Introduction to LID/BMP assessment tools

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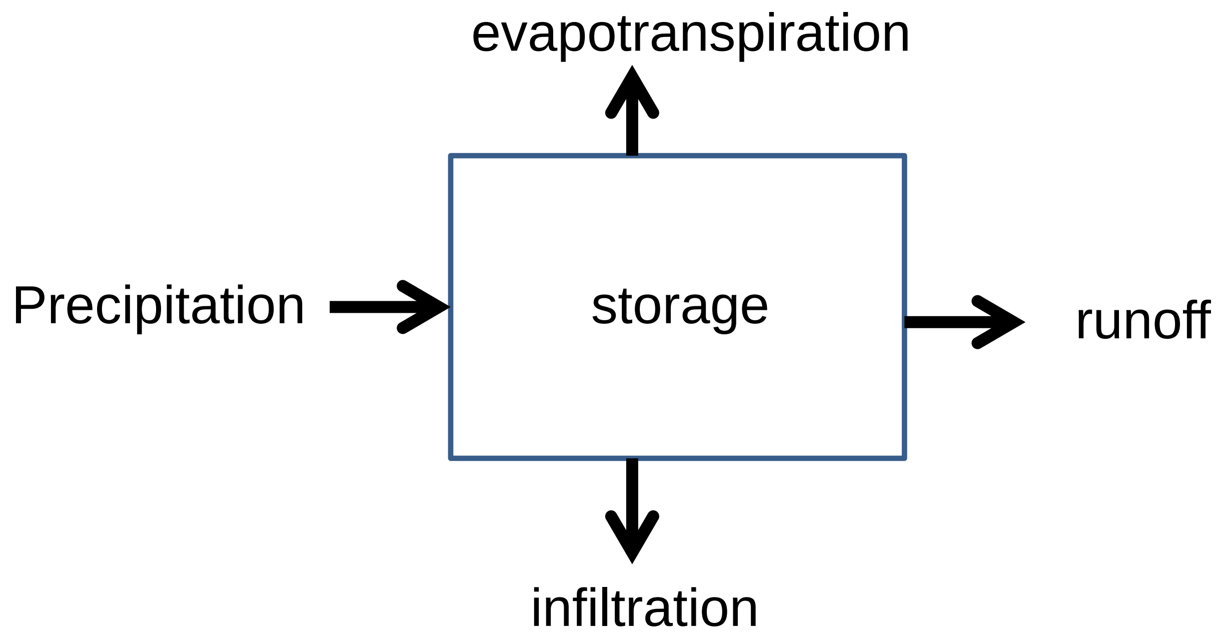
Water quantity simulation



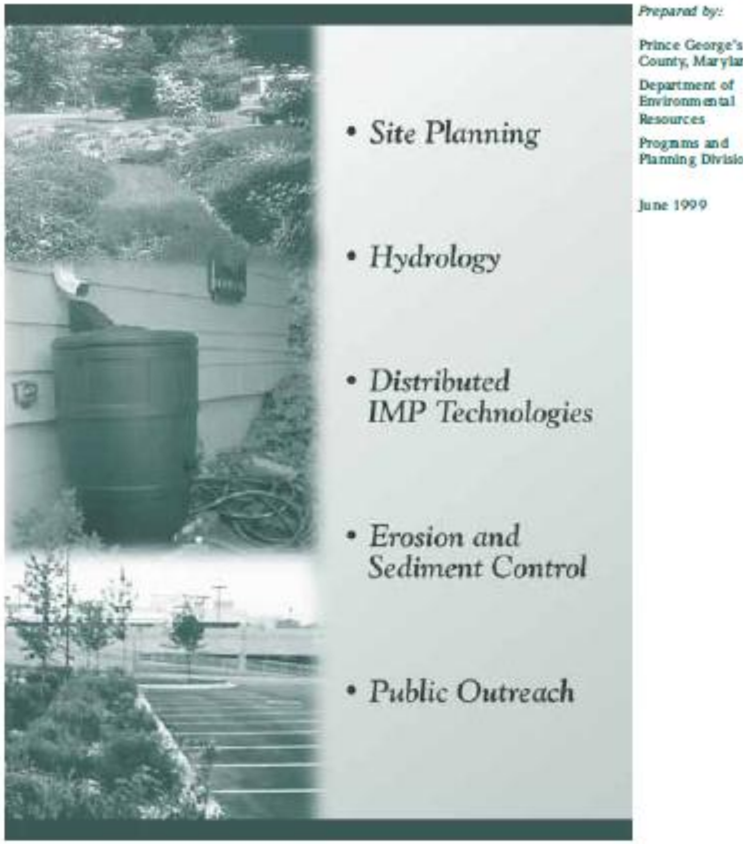
$$runoff = precipitation - evapotranspiration - infiltration - storage$$

BMP focus on

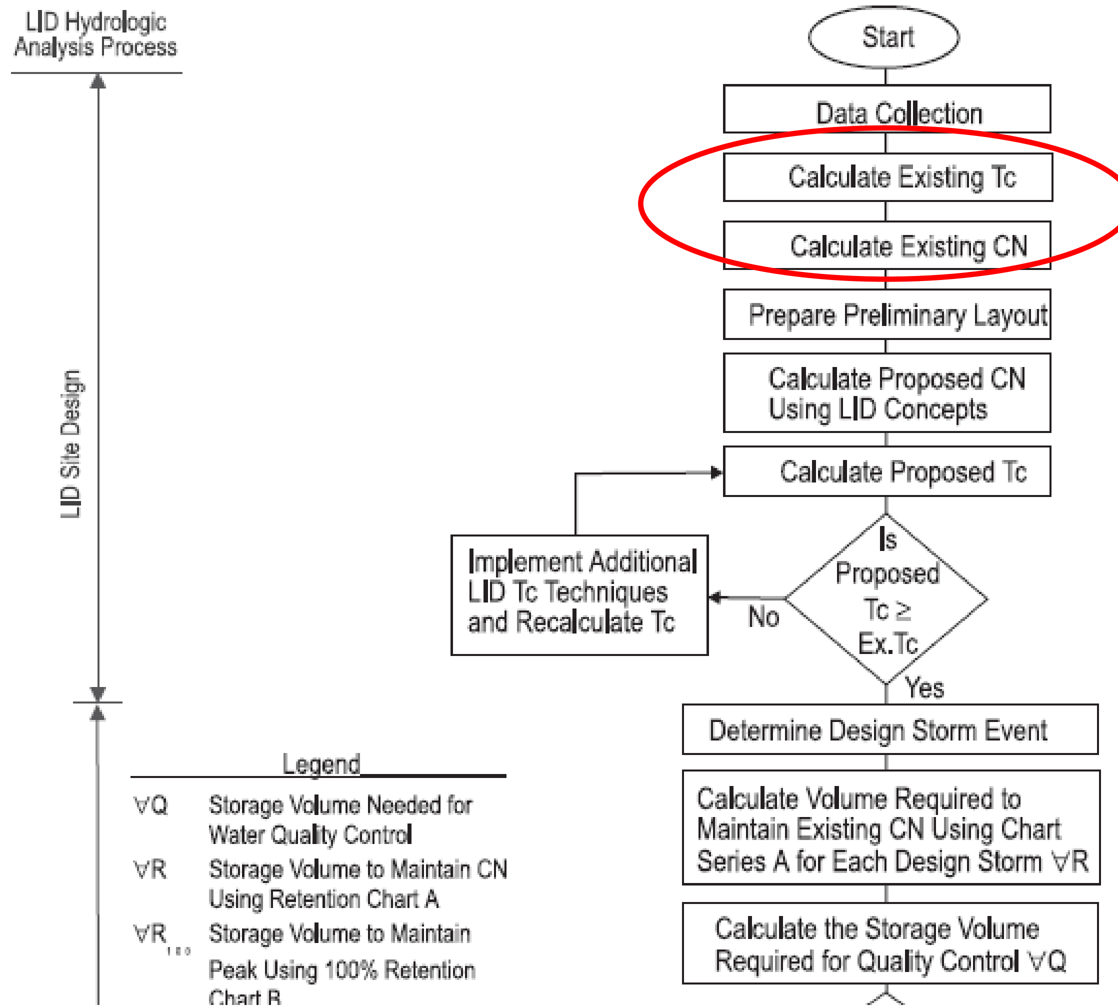
LID focus on

Hydrologic source control is at the heart of LID, which retains stormwater and disposes of it via infiltration and ET.

Low-Impact Development Design Strategies
An Integrated Design Approach



LID Hydrologic Analysis Procedure



Water quality simulation (mass balance)

$$\frac{d(VC)}{dt} = IC_I - OC - \underline{KCV}$$

V= storage volume
C= effluent concentration (well-mixed)
I= inflow rate
C_I= influent concentration
O= outflow rate
K= first-order decay coefficient
t= time

$$V\frac{dC}{dt} + C\frac{dV}{dt} = (IC_I \underline{+ L)(1 - R)} - OC - KCV - \underline{v_s(1 - F)CA_s}$$

L= other loadings
R= BMP removal fraction
v_s= settling velocity
F= fraction of soluble form
A_s= surface area

Key points

- Rainfall-runoff models can be used to evaluate water quantity performance of LID/BMP facilities.
- When consider water quality improvement, additional functions are required.

Primary urban hydrologic, hydraulic and water quality models commonly used in the United States (USEPA, 2006).

Table 3-1. Primary urban hydrologic, hydraulic and water quality models commonly used in the United States.
Source: W.C. Huber, class notes. Updated March 25, 2003.

Model	Agency/Source	Primarily Hydrology/ Hydraulics	Continuous Simulation or Storm Event	Complete Dynamic Flow Routing?	Quality Simulation?	Graphical User Interface[j]
DR3M-QUAL[a]	USGS	Hydrology	CS/SE	No	Yes	ANNIE[a,d]
FEQ[a,b]	USGS	Hydraulics	SE	Yes	No	No
HEC-1/HMS[c]	HEC/Vendors	Hydrology	SE	No	No	Yes
HEC-2/RAS[c]	HEC/Vendors	Hydraul. (backwater)	Steady state	No	No	Yes
HSPF[a,d]	EPA	Hydrology	CS/SE	No	Yes	ANNIE[a,d], EPA BASINS
InfoWorks CS[e]	HR Wallingford in UK, Montgom. Watson in US	Hydrology/Hydraulics	CS/SE	Yes	Yes	Yes
MIKE 11[f]	Danish Hydraulics Inst.	Hydraulics (open channels)	SE	Yes	Yes	Yes
MOUSE[f]	Danish Hydraulics Inst.	Hydrology/Hydraulics	CS/SE	Yes	Yes	Yes
P8[g]	Wm. W. Walker, Jr.	Hydrology	CS/SE	No	Yes	Menu
Santa Barbara	Vendors	Hydrology	SE	No	No	3rd party
SCS[h]	NRCS/Vendors	Hydrology	SE	No	No	3rd party
*SewerCAT[i]	Reid Crowther Consult.	Hydraulics	SE	Yes	No	Yes
SLAMM[l]	R. Pitt	Hydrology	CS	No	Yes	No
*STORM[c]	HEC/Vendors	Hydrology	CS	No	Yes	No
SWMM[d,i,k]	EPA/OSU	Hydrology/Hydraulics	CS/SE	Yes	Yes	3rd party
UNET[c]	HEC/Vendors	Hydraulics	SE	Yes	No	HECDSS

Other models:

- **DMSTA**: Dynamic Model for Stormwater Treatment Areas (Walker 1995, Walker and Kadlec 2002)
- **MUSIC**: Model for Urban Stormwater Improvement Conceptualization (Wong et al. 2002)
- **P8**: Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds (Walker 1990)
- **PREWET**: Pollutant Removal Estimates for Wetlands (Dortch and Gerald 1995)
- **REMM**: Riparian Ecosystem Management Model (Inamdar 1998a,b)
- **SLAMM**: Source Loading and Management Model (Pitt et al. 1999b, Pitt and Voorhees 2000)
- **VAFSWM**: Virginia Field Scale Wetland Model (Yu et al. 1998)
- **WETLAND**: Wetland water balance and nutrient dynamics model (Lee et al. 2002)
- **WMM**: Watershed Management Model (Wayne County, MI 1998)

(USEPA, 2006)

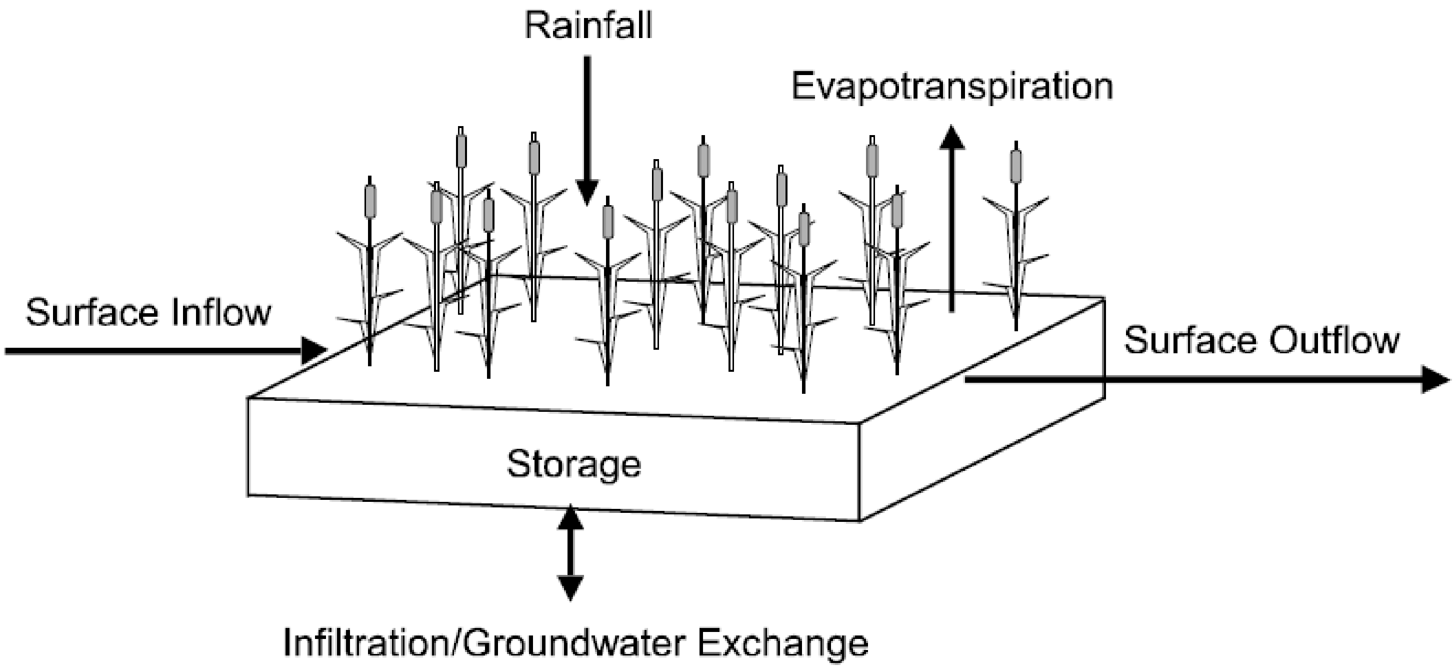
Table 5.1. Simulation models that can simulate urban BMP performance.

