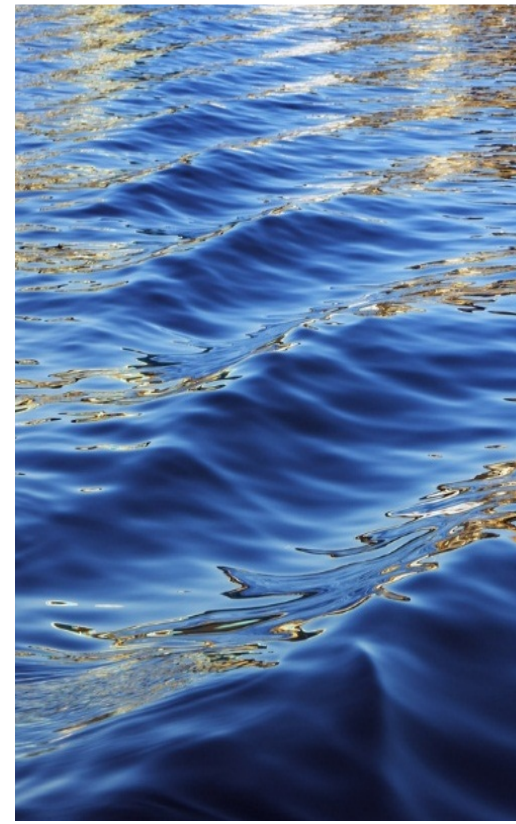
WateReuse

Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits

Richard G. Luthy, committee chair
Sybil Sharvelle, committee member
Stephanie Johnson, study director



WateReuse Webcast Series

The WateReuse Research Foundation

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WATEREUSE

Today's Presenters

Moderator
Stephanie Johnson

Richard G. Luthy

Sybil Sharvelle

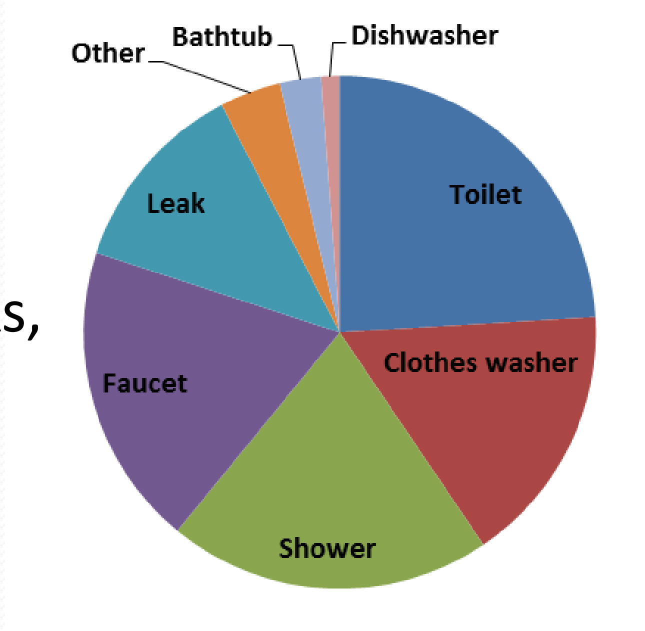
Overview

- Study Tasks
- Water Savings Potential
- Water Quality
- Risks
- State of Practice
- Costs and Benefits
- Future Research Needs

Definitions

Stormwater runoff

- Water from rainfall or snow that can be measured downstream in a pipe, culvert, or stream shortly after the precipitation event
- Includes runoff captured from rooftops



Graywater

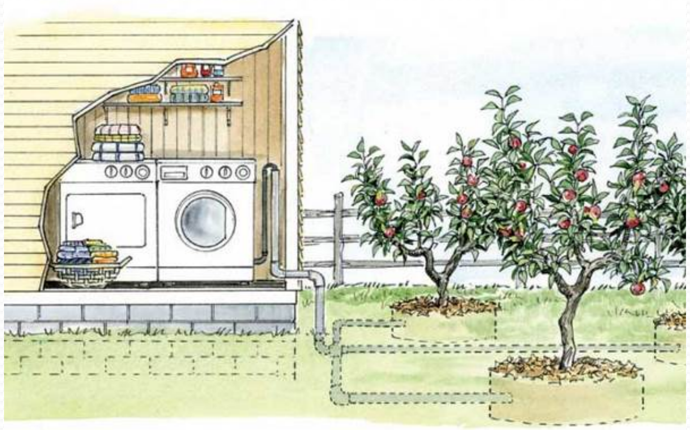
- Wastewater produced from bathroom sinks, showers, bathtubs, clothes washers, and laundry sinks. Derived from residential or commercial buildings.
- Does not include toilet or kitchen water

Study Task

1. **Quantity and suitability**. What is the potential to significantly increase stormwater and graywater use in the U.S., and where would increased practice have the most benefit?
2. **Treatment and storage**. What types of treatment are available and how do these treatment methods compare in terms of cost and energy use?

Study Task (cont.)

3. **Risks**. What are the human health and environmental risks for various uses?



4. **Costs and benefits**. What are the costs and benefits of the beneficial use of stormwater and graywater (including non-monetized costs and benefits)?
5. **Implementation.** What are the legal and regulatory constraints for use of captured stormwater and graywater?

Related to 1-5, what research is needed?

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- Water Environment Research Foundation
- Los Angeles Department of Water and Power
- City of Madison, Wisconsin
- WateReuse
- National Water Research Institute (NWRI)

