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Advanced Green Infrastructure Stormwater Treatment

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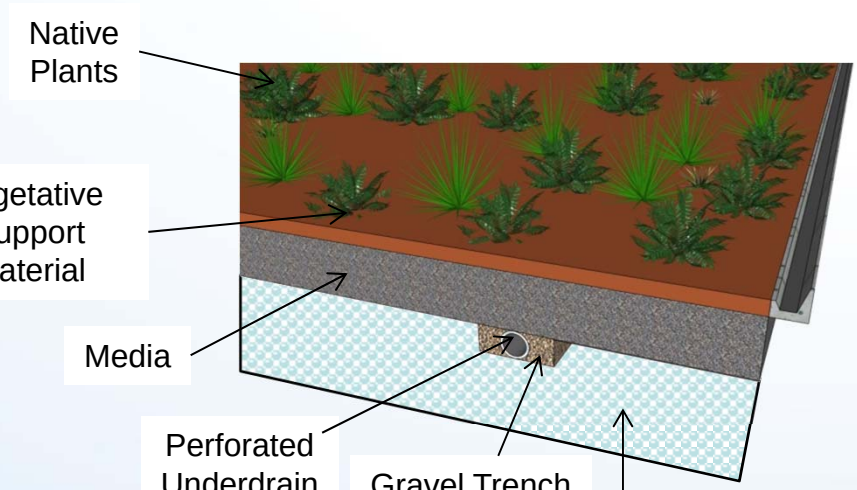
Biofiltration

Biofiltration is an innovative stormwater best management practice which uses filtering media and vegetation to capture runoff and biologically degrade pollutants in stormwater.

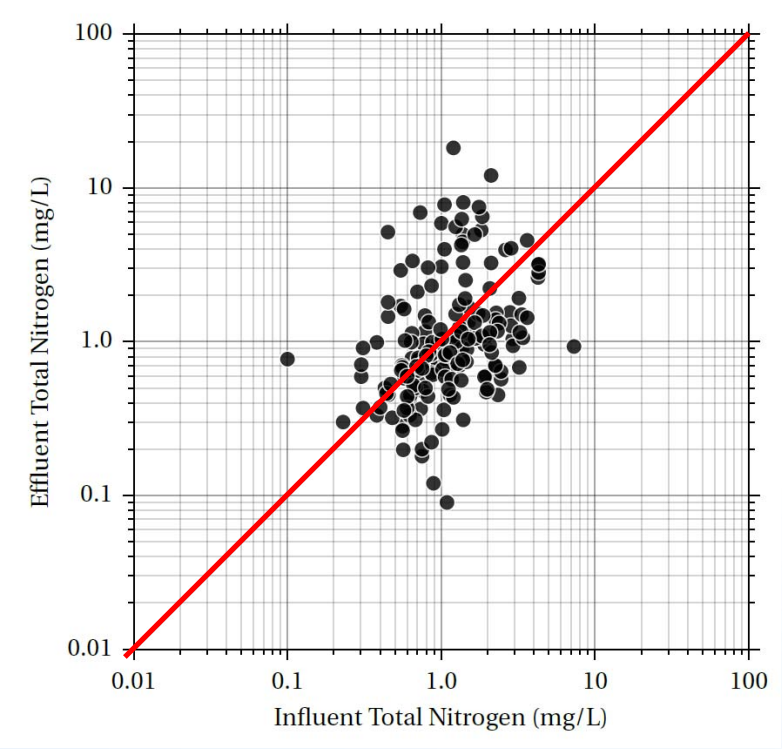


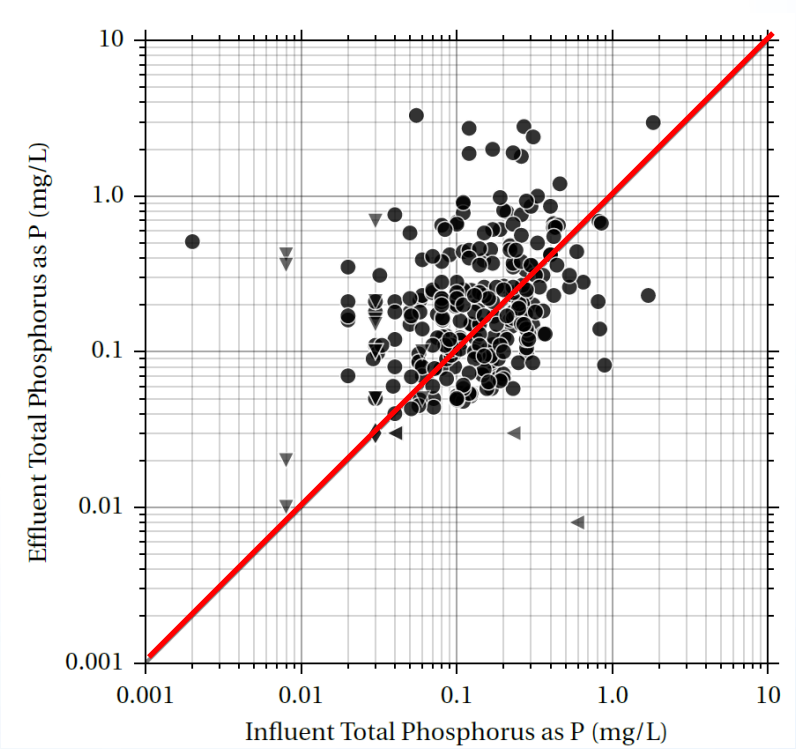
Bioretention BMPs

- There are many bioretention BMPs existing that are not working well:
  - Lack of maintenance and resulting **clogging**
  - **Poor design/Construction**
    - Lack of pre-treatment
    - Media close to clogging when built
    - Biofilter media includes pollutant sources

Problem: Variable Water Quality Performance

International BMP Database Bioretention Results





Limited removal and some export of N and P

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How can we continue to improve?

- Pre-treatment of runoff
- Specialized media components
- Outlet control/media filter hydraulics
- Media specifications and acceptance process
- Internal water storage/submerged zone
- Vegetation dynamics/soil structure/ rhizosphere

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BMPs!

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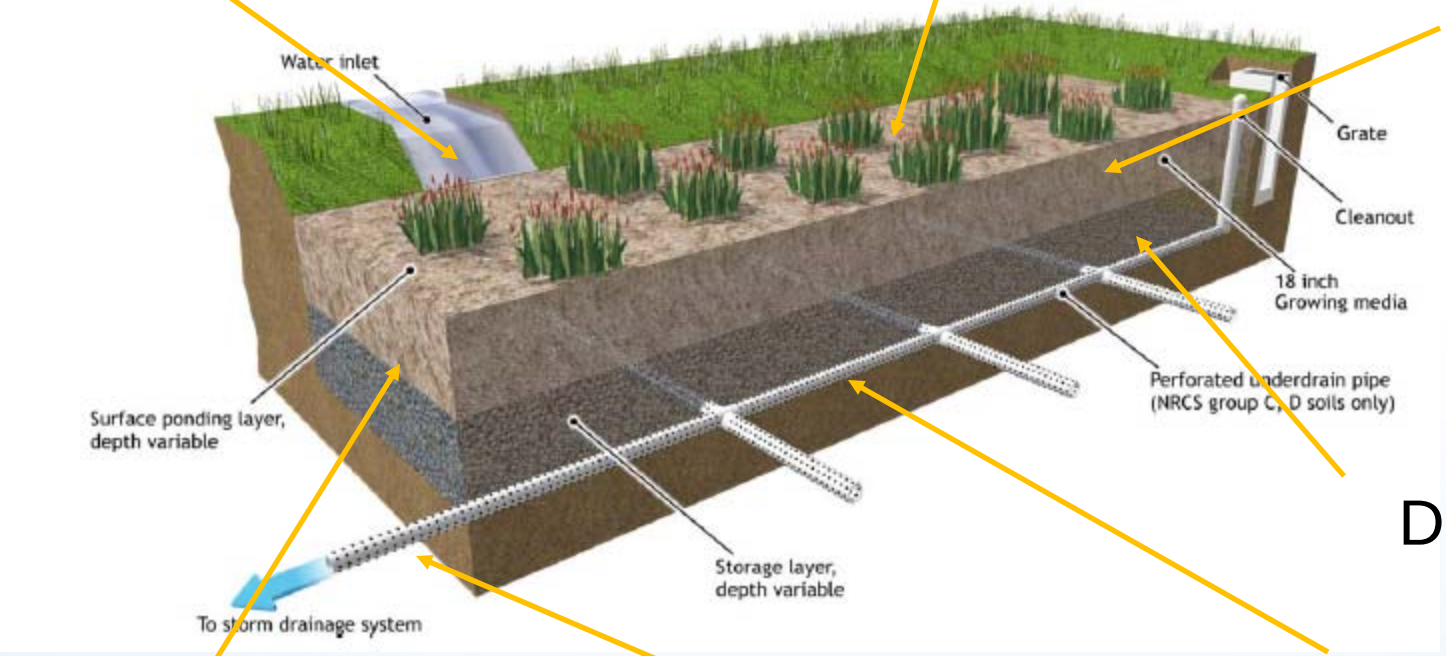
Bioretention Can Work Better

Pretreatment for Sediments

Vegetation Selection

Improved Filter Media



Deeper Drainage Layer

Media Bridging Layers

Outlet Control

Internal Water Storage

Filter Media

Improved Filter Media

- Granular Activated Carbon (GAC)
- Biochar
- Surface Modified Zeolite (SMZ)
- Natural Zeolite
- Rhyolite Sand (RS)
- Engineered Sands
- Peat Moss (PM)
- Iron Filings

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Filter Media

- Target Pollutants
- Contact Time
- Hydraulic Loading Rate
- Life Cycle (ion exchange capacity vs. clogging)
- Material availability, cost, quality and consistency

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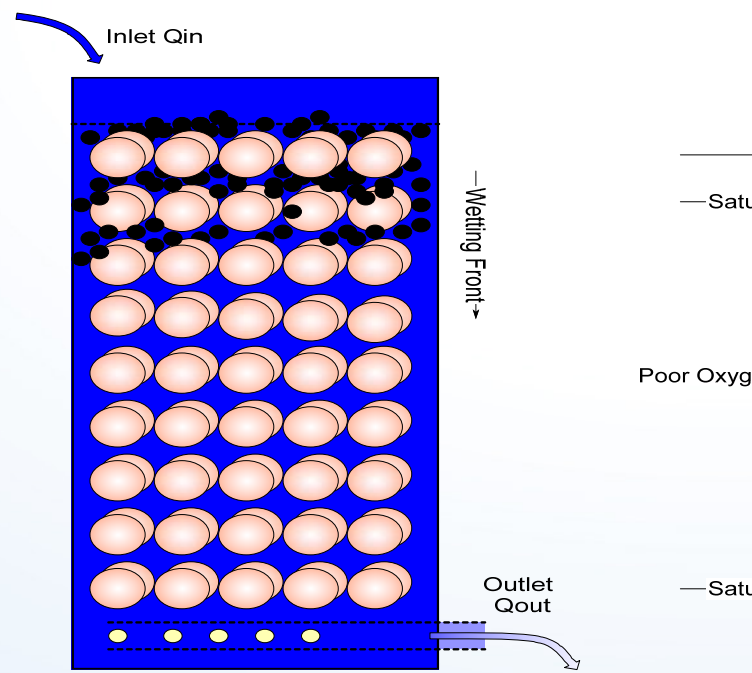
Filter Media

- Planter-style biofiltration
- $50/sf for retrofits (City of Portland Green Streets program)
- Assume half the cost for new development ($25/sf)
- Media quantity @ 2 ft depth = 0.07 cy/sf of surface area
- Conventional media = $50/cy
- “Enhanced” media = $250/cy

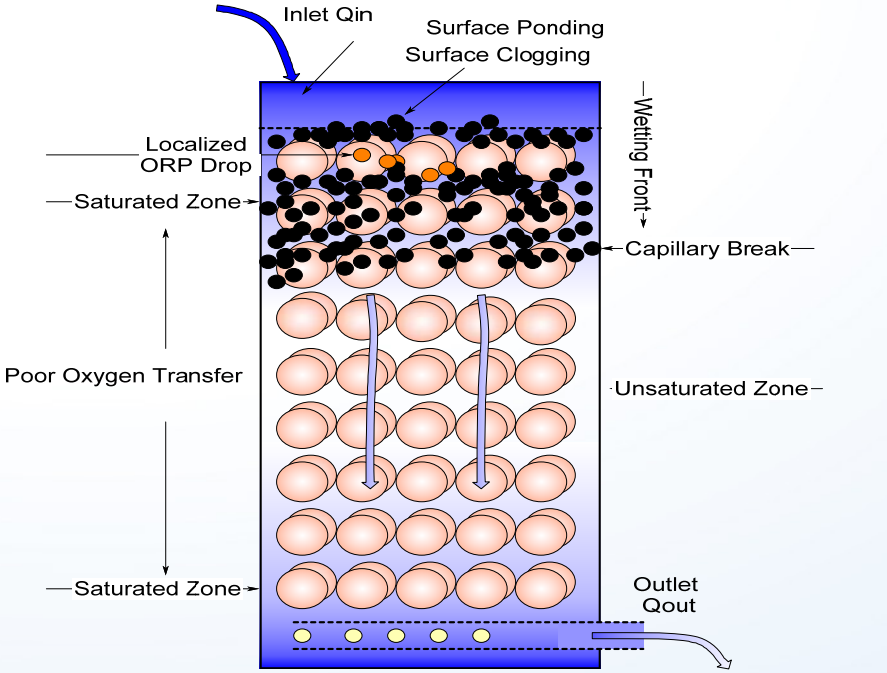
	Traditional Media	Enhanced Media
Media Cost	$3.50	$17.50
Other Cost	$21.50 to $46.50	$21.50 to $46.50
Total per SF	$25 to $50	$39 to $64
Sizing Adjustment	1.0	0.66
Effective Cost	**$25 to $50/sf**	**$26 to $43/sf**

Outlet Hydraulics – Media Controlled

Gravity Flow Media Filter Schematic (ideal)	Gravity Flow Media Filter Schematic (hydraulic failure mechanisms)



