

# Creating Green Stormwater

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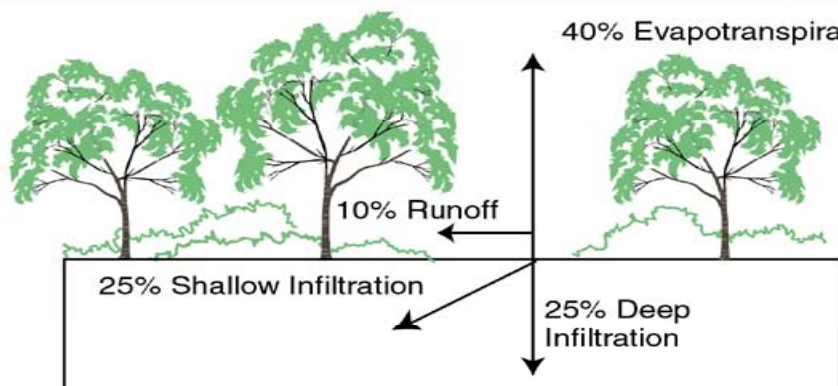
*University of Maryland  
College Park, MD 20742*

October 9, 2009

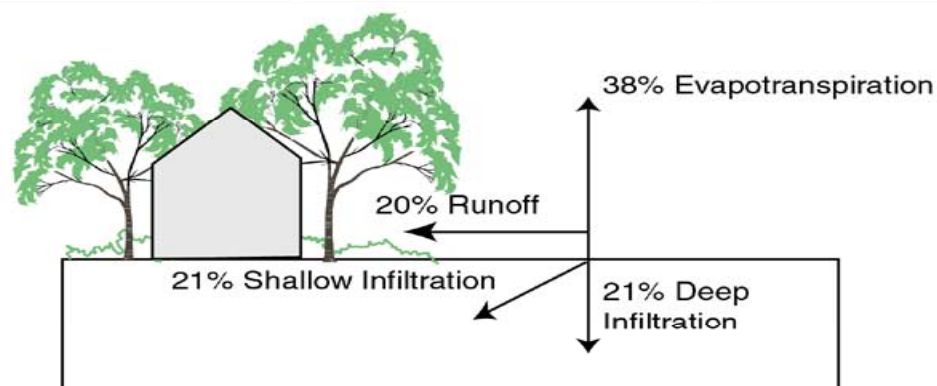




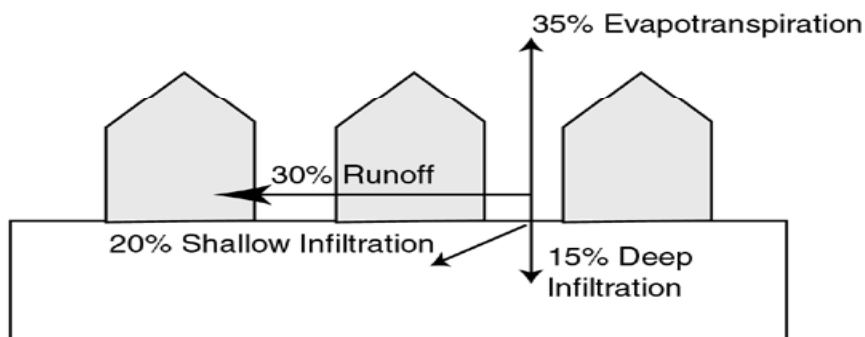
# Urban Infrastructure, Imperviousness, and Runoff



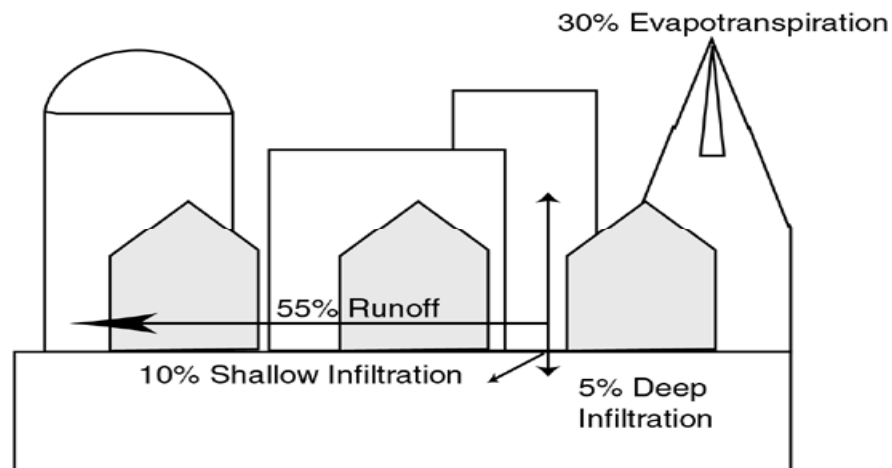
Natural Ground Cover



10% - 20% Impervious Surface



35% - 50% Impervious Surface



75% - 100% Impervious Surface

Changes in runoff flow resulting from increased impervious area (NC Dept. of Nat. Res. and Community Dev., in Livingston and McCarron, 1992.)



# Conventional



**Conventional**





*Erosive, Polluting, Ecological Impacts, Water Supply*



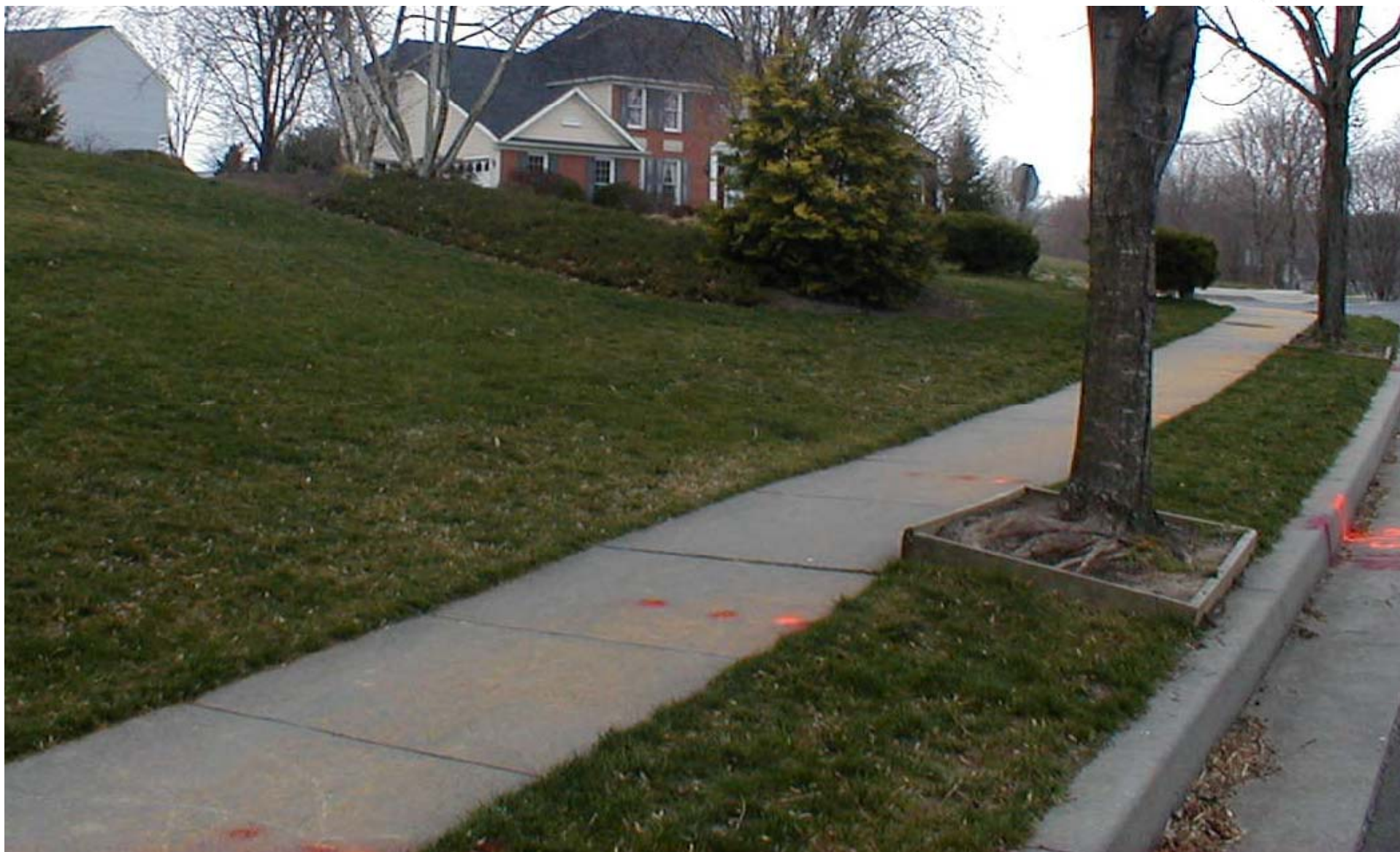


# Sources of Pollutants





# Sources of Pollutants





# *Nutrient Source*





# Sources of Pollutants



# *Novel Technologies*



# Bioretention



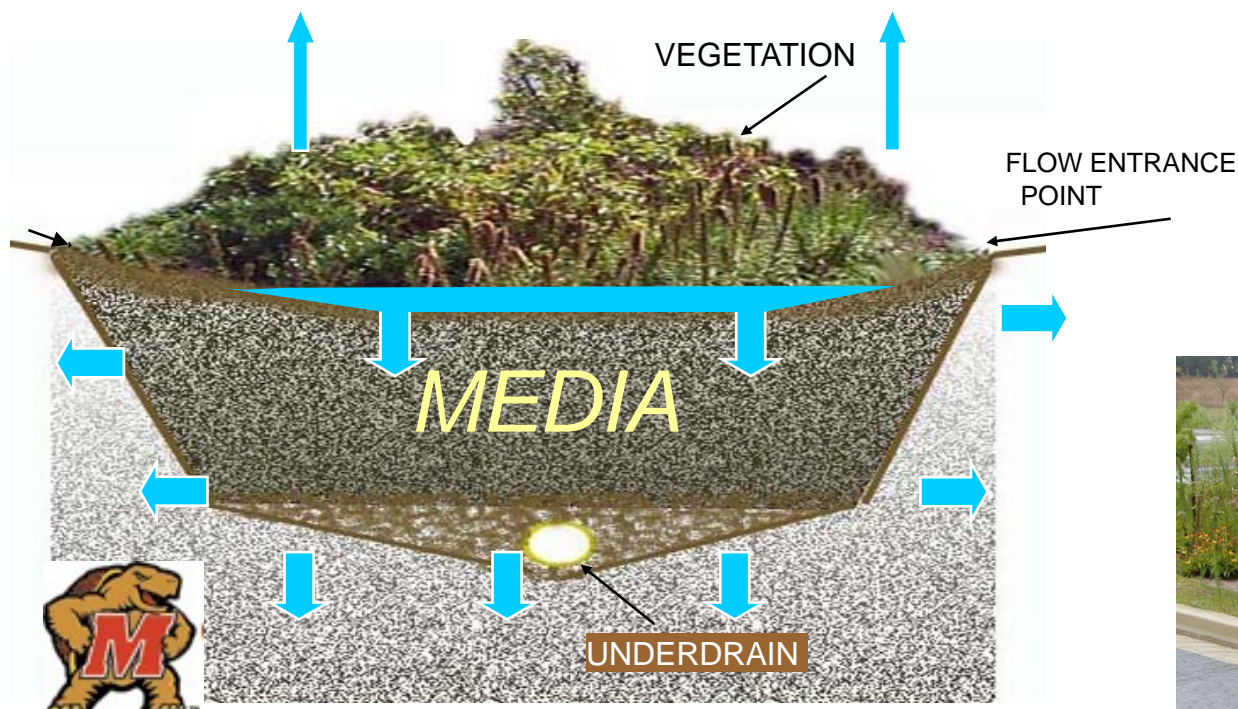


# Bioretention (Rain Gardens)

Hydrology: Pooling, Infiltration,  
& Evapotranspiration

Quality:

Filtration,  
Adsorption,  
Biodegradation



**MEDIA:** Sand, Soil,  
Organic Matter



College Park

# Bioretention

research &  
monitoring



Silver Spring

# Goals

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- Hydrology Management
- Improvements in Water Quality
- Understand Fundamentals
- Facility Design
  - Size
  - Media
- Facility Management



# Concurrent Challenge

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- What are the proper metrics for success?





