

# Stormwater Reuse Opportunities and Effects on Urban Infrastructure Management; Review of Practices and Use of WinSLAMM Modeling

Leila Talebi<sup>1</sup>, Robert Pitt<sup>2</sup> and Shirley Clark<sup>3</sup>

<sup>1</sup>PhD Candidate, Department of Civil, Construction, and Environmental Engineering, University of Alabama, P.O. Box 870205, Tuscaloosa, AL 35487

<sup>2</sup>Cudworth Professor, Urban Water Systems, Department of Civil, Construction, and Environmental Engineering, University of Alabama, P.O. Box 870205, Tuscaloosa, AL 35487

<sup>3</sup>Associate/Assistant Professor of Environmental Engineering, Penn State Harrisburg

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## Outlines

- Objectives
- Review of Case Studies of Beneficial uses of Stormwater
  - Asia
  - Africa
  - Europe
  - Australia
  - North America
- Regulations Restricting Beneficial uses of Stormwater
- Water Harvesting Potential
- Modeling

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## Objectives

- Study U.S.A and international practices of recycling of urban stormwater;
- Identify each component's key design parameters, performance, current knowledge gaps, and obstacles to their implementation;
- Review possible uses of the harvested runoff: The research focused primarily on non-potable water use (e.g. irrigation and non-potable in-house use).
- Present a method to evaluate or size water storage tanks needed to optimize the beneficial uses of stormwater.

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## Background

- This presentation summarizes a recent project supported by the Water Environment Research Foundation and the Wet Weather Flow Research Program of the US EPA.
- One part of the project compared increased beneficial uses of runoff vs. increased infiltration into shallow groundwaters by bioretention facilities.
- The major element of the project examined how much of the household irrigation needs can be satisfied with stormwater and how this beneficial use results in reduced stormwater discharges.

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## Representative Case Studies of Stormwater Beneficial Use Examined

- Asia (Singapore, Japan, Thailand, Indonesia, Philippines, Bangladesh, China, South Korea, and India)
- Africa (South Africa, Kenya, and Tanzania)
- Europe (Germany and Ireland)
- Australia (South Australia, Queensland, Victoria, and New South Wales)
- North America (US Virgin Islands, Florida, Hawaii, Washington, New York, Maryland, California, Missouri, Oregon, Washington, D.C., and North Carolina)

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Place	Project name	Study area (catchment)	Reuse Purpose			
			Irrigation.	Toilet flushing	Fire fighting	Air conditioning
Singapore	Residential area	7,420,000 m <sup>2</sup>	✓	✓		
Singapore	Changi Airport			✓	✓	
Japan		8,400 m <sup>2</sup>		✓		✓
South Korea	Star City (Seoul)	6.25 ha (62,500 m <sup>2</sup> )	✓	✓		
India	Delhi	113,000 m <sup>2</sup>	✓			
Tanzania	Makanya		✓			
Germany	Berlin; Bells-Luedecke-Strasse building	7,000 m <sup>2</sup> of roofs & 4,200 m <sup>2</sup> of streets	✓	✓		
Germany	Berlin-Lankwitz	12,000 m <sup>2</sup>	✓	✓		
Germany	Frankfurt Airport	26,800 m <sup>2</sup>	✓	✓		✓
Ireland	Queens University in Belfast	3,000 m <sup>2</sup>		✓		
South Australia	Salisbury; Parafield	1,600 ha	✓			
NSW	Black Beach Foreshore Park	100 ha	✓			

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Place	Project name	Study area (catchment)	Reuse Purpose					
			Irrigation	Toilet flushing	Fire fighting	Air conditioning	other	
Florida	West Palm Beach; Renaissance							✓
Hawaii	U.S. National Volcano Park	2.4 ha		✓				✓
Washington	Seattle, King Street Center	30,380 m <sup>2</sup>	✓	✓				
New York	Battery Park City; Solaire		✓	✓		✓		
Maryland	Annapolis; Philip Merrill Building		✓	✓	✓			
California	Santa Monica; SMURFF		✓					✓
California	Santa Monica; Robert Redford Building		✓	✓				
Missouri	Overland, Alberici Corporate Headquarters	3,920 m <sup>2</sup>		✓		✓		

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## Heavily Urbanized Developing Countries In Water Stressed Areas

- Most concerned with harvesting as much runoff as possible, with minimal concern related to water quality.
- Not only is roof runoff harvested, but also runoff from all urban areas. Usually, all paved areas are used to harvest runoff, as maximum volumes are needed to augment the poor quality and poorly available local sources.
- The water is stored in large ponds, or injected into shallow aquifers. These improve the water quality to some extent, greatly depending on the storage conditions.

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### Developing Countries With Large Rural Populations

- Most of the runoff harvesting schemes focus on collecting roof runoff for storage in tanks near homes.
- The water is used for all domestic purposes and for irrigation of food subsistence crops during dry weather.
- The storage tanks are therefore relatively large to provide seasonal storage.

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### Developed Countries With Large Urban Populations in Water Stressed Areas

- Runoff harvesting has long been used to augment the water supplies.
- In most cases, the runoff is collected from roofs and stored in large tanks adjacent to buildings where the water is used for non-potable uses.
- In some rural cases, the water is used for all domestic water uses. In large development water harvesting projects, runoff is collected from all areas and undergoes some pretreatment before storage in large (usually underground) storage tanks.
- The water then undergoes very sophisticated water treatment before use. In many cases, this highly treated harvested runoff is still restricted to non-potable uses.

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### The U.S.

- Many of the U.S. stormwater harvesting projects are either part of a LEED® certified project, and/or to help reduce stormwater discharges to combined sewer systems.
- The collected water is not used for potable uses, but mostly for irrigation uses, and sometimes for toilet flushing or for fire suppression.

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### Selected Regulations Restricting Stormwater Beneficial Uses

		Coliform Bacteria	Chlorine	pH	Turbidity
WHO	Roof water harvesting	<i>E. coli</i> . <10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	Not relevant
	Surface Runoff	<i>E. coli</i> . <10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	<15 NTU
	Sand dams	<i>E. coli</i> . <10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	<5 NTU
New South Wales (Australia)	Level 1	<1 cfu/100 mL	1 mg/L Cl <sub>2</sub> residual after 30 minutes, or equivalent level of pathogen reduction	6.5–8.5	≤ 2 NTU
	Level 2	<10 cfu/100 mL	1 mg/L Cl <sub>2</sub> residual after 30 minutes, or equivalent level of pathogen reduction	6.5–8.5	≤ 2 NTU
	Level 3	<1000 cfu/100 mL		6.5–8.5	-----
Berkeley, CA	Non-potable indoor/outdoor uses	Total coliforms <500 cfu per 100 mL Fecal coliforms <100 cfu per 100 mL			

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### Selected Regulations Restricting Stormwater Beneficial Uses

		Coliform Bacteria	Chlorine	pH	Turbidity
Texas (2006)	Non-potable indoor uses	Total coliforms <500 cfu per 100 mL Fecal coliforms <100 cfu per 100 mL			
UK (2008)	Non-potable indoor uses	Total coliforms 10/100 mL	<2 mg/L	6-8	≤ 10 NTU
Virginia (2009)	Non-potable indoor uses	Total coliforms < 500 cfu per 100 mL Fecal coliforms <100 cfu per 100 mL			

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### Modeling

WinSLAMM was developed to evaluate stormwater runoff volumes and pollutant loadings in urban areas using continuous small storm hydrology calculations, in contrast to single event hydrology methods that have been traditionally used for much larger single drainage design storms.

WinSLAMM determines the runoff based on local rain records and calculates runoff volumes and pollutant loadings from each individual source area within each land use category for each rain. Examples of source areas include: roofs, streets, small landscaped areas, large landscaped areas, sidewalks, and parking lots.

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- ### Methods and Materials
- Rain barrel/tanks, and disconnections of roof areas are some of the stormwater controls being used in residential areas in different regions of the U.S.
  - Irrigation of typical turf grass landscaping around homes was examined for typical low and medium density residential areas in six different U.S. rain zone areas:
    - Great Lakes: Madison, WI
    - East Coast: Newark, NJ
    - Central: Kansas City, MO
    - Northwest: Seattle, WA
    - Southeast: Birmingham, AL
    - Southwest: Los Angeles, CA

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### Methods and Materials

- WinSLAMM can use any length of rainfall record as determined by the user, from single rainfall events to several decades of rains.
- In this study, rain data from 1995 to 1999 was used.