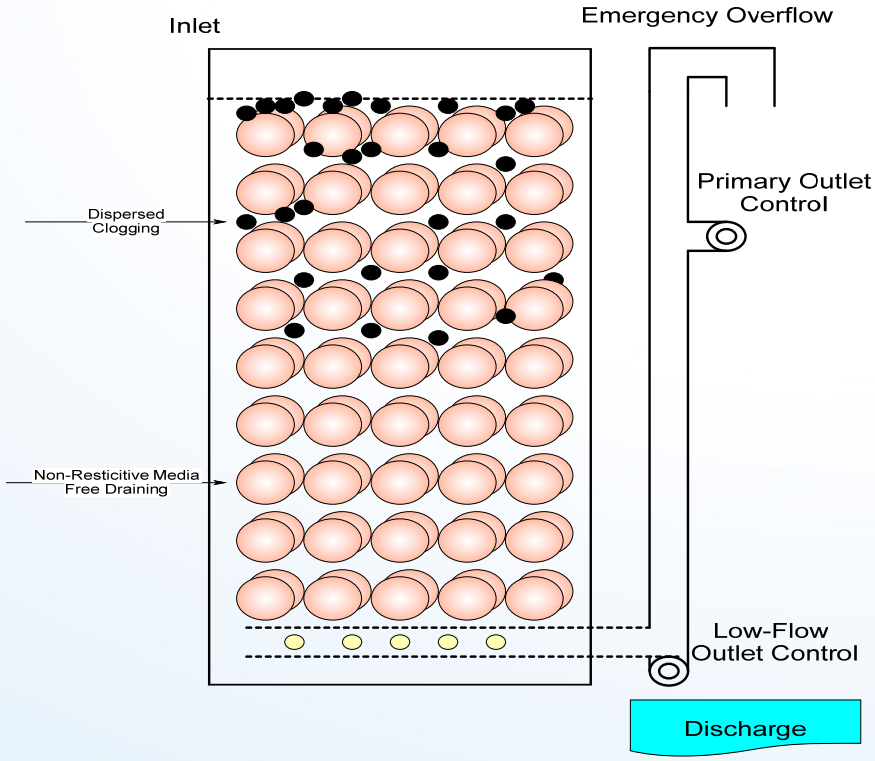
Gravity Filter Ideal Operation
Qout = Qin
CT = Media Depth/Ksat Media

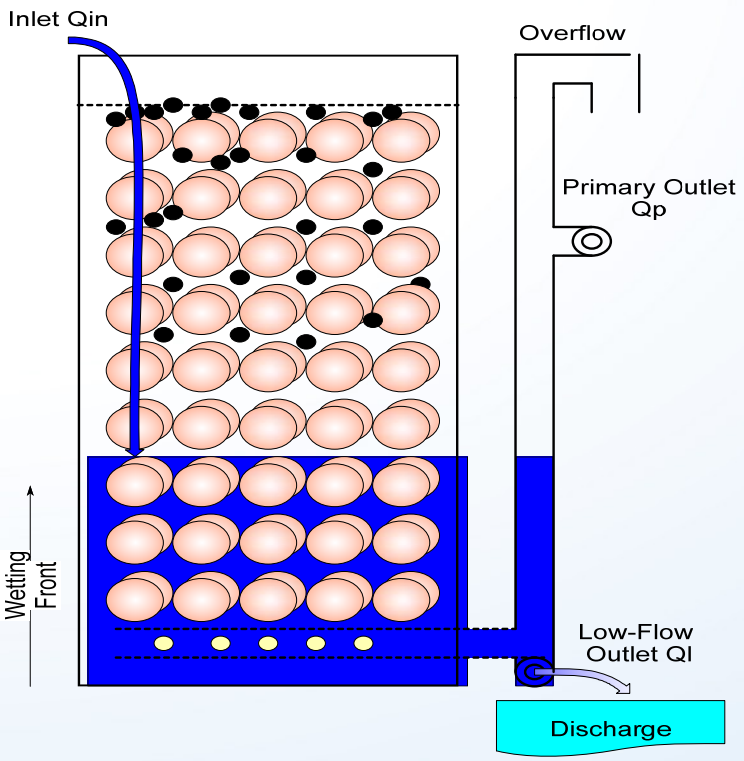


Gravity Filter Non-Ideal Operation
Qout = variable
CT = variable

Outlet Hydraulics – Outlet Controlled

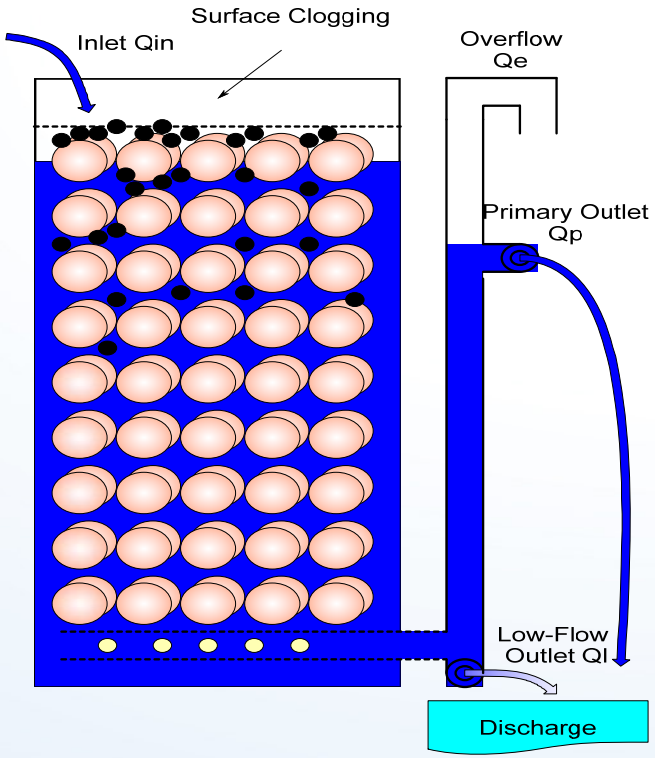
1) Empty Media Bed	2) Media Bed Filling

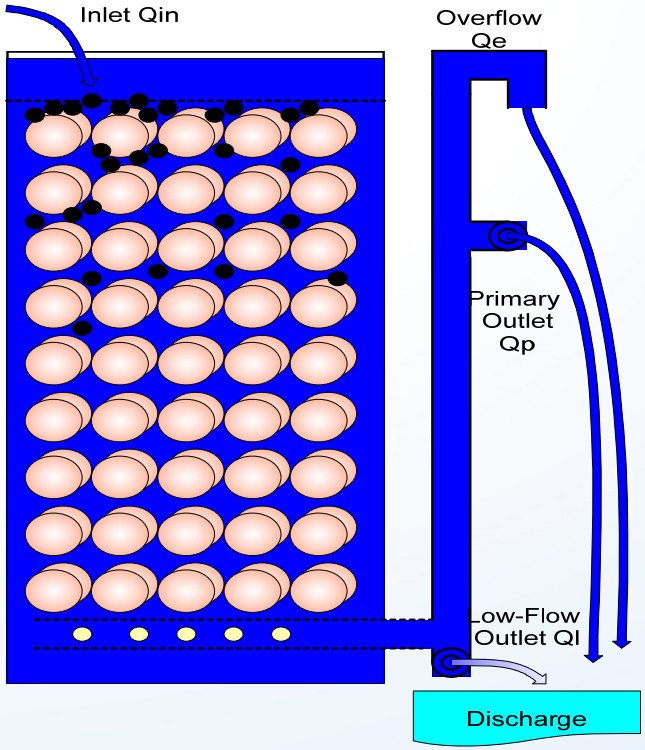




Outlet Hydraulics – Outlet Controlled

3) Design Operation	4) Overflow Condition





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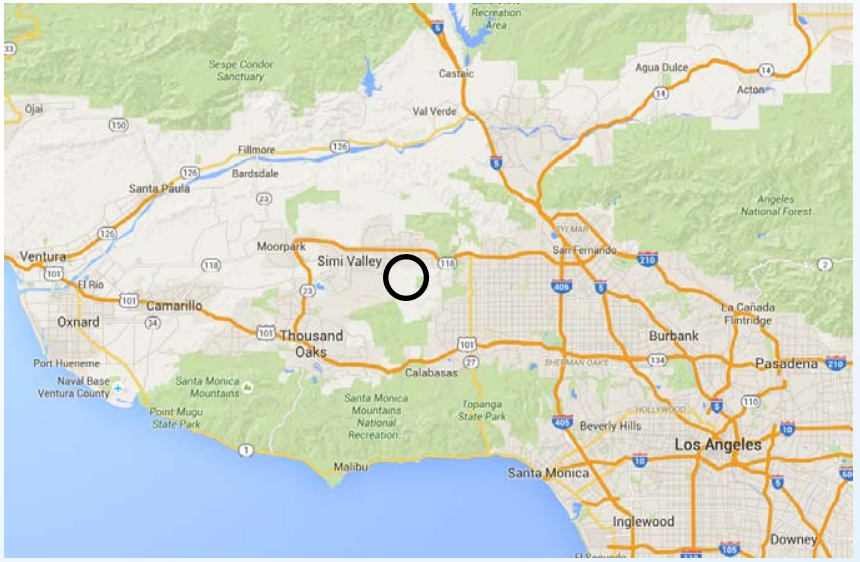
Project Example #1 - Background

The overall project was a complex of former industrial research and development facilities located on a 2,668-acre portion of Simi Valley in Southern California used mainly for the testing and development of:

- Stringent numerical permit limits for a variety of constituents.
- Client is dedicated to improving water quality at the Site.
- Retained a team of stormwater experts to support NPDES program.



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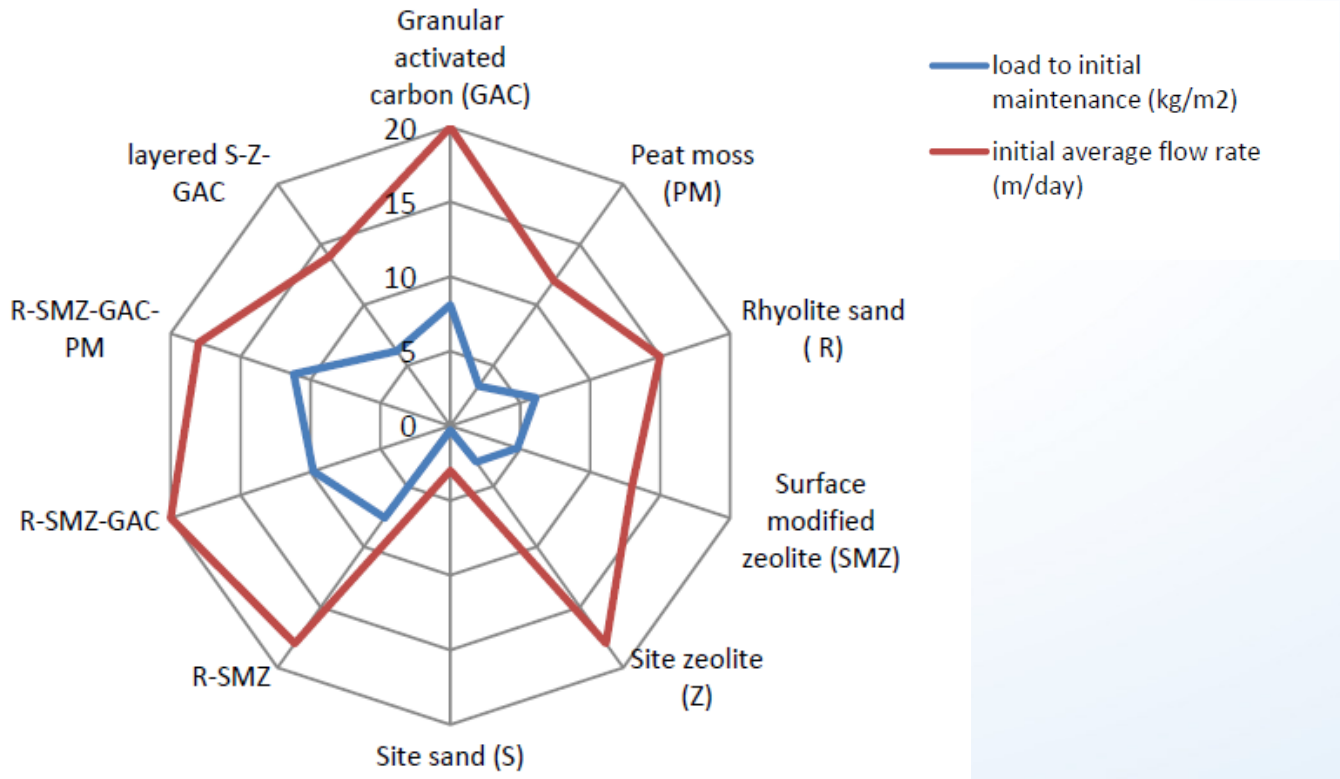
Project Example #1 - Media Study

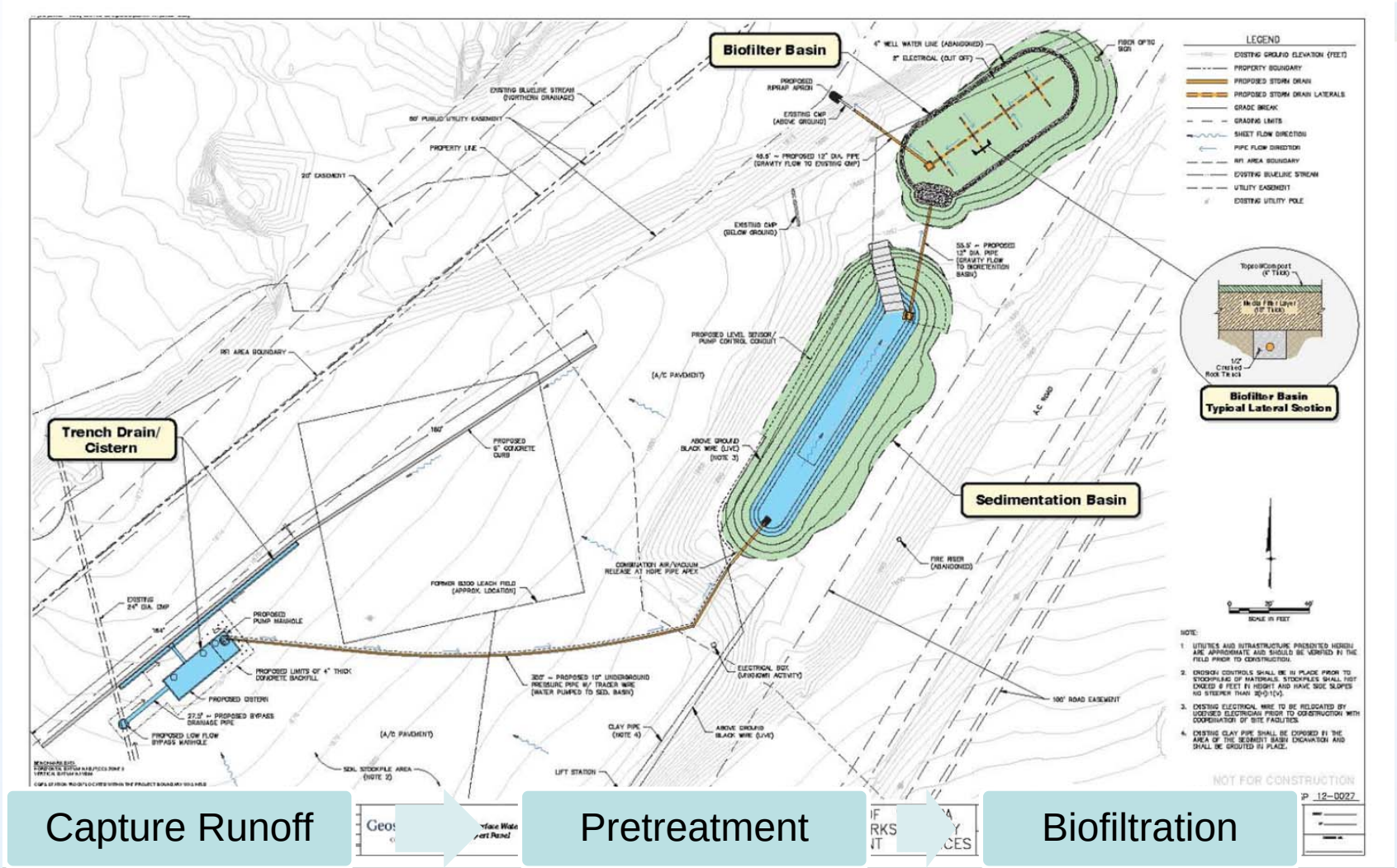
- Structural stormwater practices sited and prioritized through a rigorous statistical analysis of subarea water quality monitoring data.
- Biofiltration was identified by the team as a natural treatment BMP potentially capable of meeting all NPDES permit limits and meeting client's aesthetic goals
- A media study was conducted by Dr. Pitt and Dr. Clark to develop an engineered media for use in biofiltration systems.

Project Example #1 - Media Selection

Observed Infiltration and Clogging Characteristics for Tested Media:



Project Example #1 - Biofilter Design



Capture Runoff → Pretreatment → Biofiltration

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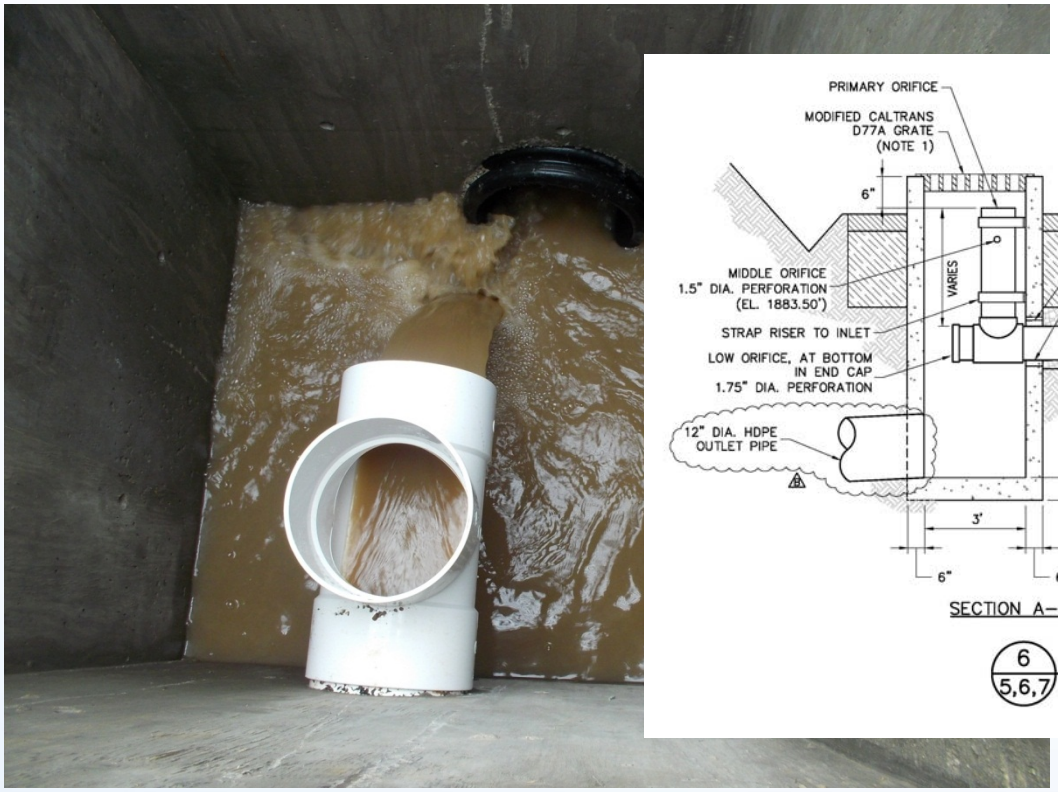
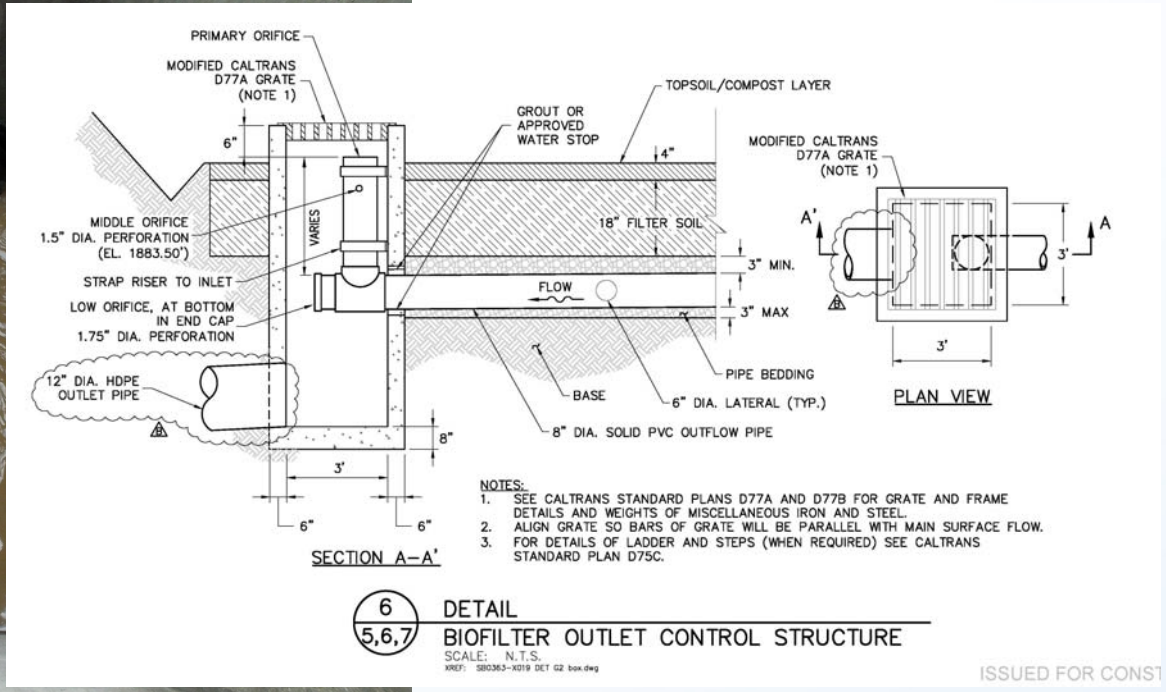
Project Example #1 – Project Site