Model	Ponds	Infiltration Trenches	Grass Swales	Extended Detention	Bio-retention and Wetlands	Dry Wells	Filter Strips	Porous Pavement	Other Devices
DMSTA	X				X				
MUSIC	X	X	X		X				
P8	X		X		X		X		
PREWET					X				
REMM							X		
SLAMM	X	X	X				X	X	X
VAFSWM					X				
WETLAND					X				
WMM	X		X	X	X				

(USEPA, 2006)

VAFSWM

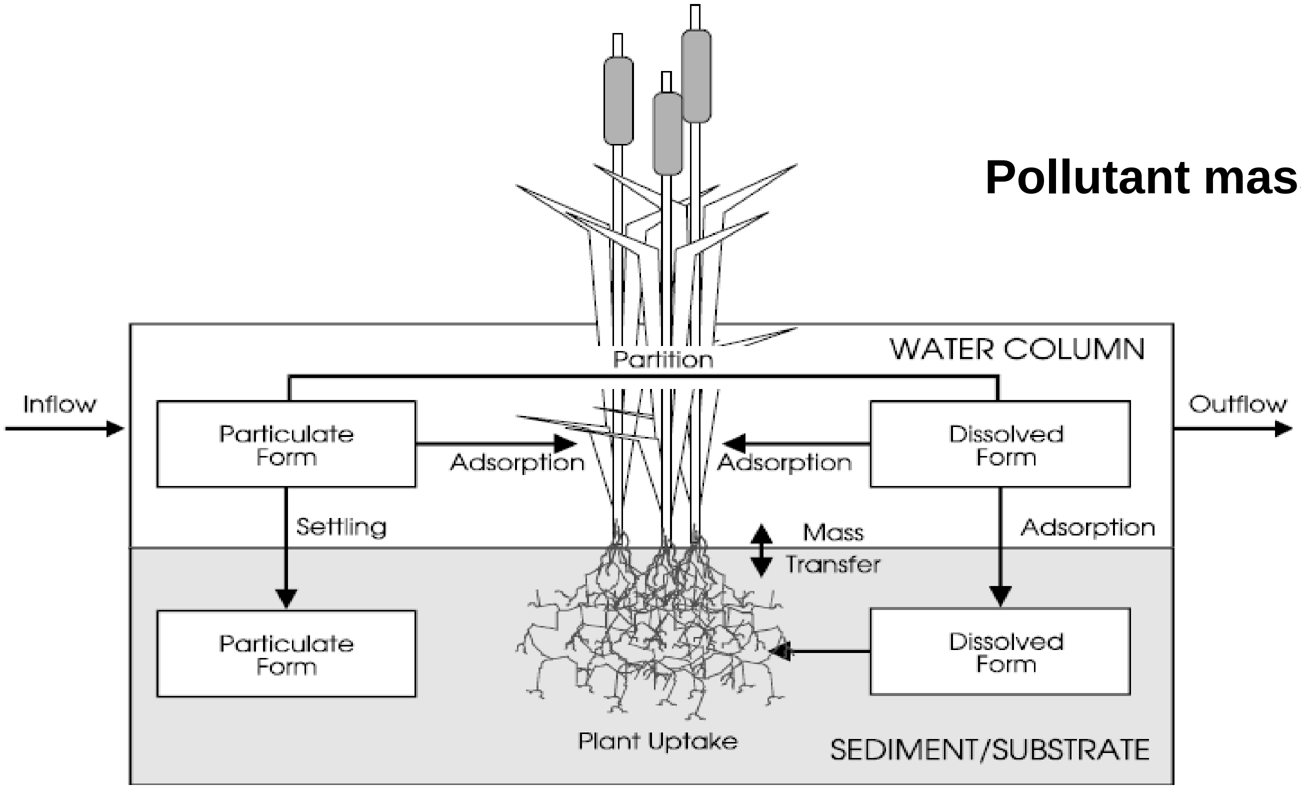
Wetland model - hydrologic balance



$$\frac{dS}{dt} = Q_{IN} - Q_{OUT} + P - EX$$

VAFSWM

Pollutant mass balance approach



$$V_W \frac{dC1}{dt} = Q_{IN}C1_{IN} - Q_{OUT}C1 - v_{SW}AC1$$

pollutant mass balances for suspended solids (C1)

$$V_W \frac{dC2}{dt} = Q_{IN}C2_{IN} - Q_{OUT}C2 - v_{SW}Af_{PW}C2 - (k_2 + k_3)Vwf_{DW}C2 + k_1A\left(f_{DS}\frac{C3}{\phi} - f_{DW}C2 \right)$$

in the water column (C2)

$$Vs\frac{dC3}{dt} = v_{SS}Af_{PS}C3 + v_{SW}Af_{PW}C2 - (k_2 + k_4)Vsf_{DS}C3 - k_1A\left(f_{DS}\frac{C3}{\phi} - f_{DW}C2 \right)$$

in the substrate (C3)

Several LID/BMP models

Simple model

1. The National Green Values™ Calculator
2. North Carolina State University Rainwater Harvesting Model

Complex model

3. SUSTAIN
4. SWMM
5. Green Build-Out Model

1. The National Green Values™ Calculator

- The National Green Values™ Calculator (GVC)is a tool for quickly comparing the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional stormwater practices.
- Developed by the Center for Neighborhood Technology (CNT) collaborated with the US EPA Office of Wetlands, Oceans, and Watersheds (OWOW) in 2004.

http://greenvalues.cnt.org/

The National GVC produces two primary hydrologic results:
1) the runoff volume capture capacity of the green infrastructure BMPs;
2) the total runoff volume produced by the pre-development, conventional development, and green development scenarios

The National GVC calculates total runoff volumes for each scenario using the USDA Soil Conservation Service Runoff Curve Number Method:

$$Q = \frac{(P-Ia)^2}{(P-Ia)+S}$$

Q = runoff in inches,
P = rainfall in inches, (determined from NOAA data)
S = potential maximum runoff after runoff begins (in) (determined by site definition and curve numbers from TR-55), and
Ia = initial abstraction (in) (Ia = 0.2S).

The National GVC compares the lifecycle costs and benefits of green infrastructure BMPs to those of a conventional stormwater design.

The lifecycle cost/benefit equation is:
(**Construction cost**) X (number of times the component would have to be replaced)
+ (**annual maintenance costs**) X (total number of years)
– (**annual benefits**) X (total number of years).

The National GVC does include the following quantified benefits:
- Reduced Air Pollutants
- Carbon Dioxide Sequestration
- Compensatory Value of Trees
- Groundwater Replenishment
- Reduced energy use
- Reduced treatment benefits

Getting Started | Lot Information | Predevelopment | Runoff Reduction Goal | Conventional Development | Green Improvements | Advanced Options

Lot Information

Zip Code:

Annual Rainfall* (in) : 25.36

Storm Type (in) : 90%

Storm Rainfall* (in) : 1.04

Size of Lot+ (acres): 1

Or give dimensions+.

Length of Lot (ft):

Width of Lot (ft):

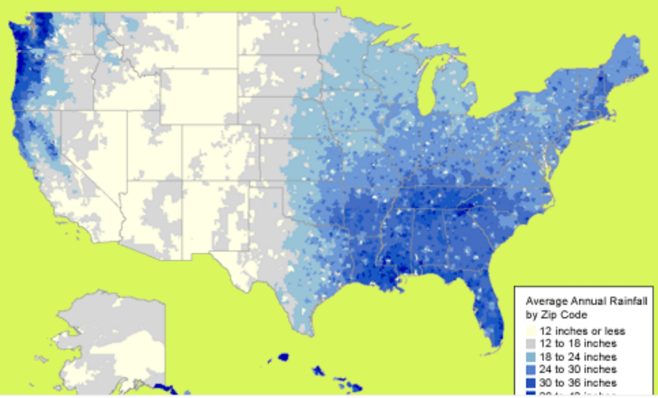
Soil Type: C

* Required fields.
+ Must have at least one of these fields filled in.

Enter the site zip code to view the annual average precipitation and the **90% storm for your site**. You can input any precipitation quantity into these values if you are interested in looking at the total runoff volume produced by each scenario under different precipitation conditions then those determined here. For example if you know and the amount of precipitation for a particular design storm and are interested in seeing total runoff volume changes under those conditions, enter that value here as either the annual or 90% storm and see the results for that same category.

Rainfall estimates may not match other reported standard values. Please consult local regulatory authorities when designing or implementing projects. Please see the Green Values methodology for details on rainfall calculation.

Average Annual Rainfall by Zip Code



Predevelopment

Getting Started | Lot Information | Predevelopment | Runoff Reduction Goal | Conventional Development | Green Improvements | Advanced Options

Predevelopment

Land Cover+

Your land coverage totals **100%**.

Impervious Area (%): 55

Lawn in good condition (%): 45

Lawn in fair condition (%):

Urban Fill (%):

Natural Desert Landscaping (%):

Newly Graded Areas, no vegetation (%):

Straight Row Crops in good condition (%):

Pasture in fair condition (%):

Meadow (%):

Woods in good condition (%):

Desert Shrub in fair condition (%):

Wetlands (%):

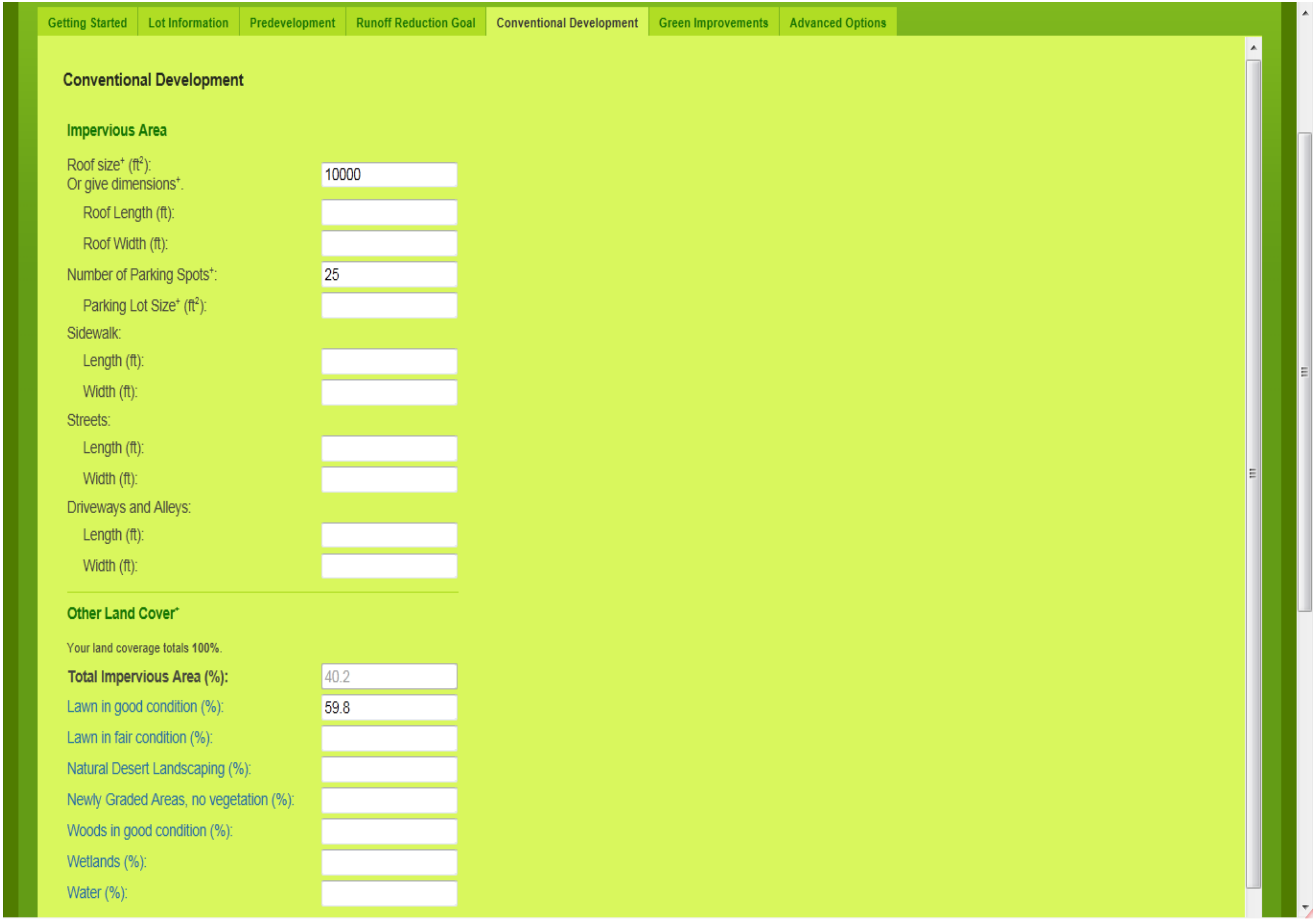
Water (%):

Local stormwater regulations may define the "predevelopment" condition as the existing condition of the site prior to the development project in question, OR as the original condition of the site prior to any human development (e.g. forest or meadow). Either definition can be satisfied here by defining the different land cover types represented on your site for either predevelopment condition. Check with local authorities to determine which definition you should use to define the predevelopment scenario in this calculator.