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### Methods and Materials

- The monthly rainfall infiltration amounts in the landscaped areas in the six study areas were calculated using continuous WinSLAMM simulations, for silty, sandy and clayey soils.
- These soil moisture contributing values were subtracted from the monthly ET requirements (adjusted for urban turf grasses) to obtain the moisture deficits per month, and the daily deficits per house per day.
- Roof runoff and water tank storage production functions were calculated for each condition.

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### Roof runoff and water tank storage production functions for medium density residential areas for the East Coast site

total roof area (%)	15.9
Landscaped area (%)	54.5
Average annual study period rain fall (in) (5-year period, 1995 to 2000)	53.01

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### Calculations

#### Irrigation Needs to Satisfy Evapotranspiration Requirements for Essex County, NJ

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly rain associated soil moisture (in./mo)	3.42	3.11	4.16	3.71	3.99	2.88	4.21	4.04	3.61	3.06	3.70	3.47
Average monthly ET (in./mo)	0.47	0.85	3.26	3.90	4.81	4.65	4.81	4.19	3.60	3.57	3.00	1.40
deficit for ET needs (in./mo)	0.00	0.00	0.00	0.19	0.81	1.77	0.60	0.15	0.00	0.51	0.00	0.00
Deficit for ET needs (gal/month/house) 0.36 acres	0	0	0	63	256	577	188	47	0	160	0	0

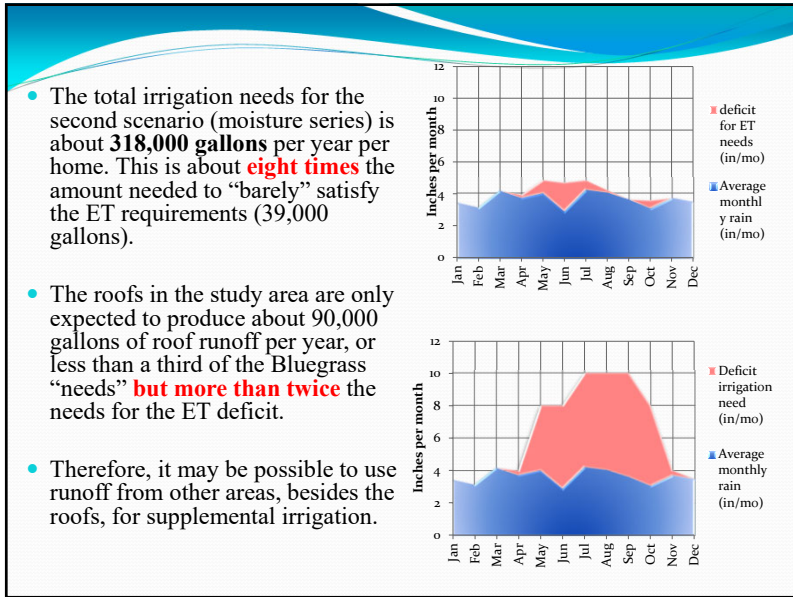
Total annual rainfall: 53 in. (43 in. will infiltrate and add to soil moisture)  
 Total annual ET requirements: 38 in.  
 The annual total household supplemental irrigation requirements are about 39,000 gallons per year (0.36 acres of turf grass per home).

