Stormwater Management Strategies for Reduction of Nitrogen and Phosphorus Loading to Surface Waters

Robert Roseen, PE, D.WRE, PhD, James Houle, CPSWQ, Thomas Ballestero, PE, PhD, PH, CGWP, PG, Alison Watts, PhD, Tim Puls
The UNH Stormwater Center
Environmental Research Group, Department of Civil Engineering
University of New Hampshire

4Th Annual Lamprey River Symposium
University of New Hampshire
Friday January 7th, 2011
Whoville has arrived
Regulatory Drivers

- NPDES Phase II has been largely an issue of due diligence with respect to SWMP.
- TMDLs are solid WQ standards which are required where SW controls have been insufficient to achieve water quality goals—due diligence does not matter.
- Region 1 has used Residual Designation Authority (RDA)—first in the US.
- RDA addresses sources of pollution not covered under existing programs----Existing development.
- 80% TSS Removal will not meet “no net increase standard.”
- Filtration/infiltration systems will be needed to meet TMDL requirements.
Load Reduction

Two Parts to Load Reduction
1. Concentration Reduction IE. System Efficiency
2. Volume Reduction

\[ \text{Pollutant} \times \left( \frac{mg}{L} \right) \times \text{Runoff Volume (L)} = \text{Load (mg)} \]
Performance Results
Solids Removal Performance by System Type

TSS %RE

Conventional
Manufactured Devices
LID

Retention Pond
Rock Lined Swale
Veg Swale
HDS Ave (3)
AquaFilter
Isolator Chamber
Subsurface Infill
Gravel Wetland
Porous Asphalt
Bioretention 1
Bioretention 2
Tree Filter
Sand Filter
DIN Removal Performance by System Type

- Conventional Manufactured Devices
  - Rock Lined Swale
  - Veg Swale
  - HDS Ave (3)
  - AquaFilter
  - Isolator Chamber
  - Subsurface Infil
  - Gravel Wetland
  - Porous Asphalt
  - Bioretention 1
  - Bioretention 2
  - Tree Filter
  - Sand Filter
TP Removal Performance by System Type

The diagram illustrates the TP removal performance by system type, comparing conventional manufactured devices and LID (Low Impact Development) systems. The performance is measured as a percentage change in TP (%RE) for various system types, including:

- Retention Pond
- Veg Swale
- Berm Swale
- HDS Ave (3)
- Aquafiler
- Isolator Chamber
- Subsurface Infil
- Gravel Wetland
- Porous Asphalt
- Bioretention 2
- Tree Filter
- Sand Filter
Where Should We Be Heading?

Design by Unit Process and Treatment Train, incorporate Filtration and Infiltration
## Precip Frequency Distribution

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Station name</th>
<th>Precipitation amount (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>CT0806</td>
<td>Bridgeport Sikorsky Airport</td>
<td>46%</td>
</tr>
<tr>
<td>CT3456</td>
<td>Hartford Airport</td>
<td>48%</td>
</tr>
<tr>
<td>MA0120</td>
<td>Amherst</td>
<td>45%</td>
</tr>
<tr>
<td>MA0770</td>
<td>Boston Logan Int'l Airport</td>
<td>49%</td>
</tr>
<tr>
<td>MA9923</td>
<td>Worcester Airport</td>
<td>48%</td>
</tr>
<tr>
<td>ME0273</td>
<td>Augusta</td>
<td>45%</td>
</tr>
<tr>
<td>ME6905</td>
<td>Portland Airport</td>
<td>49%</td>
</tr>
<tr>
<td>NH1683</td>
<td>Concord</td>
<td>49%</td>
</tr>
<tr>
<td>NH5712</td>
<td>Nashua</td>
<td>47%</td>
</tr>
<tr>
<td>RI6698</td>
<td>Providence Airport</td>
<td>48%</td>
</tr>
<tr>
<td>VT0277</td>
<td>Ball Mountain Lake</td>
<td>43%</td>
</tr>
<tr>
<td>VT1081</td>
<td>Burlington Int'l Airport</td>
<td>56%</td>
</tr>
</tbody>
</table>

Average of all stations: 48%, 45%, 7%
Mass loading for DRO, Zn, NO3, TSS as a function of normalized storm volume for two storms: (a) a large 60 mm rainfall over 1685 minutes; (b) a smaller 15 mm storm depth over 490 minutes. DRO=diesel range organics, Zn= zinc, NO3= nitrate, TSS= total suspended solids.
Concentration Reduction Based on System Size

BMP Performance Curve: Gravel Wetland
Land Use: Commercial

Pollutant Removal vs. Depth of Runoff Treated (inches)

Source: EPA Region 1, BMPDSS 2009
Concentration Reduction Based on System Size

BMP Performance Curve: Bioretention
Land Use: Commercial

Source: EPA Region 1, BMPDSS 2009
Volume Reduction

Source: AMEC Environmental 2009
Volume Reduction

Source: AMEC Environmental 2009
Example Retrofits in the Northeast
Greenland Meadows Commercial

- “Gold-Star” Commercial Development
- Cost of doing business near Impaired Waters/303D
- Saved $800k in SWM on costly piping and advanced SWM proprietary ($3.3M vs $2.5M)
- Brownfields site, ideal location, 15yrs
- Proposed site >15,000 Average Daily Traffic count on >30 acres
28 ac site, initially >95% impervious, now <10%EIC, with all drainage through filtration, expected to have minimal WQ impact except thermal and chloride
Median=0.005 mg/L TP
Median=3 mg/L TSS
Median=0.50 mg/L TN
Conclusions

High level treatment with *filtration systems* combined with volume reduction through *infiltration* is the only to achieve substantial load reduction.
Funding

Funding is provided by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) whose mission is to support the scientific development of innovative technologies for understanding and reversing the impacts of coastal and estuarine contamination and degradation.
Questions?
Tree Filter,
Portsmouth NH
Phosphorous is typically in 3 forms:

- **Soluble Reactive Phosphorous.** SRP usually consists largely of the inorganic orthophosphate (PO₄) form of phosphorous. Measurements of orthophosphate are commonly used to quantify SP.

- **Soluble Unreactive or Soluble Organic Phosphorous.** SUP are organic forms of phosphorous and chains of inorganic phosphorous molecules termed polyphosphates.

- **Particulate Phosphorous.** PP contains all material, inorganic and organic, particulate and colloidal, that is captured on a 0.45-micron membrane filter.

SRP + SUP = soluble phosphorous (SP)
SP + PP = total phosphorous (TP)
Phosphorous in Stormwater

![Box plot showing total phosphorus levels in stormwater from different land use types.](image)
Nitrogen in Stormwater Water

- Systems must be vegetated, sedimentation plays a minor role
- Biologically-mediated conversion processes, whether aerobic or anaerobic. Microbial decomposition of organic matter produces reduced NH$_3$ which is treated commonly through biological oxidation (nitrified) to NO$_2$/NO$_3$ and then treated by biological reduction anaerobically to N$_2$

\[ TN = \text{Organic N} + \text{NH}_3 + \text{NH}_4 + \text{NO}_2 + \text{NO}_3 \]
Nitrogen in Stormwater