Modeling Green Infrastructure Components in a Combined Sewer Area

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Kansas City's CSO Challenge

- Combined sewer area: 58 mi^2
- Fully developed
- Rainfall: 37 in./yr
- 36 sewer overflows/yr by rain > 0.6 in; reduce frequency by 65%.
- 6.4 billion gal overflow/yr, reduce to 1.4 billion gal/yr
- Aging wastewater infrastructure
- Sewer backups
- Poor receiving-water quality

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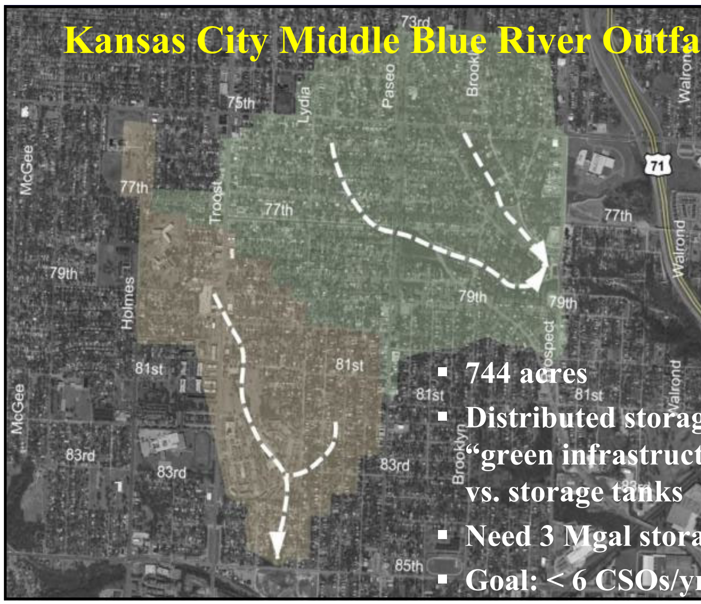
Kansas City Middle Blue River Outfalls



- 744 acres
- Distributed storage with "green infrastructure" vs. storage tanks
- Need 3 Mgal storage
- Goal: < 6 CSOs/yr

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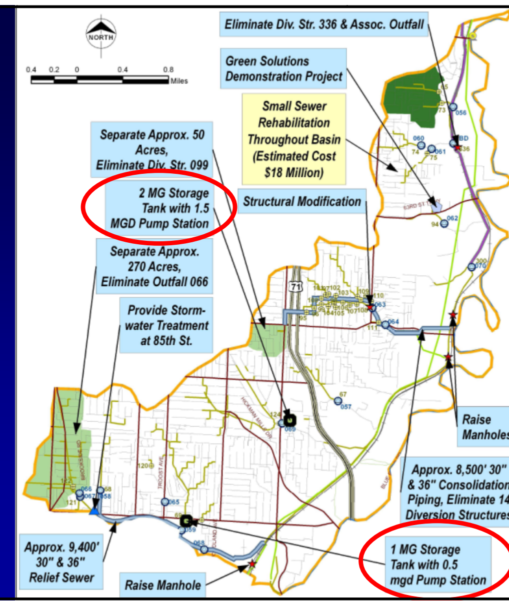
Kansas City's Original Middle Blue River Plan with CSO Storage Tanks



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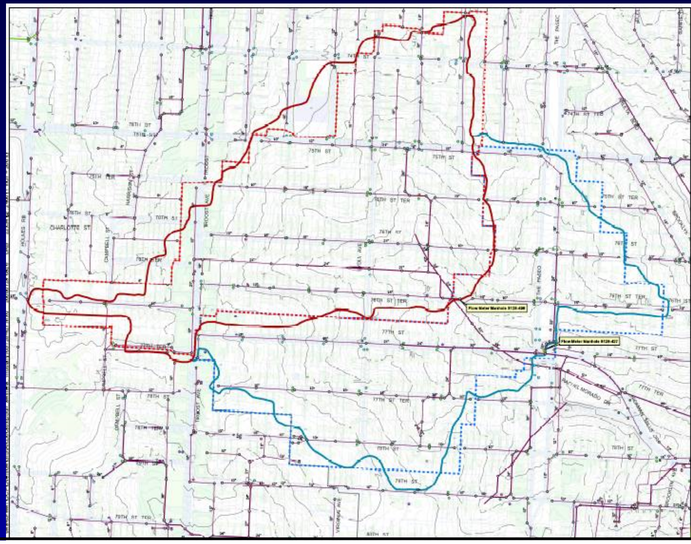
Adjacent Test and Control Watersheds



