Beneficial uses of Stormwater

Non-potable Uses and Impact on Urban Infrastructure

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Presentation Topics

- Recent reports and case studies of stormwater beneficial uses
- Water use in typical US homes
- Evapotranspiration for irrigation calculations
- Storage tank size requirements
- Beneficial uses a different scales
- Conclusions

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Recent Reports Investigating Beneficial Uses of Stormwater to Reduce Domestic Water Supply

- Pitt, R., L. Talebi. R. Bean, and S. Clark. *Stormwater Non-Potable Beneficial Uses and Effects on Urban Infrastructure*, Water Environment Research Foundation, Report No. INFR3SG09. Alexandria, VA. November 2011. 224 pgs.
- National Research Council, National Academy of Science, *Committee on the On-Site Beneficial Use of Graywater and Stormwater: An Assessment of Risks, Costs, and Benefits.* 2015.

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Stormwater beneficial uses have a long history. As an example, in the 7th century B.C. at Kamiros, Rhodes, residents carried water from the cistern at the top of the hill back down to their homes

Cistern tank collected roof runoff from adjacent temple located at top of the hill.

Ancient temple site at top of hill had roof runoff cistern. Piped water to community leader's homes near temple, others carried water to their homes.

Steps alongside cistern allowing jugs to be filled from holes in wall to cistern.

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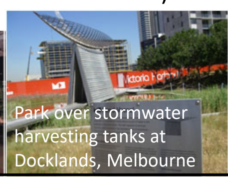
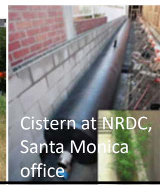
Representative Case Studies of Stormwater Beneficial Use Examined in WERF Report

- 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)


Rainwater jars in Thailand


Park over stormwater harvesting tanks at Docklands, Melbourne


Cistern at NRDC, Santa Monica office


Cistern at Wash. U., St. Louis

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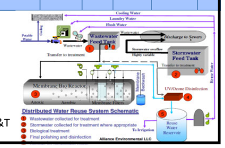
State	Project name and location	Study area (catchment size)	Treatment Method					Reuse Purpose				
			Sediment trap/sand filtration	Wetland	Chlorination	Advanced Treatment	UV Disinfection	Irrigation	Toilet flushing	Fire fighting	Air conditioning	other
Florida	West Palm Beach; Renaissance					✓						✓
Hawaii	U.S. National Volcano Park	2.4 ha	✓			✓			✓			✓
Washington	Seattle, King Street Center	30,380 m²	✓		✓			✓	✓			
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 m²	✓		✓				✓		✓	


Stormwater treatment at Kings Street Center, Seattle (http://www.psparchives.com/publications/our_work/stormwater/lid/LID_studies/rooftop_rainwater.htm).



Distributed water system at Solaire, New York. (http://www.werf.org/AM/Template.cfm?Section=Home&Template=/CM/ContentDisplay.cfm&ContentID=13317)

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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, as maximum volumes are needed to augment the poor quality and poorly available local sources.
- The water is stored in large ponds, or injected to 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

- 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.

Example Regulations for Stormwater Beneficial Uses

		Coliform Bacteria	Chlorine	pH	Turbidity	Ammonia	Aluminum	Nitrate /Nitrite
WHO	Roof water harvesting	*E. coli.* <10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	Not relevant	<1.5 mg/L	Not relevant	Not relevant
	Surface Runoff	*E. coli.*<10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	<15 NTU	<1.5 mg/L	<0.2 mg/L	<50 mg/L and <3 mg/L
	Sand dams	*E. coli.*<10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	<5 NTU	<1.5 mg/L	<0.2 mg/L	<50 mg/L and <3 mg/L
New South Wales (Australia)	Level 1	<1 cfu/100 mL	1 mg/L Cl_2 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_2 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/out door uses	Total coliforms <500 cfu per 100 mL Fecal coliforms <500 cfu per 100 mL						

Example Regulations for Stormwater Beneficial Uses (cont.)

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

- Bacteria standards are common, with *E. coli* limits ranging from 1 cfu per 100 mL for non-potable uses with public access to 1,000 cfu per 100 mL for controlled access.
- Chlorine residuals imply chlorination as a disinfectant, usually with concurrent turbidity and pH limits for more efficient disinfection.

Current Stormwater Beneficial Uses in the US

- Many of the US 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.

Example Assessment: The Urban Water Budget and Potential for Beneficial Stormwater Uses in a Southeastern U.S. Residential Area

- Two working adults and one child, in the US southeast, where the rainfall averages about 50 inches per year:
  - bathing 42%
  - laundry 11%
  - kitchen sink 15%
  - dishwasher 8%
  - bath sinks 12%
  - toilet flushing 12%

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Stormwater Beneficial Uses for a Typical House

- The estimated roof runoff for a typical 2,000 ft^2, 1- ½ level, house (roof area of about 1,300 ft^2) would be about 40,000 gallons per year, for this southeastern area having about 50 inches of rain a year.
- The total water use for this household is about 100,000 gallons per year, with the amount used for toilet flushing being about 12,000 gallons, with another 3,000 gallons used for landscaping irrigation.
- For this example, the roof runoff would supply almost three times the amount of water needed for toilet flushing and landscape irrigation.
- Additional uses of the stormwater needed to further reduce these discharges. One use is for groundwater recharge.

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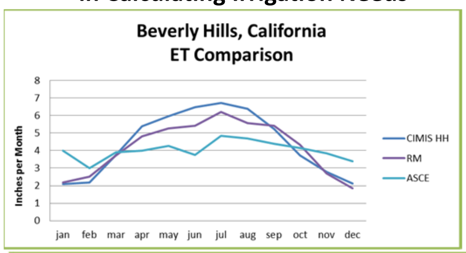
Estimated Values of Landscape Coefficient Factors

	Very Low	Low	Moderate	High
Species Factor	<0.1	0.1 to 0.3	0.4 to 0.6	0.7 to 0.9
Density Factor	-	0.5 to 0.9	1	1.1 to 1.3
Microclimate Factor	-	0.5 to 0.9	1	1.1 to 1.4

Evapotranspiration (ET) data sources are from agricultural and wildland environments which differ greatly from urban settings. The few projects that have examined urban ET values indicate large differences. Therefore, further research applying the available ET rates to disturbed urban environments is required to confirm the applicability of these rates in urban stormwater management practices.

Evapotranspiration (ET) as a Major Factor in Calculating Irrigation Needs



k values	Observed Site Conditions	Assessed Category	Estimated Coefficient
Species Factor	cool season grasses	High	.9*/.95
Density Factor	Low density groundcover	Low	0.75
Microclimate	Shaded with wind protection	Low	0.65

$K_L = k_S * k_d * k_{mc}$ Example for Oakmulgee: .43*/.46

***Slight reduction in species factor to account for early spring growing season**

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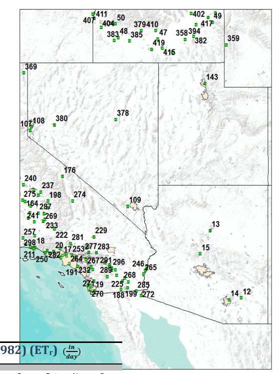
ET Rates can Vary Greatly Over Small Distances, Especially in the Western US

The WERF report has compilations of various ET databases showing monthly ET values for many regions in the US that can be used to estimate the irrigation needs for stormwater beneficial uses. Some areas have large amounts of ET data (such as CA and FL), while the data is more sparse for other locations.



Lat	Long	Elev	Station Name	Years of Data	Kimberly Penman Equation (1982) (ET_r) ($\frac{in}{day}$)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
64.84	-147.62	454	Fairbanks Alaska		Unavailable at this time											
61.08	-149.73	1480	Rabbit Creek Alaska		Unavailable at this time											
57.8	-135.13	450	Hoonah Alaska		Unavailable at this time											
33.44	-86.081	600	Talladega Alabama	5	0.07	0.13	0.18	0.24	0.26	0.26	0.25	0.24	0.23	0.21	0.13	0.09
32.96	-87.171	363	Oakmulgee Alabama	7	0.08	0.09	0.13	0.20	0.22	0.25	0.24	0.22	0.21	0.17	0.13	0.08
34.14	-87.362	804	Bankhead Alabama	7	0.06	0.12	0.17	0.24	0.25	0.26	0.25	0.25	0.23	0.20	0.13	0.09
32.45	-85.641	283	Tuskegee Alabama	5	0.08	0.13	0.17	0.24	0.26	0.27	0.27	0.25	0.23	0.19	0.13	0.07
34.76	-90.722	253	Marianna Arkansas	3	0.06	0.07	0.13	0.18	0.21	0.27	0.26	0.25	0.20	0.16	0.11	0.06
34.27	-92.393	270	Sheridan Arkansas	6	0.07	0.12	0.19	0.08	0.32	0.31	0.20	0.30	0.28	0.21	0.15	0.08
36.07	-93.357	2365	Compton Arkansas	2	0.06	0.10	0.15	0.21	0.32	0.38	0.35	0.30	0.24	0.22	0.11	0.08
35.87	-94.297	1633	Strickler Arkansas	6	0.06	0.07	0.12	0.16	0.19	0.23	0.24	0.24	0.20	0.15	0.11	0.07
32.4	-110.27	4175	Muleshoe Ranch AZ	13	0.09	0.15	0.22	0.29	0.35	0.37	0.29	0.29	0.31	0.25	0.16	0.11
35.15	-111.68	7000	Flagstaff Arizona	10	0.06	0.10	0.14	0.18	0.24	0.28	0.28	0.24	0.23	0.18	0.10	0.06
32.32	-110.81	3100	Saguaro Arizona	8	0.12	0.18	0.21	0.29	0.35	0.36	0.30	0.29	0.31	0.26	0.17	0.11

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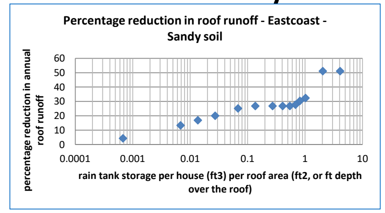
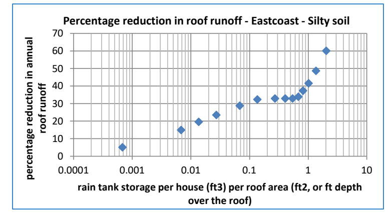
Example Irrigation Needs Calculated for Silty Soil- East Coast Conditions (as part of our NJ dry well study)

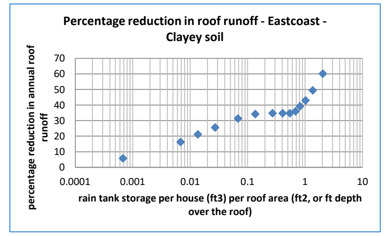
Calculated using continuous simulations and long-term rain records

	ET for site conditions (in/month)	Rainfall infiltration adding to soil moisture, from model (in/month)	Irrigation deficit (ET minus soil moisture addition from rain) (in/month)	irrigation deficit (gal/day/house)
Jan	0	3.44	n/a	0
Feb	0	2.67	n/a	0
Mar	2.79	3.67	n/a	0
Apr	4.20	3.38	0.82	102
May	4.96	4.16	0.80	96
Jun	5.10	3.18	1.92	240
Jul	5.27	4.36	0.92	109
Aug	4.65	3.44	1.21	140
Sep	3.90	3.84	0.06	7
Oct	3.10	3.00	0.11	13
Nov	1.80	3.79	n/a	0
Dec	1.24	3.35	n/a	0

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







total roof area (%)	15.9
landscaped area (%)	54.5
study period annual rain fall (in) (5-year period, 1995 to 2000)	53.01
maximum roof runoff control (%), silty soil conditions	60.1
storage tank size for max roof runoff control (ft^3 storage/ft^2 roof area), silty soil conditions	2.00*

* A more cost-effective design would likely be 0.1 ft of storage for 32% runoff reductions.

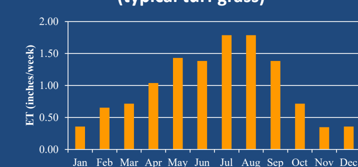
Comparison of East Coast vs. Central US Roof Runoff Harvesting Potential for Medium Density Residential Areas (can't use the same designs everywhere!)

