Low Impact Development, Green Infrastructure ~~ a Smarter Way to Handle Stormwater Runoff

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April 19, 2010, Presentation to NACWA's Legal Affairs Committee

What is the Problem that we are Trying to Solve?

Hydrology is the chief problem.

The volume of water resulting from rainfall (too much or too little) is the most significant source of WQ problems in urban/suburban areas.

The root cause is rain landing on impervious surfaces; it has nowhere to go except directly to the nearest stream or sewer.

When it rains, the stream gets too much water.

When it's not raining, the stream doesn't get enough water.

Where Does Rainwater Naturally Go?

- In the absence of development, it falls on forestland, farms, rangeland, pastures, etc.
- More than 90% infiltrates into the ground or evapotranspires; less than 10% runs off directly to the streams.
- Much of that ground water feeds rivers & streams.
- Many streams get most of their water from GW (US FS-150-99)

Where Does Rain Go After We Develop?

- Increased imperviousness – flows into streets and sewers
- Runs off quickly and with unnatural force
- Destroys streambeds and streambanks
- Starves the ground water after the rain stops

8% - 10% Imperviousness in Watershed Causes Damage

From pristine….

…to eroded with loss of natural perimeter habitat

10% up to 20% Imperviousness

10% of the drainage area is impervious here.

At 20%, substrate quality has been reduced through frequent "flushing"

Increasing Damage with Higher Imperviousness

20% (above) to highly impervious

Low Impact Development

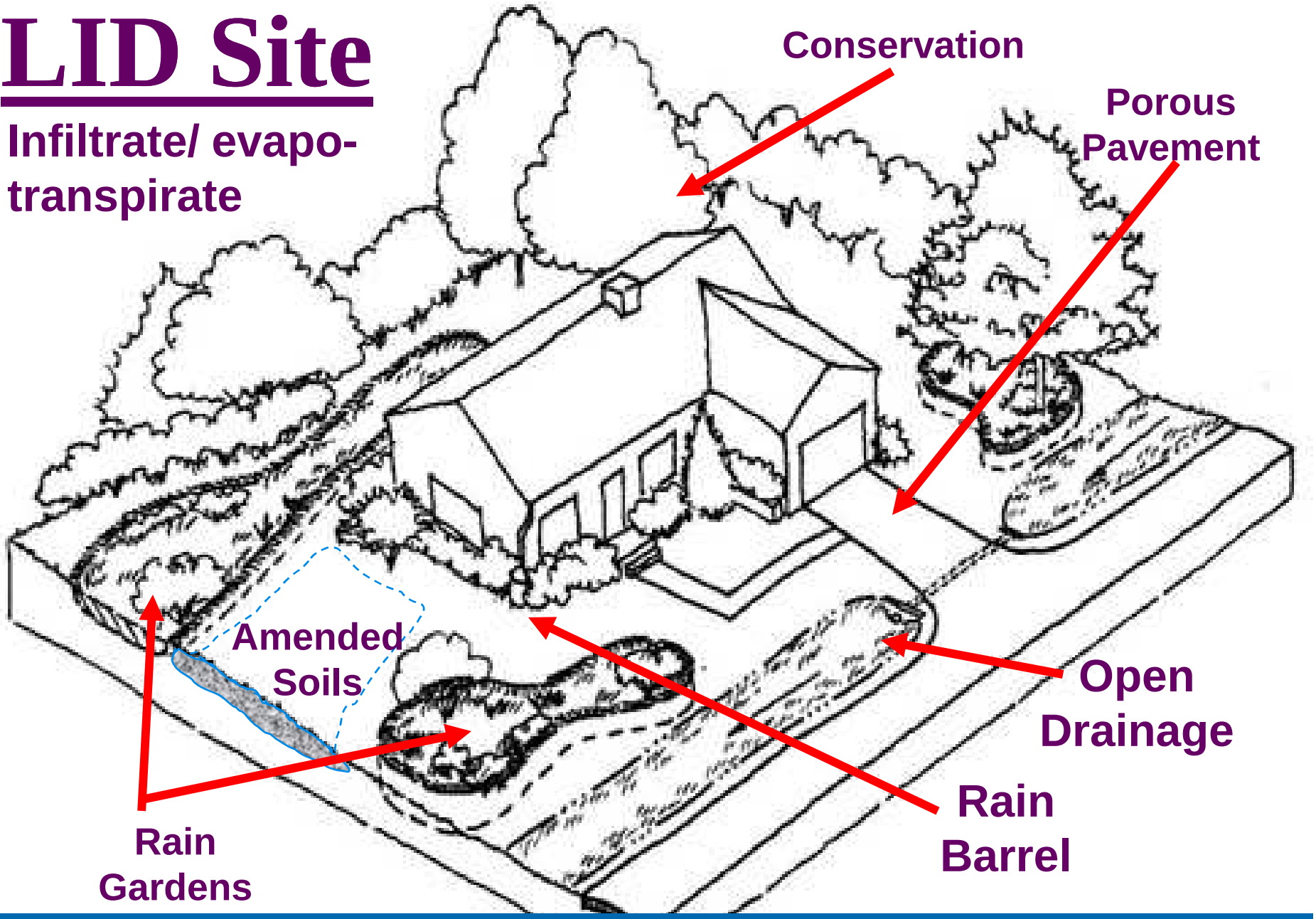
Systems and practices that use or mimic natural processes to:

- Infiltrate
- Evapo-transpirate, or
- Use

stormwater or runoff where it is generated.

LID Site

Infiltrate/ evapo-transpirate



Create a Hydrologically Functional Lot

Green Infrastructure at the Neighborhood Scale

- Less imperviousness! More vegetation! (This promotes infiltration and evapotranspiration)
  - Narrower streets, narrower or fewer sidewalks, smaller-footprint buildings, plant trees


Conventional
Low Impact
Conventional
Functional Landscape Design

Major Categories of LID Practices

- Disconnecting Downspouts and Impervious Surfaces
- Pervious Paving Materials
- Bio-retention and Rain Gardens
- Trees
- Green Roofs

Disconnectivity (from the sewer system)

Examples of disconnection and reuse of water

Downspout Disconnection: As of mid-'06, 47,000 Portland (OR) residents had disconnected their downspouts; Portland paid them $53 each.

Rain Barrels: Milwaukee Study:

Adding rain barrels to 40,000 houses could decrease runoff by 273 million gallons/yr. (= 6,500 gallons/yr/house)

NYC: At $4/gallon storage, rain barrels store 5-10 as many gallons/$$ as CSO storage options.

(Hudson Riverkeeper study)

Porous Concrete

Villanova University, To date, has captured and infiltrated runoff from all storms up to 2 inches (Dietz). (Note: project funded with PA Section 319 funds.)

CAHILL ASSOCIATES
Environmental Engineers,
Scientists, & Planners
www.thcahill.com

"Pervious Pavers": Concrete Blocks or Grids

- Turfstone and Eco-Stone: Virtually all precip. infiltrated over 6 years; another study showed 72% reduction for Eco-Stone (Dietz 2007).
- Unilock pavers: No surface runoff for events measured up to 1 ¼"/hr.
- Plastic Grids: Virtually no runoff from 2 products.

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.

Chicago Green Alleys

- Pilot projects address stormwater, urban heat island, recycled materials, energy efficiency and light pollution.
- 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).

Rain Gardens


America's Most Reliable Network.
FIREARMS
MONEY BACK

Seattle's Street Edge Alternatives Program

After Completion - January 2001

The Thirst of Trees

- One tree can reduce SW runoff by 13,000 gallons per year. 500,000 existing trees in NYC can remove 6.5 billion gallons per year. Adding 300,000 more will remove an additional 3.9 gals/yr. ("Sustainable Raindrops").
- NYC City's annual Combined Sewer Overflow is 27 billion gallons.