Most of the land cover categories below are chosen from the USDA Soil Conservation Service Technical Release 55 (TR-55): Urban Hydrology for Small Watersheds Table 2.2a-d. We tried to provide a short list of land cover categories that can be used in combination to describe a variety of sites around the country, and fit both interpretations of predevelopment. The land cover category is associated with a curve number (either a default value or user-specified) and the area assigned to each land cover type creates a composite curve number for the site under predevelopment conditions.

http://greenvalues.cnt.org/national/calculator.php

Conventional development



Getting Started | Lot Information | Predevelopment | Runoff Reduction Goal | Conventional Development | Green Improvements | Advanced Options

Conventional Development

Impervious Area

Roof size+ (ft^2): Or give dimensions+.	10000
Roof Length (ft):	
Roof Width (ft):	
Number of Parking Spots+:	25
Parking Lot Size+ (ft^2):	
Sidewalk:	
Length (ft):	
Width (ft):	
Streets:	
Length (ft):	
Width (ft):	
Driveways and Alleys:	
Length (ft):	
Width (ft):	

Other Land Cover+

Your land coverage totals **100%**.

Total Impervious Area (%):	40.2
Lawn in good condition (%):	59.8
Lawn in fair condition (%):	
Natural Desert Landscaping (%):	
Newly Graded Areas, no vegetation (%):	
Woods in good condition (%):	
Wetlands (%):	
Water (%):	

Green development

Getting Started | Lot Information | Predevelopment | Runoff Reduction Goal | Conventional Development | Green Improvements | Advanced Options

Green Improvements

The Green Infrastructure BMPs included below can provide runoff reduction benefits through infiltration, evapotranspiration, and reuse of captured stormwater for irrigation and other non-potable uses. Green infrastructure BMPs provide additional environmental benefits including carbon sequestration, reduced energy use, and groundwater recharge in addition to reduced construction and maintenance costs and extended design life. Experiment with applying different combinations of BMPs the see how you can progress towards meeting the specified runoff reduction goal, reduce total runoff volume from the site (annually and for the average storm), reduce site imperviousness, and affect lifecycle costs and benefits.

Click on each BMP title below to see a description of the BMP, as well as some common assumptions on their design and construction.

- [x] **Green Roof**
  - Amount (%): 10
  - Depth (in): 6
  - Porosity (Void Ratio): 0.35
- [x] **Planter Boxes** (disconnect downspout)
  - Area (ft^2): 25
  - Soil:
    - Depth (in): 12
    - Porosity (Void Ratio): 0.25
  - Underlying Aggregate:
    - Depth (in): 12
    - Porosity (Void Ratio): 0.35
- [ ] **Rain Garden** (disconnect downspout)
- [ ] **Cisterns / Rain Barrels** (disconnect downspout)

- [ ] **Native Vegetation**
- [ ] **Vegetation Filter Strips**
- [ ] **Amended Soil**
- [ ] **Roadside Swales** (elimination of curb and gutter)
- [ ] **Trees**

- [ ] **Swales in Parking Lot**
- [ ] **Reduced Street Width**
- [ ] **Permeable Pavement on Parking**
- [ ] **Permeable Pavement on Driveways and Alleys**
- [ ] **Permeable Pavement on Sidewalks**

* Required fields.
\+ Must have at least one of these fields filled in.

GREEN VALUES® STORMWATER TOOLBOX

GREEN VALUES® NATIONAL STORMWATER MANAGEMENT CALCULATOR

CNT

CALCULATOR

DISPLAY PRINTABLE FORMAT | CREATE A PERMANENT LINK | RESET VALUES

Getting Started | Lot Information | Predevelopment | Runoff Reduction Goal | Conventional Development | Green Improvements | Advanced Options

Natural Desert Landscaping:	63	77	85	88
Newly Graded Areas (no vegetation):	77	86	91	94
Straight Row Crops (in good condition):	67	78	85	89
Pasture (in fair condition):	49	69	79	84
Meadow:	30	58	71	78
Woods:	36	60	73	79

RESULTS

The Green Stormwater BMP(s) applied in this scenario change the site impermeable area by **0**% and capture **0**% of the runoff volume required. Compared to conventional approaches, the green practices in this scenario will change the total life-cycle construction and maintenance costs by **0**% (in net present value).

Volume Control | Coefficients and Runoff | Land Use | Costs | Benefits

Volume Control

Required Volume Capture from 1" over Impermeable Surface (ft^3)	1,458
Volume Captured by current BMPs (ft^3)	0
Percentage of Required Volume Captured by current BMPs (%)	0
Decrease in Impervious Area (%)	0

Total volume control

Results

RESULTS

The Green Stormwater BMP(s) applied in this scenario change the site impermeable area by **0**% and capture **0**% of the runoff volume required. Compared to conventional approaches, the green practices in this scenario will change the total life-cycle construction and maintenance costs by **0**% (in net present value).

Volume Control | Coefficients and Runoff | Land Use | Costs | Benefits

Comparison

Coefficients and Runoff

	Predevelopment	Conventional	Green	Predevelopment to Conventional Difference (%)	Conventional to Green Difference (%)
Average Annual Rainfall					
Total Runoff (in)	24.06	23.68	23.68	-2%	0%
Total Runoff Volume (ft^3)	87,337	85,974	85,974	-2%	0%
Cumulative Abstractions (in)		1.38	1.38		0
90% Storm					
Total Runoff (in)	0.34	0.25	0.25	-26%	0%
Total Runoff Volume (ft^3)	1,245	917	917	-26%	0%
Cumulative Abstractions (in)		0.49	0.49		0
CN	90	87	87		
Initial Abstractions (in)		0.29	0.29		0

RESULTS

The Green Stormwater BMP(s) applied in this scenario **decrease** the site impermeab
Compared to conventional approaches, the green practices in this scenario will **incre**
5% (in net present value).

Volume Control | Coefficients and Runoff | Land Use | Costs | Benefits

Benefits

	Annual Benefits ($) Green Benefits	Life Cycle Benefits ($, NPV) Green Benefits
Reduced Air Pollutants	0	0
Carbon Dioxide Sequestration	0	0
Compensatory Value of Trees	0	0
Groundwater Replenishment	0	11
Reduced Energy Use	180	5,704
Reduced Treatment benefits	0	6
Total	181	5,721

Detailed benefits sheet.

Other green benefits

2. North Carolina State University Rainwater Harvesting Model

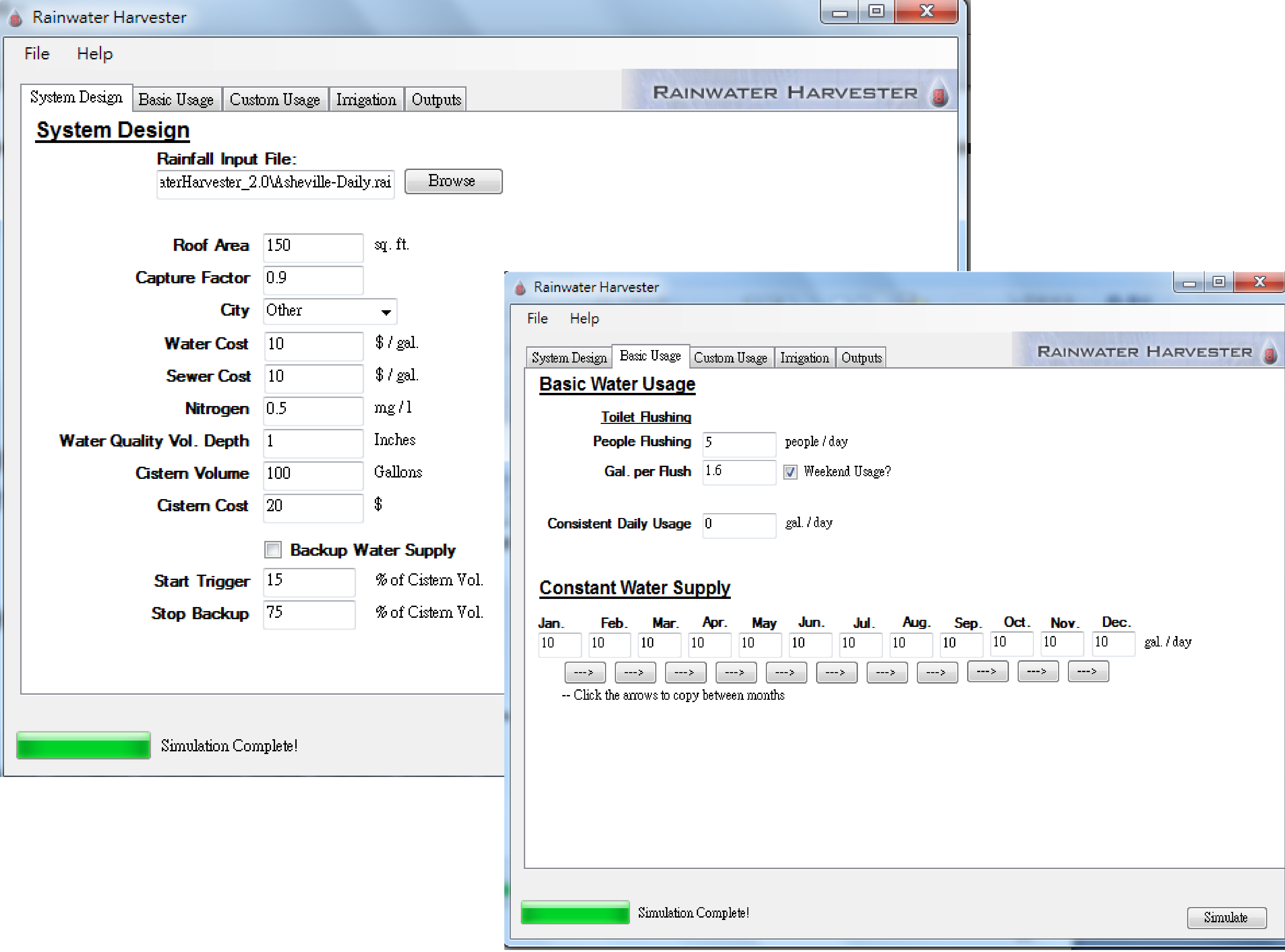
- Rainwater Harvesting for Homeowners
- Increased development and the 2007 – 2008 drought in NC have led to develop rainwater harvesting system, which can
  - captures stormwater runoff
  - stores the water for later use.
- **The Rainwater Harvester model**

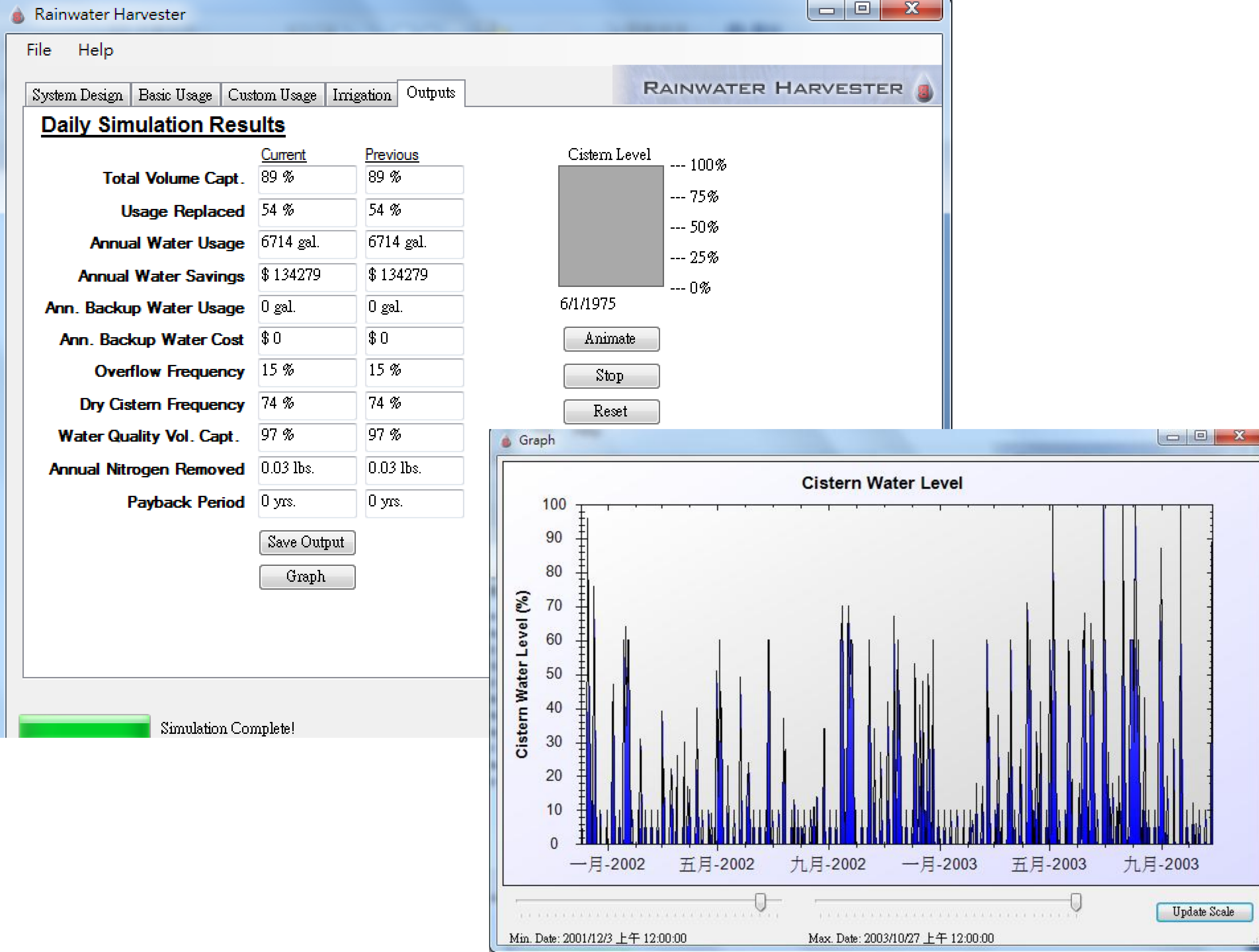
http://www.bae.ncsu.edu/topic/waterharvesting/

Basic rainwater harvesting system components

Craven Co.

