# 2007 MAFSM Conference

# Introduction to Low Impact Development and LID Modeling

The Low Impact Development Center, Inc.

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# Objectives

- Shortcomings of Conventional Site Design and Stormwater Management
- Components of LID
- Modeling LID
- Design Case Studies
- Future Directions

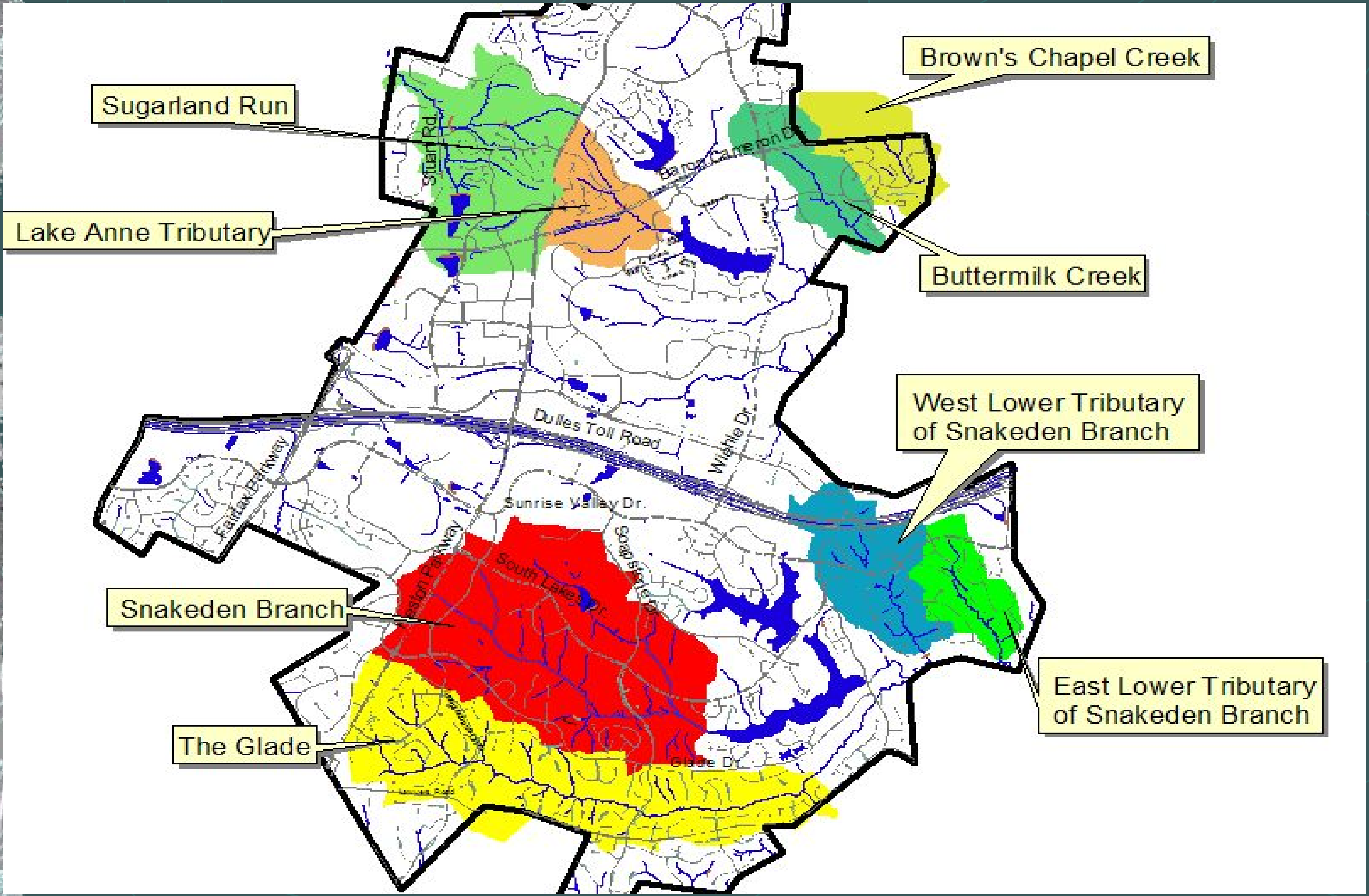

The Problem: Conventional
Site Design
Collect
Concentrate
Convey
Centralized
Control
Good Drainage Paradigm

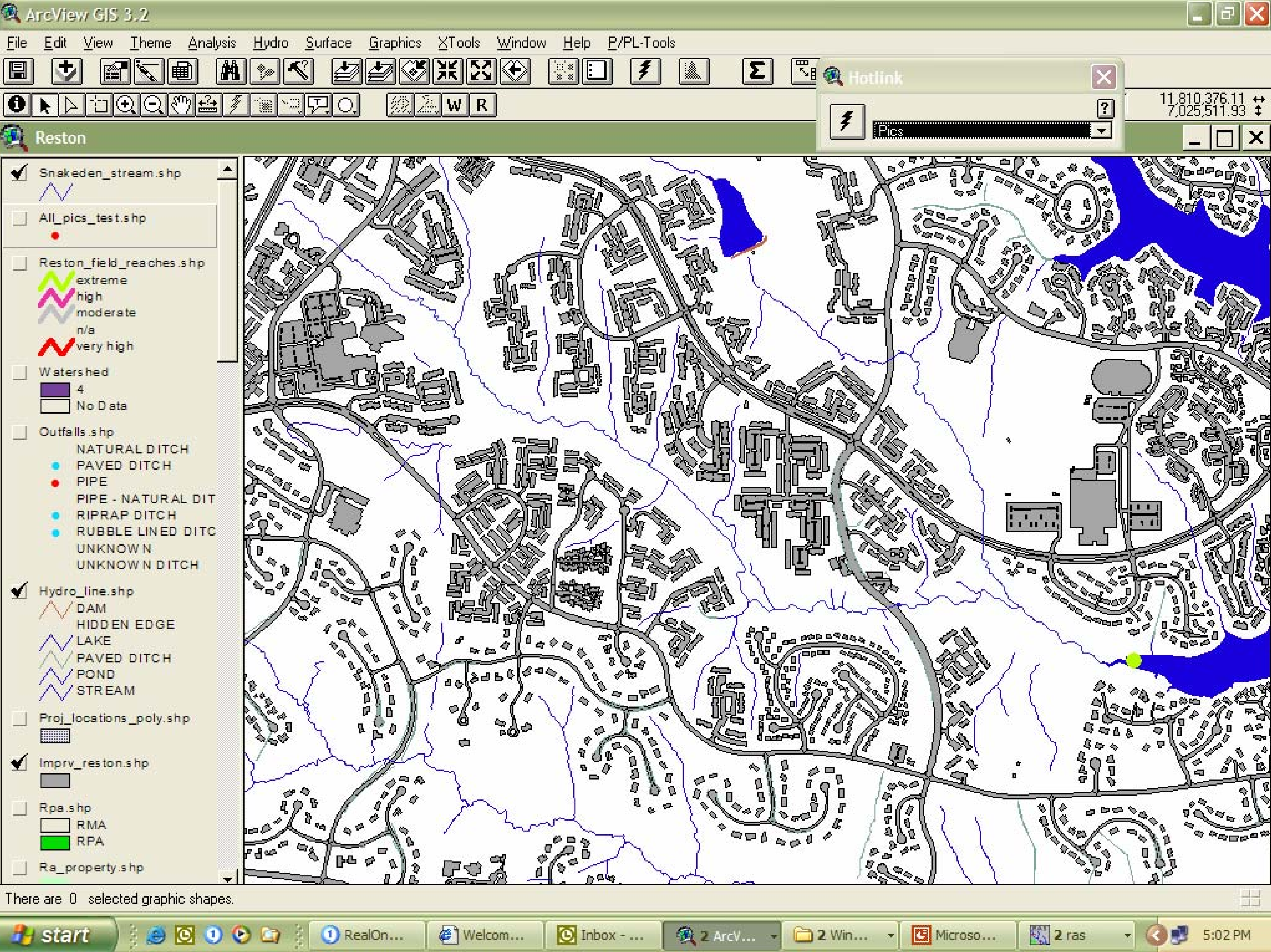

HAVERTYS
10 17'03

# Conventional Controls

- Primarily concerned with hydraulic control – reducing peak discharge flow rate
- Fail to address the increased volume of stormwater generated from development
- Fail to address the increase in the frequency of erosive runoff events
- Fail to consider watershed criteria

# Reston Watershed Management Planning

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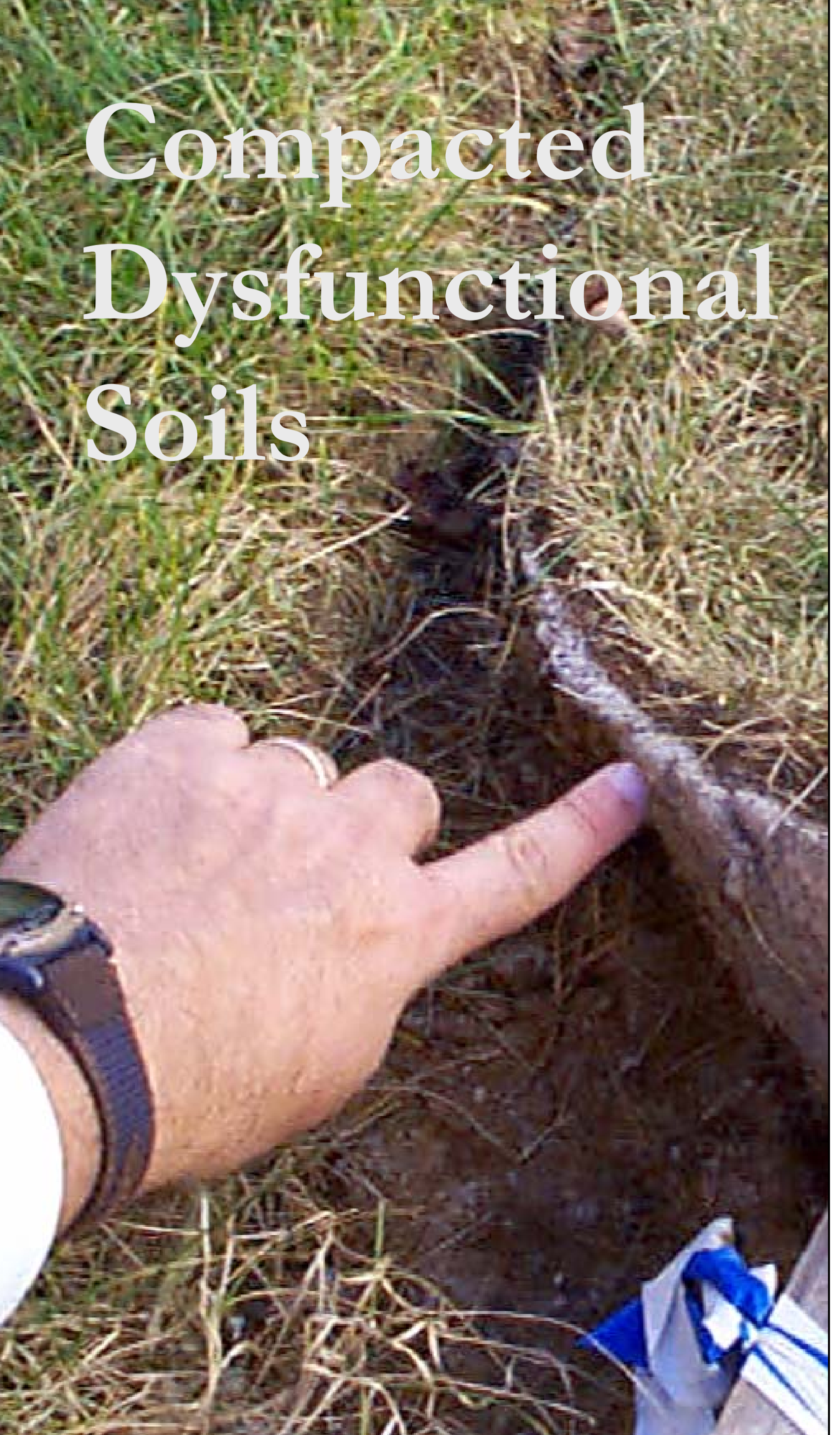
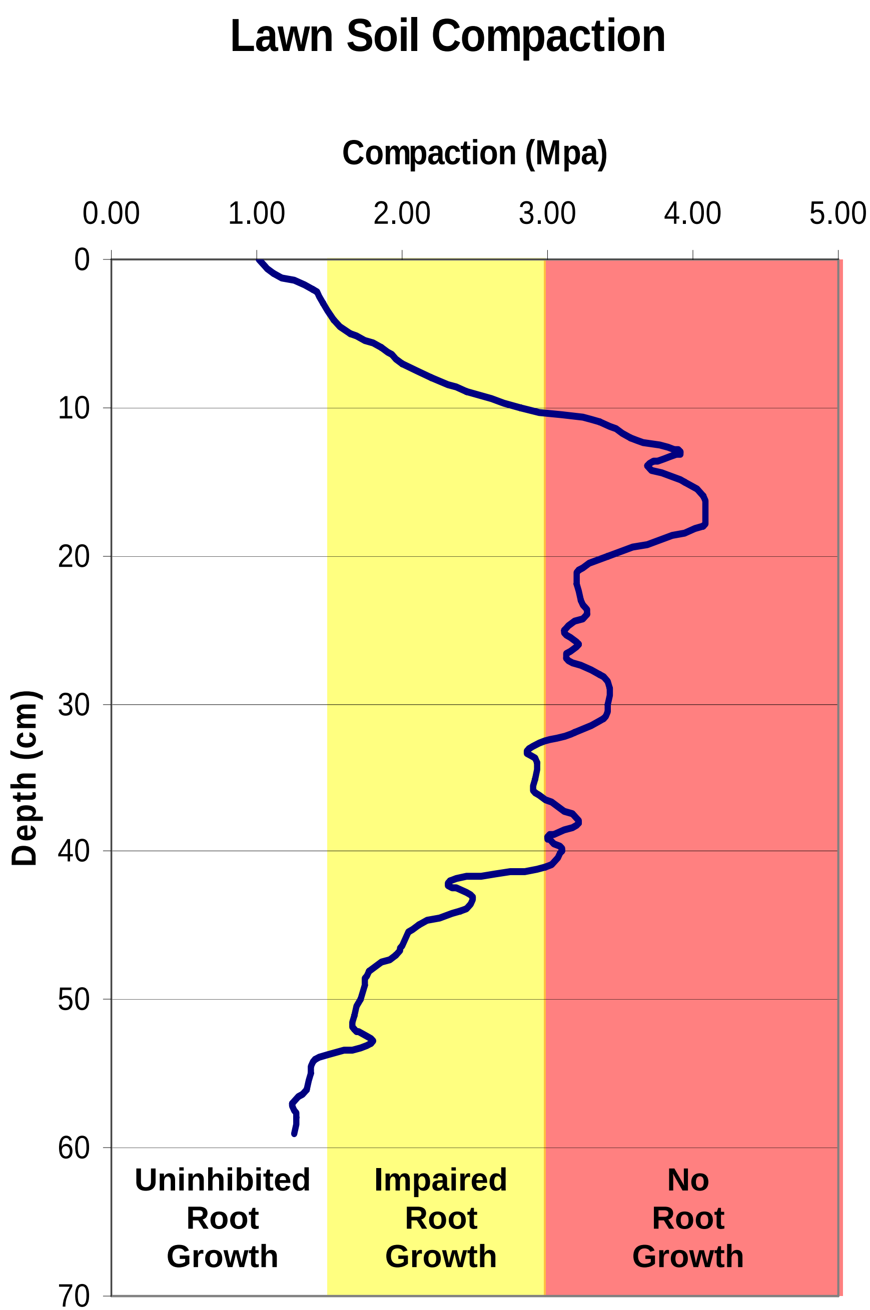
## Buttermilk off North Shore

## Buttermilk off Ring Road

# Compacted Dysfunctional Soils






The Good Old Days!

# Low Impact Development

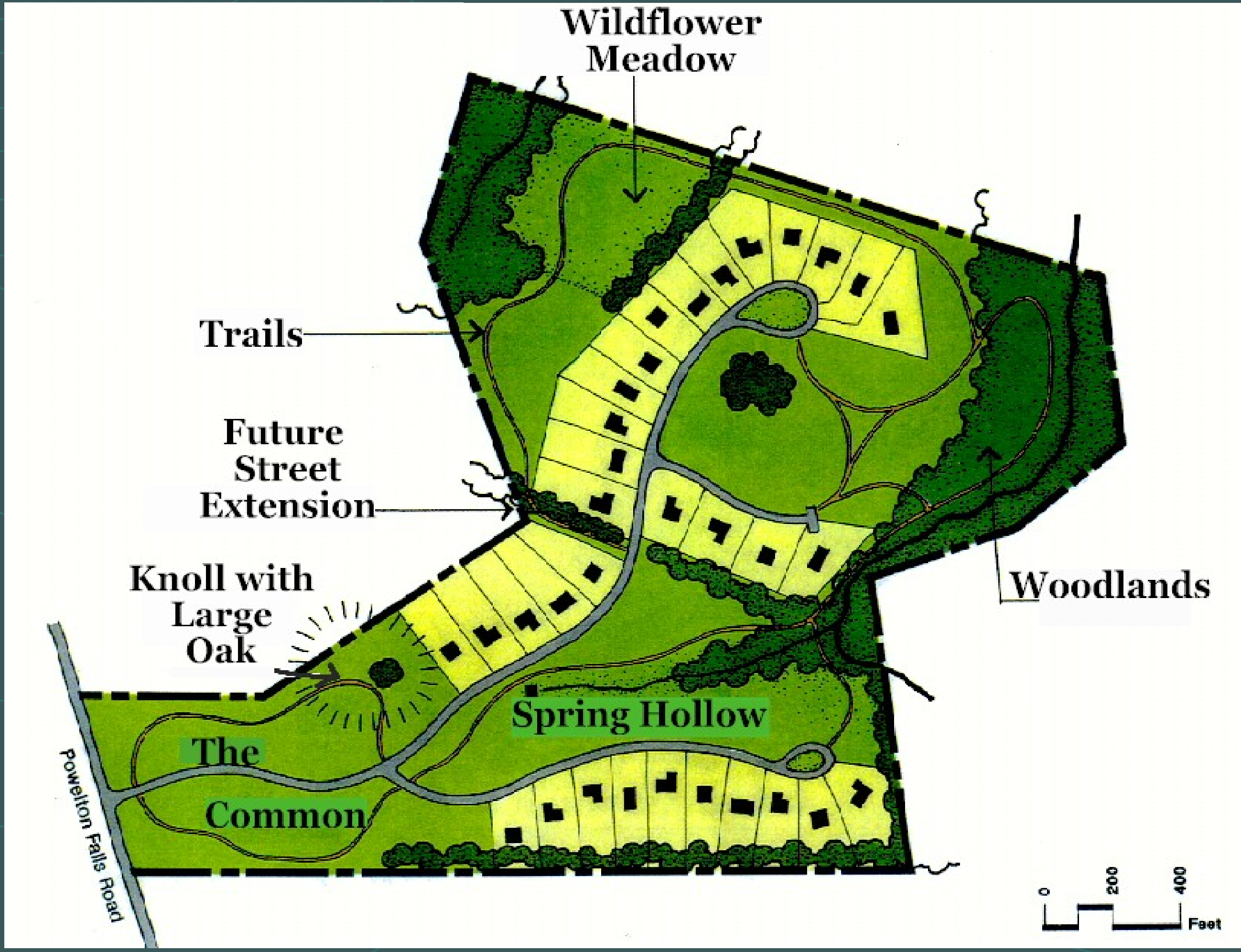
Major Components

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

# 1. Conservation Plans / Regulations

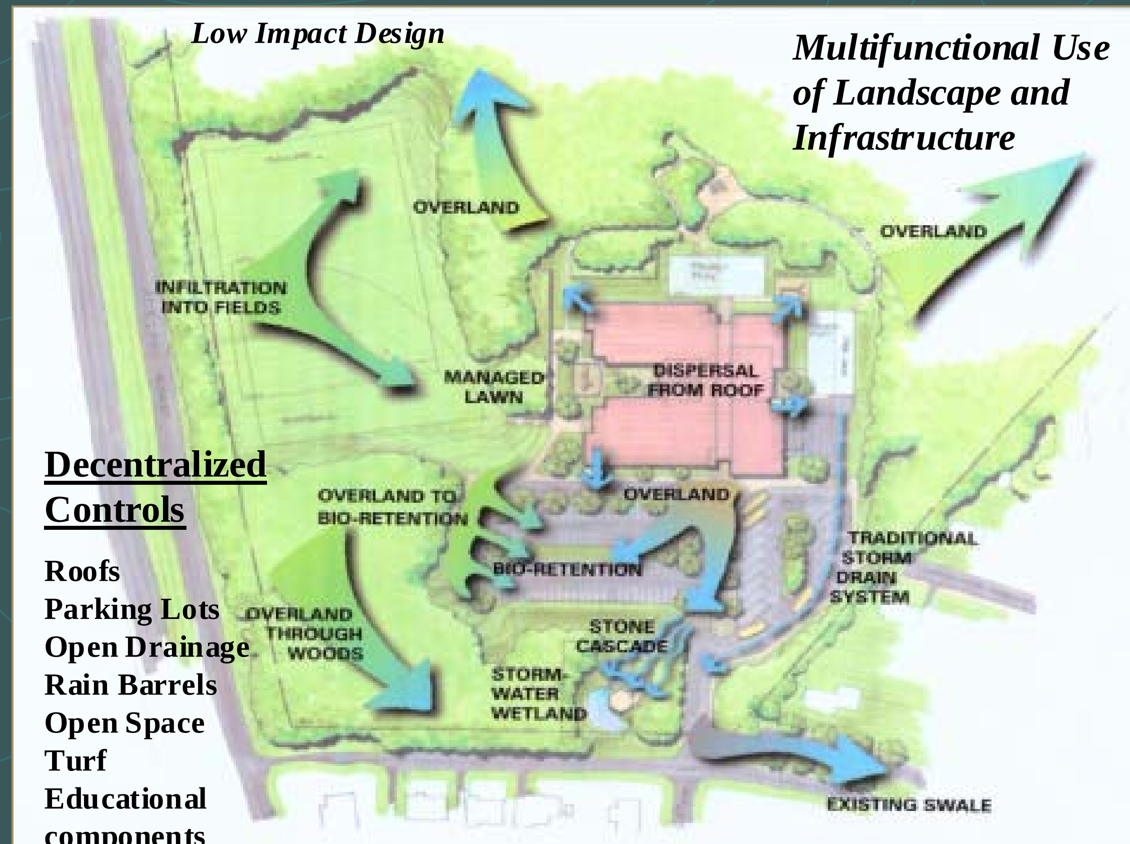
- Local Watershed and Conservation Plans
  - Forest (Contiguous and Interior Habitat)
  - Streams (Corridors)
  - Wetlands
  - Habitats
  - Step Slopes
  - Buffers
  - Critical Areas
  - Parks
  - Scenic Areas
  - Trails
  - Shorelines
  - Difficult Soils
  - Ag Lands
  - Minerals

***Large and Small Scale***



# 2. Minimize Impacts

- Minimize clearing
- Minimize grading
- Save A and B soils
- Limit lot disturbance
- Soil Amendments
- Alternative  Surfaces
- Reforestation
- Disconnect
- Reduce pipes, curb and gutters
- Reduce impervious surfaces



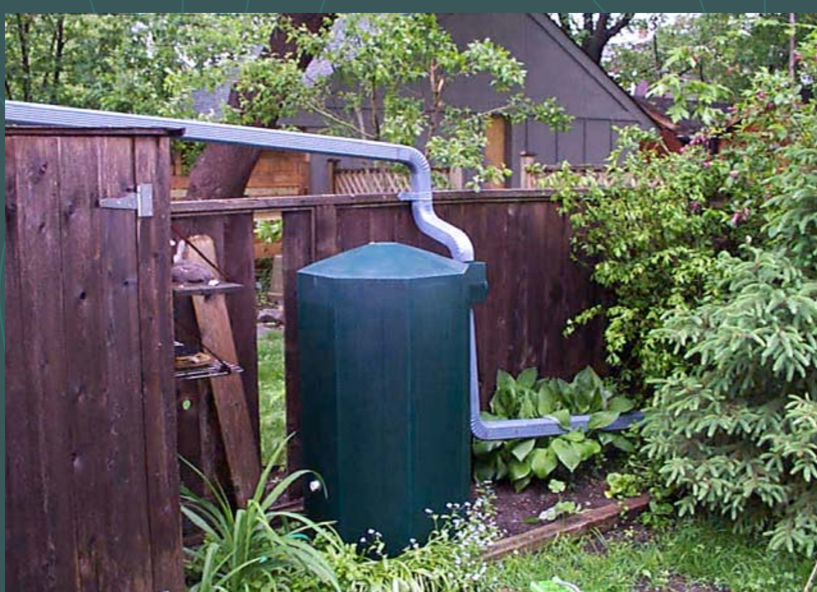
# 3. Maintain Time of Concentration and Watershed Patterns

- Open Drainage
- Use green space
- Flatten slopes
- Disperse drainage
- Lengthen flow paths
- Save headwater areas
- Vegetative swales
- Maintain natural flow paths
- Increase distance from streams
- Maximize sheet flow

# 4. Storage, Detention & Filtration
# "LID IMP's"

- Uniform Distribution at the Source
  - Open drainage swales
  - Rain Gardens / Bioretention
  - Smaller pipes and culverts
  - Small inlets
  - Depression storage
  - Infiltration
  - Rooftop storage
  - Pipe storage
  - Street storage
  - Rain Water Use
  - Soil Management

Portland BES



# 5. Pollution Prevention

***30 - 40% Reduction in N&P***

***Kettering Demonstration Project***

- Maintenance
- Proper use, handling and disposal
  - Individuals
    - Lawn / car / hazardous wastes / reporting / recycling
  - Industry
    - Good house keeping / proper disposal / reuse / spills
  - Business
    - Alternative products / Product liability


Maintenance Cost - $200 / Year
What’s a BMP?

# 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

**SEA Streets - After Construction**
**2nd Ave NW - NW 117th St to NW 120th St**

Fat Street

Skinny Street with Horizontally Challenged Person


Wetlands Mitigation?

# United States Navy Yard

# LID is Not

- A land use or zoning control
- An either this or that approach
- Independent of watershed planning
- “The” Answer

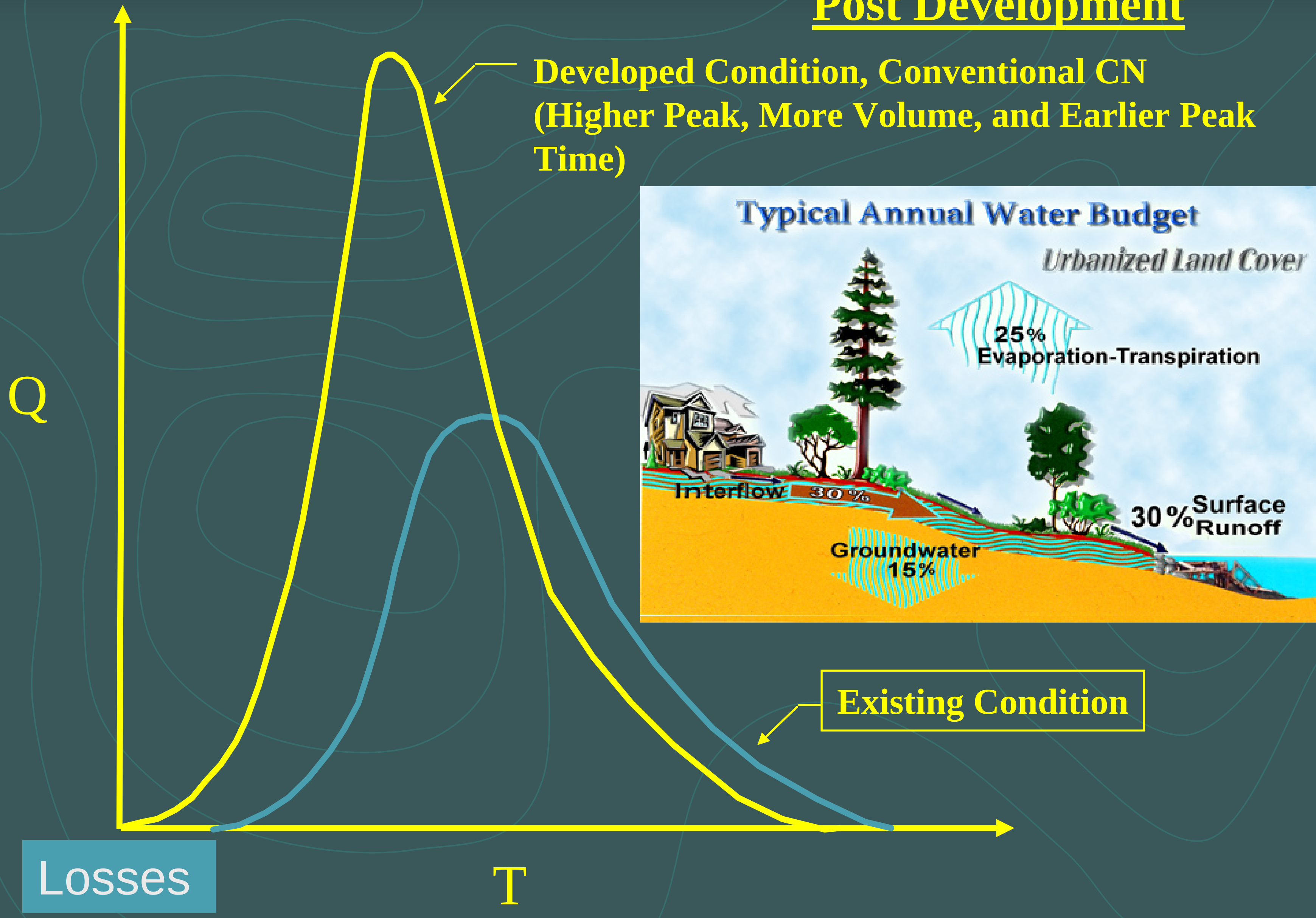
# LID is

- A Water Balance Approach to Hydrology
- A science and unit process based approach
- Decentralized and Integrated
- Technology Driven
- “The” Answer

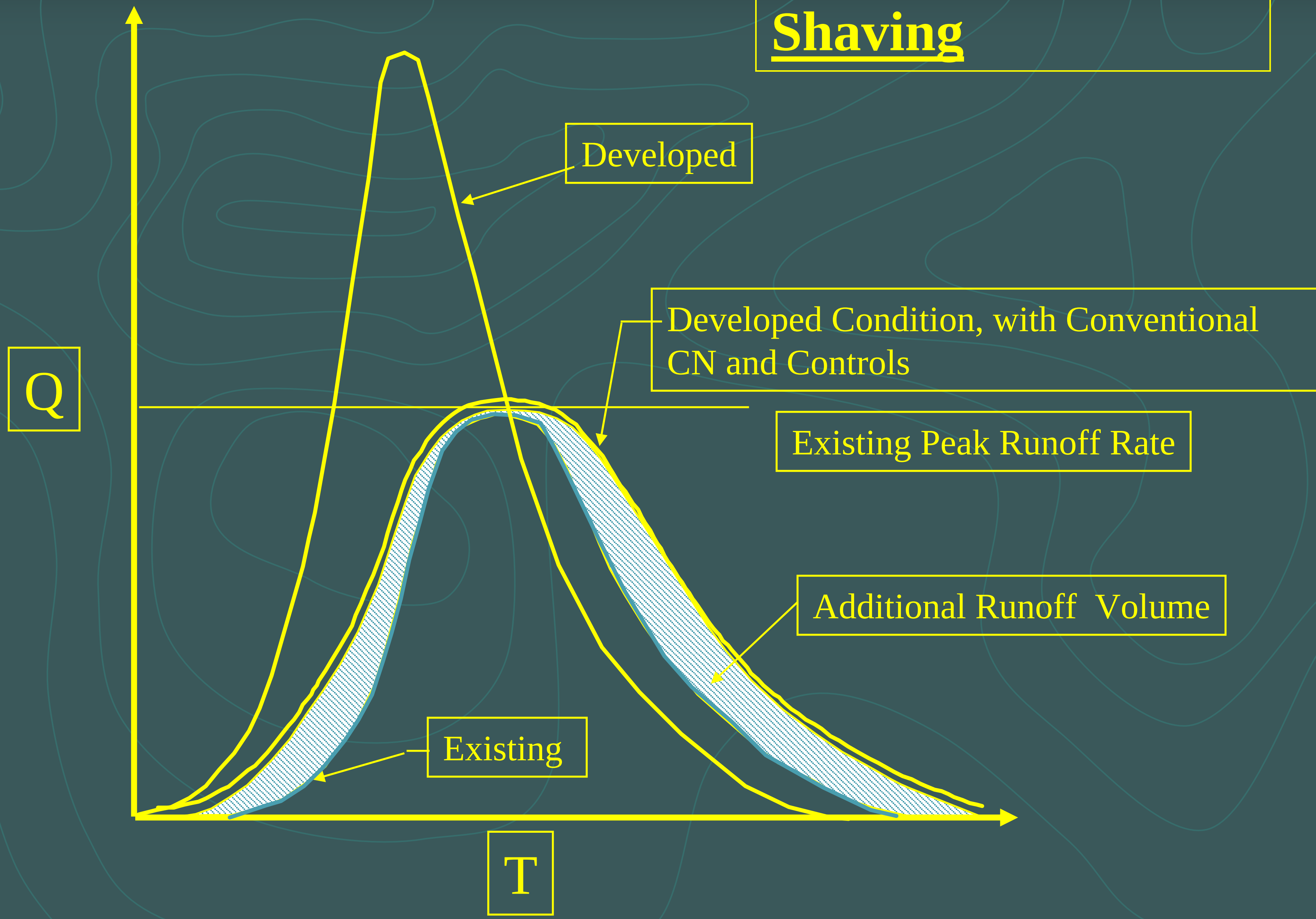
# Low-Impact Development Hydrologic Analysis and Design

- 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

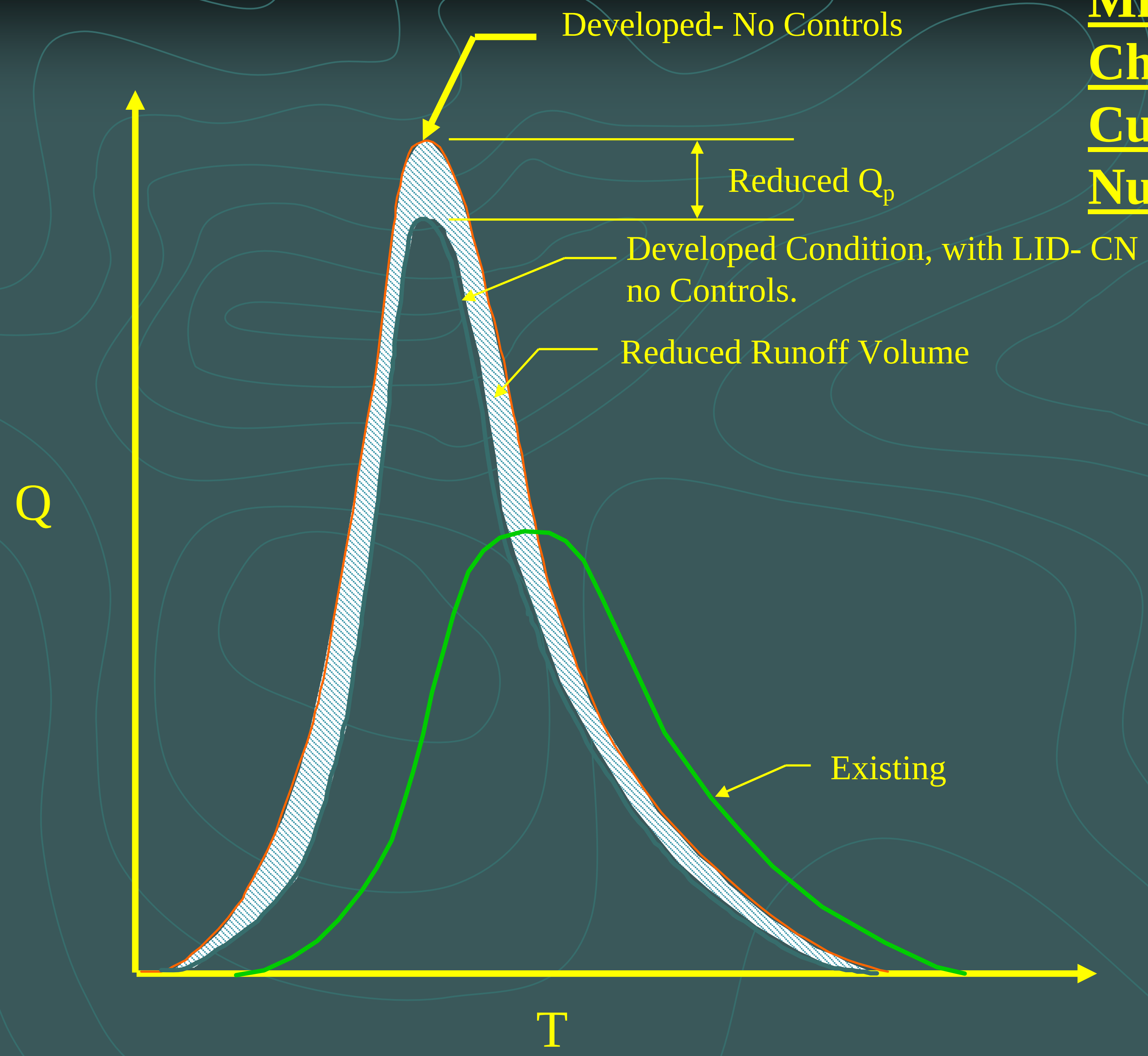
# Hydrograpgh Pre/ Post Development



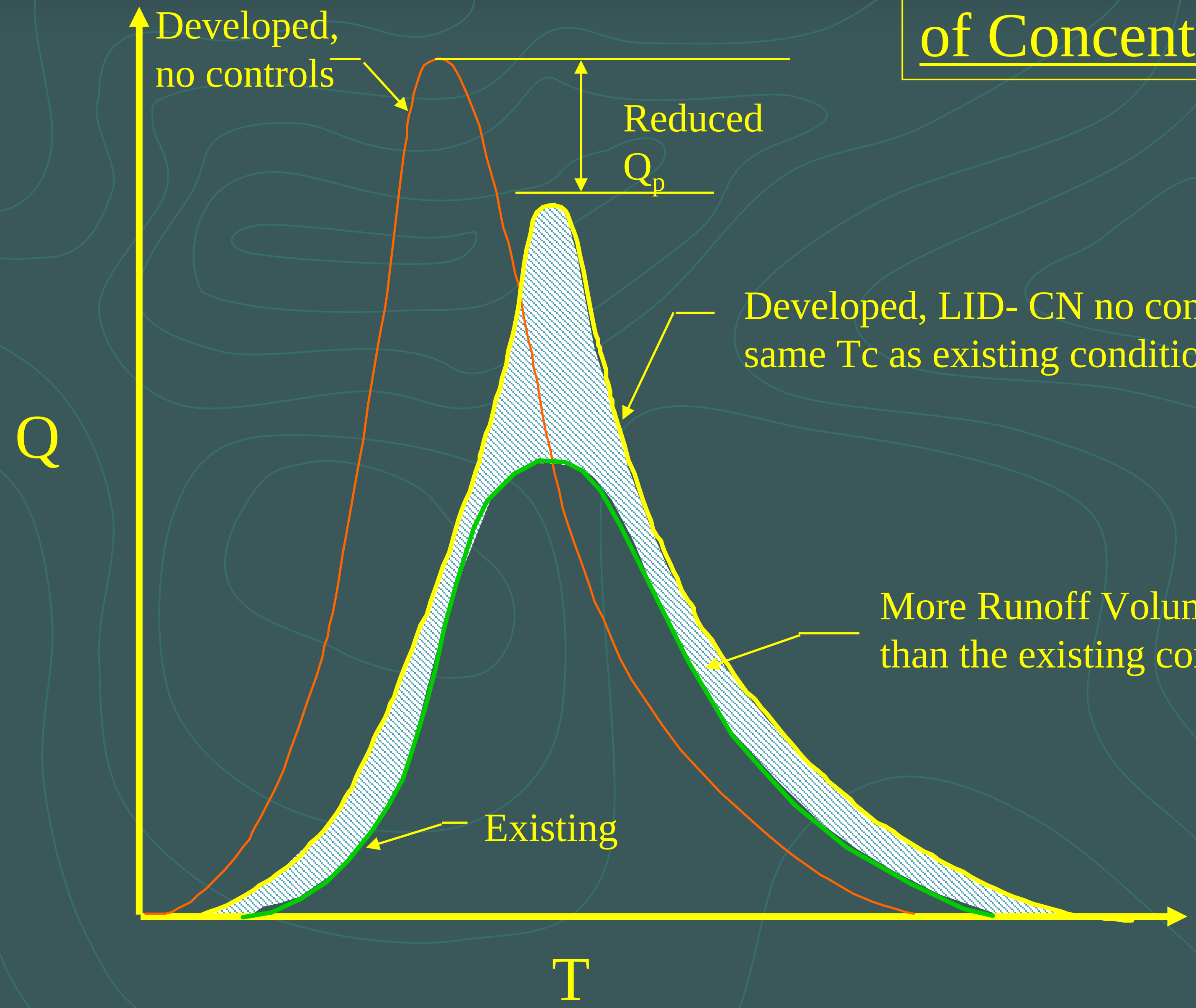
# Detention Peak Shaving



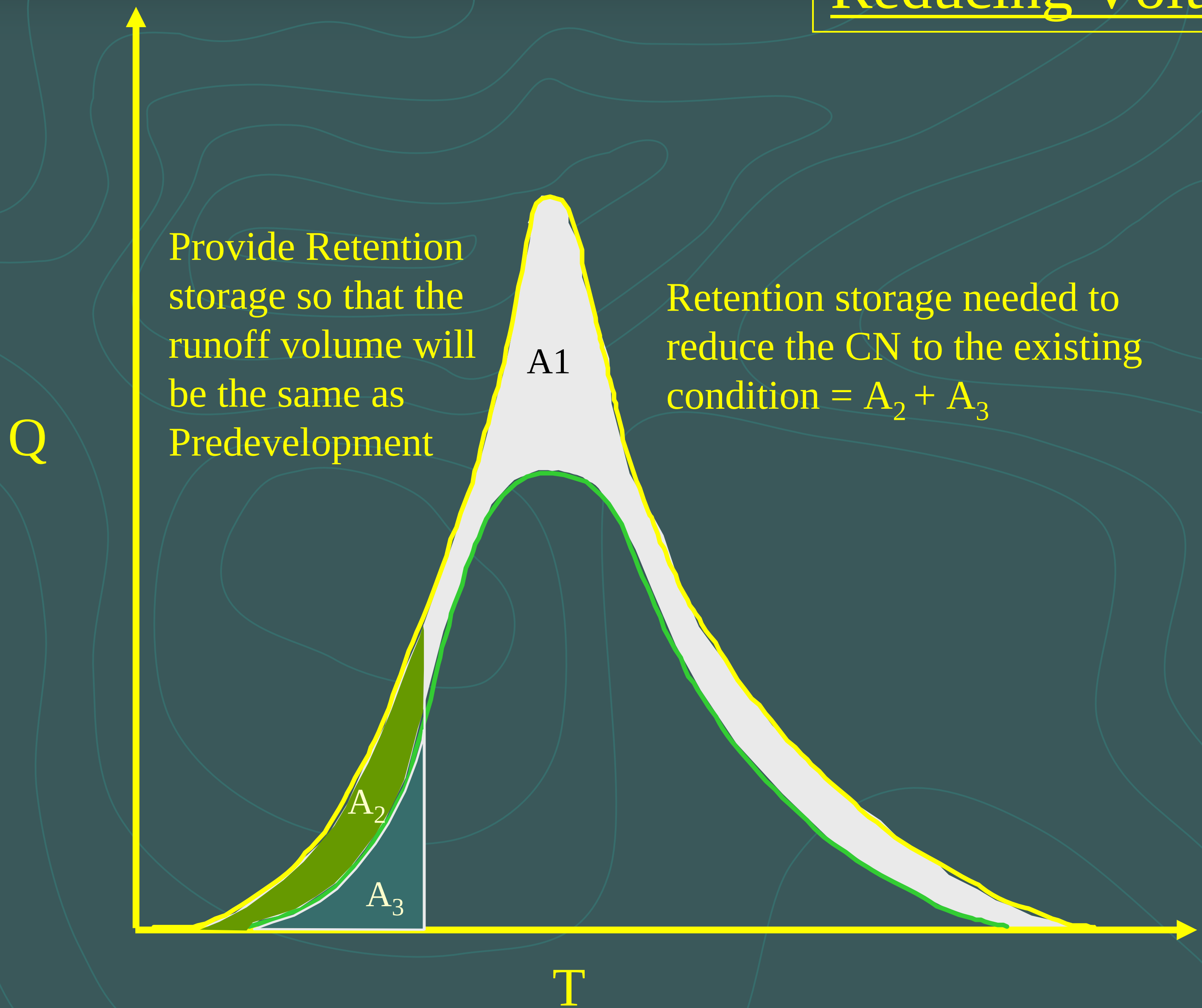
# Minimize Change in Curve Number



# Maintain Time of Concentration



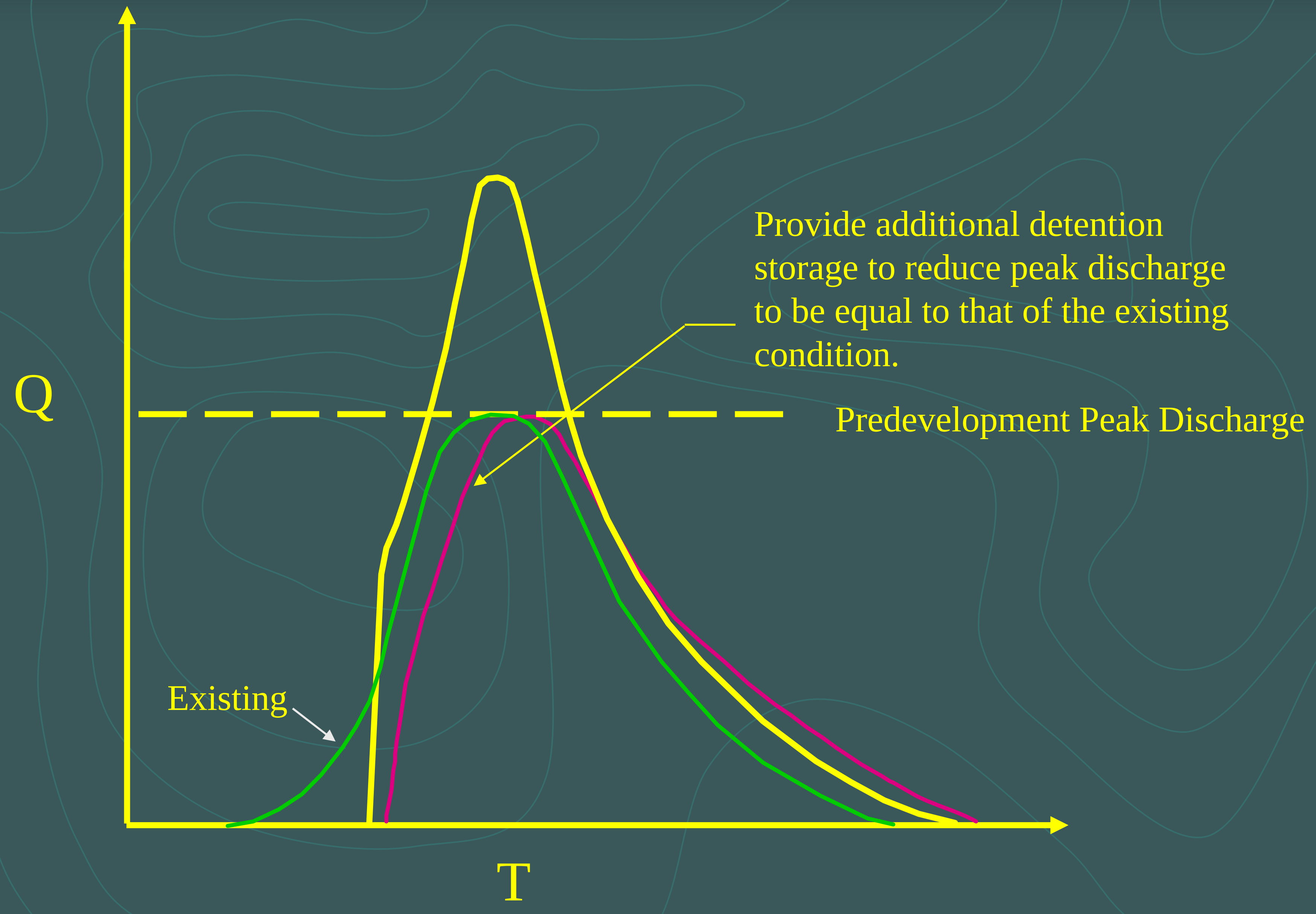
# Reducing Volume




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

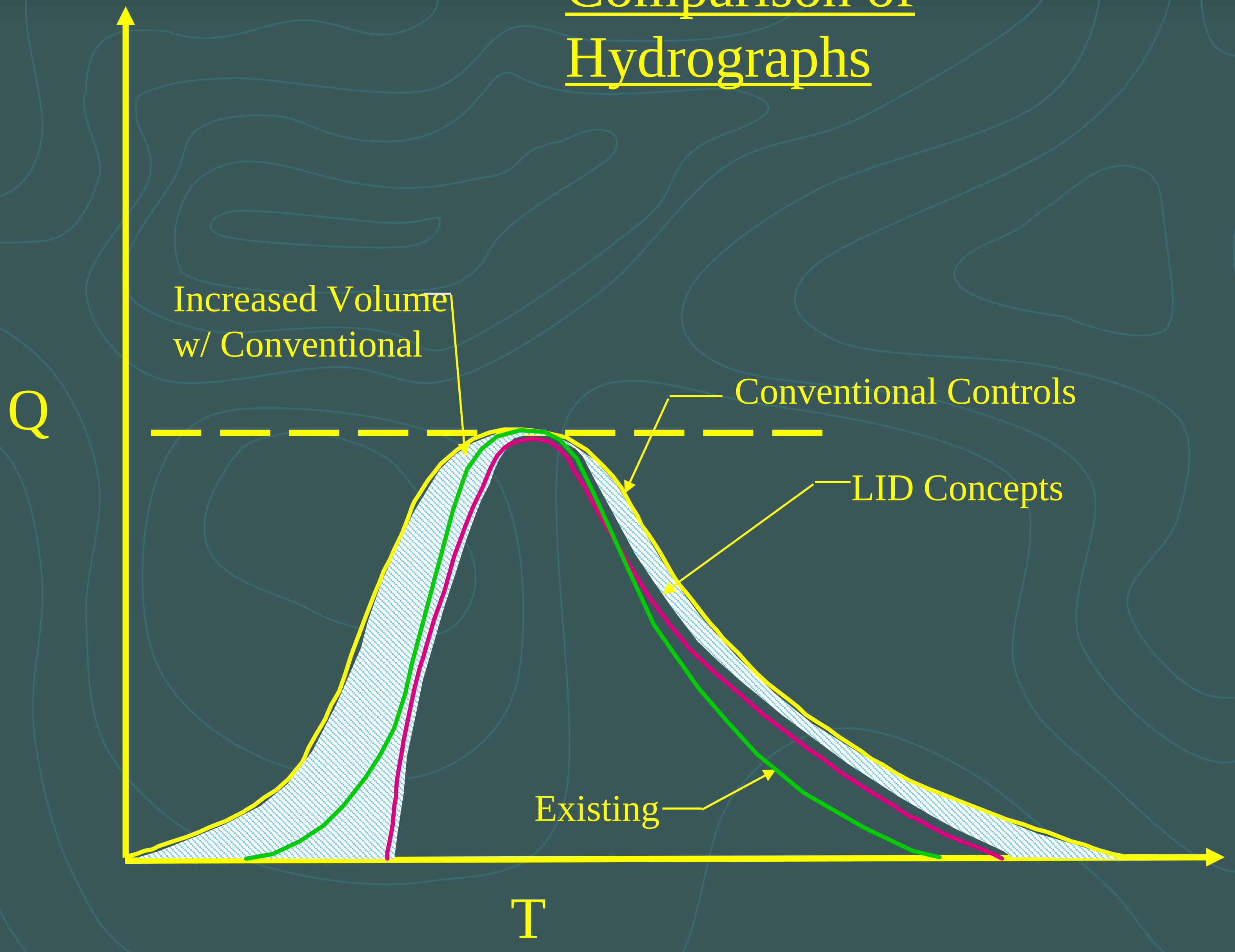
Retention storage needed to reduce the CN to the existing condition = $A_2 + A_3$

# Detention Storage

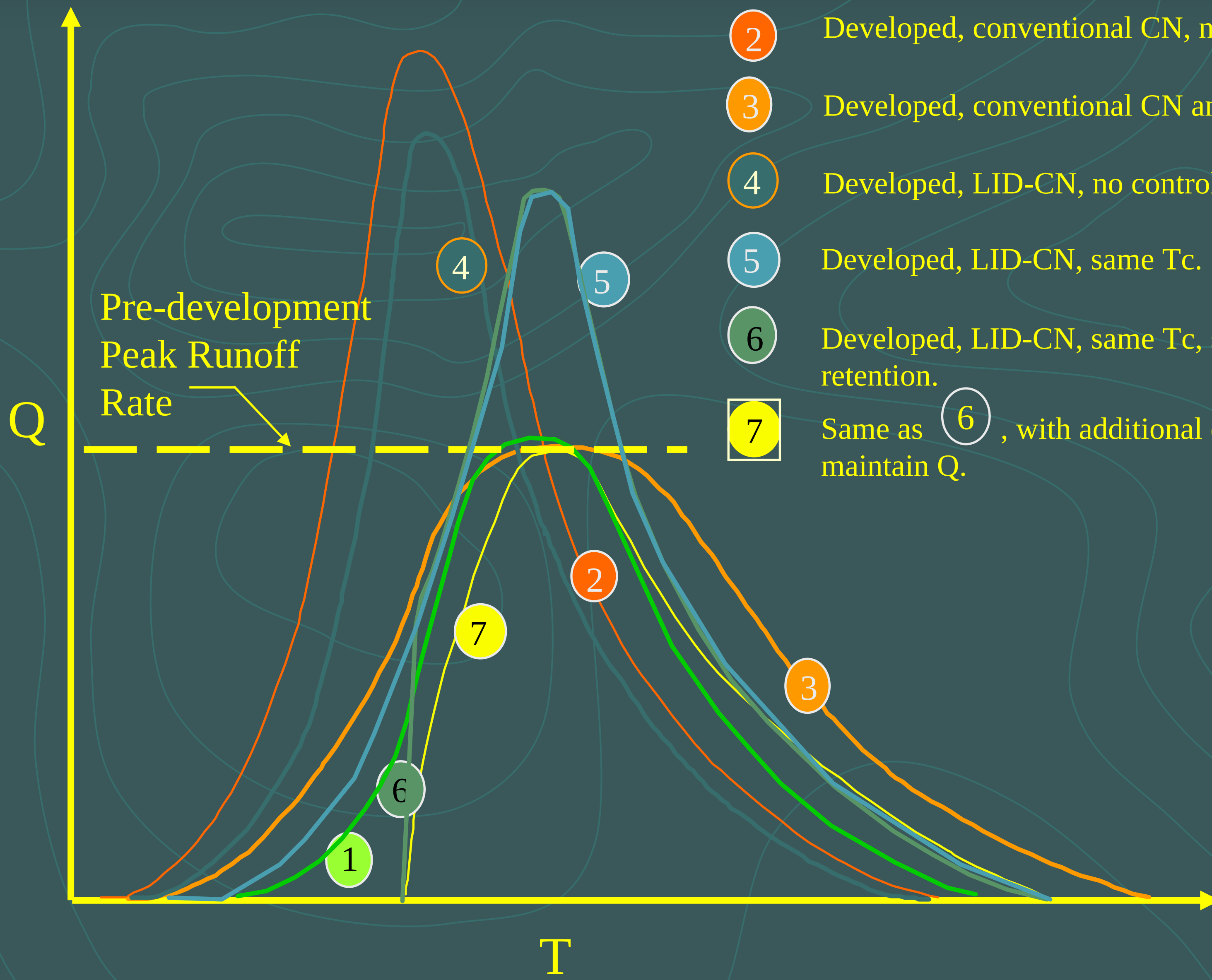



Provide additional detention storage to reduce peak discharge to be equal to that of the existing condition.