Region	total roof area (%)	landscaped area (%)	study period annual rain fall (in) (1995 to 2000)	maximum roof runoff control (%), silty soil	storage tank size for max roof runoff control (ft^3 storage/ft^2 roof area), silty soil
Central	18.1	62.5	33.5	90.6	0.72
East Coast	15.9	54.5	53.0	60.1	2.00

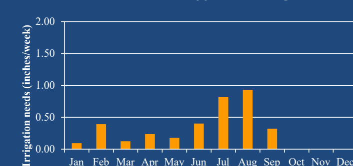
- Generally, sandy soil areas resulted in barely lower maximum levels of performance (very small difference) because more of the rainfall falling directly on the landscaped areas contributed to soil moisture, resulting in less of an irrigation demand to match the ET deficit. However, the sandy soil areas also drain faster, being able to handle more irrigation water.
- The Central US area has a higher potential level of control compared to the East Coast because the ET demands better match the rain fall pattern.
- The Southwest US area is challenging due to large mismatches in timing of ET/irrigation requirements and availability of rains (would need very large tanks for long-term storage).

Kansas City Green Infrastructure Demonstration Project: Calculations of Water Harvesting Potential of Roof Runoff

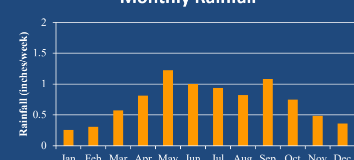
Evapotranspiration per Month (typical turf grass)



Supplemental Irrigation Needs per Month (typical turf grass)



Monthly Rainfall



Irrigation needs for the landscaped areas surrounding the homes were calculated by subtracting long-term monthly rainfall from the regional evapotranspiration demands for turf grass.

The expected per household water use (gallons/day) from cisterns for toilet flushing and outside irrigation (ET deficit only) for the Kansas City study area (6 homes per acre) is:

January	113 gal/day/house	July	428
February	243	August	479
March	126	September	211
April	175	October	71
May	149	November	71
June	248	December	71

Examples of water harvesting storage tanks in New Zealand and Australia (where they are experts in modern roof runoff harvesting):

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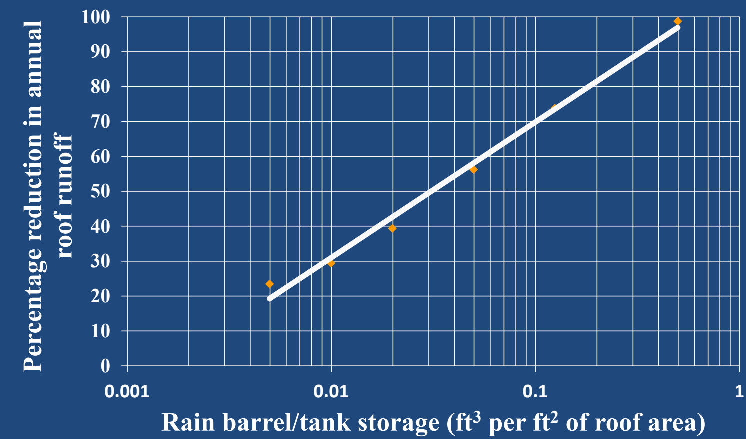
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Barrels and Water Tanks (Kansas City CSO Study Area)



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Cistern/Storage Tank Sizing vs. Performance (Kansas City Example)

Storage per house (ft^3 per ft^2 of roof area)	Reduction in annual roof runoff (%)	Number of 35 gallon rain barrels for 945 ft^2 roof	Tank height size required if 5 ft D (ft)	Tank height size required if 10 ft D (ft)
0.005	24	1	0.24	0.060
0.010	29	2	0.45	0.12
0.020	39	4	0.96	0.24
0.050	56	10	2.4	0.60
0.12	74	25	6.0	1.5
0.50	99	100	24	6.0

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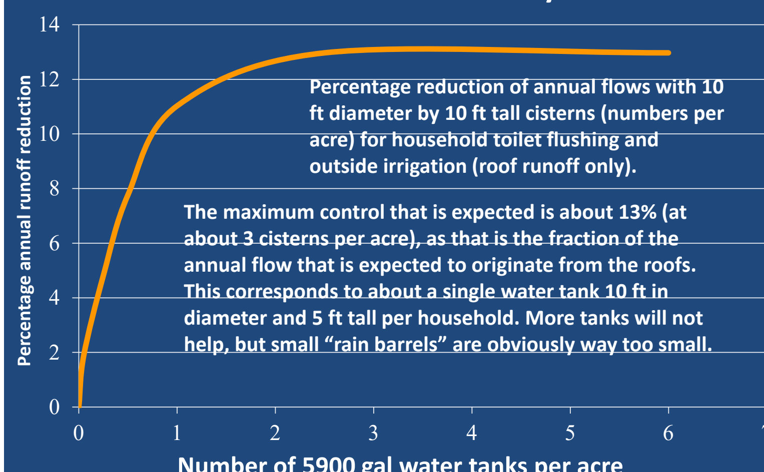
Number of water tanks and annual flow volume reductions for Kansas City test area



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Millburn, NJ

Dry well disposal of stormwater for groundwater recharge in conjunction with irrigation beneficial use

- For the past several years, the city of Millburn has required dry wells to infiltrate increased flows from newly developed areas.
- There are some underground water storage tanks now being installed to use stormwater for irrigation.
- Project was supported by the Wet Weather Flow Research Program of the US EPA. Investigated the performance of this shallow groundwater recharge (including groundwater contamination potential) in conjunction with irrigation beneficial uses of the stormwater.



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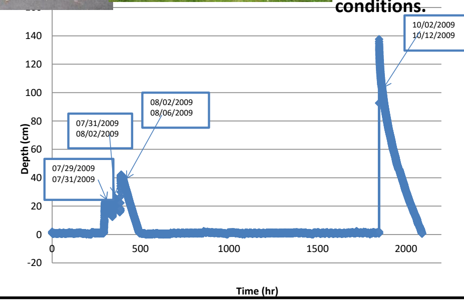
Nine dry wells were monitored in Millburn, NJ as part of EPA project for long-term hydraulic performance, and six were monitored to examine surface and subsurface water quality conditions.

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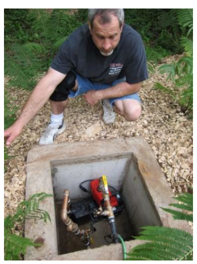

This major home restoration project included the installation of underground water storage tanks instead of dry wells. Homes in this neighborhood have summer water bills approaching $1k/month for landscape irrigation, so the economic benefits of irrigation using stormwater are very good.


