Performance and Design of Subsurface Gravel Wetlands and manufactured stormwater control measures

2013 Stormwater Treatment Engineering Workshop
University of New Hampshire Stormwater Center,
Environmental Research Group, Department of Civil Engineering
University of New Hampshire
Dedicated to the protection of water resources through effective stormwater management

- Research and development of stormwater treatment systems

- To provide resources to stormwater communities currently involved in design and implementation of Phase II requirements
### 33 Systems Tested

<table>
<thead>
<tr>
<th>System Type</th>
<th>Tested To-Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>(6) stone swale, vegetated swale, swale with filter berm, dry pond, retention pond, and a deep sump catchbasin.</td>
</tr>
<tr>
<td>Low Impact Development (LID)</td>
<td>(14) surface sand filter, 5 bioretention systems, tree filter, 2 subsurface gravel wetland, 2 porous asphalt pavements, pervious concrete, PICP, and an extensive vegetated roof.</td>
</tr>
<tr>
<td>Manufactured Treatment Device (MTD)</td>
<td>(13) 6 vortex separators, an upflow filter, 2 MTD tree filter systems, water quality inlet, subsurface chambers, large volume infiltration device, and a modular wetland system.</td>
</tr>
</tbody>
</table>
Design Sources:
In NH, WQV is a static sizing criteria meaning it is the calculated volume resulting from the WQ storm depth (1 inch in 24 hrs) across the drainage area (1 acre parking lot = 3,300 cf).

The system needs to provide storage and treatment for the WQV as if it were delivered instantaneously.
Generic Cross-Section

Influent

Saturated zone

WQV 45%

CPv or FPv elevation

Effluent

Primary outlet
Critical Design Elements

1.) Pretreatment: Can be hydrodynamic separators, swales, or other basin that is capable of holding 10% of the WQV.

2.) Two Treatment Cells: 45% of the WQV held in each of 2 treatment cells ABOVE GROUND. Not the volume of internal storage reservoir.

3.) Travel length through the gravel should be a minimum of 15 ft

4.) No Geotextile between soil and crushed stone

5.) Underlying soils should have low permeability (hydraulic conductivity $\leq 0.03$ ft/day), may need a liner
6.) The orifice control will be what throttles the flow in the system.

\[ Q = C_d A \sqrt{2gh} \]

where
- \( Q \) = flow (\( m^3/s \))
- \( C_d \) = coefficient of discharge
- \( A \) = area of orifice (\( m^2 \))
- \( g \) = acceleration from gravity (9.81 m/s)
- \( h \) = head acting on the centerline (m)
Performance
Subsurface Gravel Wetland Hydraulic Performance

**HYDRAULIC PERFORMANCE**

- **Influent**
- **Effluent**

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Summer</th>
<th>Annual Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Peak Flow Reduction</td>
<td>91%</td>
<td>93%</td>
<td>92%</td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>419</td>
<td>367</td>
<td>391</td>
</tr>
</tbody>
</table>
Median Gravel Wetland Removal Efficiencies

6 years of data with Influent EMC medians

<table>
<thead>
<tr>
<th>Substance</th>
<th>Median Gravel Wetland Removal Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>98%</td>
</tr>
<tr>
<td>TPH-D</td>
<td>99%</td>
</tr>
<tr>
<td>Zn</td>
<td>83%</td>
</tr>
<tr>
<td>DIN</td>
<td>75%</td>
</tr>
<tr>
<td>TN</td>
<td>56%</td>
</tr>
<tr>
<td>TP</td>
<td>56%</td>
</tr>
<tr>
<td>OrP</td>
<td>75%</td>
</tr>
</tbody>
</table>

- TSS: Total Suspended Solids
- TPH-D: Total Petroleum Hydrocarbons
- Zn: Zinc
- DIN: Dissolved Inorganic Nitrogen
- TN: Total Nitrogen
- TP: Total Phosphorus
- OrP: Orthophosphate
Seasonal Performance

<table>
<thead>
<tr>
<th>Season</th>
<th>TSS</th>
<th>TPH-D</th>
<th>Zn</th>
<th>DIN</th>
<th>TN</th>
<th>TP</th>
<th>OrP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>57</td>
<td>644</td>
<td>0.04</td>
<td>0.3</td>
<td>1.1</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>

Removal Efficiency

- TSS: 100%
- TPH-D: 100%
- Zn: 90%
- DIN: 80%
- TN: 70%
- TP: 60%
- OrP: 50%

Seasonal Performance Bar Chart:
- Summer: Yellow
- Winter: Purple
- Annual: Green
Mass loading for DRO, Zn, NO₃, TSS as a function of normalized storm volume for two storms: (a) a large 2.3 in rainfall over 1685 minutes; (b) a smaller 0.6 in storm depth over 490 minute. DRO=diesel range organics, Zn= zinc, NO₃= nitrate, TSS= total suspended solids
Other Questions

- What is the max design ponding depth?
  A: It depends on chosen plant communities and the possibility of driving water vertically through the wetland soil. Preferably = 18 in.

- Is the WQV storage in the system static or dynamically sized?
  A: Static. Volume of storage above-ground is equal to the WQV. Draindown is controlled by the restrictive outlet hydraulics.
Other Questions

- How important is the 2-cell treatment approach?
  A: The primary benefit is the built-in redundancy should one of the cells need repair or maintenance.

- Is there a specific reason for the 15’ flow path?
  A: Some of our tests with a horizontal flow gravel sluice verified this sizing based on performance.
BMP Performance Monitoring

Research Field Facility at UNH
Tc ~ 19 minutes
Online vs. Offline

- Online HDS
  - Upstream Catch Basin
  - Total runoff volume
  - HDS
  - Outlet

- Offline HDS
  - Upstream Catch Basin
  - Design flow conveyance
  - High Flow (non-design) Bypass
  - Combined flow conveyance
HDS Online vs. Offline Performance

HDS Performance Online vs Offline

Removal Efficiency

41 mg/L  774 ug/L  0.05 mg/L  0.36 mg/L  0.09 mg/L

Online HDS  Offline HDS

TSS  TPH-D  Zn  DIN  TP
Hydrologic Performance Results
Tree Box Flow and Volume Attenuation

Average Annual Lag Time is 19 min

HYDRAULIC PERFORMANCE

- Influent
- Effluent

Flow (GPM)

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<td>Average Peak Flow Reduction</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>Average Lag Time (minutes)</td>
<td>59</td>
<td>66</td>
<td>62</td>
</tr>
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</table>
ADS Subsurface Detention/Infiltration System Flow and Volume Attenuation

Average Annual Peak Flow Reduction is 68%
Average Annual Lag Time is 790 min

Average Peak Flow Reduction: 83%
Average Lag Time (min): 364
Hydraulic Performance

Lag Time ($k_L$)

Peak Reduction ($k_P$)

5 2 1 0.5 0.1
Other Applications

\[ \text{LID} = (\text{MC})C \]
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.
Influent and Effluent PSD

The graph illustrates the particle size distribution (PSD) of influent and effluent samples, plotted in terms of % Finer by weight against Particle size (mm). Data from different dates, such as 7/15/08 and 9/17/09, are shown in various colors for comparison.
Monthly Mean Precipitation 1981 - 2011

- Durham, NH
- Seattle
- Spokane
- Vancouver
- Yakima

Precipitation (in.)

Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
2005 Rainfall Hyetographs
Monthly Mean Temperature 1981 - 2011

Temperature (°F)

- Durham, NH
- Seattle
- Spokane
- Vancouver
- Yakima

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec