

# The Value of Monitoring in Stormwater Management

Workshop on Exemplary Local Government Stormwater Strategies to Protect and Restore Urban Watersheds:  
Combining Technology, Economics and Policy

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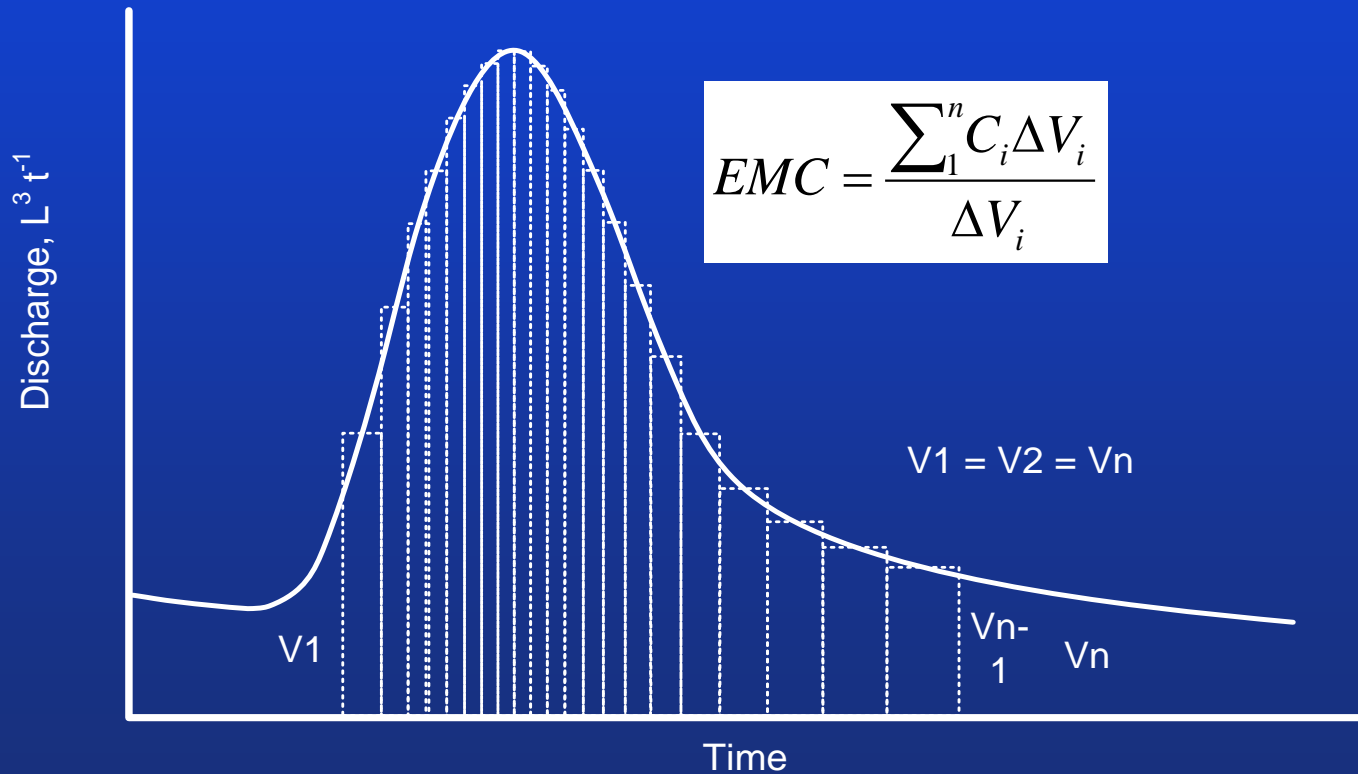
Biological Systems Engineering  
Occoquan Watershed Monitoring Laboratory

Allen P. Davis, University of Maryland, Civil and Environmental Engineering  
Thomas J. Grizzard, Virginia Tech, Civil and Environmental Engineering and OWML

# Stormwater Monitoring

$$Load = EMC * Q = \frac{mass}{volume} * \frac{volume}{time} = \frac{mass}{time}$$

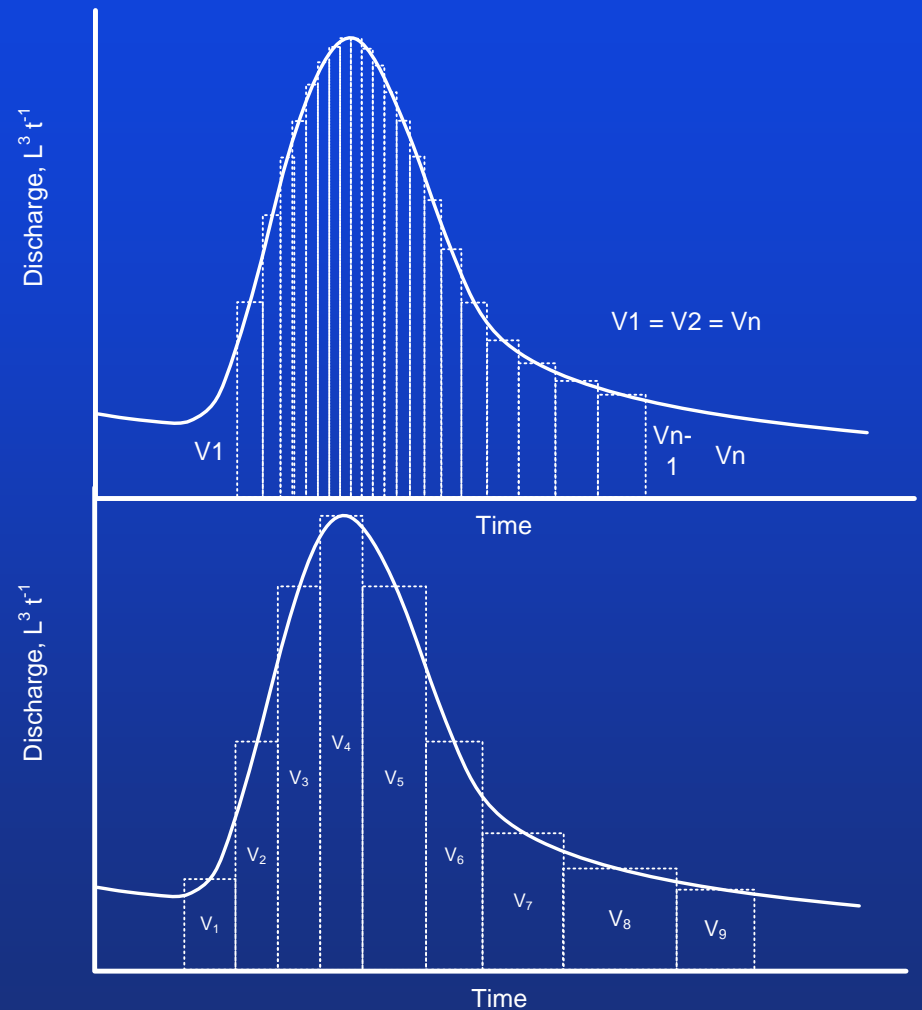
$$\frac{Load}{Area} = \frac{EMC * Q}{Area} = \frac{mass}{area * time}$$



Source: Grizzard, T. (2010), Lecture Notes.

# Methods of Compositing

- Accepted methods for compositing:
  - Equal volume/variable time composites: amenable to field compositing
  - Variable volume/variable time: construct after the fact
  - Time composite: not reliable



Source: Grizzard, T., (2010) personal communication.