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Water Conservation through Beneficial Uses of Stormwater

A summary of a recent National Academy of Science committee report

National Research Council, National Academy of Science, Committee on the On-Site Beneficial Use of Graywater and Stormwater: An Assessment of Risks, Costs, and Benefits. 2015.

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NRC Report Summary	Small-Scale Site Use
Main sources of stormwater	Possible to select specific source areas, such as rooftops, or blended from several on-site runoff sources.
Main uses of stormwater	Focus on irrigation and possibly toilet flushing, along with some special uses, such as washing equipment or buildings at specific locations (fire trucks at fire stations, window washing, etc.). Consumptive uses not likely or encouraged except with special consideration/treatment or locations.
Treatment options	Varies from storage/sedimentation, possible added sand filtering, and added disinfection.
Special considerations	Difficult/expensive to provide very large storage volumes of captured stormwater, and therefore mostly available near time of rainfall. Not a reliable source of water, but can reduce some domestic water use and reduce stormwater discharges.

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	Neighborhood- Scale Stormwater Beneficial Uses
Main sources of stormwater	Mixed runoff from all sources in the neighborhood, usually a single land use, such as an institution or residential area, but may be a mixture (such as a small commercial area plus a high density residential area).
Main uses of stormwater	Could be used for irrigation or toilet flushing at individual buildings, but would require significant infrastructure. Large-scale irrigation of adjacent parks or public gardens, or storage of firefighting water at institutional areas suitable uses. Medium-scale groundwater recharge possible. Significant use of this water would decrease demand, runoff, and in combined sewer areas, fewer and smaller sanitary sewer overflows.
Treatment options	Sedimentation in larger stormwater facilities. Possible to add available small-scale treatment systems, as needed.
Special considerations	Storage would be larger than possible with on-site options and could include small ponds. Can be integrated with conventional underground storage in combined sewer areas as part of CSO control program.

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	Community-Scale Stormwater Beneficial Uses
Main sources of stormwater	Mixed runoff from the community, including all land uses in the area, plus possible adjacent non-urban areas.
Main uses of stormwater	Small-scale reservoirs with collected water used for possible water supplies (after normal water treatment), groundwater recharge in spreading basins, or for ornamental/recreational lakes.
Treatment options	Sedimentation in larger storage facilities. If entering public water supply, water would be further treated at community water treatment facility.
Special considerations	Water contact recreation and consumptive fishing not recommended, but park water features for aesthetics possible. Groundwater recharge may be safe depending on land uses in area, effectiveness of soil-aquifer treatment, and groundwater uses.

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Small Scale Site Use Beneficial Uses of Stormwater

On-site stormwater harvesting for small-scale beneficial uses include several categories of opportunities that result in reductions in domestic water use, depending on the land use and size of buildings.

- **toilet flushing** (direct replacement of domestic water supply)
- **irrigation** of landscaped areas surrounding buildings (direct replacement of domestic water supply up to current use levels, but may exceed current use due to availability of water and for the need to empty storage tanks before expected rains)
- **storage and later controlled releases** (mostly for runoff volume reductions in areas of combined sewers, but the stored water is available for on-site use, such as irrigation and vehicle/equipment washing)
- **HVAC make-up water** (direct replacement of domestic water supply)
- **vehicle/equipment washing** (direct replacement of domestic water supply)
- **firefighting water** (evaporative make-up water from storage ponds and test water for on-site storage ponds and dry hydrants)
- **shallow aquifer recharge** (mostly for runoff volume reductions for stormwater or combined sewer management, but the groundwater recharge can benefit long-term stream flows and water supplies as a secondary/indirect benefit)
- **aesthetics and water f**eatures (direct replacement of make-up water supplied by domestic water supply due to evaporation or seepage losses for on-site ponds and fountains)

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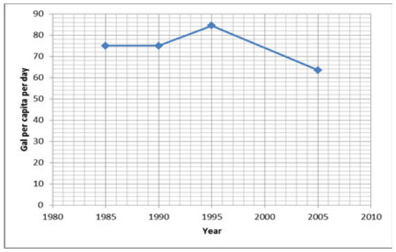
Estimates of Per Capita Water Use

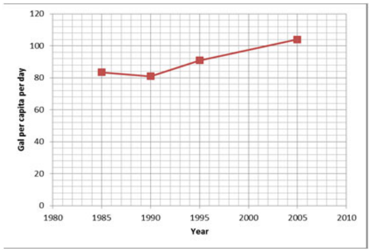
Use	Gallons Per Capita/Day	Percentage of Total
Domestic	79.2	44
Industrial	42.2	24
Commercial	26.4	15
Public	15.8	9
Loss and Waste	13.2	8
TOTAL	177	100

From: *Water Supply and Sewerage, Sixth Edition*. Terence J. McGhee. McGraw-Hill Publishing Company. 1991.

Domestic Water Use Trends in the US



Essex County NJ daily per capita Water Use.



Per capita daily Water Usage in the Kansas City MO Metropolitan Area.

These data are available from the Census Bureau and the USGS for all counties in the US as a valuable resource for studying trends in populations and water use.

Example Domestic Indoor Water Use in the US

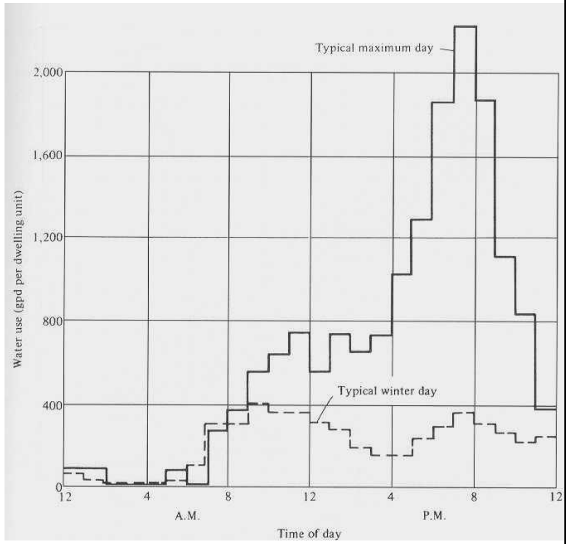
Home Uses	Daily Water Use Per Person	
	Gallons	Percent
Toilet	32	45
Bathing/Personal Hygiene	21	30
Laundry/Dishes	14	20
Drinking/Cooking	3	5
TOTAL	70	100

Reported Household Water Use and Amounts used for Toilet Flushing in Various Countries

Location	Per Capita Domestic Water Use per Day (L/c/d and date)	Toilet Usage of Indoor Water Supply (% of total supply and L/c/day)
Germany	126 (2004)	30% (38 L/c/day)
Ireland	148 (2006)	22% (33)
Poland	110 (2003) (Gdansk)	n/a
Denmark	131 (2005)	22% (29)
Finland	120 to 150 (2004)	14% (19)
The Netherlands	127 (2006)	29% (37)
Austria	125 to 135 (2007)	22% (29)
Hong Kong	230 (2004)	n/a
Nigeria	30 to 67 (cooking, drinking, bathing and washing only) (2002)	n/a
Israel	300 (1998)	n/a
Millburn, NJ	240 (2005)	n/a
Kansas City, MO	393 (2005)	n/a

Daily Water-Use Patterns in Residential Area: Maximum Day (with irrigation) and Minimum Day

From: *Water Supply and Pollution Control, Sixth Edition*. Warren Viessman, Jr. and Mark J. Hammer, Addison-Wesley. 1998.



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On-Site Building-Scale Beneficial Uses of Stormwater

Decorated rain barrels as part of EPA/Kansas City public education program for Green Infrastructure controls.

Large water storage tank at Heathcote, Australia winery.

Water storage tank at Washington, D.C. fire station storing roof runoff.

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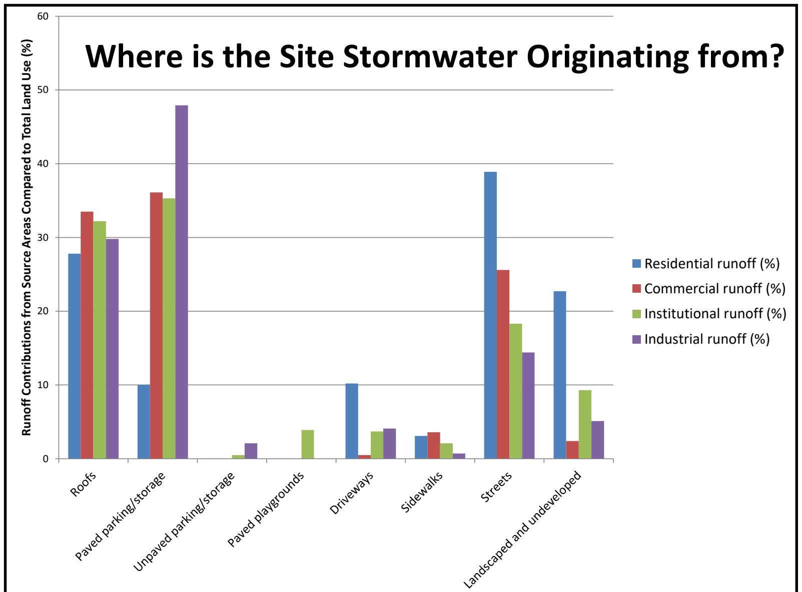
Where is the Site Stormwater Originating from?



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Irrigation Calculations

- For most irrigation calculations, minimum application of water to meet the evapotranspiration (ET) deficit is used (Et minus soil moisture from rainfall).
- For maximum use of stormwater, it is desired to irrigate at the highest rate possible, without causing harm to the plants.
- For a “healthy” lawn, total water applied (including rain) is generally about 1" of water per week, or 4" per month.
- However, 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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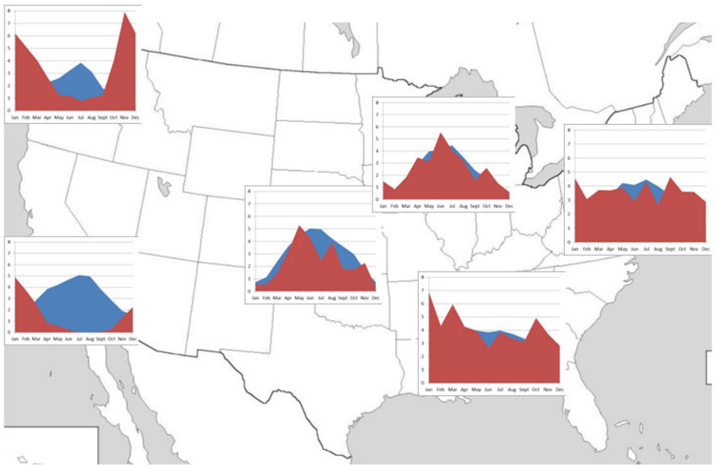
Evapotranspiration and Soil Moisture Deficit Plots Showing Minimum Irrigation Needs



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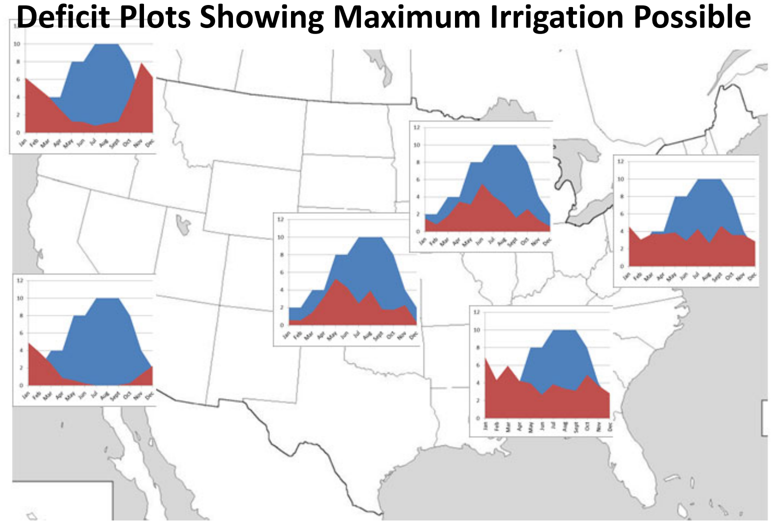
Maximum Water use by Plants and Soil Moisture Deficit Plots Showing Maximum Irrigation Possible