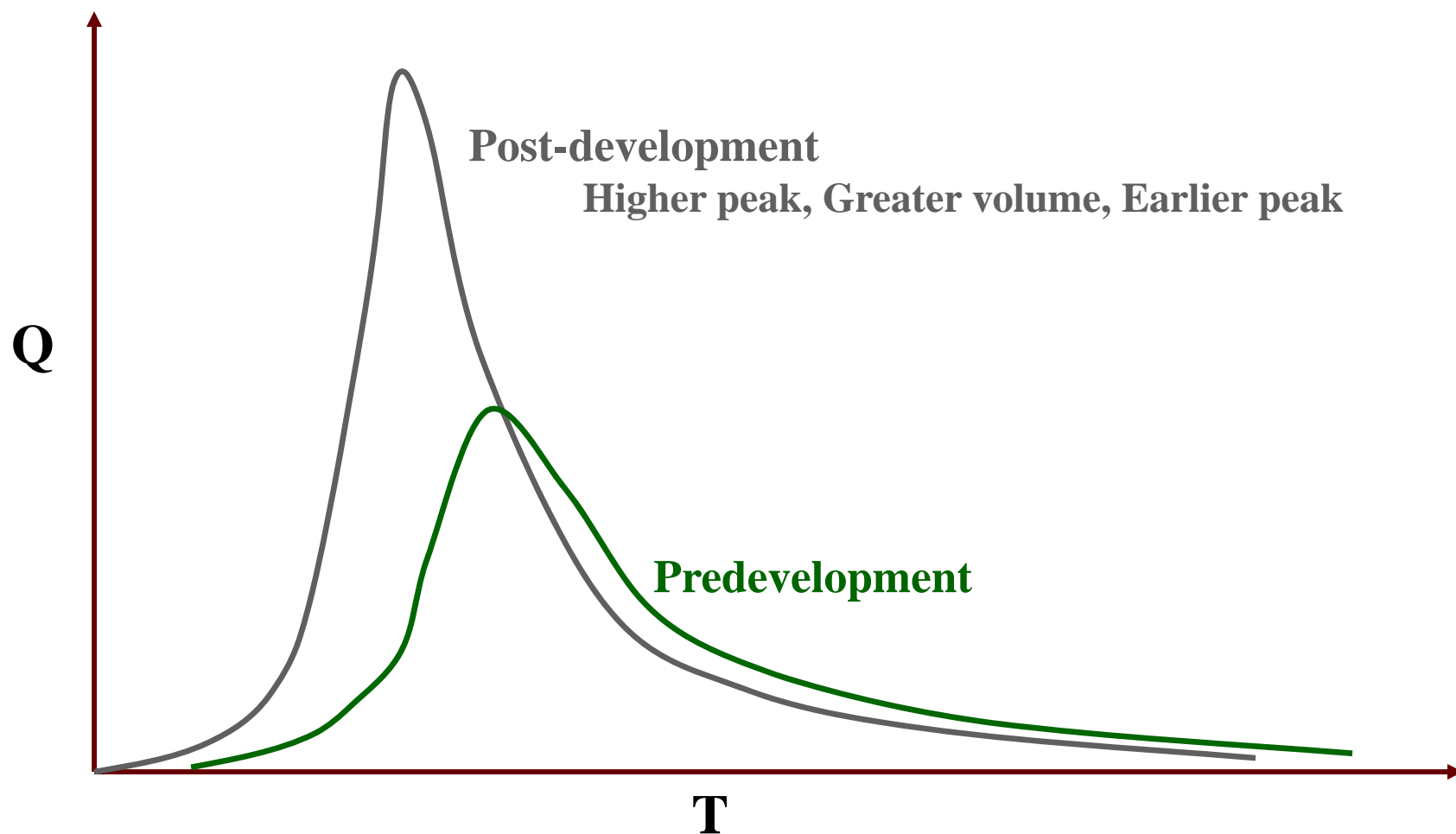


# Hydrology





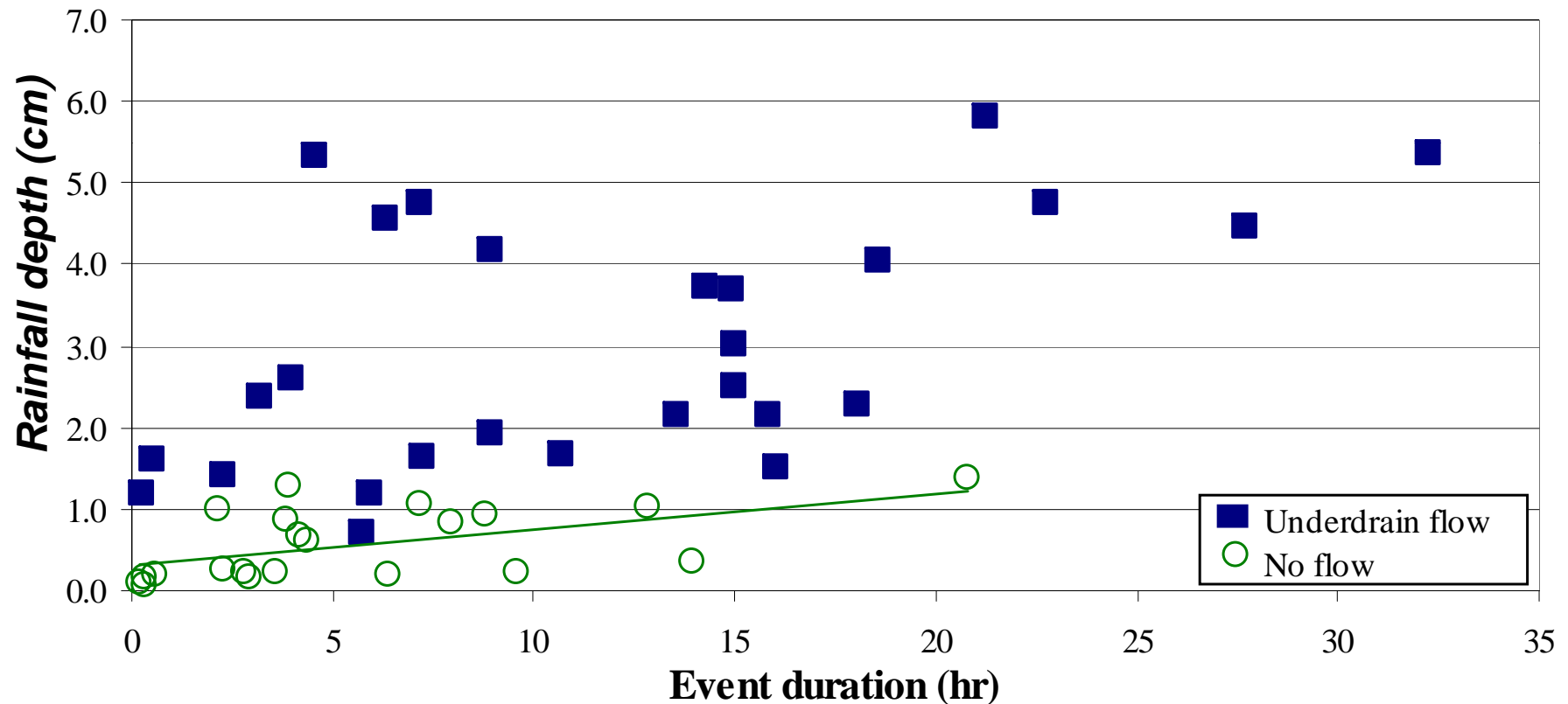
# Hydrographs



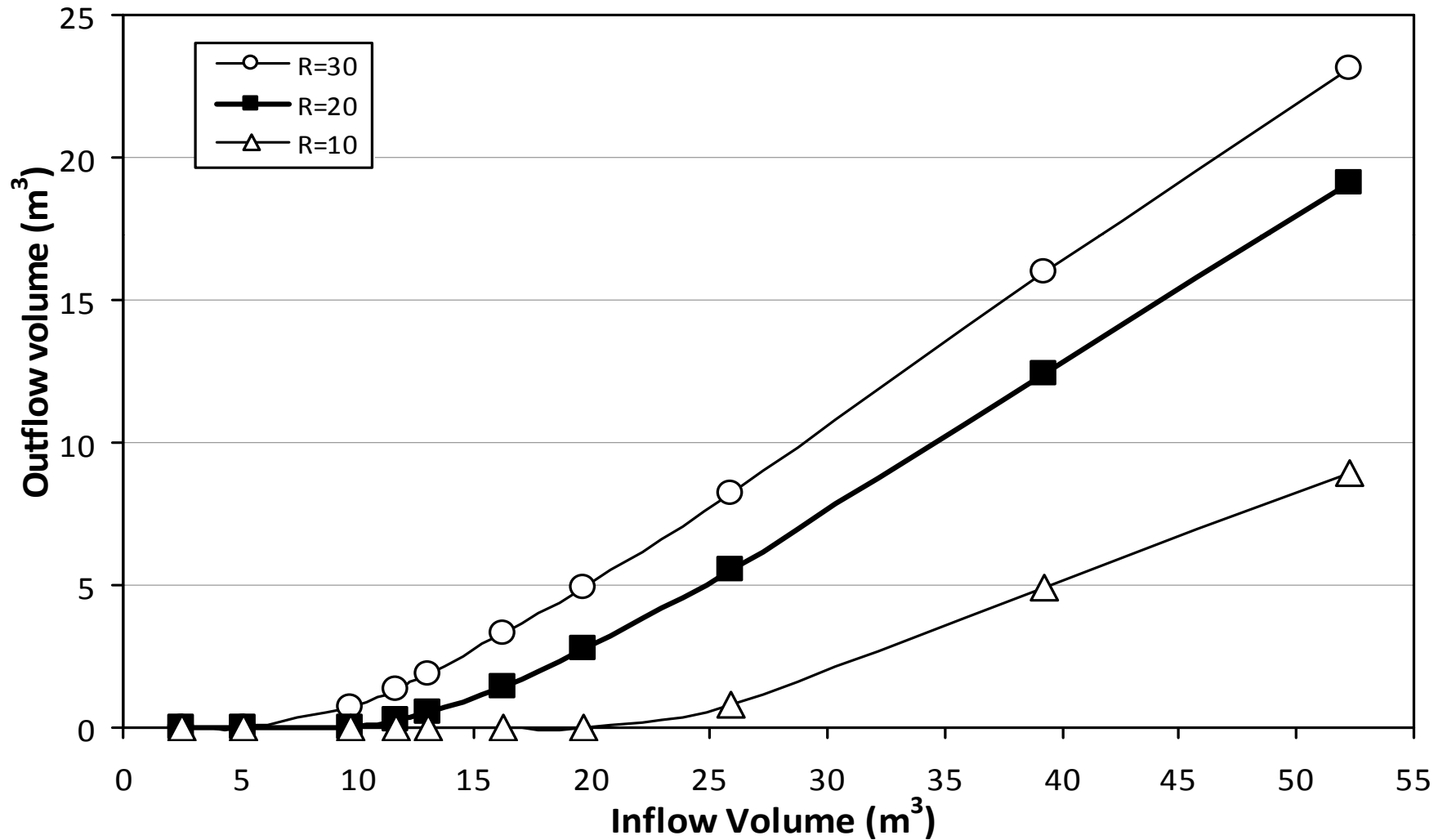


# Discharge vs. Zero-discharge events

60 events, 23 with no discharge

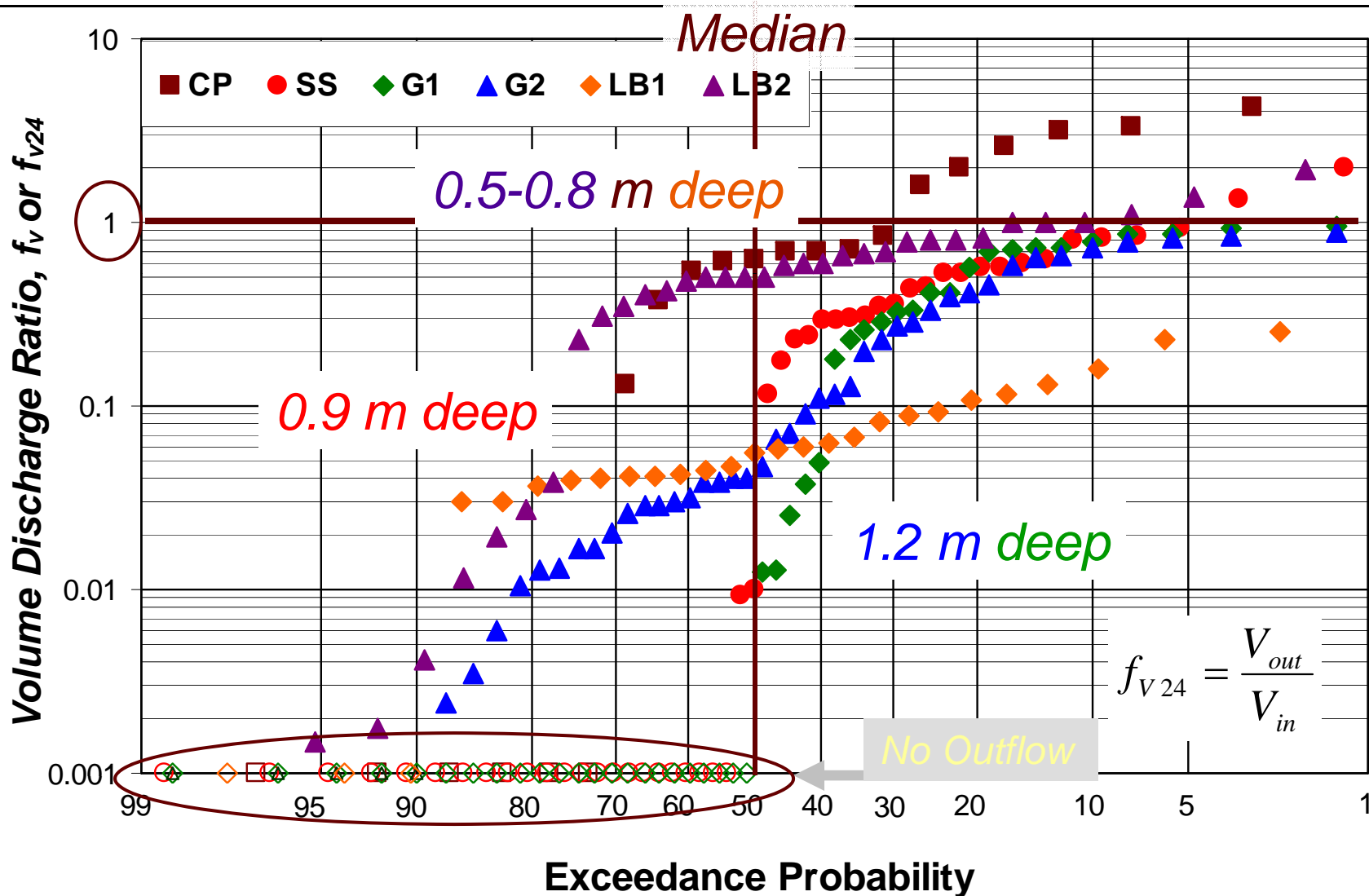


# Bioretention Modeling: Size





# Volume Reduction Ratio, $f_v$

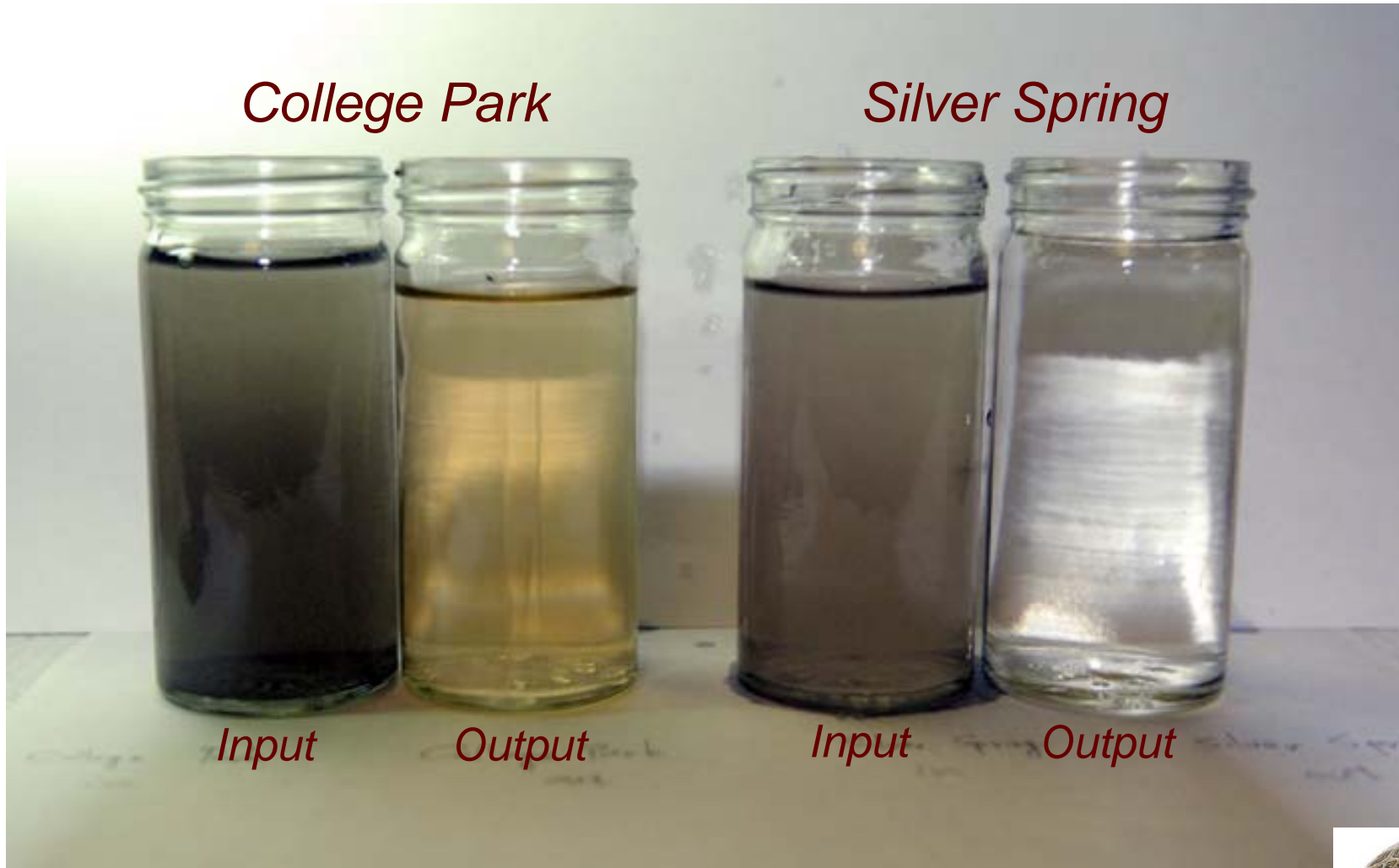


# Water Quality



*College Park*

*Silver Spring*



*Input*

*Output*

*Input*

*Output*



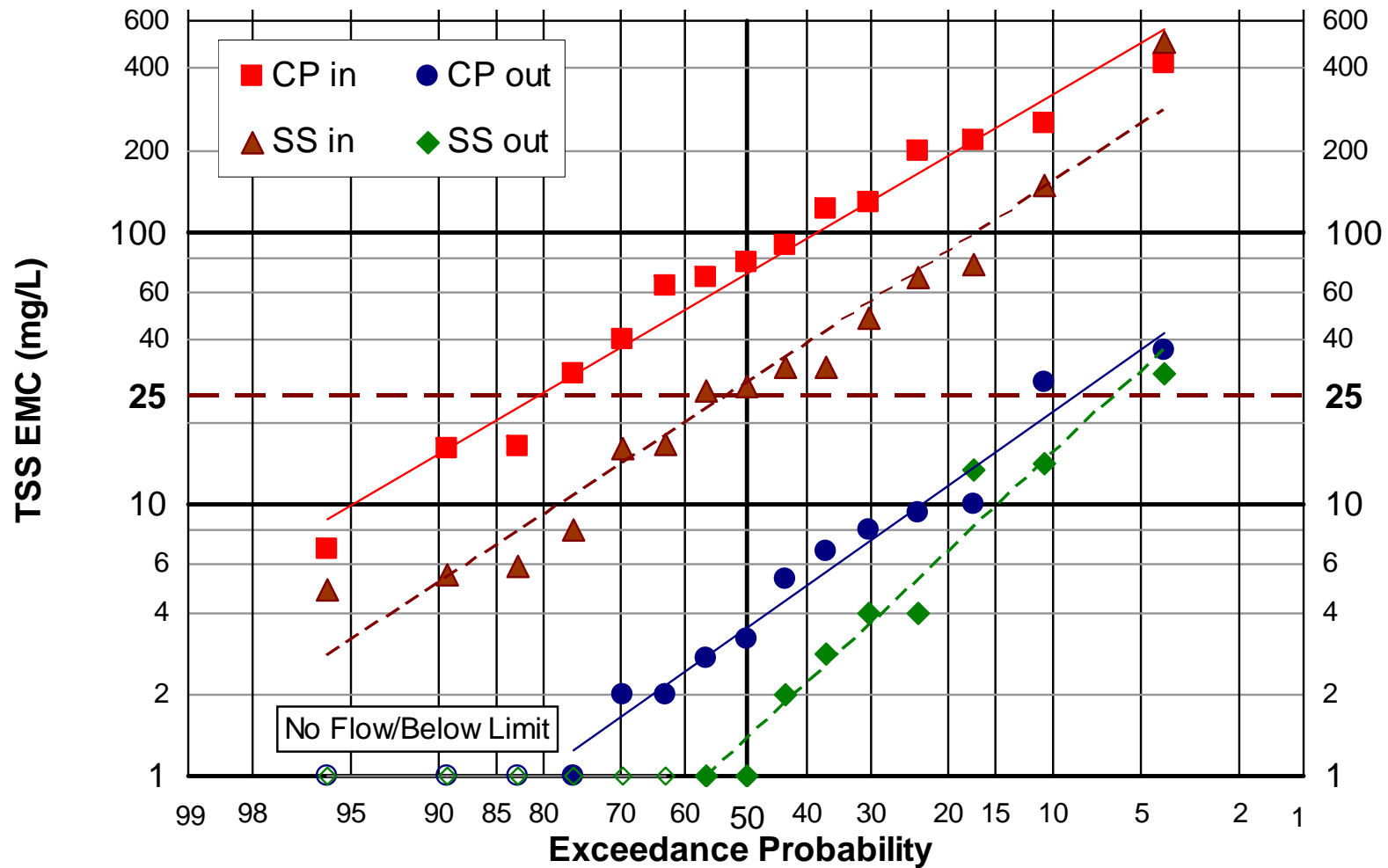