# 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.

# LID Stormwater Models

- EPA Stormwater Management Model (EPA SWMM)
- Source Loading and Management Model (SLAMM)
- Prince George's County BMP Evaluation Module
- Western Washington Hydrology Model (WWHM3) / Bay Area Hydrology Model (BAHM)

# EPA Stormwater Management Model (EPA SWMM)

| | |
|---|---|
| Developer | US EPA; Oregon State U.; Camp, Dresser and McKee (CDM) |
| Rainfall Modeled | Single Event and Continuous |
| Watershed Size | Site level to Large Watersheds |
| Primary Use | Peak Flow, Volume, and Quality |
| Land Use & Source Area | User defined land uses and source areas |
| Application to LID | Can be adapted to simulate LID controls, models storage and infiltration processes |

# Source Loading and Management Model (SLAMM)

| | |
|---|---|
| Developer | Dr. Robert Pitt, U of Alabama; John Voorhees |
| Rainfall | Continuous |
| Watershed Size | Small Watersheds |
| Land Uses | Residential, Commercial, Industrial, Highway, Institutional, and other Urban |
| Source Areas | Roofs, Sidewalks, Parking, Landscaped, Streets, Driveways, Alleys, etc. |
| Primary Use | Runoff Volume and Quality |
| Application to LID | Infiltration, Wet Ponds, Porous Pavement, Street Sweeping, Biofiltration, Vegetated Swales, Other Urban Control Device |

# Prince George's County BMP Evaluation Model

| | |
|---|---|
| Developer | US EPA; Tetra Tech Inc. and Prince George's County |
| Rainfall | Continuous |
| Watershed Size | Site Level to Small Watersheds |
| Land Uses | Low-Medium-High Density Residential, Commercial, Industrial, Forest, and Agriculture |
| Source Areas | Impervious or Pervious |
| Primary Use | Runoff Quantity and Quality |
| Application to LID | Retention and conveyance options can be adapted to simulate various LID practices |

# Western Washington Hydrology Model (WWHM3) / Bay Area Hydrology Model (BAHM)

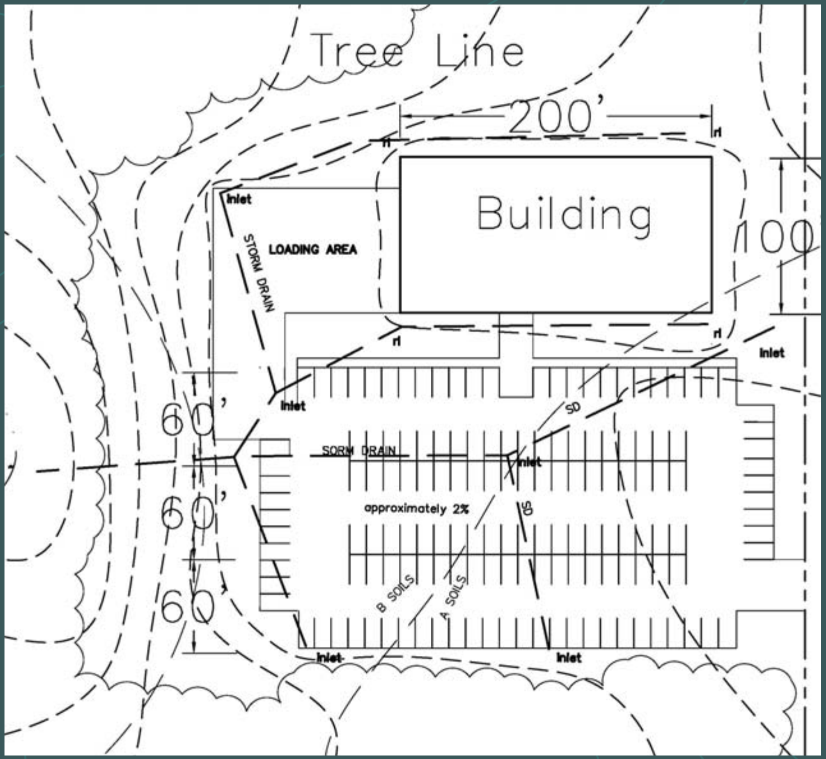
| | |
|---|---|
| Developer | Washington State Dept. of Ecology; AQUA TERRA Consultants; and Clear Creek Solutions, Inc. |
| Rainfall | Continuous |
| Watershed Size | Large to Small sites in 19 Counties of Western Washington |
| Primary Use | Runoff Quantity (Evapotranspiration, Surface Flow, Interflow, Groundwater Flow) |
| Application to LID | Ponds, Infiltration Trenches/Basins, Wetlands, Sand Filter, Gravel Trench Beds, Vaults/Tanks, Swales, Green |

# Case Studies used to Demonstrate Models

- Suburban Commercial Site
  - SWMM
  - SLAMM
- Metro West: Dense Urban Site
  - SWMM
- Village at Watt’s Creek: Traditional Neighborhood Development
  - SLAMM
- Oak Creek
  - Prince George’s County BMP Evaluation Model

# Typical Suburban Commercial Site

- Existing: Wooded
- Proposed: 4.0 Acre Commercial Site: 2.25 Acres of Impervious Cover, and 1.75 Acres of Landscaping
- Location: Walnut Creek, CA



# Suburban Commercial Site

## Demonstration Goals

This site represents a small office park, retail, or other commercial project common to green field and fringe development.  Numerous LID options are available for this type of development, including: swales, bioretention, permeable pavements, cisterns, and flow through planters.


# Suburban Commercial Site

## Modeling Objectives

- Maintain Pre-Development Peak Flows
- Reduce, Treat, and Retain Site Pollutants
- Groundwater Recharge
- Size Best Management Practices to Meet California Stormwater Standards

# Suburban Commercial Site

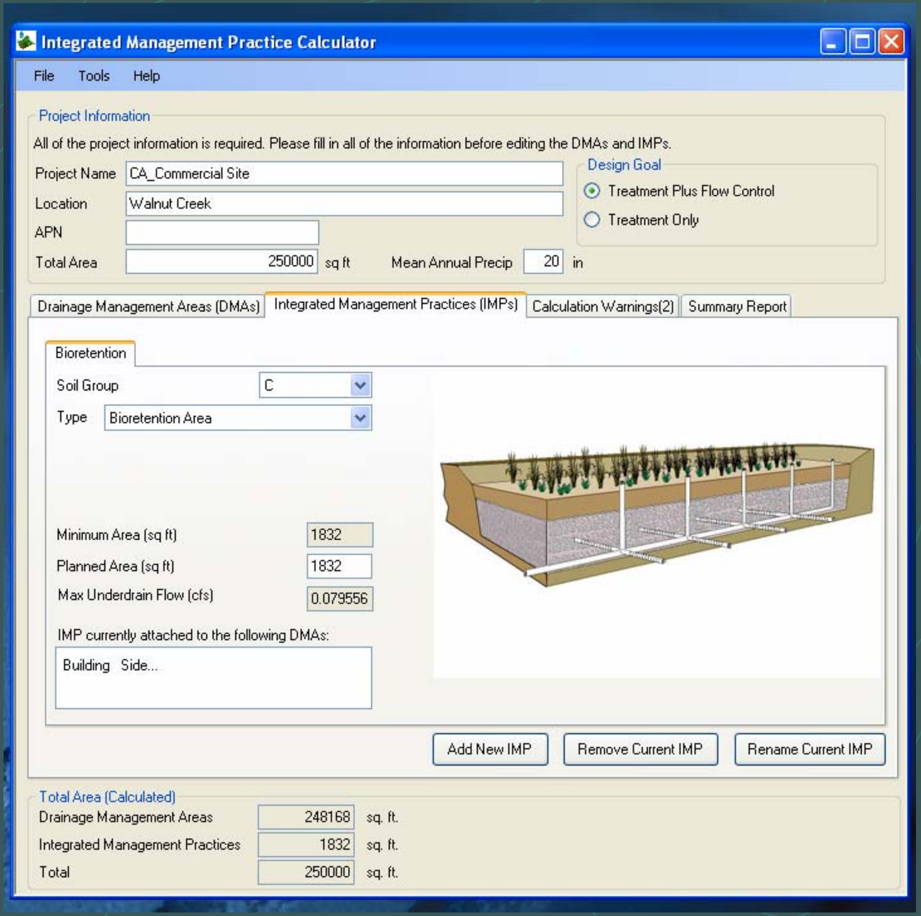
## LID Strategy Selected

| Source Areas | Best Management Practice |
|---|---|
| Roof (20000 sf)<br>Sidewalk (2700 sf) | Bioretention Cell w/ Underdrain<br>-3 ft of media depth<br>-0.5 ft of surface storage depth |
| Parking Lot and Loading Area<br>(70,000 sf) | Permeable Pavement<br>-15000 sf, located in outer parking spaces<br>-2.5 ft of aggregate depth<br>Grassed Swale<br>-4 ft bottom width |
| Landscaping | Maintain Native Soil Structure<br>Avoid Compaction<br>Deep Soil Aeration |

# Suburban Commercial Site

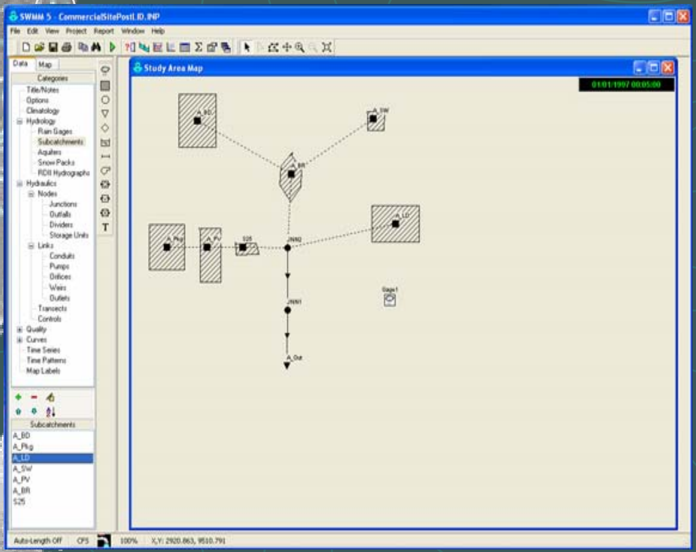
## Contra Costa IMP Sizing Calculator

- To meet Contra Costa County technical requirements for flow and treatment the following IMP sizes were calculated:
  - Bioretention cell must be sized to 1832 sf w/ underdrain
  - 420 linear ft of vegetated swales to treat and retain permeable /impervious parking lot.
- IMP design criteria are stated in Appendix C of the *Contra Costa County Stormwater C.3 Guidebook*



# Suburban Commercial Site

## Modeling Results




**Rainfall Data Used:**
**Walnut Creek, CA Rain Gage**
**1997 (total of 21.5")**

| | SWMM | | | SLAMM |
|---|---|---|---|---|
| | Evapotrans. (acre-ft) | Infiltration (acre-ft) | Runoff (acre-ft) | Runoff (acre-ft) |
| Pre-Developed | 0.11 | 4.29 | 0.08 | 0.25 |
| Post-Developed | 0.37 | 1.57 | 3.01 | 1.77 |
| Post-Developed w/ LID | 0.31 | 3.65 | 0.62 | 0.44 |
| Reduction in Runoff w/ LID | --- | --- | 79% | 75% |

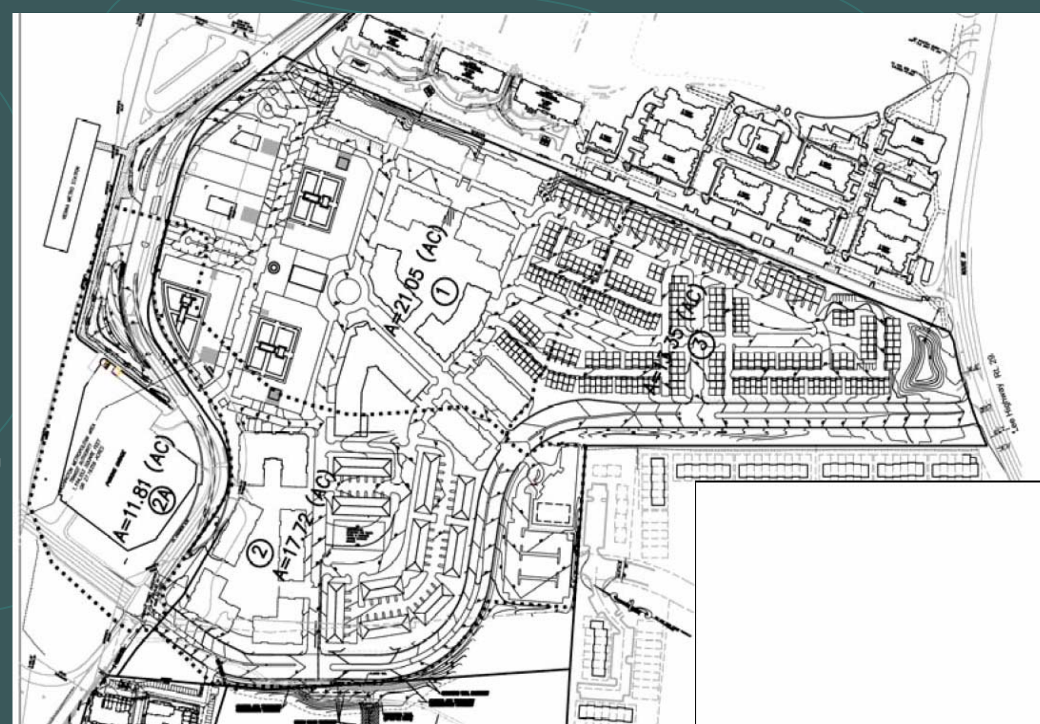
# Choosing SWMM or SLAMM

- SWMM
  - Goals include: flow routing, peak flow, volume,  and pollutant loads
  - Complex site, many source area land types
  - Inputs for BMP performance equations are available
  - If input data is accurate and detailed, Good for design
- SLAMM
  - Goals include: runoff volumes & pollutant loads
  - Site has typical landuses
  - Standard BMPs, including swales and street sweeping are used
  - Best for planning analysis, comparing scenarios