# Hydraulics of Sampling

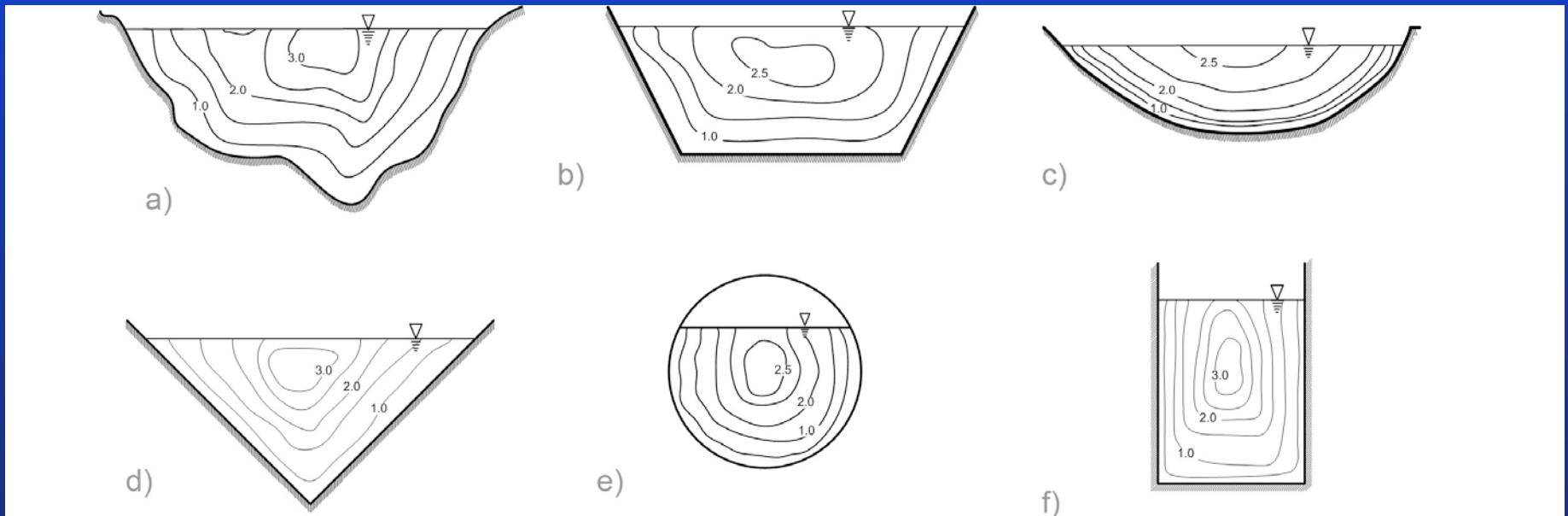
- Samplers and Flow splitters can bias results
- Hydraulic control must be provided
- Uniform flow can almost always be violated
- Flumes preferred over weirs



Source: (left) Grizzard, T. personal communication (right) Davis, A. (2005) Water Quality BMP Testing & Performance Evaluation.

# Hydraulics of Sampling

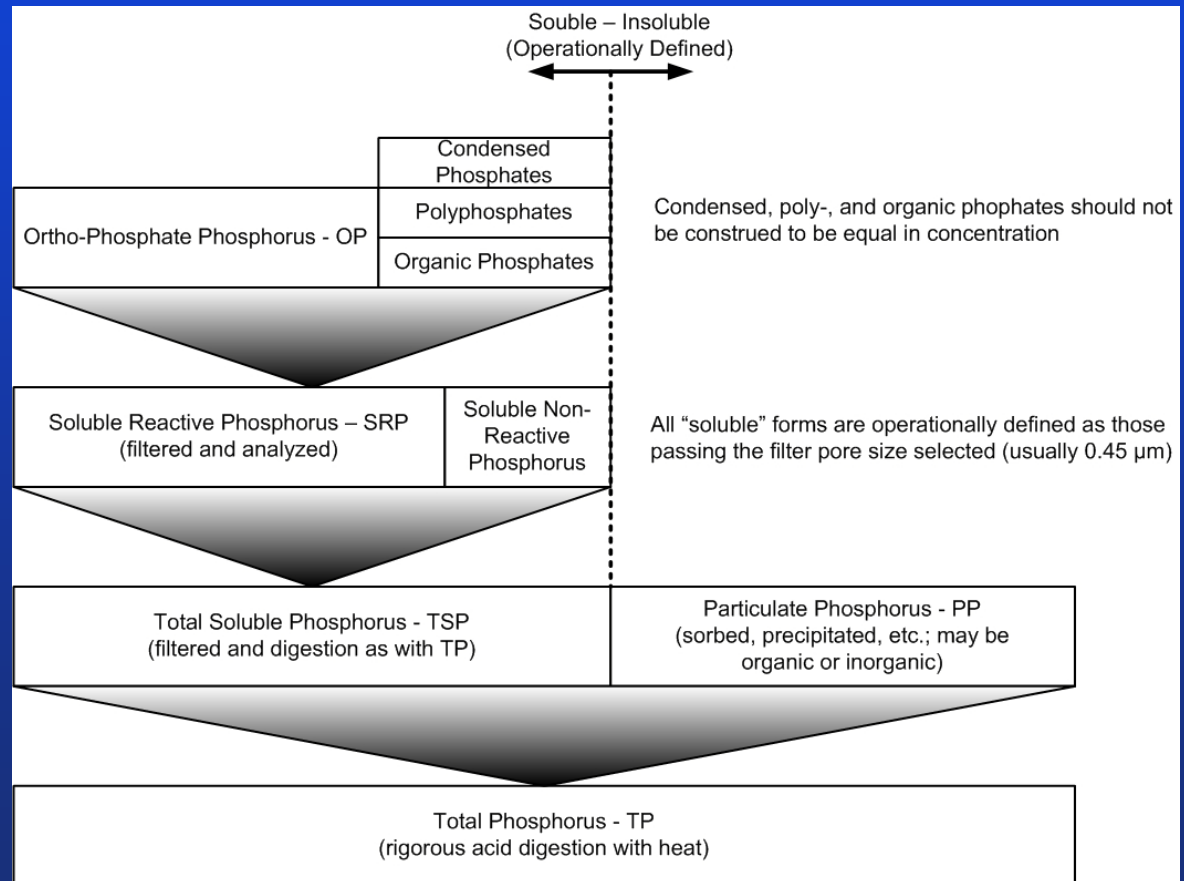
- Consider velocity distribution in sampling



Source: Chow, Ven Te, 1959. *Open-Channel Hydraulics*. Open-Channel Hydraulics. New York, NY: McGraw-Hill Book Company.

# Sediment and Particle Size are Critical

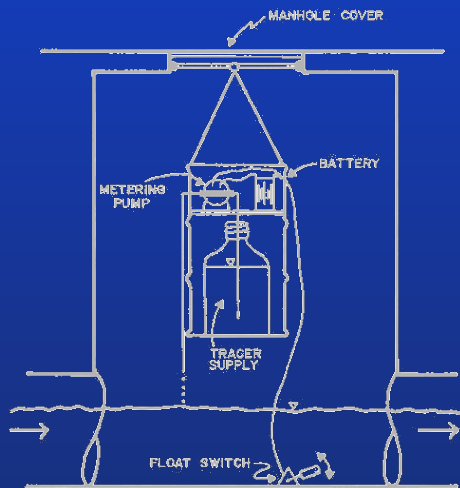
- Smaller clay particles bind to pollutants-for example, P



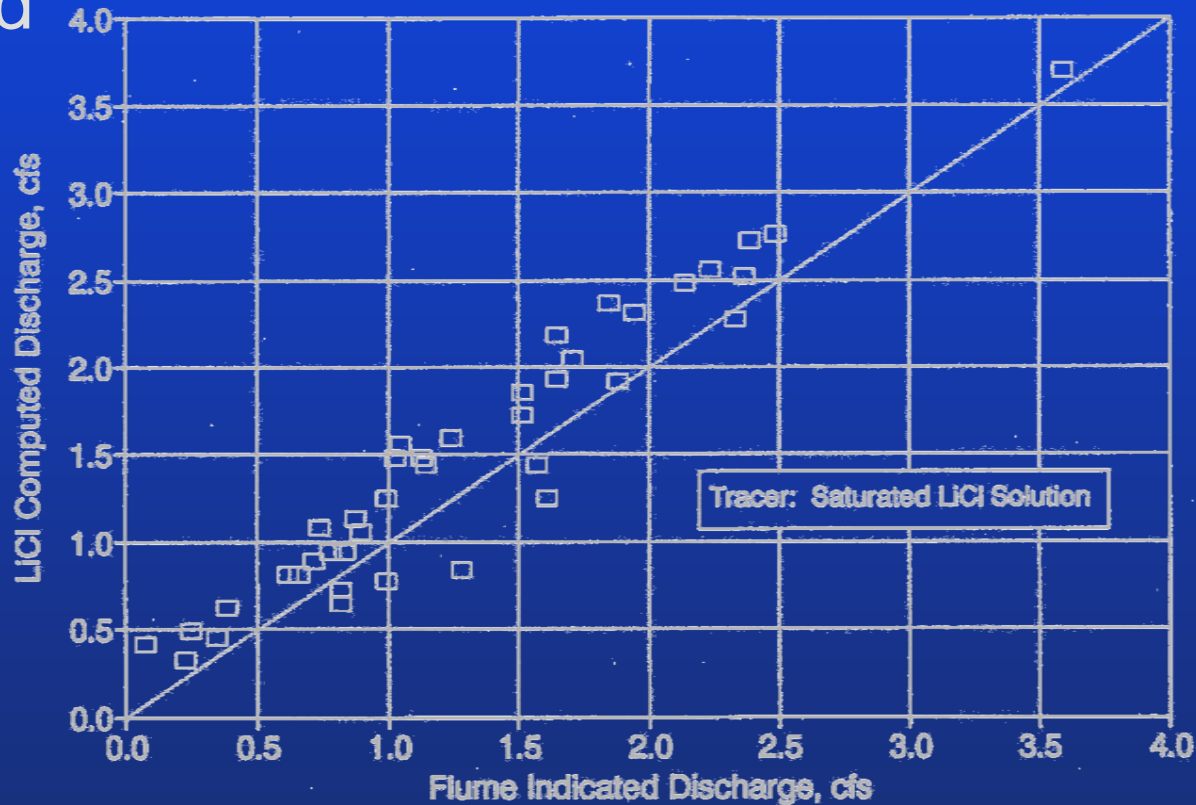
Source: Grizzard, T., personal communication.