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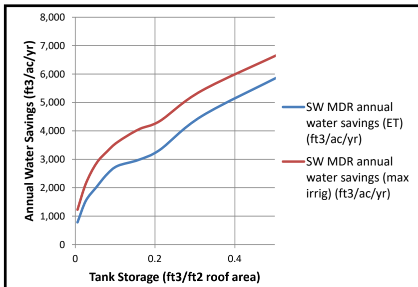

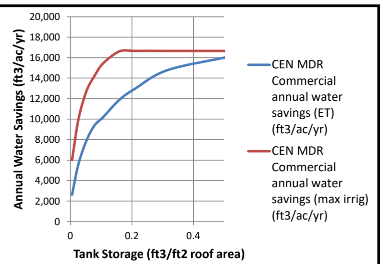

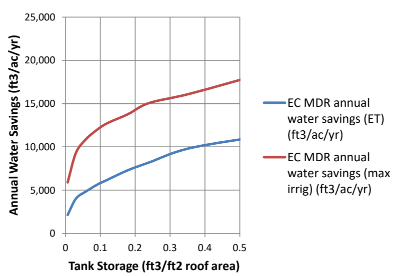

Use of roof runoff at medium density residential areas for irrigation for different sized storage tanks and US locations.

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Storage Tank Sizes for Different Ranges of Captured Runoff

storage tank volume (ft^3)	Approximate runoff removal range (% of long-term runoff for 1,000 ft^2 impervious area at six US regions)	Gallons of runoff per 1,000 ft^2 impervious area to fill tank (maximum available for beneficial uses between each event)	number of 35 gal rain barrels per 1,000 ft^2 impervious area	number of 5 ft D, 5 ft tall tanks (730 gallons; 98 ft^3) per 1,000 ft^2 impervious area	number of 10 ft D, 10 ft tall tanks (5,900 gallons; 785 ft^3) per 1,000 ft^2 impervious area
10	20 to 30	75	**2**	<1	
30	45 to 60	224	**6**	<1	
100	80 to 90	748	21	**1**	<1
300	98 to 100	2,244	64	**3**	<1
500	99 to 100	3,740	107	**5**	<1
1,000	100	7,480	214	10	**1.3**

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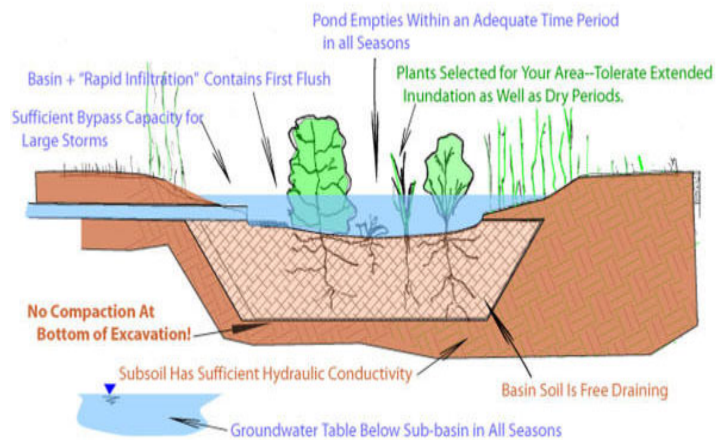
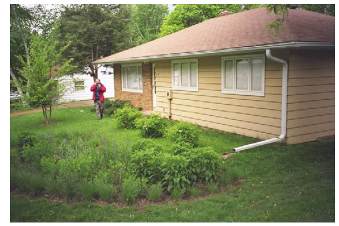
Shallow Aquifer Recharge using Stormwater

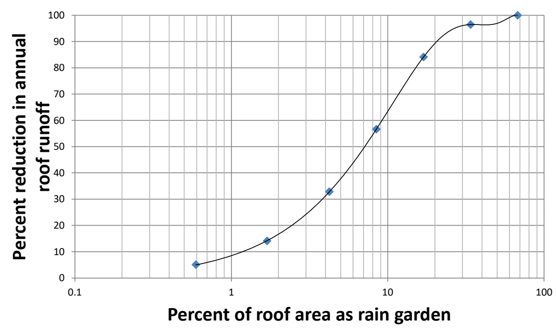


Cross-section of typical rain garden (source: Villanova University Stormwater Partnership).





Residential "rain gardens" for local groundwater recharge (MO and WI)



As the rain garden size increases in relationship to the roof area, less water is discharged to the combined sewer collection system. About 90% of the long-term runoff would be infiltrated for a rain garden that is about 20% of the roof area. For the 900 ft^2 roofs in the Kansas City study area which receives about 39 inches of rain per year, about 2,400 ft^3 of water per year per household is infiltrated with rain gardens at this size. There are 6 homes per acre in the study area, so this corresponds to more than 14,000 ft^3/yr/ac that could contribute to the shallow groundwater.

Neighborhood-Scale Beneficial Uses of Stormwater

- **Toilet flushing** using neighborhood non-potable water delivery system (direct replacement of domestic water supply; usually supplied by alternative "purple pipe" system to several buildings)
- **Shallow aquifer recharge** using mixed stormwater from multiple source areas (mostly for runoff volume reductions for stormwater or combined sewer management, but the groundwater recharge can benefit long-term stream flows and water supplies as a secondary/indirect benefit)
- Neighborhood-scale stormwater collection for **irrigation** beneficial uses (direct replacement of domestic water supply up to current use levels, but may exceed current use due to availability of water and for the need to empty storage tanks before expected rains; usually supplied by alternative "purple pipe" system to nearby areas)
- **Firefighting water supply** (evaporative make-up water from storage wet ponds having dry hydrants and test water for on-site storage ponds and dry hydrants; mostly used in institutional and industrial areas)
- **HVAC makeup water** (direct replacement of domestic water supply; mostly used in larger buildings or institutional areas)
- **Vehicle/equipment washwater** (direct replacement of domestic water supply)
- **Aesthetics and water features** (direct replacement of make-up water supplied by domestic water supply due to evaporation and seepage loses from on-site ponds and fountains)

Retrofitted curb-cut biofilters in commercial areas in Kansas City.

Large stormwater park at 18th and Broadway in downtown Kansas City integrating underground storage for beneficial irrigation use along with surface water features and infiltration.

