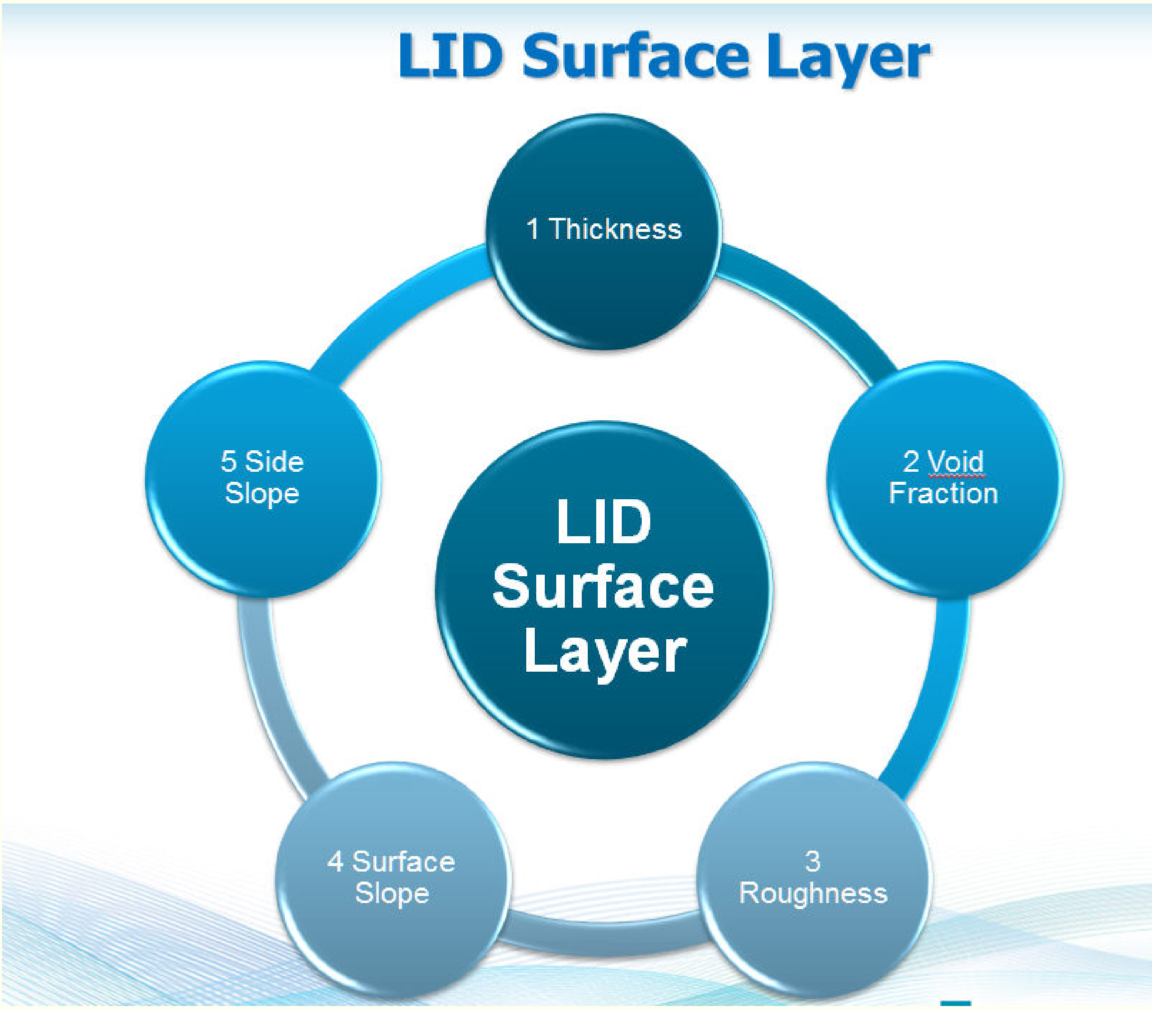

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
PEA GRAVEL
GRAVEL
Descriptions
Infiltration Trench is a type of best management practice (BMP) that is used to manage stormwater runoff, prevent flooding and downstream erosion, and improve water quality in an adjacent river, stream, lake or bay. It is a shallow excavated trench filled with gravel or crushed stone that is designed to infiltrate stormwater though permeable soils into the groundwater aquifer.
OK
Cancel

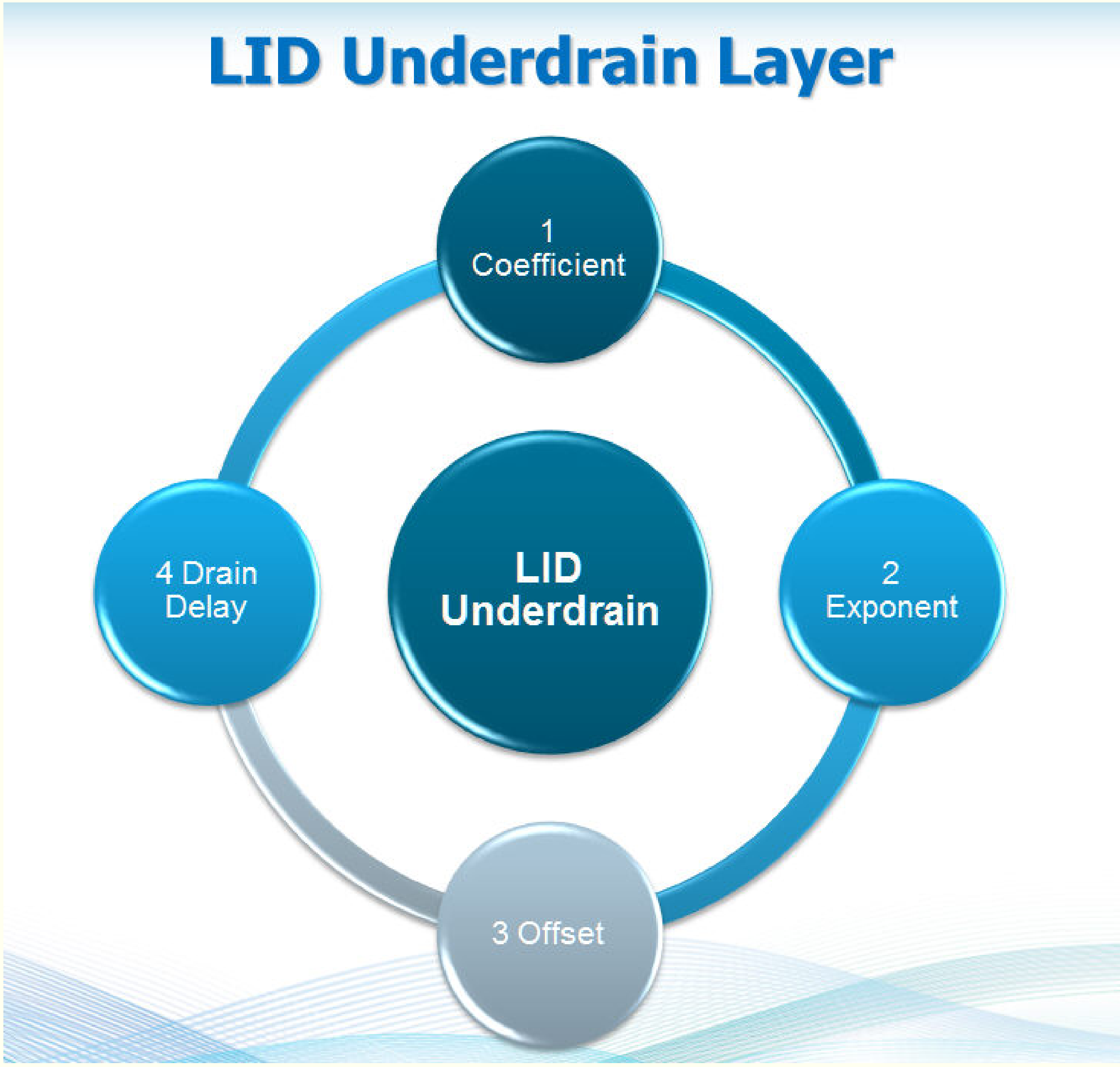

LID Siting Criteria - Infiltration Trench
Please specify siting criteria
Drainage Area (ac) < 5
Slope (%) < 15
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B
Groundwater Water Depth (ft) > 4
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel



LID Infiltration Trench Layers
Surface
LID
Infiltration
Trench
Underdrain
Storage


LID Storage Layer
1
Thickness
2 Void
volume /
total
volume
3
Infiltration
Rate
4
Clogging
factor
LID
Storage
Layer


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer



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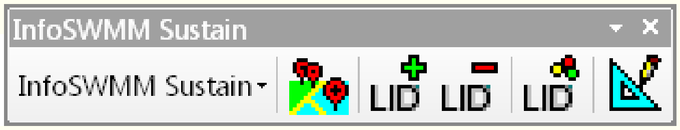
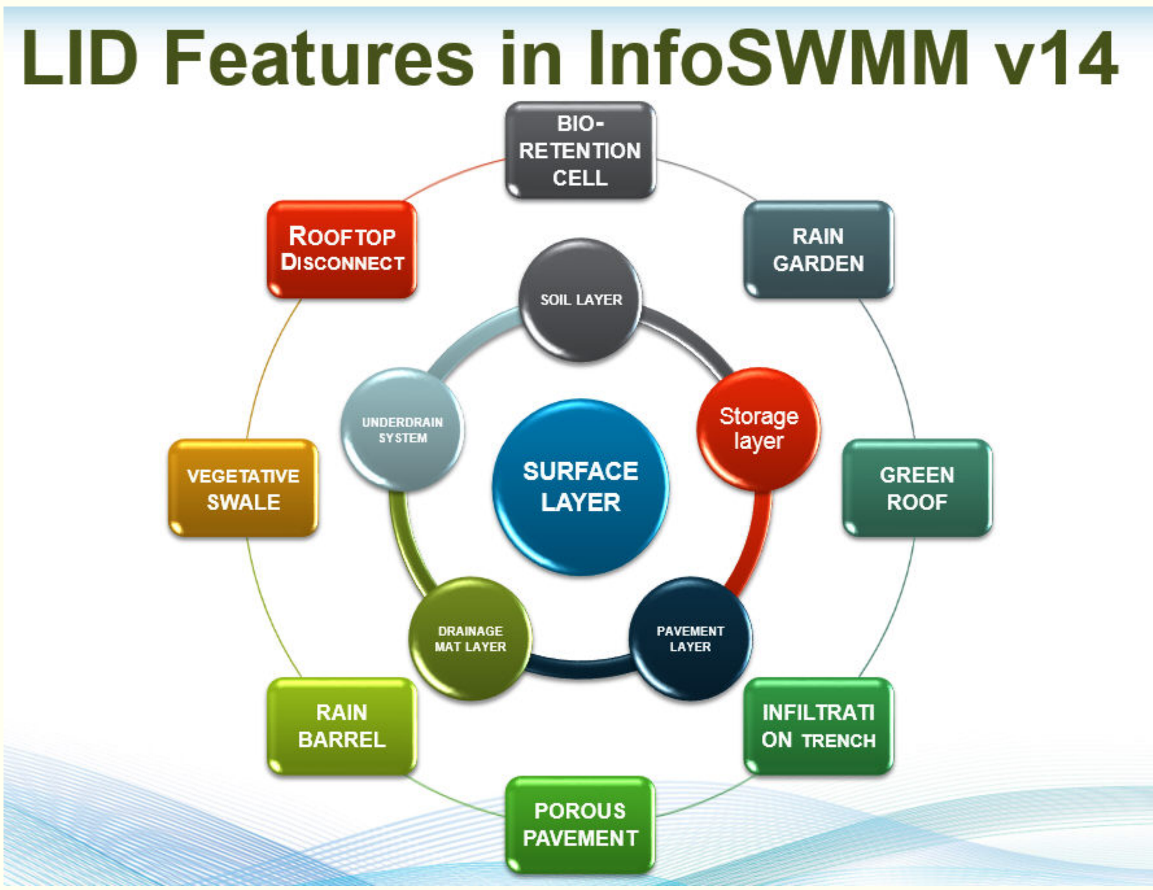
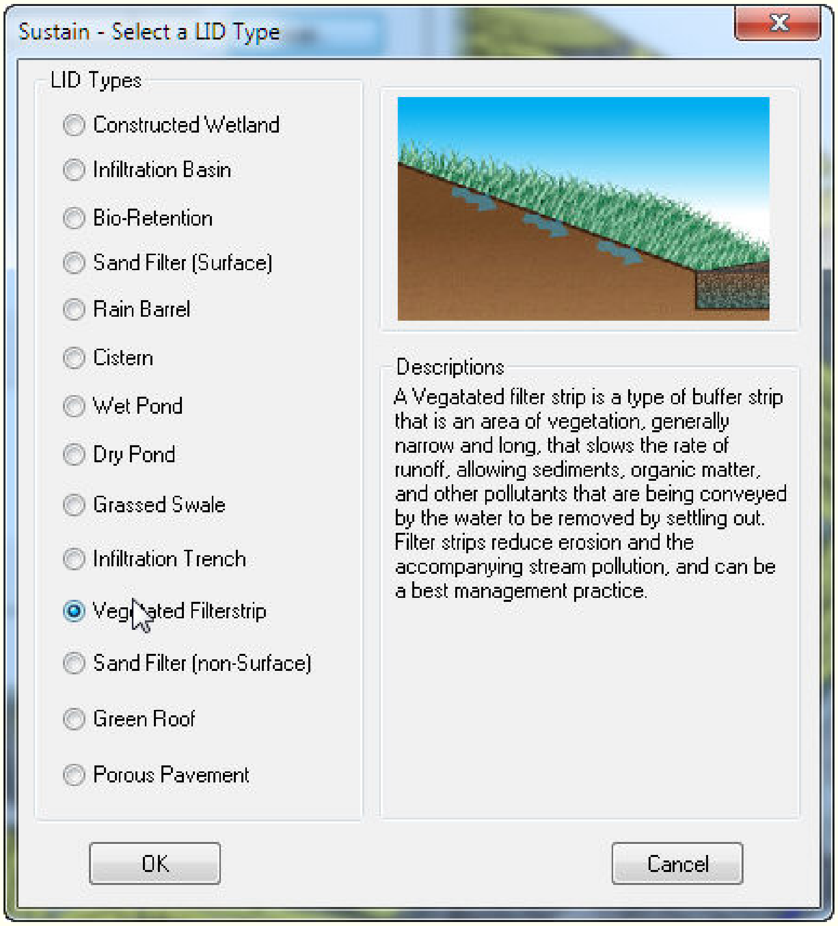

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

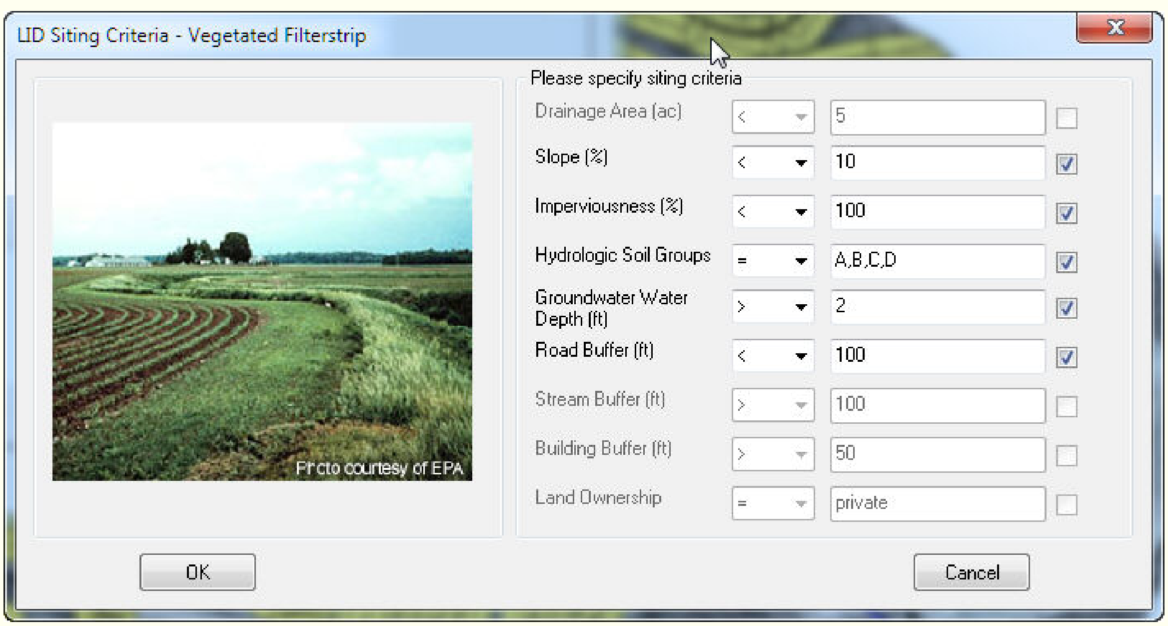
Vegetated Filterstrip

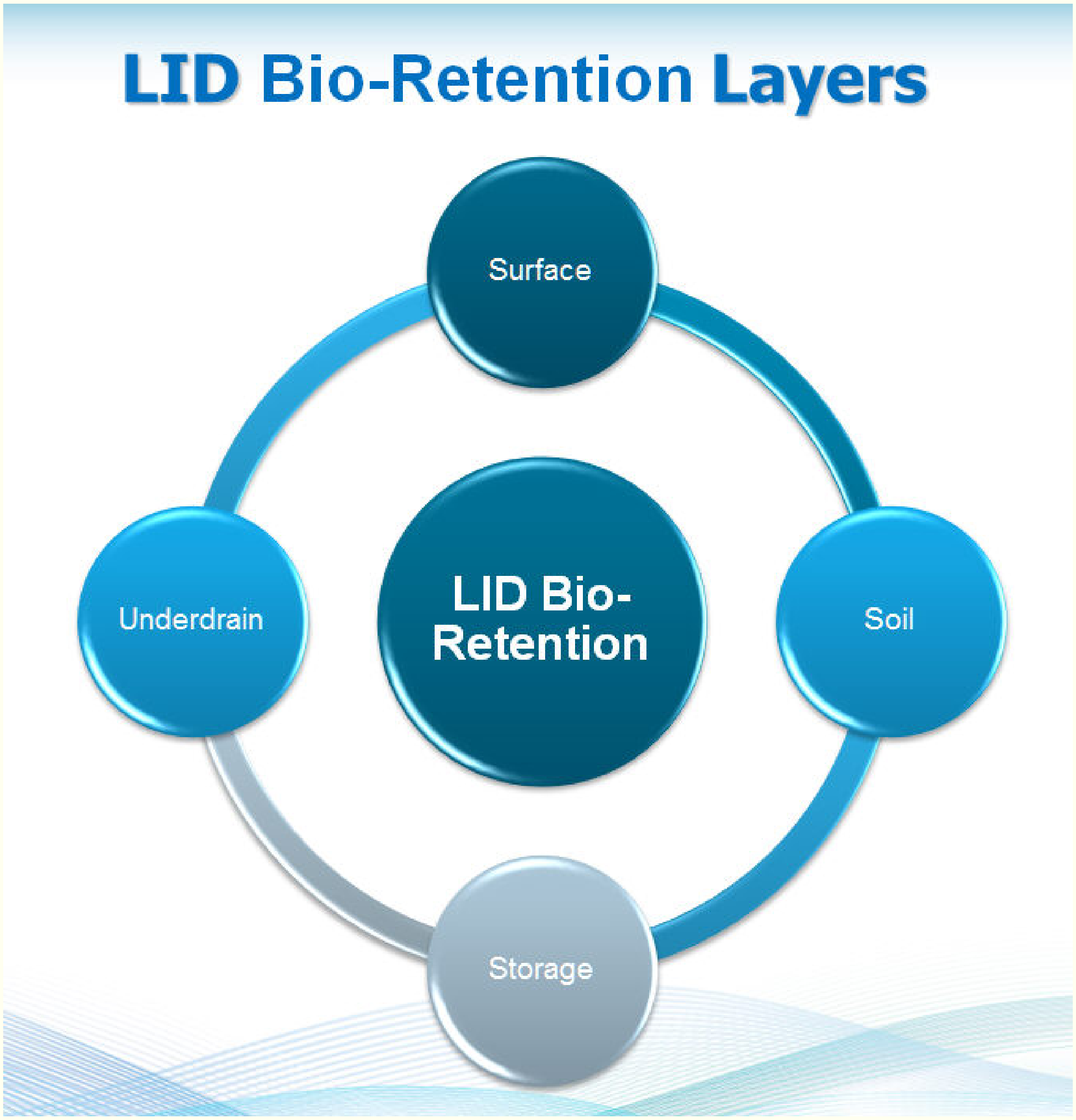
The three steps to selecting a LID Type are:

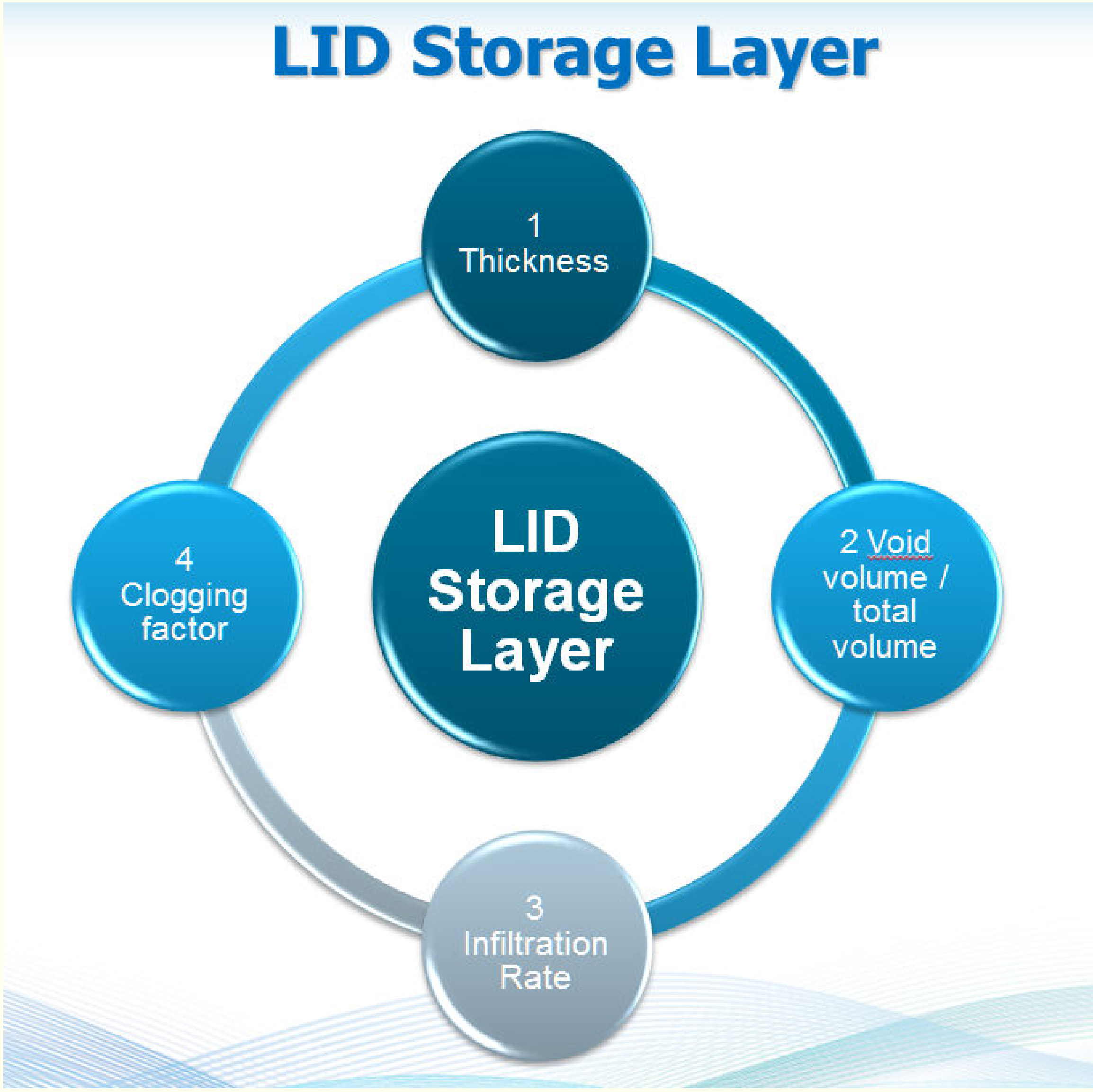
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
  - a. The number of process layers
  - b. The components of each process layer
  - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
  - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

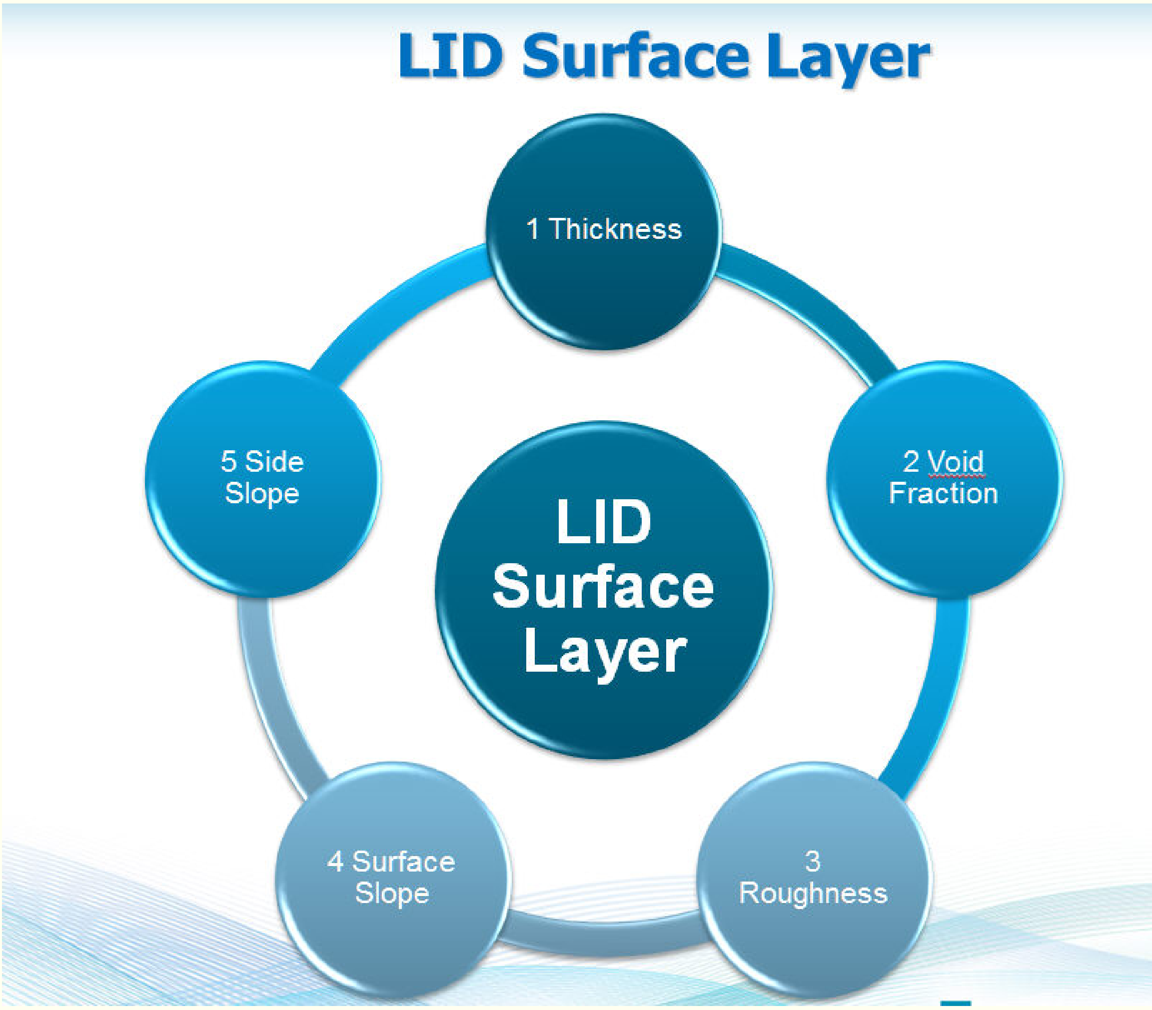


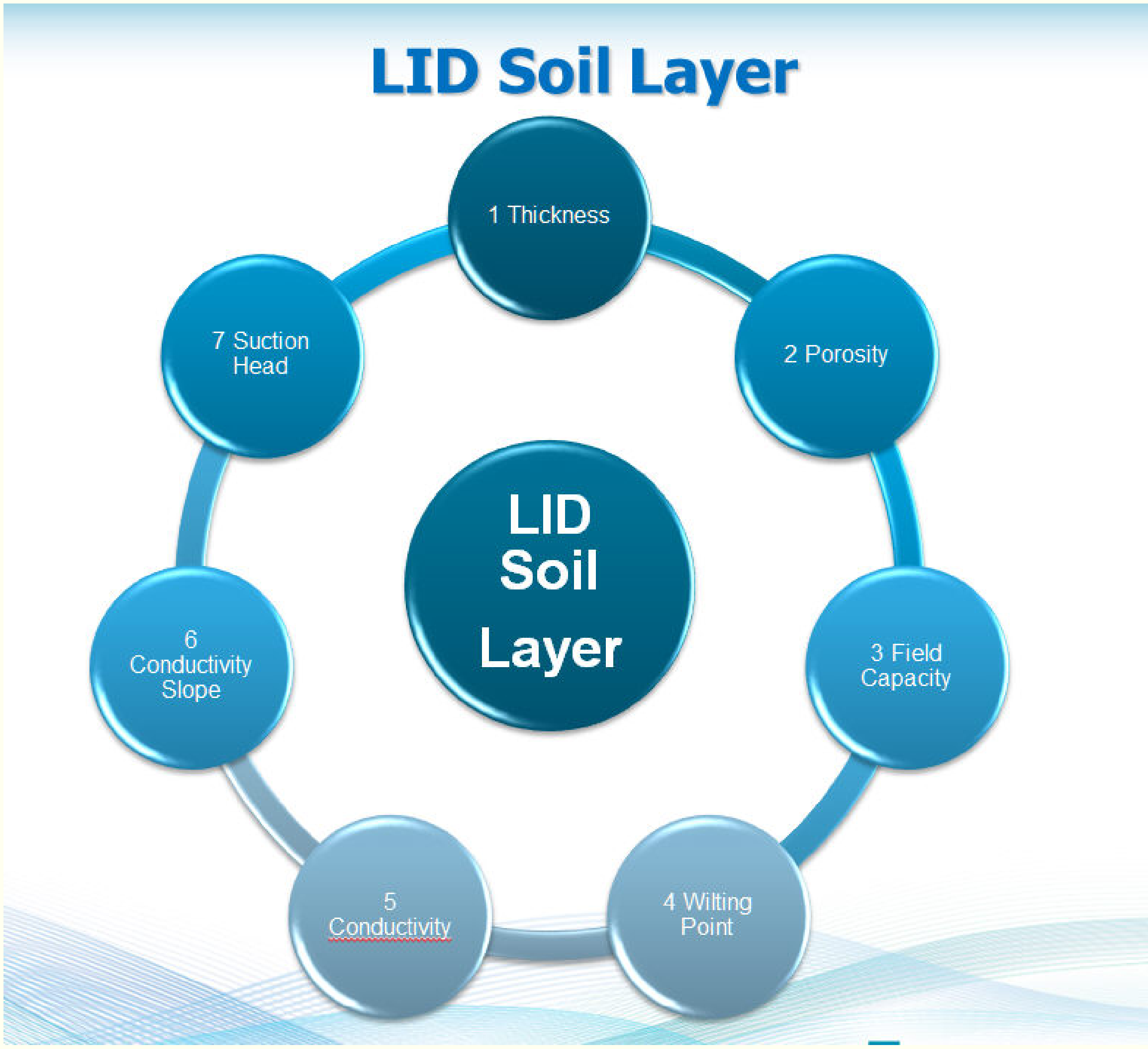

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
Descriptions
A Vegatated filter strip is a type of buffer strip that is an area of vegetation, generally narrow and long, that slows the rate of runoff, allowing sediments, organic matter, and other pollutants that are being conveyed by the water to be removed by settling out. Filter strips reduce erosion and the accompanying stream pollution, and can be a best management practice.
OK
Cancel


LID Siting Criteria - Vegetated Filterstrip
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 5
Slope (%) < 10
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel

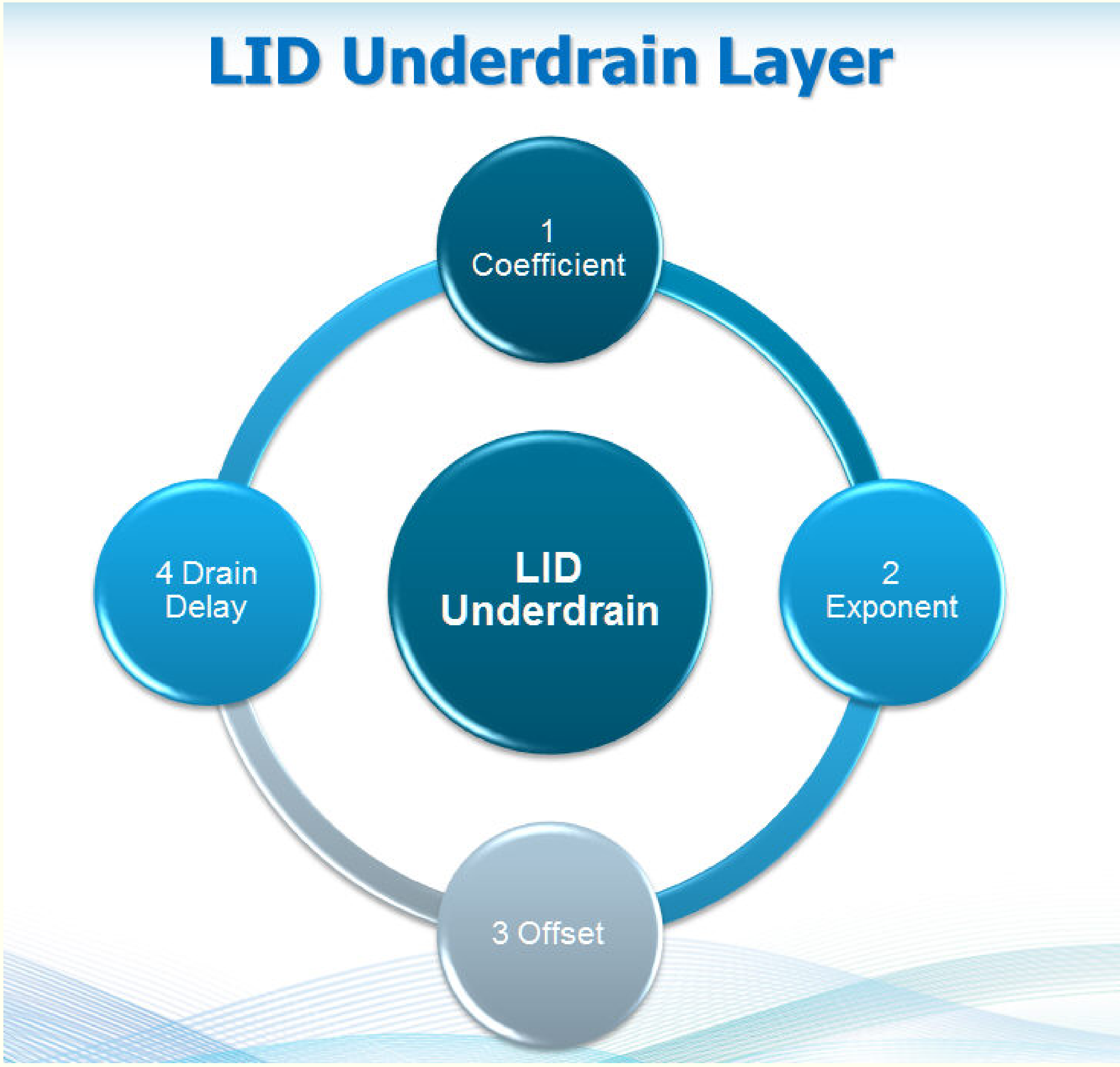

LID Bio-Retention Layers
Surface
Underdrain
LID Bio-Retention
Soil
Storage


LID Storage Layer
1
Thickness
LID
Storage
Layer
2 Void
volume /
total
volume
3
Infiltration
Rate
4
Clogging
factor


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer



LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer



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LID
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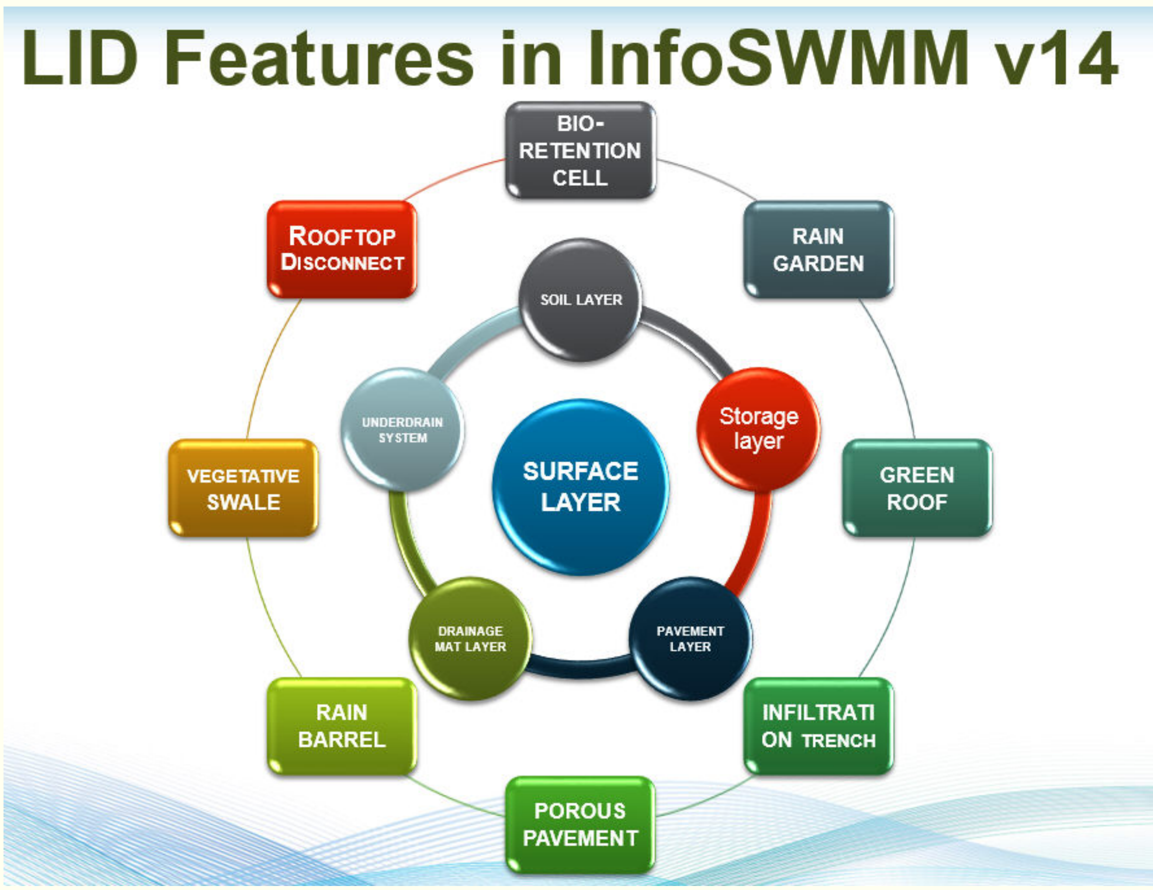
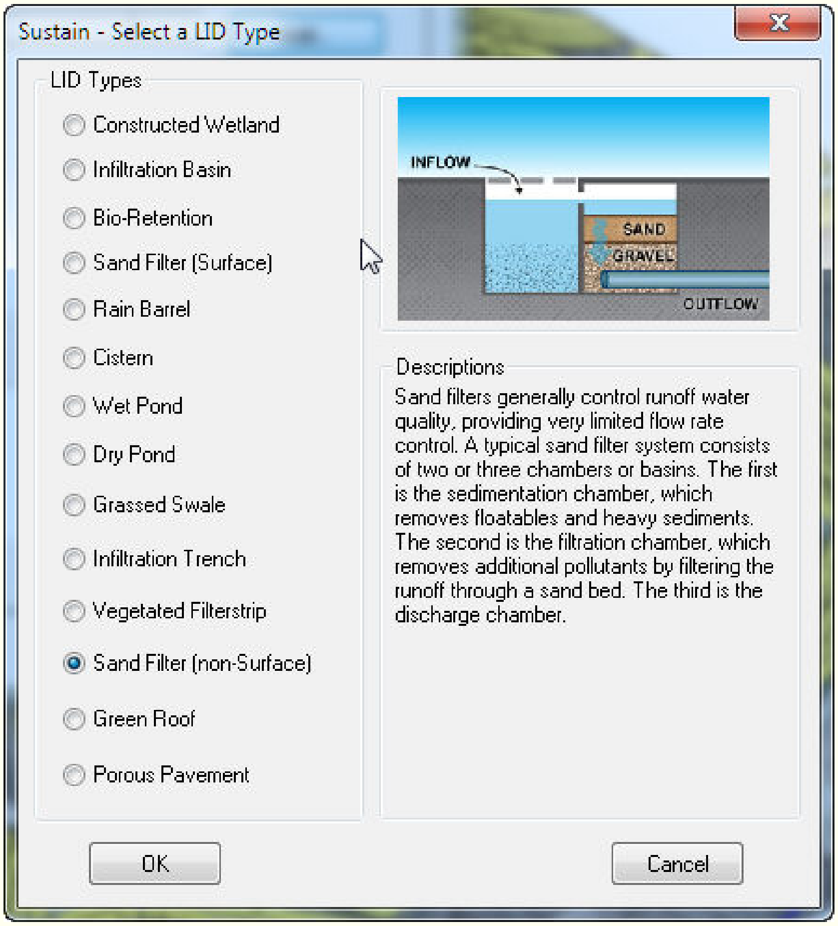
LID

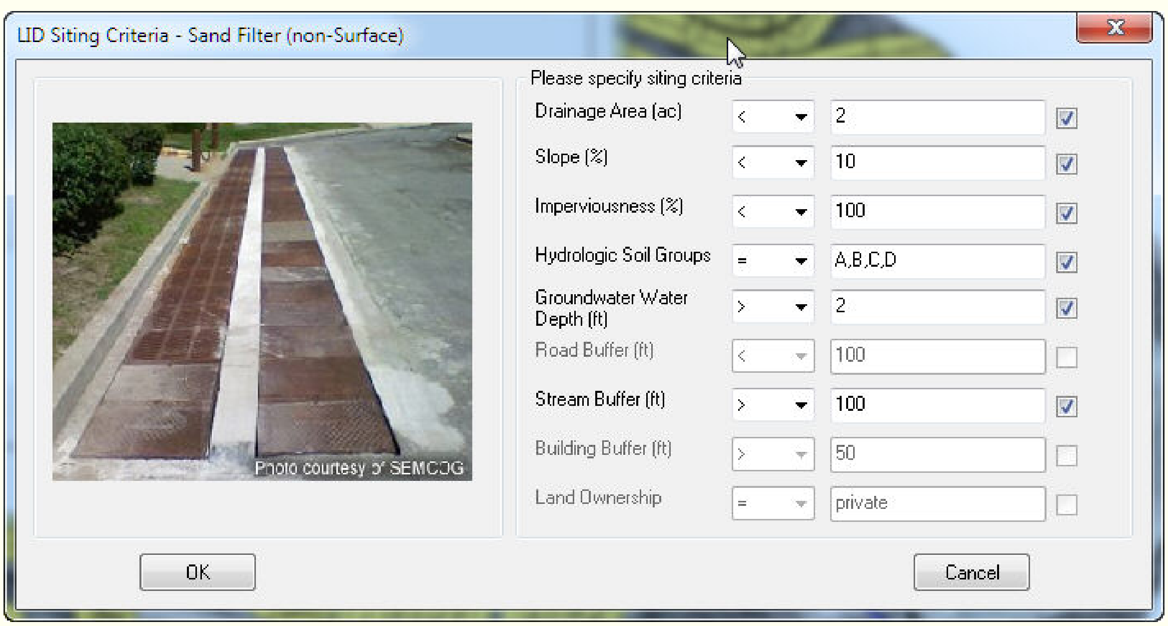
Non Surface Sand Filter

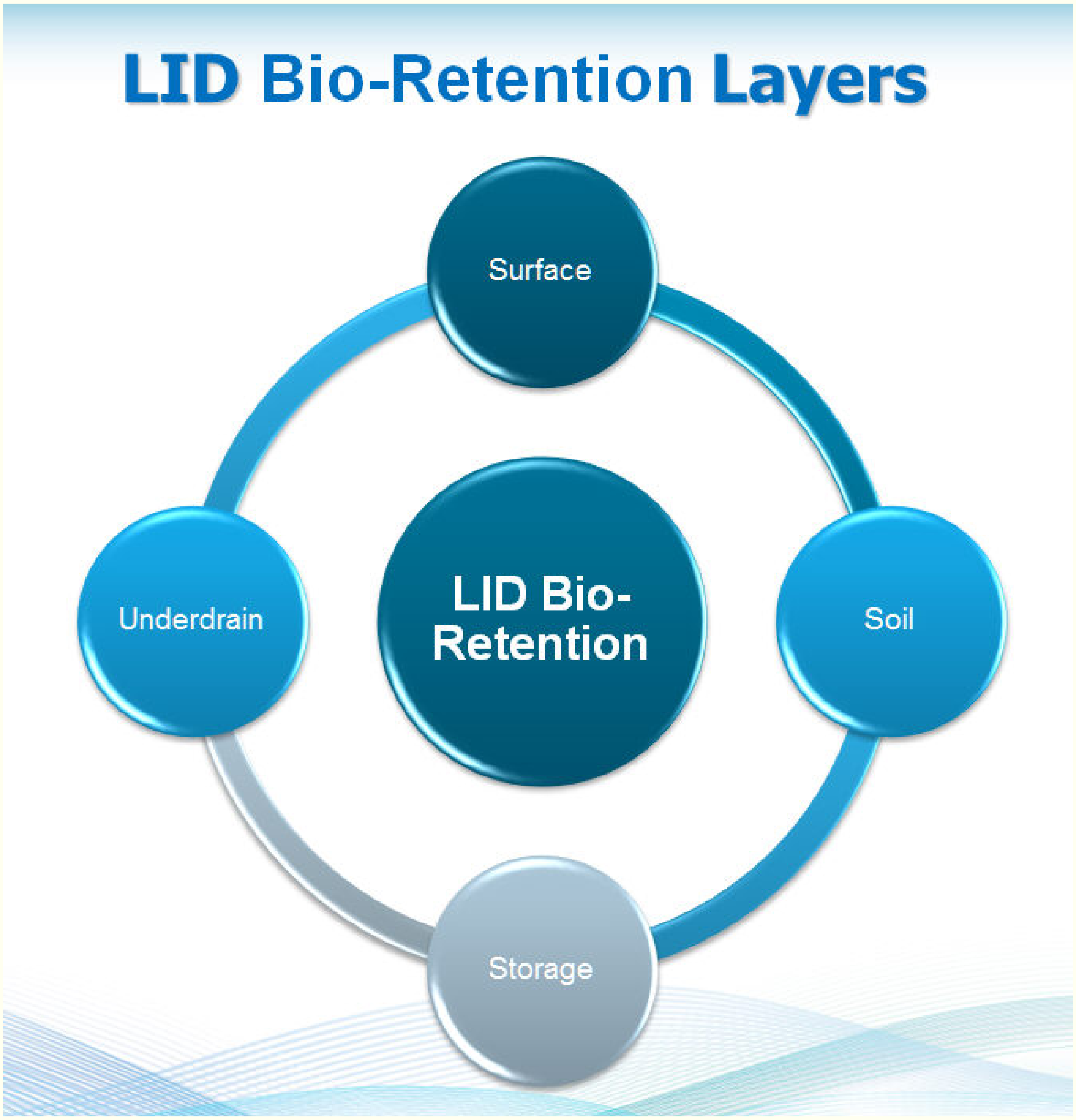
The three steps to selecting a LID Type are:

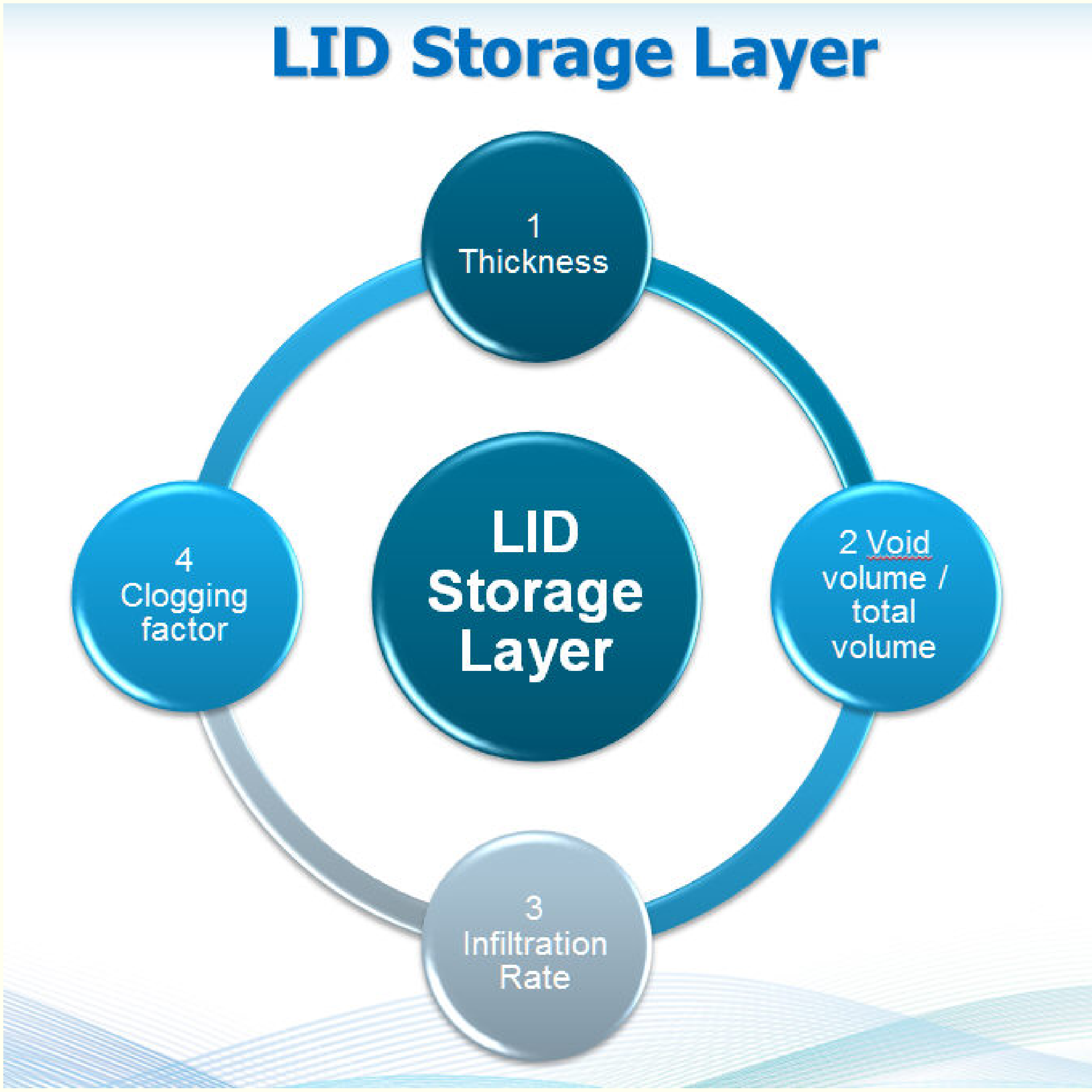
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

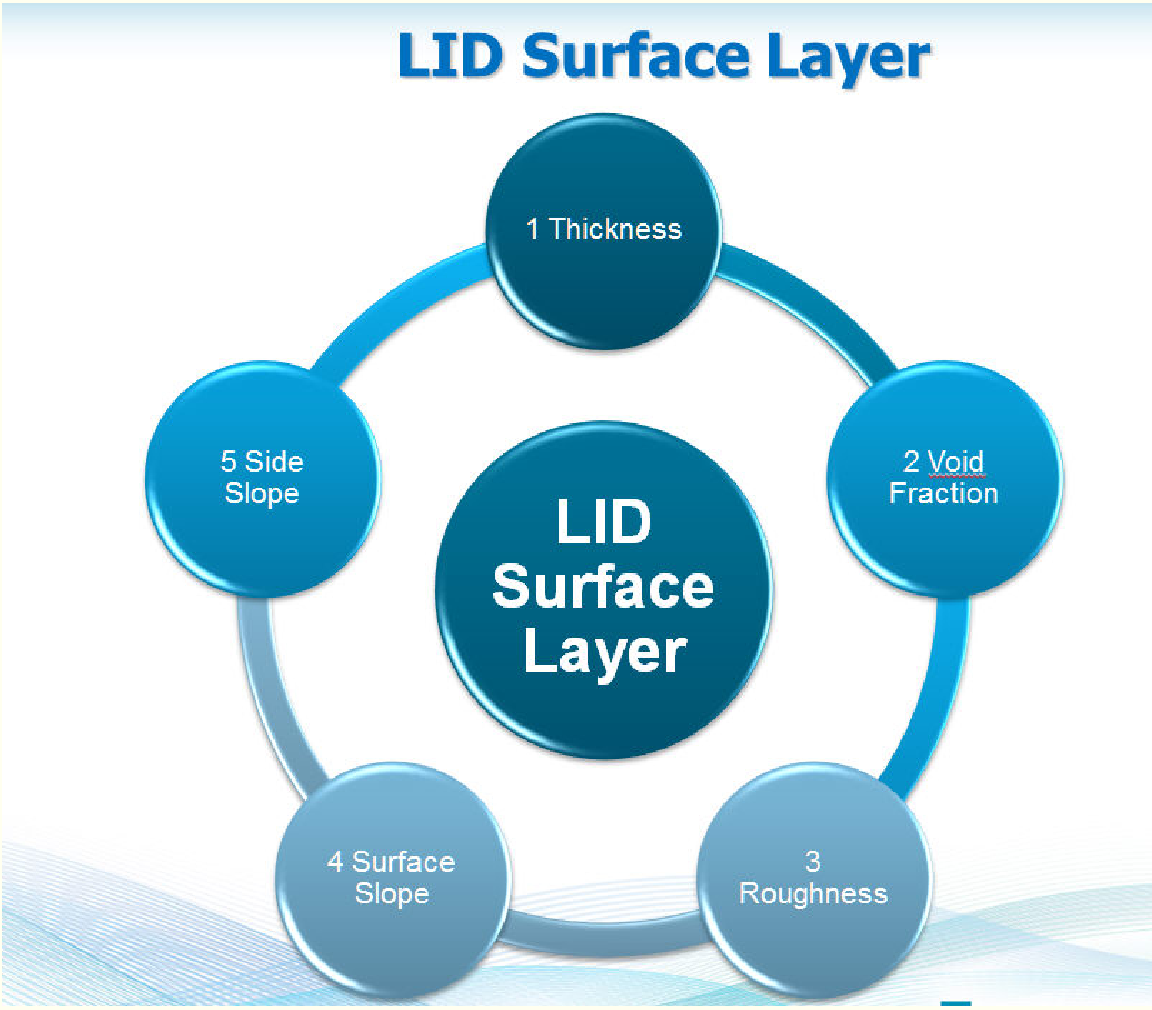


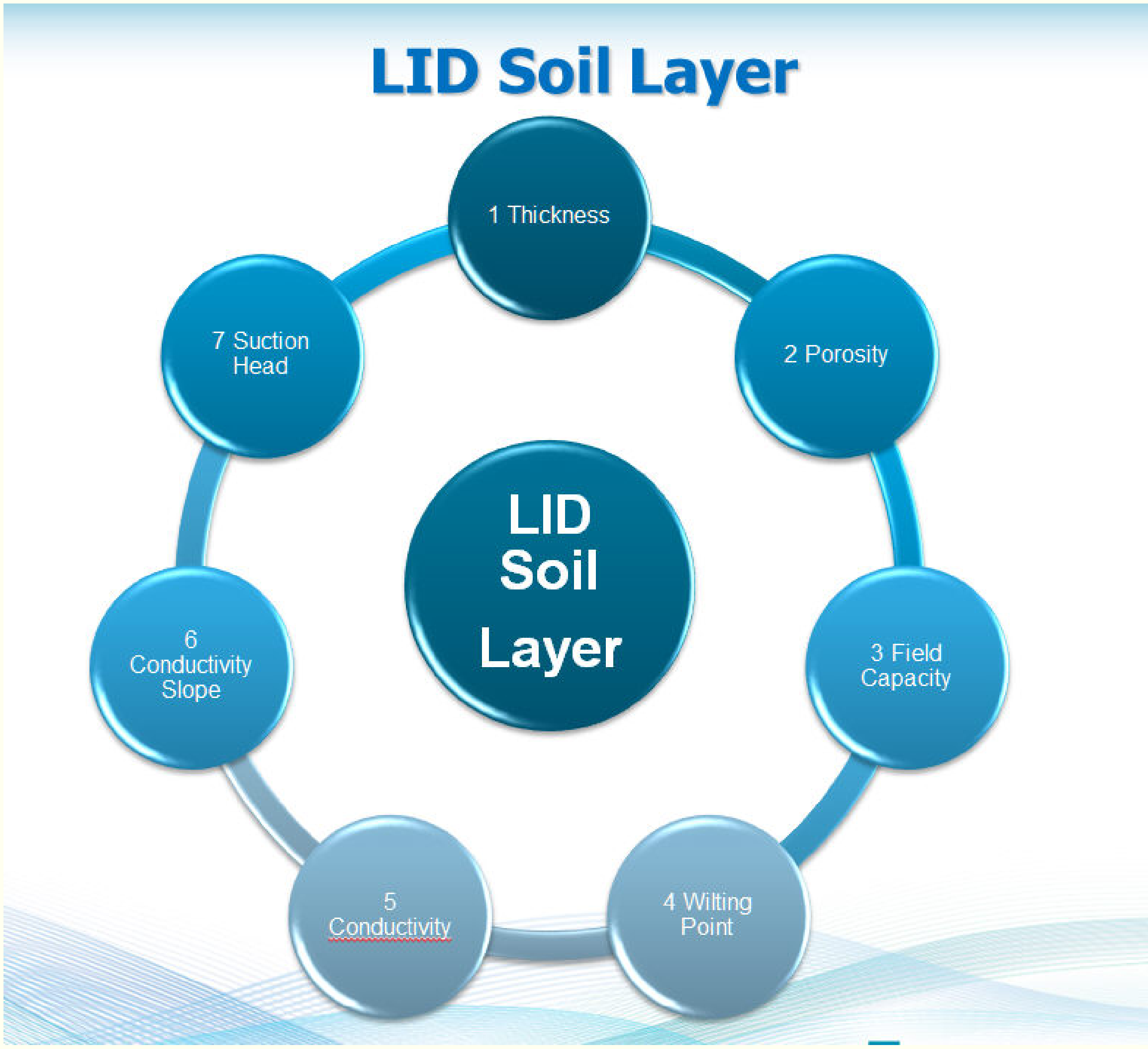

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INFLOW
SAND
GRAVEL
OUTFLOW
Descriptions
Sand filters generally control runoff water quality, providing very limited flow rate control. A typical sand filter system consists of two or three chambers or basins. The first is the sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The third is the discharge chamber.
OK
Cancel

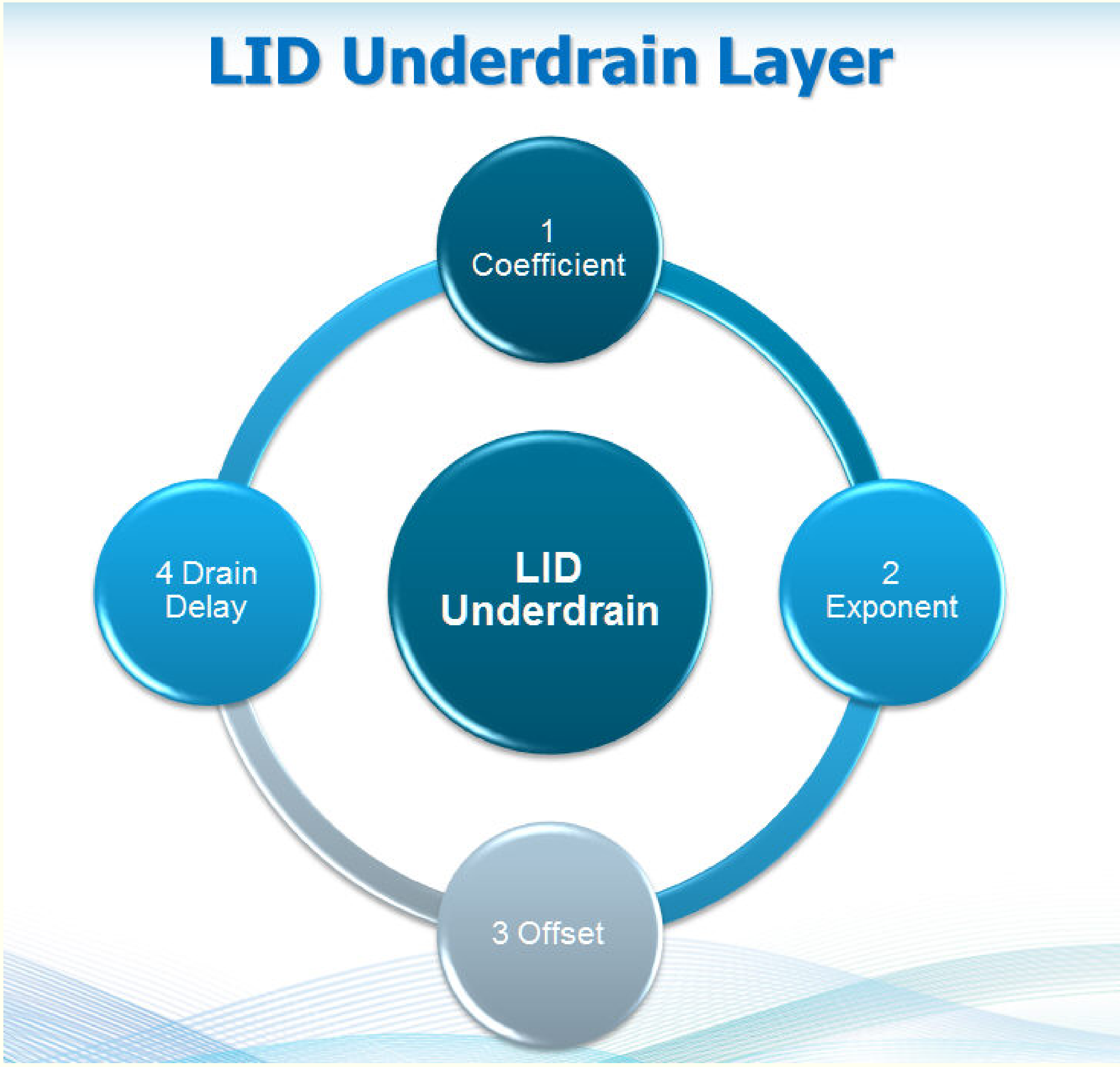

LID Siting Criteria - Sand Filter (non-Surface)
Photo courtesy of SEMCOG
Please specify siting criteria
Drainage Area (ac) < 2
Slope (%) < 10
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel


LID Bio-Retention Layers
Surface
Underdrain
LID Bio-Retention
Soil
Storage


LID Storage Layer
1
Thickness
2 Void
volume /
total
volume
3
Infiltration
Rate
4
Clogging
factor
LID
Storage
Layer


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer



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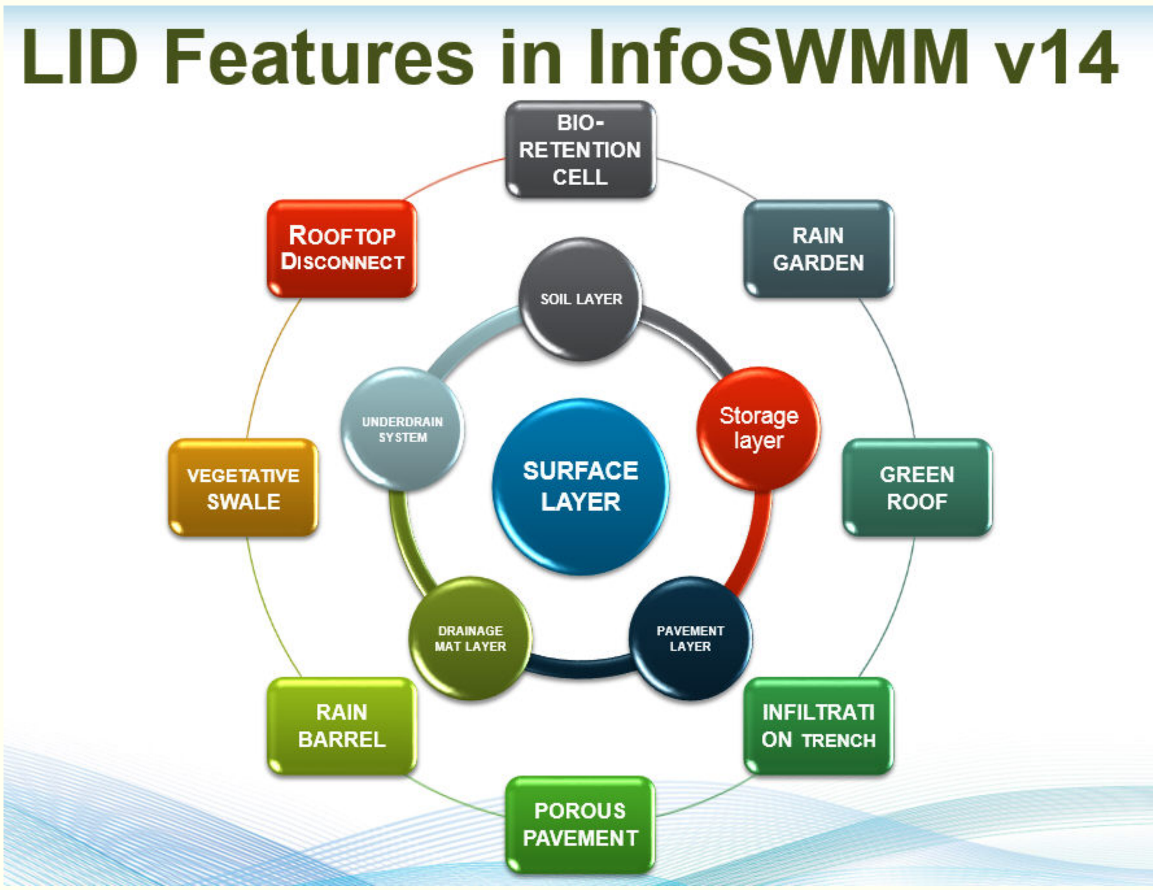
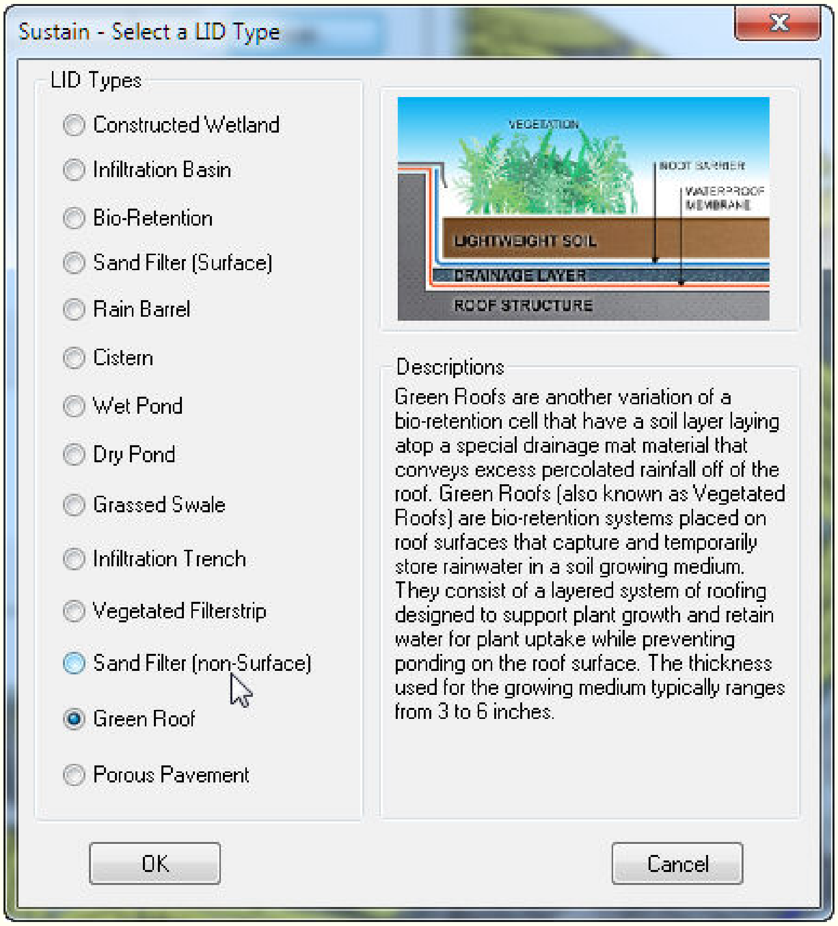
LID

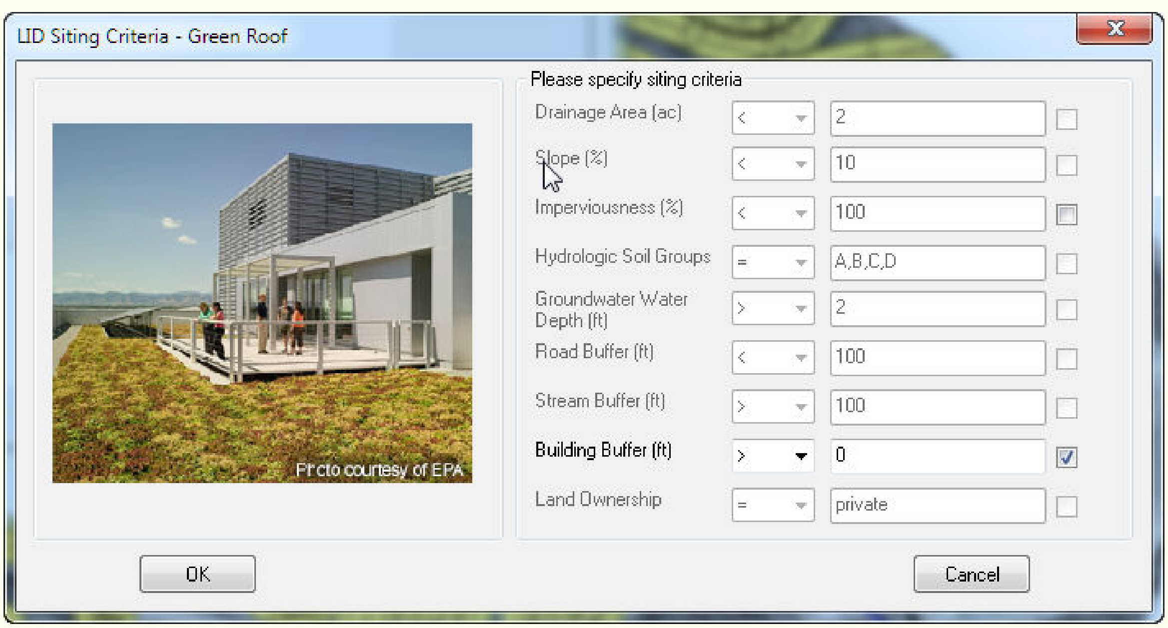
Green Roof

The three steps to selecting a LID Type are:

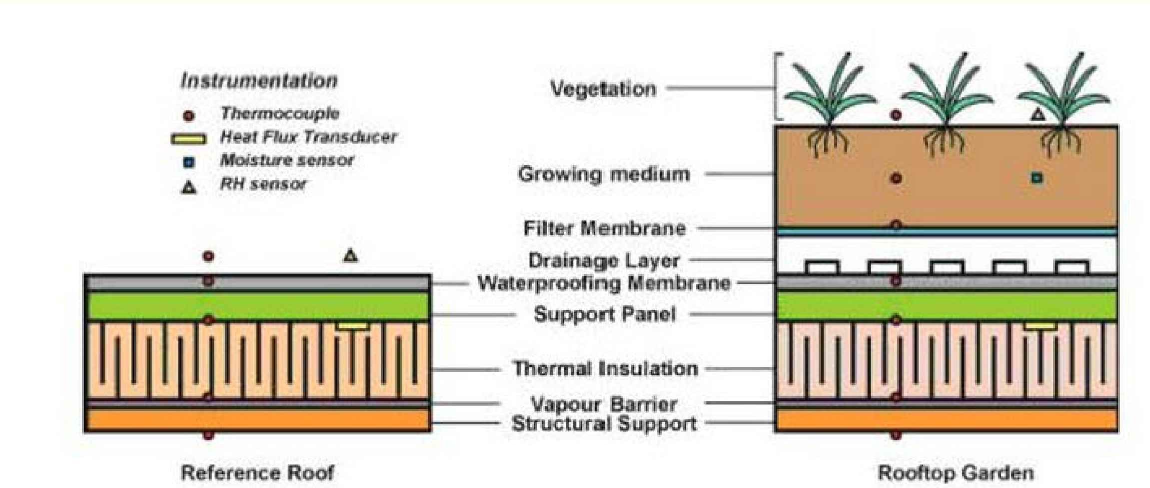
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

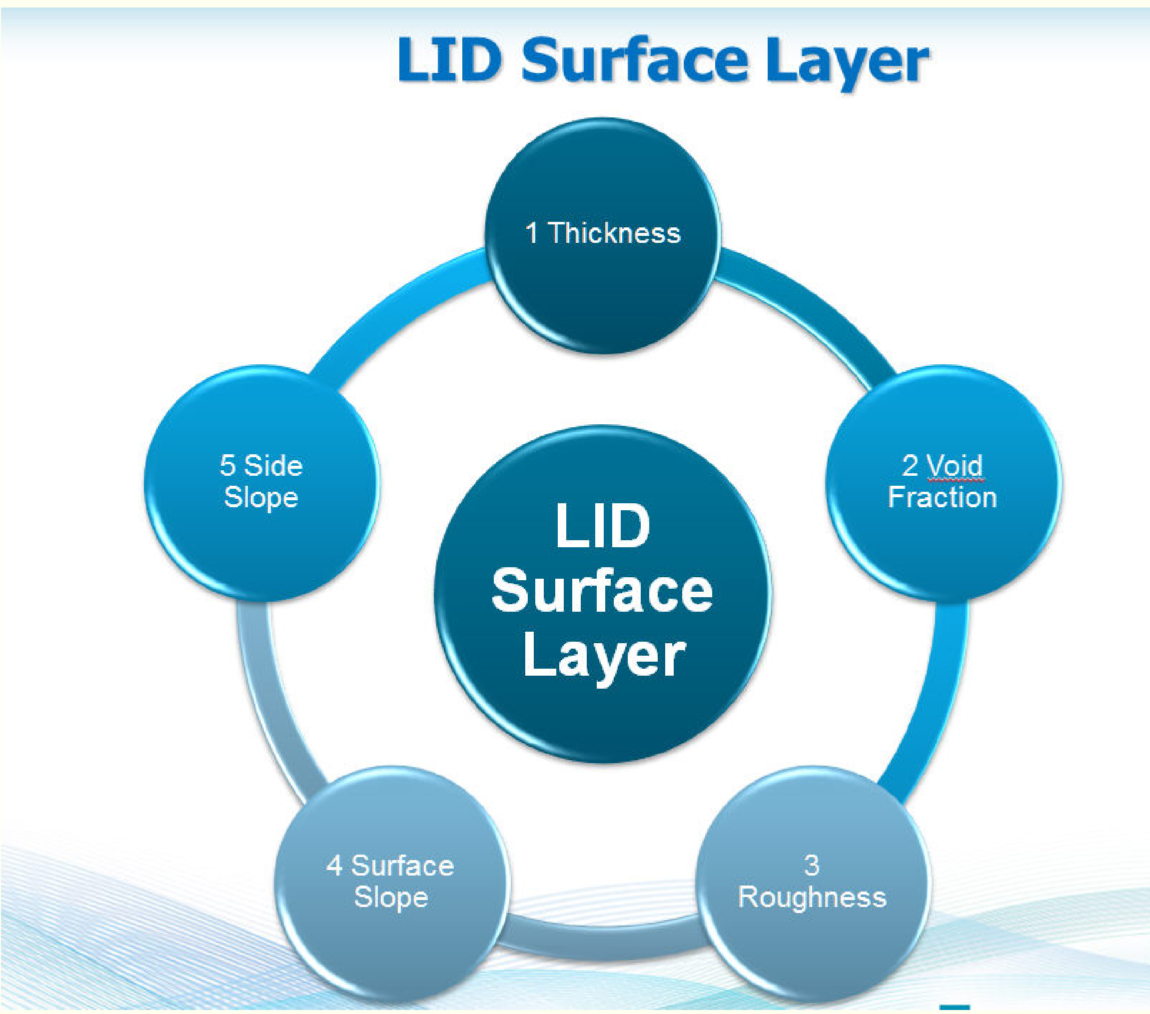


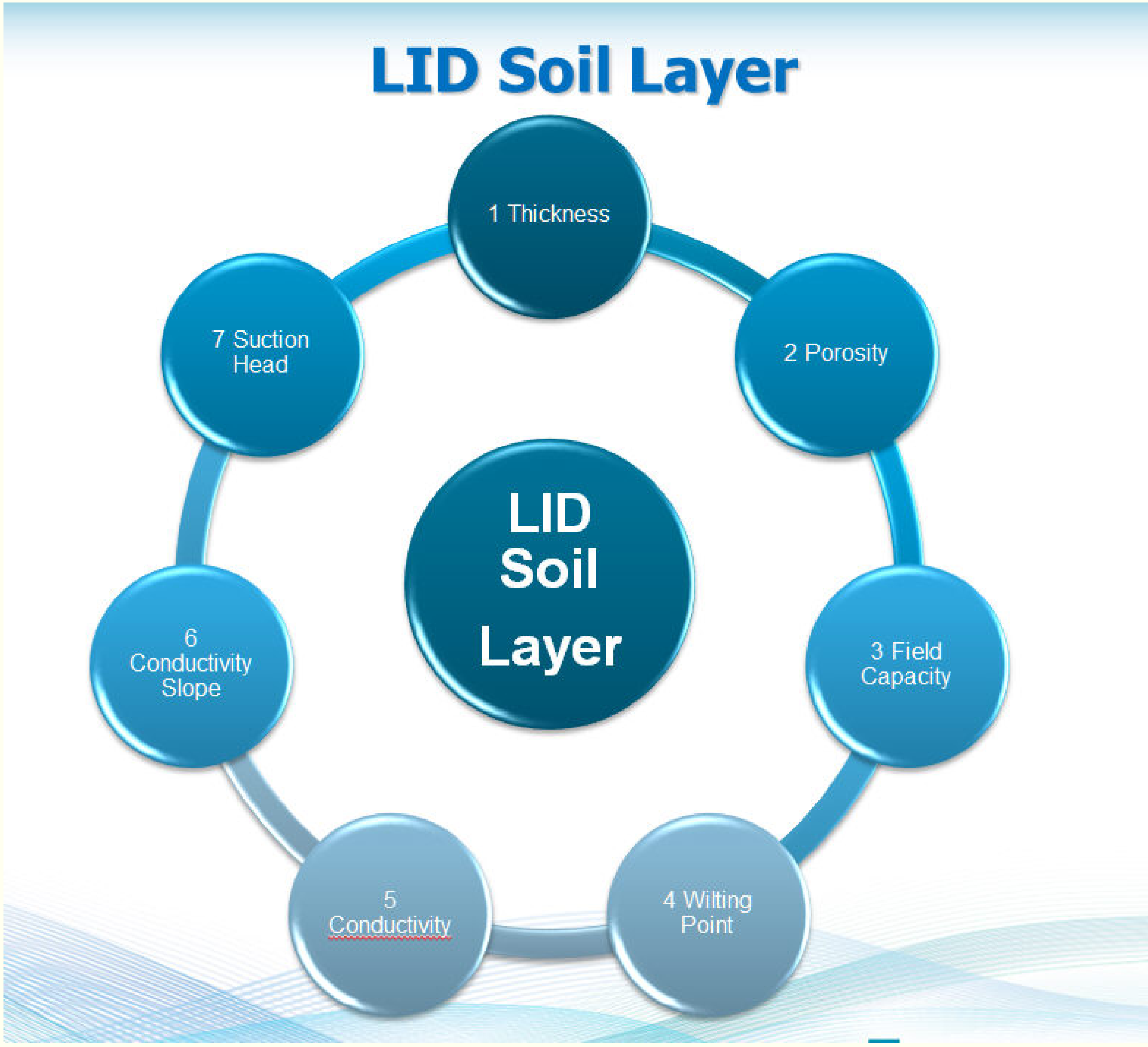

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
VEGETATION
ROOT BARRIER
WATERPROOF MEMBRANE
LIGHTWEIGHT SOIL
DRAINAGE LAYER
ROOF STRUCTURE
Descriptions
Green Roofs are another variation of a bio-retention cell that have a soil layer laying atop a special drainage mat material that conveys excess percolated rainfall off of the roof. Green Roofs (also known as Vegetated Roofs) are bio-retention systems placed on roof surfaces that capture and temporarily store rainwater in a soil growing medium. They consist of a layered system of roofing designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The thickness used for the growing medium typically ranges from 3 to 6 inches.
OK
Cancel

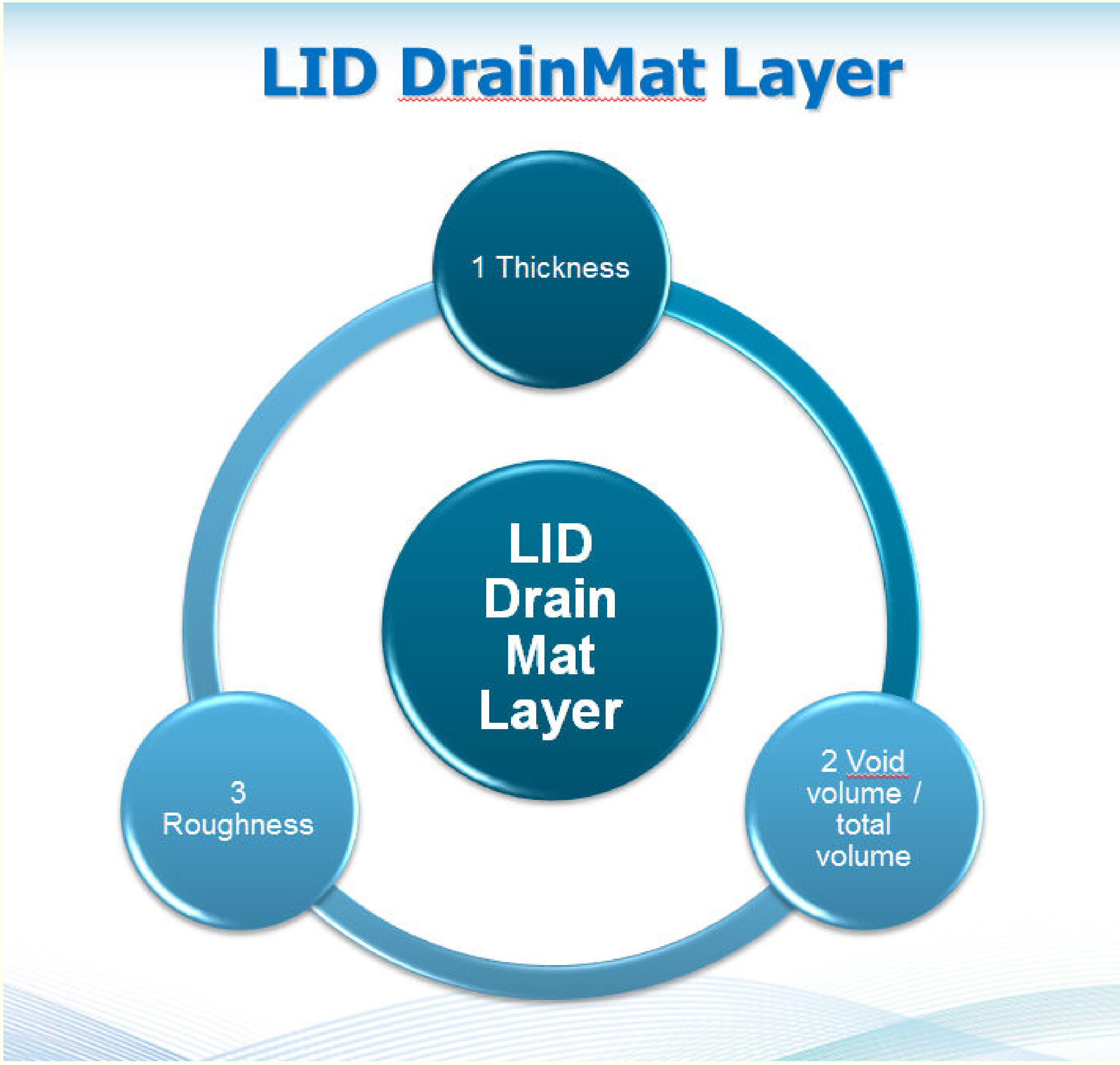

LID Siting Criteria - Green Roof
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 2
Slope (%) < 10
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 0
Land Ownership = private
OK
Cancel


LID Green Roof Layers
Surface
LID Green Roof
Drainage Mat
Soil


Instrumentation
Thermocouple
Heat Flux Transducer
Moisture sensor
RH sensor
Vegetation
Growing medium
Filter Membrane
Drainage Layer
Waterproofing Membrane
Support Panel
Thermal Insulation
Vapour Barrier
Structural Support
Reference Roof
Rooftop Garden


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Soil Layer
1 Thickness
2 Porosity
3 Field Capacity
4 Wilting Point
5 Conductivity
6 Conductivity Slope
7 Suction Head
LID Soil Layer



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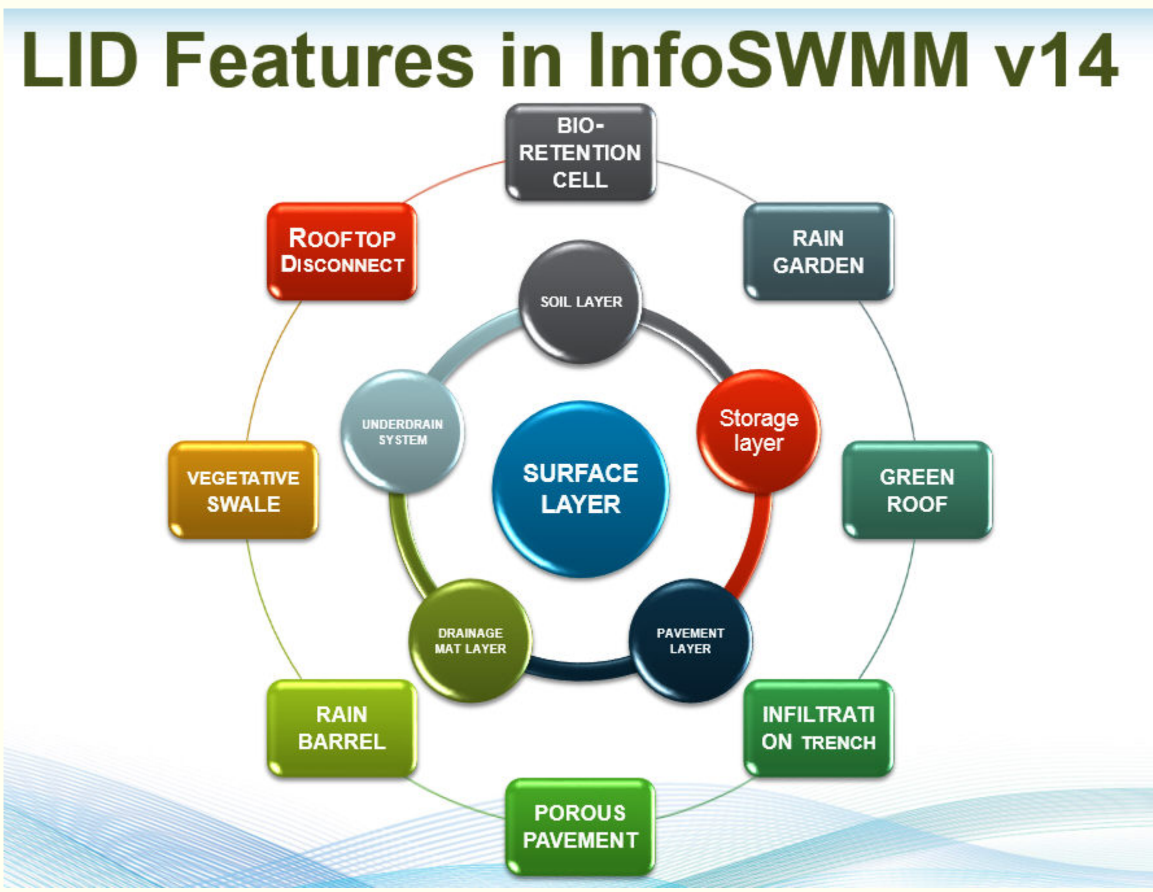
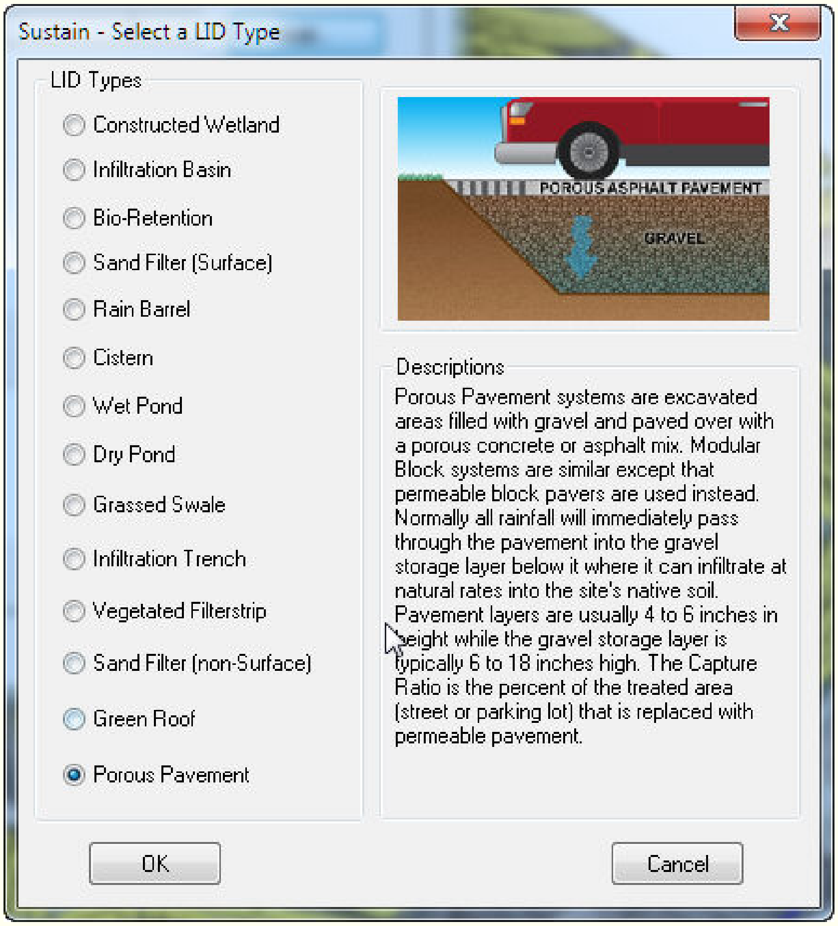
LID

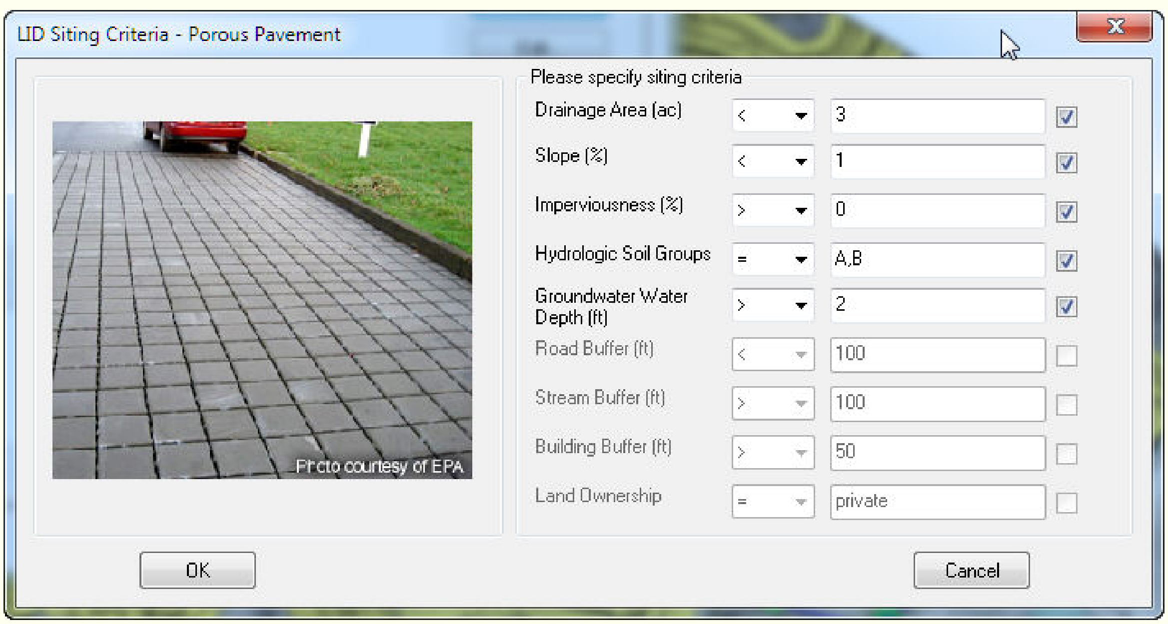
Porous Pavement

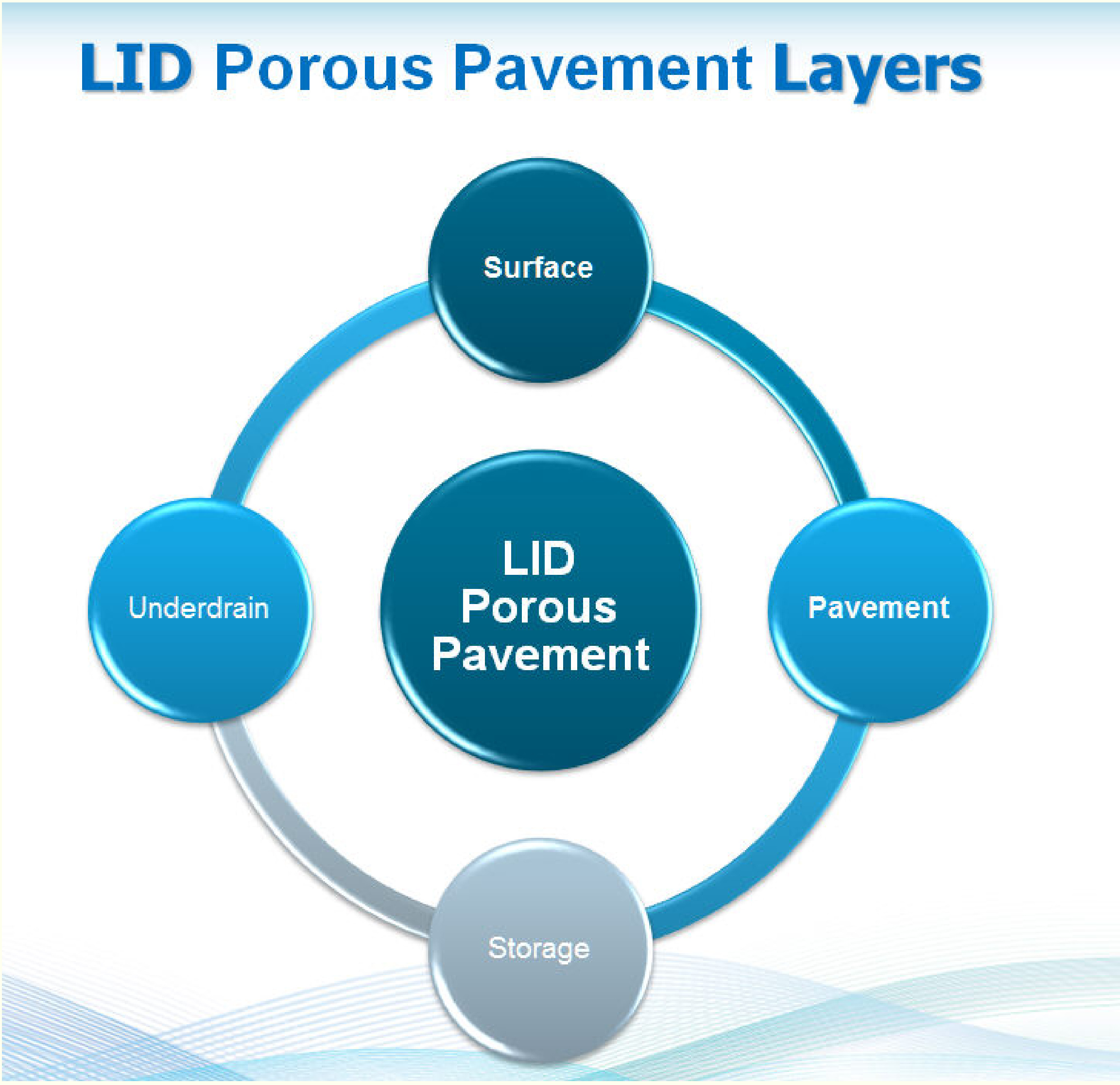
The three steps to selecting a LID Type are:

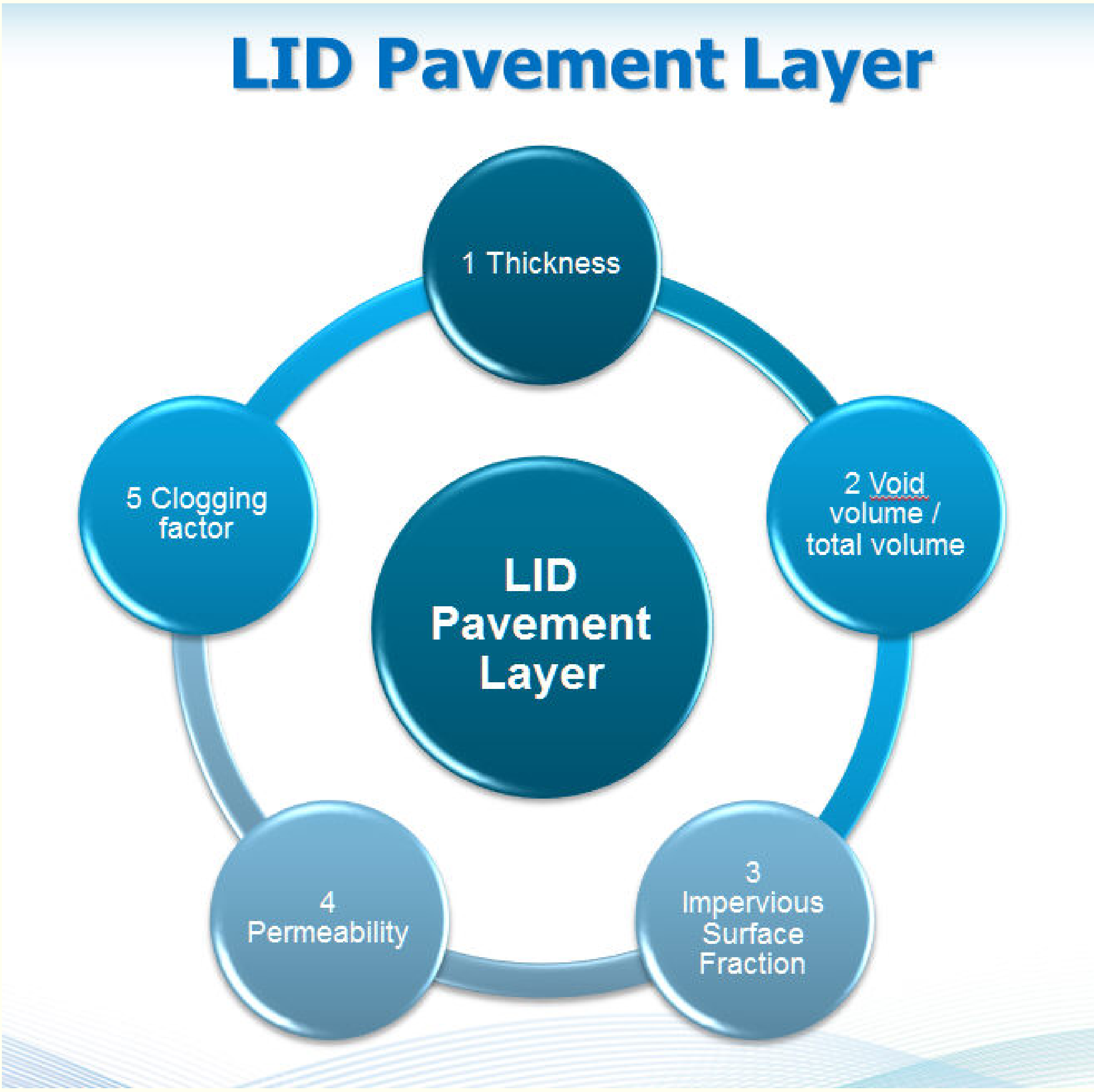
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration

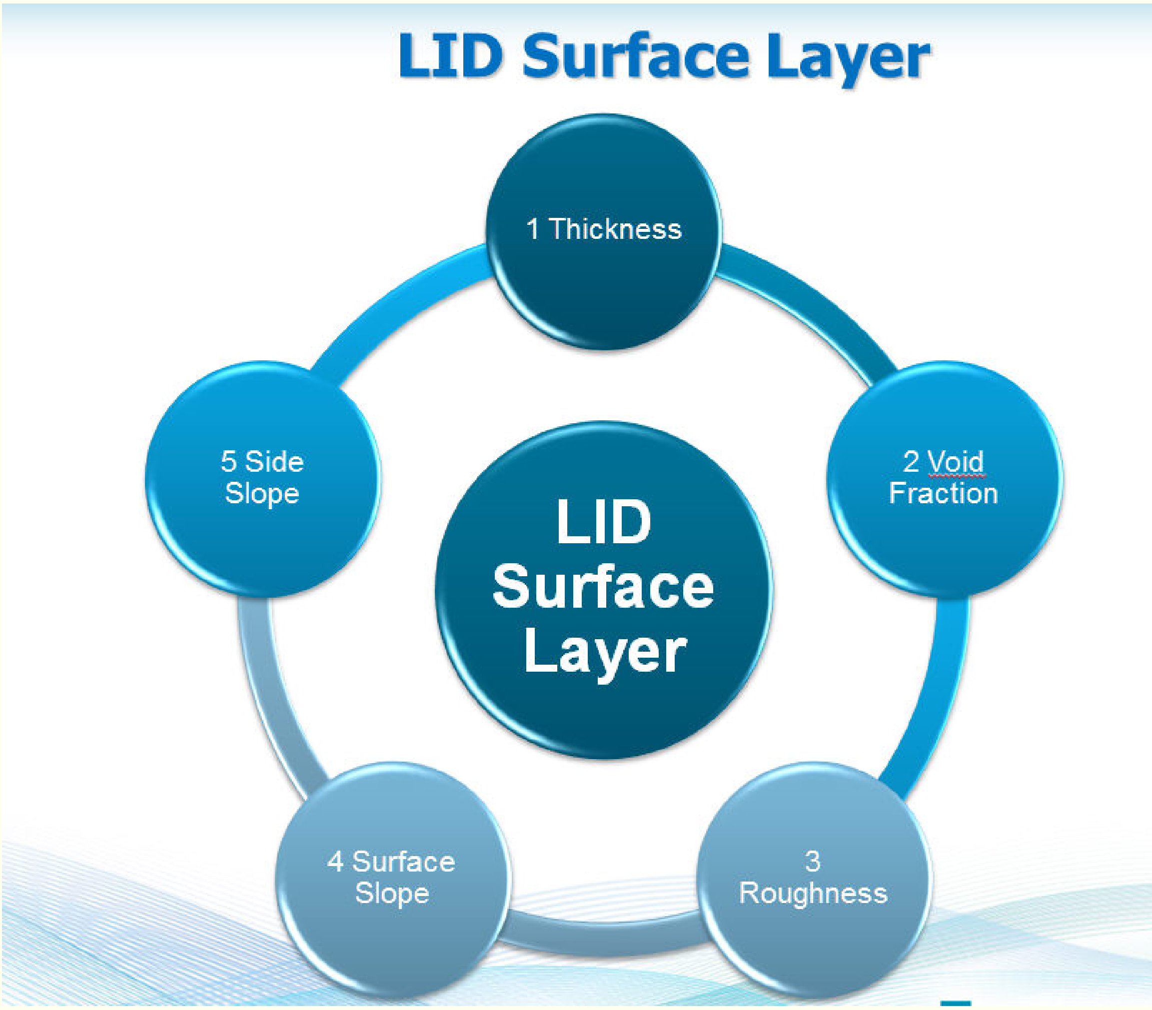


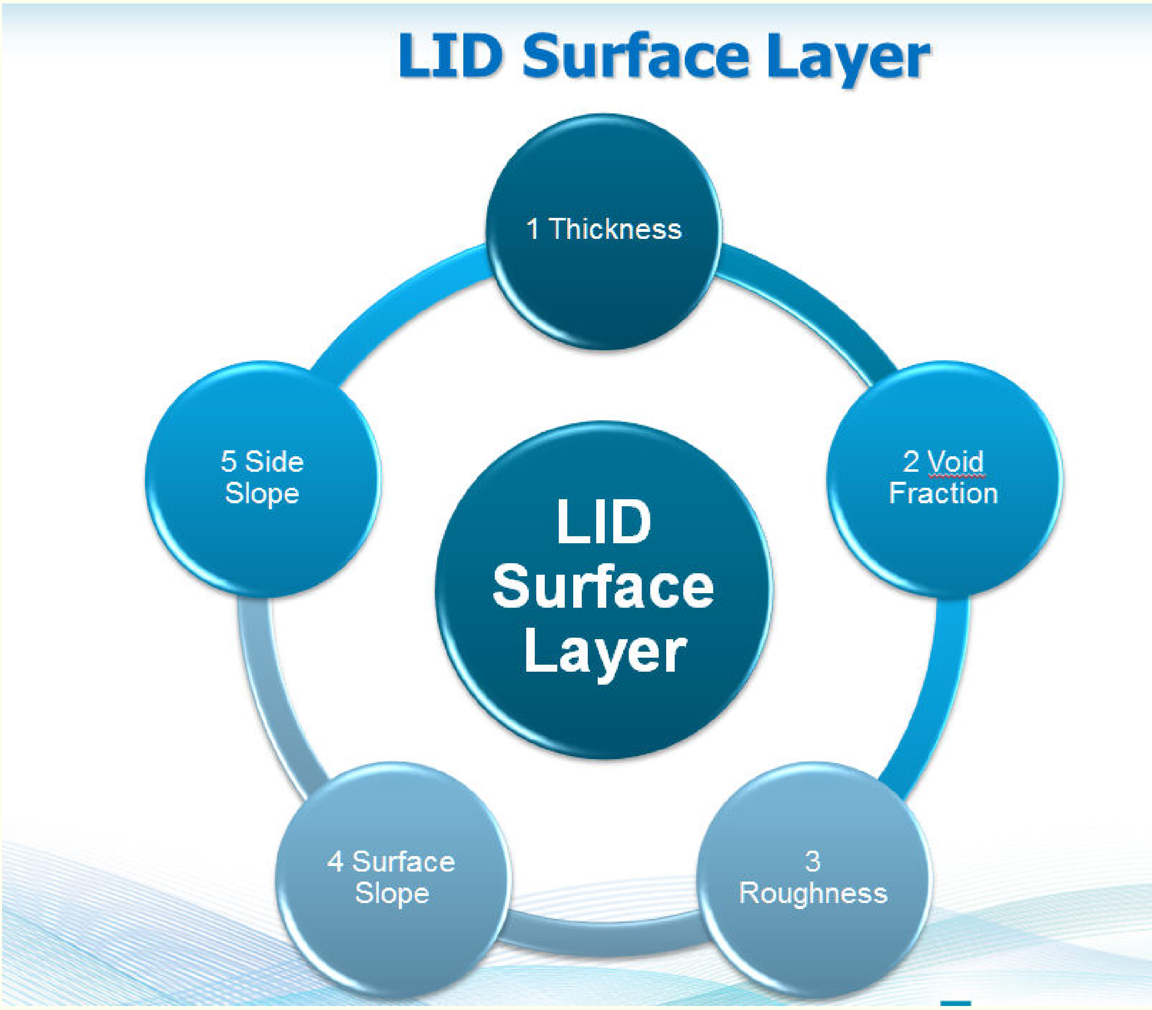

Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
POROUS ASPHALT PAVEMENT
GRAVEL
Descriptions
Porous Pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix. Modular Block systems are similar except that permeable block pavers are used instead. Normally all rainfall will immediately pass through the pavement into the gravel storage layer below it where it can infiltrate at natural rates into the site's native soil. Pavement layers are usually 4 to 6 inches in height while the gravel storage layer is typically 6 to 18 inches high. The Capture Ratio is the percent of the treated area (street or parking lot) that is replaced with permeable pavement.
OK
Cancel

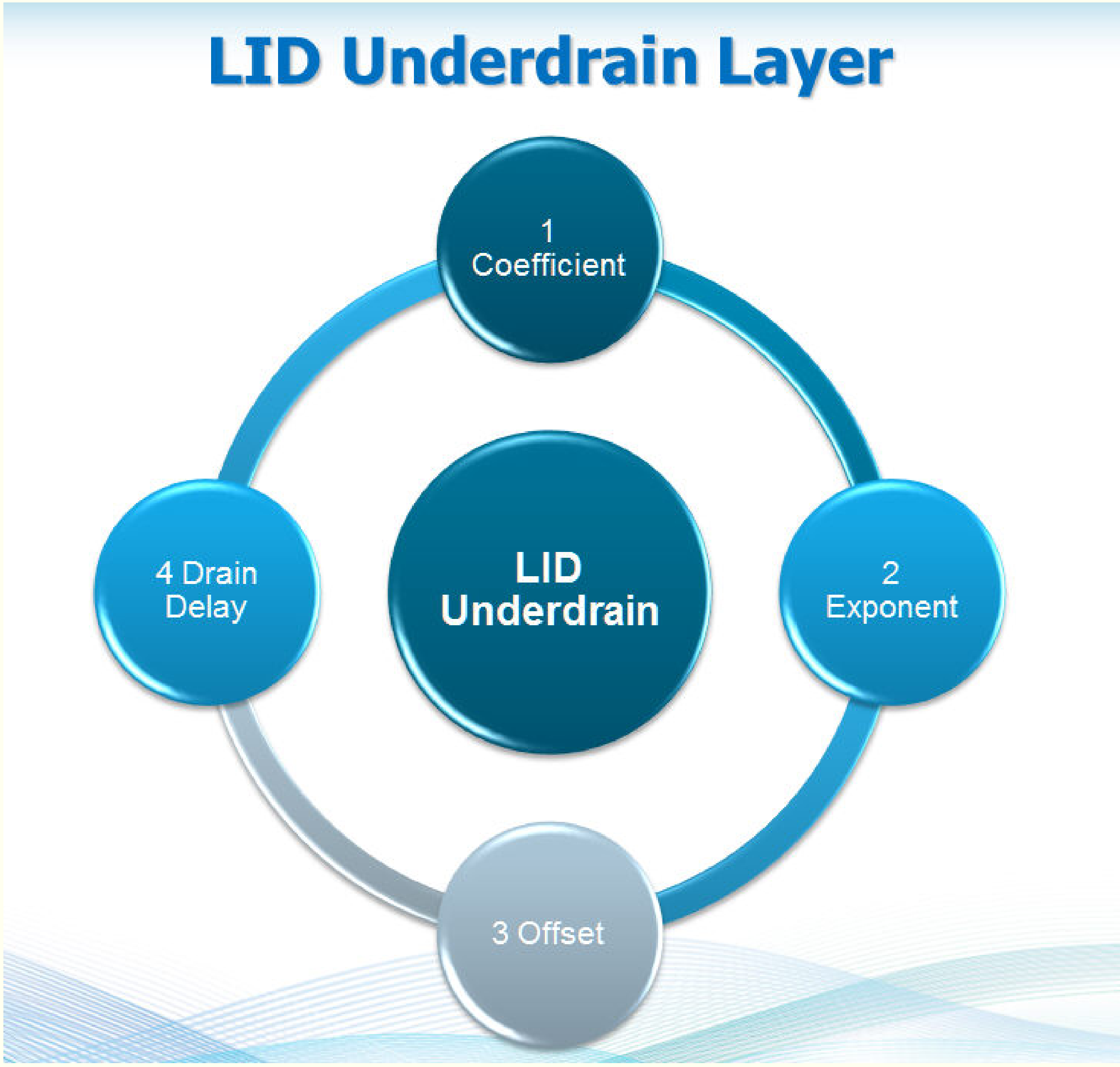

LID Siting Criteria - Porous Pavement
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 3
Slope (%) < 1
Imperviousness (%) > 0
Hydrologic Soil Groups = A,B
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel


LID Porous Pavement Layers
Surface
LID Porous Pavement
Underdrain
Pavement
Storage


LID Pavement Layer
1 Thickness
2 Void volume / total volume
3 Impervious Surface Fraction
4 Permeability
5 Clogging factor
LID Pavement Layer


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer


LID Surface Layer
1 Thickness
2 Void Fraction
3 Roughness
4 Surface Slope
5 Side Slope
LID Surface Layer



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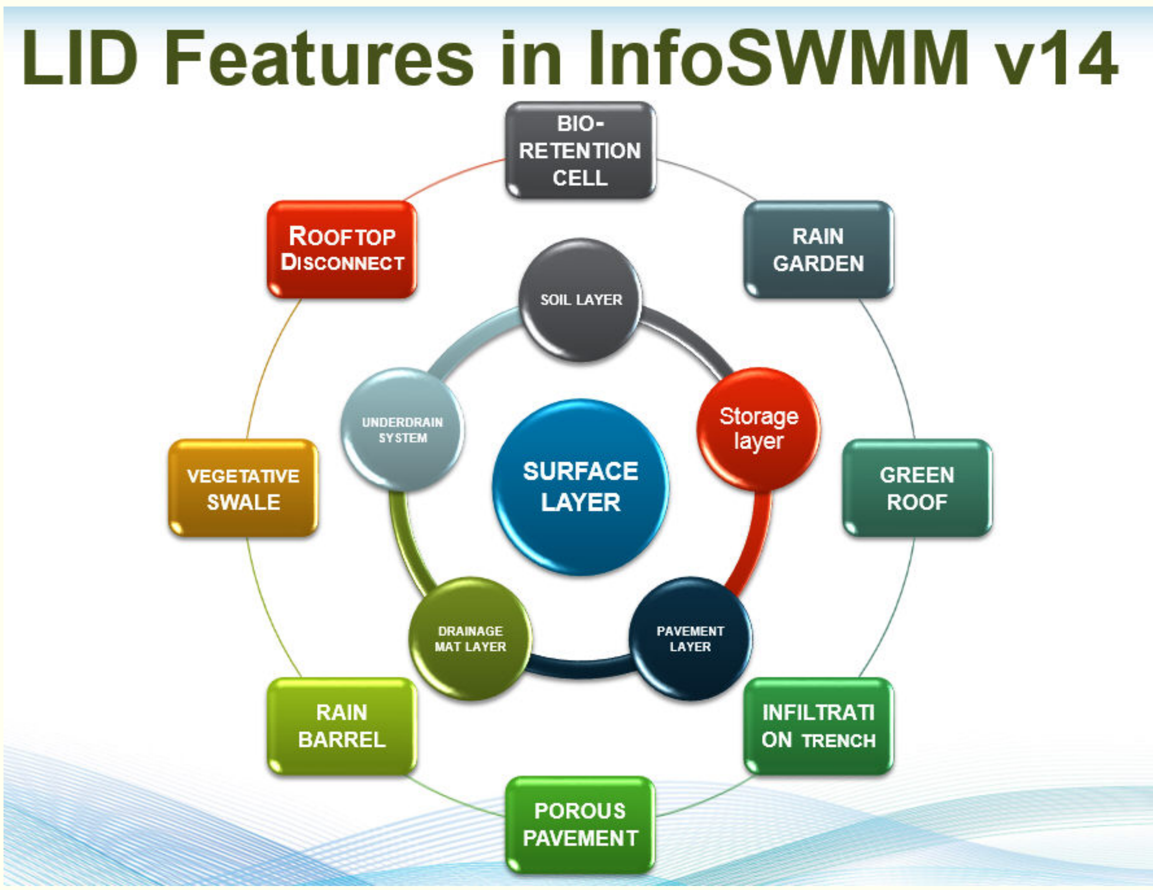
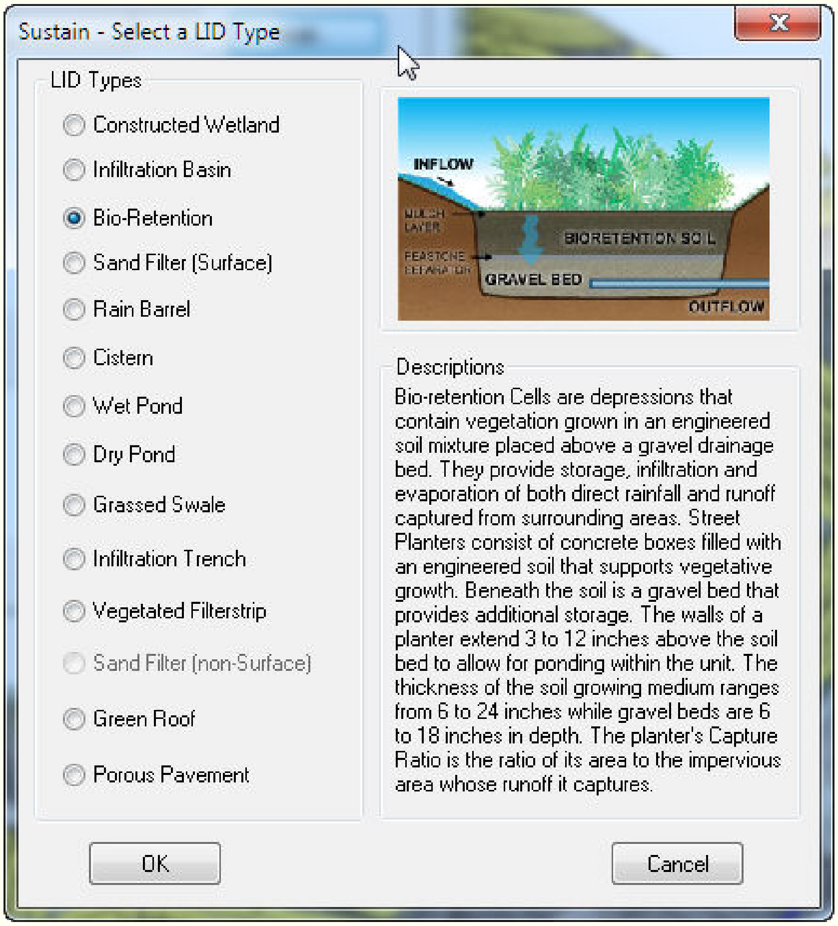
LID
LID

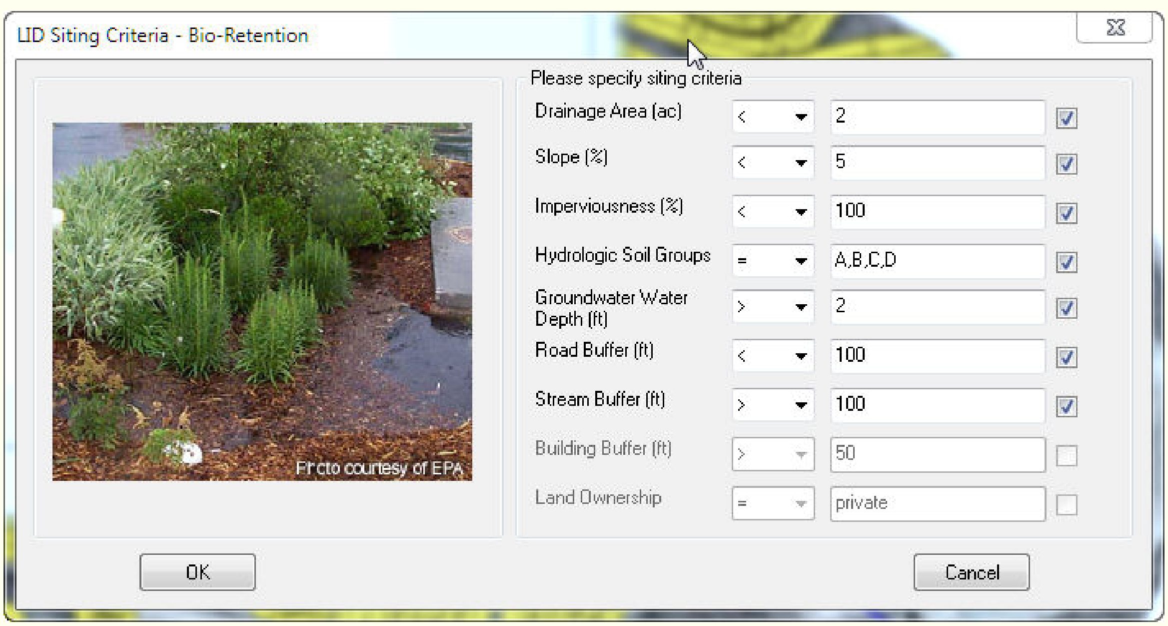
Rain Garden

The three steps to selecting a LID Type are:

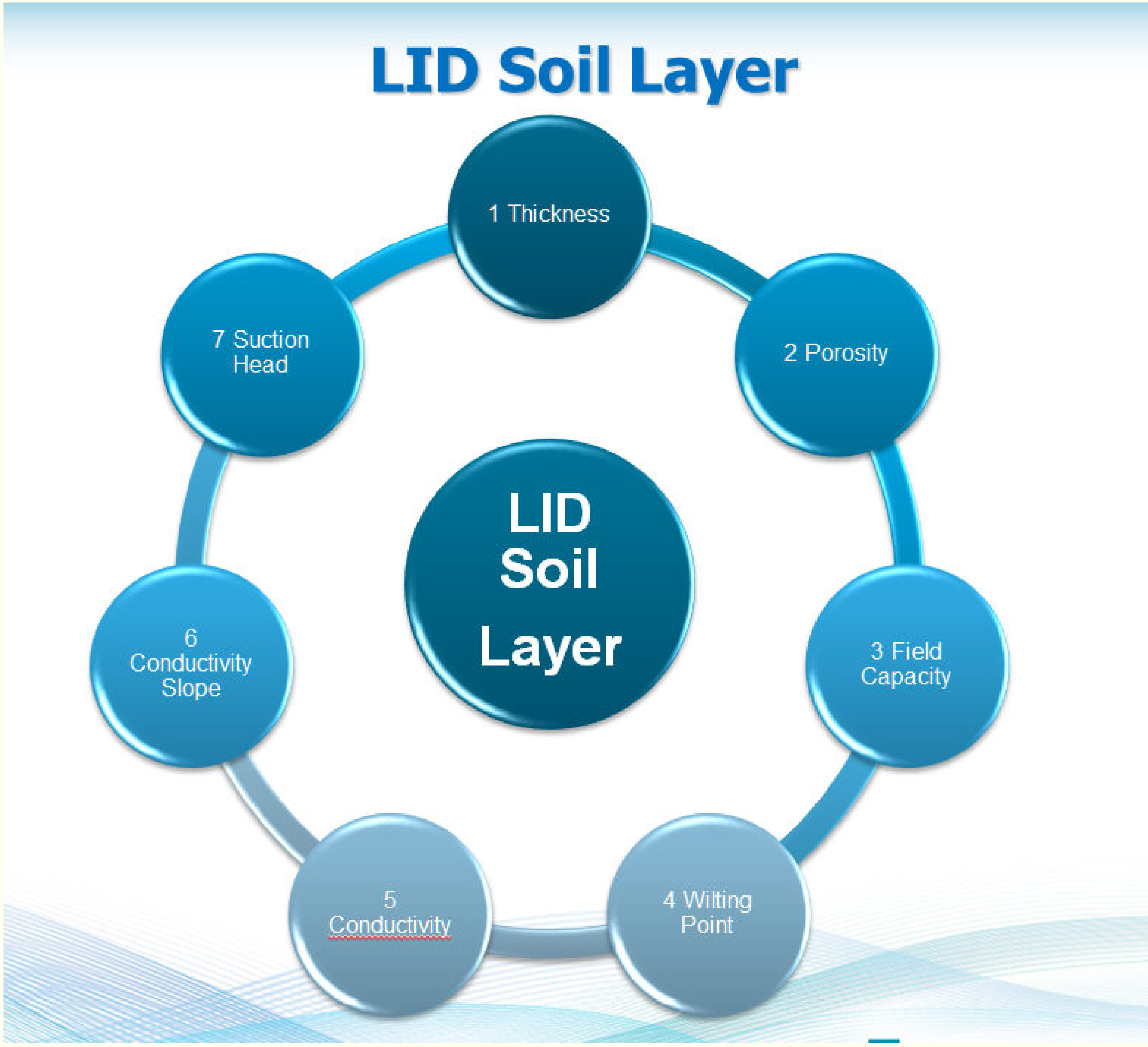
- Select the LID Type
- Set the LID Siting Criteria
- Understand the Components of the LID
    - a. The number of process layers
    - b. The components of each process layer
    - c. As an example, a Green Roof is composed of Storage, Soil and Drain Mat Layers
    - d. A Wetland, Wet Pond or Dry Pond can be either a Bio-Retention cell or a Storage Node with Evaporation and Exfiltration




Sustain - Select a LID Type
LID Types
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
INFLOW
BIORETENTION SOIL
GRAVEL BED
OUTFLOW
Descriptions
Bio-retention Cells are depressions that contain vegetation grown in an engineered soil mixture placed above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas. Street Planters consist of concrete boxes filled with an engineered soil that supports vegetative growth. Beneath the soil is a gravel bed that provides additional storage. The walls of a planter extend 3 to 12 inches above the soil bed to allow for ponding within the unit. The thickness of the soil growing medium ranges from 6 to 24 inches while gravel beds are 6 to 18 inches in depth. The planter's Capture Ratio is the ratio of its area to the impervious area whose runoff it captures.
OK
Cancel


LID Siting Criteria - Bio-Retention
Photo courtesy of EPA
Please specify siting criteria
Drainage Area (ac) < 2
Slope (%) < 5
Imperviousness (%) < 100
Hydrologic Soil Groups = A,B,C,D
Groundwater Water Depth (ft) > 2
Road Buffer (ft) < 100
Stream Buffer (ft) > 100
Building Buffer (ft) > 50
Land Ownership = private
OK
Cancel


LID Rain Garden Layers
Surface
LID
Rain
Garden
Soil



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More

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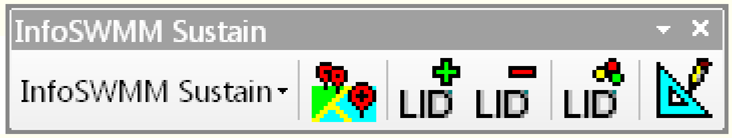
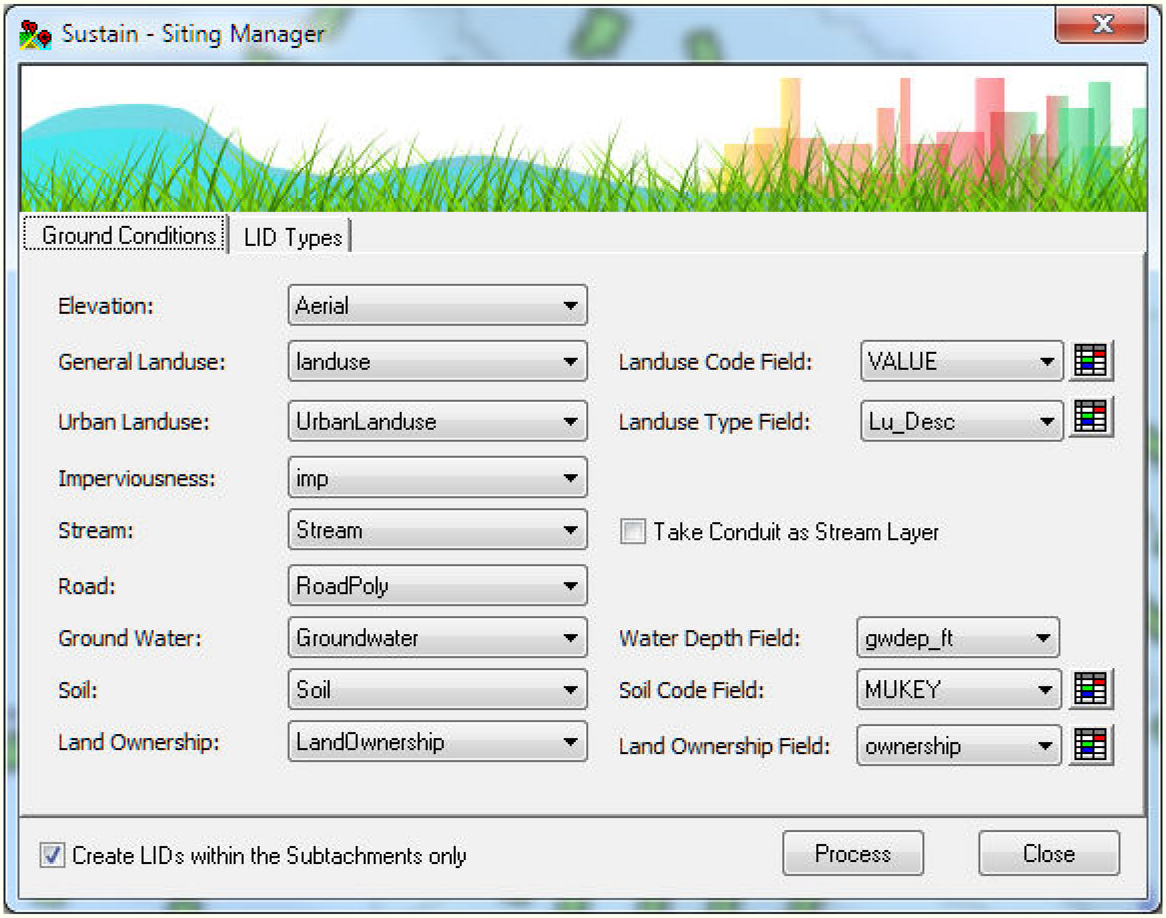

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Process Command

The Process Command 

finds all of the possible LID

Types based on the GIS Layer data selected and the added set of LID Types defined in LID Types Dialog. The found LID's can be seen in the LID Type layer of the InfoSWMM Table of Contents.



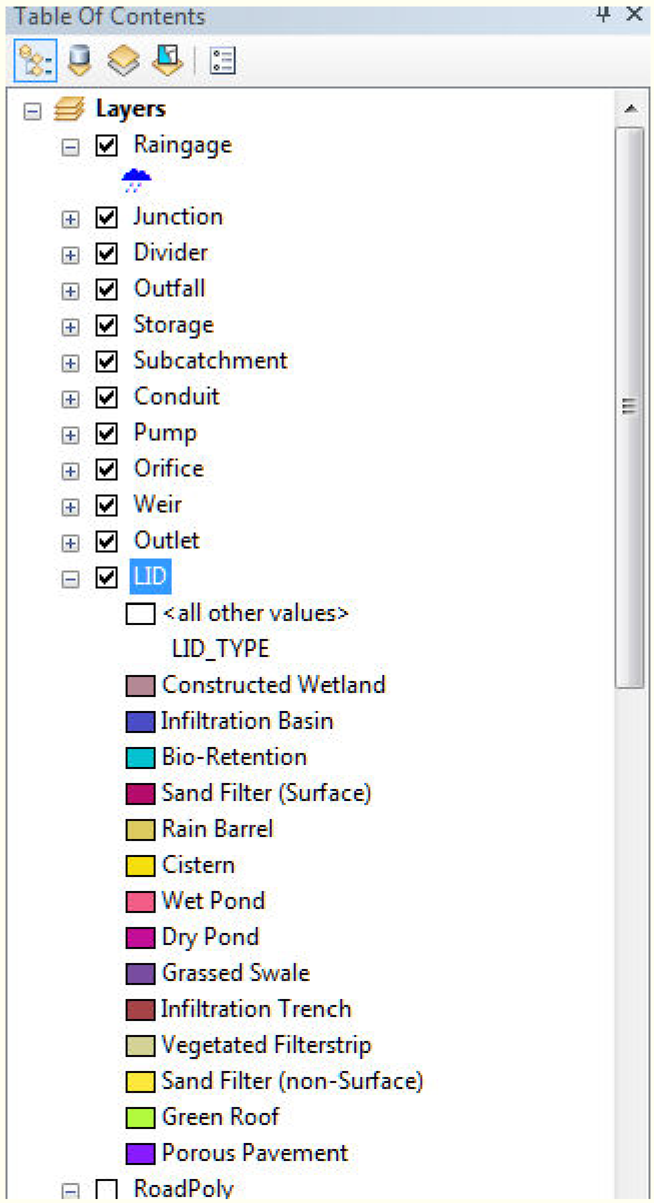


Table Of Contents
Layers
Raingage
Junction
Divider
Outfall
Storage
Subcatchment
Conduit
Pump
Orifice
Weir
Outlet
LID
<all other values>
LID_TYPE
Constructed Wetland
Infiltration Basin
Bio-Retention
Sand Filter (Surface)
Rain Barrel
Cistern
Wet Pond
Dry Pond
Grassed Swale
Infiltration Trench
Vegetated Filterstrip
Sand Filter (non-Surface)
Green Roof
Porous Pavement
RoadPoly

–

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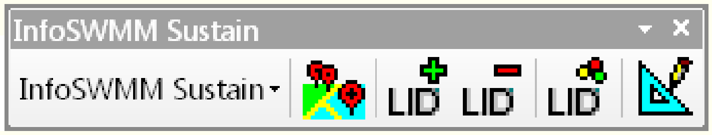
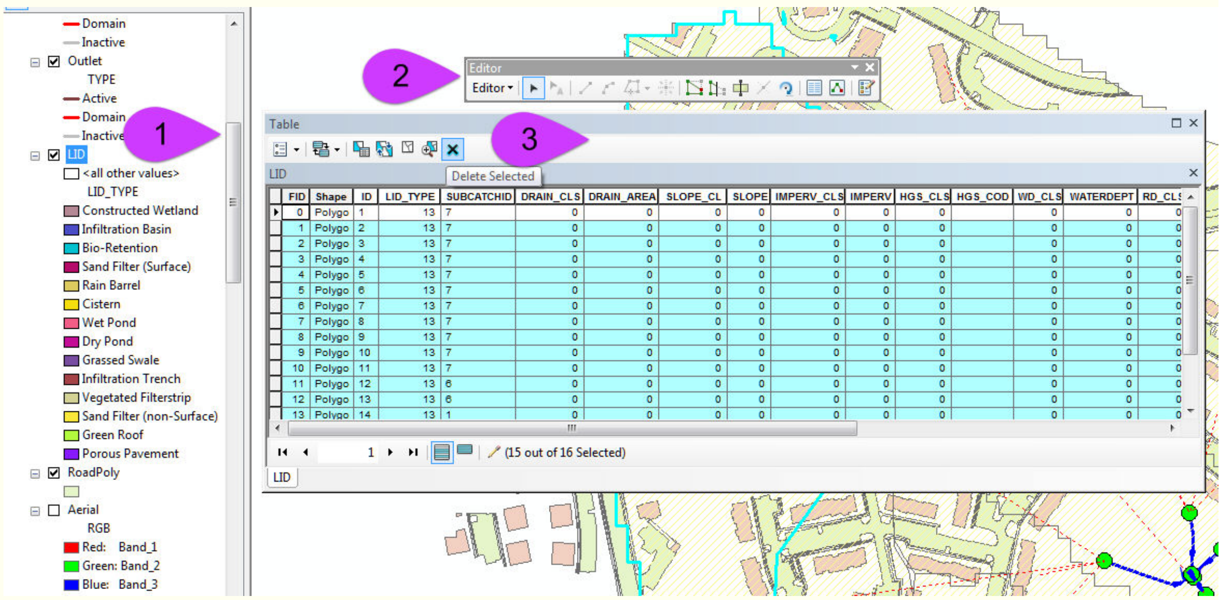


How to Delete The Current LID Types

If you want to start over then you can delete the current LID Types in the InfoSWMM Arc Map Table of Contents (TOC) by using these steps;

- Right Mouse click and edit the LID Layer
- Use the Arc Map Editor tool to delete Shapes or
- Using the Arc Map Attribute Table highlight the Rows to be deleted and then click on **X**



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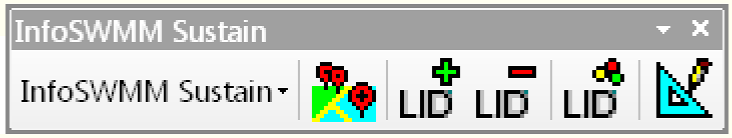
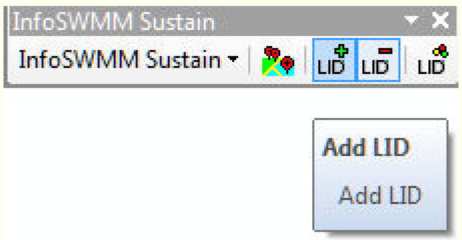
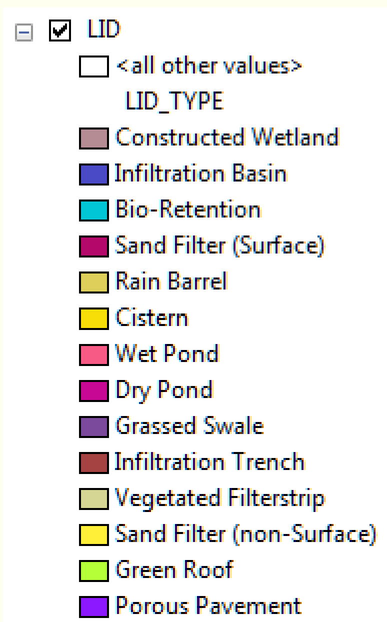

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Add A Single LID

The LID Add Icon allows you to add a single LID feature on the Arc GIS Map or a record from the InfoSWMM LID layer in the Table of Contents. The LID feature class includes up to 14 possible LID Types.





The following is from the ESRI Online Help File

Feature and geodatabase basics

To fully understand the meaning of feature in ArcGIS, you must understand a bit about geodatabases and the relationship between feature classes and maps.

The database table containing the row mentioned above is known as a feature class in ArcGIS. For example, one row in the feature class might be an infantry platoon named 1st Platoon. A second row might be an infantry platoon named 2nd Platoon.

ArcGIS-supported databases are typically referred to collectively as geodatabases, and they include file geodatabases, Microsoft Access databases, and multiuser relational DBMSs (such as Oracle, Microsoft SQL Server, PostgreSQL, Informix, or IBM DB2).

The data (the tables—the feature classes) in a geodatabase is one of two main components of ArcGIS. The other main component is the map. The map (an .mxd file for ArcMap maps, for example) contains information on how to display data stored in a geodatabase. A map does not contain geodatabase data; a map does, however, contain references to geodatabase data via the map's layers. Maps and data are distinct entities.

The relationship among maps, layers, and feature classes

Maps contain information such as the layout of the map and which layers you want to include in the map. Layers contain additional visualization information.

This is why you'll encounter discussions of ArcGIS as being separated into two categories: visualization (maps and layers) and data.

A layer in an ArcGIS map points to a feature class in a geodatabase. The layer contains information about how you want to display that feature class in a map, such as what symbols you want to use for the features in a feature class or which fields in the feature class are visible on the map.

A single feature class can be referenced (can appear in) many maps. It can even be referenced within the same map as different layers, when you want two different renderings (visualizations) of the same data. This one-to-many relationship should underscore the lesson that layers and data are distinct entities. Layers help you help your map readers visualize the data, or underlying data, as it is sometimes called. To view the data underlying a layer in ArcMap, right-click the layer and click Open Attribute Table.

Common layer/feature class types are points, lines, and polygons. The layer and feature class in the pairing must be of the same type (point, line, polygon, and so on). A point type of layer or feature class must contain only point features; a line layer must contain only lines, and so on.

Generally speaking, the coding scheme (the position 1 value of the SIDC) a military feature has or the category (warfighting, tactical graphic, and so on) a military feature is listed under in the military specification is what determines which type of layer/feature class (point, line, and polygon) the feature must live in in ArcGIS. For details and information on other factors that determine the layer type, see Identifying which layer to use for a feature.

For ArcGIS for Desktop products (as opposed to clients using feature services and editing capability), to change data stored in the feature class, you must edit the feature class in an edit session in ArcMap. To change the table schema, you can edit the feature class in ArcCatalog or ArcMap.

Esri

military feature layer packages simplify

your job of adding military features to a map because they contain the table schemas, feature templates, symbology, cartographic representations, geometric effects, unique values layers, and label

properties designed

for the symbols listed in military symbol specifications supported by ArcGIS. For details on how unique values layers are used, see Military operations points. For details on how representations and geometric effects are used, see Military

operations lines and areas.

When you save a map, you are essentially saving visualization information only. When you save edits in an edit session, you are saving changes to the underlying data—the feature class or feature classes you were editing.

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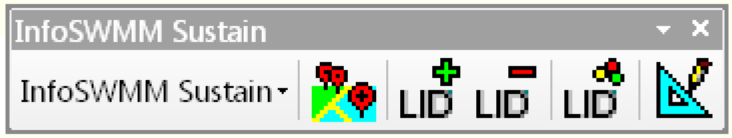
InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

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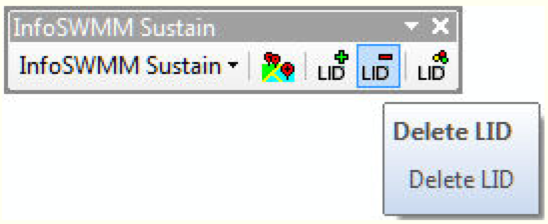

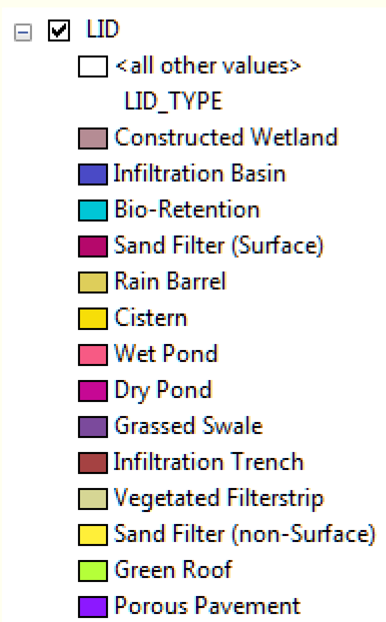

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Esri

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InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

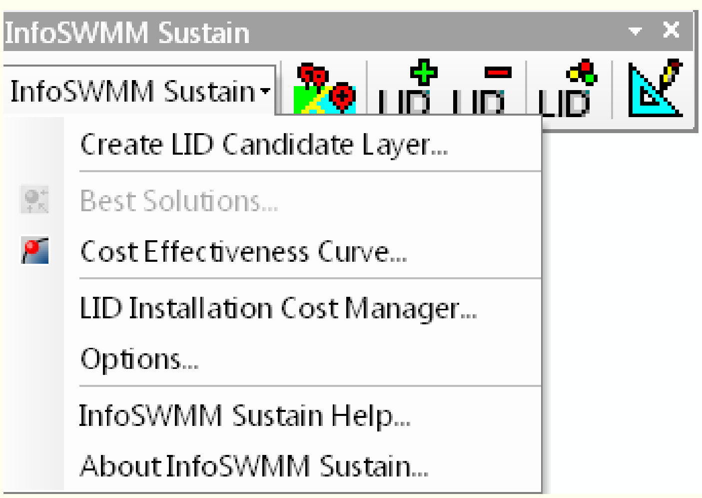
Run Optimizer

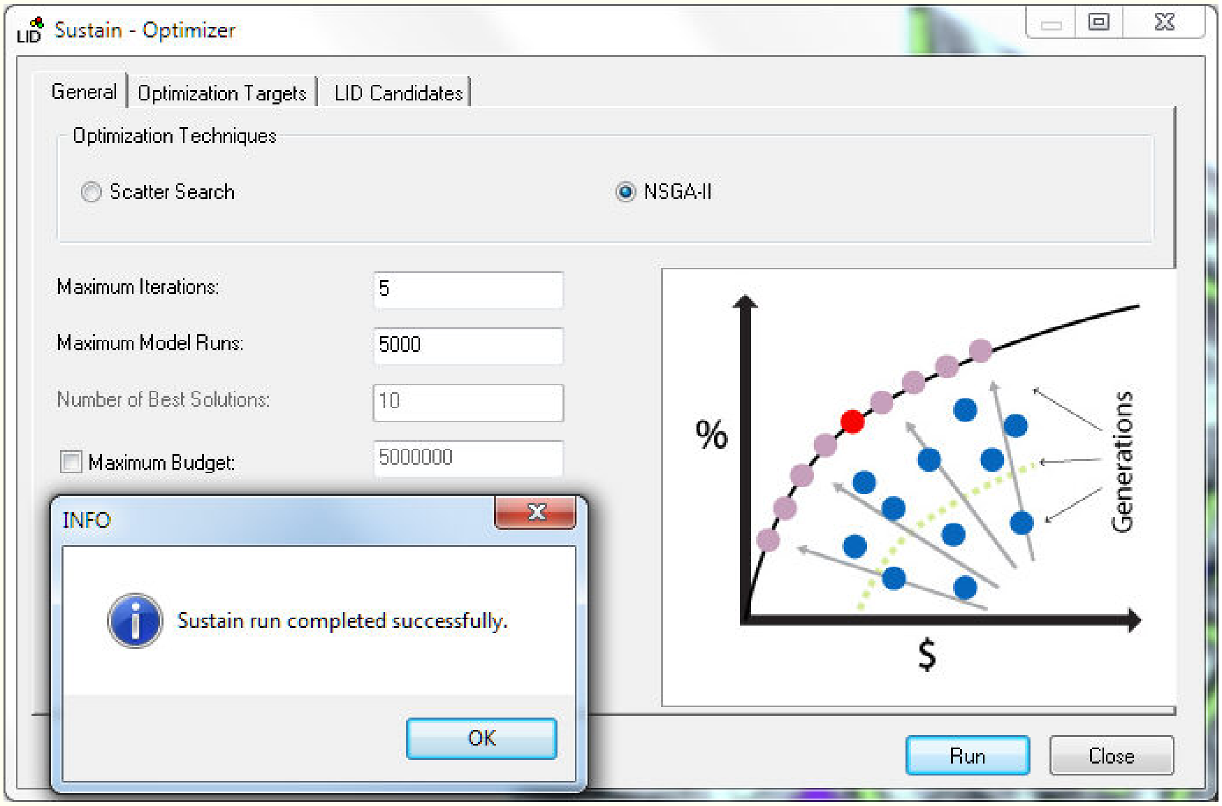
The major tasks in using InfoSWMM Sustain are the following:

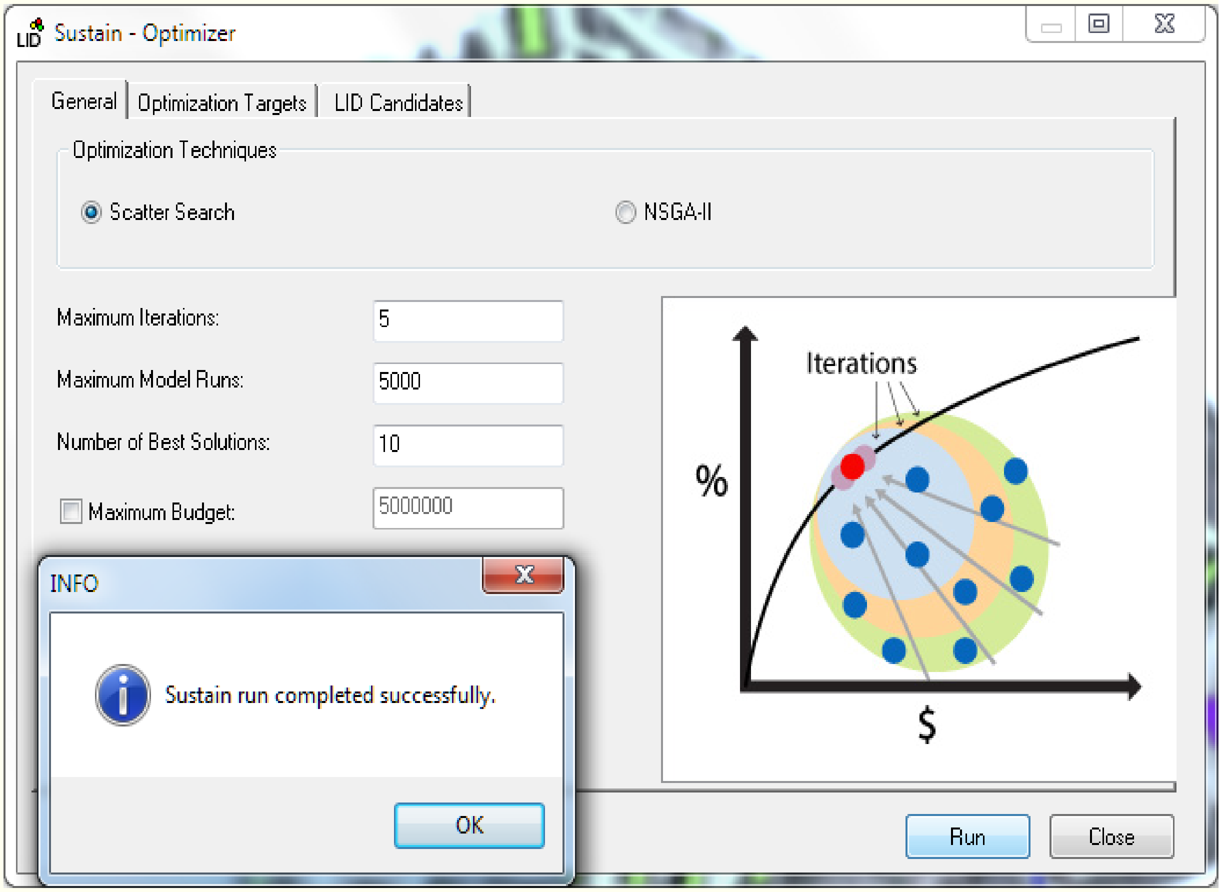
- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

The Optimizer runs many InfoSWMM runs to optimize the selected LID Types.

Click on Run and you will see a Blue progress bar at the bottom of the screen and at the end of the Run an Info Dialog Message Box.




Sustain - Optimizer
General
Optimization Targets
LID Candidates
Optimization Techniques
Scatter Search
NSGA-II
Maximum Iterations:
5
Maximum Model Runs:
5000
Number of Best Solutions:
10
Maximum Budget:
5000000
%
Generations
$
INFO
Sustain run completed successfully.
OK
Run
Close


Sustain - Optimizer
General
Optimization Targets
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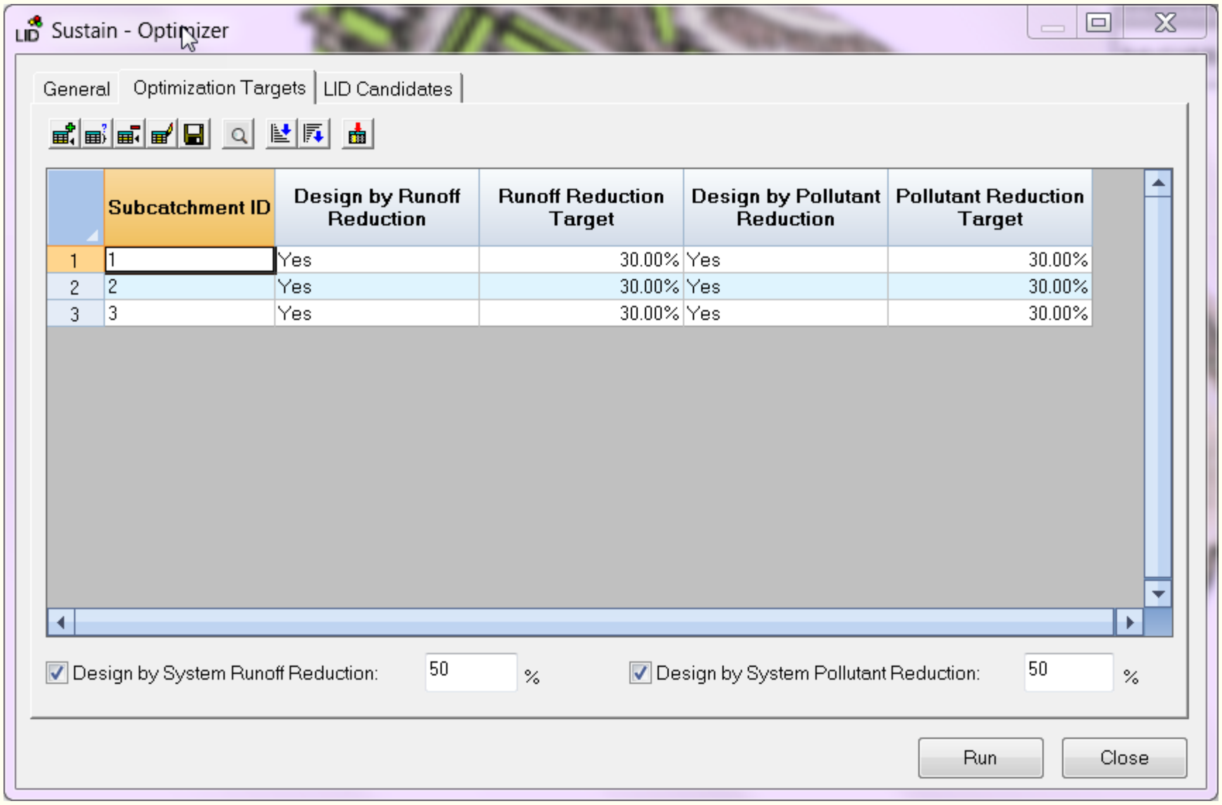
NSGA-II
Maximum Iterations:
5
Maximum Model Runs:
5000
Number of Best Solutions:
10
Maximum Budget:
5000000
INFO
Sustain run completed successfully.
OK
Iterations
%
$
Run
Close

Set Optimization Targets



InfoSWMM Sustain employs the NSGA-II: non-dominated sorting genetic algorithm. NSGA-II is known as an evolutionary multi-objective optimization (EMO) algorithm. I think your question was whether it is a multi-objective algorithm so the answer is yes.

Here are a few references that go into more specifics.

http://www.cleveralgorithms.com/nature-inspired/evolution/nsga.html

https://en.wikipedia.org/wiki/Multi-objective_optimization

SUSTAIN provides two optimization options: (1) cost minimization, and (2) cost-effectiveness curve. Option (1) uses the Scatter Search method introduced by Glover (1977), which is a meta-heuristic search technique that has been explored and used in optimizing complex systems (Glover et al. 2000; Laguna and Marti 2002; Zhen et al. 2004). Option (2) uses NSGA-II, which is an advanced genetic algorithm based on Pareto dominance, and uses non-domination and distribution instead of fitness value to score individuals (Deb et al. 2002). In the Scatter Search option, the optimization search process identifies the near-optimal solutions that meet the user-specified management targets. Multiple objectives can be defined during a Scatter Search. With the NSGA-II method, the optimization process reveals all the cost-effective solutions that provide the highest benefit at each cost interval. Only one objective can be defined when generating a cost-effectiveness curve.

Both optimization formulations are defined with the objective of minimizing cost subject to desired water quality or water quantity (or both) objectives at a specified location (assessment point). The optimization problem formulation can be mathematically expressed as below. In the formulation, a group of BMP_i ($i = 1,\ldots, n$) forms the decision matrix, which defines the optimization engine's search domain. For each potential location, the user defines the feasible range of BMP type and configuration parameters.

The objective is to

$$\text{Minimize} \sum_{i=1}^{n} Cost(BMP_i)$$

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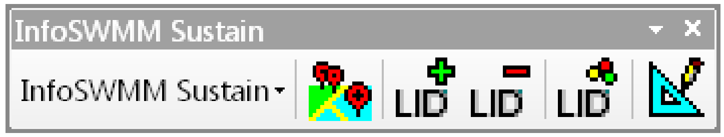

LID Candidates for Optimization in InfoSWMM Sustain 3.0

The major tasks in using InfoSWMM Sustain are the following:

- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
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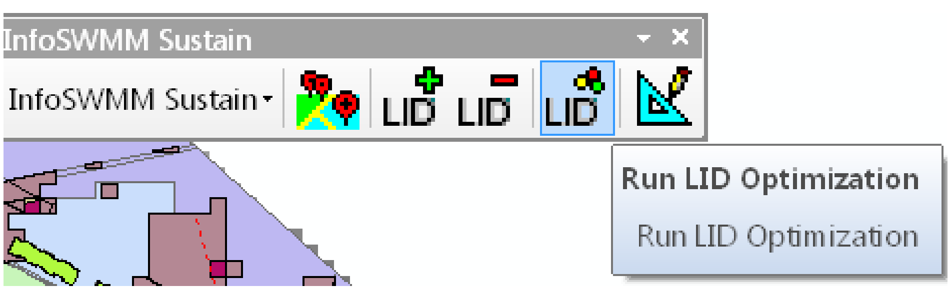
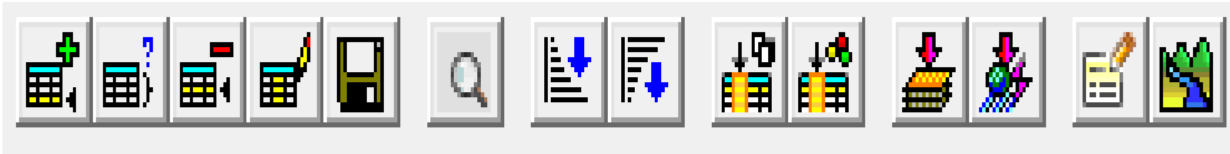
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

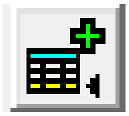
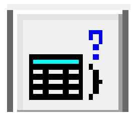
STEP 1: Use the LID Optimizer Tool

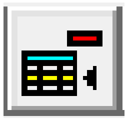
Use the LID Optimizer tool (1) to import all of the LID's with a Subcatchment (2).

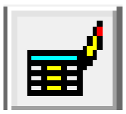


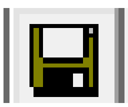
Optimization Toolbar

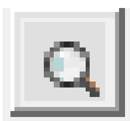


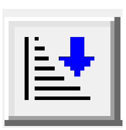
 **Append a Row** **Set Rows**

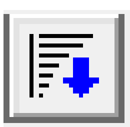
 **Delete a Row**

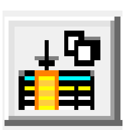
 **Block Edit a Column**

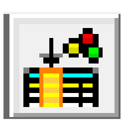
 **Save**

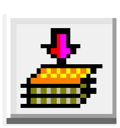
 **Zoom to a LID**

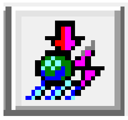
 **Sort Rows Ascending**

 **Sort Rows Decending**

 **Show/Hide Lid Attributes**

 **Show/Hide Optimization Variables**

 **Import Sustain Siting Manger Data**



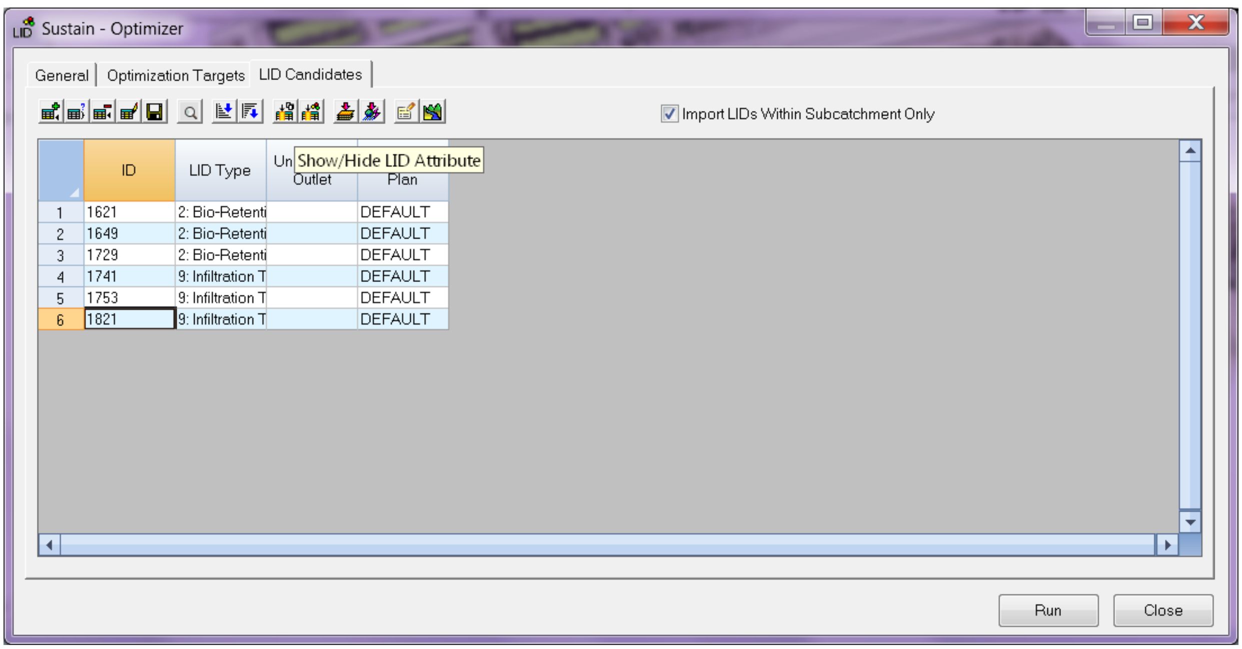
Import LID Usage Table from InfoSWMM

Edit LID Candidate

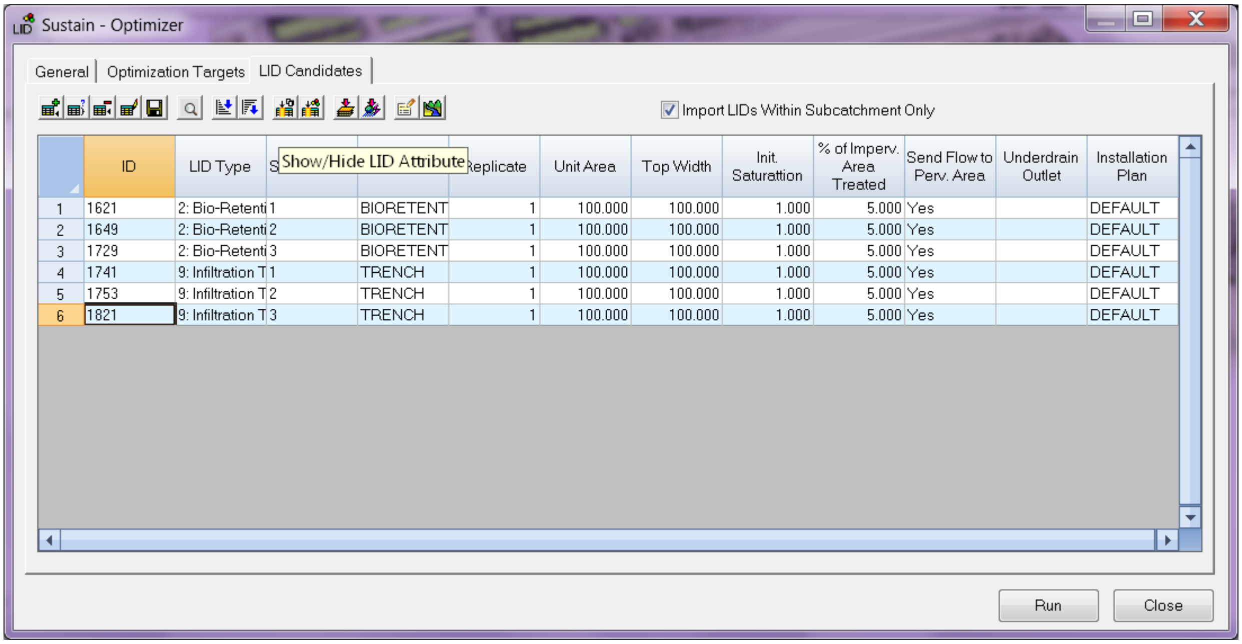
LID Control

There are three options for showing the LID candidate data

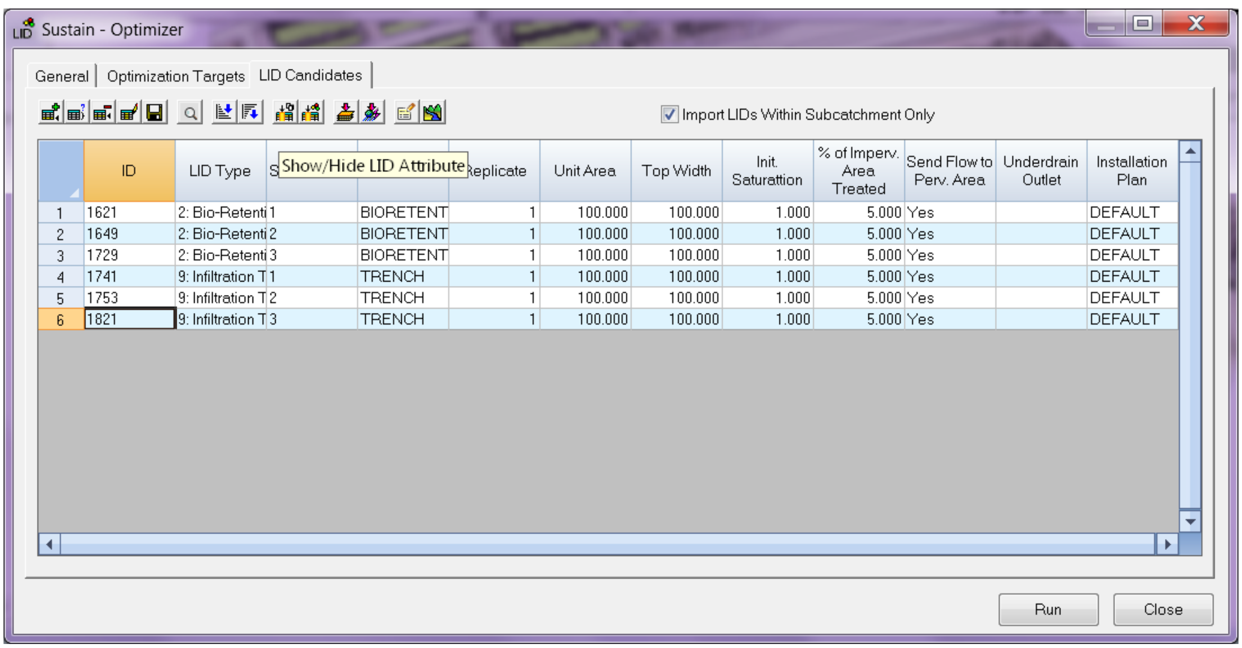
MInimal



Reduced



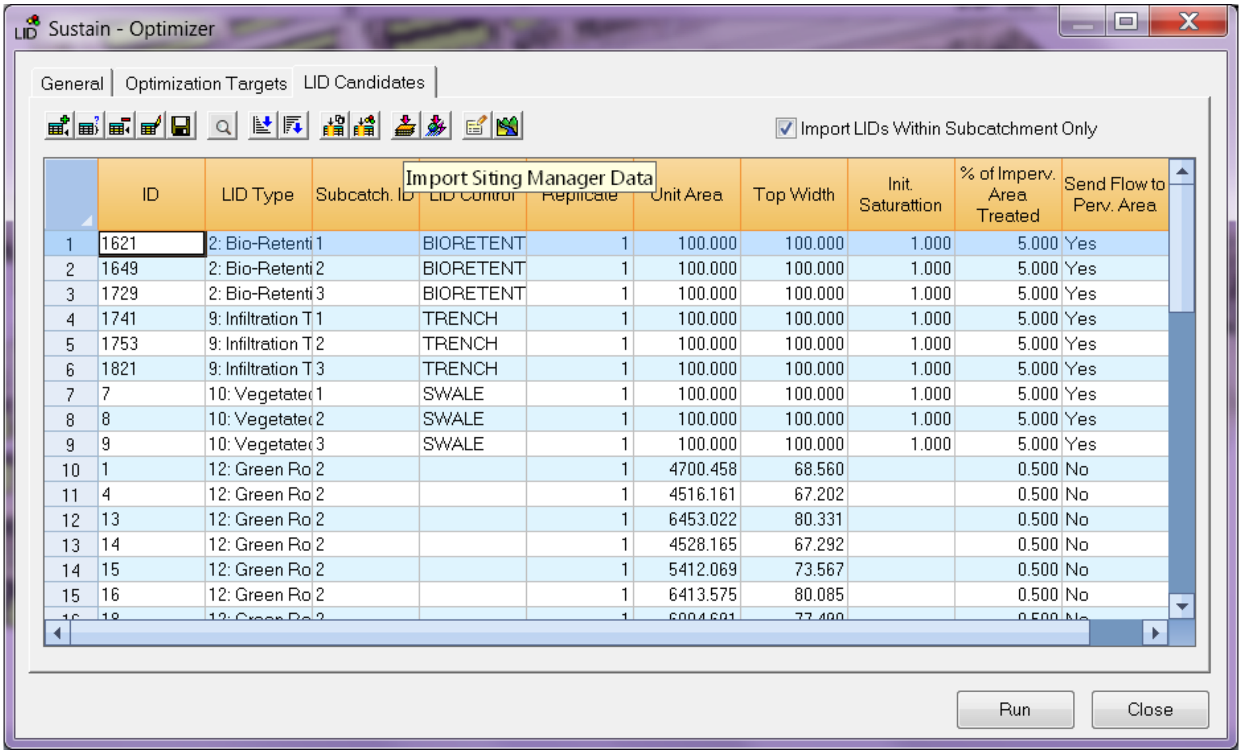
[Full]



STEP 2: Import all of the LID Candidates found by the Siting Manager of InfoSWMM Sustain

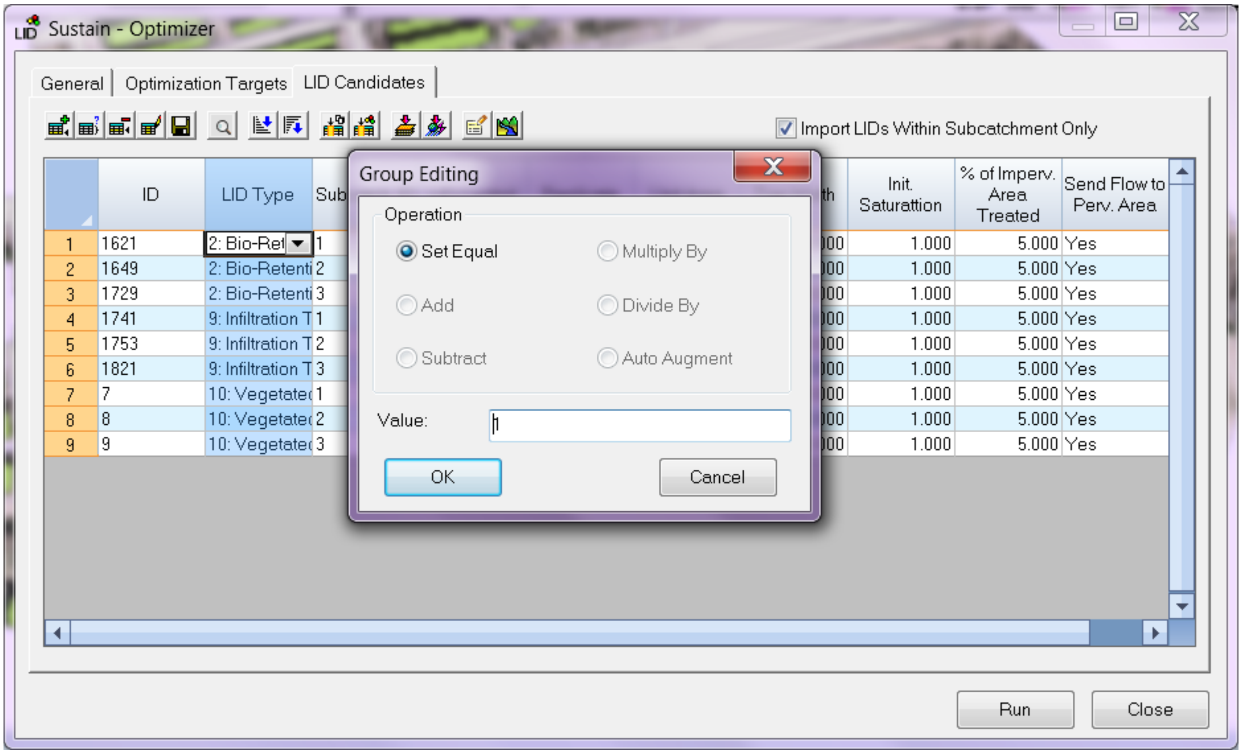
All of the possible Green Roofs on Subcatchments 1, 2 and 3 are now found. You have to decide the actual LID Control for each LID Type. It is possible to have more than one LID Control (from the Operations Tab of the

InfoSWMM Browser) for all of the Green Roofs. Click on the LID Control Box and Select a LID Control.



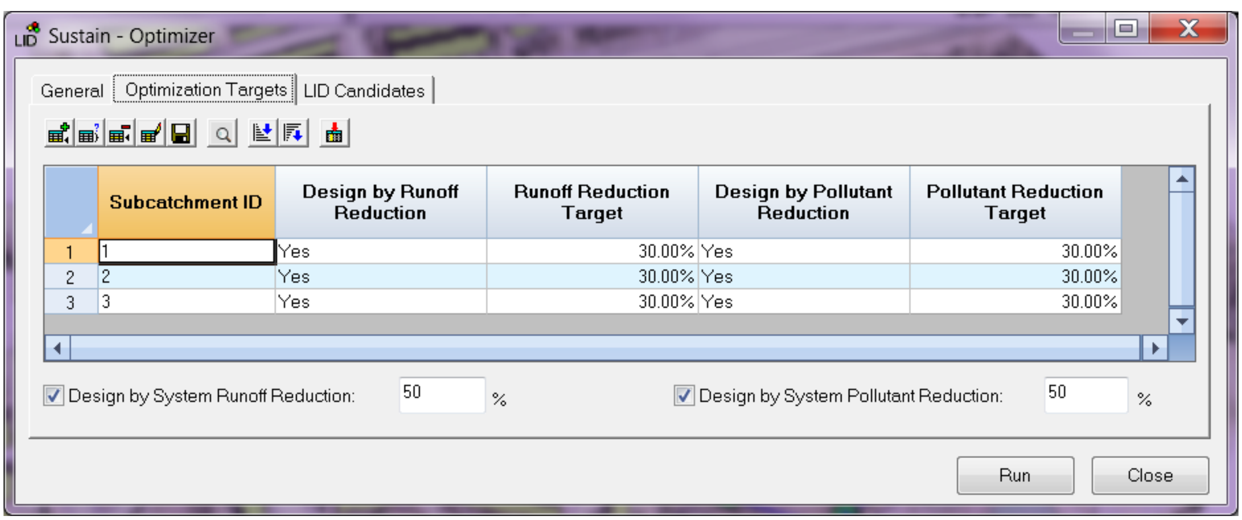
[STEP 3: Set the LID Control for all Rows of the LID Candidate Rows]()

Use the BlockEdit Tool or Icon to set the LID Control for all of the other Rows with an LID Type of Green Roof.



STEP 4: View the Optimization Targets for Runoff and Water Quality

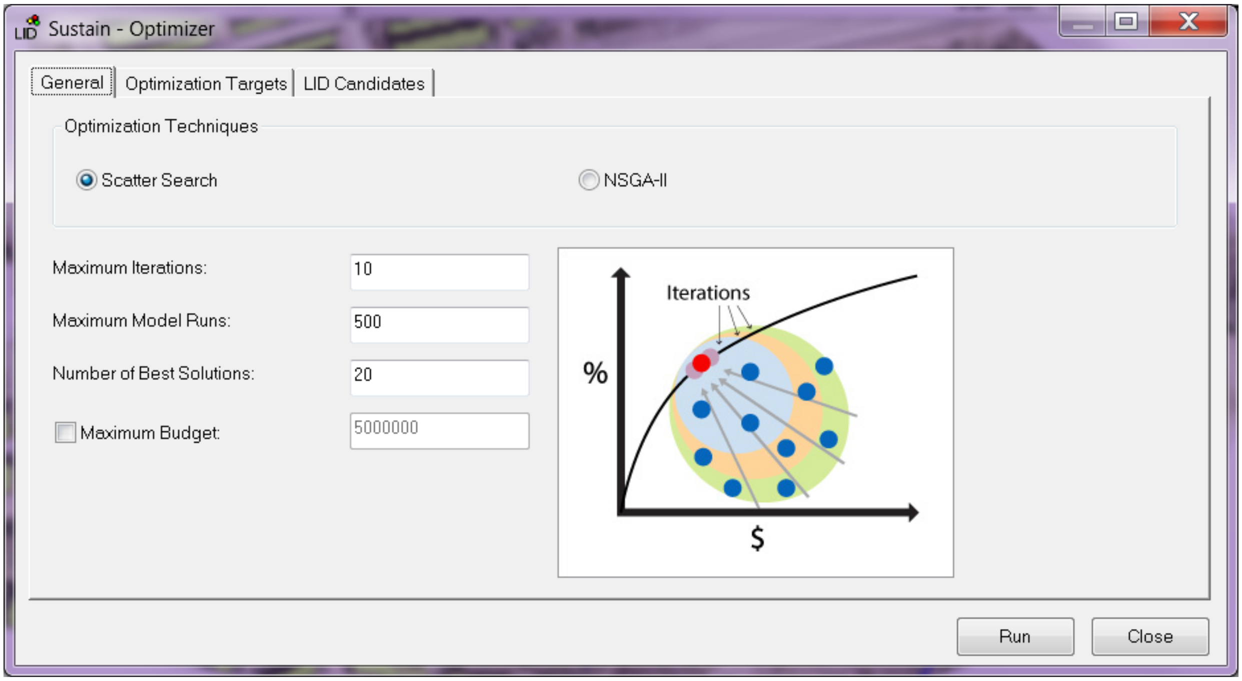
We will use the preset targets of 80 percent for Runoff and Water Quality for all of the Subcatchments.



STEP 5: Click on the General Tab to Define the Optimizer Parameters

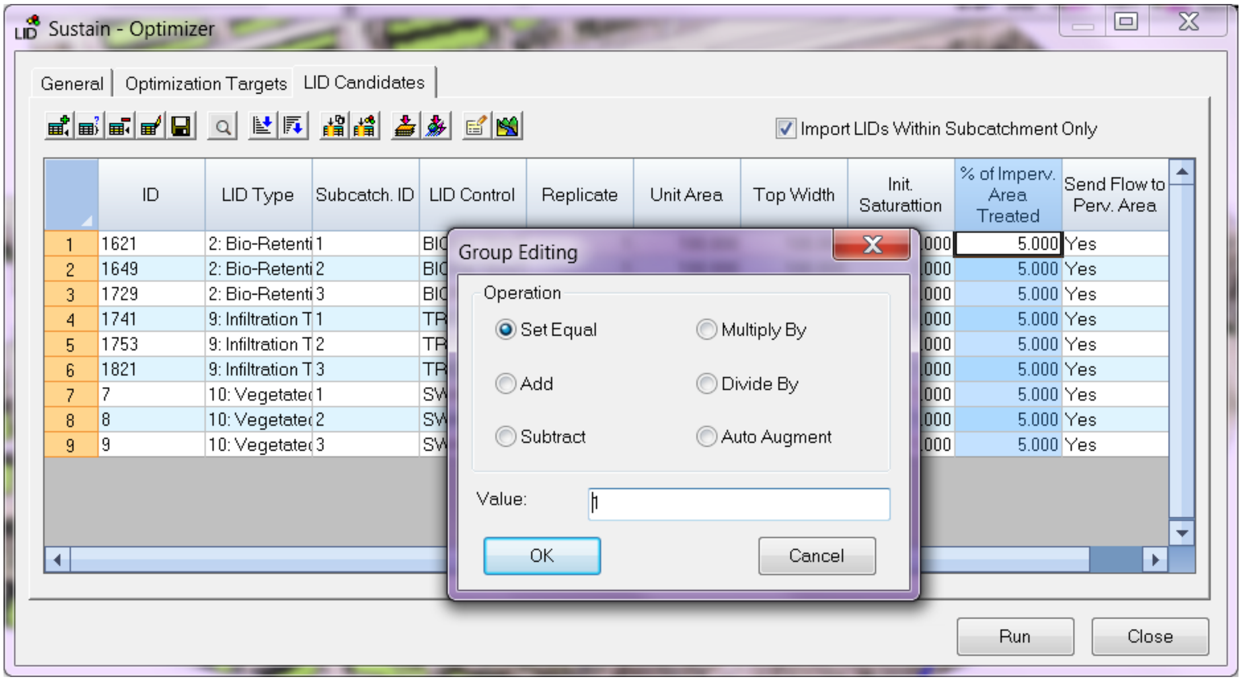
The parameters are for type of Optimization Technique, the Cost Improvement Threshold, the Maximum Number of Iterations per Model

Run, the Maximum InfoSWMM Model runs and the Number of Best Solutions to be Found during the Optimization Process.



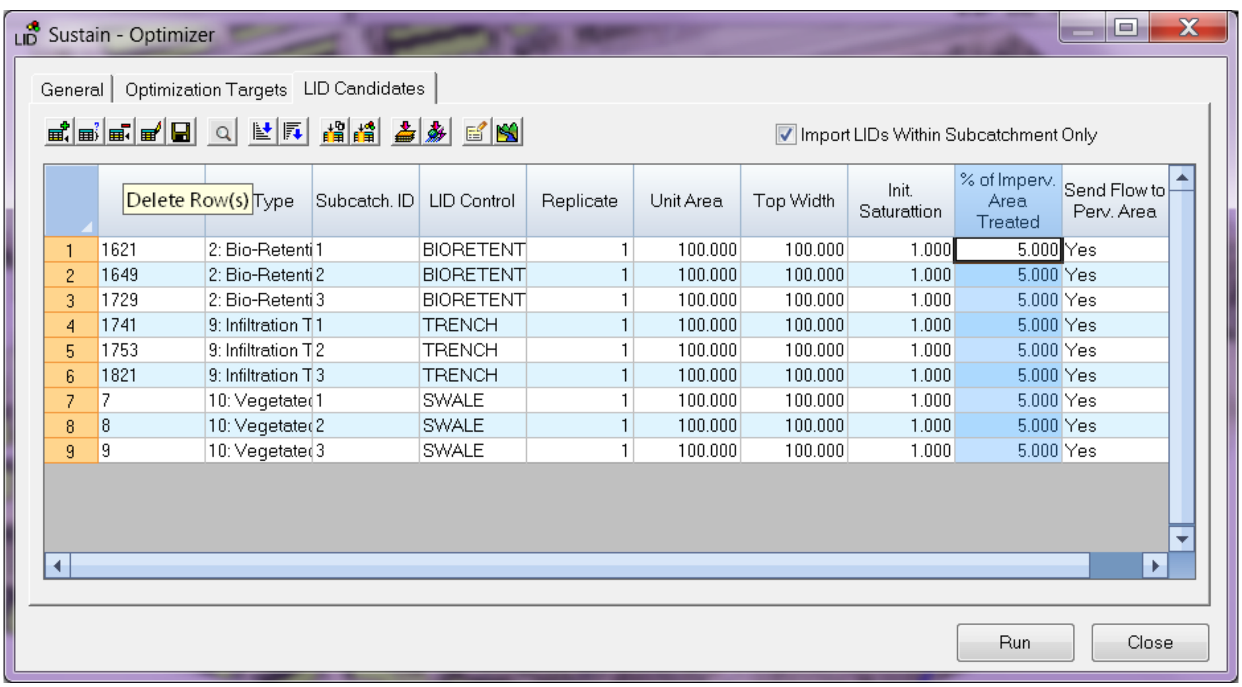
STEP 6: Modify the Percent Imperviousness Area Treated

An important rule is that the total area treated by all LID Types for a particular Subcatchment does not exceed 100 percent of the impervious area. Use the BlockEdit tool again and set the Percent Imperviousness Area Treated to 5 percent per LID Type.

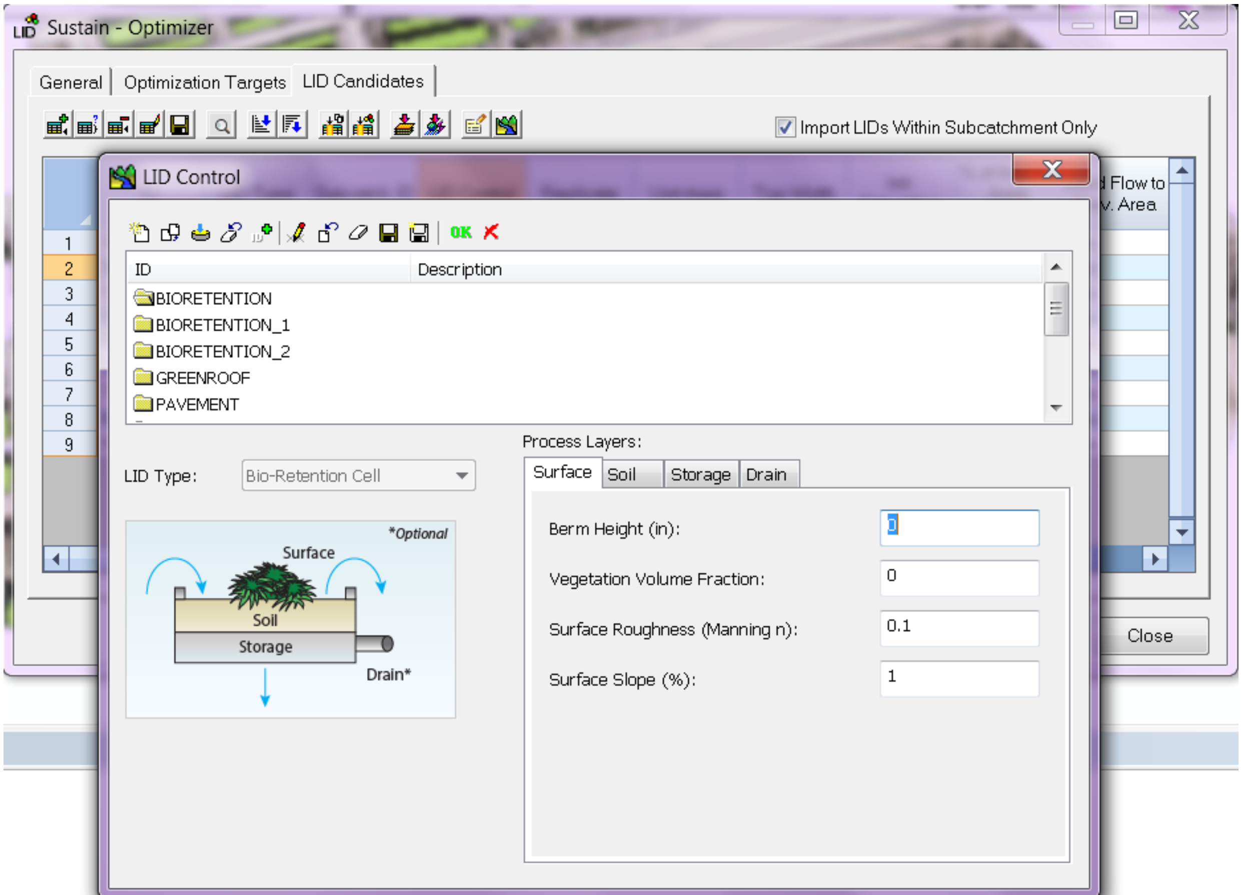


STEP 7: Reduce the Number of LID Types

You can use the delete Row Tool to delete any rows of LID Types you do not want to optimize.



The possible LID Controls that can be selected in the column LID Control are shown below. Please note that you can have multiple LID Controls of the same LID Type



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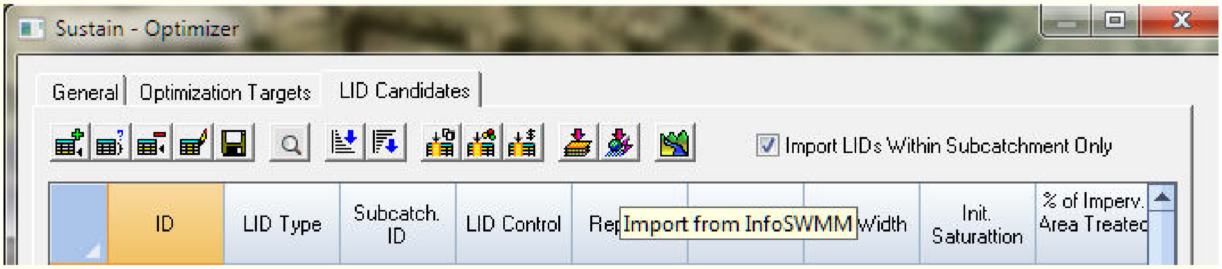
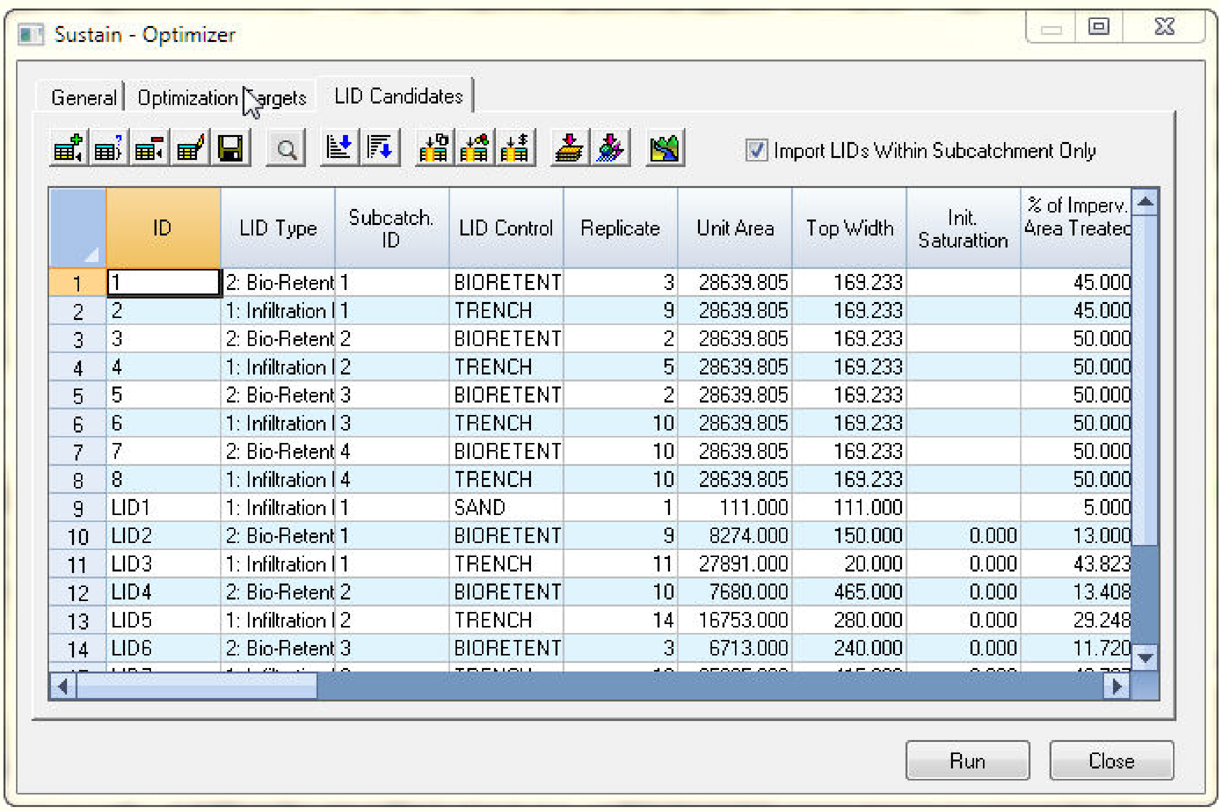
Import from InfoSWMM

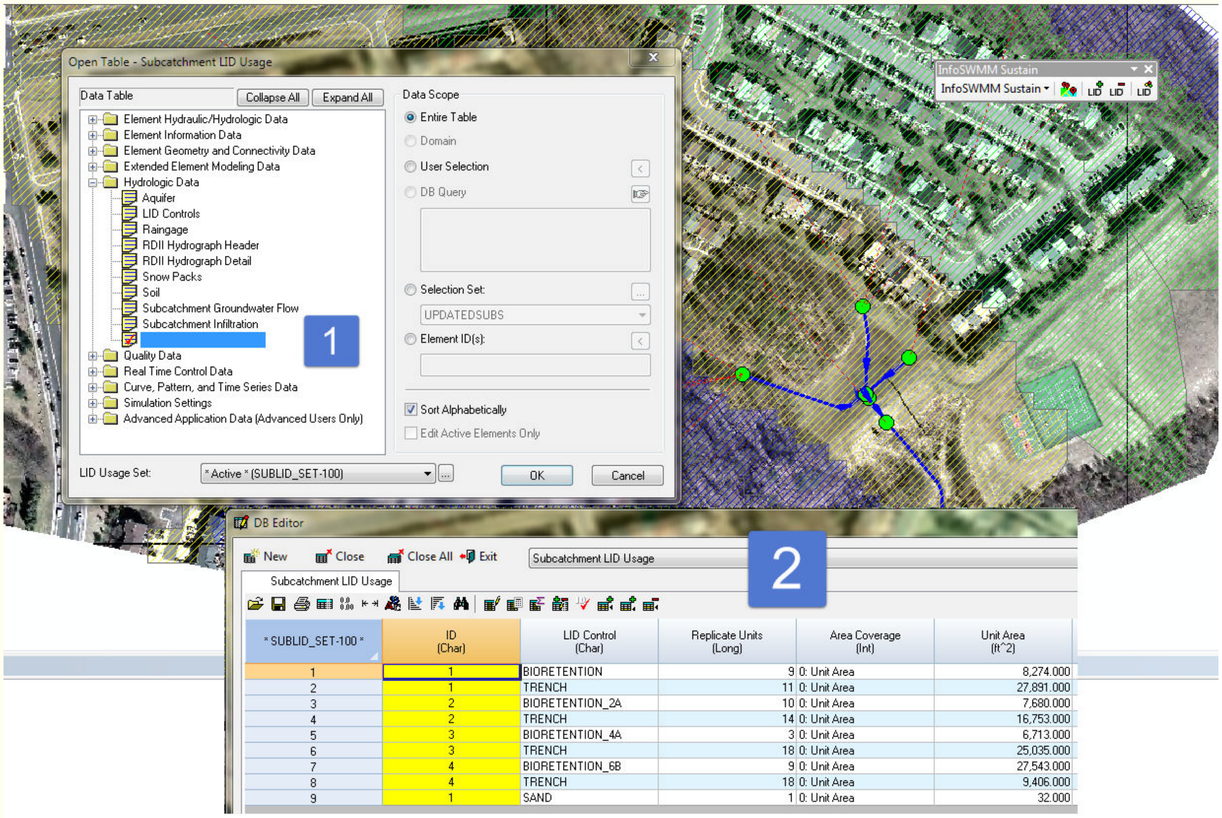
You can also import the LID coverage from the LID coverage DB Table by using this ICON



LID Candidate Table



LID Coverage Table in InfoSWMM



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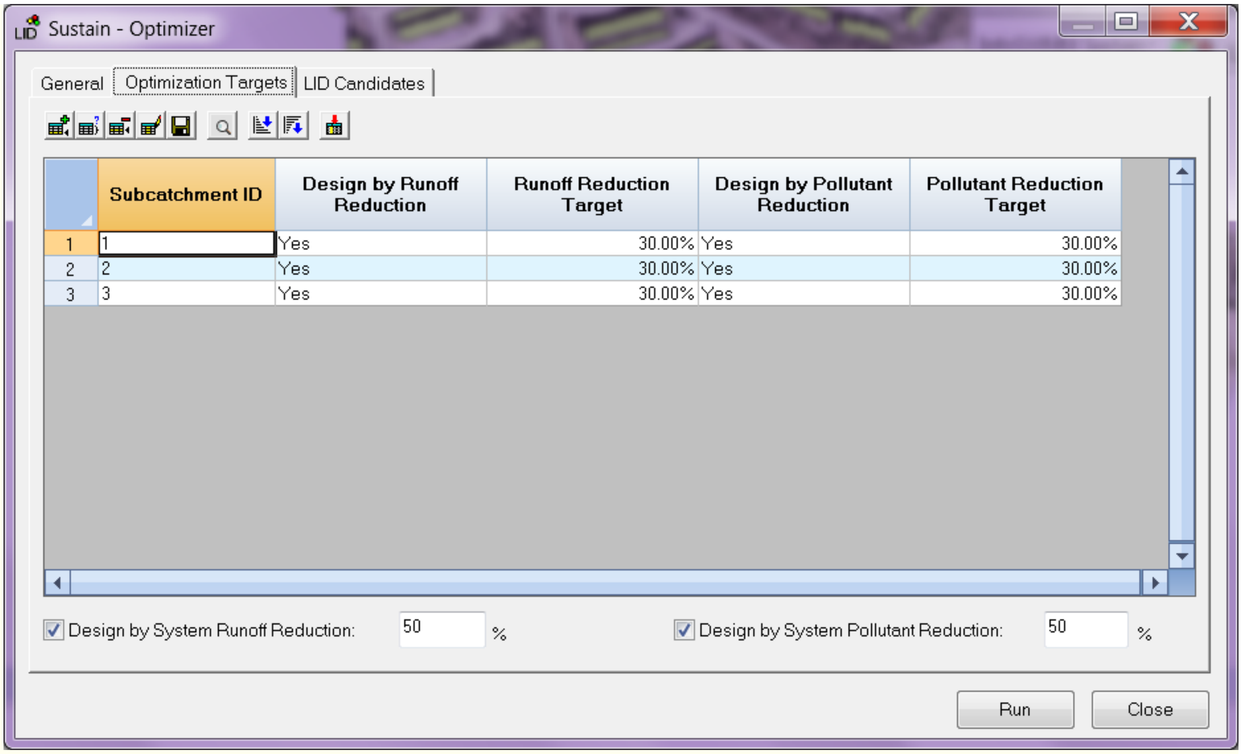
Optimization Targets

The major tasks in using InfoSWMM Sustain are the following:

- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

We will use the preset targets of 50 percent for Runoff and Water Quality for all of the Subcatchments or use an overall System Runoff and System Pollutant Target in the Sustain Optimizer Dialog.



[Water Quality in SWMM5/InfoSWMM]

The SWMM5 help file states: "Although some LID practices can also provide significant pollutant reduction benefits, at this time SWMM5 only models the reduction in mass runoff load resulting from the reduction in runoff flow volume." While pollutant loads are reduced by SWMM5 through mass removal via street sweeping, catch basins, particle separators, settling in ponds, and first-order decay, the LID component only reduces pollutant discharge as a result of reduced runoff. This simplification is reasonable for large-scale studies, but limits the model's applicability for detailed small-scale water quality analysis. Similarly, the model does not provide accounting for pollutant mass transferred into groundwater; discharges from groundwater are assigned a fixed user-specified concentration.

