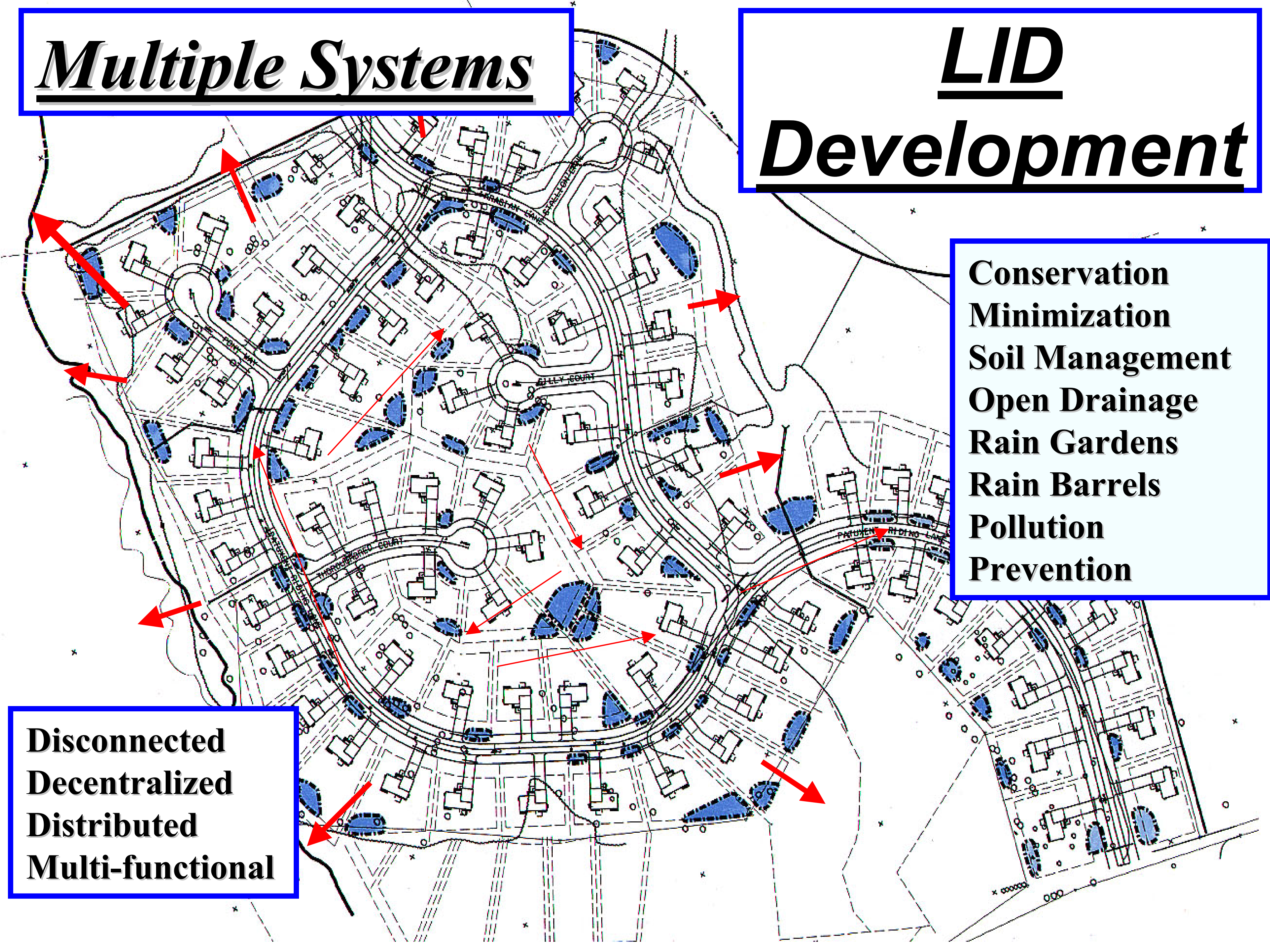
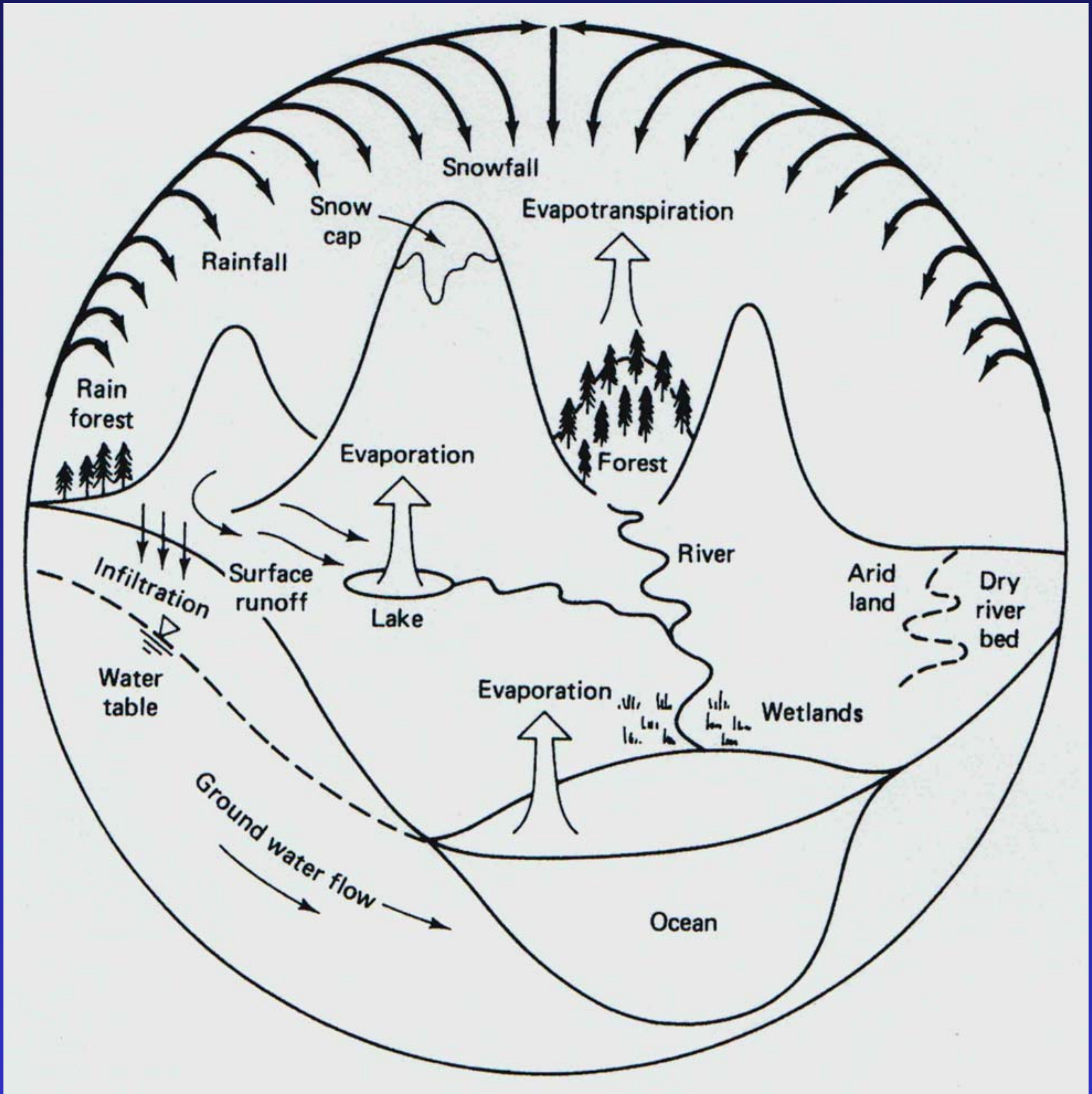
# ***Multiple Systems***

# ***LID Development***

**Conservation**
**Minimization**
**Soil Management**
**Open Drainage**
**Rain Gardens**
**Rain Barrels**
**Pollution Prevention**

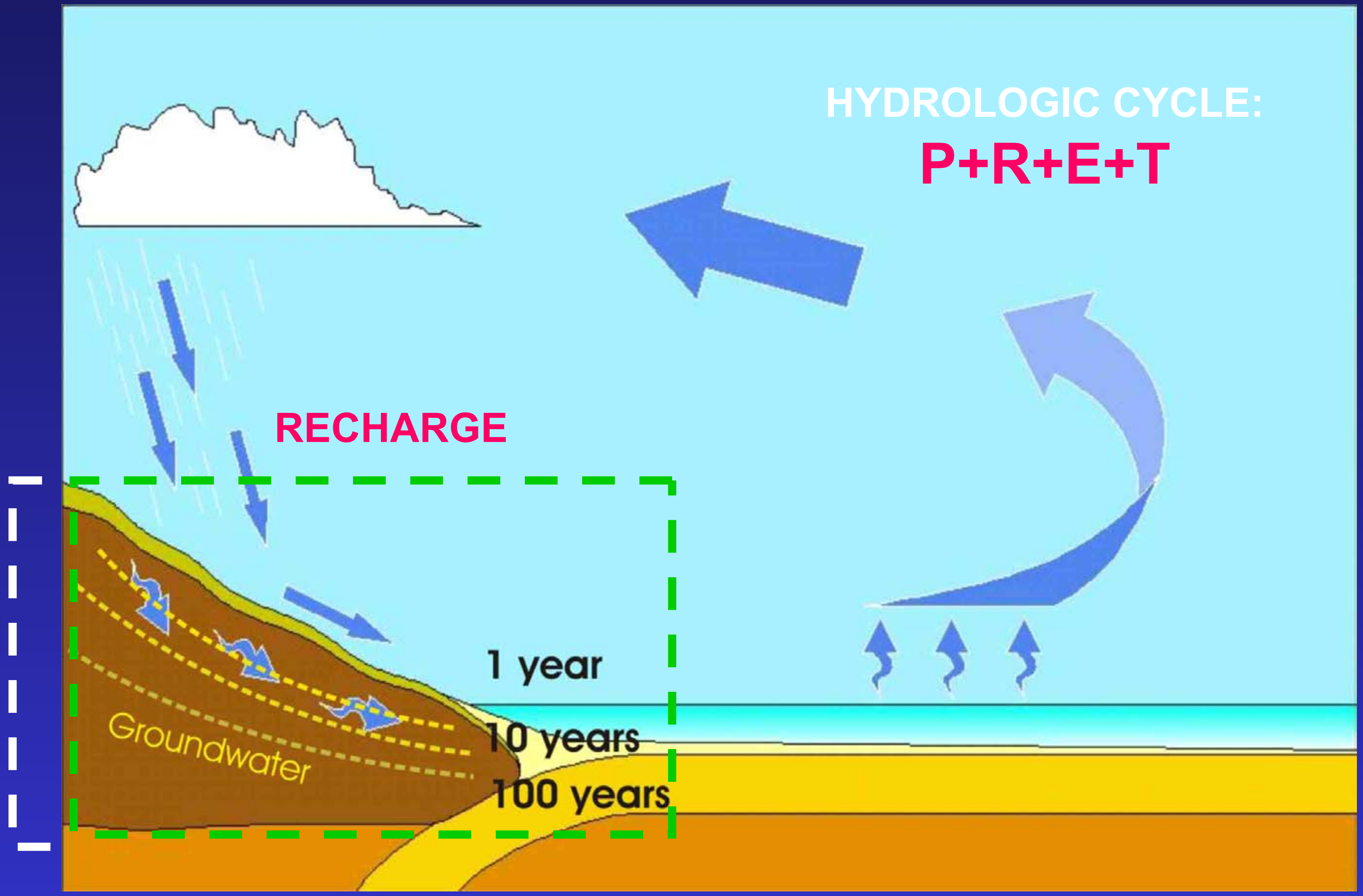


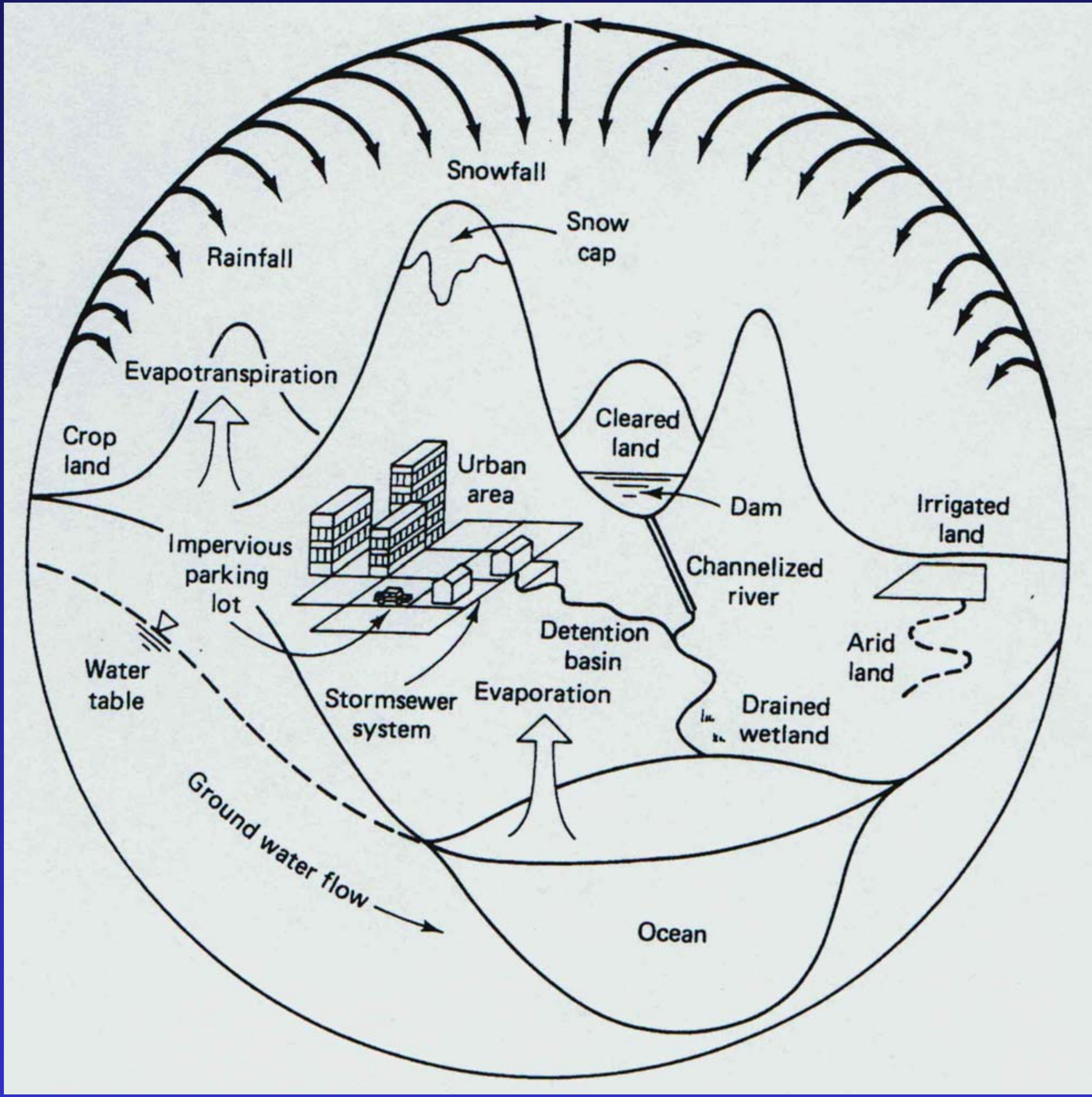
**Disconnected**
**Decentralized**
**Distributed**
**Multi-functional**




