Green Streets, Clear Skies, Blue Waters

Gerald Kauffman
Director, IPA’s Water Resources Agency

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Top Four Environmental Concerns

The top four concerns of Americans are water-related.
The Hydrologic Cycle

Streets and roads accelerate the hydrologic cycle, causing water pollution and flooding.
Hydrologic Basis

\[ P = R + I + ET - \Delta S \]

Precipitation + Impervious Cover = Stormwater Runoff
From the Science of Hydrology

The quantity and quality of stormwater runoff is directly proportional to the amount of impervious roof and pavement area from roads and streets.
City of Newark Impervious Coverage

Over 30% of the City of Newark is covered by impervious roof/pavement.
City of Newark Impervious Cover by Land Use

- Roads/Streets: 27%
- Residential/Single-Family: 21%
- Residential/Multi-Family: 7%
- University: 11%
- Industrial/Manufacturing: 24%
- Business: 13%
- Floodplain/Parks: 5%
“Architects have employed green street design for centuries.”

- Greene Countrie Towne (William Penn 1682)
- Garden City (late 18th century)
- City Beautiful (early 20th century)
- Country Place Era (roaring ’20s)
- Greenbelt (1930s, Roosevelt’s New Deal)
- New Urbanism (21st century)
- Low-Impact Development
- Smart Growth
300 BCE - Appian Way, Rome
Quote from William Penn

“Let every house be placed…in the middle of its plat, as to the breadthway of it, so that there may be ground on each side for gardens or orchards, or fields, that it may be a greene country towne, which will never be burnt and always wholesome.”

*William Penn, 30th of Sept., 1681, Philadelphia*
18th Century Philadelphia
Philadelphia, Near Independence Hall
Olmstead’s Riverside, Illinois, c. 1870
Olmstead’s Riverside, Illinois, Today
Riverside, Illinois

- Olmsted and Vaux designed in 1868
- 1600 acres total, 1000 acres as open space
- Shaded parkway and boulevards
- Preserved floodplain and parks
- Curved streets, following land contours
- Absence of perpendicular intersections
- Narrow streets, 18 ft.
- Minimize sidewalks
- F. L. Wright and J. Jensen built prairie-style homes here that incorporated green principles.
Olmstead’s Design Principles

- Walks/roads designed for positive drainage
- 600 ft. to open space from residence
- Transportation to city via railroad and parkway
- Separate walking paths from driving
- 100-ft. lot frontage
- 30-ft. minimum setback
- Visual access to open space
- Triangle parks
- Sunken roads
Olmstead’s Riverside, Illinois, Today

Notice triangular parks and narrow 18-ft.-wide roads.
Notice triangular parks and narrow 18-ft.-wide roads.
University of Delaware Campus

Marian Coffin (1920s) drew landscape plans during Country Place Era. UD campus a giant city block. Optimum Pedestrian floor/area ratio = 0.75
Greenbelt, Maryland, 1930s
Greenbelt, Maryland, 1930s

Separation of transportation modes
Typical Street Design Cross-section

Highway and street design manuals (DelDOT typ.) require wide street cross-sections. These show typical 48-ft. streets, 12-ft. lanes.
Arden, Delaware, Built 1900

Village Arts and Crafts Movement

14-ft.-wide streets
Comparison of Road Widths

Christiansted
Newark, Del.

24 ft.

Covered Bridge Farms
Newark, Del.

18 ft.
Typical New Construction

Typical suburban subdivision in Del.