Kinston


Rainwater Harvester
File
Help
System Design
Basic Usage
Custom Usage
Irrigation
Outputs
RAINWATER HARVESTER
System Design
Rainfall Input File:
aterHarvester_2.0\Asheville-Daily.rai
Browse
Roof Area
150
sq. ft.
Capture Factor
0.9
City
Other
Water Cost
10
$ / gal.
Sewer Cost
10
$ / gal.
Nitrogen
0.5
mg / l
Water Quality Vol. Depth
1
Inches
Cistern Volume
100
Gallons
Cistern Cost
20
$
Backup Water Supply
Start Trigger
15
% of Cistern Vol.
Stop Backup
75
% of Cistern Vol.
Simulation Complete!
Rainwater Harvester
File
Help
System Design
Basic Usage
Custom Usage
Irrigation
Outputs
RAINWATER HARVESTER
Basic Water Usage
Toilet Flushing
People Flushing
5
people / day
Gal. per Flush
1.6
Weekend Usage?
Consistent Daily Usage
0
gal. / day
Constant Water Supply
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
10 10 10 10 10 10 10 10 10 10 10 10
gal. / day
---> ---> ---> ---> ---> ---> ---> ---> ---> ---> --->
-- Click the arrows to copy between months
Simulation Complete!
Simulate


Rainwater Harvester
File
Help
System Design
Basic Usage
Custom Usage
Irrigation
Outputs
RAINWATER HARVESTER
Daily Simulation Results
Current
Previous
Total Volume Capt.
89 %
89 %
Usage Replaced
54 %
54 %
Annual Water Usage
6714 gal.
6714 gal.
Annual Water Savings
$ 134279
$ 134279
Ann. Backup Water Usage
0 gal.
0 gal.
Ann. Backup Water Cost
$ 0
$ 0
Overflow Frequency
15 %
15 %
Dry Cistern Frequency
74 %
74 %
Water Quality Vol. Capt.
97 %
97 %
Annual Nitrogen Removed
0.03 lbs.
0.03 lbs.
Payback Period
0 yrs.
0 yrs.
Save Output
Graph
Cistern Level
--- 100%
--- 75%
--- 50%
--- 25%
--- 0%
6/1/1975
Animate
Stop
Reset
Simulation Complete!
Graph
Cistern Water Level
Cistern Water Level (%)
100
90
80
70
60
50
40
30
20
10
0
一月-2002
五月-2002
九月-2002
一月-2003
五月-2003
九月-2003
Update Scale
Min. Date: 2001/12/3 上午 12:00:00
Max. Date: 2003/10/27 上午 12:00:00

Water Balance Model powered by QUALHYMO (Canada)

http://waterbalance.ca/

Runoff

Canadian Water Resources Association
BC Branch Newsletter
April 2008

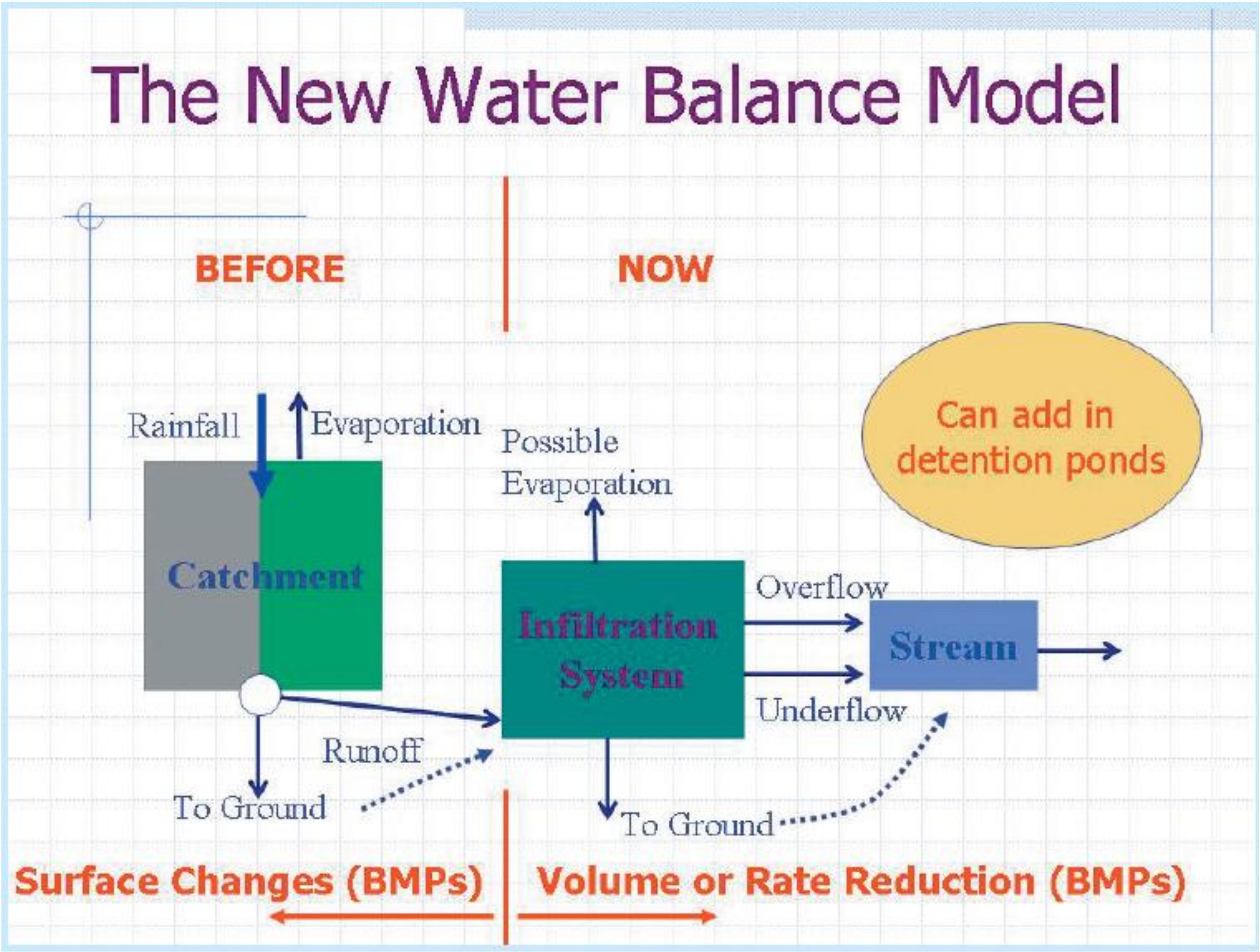
Create Liveable Communities and Protect Stream Health:
Water Balance Model powered by QUALHYMO integrates the site with the watershed and the stream

By
Ted van der Gulik (Ministry of Agriculture & Lands), Chair, Inter-Governmental Partnership
Paul Ham (City of Surrey), Chair, Green Infrastructure Partnership
Kim A Stephens, Program Coordinator, Water Sustainability Action Plan for British Columbia
Jim Dumont, Engineering Applications Authority, QUALHYMO Integration Project Team
Dr. Charles Rowney, Scientific Authority, 'Water Balance Model powered by QUALHYMO'

Two hydrologic models have been merged:

1. The **Water Balance Model for British Columbia** and
2. The **QUALHYMO (QUALity** HYdrologic Model)

The new Water Balance Model is a decision support tool that integrates the powerful continuous hydrologic simulation capabilities of QUALHYMO with the built-in suite of land use, low impact system, soil and local climate information.



臺北市公共設施用地開發保水設計技術規範

各類保水設計之保水量計算及變數說明

項目	各類保水設計之保水量Q_i(m^3)	保水量Q_i計算公式	變數說明
常用保水設計	綠地、被覆地、草溝保水量Q_1	$Q_1=A_1 \cdot k \cdot t$	A_1：綠地、被覆地、草溝面積(m^2)，草溝面積可算入草溝立體周邊面積。
	透水鋪面設計保水量Q_2	$Q_2=A_2 \cdot k \cdot t+0.15 \cdot h \cdot A_2$	A_2：透水鋪面面積(m^2) h：透水鋪面基層厚度(m)
	人工地盤花園貯留設計保水量Q_3	$Q_3=0.05 \cdot V_3$	V_3：人工地盤花園土壤體積(m^3)
特殊保水設計	地面貯留滲透設計保水量Q_4	$Q_4=A_4 \cdot k \cdot t+V_4$	A_4：貯留滲透空地面積或景觀貯留滲透水池可透水面積(m^2) V_4：貯留滲透空地可貯留體積或景觀貯留滲透水池高低水位間之體積(m^3)
	地下礫石滲透貯留保水量Q_5	$Q_5=(A_5 \cdot k \cdot t)+0.2 \cdot V_5$	A_5：礫石貯留設施地表面積(m^2) V_5：礫石貯休設施體積(m^3)
	滲透管(溝)設計保水量Q_6	$Q_6=(2.0 \cdot k \cdot L \cdot t)+(0.069 \cdot L)$	L：滲透管(溝)總長度[m]
	滲透集水井設計保水量Q_7	$Q_7=(3.0 \cdot k \cdot n \cdot t)+(0.015 \cdot n)$	n：滲透集水井個數
	滲透邊溝保水量Q_8	$Q_8=(2.0 \cdot k \cdot L \cdot t)+(0.057 \cdot L)$	L：滲透邊溝總長度[m]
	其他保水設計Q_n	由設計者提出設計圖與計算說明並經審核認定後採用之	

3. SUSTAIN

System for Urban Stormwater Treatment and Analysis Integration

- Developed by USEPA and Tetra Tech. (2009)
- *SUSTAIN* is a tool for answering 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?
  - Where, what type of, and how big should BMPs be?

- SUSTAIN = Watershed model (rainfall-runoff)

  + LID assessment tools

  + optimization program (cost analysis)

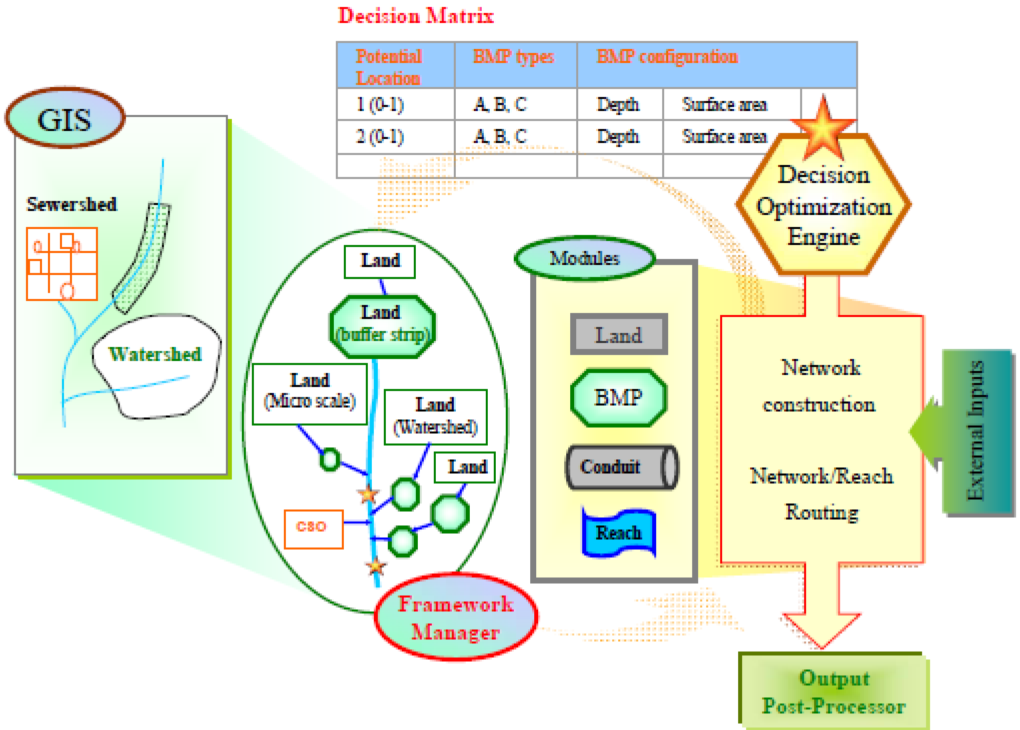


Figure 2-1. *SUSTAIN* components and flow chart.