Committee Members

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- **RICHARD ATWATER**, Southern California Water Committee
- **GLEN DAIGGER**, University of Michigan (formerly CH_2M-Hill)
- **JÖRG DREWES**, Technische Universität München, Germany
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- **ROBERT RAUCHER**, Stratus Consulting/Abt Associates
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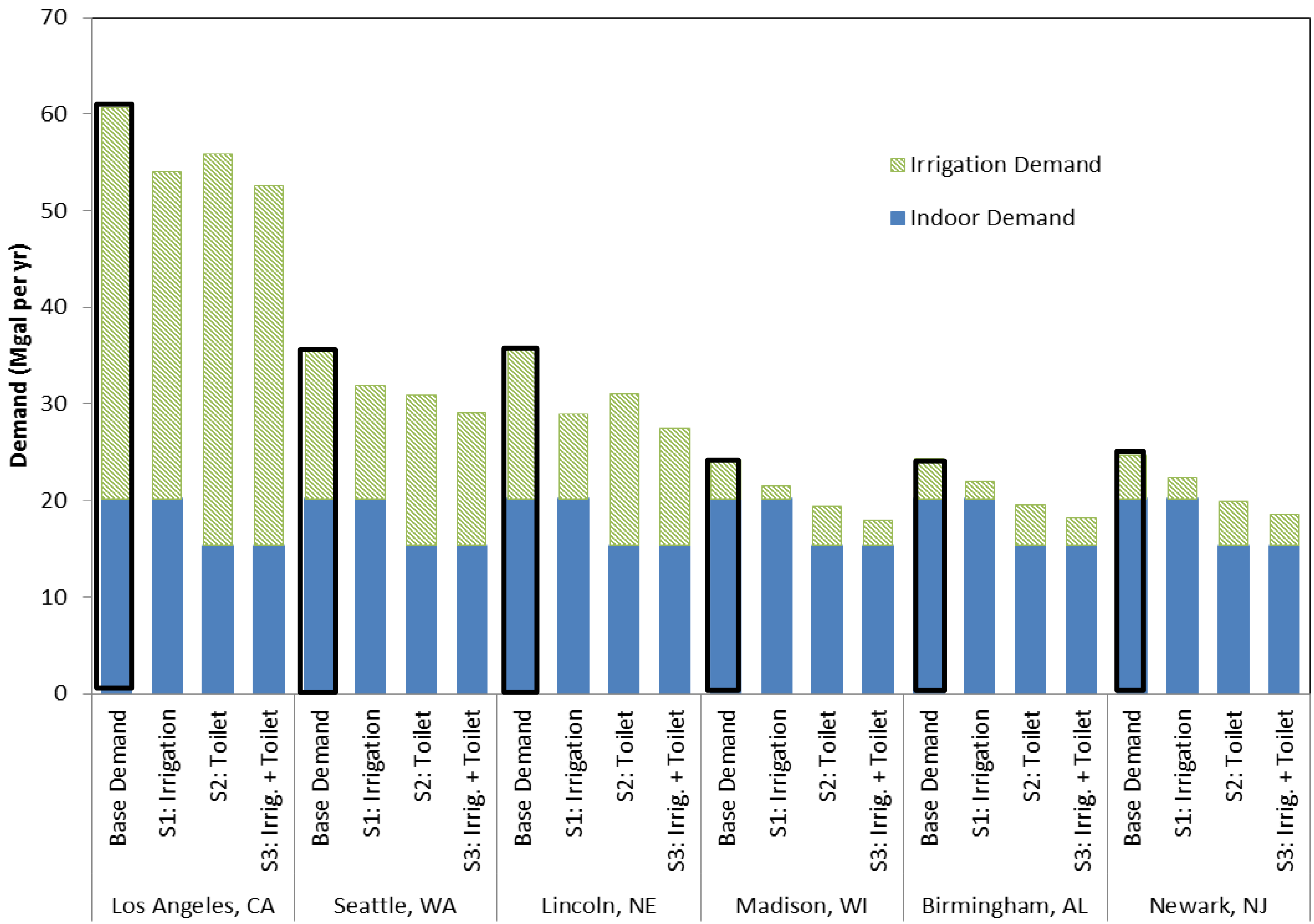
- **CLAIRE WELTY**, University of Maryland Baltimore County
- **MARYLYNN YATES**, University of California, Riverside

Committee held 6 meetings since Nov. 2013; authored consensus report.

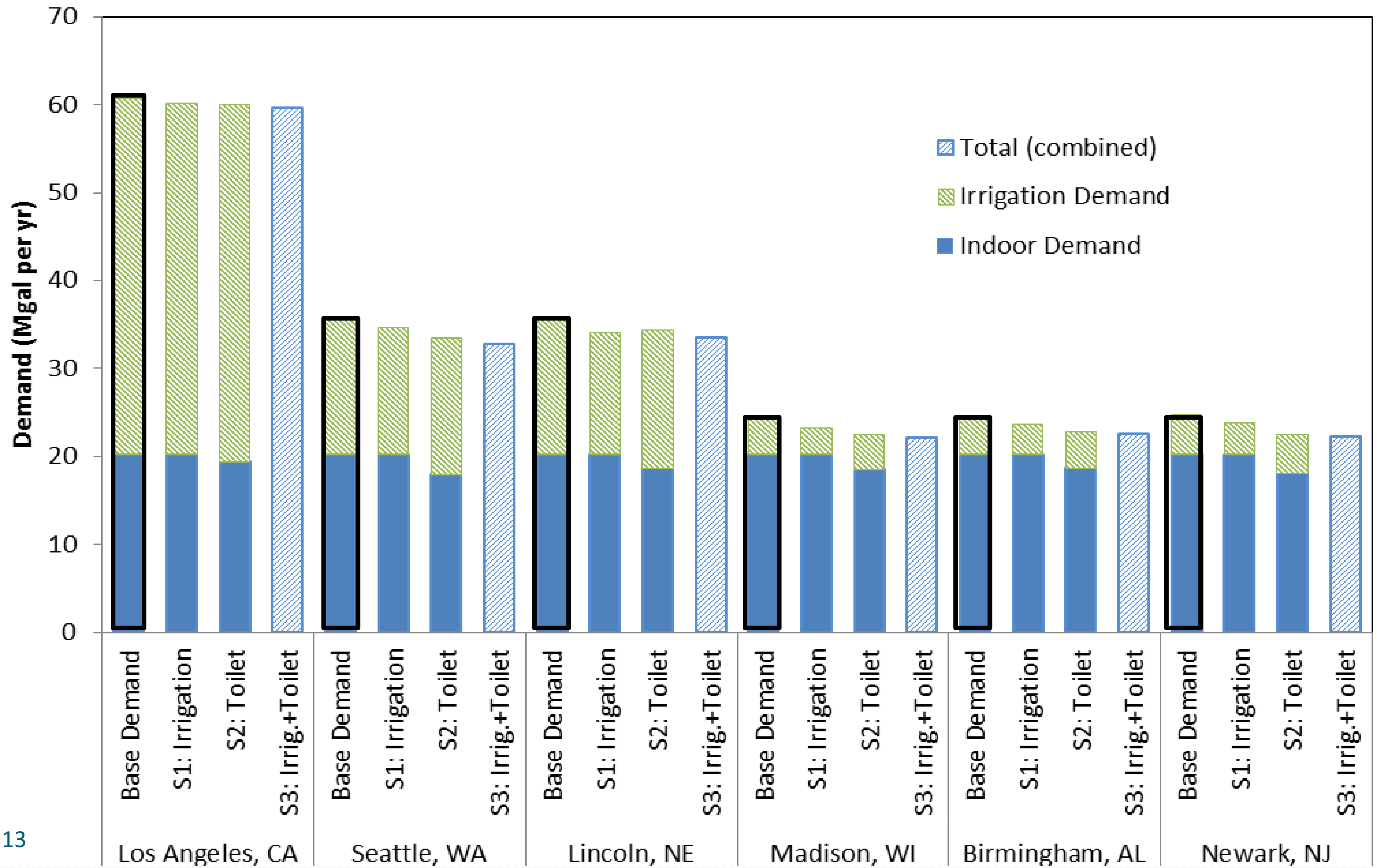
Original Analysis of Potential Savings

- Analysis of residential stormwater and graywater use:
  - 100 acres, 12 persons per acre
  - Site-specific data: LA, Seattle, Madison, Lincoln, Newark, & Birmingham
  - 1995-1999 rainfall, long-term ET to estimate monthly irrigation needs
  - Graywater assumed U.S. average graywater daily supply
- Scenarios considered:
  - Graywater: whole house and laundry to landscape (irrigation only)
  - Stormwater: roof runoff in 2 rain barrels (70 gal total) or 2,200 gal tank
- Calculated potential savings for:
  - Conservation irrigation (barely meet ET) for turfgrass
  - Toilet flushing
  - Irrigation and toilet flushing

