BMP-Decision Support System (BMP-DSS) Phase I

In

Prince George's County Maryland

LID BMP-Model Presentation

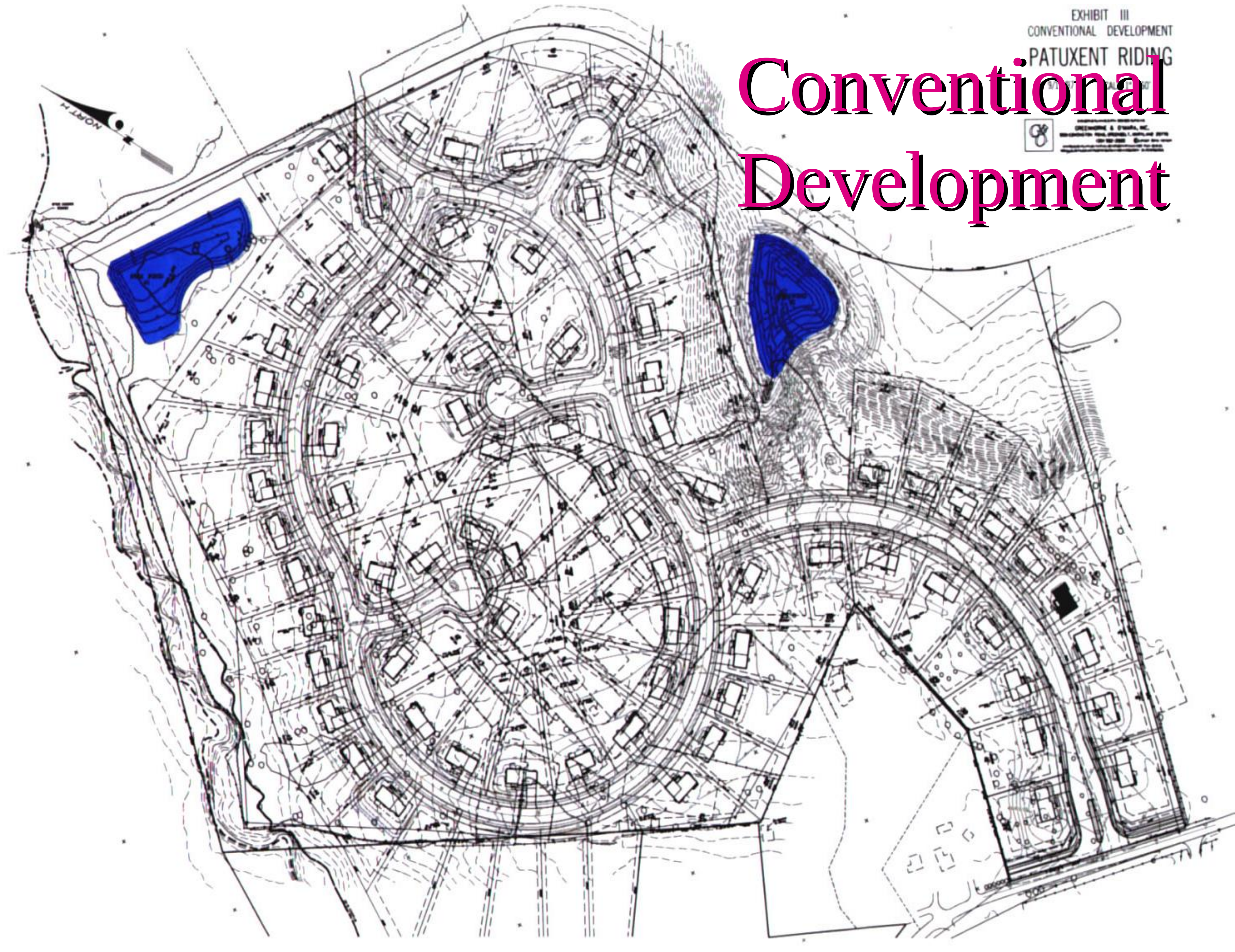
- Overview of LID Concepts
  - New Developments
  - Urban Retrofits
- Bioretention Monitoring - Model Calibration
  - University of Maryland
- BMP Model for LID

Low-Impact Development Programs

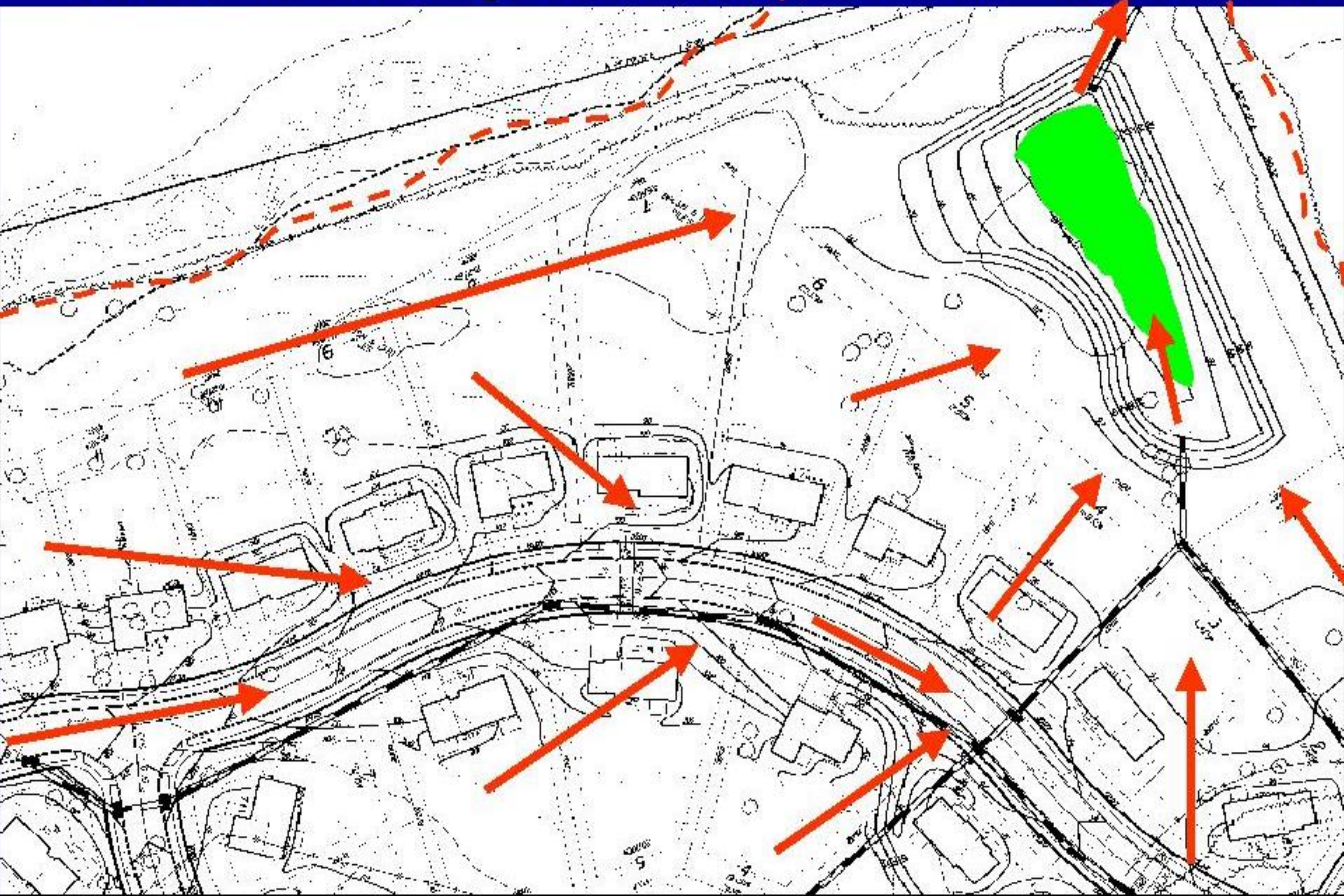
(1)

New Land Developments

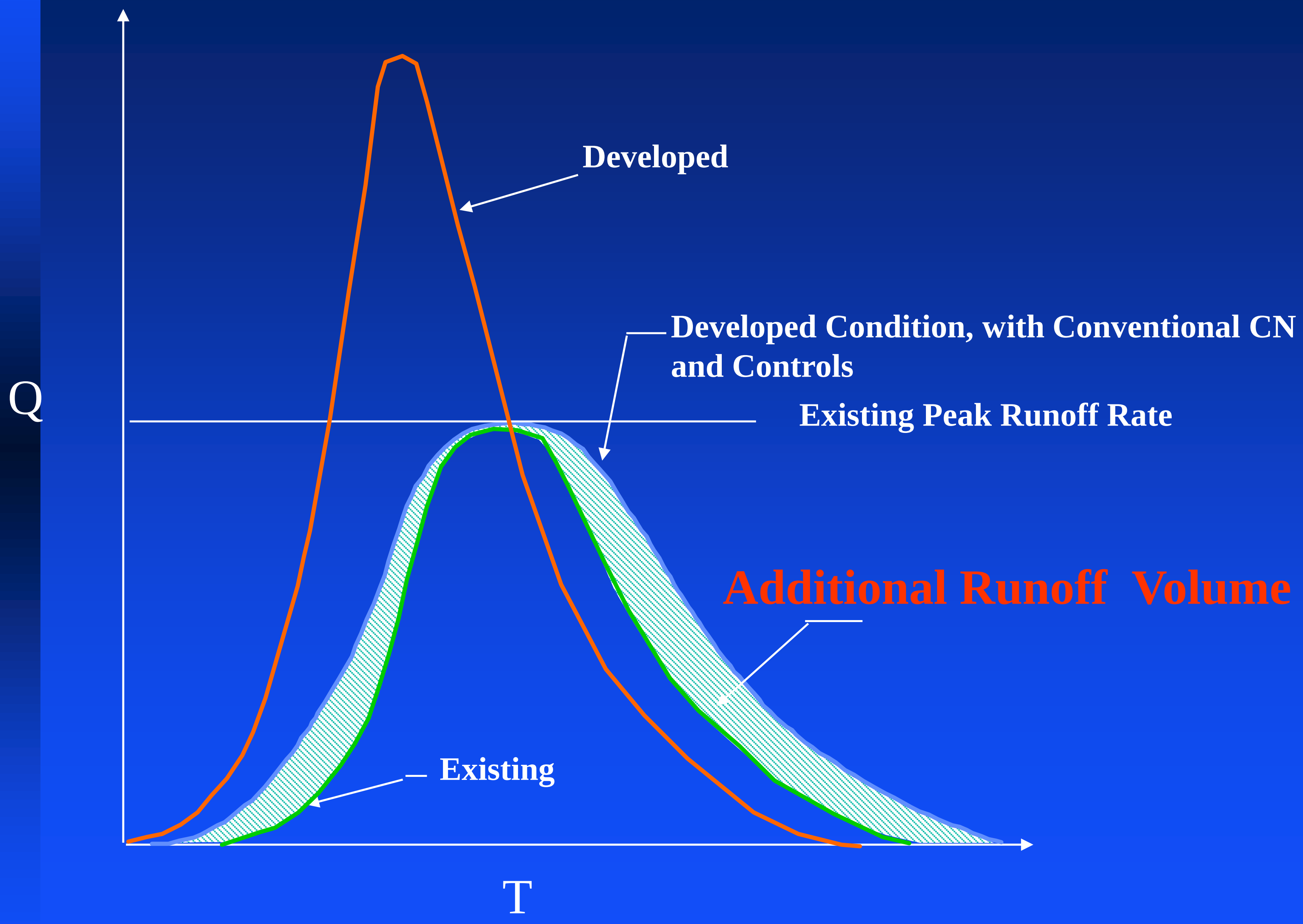
Conventional Development



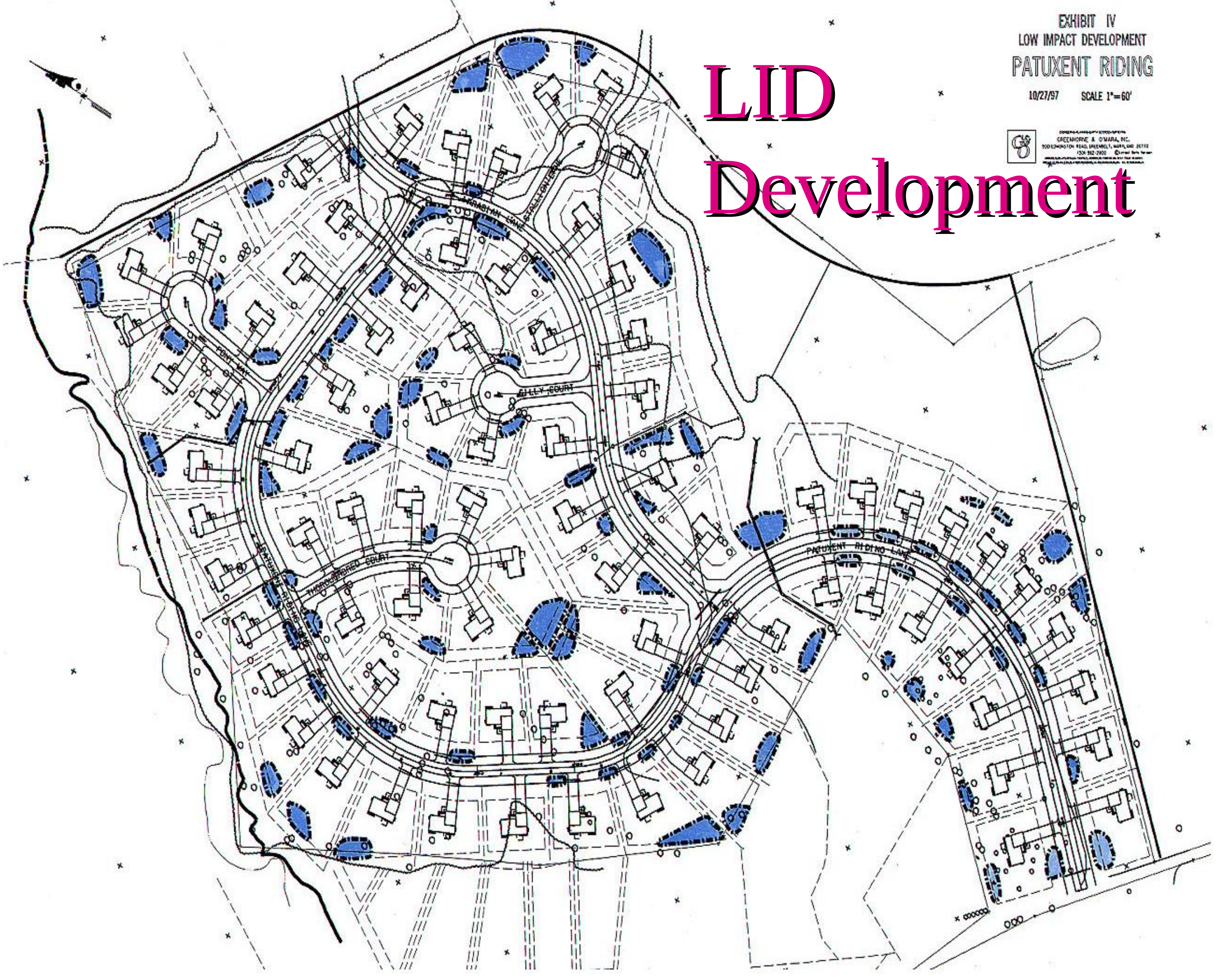
Conventional Pipe and Pond Centralized Control



Stormwater Management Pond


Developed
Developed Condition, with Conventional CN and Controls
Existing Peak Runoff Rate
Q
Additional Runoff Volume
Existing
T

LID Development

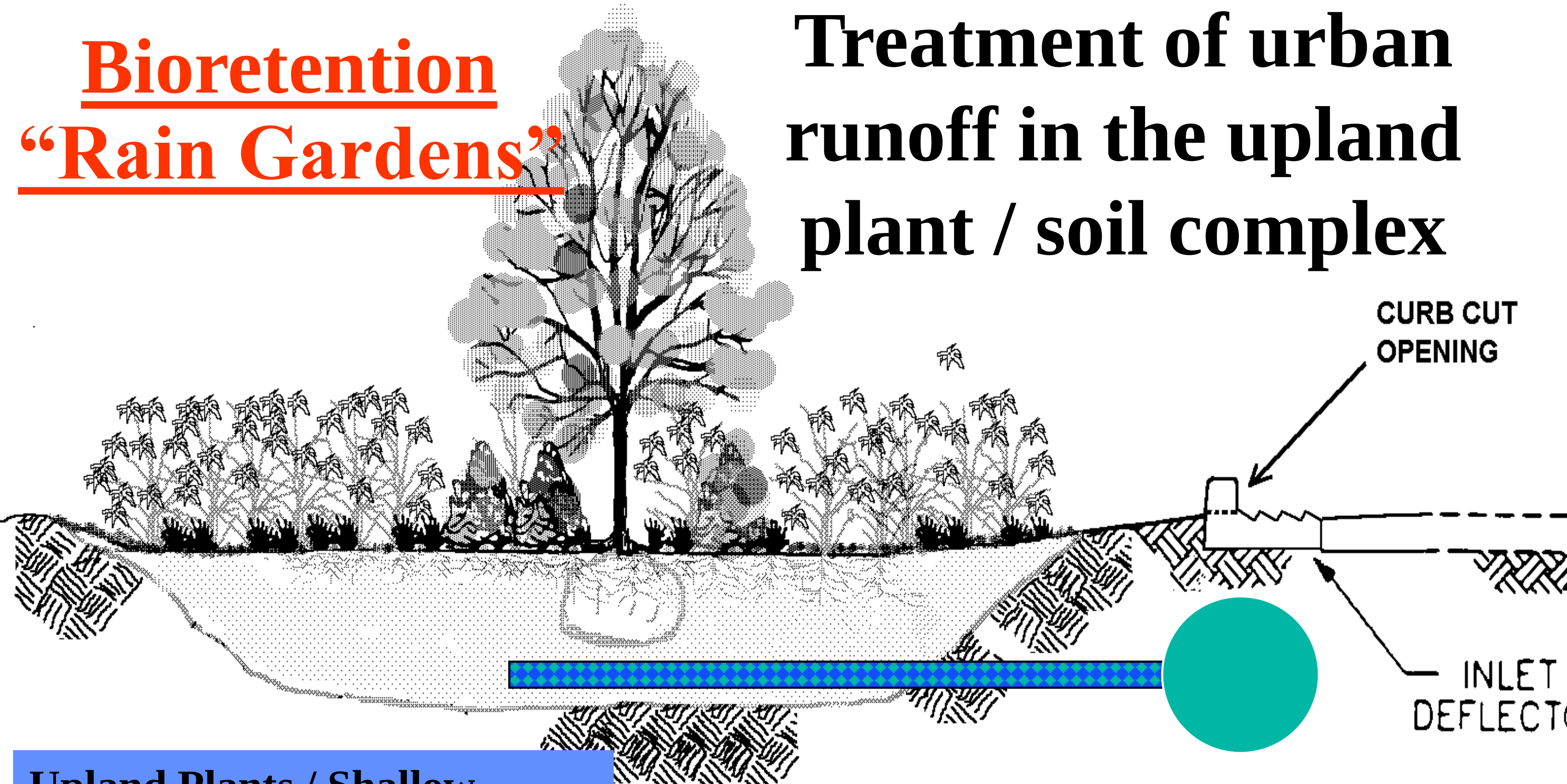


LID Uniform Distribution of Micro Controls

Residential Bioretention

Bioretention "Rain Gardens"

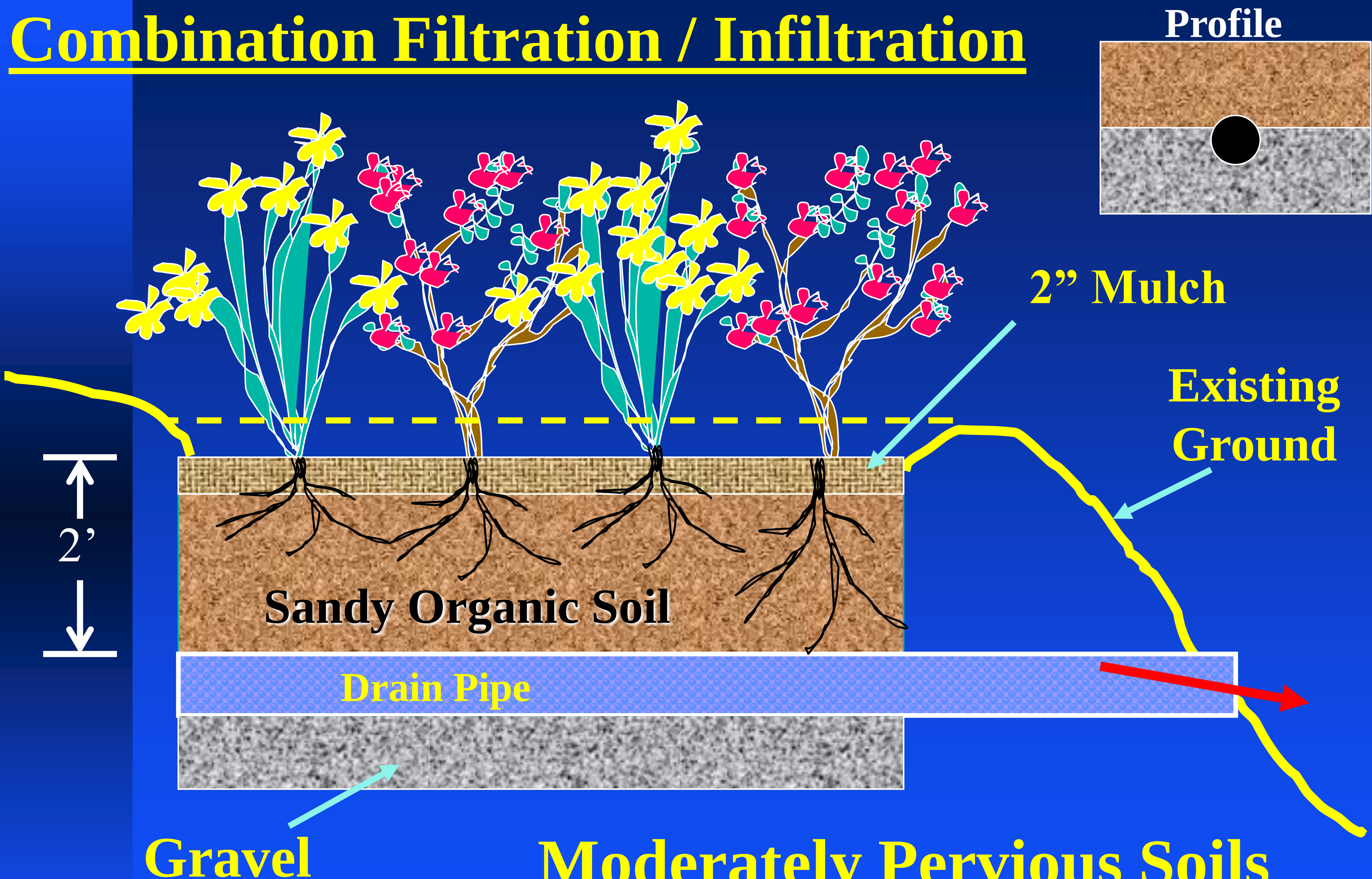
Treatment of urban runoff in the upland plant / soil complex



Upland Plants / Shallow Ponding Infiltration and/or Filtration Volume Control
Aesthetic Value
Habitat Value
Property Value
Low Cost Maintenance

Multifunctional use of green space

Combination Filtration / Infiltration

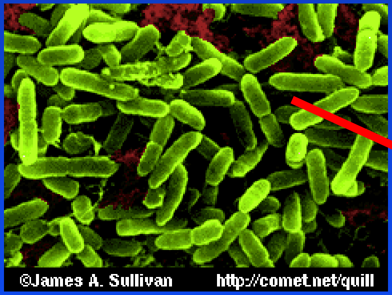


Moderately Pervious Soils

Uplands Pollutant Removal

Plants / Soil Flora -Fauna / Soil Chemistry

- Phytoremediation
  - Translocate
  - Accumulate
  - Metabolize
  - Volatilize
  - Detoxify
  - Degrade
    - Exudates
- Bioremediation
- **Soils**
  - **Capture / Immobilize Pollutants**



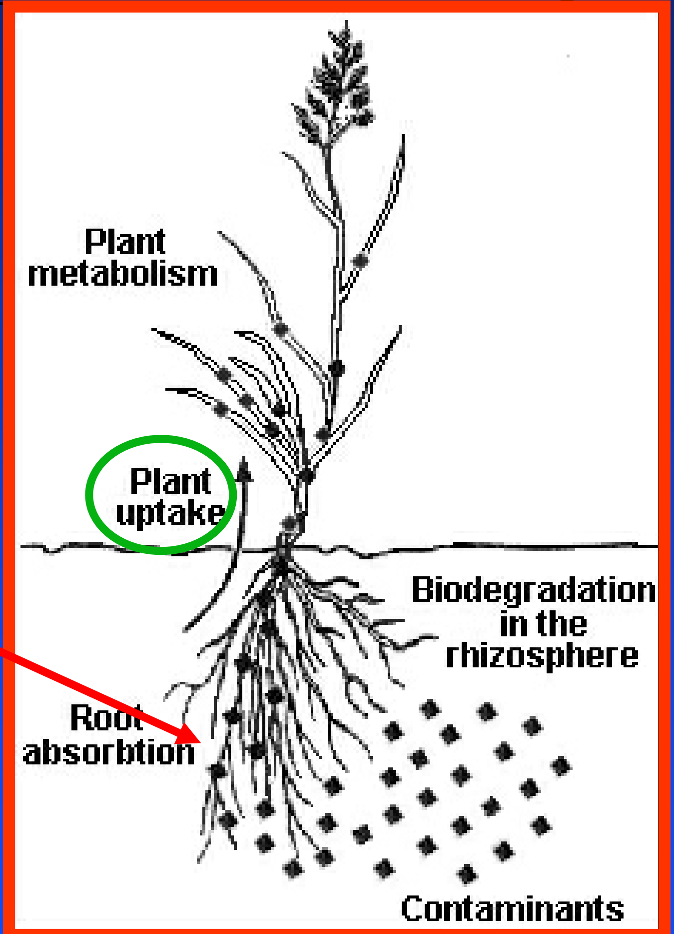


Figure 1. The fate of soil contaminants in the root-zone

Low-Impact Development Programs

(2)

Urban Retrofits

Bioretention


Disconnect
Impervious Roof
MAY 25 2001

Parking Lot Runoff

Highway Runoff Treatment

LID Practices (No Limit!)

"Creative Techniques to Treat, Use, Store, Retain, Detain and Recharge"

Bioretention / Rain Gardens
Strategic Grading
Site Finger Printing
Resource Conservation
Flatter Wider Swales
Flatter Slopes
Long Flow Paths
Tree / Shrub Depression
Turf Depression
Landscape Island Storage
Rooftop Detention /Retention
Roof Leader Disconnection
Parking Lot / Street Storage
Smaller Culverts, Pipes & Inlets

Alternative Surfaces
Reduce Impervious Surface
Surface Roughness Technology
Rain Barrels / Cisterns / Water Use
Catch Basins / Seepage Pits
Sidewalk Storage
Vegetative Swales, Buffers & Strips
Infiltration Swales & Trenches
Eliminate Curb and Gutter
Shoulder Vegetation
Maximize Sheet flow
Maintain Drainage Patterns
Reforestation………………..
Pollution Prevention…………..

Monitoring for Bioretention Facilities

COMPONENTS OF A TYPICAL BIORETENTION FACILITY

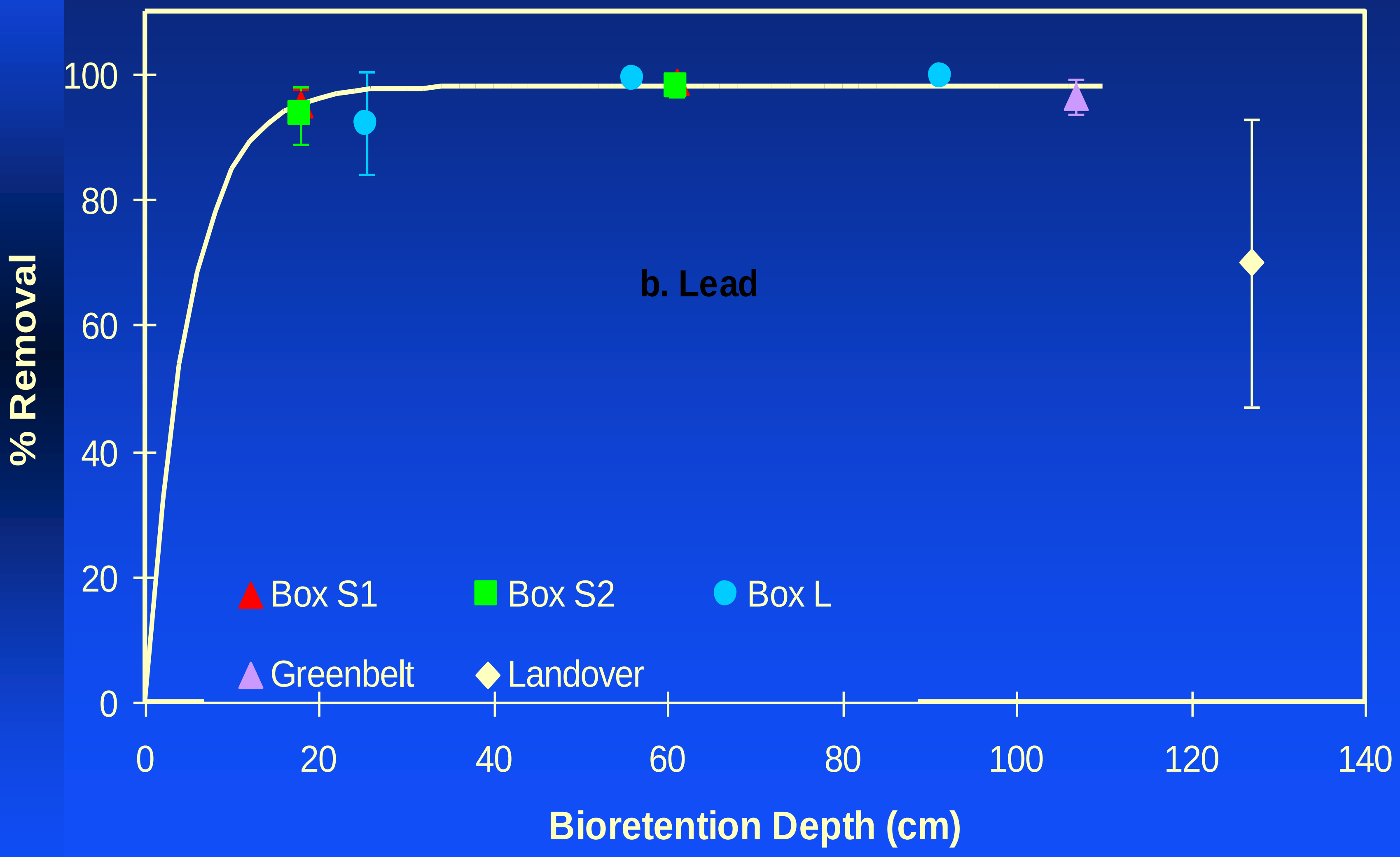
University of Maryland

Laboratory Studies (Large Box)

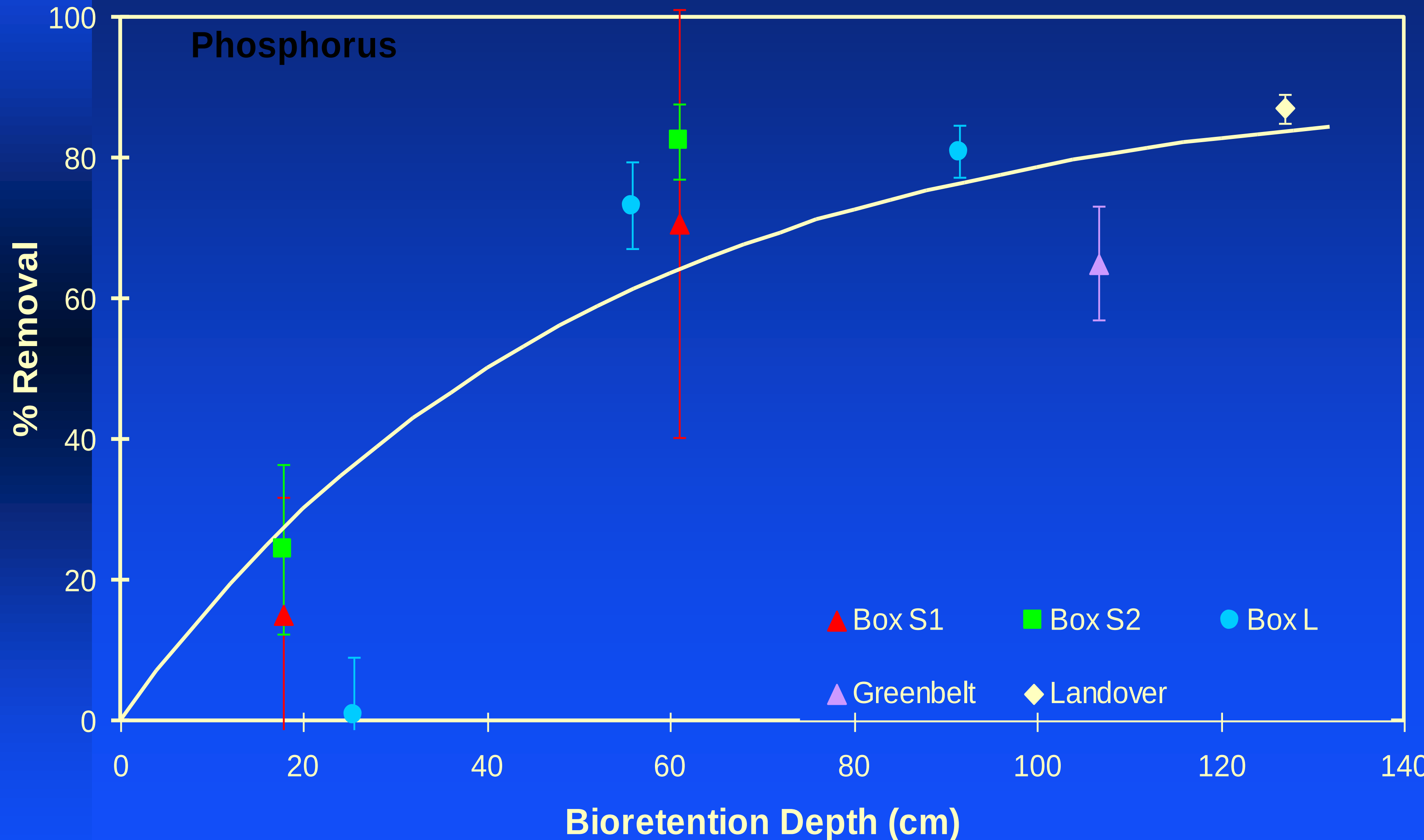
Field Studies: Beltway Plaza

Field Studies: Landover

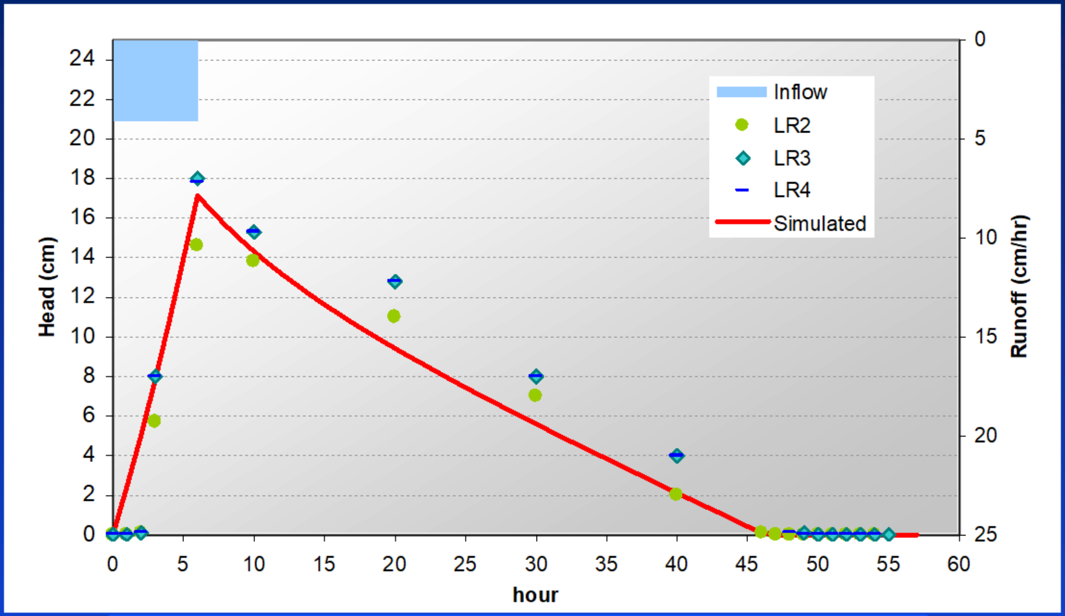
Overall Results: Lead



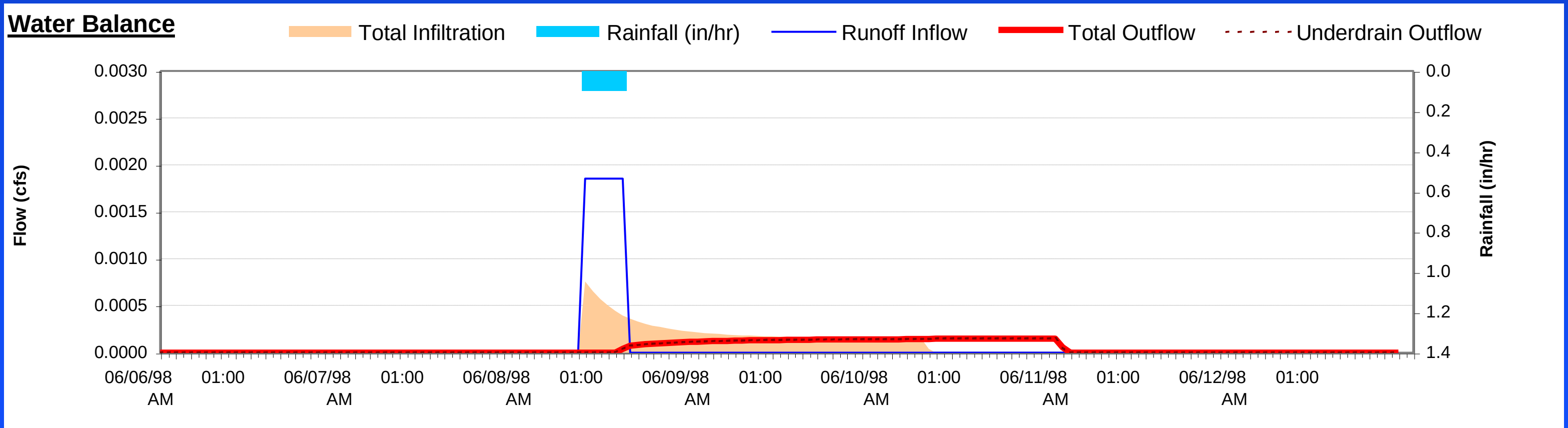
Overall Results: Phosphorus



Hydrology Calibration

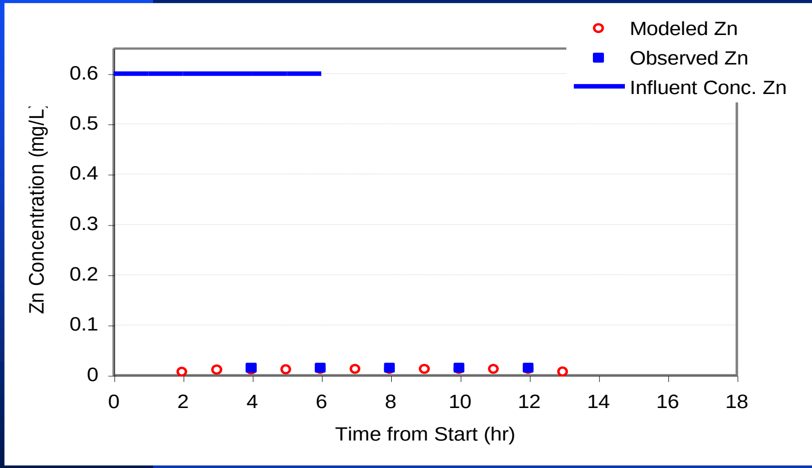


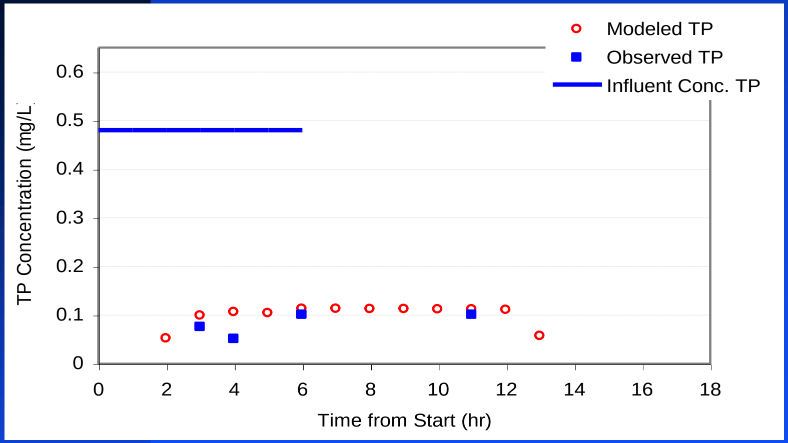
Head Development Curve (Laboratory)



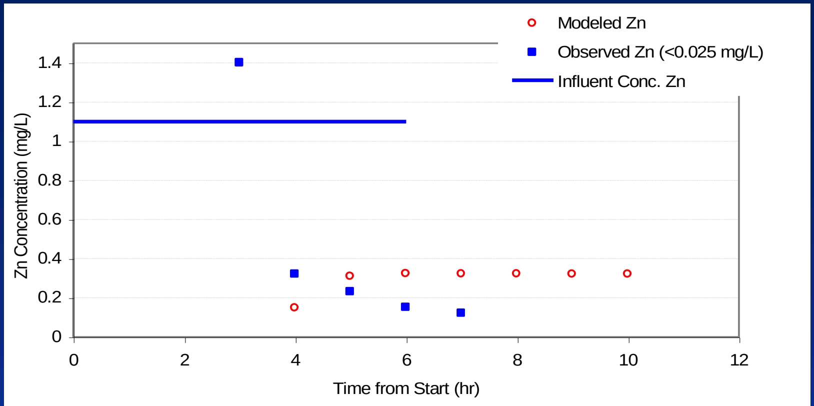
Inflow and Outflow Hydrograph and Water Balance (Laboratory)