# Field Calibration

- Flow monitoring devices must be calibrated to field conditions

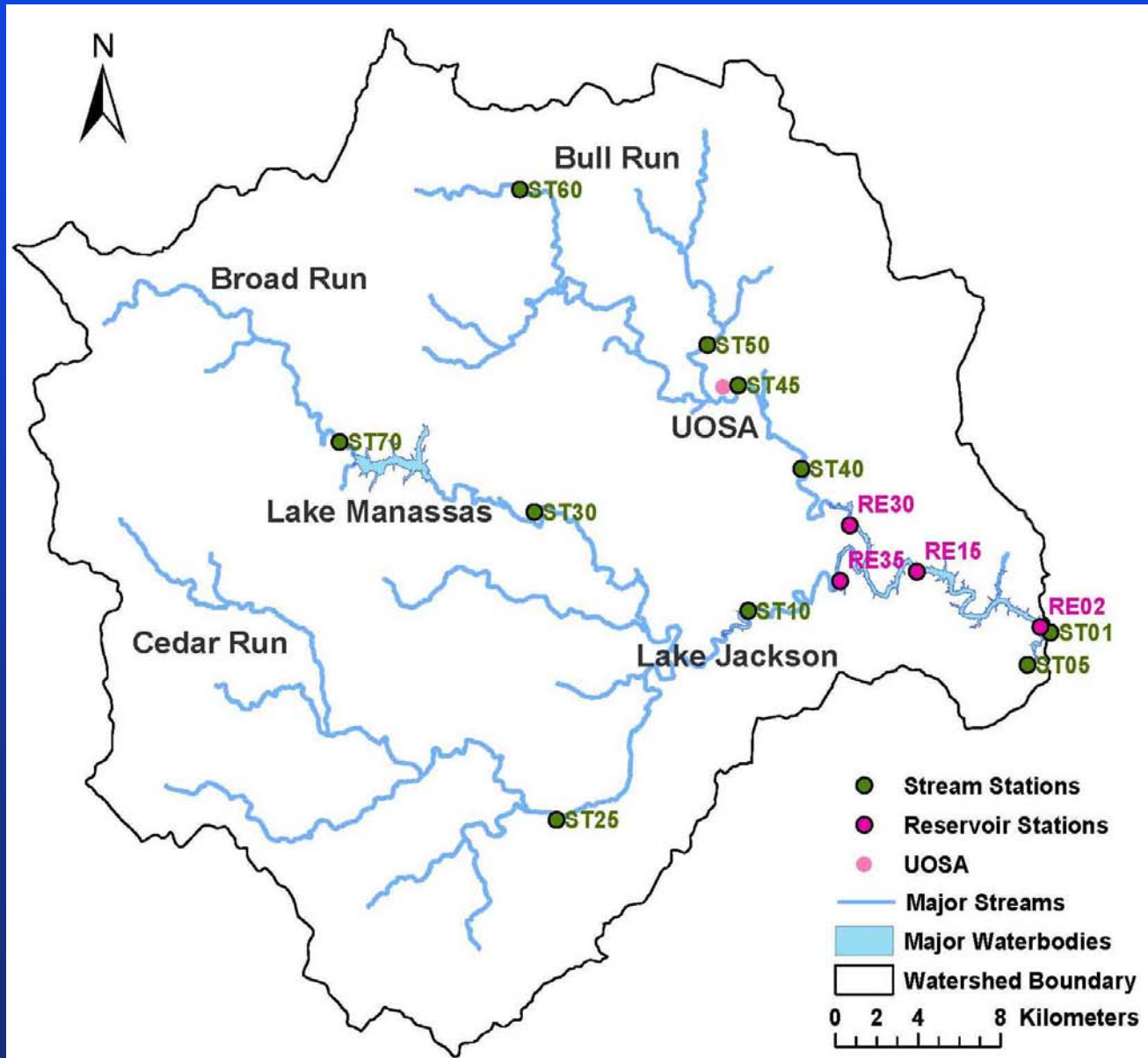


Rating Verification Results for 42 Inch Palmer-Bowlus Flume at UR15

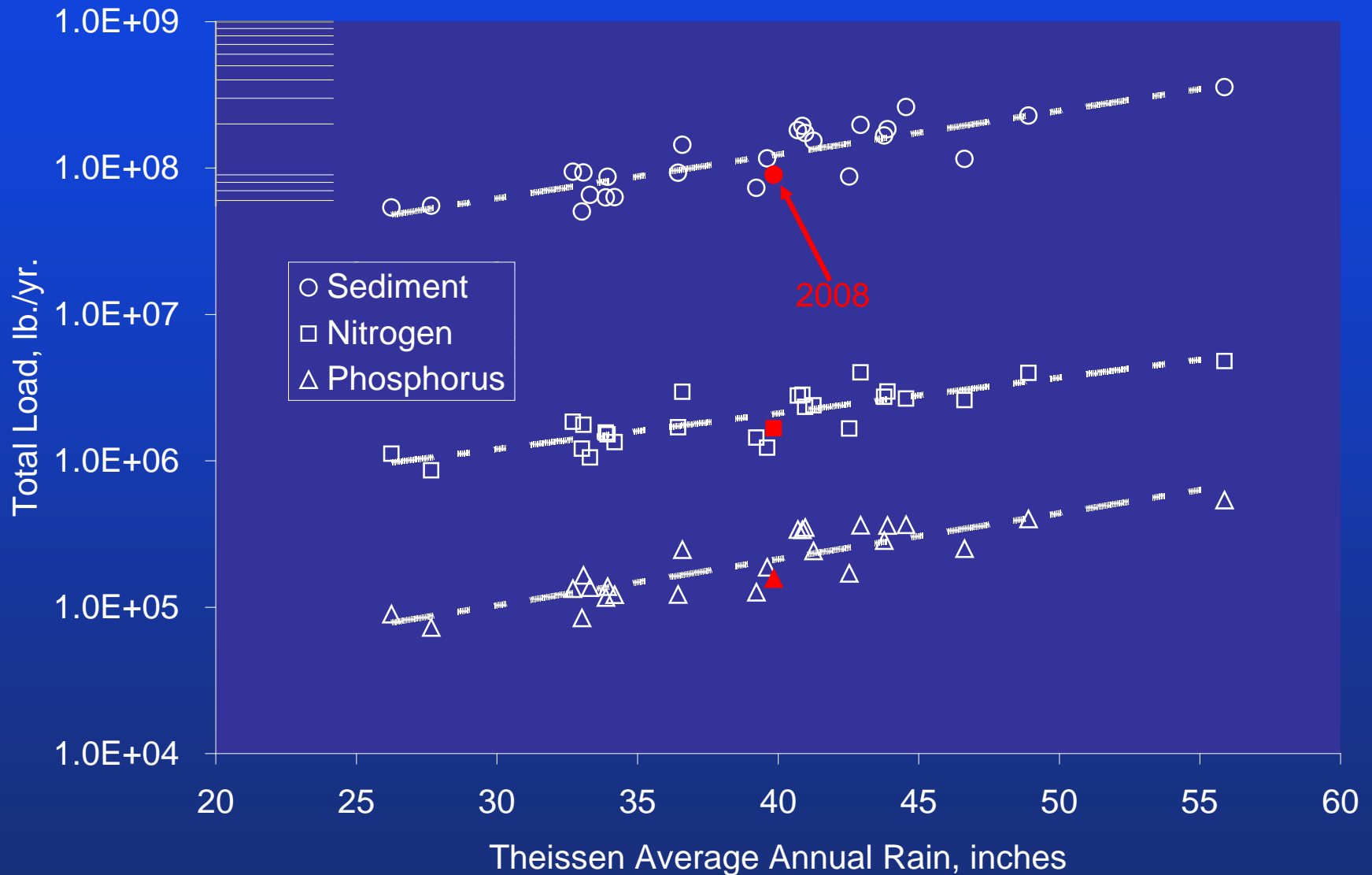


Source: Grizzard, T. (personal communication).

# Watershed Monitoring-Occoquan Watershed (570 mi<sup>2</sup>, 1,477 km<sup>2</sup>)



# Annual Pollutant Loading Dependency on Rainfall



# Pollutant Load Summary and Reservoir Trap or Conversion Efficiency: 1983 – 2008

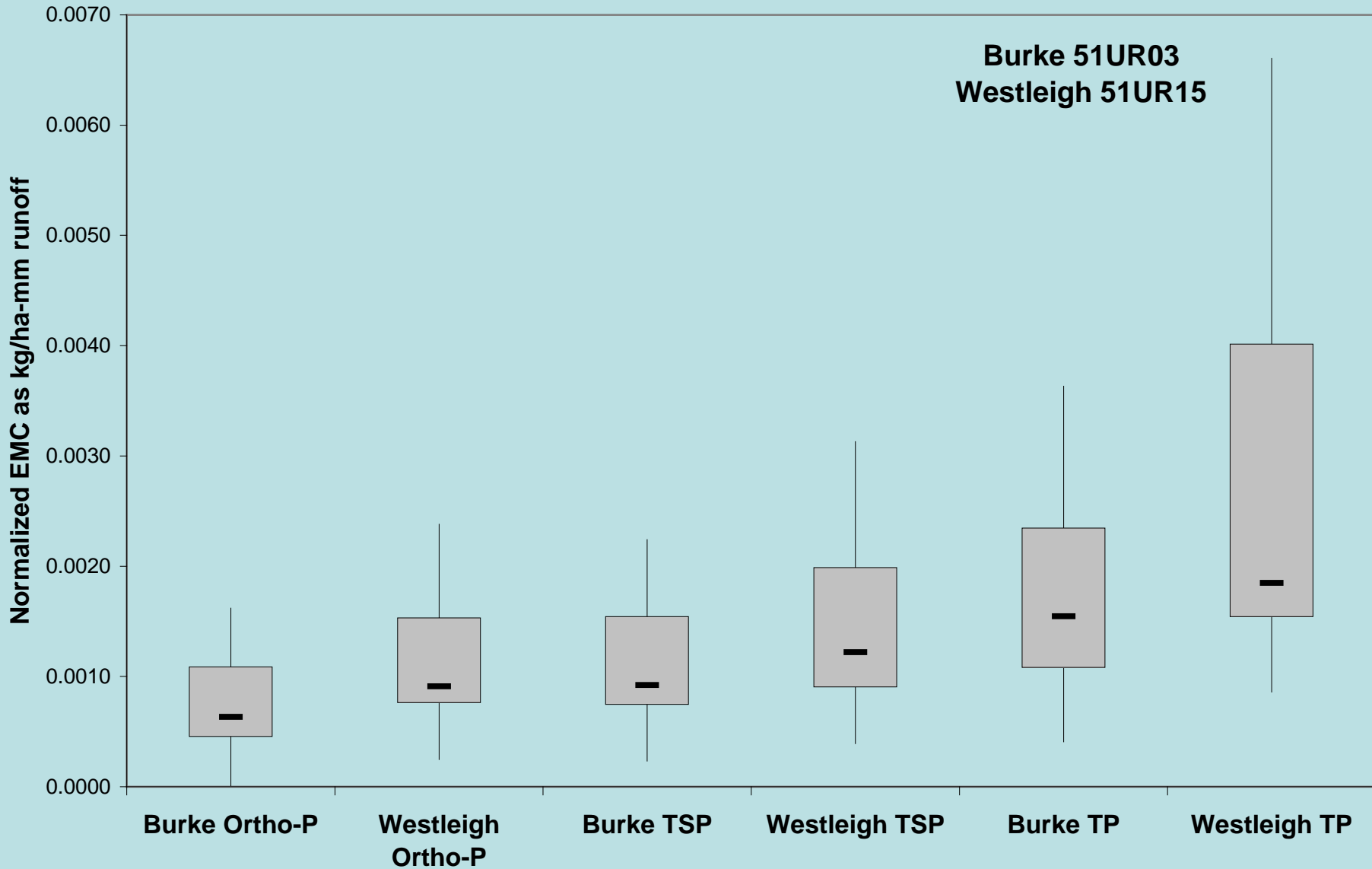
Constituent	Average Annual Load (lb.)	Nonpoint Sources (%)	POTW's (%)	Atmospheric Deposition (%)	Retention or Conversion in Reservoir (%)
Total Nitrogen	3.31E+06	66.2	33.4	0.4	27.9
Total Phosphorus	2.32E+05	98.0	1.9	0.1	56.2
Total Sediment	1.32E+08	100.0	0.0	0.0	83.4

Organic Matter in 2005-2008					
COD	2.76E+07	97.4	2.6	0.0%	18.1
TOC (Est.)	1.04E+07				

# Other Watershed based Stormwater Monitoring

- Long Term Ecological Site, Baltimore, Md.
  - Large range of watershed size 7.8 to 16,278 ha (19.2 to 40,200 ac), with impervious of 1 to 41%
  - Focus on monitoring N in base flows
- Long Term Ecological Site, Plum Island
  - 60 to 420 ha (148-1,037 ac) across a range of urban development, with impervious of 1.3-28.6%
- Fairfax County, USGS monitoring to assess program effectiveness
  - Watershed sizes in the couple of mi<sup>2</sup> range
  - Just initiated

# NURP Studies



# Stormwater Treatment Unit Operations and Processes

- Complex processes
- Many simultaneous
- Treatment Units/  
Operations

Category	Unit Processes											
	Flow		Physical			Chemical			Biological			
Unit Operations	Peak Attenuation	Volume Reduction	Sedimentation	Flotation	Flocculation	Filtration	Sorption	Precipitation	Destabilization	Phytoremediation	Transformation	Sorption
Dry Basins	●		●									
Wet vaults	●		●	●								
Wet ponds	●		●	●			●	●		●		●
Constructed wetlands			●	●			●	●		●	●	
Oil/water separators			●	●								
Vortex separators			●	●								
Precipitation			●				●	●				
Coagulation			●		●		●	●	●			
Inert media filters			●			●	●	●			●	
Sorptive media filters			●			●	●			●		
Grass Channel		●	●			●	●			●		
Wet swales			●				●			●		
Vegetated swales and strips (dry)		●	●			●	●			●		
Infiltration basins and trenches, porous pavements		●	●			●	●			●		
Bioretention	●	●	●			●	●			●		●
Vegetated roofs		●				●	●			●		●
Rainwater harvesting	●	●										

Sources: Minton, G.R. (2005) *Stormwater Treatment: Biological, Chemical, and Engineering Principles*, Resource Planning Associates, Seattle, WA.

Technical Memorandum: *The Runoff Reduction Method*, April 18, 2008, Center for Watershed Protection

# Maintenance-Physical Consideration

- Sedimentation
  - Fine particles resuspend due to scour
  - Loss of capacity
- Filtration
  - Clogging/Head loss
- Adsorption
- Testing of Parameters
  - Laboratory
  - Field Conditions

# BMP Performance Monitoring

- Traditional BMPs
  - Large, tend to be flow based-dominant variable is  $Q$
- Low Impact Development BMPs
  - Small, decentralized
  - Tend to be volume based
  - Difficult to monitor
  - Water balance, or volume is dominant

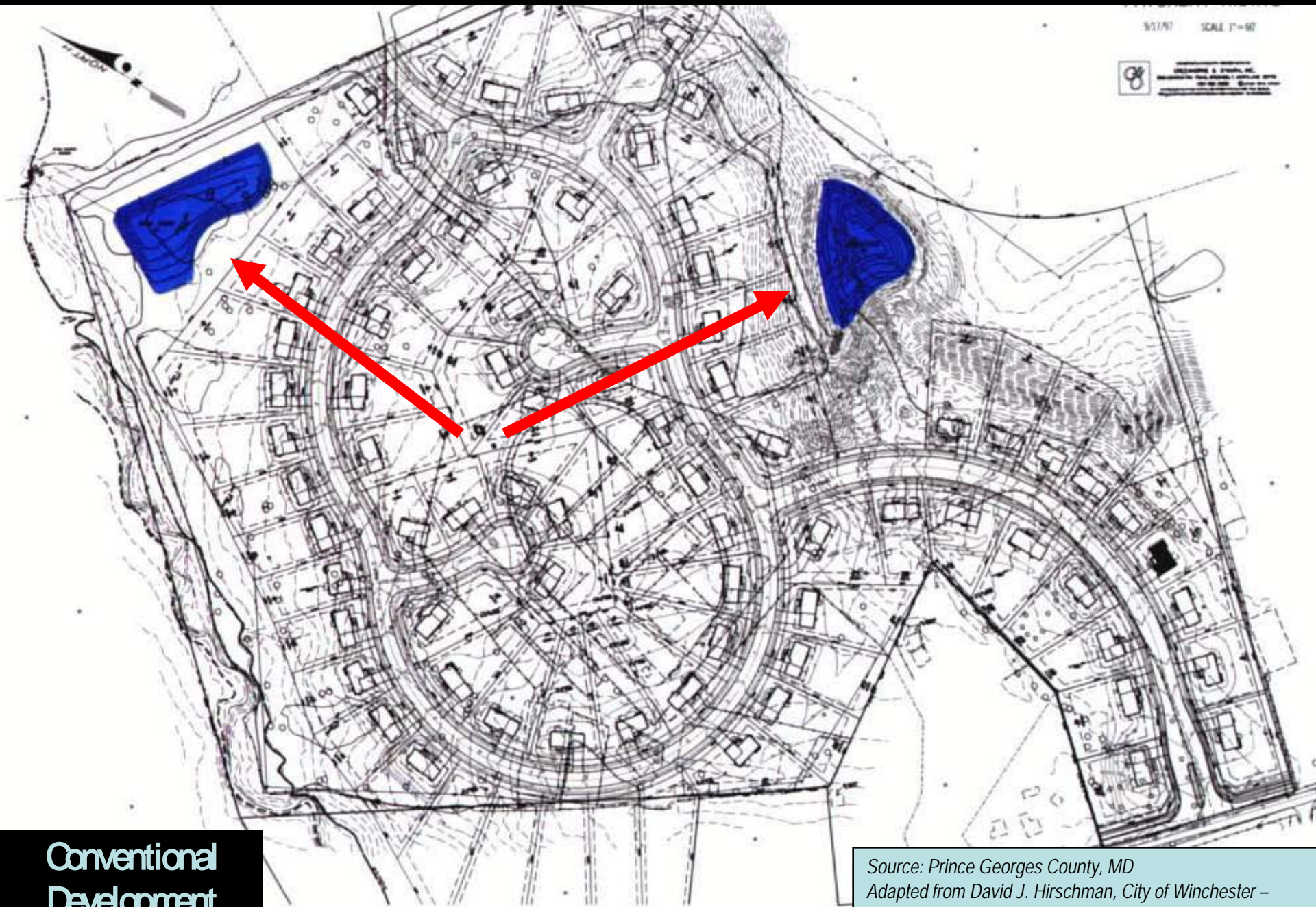
# Conventional Site Design



The "Good Drainage" Paradigm

Source: Prince Georges County, MD  
Adapted from David J. Hirschman, City of Winchester –  
Watershed Management Workshop, April 27, 2005

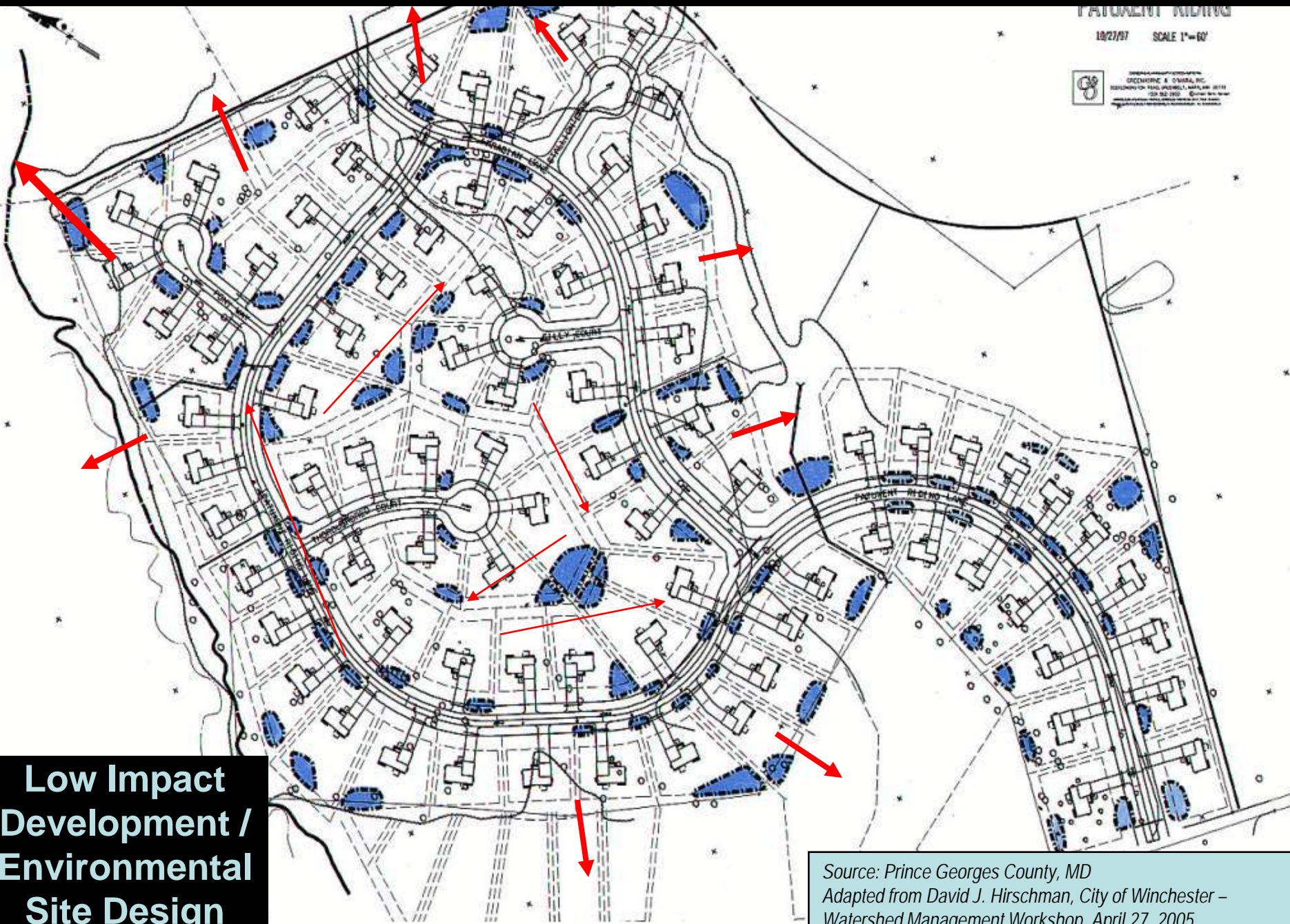
# Collect, Convey, Concentrate, Centralized Treatment



Conventional  
Development

Source: Prince Georges County, MD  
Adapted from David J. Hirschman, City of Winchester –  
Watershed Management Workshop, April 27, 2005

# Distributed, Disconnected, Decentralized





**Conventional**



**Low Impact**



**Good Drainage**



**Functional Landscape Design**

Source: Prince Georges County, MD  
Adapted from David J. Hirschman, City of Winchester –  
Watershed Management Workshop, April 27, 2005