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LID Installation Cost Manager

LID Installation Cost Manager Toolbar

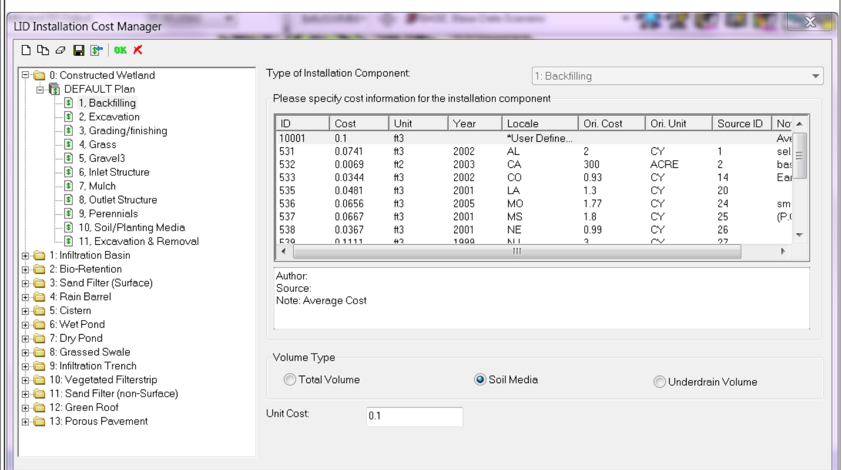
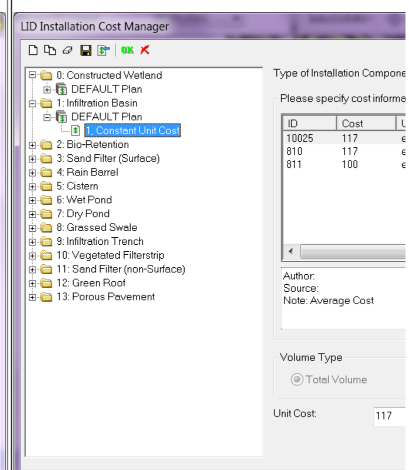
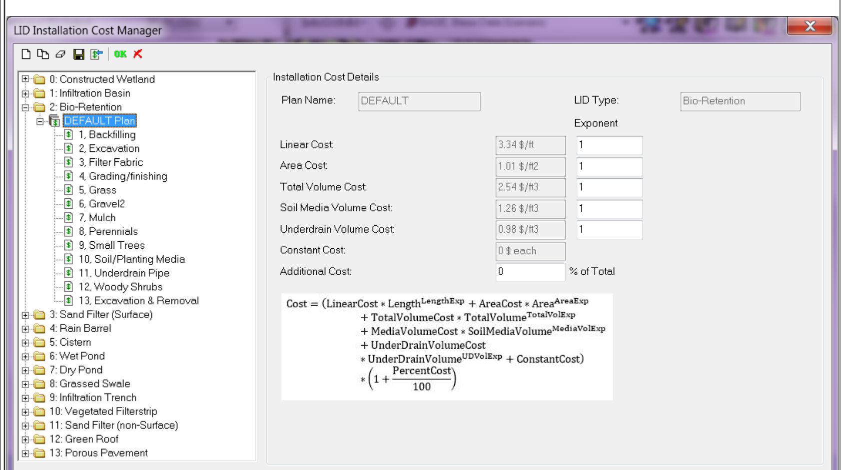
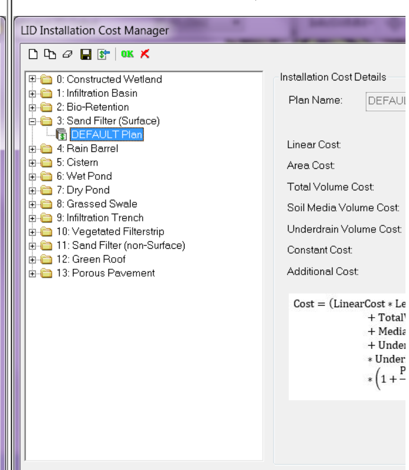
 **New Cost**

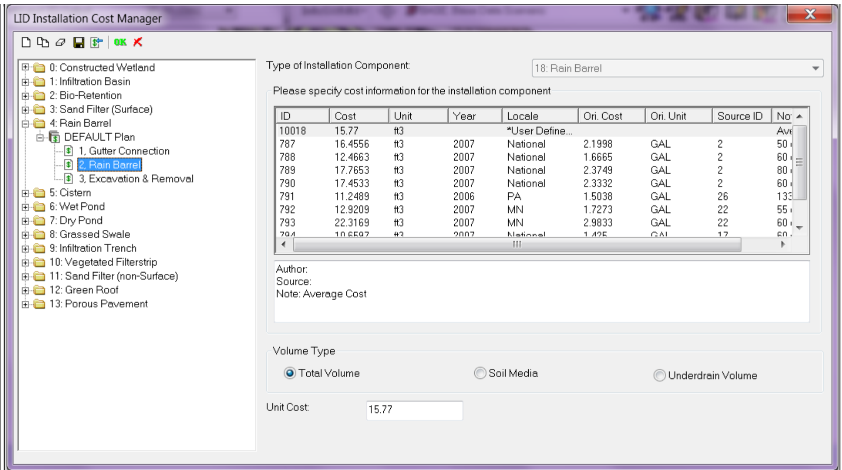
 **Clone Cost**

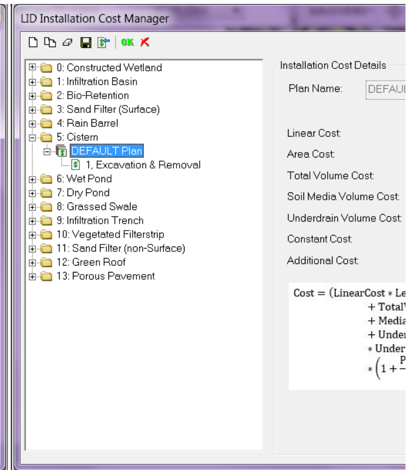
 **Delete Cost**  **Save**  **Import Cost**

 **Okay**  **Close**

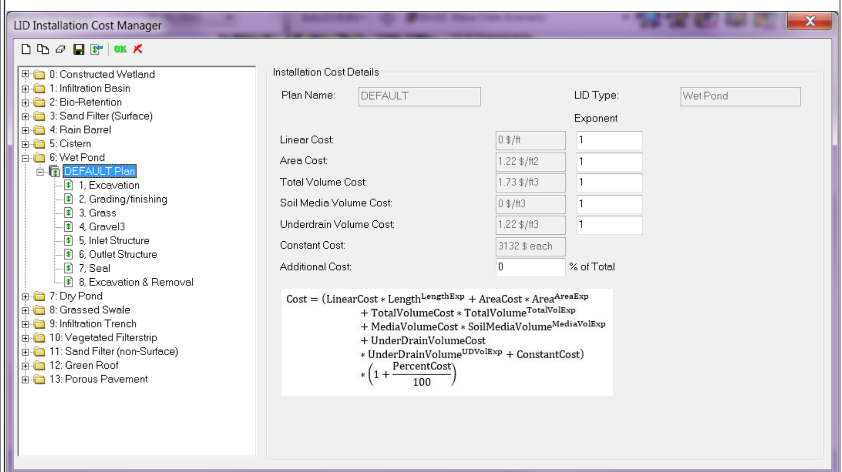
Table 1. LID Installation Cost Manager Cost Categories

0 Constructed Wetlands 	**1 Infiltration Basin** 
2 Bio-Retention  $$\begin{aligned}Cost = (&LinearCost * Length^{LengthExp} + AreaCost * Area^{AreaExp}\\&+ TotalVolumeCost * TotalVolume^{TotalVolExp}\\&+ MediaVolumeCost * SoilMediaVolume^{MediaVolExp}\\&+ UnderDrainVolumeCost\\&* UnderDrainVolume^{UDVolExp} + ConstantCost)\\&* \left(1 + \frac{PercentCost}{100}\right)\end{aligned}$$	**3 Sand Filter Surface)** 
4 Rain Barrel	**5 Cistern**

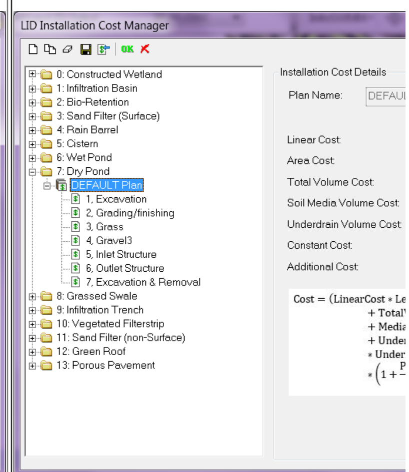




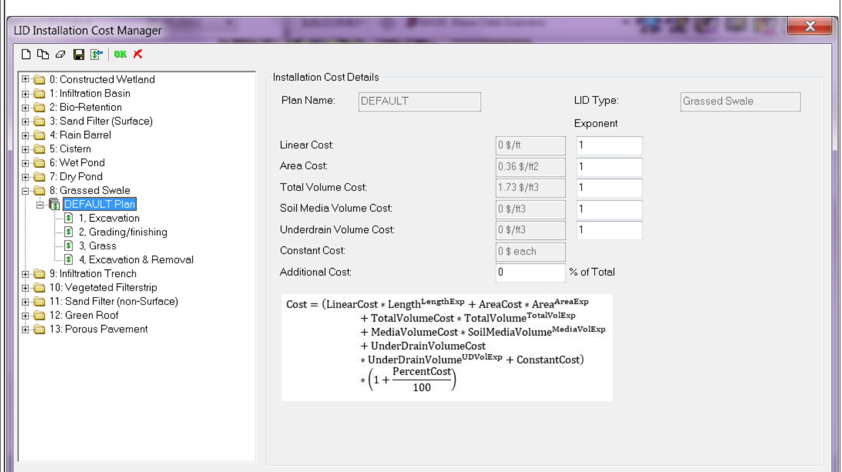
6 Wet Pond



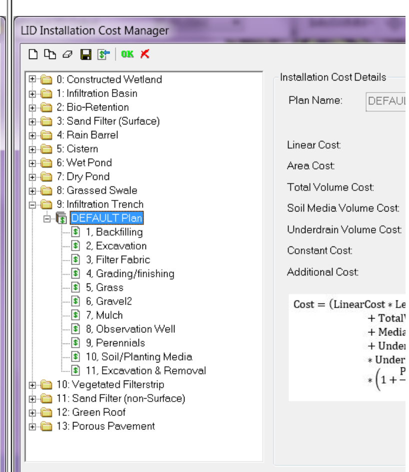
7 Dry Pond



8 Grassed Swales

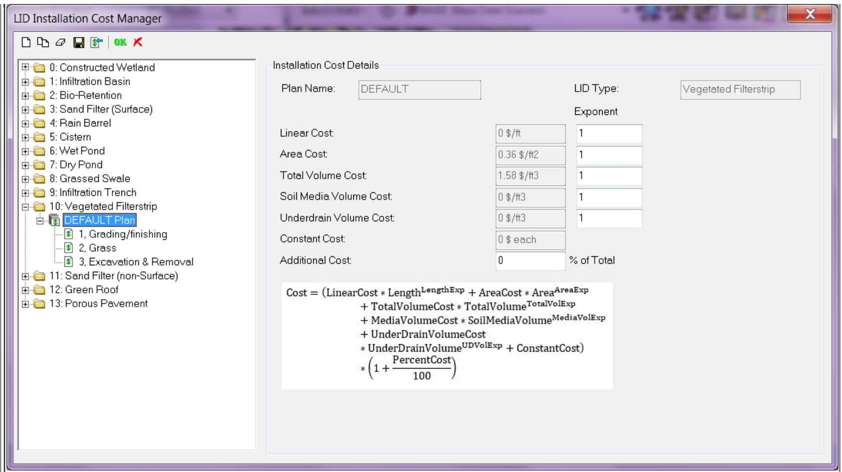


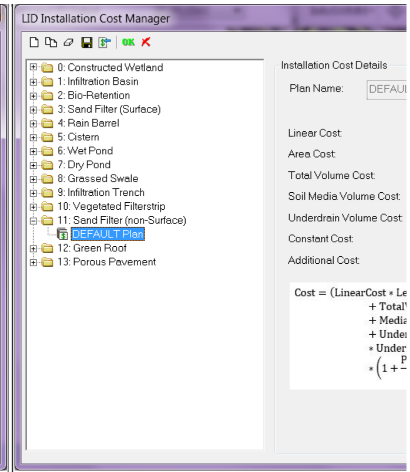
9 Infiltration Trench



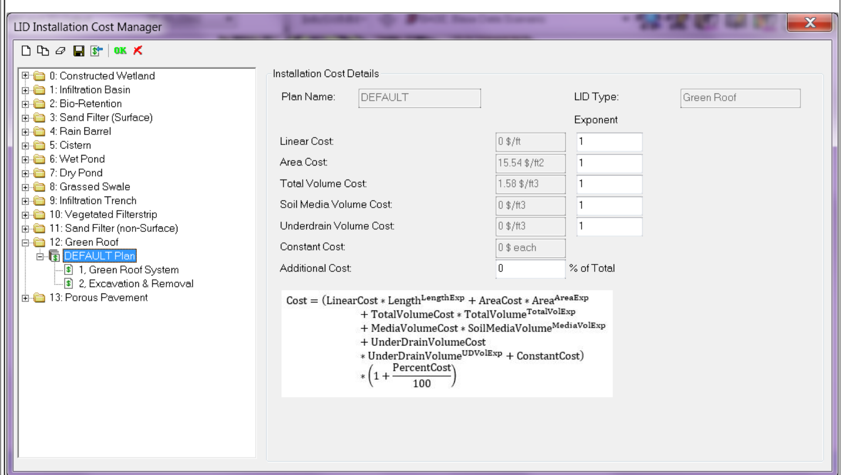
10 Vegetated Filterstrip

11 and Filter (Non Surface)

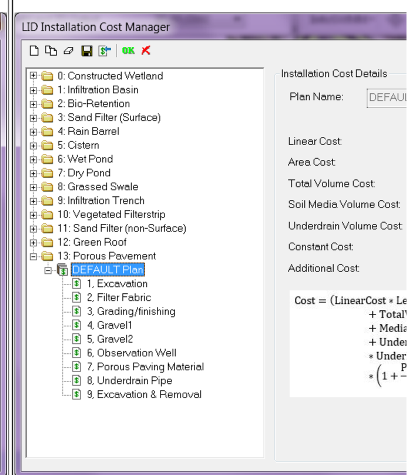




12 Green Roof



13 Porous Pavement

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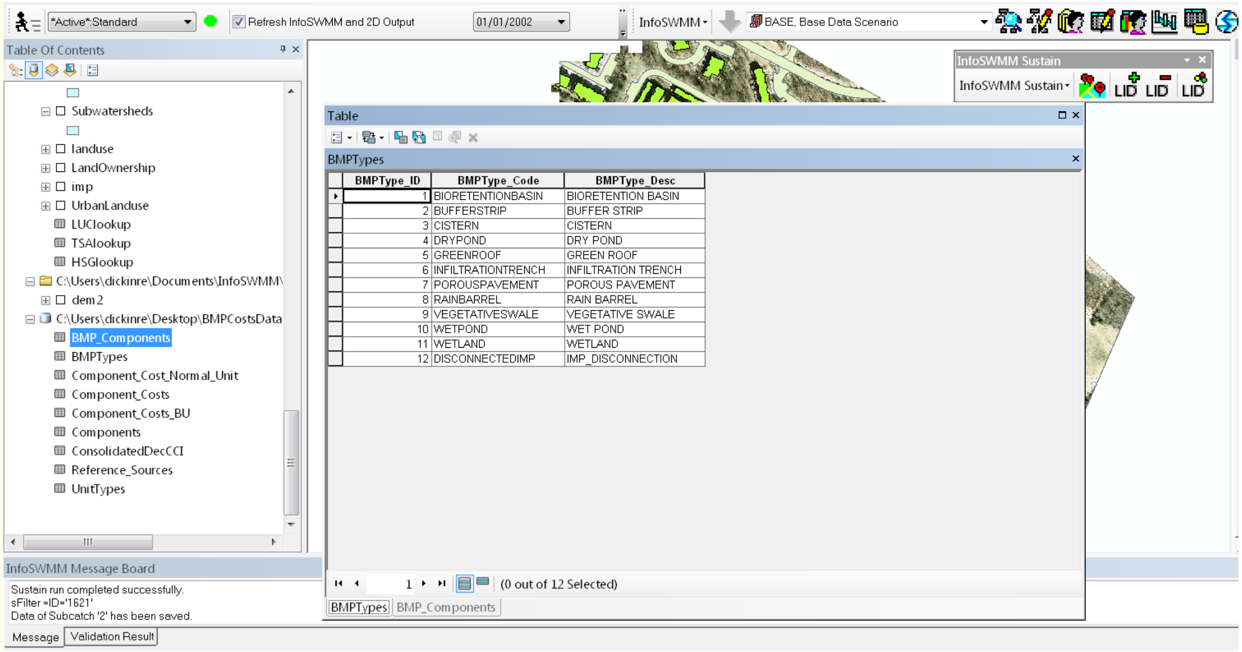
BMPCostsData.MDB

The file BMPCostsData.MDB (part of InfoSWMM Sustain 3.0) has the following tables

- BMP_Components
- BMPTypes
- Component_Cost_Normal_Unit
- Component_Costs
- Component_Costs_BU
- Components
- ConsolidatedDecCCI
- Reference_Sources
- UnitTypes

BMPType_Desc
BIORETENTION BASIN
BUFFER STRIP
CISTERN
DRY POND
GREEN ROOF
INFILTRATION TRENCH
POROUS PAVEMENT
RAIN BARREL
VEGETATIVE SWALE
WET POND
WETLAND
Impervious DISCONNECTION



*Active*Standard
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C:\Users\dickinre\Desktop\BMPCostsData
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Component_Costs_BU
Components
ConsolidatedDecCCI
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UnitTypes
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Table
BMPTypes
BMPType_ID BMPType_Code BMPType_Desc
1 BIORETENTIONBASIN BIORETENTION BASIN
2 BUFFERSTRIP BUFFER STRIP
3 CISTERN CISTERN
4 DRYPOND DRY POND
5 GREENROOF GREEN ROOF
6 INFILTRATIONTRENCH INFILTRATION TRENCH
7 POROUSPAVEMENT POROUS PAVEMENT
8 RAINBARREL RAIN BARREL
9 VEGETATIVESWALE VEGETATIVE SWALE
10 WETPOND WET POND
11 WETLAND WETLAND
12 DISCONNECTEDIMP IMP_DISCONNECTION
(0 out of 12 Selected)
BMPTypes
BMP_Components
InfoSWMM Message Board
Sustain run completed successfully.
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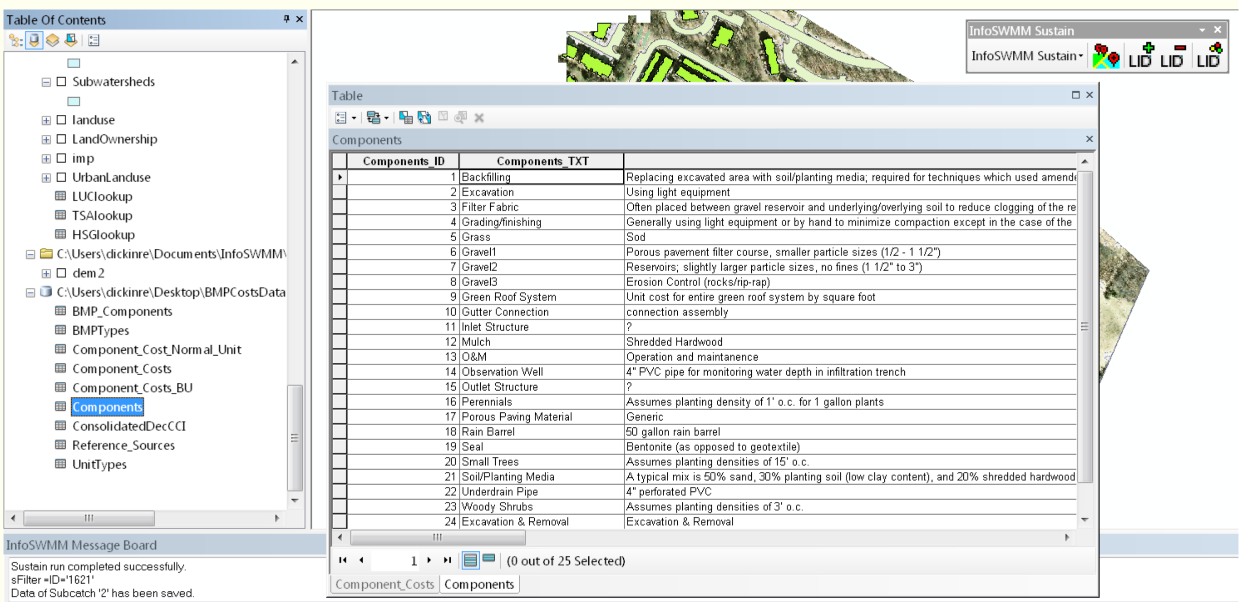
Data of Subcatch '2' has been saved.
Message
Validation Result



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BMPTypes
Component_Cost_Normal_Unit
Component_Costs
Component_Costs_BU
Components
ConsolidatedDecCCI
Reference_Sources
UnitTypes
InfoSWMM Sustain
LID
Table
Components
Components_ID Components_TXT
1 Backfilling Replacing excavated area with soil/planting media; required for techniques which used amende
2 Excavation Using light equipment
3 Filter Fabric Often placed between gravel reservoir and underlying/overlying soil to reduce clogging of the re
4 Grading/finishing Generally using light equipment or by hand to minimize compaction except in the case of the
5 Grass Sod
6 Gravel1 Porous pavement filter course, smaller particle sizes (1/2 - 1 1/2")
7 Gravel2 Reservoirs; slightly larger particle sizes, no fines (1 1/2" to 3")
8 Gravel3 Erosion Control (rocks/rip-rap)
9 Green Roof System Unit cost for entire green roof system by square foot
10 Gutter Connection connection assembly
11 Inlet Structure ?
12 Mulch Shredded Hardwood
13 O&M Operation and maintanence
14 Observation Well 4" PVC pipe for monitoring water depth in infiltration trench
15 Outlet Structure ?
16 Perennials Assumes planting density of 1' o.c. for 1 gallon plants
17 Porous Paving Material Generic
18 Rain Barrel 50 gallon rain barrel
19 Seal Bentonite (as opposed to geotextile)
20 Small Trees Assumes planting densities of 15' o.c.
21 Soil/Planting Media A typical mix is 50% sand, 30% planting soil (low clay content), and 20% shredded hardwood
22 Underdrain Pipe 4" perforated PVC
23 Woody Shrubs Assumes planting densities of 3' o.c.
24 Excavation & Removal Excavation & Removal
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Component_Costs
Components
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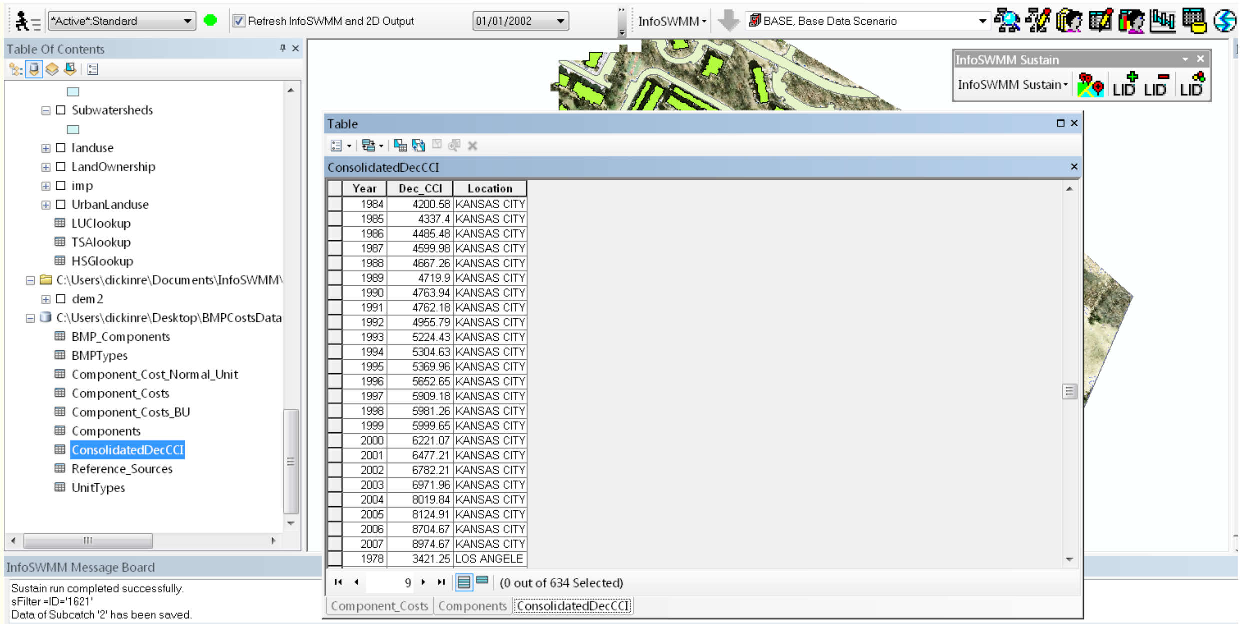

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InfoSWMM Sustain
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Table
ConsolidatedDecCCI
Year Dec_CCI Location
1984 4200.58 KANSAS CITY
1985 4337.4 KANSAS CITY
1986 4485.48 KANSAS CITY
1987 4599.98 KANSAS CITY
1988 4667.26 KANSAS CITY
1989 4719.9 KANSAS CITY
1990 4763.94 KANSAS CITY
1991 4762.18 KANSAS CITY
1992 4955.79 KANSAS CITY
1993 5224.43 KANSAS CITY
1994 5304.63 KANSAS CITY
1995 5369.96 KANSAS CITY
1996 5652.65 KANSAS CITY
1997 5909.18 KANSAS CITY
1998 5981.26 KANSAS CITY
1999 5999.65 KANSAS CITY
2000 6221.07 KANSAS CITY
2001 6477.21 KANSAS CITY
2002 6782.21 KANSAS CITY
2003 6971.96 KANSAS CITY
2004 8019.84 KANSAS CITY
2005 8124.91 KANSAS CITY
2006 8704.67 KANSAS CITY
2007 8974.67 KANSAS CITY
1978 3421.25 LOS ANGELE
9
(0 out of 634 Selected)
Component_Costs
Components
ConsolidatedDecCCI
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Sustain run completed successfully.
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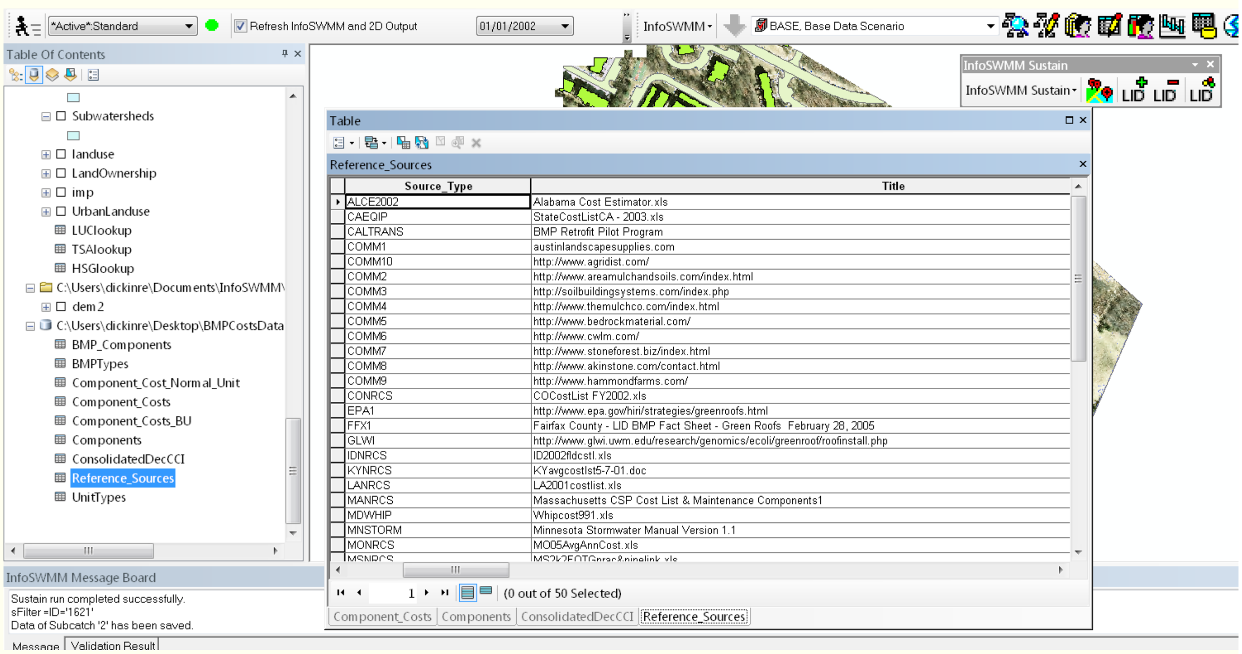

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Table
Reference_Sources
Source_Type Title
ALCE2002 Alabama Cost Estimator.xls
CAEQIP StateCostListCA - 2003.xls
CALTRANS BMP Retrofit Pilot Program
COMM1 austinlandscapesupplies.com
COMM10 http://www.agridist.com/
COMM2 http://www.areamulchandsoils.com/index.html
COMM3 http://soilbuildingsystems.com/index.php
COMM4 http://www.themulchco.com/index.html
COMM5 http://www.bedrockmaterial.com/
COMM6 http://www.cwlm.com/
COMM7 http://www.stoneforest.biz/index.html
COMM8 http://www.akinstone.com/contact.html
COMM9 http://www.hammondfarms.com/
CONRCS COCostList FY2002.xls
EPA1 http://www.epa.gov/hiri/strategies/greenroofs.html
FFX1 Fairfax County - LID BMP Fact Sheet - Green Roofs February 28, 2005
GLWI http://www.glwi.uwm.edu/research/genomics/ecoli/greenroof/roofinstall.php
IDNRCS ID2002fldcstl.xls
KYNRCS KYavgcostlst5-7-01.doc
LANRCS LA2001costlist.xls
MANRCS Massachusetts CSP Cost List & Maintenance Components1
MDWHIP Whipcost991.xls
MNSTORM Minnesota Stormwater Manual Version 1.1
MONRCS MO05AvgAnnCost.xls
1
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Message
Validation Result

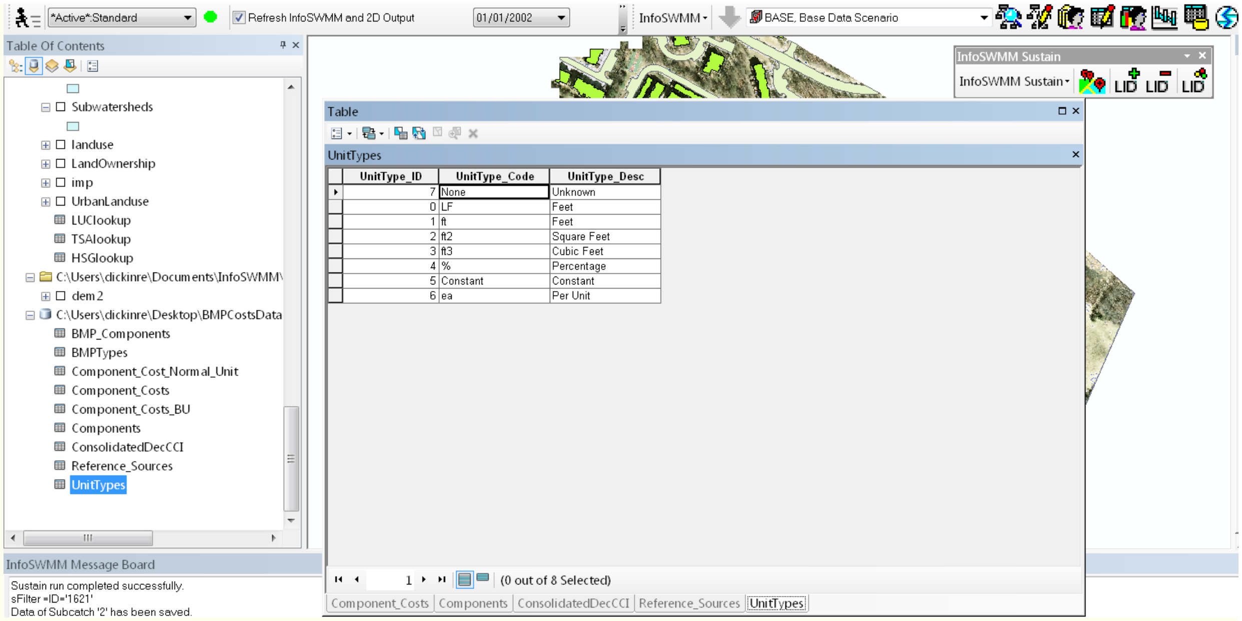
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Table
UnitTypes
UnitType_ID | UnitType_Code | UnitType_Desc
7 | None | Unknown
0 | LF | Feet
1 | ft | Feet
2 | ft2 | Square Feet
3 | ft3 | Cubic Feet
4 | % | Percentage
5 | Constant | Constant
6 | ea | Per Unit
(0 out of 8 Selected)
Component_Costs | Components | ConsolidatedDecCCI | Reference_Sources | UnitTypes
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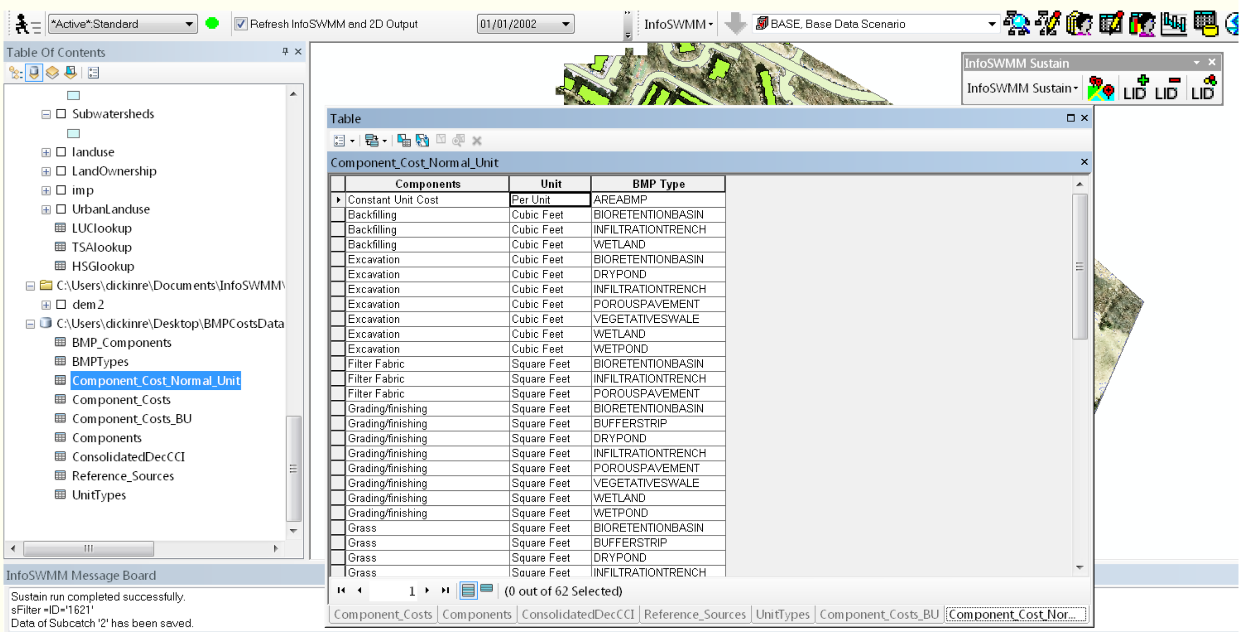
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BMPTypes
Component_Cost_Normal_Unit
Component_Costs
Component_Costs_BU
Components
ConsolidatedDecCCI
Reference_Sources
UnitTypes
InfoSWMM Sustain
Table
Component_Cost_Normal_Unit
Components | Unit | BMP Type
Constant Unit Cost | Per Unit | AREABMP
Backfilling | Cubic Feet | BIORETENTIONBASIN
Backfilling | Cubic Feet | INFILTRATIONTRENCH
Backfilling | Cubic Feet | WETLAND
Excavation | Cubic Feet | BIORETENTIONBASIN
Excavation | Cubic Feet | DRYPOND
Excavation | Cubic Feet | INFILTRATIONTRENCH
Excavation | Cubic Feet | POROUSPAVEMENT
Excavation | Cubic Feet | VEGETATIVESWALE
Excavation | Cubic Feet | WETLAND
Excavation | Cubic Feet | WETPOND
Filter Fabric | Square Feet | BIORETENTIONBASIN
Filter Fabric | Square Feet | INFILTRATIONTRENCH
Filter Fabric | Square Feet | POROUSPAVEMENT
Grading/finishing | Square Feet | BIORETENTIONBASIN
Grading/finishing | Square Feet | BUFFERSTRIP
Grading/finishing | Square Feet | DRYPOND
Grading/finishing | Square Feet | INFILTRATIONTRENCH
Grading/finishing | Square Feet | POROUSPAVEMENT
Grading/finishing | Square Feet | VEGETATIVESWALE
Grading/finishing | Square Feet | WETLAND
Grading/finishing | Square Feet | WETPOND
Grass | Square Feet | BIORETENTIONBASIN
Grass | Square Feet | BUFFERSTRIP
Grass | Square Feet | DRYPOND
Grass | Square Feet | INFILTRATIONTRENCH
(0 out of 62 Selected)
Component_Costs | Components | ConsolidatedDecCCI | Reference_Sources | UnitTypes | Component_Costs_BU | Component_Cost_Nor...
InfoSWMM Message Board
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LID
LID
LID

What is the Design Report in InfoSWMM Sustain

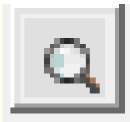
The major tasks in using InfoSWMM Sustain are the following:

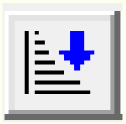
- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

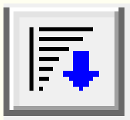
Design Report shows the LID Candidate’s optimized design parameters for:

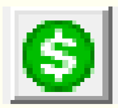
1. The LID ID
2. The Type of LID
3. The ID of the Subcatchment with the LID
4. The name of the LID Control from the Operation Tab of the InfoSWMM

   Browser
5. The Number of Units
6. the Width of the LID Unit
7. The Area of Each LID Unit
8. The Soil Thickness
9. You choose which of the Best Solutions are shown and also exported to the infoSWMM LID Usage DB Table using the Apply to InfoSWMM Command

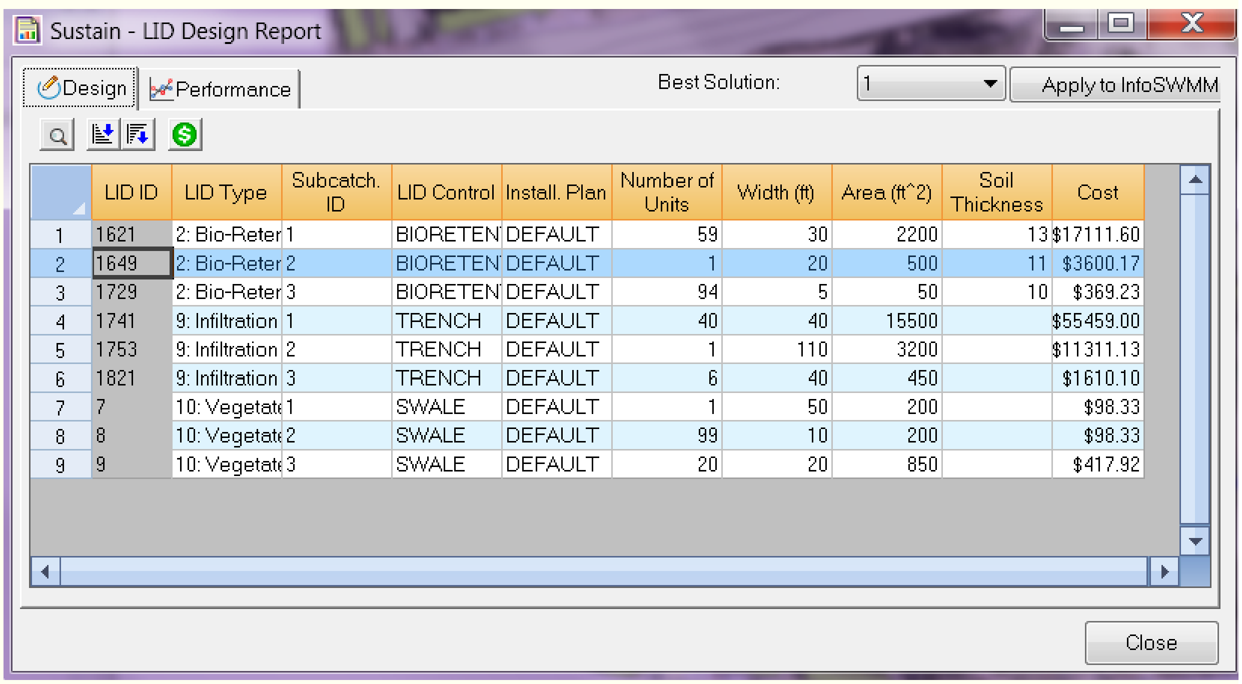
 Zoom to a LID

 Sort Rows Ascending

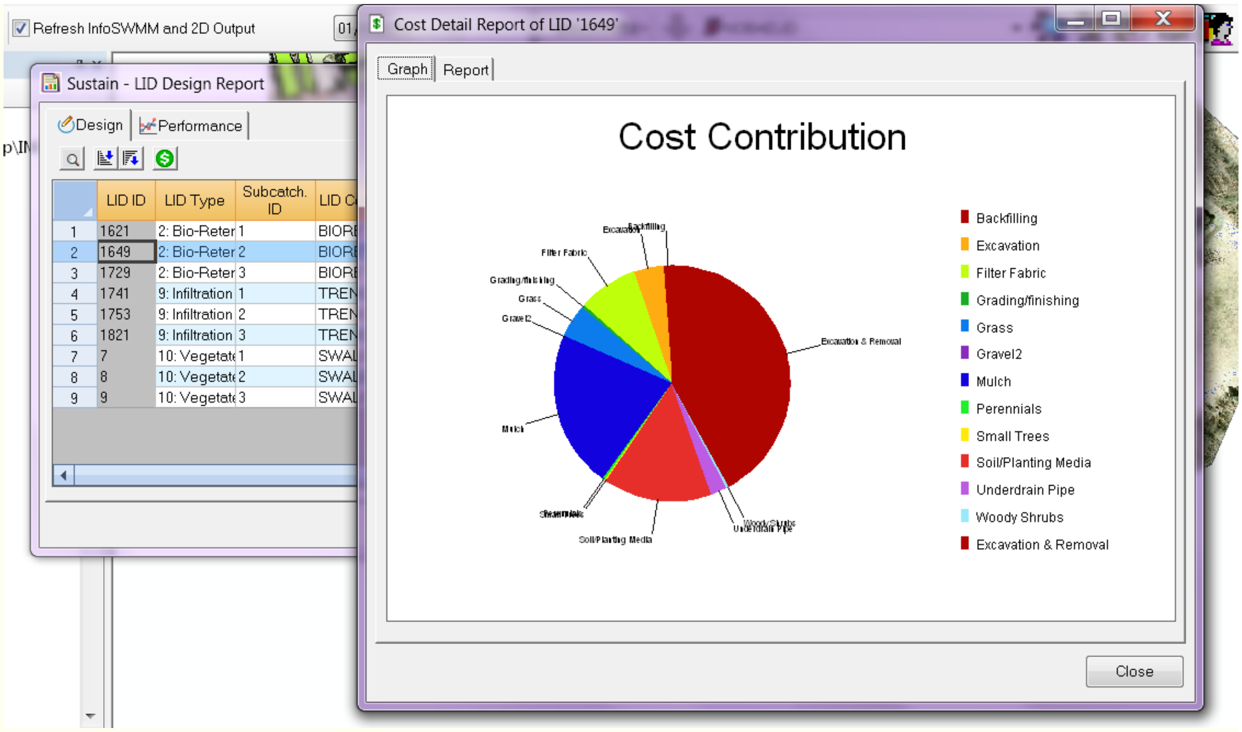
 Sort Rows Decending

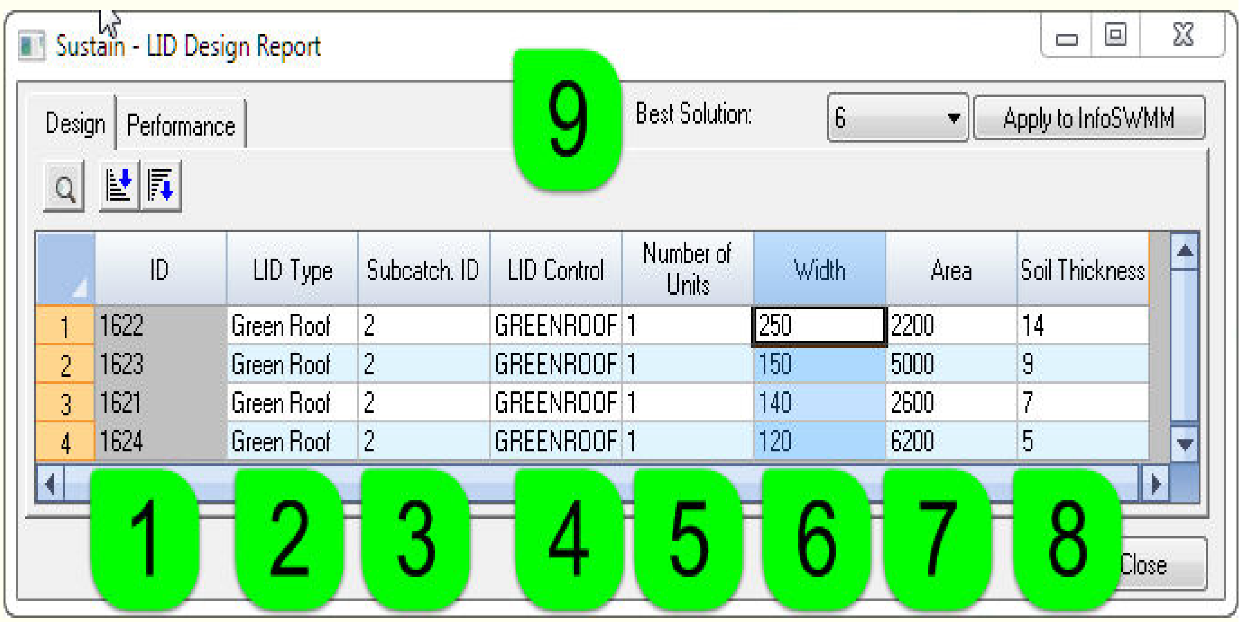


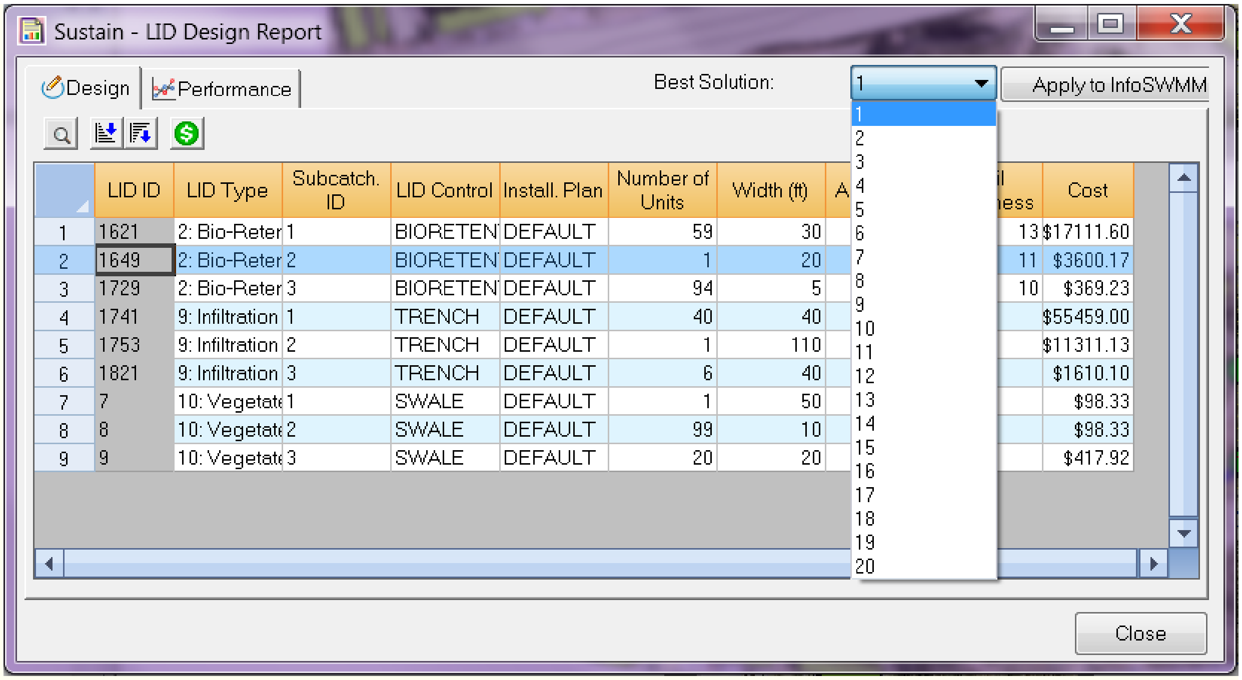
LID Costs



	LID ID	LID Type	Subcatch. ID	LID Control	Install. Plan	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness	Cost
1	1621	2: Bio-Reter	1	BIORETEN	DEFAULT	59	30	2200	13	$17111.60
2	1649	2: Bio-Reter	2	BIORETEN	DEFAULT	1	20	500	11	$3600.17
3	1729	2: Bio-Reter	3	BIORETEN	DEFAULT	94	5	50	10	$369.23
4	1741	9: Infiltration	1	TRENCH	DEFAULT	40	40	15500		$55459.00
5	1753	9: Infiltration	2	TRENCH	DEFAULT	1	110	3200		$11311.13
6	1821	9: Infiltration	3	TRENCH	DEFAULT	6	40	450		$1610.10
7	7	10: Vegetat	1	SWALE	DEFAULT	1	50	200		$98.33
8	8	10: Vegetat	2	SWALE	DEFAULT	99	10	200		$98.33
9	9	10: Vegetat	3	SWALE	DEFAULT	20	20	850		$417.92


Cost Detail Report of LID '1649'
Graph
Report
Cost Contribution
Backfilling
Excavation
Filter Fabric
Grading/finishing
Grass
Gravel2
Mulch
Perennials
Small Trees
Soil/Planting Media
Underdrain Pipe
Woody Shrubs
Excavation & Removal
Close
Sustain - LID Design Report
Design
Performance
Refresh InfoSWMM and 2D Output


Sustain - LID Design Report
Design
Performance
Best Solution:
6
Apply to InfoSWMM
ID
LID Type
Subcatch. ID
LID Control
Number of Units
Width
Area
Soil Thickness
1622 Green Roof 2 GREENROOF 1 250 2200 14
1623 Green Roof 2 GREENROOF 1 150 5000 9
1621 Green Roof 2 GREENROOF 1 140 2600 7
1624 Green Roof 2 GREENROOF 1 120 6200 5
Close
1 2 3 4 5 6 7 8 9



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What is the Performance Report

The major tasks in using InfoSWMM Sustain are the following:

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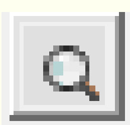
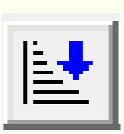
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

Performance Report is for every Subcatchment's runoff and pollutant reduction. The report shows for each

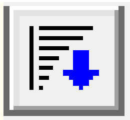
1. Subcatchment ID
2. The Best Solution Cost
3. The Runoff Control Result
4. The Water Quality Control Result for
5. Each Pollutant



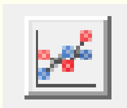
Zoom to a LID

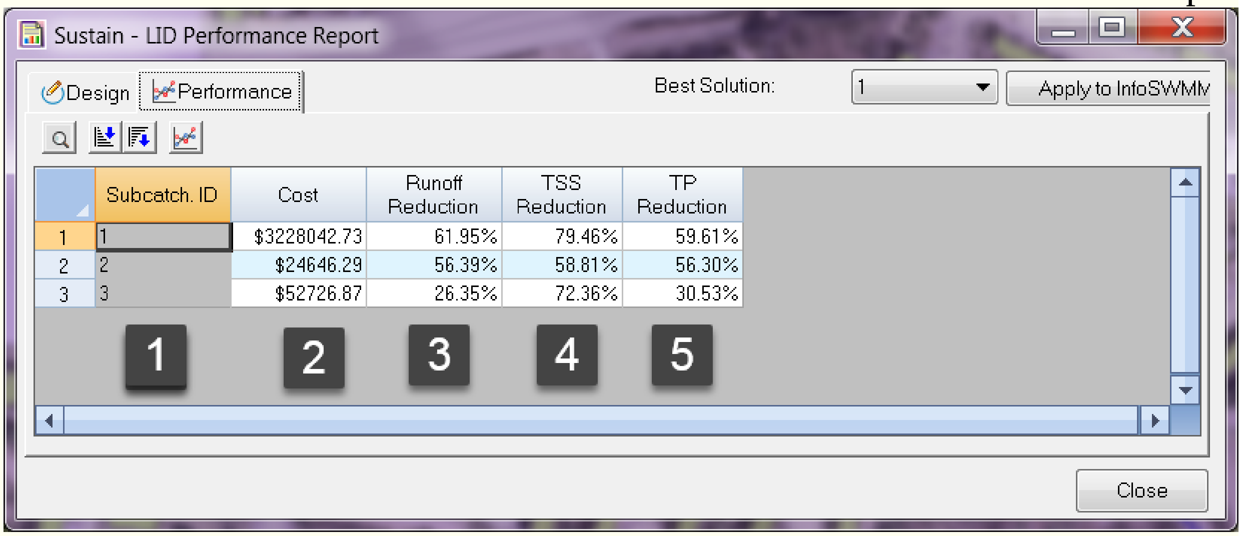


Sort Rows Ascending

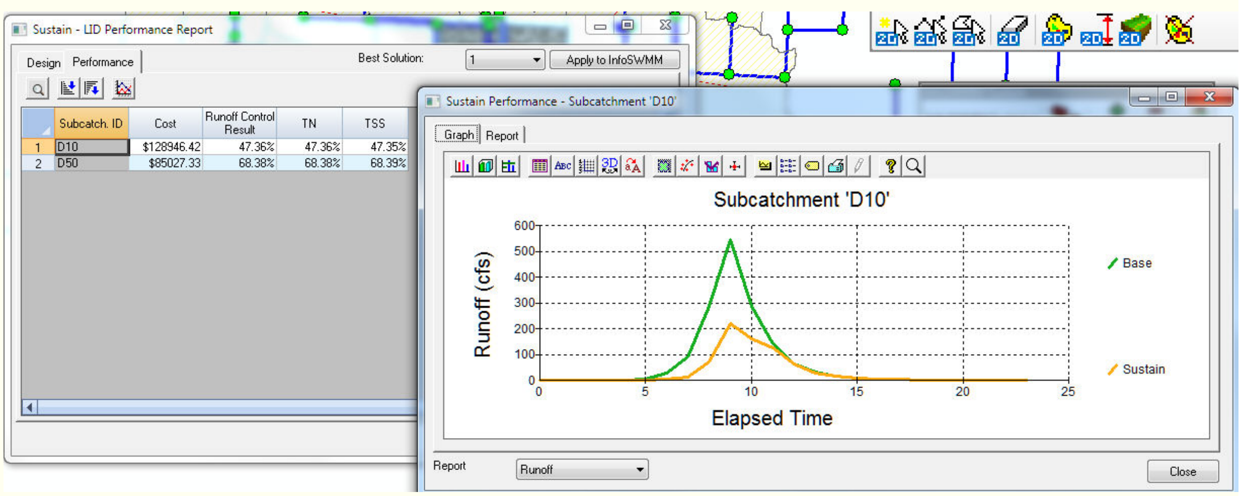


Sort Rows Decending

 Performance Graph



the Performance Graph Comparison Icon. the graphs shows the comparison between the Sustain optimization and the Base Scenario.



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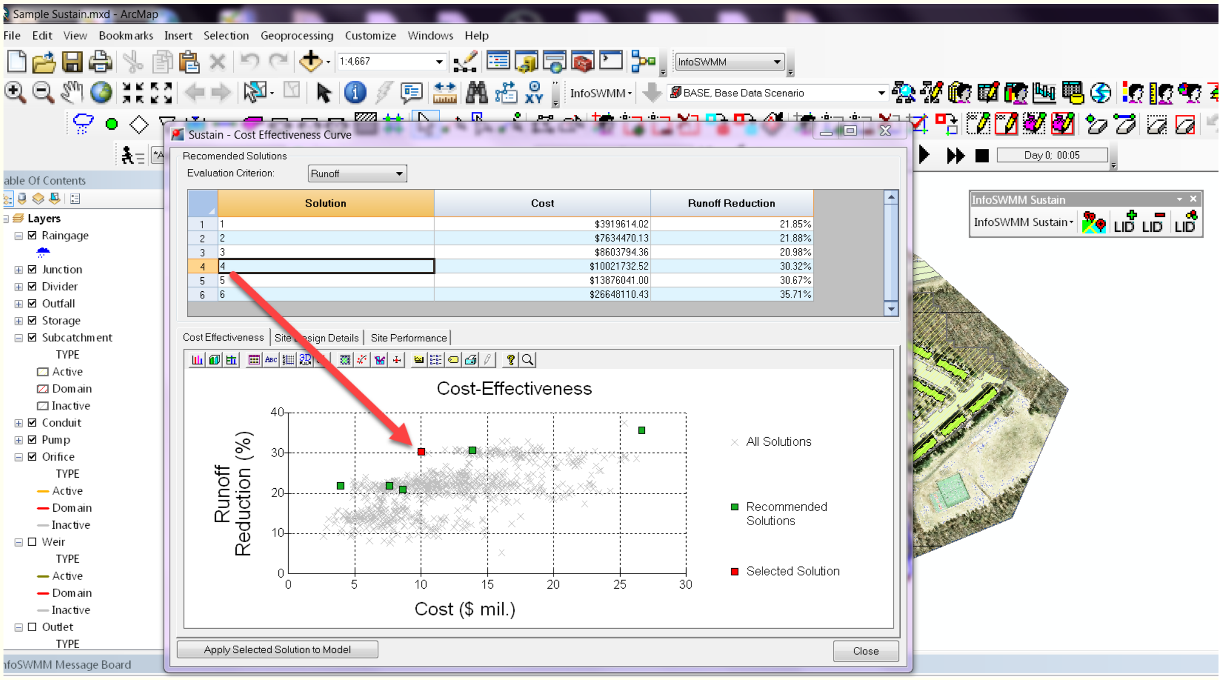
Cost Effectiveness Curve

The major tasks in using InfoSWMM Sustain are the following:

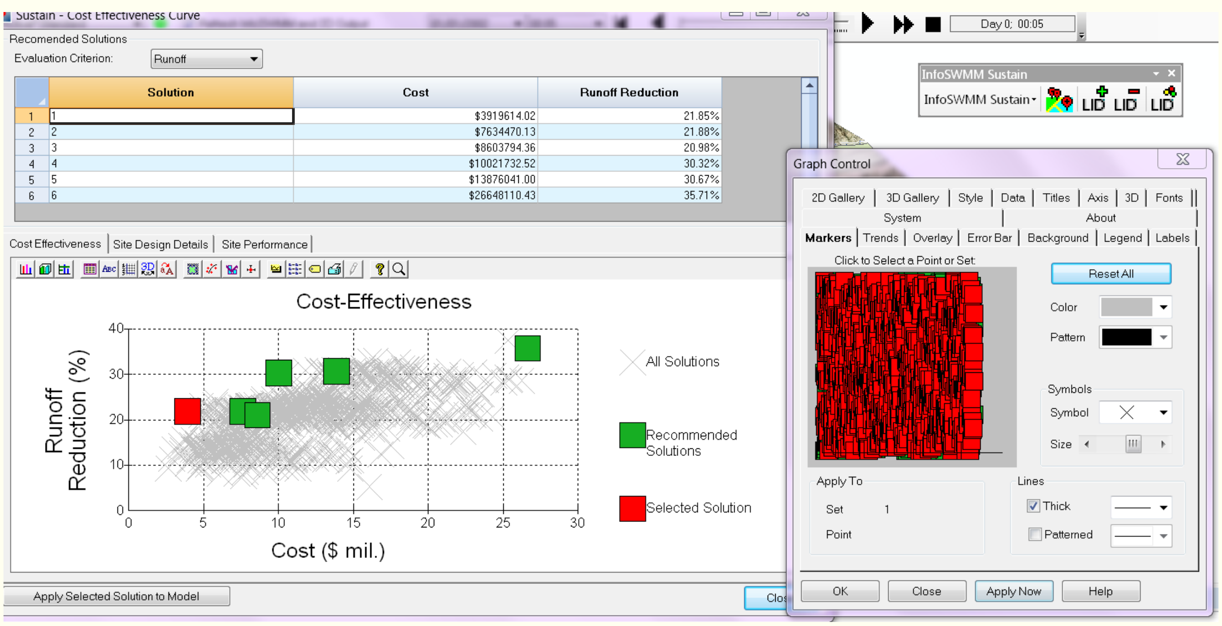
- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

The final analysis component of the post-processor is creating a cost-effectiveness curve to facilitate decision making. The post-processor can generate and display this curve directly from the output only when the NSGA-II search method is used in the optimization module. It displays the curve one pollutant constituent at a time; however, the post-processor still allows a user to evaluate the resulting benefit to other constituents gained from optimizing performance for a single constituent. For example, one can evaluate how optimizing flow reductions impacts sediment reductions. Each optimization run generates two files from which the post-processor derives the cost-effectiveness curve: (1) AllSolutions.out, which contains cost-benefit summaries for each intermediate optimization run, and (2) BestSolutions.out, which contains cost-benefit summaries for the final population of points that constitutes the optimum frontier. Figure 3-33 shows an example of a cost-effectiveness curve for sediment load reduction.

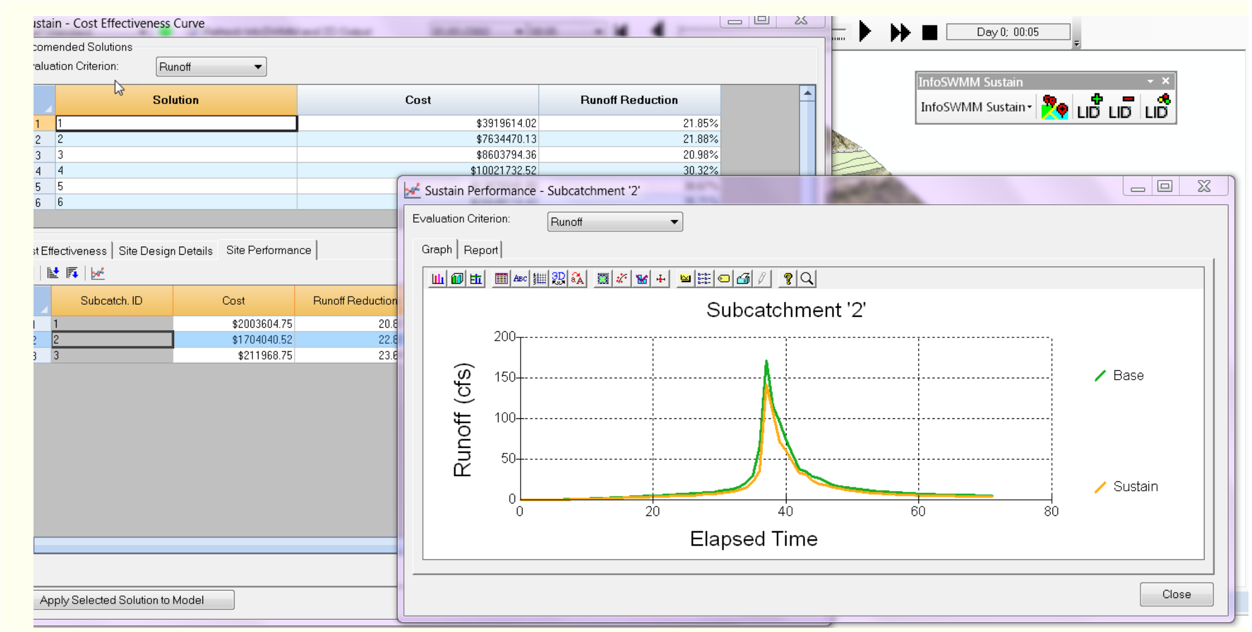
New! If you click on the recommended Solutions row the exact point on the Cost Effectiveness Curve will turn RED



How to Label the points on the Graph. Use the System/Labels Icon on the Cos-Effectiveness Graph to change the look of the Cost Effectiveness Curve.



You can see the performance curves for the Solution ID by clicking on the Performance Icon



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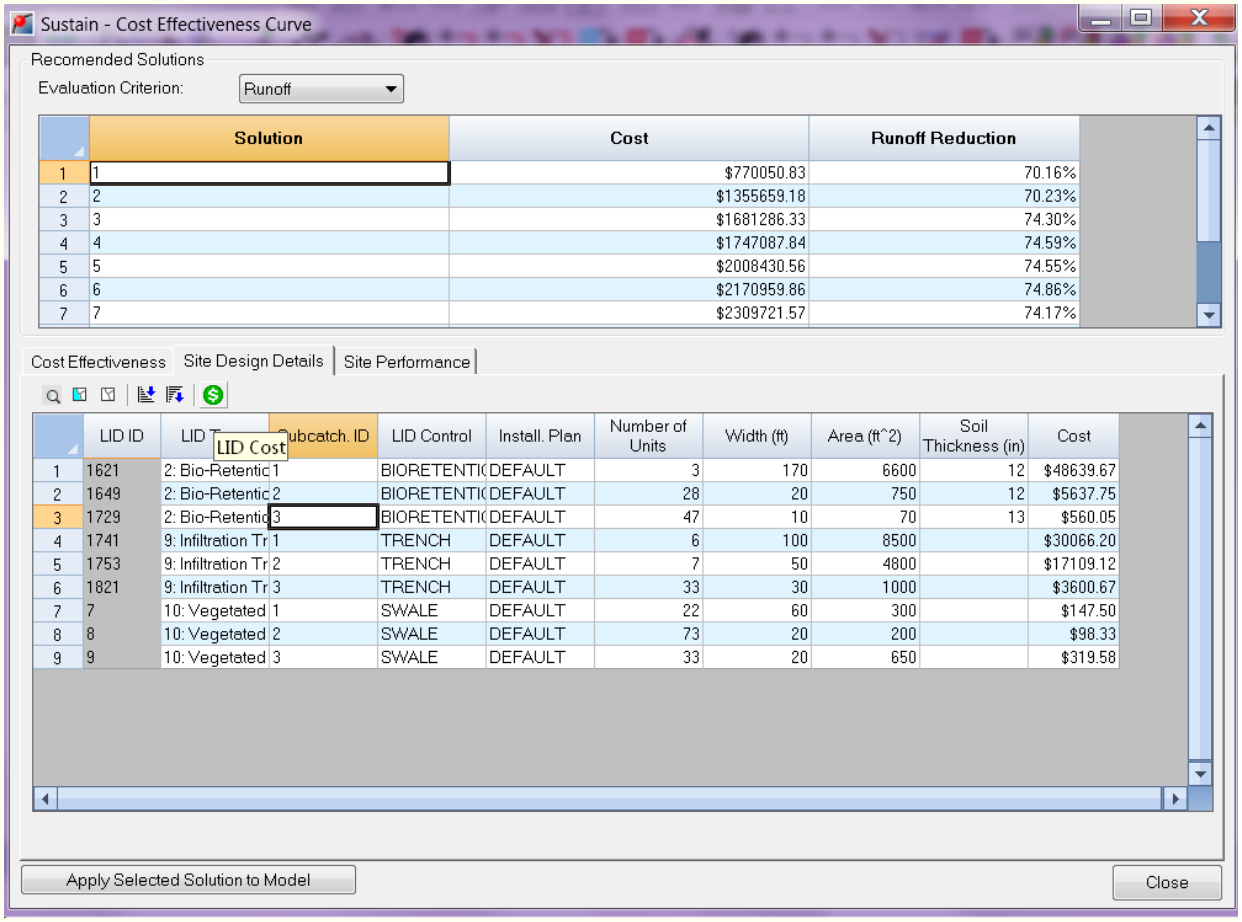
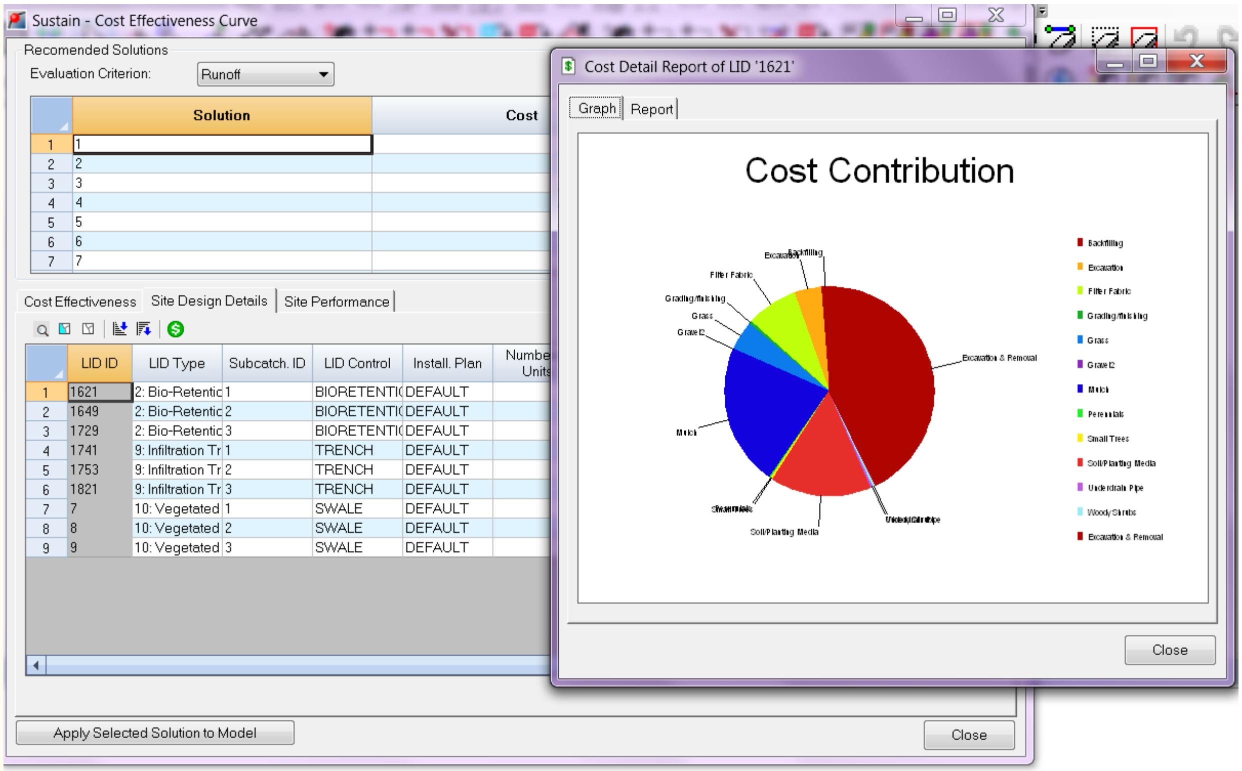
Site Design Details

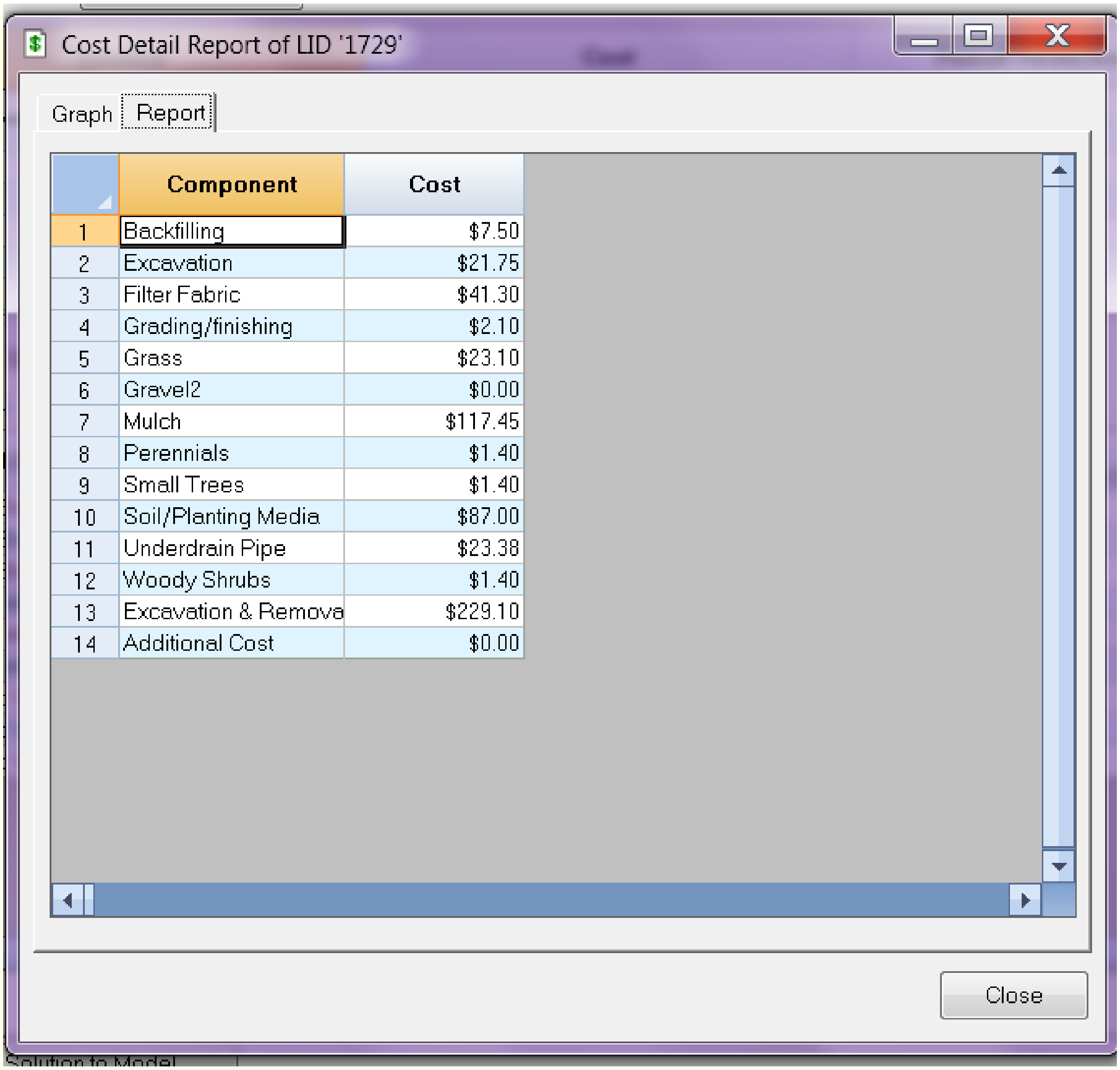
Site Design Details shows the cost install plan, the optimized number of LID units for the LID control, the optimized width, the optimized, the optimized soil thickness and the LID total cost.



The icon LID Cost will show you the cost contribution by category for each of the optimized LID's, SuDS or WSuDs.



Click on the Report Tab to see a grid of costs for the optimized LID



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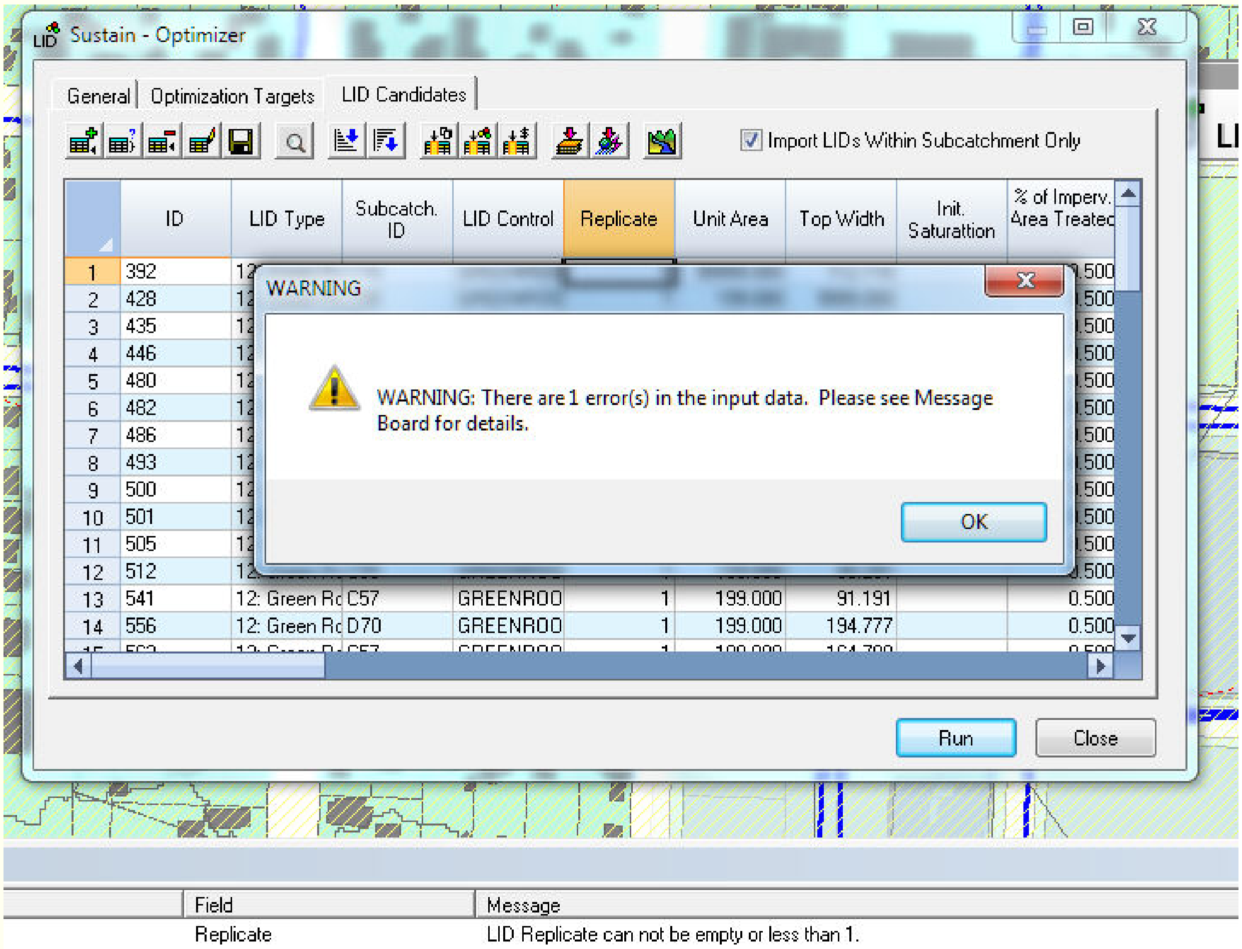
Sustain Error Messages

Error or warning messages when you do not have the proper optimization parameters



SUSTAIN-101: Runoff Control Target should be greater than 0.

SUSTAIN-102: Pollutant Control Target should be greater than 0.

SUSTAIN-001: Subcatchment ID can not be empty.

SUSTAIN-002: Subcatchment ID could not be found.

SUSTAIN-003: LID Control can not be empty.

SUSTAIN-004: LID Replicate can not be empty or less than 1.

SUSTAIN-005: Range of LID

units is too high. (Max Unit - Min Unit) / Unit Step > 1000.

SUSTAIN-006: Range of LID

width is too high. (Max Width - Min Width) / Width Step > 1000.

SUSTAIN-007: Range of LID

soil thickness is too high. (Max Thickness - Min Thickness) / Thickness Step > 1000.

SUSTAIN-008: Range of LID

area is too high. (Max Area - Min Area) / Area Step > 1000.

SUSTAIN-009: Max area of all LID candidates associated with Subcatchment '[Subcatchment ID]' is too high. Sum(Max Area * Max Unit) > 5 * Subcatchment Area.

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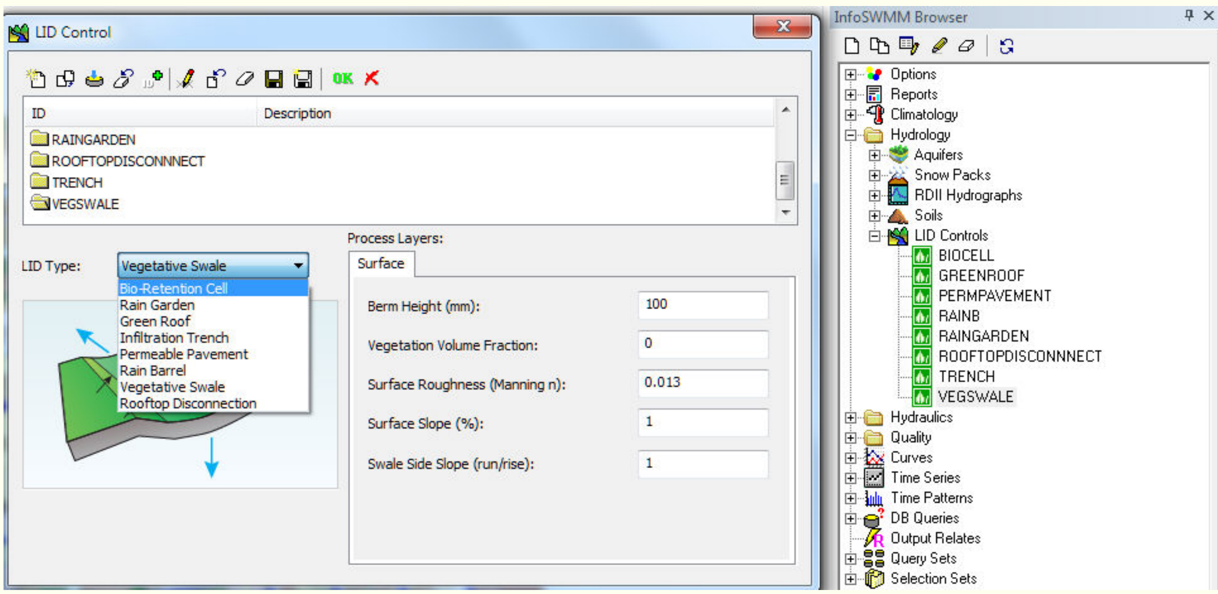
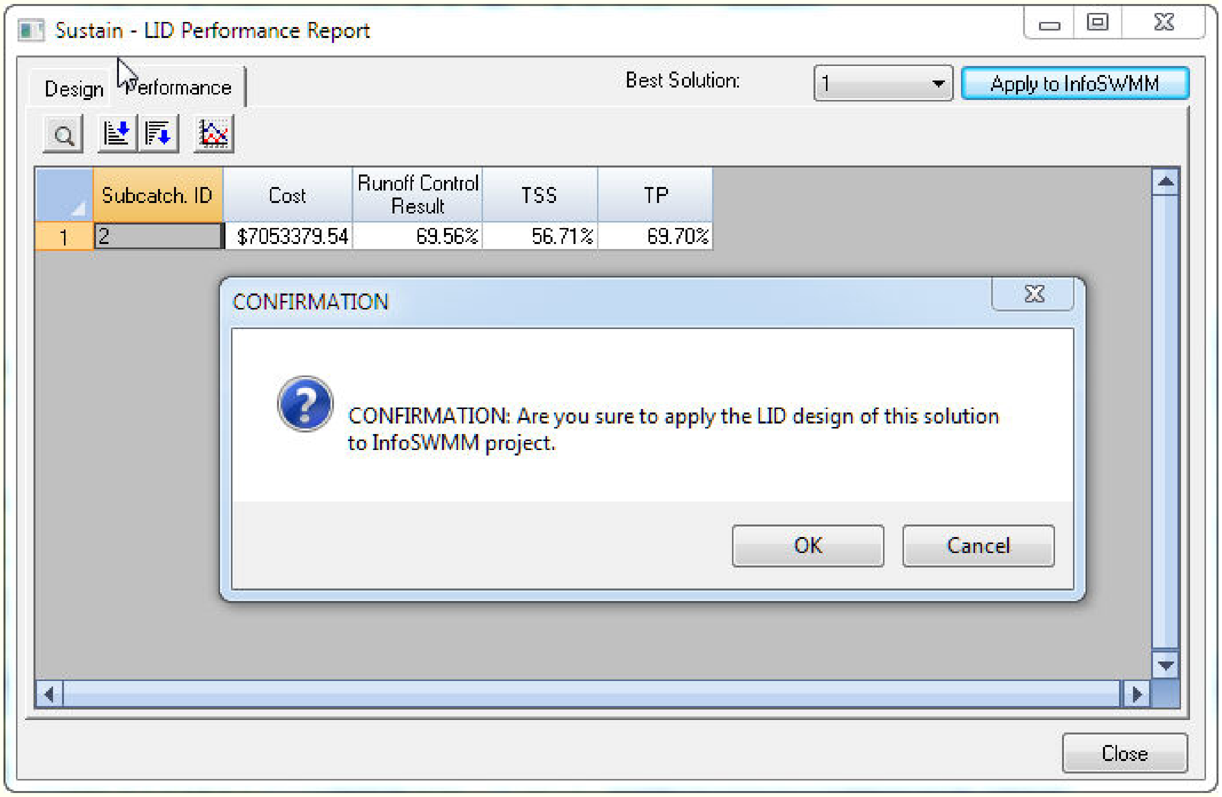
InfoSWMM LID Controls

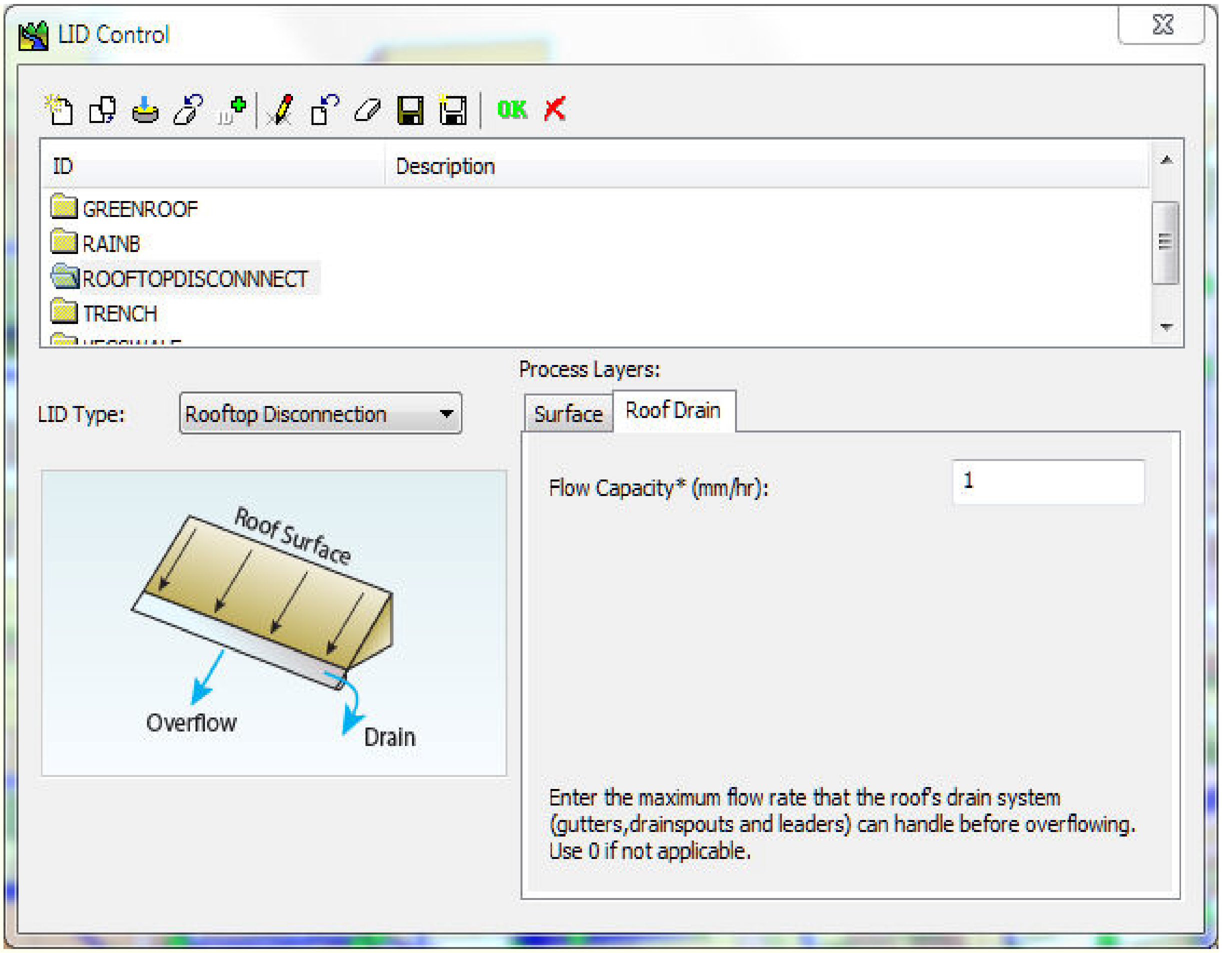
There are eight types of LID Controls in SWMM5 5.10.011 and InfoSWMM.

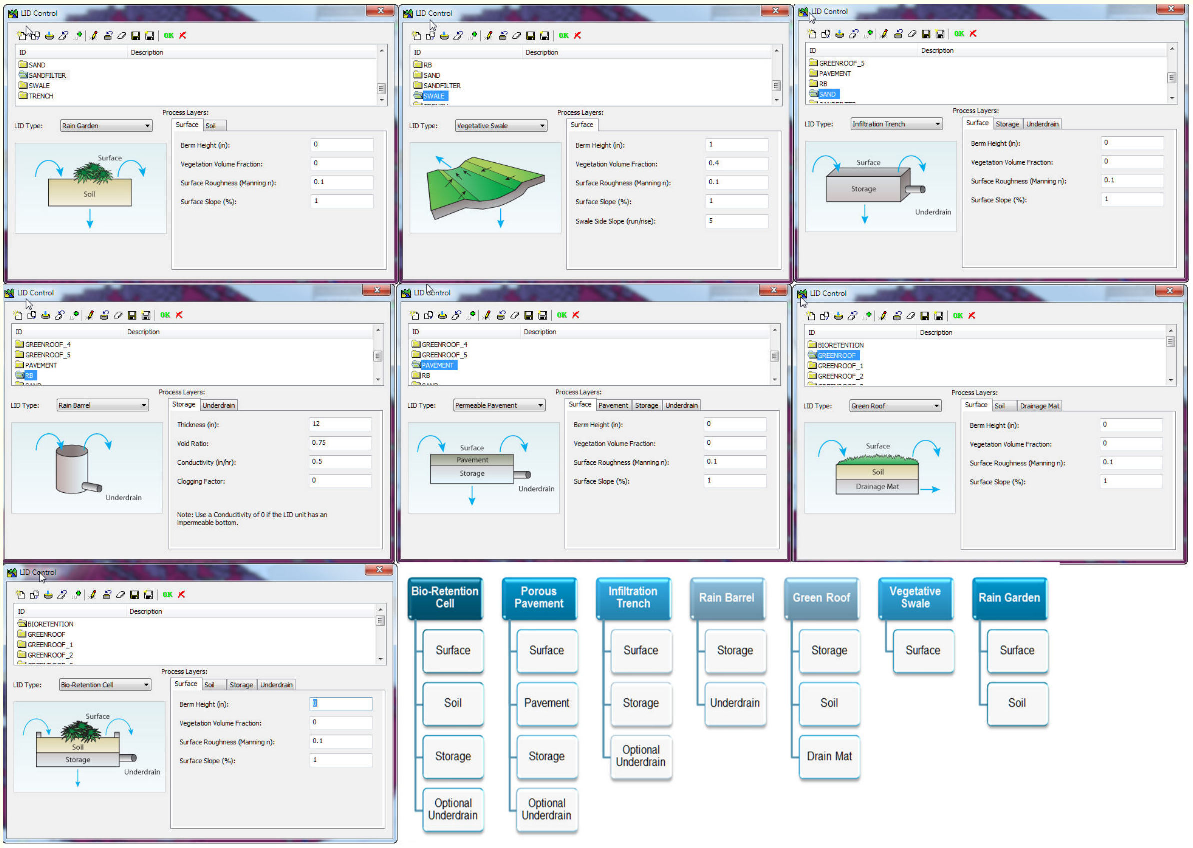
New to infoSWMM v14.7

are set defaults for the LID Controls. The LID Controls are defined in the Attribute Browser (AB) in the Operations Tab. If you click on Apply to InfoSWMM then the Optimized LID's will be exported to the LID Usage Table




Sustain - LID Performance Report
Design
Performance
Best Solution:
1
Apply to InfoSWMM
Subcatch. ID
Cost
Runoff Control Result
TSS
TP
1
2
$7053379.54
69.56%
56.71%
69.70%
CONFIRMATION
CONFIRMATION: Are you sure to apply the LID design of this solution to InfoSWMM project.
OK
Cancel
Close


LID Control
OK
ID
Description
GREENROOF
RAINB
ROOFTOPDISCONNNECT
TRENCH
Process Layers:
LID Type:
Rooftop Disconnection
Surface
Roof Drain
Flow Capacity* (mm/hr):
1
Roof Surface
Overflow
Drain
Enter the maximum flow rate that the roof's drain system (gutters,drainspouts and leaders) can handle before overflowing. Use 0 if not applicable.



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Apply to InfoSWMM

The major tasks in using InfoSWMM Sustain are the following:

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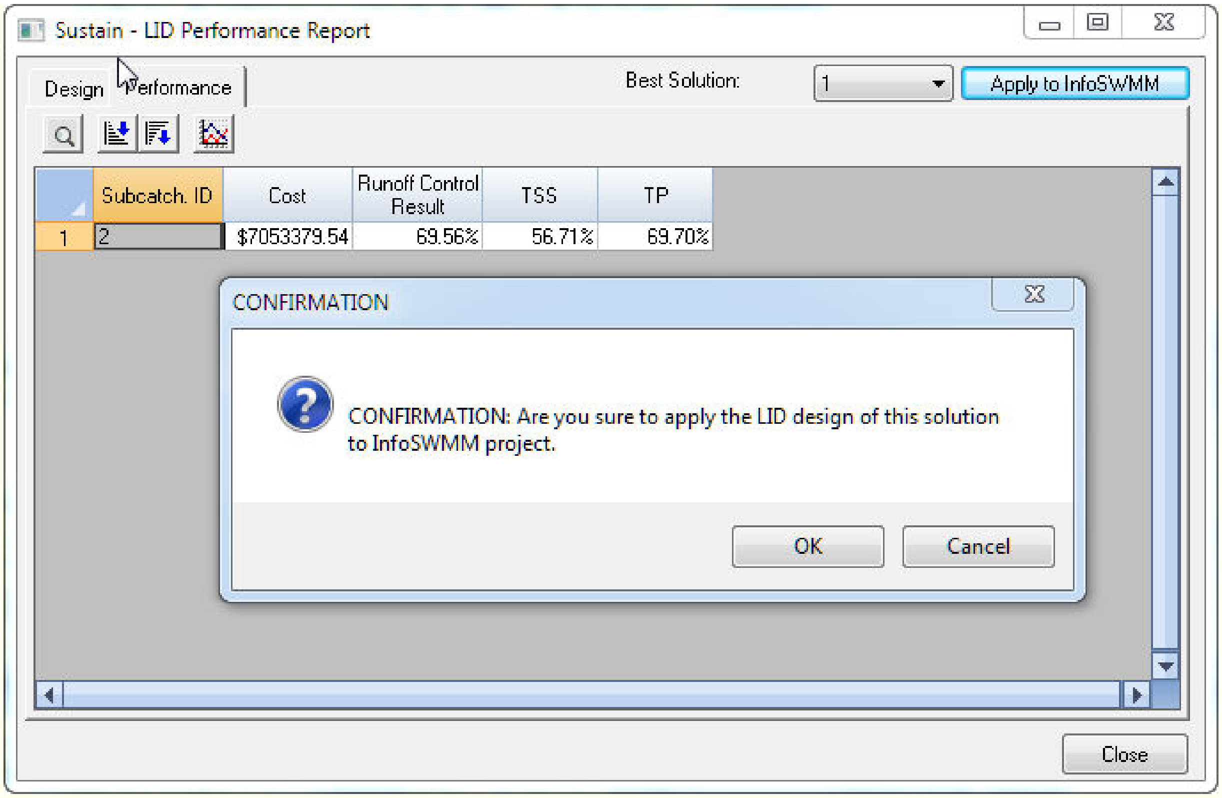
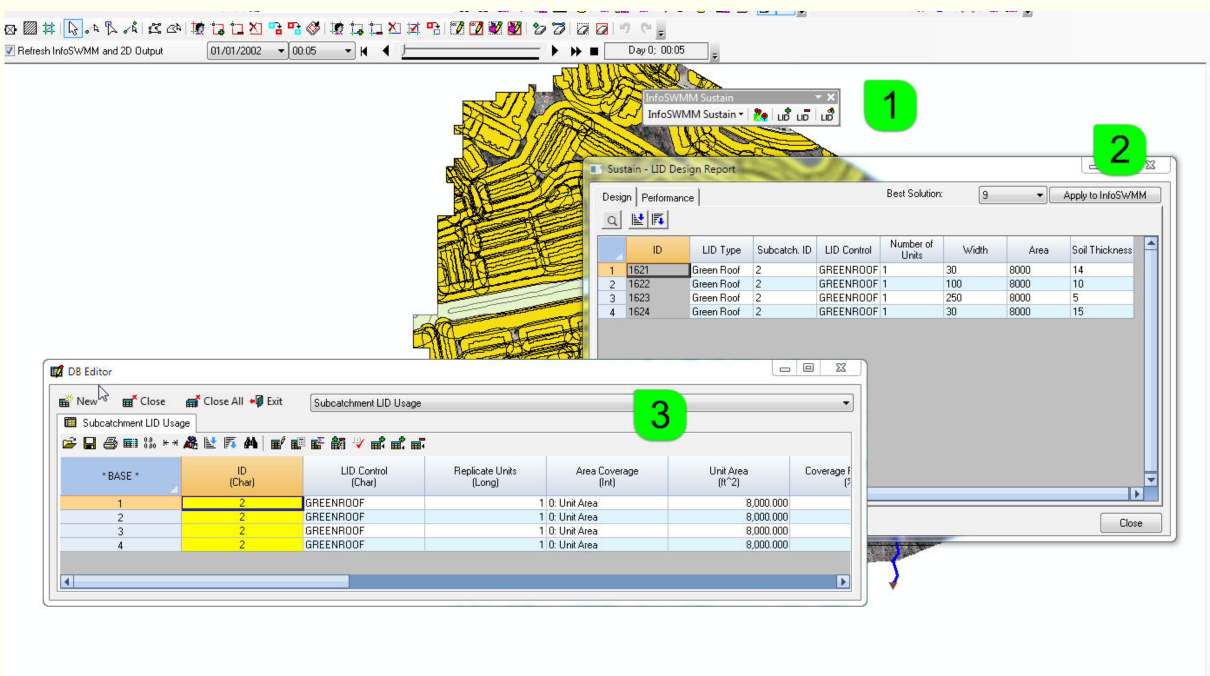
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

The Apply to InfoSWMM tool or command applies the optimized LID Candiates to the InfoSWMM DB tables. The LID Coverage DB table is altered or added to by this command.

- Use InfoSWMM Sustain to Design the LID's based on Performance Criteria
- Use the Apply to InfoSWMM Command
- The LID Usage Table is now Updated for long period InfoSWMM modeling.


Sustain - LID Performance Report
Design
Performance
Best Solution:
1
Apply to InfoSWMM
Subcatch. ID
Cost
Runoff Control Result
TSS
TP
1
2
$7053379.54
69.56%
56.71%
69.70%
CONFIRMATION
CONFIRMATION: Are you sure to apply the LID design of this solution to InfoSWMM project.
OK
Cancel
Close


Refresh InfoSWMM and 2D Output
01/01/2002
00:05
Day 0; 00:05
InfoSWMM Sustain
1
2
Sustain - LID Design Report
Design
Performance
Best Solution:
9
Apply to InfoSWMM
ID
LID Type
Subcatch. ID
LID Control
Number of Units
Width
Area
Soil Thickness
1621
Green Roof
GREENROOF
1622
1623
1624
Close
DB Editor
New
Close
Close All
Exit
Subcatchment LID Usage
3
* BASE *
ID (Char)
LID Control (Char)
Replicate Units (Long)
Area Coverage (Int)
Unit Area (ft^2)
GREENROOF
0: Unit Area
8,000.000

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LID Usage Table

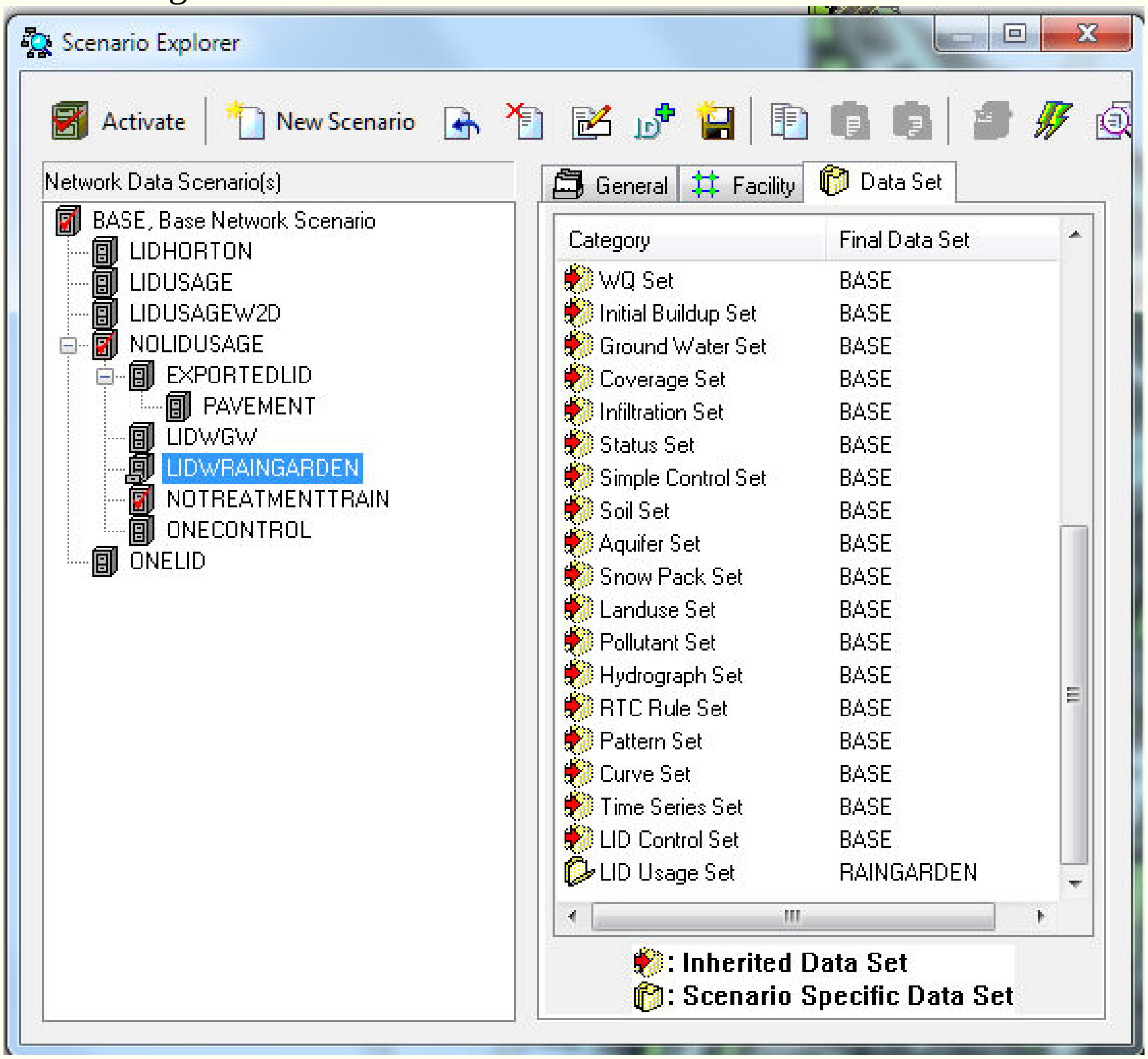
The major tasks in using InfoSWMM Sustain are the following:

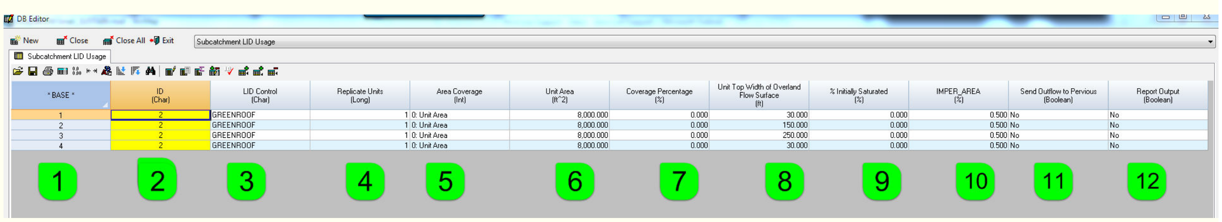
- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve
- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

The LID Usage Table

- 1. Row and DB Table
- 2. Subcatchment ID
- 3. The LID Control
- 4. The number of Replicate Controls
- 5. The type of Coverage
- 6. The unit area
- 7. The percent coverage
- 8. Top Width
- 9. Initial Saturation
- 10. Percent of Impervious area treated by the LID
- 11. Where does the LID flow go to?
- 12. Do you want a detailed Report

- 13. LID Usage Tables can also be viewed and created with the Scenario Manager





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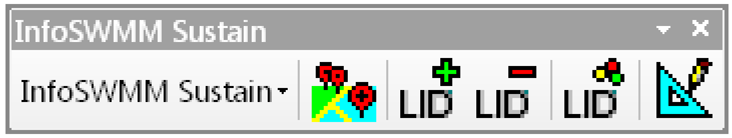
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LID
LID
LID

Introduction to LID Designer

The LID Designer is a tool in InfoSWMM Sustain

The National Stormwater Calculator is a simple to use tool for computing small site hydrology for any

location within the US. It estimates the amount of stormwater runoff generated from a site under

different development and control scenarios over a long-term period of historical rainfall. The analysis

takes into account local soil conditions, slope, land cover, and meteorology. Different types of low

impact development (LID) practices (also known as green infrastructure) can be employed to help

capture and retain rainfall on-site. Future climate change scenarios taken from internationally

recognized climate change projections can also be considered. The calculator provides planning level

estimates of capital and maintenance costs which will allow planners and managers to evaluate and

compare effectiveness and costs of LID controls.

The calculator's primary focus is informing site developers and property owners on how well they can

meet a desired stormwater retention target. It can be used to answer such questions as:

• What is the largest daily rainfall amount that can be captured by a site in either its pre-

development, current, or post-development condition?

• To what degree will storms of different magnitudes be captured on site?

• What mix of LID controls can be deployed to meet a given stormwater retention target?

• How well will LID controls perform under future meteorological projections made by global

climate change models?

• What are the relative cost (capital and maintenance) differences for various mixes of LID

controls?

The calculator seamlessly accesses several national databases to provide local soil and meteorological

data for a site. The user supplies land cover information that reflects the state of development they wish

to analyze and selects a mix of LID controls to be applied. After this information is provided, the site's

hydrologic response to a long-term record of historical hourly precipitation, possibly modified by a

particular climate change scenario, is computed. This allows a full range of meteorological conditions to

be analyzed, rather than just a single design storm event. The resulting time series of rainfall and runoff

are aggregated into daily amounts that are then used to report various runoff and retention statistics. In

addition, the site's response to extreme rainfall events of different return periods is also analyzed.

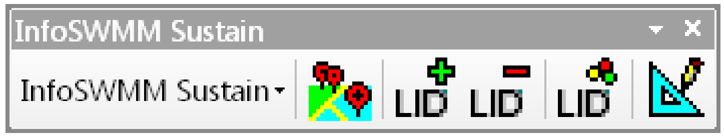
The calculator uses the EPA Storm Water Management Model (SWMM) as its computational engine (http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/). SWMM is a well-established, EPA developed

model that has seen continuous use and periodic updates for 40 years. Its hydrology component uses

physically meaningful parameters making it especially well-suited for application on a nation-wide scale.

SWMM is set up and run in the background without requiring any involvement of the user.

Green infrastructure (GI), similar to LID controls, is a relatively new and flexible term, and it has been used differently in different contexts. However, for the purposes of EPA's efforts to implement the GI Statement of Intent, EPA intends the term GI to generally refer to systems and practices that use or mimic natural water flow processes and retain stormwater or runoff on the site where it is generated. GI can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID.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InfoSWMM Sustain
LID
LID
LID

Input for LID Designer

The rate at which standing water infiltrates into a soil is measured by its saturated hydraulic conductivity. Soils with higher conductivity produce less runoff.

Check the 'View Soil Survey' box to view soil conductivity around your site. (Conductivity data might not be available for your particular site.)

Click a shaded region on the map to select its conductivity value into the edit box, or you can enter your own conductivity value directly.

If you leave the edit box blank, the default conductivity associated with the site's soil type will be used.

Soil type is identified by its Hydrologic Soil Group, a classification used by soil scientists to characterize the physical nature and runoff potential of a soil. Roughly speaking, Group A is sand, Group B sandy loam, Group C clay loam, and Group D clay. The Calculator uses soil type to infer a site's infiltration properties.

Check the 'View Soil Survey' box to view the soil types around your site. (Soil type data may not be available for your particular site.) Select a soil type from the choices listed or click a shaded region of the map to select its value.

The Calculator computes runoff for your site using a long-term record of historical hourly rainfall data recorded at a nearby National Weather Service rain gage.

Select the rain gage you would like the Calculator to use. The period of record and average annual rainfall are listed below the name of each gaging station.

Use the Save Rainfall Data option only if you need to use the data in some other application.

Monthly evaporation rates have been calculated from historical daily temperature measurements recorded at the closest National Weather Service weather stations to your site. The period of record and average potential daily rate are listed next to each station's name.

Select the weather station you would like to use as the source of evaporation rates for your site.

Use the Save Evaporation Data option only if you need to use the data in some other application.

The Results page is where the site's hydrologic response to a long term period of historical hourly rainfall is computed and reported on. Statistics for both annual and daily rainfall/runoff are presented.

The user controls on this page are grouped together in three sections: Options, Actions, and Reports.

The Options section allows you to specify how the rainfall record should be analyzed with respect to:

- the number of most recent years of rainfall record to use,

- the minimum amount of daily rainfall (or runoff) that will constitute a measureable event,

- whether subsequent days of back to back daily events should be counted or not.

The Actions section contains commands that allow you to:

- Refresh results after site data have changed.

- Use the most current results as a baseline scenario that can be compared with results from subsequent runs.

- Print the current (and baseline) results to a PDF file.

The Reports section allows you to select how the rainfall/runoff results generated for the site should be displayed. To learn more about the contents of a selected report click the Help link at the bottom right of the page.

Low Impact Development (LID) controls are landscaping practices designed to collect runoff from impervious surfaces and retain it on site.

Enter the percent of the site's impervious area you would like to be treated by the listed LID practices.

Click a practice to learn more about it or to change its design parameters.

Entering a non-zero design storm depth will allow you to automatically size an LID control to capture storms of that size when you click on the LID's name to bring up its design form.

Enter the percentage of the site's area covered by each type of non-impervious surface. The remaining area is considered to be directly connected impervious surfaces (roofs, sidewalks, streets, parking lots, etc. that drain directly off-site). Disconnecting some of this area, to run onto lawns for example, is an LID option appearing on the next page.

Choose a land cover distribution that reflects the stage of development being analyzed, such as pre-development, current or future development. Total runoff volume is highly dependent on the amount of impervious area and less so on how the non-impervious area is divided between the different land cover categories.

Non-impervious land cover type will affect the amount of rainfall captured on vegetation or in natural depressions. It also determines surface roughness. Rougher surfaces slow down overland flow allowing more opportunity for infiltration.

The various pages of the calculator are used as follows:

1. Location page - establishes the site’s location

2. Soil Type page - identifies the site’s soil type

3. Soil Drainage page - specifies how quickly the site’s soil drains

4. Topography page - characterizes the site’s surface topography

5. Precipitation page - selects a nearby rain gage to supply hourly rainfall data

6. Evaporation page - selects a nearby weather station to supply evaporation rates

7. Climate Change page – selects a climate change scenario to apply

8. Land Cover page - specifies the site’s land cover for the scenario being analyzed

9. LID Controls page - selects a set of LID control options, along with their design features, to

deploy within the site and specifies site and project considerations for cost estimation purposes

10. Results page - runs a long term hydrologic analysis and displays the results including estimates

of capital and maintenance costs.

Location

The Location page of the calculator is shown in Figure 2. You are asked to identify where in the U.S. the

site is located. This information is used to access national soils and meteorological databases as well as

Bureau of Labor Statistics (BLS) data for cost estimation purposes. It has an address lookup feature that

allows you to easily navigate to the site's location. You can enter an address or zip code in the Search

box and either click on the Search icon, or press the Enter key to move the map view to that location.

You can also use the map's pan and zoom controls to hone in on a particular area. Once the site has

been located somewhere within the map's viewport, move the mouse pointer over the site and then

left-click the mouse to mark its exact location with a red square.

A web page to search for an address with a map to show location.

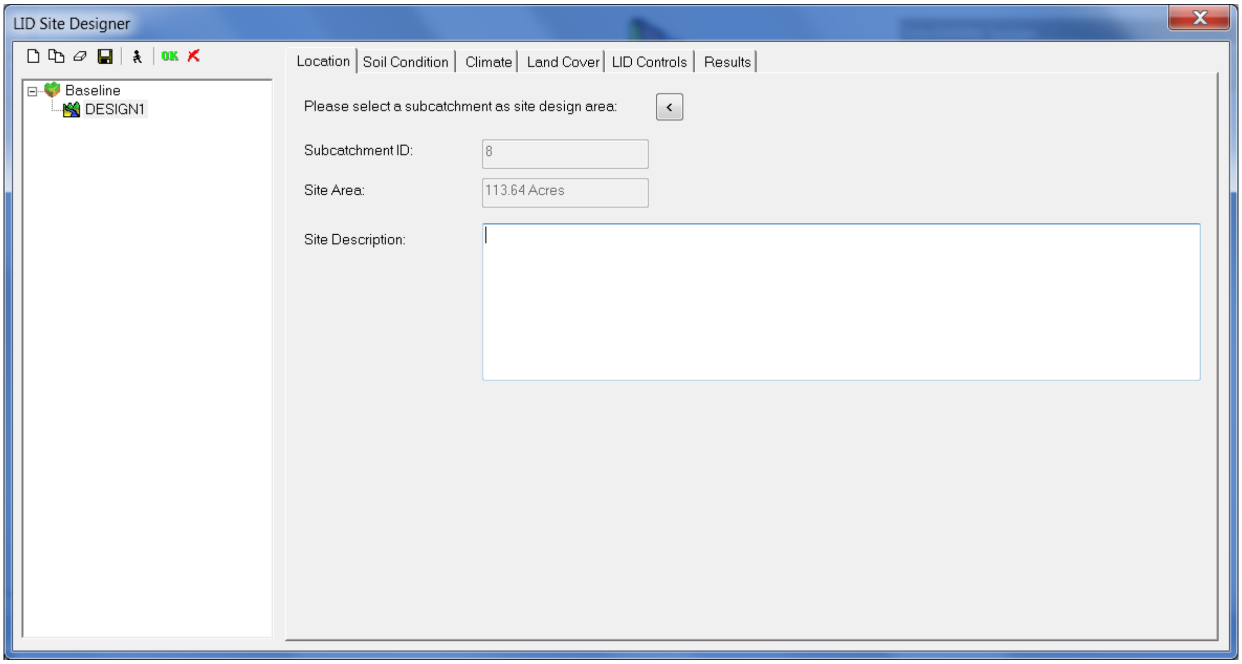


Table 1 lists the definitions of the different soil groups.

You can select a soil type based on local knowledge or by retrieving a soil map overlay from the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) SSURGO database (http://soils.usda.gov/survey/geography/ssurgo/). Simply check the View Soil Survey Data box at the top of the page's left panel to retrieve SSURGO data. (There will be a slight delay the first time that the soil data is retrieved and the color-coded overlay is drawn). displays the results from a SSURGO retrieval.

You can then select a soil type directly from the left panel or click on a color shaded region of the map. The SSURGO database houses soil characterization data for most of the U.S. that have been collected over the past forty years by federal, state, and local agencies participating in the National Cooperative Soil Survey. The data are compiled by "map units" which are the boundaries that define a particular recorded soil survey. These form the irregular shaped polygon areas that are displayed in the calculator's map pane. Soil survey data do not exist for all parts of the country, particularly in downtown core urban areas; therefore, it is possible that no data will be available for your site. In this case you will have to rely on local knowledge to designate a representative soil group.

Table 1. Definitions of Hydrologic Soil Groups (USDA, 2010).

Group Meaning

Saturated

Hydraulic

Conductivity

(in/hr)

A Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.

= 0.45

B Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. E.g., shallow loess, sandy loam.

0.30 - 0.15

C Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. E.g., clay loams, shallow sandy loam.

0.15 - 0.05

D High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay-pan or clay layer at or near the surface, and shallow soils over nearly impervious material.

0.05 - 0.00

Soil Drainage

The Soil Drainage page of the calculator (Figure 5) is used to identify how fast standing water drains into

the soil. This rate, known as the “saturated hydraulic conductivity,” is arguably the most significant

parameter in determining how much rainfall can be infiltrated.

There are several options available for assigning a hydraulic conductivity value (in inches per hour) to

the site:

a) The edit box can be left blank, in which case, a default value based on the site’s soil type will be

used (the default value is shown next to the edit box).

b) As with soil group, conductivity values from the SSURGO database can be displayed on the map

when the View Soil Survey Data checkbox is selected. Clicking the mouse on a colored region of

the map will make its conductivity value appear in the edit box.

c) If you have local knowledge of the site’s soil conductivity you can simply enter it directly into the

edit box. This is preferred over the other two choices.

Web page for soil drainage.

Figure 5. The calculator's Soil Drainage page.

It should be noted that the hydraulic conductivity values from the SSURGO database are derived from

soil texture and depth to groundwater and are not field measurements. As with soil type, there may not

be any soil conductivity data available for your particular location.

Topography

displays the Topography page of the calculator. Site topography, as measured by surface slope

(feet of drop per 100 feet of length), affects how fast excess stormwater runs off a site. Flatter slopes

results in slower runoff rates and provide more time for rainfall to infiltrate into the soil. Runoff rates

are less sensitive to moderate variations in slope. Therefore, the calculator uses only four categories of

slope – flat (2%), moderately flat (5%), moderately steep (10%) and steep (above 15%). As with soil type

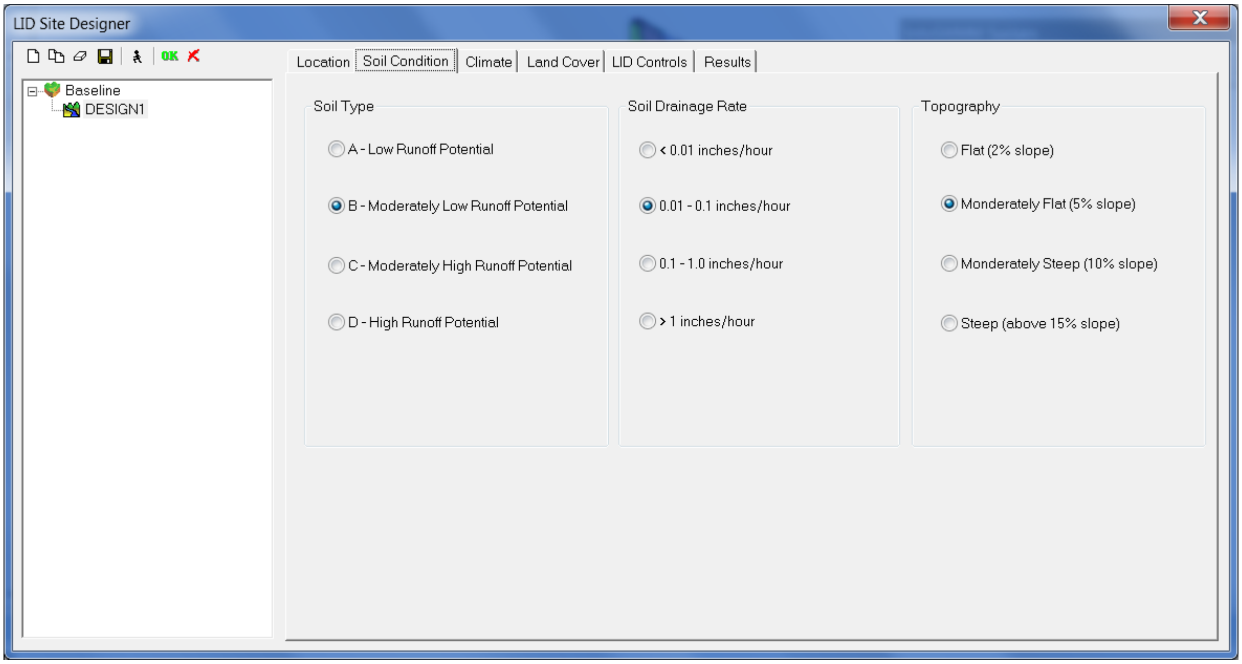
and drainage rate, any available SSURGO slope data will be displayed on the map if the View Soil Survey

checkbox is selected. You can use the resulting display as a guide or use local knowledge to describe the

site’s topography.

Table 1. Definitions of Hydrologic Soil Groups (USDA, 2010).

Group	Meaning	Saturated Hydraulic Conductivity (in/hr)
A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.	≥ 0.45
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. E.g., shallow loess, sandy loam.	0.30 - 0.15
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. E.g., clay loams, shallow sandy loam.	0.15 - 0.05
D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay-pan or clay layer at or near the surface, and shallow soils over nearly impervious material.	0.05 - 0.00



Precipitation

The Precipitation page of the calculator is shown in

. It is used to select a National Weather

Service rain gage that will supply rainfall data for the site. Rainfall is the principal driving force that

produces runoff. The calculator uses a long term continuous hourly rainfall record to make sure that it

can replicate the full scope of storm events that might occur. In addition, it identifies a set of 24-hour

extreme event storms associated with each rain gage location. These are a set of six intense storms

whose sizes are exceeded only once every 5, 10, 15, 30, 50 and 100 years, respectively.

Figure 7

Precipitation

Figure 7. The calculator's Precipitation page.

The calculator contains a catalog of over 8,000 rain gage locations from the National Weather Service's

(NWS) National Climatic Data Center (NCDC). Historical hourly rainfall data for each station have been

extracted from the NCDC's repository, screened for quality assurance, and stored on an EPA file server.

As shown in

The Evaporation page of the calculator is displayed in

, the calculator will automatically locate the five nearest gages to the site and list

their location, period of record and average annual rainfall amount. You can then choose what you

consider to be the most appropriate source of rainfall data for the site.

Figure 7

If the Save rainfall data … command label is clicked, a Save As dialog window will appear allowing you to

save the rainfall data to a text file in case you want to use the data for some other application, such as

SWMM. Each line of the file will contain the recording station identification number, the year, month,

day, hour, and minute of the rainfall reading and the measured hourly rainfall intensity in inches/hour.

Evaporation

. It is used to select a weather station that

will supply evaporation rates for the site. Evaporation determines how quickly the moisture retention

capacity of surfaces and depression storage consumed during one storm event will be restored before

the next event.

Evaporation

Figure 8. The calculator's Evaporation page.

Over 5,000 NWS weather station locations throughout the U.S. have had their daily temperature records

analyzed to produce estimates of monthly average evaporation rates (i.e., twelve values for each

station). These rates have been stored directly into the calculator. The calculator lists the five closest

locations that appear in the table along with their period of record and average daily evaporation rate

(the average of the twelve monthly rates). Note that these are “potential” evaporation rates, not

recorded values (there are only a few hundred stations across the U.S. with long term recorded

evaporation data). The rates have been estimated for bare soil using the Penman-Monteith equation;

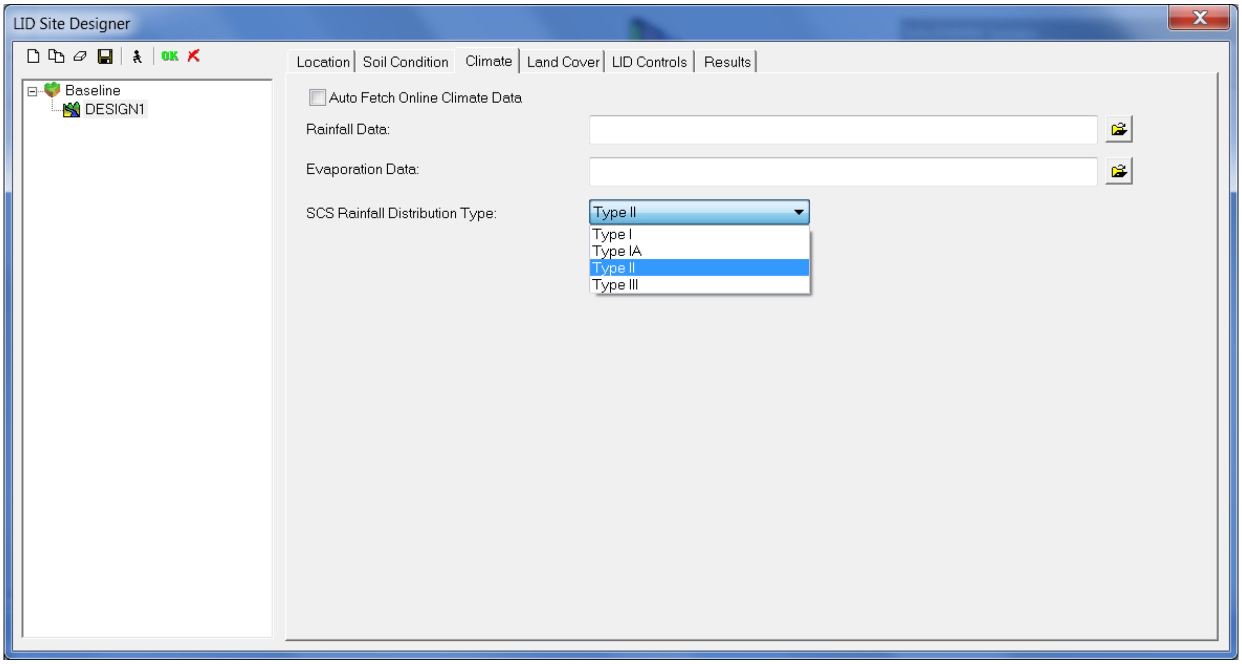
and thus, transpiration or vegetative land cover is not explicitly represented. More details are provided

in the Computational Methods section of this document.

As with rainfall, a Save evaporation data … command is available in case you would like to save the data

to a file for use in another application. If this option is selected, the data will be written to a plain text

file of your choice with the twelve monthly average rates appearing on a single line.



Land Cover

Figure 10 displays the Land Cover page of the calculator. It is used to describe the different types of

pervious land cover on the site. Infiltration of rainfall into the soil can only occur through pervious

surfaces. Different types of pervious surfaces capture different amounts of rainfall on vegetation or in

natural depressions, and have different surface roughness. Rougher surfaces slow down runoff flow

providing more opportunity for infiltration. The remaining non-pervious site area is considered to be

“directly connected impervious surfaces” (roofs, sidewalks, streets, parking lots, etc. that drain directly

off-site). Disconnecting some of this area, to run onto lawns for example, is an LID option appearing on

the next page of the calculator.

You are asked to supply the percentage of the site covered by each of four different types of pervious surfaces:

""

Figure 10. The calculator's Land Cover page.

1. Forest – stands of trees with adequate brush and forested litter cover

2. Meadow – non-forested natural areas, scrub and shrub rural vegetation

3. Lawn – sod lawn, grass, and landscaped vegetation

4. Desert – undeveloped land in arid regions with saltbush, mesquite, and cactus vegetation

You should assign land cover categories to the site that reflects the specific condition you wish to

analyze: pre-development, current, or post-development. A pre-development land cover will most likely

contain some mix of forest, meadow, and perhaps desert. Local stormwater regulations might provide

guidance on how to select a pre-development land cover or you could use a nearby undeveloped area as

an example. Viewing the site map in bird’s eye view, as shown in

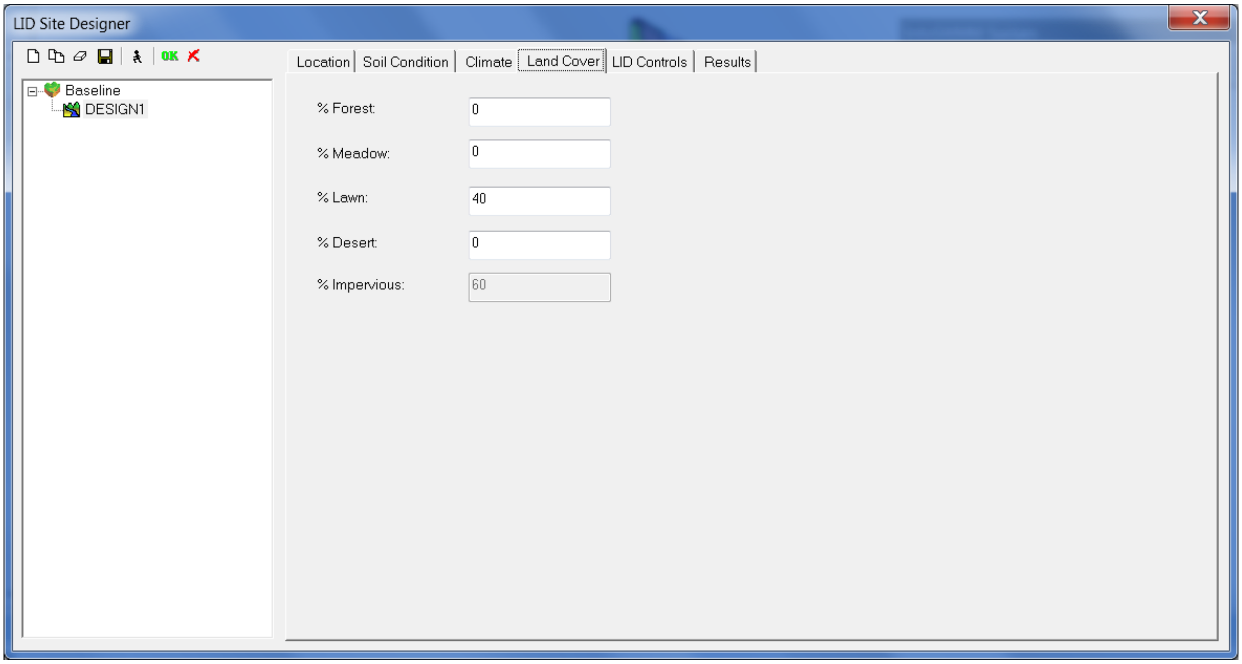
Figure 10, would help identify the land

cover for current conditions. Post-development land cover could be determined from a project’s site

development plan map. Keep in mind that total runoff volume is highly dependent on the amount of

impervious area on the site while it is less sensitive to how the non-impervious area is divided between

the different land cover categories.



LID Controls (including cost estimation options)

The LID Controls page of the calculator is depicted in Figure 11. It is used to deploy low impact

development (LID) controls throughout the site. These are landscaping practices designed to capture

and retain stormwater generated from impervious surfaces that would otherwise run off the site. As

seen in Figure 11, there are seven different types of green infrastructure (GI) LID controls available. You

can elect to apply any mix of these LID controls by simply telling the calculator what percentage of the

impervious area is treated by each type of control. Each control has been assigned a reasonable set of

design parameters, but these can be modified by clicking on the name of the control. You have the

option to specify a 24-hour design storm to assist you with sizing the selected LID controls. More details on each type of control practice, its design parameters and sizing it to retain a given design storm are

provided in the LID Controls section of this user's guide. For the purposes of cost estimation, the

calculator factors in the cost implications of construction feasibility and site suitability, and adjusts the

cost of the LID Controls based on regional cost differences associated with a site's location. Refer to the

Cost Estimation section of this user guide (page 80) for a brief discussion of the cost curve approach

used to generate estimates of probable capital and maintenance costs in the calculator. By indicating

whether the project is new- or re-development and selecting from poor, moderate, or excellent for site

suitability for placing LID controls along with other user input information, the calculator computes and

applies the appropriate cost curve for the project.

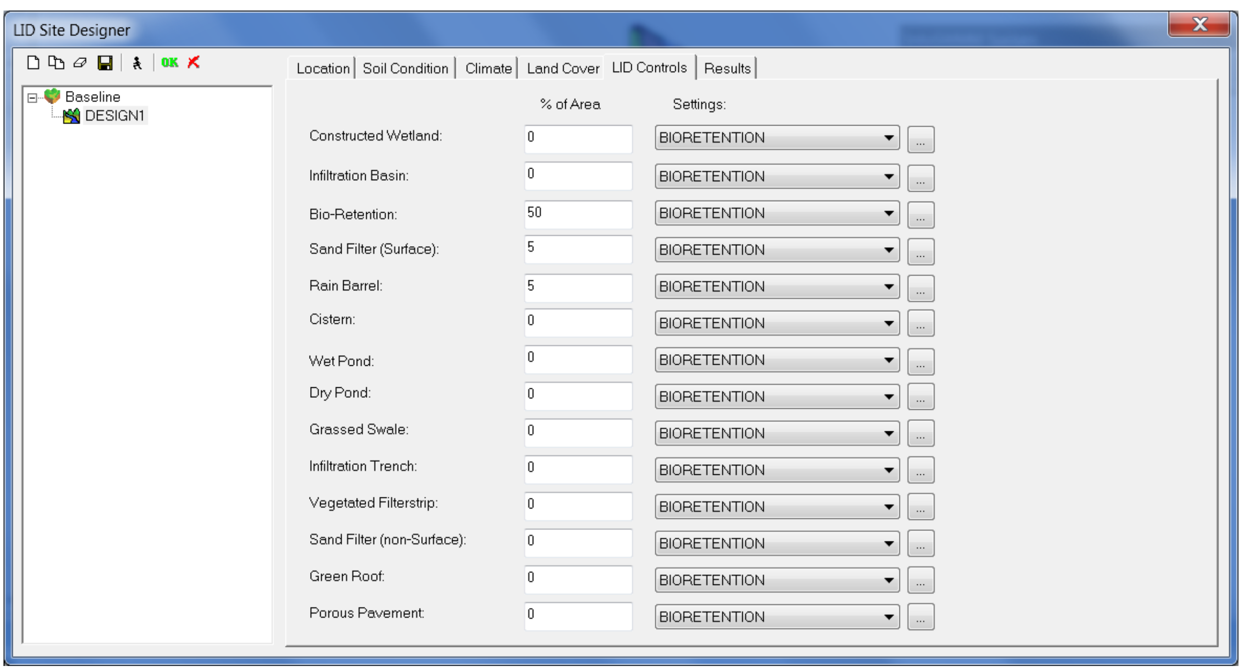
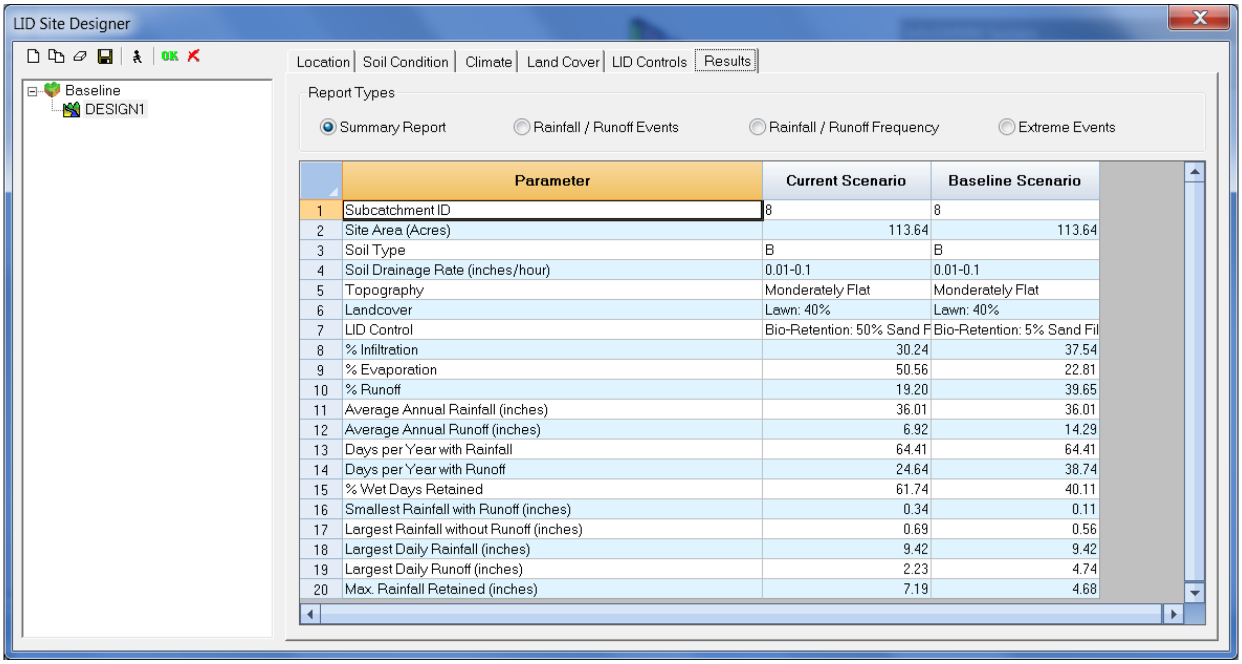


Table 2. Descriptions of LID practices included in the calculator.

LID Practice	Description
 Disconnection	Disconnection refers to the practice of directing runoff from impervious areas, such as roofs or parking lots, onto pervious areas, such as lawns or vegetative strips, instead of directly into storm drains.
 Rain Harvesting	Rain harvesting systems collect runoff from rooftops and convey it to a cistern tank where it can be used for non-potable water uses and on-site infiltration.
 Rain Gardens	Rain Gardens are shallow depressions filled with an engineered soil mix that supports vegetative growth. They provide opportunity to store and infiltrate captured runoff and retain water for plant uptake. They are commonly used on individual home lots to capture roof runoff.
 Green Roofs	Green roofs (also known as vegetated roofs) are bioretention systems placed on roof surfaces that capture and temporarily store rainwater in a soil medium. They consist of a layered system of roofing designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface.
 Street Planters	Street Planters are typically placed along sidewalks or parking areas. They consist of concrete boxes filled with an engineered soil that supports vegetative growth. Beneath the soil is a gravel bed that provides additional storage as the captured runoff infiltrates into the existing soil below.
 Infiltration Basins	Infiltration basins are shallow depressions filled with grass or other natural vegetation that capture runoff from adjoining areas and allow it to infiltrate into the soil.
 Porous Pavement	Porous Pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix or with modular porous blocks. Normally all rainfall will immediately pass through the pavement into the gravel storage layer below it where it can infiltrate at natural rates into the site's native soil.



	Parameter	Current Scenario	Baseline Scenario
1	Subcatchment ID	8	8
2	Site Area (Acres)	113.64	113.64
3	Soil Type	B	B
4	Soil Drainage Rate (inches/hour)	0.01-0.1	0.01-0.1
5	Topography	Monderately Flat	Monderately Flat
6	Landcover	Lawn: 40%	Lawn: 40%
7	LID Control	Bio-Retention: 50% Sand F	Bio-Retention: 5% Sand Fil
8	% Infiltration	30.24	37.54
9	% Evaporation	50.56	22.81
10	% Runoff	19.20	39.65
11	Average Annual Rainfall (inches)	36.01	36.01
12	Average Annual Runoff (inches)	6.92	14.29
13	Days per Year with Rainfall	64.41	64.41
14	Days per Year with Runoff	24.64	38.74
15	% Wet Days Retained	61.74	40.11
16	Smallest Rainfall with Runoff (inches)	0.34	0.11
17	Largest Rainfall without Runoff (inches)	0.69	0.56
18	Largest Daily Rainfall (inches)	9.42	9.42
19	Largest Daily Runoff (inches)	2.23	4.74
20	Max. Rainfall Retained (inches)	7.19	4.68

Innovyze Help File Updated January 30, 2019

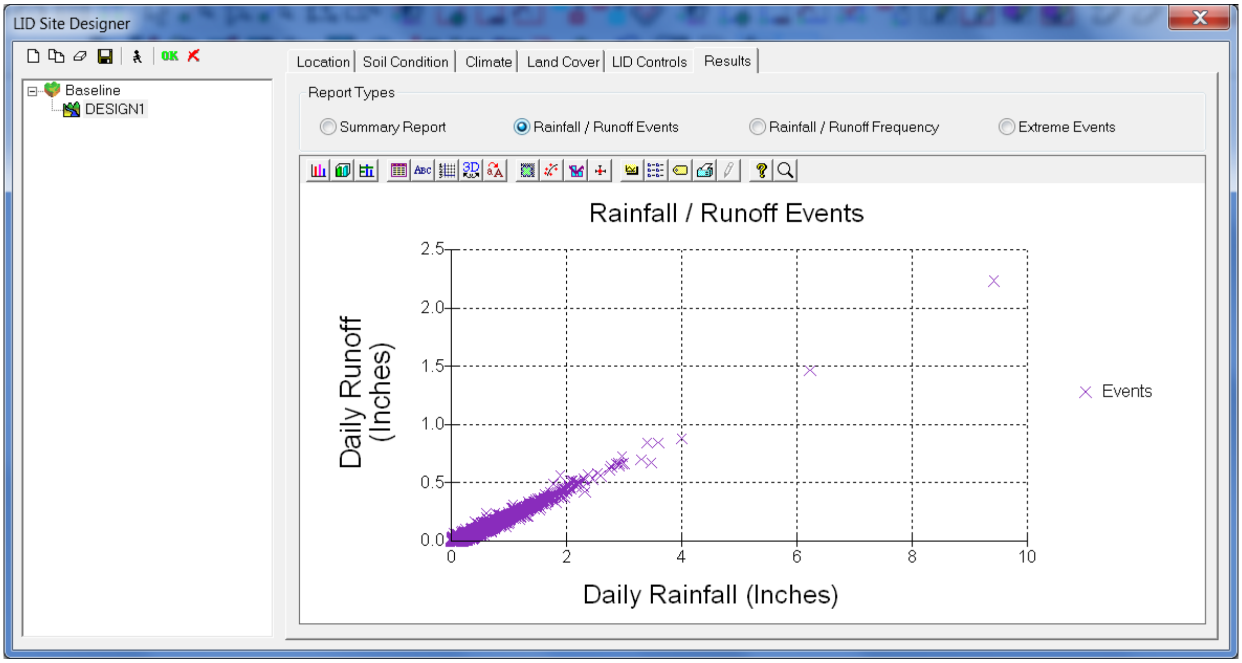
InfoSWMM uses the EPA SWMM 5.1.013 Engine

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


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Output of LID Designer



Runoff by Rainfall Percentile

The Runoff by Rainfall Percentile report produced by the calculator is displayed in

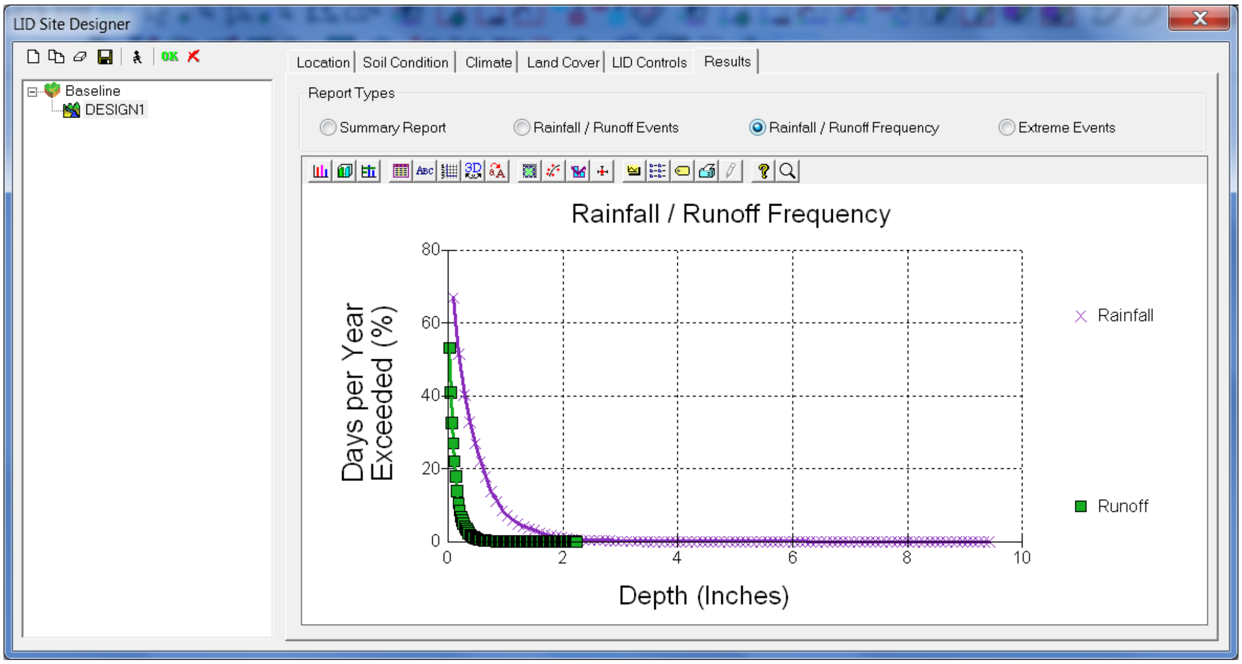
It shows what percentage of total measurable runoff is attributable to different size rainfall events. The bottom

axis is divided into intervals of daily rainfall event percentiles. The top axis shows the rainfall depth

corresponding to each end-of-interval percentile. The bars indicate what percentage of total measurable

runoff is generated by the rainfall within each size interval. This provides a convenient way of determining what rainfall depth corresponds to a given percentile (percentiles are listed along the

bottom of the horizontal axis while their corresponding depths are listed across the top of the axis.)



Rainfall / Runoff Events

The calculator’s Rainfall/Runoff report contains a scatter plot of the daily runoff depth associated with

each daily rainfall event over the period of record analyzed. Only days with rainfall above the event

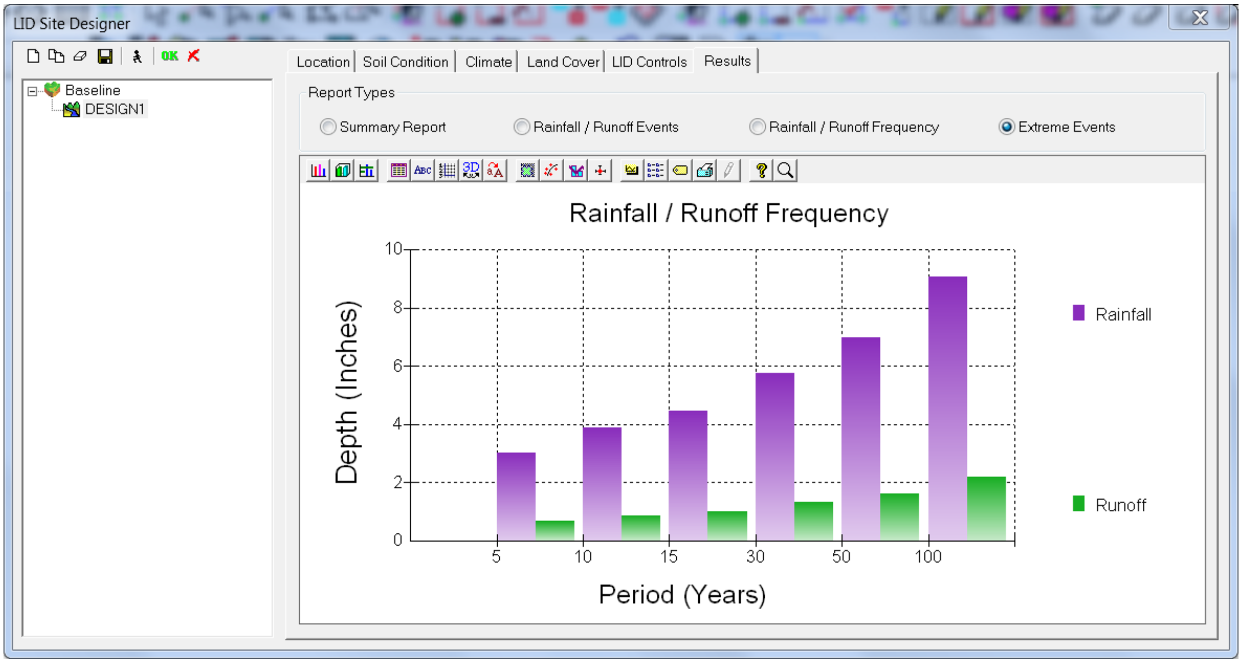
threshold (see

) are plotted. Events that are completely captured on site (i.e., have

runoff below the event threshold) show up as points that lie along the horizontal axis. There is not

always a consistent relationship between rainfall and runoff. Days with similar rainfall amounts can

produce different amounts of runoff depending on how that rainfall was distributed over the day and on how much rain occurred in prior days.



Extreme Event Rainfall/Runoff

The Extreme Event Rainfall/Runoff report shows the rainfall and resulting runoff for a series of extreme

event (high intensity) storms that occur at different return periods. An example is shown in Figure 21.

Each stacked bar displays the annual max day rainfall that occurs with a given return period and the

runoff that results from it for the current set of site conditions. The max day rainfalls correspond to

those shown on the Climate Change page for the scenario you selected (or to the historical value if no

climate change option was chosen).

Note that the max day rainfalls at different return periods are a different statistic than the daily rainfall

percentiles that are shown in the Runoff by Rainfall Percentile report (see Figure 20). The latter represents the frequency with which any daily rainfall amount is exceeded while the former estimates

how often the largest daily rainfall in a year will be exceeded (hence its designation as an extreme storm

event). Most stormwater retention standards are stated with respect to rainfall percentiles while

extreme event rainfalls are commonly used to define design storms that are used to size stormwater

control measures. The extreme event rainfall amounts are generated using a statistical extrapolation

technique (as described in the Computational Methods section) that allows one to estimate the once in

X year event when fewer than X years of observed rainfall data are available.

Results

The final page of the calculator is where a hydrologic analysis of the site is run; its results are displayed

along with estimates of probable capital and maintenance costs. As shown in

, by selecting the

Site Description report option you can first review the data that you entered for the site and go back to

make changes if needed.

Figure 15

""

1. The number of years of rainfall record to use (moving back from the most recent year on

record).

2. The event threshold, which is the minimum amount of rainfall (or runoff) that must occur over a

day for that day to be counted as having rainfall (or runoff). Rainfall (or runoff) above this

threshold is referred to as “observable” or “measureable”.

3. The choice to ignore consecutive wet days when compiling runoff statistics (i.e., a day with

measurable rainfall must be preceded by at least two days with no rainfall for it to be counted).

Figure 15. The calculator’s Results page.

The input controls on this page are grouped together in three sections: Options, Actions, and Reports.

The Options section allows you to control how the rainfall record is analyzed via the following settings:

The latter option appears in some state and local stormwater regulations as a way to exempt extreme

storm events, such as hurricanes, from any stormwater retention requirements. Normally, you would

not want to select this option as it will produce a less realistic representation of the site’s hydrology.

Note that although results are presented as annual and daily values, they are generated by considering

the site’s response to the full history of hourly rainfall amounts.

The Actions section of the page contains commands that perform the following actions:

Refresh Results - runs a long term simulation of the site’s hydrology and updates the output displays

with new results (it will be disabled if results are currently available and no changes have been made to the site’s data).

Use as Baseline Scenario – uses the current site data and its simulation results as a baseline against

which future runs will be compared in the calculator’s output reports (this option is disabled if there are

no current simulation results available).

Remove Baseline Scenario – removes any previously designated baseline scenario from all output

reports.

Print Results to PDF File – writes the calculator’s results for both the current and any baseline scenario

to a PDF file that can be viewed with a PDF reader at a future time.

The Reports section of the page allows you to choose how the rainfall / runoff results for the site should

be displayed. A complete description of each type of report available will be given in the next section of

this guide.

When the calculator first loads or begins to analyze a new site the following default values are used:

Soil Group: B

Conductivity: 0.4 inches/hour

Surface Slope: 5%

Rainfall Station: Nearest cataloged station

Evaporation Station: Nearest cataloged station

Climate Change Scenario: None

Land Cover: 40% Lawn, 60% impervious

LID Controls: None

Years to Analyze: 20

Event Threshold: 0.10 inches

Ignore Consecutive Days: No

3. Interpreting the Calculator's Results

) contains a list of reports that can be generated from its

computed results. Before discussing what these reports contain it will be useful to briefly describe how

the calculator derives its results. After you select the Refresh Results command, the calculator computes

an estimate of probable capital and maintenance costs and internally performs the following operations:

The Results page of the calculator (

Figure 15

1. A SWMM input file is created for the site using the information you provided to the calculator.

2. The historical hourly rainfall record for the site is adjusted for any climate change scenario

selected.

3. SWMM is run to generate a continuous time series of rainfall and runoff from the site at 15-

minute intervals for the number of years specified.

4. The 15-minute time series of rainfall and runoff are accumulated into daily values by calendar

day (midnight to midnight).

5. Various statistics of the resulting daily rainfall and runoff values are computed.

6. The SWMM input file is modified and run once more to compute the runoff resulting from a set

of 24-hour extreme rainfall events associated with different return periods. The rainfall

magnitudes are derived from your choice of climate change scenario or from the historical

record if climate change is not being considered.

Thus for the continuous multi-year run, the rainfall / runoff output post-processed by the calculator are

the 24-hour totals for each calendar day of the period simulated. A number of different statistical

measures are derived from these data, some of which will be more relevant than others depending on

the context in which the calculator is being used.

Summary Results

The calculator's Summary Results report, an example of which is shown in Figure 16, contains the

following items:

• A pie chart showing the percentage of total rainfall that infiltrates, evaporates, and becomes

runoff. Note that because the calculator does not explicitly account for the loss of soil moisture to

vegetative transpiration, the latter quantity shows up as infiltration in this chart.

• Average Annual Rainfall: Total rainfall (in inches) that falls on the site divided by the number of

years simulated. It includes all precipitation amounts recorded by the station assigned to the site,

even those that fall below the Event Threshold.

• Average Annual Runoff: Total runoff (in inches) produced by the site divided by the number of years simulated. It includes all runoff amounts, even those that fall below the Event Threshold.

• Days per Year with Rainfall: The number of days with measurable rainfall divided by the number

of years simulated, i.e., the average number of days per year with rainfall above the Event

Threshold.

""

""

• Days per Year with Runoff: The number of days with measurable runoff divided by the number of

years simulated, i.e., the average number of days per year with runoff above the Event Threshold.

• Percent of Wet Days Retained: The percentage of days with measurable rainfall that do not have

any measurable runoff generated. It is computed by first counting the number of days that have

rainfall above the Event Threshold but runoff below it. This number is then divided by the total

number of rainfall days above the threshold and multiplied by 100.

• Smallest Rainfall w/ Runoff: The smallest daily rainfall that produces measurable runoff. All days

with rainfall less than this amount have runoff below the threshold.

• Largest Rainfall w/o Runoff: The largest daily rainfall that produces no runoff. All days with more

rainfall than this will have measurable runoff. Of the wet days that lie between this depth and the

smallest rainfall with runoff, some will have runoff and others will not.

• Max. Retention Volume: The largest daily rainfall amount retained on site over the period of

record. This includes days that produce runoff from storms that are only partly captured.

Figure 16. The calculator’s Summary Results report.

Note that if the Ignore Consecutive Wet Days option is in effect then the retention statistics listed above

are computed by ignoring any subsequent back to back wet days for a period of 48 hours following an

initial wet day.

Direct interception of rainfall and transpiration by the tree canopy may be important processes

depending on the site you are modeling. While the SWC (Stormwater Calculator) doesn’t

explicitly include these processes, the model i-Tree Hydro can be used to determine the effect of

trees on urban hydrology for stormwater management at the catchment scale (USFS, 2014). For

more information about i-Tree Hydro visit: http://www.itreetools.org/hydro/index.php.

Rainfall / Runoff Events

The calculator’s Rainfall/Runoff report contains a scatter plot of the daily runoff depth associated with

each daily rainfall event over the period of record analyzed. Only days with rainfall above the event threshold (see

) are plotted. Events that are completely captured on site (i.e., have

runoff below the event threshold) show up as points that lie along the horizontal axis. There is not

always a consistent relationship between rainfall and runoff. Days with similar rainfall amounts can

produce different amounts of runoff depending on how that rainfall was distributed over the day and on

how much rain occurred in prior days.

Figure 17 page

34

""

. It shows how

many times per year, on average, a given daily rainfall depth or runoff depth will be exceeded. As an

example, from

Figure 17. The calculator's Rainfall / Runoff Event report.

Rainfall / Runoff Frequency

An example of the calculator’s Rainfall / Runoff Frequency report is seen in

Figure 18

we see that there are three days per year where it rains more than two inches,

but only one day per year where there is more than this amount of runoff. Events with more than four

inches of rain occur only once every two years.

Figure 18

""

Figure 18. The calculator’s Rainfall / Runoff Frequency report.

The rainfall frequency curve is generated by simply ordering the measurable daily rainfall results from

the long-term simulation from lowest to highest and then counting how many days have rainfall higher

than a given value. The same procedure is used to generate the daily runoff frequency curve. Curves like

these are useful in comparing the complete range of rainfall / runoff results between different

development, control and climate change scenarios. Examples might include determining how close a

post-development condition comes to meeting pre-development hydrology or seeing what effect future

changes in precipitation due to climate change might have on LID control effectiveness.

On any of the calculator’s line or bar charts you can make the numerical value of a plotted point

appear in a popup label by moving the mouse over the point on the line or bar you wish to

examine. You can also zoom in on any area of the chart by pressing the left mouse button while

dragging the mouse pointer across the area. To return to full view, you would right-click on the

chart and select Un-Zoom from the pop-up menu that appears.

Rainfall Retention Frequency

Another type of report generated by the calculator is the Rainfall Retention Frequency plot as shown in

Figure 19. It graphs the frequency with which a given depth of rainfall will be retained on site for the

scenario being simulated. For a given daily rainfall depth X the corresponding percent of time it is

retained represents the fraction of storms below this depth that are completely captured plus the

fraction of storms above it where at least X inches are captured. A rainfall event is considered to be

completely captured if its corresponding runoff is below the user stipulated Event Threshold.

To make this concept clearer, consider a run of the calculator that resulted in 1,000 days of measurable

rainfall and associated runoff for a site. Suppose there were 300 days with rainfall below one inch that

had no measurable runoff and 100 days where it rained more than an inch but the runoff was less than

an inch. The retention frequency for a one-inch rainfall would then be (300 + 100) / 1,000 or 40 percent.

The Rainfall Retention Frequency report is useful for determining how reliably a site can meet a required

stormwater retention standard. Looking at

, any retention standard above one inch would only

be met about 32% of the time (i.e., only one in three wet days would meet the target). Note that any

rainfall events below the target depth that are completely captured are counted as having attained the

target (e.g., a day with only 0.3 inches of rainfall will be counted towards meeting a retention target of

1.0 inches if no runoff is produced). That is why the plot tails off to the right at a constant level of 29 percent, which happens to be the percent of all wet days fully retained for this example (refer to the

Percent of Wet Days Retained entry in the Summary Results report of

Figure 19

Figure 16

).

""

Figure 19. The calculator’s Rainfall Retention Frequency report.

Runoff by Rainfall Percentile

The Runoff by Rainfall Percentile report produced by the calculator is displayed in

. It shows

what percentage of total measurable runoff is attributable to different size rainfall events. The bottom

axis is divided into intervals of daily rainfall event percentiles. The top axis shows the rainfall depth

corresponding to each end-of-interval percentile. The bars indicate what percentage of total measurable

runoff is generated by the rainfall within each size interval. This provides a convenient way of

determining what rainfall depth corresponds to a given percentile (percentiles are listed along the

bottom of the horizontal axis while their corresponding depths are listed across the top of the axis.)

Figure 20

""

Figure 20. The calculator's Runoff by Rainfall Percentile report.

The X-th percentile storm is the daily rainfall amount that occurs at least X percent of the time,

i.e., X percent of all rainfall days will have rainfall amounts less than or equal to the percentile

value. It is found by first ordering all days with rainfall above the Event Threshold from smallest

to highest value. The X-th percentile is the X-th percent highest value (e.g., if there were 1000

days with observable rainfall the 85-th percentile would be 850-th value in the sorted listing of

rainfall amounts).

As an example of how to interpret this plot, look at the bar in

associated with the 90th to 95th

percentile storm interval (daily rainfalls between 1.38 and 1.81 inches). Storms of this magnitude make

up 16 % of the total runoff (for this particular site and its land cover). Note that by definition the number

of events within this 5 percentile interval is 5 % of the total number of daily rainfall events.

Figure 20

Extreme Event Rainfall/Runoff

The Extreme Event Rainfall/Runoff report shows the rainfall and resulting runoff for a series of extreme

event (high intensity) storms that occur at different return periods. An example is shown in Figure 21.

Each stacked bar displays the annual max day rainfall that occurs with a given return period and the

runoff that results from it for the current set of site conditions. The max day rainfalls correspond to those shown on the Climate Change page for the scenario you selected (or to the historical value if no

climate change option was chosen).

Note that the max day rainfalls at different return periods are a different statistic than the daily rainfall

percentiles that are shown in the Runoff by Rainfall Percentile report (see Figure 20). The latter

represents the frequency with which any daily rainfall amount is exceeded while the former estimates

how often the largest daily rainfall in a year will be exceeded (hence its designation as an extreme storm

event). Most stormwater retention standards are stated with respect to rainfall percentiles while

extreme event rainfalls are commonly used to define design storms that are used to size stormwater

control measures. The extreme event rainfall amounts are generated using a statistical extrapolation

technique (as described in the Computational Methods section) that allows one to estimate the once in

X year event when fewer than X years of observed rainfall data are available.

""

Figure 21. The calculator’s Extreme Event Rainfall / Runoff report.

Cost Summary

The final report produced by the calculator shows estimates of probable LID construction and annual

maintenance costs. Tables and charts in the results tab, show construction and annual maintenance costs applied to the site. All the cost estimates produced after February of the current year are adjusted

to be current for the previous year. For instance, running the calculator after February 2016 produces

cost estimates in 2015 dollars. Site complexity and suitability variables that affect costs and the cost

regionalization option selected by the user are also shown below.

is an example of the tabular

representation of capital costs. All costs are presented as a range. Note that if a baseline scenario is

provided, the calculator shows the differences in costs between the baseline scenario and the current

scenario. The tabular and graphical examples provided do not account for baseline levels or amounts of

LID controls in place, which could be typical of new development sites or redevelopment sites without

LID controls.

Figure 22

shows a graphical representation of the capital costs. Error bars are used to

indicate the size of the cost range computed for each LID control. Similarly,

Figure 23

Figure 24

shows a tabular

representation of theannual maintenance costs, whileFigure25shows a graphical representationof

the annual maintenance costs.Note that the annualmaintenance costs are estimatesof current average

annualmaintenanceand are not basedon an assumed lifespanor lifecyclefor the LID controls.In otherwords,the annualmaintenance costs shown do not represent annualized present valueestimatesof thecost of maintenance over the lifeof the LID control.Other tools such as theWater Environment andReuseFoundation (WE&RF) BMPand LID Whole List Cost Modelsmay be useful for estimating lifecyclecosts.The numbers shownin the tables and charts representthe resultsusingthe example described inSection5.

""

Figure22. Tabularrepresentation of thecalculator's estimateof capitalcosts.

41

""

Figure 23. Graphical representation of the calculator's estimate of capital costs.

""

Figure 24. Tabular representation of the calculator's estimate of annual maintenance costs.

""

Figure 25. Graphical representation of the calculator's estimate of annual maintenance costs.

Printing Output Results

As mentioned previously, all of the information displayed on the Runoff pages of the calculator can be

written to a PDF file to provide a permanent record of the analysis made for a site. You simply select the

Print Results to PDF File command in the upper left panel of the Runoff page and then enter a name for

the file to which the results will be written.

4. Applying LID Controls

LID controls are landscaping practices designed to capture and retain stormwater generated from impervious surfaces that would otherwise run off the site. The Stormwater Calculator allows you to

apply a mix of seven different types of LID practices to a site. These are displayed in Table 2 along with

brief descriptions of each. This particular set of GI practices was chosen because they can all be sized on

the basis of just area. Two other commonly used controls, vegetative swales and infiltration trenches,

are not included because their sizing depends on their actual location and length within the site,

information which is beyond the scope of the calculator.

Each LID practice is assigned a set of default design and sizing parameters, so to apply a particular

practice to a site, you only have to specify what percentage of the site's impervious area will be treated

by the practice (see Figure 10). You can, however, modify the default settings by clicking on the name of

the particular practice you wish to edit. For example, Figure 26 displays the resulting LID Design dialog

window that appears when the Street Planter LID is selected. All of the LID controls have similar LID

Design dialogs that contain a sketch and brief description of the LID control along with a set of edit

boxes for its design parameters. The Learn More … link will open your web browser to a page that

provides more detailed information about the LID practice.

Table 3lists the various parameters that can be edited with the LID Design dialogs along with their default factory setting. Arguably the most important of these is the Capture Ratio parameter. This

determines the size of the control relative to the impervious area it treats. Note that because the

calculator does not require that the actual area of the site be specified, all sub-areas are stated on a

percentage basis. So, total impervious area is some percentage of the total site area, the area treated by

a particular LID control is some percentage of the total impervious area, and the area of the LID control

is some percentage of the area it treats.

Pressing the Size for Design Storm button on an LID Design form will make the calculator automatically

size the LID control to capture the Design Storm Depth that was entered on the LID Control page (see

Figure 10). This computes a Capture Ratio (area of LID relative to area being treated) for Rain Gardens,

Street Planters, Infiltration Basins, and Porous Pavement by taking the ratio of the design storm depth to

the depth of available storage in the LID unit. For Infiltration Basins it also determines the depth that will

completely drain the basin within 48 hours. For Rainwater Harvesting it calculates how many cisterns of

the user-supplied size will be needed to capture the design storm. Automatic sizing is not available for

Disconnection, since no storage volume is used with this practice, and for Green Roofs, since the ratio is

100% by definition. The methods used to automatically size the LID controls are described in the

Computational Methods section of this user’s guide. Note that even when sized in this fashion, a LID control might not fully capture the design storm because it may not have drained completely prior to

the start of the storm or the rainfall intensity during some portion of the storm event may overwhelm its

infiltration capacity. The calculator is able to capture such behavior because it continuously simulates

the full range of past precipitation events.

Table 2. Descriptions of LID practices included in the calculator.

LID Practice Description

Disconnection Photo of drainage pipe along outside wall of house.

Disconnection refers to the practice of directing runoff from impervious areas, such as roofs or parking lots, onto pervious areas, such as lawns or vegetative strips, instead of directly into storm drains.

Rain Harvesting Photo of rain barrel collecting water runoff from roof.

Rain harvesting systems collect runoff from rooftops and convey it to a cistern tank where it can be used for non-potable water uses and on-site infiltration.

Rain Gardens Photo of a garden by a home that will help to retain water.

Rain Gardens are shallow depressions filled with an engineered soil mix that supports vegetative growth. They provide opportunity to store and infiltrate captured runoff and retain water for plant uptake. They are commonly used on individual home lots to capture roof runoff.

Green Roofs Vegetation on a roof that catches rain water.

Green roofs (also known as vegetated roofs) are bioretention systems placed on roof surfaces that capture and temporarily store rainwater in a soil medium. They consist of a layered system of roofing designed to

support plant growth and retain water for plant uptake while
preventing ponding on the roof surface.
Street Planters streetplanter.bmp
Street Planters are typically placed along sidewalks or parking areas.
They consist of concrete boxes filled with an engineered soil that
supports vegetative growth. Beneath the soil is a gravel bed that
provides additional storage as the captured runoff infiltrates into the
existing soil below.
Infiltration Basins InfiltrationBasin5.jpg
Infiltration basins are shallow depressions filled with grass or other
natural vegetation that capture runoff from adjoining areas and allow it
to infiltrate into the soil.
Porous Pavement PorousPavement2.bmp
Porous Pavement systems are excavated areas filled with gravel and
paved over with a porous concrete or asphalt mix or with modular
porous blocks. Normally all rainfall will immediately pass through the
pavement into the gravel storage layer below it where it can infiltrate at
natural rates into the site's native soil.
""

1. The area devoted to Disconnection, Rain Gardens, and Infiltration Basins is assumed to come

from the site’s collective amount of pervious land cover while the area occupied by Green Roofs,

Street Planters and Porous Pavement comes from the site’s store of impervious area.

2. Underdrains (slotted pipes placed in the gravel beds of Street Planter and Porous Pavement

areas to prevent the unit from flooding) are not provided for. However, since underdrains are

typically oversized and placed at the top of the unit's gravel bed, the effect on the amount of

excess runoff flow bypassed by the unit is the same whether it flows out of the underdrain or

simply runs off of a flooded surface.

3. The amount of void space in the soil, gravel, and pavement used in the LID controls are listed in

Table 4 below. They typically have a narrow range of acceptable values and results are not

terribly sensitive to variations within this range.

Figure 26. Example of a LID Design dialog for a street planter.

There are some additional points to keep in mind when applying LID controls to a site:

Table 1. Definitions of Hydrologic Soil Groups (USDA, 2010).

Group	Meaning	Saturated Hydraulic Conductivity (in/hr)
A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.	≥ 0.45
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. E.g., shallow loess, sandy loam.	0.30 - 0.15
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. E.g., clay loams, shallow sandy loam.	0.15 - 0.05
D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay-pan or clay layer at or near the surface, and shallow soils over nearly impervious material.	0.05 - 0.00

Table 3. Editable LID parameters.

LID Type	Parameter	Default Value
Disconnection	Capture Ratio	100 %
Rain Harvesting	Cistern Size	100 gal
	Cistern Emptying Rate	50 gal/day
	Number of Cisterns	4 per 1,000 sq ft
Rain Gardens	Capture Ratio	5 %
	Ponding Depth	6 inches
	Soil Media Thickness	12 inches
	Soil Media Conductivity	10 inches/hour
Green Roofs	Soil Media Thickness	4 inches
	Soil Media Conductivity	10 inches/hour
Street Planters	Capture Ratio	6 %
	Ponding Depth	6 inches
	Soil Media Thickness	18 inches
	Soil Media Conductivity	10 inches/hour
	Gravel Bed Thickness	12 inches
Infiltration Basins	Capture Ratio	5 %
	Basin Depth	6 inches
Porous Pavement	Capture Ratio	100 %
	Pavement Thickness	4 inches
	Gravel Bed Thickness	18 inches

Table 4. Void space values of LID media.

Property	LID Controls	Default Value
Soil Media Porosity	Rain Gardens, Green Roofs and Street Planters	45 %
Gravel Bed Void Ratio	Street Planters and Porous Pavement	75 %
Pavement Void Ratio	Porous Pavement	12 %

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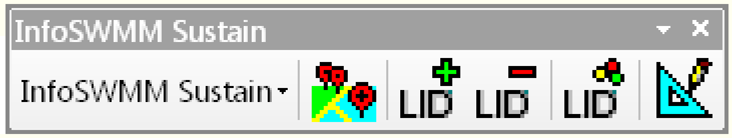
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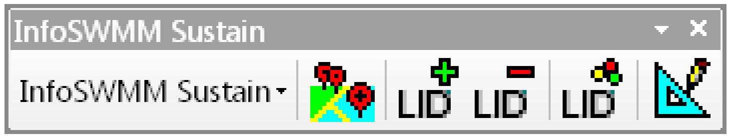
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LID Designer References

ACRONYMS AND ABBREVIATIONS

ASCE = American Society of Civil Engineers

BLS = United States Bureau of Labor Statistics

CMIP3 = Coupled Model Intercomparison Project Phase 3

CREAT = Climate Resilience Evaluation and Awareness Tool EPA = United States Environmental Protection Agency GCM = General Circulation Model

GEV = Generalized Extreme Value

GI = Green Infrastructure

HSG = Hydrologic Soil Group

IMD = initial moisture deficit

IPCC = Intergovernmental Panel on Climate Change

Ksat = saturated hydraulic conductivity

LID = Low impact development

NCDC = National Climatic Data Center

NRCS = Natural Resources Conservation Service

NWS = National Weather Service

OW = Office of Water

SWAT = Soil and Water Assessment Tool

SWC = Stormwater Calculator

SWMM = Storm Water Management Model

UDFCD = Urban Drainage and Flood Control District US = United States

USDA = United States Department of Agriculture

WCRP = World Climate Research Programme

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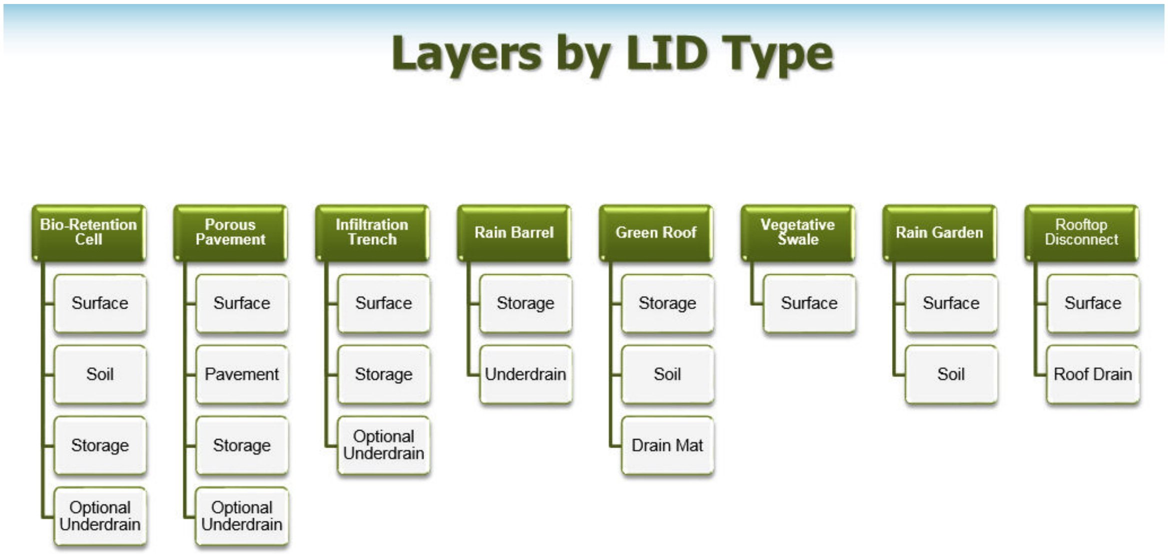
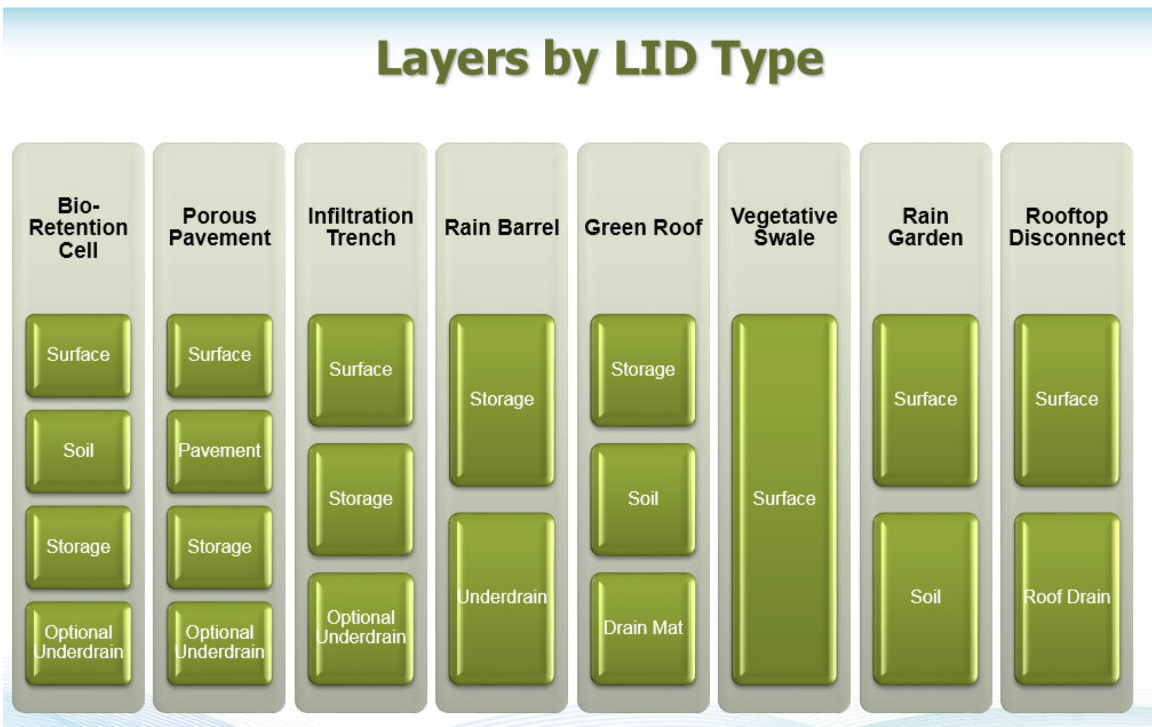
General LID Features

The number of LID Controls is unlimited and very flexible. In addition to the 5 main LID controls:

1. Rain Barrel
2. Bio-Retention Cell
3. Infiltration Trench
4. Porous Pavement
5. Vegetative Swale
6. Green Roof
7. Rain Garden
8. Rooftop Disconnection

LID Controls
Rain Barrel
Rain Garden
Green Roof
Infiltration Trench
Bio-Retention Cell
Permeable Pavement
Vegetative Swale
Roof Top Disconnec t
LID Controls





You can also simulate real housing features such as: a. Variable Pervious Areas,

b. Small Orchards,

c. Rain Gutters and Street Gutters,

d. Sand Filters,

e. French Drains,

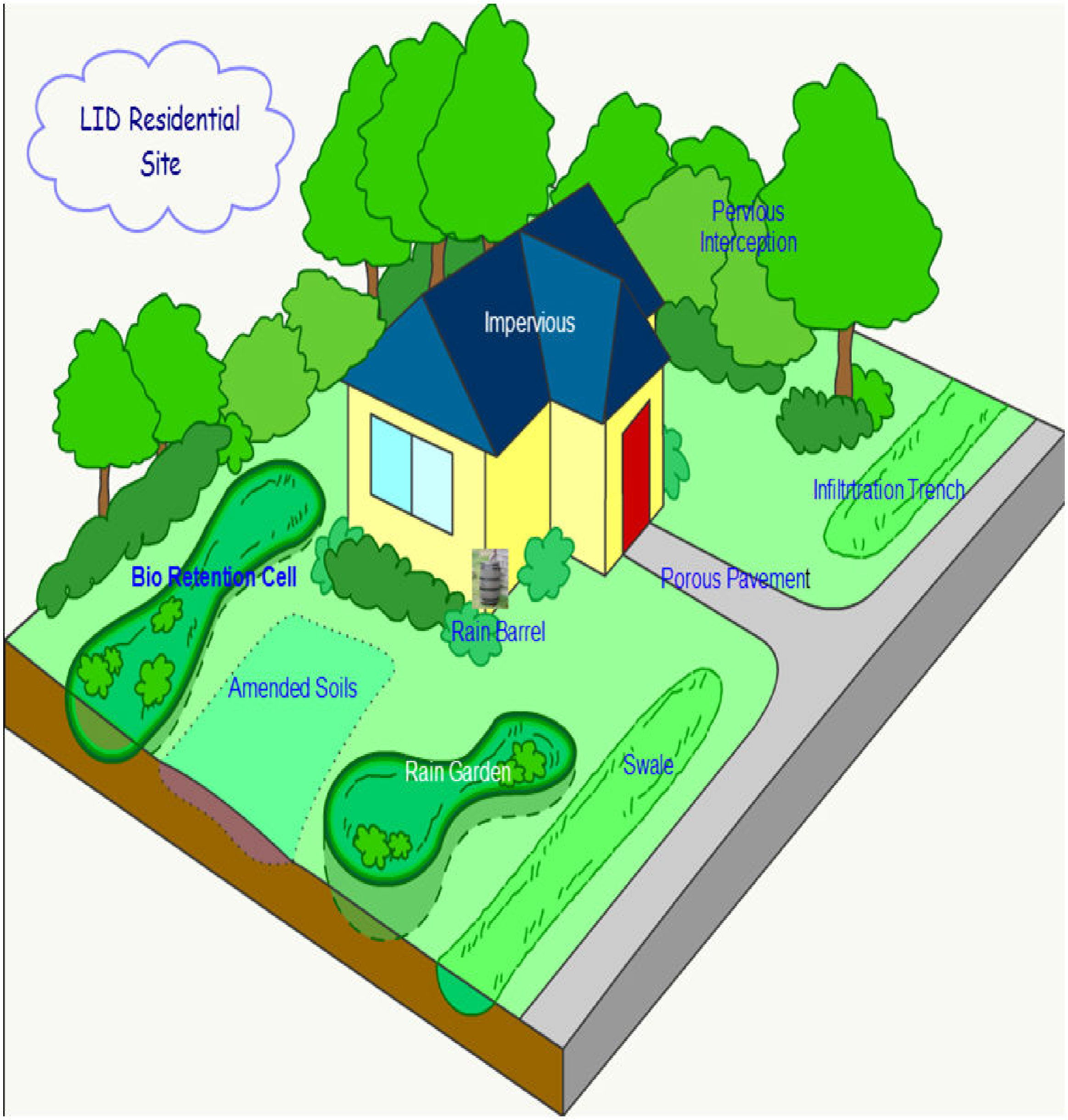
f. Bio Swales

g. Green Roofs

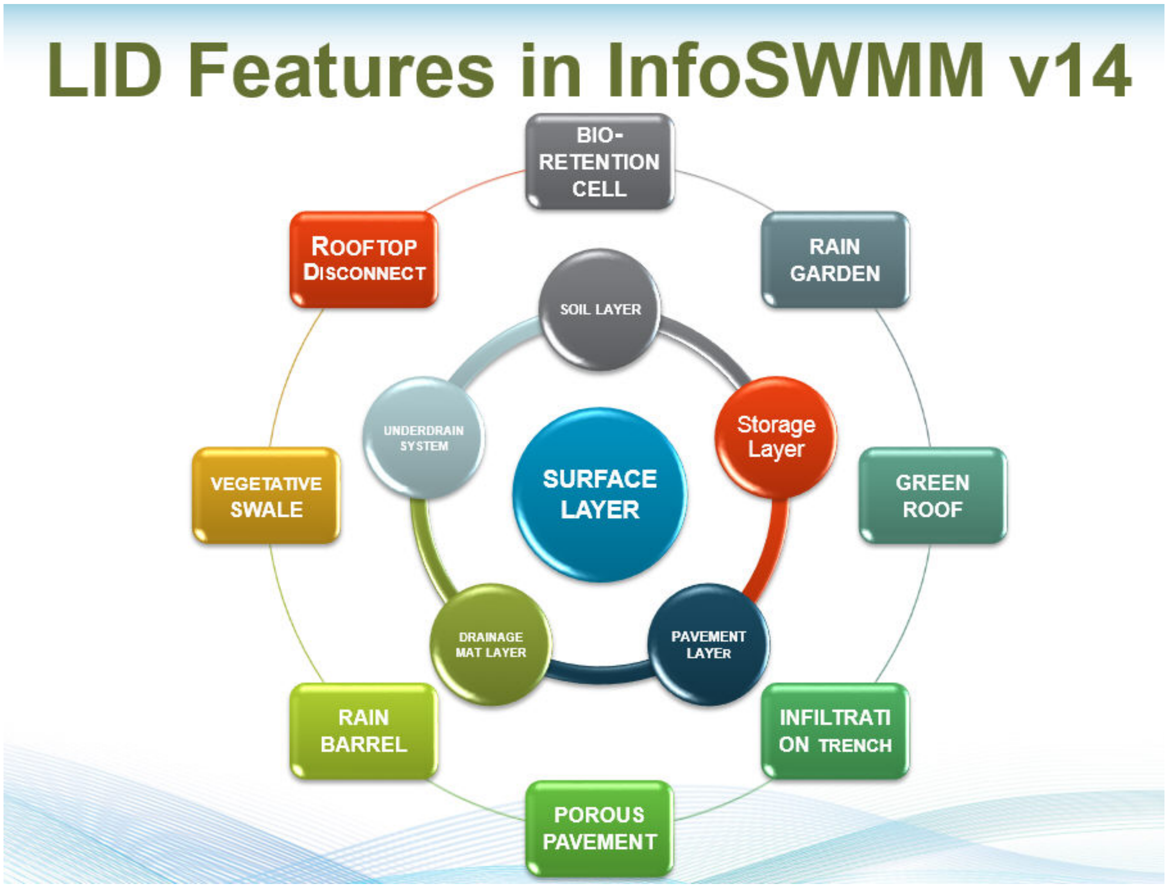
h. Cisterns

i. Better Simulated Retention Ponds

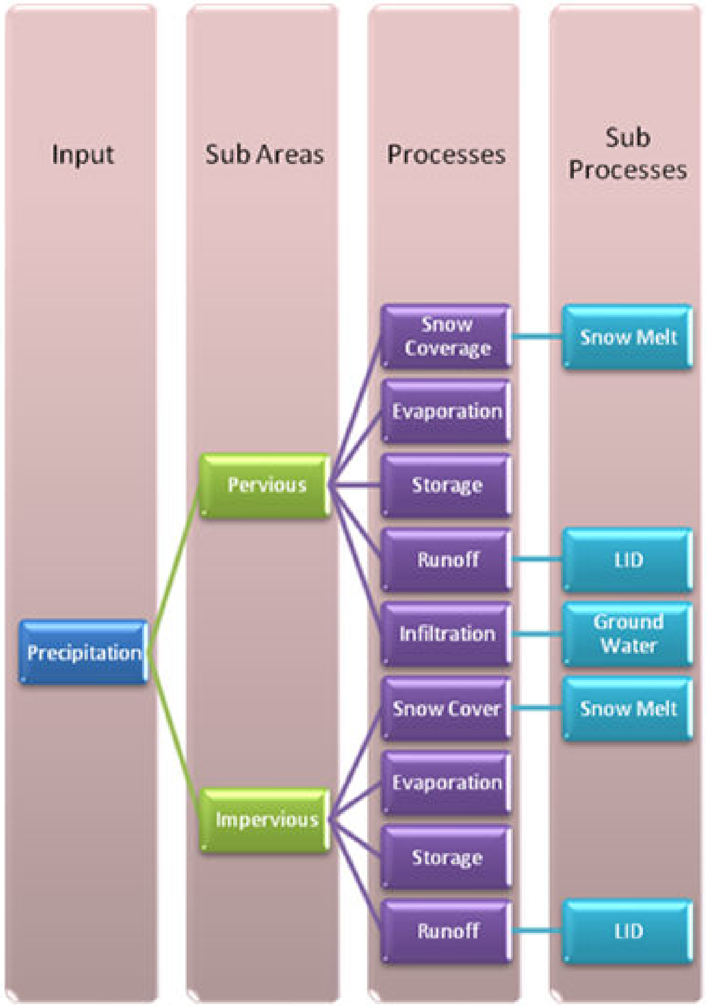
j. Better Simulated Detention Ponds



Combining the LID Controls and the LID layers per control is shown in the following Figure.



LID Connection to the Subcatchment Processes for Pervious and Impervious Areas.



There are seven Types of LID Controls possible per Subcatchment. The number of controls are unlimited.

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LID Placement

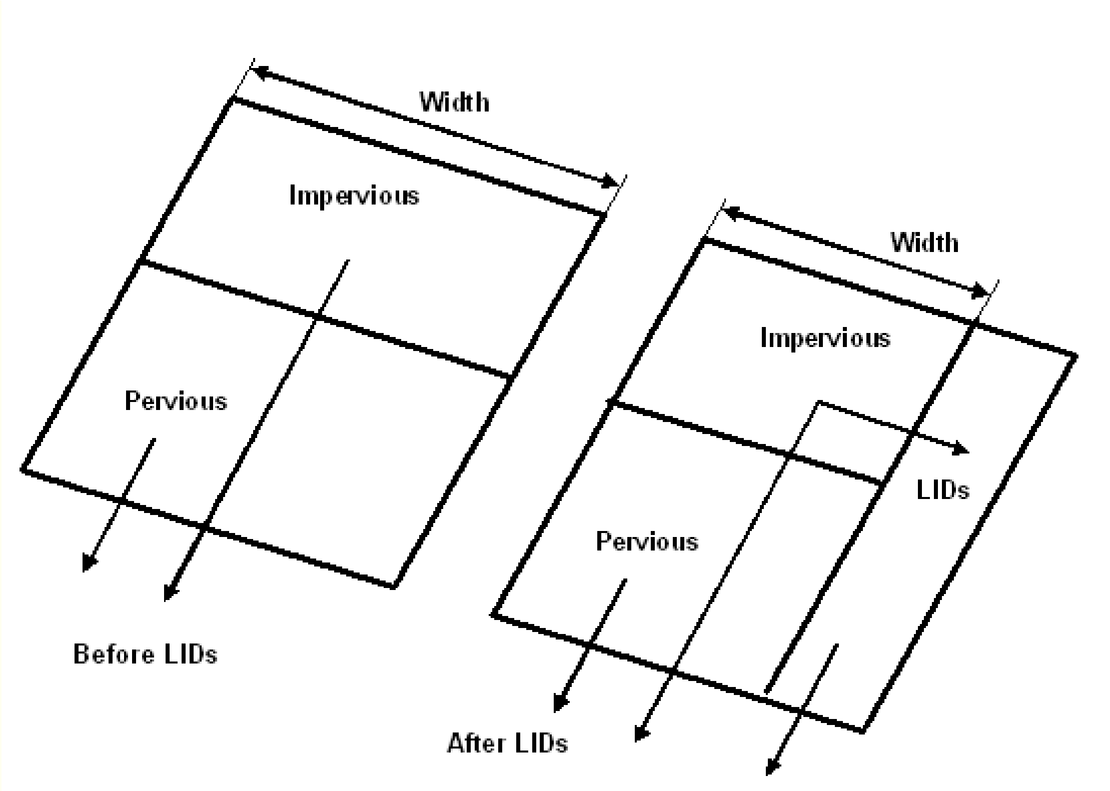
There are two different approaches for placing LID controls within a Subcatchment:

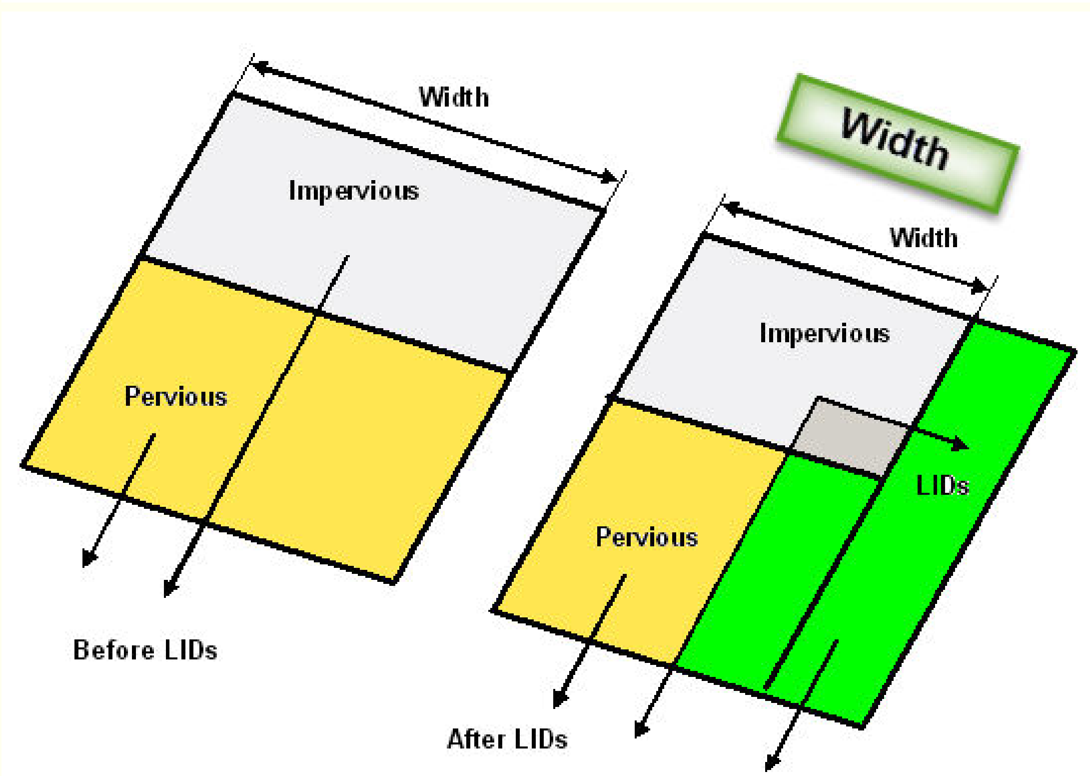
- 1. place one or more controls in an existing Subcatchment that will displace an equal amount of non-LID area from the Subcatchment
- 2. create a new Subcatchment devoted entirely to just a single LID practice.

The first approach allows a mix of LIDs to be placed into a Subcatchment, each treating a different portion of the runoff generated from the non-LID

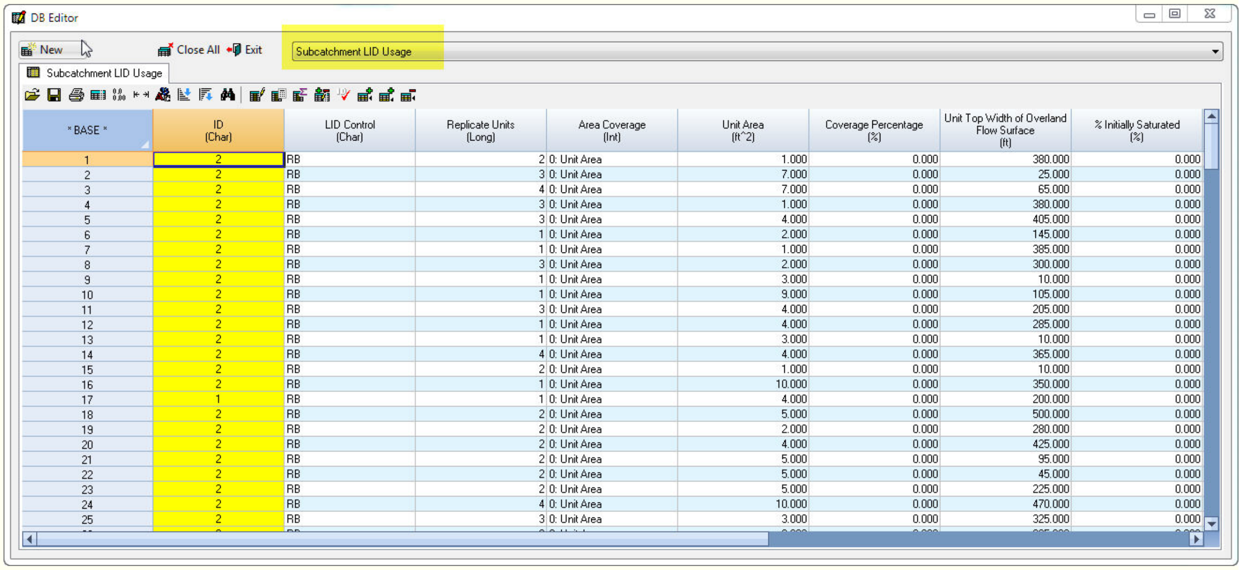
fraction of the Subcatchment. Note that under this option the sub catchment’s LIDs act in parallel -- it is not possible to make them act in series (i.e., have the outflow from one LID control become the inflow to another LID). Also, after LID placement the sub catchment’s Percent Impervious and Width properties may require adjustment to compensate for the amount of original Subcatchment area that has now been replaced by LIDs (see the figure below). For example, suppose that a Subcatchment which is 40%

impervious has 75% of that area converted to a porous pavement LID. After the LID is added the sub catchment’s percent imperviousness should be changed to the percent of impervious area remaining divided by the percent of non-LID area remaining. This works out to (1 - 0.75)*40 / (100 - 0.75*40) or 14.3 %.





The second approach allows LID controls to be strung along in series and also allows runoff from several different upstream sub catchments to be routed onto the LID Subcatchment. If these single-LID sub catchments are carved out of existing sub catchments, then once again some adjustment of the Percent Impervious, Width and also the Area properties of the latter may be necessary. In addition, whenever an LID occupies the entire Subcatchment the values assigned to the sub catchment's standard surface properties (such as imperviousness, slope, roughness, etc.) are overridden by those that pertain to the LID unit.



* BASE *	ID (Char)	LID Control (Char)	Replicate Units (Long)	Area Coverage (Int)	Unit Area (ft^2)	Coverage Percentage (%)	Unit Top Width of Overland Flow Surface (ft)	% Initially Saturated (%)
1	2	RB	2	0: Unit Area	1.000	0.000	380.000	0.000
2	2	RB	3	0: Unit Area	7.000	0.000	25.000	0.000
3	2	RB	4	0: Unit Area	7.000	0.000	65.000	0.000
4	2	RB	3	0: Unit Area	1.000	0.000	380.000	0.000
5	2	RB	3	0: Unit Area	4.000	0.000	405.000	0.000
6	2	RB	1	0: Unit Area	2.000	0.000	145.000	0.000
7	2	RB	1	0: Unit Area	1.000	0.000	385.000	0.000
8	2	RB	3	0: Unit Area	2.000	0.000	300.000	0.000
9	2	RB	1	0: Unit Area	3.000	0.000	10.000	0.000
10	2	RB	1	0: Unit Area	9.000	0.000	105.000	0.000
11	2	RB	3	0: Unit Area	4.000	0.000	205.000	0.000
12	2	RB	1	0: Unit Area	4.000	0.000	285.000	0.000
13	2	RB	1	0: Unit Area	3.000	0.000	10.000	0.000
14	2	RB	4	0: Unit Area	4.000	0.000	365.000	0.000
15	2	RB	2	0: Unit Area	1.000	0.000	10.000	0.000
16	2	RB	1	0: Unit Area	10.000	0.000	350.000	0.000
17	1	RB	1	0: Unit Area	4.000	0.000	200.000	0.000
18	2	RB	2	0: Unit Area	5.000	0.000	500.000	0.000
19	2	RB	2	0: Unit Area	2.000	0.000	280.000	0.000
20	2	RB	2	0: Unit Area	4.000	0.000	425.000	0.000
21	2	RB	2	0: Unit Area	5.000	0.000	95.000	0.000
22	2	RB	2	0: Unit Area	5.000	0.000	45.000	0.000
23	2	RB	2	0: Unit Area	5.000	0.000	225.000	0.000
24	2	RB	4	0: Unit Area	10.000	0.000	470.000	0.000
25	2	RB	3	0: Unit Area	3.000	0.000	325.000	0.000

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LID Process

A LID Process consists of seven structured components or layers: 1. Drain or UnderDrain

2. Storage

3. Soil

4. Pavement

5. Surface

6. Drainage Mat

7. Roof Drainage

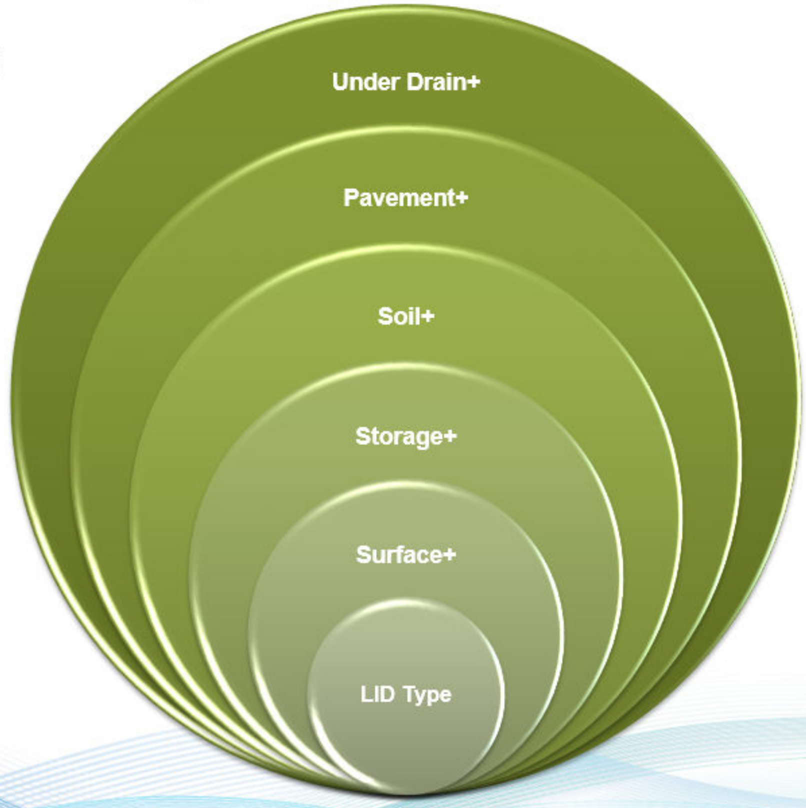
Each of the 8 types of LID Controls: (1) Bio-Retention Cell, (2) Porous Pavement, (3) Infiltration Trench, (4) Rain Barrel, (5) Green Roof, (6) Vegetative Swale, (7) Rain Garden and (8) Rooftop Disconnection have different required and optional components.

The LID Processes consists of five structured components or layer types: Surface, Storage, Soil, Pavement and Under Drains.

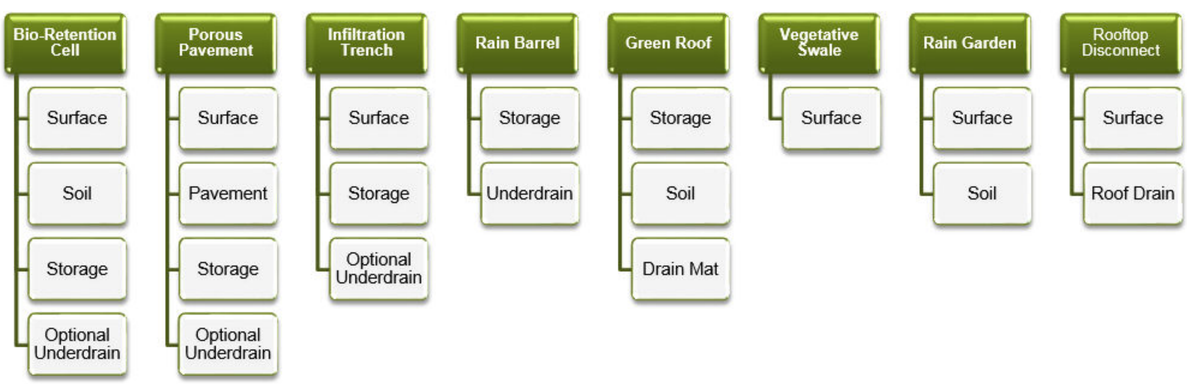
LID Process Layer Types

A LID Process consists of five structured components or layers:

1. **Surface**
2. **Storage**
3. **Soil**
4. **Pavement**
5. **Under Drain**



Layers by LID Type



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LID Utilization

Utilizing LID controls within a project is a two phase process that:

1. creates a set of scale-independent LID controls that can be deployed throughout the study area,

2. assigns any desired mix and sizing of these controls to selected Subcatchments.

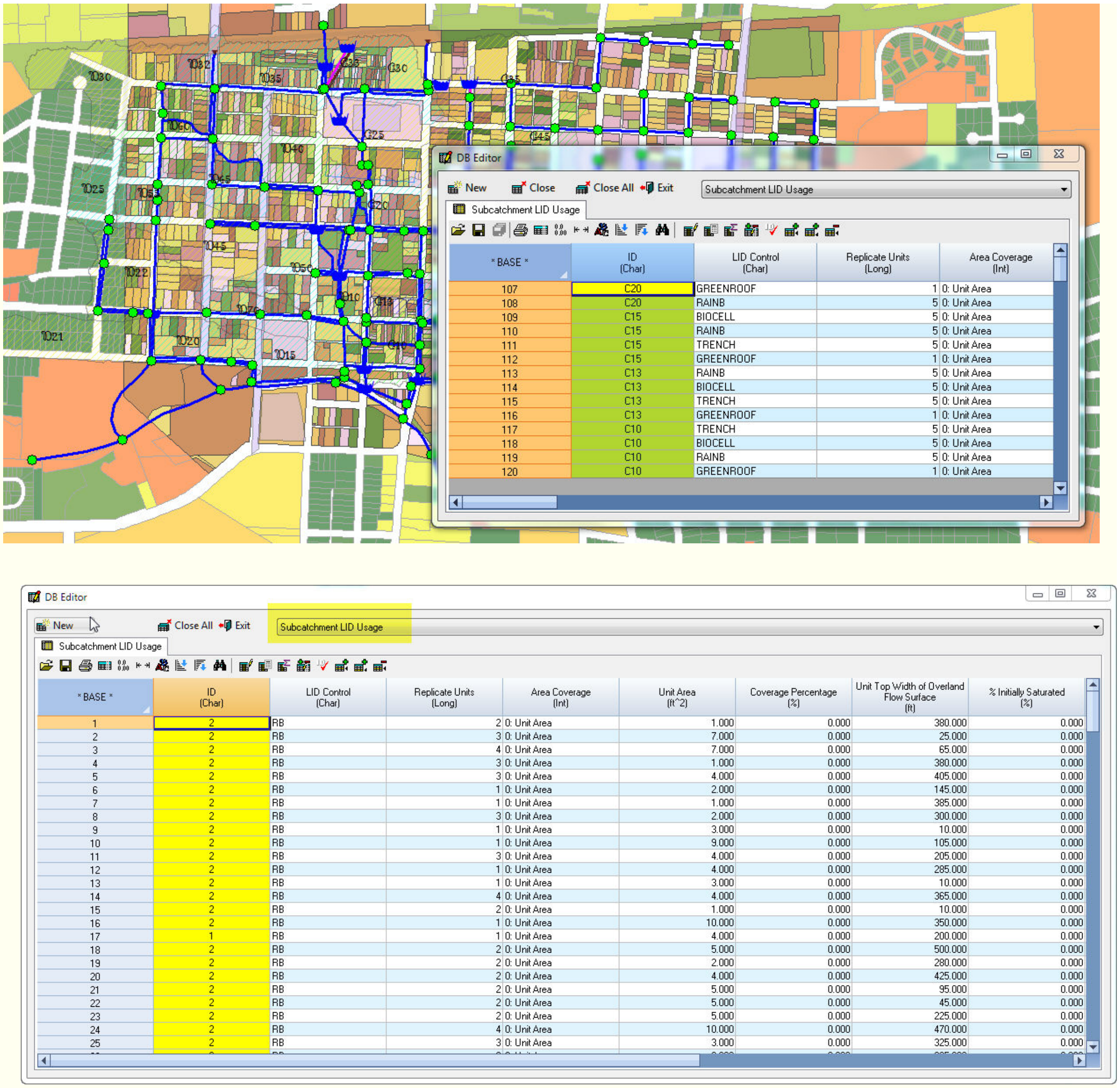
Bear in mind that when LIDs are added to a Subcatchment, the Subcatchment's Area property is the total area of the Subcatchment (both non-LID and LID portions) while the Percent Imperviousness and Width parameters apply only to the non-LID portion of the Subcatchment.

To implement the first phase, one selects the Hydrology | LID Controls category from the Data Browser to add, edit or delete individual LID control objects. The LID

Control Editor is used to edit the properties of the various component layers that comprise each LID control object.

For the second phase, for each Subcatchment that will utilize LIDs, one selects the LID Controls property in the Subcatchment's Property Editor to launch the LID Group Editor. This editor is used to add or delete individual LID controls from the Subcatchment. For each control added the LID Usage Editor is used to specify the size of the control and what portion of the Subcatchment's area that it treats.

LID’s are Unlimited per Subcatchment



DB Editor

New | Close | Close All | Exit | Subcatchment LID Usage

Subcatchment LID Usage

* BASE *	ID (Char)	LID Control (Char)	Replicate Units (Long)	Area Coverage (Int)
107	C20	GREENROOF	1	0: Unit Area
108	C20	RAINB	5	0: Unit Area
109	C15	BIOCELL	5	0: Unit Area
110	C15	RAINB	5	0: Unit Area
111	C15	TRENCH	5	0: Unit Area
112	C15	GREENROOF	1	0: Unit Area
113	C13	RAINB	5	0: Unit Area
114	C13	BIOCELL	5	0: Unit Area
115	C13	TRENCH	5	0: Unit Area
116	C13	GREENROOF	1	0: Unit Area
117	C10	TRENCH	5	0: Unit Area
118	C10	BIOCELL	5	0: Unit Area
119	C10	RAINB	5	0: Unit Area
120	C10	GREENROOF	1	0: Unit Area

DB Editor

New | Close All | Exit | Subcatchment LID Usage

Subcatchment LID Usage

* BASE *	ID (Char)	LID Control (Char)	Replicate Units (Long)	Area Coverage (Int)	Unit Area (ft^2)	Coverage Percentage (%)	Unit Top Width of Overland Flow Surface (ft)	% Initially Saturated (%)
1	2	RB	2	0: Unit Area	1.000	0.000	380.000	0.000
2	2	RB	3	0: Unit Area	7.000	0.000	25.000	0.000
3	2	RB	4	0: Unit Area	7.000	0.000	65.000	0.000
4	2	RB	3	0: Unit Area	1.000	0.000	380.000	0.000
5	2	RB	3	0: Unit Area	4.000	0.000	405.000	0.000
6	2	RB	1	0: Unit Area	2.000	0.000	145.000	0.000
7	2	RB	1	0: Unit Area	1.000	0.000	385.000	0.000
8	2	RB	3	0: Unit Area	2.000	0.000	300.000	0.000
9	2	RB	1	0: Unit Area	3.000	0.000	10.000	0.000
10	2	RB	1	0: Unit Area	9.000	0.000	105.000	0.000
11	2	RB	3	0: Unit Area	4.000	0.000	205.000	0.000
12	2	RB	1	0: Unit Area	4.000	0.000	285.000	0.000
13	2	RB	1	0: Unit Area	3.000	0.000	10.000	0.000
14	2	RB	4	0: Unit Area	4.000	0.000	365.000	0.000
15	2	RB	2	0: Unit Area	1.000	0.000	10.000	0.000
16	2	RB	1	0: Unit Area	10.000	0.000	350.000	0.000
17	1	RB	1	0: Unit Area	4.000	0.000	200.000	0.000
18	2	RB	2	0: Unit Area	5.000	0.000	500.000	0.000
19	2	RB	2	0: Unit Area	2.000	0.000	280.000	0.000
20	2	RB	2	0: Unit Area	4.000	0.000	425.000	0.000
21	2	RB	2	0: Unit Area	5.000	0.000	95.000	0.000
22	2	RB	2	0: Unit Area	5.000	0.000	45.000	0.000
23	2	RB	2	0: Unit Area	5.000	0.000	225.000	0.000
24	2	RB	4	0: Unit Area	10.000	0.000	470.000	0.000
25	2	RB	3	0: Unit Area	3.000	0.000	325.000	0.000

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LID Controls - Introduction

LID Controls are low impact development practices designed to capture surface runoff and provide some combination of detention, infiltration, and evapotranspiration to it. They are considered as properties of a given Subcatchment, similar to how Aquifers and Snow Packs are treated. SWMM

can explicitly model five different generic types of LID controls:

- Bio-retention Cells are depressions that contain vegetation grown in an engineered soil mixture placed above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas. Rain gardens, street planters, and green roofs are all variations of bio-retention cells.
- Infiltration Trenches are narrow ditches filled with gravel that intercept runoff from upslope impervious areas. They provide storage volume and additional time for captured runoff to infiltrate the native soil below.
- Continuous Porous Pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix.

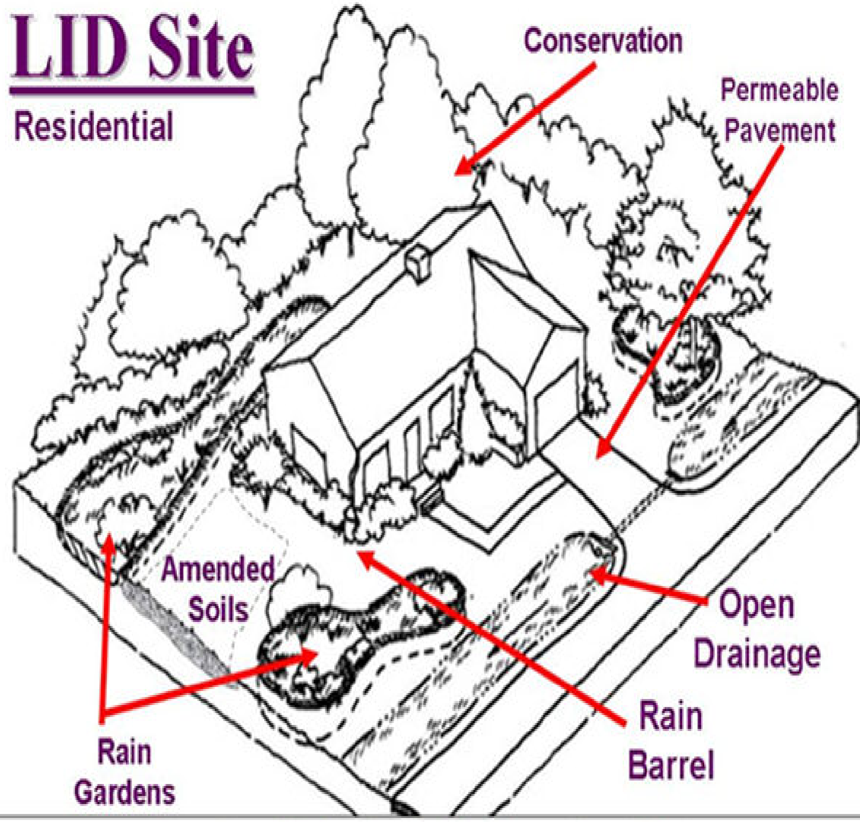
  Normally all rainfall will immediately pass through the pavement into the gravel storage layer below it where it can infiltrate at natural rates into the site's native soil. Block Paver systems consist of impervious paver blocks placed on a sand or pea gravel bed with a gravel storage layer below. Rainfall is captured in the open spaces between the blocks and conveyed to the storage zone and native soil below.
- Rain Barrels (or Cisterns) are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods.
- Vegetative Swales are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate the native soil beneath it.

LID Controls
Rain Barrel
Rain Garden
Green Roof
Infiltration Trench
Bio-Retention Cell
Permeable Pavement
Vegetative Swale
Roof Top Disconnec t
LID Controls

Low Impact Development features are small and part of the subcatchment runoff flow. They are best simulated as part of the subcatchment and to be successfully modeled they need to be varied and unlimited in number.

LID Site

Residential

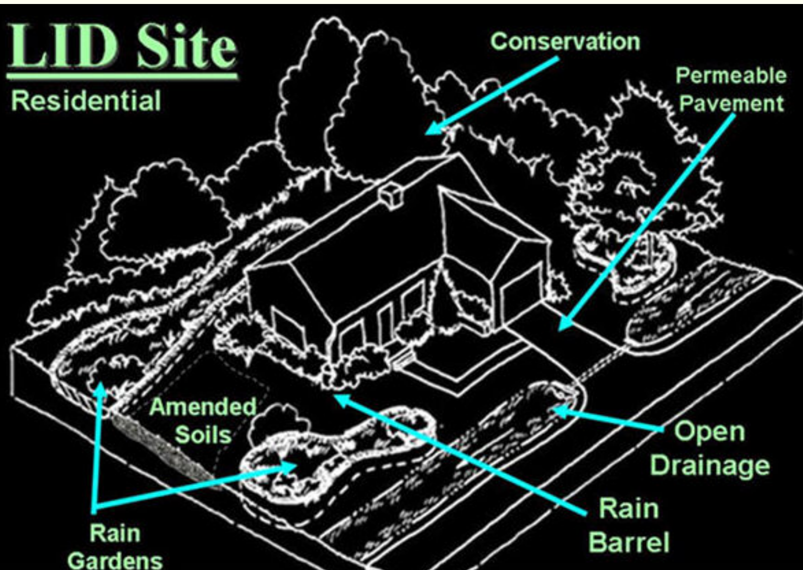


Create a Hydrologically Functional Lot

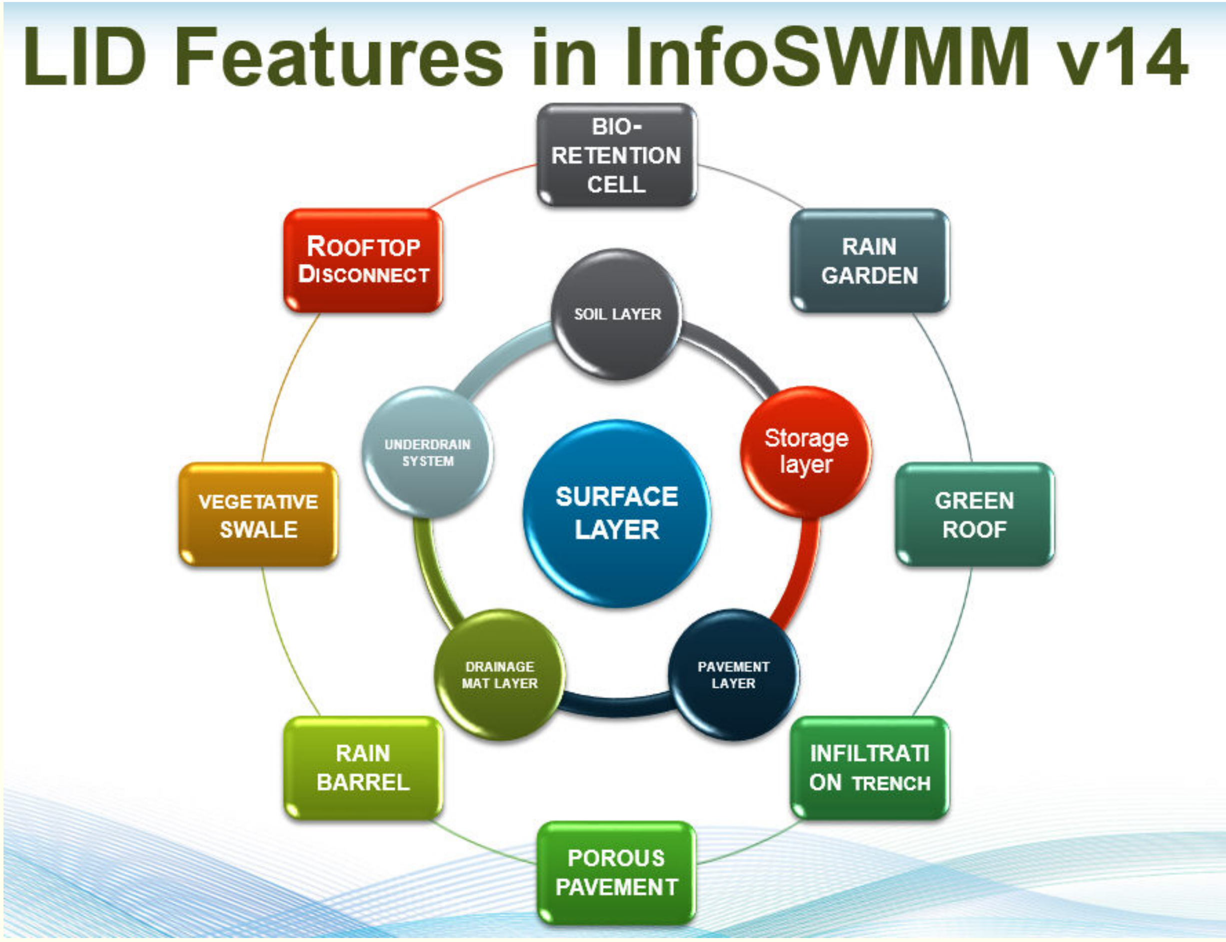
Low Impact Development features are small and part of the subcatchment runoff flow. They are best simulated as part of the subcatchment and to be successfully modeled they need to be varied and unlimited in number.

LID Site

Residential



Create a Hydrologically Functional Lot



Bio-retention cells, infiltration trenches, and porous pavement systems can all contain optional underdrain systems in their gravel storage beds to convey captured runoff off of the site rather than letting it all infiltrate.

They can also have an impermeable floor or liner that prevents any infiltration into the native soil from occurring. Infiltration trenches and porous pavement systems can also be subjected to a decrease in hydraulic conductivity over time due to clogging.

Although some LID practices can also provide significant pollutant reduction benefits, at this time SWMM5, InfoSWMM and H2OMAP SWMM only models their hydrologic performance. For more details on using LID controls within SWMM5, InfoSWMM and H2OMAP SWMM see the following topics:

- LID Representation
- LID Utilization

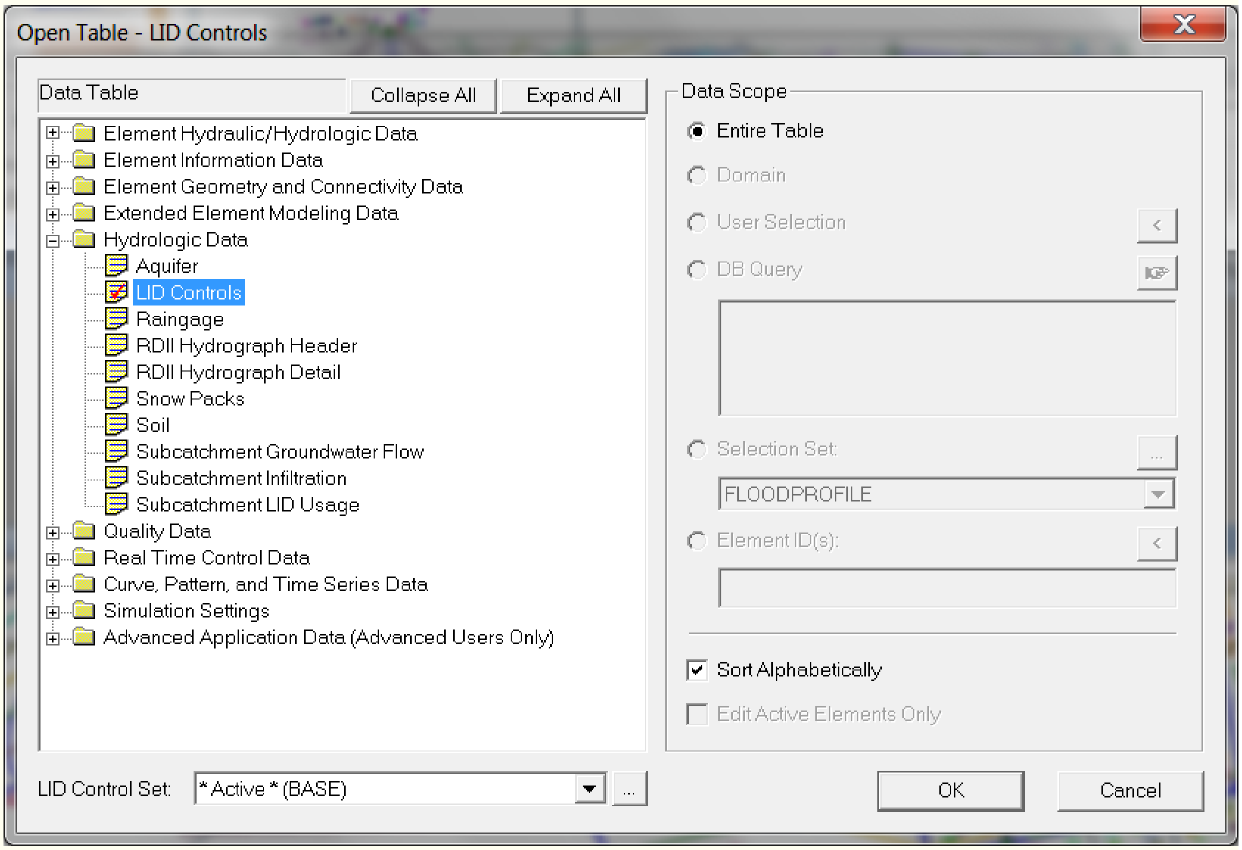
- LID

  Placement
- LID

  Results

General location note for DB Tables and Attribute Browser

The LID DB Tables are in the Hydrologic Data Tables, You can access the LID Controls as well by using the Operations Tab of the Attribute Browser.



Chapter 6 - Low Impact Development Controls

Excerpt from the EPA manual Storm

Water Management Model Reference Manual Volume III – Water Quality (PDF) which can be found

here

6.1 Introduction

Low impact development (LID) controls are landscaping practices designed to capture and retain stormwater generated from impervious surfaces that would otherwise run off of a site. They are also referred to as green infrastructure (GI), integrated management practices (IMPs) sustainable urban drainage systems (SUDS), and stormwater control measures (SCMs). See Fletcher et al. (2015) for a review of this terminology. Prince Georges County (1999a) describes the LID concept and its application to stormwater management in more detail.

Additional informational resources are available from the following US EPA web sites:

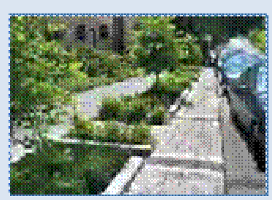
- http://water.epa.gov/polwaste/green/
- http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm

and from the Low Impact Development Center

(http://lowimpactdevelopment.org).

SWMM 5 can explicitly model the following types of LID practices:

Bio-retention Cells are depressions that contain vegetation grown in an engineered soil mixture placed above a gravel storage bed. They provide storage, infiltration and evaporation of both direct rainfall and



runoff captured from surrounding areas. Street planters and bio-swales are common examples of bio-retention cells.

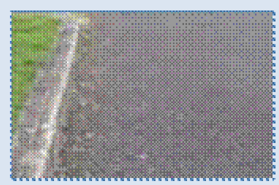
Rain Gardens are a

type of bio-retention cell consisting of just the engineered soil layer with no gravel bed below it.

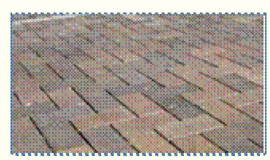
Green Roofs are another variation of a bio-retention cell that have a soil layer above a thin layer of synthetic drainage mat material or coarse aggregate that conveys excess water draining through the soil layer off of the roof.

Infiltration Trenches are narrow ditches filled with gravel that intercept runoff from upslope impervious areas. They provide storage volume and additional time for captured runoff to infiltrate into the native soil below.

Continuous Permeable Pavement systems are street or parking areas paved with a porous concrete or asphalt mix that sits above a gravel storage layer. Rainfall passes through the pavement into the storage layer where it can infiltrate into the site's native soil.



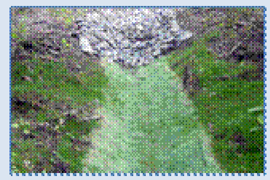
Block Paver systems consist of impervious paver blocks placed on a sand or pea gravel bed with a gravel storage layer below. Rainfall is captured in the open spaces between the blocks and conveyed to the storage zone where it can infiltrate into the site's native soil.



Rain Barrels (or ***Cisterns***) are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods.

Rooftop Disconnection has roof downspouts discharge to pervious landscaped areas and lawns instead of directly into storm drains. It can also model roofs with directly connected drains that overflow onto pervious areas.

Vegetative Swales are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate into the native soil.



Bio-retention cells, infiltration trenches, and permeable pavement systems can contain optional underdrain systems in their gravel storage beds to convey excess captured runoff off of the site and prevent the unit from flooding. They can also have an impermeable floor or liner that prevents any infiltration into the native soil from occurring. Infiltration trenches and permeable pavement systems can also be subjected to a decrease in hydraulic conductivity over time due to clogging. Other LID practices, such as preservation of natural areas, reduction of impervious cover, and soil restoration, can be modeled by using SWMM's conventional runoff elements.

LID is a distributed method of runoff source control, that uses surface and landscape modifications located on or adjacent to impervious areas that generate most of the runoff in urbanized areas. For this reason SWMM considers LID controls to be part of its Subcatchment object, where each control is assigned a fraction of the subcatchment's impervious area whose runoff it captures.

The design variables that affect the hydrologic performance of LID controls include the properties of the media (soil and gravel) contained within the unit, the vertical depth

of its media layers, the hydraulic capacity of any underdrain system used, and the surface area of the unit itself. Although some LID practices can also provide significant pollutant reduction benefits (Hunt et al., 2006; Li and Davis, 2009), at this time SWMM only captures the reduction in runoff mass load resulting from the reduction in runoff flow volume.

Several different approaches have been used in the past to model LID hydrology. One simple scheme uses the void volume available in the LID unit (Davis and McCuen, 2005), possibly combined with a modified Curve Number for LID areas (Prince Georges County, 1999b), to determine what depth of storm event will be captured. Although useful for initial sizing, it ignores the effects that varying rainfall intensity and event frequency have on surface infiltration, soil moisture retention, and storage capacity. At the other end of the spectrum are detailed soil physics models, typically based on the Richards equation, that estimate the flows and moisture levels for a single LID unit over the course of a rainfall event (see Dussaillant et al., (2004) and He and Davis, (2011)). These approaches are too computationally intensive to be used in a general purpose engineering model like SWMM, where hundreds of LID units might be deployed throughout a large study area. A third approach, suggested by Huber et al. (2006) is to utilize SWMM’s conventional elements and features, such as internal routing within subcatchments and multiple storage units connected by flow regulator links, to approximate the behavior of LID units. Unfortunately, an accurate representation of LID behavior can require a very complex arrangement of SWMM elements (see Zhang et al. (2006) and Lucas (2010) for examples). To circumvent these issues, SWMM 5 treats LID controls as an additional type of discrete element, using a unit process-based representation of their behavior (Rossman, 2010) that provides a reasonable level of accuracy for simulating dynamic rainfall events in a computationally efficient manner.

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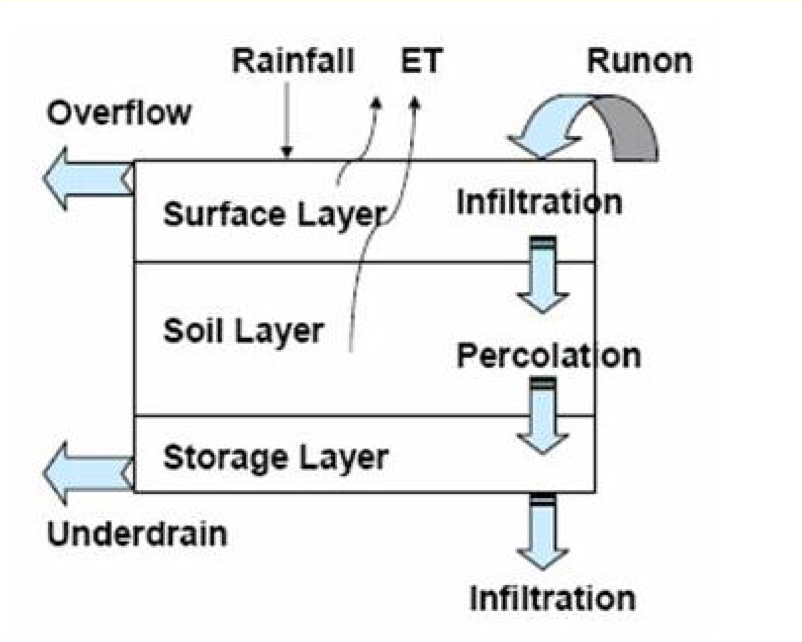
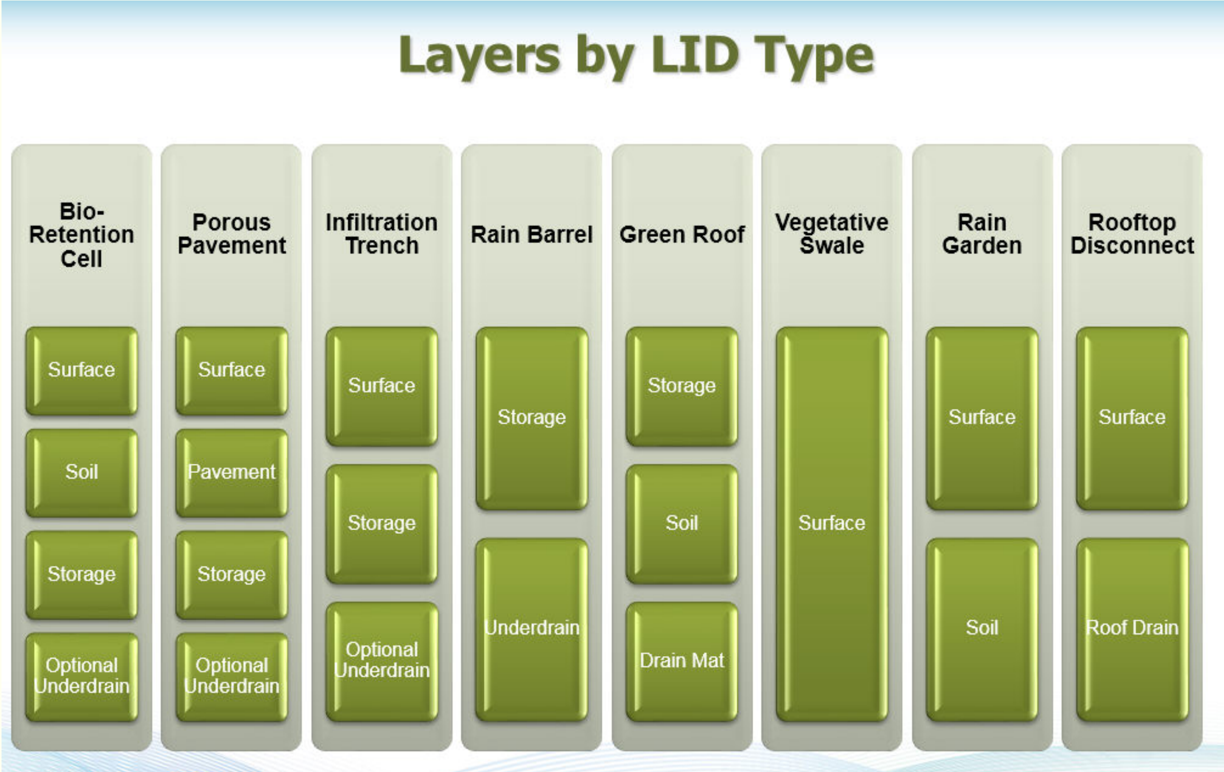
Low Impact Development (LID) Representation

LID controls are represented by a combination of vertical layers whose properties are defined on a per-unit-area basis. This allows LIDs of the same design but differing areal coverage to easily be placed within different Subcatchments in a study area. During a simulation SWMM5 performs a moisture balance that keeps track of how much water moves between and is stored within each LID layer. As an example, the layers used to model a bio-retention cell and the flow pathways between them are shown below:



The following table indicates which combination of layers applies to each type of LID (required if listed and underdrain is optional for three types of LID’s):



When a user adds a specific type of LID control object to a SWMM5 project the LID Control Editor is used to set the design properties of each relevant layer (such as thickness, void volume, hydraulic conductivity, underdrain characteristics, etc.). These LID objects can then be placed within selected Subcatchments at any desired sizing (or areal coverage) by editing the Subcatchment's LID Controls property.

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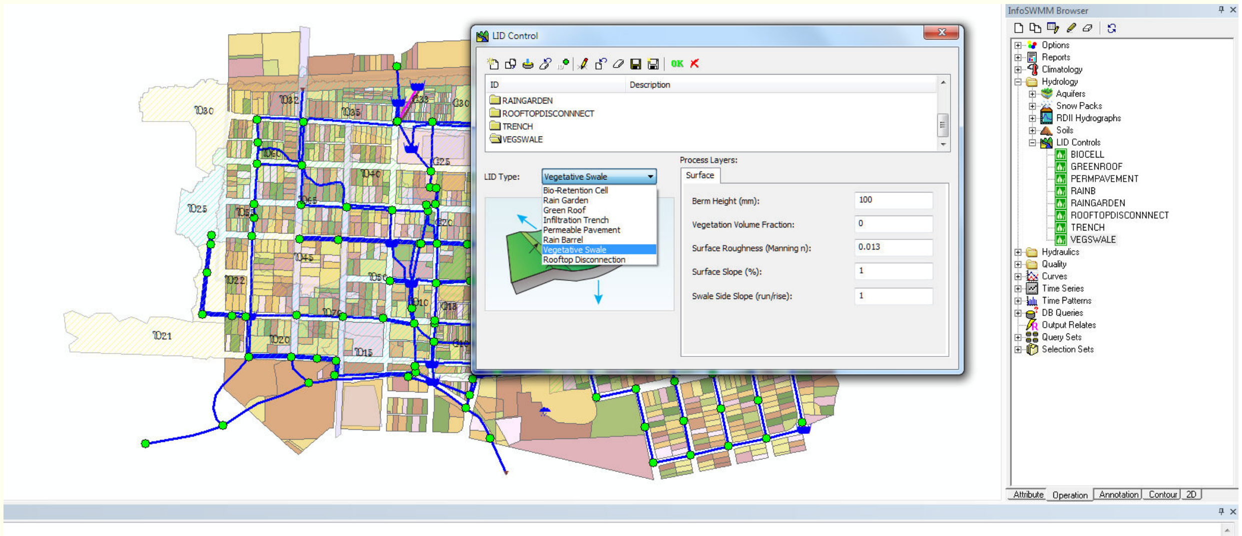
LID Control Editor

The **LID Control Editor** is used to define a low impact development control that can be deployed throughout a study area to store, infiltrate, and evaporate Subcatchment runoff.

The design of the control is made on a per-unit-area basis so that it can be placed in any number of Subcatchments at different sizes or number of replicates.



The editor contains the following data entry fields:

Control Name

A name used to identify the particular LID control.

LID Type

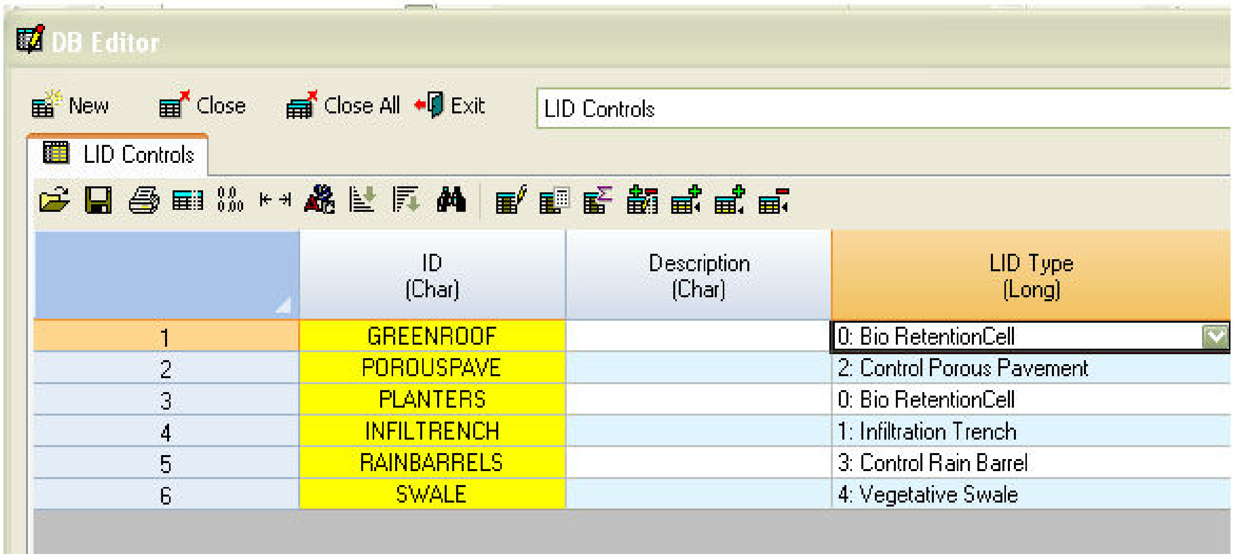
The generic type of LID being defined (bio-retention cell, porous pavement, infiltration trench, rain barrel, or vegetative swale).

Process Layers

These are a tabbed set of pages containing data entry fields for the vertical layers and underdrain that comprise an LID control. They include some combination of the following, depending on the type of LID selected:

- Surface Layer

- Pavement Layer
- Soil Layer
- Storage Layer
- Underdrain System
- Drain Mat Layer



6.5 Parameter Estimates

The variety of LID controls modeled by SWMM introduces a significant number of design variables and parameters that must be assigned values by the user. These include sizing parameters (surface area, layer depths, and capture ratio), surface parameters (freeboard depth, outflow face width, slope, and roughness), soil parameters (moisture limits and hydraulic conductivity), pavement parameters (void ratio and permeability), storage parameters (void ratio and native soil conductivity), drain parameters (discharge coefficient and exponent, roof drain capacity, and drain mat roughness), and clogging parameter. Because of the high interest and acceptance of LID, many local and state agencies have prepared design manuals that recommend ranges for many key parameters. Table 6-1 lists a selection of these manuals, all available online. Unless otherwise noted, these manuals served as the source of the LID parameter values described in the sub-sections that follow.

Excerpt from the EPA manual Storm Water Management Model Reference Manual Volume III – Water Quality (PDF) which can be found

here

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LID Placement for Controls

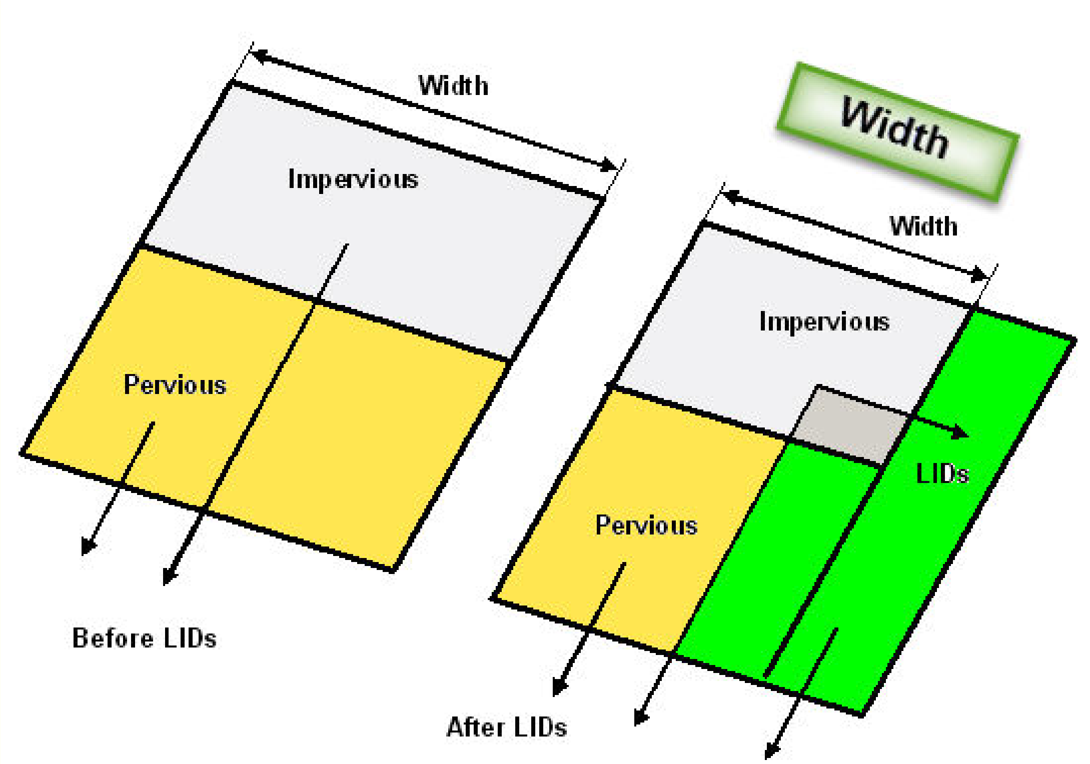
There are two different approaches for placing LID controls within a Subcatchment:

- place one or more controls in an existing Subcatchment that will displace an equal amount of non-LID area from the Subcatchment
- create a new Subcatchment devoted entirely to just a single LID practice.