# Particulate Matter & Bacteria





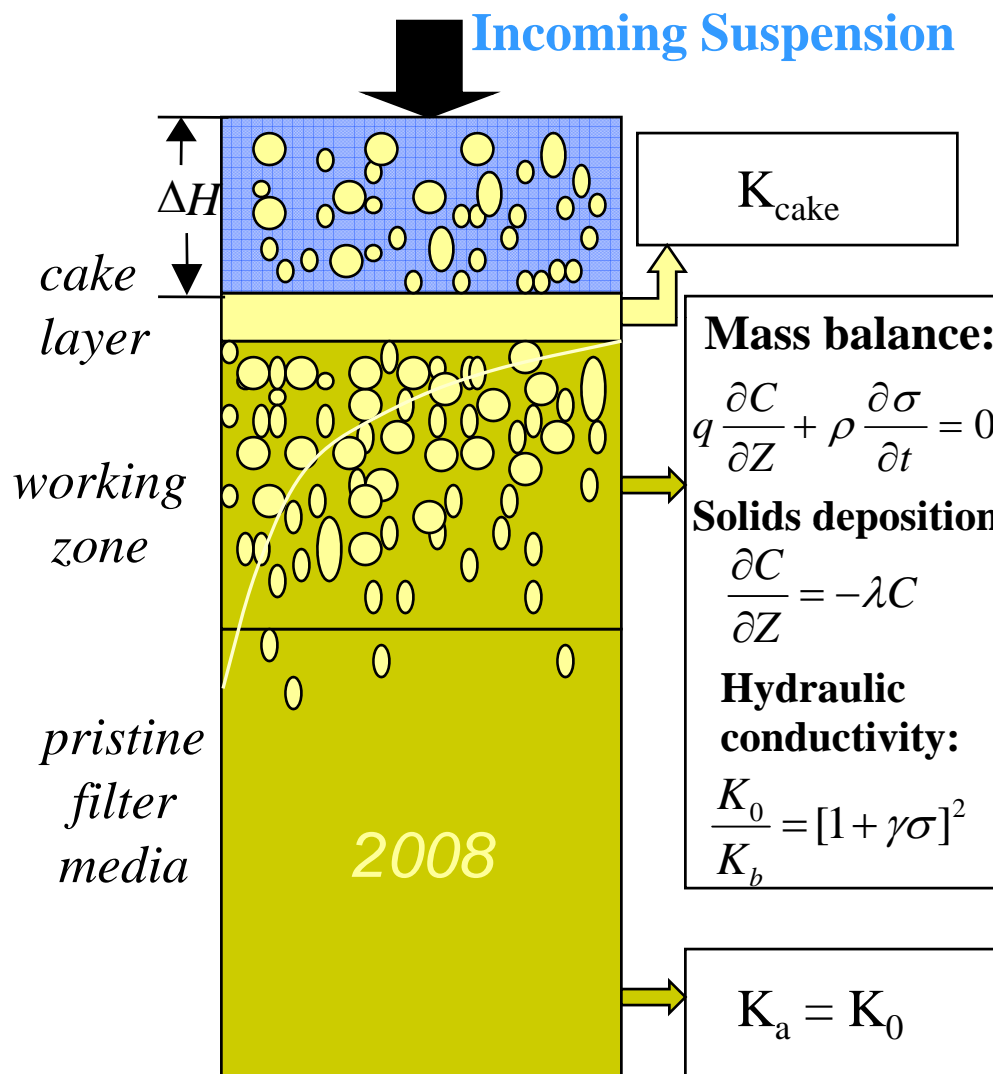
# Bioretention TSS (CP & SS)





# Suspended Solids Filtration

➤ A three-layer model



# Bioretention





# TSS Accumulation

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- Intermittent flow conditions allow more particulate capture than continuous flow
- **SS do not penetrate below 5-20 cm in the media**
- Periodic surface media replacement can be used to recover hydraulic conductivity.