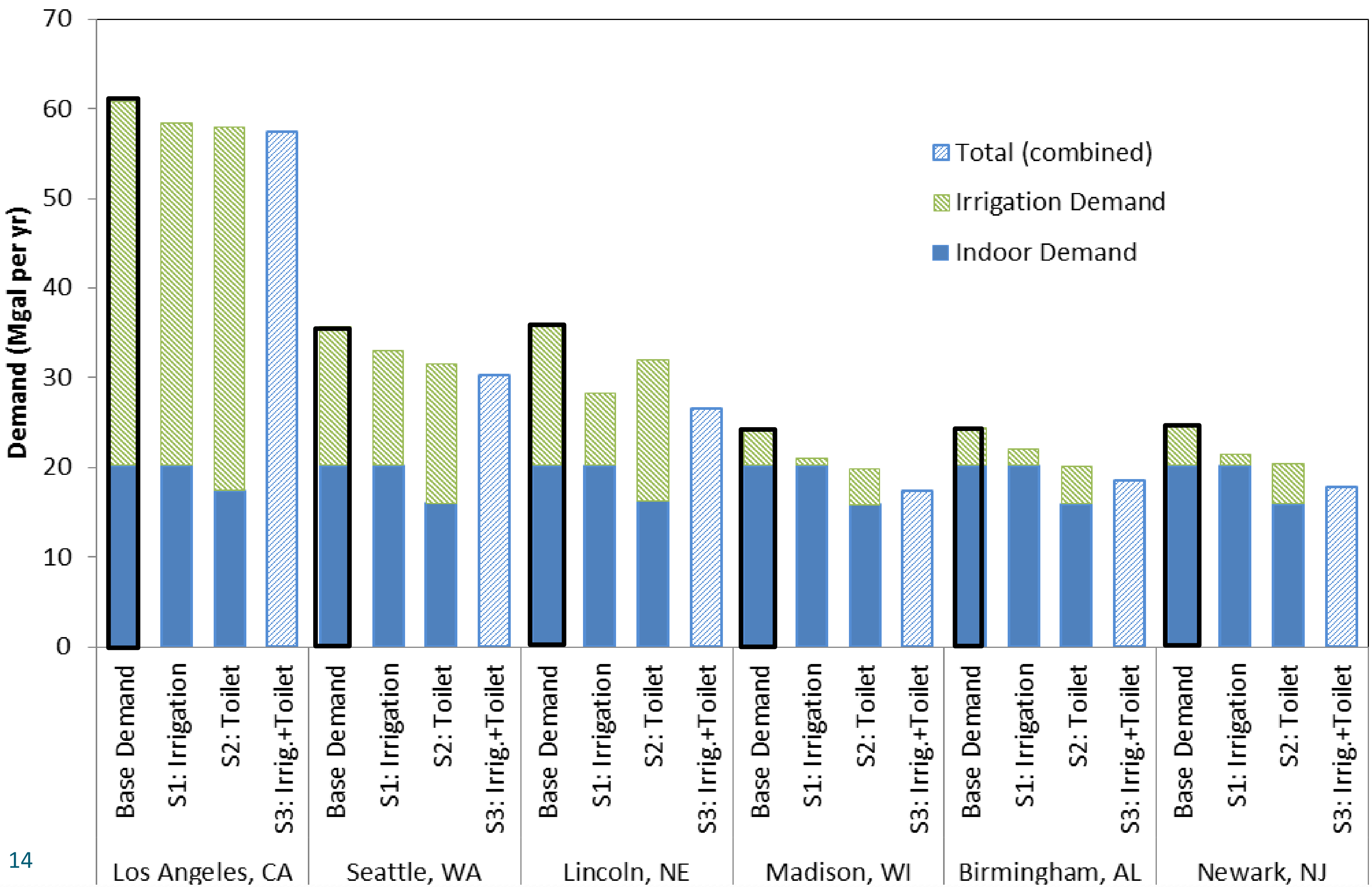
Potential Household Graywater Savings

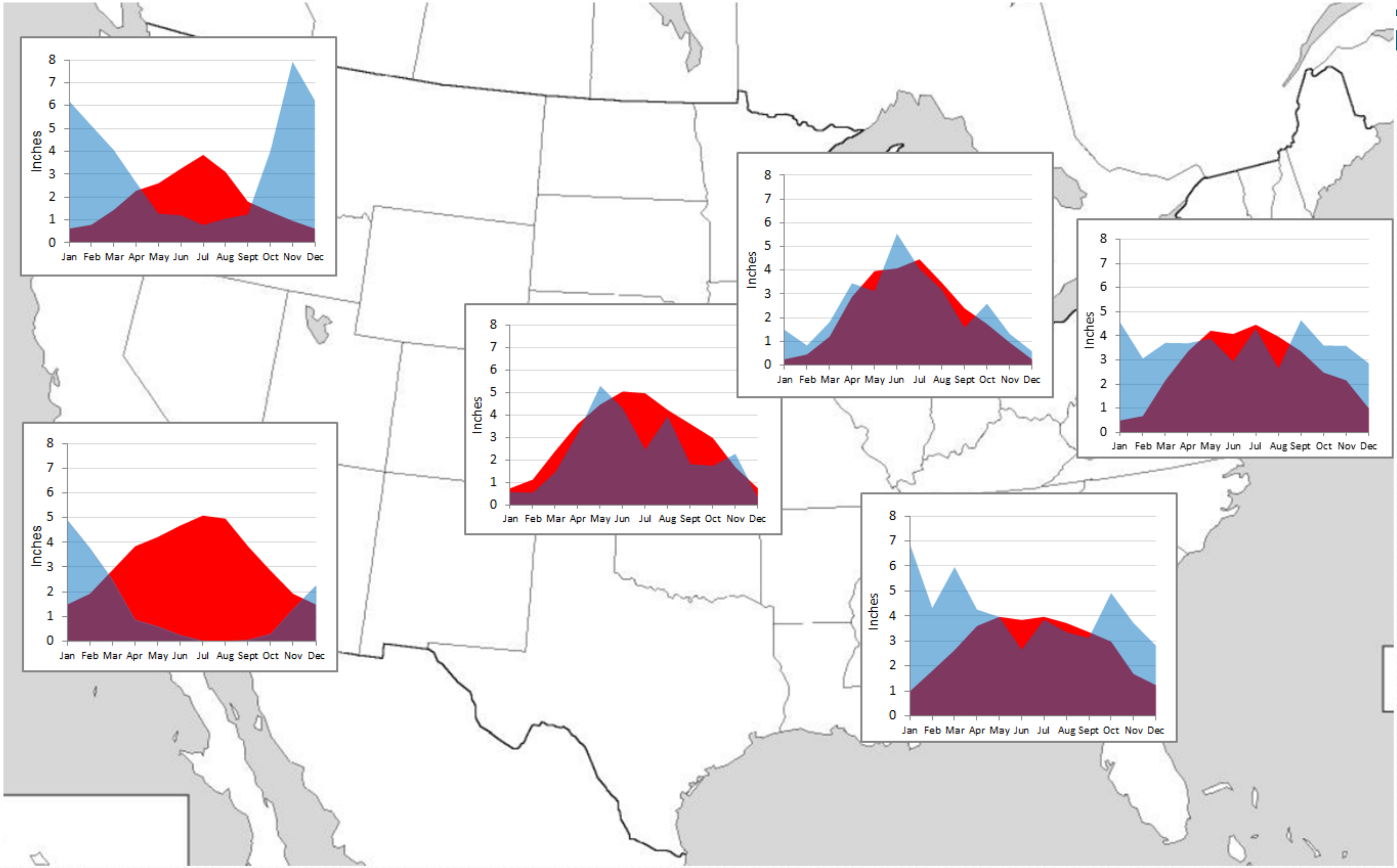


Rooftop Capture: Potential Rain Barrel Savings



Rooftop Capture: Potential 2,200 Gal Tank Savings





Blue=rainfall; red=irrigation demand

Water Availability

Stormwater:

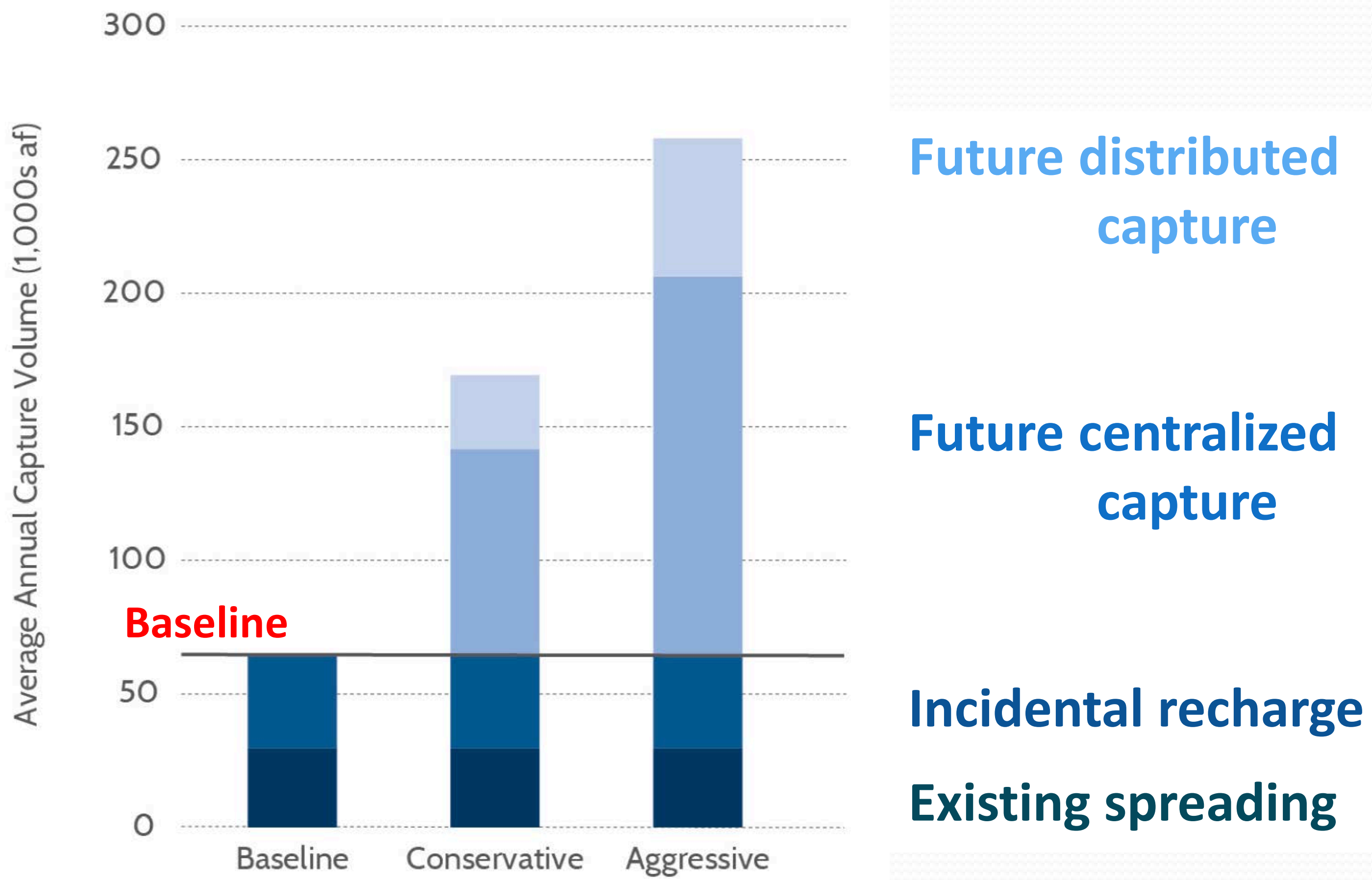
- Dependent on tank size and amount/timing of precipitation relative to demand