# Natural Hydrologic Cycle

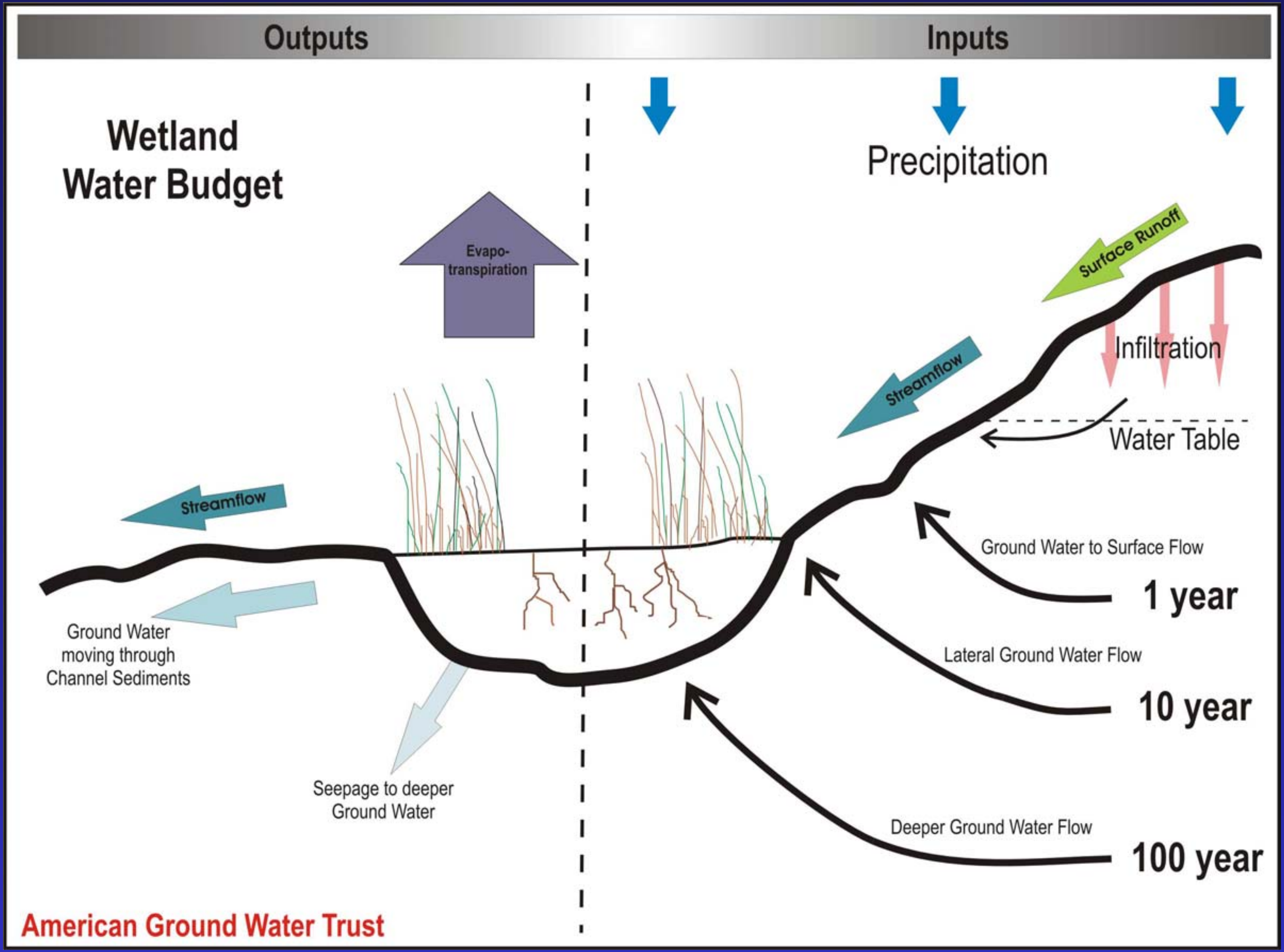
McCuen, 1999


HYDROLOGIC CYCLE:
P+R+E+T
RECHARGE
1 year
10 years
100 years
Groundwater

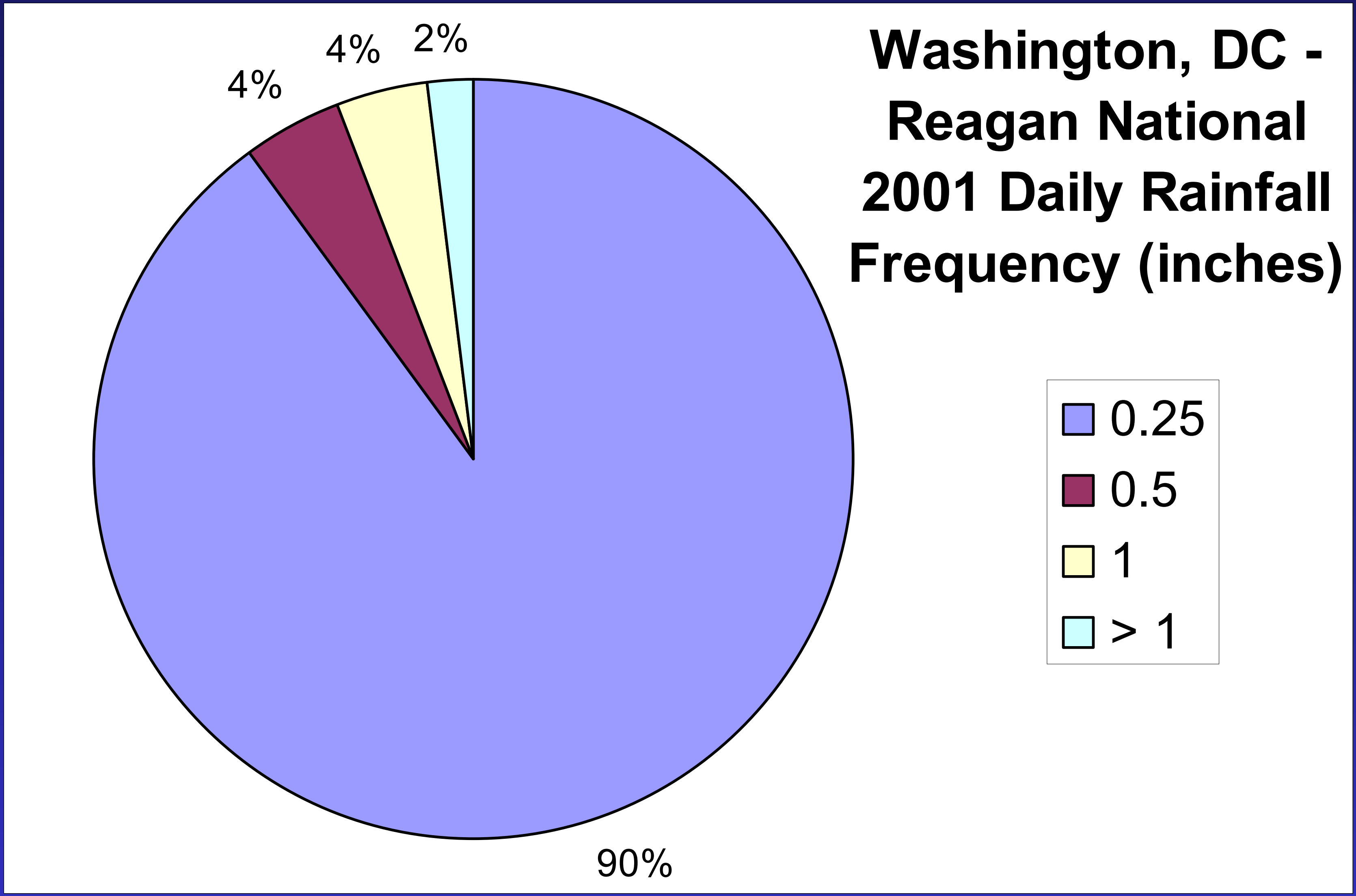



# Developed Hydrologic Cycle

McCuen, 1999




# Wetlands Recharge




Volume/Frequency

# How Does LID Maintain or Restore The Hydrologic Regime?

- **Creative ways to:**
  - **Maintain / Restore Storage Volume**
    - **interception, depression, channel**
  - **Maintain / Restore Infiltration Volume**
  - **Maintain / Restore Evaporation Volume**
  - **Maintain / Restore Runoff Volume**
  - **Maintain Flow Paths**
- **Engineer a site to mimic the natural water cycle functions / relationships**

# *Key LID Principles*
# *"Volume"*
## *"Hydrology as the Organizing Principle "*

- Unique Watershed Design
  - Match Initial Abstraction Volume
  - Mimic Water Balance
- Uniform Distribution of Small-scale Controls
- Cumulative Impacts of Multiple Systems
  - filter / detain / retain / use / recharge / evaporate
- Decentralized / Disconnection
- Multifunctional Multipurpose Landscaping & Architecture
- Prevention

# Defining LID Technology

## Major Components

1. Conservation (Watershed and Site Level )
2. Minimization (Site Level)
3. Strategic Timing (Watershed and Site Level)
4. Integrated Management Practices (Site Level)
   Retain / Detain / Filter / Recharge / Use
5. Pollution Prevention
   Traditional Approaches

# 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…………..

# LID Hydrologic Analysis

## Dr. Mow-Soung Cheng

Compensate for the loss of rainfall abstraction

Infiltration

Evapotranspiration

Surface storage

Time of travel

# LID Design Procedure Highlights

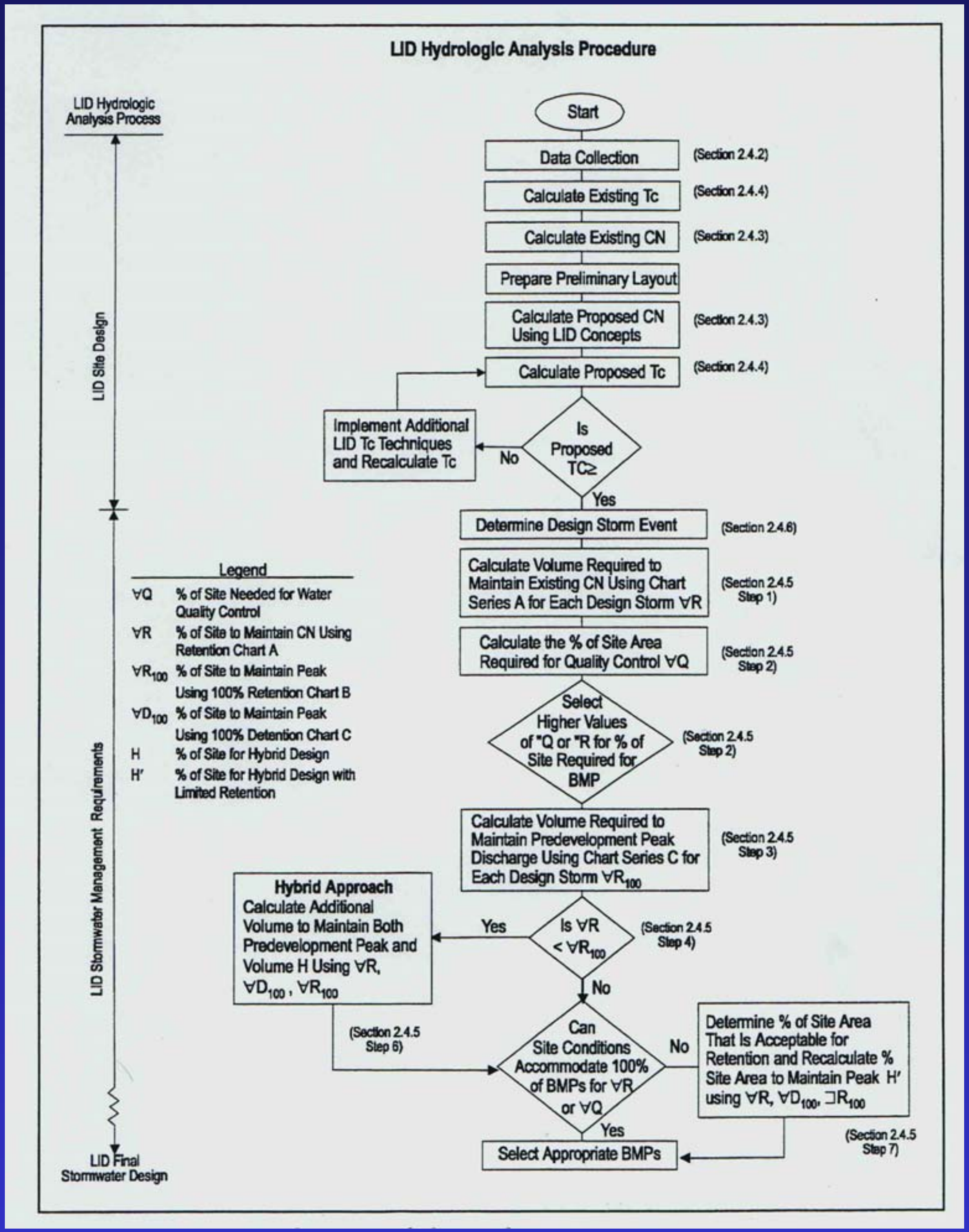
- Site Analysis
- Determine Unique Design Storm
- Maintain Flow Patterns and Tc
- Conservation and Prevention
- Develop LID CN
- Compensatory Techniques. Stress Volume Control then Detention or Hybrid for Peak

# Low-Impact Development Hydrologic Analysis and Design

- Based on NRCS technology, can be applied nationally
- Analysis components use same methods as NRCS
- Designed to meet both storm water quality and quantity requirements

# Other Models Acceptable!!!

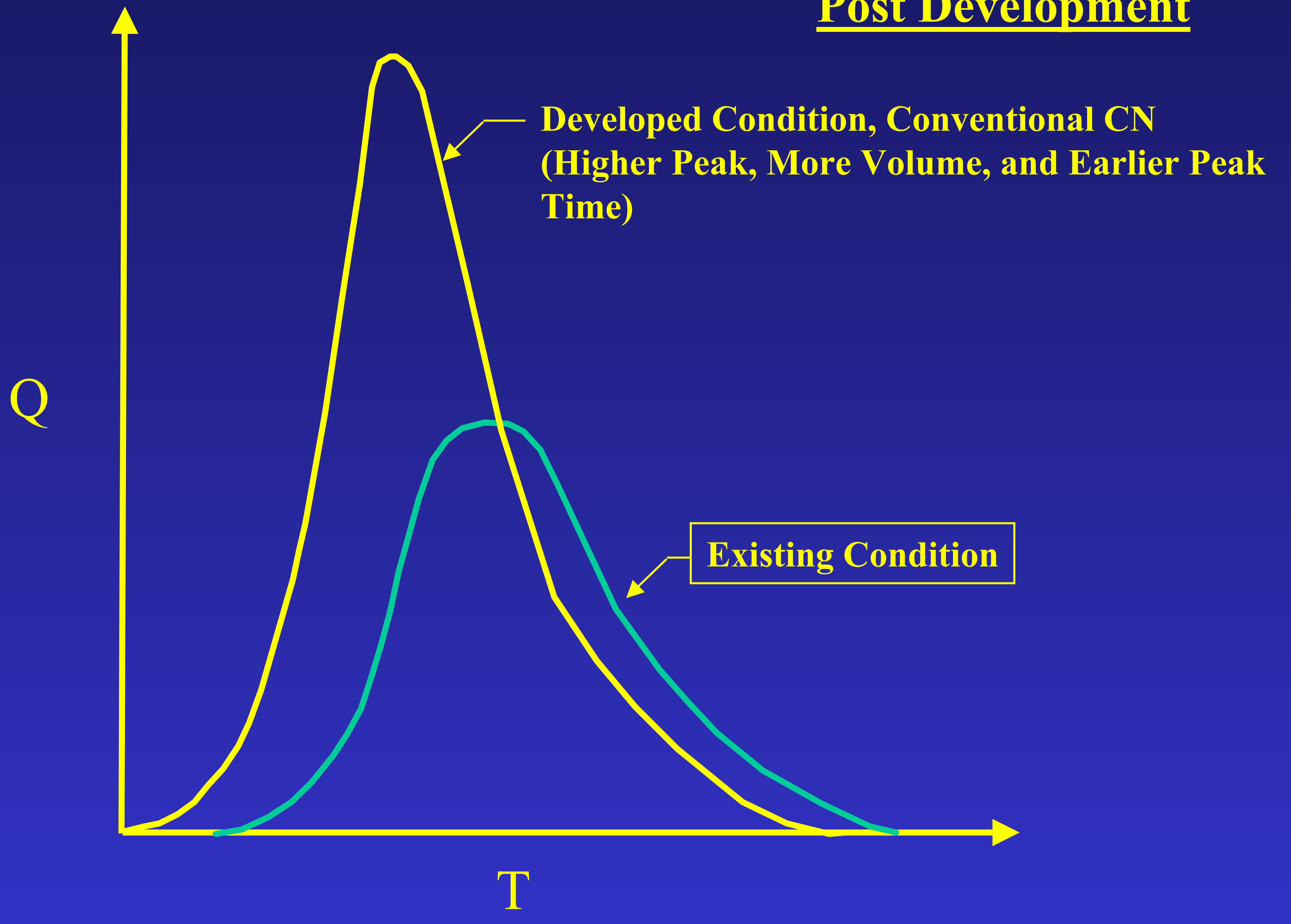
- TR-55 used as a basic design tool for local government use. COMMON PRACTICAL PLATFORM
- Still an ungaged and uncalibrated model!!
- Other more sophisticated, data and time intensive models exist for calibration/verification
- Continuous simulation recognized as the most rigorous



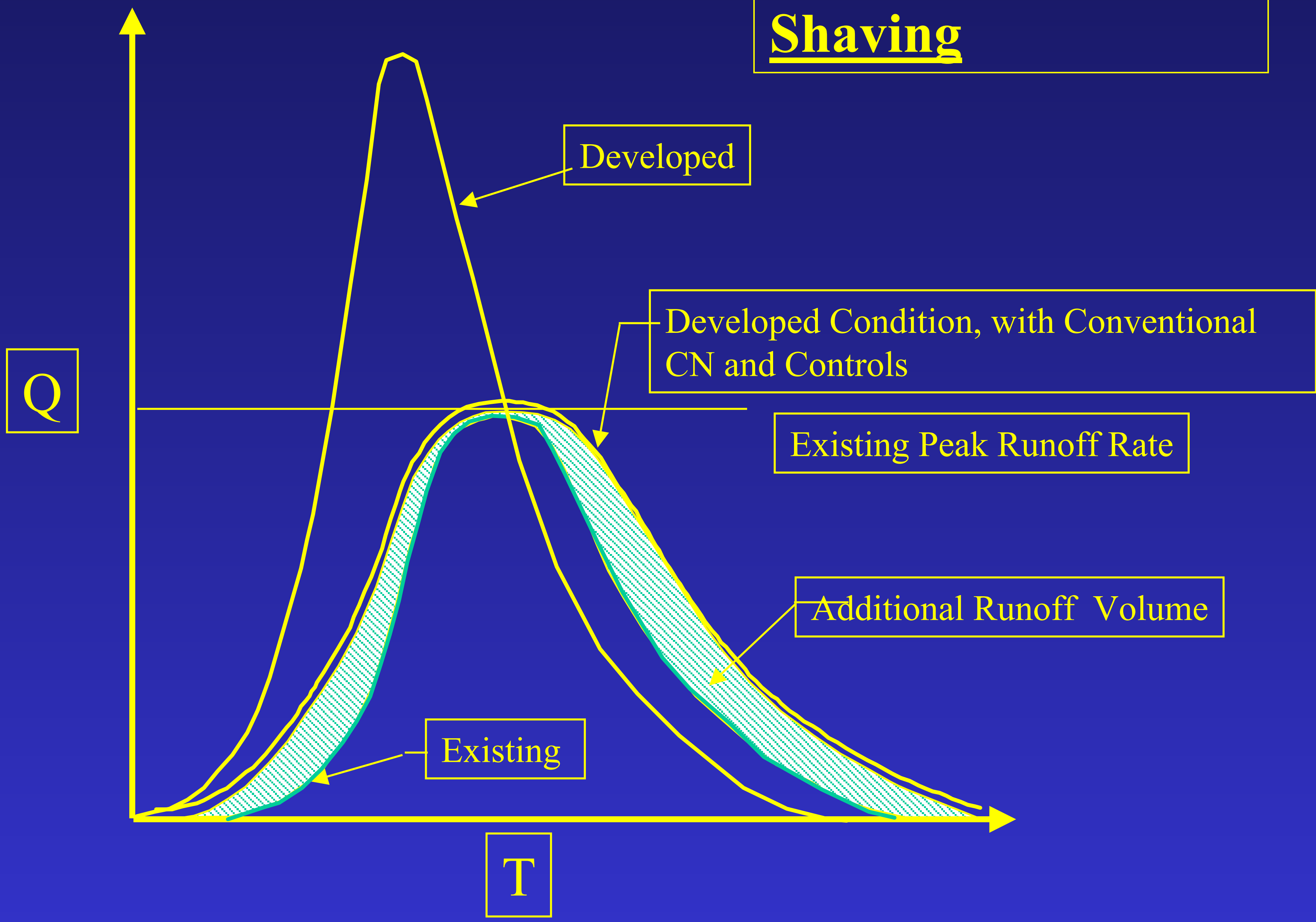

# LID Manual

# H and H Process

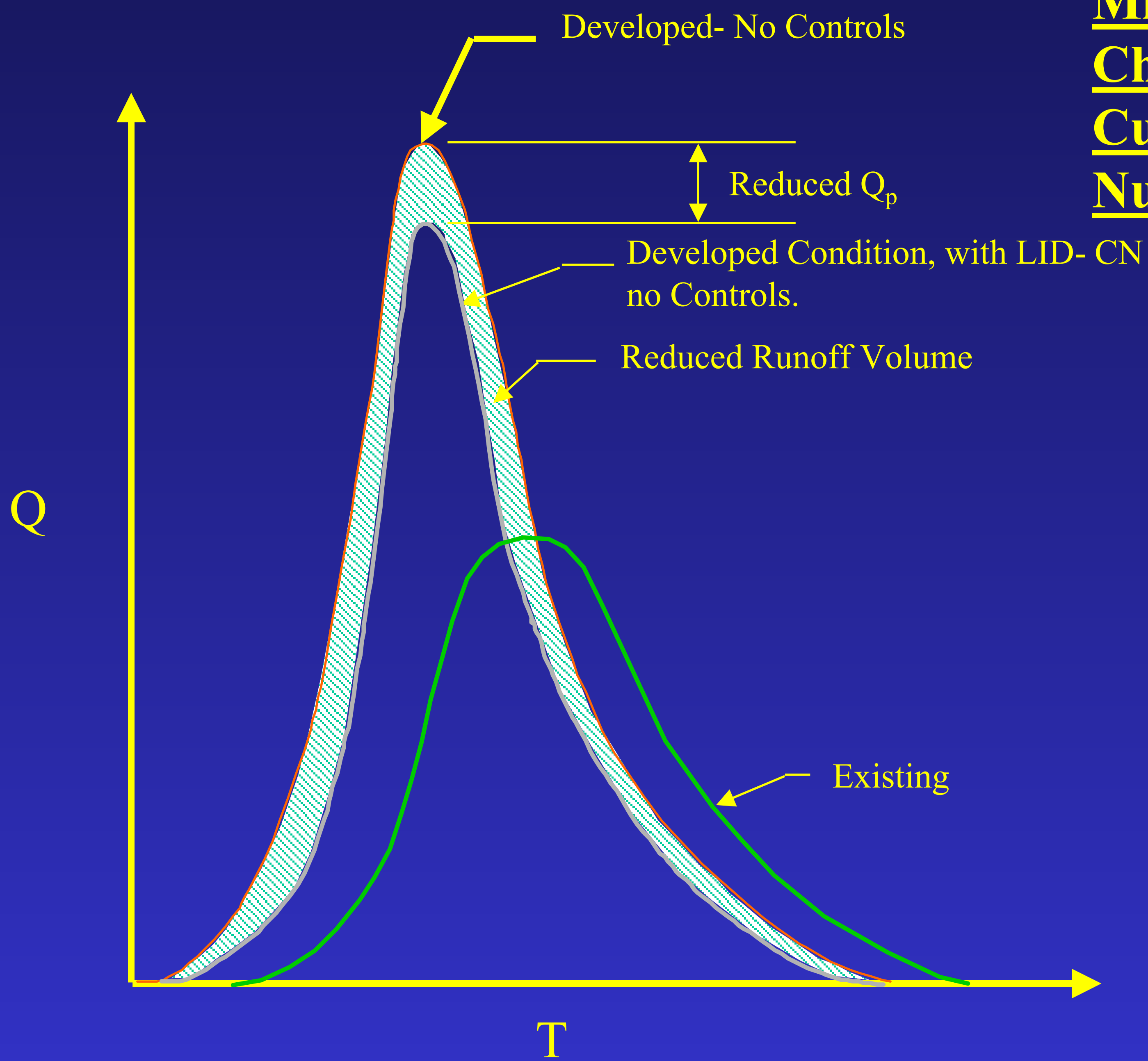
# Hydrograpgh Pre/ Post Development



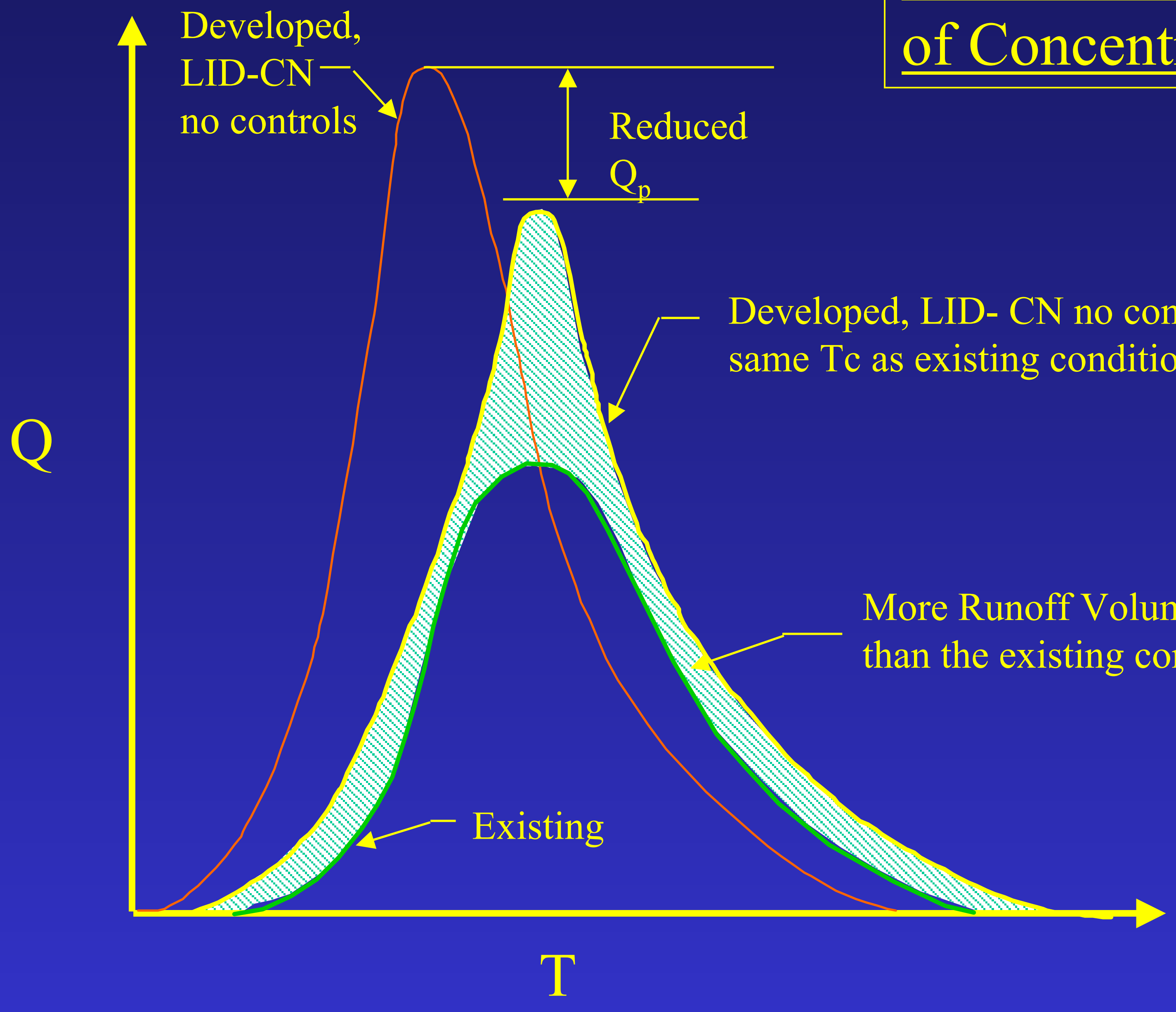
# Detention Peak Shaving



# Minimize Change in Curve Number



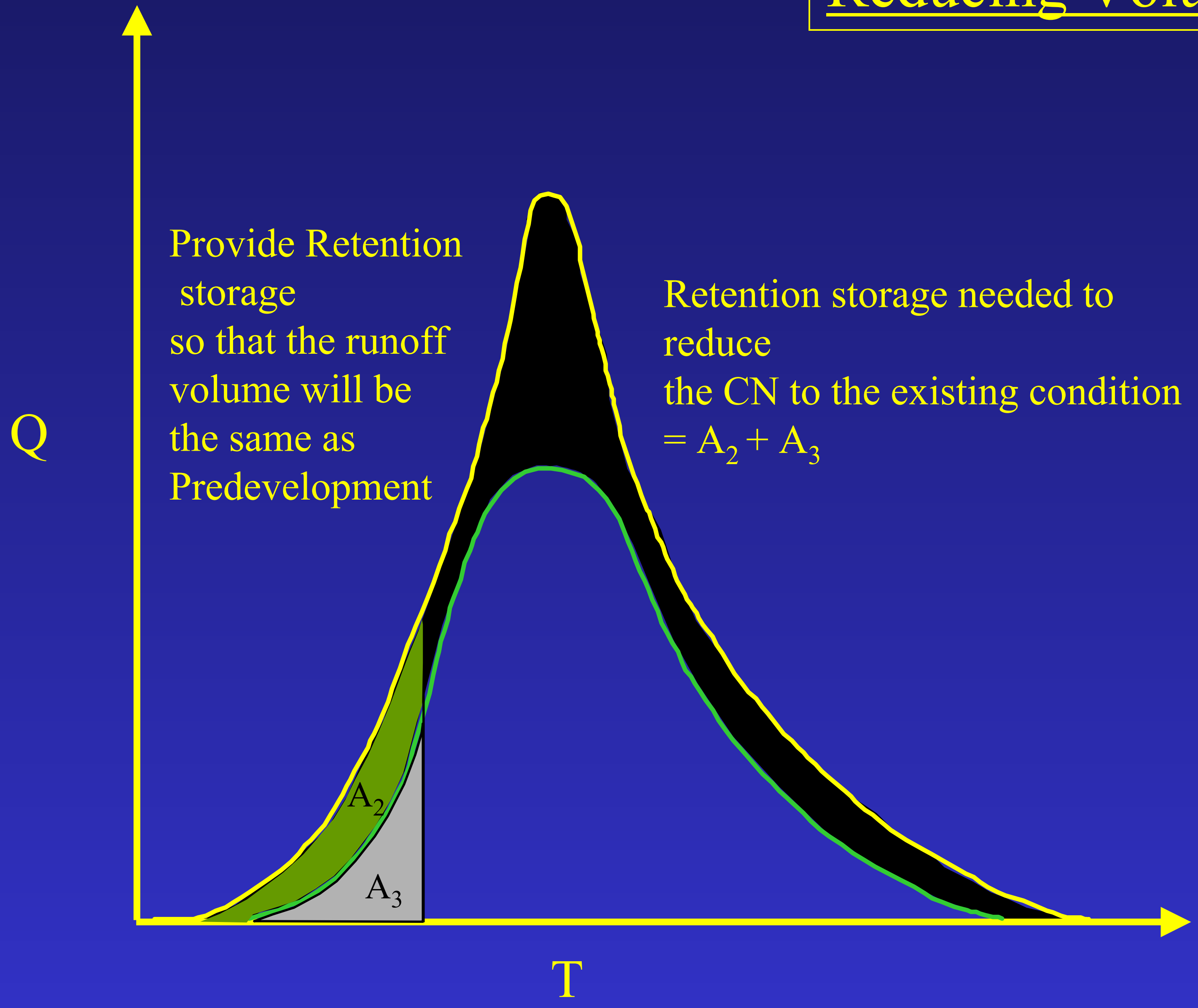
# Maintain Time of Concentration



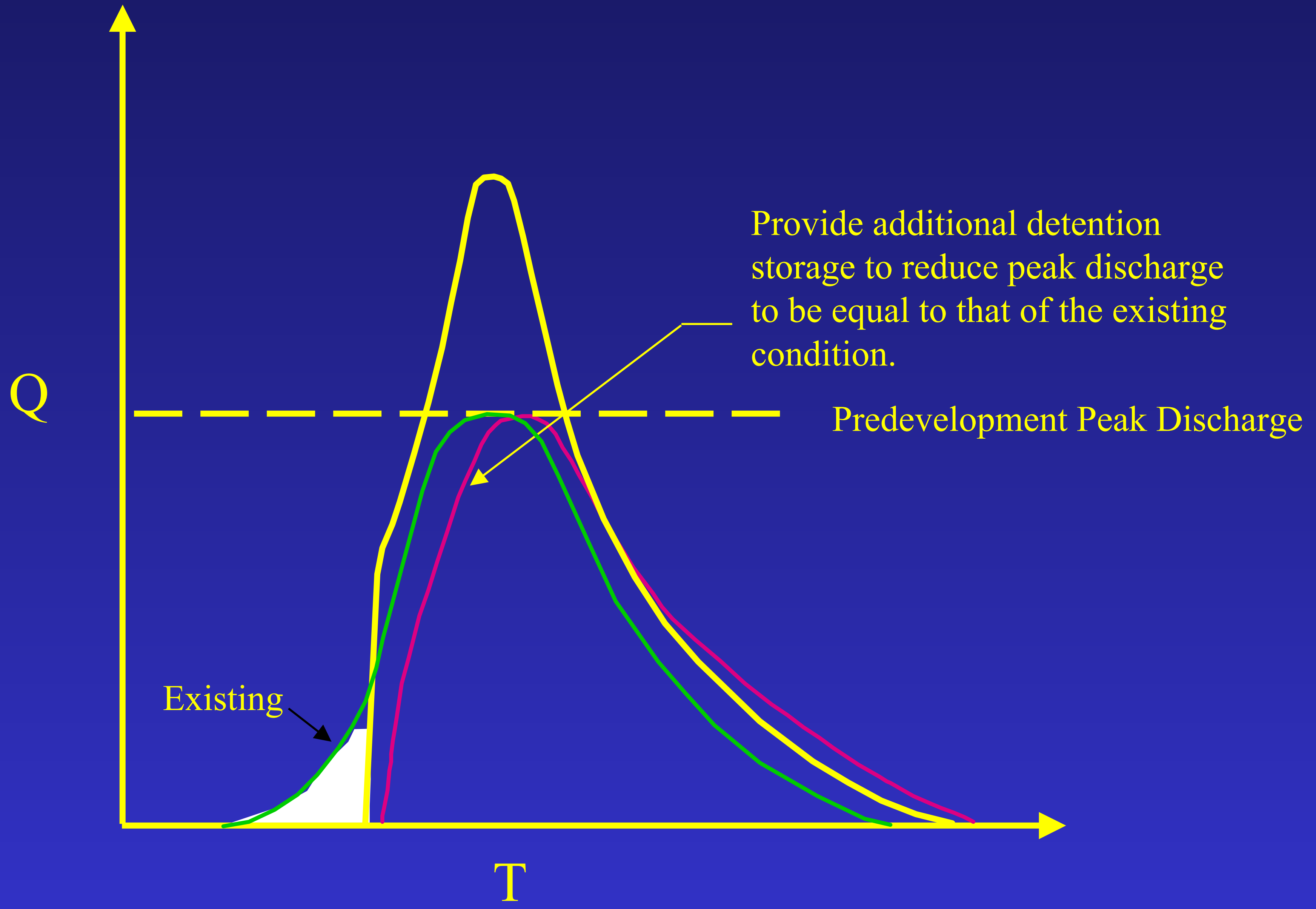
# Reducing Volume

Provide Retention storage so that the runoff volume will be the same as Predevelopment

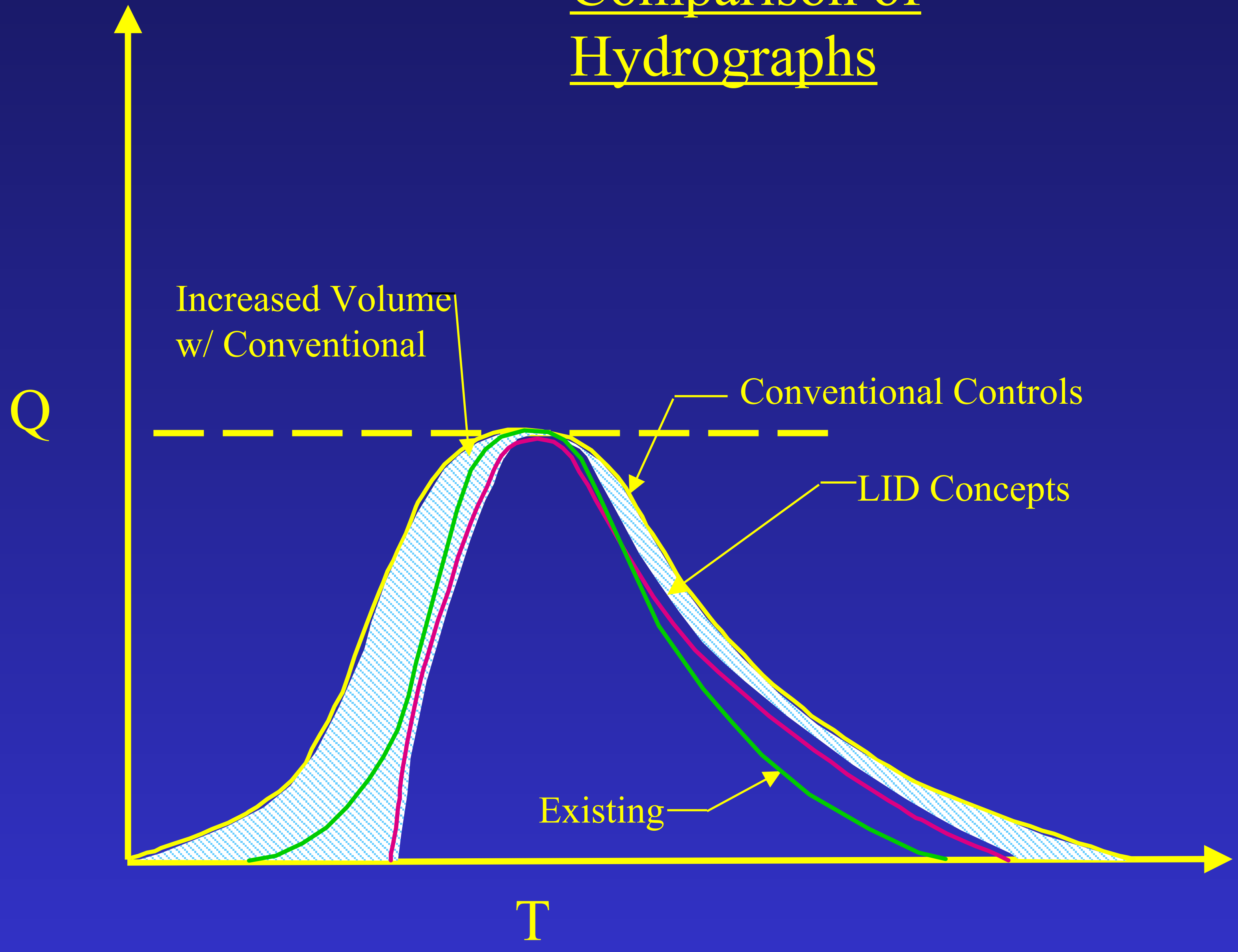
Retention storage needed to reduce the CN to the existing condition $= A_2 + A_3$



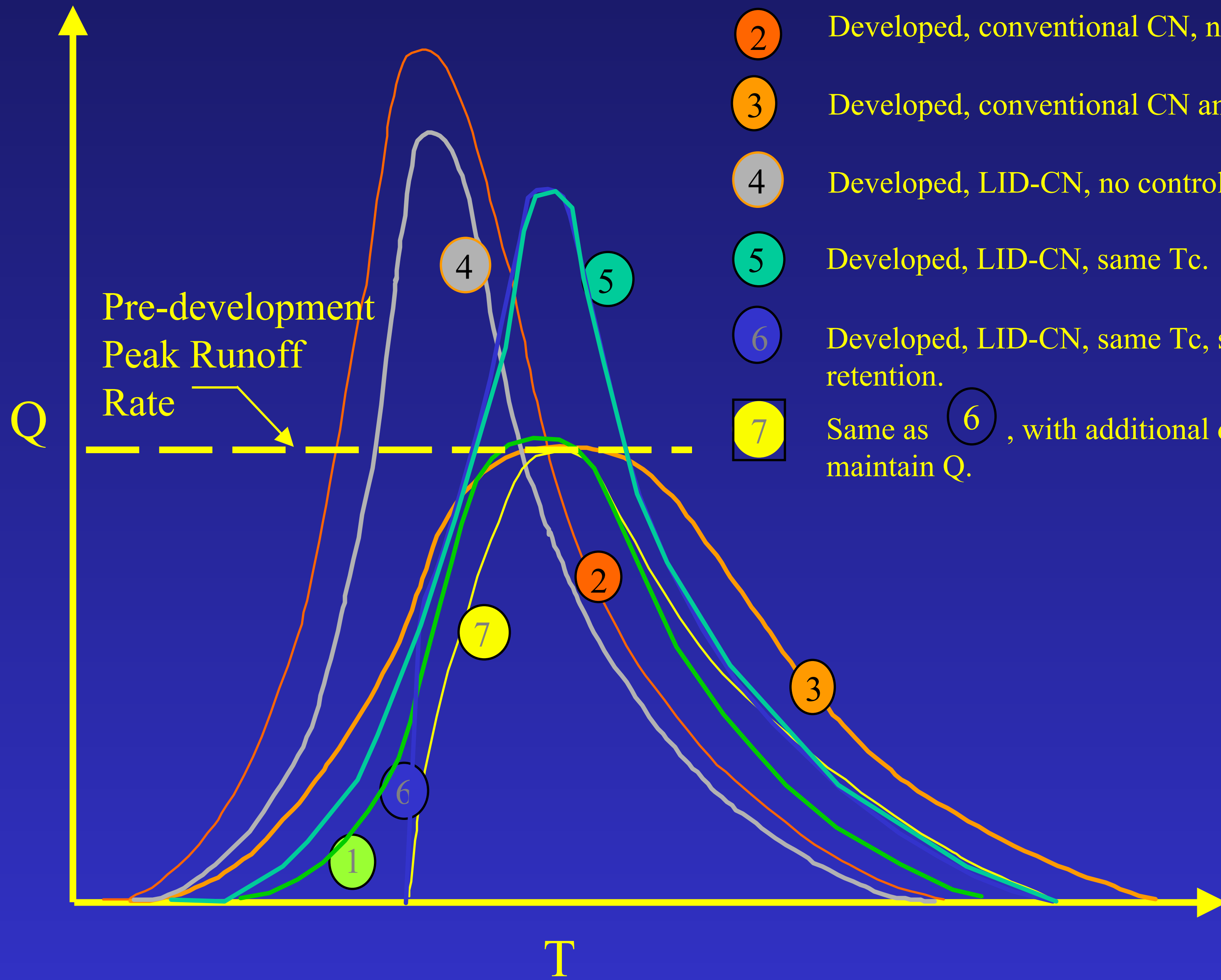
# Detention Storage



# Comparison of Hydrographs



# Hydrograph Summary




1 Existing

2 Developed, conventional CN, no control.

3 Developed, conventional CN and control.

4 Developed, LID-CN, no control.

5 Developed, LID-CN, same Tc.

6 Developed, LID-CN, same Tc, same CN with retention.

7 Same as 6, with additional detention to maintain Q.

# Comparison of Conventional and L I D Curve Numbers (CN) for 1- Acre Residential Lots

Conventional CN

***Disconectiveness***

R)

Customize Curb Number to Maximize Land Cover and Disconnectivity

25 % Woods

60 % Grass

$P_{IMP}$ = Percent of imp. site

Curve Number is reduced by using LID Land Uses.

# LI D to Maintain the Time of Concentration

## *"Uniformly Distributed Controls"*

* Minimize Disturbance

* Flatten Grades

* Reduce Height of Slopes

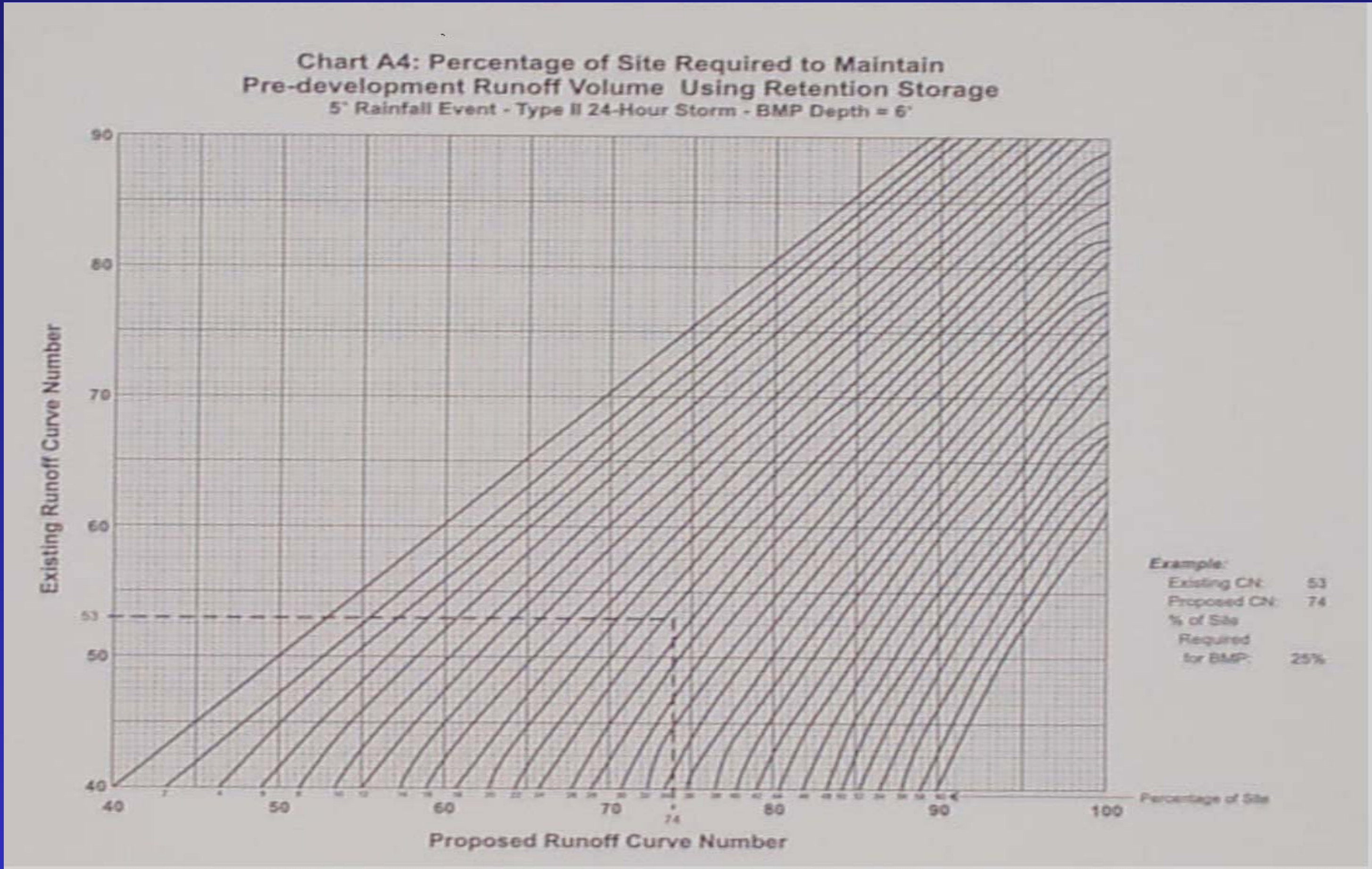
* Increase Flow Path

* Increase Roughness " n "

# Retention LID Storage Options (On-Site)

* Infiltration
* Retention
* Roof Top Storage
* Rain Barrels
* Bioretention
* Irrigation Pond

# Determining LID BMP Sizing




8% BMP

# Methods of Detaining Storage to Reduce Peak Runoff Rate

* Larger Swales with less slope
* Swales with check dams
* Smaller or constricted drainage pipes
* Rain barrels
* Rooftop storage
* Diversion structures

# LID Techniques and Objectives

Low-Impact Development Technique

| Low Impact Development Objective | Flatten Slope | Increase Flow Path | Increase Sheet Flow | Increase Roughness | Minimize Disturbance | Larger Swales | Flatten Slopes on Swales | Infiltration Swales | Vegetative Filter Strips | Constricted Pipes | Disconnected Impervious Areas | Reduce Curb and Gutter | Rain Barrels | Rooftop Storage | Bioretention | Re-Vegetation | Vegetation Preservation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Increase Time of Concentration** | X | X | X | X | | | | | X | X | X | X | X | X | X | | |
| **Increase Detention Time** | | | | | | | X | | | X | | | X | X | | | |
| **Increase Storage** | | | | | | X | | X | X | | | | | | X | X | X |
| **Lower Post Development CN** | | | | | X | | | | | | X | | | | X | X | X |

# Maintain Time of Concentration (Tc)

Low-Impact Development Technique

| Low Impact Development objective to Maintain Time of Concentration (Tc) | Balance cut and fill on lot. | Network Smaller Swales | Clusters of Trees and Shrubs in Flow Path | Provide Tree Conservation on Lots | Eliminate Storm Drain Pipes | Disconnect Impervious Areas | Save Trees in Smaller Clusters | Terrace Yards | Drain from House and then Reduce Grades |
|---|---|---|---|---|---|---|---|---|---|
| **Minimize Disturbance** | X | | X | X | X | X | X | X | |
| **Flatten Grades** | | X | | | X | | | X | X |
| **Reduce Height of Slopes** | | | | | X | | | X | X |
| **Increase Flow Path (Divert and Redirect)** | | X | X | | X | X | X | | X |
| **Increase Roughness "n"** | | | X | X | X | X | X | | |

# Summary of LID Techniques

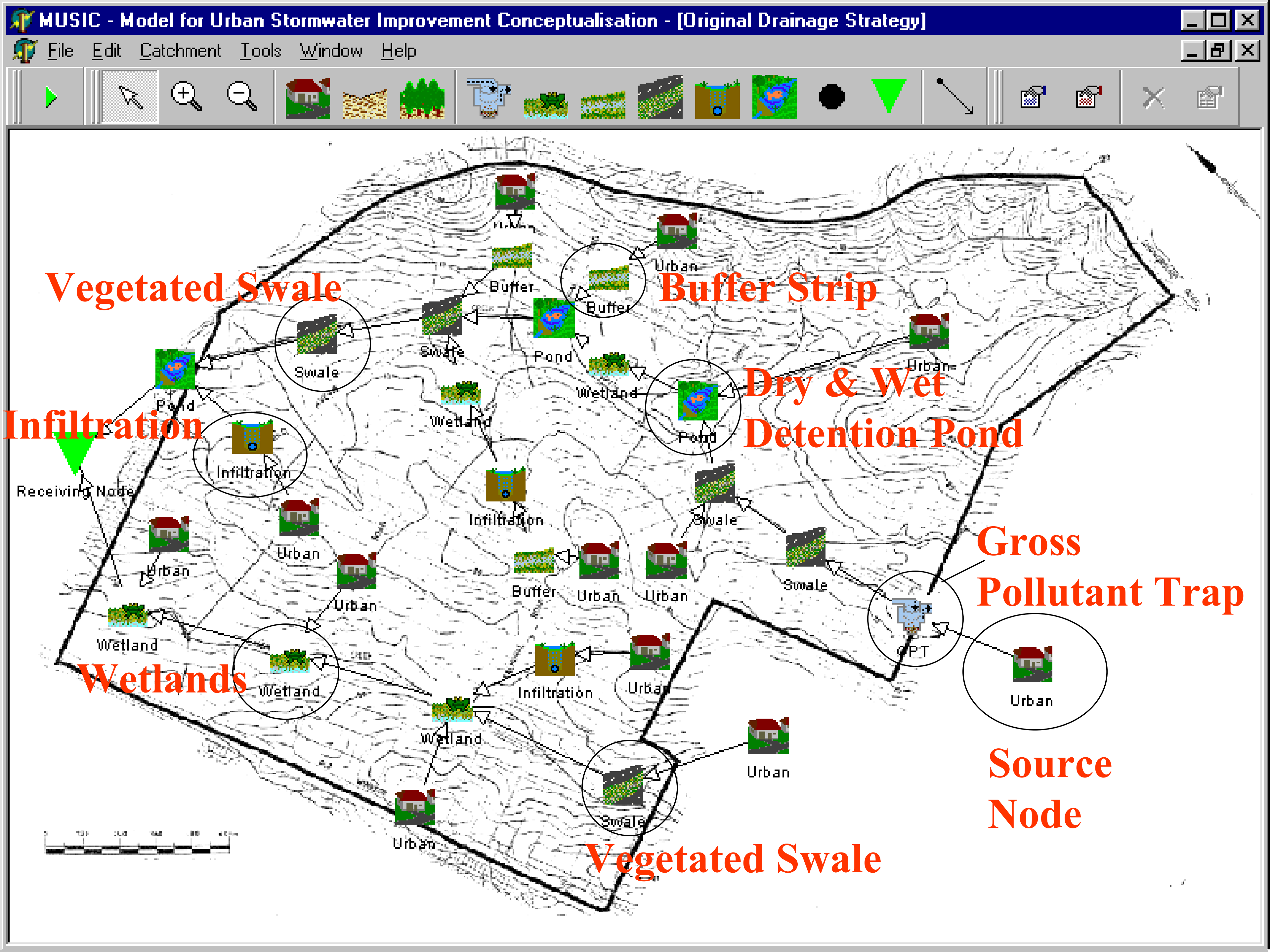
(1) Recalculate Postdevelopment CN based on LID land use.

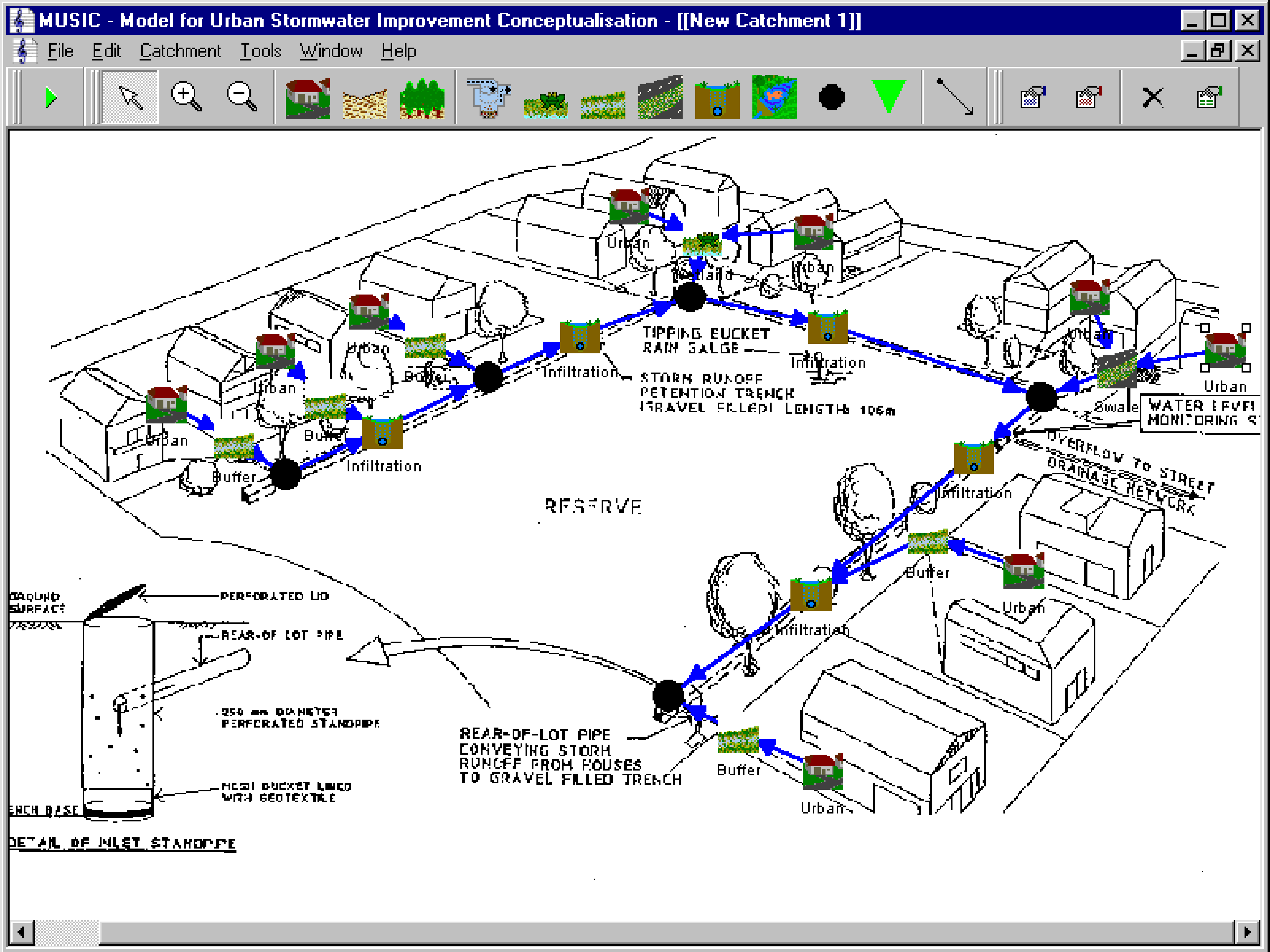
(2) Increase Travel Time (TT) using LID techniques to achieve the same Tc as Existing conditions.

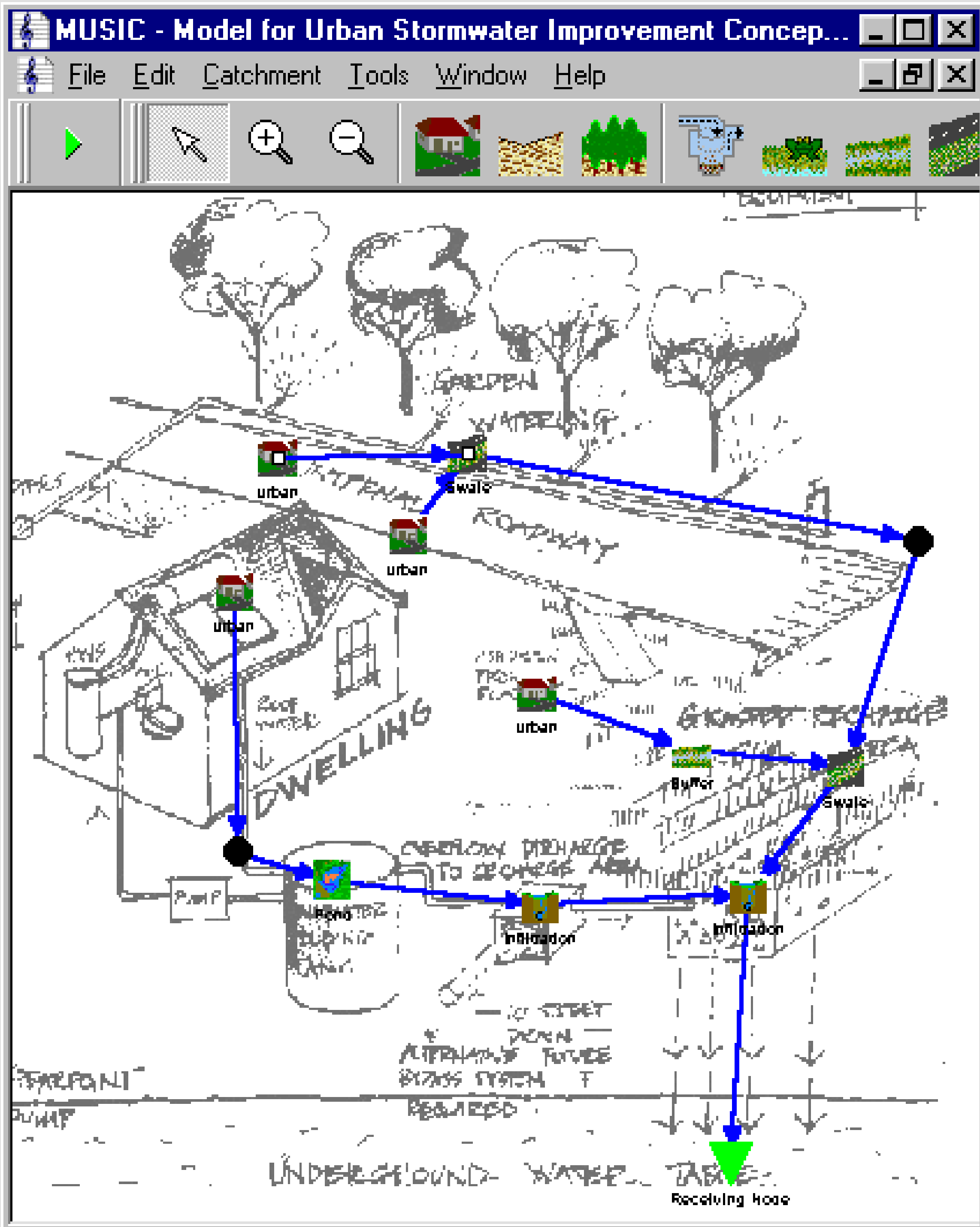
(3) Retention: Provide permanent storage (Infiltration/Retention) using LID techniques to maintain the CN and runoff volume of existing conditions.

(4) Detention: Provide additional detention storage to maintain the same peak discharge as existing conditions.

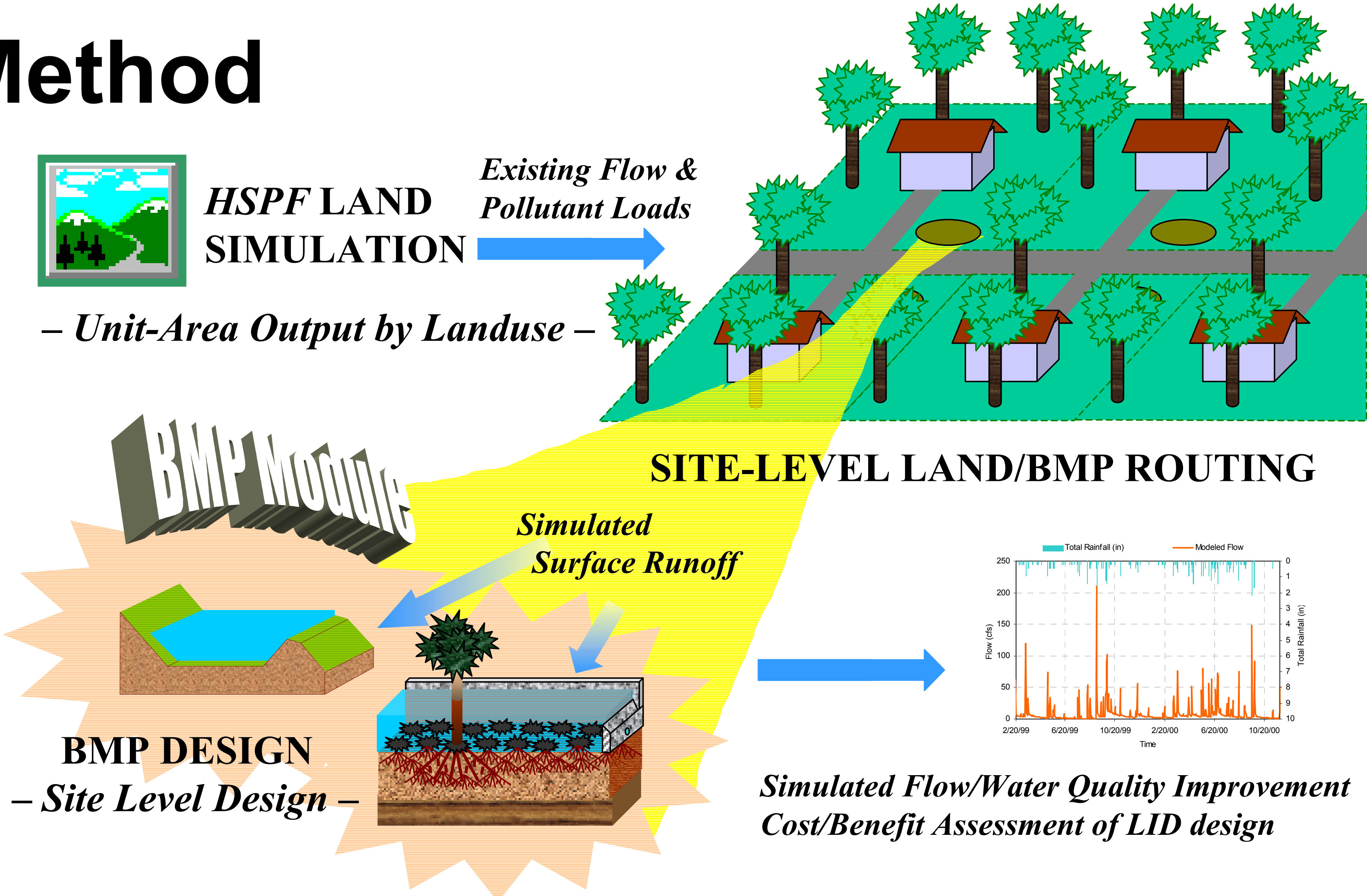
# VIEW OF LOT WITH STORAGE AND BIORETENTION


MUSIC - Model for Urban Stormwater Improvement Conceptualisation - [Original Drainage Strategy]
File Edit Catchment Tools Window Help
Vegetated Swale
Buffer Strip
Dry & Wet
Detention Pond
Infiltration
Gross
Pollutant Trap
Wetlands
Source
Node
Vegetated Swale
Urban
Buffer
Swale
Pond
Wetland
Infiltration
Receiving Node
GPT

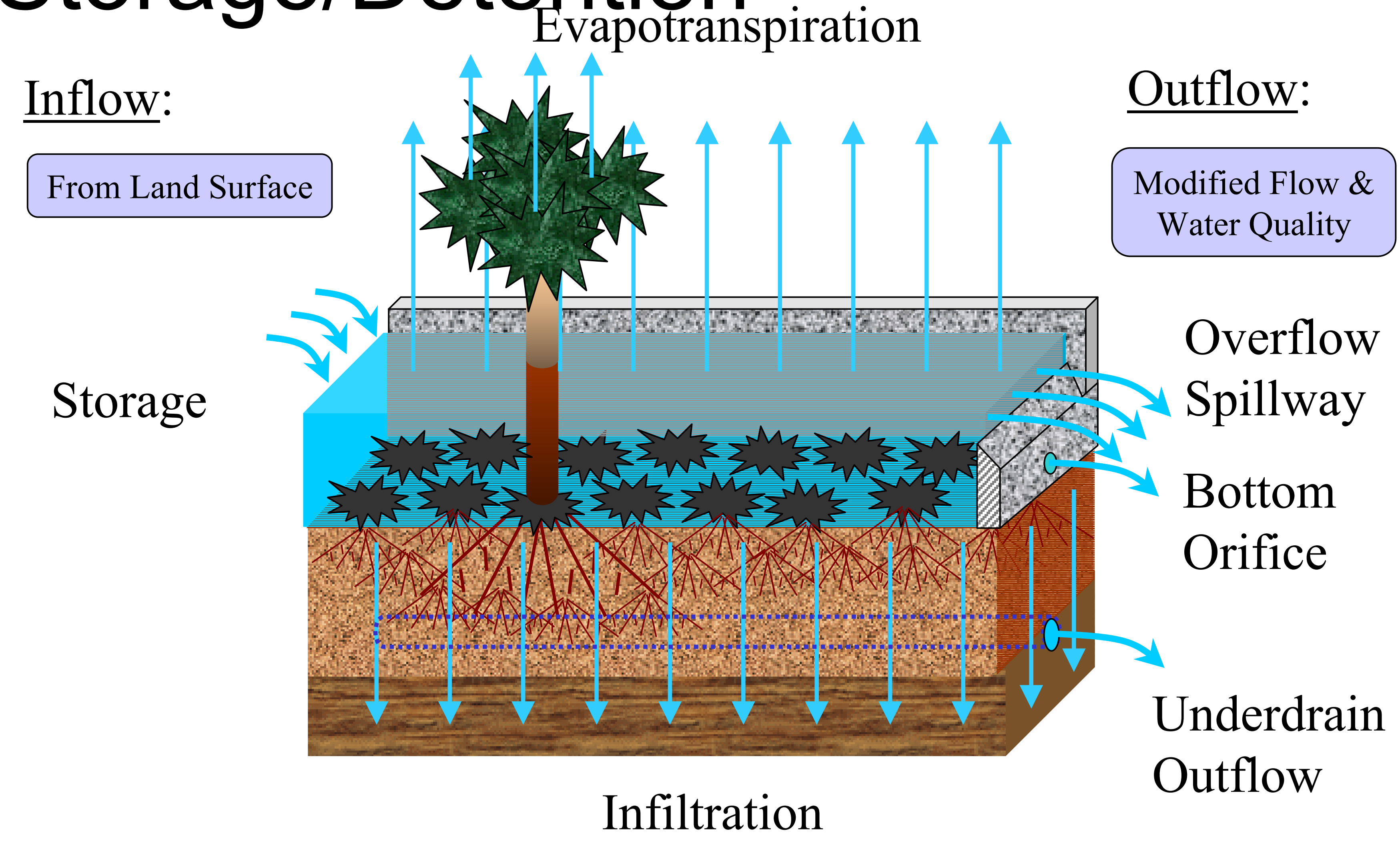

MUSIC - Model for Urban Stormwater Improvement Conceptualisation - [[New Catchment 1]]
File
Edit
Catchment
Tools
Window
Help
Urban
Wetland
Buffer
Infiltration
Swale
TIPPING BUCKET RAIN GAUGE
STORM RUNOFF RETENTION TRENCH
OVERFLOW TO STREET DRAINAGE NETWORK
RESERVE
PERFORATED LID
REAR-OF-LOT PIPE
REAR-OF-LOT PIPE CONVEYING STORM RUNOFF FROM HOUSES TO GRAVEL FILLED TRENCH
DETAIL OF INLET STANDPIPE

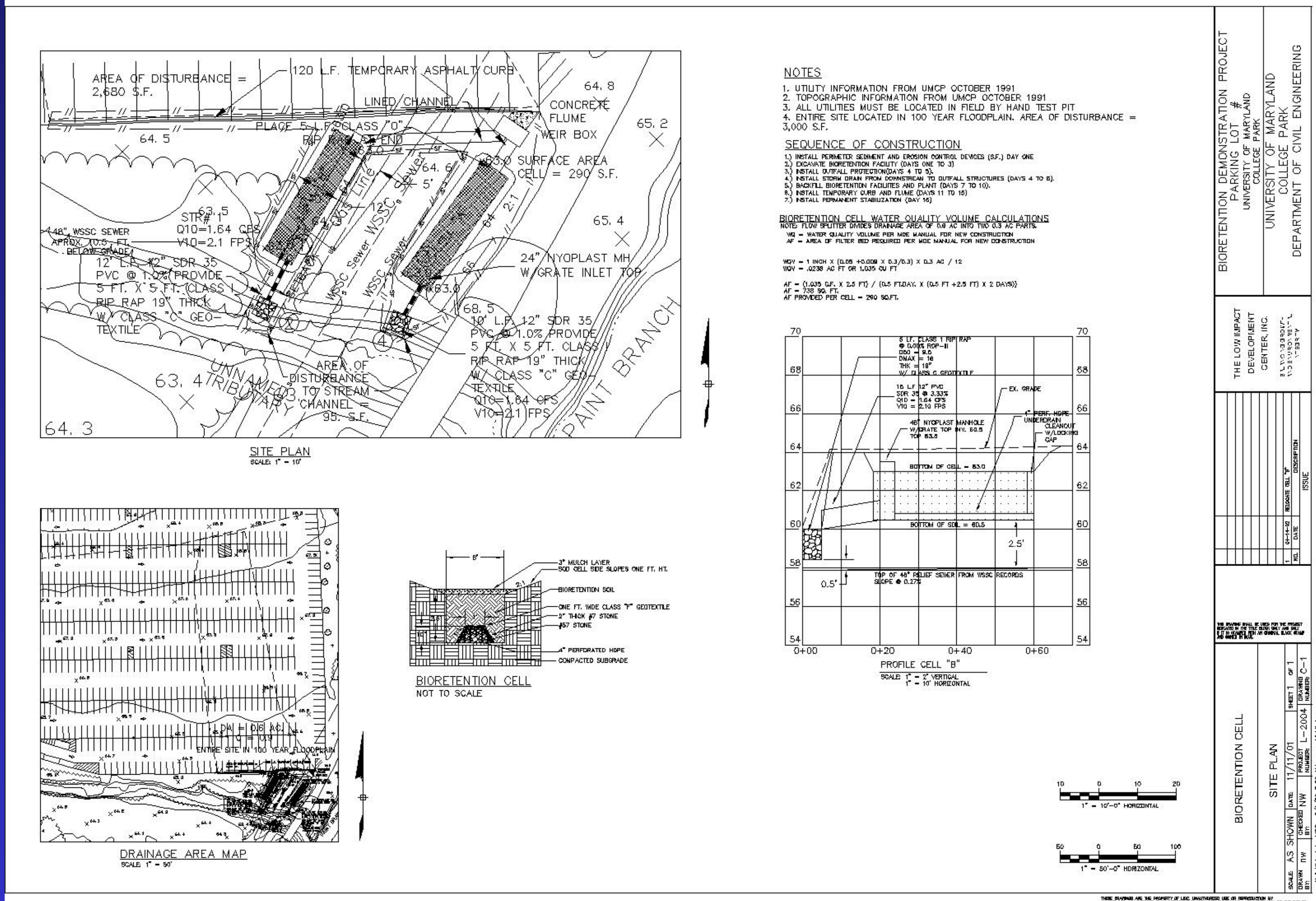

MUSIC - Model for Urban Stormwater Improvement Concep...
File
Edit
Catchment
Tools
Window
Help
urban
Swale
urban
urban
urban
Buffer
Swale
Pond
Infiltration
Infiltration
Receiving Node
DWELLING

# BMP Evaluation Method

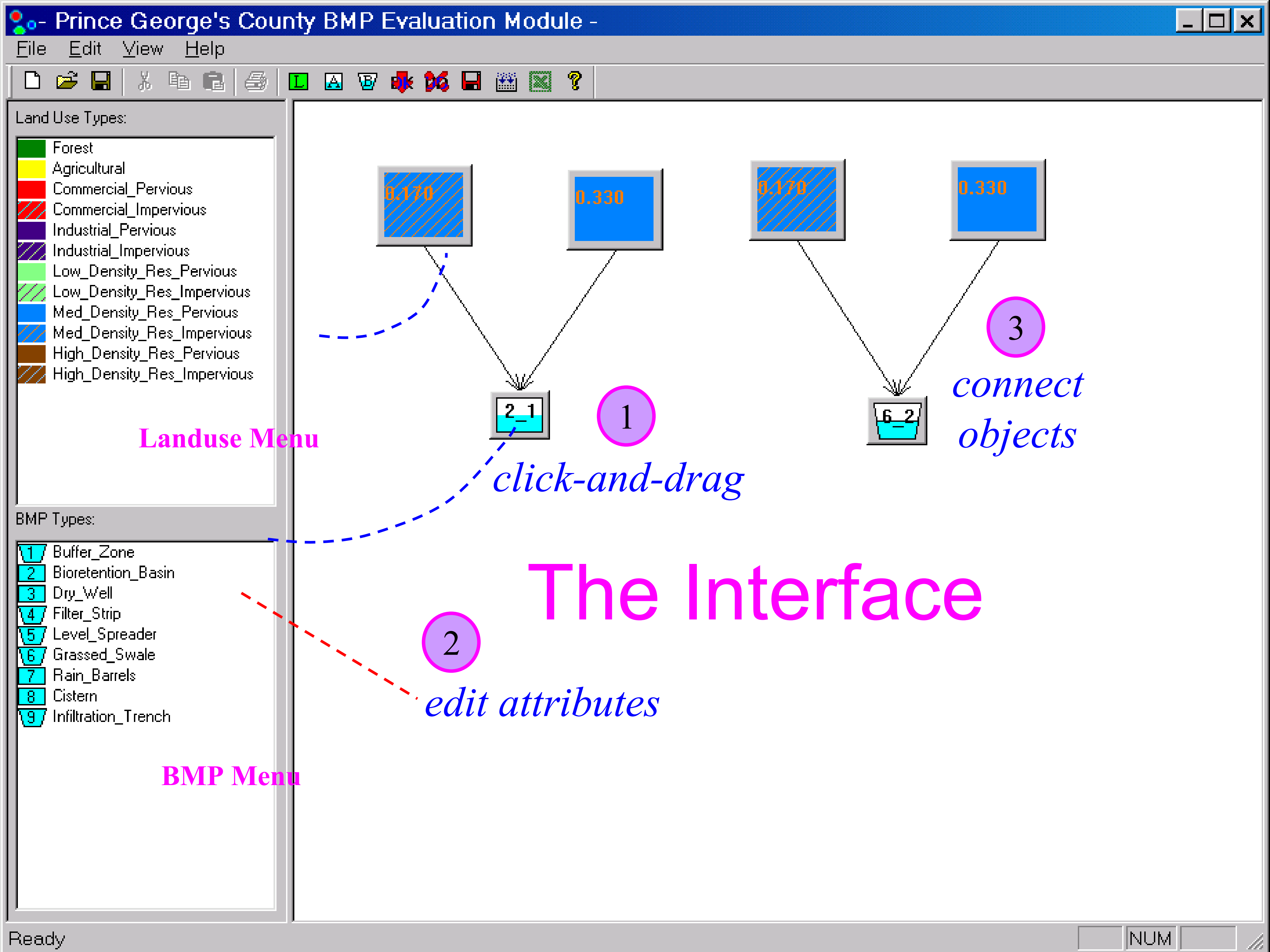


# BMP Class A: Storage/Detention



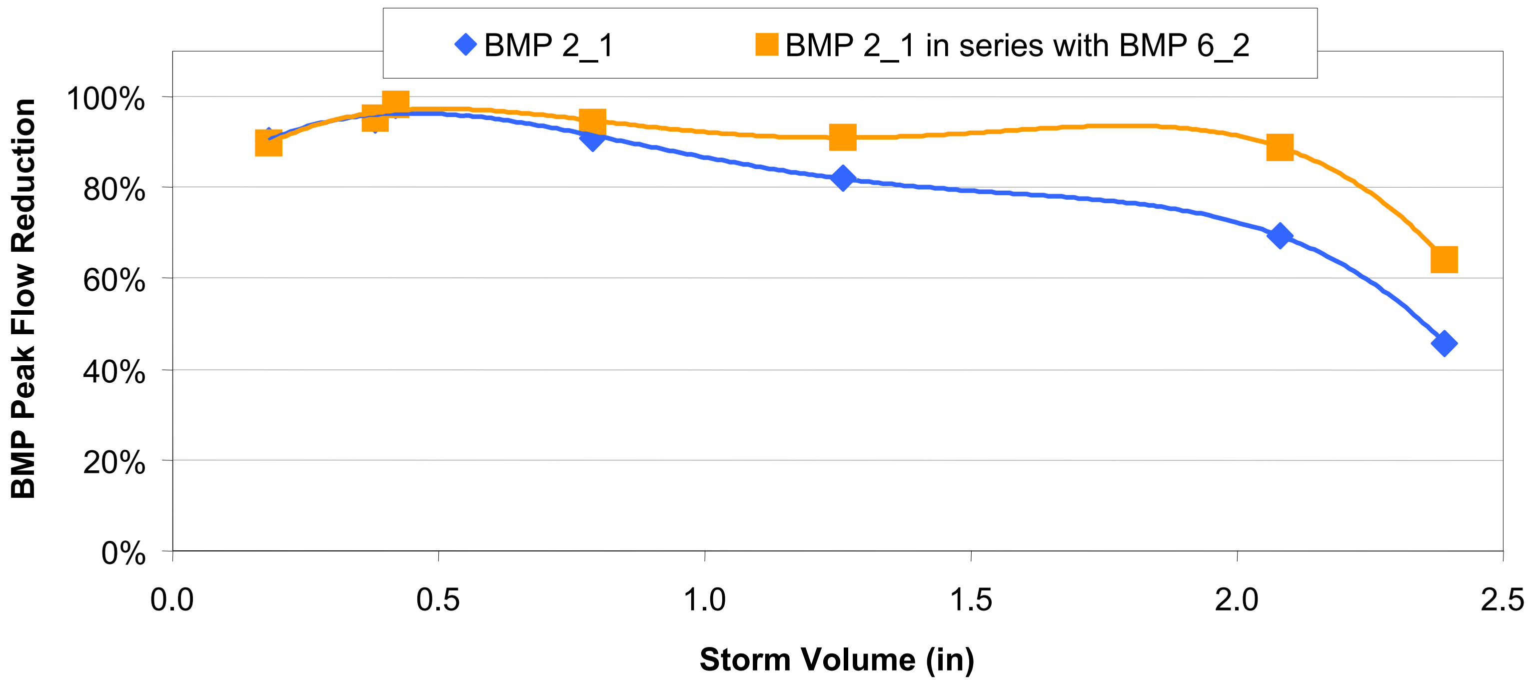

AREA OF DISTURBANCE = 2,680 S.F.
120 L.F. TEMPORARY ASPHALT CURB
LINED CHANNEL
CONCRETE FLUME
WEIR BOX
SURFACE AREA CELL = 290 S.F.
24" NYOPLAST MH W/GRATE INLET TOP
UNNAMED TRIBUTARY
PAINT BRANCH
SITE PLAN
SCALE: 1" = 10'
NOTES
1. UTILITY INFORMATION FROM UMCP OCTOBER 1991
2. TOPOGRAPHIC INFORMATION FROM UMCP OCTOBER 1991
3. ALL UTILITIES MUST BE LOCATED IN FIELD BY HAND TEST PIT
4. ENTIRE SITE LOCATED IN 100 YEAR FLOODPLAIN. AREA OF DISTURBANCE = 3,000 S.F.
SEQUENCE OF CONSTRUCTION
1.) INSTALL PERIMETER SEDIMENT AND EROSION CONTROL DEVICES (S.F.) DAY ONE
2.) EXCAVATE BIORETENTION FACILITY (DAYS ONE TO 3)
3.) INSTALL OUTFALL PROTECTION(DAYS 4 TO 5).
4.) INSTALL STORM DRAIN FROM DOWNSTREAM TO OUTFALL STRUCTURES (DAYS 4 TO 6).
5.) BACKFILL BIORETENTION FACILITIES AND PLANT (DAYS 7 TO 10).
6.) INSTALL TEMPORARY CURB AND FLUME (DAYS 11 TO 15)
7.) INSTALL PERMANENT STABILIZATION (DAY 16)
BIORETENTION CELL WATER QUALITY VOLUME CALCULATIONS
NOTE: FLOW SPLITTER DIVIDES DRAINAGE AREA OF 0.6 AC INTO TWO 0.3 AC PARTS.
WQ = WATER QUALITY VOLUME PER MDE MANUAL FOR NEW CONSTRUCTION
AF = AREA OF FILTER BED REQUIRED PER MDE MANUAL FOR NEW CONSTRUCTION
WQV = 1 INCH X (0.05 +0.009 X 0.3/0.3) X 0.3 AC / 12
WQV = .0238 AC FT OR 1,035 CU FT
AF = (1,035 C.F. X 2.5 FT) / (0.5 FT/DAY X (0.5 FT +2.5 FT) X 2 DAYS))
AF = 738 SQ. FT.
AF PROVIDED PER CELL = 290 SQ.FT.
PROFILE CELL "B"
SCALE: 1" = 2' VERTICAL
1" = 10' HORIZONTAL
BIORETENTION CELL
NOT TO SCALE
DRAINAGE AREA MAP
SCALE: 1" = 50'
ENTIRE SITE IN 100 YEAR FLOODPLAIN
BIORETENTION DEMONSTRATION PROJECT
PARKING LOT #
UNIVERSITY OF MARYLAND
COLLEGE PARK
UNIVERSITY OF MARYLAND
COLLEGE PARK
DEPARTMENT OF CIVIL ENGINEERING
THE LOW IMPACT DEVELOPMENT CENTER, INC.
BIORETENTION CELL
SITE PLAN
AS SHOWN
11/11/01
L-2004
C-1


