Bioretention Soil Mix Parameters and Structural Configuration for Nitrogen and Phosphorus Removal

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East Coast Excavating
Green Infrastructure and Low Impact Development

Modeling designs after natural systems
Design and Performance

Not all bioretention systems function equally

• There is a tremendous amount of variety within design specifications and resulting performance that is not well understood
• Bioretention systems vary widely with respect to design features
• We surveyed over 175 systems in the literature, from a range of databases
Design Features and Specifications

- Drainage Area
- Surface Area to Drainage Area Ratio (1:##)
- % Impervious
- Land Use
- Watershed Cover Type
- Avg Depth of Precip
- Avg Annual Precip.
- Avg Annual Daytime Temp
- % Sand
- % Compost
- % Amendment
- Amendment Type
- % Fines (<22 micron)
- P-index (Mehlich 3)
- Soil pH
- % Organic Matter
- CEC
- Underdrain
- Internal Storage Reservoir
- Design Media Thickness
- Design Infiltration Rates
- Slope
- Ponding Depth
- Drawdown Time (hours)
- Sizing (flow control or WQ)
- Methodology (static, dynamic)
- Pretreatment
- Online/Offline System
- Season
- Age of System
- Actual Infiltration Rates
- Hydraulic Residence Time
- Compost Quality
- Vegetation Cover (grass, flowers, species type)
- Maintenance
- Volume Treated (cu ft/in of rain)
- Flow Range
WHY DO WE CARE?

• System performance determines the degree and intensity of usage of a technology, and influence the cost of implementation

• Municipalities will be developing implementation plans for managing nutrients

• Improvements in performance could result in reduced cost of implementation
Blue Line is at median INFLUENT concentration for all systems.
Red Line is at median EFFLUENT concentration for all systems.
Green Line, when present, indicates median EFFLUENT concentration of categories with particularly good performance.

**TP**
Median INF = 0.12 mg/L
Median EFF = 0.10 mg/L
Median %RE = 55%
Blue Line is at median INFLUENT concentration for all systems.
Red Line is at median EFFLUENT concentration for all systems.
Green Line, when present, indicates median EFFLUENT concentration of categories with particularly good performance.

**NO3**
Median INF = 0.36 mg/L
Median EFF = 0.22 mg/L
Median %RE = 14%
Blue Line is at median INFLUENT concentration for all systems.
Red Line is at median EFFLUENT concentration for all systems.
Green Line, when present, indicates median EFFLUENT concentration of categories with particularly good performance.

\[ \text{TN} \]
Median INF = 1.3 mg/L
Median EFF = 1.1 mg/L
Median %RE = 42%
Summary Findings

General

• Internal storage reservoirs have strong benefit for nutrients
• Characterization of compost is very important as is evident by large range of effluent performance
• Caution should be used when drawing conclusions based on limited to studies.

TSS

• Pretreatment improves performance (~6mg/L effluent < overall. median)
  -Systems with fast media (>1 in/hr), thick media layer (>=24 in) & pretreatment all have effluent median <10mg/L
• Evidence of relationship between media thickness and effluent concentration.
Summary Findings (Cont’d)

TN
• Mixes with high sand content performs well (median effluent ~0.8mg/L)
• Systems with internal storage reservoir (ISR) perform much better than those without (median 0.75 vs. 1.64mg/L)

NO3
• Very poor overall performance
• No ISR systems with <24 in media thickness have highest effluent concentrations (>1 mg/L median)
• ISR, 40-69% sand, and pretreated systems perform well (effluent ~0.2mg/L)

TP
• High sand mixes are top performers (median effluent ~0.07mg/L)
• ISR and underdrain systems all do well.
WHAT WAS DONE?

• Filter media composition can be optimized for phosphorus removal.