# Techniques for Monitoring LID

- Before-After/control Impact (BACI)
- Comparison of Traditional and LID development
- Comparison of a LID retrofit watershed to preretrofit conditions
- Multiple techniques

*Source: Geosyntec and Wright water Engineers (2009) Urban Stormwater BMP Performance Monitoring*

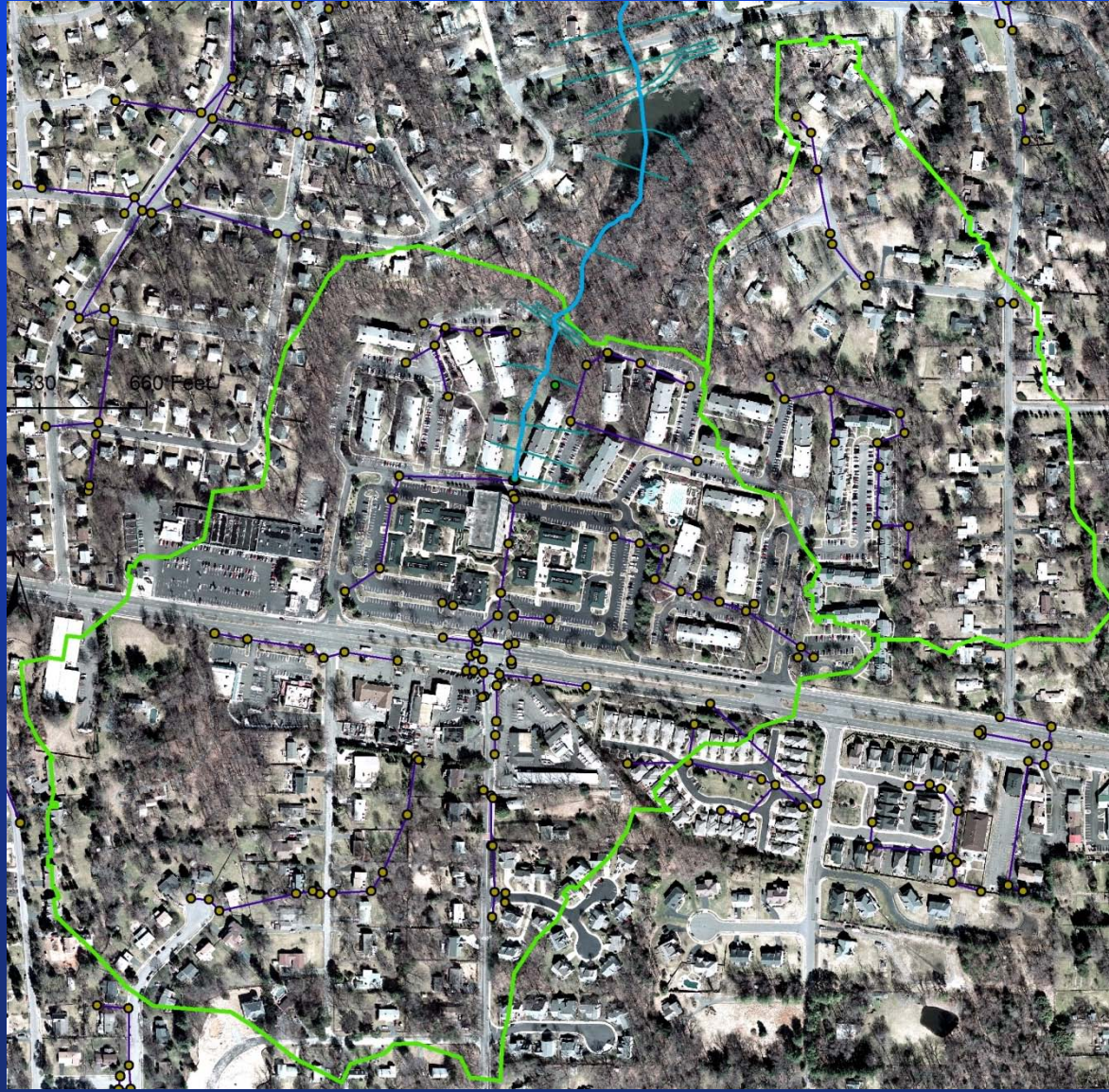
# Ultra Urban BMPs and Manufactured Treatment Devices

- Must balance conflicting goals
  - Water quality
  - Investment return
  - Scientific advancement
- Certification assist local government in making hard choices
- Existing Protocols
  - TARP
  - TAPE

*Source: (*

# Traditional BMP in City of Fairfax (wet pond)

- 3 subwatersheds
  - West: 90 acres, 47% imp.
  - East: 33 acres, 30% imp.
  - Direct: 16 acres, 10% imp.
- Performing detailed audit upstream
- Project is to retrofit pond, and install floating wetland systems



# LID Design/Implementation Science Museum, Richmond

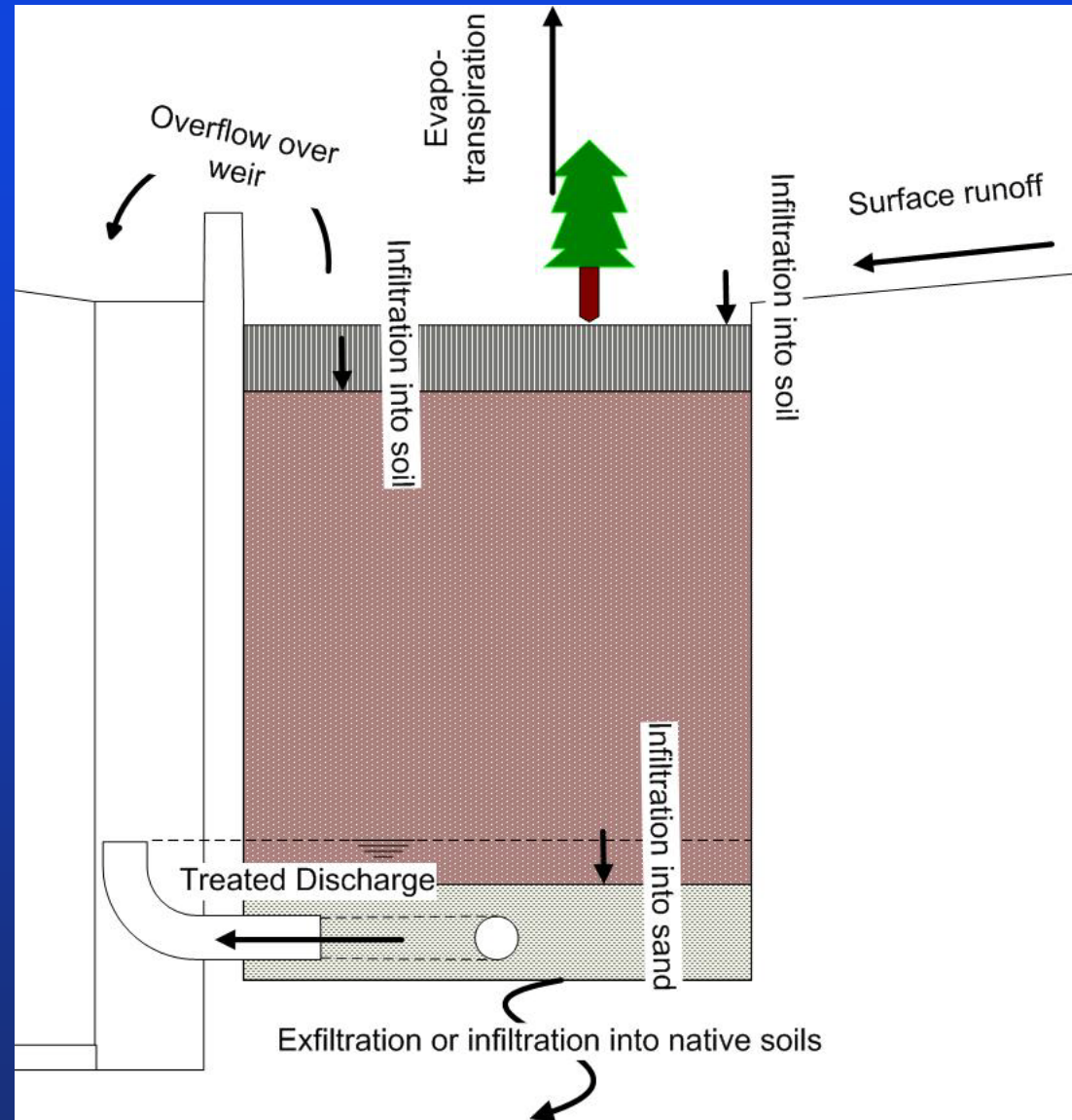
- Bioretention
- Permeable pavement
- Tree-box filters
- Rainwater Harvesting
- Vegetated Roof