UMCP Bioretention

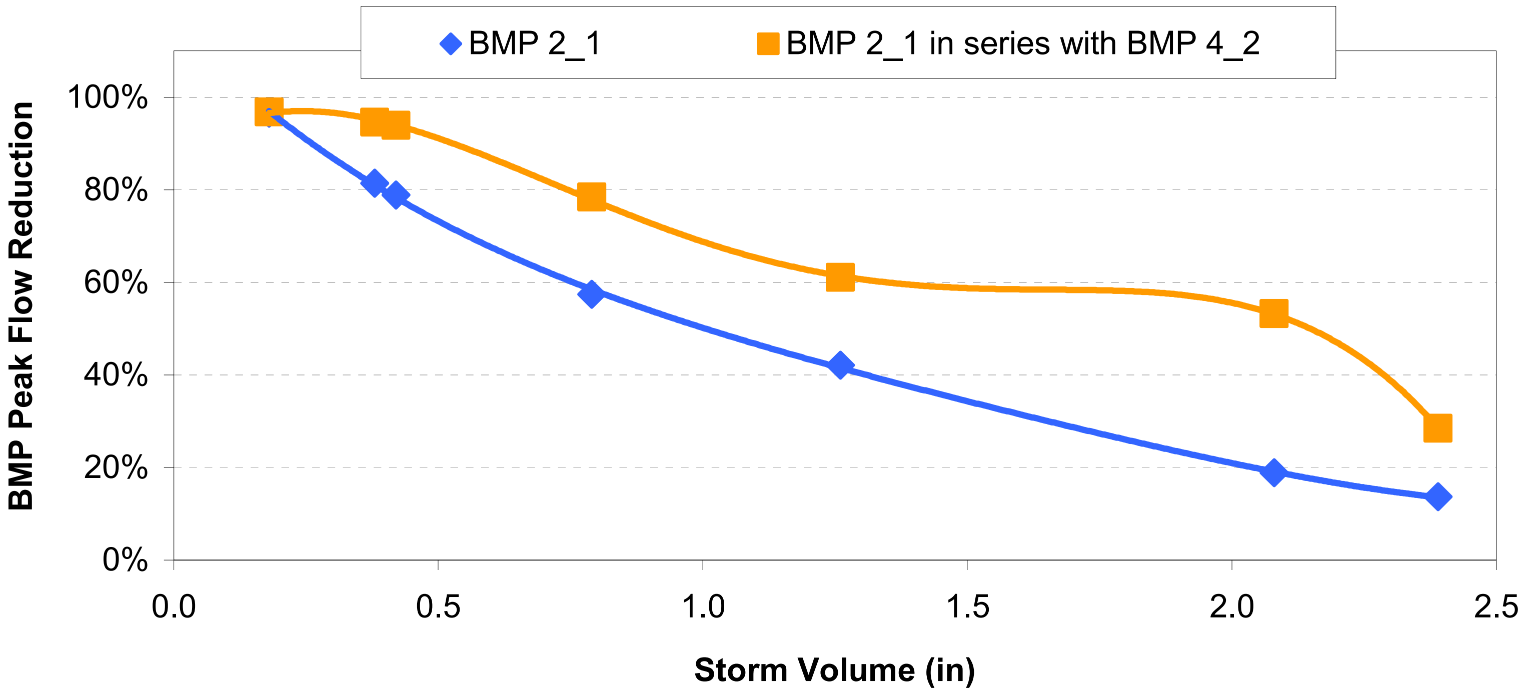


Prince George's County BMP Evaluation Module -
File Edit View Help
Land Use Types:
Forest
Agricultural
Commercial_Pervious
Commercial_Impervious
Industrial_Pervious
Industrial_Impervious
Low_Density_Res_Pervious
Low_Density_Res_Impervious
Med_Density_Res_Pervious
Med_Density_Res_Impervious
High_Density_Res_Pervious
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
The Interface
Ready
NUM

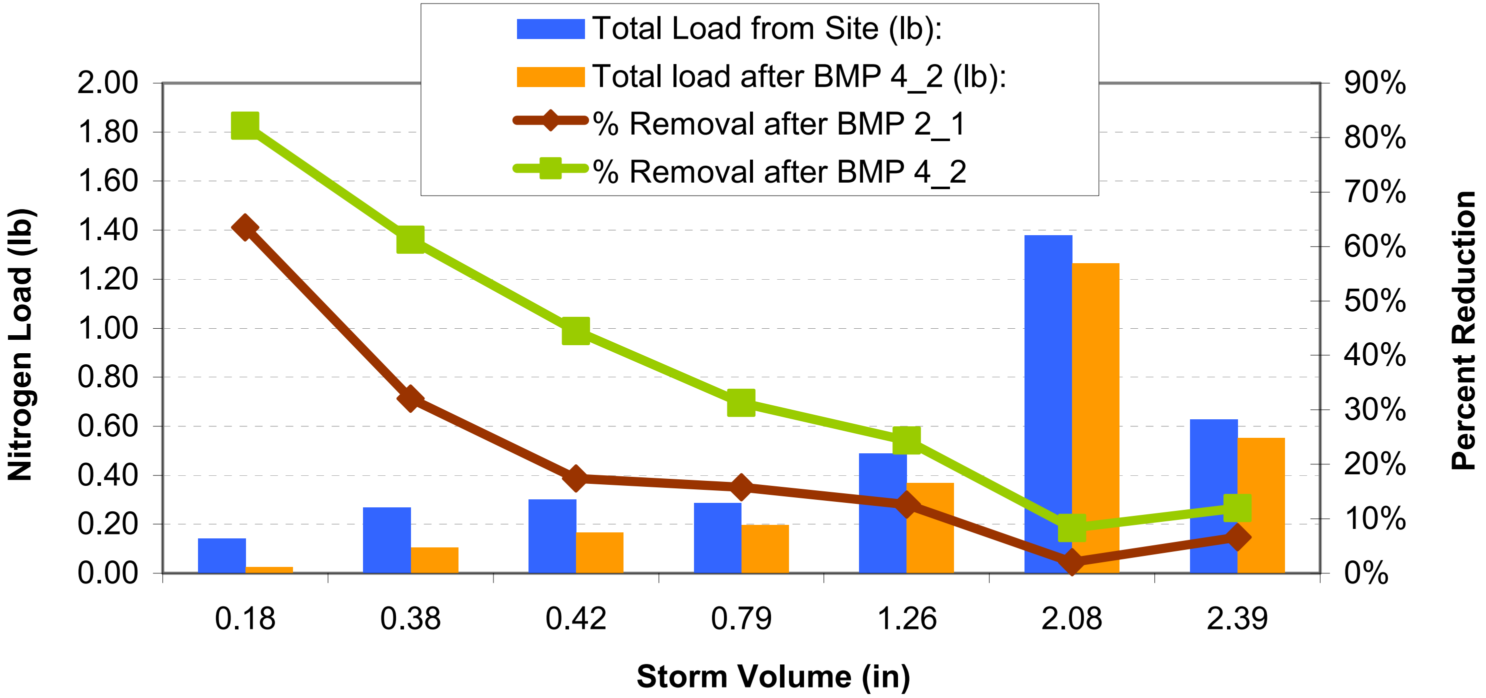
| General Assessment of BMP Effectiveness | | | | | | | |
|---|---|---|---|---|---|---|---|
| Storm Volume (in) | 0.180 | 0.380 | 0.420 | 0.790 | 1.260 | 2.080 | 2.390 |
| Peak Flow Reduction 2_1 | 90.3% | 94.7% | 98.0% | 90.9% | 82.1% | 69.3% | 45.7% |
| Peak Flow Reduction 6_2 | 89.7% | 95.3% | 98.3% | 94.4% | 91.1% | 88.8% | 64.0% |



| General Assessment of BMP Effectiveness | | | | | | | |
|---|---|---|---|---|---|---|---|
| Storm Volume (in) | 0.180 | 0.380 | 0.420 | 0.790 | 1.260 | 2.080 | 2.390 |
| Peak Flow Reduction 2_1 | 96.6% | 81.4% | 78.8% | 57.4% | 42.1% | 18.9% | 13.7% |
| Peak Flow Reduction 4_2 | 96.8% | 94.6% | 93.9% | 78.4% | 61.0% | 53.2% | 28.5% |

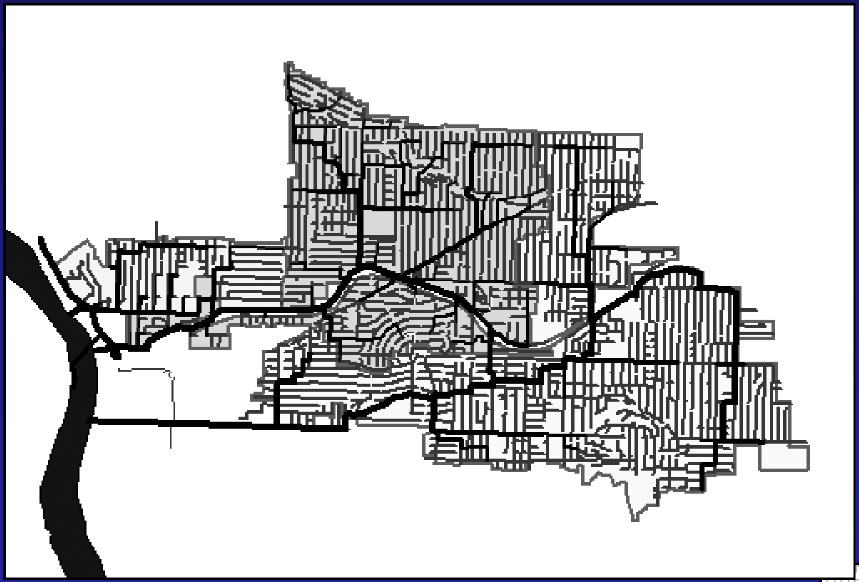


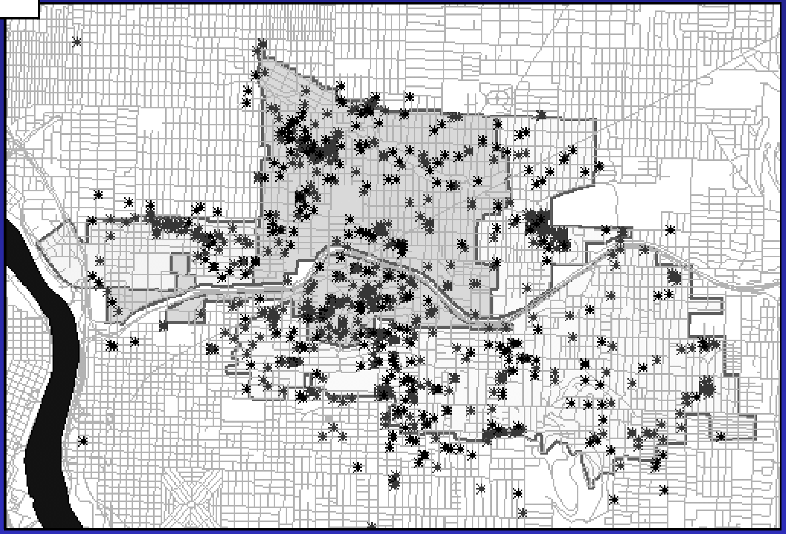
| General Assessment of BMP Effectiveness | | | | | | | |
|---|---|---|---|---|---|---|---|
| Storm Volume (in) | 0.180 | 0.380 | 0.420 | 0.790 | 1.260 | 2.080 | 2.390 |
| Total Load from Site (lb): | 0.142 | 0.269 | 0.303 | 0.287 | 0.489 | 1.379 | 0.628 |
| Total load after BMP 4_2 (lb): | 0.025 | 0.104 | 0.168 | 0.197 | 0.370 | 1.264 | 0.552 |
| Lost or Trapped (lb): | 0.117 | 0.165 | 0.135 | 0.090 | 0.119 | 0.114 | 0.075 |
| Total Nitrogen Removal (%) | 82.14% | 61.23% | 44.50% | 31.27% | 24.40% | 8.30% | 12.00% |



# Other Models

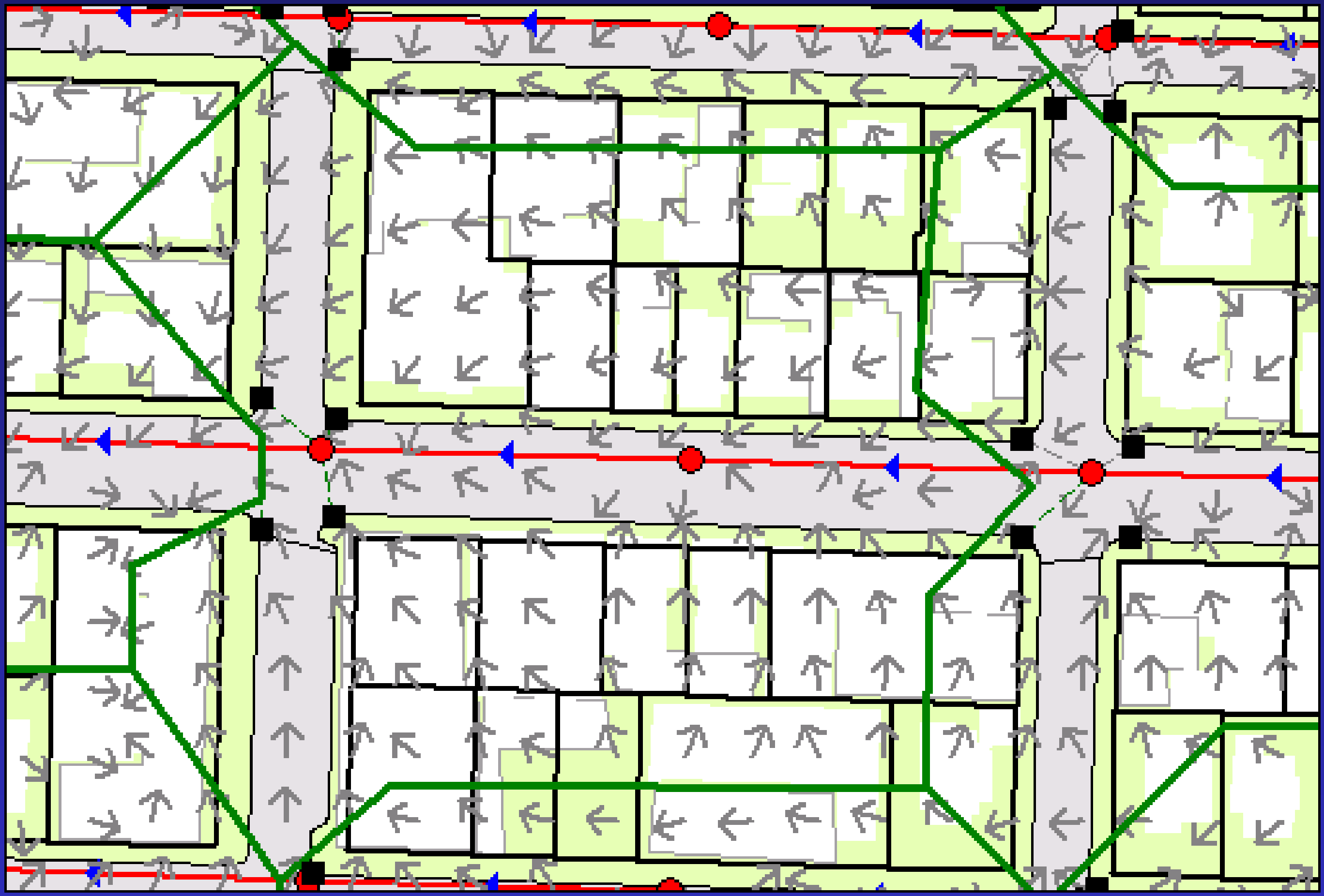
- PC SWMM/Permeable Pavers (Unilock)
- PCSLAMM/(UAB)
- SWMM for Microscale Practices (USEPA) OPTIMIZATION!!
- TR-20 Windows (NRCS)
- EPA SWMM Optimization
- Music (Monash University)
- Delaware Conservation and LID Model (TR-20)





