Adapting Porous Pavement and other Infiltration BMPs to a Cold Climate

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Outline

- The Problem
- Conventional SWM
- “Better” SWM
  - Conservation Design
  - Volume Control and Water Quality
- Cold Climate Case Studies
- Site, Design, and Construction Criteria
- Variations on the theme
The Problem
Stormwater Impacts of Land Development

- Cumulative downstream flooding issues
- Reduction in stream baseflow, water table decline, wetland loss
- Nonpoint source pollution
- Riparian losses/stream morphology
- Stream temperature
Balancing the Water Cycle
Annual Hydrologic Cycle
For an Average Year

RAINFALL
45"

EVAPO-TRANSPIRATION
22"

SOIL

FRACTURED BEDROCK

INfiltrATION

AQUIFER

RUNOFF
8"

BASEFLOW
15" or 1,122 gpd/acre
Altered Hydrologic Cycle

- **Rainfall (45"/yr)**
- **Evaporative Loss from Impervious Surfaces (2")**
- **Reduced Infiltration Through Regraded and Compacted Soils in Grasses**
- **0" of Infiltration Under Impervious Surfaces**
- **Reduction in Base Flow by 15"/yr Under Impervious Surfaces**
- **43" Runoff from Impervious Cover**

Note: The runoff from impervious surfaces is conveyed by driveways and roads to the stream system.
New Development – Detention Basins
Conventional Stormwater Management

- Controls Peak Rate of Runoff to Predevelopment Conditions for large storms
- Fails to Control Volume of Runoff
- Fails to Control NPS Pollutant Loadings
- Fails to Recharge Groundwater
DISTRIBUTION OF RAINFALL BY EVENT MAGNITUDE

- 0"-1"": 54%
- 1"-2": 31%
- 2"-3": 11%
- 3"-4": 3%
- >4": 1%
Dry Channels...

Eroded Streambanks...
Stormwater Runoff Hydrograph
AFTER DEVELOPMENT WITH DETENTION

Predevelopment
Post Development
With Detention

Discharge

Time
Effects of Detention in a Hypothetical Watershed

- Hydrograph with Detention
- Pre-development Hydrograph
- Basins 1, 2, 3-4, 5 (labeled on the graph)

Discharge vs. Time graph showing the impact of detention on water flow.
What to Do?

First Reduce Site Disturbance

- Conservation Design / LID
- Preserve Important Natural Features
- Reduce Earthwork
- Fit Structures to Topography
IT'S GOING TO BE A HOUSING DEVELOPMENT CALLED AUDUBON WOODS.
Conservation Design / Low-Impact Development Example

Brandywine Conservancy
• 33-acre site
• 23 one-acre lots
• % Undisturbed: 15%
• % Impervious: 12.6%
• 33-acre site
• 23 half-acre lots
• % Undisturbed: 62%
• % Impervious: 7.4%
Large-Lot Conservation Layout

- 33-acre site
- 23 one-acre lots
- % Undisturbed: 38%
- % Impervious: 9.7%
Cost Comparison:

Conventional Development $561,650
Conservation Design-Clustered $244,800
Stormwater “Better” Management Practices

- Porous Pavement
- Infiltration Planting Beds & Playfields
- Infiltration Trenches/Berms
- Bioretention / Rain Gardens
- Infiltration Basins
- Runoff Capture & Reuse
- Vegetated Roofs
Benefits of Infiltration

• Maintain Hydrologic Balance
• Remove Pollutants
• Prevent increased downstream flows
• Recharge Groundwater
• Maintain Stream flow & temperature
<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>INFILTRATION PRACTICES</th>
<th>Stormwater Wetlands</th>
<th>Stormwater Ponds Wet</th>
<th>Filtering Practices</th>
<th>Water Quality Swales</th>
<th>Stormwater Dry Ponds</th>
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<td>Total Phosphorus</td>
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<td>51</td>
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Porous Bituminous Pavement
Porous Paving w/ Infiltration