- Neighborhood and regional-scale projects can contribute significantly to urban water supplies

Graywater:

- Substantial potential savings, particularly useful in arid regions

If water conservation is the objective, strategies to reduce outdoor water use should first be examined.

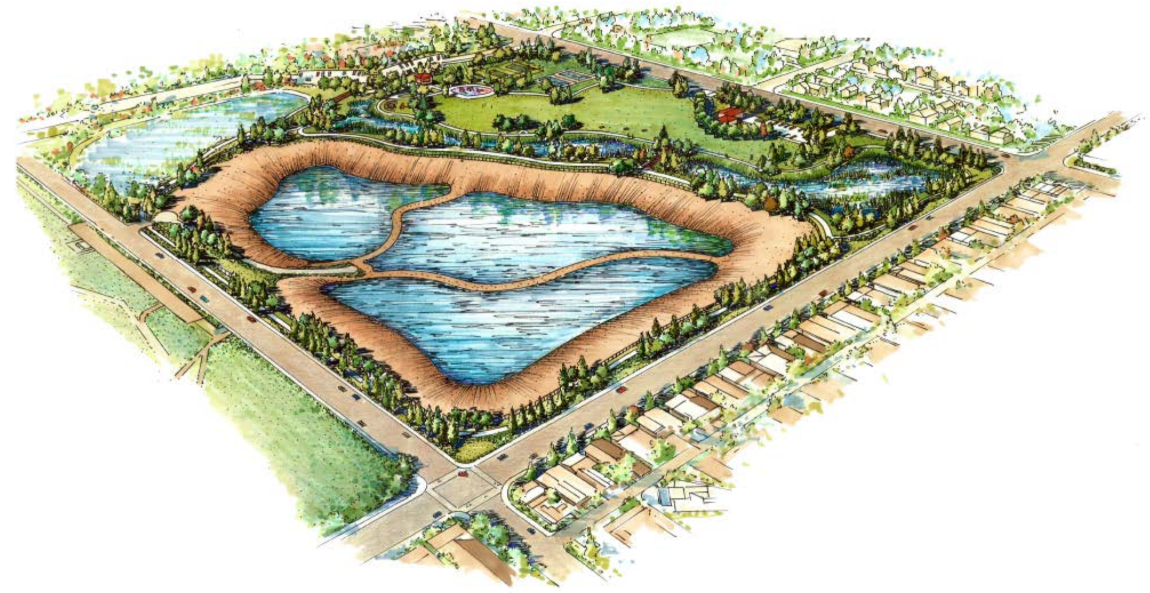
Urban Stormwater Capture & Recharge



LA's stormwater capture master plan --- an aggressive path *this century* could add nearly 200,000 afy from today's baseline (SWCMP, 2015)