The first approach allows a mix of LIDs to be placed into a Subcatchment, each treating a different portion of the runoff generated from the non-LID

fraction of the Subcatchment. Note that under this option the sub catchment's LIDs act in parallel -- it is not possible to make them act in series (i.e., have the outflow from one LID control become the inflow to another LID). Also, after LID placement the sub catchment's Percent Impervious and Width properties may require adjustment to compensate for the amount of original Subcatchment area that has now been replaced by LIDs (see the figure below). For example, suppose that a Subcatchment which is 40%

impervious has 75% of that area converted to a porous pavement LID. After the LID is added the sub catchment's percent imperviousness should be changed to the percent of impervious area remaining divided by the percent of non-LID area remaining. This works out to (1 - 0.75)*40 / (100 - 0.75*40) or 14.3 %.



The second approach allows LID controls to be strung along in series and also allows runoff from several different upstream sub catchments to be routed onto the LID Subcatchment. If these single-LID sub catchments are carved out of existing sub catchments, then once again some adjustment of the Percent Impervious, Width and also the Area properties of the latter may be necessary. In addition, whenever an LID occupies the entire Subcatchment the values assigned to the sub catchment's standard surface properties (such as imperviousness, slope, roughness, etc.) are overridden by those that pertain to the LID unit.

Excerpt from the EPA manual Storm

Water Management Model Reference Manual Volume III – Water Quality (PDF)

which can be found

here

6.3 LID Deployment

Before discussing the computational steps used to solve the governing LID equations it will be useful to describe the various options available for deploying LID controls within a SWMM project. Utilizing LID controls is a two phase process that first creates a set of scale-independent LID designs and then assigns any desired mix and sizing of these designs to selected subcatchments. Because all calculations are made on a per unit area basis, this approach also allows one to treat replicate units of a given design (e.g., forty 50-gallon rain barrels) as if it were one larger LID unit.

There are two different approaches for placing LID controls within the subcatchments of a SWMM model:

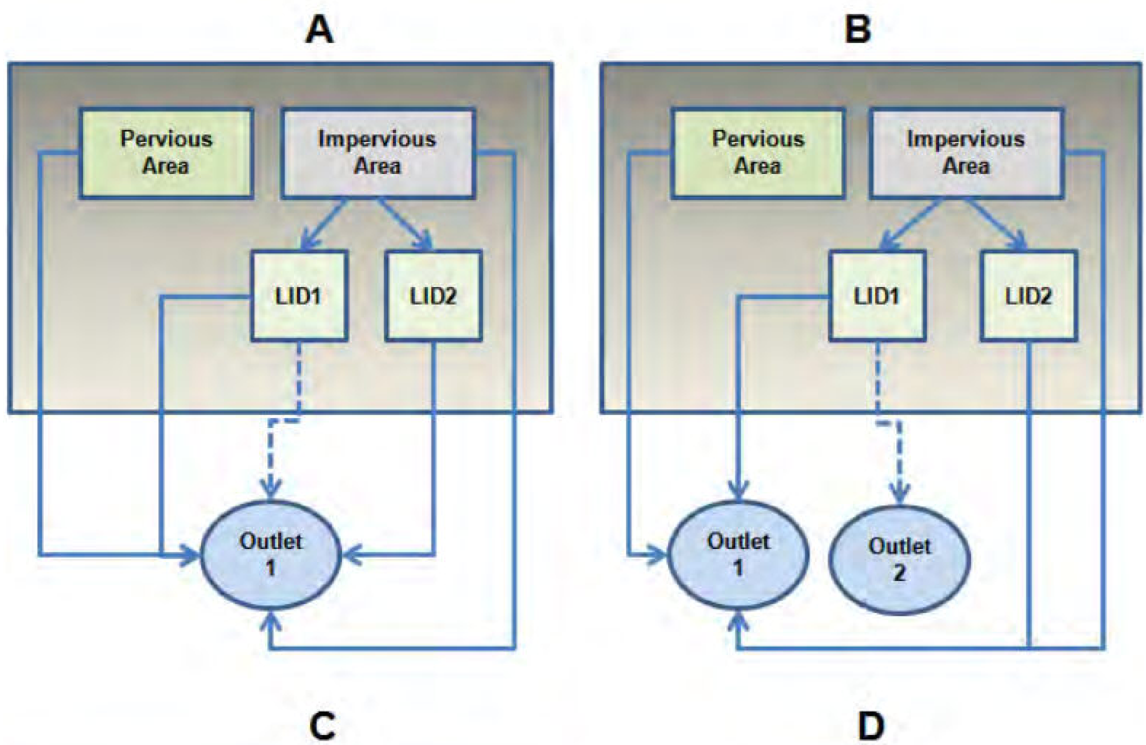
1. One or more controls are assigned to an existing subcatchment. Each control receives some specified fraction of the runoff generated by the subcatchment's impervious area.
2. A single LID control (or replicate units of the same design) occupies the full area of a subcatchment. Its inflow consists of direct rainfall plus runoff from any upstream subcatchments connected to the subcatchment containing the LID unit.

The first approach would typically be used in larger, area-wide studies where a mix of controls would be deployed over many different subcatchments. The second approach might apply to smaller study areas where detailed analysis of a particular LID treatment train would be desired.

If a subcatchment with multiple LID units receives runoff from upstream subcatchments then that flow is first distributed uniformly over the pervious and impervious areas. The resulting impervious area runoff is then routed onto the various LID units. The options for routing any surface overflow and underdrain flow generated by an LID unit can be summarized as follows:

1. The default is to send these flows to the parent subcatchment's outlet destination.
2. If so desired, underdrain flow from each unit can be routed to a separate destination.
3. Another option, particularly appropriate for rain barrels, is to route the unit's entire outflow back onto the subcatchment's pervious area.

Figure 6-6 illustrates some the options available for placing LID controls. Panel A of the figure shows a subcatchment containing two different types of controls, each receiving a different fraction of the subcatchment's impervious area runoff. LID1 contains an underdrain while LID2 does not. Any surface or underdrain flows from the units are sent to the same outlet node that was designated for the subcatchment as a whole. Panel B is similar to Panel A except that LID1 sends its underdrain flow to a different outlet than the subcatchment as a whole. In Panel C of the figure, LID1 now sends its surface overflow and underdrain flow back to the subcatchment's pervious area. Finally Panel D illustrates the case of two LID units in series, where each unit occupies its entire subcatchment. The inflow to LID1 comes from an upstream subcatchment and its surface overflow is routed to LID2. Its underdrain flow is sent to the same outlet location used by LID2.



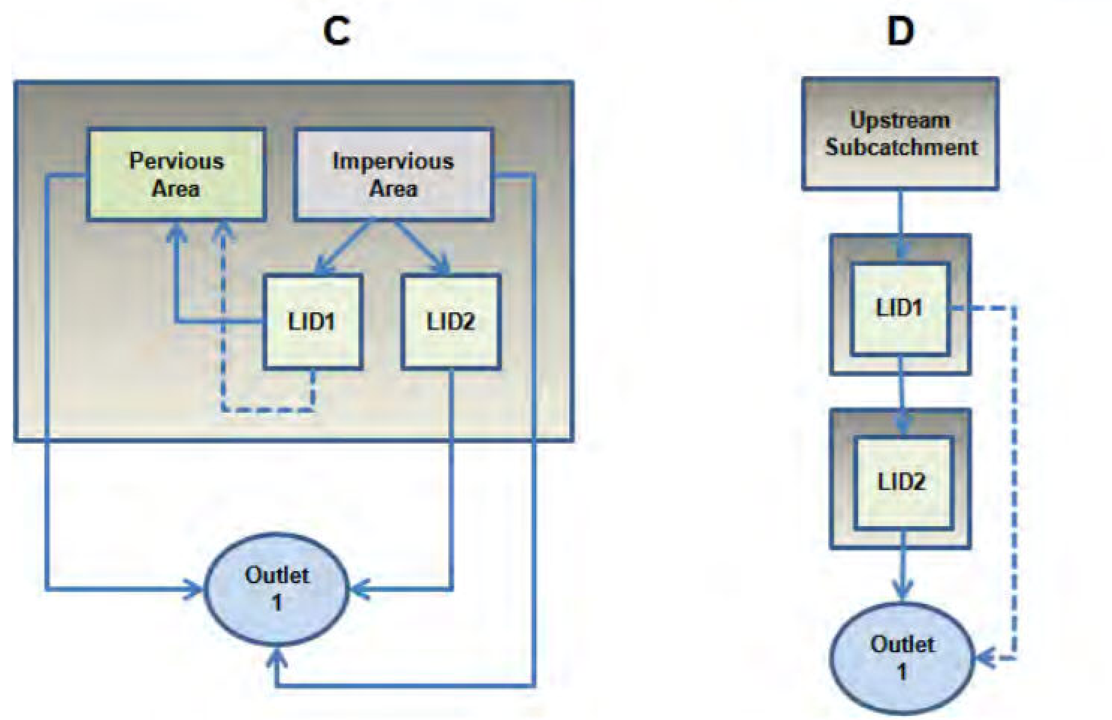


Figure 6-6 Different options for placing LID controls

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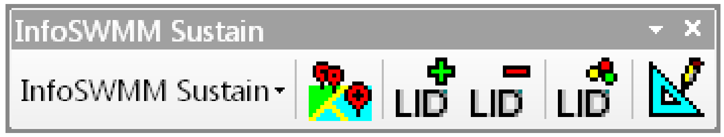
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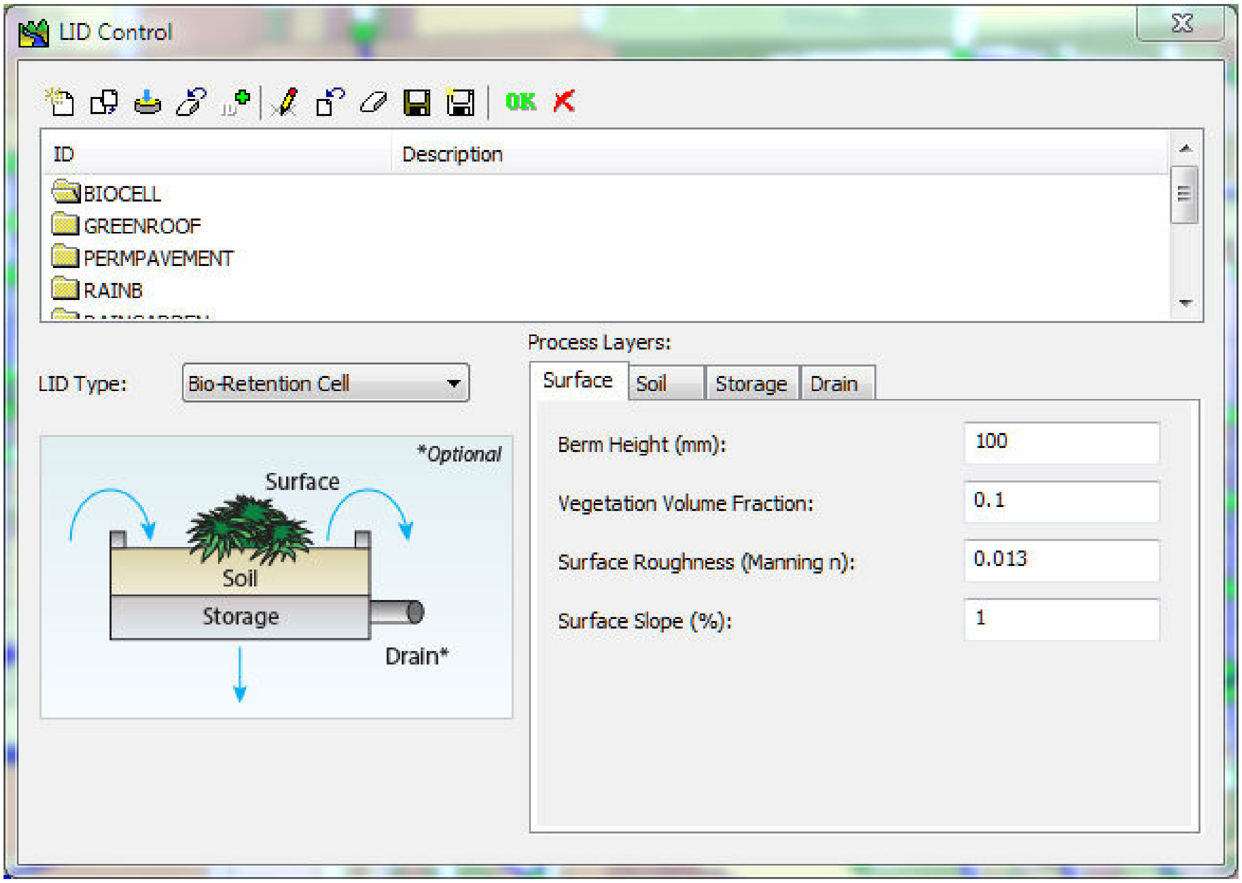
Bio-Retention Cell LID Control

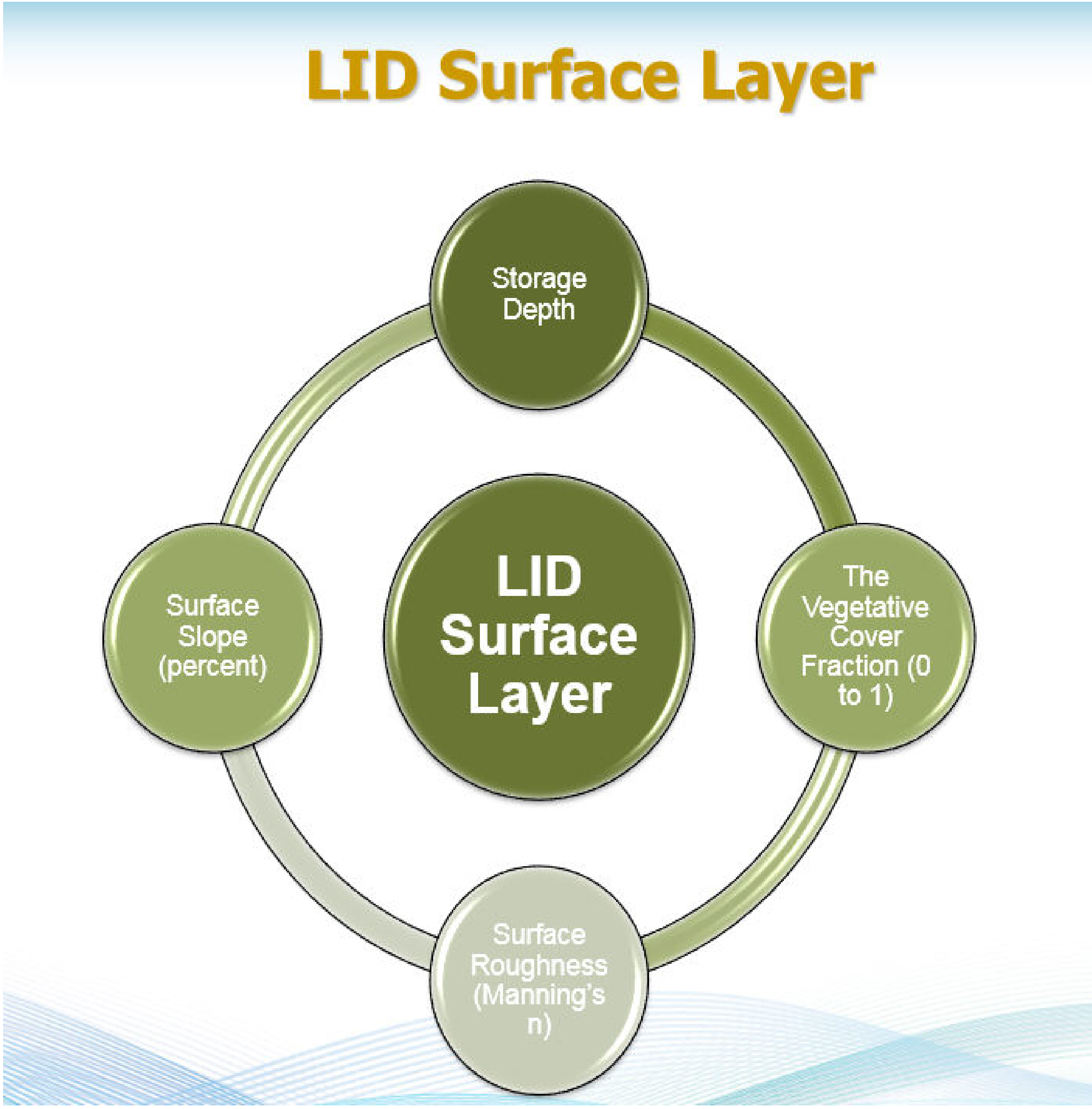
This is an introduction along with images of the LID Control and data require3ments in InfoSWMM. Every InfoSWMM Control uses from one to 5 layers of data - each with different data requirements. You can use the Siting Manger of InfoSWMM Sustain to find LID locations and the LID Optimizer to find the optimized number of units, cost of units, area and thickness of the LID layers based on your runoff and water quality control objectives.

The Bio-Retention LID Control has four components or Process Layers: Surface, Soil, Storage and Underdrain.

The Surface Process Layer consists of:

- The Storage Depth in inches or millimeters
- The Vegetative Cover Fraction (0 to 1),
- Surface Roughness (Manning’s n)
- Surface Slope (percent).

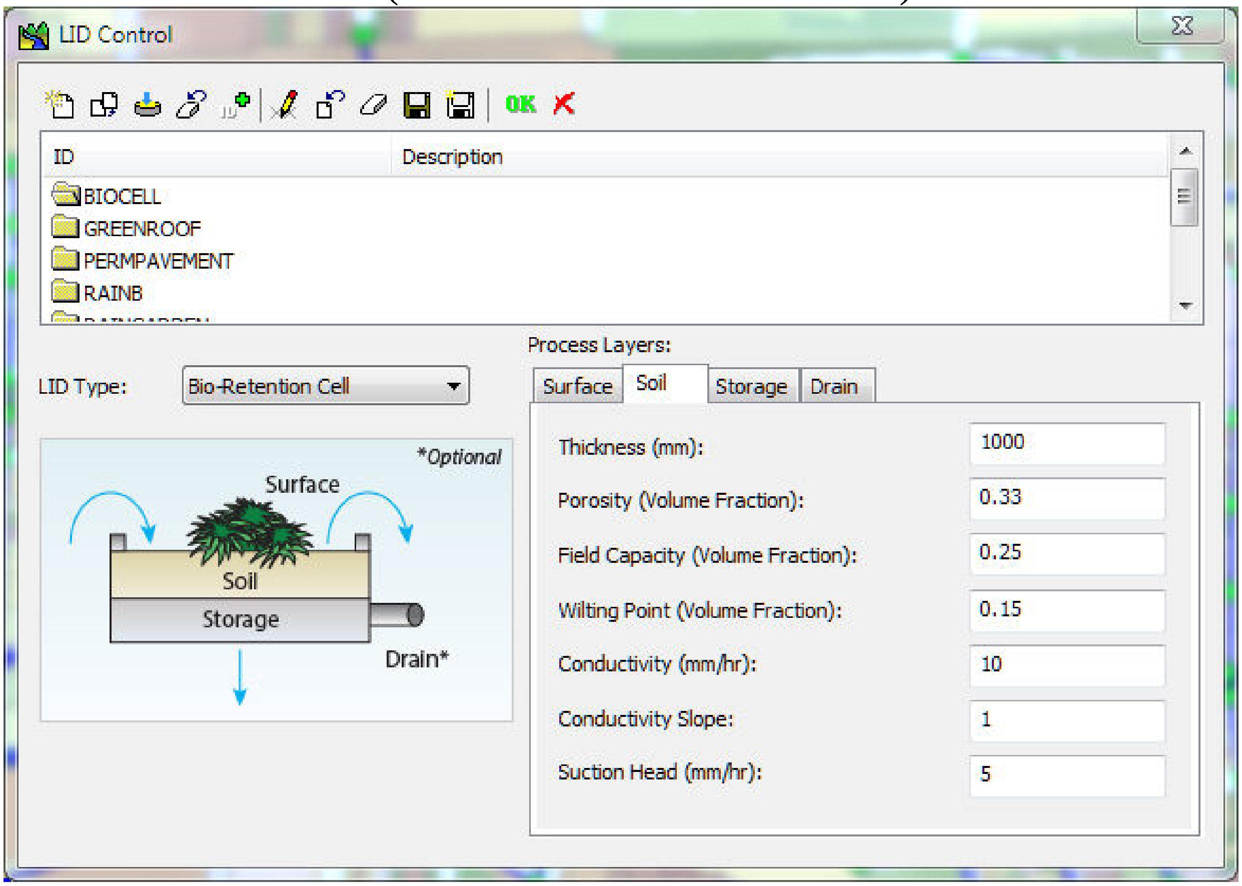

LID Control
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
LID Type:
Bio-Retention Cell
Process Layers:
Surface
Soil
Storage
Drain
Berm Height (mm):
100
Vegetation Volume Fraction:
0.1
Surface Roughness (Manning n):
0.013
Surface Slope (%):
1
*Optional
Surface
Soil
Storage
Drain*



The Soil Process Layer consists of:

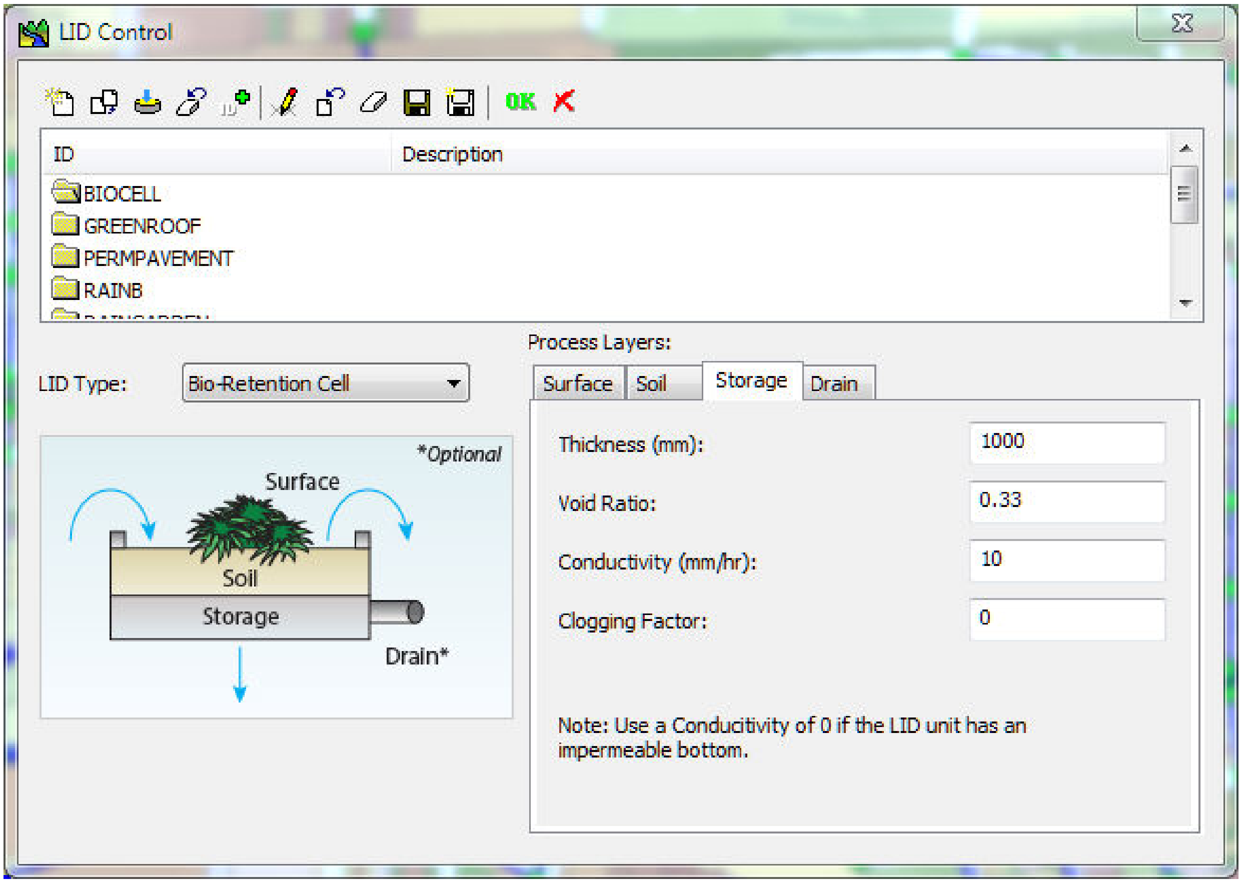
- Soil Thickness in inches or millimeters,
- Porosity as a Fraction (0 to 1),
- Field Capacity as a Fraction (0 to 1),
- Wilting Point as a Fraction (0 to 1),
- Conductivity (inches/hour or millimeters/hour),
- Conductivity Slope,

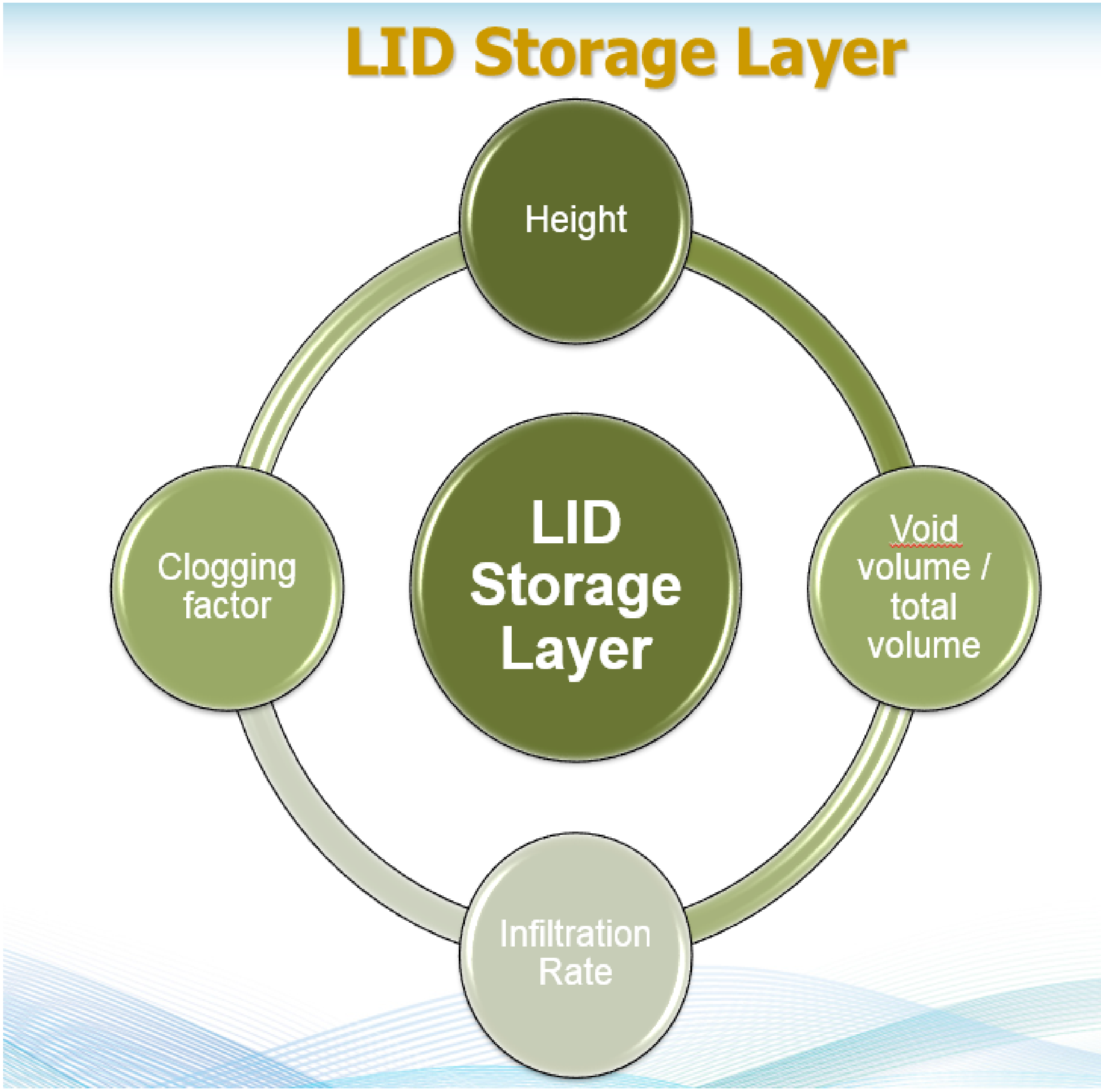
- Suction Head (inches/hour or millimeters/hour)



The Storage Process Layer consists of:

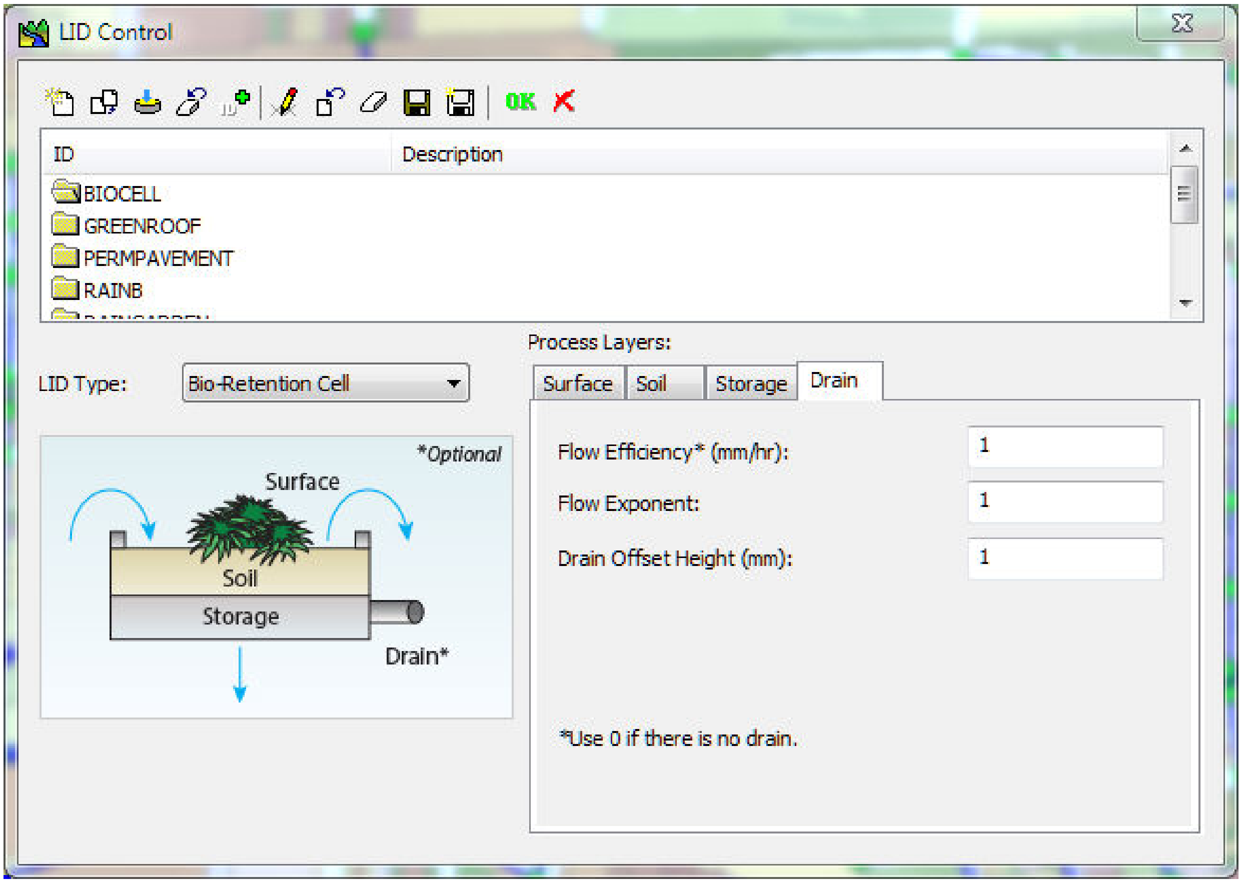
- The Storage Height in inches or millimeters,
- The Void Ratio as a Fraction (0 to 1),
- Surface Conductivity in inches/hour or millimeters/hour,
- Clogging Factor

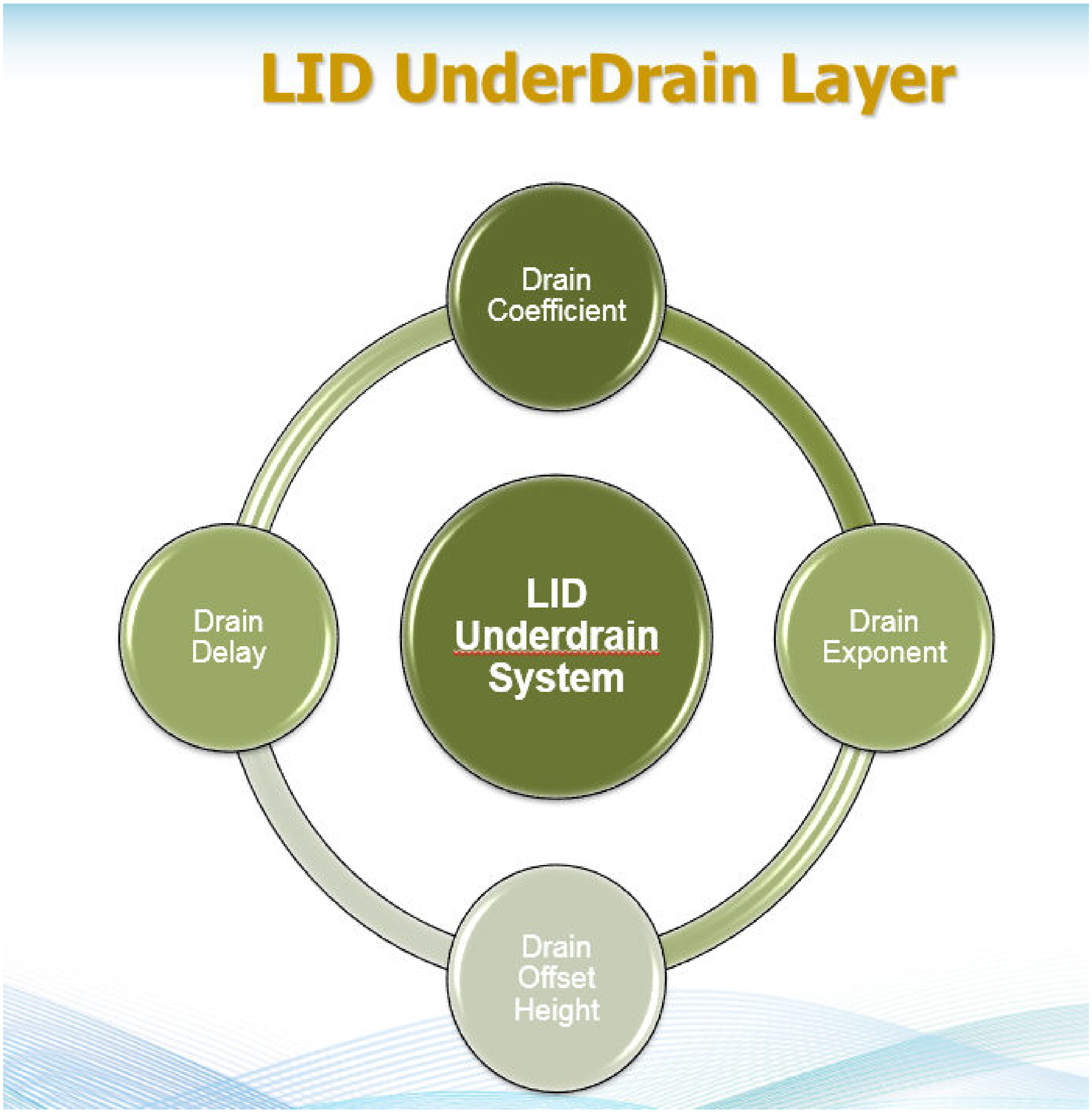

LID Control
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
Process Layers:
LID Type:
Bio-Retention Cell
Surface
Soil
Storage
Drain
*Optional
Surface
Soil
Storage
Drain*
Thickness (mm):
1000
Void Ratio:
0.33
Conductivity (mm/hr):
10
Clogging Factor:
0
Note: Use a Conductivity of 0 if the LID unit has an impermeable bottom.



The Underdrain Process Layer consists of:

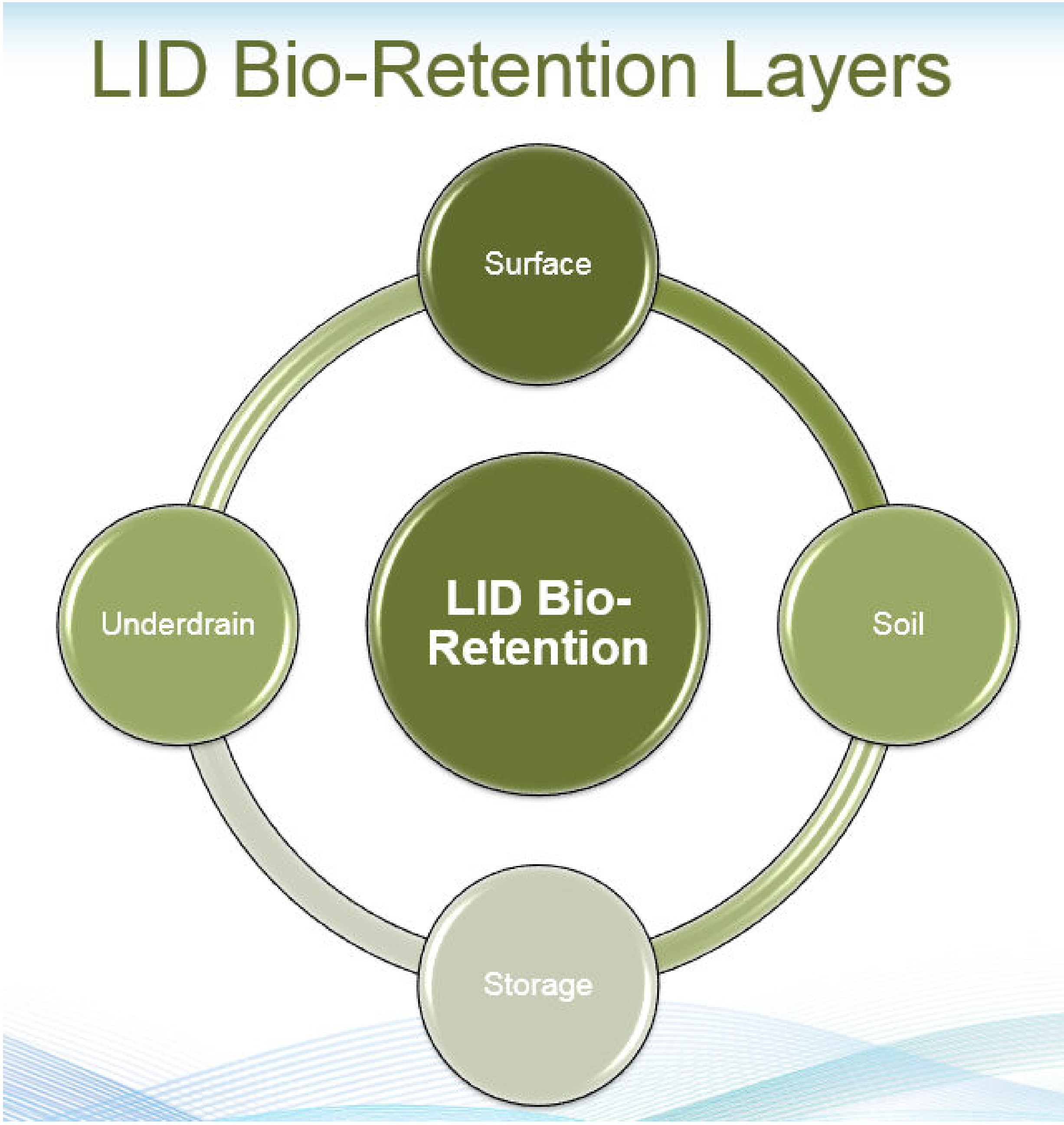
- Drain Coefficient (inches/hour or millimeters/hour)
- The Void Ratio as a Fraction (0 to 1),
- Drain Exponent,
- Drain Offset Height (inches or millimeters)


LID Control
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
Process Layers:
LID Type:
Bio-Retention Cell
Surface
Soil
Storage
Drain
*Optional
Surface
Soil
Storage
Drain*
Flow Efficiency* (mm/hr):
1
Flow Exponent:
1
Drain Offset Height (mm):
1
*Use 0 if there is no drain.


LID UnderDrain Layer
Drain Coefficient
Drain Delay
LID Underdrain System
Drain Exponent
Drain Offset Height

An example of a Bio-Retention Cell.

The four layers used in a simulation for a Bio-Retention Cell LID are shown in the following image.



Innovyze Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 Engine

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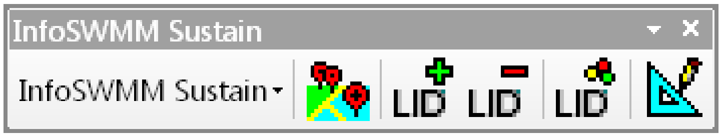
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LID
LID
LID

Bio-Retention Cell LID Reference Values

Excerpt from the EPA manual [Storm Water Management Model Reference Manual Volume III – Water Quality (PDF)] which can be found here

6.2 Governing Equations

6.2.1 Bio-Retention Cells

A typical bio-retention cell (see panel A of Figure 6-1) will serve as an example for developing a generic LID performance model. This generic model can then be customized as need be to describe the behavior of other types of LID controls.

Conceptually a bio-retention cell can be represented by a number of horizontal layers as shown in panel B of Figure 6-1. The surface layer (layer 1) receives both direct rainfall and runoff captured from other areas. It loses water through infiltration into the soil layer below it, by evapotranspiration (ET) of any ponded surface water, and by any surface runoff that might occur. The soil layer (layer 2) contains an engineered soil mix that can support vegetative growth. It receives infiltration from the surface layer and loses water through ET and by percolation into the storage layer below it. The storage layer (layer 3) consists of coarse crushed stone or gravel. It receives percolation from the soil zone above it and loses water by infiltration into the underlying natural soil and by outflow through a perforated pipe underdrain system if present.

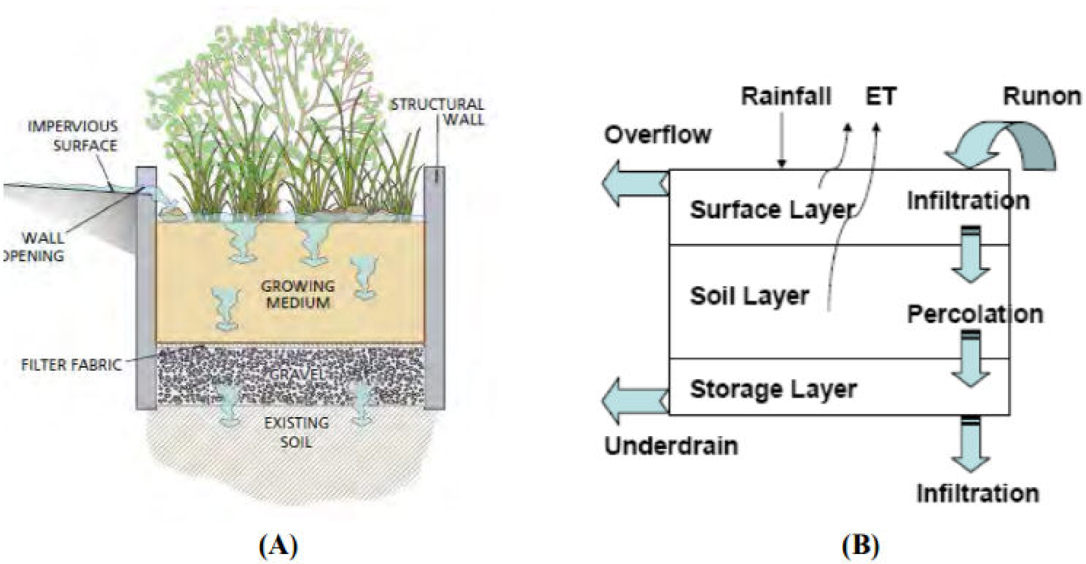


Figure 6-1 A typical bio-retention cell

To model the hydrologic performance of this LID unit the following simplifying assumptions are made:

1. The cross-sectional area of the unit remains constant throughout its depth.
2. Flow through the unit is one-dimensional in the vertical direction.
3. Inflow to the unit is distributed uniformly over the top surface.
4. Moisture content is uniformly distributed throughout the soil layer.
5. Matric forces within the storage layer are negligible so that it acts as a simple reservoir that stores water from the bottom up.

Under these assumptions the LID unit can be modeled by solving a set of simple flow continuity equations. Each equation describes the change in water content in a particular layer over time as the difference between the inflow and the outflow water flux rates that the layer sees, expressed as volume per unit area per unit time. These equations can be written as follows:

$$\phi_1 \frac{\partial d_1}{\partial t} = i + q_0 - e_1 - f_1 - q_1 \qquad \text{Surface Layer} \qquad (6\text{-}1)$$

$$D_2 \frac{\partial \theta_2}{\partial t} = f_1 - e_2 - f_2 \qquad \text{Soil Layer} \qquad (6\text{-}2)$$

$$\phi_3 \frac{\partial d_3}{\partial t} = f_2 - e_3 - f_3 - q_3 \qquad \text{Storage Layer} \qquad (6\text{-}3)$$

where:

d_1 = depth of water stored on the surface (ft),
θ_2 = soil layer moisture content (volume of water / total volume of soil),
d_3 = depth of water in the storage layer (ft),

i = precipitation rate falling directly on the surface layer (ft/sec),
q_0 = inflow to the surface layer from runoff captured from other areas (ft/sec),

q_1 = surface layer runoff or overflow rate (ft/sec),
q_3 = storage layer underdrain outflow rate (ft/sec),

e_1 = surface ET rate (ft/sec),
e_2 = soil layer ET rate (ft/sec),
e_3 = storage layer ET rate (ft/sec),

f_1 = infiltration rate of surface water into the soil layer (ft/sec),

f_2 = percolation rate of water through the soil layer into the storage layer (ft/sec),

f_3 = exfiltration rate of water from the storage layer into native soil (ft/sec),

ϕ_1 = void fraction of any surface volume (i.e., the fraction of freeboard above the surface not filled with vegetation)

ϕ_2 = porosity (void volume / total volume) of the soil layer (used later on),

ϕ_3 = void fraction of the storage layer (void volume / total volume),

D_1 = freeboard height for surface ponding (ft) (used later on),

D_2 = thickness of the soil layer (ft),

D_3 = thickness of the storage layer (ft) (used later on).

The flux terms (q, e, and f) in these equations are functions of the current water content in the various layers (d_1, θ_2, and d_3) and specific site and soil characteristics. This set of coupled equations can be solved numerically at each runoff time step to determine how an inflow hydrograph to the LID unit ($i + q_0$) is converted into hydrographs for surface runoff (q_1), underdrain outflow (q_3), and exfiltration into the surrounding native soil (f_3). As applied to a bio-retention cell, this generic model is similar in spirit to the RECARGA model developed at the University of Wisconsin – Madison (Atchison and Severson, 2004) for rain gardens with no gravel storage zone. How each of the flux terms in Equations 6-1 to 6-3 is computed will now be discussed.

Surface Inflow ($i + q_0$)

Inflow to the surface layer comes from both direct rainfall (i) and runoff from impervious areas captured by the bio-retention cell (q_0). Within each runoff time step these values are provided by SWMM's runoff computation as described in Chapter 3 of Volume I of this manual.

Surface Infiltration (f_1)

The infiltration of surface water into the soil layer, f_1, can be modeled with the Green-Ampt equation:

$$f_1 = K_{2S}\left(1 + \frac{(\phi_2 - \theta_{20})(d_1 + \psi_2)}{F}\right) \tag{6-4}$$

where

f_1	=	infiltration rate (ft/sec),
K_{2S}	=	soil's saturated hydraulic conductivity (ft/sec)
θ_{20}	=	moisture content at the top of the soil layer (fraction),
ψ_2	=	suction head at the infiltration wetting front formed in the soil (ft)
F	=	cumulative infiltration volume per unit area over a storm event (ft)

This equation applies only after a saturated condition develops at the top of the soil zone. Prior to this all inflow ($i + q_0$) infiltrates. The initial value of θ_{20} for a dry soil would be its residual moisture content or its wilting point. It increases after each rainfall event, then decreases during dry periods. The details of implementing the Green-Ampt model over successive time steps are described in Chapter 4 of Volume I of this manual. The properties K_{2S}, ϕ_2, and ψ_2 for the bio-retention cell's amended soil can be different from those of the site's natural soil. This can produce a different infiltration rate into the LID unit when compared to that for rest of the subcatchment.

Evapotranspiration (e)

Evapotranspiration (ET) of water stored within the bio-retention cell is computed from the same user-supplied time series of daily potential ET rates that are used in SWMM's runoff module (see Chapter 2 of Volume I). The calculation proceeds from the surface layer downwards, where any un-used potential ET is made available to the next lower layer. So at any time t:

$$e_1 = min[E_0(t), d_1/\Delta t] \tag{6-5}$$

$$e_2 = min[E_0(t) - e_1, (\theta_2 - \theta_{WP})D_2/\Delta t] \tag{6-6}$$

$$e_3 = \begin{cases} min[E_0(t) - e_1 - e_2, \phi_3 d_3/\Delta t], & \theta_2 < \phi_2 \\ 0, & \theta_2 \geq \phi_2 \end{cases} \tag{6-7}$$

where $E_0(t)$ is the potential ET rate that applies for time t, Δt is the time step used to numerically evaluate the governing flow balance equations 6-1 to 6-3, and θ_{WP} is the user-supplied wilting point soil moisture content. A soil's wilting point is the moisture content below which plants can no longer extract water from the soil. Thus when the soil moisture θ_2 reaches the wilting point there is no contribution to ET from the soil layer.

Note how ET from each layer is limited by the amount of potential ET remaining and the amount of water stored in the layer. In addition:

- e_3 is zero when the soil zone becomes saturated.
- e_2 and e_3 are zero during periods with surface infiltration ($f_1 > 0$) since it is assumed that the resulting vapor pressure will be high enough to prevent any ET from occurring.

Soil Percolation (f_2)

The rate of percolation of water through the soil layer into the storage layer below it (f_2) can be modeled using Darcy's Law in the same manner used in SWMM's existing groundwater module (see Chapter 5 of Volume I). The resulting equation for this flux is:

$$f_2 = \begin{cases} K_{2S} exp(-HCO(\phi_2 - \theta_2)), & \theta_2 > \theta_{FC} \\ 0, & \theta_2 \leq \theta_{FC} \end{cases} \tag{6-8}$$

where K_{2S} is the soil's saturated hydraulic conductivity (ft/sec), HCO is a decay constant derived from moisture retention curve data that describes how conductivity decreases with decreasing

Bottom Exfiltration (f_3)

The exfiltration rate from the bottom of the storage zone into native soil would normally depend on the depth of stored water and the moisture profile of the soil beneath the LID unit. Since the latter is not known, SWMM assumes that the exfiltration rate f_3 is simply the user-supplied saturated hydraulic conductivity of the native soil beneath the LID unit, K_{3S}. Setting K_{3S} to zero indicates that the bio-retention cell has an impermeable bottom.

Underdrain Flow (q_3)

Because the hydraulics of perforated pipe underdrains can be complicated (see van Schilfgaarde 1974) SWMM uses a simple empirical power law to model underdrain outflow q_3:

$$q_3 = C_{3D}(h_3)^{\eta_{3D}} \tag{6-9}$$

where

h_3	=	hydraulic head seen by underdrain, (ft)
C_{3D}	=	underdrain discharge coefficient ($\text{ft}^{-(\eta_{3D}-1)}/\text{sec}$)
η_{3D}	=	underdrain discharge exponent

The hydraulic head h_3 seen by the underdrain varies with the height of water above it in the following fashion:

$$h_3 = 0 \qquad \text{for } d_3 \leq D_{3D}$$

$$h_3 = d_3 - D_{3D} \qquad \text{for } D_{3D} < d_3 < D_3$$

$$h_3 = (D_3 - D_{3D}) + (\theta_2 - \theta_{FC})/(\phi_2 - \theta_{FC})D_2 \qquad \text{for } d_3 = D_3 \text{ and } \theta_{FC} < \theta_2 < \phi_2$$

$$h_3 = (D_3 - D_{3D}) + D_2 + d_1 \qquad \text{for } d_3 = D_3 \text{ and } \theta_2 = \phi_2$$

where D_{3D} is the height of drain opening above bottom of storage layer (ft) and θ_{FC} is the soil layer's field capacity moisture content below which water does not drain freely from the soil.

Underdrains introduce three additional parameters C_{3D}, η_{3D}, and D_{3D}, into the description of a bio-retention cell. There is no underdrain flow until the depth of water in the storage layer reaches the drain offset height. Choosing a value of 0.5 for η_{3D} makes the drain flow formula equivalent to the standard orifice equation, where C_{3D} incorporates both the normal orifice discharge coefficient and available flow area. Setting C_{3D} to zero indicates that no underdrain is present. The flow rate computed with Equation 6-9 should be considered a maximum potential value. The actual underdrain flow at any time step will be the smaller of this value and the amount of water available to the underdrain.

Surface Runoff (q_1)

It is assumed that any ponded surface water in excess of the maximum freeboard (or depression storage) height D_1 becomes immediate overflow. Therefore:

$$q_1 = max[(d_1 - D_1)/\Delta t, 0] \quad (6\text{-}10)$$

Flux Limits

Limits must be imposed on the various bio-retention cell flux rates to insure that at any given time step the moisture levels in the soil and storage layers do not go negative nor exceed the layer's capacity. These limits are evaluated in the order listed below.

1. The soil percolation rate f_2 is limited by the amount of drainable water currently in the soil layer plus the net amount of water added to it over the time step:

$$f_2 = min[f_2, (\theta_2 - \theta_{FC})D_2/\Delta t + f_1 - e_2] \quad (6\text{-}11)$$

2. The storage exfiltration rate f_3 is limited by the amount of water currently in the storage layer plus the net amount of water added to it over the time step:

$$f_3 = min[f_3, d_3\phi_3/\Delta t + f_2 - e_3] \quad (6\text{-}12)$$

3. When an underdrain is used, the drain flow q_3 is limited by the amount of water stored above the drain offset plus any excess inflow from the soil layer that remains after storage exfiltration is accounted for:

$$q_3 = min[q_3\,, (d_3 - D_{3D})\phi_3/\Delta t + f_2 - f_3 - e_3] \tag{6-13}$$

4. The soil percolation rate is also limited by the amount of unused volume in the storage layer plus the net amount of water removed from storage over the time step.

$$f_2 = min[f_2\,, (D_3 - d_3)\phi_3/\Delta t + f_3 + q_3 + e_3] \tag{6-14}$$

5. The rate f_1 at which water can infiltrate into the soil layer is limited by the amount of empty pore space available plus the volume removed by drainage and evaporation over the time step.

$$f_1 = min[f_1\,, (\phi_2 - \theta_2)D_2/\Delta t + f_2 + e_2] \tag{6-15}$$

When the unit becomes completely saturated (i.e., $\theta_2 = \phi_2$ and $d_3 = D_3$) then the vertical flux of water through both the soil and storage layers has to be the same since there is a common fully wetted interface between them. For this special case, if $f_2 > f_3 + q_3$ then $f_2 = f_3 + q_3$. Otherwise $f_3 = min[f_3\,, f_2]$ and $q_3 = max[f_3 - f_2\,, 0]$. In addition the surface infiltration rate f_1 cannot exceed the adjusted soil percolation rate: $f_1 = min[f_1, f_2]$. (Note that because the unit is saturated no sub-surface ET occurs and therefore does not influence these limits.)

It is worth noting that this simple representation of a bio-retention cell uses a total of 15 user-supplied parameters in its description: two surface layer parameters (ϕ_1, D_1) seven soil layer parameters (ϕ_2, θ_{FC}, θ_{WP}, K_{2S}, ψ_2, HCO, D_2), three storage layer parameters (ϕ_3, K_{3S}, D_3) and three underdrain parameters (C_{3D}, η_{3D}, D_{3D}). The six constants that define the soil layer's moisture limits ($\phi_2, \psi_2, \theta_{FC}, \theta_{WP}$) and hydraulic conductivity (K_{2S}, HCO) are the same parameters used for infiltration and groundwater flow in SWMM's hydrology module (see Chapters 4 and 5 of Volume I). Because the soil used in a bio-retention cell is an engineered mix chosen to provide good drainage and support plant growth its properties will likely be different than those of the site's native soil. Recommended values for the various parameters associated with all types of LID controls will be presented later on in Section 6.6.

The governing flow balance equations for the other LID controls modeled by SWMM are similar in form to those for bio-retention cells. The following sub-sections discuss the models for rain gardens, green roofs, infiltration trenches, permeable pavement, rain barrels, rooftop disconnection, and vegetative swales in that order.

6.5.1 Bio-Retention Cells and Rain Gardens

Table 6-2 lists ranges of parameter values for bio-retention cells and rain gardens, expressed in their typical US units of inches and hours. They are internally converted to feet and seconds for use in the governing conservation equations.

The soil moisture limits in the table are based on ranges computed for sand, loamy sand, and sandy loam textures using the SPAW model (Saxton and Rawls, 2006) with organic contents ranging between 2.5 and 8%. The model can be used to estimate specific limits from knowledge of a soil's sand, clay and organic content. For example, a typical engineered soil might consist of 85% sand, 5% clay and 5% organic matter by weight. Using the SPAW calculator for this soil produces the characteristics listed in Table 6-3. The percolation decay constant *HCO* was estimated by using the calculator to compute hydraulic conductivity K_2 for a range of moisture contents θ and then regressing $-ln(K_2/K_{2S})$ against $\phi_2 - \theta$ to find a best-fit value for *HCO*. The equation used to estimate suction head was introduced in Section 4.4 of Volume I.

6.5 Parameter Estimates

The variety of LID controls modeled by SWMM introduces a significant number of design variables and parameters that must be assigned values by the user. These include sizing parameters (surface area, layer depths, and capture ratio), surface parameters (freeboard depth, outflow face width, slope, and roughness), soil parameters (moisture limits and hydraulic conductivity), pavement parameters (void ratio and permeability), storage parameters (void ratio and native soil conductivity), drain parameters (discharge coefficient and exponent, roof drain capacity, and drain mat roughness), and clogging parameter. Because of the high interest and acceptance of LID, many local and state agencies have prepared design manuals that recommend ranges for many key parameters. Table 6-1 lists a selection of these manuals, all available online. Unless otherwise noted, these manuals served as the source of the LID parameter values described in the sub-sections that follow.

6.5.1 Bio-Retention Cells and Rain Gardens Parameter Values

Table 6-2 lists ranges of parameter values for bio-retention cells and rain gardens, expressed in their typical US units of inches and hours. They are internally converted to feet and seconds for use in the governing conservation equations.

The soil moisture limits in the table are based on ranges computed for sand, loamy sand, and sandy loam textures using the SPAW model (Saxton and Rawls, 2006) with organic contents ranging between 2.5 and 8%. The model can be used to estimate specific limits from knowledge of a soil's sand, clay and organic content. For example, a typical engineered soil might consist of 85% sand, 5% clay and 5% organic matter by weight. Using the SPAW calculator for this soil produces the characteristics listed in Table 6-3. The percolation decay constant *HCO* was estimated by using the calculator to compute hydraulic conductivity K_2 for a range of moisture contents θ and then regressing $-ln(K_2/K_{2S})$ against $\phi_2 - \theta$ to find a best-fit value for *HCO*. The equation used to estimate suction head was introduced in Section 4.4 of Volume I.

Table 6-1 Design manuals used as sources for LID parameter values

Organization	Manual Title	Year	URL
Prince Georges County Maryland	Low-Impact Development Design: An Integrated Design Approach	1999	http://water.epa.gov/polwaste/green/upload/lidnatl.pdf
Denver Urban Drainage and Flood Control District	Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices	2010	http://udfcd.org/wp-content/uploads/uploads/vol3%20criteria%20manual/USDCM%20Volume%203.pdf
Toronto and Region Conservation Authority	Low Impact Development Stormwater Management Planning and Design Guide	2010	http://www.creditvalleyca.ca/wp-content/uploads/2014/04/LID-SWM-Guide-v1.0_2010_1_no-appendices.pdf
Washington State University Extension	Low Impact Development Technical Guidance Manual for Puget Sound	2012	http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf
District of Columbia	Stormwater Management Guidebook	2013	http://doee.dc.gov/swguidebook
Philadelphia Water Department	Stormwater Management Guidance Manual, Version 2.1	2014	http://www.pwdplanreview.org/upload/pdf/Full%20Manual%20%2

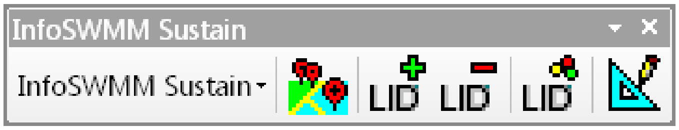
			8Manual%20Version%202.1%29.pdf
University of New Hampshire Stormwater Center	UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds	2014	http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/unhsc_pa_spec_10_09.pdf
NY State Department of Environmental Conservation	Stormwater Management Design Manual	2015	http://www.dec.ny.gov/docs/water_pdf/swdm2015entire.pdf

Table 6-2 Typical ranges for bio-retention cell parameters

Parameter	Range
Maximum Freeboard, inches (D_1)	6 – 12
Surface Void Fraction (f_1)	0.8 – 1.0
Soil Layer Thickness, inches (D_2)	24 – 48
Soil Properties:	
Porosity (f_2)	0.45 – 0.6
Field Capacity (q_{FC})	0.15 – 0.25
Wilting Point (q_{WP})	0.05 – 0.15
Saturated Hydraulic Conductivity, in/hr (K_{2S})	2.0 – 5.5
Wetting Front Suction Head, inches (y_2)	2 – 4
Percolation Decay Constant (*HCO*)	30 – 55
Storage Layer Thickness, inches (D_3)	6 – 36
Storage Void Fraction (f_3)	0.2 – 0.4
Capture Ratio (R_{LID})	5 – 15

Table 6-3 Soil characteristics for a typical bio-retention cell soil

Soil Property	Value
Porosity (f_2)	0.52
Field Capacity (q_{FC})	0.15
Wilting Point (q_{WP})	0.08
Saturated Hydraulic Conductivity, in/hr (K_{2S})	4.7
Percolation Decay Constant (HCO)	39.3
Wetting Front Suction Head, inches ($y_2 = 3.23(K_{2S})^{-0.328}$)	1.9


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

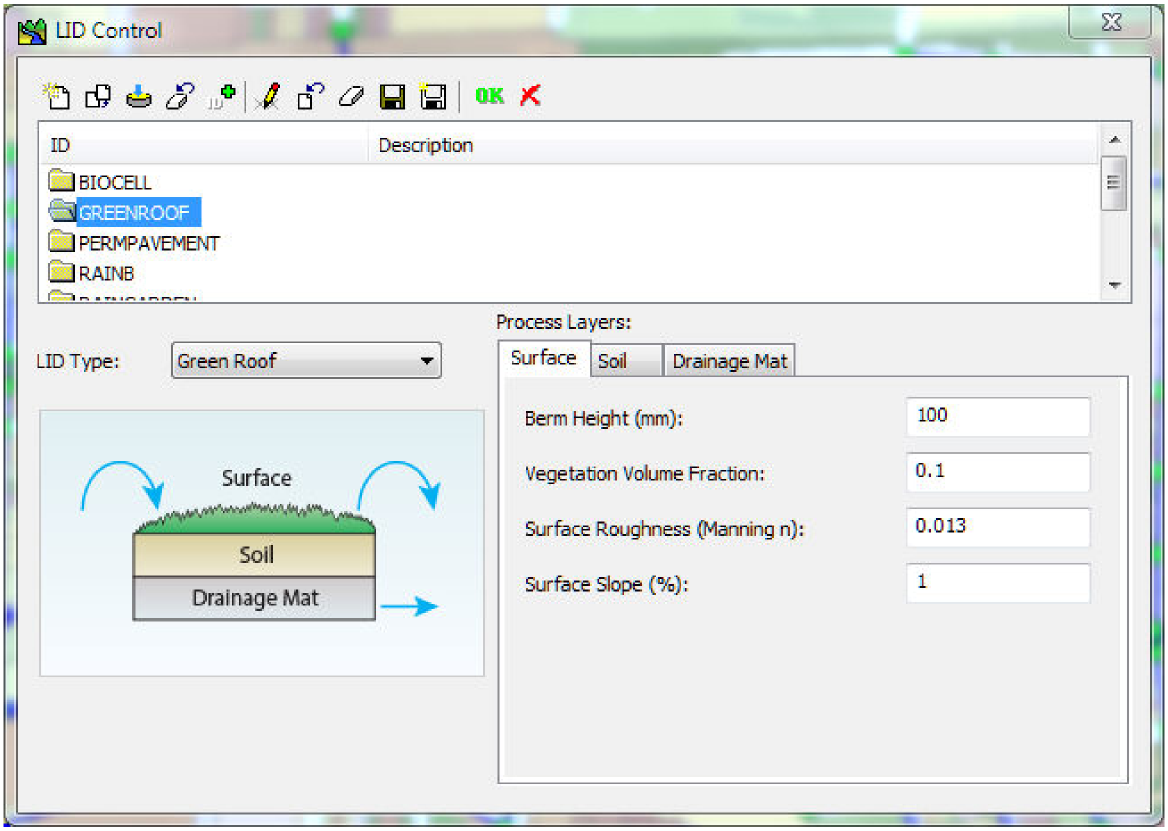
LID Green Roof Control

This is an introduction along with images of the LID Control and data require3ments in InfoSWMM. Every InfoSWMM Control uses from one to 5 layers of data - each with different data requirements. You can use the Siting Manger of InfoSWMM Sustain to find LID locations and the LID Optimizer to find the optimized number of units, cost of units, area and thickness of the LID layers based on your runoff and water quality control objectives.

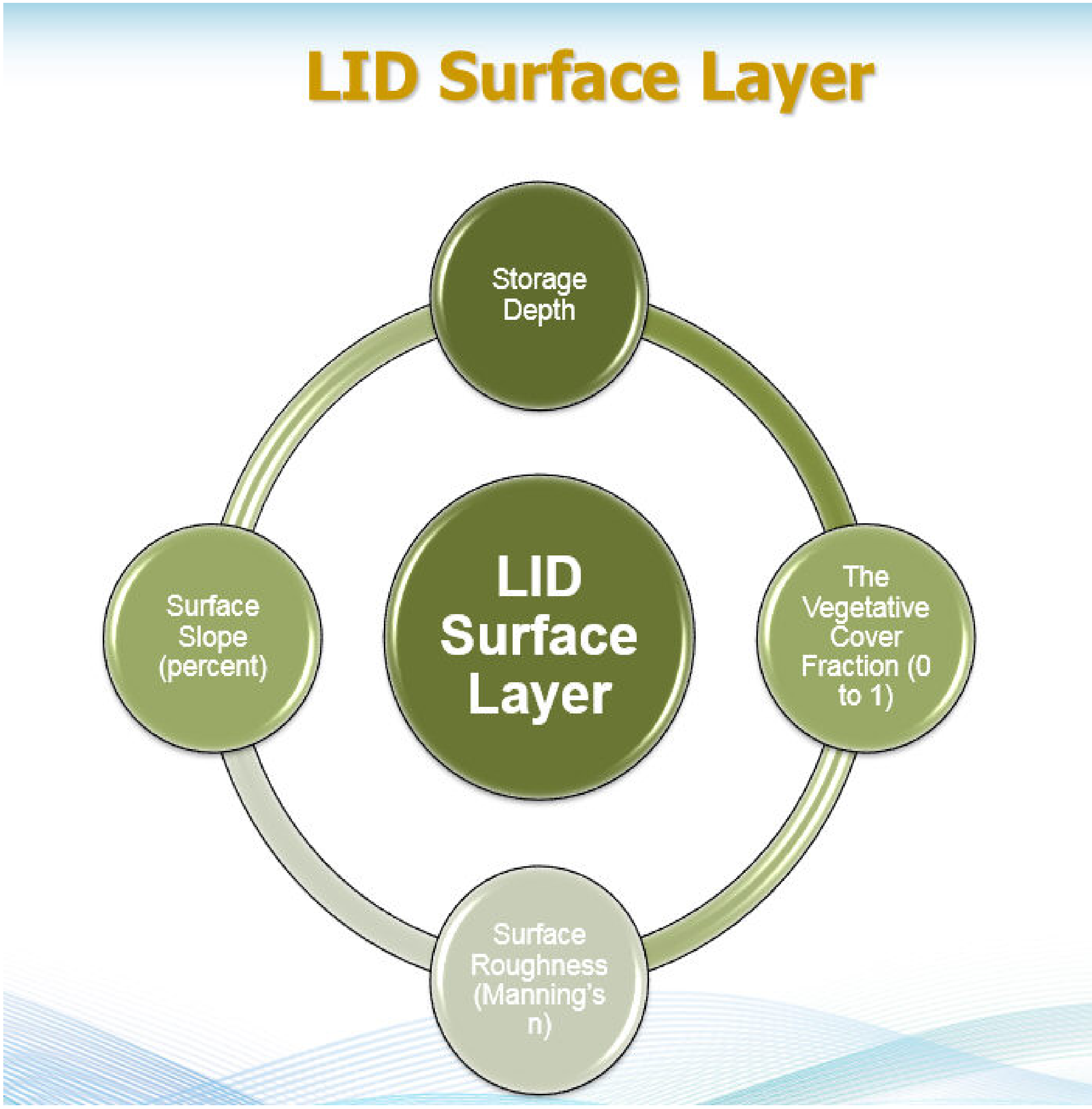
GreenRoof: Green Roofs are another variation of a bio-retention cell that have a soil layer laying atop a special drainage mat material that conveys excess percolated rainfall off of the roof. Green Roofs (also known as Vegetated Roofs) are bio-retention systems placed on roof surfaces that capture and temporarily store rainwater in a soil growing medium. They consist of a layered system of roofing designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The thickness used for the growing medium typically ranges from 3 to 6 inches.

The Surface Process Layer consists of:

- The Storage Depth in inches or millimeters
- The Vegetative Cover Fraction (0 to 1),
- Surface Roughness (Manning’s n)
- Surface Slope (percent).

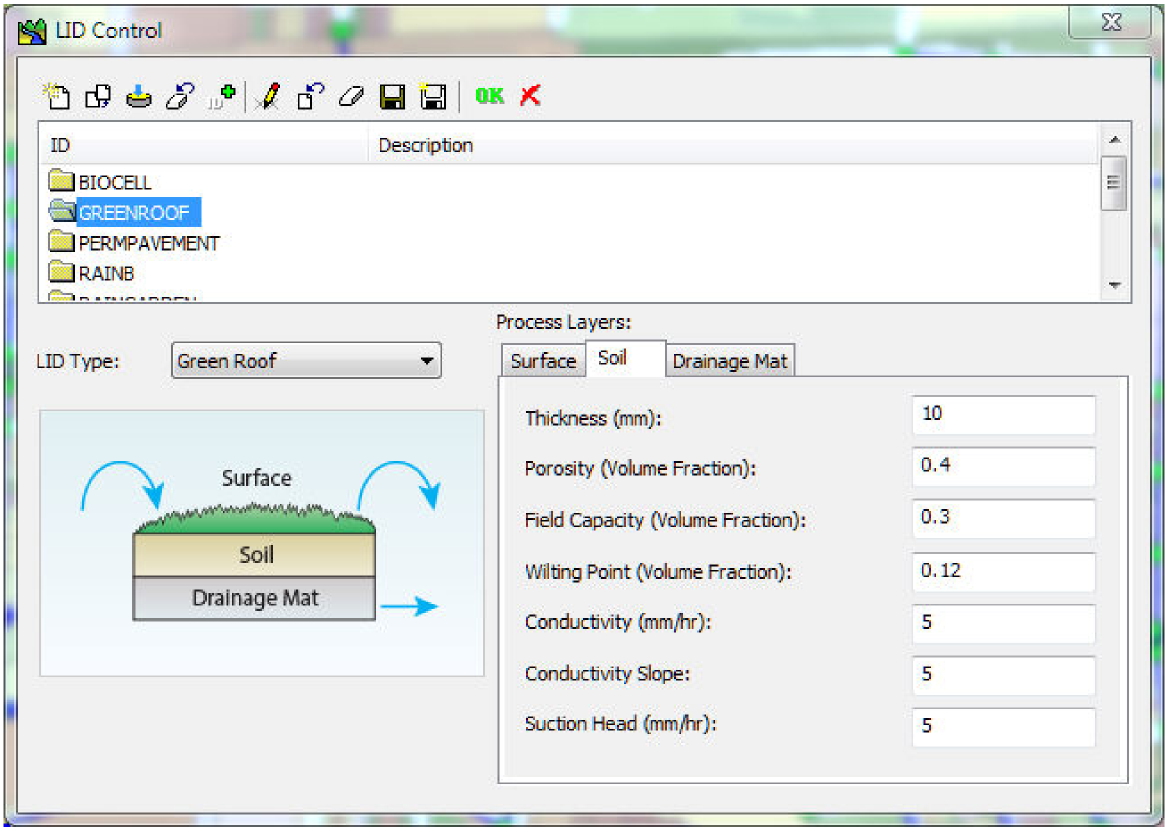


LID Control
OK
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
Process Layers:
LID Type:
Green Roof
Surface
Soil
Drainage Mat
Berm Height (mm):
100
Vegetation Volume Fraction:
0.1
Surface Roughness (Manning n):
0.013
Surface Slope (%):
1
Surface
Soil
Drainage Mat



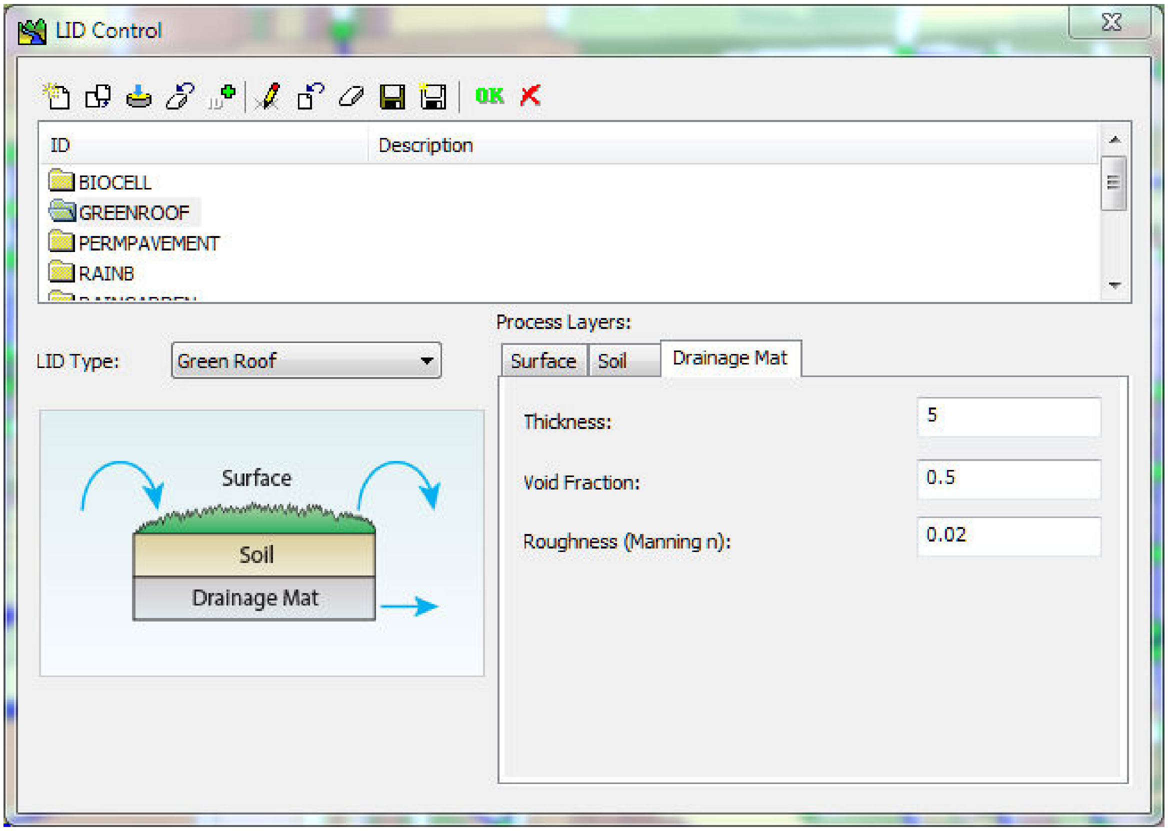
The Soil Process Layer consists of:

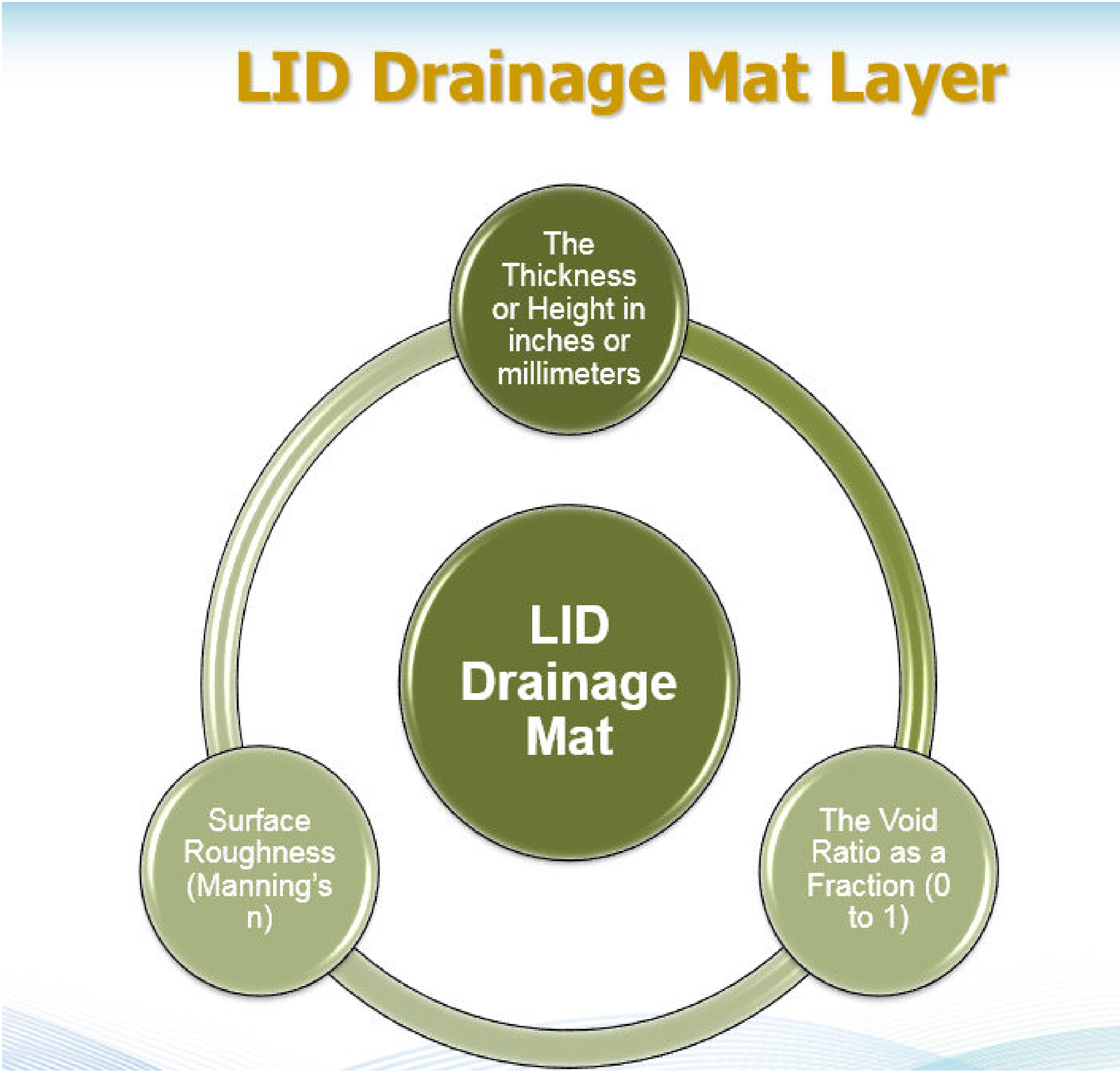
- Soil Thickness in inches or millimeters,
- Porosity as a Fraction (0 to 1),
- Field Capacity as a Fraction (0 to 1),
- Wilting Point as a Fraction (0 to 1),
- Conductivity (inches/hour or millimeters/hour),
- Conductivity Slope,
- Suction Head (inches/hour or millimeters/hour)


LID Control
OK
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
Process Layers:
LID Type:
Green Roof
Surface
Soil
Drainage Mat
Thickness (mm):
10
Porosity (Volume Fraction):
0.4
Field Capacity (Volume Fraction):
0.3
Wilting Point (Volume Fraction):
0.12
Conductivity (mm/hr):
5
Conductivity Slope:
5
Suction Head (mm/hr):
5
Surface
Soil
Drainage Mat

The Drainage Mat Process Layer consists of:

- The Thickness or Height in inches or millimeters,
- The Void Ratio as a Fraction (0 to 1),
- Surface Roughness (Manning's n)


LID Control
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
LID Type:
Green Roof
Process Layers:
Surface
Soil
Drainage Mat
Thickness:
5
Void Fraction:
0.5
Roughness (Manning n):
0.02
Surface
Soil
Drainage Mat



The three layers used in a simulation for a Green Roof LID are shown in the following image.

Excerpt from the EPA manual [Storm Water Management Model Reference Manual Volume III – Water Quality (PDF)] which can be found [here]

6.2.3 Green Roofs

SWMM's green roof is also similar to a bio-retention cell, except it uses a drainage mat instead of gravel aggregate in its storage layer. Drainage mats are thin, multi-layer fabric mats with ribbed undersides that convey water. They have somewhat limited water storage and drainage capacity and are therefore mostly used on sloped roofs. Another type of roof drainage system also suitable for flatter roofs uses slotted pipes placed in a gravel bed and is therefore functionally equivalent to a bio-retention cell with an impermeable bottom ($K_{3S} = 0$) and an underdrain.

The governing equations for a green roof with a drainage mat would be:

$$\phi_1 \frac{\partial d_1}{\partial t} = i - e_1 - f_1 - q_1 \qquad \text{Surface Layer} \qquad (6\text{-}18)$$

$$D_2 \frac{\partial \theta_2}{\partial t} = f_1 - e_2 - f_2 \qquad \text{Soil Layer} \qquad (6\text{-}19)$$

$$\phi_3 \frac{\partial d_3}{\partial t} = f_2 - e_3 - q_3 \qquad \text{Drainage Mat Layer} \qquad (6\text{-}20)$$

Note the absence of the captured runoff term q_0 in Equation 6-18 since a green roof would only be capturing direct rainfall. There is also no exfiltration term f_3 since the bottom of a green roof consists of an impermeable membrane.

The runoff rate from the soil layer surface (q_1) is computed using the Manning equation for uniform overland flow. Under the assumption that the width of the flow area is much greater than the depth of flow the Manning equation becomes:

$$q_1 = \frac{1.49}{n_1} \sqrt{S_1} (W_1/A_1) \phi_1 (d_1 - D_1)^{5/3} \qquad (6\text{-}21)$$

where

n_1	=	surface roughness coefficient,
S_1	=	surface slope (ft/ft),
W_1	=	total length along edge of the roof where runoff is collected (ft),
D_1	=	surface depression storage depth (ft),
A_1	=	roof surface area (ft^2).

All of these surface parameters are supplied by the user as part of the green roof's design. The "surface" that these parameters describe is the surface of the soil layer. The W_1/A_1 term represents the length of the flow path that excess water takes before it enters the roof's drain system (see Figure 6-2). When the depth of ponded water d_1 is at or below the depression storage depth D_1 then no surface outflow occurs.

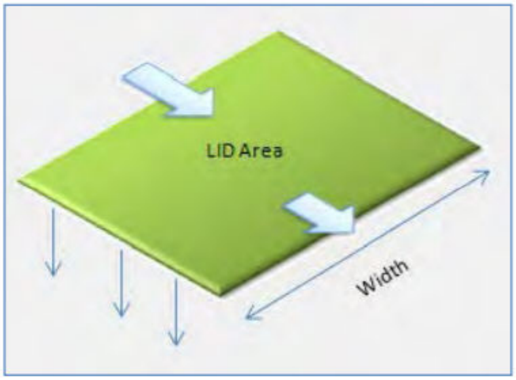


Figure 6-2 Flow path across the surface of a green roof

Another option for surface outflow is to have any ponded surface water in excess of the depression storage D_1 become instantaneous runoff using Equation 6-10. This is done by setting either n_1, S_1, or W_1 to zero. This may be a better choice for roofs with short flow path lengths or flat roofs that use internal roof drains.

The drainage mat flow rate q_3 in Equation 6-20 is assumed to obey uniform open channel flow within the channels of the mat. Thus it can be expressed as:

$$q_3 = \frac{1.49}{n_3}\sqrt{S_1}(W_1/A_1)\phi_3(d_3)^{5/3} \tag{6-22}$$

where n_3 is a roughness coefficient for the mat and S_1, W_1, and A_1 are the same slope, outflow face width, and roof surface area, respectively, used to evaluate surface overflow (q_1).

The remaining flux rates in Equations 6-18 to 6-20 are evaluated in the same fashion as for the bio-retention cell. In addition, the same flux limiting conditions for the bio-retention cell (Equations 6-11 through 6-15) are applied to the green roof to insure that the values used for f_1, f_2, and q_3 maintain feasible moisture levels for the soil and drainage layers after each time step.

6.5.1 Green Roofs Parameter Values

Typical ranges of parameter values for Green Roofs are listed in Table 6-4. These are for extensive green roofs of relatively shallow thickness.

Table 6-4 Typical ranges for green roof parameters

Parameter	Range
Maximum Freeboard, inches (D_1)	0 – 3
Surface Void Fraction (f_1)	0.8 – 1.0

Soil Layer Thickness, inches (D_2)	2 – 6
Soil Parameters:	
Porosity (f_2)	0.45 – 0.6
Field Capacity (q_{FC})	0.3 – 0.5
Wilting Point (q_{WP})	0.05 – 0.2
Plant Available Water (q_{FC} - q_{WP})	0.25 – 0.3
Saturated Hydraulic Conductivity, in/hr (K_{2S})	40 – 140
Wetting Front Suction Head, inches (y_2)	2 – 4
Percolation Parameter (*HCO*)	30 – 55
Drainage Layer Thickness, inches (D_3)	0.5 – 2
Drainage Layer Void Fraction (f_3)	0.2 – 0.4
Drainage Layer Roughness (n_3)	0.01 – 0.03
Capture Ratio (R_{LID})	0

The "soil" used as a growth media for green roofs is very different from naturally occurring soils. It is an engineered mixture of aggregate (such as expanded slate or shale, pumice, or zeolite), sand, and organic matter producing a light weight product with high porosity and water holding capacity. There is a limited amount of information on the standard agronomic properties of such mixtures. The moisture limits and conductivity values listed in Table 6-4 are based on a literature review provided by Perelli (2014). When compared to the properties for bio-retention cell media, the green roof media's hydraulic conductivity is much higher. The ranges for suction head and the percolation parameter were defaulted to those typical of loam and sandy loam soils. The capture ratio for a green roof should be 0 since its only inflow is direct rainfall.

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LID

LID Rain Garden Control

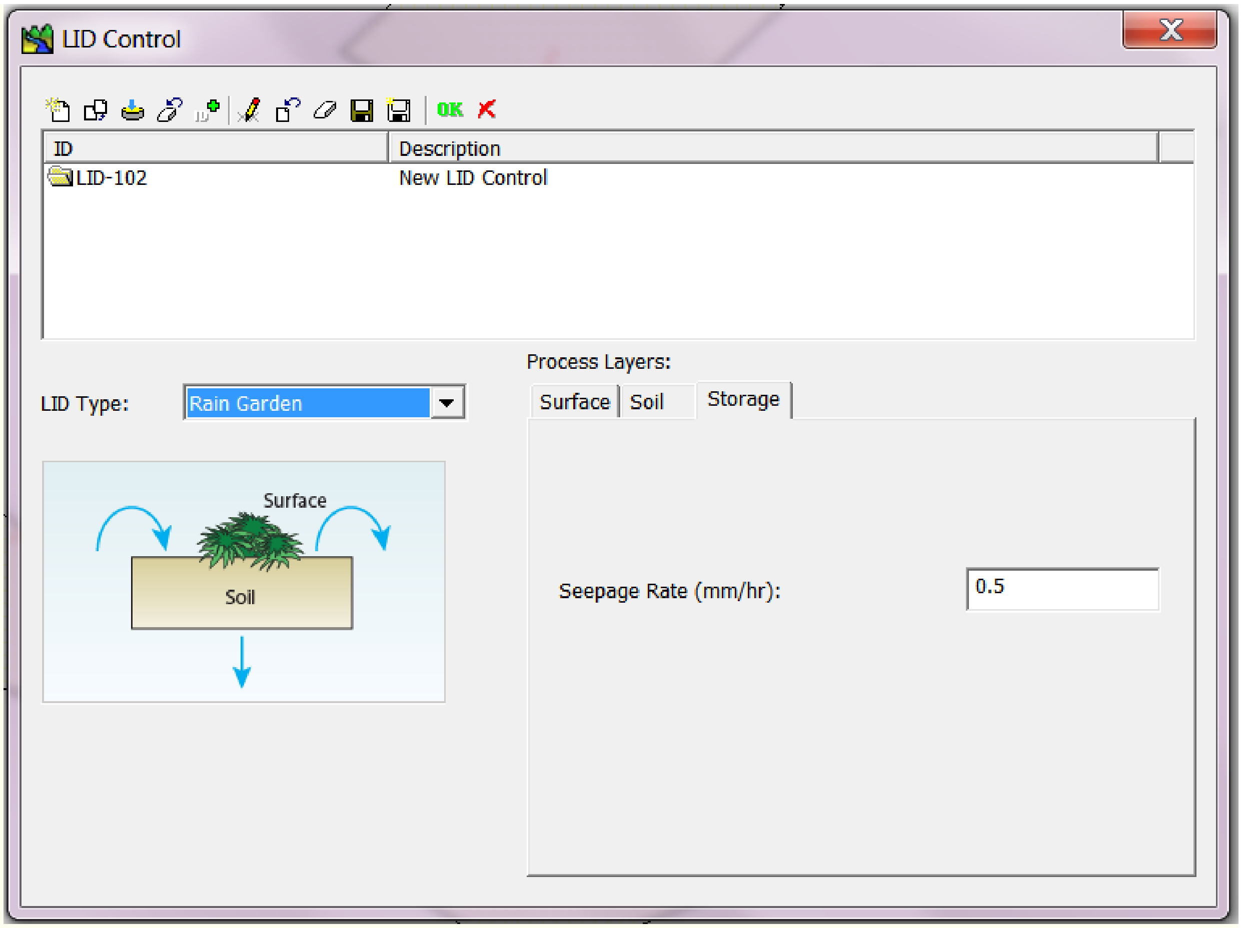
This is an introduction along with images of the LID Control and data require3ments in InfoSWMM. Every InfoSWMM Control uses from one to 5 layers of data - each with different data requirements. You can use the Siting Manger of InfoSWMM Sustain to find LID locations and the LID Optimizer to find the optimized number of units, cost of units, area and thickness of the LID layers based on your runoff and water quality control objectives.

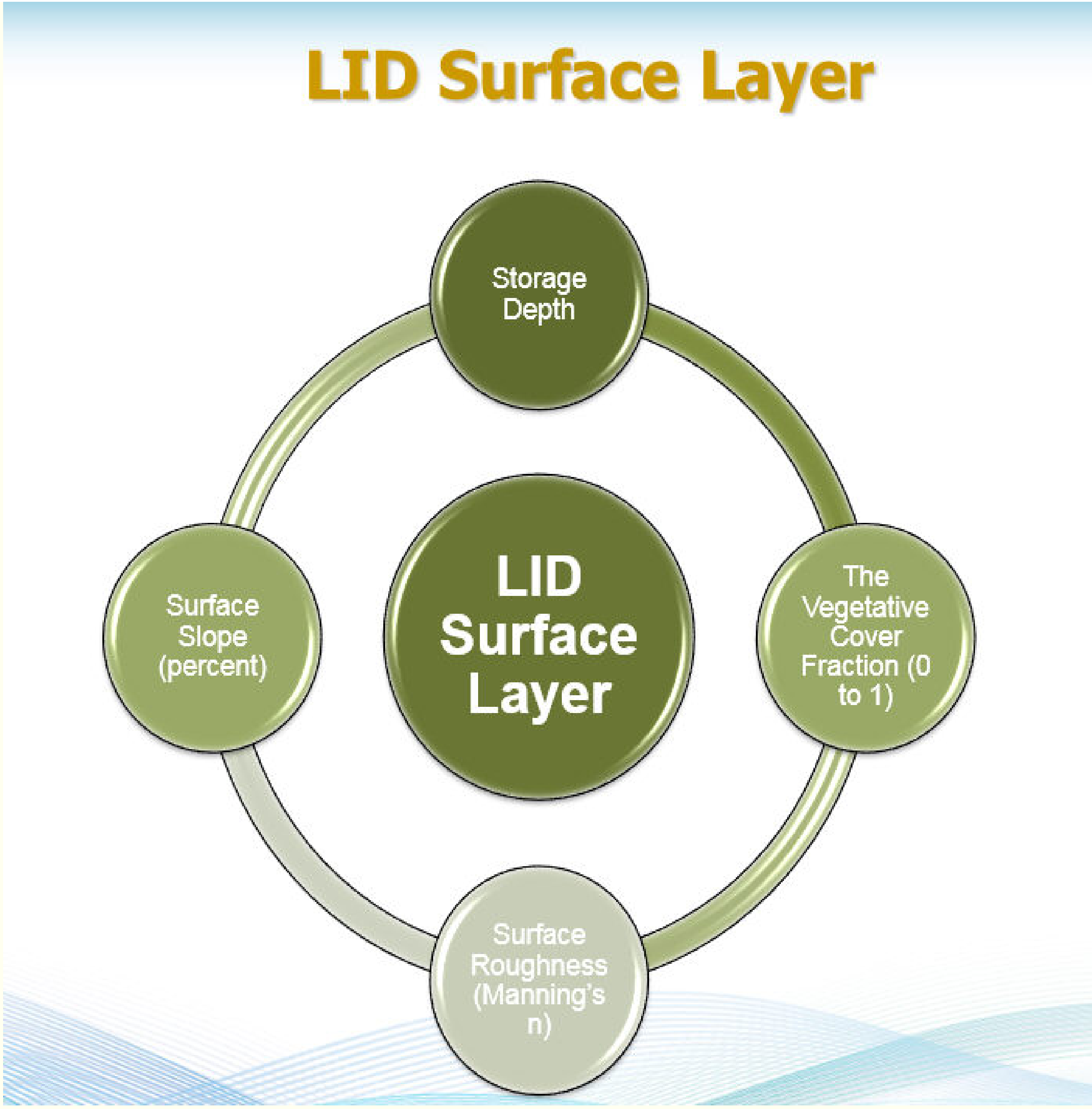
Rain Gardens are a type of bio-retention cell consisting of just the engineered soil layer with no gravel bed below it. Rain Gardens are shallow depressions filled with an engineered soil mix that supports vegetative growth. They are usually used on individual home lots to capture roof runoff. Typical soil depths range from 6 to 18 inches. The capture ratio is the ratio of the rain garden's area to the impervious area that drains onto it. New to SWMM 5.1.011 is the Storage layer for Rain Gardens.

The Surface Process Layer consists of:

- The Storage Depth in inches or millimeters
- The Vegetative Cover Fraction (0

  to 1),
- Surface Roughness (Manning’s n)
- Surface Slope (percent).

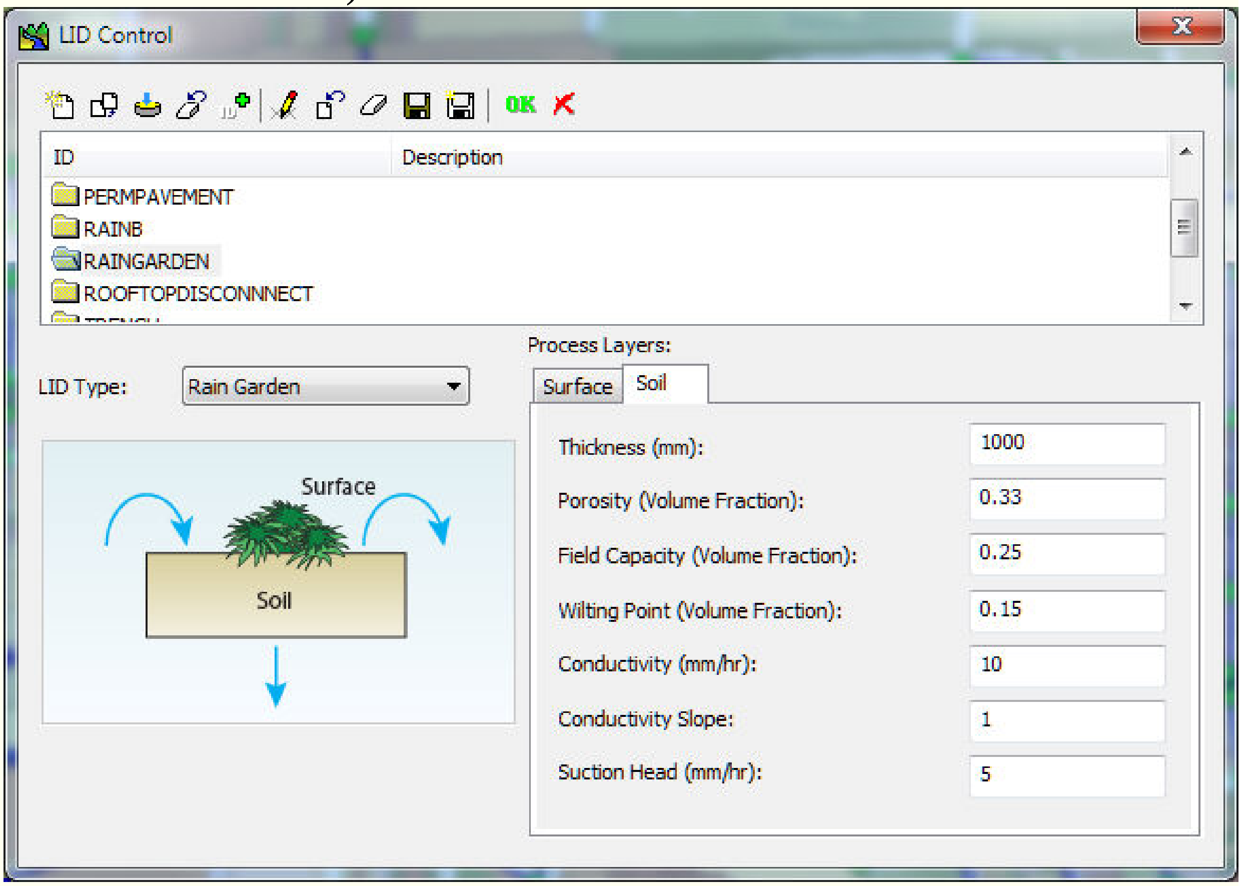

LID Control
ID
Description
LID-102
New LID Control
Process Layers:
LID Type:
Rain Garden
Surface
Soil
Storage
Surface
Soil
Seepage Rate (mm/hr):
0.5



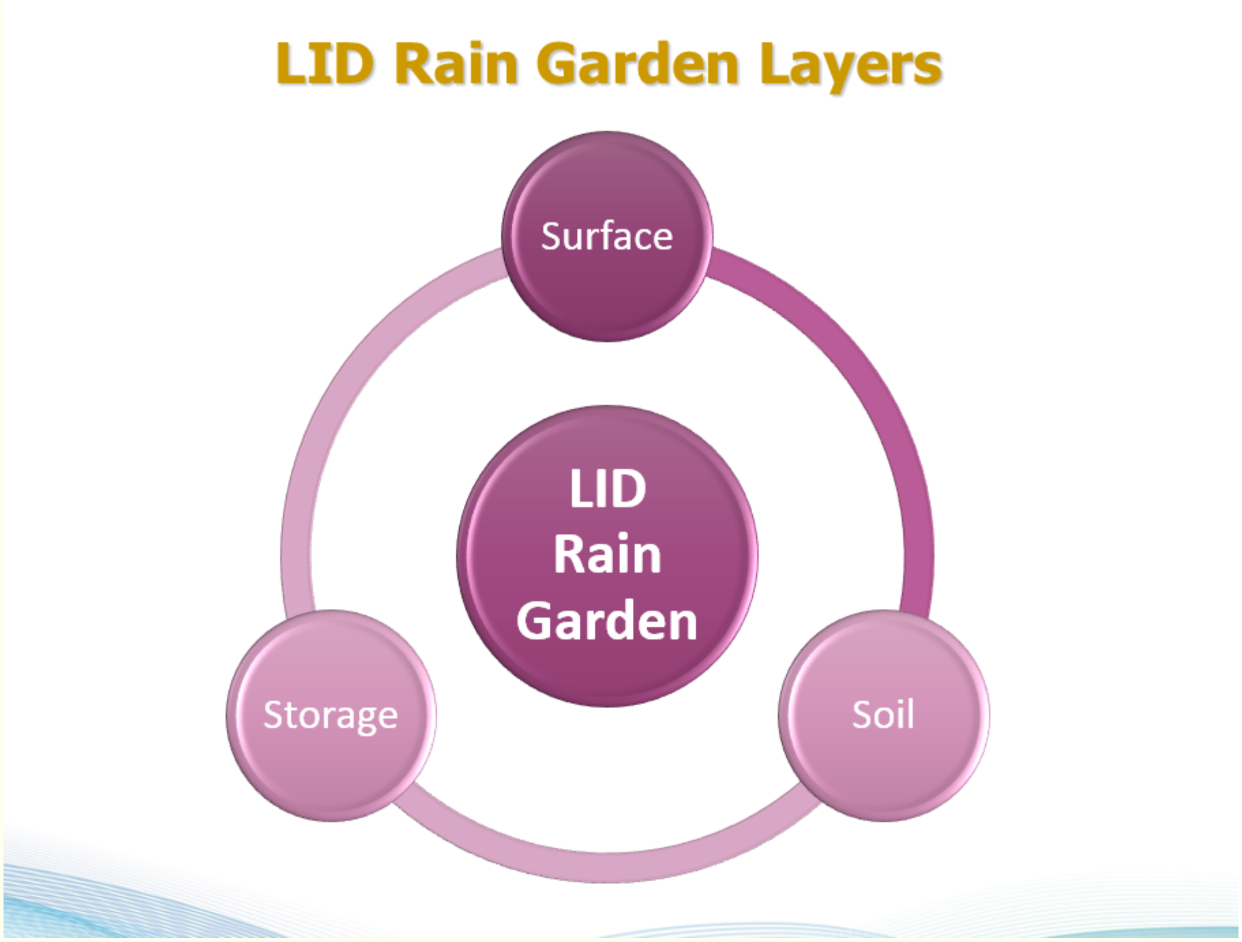
The Soil Process Layer consists of:

- Soil Thickness in inches or millimeters,
- Porosity as a Fraction (0 to 1),
- Field Capacity as a Fraction (0 to 1),
- Wilting Point as a Fraction (0 to 1),
- Conductivity (inches/hour or millimeters/hour),

- Conductivity Slope,
- Suction Head (inches/hour or millimeters/hour)



The two layers used in a simulation for a Rain Garden LID are shown in the following image.



Excerpt from the EPA manual [Storm Water Management Model Reference Manual Volume III – Water Quality (PDF)]

which can be found

here

6.2.2 Rain Gardens

SWMM defines a rain garden as a bio-retention cell without a storage layer. Its governing equations are therefore:

$$\phi_1 \frac{\partial d_1}{\partial t} = i + q_0 - e_1 - f_1 - q_1 \qquad \text{Surface Layer} \qquad (6\text{-}16)$$

$$D_2 \frac{\partial \theta_2}{\partial t} = f_1 - e_2 - f_2 \qquad \text{Soil Layer} \qquad (6\text{-}17)$$

The nominal soil percolation rate f_2 is computed via Equation 6-8. It is then limited to the smaller of this value, the amount of drainable water available in the soil layer (Equation 6-11) and the saturated hydraulic conductivity of the native soil beneath the rain garden (K_{3S}). The remaining flux rates are computed as described earlier.

See the topic Bio-Retention_Cell_LID_Reference_Values.htm

for a discussion of parameter values for Rain Gardens.

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LID
LID

Vegetative Swale LID Control

This is an introduction along with images of the LID Control and data require3ments in InfoSWMM. Every InfoSWMM

Control uses from one to 5 layers of data - each with different data requirements.

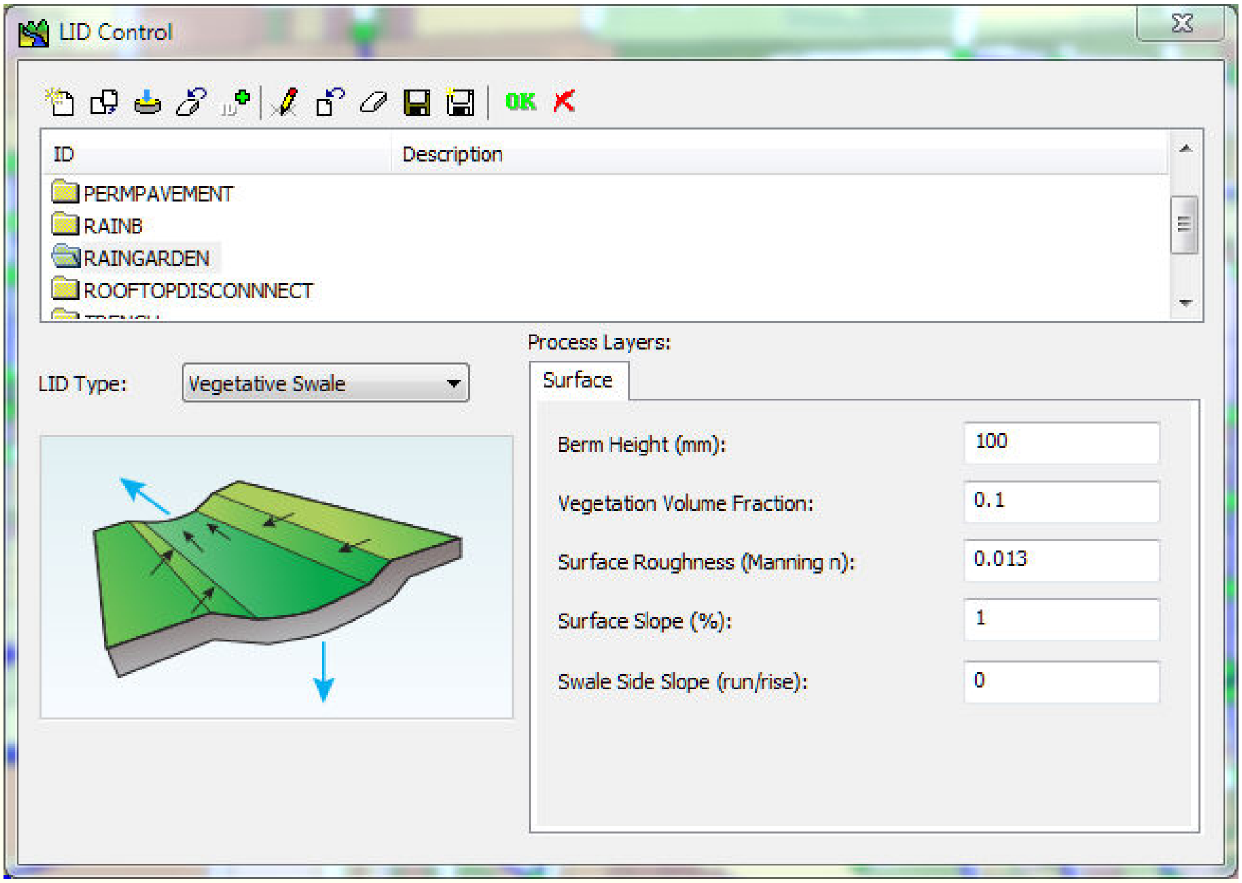
You can use the Siting Manger of InfoSWMM Sustain to find LID locations and the LID Optimizer to find the optimized number of units, cost of units, area and thickness of the LID layers based on your runoff and water quality control objectives.

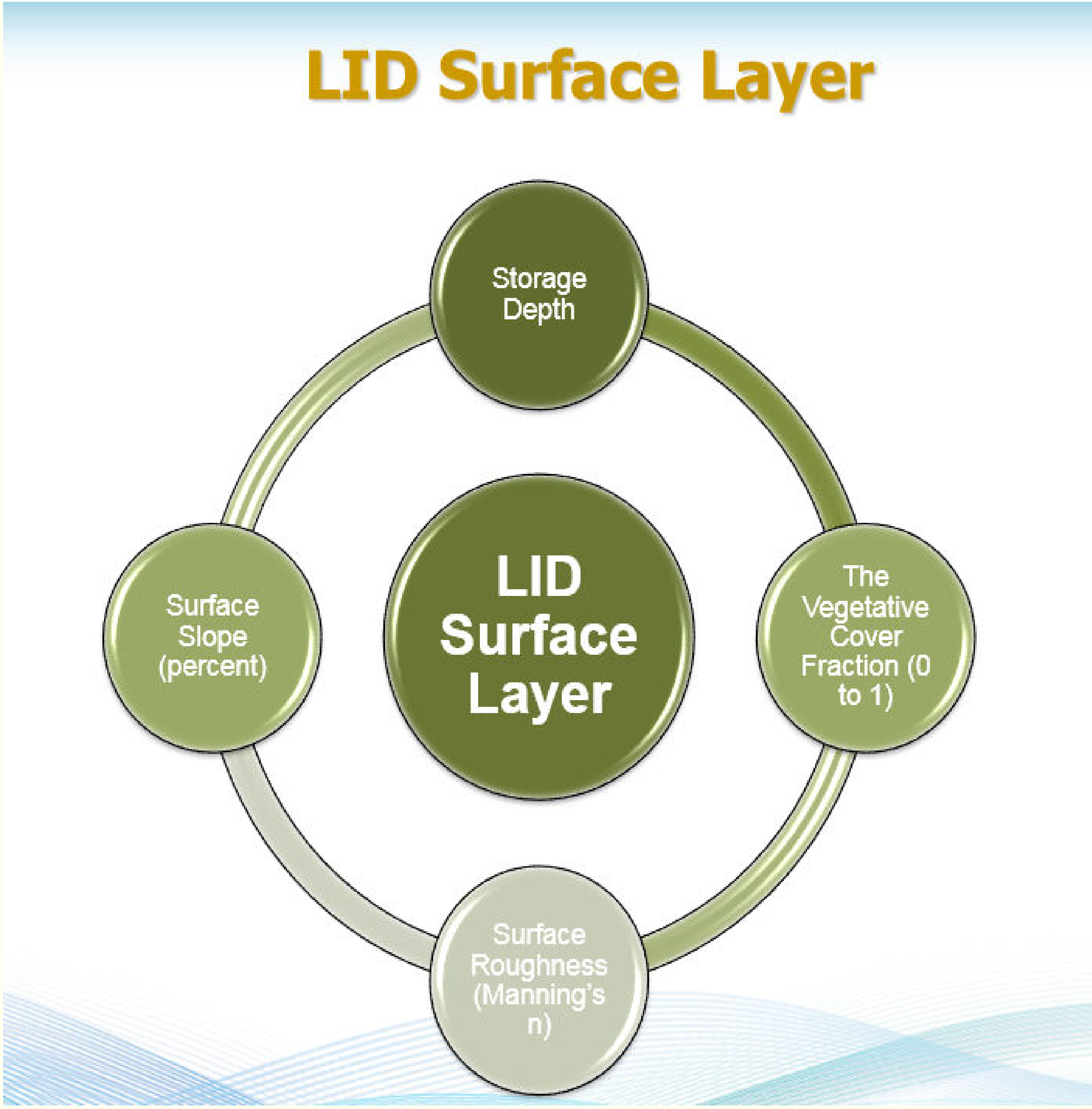
Vegetative Swales are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate the native soil beneath it.

The Surface Process Layer consists of:

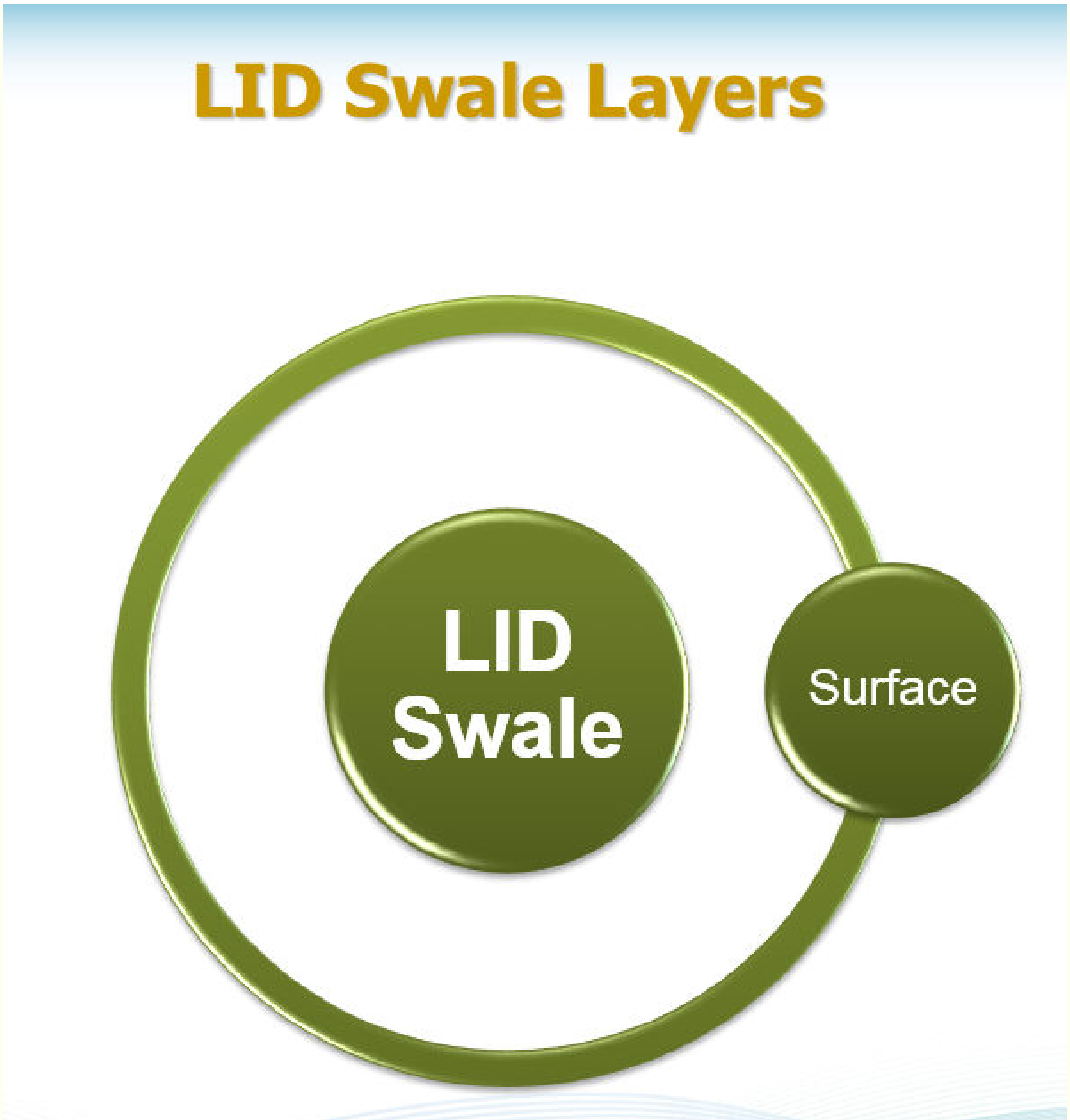
- The Storage Depth in inches or millimeters
- The Vegetative Cover Fraction (0

  to 1),
- Surface Roughness (Manning’s n)
- Surface Slope (percent).


LID Control
OK
ID
Description
PERMPAVEMENT
RAINB
RAINGARDEN
ROOFTOPDISCONNNECT
Process Layers:
LID Type:
Vegetative Swale
Surface
Berm Height (mm):
100
Vegetation Volume Fraction:
0.1
Surface Roughness (Manning n):
0.013
Surface Slope (%):
1
Swale Side Slope (run/rise):
0



The one layer used in a simulation for a Vegetative Swale LID are shown in the following image.



Excerpt from the EPA manual Storm Water Management Model Reference Manual Volume III – Water Quality (PDF)

which can be found

here

6.2.8 *Vegetative Swale*

As shown in Figure 6-5, SWMM considers a vegetative swale to be a natural grass-lined trapezoidal channel that conveys captured runoff to another location while allowing it to infiltrate into the soil beneath it. It can be modeled with a single surface layer whose continuity equation is:

$$A_1 \frac{\partial d_1}{\partial t} = (i + q_0)A - (e_1 + f_1)A_1 - q_1 A \qquad \text{Surface Layer} \qquad (6\text{-}51)$$

where A_1 is the surface area at water depth d_1 and A is the user-supplied surface area occupied by the swale across its full height D_1. Unlike the other LID controls that were assumed to have a constant surface area throughout all layers, this equation accounts for a varying surface area as the depth of water in the swale changes.

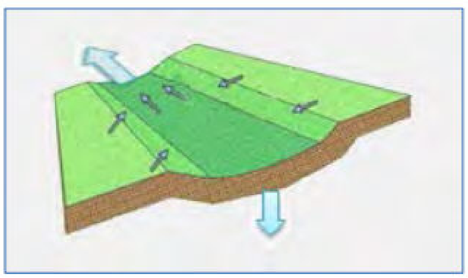


Figure 6-5 Representation of a vegetative swale

From simple geometry, the relation between surface area A_1 and depth of flow d_1 is:

$$A_1 = \frac{A}{W_1}[W_1 - 2S_X(D_1 - d_1)] \qquad (6\text{-}52)$$

where W_1 is the width of the swale at its full height D_1 and S_X is the slope (run over rise) of its trapezoidal side walls. The volume of water contained in the swale, V_1, is the longitudinal length of the swale, A/W_1, multiplied by the area of the wetted cross-section, A_X.

$$V_1 = (A/W_1)A_X \qquad (6\text{-}53)$$

The wetted cross-sectional area is:

$$A_X = d_1(W_X + d_1 S_X)\phi_1 \qquad (6\text{-}54)$$

where W_X is the width across the bottom of the swale's cross section (equal to $W_1 - 2S_X D_1$) and ϕ_1 is the fraction of the volume above the surface not occupied by vegetation.

The volumetric rate of evaporation of surface water in the swale, $e_1 A_1$, is the smaller of the external potential ET rate, $E_0(t)A_1$ and the available volume of surface water over the time step, $V_1/\Delta t$. Because the swale is assumed to sit on top of the subcatchment's native soil, the infiltration rate f_1 is the same value computed for the pervious area of the subcatchment by SWMM's runoff module (see Chapter 4 of Volume I for details).

The swale's volumetric outflow rate, $q_1 A$, is computed using the Manning equation:

$$q_1 A = \frac{1.49}{n_1}\sqrt{S_1}\, A_X\, R_X^{2/3} \tag{6-55}$$

where n_1 is the roughness of the swale's surface, S_1 is its slope in the direction of flow, and R_X is its hydraulic radius (ft). The latter quantity is given by:

$$R_X = \frac{A_X}{\left(W_X + 2d_1\sqrt{1 + S_X^2}\right)} \tag{6-56}$$

To summarize, the parameters required to model a vegetative swale include its total surface area A, its top width W_1, its maximum depth D_1, its surface roughness n_1, its longitudinal slope S_1, the slope of its side walls S_x, and fraction of its volume not occupied by vegetation ϕ_1.

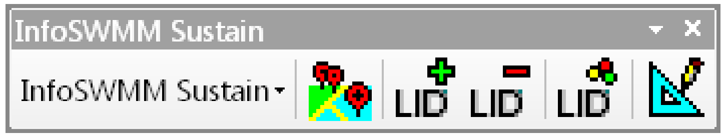
6.5.7 *Vegetative Swales*

Typical values for the parameters associated with vegetative swales are listed in table 6-7. The top width of the swale at full depth (W_1) equals $W_X + 2D_1 S_X$. The maximum surface area covered by the swale (A_{LID}) can be found by multiplying W_1 by the length of the swale.

Table 6-7 Typical ranges for vegetative swale parameters

Parameter	Range
Maximum Depth, feet (*D1*)	0.5 – 2.0
Surface Void Fraction (*f1*)	0.8 - 1.0

Bottom Width, feet (*WX*)	2.0 – 8.0
Surface Slope, percent (*S1*)	0.5 – 3.0
Side Slope, horizontal : vertical (*SX*)	2.5 : 1 – 4 : 1
Surface Roughness (*n1*)	0.03 – 0.2
Capture Ratio (*RLID*)	5 – 10


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

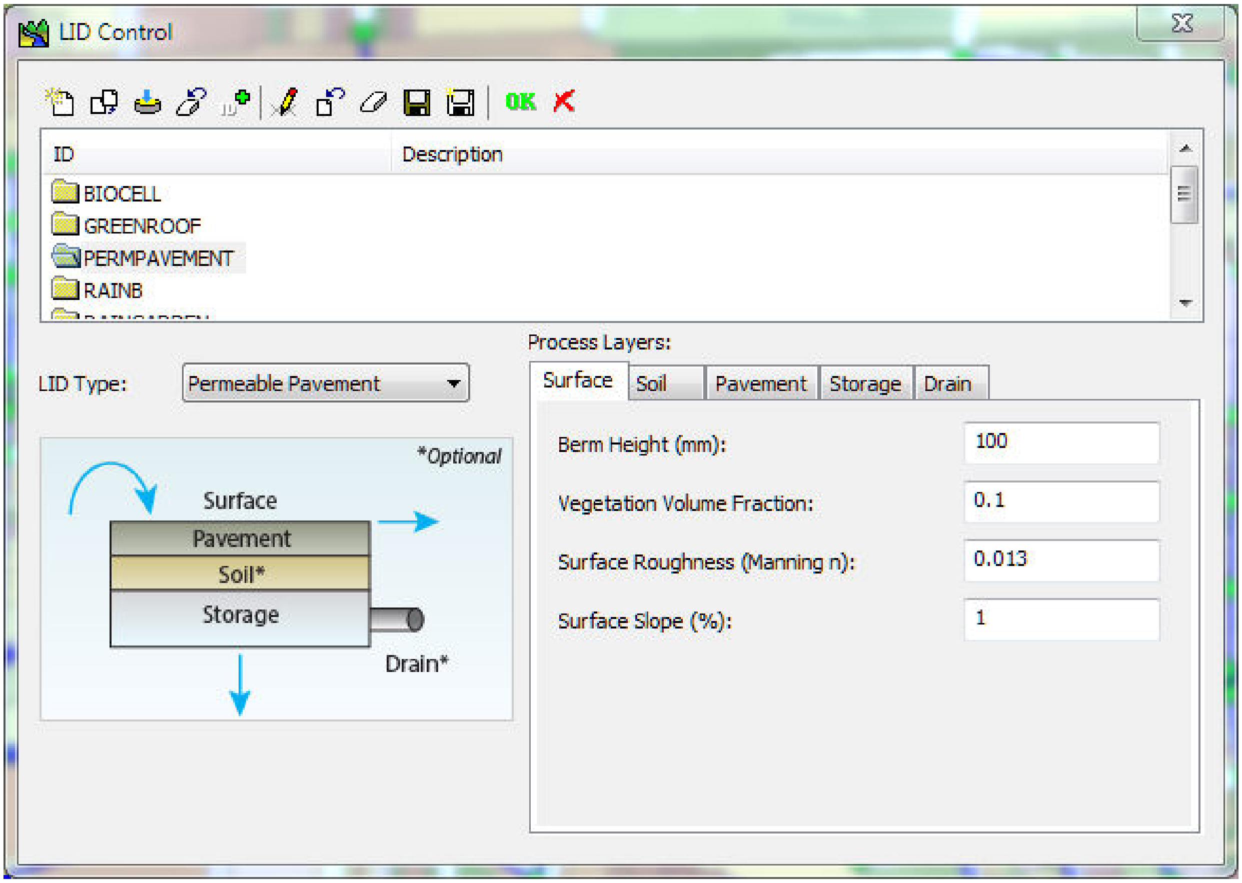
Porous Pavement LID Control

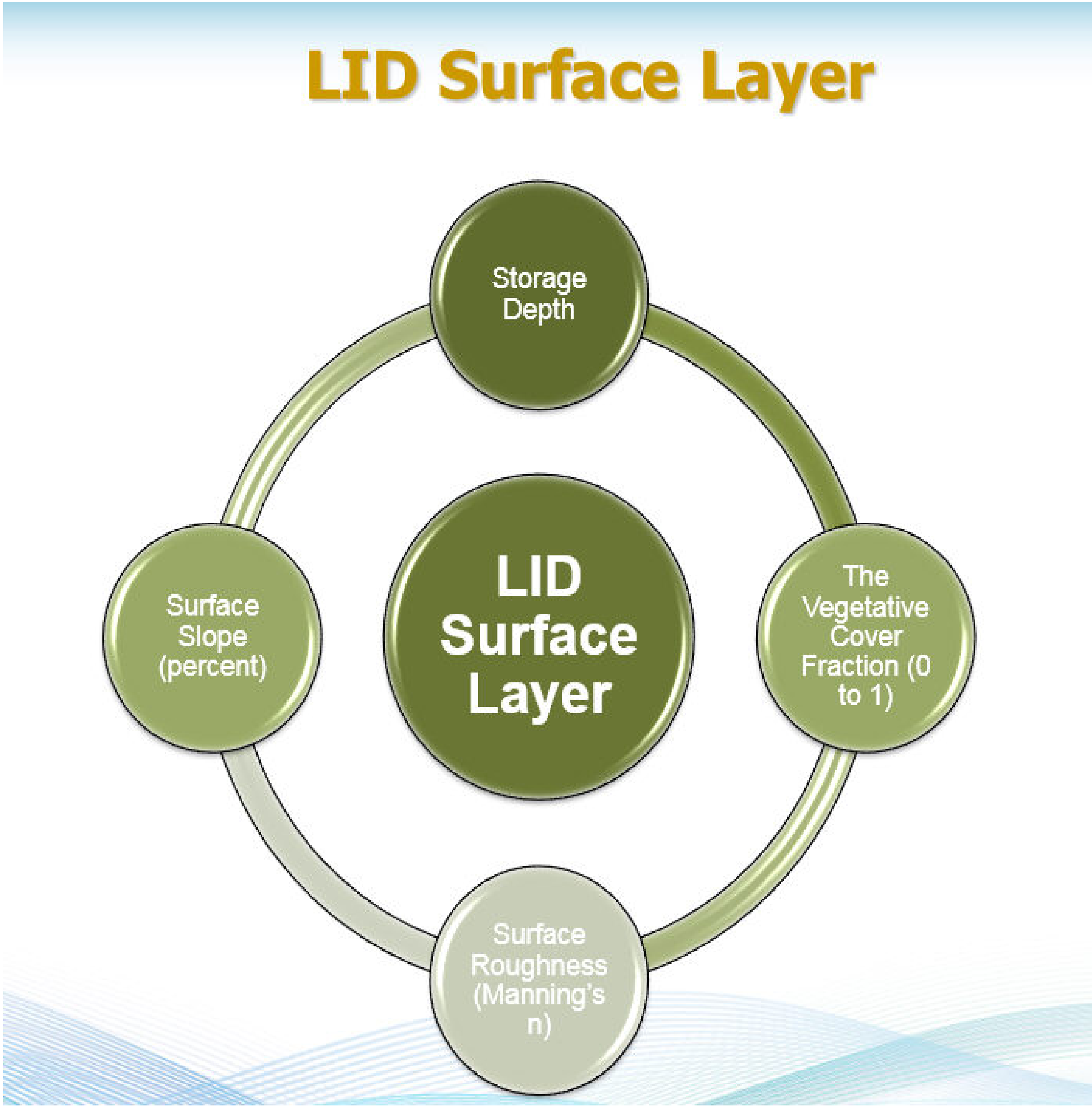
This is an introduction along with images of the LID Control and data require3ments in InfoSWMM. Every InfoSWMM Control uses from one to 5 layers of data - each with different data requirements. You can use the Siting Manger of InfoSWMM Sustain to find LID locations and the LID Optimizer to find the optimized number of units, cost of units, area and thickness of the LID layers based on your runoff and water quality control objectives.

The Porous Pavement LID Control has five components or Process Layers: Surface, Pavement, Storage and Underdrain.

The Surface Process Layer consists of:

- The Storage Depth in inches or millimeters
- The Vegetative Cover Fraction (0 to 1),
- Surface Roughness (Manning's n)
- Surface Slope (percent).

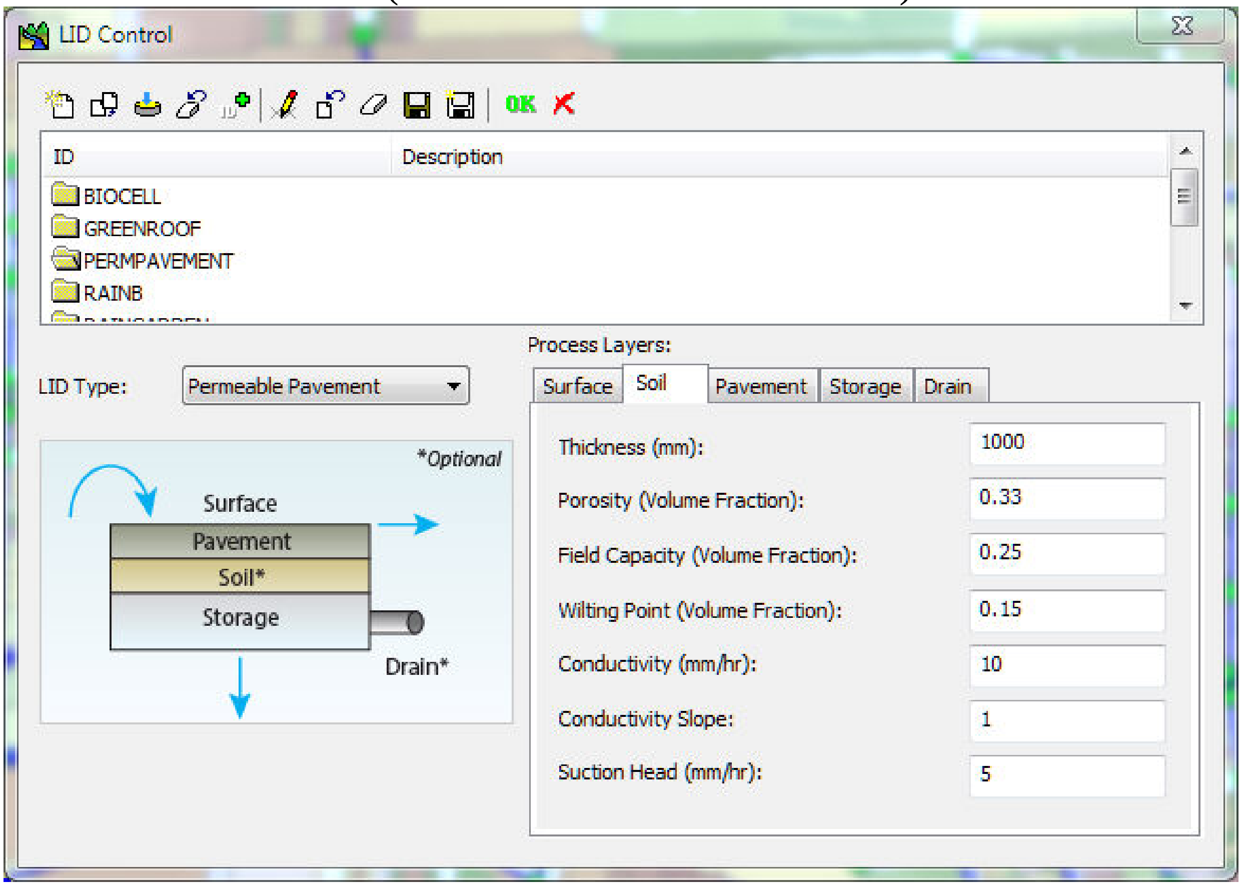

LID Control
OK
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
LID Type:
Permeable Pavement
Process Layers:
Surface
Soil
Pavement
Storage
Drain
*Optional
Surface
Pavement
Soil*
Storage
Drain*
Berm Height (mm):
100
Vegetation Volume Fraction:
0.1
Surface Roughness (Manning n):
0.013
Surface Slope (%):
1



The Soil Process Layer consists of:

- Soil Thickness in inches or millimeters,
- Porosity as a Fraction (0 to 1),
- Field Capacity as a Fraction (0 to 1),
- Wilting Point as a Fraction (0 to 1),
- Conductivity (inches/hour or millimeters/hour),
- Conductivity Slope,

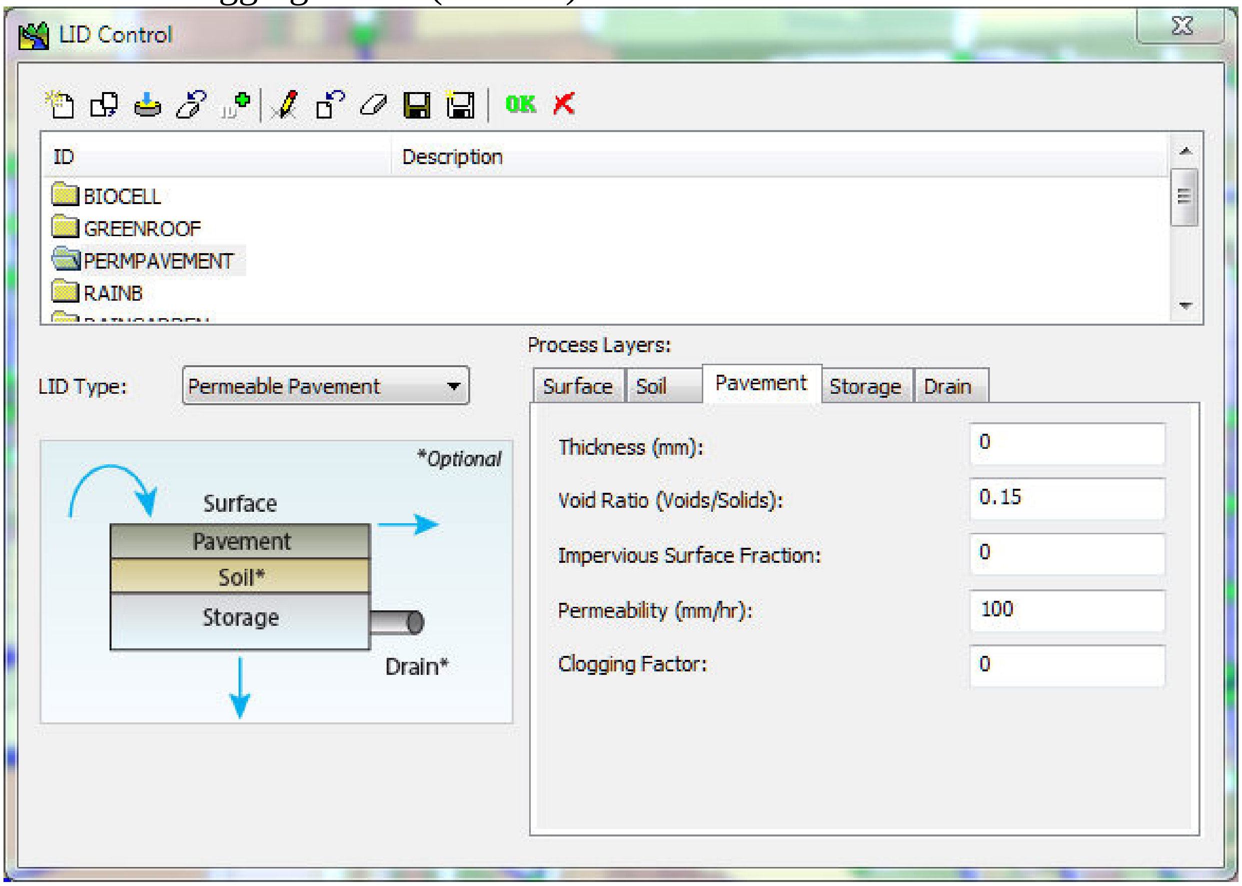
- Suction Head (inches/hour or millimeters/hour)

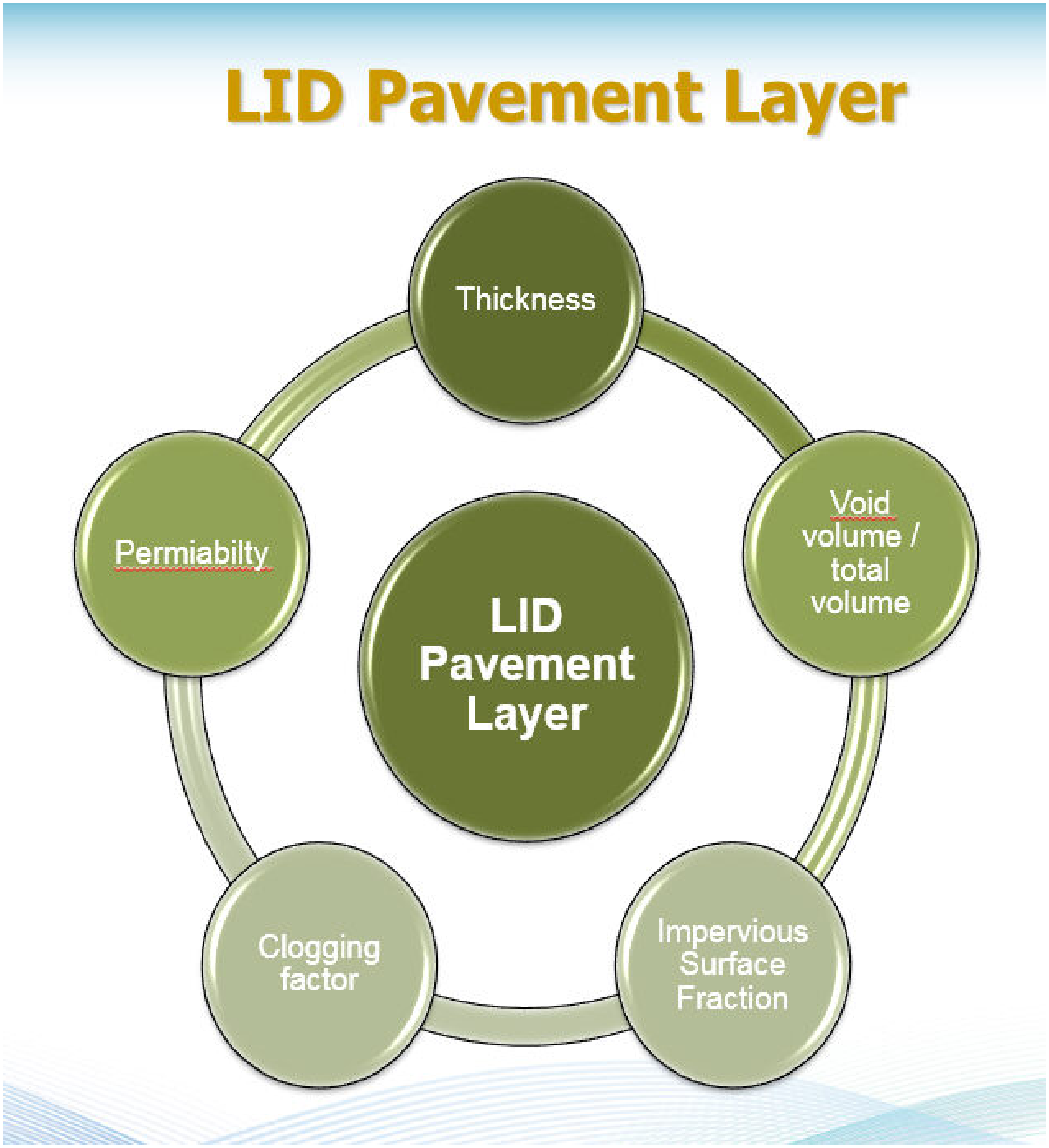


The Pavement Process Layer consists of:

- The Pavement Thickness in inches or millimeters
- The Void Ratio (Voids/Solids) (0 to 1),
- Impervious Surface Fraction,
- Pavement Permeability in inches/hour or millimeters per hour,

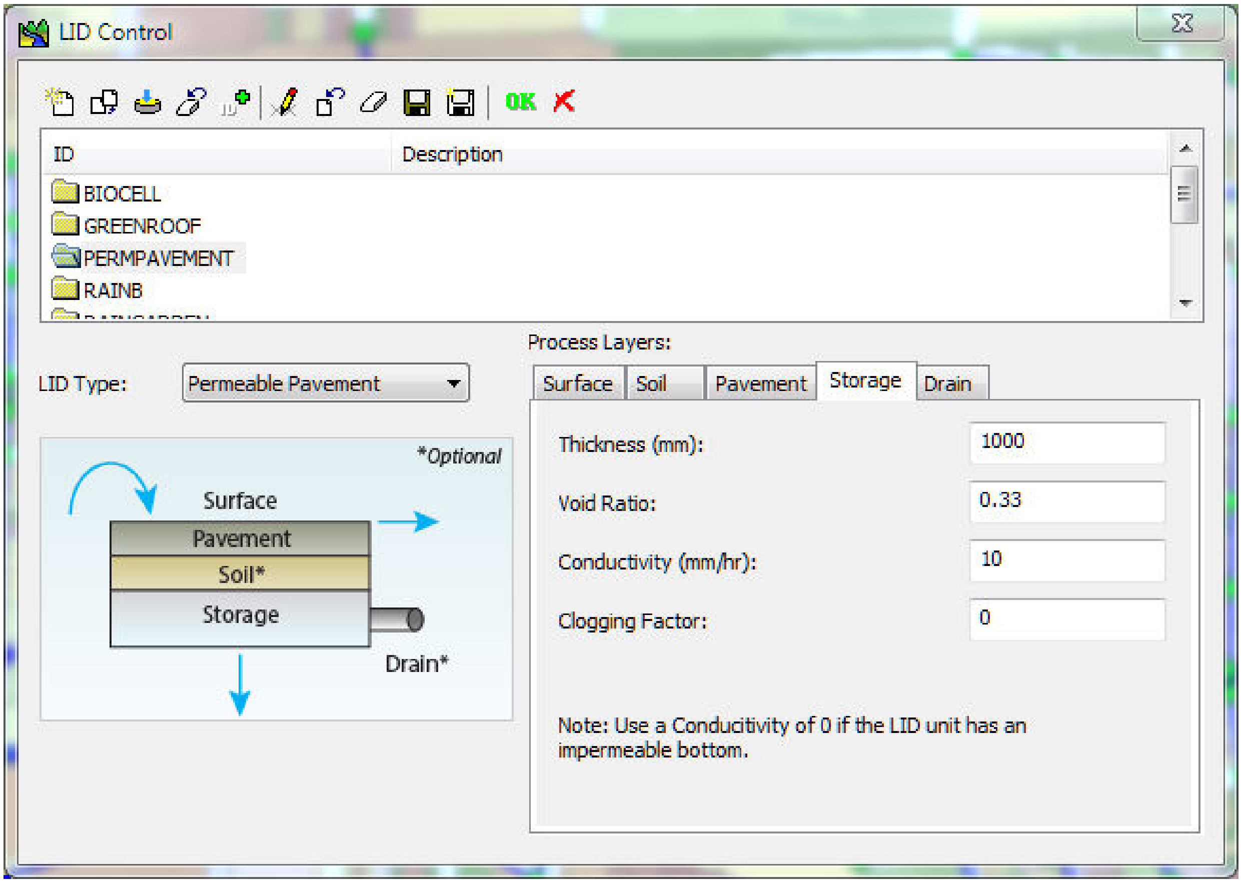
- Clogging Factor (fraction).

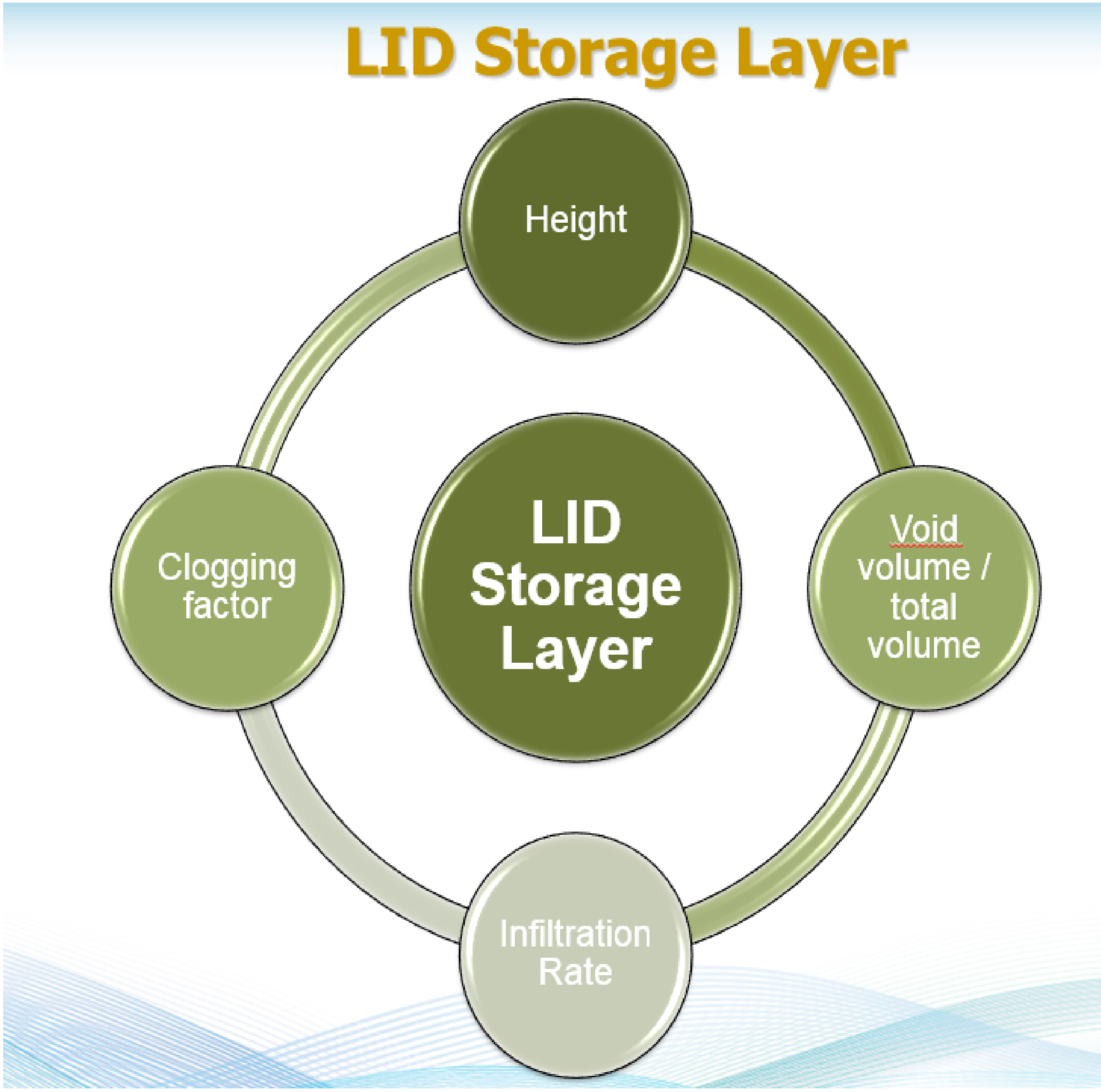




The Storage Process Layer consists of:

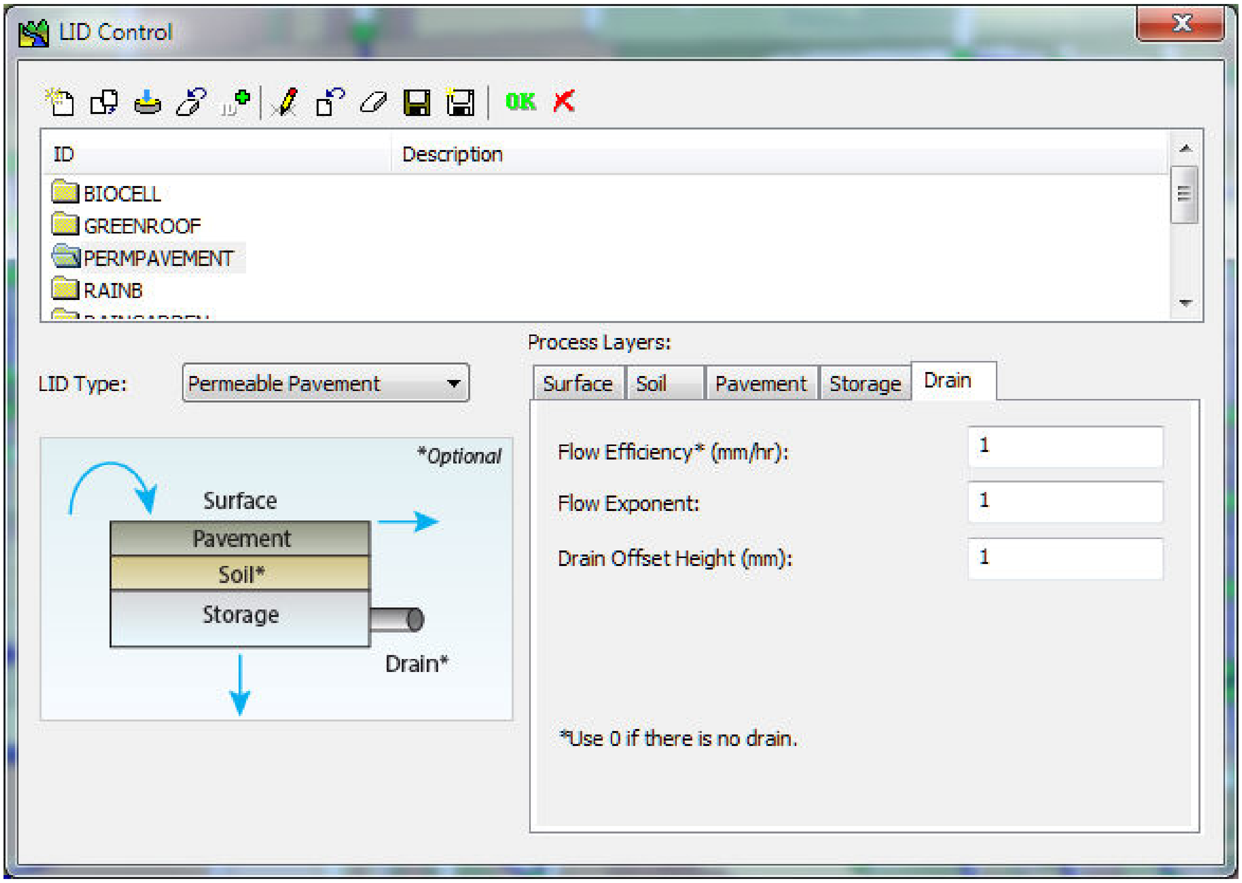
- The Storage Height in inches or millimeters,
- The Void Ratio as a Fraction (0 to 1),
- Surface Conductivity in inches/hour or millimeters/hour,
- Clogging Factor

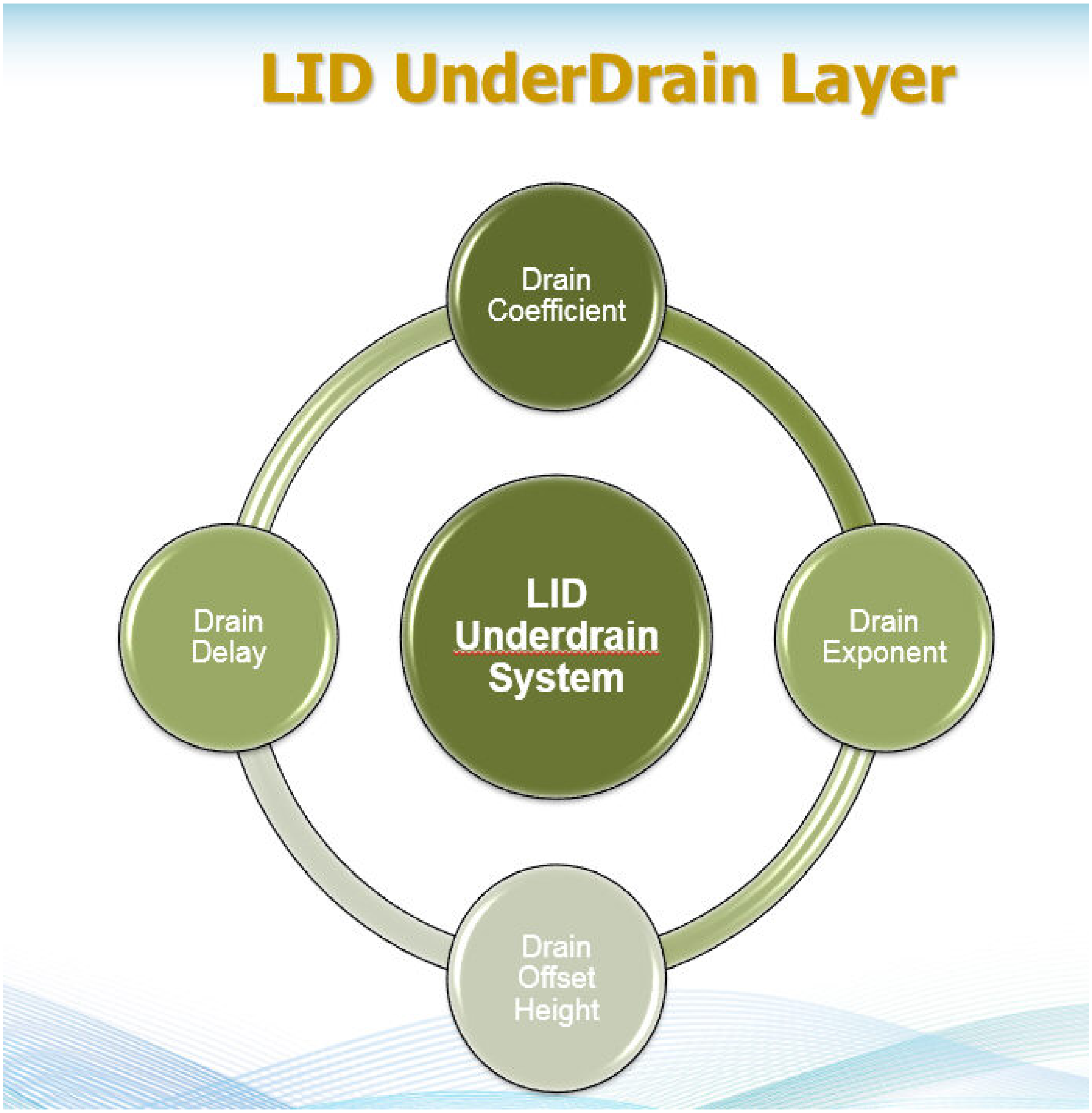

LID Control
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
Process Layers:
LID Type:
Permeable Pavement
Surface
Soil
Pavement
Storage
Drain
*Optional
Surface
Pavement
Soil*
Storage
Drain*
Thickness (mm):
1000
Void Ratio:
0.33
Conductivity (mm/hr):
10
Clogging Factor:
0
Note: Use a Conductivity of 0 if the LID unit has an impermeable bottom.



The Underdrain Process Layer consists of:

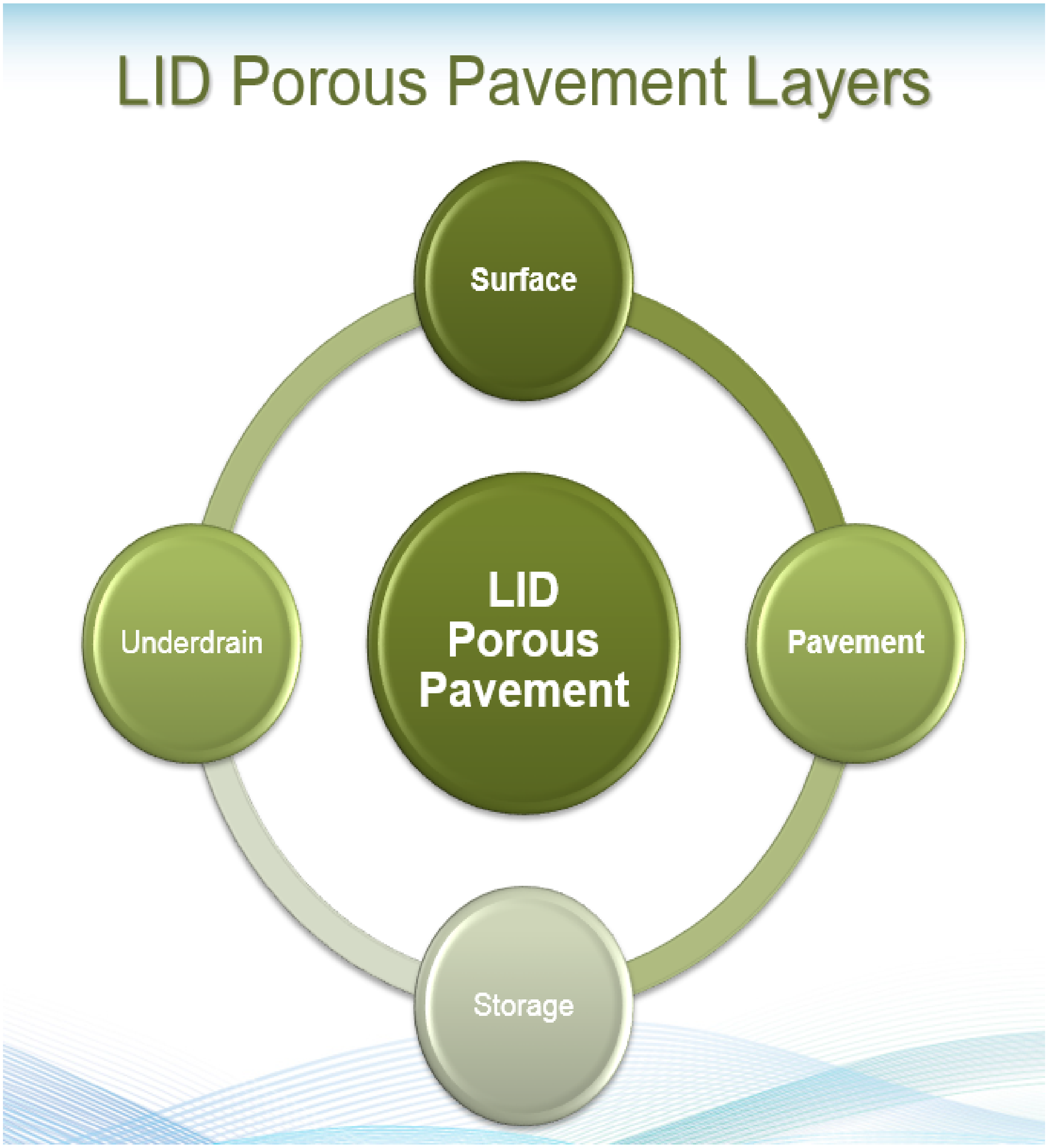
- Drain Coefficient (inches/hour or millimeters/hour)
- The Void Ratio as a Fraction (0 to 1),
- Drain Exponent
- Drain Offset Height (inches or millimeters)


LID Control
OK
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
Process Layers:
LID Type:
Permeable Pavement
Surface
Soil
Pavement
Storage
Drain
*Optional
Surface
Pavement
Soil*
Storage
Drain*
Flow Efficiency* (mm/hr):
1
Flow Exponent:
1
Drain Offset Height (mm):
1
*Use 0 if there is no drain.


LID UnderDrain Layer
Drain Coefficient
LID Underdrain System
Drain Delay
Drain Exponent
Drain Offset Height

An example of a Porous Pavement Driveway.

The four layers used in a simulation for a Permeable Pavement LID are shown in the following image.


LID Porous Pavement Layers
Surface
Underdrain
LID Porous Pavement
Pavement
Storage

Low Impact Development Pavement Layer

The **Pavement Layer** page of the LID Control Editor supplies values for the following properties of a porous pavement LID:

Thickness

The thickness of the pavement layer (inches or mm). Typical values are 4 to 6 inches (100 to 150 mm).

Void Ratio

The volume of void space relative to the volume of solids in the pavement for continuous systems or for the fill material used in modular systems. Typical values for pavements are 0.12 to 0.21. Note that porosity = void ratio / (1 + void ratio).

Impervious Surface Fraction

Ratio of impervious paver material to total area for modular systems; 0 for continuous porous pavement systems.

Permeability

Permeability of the concrete or asphalt used in continuous systems or hydraulic conductivity of the fill material (gravel or sand) used in modular systems (in/hr or mm/hr). The permeability of new porous concrete or asphalt is very high (e.g., hundreds of in/hr) but can drop off over time due to clogging by fine particulates in the runoff (see below).

Clogging Factor

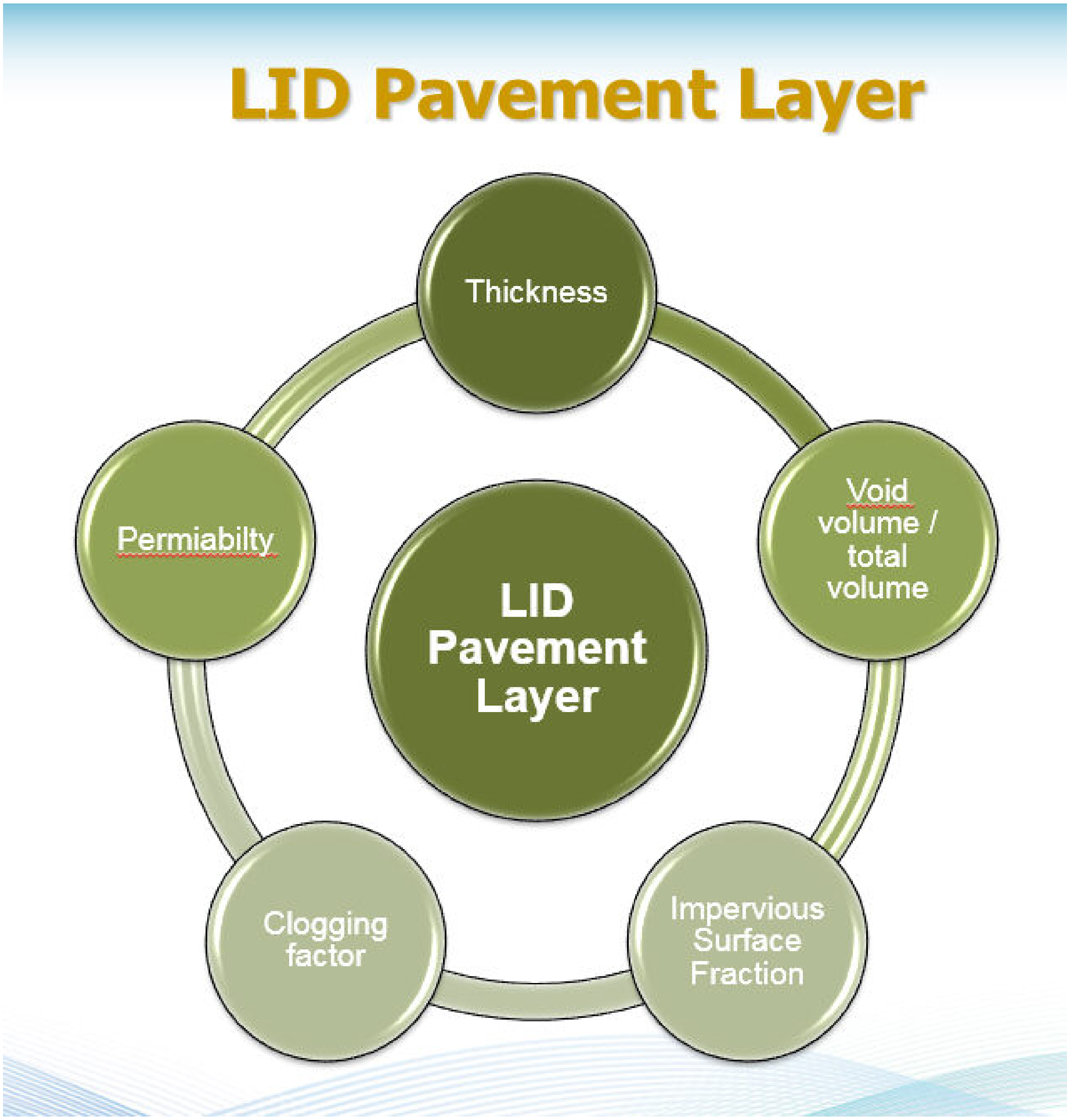
Number of pavement layer void volumes of runoff treated it takes to completely clog the pavement. Use a value of 0 to ignore clogging. Clogging progressively reduces the pavement's permeability in direct proportion to the cumulative volume of runoff treated.

If one has an estimate of the number of years it takes to fully clog the system (Yclog), the Clogging Factor can be computed as: Yclog * Pa * CR * (1 + VR) * (1 - ISF) / (T * VR) where Pa is the annual rainfall amount over the site, CR is the pavement's capture ratio (area that contributes runoff to the pavement divided by area of the pavement itself), VR is the system's Void

Ratio, ISF is the Impervious Surface Fraction, and T is the pavement layer Thickness.

As an example, suppose it takes 5 years to clog a continuous porous pavement system that serves an area where the annual rainfall is 36 inches/year. If the pavement is 6 inches thick, has a void ratio of 0.2 and captures runoff only from its own surface, then the Clogging Factor is 5 x 36 x (1 + 0.2) / 6 / 0.2 = 180.

ID (Char)	Pavement - Thickness (in)	Pavement - Void Ratio (Double)	Pavement - Impervious Surface Fraction (Double)	Pavement - Permeability (in/hr)	Pavement - Clogging Factor (Double)
GREENROOF					
POROUSPAVE	6.000	0.150	0.000	100.000	0.000
PLANTERS					
INFILTRENCH					
RAINBARRELS					
SWALE					



Excerpt from the EPA manual Storm Water Management Model Reference Manual Volume III – Water Quality (PDF) which can be found here

6.2.5 *Permeable Pavement*

Figure 6-3 illustrates a typical continuous permeable pavement system. It consists of a pervious concrete or asphalt top layer, an optional sand filter or bedding layer beneath that and a gravel storage layer on the bottom which can contain an optional slotted pipe underdrain system. It introduces a new type of layer, a pavement layer (layer 4), which is characterized by its thickness (D_4), porosity (ϕ_4), and permeability K_4. A block paver system would look the same but with an additional parameter (F_4) representing the fraction of the surface area taken up by the impermeable paver blocks and where the porosity and permeability refer to the fine gravel used to fill the seams between blocks. For continuous systems F_4 would be 0.

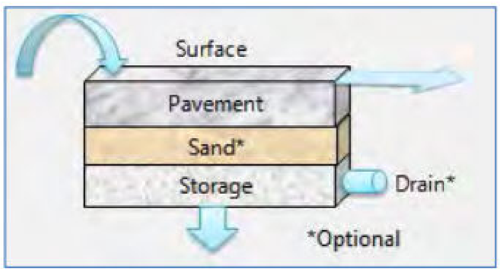


Figure 6-3 Representation of a permeable pavement system

The governing equations for permeable pavement with a sand layer included are:

$$\frac{\partial d_1}{\partial t} = i + q_0 - e_1 - f_1 - q_1 \qquad \text{Surface Layer} \qquad (6\text{-}29)$$

$$D_4(1 - F_4)\frac{\partial \theta_4}{\partial t} = f_1 - e_4 - f_4 \qquad \text{Pavement Layer} \qquad (6\text{-}30)$$

$$D_2\frac{\partial \theta_2}{\partial t} = f_4 - e_2 - f_2 \qquad \text{Sand Layer} \qquad (6\text{-}31)$$

$$\phi_3\frac{\partial d_3}{\partial t} = f_2 - e_3 - f_3 - q_3 \qquad \text{Storage Layer} \qquad (6\text{-}32)$$

where θ_4 is the moisture content of the permeable pavement layer, f_4 is the rate at which water drains out of the pavement layer, and all other terms have been defined previously. Note that when no sand layer is present, Equation 6-31 is removed and f_4 replaces f_2 in the storage layer Equation 6-32. Also, the surface void fraction ϕ_1 does not appear in the surface layer equation since a paved surface would have no vegetative growth above it.

The flux terms in these equations are evaluated in the same manner as for the bio-retention cell with the following exceptions:

1. Evaporation of any water stored in the pavement layer, e_4, would proceed at the rate:

$$e_4 = min[E_0(t) - e_1\,, \theta_4 D_4(1 - F_4)/\Delta t] \qquad (6\text{-}33)$$

   with $E_0(t)$ subsequently reduced by e_4 when ET from the layers below it is evaluated.

1. Evaporation of any water stored in the pavement layer, e_4, would proceed at the rate:

$$e_4 = min[E_0(t) - e_1 , \theta_4 D_4 (1 - F_4)/\Delta t] \tag{6-33}$$

with $E_0(t)$ subsequently reduced by e_4 when ET from the layers below it is evaluated.

2. The nominal flux rate from the surface layer into the pavement layer (f_1) is the same as for an infiltration trench:

$$f_1 = i + q_0 + d_1/\Delta t \tag{6-34}$$

3. The nominal flux rate leaving the pavement layer (f_4) is equal to the pavement's permeability K_4.

4. When evaluating underdrain outflow q_3, once both the storage layer and sand layer (if present) become saturated, the head on the underdrain becomes:

$$h_3 = (D_3 - D_{3D}) + D_2 + \theta_4 D_4/\phi_4 \tag{6-35}$$

5. The flux rate from the surface into the pavement is limited by the rate at which the pavement can accept inflow:

The following adjustments are applied to the nominal flux rates in the order listed so that feasible moisture levels are maintained:

1. Pavement flux rate f_4 :

$$f_4 = min[f_4\,, \theta_4 D_4/\Delta t + f_1 - e_4] \tag{6-36}$$

2. Soil percolation rate f_2:

$$f_2 = min[f_2\,, (\theta_2 - \theta_{FC})D_2/\Delta t + f_4 - e_4] \tag{6-37}$$

3. Storage exfiltration rate f_3 :

$$f_3 = min[f_3\,, d_3\phi_3/\Delta t + f_2 - e_3] \tag{6-38}$$

where $f_2 = f_4$ if there is no soil layer.

4. Underdrain flow q_3 (when present):

$$q_3 = min[q_3\,, (d_3 - D_{3D})\phi_3/\Delta t + f_2 - f_3 - e_3] \tag{6-39}$$

where again $f_2 = f_4$ if there is no soil layer.

5. Pavement flux rate f_4 :

$$f_4 = \min[f_4\,, (\phi_2 - \theta_2)D_2/\Delta t + f_2 + e_2] \quad \text{with soil layer} \tag{6-40}$$

$$f_4 = \min[f_4\,, (D_3 - d_3)\phi_3/\Delta t + e_3 + f_3 + q_3] \quad \text{without soil layer} \tag{6-41}$$

6. Soil percolation rate f_2:

$$f_2 = min[f_2\,, (D_3 - d_3)\phi_3/\Delta t + f_3 + q_3 + e_3] \tag{6-42}$$

7. Pavement inflow rate f_1 :

$$f_1 = min[f_1\,, (\phi_4 - \theta_4)D_4(1 - F_4)/\Delta t + f_4 + e_4] \tag{6-43}$$

The flux adjustments for fully saturated storage and sand layers follow those used for a bio-retention cell. When all of the sub-surface layers become saturated ($\theta_2 = \phi_2$, $d_3 = D_3$ and $\theta_4 = \phi_4$), and the unit is still receiving rainfall/runon then all flux rates are set equal to the limiting rate. The latter is the smaller of f_1, f_4, f_2 (if a sand layer is present), and $f_3 + q_3$. If the storage layer does not contain the limiting flux f*, then its outflow streams are adjusted as follows: $q_3 = min[q_3\,, f^*]$ and $f_3 = f^* - q_3$.

6.5.1 Permeable Pavement Parameter Values

Table 6-6 lists typical parameter ranges for permeable pavement installations. The maximum storage height on the surface layer, D1, now represents the depth of depression storage on the pavement surface. Its suggested range is characteristic of impervious surfaces in general (ASCE, 1992). The pavement layer properties in the table distinguish between continuous concrete or asphalt pavement systems and block paver systems.

UNHSC (2009) recommends that the optional sand filter layer be composed of coarse sand/fine gravel (bank run gravel). It aids in pollutant removal and in slowing down the movement of water through the unit. Because of the very high conductivity of permeable pavement, with no sand layer present the unit acts in the same manner as an infiltration trench whose change in water level over each time step is simply the difference between the applied surface inflow rate and the exfiltration rate out of the bottom (assuming no underdrain).

Table 6-6 Typical ranges for permeable pavement parameters

Parameter	Range
Surface Depression Storage, inches (D_1)	0 – 0.1
Surface Void Fraction (f_1)	1.0
Pavement Thickness, inches (D_4)	3 – 8
Continuous Pavement:	

Porosity (f_4)	0.15 – 0.25
Permeability, in/hr (K_4)	28 – 1750
Surface Opening Fraction ($1 - F_4$)	0
Block Pavers:	
Porosity (f_4)	0.1 – 0.4
Permeability, in/hr (K_4)	5 – 150
Surface Opening Fraction ($1 - F_4$)	0.08 – 0.10
Sand Filter Layer:	
Thickness, inches (D_2)	8 – 12
Porosity (f_2)	0.25 – 0.35
Field Capacity (q_{FC})	0.15 – 0.25
Wilting Point (q_{WP})	0.05 – 0.10
Saturated Hydraulic Conductivity, in/hr (K_{2S})	5 – 30
Wetting Front Suction Head, inches (y_2)	2 – 4
Percolation Parameter (HCO)	30 – 55
Storage Layer Thickness, inches (D_3)	6 – 36
Storage Void Fraction (f_3)	0.2 – 0.4
Capture Ratio (R_{LID})	0 – 5

Innovyze Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 Engine

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

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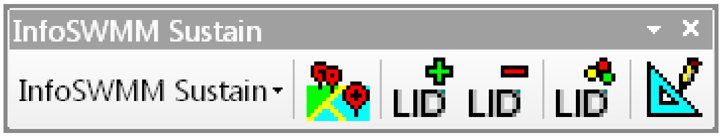

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

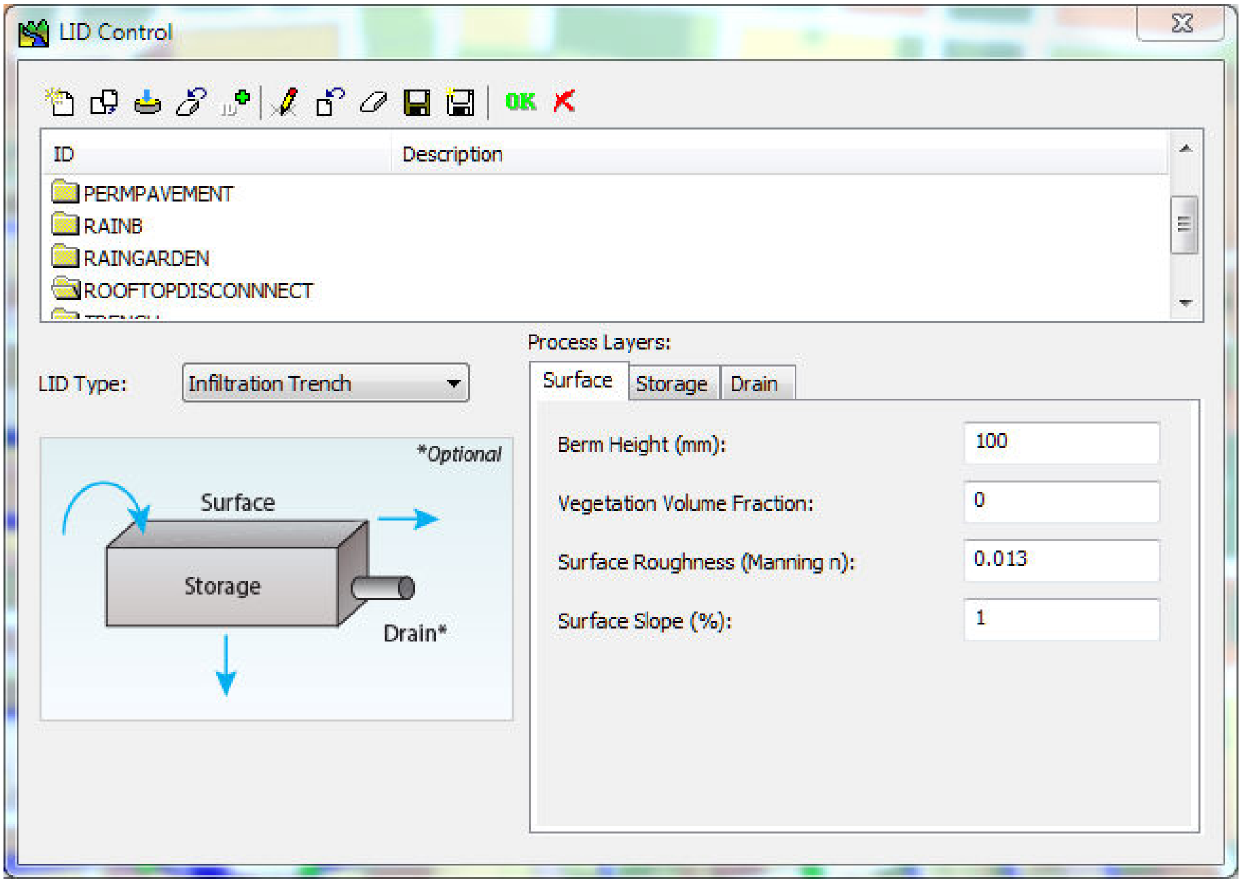
Infiltration Trench LID Control

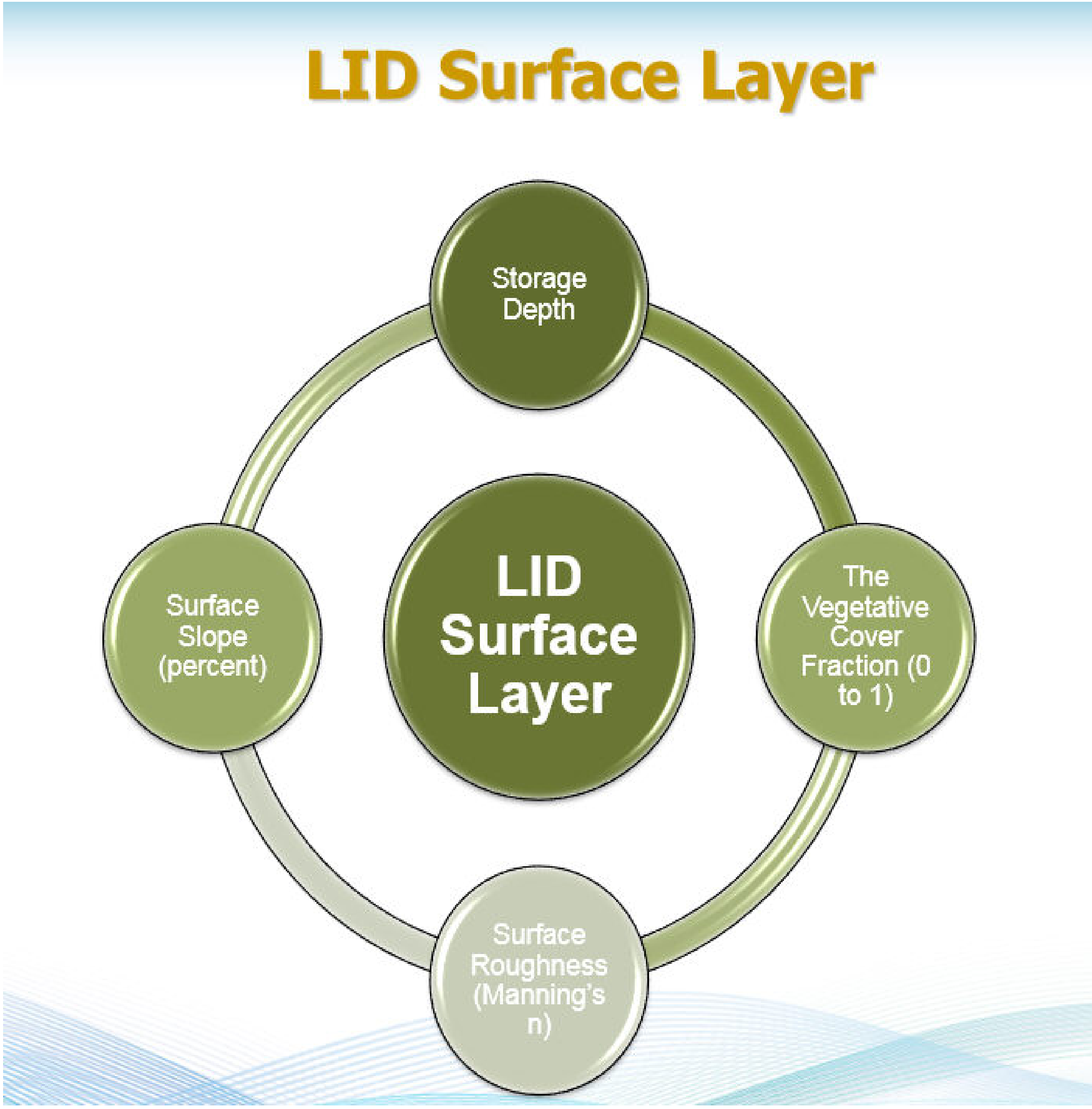
This is an introduction along with images of the LID Control and data require3ments in InfoSWMM. Every InfoSWMM Control uses from one to 5 layers of data - each with different data requirements. You can use the Siting Manger of InfoSWMM Sustain to find LID locations and the LID Optimizer to find the optimized number of units, cost of units, area and thickness of the LID layers based on your runoff and water quality control objectives.

The Infiltration Trench LID Control has three components or Process Layers: Surface, Storage and Underdrain.

The Surface Process Layer consists of:

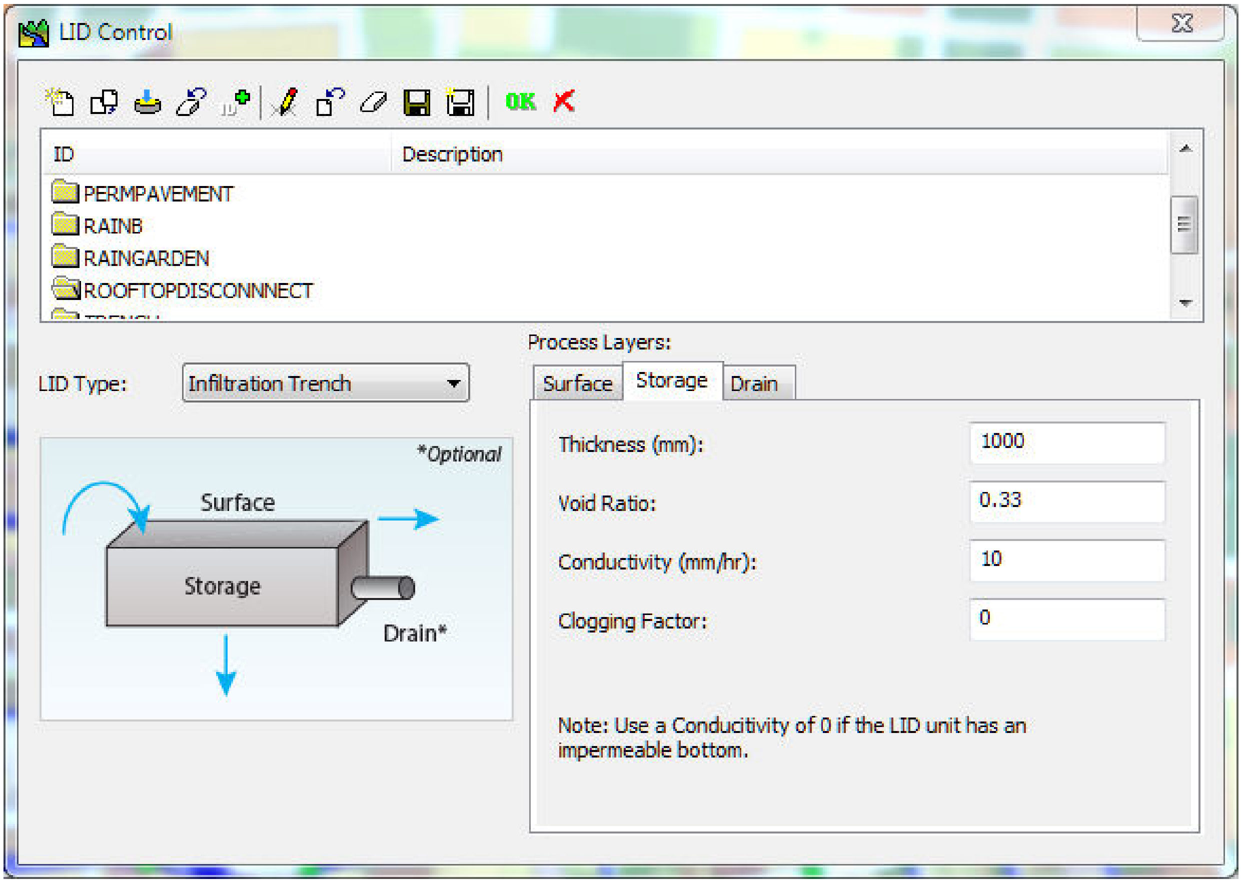
- The Storage Depth in inches or millimeters
- The Vegatative Cover Fraction (0 to 1),
- Surface Roughness (Manning's n)
- Surface Slope (percent).

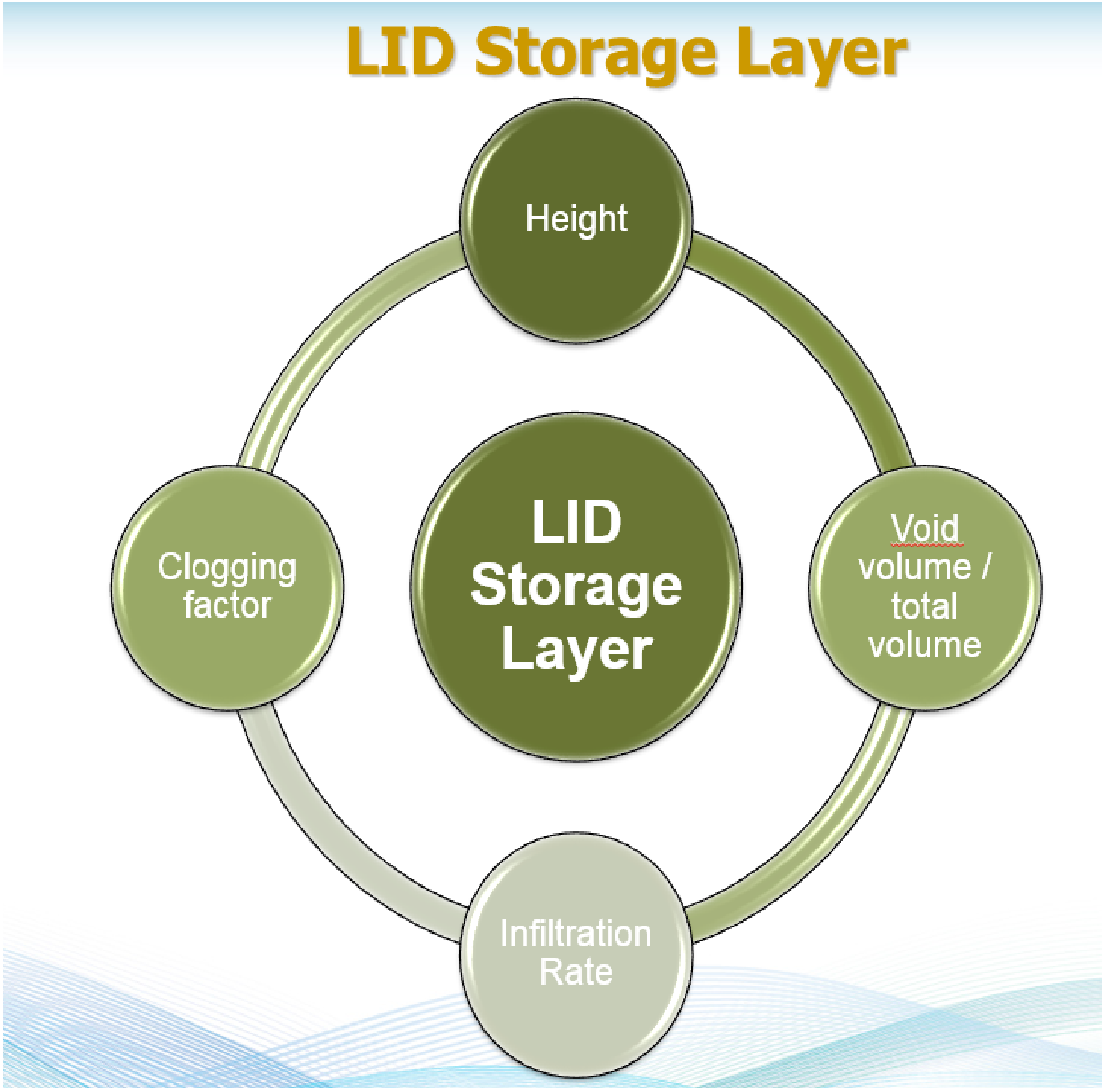

LID Control
OK
ID
Description
PERMPAVEMENT
RAINB
RAINGARDEN
ROOFTOPDISCONNNECT
Process Layers:
LID Type:
Infiltration Trench
Surface
Storage
Drain
*Optional
Surface
Storage
Drain*
Berm Height (mm):
100
Vegetation Volume Fraction:
0
Surface Roughness (Manning n):
0.013
Surface Slope (%):
1



The Storage Process Layer consists of:

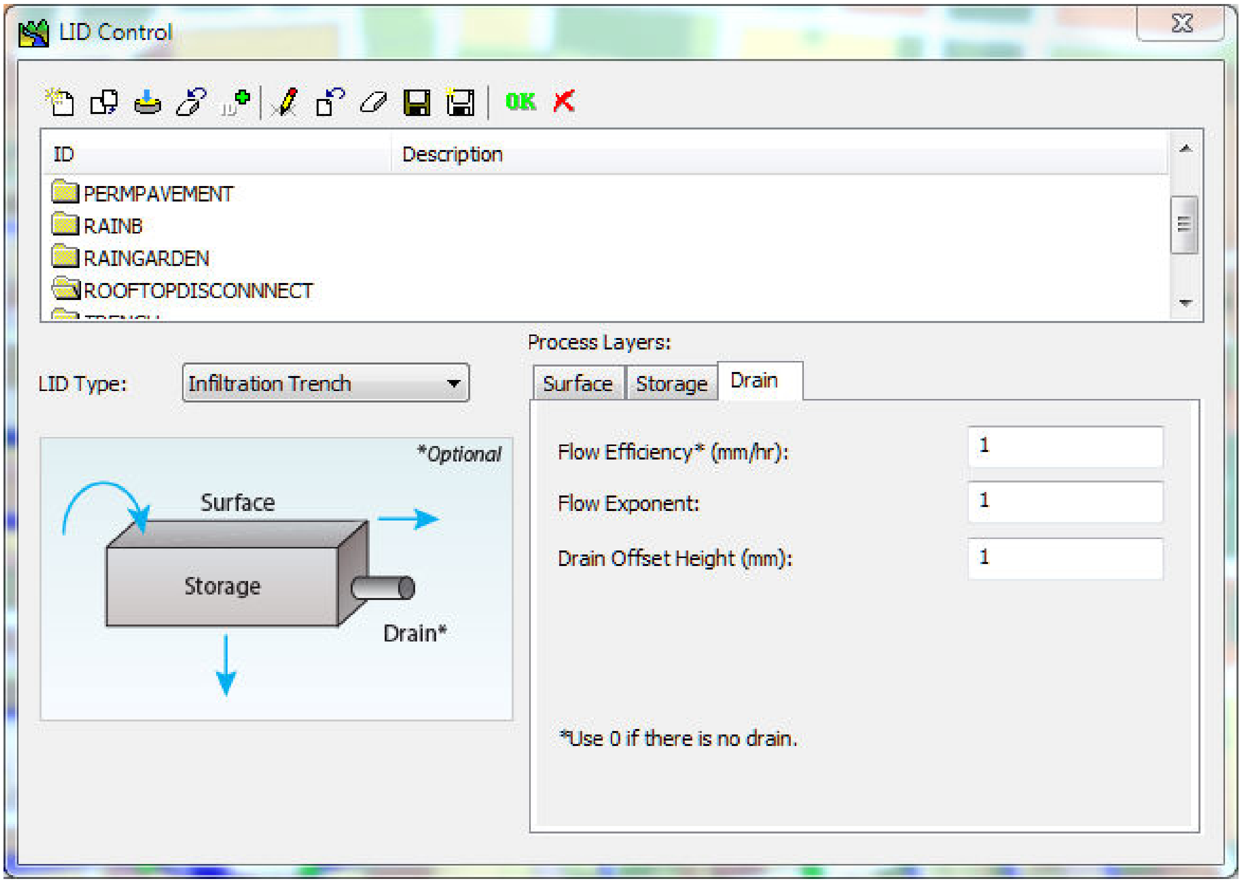
- The Storage Height in inches or millimeters,
- The Void Ratio as a Fraction (0 to 1),
- Surface Conductivity in inches/hour or millimeters/hour,
- Clogging Factor

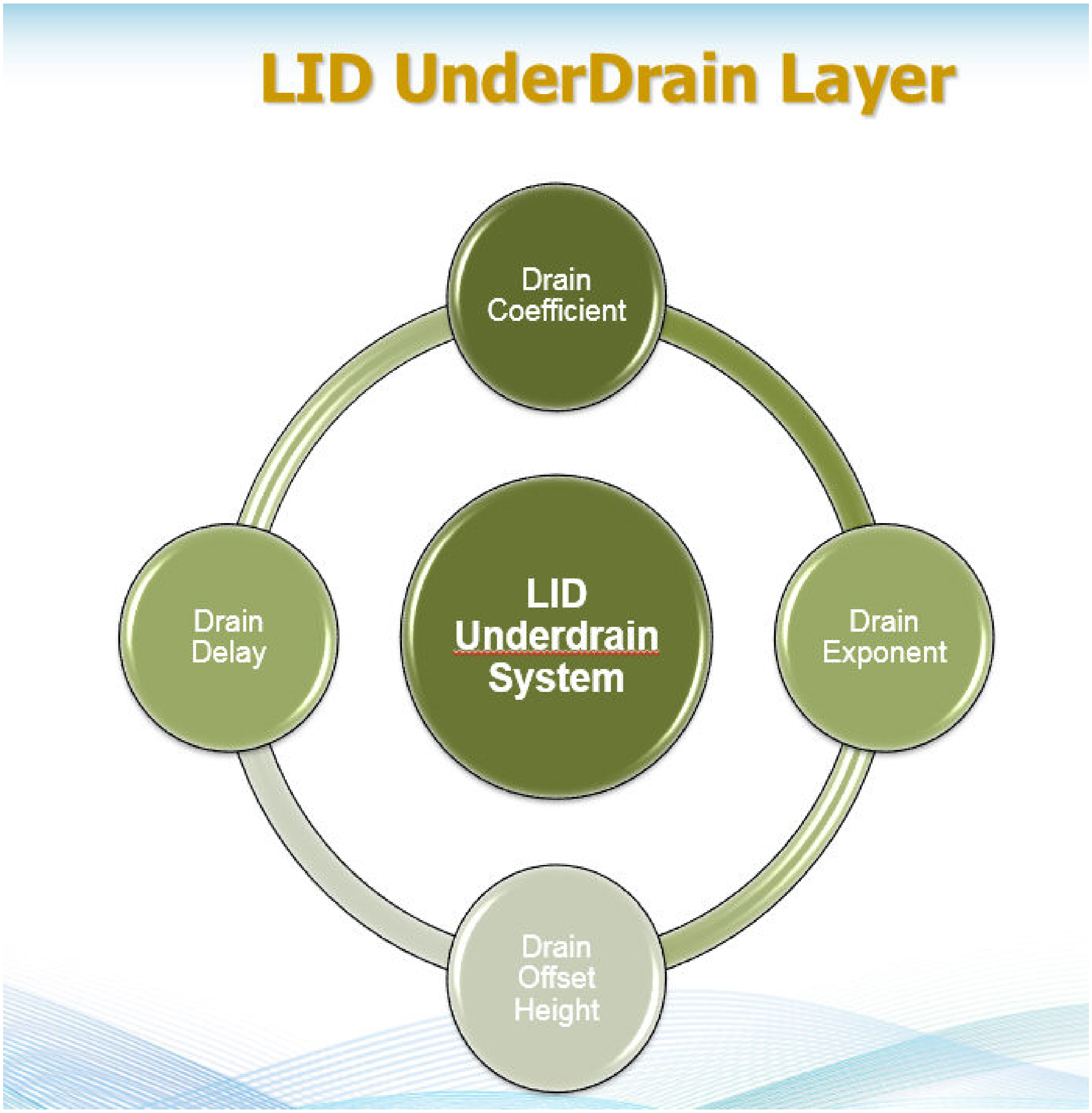

LID Control
OK
ID
Description
PERMPAVEMENT
RAINB
RAINGARDEN
ROOFTOPDISCONNNECT
Process Layers:
LID Type:
Infiltration Trench
Surface
Storage
Drain
*Optional
Surface
Storage
Drain*
Thickness (mm):
1000
Void Ratio:
0.33
Conductivity (mm/hr):
10
Clogging Factor:
0
Note: Use a Conductivity of 0 if the LID unit has an impermeable bottom.



The Underdrain Process Layer consists of:

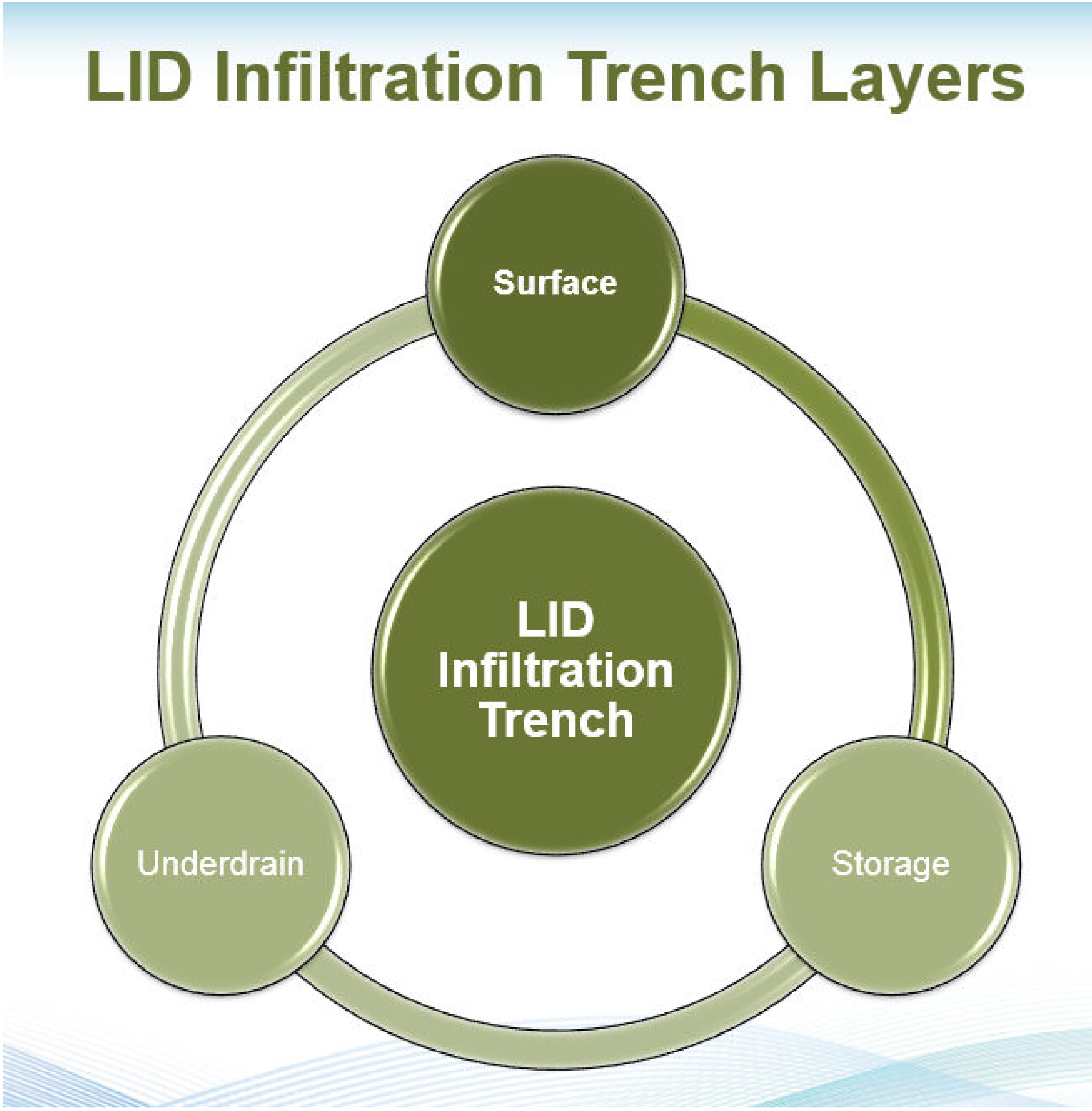
- Drain Coefficient (inches/hour or millimeters/hour)
- The Void Ratio as a Fraction (0 to 1),
- Drain Exponent,
- Drain Offset Height (inches or millimeters)


LID Control
ID
Description
PERMPAVEMENT
RAINB
RAINGARDEN
ROOFTOPDISCONNNECT
Process Layers:
LID Type:
Infiltration Trench
Surface
Storage
Drain
*Optional
Surface
Storage
Drain*
Flow Efficiency* (mm/hr):
1
Flow Exponent:
1
Drain Offset Height (mm):
1
*Use 0 if there is no drain.


LID UnderDrain Layer
Drain Coefficient
Drain Delay
LID Underdrain System
Drain Exponent
Drain Offset Height

An example of an Infiltration Trench.

The three layers used in a simulation for a Infiltration Trench LID are shown in the following image.



Excerpt from the EPA manual [Storm Water Management Model Reference Manual Volume III – Water Quality (PDF)] which can be found [here]

6.2.4 Infiltration Trenches

An infiltration trench can be represented in the same fashion as a bio-retention cell but having just a surface and a storage layer. The governing equations are:

$$\frac{\partial d_1}{\partial t} = i + q_0 - e_1 - f_1 - q_1 \quad \text{Surface Layer} \quad (6\text{-}23)$$

$$\phi_3 \frac{\partial d_3}{\partial t} = f_1 - e_3 - f_3 - q_3 \quad \text{Storage Layer} \quad (6\text{-}24)$$

where now f_1 is the trench's external inflow plus any ponded surface water that drains into the storage layer over the time step:

$$f_1 = i + q_0 + d_1/\Delta t \quad (6\text{-}25)$$

Nominal values for the remaining flux terms are evaluated in the same fashion as for the bio-retention cell. The surface void fraction ϕ_1 does not appear in the surface layer equation since a gravel-filled trench would have no vegetative growth above it.

These nominal rates are subject to the following constraints:

1. The storage exfiltration rate f_3 is limited by the amount of water currently in the storage layer plus the net amount of water added to it over the time step:

$$f_3 = min[f_3\,, d_3\phi_3/\Delta t + f_1 - e_3] \quad (6\text{-}26)$$

2. When an underdrain is used, the drain flow q_3 is limited by the amount of water stored above the drain offset plus any excess inflow from the surface that remains after storage exfiltration is accounted for:

$$q_3 = min[q_3\,, (d_3 - D_{3D})\phi_3/\Delta t + f_1 - f_3 - e_3] \quad (6\text{-}27)$$

3. The surface inflow rate f_1 is limited by the amount of empty storage layer space available plus the volume removed by exfiltration, underdrain flow, and evaporation over the time step:

$$f_1 = min[f_1\,, (D_3 - d_3)\phi_3/\Delta t + f_3 + q_3 + e_3] \quad (6\text{-}28)$$

6.5.1 Infiltration Trenches Parameter Values

Suggested ranges for the parameters associated with infiltration trenches are listed in Table 6-5. Because there is no soil layer to slow down and retain water in excess of gravity drainage, the trench acts as a simple "storage pit" whose change in stored volume over a given time step is simply the difference between the captured runoff/rainfall rate entering through its surface and the rate of exfiltration leaving through its bottom (assuming no underdrain).

Table 6-5 Typical ranges for infiltration trench parameters

Parameter	Range
Maximum Freeboard, inches (D_1)	0 – 12
Surface Void Fraction (f_1)	1.0
Storage Layer Thickness, inches (D_3)	36 – 144
Storage Void Fraction (f_3)	0.2 – 0.4
Contributing Area, acres	1 – 5
Capture Ratio (R_{LID})	5 – 20

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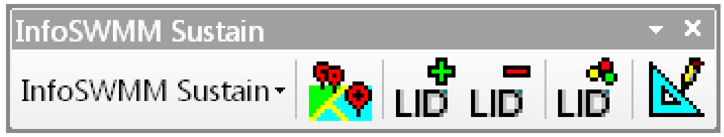
InfoSWMM



Rain Barrel LID Control

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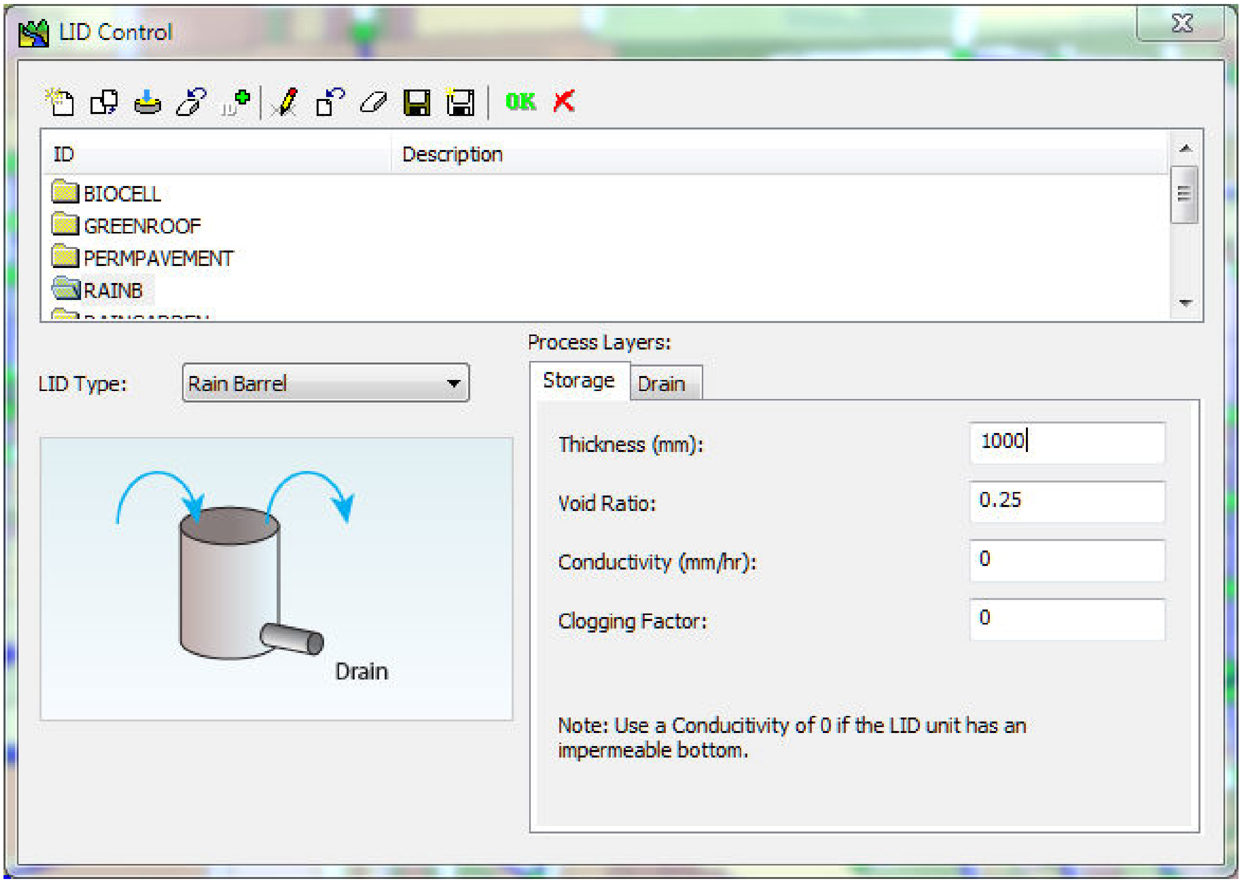
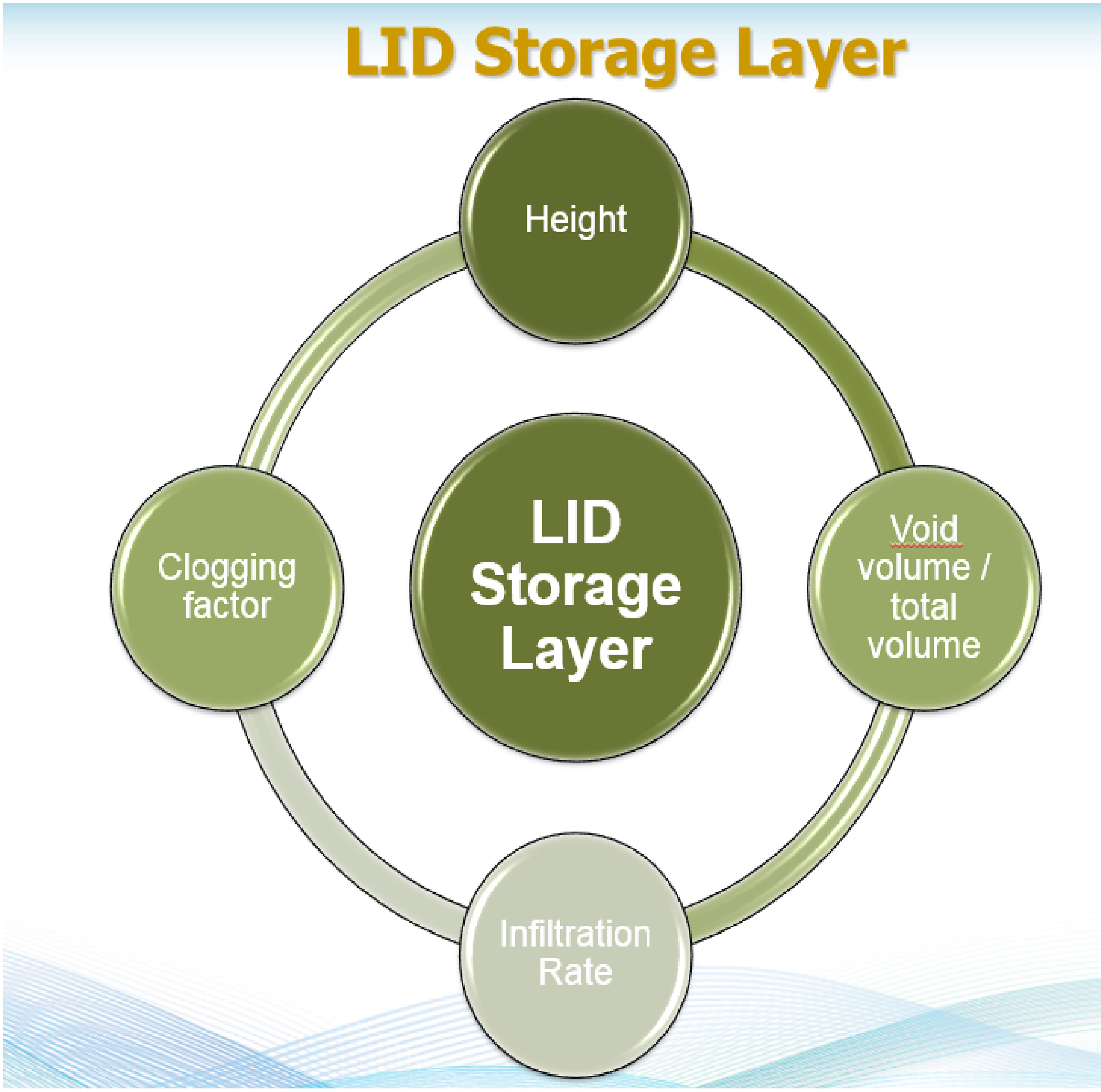
The Rain Barrel LID Control has five parameters:

- The Rain Barrel Height in inches,
- A drain coefficient in inches per hour or millimeters per hour,
- A drain exponent (dimensionless),
- A Drain Offset Height (inches or millimeters) and a
- Drain Delay (hours)

The Surface Process Layer of the Rain Barrel consists of:

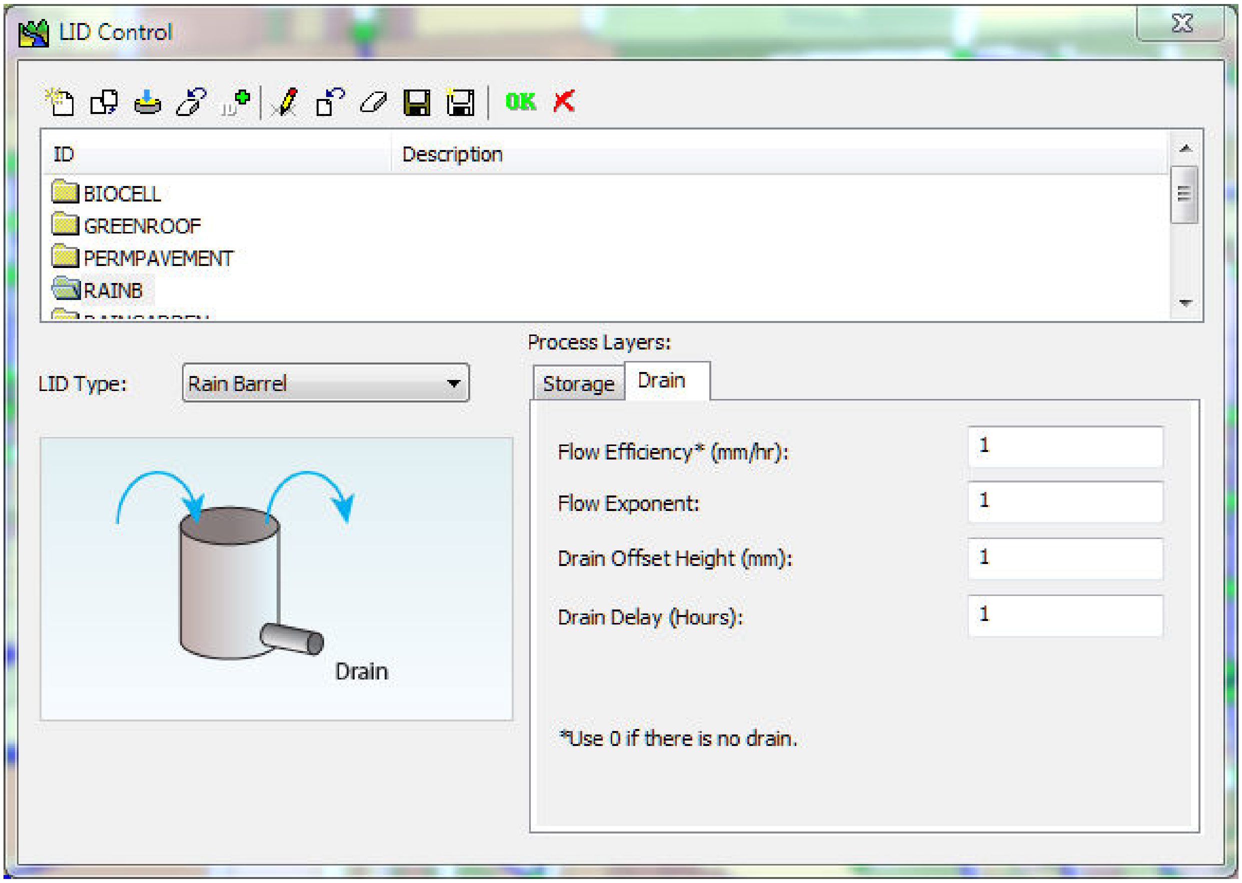
- The Storage Depth in inches or millimeters
- The Vegatative Cover Fraction (0 to 1),
- Surface Roughness (Manning’s n)
- Surface Slope (percent).

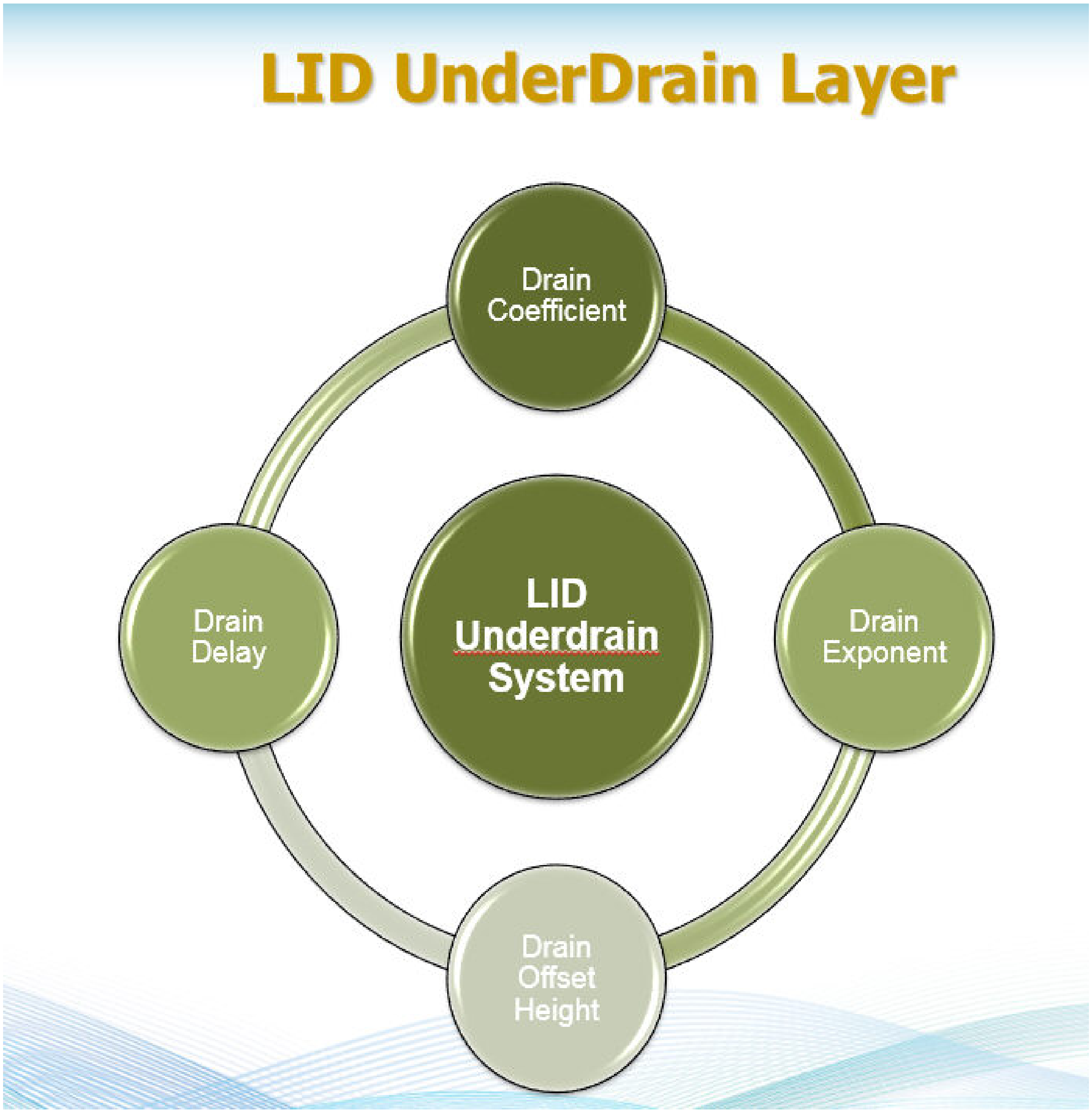

LID Control
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
Process Layers:
LID Type:
Rain Barrel
Storage
Drain
Thickness (mm):
1000
Void Ratio:
0.25
Conductivity (mm/hr):
0
Clogging Factor:
0
Drain
Note: Use a Conductivity of 0 if the LID unit has an impermeable bottom.

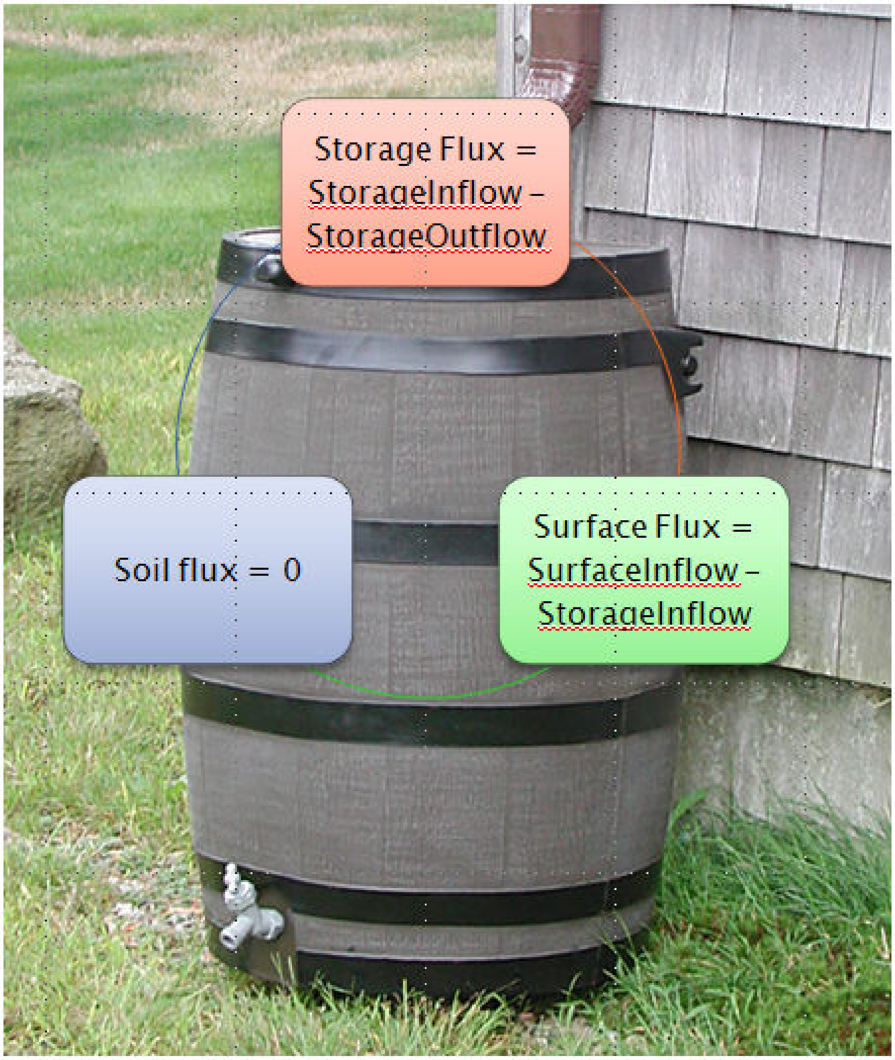


The Underdrain Process Layer of the Rain Barrel consists of:

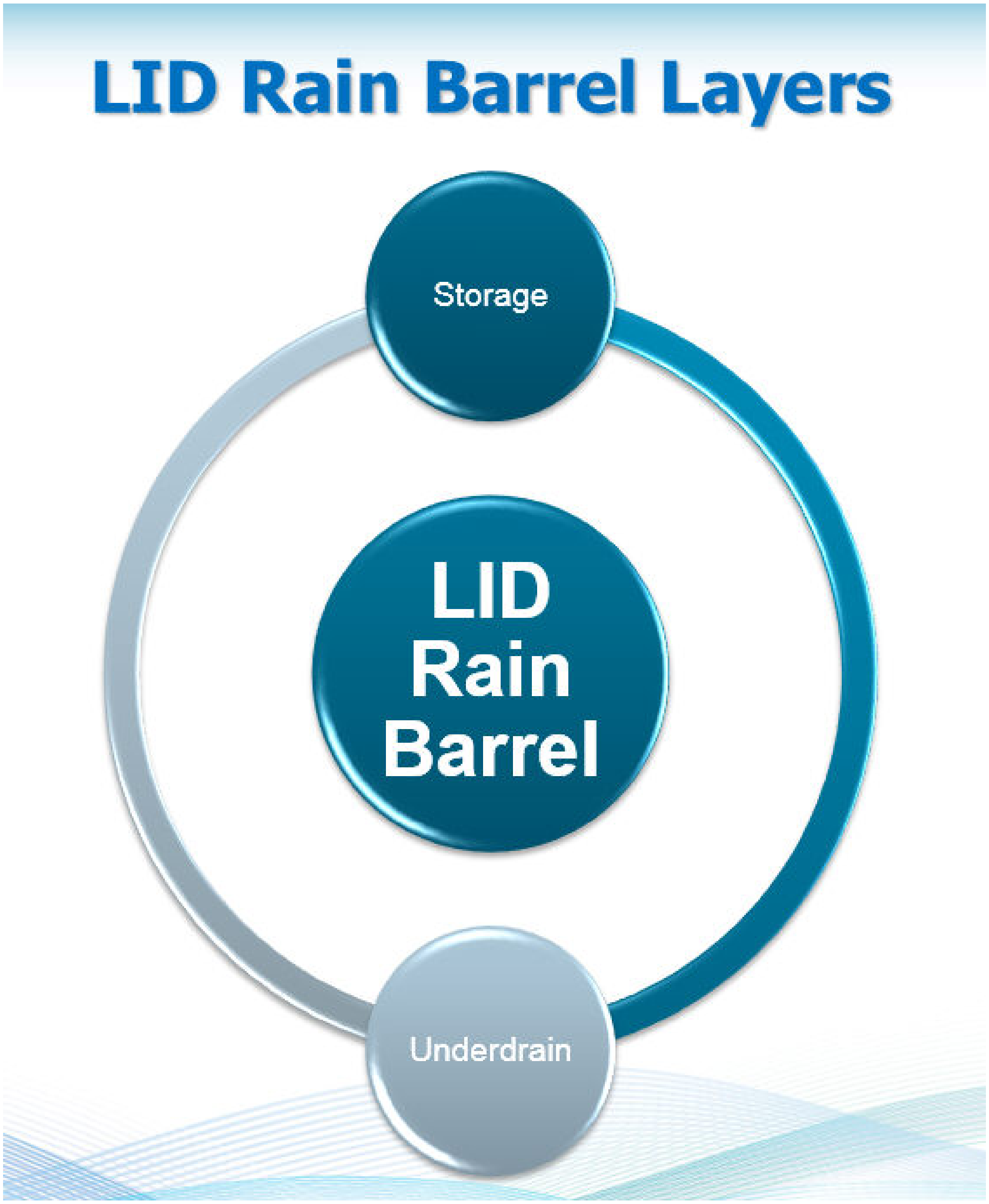
- Drain Coefficient (inches/hour or millimeters/hour)
- The Void Ratio as a Fraction (0 to 1),
- Drain Exponent,
- Drain Offset Height (inches or millimeters)


LID Control
OK
ID
Description
BIOCELL
GREENROOF
PERMPAVEMENT
RAINB
LID Type:
Rain Barrel
Drain
Process Layers:
Storage
Drain
Flow Efficiency* (mm/hr):
1
Flow Exponent:
1
Drain Offset Height (mm):
1
Drain Delay (Hours):
1
*Use 0 if there is no drain.


LID UnderDrain Layer
Drain Coefficient
LID Underdrain System
Drain Delay
Drain Exponent
Drain Offset Height



The two layers used in a simulation for a Rain Barrel LID are shown in the following image.



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6.2.6 *Rain Barrels*

A rain barrel can be modeled as just a storage layer that is all void space with a drain valve placed above an impermeable bottom. Only a single continuity equation is required:

$$\frac{\partial d_3}{\partial t} = f_1 - q_1 - q_3 \qquad \text{Storage Layer} \qquad (6\text{-}44)$$

where f_1 now represents the amount of surface inflow captured by the barrel. Because the barrel is assumed to be covered there is no precipitation input and no evaporation flux. The general underdrain equation 6-7 would still be used to compute the barrel's drain flow q_3. If the standard orifice equation is used to compute the drain outflow, then η_{3D} in Equation 6-7 would be 0.5 and C_{3D} would be:

$$C_{3D} = 0.6(A_3/A_1)\sqrt{2g} \qquad (6\text{-}45)$$

where A_1 is the surface area of the barrel, A_3 is the area of the drain valve opening (ft^2) and g is the acceleration of gravity (i.e., 32.2 ft/sec^2). The outflow over a time step Δt would be limited by the volume of water stored in the barrel:

$$q_3 = min[q_3\,, d_3/\Delta t] \qquad (6\text{-}46)$$

SWMM allows the drain valve to be closed prior to a rainfall event and then opened at some stipulated number of hours after rainfall ceases. If the valve is closed then q_3 would be 0.

The inflow to the barrel is the smaller of the external runoff q_0 applied to the barrel and the amount of empty storage available over the time step:

$$f_1 = min[q_0\,, (D_3 - d_3)/\Delta t + q_3] \qquad (6\text{-}47)$$

And finally the barrel overflows at a rate q_1 when the runoff applied to the barrel exceeds its capacity to accept that amount of inflow:

$$q_1 = max[0\,, q_0 - f_1] \qquad (6\text{-}48)$$

6.5.1 Rain Barrels Parameter Values

The Rain Barrel LID control can be used to model both rain barrels and cisterns. Rain barrels are typically 50 to 100 gallons in capacity and are used at individual home lots to collect roof runoff for possible landscape irrigation. Cisterns have much larger capacity, typically from 250 to 30,000 gallons, used to harvest rainwater from both homes and commercial facilities for non- potable indoor use. The parameters required for Rain Barrels/Cisterns are the height of the storage vessel (D3), its volume (from which its surface area ALID can be derived), its drain parameters, and possibly its drain delay time.

The height and volume of the rain barrel/cistern would be determined by commercially available sizes. The drain offset is typically 6 inches from the bottom (to trap sediment). Alternatively, one could use an offset of 0 and reduce the vessel height accordingly.

The drain flow parameters can be established from the orifice equation (Equation 6-38). The flow exponent would be 0.5 and the flow coefficient would be 4.8 times the ratio of the drain diameter to the barrel diameter squared. The latter quantity has units of ft$^{0.5}$/sec. To convert to the in$^{0.5}$/hr (or mm$^{0.5}$/hr) used in SWMM’s input data set multiply by 12,471 (or 62,768).

As an example, a 2-foot diameter rain barrel with a 3/4 inch spigot would have a drain flow coefficient of 4.8 ´ (0.75 / (2´12))^2 ´ 12,471 = 58.5 in$^{0.5}$/hr. This is high enough to drain 4 feet of captured water (94 gallons) in less than 15 minutes. A slower release rate for landscape irrigation can be achieved by leaving the spigot valve only partially open or by using a soaker hose. This action can be simulated by using a reduced drain diameter when computing a drain flow coefficient.

The drain delay time is the period of time after rainfall ceases until the rain barrel is allowed to drain. If the delay time is set to 0 then the drain line is considered to be always open. This option might be appropriate for modeling rainwater harvesting with larger cisterns. Otherwise a choice of delay time will depend on what assumptions one makes about homeowner behavior.

Drain Advisor

An LID unit's drain system is performance-based rather than design-based. The user specifies its height above the bottom of the unit's storage layer as well as how its volumetric flow rate (per unit area) varies with the height of saturated media above it. There are several things to keep in mind when specifying the parameters of an LID drain:

- If the storage layer that contains the drain has an impermeable bottom then it's best to place the drain at the bottom with a zero offset. Otherwise, to allow the full storage volume to fill before draining occurs, one would place the drain at the top of the storage layer.
- If the storage layer has no drain then set the drain coefficient to 0.
- If the drain can carry whatever flow enters the storage layer up to some specific limit then set the drain coefficient to the limit and the drain exponent to 0.
- If the drain consists of slotted pipes where the slots act as orifices, then the drain exponent would be 0.5 and the drain coefficient would be 60,000 times the ratio of total slot area to LID area. For example, drain pipe with five 1/4" diameter holes per foot spaced 50 feet apart would have an area ratio of 0.000035 and a drain coefficient of 2.
- If the goal is to drain a fully saturated unit in a specific amount of time then set the drain exponent to 0.5 (to represent orifice flow) and the drain coefficient to 2D1/2/T where D is the distance from the drain to the surface plus any berm height (in inches or mm) and T is the time in hours to drain. For example, to drain a depth of 36 inches in 12 hours requires a drain coefficient of 1. If this drain consisted of the slotted pipes described in the previous bullet, whose coefficient was 2, then a flow regulator, such as a cap orifice, would have to be placed on the drain outlet to achieve the reduced flow rate.

Innovyze Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 Engine

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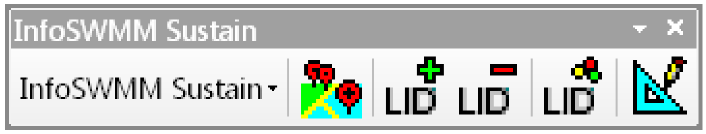

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

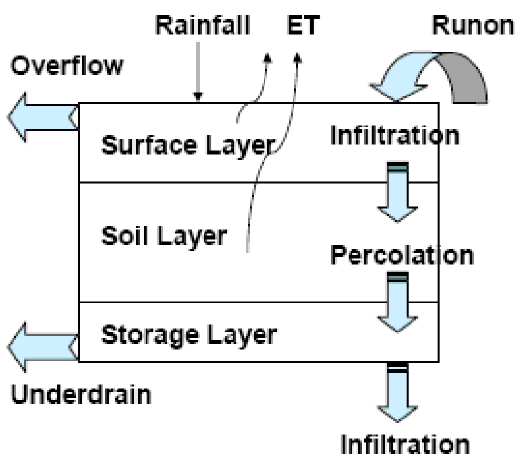
Rooftop Disconnection LID Control

This is an introduction along with images of the LID Control and data require3ments in InfoSWMM. Every InfoSWMM Control uses from one to 5 layers of data - each with different data requirements. You can use the Siting Manger of InfoSWMM Sustain to find LID locations and the LID Optimizer to find the optimized number of units, cost of units, area and thickness of the LID layers based on your runoff and water quality control objectives.

Rooftop Disconnection has two process layers: (1) Surface and (2) Roof Drain

LID controls are represented by a combination of vertical layers whose properties are defined on a per-unit-area basis. This allows LIDs of the same design but differing areal coverage to easily be placed within different Subcatchments in a study area.

During a simulation SWMM performs a moisture balance that keeps track of how much water moves between and is stored within each LID layer. As an example, the layers used to model a bio-retention cell and the flow pathways between them are shown below:

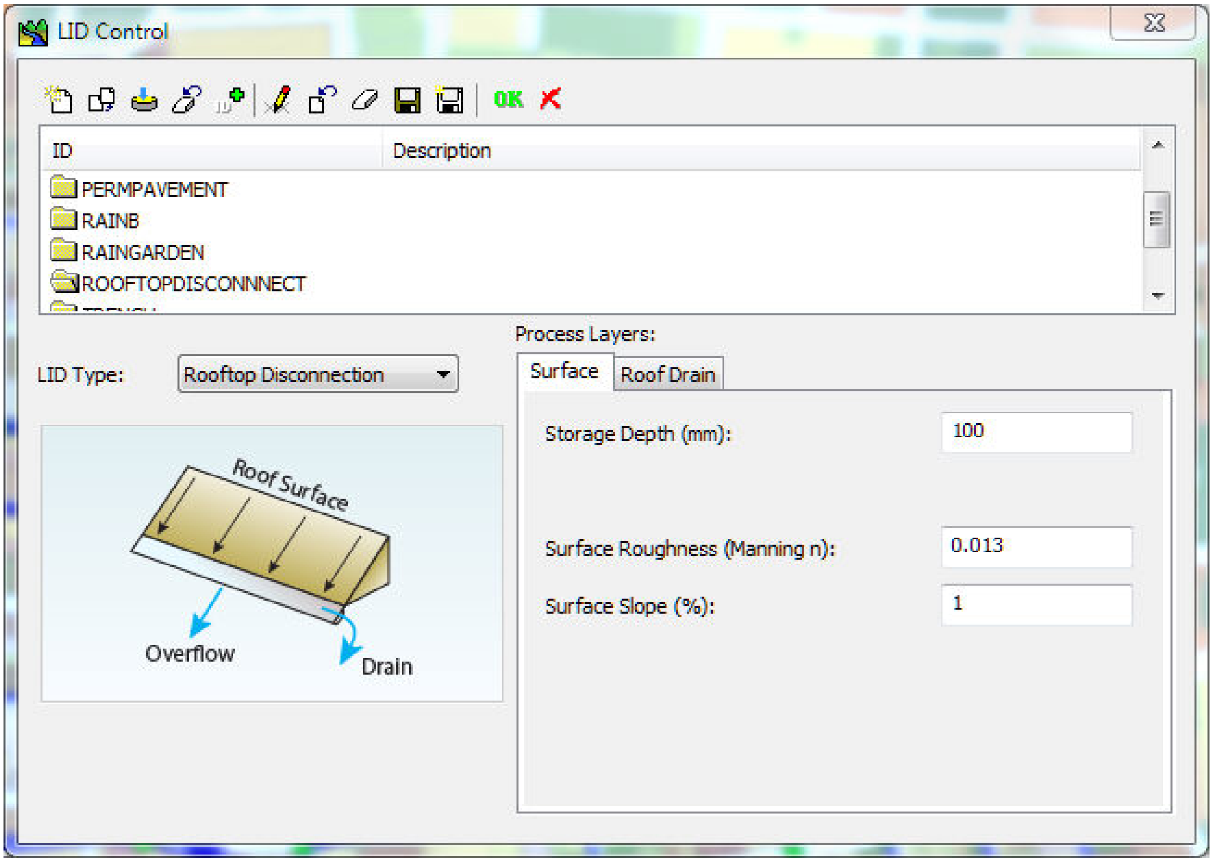


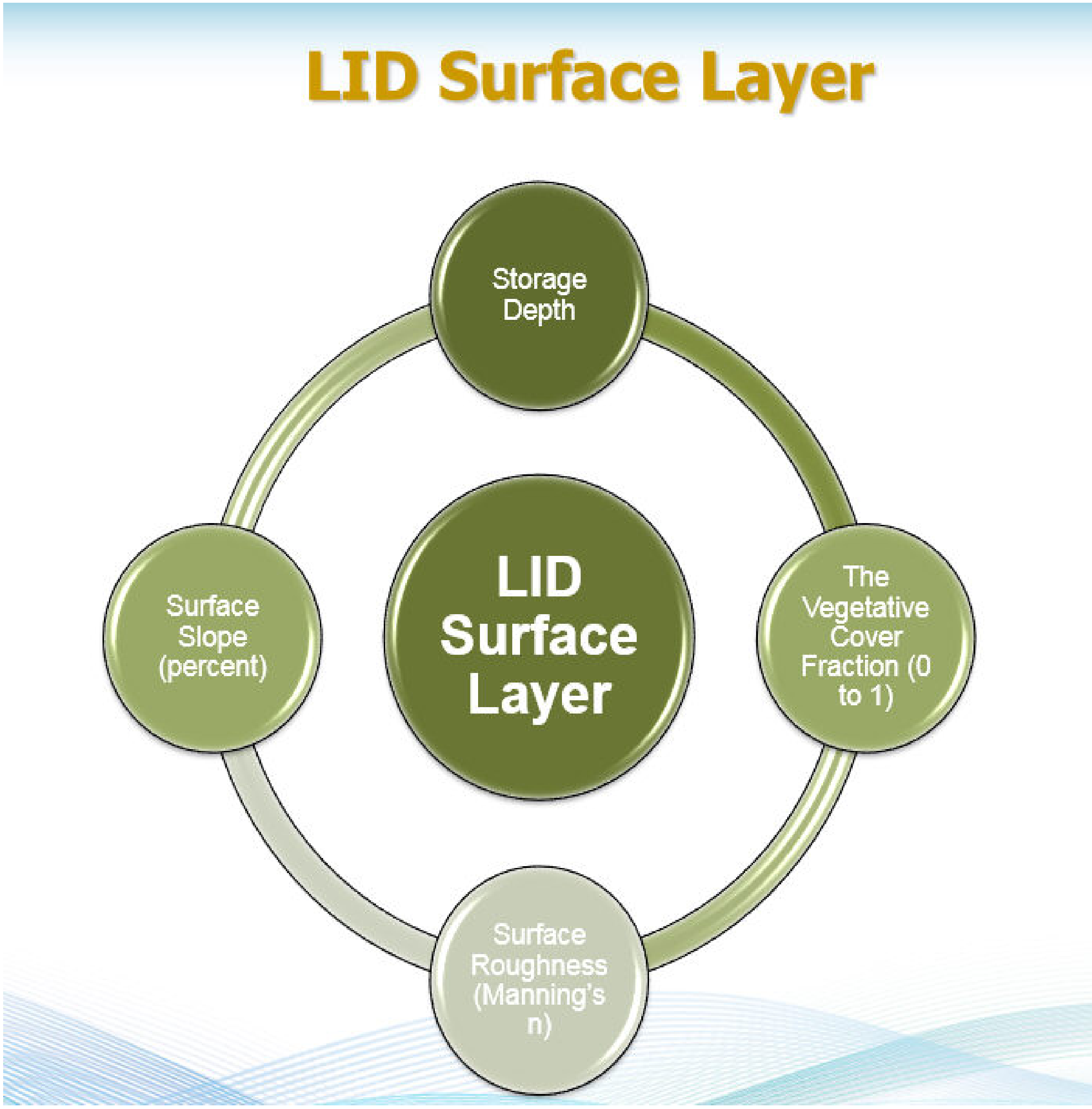
The following table indicates which combination of layers applies to each type of LID (**x** means required, **o** means optional):

LID Type	Surface	Pavement	Soil	Storage	Drain	Drainage Mat

Bio-Retention Cell	**x**		**x**	**x**	**o**	
Rain Garden	**x**		**x**			
Green Roof	**x**		**x**			**x**
Infiltration Trench	**x**			**x**	**o**	
Permeable Pavement	**x**	**x**	**o**	**x**	**o**	
Rain Barrel				**x**	**x**	
Rooftop Disconnection	**x**				**x**	
Vegetative Swale	**x**					

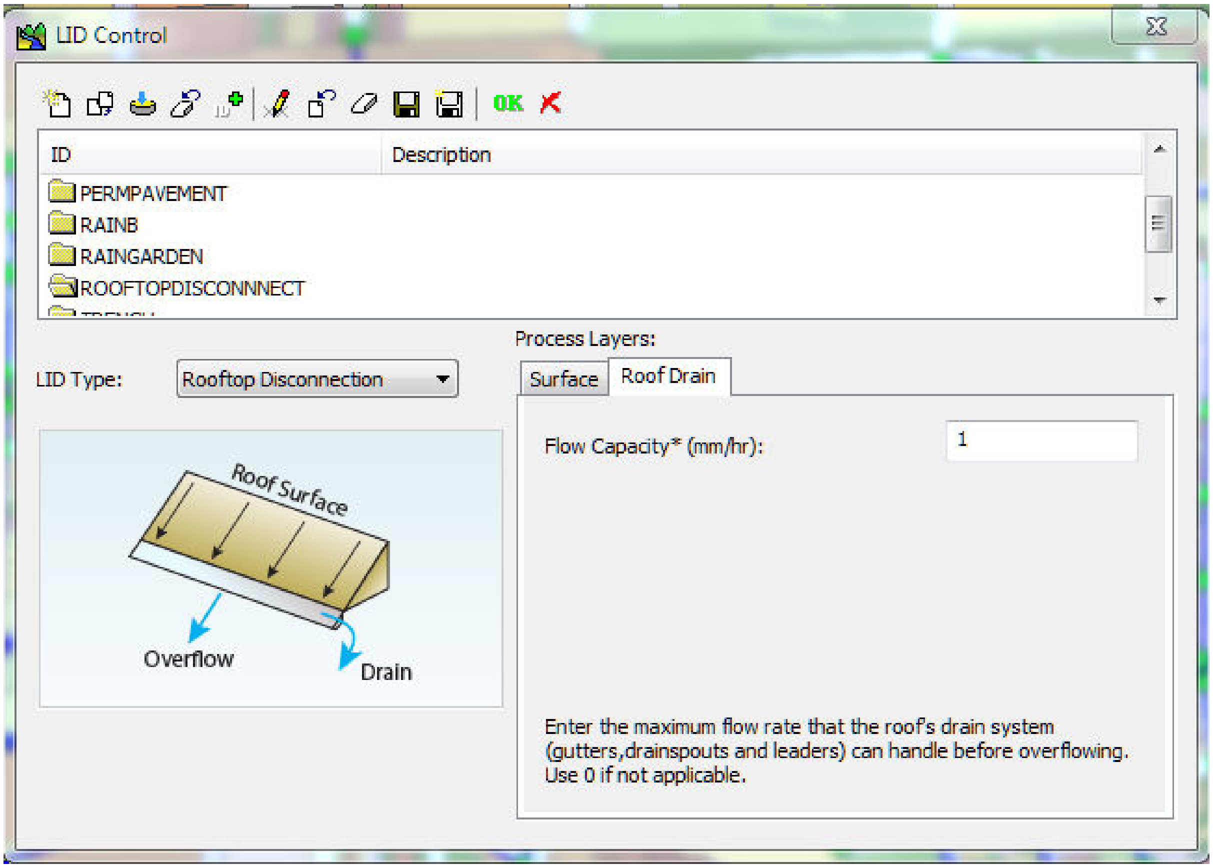
When a user adds a specific type of LID control object to a InfoSWMM project the LID Control Editor is used to set the design properties of each relevant layer (such as thickness, void volume, hydraulic conductivity, drain characteristics, etc.). These LID objects can then be placed within selected Subcatchments at any desired sizing (or areal coverage) by editing the Subcatchment's **LID Controls** property.

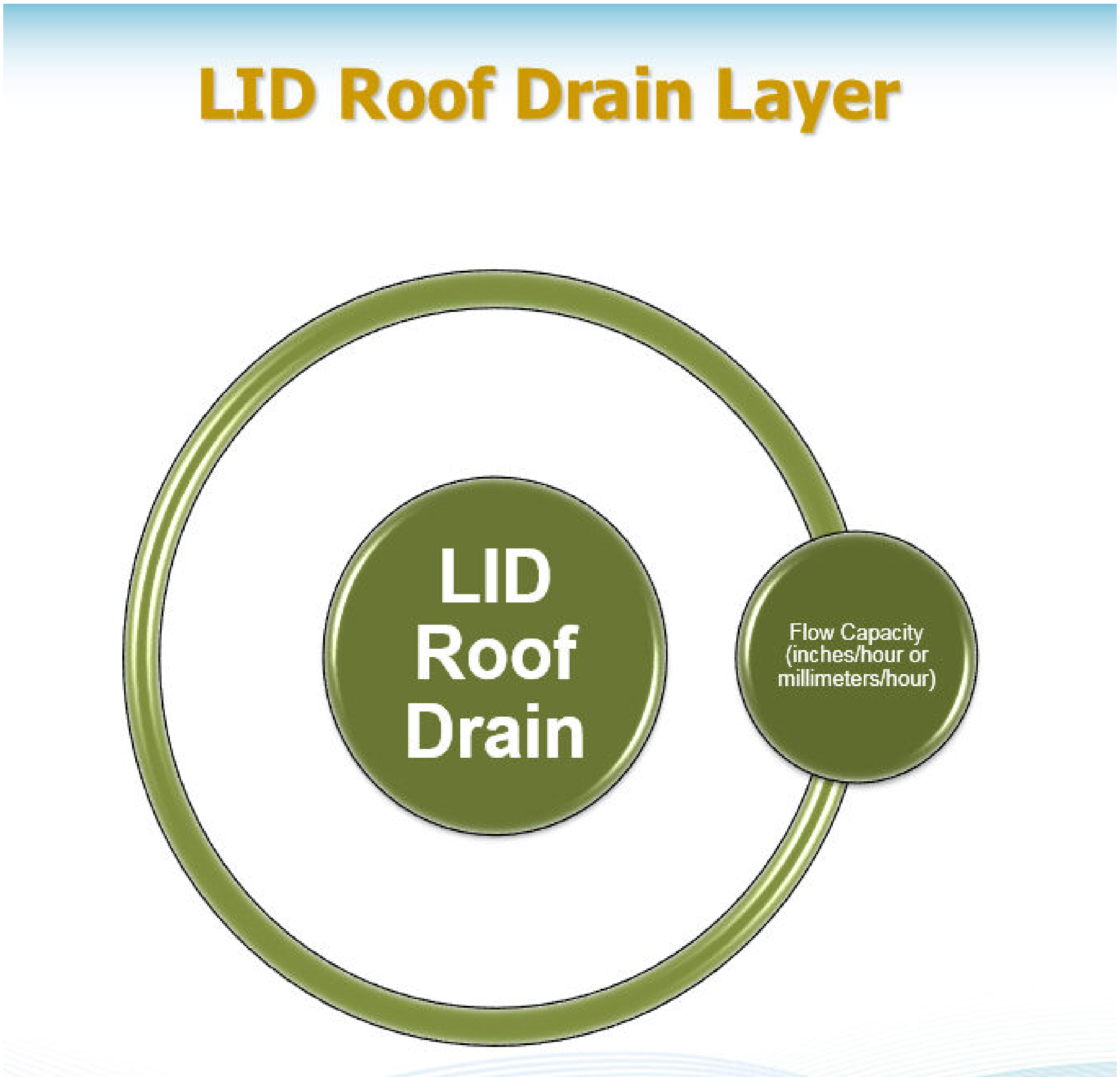

LID Control
OK
ID
Description
PERMPAVEMENT
RAINB
RAINGARDEN
ROOFTOPDISCONNNECT
Process Layers:
LID Type:
Rooftop Disconnection
Surface
Roof Drain
Storage Depth (mm):
100
Surface Roughness (Manning n):
0.013
Surface Slope (%):
1
Roof Surface
Overflow
Drain



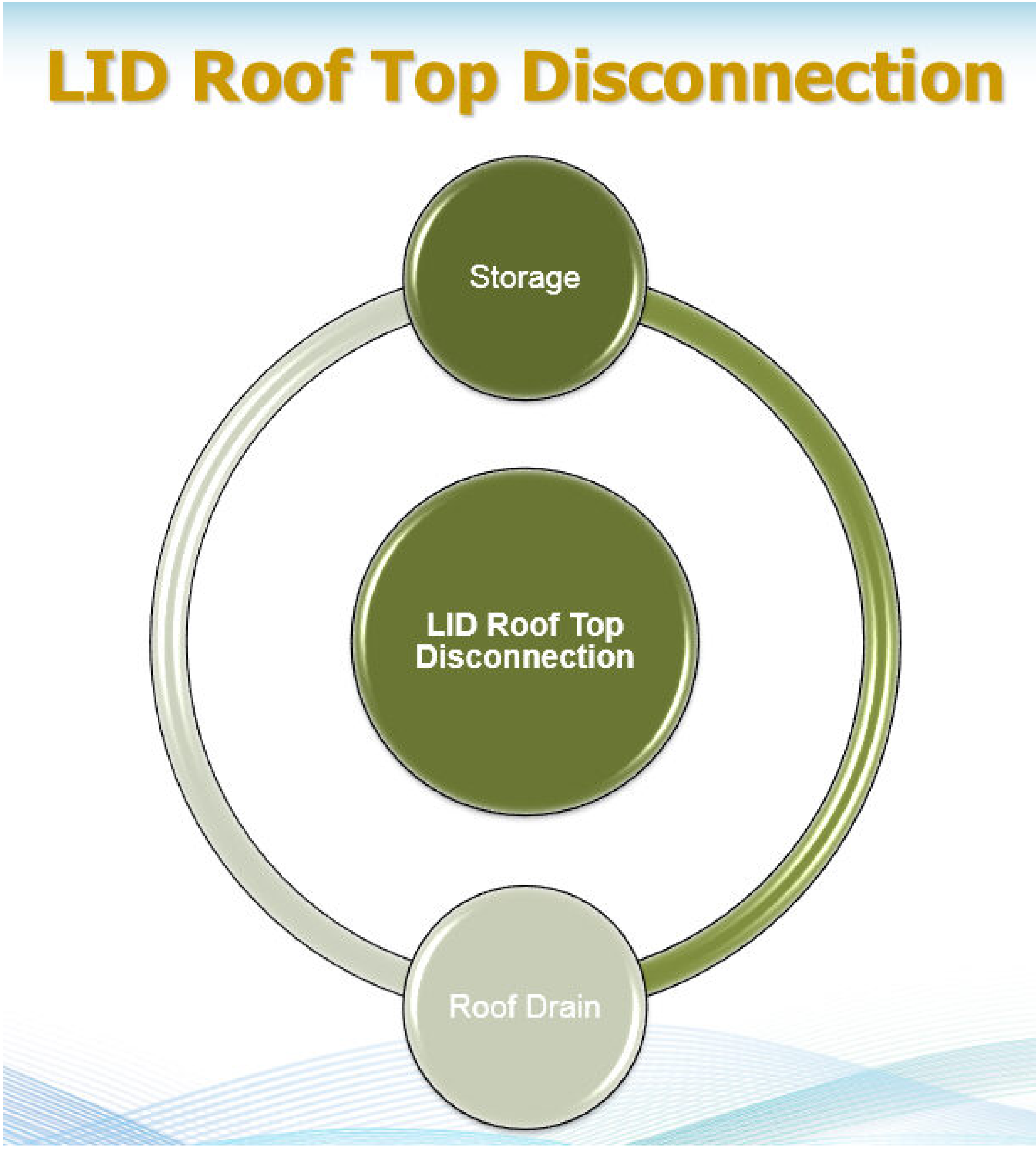
The Roof Drain Process Layer of the RoofTop Disconnection consists of:

- Flow Capacity (inches/hour or millimeters/hour)


LID Control
OK
ID
Description
PERMPAVEMENT
RAINB
RAINGARDEN
ROOFTOPDISCONNNECT
Process Layers:
LID Type:
Rooftop Disconnection
Surface
Roof Drain
Flow Capacity* (mm/hr):
1
Roof Surface
Overflow
Drain
Enter the maximum flow rate that the roof's drain system (gutters,drainspouts and leaders) can handle before overflowing. Use 0 if not applicable.



The two layers used in a simulation for a Rooftop Disconnection LID are shown in the following image.



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6.2.7 *Rooftop Disconnection*

Rooftop areas contained within a SWMM subcatchment are normally treated as impervious surfaces whose runoff is directly connected to the subcatchment's storm drain outlet. By using SWMM's overland flow re-routing option it is possible to disconnect the rooftop area and make its runoff flow over the subcatchment's pervious area where it has the opportunity to infiltrate into the soil (see Section 3.6 of Volume I). The rooftop disconnection LID control provides another alternative to model rooftop runoff that allows for a higher level of detail than overland flow re-routing.

Figure 6-4 shows the physical configuration modeled by rooftop disconnection. Runoff from the roof surface is collected in a drain system of gutters, downspouts, and leaders. Any flow that exceeds the capacity of the roof drain system becomes overflow that can be re-routed onto pervious area. The roof drain flow can also be routed back onto pervious area (to disconnect the roof) or be sent to a storm sewer to keep the roof directly connected. Another option, used when modeling dual drainage systems (both street flow and sewer flow), is to allow the overflow to contribute to the major (street) system and the roof drain flow to the minor (sewer) system.

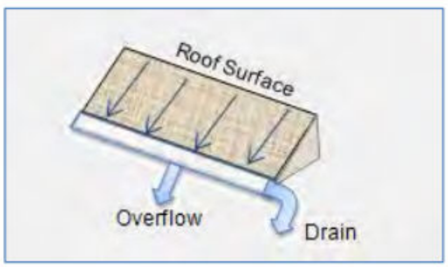

Figure 6-4 Representation of rooftop disconnection

To model a rooftop in the same fashion as the other LID controls requires a single flow continuity equation for the roof surface:

$$\frac{\partial d_1}{\partial t} = i - e_1 - q_1 - q_3 \qquad \text{Surface Layer} \qquad (6\text{-}49)$$

where now q_3 is interpreted as the flow rate per unit of roof area through the roof drain system and q_1 is the overflow rate from that system.

Evaporation from the roof surface (e_1) is computed in the same fashion as for the surface of a bio-retention cell (Equation 6-4). The nominal runoff q_1 from the roof's surface, prior to entering the roof gutter, is also computed the same as for a green roof. The Manning equation 6-21 is used if information is provided on the roof's width, slope, and surface roughness. However now the roughness is for the roof surface itself and not the growth media found on a green roof. Otherwise Equation 6-10 is used to convert all flow in excess of any rooftop depression storage (D_1) into immediate runoff. The amount of flow through the roof drain, q_3, is the smaller of the nominal q_1 and the flow capacity of the roof drain system (q_{3max}):

$$q_3 = min[q_1\,, q_{3max}] \qquad (6\text{-}50)$$

Note that q_{3max} is a user-supplied parameter with units of cfs per square foot of roof area. The actual overflow rate q_1 is simply the difference between its nominal rate and q_3.

6.5.1 Rooftop Disconnection

The parameters required for rooftop disconnection are the length of the flow path for roof runoff (the inverse of the W_1/A_1 term in Equation 6-21), the roof slope, the roughness coefficient for the roof surface, the depression storage depth of the roof's surface, and the flow capacity of the roof drain system (q_{3max}).

The flow path length and its slope are obtained directly from the roof's dimensions. Roughness coefficients for roofing material would be similar to those for asphalt and clay tile, 0.013 to

0.016. Depression storage would range from 0.05 to 0.1 inches with sloped roofs at the low end of this range and flat roofs having possibly higher values. The flow capacity of the roof's gutters in ft/sec can be estimated from the following equations (Beij, 1934):

$$q_{3max} = 0.52\, w_g^{2.5}/A_r \quad \text{for semicircular gutters} \tag{6-68}$$

$$q_{3max} = 7.75\left(d_g/w_g\right)^{1.6}\left(w_g/L_g\right)^{0.3} w_g^{2.5}/A_r \quad \text{for rectangular gutters} \tag{6-69}$$

where w_g is the gutter width in feet, d_g is the gutter depth in feet, A_r is the area of the roof serviced by the gutter in square feet, and L_g is the length of the gutter in feet. To convert q_{3max} to the in/hr or mm/hr required by the SWMM 5 input format, multiply by 43,200 or 1,097,280, respectively.


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LID
LID
LID

Clogging

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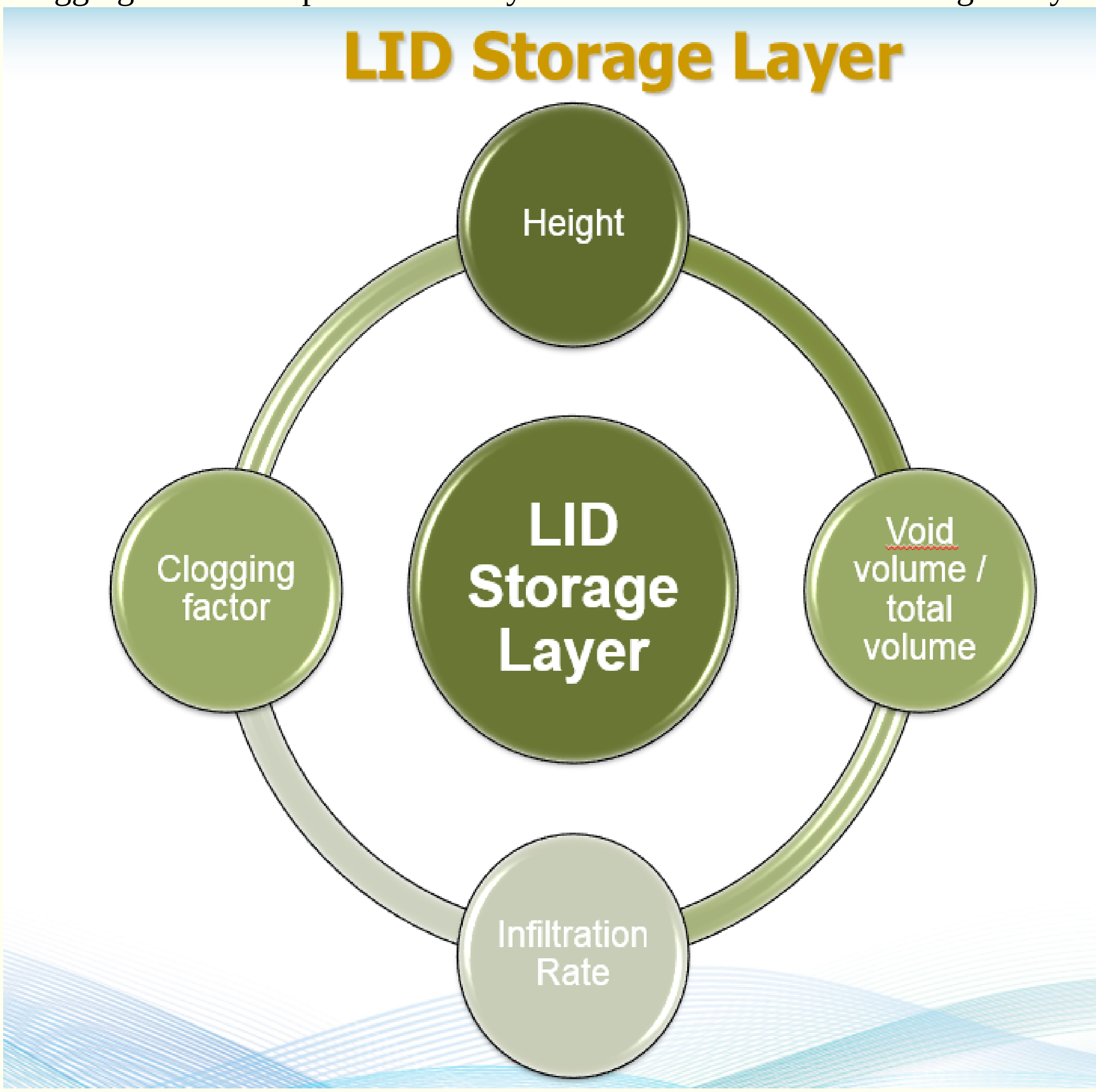
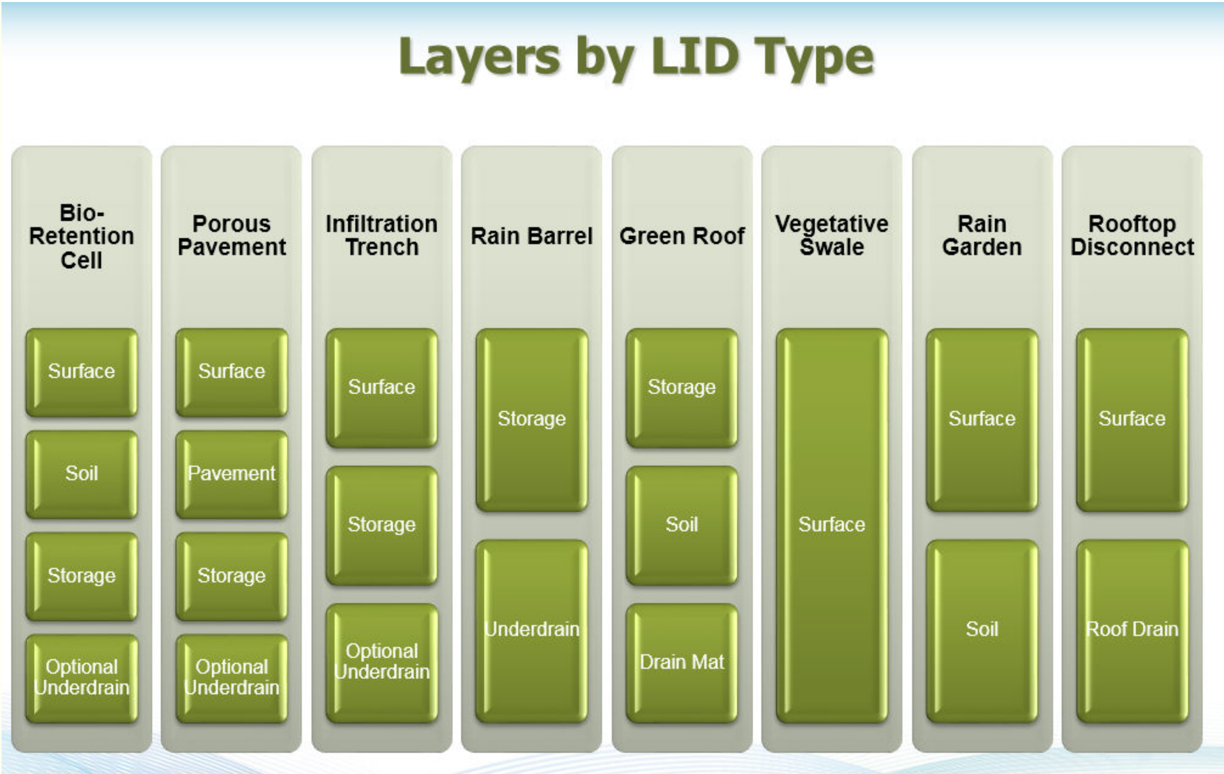
here

Clogging is a component of any LID Control with a Storage Layer





Layers by LID Type
Bio-Retention Cell
Surface
Soil
Storage
Optional Underdrain
Porous Pavement
Surface
Pavement
Storage
Optional Underdrain
Infiltration Trench
Surface
Storage
Optional Underdrain
Rain Barrel
Storage
Underdrain
Green Roof
Storage
Soil
Drain Mat
Vegetative Swale
Surface
Rain Garden
Surface
Soil
Rooftop Disconnect
Surface
Roof Drain

6.5.9 Clogging

Because clogging is a long-term process, it would only apply to simulations of several months or more duration. SWMM assumes that clogging (i.e., reduction of infiltration rates for permeable pavement systems and infiltration trenches) proceeds at a constant rate proportional to the number of void volumes that the LID unit treats over time. The clogging rate constant (or clogging factor *CF*) can be computed from the number of years T_{clog} it takes to fractionally reduce an infiltration rate to a degree F_{clog}. For example, a CF for permeable pavement can be estimated from:

$$CF_4 = \frac{I_a(1 + R_{LID})T_{clog}}{\phi_4 D_4(1 - F_4)F_{clog}} \tag{6-76}$$

where I_a is the annual volume of rainfall in inches, R_{LID} is the unit's capture ratio, ϕ_4 is the porosity of the pavement layer, D_4 is the thickness of the pavement layer, and F_4 is the fraction of the surface area covered by impermeable pavers. A similar expression would apply to the CF of an infiltration trench's storage layer using the layer's porosity and thickness in the expression with F_4 set to 0.

For permeable pavement, the rate at which clogging proceeds depends on many factors, such as the type of permeable pavement system employed, the pore sizes in the pavement or in the fill material between paver blocks, the amount and size of the particulate matter in the runoff it treats, and the amount of vehicular traffic passing over it. Perhaps the most important factor for both permeable pavement and infiltration trenches is the capture ratio since that will affect how much solids loading the unit receives over a given span of years. That is, with all other factors being equal, an LID unit with a higher capture ratio will clog in less time than one with a lower capture ratio.

Kumar et al. (2016) measured reductions in infiltration rates of 71 to 85 % after 3 years for a permeable pavement parking lot. Pitt and Voorhees (2000) quote a possible 50 % drop in permeable pavement permeability in 3 years. In simulated loading conditions, Yong et al. (2013) found that permeable asphalt pavement became completely clogged in 8 to 12 years. Bergman et al. (2011) found a 74 % drop in infiltration rate over 15 years for a pair of infiltration trenches in Copenhagen.

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Help File Updated January 30,

2019

InfoSWMM uses

the EPA SWMM 5.1.013

Engine

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LID
LID
LID

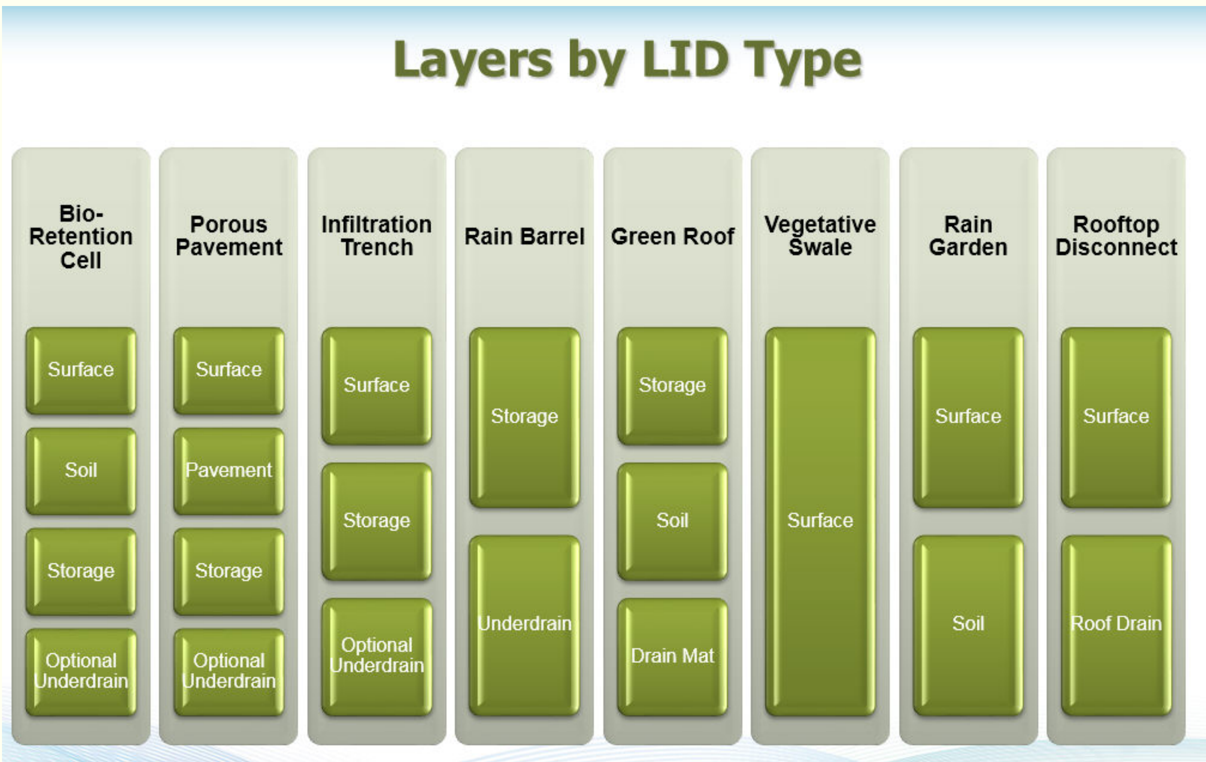
Underdrain

Excerpt from the EPA manual [Storm Water Management Model Reference Manual Volume III – Water Quality (PDF)]

which can be found

here

Underdrains are used in the following LID Controls



6.5.1 Underdrains

Underdrains are either recommended or required when the natural soil infiltration rate is insufficient to prevent the LID unit from flooding. There are three user-supplied parameters that describe underdrain flow: a discharge coefficient (C3D), a discharge exponent (h3D), and a drain offset height (DD3). While the drain offset is part of the cell's physical design, the discharge coefficient and exponent must be inferred from the hydraulics of underdrain flow. There are several approaches that can be used for this:

1. Assume the flow rate is limited by the flow capacity of the slotted pipe used as the underdrain.

2. Assume the flow rate is limited by the rate at which water can enter the slots in the drain pipes.

3. Assume the flow rate is limited by a flow restriction (such as a throttling valve or cap orifice) on the drain's discharge line.

To use option 1, the full flow capacity of the drain pipe can be computed from the Manning equation as follows:

$$Q_{full} = (0.464/n_{pipe})S_{pipe}^{0.5}D_{pipe}^{2.67} \tag{6-70}$$

where Q_{full} is the flow rate (cfs), n_{pipe} is the roughness coefficient for the pipe's material, S_{pipe} is the slope at which the pipe is laid (ft/ft), and D_{pipe} is the pipe's diameter (ft). To convert this value into a set of underdrain discharge parameters, set the drain exponent η_{3D} to zero and the drain coefficient C_{3D} to

$$C_{3D} = N_{pipe}Q_{full}/A_{LID} \tag{6-71}$$

where N_{pipe} is the number of drain pipes in the unit and A_{LID} is the area (ft^2) of the unit. Because η_{3D} is zero, the units of C_{3D} are ft/sec. To convert these to the in/hr or mm/hr required by the SWMM 5 input format, multiply by 43,200 or 1,097,280, respectively.

As an example, using this method to specify the underdrain parameters for two 4-inch diameter plastic drain lines with roughness of 0.01 placed at a 0.5% slope in a 1,000 sq. ft. bio-retention cell would produce a drain coefficient equal to

$$C_{3D} = 2(0.464/0.01)(0.005)^{0.5}(4/12)^{2.67}/1000 = 0.00035\ ft/sec = 15\ in/hr\ .$$

Once the water height in the storage layer reaches the drain's offset height, any inflow from percolation out of the soil layer will immediately flow out of the underdrain as long as its flow rate is below 15 in/hr (as per Equation 6-8) and the storage volume above the offset height will never be used.

For option 2, one can assume that the standard orifice equation can replace the underdrain flow expression Equation 6-7 so that:

$$q_3 = C_{3D}(h_3)^{0.5} \tag{6-72}$$

$$C_{3D} = 0.6\sqrt{2g}(A_{slot}/A_{LID}) \tag{6-73}$$

with A_{slot} being the total area (ft^2) of the slots in the drain pipe and g the acceleration of gravity (32.2 ft/sec^2). Note that the units of C_{3D} are $ft^{0.5}$/sec so when used in Equation 6-63 the resulting underdrain flux has units of ft/sec (or cfs/ft^2). To convert C_{3D} to $in^{0.5}$/hr, which are the US units used in the program's input, one would multiply by 12,471. To convert to $mm^{0.5}$/hr for SI units, multiply by 62,852.

The ratio of the total slot area to LID area can be determined from the dimensions of a slot, the spacing between slots along the drain pipe, and the spacing between individual drain pipes:

$$A_{slot}/A_{LID} = \frac{N_{pipe}N_{slot}A_{slot}}{(N_{pipe}+1)\Delta_{pipe}} \tag{6-74}$$

where

N_{pipe}	=	number of underdrain pipes
N_{slot}	=	number of slots per length of pipe (ft^{-1})
A_{slot}	=	area of a single slot (ft^2)
Δ_{pipe}	=	spacing between pipes (ft)

As an example, consider an underdrain system consisting of two slotted pipes with inlet area of 1 in^2 per foot of pipe spaced 50 ft apart. The area ratio used to compute C_{3D} would be:

$$A_{slot}/A_{LID} = 2 \times (1/144)/(3 \times 50) = 0.0000926$$

Using this value in Equation 6-64 to compute C_{3D} produces:

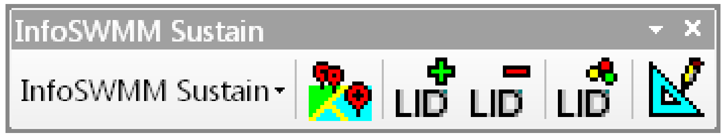
$$C_{3D} = 0.6 \times \sqrt{64.4} \times 0.0000926 = 0.00045\ ft^{0.5}/sec = 5.5\ in^{0.5}/hr$$

Regarding the third option for underdrain parameters, the underdrain flow expression can again be replaced by the standard orifice equation, this time applied to the discharge point of the underdrain system (such as the outlet of a pipe manifold fitted with a cap orifice):

$$C_{3D} = 0.6\sqrt{2g}(A_{out}/A_{LID}) \tag{6-75}$$

where A_{out} is the cross-sectional area (ft^2) of the outlet fitting. The same conversion factors described previously would be used to convert C_{3D} from $ft^{0.5}$/sec to either $in^{0.5}$/hr or $mm^{0.5}$/hr.

Applying this approach to the previously mentioned pair of 4-inch diameter drain pipes servicing a 1,000 ft^2 cell without any flow restriction would result in a C_{3D} value of 10.5 $in^{0.5}$/hr. This is much higher than the 5.5 $in^{0.5}$/hr based on inlet control. Hence the latter number would be used for C_{3D} under these particular circumstances. If the two underdrain pipes were connected by a tee fitting to a single 4-inch diameter outflow then the discharge coefficient would be 5.25 $in^{0.5}$/hr and the drain would operate under outlet control.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LID Defaults from the EPA SWC

The following defaults are from the EPA Stormwater Calculator

https://www.epa.gov/water-research/national-stormwater-calculator

A few of these parameters such as the capture ratio are not parameters in InfoSWMM Sustain

There are some additional points to keep in mind when applying LID controls to a site:

1. The area devoted to *Disconnection*, *Rain Gardens*, and *Infiltration Basins* is assumed to come from the site's collective amount of pervious land cover while the area occupied by *Green Roofs*, *Street Planters* and *Porous Pavement* comes from the site's store of impervious area.
2. Underdrains (slotted pipes placed in the gravel beds of *Street Planter* and *Porous Pavement* areas to prevent the unit from flooding) are not provided for. However since underdrains are typically oversized and placed at the top of the unit's gravel bed, the effect on the amount of excess runoff flow bypassed by the unit is the same whether it flows out of the underdrain or simply runs off of a flooded surface.

3. The amount of void space in the soil, gravel, and pavement used in the LID controls are listed in Table 4 below. They typically have a narrow range of acceptable values and results are not terribly sensitive to variations within this range.

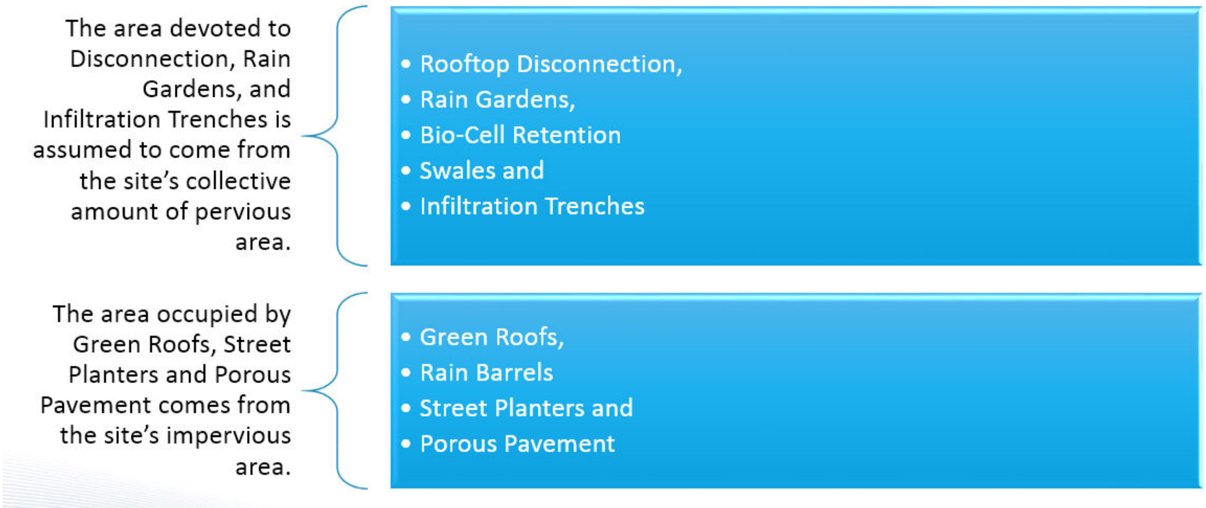

Table 3. Editable LID parameters.

LID Type	Parameter	Default Value
Disconnection	Capture Ratio	100 %
Rain Harvesting	Cistern Size	100 gal
	Cistern Emptying Rate	50 gal/day
	Number of Cisterns	4 per 1,000 sq ft
Rain Gardens	Capture Ratio	5 %
	Ponding Depth	6 inches
	Soil Media Thickness	12 inches
	Soil Media Conductivity	10 inches/hour
Green Roofs	Soil Media Thickness	4 inches
	Soil Media Conductivity	10 inches/hour
Street Planters	Capture Ratio	6 %
	Ponding Depth	6 inches
	Soil Media Thickness	18 inches
	Soil Media Conductivity	10 inches/hour
	Gravel Bed Thickness	12 inches

Infiltration Basins	Capture Ratio	5 %
	Basin Depth	6 inches
Porous Pavement	Capture Ratio	100 %
	Pavement Thickness	4 inches
	Gravel Bed Thickness	18 inches

Table 4. Void space values of LID media.

Property	**LID Controls**	**Default Value**
Soil Media Porosity	Rain Gardens, Green Roofs and Street Planters	45 %
Gravel Bed Void Ratio	Street Planters and Porous Pavement	75 %
Pavement Void Ratio	Porous Pavement	12 %


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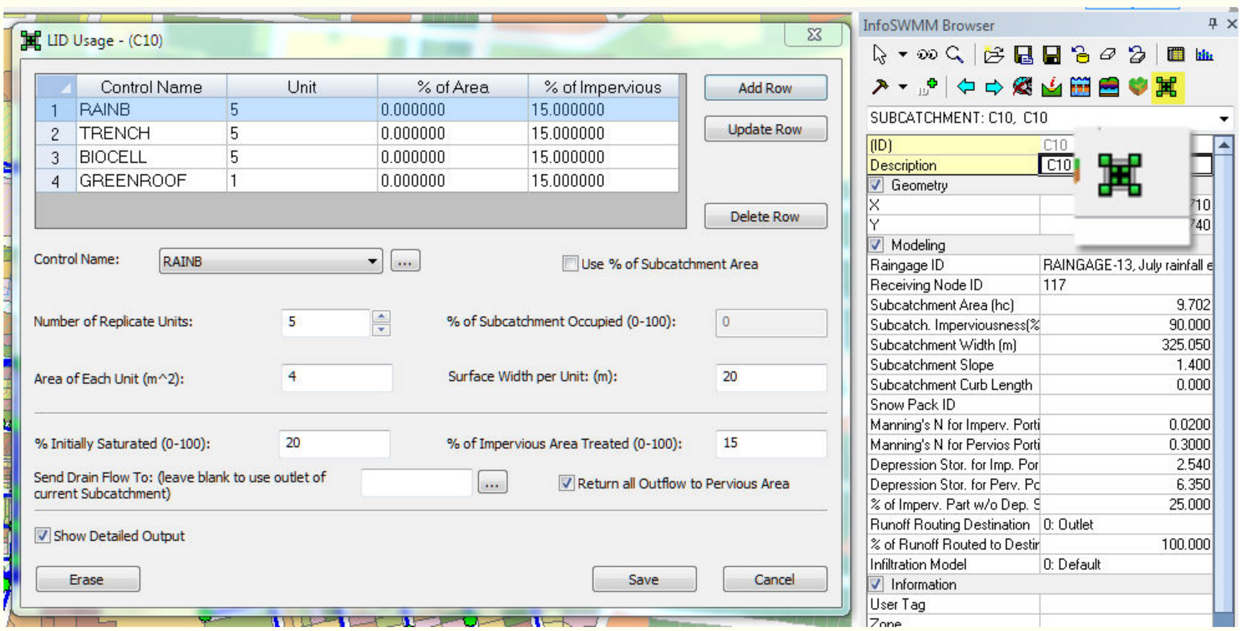
LID Usage Editor

The LID Usage Editor is invoked when the LID Usage Icon of a Subcatchment is selected for editing. It is used to identify a group of previously defined LID controls that will be placed within the Subcatchment, the sizing of each control, and what percent of runoff from the non-LID portion of the Subcatchment each should treat.

The editor displays the current group of LIDs placed in the Subcatchment along with buttons for adding an LID unit, editing a selected unit, and deleting a selected unit. These actions can also be chosen by hitting the Add Row, the Update Row, and the Delete Row, respectively. Clicking on the LID Icon will bring up an LID Usage Editor where one can enter values for the data fields shown in the Usage Editor.

LID Usage Icon in the Browser that calls up the LID Usage Editor.



LID Usage Editor

Note that the total % Of Area

for all of the LID units within a Subcatchment must not exceed 100%. The same applies to % From Impervious.

The LID Usage Editor is invoked from a Subcatchment's LID Group Editor to specify how a particular LID

control will be deployed within the Subcatchment. It contains the following data entry fields:

- Control Name
  - The name of a previously defined LID control to be used in the Subcatchment. (LID controls are added to a project by using the Data Browser -- see LID Utilization)
- Number of Replicate Units
  - The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.
- Area of Each Unit
  - The surface area devoted to each replicate LID unit (sq.

    ft or sq. m). If the ***LID***

    Occupies Full Subcatchment box is checked, then this field becomes disabled and will display the total Subcatchment area divided by the number of replicate units. (See LID

    Placement for options on placing LIDs within sub catchments.) The label below this field indicates how much of the total Subcatchment area is devoted to the particular LID being deployed and gets updated as changes are made to the number of units and area of each unit.
- Top Width of Overland Flow

  Surface
  - The width of the outflow face of each identical LID unit (in ft or m). This parameter only applies to LID processes such as Porous Pavement and Vegetative Swales that use overland flow to convey surface runoff off of the unit. (The other LID processes, such as Bio-Retention Cells and Infiltration Trenches simply spill any excess captured runoff over their berks.)
- % Initially Saturated

- For Bio-Retention Cells this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

- % of Impervious Area Treated
  - The percent of the impervious portion of the sub catchment’s non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

- Send Outflow to Pervious

  Area
  - Select this option if the outflow from the LID is returned onto the sub catchment’s pervious area rather than going to the sub catchment’s outlet. An example of where this might apply is a rain barrel whose contents are used to irrigate a lawn area.

    This field is ignored if the LID takes up the entire Subcatchment.

- Save Detailed Report File
  - The name of an optional file where detailed time series results for the LID will be written. Turn off the checkbox to remove any detailed reporting. Consult the LID

    Results topic to learn more about the contents of this file.

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LID Soil Layer

The **Soil Layer page** of the LID Control Editor describes the properties of the engineered soil mixture used in bio-retention types of LIDs. These properties are:

- Thickness
  - The thickness of the soil layer (inches or mm). Typical values range from 18 to 36 inches (450 to 900 mm) for rain gardens, street planters and other types of land-based bio-retention units, but only 3 to 6 inches (75 to 150 mm) for green roofs.
- Porosity
  - The volume of pore space relative to total volume of soil (as a fraction).
- Field Capacity
  - Volume of pore water relative to total volume after the soil has been allowed to drain fully (as a fraction). Below this level, vertical drainage of water through the soil layer does not occur.
- Wilting Point
  - Volume of pore water relative to total volume for a well dried soil where only bound water remains (as a fraction). The moisture content of the soil cannot fall below this limit.
- Conductivity
  - Hydraulic conductivity for the fully saturated soil (in/hr or mm/hr).
- Conductivity Slope
  - Slope of the curve of log(conductivity) versus soil moisture content (dimensionless). Typical values range from 5 for sands to 15 for silty clay.
- Suction Head
  - The average value of soil capillary suction along the wetting front (inches or mm). This is the same parameter as used in the Green-

Ampt infiltration model.

- Porosity, field capacity, conductivity and conductivity slope are the same soil properties used for Aquifer objects when modeling groundwater, while suction head is the same parameter used for Green-Ampt infiltration. Except here they apply to the special soil mix used in a LID unit rather than the site's naturally occurring soil.

Close All Exit LID Controls

ID (Char)	Soil - Thickness (in)	Soil - Porosity (Double)	Soil - Field Capacity (Double)	Soil - Wilting Point (Double)	Soil - Conductivity (in/hr)	Soil - Conductivity Slope (Double)	Soil - Suction Head (in)
GREENROOF	3.000	0.500	0.200	0.100	0.500	10.000	3.500
POROUSPAVE							
PLANTERS	12.000	0.500	0.200	0.100	0.500	10.000	3.500
INFILTRENCH							
RAINBARRELS							
SWALE							


LID Soil Layer
Thickness
Porosity
Conductivity Slope
LID Soil Layer
Field Capacity
Suction Head
Wilting Point
Conductivity

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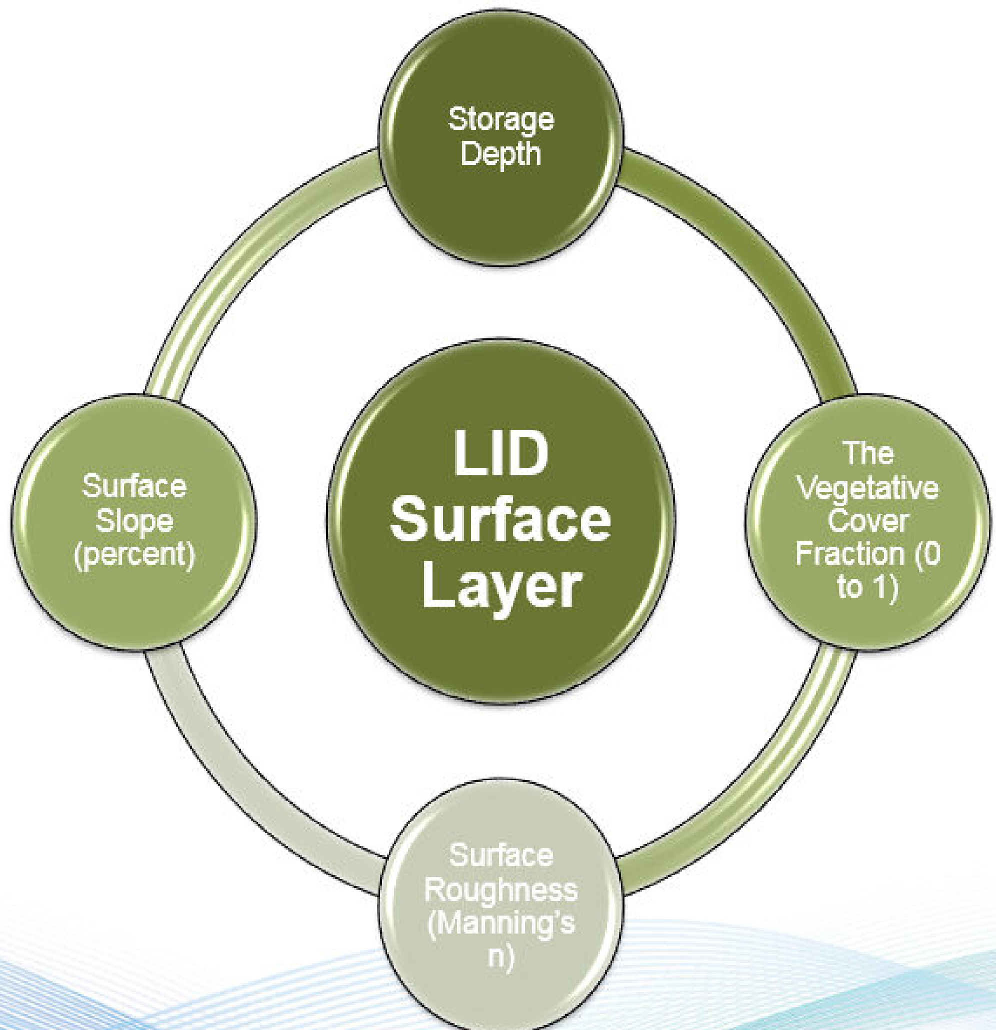
LID Surface Layer

The **Surface Layer** page of the LID Control Editor is used to describe the surface properties of bio-retention cells, porous pavement, infiltration trenches, and vegetative swales. These properties are:

- Storage Depth
  - When confining walls or berms are present this is the maximum depth to which water can pond above the surface of the unit before overflow occurs (in inches or mm). For LIDs that experience overland flow it is the height of any surface depression storage. For swales, it is the height of its trapezoidal cross section.
- Vegetation Volume Fraction
  - The fraction of the volume within the storage depth filled with vegetation. This is the volume occupied by stems and leaves, not their surface area coverage. Normally this volume can be ignored, but may be as high as 0.1 to 0.2 for very dense vegetative growth.
- Surface Roughness
  - Manning's n for overland flow over the surface of porous pavement or a vegetative swale. Use 0 for other types of LIDs.
- Surface Slope
  - Slope of porous pavement surface or vegetative swale (percent).

    Use 0 for other types of LIDs.
- Swale or Surface Side Slope
  - Slope (run over rise) of the side walls of a vegetative swale's cross section. This value is ignored for other types of LIDs.
  - If either the Surface Roughness or Surface Slope values are 0 then any ponded water that exceeds the storage depth is assumed to completely overflow the LID control within a single time step.

LID Surface Layer



LID Type (Long)	Surface - Storage Depth (in)	Surface - Vegetative Cover Fraction (Double)	Surface - Surface Roughness (Double)	Surface - Surface Slope (%)	Surface - Sideslope (%)
0: Bio RetentionCell	0.000	0.000	0.100	1.000	5.000
2: Control Porous Pavement	0.000	0.000	0.020	2.000	5.000
0: Bio RetentionCell	6.000	0.000	0.000	0.000	5.000
1: Infiltration Trench	0.000	0.000	0.240	0.400	5.000
3: Control Rain Barrel					
4: Vegetative Swale	36.000	0.000	0.240	1.000	5.000

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LID Storage Layer

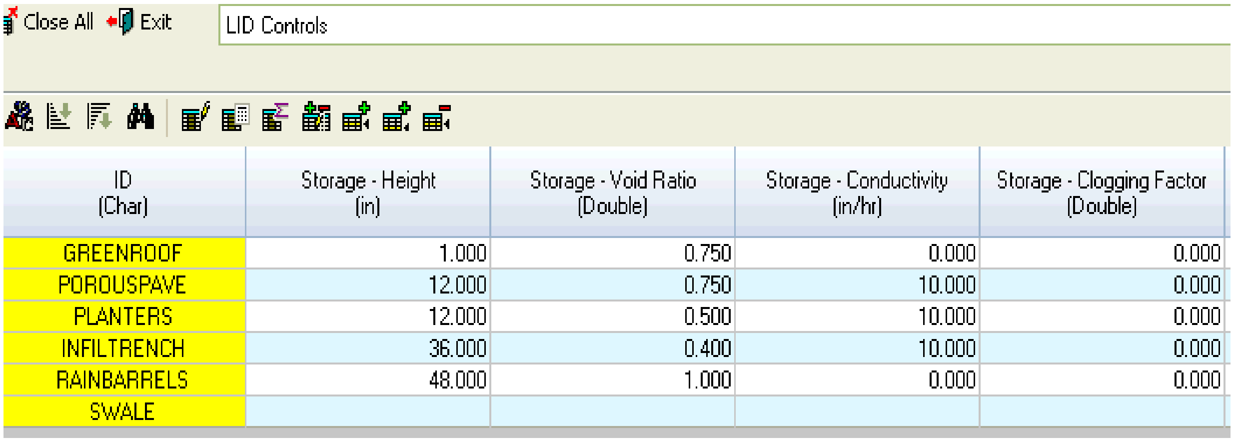
The **Storage Layer** page of the LID

Control Editor describes the properties of the crushed stone or gravel layer used in bio-retention cells, porous pavement systems, and infiltration trenches as a bottom storage/drainage layer. It is also used to specify the height of a rain barrel (or cistern). The following data fields are displayed:

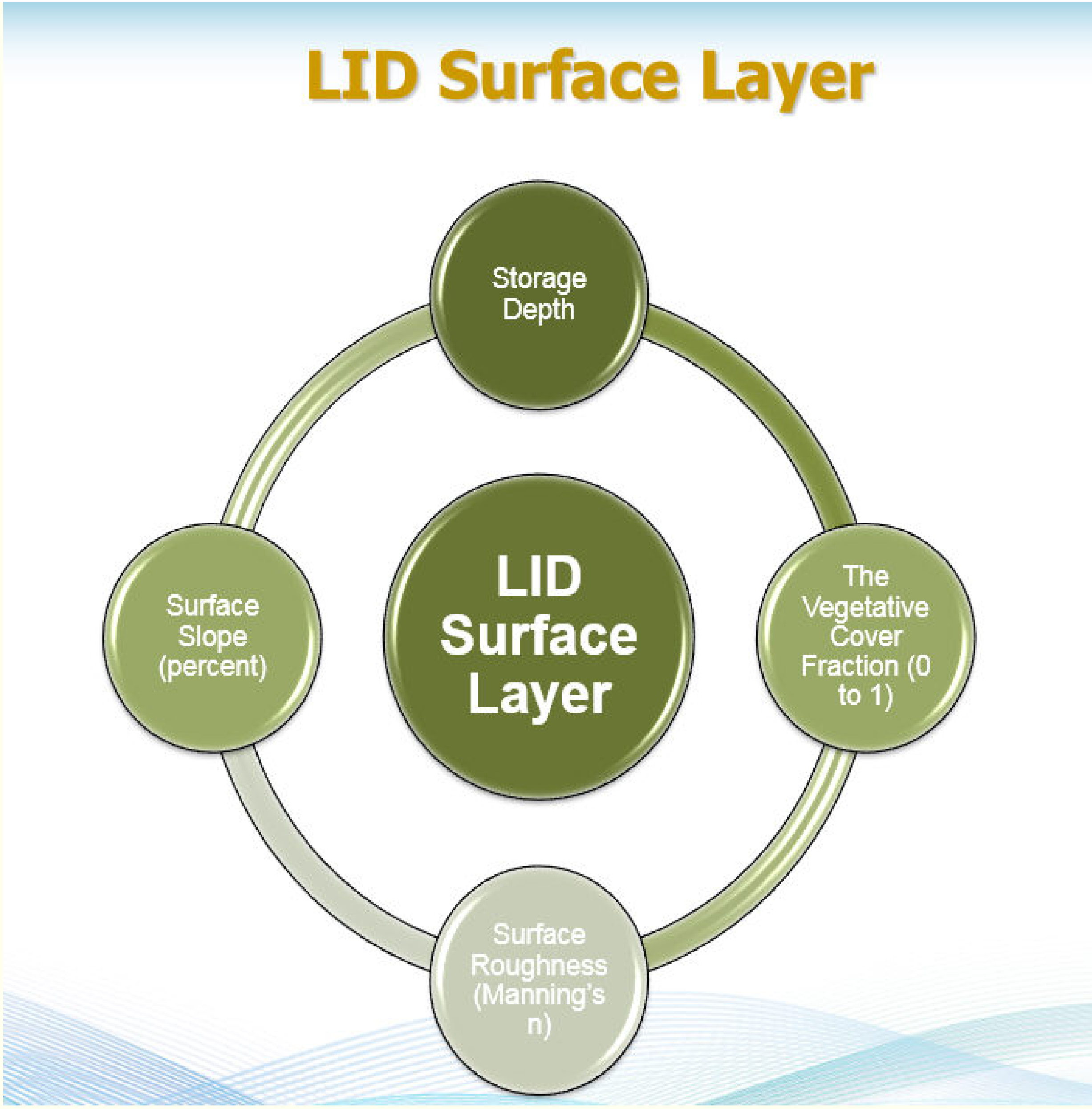
- Height
    - This is the height of a rain barrel or thickness of a gravel layer (inches or mm). Crushed stone and gravel layers are typically 6 to 18 inches (150 to 450 mm) thick while single family home rain barrels range in height from 24 to 36 inches (600 to 900

      mm).
    - The following data fields do not apply to Rain Barrels.
- Void Ratio
    - The volume of void space relative to the volume of solids in the layer. Typical values range from 0.5 to 0.75 for gravel beds. Note that porosity = void ratio / (1 + void ratio).
- Infiltration Rate
    - The rate at which water infiltrates into the native soil below the layer (in inches/hour or mm/hour).This would typically be the Saturated Hydraulic Conductivity of the surrounding Subcatchment if Green-Ampt infiltration is used or the Minimum Infiltration Rate for Horton infiltration. If there is an impermeable floor or liner below the layer then use a value of 0.
- Clogging Factor
    - Total volume of treated runoff it takes to completely clog the bottom of the layer divided by the void volume of the layer.

      Use a value of 0 to ignore clogging. Clogging progressively reduces the Infiltration Rate in direct proportion to the cumulative volume of runoff treated and may only be of concern for infiltration trenches with permeable bottoms and no under drains. Refer to the Pavement Layer page for more discussion of the Clogging Factor.



ID (Char)	Storage - Height (in)	Storage - Void Ratio (Double)	Storage - Conductivity (in/hr)	Storage - Clogging Factor (Double)
GREENROOF	1.000	0.750	0.000	0.000
POROUSPAVE	12.000	0.750	10.000	0.000
PLANTERS	12.000	0.500	10.000	0.000
INFILTRENCH	36.000	0.400	10.000	0.000
RAINBARRELS	48.000	1.000	0.000	0.000
SWALE				



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LID Pavement Layer

The **Pavement Layer** page of the LID Control Editor supplies values for the following properties of a porous pavement LID:

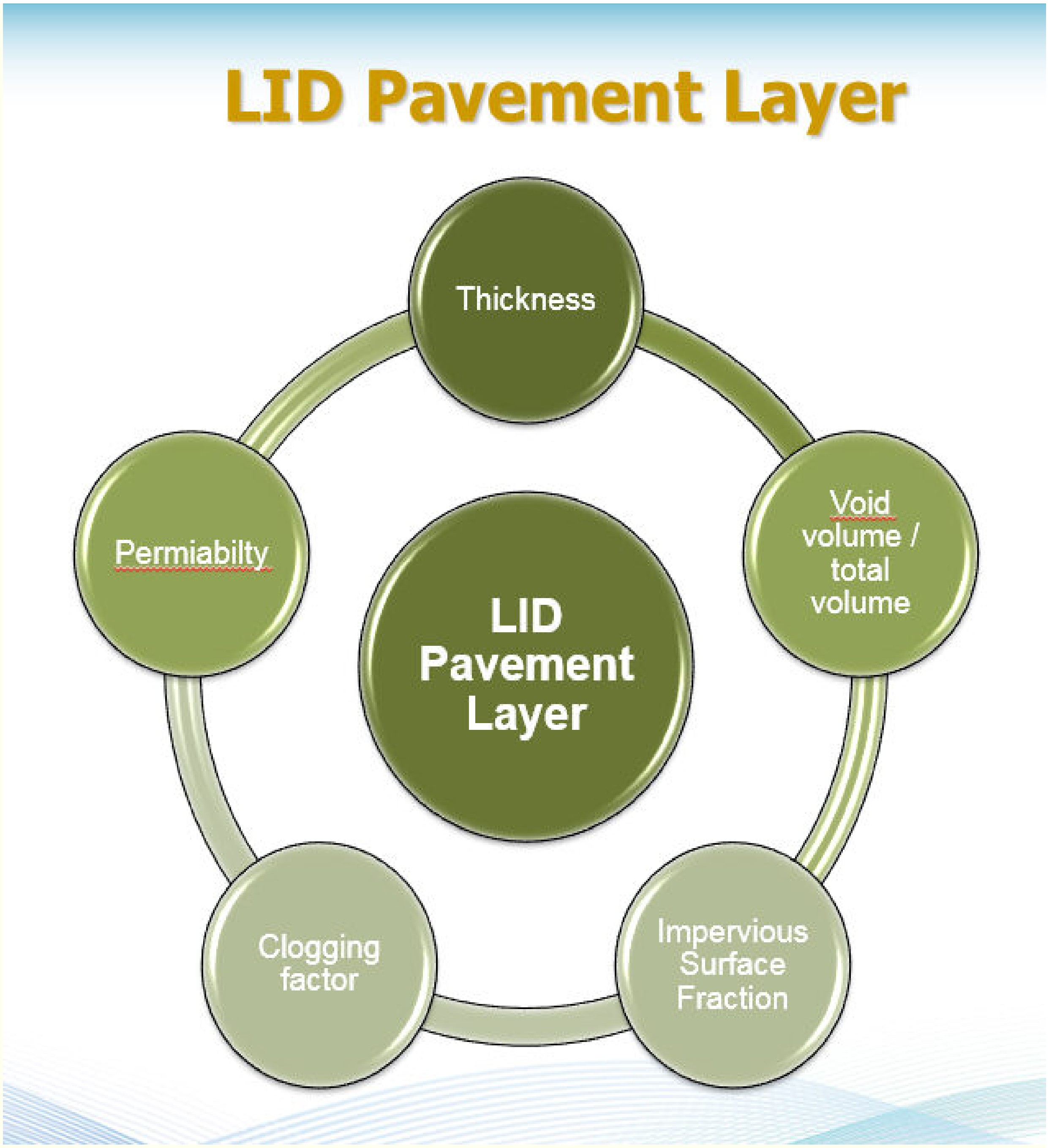
- Thickness
  - The thickness of the pavement layer (inches or mm). Typical values are 4 to 6 inches (100 to 150 mm).
- Void Ratio
  - The volume of void space relative to the volume of solids in the pavement for continuous systems or for the fill material used in modular systems. Typical values for pavements are 0.12

    to 0.21. Note that porosity = void ratio / (1 + void ratio).
- Impervious Surface Fraction
  - Ratio of impervious paver material to total area for modular systems; 0 for continuous porous pavement systems.
- Permeability
  - Permeability of the concrete or asphalt used in continuous systems or hydraulic conductivity of the fill material (gravel or sand) used in modular systems (in/hr or mm/hr). The permeability of new porous concrete or asphalt is very high (e.g., hundreds of in/hr) but can drop off over time due to clogging by fine particulates in the runoff (see below).
- Clogging Factor
  - Number of pavement layer void volumes of runoff treated it takes to completely clog the pavement. Use a value of 0 to ignore clogging. Clogging progressively reduces the pavement's permeability in direct proportion to the cumulative volume of runoff treated.
  - If one has an estimate of the number of years it takes to fully clog the system (Yclog), the Clogging Factor can be computed as: Yclog * Pa * CR * (1 + VR) * (1 - ISF) / (T * VR) where Pa is the

annual rainfall amount over the site, CR is the pavement's capture ratio (area that contributes runoff to the pavement divided by area of the pavement itself), VR is the system's Void Ratio, ISF is the Impervious Surface Fraction, and T is the pavement layer Thickness.

- As an example, suppose it takes 5 years to clog a continuous porous pavement system that serves an area where the annual rainfall is 36 inches/year. If the pavement is 6 inches thick, has a void ratio of 0.2 and captures runoff only from its own surface, then the Clogging Factor is 5 x 36 x (1 + 0.2) / 6 / 0.2 = 180.

ID (Char)	Pavement - Thickness (in)	Pavement - Void Ratio (Double)	Pavement - Impervious Surface Fraction (Double)	Pavement - Permeability (in/hr)	Pavement - Clogging Factor (Double)
GREENROOF					
POROUSPAVE	6.000	0.150	0.000	100.000	0.000
PLANTERS					
INFILTRENCH					
RAINBARRELS					
SWALE					


LID Pavement Layer
Thickness
Void volume / total volume
Impervious Surface Fraction
Clogging factor
Permiabilty
LID Pavement Layer

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LID Under Drain Layer

LID storage layers can contain an optional underdrain system that collects stored water from the bottom of the layer and conveys it to a conventional storm drain. The Underdrain page of the LID

Control Editor describes the properties of this system. It contains the following data entry fileds:

- Drain Coefficient and Drain Exponent
    - Coefficient C and exponent n that determines the rate of flow through the underdrain as a function of height of stored water above the drain height. The following equation is used to compute this flow rate (per unit area of the LID unit):
    - q = C(h-Hd)n
    - where q is outflow (in/hr or mm/hr), h height of stored

      water (inches or mm), and Hd is the drain height. If the layer does not have an underdrain then set C to 0.

      A typical value for n would be 0.5 (making the drain act like an orifice). A rough estimate for C can be based on the time T

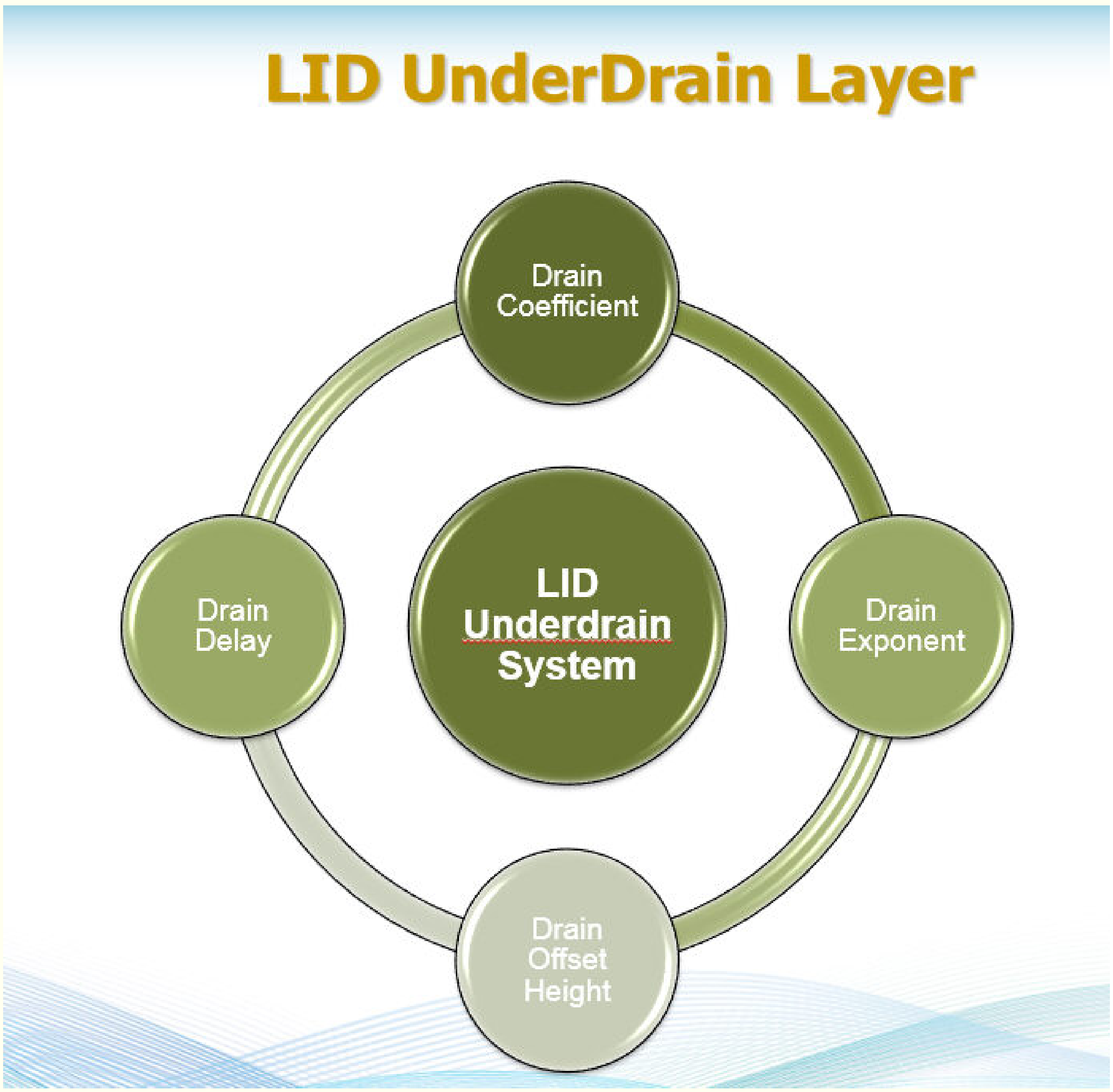
      required to drain a depth D of stored water. For n = 0.5, C =

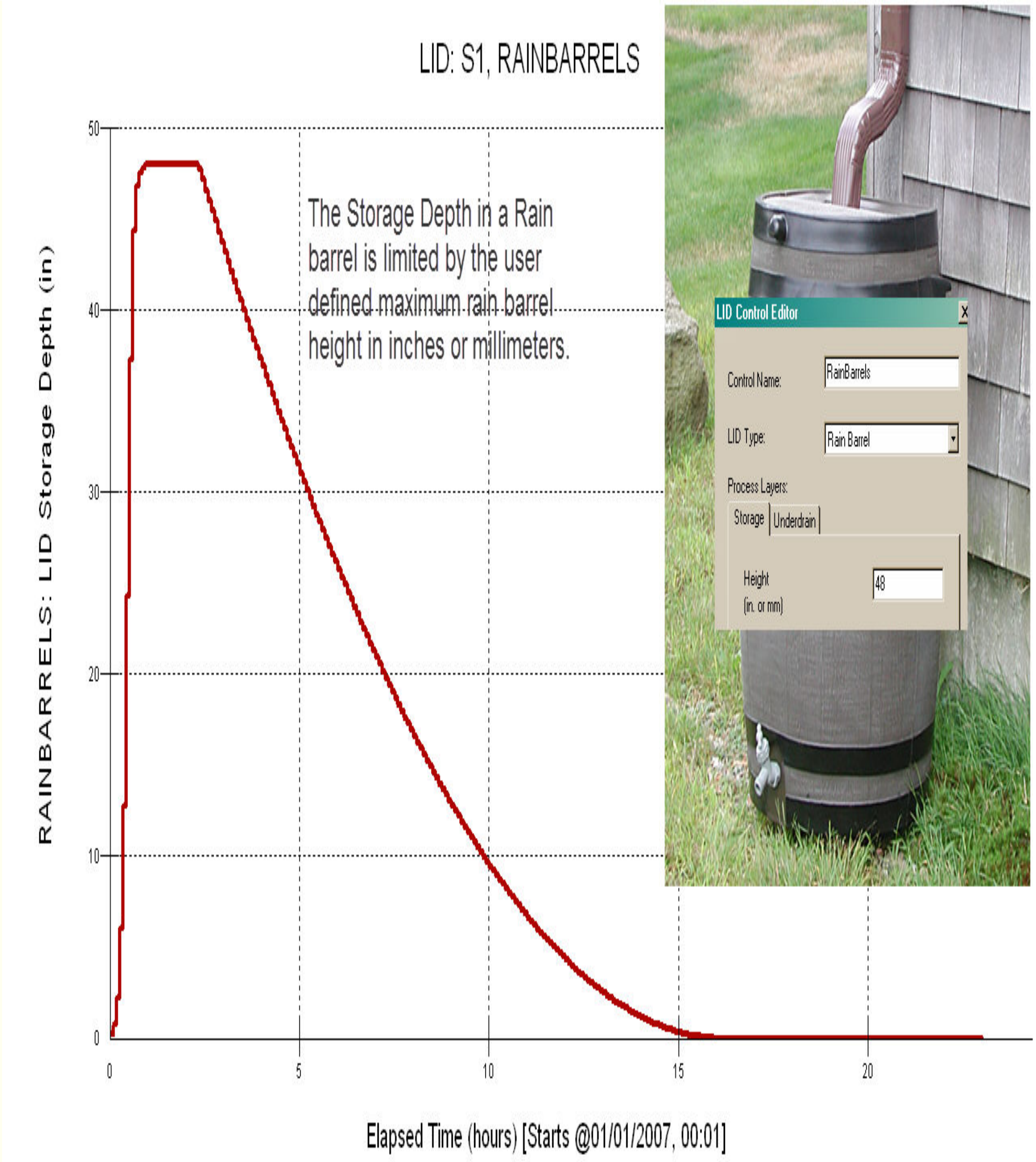
      2D1/2/T.
- Drain Offset Height
    - Height of any underdrain piping above the bottom of a storage layer or rain barrel (inches or mm).
    - Drain Delay (for Rain

      Barrels only)
    - The number of dry weather hours that must elapse before

      the drain line in a rain barrel is opened (the line is assumed to be closed once rainfall begins). This parameter is ignored for other types of LIDs.

ID (Char)	Pavement - Thickness (in)	Pavement - Impervious Surface Fraction	Pavement - Permeability (in/hr)	Pavement - Clogging Factor	Underdrain - Drain Coefficient (in/hr)	Underdrain - Drain Exponent (Double)	Underdrain - Drain Offset Height (in)	Underdrain - Drain Delay (Double)
GREENROOF					1.000	0.500	0.000	6.000
POROUSPAVE	6.000	0.000	100.000	0.000	0.000	0.500	0.000	6.000
PLANTERS					0.000	1.000	0.500	6.000
INFILTRENCH					0.000	0.500	0.000	6.000
RAINBARRELS					1.000	0.500	0.000	6.000
SWALE								




LID: S1, RAINBARRELS
The Storage Depth in a Rain barrel is limited by the user defined maximum rain barrel height in inches or millimeters.
RAINBARRELS: LID Storage Depth (in)
Elapsed Time (hours) [Starts @01/01/2007, 00:01]
0
10
20
30
40
50
0
5
10
15
20
LID Control Editor
Control Name:
RainBarrels
LID Type:
Rain Barrel
Process Layers:
Storage
Underdrain
Height
(in. or mm)
48

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LID Graphs

The LID Graphs in Output Report Manager graphs the LID pathway values for individual timesteps for each LID Control on every Subcatchment for these parameters:

1. Surface Inflow normalized to the

   area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

2. Evaporation normalized to the area

   of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

3. Surface Infiltration normalized to

   the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous)

4. Soil Percolation normalized to the

   area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

5. Storage Infiltration normalized to

   the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

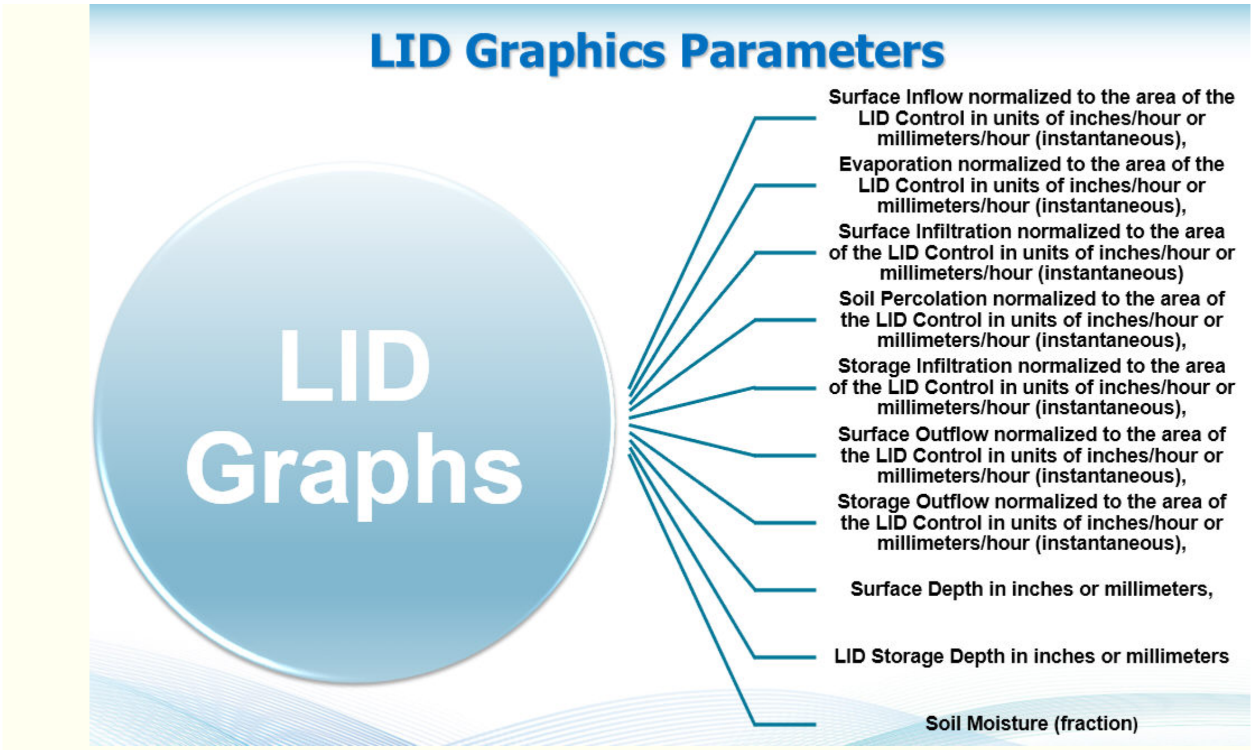
6. Surface Outflow normalized to the

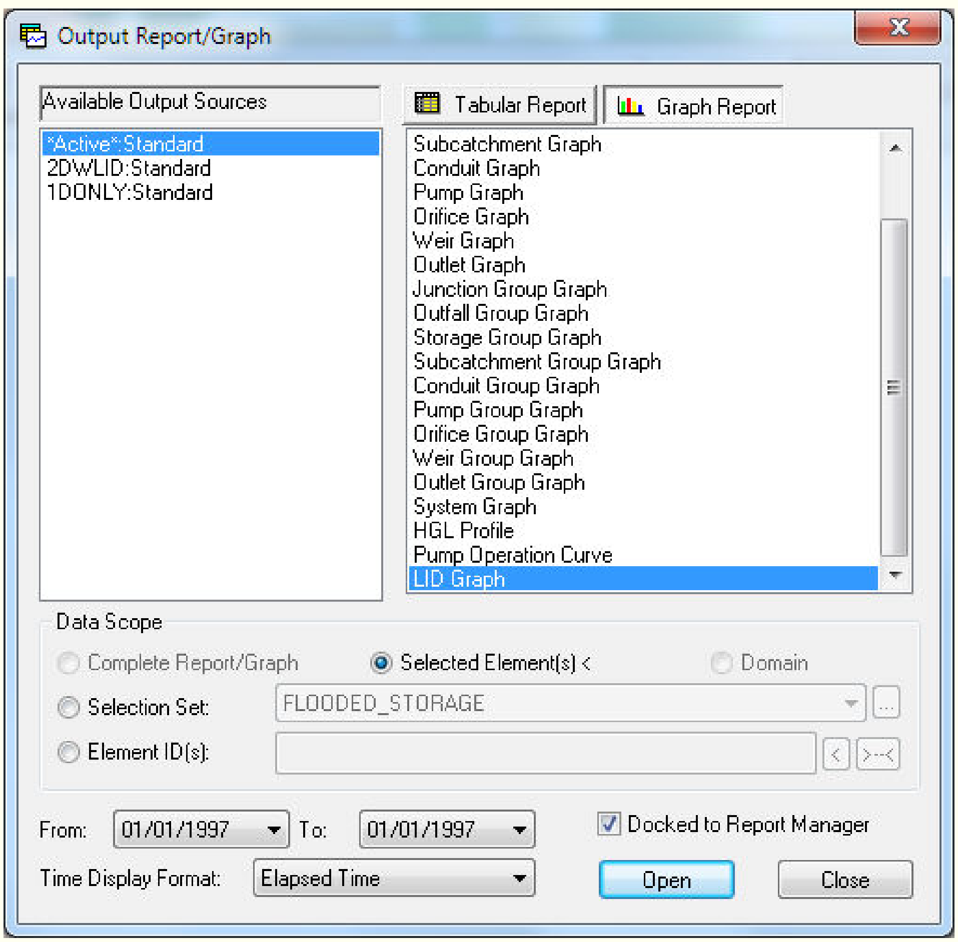
   area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

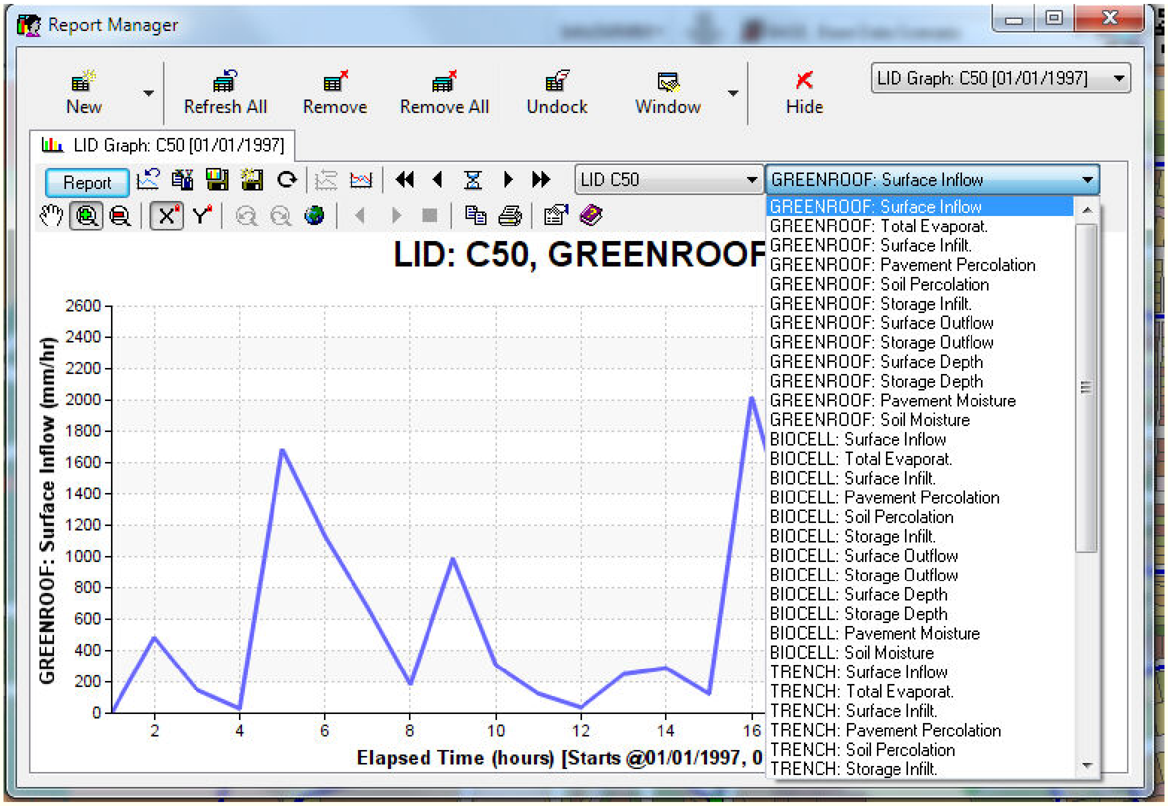
7. Storage Outflow normalized to the

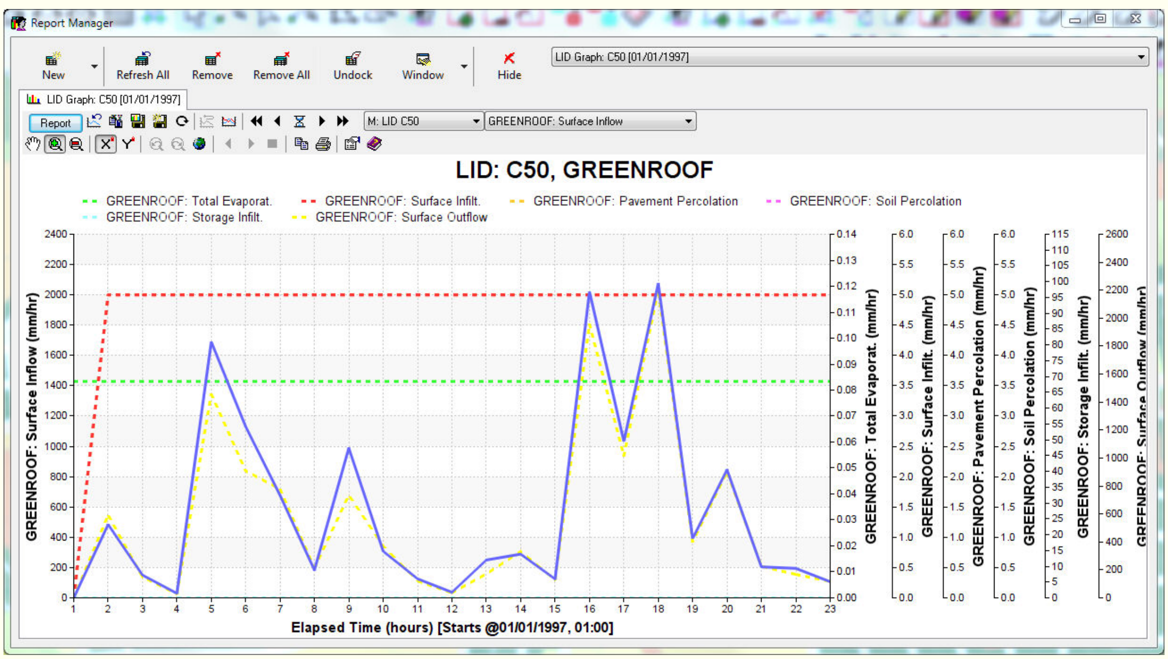
   area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

8. Surface Depth in inches or millimeters,
9. LID Storage Depth in inches or millimeters and
10. Soil Moisture (fraction)


LID Graphics Parameters
LID Graphs
Surface Inflow normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),
Evaporation normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),
Surface Infiltration normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous)
Soil Percolation normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),
Storage Infiltration normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),
Surface Outflow normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),
Storage Outflow normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),
Surface Depth in inches or millimeters,
LID Storage Depth in inches or millimeters
Soil Moisture (fraction)


Output Report/Graph
Available Output Sources
Active:Standard
2DWLID:Standard
1DONLY:Standard
Tabular Report
Graph Report
Subcatchment Graph
Conduit Graph
Pump Graph
Orifice Graph
Weir Graph
Outlet Graph
Junction Group Graph
Outfall Group Graph
Storage Group Graph
Subcatchment Group Graph
Conduit Group Graph
Pump Group Graph
Orifice Group Graph
Weir Group Graph
Outlet Group Graph
System Graph
HGL Profile
Pump Operation Curve
LID Graph
Data Scope
Complete Report/Graph
Selected Element(s) <
Domain
Selection Set:
FLOODED_STORAGE
Element ID(s):
From:
01/01/1997
To:
01/01/1997
Docked to Report Manager
Time Display Format:
Elapsed Time
Open
Close


Report Manager
New
Refresh All
Remove
Remove All
Undock
Window
Hide
LID Graph: C50 [01/01/1997]
Report
LID C50
GREENROOF: Surface Inflow
LID: C50, GREENROOF
GREENROOF: Surface Inflow (mm/hr)
Elapsed Time (hours) [Starts @01/01/1997, 0
GREENROOF: Surface Inflow
GREENROOF: Total Evaporat.
GREENROOF: Surface Infilt.
GREENROOF: Pavement Percolation
GREENROOF: Soil Percolation
GREENROOF: Storage Infilt.
GREENROOF: Surface Outflow
GREENROOF: Storage Outflow
GREENROOF: Surface Depth
GREENROOF: Storage Depth
GREENROOF: Pavement Moisture
GREENROOF: Soil Moisture
BIOCELL: Surface Inflow
BIOCELL: Total Evaporat.
BIOCELL: Surface Infilt.
BIOCELL: Pavement Percolation
BIOCELL: Soil Percolation
BIOCELL: Storage Infilt.
BIOCELL: Surface Outflow
BIOCELL: Storage Outflow
BIOCELL: Surface Depth
BIOCELL: Storage Depth
BIOCELL: Pavement Moisture
BIOCELL: Soil Moisture
TRENCH: Surface Inflow
TRENCH: Total Evaporat.
TRENCH: Surface Infilt.
TRENCH: Pavement Percolation
TRENCH: Soil Percolation
TRENCH: Storage Infilt.


Report Manager
New
Refresh All
Remove
Remove All
Undock
Window
Hide
LID Graph: C50 [01/01/1997]
Report
M: LID C50
GREENROOF: Surface Inflow
LID: C50, GREENROOF
GREENROOF: Total Evaporat.
GREENROOF: Surface Infilt.
GREENROOF: Pavement Percolation
GREENROOF: Soil Percolation
GREENROOF: Storage Infilt.
GREENROOF: Surface Outflow
GREENROOF: Surface Inflow (mm/hr)
GREENROOF: Total Evaporat. (mm/hr)
GREENROOF: Surface Infilt. (mm/hr)
GREENROOF: Pavement Percolation (mm/hr)
GREENROOF: Soil Percolation (mm/hr)
GREENROOF: Storage Infilt. (mm/hr)
Elapsed Time (hours) [Starts @01/01/1997, 01:00]

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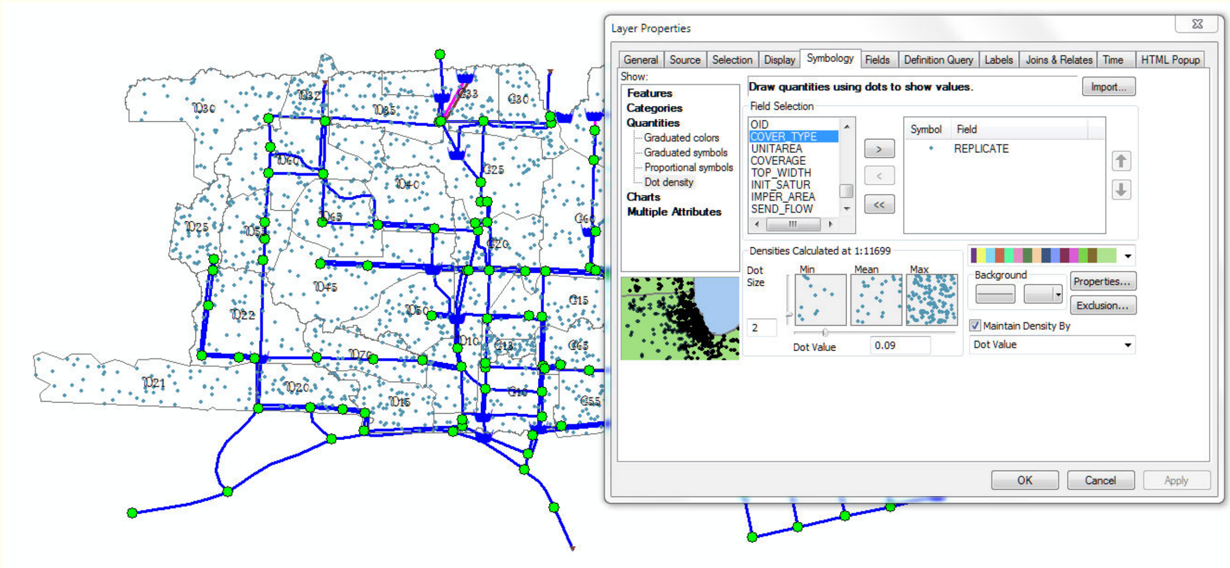
LID Map Display

LID database data and active output data can be seen using the Map Display command.



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LID Results - Summary Report

The performance of the LID controls placed in a Subcatchment is reflected in the overall runoff, infiltration, and evaporation rates computed for the Subcatchment as normally reported by SWMM5. The SWMM's Output Modeling Report also contains a section entitled LID Performance Summary that provides an overall water balance for each LID control placed in each Subcatchment.

The components of this water balance include total inflow, infiltration, evaporation, surface runoff, underdrain flow and initial and final stored volumes, all expressed as inches (or mm) over the LID's area. This report is listed in the text RPT file and the Output Report Manager Table.

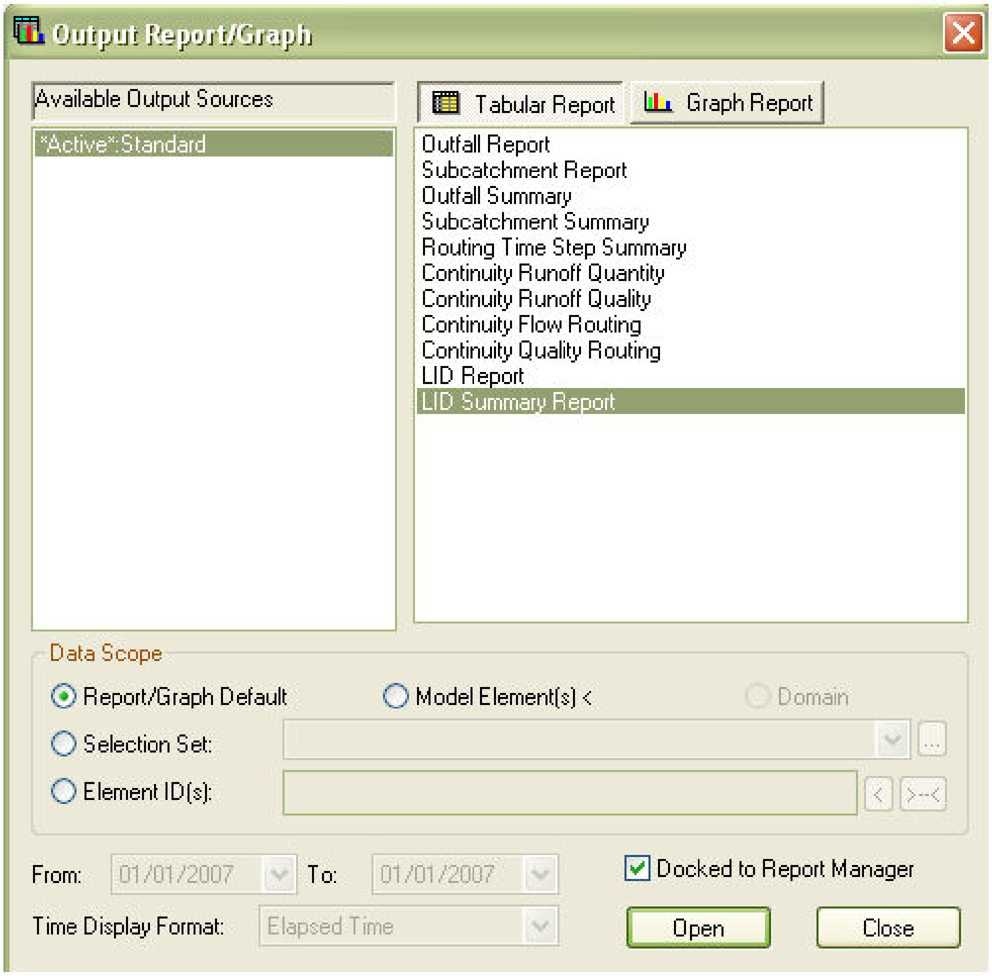
```
***************************
 LID Performance Summary
***************************
```

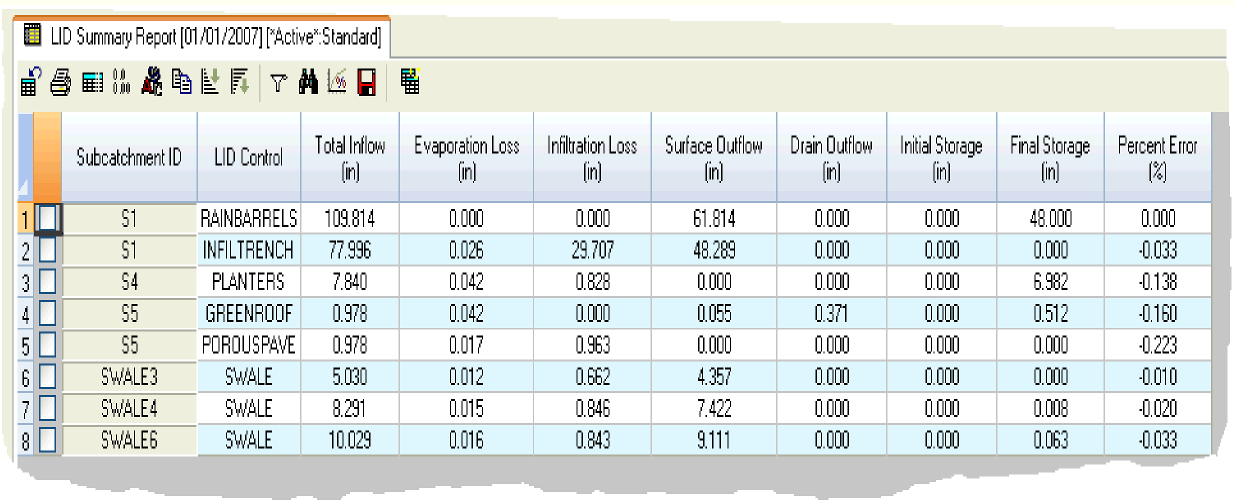
Subcatchment	LID Control	Total Inflow in	Evap Loss in	Infil Loss in	Surface Outflow in	Drain Outflow in	Init. Storage in	Final Storage in	Pcnt. Error
S1	RAINBARRELS	109.81	0.00	0.00	61.81	0.00	0.00	48.00	0.00
S1	INFILTRENCH	78.00	0.03	29.71	48.29	0.00	0.00	0.00	-0.03
S4	PLANTERS	7.84	0.04	0.83	0.00	0.00	0.00	6.98	-0.14
S5	GREENROOF	0.98	0.04	0.00	0.05	0.37	0.00	0.51	-0.16
S5	POROUSPAVE	0.98	0.02	0.96	0.00	0.00	0.00	0.00	-0.22
SWALE3	SWALE	5.03	0.01	0.66	4.36	0.00	0.00	0.00	-0.01
SWALE4	SWALE	8.29	0.02	0.85	7.42	0.00	0.00	0.01	-0.02
SWALE6	SWALE	10.03	0.02	0.84	9.11	0.00	0.00	0.06	-0.03

The LID Summary Report in Output Report Manager lists the overall simulation summary for each LID Control on every Subcatchment for these parameters:

1. Subcatchment ID
2. LID Control in the Subcatchment
3. Total Inflow
4. Evaporation Loss

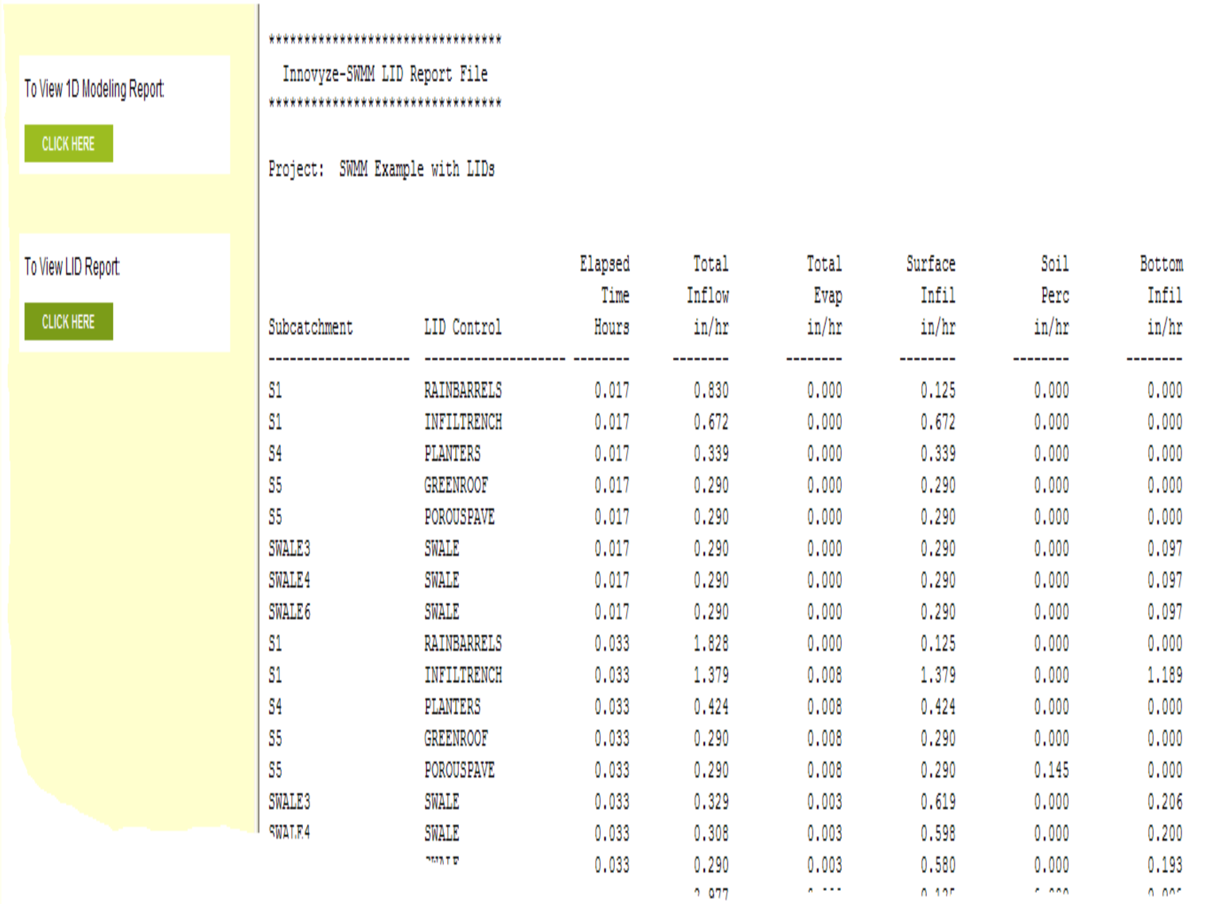
5. Infiltration Loss
6. Surface Outflow
7. Drain Outflow
8. Initial Storage
9. Final Storage
10. Percent Error




LID Summary Report [01/01/2007] [*Active*:Standard]

	Subcatchment ID	LID Control	Total Inflow (in)	Evaporation Loss (in)	Infiltration Loss (in)	Surface Outflow (in)	Drain Outflow (in)	Initial Storage (in)	Final Storage (in)	Percent Error (%)
1	S1	RAINBARRELS	109.814	0.000	0.000	61.814	0.000	0.000	48.000	0.000
2	S1	INFILTRENCH	77.996	0.026	29.707	48.289	0.000	0.000	0.000	-0.033
3	S4	PLANTERS	7.840	0.042	0.828	0.000	0.000	0.000	6.982	-0.138
4	S5	GREENROOF	0.978	0.042	0.000	0.055	0.371	0.000	0.512	-0.160
5	S5	POROUSPAVE	0.978	0.017	0.963	0.000	0.000	0.000	0.000	-0.223
6	SWALE3	SWALE	5.030	0.012	0.662	4.357	0.000	0.000	0.000	-0.010
7	SWALE4	SWALE	8.291	0.015	0.846	7.422	0.000	0.000	0.008	-0.020
8	SWALE6	SWALE	10.029	0.016	0.843	9.111	0.000	0.000	0.063	-0.033

Optionally, the entire time series of flux rates and moisture levels for a selected LID control in a given Subcatchment can be written to a tab delimited text file for easy viewing and graphing in a spreadsheet program (such as Microsoft Excel). The detailed LID Report File can be found using a Tab in the output browser.




```
*******************************
  Innovyze-SWMM LID Report File
*******************************

Project:  SWMM Example with LIDs
```

Subcatchment	LID Control	Elapsed Time Hours	Total Inflow in/hr	Total Evap in/hr	Surface Infil in/hr	Soil Perc in/hr	Bottom Infil in/hr
S1	RAINBARRELS	0.017	0.830	0.000	0.125	0.000	0.000
S1	INFILTRENCH	0.017	0.672	0.000	0.672	0.000	0.000
S4	PLANTERS	0.017	0.339	0.000	0.339	0.000	0.000
S5	GREENROOF	0.017	0.290	0.000	0.290	0.000	0.000
S5	POROUSPAVE	0.017	0.290	0.000	0.290	0.000	0.000
SWALE3	SWALE	0.017	0.290	0.000	0.290	0.000	0.097
SWALE4	SWALE	0.017	0.290	0.000	0.290	0.000	0.097
SWALE6	SWALE	0.017	0.290	0.000	0.290	0.000	0.097
S1	RAINBARRELS	0.033	1.828	0.000	0.125	0.000	0.000
S1	INFILTRENCH	0.033	1.379	0.008	1.379	0.000	1.189
S4	PLANTERS	0.033	0.424	0.008	0.424	0.000	0.000
S5	GREENROOF	0.033	0.290	0.008	0.290	0.000	0.000
S5	POROUSPAVE	0.033	0.290	0.008	0.290	0.145	0.000
SWALE3	SWALE	0.033	0.329	0.003	0.619	0.000	0.206
SWALE4	SWALE	0.033	0.308	0.003	0.598	0.000	0.200
[illegible]	[illegible]	0.033	0.290	0.003	0.580	0.000	0.193

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LID Output Tabular Reports (Time Series Report)

The LID Report in Output Report Manager lists the LID pathway values for individual timesteps for each LID Control on every Subcatchment for these parameters:

1. Surface Inflow normalized to the

   area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

2. Evaporation normalized to the area

   of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

3. Surface Infiltration normalized to

   the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

4. Percolation through pavement layer
5. Soil Percolation through the Soil

   Layer normalized to the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

6. Storage Infiltration normalized to

   the area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

7. Surface Outflow normalized to the

   area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

8. Storage Outflow normalized to the

   area of the LID Control in units of inches/hour or millimeters/hour (instantaneous),

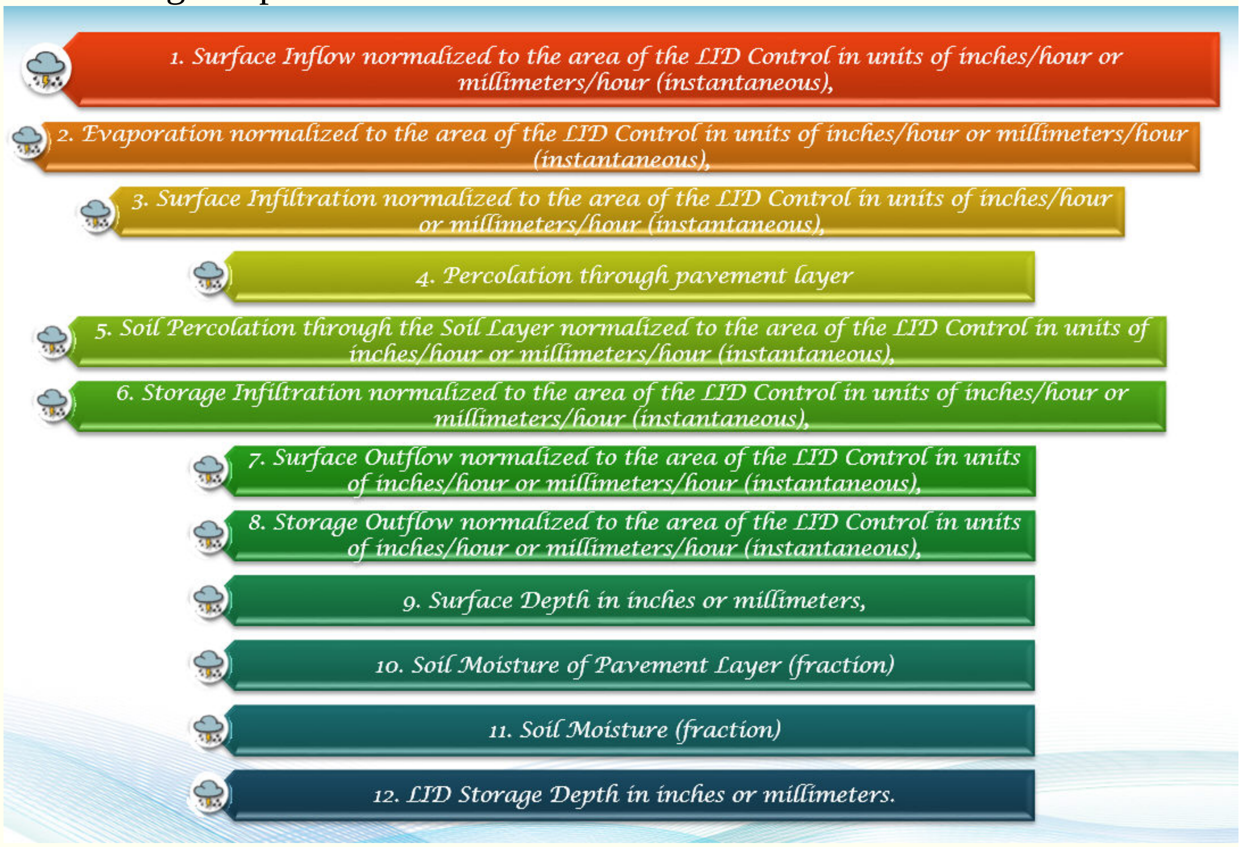
9. Surface Depth in inches or millimeters,

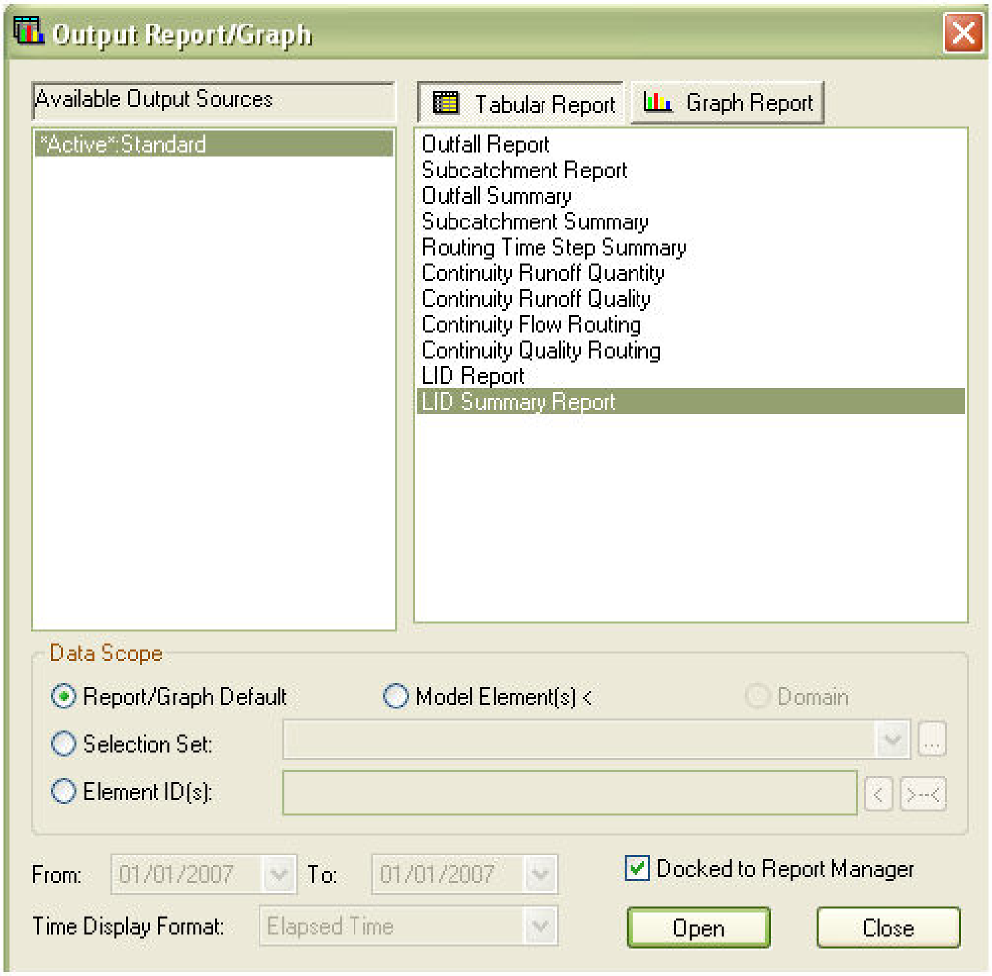
10. Soil Moisture of Pavement Layer (fraction)

11. Soil Moisture (fraction)

12. LID

Storage Depth in inches or millimeters




Output Report/Graph
Available Output Sources
Active:Standard
Tabular Report
Graph Report
Outfall Report
Subcatchment Report
Outfall Summary
Subcatchment Summary
Routing Time Step Summary
Continuity Runoff Quantity
Continuity Runoff Quality
Continuity Flow Routing
Continuity Quality Routing
LID Report
LID Summary Report
Data Scope
Report/Graph Default
Model Element(s) <
Domain
Selection Set:
Element ID(s):
From:
01/01/2007
To:
01/01/2007
Docked to Report Manager
Time Display Format:
Elapsed Time
Open
Close

LID Report Variables

LID Report [01/01/2007] [*Active*:Standard]

Day 0; 01:31

	ID	LID Control	Surface Inflow (in/hr)	Total Evaporation (in/hr)	Surface Infiltration (in/hr)	Soil Percolation (in/hr)	Storage Infiltration (in/hr)	Surface Outflow (in/hr)	Storage Outflow (in/hr)	Surface Depth (in)	LID Storage Depth (in)	Soil Moisture
1	S1	RAINBARRELS	18.035	0.000	0.169	0.000	0.000	18.170	0.000	0.000	48.000	0.000
2	S4	PLANTERS	1.262	0.008	1.218	0.062	0.061	0.000	0.000	4.886	0.003	0.293
3	S5	GREENROOF	0.150	0.008	0.150	0.112	0.000	0.000	0.110	0.000	0.012	0.351
4	S5	POROUSPAVE	0.150	0.008	0.150	0.148	0.152	0.000	0.000	0.000	0.006	0.000
5	SWALE3	SWALE	0.812	0.003	0.405	0.000	0.148	1.133	0.000	1.761	0.000	0.000
6	SWALE4	SWALE	1.760	0.003	0.457	0.000	0.184	2.722	0.000	3.767	0.000	0.000
7	SWALE6	SWALE	3.542	0.003	0.503	0.000	0.211	4.785	0.000	4.653	0.000	0.000

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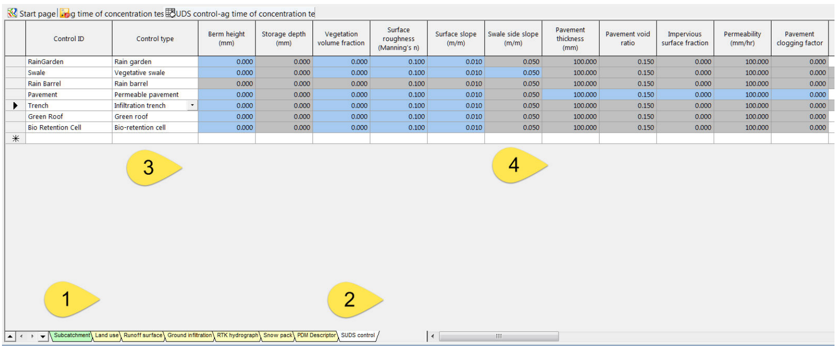
SuDS in InfoWorks ICM

In InfoWorks ICM 6.5 and later the SWMM 5 LID Controls were added to the Subcatchment Grid of ICM. Here is a copy of the ICM Help File. The LID Controls are entered in the Subcatchment Grid (1), in the SuDS or LID Tab (2), it uses SWMM 5 LID Control Types (3) and has a grid of all of the LID or SuDS data.



Control ID	Control type	Berm height (mm)	Storage depth (mm)	Vegetation volume fraction	Surface roughness (Manning's n)	Surface slope (m/m)	Swale side slope (m/m)	Pavement thickness (mm)	Pavement void ratio	Impervious surface fraction	Permeability (mm/hr)	Pavement clogging factor
RainGarden	Rain garden	0.000	0.000	0.000	0.100	0.010	0.050	100.000	0.150	0.000	100.000	0.000
Swale	Vegetative swale	0.000	0.000	0.000	0.100	0.010	0.050	100.000	0.150	0.000	100.000	0.000
Rain Barrel	Rain barrel	0.000	0.000	0.000	0.100	0.010	0.050	100.000	0.150	0.000	100.000	0.000
Pavement	Permeable pavement	0.000	0.000	0.000	0.100	0.010	0.050	100.000	0.150	0.000	100.000	0.000
Trench	Infiltration trench	0.000	0.000	0.000	0.100	0.010	0.050	100.000	0.150	0.000	100.000	0.000
Green Roof	Green roof	0.000	0.000	0.000	0.100	0.010	0.050	100.000	0.150	0.000	100.000	0.000
Bio Retention Cell	Bio-retention cell	0.000	0.000	0.000	0.100	0.010	0.050	100.000	0.150	0.000	100.000	0.000

Table 2. All Columns from the Help File from InfoWorks ICM SuDS Table

Help Text	Database Field	Data Type	Size	Units	Precision	Default	Error Lower Limit
Control ID	The name that identifies this control object.	control_id	Text	64			
Control type	The type of SUDS control can be selected from the drop-down list.	control_type	Text	25			Bio-retention cell
Berm height	Storage height.	surf_berm_height	Double		Pipe size	3	0
Storage depth	Storage depth.	surf_storage_depth	Double		Pipe size	3	0
Vegetation volume fraction	Fraction of the area above the surface that is filled with vegetation.	surf_veg_vol_fraction	Double			3	0
Surface roughness (Manning’s n)	Manning’s n for overland flow. This surface roughness cannot be 0 for permeable	surf_roughness_n	Double			3	0.1

	pavements, green roofs or vegetative swales.						
Surface slope	The gradient of the surface slope.	surf_slope	Double		Gradient	3	0.01
Swale side slope	The gradient of the slope of side walls.	surf_xslope	Double		Gradient	3	0.05
Pavement thickness	The thickness of the pavement layer.	pave_thickness	Double		Pipe size	3	100
Pavement void ratio	The void ratio of the pavement layer.	pave_void_ratio	Double			3	0.15
Impervious surface fraction	Ratio of impervious paver material to total area.	pave_impervious_surf_fraction	Double			3	0
Permeability	Permeability of the concrete or asphalt used in continuous systems or hydraulic conductivity of the fill material (gravel or sand) used in modular systems.	pave_permeability	Double		Integer	3	100
Pavement clogging factor	Number of pavement layer void volumes of runoff treated it takes to completely clog the pavement.	pave_clogging_factor	Double			3	0
Soil class	The class of soil can be selected from a drop-down list.	soil_class	Text	20			

Soil thickness	Thickness of layer.	soil_thickness	Double		Pipe size	3	500
Soil porosity	Porosity of the soil. This field is automatically populated when the soil Class is selected.	soil_porosity	Double			3	0.5
Field capacity	Soil field capacity. This field is automatically populated when the soil Class is selected.	soil_field_capacity	Double			3	0.2
Wilting point	Soil wilting point. This field is automatically populated when the soil Class is selected.	soil_wilting_point	Double			3	0.1
Conductivity	Soil's saturated hydraulic conductivity. This field is automatically populated when the soil Class is selected.	soil_conductivity	Double		Integer	3	12.7
Conductivity slope	Slope of the curve of log (conductivity) versus soil moisture content.	soil_conductivity_slope	Double			3	10
Suction head	Soil capillary suction. This field is automatically populated when the soil Class is selected.	soil_suction_head	Double		Pipe size	3	88.9

Barrel height	Height of a rain barrel.	storage_barrel_height	Double		Pipe size	3	0
Storage thickness	Thickness of the storage layer.	storage_thickness	Double		Pipe size	3	150
Storage void ratio	The storage void ratio.	storage_void_ratio	Double			3	0.75
Seepage rate	The filtration rate of the layer when first constructed.	storage_seepage_rate	Double		Integer	3	10
Storage clogging factor	Number of storage layer void volumes of runoff treated it takes to completely clog the layer.	storage_clogging_factor	Double			3	0
Flow coefficient	Coefficient C that determines the rate of flow through the underdrain as a function of height of stored water above the drain bottom.	underdrain_flow_coefficient	Double			3	0
Flow exponent	Exponent n that determines the rate of flow through the underdrain as a function of height of stored water above the drain outlet.	underdrain_flow_exponent	Double			3	0.5
Offset height	Height of underdrain piping or outlet above the bottom of the storage	underdrain_offset_height	Double		Pipe size	3	150

	layer or rain barrel.						
Delay	The number of dry weather hours that must elapse before the drain line in a rain barrel is opened.	underdrain_delay	Double		Hours	3	6
Flow capacity	The flow capacity of the storage layer or rain barrel.	underdrain_flow_capacity	Double			4	6
Mat thickness	The thickness of the drainage mat layer.	drainagemat_thickness	Double		Pipe size	3	75
Mat void fraction	The void fraction of the drainage mat.	drainagemat_void_fraction	Double			3	0.5
Mat roughness (Manning's n)	Roughness of the drainage mat.						

Table 3. Only the 1st Columns from the Help File InfoWorks ICM SuDS Table

Field Name	Help Text
Control ID	The name that identifies this control object.
Control type	The type of SUDS control can be selected from the drop-down list.
Berm height	Storage height.
Storage depth	Storage depth.
Vegetation volume fraction	Fraction of the area above the surface that is filled with vegetation.
Surface roughness (Manning's n)	Manning's n for overland flow. This surface roughness cannot be 0 for permeable pavements, green roofs or vegetative swales.
Surface slope	The gradient of the surface slope.
Swale side slope	The gradient of the slope of side walls.
Pavement thickness	The thickness of the pavement layer.
Pavement void ratio	The void ratio of the pavement layer.
Impervious surface fraction	Ratio of impervious paver material to total area.

Permeability	Permeability of the concrete or asphalt used in continuous systems or hydraulic conductivity of the fill material (gravel or sand) used in modular systems.
Pavement clogging factor	Number of pavement layer void volumes of runoff treated it takes to completely clog the pavement.
Soil class	The class of soil can be selected from a drop-down list.
Soil thickness	Thickness of layer.
Soil porosity	Porosity of the soil. This field is automatically populated when the soil Class is selected.
Field capacity	Soil field capacity. This field is automatically populated when the soil Class is selected.
Wilting point	Soil wilting point. This field is automatically populated when the soil Class is selected.
Conductivity	Soil's saturated hydraulic conductivity. This field is automatically populated when the soil Class is selected.
Conductivity slope	Slope of the curve of log (conductivity) versus soil moisture content.
Suction head	Soil capillary suction. This field is automatically populated when the soil Class is selected.
Barrel height	Height of a rain barrel.
Storage thickness	Thickness of the storage layer.
Storage void ratio	The storage void ratio.
Seepage rate	The filtration rate of the layer when first constructed.
Storage clogging factor	Number of storage layer void volumes of runoff treated it takes to completely clog the layer.
Flow coefficient	Coefficient C that determines the rate of flow through the underdrain as a function of height of stored water above the drain bottom.
Flow exponent	Exponent n that determines the rate of flow through the underdrain as a function of height of stored water above the drain outlet.
Offset height	Height of underdrain piping or outlet above the bottom of the storage layer or rain barrel.
Delay	The number of dry weather hours that must elapse before the drain line in a rain barrel is opened.
Flow capacity	The flow capacity of the storage layer or rain barrel.
Mat thickness	The thickness of the drainage mat layer.
Mat void fraction	The void fraction of the drainage mat.
Mat roughness (Manning's n)	Roughness of the drainage mat.

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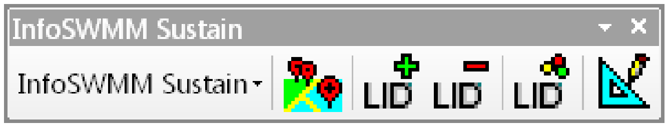
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LID
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Treatment in BMP's and LID's

5.1 Treatment

Excerpt from the EPA manual Storm Water Management Model Reference Manual Volume III – Water Quality (PDF) which can be found here

5.1.1 Background

Management of stormwater quality is usually performed through a combination of so-called “best management practices” (BMPs) and a form of hydrologic source control popularly known as “low impact development” (LID). Treatment of stormwater runoff, either by natural means or by engineered devices, can occur at both the source of the generated runoff or at locations within the conveyance network. Source treatment through LID is discussed in the next chapter. This section describes how SWMM models treatment applied to flows already captured and transported within a conveyance system.

Table 5-1, adapted from Huber et al. (2006), categorizes the different unit treatment processes used by various types of conveyance system BMPs. Ideally one would like to model these processes at a fundamental level, to be able to estimate pollutant removal based on physical design parameters, hydraulic variables, and intrinsic chemical properties and reaction rates. With a few exceptions, the state of our knowledge does not permit this, at least within the scope of a general purpose stormwater management model like SWMM. Instead one has to rely on empirical relationships developed from site-specific monitoring data.

Strecker et al. (2001) discuss the challenges of using monitoring data to develop consistent estimates of BMP effectiveness and pollutant removal. The International Stormwater BMP Database (www.bmpdatabase.org) provides a comprehensive compilation of BMP performance data from over 500 BMP studies on 17 different categories of BMPs and LID practices. It is continually updated with new data contributed by the stormwater management community. Table 5-2 lists the median influent and effluent event mean concentrations (EMCs) for a variety of BMP categories and pollutants that were compiled from this database. The cells highlighted in yellow indicate that a statistically significant removal of the pollutant was achieved by the BMP category. A summary of the median removal percentages of several common pollutants treated by filtration, ponds, and wetlands published in the Minnesota Stormwater Manual is listed in Table 5-3. Most of these percentages are consistent with those inferred from median EMC numbers in the BMP database table 5-2.

Table 5-1 Treatment processes used by various types of BMPs

Process	Definition	Example BMPs
Sedimentation	Gravitational settling of suspended particles from the water column.	Ponds, wetlands, vaults, and tanks.
Flotation	Separation of particulates with a specific gravity less than water (e.g., trash, oil and grease).	Oil-water separators, density separators, dissolved-air flotation.
Filtration	Removal of particulates by passing water through a porous medium like sand, gravel, soil, etc.	Sand filters, screens, and bar racks.
Infiltration	Allowing captured runoff to infiltrate into the ground reducing both runoff volume and loadings of particulates and dissolved nutrients and heavy metals.	Infiltration basins, ponds, and constructed wetlands.
Adsorption	Binding of contaminants to clay particles, vegetation or certain filter media.	Infiltration systems, sand filters with iron oxide, constructed wetlands.
Biological Uptake and Conversion	Uptake of nutrients by aquatic plants and microorganisms; conversion of organics to less harmful compounds by bacteria and other organisms.	Ponds and wetlands.
Chemical Treatment	Chemicals used to promote settling and filtration. Disinfectants used to treat combined sewer overflows.	Ponds, wetlands, rapid mixing devices.
Natural Degradation (volatilization, hydrolysis, photolysis)	Chemical decomposition or conversion to a gaseous state by natural processes.	Ponds and wetlands.
Hydrodynamic Separation	Uses the physics of flowing water to create a swirling vortex to remove both settleable particulates and flotables.	Swirl concentrators, secondary current devices, oil-water separators.

Table 5-2 Median inlet and outlet EMCs for selected stormwater treatment practices

Pollutant	Media Filtration		Detention Basin		Retention Pond		Wetland Basin		Manufactured Device	
	In	Out	In	Out	In	Out	In	Out	In	Out

TSS mg/L	52.7	8.7	66.8	24.2	70.7	13.5	20.4	9.06	34.5	18.4
F. Coliform, #/100mL	1350	542	1480	1030	1920	707	13000	6140	2210	2750
Cadmium, ug/L	0.31	0.16	0.39	0.31	0.49	0.23	0.31	0.18	0.40	0.28
Chromium, ug/L	2.02	1.02	5.02	2.97	4.09	1.36			3.66	2.82
Copper, ug/L	11.28	6.01	10.62	5.67	9.57	4.99	5.61	3.57	13.42	10.16
Lead, ug/L	10.5	1.69	6.08	3.10	8.48	2.76	2.03	1.21	8.24	4.63
Nickel, ug/L	3.51	2.20	5.64	3.35	4.46	2.19			3.84	4.51
Zinc, ug/L	77.3	17.9	70.0	17.9	53.6	21.2	48.0	22.0	87.7	58.5
Total P, mg/L	0.18	0.09	0.28	0.22	0.30	0.13	0.13	0.08	0.19	0.12
Orthophosphate, mg/L	0.05	0.03	0.53	0.39	0.10	0.04	0.04	0.02	0.21	0.10
Total N, mg/L	1.06	0.82	1.40	2.37	1.83	1.28	1.14	1.19	2.27	2.22
TKN, mg/L	0.96	0.57	1.49	1.61	1.28	1.05	0.95	1.01	1.59	1.48
NO_X, mg/L	0.33	0.51	0.55	0.36	0.43	0.18	0.24	0.08	0.41	0.41

Source: International Stormwater BMP Database, "International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals", July 2012 (www.bmpdatabase.org).

Table 5-3 Median pollutant removal percentages for select stormwater BMPs

Pollutant	**Sand Filter**	**Ponds**	**Wetlands**
Total Suspended Solids	85	84	73
Total Phosphorus	77	50	38
Particulate Phosphorus	91	91	69
Dissolved Phosphorus	60	0	0
Total Nitrogen	35	30	30
Zinc and Copper	50	70	70
Bacteria	80	60	60

Source: Minnesota Stormwater Manual (http://stormwater.pca.state.mn.us).

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BMP Treatment Representation

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here

SWMM 5 allows treatment to be applied to any water quality constituent at any node of the conveyance network.

Treatment will act to reduce the nodal concentration of the constituent from the value it had after Step 2 of the water quality routing procedure described in section 5.3 (after a new mixture concentration has been computed for the node but before any outflow from the node is sent into any downstream links).

The degree of treatment for a constituent is prescribed by the user, either as a concentration remaining after treatment or as the fractional removal achieved. It can be a function of the current concentration or fractional removal of any set of constituents as well as the current flow rate. For storage nodes, it can also depend on water depth, surface area, routing time step, and hydraulic residence time. Because treatment is applied at every time step, the resulting pollutant concentrations can vary throughout a storm event and will not necessarily represent an event mean concentration (EMC). The exception, of course, would be if treatment is specified as simply a constant concentration that is not dependent on any other variables.

The effect of treatment for a particular pollutant at a particular node can be expressed mathematically using one of the following general expressions (some specific examples will be presented later on):

$$c(t + \Delta t) = c(\boldsymbol{C}, \boldsymbol{R}, \boldsymbol{H}) \quad (5\text{-}10)$$

$$c(t + \Delta t) = \big(1 - r(\boldsymbol{C}, \boldsymbol{R}, \boldsymbol{H})\big)C_{in}(t + \Delta t) \quad (5\text{-}11)$$

where:

c	=	nodal pollutant concentration after treatment is applied
C_{in}	=	pollutant concentration in the node's inflow stream
$c(\ldots)$	=	concentration-based treatment function
$r(\ldots)$	=	removal-based treatment function
$\boldsymbol{C}$	=	vector of nodal pollutant concentrations before treatment is applied
$\boldsymbol{C_{in}}$	=	vector of pollutant concentrations in the node's inflow stream
$\boldsymbol{R}$	=	vector of fractional removals resulting from treatment
$\boldsymbol{H}$	=	vector of hydraulic variables at the current time step.

Note that if treatment is made a function of pollutant concentrations, then for concentration-based treatment these represent the concentrations at the node prior to treatment while for removal-based functions they are the concentrations in the node's combined influent stream. If the node has no volume (e.g., is a non-storage node) then these two types of concentrations are equivalent.

The hydraulic variables that can appear in a treatment expression include the following:

FLOW	flow rate into the node in user defined flow units
DEPTH	average water depth in the node over the time step (ft or m)
AREA	average surface area of the node over the time step (ft^2 or m^2)
DT	current routing time step (seconds)
HRT	hydraulic residence time of water in a storage node (hours).

The hydraulic residence time is the average time that water has spent within a completely mixed storage node. It is continuously updated for each storage node as the simulation progresses by evaluating the following expression:

Figure 5.4 shows the result of using this treatment expression when routing a 6-hour runoff hydrograph with a peak flow of 20 cfs through a half acre dry detention pond whose outlet is a 9" high by 18" wide orifice. The TSS in the runoff has a constant EMC of 100 mg/L. The resulting TSS concentration in the pond over both the filling and emptying periods are plotted in the figure, as are the inflow hydrograph and pond water depth. Note that during the inflow period the TSS remains at 100 mg/L and begins to settle out once the inflow ceases. As the pond depth decreases while it empties more solids settle out reducing the TSS level until the residual concentration of 20 mg/L is reached.

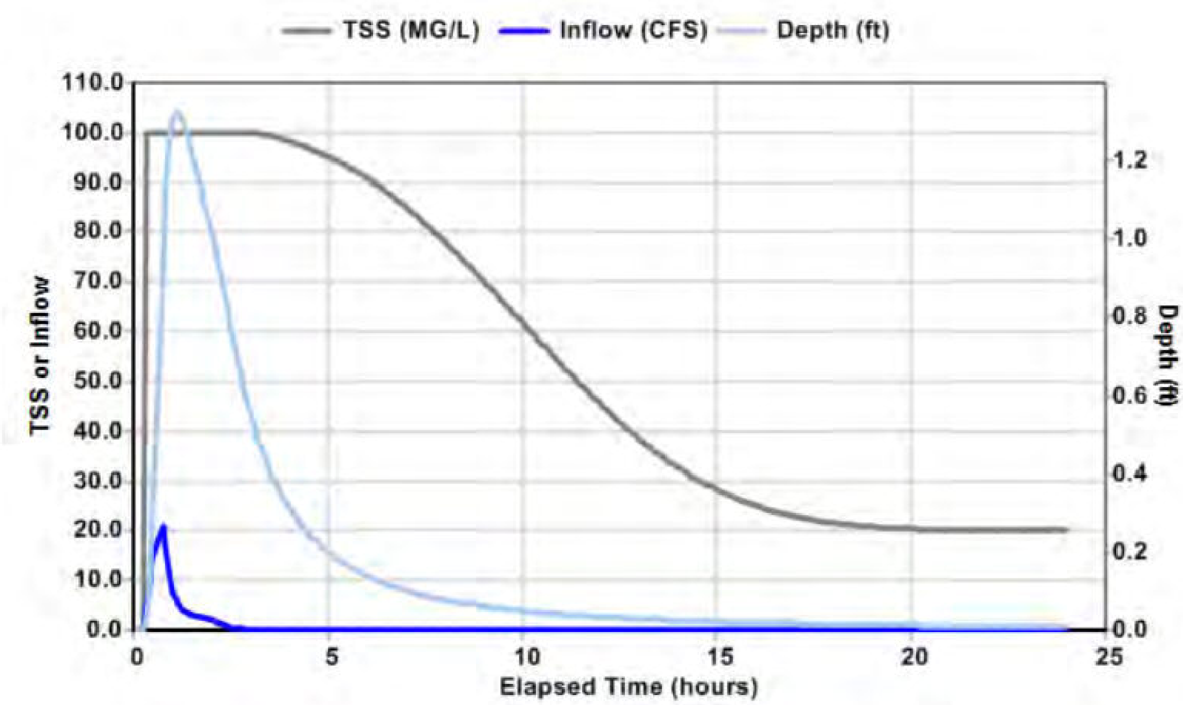

Figure 5-4 Gravity settling treatment of TSS within a detention pond

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LID Computational Steps in SWMM5

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LID computations are a sub-procedure of SWMM's runoff calculations. They are made at each runoff time step, for each subcatchment that contains LID controls, immediately after the runoff from the non-LID portions (both pervious and impervious) of the subcatchment have been found and before any groundwater calculations are made (see Section 3.4 of Volume I). The computations for an individual LID unit include the following four steps:

1. Determine the amount of inflow ($i + q_0$) treated by the LID unit.
2. Evaluate the various flux terms (*e, f* and *q*) on the right-hand side of the applicable flow continuity equations.
3. Solve the continuity equations for the new value of each layer's moisture level at the end of the time step.
4. Add the unit's surface runoff (q_1), infiltration (f_3), and underdrain flow (q_3) to the subcatchment's totals.

The process of determining the inflow to the LID unit in step 1 depends on whether the unit comprises only a portion of its subcatchment's area or if it occupies the entire subcatchment. In the former case the runoff rate q_0 treated by the unit can be computed as:

$$q_0 = q_{imp} F_{out} R_{LID} \tag{6-61}$$

where

q_{imp} = total impervious area runoff rate (ft/sec),

F_{out} = fraction of impervious area runoff routed to the subcatchment's outlet,

R_{LID} = capture ratio of the LID unit.

Note that F_{out} accounts for the possibility that the user has assigned some portion of the subcatchment's impervious area runoff to be re-routed onto its pervious area using SWMM's overland flow re-routing option (explained in Section 3.6 of Volume I). When there is no internal re-routing (or disconnecting) of impervious area F_{out} is equal to 1.0. Also introduced is a new parameter, the LID unit's capture ratio R_{LID}. It is defined as the amount of the subcatchment's impervious area that is directly connected to the LID unit divided by the area of the LID unit itself.

When a single LID unit occupies the entire subcatchment q_0 is comprised of any external overland flow routed onto the subcatchment. Such flow can consist of runoff originating from other upstream subcatchments as well as any underdrain flow from other LID units routed onto the subcatchment.

Step 2 of the computational procedure evaluates the flux terms on the right hand side of the governing continuity equation for each layer of the LID unit being analyzed. These terms depend on the current moisture level stored in each layer. Section 6.2 has discussed in detail how each flux term is computed. Recall that evapotranspiration is evaluated first, moving from the top to the bottom of the LID unit. The remaining flux terms are then evaluated in the opposite direction, moving from the bottom to the topmost layer of the unit.

Step 3 integrates the governing continuity equations over a single time step to find new values for the moisture content in each of the LID unit's layers. Let $\boldsymbol{x}$ be the vector of the layer moisture contents, where $\boldsymbol{x} = [\phi_1 d_1, D_2\theta_2, \phi_3 d_3, D_4(1-F_4)\theta_4]$, and let $\boldsymbol{\Gamma} = [\Gamma_1, \Gamma_2, \Gamma_3, \Gamma_4]$ be the vector of the net flux (inflow minus outflow) of water through each layer (i.e., the right hand side value of each layer's continuity equation). If a particular layer i does not apply to a given LID unit, such as the soil layer for a rain barrel, then both x_i and Γ_i would be zero. Now the flow continuity equations can be written more compactly as:

$$\frac{\partial \boldsymbol{x}}{\partial t} = \boldsymbol{\Gamma}(\boldsymbol{x}(t)) \tag{6-62}$$

where in general $\boldsymbol{\Gamma}$ is a nonlinear function of $\boldsymbol{x}$.

This system of equations can be solved numerically by using the trapezoidal method (Ascher and Petzold, 1998) to discretize them in time as follows:

$$\boldsymbol{x}(t+\Delta t) = \boldsymbol{x}(t) + [\Omega\boldsymbol{\Gamma}(\boldsymbol{x}(t+\Delta t) + (1-\Omega)\boldsymbol{\Gamma}(\boldsymbol{x}(t))]\Delta t \qquad (6\text{-}63)$$

where $\Omega = 0.5$ and Δt is the wet hydrologic time step used for computing runoff. (See Section 3.5 of Volume I for a discussion of SWMM's runoff time steps.) This equation makes the new moisture content in the LID unit equal to the previous moisture content plus the average net flow volume occurring over the time step. At time 0 the moisture content in the LID unit's soil and storage layers is set to a user-supplied percent of saturation while the other layer moisture levels 00start at 0.

Because $\boldsymbol{\Gamma}(\boldsymbol{x}(t+\Delta t))$ appearing on the right hand side of Equation 6-55 depends on the unknown new moisture content, an iterative method must be used to solve the equation. Let $\boldsymbol{x}(t+\Delta t)^{\nu}$ be the estimate of $\boldsymbol{x}(t+\Delta t)$ at iteration ν, where initially $\boldsymbol{x}(t+\Delta t)^0 = \boldsymbol{x}(t)$. (Note that ν is an iteration counter, not a power.) Then for iteration $\nu+1$ the new estimate of $\boldsymbol{x}(t+\Delta t)$ is:

$$\boldsymbol{x}(t+\Delta t)^{\nu+1} = \boldsymbol{x}(t) + [\Omega\boldsymbol{\Gamma}(\boldsymbol{x}(t+\Delta t)^{\nu} + (1-\Omega)\boldsymbol{\Gamma}(\boldsymbol{x}(t))]\Delta t \qquad (6\text{-}64)$$

with the iterations stopping when the change in $\boldsymbol{x}(t+\Delta t)$ is sufficiently small. SWMM uses a tolerance of 0.00328 feet (or 1.0 millimeter) as a stopping tolerance.

If Ω is chosen as 0, then Equation 6-64 becomes equivalent to the Euler method and thus:

$$\boldsymbol{x}(t+\Delta t) = \boldsymbol{x}(t) + \boldsymbol{\Gamma}(\boldsymbol{x}(t))\Delta t \qquad (6\text{-}65)$$

which can be solved directly without resorting to any iterative scheme. Numerical testing has shown that the simpler Euler method works well with all types of controls except for vegetative swales. The latter requires the iterative trapezoidal method with a Ω of 0.5 to produce results with acceptable continuity errors.

When using either Equation 6-64 or 6-65 to update the LID unit's moisture state at each time step, the following lower and upper physical limits on moisture levels must be enforced:

$$0 \le d_1 \le D_1$$
$$\theta_{WP} \le \theta_2 \le \phi_2$$
$$0 \le d_3 \le D_3$$
$$0 \le \theta_4 \le \phi_4$$

Finally, Step 4 merges the outflows from the LID unit with those of the subcatchment as a whole. Any infiltration into the native soil produced by the LID unit is added onto the total infiltration for the subcatchment, which is eventually passed onto SWMM's groundwater module. Any underdrain flow from the LID unit is kept track of separately, so that it can be routed to its designated destination (either another subcatchment or some location in the conveyance system). It is not included as part of the subcatchment's reported surface runoff. Any surface runoff or overflow from the unit $(q_1 A)$ is added to the subcatchment's total runoff flow rate, except if the unit's outflow has been designated for return to the subcatchment's pervious area. In the latter case a separate account is kept of the total return flow and the LID surface flow is added to it.

As regards to water quality, no explicit changes in constituent concentrations are computed as runoff passes through or over an LID control. A subcatchment's pollutant washoff concentration is computed as described in Section 4.3, as if no LID controls existed. Any surface outflow or underdrain flow from each of the subcatchment's LID controls is assigned this concentration.

There are two exceptions to this convention. One applies when the LID units take up less than the full area of the subcatchment and a pollutant has a non-zero rainfall concentration. In that case the washoff load from the non-LID portion of the subcatchment (which already accounts for any wet deposition) is combined with the direct rainfall load from the LID areas to arrive at a modified outflow concentration:

$$C_{out} = \frac{\left[(C_{out} Q_{out})_{non-LID} + C_{ppt} i A_{LID}\right]}{Q_{out,non-LID} + i A_{LID}} \tag{6-66}$$

where

C_{out}	=	concentration of a pollutant in the subcatchment's outflow streams after LID treatment (mass/L),
$C_{out,non\text{-}LID}$	=	concentration of a pollutant in the subcatchment's outflow streams prior to LID treatment (mass/L),
$Q_{out,non\text{-}LID}$	=	surface runoff flow rate leaving the subcatchment prior to any LID treatment (cfs),
C_{ppt}	=	concentration of the pollutant in rainfall (mass/L),
i	=	rainfall rate (ft/sec),
A_{LID}	=	total surface area of all LID units in the subcatchment (ft^2).

The second exception is when a single LID unit occupies its entire subcatchment. In that case there would be no washoff load generated by any non-LID surfaces and the pollutant concentration in the unit's outflow streams would equal that of its inflow stream. Thus for any particular pollutant,

$$C_{out} = \frac{\left((W_{runon}/28.3) + C_{ppt} i A_{LID}\right)}{Q_{runon} + i A_{LID}} \tag{6-67}$$

where Q_{runon} is the combined runoff flow rate (cfs) of all upstream subcatchments routed onto the LID subcatchment, W_{runon} is the total pollutant load (mass/sec) contained in this runoff inflow, and the factor 28.3 converts from cubic feet to liters.

Thus although an LID control does not modify the concentration of a water quality constituent it sees in its inflow stream, it does reduce the total pollutant load passed on to downstream

locations in direct proportion

to the reduction in runoff it produces. When a storm is completely captured by an LID unit its effective pollutant removal efficiency is 100 percent.

6.6 Numerical Example

A numerical example will help demonstrate how SWMM is able to model the dynamic behavior that LID controls exhibit during a rainfall event. Consider a bio-retention cell that captures all of the runoff from a parking lot. It consists of a 24 inch soil layer above a 12 inch gravel reservoir and has a 6-inch high berm surrounding it. The growth medium in the soil layer is the same 85% sand, 5% clay and 5% organic matter blend whose properties were listed previously in Table 6-3 (porosity of 0.52, field capacity of 0.15, wilting point of 0.08, saturated hydraulic conductivity of 4.7 in/hr, suction head of 1.9 inches, and percolation decay constant of 39.3). The void fraction of the gravel storage layer is 0.4 and the exfiltration rate out of this layer into the native soil is 0.4 in/hr. Initially it is assumed that the bio-retention cell is not equipped with an underdrain.

The parking lot is completely impervious and is modeled so that all rainfall becomes immediate runoff. The bio-retention cell takes up 5 % of the total catchment area. Thus its Capture Ratio is $(1 - 0.05) / 0.05 = 19$. The total storage volume contained in the bio-retention cell is 6 inches of above ground surface storage plus $24 \times (0.52 - 0.08)$ inches of soil pore volume plus 12×0.4 inches of gravel volume for a total of 21.36 inches. Considering the unit's capture ratio of 19 plus the area of the unit itself translates into a capacity of $21.36 / (19 + 1) = 1.07$ inches for the entire catchment area. Thus it should be capable of completely capturing and infiltrating all storms at or below this depth. This is just an estimate since it ignores the effect that the 0.4 in/hr exfiltration rate out of the bottom of the unit has in making more storage available as an event unfolds.

The parking lot and bio-retention cell were subjected to the 1 inch storm event depicted in Figure 6-7. This is an actual event recorded at a rain gage in Philadelphia, PA during the month of May. The potential evaporation rate for that time of year was 0.18 in/day. SWMM 5 was used to compute the hydrologic response of the parking lot and its LID control to this storm event over a 48-hour period starting with completely dry conditions. Results for the bio-retention cell are shown in Figures 6-8 and 6-9. Figure 6-8 shows the variation over time of the surface inflow, soil layer percolation, and storage layer exfiltration. Figure 6-9 shows how the moisture level within each layer, as a percentage of its full storage capacity, varies with time.

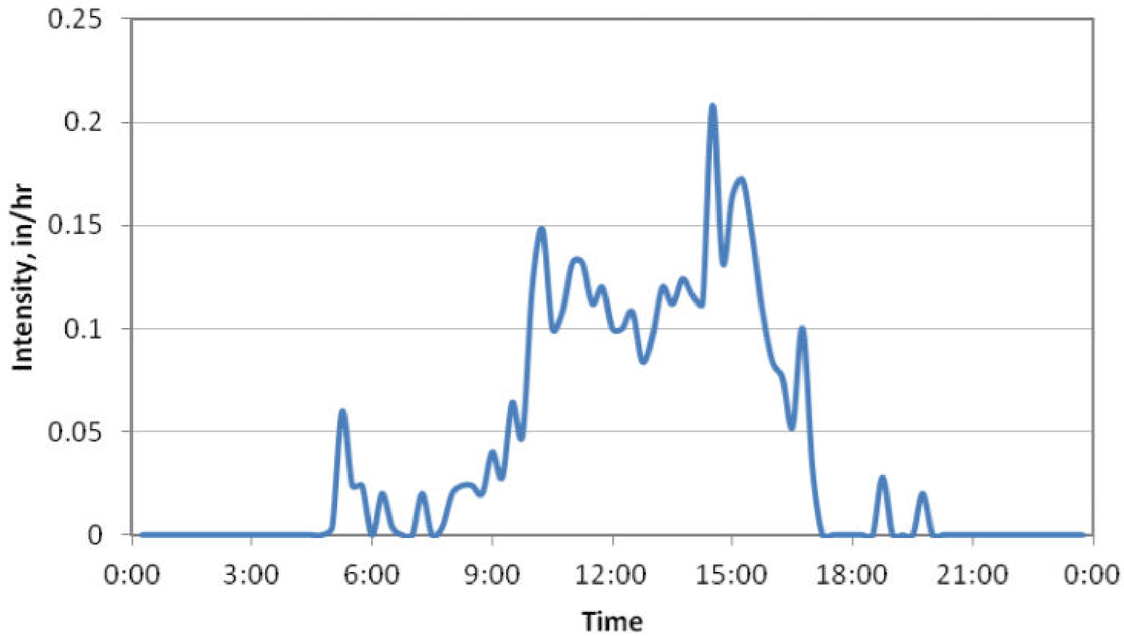

Figure 6-7 Storm event used for the LID example

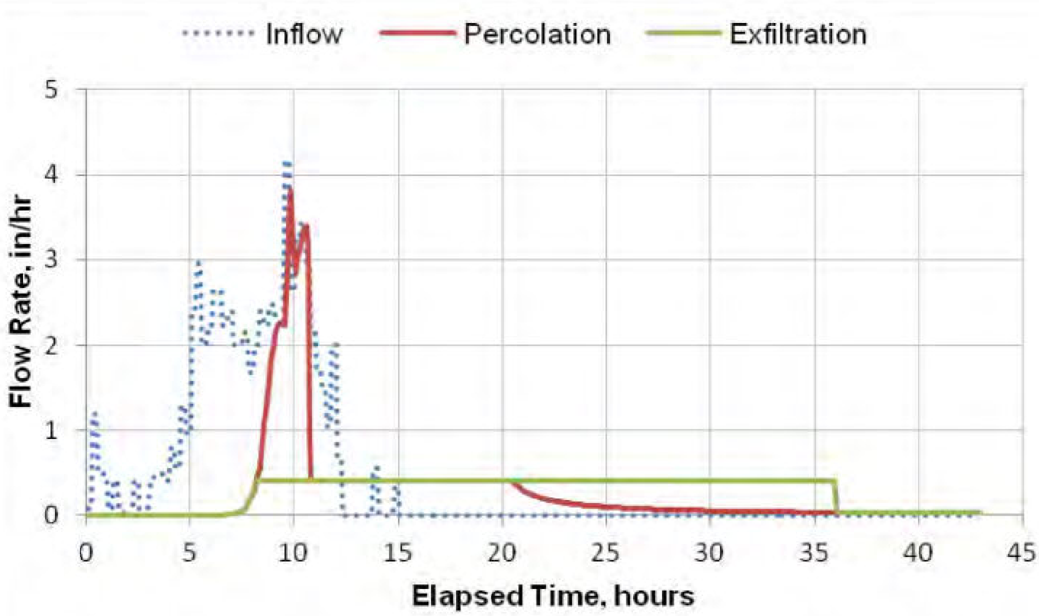

Figure 6-8 Flux rates through the bio-retention cell with no underdrain

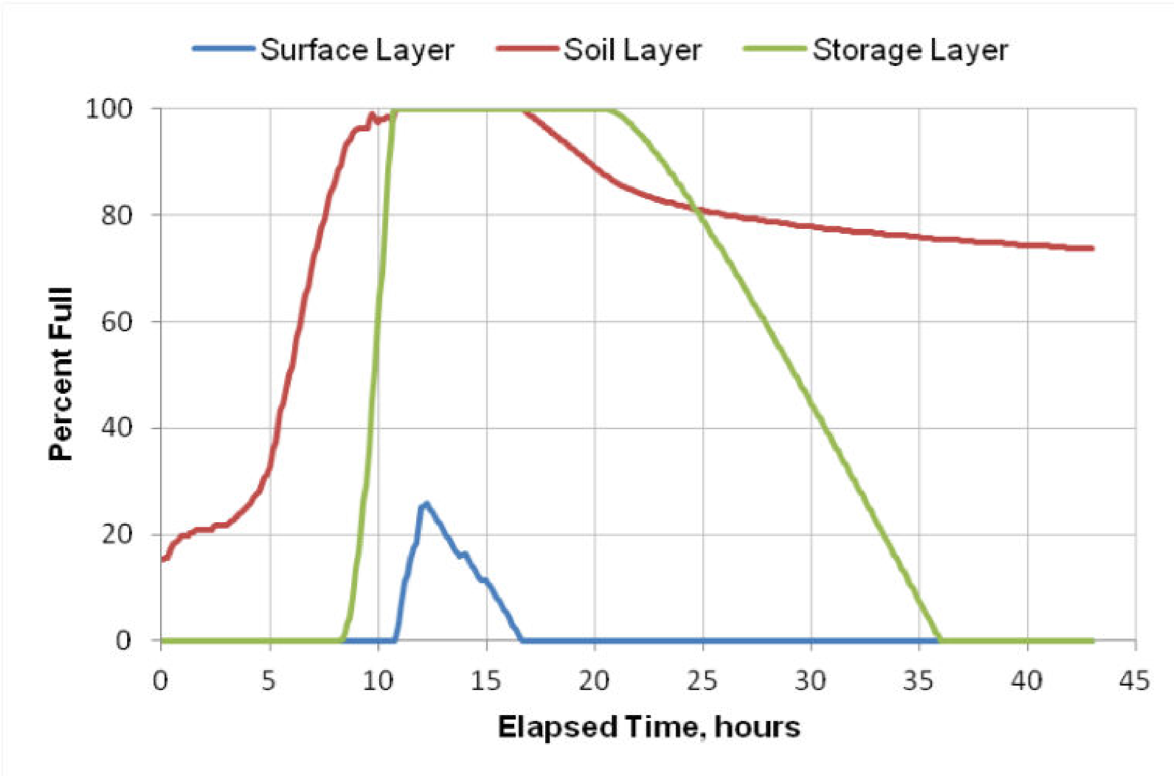

Figure 6-9 Moisture levels in the bio-retention cell with no underdrain

The bio-retention cell is able to completely capture this 1-inch storm. Although both the storage and soil zones become saturated and some surface ponding occurs (up to a maximum $0.25 \times 6 = 1.5$ inches), no runoff is produced. The dynamics of flow through the unit can be broken up into five distinct phases:

1. Wetting Phase:
   For the first 5 hours of the storm event the soil fills with water up to its field capacity of 0.15 (29% of saturation). During this time the soil layer accepts all inflow to the unit without sending any outflow to the storage layer.

2. Filling Phase:
   During the next 6 hours as the unit continues to receive inflow, water begins to percolate out of the soil layer and into the storage layer at an increasing rate. For the first 3 hours of this period, while the percolation rate is below the bottom exfiltration rate, all of this water leaves the unit and keeps the storage layer dry. Eventually the soil moisture content becomes high enough so that the percolation rate exceeds the exfiltration rate and the storage layer fills in a matter of 3 hours. During this entire phase the unit is still able to accept all of the inflow as shown by the absence of any ponded surface water.

3. Saturation Phase:
   After approximately 11 hours both the soil and storage layers have become full. At this point even though the soil conductivity has risen above 4 in/hr, it cannot transmit water any faster than the full storage layer can exfiltrate it at only 0.4 in/hr. During the next 4 hours as the unit continues to receive inflow while full, the excess ponds atop the surface.

4. Draining Phase:
   Once inflow to the unit ceases at about 15 hours it begins to drain and water levels recede from the top on down. Surface ponding is gone by 16.5 hours. Then the soil begins to drain down at a rate still limited by the slower bottom exfiltration rate since the storage layer remains full. At about hour 21 the soil percolation rate becomes less than the exfiltration rate and the storage layer begins to empty. It then takes another 15 hours for the storage layer to drain down completely.

5. Drying Phase:
   After the storage layer has completely drained, water continues to drain out of the soil layer at a rate lower than the bottom exfiltration rate, so all of it infiltrates into the native soil. This continues until the soil's field capacity moisture is reached. After that, the soil will continue to dry by evapotranspiration until its wilting point is reached.

Now consider what happens when an underdrain is added to the bio-retention cell. The drain is placed at the top of the storage layer so that the layer's full storage capacity can be utilized.

It is assumed to be over-designed so its discharge coefficient is assigned a very large value. The resulting time history of moisture content throughout the cell with the underdrain is shown in Figure 6-10. The drain has prevented any inflow from ponding on top of the unit. As shown in Figure 6-11, the drain carries flow only during the period of time that the storage layer is full. Because it is oversized, it can accept the full amount of water remaining from soil percolation after the bottom exfiltration is accounted for. Compare this with the case of no drain in Figure 6- 8, where the soil percolation rate is limited by the exfiltration rate during the time that the storage layer is full.

The total volume of flow carried away by the underdrain is about 14

% of the total storm volume.

If this flow is sent to a storm sewer which is typically the case, then the bio-retention cell can no longer be said to have fully captured and eliminated runoff from this 1-inch storm.

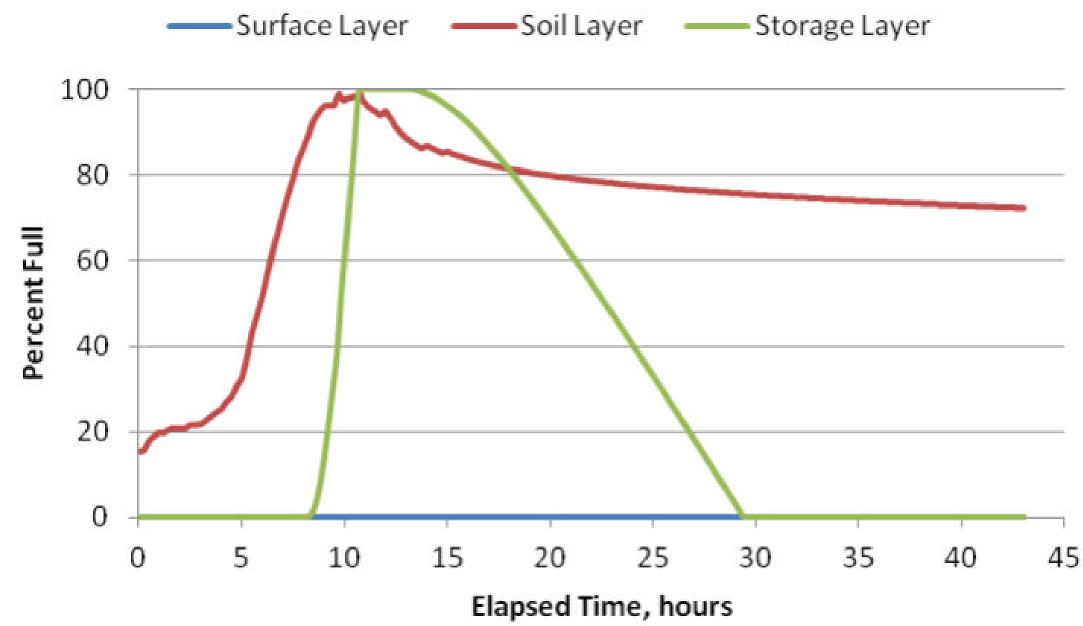

Figure 6-10 Moisture levels in the bio-retention cell with underdrain

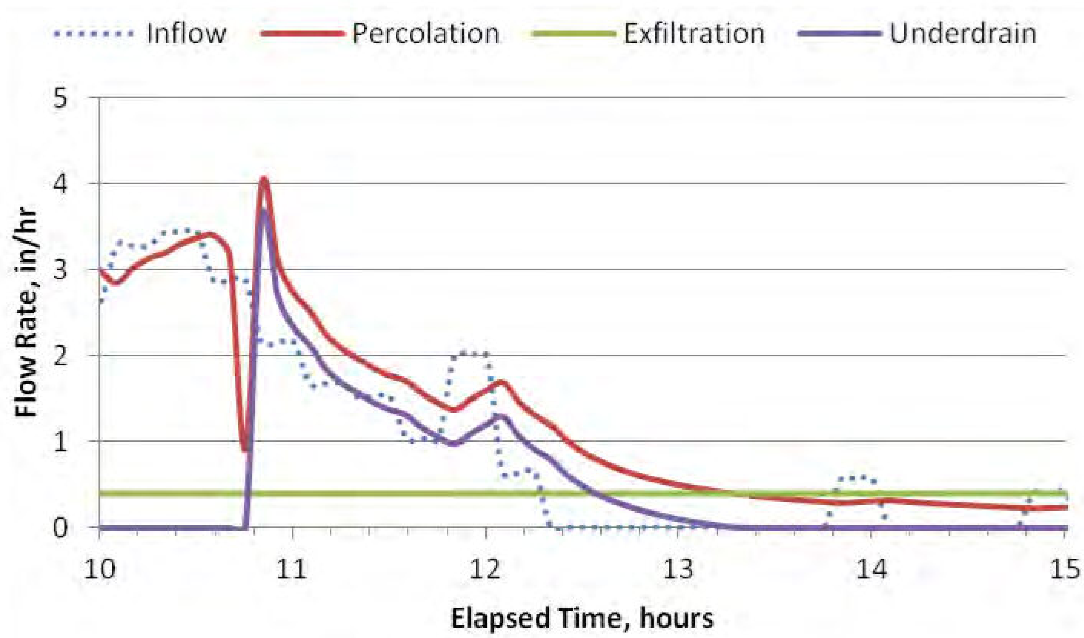

Figure 6-11 Flux rates through the bio-retention cell with underdrain

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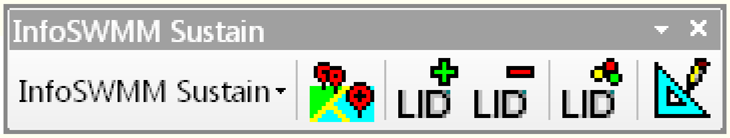
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FInstallation Guide

System Requirements for InfoSWMM w 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, 10.3, 10.4, and 10.5 (**Check your PC ability to run ArcG**
Prerequisites:	**Microsoft Visual C++ 2008 Redistributable - x64 v9.0.30729.17**/**Microsoft Visual C++ 2008 x86 v9.0.30729.17**, **Microsoft Visual C++ 2010 Redistributable - x86 v10.0.40219.1**/**Microsof 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 di much free disk space available as possible. Its virtual memory system needs additional free working on large projects Video/Graphics Adapter: 64 MB RAM minimum, 256 MB RAM or higher recommended. INTEL chipsets supported Networking Hardware: Simple TCP/IP, Network Card or Microsoft Loopback Adapter is requi Manager **Language:** Support Multiple Languages (English, French: Menu, German: Menu & Dialogu Spanish: Menu, and Turkish: Menu) - To change display languages: Control Pa Language -> Formats tab -> select [Language] from the Format select box. **(For the display of InfoSWMM Language Setting)**

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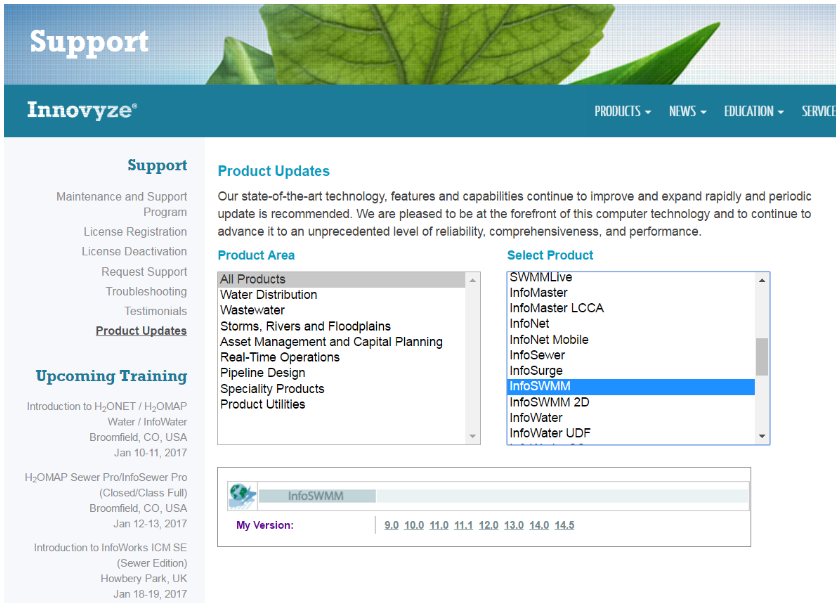
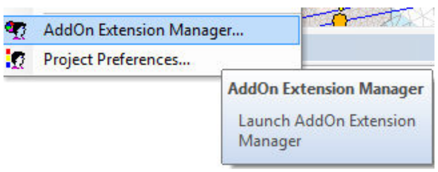
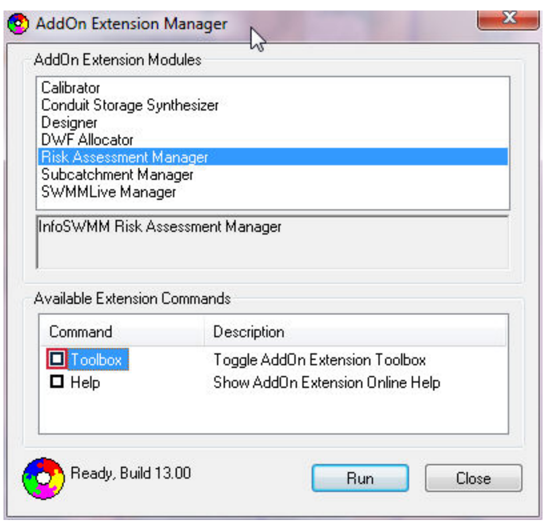
Innovyze programs can only be installed from our Internet website. To install this program or a single user, perform the following procedure:

- Turn on your computer and start Windows. Close any other applications that are currently running.
- 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.
- 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.



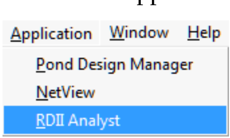
Upon successful installation of the program, the program is initialized from inside H2OMap SWMM InfoSWMM by using the “AddOn Extension Manager” tool. From the Tool Menul, select an Add On as shown below.

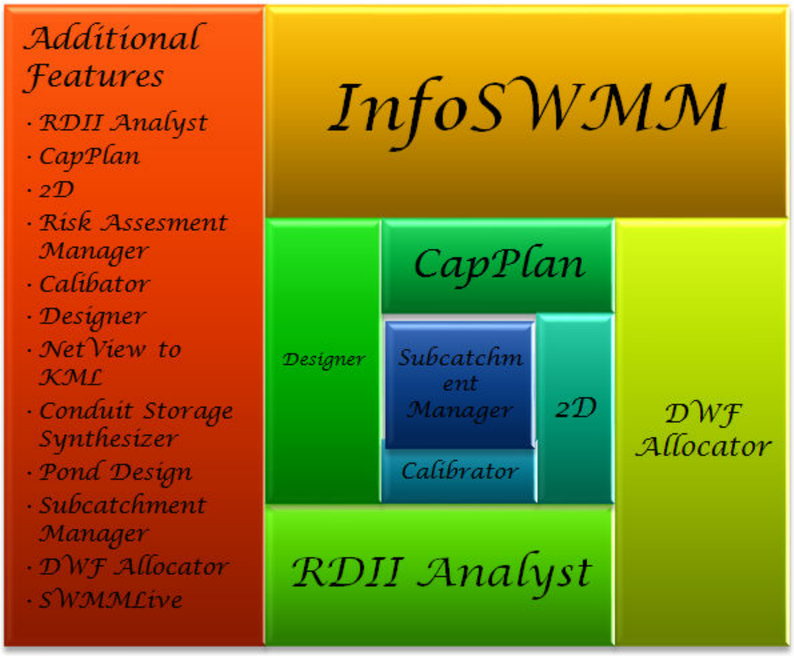




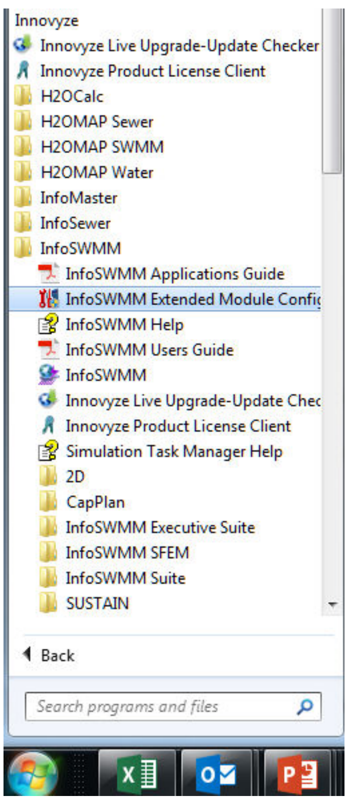
The selected run dialog appears, and it is now available for use. Section 2 discusses each icon and the menu shown below in detail. This program is part of the H2OMap SWMM InfoSWMM Suite.

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.



Using the On Line 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.

StartingInnovyze Help

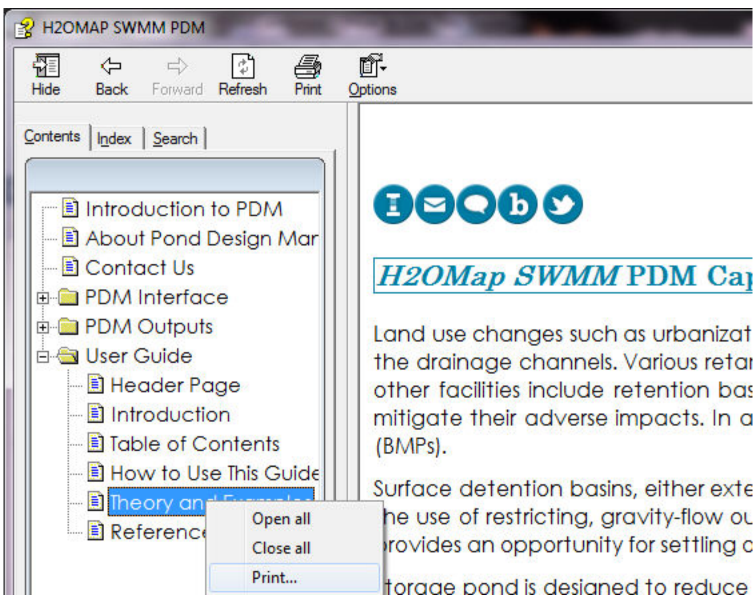
Innovyze Help is available by opening any Innovyze dialog box and pressing the F1 key. You may click on any portion of the dialog box in the help topic for more information.

Navigating the On Line 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

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.

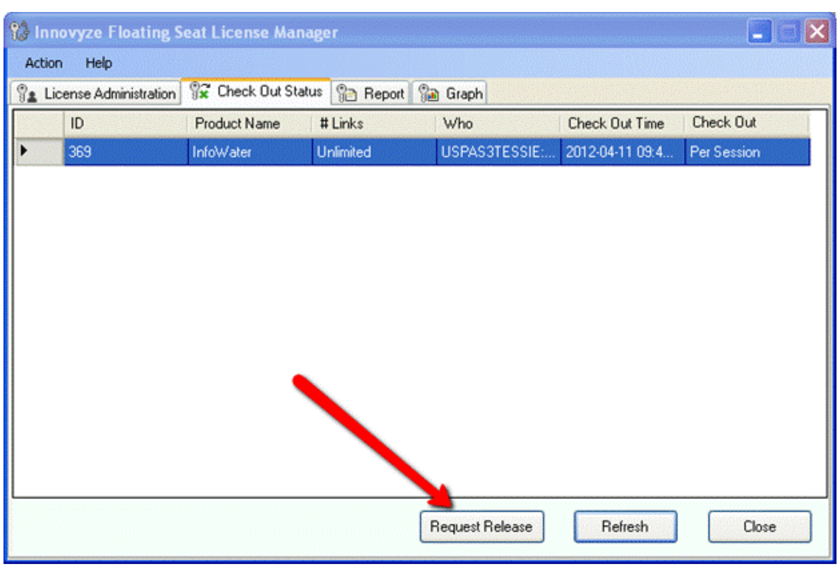
15. Press the **Apply** button. A new Expiration Date should appear.

Press the Close button

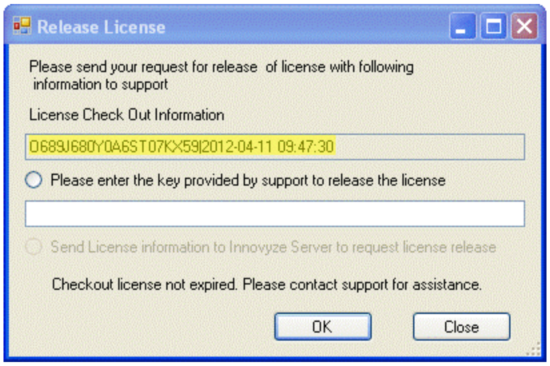
Please follow the instructions below to request a license release key for a floating license.

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 January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 Engine

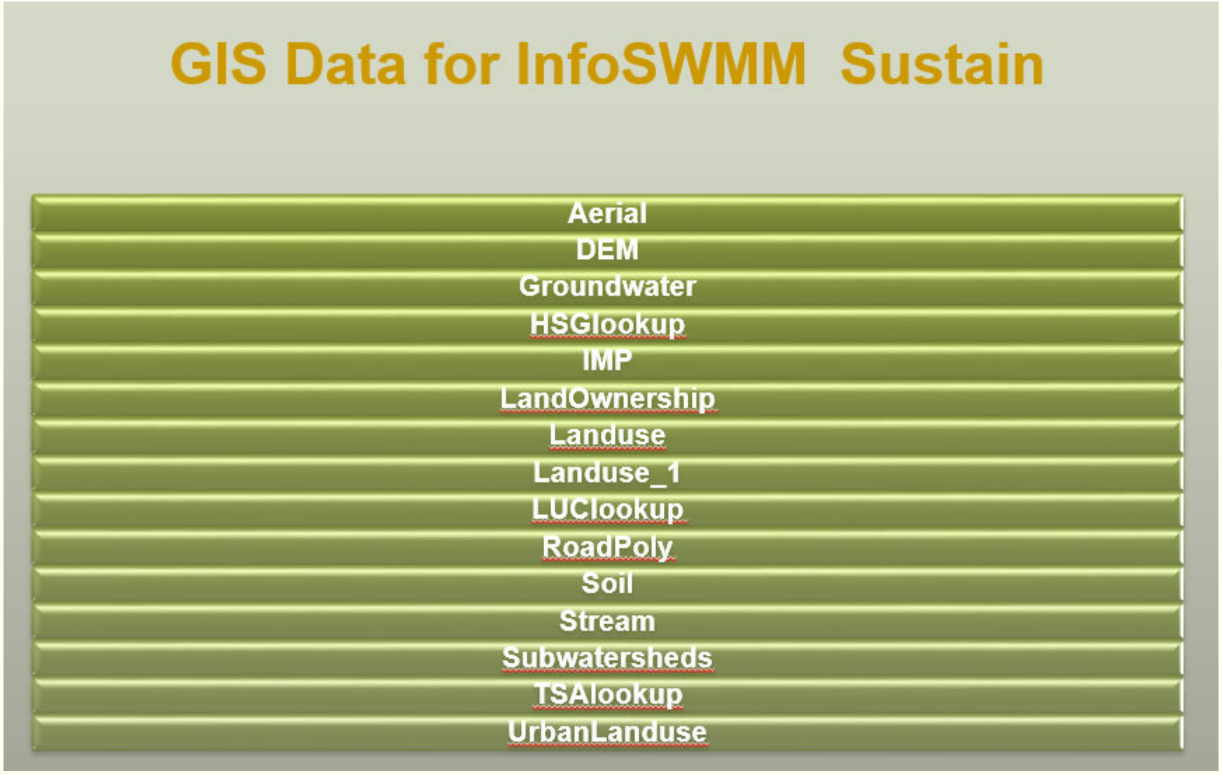
More Questions? Further Help Can be Found by Emailing Support@Innovyze.com or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM

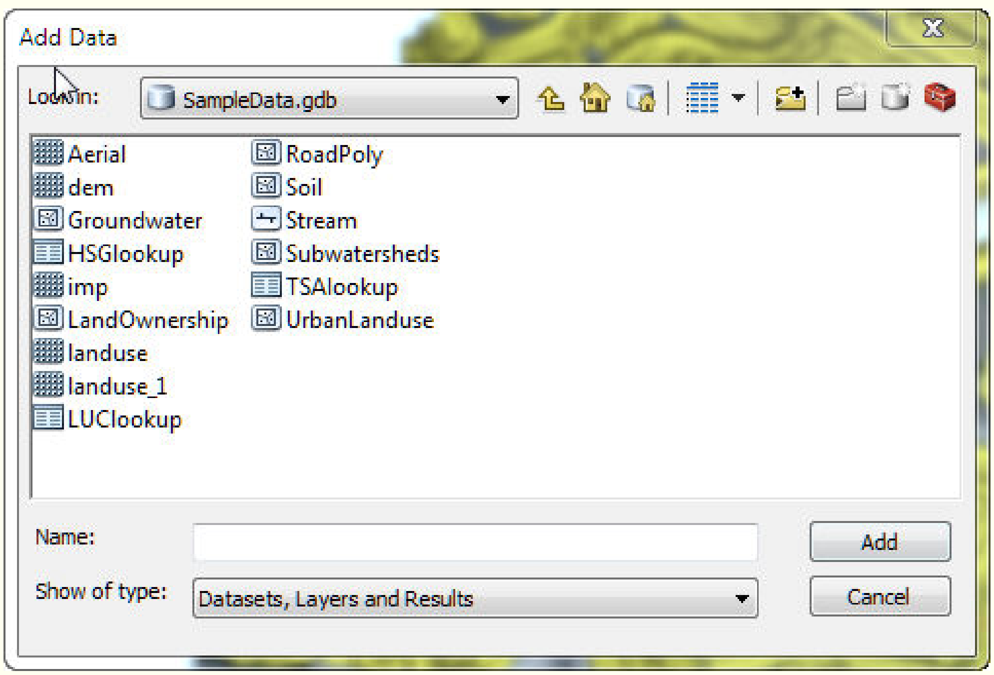
InfoSWMM

GIS Data for InfoSWMM Sustain Tutorials

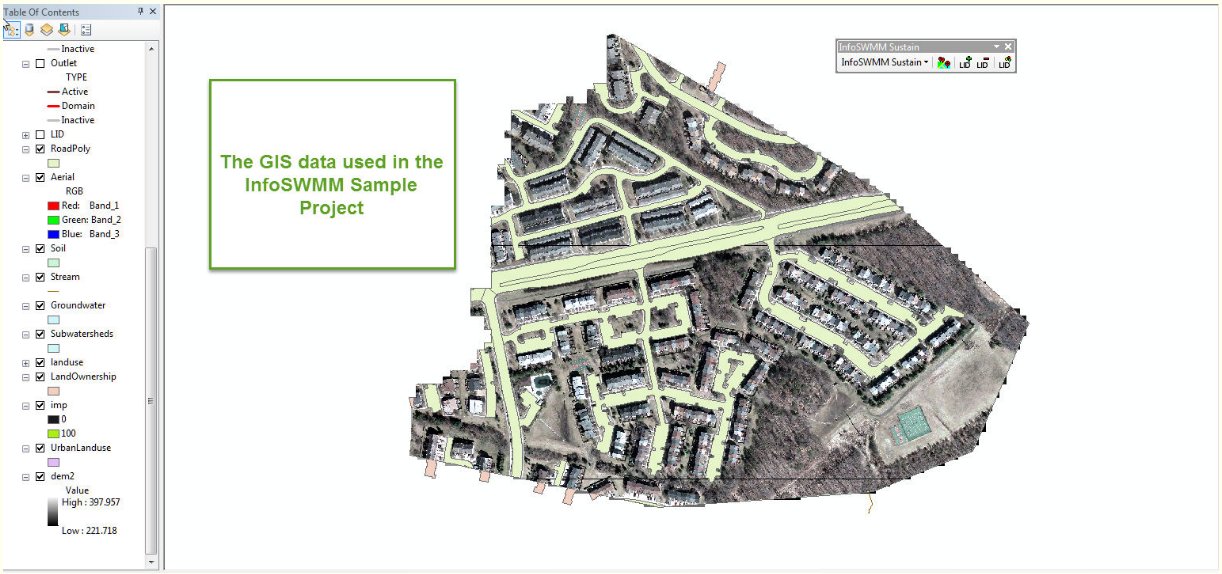
The GIS data needed for the InfoSWMM Tutorials is in the file SampleData.gdb The data includes

1. Aerial
2. DEM
3. Groundwater
4. HSGlookup
5. IMP
6. LandOwnership
7. Landuse
8. Landuse_1
9. LUClookup
10. RoadPoly
11. Soil
12. Stream
13. Subwatersheds
14. TSAlookup
15. UrbanLanduse



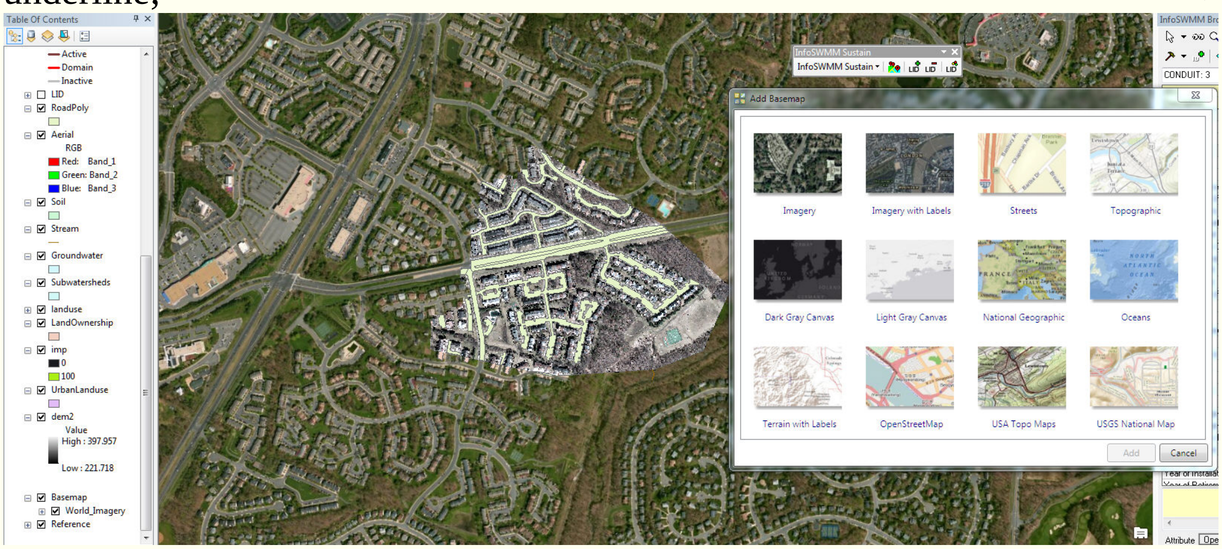


All of the GIS data used in the InfoSWMM Sustain Sample Project font-family: 'Century Gothic', sans-serif; margin-left: 0px; text-decoration: underline; ">l

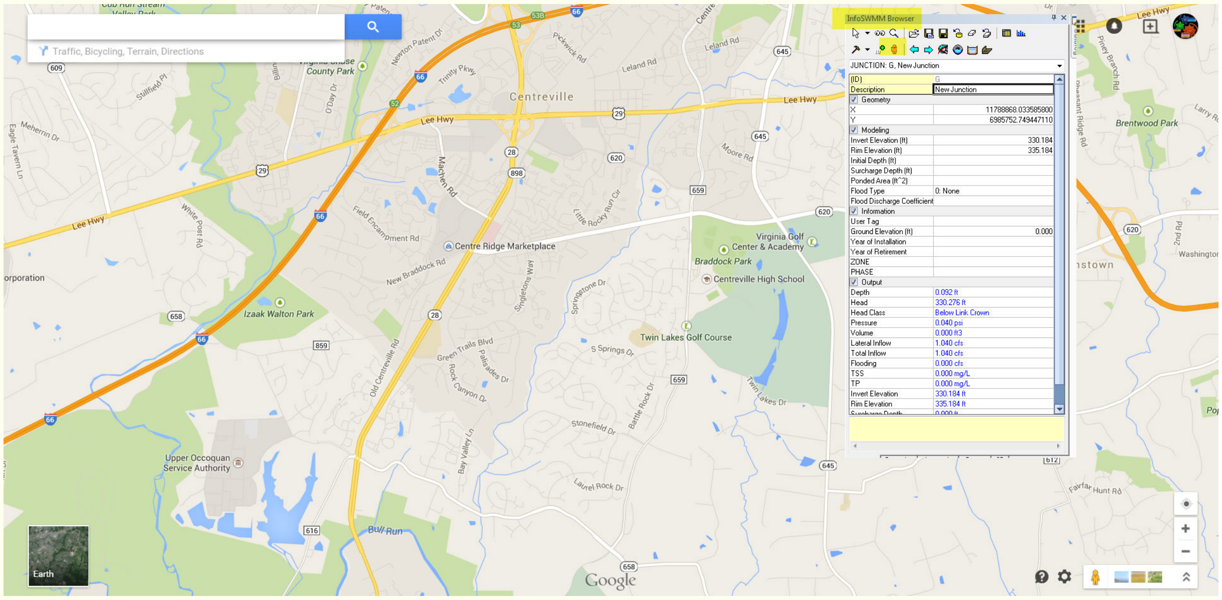


The project site as shown with an ESRI Basemap

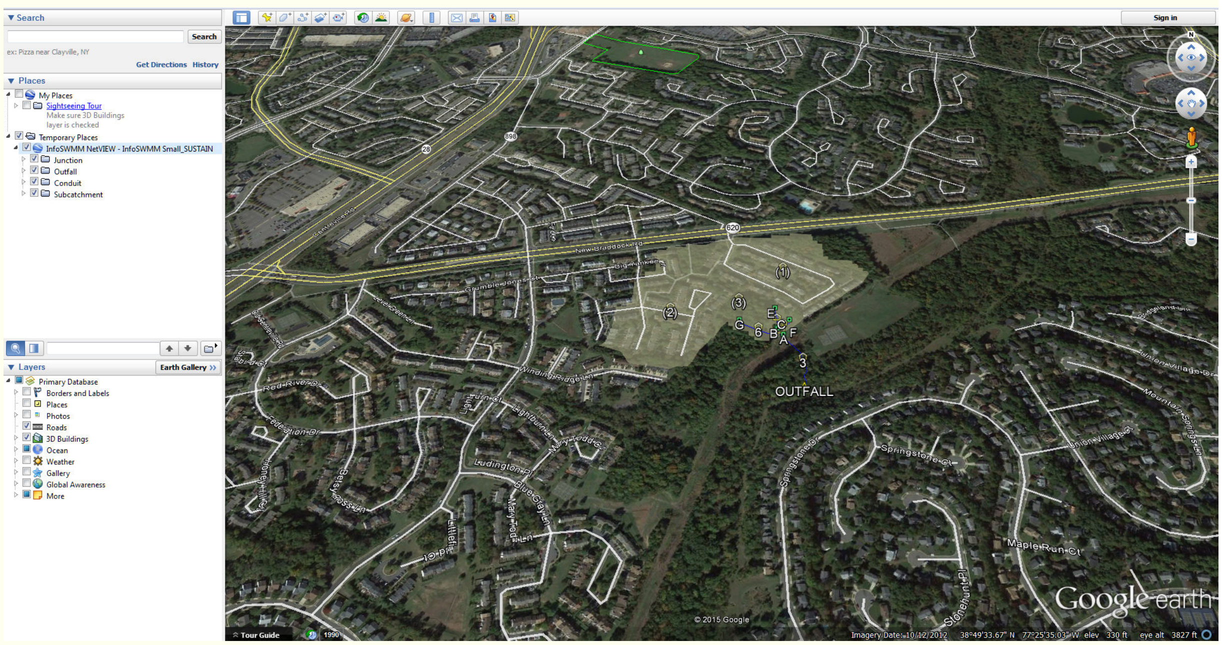
font-family: 'Century Gothic', sans-serif; margin-left: 0px; text-decoration: underline; ">



The Project Site as shown in Google Maps by clicking on the Node Google Map Icon in the InfoSWMM Attribute Browser.



The Project Site as shown in Google Earth by using the InfoSWMM Suite Tool Netview.



Innovyze

Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013

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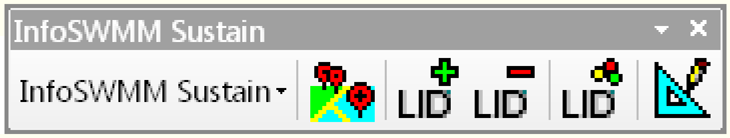
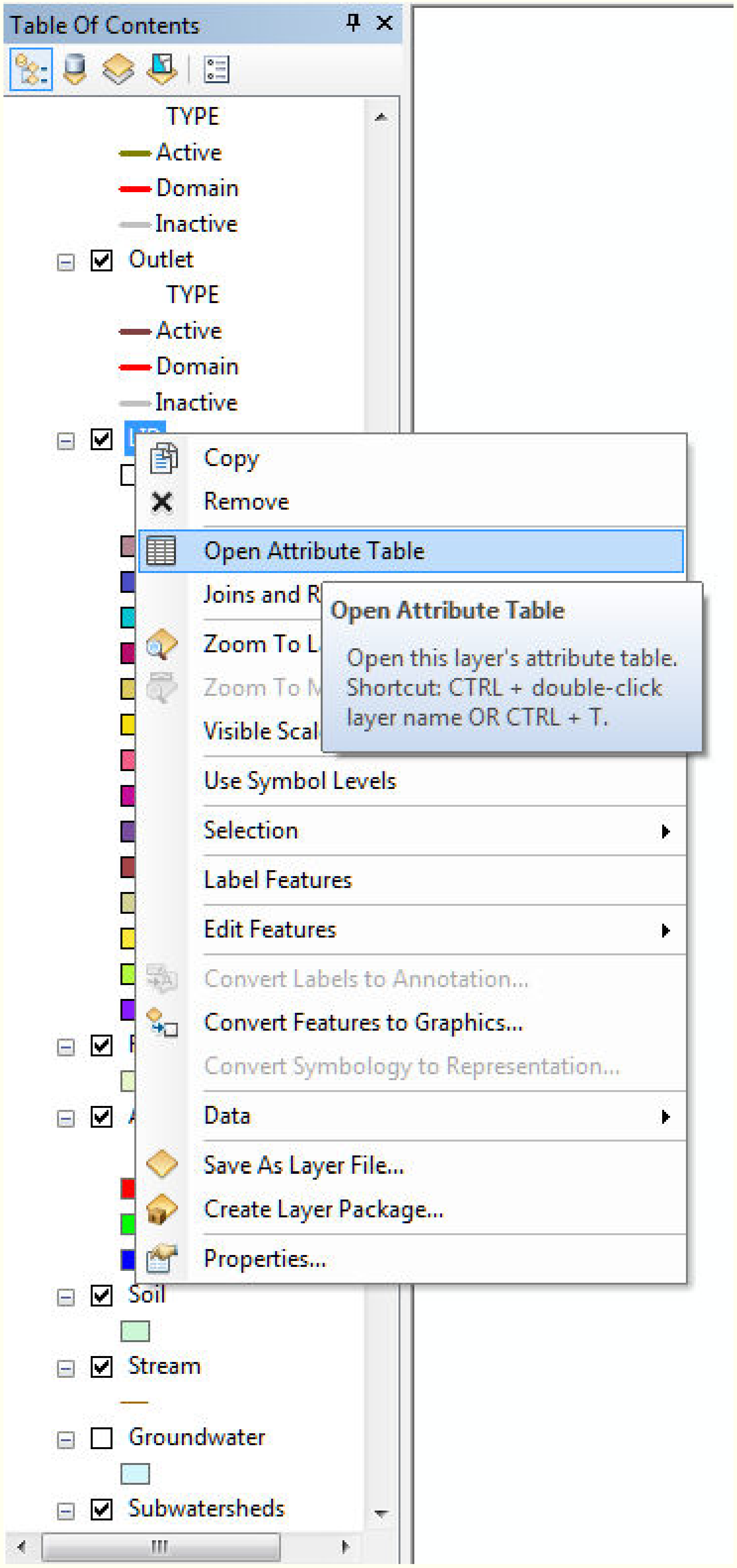

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

How to Delete Existing LID Candidates

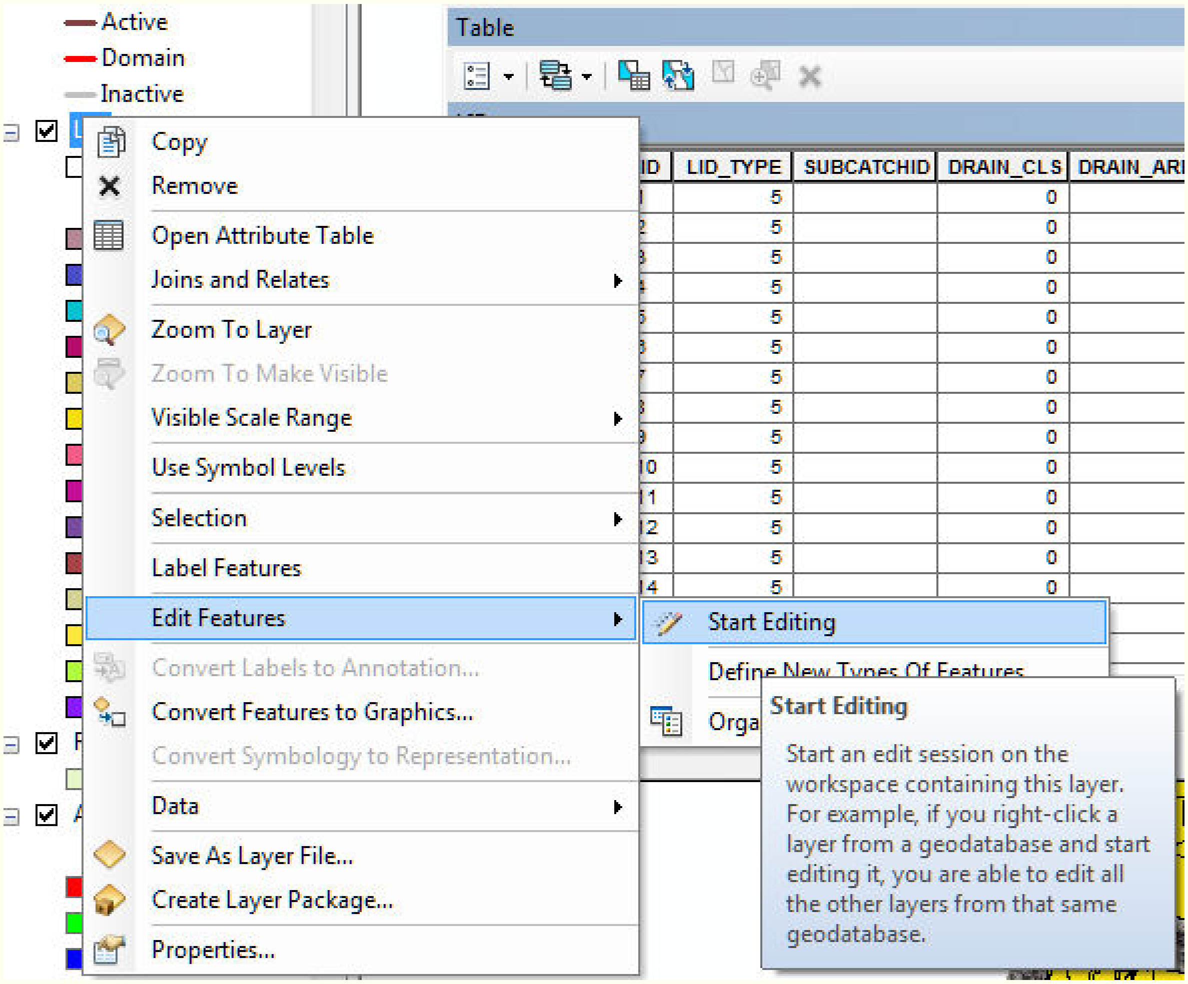
If you have existing LID Candidates in the LID Layer in the Arc Map Table of Contents then you can delete the Candidates by performing the following commands:

Step 1. Right Mouse Click and Open the Attribute Table



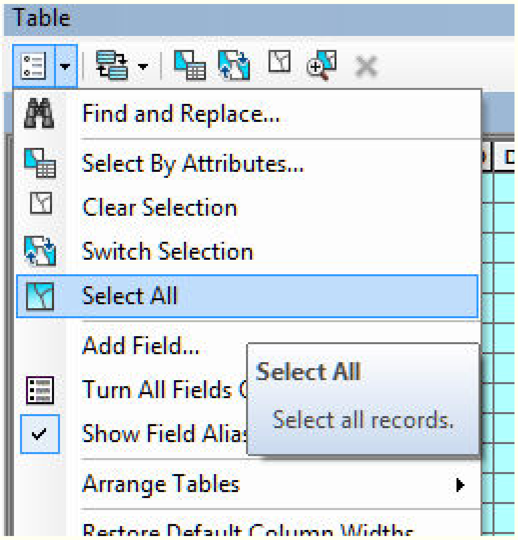
Step 2. Right Mouse Click and Edit the Attribute Table when the Attribute Table is Open

font-family: 'Century Gothic', sans-serif; margin-left: 0px; text-decoration: underline; ">

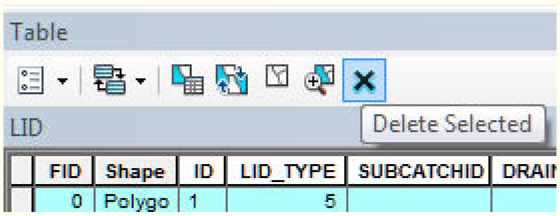


Step 3. Select All

Records.



Step 4. Delete Selected Records.



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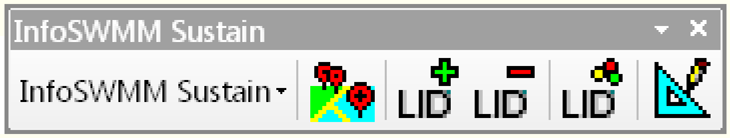

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Expanded Graphing Help

The following functions are available for customizing the graph display in the Sustain Cost Effectiveness Curve. If you do not see one or more of the following buttons while a graph is being displayed, that function is not available for the currently displayed graph type.

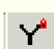
All functions may not be available for all graph types.

 Pan - After zooming in on a portion of the graph, use the Pan feature to shift the graph left and right and up and down.

 Zoom In - Drag and drop the outline around a portion of the graph to zoom in.

 Zoom Out - Click on the graph to zoom out by a fixed amount.

 Horizontal Lock - Locks the graph horizontally so that the pan function will only allow movement in the left and right direction.

 Vertical Lock - Locks the Vertically so that the pan function will only allow movement in the up and down direction.

 Previous Extents - Returns the graph view to the previous extent.

Next Extents - Returns the graph view to the next extent after the previous extent has been used.

Full Extent - Returns the graph view to the full extent.

Auto Pan Left - Automatically pans the zoomed view left. Press Stop Auto Pan to stop.

Auto Pan Right - Automatically pans the zoomed view right. Press Stop Auto Pan to stop.

Auto Pan Stop - Stops the Auto Pan Right or Left.

Copy - Copy Graph - Copies the current graph image to the Clipboard. The contents of the clipboard can be pasted into other applications such as MS Word or Excel.

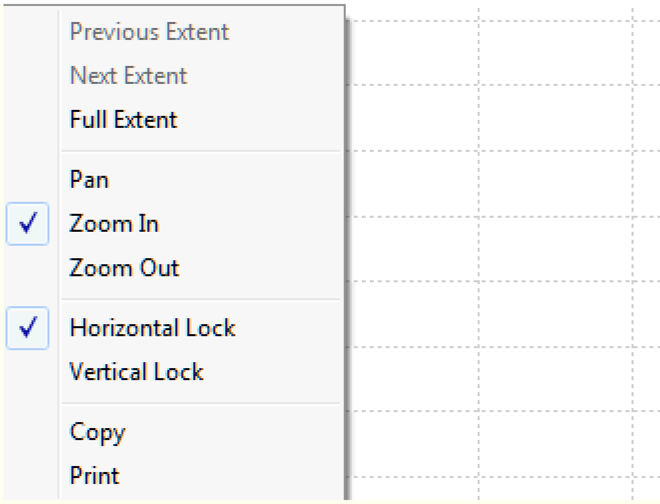
Print - Prints the current graph. You may indicate print margins, whether or not the graphs will be printed in color, and whether or not a border will be included on the graph printout. Click here to learn more.

