Roadside Swales Infiltration Performance Calculator

2017 TRB Summer Workshop
May 18-21, 2017

John S. Gulliver
Dept. Civil, Environmental and Geo-Engineering, U. of Minnesota

Grad Student: Maria Garcia-Serrana Co-PI: John L. Nieber
Problem Statement

Stormwater Runoff: non-point source of pollution

Water Quality

Runoff from highways: TSS, Nutrients, Metals, Organic Compounds

Water Quantity

Liu et al., 2014
Green Infrastructure

“reduces and treats stormwater at its source” US. EPA

- Ponds
- Infiltration basins
- Rain gardens
- Green roofs

Roadside Drainage Ditches = Filter Strips / Swales

Twincities.com
Roadside Drainage Ditches / Swales

Project Steps:

1. Field tests
2. Model
3. Simplified Model = Calculator
Field Experiments
Field Experiments

- **Simulated Runoff Tests**
  - 4 Highways in TC Metro Area
    - 2 sites/Hwy
  - 3 intensities
    - 1, 2, 10-year storms
  - 3 Seasons
    - Fall, Spring, and Summer

ST. ANTHONY FALLS LABORATORY
Field Experiments

Soil Types
- Loam
- Loamy sand
- Sandy loam
- Sandy clay loam

- 53% soils found in Minnesota road embankments
Field Experiments
Field Experiments
Field Experiments

Saturated Hydraulic Conductivity ($K_{sat}$) measurements

<table>
<thead>
<tr>
<th></th>
<th>$K_{sat}$ (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hwy 51</td>
<td>3.54 (1.44)*</td>
</tr>
<tr>
<td>Hwy 77</td>
<td>5.74 (0.94)*</td>
</tr>
<tr>
<td>Hwy 47</td>
<td>3.47 (1.29)*</td>
</tr>
<tr>
<td>Hwy 13</td>
<td>4.14 (1.87)*</td>
</tr>
</tbody>
</table>
Field Experiments

Results

![Graph showing the relationship between intensity and fraction of wetted area. The equation is given as Fraction of Wetted Area = 0.00225 x Intensity + 0.581, with R² = 0.999.](image-url)
Field Experiments

Results

![Bar chart showing percentage infiltration for different flux levels: Fall Medium Flux, Spring Medium Flux, Low Flux, High Flux. The chart indicates that Fall Medium Flux has the highest percentage infiltration, followed by Spring Medium Flux, Low Flux, and then High Flux.]
Infiltration-Overland Flow Model
Infiltration-Overland Flow Model

Reality

Model

Concentrated Flow (fw)

Non Concentrated Flow (1-fw)
Infiltration-Overland Flow Model
Infiltration-Overland Flow Model Validation

- N=12
- RMSE = 6%
- Normalized MSE = 12%

K\text{sat input: estimated in the field}

Graph showing %Infiltration Measured vs Predicted
Infiltration-Overland Flow Model Validation

![Graph showing runoff rate over time for different flux levels (low, medium, high) with simulated and measured outflow data.](image)
Infiltration-Overland Flow Model

Matlab Model

Inputs:

• Rainfall intensity (i)
• Duration of storm event (t)
• Length of side slope (L)
• Soil suction head (ψ)
• Soil water deficit (Δθ)
• Saturated Hydraulic Conductivity (K_s)
• Width of swale and channel (w) (B)
• Fraction wetted (f_w)
• Side slope (S)
• Manning’s n (n)
• Depression storage (ds)
Simplification of the Model = Swale Calculator
Simplification of the Model

Sensitivity and Uncertainty Analyses

Percentage of Sensitivity * Uncertainty

- Ksat: 9%
- \( \psi \): 8%
- \( \Delta \theta \): 4%
- fw
- B
- n
- ds
- S

ST. ANTHONY FALLS LABORATORY

UNIVERSITY OF MINNESOTA
Driven to Discover™
Swale Calculator

1- Saturated Hydraulic Conductivity ($K_{\text{sat}}$)

Ahmed et al. (2015)

2- Width of the road and side slope

3- $K_{\text{sat}} + W_{\text{swale}} / W_{\text{road}} = \% \text{ Infiltration}$

4- Location (Percentile Rainfall Volume)
Swale Calculator

Example:
Ksat = 2cm/h
0.79 in/h

Wroad = 10m
33 ft

Wswale = 4m
13 ft
Swale Calculator – Case Study

California
Caltrans (2003)

<table>
<thead>
<tr>
<th>Location</th>
<th>Filter Width [m]</th>
<th>$K_{sat}$ [cm/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacramento</td>
<td>1.1</td>
<td>4.08</td>
</tr>
<tr>
<td></td>
<td>4.6</td>
<td>2.41</td>
</tr>
<tr>
<td></td>
<td>6.6</td>
<td>2.17</td>
</tr>
<tr>
<td></td>
<td>8.4</td>
<td>2.39</td>
</tr>
<tr>
<td>Moreno Valley</td>
<td>2.6</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>4.9</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>9.9</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Sacramento vs Moreno Valley

Observed vs Predicted

Observed = Predicted
Download Calculator

- http://stormwater.safl.umn.edu

- Resources/Roadside Swale Calculator

- Publications/Reports
Acknowledgements

• Local Road Research Board (LRRB)
• Minnesota Department of Transportation (MnDOT)
  – Barbara Loida, Technical Liaison
  – Bruce Holdhusen, Project Coordinator.
• Kellie Thom, David Bauer, and Madison Rogers (MnDOT)
• Student researchers David Liddell, Raphael Martins, Tyler Olsen, and Anthony Vecchi.

➤ http://stormwater.safl.umn.edu
Roadside Drainage Ditches/Swales = Stormwater Management Practice

SMPs are closer than they appear

gulli003@umn.edu