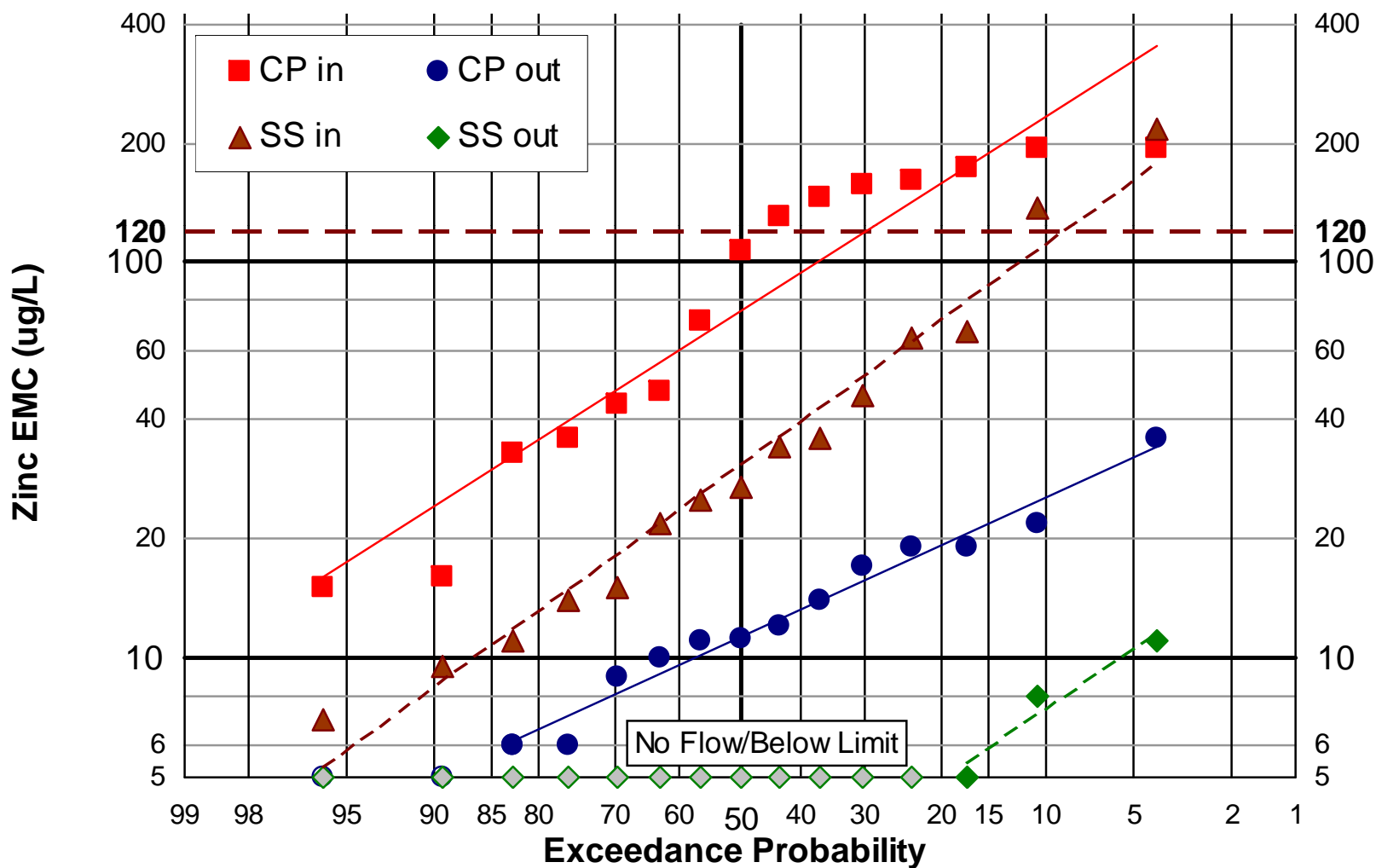


# Metals & Hydrocarbons

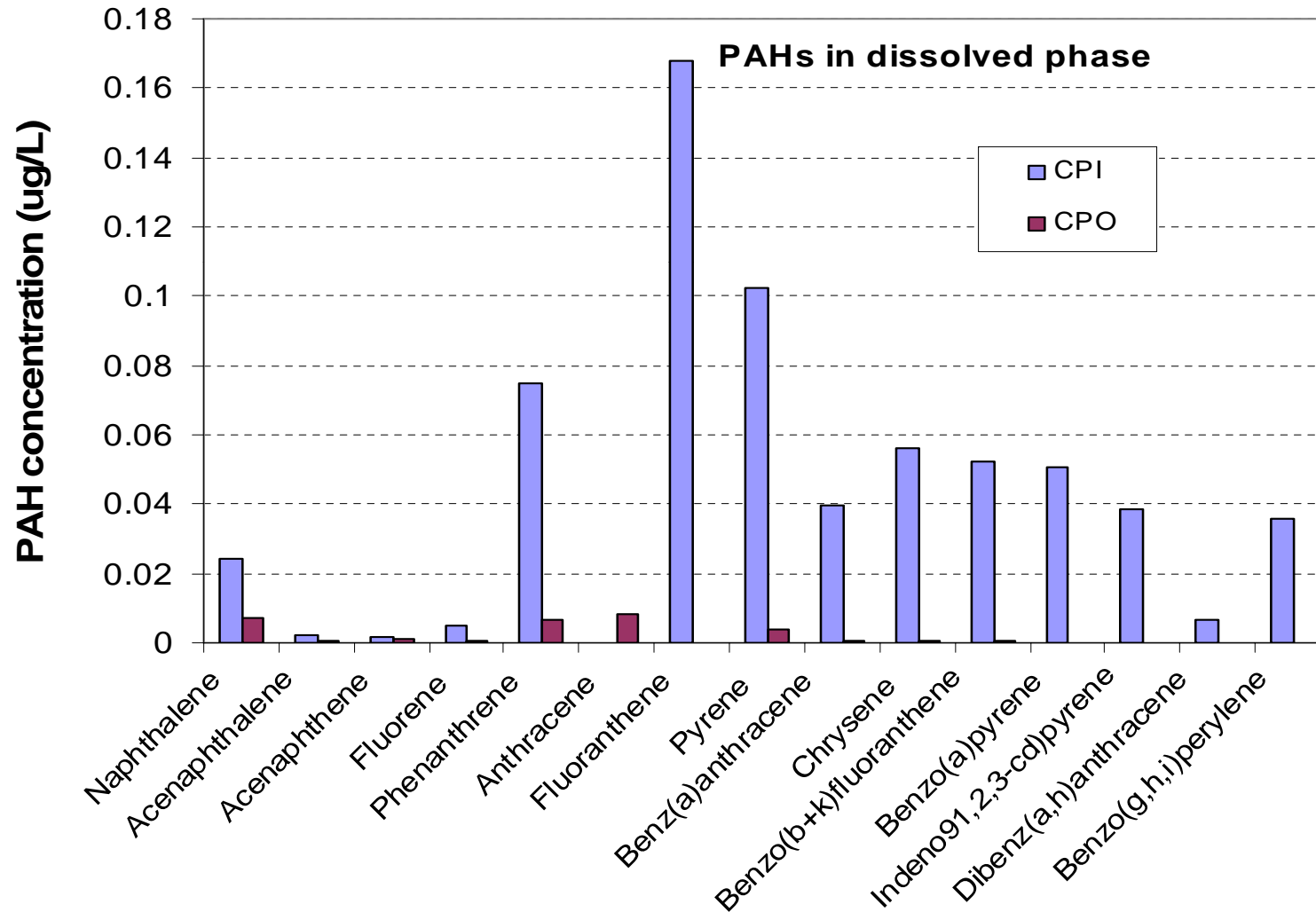




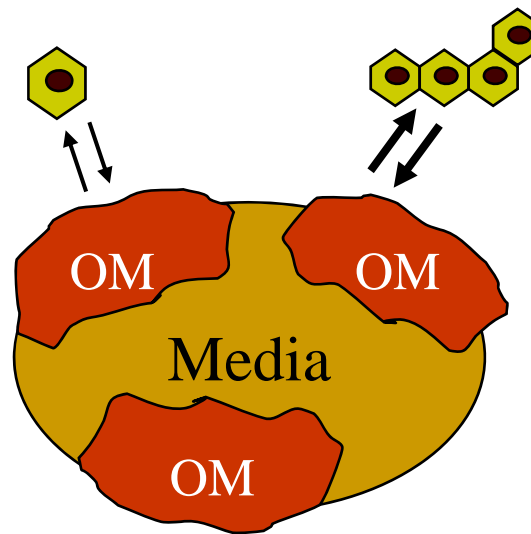
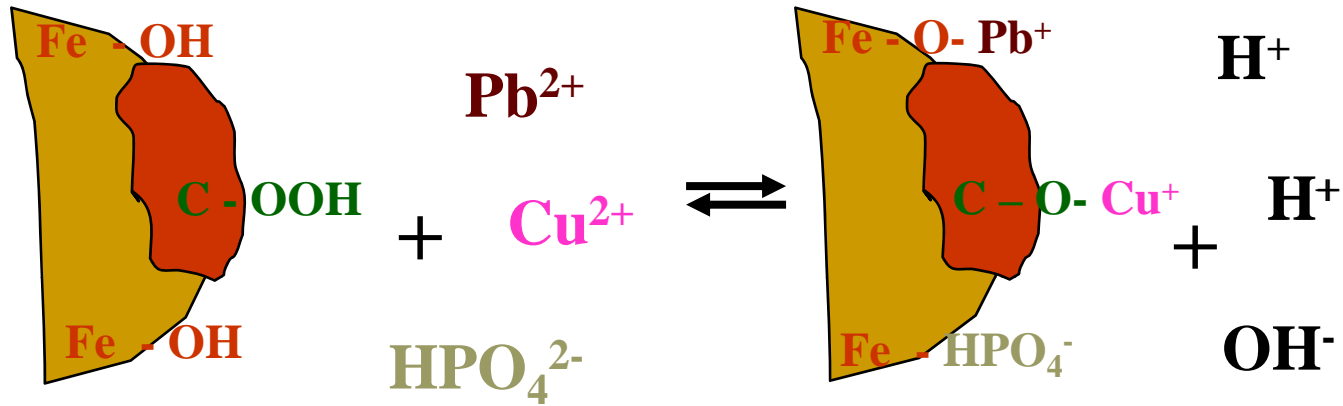
# Zinc (CP & SS)



# Bioretention PAH (CP)



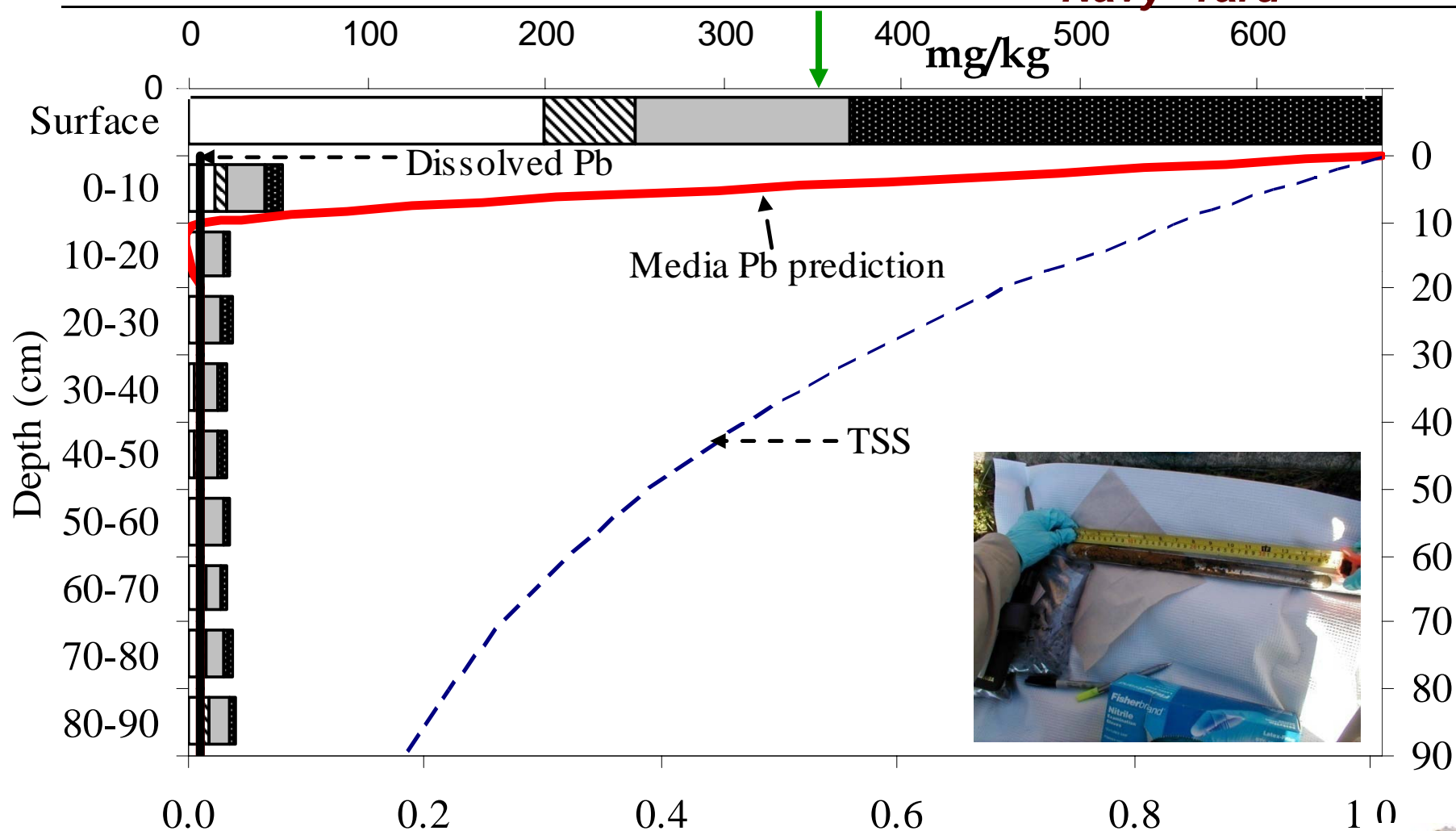
# Metal & Organic Adsorption





# Metals Accumulation - Pb

Navy Yard



Dimensionless TSS or Normalized Captured Pb Deposit





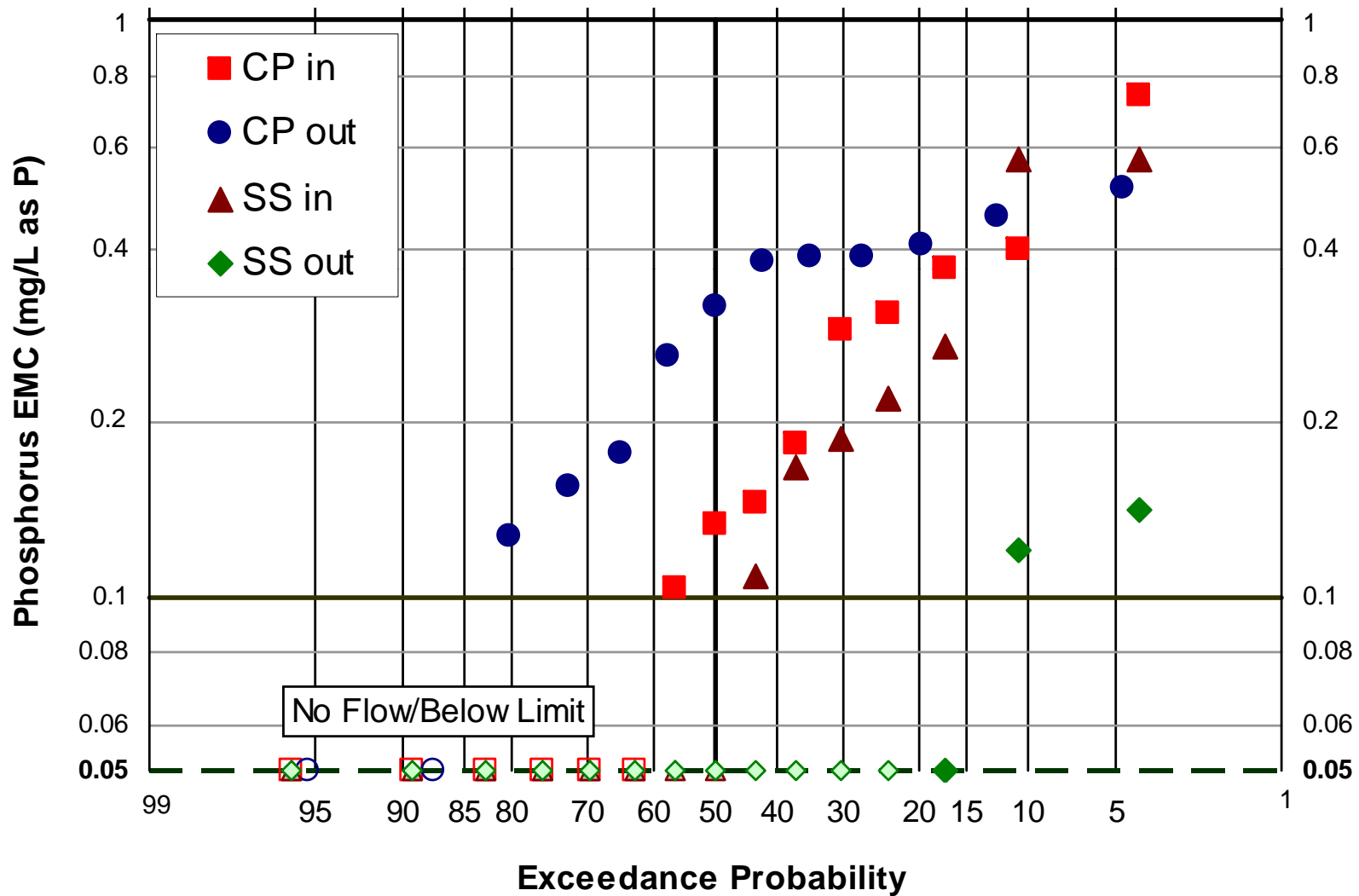


# Nitrogen & Phosphorus



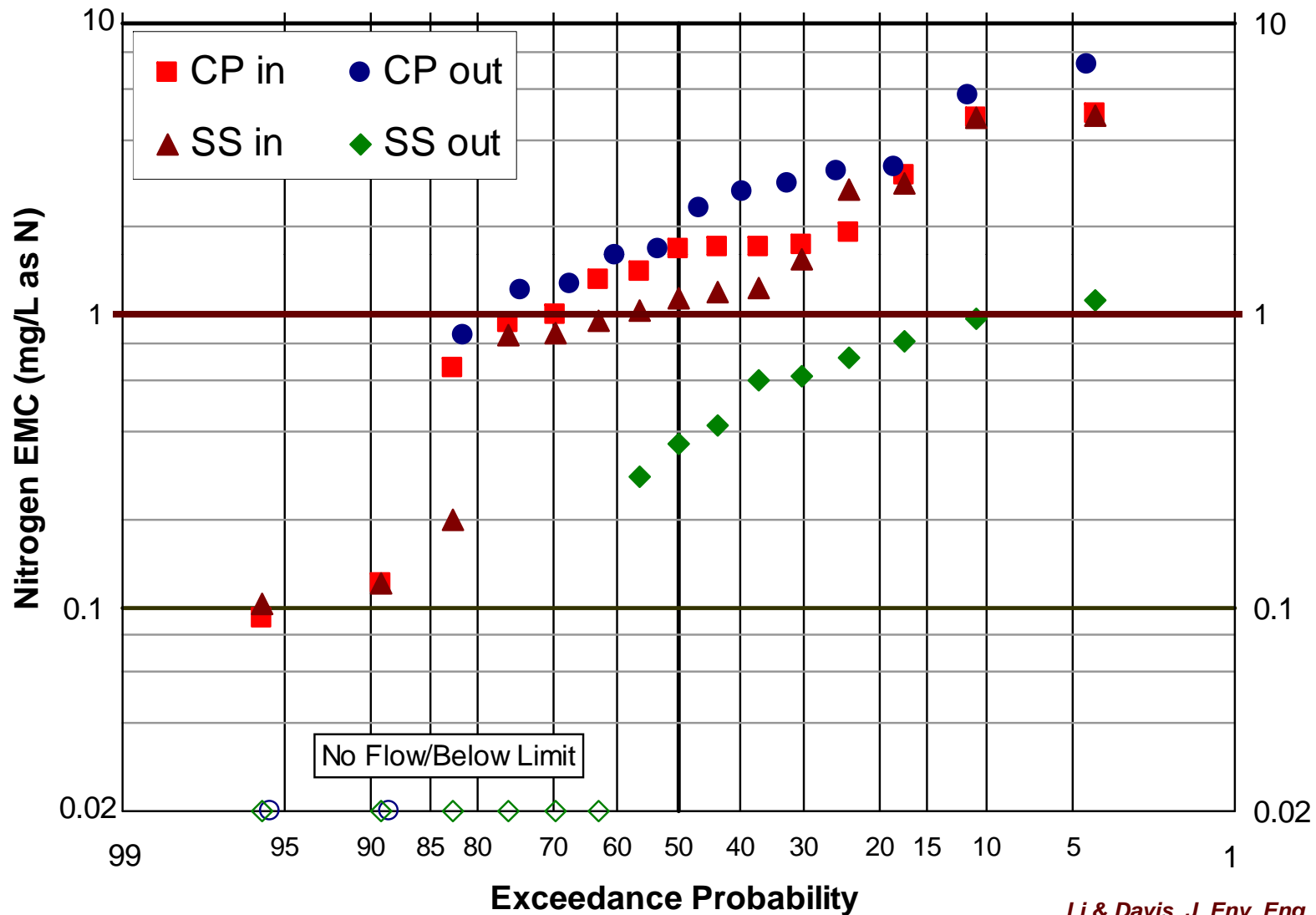


# Total Phosphorus (CP & SS)





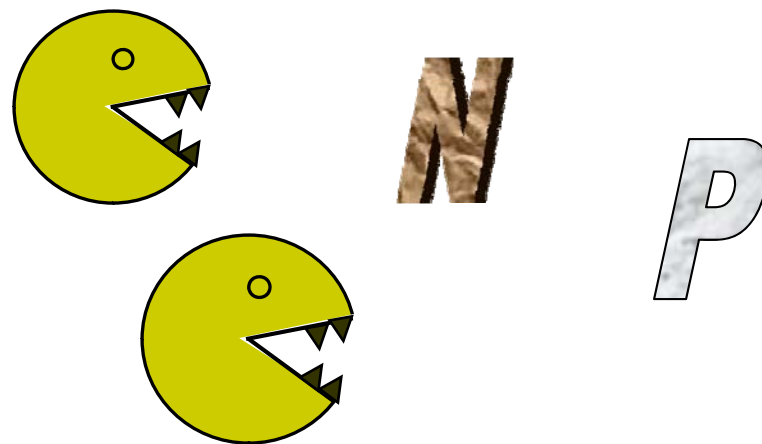
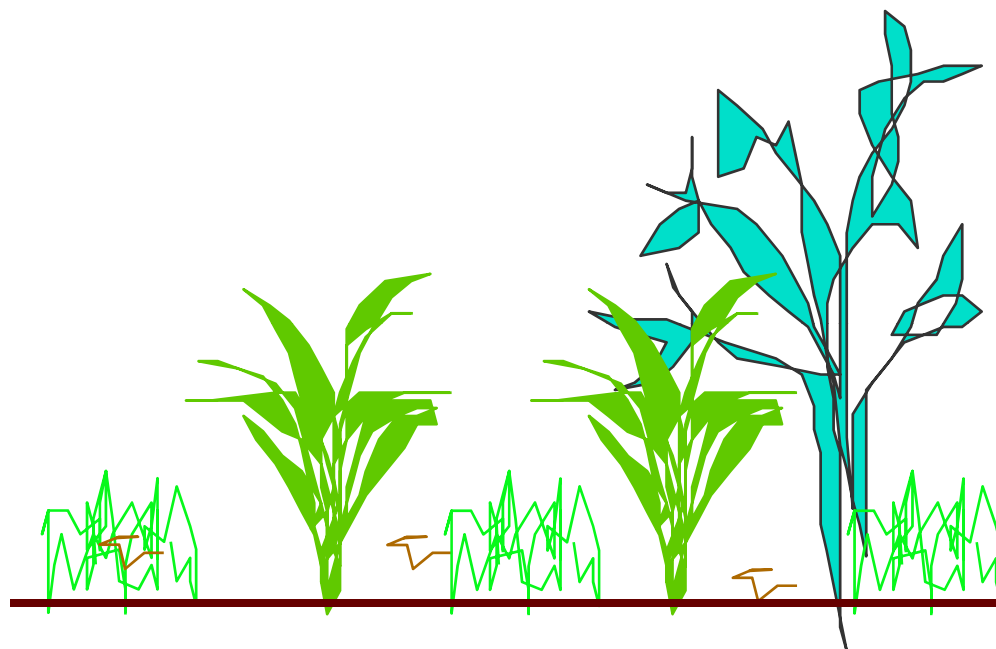
# Bioretention TN (CP & SS)

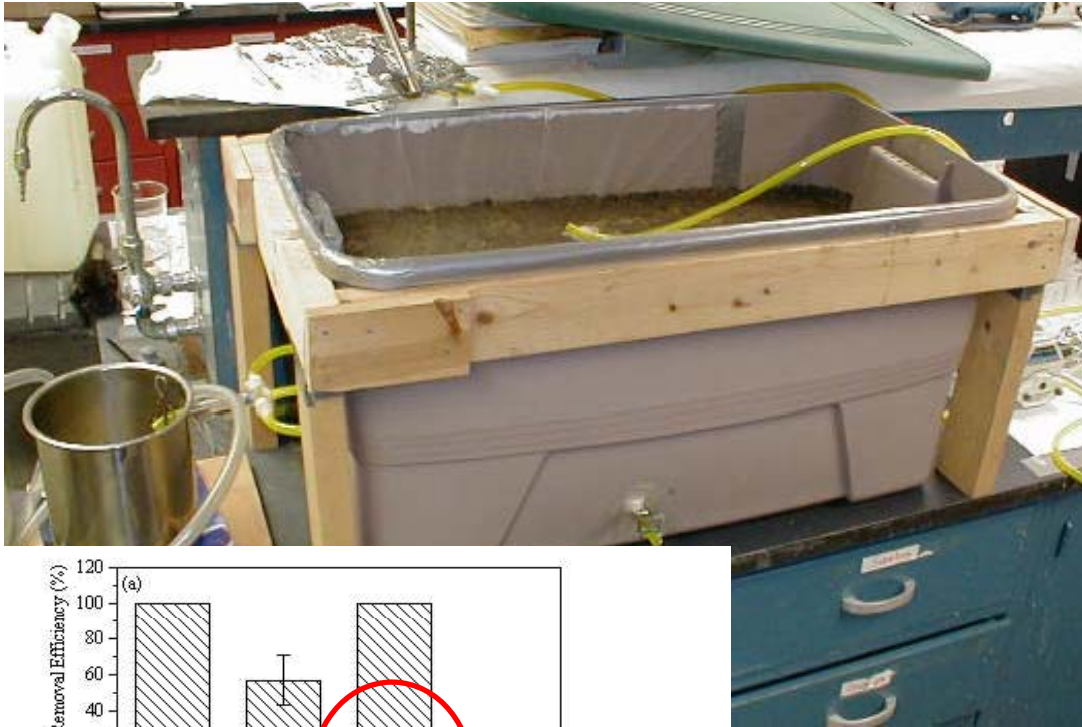


# Nutrient Processes

- Phosphorus
  - Filtration
  - Adsorption
  - Bio-uptake
  - Plant Uptake
  - Decay & Discharge

- Nitrogen
  - Nitrification
  - Denitrification
  - Plant Uptake
  - Decay & Discharge

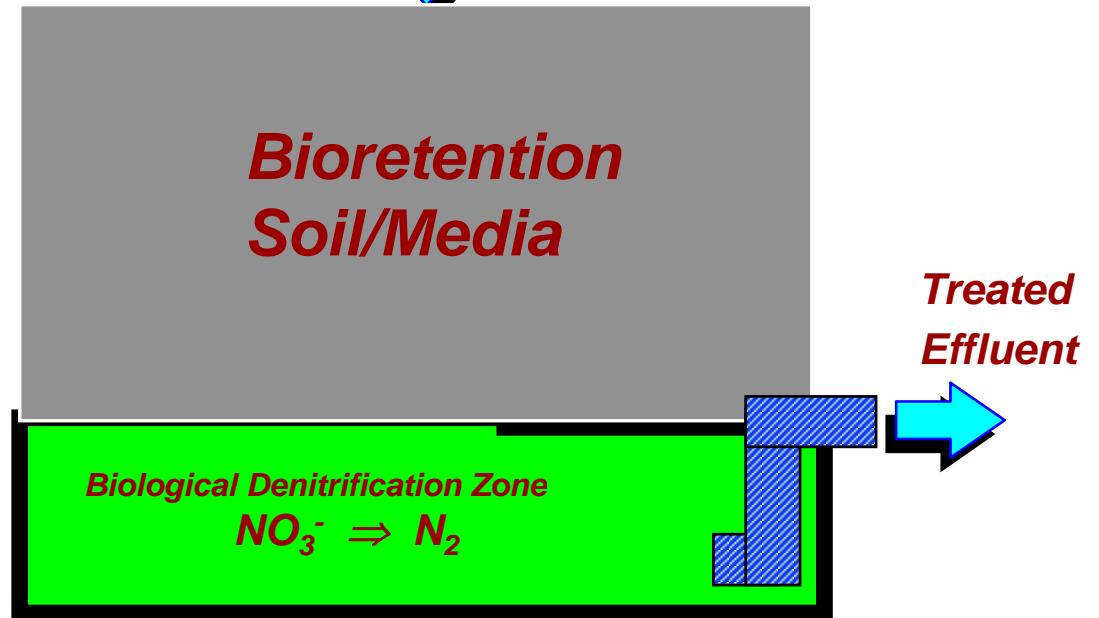
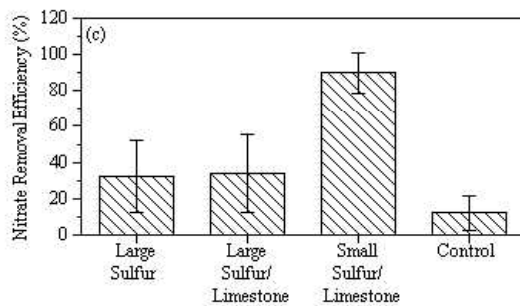
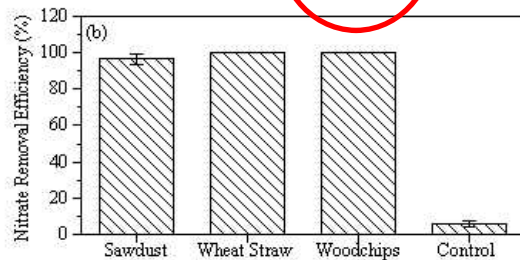
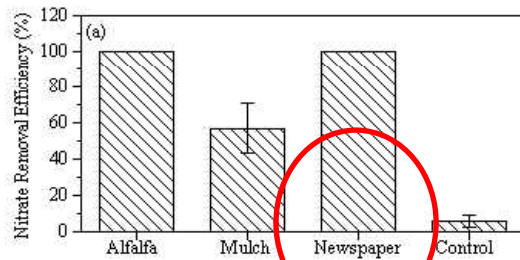




# Nitrate



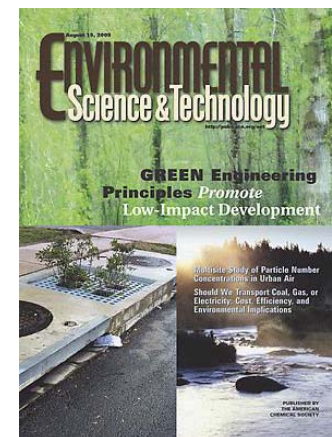
## Enhanced Nitrate Removal with Internal Storage





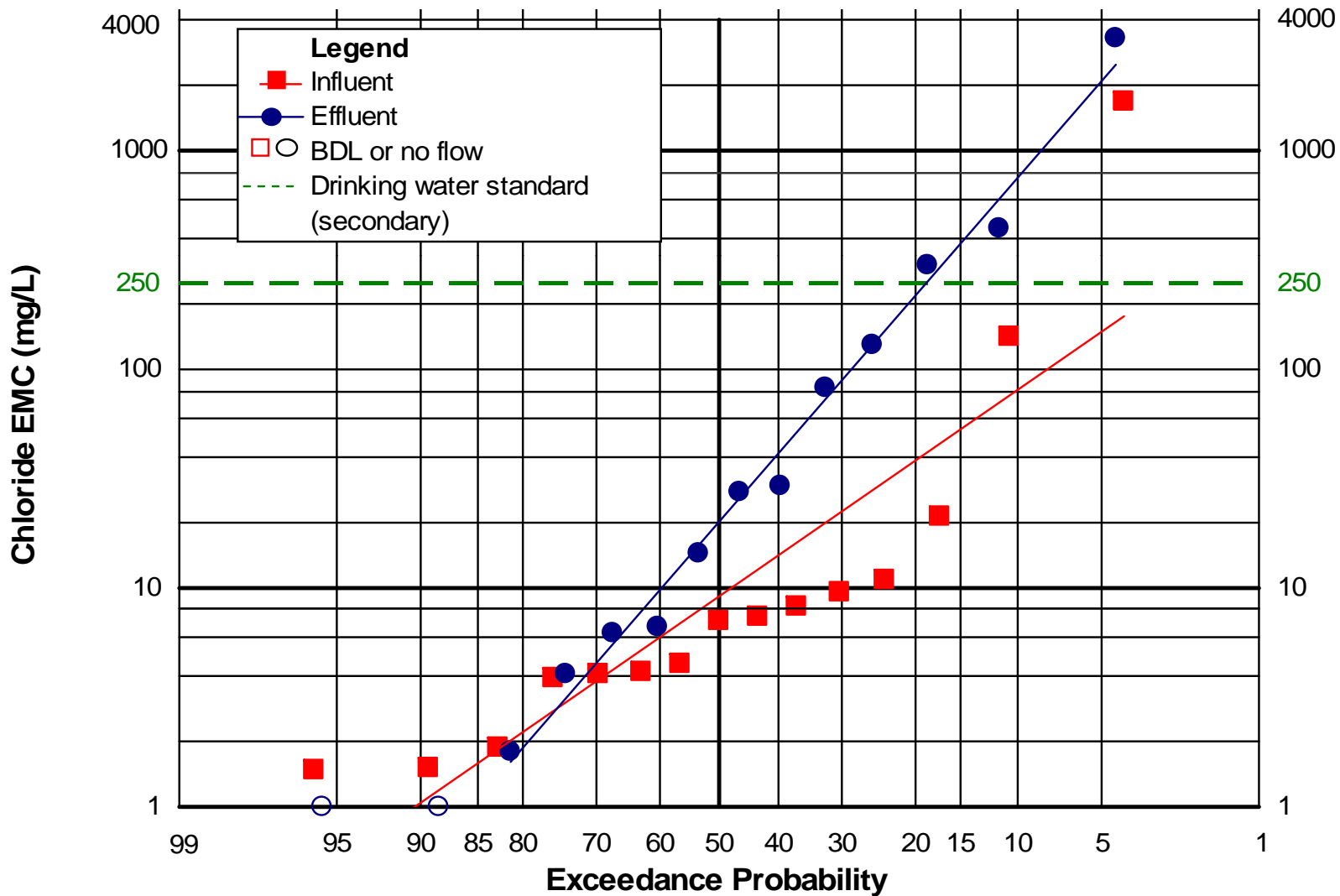
# What we know so far...