Water Quality

- Stormwater :
  - Highly variable over space and time, although related to land use
  - Little is known regarding human pathogens and organic chemicals in stormwater, additional research is needed
- Graywater:
  - Pathogens & organic matter necessitate treatment for uses with human contact

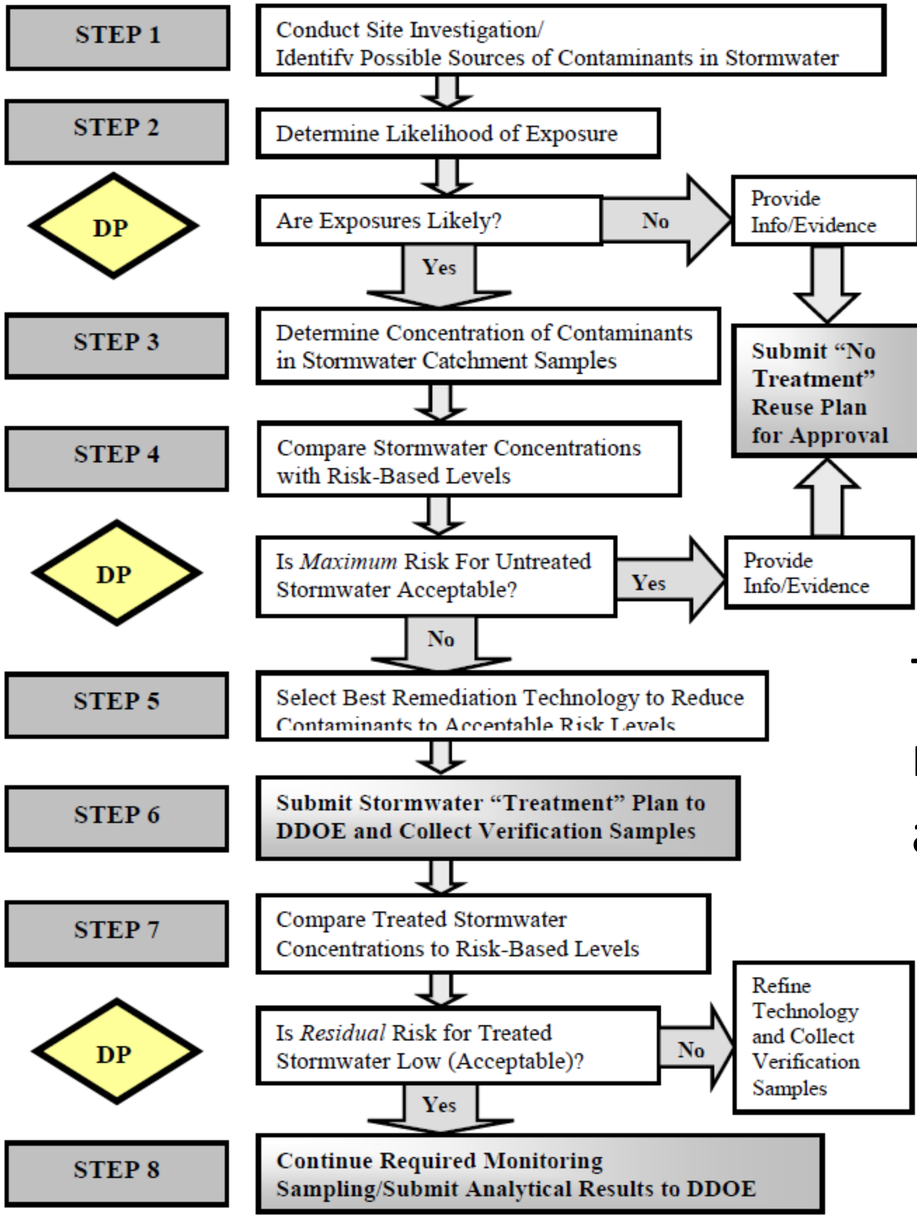


Risk

- Risk assessment provides a means to determine "fit-for-purpose" criteria or treatment needs based on exposures
- Pathogens: the most significant acute risks
  - Extremely limited data, which precludes a full assessment of risk, particularly for roof runoff.
- Stormwater recharge poses risks of groundwater contamination and necessitates careful design to minimize those risks

Risk: Irrigation Methods

- *Subsurface irrigation*
  - Water is supplied through drip systems (buried or covered by landscape)
- *Surface irrigation*
  - Drip irrigation (no cover)
- *Spray irrigation*



Tiered risk assessment and management approach applied by DC for stormwater

DDOE Microbial Risk-based Levels for Stormwater Use Based on Human Exposure Category

Contaminant (µg/L)	Swimming	Direct Human Exposure Category		
		High	Medium	Low
E. coli (CFU/100 mL)	126	1714	4615	50,000
Cryptosporidium (oocytes/L)	NA	0.016	0.033	0.320

Water Quality:
Graywater Use to Flush Toilets

	BOD_5 (mg L^{-1})	TSS (mg L^{-1})	Turbidity (NTU)	Total Coliform (cfu/ 100ml)	E. Coli (cfu/ 100ml)	Disinfection
California	10	10	2	2.2	2.2	0.5 – 2.5 mg/L residual chlorine
New Mexico	30	30	-	-	200	-
Oregon	10	10	-	-	2.2	-
Georgia	-	-	10	500	100	-
Texas	-	-	-	-	20	-
Massachusetts	10	5	2	-	14	-
Wisconsin	200	5	-	-	-	0.1 – 4 mg L^{-1} residual chlorine
Colorado	10	10	2	-	2.2	0.5 – 2.5 mg/L residual chlorine
Typical Graywater	80 - 380	54 -280	28-1340	$10^{7.2}$ – $10^{8.8}$	$10^{5.4}$ – $10^{7.2}$	N/A

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Roof Runoff: Indoor Use

	Turbidity (NTU)	E. Coli (CFU/100ml)	Total Coliforms (CFU/100ml)
California	10	< 100	-
Texas	-	< 100	< 500
Georgia	-	< 100	< 500

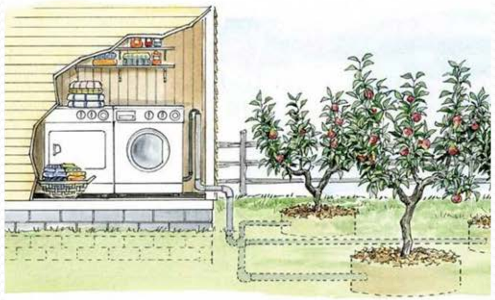
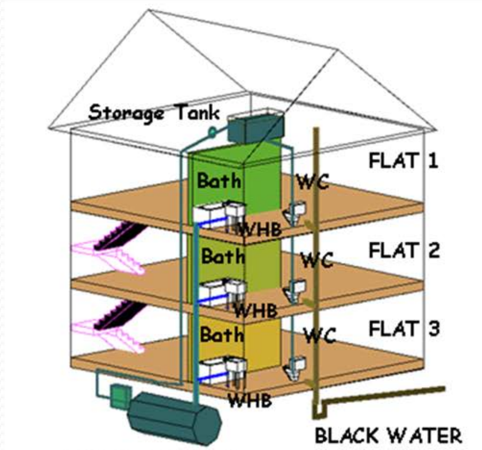
DDOE high human exposure pathway for stormwater use:
1714 CFU/100 ml

Graywater Use for Toilet Flushing:
Total Coliforms: 2.2 – 500 CFU/100ml
E. Coli: 2.2 – 200 CFU/100ml

National Sanitation Foundation 350 Water Quality for Graywater Use for Toilet Flushing

Parameter	Class R[a]		Class C[b]	
	Test Average	Single Sample Maximum	Test Average	Single Sample Maximum
$CBOD_5$ (mg/l)	10	25	10	25
TSS (mg/l)	10	30	10	30
Turbidity (NTU)	5	10	2	5
E. coli (MPN/100 ml)	14	240	2.2	200
pH (SU)	6.0-9.0		6.0-9.0	
Storage vessel residual chlorine (mg/l)	≥ 0.5 - ≥ 2.5		≥ 0.5 - ≥ 2.5	

[a] Class R: Flows through graywater system are less than 400gpd
[b] Class C: Flows through graywater system are less than 1500gpd