# Metro West

## Medium to High Density Mixed Use Development

- Existing: Low Density Residential
- Proposed: 52 Acre Pedestrian and Transit Oriented Mixed-Use Community: Townhomes, Condominiums, Apartments, Retail, Offices, and Public Spaces
- Proposed LID: Bioretention, Permeable Pavement, and Green Roofs



# Metro West
## Demonstration Goals

*Source: Pulte Homes Corporation, Inc.*

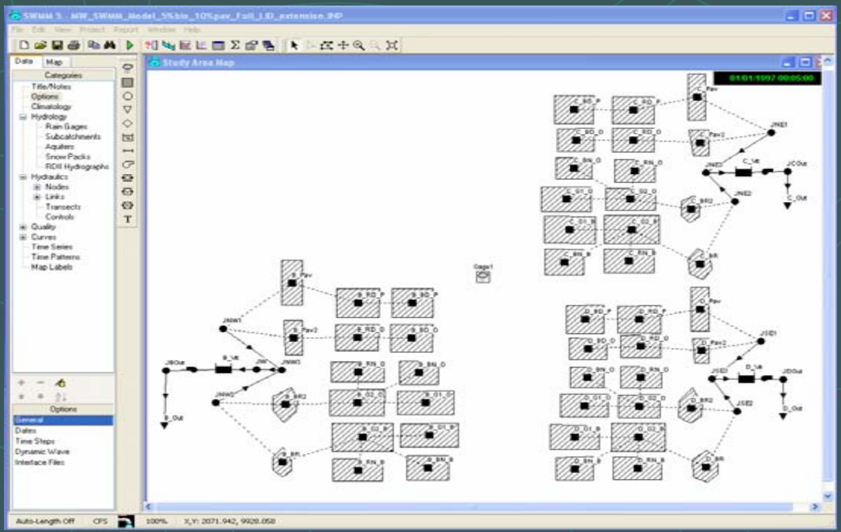
A high density development like Metro West may reduce the overall footprint of development, but it is at an extremely high density that will result in high runoff volume and peak rates and concentrated pollutant loads. Modeling will show that strategically placed and integrated best management practices will reduce or eliminate the need for large stormwater infrastructure.

# Metro West

## Modeling Objectives

- Maintain Annual Load (Volume, Pollutants)
- Manage Peak Storm Events (2-, 10-, and 100-yr. 24-hour)
- Infrastructure Requirements per design manual and physical limitations
- BMP Sizing based on current regulations

# Metro West
## SWMM Runoff Volume Results



Rainfall Data Used:

1992 Washington Dulles Intl. Rain Gage (total of 41.26”)

| | Runoff (acre-ft) |
|---|---|
| Pre-Developed | 6.2 |
| Existing | 24.2 |
| Post-Developed w/ SWM | 76.4 |
| Post-Developed w/ SWM & LID | 58.5 |
| Reduction in Runoff w/ LID | 23% |

# Metro West

## SWMM Peak Discharge Results for a 2yr-24hr storm

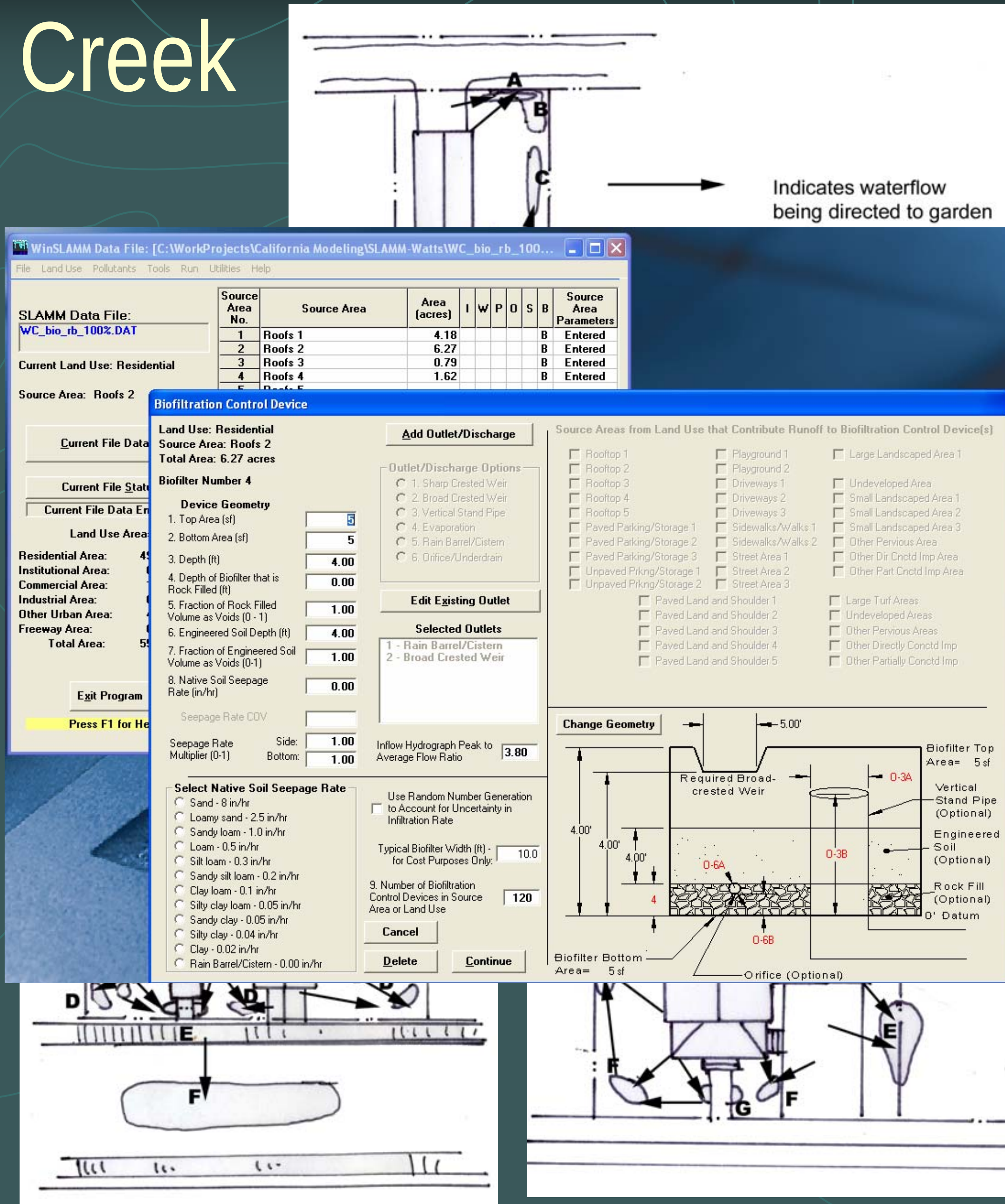
| Condition | | Areas A (cfs) | Area B (cfs) | Area C (cfs) |
|---|---|---|---|---|
| Without LID | Inflow | 100.5 | 74.4 | 48.8 |
| | Outflow | 9.5 | 20.8 | 11.6 |
| With LID | Inflow | 84.0 | 61.0 | 36.7 |
| | Outflow | 8.5 | 16.8 | 6.6 |
| % Reduction in Outflow w/ LID | | 11% | 19% | 43% |

# Village at Watt's Creek
## Traditional Neighborhood Development (TND)

- 55 acre site consiting of mixed-use buildings, townhomes, two-family, single family homes on small lots
- Other features, alley loaded lots, common green space, narrow and pedestrian friendly streets

# Village at Watt's Creek
## LID Options

- Rain Barrels
- Bioretention Cells
- Permeable Driveways/Alleys
- Street Planters

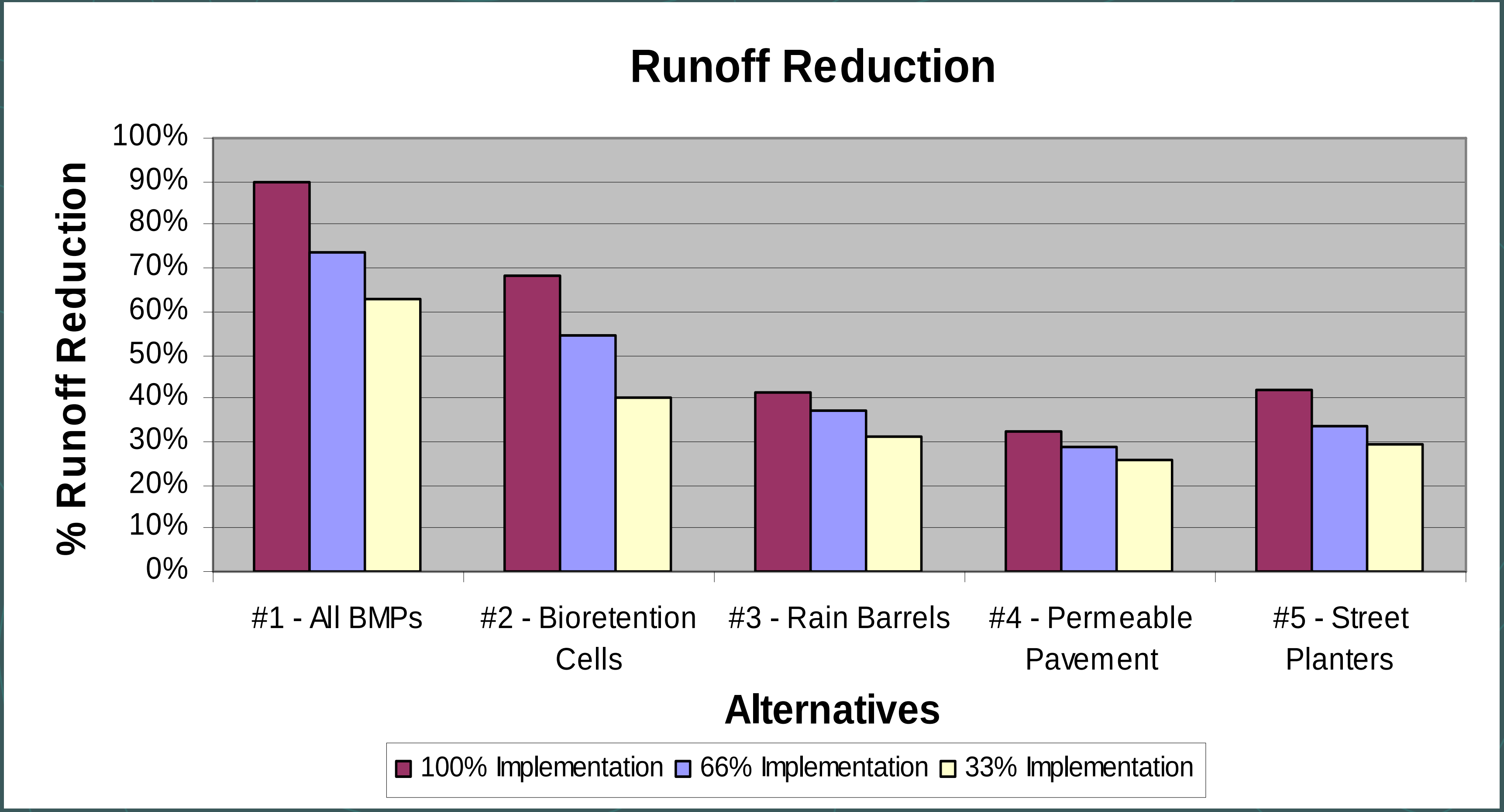


# Village at Watt's Creek

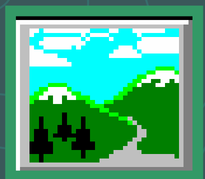
## The LID Scenarios

| Scenario | Catchbasin With Sumps | Residential Downspout Disconnection | Residential Bioretention Cells | Residential Rain Barrels | Permeable Pavement for Alleys and Driveways | Street Bioretention Planters |
|---|---|---|---|---|---|---|
| No BMPs | ✓ | | | | | |
| #1 – All BMPs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| #2 – Bio. Cells | ✓ | ✓ | ✓ | | | |
| #3 – Rain Barrels | ✓ | ✓ | | ✓ | | |
| #4 – Permeable Pvt. | ✓ | ✓ | | | ✓ | |
| #5 – Street Planters | ✓ | ✓ | | | | ✓ |

# Village at Watt's Creek
## SLAMM Runoff Reduction Results



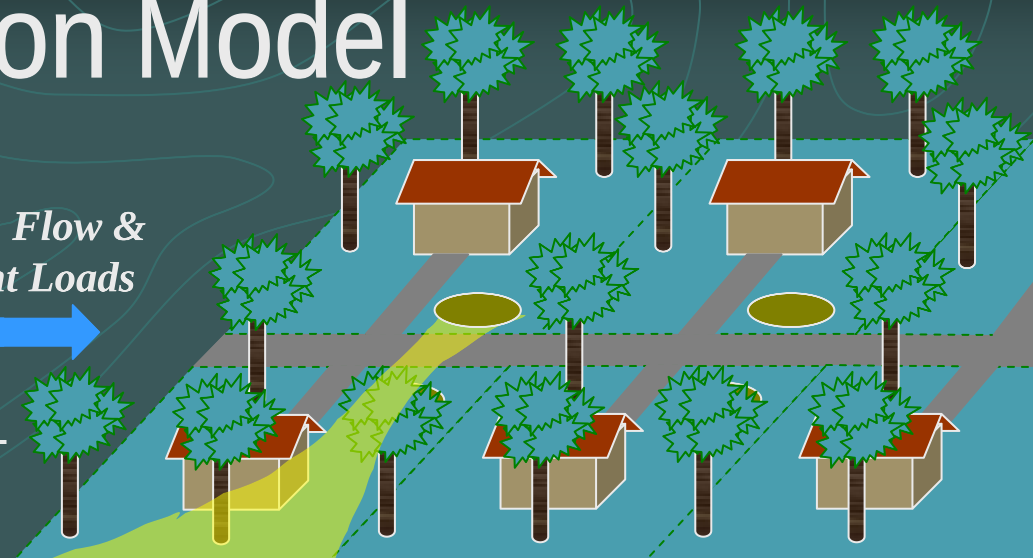
# PG BMP Evaluation Model



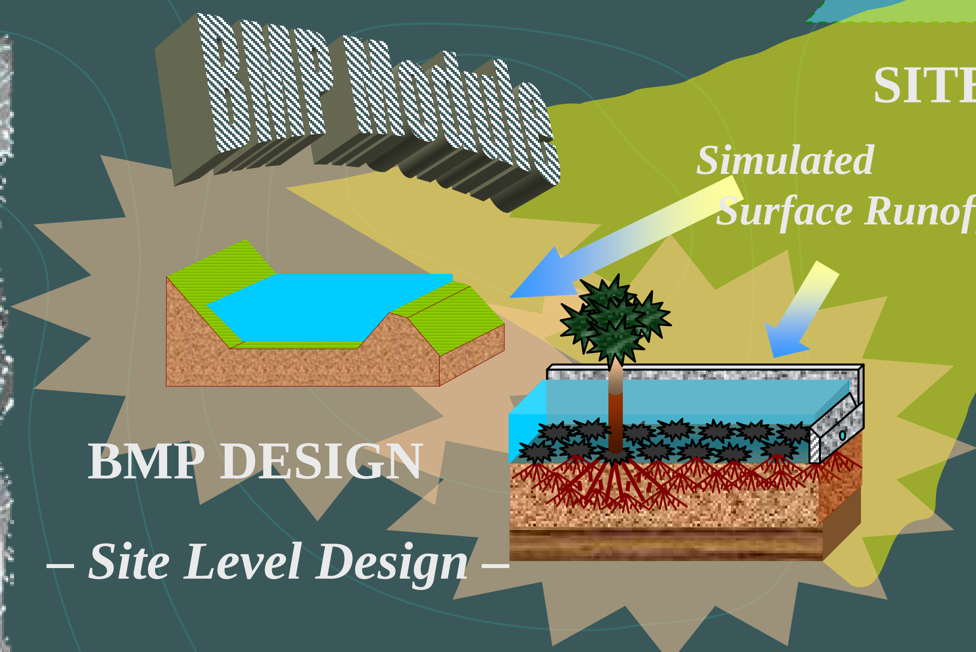
***HSPF* LAND SIMULATION**

*Existing Flow & Pollutant Loads*

***– Unit-Area Output by Landuse –***



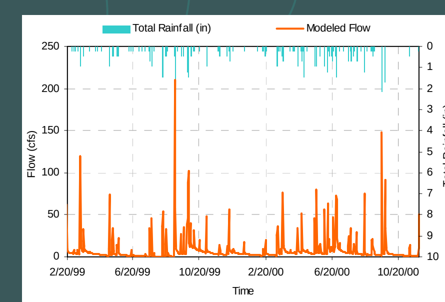
**SITE-LEVEL LAND/BMP ROUTING**




*Simulated Surface Runoff*

**BMP DESIGN**

***– Site Level Design –***



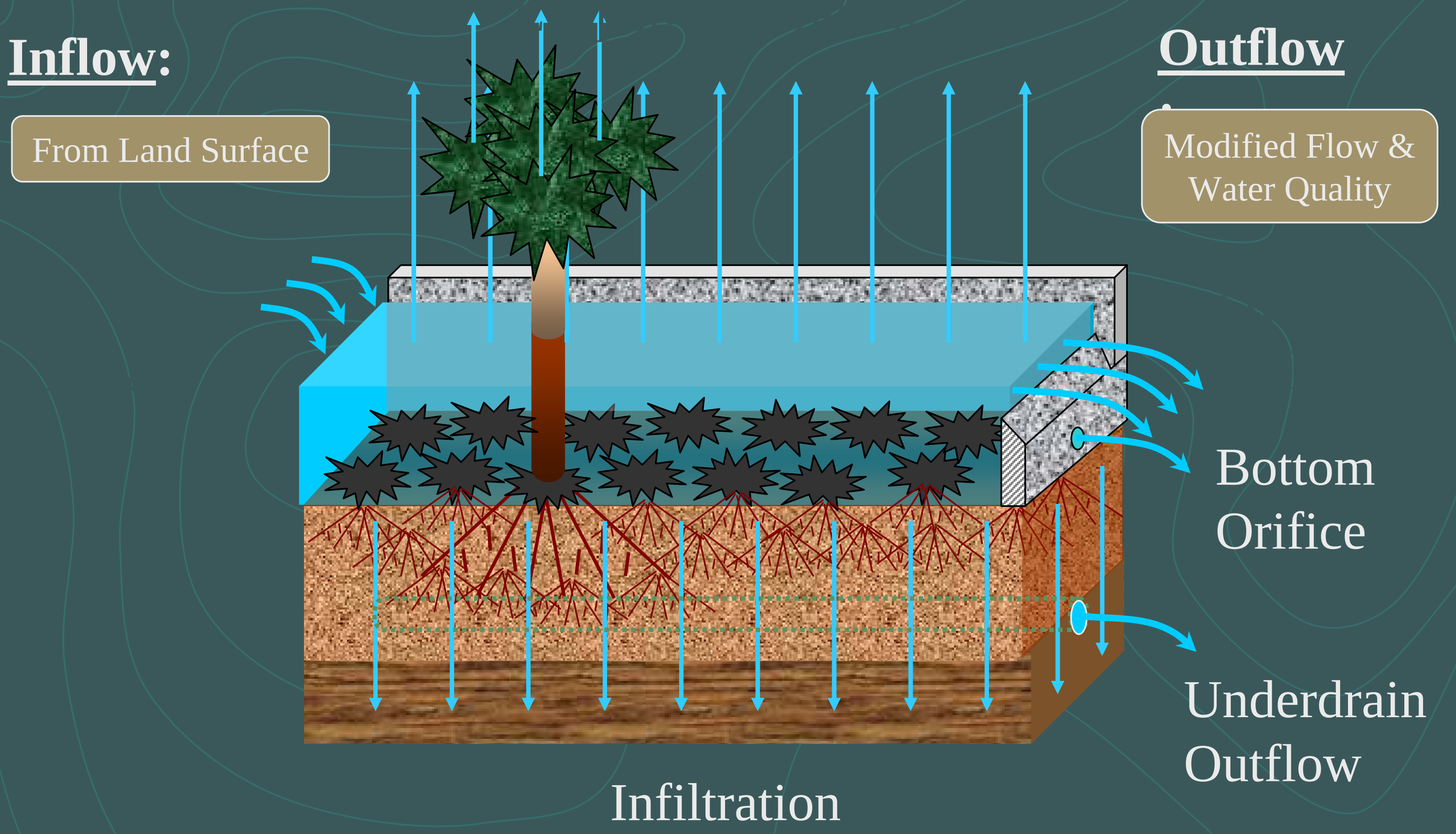

*Simulated Flow/Water Quality Improvement*

*Cost/Benefit Assessment of LID design*

# BMP Physical Processes

- Possible 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



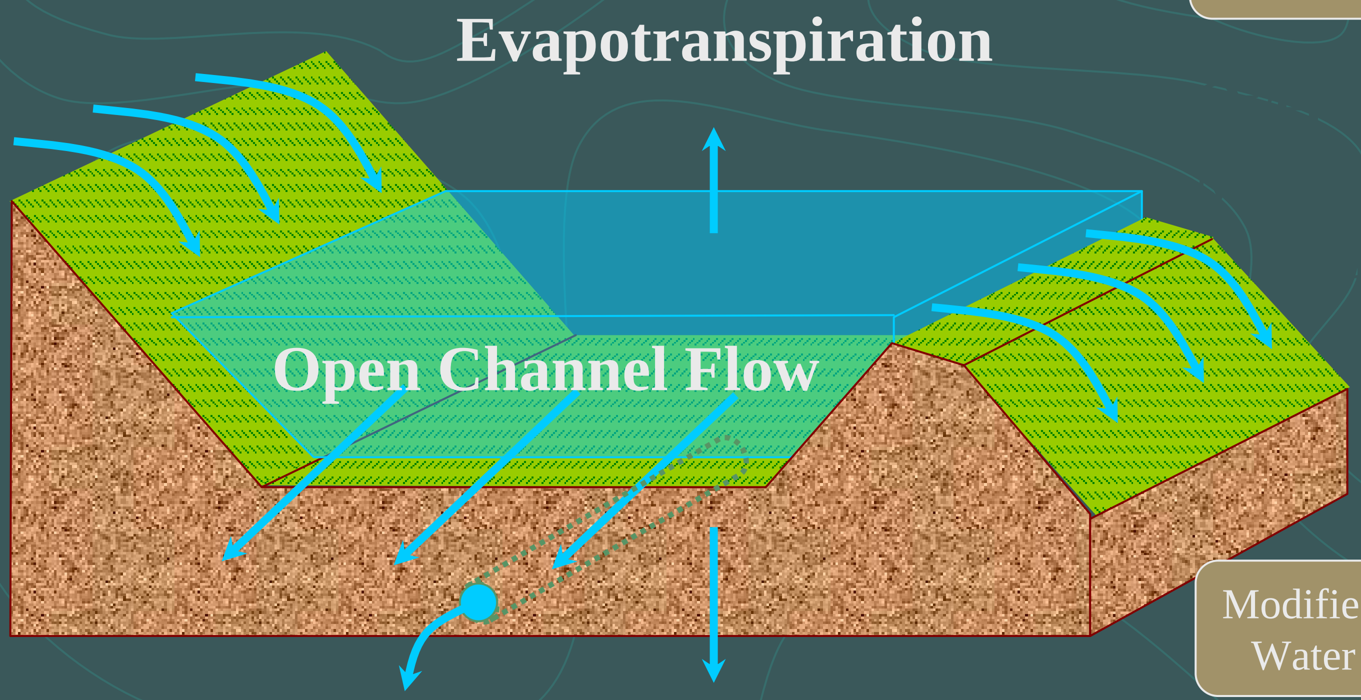
# BMP Class B: Open Channel

**Inflow:**

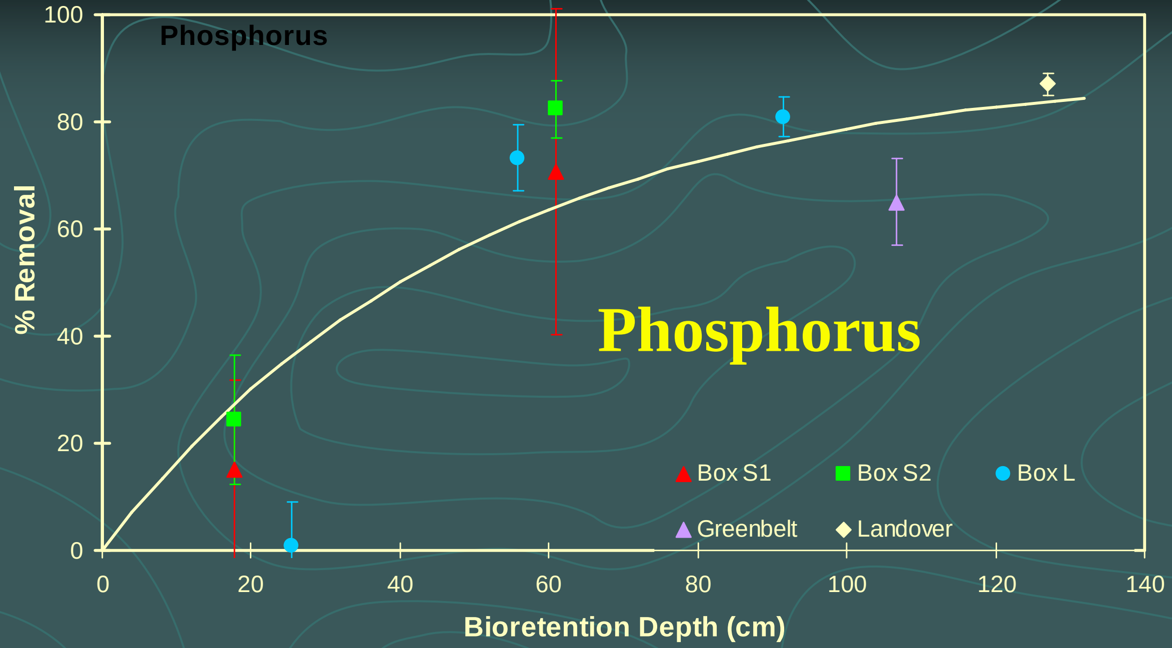
From Land Surface

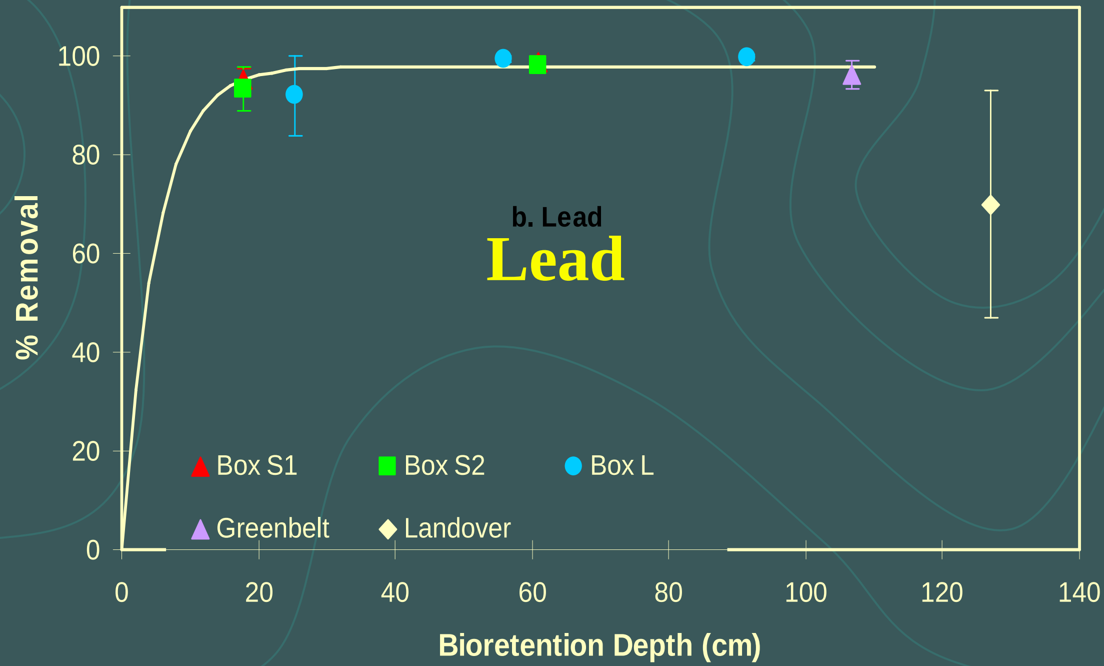
**Outflow:**

Modified Flow & Water Quality




Modified Flow & Water Quality




Calibrated BMPs!!!