BMP options in SUSTAIN

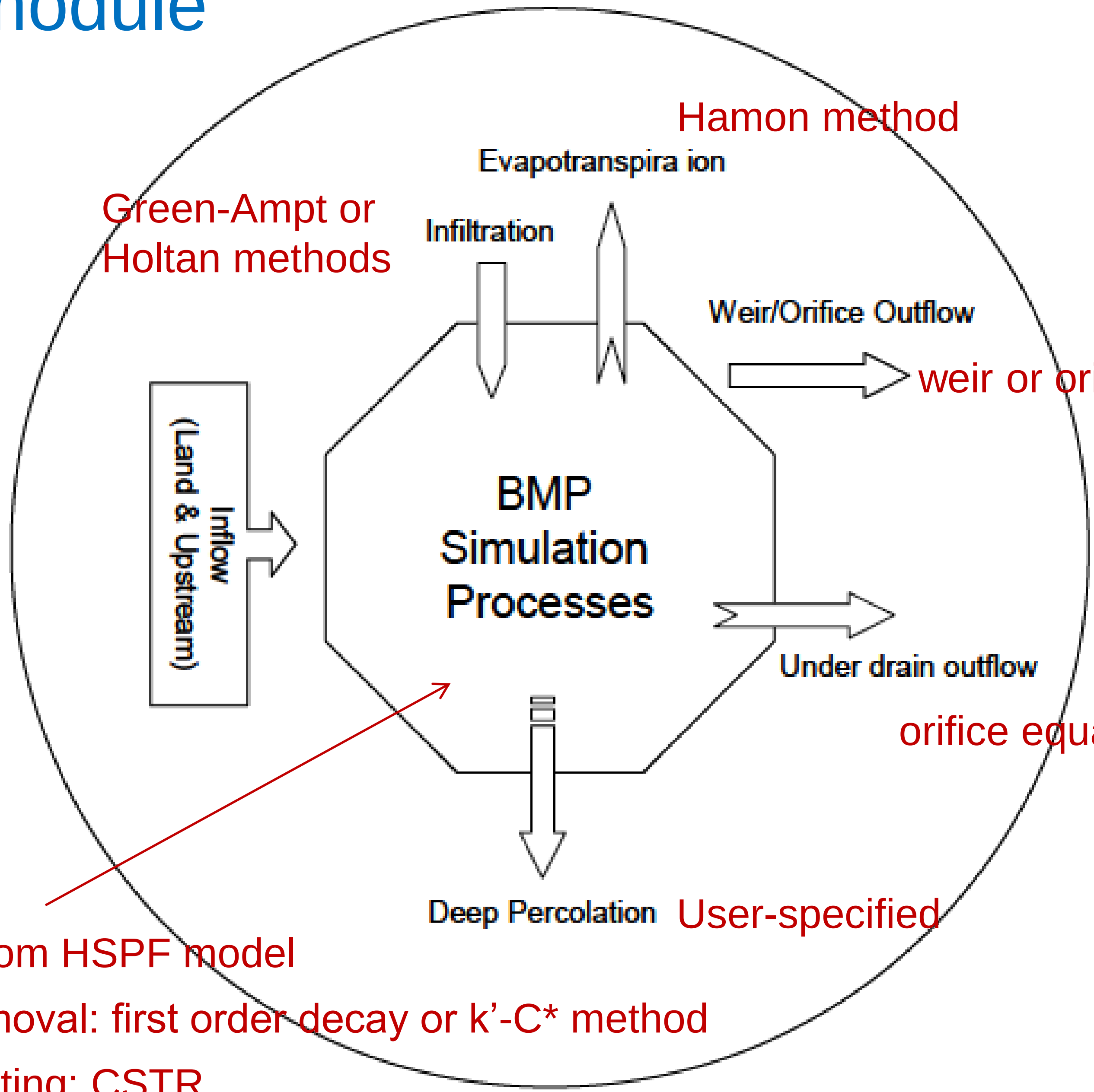
BMP Option 14	BMP Type
Bioretention	Point LID
Cistern	Point LID
Constructed Wetland	Point BMP
Dry Pond	Pont BMP
Grassed Swale	Linear BMP
Green Roof	Area BMP
Infiltration Basin	Point BMP
Infiltration Trench	Linear BMP
Porous Pavement	Area BMP
Rain Barrel	Point LID
Sand Filter (non-surface)	Linear BMP
Sand Filter (surface)	Point BMP
Vegetated Filter strip	Linear BMP
Wet Pond	Point BMP

SUSTAIN modules

SUSTAIN has seven modules:

- Framework Manager
- BMP Siting Tool
- **Land Module**
  - Computes runoff and pollutant loads from land by SWMM and HSPF
- **BMP Module**
  - simulation of flow and pollutant transport for BMPs
- Conveyance Module
- **Optimization Module**
  - cost-effective BMP placement and selection strategies
- Post-Processor
  - analyzing and interpreting simulation outputs

BMP module



Hamon method

Green-Ampt or
Holtan methods

weir or orifice equations

orifice equations

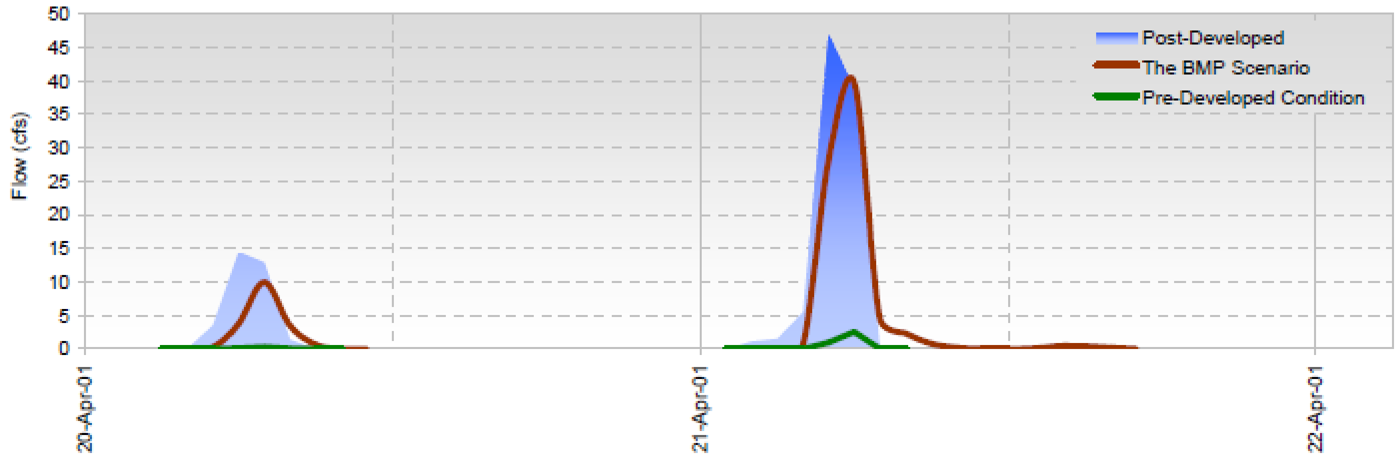
User-specified

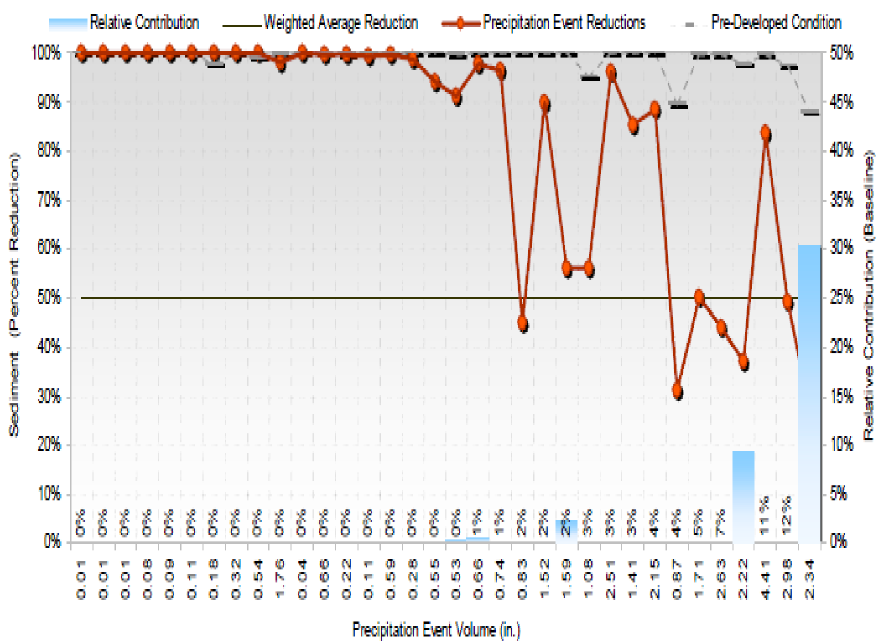
Sediment: from HSPF model

Pollutant removal: first order decay or k’-C* method

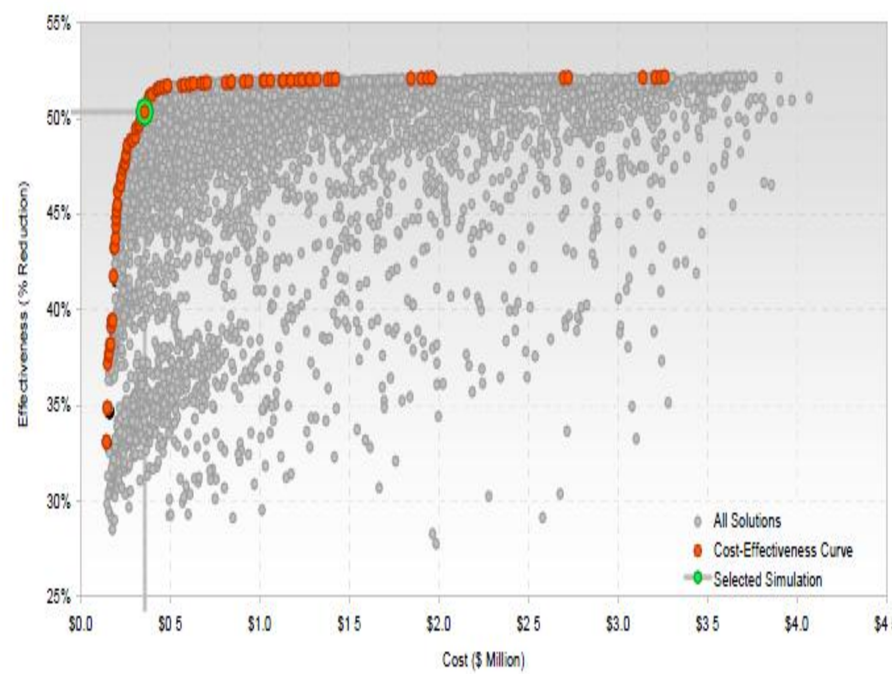
Pollutant routing: CSTR

Performance results



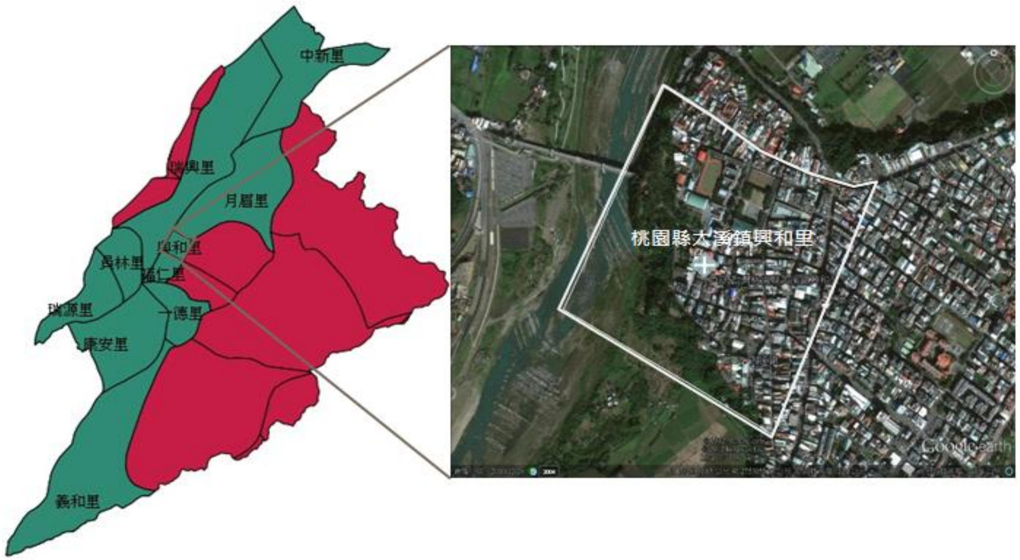


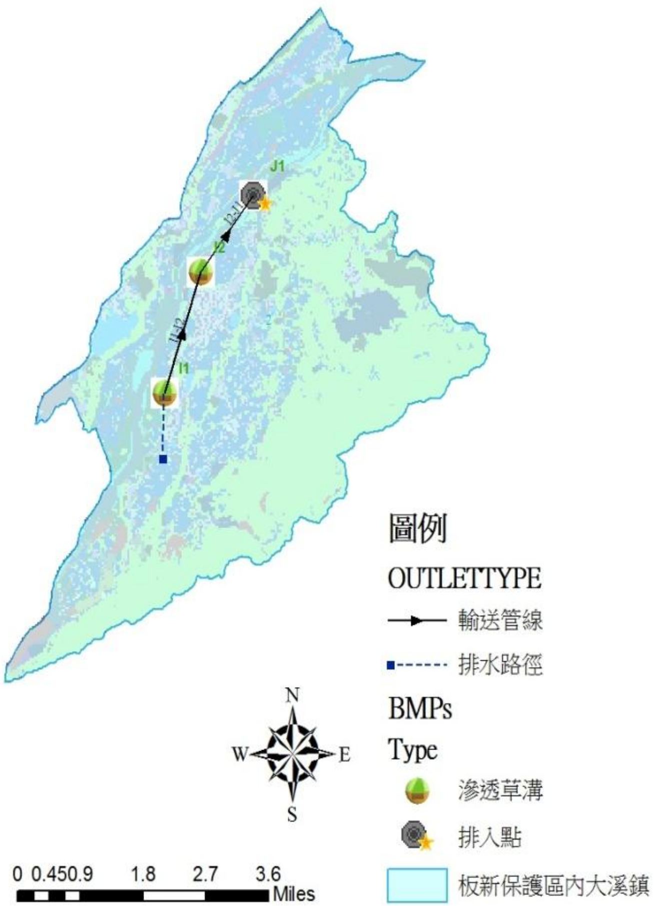
performance summary report graph



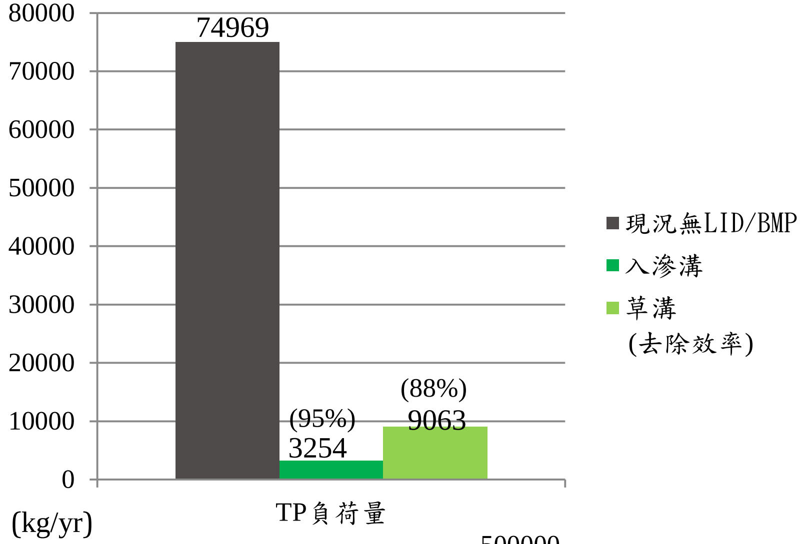
cost-effectiveness curve

Preliminary application of SUSTAIN in Taiwan

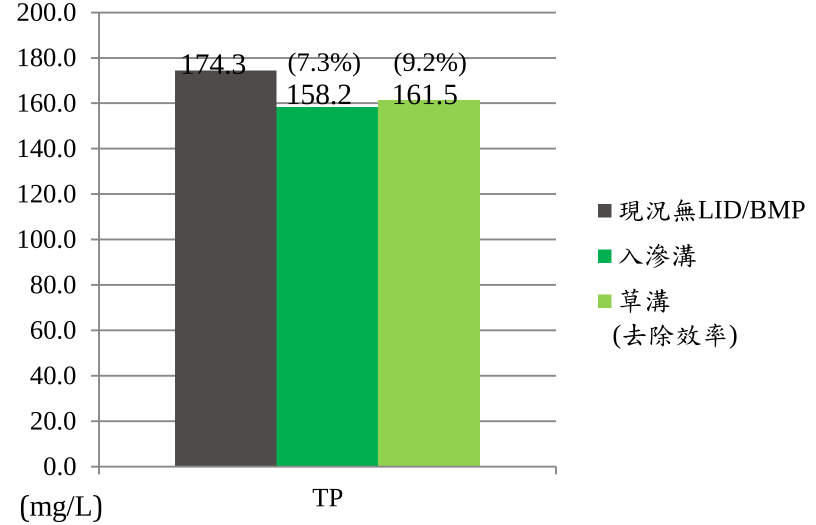




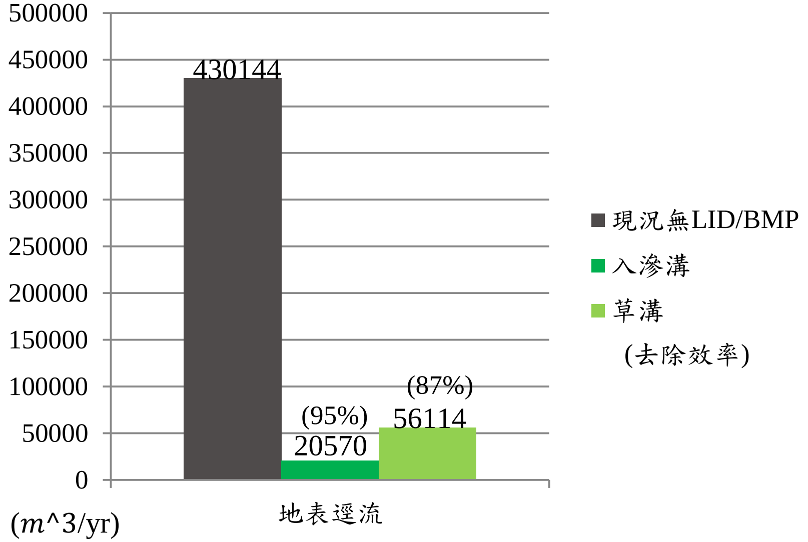
各設施效益比較-線型



80000
70000
60000
50000
40000
30000
20000
10000
0
74969
(95%)
3254
(88%)
9063
(kg/yr)
TP負荷量
現況無LID/BMP
入滲溝
草溝
(去除效率)

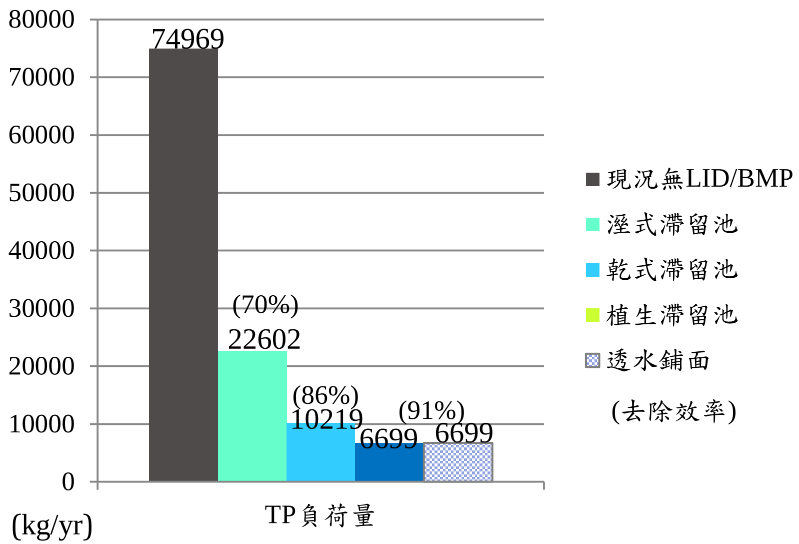


200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
174.3
(7.3%)
158.2
(9.2%)
161.5
(mg/L)
TP
現況無LID/BMP
入滲溝
草溝
(去除效率)

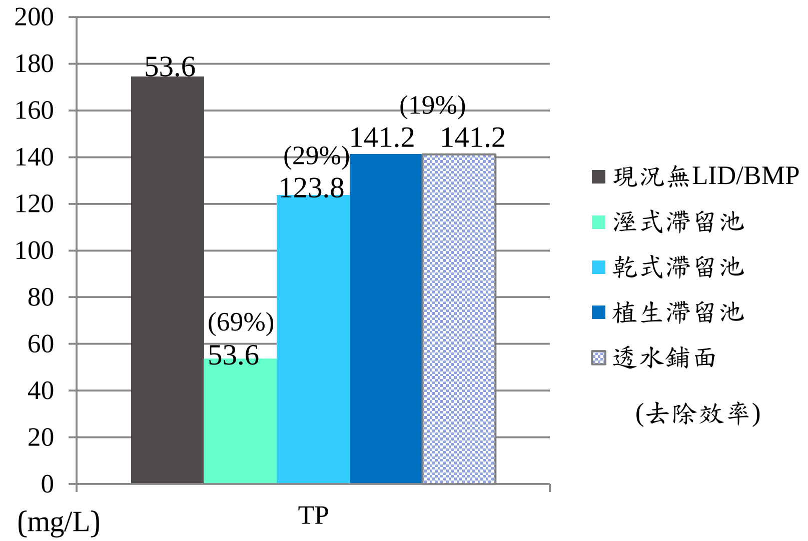


500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
430144
(95%)
20570
(87%)
56114
(m^3/yr)
地表逕流
現況無LID/BMP
入滲溝
草溝
(去除效率)

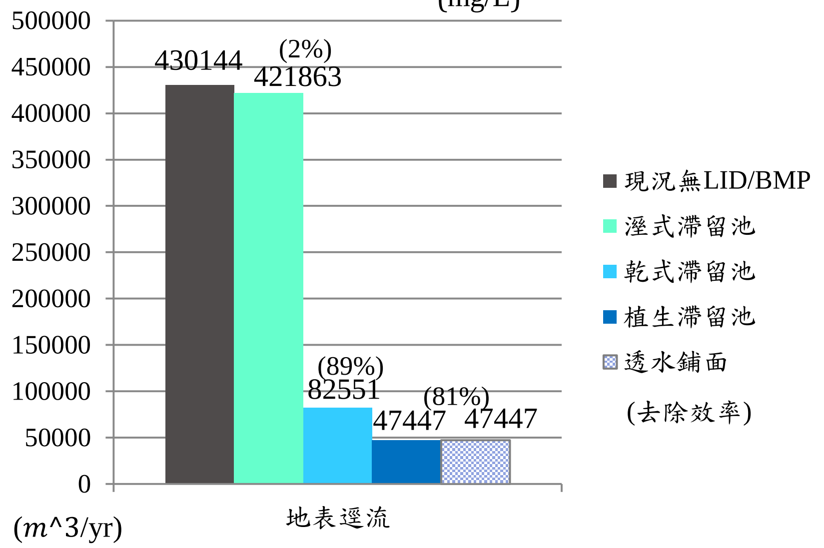
各設施效益比較-面型



80000
70000
60000
50000
40000
30000
20000
10000
0
74969
(70%)
22602
(86%)
10219
(91%)
6699
6699
(kg/yr)
TP負荷量
現況無LID/BMP
溼式滯留池
乾式滯留池
植生滯留池
透水鋪面
(去除效率)



200
180
160
140
120
100
80
60
40
20
0
53.6
(69%)
53.6
(29%)
123.8
(19%)
141.2
141.2
(mg/L)
TP
現況無LID/BMP
溼式滯留池
乾式滯留池
植生滯留池
透水鋪面
(去除效率)

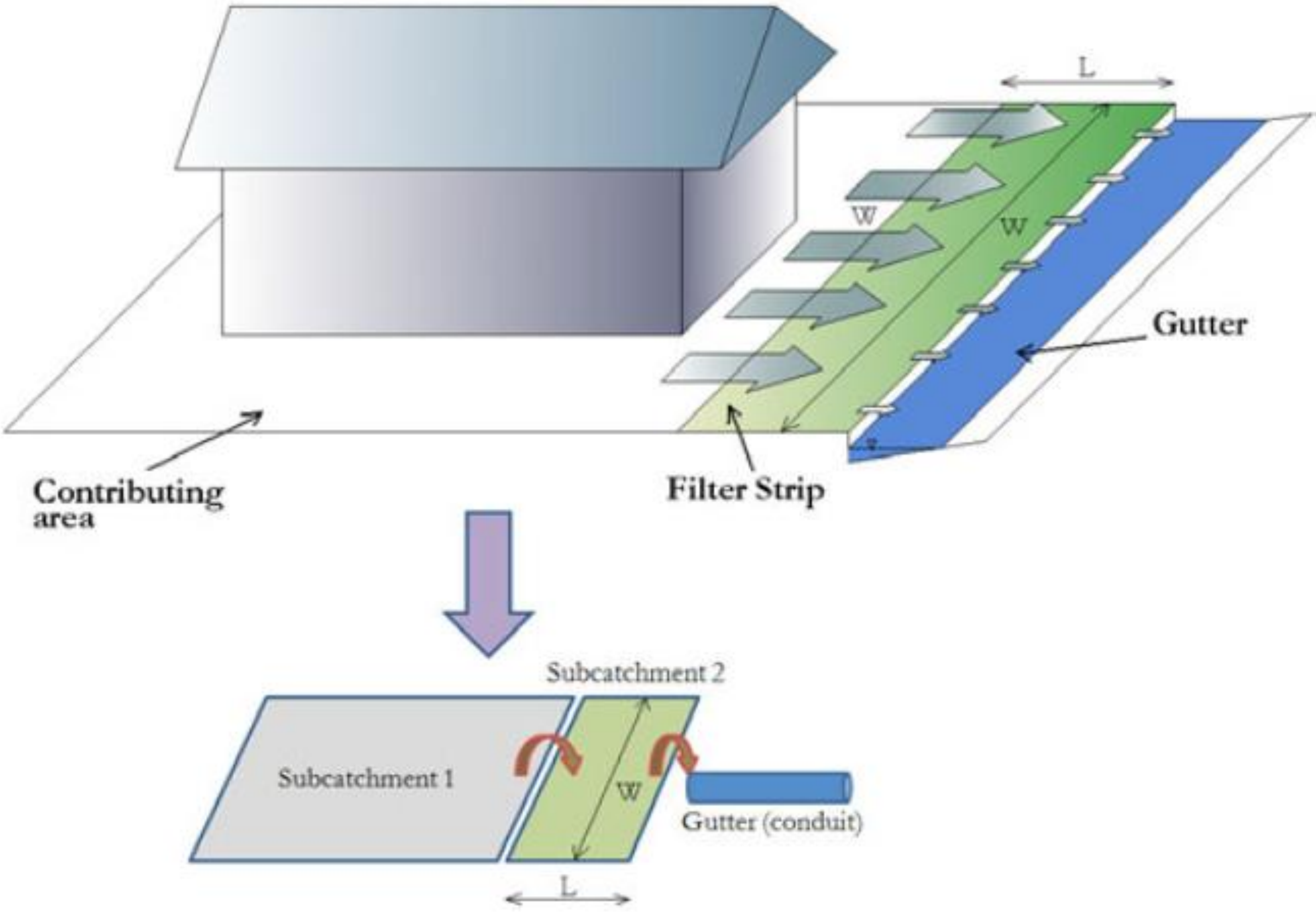


500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
430144
(2%)
421863
(89%)
82551
(81%)
47447
47447
(m^3/yr)
地表逕流
現況無LID/BMP
溼式滯留池
乾式滯留池
植生滯留池
透水鋪面
(去除效率)

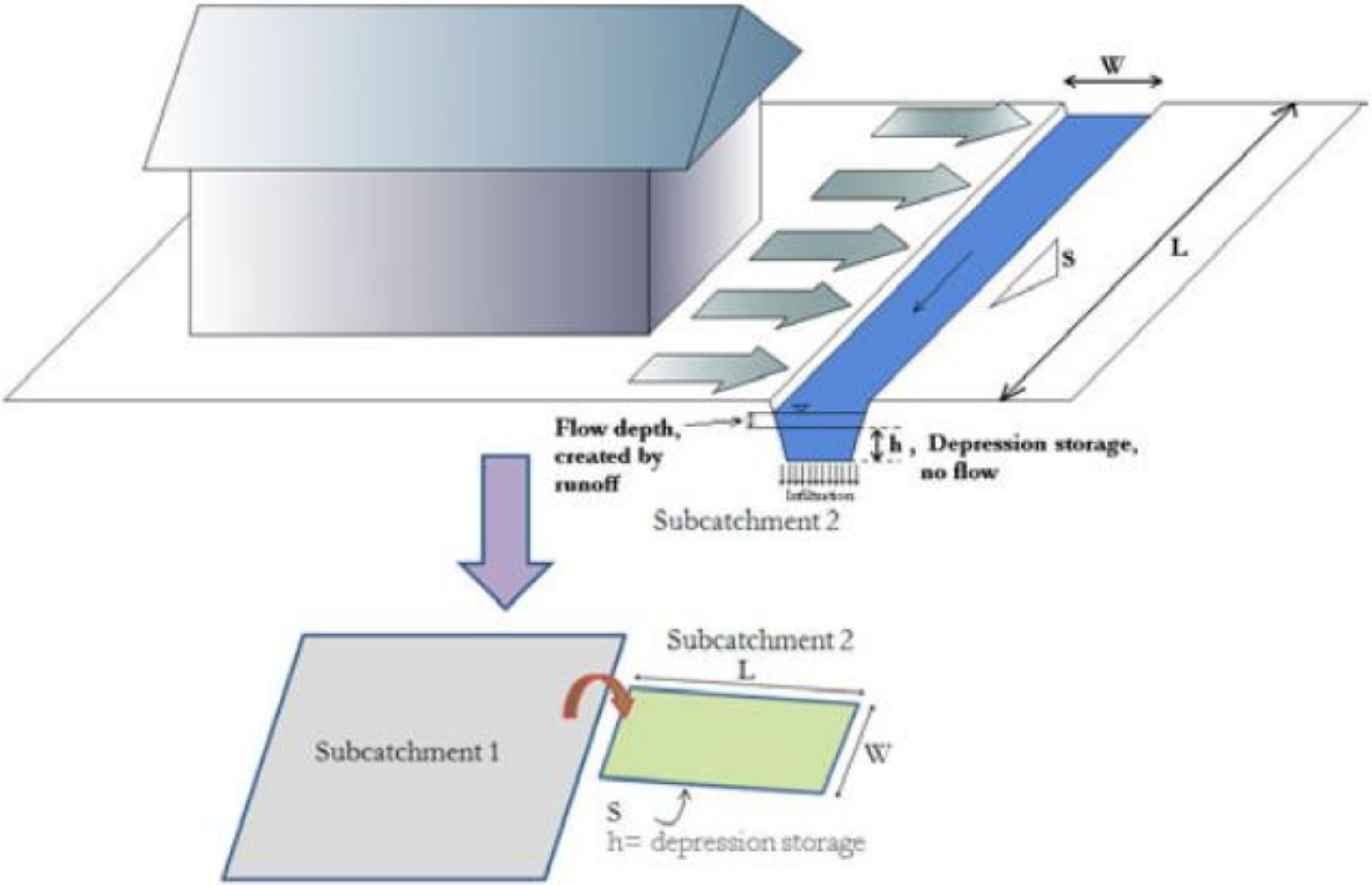
4. SWMM
Storm Water Management Model

- USEPA's Storm Water Management Model (SWMM) was first developed in 1971.
  - urban hydrology and conveyance system hydraulics
  - dynamic rainfall-runoff simulation model used for single event or long-term (continuous)
  - simulation of runoff quantity and quality
- SWMM 5 is extended to model the hydrologic performance of low impact development (LID) controls. (2009)

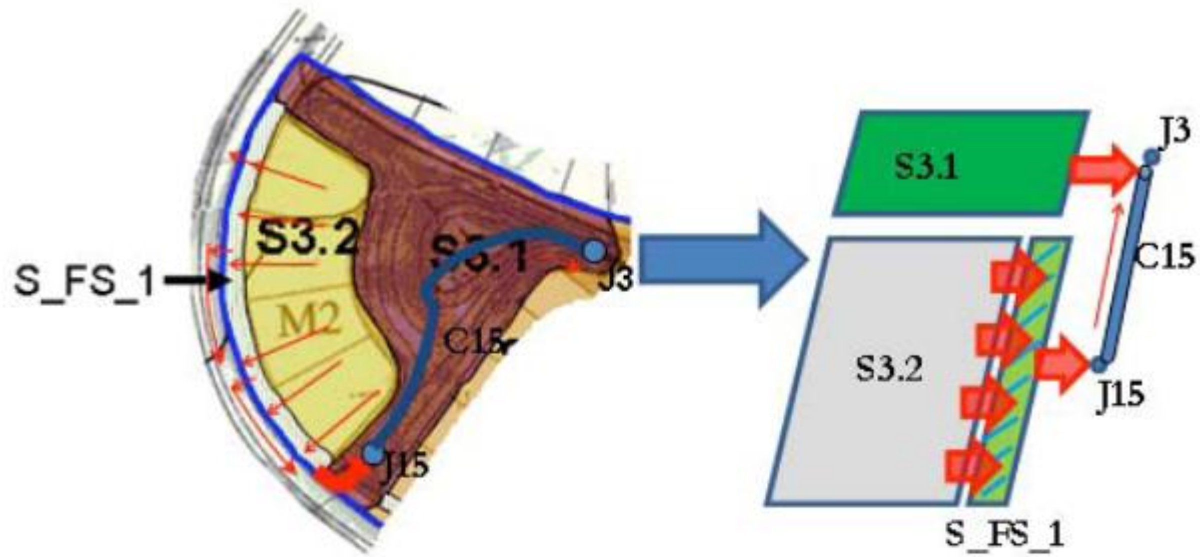
- SWMM is better suited to simulating some types of hydrologic source control techniques than others.
  - filter strips
  - infiltration trenches

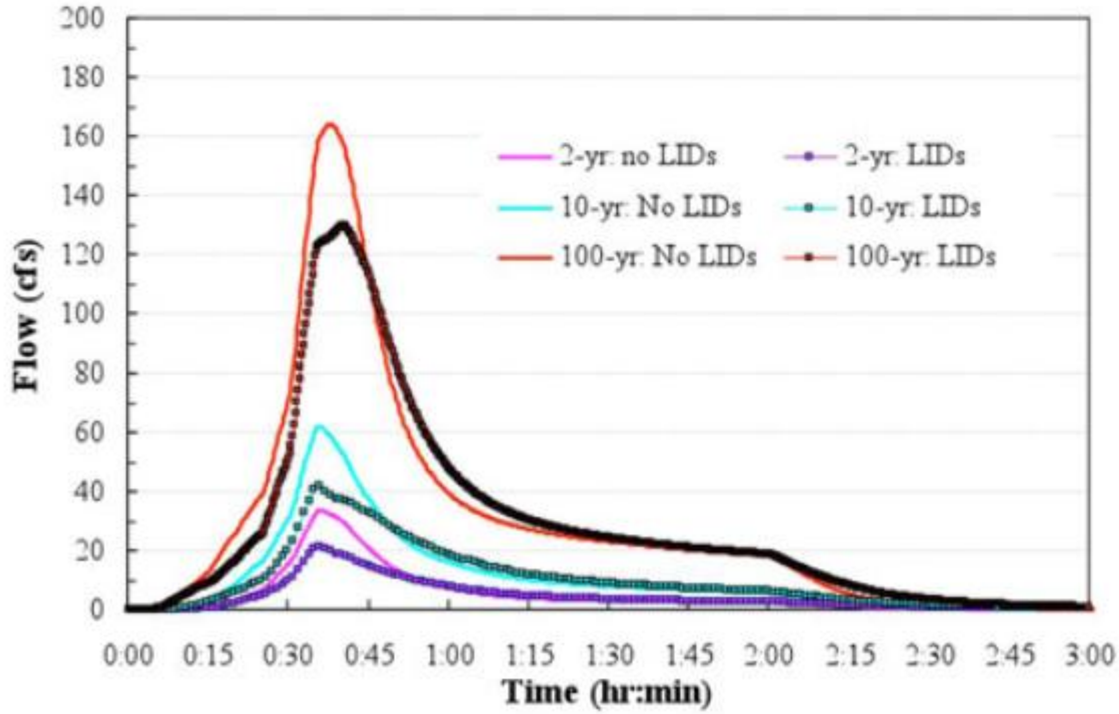


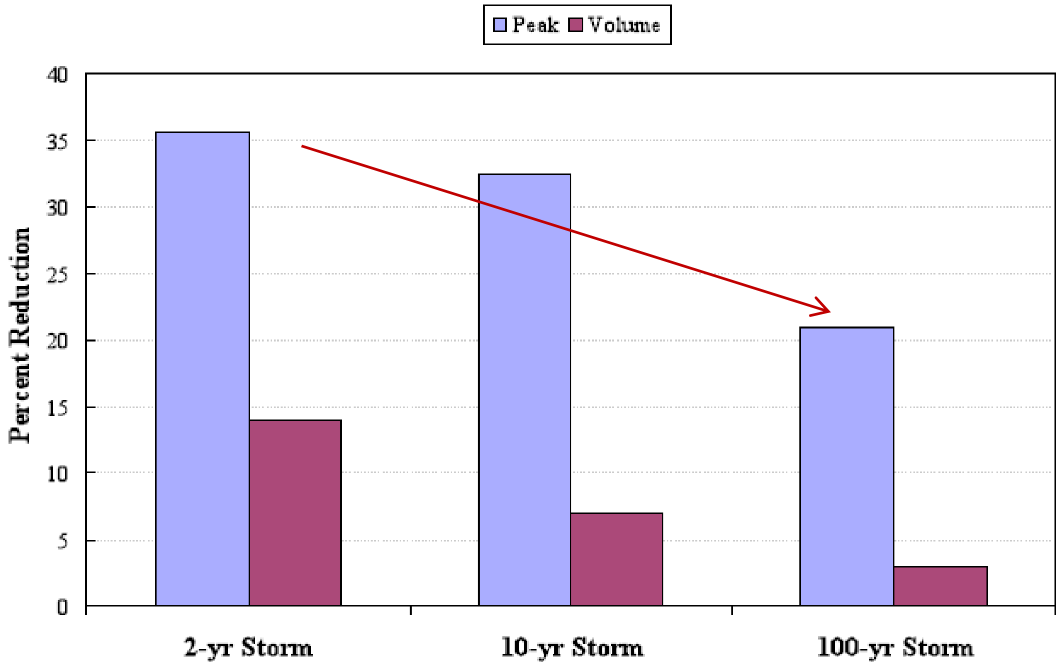
Schematic representation of a filter strip in SWMM model