• Structural configuration optimized for nitrogen removal.
Hybrid System Background

Gravel Wetlands

Bioretention
System Layout

\[ V_{ISR}/WQV = 0.2 \]

\[ V_{ISR}/WQV = 0.1 \]
EXPERIMENTAL DESIGN

Component Characterization

Component Isotherms

BSM Column Study

Mix Validation

Field Installation

Model Development
Standard BSM mix with compost is leaching oP

BSM mix without compost removes oP

BSM mix with WTR removes oP
FIELD RESULTS AND UNHSC STUDY COMPARISONS
**CONCLUSIONS**

- Mixes with WTR processed to ~33% solids consistently removed >99% OP in column studies
- Modified bioretention field system performance showed improvement of P removal over typical bio systems: 20% RE for OP, 55%RE for TP
- ISR design improved NO3 removal by 15-46%
  - 14% RE in SPU Bioretention Database
  - ~40% RE in other UNH bioretention systems
  - 60% RE in modified Bio-5 system
- Compost appears to be problematic
- Quality of WTR varies substantially
- Construction cost are modest increase
  - Bioretention system with ISR = $24,800
  - Bioretention system without ISR = $23,800

MORE MONITORING NEEDED
2011 Berry Brook Urban Watershed Renewal, Dover, NH

- Impervious Cover Reduction through the targeted implementation of Low Impact Development
- Stream and Wetland Restoration, and Base Flow Augmentation,
- Community Engagement and Public Participation.
Watershed Urbanization and IC

Source: Impacts of Impervious cover on Aquatic Systems, CWP March 2010.

Source: Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-03, USGS 2005
Berry Brook Watershed Renewal Project

Berry Brook Dover, NH
- NHDES named Berry Brook to the 303d list of impaired surface waters due to lack of aquatic life support.

Project Comprises of 2 Components
1) Stream and wetland restoration (~800ft)
2) Stormwater management (13 LID Systems)
   - Treatment of 20.7 IC acres

Berry Brook Watershed area ~185 acres
Berry Brook stream length is approx. 1.15 miles
Urbanized - high density area
Berry Brook LIDs

Page Ave. - Swale

Horne St. School - Bioretention

Central Ave. - Gravel Wetland

Snow Ave. – Bioretention & Bioswale
EIC Pre vs. Post (Station)

Direct Runoff (in) vs. Rainfall Depth (in)

ICpre (30.1%)

ICpost (18.9%)
Storm Event Water Quality at Lower Watershed (Station, DA = 184.8 acres) for 11 Storms PreLID (06/11-10/11) and 4 Storms PostLID (10/12-12/12)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>PreLID (IC=30.1%, EIC=15.6%)</th>
<th>PostLID (IC=18.9%, EIC = 11.2%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS (mg/L)</td>
<td>0.018</td>
<td>0.026</td>
</tr>
<tr>
<td>Zn (mg/L)</td>
<td>0.026</td>
<td>0.388</td>
</tr>
<tr>
<td>NO3 (mg/L)</td>
<td>0.395</td>
<td>0.310</td>
</tr>
<tr>
<td>TN (mg/L)</td>
<td>0.002</td>
<td>0.034</td>
</tr>
<tr>
<td>TP (mg/L)</td>
<td>0.300</td>
<td>0.238</td>
</tr>
</tbody>
</table>

Storm Event Pollutant Loads per Rainfall Inch at Lower Watershed (Station, DA = 184.8 acres) for 6 Storms PreLID (06/11-10/11) and 4 Storms PostLID (10/12-12/12)

<table>
<thead>
<tr>
<th>Pollutant</th>
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<th>PostLID (IC=18.9%, EIC = 11.2%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS (Kg/in)</td>
<td>0.019</td>
<td>0.019</td>
</tr>
<tr>
<td>Zn (Kg/in)</td>
<td>0.019</td>
<td>0.019</td>
</tr>
<tr>
<td>NO3 (Kg/in)</td>
<td>0.057</td>
<td>0.130</td>
</tr>
<tr>
<td>TKN (Kg/in)</td>
<td>0.130</td>
<td>0.130</td>
</tr>
<tr>
<td>TN (Kg/in)</td>
<td>0.130</td>
<td>0.130</td>
</tr>
<tr>
<td>TP (Kg/in)</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>Ortho-P (g/in)</td>
<td>0.238</td>
<td>0.238</td>
</tr>
</tbody>
</table>