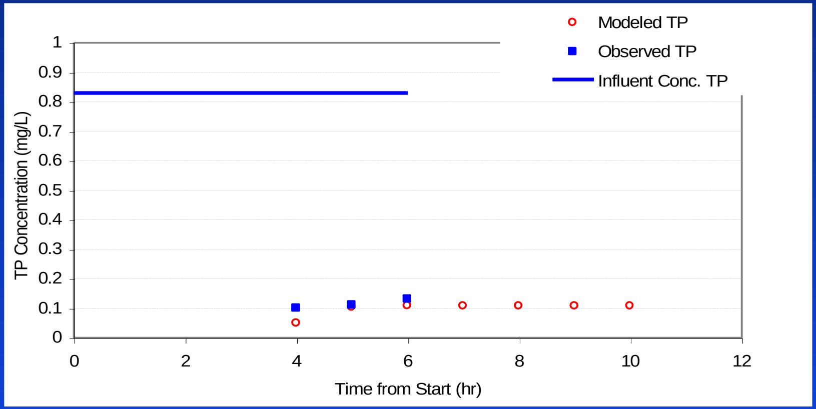
Water Quality Calibration

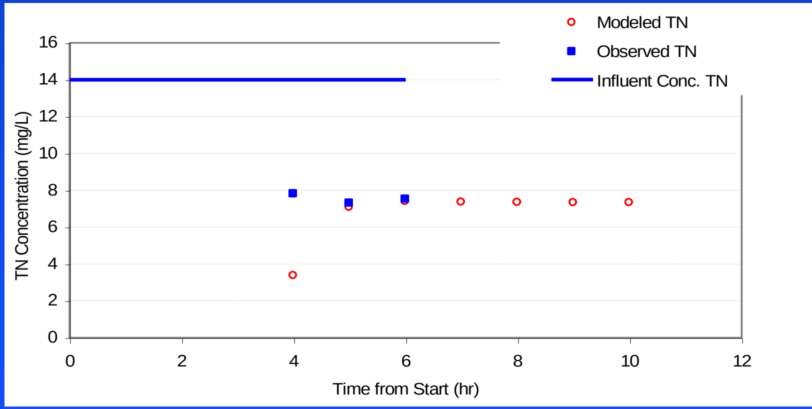




Removal of Zn and TP through bioretention box







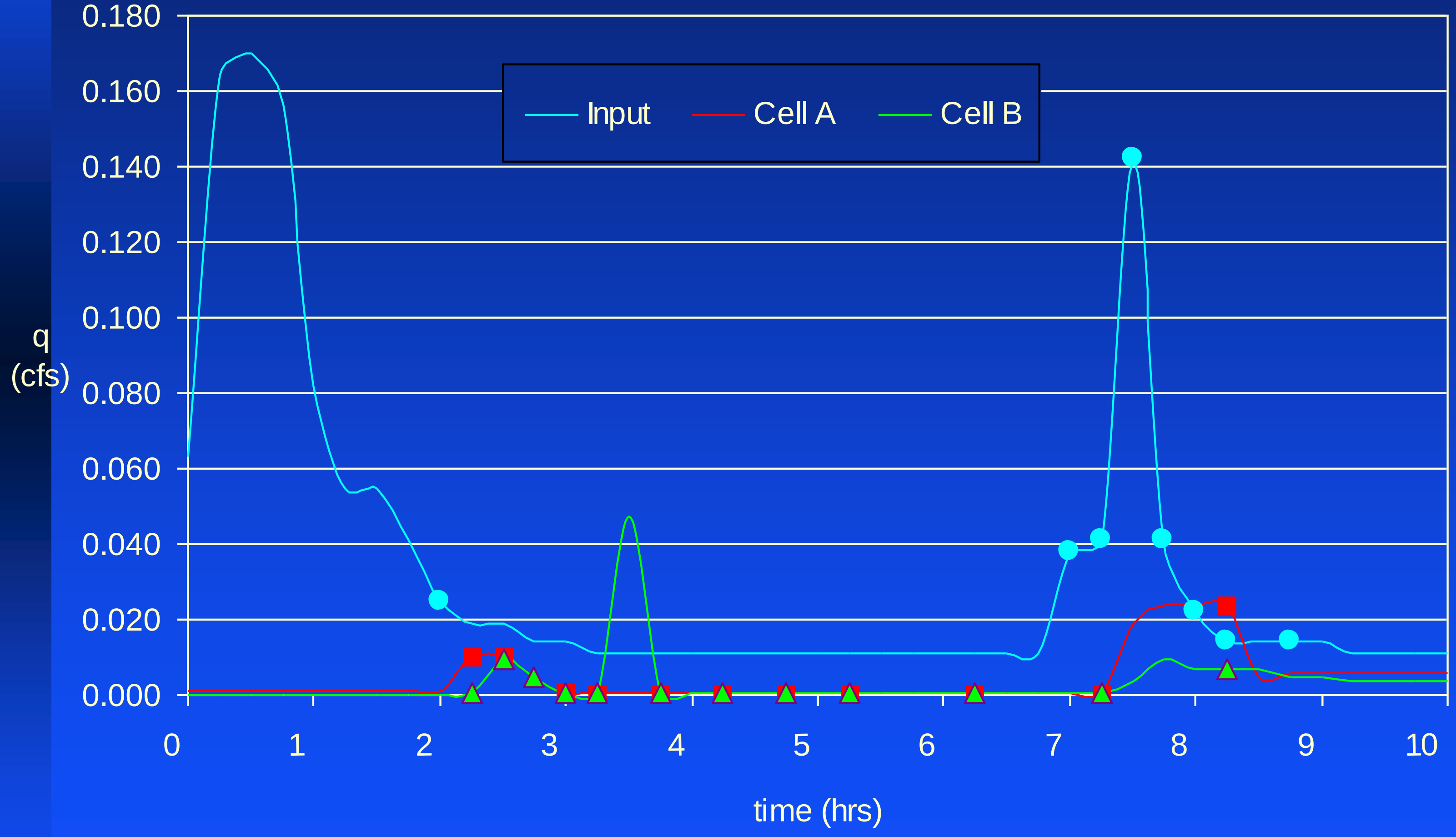
Removal of Zn, TP, and TN through Inglewood (Largo) Biorentention system.

Overhead View of the Site

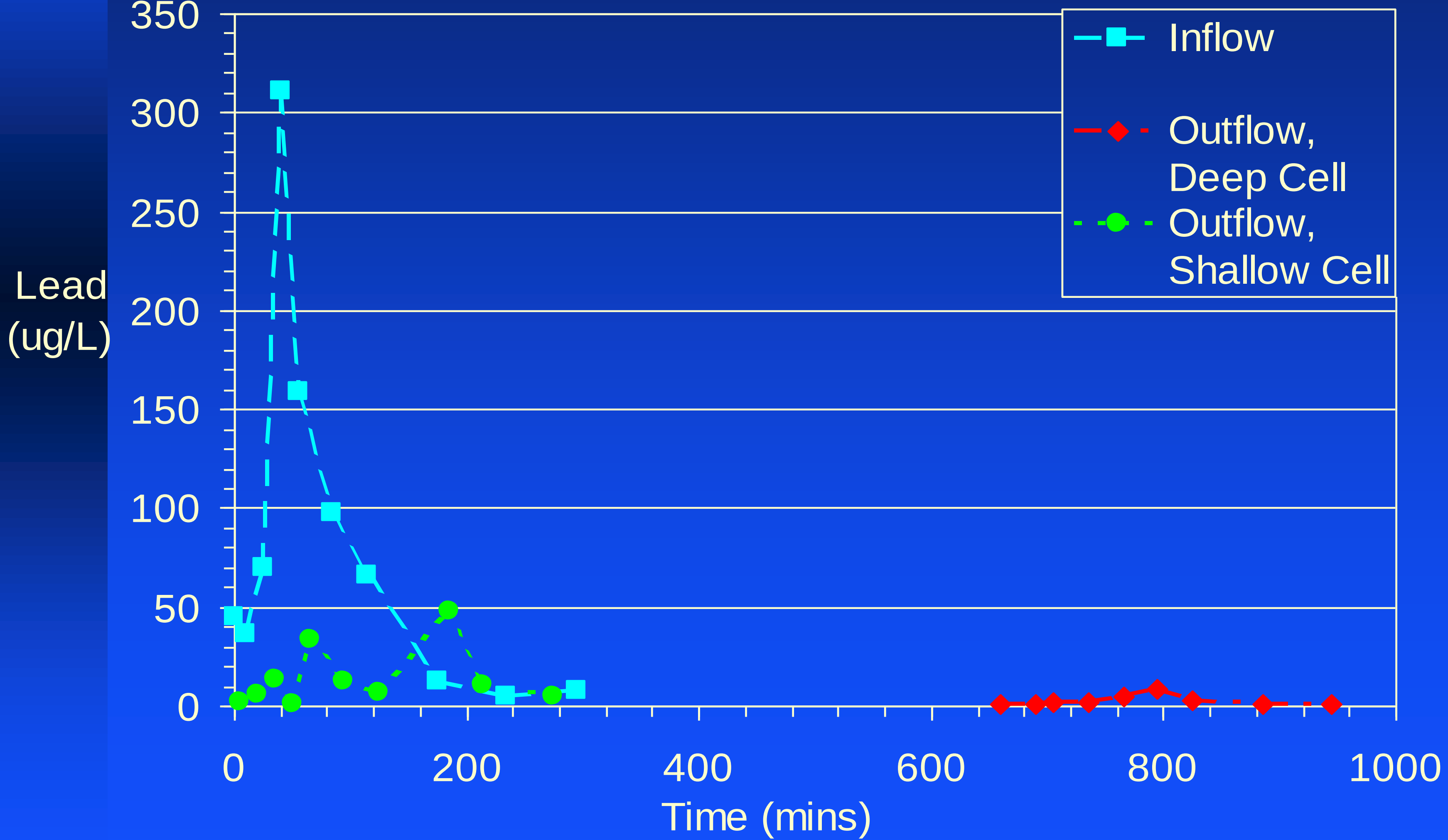
Cell A

Cell B

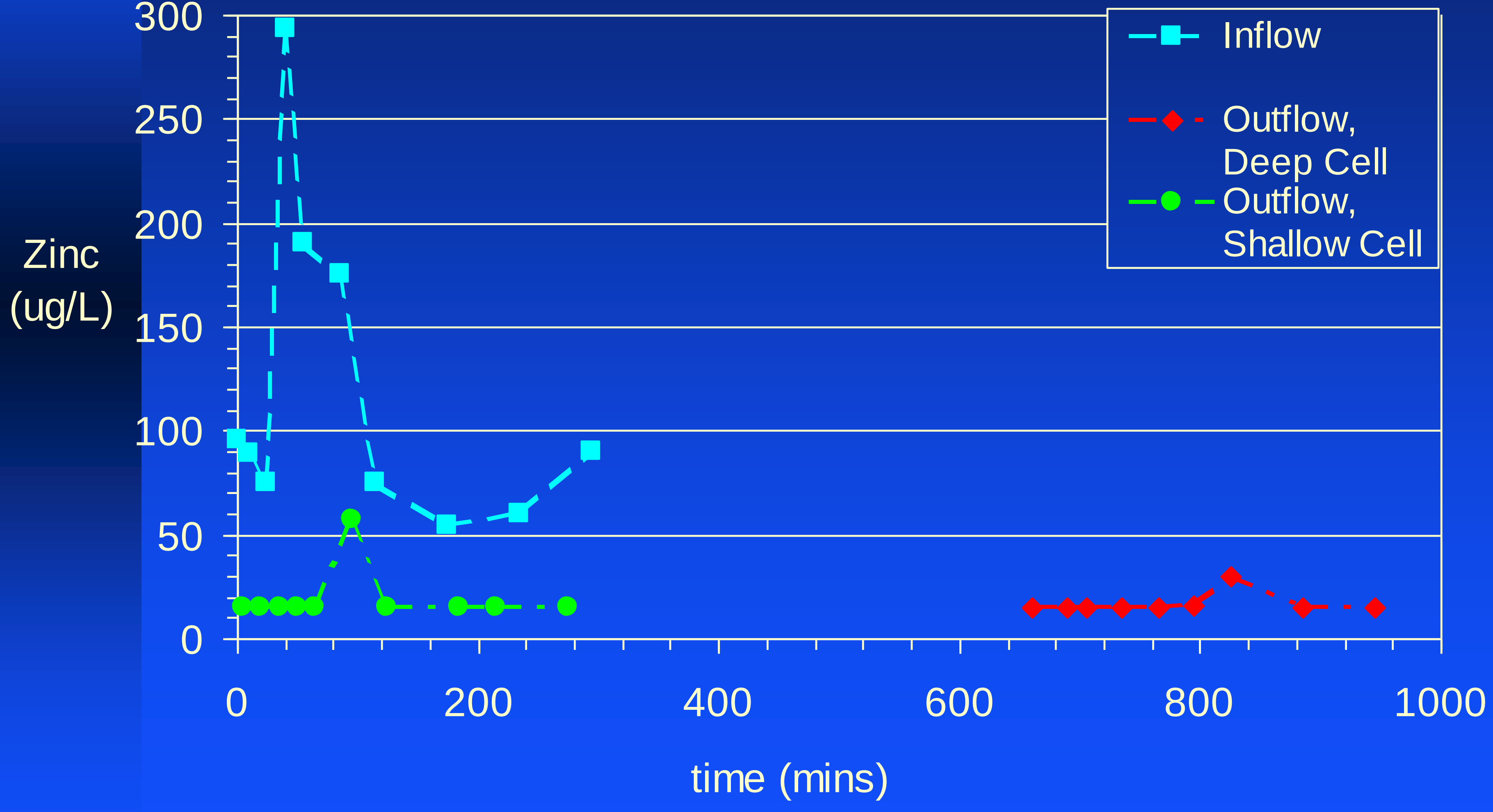
UMD Bioretention Hydrograph, July 28-29, 2003



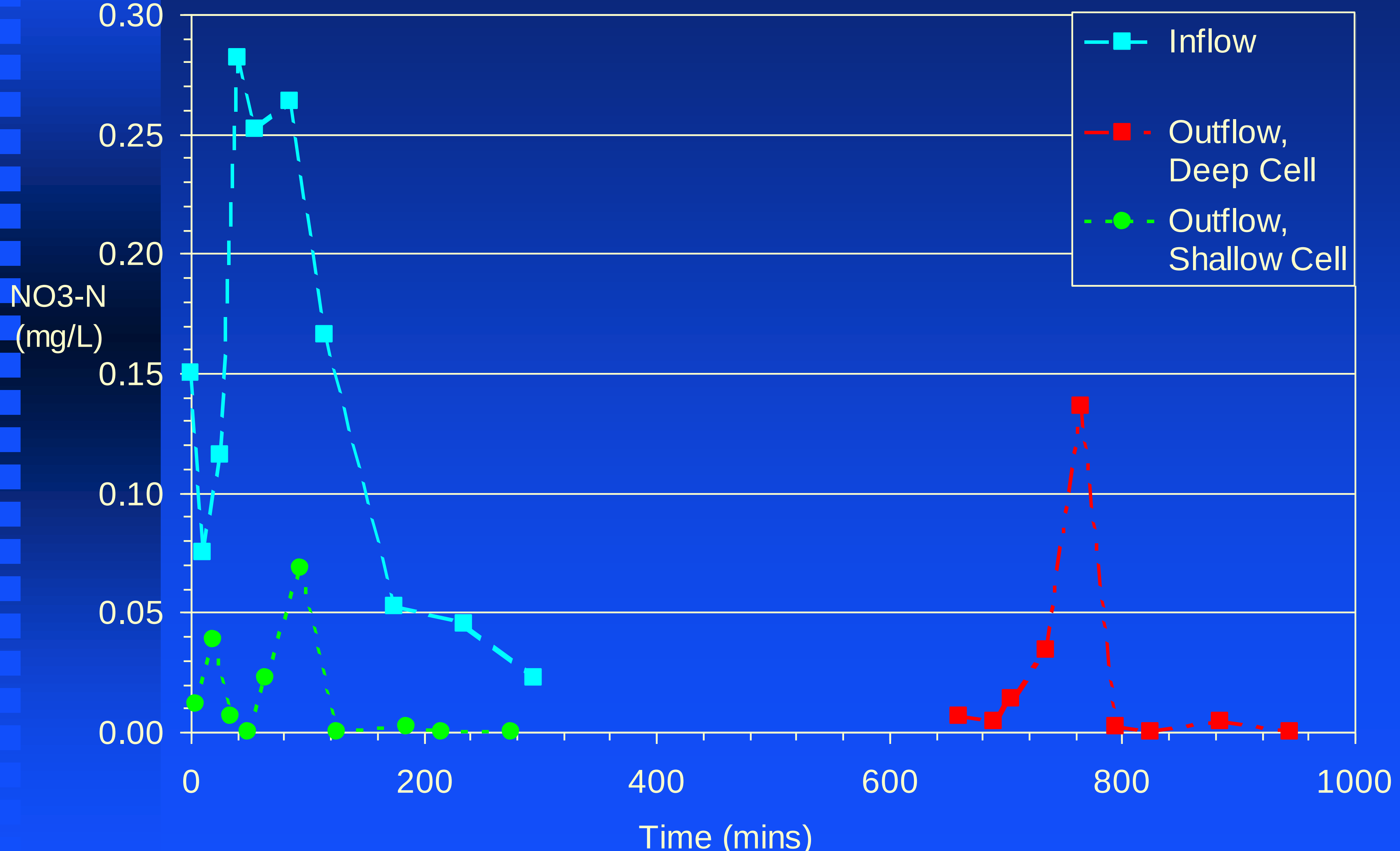
Total Lead, November 28, 2003



Total Zinc, November 28, 2003



Nitrate, November 28, 2003



BMP Evaluation Computer Module
BMP-DSS Phase I

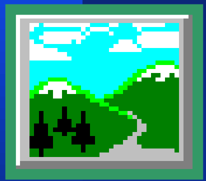
Project Background

- County-wide storm water monitoring
  - 1993 to present
- Development of HSPF model parameter database
  - 1995-1999
- BMP Module development
  - Phase I: 1999 to 2003
    - 100% County funded ($80,000)
  - Phase II: 2003 to Present
    - 80% EPA Region III; 20% County ($250,000)
    - EPA Office of Research & Development ($250,000)

Minimum Software Required:

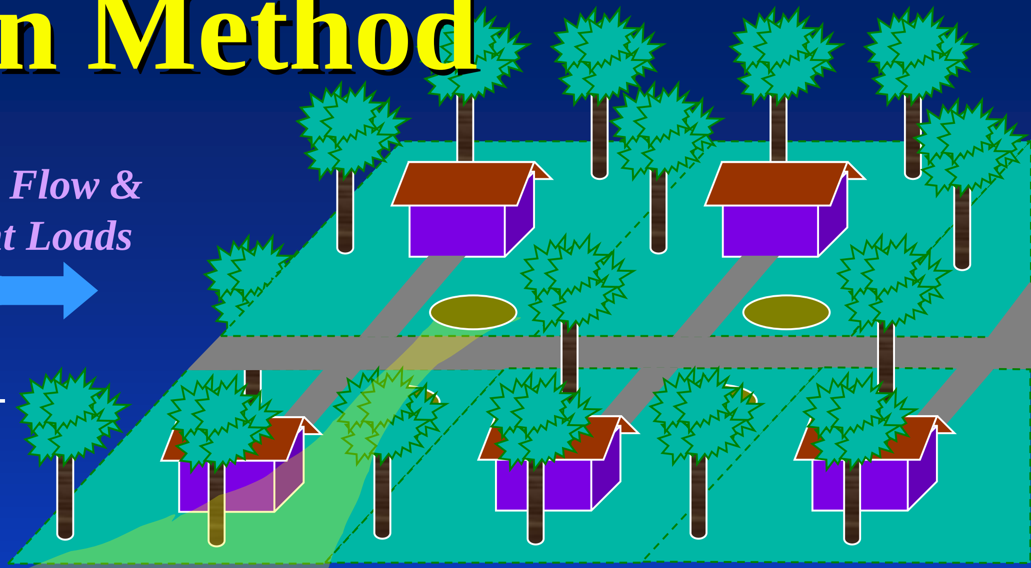
Microsoft Office 2000 Professional

BMP Evaluation Method



HSPF LAND
SIMULATION

Existing Flow &
Pollutant Loads

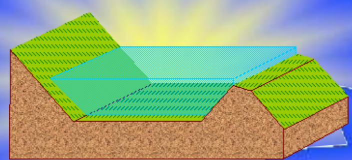


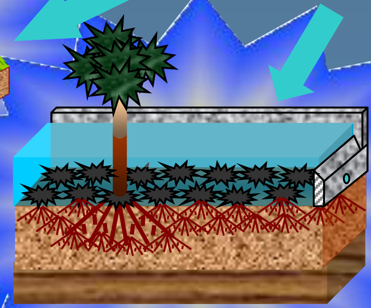
– Unit-Area Output by Landuse –

SITE-LEVEL LAND/BMP ROUTING

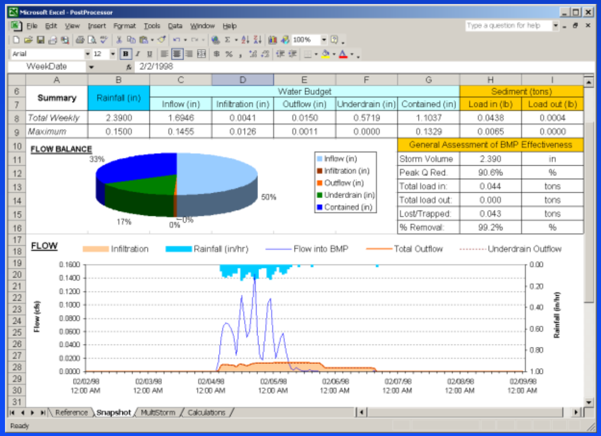
BMP Module

Simulated
Surface Runoff



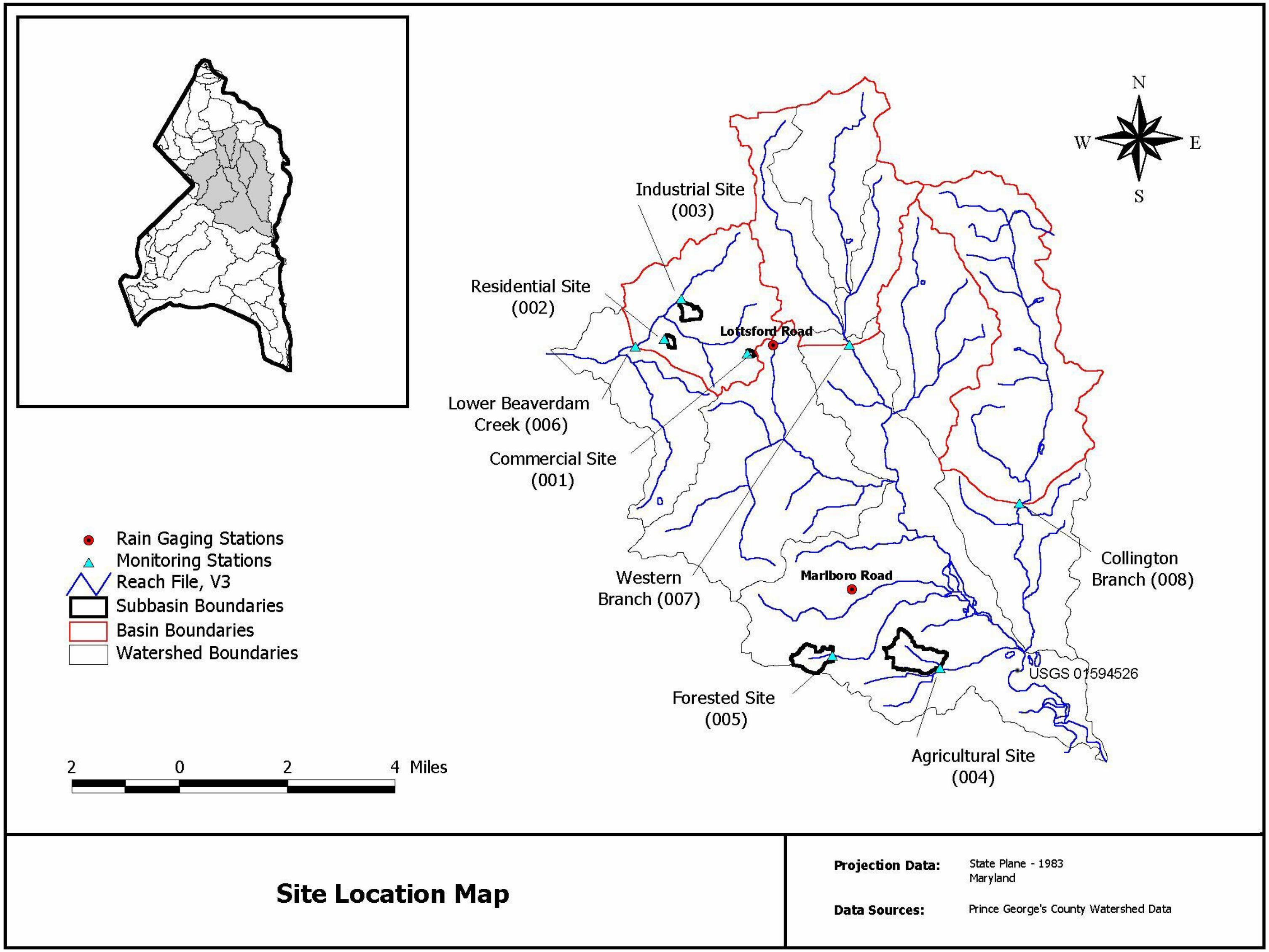


BMP DESIGN
– Site Level Design –



Simulated Flow and Water Quality Assessment

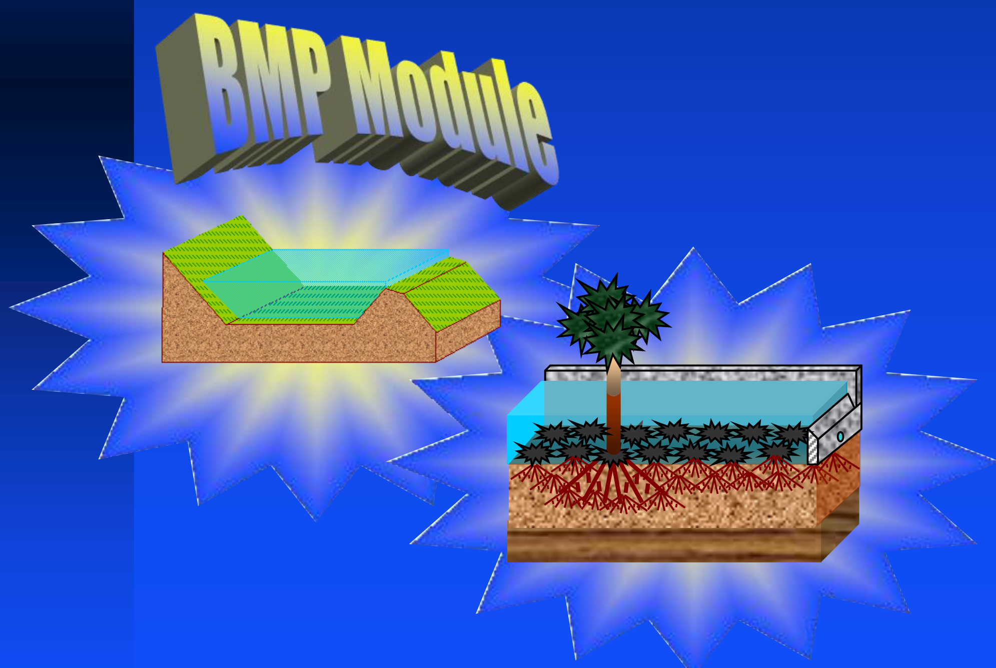
HSPF Landuse Representation



Computational Design

INPUT DATA:

Surface runoff flow and pollutant loads from contributing areas in site



BMP SIMULATION:

User designs/selects each BMP and defines the flow routing at the site

Flow and pollutant time series routed through the BMP or IMP network

Physical processes are simulated in the BMP

Output timeseries and data summary available at each land, BMP, or watershed outlet

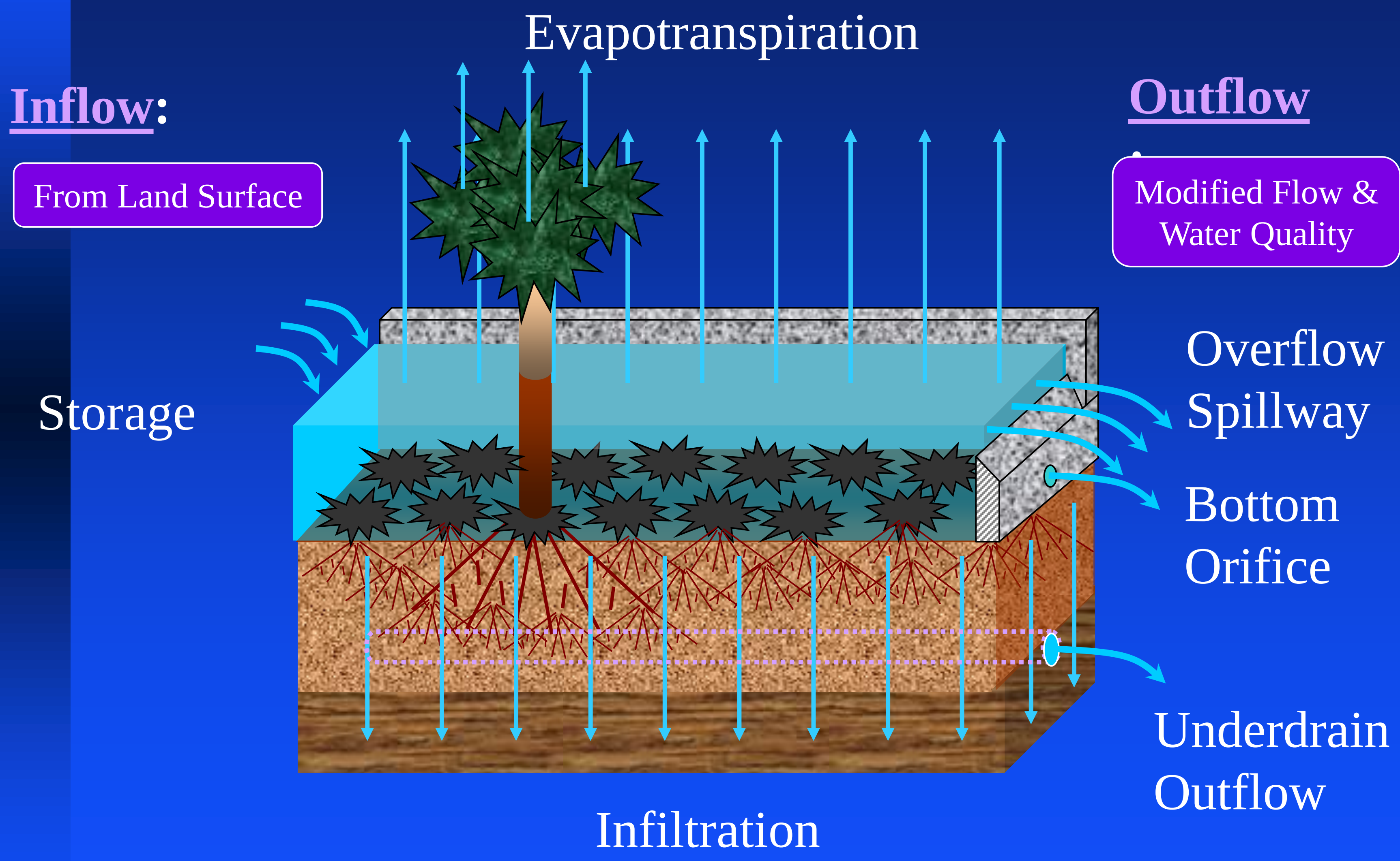
BMP Physical Processes

Possible storage processes include:

- Evapotranspiration
- Infiltration
- Orifice outflow
- Weir-controlled overflow spillway
- Underdrain outflow
- Bottom slope influence
- Bottom roughness influence
- General loss or decay of pollutant
  (Due to settling, plant-uptake, volatilization, etc)
- Pollutant filtration through soil medium
  (Represented with underdrain outflow)

Depending on the design and type of the BMP, any combination of processes may occur during simulation

BMP Class A: Storage/Detention



BMP Class B: Open Channel

Inflow:

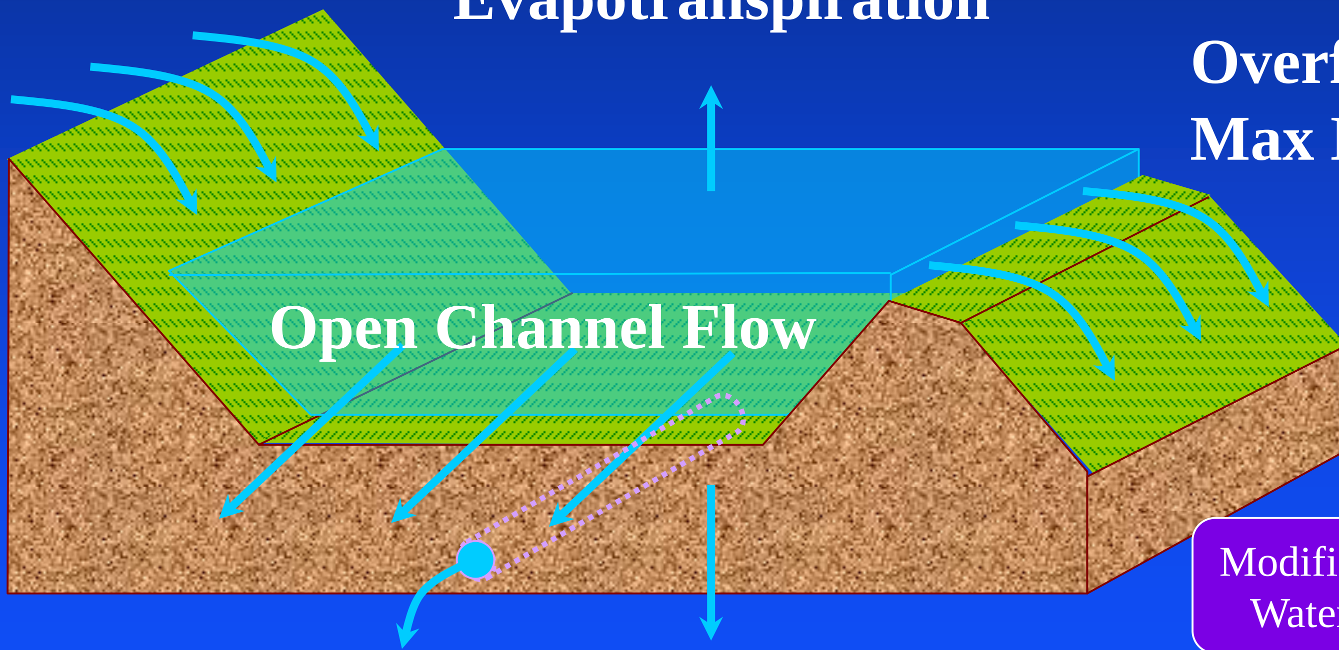
From Land Surface

Outflow:

Modified Flow & Water Quality

Evapotranspiration

Overflow at Max Design Depth



Modified Flow & Water Quality

Underdrain Outflow

Infiltration

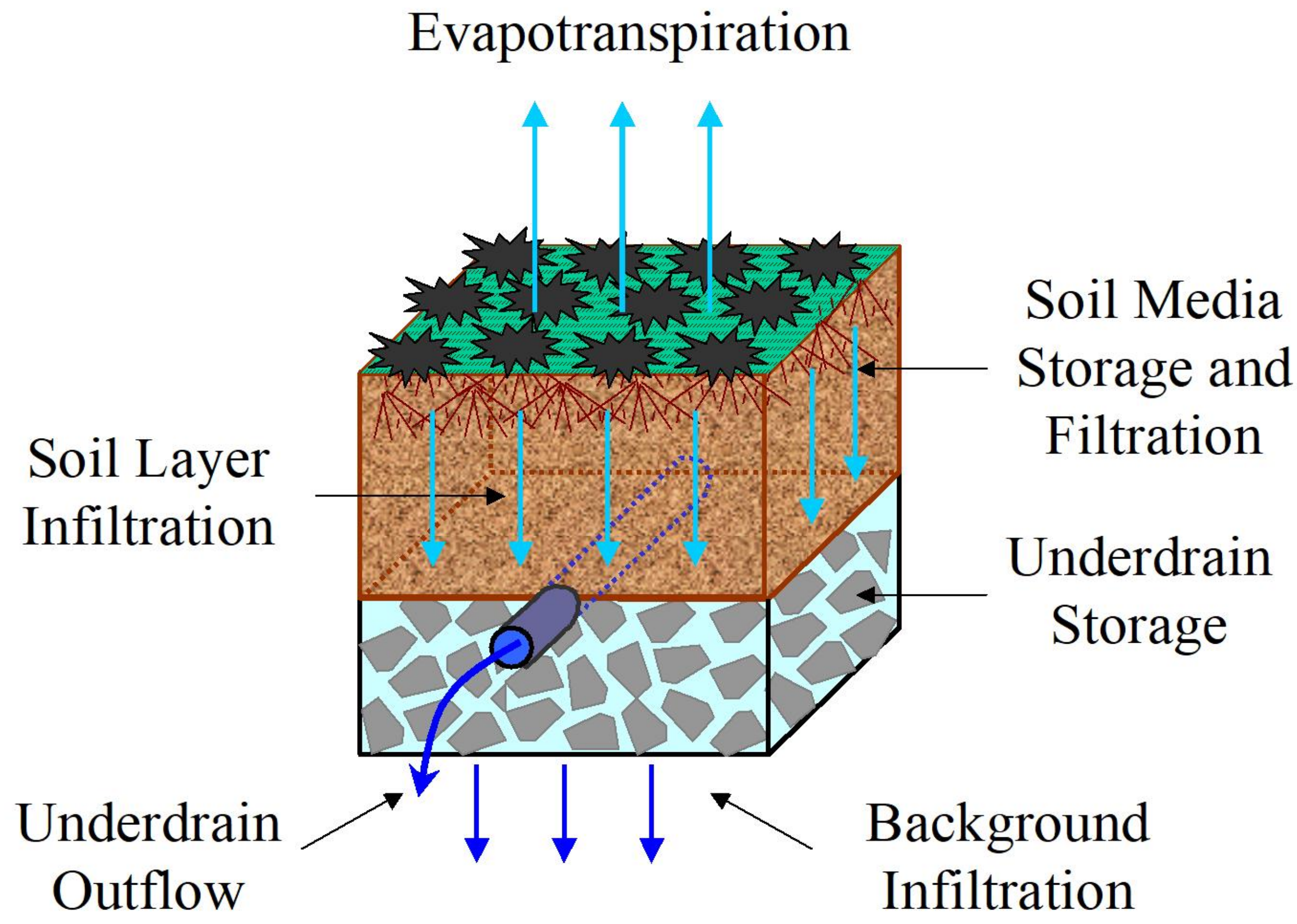
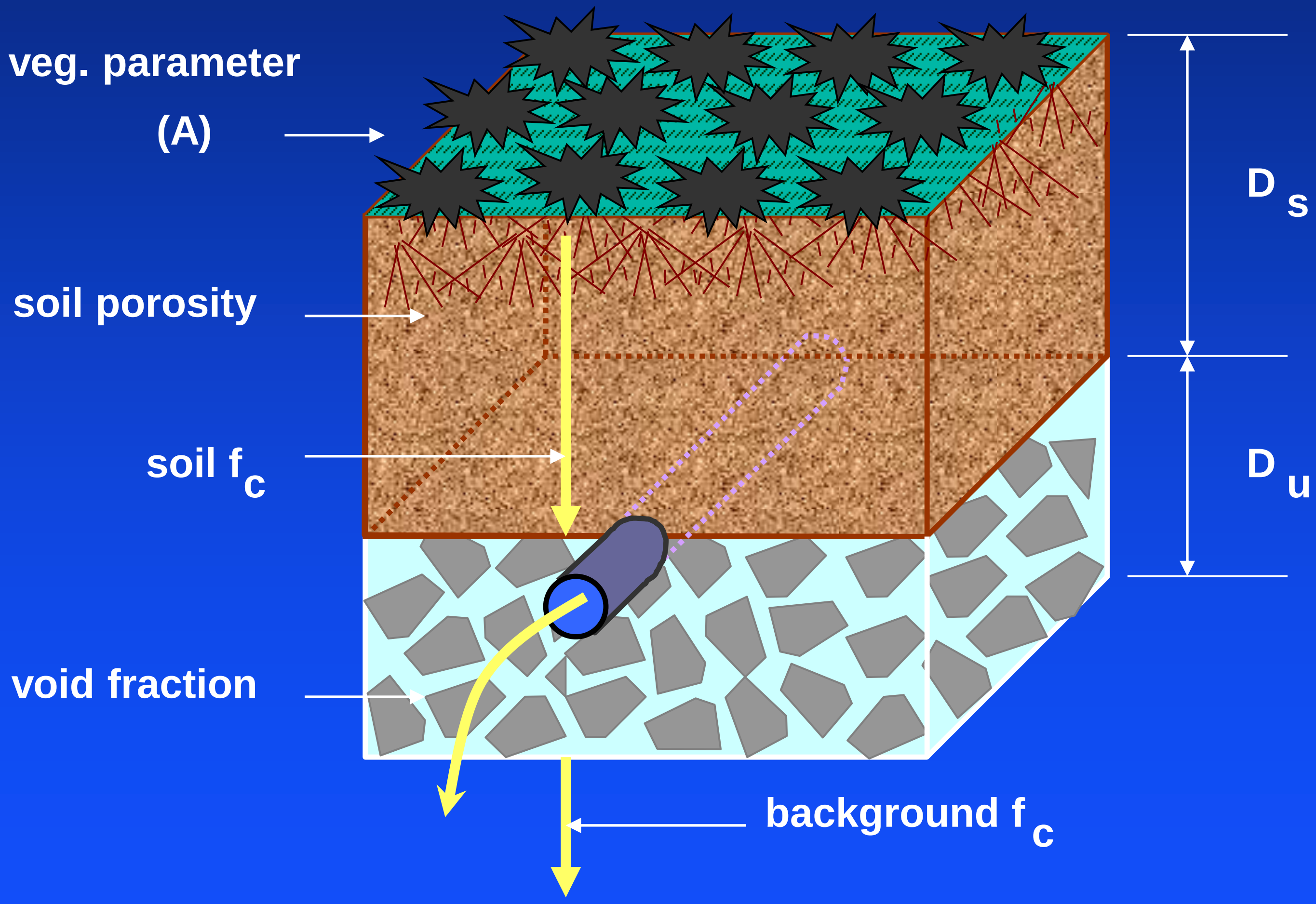


Figure 2.6 Processes considered in an underdrain struture

Holtan Infiltration Model

$$f = GI\,AS_a^{1.4} + f_c$$



$$f = GI\,A\,S_a^{1.4} + f_c$$

Where

***GI*: Growth Index of vegetation (% maturity, 10% to 100%)**

A : Vegetative parameter

S_a: Available storage in the soil layer (inches)

f_c: Final constant infiltration rate (in/hr)

Estimates of Vegitative Parameter **A** in Holtan Infiltration Model

Land Cover	Basal area rating	
	Poor condition	Good condition
Fallow	0.10	0.30
Row crops	0.10	0.20
Small grains	0.20	0.30
Hay (legumes)	0.20	0.40
Hay (sod)	0.40	0.60
Pasture (bunch grass)	0.20	0.40
Temporary pasture (sod)	0.20	0.60
Permanent pasture (sod)	0.80	1.00
Woods and forests	0.80	1.00

(Source: Table 5.5.3 -- Maidment, 1993. p. 5.31))

Final Infiltration Rates *fc* by Hydrologic Soil Groups

Hydrologic Soil Group	Final rate, f_c (in/hr) min	max
A	0.30	0.76
B	0.15	0.30
C	0.05	0.15
D	0.00	0.05

(Source: Table 5.5.4 -- Maidment, 1993. p. 5.31)

General Water Quality

First Order Decay Representation

$$Mass_2 = Mass_1 \times e^{-k\,t}$$

Pollutant Removal is a function of the detention time

BMP Retention Loss Rates (1/day)

BMP ID	SOSLD	SOQUAL (BOD, 5 D
1	0.510800	1.204000
2	0.287700	0.356700
3	2.302600	1.204000
4	1.204000	1.204000
5	0.693100	0.356700
6	0.693100	0.223100
7	0.105400	0.223100