FINISH GRADE

PERVIOUS PAVING - SURFACE COURSE 2 1/2"

CHOKER COURSE: AASHTO No. 57 - 1" OR MORE
SUFFICIENT TO FILL LARGE AGGREGATE SPACE

CLEAN, UNIFORMLY GRADED COARSE
AGGREGATE, AASHTO No. 2

NON-WOVEN GEOTEXTILE

BED BOTTOM ELEVATION

UNCOMPACTED SUBGRADE

VARIES
# Porous Asphalt Mix

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<th>US Standard Sieve Size</th>
<th>Percent Passing</th>
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<td>1/2&quot;</td>
<td>100</td>
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<td>3/8&quot;</td>
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<td>#30</td>
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- 5.75% to 6% Asphalt
Early Example – Dupont Barley Mills Complex 1985
photo of standard and porous asphalt - DuPont
Porous Pavement

- Over 50 installations
- Oldest systems 1980-82
  - DuPont, Verizon, SmithKline, Siemen’s
  - National Park Service, Fish & Wildlife, National Forest Service
  - Libraries, Religious Centers, Prisons
  - Industrial – Ford & ALCOA
  - Office Parks, Shopping Malls, Municipal Buildings
  - Universities – UNC, URI, UM, Penn, PSU, Swarthmore
Costs of Porous Pavement

• Generally costs the same or less
• Eliminates Piping Infrastructure and Basins
• Penn State Berks Campus – 320 spaces 1999
  – $3500 / space budgeted
  – $2700 actual cost
“Porous Pavement in a Cold Climate”

• Research in Northern Sweden concluded that porous pavement performed better or equivalent to conventional pavement across the board:

Backstrom, M. 1999. Lulea University of Technology, Sweden
“Porous Pavement in a Cold Climate”

• “The porous pavement was more resistant to freezing than the impermeable pavement”
• “Thawing of porous pavement was a rapid process”
• “The full-scale porous pavement construction was not damaged by frost-heave and the frost heave … was less or equal to … comparable impermeable pavement”
• “Porous pavements have the potential to reduce meltwater runoff”
• 9-yr old system functioning without any maintenance
• 4.5-yr old system w/ infiltration rate of 65 mm/min (153”/hr)

Backstrom, M. 1999. Lulea University of Technology, Sweden
Stormwater BMP #25
Snowman Melting on Porous Pavement
“Cold Climate” Case Studies

• Centre County/Penn State, State College
• University of Rhode Island, South Kingston
• University of Michigan, Ann Arbor
• Ford Motor Company, Dearborn, Michigan
• Commerce Plaza, Allentown, Pennsylvania
• Walden Pond, Massachusetts
Centre County/Pennsylvania State University Visitor Center

- Porous Pavement
- Vegetated Infiltration Beds
- Infiltration Trenches
- Porous Concrete
- Rain Gardens / Bioretention
Porous Pavement System

• Monitored for over 2 years
• “…the stormwater BMP [porous pavement] at the Visitor’s Center has achieved zero discharge over the past two years, despite heavy rainfalls [and snow]”
• The parking lots do not receive deicing agents or anti-skid materials “mainly because there has not been a need for them.”

Rain Gardens / Bioretention

- Modified Soils
- Depression Storage
- Native Plantings
- Reduced Fertilization
Penn State Visitor Center
Infiltration Trench

- “Leaky” perforated pipe in stone bed.
- Placed along contour.
- Convey large storms, infiltrate small storms.
INfiltration Trench

- Surface Swale
- Stone Bed wrapped with Geotextile
- Undisturbed Sub-Soil
- Perforated Pipe for Distribution and Overflow
Penn State Visitor Center – Infiltration Trench
Infiltration Beds

- Stone Bed Below Soil
- Planting Areas
- Playfields
University of Rhode Island

- South Kingston, RI
- 800- and 200-vehicle porous pavement parking lots constructed in 2002
- University now searching for opportunities to retrofit existing standard pavement lots
University of Michigan

• Porous Pavement Parking Lots
  – Retrofit of existing lot in urban portion of main campus – well draining soils
  – New lot at University Botanical Gardens – poorly draining soils near pond
    • Beds will slowly discharge to vegetated swale
Ford Motor Company

- Porous Pavement with slow discharge to vegetated systems
  - First lot constructed in 2000
  - Additional 10+ acres constructed 2003
- Vegetated Infiltration Swales
Ford Rouge Center
Dearborn, Michigan

Artist Richard Rochon's rendering of an aerial view of the Ford Rouge Center that includes the new Ford assembly plant.
Excellent winter performance

- porous asphalt
- standard asphalt

Water quality swales
Vegetated Infiltration Swale

Stormwater surface storage and infiltration through vegetated layer and planting layer for water quality treatment

Conceptual only: drawing not to scale

Discharge of untreated stormwater to planting area (either surface runoff from roads/parking or point discharges)

Discharge of untreated stormwater into soil mix via perforated distribution pipes

18" Soil/Planting Mix

20" Rainstore on 4" gravel base

30' +/-

Modify width as needed based on available area and coordination with landscape plan.

NOTE: Rainstore system can serve as cistern for irrigation needs as desired.
Commerce Plaza Office Building

- Infiltration Basin
- Narrow driveways, reduced impervious
- Uncurbed parking areas
- Grassed swales & level spreaders
Infiltration Basin – Commerce Plaza Plaza 1983
Walden Pond*

- Northwest of Boston, MA
- 1977 Demonstration Project by the Commonwealth of Massachusetts
- Very busy parking lot
- No need to repave after 26 years!!
- Not damaged by significant freeze-thaw cycles – no potholes!

* No involvement with the project. Information based on information brochure and website (A. Richard Miller) and personal site visits.
Designing Infiltration Systems
Site Criteria

- Soil Permeability greater than 0.25 in./hr
- Minimum Bedrock Separation of 2 feet
- Infiltration device at least 3 feet above seasonally high water table
- Evaluate potential sediment and pollutant loadings
Design Criteria

• Spread It Out!
  – 5:1 Impervious to Recharge Area Maximum
• Minimize excavation / maximize soil buffer
• Pre-treatment
• Construction oversight!!
  – Meet with contractors before construction
  – Inspect at critical points
• Level Bed Bottoms
• Keep it Clean – E&S Control
SPRINGBROOK
JOHN ALGER PARCEL
CONCEPTUAL STORMWATER
MANAGEMENT PLAN
FEBRUARY 2003
Level Infiltration Beds with Sloping Surface

2 1/2" Pervious paving surface course
Choker course (AASHTO No. 57 - Washed)

3' wide earthen berm
W/ 2:1 side slopes

4% maximum

Uncompacted subgrade

Existing undisturbed soil

Clean-washed, uniformly graded base course, AASHTO No. 2

Geotextile (bottom & sides)
Construction Criteria

- Protect infiltration BMPs from sediment until drainage area is completely stabilized!
- Do not compact soil under infiltration areas!
- Use clean aggregate
- Establish dense vegetation
- Staging/stockpiling
Hydrologic Calculations

- Net increase in Volume for 2-year storm
- Mitigate Peak Rate for larger storms
- Excellent Water Quality performance
Comparison of Detention vs. Infiltration Design Systems
How we Manage Stormwater on a Site-by-Site Basis affects the entire Watershed
Variations on the Theme...
Swarthmore College

Excellent winter performance
Penn State University
Berks Campus
Trammel Crow Office Complex
University of Pennsylvania-Alexander School, Philadelphia, PA
Washington National Cathedral
Infiltration Berm through Woods
Retrofitting an Existing Detention Basin
Underground Cistern for Irrigation

4000 GALLON CISTERN STORES RAINFALL FROM ROOFTOPS FOR IRRIGATION

CISTERN PUMP & IRRIGATION CONTROL BOX

WATER PUMP
Carmichael Field Section
"I'm thirsty. What kind of water does your mother buy?"