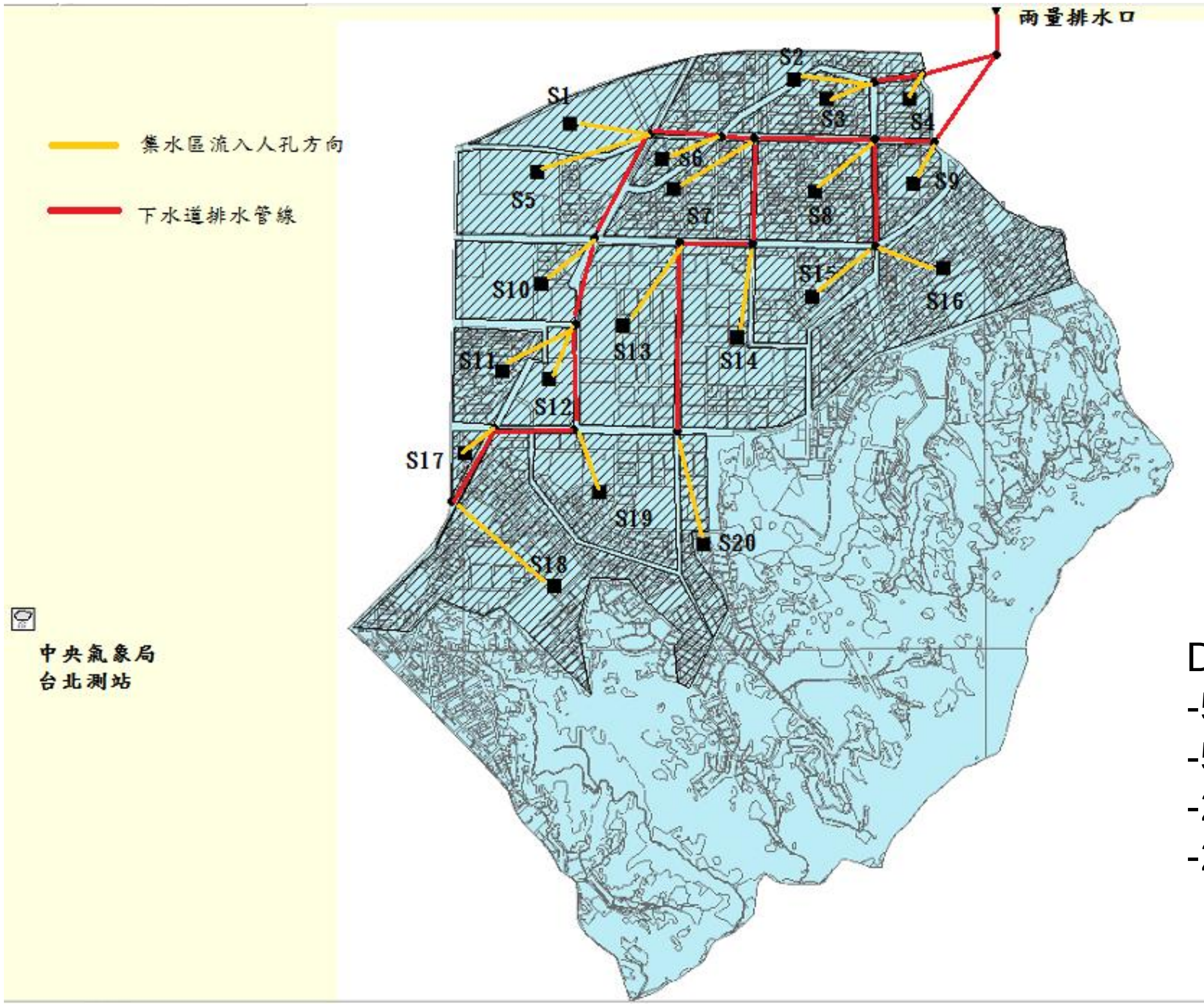
Schematic representation of a infiltration trench in SWMM model


S3.2
S3.1
S_FS_1
M2
C15
J3
J15
S3.1
J3
C15
S3.2
J15
S_FS_1


Flow (cfs)
200
180
160
140
120
100
80
60
40
20
0
0:00 0:15 0:30 0:45 1:00 1:15 1:30 1:45 2:00 2:15 2:30 2:45 3:00
Time (hr:min)
2-yr: no LIDs
2-yr: LIDs
10-yr: No LIDs
10-yr: LIDs
100-yr: No LIDs
100-yr: LIDs

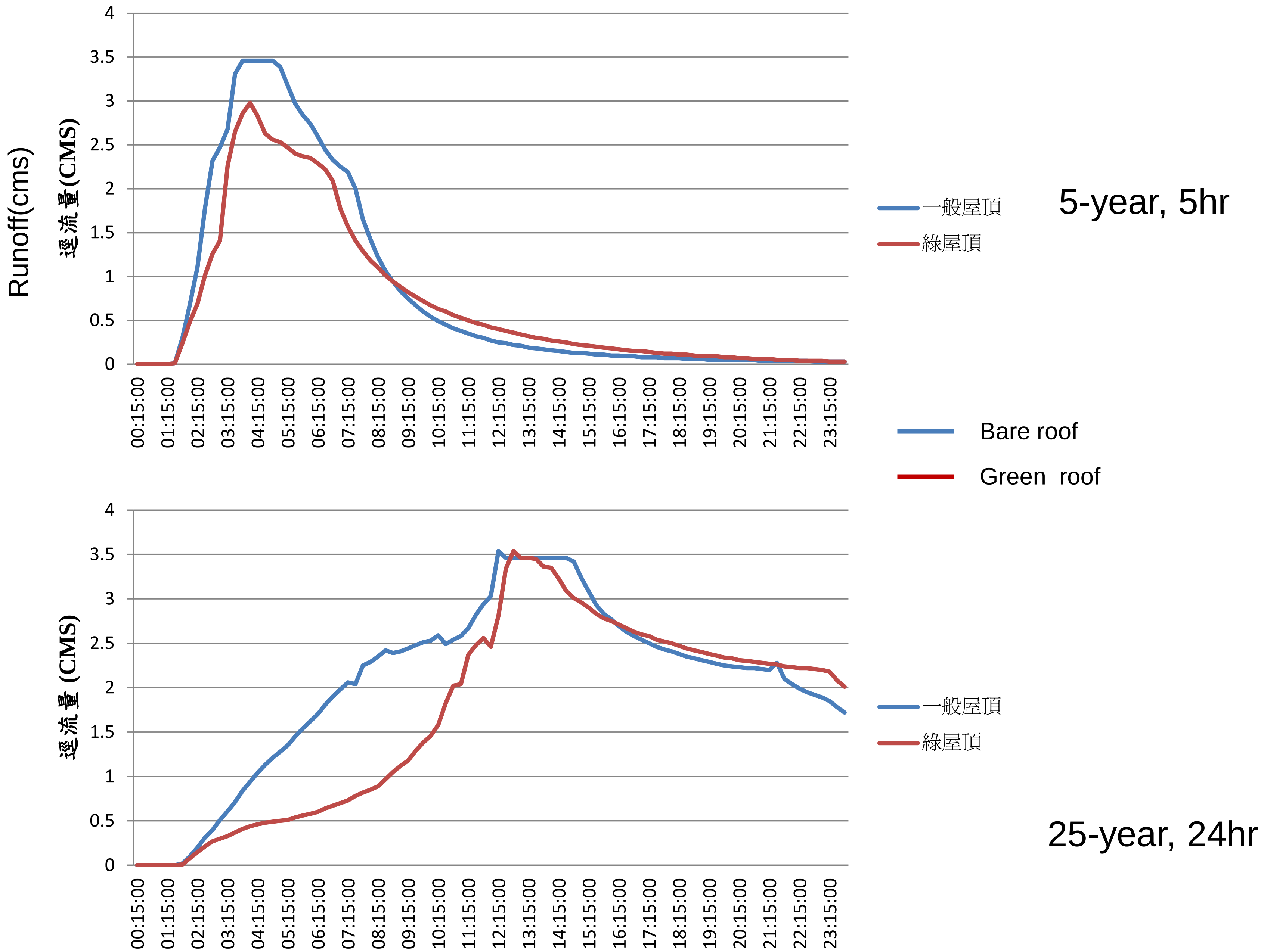

Peak
Volume
Percent Reduction
40
35
30
25
20
15
10
5
0
2-yr Storm
10-yr Storm
100-yr Storm

Application of SWMM on green roofs simulation-HsinYi district, Taipei City



70% bare roofs are replaced by green roofs.

Design storm:
-5-year of return period, 5hr
-5-year of return period, 24hr
-25-year of return period, 5hr
-25-year of return period, 24hr



Runoff(cms)
逕流量(CMS)
5-year, 5hr
一般屋頂
綠屋頂
Bare roof
Green roof
逕流量 (CMS)
25-year, 24hr
0
0.5
1
1.5
2
2.5
3
3.5
4
00:15:00
01:15:00
02:15:00
03:15:00
04:15:00
05:15:00
06:15:00
07:15:00
08:15:00
09:15:00
10:15:00
11:15:00
12:15:00
13:15:00
14:15:00
15:15:00
16:15:00
17:15:00
18:15:00
19:15:00
20:15:00
21:15:00
22:15:00
23:15:00

5. Green Build-Out Model

- Developed by Casey Trees (NPO) and LimnoTech (environmental engineering firm) under USEPA grant.
- Adds the “green component” to the existing hydrologic and hydraulic model of the Mike Urban Model.
  - **Trees**
  - **Green roofs**
  - **Tree boxes**

In this case:
Costs are high for pipes and tunnels.
Space is limited for detention and retention ponds, infiltration controls, grassed swales, and rain gardens.

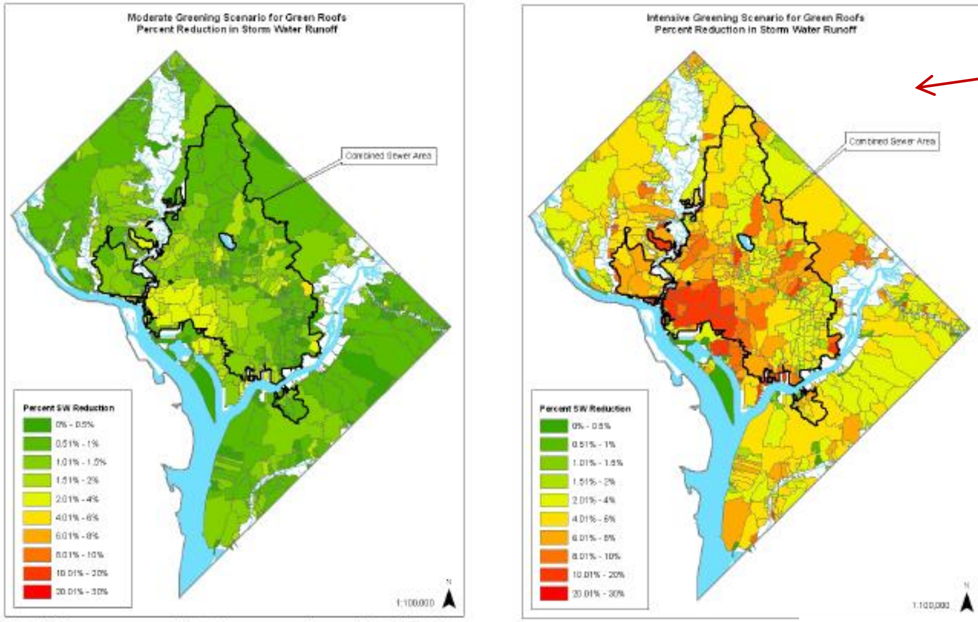
LID strategy for the District:
To plant trees and build green roofs.

The Mike Urban model builds from the basic run-off equation:

$$Runoff = Precipitation - potential\ evapotranspiration - infiltration - \underline{storage}$$

Storage amounts for trees and green roofs were added to the model:

$$Storage = Interception\ storage * coverage\ area$$



Results of runoff reduction under different greening scenario for green roofs

Note: White areas on map indicated nonsewered area within the District.

Figure A2: Sewershed comparison of Moderate Greening and Intensive Greening Scenarios for percent redu runoff from greenroof cover

Table 6: Summary of Stormwater Runoff and Sewer System Discharge Reductions for Moderate and Intensive Greening Scenarios

	Moderate Greening Scenario		Intensive Greening Scenario	
	MG	%	MG	%
Stormwater Runoff Reductions (See Table A8)				
CSS	170	2.2	634	8.3
MS4	140	1.6	581	6.6
Entire Sewer System	311	1.9	1216	7.4
Sewer System Discharge Reductions (See Table A1)				
CSS	141	6.1	514	22.0
MS4	141	1.6	581	6.6
Entire Sewer System	282	2.6	1095	10.0

Note: Runoff reductions are annual average reductions in stormwater entering the sewer systems. Sewer system discharge reductions are reductions in stormwater and untreated sewage entering the rivers.

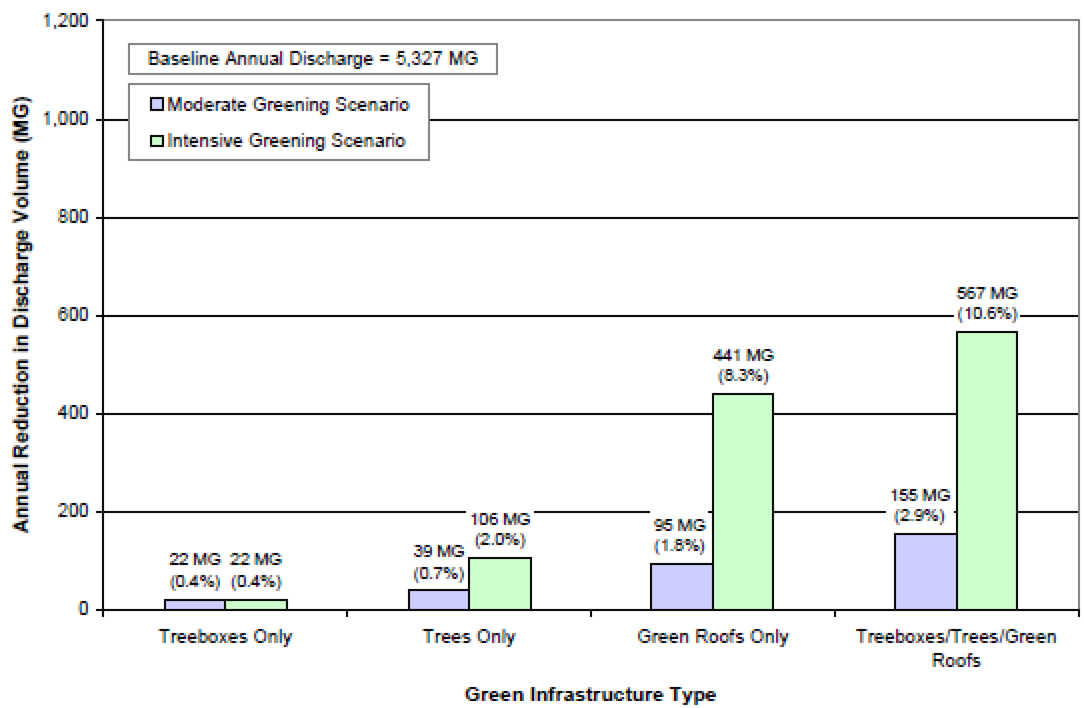


Figure A4: Reduction in CSO and Stormwater Discharge to the Anacostia River

Take home messages

- LID is a source control method, emphasizing the vertical flow enhancement.
- It is better to use simple tools with sufficient local data than to use complex ones without field information.
- These tools are to assess the efficiency of LID/BMP, but not to “verify” their performance.

Thank you for your attention.