# Lumped or Specific Issues?

How do we evaluate/monitor/model/ review/determine effectiveness

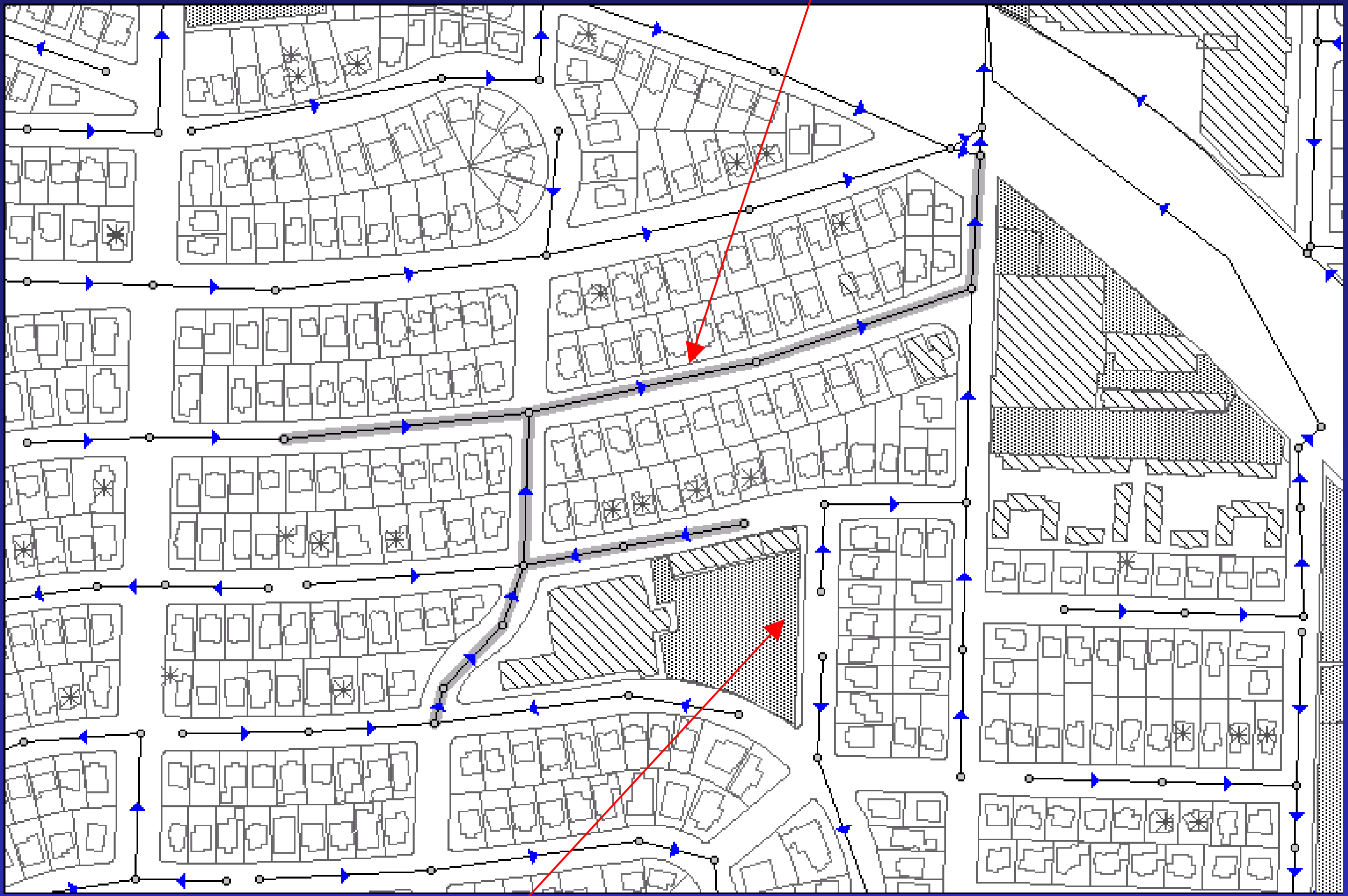


Hoffman and Crawford, 2000

# Existing Problems and Future High Risks

Hoffman and Crawford, 2000

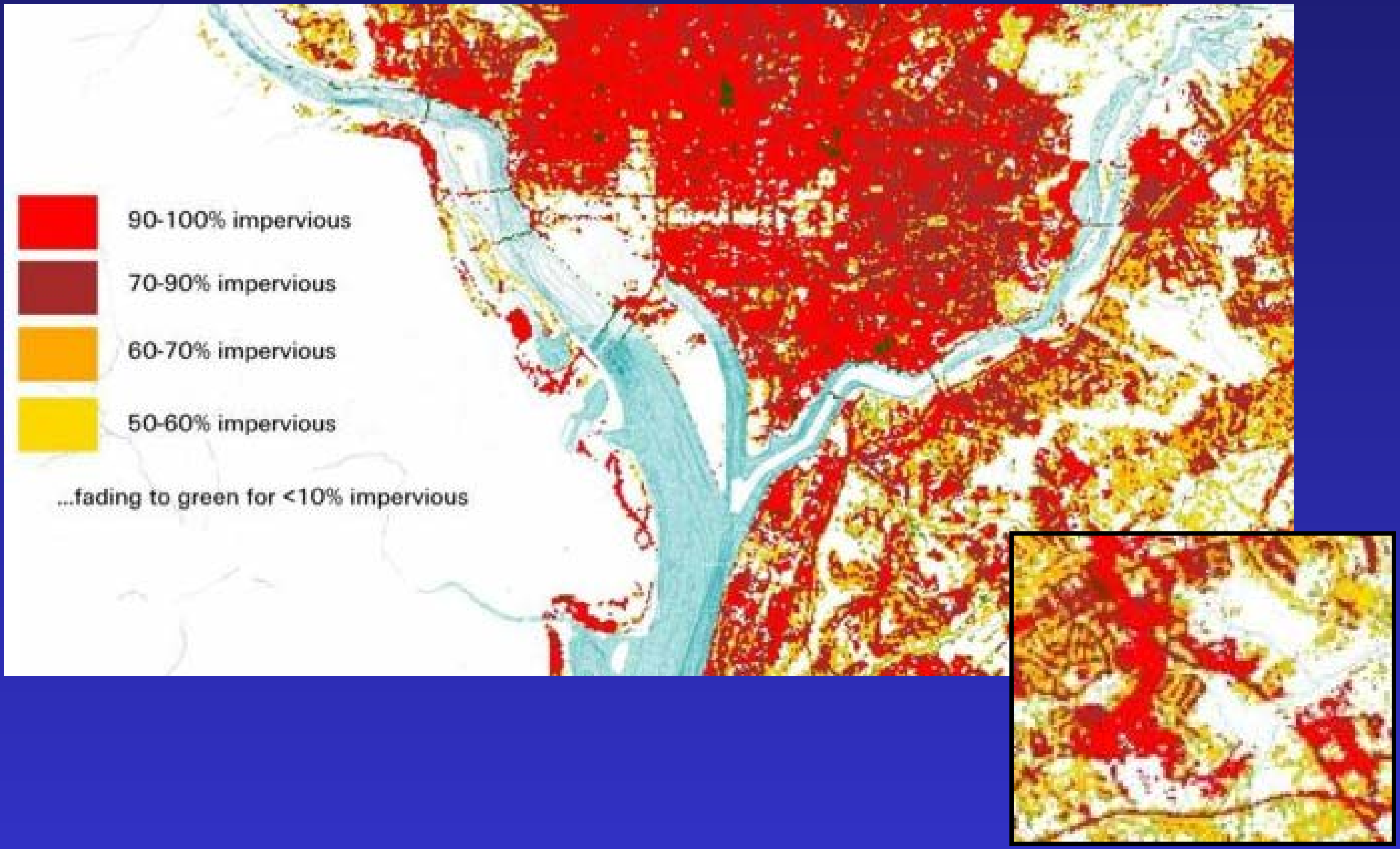
Oversize Pipes



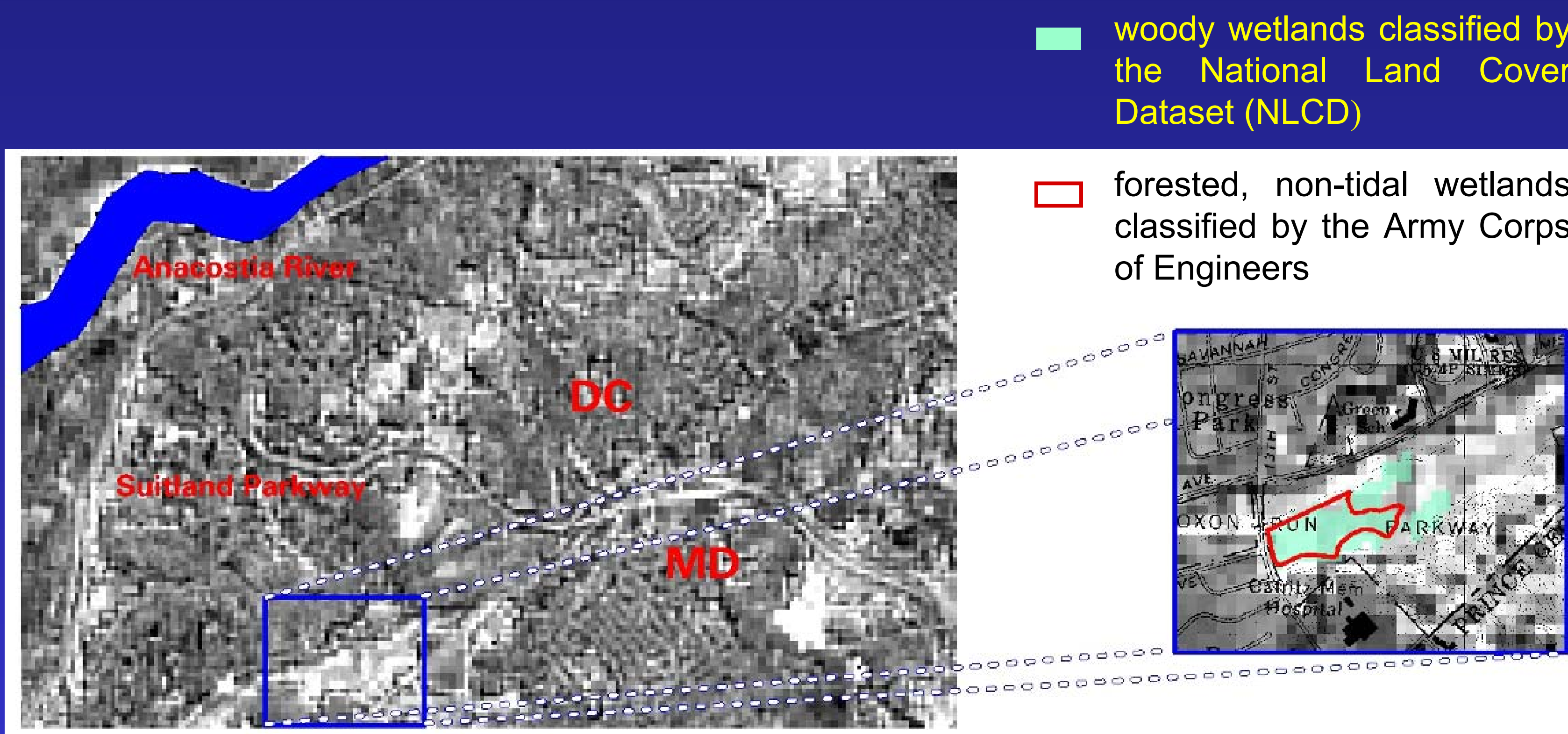
Remove Large Impervious Areas

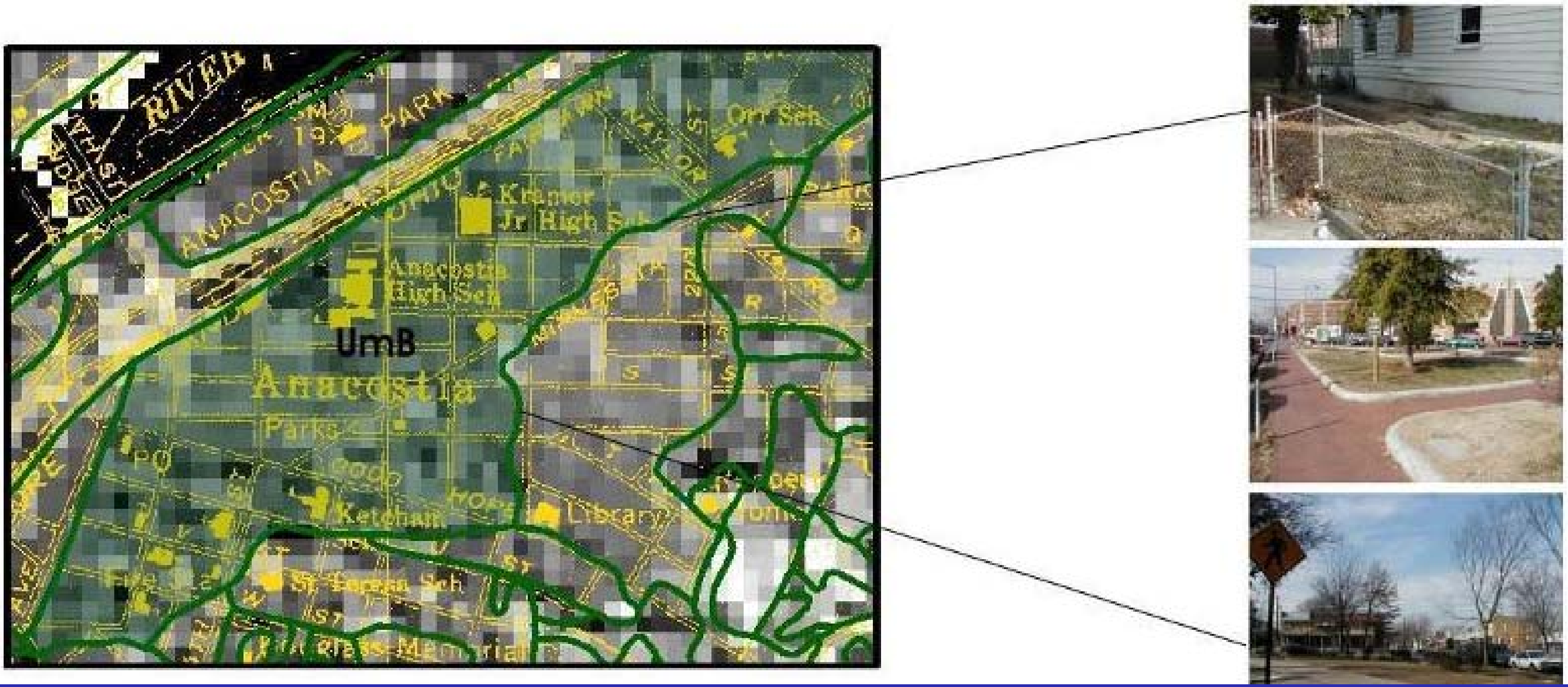
Comparison of Conventional and LID Strategies

**An estimate of imperviousness can be derived directly from the satellite image for developed areas.** (Water bodies from the USGS topographic maps are overlaid for orientation, and areas identified as undeveloped in the National Land Cover dataset are left white.)



**Soil moisture maps** can be generated using the vegetation and surface temperature data with a surface climate model. The gray-scale image is dark for surfaces with a dried out top layer and bright or white for surfaces that are wet. This information can be used to locate areas with very moist surface layers near identified wetlands that can be easily converted to wetlands themselves.






Ground Truthing Image

Good Hope Road
Tree Box Filter
Martin Luther King Jr. Boulevard
Permeable Pavement
Rain Barrel
Rain Garden
13th Street SE
U Street SE

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

$$S = \frac{1000}{CN} - 10$$

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