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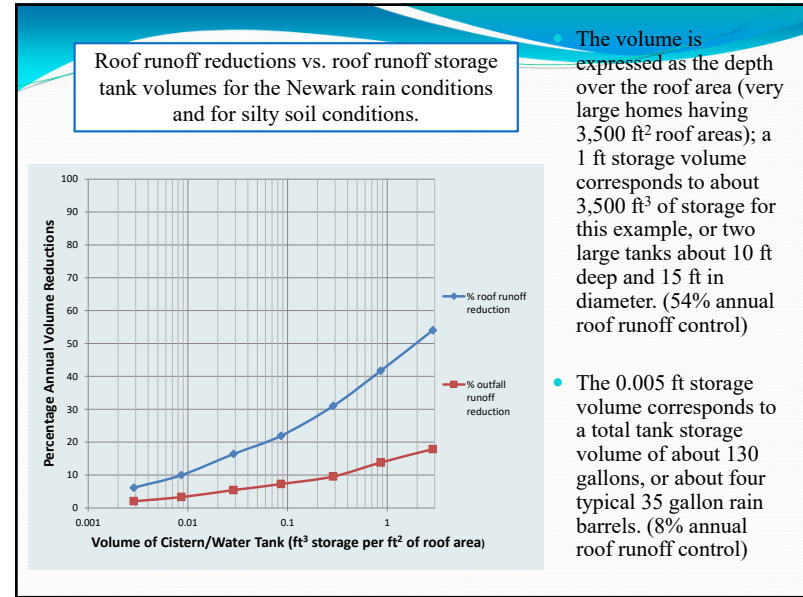
### Calculations

- For maximum use of the roof runoff, it is desired to irrigate at the highest rate possible (beyond the minimum ET requirements), without causing harm to the plants. Any excess water not used by the plants would infiltrate and contribute to the shallow groundwater.
- For a “healthy” lawn, total water applied (including rain) is generally about 1" of water per week, or 4" per month.
- Kentucky Bluegrass, the most common lawn grass in the US, needs about 2.5 in/week, or more, during the heat of the summer, and should also receive some moisture during the winter

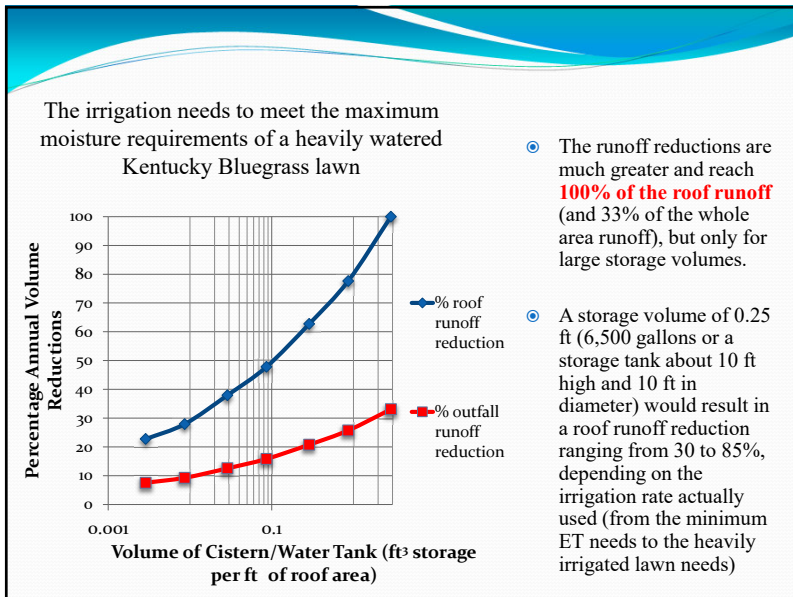
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### Results and Conclusion

Roof Runoff Harvesting Benefits for Regional Conditions (Medium Density Residential Land Uses, silty soil conditions) (Pitt and Talebi, 2012)

Region	total roof area (% of total residential area)	landscaped area (% of total residential area)	representative city for rainfall and ET values	study period annual rain fall (average inches per year) (1995 to 2000)	roof runoff control (%) for 0.025 ft³ storage/ft² roof area (about 5 rain barrels per 1,000 ft² roof)	roof runoff control (%) for 0.25 ft³ storage/ft² roof area (9 ft high by 6 ft diameter tank per 1,000 ft² roof)
Central	18.1	62.5	Kansas City, MO	33.5	40%	78%
East Coast	15.9	54.5	Newark, NJ	53.0	24%	33%
Southeast	8.8	81.1	Birmingham, AL	49.8	34%	41%
Southwest	15.4	61.2	Los Angeles, CA	16.7	35%	44%
Northwest	15.4	61.2	Seattle, WA	41.7	16%	16%
Great Lakes	15.0	57.5	Madison, WI	28.7	46%	68%

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