32 ft.
The Math of Street Impervious

Street pavement cost per mile
(2-in. asphalt @ $10/\text{yd}^2)$

- 32-ft. street = $168,960 \text{ ft}^2 = 18,773 \text{ yd}^2 = $187,730$
- 24-ft. street = $126,720 \text{ ft}^2 = 14,080 \text{ yd}^2 = $140,800$
- 18-ft. street = $95,040 \text{ ft}^2 = 10,560 \text{ yd}^2 = $105,560$
“Green Street” Techniques

“available to mitigate impervious impacts”

• 1. Rain Harvesting
• 2. Rain Gardens
• 3. Stormwater Planters
• 4. Permeable Paving
• 5. Green Roofs

Sources: Cities of Portland and Seattle and EPA
Anatomy of a Green Street

- Pedestrian friendly
- 1000 cf soil volume for street tree boxes
- Landscape areas
- Permeable sidewalks
- Transit oriented
- Shielded, Energy efficient street fixtures
- Recycled materials used
- Mature Street Trees
- Compost amended soils
- Permeable pavement in parking lane
- Bike Rack
- Bioretention
- Interpretative signs
Examples
Examples
1. Rain Harvesting

Rain Barrel Connected to Downspout

Overflow shall flow to a conveyance zone

Leaf Rock/Screen

Latch or Lock

2" Dia. Overflow Pipe

1/2" Outlet Pipe w/Valve

Drain Rock or Splash Block

Conveyance Zone
Examples
Cisterns at CBF Headquarters

Photo: Chesapeake Bay Foundation
Rain Spout

Dansko, West Grove, Pa.
Cistern

Cistern
Rain, stream, ocean
Woodlawn Library
Wilmington, Del.
2. Rain Gardens

Rain Garden

- Plants for drier and fluctuating conditions
- 2-3" mulch or compost
- 18" amended soil (if required)
- 18" drain rock
- Optional perforated pipe to PSD
- Plants that tolerate fluctuating water conditions
- Plants for drier conditions
- Existing soil
- Optional overflow to PSD or NDS (in lieu of perforated pipe to PSD)
- Geotextile
Residential Rain Garden

Rain gardens can be planted and shaped to fit the character of individual residences.
Design

A - *Taxodium distichum* (Bald Cypress) (zone 6b-7b)
   *Betula nigra* 'Heritage' or 'Dura-Heat' (River Birch)
B - *Cornus sericea* (Redosier Dogwood), 4' o.c.
C - *Cephalanthus occidentalis* (Buttonbush), 6' o.c.
D - *Ilex verticillata* (Winterberry), 6' o.c.
E - *Physostegia virginiana* (Obedient Plant), 2' o.c.
F - *Ilex verticillata* 'Maryland Beauty' (Maryland Beauty Winterberry; Red Sprite OK too), 3' o.c.
G - *Itea virginiana* 'Henry's Garnet', 4' o.c.
H - *Acer campesire* (Hedge maple)
I - *Iris versicolor* (Northern Blue Flag), 18' o.c.

note: o.c = on center
"requires 1 male ('Jim Dandy') and 4 females ('Afterglow')

**TREES AND SHRUBS BORDER RAINGARDEN**  550 SF

- Full Sun
- Zones 6b-7b
- Piedmont
- Scale: 1/4" = 1'

INSTITUTE FOR PUBLIC ADMINISTRATION • COLLEGE OF EDUCATION & PUBLIC POLICY
Rain Garden

Rain Garden
Dansko
West Grove, Pa.
Rain Garden

Rain Garden
UD
Newark, Del.
A Rain Garden’s Benefits and Beauty

What is a “Rain Garden”? A rain garden is a shallow landscape depression that captures the rain as it runs off impervious surfaces. This allows the collected water to evaporate into the air, soak into the ground, or be absorbed by plants and turned into oxygen.

Why do we need “Rain Gardens”? As you look around and notice sidewalks, driveways, parking lots, and rooftops, these surfaces do not allow rain to soak into the earth. Rain falls on these surfaces and immediately runs off directly into our streams and rivers, often collecting ground pollution such as fertilizers, pesticides, oil from cars, dog waste, and garbage. This results in an accumulation of large volumes of stormwater runoff, sending nutrients and other pollutants into our waterways, contaminating all sorts of pollutants with it. This is not only harmful to the plants and animals living in these waterways but also to people, as many people depend on these surface waters for their clean drinking water. Those who get their clean drinking water pumped up from the ground are also affected, because the impervious surfaces do not allow water to soak back into the ground to replenish the supply.

