Green Infrastructure Approaches for Stormwater & CSO Control

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Stormwater’s Effect on National Water Quality

- Combined sewer systems in 746 municipalities in 31 states and the District of Columbia.
- An estimated 850 billion gallons of CSO discharges each year.
- In 2007, stormwater caused more than 10,000 beach closing and advisory days; sewage spills and overflows caused more than 4,000.

Wet Weather Pollution Problems are Large and Growing

- 67% of wadeable streams are in fair or poor condition
- EPA predicts that sewage pollution will exceed 1968 levels by 2025
- Upward trend for
  - Beach closings
  - Red tides
  - Dead Zones
  - Coral reef damage
  - Water shortages

Estimated Cost of Mitigating Stormwater Runoff

- $60 billion in capital investment for CSO control.
- $10 billion for stormwater management programs.

Water Quality Issues
In the 1970s, Seattle city planners anticipated electricity capacity shortage. Seattle City Light and Mayor proposed investing in two new nuclear power plants to add capacity. In 1976, the City Council voted against the plan and instead passed conservation resolutions. Prevented new power plant construction for 20 years, at 20% of the cost of new generation capacity.
Demand Management for Stormwater

- Creating peak and baseload capacity with green infrastructure and conservation.
- Adapting, (re)naturalizing built landscape to absorb, clean, and hold water.
- Introducing trees, vegetation, open space and buffers into urban areas to manage and treat precipitation naturally rather than collecting it in a sewer system.
- Using engineered systems such as green roofs, bioretention cells, vegetated swales and infiltration practices to mimic nature and “green” urban areas.

*Slide courtesy of the Center for Neighborhood Technology.*
Green Infrastructure Economic Advantages

- Incremental approach stages funding – less debt service.
- Less capital intensive, lower cost.
- Effectively extends existing capacity.
- Captures asset value of clean water, soil capacity, open space amenities.

*Slide courtesy of the Center for Neighborhood Technology.*
Additional Benefits of Green Infrastructure

- Reduces heat island effect
- Improves air quality
- Provides wildlife habitat and recreational space
- Improves energy efficiency
- Improves urban aesthetics
- Increases property values
- Often less expensive than conventional approaches

Lincoln Mercury Headquarters Green Roof, Irvine, CA. Photo courtesy of Roofscapes, Inc.
Where did it all start?
Portland, Oregon

- City code requires on-site stormwater management for new and re-development.
- Subsidized downspout disconnection program.
  - 45,000 participating households.
- Infiltrates 1.5 billion gallons of rainwater annually.

Vegetated Planter at Portland State University. Photo courtesy of Martina Frey.
Vegetated Curb Extensions

- Flow testing demonstrated 88% reduction in peak flow and 85% reduction in CSS inflow for 25-year storm event.
- Sufficient to protect local basements from flooding.
- Project cost $15,000 and required two weeks to install.

Vegetated Curb Extensions. Photo courtesy of the Portland Bureau of Environmental Services.
Portland Street Side Infiltration Planters

Photos courtesy of Martina Frey.
Portland, Oregon (cont.)

Permeable Paver Blocks

- Used in a similar manner to curb extensions to manage street runoff.
- Allow hardscape function to be retained.
- Have virtually eliminated runoff from the street.

Permeable paver block installation.
Green Roofs

- Zoning bonus allows additional building square footage for buildings with a green roof.
- Two years of monitoring demonstrated that 58% of rainfall was retained.
- Nearly 100% retention of warm season rainfall.

Hamilton Apartments Ecoroof. Photo courtesy of the Portland Bureau of Environmental Services.
Portland Infiltration Planter
Vancouver, British Columbia

- Uses naturalized streetscapes, infiltration bulges and Country Lanes to manage stormwater from roadways.
- More than 30 green roofs installed in the city.
- First SEA street design projected to reduce annual runoff 90%.

Country Lane. Photo courtesy of City of Vancouver Greenways Program.
Chicago Green Alleys

- 13,000 alleys – more than 1,900 miles.
- 3,500 acres of impervious surface.
- 20% unimproved; 20% need repair.
- Alleys not connected to storm sewers, cause of flooding.