OK Cancel

Underdrain Water Quality

Percent Removal

$$Mass_{out} = Mass_{in} \times (1 - \mathit{PCTREM})$$

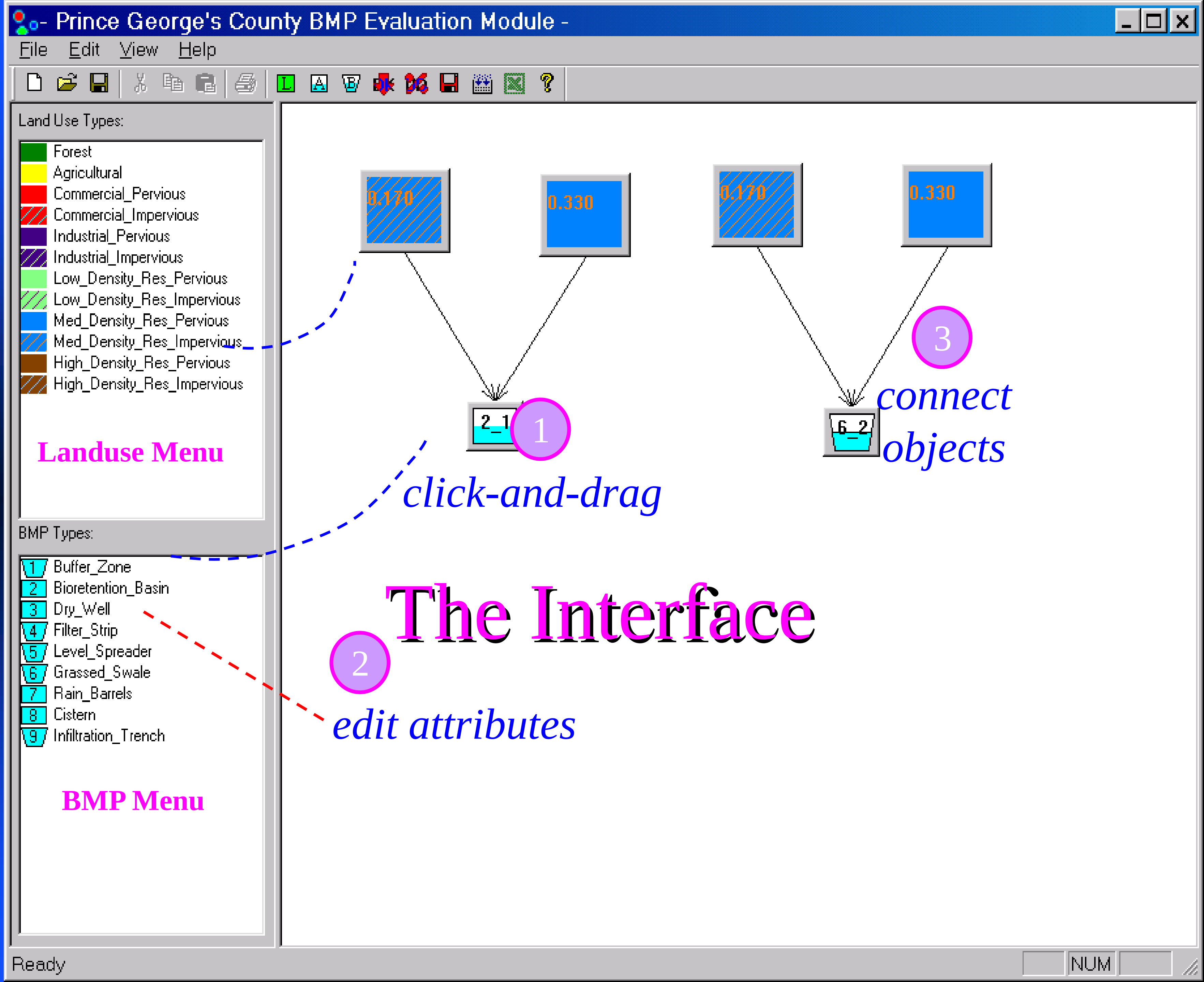
Underdrain percent removal is a function of the soil media

$$Mass_{in} = \text{Surface conc} * \text{underdrain flow}$$

Underdrain Percent Removal (0-1)

BMP ID	SOSLD	SOQUAL (BOD, 5 D
1	0.100000	0.100000
2	1.000000	0.200000
3	0.300000	0.300000
4	0.400000	0.400000
5	0.500000	0.500000
6	1.000000	0.600000
7	0.700000	0.700000

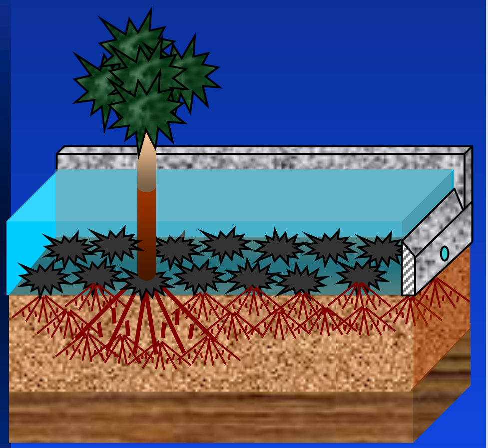
OK Cancel

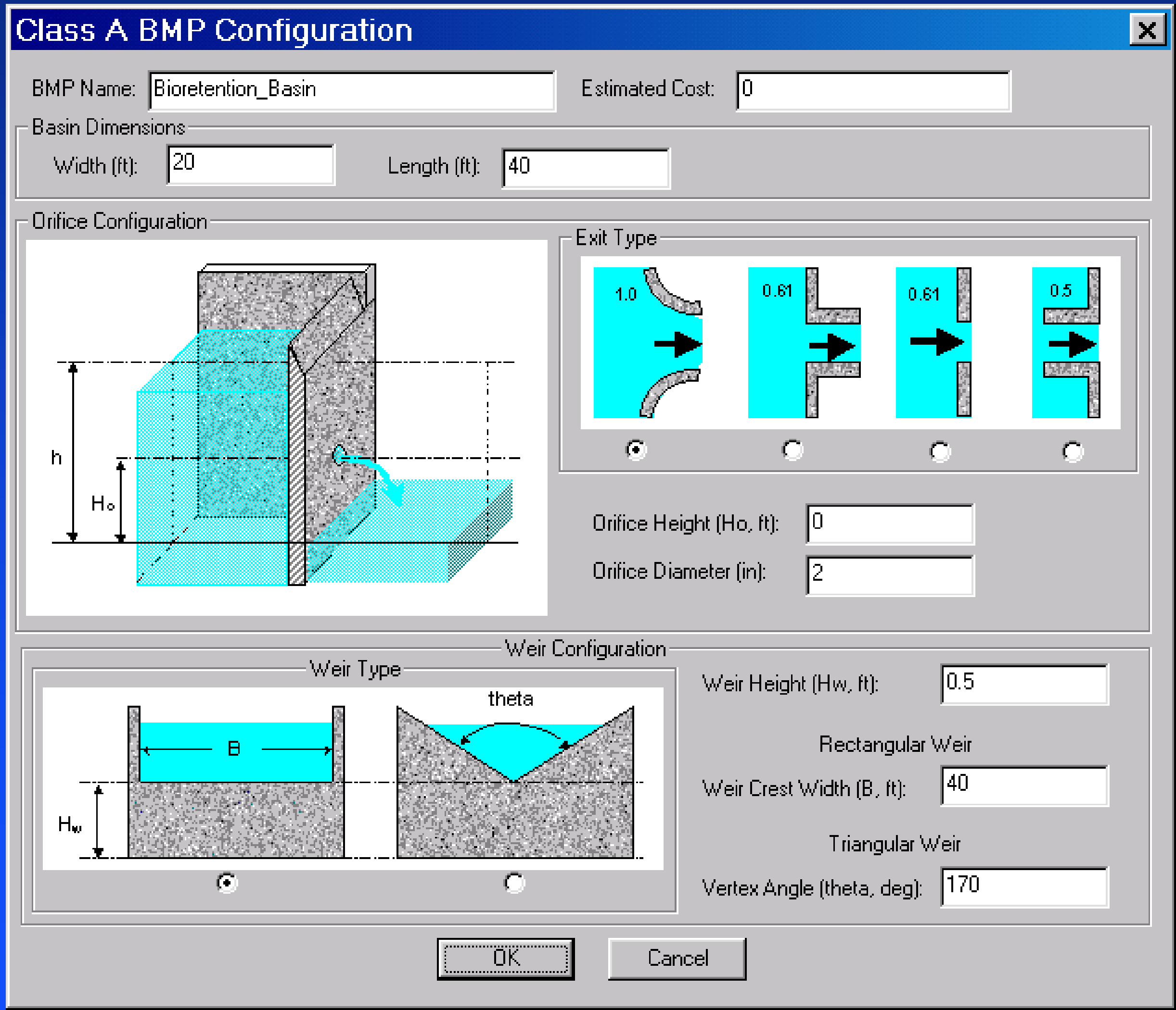


The Interface
Prince George's County BMP Evaluation Module -
File
Edit
View
Help
Land Use Types:
Forest
Agricultural
Commercial_Pervious
Commercial_Impervious
Industrial_Pervious
Industrial_Impervious
Low_Density_Res_Pervious
Low_Density_Res_Impervious
Med_Density_Res_Pervious
Med_Density_Res_Impervious
High_Density_Res_Pervious
High_Density_Res_Impervious
Landuse Menu
BMP Types:
1 Buffer_Zone
2 Bioretention_Basin
3 Dry_Well
4 Filter_Strip
5 Level_Spreader
6 Grassed_Swale
7 Rain_Barrels
8 Cistern
9 Infiltration_Trench
BMP Menu
0.170
0.330
0.170
0.330
2_1
6_2
1
click-and-drag
2
edit attributes
3
connect objects
Ready
NUM

BMP Class A Example:

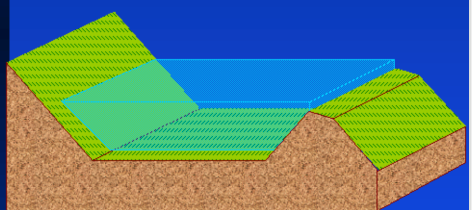
Bioretention



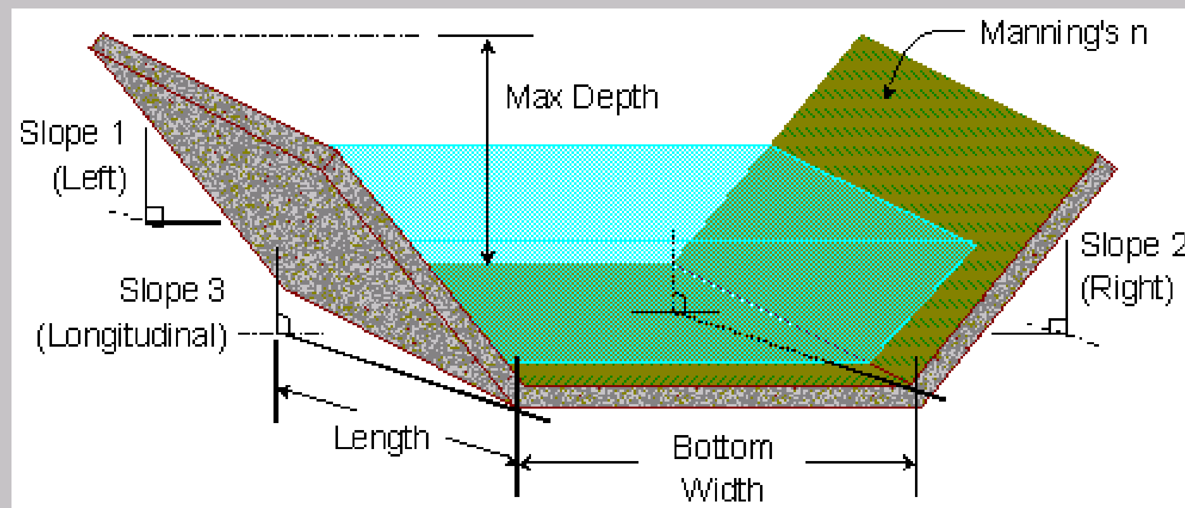


BMP Class B Example:

Grassed Swale



Class B BMP Design



Width (ft):	100	Slope 1:	0.05
Length (ft):	25	Slope 2:	0.05
Max Depth (ft):	1	Slope 3:	0.05
BMP Name:	Buffer_Zone	Manning's n:	0.1

Estimated Cost: 0

OK Cancel

BMP Underdrain System:

Holtan Infiltration Method

Soil and subsurface flow configuration is available for both Class-A and Class-B BMPs

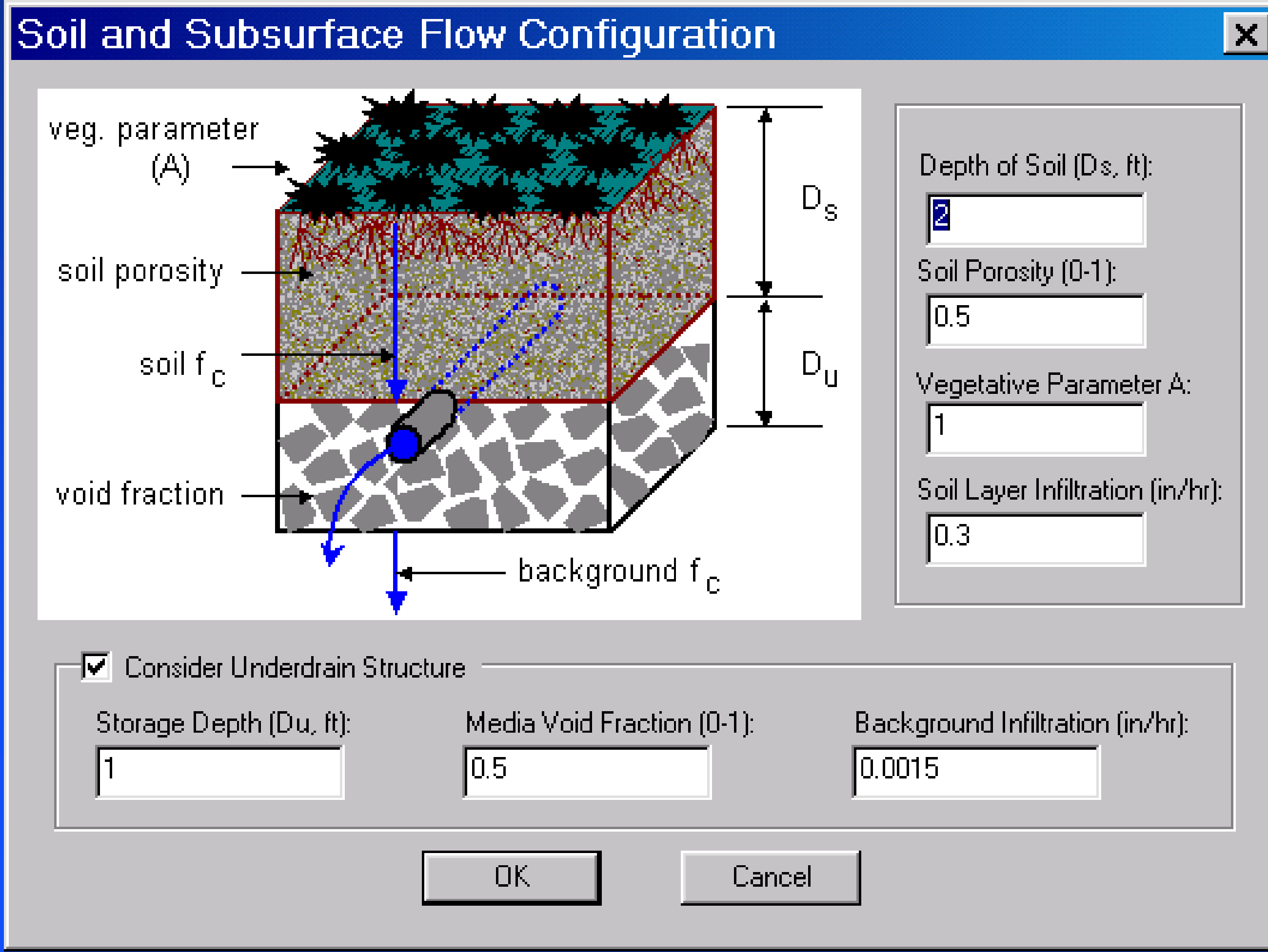
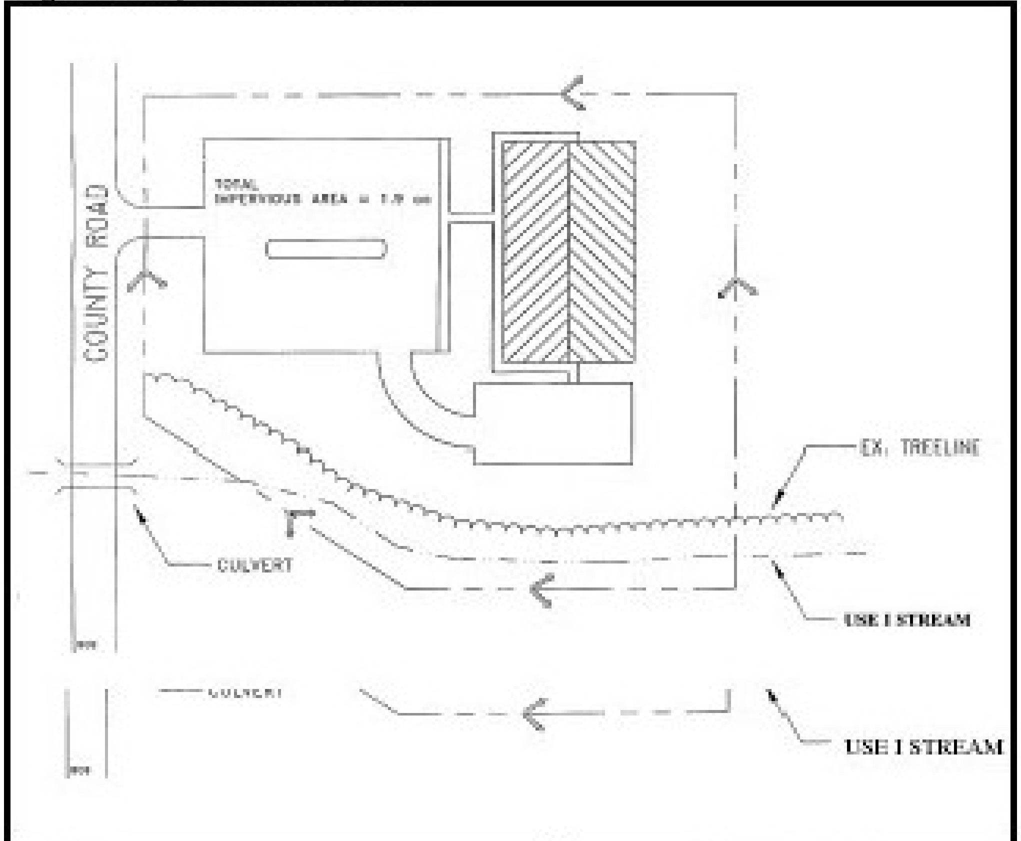


Figure 2.9 Claytor Community Center



Base Data
Location: Easton, MD
Site Area = Total Drainage Area (A) = 3.0 ac
Impervious Area = 1.9 ac; I= 1.9/3.0 = 63.3%
R_v = 0.05 + (63.3)(0.009) = 0.62
Soils Type "B"
Stream Use Designation I

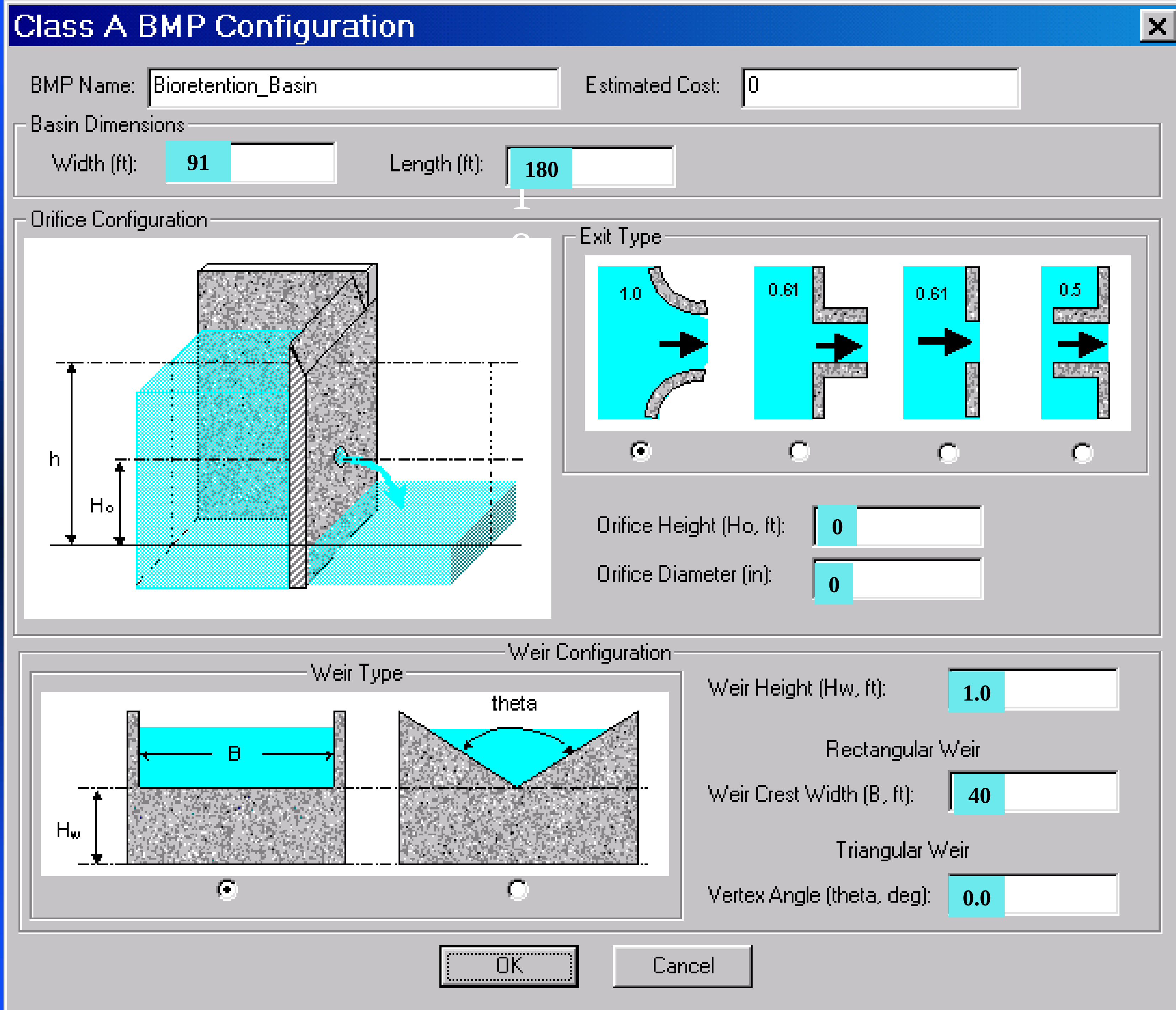
Hydrologic Data		
	Pre	Post
CN	57	83
t_c	0.42 hr	0.16 hr

Figure 6. MDE Design Example

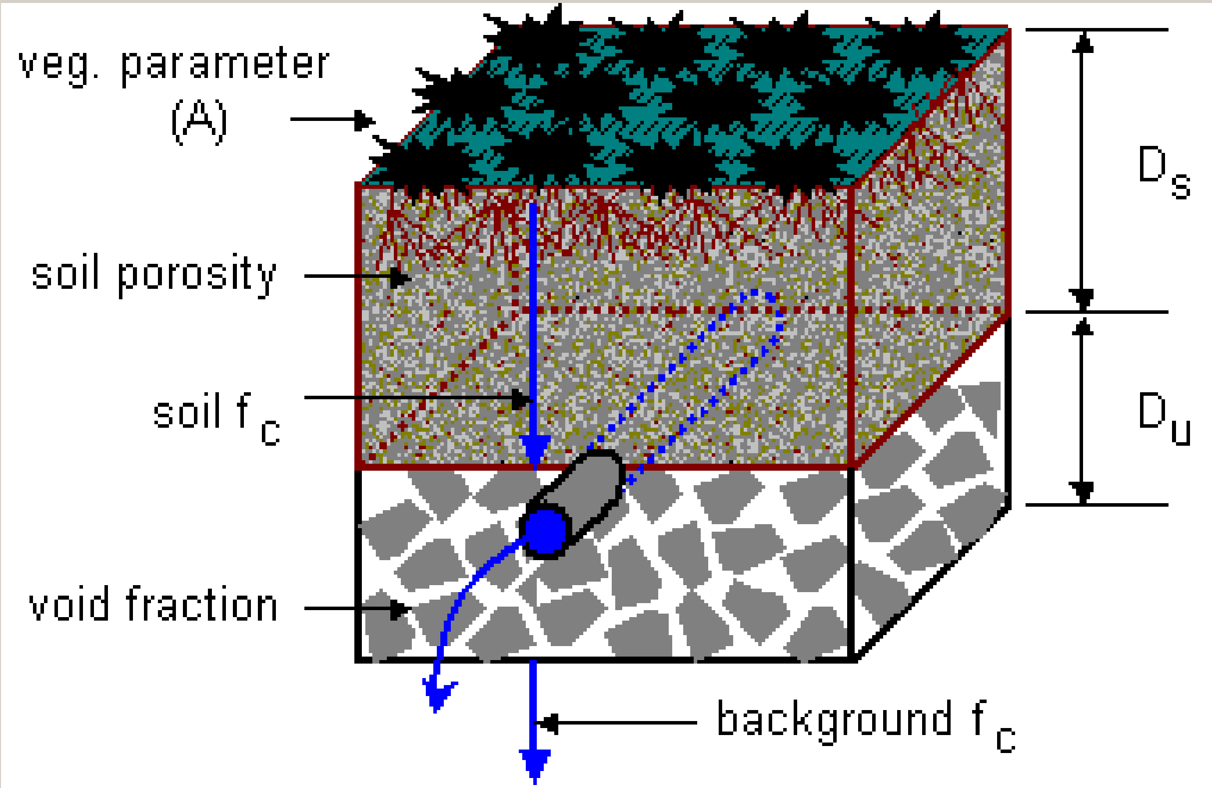
Commercial Development Maryland State Manual Example

LID Design Parameters

Design Example No. 2: Commercial Development - Claytor Community Center		
1. Forest Condition: 3.0 Acre		
2. Developed Condition: Commercial Development		
	1.9 acre Impervious	
	0.4 acre Woods	
	0.7 acre Pervious	
	Soil Type B:	CN= 87 (proposed)
		CN= 57 (Existing Condition; woods)
		Design Storm = 3 in
		12" Bioretention Storage = 0.375 acre (12.5% of the area)
		2' Soil Layer in Bioretantion
		Volume =0.375 acre-ft = 16335 ft^3
3. Use Bioretention Basins of 91' X 180', total 0.376 acre		


Class A BMP Configuration
BMP Name: Bioretention_Basin
Estimated Cost: 0
Basin Dimensions
Width (ft): 91
Length (ft): 180
Orifice Configuration
h
Ho
Exit Type
1.0
0.61
0.61
0.5
Orifice Height (Ho, ft): 0
Orifice Diameter (in): 0
Weir Configuration
Weir Type
B
Hw
theta
Weir Height (Hw, ft): 1.0
Rectangular Weir
Weir Crest Width (B, ft): 40
Triangular Weir
Vertex Angle (theta, deg): 0.0
OK
Cancel

Soil and Subsurface Flow Configuration



Depth of Soil (Ds, ft): 2

Soil Porosity (0-1): 0.3

Vegetative Parameter A: 0.8

Soil Layer Infiltration (in/hr): 0.3

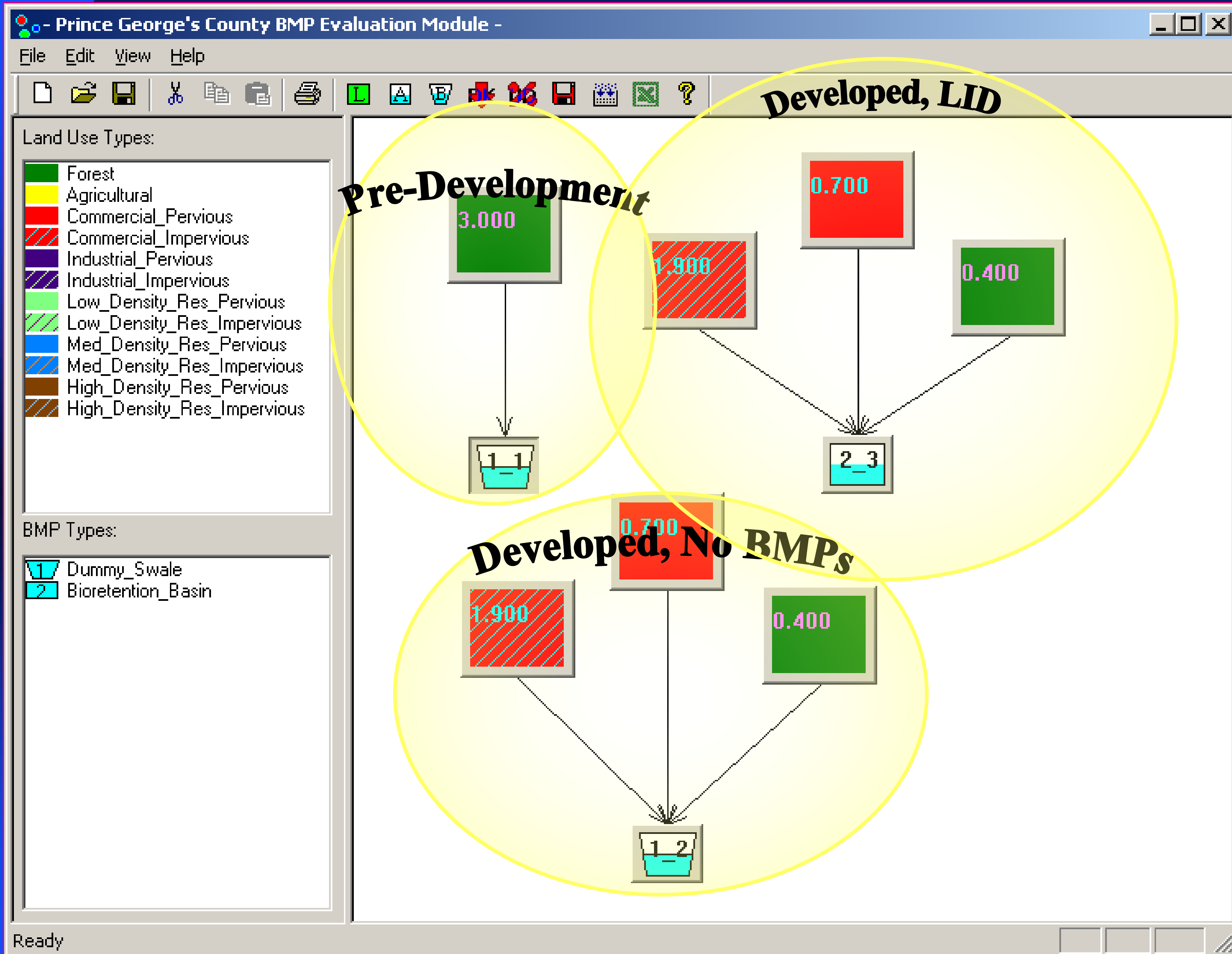
☑ Consider Underdrain Structure

Storage Depth (Du, ft): 2

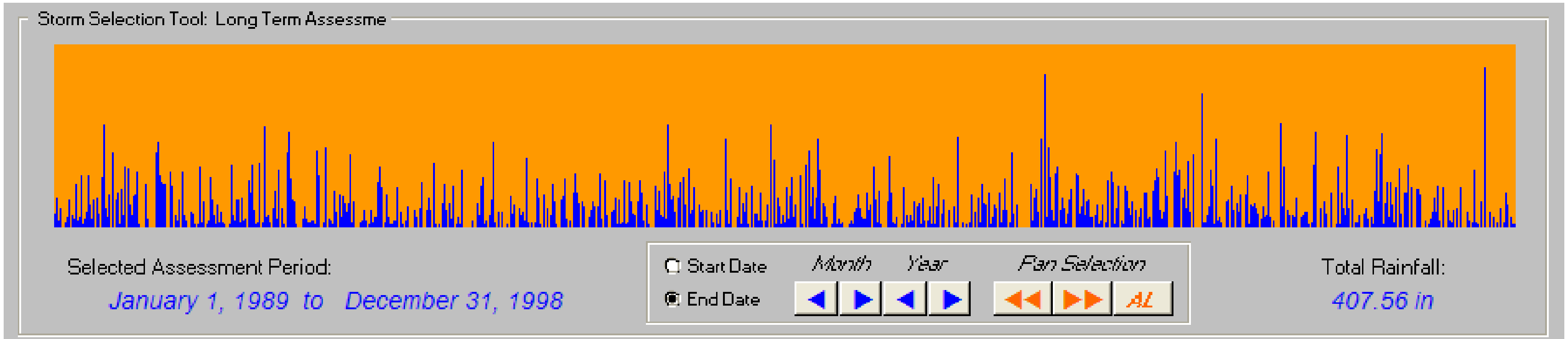
Media Void Fraction (0-1): 0.5

Background Infiltration (in/hr): 0.25

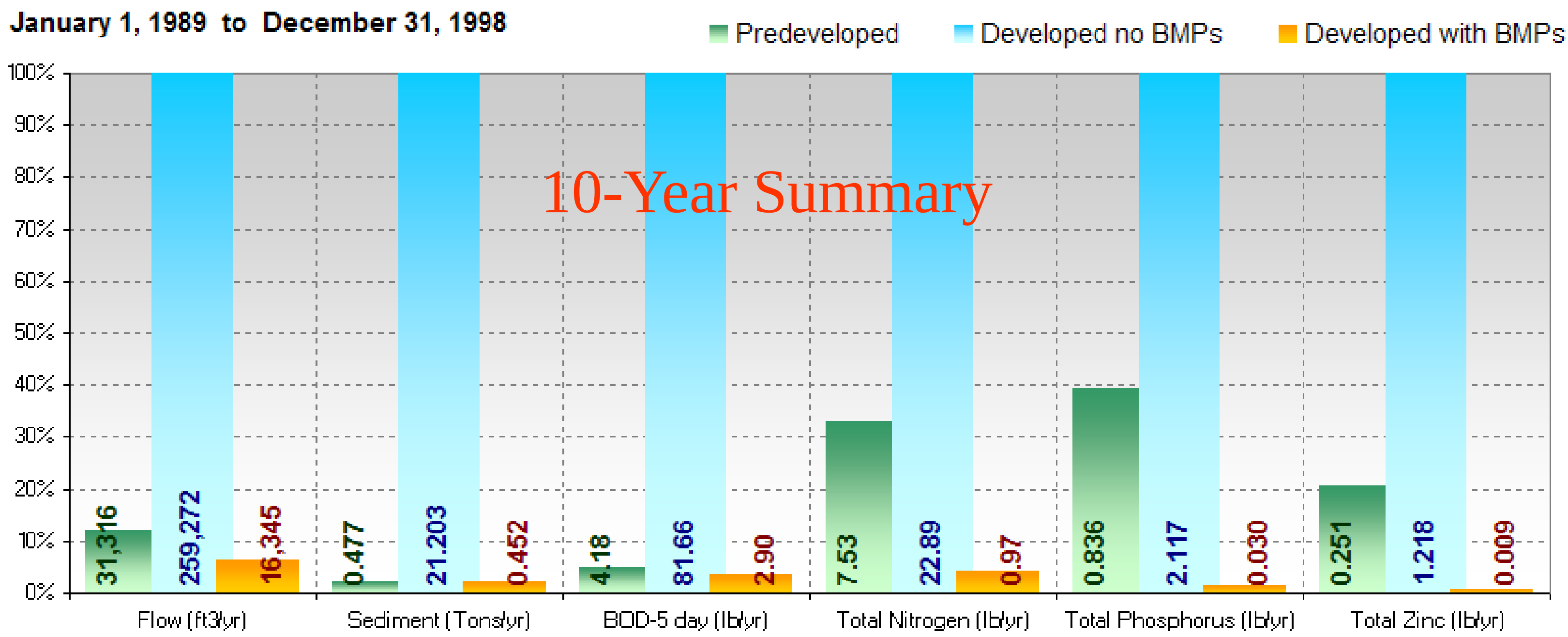
OK | Cancel


- Prince George's County BMP Evaluation Module -
File Edit View Help
Land Use Types:
Forest
Agricultural
Commercial_Pervious
Commercial_Impervious
Industrial_Pervious
Industrial_Impervious
Low_Density_Res_Pervious
Low_Density_Res_Impervious
Med_Density_Res_Pervious
Med_Density_Res_Impervious
High_Density_Res_Pervious
High_Density_Res_Impervious
BMP Types:
Dummy_Swale
Bioretention_Basin
Developed, LID
Pre-Development
3.000
0.700
1.900
0.400
1_1
2_3
Developed, No BMPs
0.700
1.900
0.400
1_2
Ready

10-Year Summary

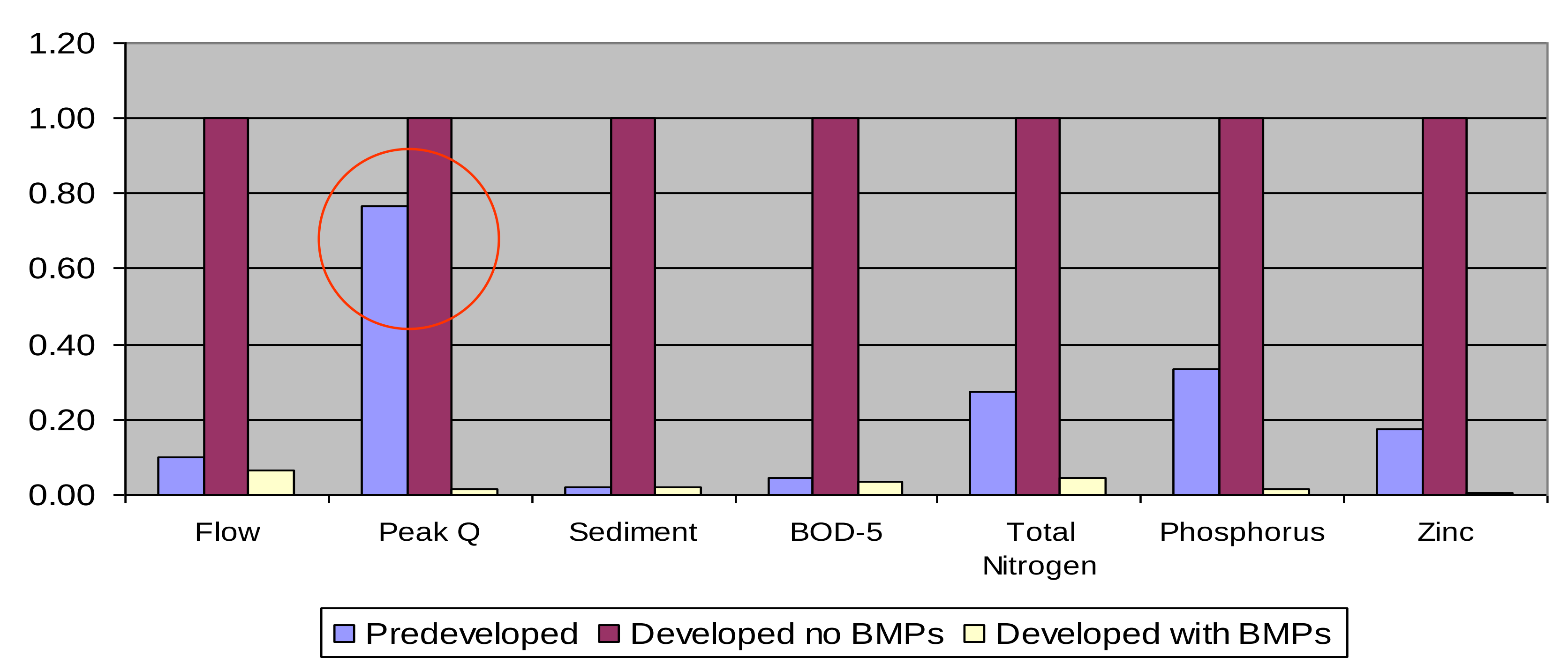


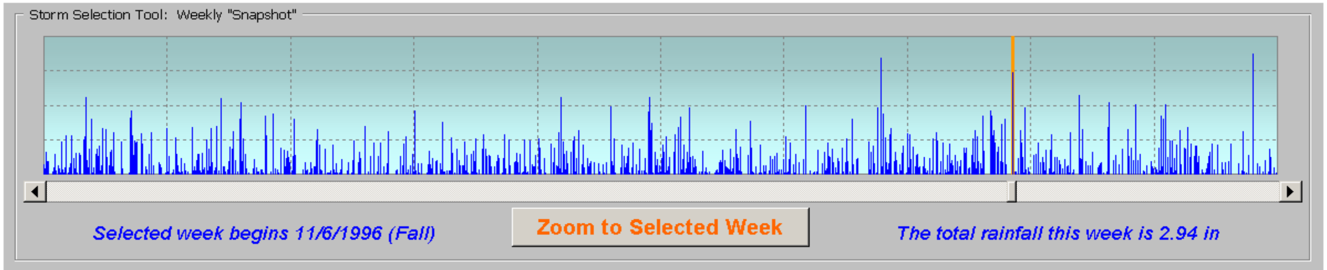
Indicator	Units	Predeveloped	Developed no BMPs	Developed with BMPs
Flow	ft^3/yr	31,316	259,272	16,345
Sediment	Tons/yr	0.477	21.203	0.452
BOD-5 day	lb/yr	4.18	81.66	2.90
Total Nitrogen	lb/yr	7.53	22.89	0.97
Total Phosphorus	lb/yr	0.836	2.117	0.030
Total Zinc	lb/yr	0.251	1.218	0.009



Commercial Site

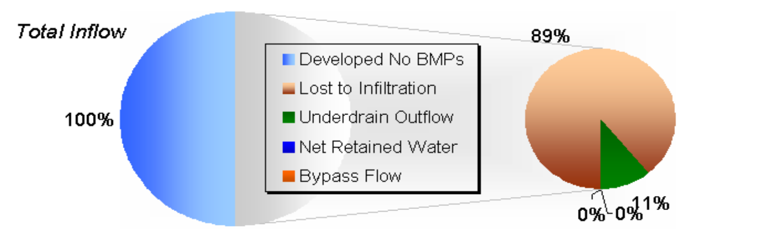
1. Forest Condition: 2.5 Acre				
2. Developed Condition: Commercial Development				
	80% Impervious			
	5% Woods			
	15% Pervious			
	Soil Type B:	CN=90 (proposed)		
		CN= 55 (Existing Condition; woods, good condition)		
		Design Storm = 3 in		
		Curve A = 1.80"		
		Curve B = 1.78"		
		Volume = 2.5 x 1.80 /12 =0.375 acre-ft = 16335 ft^3		
3. Develped with BMPs: 5 Bioretentions (55' x 60') with 12" top storage, A =16500 ft^2 (15% of Site)				

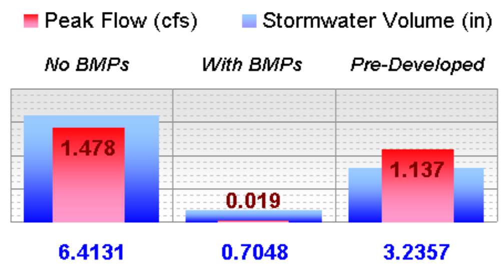




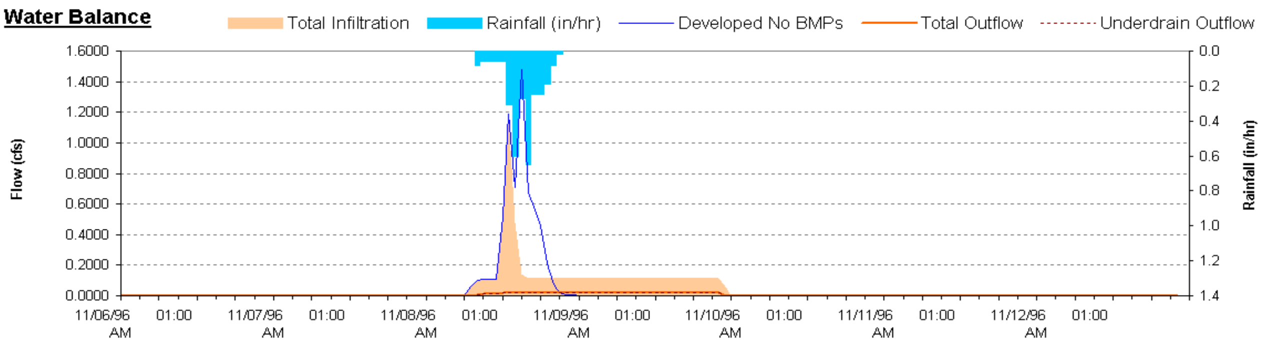
Summary	Rainfall (in)	Water Budget (in)					Runoff
		Developed No BMPs	Lost to Infiltration	Underdrain Outflow	Net Retained Water	Bypass Flow	Pre-Developed
Total Weekly	2.9400	6.4131	5.7104	0.7048	0.0000	0.0000	3.2357
Max Hourly	0.6500	1.4779	1.1692	0.0191	Not Applicable	0.0000	1.1374

Water Budget for the Week

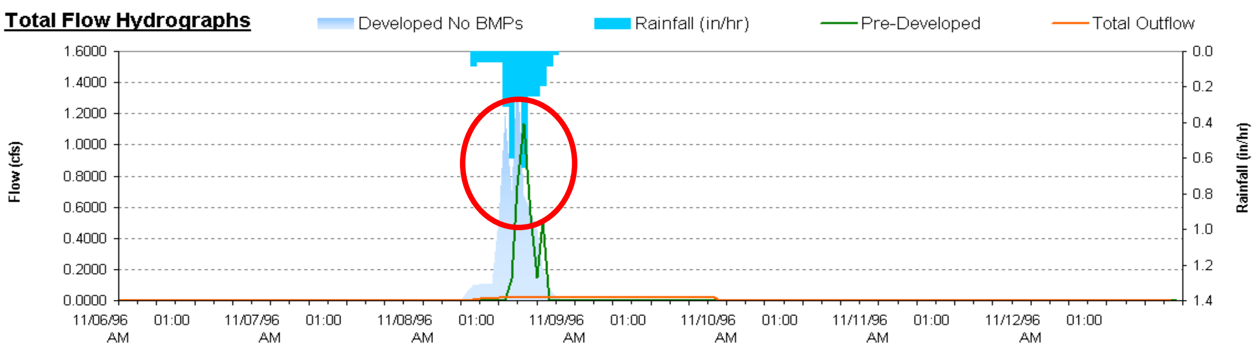




Water Balance



Total Flow Hydrographs



Fall Storm 1

14-hour duration double-peak storm

14 hours duration
2.94 inches volume

Factors:

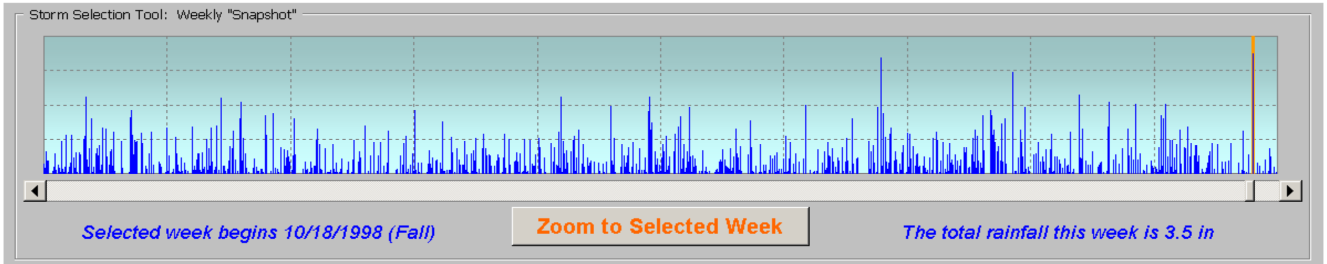
Short duration and very high intensity

Double peak within storm, causes high second peak for forested land

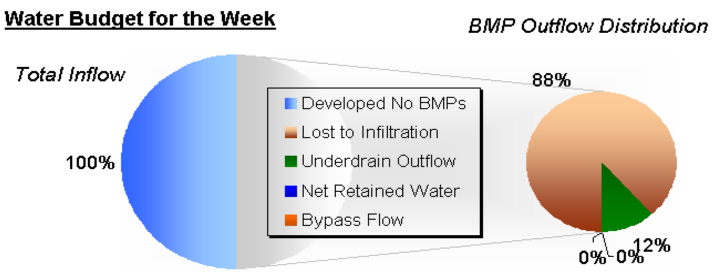
The water is falling faster than it can infiltrate into the ground

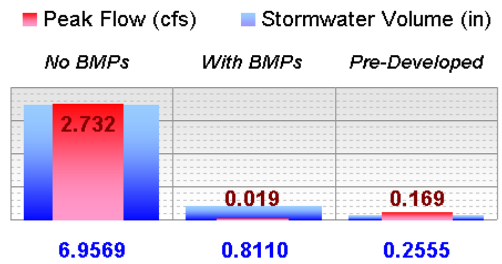
Multiple Scenario Peak Flow Comparisons for Selected Storms

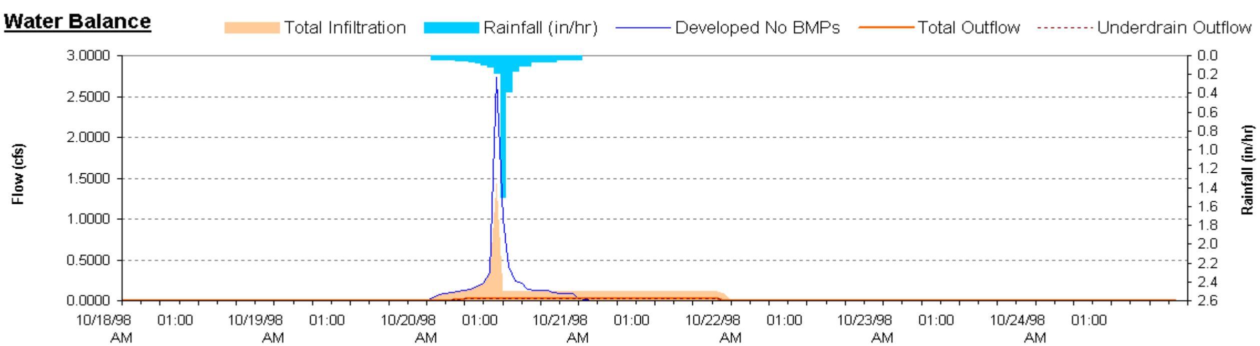
Date	Rainfall (inches)	Type	Peak Discharge (cfs)		
			Existing	Proposed w/o BMP	Proposed with BMPs
11/24/1993	4.03	Fall	1.80	1.96	0.03
10/13/1995	3.36	Fall	1.46	1.69	0.02
11/6/1996	2.94	Fall	1.14	1.48	0.02
2/2/1998	2.39	Winter	0.11	0.30	0.02
8/1/1993	1.95	Summer	0.00	0.78	0.02

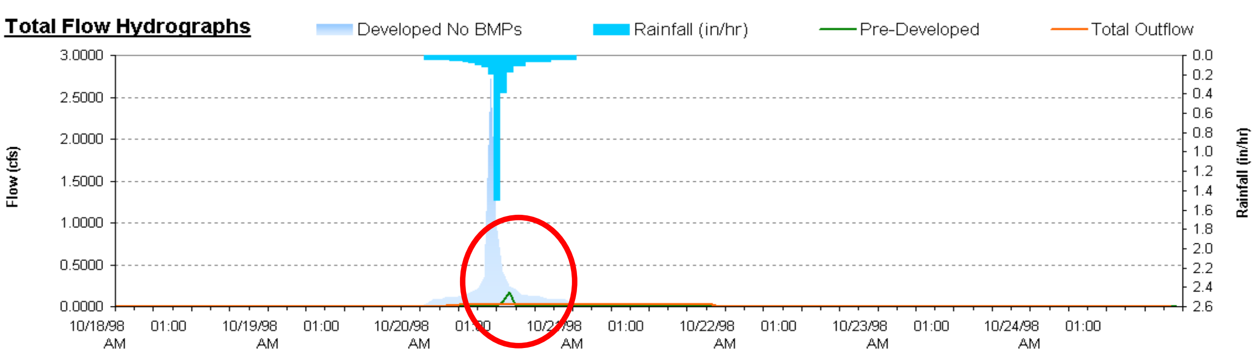


Summary	Rainfall (in)	Water Budget (in)					Runoff
		Developed No BMPs	Lost to Infiltration	Underdrain Outflow	Net Retained Water	Bypass Flow	Pre-Developed
Total Weekly	3.5000	6.9569	6.1482	0.8110	0.0000	0.0000	0.2555
Max Hourly	1.4980	2.7315	1.4222	0.0191	Not Applicable	0.0000	0.1692









Design Storm

24-hour Synthetic

USDA-SCS & U.S. Weather Bureau

Storm placed in the Fall (like the others)

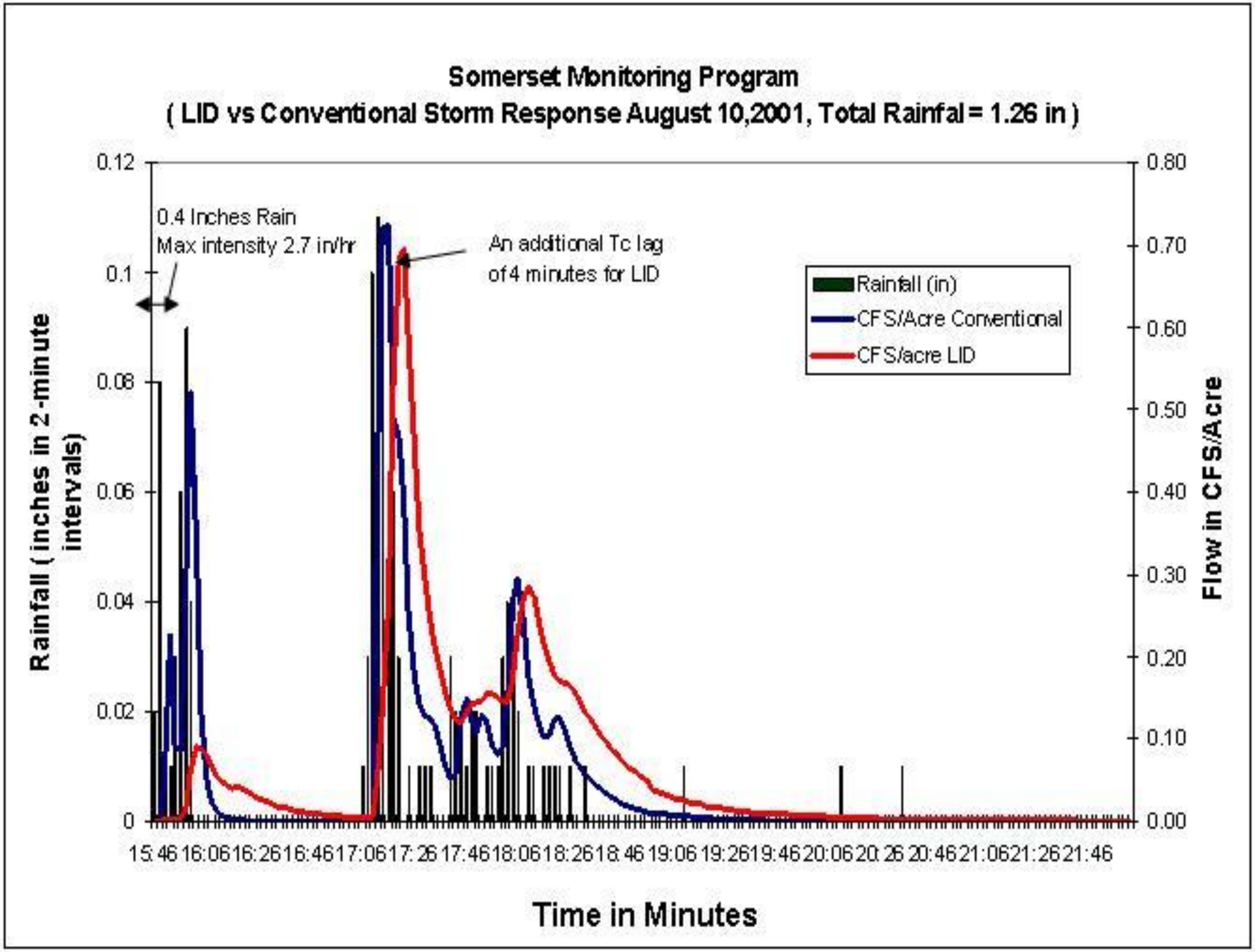
Factors:

24-hour duration (much longer than others), single peak

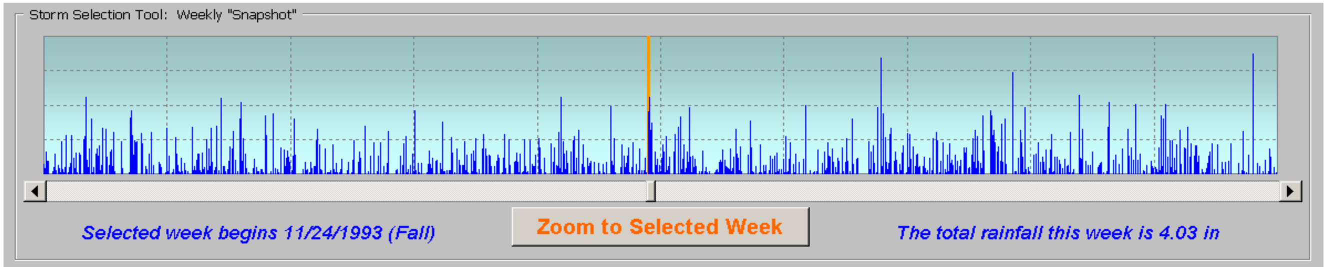
10 dry-days prior to the start of the storm

Under this idealized condition, the forest peak flow is 94% lower than the urban composite

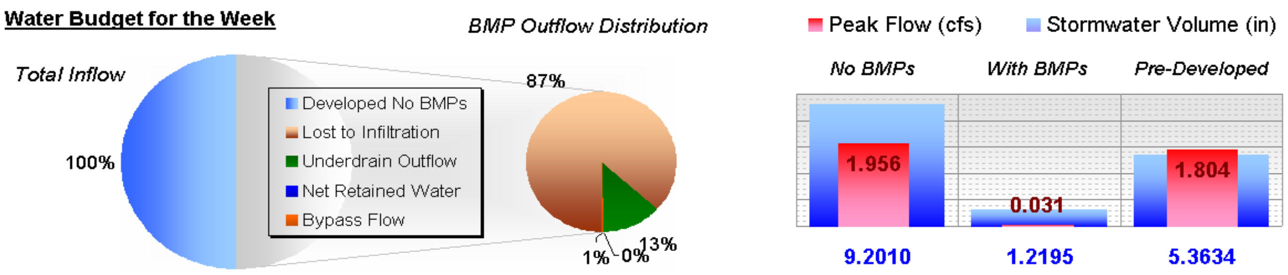
Somerset Subdivision

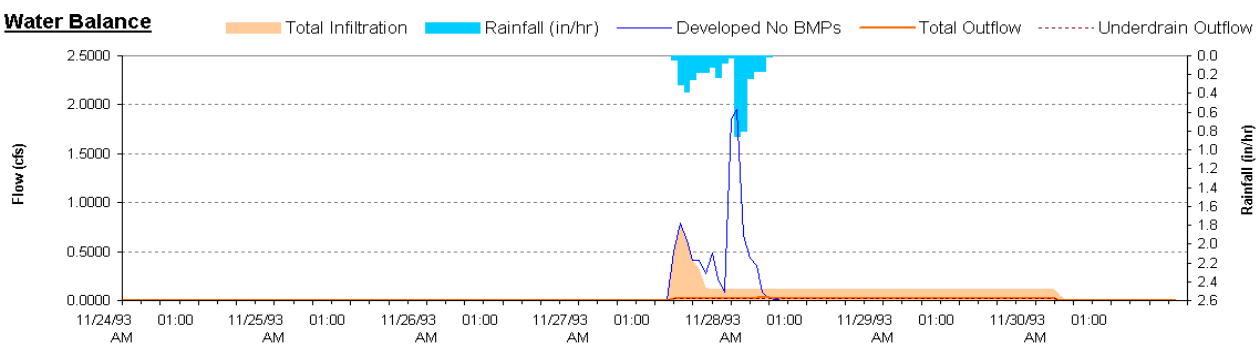


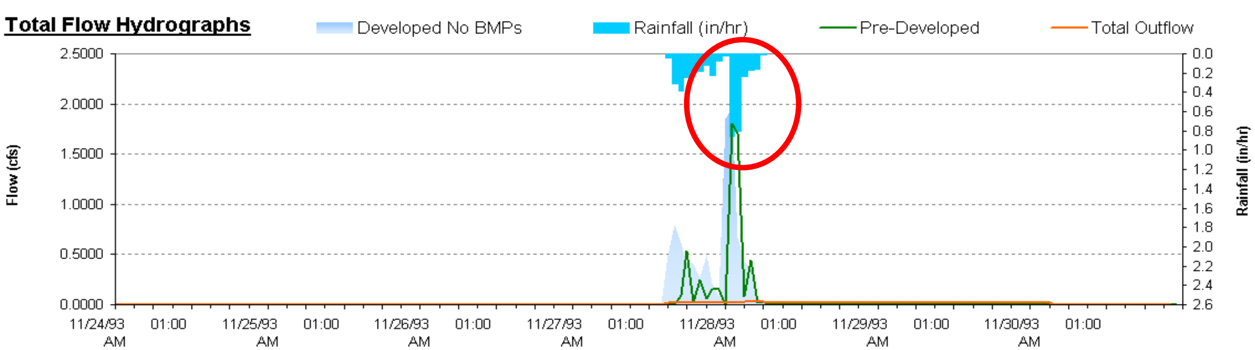
Somerset Monitoring Program
(LID vs Conventional Storm Response August 10,2001, Total Rainfal = 1.26 in)
0.4 Inches Rain
Max intensity 2.7 in/hr
An additional Tc lag
of 4 minutes for LID
Rainfall (in)
CFS/Acre Conventional
CFS/acre LID
Rainfall (inches in 2-minute intervals)
Flow in CFS/Acre
Time in Minutes
0.12
0.1
0.08
0.06
0.04
0.02
0
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
15:46 16:06 16:26 16:46 17:06 17:26 17:46 18:06 18:26 18:46 19:06 19:26 19:46 20:06 20:26 20:46 21:06 21:26 21:46



Summary	Rainfall (in)	Water Budget (in)					Runoff
		Developed No BMPs	Lost to Infiltration	Underdrain Outflow	Net Retained Water	Bypass Flow	Pre-Developed
Total Weekly	4.0300	9.2010	7.9845	1.1649	0.0000	0.0546	5.3634
Max Hourly	0.8600	1.9561	0.7722	0.0191	Not Applicable	0.0119	1.8038







Fall Storm 2

12-hour duration double-peak storm

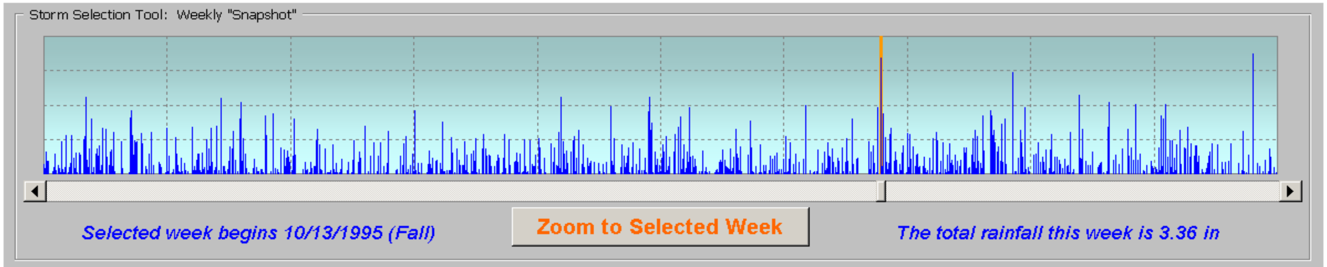
2 consecutive hours of intense rainfall in 2nd peak (0.86, 0.8)

Factors:

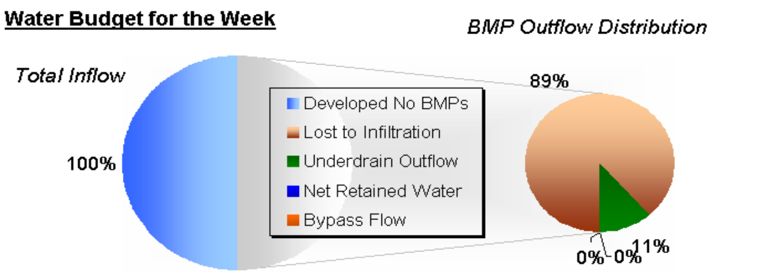
16 hour storm duration 4.03 in total rainfall 1.66 inches in 2 hours

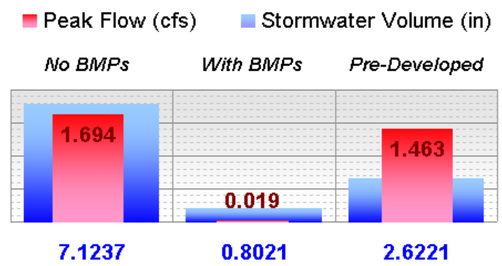
Generally higher GW (not shown) due to wetter-than-usual Fall

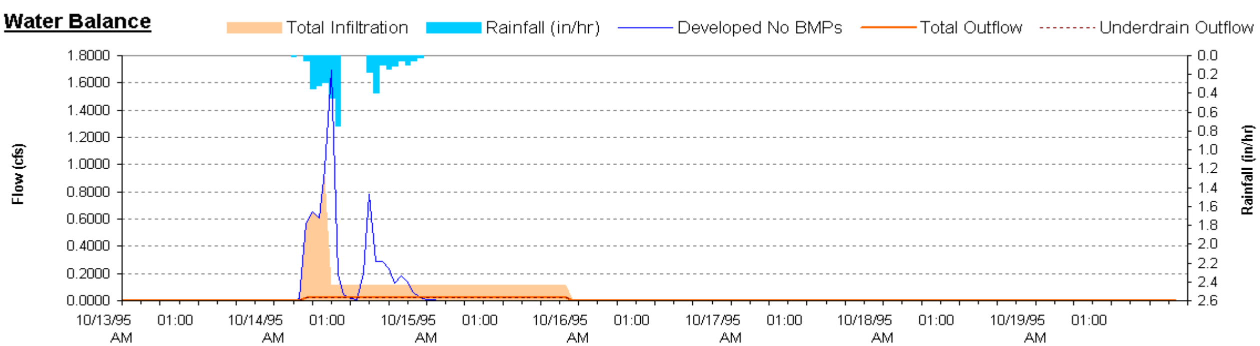
The water is falling faster than it can infiltrate into the ground

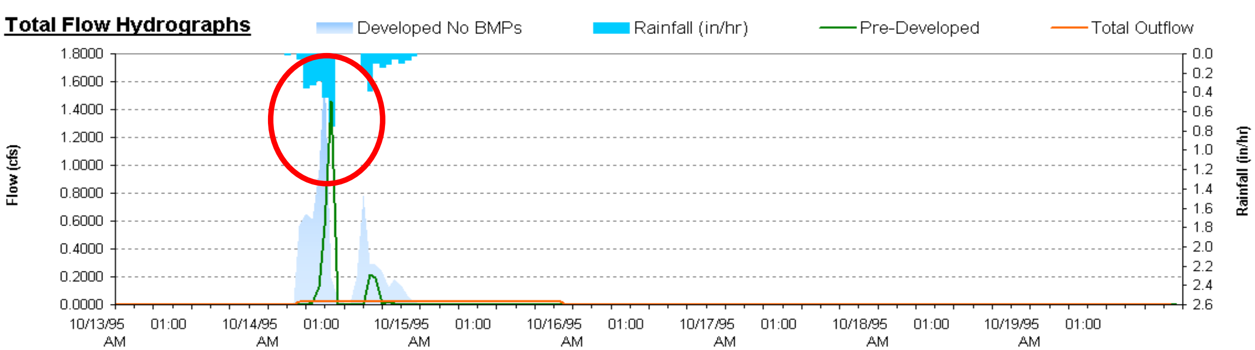


Summary	Rainfall (in)	Water Budget (in)					Runoff
		Developed No BMPs	Lost to Infiltration	Underdrain Outflow	Net Retained Water	Bypass Flow	Pre-Developed
Total Weekly	3.3600	7.1237	6.3240	0.8021	0.0000	0.0000	2.6221
Max Hourly	0.7500	1.6943	0.8982	0.0191	Not Applicable	0.0000	1.4627









Fall Storm 3

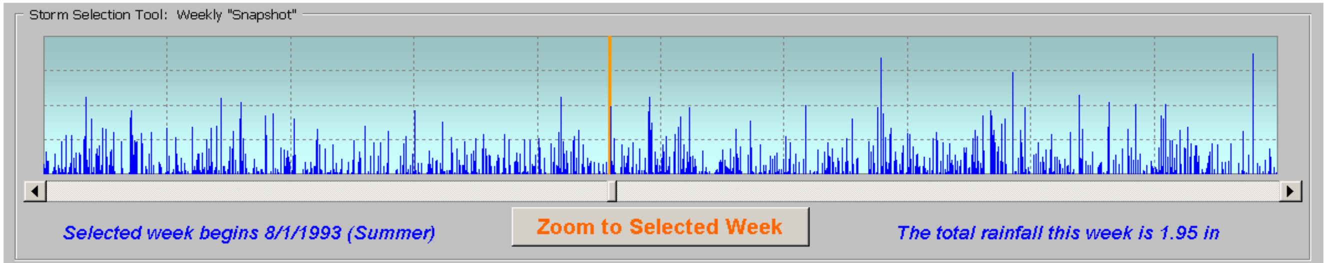
2 consecutive events

#1: 8 hrs, 2.21 inches
#2: 9 hrs, 1.15 inches

Factors:

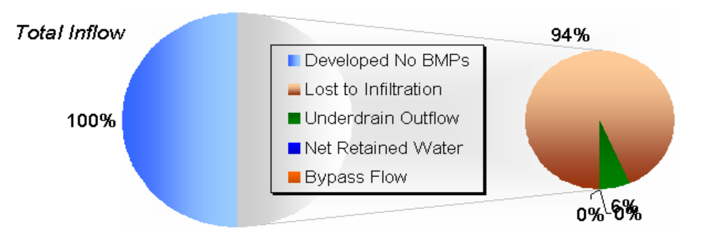
Short duration + High intensity

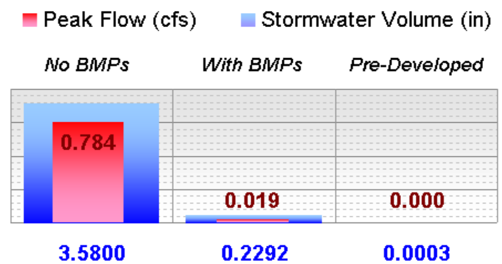
Rainfall is coming faster than the ground can infiltrate within that time period



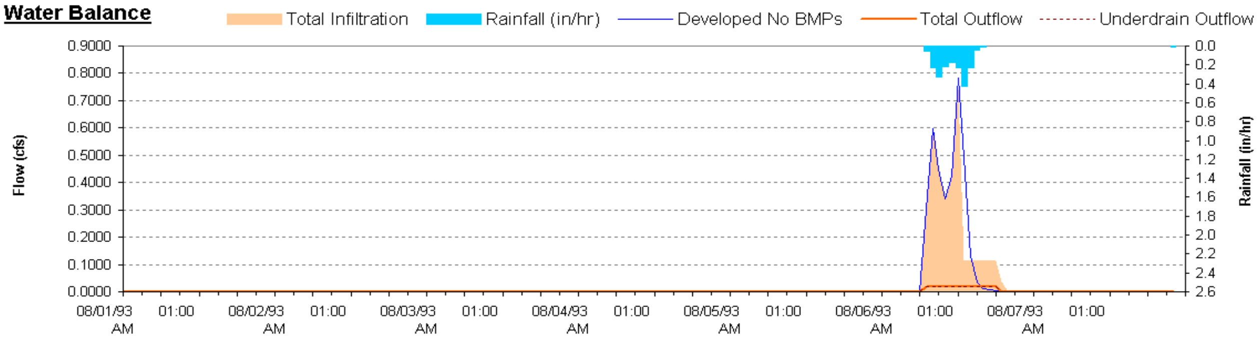
Summary	Rainfall (in)	Water Budget (in)					Runoff
		Developed No BMPs	Lost to Infiltration	Underdrain Outflow	Net Retained Water	Bypass Flow	Pre-Developed
Total Weekly	1.9500	3.5800	3.3520	0.2292	0.0000	0.0000	0.0003
Max Hourly	0.4300	0.7838	0.7212	0.0191	Not Applicable	0.0000	0.0002

Water Budget for the Week

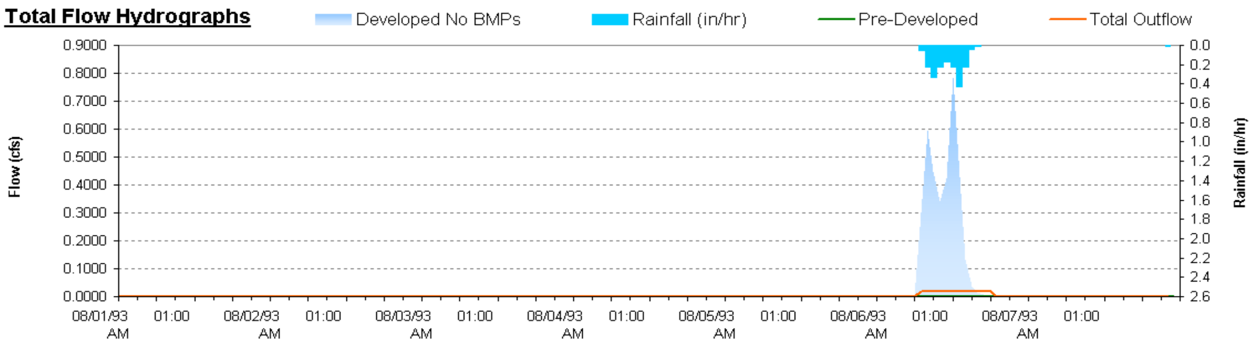




Water Balance



Total Flow Hydrographs



Summer Storm 1

Double-peak event

10 hour duration
1.95 inch volume

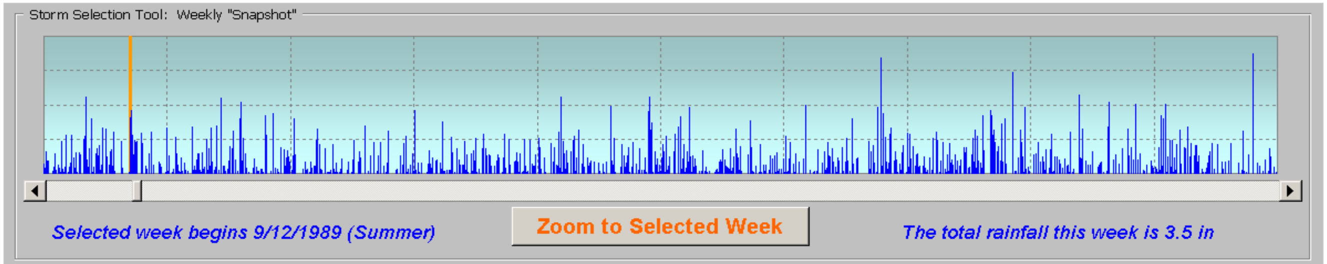
Almost no runoff from forest

Factors:

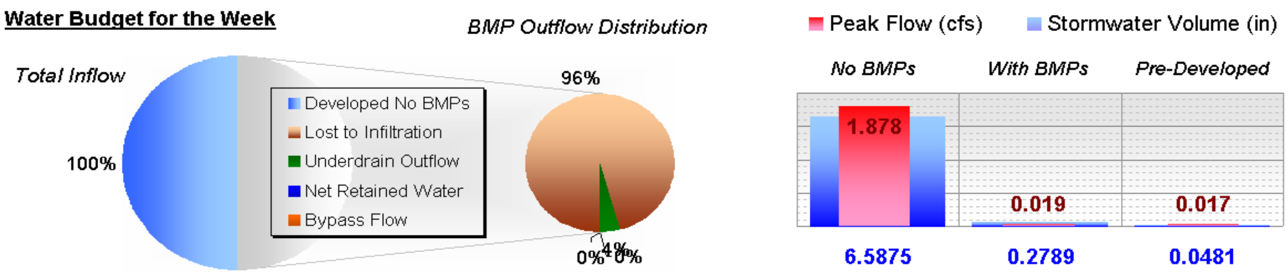
Summer event means higher interception, evapotransporation

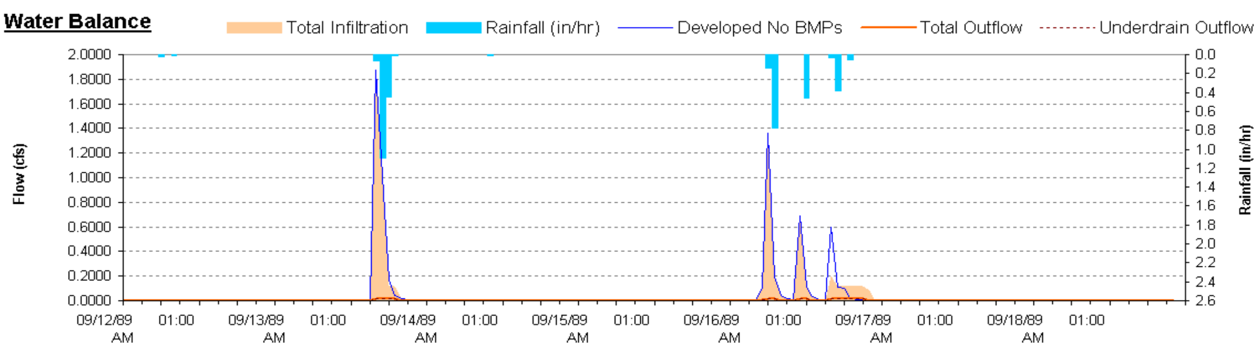
Higher infiltration potential, lower runoff potential

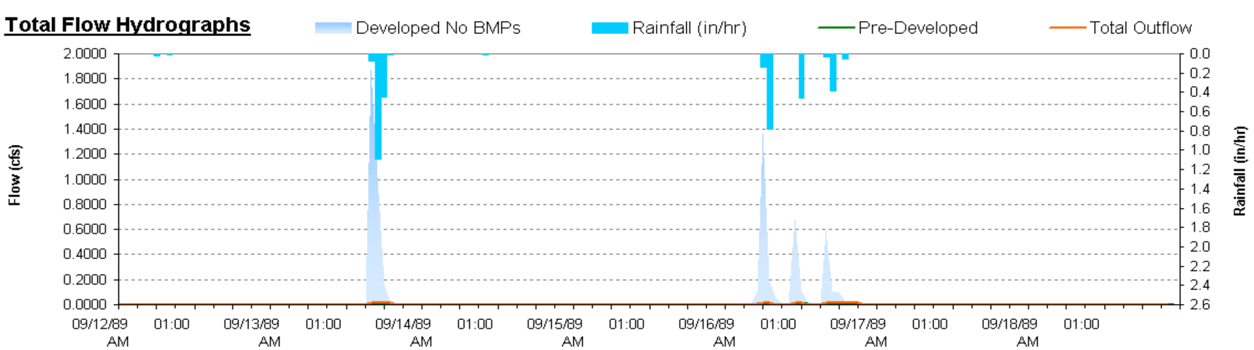
This intense double peak event responds differently because of the season of the year



Summary	Rainfall (in)	Water Budget (in)					Runoff
		Developed No BMPs	Lost to Infiltration	Underdrain Outflow	Net Retained Water	Bypass Flow	Pre-Developed
Total Weekly	3.5000	6.5875	6.3108	0.2789	0.0000	0.0000	0.0481
Max Hourly	1.0900	1.8779	1.8595	0.0191	Not Applicable	0.0000	0.0169







Summer Storm 2

1.62 in. over 4 hours with 1.09 in. for 1 hr

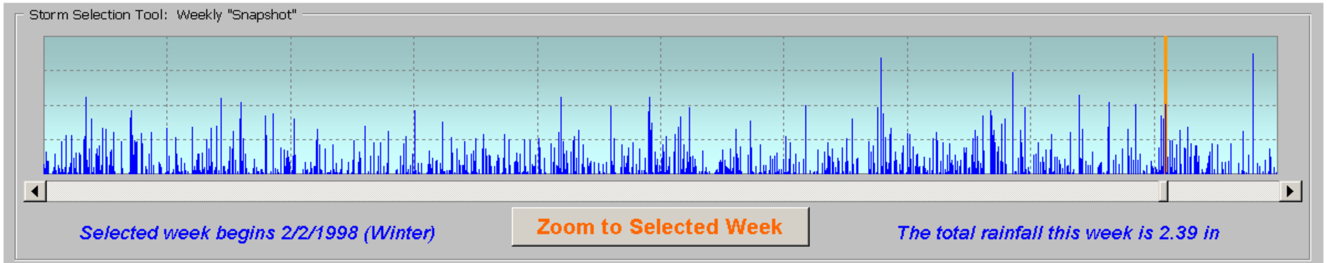
1.84 in. scattered over 14 hours with 0.78 in/hour peak

Factors:

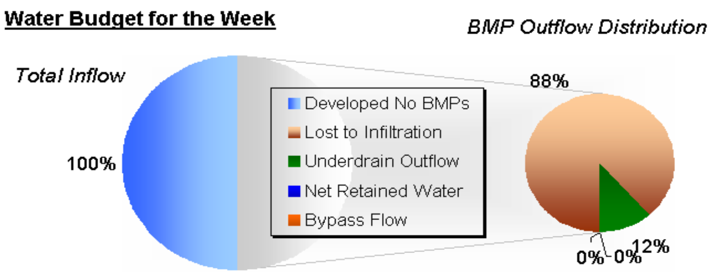
Summer event means higher interception, evapotransporation

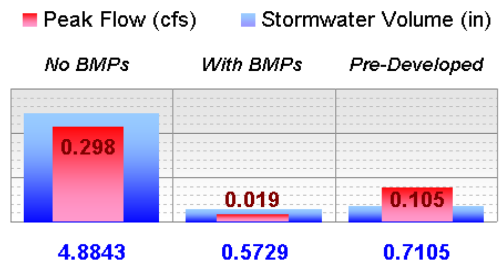
Higher infiltration potential, lower runoff potential

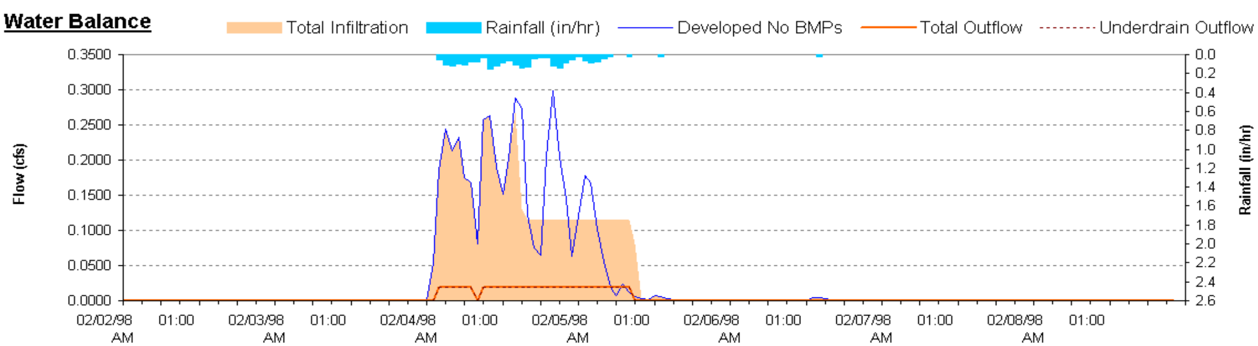
These intense rainfall events respond differently because of the season of the year

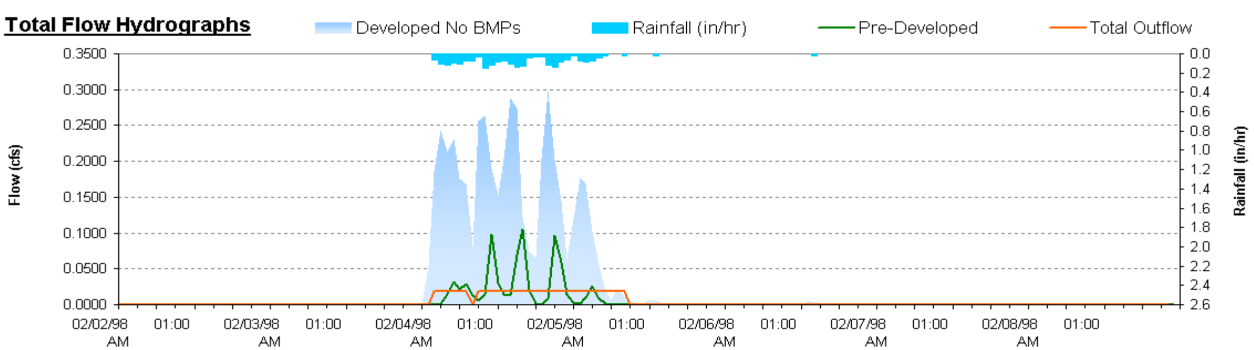


Summary	Rainfall (in)	Water Budget (in)					Runoff
		Developed No BMPs	Lost to Infiltration	Underdrain Outflow	Net Retained Water	Bypass Flow	Pre-Developed
Total Weekly	2.3900	4.8843	4.3130	0.5729	0.0000	0.0000	0.7105
Max Hourly	0.1500	0.2984	0.2482	0.0191	Not Applicable	0.0000	0.1049









Winter Storm 1

2.39 inches volume
28 hour duration

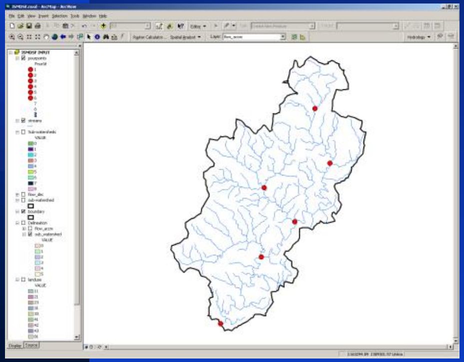
Factors:

Storm occurs in a wet part of the year

Low intensity, long duration storm

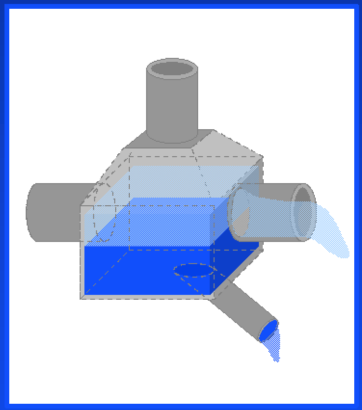
Even though it is a wet season, forest peak is 65% lower than urban because for this case, duration has a stronger influence on peak flow than volume

Major Module Enhancements Phase II



GIS Linkage

LID – CSO Linkage



Optimization