What do “Rain Gardens” do? Reduce the opportunity for flooding Reduce the opportunity for flooding Create habitat for wildlife like birds and butterflies Protect rivers and streams from erosion and pollution Conserve water by utilizing a natural resource like rain for free Promote infiltration of water to replenish groundwater Enhance aesthetic appeal, thereby increasing property value Reduce landscape maintenance by eliminating the need for fertilizers, pesticides, and mowing

Designing a Rain Garden
1. Determine your ideal rain garden site. Always locate the rain garden near a stormwater outlet like an existing grate or a place where any overflow above the garden’s capacity.
2. Determine the amount of rain draining into the garden.
3. Determine the desired size of your rain garden.
4. Determine the infiltration rate of which rain soaks into the soil of the rain garden. Initially, this rain garden did not infiltrate all of the collected stormwater within the ideal timeframe. Further investigations found that under the top four feet of clay was a sand layer and then a gravel layer. Thirteen feet below the surface was layered with sand and gravel layer and then backfilled with ballast stones. This allowed the water to infiltrate within the ideal time period.

The observation patio area you are standing on was made using a permeable paving technique that promotes stormwater infiltration and decreases runoff. The patio and steps were installed by Creative Pavers (www.creativepavers.com).

UD Rain Garden Educational Signage
UD Rain Garden

Rain Garden
UD
Newark, Del.
UD Rain Garden
Rain Garden

Rain Garden
Woodlawn Library
Wilmington, Del.
3. Stormwater Planters

Adapted from:
Stormwater Planters

Stormwater Planter

NTS
Stormwater Planters

**Stormwater Planter**

Alternative Names: Infiltration Planter, Flow-Through Planter, Contained Planter

**DESCRIPTION**

A stormwater planter is a small, contained vegetated area that collects and treats stormwater using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems, where pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Treated stormwater is then infiltrated into the ground as groundwater (Infiltration Planter) or, if infiltration is not appropriate, discharged into a traditional stormwater drainage system (Flow-Through Planter). Stormwater planters do not require a large amount of space and can add aesthetic appeal and wildlife habitat to city streets, parking lots, and commercial and residential properties. Stormwater planters typically contain native, hydrophilic flowers, grasses, shrubs and trees.
Street-side Application
Street-side Application
Street-side Application

Grass-lined swale in the NDS with the PSD buried below

Vegetated swale in the NDS with the PSD buried below
Example Swales

NDS (grass-lined swale in ROW)

NDS (vegetated swale in ROW)
Example
4. Permeable Paving

- Water infiltrates through porous gravel mat
- Pavers on a porous base with sand-filled joints
- Water passes through void spaces in porous concrete
Permeable Paving

Woodlawn Library
Wilmington, Del.
Woodlawn Library, Wilmington, Del.

Stormwater Management System

Though the parking lot looks like a typical pavement—it isn’t!

Most of this parking lot has been paved with pervious asphalt that allows rainwater to soak into a storage bed below the surface. Rather than letting rainwater flow off the surface, this parking lot acts like a sponge and absorbs stormwater, allowing it to soak into the groundwater aquifer—just like it did before we built anything. Because the pavement is porous, it can’t be used everywhere (gas stations, loading docks, etc.) and requires different maintenance such as mechanical street sweeping to keep the pores open.

Porous Pavement • A Pervious Parking Surface
Porous asphalt is a surface that is designed to allow infiltration. This material can be used for vehicular or pedestrian areas. Suppliers may require a minimum order due to asphalt-manufacturing limitations.
Examples of Permeable Pavement

Permeable pavement sections surfaced with (left to right) pervious concrete, permeable interlocking concrete pavers with 12.9% open surface area (PICP1), concrete grid pavers, and permeable interlocking concrete pavers with 8.5% open surface area (PICP2).
Parking Lot Cross-Section

measurements in meters
Abstract

This study examined the long-term effectiveness of permeable pavement as an alternative to traditional impervious asphalt pavement in a parking area. Four commercially available permeable pavement systems were evaluated after six years of daily parking usage for structural durability, ability to infiltrate precipitation, and impacts on infiltrate water quality. All four permeable pavement systems showed no major signs of wear. Virtually all rainwater infiltrated through the permeable pavements, with almost no surface runoff. The infiltrated water had significantly lower levels of copper and zinc than the direct surface runoff from the asphalt area. Motor oil was detected in 89% of samples from the asphalt runoff but not in any water sample infiltrated through the permeable pavement. Neither lead nor diesel fuel were detected in any sample. Infiltrate measured five years earlier displayed significantly higher concentrations of zinc and significantly lower concentrations of copper and lead.
Driveway Reduction

Driveway reduction

impervious: 503 sf  impervious: 786 sf  impervious: 503 sf

“Hollywood Drive” style

Reduction in length with wheel stops

NTS
Impervious Surface Reduction

This example shows the use of a porous gravel mat for patios and porous pavement for the driveways as strategies to reduce the impervious surface area.

“Hollywood Drive” with reduced length

porous concrete driveway

porous gravel mat patio
5. Green Roof
Green Roof

Dansko
West Grove, Pa.
Typical Daily Water Use

Outdoor watering used 38% of water in office buildings that can be supplemented by green-streets techniques.

<table>
<thead>
<tr>
<th>Daily Use</th>
<th>Office Buildings</th>
<th>Hotels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Potable indoor uses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Showers</td>
<td>—</td>
<td>27%</td>
</tr>
<tr>
<td>• Faucets</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>• Kitchen</td>
<td>3%</td>
<td>10%</td>
</tr>
<tr>
<td>• Other uses</td>
<td>10%</td>
<td>19%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>14%</td>
<td>57%</td>
</tr>
<tr>
<td><strong>Non-potable indoor uses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Toilets/urinals</td>
<td>25%</td>
<td>9%</td>
</tr>
<tr>
<td>• Laundry</td>
<td>—</td>
<td>14%</td>
</tr>
<tr>
<td>• Cooking</td>
<td>23%</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td>48%</td>
<td>33%</td>
</tr>
<tr>
<td><strong>Outdoor uses</strong></td>
<td>38%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Estimated Energy Consumption for Water Treatment and Distribution

“The transport and treatment of water has high energy demands, 1,450 kWh per MG of water.”

<table>
<thead>
<tr>
<th>Activity</th>
<th>Energy Consumption (kWh/MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply and conveyance</td>
<td>150</td>
</tr>
<tr>
<td>Water treatment</td>
<td>100</td>
</tr>
<tr>
<td>Distribution</td>
<td>1,200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,450</strong></td>
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</table>
Carbon Dioxide Emissions from Electric Power Generation

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>CO$_2$ Output Rate Lbs. CO$_2$ / kWh</th>
<th>CO$_2$ Output / MG Water Delivered (x 1,450kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>2.117</td>
<td>3,070 lbs.</td>
</tr>
<tr>
<td>Petroleum</td>
<td>1.915</td>
<td>2,775 lbs.</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.314</td>
<td>1,905 lbs.</td>
</tr>
</tbody>
</table>

The carbon reductions associated with rainwater harvesting are admittedly not on the order of magnitude required to significantly impact climate change. However, the connection between potable-water use and energy demand is important to recognize in the broader context of sustainable water management.
American Clean Energy Act of 2009
(approved by House, pending in Senate)

- Changes the green economy
- Puts price on carbon
- Incentives for white roofs and pavement
- Investments in reforestation by power companies to cool streets and buildings
Sustainability
= People, Planet, Prosperity
= Equity, Environment, Economy

• Maintenance concerns of green streets?
• Why not stormwater fees to pay for O&M?
• Don’t we need a UD School of Architecture?
• Revamp DNREC as the Delaware Department of Environmental Sustainability.