Properties - Allows the user to adjust the Graph Style and Axis properties of the current graph. See Graph Properties below for details.

Help -

Opens the graph help or Press F1

A Right Mouse Click - Opens up the same set of menu commands.


Previous Extent
Next Extent
Full Extent
Pan
Zoom In
Zoom Out
Horizontal Lock
Vertical Lock
Copy
Print

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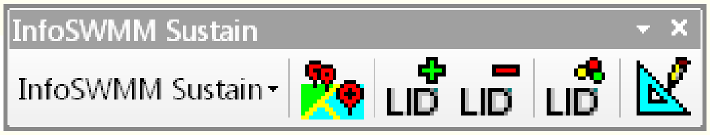
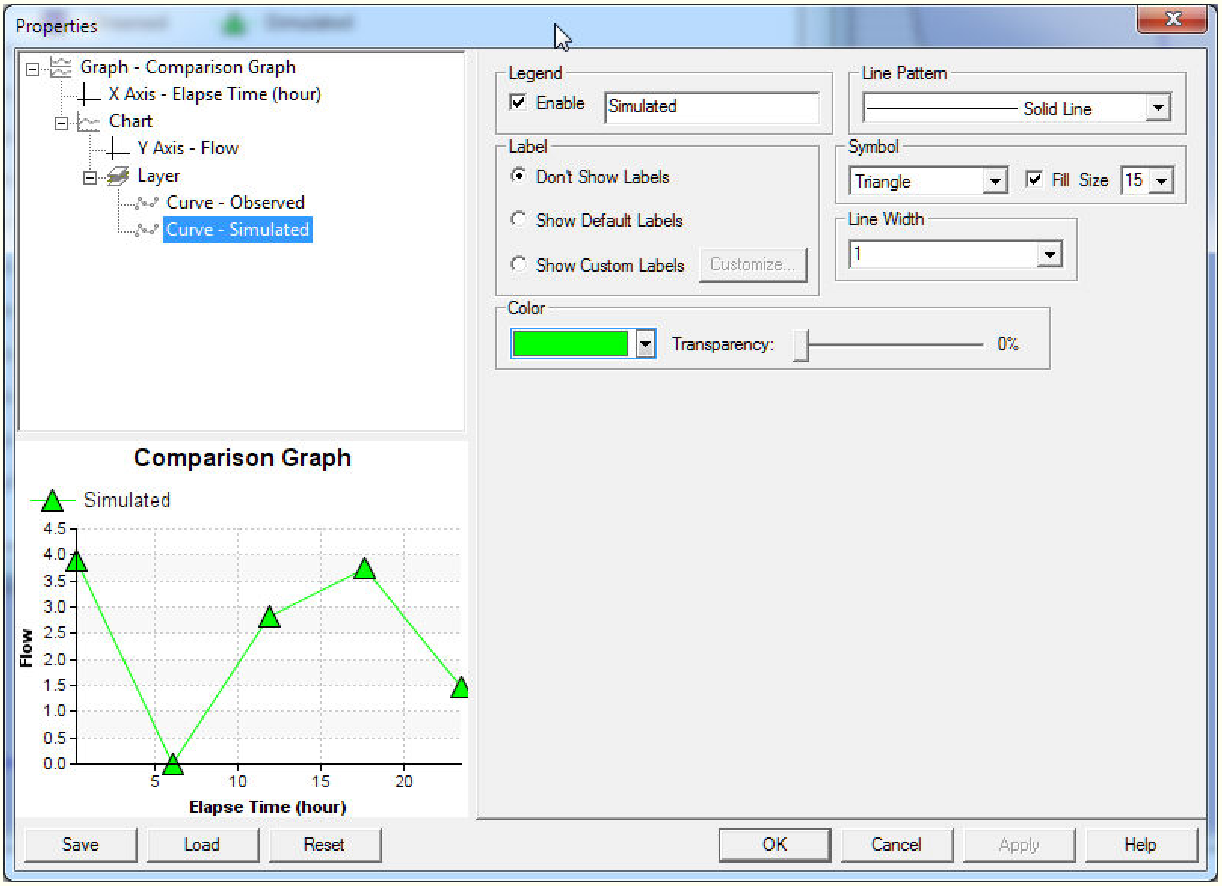
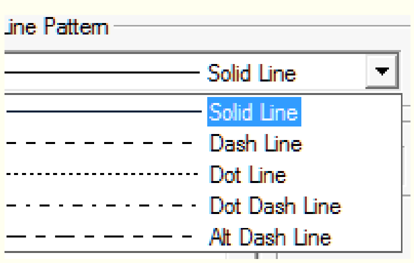

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Graphing Properties

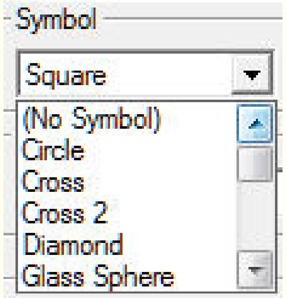
The Graph Property Dialog



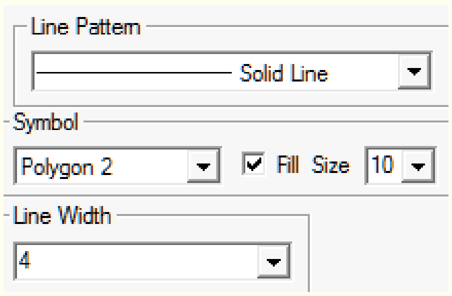
Layer Curve Line Pattern allows you to choose a different line pattern for the data curves.



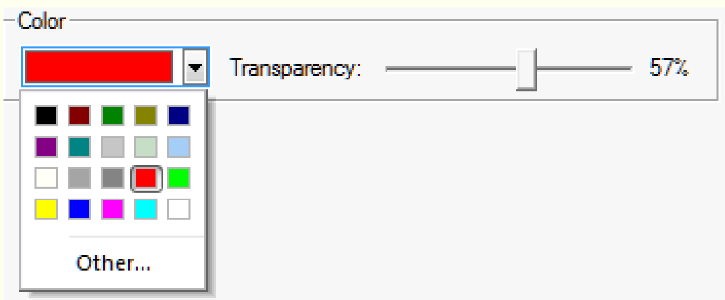
Layer Curve Symbols allows you to choose a different symbol for the data curves.



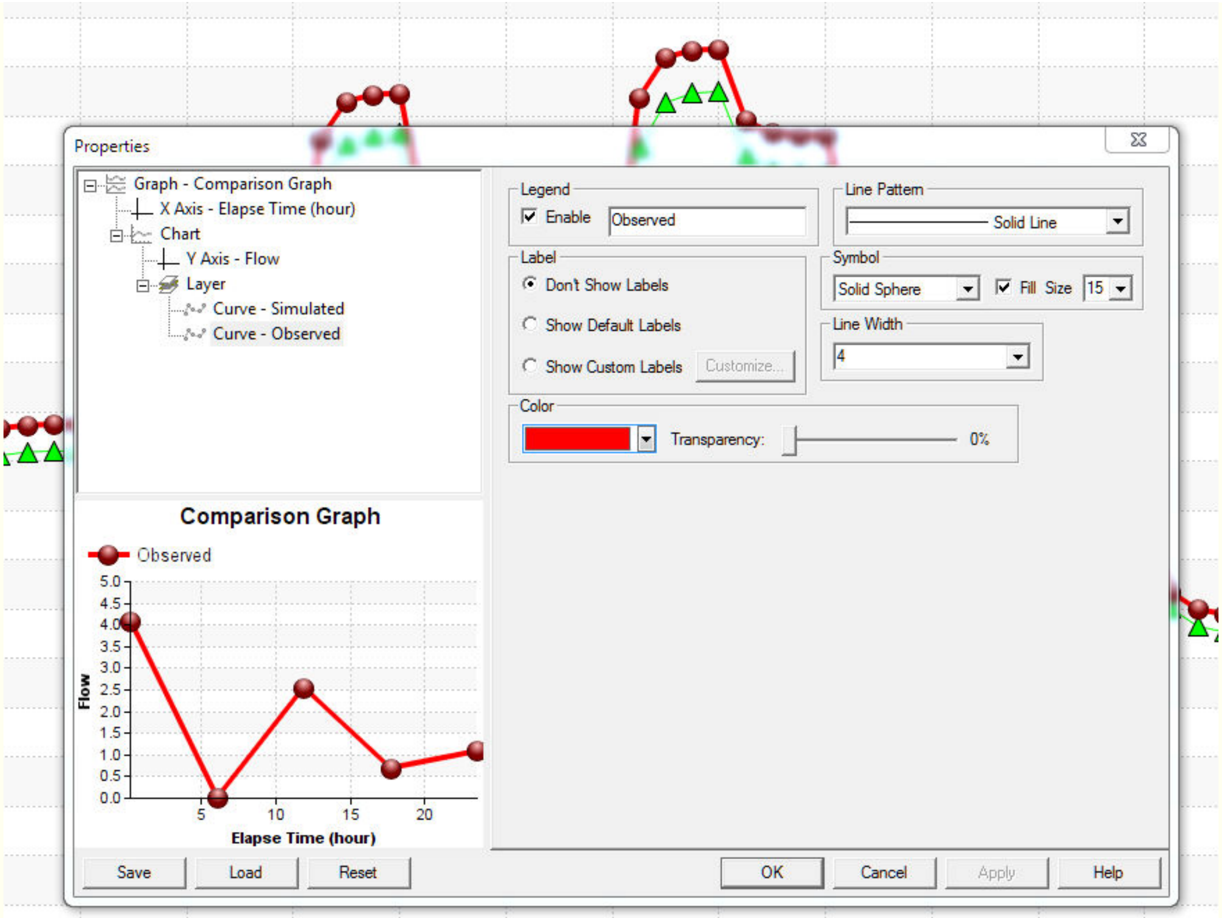
Other options are Fill Size and Line Width



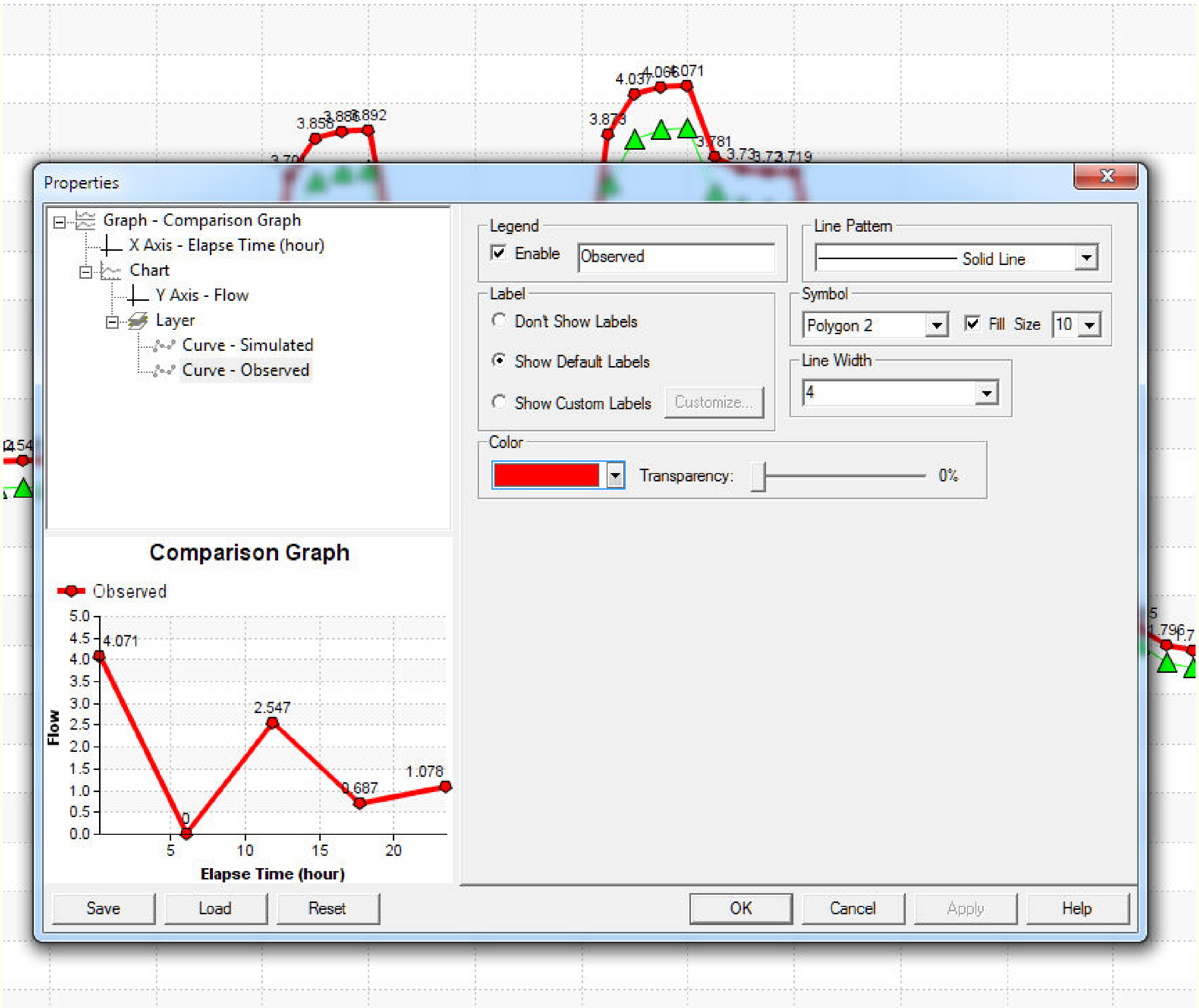
Color and Transparency apply to both the symbols and lines/bars/area.



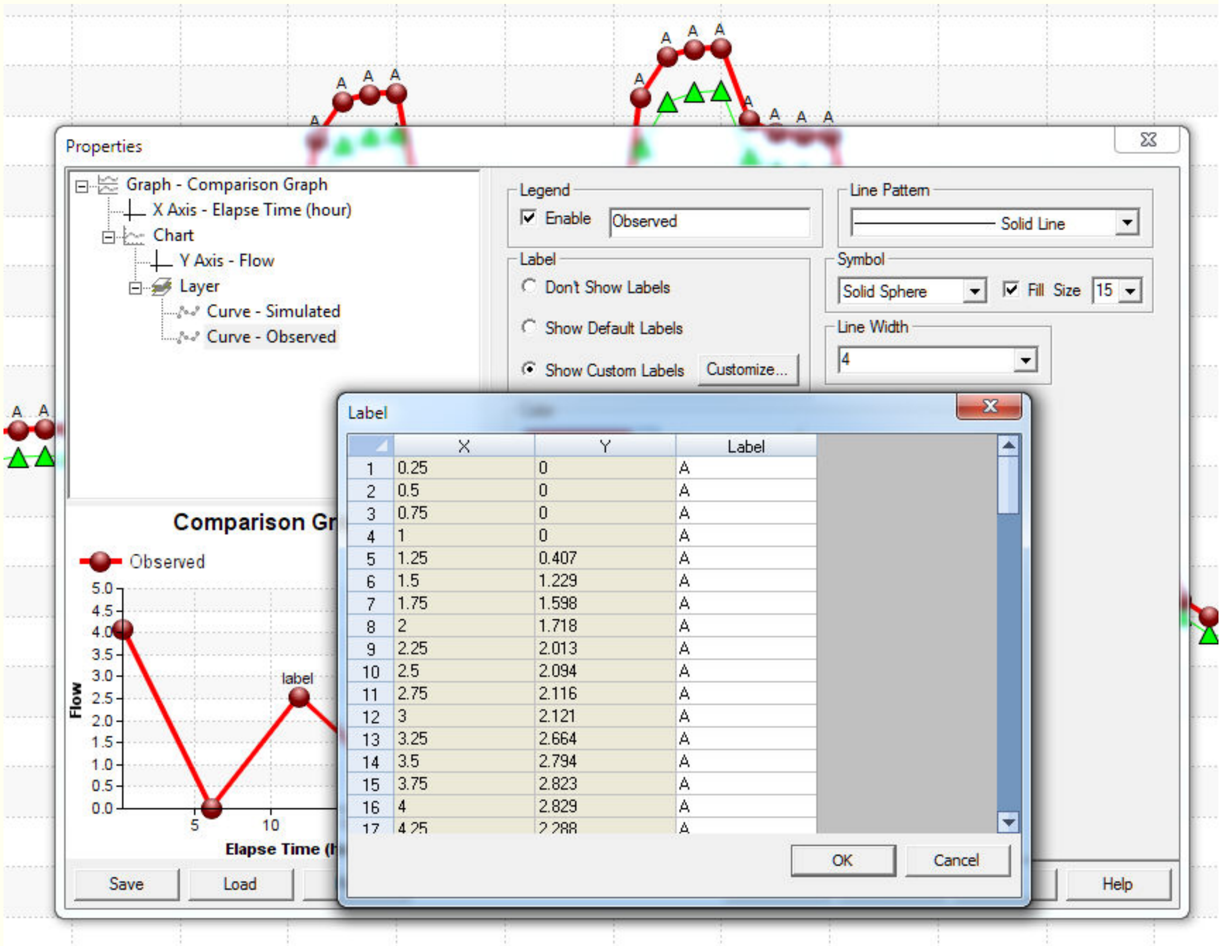
Don't Show the Default Labels



Show the Default Labels

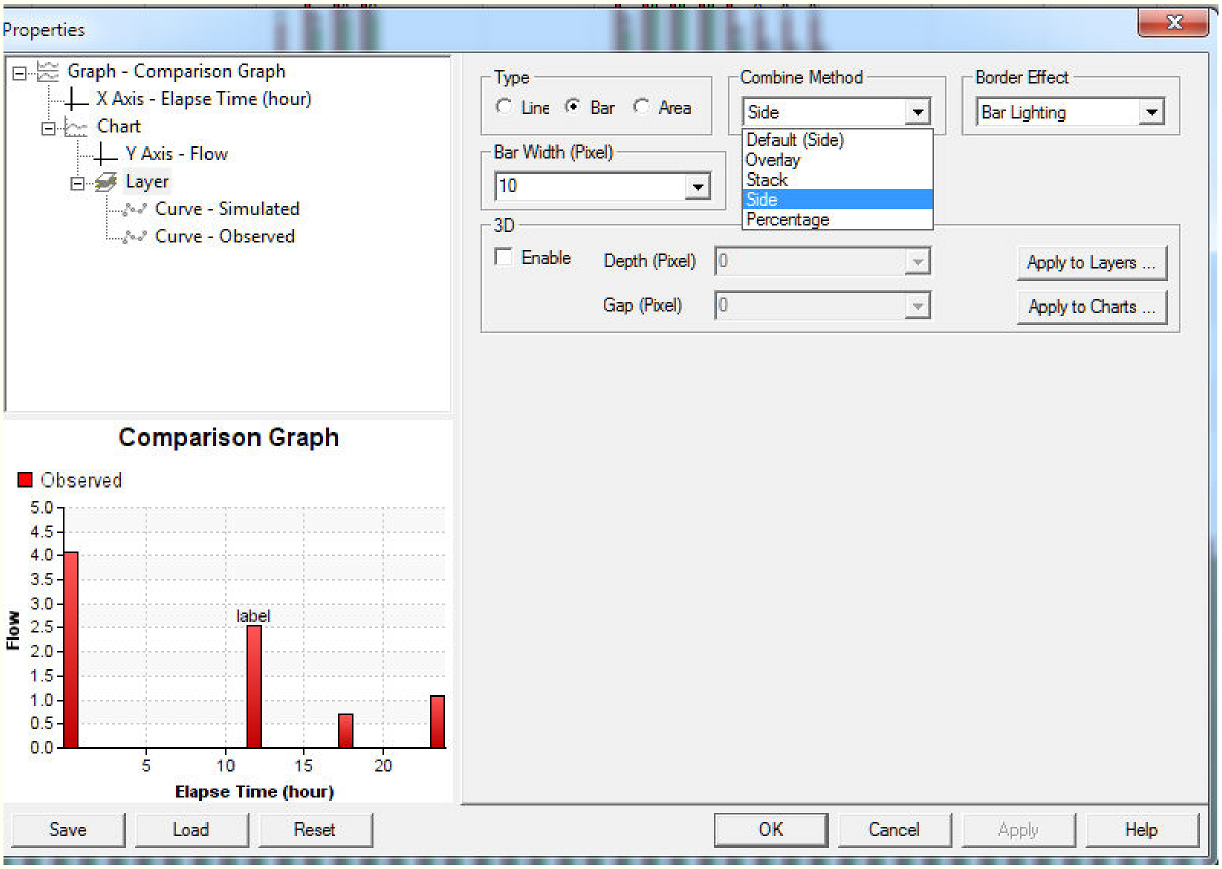


Show the User Defined Labels

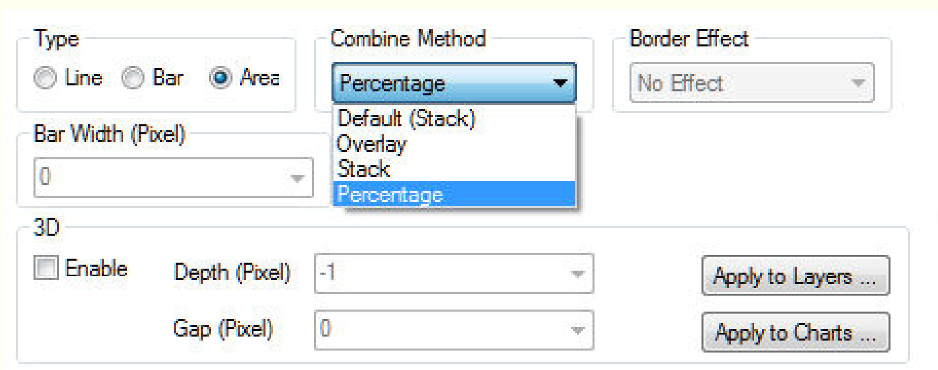


	X	Y	Label
1	0.25	0	A
2	0.5	0	A
3	0.75	0	A
4	1	0	A
5	1.25	0.407	A
6	1.5	1.229	A
7	1.75	1.598	A
8	2	1.718	A
9	2.25	2.013	A
10	2.5	2.094	A
11	2.75	2.116	A
12	3	2.121	A
13	3.25	2.664	A
14	3.5	2.794	A
15	3.75	2.823	A
16	4	2.829	A
17	4.25	2.288	A

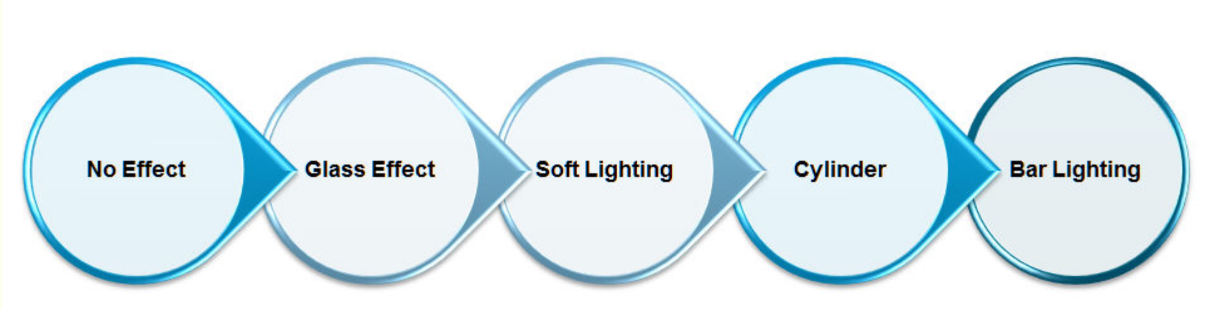
You can define the Combine Method as well as the Border Effects and change the graphs to Line, Bars and Areas



The options for Bar Combine Effects include:



and for the border effects



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Help File Updated January 30,

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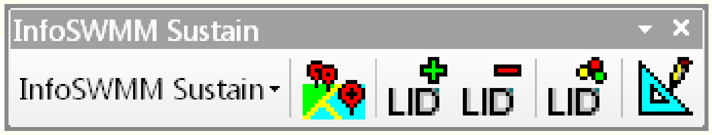
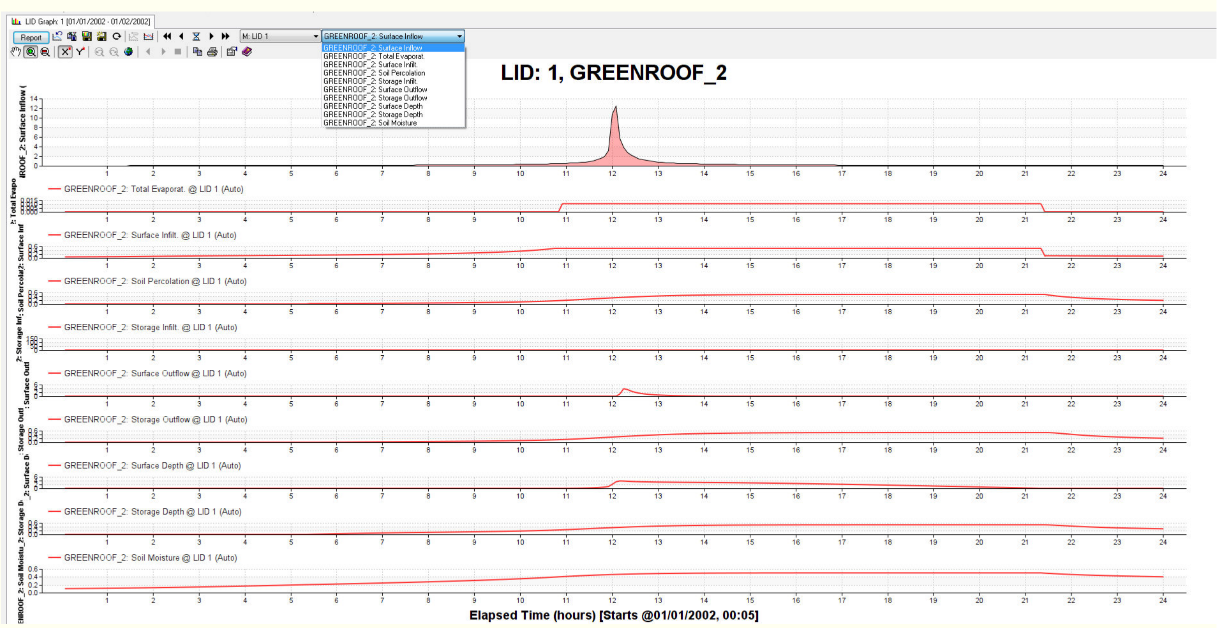

InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

LID Graphs in InfoSWWMM

The Ten possible LID Graphs per Subcatchment in InfoSWMM

- Surface Inflow
- Total Evaporation
- Surface Infiltration
- Soil Percolation
- Storage Infiltration
- Surface Outflow
- Storage Outflow
- Surface Depth
- Storage Depth
- Soil Moisture



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InfoSWMM Sustain
LID
LID
LID

How to Compare LID and No LID Scenarios

How to Compare LID and No LID Scenarios as Graphs and Reports in InfoSWMM.

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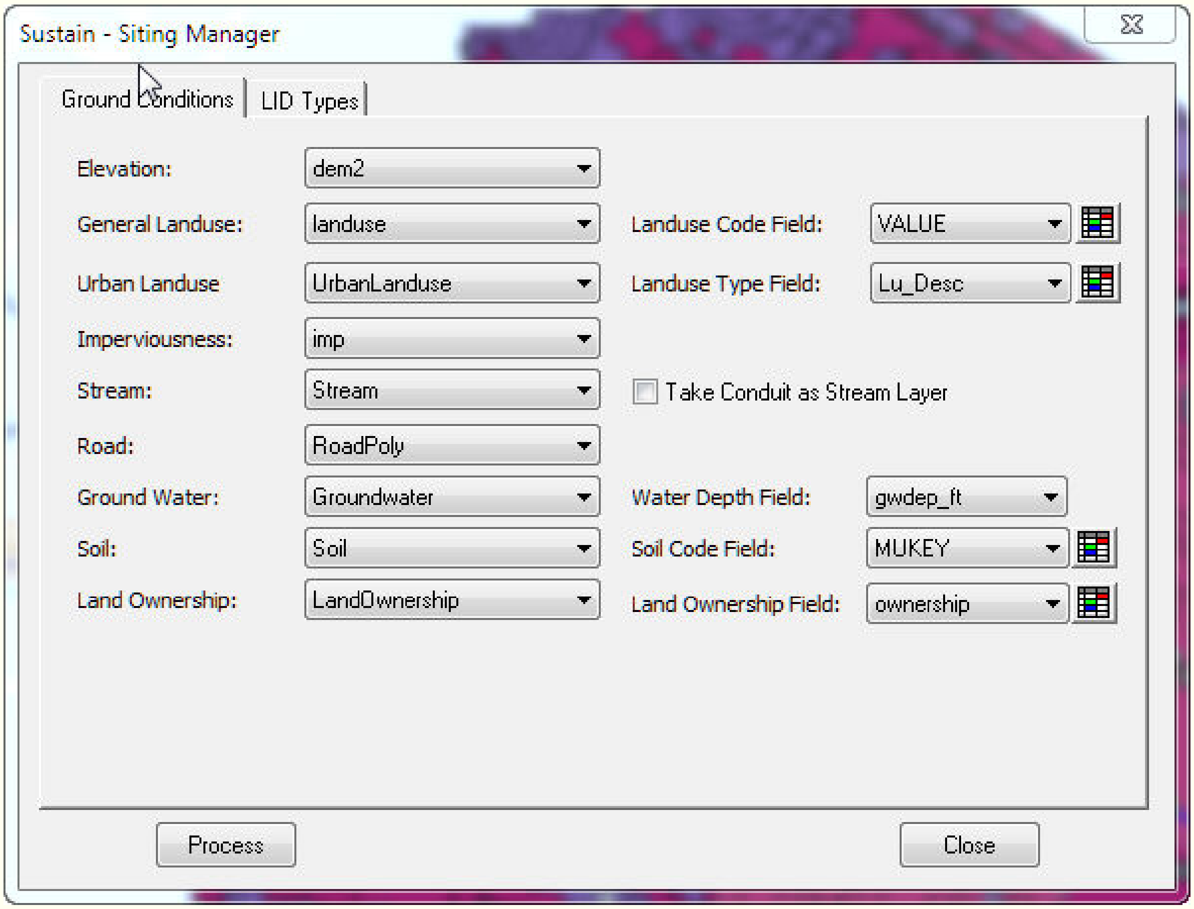
InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

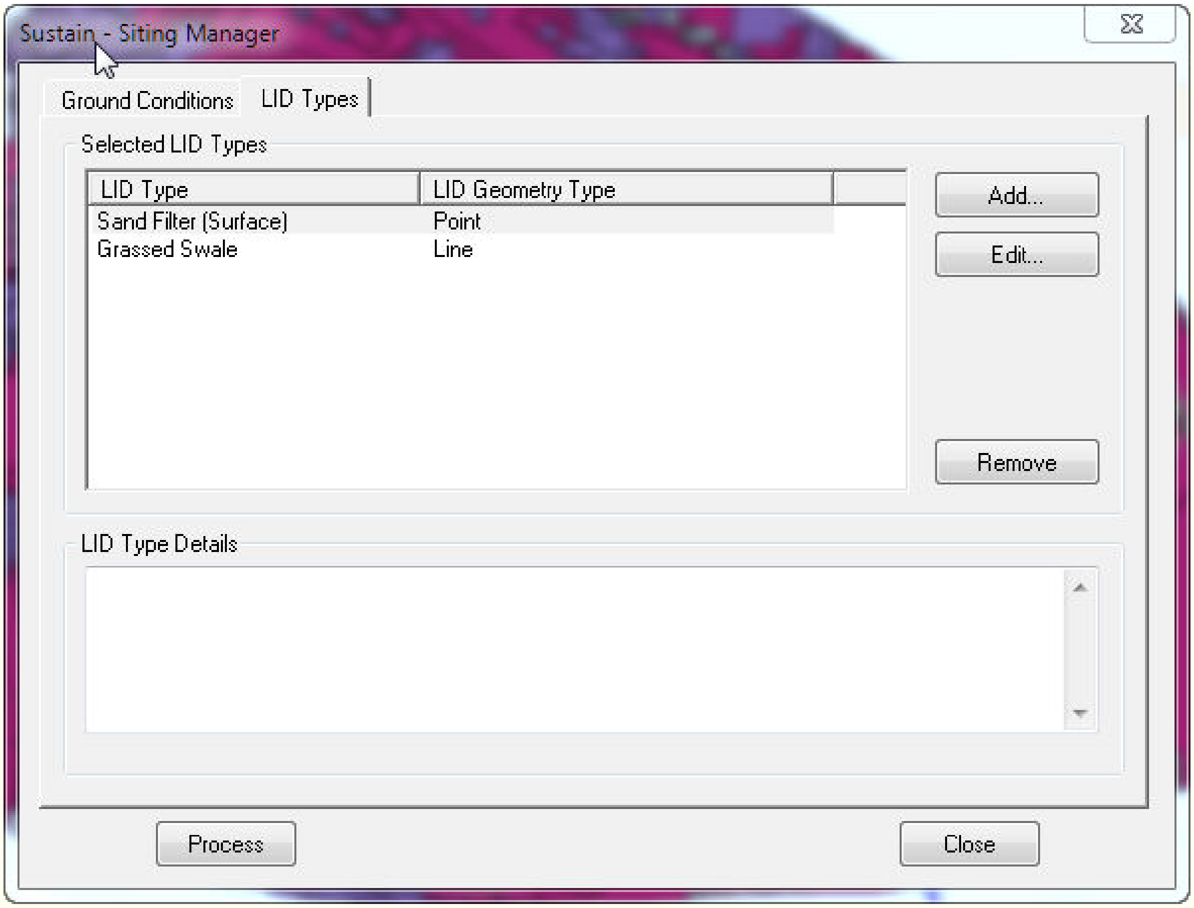
Guide to Sample Sustain.MXD

The following images show how the Sample Sustain.MXD should look like before any user changes.

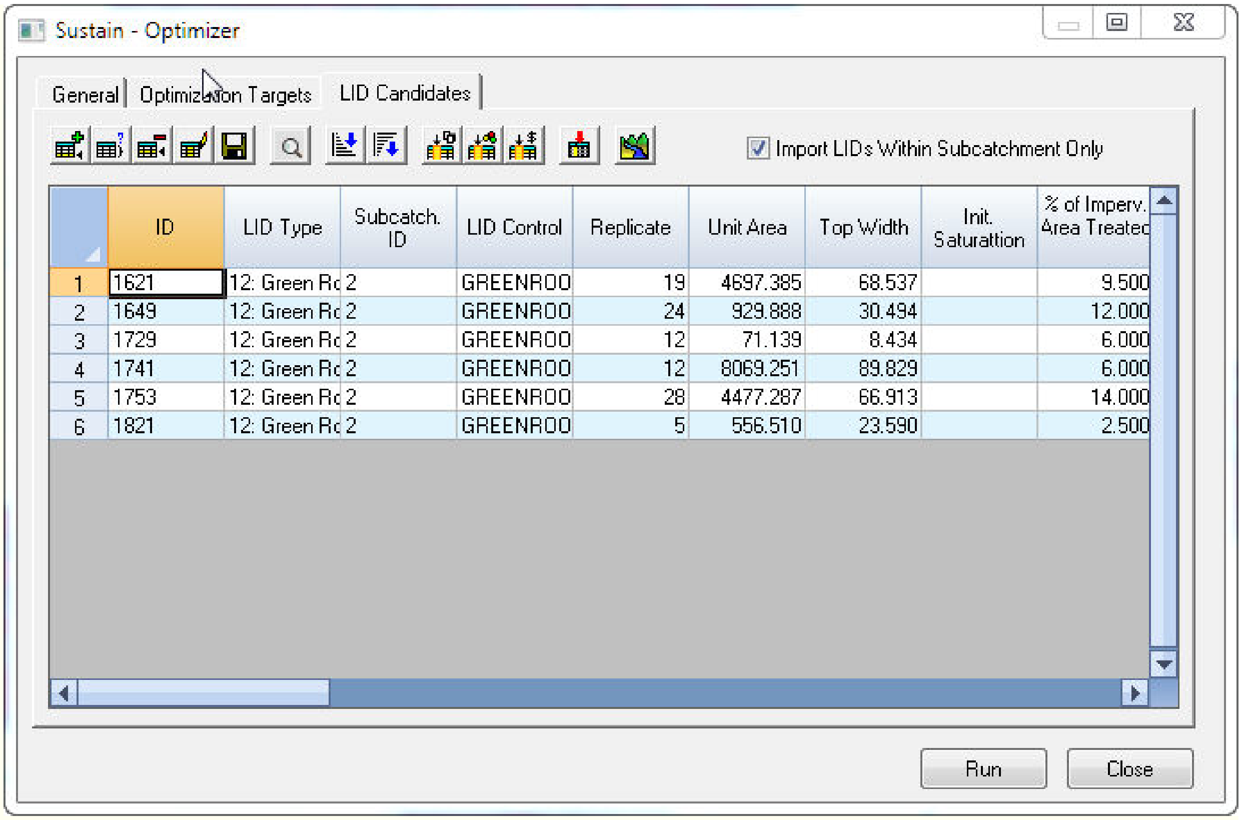
- Siting Manager Setup



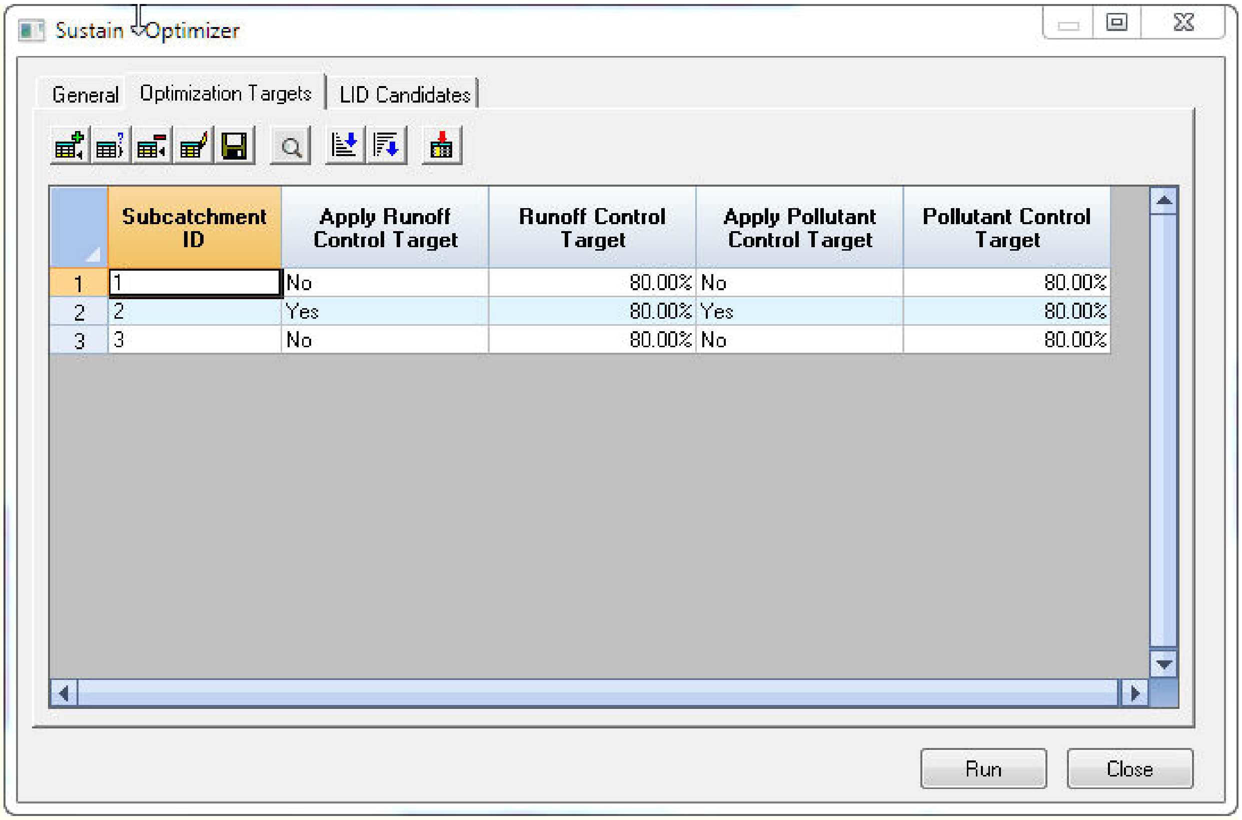
- LID Types in the Siting Manager



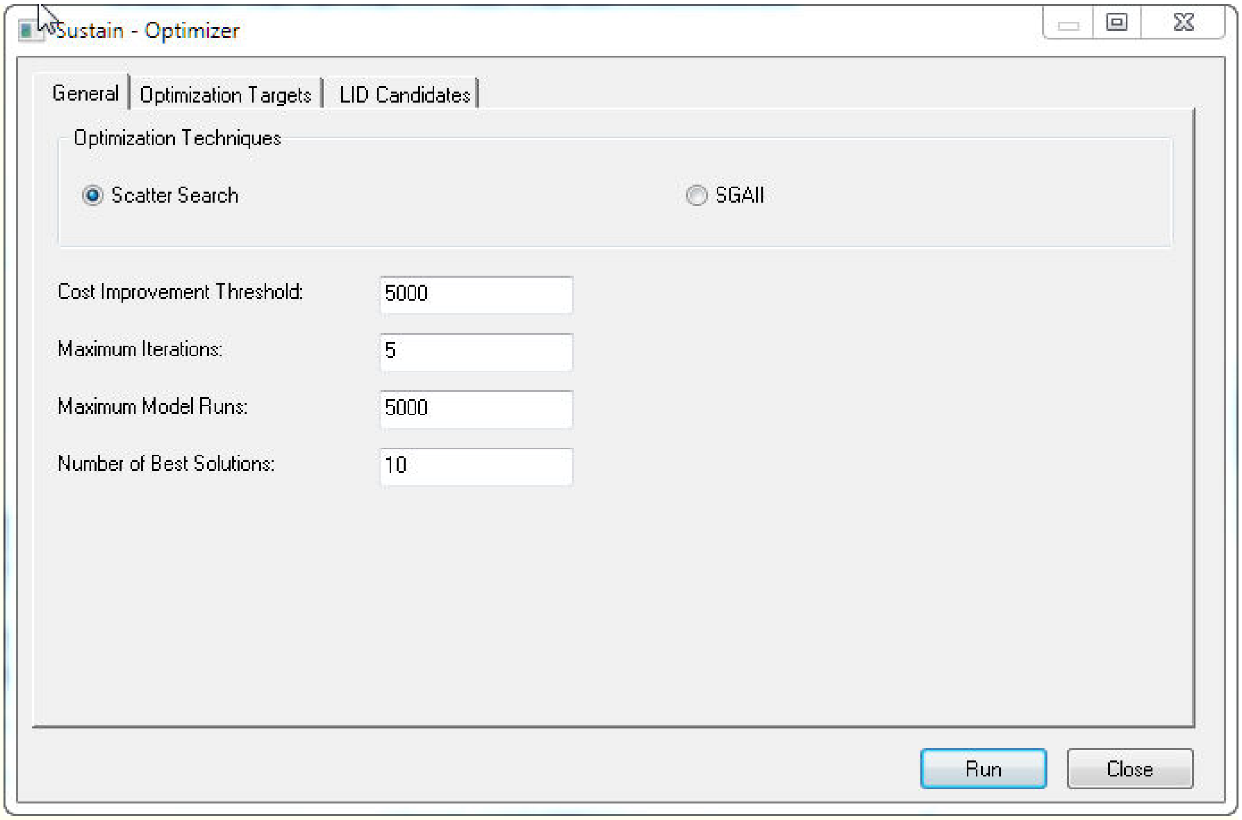
- The LID Candidates and Replicate Counts for this model



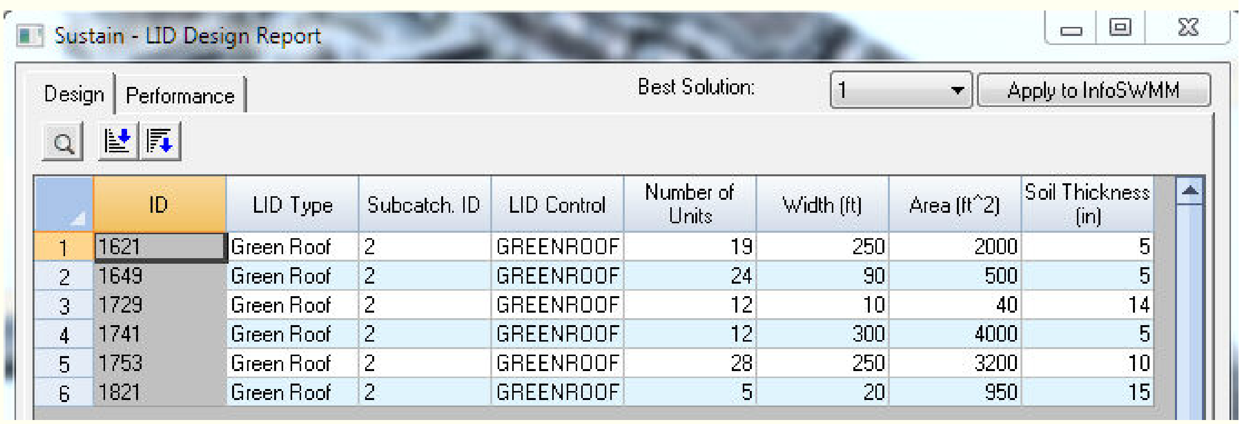
- The Sustain Optimization Targets



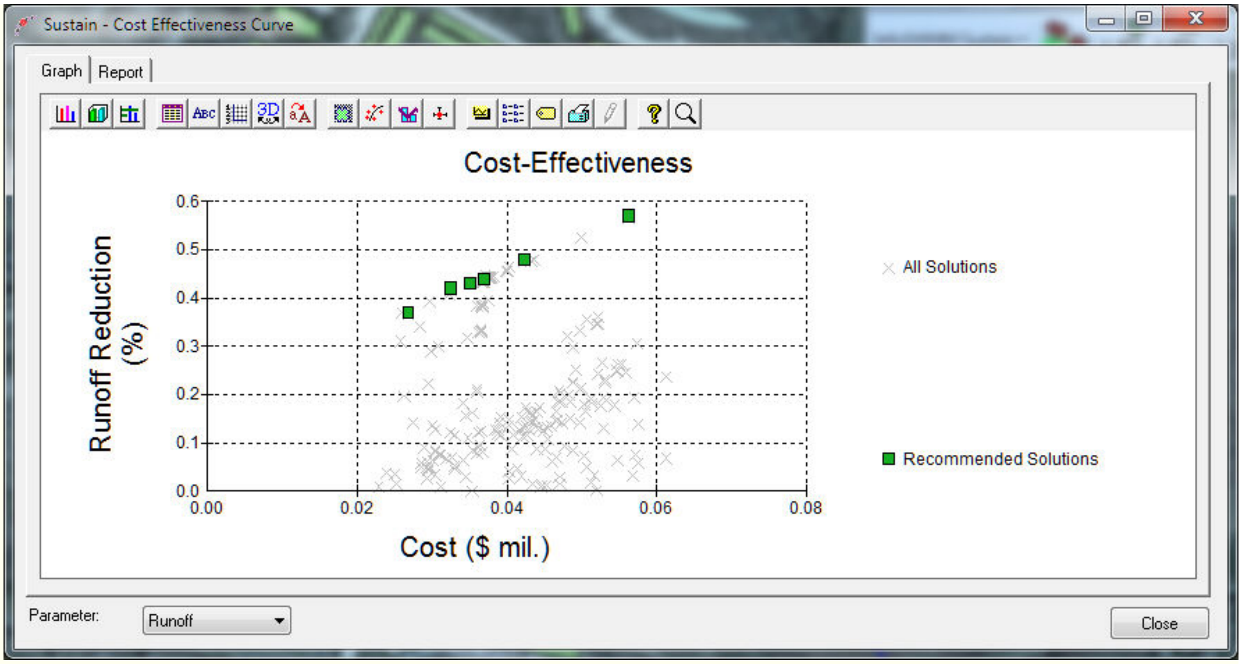
- Optimizer Options



- Design Report

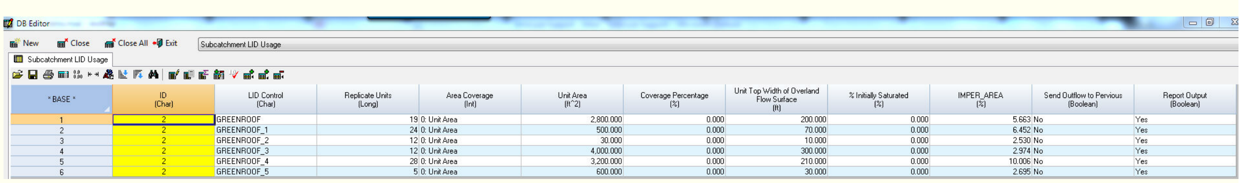


- The Recommended and All Solutions for this Optimization.



- The LID Controls in InfoSWMM in the model, the Green Roof Controls were Optimized by InfoSWMM Sustain.

The LID Usage from the Optimization. It uses replicate Green Roofs to aggregate the Roofing area.



DB Editor

Subcatchment LID Usage

* BASE *	ID (Char)	LID Control (Char)	Replicate Units (Long)	Area Coverage (Int)	Unit Area (ft^2)	Coverage Percentage (%)	Unit Top Width of Overland Flow Surface (ft)	% Initially Saturated (%)	IMPER_AREA (%)	Send Outflow to Pervious (Boolean)	Report Output (Boolean)
1	2	GREENROOF	19	0: Unit Area	2,800.000	0.000	200.000	0.000	5.663	No	Yes
2	2	GREENROOF_1	24	0: Unit Area	500.000	0.000	70.000	0.000	6.452	No	Yes
3	2	GREENROOF_2	12	0: Unit Area	30.000	0.000	10.000	0.000	2.530	No	Yes
4	2	GREENROOF_3	12	0: Unit Area	4,000.000	0.000	300.000	0.000	2.974	No	Yes
5	2	GREENROOF_4	28	0: Unit Area	3,200.000	0.000	210.000	0.000	10.006	No	Yes
6	2	GREENROOF_5	5	0: Unit Area	600.000	0.000	30.000	0.000	2.695	No	Yes

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Back to the Basics:

Computational Methods in Low Impact

Development Stormwater Controls -

Part 1: Hydrology and Hydraulics

LID Computational Methods Task Committee Report

Back to the Basics: Computational Methods in Low Impact Development Stormwater Controls - Part 1: Hydrology and Hydraulics

LID Computational Methods Task Committee Report

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ABSTRACT

The goal of Low Impact Development (LID) is to replicate or preserve so-called "natural" hydrology and mitigate pollutant loads from either new or existing developed areas. Several key objectives define this goal: maintain groundwater recharge, minimize increases in runoff volume, minimize changes in runoff flow rate duration-frequency, and minimize increases in pollutant loads, all in a manner that approximates the temporal and spatial distribution of pre-development conditions. Runoff generation, infiltration, evapotranspiration, flow conveyance and detention comprise the basic hydrologic and hydraulic processes that must be addressed to meet these objectives. Pollutant filtration, sedimentation, adsorption, uptake and immobilization comprise basic pollutant removal processes. The discussion on computational approaches can be segregated into hydrologic/hydraulic approaches and pollutant removal approaches. This paper focuses on the former.

The aim of this paper is to describe fundamental physically-based representations of the hydrologic and hydraulic processes in selected LID controls. The paper proposes a hierarchy where more complex processes are recognized in terms of interactions between fundamental mechanisms. Thorough understanding of the basic mechanisms underlying these processes is thus essential to provide the framework for reviewing various computational approaches. This is particularly relevant in the case of vegetated systems, in which classic matric flow relationships often do not correspond to responses observed in the field. Although understanding of these mechanisms has improved considerably in recent decades, the most widely used computational methods reflect computational capabilities and process perspectives developed decades ago. The basic mechanisms underlying these processes are discussed to provide a framework for evaluating computational approaches that reflect current knowledge.

Keywords: Low Impact Development, Hydrology, Hydraulics, Runoff, Infiltration, Conveyance, Routing, Detention, Modeling.

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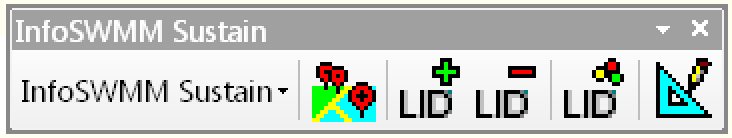
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Green Roof Simple Cost and Optimization Example

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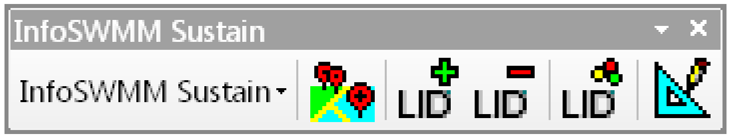


Glossary

The source of this Glossary is

SWMM Reference Manual Volume III - Water Quality and LID.

https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P2NY.PDF?Dockey=P100P2NY.PDF

A

Advection-Dispersion Equation – the partial differential equation that expresses conservation of mass for a water quality constituent with respect to time and space across an element offluid.

Aquifer – as defined in SWMM, it is the underground water bearing layer below a land surface, containing both an upper unsaturated zone and a lower saturated zone.

Availability Factor – the fraction of buildup on a land use that is available for removal by street sweeping.

B

Best Management Practice - structural or engineered control devices and systems (e.g. retention ponds) as well as operational or procedural practices used to treat polluted stormwater.

Bio-Retention Cell – a LID control that contains vegetation grown in an engineered soil mixture placed above a gravel storage bed providing storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas.

BMP Removal Factor – the fractional reduction in runoff pollutant load achieved by implementing a specific BMP.

C

Capillary Suction Head - the soil water tension at the interface between a fully saturated and partly saturated soil.

Capture Ratio – the amount of the subcatchment's impervious area that is directly connected to an LID unit divided by the area of the LID unit itself.

Completely Mixed Reactor – a reactor where the concentration of all water quality constituents are uniform throughout the reactor's volume.

Continuous Simulation - refers to a simulation run that extends over more than just a single rainfall event.

Co-Pollutant – a pollutant whose runoff concentration is a fixed fraction of some other pollutant (e.g., phosphorus adsorbed onto suspended solids).

Curve Number - a factor, dependent on land cover, used to compute a soil's maximum moisture storage capacity.

Curve Number Method - a method that uses a soil's maximum moisture storage capacity as derived from its curve number to determine how cumulative infiltration changes with cumulative rainfall during a rainfall event. Not to be confused with the NRCS (formerly SCS) Curve Number runoff method as embodied in TR-55.

D

Darcy's Law - states that flow velocity of water through a porous media equals the hydraulic conductivity of the media times the gradient of the hydraulic head it experiences.

Depression Storage – the volume over a surface that must be filled prior to the occurrence of runoff. It represents such initial abstractions as surface ponding, interception by flat roofs and vegetation, and surface wetting.

Design Storm - a rainfall hyetograph of a specific duration whose total depth corresponds to a particular return period (or recurrence interval), usually chosen from an IDF curve.

Directly Connected Impervious Area - impervious area whose runoff flows directly into the collection system without the opportunity to run onto pervious areas such as lawns.

Drainage Mat - thin, multi-layer fabric mats with ribbed undersides that carries away any water that drains through the soil layer of a green roof.

Dry Deposition – pollutants deposited on land surfaces, typically in the form of particles, during periods of dry weather.

Dry Weather Flow - the continuous discharge of sanitary or industrial wastewater directly into a sewer system.

Dust and Dirt – street surface accumulation that passes through a quarter-inch mesh screen.

Dynamic Wave Flow Routing – a method of modeling non-uniform unsteady open channel flow that solves the full Saint Venant equations for both continuity and momentum. It can account for channel storage, backwater effects, and flow reversals.

E

Event Mean Concentration – the average concentration of a pollutant in the runoff produced by a single storm event.

F

Field Capacity - the amount of water a well-drained soil holds after free water has drained off, or the maximum soil moisture held against gravity.

Usually defined as the moisture content at a tension of 1/3 atmospheres.
First Order Decay – a pollutant decay reaction whose rate is proportional to the concentration of pollutantremaining.

G

Green-Ampt Method - a method for computing infiltration of rainfall into soil that is based on Darcy's Law and assumes there is a sharp wetting front that moves downward from the surface, separating saturated soil above from drier soil below.
Green Roof – a type of bio-retention cell used on a roof that has a soil layer above a thin layer of synthetic drainage mat material that conveys excess water draining through the soil layer off of the roof.

H

Hydraulic Conductivity - the rate of water movement through soil under a unit gradient of hydraulic head. Its value increases with increasing soil moisture, up to a maximum for a completely saturated soil (known as the saturated hydraulic conductivity or K_{sat}).
Hydraulic Residence Time - the average time that water has spent within a completely mixed reactor.

I

Impervious Surface – a surface that does not allow infiltration of rain water, such as a roof, roadway or parking lot.
Infiltration – the process by which rainfall penetrates the ground surface and fills the pores of the underlying soil.
Infiltration Trench – a narrow ditch filled with gravel that intercepts runoff from upslope impervious areas and provides storage volume and additional time for captured runoff to infiltrate into the native soil.
Initial Abstraction – precipitation that is captured on vegetative cover or within surface depressions that is not available to become runoff and is removed by either infiltration or evaporation.

L

Land Use Object - categories of development activities or land surface characteristics used to account for spatial variation in pollutant buildup and washoff rates.

LID Control – a low impact development practice that provides detention storage, enhanced infiltration and evapotranspiration of runoff from localized surrounding areas. Examples include rain gardens, rain barrels, green roofs, vegetative swales, and bio-retention cells.

Link – a connection between two nodes of a SWMM conveyance network that transports water. Channels, pipes, pumps, and regulators (weirs and orifices) are all represented as links in a SWMM model.

Longitudinal Dispersion – the process whereby a portion of a constituent's mass inside a parcel of water mixes with the contents of parcels on either side of it due to velocity and concentration gradients.

M

Manning Equation – the equation that relates flow rate to the slope of the hydraulic grade line for gravity flow in open channels.

Manning Roughness – a coefficient that accounts for friction losses in the Manning flow equation.

Moisture Deficit – the difference between a soil's current moisture content and its moisture content at saturation.

N

Node – a point in a runoff conveyance system that receives runoff and other inflows, that connects conveyance links together, or that discharges water out of the system. Nodes can be simple junctions, flow dividers, storage units, or outfalls. Every conveyance system link is attached to both an upstream and downstream node.

O

Overland Flow Path – the path that runoff follows as it flows over a surface until it reaches a collection channel or drain.

P

Permeable Pavement - street or parking areas paved with a porous concrete or asphalt mix that sits above a gravel storage layer allowing rainfall to pass through it into the storage layer where it can infiltrate into the site's native soil.

Pervious Surface – a surface that allows water to infiltrate into the soil below it, such as a natural undeveloped area, a lawn or a gravel roadway.

Pollutant Object – the representation of a water quality constituent within SWMM.

Pollutograph – a plot of the concentration of a pollutant in runoff versus time.
Porosity - the fraction of void (or air) space in a volume of soil.
Potency Factor – relates the concentration of the particulate form of a pollutant (such as phosphorous or heavy metals) to the concentration of total suspended solids.

R

Rainfall Dependent Inflow and Infiltration - stormwater flows that enter sanitary or combined sewers due to "inflow" from direct connections of downspouts, sump pumps, foundation drains, etc. as well as "infiltration" of subsurface water through cracked pipes, leaky joints, poor manhole connections, etc.

Rain Barrel – a container that collects roof runoff during storm events and can either release or re-use the rainwater during dry periods.
Rain Garden - a type of bio-retention cell consisting of just an engineered soil layer with no gravel bed below it.
Richards Equation – the nonlinear partial differential equation that describes the physics of water flow in unsaturated soil as a function of moisture content and moisture tension.
Rooftop Disconnection – the practice of directing roof downspouts onto pervious landscaped areas and lawns instead of directly into storm drains.

S

Steady Flow Routing – a method of modeling uniform steady open channel flow that translates inflow hydrographs at the upstream end of the channel to the downstream end, with no delay or change in shape.
Subcatchment – a sub-area of a larger catchment area whose runoff flows into a single drainage pipe or channel (or onto another subcatchment).

T

Tanks in Series Model – an approach to solving constituent transport where conduits are represented as completely mixed reactors connected together at junctions or at completely mixed storage nodes.

U

Underdrain – slotted pipes placed in the storage layer of an LID unit that conveys excess captured runoff off of the site and prevents the unit from flooding.

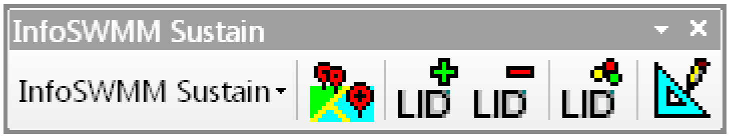
V

Vegetative Swale - channels or depressed areas with sloping sides covered with grass and other vegetation that slows down the conveyance of collected runoff and allows it more time to infiltrate into the native soil.

W

Wet Deposition - pollutant loads contributed by direct rainfall on a catchment.

Wilting Point - the soil moisture content at which plants can no longer extract moisture to meet their transpiration requirements. It is usually defined as the moisture content at a tension of 15 atmospheres.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LID Computational Methods Task Committee Report

Back to the Basics:
Computational Methods in Low Impact Development Stormwater Controls - Part 1: Hydrology and Hydraulics

LID Computational Methods Task Committee Report

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INTRODUCTION

The many adverse impacts of converting pervious areas (whether natural or not) into hardscaped development have been recognized for some time (as reviewed by Lucas, 2004). The goal of Low Impact Development (LID) is to preserve or replicate so-called “natural” hydrology and pollutant loads from both new, as well as existing developed areas.

Depending on the ecoregion, the “natural” hydrology is typically thought to be forested or meadow. However, the landscape in many areas has been so altered by human activities over the centuries that an altered hydrology that does not further destabilize stream channels is often considered as a suitable target criterion. There may also be circumstances where surface water bodies rely on runoff from existing impervious surfaces, in which case replicating “natural” hydrology would be inappropriate.

Thus these criteria are thus site specific, and best determined by stakeholder consensus.

In essence, the LID approach is to minimize impacts of urbanization and development as much as possible, using techniques that utilize landscape and building elements as part of an integrated treatment train of stormwater controls1 to manage runoff in a manner that approximates the temporal and spatial distribution of pre-development conditions. In recent years there have been considerable advances in understanding how LID stormwater controls operate, so these advances need to be addressed by appropriate computational methods.

The following key objectives address the goal of replicating the spatial and temporal distribution of hydrologic and pollutant loads from natural conditions:

· Restore/Maintain Groundwater

Recharge,

· Eliminate/Minimize Increases

in Runoff Volume,

· Eliminate/Minimize Changes

in Runoff Flow Duration-Frequency, and

· Eliminate/Minimize Increases

in Pollutant Loads.

In meeting these objectives, LID stormwater controls address the following processes:

· Rainfall Infiltration

· Rainfall Evapotranspiration

· Runoff Generation

· Runoff Conveyance

· Runoff Detention

· Pollutant Filtration

· Pollutant Sedimentation

· Pollutant Adsorption/Transformation

· Pollutant Uptake/Immobilization

1 The term “Best Management Practice” is perhaps valid if justifiably applied to only one of many stormwater controls.

As typically used, it is applied to every control in a particular category of stormwater controls, suggesting they are somehow vastly superior to other management measures. However “best” is not only inaccurate and misleading, it indicates an unwarranted hubris compared to other measures. This paper uses the term “stormwater control” to denote generically all stormwater management measures

The first five processes pertain to hydrologic/hydraulic processes involved in runoff generation and routing, while the latter pollutant treatment processes influence the eventual concentration of discharged pollutants. Stormwater control processes in this paper are defined as a “naturally occurring or designed sequence of changes of properties or attributes of a...system”, while mechanisms are defined as “some technical aspect of a larger process ... a part or combination of parts designed to perform a particular function.” The definition herein thus elevates the term process from a basic mechanism to comprise the resultant operation of several mechanisms. This paper examines how basic mechanisms interact to develop the resulting processes in various stormwater controls.

These processes provide the framework for reviewing various computational approaches. The various physical, biological and chemical mechanisms involved in pollutant removal processes can be quite complex and are very different from hydrologic/hydraulic processes. As a result, the discussion on computational approaches can be segregated into hydrologic/hydraulic processes and pollutant removal processes. Since the mechanisms involved in pollutant removal processes are so different from hydrologic/hydraulic processes, they require different computational approaches. Furthermore, since many pollutant removal processes are determined by hydraulic parameters, fundamental hydrological and hydraulic aspects are essential to understand pollutant removal processes. This paper thus focuses upon hydrological/ hydraulic processes and their computational approaches.

A subsequent paper will address pollutant removal mechanisms.

The processes by which many LID stormwater controls operate do not lend themselves easily to classical design approaches typically utilized to meet regulatory criteria. This paper provides a rigorous basis for LID design that not only meets such criteria, but also addresses many impacts of development that have only recently been accorded regulatory protection. In the process, assumptions about the performance of the classical design approaches are reexamined.

OVERVIEW OF LID STORMWATER CONTROLS

While structural stormwater controls such as detention basins and infiltration facilities can meet these objectives, LID stormwater controls greatly expand the "toolbox" available to the stormwater control designer. As such, the definition of LID includes not only Conservation Design, but also distributed Green Infrastructure stormwater controls. Distributed controls provide the best opportunity to replicate the temporal and spatial distributions of runoff and recharge under undisturbed conditions. However, while very effective in many instances, many distributed LID stormwater controls are not always capable of meeting design discharge criteria (particularly for flood control), and conventional stormwater management controls are sometimes necessary.

Furthermore, while they may not replicate spatial distribution, end-of pipe controls can effectively replicate the temporal distribution of runoff and recharge. Therefore, since this paper re-examines basic mechanisms, it also includes centralized structural approaches. In all of the stormwater controls examined, the goal is primarily hydrologic control and pollutant load reduction through volume management, as well as ensuring flows that prevent channel erosion and provide adequate base flow. Because most LID practices also reduce pollutant

concentrations, the mass load benefits are even greater than that from volume reduction alone.

LID practices in this paper are broadly segregated into the categories of Conservation Design, "Green Infrastructure" stormwater controls, and Structural Practice stormwater controls. Conservation Design represents overall site design approaches to reduce development impacts. "Green Infrastructure" stormwater controls are vegetated landscape elements integrated into site designs that are engineered to further reduce impacts as runoff is conveyed throughout the site. As such, these controls are usually distributed through the site. However, many of these controls can also be effectively located at the end of the pipe.

On the other hand, Structural Practices are classified as constructed stormwater controls that are typically located at the conventional "end of pipe" location. However, even though vegetation may be absent in most of these systems, they too can be distributed through a site.

As such, the LID toolkit is intended to include all stormwater controls, whether vegetated or not and whether distributed or centralized.

We emphasize that our focus here on how the adverse "impacts" of "development" can be "lowered". This is the true intent of Low Impact Development. The semantics of the nomenclature, location and arrangement of particular controls have no bearing on the fundamental processes that are the subject of this paper.

Conservation Design Stormwater Controls

Conservation Design is the concept of reducing the overall impact of development and allocating those impacts into the part of the site most able to accommodate such impacts. This concept was first formalized by McHarg (1972), and is now widely used in many site design manuals (see DNREC, 2002). The basic elements of conservation design and the processes addressed are summarized briefly below: Minimizing Impervious Area: The main goal of minimizing imperviousness is to reduce runoff volume. This is the basic concept underlying cluster and multifamily development, where dwellings are provided in lots smaller than typically required. Given the same number of units, this approach reduces the length of roadways and driveways. Further design elements also include the use of narrower streets, shared driveways and multistory buildings and parking facilities.

Maximizing “Natural” Areas: This is a concept complementary to minimizing imperviousness, where the buildings are concentrated away from environmentally sensitive areas such as woodlands, well-drained soils, slopes and wetlands. This stormwater control approach reduces runoff where conserved upland areas have better infiltration properties than disturbed upland areas.

Runoff Harvesting: Runoff Harvesting is included as part of Conservation Design as another means for reducing runoff, since it re-uses runoff at its source from impervious areas (typically roofs). Well developed in Australia, it is a recent trend in other regions of the world.

However, there can be regulatory issues when downstream water users rely on this runoff for irrigation.

Green Infrastructure Stormwater Controls

In contrast to overall site design practices used in Conservation Design, Green Infrastructure stormwater controls are stormwater controls specifically engineered to control runoff from discrete portions of a site. As such, they comprise a “Technology”, as opposed to an overall design approach. As its name suggests, Green Infrastructure stormwater controls involve vegetation, hence the term “Green,” although it is possible to implement some of these controls in arid regions without vegetation. These vegetated controls are typically distributed throughout the site, so they are differentiated from non vegetated structural controls typically located at the “end of pipe.” However, this distinction does not always occur in actual practice for Green Infrastructure controls such as bioretention facilities, and particularly in the case of wetlands.

Soil Engineering: Soil Engineering involves improving the pervious areas disturbed by grading and construction. Studies show that such soils often have considerably poorer infiltration properties than most native soils (Pitt et al, 1999, OCSCD, 2000), resulting in increased runoff. Infiltration performance in disturbed soils is improved by means of deep tillage and compost amendments (Pitt et al, 1999), as well as plantings with deep-rooted native species (Rachman et al, 2004a,b). This stormwater control reduces runoff by increasing infiltration and evapotranspiration.

Impervious Area Disconnection: Impervious area disconnection design specifically routes runoff from impervious areas such as roofs, driveways and roads over adjacent pervious areas. There is little design guidance on disconnection, and much of what exists is not based upon empirically based processes (e.g., MDE, 2000). This stormwater control reduces runoff volume by increasing infiltration and evapotranspiration, and runoff rate by reducing volume and by providing a slower routing mechanism (increased roughness and longer flow paths).

Landscape Infiltration: Landscape Infiltration is actually a variant of impervious area disconnection. In this case, the receiving pervious areas are either natural areas with high infiltration capabilities, or engineered soils with plants selected to improve infiltration performance.

These stormwater controls also reduce runoff by volume and rate, for reasons comparable to the impervious area disconnection noted above.

Filter Strips: Filter Strips are wide, flat vegetated slopes over which entering flows are spread out as sheet flow. Because inflows travel at very shallow flow depths down a vegetated slope, the coarser fractions of incoming sediments settle out, providing pollutant sedimentation benefits. Contrary to popular misconception, filter strips provide very little filtration or adsorption benefits (Lucas, 2004). These stormwater controls also provide impervious area disconnection, reduce runoff by increasing infiltration, and have the potential to retard runoff flows.

Biofiltration Swales: Biofiltration Swales are wide flat swales planted with dense vegetation, usually grass. While deeper than sheet flow, flow depths are shallow enough that most fractions of incoming sediments settle out along the length of the swale. Biofiltration swales provide good pollutant sedimentation, but very little filtration or adsorption (Lucas, 2004). This stormwater control also infiltrates impervious area flows, reducing runoff. Biofiltration swales are an effective conveyance stormwater control in retarding runoff flow. When check dams are added, biofiltration swales also provide runoff detention, which also increases infiltration volumes and further retards flows.

Bioretention Systems: Bioretention systems are impoundments, typically shallow, in which the majority of runoff exfiltrates through a soil medium engineered for high infiltration rates and high pollutant adsorption properties. Treated runoff then exfiltrates into the surrounding soils, and/or is collected by an underdrain system, if the surrounding soils have poor infiltration rates. Bioretention systems provide very high pollutant sedimentation, filtration, and adsorption/transformation benefits, while uptake and immobilization benefits are less prominent due to the high hydraulic loads. This stormwater control reduces runoff by increasing infiltration and evapotranspiration, retards runoff flows discharged through underdrains, and detains runoff in the surface impoundment. As such, bioretention systems are capable of providing perhaps the most comprehensive benefits of all stormwater controls.

Small systems without underdrains or outlet control devices are called rain gardens. Biofiltration swales with bioretention media and underdrains are called bioretention swales, which not only treat, but also convey runoff.

Green Roofs: Extensive green roofs are comprised of short, drought-tolerant plantings growing in several inches of light-weight soil medium spread over flat roofs. The less common intensive green roofs have deeper media in planter boxes capable of supporting larger plant material.

The medium in green roofs has very high water absorption capabilities, providing substantial storage and high water-retention. While extensive green roofs provide pollutant uptake and immobilization, such benefits are insubstantial, since rainfall is relatively unpolluted in the first place. However, these systems substantially reduce runoff by providing depression storage and subsequent evapotranspiration, as well as runoff flow retardation.

Constructed Wetlands: Constructed wetlands are systems in which plants grow in a saturated medium, which can be gravel, soil or a variety of different media selected for their nutrient adsorption properties (e.g., Johansson-Westholm, 2006). Constructed wetlands range from open water systems, where the media is under several feet of water, to surface flow (SF) wetlands where runoff flows at a shallow depth over the top of the media, to subsurface flow (SSF) wetlands, where runoff flows laterally through the media. Recent advances in constructed wetland systems include combinations of SSF and SF systems, in which there is a vertical flow component as flows transition between SF and SSF regimes. Note that this is similar to bioretention systems, except that wetland systems are almost always saturated. A common element in all constructed wetlands is their dominance by emergent wetland plants, which are responsible for many of the pollutant removal processes. Constructed wetlands provide high pollutant sedimentation and adsorption/ transformation benefits, as well as high uptake and immobilization capabilities. Although they can provide substantial evapotranspiration, the main hydraulic benefit of constructed wetlands is their ability to provide flow retardation through extended detention.

Structural Stormwater Controls

Structural stormwater controls include the conventional controls that have been used ever since stormwater management was recognized as an issue to be addressed. In contrast to distributed Green Infrastructure controls that address runoff as its source, most structural controls are commonly located at the “end of pipe”, typically where all drainage from a site collects. However, this distinction does not always occur in practice, particularly in the case of porous pavement, infiltration facilities or media/sand filters. Another prominent distinction from Green Infrastructure controls is that these systems do not rely on vegetation as an integral element of their operational design. However, both wet basins and dry basins do have vegetation that improves pollutant removal performance. However, since vegetation generally has minimal effect on the hydraulic routing of these controls, they have been classified as structural.

Porous Pavement: Porous pavement systems include permeable asphalt, porous concrete, interlocking paver blocks, and open-grid turf reinforced block systems. In most of these systems, a layer of uniformly graded stone with a high porosity is placed under the porous surface contact course. These systems reduce runoff by increasing storage and subsequent infiltration. Even though the subbase is typically compacted to ensure stability, porous pavement systems can provide appreciable infiltration in addition to providing detention benefits. This is due to low annual hydraulic loads being infiltrated over large surfaces.

Infiltration Systems: Infiltration systems include infiltration trenches and infiltration basins. The former are stone-filled trenches where the infiltration into the native soils occurs at depth underground.

If properly pre-treated to prevent clogging, these are very effective systems for reducing runoff volume by means of infiltration. However, it most be recognized that these systems cause localized increases in groundwater elevation (mounding), which can compromise this capability.

They are most suitable for roof runoff which needs little pretreatment.

Infiltration basins are impoundments over permeable soils where infiltration occurs at the surface. Being exposed to the sun, infiltration basins are more prone to the formation of algal mats if runoff persists for any appreciable amount of time, which often happens if clogging begins due to a lack of pretreatment. These systems can provide detention, but this is not recommended due to the formation of algae. Being non vegetated, there is minimal uptake, immobilization, or transformation, while adsorption of pollutants is a function of the sorption capacity of the underlying soils.

Media/Sand Filters: Media/sand filters are enclosed filter systems designed to treat runoff by filtration through an engineered medium.

Their primary benefit is sedimentation, filtration and adsorption of pollutants. Even though non vegetated, uptake, immobilization and transformation processes still occur on biofilms surrounding the media particles. Placed underground, there is relatively little evapotranspiration, and by discharging through underdrains, there is no infiltration.

There is some detention of the design flow volume, with potentially substantial flow retardance if the flow through the media is retarded by outlet controls.

assumes that mounding is evaluated on a case by case basis, and is properly addressed from a surface control design perspective.

Mechanisms Involved Matric Flow

Studies of matric flow underlie the vast literature on the process of liquid transport through porous media. There are two mechanisms of fluid transport in isotropic media, matric flow characterized by hydraulic conductivity, and capillary suction, characterized by the matric potential. Matric flow is driven by elevation and pressure head, while matric potential is independent of gravity. Hydraulic conductivity is highest at saturated conditions (Ksat), while suction head (or negative matric potential) is highest under dry conditions.

Matric flow rapidly declines once conditions become unsaturated, as flow resistance by media increases in proportion to the decreased cross-section area of flow, while surface tension effects due to presence of air spaces further restricts flow due to gravity. Initially rapid matric flow drainage at saturation declines to no flow at field capacity when drainage is counteracted by matric suction. As moisture declines below field capacity, matric drainage is effectively absent, while upward matric suction from the water table increases. Meanwhile, downward suction also draws water from the upper profile, thus equilibrating drainage conditions through the lower profile. Moisture within the soil profile also moves according to temperature and humidity gradients.

Soil texture plays a dominant role in determining hydraulic conductivity and matric potential. Sandy soils have very high conductivity, but low matric potential. On the other hand, clays soils have very low conductivity, but high matric potential. Within this gradient, the uniformity of soils affects these parameters. Highly uniform sands will have higher conductivity than sands with a mix of particle sizes, since the smaller particles fill voids between larger particles. On the other hand, this denser packing increases capillary suction. In sandy soils, the higher the clay content is, the higher the bulk density will be, while the conductivity and porosity will be lower. However, Green Infrastructure systems are even more complex due to the presence of vegetation, as well as the development of soil aggregates.

Bulk density is thus another important determinant of infiltration properties. Higher bulk densities (compaction) are associated with lower hydraulic conductivity. This effect is pronounced in the case in sand, where excessive compaction can reduce infiltration rates by an order of magnitude (Pitt, 1987, OCSCD et al, 2001; Pitt, 2003).

This is explicitly addressed in the pedotransfer function (PTF) of Saxton and Rawls (2006) as the bulk density parameter. In contrast to compaction, soil organic matter increases infiltration rates in loam soils, and field capacity in sandy soils. Part of the effect of organic matter upon infiltration rates is thought to be related to the plasticity of organic soils inhibiting compaction.

The PTF of Saxton and Rawls (2006) includes terms for silt, bulk density, salinity, and organic matter (OM). This series of 24 different equations has been used to project Ksat, the suction head ψ, and available water capacity (AWC) parameters. This PTF was found to match a great proportion of field observations, thus providing considerable utility to this approach. It has been incorporated into the SPAW model (Saxton, 2005). It has the

advantage of addressing the effects of compaction and organic matter, which can substantially affect soil properties.

Macropore Flow

It has been known for several decades that infiltration properties in the upper soil profile are affected by the presence of macropores.

Macropores are formed by the decay of roots and the burrows of invertebrates, as well as shrink-swell cracks in clayey soils. Horizontal macropores from the decay of trees can be substantial and extensive, conveying a substantial amount of flow. Macropores are classified according to diameter, tortuousity, and connectedness. Higher values in these categories result in higher effective infiltration rates. The effective infiltration rates are typically an order of magnitude greater than matric rates in fine textured soils.

Well-developed fine textured soils also form soil aggregates that provide soil structure. Given enough time without disturbance, soil structure can be extensive enough that remarkably high infiltration rates can be found in soils with even high clay content. Together with macropores developed from bioturbation and roots, a well-developed soil structure can increase profile hydraulic conductivity by up to several orders of magnitude in tight soils. In sandy soils with high infiltration rates, structure and macroporosity are less important.

The effect of macropores thus introduces a substantial determinant of actual infiltration rates. It is worth noting that macroporosity is diminished when vegetation is absent. It is only recently that the literature has begun to address how media properties such as texture and organic matter interact with soil structure and vegetation to affect the matrix infiltration and percolation response (e.g., Sharma et al, 2006).

Surface Sealing and Clogging

In contrast to macropores, surface sealing and clogging have the opposite effect of reducing infiltration rates. Surface sealing occurs when exposed soils are pounded by raindrops so that the clay fraction is spread out, clogging surface cracks and macropores. The dried clay is very resistant to wetting, so rainfall runs off until the surface becomes wet enough. This process often occurs in fine-textured soils that are highly hydrophobic. Sealing can be alleviated with a mulch of wood chips or gravel that inhibits very dry surface conditions.

Sealing is less common and persistent in densely vegetated settings.

It should be noted that the median particle size of suspended solids in urban runoff is that of a fine silt (~20µ). As these fine particles settle onto the medium, they are “strained” by the bioretention medium.

At the typical ratio of runoff particle size to that of a sandy medium, most of these particles are captured within short distances (Teng and Sansalone, 2004). As particles collect, infiltration rates will decline to values in the range of several centimeters per hour. Therefore design infiltration rates will persist only if runoff is pretreated, or if the surface profile is replaced. Once the hydraulic conductivity declines enough due to particles accumulating in the media, particles then accumulate on the surface of the medium, forming a noticeable deposit (Hatt et al, 2007). This deposit reduces overall hydraulic conductivity to ranges from 4.0 cm-hr-1 (Urbonas, 1999) to below 0.1

cm/h (Hatt et al, 2007). However, even when a deposit may have low permeability, if it is relatively thin hydraulic head on the overlying layers can partially overcome the ensuing resistance according to Darcy’s Law.

Bioturbation and Vegetation effects

The preceding discussion on macropores mentions the effect of vegetation.

Many other biological processes also affect infiltration properties. Soil structure formation is accelerated by the presence of glomalin, a complex polysaccharide exuded by mycorhizzal fungi, which live in symbiosis with plants. Plants exude simple carbon compounds which are utilized by fungi and bacteria as they ramify throughout the profile. Fungi and bacteria metabolic activities mobilize nutrients from soils for plant uptake. As this process proceeds, soils evolve from compacted isotropic conditions (which determine initial matric flow responses) to complex systems as soils coalesce into aggregates interlaced with a network of macropores.

This is the reason disturbed urban soils cannot be treated as hydrologically equivalent to the undisturbed soils from which they were derived.

Another important effect of plants is their effect on cracking surface sealing and deposits. Plant movement in the wind tugs at the soil surface, breaking seals, and cracking through deposits. Ponded rainfall can then more easily penetrate the surface barriers, increasing infiltration rates.

The preceding implications upon infiltration by vegetative mechanisms have only been recently acknowledged by the soil science community.

These processes associated with vegetation are remarkably effective in restoring and/or enhancing infiltration rates. Vegetation roots penetrate confining layers, opening up soil structure (Gilker et al, 2002). Root turnover promotes the formation of macropores. Field infiltration rates in native grass hedges are much higher than found in adjacent croplands (Rachman et al, 2004; Blanco-Canqui et al, 2004a, 2004b; Seobi et al, 2005). The beneficial effects of native plants on infiltration rates persist even in depositional situations where sediments accumulate (Rachman et al, 2004). In bioretention columns, Culbertson and Hutchinson (2004) have documented that switchgrass (Panicum virgatum.) increased infiltration rates in bare soils from 0.5 cm-h-1 to 128 cm-h-1, an increase well over two orders of magnitude. These authors noted that the dense root system reached 90cm depth after a single growing season.

The presence of vegetation can thus result in infiltration rates several orders of magnitude higher than predicted by underlying soil properties (Ralston, 2004). Therefore, the presence of vegetation can play a much more important role in determining the infiltration and percolation response than the underlying soil texture composition. As such, we find that the classical approaches discussed below are only a point of departure for evaluating LID stormwater controls. For this reason, measurements of the Green-Ampt parameters Ksat and $\psi 0$ should be conducted in established stormwater controls, rather than based upon measurements of matrix properties alone.

This will provide a much better understanding of hydraulic performance capabilities. Achieving a better understanding of the complex interactions involved between plants and the media will enable the science to be optimally combined with the engineering design to improve stormwater bioretention technologies

Innovyze

Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013

Engine

More

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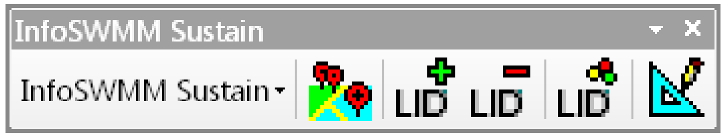
InfoSWMM Sustain
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Tutorial 1 Creating a Simple Green Roof Optimization for Sustain 4.0

In Tutorial 1 we will use the Siting Manager to Site Green Roof LID Types for later Optimization and Export to the InfoSWMM LID Usage DB Table. Tutorial 1 is designed for first-time users of InfoSWMM Sustain and provides a guided tour to core commands and functions used to create and execute a Siting and Optimization run in InfoSWMM Sustain. As such, it should be used as a launching point to a more comprehensive understanding of the program. This tutorial assumes you have already added your GIS data to the example model of InfoSWMM Sustain.

The GIS data and the Sample Sustain Model will be found in your InfoSWMM Examples folder

C:\Users\Public\Documents\InfoSWMM\Examples

The folder will have the Arc Map MXD file, the DB folder and the GIS Data needed for Tutorial 1.

Name	Date modified	Type	Size
GIS Data	3/3/2015 7:15 PM	File folder	
SAMPLE SUSTAIN.ISDB	3/5/2015 4:33 PM	File folder	
SAMPLE SUSTAIN.OUT	3/5/2015 4:33 PM	File folder	
SampleData.gdb	3/4/2015 6:25 PM	File folder	
Sample Sustain.mxd	3/5/2015 4:19 PM	ArcGIS ArcMap D...	634 KB

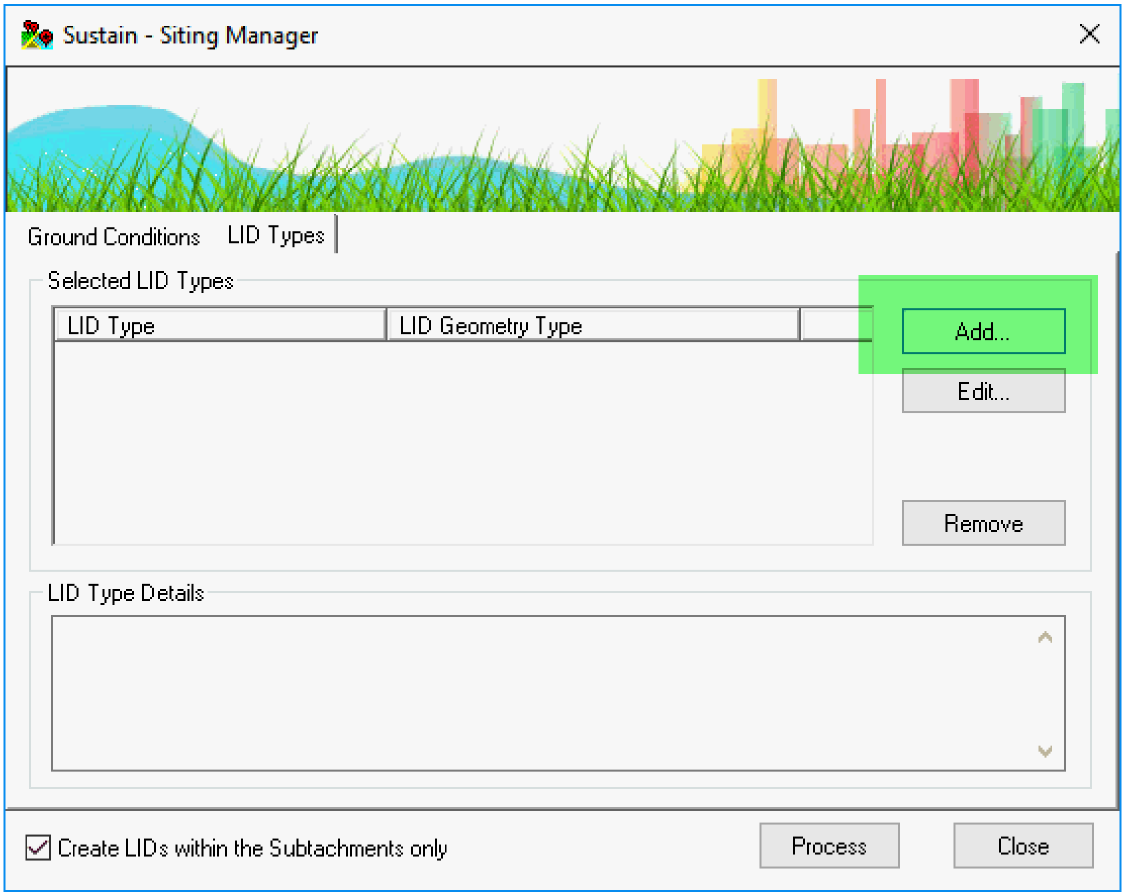
The major tasks in using InfoSWMM Sustain are the following:

- Use the Siting Manager to Add New LID's based on the GIS Rules as set up in the Ground Conditions Dialog
- Use the Optimizer tool to select LID Candidates for Optimization
- Optimize or find the Best Solutions using Scatter Search or the Optimal Cost Solution using GA
- Review the Design Report, Performance Report and Cost Effectiveness Curve

- Decide which of the Designs will be applied to InfoSWMM
- Use the LID Usage Table exported from Sustain in your InfoSWMM model.

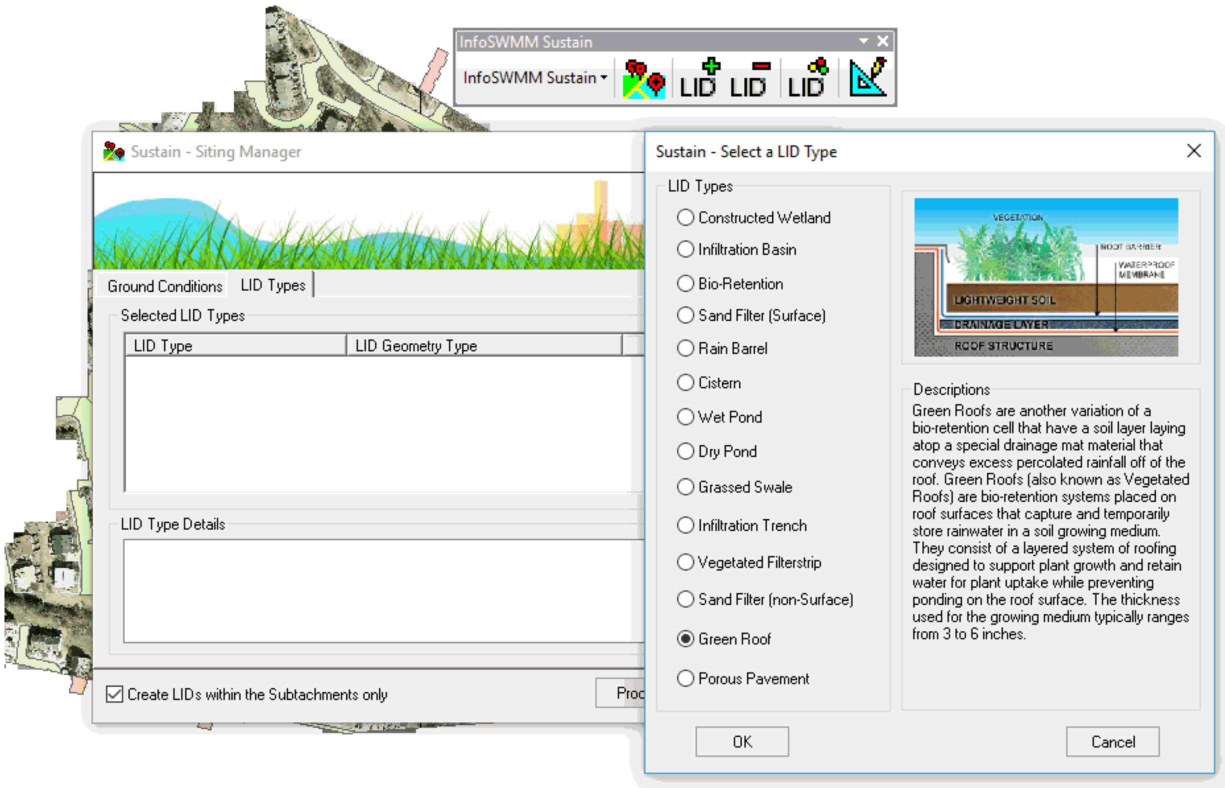
STEP 1: Use the Siting Manager to Choose Green Roofs

Use the Siting Manager and Click on the Add LID Types



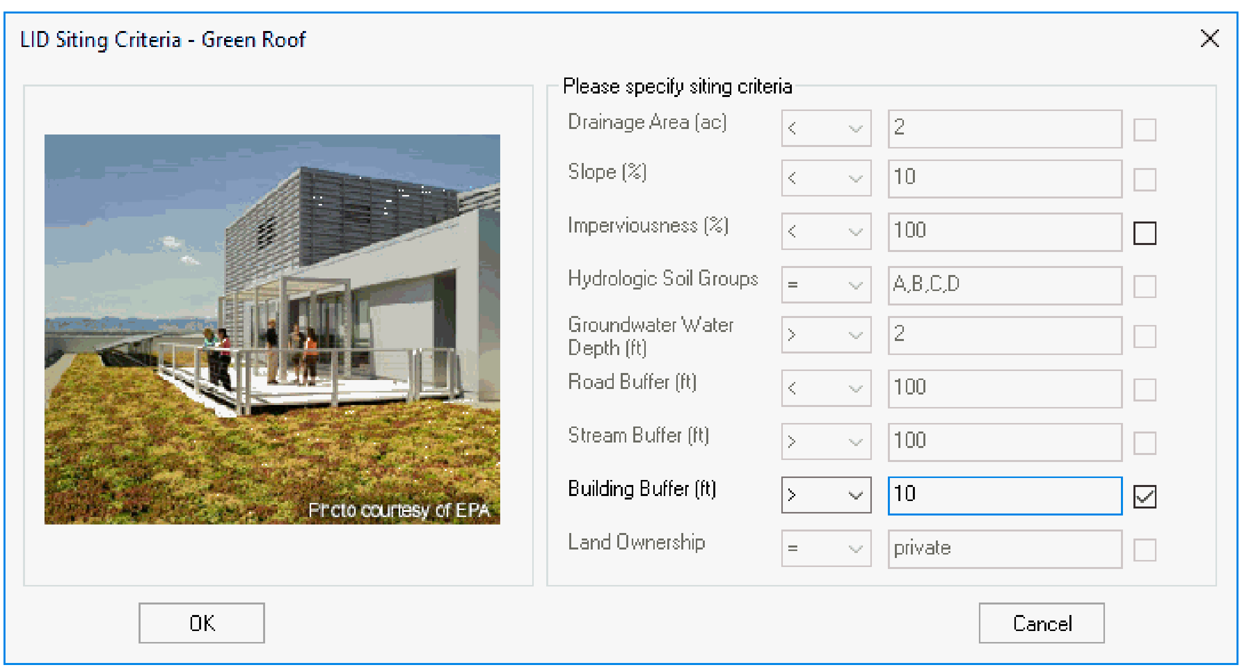
STEP 2: Select the Green Roof LID Type

You add one LID Type and define the Siting Criteria one LID Type at a time.



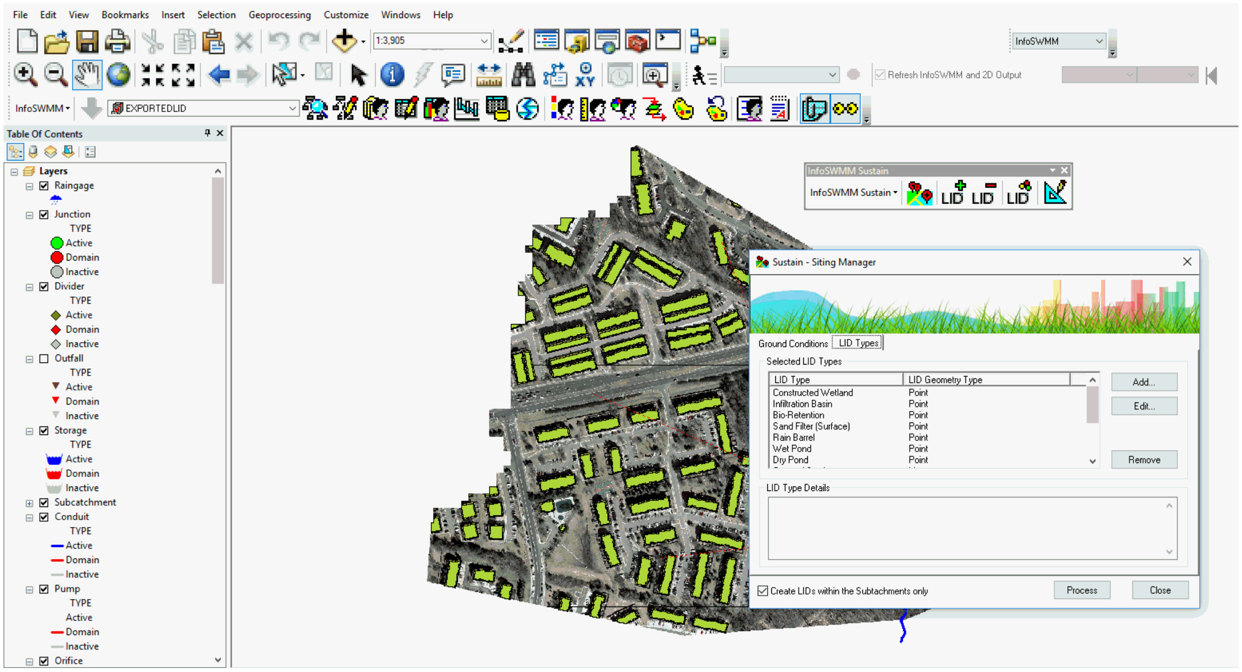
STEP 3: Define the LID Siting Criteria for Green Roofs

Use only the Criteria for Building Buffer and Percent Imperviousness as shown below:



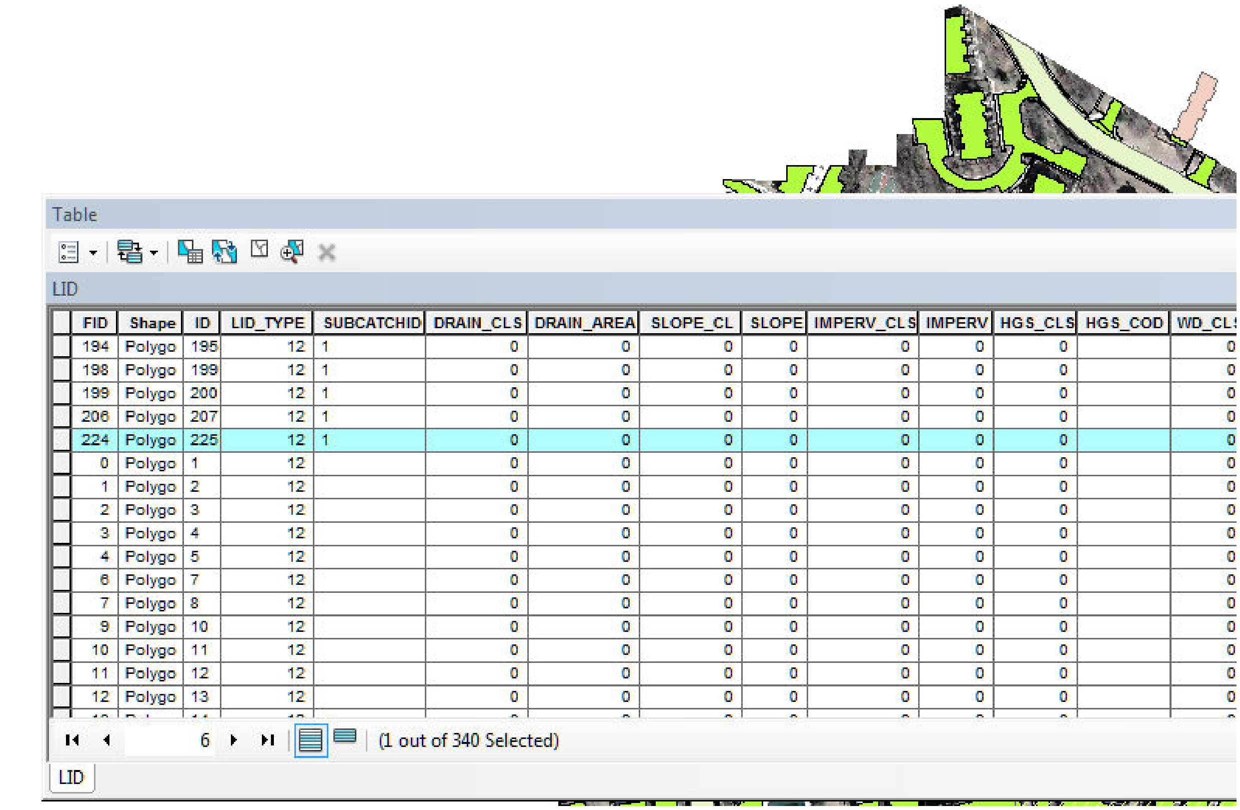
STEP 4: Click on Process to Find the Possible Sites for the Green Roofs

The InfoSWMM Message Board Window will show creation notes and whether there were any errors in the creation of the Green Roofs.



STEP 5: Open the LID Types Atrribute Table to see the Green Roof Possible Locations

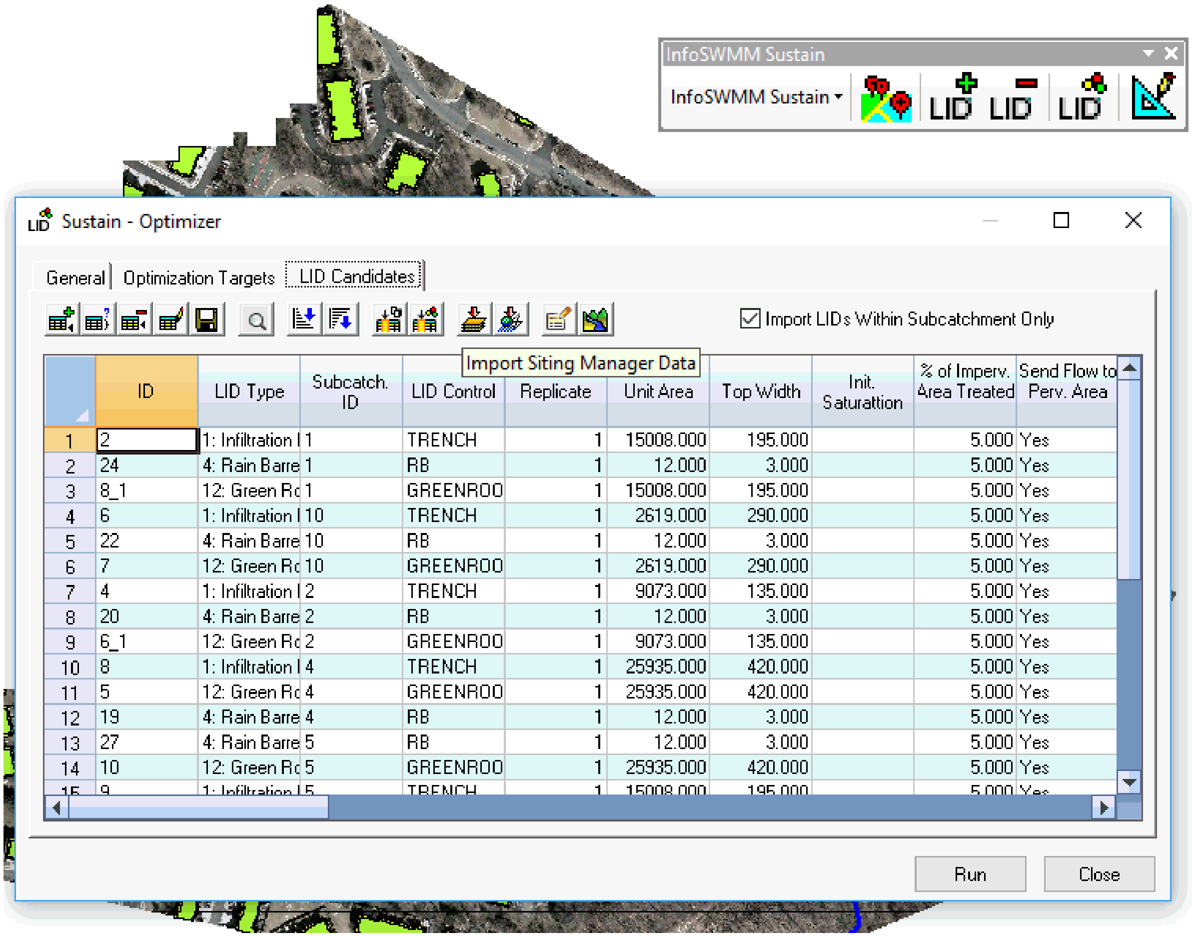
The Siting Manager will find Green Roofs for the whole watershed but we will only use the LID Types on a Subcatchment.



FID	Shape	ID	LID_TYPE	SUBCATCHID	DRAIN_CLS	DRAIN_AREA	SLOPE_CL	SLOPE	IMPERV_CLS	IMPERV	HGS_CLS	HGS_COD	WD_CL
194	Polygo	195	12	1	0	0	0	0	0	0	0		0
198	Polygo	199	12	1	0	0	0	0	0	0	0		0
199	Polygo	200	12	1	0	0	0	0	0	0	0		0
206	Polygo	207	12	1	0	0	0	0	0	0	0		0
224	Polygo	225	12	1	0	0	0	0	0	0	0		0
0	Polygo	1	12		0	0	0	0	0	0	0		0
1	Polygo	2	12		0	0	0	0	0	0	0		0
2	Polygo	3	12		0	0	0	0	0	0	0		0
3	Polygo	4	12		0	0	0	0	0	0	0		0
4	Polygo	5	12		0	0	0	0	0	0	0		0
6	Polygo	7	12		0	0	0	0	0	0	0		0
7	Polygo	8	12		0	0	0	0	0	0	0		0
9	Polygo	10	12		0	0	0	0	0	0	0		0
10	Polygo	11	12		0	0	0	0	0	0	0		0
11	Polygo	12	12		0	0	0	0	0	0	0		0
12	Polygo	13	12		0	0	0	0	0	0	0		0

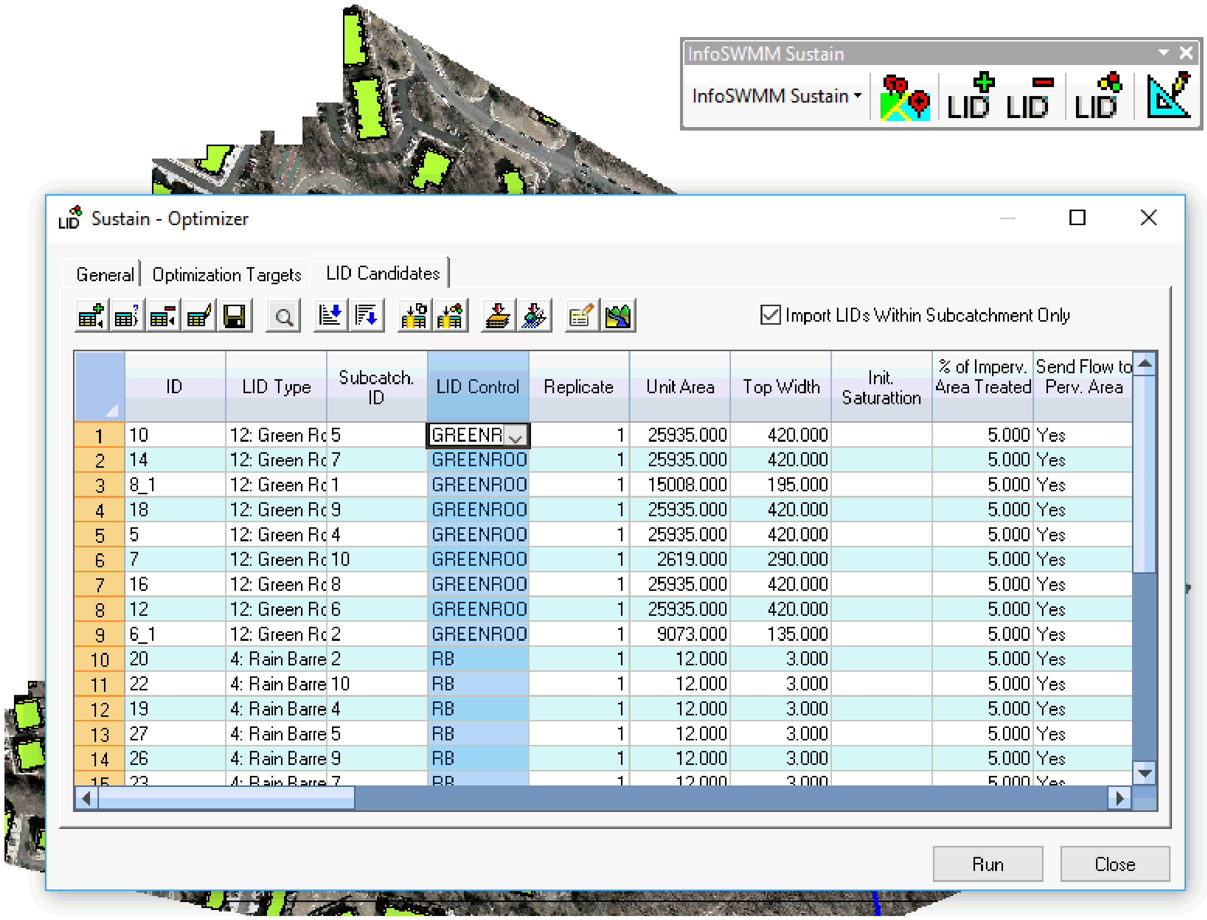
STEP 6: Use the LID Optimizer Tool

Use the LID Optimizer tool (1) to import all of the LID's with a Subcatchment (2).



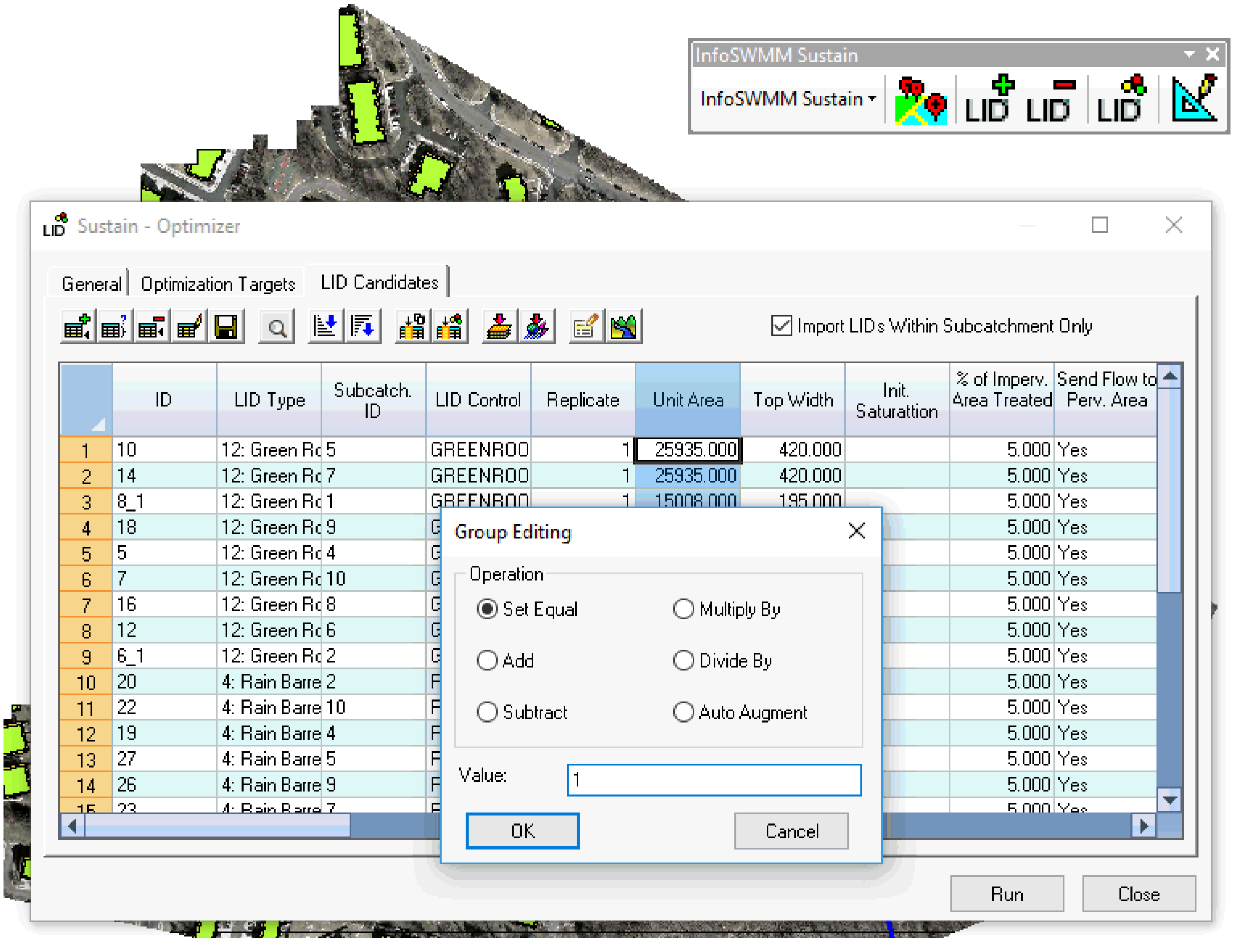
[STEP 7: Import all of the LID Candidates found by the Siting Manager of InfoSWMM Sustain]()

All of the possible Green Roofs on Subcatchments 1, 2 and 3 are now found. You have to decide the actual LID Control for each LID Type. It is possible to have more than one LID Control (from the Operations Tab of the InfoSWMM Browser) for all of the Green Roofs. Click on the LID Control Box and Select a LID Control.



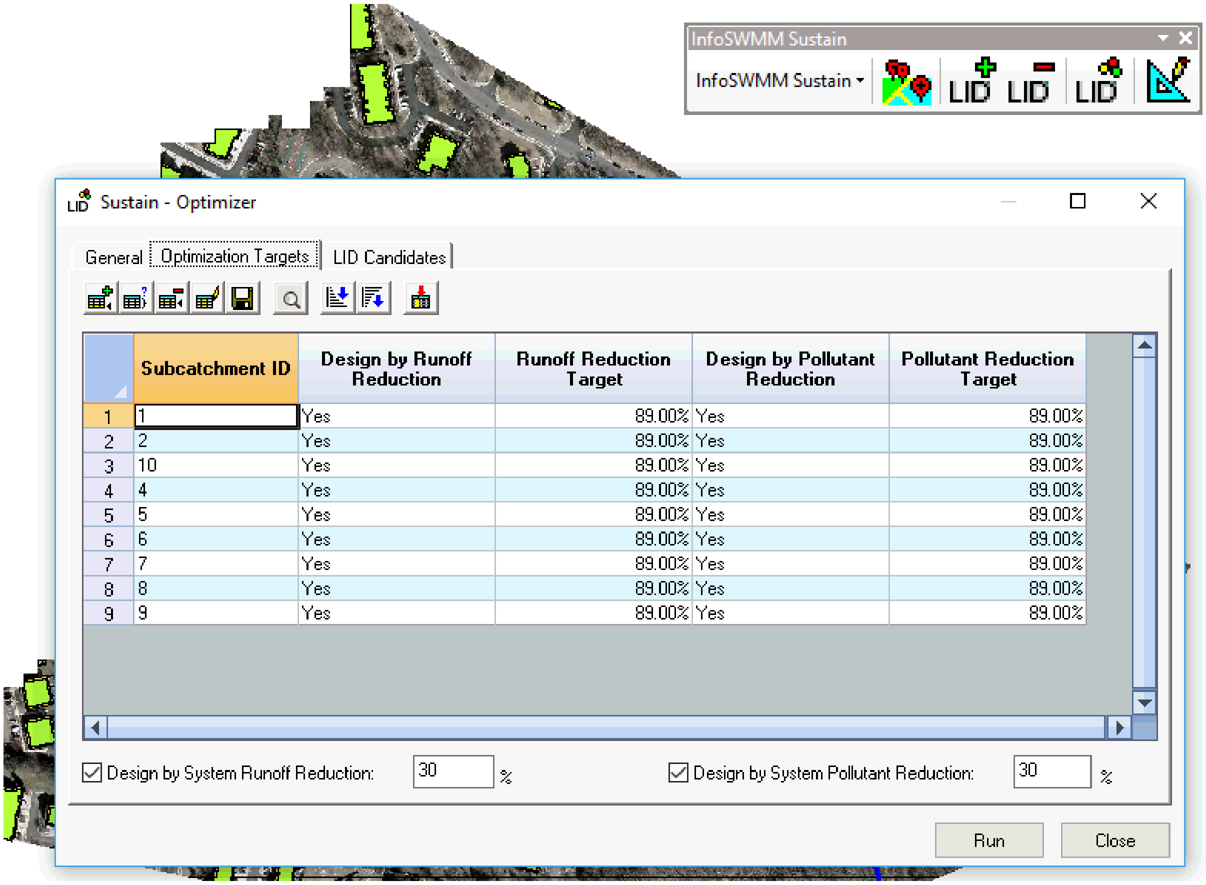
[STEP 8: Set the LID Control for all Rows of the LID Candidate Rows]

Use the BlockEdit Tool or Icon to set the LID Control for all of the other Rows with an LID Type of Green Roof.



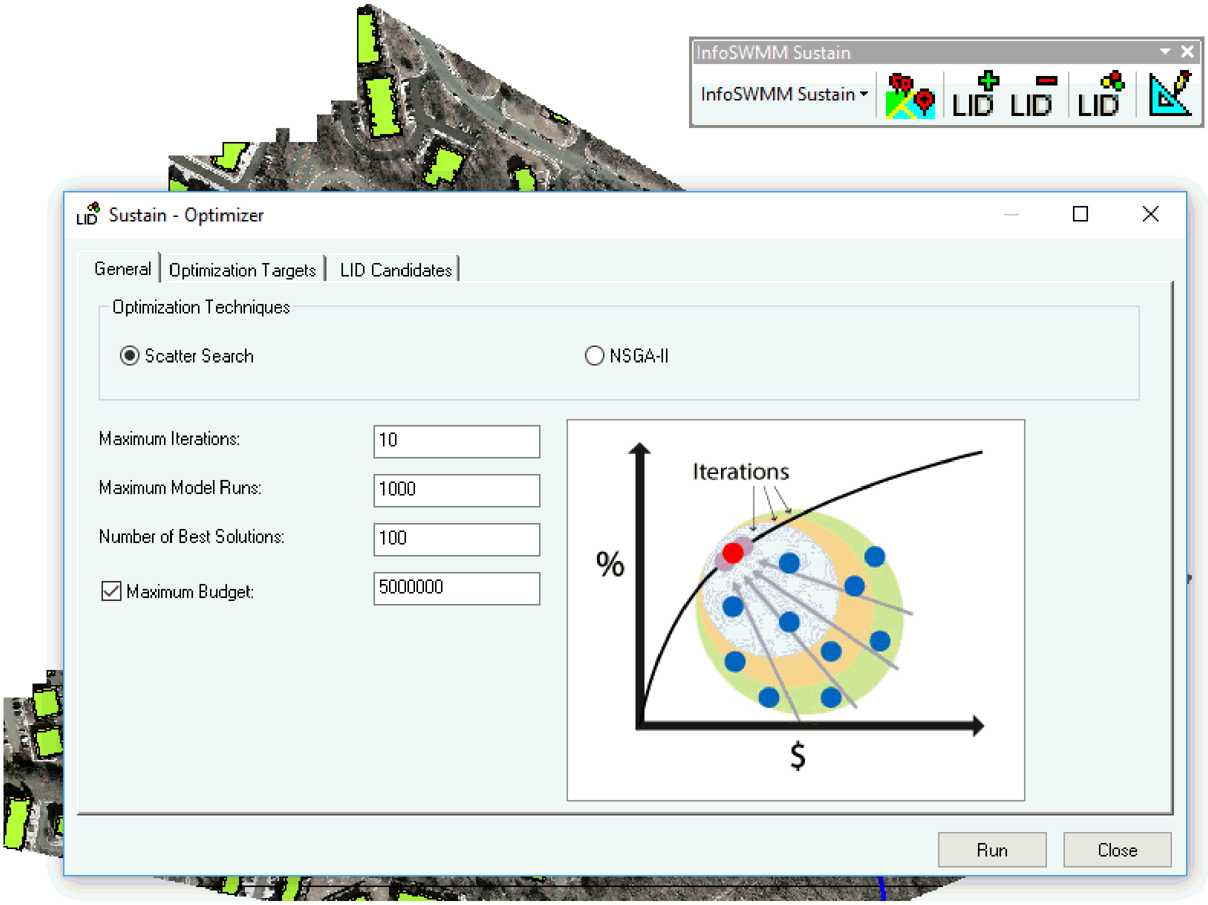
STEP 9: View the Optimization Targets for Runoff and Water Quality

We will use the preset targets of 89 percent for Runoff and Water Quality for all of the Subcatchments.



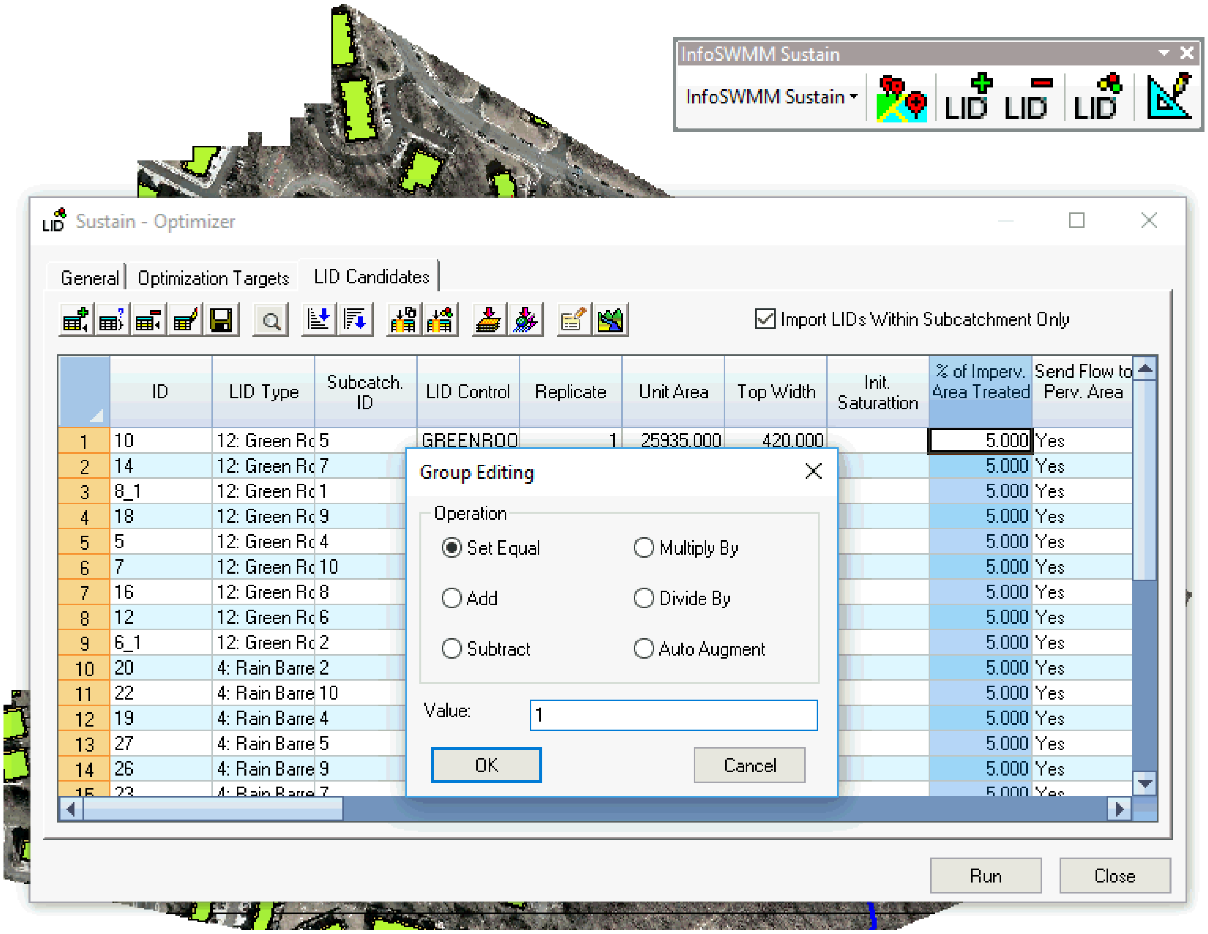
STEP 10: Click on the General Tab to Define the Optimizer Parameters

The parameters are for type of Optimization Technique, the Cost Improvement Threshold, the Maximum Number of Iterations per Model Run, the Maximum InfoSWMM Model runs and the Number of Best Solutions to be Found during the Optimization Process.



STEP 11: Moodify the Percent Imperviousness Area Treated

An important rule is that the total area treated by all LID Types for a particular Subcatchment does not exceed 100 percent of the impervious area. Use the BlockEdit tool again and set the Percent Imperviousness Area Treated to 5 percent per LID Type.

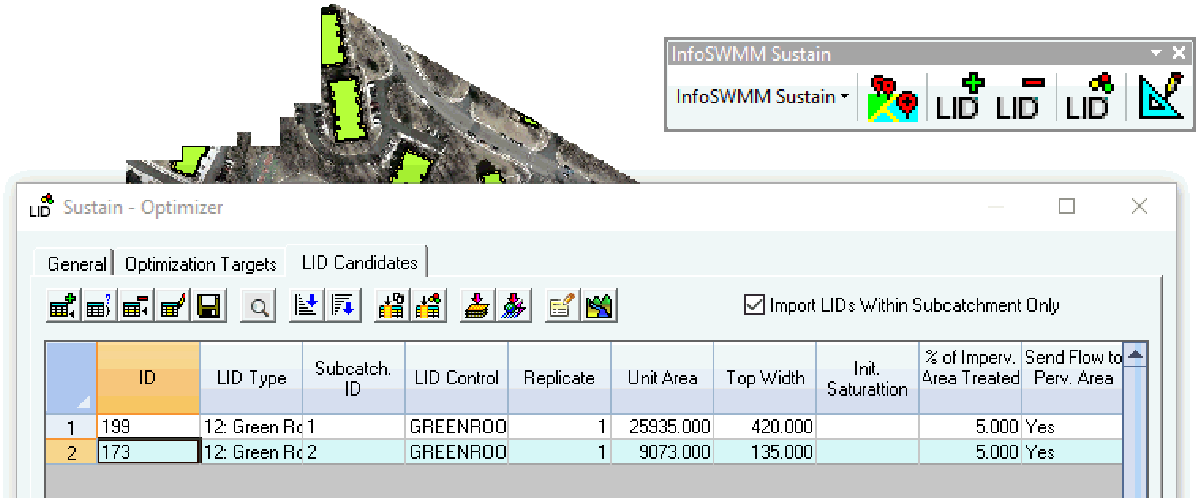


[STEP 12: Reduce the Number of LID Types for this Introductory Tutorial]

Sort the LID Type Rows by Unit Area and then using the delete Row Icon delete all except the 1st Two Rows

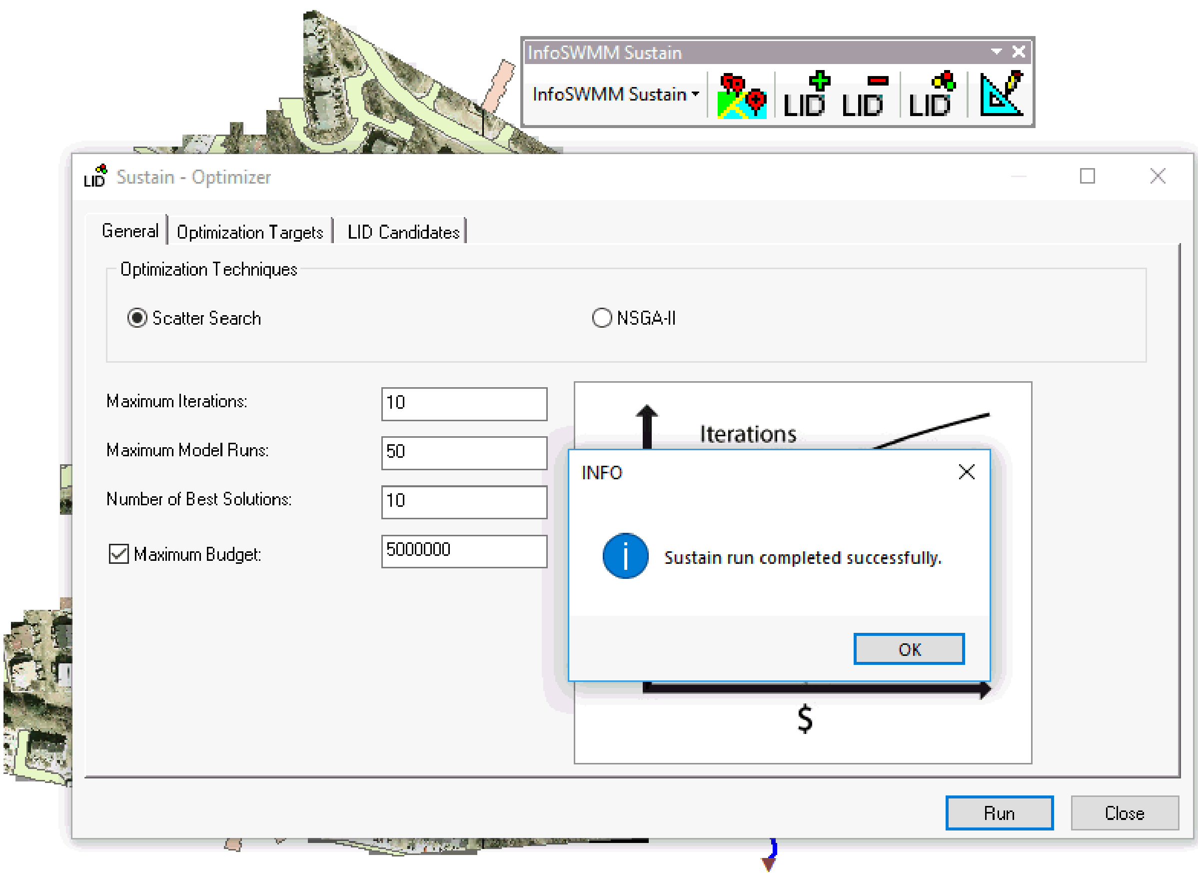
[STEP 13: The Reduced Number of LID Candidates]

The Number LID Candidates should be two now and the ID's should be 173 for Subcatchment 2 and ID 199 for Subcatchment 1.



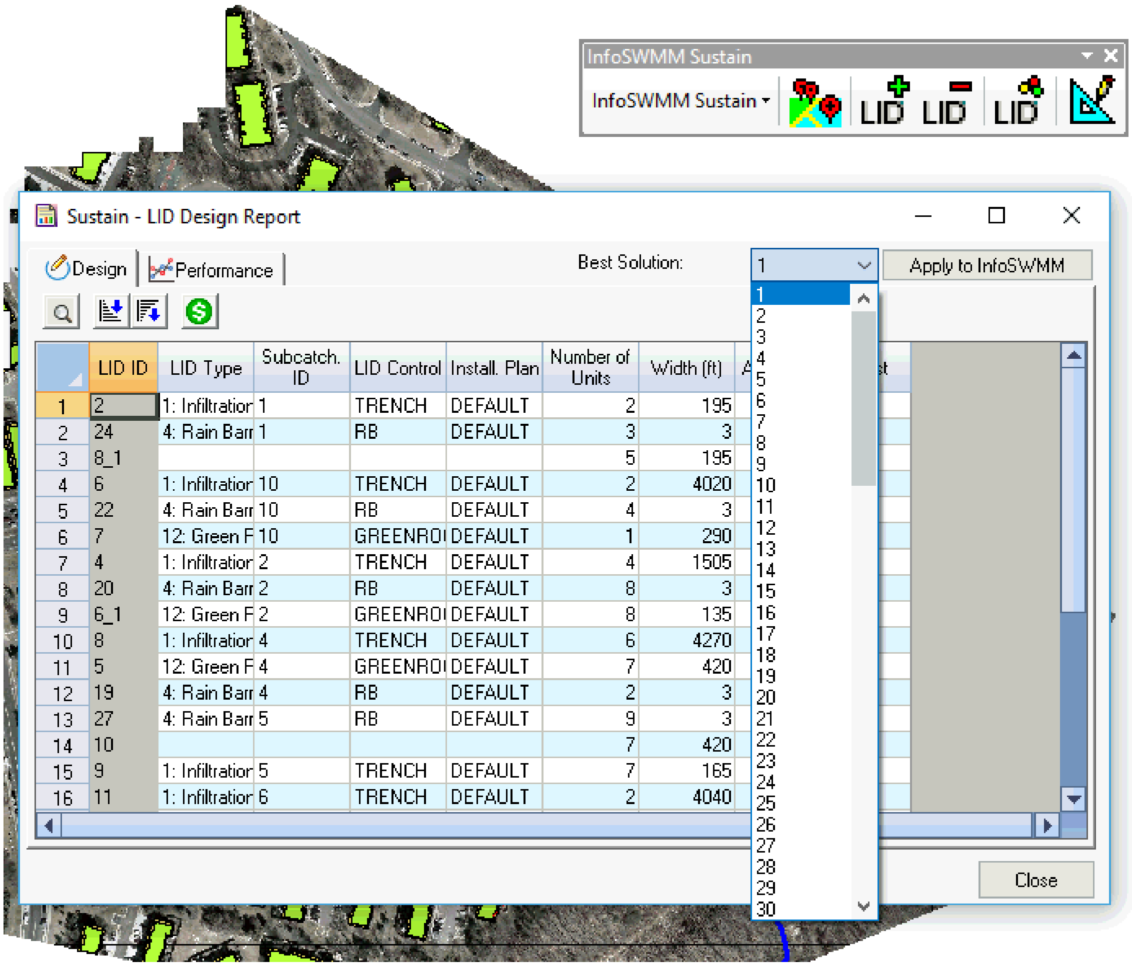
STEP 14: Run the Optimizer

The Optimizer runs many InfoSWMM runs to optimize the selected LID Types. Click on Run and you will see a Blue progress bar at the bottom of the screen and at the end of the Run an Info Dialog Message Box.



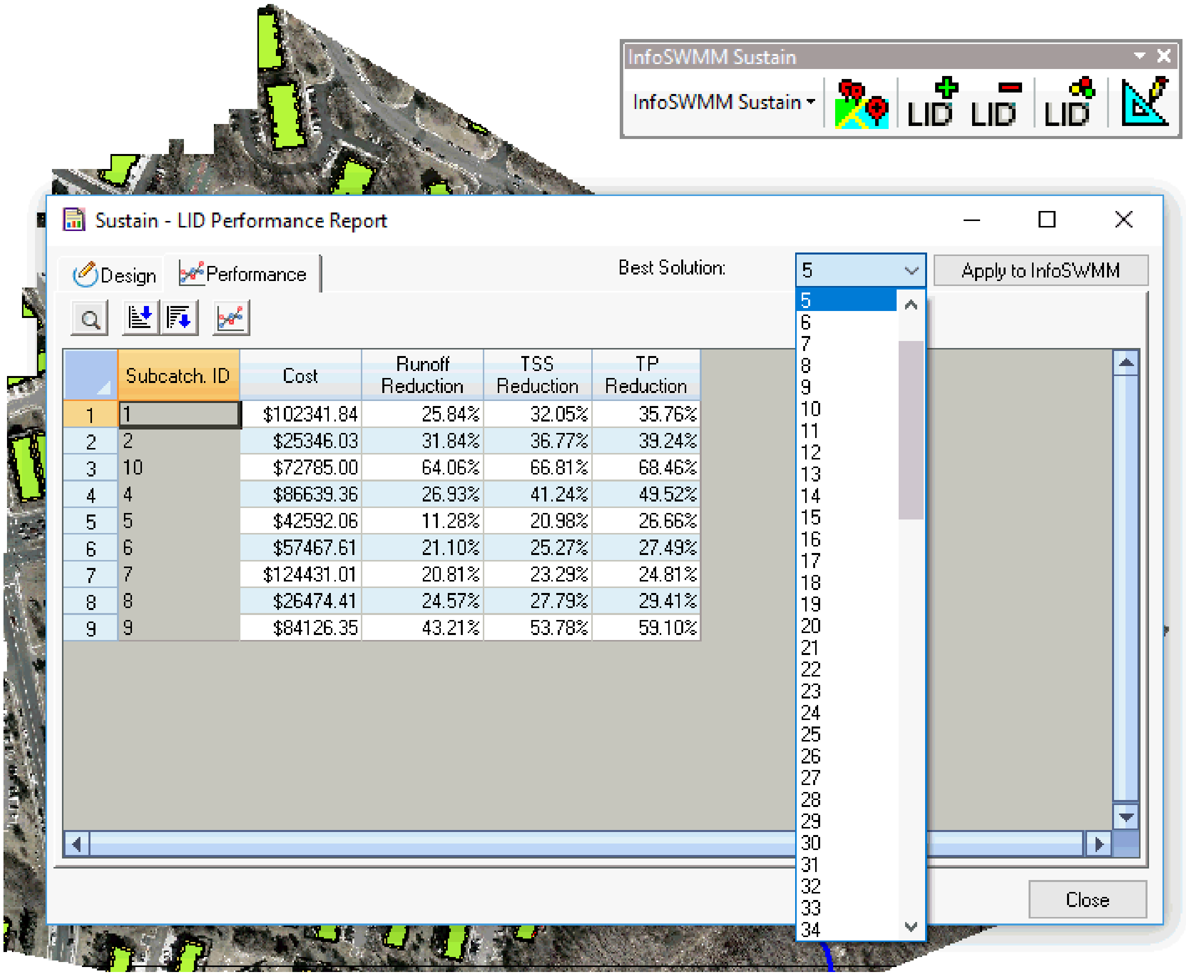
STEP 15: Click on the Design Report to See the Optimized Solutions.

The Optimized solution for each of the found Best Solutions are shown in the Report Grid.



STEP 16: Click on the Performance Report to see if the Control Targets were Met during the Run.

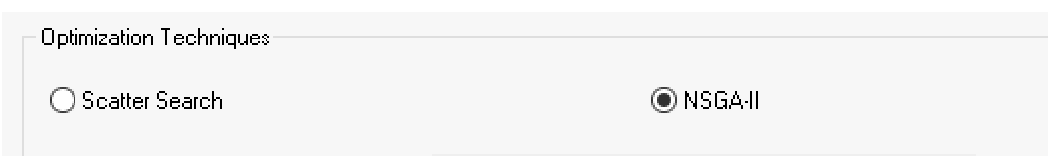
The Control targets of 89 percent for Runoff and Water quality were met in this Optimization Run.

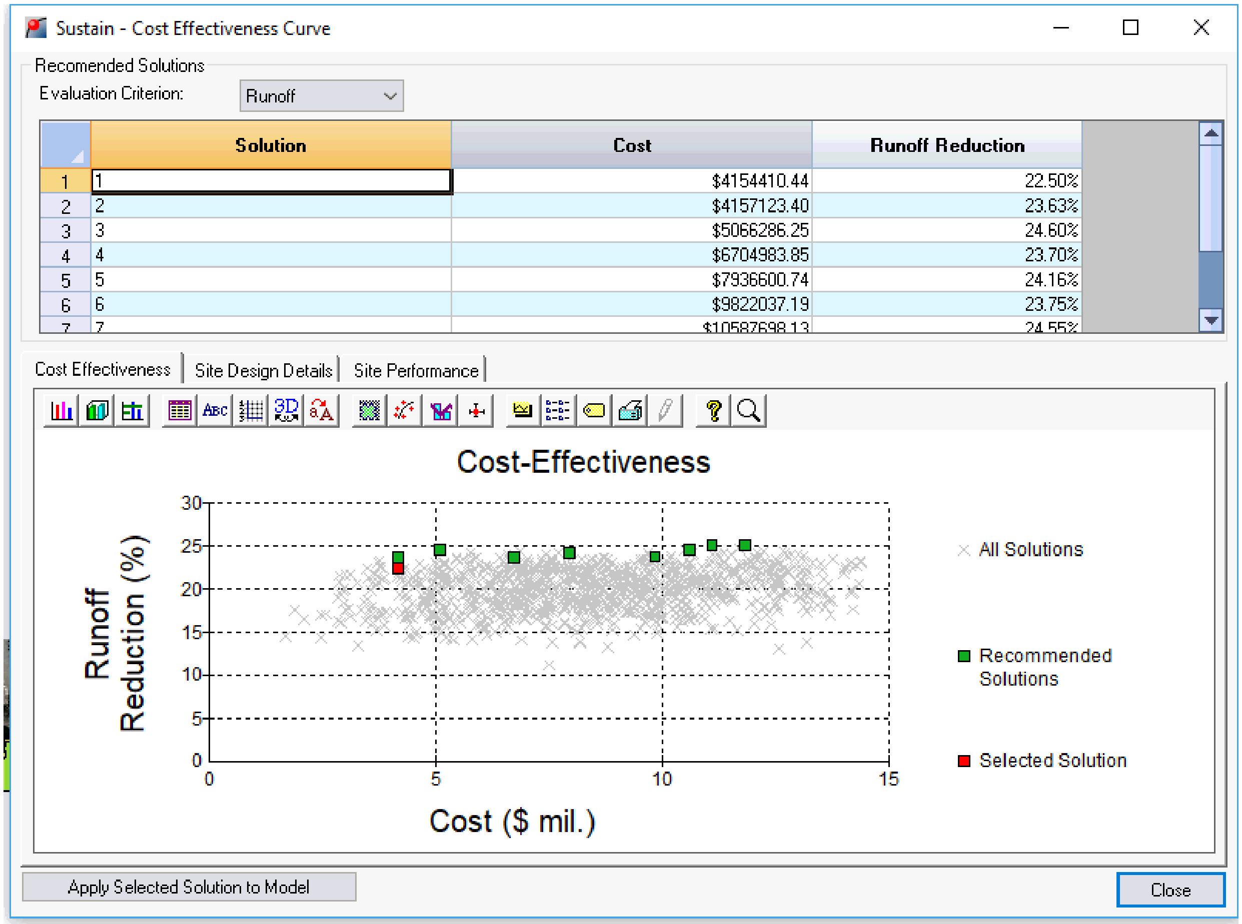


	Subcatch. ID	Cost	Runoff Reduction	TSS Reduction	TP Reduction
1	1	$102341.84	25.84%	32.05%	35.76%
2	2	$25346.03	31.84%	36.77%	39.24%
3	10	$72785.00	64.06%	66.81%	68.46%
4	4	$86639.36	26.93%	41.24%	49.52%
5	5	$42592.06	11.28%	20.98%	26.66%
6	6	$57467.61	21.10%	25.27%	27.49%
7	7	$124431.01	20.81%	23.29%	24.81%
8	8	$26474.41	24.57%	27.79%	29.41%
9	9	$84126.35	43.21%	53.78%	59.10%

STEP 17: Cost Effectiveness Curve for Sustain 4.0

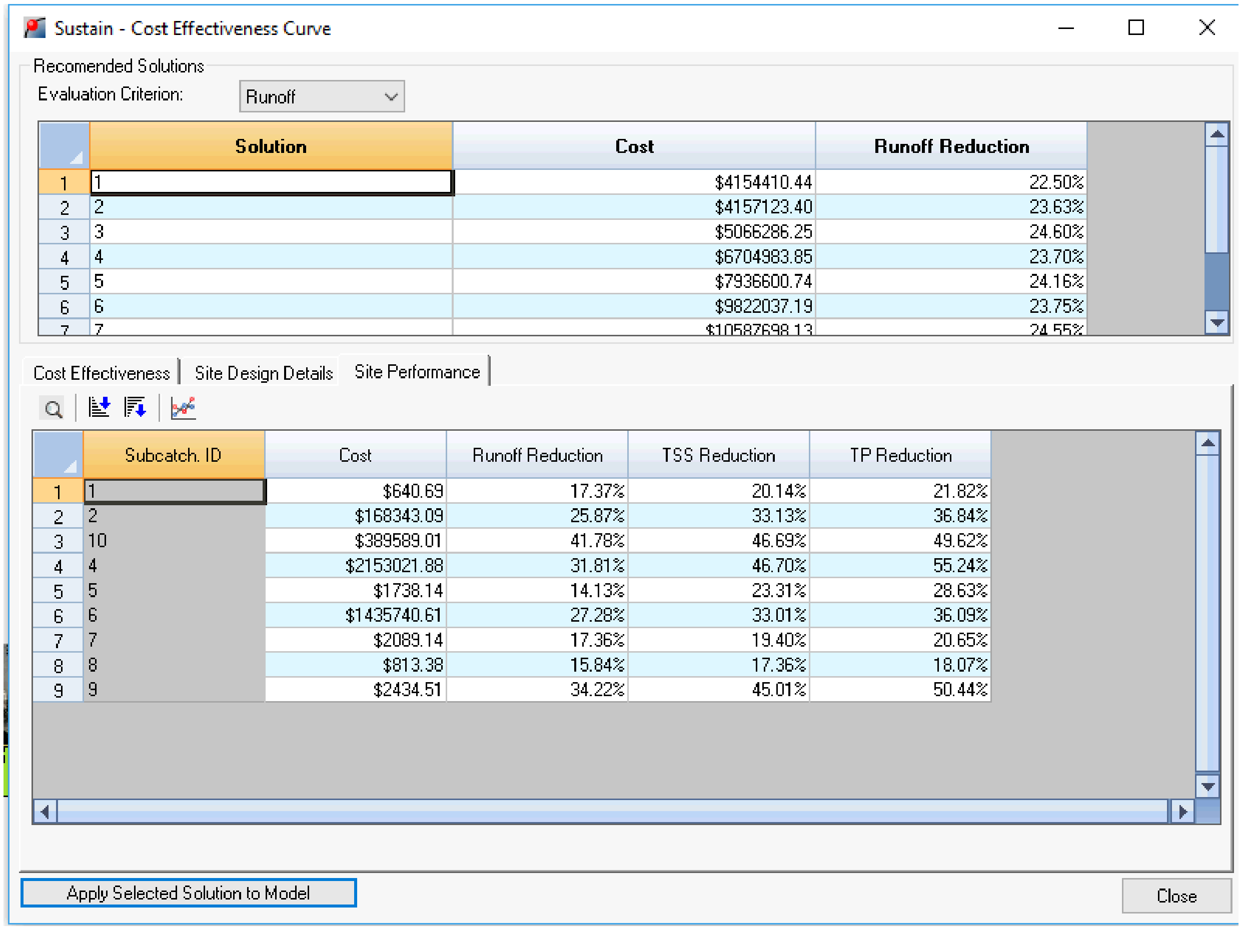
The Cost Effectiveness Curve shows the Recommended Solutions (Green), Best Solution (red) and all of the Solutions (grey).





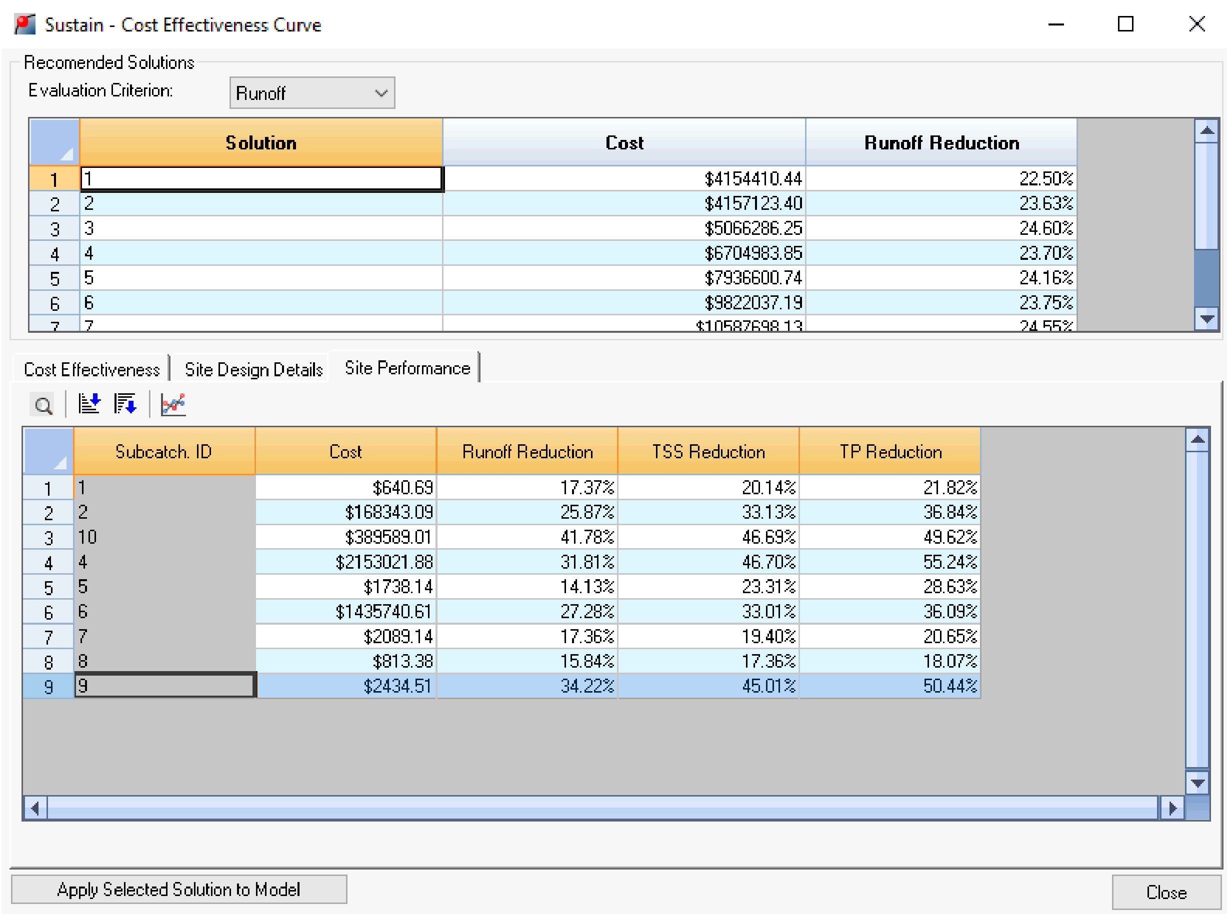
STEP 18: The Cost Effectiveness Curve Report for Sustain 4.0

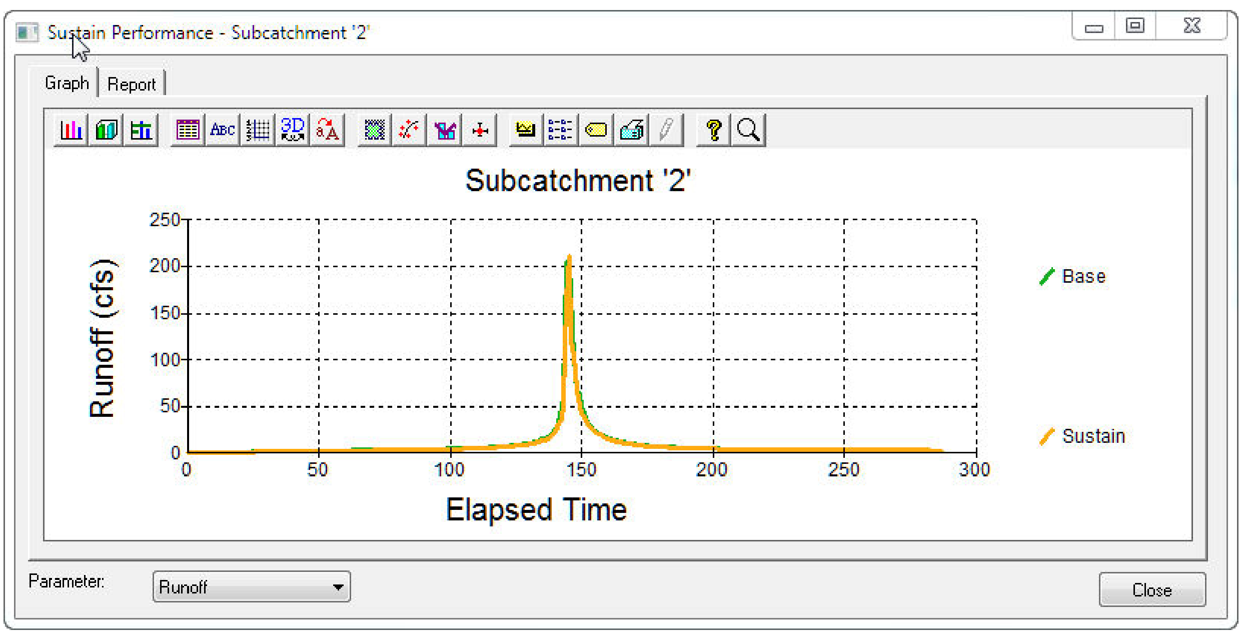
Click on the Report Tab of the Cost Effectiveness Curve to see the Runoff Reduction and Performance for all of the Recommended Solutions.



STEP 19: Click on the LID Performance Report to choose a Best Solution to Apply to the InfoSWMM LID Usage Table

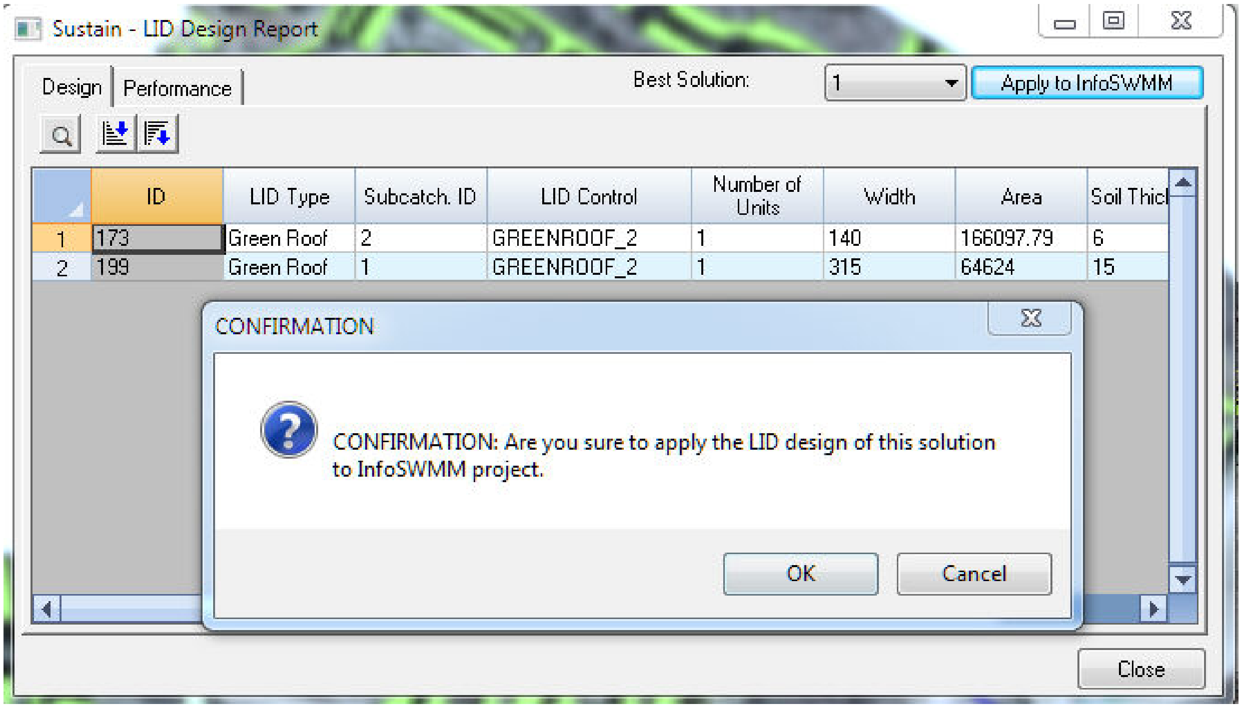
Decide on which solution to Apply to InfoSWMM. The Graph Icon report will help you decide.





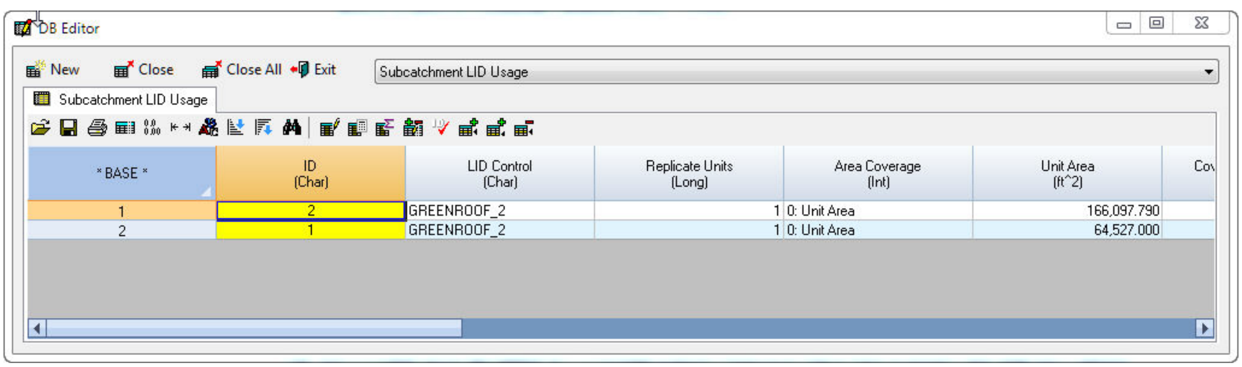
STEP 20: Click on Apply to InfoSWMM

If the InfoSWMM LID Usage Table has been updated then your will get a Confirmation Message Dialog Box.



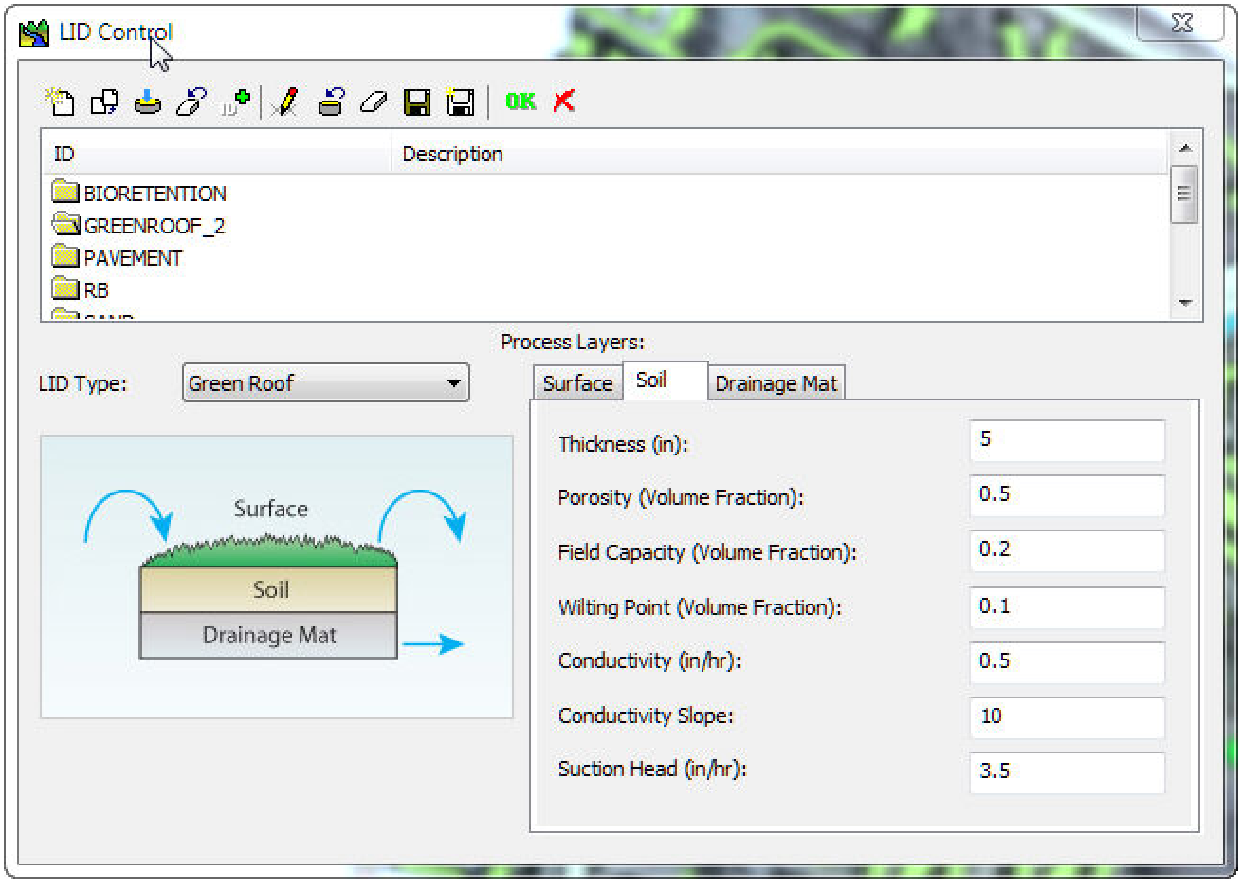
STEP 21: Edit the InfoSWMM DB Tables and Select LID Usage

You will see the LID Controls that were applied from InfoSWMM Sustain to InfoSWMM. These LID's will be used in the InfoSWMM Simulation.



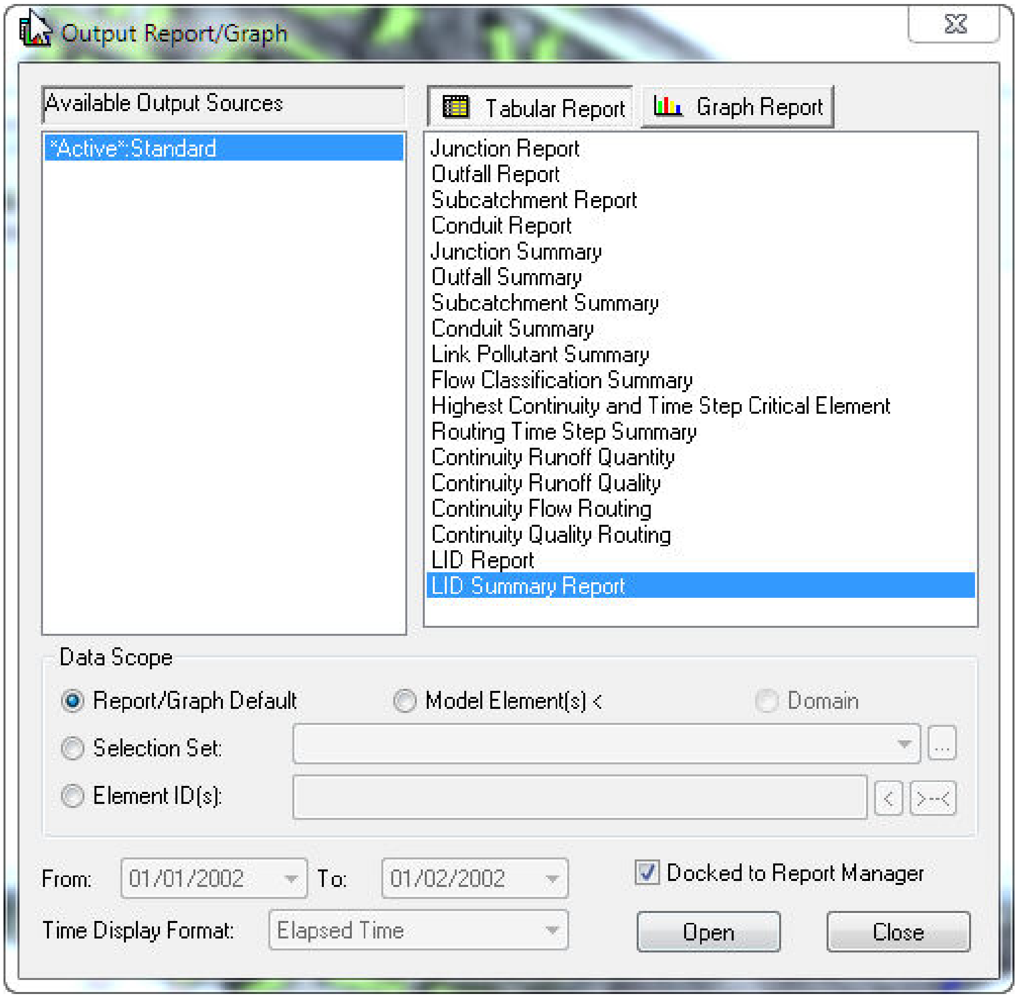
STEP 22: Click on the LID Controls under Hydrology in the InfoSWMM Attribute Browser.

The optimized Green Roof parameters will be shown for each Process Layer.



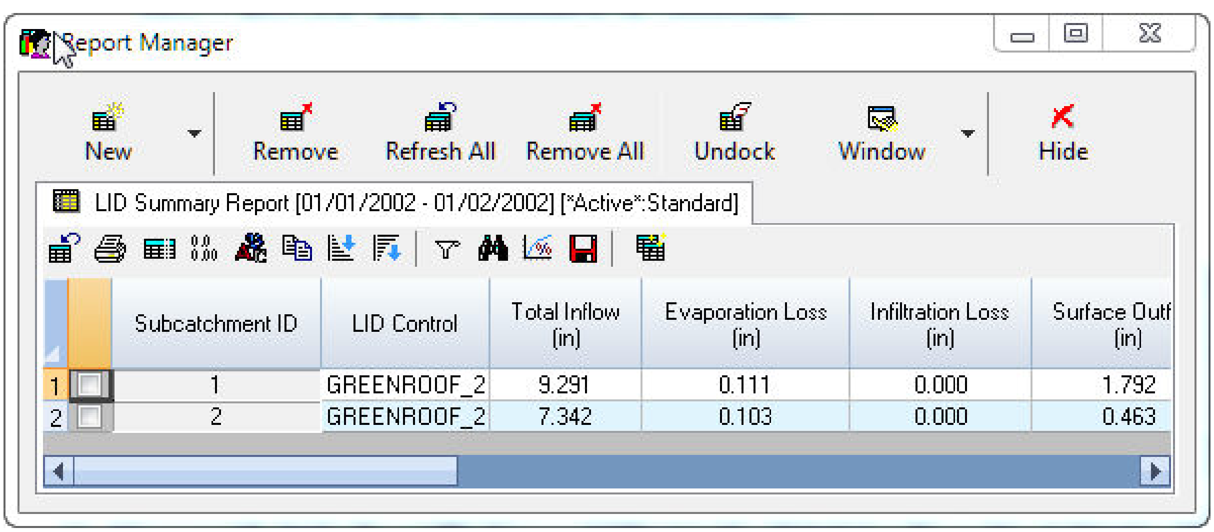
STEP 23: Click on Report Manager to see the LID Result Reports

The LID results can be seen graphically, in the LID Report and in the LID Summary Report.



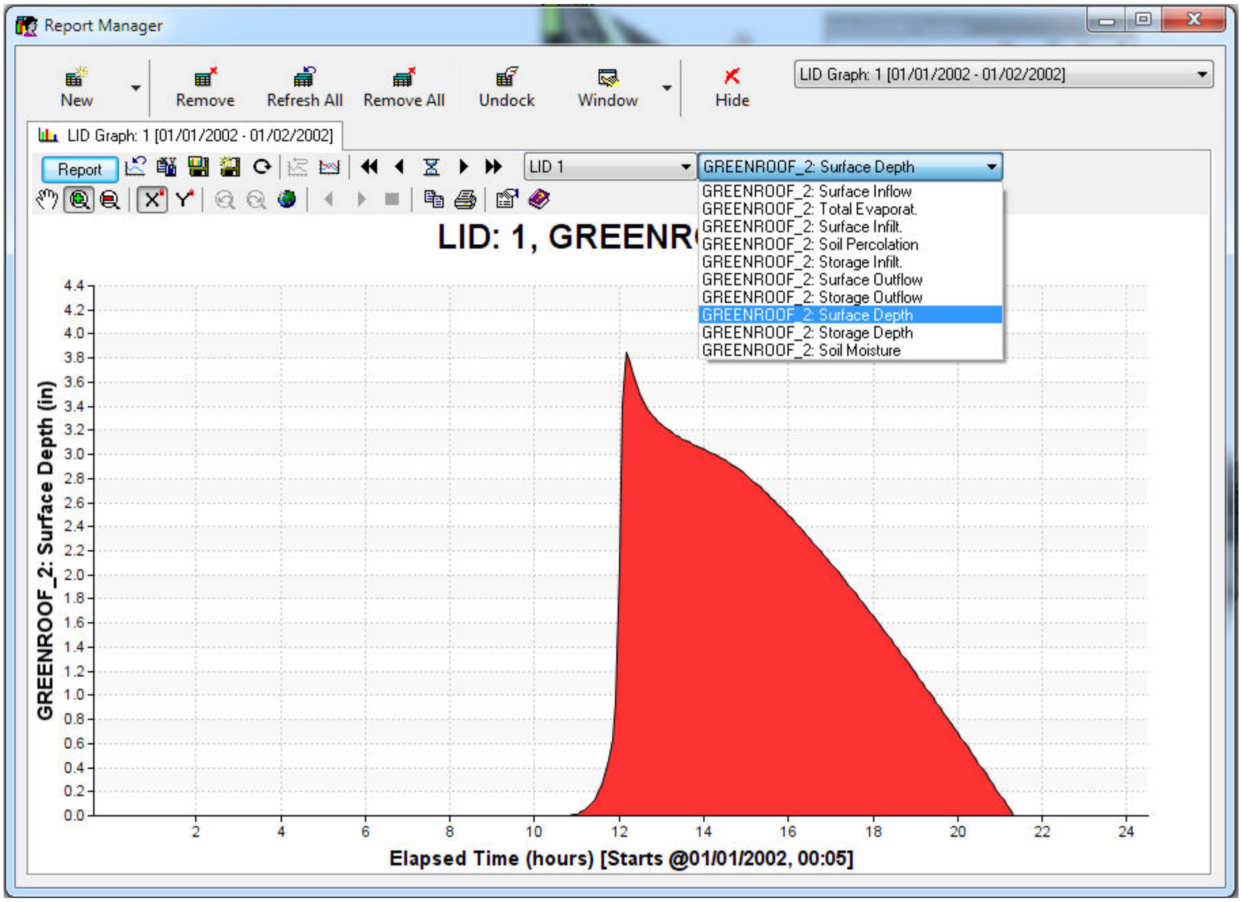
STEP 24: Click on Report Manager to see the LID Summary Reports

This summary table can also be seen in the HTML LID Report of InfoSWMM.



STEP 25: Click on Report Manager to see the LID Graphs

You can see up to 10 Process Graphs for LID's in InfoSWMM.



This ends the short tutorial for optimizing Green Roofs in InfoSWMM Sustain. The remaining Tutorials will expand on this view of InfoSWMM Sustain.

Innovyze Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 Engine

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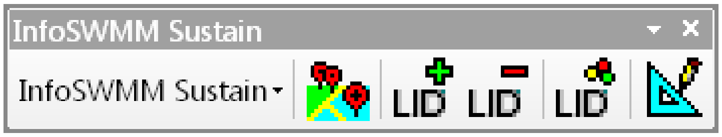
or by Using Our Social Media Websites or Searching the Internet for #INFOSWMM


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 2 Optimizing Rain Barrels for Sustain 4.0

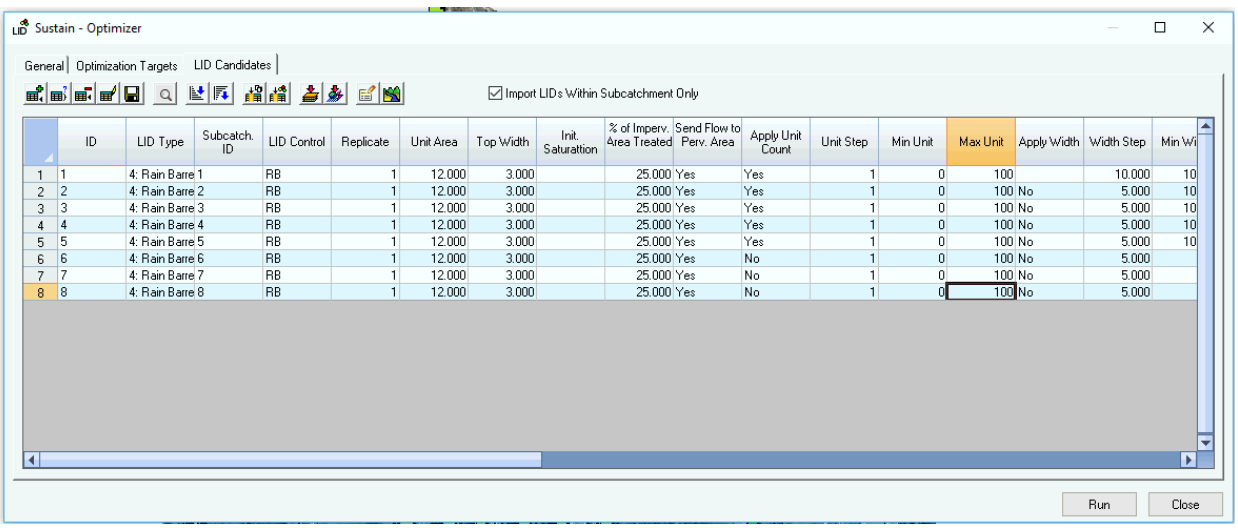
This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Rain Barrels on the ten Subcatchments.

1. Turn off Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow into the Rain Barrels



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturattion	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min Unit	Max Unit	Apply Width	Width Step	Min Wi
1	1	4: Rain Barre	1	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100		10.000	10
2	2	4: Rain Barre	2	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
3	3	4: Rain Barre	3	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
4	4	4: Rain Barre	4	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
5	5	4: Rain Barre	5	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
6	6	4: Rain Barre	6	RB	1	12.000	3.000		25.000	Yes	No	1	0	100	No	5.000	
7	7	4: Rain Barre	7	RB	1	12.000	3.000		25.000	Yes	No	1	0	100	No	5.000	
8	8	4: Rain Barre	8	RB	1	12.000	3.000		25.000	Yes	No	1	0	100	No	5.000	

A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media Volume Cost Under Drain Volume Cost Constant Cost Percentage of other Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent Underdrain Outlet Installation Plan

1 4: Rain Barrel 1 RB 1 12.000 3.000 25.000 Yes No Yes 1 0 100 10.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 0.000 0.000 17.350 0.000 0.000 50.000 0.000 1.000 1.000 1.000 1.000 1.000 DEFAULT

2 4: Rain Barrel 2 RB 1 12.000 3.000 25.000 Yes No Yes 1 0 100 No 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 0.000 0.000 17.350 0.000 0.000 50.000 0.000 1.000 1.000 1.000 1.000 1.000 DEFAULT

3 4: Rain Barrel 3 RB 1 12.000 3.000 25.000 Yes No Yes 1 0 100 No 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 0.000 0.000 17.350 0.000 0.000 50.000 0.000 1.000 1.000 1.000 1.000 1.000 DEFAULT

4 4: Rain Barrel 4 RB 1 12.000 3.000 25.000 Yes No Yes 1 0 100 No 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 0.000 0.000 17.350 0.000 0.000 50.000 0.000 1.000 1.000 1.000 1.000 1.000 DEFAULT

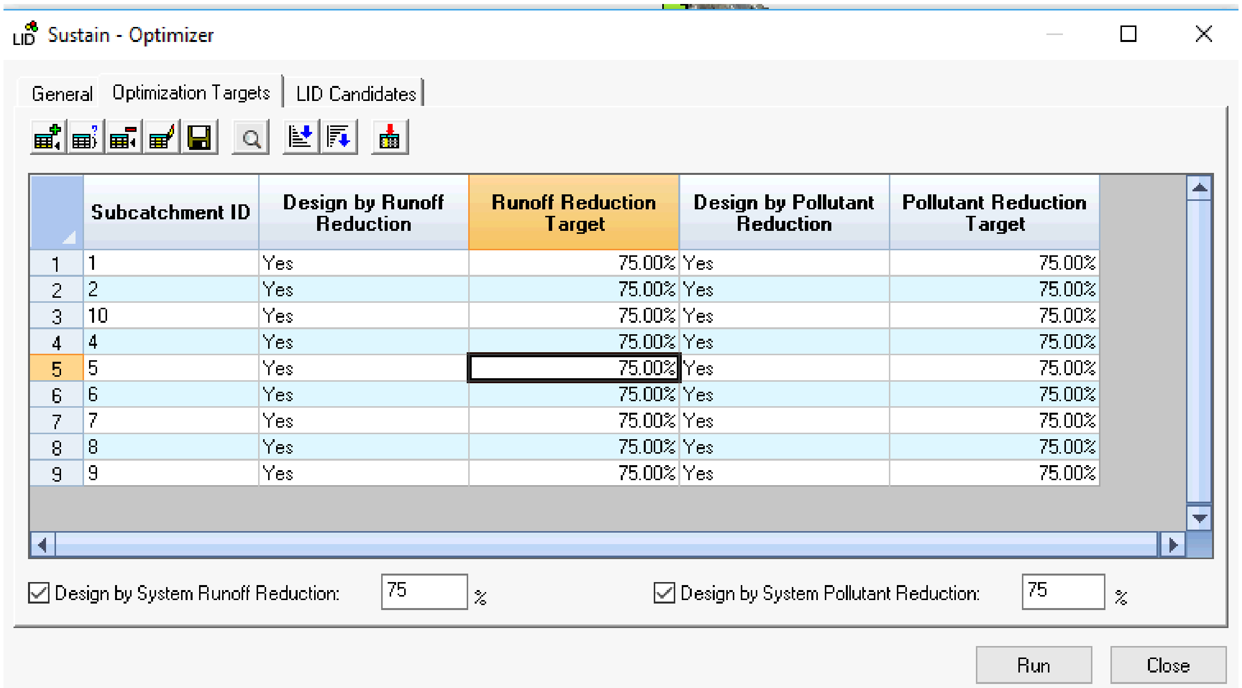
5 4: Rain Barrel 5 RB 1 12.000 3.000 25.000 Yes No Yes 1 0 100 No 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 0.000 0.000 17.350 0.000 0.000 50.000 0.000 1.000 1.000 1.000 1.000 1.000 DEFAULT

6 4: Rain Barrel 6 RB 1 12.000 3.000 25.000 Yes No No 1 0 100 No 5.000 No No DEFAULT

7 4: Rain Barrel 7 RB 1 12.000 3.000 25.000 Yes No No 1 0 100 No 5.000 No No DEFAULT

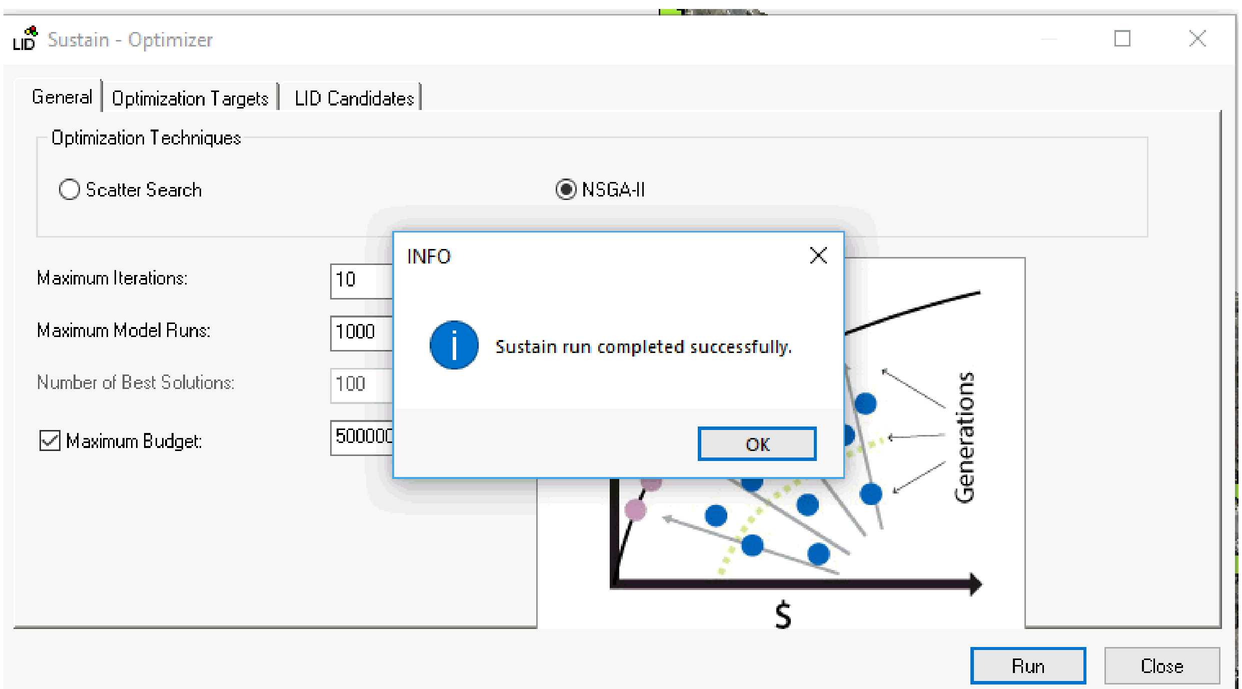
8 4: Rain Barrel 8 RB 1 12.000 3.000 25.000 Yes No No 1 0 100 No 5.000 No No DEFAULT

Our Optimization Goals

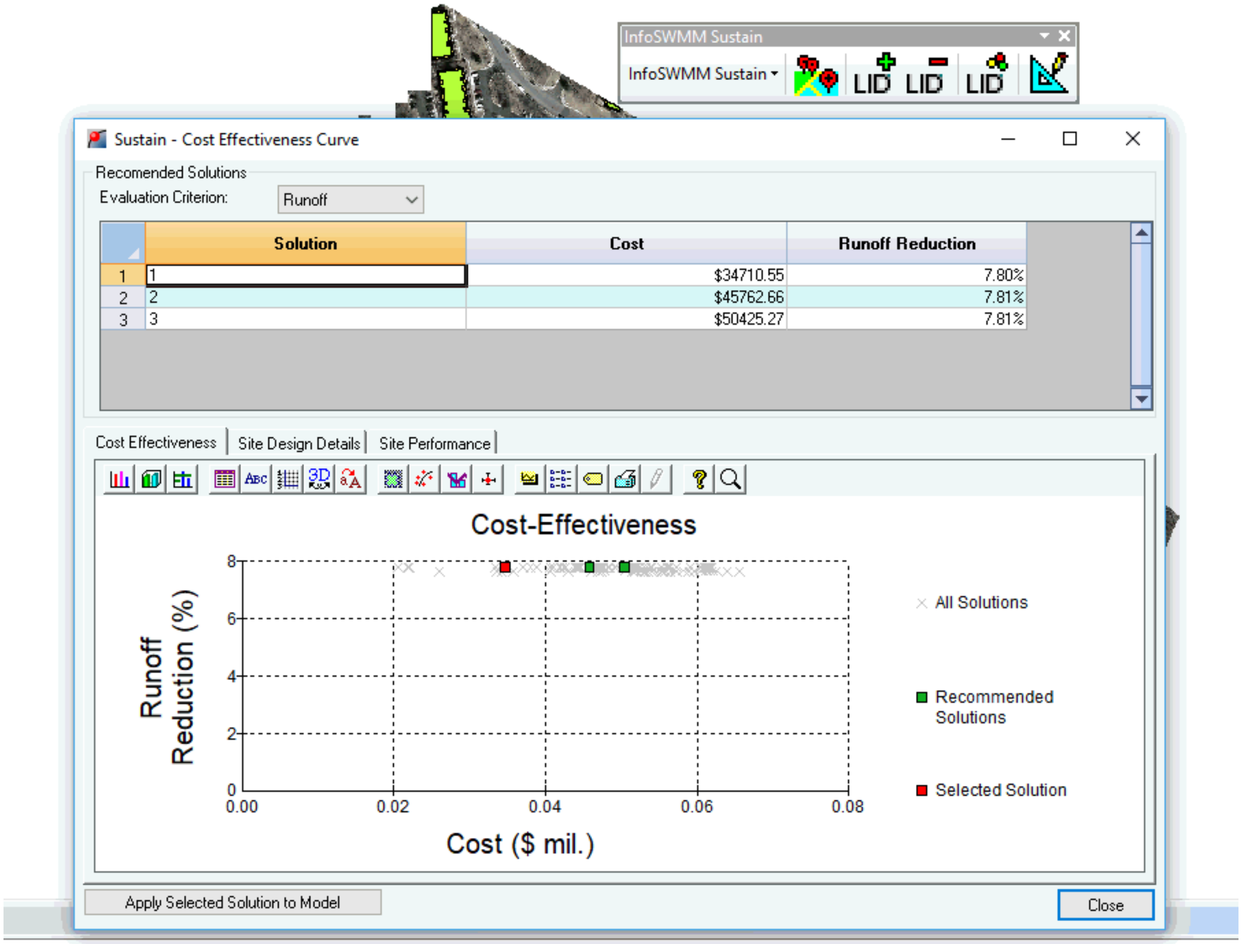


	Subcatchment ID	Design by Runoff Reduction	Runoff Reduction Target	Design by Pollutant Reduction	Pollutant Reduction Target
1	1	Yes	75.00%	Yes	75.00%
2	2	Yes	75.00%	Yes	75.00%
3	10	Yes	75.00%	Yes	75.00%
4	4	Yes	75.00%	Yes	75.00%
5	5	Yes	75.00%	Yes	75.00%
6	6	Yes	75.00%	Yes	75.00%
7	7	Yes	75.00%	Yes	75.00%
8	8	Yes	75.00%	Yes	75.00%
9	9	Yes	75.00%	Yes	75.00%

Use NSGA-II Optimization to find the Cost Boundary Curve

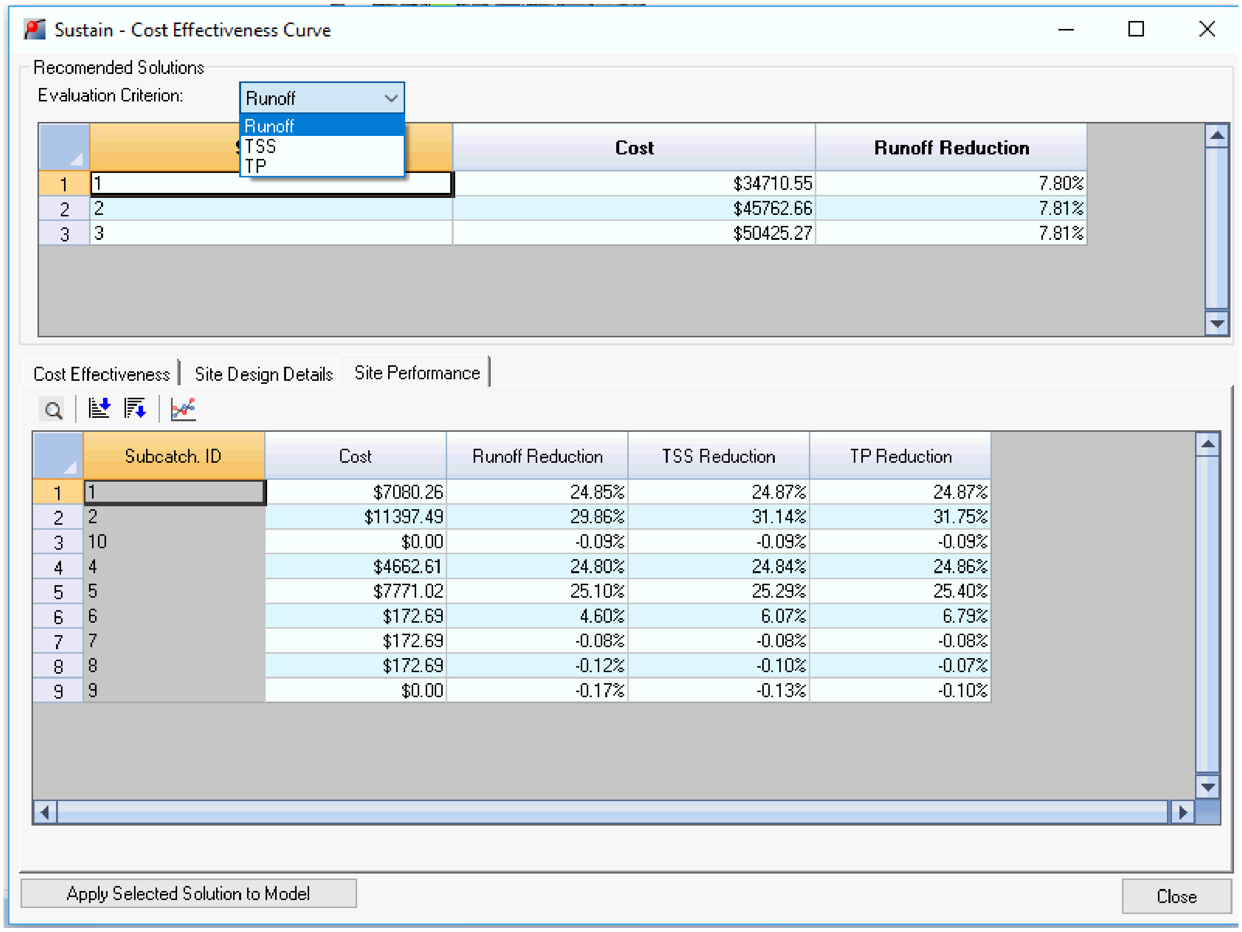


The Cost Effectiveness Curves for Runoff and Water Quality

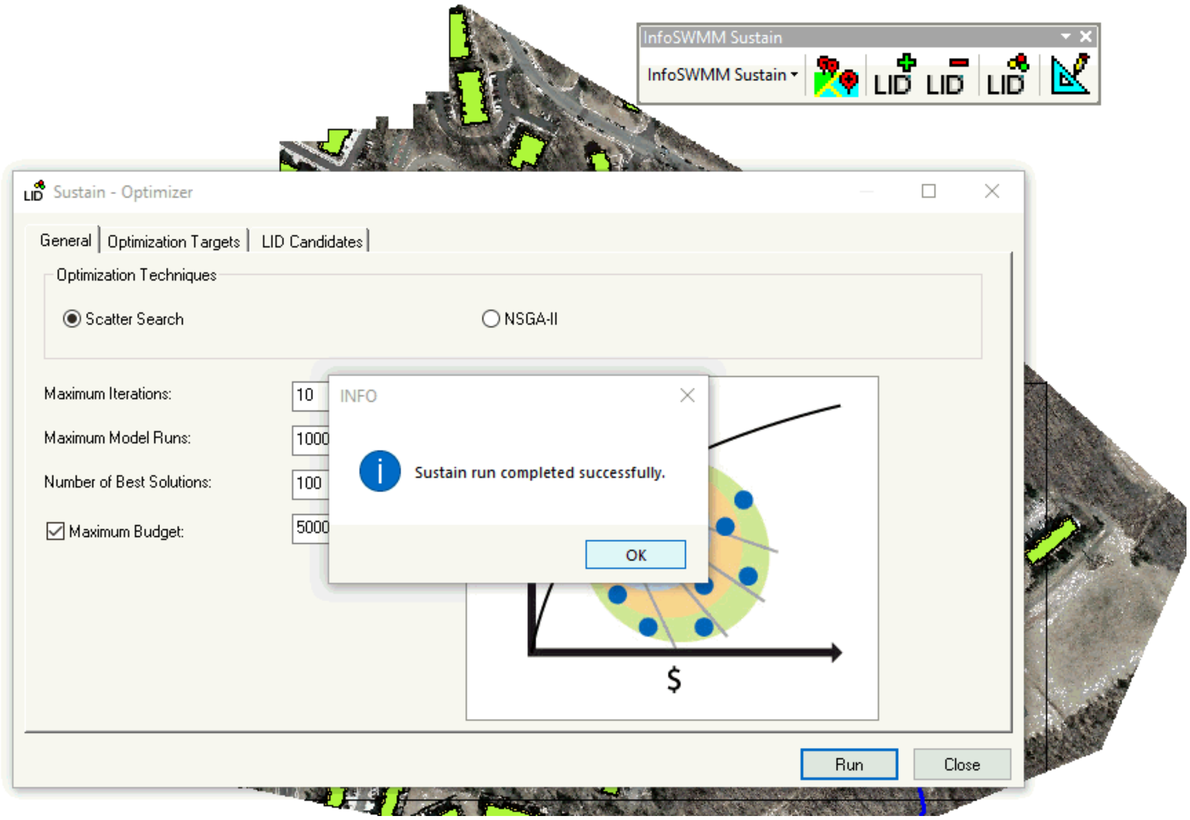


The Cost Effectiveness Report for Runoff and Water Quality

There is little removal as the Rain Barrels are not sending the overflow to the pervious area and there is little storage in a Rain Barrel.

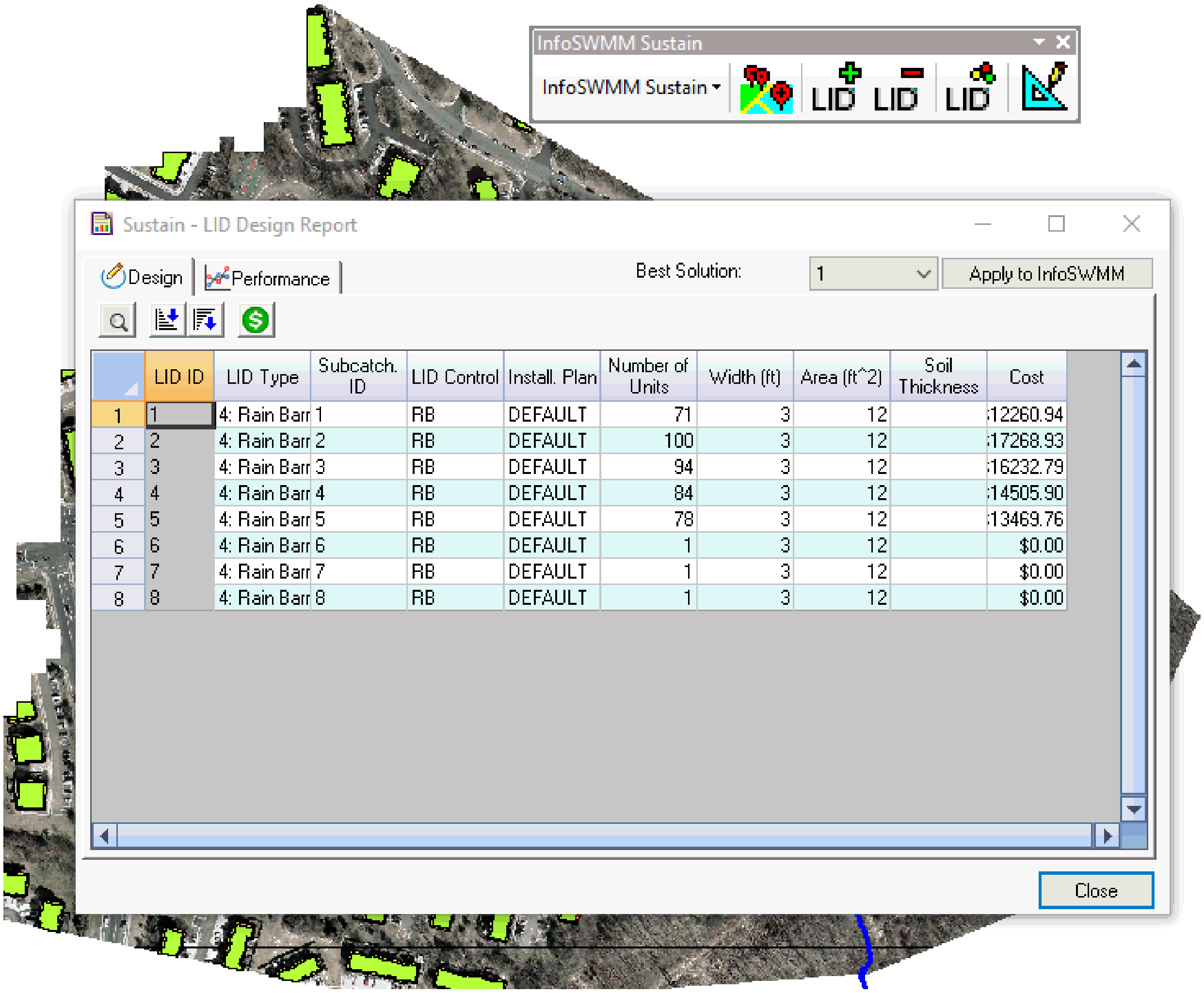


Use Scatter Search to Find the Best Solutions

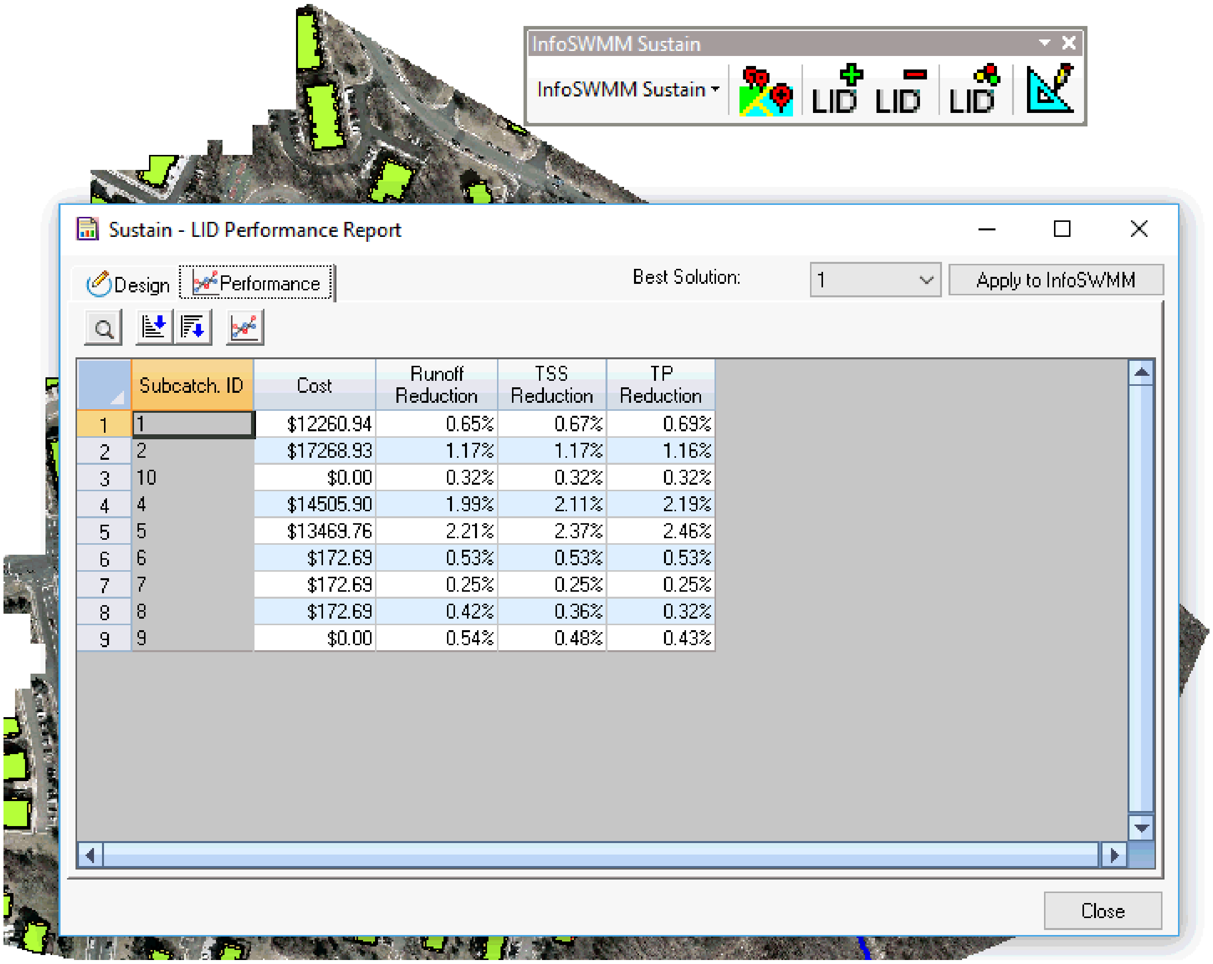


The Design Report and Performance Curve

The lack of a treatment train reduces the impact of the Rain Barrels

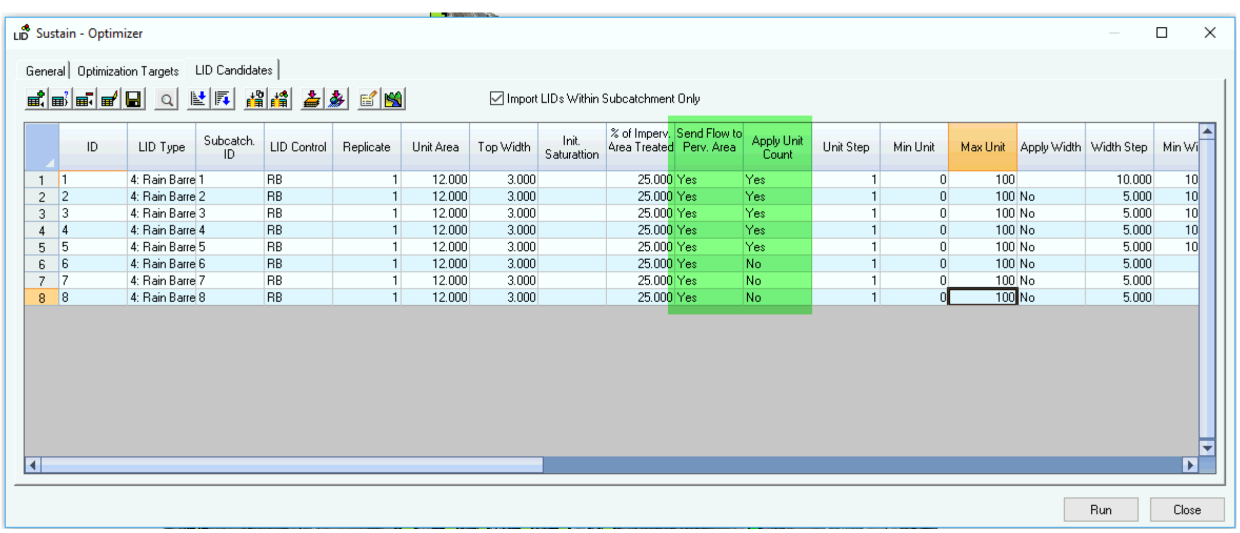


	LID ID	LID Type	Subcatch. ID	LID Control	Install. Plan	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness	Cost
1	1	4: Rain Barr	1	RB	DEFAULT	71	3	12		12260.94
2	2	4: Rain Barr	2	RB	DEFAULT	100	3	12		17268.93
3	3	4: Rain Barr	3	RB	DEFAULT	94	3	12		16232.79
4	4	4: Rain Barr	4	RB	DEFAULT	84	3	12		14505.90
5	5	4: Rain Barr	5	RB	DEFAULT	78	3	12		13469.76
6	6	4: Rain Barr	6	RB	DEFAULT	1	3	12		$0.00
7	7	4: Rain Barr	7	RB	DEFAULT	1	3	12		$0.00
8	8	4: Rain Barr	8	RB	DEFAULT	1	3	12		$0.00



	Subcatch. ID	Cost	Runoff Reduction	TSS Reduction	TP Reduction
1	1	$12260.94	0.65%	0.67%	0.69%
2	2	$17268.93	1.17%	1.17%	1.16%
3	10	$0.00	0.32%	0.32%	0.32%
4	4	$14505.90	1.99%	2.11%	2.19%
5	5	$13469.76	2.21%	2.37%	2.46%
6	6	$172.69	0.53%	0.53%	0.53%
7	7	$172.69	0.25%	0.25%	0.25%
8	8	$172.69	0.42%	0.36%	0.32%
9	9	$0.00	0.54%	0.48%	0.43%

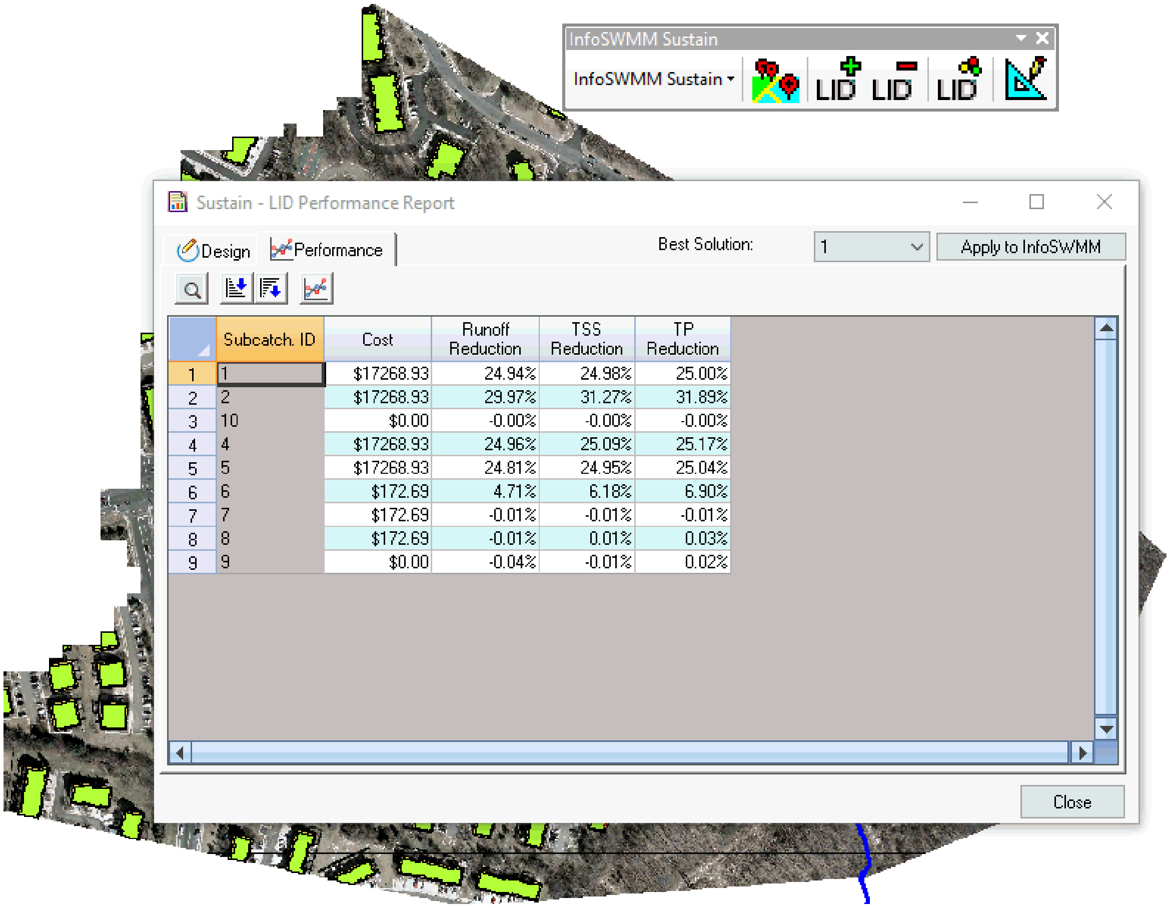
Add a Treatment Train by allowing the Rain Barrels to flow onto the Pervious Area of the Subcatchments



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturattion	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min Unit	Max Unit	Apply Width	Width Step	Min Wi
1	1	4: Rain Barre	1	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100		10.000	10
2	2	4: Rain Barre	2	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
3	3	4: Rain Barre	3	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
4	4	4: Rain Barre	4	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
5	5	4: Rain Barre	5	RB	1	12.000	3.000		25.000	Yes	Yes	1	0	100	No	5.000	10
6	6	4: Rain Barre	6	RB	1	12.000	3.000		25.000	Yes	No	1	0	100	No	5.000	
7	7	4: Rain Barre	7	RB	1	12.000	3.000		25.000	Yes	No	1	0	100	No	5.000	
8	8	4: Rain Barre	8	RB	1	12.000	3.000		25.000	Yes	No	1	0	100	No	5.000	

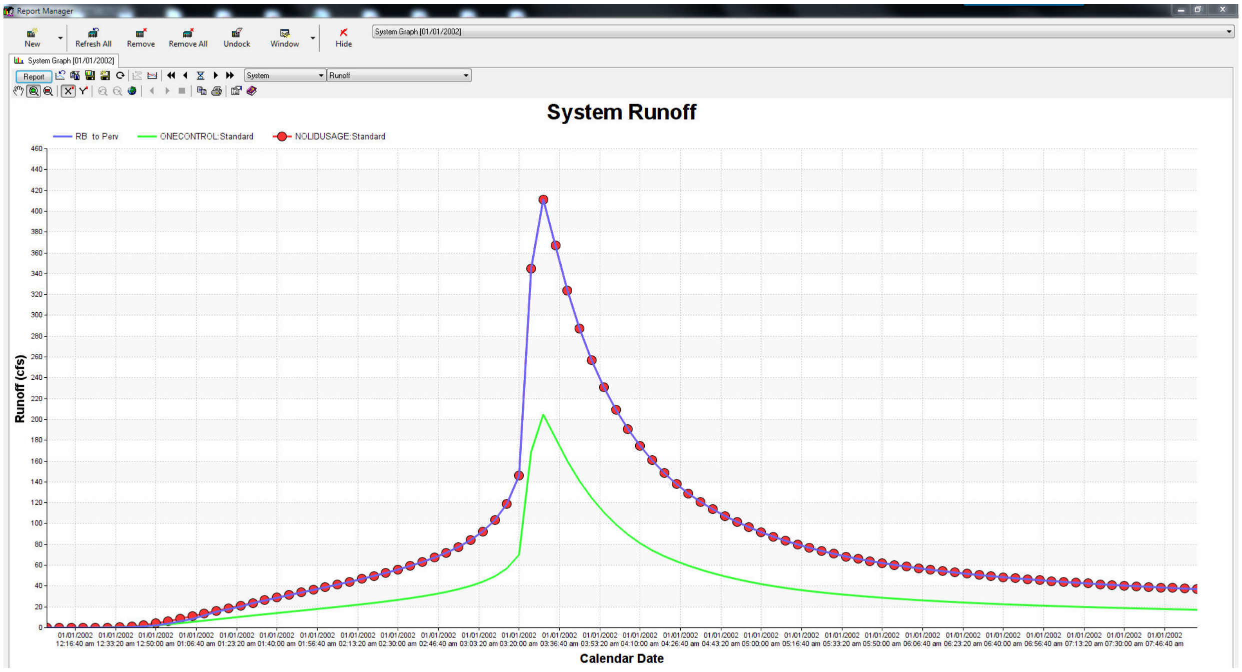
The Design Report and Performance Curve

The treatment train improves the impact of the Rain Barrels



The Effect of the Treatment Train in InfoSWMM

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious area from the Rain Barrels. The Red Dot Scenario is the Rain Barrels NOT flowing to pervious area but the outlet of the Subcatchment. The Green line is the Rain Barrel flowing to the pervious area. See also Tutorial 10.



Innovyze Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 Engine

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


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 3 Optimizing Green Roofs for Sustain 4.0

This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Green Roofs on the ten Subcatchments.

1. Turn on Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow onto the Green or Blue Roofs

Area of Each Unit

The surface area devoted to each replicate LID unit (sq. ft or sq. m).

Number of Replicate Units

The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.

Surface Width Per Unit

The width of the outflow face of each identical LID unit (in ft or m). This parameter applies to green roofs, permeable pavement, infiltration trenches, and vegetative swales that use overland flow to convey surface runoff off of the unit. It can be set to 0 for other LID processes, such as bio-retention cells, rain gardens, and rain barrels that simply spill any excess captured runoff over their berms.

% Initially Saturated

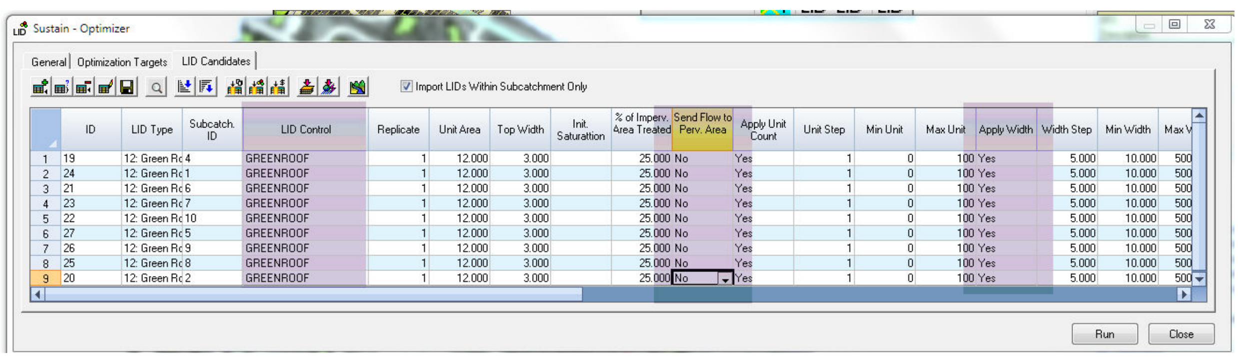
For bio-retention cells, rain gardens, and green roofs this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

% of Impervious Area Treated

The percent of the impervious portion of the Subcatchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

Return All Outflow To Pervious Area

Select this option if the surface and underdrain flow from the LID unit should be routed back onto the pervious area of the Subcatchment that contains it. This would be a common choice to make for rain barrels and possibly green roofs.



A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media Volume Cost Under Drain Volume Cost Constant Cost Percentage of other Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent

19 12: Green Roof 4 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

24 12: Green Roof 1 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

21 12: Green Roof 6 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

23 12: Green Roof 7 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

22 12: Green Roof 10 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

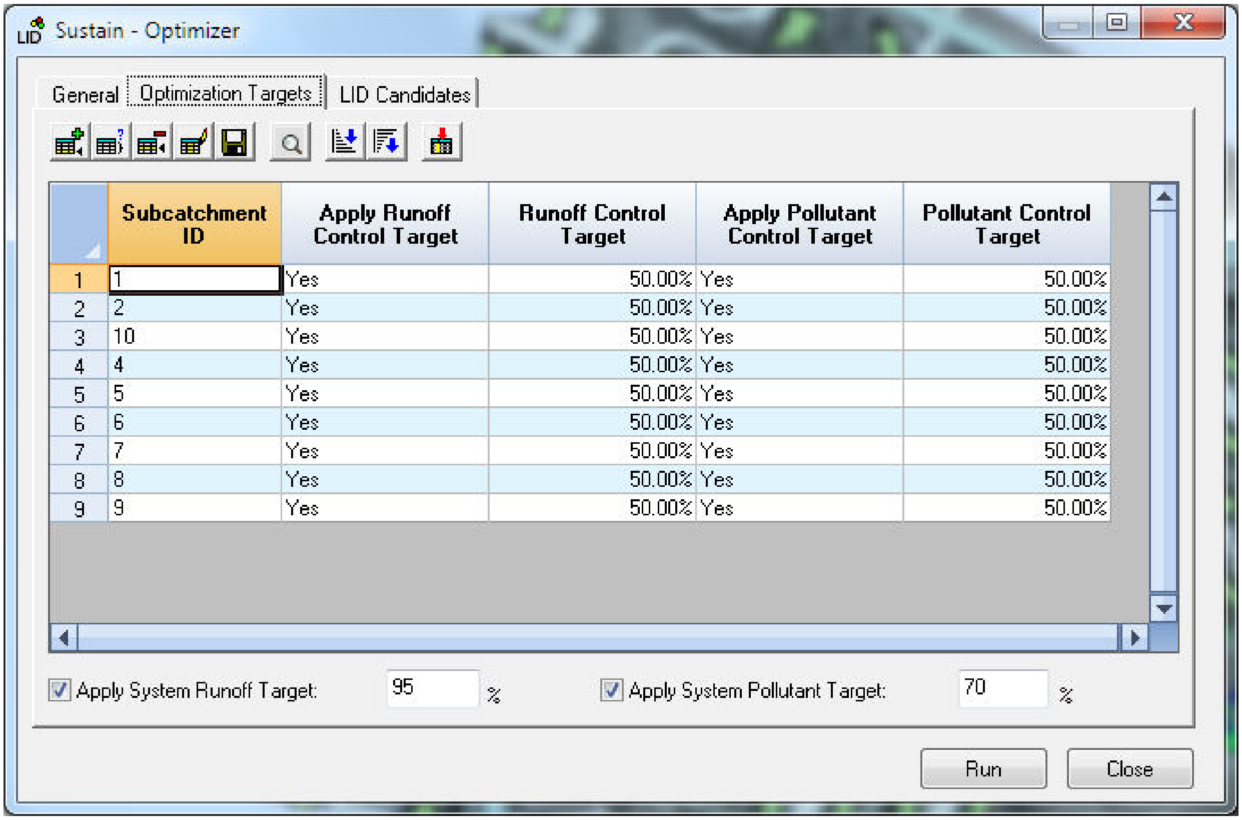
27 12: Green Roof 5 GREENROOF 1 12.000 3.000 25.000 No No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

26 12: Green Roof 9 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

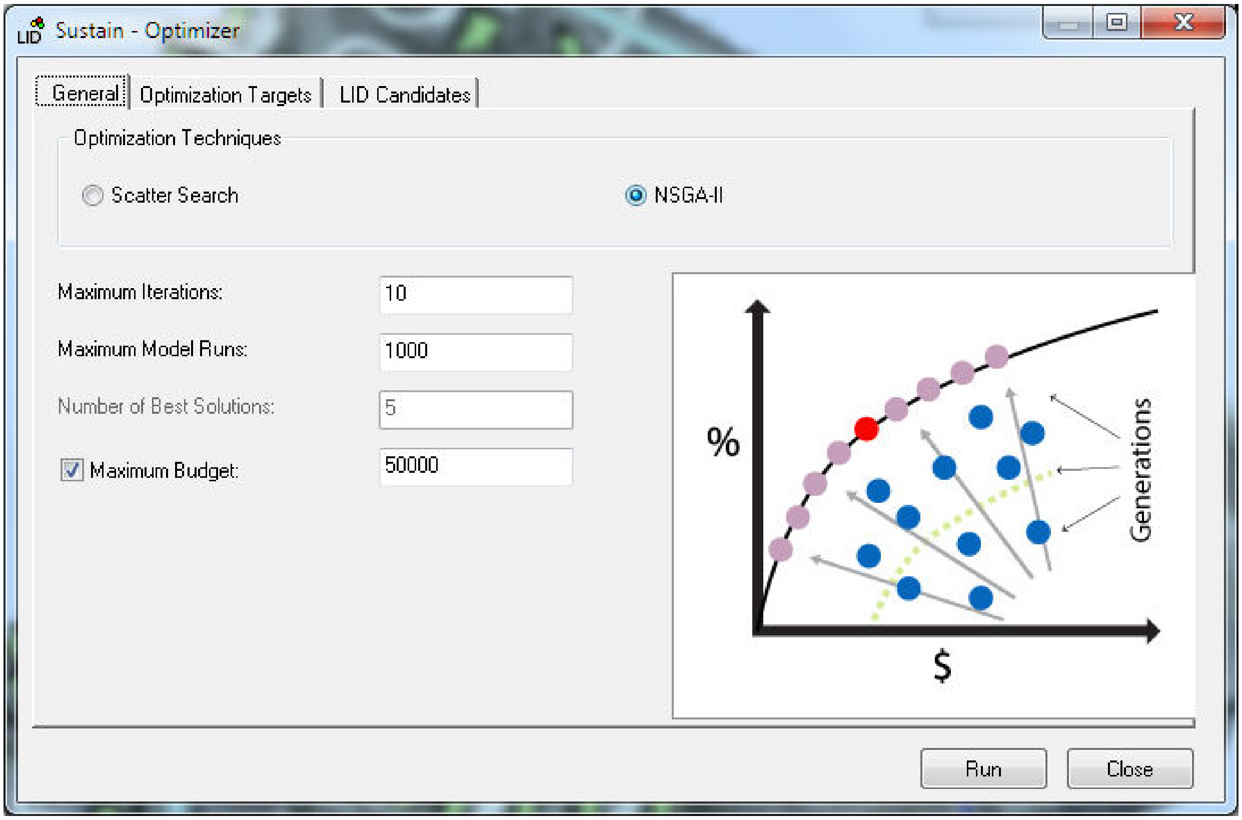
25 12: Green Roof 8 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

20 12: Green Roof 2 GREENROOF 1 12.000 3.000 25.000 Yes No Yes 1 0 100 Yes 5.000 10.000 5000.000 Yes 1.000 1.000 25.000 No 1.000 1.000 28639.805 1.000 1.000 1.000 1.000 1.000 50.000 20.000 1.000 1.000 1.000 1.000 1.000

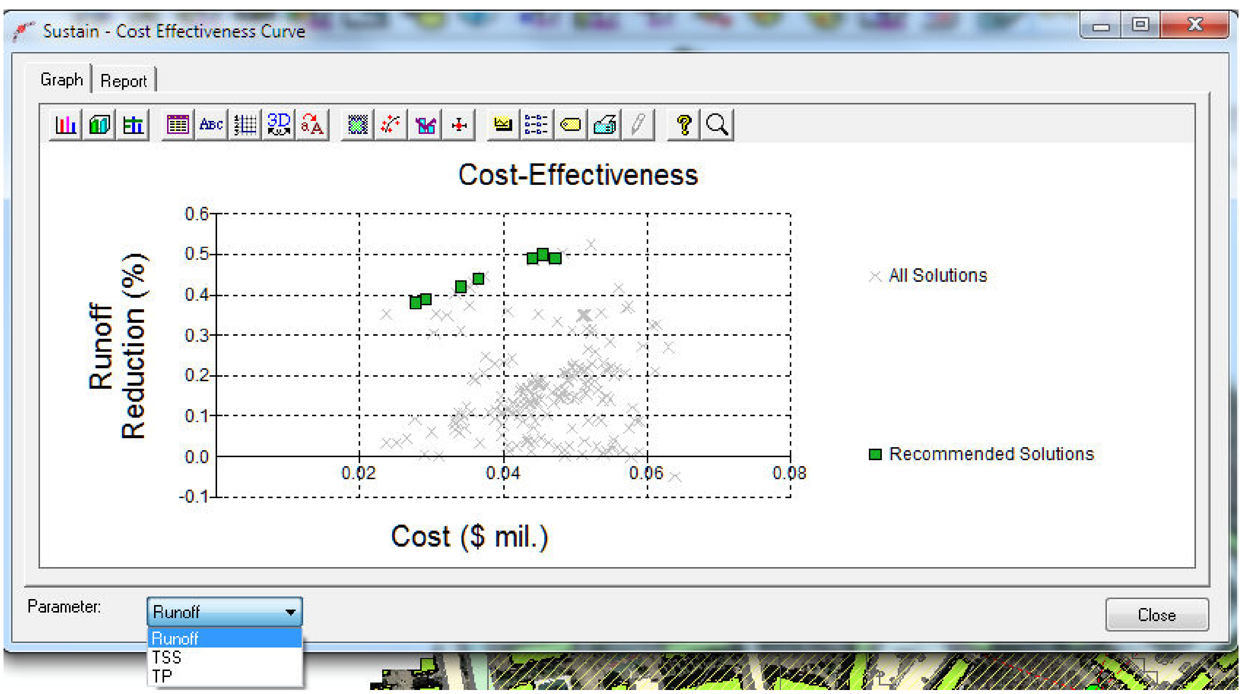
Our Optimization Goals



Use NSGA-II Optimization to find the Cost Boundary Curve

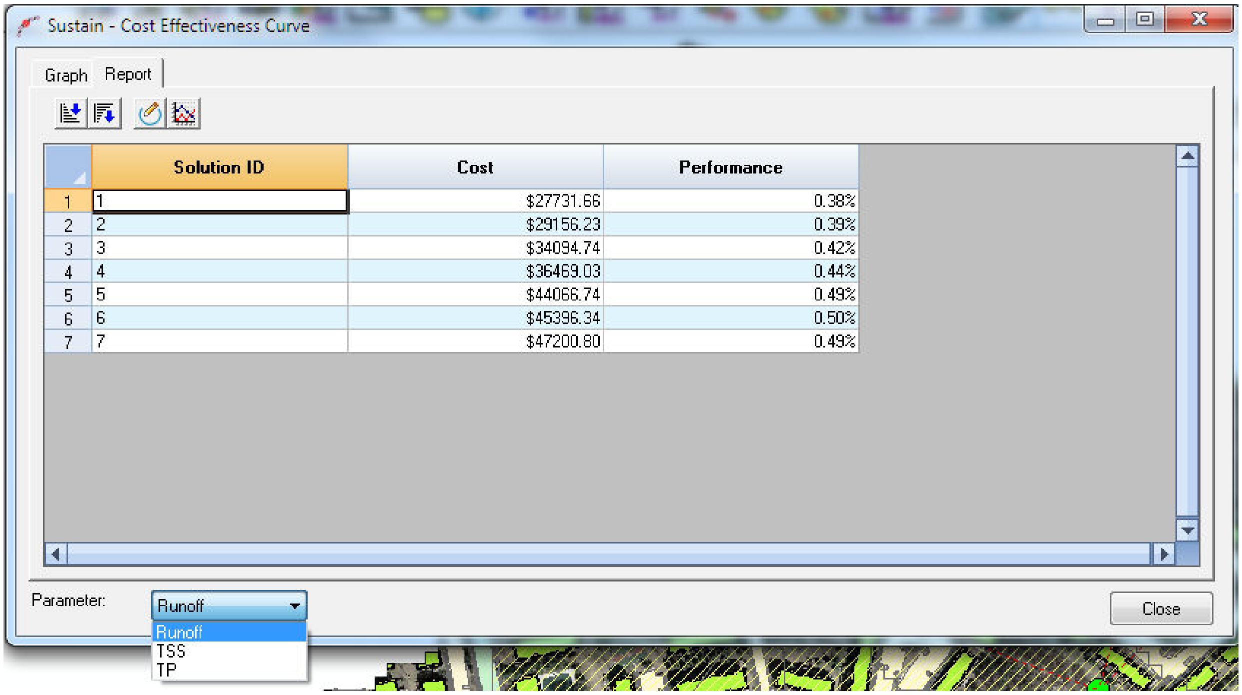


The Cost Effectiveness Curves for Runoff and Water Quality

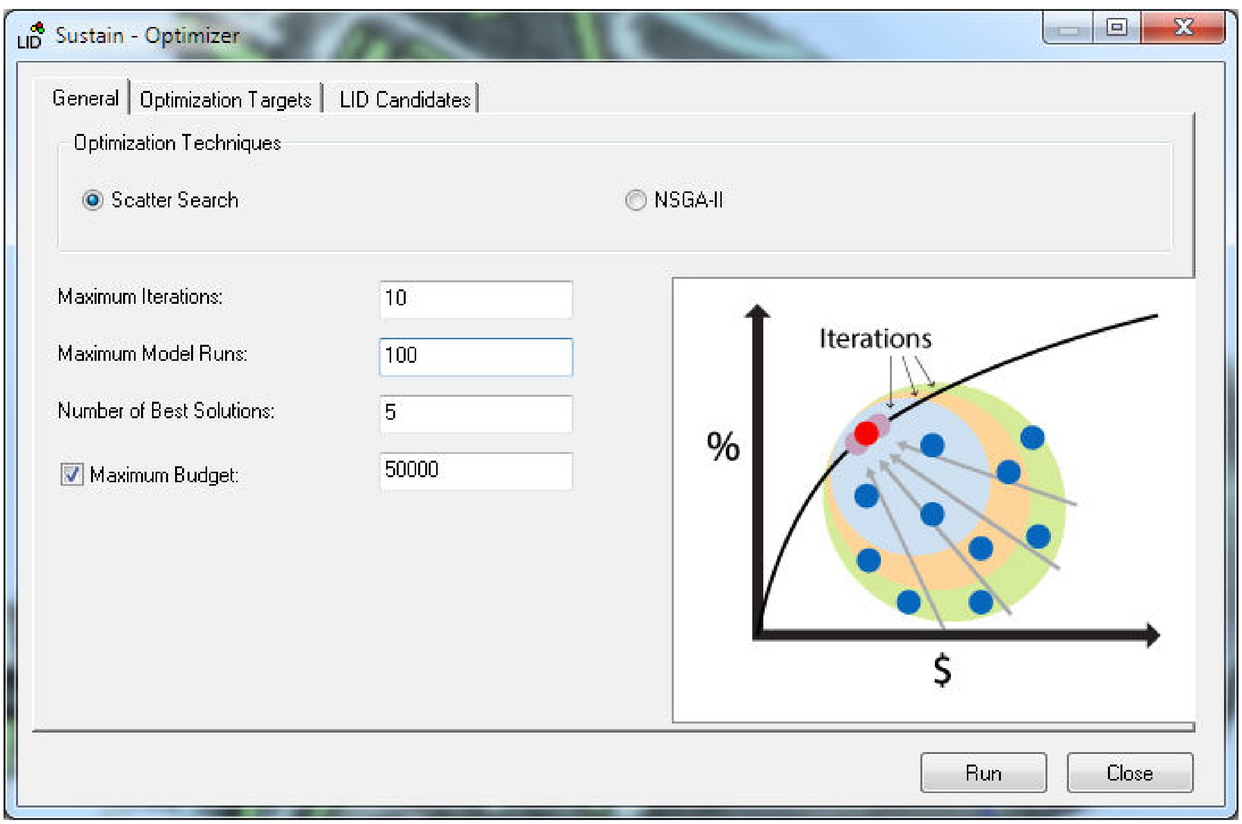


The Cost Effectiveness Report for Runoff and Water Quality

There is little removal as the Rain Barrels are not sending the overflow to the pervious area and there is little storage in a Rain Barrel.