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Curb-cut biofilter monitored at Kansas City during the EPA's National Demonstration Project of Green Infrastructure.

Monitored large biofilters in Cincinnati at a community college.

Large biofilter series at St. Francis apartments, Cincinnati.

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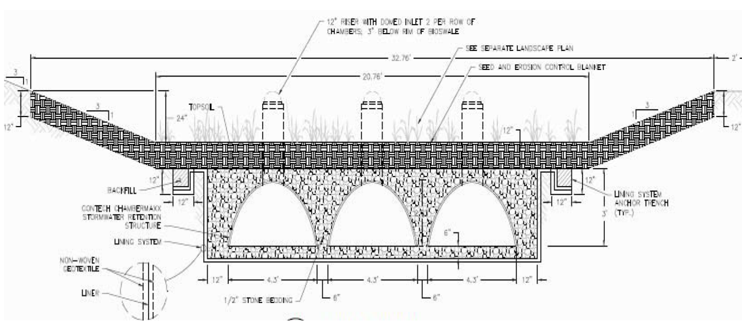
Multi-Use "Bioswale" to Transport, Treat, and Store Runoff for Later Beneficial Use



Biofilter/swale with underground water storage vaults for irrigation use (drawing used with permission from Geosyntec and Boeing).

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Land Use Community-Scale Beneficial Uses of Stormwater

- **toilet flushing** in surrounding buildings (direct replacement of domestic water supply; delivered in a secondary water supply system of "purple pipes" to distinguish from the normal domestic water supply)
- **irrigation** of landscaped lands in the surrounding area (direct replacement of domestic water supply; delivered in a secondary water supply system of "purple pipes" to distinguish from the normal domestic water supply)
- **deep aquifer recharge** (long-term storage with partial recovery of water through a system of injection and recovery wells; water is usually used to augment the public water supply; typically undergoes extensive treatment before injection and also receives additional treatment through soil-aquifer treatment processes).
- **shallow aquifer recharge** (long-term storage with partial recovery; infiltration may occur in impoundments along major river channels or in special off-line storage areas located in natural recharge zones; long-term recovery through wells and water is usually used to augment the public water supply)
- **storage reservoirs** (located to collect stormwater from surrounding area to directly augment local water supply)
- **aesthetics and water features** (direct replacement of evaporative make-up water in park ponds or waterways)

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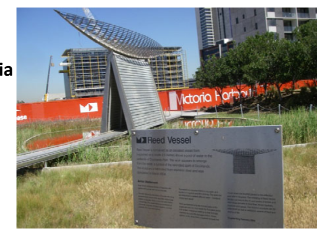
Toilet Flushing using Community Non-Potable Water Delivery System

- Toilet flushing may require about 35 gallons/person/day. The population density for single family residential areas (the most common land use in large areas) is estimated to be about 10 persons/acre for this example. Toilet flushing therefore can use about 350 gallons/day/acre. For a 100 acre residential area, this comes out to about 12 million gallons/year, or 1.7 million ft^3/yr (or about 40 ac-ft/yr for 100 acres).
- In large systems, sizing the storage volume to match the use pattern is usually not critical, as double mass balance curves are usually used to determine reservoir storage volumes based on inflow fluctuations and demand curves. Therefore, it is assumed that sufficient storage is available to capture all of the stormwater runoff for an area.
- Previous summaries on expected runoff volumes from medium density residential areas ranged from about 25,000 $ft^3/ac/yr$ for the arid southwest (as represented by Los Angeles, CA) to about 65,000 $ft^3/ac/yr$ for the wetter east coast (as represented by Newark, NJ). For 100 acres, the total stormwater runoff would therefore be about 2.5 million ft^3/yr (or about 60 ac-ft/yr for 100 acres) in the arid southwest to about 6.5 million ft^3/yr (or about 150 ac-ft/yr for 100 acres) for the wetter east coast.
- Therefore, most areas of the US can supply the toilet flushing requirements, except possibly for the most arid locations, with additional water available for other uses (such as irrigation or equipment/building washwater).
- All of the stormwater used for these beneficial uses would directly decrease the demand on the normal public water supply system.

Irrigation Beneficial Uses using Community Non-Potable Water Delivery System

- Irrigation of landscaped areas varies greatly for different locations and application rates. As noted above for toilet flushing, it is assumed that the storage systems are capable for retaining all of the stormwater for an area (except for unusually rare very high flow conditions) based on flow and demand double mass balance calculations.
- For a 100 acre medium density residential area, total stormwater flows would be about 2.5 million ft^3/yr (or about 60 ac-ft/yr for 100 acres) in the arid southwest to about 6.5 million ft^3/yr (or about 150 ac-ft/yr for 100 acres) for wetter areas. Irrigation needs are obviously greater for the arid locations (assuming conservation plantings are also not utilized) than for the wetter areas.
- Seasonal use and rainfall patterns which dramatically affect the efficiency of irrigation using harvested roof runoff in small on-site locations would not be an issue for the expected much larger community stormwater impoundments which are designed to collect and store most of the yearly runoff.

Docklands, downtown Melbourne, Australia showing public sculpture garden in wetland area near large underground tanks.

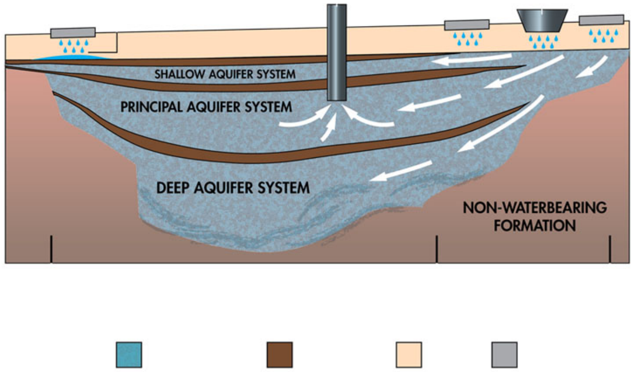


An example of a large stormwater storage facility for later beneficial uses is at the Docklands Park in Melbourne, Australia. Docklands Park is a downtown open space with an area of 2.7 ha. The park collects stormwater from the adjacent ultra-urban catchment of downtown Melbourne, providing water for park irrigation. Stormwater is collected from the NAB building roof and forecourt, Harbour Esplanade, Grand Plaza, and a portion of the Bourke St. extension. The water is directed by gravity or pumped to the Docklands Park underground stormwater storage tanks after passing through three wetlands which are capable of treating approximately 80% of the runoff generated from the 4.8 ha catchment area. Treated stormwater is stored in the underground storage tanks and the captured stormwater is also treated using UV prior to use. The three underground storage tanks have a combined capacity of 500 m^3.