# General Water Quality

$$\text{Mass}_2 = \text{Mass}_1 \times e^{-k\,t}$$

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

*Underdrain percent removal is a function of the soil media*

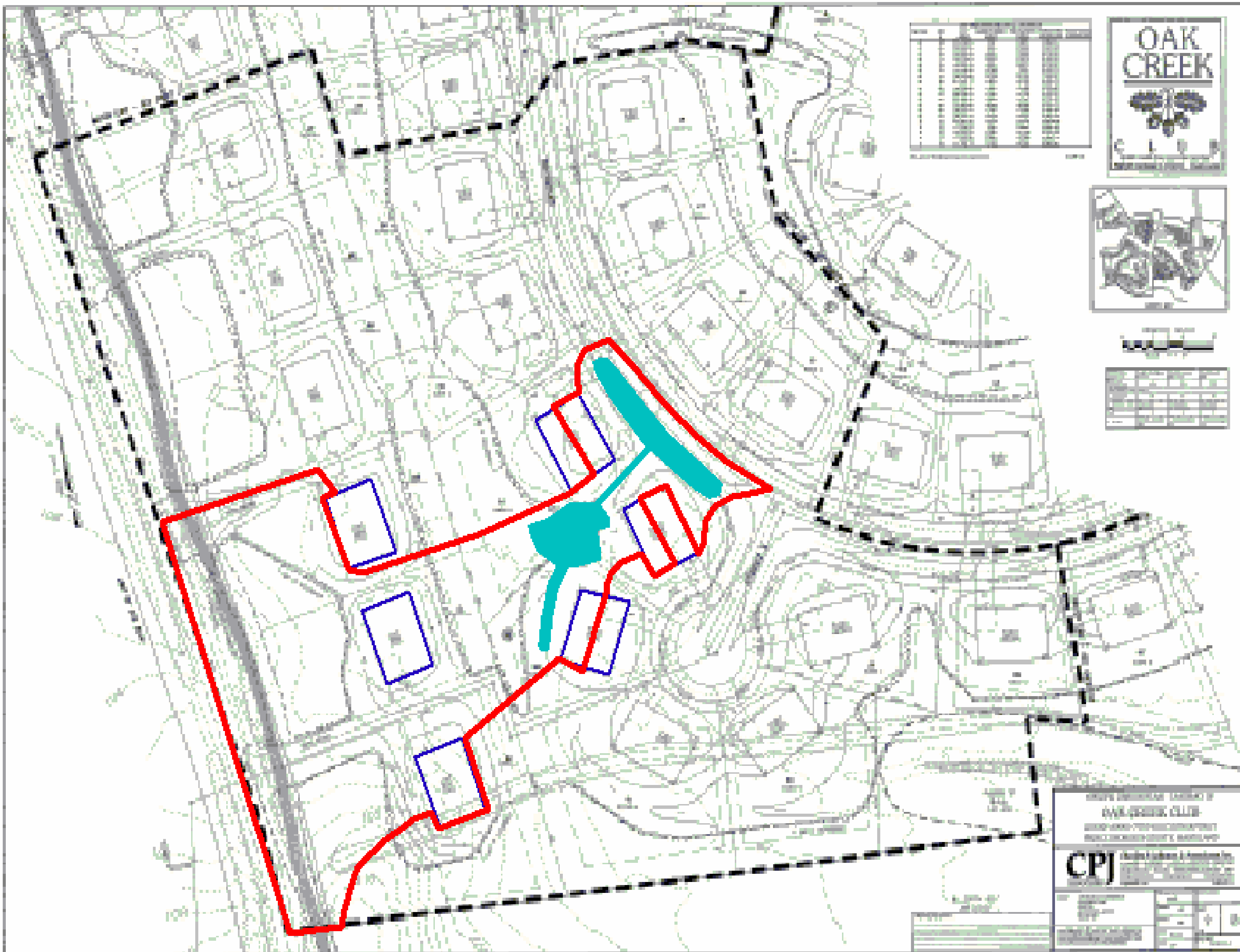
$$Mass_{out} = Mass_{in} \times (1 - PCTREM)$$

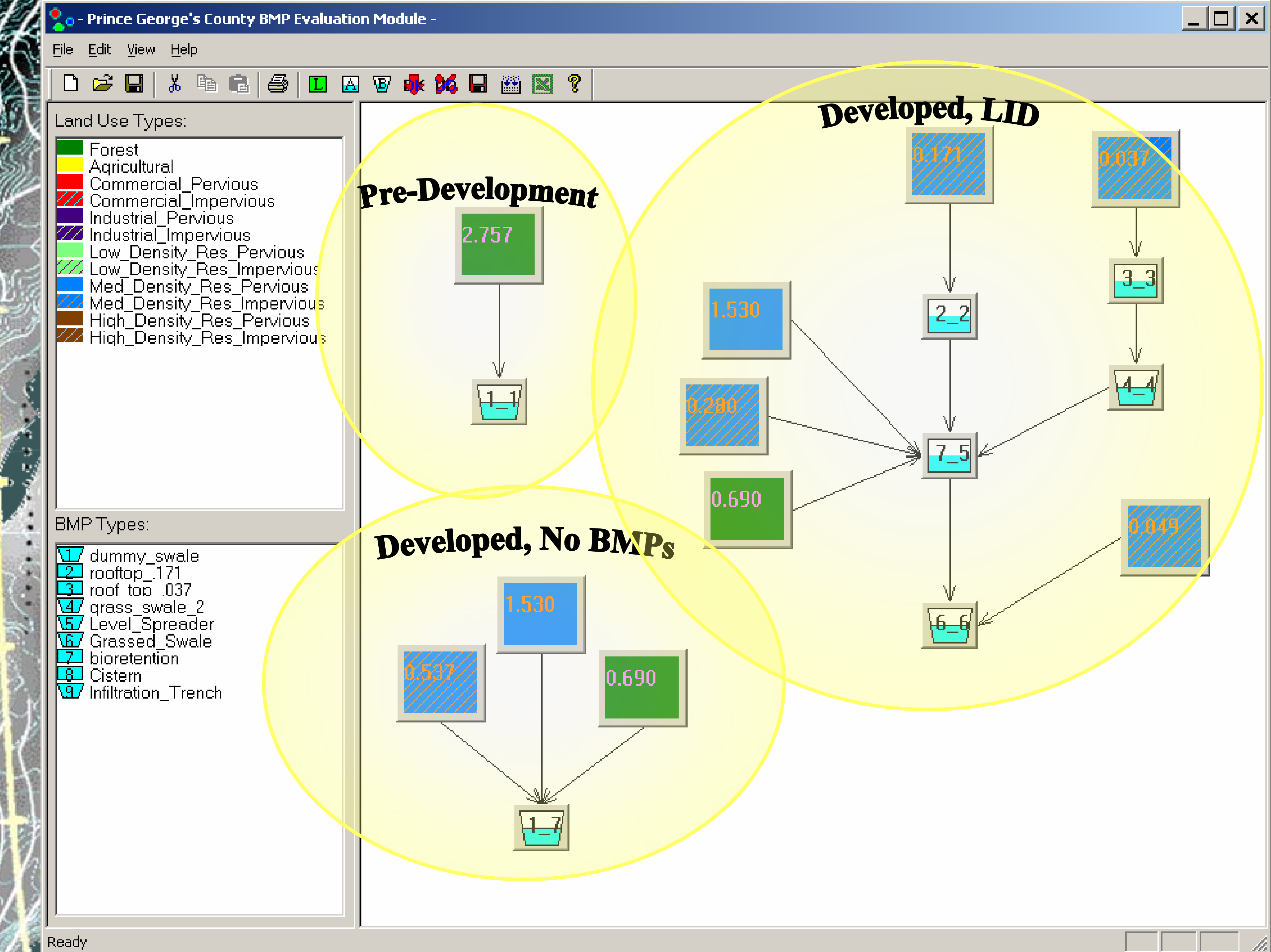
$$Mass_{in} = \text{Surface conc} * \text{underdrain flow}$$

**Underdrain Percent Removal (0-1)**

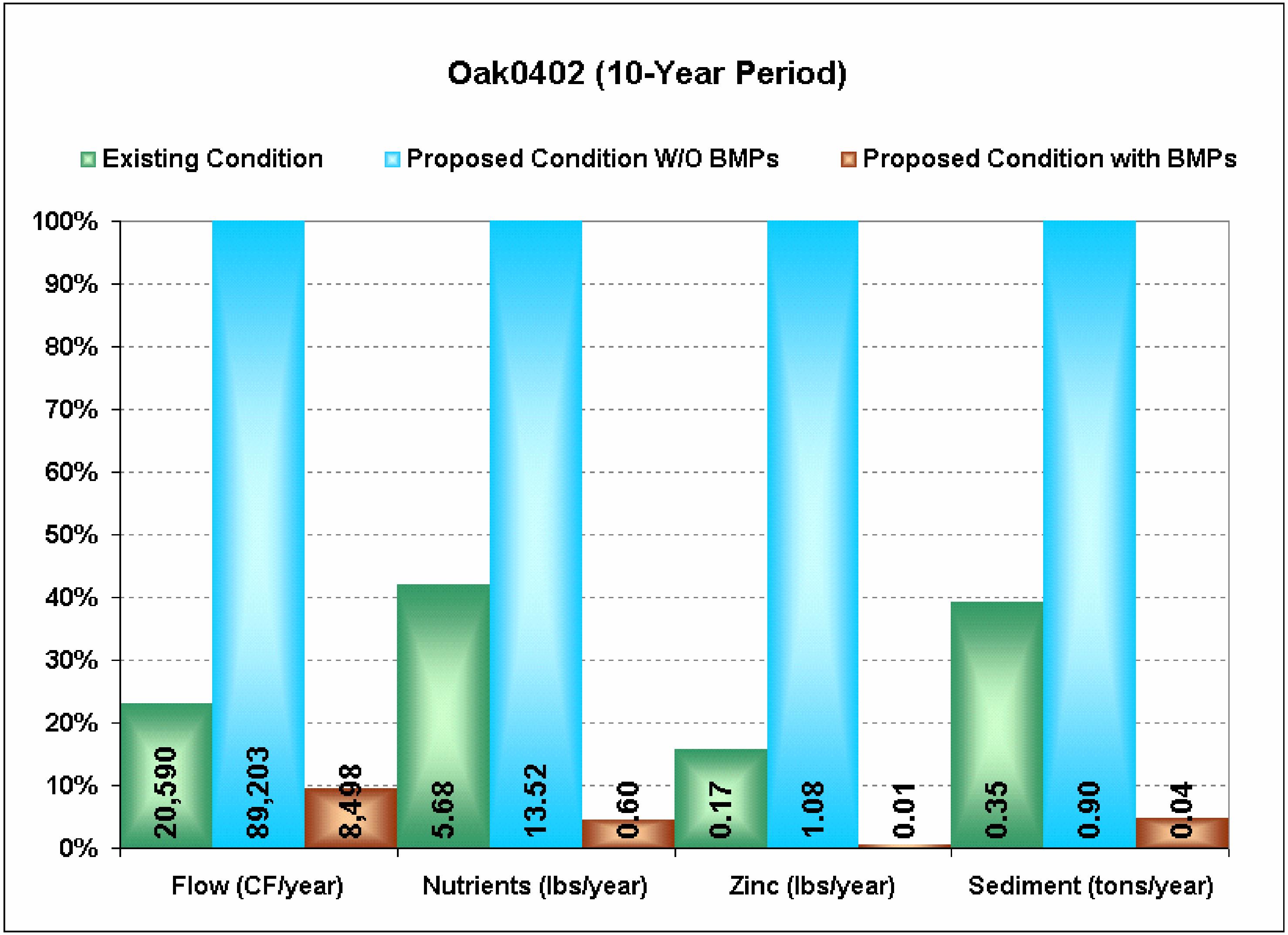
| BMP ID | SOSLD | SOQUAL (BOD, 5 D |
|---|---|---|
| 1 | 0.100000 | 0.100000 |
| 2 | 1.000000 | 0.200000 |
| 3 | 0.300000 | 0.300000 |
| 4 | 0.400000 | 0.400000 |
| 5 | 0.500000 | 0.500000 |
| 6 | 1.000000 | 0.600000 |
| 7 | 0.700000 | 0.700000 |

OK Cancel


OAK CREEK
CPJ


- 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:
1 dummy_swale
2 rooftop_.171
3 roof top .037
4 grass_swale_2
5 Level_Spreader
6 Grassed_Swale
7 bioretention
8 Cistern
9 Infiltration_Trench
Pre-Development
2.757
1_1
Developed, LID
0.171
0.037
1.530
2_2
3_3
0.280
4_4
7_5
0.690
0.049
6_6
Developed, No BMPs
1.530
0.537
0.690
1_7
Ready

| | Existing Condition | Proposed Condition W/O BMPs | Proposed Condition with BMPs |
|---|---|---|---|
| Flow (CF/year) | 20,590 | 89,203 | 8,498 |
| Nutrients (lbs/year) | 5.68 | 13.52 | 0.60 |
| Zinc (lbs/year) | 0.17 | 1.08 | 0.01 |
| Sediment (tons/year) | 0.35 | 0.90 | 0.04 |



# Future Directions

- More GIS integration with modeling software
- Models are adding optimization functions
- EPA SWMM
  - EPA Study on SWMM BMP Modeling Improvements
  - Interface w/ SLAMM
- New regional models and tools are linking LID integration with regulatory compliance in a simple and easy to use way.

# Conclusions

- Continuous hydrologic simulation needed to evaluate stormwater treatment effectiveness and the mitigation of hydromodification.
  - The majority of runoff and stormwater pollution come from small storms of 1” or less.
- No runoff model is perfect.  A few factors to consider when choosing a model:
    - Goals (flow, quantity, quality)
    - User’s Skill Level
    - Project Size and Complexity
    - LID Modeling Capability
    - Available Precipitation Data
    - Cost Optimization
- Recognize model limitations in results analysis