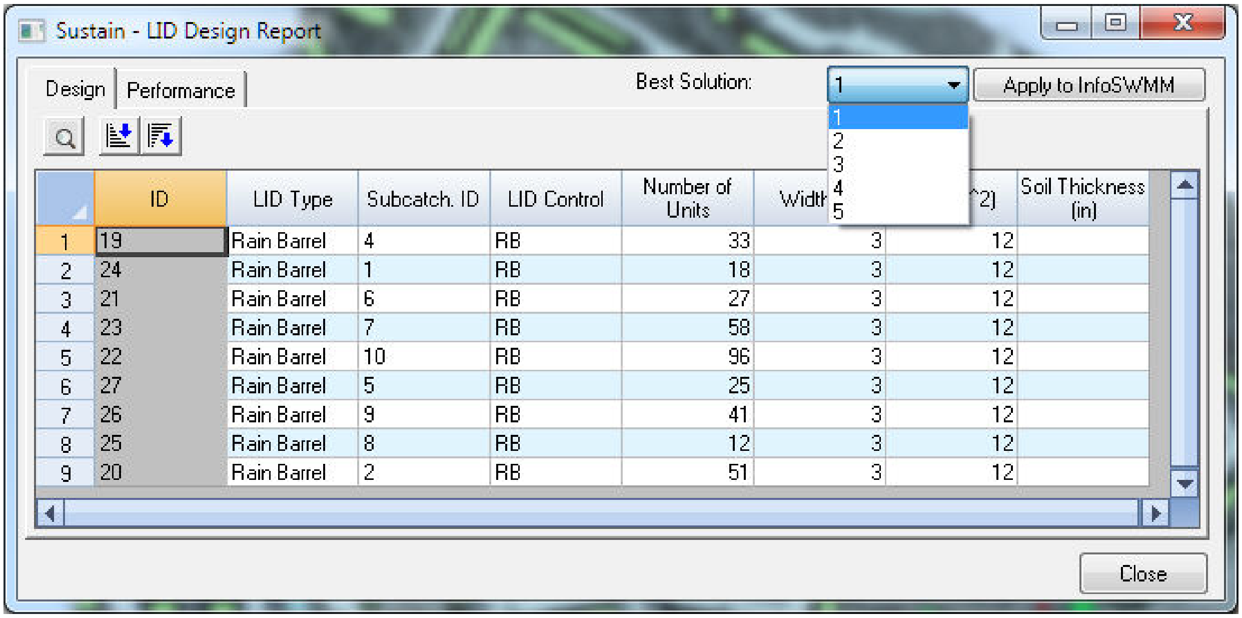


Use Scatter Search to Find the Best Solutions

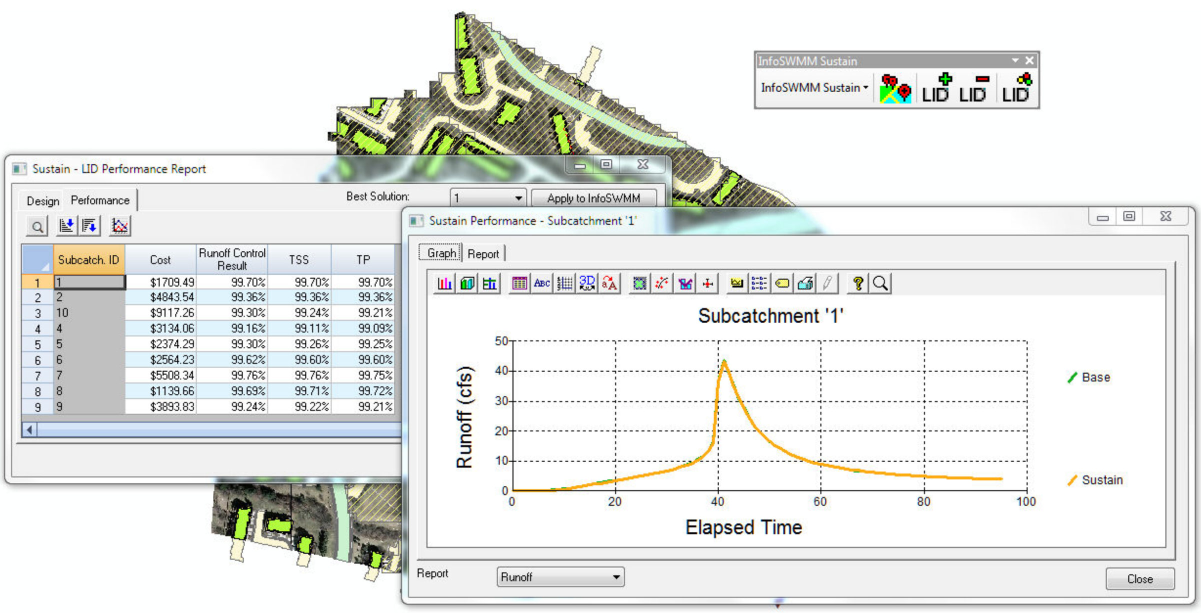


The Design Report and Performance Curve

The lack of a treatment train reduces the impact of the Rain Barrels

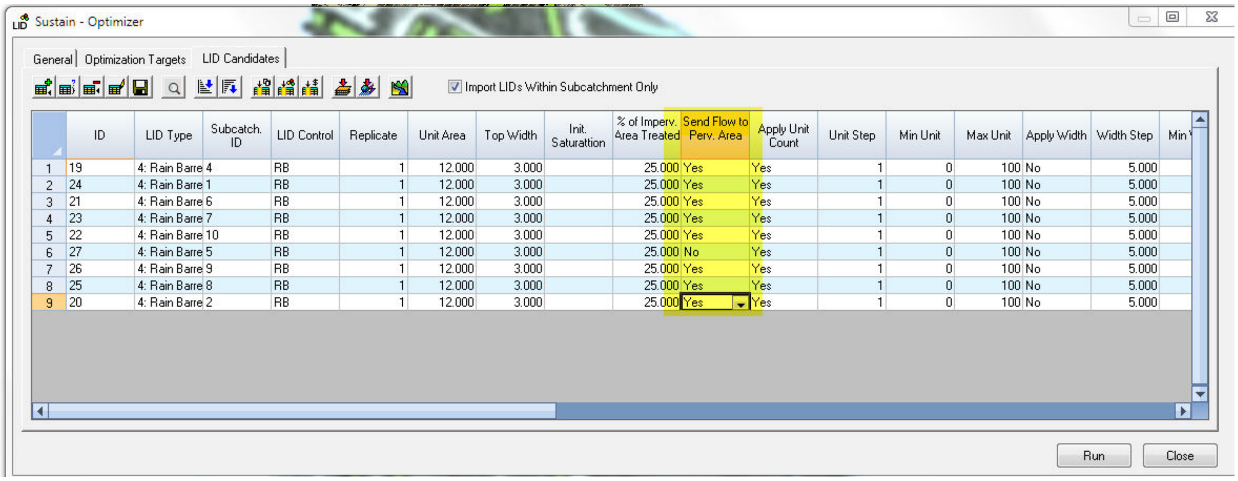


	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width	^2)	Soil Thickness (in)
1	19	Rain Barrel	4	RB	33	3	12	
2	24	Rain Barrel	1	RB	18	3	12	
3	21	Rain Barrel	6	RB	27	3	12	
4	23	Rain Barrel	7	RB	58	3	12	
5	22	Rain Barrel	10	RB	96	3	12	
6	27	Rain Barrel	5	RB	25	3	12	
7	26	Rain Barrel	9	RB	41	3	12	
8	25	Rain Barrel	8	RB	12	3	12	
9	20	Rain Barrel	2	RB	51	3	12	



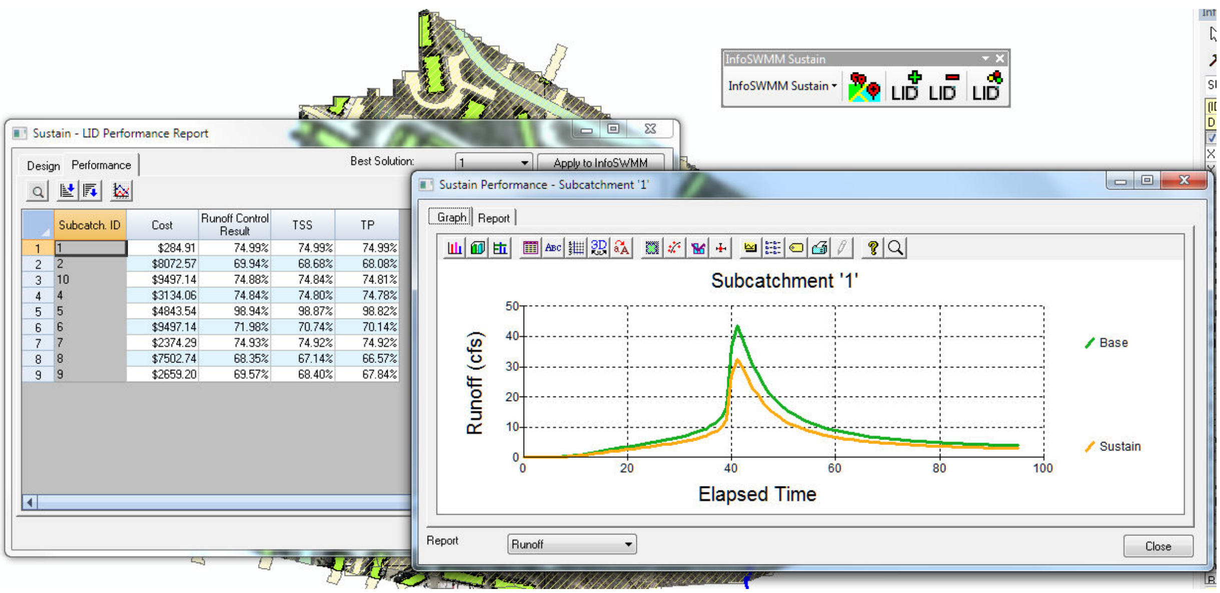
	Subcatch. ID	Cost	Runoff Control Result	TSS	TP
1	1	$1709.49	99.70%	99.70%	99.70%
2	2	$4843.54	99.36%	99.36%	99.36%
3	10	$9117.26	99.30%	99.24%	99.21%
4	4	$3134.06	99.16%	99.11%	99.09%
5	5	$2374.29	99.30%	99.26%	99.25%
6	6	$2564.23	99.62%	99.60%	99.60%
7	7	$5508.34	99.76%	99.76%	99.75%
8	8	$1139.66	99.69%	99.71%	99.72%
9	9	$3893.83	99.24%	99.22%	99.21%

Add a Treatment Train by allowing the Rain Barrels to flow onto the Pervious Area of the Subcatchments



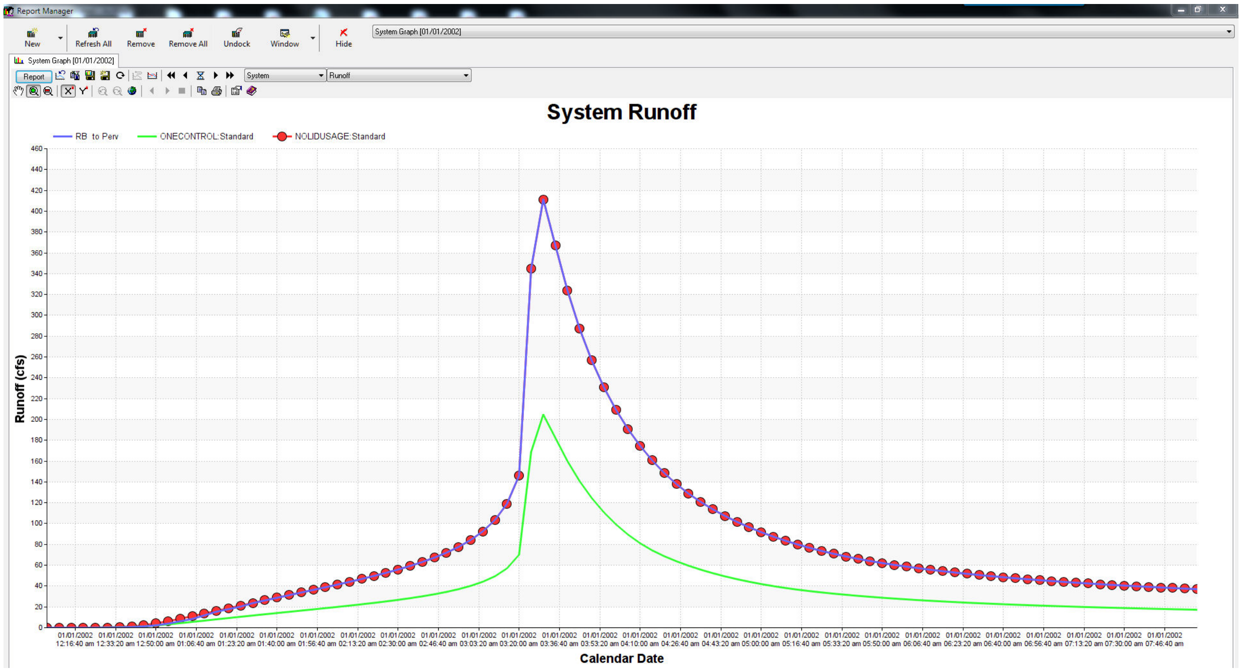
[The Design Report and Performance Curve]

The treatment train improves the impact of the Rain Barrels



[The Effect of the Treatment Train in InfoSWMM]

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious areq from tjje Rain Barrels. The Red Dot Scenario is the Rain Barrels NOT flowing to pervious area but the outlet of the Subcatchment. The Green line is the Rain Barrel flowing to the pervious area.



Innovyze Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 Engine

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Tutorial 4 Optimizing Infiltration Trenches for Sustain 4.0

This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Infiltration Trenches on the ten Subcatchments.

1. Turn off Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow into the Rain Gardens

Area of Each Unit

The surface area devoted to each replicate LID unit (sq. ft or sq. m).

Number of Replicate Units

The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.

Surface Width Per Unit

The width of the outflow face of each identical LID unit (in ft or m). This parameter applies to green roofs, permeable pavement, infiltration trenches, and vegetative swales that use overland flow to convey surface runoff off of the unit. It can be set to 0 for other LID processes, such as bio-retention cells, rain gardens, and rain barrels that simply spill any excess captured runoff over their berms.

% Initially Saturated

For bio-retention cells, rain gardens, and green roofs this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the

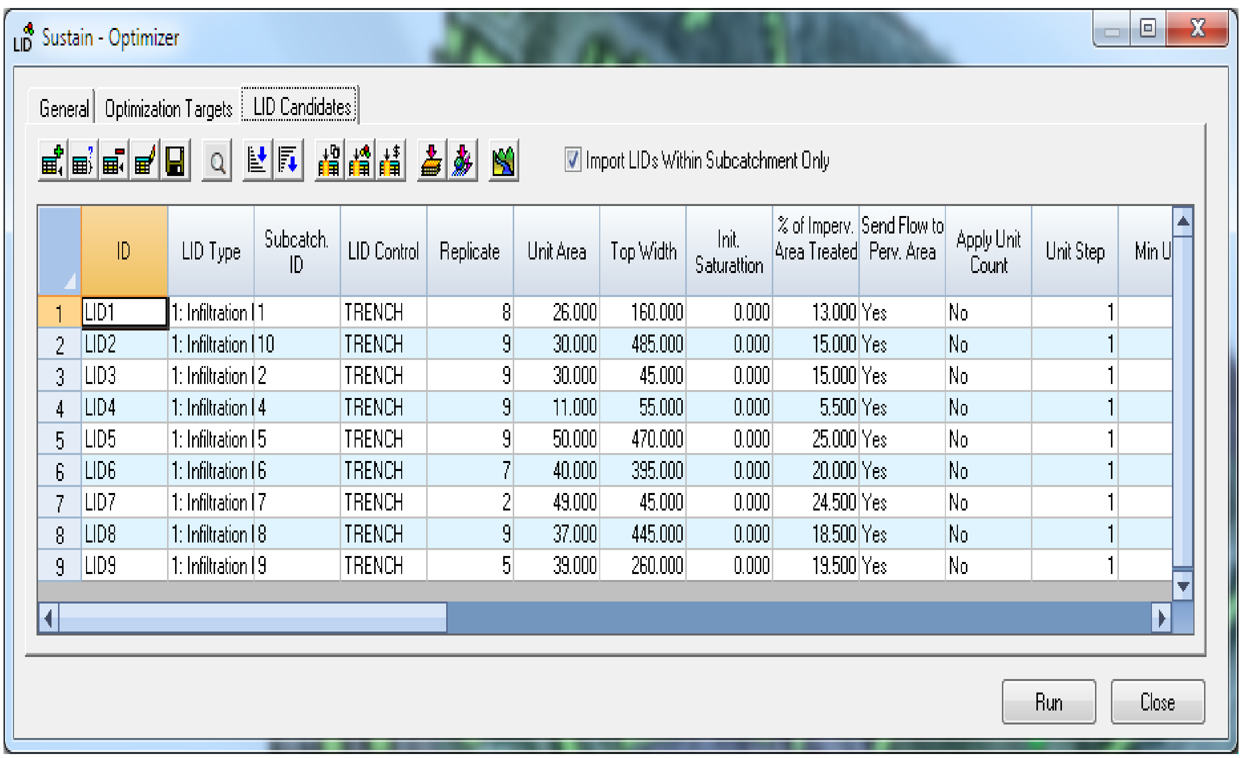
cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

% of Impervious Area Treated

The percent of the impervious portion of the Subcatchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

Return All Outflow To Pervious Area

Select this option if the surface and underdrain flow from the LID unit should be routed back onto the pervious area of the Subcatchment that contains it. This would be a common choice to make for rain barrels and possibly green roofs.



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturation	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min U
1	LID1	1: Infiltration I	1	TRENCH	8	26.000	160.000	0.000	13.000	Yes	No	1	
2	LID2	1: Infiltration I	10	TRENCH	9	30.000	485.000	0.000	15.000	Yes	No	1	
3	LID3	1: Infiltration I	2	TRENCH	9	30.000	45.000	0.000	15.000	Yes	No	1	
4	LID4	1: Infiltration I	4	TRENCH	9	11.000	55.000	0.000	5.500	Yes	No	1	
5	LID5	1: Infiltration I	5	TRENCH	9	50.000	470.000	0.000	25.000	Yes	No	1	
6	LID6	1: Infiltration I	6	TRENCH	7	40.000	395.000	0.000	20.000	Yes	No	1	
7	LID7	1: Infiltration I	7	TRENCH	2	49.000	45.000	0.000	24.500	Yes	No	1	
8	LID8	1: Infiltration I	8	TRENCH	9	37.000	445.000	0.000	18.500	Yes	No	1	
9	LID9	1: Infiltration I	9	TRENCH	5	39.000	260.000	0.000	19.500	Yes	No	1	

A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit

Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media Volume Cost Under Drain Volume Cost Constant Cost Percentage of other Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent Underdrain Outlet

LID1 1: Infiltration Basin 1 TRENCH 8 0 26.000 0.000 160.000 0.000 13.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 26.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID2 1: Infiltration Basin 10 TRENCH 9 0 30.000 0.000 485.000 0.000 15.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID3 1: Infiltration Basin 2 TRENCH 9 0 30.000 0.000 45.000 0.000 15.000 Yes No No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID4 1: Infiltration Basin 4 TRENCH 9 0 11.000 0.000 55.000 0.000 5.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 11.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID5 1: Infiltration Basin 5 TRENCH 9 0 50.000 0.000 470.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

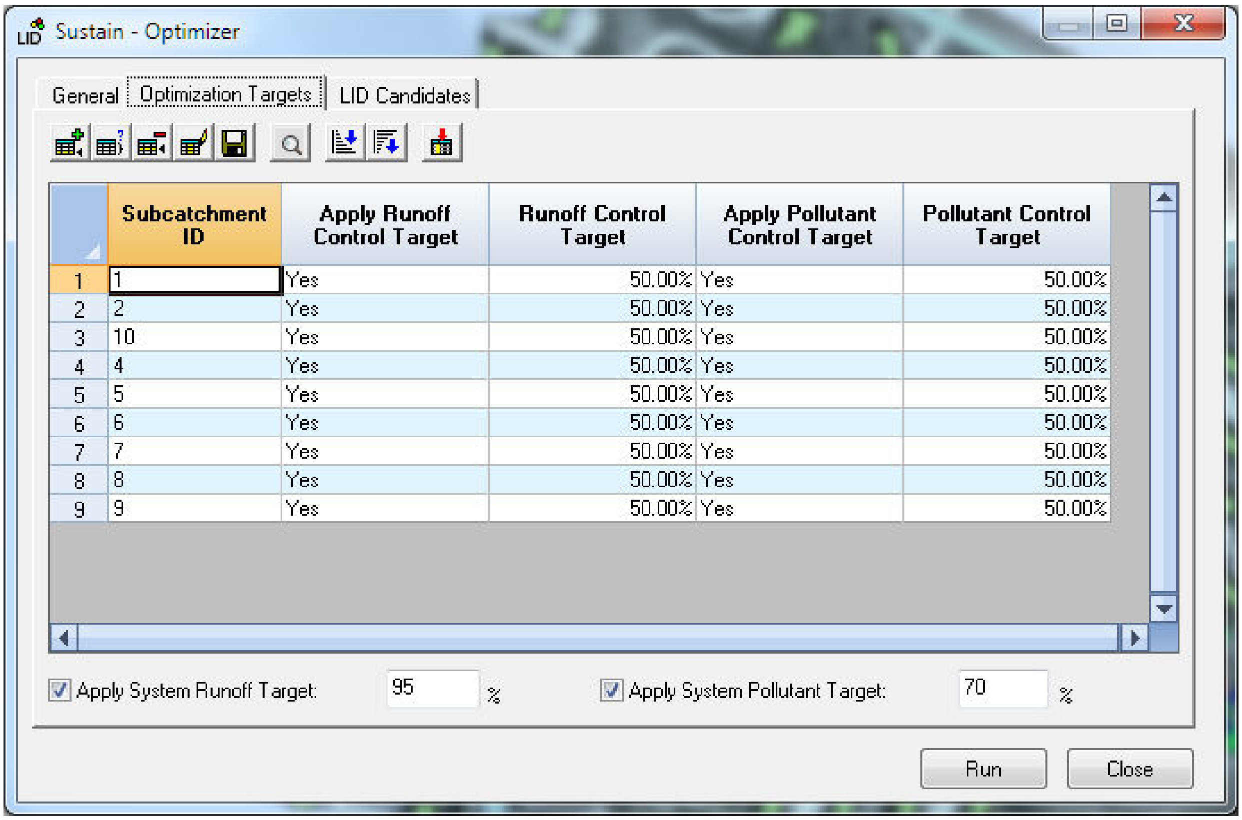
LID6 1: Infiltration Basin 6 TRENCH 7 0 40.000 0.000 395.000 0.000 20.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 40.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID7 1: Infiltration Basin 7 TRENCH 2 0 49.000 0.000 45.000 0.000 24.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 49.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

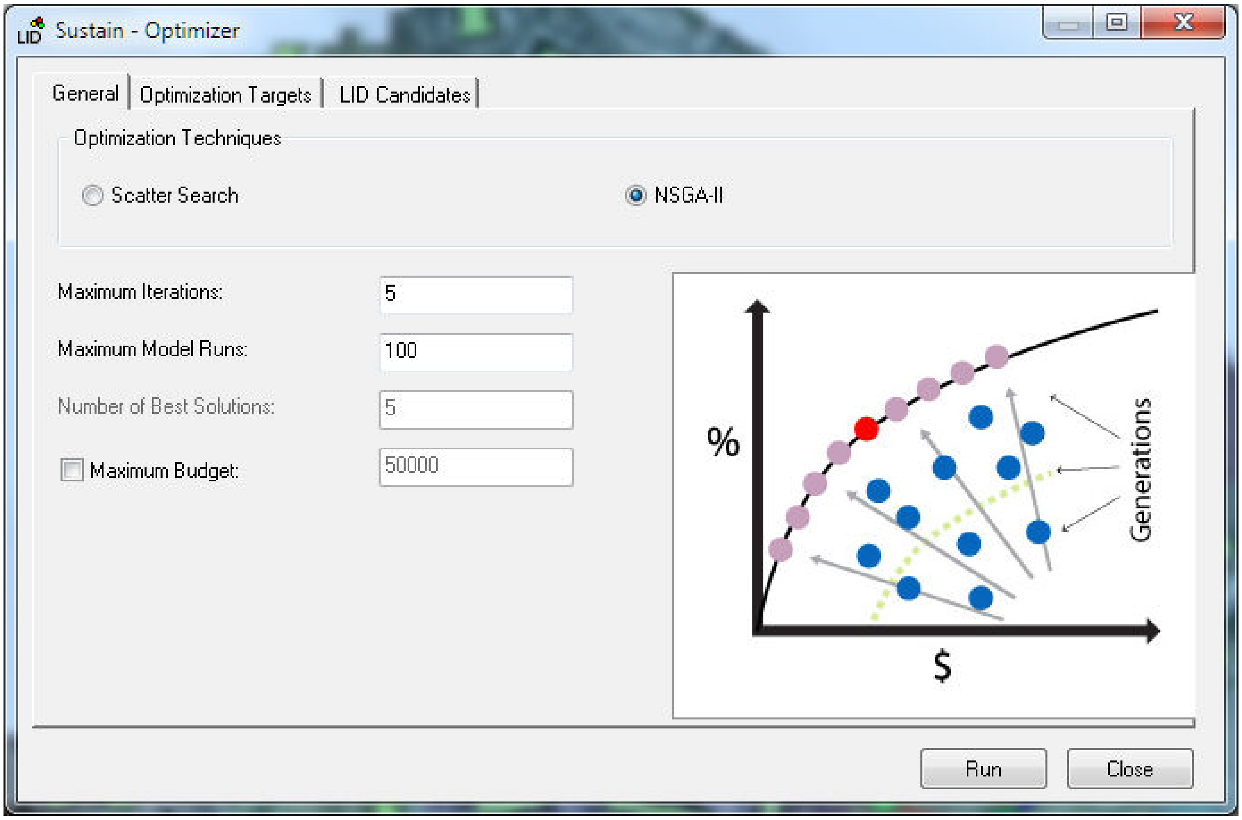
LID8 1: Infiltration Basin 8 TRENCH 9 0 37.000 0.000 445.000 0.000 18.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 37.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID9 1: Infiltration Basin 9 TRENCH 5 0 39.000 0.000 260.000 0.000 19.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 39.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

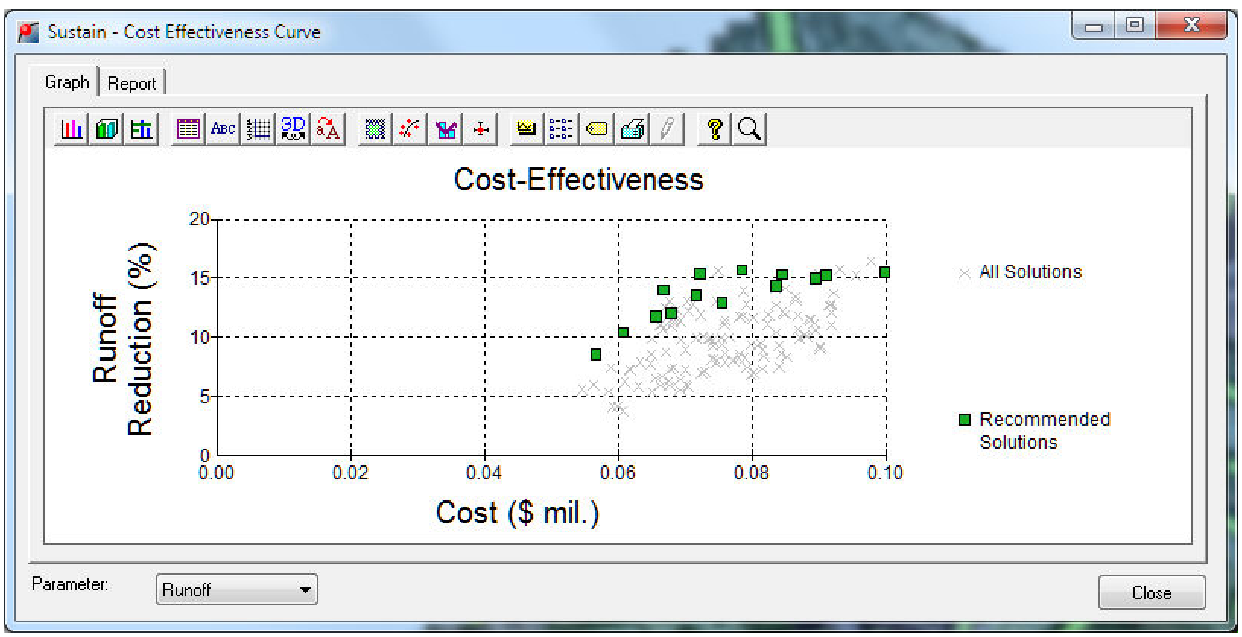
Our Optimization Goals



Use NSGA-II Optimization to find the Cost Boundary Curve

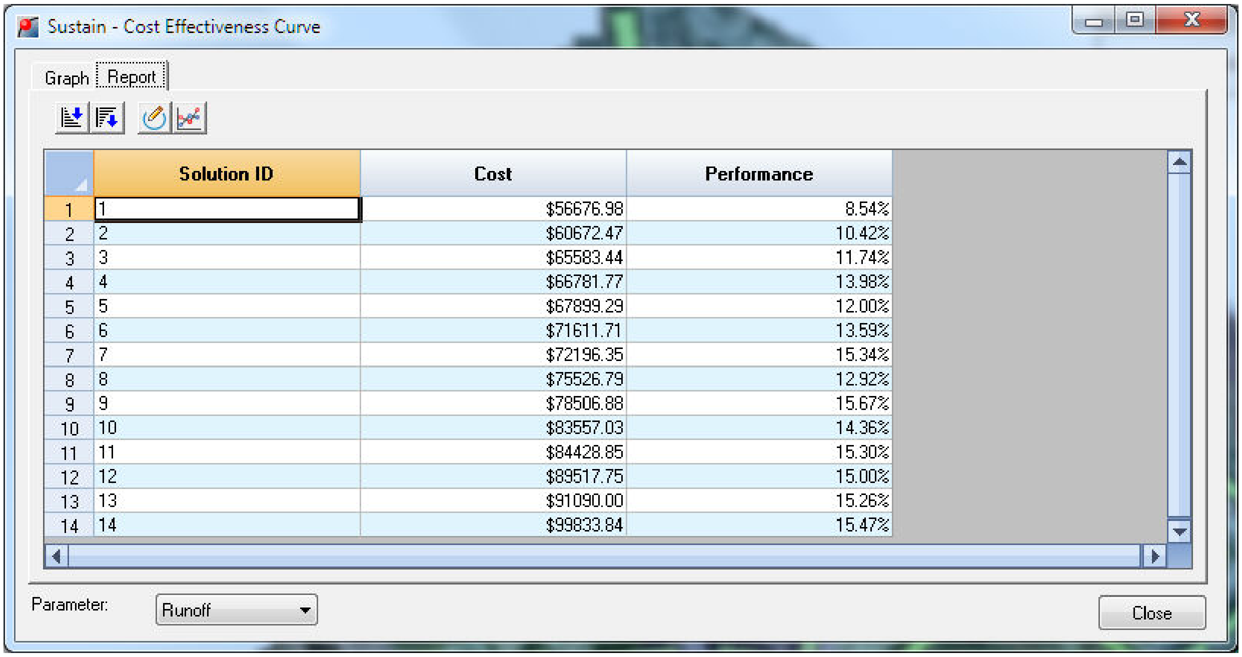


The Cost Effectiveness Curves for Runoff and Water Quality



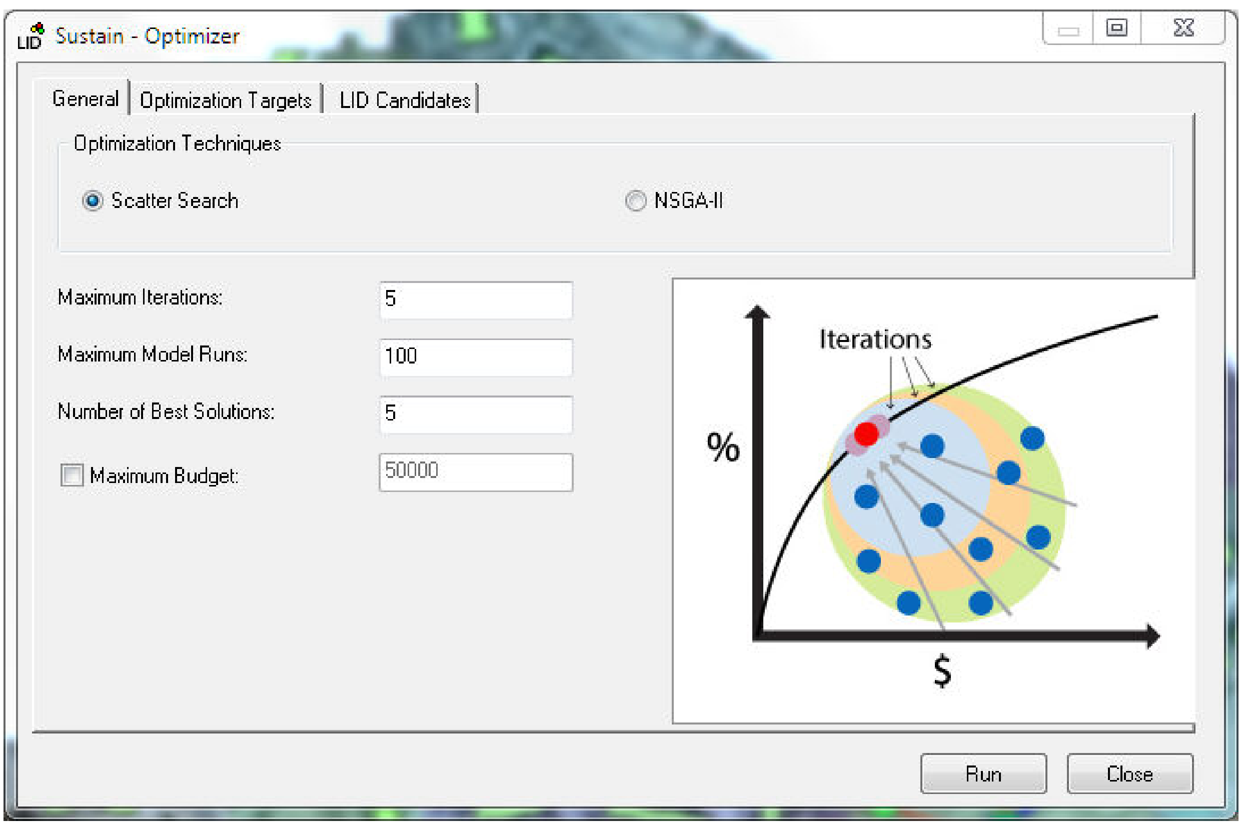
The Cost Effectiveness Report for Runoff and Water Quality

There is little removal as the Rain Barrels are not sending the overflow to the pervious area and there is little storage in a Rain Barrel.



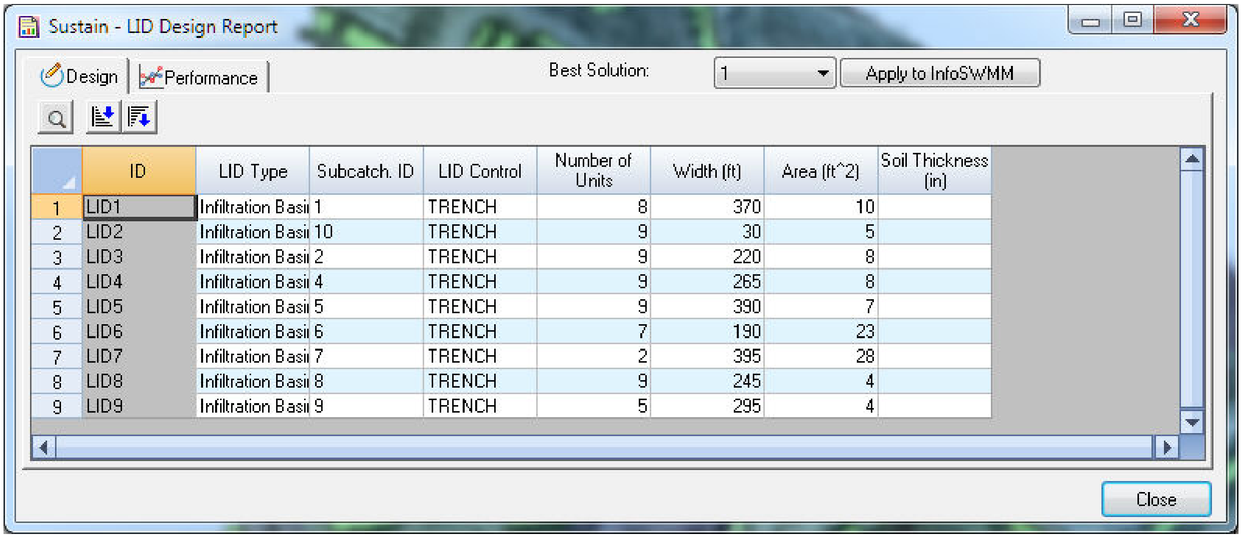
	Solution ID	Cost	Performance
1	1	$56676.98	8.54%
2	2	$60672.47	10.42%
3	3	$65583.44	11.74%
4	4	$66781.77	13.98%
5	5	$67899.29	12.00%
6	6	$71611.71	13.59%
7	7	$72196.35	15.34%
8	8	$75526.79	12.92%
9	9	$78506.88	15.67%
10	10	$83557.03	14.36%
11	11	$84428.85	15.30%
12	12	$89517.75	15.00%
13	13	$91090.00	15.26%
14	14	$99833.84	15.47%

[Use Scatter Search to Find the Best Solutions]

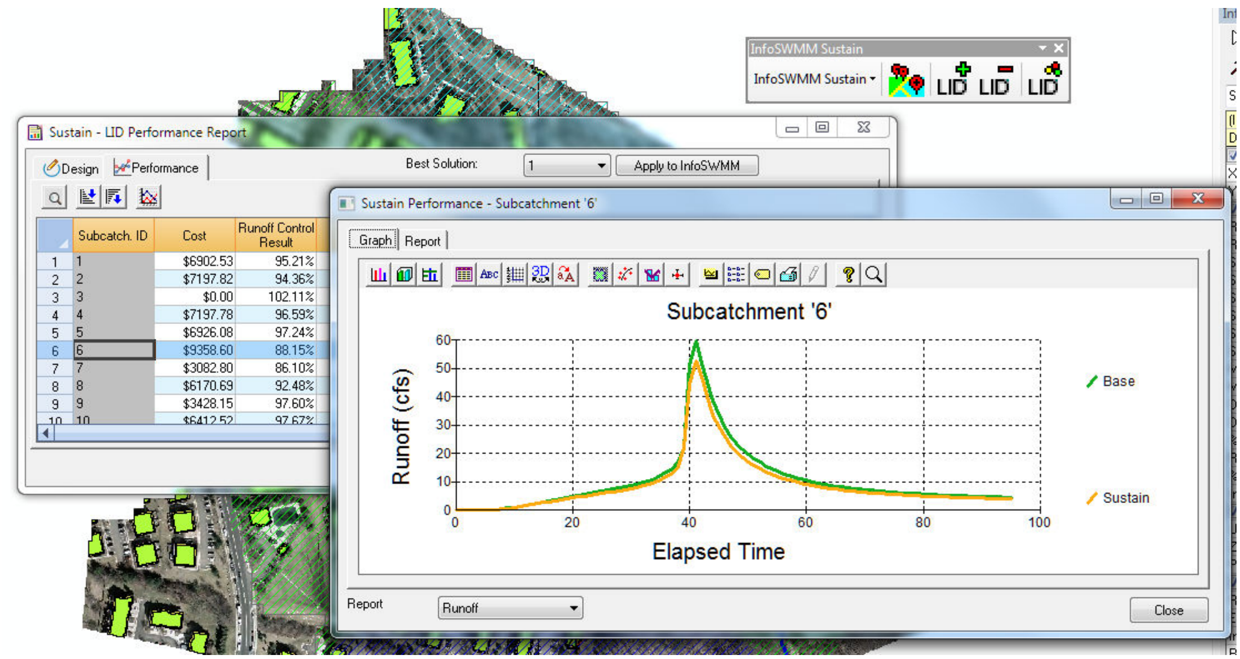


[The Design Report and Performance Curve]

The effect of the perviouus area treatment train on the Rain Gardens

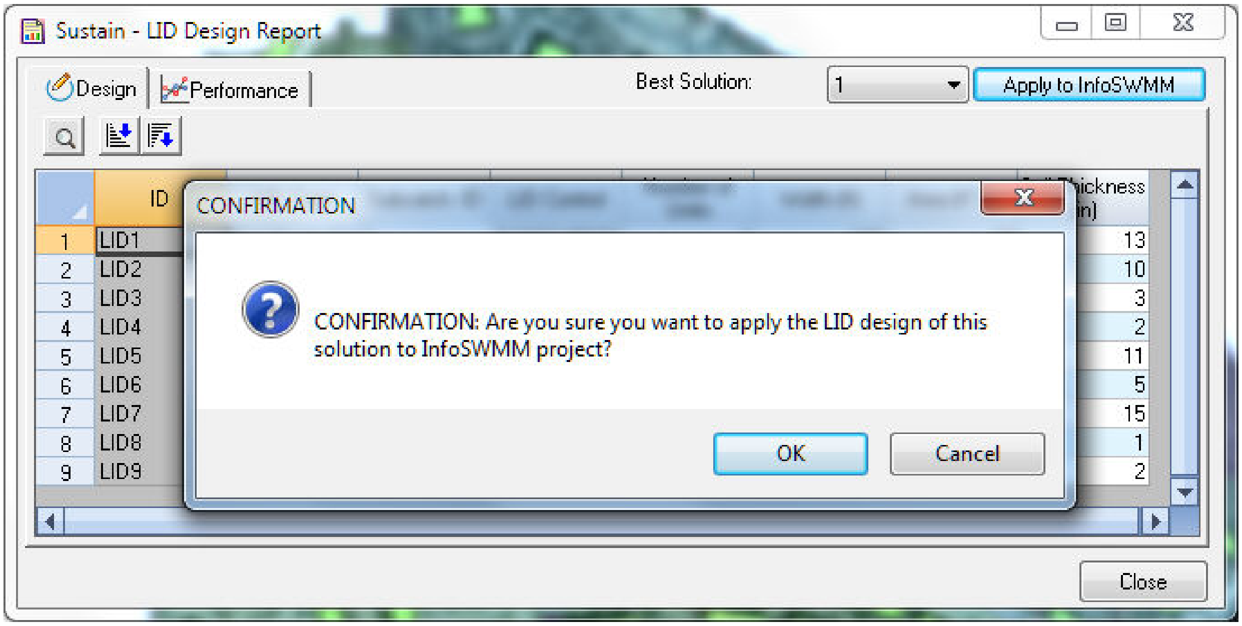


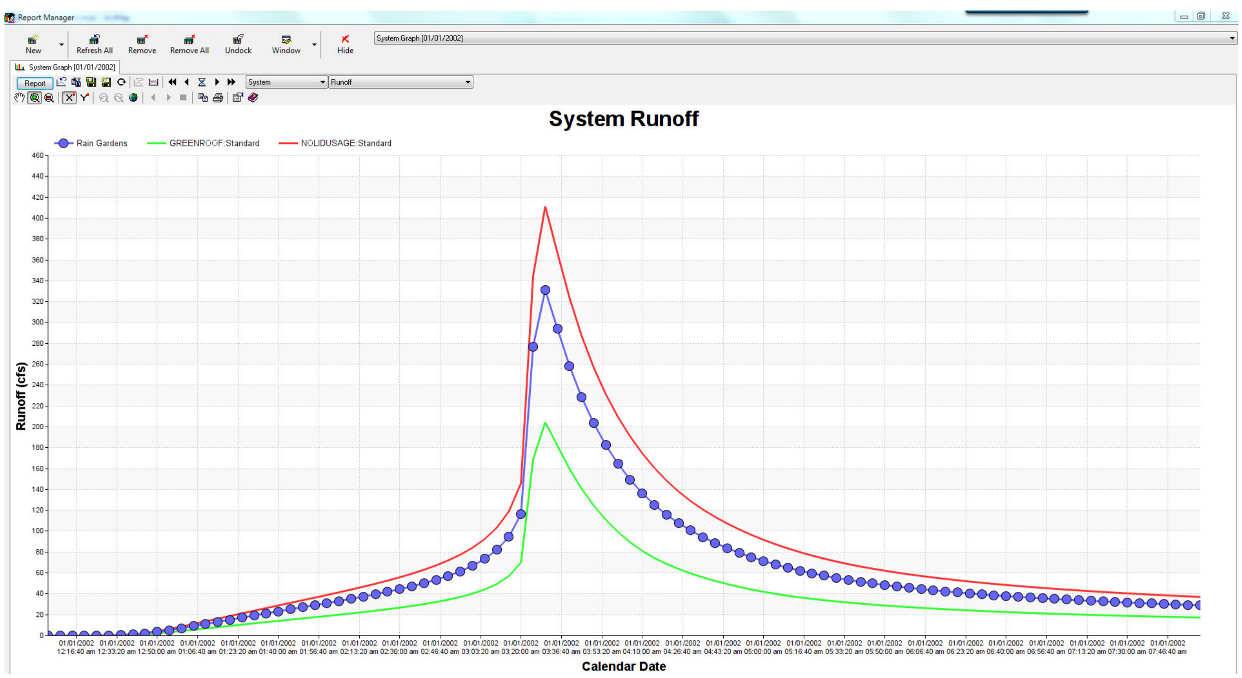
	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness (in)
1	LID1	Infiltration Basi	1	TRENCH	8	370	10	
2	LID2	Infiltration Basi	10	TRENCH	9	30	5	
3	LID3	Infiltration Basi	2	TRENCH	9	220	8	
4	LID4	Infiltration Basi	4	TRENCH	9	265	8	
5	LID5	Infiltration Basi	5	TRENCH	9	390	7	
6	LID6	Infiltration Basi	6	TRENCH	7	190	23	
7	LID7	Infiltration Basi	7	TRENCH	2	395	28	
8	LID8	Infiltration Basi	8	TRENCH	9	245	4	
9	LID9	Infiltration Basi	9	TRENCH	5	295	4	



[The Effect of the Treatment Train in InfoSWMM]

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious are from the Infiltration Trenches.

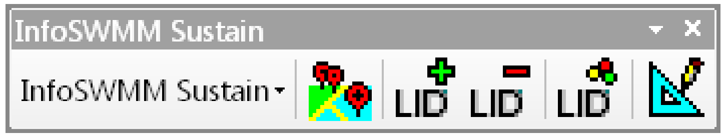

Sustain - LID Design Report
Design
Performance
Best Solution:
1
Apply to InfoSWMM
ID
LID1
LID2
LID3
LID4
LID5
LID6
LID7
LID8
LID9
CONFIRMATION
CONFIRMATION: Are you sure you want to apply the LID design of this solution to InfoSWMM project?
OK
Cancel
Close


System Runoff
Rain Gardens
GREENROOF:Standard
NOLIDUSAGE:Standard
Runoff (cfs)
Calendar Date

InfoSWMM uses the EPA SWMM 5.1.013 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


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 5 Optimizing Permeable or Porous Pavements for Sustain 4.0

This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Rain Gardens on the ten Subcatchments.

1. Turn off Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow into the Rain Gardens

Area of Each Unit

The surface area devoted to each replicate LID unit (sq. ft or sq. m).

Number of Replicate Units

The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.

Surface Width Per Unit

The width of the outflow face of each identical LID unit (in ft or m). This parameter applies to green roofs, permeable pavement, infiltration trenches, and vegetative swales that use overland flow to convey surface runoff off of the unit. It can be set to 0 for other LID processes, such as bio-retention cells, rain gardens, and rain barrels that simply spill any excess captured runoff over their berms.

% Initially Saturated

For bio-retention cells, rain gardens, and green roofs this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the

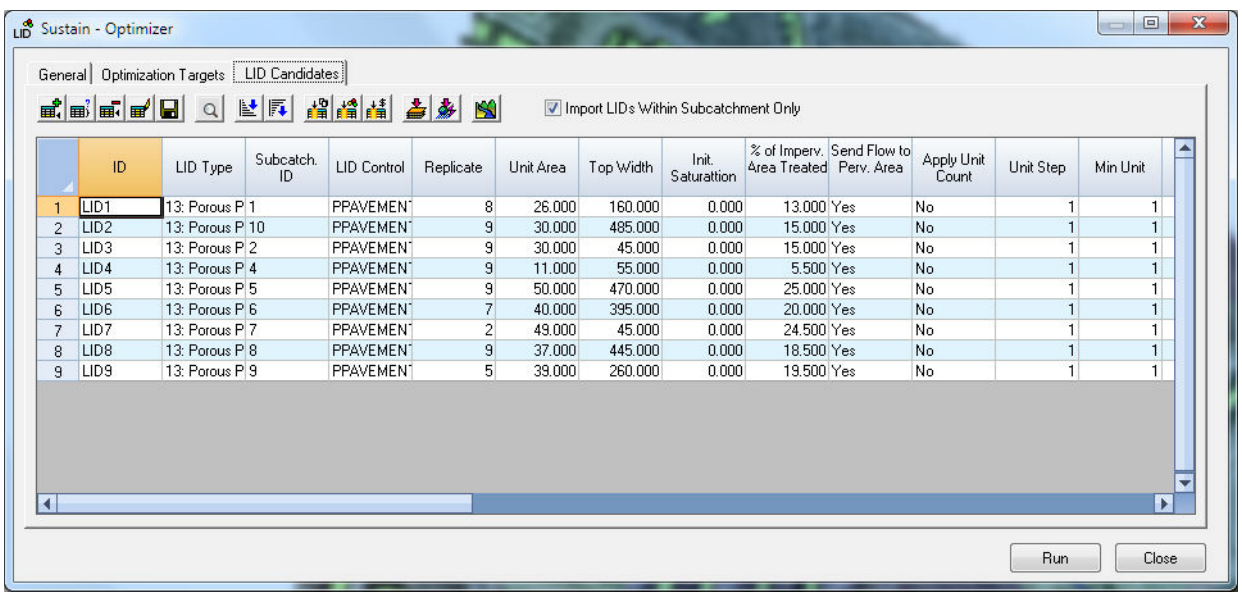
cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

% of Impervious Area Treated

The percent of the impervious portion of the Subcatchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

Return All Outflow To Pervious Area

Select this option if the surface and underdrain flow from the LID unit should be routed back onto the pervious area of the Subcatchment that contains it. This would be a common choice to make for rain barrels and possibly green roofs.



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturattion	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min Unit
1	LID1	13: Porous P	1	PPAVEMEN	8	26.000	160.000	0.000	13.000	Yes	No	1	1
2	LID2	13: Porous P	10	PPAVEMEN	9	30.000	485.000	0.000	15.000	Yes	No	1	1
3	LID3	13: Porous P	2	PPAVEMEN	9	30.000	45.000	0.000	15.000	Yes	No	1	1
4	LID4	13: Porous P	4	PPAVEMEN	9	11.000	55.000	0.000	5.500	Yes	No	1	1
5	LID5	13: Porous P	5	PPAVEMEN	9	50.000	470.000	0.000	25.000	Yes	No	1	1
6	LID6	13: Porous P	6	PPAVEMEN	7	40.000	395.000	0.000	20.000	Yes	No	1	1
7	LID7	13: Porous P	7	PPAVEMEN	2	49.000	45.000	0.000	24.500	Yes	No	1	1
8	LID8	13: Porous P	8	PPAVEMEN	9	37.000	445.000	0.000	18.500	Yes	No	1	1
9	LID9	13: Porous P	9	PPAVEMEN	5	39.000	260.000	0.000	19.500	Yes	No	1	1

A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media

Volume Cost Under Drain Volume Cost Constant Cost Percentage of other Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent Underdrain Outlet

LID1 13: Porous Pavement 1 PPAVEMENT 8 0 26.000 0.000 160.000 0.000 13.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 26.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID2 13: Porous Pavement 10 PPAVEMENT 9 0 30.000 0.000 485.000 0.000 15.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID3 13: Porous Pavement 2 PPAVEMENT 9 0 30.000 0.000 45.000 0.000 15.000 Yes No No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID4 13: Porous Pavement 4 PPAVEMENT 9 0 11.000 0.000 55.000 0.000 5.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 11.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID5 13: Porous Pavement 5 PPAVEMENT 9 0 50.000 0.000 470.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID6 13: Porous Pavement 6 PPAVEMENT 7 0 40.000 0.000 395.000 0.000 20.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 40.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

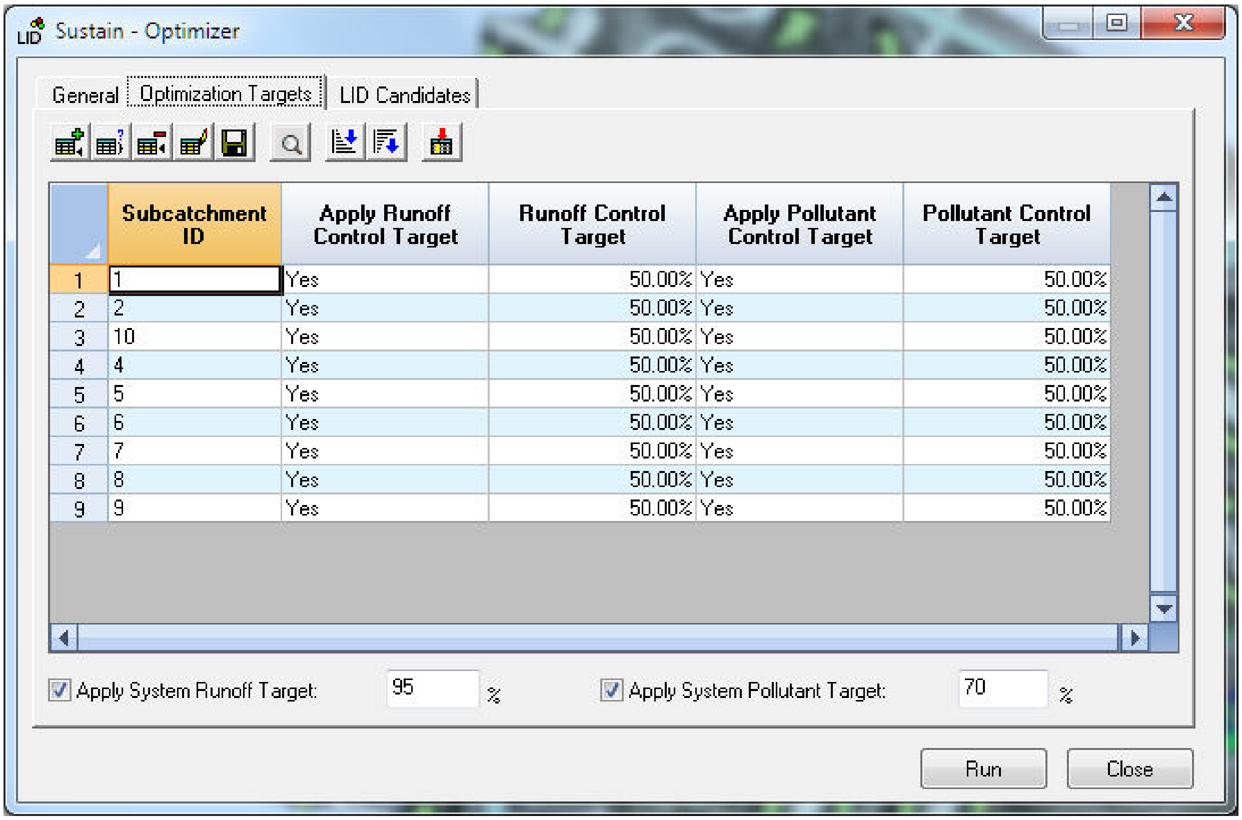
LID7 13: Porous Pavement 7 PPAVEMENT 2 0 49.000 0.000 45.000 0.000 24.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 49.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID8 13: Porous Pavement 8 PPAVEMENT 9 0 37.000 0.000 445.000 0.000 18.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000

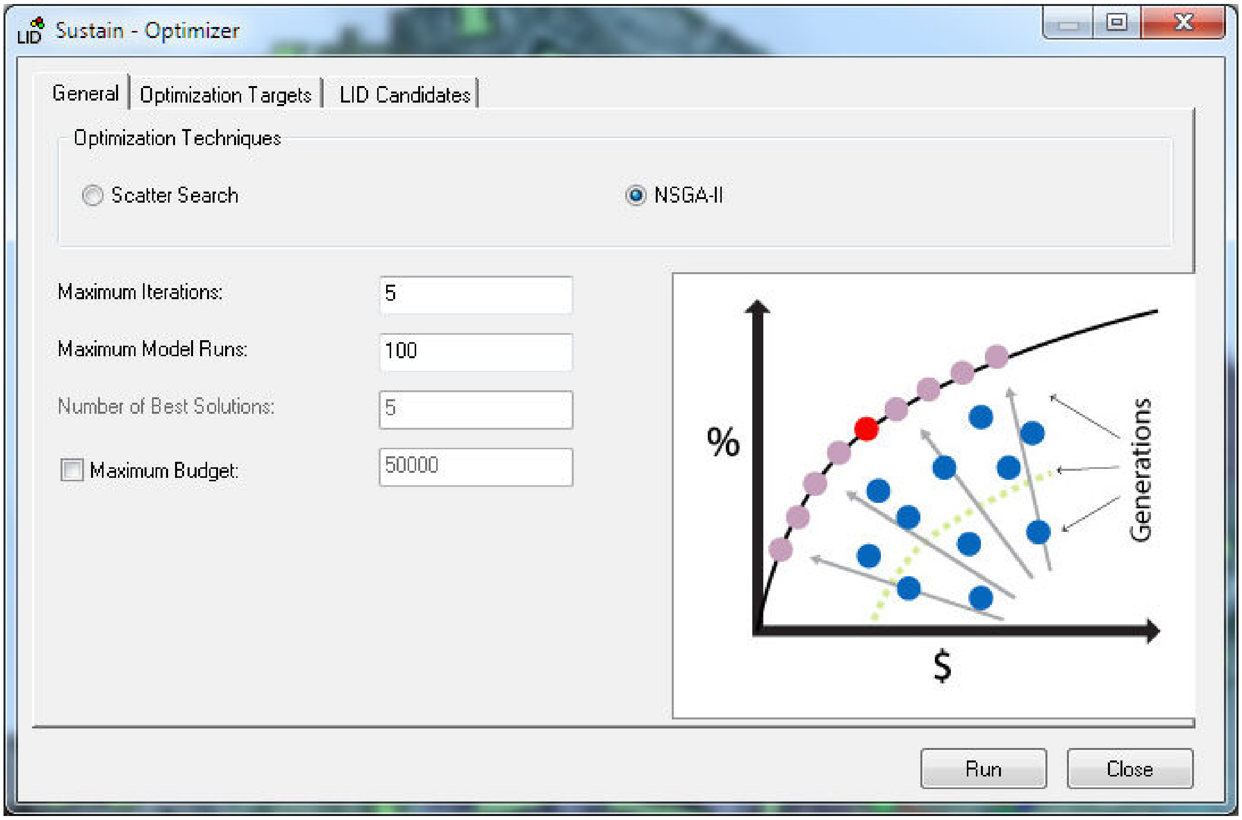
Yes 1.000 1.000 37.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID9 13: Porous Pavement 9 PPAVEMENT 5 0 39.000 0.000 260.000 0.000 19.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 39.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

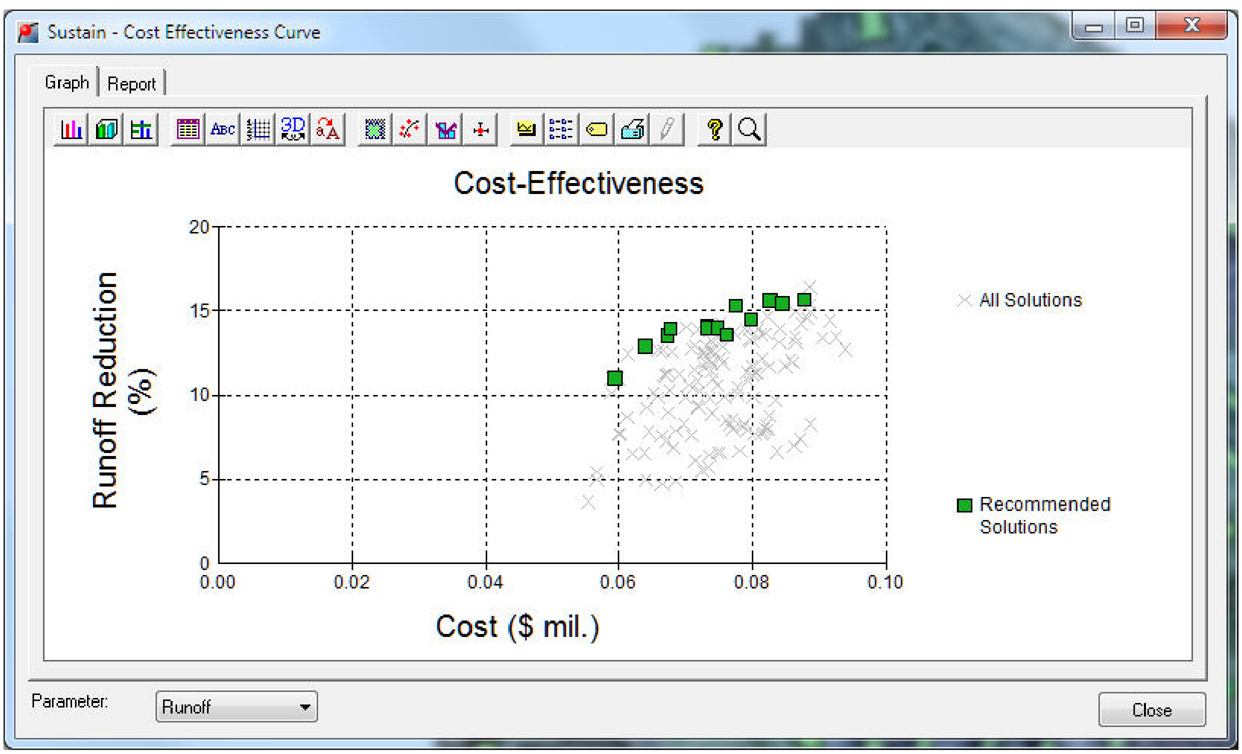
Our Optimization Goals



Use NSGA-II Optimization to find the Cost Boundary Curve

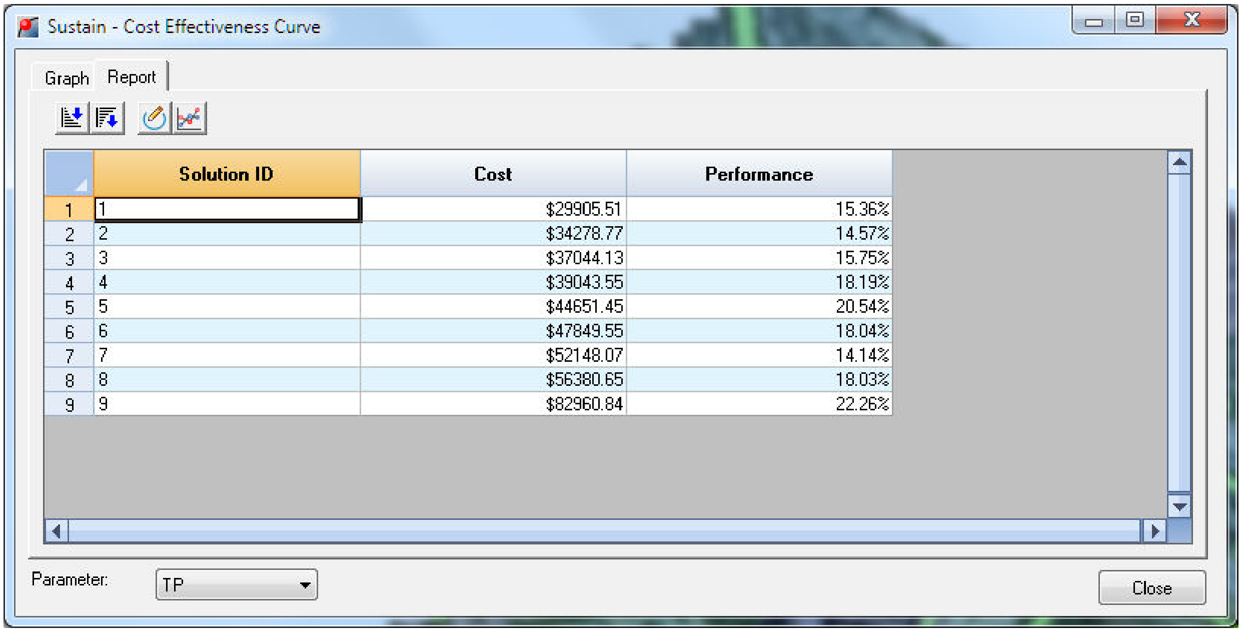


[The Cost Effectiveness Curves for Runoff and Water Quality]()



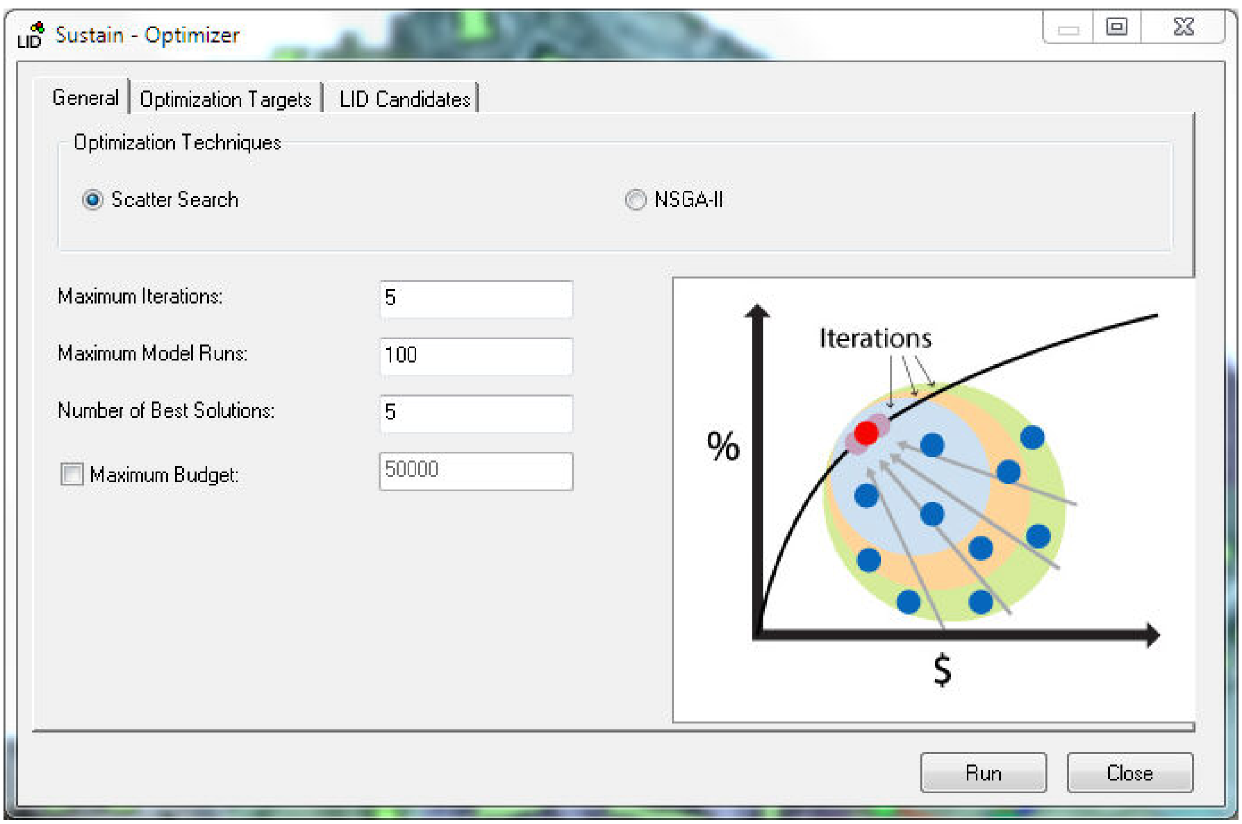
[The Cost Effectiveness Report for Runoff and Water Quality]()

There is little removal as the Rain Barrels are not sending the overflow to the pervious area and there is little storage in a Rain Barrel.



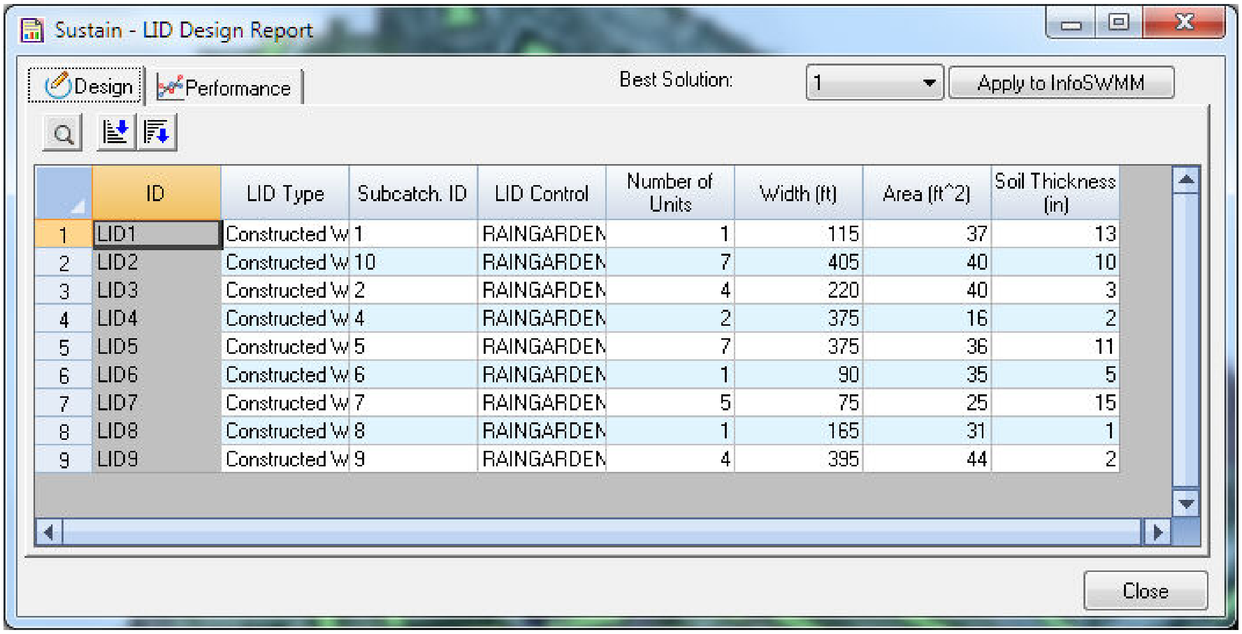
	Solution ID	Cost	Performance
1	1	$29905.51	15.36%
2	2	$34278.77	14.57%
3	3	$37044.13	15.75%
4	4	$39043.55	18.19%
5	5	$44651.45	20.54%
6	6	$47849.55	18.04%
7	7	$52148.07	14.14%
8	8	$56380.65	18.03%
9	9	$82960.84	22.26%

Use Scatter Search to Find the Best Solutions

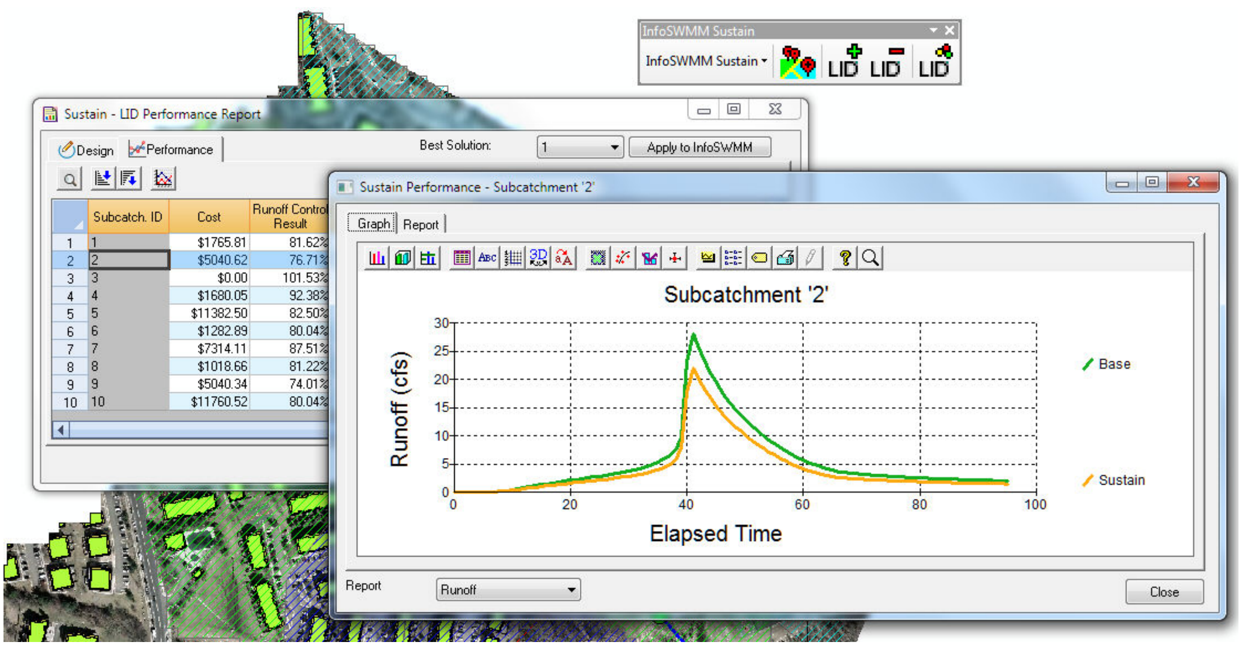


The Design Report and Performance Curve

The effect of the perviouus area treatment train on the Rain Gardens

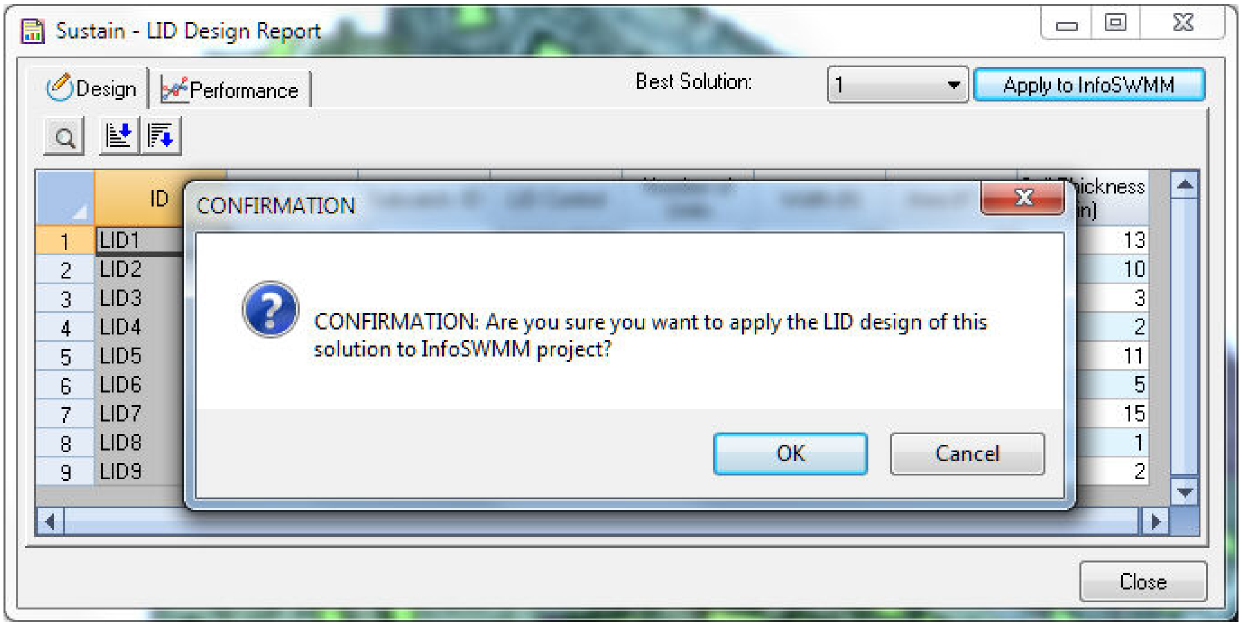


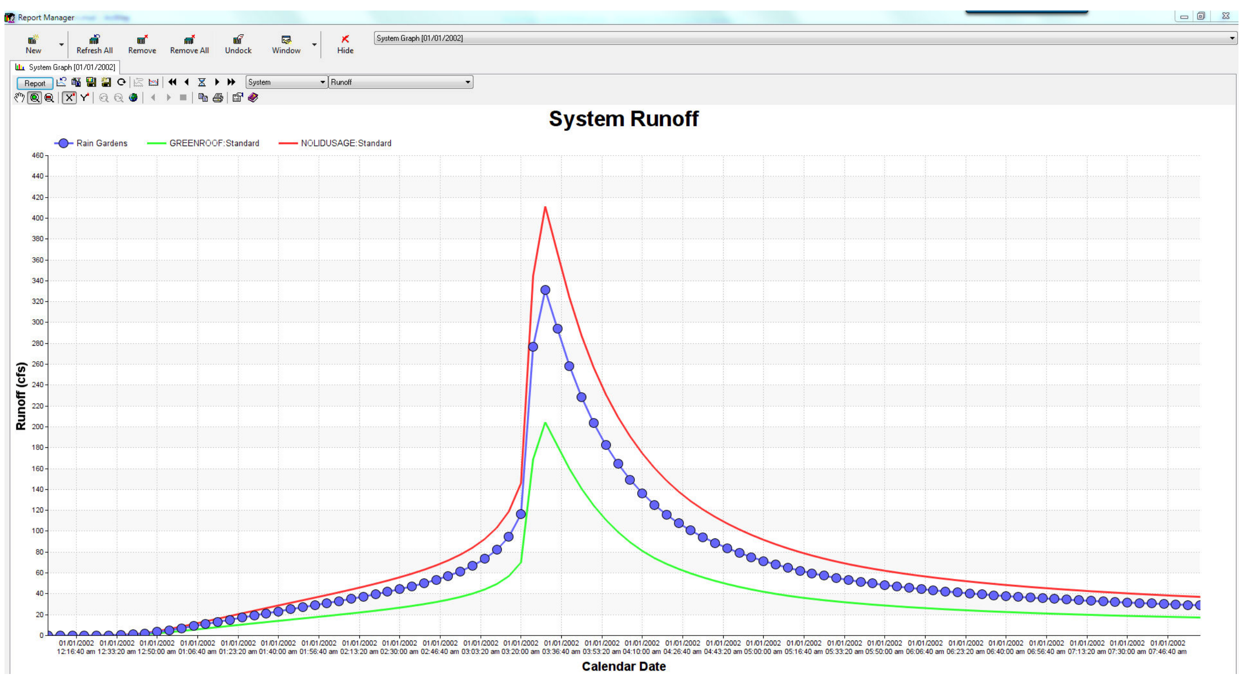
	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness (in)
1	LID1	Constructed W	1	RAINGARDEN	1	115	37	13
2	LID2	Constructed W	10	RAINGARDEN	7	405	40	10
3	LID3	Constructed W	2	RAINGARDEN	4	220	40	3
4	LID4	Constructed W	4	RAINGARDEN	2	375	16	2
5	LID5	Constructed W	5	RAINGARDEN	7	375	36	11
6	LID6	Constructed W	6	RAINGARDEN	1	90	35	5
7	LID7	Constructed W	7	RAINGARDEN	5	75	25	15
8	LID8	Constructed W	8	RAINGARDEN	1	165	31	1
9	LID9	Constructed W	9	RAINGARDEN	4	395	44	2



[The Effect of the Treatment Train in InfoSWMM]

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious are from the Rain Gardens. The Red Dot Scenario is the Rain Barrels NOT flowing to pervious area but the outlet of the Subcatchment. The Green line is the Rain Barrel flowing to the pervious area. See also Tutorial 10.


Sustain - LID Design Report
Design
Performance
Best Solution:
1
Apply to InfoSWMM
ID
1 LID1
2 LID2
3 LID3
4 LID4
5 LID5
6 LID6
7 LID7
8 LID8
9 LID9
CONFIRMATION
CONFIRMATION: Are you sure you want to apply the LID design of this solution to InfoSWMM project?
OK
Cancel
13
10
3
2
11
5
15
1
2
Close

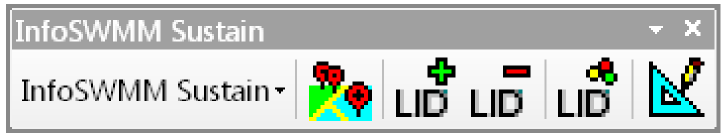

Report Manager
New
Refresh All
Remove
Remove All
Undock
Window
Hide
System Graph [01/01/2002]
Report
System
Runoff
System Runoff
Rain Gardens
GREENROOF:Standard
NOLIDUSAGE:Standard
Runoff (cfs)
Calendar Date

InfoSWMM uses the EPA SWMM 5.1.013 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® InfoSWMM Innovyze®


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 6 Optimizing Rain Gardens for Sustain 4.0

This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Rain Gardens on the ten Subcatchments.

1. Turn off Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow into the Rain Gardens

Area of Each Unit

The surface area devoted to each replicate LID unit (sq. ft or sq. m).

Number of Replicate Units

The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.

Surface Width Per Unit

The width of the outflow face of each identical LID unit (in ft or m). This parameter applies to green roofs, permeable pavement, infiltration trenches, and vegetative swales that use overland flow to convey surface runoff off of the unit. It can be set to 0 for other LID processes, such as bio-retention cells, rain gardens, and rain barrels that simply spill any excess captured runoff over their berms.

% Initially Saturated

For bio-retention cells, rain gardens, and green roofs this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the

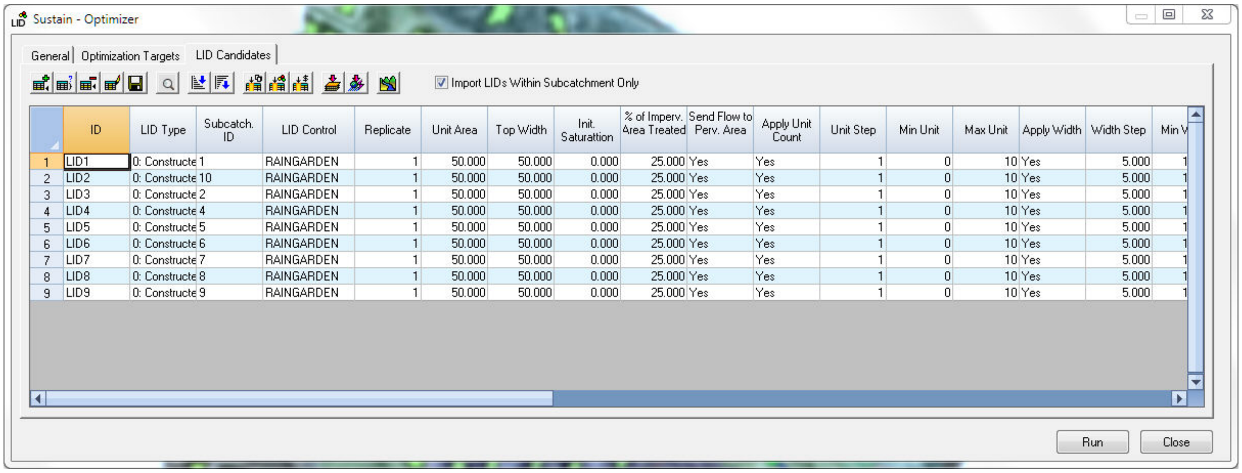
cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

% of Impervious Area Treated

The percent of the impervious portion of the Subcatchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

Return All Outflow To Pervious Area

Select this option if the surface and underdrain flow from the LID unit should be routed back onto the pervious area of the Subcatchment that contains it. This would be a common choice to make for rain barrels and possibly green roofs.



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturattion	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min Unit	Max Unit	Apply Width	Width Step	Min V
1	LID1	0: Constructe	1	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
2	LID2	0: Constructe	10	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
3	LID3	0: Constructe	2	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
4	LID4	0: Constructe	4	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
5	LID5	0: Constructe	5	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
6	LID6	0: Constructe	6	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
7	LID7	0: Constructe	7	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
8	LID8	0: Constructe	8	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1
9	LID9	0: Constructe	9	RAINGARDEN	1	50.000	50.000	0.000	25.000	Yes	Yes	1	0	10	Yes	5.000	1

A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media Volume Cost Under Drain Volume Cost Constant Cost Percentage of other Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent Underdrain Outlet

LID1 0: Constructed Wetland 1 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

LID2 0: Constructed Wetland 10 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

LID3 0: Constructed Wetland 2 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes No Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

LID4 0: Constructed Wetland 4 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

LID5 0: Constructed Wetland 5 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

LID6 0: Constructed Wetland 6 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

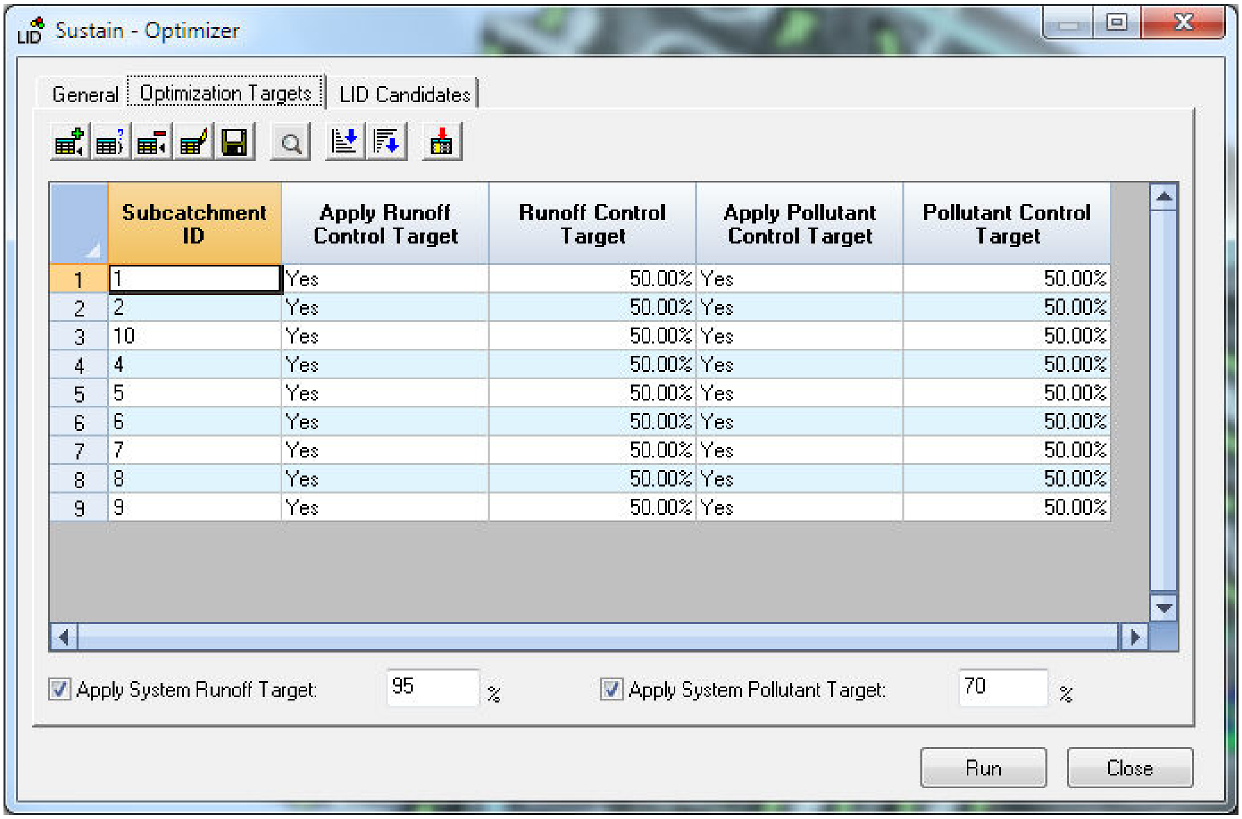
LID7 0: Constructed Wetland 7 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

LID8 0: Constructed Wetland 8 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

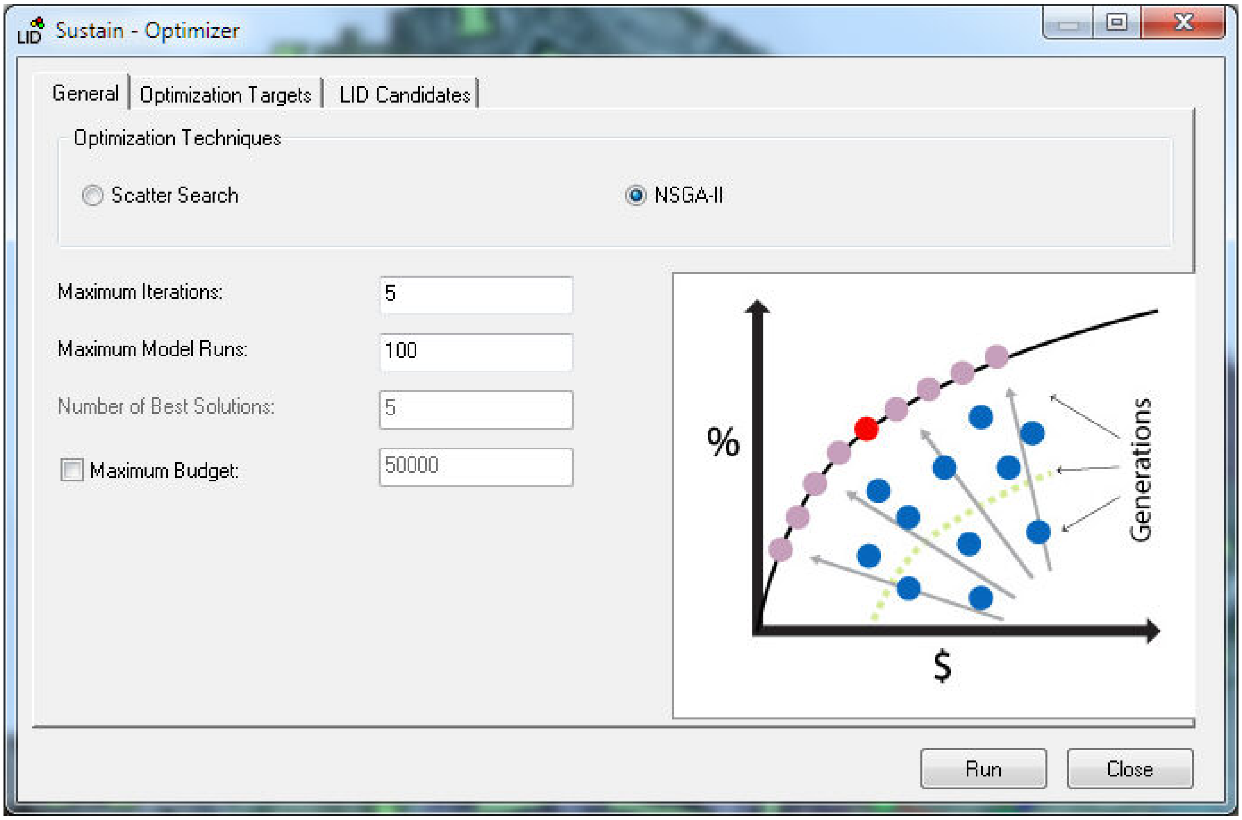
LID9 0: Constructed Wetland 9 RAINGARDEN 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes Yes 1 0 10 Yes 5.000 10.000 500.000 Yes 1.000 1.000

15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.000 1.000 1.000

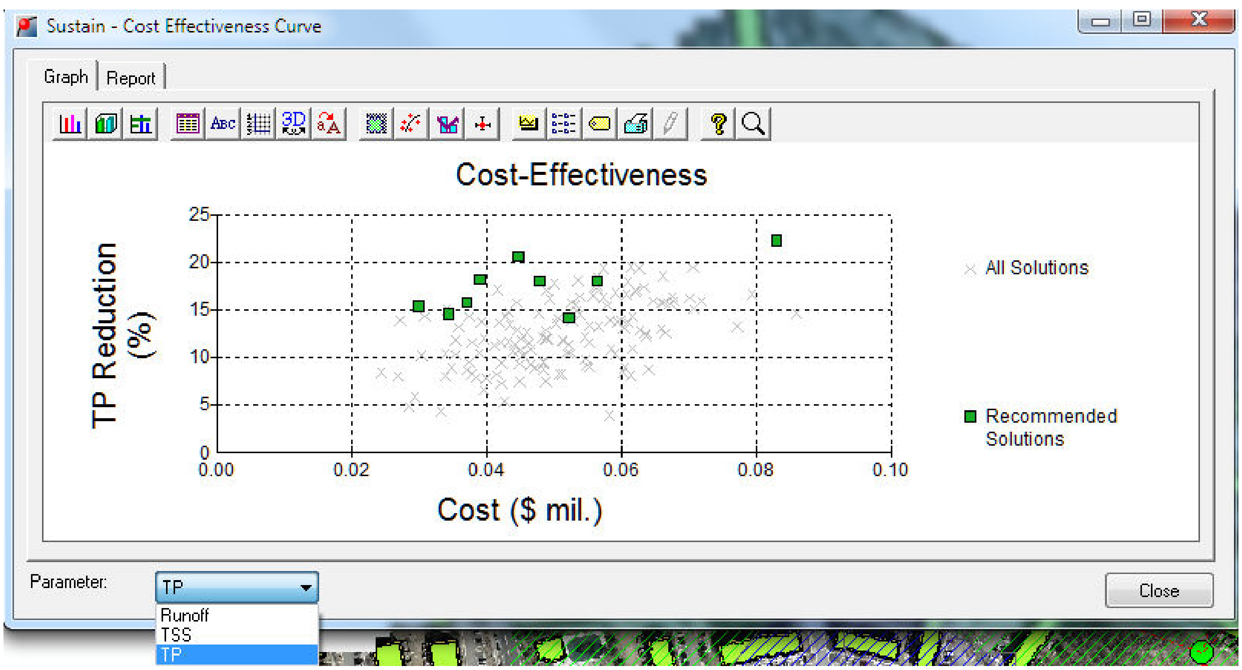
Our Optimization Goals



Use NSGA-II Optimization to find the Cost Boundary Curve

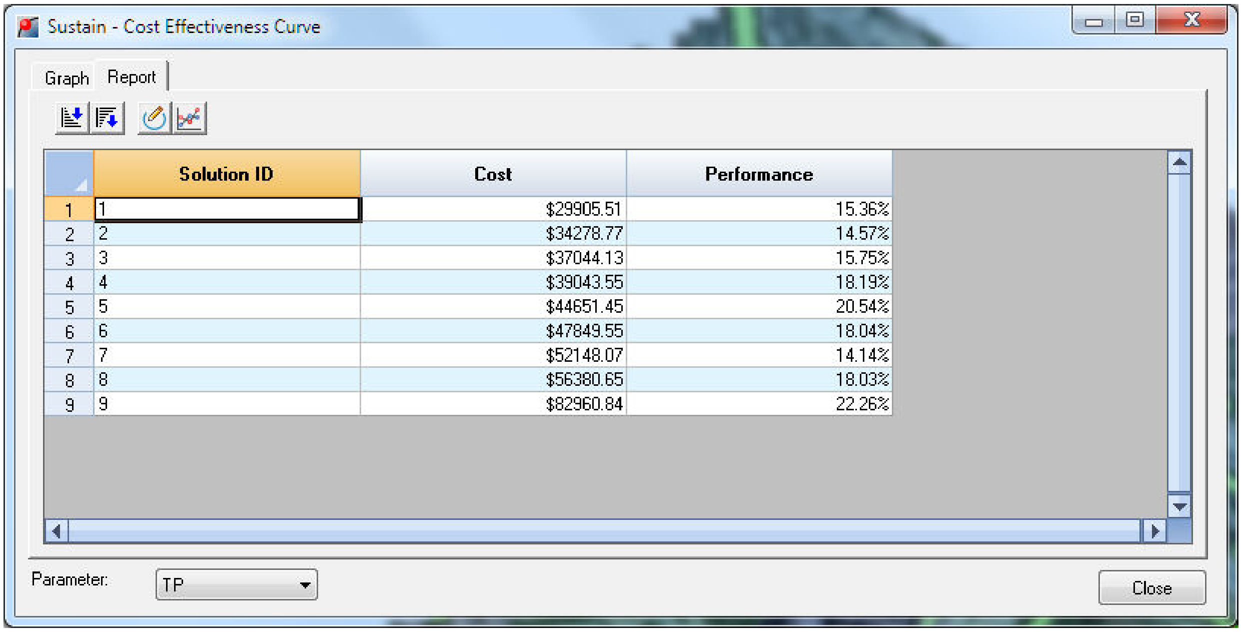


[The Cost Effectiveness Curves for Runoff and Water Quality]



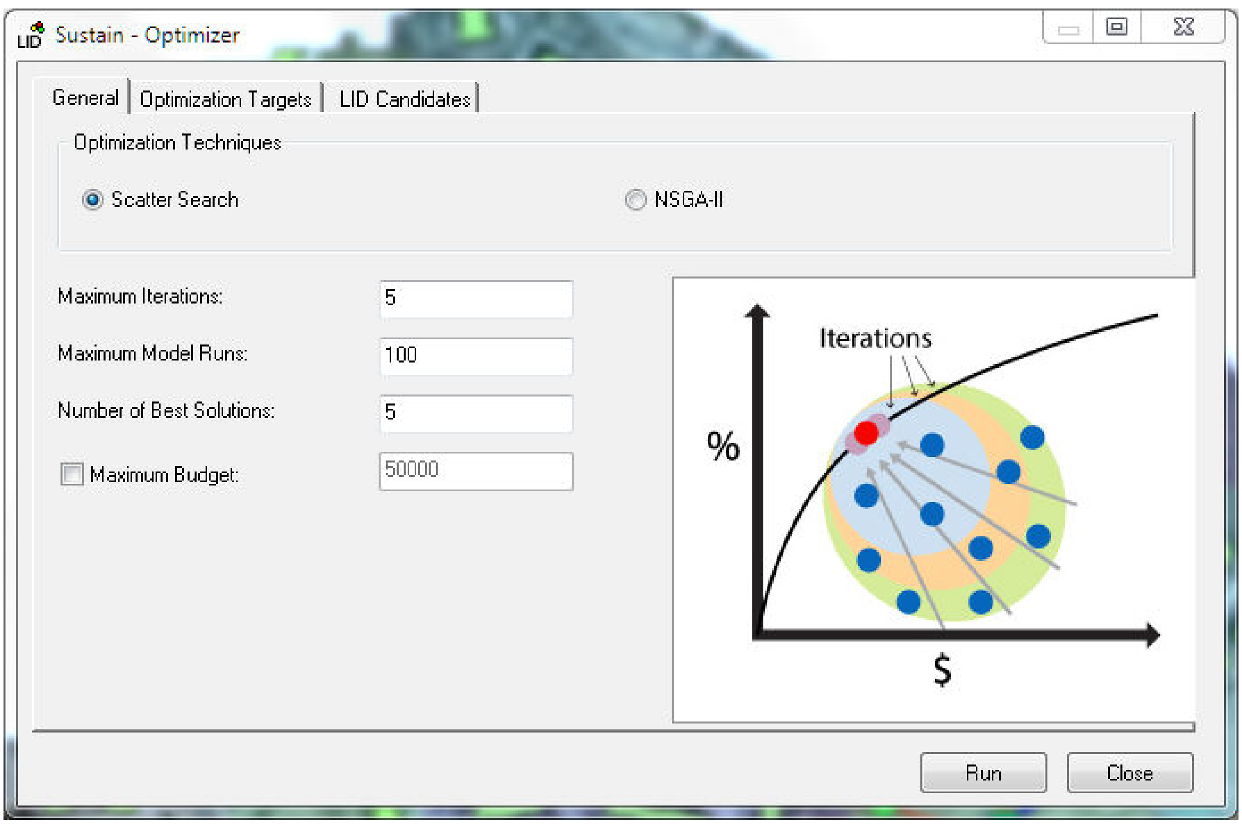
[The Cost Effectiveness Report for Runoff and Water Quality]

There is little removal as the Rain Barrels are not sending the overflow to the pervious area and there is little storage in a Rain Barrel.



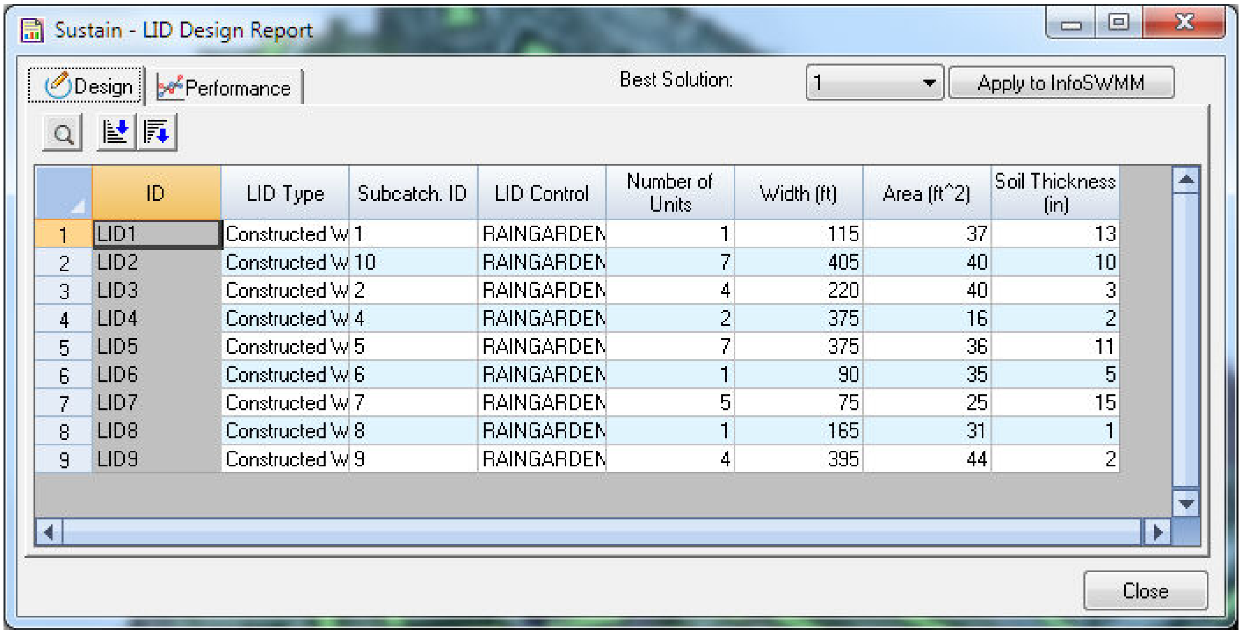
	Solution ID	Cost	Performance
1	1	$29905.51	15.36%
2	2	$34278.77	14.57%
3	3	$37044.13	15.75%
4	4	$39043.55	18.19%
5	5	$44651.45	20.54%
6	6	$47849.55	18.04%
7	7	$52148.07	14.14%
8	8	$56380.65	18.03%
9	9	$82960.84	22.26%

Use Scatter Search to Find the Best Solutions

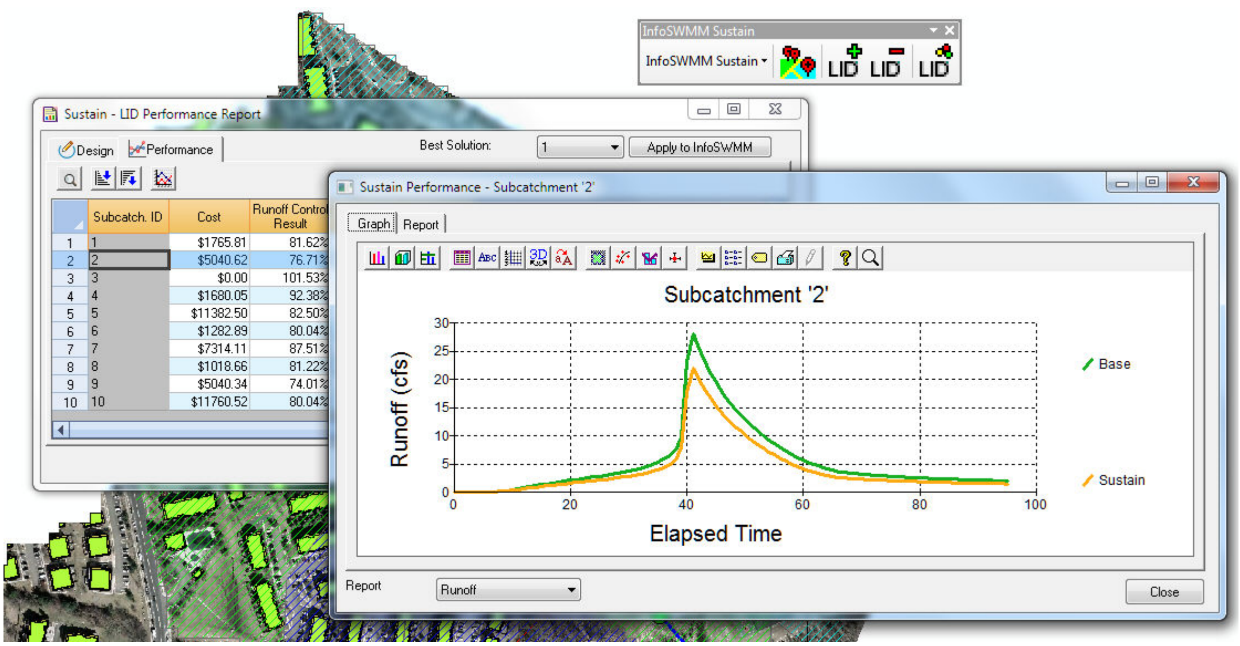


The Design Report and Performance Curve

The effect of the perviouus area treatment train on the Rain Gardens

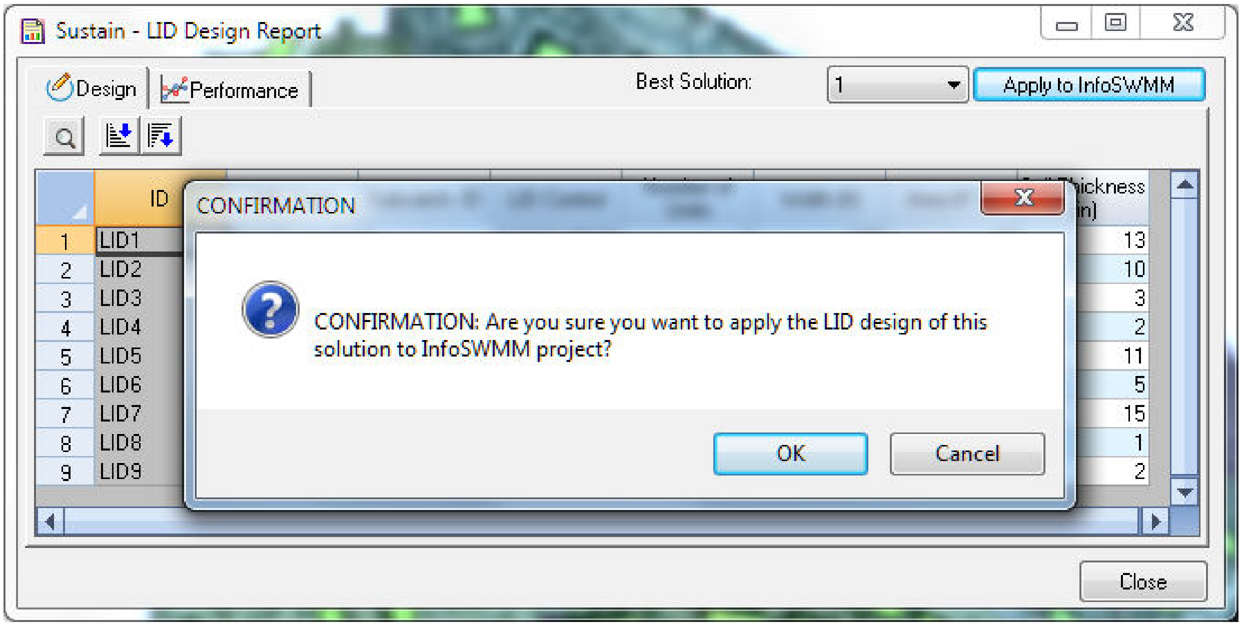


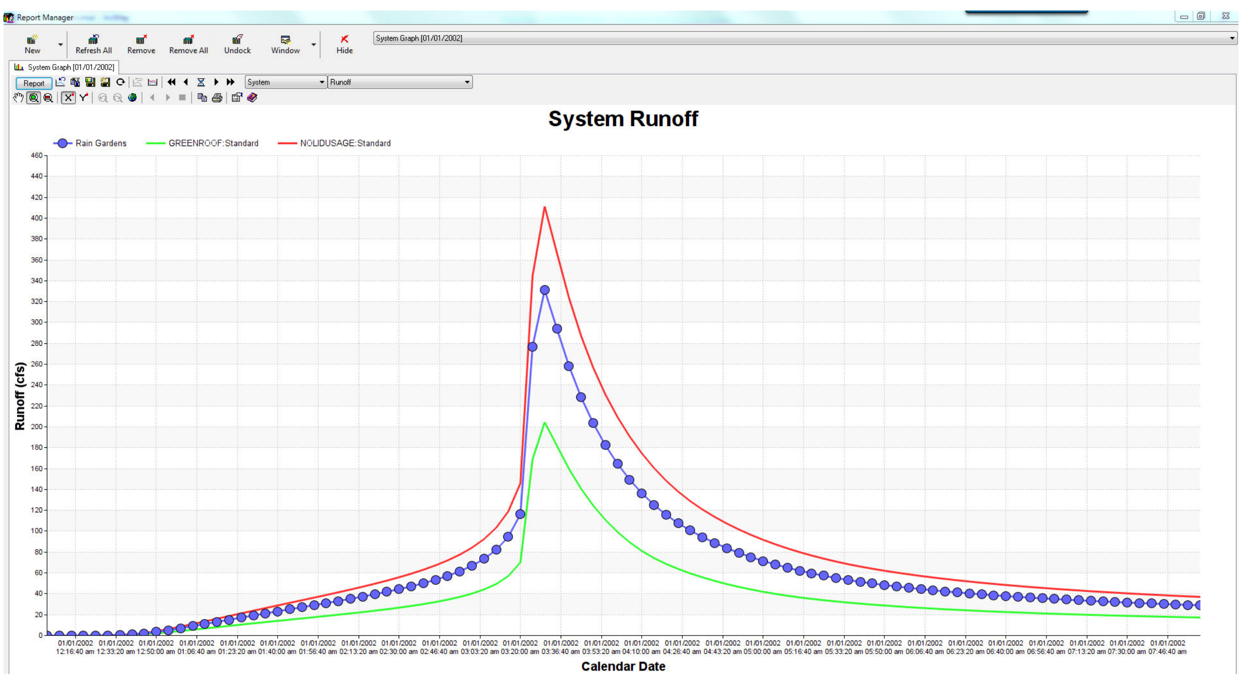
	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness (in)
1	LID1	Constructed W	1	RAINGARDEN	1	115	37	13
2	LID2	Constructed W	10	RAINGARDEN	7	405	40	10
3	LID3	Constructed W	2	RAINGARDEN	4	220	40	3
4	LID4	Constructed W	4	RAINGARDEN	2	375	16	2
5	LID5	Constructed W	5	RAINGARDEN	7	375	36	11
6	LID6	Constructed W	6	RAINGARDEN	1	90	35	5
7	LID7	Constructed W	7	RAINGARDEN	5	75	25	15
8	LID8	Constructed W	8	RAINGARDEN	1	165	31	1
9	LID9	Constructed W	9	RAINGARDEN	4	395	44	2



[The Effect of the Treatment Train in InfoSWMM]

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious are from the Rain Gardens. The Red Dot Scenario is the Rain Barrels NOT flowing to pervious area but the outlet of the Subcatchment. The Green line is the Rain Barrel flowing to the pervious area. See also Tutorial 10.

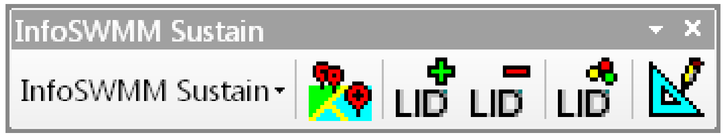

Sustain - LID Design Report
Design
Performance
Best Solution:
1
Apply to InfoSWMM
ID
1 LID1
2 LID2
3 LID3
4 LID4
5 LID5
6 LID6
7 LID7
8 LID8
9 LID9
13
10
3
2
11
5
15
1
2
CONFIRMATION
CONFIRMATION: Are you sure you want to apply the LID design of this solution to InfoSWMM project?
OK
Cancel
Close


System Runoff
Rain Gardens
GREENROOF:Standard
NOLIDUSAGE:Standard
Runoff (cfs)
Calendar Date

InfoSWMM uses the EPA SWMM 5.1.013 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


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 7 Optimizing the Swale Control for Sustain 4.0

This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Swales on the ten Subcatchments.

1. Turn off Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow into the Rain Gardens

Area of Each Unit

The surface area devoted to each replicate LID unit (sq. ft or sq. m).

Number of Replicate Units

The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.

Surface Width Per Unit

The width of the outflow face of each identical LID unit (in ft or m). This parameter applies to green roofs, permeable pavement, infiltration trenches, and vegetative swales that use overland flow to convey surface runoff off of the unit. It can be set to 0 for other LID processes, such as bio-retention cells, rain gardens, and rain barrels that simply spill any excess captured runoff over their berms.

% Initially Saturated

For bio-retention cells, rain gardens, and green roofs this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the

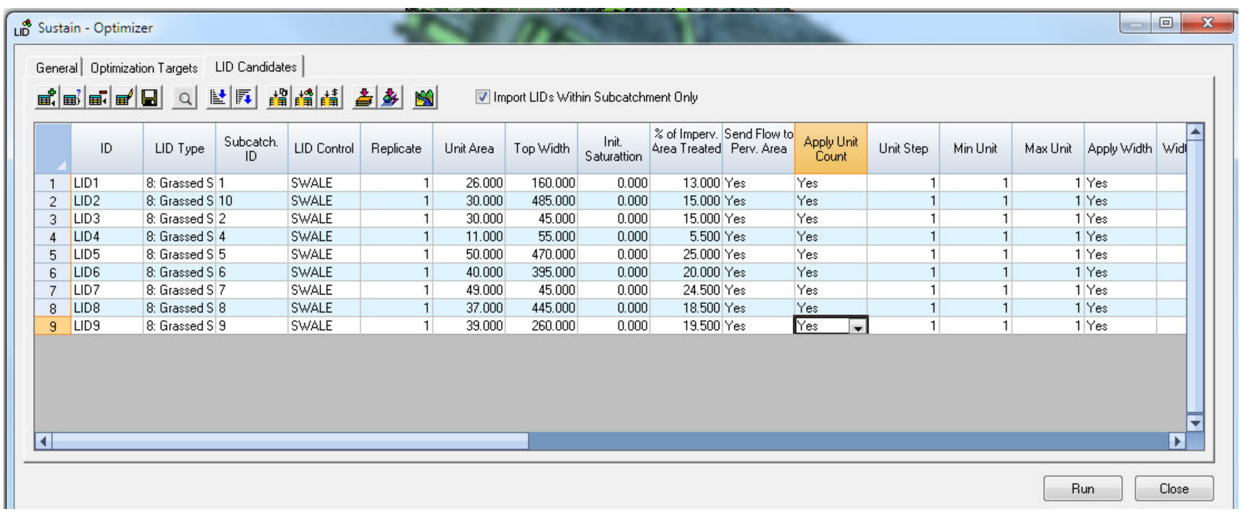
cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

% of Impervious Area Treated

The percent of the impervious portion of the Subcatchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

Return All Outflow To Pervious Area

Select this option if the surface and underdrain flow from the LID unit should be routed back onto the pervious area of the Subcatchment that contains it. This would be a common choice to make for rain barrels and possibly green roofs.



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturattion	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min Unit	Max Unit	Apply Width	Widt
1	LID1	8: Grassed S	1	SWALE	1	26.000	160.000	0.000	13.000	Yes	Yes	1	1	1	Yes	
2	LID2	8: Grassed S	10	SWALE	1	30.000	485.000	0.000	15.000	Yes	Yes	1	1	1	Yes	
3	LID3	8: Grassed S	2	SWALE	1	30.000	45.000	0.000	15.000	Yes	Yes	1	1	1	Yes	
4	LID4	8: Grassed S	4	SWALE	1	11.000	55.000	0.000	5.500	Yes	Yes	1	1	1	Yes	
5	LID5	8: Grassed S	5	SWALE	1	50.000	470.000	0.000	25.000	Yes	Yes	1	1	1	Yes	
6	LID6	8: Grassed S	6	SWALE	1	40.000	395.000	0.000	20.000	Yes	Yes	1	1	1	Yes	
7	LID7	8: Grassed S	7	SWALE	1	49.000	45.000	0.000	24.500	Yes	Yes	1	1	1	Yes	
8	LID8	8: Grassed S	8	SWALE	1	37.000	445.000	0.000	18.500	Yes	Yes	1	1	1	Yes	
9	LID9	8: Grassed S	9	SWALE	1	39.000	260.000	0.000	19.500	Yes	Yes	1	1	1	Yes	

A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media Volume Cost Under Drain Volume Cost Constant Cost Percentage of other

Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent

LID1 8: Grassed Swale 1 SWALE 1 0 26.000 0.000 160.000 0.000 13.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 26.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID2 8: Grassed Swale 10 SWALE 1 0 30.000 0.000 485.000 0.000 15.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID3 8: Grassed Swale 2 SWALE 1 0 30.000 0.000 45.000 0.000 15.000 Yes No No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID4 8: Grassed Swale 4 SWALE 1 0 11.000 0.000 55.000 0.000 5.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 11.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID5 8: Grassed Swale 5 SWALE 1 0 50.000 0.000 470.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

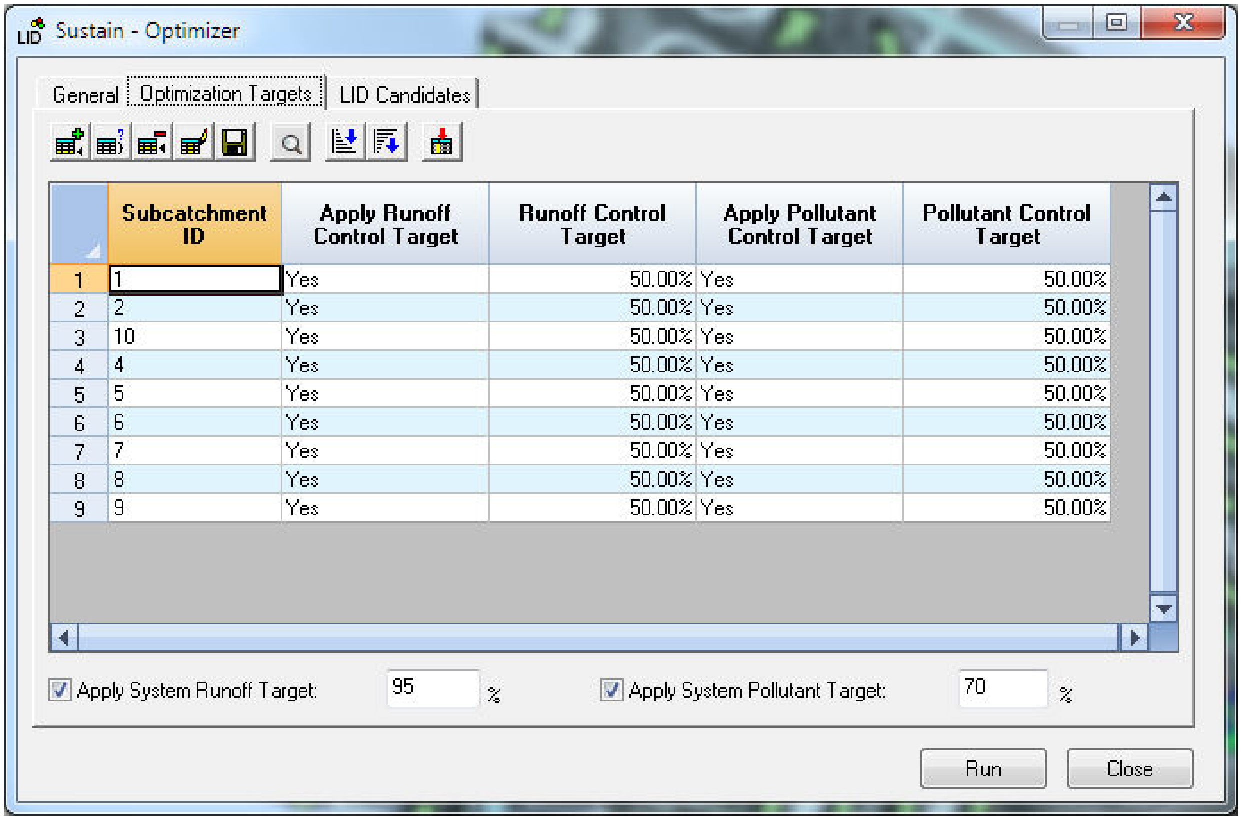
LID6 8: Grassed Swale 6 SWALE 1 0 40.000 0.000 395.000 0.000 20.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 40.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID7 8: Grassed Swale 7 SWALE 1 0 49.000 0.000 45.000 0.000 24.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 49.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID8 8: Grassed Swale 8 SWALE 1 0 37.000 0.000 445.000 0.000 18.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 37.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

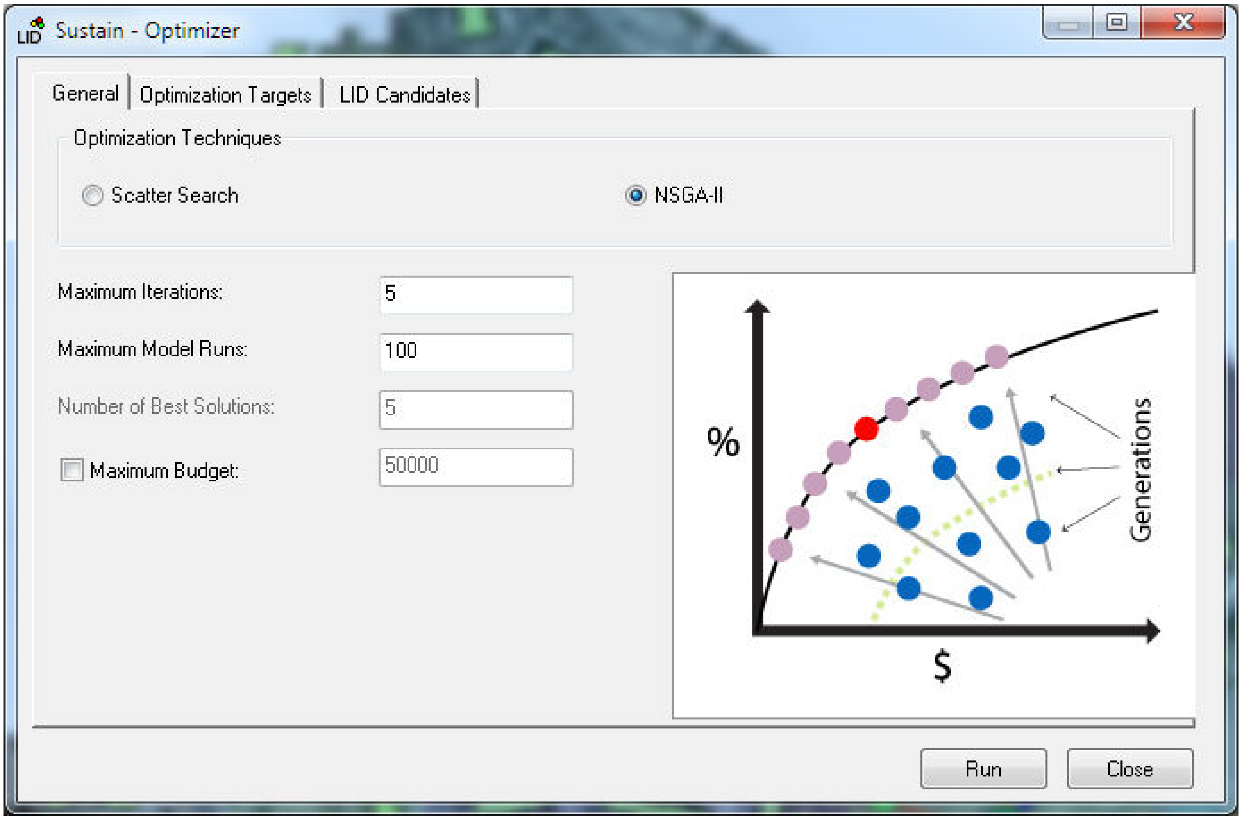
LID9 8: Grassed Swale 9 SWALE 1 0 39.000 0.000 260.000 0.000 19.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 39.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

Our Optimization Goals

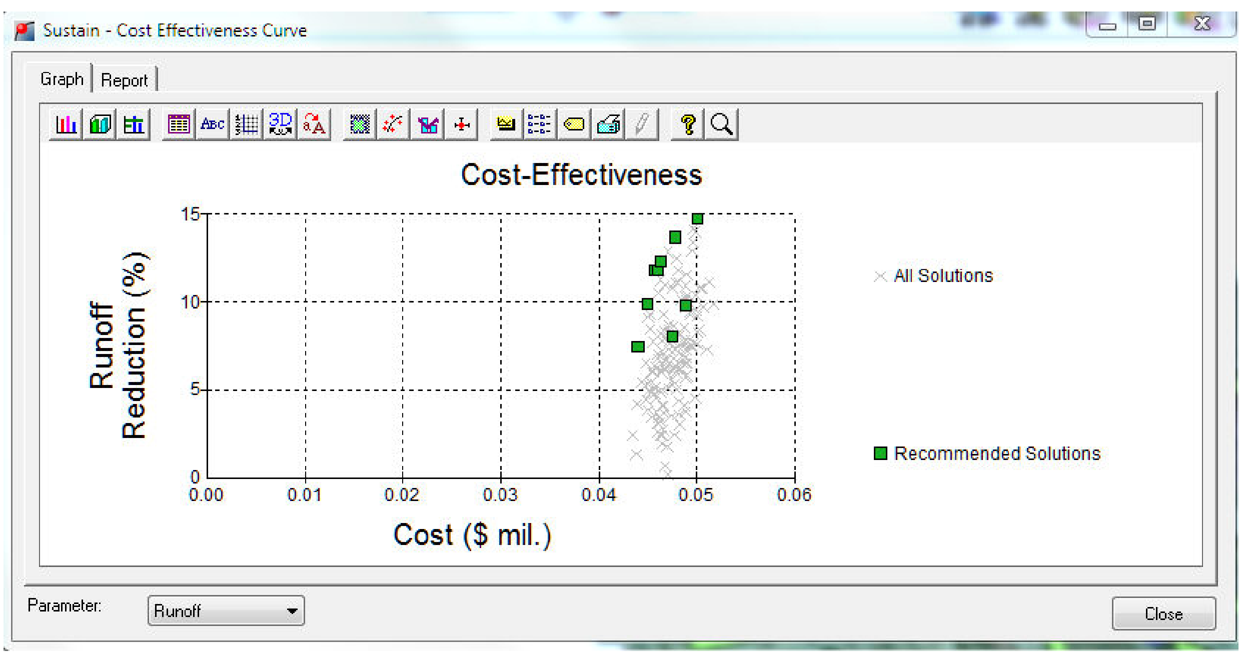


	Subcatchment ID	Apply Runoff Control Target	Runoff Control Target	Apply Pollutant Control Target	Pollutant Control Target
1	1	Yes	50.00%	Yes	50.00%
2	2	Yes	50.00%	Yes	50.00%
3	10	Yes	50.00%	Yes	50.00%
4	4	Yes	50.00%	Yes	50.00%
5	5	Yes	50.00%	Yes	50.00%
6	6	Yes	50.00%	Yes	50.00%
7	7	Yes	50.00%	Yes	50.00%
8	8	Yes	50.00%	Yes	50.00%
9	9	Yes	50.00%	Yes	50.00%

Use NSGA-II Optimization to find the Cost Boundary Curve

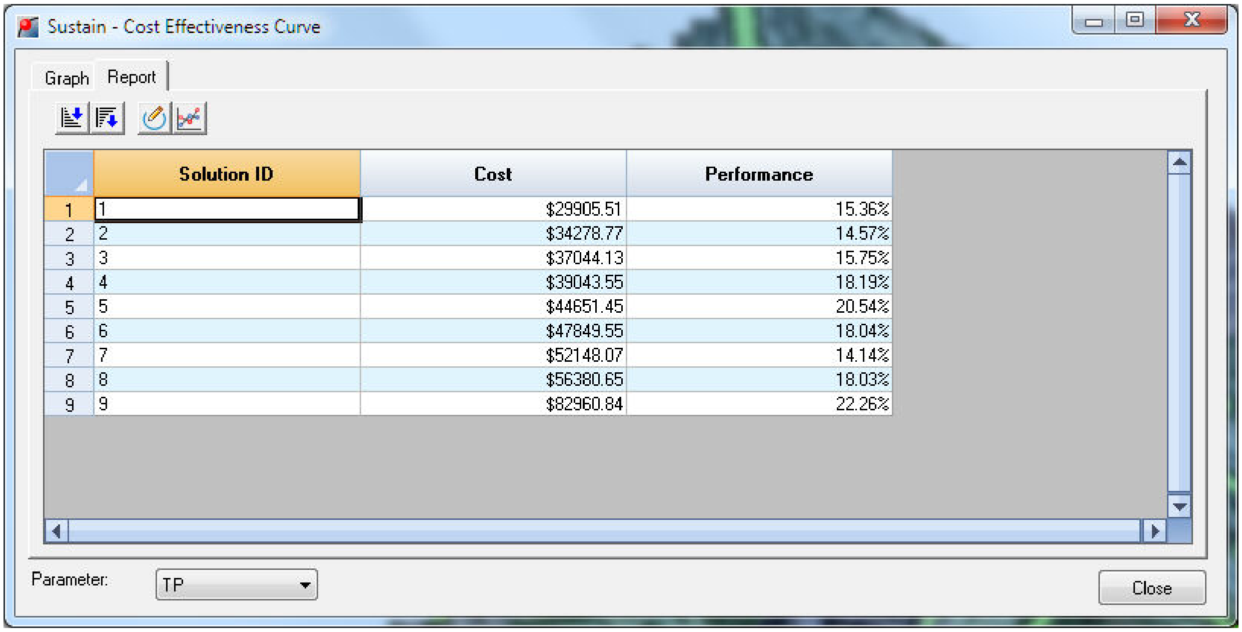


The Cost Effectiveness Curves for Runoff and Water Quality



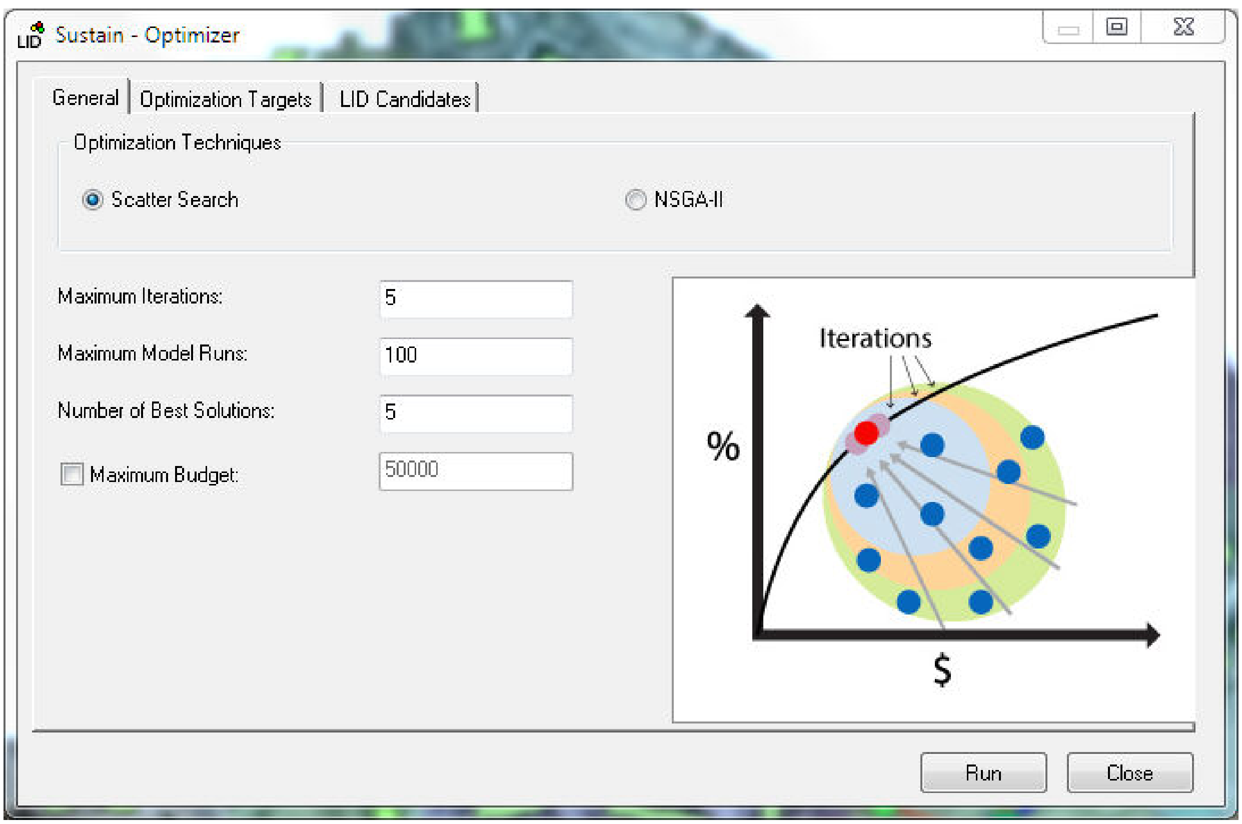
The Cost Effectiveness Report for Runoff and Water Quality

There is little removal as the Rain Barrels are not sending the overflow to the pervious area and there is little storage in a Rain Barrel.



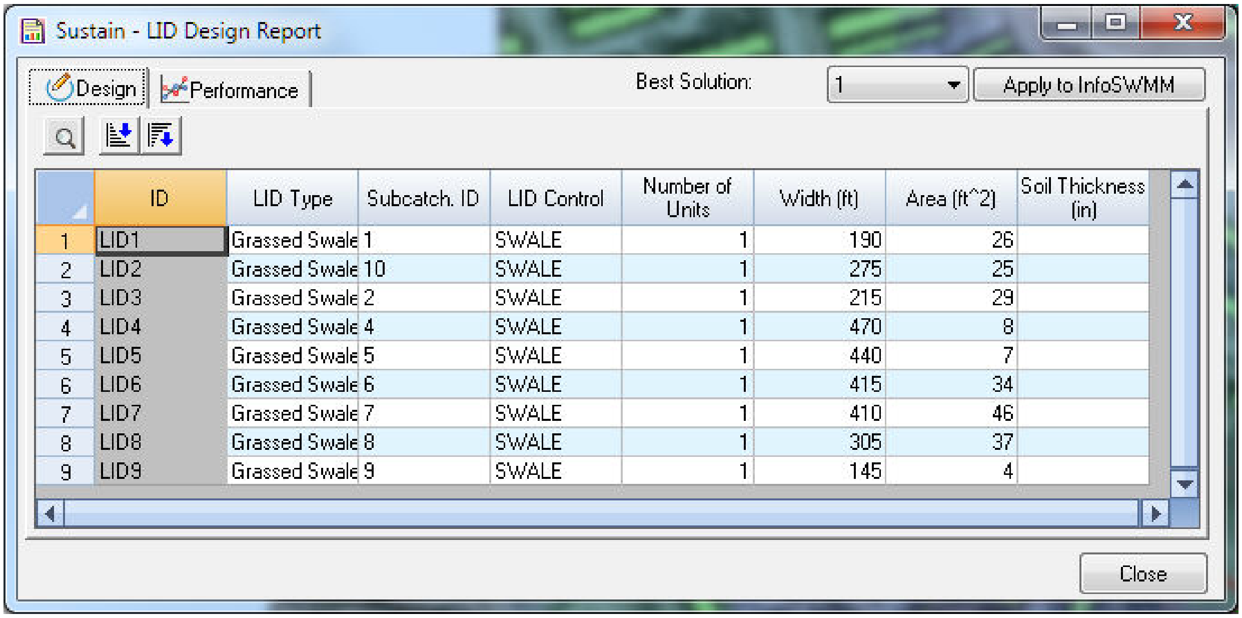
	Solution ID	Cost	Performance
1	1	$29905.51	15.36%
2	2	$34278.77	14.57%
3	3	$37044.13	15.75%
4	4	$39043.55	18.19%
5	5	$44651.45	20.54%
6	6	$47849.55	18.04%
7	7	$52148.07	14.14%
8	8	$56380.65	18.03%
9	9	$82960.84	22.26%

Use Scatter Search to Find the Best Solutions

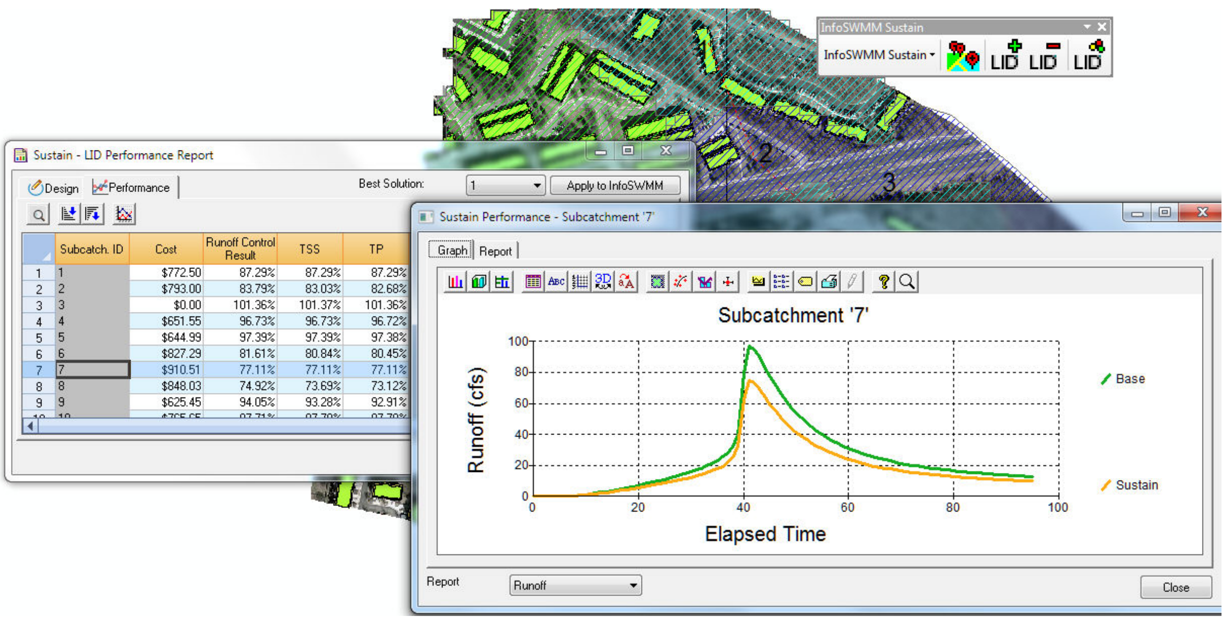


The Design Report and Performance Curve

The effect of the pervious area treatment train on the Swales

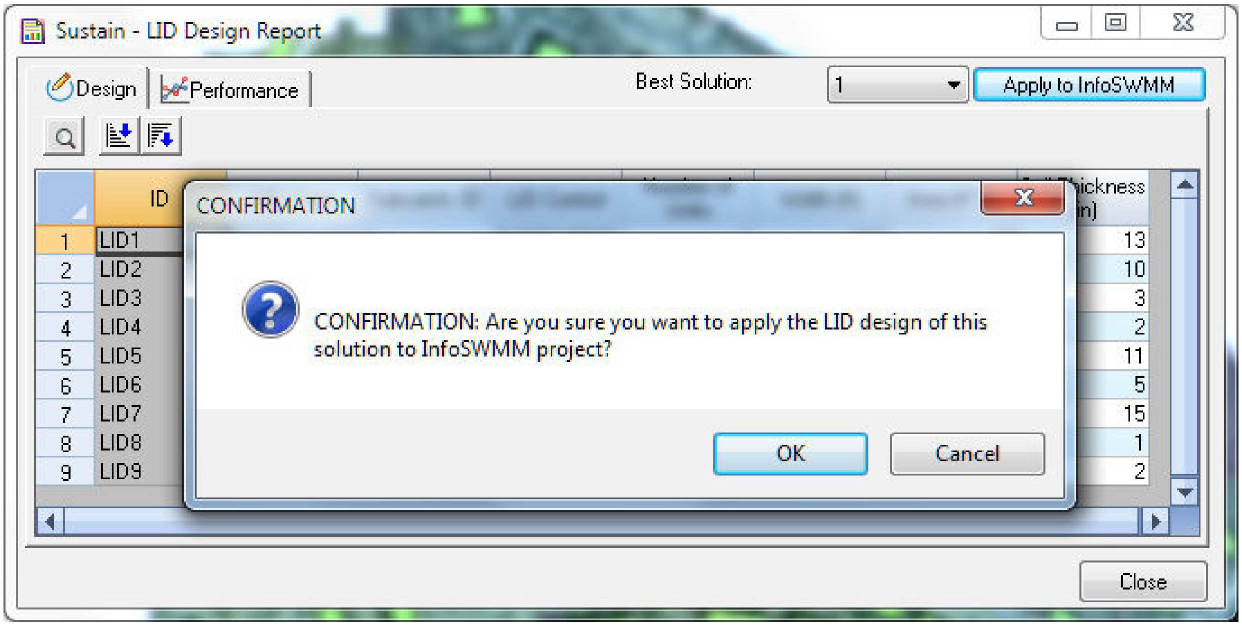


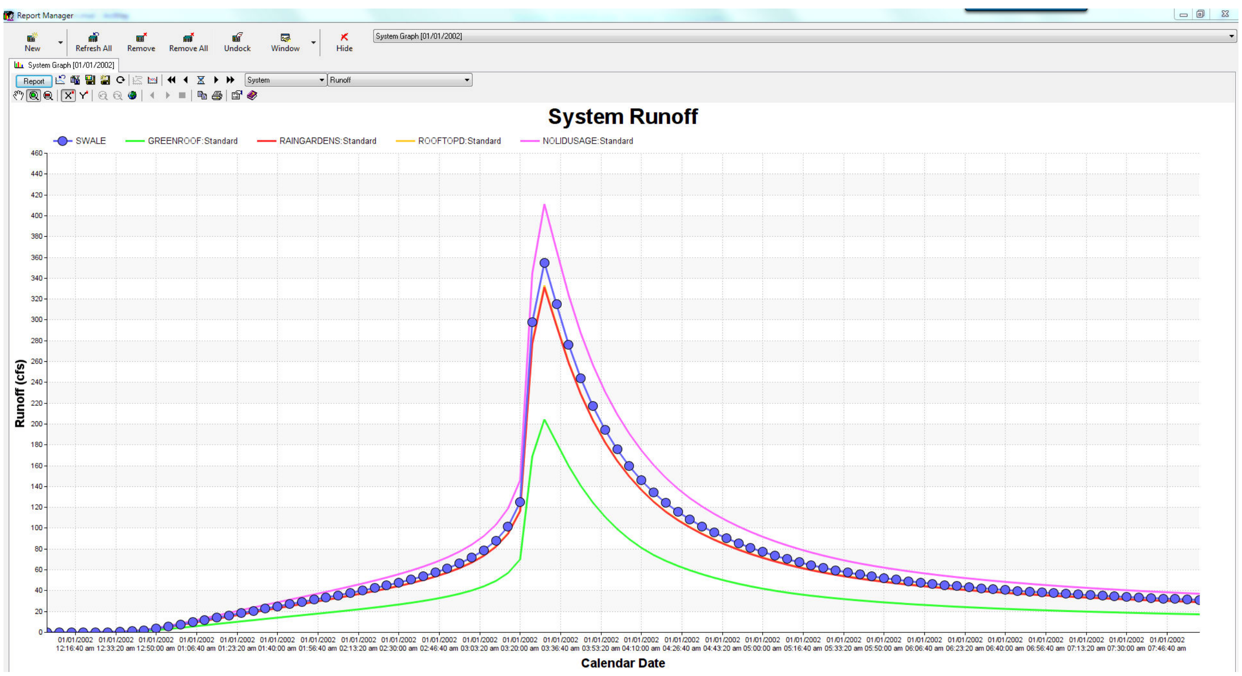
	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness (in)
1	LID1	Grassed Swale	1	SWALE	1	190	26	
2	LID2	Grassed Swale	10	SWALE	1	275	25	
3	LID3	Grassed Swale	2	SWALE	1	215	29	
4	LID4	Grassed Swale	4	SWALE	1	470	8	
5	LID5	Grassed Swale	5	SWALE	1	440	7	
6	LID6	Grassed Swale	6	SWALE	1	415	34	
7	LID7	Grassed Swale	7	SWALE	1	410	46	
8	LID8	Grassed Swale	8	SWALE	1	305	37	
9	LID9	Grassed Swale	9	SWALE	1	145	4	



[The Effect of the Treatment Train in InfoSWMM]

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious are from the Swales.


Sustain - LID Design Report
Design
Performance
Best Solution:
1
Apply to InfoSWMM
ID
LID1
LID2
LID3
LID4
LID5
LID6
LID7
LID8
LID9
CONFIRMATION
CONFIRMATION: Are you sure you want to apply the LID design of this solution to InfoSWMM project?
OK
Cancel
Close


Report Manager
System Runoff
SWALE
GREENROOF:Standard
RAINGARDENS:Standard
ROOFTOPD:Standard
NOLIDUSAGE:Standard
Runoff (cfs)
Calendar Date

InfoSWMM uses the EPA SWMM 5.1.013 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® InfoSWMM Innovyze®


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 8 Optimizing Bio-Retention Cells for Sustain 4.0

This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Bio Cells on the ten Subcatchments.

1. Turn off Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow into the Rain Gardens

Area of Each Unit

The surface area devoted to each replicate LID unit (sq. ft or sq. m).

Number of Replicate Units

The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.

Surface Width Per Unit

The width of the outflow face of each identical LID unit (in ft or m). This parameter applies to green roofs, permeable pavement, infiltration trenches, and vegetative swales that use overland flow to convey surface runoff off of the unit. It can be set to 0 for other LID processes, such as bio-retention cells, rain gardens, and rain barrels that simply spill any excess captured runoff over their berms.

% Initially Saturated

For bio-retention cells, rain gardens, and green roofs this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the

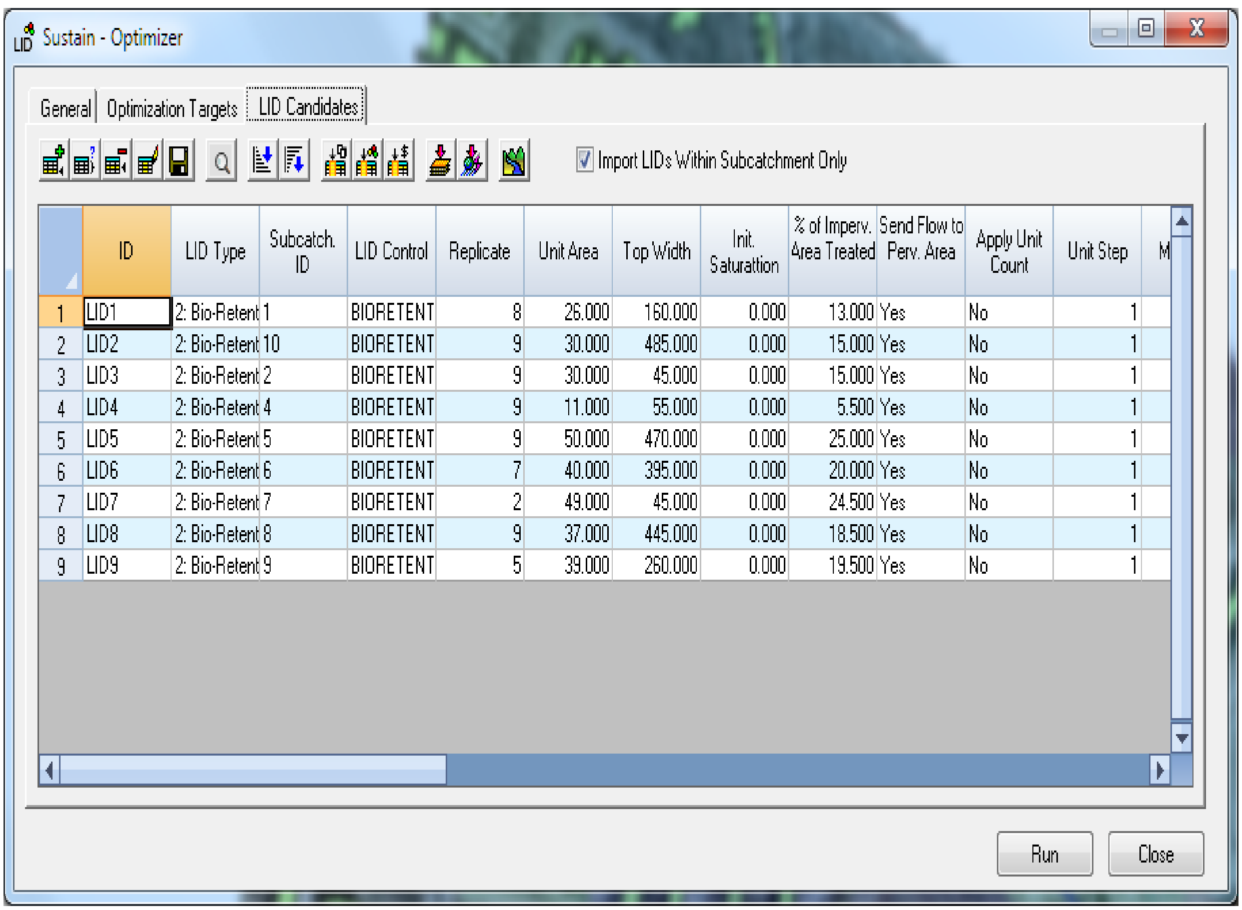
cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

% of Impervious Area Treated

The percent of the impervious portion of the Subcatchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

Return All Outflow To Pervious Area

Select this option if the surface and underdrain flow from the LID unit should be routed back onto the pervious area of the Subcatchment that contains it. This would be a common choice to make for rain barrels and possibly green roofs.



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturation	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	M
1	LID1	2: Bio-Retent	1	BIORETENT	8	26.000	160.000	0.000	13.000	Yes	No	1	
2	LID2	2: Bio-Retent	10	BIORETENT	9	30.000	485.000	0.000	15.000	Yes	No	1	
3	LID3	2: Bio-Retent	2	BIORETENT	9	30.000	45.000	0.000	15.000	Yes	No	1	
4	LID4	2: Bio-Retent	4	BIORETENT	9	11.000	55.000	0.000	5.500	Yes	No	1	
5	LID5	2: Bio-Retent	5	BIORETENT	9	50.000	470.000	0.000	25.000	Yes	No	1	
6	LID6	2: Bio-Retent	6	BIORETENT	7	40.000	395.000	0.000	20.000	Yes	No	1	
7	LID7	2: Bio-Retent	7	BIORETENT	2	49.000	45.000	0.000	24.500	Yes	No	1	
8	LID8	2: Bio-Retent	8	BIORETENT	9	37.000	445.000	0.000	18.500	Yes	No	1	
9	LID9	2: Bio-Retent	9	BIORETENT	5	39.000	260.000	0.000	19.500	Yes	No	1	

A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media Volume Cost Under Drain Volume Cost Constant Cost Percentage of other Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent Underdrain Outlet

LID1 2: Bio-Retention 1 BIORETENTION 8 0 26.000 0.000 160.000 0.000 13.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 26.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID2 2: Bio-Retention 10 BIORETENTION 9 0 30.000 0.000 485.000 0.000 15.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID3 2: Bio-Retention 2 BIORETENTION 9 0 30.000 0.000 45.000 0.000 15.000 Yes No No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 30.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID4 2: Bio-Retention 4 BIORETENTION 9 0 11.000 0.000 55.000 0.000 5.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 11.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID5 2: Bio-Retention 5 BIORETENTION 9 0 50.000 0.000 470.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

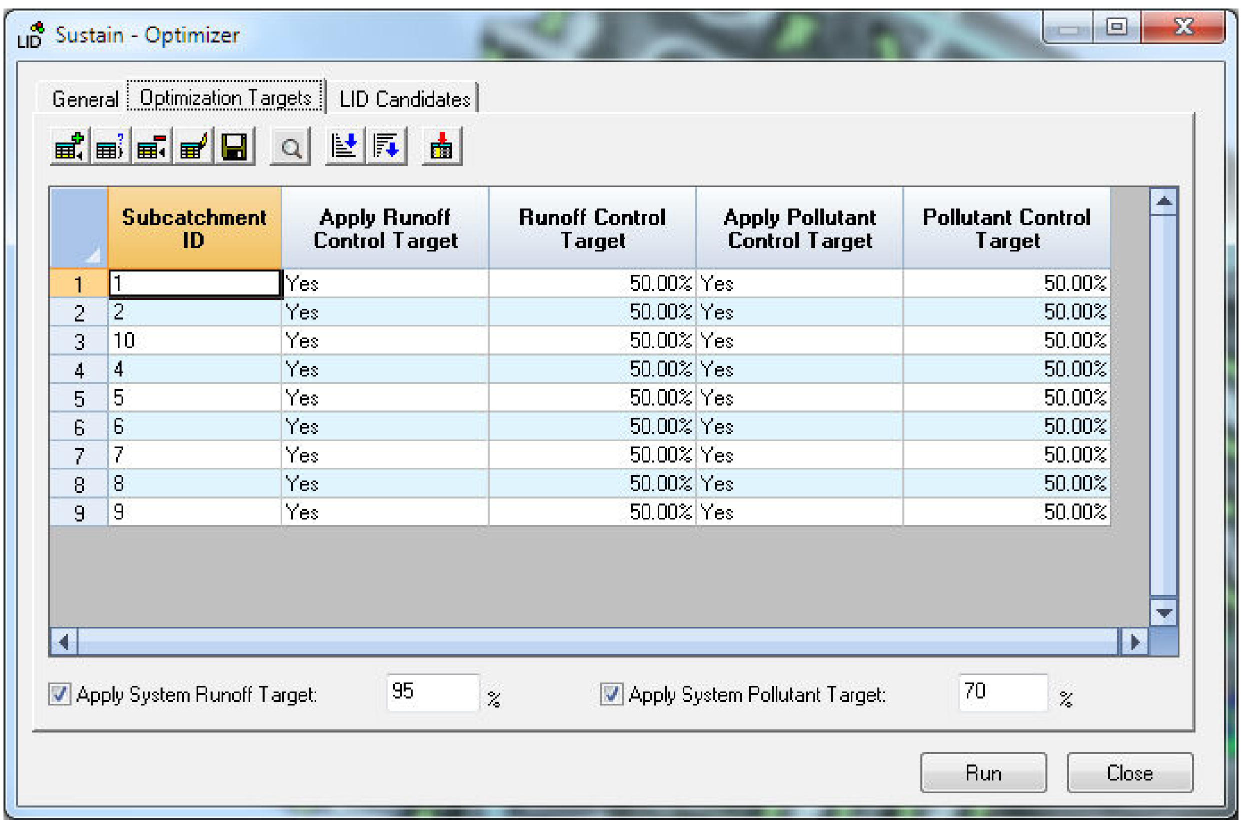
LID6 2: Bio-Retention 6 BIORETENTION 7 0 40.000 0.000 395.000 0.000 20.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 40.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID7 2: Bio-Retention 7 BIORETENTION 2 0 49.000 0.000 45.000 0.000 24.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 49.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

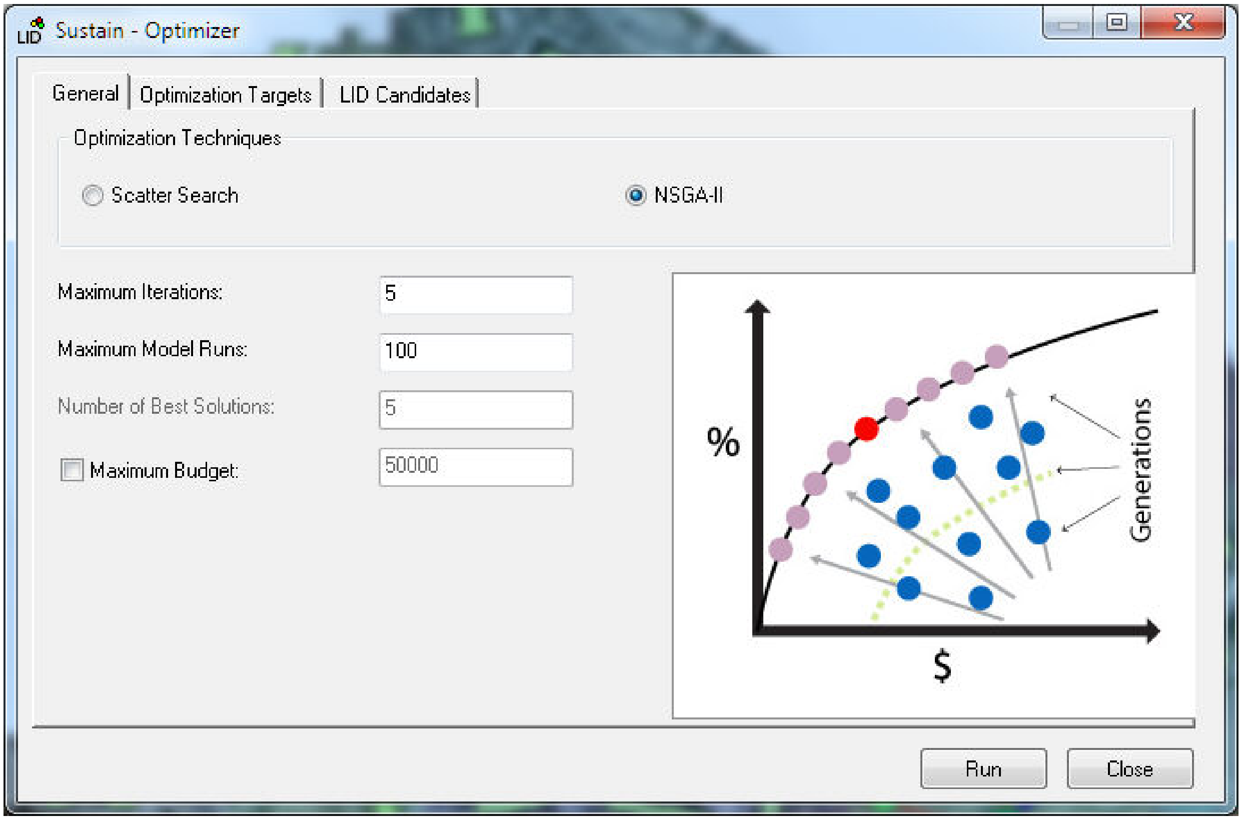
LID8 2: Bio-Retention 8 BIORETENTION 9 0 37.000 0.000 445.000 0.000 18.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 37.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID9 2: Bio-Retention 9 BIORETENTION 5 0 39.000 0.000 260.000 0.000 19.500 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 39.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

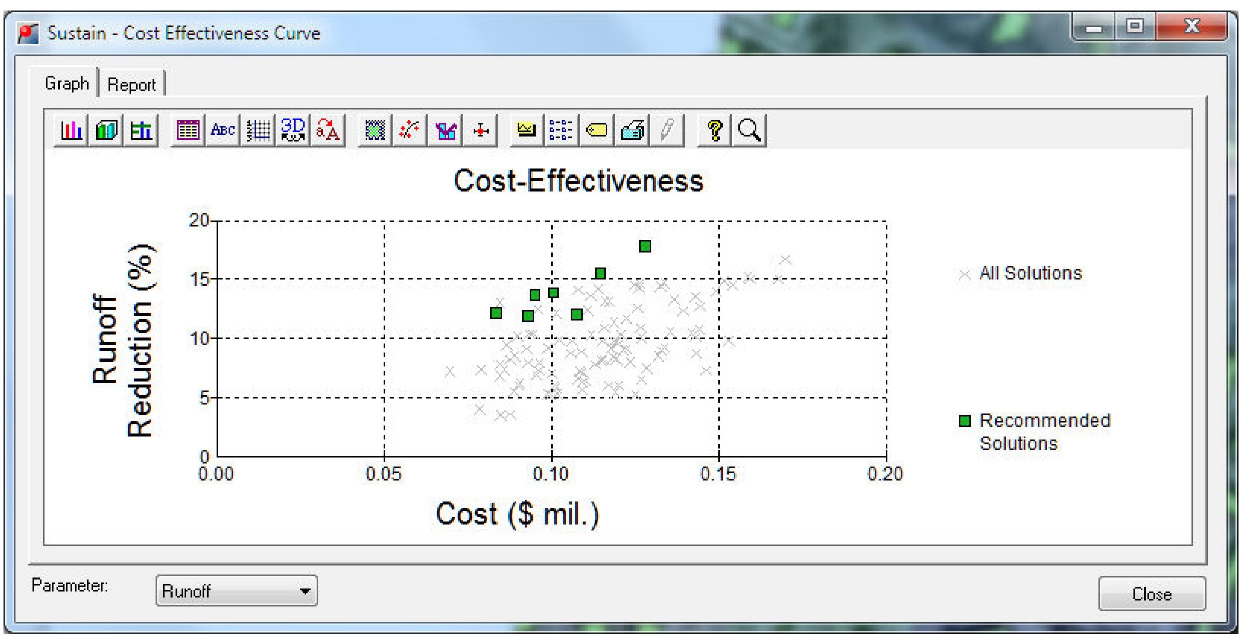
Our Optimization Goals



Use NSGA-II Optimization to find the Cost Boundary Curve

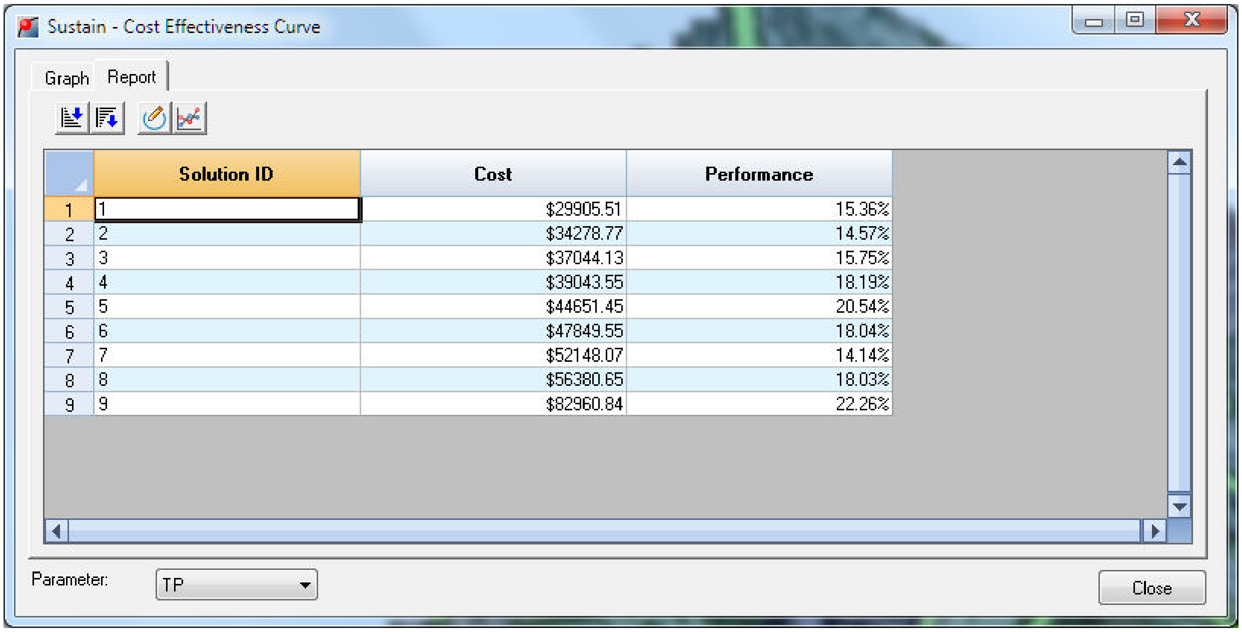


The Cost Effectiveness Curves for Runoff and Water Quality

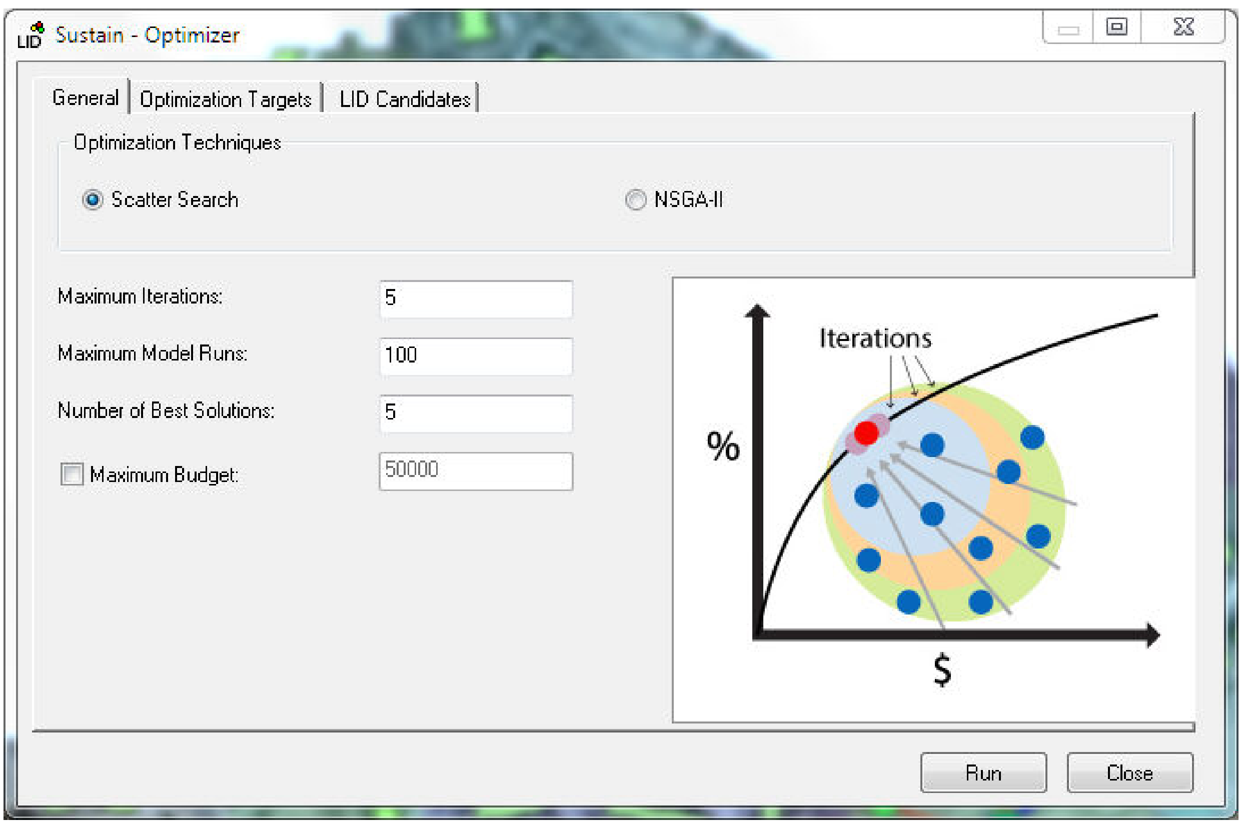


The Cost Effectiveness Report for Runoff and Water Quality

There is little removal as the Bio Cell are not sending the overflow to the pervious area and there is little storage in a Bio Cell.

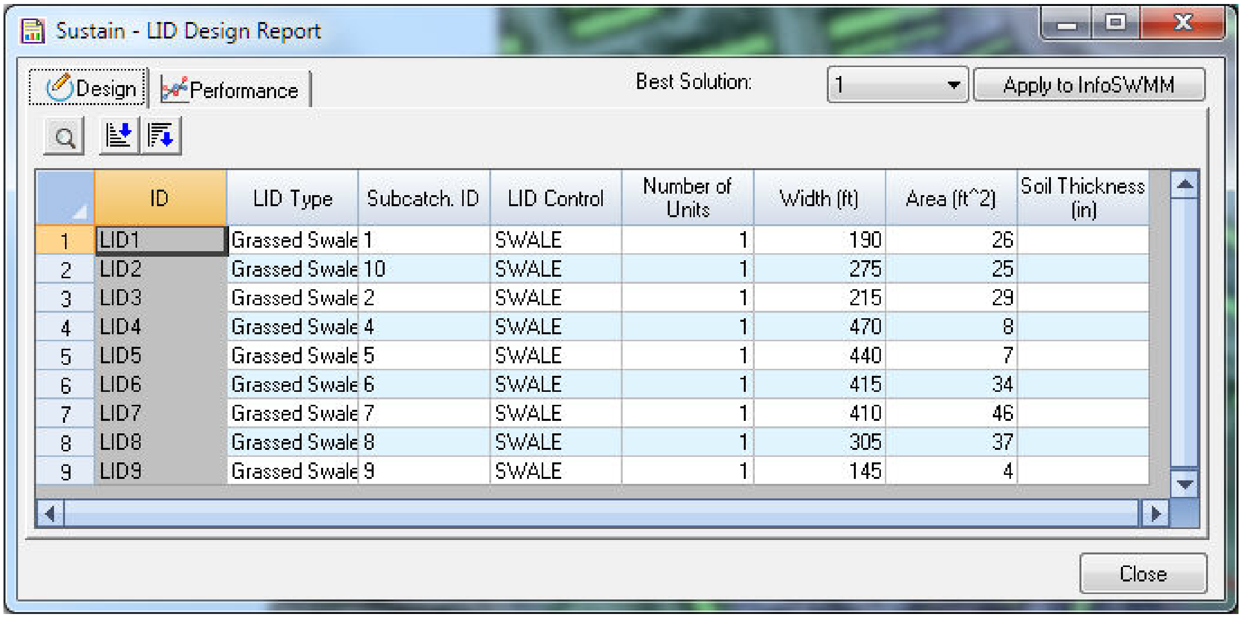


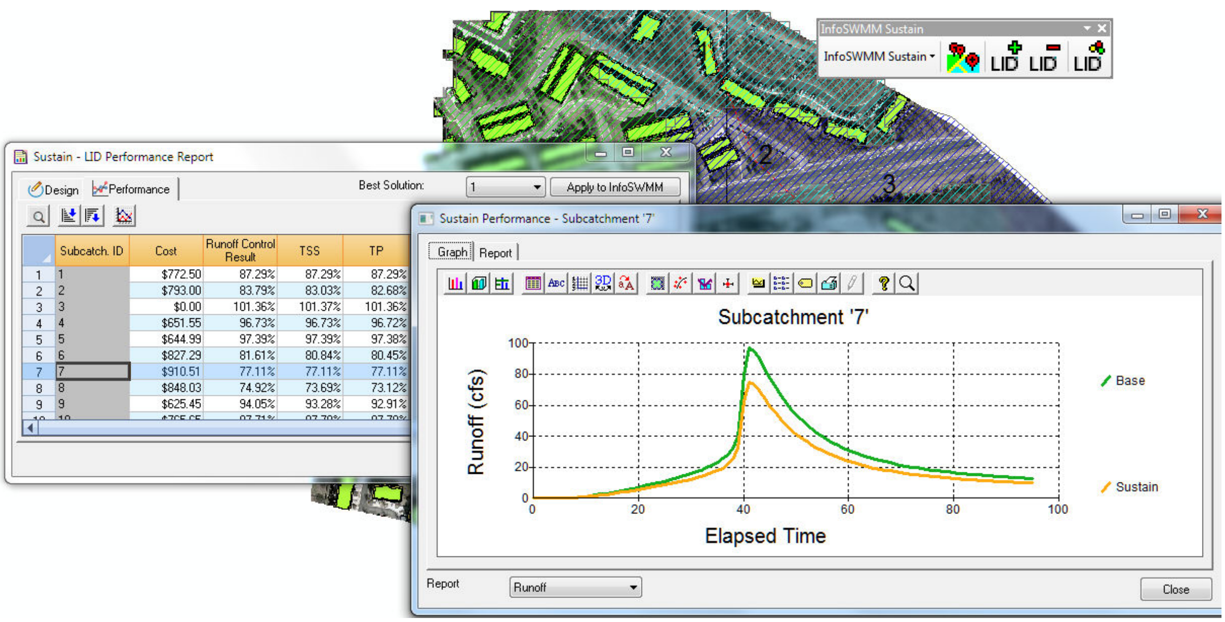
Use Scatter Search to Find the Best Solutions



The Design Report and Performance Curve

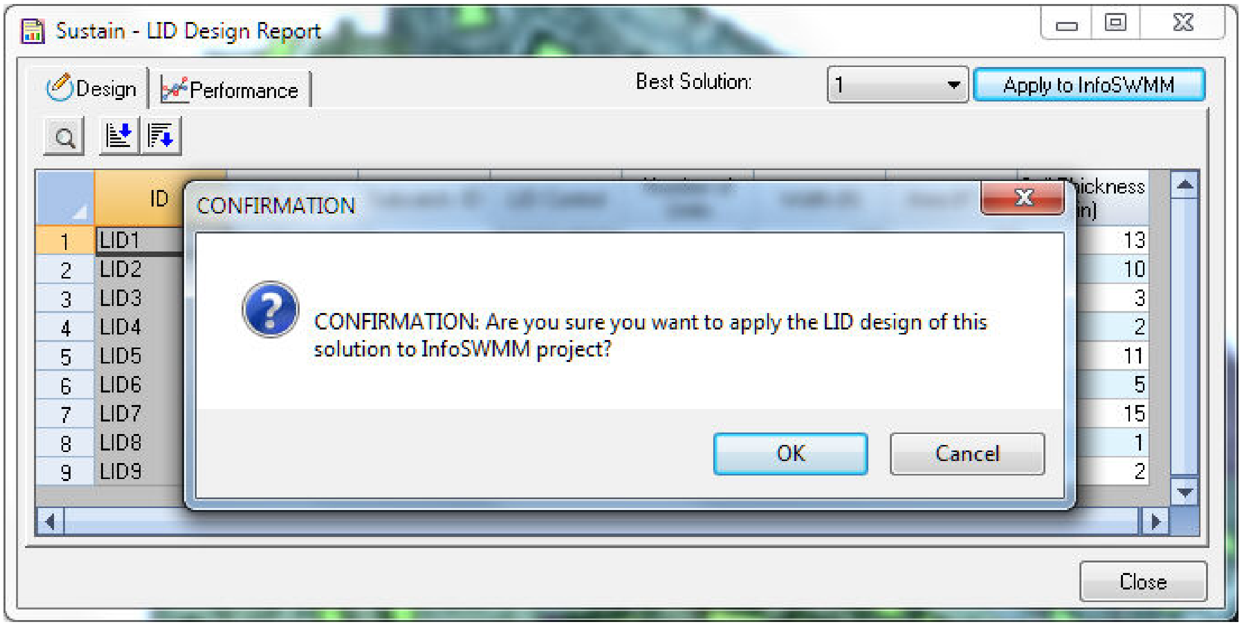
The effect of the pervious area treatment train on the Bio Cell.

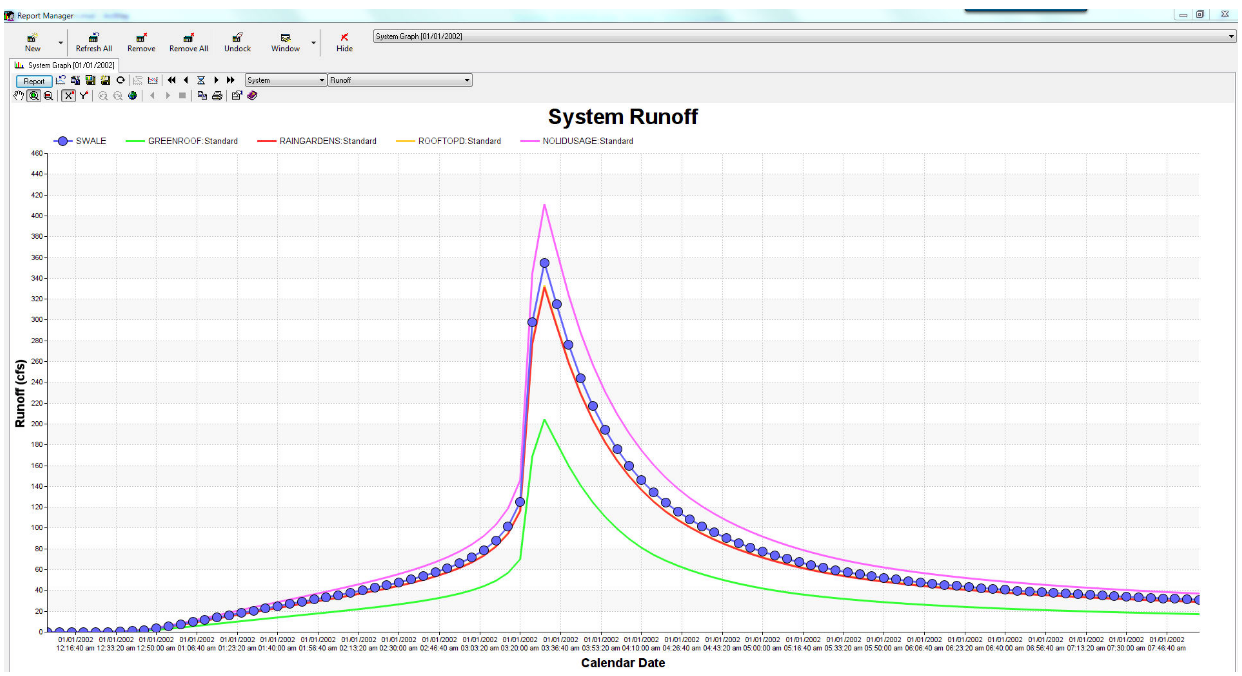




[The Effect of the Treatment Train in InfoSWMM]()

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious are from the Bio Cell.





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Innovyze Help File Updated January 30, 2019

InfoSWMM uses the EPA SWMM 5.1.013 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

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InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 9 Optimizing Rooftop Disconnections for Sustain 4.0

This example shows the importance of a treatment train, the percent imperious draining to the LID's on a Subcatchment, the importance of optimizing for the number of units, area and soil thickness. Sustain will optimize the number of Rooftop Disconnections on the ten Subcatchments.

1. Turn off Width and Thickness on the LID Candidates Grid

2. Allow the number of Units to increase

3. Do NOT send the drainage of the Rain Barrels to the pervious area - no treatment train

4. Allow most of the Rooftop drainage to flow into the Rain Gardens

Area of Each Unit

The surface area devoted to each replicate LID unit (sq. ft or sq. m).

Number of Replicate Units

The number of equal size units of the LID practice (e.g., the number of rain barrels) deployed within the Subcatchment.

Surface Width Per Unit

The width of the outflow face of each identical LID unit (in ft or m). This parameter applies to green roofs, permeable pavement, infiltration trenches, and vegetative swales that use overland flow to convey surface runoff off of the unit. It can be set to 0 for other LID processes, such as bio-retention cells, rain gardens, and rain barrels that simply spill any excess captured runoff over their berms.

% Initially Saturated

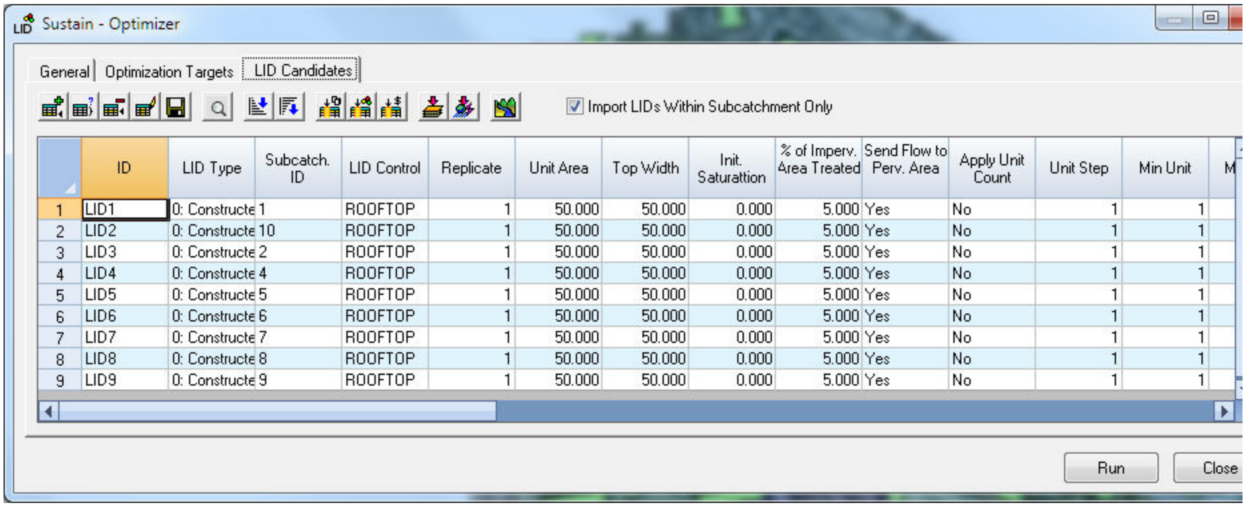
For bio-retention cells, rain gardens, and green roofs this is the degree to which the unit's soil is initially filled with water (0 % saturation corresponds to the wilting point moisture content, 100 % saturation has the moisture content equal to the porosity). The storage zone beneath the soil zone of the cell is assumed to be completely dry. For other types of LIDs it corresponds to the degree to which their storage zone is initially filled with water.

% of Impervious Area Treated

The percent of the impervious portion of the Subcatchment's non-LID area whose runoff is treated by the LID practice. (E.g., if rain barrels are used to capture roof runoff and roofs represent 60% of the impervious area, then the impervious area treated is 60%). If the LID unit treats only direct rainfall, such as with a green roof, then this value should be 0. If the LID takes up the entire Subcatchment then this field is ignored.

Return All Outflow To Pervious Area

Select this option if the surface and underdrain flow from the LID unit should be routed back onto the pervious area of the Subcatchment that contains it. This would be a common choice to make for rain barrels and possibly green roofs.



	ID	LID Type	Subcatch. ID	LID Control	Replicate	Unit Area	Top Width	Init. Saturation	% of Imperv. Area Treated	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min Unit	M
1	LID1	0: Constructe	1	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
2	LID2	0: Constructe	10	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
3	LID3	0: Constructe	2	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
4	LID4	0: Constructe	4	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
5	LID5	0: Constructe	5	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
6	LID6	0: Constructe	6	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
7	LID7	0: Constructe	7	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
8	LID8	0: Constructe	8	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	
9	LID9	0: Constructe	9	ROOFTOP	1	50.000	50.000	0.000	5.000	Yes	No	1	1	

A Data Copy of the Grid

ID LID Type Subcatch. ID LID Control Replicate Coverage Type Unit Area Coverage Top Width Init. Saturattion % of Imperv. Area Treated Send Flow to Perv. Area Print Report Apply Unit Count Unit Step Min Unit Max Unit Apply Width Width Step Min Width Max Width Apply Soil Thickness Thickness Step Min Thickness Max Thickness Apply LID Area Area Step Min Area Max Area Linear Cost Area Cost Total Volume Cost Soil Media Volume Cost Under Drain Volume Cost Constant Cost Percentage of other Cost Width Exponent Area Exponent Total Volume Exponent Media Volume Exponent Under Drain Volume Exponent Underdrain Outlet

LID1 0: Constructed Wetland 1 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID2 0: Constructed Wetland 10 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID3 0: Constructed Wetland 2 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes No No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID4 0: Constructed Wetland 4 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID5 0: Constructed Wetland 5 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

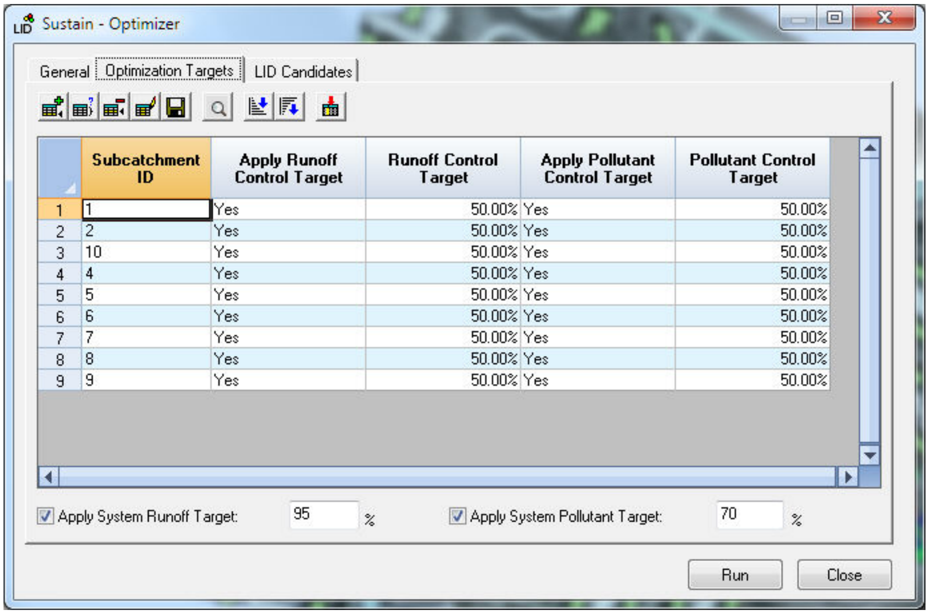
LID6 0: Constructed Wetland 6 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID7 0: Constructed Wetland 7 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

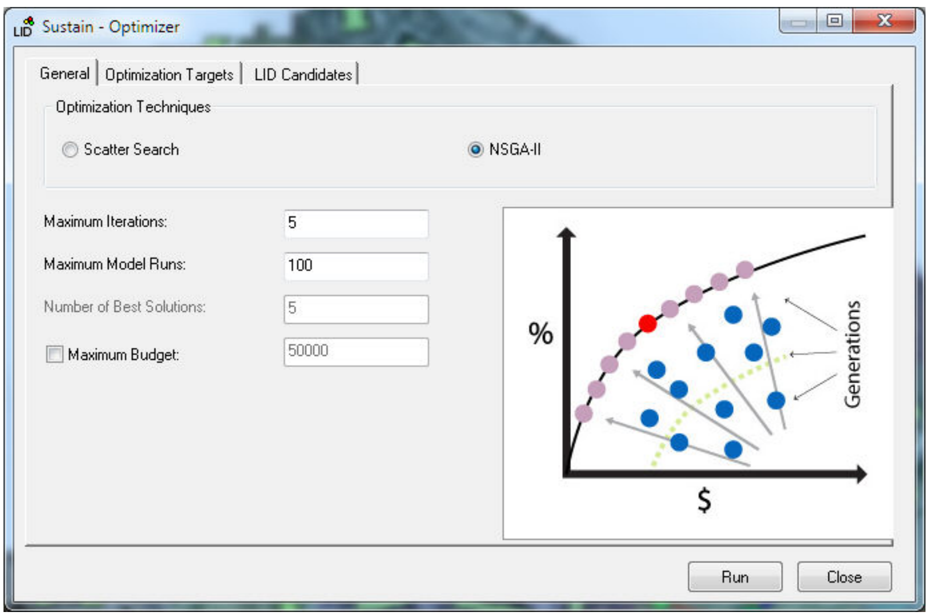
LID8 0: Constructed Wetland 8 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

LID9 0: Constructed Wetland 9 ROOFTOP 1 0 50.000 0.000 50.000 0.000 25.000 Yes Yes No 1 1 1 Yes 5.000 10.000 500.000 Yes 1.000 1.000 15.000 Yes 1.000 1.000 50.000 1.000 5.000 5.000 10.000 5.000 500.000 20.000 1.200 1.000 1.300 1.100 1.500

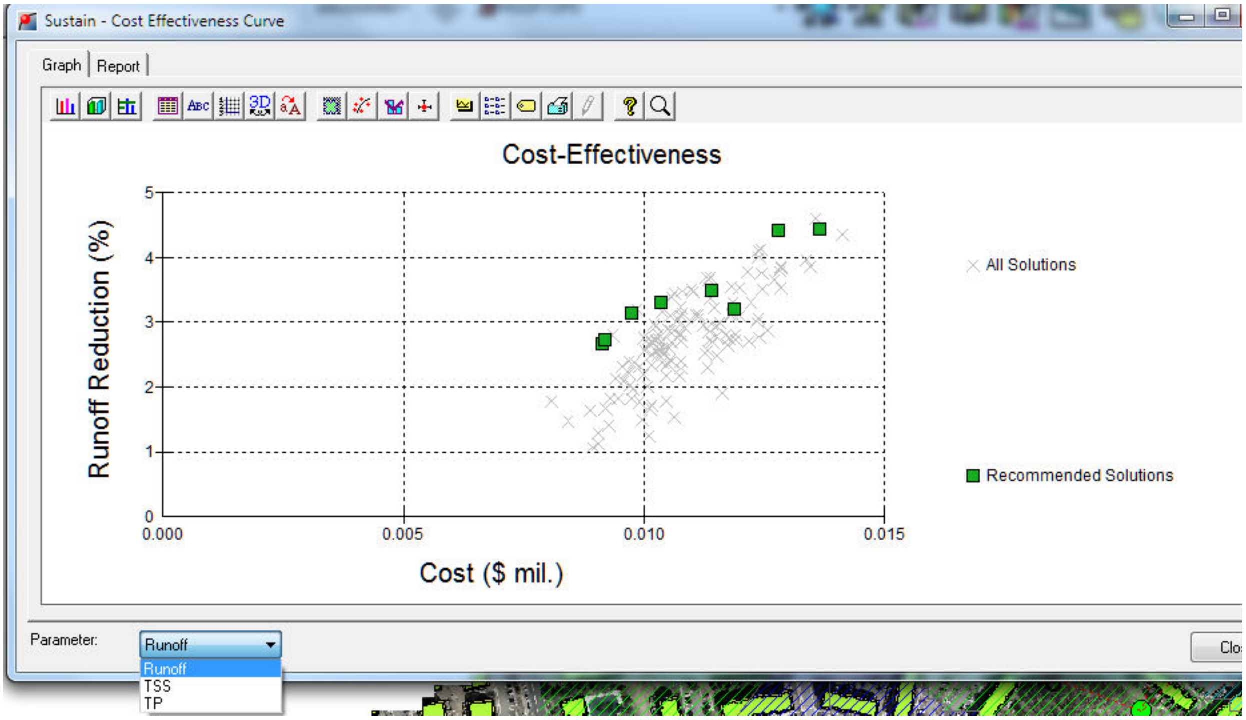
Our Optimization Goals



Use NSGA-II Optimization to find the Cost Boundary Curve

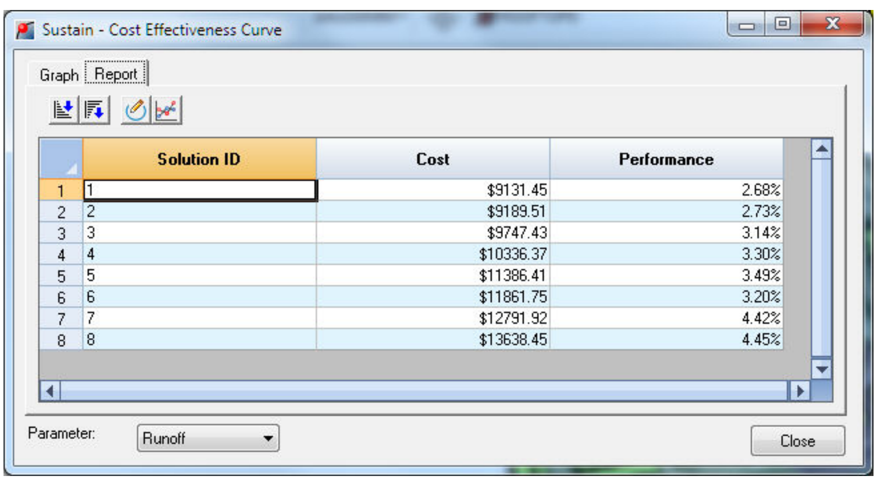


The Cost Effectiveness Curves for Runoff and Water Quality



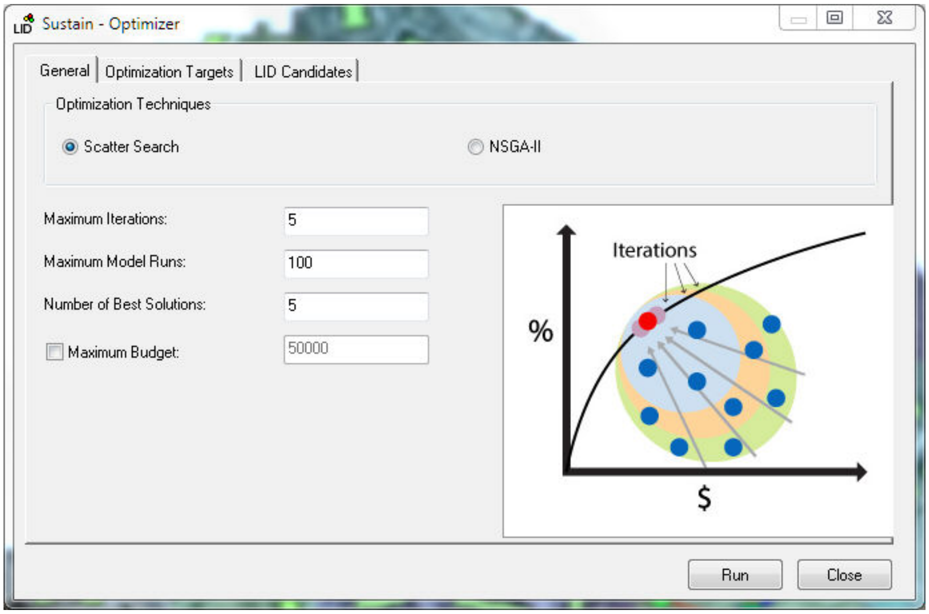
[The Cost Effectiveness Report for Runoff and Water Quality]

There is little removal as the Rain Barrels are not sending the overflow to the pervious area and there is little storage in a Rain Barrel.



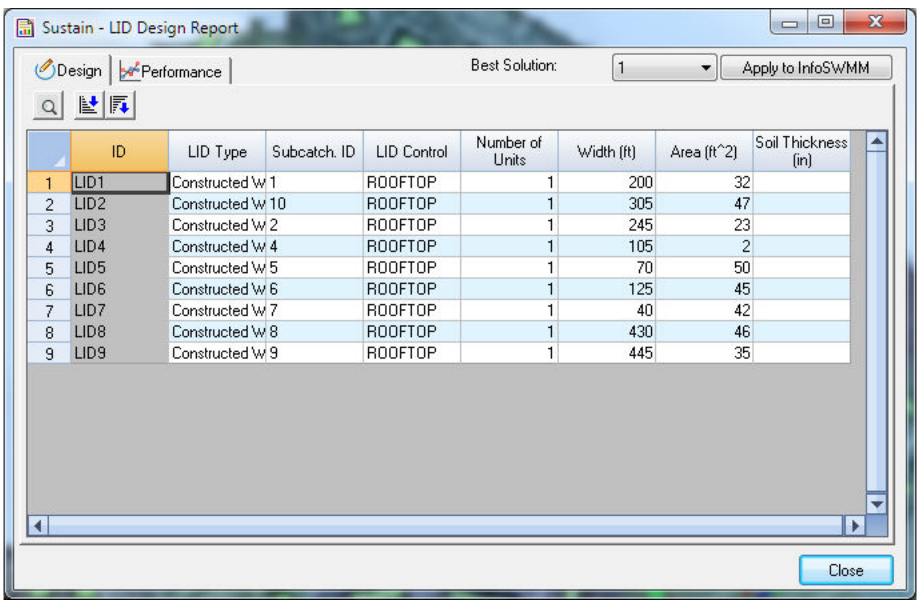
	Solution ID	Cost	Performance
1	1	$9131.45	2.68%
2	2	$9189.51	2.73%
3	3	$9747.43	3.14%
4	4	$10336.37	3.30%
5	5	$11386.41	3.49%
6	6	$11861.75	3.20%
7	7	$12791.92	4.42%
8	8	$13638.45	4.45%

[Use Scatter Search to Find the Best Solutions]

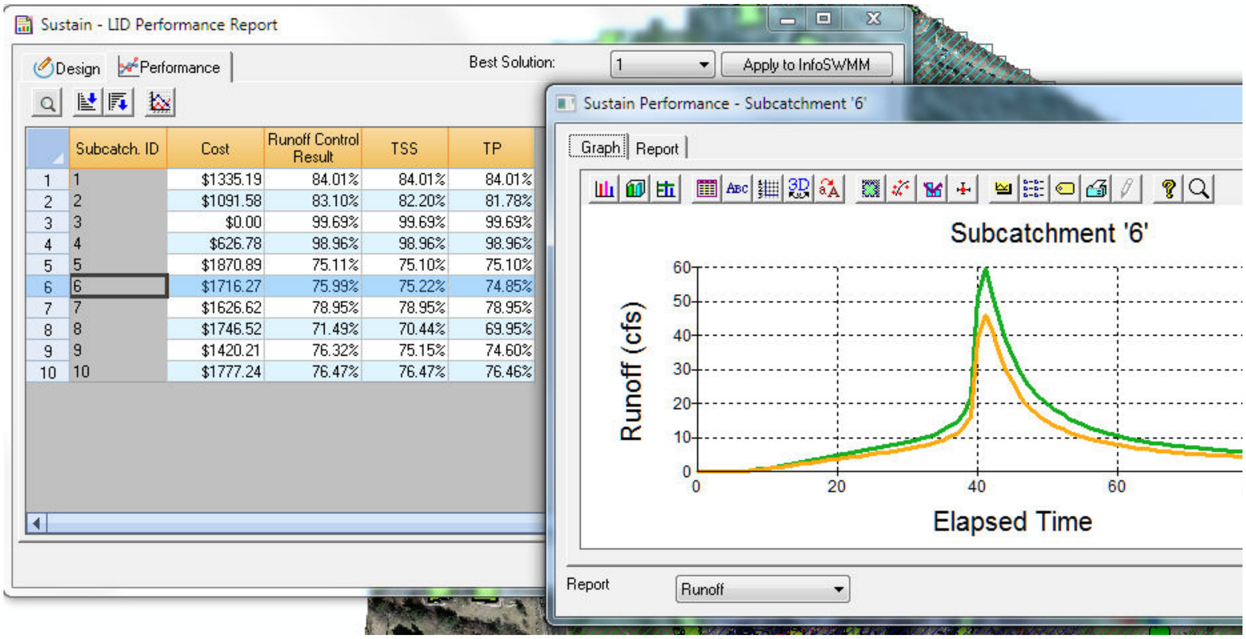


[The Design Report and Performance Curve]()

The effect of the perviouus area treatment train on the Rain Gardens

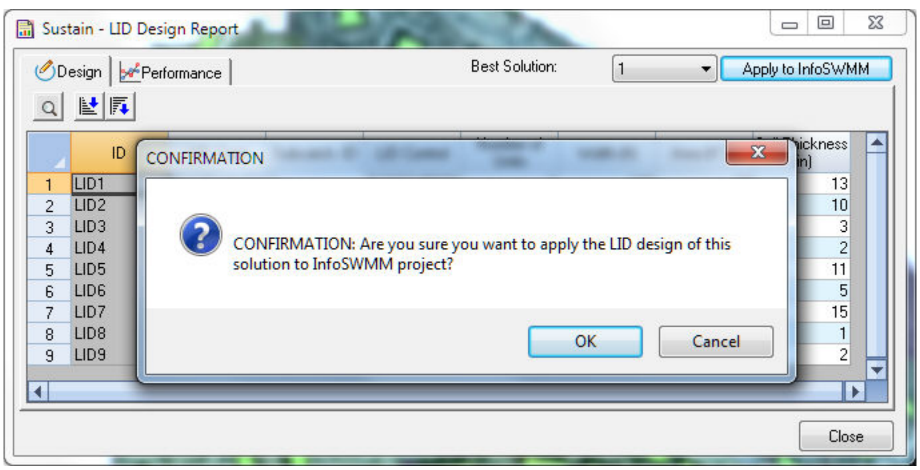


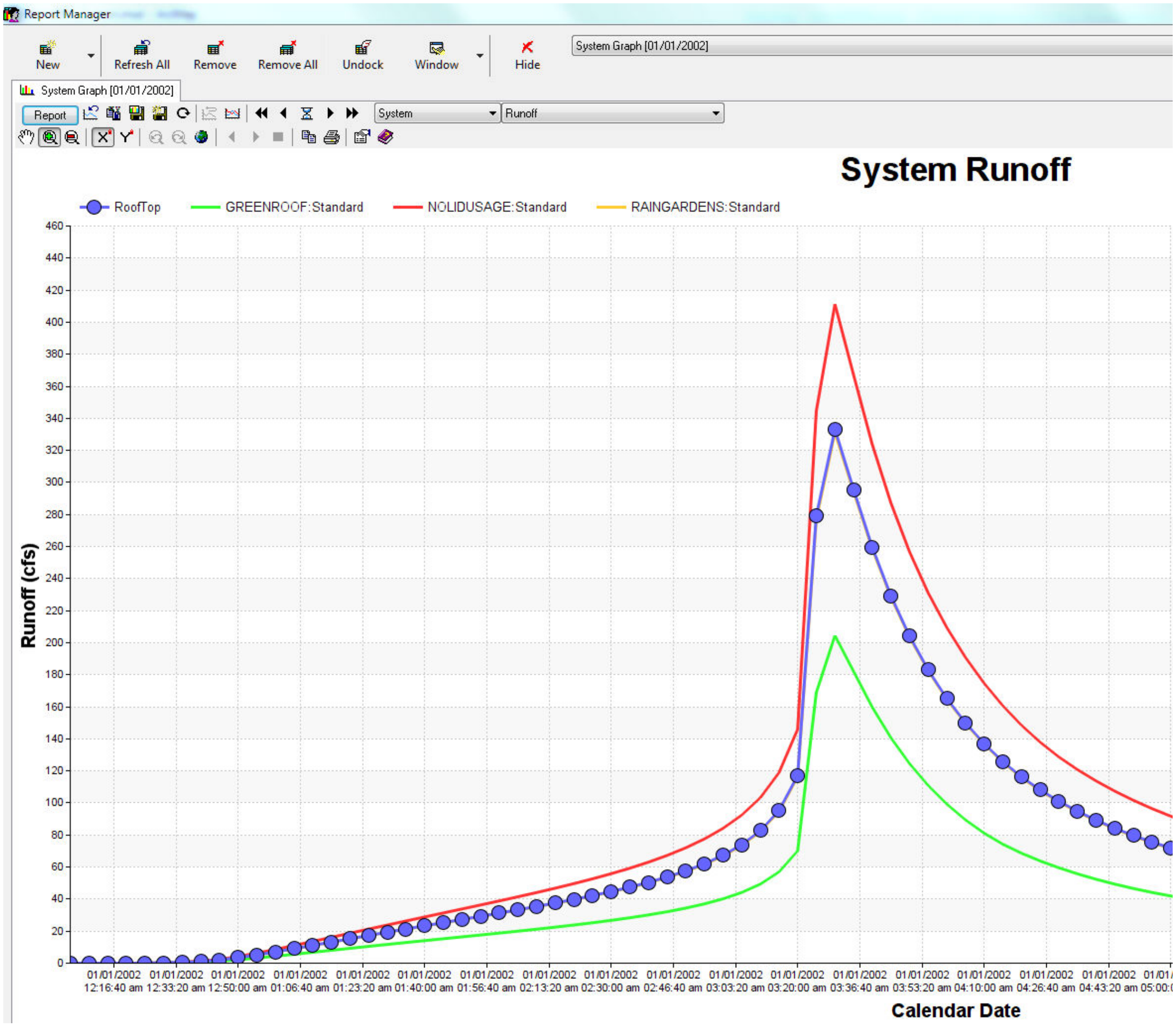
	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness (in)
1	LID1	Constructed W	1	ROOFTOP	1	200	32	
2	LID2	Constructed W	10	ROOFTOP	1	305	47	
3	LID3	Constructed W	2	ROOFTOP	1	245	23	
4	LID4	Constructed W	4	ROOFTOP	1	105	2	
5	LID5	Constructed W	5	ROOFTOP	1	70	50	
6	LID6	Constructed W	6	ROOFTOP	1	125	45	
7	LID7	Constructed W	7	ROOFTOP	1	40	42	
8	LID8	Constructed W	8	ROOFTOP	1	430	46	
9	LID9	Constructed W	9	ROOFTOP	1	445	35	



[The Effect of the Treatment Train in InfoSWMM]

If you export the optimized LID's to InfoSWMM (LID Usage DB Table) then you can see the effect of sending the flow to the pervious are from the Rooftop Disconnections. The Red Dot Scenario is the Rooftop Disconnections NOT flowing to pervious area but the outlet of the Subcatchment.





InfoSWMM uses the EPA SWMM 5.1.013 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


InfoSWMM Sustain
InfoSWMM Sustain
LID
LID
LID

Tutorial 10 LID Coverage In the Output File for Sustain 4.0

Three

important effectiveness options are:

- Percent Imperviousness

  captured

- Is the outlet of the

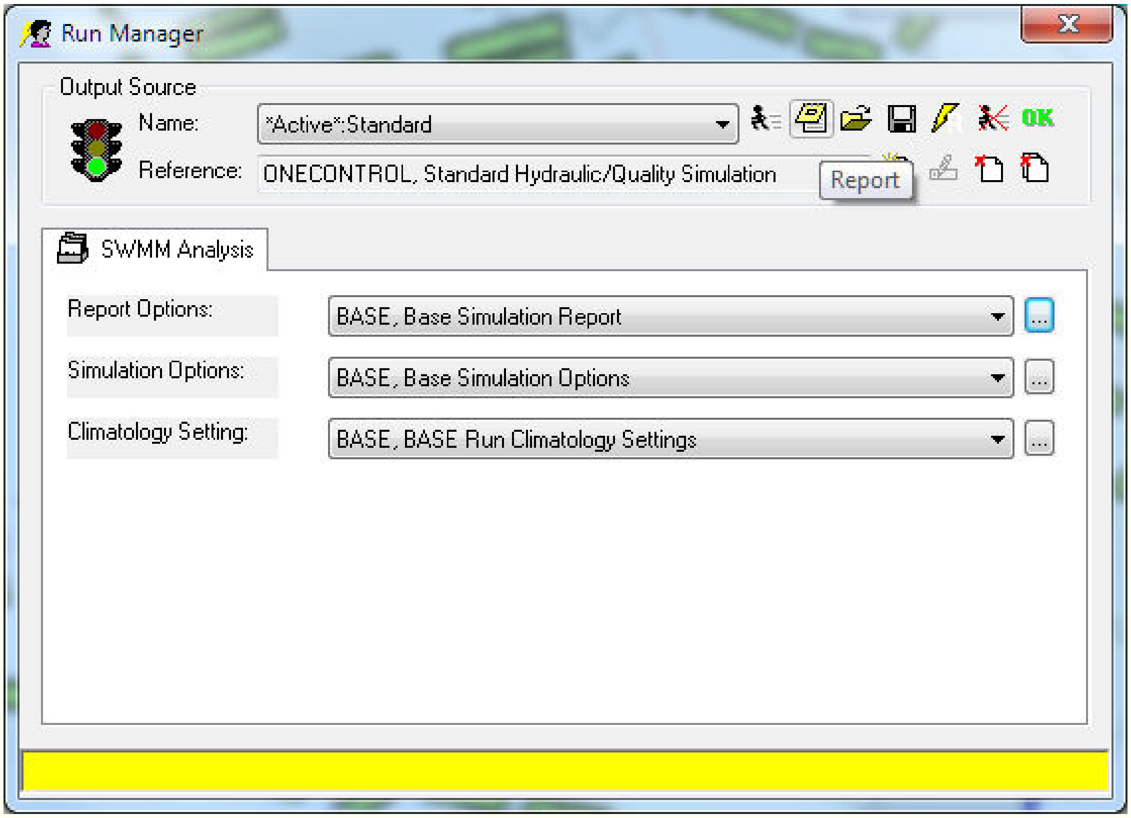
  LID Control the Pervious Area or the Subcatchment Outlet (the Treatment Train)

- The percent coverage

  of the LID over the Subcatchment (Cost)

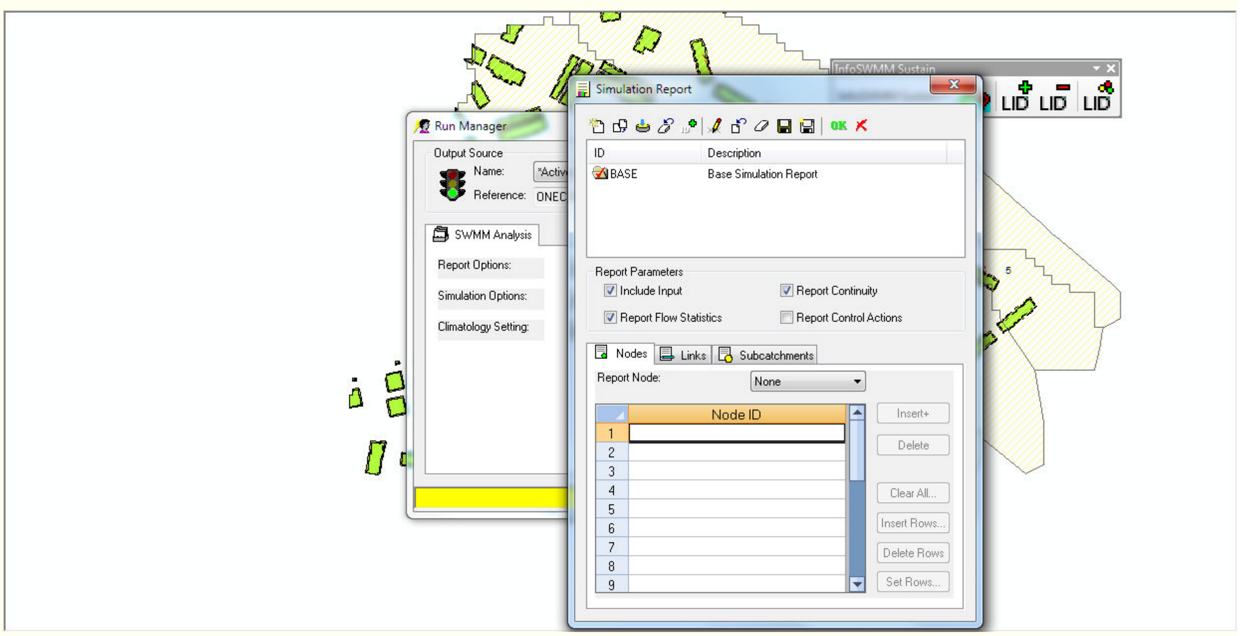
You

can see these parameters in the RPT file output by viewing the Notepad Report icon.



The

report file is generated with the input parameters if you choose Include Input in the simulation report options.



The

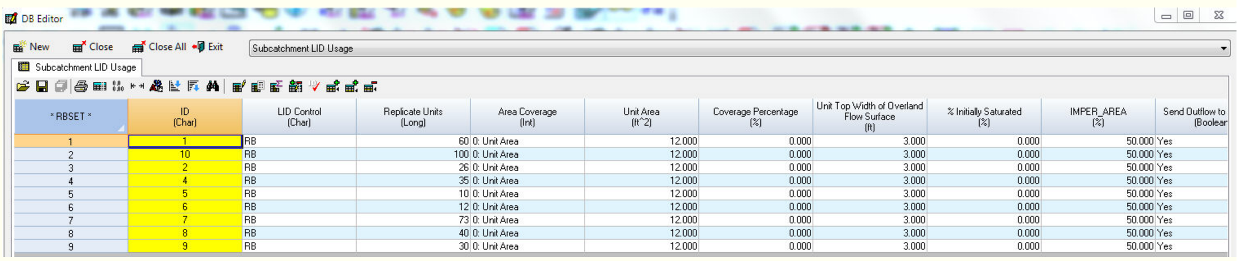
LID Control Summary Table shows the Number of Units, Area covered and Impervious coverage percentage.

```
**********************
  LID Control Summary
**********************
```

Subcatchment	LID Control	No. of Units	Unit Area	Unit Width	% Area Covered	% Imperv Treated
1	RB	60	12.00	3.00	0.02	50.00
10	RB	100	12.00	3.00	0.06	50.00
2	RB	26	12.00	3.00	0.02	50.00
4	RB	35	12.00	3.00	0.03	50.00
5	RB	10	12.00	3.00	0.01	50.00
6	RB	12	12.00	3.00	0.00	50.00
7	RB	73	12.00	3.00	0.01	50.00
8	RB	40	12.00	3.00	0.01	50.00
9	RB	30	12.00	3.00	0.02	50.00

The

LID Summary Table reflects the LID Usage with Summary columns.