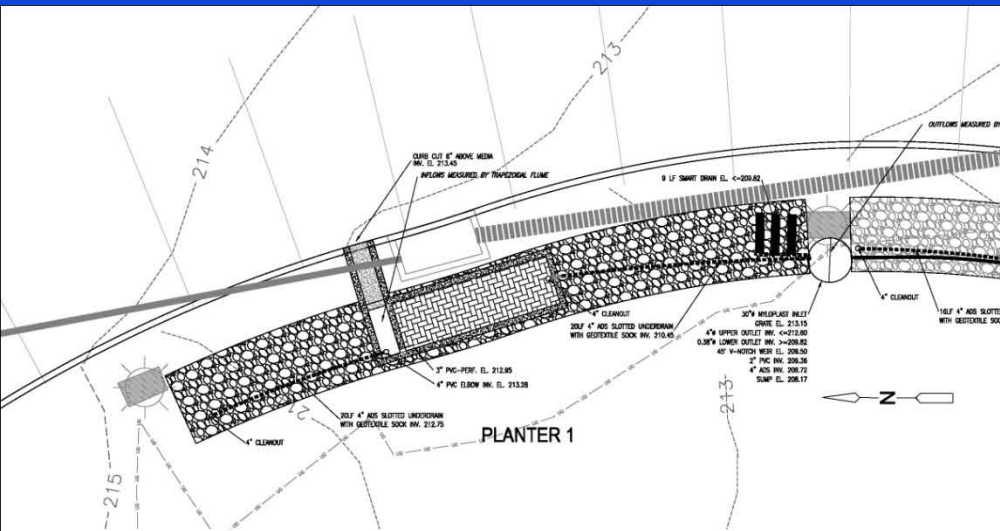


# Within BMP, Process Modeling

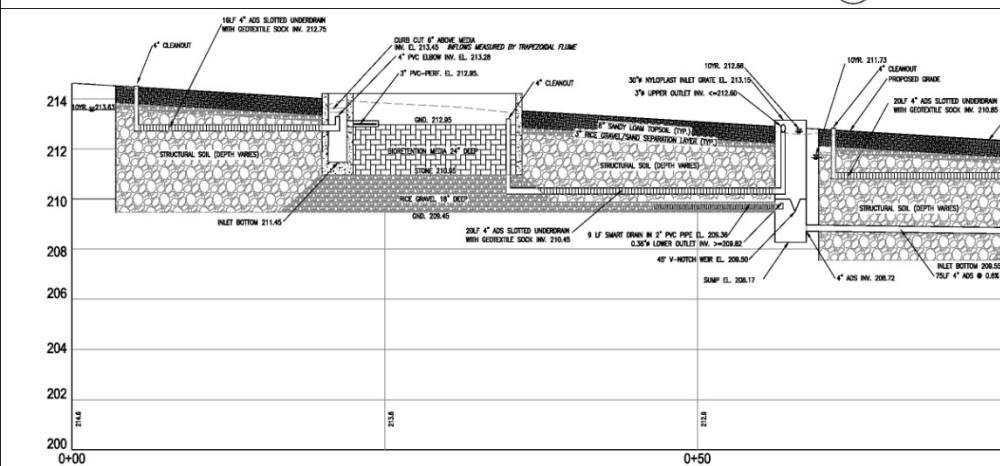
- Goal to capture system behavior
- Example shown, bioretention
- Ultimately would like to monitor
  - Flows in/out
  - Groundwater
  - ET
  - Soil Moisture



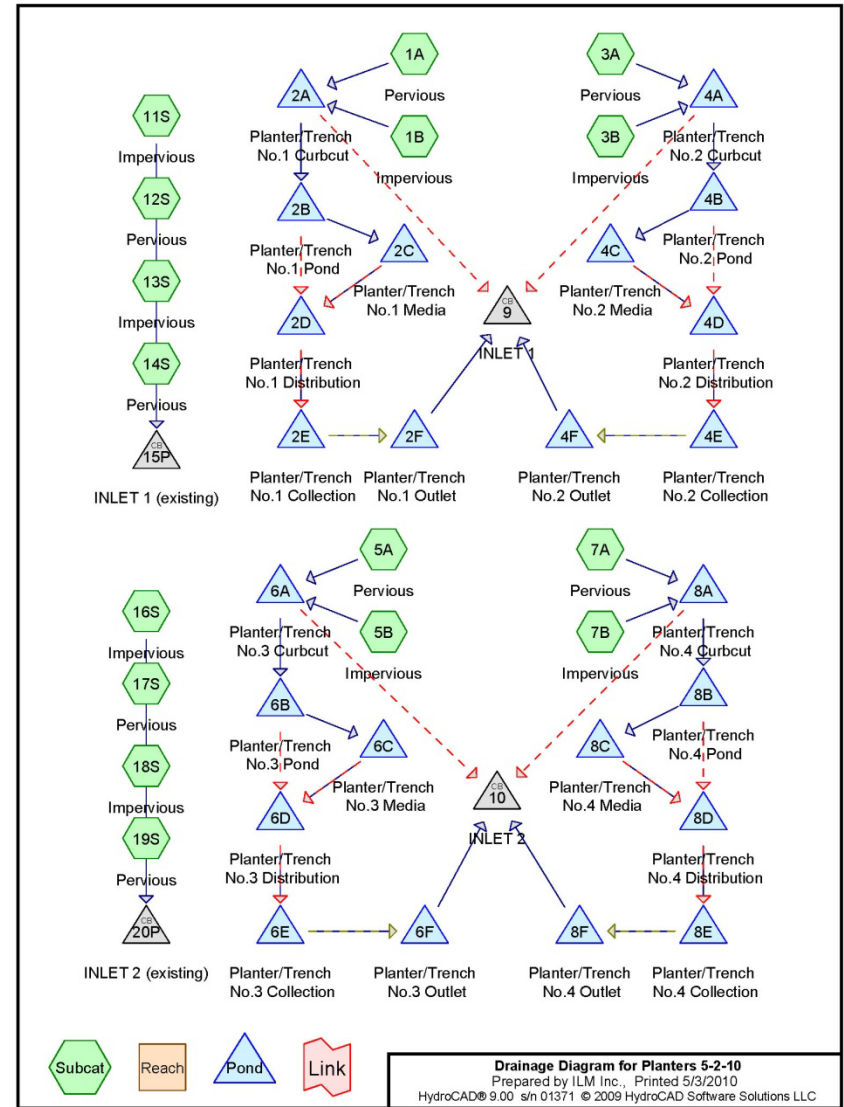
# Extending Performance Predictions with Models