	Graywater	Stormwater
Household		
Neighborhood/Multi-		
Regional		

Graywater Reuse: Consideration of Scale

<table>
<tr><th></th><th>Household</th><th>Neighborhood/Multi-residential</th><th>Commercial and Institutional</th></tr>
<tr><td>Irrigation</td><td>Drip or subsurface irrigation required, sometimes not practical in grassy areas.</td><td>Multi-residential: more graywater is often generated than required for irrigation.
Human health risks from untreated graywater are higher than at the household scale.</td><td rowspan="2">Graywater generation rates vary widely
Often graywater production is not sufficient to meet end use demands,
Can be suitable when showers or laundry are on-site (e.g. fitness facilities, hotels, offices with showers, aquatics centers).
Hospitals are not appropriate sites for graywater use due to contamination potential.</td></tr>
<tr><td>Toilet Flushing</td><td>Treatment is required and systems can be complex for homeowners to maintain.
Risk for cross connection and improper maintenance</td><td>Graywater volume generated is often suitable for toilet flushing.
Maintenance activities can be performed by facilities staff.</td></tr>
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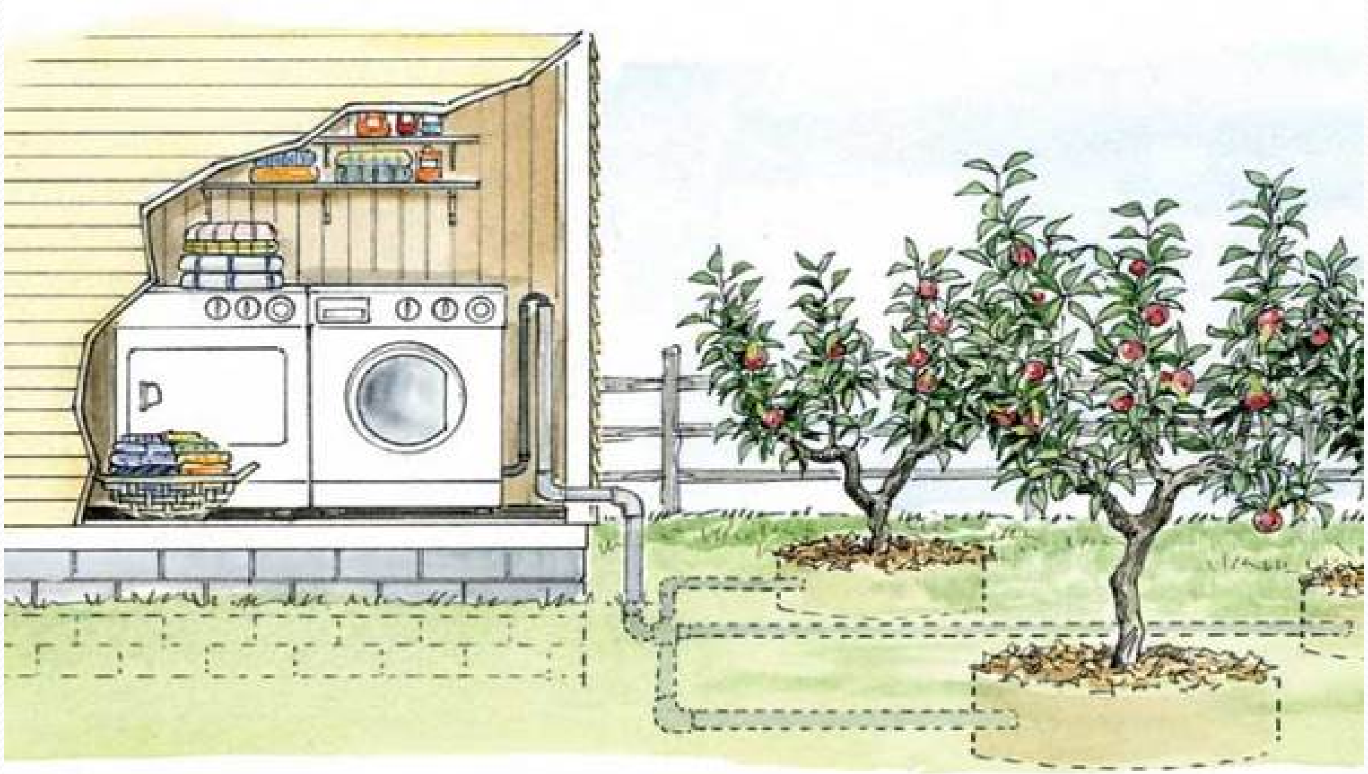
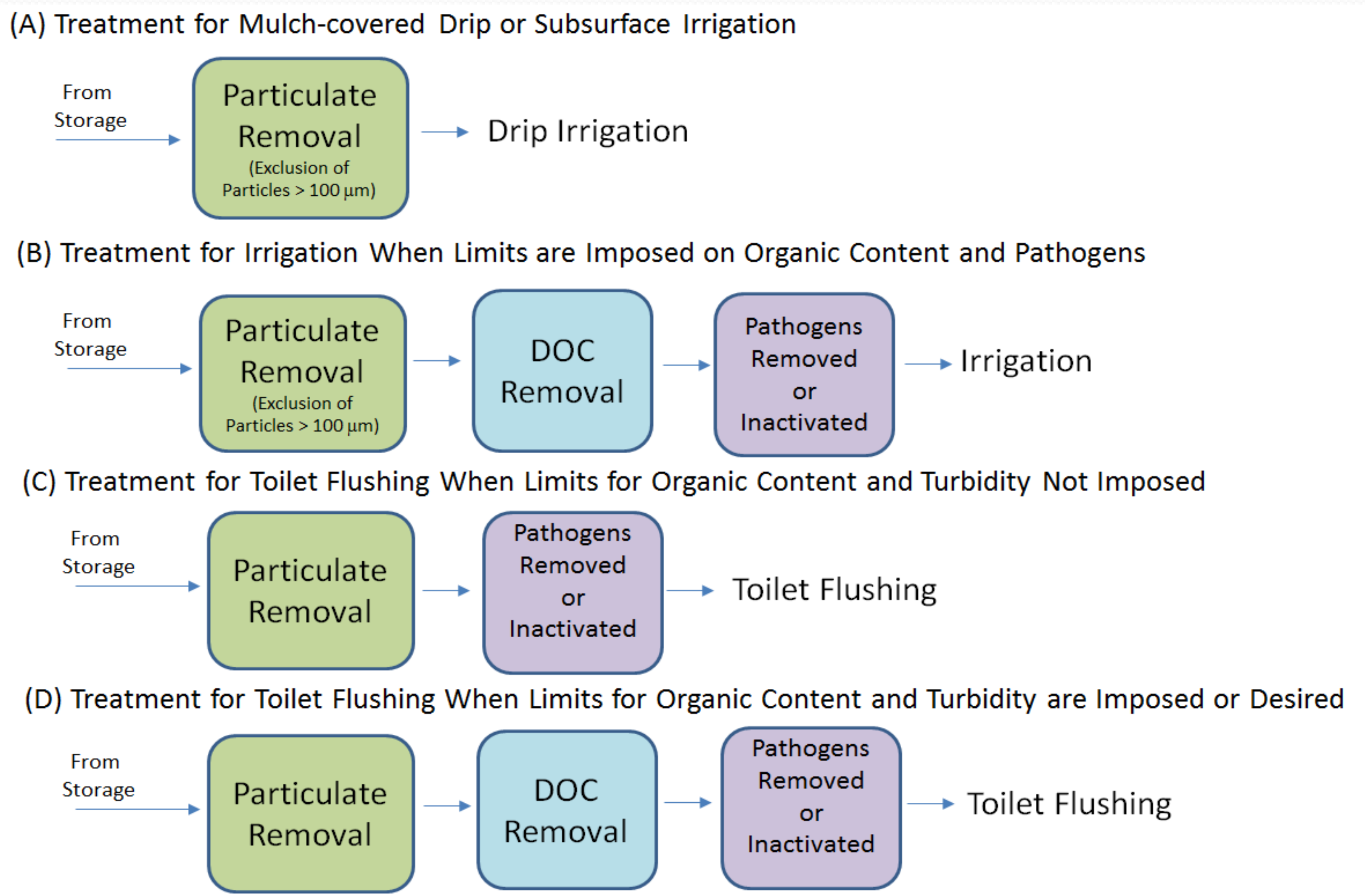
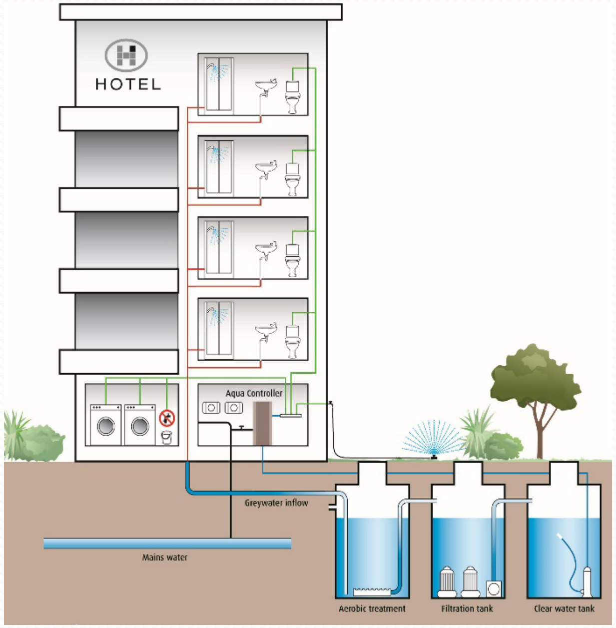
Graywater Systems: Laundry to Landscape



Graywater Treatment Systems



State of Practice: Graywater



- Irrigation at the household scale can be achieved with simple systems
- Reuse for toilet flushing are most appropriate in multi-residential buildings
- Many state graywater treatment standards for toilet flushing are not risk-based or fit-for-purpose
- New developments provide opportunities for rethinking the use of water and waste streams for saving money, energy, & water

State of Practice: Stormwater

- The state of practice for cost-effective, safe roof-runoff capture systems are hindered by the lack of data on human pathogens.

- Stormwater infiltration for aquifer recharge is commonly practiced, but designs and regulations in the United States may not be adequately protective of groundwater quality for new systems in urban areas.

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State of Practice: Operations

- Operations and maintenance of household and neighborhood graywater and stormwater use systems is not well guided or monitored.
- Many states require that systems meet water quality targets, but ongoing monitoring is not required.
- Online monitoring of surrogate parameters (e.g., residual chlorine, turbidity) should be considered.

Costs and Benefits

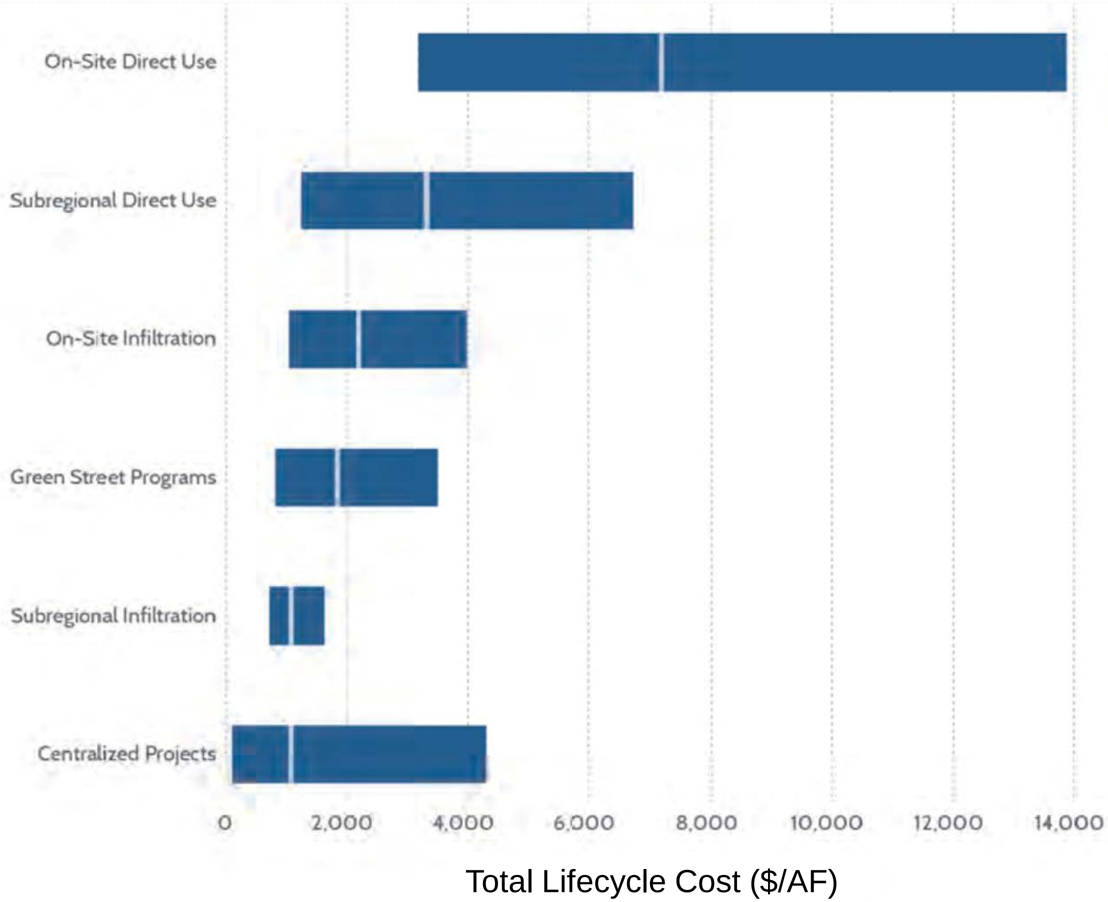
It is important to recognize the full suite of benefits—as well as the full costs—of graywater and stormwater projects, although it may be challenging to do so.

- Financial cost data are extremely limited
- Social & environmental costs and benefits rarely monetized
- Energy savings are possible, but data for a sound assessment are lacking.

Committee’s Scenario Cost Analysis for Graywater Irrigation

	Laundry-to-Landscape		Household Graywater	
	Household water savings (gallons/year)	Estimated annual cost savings ($/year)	Household water savings (gallons/year)	Estimated annual cost savings ($/year)
Los Angeles	5,400	54	13,000	130
Seattle	2,800	28	7,800	78
Lincoln	7,400	74	13,000	131
Madison	3,900	39	6,200	62
Birmingham	5,500	55	9,000	90
Newark	2,800	28	5,000	50

Costs and Benefits



- Simple systems can offer reasonable financial payback periods under certain scenarios/climates.
  - However, behavioral factors on water use are poorly understood
- Economies of scale are evident

Legal and Regulatory

- In most western states, acquisition of water rights is a requirement for inland large-scale projects and may limit stormwater and graywater projects.
- Substantial variation in on-site regulations at the state level, allowing for varying exposures and risk.
- The lack of authoritative, risk-based guidelines for the design and potential applications of graywater and stormwater in the United States is a major impediment to their expanded use.

Research Needs

Risk and water quality

1. Assess the occurrence and fate of pathogens in graywater and stormwater
2. Assess the occurrence and fate of chemical contaminants in stormwater
3. Understand the implications of enhanced water conservation on graywater quality and use
4. Develop risk-based water quality guidance for various uses that could serve as a basis to develop standards of practice
5. Develop monitoring technology and strategies to assure compliance with water quality criteria

Research Needs

Treatment technology

6. Develop treatment systems to meet tailored (fit-for-purpose) water quality objectives across a range of scales
7. Understand the long-term performance and reliability of graywater and stormwater treatment systems (from small to large scales)

Infrastructure

8. Envision opportunities for water- and energy-conserving infrastructure designs in new construction and demonstrate performance
9. Identify strategies to retrofit existing infrastructure for enhanced beneficial use of stormwater

Research Needs

Social science and decision analysis

10. Understand behavioral impacts on overall water use in the context of graywater and stormwater projects
11. Collect performance data (e.g., cost, energy, water savings, water quality, and other benefits) in support of integrated water supply management, decision making, and refinement of decision tools

Policy and regulatory issues

12. Identify incentives and various regulatory strategies that have proven effective in the implementation of stormwater or graywater systems to conserve water supplies

Summary

- Graywater and stormwater capture and use can expand local water availability while providing additional benefits.

- Treatment can help address contaminants in the water, but a lack of risk-based treatment guidelines hinders the broader use of stormwater and graywater.

- There is no single best way to use graywater or stormwater to address local water needs
  - many important considerations—including legal and regulatory constraints, potential applications, climate, and source water availability—vary widely with local conditions.

- Research on information about costs, benefits, risks, treatment needs, and behavioral factors would enhance decision making.

More Resources

- Full report at http://www.nap.edu/
- Additional resources under "Resources" tab:
  - 4-page report in brief
  - Press release
- Final book to be printed this spring

REPORT IN BRIEF

December 2015

Water Science and Technology Board

DIVISION ON EARTH AND LIFE STUDIES

Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits

Graywater and stormwater capture and use can expand local water availability while providing additional benefits, such as reduced water pollution (for stormwater) and a drought-resistant year-round water supply (for graywater). Treatment can help address contaminants in the water, but a lack of risk-based treatment guidelines hinders the broader use of stormwater and graywater. There is no single best way to use graywater or stormwater to address local water needs, and many important considerations—including legal and regulatory constraints, potential applications, and source water availability—vary widely with local conditions. Additional information about these factors could make it easier for businesses, households, and water authorities to use stormwater and graywater to augment water supplies.

In many regions of the United States, water is in short supply. Climate change is causing shifts in patterns of precipitation, and multi-year droughts in California and the Colorado River Basin have drained reservoirs to near record-low levels. At the same time, rapid population growth is increasing water demand in many of the nation's most water-scarce regions, including California, Nevada, Arizona, Texas, and Florida, which saw population increase between 85 and 400 percent from 1970 and 2009, compared to 50 percent across the United States during the same period. As a result, the potential use of graywater and stormwater to supplement water supplies is gaining increasing attention.

Some households and businesses have already started to use stormwater and graywater for irrigation and toilet flushing. Some communities also capture stormwater at neighborhood and regional scales to recharge groundwater. In addition to augmenting water supply, capturing and using stormwater reduces pollution from flowing into rivers, lakes, and oceans and lessens the overloading of wastewater treatment facilities after heavy rains. Similarly, the reuse of graywater can enhance water supply reliability and extend the capacity of wastewater systems in quickly growing cities.

Alternative water sources such as stormwater and graywater could help supplement scarce water supplies.

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Type Your Questions in the Chat Box

Early draft found here:
http://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an

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