* RBSET *	ID (Char)	LID Control (Char)	Replicate Units (Long)	Area Coverage (Int)	Unit Area (ft^2)	Coverage Percentage (%)	Unit Top Width of Overland Flow Surface (ft)	% Initially Saturated (%)	IMPER_AREA (%)	Send Outflow to (Boolear
1	1	RB	60	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
2	10	RB	100	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
3	2	RB	26	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
4	4	RB	35	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
5	5	RB	10	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
6	6	RB	12	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
7	7	RB	73	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
8	8	RB	40	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes
9	9	RB	30	0: Unit Area	12.000	0.000	3.000	0.000	50.000	Yes

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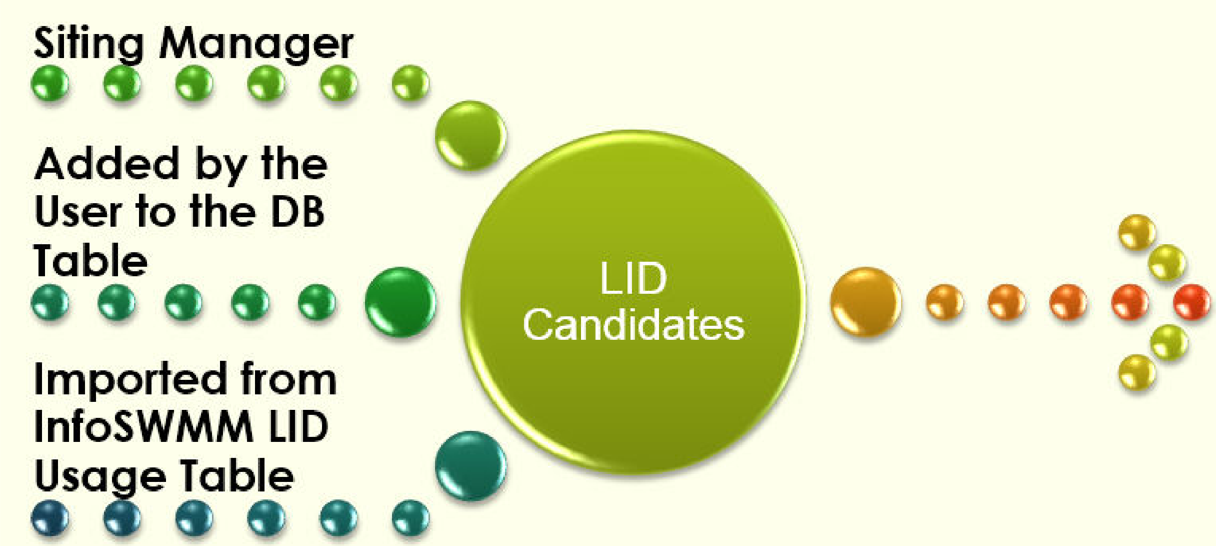
Tutorial 11 Importing a LID

from InfoSWMM LID Coverage DB Table for Sustain 4.0

In

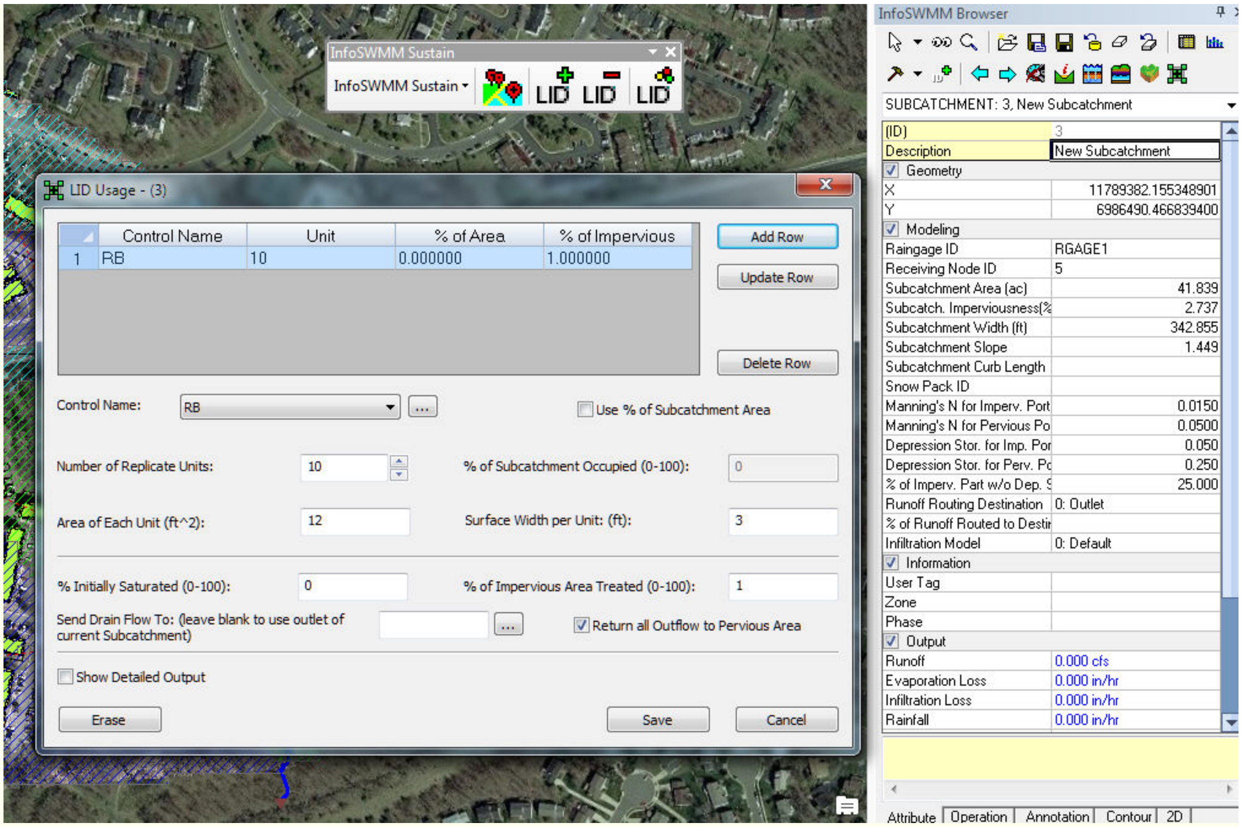
addition to the LID Candidates found by the Siting Manager or added by the Sustain User directly to the LID Candidates Grid you can also import any LID's defined in the LID Usage DB Table. Three ways to import or create the LID Candidate Rows.

+



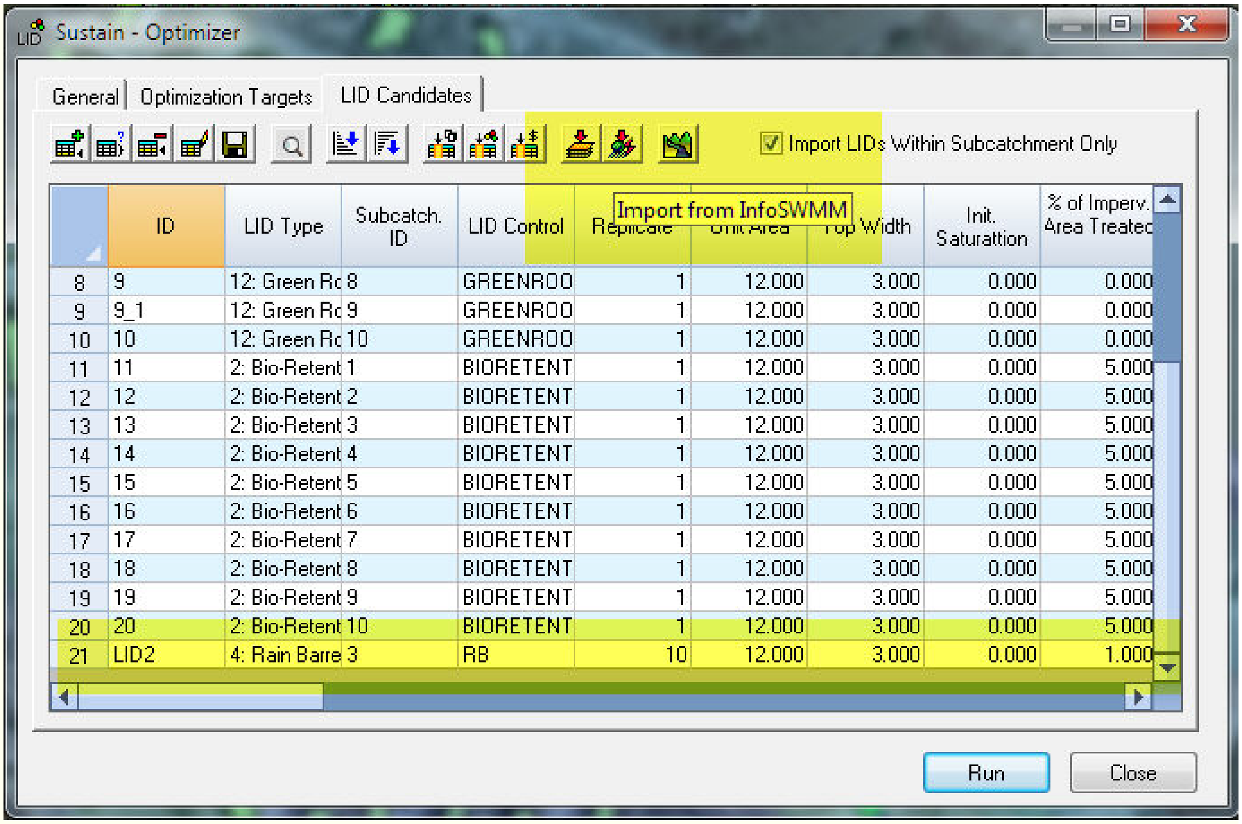
LID

Usage table for Subcatchment 3.



Imported

LID Coverage and Control from Subcatchment 3. The imported control is a Rain Barrel.



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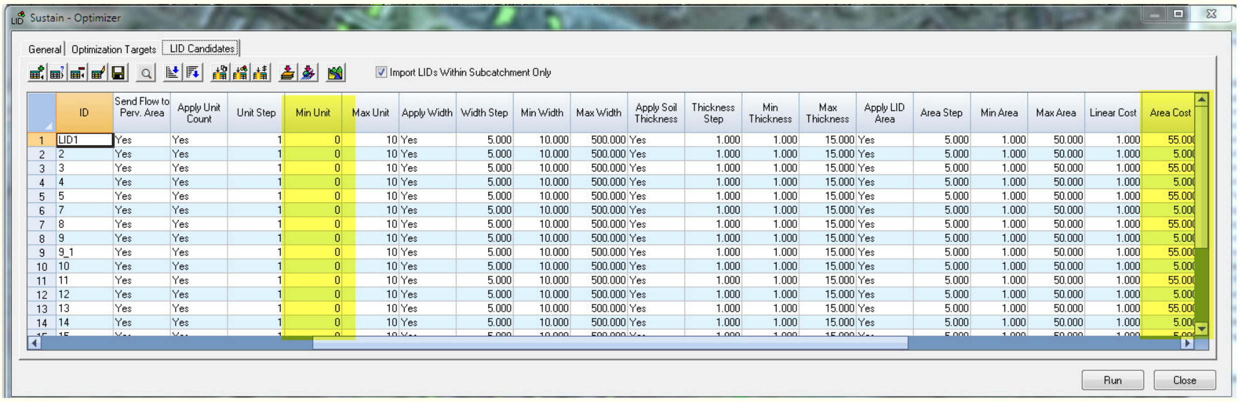
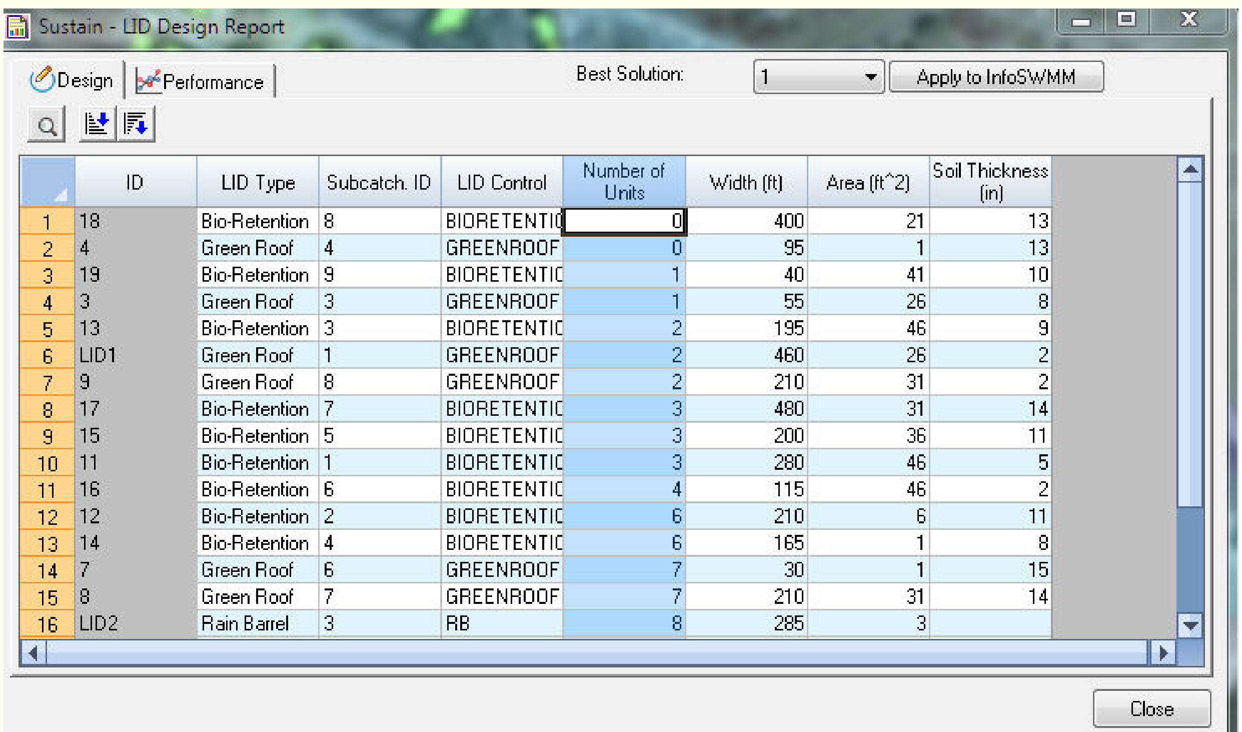
How to Use Minimum Units in the LID Candidates Table

Tutorial 12 How to Use Minimum Units in the LID Candidates Table for Sustain 4.0



	ID	Send Flow to Perv. Area	Apply Unit Count	Unit Step	Min Unit	Max Unit	Apply Width	Width Step	Min Width	Max Width	Apply Soil Thickness	Thickness Step	Min Thickness	Max Thickness	Apply LID Area	Area Step	Min Area	Max Area	Linear Cost	Area Cost
1	LID1	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	55.00
2	2	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	5.00
3	3	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	55.00
4	4	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	5.00
5	5	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	55.00
6	7	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	5.00
7	8	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	55.00
8	9	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	5.00
9	9_1	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	55.00
10	10	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	5.00
11	11	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	55.00
12	12	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	5.00
13	13	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	55.00
14	14	Yes	Yes	1	0	10	Yes	5.000	10.000	500.000	Yes	1.000	1.000	15.000	Yes	5.000	1.000	50.000	1.000	5.00



	ID	LID Type	Subcatch. ID	LID Control	Number of Units	Width (ft)	Area (ft^2)	Soil Thickness (in)
1	18	Bio-Retention	8	BIORETENTIC	0	400	21	13
2	4	Green Roof	4	GREENROOF	0	95	1	13
3	19	Bio-Retention	9	BIORETENTIC	1	40	41	10
4	3	Green Roof	3	GREENROOF	1	55	26	8
5	13	Bio-Retention	3	BIORETENTIC	2	195	46	9
6	LID1	Green Roof	1	GREENROOF	2	460	26	2
7	9	Green Roof	8	GREENROOF	2	210	31	2
8	17	Bio-Retention	7	BIORETENTIC	3	480	31	14
9	15	Bio-Retention	5	BIORETENTIC	3	200	36	11
10	11	Bio-Retention	1	BIORETENTIC	3	280	46	5
11	16	Bio-Retention	6	BIORETENTIC	4	115	46	2
12	12	Bio-Retention	2	BIORETENTIC	6	210	6	11
13	14	Bio-Retention	4	BIORETENTIC	6	165	1	8
14	7	Green Roof	6	GREENROOF	7	30	1	15
15	8	Green Roof	7	GREENROOF	7	210	31	14
16	LID2	Rain Barrel	3	RB	8	285	3	

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Tutorial 13 How are the Costs Used in the LID Candidate Table? for Sustain 4.0

There

are seven type of costs associated with a LID or SuDS in InfoSWMM Sustain as shown in the following table.

Type of Cost	**Description of Cost**
Linear Cost	Cost per linear unit of the LID or SuDs or $/foot or $/meter. Linear is Unit Area / Unit Width
Area Cost	Cost per area of the LID $/foot^2 or $/meter^2
Total Volume Cost	Cost per volume of the LID $/foot^3or $/meter^3
Soil Media Volume Cost	Cost per volume of the LID $/foot^3or $/meter^3
Under Drain Volume Cost	Cost per volume of the LID $/foot^3or $/meter^3
Constant Cost	Constant Cost per Unit or Replicate
Percentage of other Costs	Percentage of the Other Costs or Overhead/Multiplier Costs

A Good Estimate of LID or SuDS

Costs

The

source is https://coast.noaa.gov/data/docs/digitalcoast/gi-econ.pdf

Green

infrastructure practice Cost estimate** Existing forests and wetlands It depends on value of land, opportunity costs. Stormwater wetlands Capital cost: $1 to $2 per cubic foot of storage provided. Blue roofs Capital cost: $2 to $10 per cubic foot of storage provided ($1 to $5 per square foot with a 6” depth). Green roofs Capital cost is $18 to $64 per cubic foot of storage provided ($9 to $32 per square foot with a 6’’ depth).

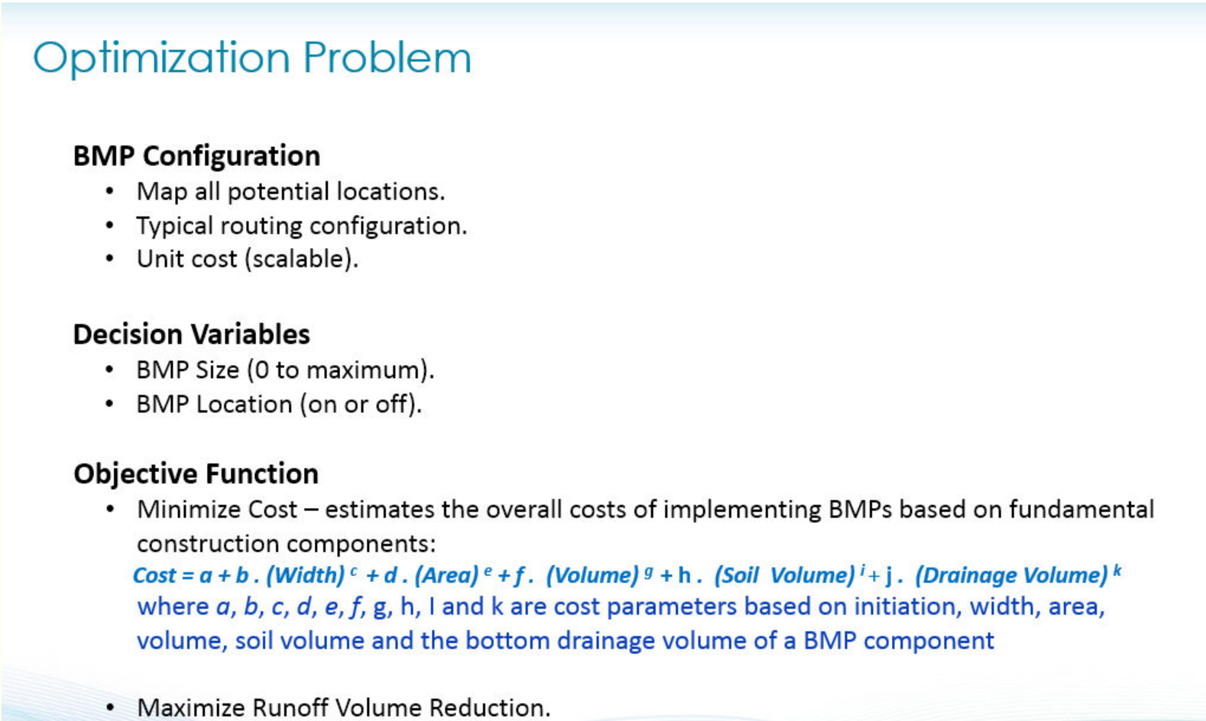
Tree plantings Capital cost: Tree cost is about $175 to $400. Tree box filter Capital cost is about $270 to $330 per cubic foot of storage provided (includes tree box filter and additional soil). Trees are an additional cost. Permeable pavement Capital cost: For sidewalks, the cost is about $16 to $17 per cubic foot of storage provided. Bioretention (bioswales, rain gardens) Capital cost is about $7 to $60 per cubic foot of storage provided (depending on the type of bioretention). Rain barrels Capital cost is about $7 to $13 per cubic foot of storage provided.

Green infrastructure practice	Cost estimate**
Existing forests and wetlands	It depends on value of land, opportunity costs.
Stormwater wetlands	Capital cost: $1 to $2 per cubic foot of storage provided.
Blue roofs	Capital cost: $2 to $10 per cubic foot of storage provided ($1 to $5 per square foot with a 6" depth).
Green roofs	Capital cost is $18 to $64 per cubic foot of storage provided ($9 to $32 per square foot with a 6" depth).
Tree plantings	Capital cost: Tree cost is about $175 to $400.
Tree box filter	Capital cost is about $270 to $330 per cubic foot of storage provided (includes tree box filter and additional soil). Trees are an additional cost.
Permeable pavement	Capital cost: For sidewalks, the cost is about $16 to $17 per cubic foot of storage provided.
Bioretention (bioswales, rain gardens)	Capital cost is about $7 to $60 per cubic foot of storage provided (depending on the type of bioretention).
Rain barrels	Capital cost is about $7 to $13 per cubic foot of storage provided. An average rain barrel holds about 55 gallons or 7.3 cubic feet.

**A cubic foot of storage is about 7.5 gallons of water.*

**The cost estimates do not account for construction costs or maintenance. Maintenance estimates can be found on the Center for Neighborhood Technology Green Values Calculator cost details sheet, where information is provided in costs per square foot of storage (*http://greenvalues.cnt.org/national/cost_detail.php*).

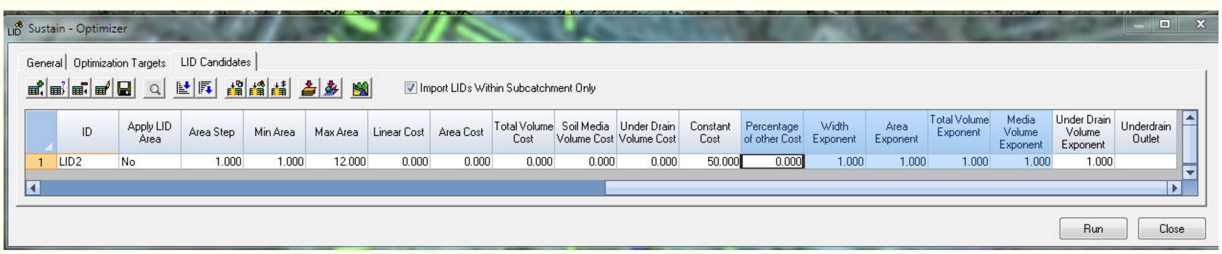
Cost are part of the Objective Function



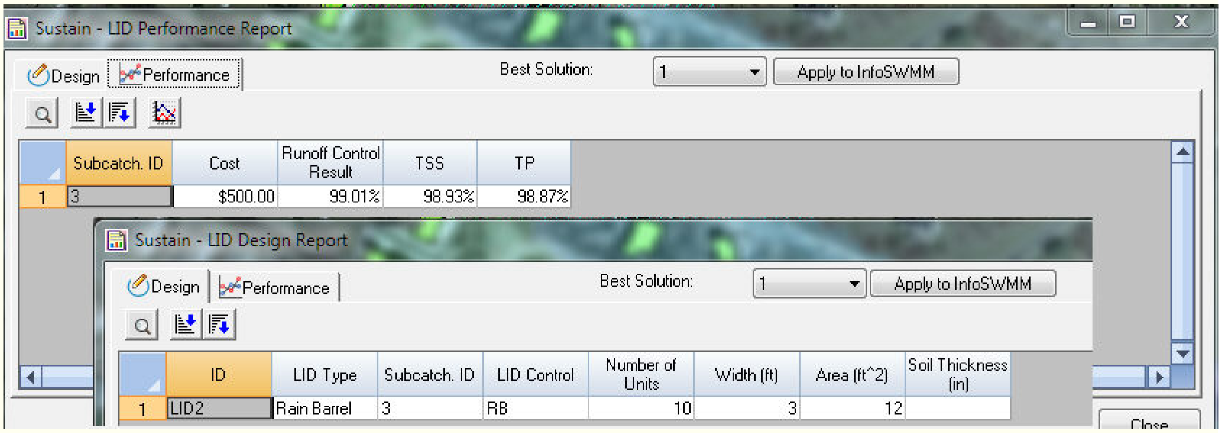
[Cost Example 1 - Constant Cost]

In

this example we have a constant cost of $50 per Rain Barrel The optimum solution is 10 Rain Barrels or a total cost of $500.



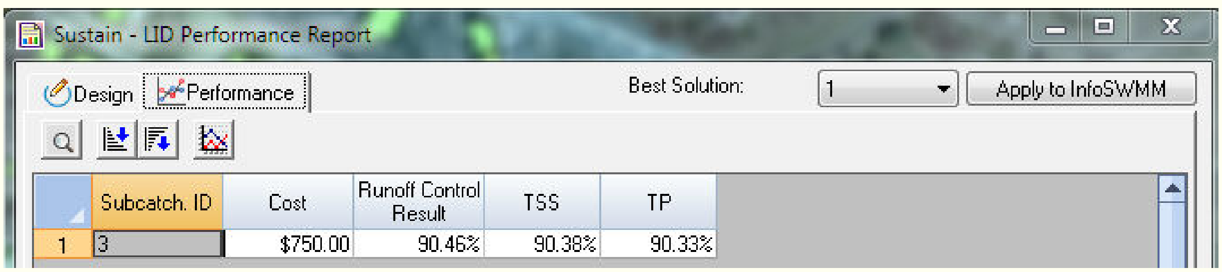
	ID	Apply LID Area	Area Step	Min Area	Max Area	Linear Cost	Area Cost	Total Volume Cost	Soil Media Volume Cost	Under Drain Volume Cost	Constant Cost	Percentage of other Cost	Width Exponent	Area Exponent	Total Volume Exponent	Media Volume Exponent	Under Drain Volume Exponent	Underdrain Outlet
1	LID2	No	1.000	1.000	12.000	0.000	0.000	0.000	0.000	0.000	50.000	0.000	1.000	1.000	1.000	1.000	1.000	



[Cost Example 2 - Constant Cost + Percentage of Other Cost]

In

this example we have a constant cost of $50 per Rain Barrel + 50 percent of other cost. The optimum solution is 10 Rain Barrels or a total cost of $750.

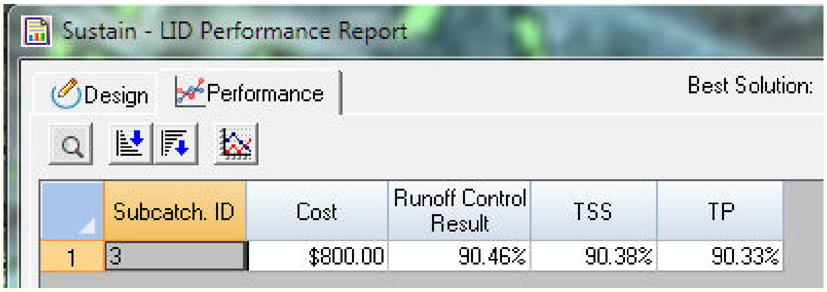


[Cost Example 3 - Constant Cost + Linear Cost]

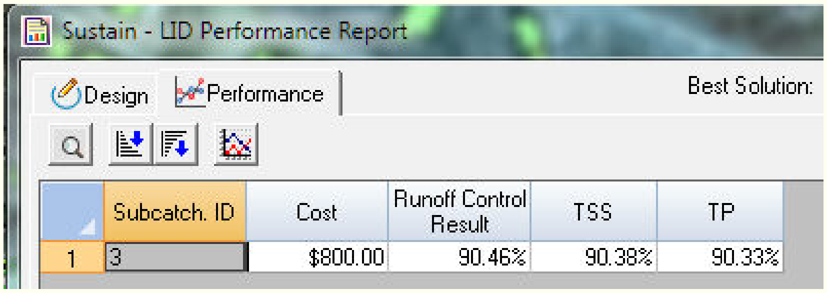
In

this example we have a constant cost of $50 per Rain Barrel + $10 - Linear Cost. We will change the area and width as we as now optimizing Cisterns. The optimum solution is 10 Cisterns or a total cost of $800 or 10 * $50 + 10*$3*$10 The linear unit is 12

feet^2/4 feet width



	Subcatch. ID	Cost	Runoff Control Result	TSS	TP
1	3	$800.00	90.46%	90.38%	90.33%



	Subcatch. ID	Cost	Runoff Control Result	TSS	TP
1	3	$800.00	90.46%	90.38%	90.33%

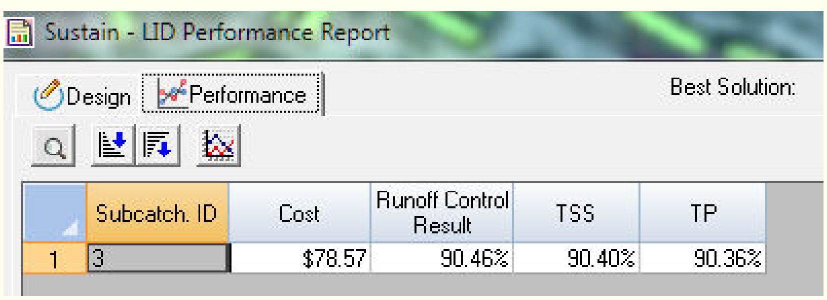
Cost Example 4 - Area Cost

In

this example we have a constant cost of $0 per Rain Barrel + $10 Area Cost. We will change the area and width as we as now optimizing Cisterns. The optimum solution is 10 Cisterns or a total cost of $78.57

For

a RB or Cistern the area of the LID is BMParea = 3.142857/4.0*length^2).



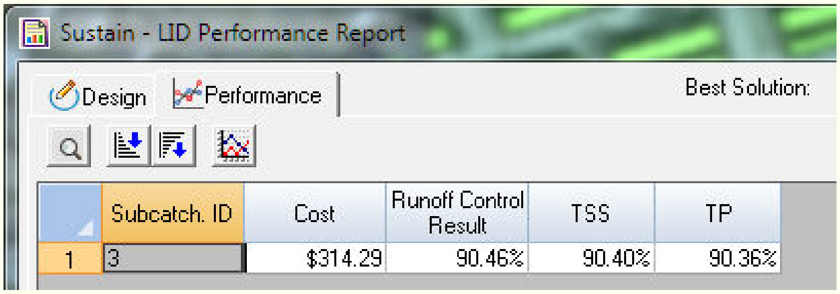
	Subcatch. ID	Cost	Runoff Control Result	TSS	TP
1	3	$78.57	90.46%	90.40%	90.36%

Cost Example 5 - Volume Cost

In

this example we have a constant cost of $0 per Rain Barrel + $10 Volume Cost. We will change the area and width as we as now optimizing Cisterns.

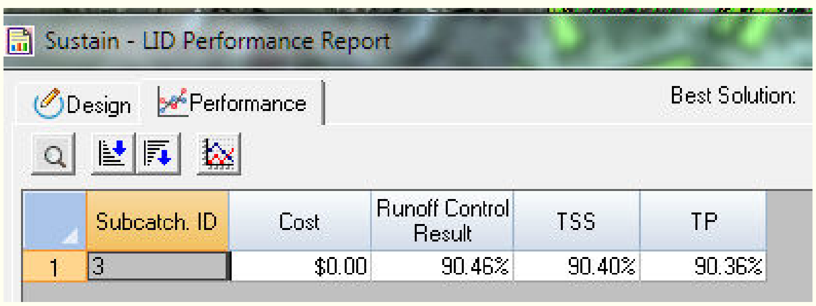
The optimum solution is 10 Cisterns or a total cost of $314.29



Cost Example 7 - Underdrain Volume Cost

In

this example we have a constant cost of $0 per Rain Barrel + $10 Under Drain Volume Cost. We will change the area and width as we as now optimizing Cisterns. The optimum solution is 10 Cisterns or a total cost of $314.29



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Home > InfoSWMM Sustain Help File and User Guide > Tutorials or Examples > **Simple SI Unit Model for SWMM5 LID with 100 mm Rainfall**

Simple SI Unit Model for SWMM5 LID with 100 mm Rainfall

Simple SI Unit Model for SWMM5 LID with 100 mm Rainfall.

Reading this blog and using the embedded SWMM 5 example file, you will run a simple SI unit model based on factors of 1 and 10. The LID (Bio-Retention Cell) is designed to have zero outflows, Figure 1, as the storage is set to 1000 mm. The Subcatchment area is 1 hectare, the prevent impervious is ½ hectare divided into ¼ hectare sections with and without depression storage, the pervious area is ½ hectare (Figure 2). The LID Bio-Retention area is ¼ hectare or 25 percent of the Subcatchment. The SWMM5 divides the Subcatchment into nonLID and Lid sections (Figure 3) and the impervious area and pervious areas are automatically reduced by the SWMM5 engine (Figure 6). The internal pervious area is 0.375 hectares, the nonLID area is 0.75 hectares and the two impervious area are 0.1875 hectares each. The example uses 100 mm of rainfall or precipitation to make the comparisons easier.

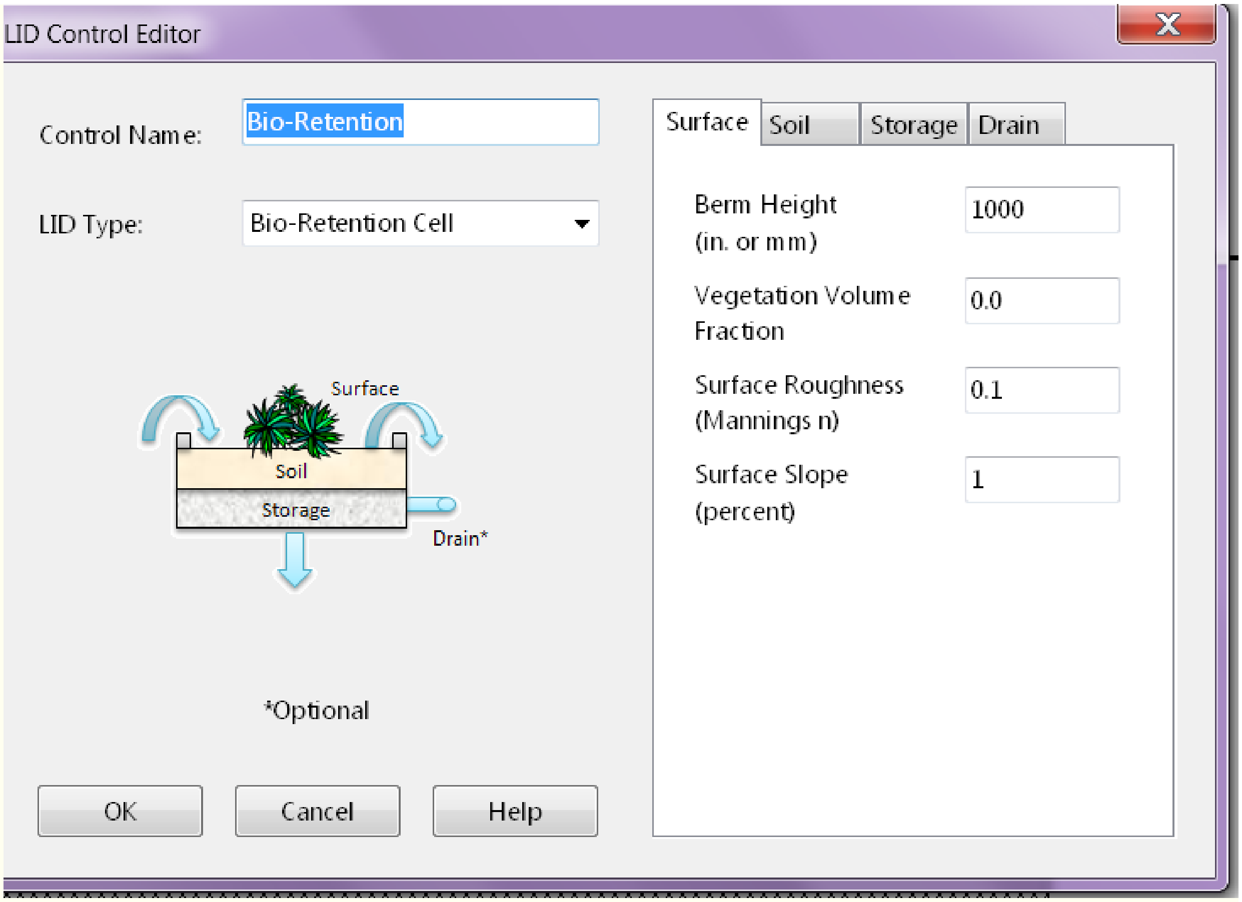

Figure 1 SWMM 5 Bio-Retention Cell Example with settings based on 10 so that no flow leaves the LID. The Berm and Storage Height are set to 1000 mm.

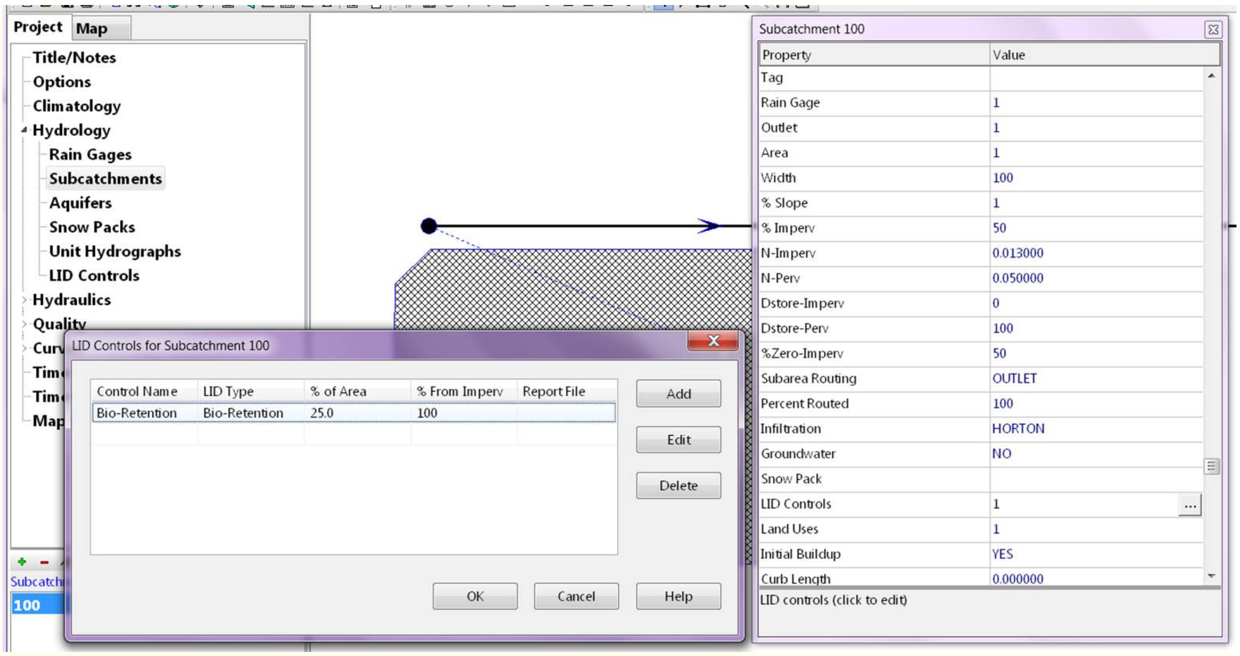

Figure 2 Power of 10 SI unit example for Subcatchment and LID in SWMM5. The Subcatchment area is 1 hectare, the prevent impervious is ½ hectare divided into ¼ hectare sections with and without depression storage, the pervious area is ½ hectare

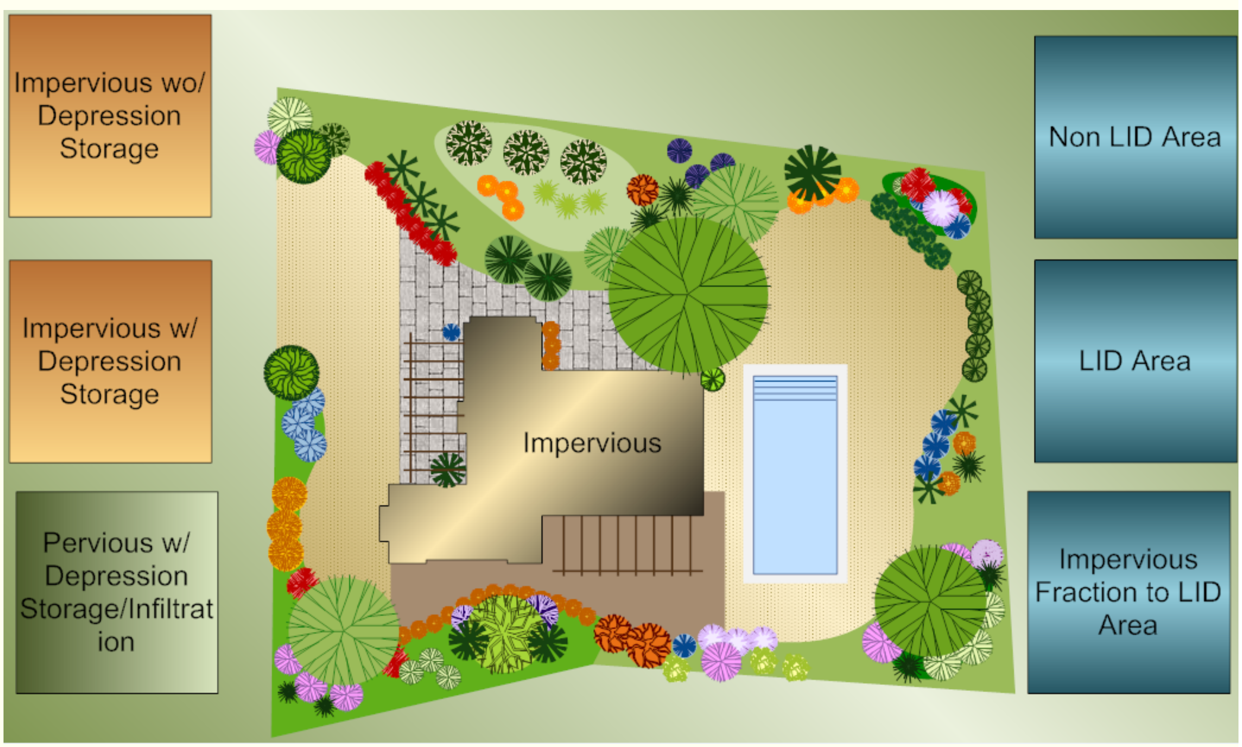

Figure 3 Four types of Runoff Surfaces in SWMM5 with LID's

Topic: Subcatchment Runoff   Click a column header to sort the column.

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
100	100.00	0.00	0.00	37.50	0.00	0.00	0.00	0.000

Figure 4 Subcatchment Summary in SWMM5 - there is no Runoff and all of the Pervious Flow Infiltrates. The pervious infiltration is 37.5 mm which is the percentage of the 1 Hectare Subcatchment covered by the pervious area.

Topic: LID Performance   Click a column header to sort the column.

Subcatchment	LID Control	Total Inflow mm	Evap Loss mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm	Continuity Error %
100	Bio-Retention	250.41	0.00	0.00	0.00	0.00	100.00	350.41	0.00

Figure 5 LID Summary - no flow out of the LID, only storage. The LID area has initial and final storage - the final storage is the total inflow + the initial storage. The total inflow is 100 mm of rainfall + 37.5 mm of Impervious Runoff / 0.25 Hectares or 150 mm for a total of 250 mm.

Subcatchment Area (ha)	Impervious no DS Area (ha)	Impervious w/ DS Area (ha)	Pervious Area (ha)	Subcatchment Non LID Area (ha)	LID Area (ha)	LID Impervious Area (%)
1.000	0.188	0.188	0.375	0.750	0.250	100.000
1.000	0.188	0.188	0.375	0.750	0.250	100.000
1.000	0.188	0.188	0.375	0.750	0.250	100.000
1.000	0.188	0.188	0.375	0.750	0.250	100.000

Figure 6 Division of 1 Hectare Subcatchment into LID and NonLID

Areas. The internal pervious area is 0.375 hectares, the nonLID area is 0.75 hectares and the two impervious area are 0.1875 hectares each.

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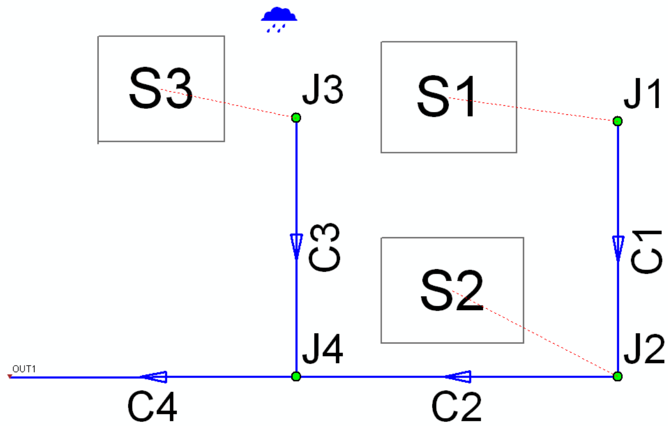
InfoSWMM SA for the EPA SWMM5 Tutorial

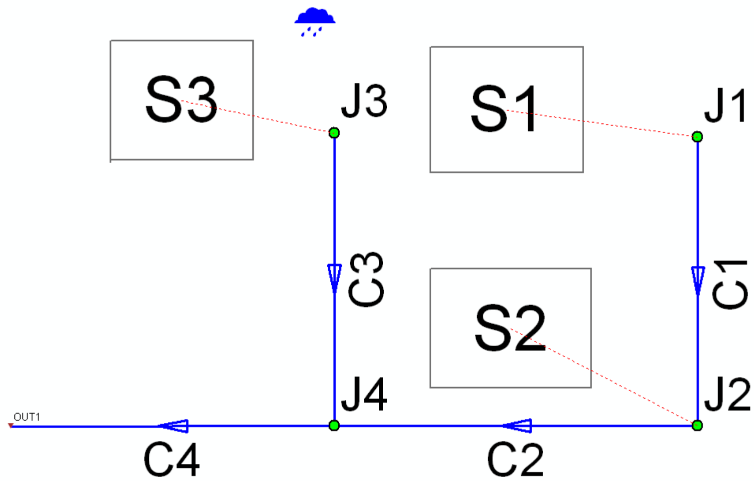
This is a one HTML file version of the SWMM 5 Tutorial for InfoSWMM SA (Standalone) for modeling the quantity and quality of stormwater runoff produced from urban areas. More images have been added to the EPA SWMM tutorial and this particular tutorial is an introduction to the InfoSWMM SA GUI. The topics to be covered include:

- Constructing a InfoSWMM SA Model
- Setting the Properties of InfoSWMM SA Objects
- Saving and Opening Projects
- Running a Single Event Analysis
- Viewing Simulation Results
- Simulating Runoff Water Quality
- Running a Continuous Simulation



In this tutorial we will model the drainage system serving a 12 acre residential area. The system layout is shown below and consists of subcatchment areas S1 through S3 A *subcatchment is an area of land containing a mix of pervious and impervious surfaces whose runoff drains to a common outlet point, which could be either a node of the drainage network or another subcatchment.* Storm sewer conduits C1 through C4, and conduit junctions J1 through J4. The system discharges to a creek at the point labeled Out1. We will first go through the steps of creating the objects shown in this diagram on InfoSWMM SA's Study Area Map and setting the various properties of these objects. Then we will simulate the water quantity and quality response to a 3-inch, 6-hour rainfall event, as well as a continuous, multi-year record.

You can click the **View Map** button that appears in each topic's header panel to refer to this drawing at any time.



Use the button

Our first task is to create a new project in InfoSWMM SA and make sure that certain default options are selected. Using these defaults will simplify the data entry tasks later on.

1. Launch InfoSWMM SA if it is not already running and select **File | New Project** to create a new project. Use these coordinates so that it matches the EPA SWMM5 coordinate system.

   Name: Unknown

   Alias:

   Abbreviation:

   Remarks:

   Factory Code: 0

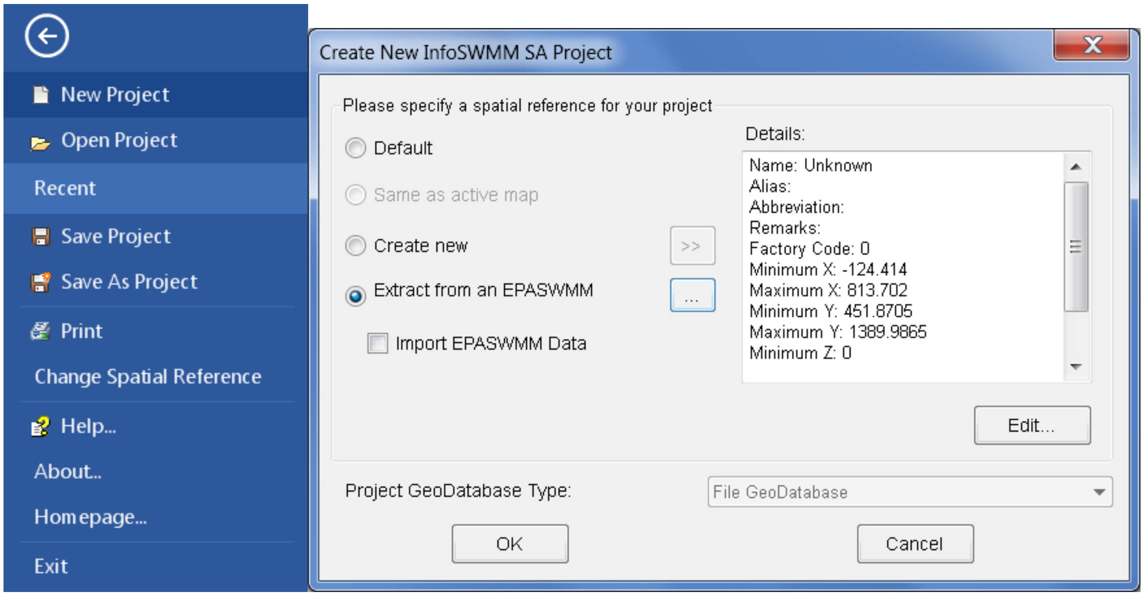
   Minimum X: -124.414

   Maximum X: 813.702

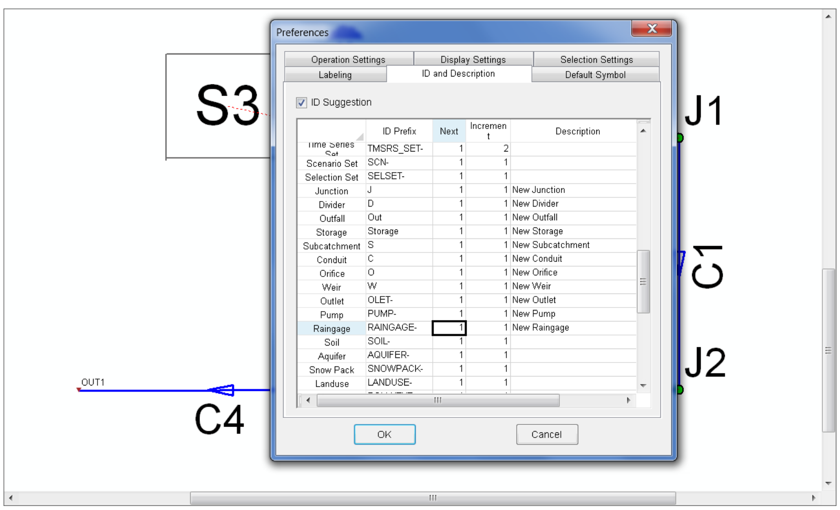
   Minimum Y: 451.8705

   Maximum Y: 1389.9865

   Minimum Z: 0



2. Select Home / **Project Preferences / ID and Description** to open the **ID and Description** dialog



3. On the **ID and Description** dialog, set the ID Prefixes as follows (leave the others at their default):

Rain Gages: Gage

Subcatchments: S

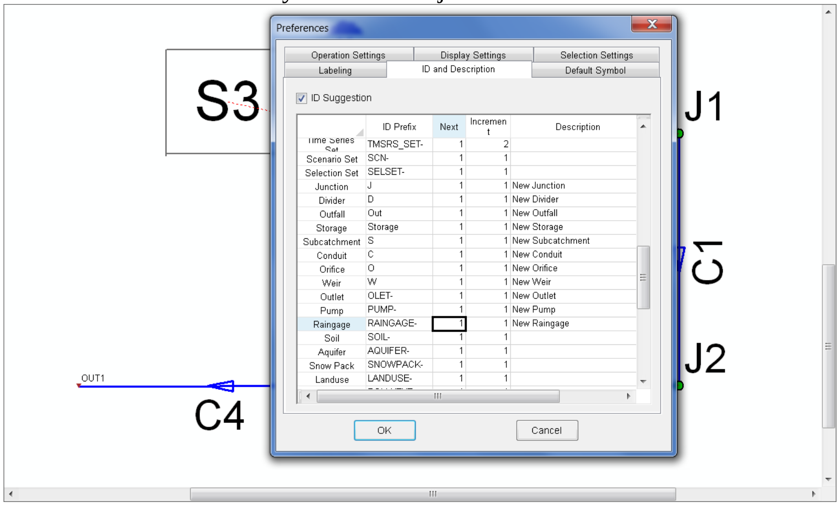
Junctions: J

Outfalls: Out

Conduits: C

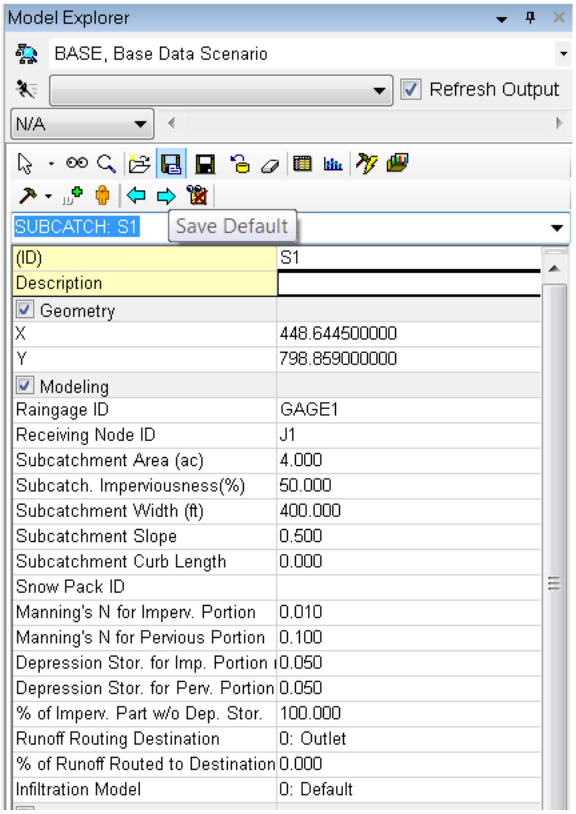
ID Increment: 1

This will make InfoSWMM SA automatically label new objects with consecutive numbers following the designated prefix.



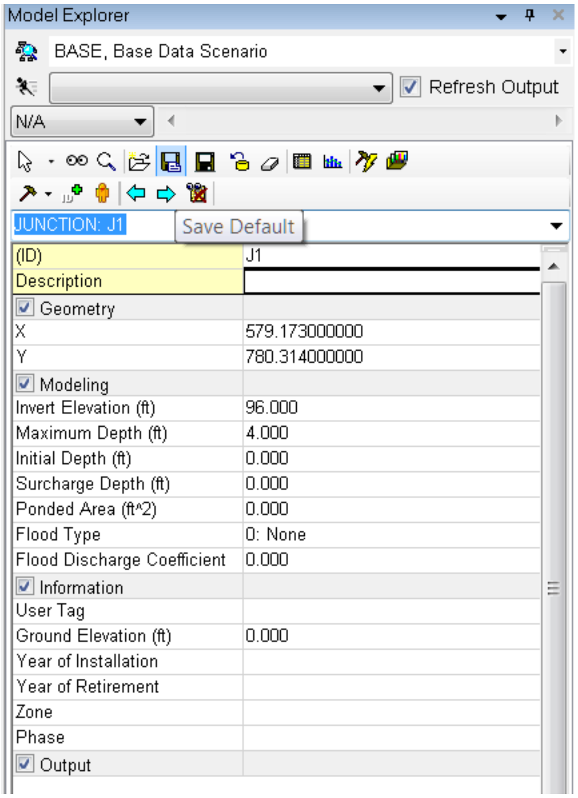
4. On the Subcatchments page of the dialog set the following default values:

Area:	4
Width:	400
% Slope:	0.5
% Imperv:	50
N-Imperv:	0.01
N-Perv:	0.10
Dstore-Imperv:	0.05
Dstore-Perv:	0.05
%Zero-Imperv:	25.0
Infil. Model	<click to edit>
Method:	Modified Green-Ampt
Suction Head:	3.5
Conductivity:	0.5
Initial Deficit:	0.26



5. On the Nodes/Links page set the following default values:

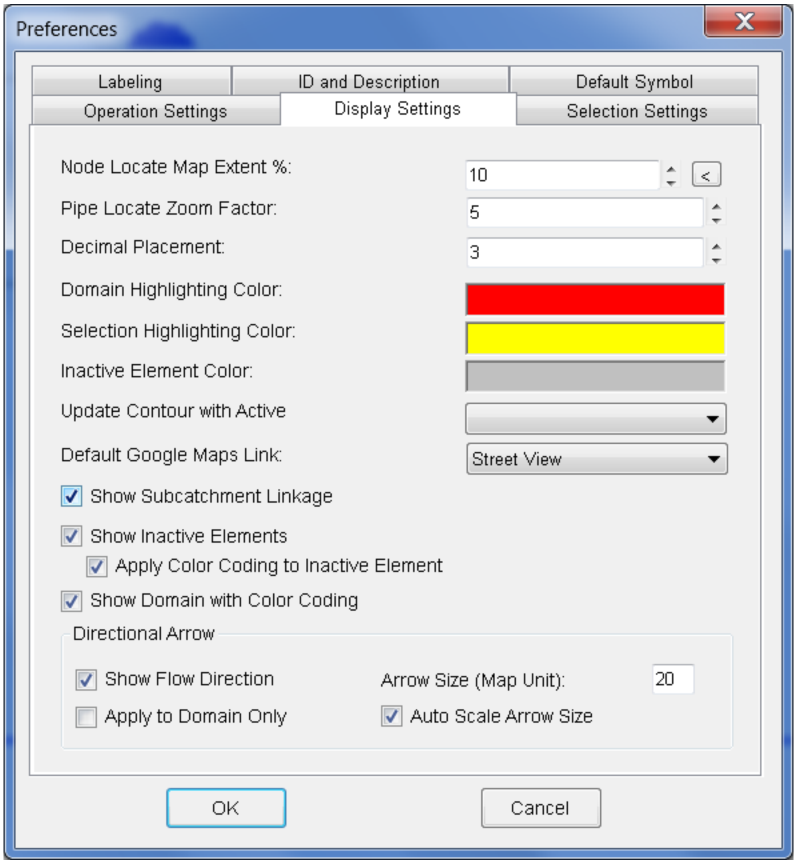
Node Invert:	0
Node Max. Depth:	4
Node Ponded Area	0
Conduit Length:	400
Conduit Geometry:	<click to edit>
Shape:	Circular
Max. Depth:	1.0
Barrels	1
Conduit Roughness:	0.01
Flow Units:	CFS
Link Offsets:	DEPTH
Routing Model:	Kinematic Wave



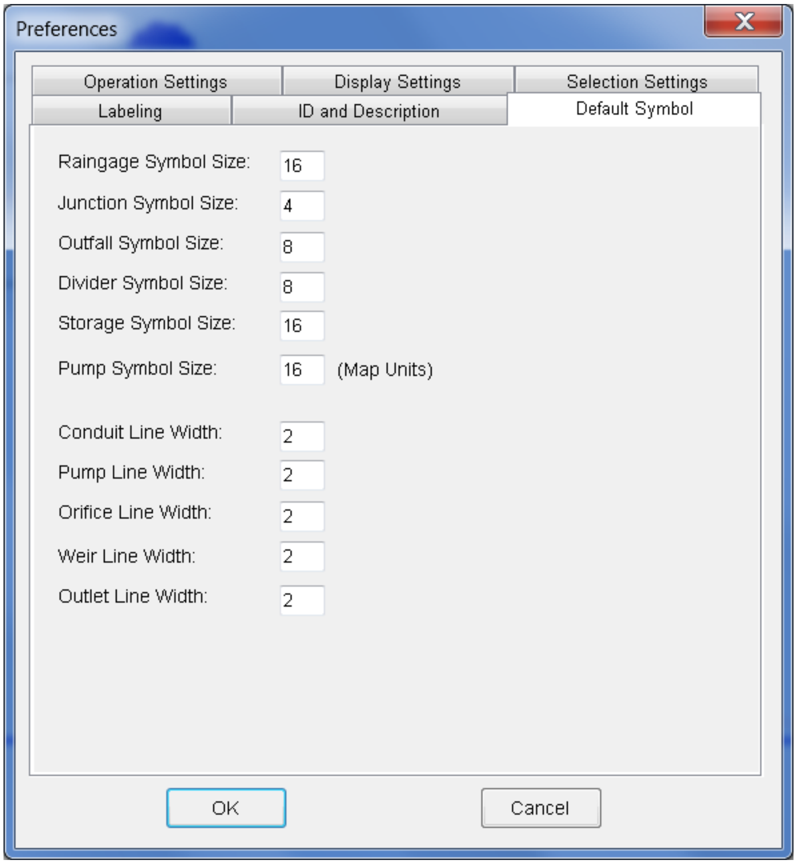
Click **OK** to accept these choices and close the dialog.

Next we will set some map display options so that ID labels and symbols will be displayed as we add objects to the study area map, and links will have direction arrows.

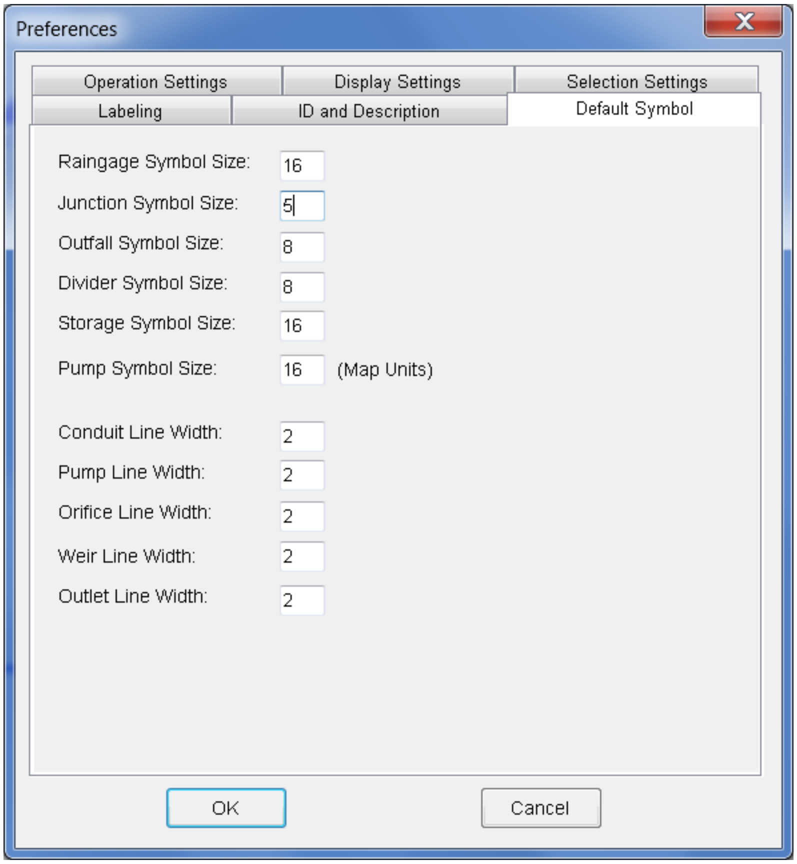
1. Select **Tools | Map Display Settings** to bring up the Display dialog.



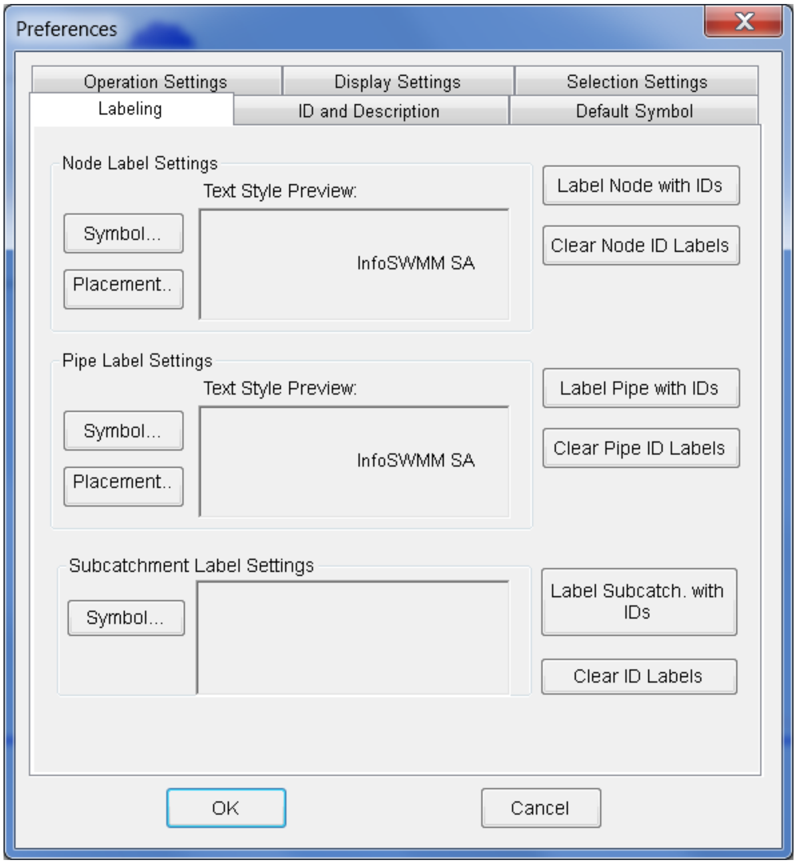
2. Select the Default Symbol Tab.



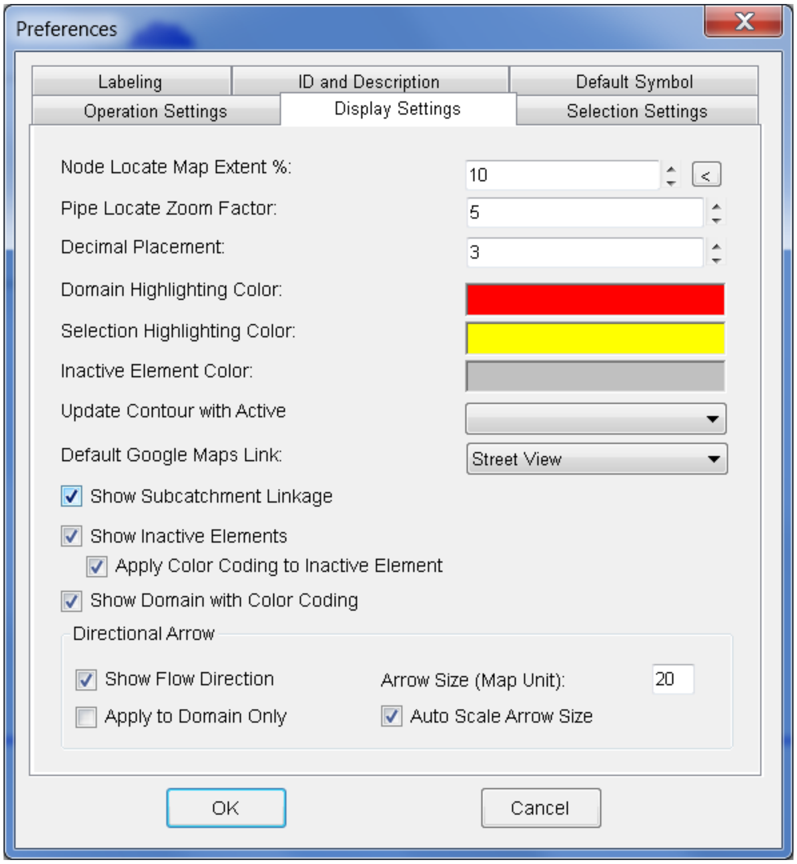
3. Then select the Select the Default Symbol Tab. and set the Node Size to **5**.



4. Select the Labeling Tab and check off the boxes that will display ID labels for Subcatchments, Rain Gages, Nodes, and Links.



5. Finally, select the Flow Arrows page set the arrow size to **20**.

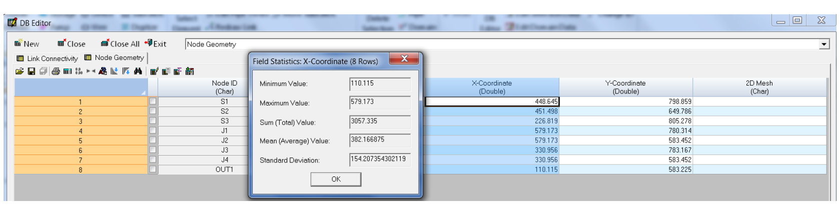


6. Click the **OK** button to accept these choices and close the Project Preferences dialog.

Before placing objects on the map we should set its dimensions.

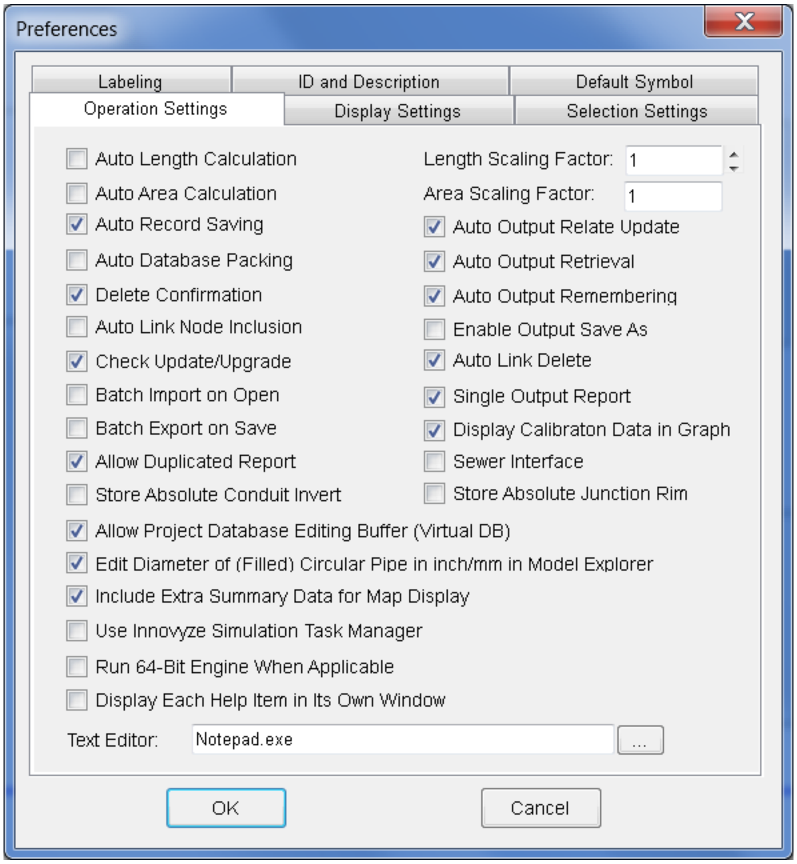
1. Select **View | Dimensions** to bring up the Map Dimensions dialog. You cannot see this in InfoSWMM SA but be seen in the DB Node Geometry Table using the DB Editor.

2. You can leave the dimensions at their default values for this example or the EPA Extents in the SWMM input file..



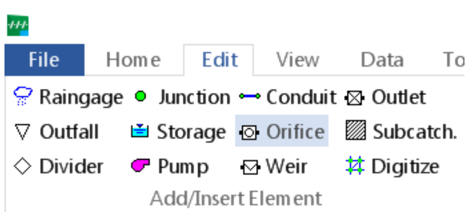
Finally, look in the status bar at the bottom of the main window and check that the Auto-Length Calculation feature is off. If it is on, then click the down arrow button and select "Auto-Length: Off" from the popup menu that appears. Also make sure that the Offsets option is set to Depth. If set to Elevation then click the down arrow button and select "Depth Offsets" from the popup menu that appears.

The equivalent commands in InfoSWMM SA are located in the Project Preferences dialog Operation Settings Tab. Turn off Auto Length Calculation and ensure that the flag for Store Absolute Conduit Invert is turned off.



We are now ready to begin adding components to the Study Area Map. We will start with the subcatchments. Remember that you can click the **View Map** button of this tutorial at any time to see how we want our map to look eventually. *Drawing objects on the map is just one way of creating a project. For large projects it will be more convenient to first construct an EPA SWMM project file external to the program. The project file is a text file that describes each object in a specified format as described in the Users Manual. Data extracted from various sources, such as CAD drawings or GIS files, can be used to create the project file.* ***This of course is very easy to do in InfoSWMM SA using GIS Gateway and Import Manager.***

1. Begin by selecting the **Subcatchments** category (under Hydrology) in the Edit Menu Ribbon.

2. 

   Then click the button on the toolbar underneath the object category listing in the Project panel (or select **Project | Add a New Subcatchment** from the Edit Ribbon Menu). Notice how the mouse cursor changes shape to a pencil when you move it over the map.

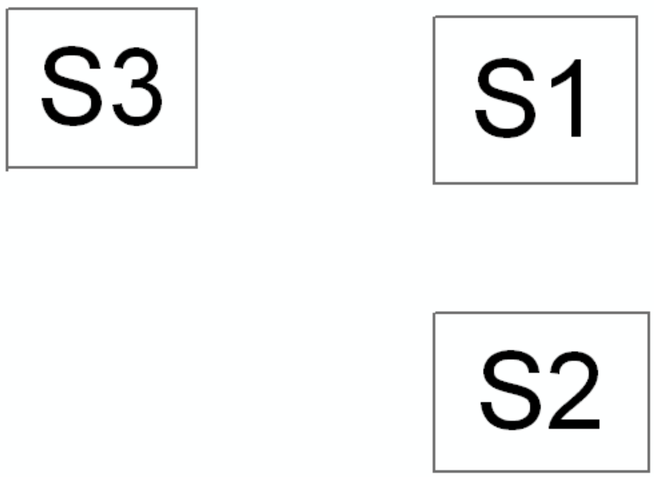
3. Move the mouse to the map location where one of the corners of subcatchment **S1** lies and left-click the mouse.

4. Do the same for the next three corners and then right-click the mouse (or hit the **Enter** key) to close up the rectangle that represents subcatchment **S1**. You can press the **Esc** key if instead you wanted to cancel your

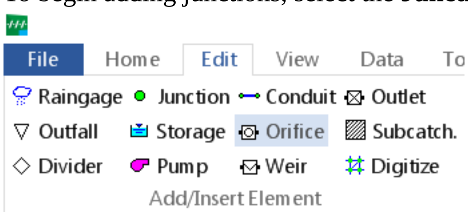
partially drawn subcatchment and start over again. Don't worry if the shape or position of the object isn't quite right. We will go back later and show how to fix this.

5. Next move the mouse to subcatchment **S2**'s location and draw its outline. Then repeat for subcatchment **S3**. If you right-click (or press Enter) after adding the first point of a subcatchment\'s outline, the subcatchment will be shown as just a single point.

Observe how sequential ID labels are generated automatically as we add objects to the map.

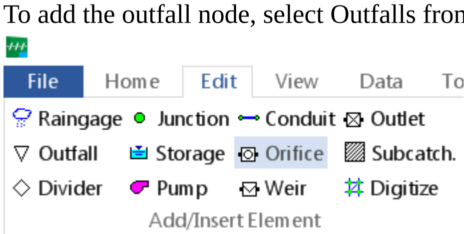


Next we will add in the junction nodes and the outfall node that comprise part of the drainage network.

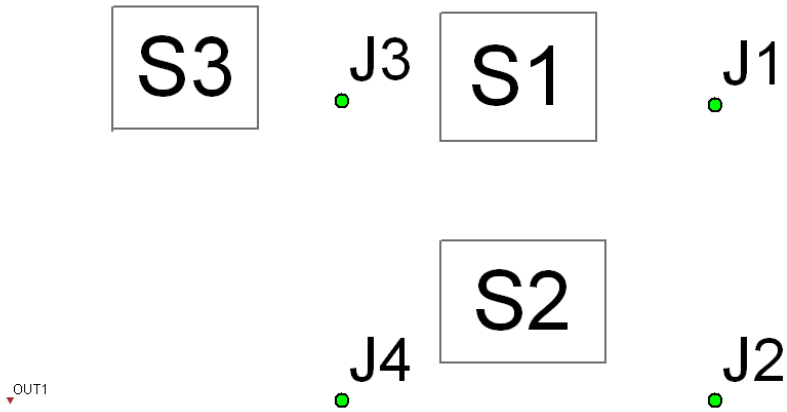
1. To begin adding junctions, select the **Junctions** category from Edit Menu Ribbon and click the 

button or select **Project Add a New Junction** from the main menu.

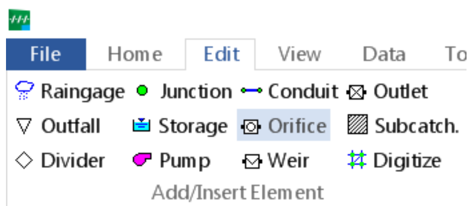
2. Move the mouse to the position of junction **J1** and left-click it. Do the same for junctions **J2** through **J4**.

3. To add the outfall node, select Outfalls from the Project Browser, click the 

button or select **Add a New Outfall** from the main menu, move the mouse to the outfall's location on the map, and left-click. Note how the outfall is automatically given the name **Out1**.



Now we will add the storm sewer conduits that connect our drainage system nodes to one another. (You must have created a link's end nodes as described in the previous topic before you can create the link.) We will begin with conduit **C1** which connects junction **J1** to **J2**.

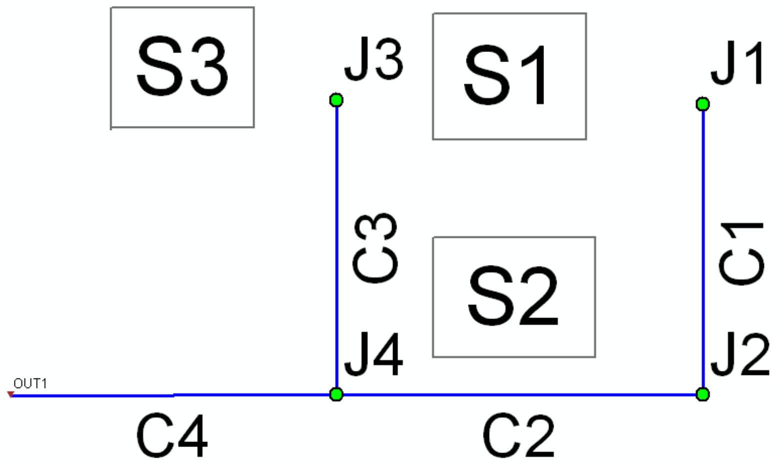
1. Select the Conduits from Edit Menu Ribbon 

button or select **Add a New Conduit** from the main menu. The mouse cursor will change shape to a cross hair when moved onto the map.

2. Left click the mouse on junction **J1**. Note how the mouse cursor now changes shape to a pencil.

3. Move the mouse over to junction **J2** (note how an outline of the conduit is drawn as you move the mouse) and left-click to create the conduit. You could have canceled the operation by either right-clicking or by hitting the **Esc** key.

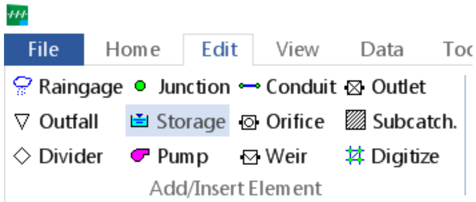
Repeat steps 2 and 3 for conduits **C2** through **C4**. *Although all of our conduits were drawn as straight lines, it is possible to draw a curved link by left-clicking at intermediate points where the direction of the link changes before clicking on the end node.*



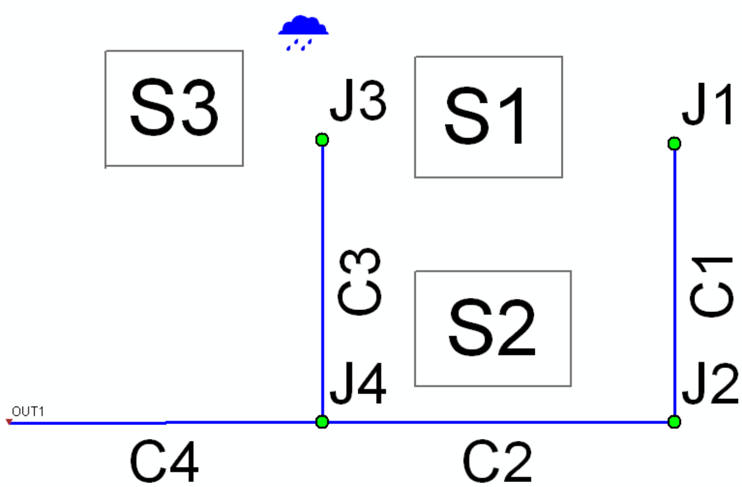
To complete the construction of our study area schematic we need to add a rain gage.

2. Move the mouse over the Study Area Map to where the gage should be located and left-click the mouse.

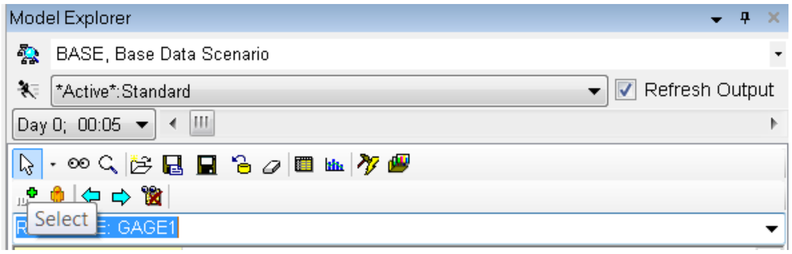
1. Select the Rain Gages category from the Edit Menu Ribbon and either click the



 button or select **Add a New Rain Gage** from the main menu.



At this point we have completed drawing the example study area. Your system should look like the one seen by pressing the View Map button above. If the rain gage, subcatchments or nodes are out of position you can move them around by

1. clicking the 

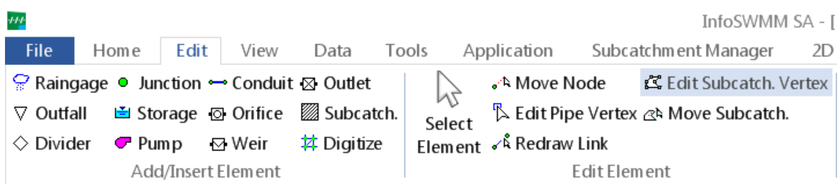
button on the InfoSWMM SA Attribute Browser (AB) to place the map in Object Selection mode,

2. clicking on the object to be moved,

3. dragging the object with the left mouse button held down to its new position.

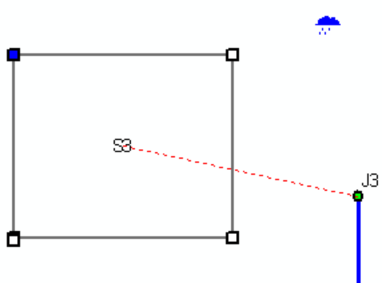
To re-shape a subcatchment's outline:

1. With the map in Object Selection mode, click on the subcatchment's centroid (indicated by a solid square within the subcatchment) to select it.

2. 

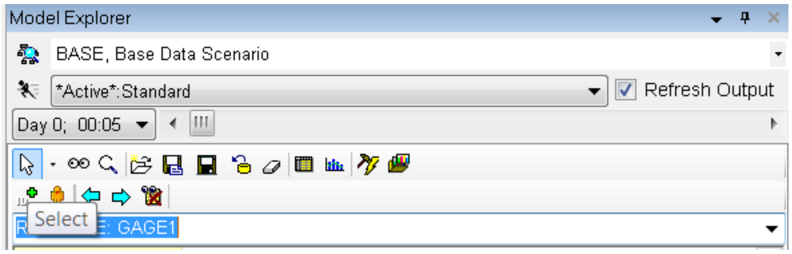
Then click the  button on the Map Toolbar to put the map into Vertex Selection mode.

3. Select a vertex point on the subcatchment outline by clicking on it (note how the selected vertex is indicated by a filled solid square).



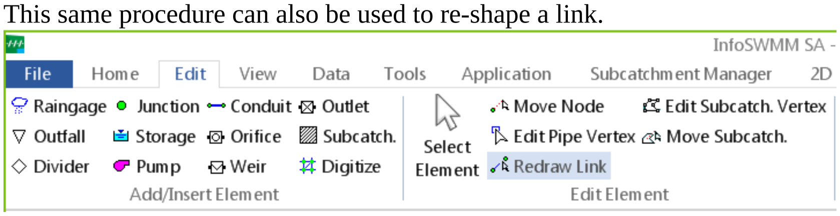
4. Drag the vertex to its new position with the left mouse button held down.

5. If need be, vertices can be added to or deleted from the outline by right-clicking the mouse and selecting the appropriate option from the popup menu that appears.

6. When finished, click the 

button to return to Object Selection mode.

This same procedure can also be used to re-shape a link.

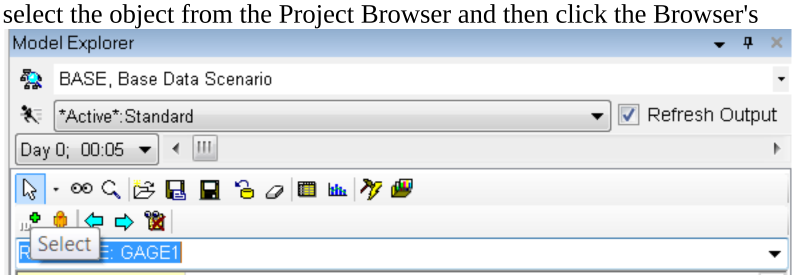


As visual objects are added to our project, SWMM assigns them a default set of properties. To change the value of a specific property for an object we must select the object into the Property Editor (shown below). There are several different ways to do this. If the Editor is already visible then you can simply click on the object or select it from the Project Browser. If the Editor is not visible then you can make it appear by one of the following actions:

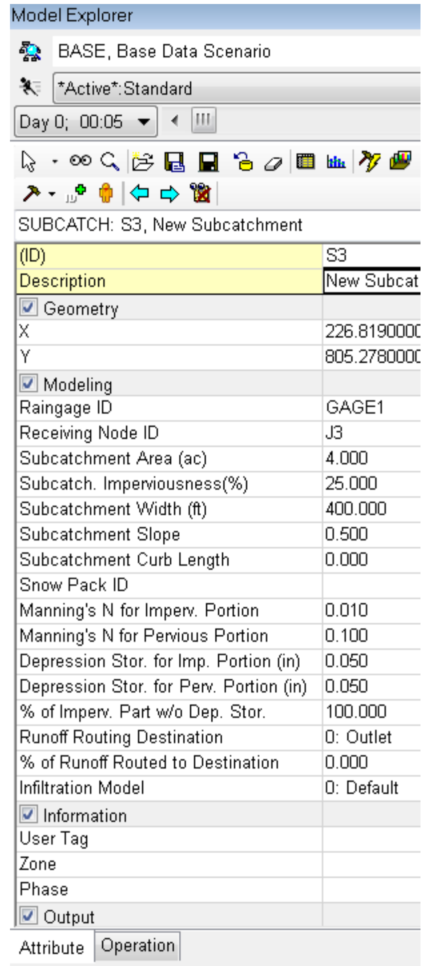
· double-click the object on the map

· Use the white arrow icon in Model Explorer to choose an element.

· select the object from the Project Browser and then click the Browser's

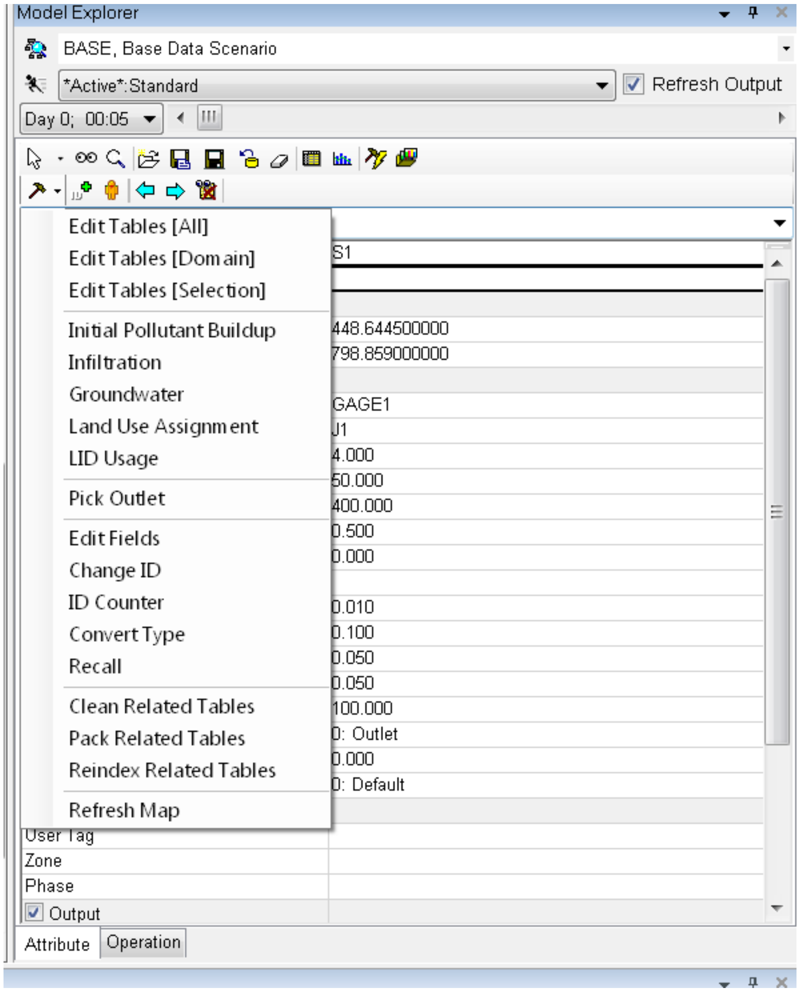


button.

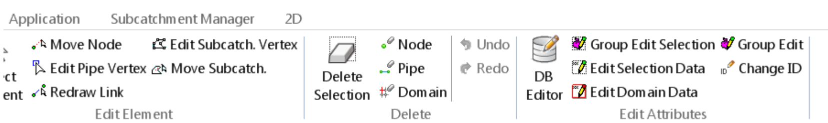


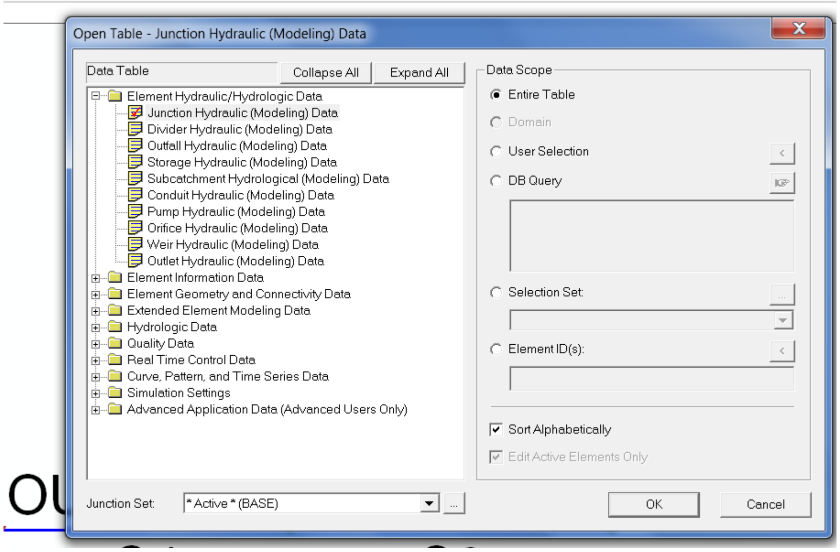
Whenever the Model Explorer has the focus you can press the F1 key to obtain a more detailed description of the properties listed.

Two key properties of our subcatchments that need to be set are the rain gage that supplies rainfall data to the subcatchment and the node of the drainage system that receives runoff from the subcatchment. Since all of our subcatchments utilize the same rain gage, **Gage1**, we can use a shortcut method to set this property for all subcatchments at once:



1. From the Edit Menu select DB Editor.

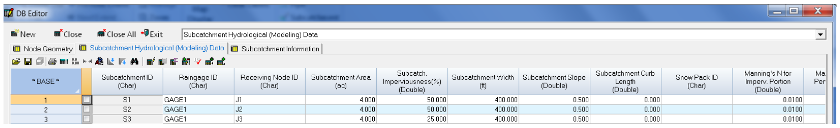




2. Then select **Entire Table to show all Active Junction Data.**

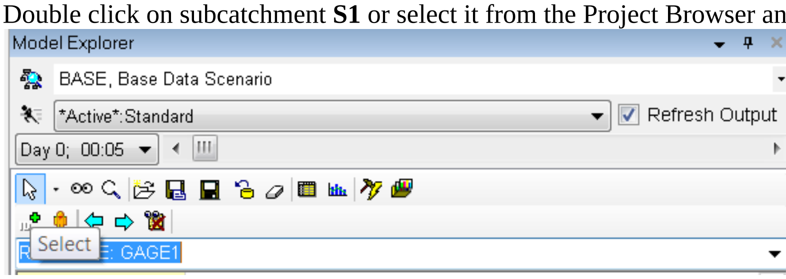
3. Select **Subcatchments** as the class of object to edit, **Raingage** as the property to edit, and type in **Gage1** as the new value.

4. Click **OK** to change the rain gage of all subcatchments to **Gage1**. A confirmation dialog will appear noting that 3 subcatchments have changed. Select **No** when asked to continue editing.



* BASE *		Subcatchment ID (Char)	Raingage ID (Char)	Receiving Node ID (Char)	Subcatchment Area (ac)	Subcatch. Imperviousness(%) (Double)	Subcatchment Width (ft)	Subcatchment Slope (Double)	Subcatchment Curb Length (Double)	Snow Pack ID (Char)	Manning's N for Imperv. Portion (Double)	Ma Per
1		S1	GAGE1	J1	4.000	50.000	400.000	0.500	0.000		0.0100	
2		S2	GAGE1	J2	4.000	50.000	400.000	0.500	0.000		0.0100	
3		S3	GAGE1	J3	4.000	25.000	400.000	0.500	0.000		0.0100	

To set the outlet node of our subcatchments we have to proceed one by one, since these vary by subcatchment:

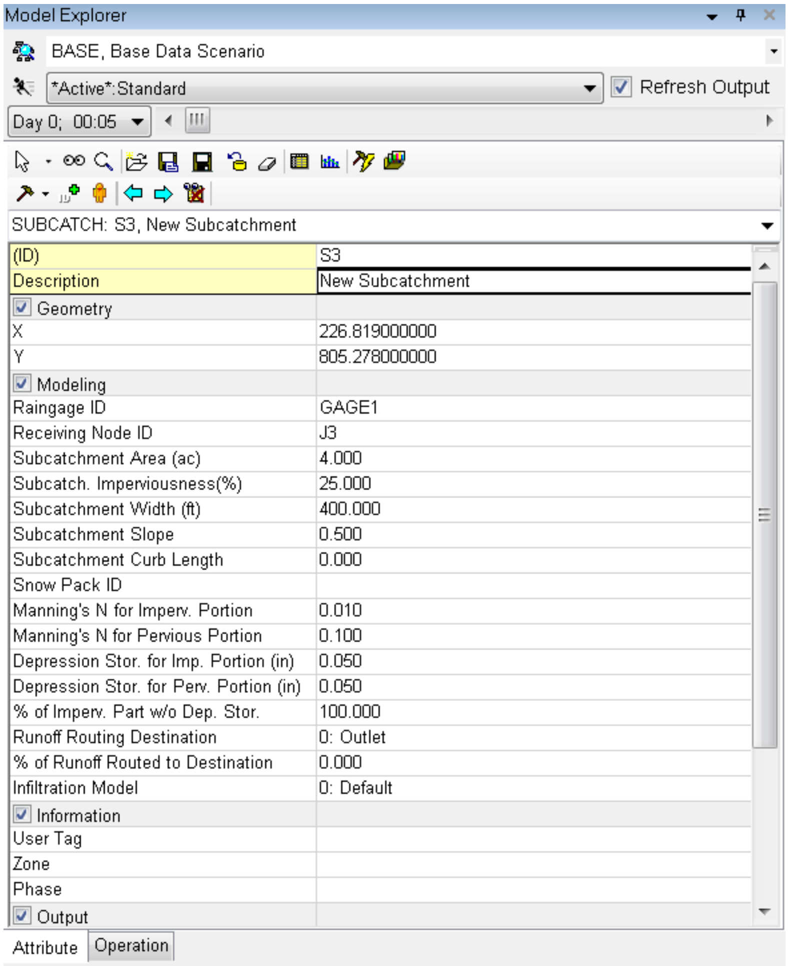
1. Double click on subcatchment **S1** or select it from the Project Browser and click the Browser's  button to bring up the Property Editor.

2. Type **J1** in the Outlet field and press **Enter**. Note how a dotted line is drawn between the subcatchment and the node.

3. Click on subcatchment **S2** and enter **J2** as its Outlet.

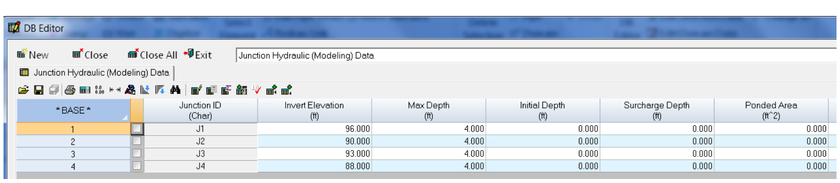
4. Click on subcatchment **S3** and enter **J3** as its Outlet.

Finally, we wish to represent area **S3** as being less developed than the others. Select **S3** into the Property Editor and set its % Imperviousness to **25**.

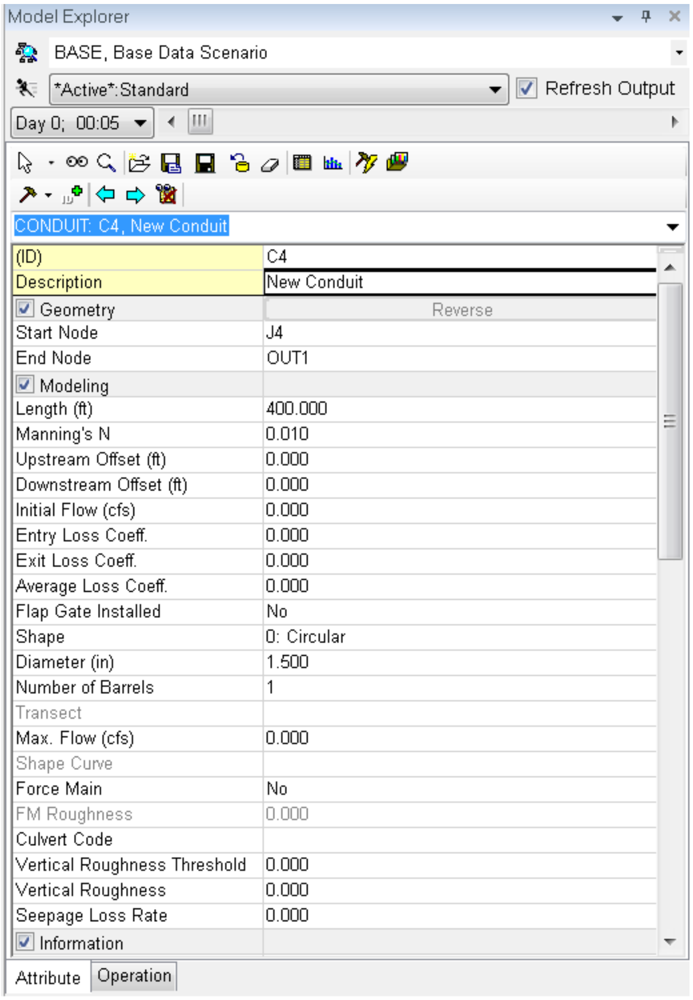


The junctions and outfall of our drainage system need to have invert elevations assigned to them. As we did with the subcatchments, select each junction individually into the Property Editor and set its **Invert Elevation** to the value shown in the table below. *An alternative way to move from one object of a given type to the next in order (or to the previous one) in the Property Editor is to hit the Page Down (or Page Up) key.*

Node	**Invert**
J1	**96**
J2	**90**
J3	**93**
J4	**88**
Out1	**85**



Only one of the conduits in our example system has a non-default property value. This is conduit **C4**, the outlet pipe, whose diameter should be 1.5 ft. instead of 1 ft. To change its diameter, select conduit **C4** into the Property Editor and set the Max. Depth value to **1.5**.



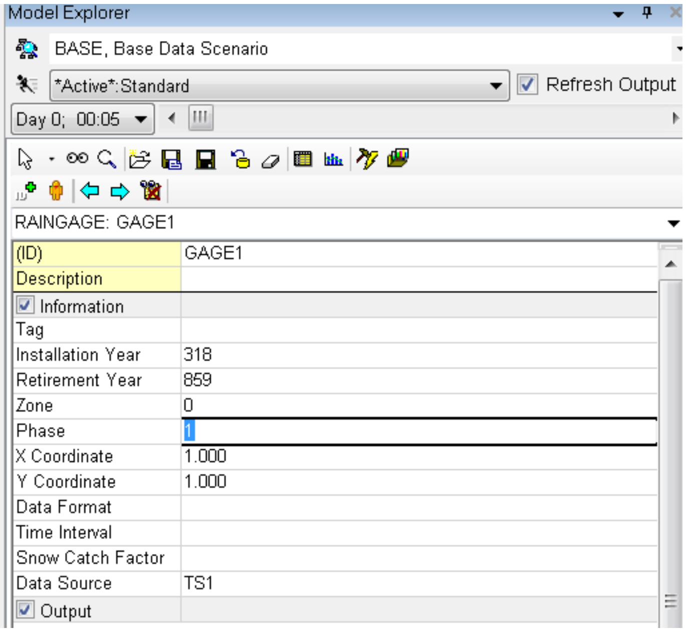
In order to provide a source of rainfall input to our project we need to set the rain gage properties. Select **Gage1** into the Property Editor and set the following properties:

Rain Format: INTENSITY

Rain Interval: 1:00

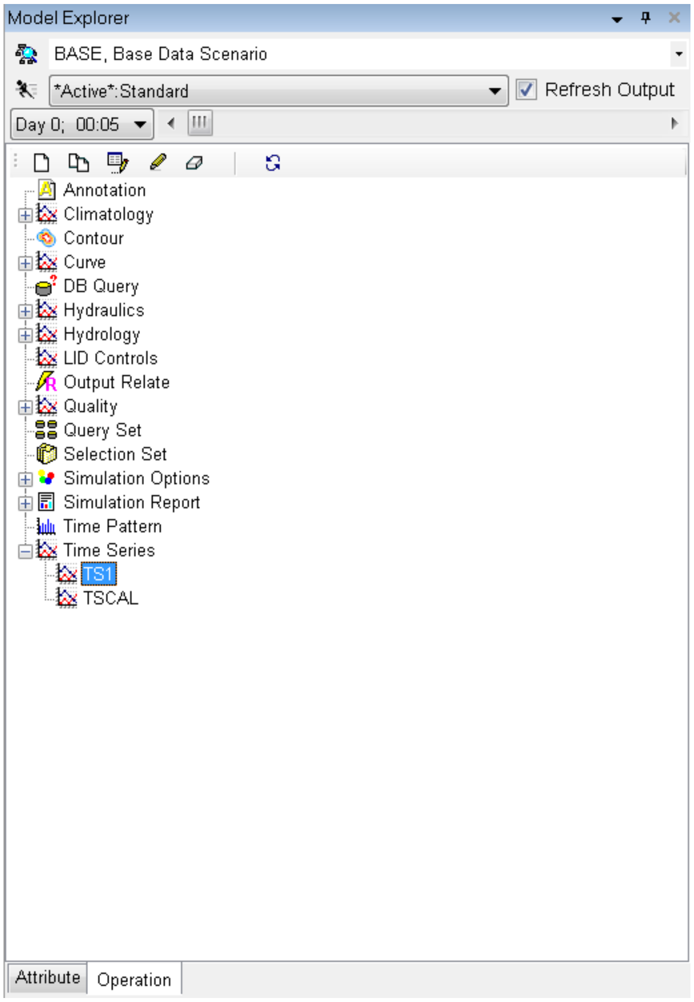
Data Source: TIMESERIES

Series Name: TS1



As mentioned earlier, we want to simulate the response of our study area to a 3-inch, 6-hour design storm. A time series named **TS1** will contain the hourly rainfall intensities that make up this storm. Thus we need to create a time series object and populate it with data. To do this:

1. From the Model Explorer / Operations Tab select the Time Series category of objects.
2. Click the button on the Browser which will bring up a Time Series Editor form. Leaving off the dates for a time series means that InfoSWMM SA will interpret the time values as hours from the start of the simulation. *Otherwise, the time series follows the date\/time values specified by the user.*



3. Enter **TS1** in the Time Series Name field.

4. Enter the following values into the Time and Value columns of the data entry grid (leave the Date column blank): *The Time Series Editor can also be launched directly from the Rain Gage Property Editor by selecting the editor\'s Series Name field and double clicking on it. "*

0 0

1 0.5

2 1.0

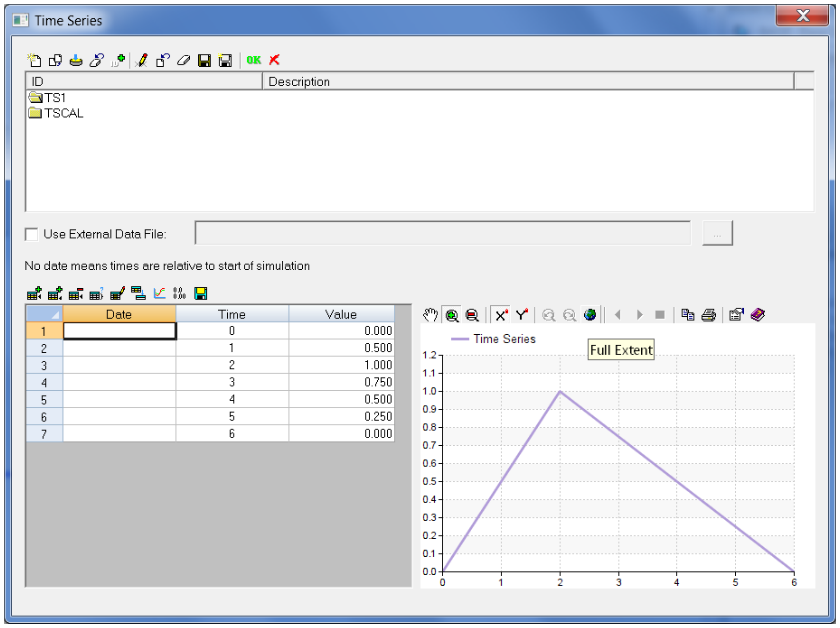
3 0.75

4 0.5

5 0.25

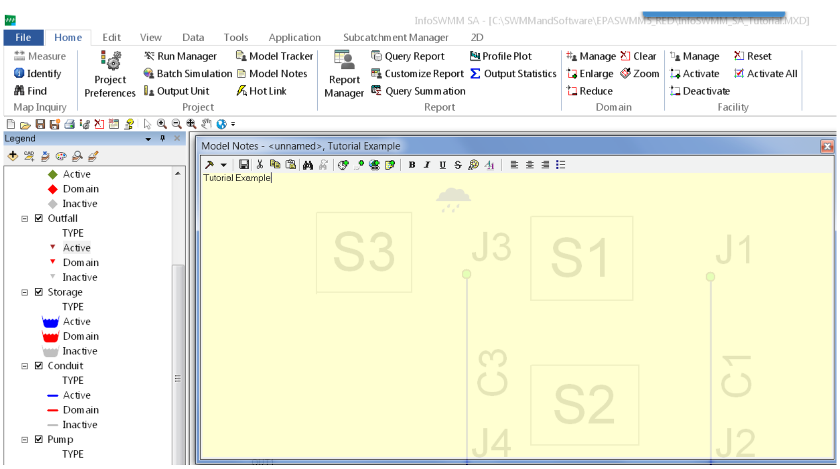
6 0

5. You can click the **View** button on the dialog to see a graph of the time series values. Click the **OK** button to accept the new time series.



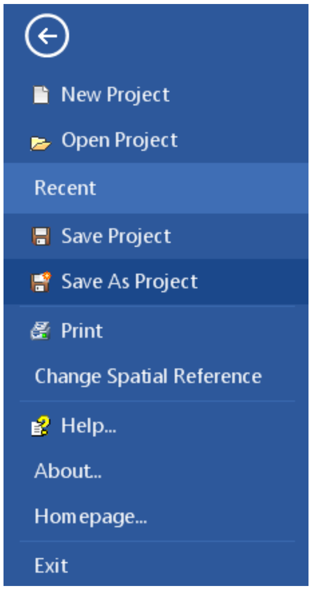
Having completed the initial design of our example project it is a good idea to give it a title and save our work to a file at this point. To do this:

1. Select the **Title/Notes** category from the Project Browser and click the note track button.

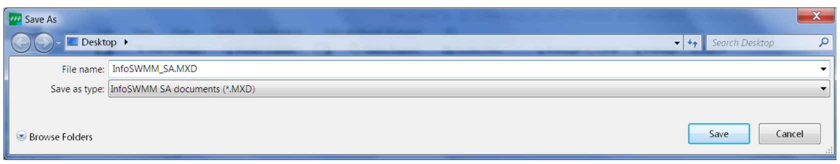


2. In the Project Title/Notes dialog that appears, enter "Tutorial Example" as the title of our project and click the **OK** button to close the dialog.

3. From the **File** menu select the **Save As** option.



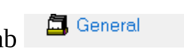
4. In the Save As dialog that appears, select a folder and file name under which to save this project. We suggest naming the file **tutorial.inp**. (An extension of .inp will be added to the file name if one is not supplied.)

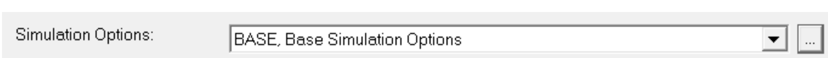


5. Click **OK** to save the project to file.

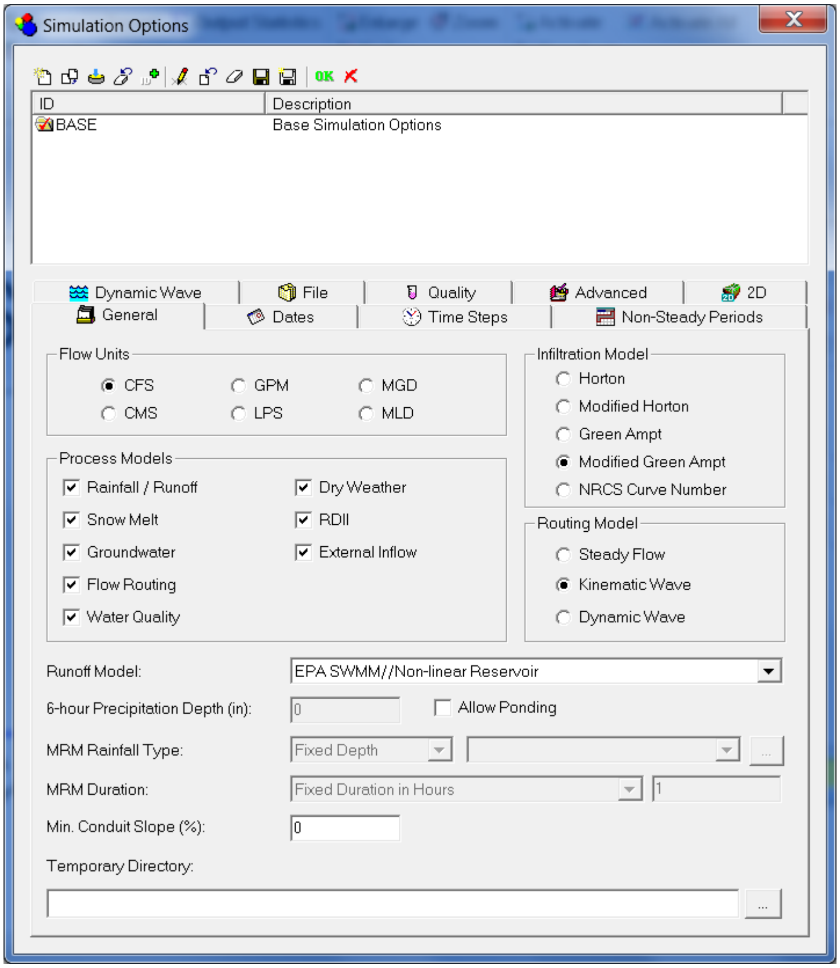
The project data is saved to the file in a readable text format. You can view what the file looks like by selecting **Project | Details** from the main menu. To open our project at some later time, we would select the **Open** command from the **File** menu.

Before analyzing the performance of our example drainage system we need to set some options that determine how the analysis will be carried out. To do this:

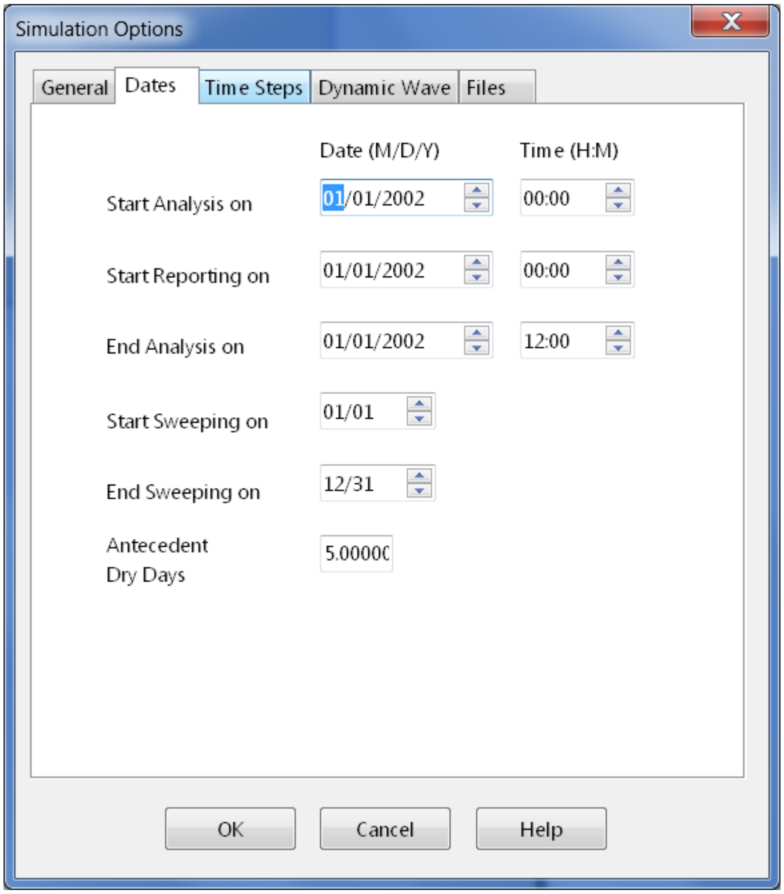
1. From the Run Manager select the **Options** category and click the General Tab .



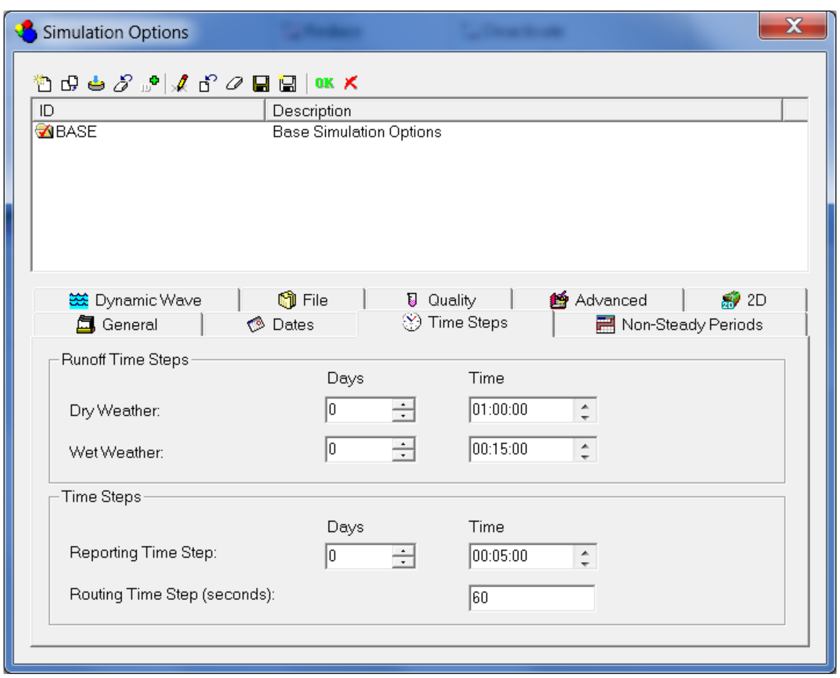
2. On the General page of the Simulation Options dialog that appears, select **Kinematic Wave** as the flow routing method. The flow units should already be set to **CFS** and the infiltration method to Modified **Green-Ampt**. The Allow Ponding option should be unchecked.



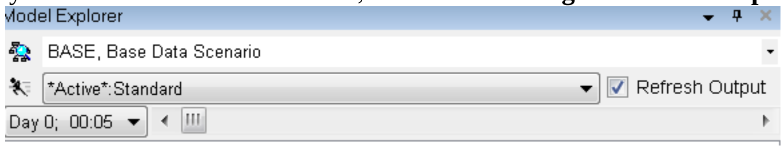
3. On the Dates page of the dialog, set the End Analysis time to **12:00**.



4. On the Time Steps page, set the Routing Time Step to **60** sec.



5. Click **OK** to close the Simulation Options dialog.

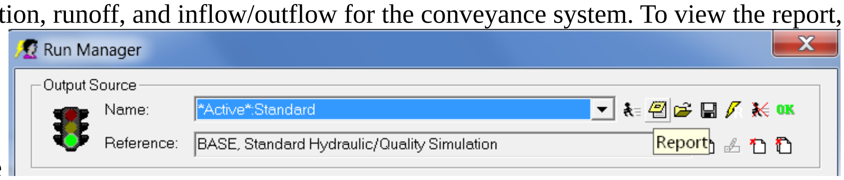
We are now ready to run the simulation. To do so, select **Run Manager on Model Explorer** on the main menu (or simply click the 

button).

If there was a problem in running the simulation, a Status Report will appear describing what errors occurred.

Upon successfully completing a run, there are numerous ways in which to view the results of the simulation. We will illustrate just a few here:

- Viewing the Status Report
- Viewing the Summary Report
- Viewing results on the map
- Viewing a time series plot
- Viewing a profile plot

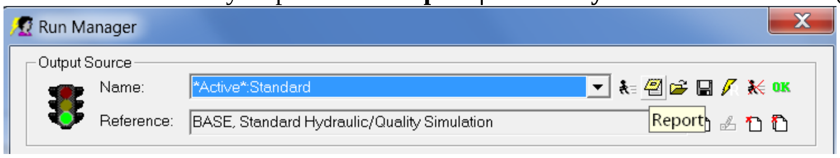
The Status Report contains useful information about the quality of a simulation run, including a mass balance on rainfall, infiltration, evaporation, runoff, and inflow/outflow for the conveyance system. To view the report, select **Report | Status** (or click the 

button on the Standard Toolbar and then select **Status Report**).

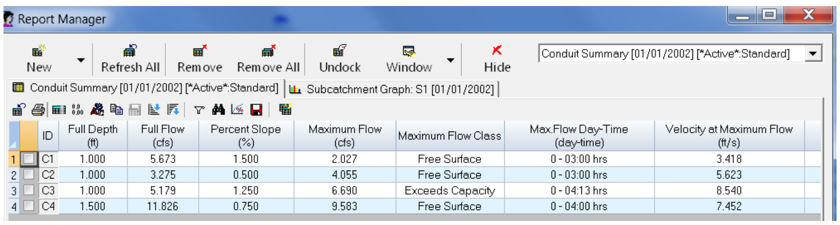
For the system we just analyzed the report indicates the quality of the simulation is quite good, with negligible mass balance continuity errors for both runoff and routing (-0.22% and 0.03%, respectively, if all data were entered correctly). Also, of the 3 inches of rain that fell on the study area, 1.75 infiltrated into the ground and essentially the remainder became runoff.

```
**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         3.000         3.000
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         1.749         1.749
Surface Runoff ...........         1.257         1.257
Final Surface Storage ....         0.000         0.000
Continuity Error (%) .....        -0.222
```

The Summary Report contains tables listing summary results for each subcatchment, node and link in the drainage system. Total rainfall, total runoff, and peak runoff for each subcatchment, peak depth and and hours flooded for each node, and peak flow, velocity, and depth for each conduit are just some of the outcomes included in the summary report.

To view the Summary Report select **Report | Summary** from the main menu (or click the 

button on the Standard Toolbar and then select **Summary Report** from the drop down menu). The report's window has a drop down list from which you select a particular report to view. For our example, the Node Flooding Summary table indicates there was internal flooding in the system at node **J2**. *In InfoSWMM SA or EPA SWMM, flooding will occur whenever the water surface at a node exceeds the maximum defined depth. Normally such water will be lost from the system. The option also exists to have this water pond atop the node and be re-introduced into the drainage system when capacity exists to do so* . The Conduit Surcharge Summary table shows that Conduit **C2**, just downstream of node **J2**, was at full capacity and therefore appears to be slightly undersized.



	ID	Full Depth (ft)	Full Flow (cfs)	Percent Slope (%)	Maximum Flow (cfs)	Maximum Flow Class	Max.Flow Day-Time (day-time)	Velocity at Maximum Flow (ft/s)
1	C1	1.000	5.673	1.500	2.027	Free Surface	0 - 03:00 hrs	3.418
2	C2	1.000	3.275	0.500	4.055	Free Surface	0 - 03:00 hrs	5.623
3	C3	1.000	5.179	1.250	6.690	Exceeds Capacity	0 - 04:13 hrs	8.540
4	C4	1.500	11.826	0.750	9.583	Free Surface	0 - 04:00 hrs	7.452

Simulation results (as well as some design parameters, such as subcatchment area, node invert elevation, link maximum depth) can be viewed in color-coded fashion on the study area map. To view a particular variable in this fashion:

1. Select the Map page of the Browser panel.

2. Select the variables to view for Subcatchments, Nodes, and Links from the dropdown combo boxes in the Themes panel.

3. The color coding used for a particular variable is displayed with a legend on the study area map. To toggle the display of a legend, select **View | Legends**.

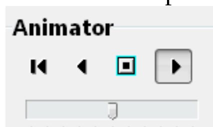
4. To move a legend to another location, drag it with the left mouse button held down.

5. To change the color coding and the breakpoint values for different colors, select **View | Legends | Modify** and then the pertinent class of object (or if the legend is already visible, simply right-click on it).

6. To view numerical values for the variables being displayed on the map, select **Tools | Map Display Options** and then select the Annotation page of the Map Options dialog. Use the check boxes for Rain Gages, Subcatchments, Nodes, and Links to specify what kind of annotation to add.

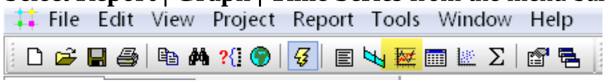
7. The Date / Time of Day / Elapsed Time controls on the Map Browser can be used to move through the simulation results in time.

8. You can use the controls in the Animator panel of the Map Browser to animate the map display through time.

For example, pressing the 

button will run the animation forward in time.

To generate a time series plot of a simulation result:

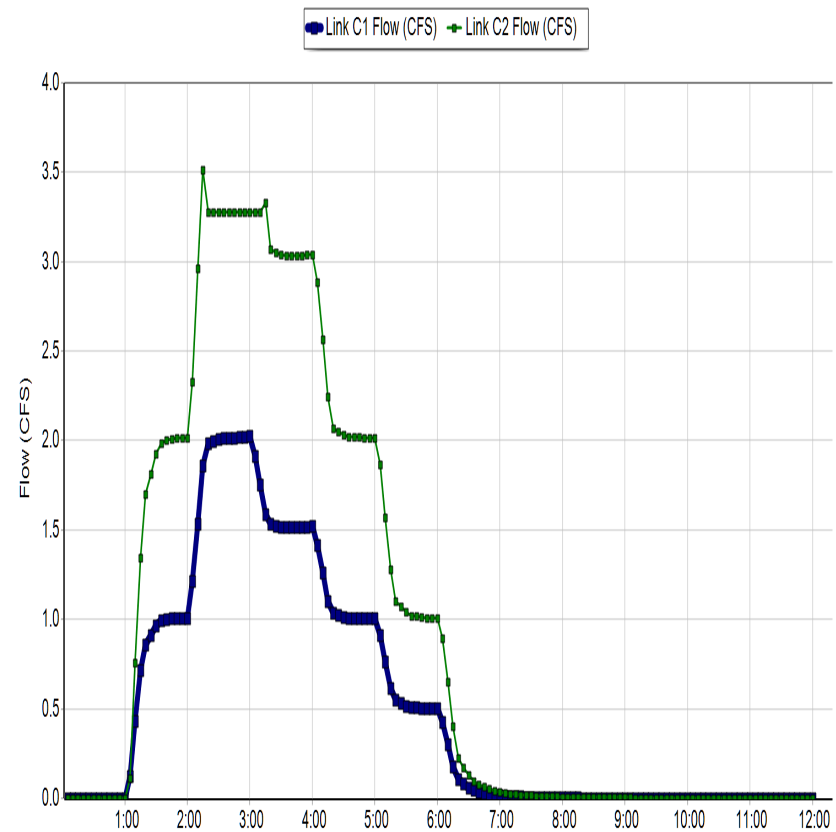
1. Select **Report | Graph | Time Series** from the menu bar or simply click 

on the Standard Toolbar..

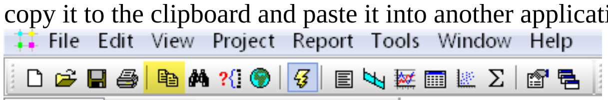
2. A Time Series Plot Selection dialog will appear. It is used to select the objects and variables to be plotted.

For our example, this dialog can be used to graph the flows in conduits **C1** and **C2** as follows:

1. Select conduit **C1** on the map or in the Project Browser and then click the **Add** button on the dialog.
2. A Data Series Selection page will appear. Select **Flow** as the Variable to plot.
3. Click the **Accept** button to return to the Plot Selection page of the dialog.
4. Repeat the above steps for conduit **C2** and press **OK** to create the plot.



After a plot is created you can:

- customize its appearance by selecting **Report | Customize** or right clicking on the plot,
- copy it to the clipboard and paste it into another application by selecting **Edit | Copy To** or clicking 

 on the Standard Toolbar
- print it by selecting **File | Print** or **File | Print Preview** (use **File | Page Setup** first to set margins, orientation, etc.).

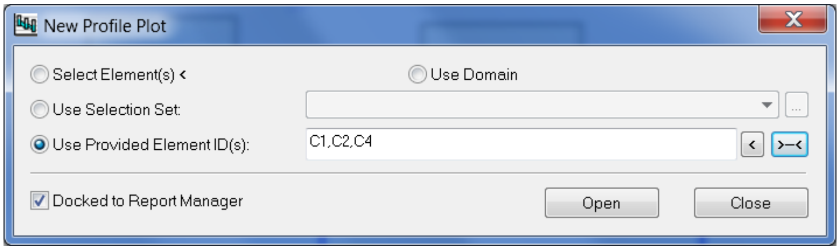
SWMM can generate profile plots showing how water surface depth varies across a path of connected nodes and links. Let's create such a plot for the conduits connecting junction **J1** to the outfall **Out1** of our example drainage system. To do this:

1. Select Report | Graph | Profile or simply click 

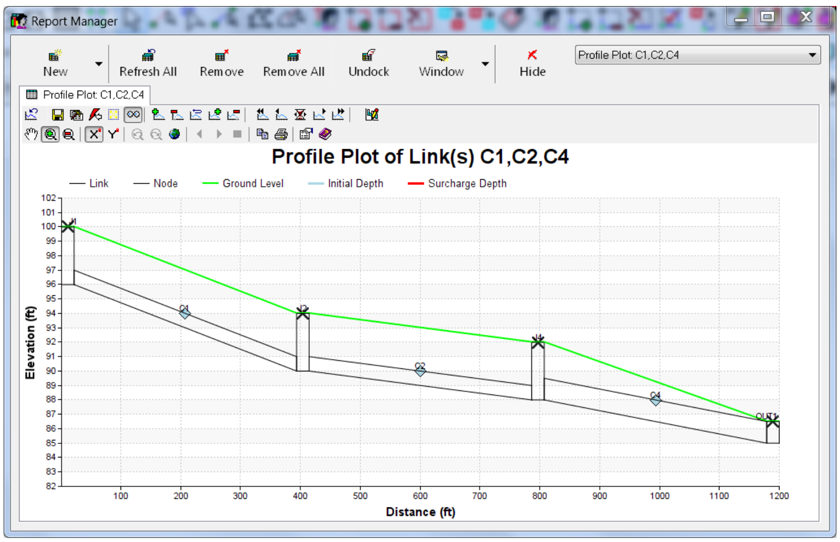
 on the Standard Toolbar.
2. Either enter **J1** in the Start Node field of the Profile Plot dialog that appears or select it on the map or from the Project Browser and click the 

 button next to the field.
3. Do the same for node **Out1** in the End Node field of the dialog.

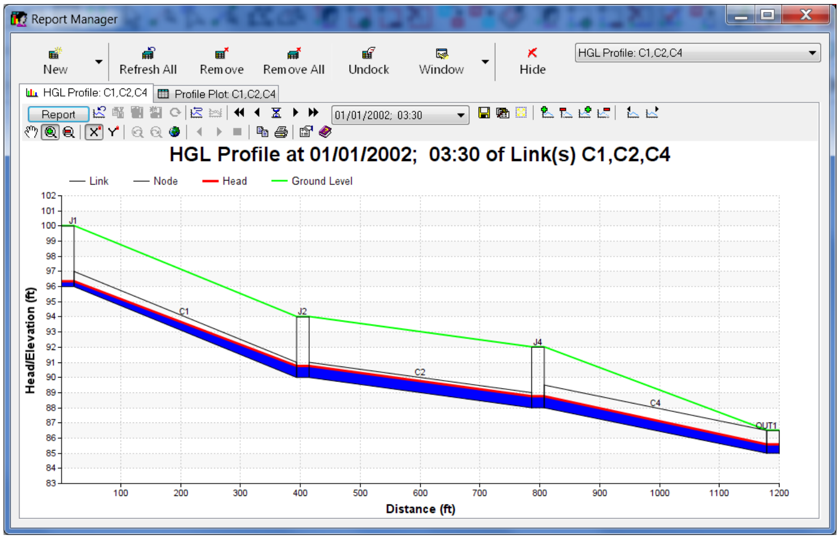
4. Click the **Find Path** button. An ordered list of the links which form a connected path between the specified Start and End nodes will be displayed in the Links in Profile box. You can edit the entries in this box if need be.



5. Click the **OK** button to create the plot, showing the water surface profile as it exists at the simulation time currently selected in the Map Browser.



Press the Toggle icon to show the simulation HGL



As you move through time using the Map Browser or with the Animator control, the water depth profile on the plot will be updated. Observe how node **J2** becomes flooded between hours 2 and 3 of the storm event.

The appearance of a profile plot can be customized or it can be copied or printed using the same procedures as for a time series plot.

In the analysis just run we chose to use the Kinematic Wave method of routing flows through our drainage system. This is an efficient but simplified approach that cannot deal with such phenomena as backwater effects, pressurized flow, flow reversal, and non-dendritic layouts. SWMM also includes a Dynamic Wave routing procedure that can represent these conditions. This procedure, however, requires more computation time, due to the need for smaller time steps to maintain numerical stability.

Most of the effects mentioned above would not apply to our example. However we had one conduit, **C2**, that flowed full and caused its upstream junction to flood. It could be that this pipe is actually being pressurized and could therefore convey more flow than was computed using Kinematic Wave routing. We would now like to see what would happen if we apply Dynamic Wave routing instead.

To run the analysis with Dynamic Wave routing:

1. From the Project Browser, select the Options category and click the button.

2. On the General page of the Simulation Options dialog that appears, select **Dynamic Wave** as the flow routing method.

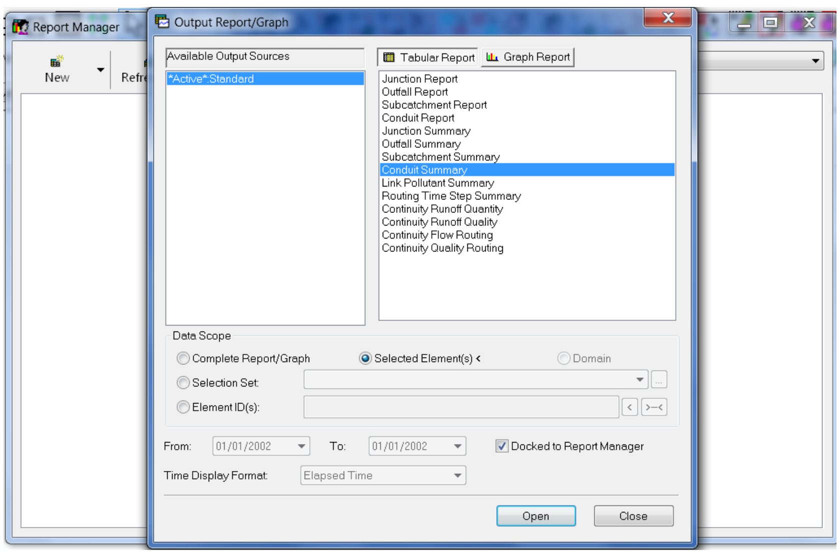
3. Click **OK** to close the form and select **Project | Run Simulation** (or click the button) to re-run the analysis. *Normally when running a Dynamic Wave analysis, one would also want to reduce the routing time step (on the Time Steps page of the dialog) and perhaps select the Variable Time Step option (on the Dynamic Wave page of the dialog) as well.*

If you look at the Status Report for this run you will see that there is no longer any flooding and that the peak flow carried by conduit **C2** has been increased from 3.52 cfs to 4.05 cfs.

```
**************************        Volume         Volume
Flow Routing Continuity          acre-feet      10^6 gal
**************************       ---------      ---------
Dry Weather Inflow .......           0.000          0.000
Wet Weather Inflow .......           1.257          0.410
Groundwater Inflow .......           0.000          0.000
RDII Inflow ..............           0.000          0.000
External Inflow ..........           0.000          0.000
External Outflow .........           1.257          0.410
Flooding Loss ............           0.000          0.000
Evaporation Loss .........           0.000          0.000
Exfiltration Loss ........           0.000          0.000
Initial Stored Volume ....           0.000          0.000
Final Stored Volume ......           0.000          0.000
Continuity Error (%) .....           0.007
```

```
********************
  Link Flow Summary
********************

-------------------------------------------------------------------------------------------------------------------------------------------
                                 Maximum  Time of Max      Maximum  Time of Max   Max/   Maximum  Time of Max   Max/  Time of Max
                               |Run Flow|  Occurrence |Output Flow|  Occurrence   Full   |Veloc|  Occurrence   Full   Occurrence
Link                 Type            CFS  days hr:min          CFS  days hr:min   Flow   ft/sec  days hr:min  Depth  days hr:min
-------------------------------------------------------------------------------------------------------------------------------------------
C1                   CONDUIT        2.03     0  03:01         2.03     0  03:00   0.36     6.62     0  03:02   0.41     0  03:01
C2                   CONDUIT        3.52     0  02:15         3.52     0  02:15   1.07     4.91     0  03:14   1.00     0  02:16
C3                   CONDUIT        1.01     0  03:01         1.01     0  03:00   0.19     5.13     0  03:02   0.30     0  03:01
C4                   CONDUIT        4.39     0  02:16         4.36     0  02:15   0.37     6.27     0  02:16   0.42     0  02:15
```



In the next phase of this tutorial we will add water quality analysis to our example project. SWMM has the ability to analyze the buildup, washoff, transport and treatment of any number of water quality constituents. The steps needed to accomplish this are:

1. Identify the pollutants to be analyzed.

2. Define the categories of land uses that generate these pollutants.

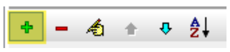
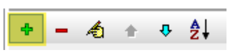
3. Set the parameters of buildup and washoff functions that determine the quality of runoff from each land use.

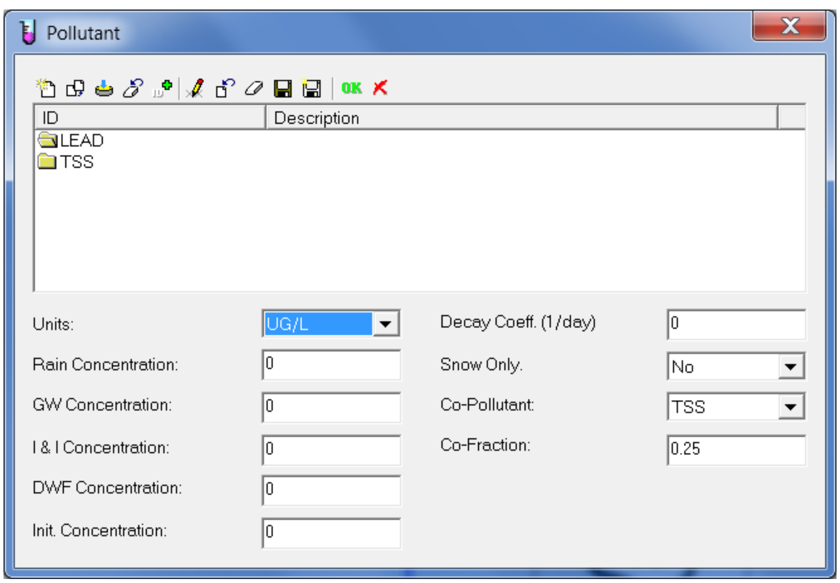
4. Assign a mixture of land uses to each subcatchment area

5. Define pollutant removal functions for nodes within the drainage system that contain treatment facilities.

We will now apply each of these steps, with the exception of number 5, to our example project. *Aside from direct runoff, EPA SWMM allows pollutants to be introduced into the nodes of a drainage system through:\n\r- user-defined time series of direct inflows\n\r- dry weather inflows\n\r- groundwater interflow\n\r- rainfall derived inflow\/infiltration*

For this tutorial example we will define two runoff pollutants; total suspended solids (TSS), measured as mg/L, and total Lead, measured in ug/L. In addition, we will specify that the concentration of Lead in runoff is a fixed fraction (0.25) of the TSS concentration. To add these pollutants to our project:

1. Under the Quality category in the Project Browser, select the **Pollutants** sub-category beneath it.
2. Click the  button to add a new pollutant to the project.
3. In the Pollutant Editor form that appears, enter **TSS** for the pollutant name and leave the other data fields at their default settings.
4. Click the **OK** button to close the Editor.
5. Click the  button on the Project Browser again to add our next pollutant.
6. In the Pollutant Editor, enter **Lead** for the pollutant name, select **ug/L** for the concentration units, enter **TSS** as the name of the Co-Pollutant, and enter **0.25** as the Co-Fraction value.
7. Click the **OK** button to close the Editor.

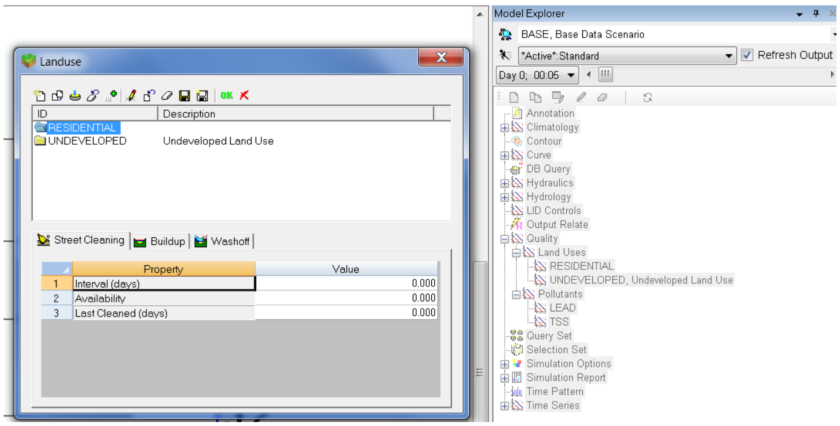


In SWMM, pollutants associated with runoff are generated by specific land uses assigned to subcatchments. In our example, we will define two categories of land uses: Residential and Undeveloped. To add these land uses to the project:

1. Under the Quality category in the Project Browser, select the Land Uses sub-category and click the  button.

2. In the Land Use Editor form that appears, enter **Residential** in the Name field and then click the **OK** button.

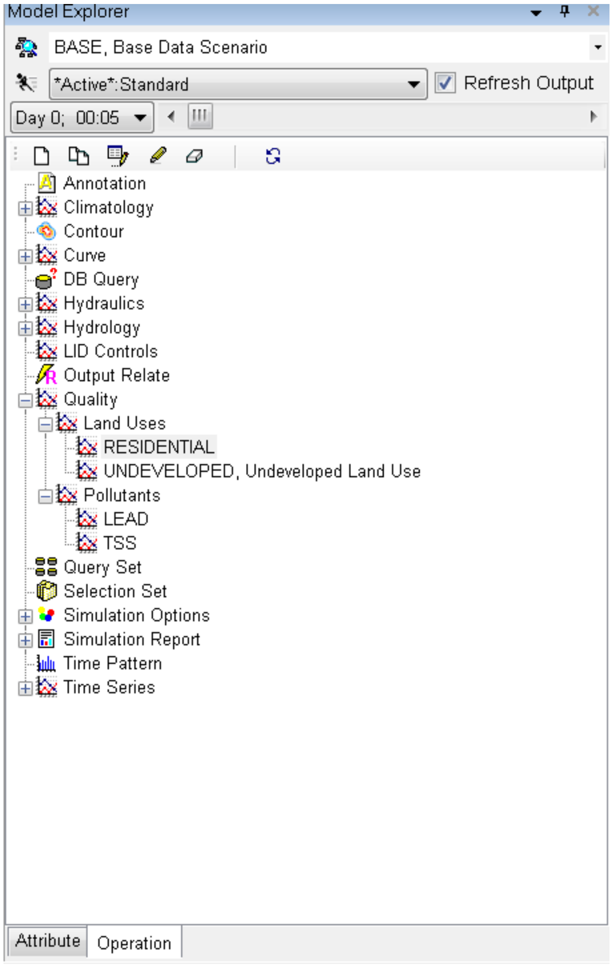
3. Repeat steps 1 and 2 for the **Undeveloped** land use category.



Next we need to define buildup and washoff functions for TSS in each of our land use categories. Functions for Lead are not needed since its runoff concentration was defined to be a fixed fraction of the TSS concentration. Normally, defining these functions requires site specific calibration.

In this example we will assume that suspended solids in Residential areas builds up at a constant rate of 1 pound per acre per day until a limit of 50 lbs per acre is reached. For the Undeveloped area we will assume that buildup is only half as much. For the washoff function, we will assume a constant event mean concentration of 100 mg/L for Residential land and 50 mg/L for undeveloped land. To define these functions for the Residential land use:

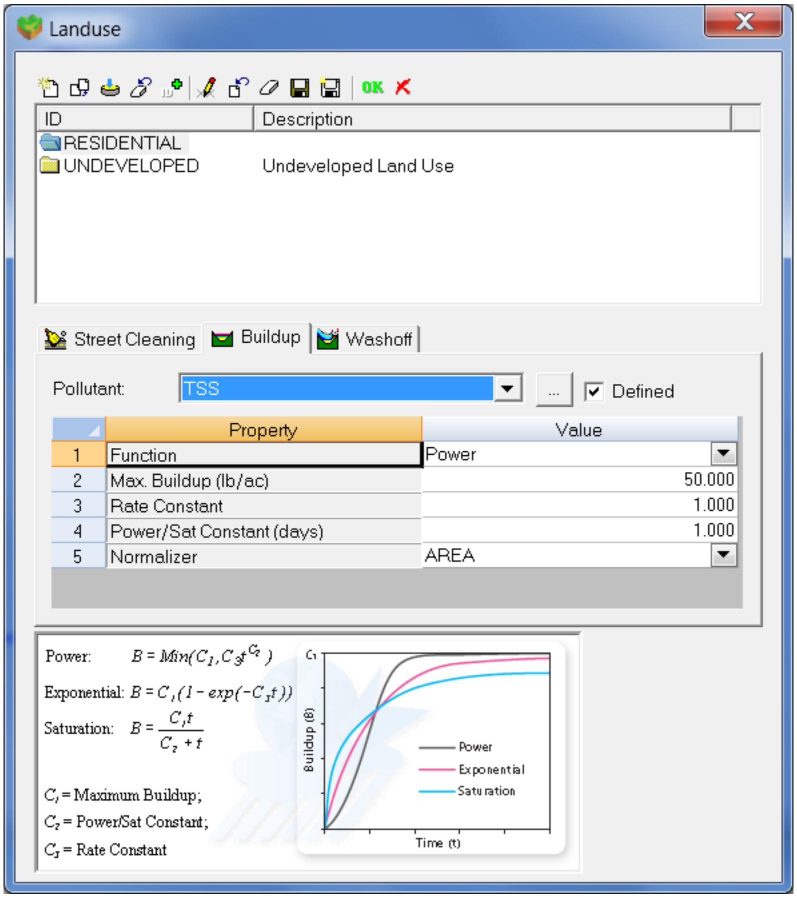
1. Select the **Residential** land use category from the Operations Tab of the Attribute Browser (AB).



2. In the Land Use Editor dialog, move to the Buildup page.

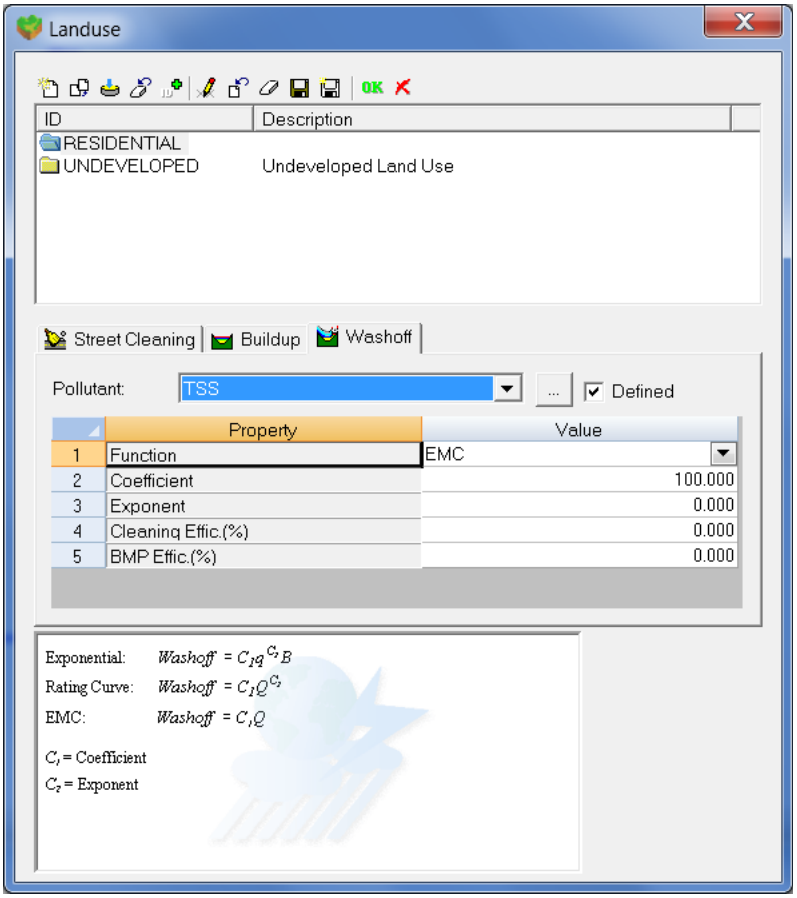
3. Select **TSS** as the pollutant and **POW** (for Power function) as the function type.

4. Assign the function a maximum buildup of **50**, a rate constant of **1.0**, a power of **1** and select **AREA** as the normalizer.



5. Move to the Washoff page of the dialog and select **TSS** as the pollutant, **EMC** as the function type, and enter **100** for the coefficient. Fill the other fields with **0**.

6. Click the **OK** button to accept your entries.



Now do the same for the **Undeveloped** land use category, except use a maximum buildup of **25**, a buildup rate constant of **0.5**, a buildup power of **1**, and a washoff EMC of **50**.

The final step in our water quality example is to assign a mixture of land uses to each subcatchment area:

1. Select subcatchment **S1** into the Property Editor.

2. Select the Land Uses property and click the ellipsis button (or press **Enter**).

3. In the Land Use Assignment form that appears, enter **75** for the % Residential and **25** for the % Undeveloped. Then click the **OK** button to close the dialog.

4. Repeat the same three steps for subcatchment **S2**.

5. Repeat the same for subcatchment **S3**, except assign the land uses as **25**% Residential and **75**% Undeveloped.

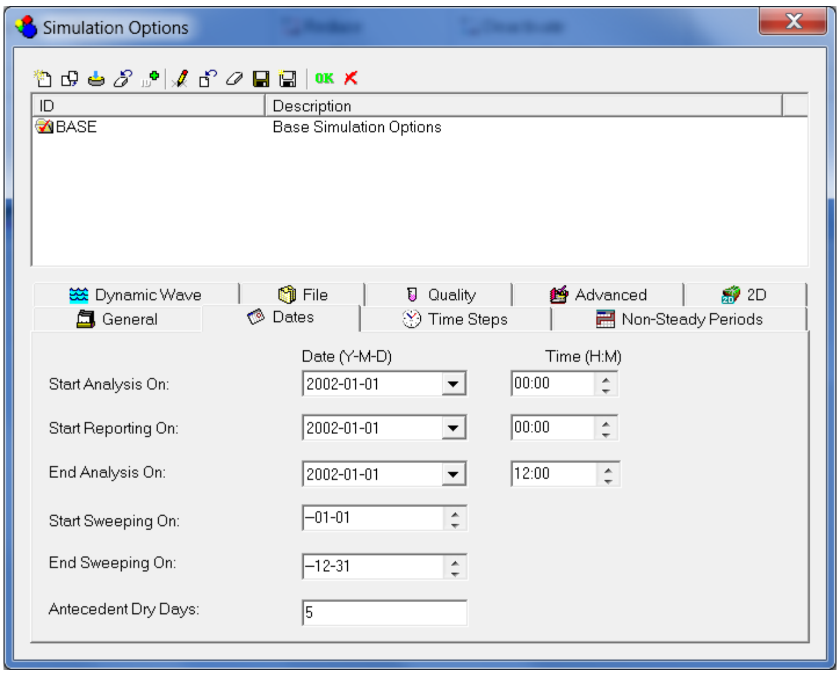
Before we simulate the runoff quantities of TSS and Lead from our study area, an initial buildup of TSS should be defined so it can be washed off during our single rainfall event. We can either specify the number of antecedent dry days prior to the simulation or directly specify the initial buildup mass on each subcatchment. We will use the former method:

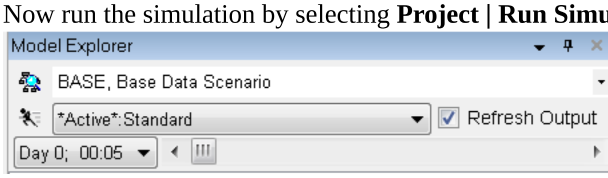
1. From the Options category of the Project Browser, select the Dates sub-category and click the  button.

2. In the Simulation Options dialog that appears, enter **5** into the Antecedent Dry Days field.

3. Leave the other simulation options the same as they were for the dynamic wave flow routing we just completed.

4. Click the **OK** button to close the dialog.



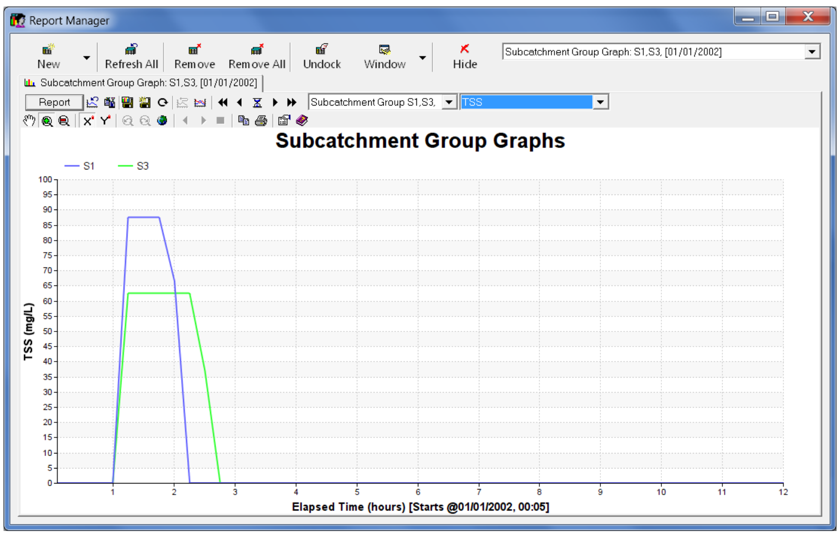
Now run the simulation by selecting **Project | Run Simulation** or by clicking 

on the InfoSWMM SA Attribute Browser (AB).

When the run is completed, view its Status Report. Note that two new sections have been added for Runoff Quality Continuity and Quality Routing Continuity. From the Runoff Quality Continuity table we see that there was an initial buildup of 47.5 lbs of TSS on the study area and an additional 2.2 lbs of buildup added during the dry periods of the simulation. About 48 lbs were washed off during the rainfall event. The quantity of Lead washed off is a fixed fraction (0.25 times 0.001 to convert from mg to ug) of the TSS as was specified.

```
**************************        TSS          LEAD
Runoff Quality Continuity         lbs           lbs
**************************    ----------    ----------
Initial Buildup ..........        47.500         0.000
Surface Buildup ..........         2.182         0.012
Wet Deposition ...........         0.000         0.000
Sweeping Removal .........         0.000         0.000
Infiltration Loss ........         0.000         0.000
BMP Removal ..............         0.000         0.000
Surface Runoff ...........        47.896         0.012
Remaining Buildup ........         1.786         0.000
Continuity Error (%) .....         0.000         0.000
```

If you plot the runoff concentration of TSS for subcatchment **S1** and **S3** together on the same time series graph you will see the difference in concentrations resulting from the different mix of land uses in these two areas. You can also see that the duration over which pollutants are washed off is much shorter than the duration of the entire runoff hydrograph (i.e., 1 hour versus about 6 hours). This results from having exhausted the available buildup of TSS over this period of time.



As a final exercise in this tutorial we will demonstrate how to run a long term continuous simulation using a historical rainfall record and how to perform a statistical frequency analysis on the results. The rainfall record will come from a file named sta310301.dat which was included with the example data sets provided with EPA SWMM. It contains several years of hourly rainfall beginning in January 1998. The data are stored in the National Climatic Data Center's DSI 3240 format which SWMM can automatically recognize. *The example data sets can be found in My Documents | EPA SWMM Projects | Examples*

To run a continuous simulation with this rainfall record:

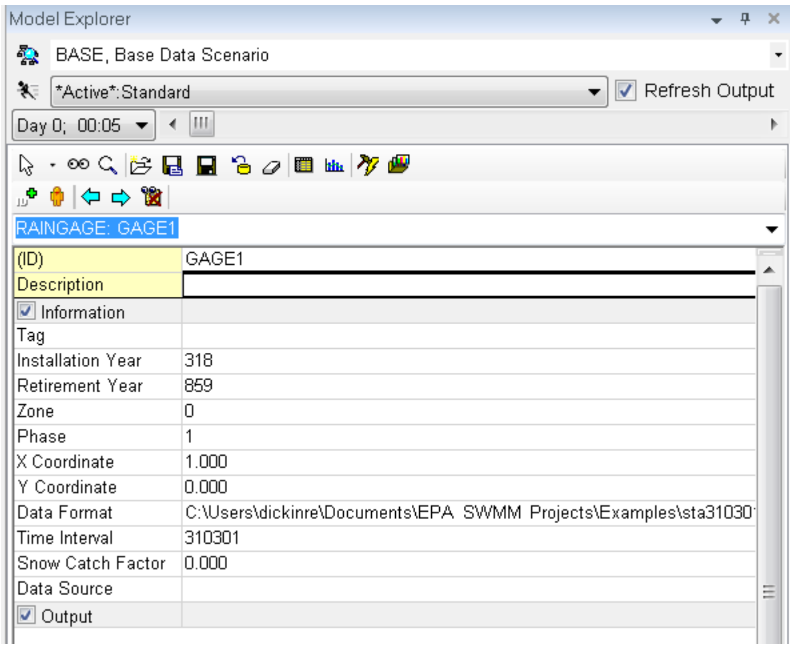
1. Select the rain gage **Gage1** into the Property Editor.

2. Change the selection of Data Source to **FILE**.

3. Select the File Name data field and click the ellipsis button (or press the **Enter** key) to bring up a Windows File Selection dialog.

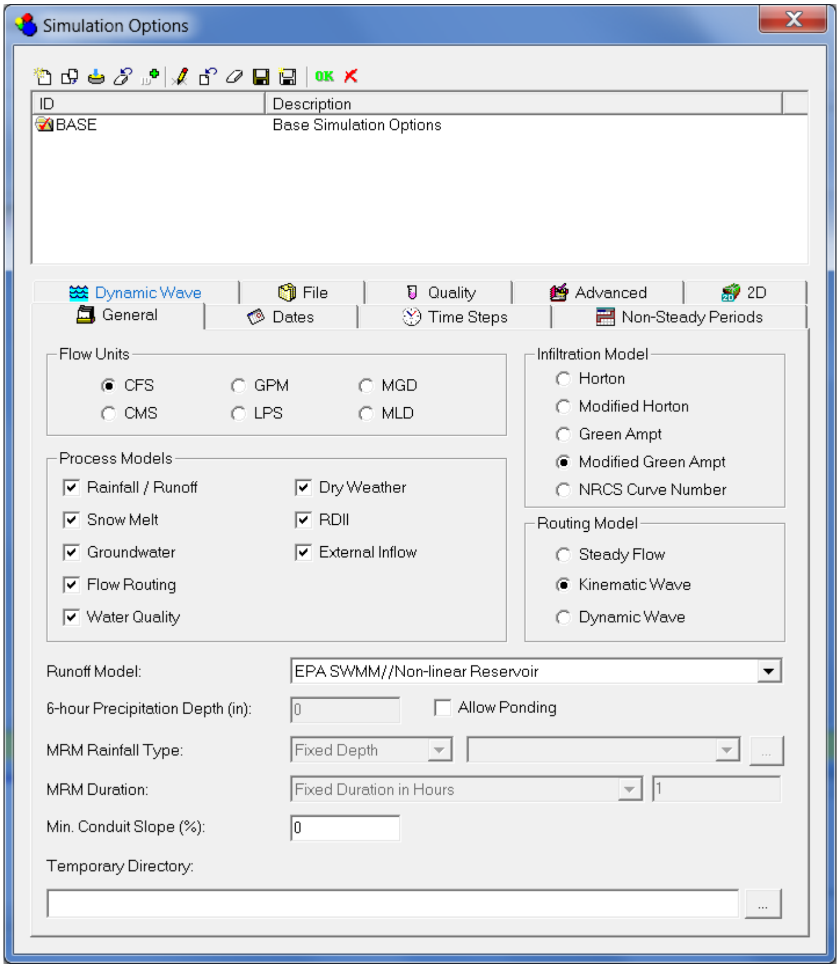
4. Navigate to the folder where the SWMM example files were stored, select the file named **sta310301.dat**, and click **Open** to select the file and close the dialog.

5. In the Station No. field of the Property Editor enter **310301**.

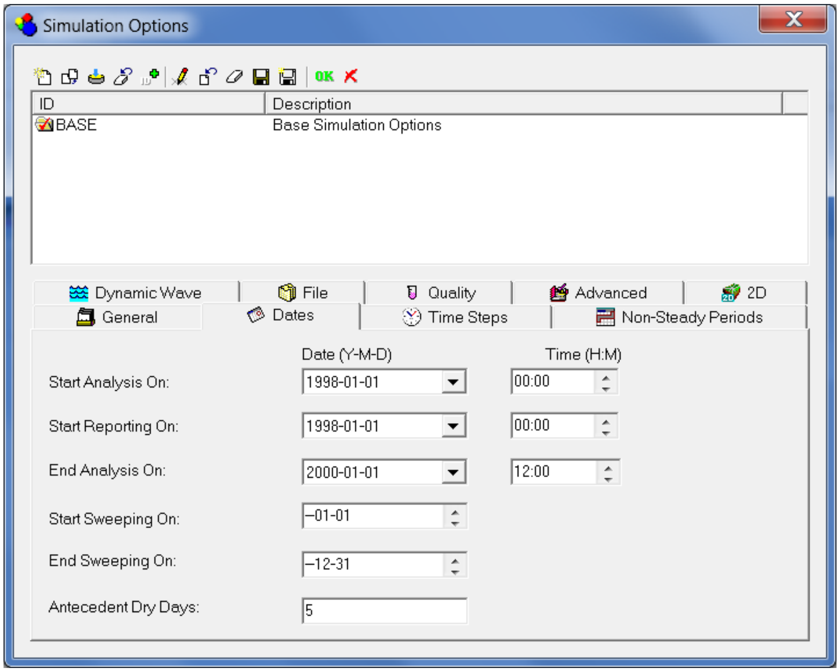


6. Select the Options category in the Project Browser and click the  button to bring up the Simulation Options form.

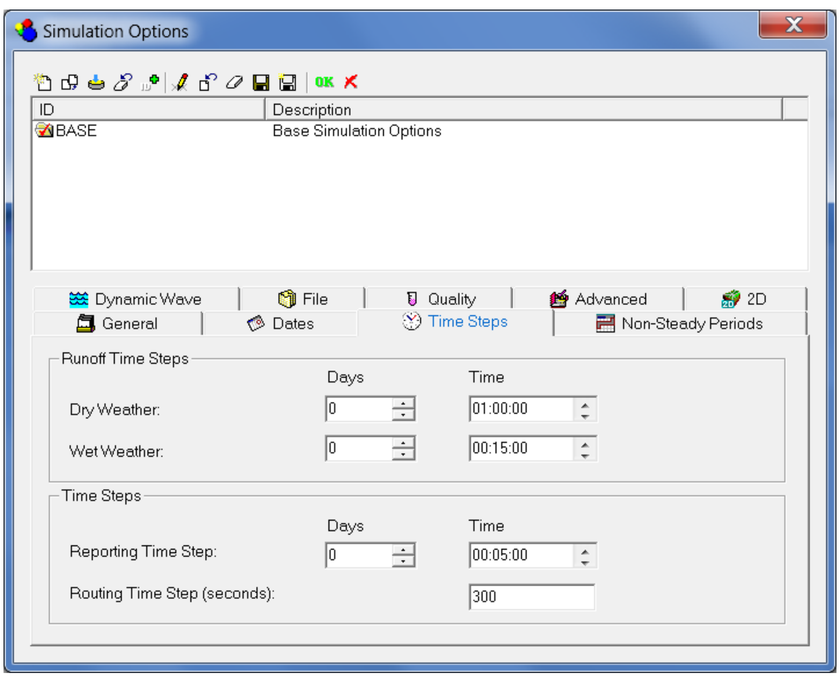
7. On the General Tab of the Run Manager, select **Kinematic Wave** as the Routing Method (this will help speed up the computations).

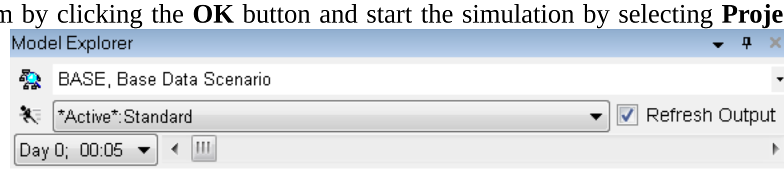


8. On the Dates page of the form, set both the Start Analysis and Start Reporting dates to **01/01/1998**, and set the End Analysis date to **01/01/2000**.



9. On the Time Steps page of the form, set the Routing Time Step to **300** seconds.

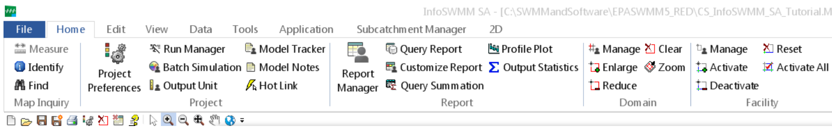


10. Close the Simulation Options form by clicking the **OK** button and start the simulation by selecting **Project | Run Simulation** (or by clicking 

on the Standard Toolbar).

After our continuous simulation is completed we can perform a statistical frequency analysis on any of the variables produced as output. For example, to determine the distribution of rainfall volumes within each storm event over the two-year period simulated:

1. Select **Report | Statistics** or click the button on the Standard Toolbar.

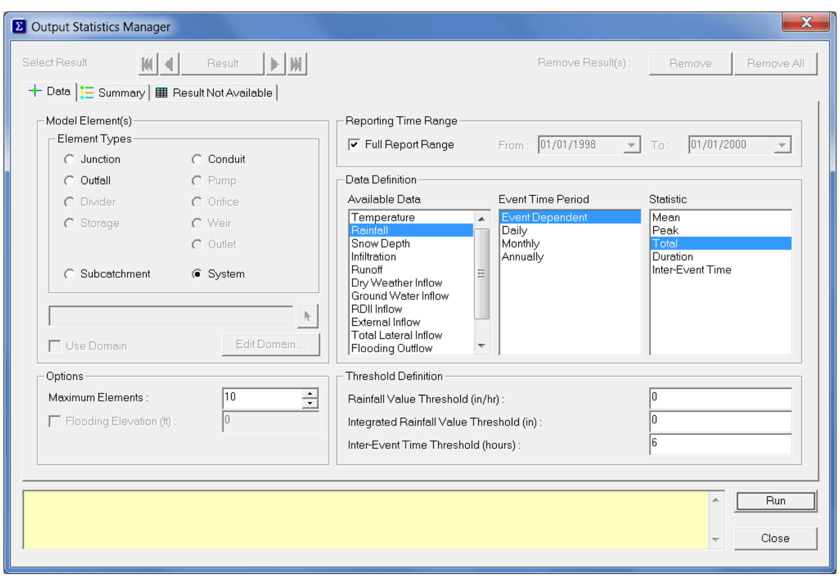


2. In the Statistics Selection form that appears, enter the values as shown below:

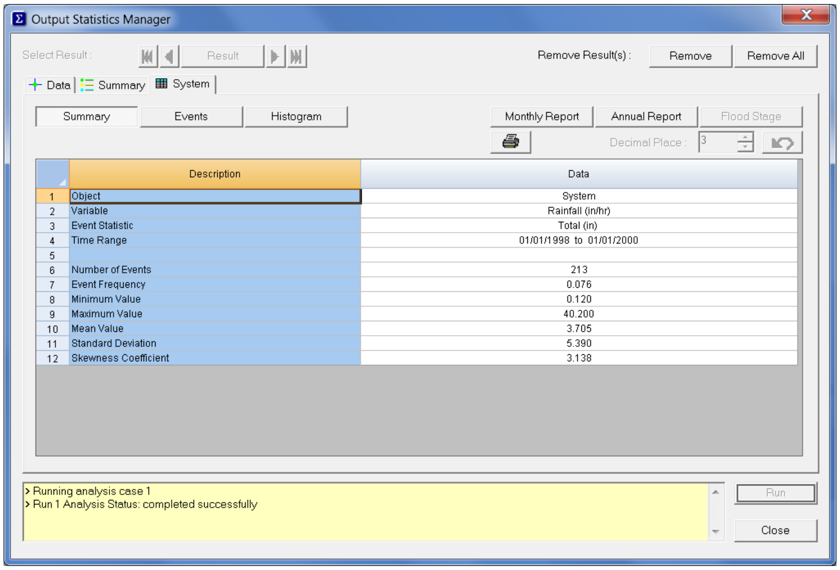
Object Category:	System
Variable Analyzed:	Precipitation
Event Time Period:	Event-Dependent
Statistic:	Total
Event Thresholds:	
Rainfall	0
Event Volume	0
Inter-Event Hours	6

This will identify the rainfall volume from each event which is separated by 6 or more hours without rainfall.

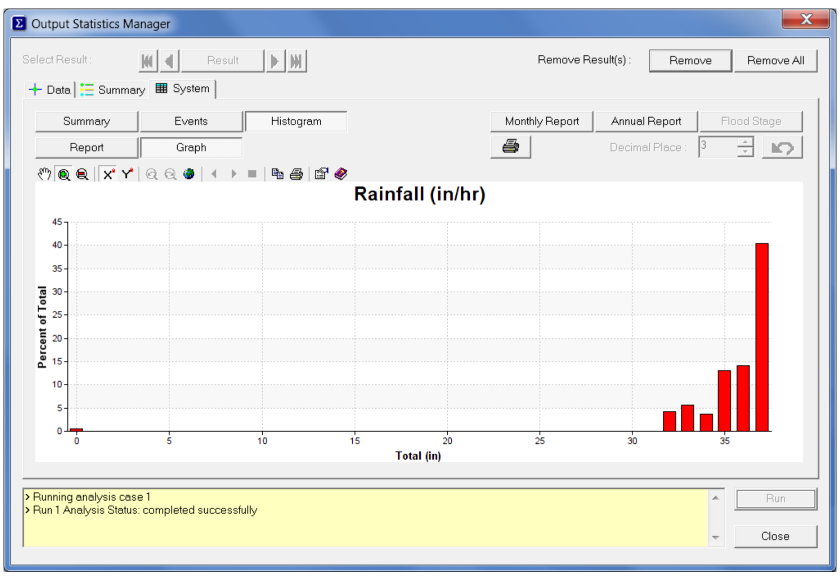
3. Click the **Run** button to close the form.



The results of this request will be a Statistics Report form containing four tabbed pages: a Summary page, a page containing a rank-ordered listing of each event, a page containing a histogram of the occurrence frequency versus event magnitude, and a Frequency Plot page that plots event magnitude versus cumulative frequency.



The Summary page shows that there was a total of 213 rainfall events. The Events page shows that the largest rainfall event had a volume of 3.35 inches and occurred over a 24- hour period. There were no events that matched the 3-inch, 6-hour design storm event used in our previous single-event analysis which had produced some internal flooding. In fact, the status report for this continuous simulation indicates that there were no flooding or surcharge occurrences over the simulation period.



We have only touched the surface of InfoSWMM SA's capabilities. Some additional features of the program that you will find useful include:

- utilizing additional types of drainage elements, such as storage units, flow dividers, pumps, and regulators, to model more complex types of systems
- using control rules to simulate real-time operation of pumps and regulators

- employing different types of externally-imposed inflows at drainage system nodes, such as direct time series inflows, dry weather inflows, and rainfall-derived inflow/infiltration

- modeling groundwater interflow between aquifers beneath subcatchment areas and drainage system nodes

- modeling snow fall accumulation and melting within subcatchments

- adding calibration data to a project so that simulated results can be compared with measured values

- utilizing a background street, site plan, or topo map to assist in laying out a system's drainage elements and to help relate simulated results to real-world locations.

You can find more information on these and other features in the InfoSWMM SA User's Manual.

HAPPY InfoSWMM SA Modeling or Modelling!

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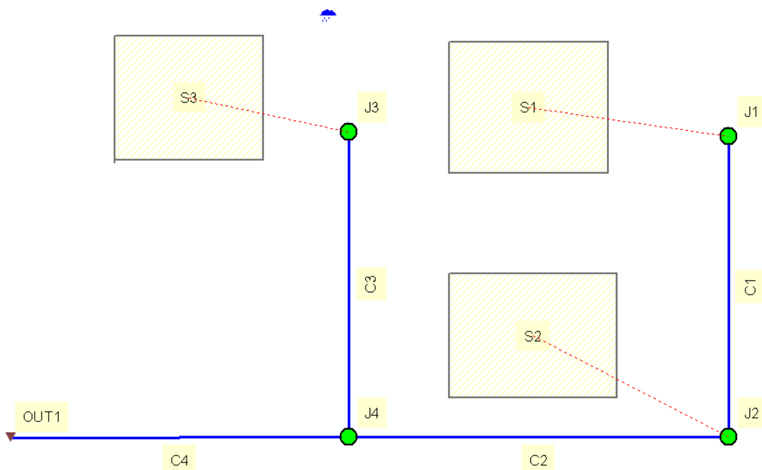
InfoSWMM for the EPA SWMM5 Tutorial

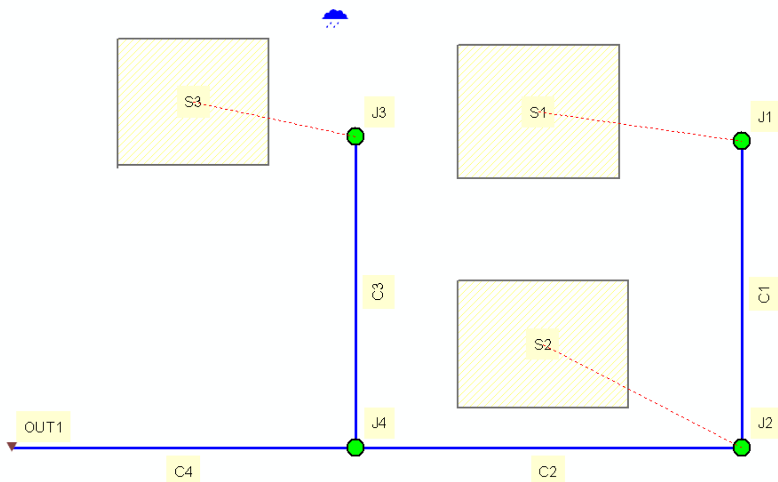
This is a one HTML file version of the SWMM 5 Tutorial for InfoSWMM (Esri Extension) for modeling the quantity and quality of stormwater runoff produced from urban areas. More images have been added to the EPA SWMM tutorial and this particular tutorial is an introduction to the InfoSWMM GUI. The topics to be covered include:

- Constructing a InfoSWMM Model
- Setting the Properties of InfoSWMM Objects
- Saving and Opening Projects
- Running a Single Event Analysis
- Viewing Simulation Results
- Simulating Runoff Water Quality
- Running a Continuous Simulation



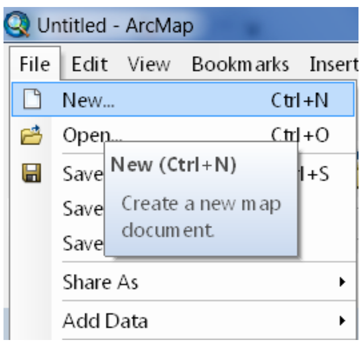
In this tutorial we will model the drainage system serving a 12 acre residential area. The system layout is shown below and consists of subcatchment areas S1 through S3 A *subcatchment is an area of land containing a mix of pervious and impervious surfaces whose runoff drains to a common outlet point, which could be either a node of the drainage network or another subcatchment.* Storm sewer conduits C1 through C4, and conduit junctions J1 through J4. The system discharges to a creek at the point labeled Out1. We will first go through the steps of creating the objects shown in this diagram on InfoSWMM SA's Study Area Map and setting the various properties of these objects. Then we will simulate the water quantity and quality response to a 3-inch, 6-hour rainfall event, as well as a continuous, multi-year record.

You can click the **View Map** button that appears in each topic's header panel to refer to this drawing at any time.



Use the button

Our first task is to create a new project in InfoSWMM and make sure that certain default options are selected. Using these defaults will simplify the data entry tasks later on.



1. Launch InfoSWMM if it is not already running and select **File | New Project** to create a new project. Use these coordinates so that it matches the EPA SWMM5 coordinate system.

   Name: Unknown

   Alias:

   Abbreviation:

   Remarks:

   Factory Code: 0

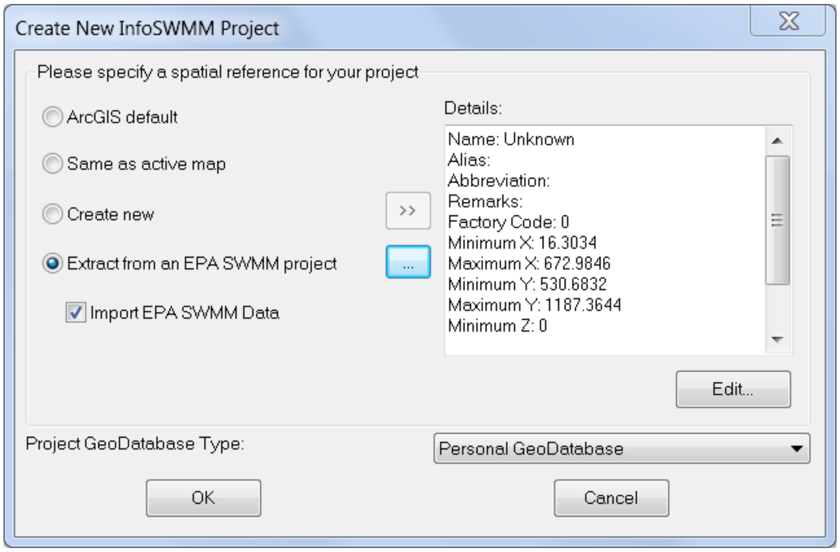
   Minimum X: -124.414

   Maximum X: 813.702

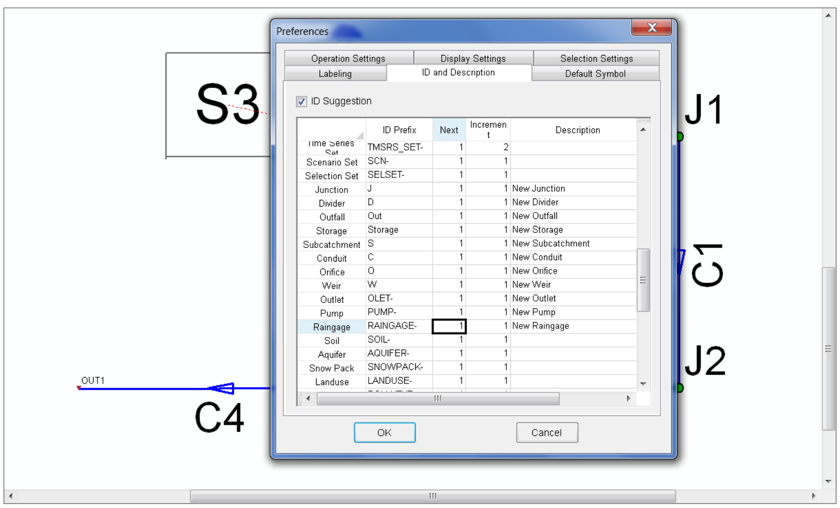
   Minimum Y: 451.8705

   Maximum Y: 1389.9865

   Minimum Z: 0



2. Select Home / **Project Preferences / ID and Description** to open the **ID and Description** dialog



3. On the **ID and Description** dialog, set the ID Prefixes as follows (leave the others at their default):

Rain Gages: Gage

Subcatchments: S

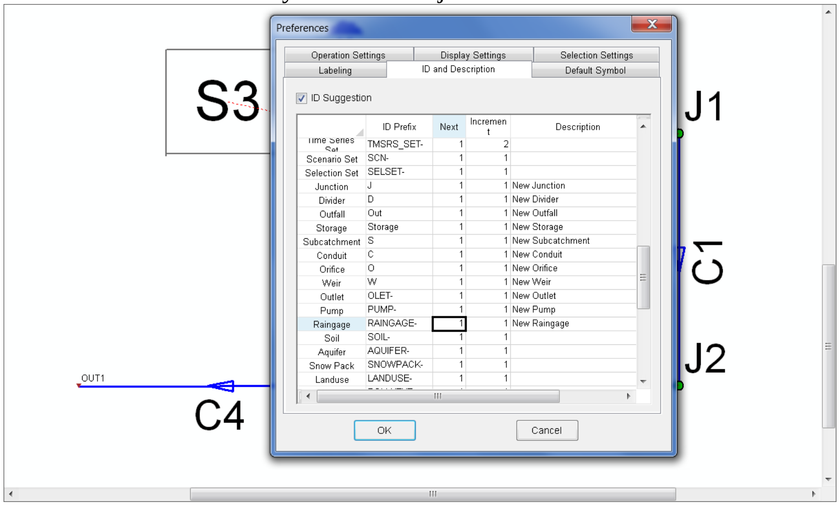
Junctions: J

Outfalls: Out

Conduits: C

ID Increment: 1

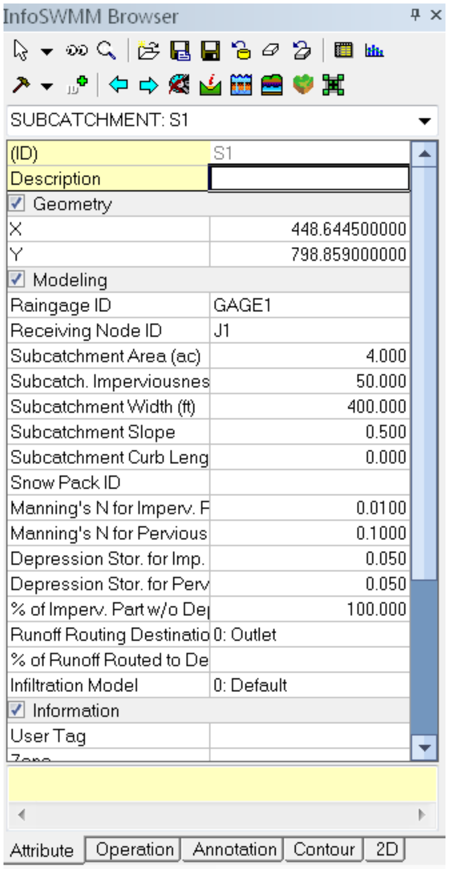
This will make InfoSWMM SA automatically label new objects with consecutive numbers following the



designated prefix.

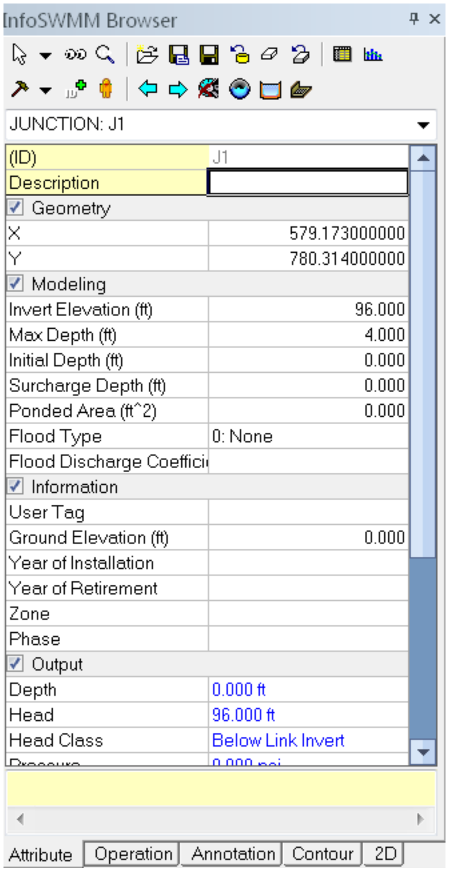
4. On the Subcatchments page of the dialog set the following default values:

Area:	4
Width:	400
% Slope:	0.5
% Imperv:	50
N-Imperv:	0.01
N-Perv:	0.10
Dstore-Imperv:	0.05
Dstore-Perv:	0.05
%Zero-Imperv:	25.0
Infil. Model	<click to edit>
Method:	Modified Green-Ampt
Suction Head:	3.5
Conductivity:	0.5
Initial Deficit:	0.26



5. On the Nodes/Links page set the following default values:

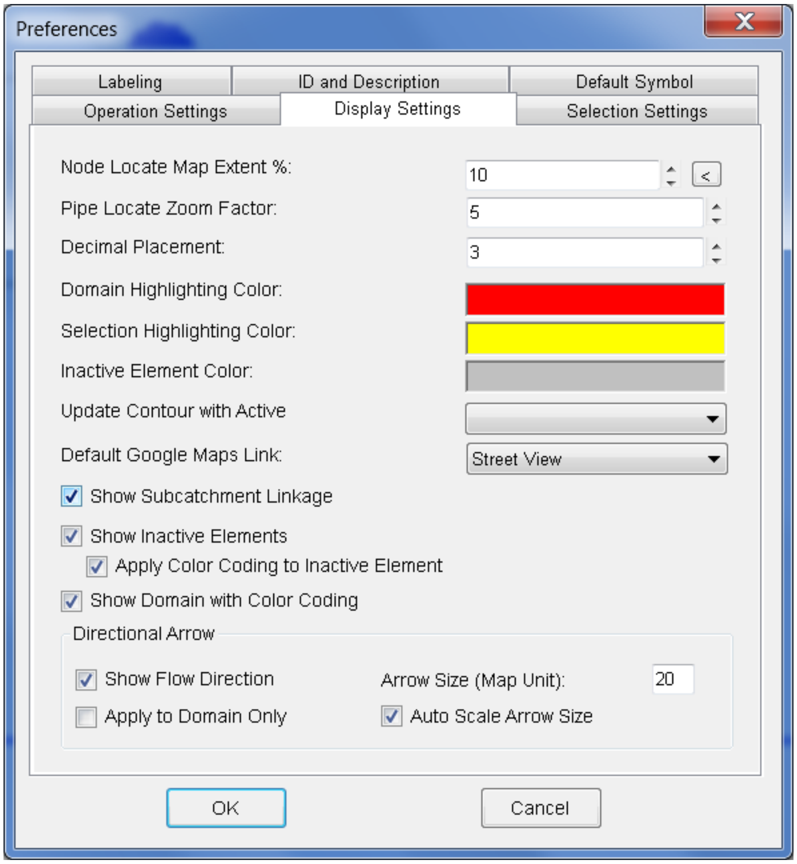
Node Invert:	0
Node Max. Depth:	4
Node Ponded Area	0
Conduit Length:	400
Conduit Geometry:	<click to edit>
Shape:	Circular
Max. Depth:	1.0
Barrels	1
Conduit Roughness:	0.01
Flow Units:	CFS
Link Offsets:	DEPTH
Routing Model:	Kinematic Wave



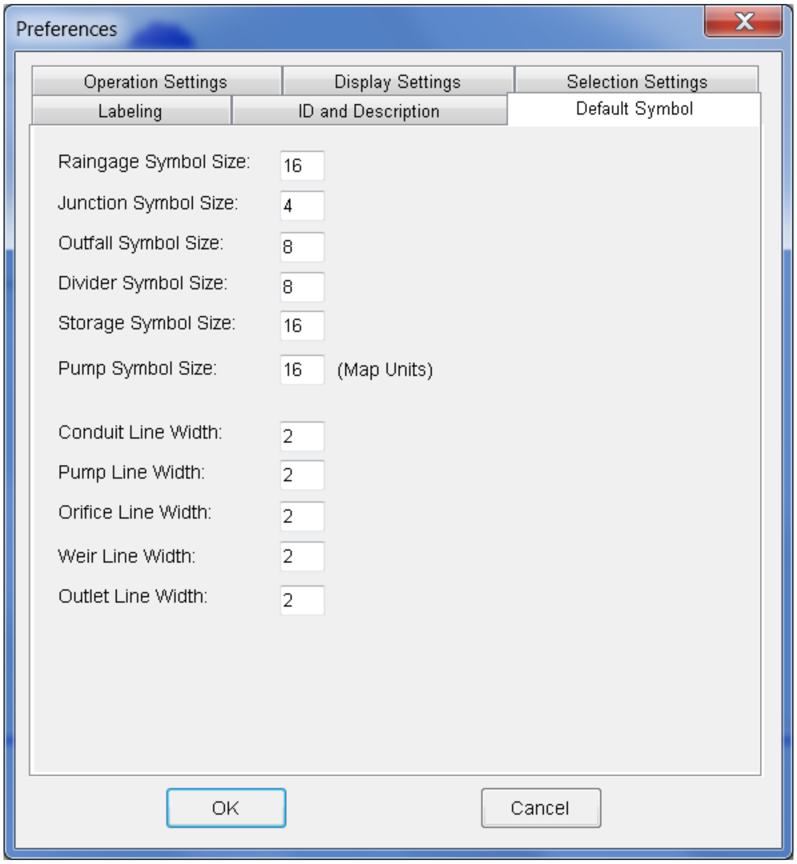
Click **OK** to accept these choices and close the dialog.

Next we will set some map display options so that ID labels and symbols will be displayed as we add objects to the study area map, and links will have direction arrows.

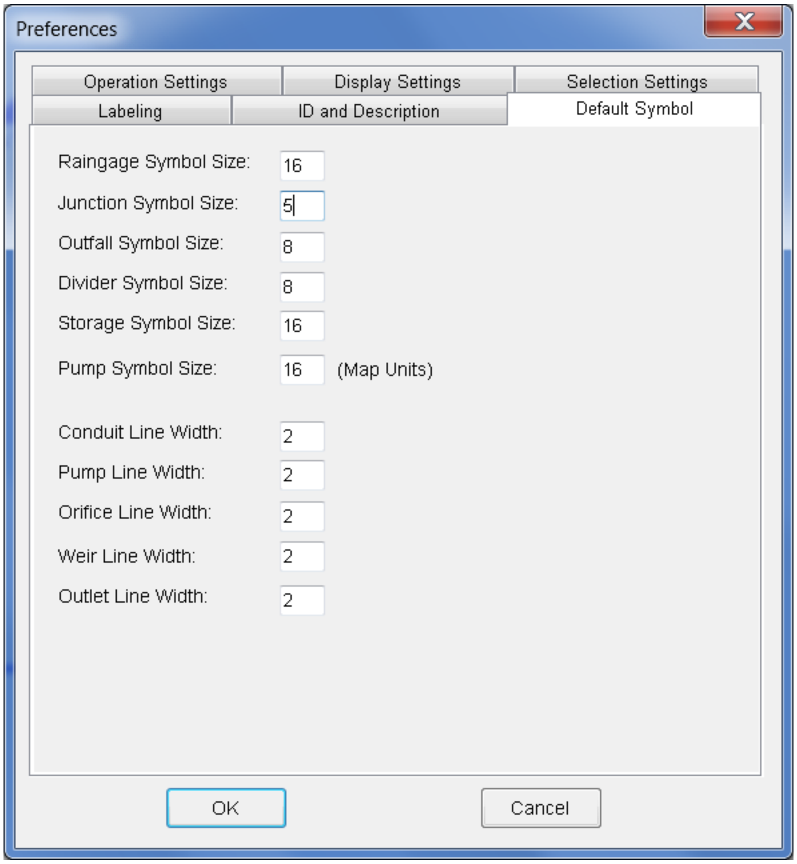
1. Select **Tools | Map Display Settings** to bring up the Display dialog.



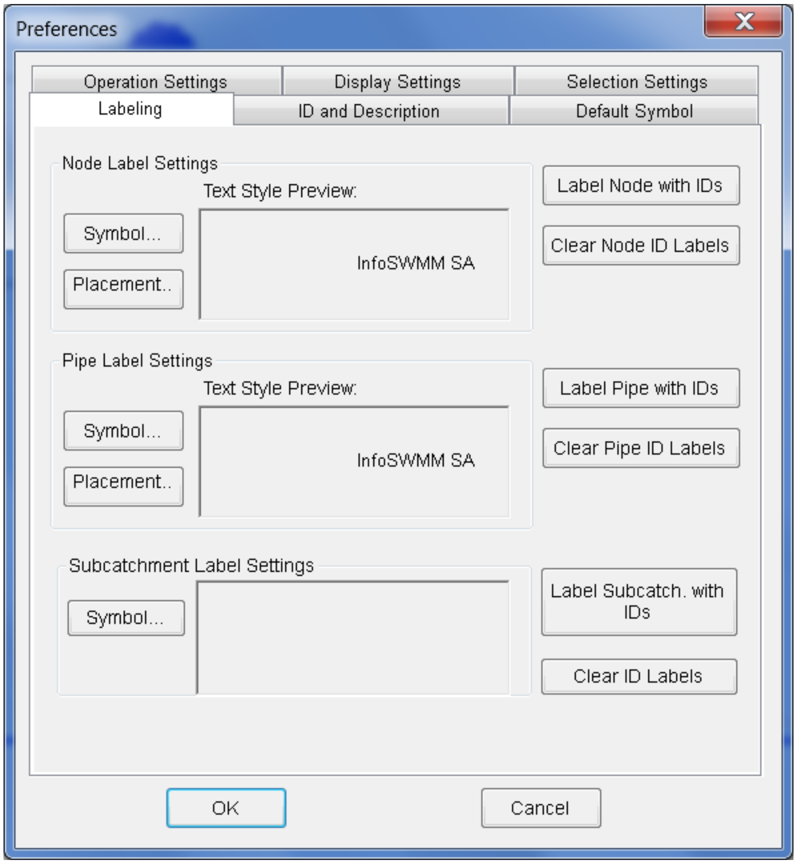
2. Select the Default Symbol Tab.



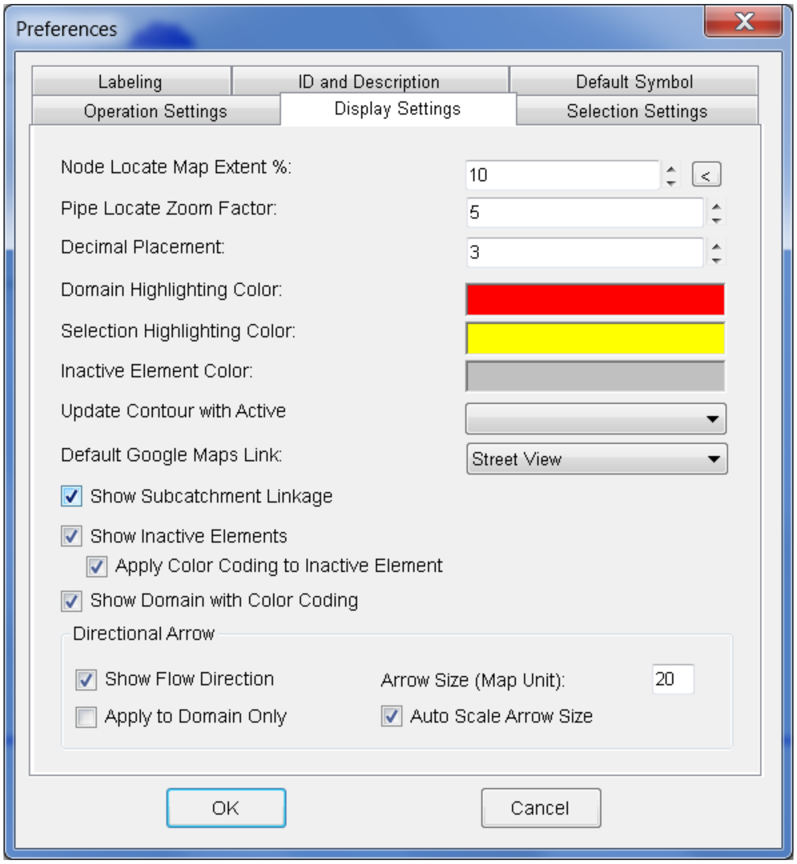
3. Then select the Select the Default Symbol Tab. and set the Node Size to **5**.



4. Select the Labeling Tab and check off the boxes that will display ID labels for Subcatchments, Rain Gages, Nodes, and Links.



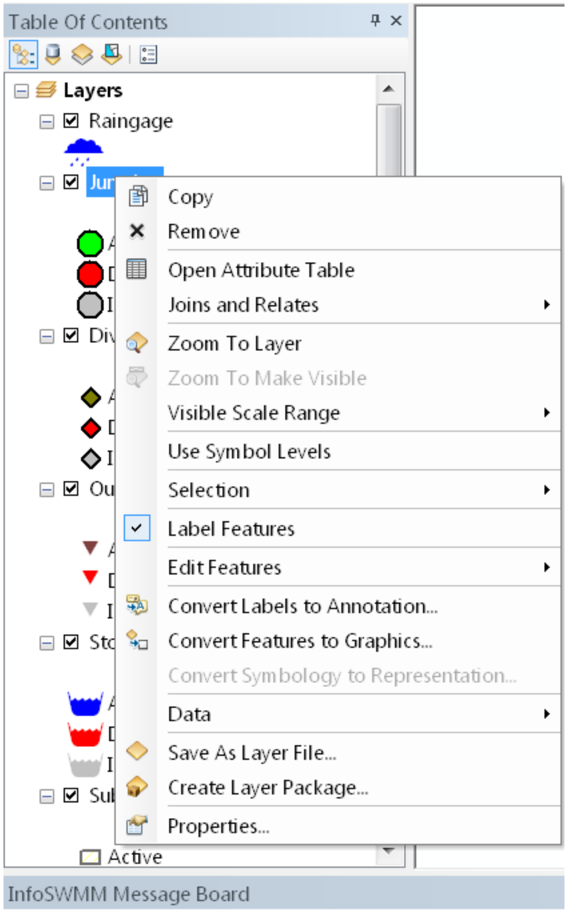
5. Finally, select the Flow Arrows page set the arrow size to **20**.

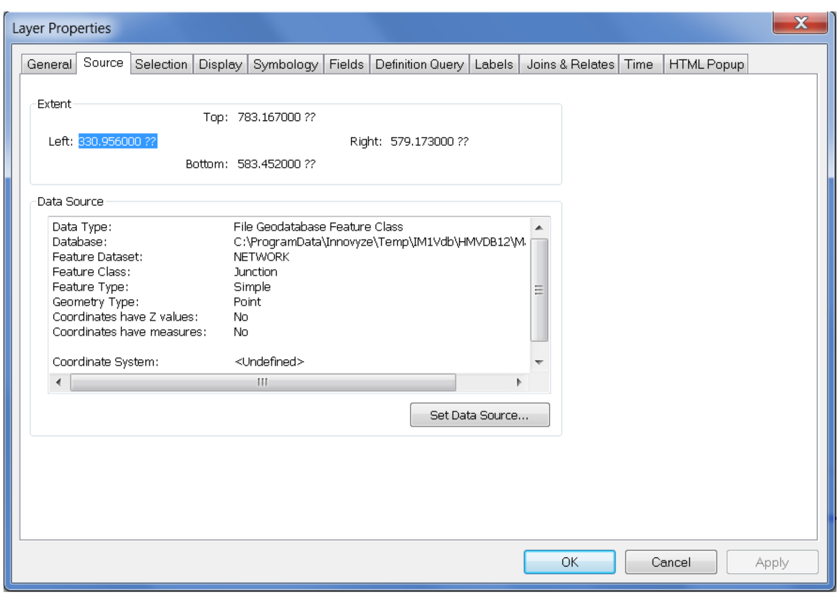


6. Click the **OK** button to accept these choices and close the Project Preferences dialog.

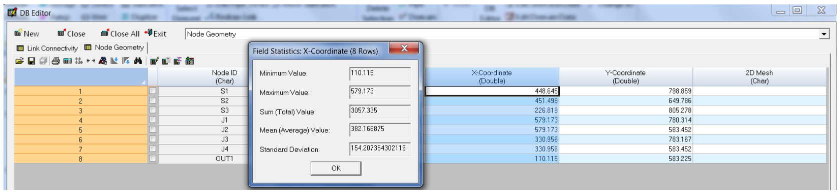
Before placing objects on the map we should set its dimensions.

1. Right mouse click on any InfoSWMM layer on the Arc Map Table of Contents (TOC) and show the Layer prc source tab will show the Extent of the layer.



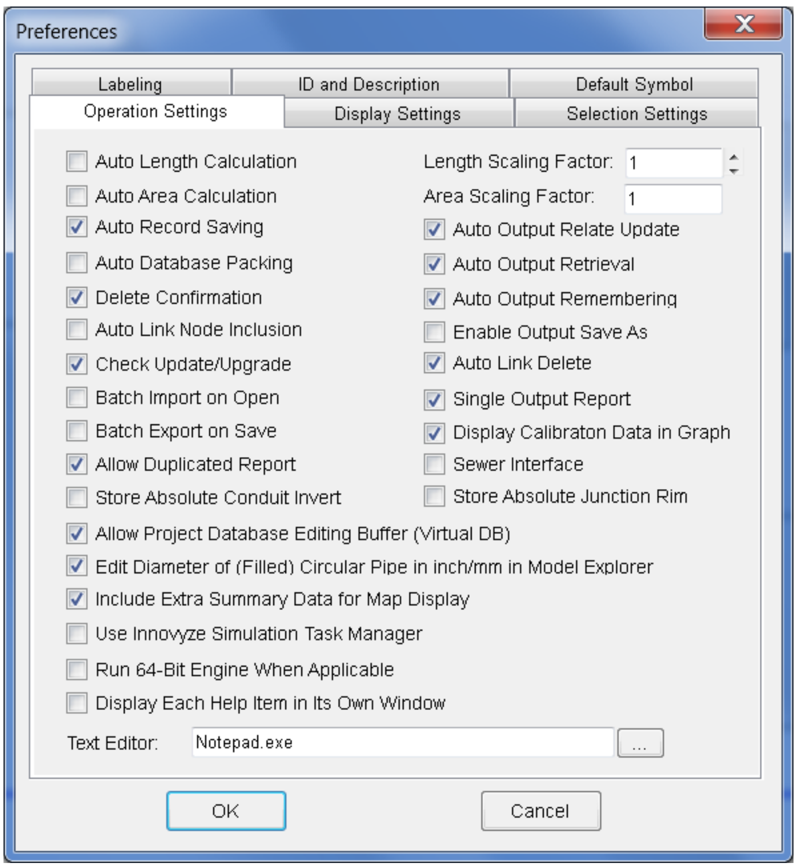


2. You can leave the dimensions at their default values for this example or the EPA Extents in the SWMM input file..



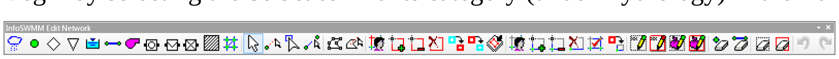
Finally, look in the status bar at the bottom of the main window and check that the Auto-Length Calculation feature is off. If it is on, then click the down arrow button and select "Auto-Length: Off" from the popup menu that appears. Also make sure that the Offsets option is set to Depth. If set to Elevation then click the down arrow button and select "Depth Offsets" from the popup menu that appears.

The equivalent commands in InfoSWMM are located in the Project Preferences dialog Operation Settings Tab. Turn off Auto Length Calculation and ensure that the flag for Store Absolute Conduit Invert is turned off.



We are now ready to begin adding components to the Study Area Map. We will start with the subcatchments. Remember that you can click the **View Map** button of this tutorial at any time to see how we want our map to look eventually. *Drawing objects on the map is just one way of creating a project. For large projects it will be more convenient to first construct an EPA SWMM project file external to the program. The project file is a text file that describes each object in a specified format as described in the Users Manual. Data extracted from various sources, such as CAD drawings or GIS files, can be used to create the project file.* ***This of course is very easy to do in InfoSWMM SA using GIS Gateway and Import Manager.***

1. Begin by selecting the **Subcatchments** category (under Hydrology) in the Edit Menu Toolbar.



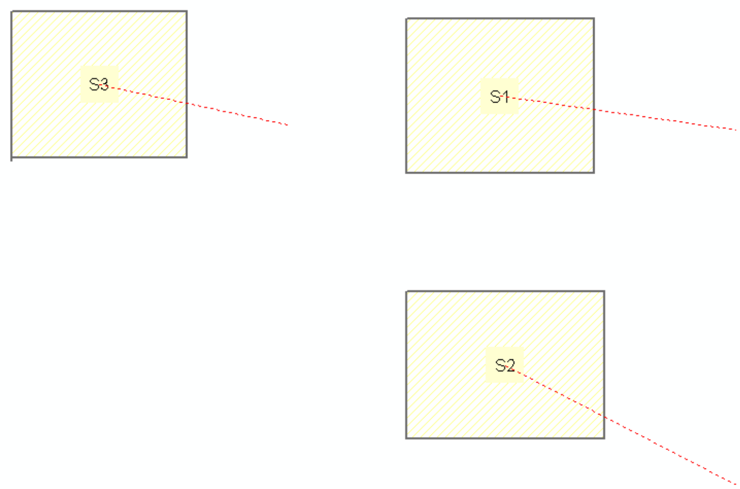
2. Then click the button on the toolbar underneath the object category listing in the Project panel (or select **Project | Add a New Subcatchment** from the Edit Ribbon Menu). Notice how the mouse cursor changes shape to a pencil when you move it over the map.

3. Move the mouse to the map location where one of the corners of subcatchment **S1** lies and left-click the mouse.

4. Do the same for the next three corners and then right-click the mouse (or hit the **Enter** key) to close up the rectangle that represents subcatchment **S1**. You can press the **Esc** key if instead you wanted to cancel your partially drawn subcatchment and start over again. Don't worry if the shape or position of the object isn't quite right. We will go back later and show how to fix this.

5. Next move the mouse to subcatchment **S2**'s location and draw its outline. Then repeat for subcatchment **S3**. If you right-click (or press Enter) after adding the first point of a subcatchment\'s outline, the subcatchment will be shown as just a single point.

Observe how sequential ID labels are generated automatically as we add objects to the map.

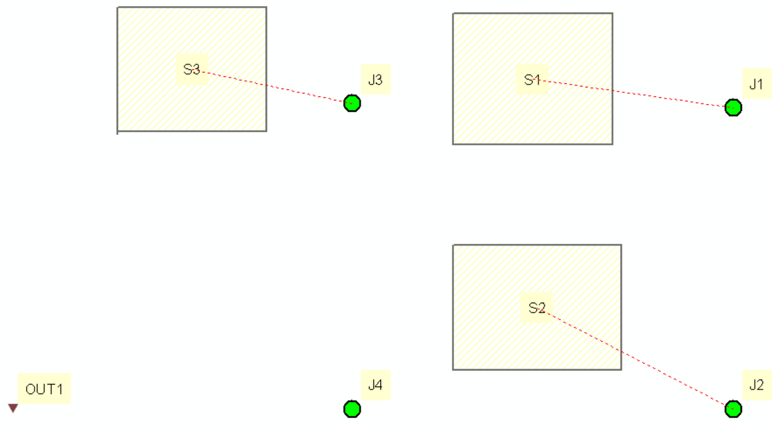


Next we will add in the junction nodes and the outfall node that comprise part of the drainage network.

1. To begin adding junctions, select the **Junctions** category from Edit Menu Ribbon and click the button or select **Project Add a New Junction** from the Edit Toolbar.

2. Move the mouse to the position of junction **J1** and left-click it. Do the same for junctions **J2** through **J4**.

3. To add the outfall node, select Outfalls from the Project Browser, click the button or select **Add a New Outfall** from the main menu, move the mouse to the outfall's location on the map, and left-click. Note how the outfall is automatically given the name **Out1**.



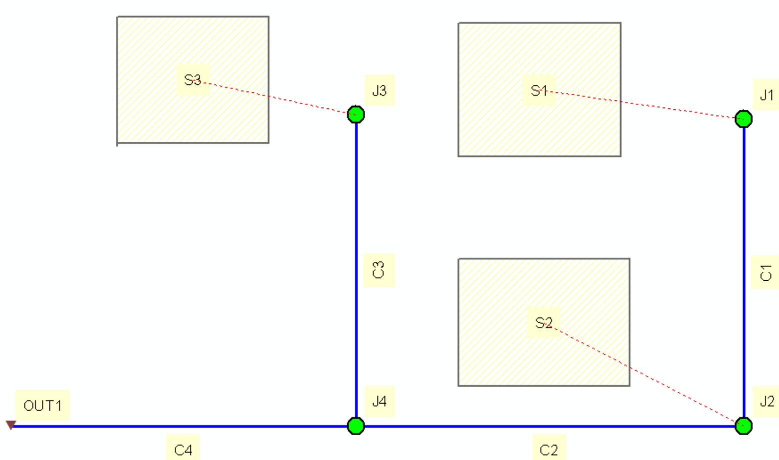
Now we will add the storm sewer conduits that connect our drainage system nodes to one another. (You must have created a link's end nodes as described in the previous topic before you can create the link.) We will begin with conduit **C1** which connects junction **J1** to **J2**.

1. Select the Conduits from Edit Toolbar Icon or select **Add a New Conduit** from the main menu. The mouse cursor will change shape to a cross hair when moved onto the map.

2. Left click the mouse on junction **J1**. Note how the mouse cursor now changes shape to a pencil.

3. Move the mouse over to junction **J2** (note how an outline of the conduit is drawn as you move the mouse) and left-click to create the conduit. You could have canceled the operation by either right-clicking or by hitting the **Esc** key.

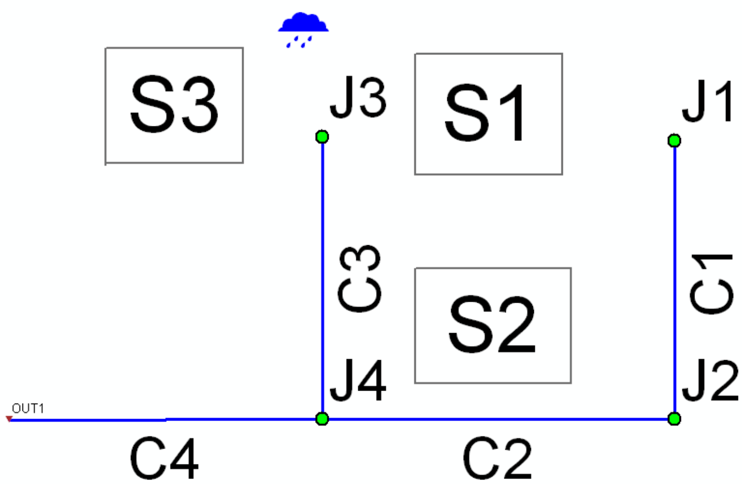
Repeat steps 2 and 3 for conduits **C2** through **C4**. *Although all of our conduits were drawn as straight lines, it is possible to draw a curved link by left-clicking at intermediate points where the direction of the link changes before clicking on the end node.*



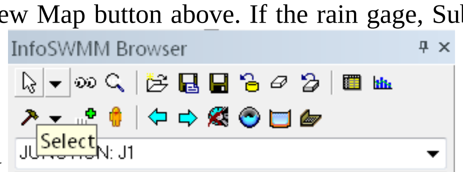
To complete the construction of our study area schematic we need to add a rain gage.

2. Move the mouse over the Study Area Map to where the gage should be located and left-click the mouse.

1. Select the Rain Gages category from the InfoSWMM Edit Network Toolbar and either click the button or select **Add a New Rain Gage** from the main menu.



At this point we have completed drawing the example study area. Your system should look like the one seen by pressing the View Map button above. If the rain gage, Subcatchments or nodes are out of position you can move



them around by

1. clicking the button on the InfoSWMM Attribute Browser (AB) to place the map in Object Selection mode,

2. clicking on the object to be moved,

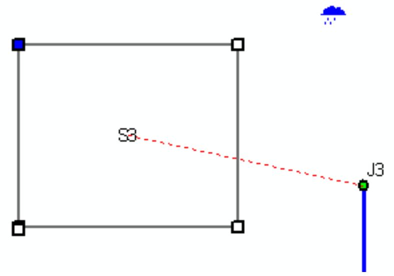
3. dragging the object with the left mouse button held down to its new position.

To re-shape a subcatchment's outline:

1. With the map in Object Selection mode, click on the subcatchment's centroid (indicated by a solid square within the subcatchment) to select it.

2. Then click the button on the Map Toolbar to put the map into Vertex Selection mode.

3. Select a vertex point on the subcatchment outline by clicking on it (note how the selected vertex is indicated by a filled solid square).



4. Drag the vertex to its new position with the left mouse button held down.

5. If need be, vertices can be added to or deleted from the outline by right-clicking the mouse and selecting the appropriate option from the popup menu that appears.

6. When finished, click the button to return to Object Selection mode.

This same procedure can also be used to re-shape a link. The redraw link icon on the InfoSWMM Edit Network.

As visual objects are added to our project, SWMM assigns them a default set of properties. To change the value of a specific property for an object we must select the object into the Property Editor (shown below). There are several different ways to do this. If the Editor is already visible then you can simply click on the object or select it from the Project Browser. If the Editor is not visible then you can make it appear by one of the following actions:

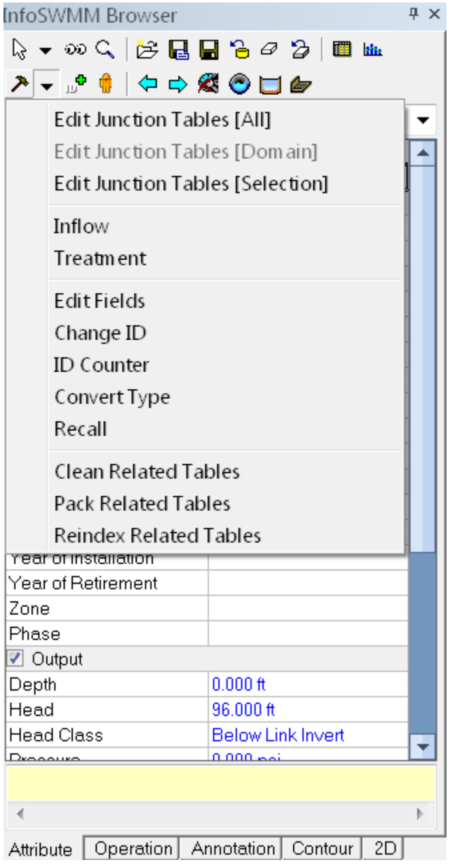
· double-click the object on the map

· Use the white arrow icon in Model Explorer to choose an element.

· select the object from the Project Browser and then click the Browser's button.

Whenever the Model Explorer has the focus you can press the F1 key to obtain a more detailed description of the properties listed.

Two key properties of our subcatchments that need to be set are the rain gage that supplies rainfall data to the subcatchment and the node of the drainage system that receives runoff from the subcatchment. Since all of our subcatchments utilize the same rain gage, **Gage1**, we can use a shortcut method to set this property for all subcatchments at once:



1. From the Edit Menu select DB Editor.

2. Then select **Entire Table to show all Active Junction Data.**

3. Select **Subcatchments** as the class of object to edit, **Raingage** as the property to edit, and type in **Gage1** as the new value.

4. Click **OK** to change the rain gage of all subcatchments to **Gage1**. A confirmation dialog will appear noting that 3 subcatchments have changed. Select **No** when asked to continue editing.

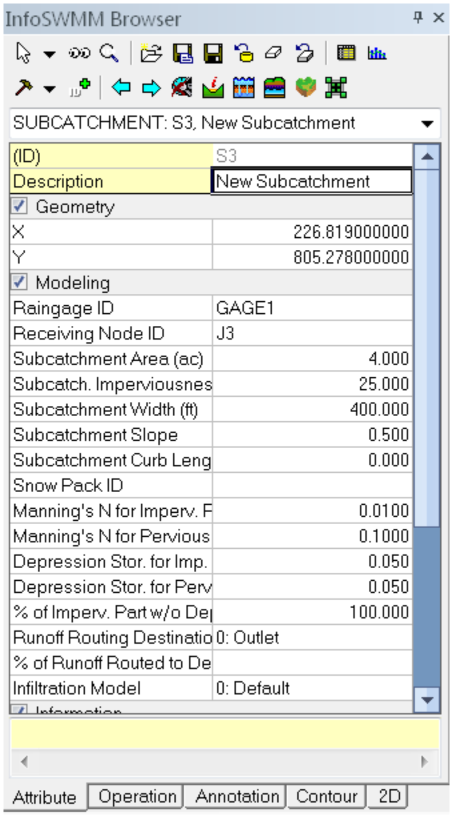
To set the outlet node of our subcatchments we have to proceed one by one, since these vary by subcatchment:

2. Type **J1** in the Outlet field and press **Enter**. Note how a dotted line is drawn between the subcatchment and the node.

3. Click on subcatchment **S2** and enter **J2** as its Outlet.

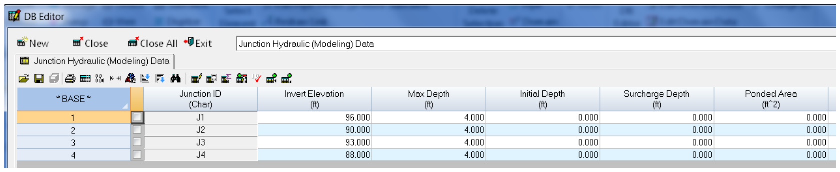
4. Click on subcatchment **S3** and enter **J3** as its Outlet.

Finally, we wish to represent area **S3** as being less developed than the others. Select **S3** into the Property Editor and set its % Imperviousness to **25**.

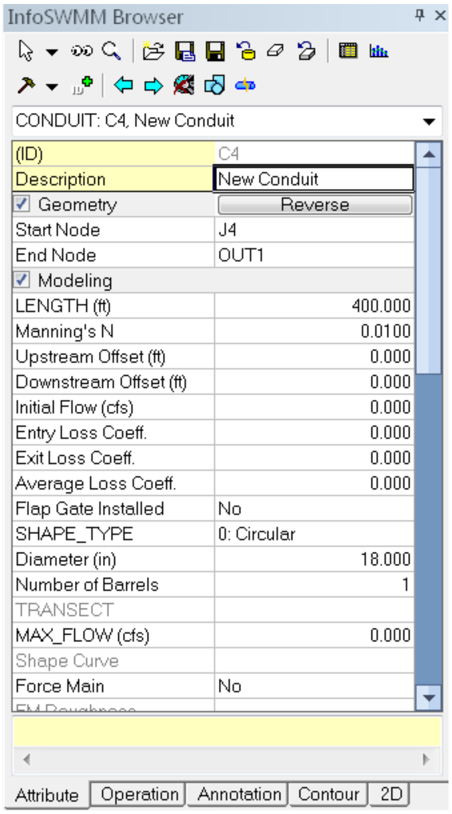


The junctions and outfall of our drainage system need to have invert elevations assigned to them. As we did with the subcatchments, select each junction individually into the Property Editor and set its **Invert Elevation** to the value shown in the table below. *An alternative way to move from one object of a given type to the next in order (or to the previous one) in the Property Editor is to hit the Page Down (or Page Up) key.*

Node	**Invert**
J1	**96**
J2	**90**
J3	**93**
J4	**88**
Out1	**85**



Only one of the conduits in our example system has a non-default property value. This is conduit **C4**, the outlet pipe, whose diameter should be 1.5 ft. instead of 1 ft. To change its diameter, select conduit **C4** into the Property Editor and set the Max. Depth value to **1.5**.