TREES

- Trees provide shade, cooling, and transpiration of water.
- New techniques promise to provide more water to urban trees' root systems; produce larger, healthier trees; and thus increase infiltration/evapotranspiration:
  - Cornell U. **Structural Soil** (mix of 80% stone aggregate and 20% soil, with some polymer gel).
  - Newer **support systems** that may prove to be even better, enable large spaces under concrete to be used by tree roots.
  - Larger openings or use of porous pavements above the tree roots

Green Roofs

- Reduces SW by 60-80% (per Dietz, Toronto, others)
- More expensive than most other LID practices, but:
  - Reduces energy use & “heat island effect”; aesthetics; attracts birds and butterflies.
  - Green roofs can be the best overall -- and most cost-effective -- solution for crowded downtown areas.
- As of mid-’06, Chicago had over 200 green roofs, 2.5 million sq. ft. (about 1/10 of a square mile). For more info on trends, 650 green roofs are linked at http://www.greenroofs.com/projects/plist.php.

Summary of Cost Comparisons

Table 2. Summary of Cost Comparisons Between Conventional and LID Approaches[a]

Project	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Difference[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	–$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

[a] The Central Park Commercial Redesigns, Crown Street, Poplar Street Apartments, Prairie Crossing, Portland Downspout Disconnection, and Toronto Green Roofs study results do not lend themselves to display in the format of this table.

[b] Negative values denote increased cost for the LID design over conventional development costs.

[c] Mill Creek costs are reported on a per-lot basis.

How did LID Save Money?

- Primarily through costs avoided/reduced thanks to the implementation of LID Practices instead of expensive conventional practices:
  - Eliminate or reduce stormwater ponds
  - Eliminate or reduce storm sewer pipes
  - Reduce stormwater or sewer overflow storage
  - Reduce other hard infrastructure:
    - Narrower streets
    - Less sidewalk
    - Reduce stormwater treatment devices
    - Avoid land purchase for ponds, etc.

    Use saved land to build more lots

Benefits

Air Quality

- One square meter green roof can remove .2 kg particulates per year
- 5 square meters = capture from 10,000 vehicle miles traveled

Energy Savings

- **Chicago citywide projection: $100 million energy savings and 720 megawatts (= 3 coal fired power plants)**

Data source: Weston Design Consultants

Urban Cooling

- **Trees:**

  10% canopy increase →5-10% energy savings from shading, windblocking

- **Toronto study: permeable pavements reduce heat island**

Los Angeles Green Roof Potential

- 15% Green Roof Coverage
- 5-9 degree heat island reduction
- .5 - 1 **Gigawatt** peak power savings

Lawrence Berkely Labs Heat Island Group, 2000

Water Supply

- **Cook County Estimate: Apply Various Green Infrastructure →**
- **40% runoff reduction**
- **Aquifer & lake recharge equivalent to additional supply for >1 million people**

Crime Prevention

Compared with areas that had little or no vegetation, buildings with high levels of greenery had 52% fewer crimes

Landscape and Human Health Laboratory
University of Illinois at Urbana-Champaign

Community Health

"exposure to green surroundings reduces mental fatigue and the feelings of irritability that come with it. The ability to concentrate is refreshed by green views, along with the ability and willingness to deal with problems thoughtfully and less aggressively. And, in this study, ***even small amounts of greenery—a few trees and a patch of grass—helped inner city residents have safer, less violent domestic environments****."*

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Climate Change Mitigation

- Approximately 800 million tons of carbon are stored in U.S. urban forests.
- Planting trees remains one of the cheapest, most effective means of drawing excess CO2 from the atmosphere.
- A single mature tree can absorb carbon dioxide at a rate of 48 lbs./year and release enough oxygen back into the atmosphere to support 2 human beings.
- A healthy tree stores about 13 pounds of carbon annually -- or 2.6 tons per acre each year. An acre of trees absorbs enough CO2 over one year to equal the amount produced by driving a car 26,000 miles.

Habitat

Recreation

Energy Independence and Security Act of 2007

"Sec. 438. Storm Water Runoff Requirements for Federal Development Projects. The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."

Performance Options

Option 1: Control 95th Percentile Rainfall Event

- Manage rainfall onsite
- Infiltrate, Evapotranspire, Harvest and Use Runoff

Note: The 95th percentile rainfall event is the event whose precipitation total is greater than or equal to 95 percent of all 24-hour storms on an annual basis.

Example 95th Percentile Storms

City	95th Percentile Event Rainfall Total (in)	City	95th Percentile Event Rainfall Total (in)
Atlanta, GA	1.8	Kansas City, MO	1.7
Baltimore, MD	1.6	Knoxville, TN	1.5
Boston, MA	1.5	Louisville, KY	1.5
Buffalo, NY	1.1	Minneapolis, MN	1.4
Burlington, VT	1.1	New York, NY	1.7
Charleston, WV	1.2	Salt Lake City, UT	0.8
Coeur D'Alene, ID	0.7	Phoenix, AZ	1.0
Cincinnati, OH	1.5	Portland, OR	1.0
Columbus, OH	1.3	Seattle, WA	1.6
Concord, NH	1.3	Washington, DC	1.7
Denver, CO	1.1		

Performance Options

Option 2: Preserve predevelopment hydrology (rate, volume, duration & temperature)

Determine these values for your particular site.

A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds

Final Report

Prepared for:

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Table 5.1. City-wide present value benefits of key CSO options: Cumulative through 2049 (2009 million USD)

Benefit categories	50% LID option	30' Tunnel option[a]
Increased recreational opportunities	$524.5	
Improved aesthetics/property value (50%)	$574.7	
Reduction in heat stress mortality	$1,057.6	
Water quality/aquatic habitat enhancement	$336.4	$189.0
Wetland services	$1.6	
Social costs avoided by green collar jobs	$124.9	
Air quality improvements from trees	$131.0	
Energy savings/usage	$33.7	$(2.5)
Reduced (increased) damage from SO_2 and NO_x emissions	$46.3	$(45.2)
Reduced (increased) damage from CO_2 emissions	$21.2	$(5.9)
Disruption costs from construction and maintenance	$(5.6)[b]	$(13.4)
Total	**$2,846.4**	**$122.0**

a. 28' Tunnel option in Delaware River Watershed.
b. Parentheses indicate negative values.

Table 5.2. City-wide natural unit benefits of key CSO options: Cumulative through 2049

Benefit categories	50% LID option	30' Tunnel option[a]
Additional creekside recreational user days	247,524,281	
Additional non-creekside recreational user days	101,738,547	
Reduction in number of heat-related fatalities	196	
Annual WTP per household for water quality and aquatic habitat improvements[b]	$9.70–$15.54	$5.63–$8.59
Wetlands created or restored (acres)	193	
Green collar jobs (job years)	15,266	
Change in particulate matter ($PM_{2.5}$) due to increased trees ($\mu g/m^3$)	0.01569	
Change in seasonal ozone due to increased trees (ppb)	0.04248	
Electricity savings due to cooling effect of trees (kWh)	369,739,725	
Natural gas savings due to cooling effect of trees (kBtu)	599,199,846	
Fuel used (vehicles for construction and O&M) (gallons)	493,387	1,132,409
SO_2 emissions (metric tons)	(1,530)	1,452
NO_x emissions (metric tons)	(38)	6,356,083
CO_2 emissions (metric tons)	(1,091,433)	347,970
Vehicle delay from construction and maintenance (hours of delay)	346,883	796,597

a. 28' Tunnel option in Delaware River Watershed.
b. WTP per household in Philadelphia, MA, including Bucks, Chester, Delaware, Montgomery, and Philadelphia counties.

Stormwater Permits with Green Elements

Final Permits:

- West Virginia small MS4
- Anchorage, Alaska (EPA issued)
- Big Darby Creek Watershed, Ohio
- Ventura County, California
- New Jersey state stormwater rules
- North Carolina small residential

North Carolina

The North Carolina permit To Construct, Operate and Maintain Impervious Areas and BMPs Associated with Residential Development Disturbing Less Than 1 Acre, includes the following:

Stormwater runoff shall be managed using any one or combination of the following practices:
a. Install rain cisterns or rain barrels designed to collect all rooftop runoff from the first one and one-half inches of rain. Rain barrels and cisterns shall be installed in such a manner as to facilitate the reuse of the collected rain water on site and shall be installed in such a manner that any overflow from these devices is directed to a vegetated area in a diffuse flow. Construct all uncovered driveways, uncovered parking areas, uncovered walkways, and uncovered patios out of permeable pavement or other pervious materials.
b. Direct rooftop runoff from the first one and one-half inches of rain to an appropriately sized and designed rain garden. Construct all uncovered driveways, uncovered parking areas, uncovered walkways, and uncovered patios out of permeable pavement or other pervious materials.
c. Install any other stormwater best management practice that meets the requirements of 15A NCAC 02H .1008 to control and treat the stormwater runoff from all built upon areas of the site from the first one and one-half inches of rain.

New Jersey

The New Jersey Stormwater Management Rules at N.J.A.C. 7:8 require that a "major development" project, which is one that disturbs at least 1 acre of land or creates at least 0.25 acres of new or additional impervious surface, must comply with one of the following two groundwater recharge requirements:

- *Demonstrate through hydrologic and hydraulic analysis that the site and its stormwater management measures maintain 100 percent of the average annual preconstruction groundwater recharge volume for the site; or*
- *Demonstrate through hydrologic and hydraulic analysis that the increase of stormwater runoff volume from pre-construction to post-construction for the two year storm is infiltrated.*

The State has a spreadsheet for documenting how the recharge rate requirement is being met. Chapter 6 of the New Jersey Stormwater Best Management Practices Manual discusses the groundwater recharge methodology, the groundwater recharge design storm, and the details of the New Jersey Groundwater Recharge Spreadsheet.

Ohio

The Ohio construction general permit for the Big Darby Creek Watershed near Columbus, where significant growth is projected, includes post-construction infiltration requirements. This permit requires that *post-development groundwater recharge be equal to or exceed the pre-construction groundwater recharge*. The permit specifies that the SWPPP must describe the conservation development strategies, stormwater control measures and other practices deemed necessary by the permittee to maintain or improve pre-development rates of groundwater recharge. The permit includes a formula and standard values for gauging groundwater recharge rates, and includes provisions to ensure preservation of open space where infiltration will occur. Protection of open space (infiltration areas) is to be achieved by binding conservation easements that identify a third party management agency, such as a homeowners association, condominium association, political jurisdiction or third party land trust. If the post-development recharge volume will be less than the pre-construction recharge volume, mitigation is required.

Settled Consent Decrees with Proposed Long-Term Control Plans (LTCPs) Incorporating Green Infrastructure

- Louisville, KY
- Sanitation District #1, KY
- Hamilton Co., Cincinnati, OH

Louisville, KY
(Concluded CD)

- 19 Green Demonstration Projects
- Green roofs, green streets, urban reforestation bioswales, rain gardens, permeable alleys, green parking lots
- $40 million savings compared to grey for initial GI projects
- Potential for $120 million savings, depending on performance results and future green/grey mix of controls

Sanitation District #1, KY
(Concluded CD)

- Watershed approach to water pollution sources and impacts on receiving waters
- Initial proposed green infrastructure investment valued at 3.5% of total program cost

Hamilton County/Cincinnati, OH
(Concluded CD)

- CD includes a provision for substitution of green for grey on a project by project basis
- Pilot projects in Deer Park and Silverton
  - $13.2 M in GI v. $29.9 M in grey for the same level of CSO reduction
  - Net savings: $16.7 M
- East Ohio Opportunities Project
  - $7.2 M in GI v. $13.6 M in grey for the same level of CSO reductionNet savings: $6.4 M