Project Example #1- Outlet Control





Project Example #1 - Proper vegetation

Roots of Salt grass Day 128

Roots of California Fuschia on Day 128

Project Example #1 – Water Quality Performance

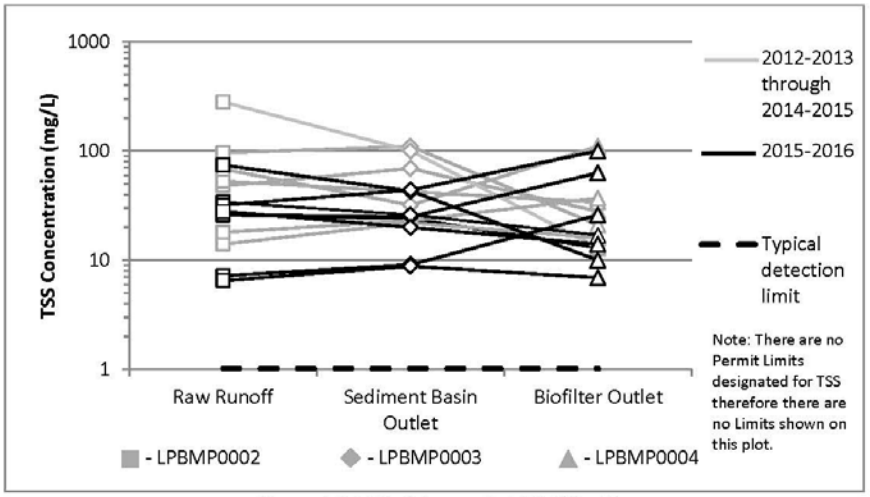


Figure 10. TSS at Lower Lot Biofilter[10]

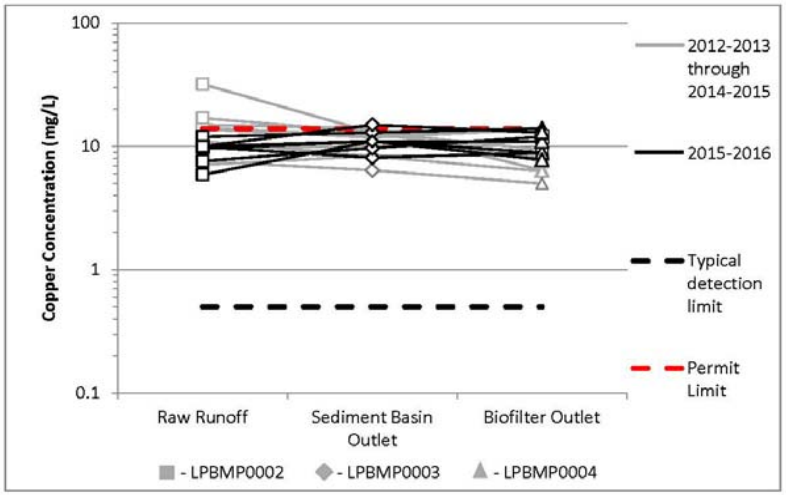


Figure 44. Copper at Lower Lot Biofilter

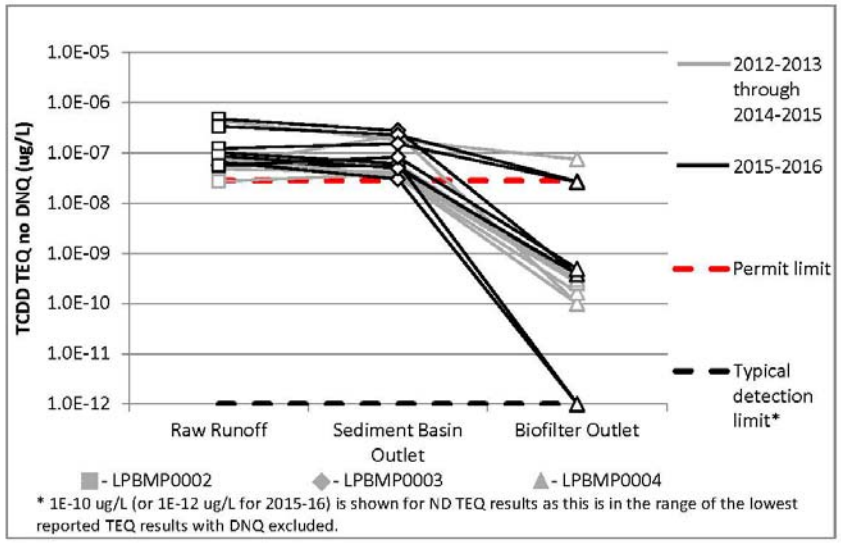


Figure 22. Dioxins at Lower Lot Biofilter

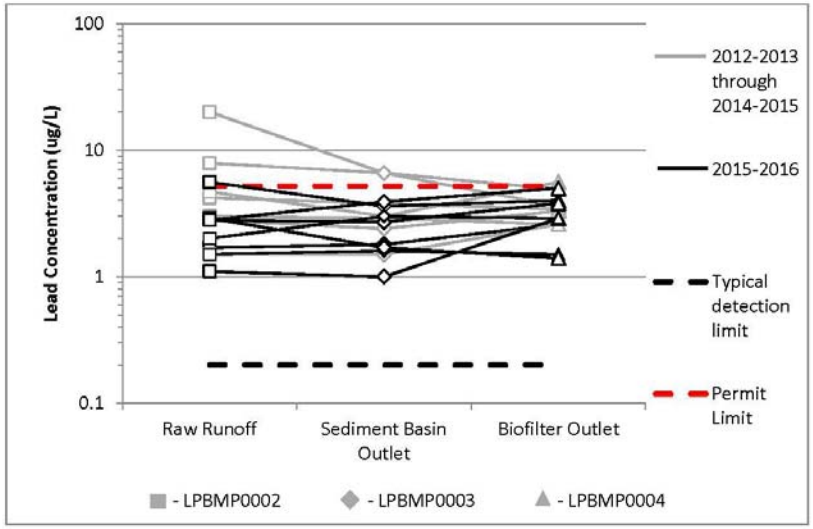
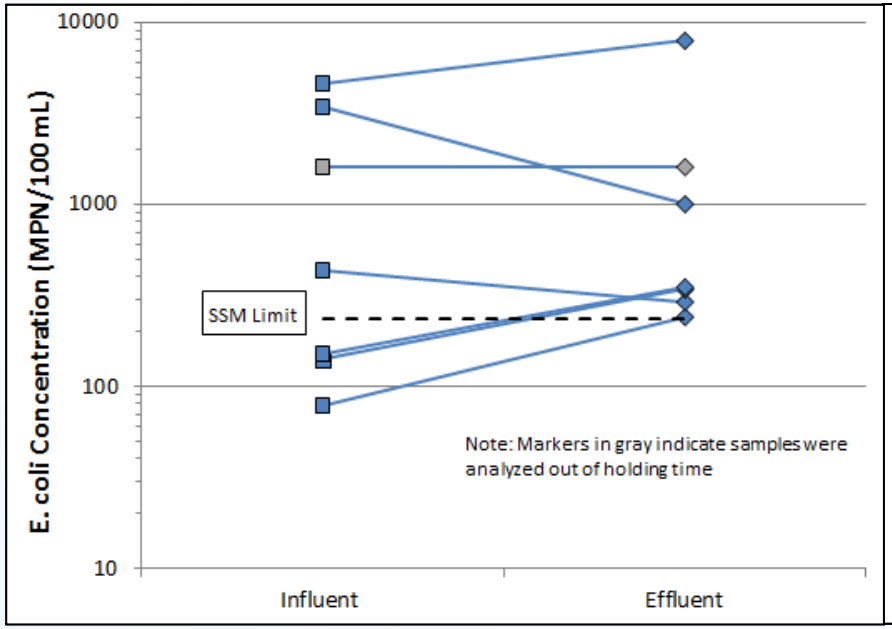