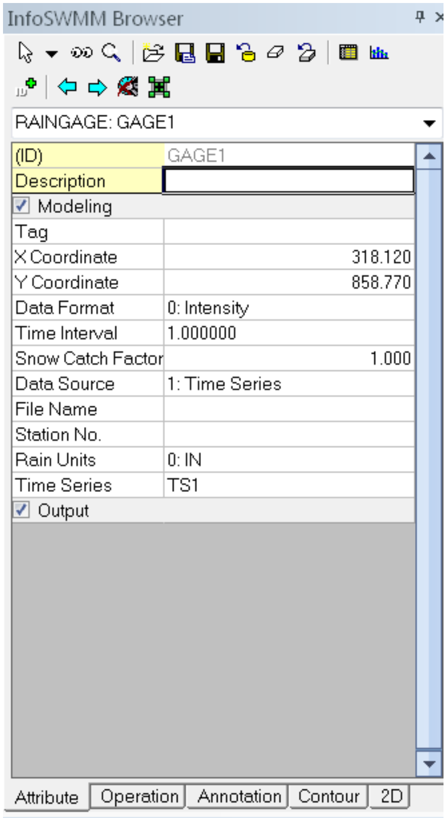
In order to provide a source of rainfall input to our project we need to set the rain gage properties. Select **Gage1** into the Property Editor and set the following properties:

Rain Format: INTENSITY

Rain Interval: 1:00

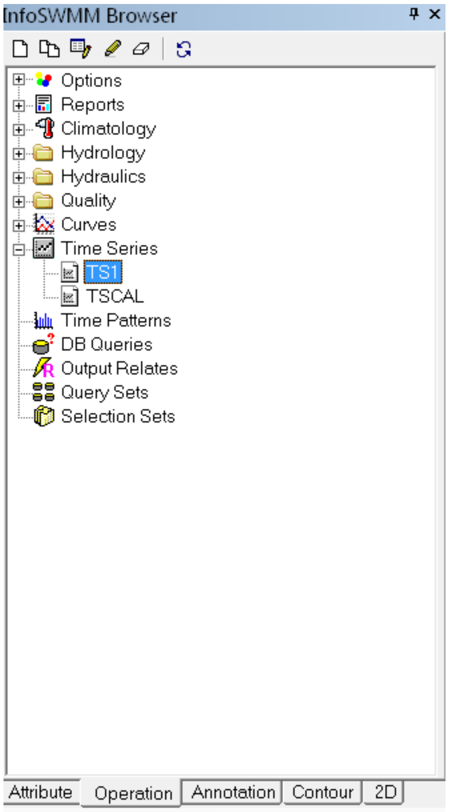
Data Source: TIMESERIES

Series Name: TS1



As mentioned earlier, we want to simulate the response of our study area to a 3-inch, 6-hour design storm. A time series named **TS1** will contain the hourly rainfall intensities that make up this storm. Thus we need to create a time series object and populate it with data. To do this:

1. From the InfoSWMM Attribute Browser / Operations Tab select the Time Series category of objects.
2. Click the button on the Browser which will bring up a Time Series Editor form. Leaving off the dates for a time series means that InfoSWMM will interpret the time values as hours from the start of the simulation. *Otherwise, the time series follows the date\/time values specified by the user.*



3. Enter **TS1** in the Time Series Name field.

4. Enter the following values into the Time and Value columns of the data entry grid (leave the Date column blank): *The Time Series Editor can also be launched directly from the Rain Gage Property Editor by selecting the editor\'s Series Name field and double clicking on it. "*

0 0

1 0.5

2 1.0

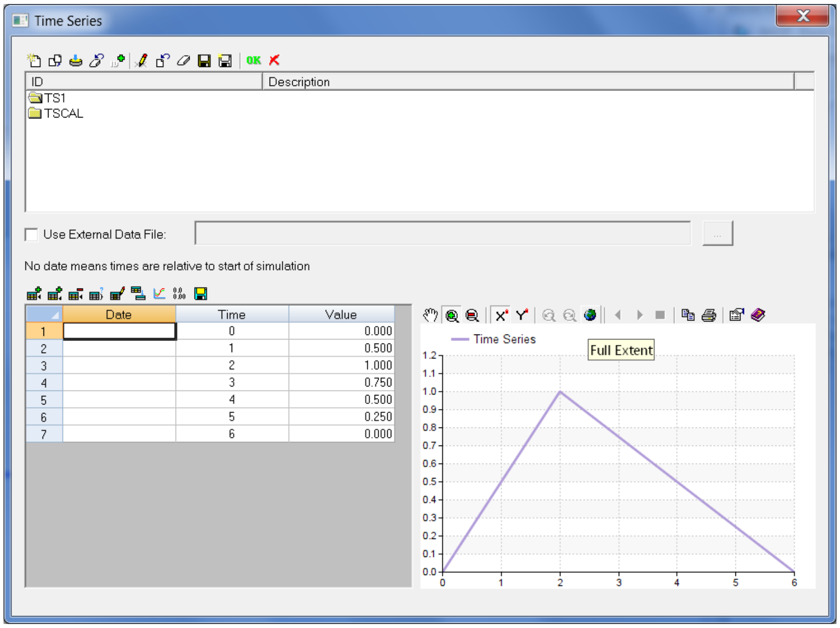
3 0.75

4 0.5

5 0.25

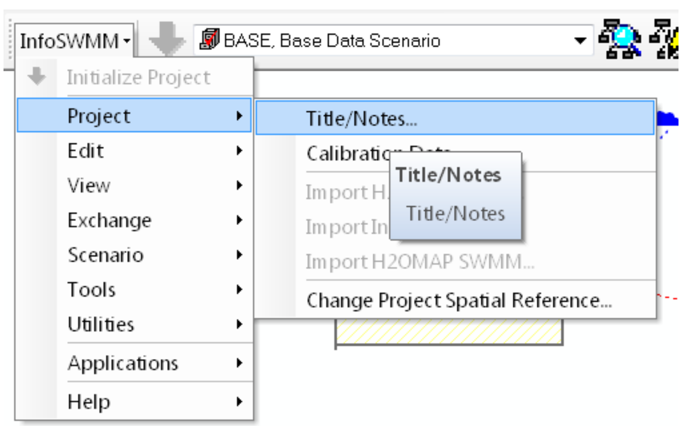
6 0

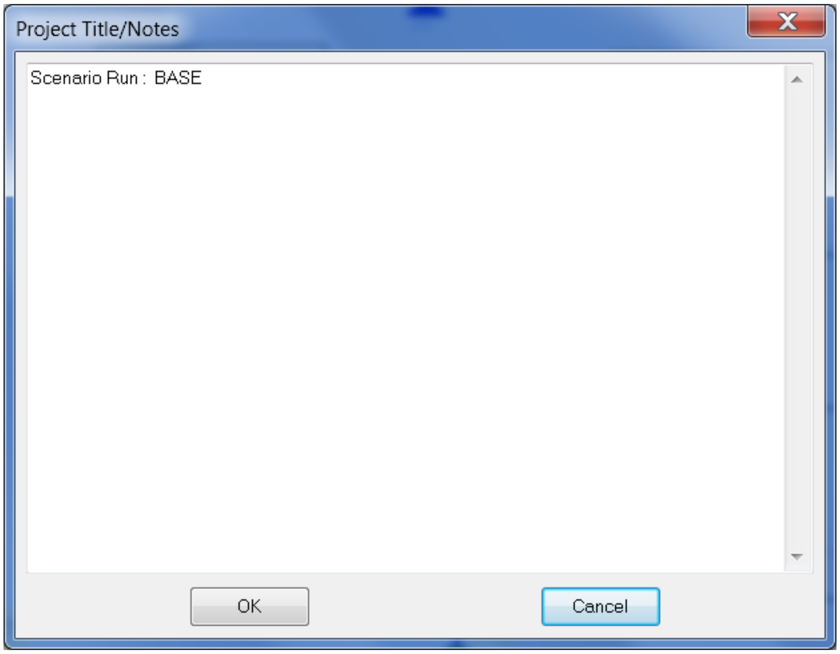
5. You can click the **View** button on the dialog to see a graph of the time series values. Click the **OK** button to accept the new time series.



Having completed the initial design of our example project it is a good idea to give it a title and save our work to a file at this point. To do this:

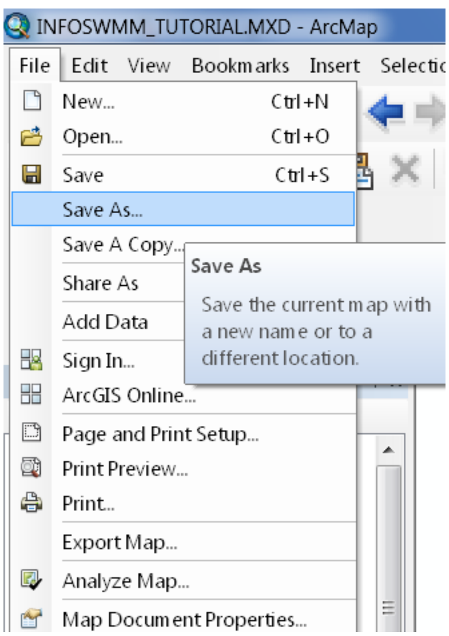
1. Select the **Title/Notes** category from the Project Browser and click the note track button.



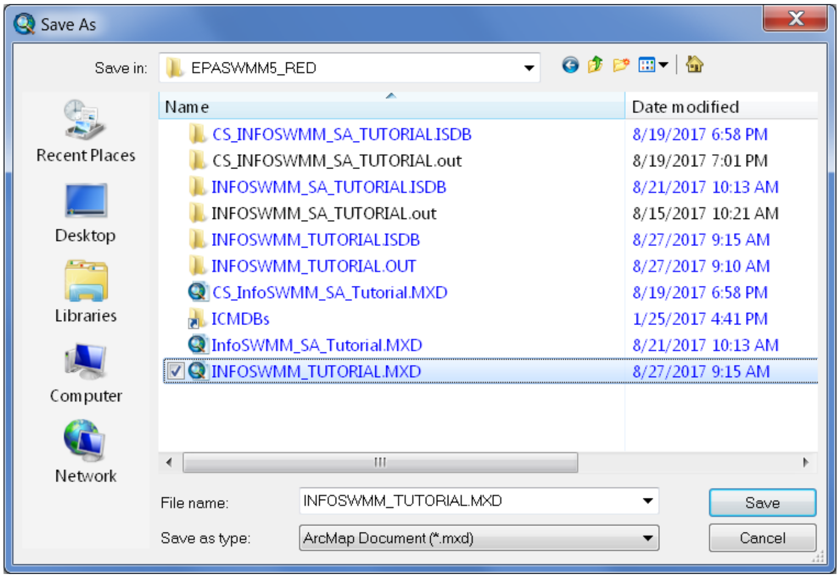


2. In the Project Title/Notes dialog that appears, enter "Tutorial Example" as the title of our project and click the **OK** button to close the dialog.

3. From the **File** menu select the **Save As** option.



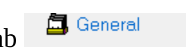
4. In the Save As dialog that appears, select a folder and file name under which to save this project. We suggest naming the file **tutorial.inp**. (An extension of .inp will be added to the file name if one is not supplied.)

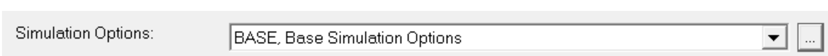


5. Click **OK** to save the project to file.

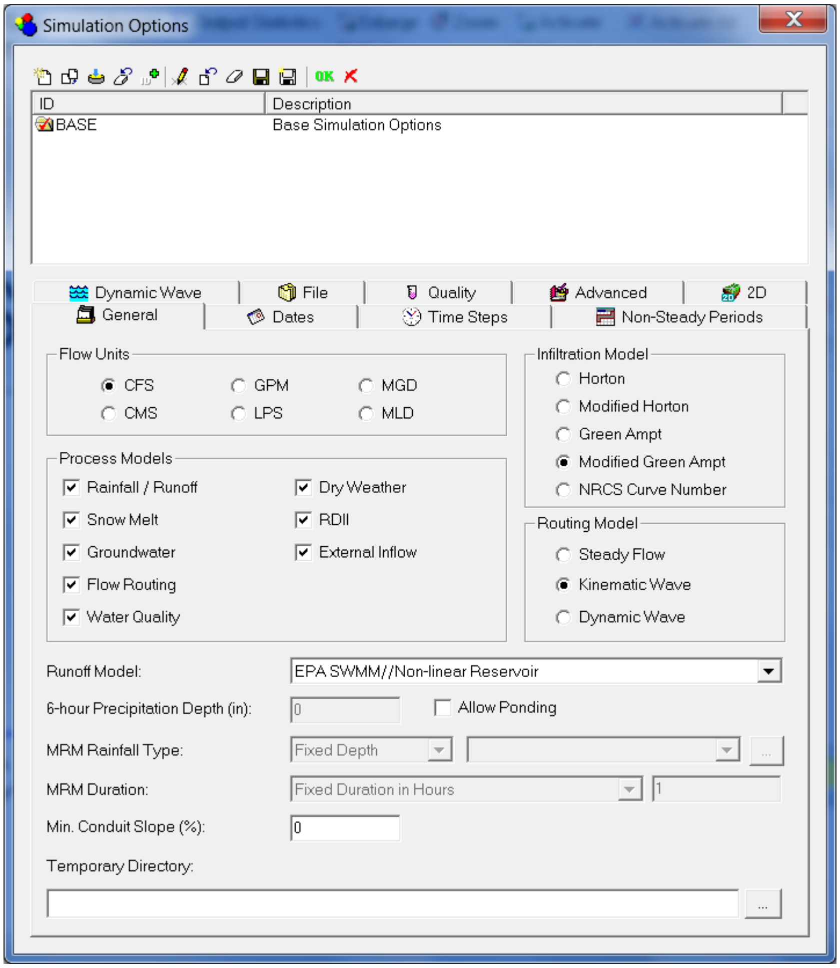
The project data is saved to the file in a readable text format. You can view what the file looks like by selecting **Project | Details** from the main menu. To open our project at some later time, we would select the **Open** command from the **File** menu.

Before analyzing the performance of our example drainage system we need to set some options that determine how the analysis will be carried out. To do this:

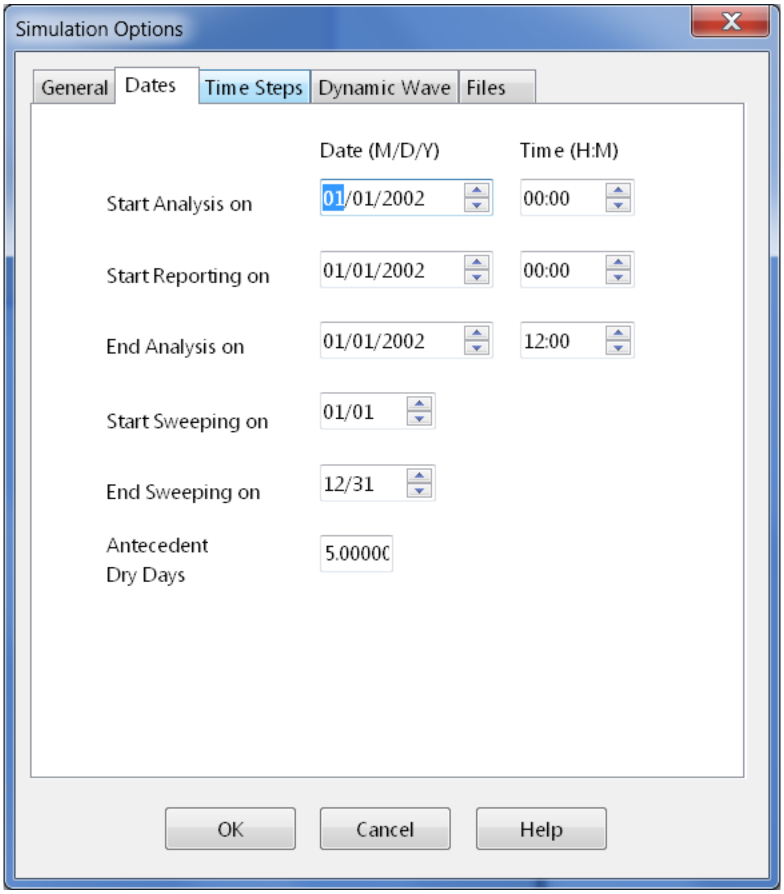
1. From the Run Manager select the **Options** category and click the General Tab .



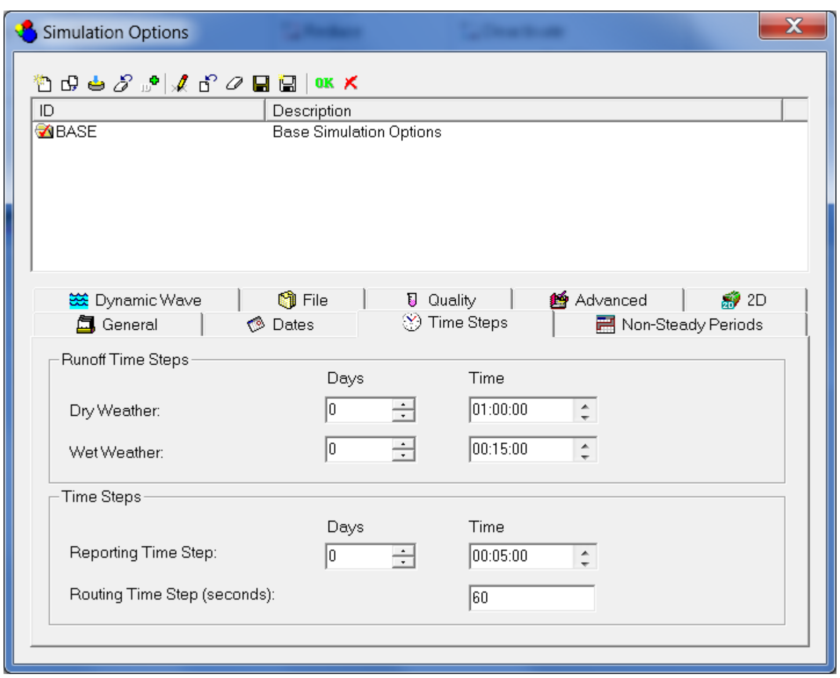
2. On the General page of the Simulation Options dialog that appears, select **Kinematic Wave** as the flow routing method. The flow units should already be set to **CFS** and the infiltration method to Modified **Green-Ampt**. The Allow Ponding option should be unchecked.



3. On the Dates page of the dialog, set the End Analysis time to **12:00**.

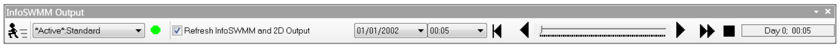


4. On the Time Steps page, set the Routing Time Step to **60** sec.



5. Click **OK** to close the Simulation Options dialog.

We are now ready to run the simulation. To do so, select **Run Manager on the InfoSWMM Output Toolbar**

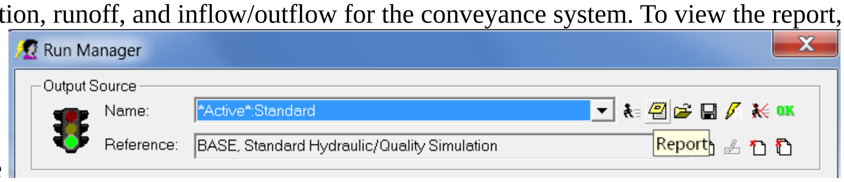


If there was a problem in running the simulation, a Status Report will appear describing what errors occurred.

Upon successfully completing a run, there are numerous ways in which to view the results of the simulation. We will illustrate just a few here:

- Viewing the Status Report
- Viewing the Summary Report
- Viewing results on the map
- Viewing a time series plot
- Viewing a profile plot

The Status Report contains useful information about the quality of a simulation run, including a mass balance on rainfall, infiltration, evaporation, runoff, and inflow/outflow for the conveyance system. To view the report, select **Report | Status** (or click the



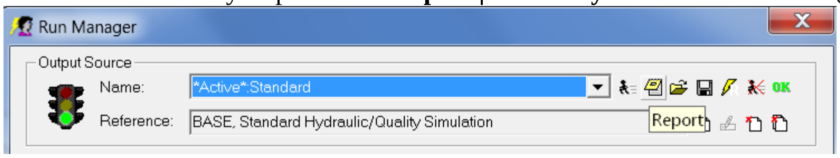
button on the Standard Toolbar and then select **Status Report**).

For the system we just analyzed the report indicates the quality of the simulation is quite good, with negligible mass balance continuity errors for both runoff and routing (-0.22% and 0.03%, respectively, if all data were entered correctly). Also, of the 3 inches of rain that fell on the study area, 1.75 infiltrated into the ground and essentially the remainder became runoff.

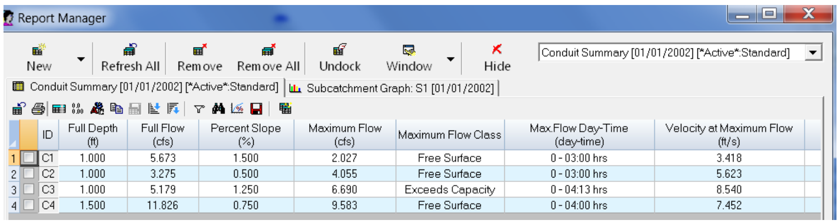
```
**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         3.000         3.000
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         1.749         1.749
Surface Runoff ...........         1.257         1.257
Final Surface Storage ....         0.000         0.000
Continuity Error (%) .....        -0.222
```

The Summary Report contains tables listing summary results for each subcatchment, node and link in the drainage system. Total rainfall, total runoff, and peak runoff for each subcatchment, peak depth and and hours flooded for each node, and peak flow, velocity, and depth for each conduit are just some of the outcomes included in the summary report.

To view the Summary Report select **Report | Summary** from the main menu (or click the



button on the Standard Toolbar and then select **Summary Report** from the drop down menu). The report's window has a drop down list from which you select a particular report to view. For our example, the Node Flooding Summary table indicates there was internal flooding in the system at node **J2**. *In InfoSWMM SA or EPA SWMM, flooding will occur whenever the water surface at a node exceeds the maximum defined depth. Normally such water will be lost from the system. The option also exists to have this water pond atop the node and be re-introduced into the drainage system when capacity exists to do so* . The Conduit Surcharge Summary table shows that Conduit **C2**, just downstream of node **J2**, was at full capacity and therefore appears to be slightly undersized.



Simulation results (as well as some design parameters, such as subcatchment area, node invert elevation, link maximum depth) can be viewed in color-coded fashion on the study area map. To view a particular variable in this fashion:

1. Select the Map page of the Browser panel.

2. Select the variables to view for Subcatchments, Nodes, and Links from the dropdown combo boxes in the Themes panel.

3. The color coding used for a particular variable is displayed with a legend on the study area map. To toggle the display of a legend, select **View | Legends**.

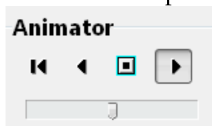
4. To move a legend to another location, drag it with the left mouse button held down.

5. To change the color coding and the breakpoint values for different colors, select **View | Legends | Modify** and then the pertinent class of object (or if the legend is already visible, simply right-click on it).

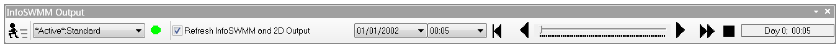
6. To view numerical values for the variables being displayed on the map, select **Tools | Map Display Options** and then select the Annotation page of the Map Options dialog. Use the check boxes for Rain Gages, Subcatchments, Nodes, and Links to specify what kind of annotation to add.

7. The Date / Time of Day / Elapsed Time controls on the Map Browser can be used to move through the simulation results in time.

8. You can use the controls in the Animator panel of the Map Browser to animate the map display through time.

For example, pressing the 

button will run the animation forward in time.



To generate a time series plot of a simulation result:

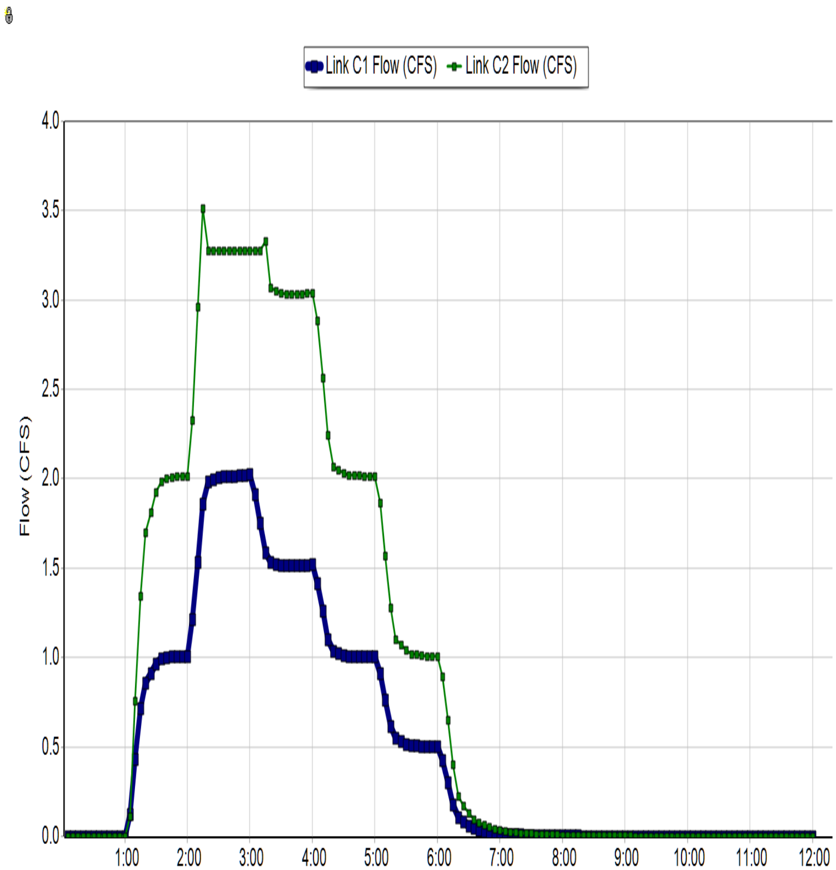
1. Select **Report | Graph | Time Series** from the menu bar or simply click 

on the Standard Toolbar..

2. A Time Series Plot Selection dialog will appear. It is used to select the objects and variables to be plotted.

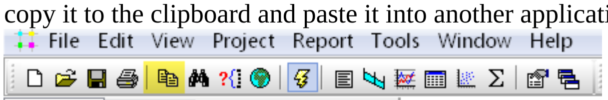
For our example, this dialog can be used to graph the flows in conduits **C1** and **C2** as follows:

1. Select conduit **C1** on the map or in the Project Browser and then click the **Add** button on the dialog.
2. A Data Series Selection page will appear. Select **Flow** as the Variable to plot.
3. Click the **Accept** button to return to the Plot Selection page of the dialog.
4. Repeat the above steps for conduit **C2** and press **OK** to create the plot.



After a plot is created you can:

· customize its appearance by selecting **Report | Customize** or right clicking on the plot,

· copy it to the clipboard and paste it into another application by selecting **Edit | Copy To** or clicking 

on the Standard Toolbar

· print it by selecting **File | Print** or **File | Print Preview** (use **File | Page Setup** first to set margins, orientation, etc.).

SWMM can generate profile plots showing how water surface depth varies across a path of connected nodes and links. Let's create such a plot for the conduits connecting junction **J1** to the outfall **Out1** of our example drainage system. To do this:

1. Select Report | Graph | Profile or simply click 

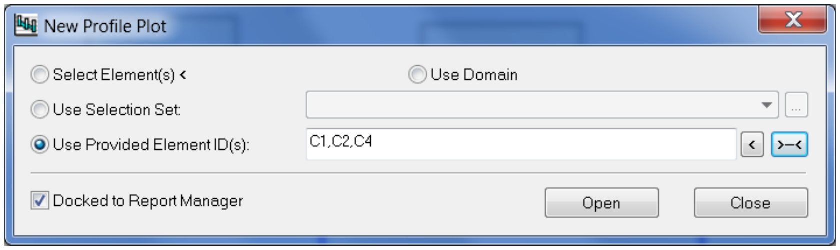
on the Standard Toolbar.

2. Either enter **J1** in the Start Node field of the Profile Plot dialog that appears or select it on the map or from the Project Browser and click the 

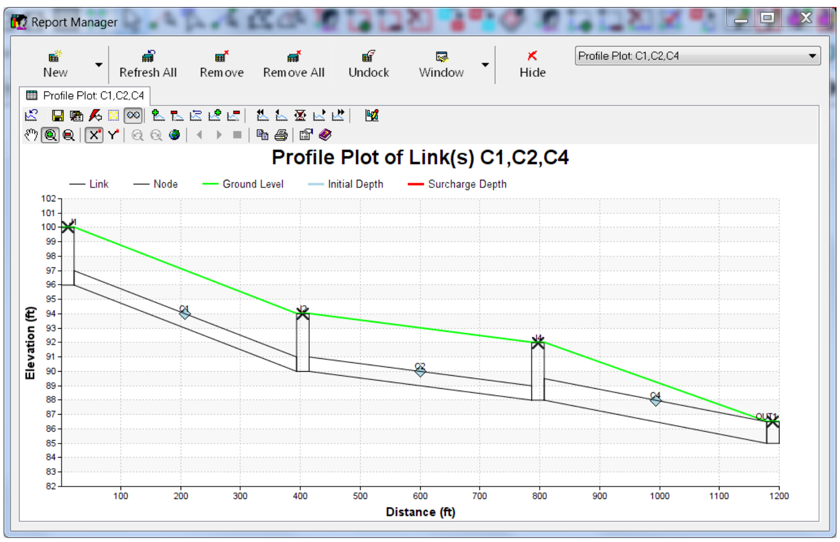
button next to the field.

3. Do the same for node **Out1** in the End Node field of the dialog.

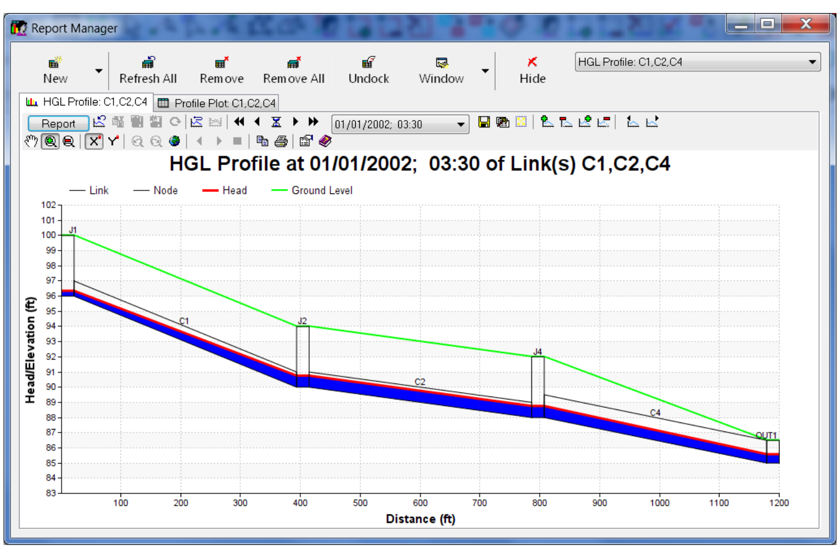
4. Click the **Find Path** button. An ordered list of the links which form a connected path between the specified Start and End nodes will be displayed in the Links in Profile box. You can edit the entries in this box if need be.



5. Click the **OK** button to create the plot, showing the water surface profile as it exists at the simulation time currently selected in the Map Browser.



Press the Toggle icon to show the simulation HGL



As you move through time using the Map Browser or with the Animator control, the water depth profile on the plot will be updated. Observe how node **J2** becomes flooded between hours 2 and 3 of the storm event.

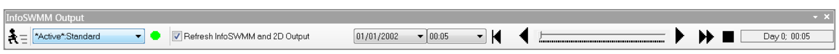
The appearance of a profile plot can be customized or it can be copied or printed using the same procedures as for a time series plot.

In the analysis just run we chose to use the Kinematic Wave method of routing flows through our drainage system. This is an efficient but simplified approach that cannot deal with such phenomena as backwater effects, pressurized flow, flow reversal, and non-dendritic layouts. SWMM also includes a Dynamic Wave routing procedure that can represent these conditions. This procedure, however, requires more computation time, due to the need for smaller time steps to maintain numerical stability.

Most of the effects mentioned above would not apply to our example. However we had one conduit, **C2**, that flowed full and caused its upstream junction to flood. It could be that this pipe is actually being pressurized and could therefore convey more flow than was computed using Kinematic Wave routing. We would now like to see what would happen if we apply Dynamic Wave routing instead.

To run the analysis with Dynamic Wave routing:

1. From the the InfoSWMM Output Toolbar and click the Run Manager.



2. On the General page of the Simulation Options dialog that appears, select **Dynamic Wave** as the flow routing method.

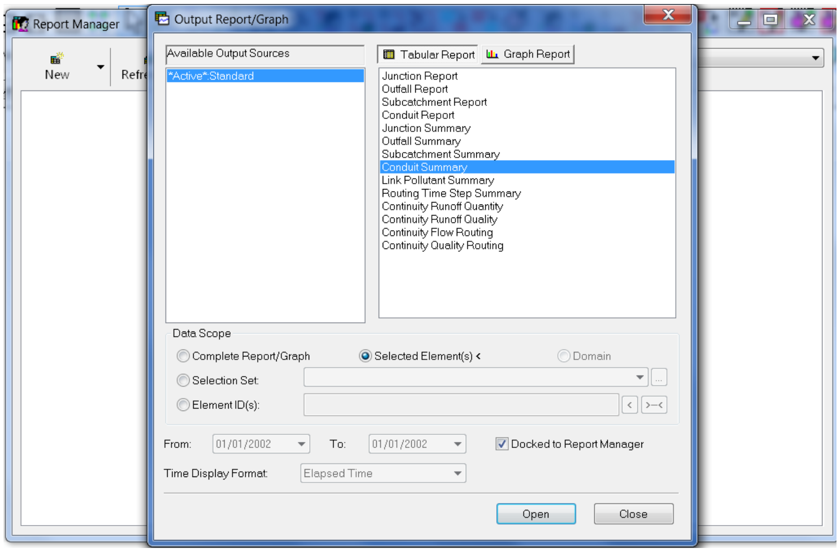
3. Click **OK** to close the form and select **Run Manager** to re-run the analysis. *Normally when running a Dynamic Wave analysis, one would also want to reduce the routing time step (on the Time Steps page of the dialog) and perhaps select the Variable Time Step option (on the Dynamic Wave page of the dialog) as well.*

If you look at the Status Report for this run you will see that there is no longer any flooding and that the peak flow carried by conduit **C2** has been increased from 3.52 cfs to 4.05 cfs.

```
**************************        Volume         Volume
Flow Routing Continuity         acre-feet       10^6 gal
**************************      ---------      ---------
Dry Weather Inflow .......          0.000          0.000
Wet Weather Inflow .......          1.257          0.410
Groundwater Inflow .......          0.000          0.000
RDII Inflow ..............          0.000          0.000
External Inflow ..........          0.000          0.000
External Outflow .........          1.257          0.410
Flooding Loss ............          0.000          0.000
Evaporation Loss .........          0.000          0.000
Exfiltration Loss ........          0.000          0.000
Initial Stored Volume ....          0.000          0.000
Final Stored Volume ......          0.000          0.000
Continuity Error (%) .....          0.007
```

```
********************
  Link Flow Summary
********************

-------------------------------------------------------------------------------------------------------------------------------
                                 Maximum   Time of Max         Maximum  Time of Max    Max/   Maximum  Time of Max   Max/  Time of Max
                               |Run Flow|   Occurrence   |Output Flow|   Occurrence    Full    |Veloc|   Occurrence   Full   Occurrence
Link              Type              CFS   days hr:min            CFS   days hr:min    Flow    ft/sec   days hr:min  Depth  days hr:min
-------------------------------------------------------------------------------------------------------------------------------
C1                CONDUIT          2.03      0  03:01           2.03      0  03:00    0.36      6.62      0  03:02   0.41     0  03:01
C2                CONDUIT          3.52      0  02:15           3.52      0  02:15    1.07      4.91      0  03:14   1.00     0  02:16
C3                CONDUIT          1.01      0  03:01           1.01      0  03:00    0.19      5.13      0  03:02   0.30     0  03:01
C4                CONDUIT          4.39      0  02:16           4.36      0  02:15    0.37      6.27      0  02:16   0.42     0  02:15
```



In the next phase of this tutorial we will add water quality analysis to our example project. SWMM has the ability to analyze the buildup, washoff, transport and treatment of any number of water quality constituents. The steps needed to accomplish this are:

1. Identify the pollutants to be analyzed.

2. Define the categories of land uses that generate these pollutants.

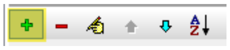
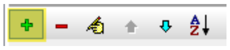
3. Set the parameters of buildup and washoff functions that determine the quality of runoff from each land use.

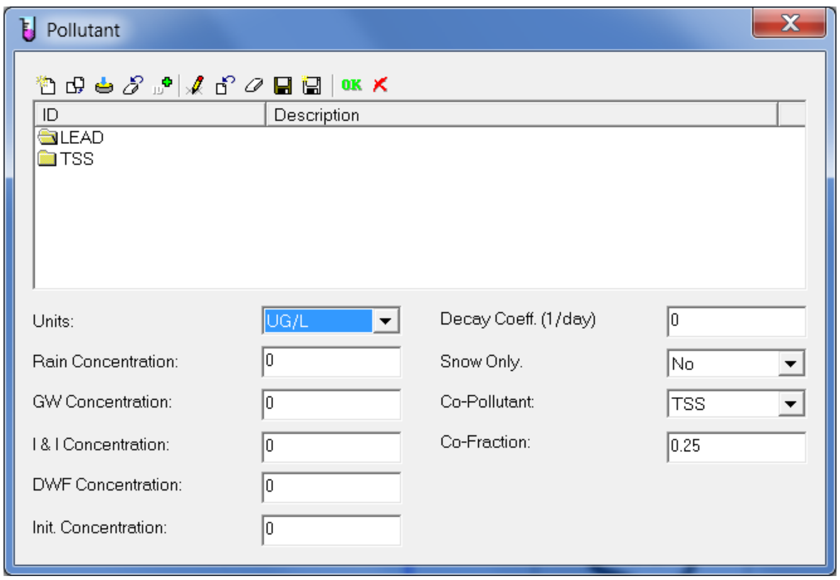
4. Assign a mixture of land uses to each subcatchment area

5. Define pollutant removal functions for nodes within the drainage system that contain treatment facilities.

We will now apply each of these steps, with the exception of number 5, to our example project. *Aside from direct runoff, EPA SWMM allows pollutants to be introduced into the nodes of a drainage system through:\n\r- user-defined time series of direct inflows\n\r- dry weather inflows\n\r- groundwater interflow\n\r- rainfall derived inflow\/infiltration*

For this tutorial example we will define two runoff pollutants; total suspended solids (TSS), measured as mg/L, and total Lead, measured in ug/L. In addition, we will specify that the concentration of Lead in runoff is a fixed fraction (0.25) of the TSS concentration. To add these pollutants to our project:

1. Under the Quality category in the Project Browser, select the **Pollutants** sub-category beneath it.
2. Click the  button to add a new pollutant to the project.
3. In the Pollutant Editor form that appears, enter **TSS** for the pollutant name and leave the other data fields at their default settings.
4. Click the **OK** button to close the Editor.
5. Click the  button on the Project Browser again to add our next pollutant.
6. In the Pollutant Editor, enter **Lead** for the pollutant name, select **ug/L** for the concentration units, enter **TSS** as the name of the Co-Pollutant, and enter **0.25** as the Co-Fraction value.
7. Click the **OK** button to close the Editor.

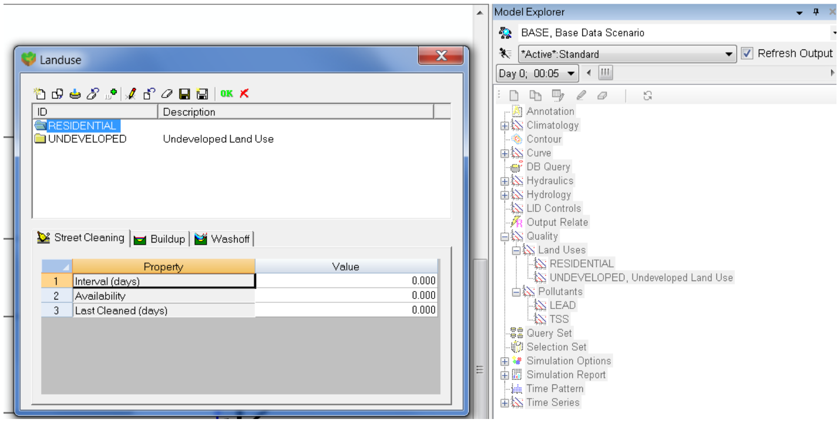


In SWMM, pollutants associated with runoff are generated by specific land uses assigned to subcatchments. In our example, we will define two categories of land uses: Residential and Undeveloped. To add these land uses to the project:

1. Under the Quality category in the Project Browser, select the Land Uses sub-category and click the  button.

2. In the Land Use Editor form that appears, enter **Residential** in the Name field and then click the **OK** button.

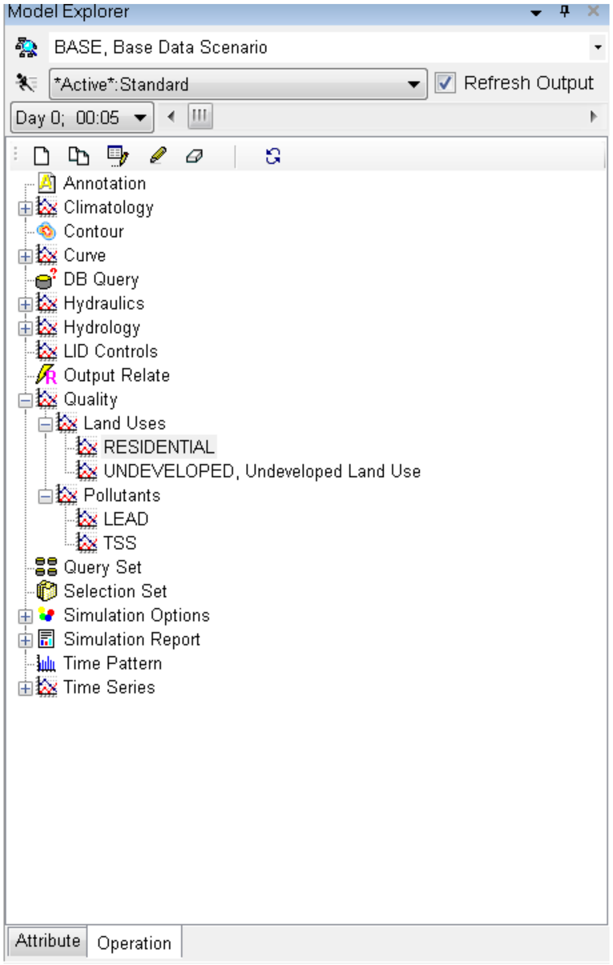
3. Repeat steps 1 and 2 for the **Undeveloped** land use category.



Next we need to define buildup and washoff functions for TSS in each of our land use categories. Functions for Lead are not needed since its runoff concentration was defined to be a fixed fraction of the TSS concentration. Normally, defining these functions requires site specific calibration.

In this example we will assume that suspended solids in Residential areas builds up at a constant rate of 1 pound per acre per day until a limit of 50 lbs per acre is reached. For the Undeveloped area we will assume that buildup is only half as much. For the washoff function, we will assume a constant event mean concentration of 100 mg/L for Residential land and 50 mg/L for undeveloped land. To define these functions for the Residential land use:

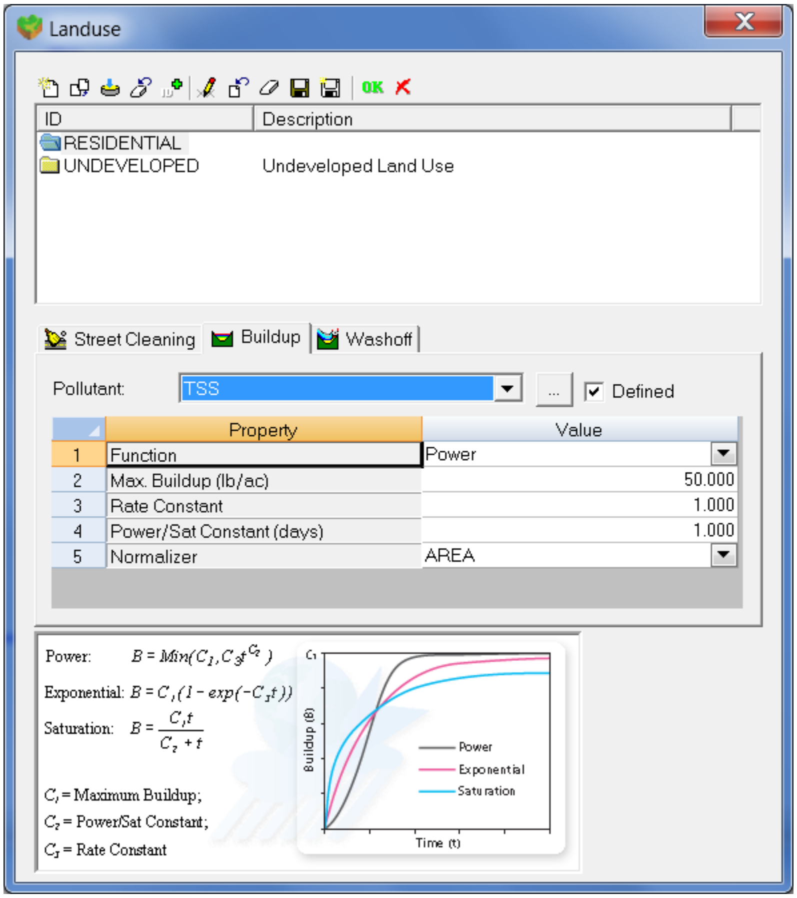
1. Select the **Residential** land use category from the Operations Tab of the Attribute Browser (AB).



2. In the Land Use Editor dialog, move to the Buildup page.

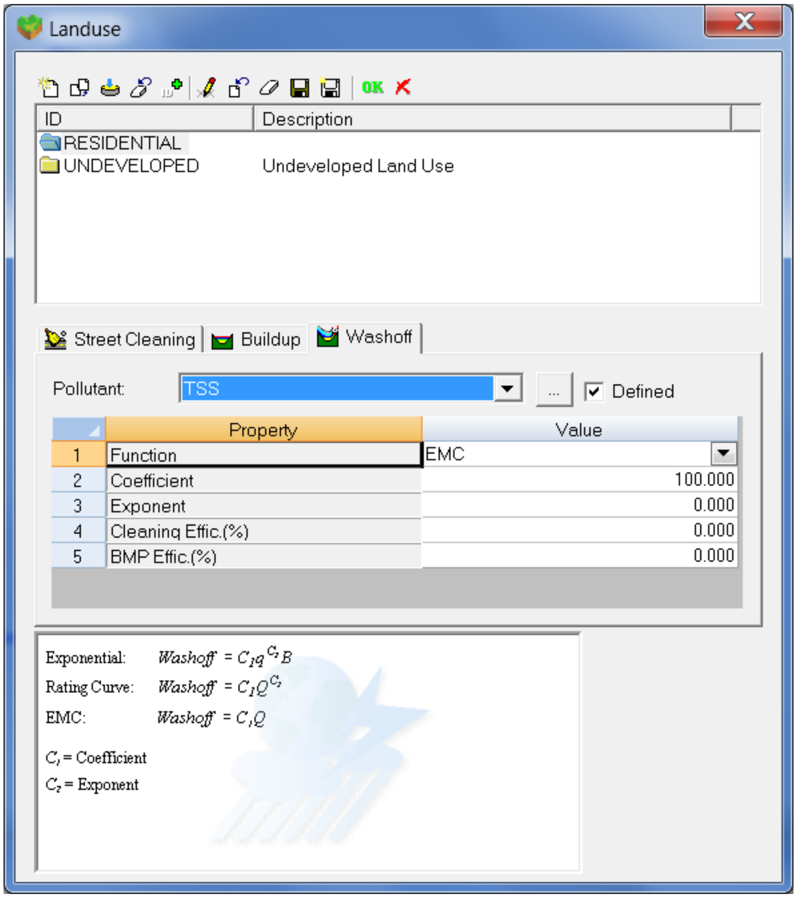
3. Select **TSS** as the pollutant and **POW** (for Power function) as the function type.

4. Assign the function a maximum buildup of **50**, a rate constant of **1.0**, a power of **1** and select **AREA** as the normalizer.



5. Move to the Washoff page of the dialog and select **TSS** as the pollutant, **EMC** as the function type, and enter **100** for the coefficient. Fill the other fields with **0**.

6. Click the **OK** button to accept your entries.



Now do the same for the **Undeveloped** land use category, except use a maximum buildup of **25**, a buildup rate constant of **0.5**, a buildup power of **1**, and a washoff EMC of **50**.

The final step in our water quality example is to assign a mixture of land uses to each subcatchment area:

1. Select subcatchment **S1** into the Property Editor.

2. Select the Land Uses property and click the ellipsis button (or press **Enter**).

3. In the Land Use Assignment form that appears, enter **75** for the % Residential and **25** for the % Undeveloped. Then click the **OK** button to close the dialog.

4. Repeat the same three steps for subcatchment **S2**.

5. Repeat the same for subcatchment **S3**, except assign the land uses as **25**% Residential and **75**% Undeveloped.

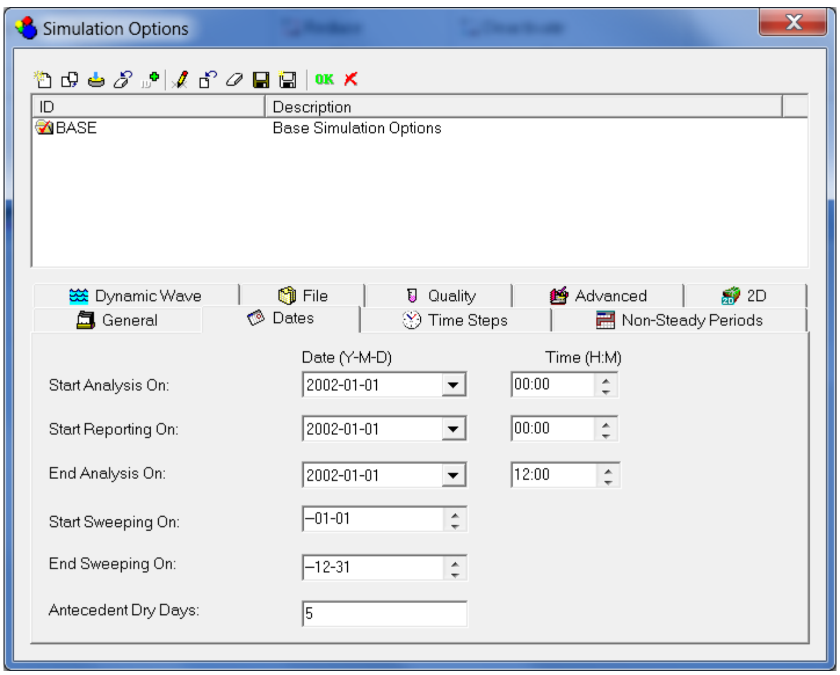
Before we simulate the runoff quantities of TSS and Lead from our study area, an initial buildup of TSS should be defined so it can be washed off during our single rainfall event. We can either specify the number of antecedent dry days prior to the simulation or directly specify the initial buildup mass on each subcatchment. We will use the former method:

1. From the Options category of the Project Browser, select the Dates sub-category and click the  button.

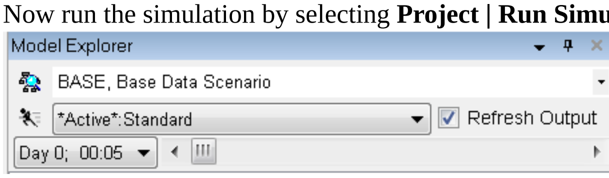
2. In the Simulation Options dialog that appears, enter **5** into the Antecedent Dry Days field.

3. Leave the other simulation options the same as they were for the dynamic wave flow routing we just completed.

4. Click the **OK** button to close the dialog.



Now run the simulation by selecting **Project | Run Simulation** or by clicking

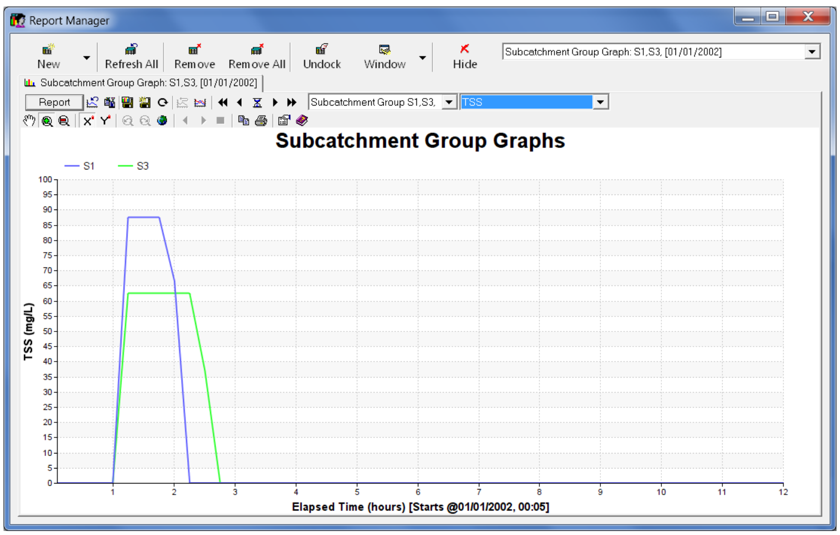


on the InfoSWMM SA Attribute Browser (AB).

When the run is completed, view its Status Report. Note that two new sections have been added for Runoff Quality Continuity and Quality Routing Continuity. From the Runoff Quality Continuity table we see that there was an initial buildup of 47.5 lbs of TSS on the study area and an additional 2.2 lbs of buildup added during the dry periods of the simulation. About 48 lbs were washed off during the rainfall event. The quantity of Lead washed off is a fixed fraction (0.25 times 0.001 to convert from mg to ug) of the TSS as was specified.

```
**************************           TSS           LEAD
Runoff Quality Continuity            lbs            lbs
**************************    ----------     ----------
Initial Buildup ..........        47.500          0.000
Surface Buildup ..........         2.182          0.012
Wet Deposition ...........         0.000          0.000
Sweeping Removal .........         0.000          0.000
Infiltration Loss ........         0.000          0.000
BMP Removal ..............         0.000          0.000
Surface Runoff ...........        47.896          0.012
Remaining Buildup ........         1.786          0.000
Continuity Error (%) .....         0.000          0.000
```

If you plot the runoff concentration of TSS for subcatchment **S1** and **S3** together on the same time series graph you will see the difference in concentrations resulting from the different mix of land uses in these two areas. You can also see that the duration over which pollutants are washed off is much shorter than the duration of the entire runoff hydrograph (i.e., 1 hour versus about 6 hours). This results from having exhausted the available buildup of TSS over this period of time.



As a final exercise in this tutorial we will demonstrate how to run a long term continuous simulation using a historical rainfall record and how to perform a statistical frequency analysis on the results. The rainfall record will come from a file named sta310301.dat which was included with the example data sets provided with EPA SWMM. It contains several years of hourly rainfall beginning in January 1998. The data are stored in the National Climatic Data Center's DSI 3240 format which SWMM can automatically recognize. *The example data sets can be found in My Documents | EPA SWMM Projects | Examples*

To run a continuous simulation with this rainfall record:

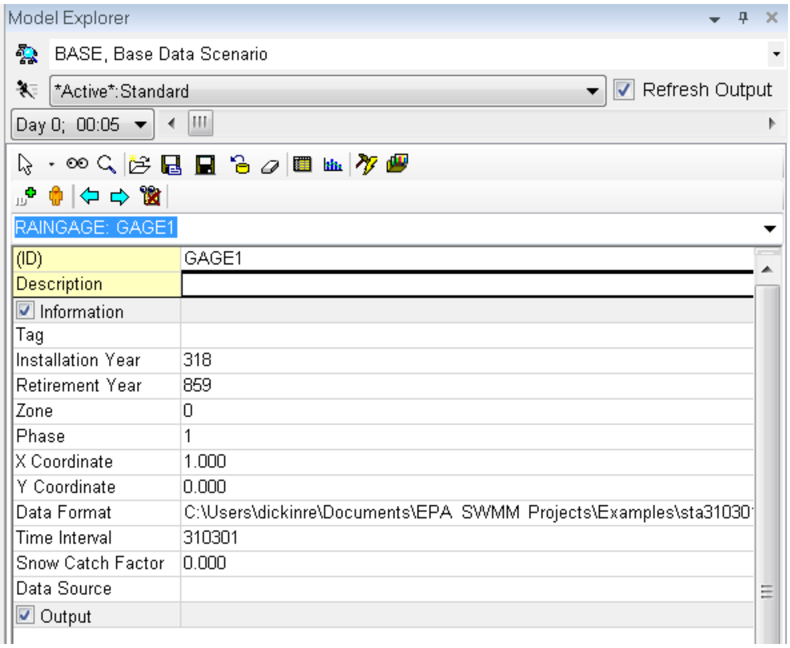
1. Select the rain gage **Gage1** into the Property Editor.

2. Change the selection of Data Source to **FILE**.

3. Select the File Name data field and click the ellipsis button (or press the **Enter** key) to bring up a Windows File Selection dialog.

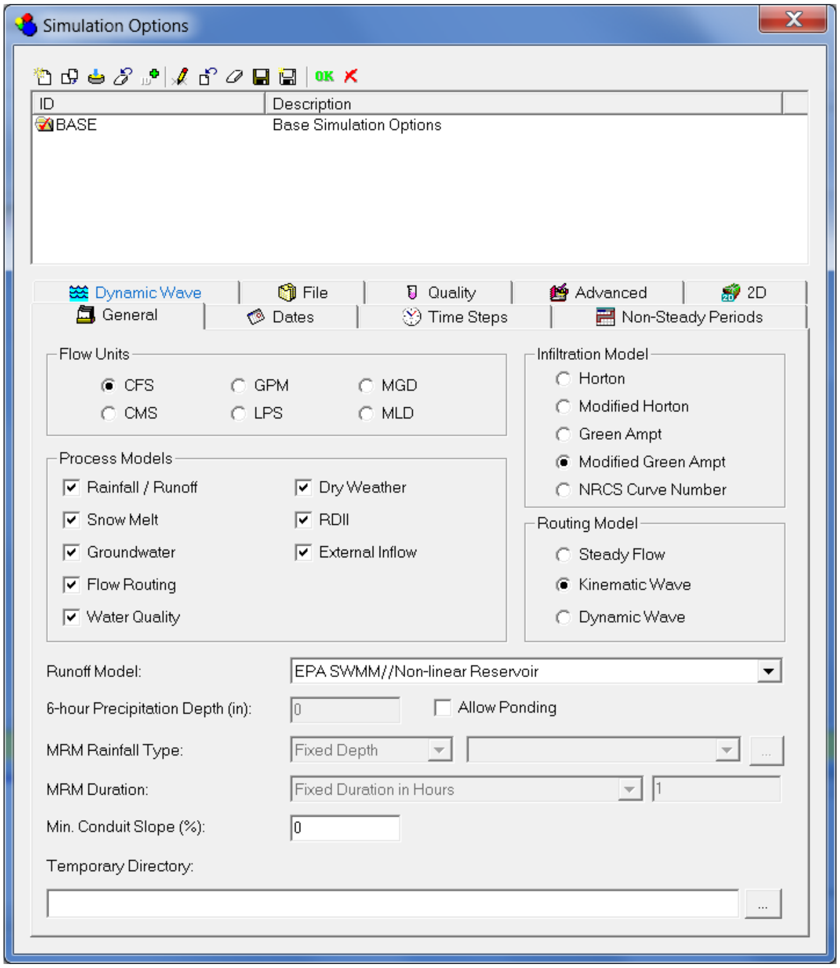
4. Navigate to the folder where the SWMM example files were stored, select the file named **sta310301.dat**, and click **Open** to select the file and close the dialog.

5. In the Station No. field of the Property Editor enter **310301**.

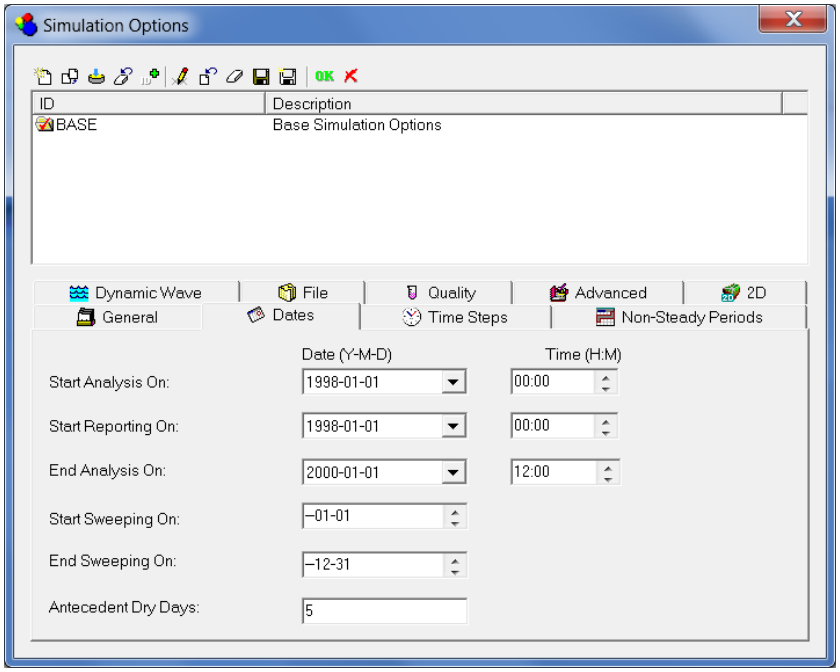


6. Select the Options category in the Project Browser and click the  button to bring up the Simulation Options form.

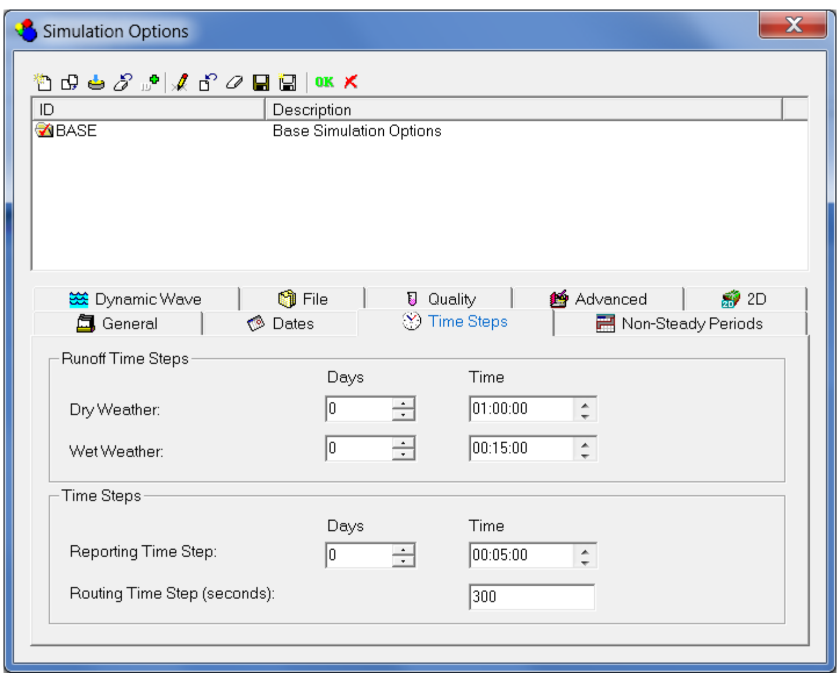
7. On the General Tab of the Run Manager, select **Kinematic Wave** as the Routing Method (this will help speed up the computations).

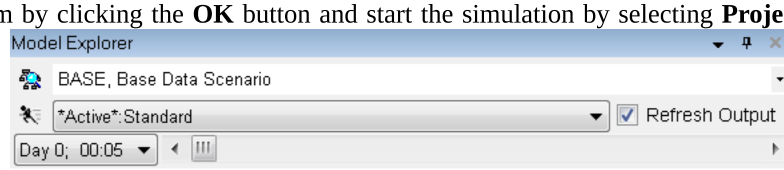


8. On the Dates page of the form, set both the Start Analysis and Start Reporting dates to **01/01/1998**, and set the End Analysis date to **01/01/2000**.



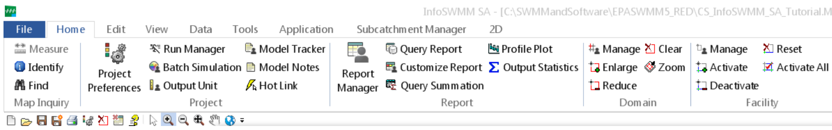
9. On the Time Steps page of the form, set the Routing Time Step to **300** seconds.



10. Close the Simulation Options form by clicking the **OK** button and start the simulation by selecting **Project | Run Simulation** (or by clicking  on the Standard Toolbar).

After our continuous simulation is completed we can perform a statistical frequency analysis on any of the variables produced as output. For example, to determine the distribution of rainfall volumes within each storm event over the two-year period simulated:

1. Select **Report | Statistics** or click the button on the Standard Toolbar.

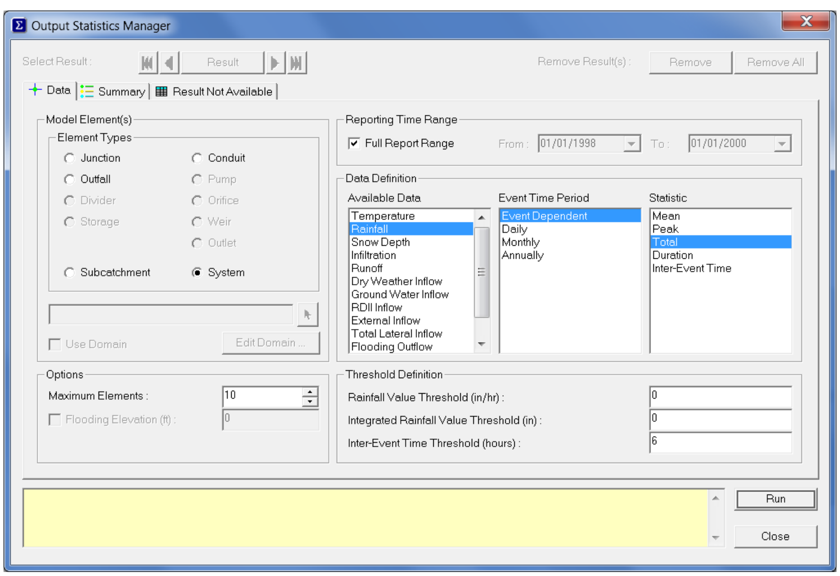


2. In the Statistics Selection form that appears, enter the values as shown below:

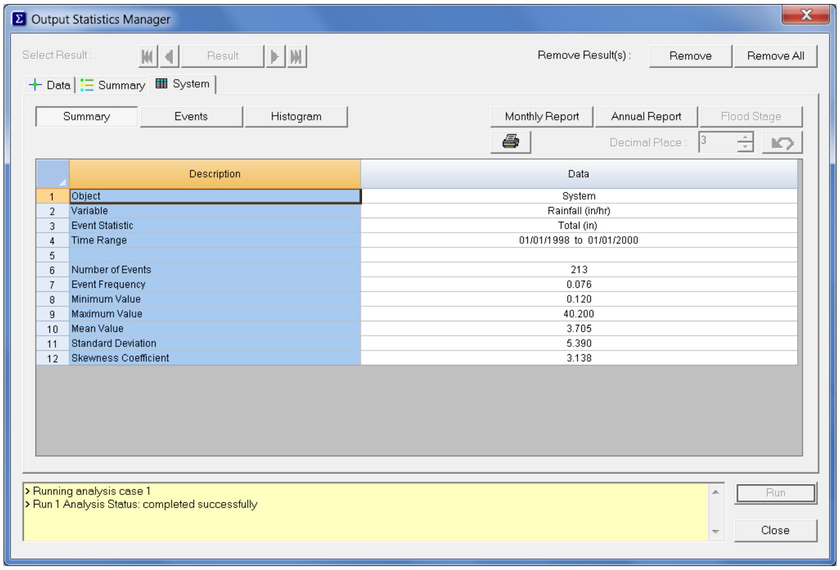
Object Category:	System
Variable Analyzed:	Precipitation
Event Time Period:	Event-Dependent
Statistic:	Total
Event Thresholds:	
Rainfall	0
Event Volume	0
Inter-Event Hours	6

This will identify the rainfall volume from each event which is separated by 6 or more hours without rainfall.

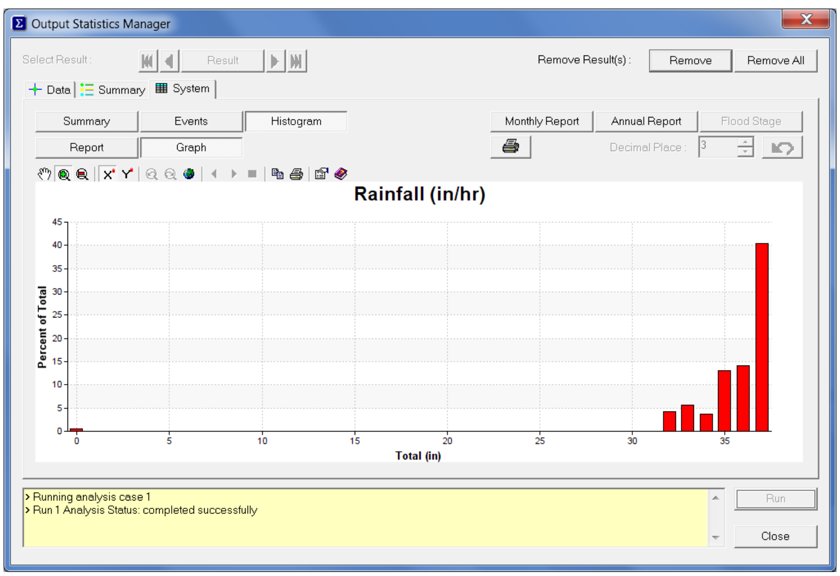
3. Click the **Run** button to close the form.



The results of this request will be a Statistics Report form containing four tabbed pages: a Summary page, a page containing a rank-ordered listing of each event, a page containing a histogram of the occurrence frequency versus event magnitude, and a Frequency Plot page that plots event magnitude versus cumulative frequency.



The Summary page shows that there was a total of 213 rainfall events. The Events page shows that the largest rainfall event had a volume of 3.35 inches and occurred over a 24- hour period. There were no events that matched the 3-inch, 6-hour design storm event used in our previous single-event analysis which had produced some internal flooding. In fact, the status report for this continuous simulation indicates that there were no flooding or surcharge occurrences over the simulation period.



We have only touched the surface of InfoSWMM SA's capabilities. Some additional features of the program that you will find useful include:

- utilizing additional types of drainage elements, such as storage units, flow dividers, pumps, and regulators, to model more complex types of systems
- using control rules to simulate real-time operation of pumps and regulators

- employing different types of externally-imposed inflows at drainage system nodes, such as direct time series inflows, dry weather inflows, and rainfall-derived inflow/infiltration

- modeling groundwater interflow between aquifers beneath subcatchment areas and drainage system nodes

- modeling snow fall accumulation and melting within subcatchments

- adding calibration data to a project so that simulated results can be compared with measured values

- utilizing a background street, site plan, or topo map to assist in laying out a system's drainage elements and to help relate simulated results to real-world locations.

You can find more information on these and other features in the InfoSWMM User's Manual.

HAPPY InfoSWMM Modeling or Modelling!

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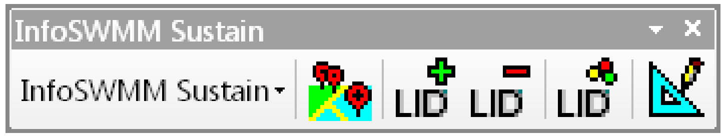
InfoSWMM Sustain
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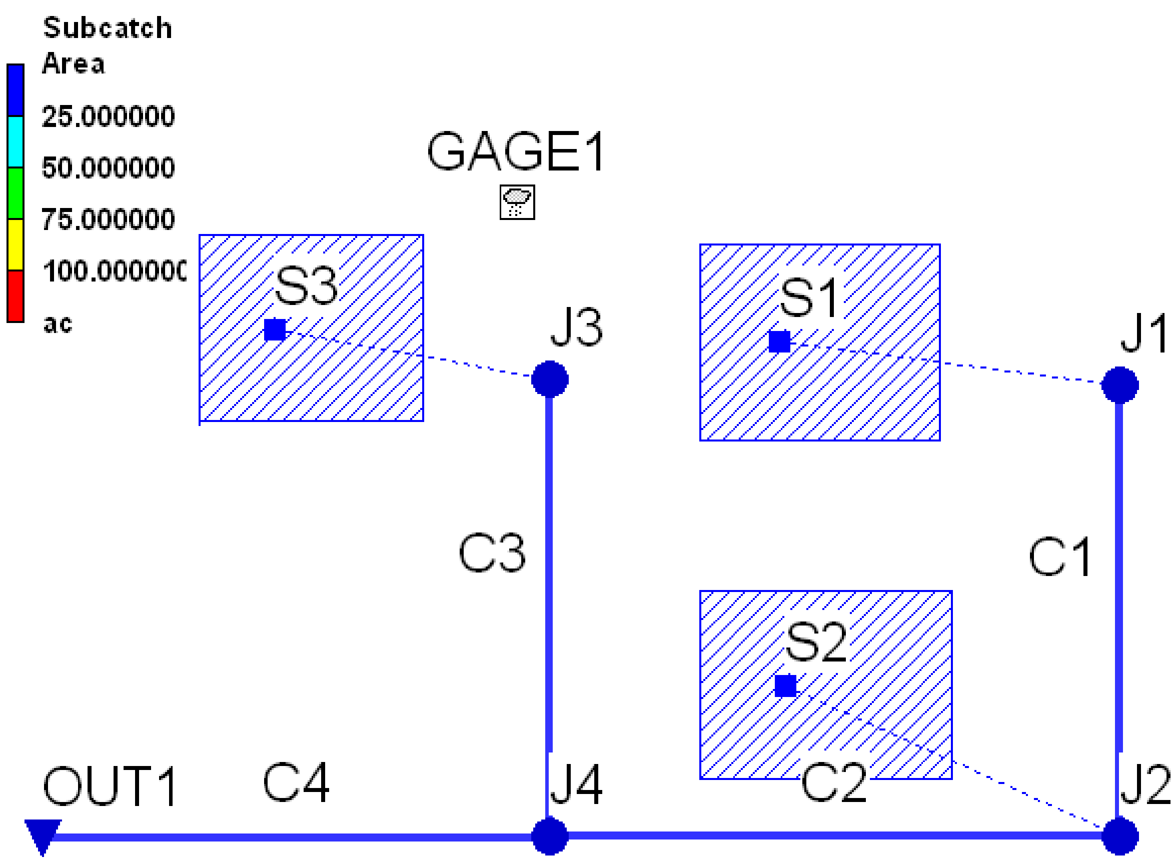
EPA SWMM5 Tutorial

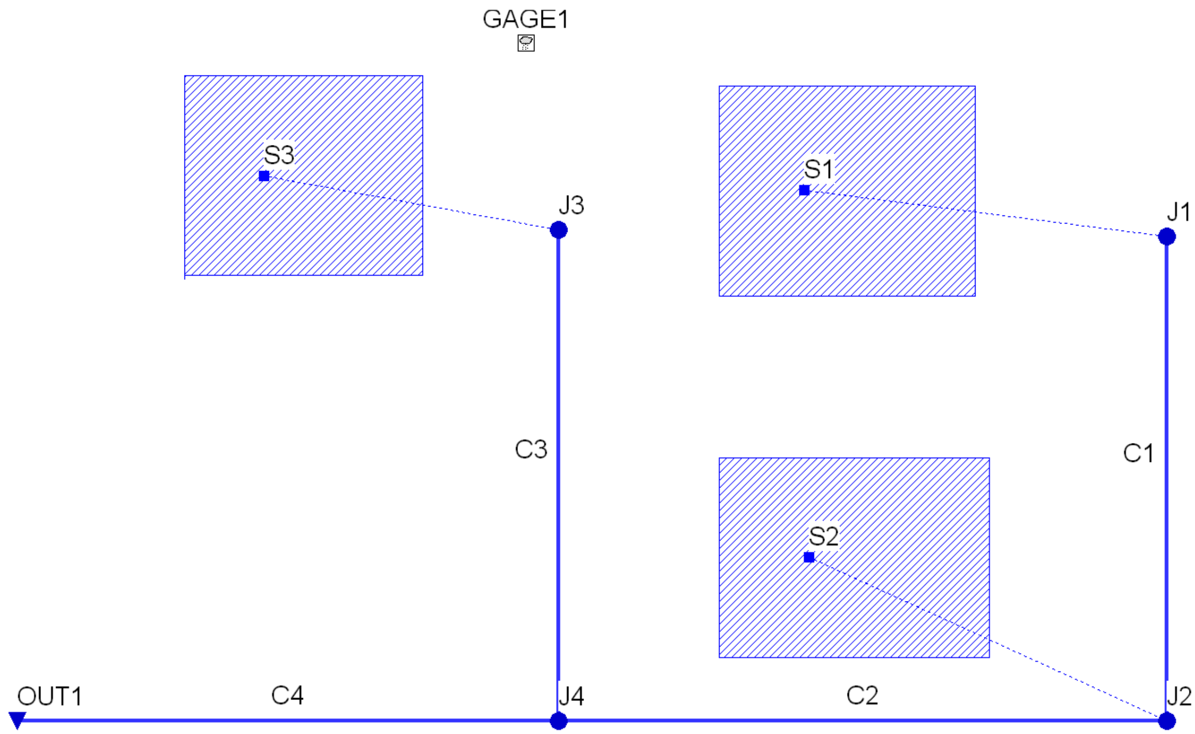
This is a one HTML file version of the SWMM 5 Tutorial for modeling the quantity and quality of stormwater runoff produced from urban areas. More images have been added. The topics to be covered include:

- Constructing a SWMM Model
- Setting the Properties of SWMM Objects
- Saving and Opening Projects
- Running a Single Event Analysis
- Viewing Simulation Results
- Simulating Runoff Water Quality
- Running a Continuous Simulation



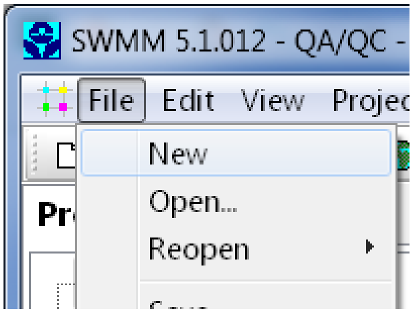
In this tutorial we will model the drainage system serving a 12 acre residential area. The system layout is shown below and consists of subcatchment areas S1 through S3 A *subcatchment is an area of land containing a mix of pervious and impervious surfaces whose runoff drains to a common outlet point, which could be either a node of the drainage network or another subcatchment.* Storm sewer conduits C1 through C4, and conduit junctions J1 through J4. The system discharges to a creek at the point labeled Out1. We will first go through the steps of creating the objects shown in this diagram on SWMM's Study Area Map and setting the various properties of these objects. Then we will simulate the water quantity and quality response to a 3-inch, 6-hour rainfall event, as well as a continuous, multi-year record.

You can click the **View Map** button that appears in each topic's header panel to refer to this drawing at any time. Use the button

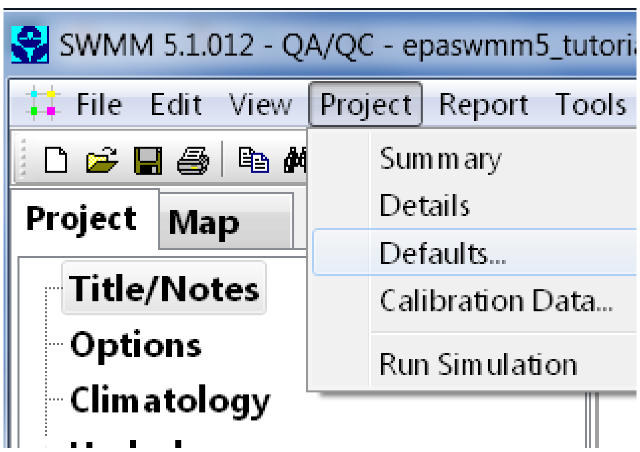


Our first task is to create a new project in EPA SWMM and make sure that certain default options are selected. Using these defaults will simplify the data entry tasks later on.

1. Launch EPA SWMM if it is not already running and select **File | New** to create a new project.



2. Select Home / **Project Preferences / ID and Description** to open the **ID and Description** dialog

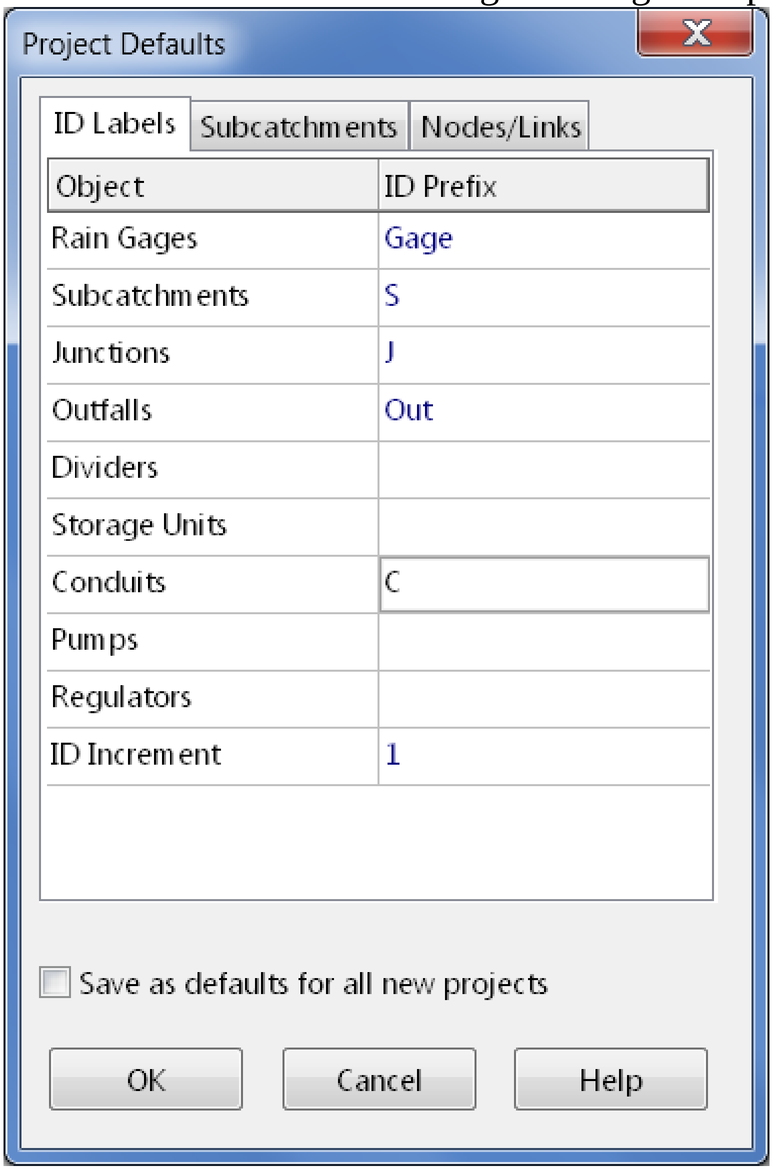


3. On the **ID and Description** dialog, set the ID Prefixes as follows (leave the others at their default):

Rain Gages:	Gage
Subcatchments:	S
Junctions:	J
Outfalls:	Out
Conduits:	C

ID Increment: 1

This will make EPA SWMM automatically label new objects with consecutive numbers following the designated prefix.

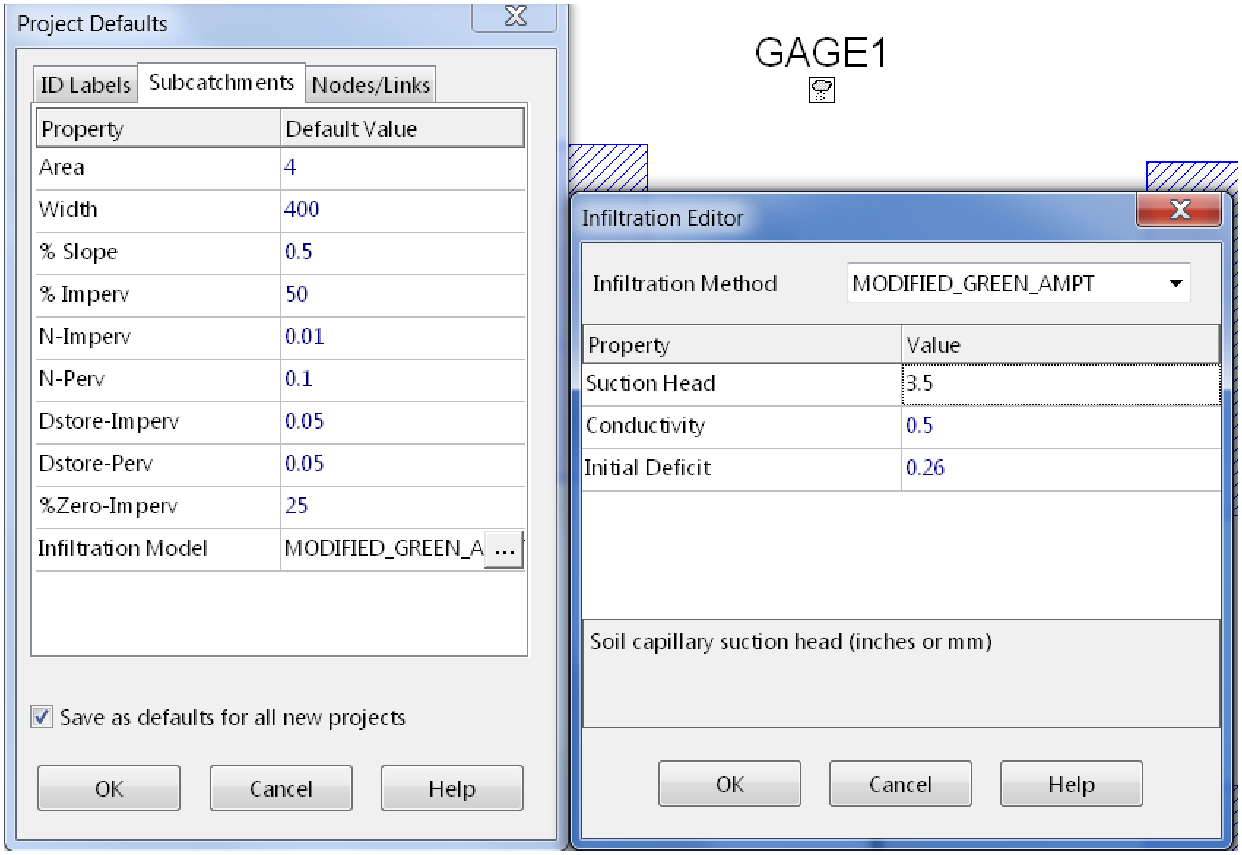


4. On the Subcatchments page of the dialog set the following default values:

Area: 4

Width: 400

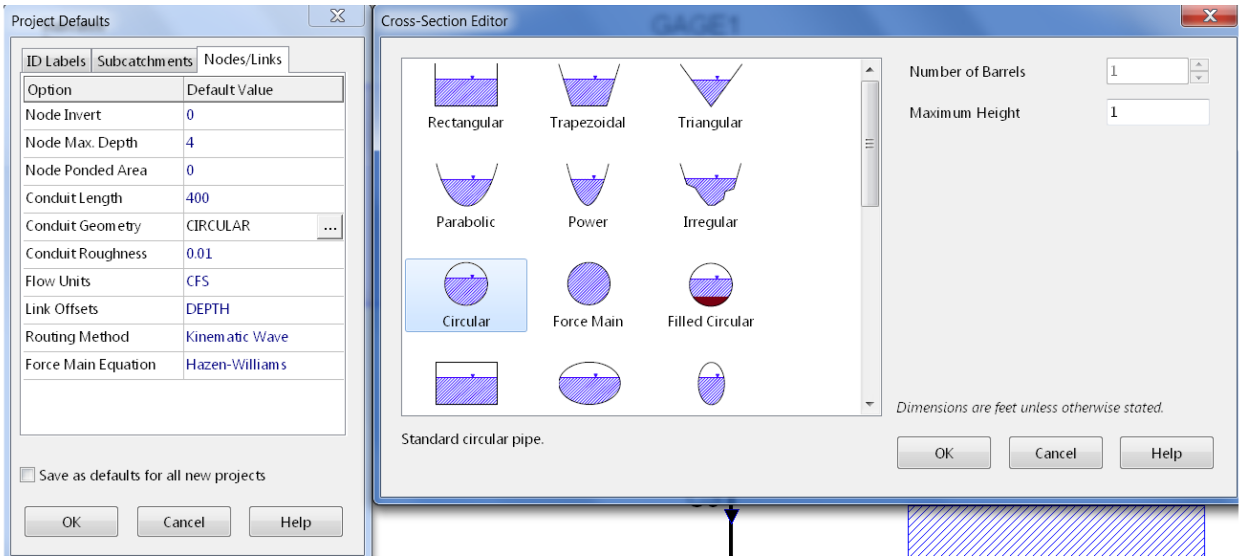
% Slope:	0.5
% Imperv:	50
N-Imperv:	0.01
N-Perv:	0.10
Dstore-Imperv:	0.05
Dstore-Perv:	0.05
%Zero-Imperv:	25.0
Infil. Model	<click to edit>
Method:	Modified Green-Ampt
Suction Head:	3.5
Conductivity:	0.5
Initial Deficit:	0.26



5. On the Nodes/Links page set the following default values:

Node Invert:	0
Node Max. Depth:	4
Node Ponded Area	0
Conduit Length:	400
Conduit Geometry:	<click to edit>
Shape:	Circular
Max. Depth:	1.0
Barrels	1

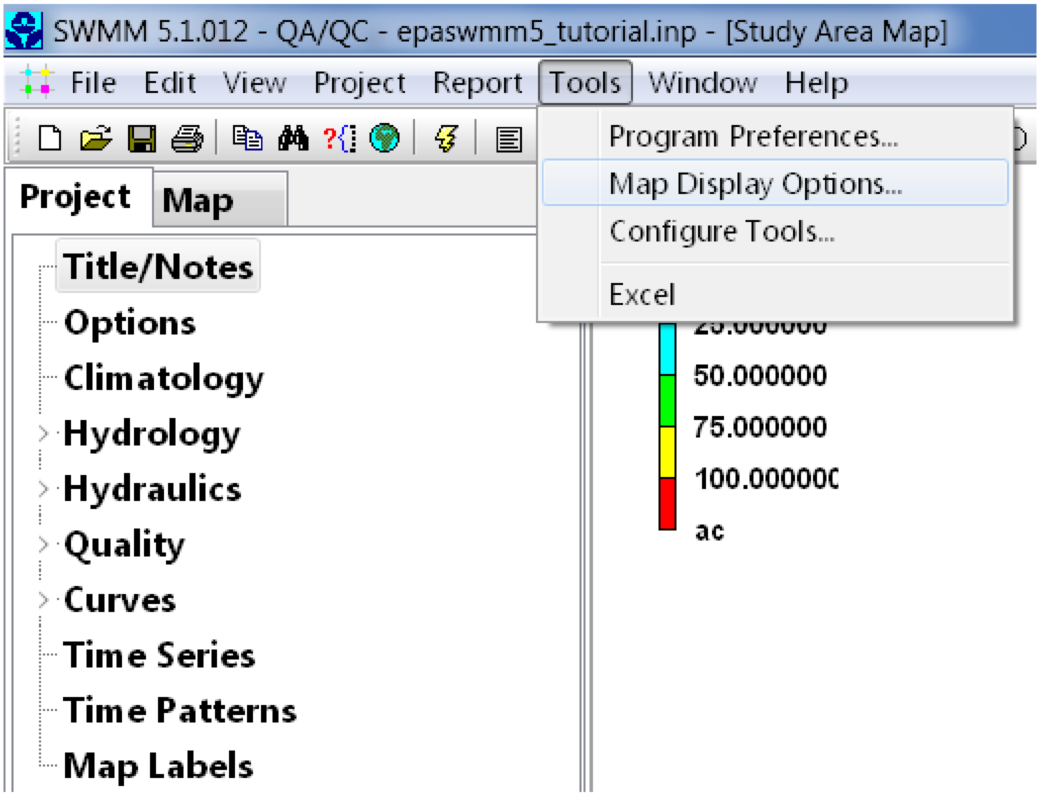
Conduit Roughness:	0.01
Flow Units:	CFS
Link Offsets:	DEPTH
Routing Model:	Kinematic Wave



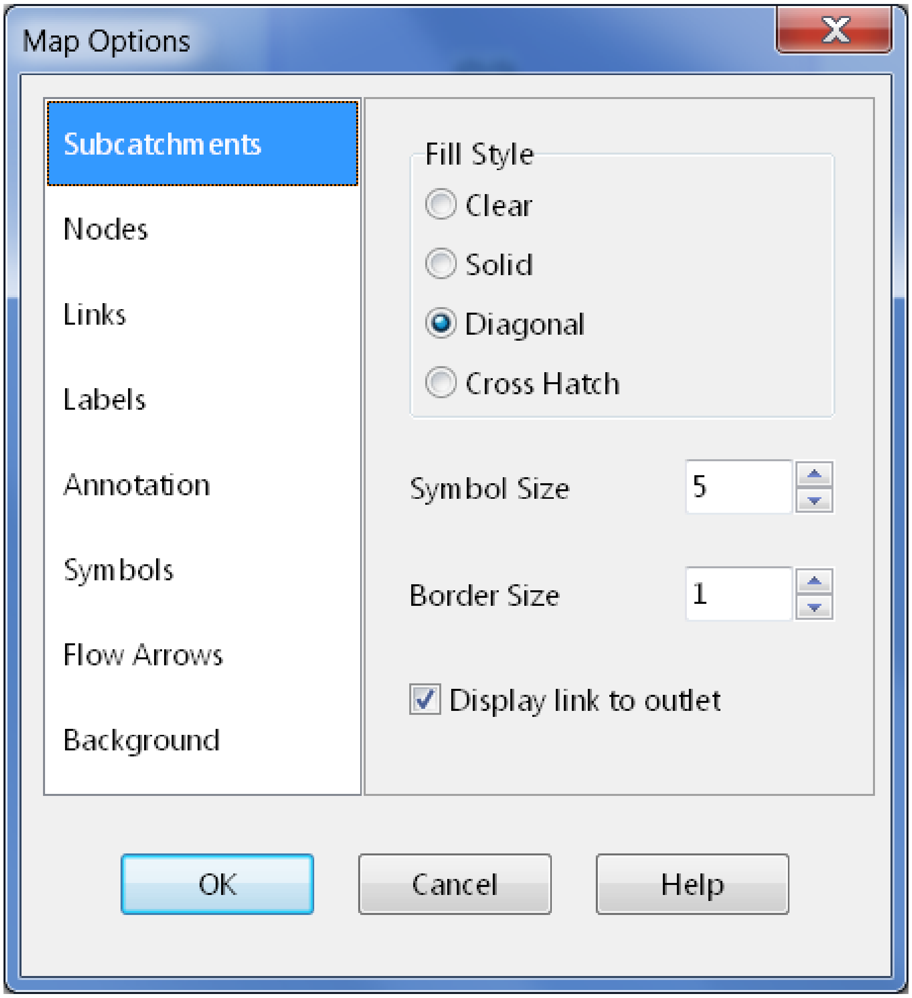
. Click **OK** to accept these choices and close the dialog.

Next we will set some map display options so that ID labels and symbols will be displayed as we add objects to the study area map, and links will have direction arrows.

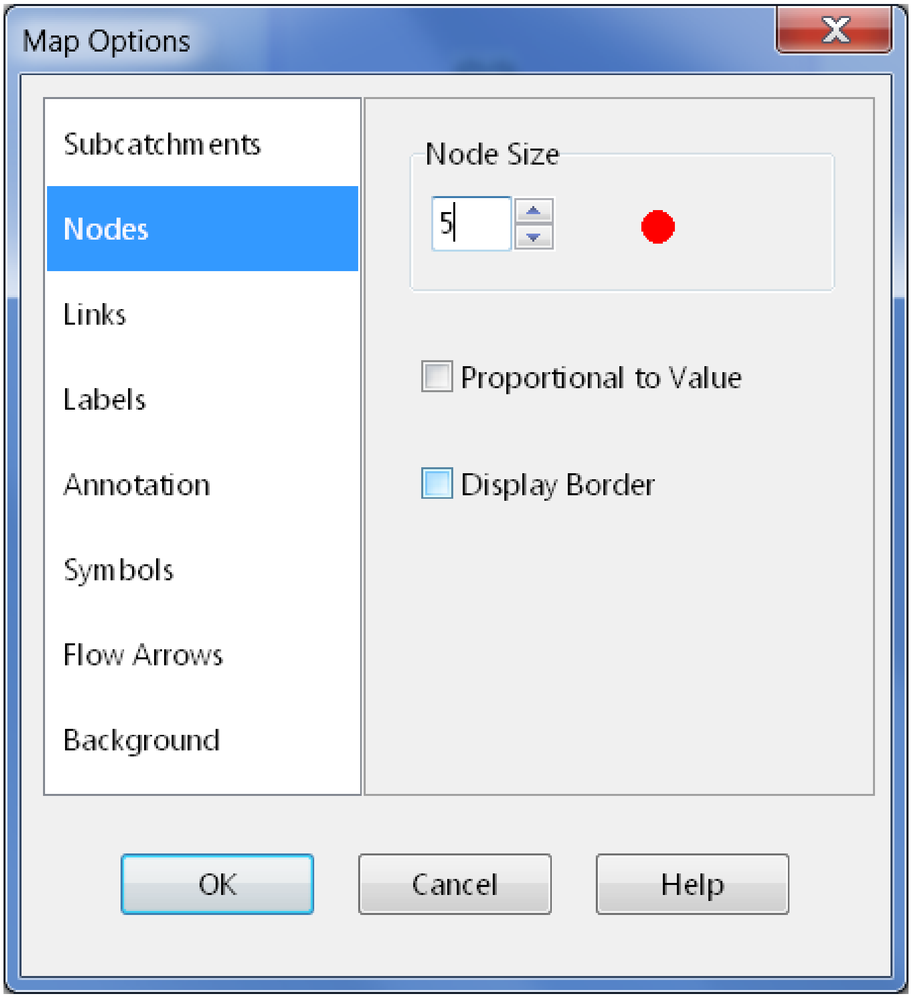
1. Select **Tools | Map DisplayOptions** to bring up the Map Options dialog.



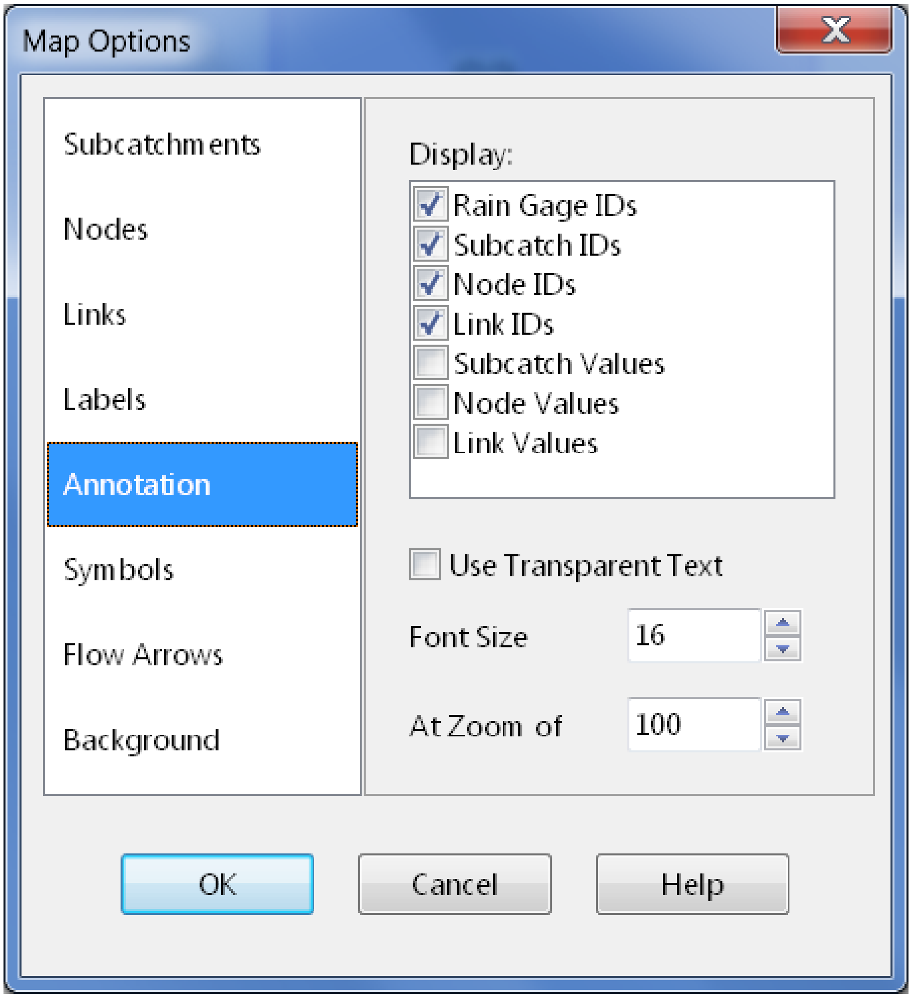
2. Select the Subcatchments page, set the Fill Style to **Diagonal** and the Symbol Size to **5**.



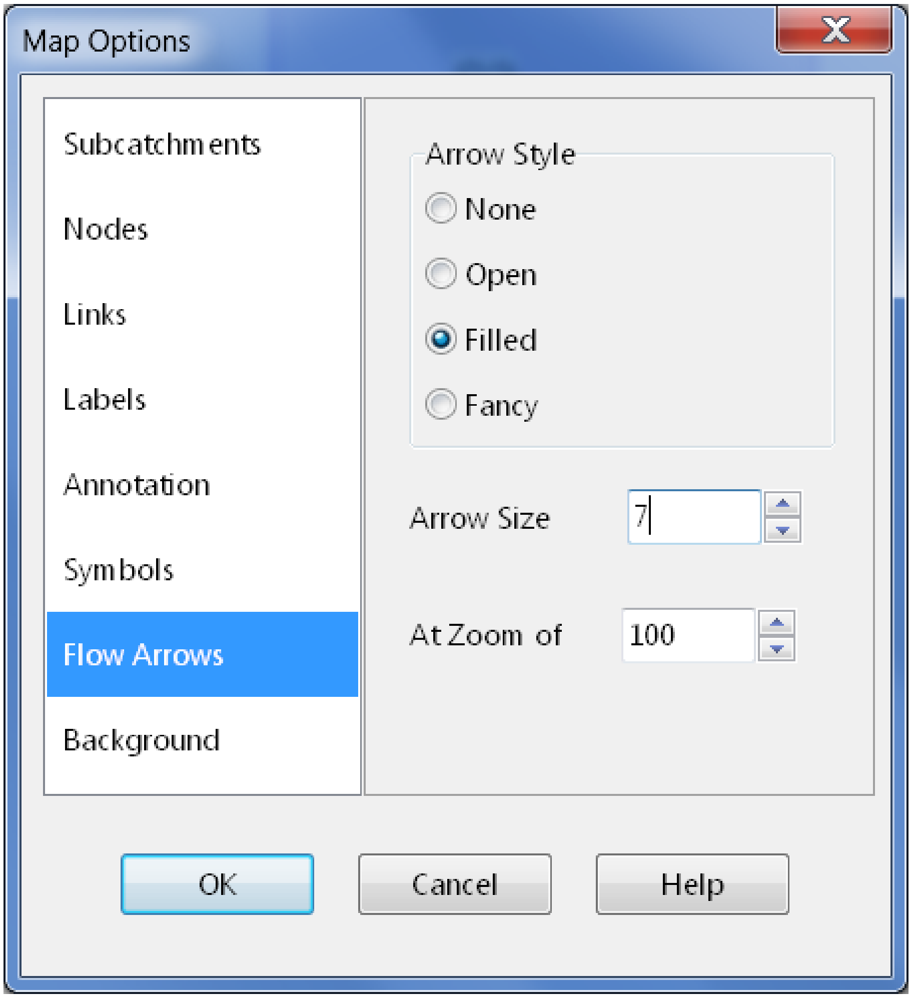
3. Then select the Nodes page and set the Node Size to **5**.



4. Select the Annotation page and check off the boxes that will display ID labels for Subcatchments, Rain Gages, Nodes, and Links. Leave the others un-checked.



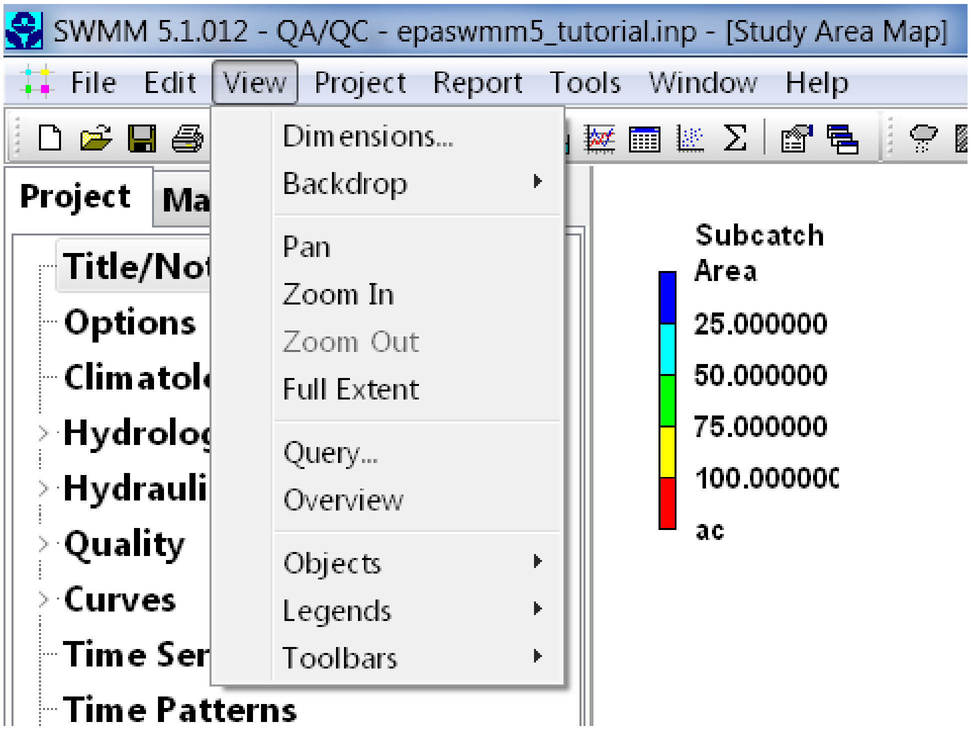
5. Finally, select the Flow Arrows page, select the **Filled** arrow style, and set the arrow size to **7**.



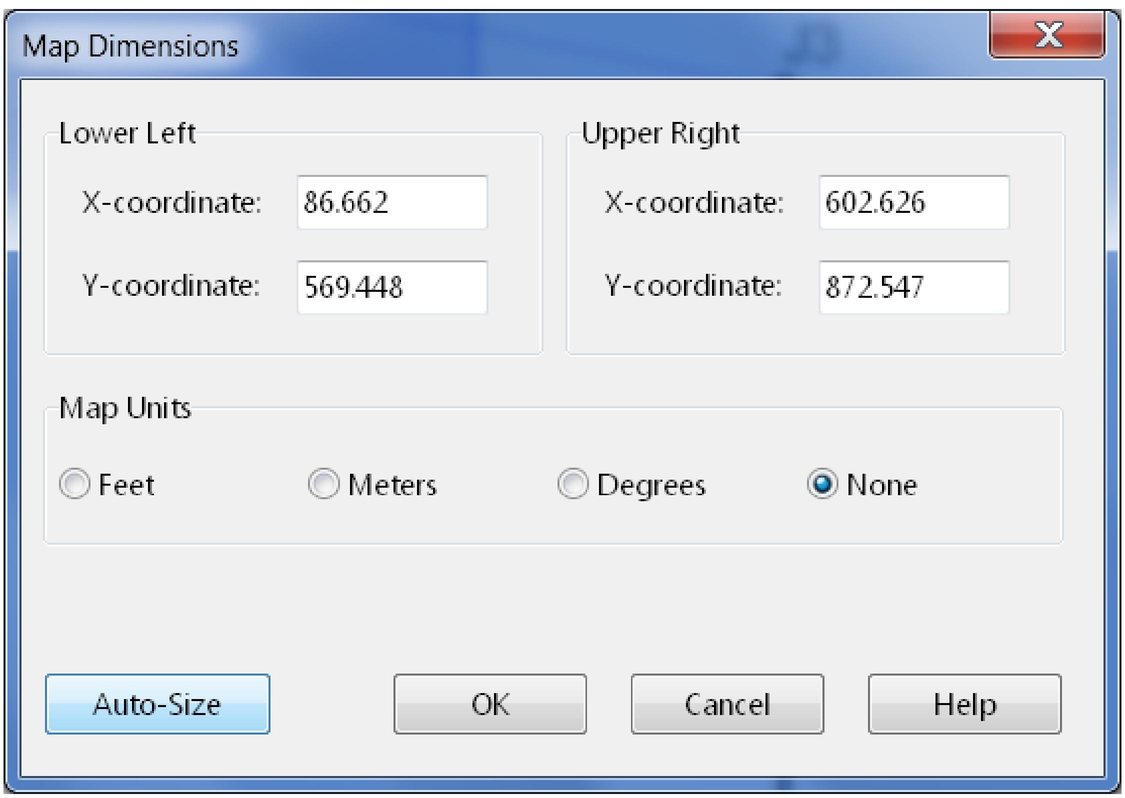
6. Click the **OK** button to accept these choices and close the dialog.

Before placing objects on the map we should set its dimensions.

1. Select **View | Dimensions** to bring up the Map Dimensions dialog.



2. You can leave the dimensions at their default values for this example.



Finally, look in the status bar at the bottom of the main window and check that the Auto-Length feature is off. If it is on, then click the down arrow button and select "Auto-Length: Off" from the popup menu that appears. Also make sure that the Offsets option is set to Depth. If set to Elevation then click the down arrow button and select "Depth Offsets" from the popup menu that appears.

We are now ready to begin adding components to the Study Area Map. We will start with the subcatchments. Remember that you can click the **View Map** button of this tutorial at any time to see how we want our map to look eventually. *Drawing objects on the map is just one way of creating a project. For large projects it will be more convenient to first construct an EPA SWMM project file external to the program. The project file is a text file that describes each object in a specified format as described in the Users Manual. Data extracted from various sources, such as CAD drawings or GIS files, can be used to create the project file.*

1. Begin by selecting the **Subcatchments** category (under Hydrology) in the Project Browser panel (on the left side of the main window).

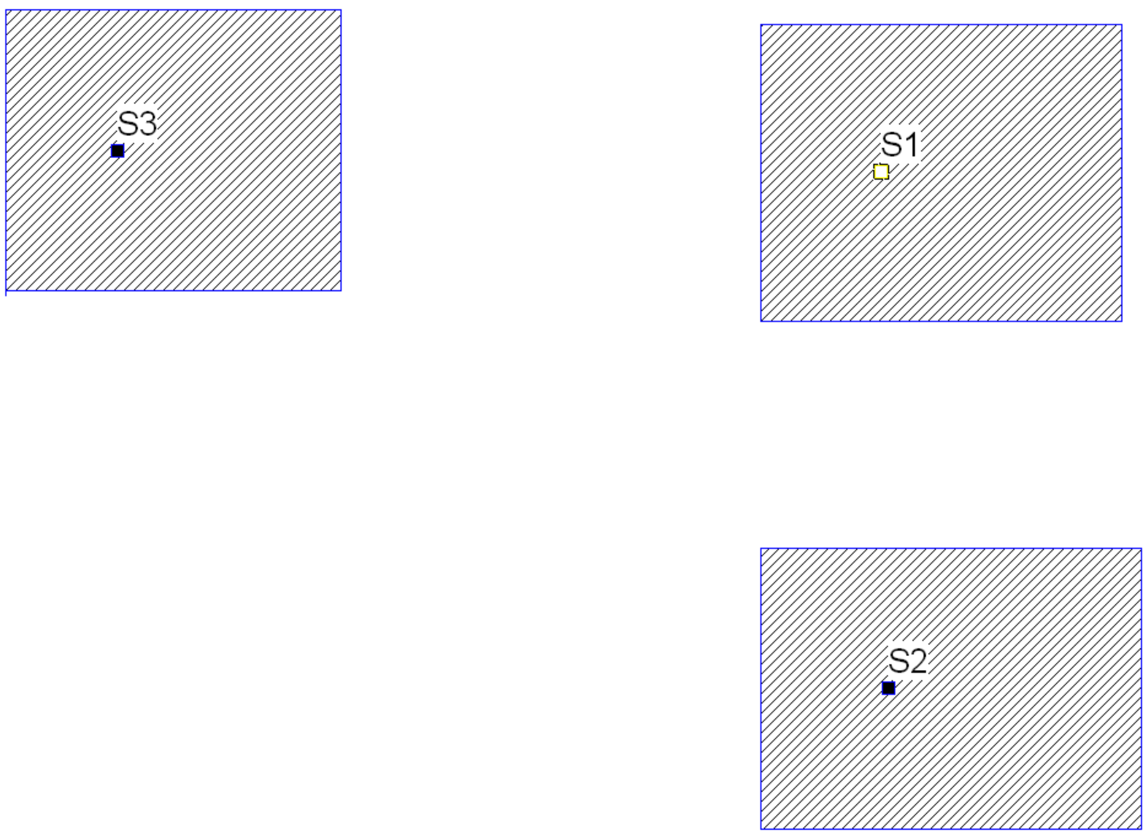
2. Then click the  button on the toolbar underneath the object category listing in the Project panel (or select **Project | Add a New Subcatchment** from the main menu). Notice how the mouse cursor changes shape to a pencil when you move it over the map.

3. Move the mouse to the map location where one of the corners of subcatchment **S1** lies and left-click the mouse.

4. Do the same for the next three corners and then right-click the mouse (or hit the **Enter** key) to close up the rectangle that represents subcatchment **S1**. You can press the **Esc** key if instead you wanted to cancel your partially drawn subcatchment and start over again. Don't worry if the shape or position of the object isn't quite right. We will go back later and show how to fix this.

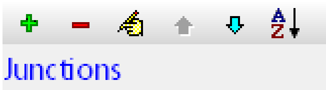
5. Next move the mouse to subcatchment **S2**'s location and draw its outline. Then repeat for subcatchment **S3**. If you right-click (or press Enter) after adding the first point of a subcatchment\'s outline, the subcatchment will be shown as just a single point.

Observe how sequential ID labels are generated automatically as we add objects to the map.



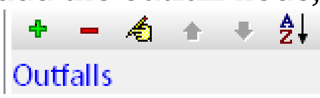
Next we will add in the junction nodes and the outfall node that comprise part of the drainage network.

1. To begin adding junctions, select the **Junctions** category from the Project Browser (under Hydraulics -> Nodes) and click the

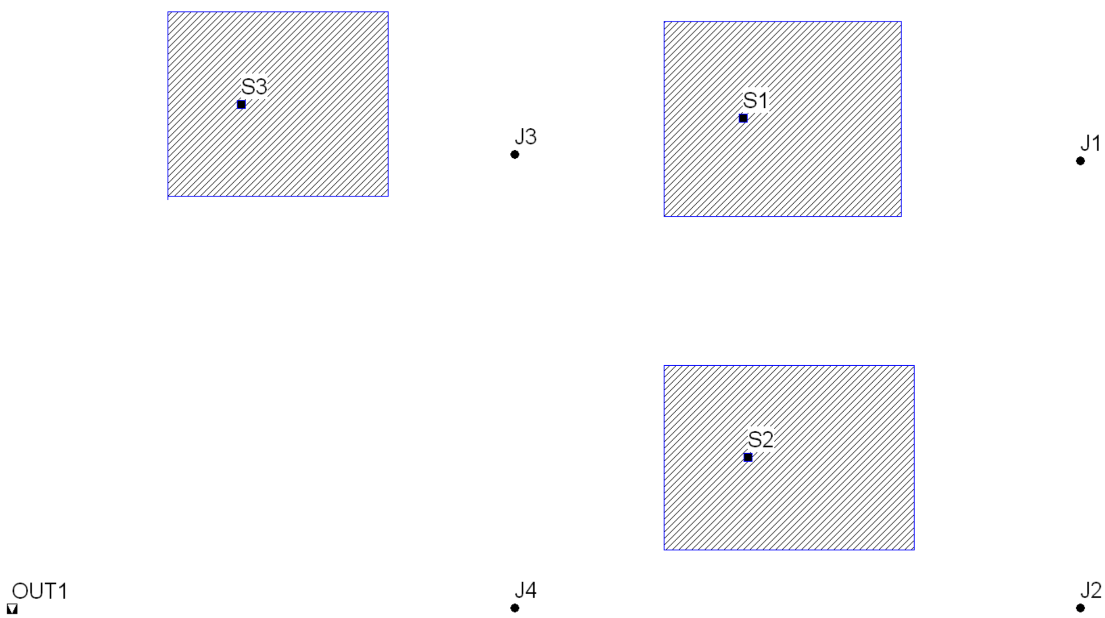


button or select **Project | Add a New Junction** from the main menu.

2. Move the mouse to the position of junction **J1** and left-click it. Do the same for junctions **J2** through **J4**.

3. To add the outfall node, select Outfalls from the Project Browser, click the 

button or select **Project | Add a New Outfall** from the main menu, move the mouse to the outfall's location on the map, and left-click. Note how the outfall is automatically given the name **Out1**.



Now we will add the storm sewer conduits that connect our drainage system nodes to one another. (You must have created a link's end nodes as described in the previous topic before you can create the link.) We will begin with conduit **C1** which connects junction **J1** to **J2**.

1. Select the Conduits from the Project Browser (under Hydraulics -> Links) and press the 

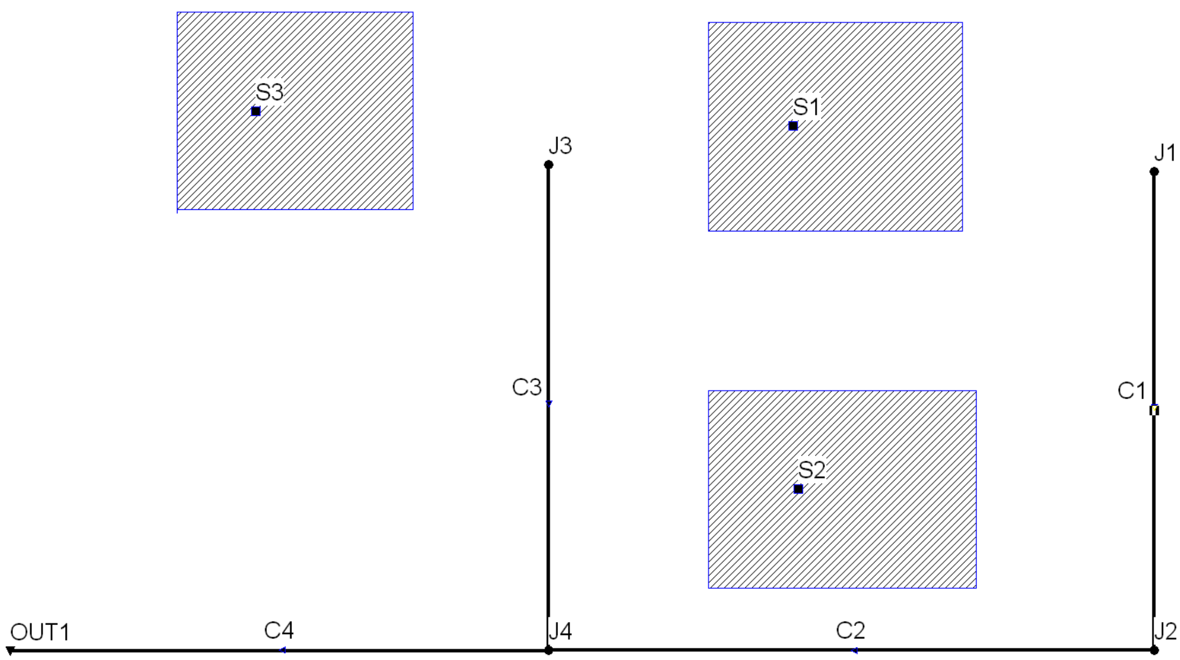
button or select **Project | Add**

a **New Conduit** from the main menu. The mouse cursor will change shape to a cross hair when moved onto the map.

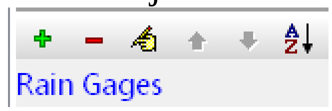
2. Left click the mouse on junction **J1**. Note how the mouse cursor now changes shape to a pencil.

3. Move the mouse over to junction **J2** (note how an outline of the conduit is drawn as you move the mouse) and left-click to create the conduit. You could have canceled the operation by either right-clicking or by hitting the **Esc** key.

Repeat steps 2 and 3 for conduits **C2** through **C4**. *Although all of our conduits were drawn as straight lines, it is possible to draw a curved link by left-clicking at intermediate points where the direction of the link changes before clicking on the end node.*

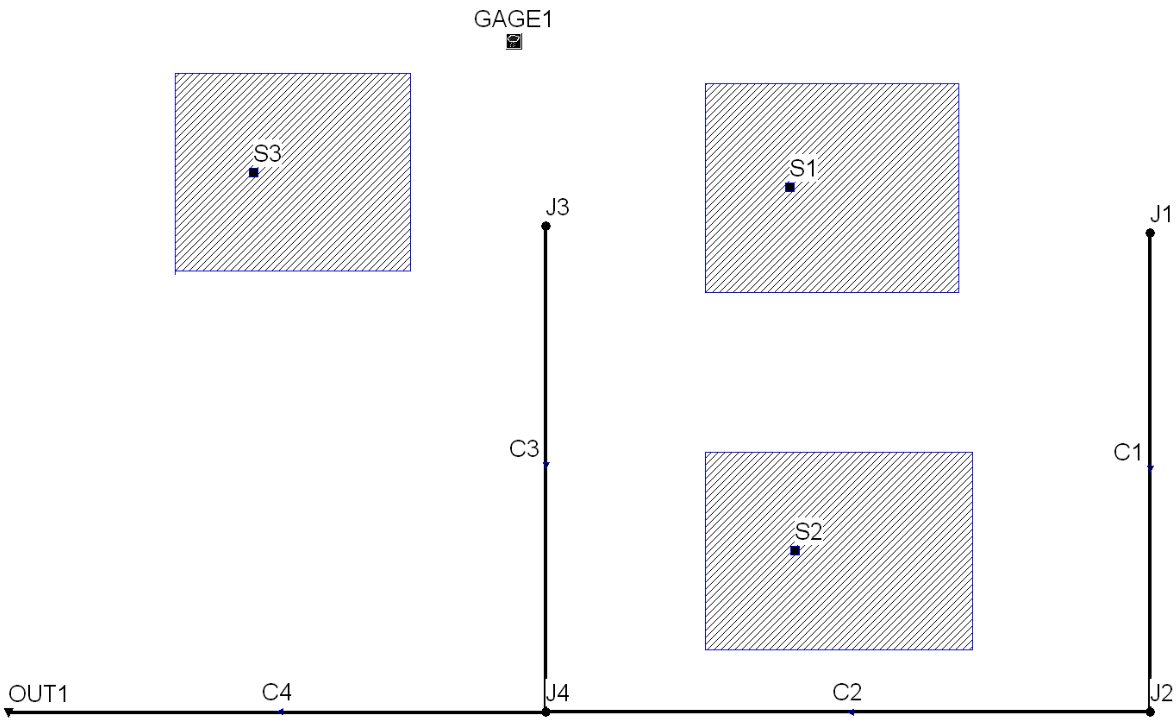


To complete the construction of our study area schematic we need to add a rain gage.

1. Select the Rain Gages category from the the Project Browser panel (under Hydrology) and either click the 

button or select **Project | Add a New Rain Gage** from the main menu.

2. Move the mouse over the Study Area Map to where the gage should be located and left-click the mouse.



At this point we have completed drawing the example study area. Your system should look like the one seen by pressing the View Map button above. If the rain gage, subcatchments or nodes are out of position you can move them around by

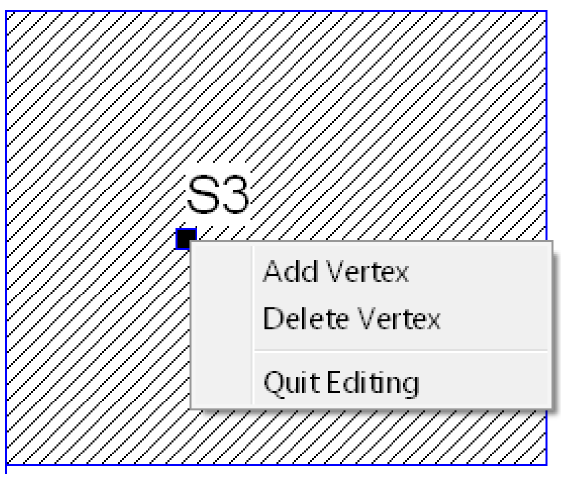
1. clicking the  button on the Map Toolbar to place the map in Object Selection mode,

2. clicking on the object to be moved,

3. dragging the object with the left mouse button held down to its new position.

To re-shape a subcatchment's outline:

1. With the map in Object Selection mode, click on the subcatchment's centroid (indicated by a solid square within the subcatchment) to select it.
2. Then click the  button on the Map Toolbar to put the map into Vertex Selection mode.
3. Select a vertex point on the subcatchment outline by clicking on it (note how the selected vertex is indicated by a filled solid square).



4. Drag the vertex to its new position with the left mouse button held down.
5. If need be, vertices can be added to or deleted from the outline by right-clicking the mouse and selecting the appropriate option from the popup menu that appears.

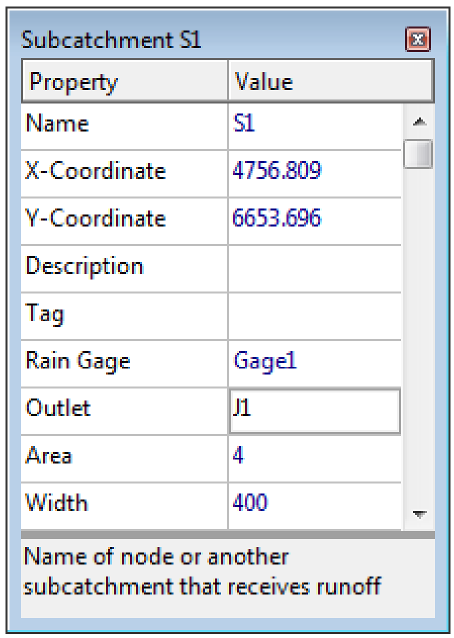
6. When finished, click the  button to return to Object Selection mode.

This same procedure can also be used to re-shape a link.

As visual objects are added to our project, SWMM assigns them a default set of properties. To change the value of a specific property for an object we must select the object into the Property Editor (shown below). There are several different ways to do this. If the Editor is already visible then you can simply click on the object or select it from the Project Browser. If the Editor is not visible then you can make it appear by one of the following actions:

- double-click the object on the map
- right-click on the object and select **Properties** from the pop-up menu that appears
- select the object from the Project Browser and then click the Browser's 

button.



Whenever the Property Editor has the focus you can press the F1 key to obtain a more detailed description of the properties listed.

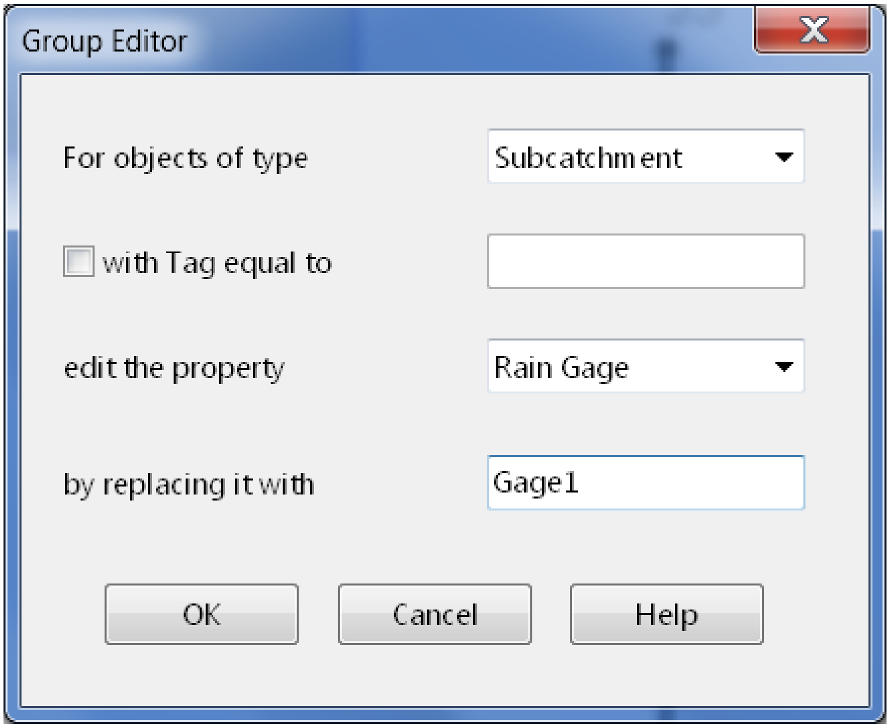
Two key properties of our subcatchments that need to be set are the rain gage that supplies rainfall data to the subcatchment and the node of the drainage system that receives runoff from the subcatchment. Since all of our subcatchments utilize the same rain gage, **Gage1**, we can use a shortcut method to set this property for all subcatchments at once:

1. From the main menu select **Edit | Select All**.

2. Then select **Edit | Group Edit** to make a Group Editor dialog appear.

3. Select **Subcatchments** as the class of object to edit, **Raingage** as the property to edit, and type in **Gage1** as the new value.

4. Click **OK** to change the rain gage of all subcatchments to **Gage1**. A confirmation dialog will appear noting that 3 subcatchments have changed. Select **No** when asked to continue editing.



To set the outlet node of our subcatchments we have to proceed one by one, since these vary by subcatchment:

1. Double click on subcatchment **S1** or select it from the Project Browser and click the Browser's  button to bring up the Property Editor.

2. Type **J1** in the Outlet field and press **Enter**. Note how a dotted line is drawn between the subcatchment and the node.

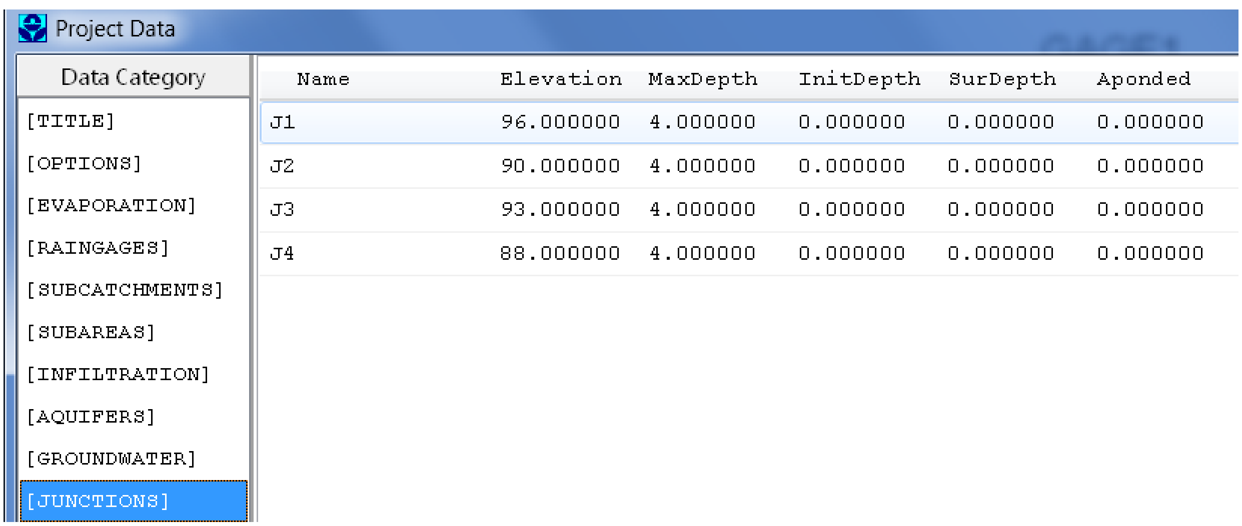
3. Click on subcatchment **S2** and enter **J2** as its Outlet.

4. Click on subcatchment **S3** and enter **J3** as its Outlet.

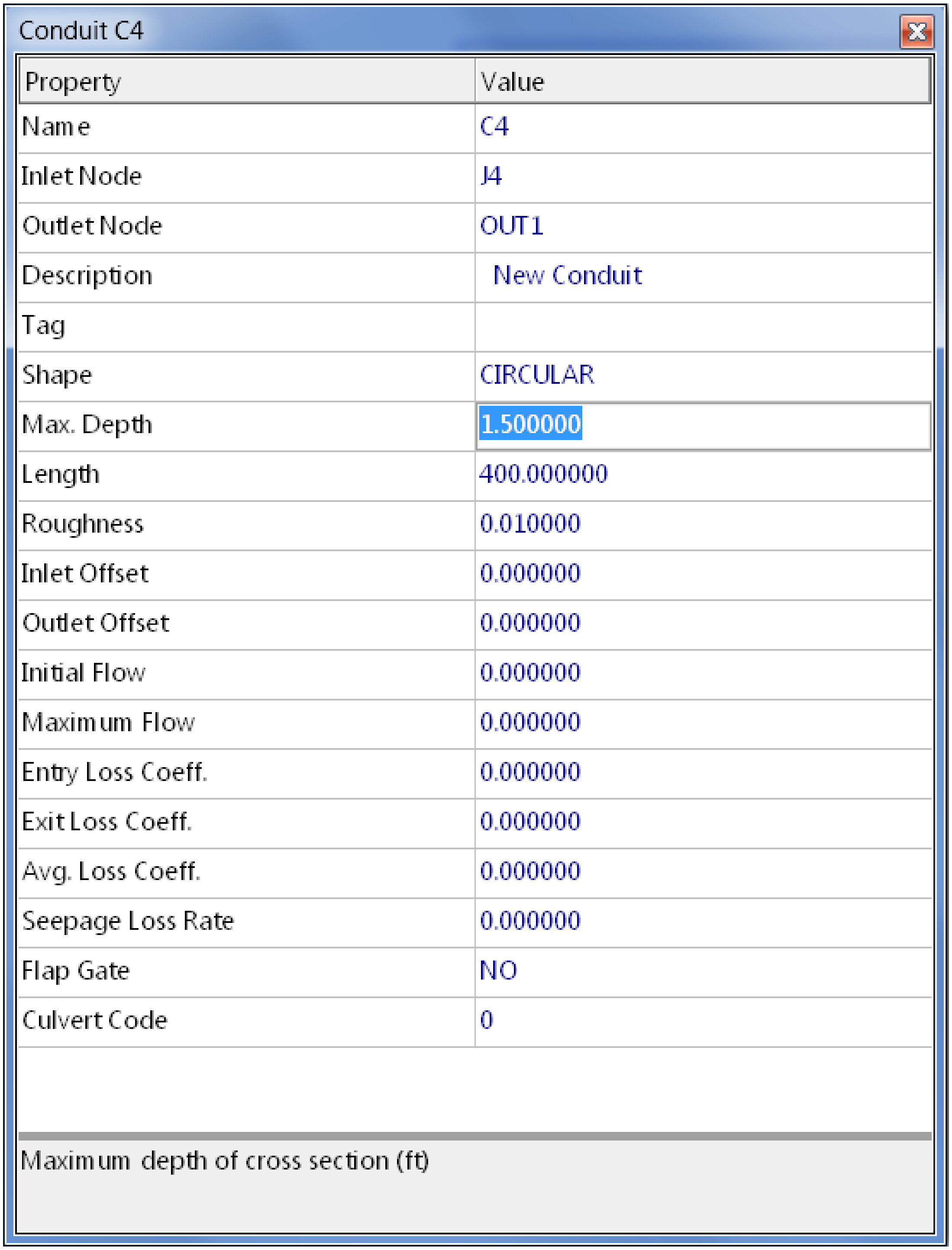
Finally, we wish to represent area **S3** as being less developed than the others. Select **S3** into the Property Editor and set its % Imperviousness to **25**.

The junctions and outfall of our drainage system need to have invert elevations assigned to them. As we did with the subcatchments, select each junction individually into the Property Editor and set its **Invert Elevation** to the value shown in the table below. *An alternative way to move from one object of a given type to the next in order (or to the previous one) in the Property Editor is to hit the Page Down (or Page Up) key.*

Node	**Invert**
J1	**96**
J2	**90**
J3	**93**
J4	**88**
Out1	**85**



Only one of the conduits in our example system has a non-default property value. This is conduit **C4**, the outlet pipe, whose diameter should be 1.5 ft. instead of 1 ft. To change its diameter, select conduit **C4** into the Property Editor and set the Max. Depth value to **1.5**.



Conduit C4

Property	Value
Name	C4
Inlet Node	J4
Outlet Node	OUT1
Description	New Conduit
Tag	
Shape	CIRCULAR
Max. Depth	1.500000
Length	400.000000
Roughness	0.010000
Inlet Offset	0.000000
Outlet Offset	0.000000
Initial Flow	0.000000
Maximum Flow	0.000000
Entry Loss Coeff.	0.000000
Exit Loss Coeff.	0.000000
Avg. Loss Coeff.	0.000000
Seepage Loss Rate	0.000000
Flap Gate	NO
Culvert Code	0

Maximum depth of cross section (ft)

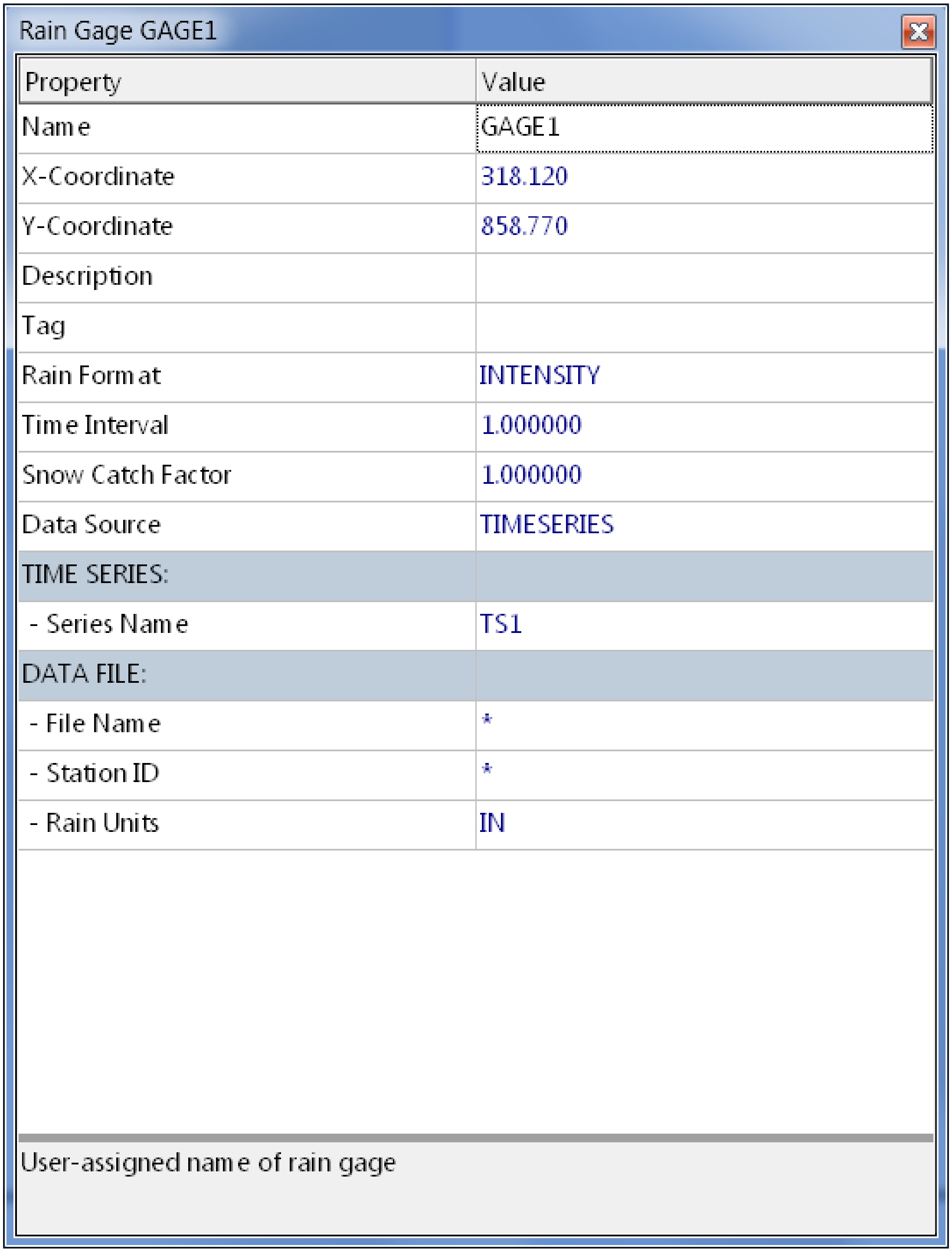
In order to provide a source of rainfall input to our project we need to set the rain gage properties. Select **Gage1** into the Property Editor and set the following properties:

Rain Format: INTENSITY

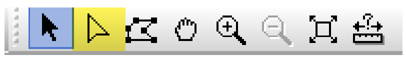
Rain Interval: 1:00

Data Source: TIMESERIES

Series Name: TS1



As mentioned earlier, we want to simulate the response of our study area to a 3-inch, 6-hour design storm. A time series named **TS1** will contain the hourly rainfall intensities that make up this storm. Thus we need to create a time series object and populate it with data. To do this:

1. From the Project Browser select the Time Series category of objects.
2. Click the  button on the Browser which will bring up a Time Series Editor form. Leaving off the dates for a time series means that SWMM will interpret the time values as hours from the start of the simulation. *Otherwise, the time series follows the date\/time values specified by the user.*

3. Enter **TS1** in the Time Series Name field.

4. Enter the following values into the Time and Value columns of the data entry grid (leave the Date column blank): *The Time Series Editor can also be launched directly from the Rain Gage Property Editor by selecting the editor\'s Series Name field and double clicking on it. "*

0 0

1 0.5

2 1.0

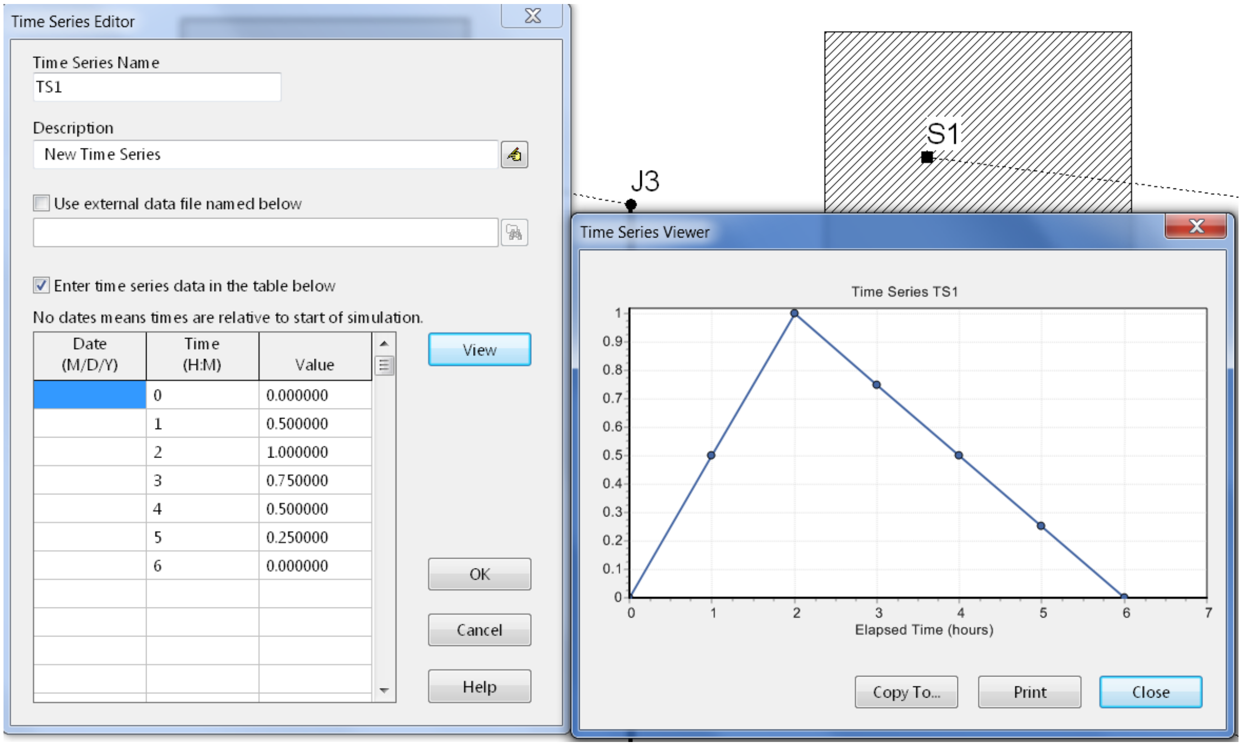
3 0.75

4 0.5

5 0.25

6 0

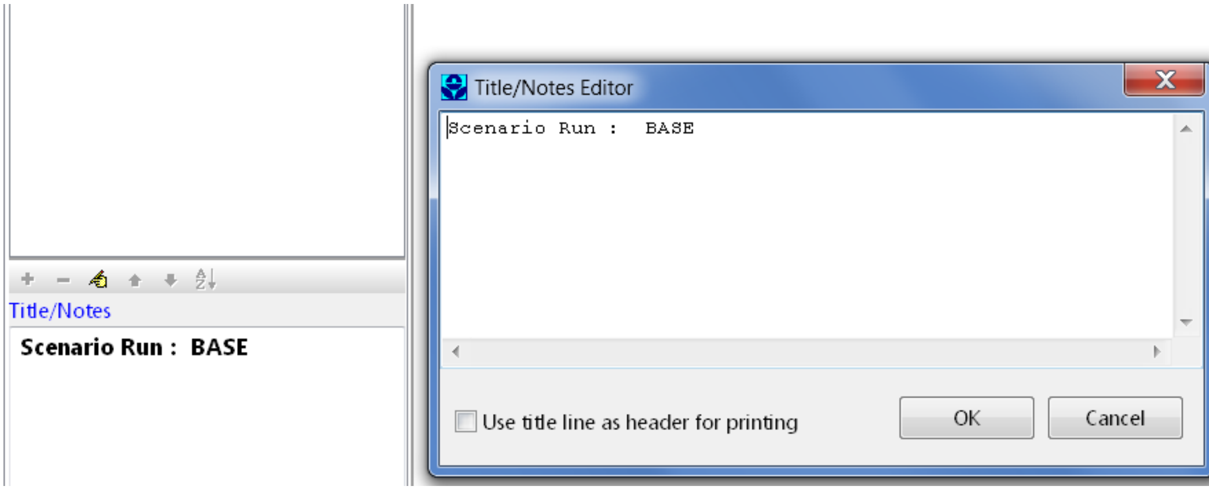
5. You can click the **View** button on the dialog to see a graph of the time series values. Click the **OK** button to accept the new time series.



Having completed the initial design of our example project it is a good idea to give it a title and save our work to a file at this point. To do this:

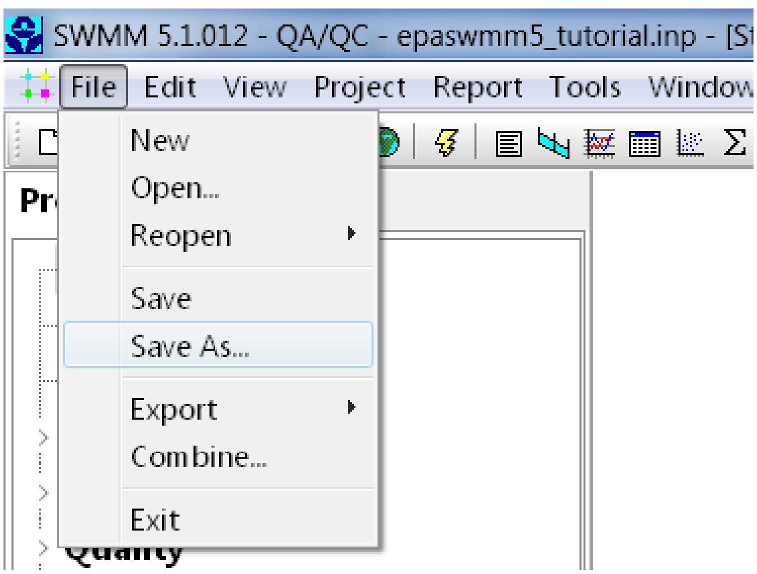
1. Select the **Title/Notes** category from the Project Browser and click the 

button.

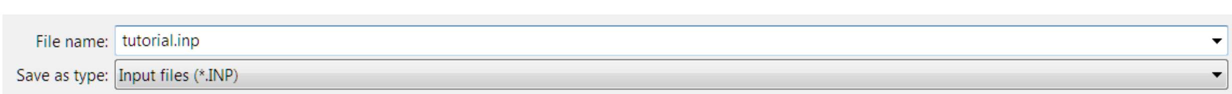


2. In the Project Title/Notes dialog that appears, enter "Tutorial Example" as the title of our project and click the **OK** button to close the dialog.

3. From the **File** menu select the **Save As** option.



4. In the Save As dialog that appears, select a folder and file name under which to save this project. We suggest naming the file **tutorial.inp**. (An extension of .inp will be added to the file name if one is not supplied.)



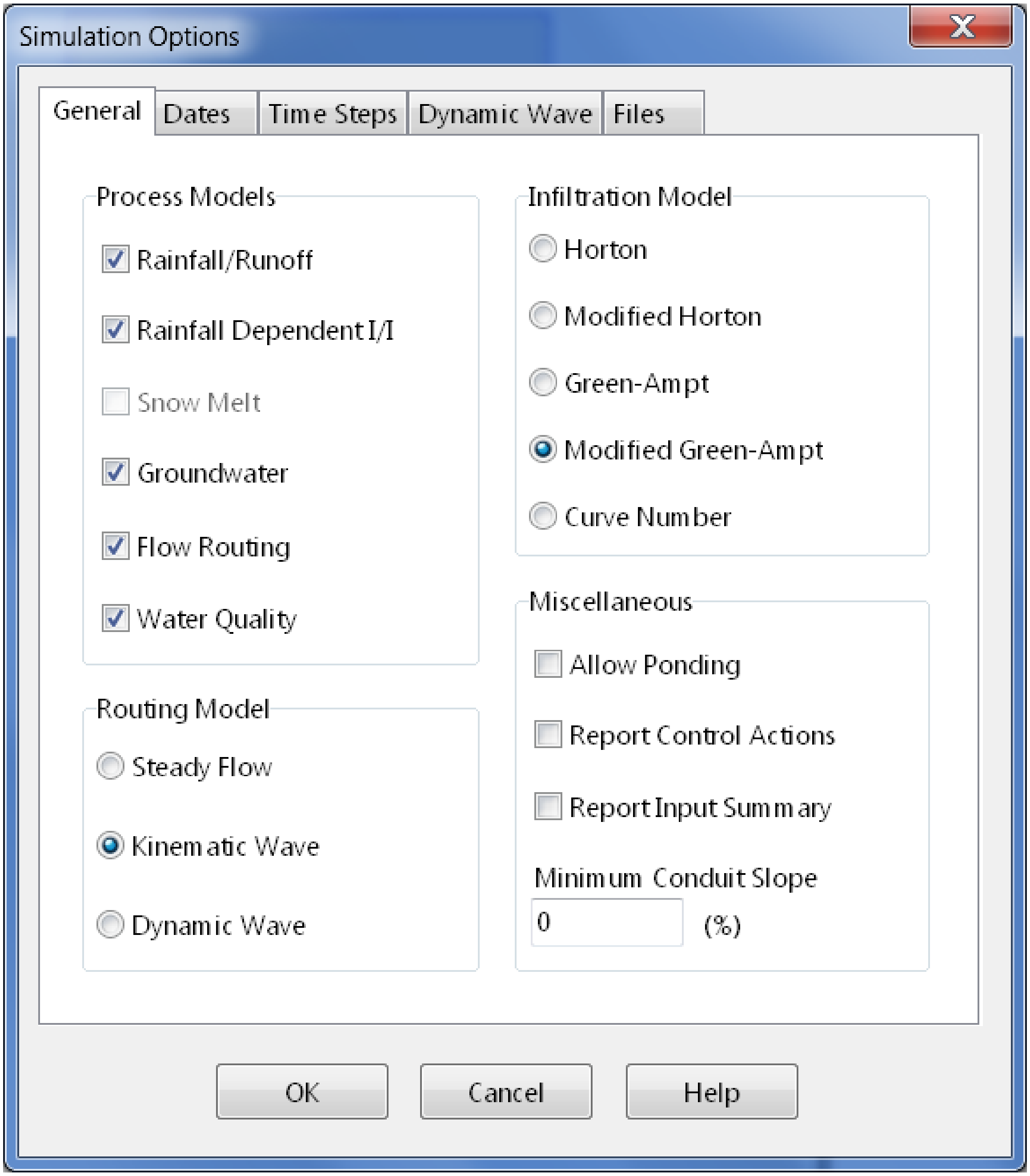
5. Click **OK** to save the project to file.

The project data is saved to the file in a readable text format. You can view what the file looks like by selecting **Project | Details** from the main menu. To open our project at some later time, we would select the **Open** command from the **File** menu.

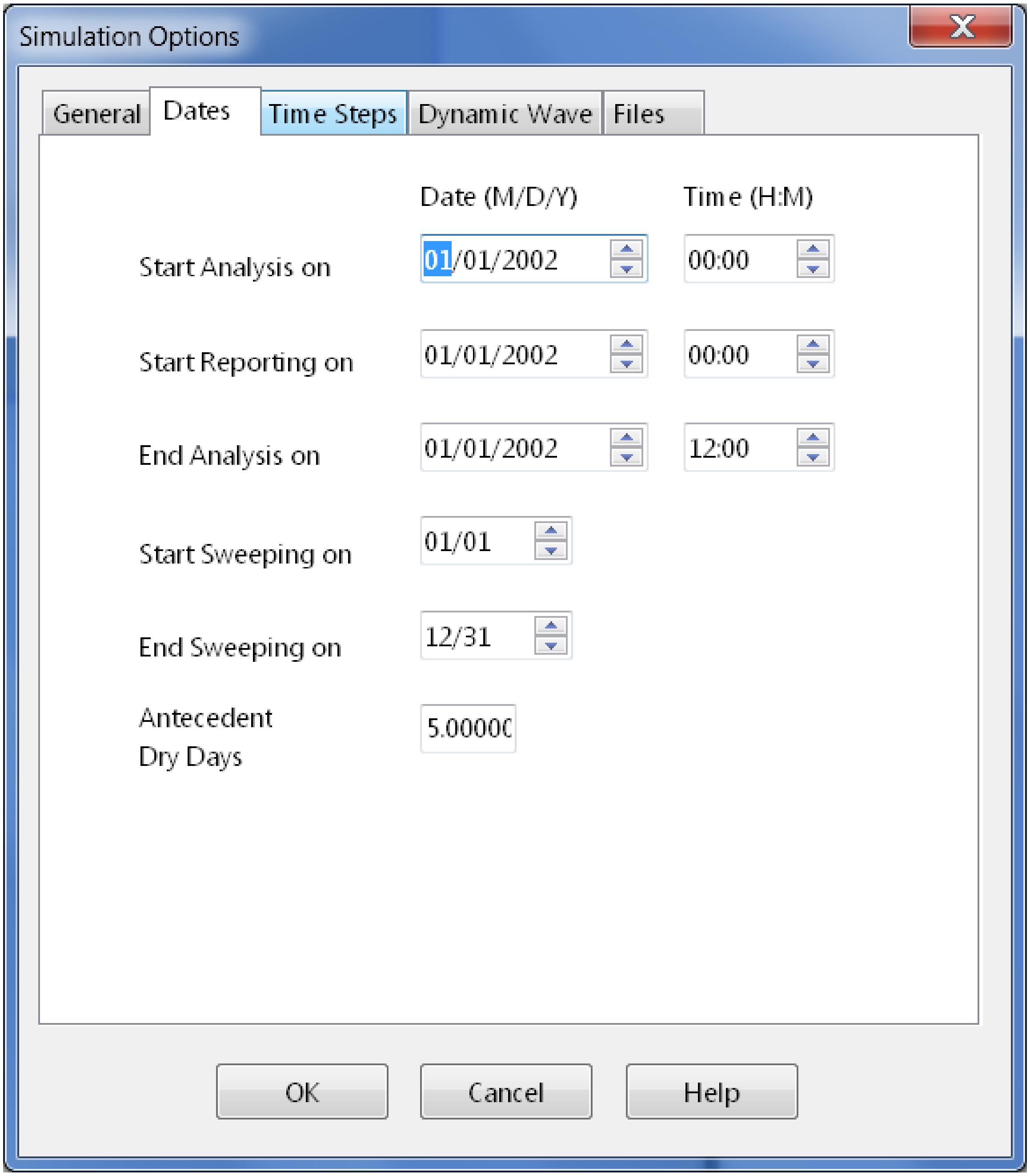
Before analyzing the performance of our example drainage system we need to set some options that determine how the analysis will be carried out. To do this:

1. From the Project Browser, select the **Options** category and click the  button.

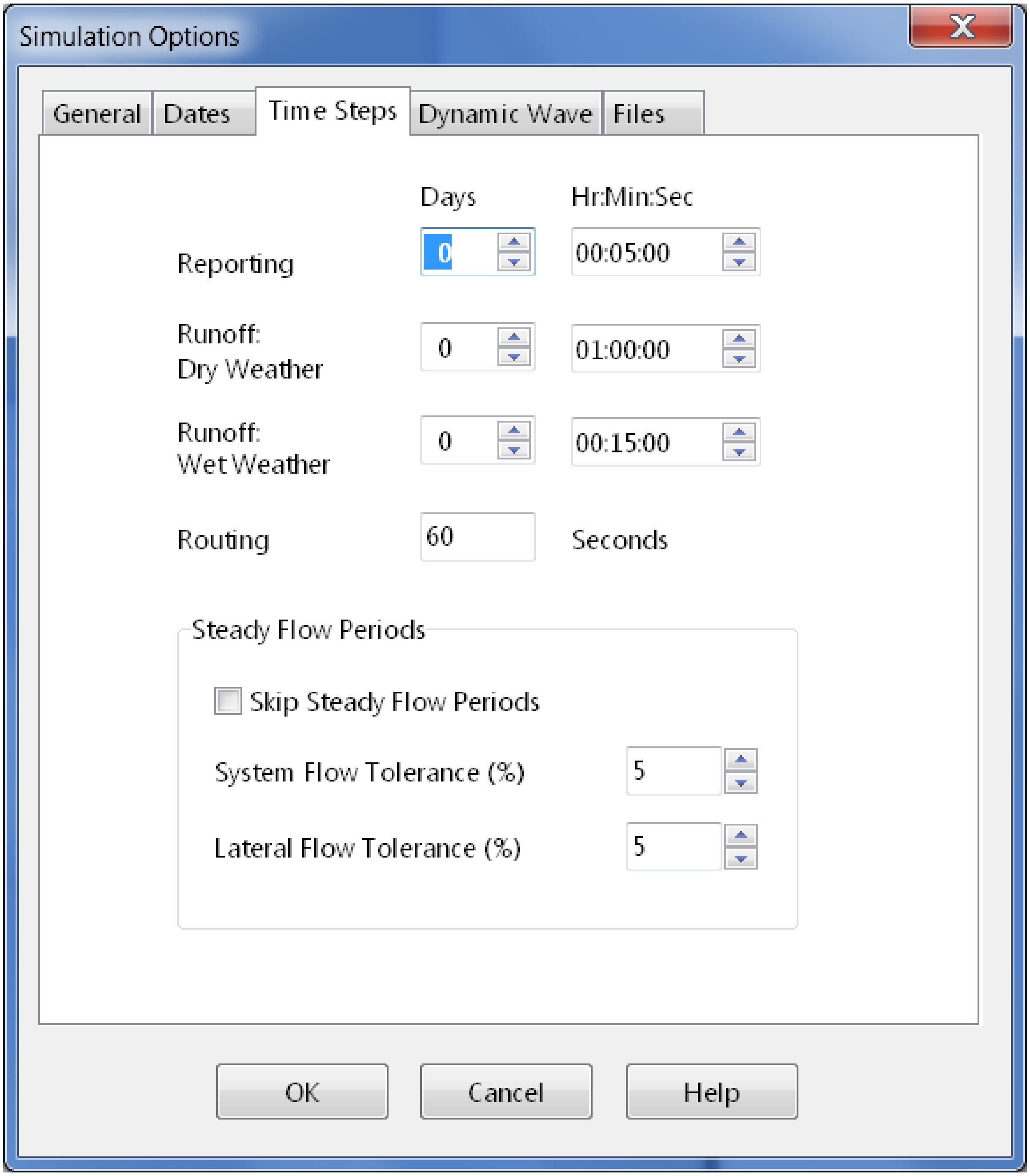
2. On the General page of the Simulation Options dialog that appears, select **Kinematic Wave** as the flow routing method. The flow units should already be set to **CFS** and the infiltration method to Modified **Green-Ampt**. The Allow Ponding option should be unchecked.



3. On the Dates page of the dialog, set the End Analysis time to **12:00**.



4. On the Time Steps page, set the Routing Time Step to **60** sec.



5. Click **OK** to close the Simulation Options dialog.

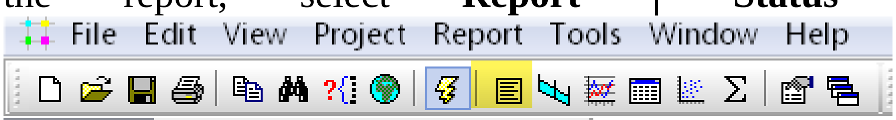
We are now ready to run the simulation. To do so, select **Project | Run Simulation** on the main menu (or simply click the  button).

If there was a problem in running the simulation, a Status Report will appear describing what errors occurred.

Upon successfully completing a run, there are numerous ways in which to view the results of the simulation. We will illustrate just a few here:

- Viewing the Status Report
- Viewing the Summary Report
- Viewing results on the map
- Viewing a time series plot
- Viewing a profile plot

The Status Report contains useful information about the quality of a simulation run, including a mass balance on rainfall, infiltration, evaporation, runoff, and inflow/outflow for the conveyance system. To view the report, select **Report | Status** (or click the



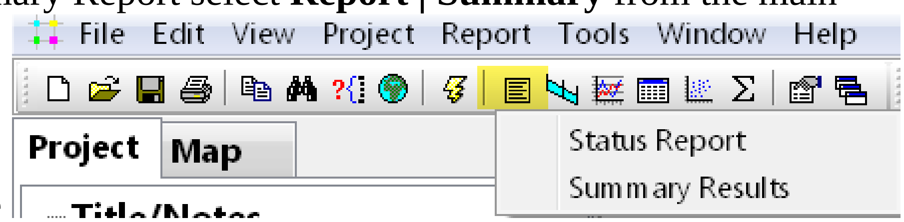
button on the Standard Toolbar and then select **Status Report** from the drop down menu).

For the system we just analyzed the report indicates the quality of the simulation is quite good, with negligible mass balance continuity errors for both runoff and routing (-0.22% and 0.03%, respectively, if all data were entered correctly). Also, of the 3 inches of rain that fell on the study area, 1.75 infiltrated into the ground and essentially the remainder became runoff.

```
**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         3.000         3.000
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         1.749         1.749
Surface Runoff ...........         1.257         1.257
Final Storage ............         0.000         0.000
Continuity Error (%) .....        -0.222
```

The Summary Report contains tables listing summary results for each subcatchment, node and link in the drainage system. Total rainfall, total runoff, and peak runoff for each subcatchment, peak depth and and hours flooded for each node, and peak flow, velocity, and depth for each conduit are just some of the outcomes included in the summary report.

To view the Summary Report select **Report | Summary** from the main



menu (or click the button on the Standard Toolbar and then select **Summary Report** from the drop down menu). The report's window has a drop down list from which you select a particular report to view. For our example, the Node Flooding Summary table indicates there was internal flooding in the system at node **J2**. *In EPA SWMM, flooding will occur whenever the water surface at a node exceeds the maximum defined depth. Normally such water will be lost from the system. The option also exists to have this water pond atop the node and be re-introduced into the drainage system when capacity exists to do so* . The Conduit Surcharge Summary table shows that Conduit **C2**, just downstream of node **J2**, was at full capacity and therefore appears to be slightly undersized.

Topic: Conduit Surcharge — Click a column header to sort the column.

Conduit	Hours Both Ends Full	Hours Upstream Full	Hours Dnstream Full	Hours Above Normal Flow	Hours Capacity Limited
C2	1.03	1.03	1.03	1.05	1.03

Simulation results (as well as some design parameters, such as subcatchment area, node invert elevation, link maximum depth) can be viewed in color-coded fashion on the study area map. To view a particular variable in this fashion:

1. Select the Map page of the Browser panel.

2. Select the variables to view for Subcatchments, Nodes, and Links from the dropdown combo boxes in the Themes panel.

3. The color coding used for a particular variable is displayed with a legend on the study area map. To toggle the display of a legend, select **View | Legends**.

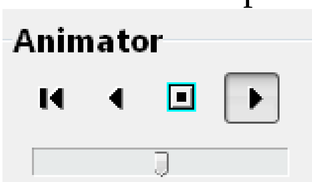
4. To move a legend to another location, drag it with the left mouse button held down.

5. To change the color coding and the breakpoint values for different colors, select **View | Legends | Modify** and then the pertinent class of object (or if the legend is already visible, simply right-click on it).

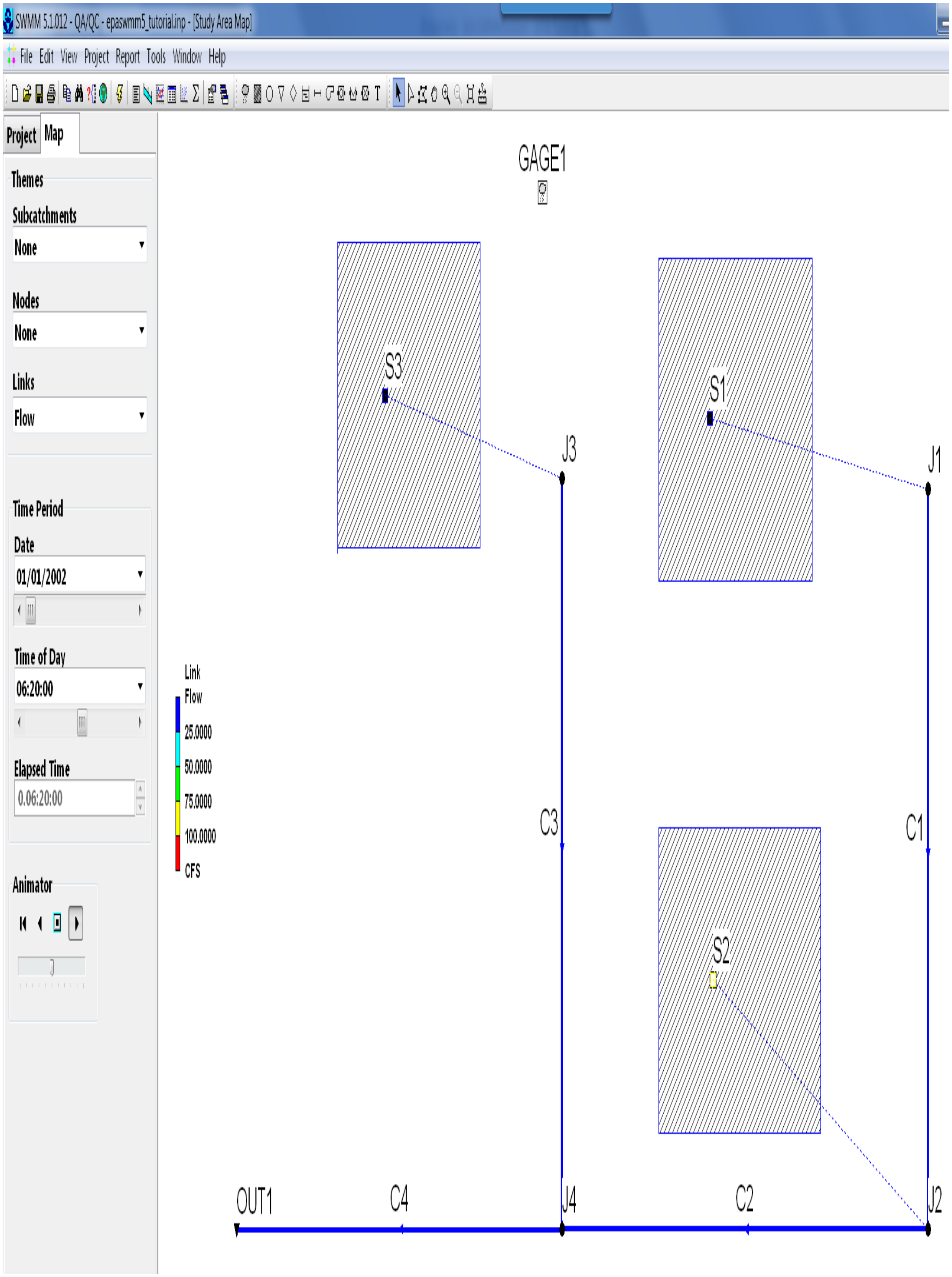
6. To view numerical values for the variables being displayed on the map, select **Tools | Map Display Options** and then select the Annotation page of the Map Options dialog. Use the check boxes for Rain Gages,

Subcatchments, Nodes, and Links to specify what kind of annotation to add.

7. The Date / Time of Day / Elapsed Time controls on the Map Browser can be used to move through the simulation results in time.

8. You can use the controls in the Animator panel of the Map Browser to animate the map display through time. For example, pressing the 

button will run the animation forward in time.


SWMM 5.1.012 - QA/QC - epaswmm5_tutorial.inp - [Study Area Map]
File Edit View Project Report Tools Window Help
Project Map
Themes
Subcatchments
None
Nodes
None
Links
Flow
Time Period
Date
01/01/2002
Time of Day
06:20:00
Elapsed Time
0.06:20:00
Animator
Link
Flow
25.0000
50.0000
75.0000
100.0000
CFS
GAGE1
S3
S1
S2
J3
J1
J4
J2
C3
C1
C4
C2
OUT1

To generate a time series plot of a simulation result:

1. Select **Report | Graph | Time Series** from the menu bar or simply click 

on the Standard Toolbar..

2. A Time Series Plot Selection dialog will appear. It is used to select the objects and variables to be plotted.

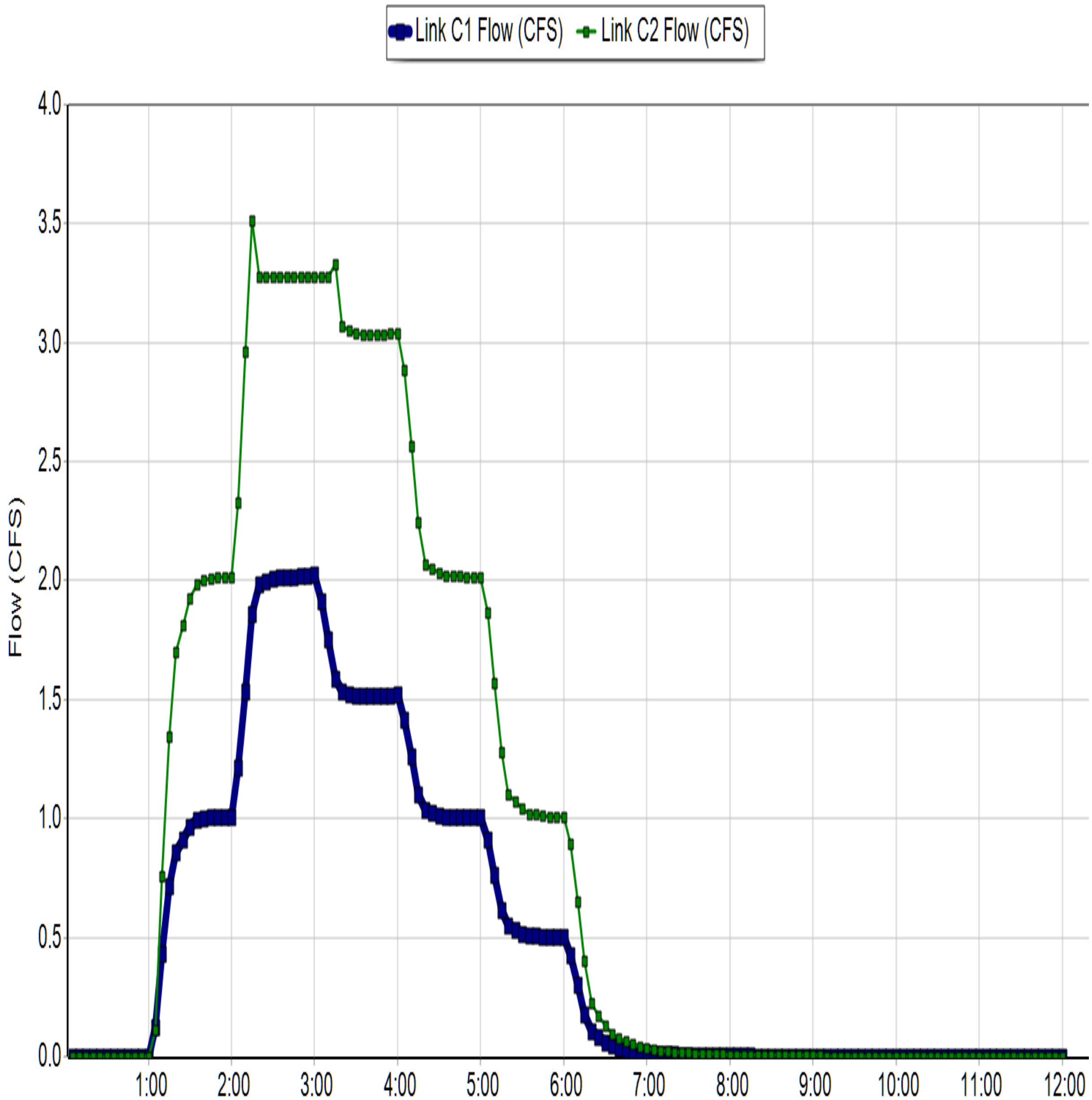
For our example, this dialog can be used to graph the flows in conduits **C1** and **C2** as follows:

1. Select conduit **C1** on the map or in the Project Browser and then click the **Add** button on the dialog.

2. A Data Series Selection page will appear. Select **Flow** as the Variable to plot.

3. Click the **Accept** button to return to the Plot Selection page of the dialog.

4. Repeat the above steps for conduit **C2** and press **OK** to create the plot.



After a plot is created you can:

- customize its appearance by selecting **Report | Customize** or right clicking on the plot,
- copy it to the clipboard and paste it into another application by selecting **Edit | Copy To** or clicking

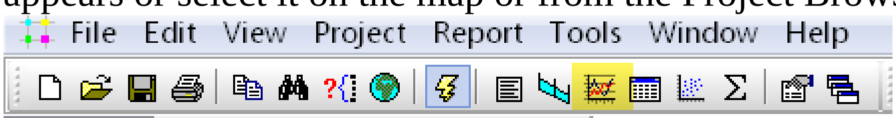
on the Standard Toolbar

· print it by selecting **File | Print** or **File | Print Preview** (use **File | Page Setup** first to set margins, orientation, etc.).

SWMM can generate profile plots showing how water surface depth varies across a path of connected nodes and links. Let's create such a plot for the conduits connecting junction **J1** to the outfall **Out1** of our example drainage system. To do this:

1. Select Report | Graph | Profile or simply click 

on the Standard Toolbar.

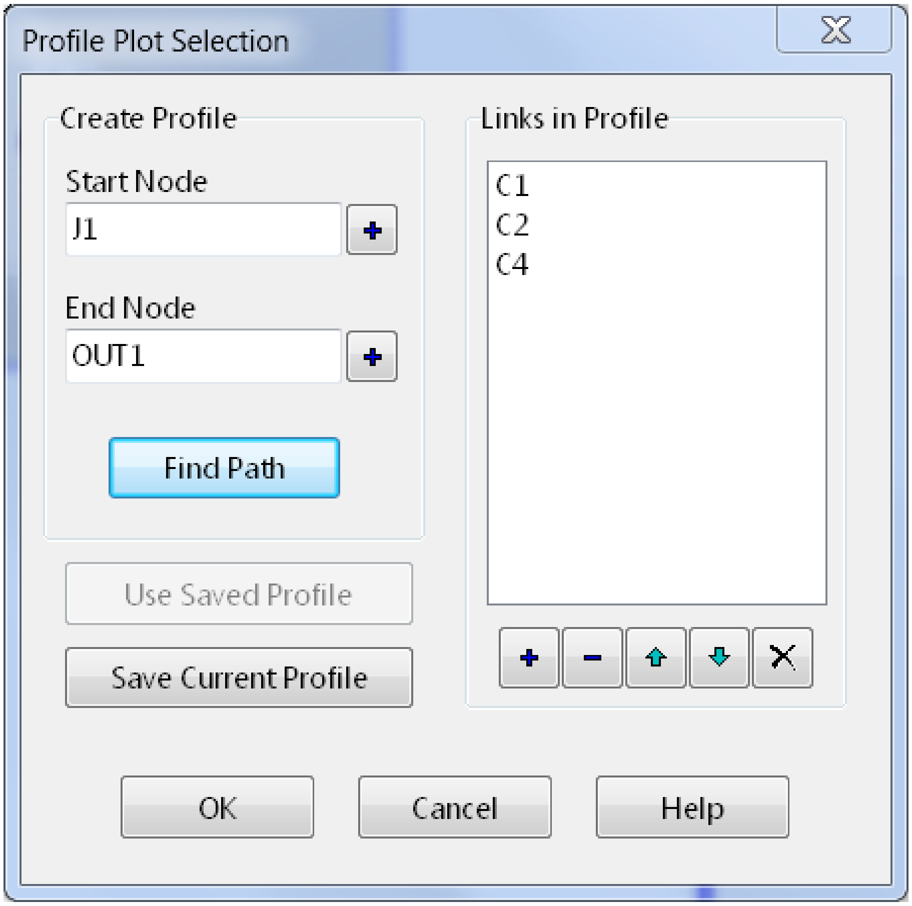
2. Either enter **J1** in the Start Node field of the Profile Plot dialog that appears or select it on the map or from the Project Browser and click the 

button next to the field.

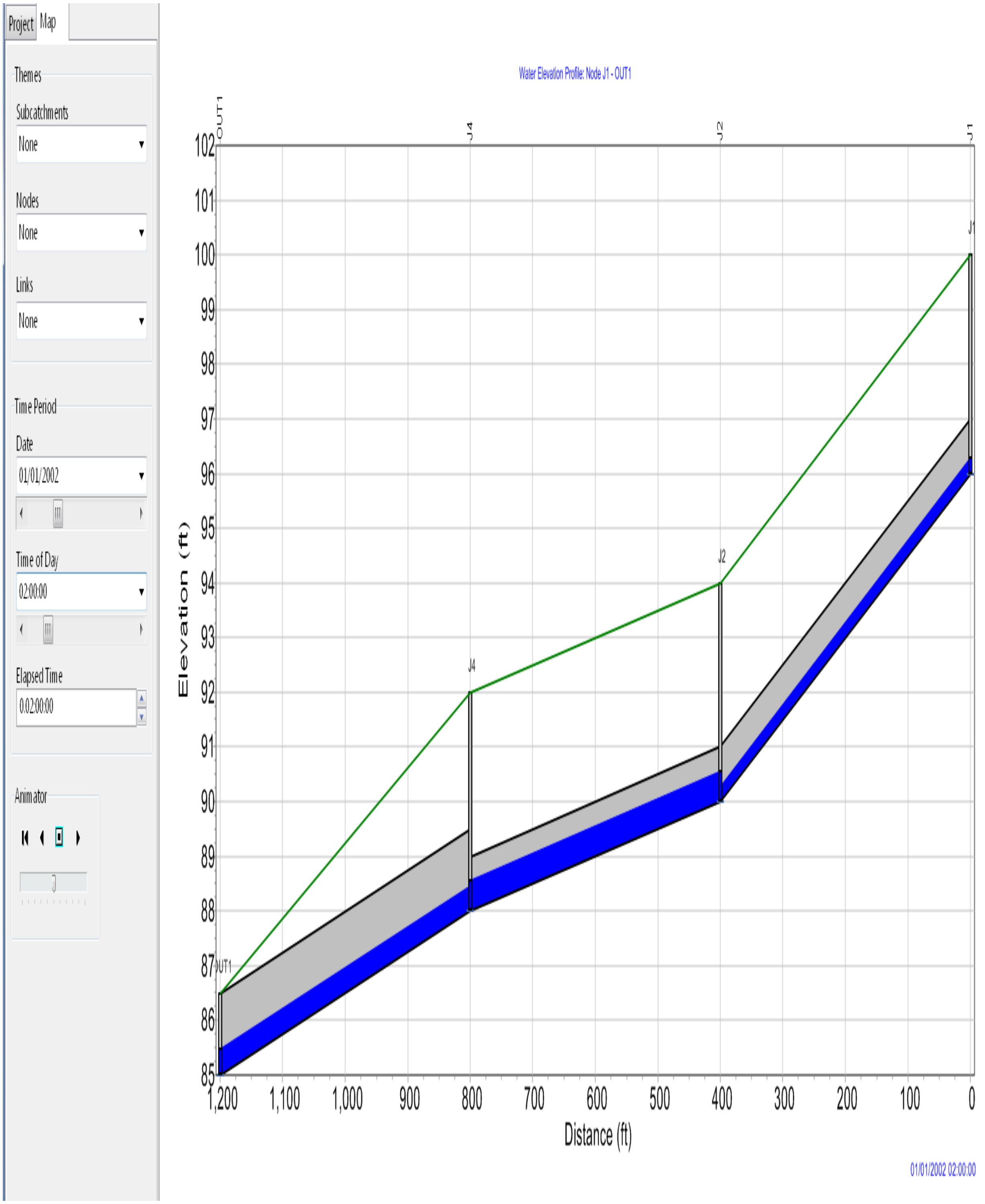
3. Do the same for node **Out1** in the End Node field of the dialog.

4. Click the **Find Path** button. An ordered list of the links which form a connected path between the specified Start and End nodes will be displayed in the Links in Profile box. You can edit the entries in this box if need be.

5. Click the **OK** button to create the plot, showing the water surface profile as it exists at the simulation time currently selected in the Map Browser.



As you move through time using the Map Browser or with the Animator control, the water depth profile on the plot will be updated. Observe how node **J2** becomes flooded between hours 2 and 3 of the storm event.



The appearance of a profile plot can be customized or it can be copied or printed using the same procedures as for a time series plot.

In the analysis just run we chose to use the Kinematic Wave method of routing flows through our drainage system. This is an efficient but simplified approach that cannot deal with such phenomena as backwater effects, pressurized flow, flow reversal, and non-dendritic layouts. SWMM also includes a Dynamic Wave routing procedure that can represent these conditions. This procedure, however, requires more computation time, due to the need for smaller time steps to maintain numerical stability.

Most of the effects mentioned above would not apply to our example. However we had one conduit, **C2**, that flowed full and caused its upstream junction to flood. It could be that this pipe is actually being pressurized and could therefore convey more flow than was computed using Kinematic Wave routing. We would now like to see what would happen if we apply Dynamic Wave routing instead.

To run the analysis with Dynamic Wave routing:

1. From the Project Browser, select the Options category and click the  button.

2. On the General page of the Simulation Options dialog that appears, select **Dynamic Wave** as the flow routing method.

3. Click **OK** to close the form and select **Project | Run Simulation** (or click the 

button) to re-run the analysis. *Normally when running a Dynamic Wave analysis, one would also want to reduce the routing time step (on the Time Steps page of the dialog) and perhaps select the Variable Time Step option (on the Dynamic Wave page of the dialog) as well.*

If you look at the Status Report for this run you will see that there is no longer any flooding and that the peak flow carried by conduit **C2** has been increased from 3.52 cfs to 4.05 cfs.

```
**************************        Volume         Volume
Flow Routing Continuity          acre-feet      10^6 gal
**************************       ---------      ---------
Dry Weather Inflow .......           0.000          0.000
Wet Weather Inflow .......           1.257          0.410
Groundwater Inflow .......           0.000          0.000
RDII Inflow ..............           0.000          0.000
External Inflow ..........           0.000          0.000
External Outflow .........           1.257          0.410
Flooding Loss ............           0.000          0.000
Evaporation Loss .........           0.000          0.000
Exfiltration Loss ........           0.000          0.000
Initial Stored Volume ....           0.000          0.000
Final Stored Volume ......           0.000          0.000
Continuity Error (%) .....           0.007
```

Topic: Link Flow   Click a column header to sort the column.

Link	Type	Maximum |Flow| CFS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| ft/sec	Max / Full Flow	Max / Full Depth
C1	CONDUIT	2.03	0	03:00	3.42	0.36	0.71
C2	CONDUIT	4.05	0	03:00	5.74	1.24	0.84
C3	CONDUIT	1.01	0	03:00	4.48	0.19	0.49
C4	CONDUIT	5.06	0	03:00	6.43	0.43	0.46

In the next phase of this tutorial we will add water quality analysis to our example project. SWMM has the ability to analyze the buildup, washoff, transport and treatment of any number of water quality constituents. The steps needed to accomplish this are:

1. Identify the pollutants to be analyzed.

2. Define the categories of land uses that generate these pollutants.

3. Set the parameters of buildup and washoff functions that determine the quality of runoff from each land use.

4. Assign a mixture of land uses to each subcatchment area

5. Define pollutant removal functions for nodes within the drainage system that contain treatment facilities.

We will now apply each of these steps, with the exception of number 5, to our example project. *Aside from direct runoff, EPA SWMM allows pollutants to be introduced into the nodes of a drainage system through:\n\r- user-defined time series of direct inflows\n\r- dry weather inflows\n\r- groundwater interflow\n\r- rainfall derived inflow\/infiltration*

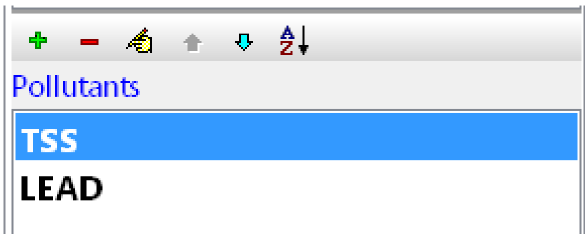
For this tutorial example we will define two runoff pollutants; total suspended solids (TSS), measured as mg/L, and total Lead, measured in ug/L. In addition, we will specify that the concentration of Lead in runoff is a fixed fraction (0.25) of the TSS concentration. To add these pollutants to our project:

1. Under the Quality category in the Project Browser, select the **Pollutants** sub-category beneath it.
2. Click the  button to add a new pollutant to the project.
3. In the Pollutant Editor form that appears, enter **TSS** for the pollutant name and leave the other data fields at their default settings.
4. Click the **OK** button to close the Editor.

5. Click the  button on the Project Browser again to add our next pollutant.

6. In the Pollutant Editor, enter **Lead** for the pollutant name, select **ug/L** for the concentration units, enter **TSS** as the name of the Co-Pollutant, and enter **0.25** as the Co-Fraction value.

7. Click the **OK** button to close the Editor.

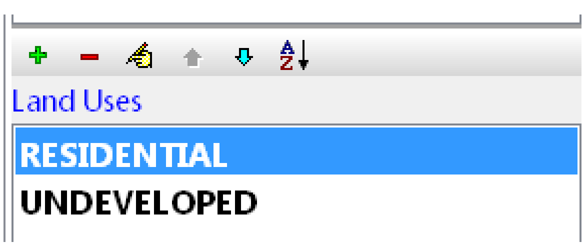


In SWMM, pollutants associated with runoff are generated by specific land uses assigned to subcatchments. In our example, we will define two categories of land uses: Residential and Undeveloped. To add these land uses to the project:

1. Under the Quality category in the Project Browser, select the Land Uses sub-category and click the  button.

2. In the Land Use Editor form that appears, enter **Residential** in the Name field and then click the **OK** button.

3. Repeat steps 1 and 2 for the **Undeveloped** land use category.



Next we need to define buildup and washoff functions for TSS in each of our land use categories. Functions for Lead are not needed since its runoff concentration was defined to be a fixed fraction of the TSS concentration. Normally, defining these functions requires site specific calibration.

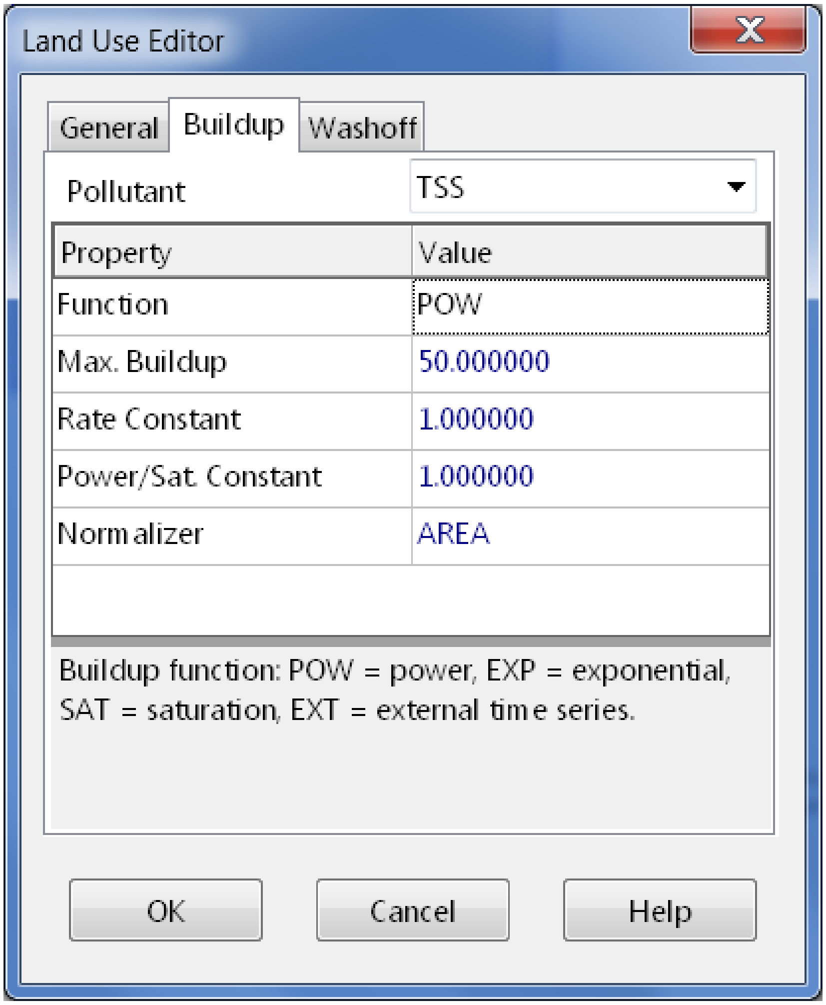
In this example we will assume that suspended solids in Residential areas builds up at a constant rate of 1 pound per acre per day until a limit of 50 lbs per acre is reached. For the Undeveloped area we will assume that buildup is only half as much. For the washoff function, we will assume a constant event mean concentration of 100 mg/L for Residential land and 50 mg/L for undeveloped land. To define these functions for the Residential land use:

1. Select the **Residential** land use category from the Project Browser and click the  button.

2. In the Land Use Editor dialog, move to the Buildup page.

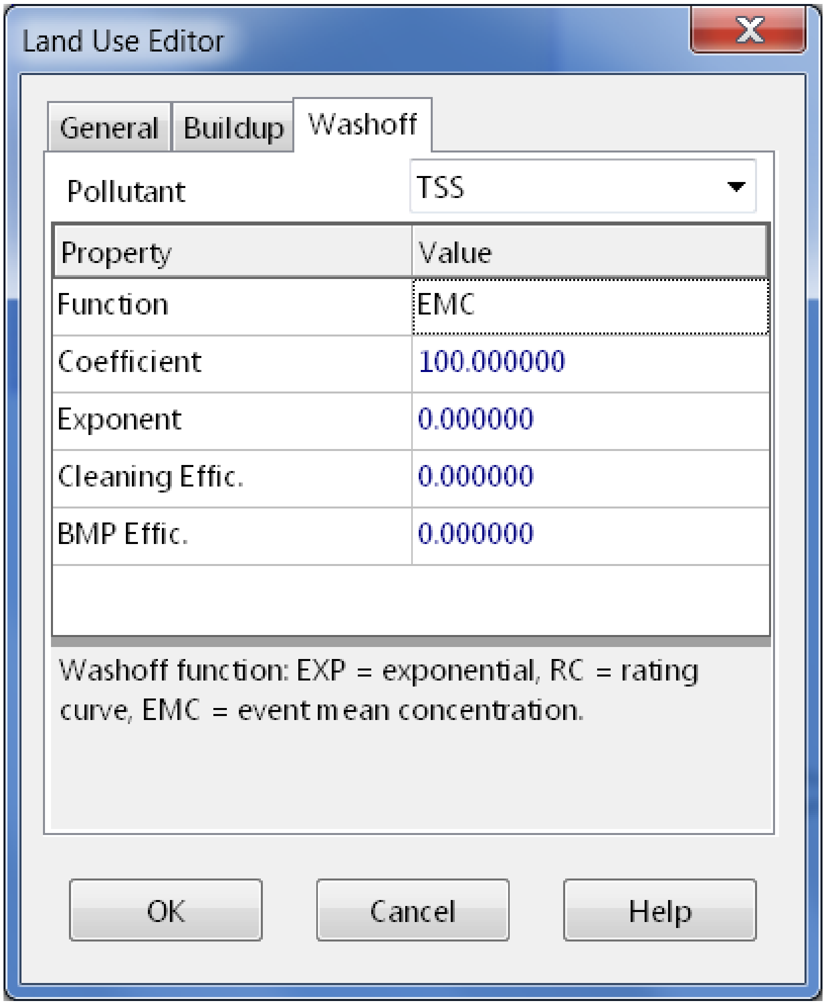
3. Select **TSS** as the pollutant and **POW** (for Power function) as the function type.

4. Assign the function a maximum buildup of **50**, a rate constant of **1.0**, a power of **1** and select **AREA** as the normalizer.



5. Move to the Washoff page of the dialog and select **TSS** as the pollutant, **EMC** as the function type, and enter **100** for the coefficient. Fill the other fields with **0**.

6. Click the **OK** button to accept your entries.



Now do the same for the **Undeveloped** land use category, except use a maximum buildup of **25**, a buildup rate constant of **0.5**, a buildup power of **1**, and a washoff EMC of **50**.

The final step in our water quality example is to assign a mixture of land uses to each subcatchment area:

1. Select subcatchment **S1** into the Property Editor.

2. Select the Land Uses property and click the ellipsis button (or press **Enter**).

3. In the Land Use Assignment form that appears, enter **75** for the % Residential and **25** for the % Undeveloped. Then click the **OK** button to close the dialog.

4. Repeat the same three steps for subcatchment **S2**.

5. Repeat the same for subcatchment **S3**, except assign the land uses as **25**% Residential and **75**% Undeveloped.

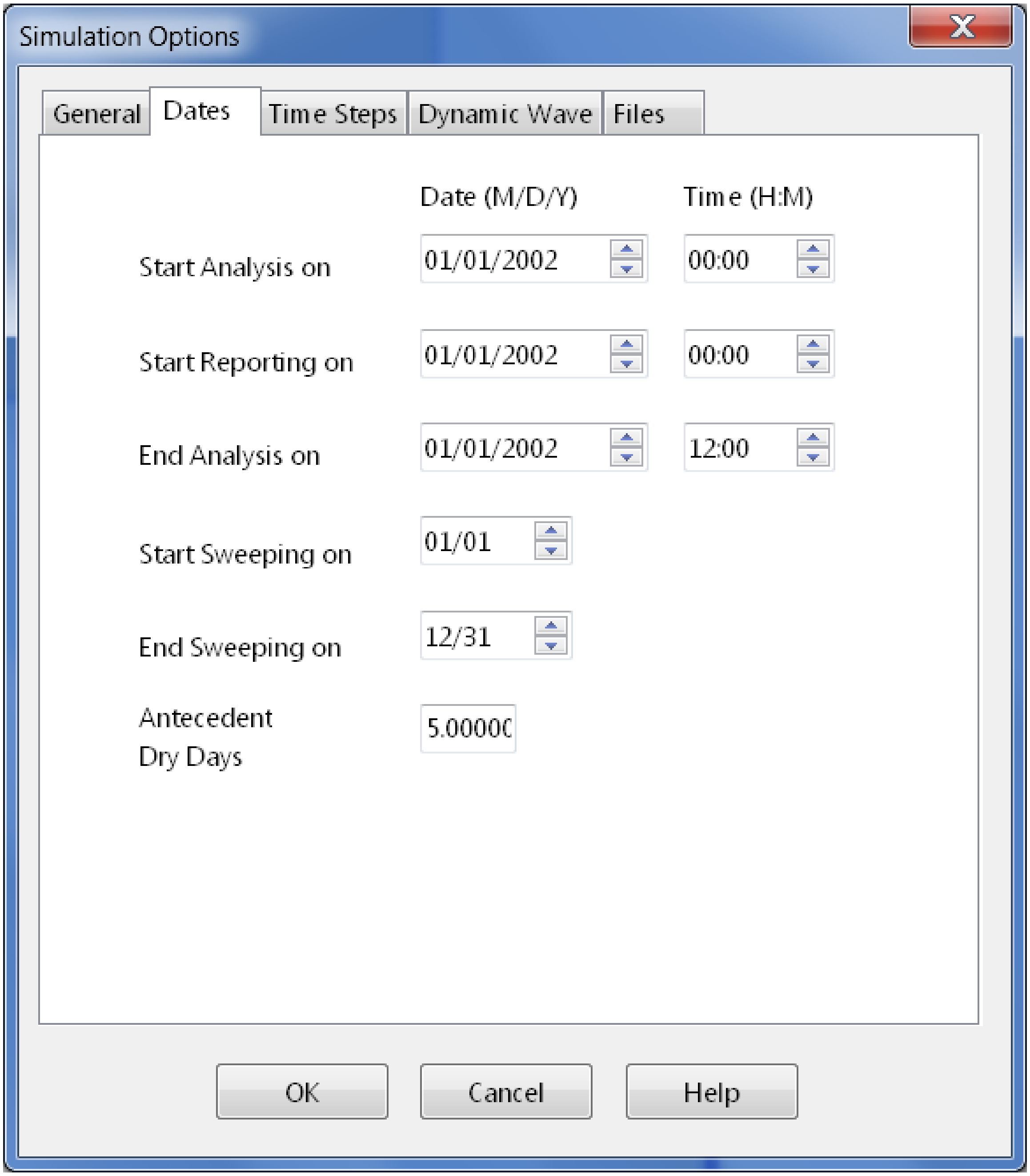
Before we simulate the runoff quantities of TSS and Lead from our study area, an initial buildup of TSS should be defined so it can be washed off during our single rainfall event. We can either specify the number of antecedent dry days prior to the simulation or directly specify the initial buildup mass on each subcatchment. We will use the former method:

1. From the Options category of the Project Browser, select the Dates sub-category and click the  button.

2. In the Simulation Options dialog that appears, enter **5** into the Antecedent Dry Days field.

3. Leave the other simulation options the same as they were for the dynamic wave flow routing we just completed.

4. Click the **OK** button to close the dialog.



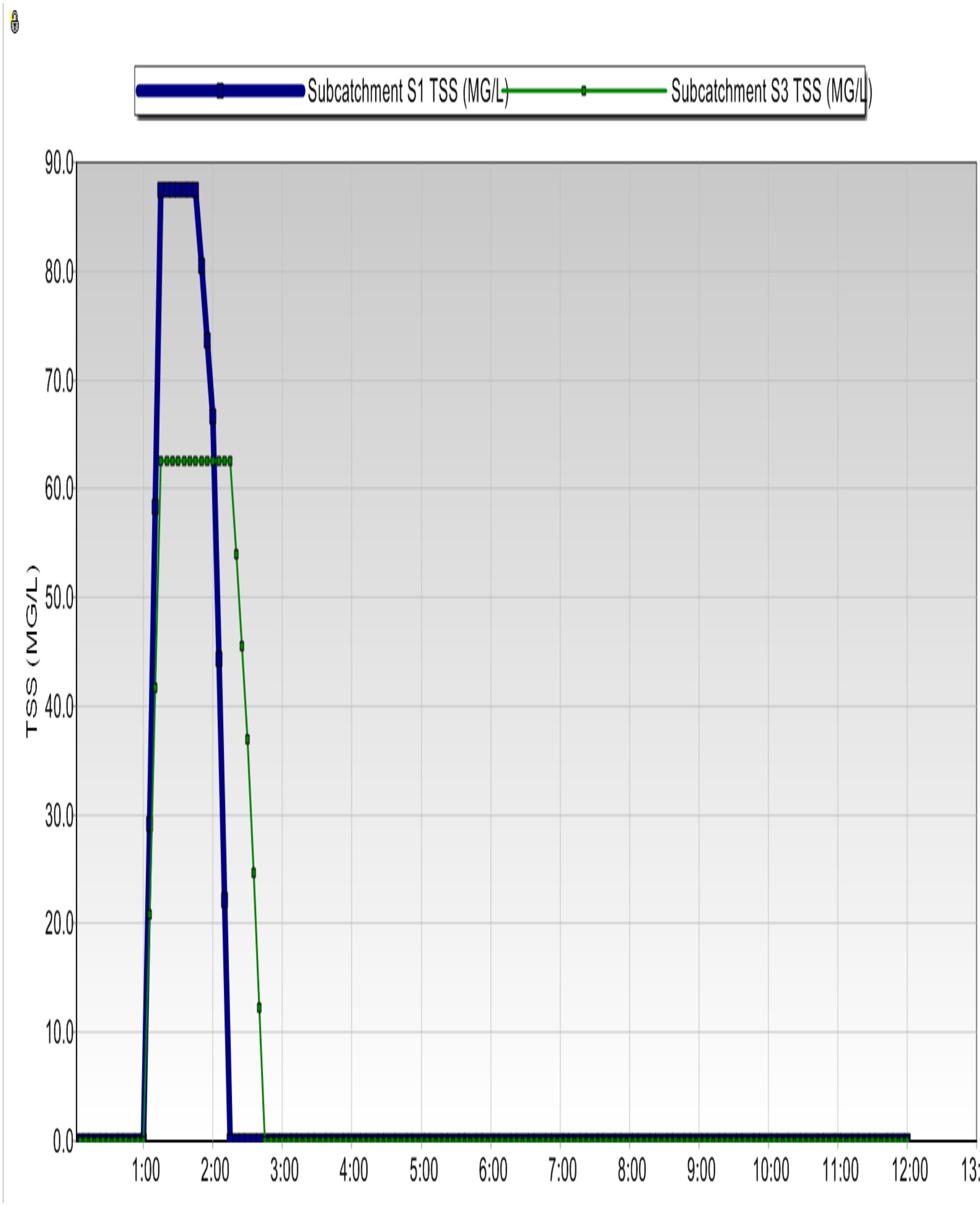
Now run the simulation by selecting **Project | Run Simulation** or by clicking 

on the Standard Toolbar.

When the run is completed, view its Status Report. Note that two new sections have been added for Runoff Quality Continuity and Quality Routing Continuity. From the Runoff Quality Continuity table we see that there was an initial buildup of 47.5 lbs of TSS on the study area and an additional 2.2 lbs of buildup added during the dry periods of the simulation. About 48 lbs were washed off during the rainfall event. The quantity of Lead washed off is a fixed fraction (0.25 times 0.001 to convert from mg to ug) of the TSS as was specified.

```
**************************        TSS         LEAD
Runoff Quality Continuity         lbs          lbs
**************************    ----------   ----------
Initial Buildup ..........        47.500        0.000
Surface Buildup ..........         2.182        0.012
Wet Deposition ...........         0.000        0.000
Sweeping Removal .........         0.000        0.000
Infiltration Loss ........         0.000        0.000
BMP Removal ..............         0.000        0.000
Surface Runoff ...........        47.896        0.012
Remaining Buildup ........         1.786        0.000
Continuity Error (%) .....         0.000        0.000
```

If you plot the runoff concentration of TSS for subcatchment **S1** and **S3** together on the same time series graph you will see the difference in concentrations resulting from the different mix of land uses in these two areas. You can also see that the duration over which pollutants are washed off is much shorter than the duration of the entire runoff hydrograph (i.e., 1 hour versus about 6 hours). This results from having exhausted the available buildup of TSS over this period of time.



As a final exercise in this tutorial we will demonstrate how to run a long term continuous simulation using a historical rainfall record and how to perform a statistical frequency analysis on the results. The rainfall record will come from a file named sta310301.dat which was included with the example data sets provided with EPA SWMM. It contains several years of hourly rainfall beginning in January 1998. The data are stored in the National Climatic Data Center's DSI 3240 format which SWMM can automatically recognize. *The example data sets can be found in My Documents | EPA SWMM Projects | Examples*

To run a continuous simulation with this rainfall record:

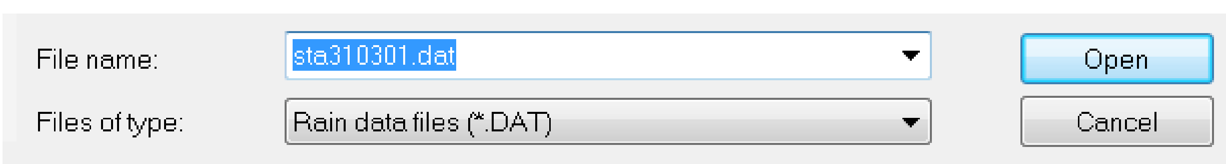
1. Select the rain gage **Gage1** into the Property Editor.

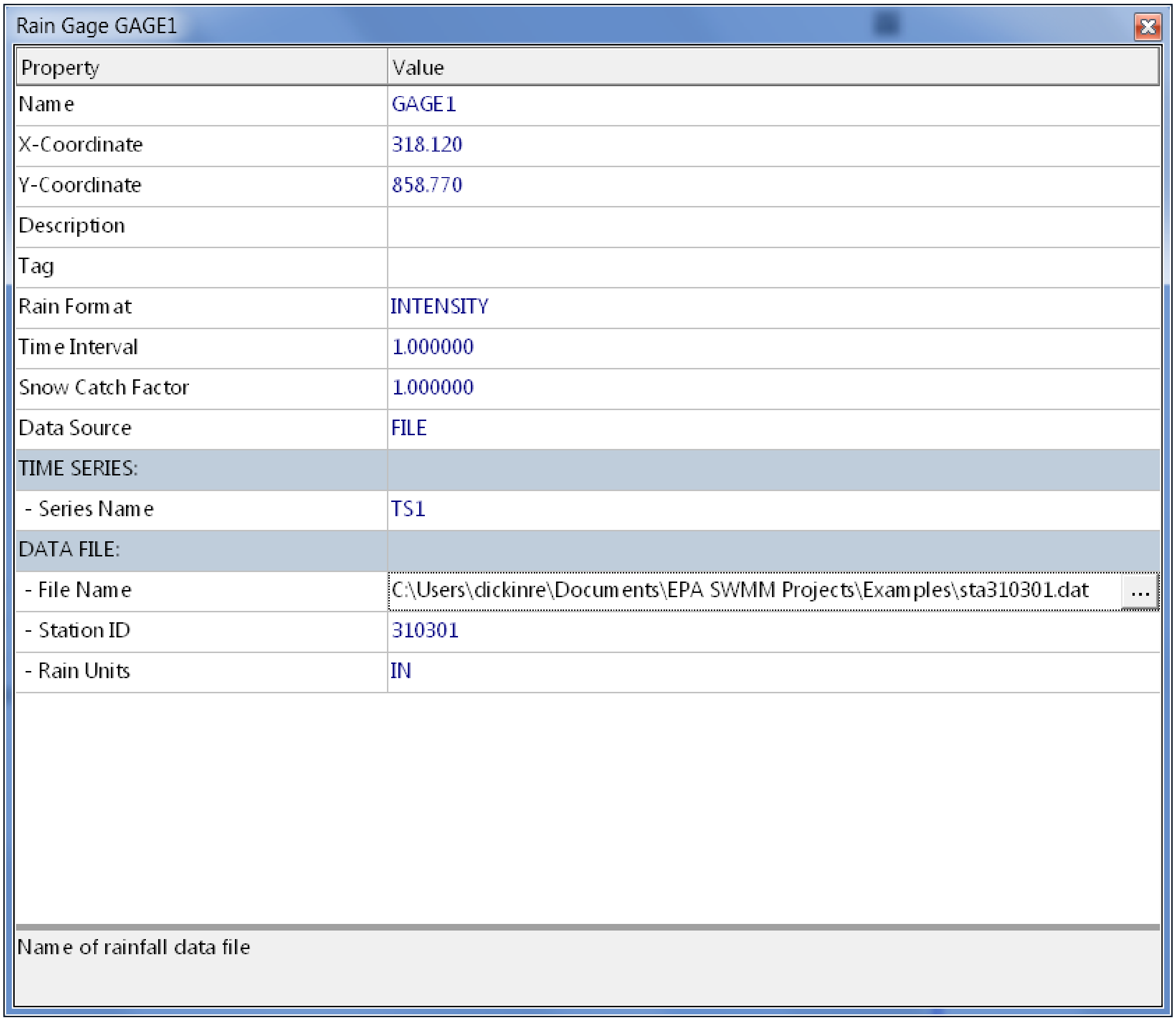
2. Change the selection of Data Source to **FILE**.

3. Select the File Name data field and click the ellipsis button (or press the **Enter** key) to bring up a Windows File Selection dialog.

4. Navigate to the folder where the SWMM example files were stored, select the file named **sta310301.dat**, and click **Open** to select the file and close the dialog.

5. In the Station No. field of the Property Editor enter **310301**.





Rain Gage GAGE1

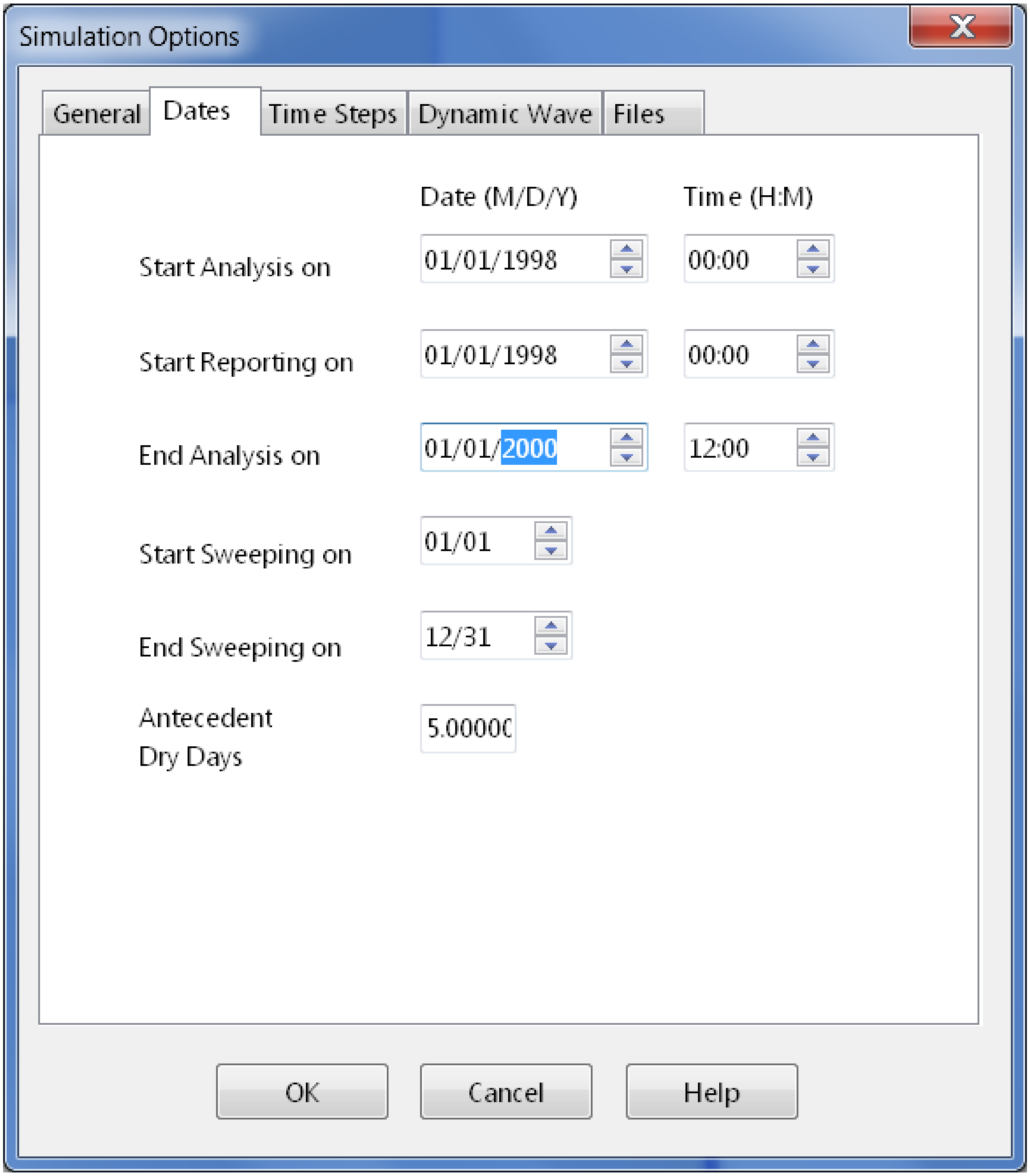
Property	Value
Name	GAGE1
X-Coordinate	318.120
Y-Coordinate	858.770
Description	
Tag	
Rain Format	INTENSITY
Time Interval	1.000000
Snow Catch Factor	1.000000
Data Source	FILE
TIME SERIES:	
- Series Name	TS1
DATA FILE:	
- File Name	C:\Users\dickinre\Documents\EPA SWMM Projects\Examples\sta310301.dat ...
- Station ID	310301
- Rain Units	IN

Name of rainfall data file

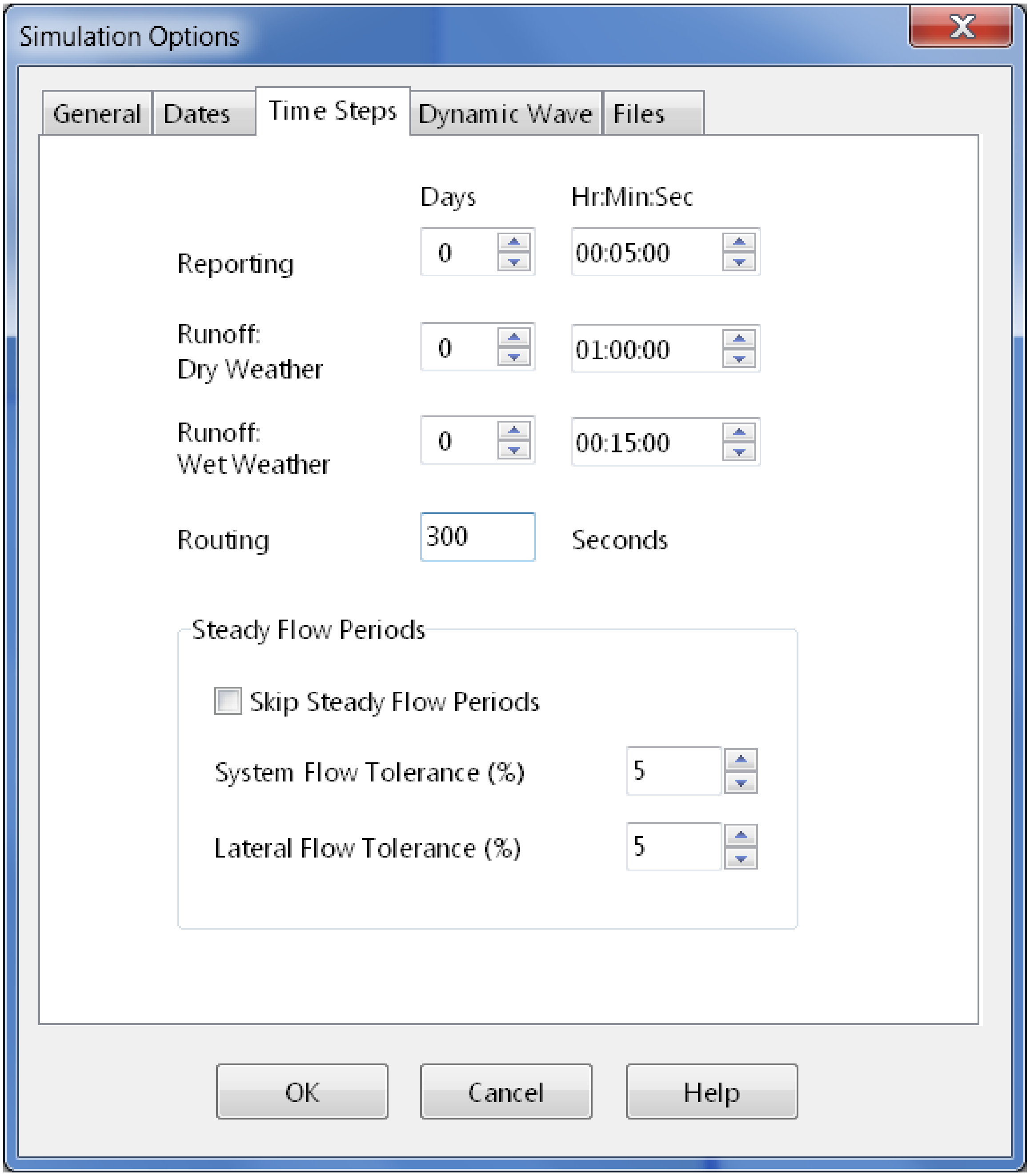
6. Select the Options category in the Project Browser and click the  button to bring up the Simulation Options form.

7. On the General page of the form, select **Kinematic Wave** as the Routing Method (this will help speed up the computations).

8. On the Dates page of the form, set both the Start Analysis and Start Reporting dates to **01/01/1998**, and set the End Analysis date to **01/01/2000**.



9. On the Time Steps page of the form, set the Routing Time Step to **300** seconds.



10. Close the Simulation Options form by clicking the **OK** button and start the simulation by selecting **Project | Run Simulation** (or by clicking 

on the Standard Toolbar).

After our continuous simulation is completed we can perform a statistical frequency analysis on any of the variables produced as output. For example, to determine the distribution of rainfall volumes within each storm event over the two-year period simulated:

1. Select **Report | Statistics** or click the 

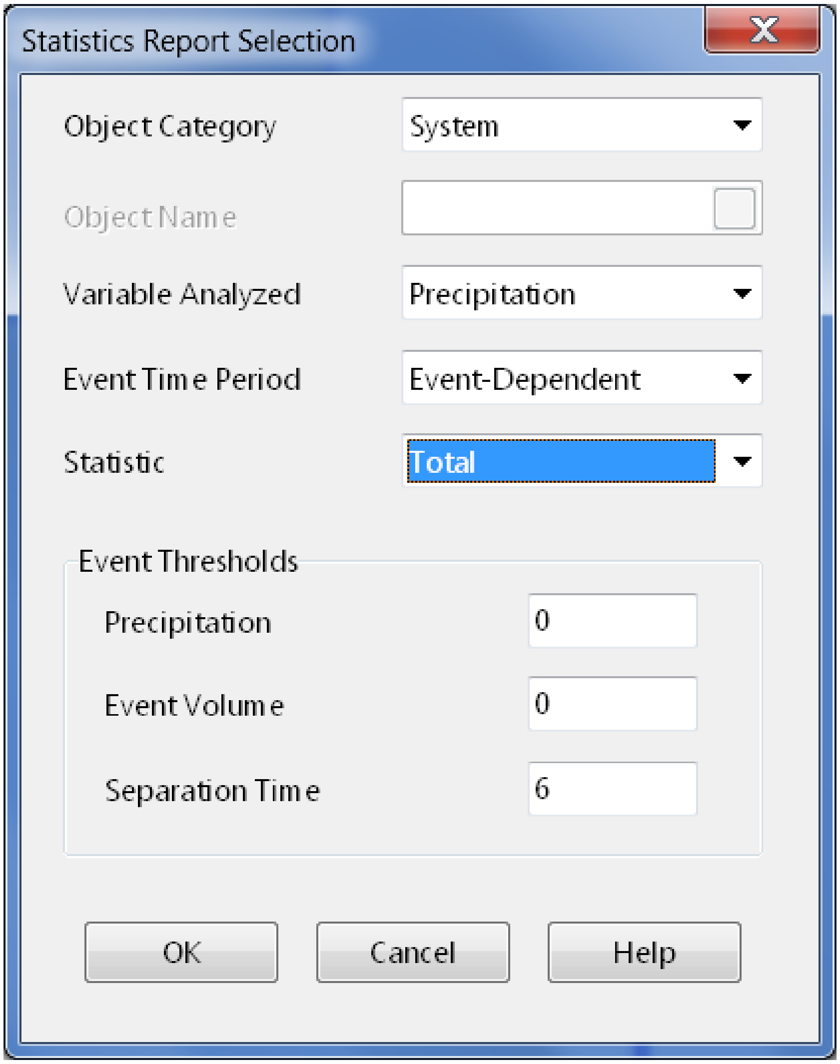
button on the Standard Toolbar.

2. In the Statistics Selection form that appears, enter the values as shown below:

Object Category:	System
Variable Analyzed:	Precipitation
Event Time Period:	Event-Dependent
Statistic:	Total
Event Thresholds:	
Rainfall	0
Event Volume	0
Inter-Event Hours	6

This will identify the rainfall volume from each event which is separated by 6 or more hours without rainfall.

3. Click the **OK** button to close the form.



The results of this request will be a Statistics Report form containing four tabbed pages: a Summary page, a page containing a rank-ordered listing of each event, a page containing a histogram of the occurrence frequency versus event magnitude, and a Frequency Plot page that plots event magnitude versus cumulative frequency.

Summary | Events | Histogram | Frequency Plot

```
S U M M A R Y   S T A T I S T I C S
===================================
Object  .............. System
Variable ............. Precipitation  (1in/hr)
Event Period ......... Variable
Event Statistic ...... Total (in)
Event Threshold ...... Precipitation > 0.0000  (1in/hr)
Event Threshold ...... Event Volume > 0.0000 (in)
Event Threshold ...... Separation Time >= 6.0  (hr)
Period of Record ..... 01/01/1998 to 01/01/2000

Number of Events ..... 213
Event Frequency*...... 0.076
Minimum Value ........ 0.010
Maximum Value ........ 3.350
Mean Value ........... 0.309
Std. Deviation ....... 0.449
Skewness Coeff. ...... 3.161

*Fraction of all reporting periods belonging to an event.
```

The Summary page shows that there was a total of 213 rainfall events. The Events page shows that the largest rainfall event had a volume of 3.35 inches and occurred over a 24- hour period. There were no events that matched the 3-inch, 6-hour design storm event used in our previous single-event analysis which had produced some internal flooding. In fact, the status report for this continuous simulation indicates that there were no flooding or surcharge occurrences over the simulation period.

We have only touched the surface of SWMM's capabilities. Some additional features of the program that you will find useful include:

- utilizing additional types of drainage elements, such as storage units, flow dividers, pumps, and regulators, to model more complex types of systems

- using control rules to simulate real-time operation of pumps and regulators

- employing different types of externally-imposed inflows at drainage system nodes, such as direct time series inflows, dry weather inflows, and rainfall-derived inflow/infiltration

- modeling groundwater interflow between aquifers beneath subcatchment areas and drainage system nodes

- modeling snow fall accumulation and melting within subcatchments

- adding calibration data to a project so that simulated results can be compared with measured values

- utilizing a background street, site plan, or topo map to assist in laying out a system's drainage elements and to help relate simulated results to real-world locations.

You can find more information on these and other features in the SWMM User's Manual.

HAPPY SWMMING!

InfoSWMM uses the EPA SWMM 5.1.013 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

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