Community Collection of Stormwater to Augment General Water Supply by Shallow or Deep Aquifer Recharge or Surface Impoundments

- An important use of stormwater in some areas is to recharge the regional aquifers for future withdrawal to augment the local water supply. This can be accomplished through such practices as river bank infiltration systems and off-line infiltration basins (for shallow aquifer recharge in natural recharge areas), or through injection wells.
- Deep aquifers may store the water for several years (or decades) while it travels to withdrawal locations. In these cases, not all of the water that is used for recharge is withdrawn. It is also possible to capture the stormwater in surface impoundments that are integral components of the water supply system, without passing through aquifers. In this case, almost all of the stormwater is available for augmenting the water supply (except for evaporation or seepage loses).
- A 100 acre medium density residential area would produce annual runoff yields varying from about 60 to 150 ac-ft/yr (southwest arid to wetter east coast conditions). Assuming a population density of about 10 persons/acre and a conventional total water use of about 80 gallons/person/day (which excludes extensive outside water use), the total water demand for 100 acres of medium density residential land use would be about 90 ac-ft/yr.
- Therefore, the stormwater could supply about 65% of the total domestic water demand in arid southwest, and supply about twice the water demand for the wetter east coast conditions, not considering outdoor water use.

Percolation of Stormwater for Later use



Source: SCWC Stormwater White Paper

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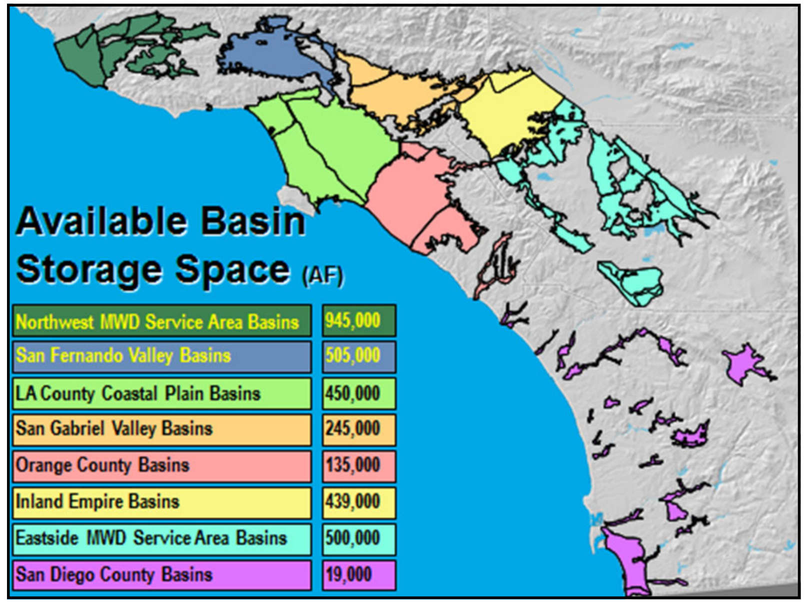

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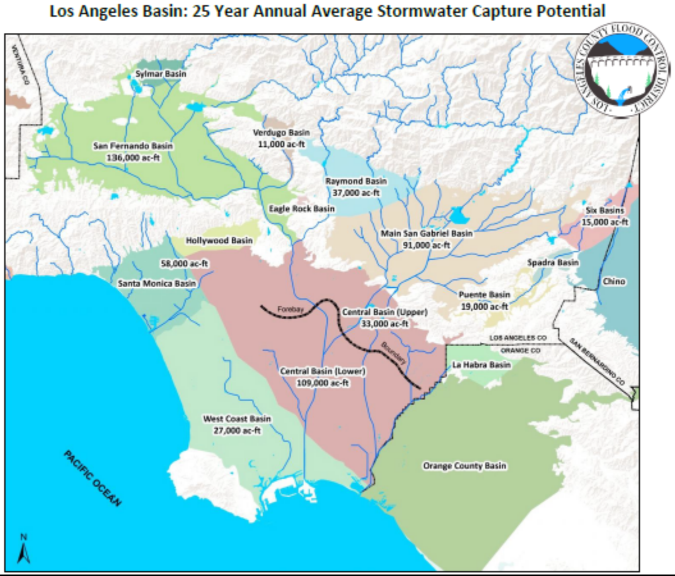
Los Angeles Basin: 25 Year Annual Average Stormwater Capture Potential



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Conclusions

- Public water supplies are being stressed with increasing populations and diminishing available supplies.
- Beneficial uses of stormwater can replace some of the non-consumptive used of the domestic water supply (especially irrigation and toilet flushing)
- With suitable storage, stormwater can supply most/all of these non-consumptive needs, reducing water demands from the public water supply by significant amounts.
- Availability vs. demand time-series, water quality, necessary treatment, and costs currently restrict the wide-spread use of beneficial use of stormwater.

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Conclusions (cont.)

- The range of approaches being used for stormwater beneficial uses is vast, with some areas simply concerned with capturing any available runoff possible to augment scarce local supplies, while other examples are in water-rich areas and the runoff is being harvested for beneficial uses to conserve already abundant water supplies.
- The methods used for storage and treatment are also seen to vary greatly, from local clay jars to vast underground reservoirs, and many recharging aquifers for later withdrawal.
- The uses of the harvested runoff also vary from irrigation and toilet flushing only, to all domestic water uses, plus a variety of commercial and industrial uses.

Conclusions (cont.)

- The safest beneficial uses of stormwater are mainly for purposes having low potentials for human contact, such as irrigation.
- Treatment also is seen to vary from virtually none to very sophisticated water treatment systems. Treatment is generally based on general stormwater pollution control techniques, however, advanced techniques together with disinfection are used if there is a higher potential for human contact.
- Beneficial uses of stormwater are not effectively regulated at this time (most reuse regulations are based on beneficial uses of treated sanitary wastewaters, for example). Given the potential for beneficial uses of stormwater in many areas of the US, higher priority should be given to development of specific guidelines.