- **Excellent Management of Hydrology**
  - Media Area & Depth
- **Filtration: Excellent Particulate Matter Removal**
  - Media Depth not Important; Surface Accumulation
- **Adsorption**
  - Metals, PAH Excellent: Surface Accumulation
  - Phosphorus, TKN, Complex, Depth important
- **Biodegradation Processes Important**
  - Denitrification
  - Biological Predation
  - Vegetation in uptake & degradation





# Chloride (CP)





# Co-Workers

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## 💧 Students

- 💧 Mohammad Shokuhian
- 💧 Houngh Li
- 💧 Himanshu Sharma
- 💧 Eunyoung Hong
- 💧 Ameya Pradhan
- 💧 Xueli Sun
- 💧 Rebecca Stack
- 💧 Zhuangxiang He
- 💧 Roman Hsieh
- 💧 Lan Zhang
- 💧 Hunho Kim
- 💧 Kelly Flint
- 💧 Christie Minami
- 💧 Philip Jones
- 💧 Thomas Wild

## 💧 Others

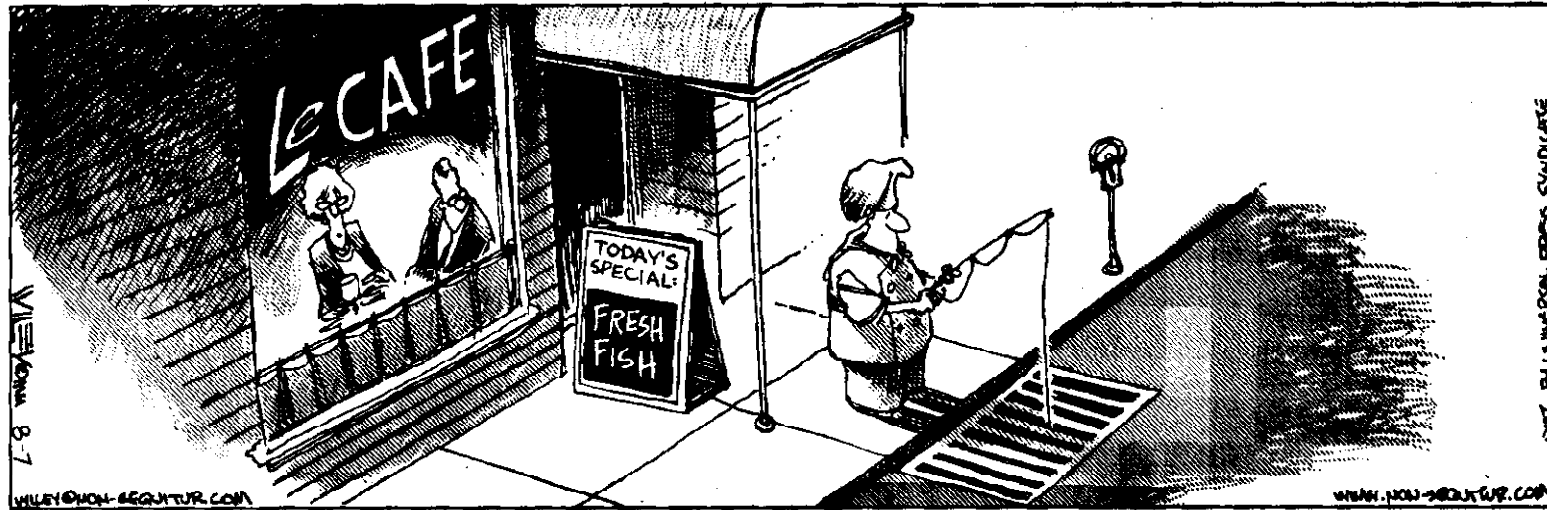
- 💧 Eric Seagren
- 💧 Brian Needelman
- 💧 Upal Ghosh & Katie DiBlasi
- 💧 Bill Hunt & Lucas Sharkey
- 💧 Jeff Karns
- 💧 Robert Traver
- 💧 Neil Weinstein
- 💧 Rufus Chaney



# Research Sponsors



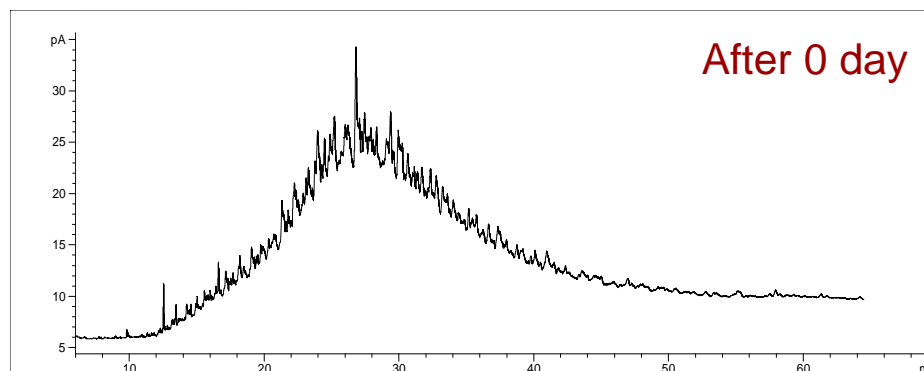
NON SEQUITUR WILEY



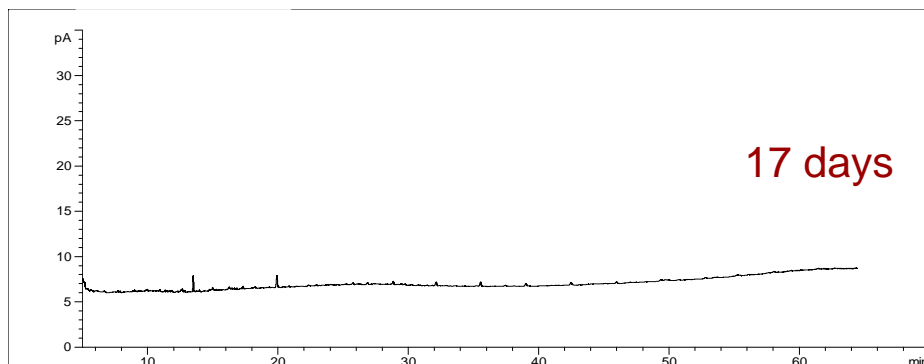
[www.ence.umd.edu/~apdavis/Bioret.htm](http://www.ence.umd.edu/~apdavis/Bioret.htm)



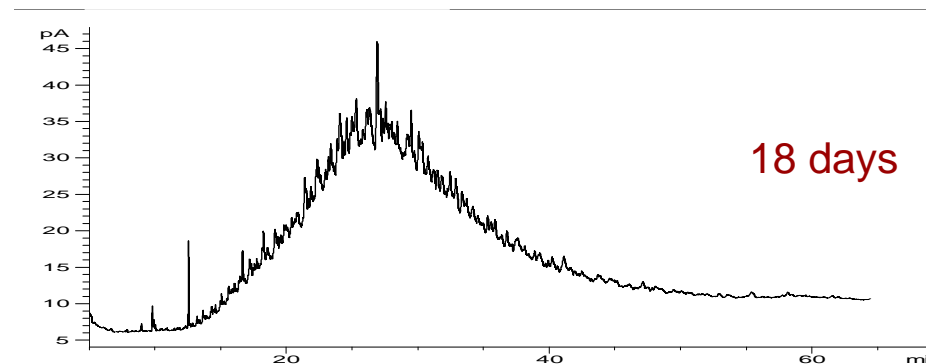
# Motor Oil



**Bench Reactor**



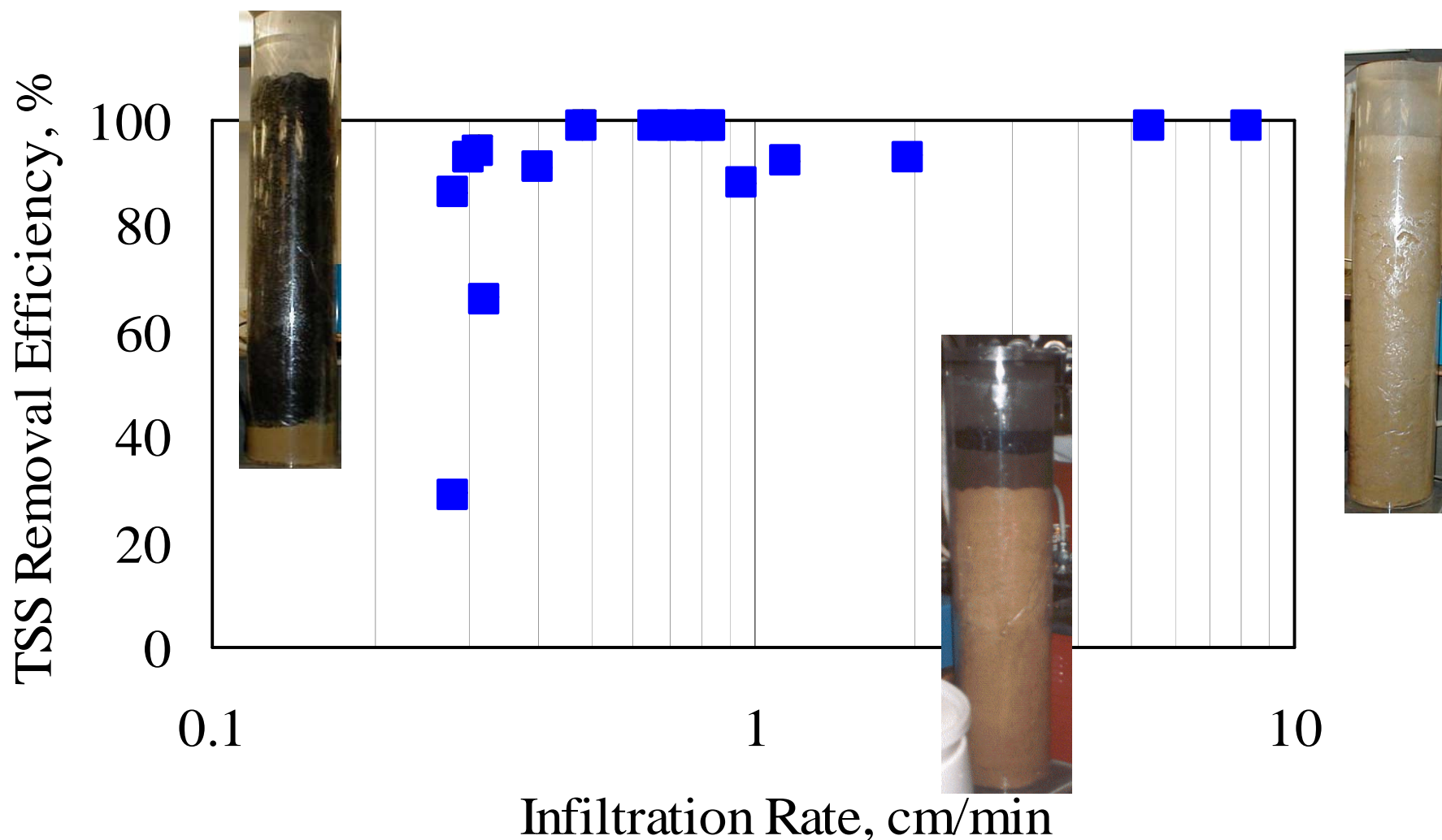
**Biotic**



**Inhibited**



# Media & Suspended Solids (*O&G, Pb*)





# Challenges

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## Practical

- Lack of Understanding
- Space/Utilities
- Regulatory Hurdles
- Inertia
- Contractor Inexperience
- Ownership of Pollutants
- Maintenance

## Research

- Long term
- Chloride
- Design/  
Performance
- Vegetation
- Variability
- Metrics of Success



# Mass Loads (kg/ha/yr)

|          | CP   |       | SS   |        |
|----------|------|-------|------|--------|
|          | In   | Out   | In   | Out    |
| TSS      | 1190 | 37    | 570  | 38     |
| Chromium | 0.09 | 0.015 | 0.02 | ~0.007 |
| Copper   | 0.26 | 0.073 | 0.12 | 0.045  |
| Lead     | 0.09 | 0.013 | 0.03 | ~0.005 |
| Zinc     | 1.0  | 0.063 | 0.36 | 0.017  |
| Chloride | 6800 | 458   | 320  | 25     |
| TN       | 27   | 7.2   | 9.6  | 3.6    |
| Nitrate  | 12   | 2.5   | 3.7  | ~0.19  |
| TKN      | 15   | 4.1   | 6.0  | 3.6    |
| TP       | 3.6  | 0.72  | 0.9  | 0.38   |
| TOC      | 44   | 154   | 43   | 78     |