1 PLAN-PLANTERS  
SCALE: 1"=5'

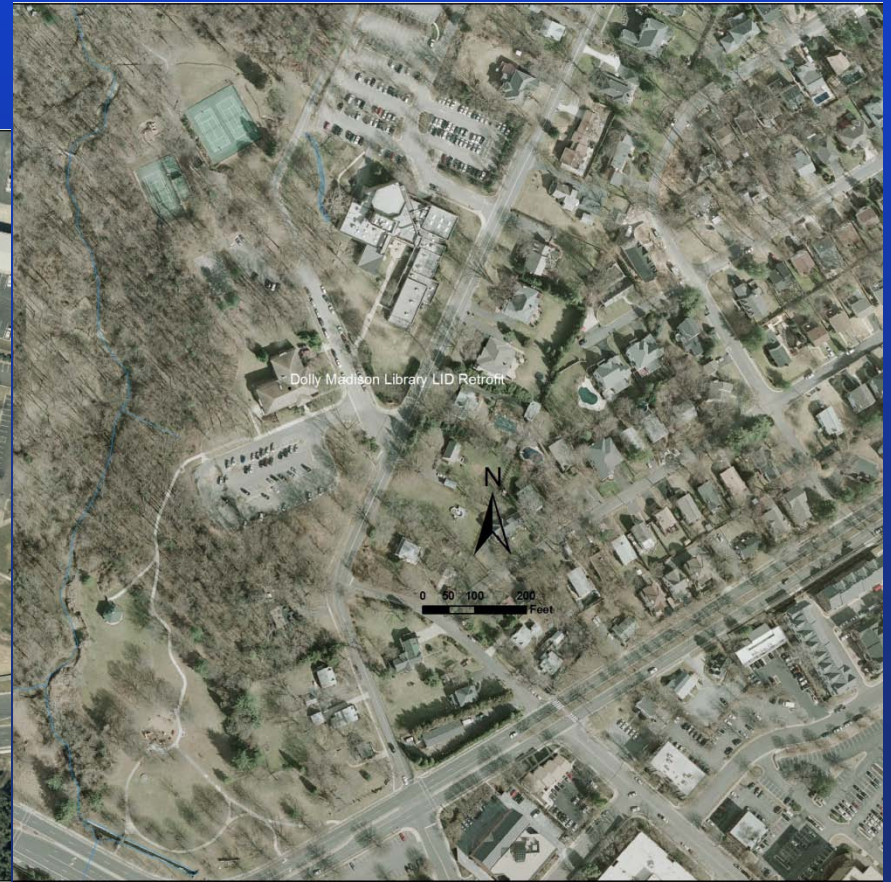
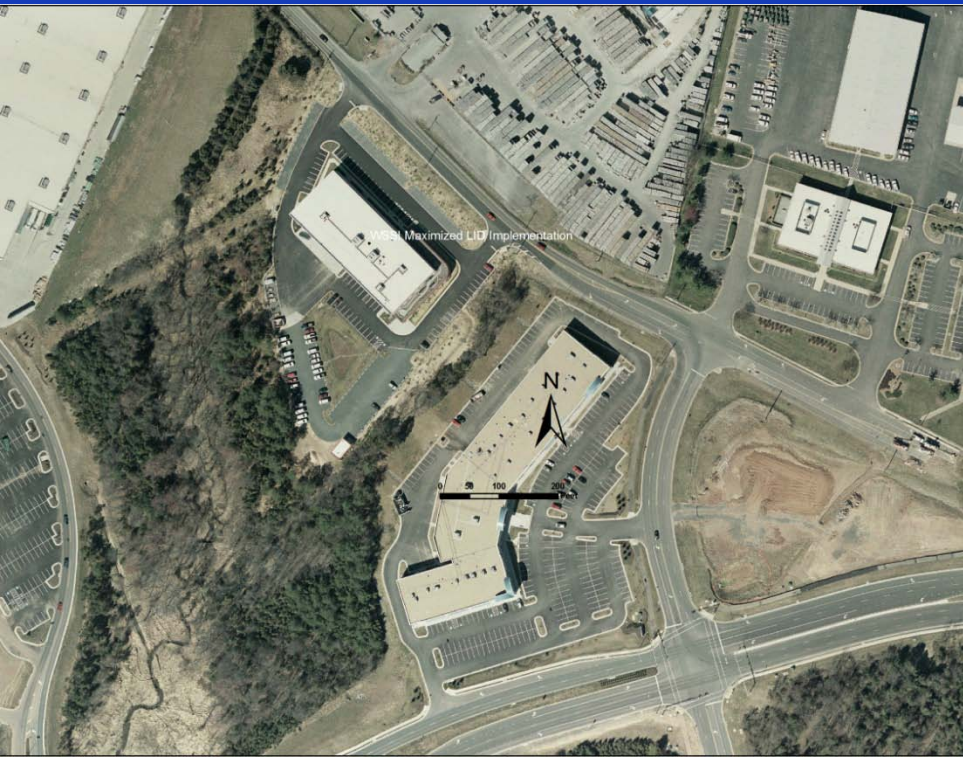


2 PROFILE-PLANTERS 1  
SCALE: 1"=5', 2"1 VERT. EXAGG



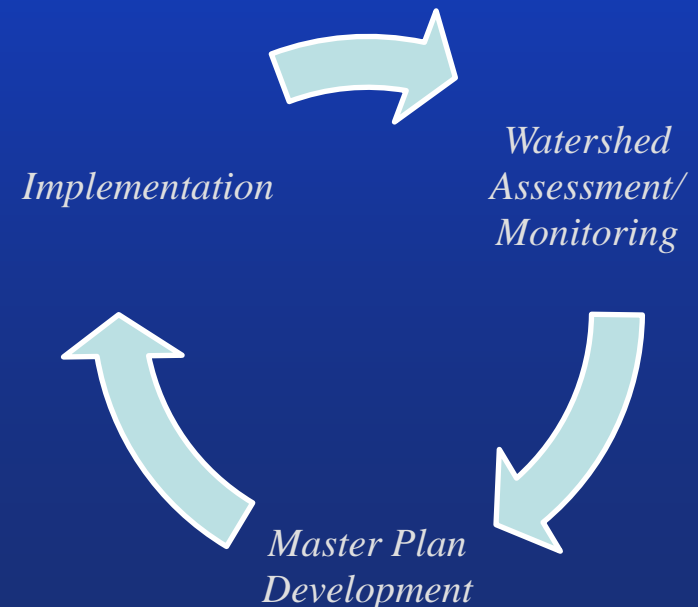
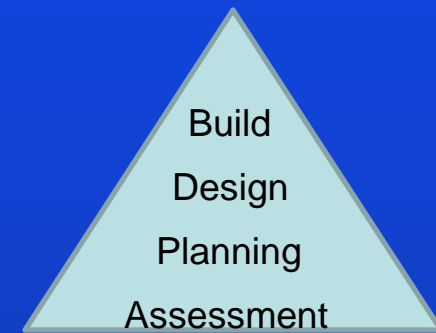
# Site Based Monitoring of LID

- WSSI site in Gainesville, Dolly Madison Library in McLean
- Monitoring for flow, nutrients, TSS for 15 months-while developing and calibrating within site process models.
- Using the models to extend the results of the monitoring analysis

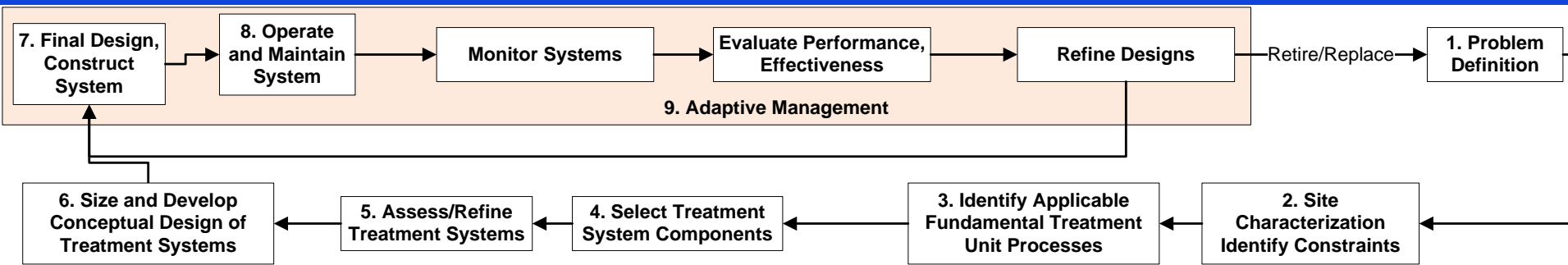


# Resources in LID Implementation

- Local governments
  - Focus upon implementation with limited \$
  - Impressive investments in planning and implementation
- State Agencies
  - Focus upon implementation with limited \$
- Federal Agencies
  - Results-focus upon implementation
  - Recent CBP shifts in monitoring resources



# Monitoring and Adaptive Design



- Conceptualization of design process
- Monitoring of processes and performance is essential to improving designs
- Often ignored, it includes Operation and Maintenance
- Need to also monitor costs. Cost/performance is how much control we are getting for the \$.

# Summary-The Value of Monitoring

- We cannot monitor “everything everywhere all the time.
- Selective monitoring performance is essential to improving BMP design.
- We are not doing enough monitoring, particularly:
  - Small urban, homogenous sites
  - Urban BMP performance, particularly LID
  - Manufactured Treatment Devices
- Need to focus on doing monitoring well rather than doing a lot of monitoring
- Monitoring works in tandem with models at various scales: subsite, site, and watershed based.

**Questions?**