High albedo permeable pavers in Chicago Alley. Photo courtesy of Abby Hall, U.S. EPA.
Chicago Green Alleys (cont.)

- Pilot projects address stormwater, urban heat island, recycled materials, energy efficiency and light pollution.
- Transformed from a source to a sink.
- Early pilot alley retains the volume of a 3-inch, 1-hour event.
- Created a market for permeable concrete - $145/yd to $45/yd one year later (regular concrete $50/yd).

High albedo concrete and permeable concrete trench in Chicago Alley. Photo courtesy of Abby Hall, U.S. EPA.
Toronto Policy Approach

- Urban stormwater identified as a leading cause of degradation – polluted runoff and CSOs.
- In 2003, the City Council adopted a 25-year stormwater plan.
- Plan augments conventional infrastructure with green infrastructure.

Toronto Policy Approach

Wet Weather Plan is based on four principles.

1. Recognizing rainwater and snowmelt as a valuable resource.
2. Managing wet weather flows on a watershed basis.
3. Establishing a hierarchy of management practices.
   a. Source
   b. Conveyance
   c. End-of-Pipe
4. Educating communities and involving the public.

- More than 100 green roofs have been installed in the city, which reduce roof runoff by more than 50%.
- City provides free downspout disconnection.
Ryerson University study modeled impacts of installing green roofs on all city roofs >3,750 ft².
- Would result in 12,000 acres of green roofs – 8% of total city land area.
- Estimated nearly $270 million in municipal capital cost savings and more than $30 million of annual savings.

Source: Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto
**Green Roofs: Air Quality**

**Quantity of Air Pollutants Removed by a 1.4 Acre Green Roof**  
(Currie and Bass, 2005)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Mass Removed Annually (lbs)</th>
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<tr>
<td>O$_3$</td>
<td>2,800</td>
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<tr>
<td>PM$_{10}$</td>
<td>1,940</td>
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<tr>
<td>NO$_2$</td>
<td>1,430</td>
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<tr>
<td>CO</td>
<td>310</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>550</td>
</tr>
</tbody>
</table>

Note: Annual pollutant removals based upon UFORE model results for Toronto.
The temperature above Chicago’s City Hall green roof averages 10 -15°F lower than the black tar roof. Difference can be 50°F or greater during the summer.

Energy savings of $3,600 per year.
Urban Heat Island (cont.)

- Portland Central Eastside Industrial District green roof study.
- Full implementation for 670 acres.
- Cooling of 0.5 – 0.9°F in District
- Downwind cooling of 0.4°F up to one mile.

Photo courtesy of the Portland Bureau of Environmental Services.
Green Roof Energy Savings (cont.)

- Can reduce heating & cooling costs 10-15%.
- 10% energy savings for 50,000 SF office building = 49,000 kWh
- 2.095 lbs of CO$_2$ emissions per kWh for coal-fired power.
- CO$_2$ reduction of 50 tons.

Sources: Energy Information Administration, Department of Energy, and Environmental Protection Agency.
Rainwater Harvesting
King Street Center – Seattle, WA

- Over 16,000 gallons of storage at 327,000 ft²
  King Street Center used for toilets and irrigation.
  Provides 60% (1.4 million gallons) of toilet flushing water annually.

- Water supply, conveyance, treatment & distribution = 1,450 kWh/MG

- CO₂ reduction of 2 tons.

Sources: California Energy Commission, Department of Energy, and Environmental Protection Agency.
Green infrastructure is an effective stormwater and CSO control that is currently underutilized.

A philosophical change is needed in stormwater/CSO management.
- A move away from collect and detain to source control and prevention.
- Focus on hydrology and ecology as well as water chemistry.

2007 – A.A. Ben Grumbles memo endorses green infrastructure for CSO, SSO, and stormwater control and Administrator Johnson announces Green Infrastructure Partnership

EPA Green Infrastructure Action Strategy
- http://cfpub.epa.gov/npdes/home.cfm?program_id=298
- http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy