OBJECTIVE

• To examine and explain the long-term performance of three infiltration BMPs at Villanova
  - Longevity
  - Seasonal Variations

• Focus on the infiltration process not the overall BMP effectiveness (more applicable elsewhere)

OUTLINE

• Introduction
  - Background on BMPs
  - Performance Indicator/Methods

• Results
  - Seasonal Variation
  - Longevity

• Discussion
  - What impacts long-term infiltration?

• Conclusions
  - What are the implications

INfiltration BMPs

Pervious Concrete Infiltration Basin (PCIB)

- 1.3 Ac
- 62% Impervious
- 6:1 DCIA to BMP (3:1)

Philadelphia Water Department 1902-2000

Thanks to the William Penn Foundation and the 319 and Pennsylvania Growing Greener Programs
INFILTRATION BMPs

Pervious Concrete Infiltration Basin

- Shallow (18”), underground crushed stone storage bed
- Constructed in 2002
- Depth measured using a pressure transducer (~2 year record)

INFILTRATION BMPs

BioInfiltration Traffic Island (BTI)

- 1.3 Ac
- 46% Impervious
- 10:1 DCIA to BMP
- 450 in/yr

INFILTRATION BMPs

BioInfiltration Traffic Island (BTI)

- Shallow (18”), open, vegetated depression, sand:soil mixture, with initial mulch layer
- Constructed in 2001
- Depth measured using an ultrasonic level detector (~4 year record)

INFILTRATION BMPs

Infiltration Trench - IT

- 0.47 Ac
- 100% Impervious
- 130 DCIA to BMP
- 5,900 in/yr

INFILTRATION BMPs

Infiltration Trench - IT

- Constructed in 2004
- Depth measured using a pressure transducer (~2.75 year record)
- Intentionally under designed

PERFORMANCE INDICATOR

- One-dimensional flow (BTI, PCIB)
- Saturated conditions (no soil moisture potential, ?)
- Homogeneous (area averaged) (BTI, PCIB)
PERFORMANCE INDICATOR

Hydraulic Conductivity

- PCIB: slope of stage hydrograph recession limb*, corrected for stone bed porosity
- BTI: slope of stage hydrograph
- IT: Monte Carlo method used to determine best fit estimate for bottom and sides

* Green & Ampt analyses indicate that the recession rate is an acceptable approximation of hydraulic conductivity.

METHODS

- Each BMP has been the subject of long-term continuous monitoring; in total, approximately ten years
- Needed an impartial, quantitative, and efficient method to find and calculate hundreds of slopes
- Visual Basic program created to do the dirty work (SlopeFinder)

RESULTS

Output from SlopeFinder program

Incremental Slopes (PCIB and IT)

PCIB (2 years of data)

BTI (4.25 years of data)

IT (2.75 years of data) *notice log-scale
RESULTS

- Each BMP shows significant seasonal variation
- Only the IT shows (by eye) a systematic decrease

What is the origin of seasonal variation?
Why does only one show a systematic decrease?

RESULTS  Seasonal Variation

What is the origin of seasonal variation?

BioInfiltration Traffic Island

RESULTS  Seasonal Variation

What is the origin of seasonal variation?

PCIB / IT

RESULTS  Seasonal Variation

What is the origin of seasonal variation?

PCIB / IT

RESULTS  Seasonal Variation

- The viscosity of water varies ~two-fold over average annual temp. ranges

\[ K = \frac{k \times \rho g}{\mu} \]

Where:
- \( K \) = hydraulic conductivity [LT^{-1}]
- \( k \) = intrinsic permeability [L^2]
- \( \rho \) = fluid density [L^{-1}T^{-1}]
- \( g \) = gravitational acc. [LT^{-2}]
- \( \mu \) = fluid dynamic viscosity [ML^{-1}T^{-1}]

RESULTS  Seasonal Variation

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RESULTS  Linear Regressions

Multiple linear regressions (temperature & age)

• The IT data show undeniable evidence of a decrease over time.

• To be fair, the IT data includes first 1.5 yr of operation (PCIB and BTI do not)

RESULTS  Longevity

Do the PCIB or BTI show any signs of a systematic decrease over time?

• Multiple linear regressions (temperature & age)

<table>
<thead>
<tr>
<th>Slope (Temp.)</th>
<th>Slope (Age)</th>
<th>PCIB</th>
<th>BTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0015</td>
<td>0.0036</td>
<td>0.0023</td>
<td>0.0036</td>
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<tr>
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<td>0.0010</td>
<td>0.0011</td>
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<tr>
<td>0.0046</td>
<td>0.190</td>
<td>0.0005</td>
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</table>
RESULTS  Longevity
Do the PCIB or BTI show any signs of a systematic decrease over time?

- Multiple linear regressions (temperature & age)

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<tr>
<td>PCIB</td>
<td>-0.0009</td>
<td>0.0003</td>
</tr>
<tr>
<td>BTI</td>
<td>0.0037</td>
<td>0.0015</td>
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</table>

DISCUSSION  Longevity
What impacts long-term infiltration in BMPs?

- There are many processes that tend to decrease the rate of infiltration.
- There are also many processes and soil characteristics that resist degradation and can improve the overall rate of infiltration.

- not including soil type, depth to groundwater, and construction techniques

Good  Not so good  Bad

- PCIB
  - Low (3-6:1) ratio of DCIA to BMP area
  - Inflow with characteristically low TSS concentrations
  - Shallow bed
  - Closed bed, no vegetation, mulch, organic matter, or freeze-thaw.

- BTI
  - Heavily vegetated
  - Protective mulch layer
  - High organic matter content in surficial soil
  - Some level of TSS pretreatment
  - Shallow bed
  - Freeze-thaw action
  - Moderate (~10:1) DCIA to BMP ratio

- IT
  - Extremely high (130:1) ratio of DCIA to BMP area
  - Inflow with characteristically high TSS concentrations
  - Deep
  - Closed bed, no vegetation, mulch, organic matter, or freeze-thaw.

Points to Ponder Re: IT

- PA BMP Manual
  - (~5:1 DCIA to BMP ratio)
- IT (~130:1)
  - [130 / 5] = 26
  - 26 times the annual sediment load
- ~80 equivalent years of operation
CONCLUSIONS

• Seasonal variation appears to be explained by temperature-induced viscosity changes of water.
• Careful design and construction techniques can produce infiltration BMPs that will continue to meet their original design criteria.

QUESTIONS

• SAVE THESE DATES!
Announcing the 2007 Pennsylvania Stormwater Management Symposium – October 2007 – Villanova University

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