Figure 34. Lead at Lower Lot Biofilter

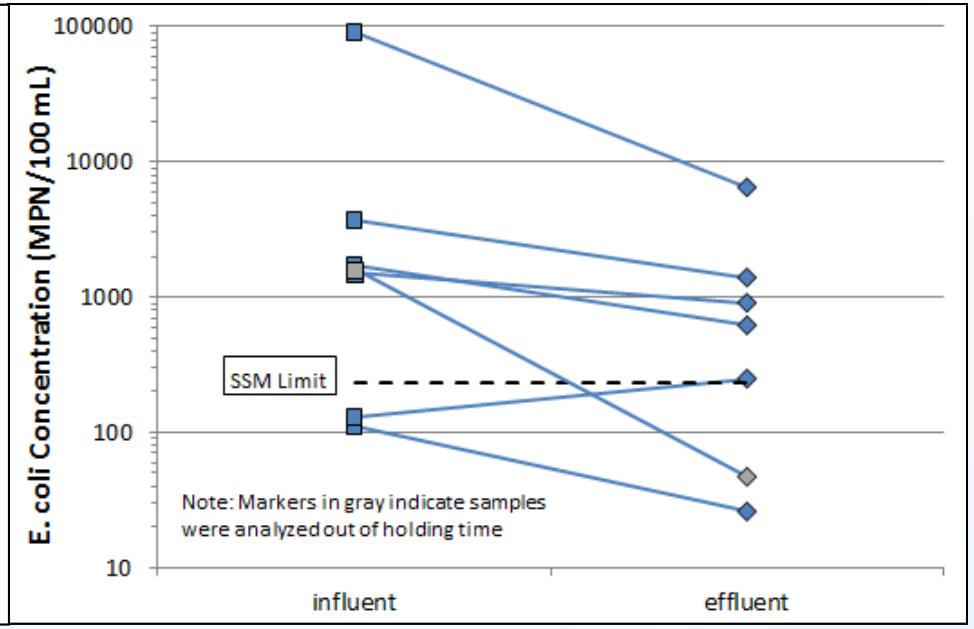
PRELIMINARY RESULTS SUBJECT TO CHANGE

Project Example #1 – Water Quality Performance

Without outlet control



With outlet control



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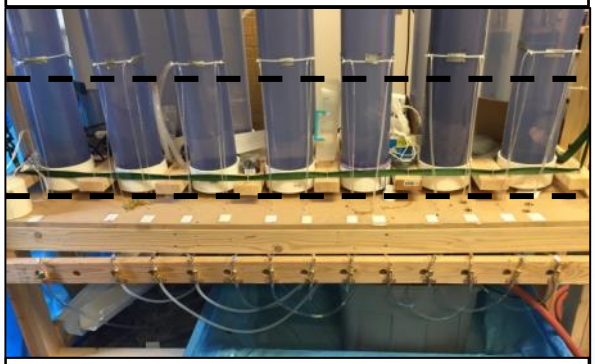
Project Example #2 - Objectives

- **Mitigate risk of pollutant leaching**
  - Standard local county specification includes 20 to 40% compost
  - This project will require ongoing monitoring, including nutrients and wide range of other parameters
- **Assess material availability, quality, consistency**
  - Project will require 15,000 to 30,000 CY of media – need to get it right!
- **Evaluate media performance in representative hydraulic environment**
  - Outlet controlled
  - Choking layer (rather than filter fabric)
  - Internal water storage

Project Example #2 - Media

Material Survey, Component Testing, and Bench Scale Column Study for Enhanced Biofiltration Design

3. Effluent Tubing



Bend in outflow tubing 18” above outlet elevation for static water level control

TSS amendment (silty soil)

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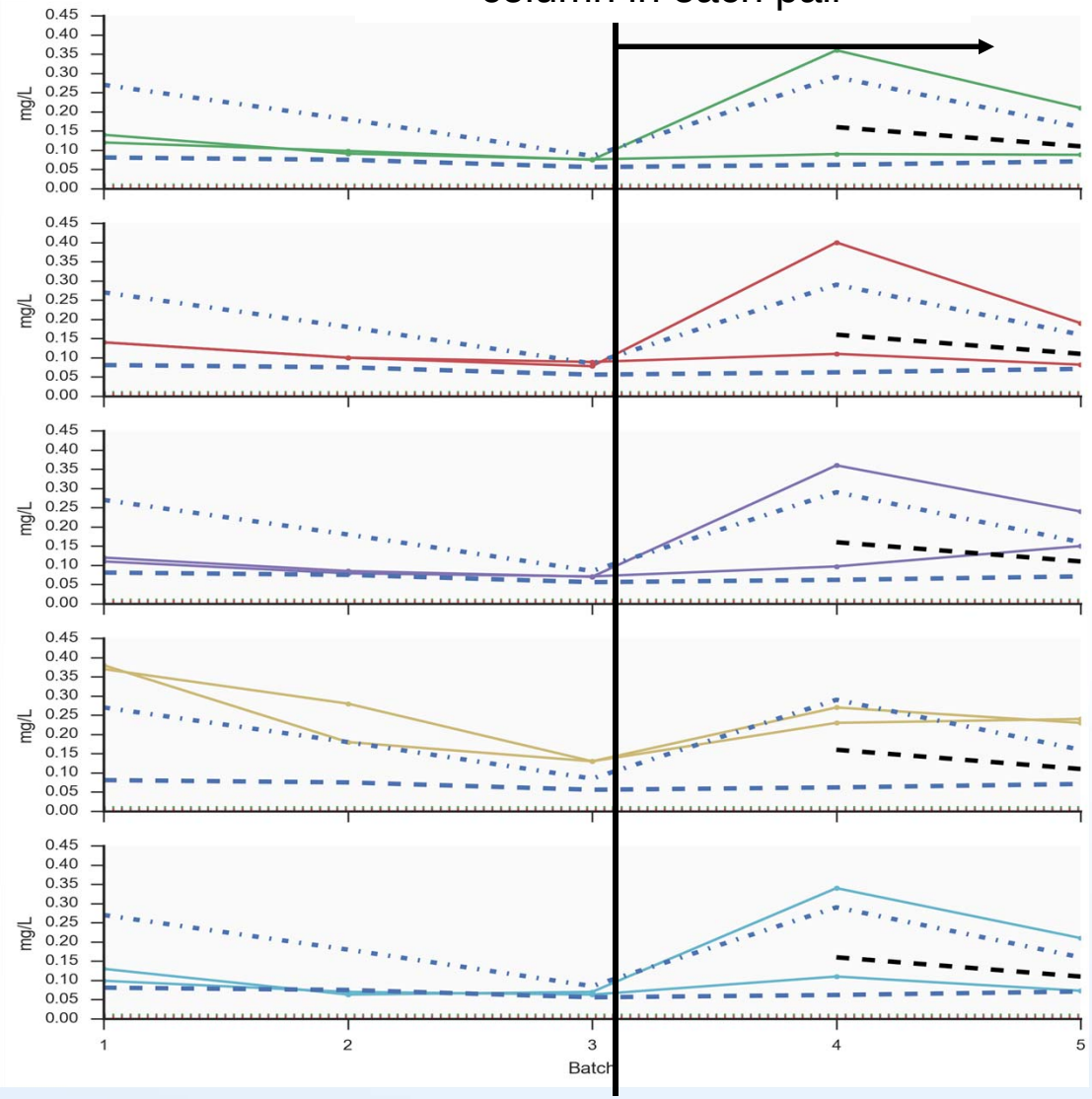
Project Example #2 - Objectives

- **Evaluate potential mixes against performance criteria**
  - Pollutant treatment
    - Conventional pollutants
    - dCu/dZn
    - Bacteria
    - Nutrients
  - Hydraulics
  - Cost/feasibility
  - Constructability
  - Support for vegetation
  - Replicability for future media replacement

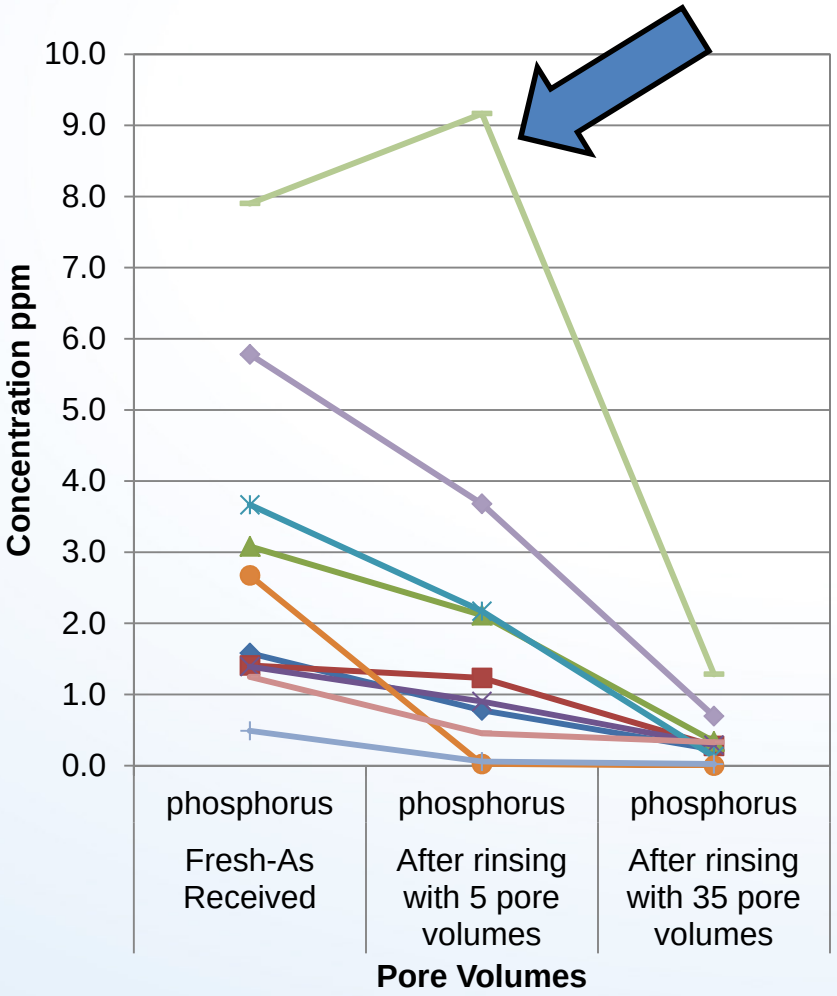
Project Example #2 - Column Results - Total Phosphorus

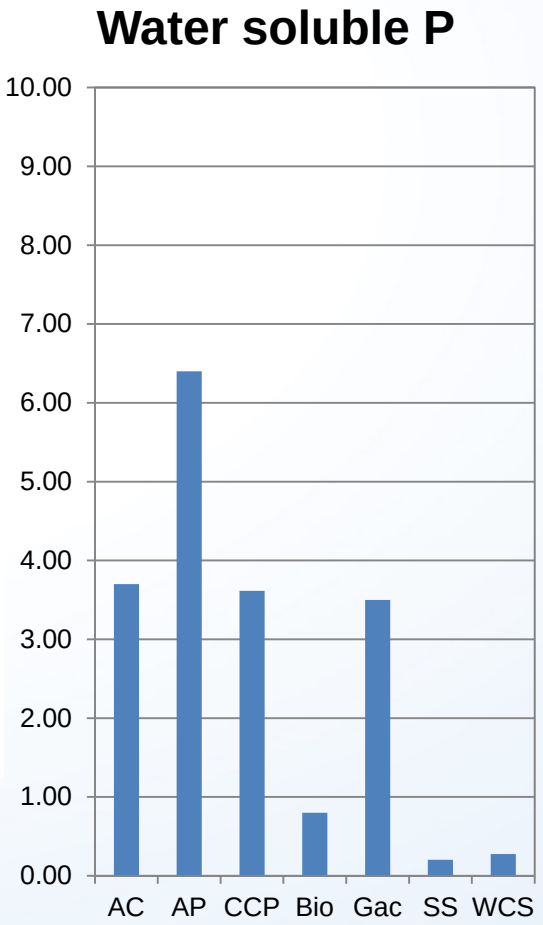
2” of compost added to one column in each pair



- Mix 9 showed about +50% export; sustained over all 6 batches
- Except mix 9, moderate to good removal
- Even small compost addition was clearly important
- All were below background of 0.58 mg/l

Project Example #2 - Whole Mix Testing Example – Phosphorus Leaching





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Project Example #2 – Column Study Findings

- Strong TSS performance for all mixes (including 100% sand control)
  - Likely due to outlet control and careful bridging layer design
- Nutrient washout (P, N) mostly controllable
  - P export appears unavoidable when compost is used
  - Plants could improve long-term performance (mostly for N)
- Provided insight into appropriate expectations for passive removal of bacteria
  - Complement treatment with source controls, watershed-scale load reduction strategy, high flow suspension in RW
- Column study validated integrated dynamics of chemistry and hydraulics of media bed
- Also validated performance of outlet control and bridging design

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General Takeaways for Biofiltration Design

- Significant opportunities exist to enhance performance of biofiltration/bioretention systems
- Consider hydraulics as part of the “treatment” and long-term performance assessment
- Providing diverse removal mechanisms can help achieve cleaner effluent and greater consistency
- It can be worthwhile to do a cost-effectiveness comparison for retrofits
- Material surveys and component testing can have high ROI for a private or public entity

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Thank you!

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