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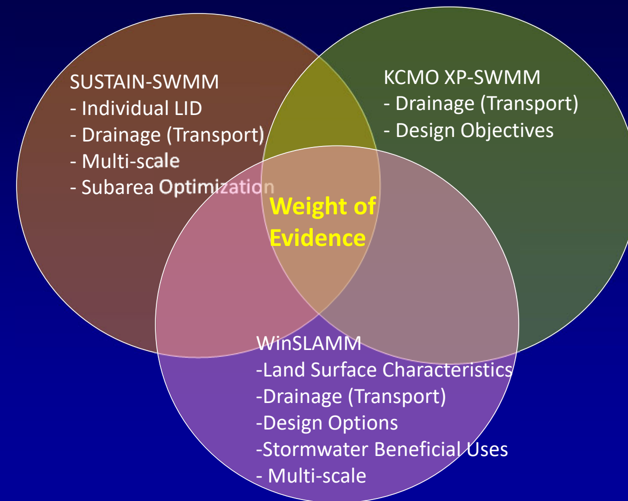
KC's Modeling Connections



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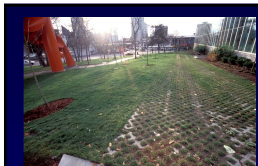
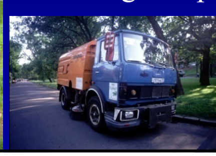
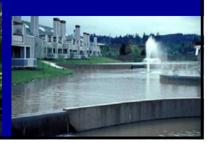


Control Devices Included in WinSLAMM

- Hydrodynamic devices
- Development characteristics
- Wet detention ponds
- Porous pavement
- Street cleaning
- Green roofs
- Catchbasin cleaning
- Grass swales and grass filtering
- Biofiltration and bioretention
- Cisterns and stormwater use
- Media filtration/ion exchange/sorption



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Major Land Use Components in Residential Portion of Study Area (% of area and % of total annual flow contributions)

	Roofs	Drive-ways	Side-walks	Park-ing	Streets	Land-scaped	Total
Directly connected	2 (6)	4 (9)	1 (3)	2 (5)	9 (21)		18 (44)
Disconnected	11 (7)	4 (3)	1 (1)				16 (11)
Landscaped						66 (45)	66 (45)
Total area	13	8	2	2	9	66	100

Based on KCMO GIS mapping and detailed site surveys, along with WinSLAMM calculations.

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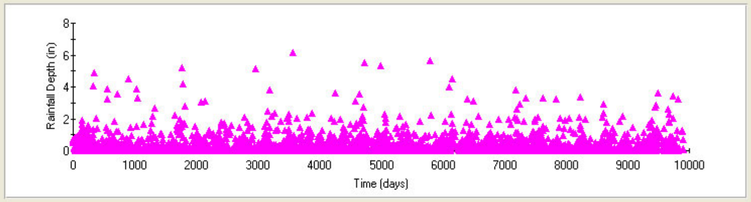
Kansas City 1972 to 1999 Rain Series

Rainfall Parameter File

File

Rain File Name: C:\PROGRAM FILES\WINSLAMM\RAIN FILES\MO KANSAS CITY INTL AP 7299.RAN



November 1972

Redraw Graph

Start Date: 11/01/72

End Date: 12/19/99

Rain Number	Julian Starting Date	Starting Date	Starting Time	Ending Date	Ending Time	Rainfall Depth (in)	Duration (hrs)	Intensity (in/hr)	Interevent Time (days)
1	0.00	11/01/72	00:00	11/01/72	17:00	0.72	17.00	0.04	4.58
2	5.29	11/06/72	07:00	11/06/72	18:00	0.51	11.00	0.05	2.75
3	8.50	11/09/72	12:00	11/10/72	01:00	0.60	13.00	0.05	2.63
4	11.67	11/12/72	16:00	11/13/72	19:00	0.72	27.00	0.03	2.25
5	15.04	11/16/72	01:00	11/16/72	09:00	0.14	8.00	0.02	2.46
6	17.83	11/18/72	20:00	11/19/72	04:00	0.11	8.00	0.01	5.46
7	23.63	11/24/72	15:00	11/25/72	04:00	0.20	13.00	0.02	9.04
8	33.21	12/04/72	05:00	12/04/72	10:00	0.02	5.00	0.00	0.75
9	34.17	12/05/72	04:00	12/05/72	06:00	0.02	2.00	0.01	0.58
10	34.83	12/05/72	20:00	12/05/72	21:00	0.02	1.00	0.02	3.42
11	38.29	12/09/72	07:00	12/09/72	13:00	0.25	6.00	0.04	1.96

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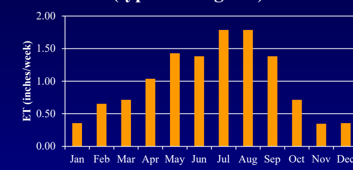
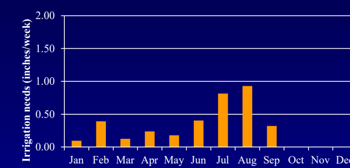
Water Harvesting Potential of Roof Runoff

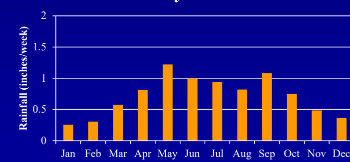
Evapotranspiration per Month (typical turfgrass)



Supplemental Irrigation Needs per Month (typical turfgass)



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.

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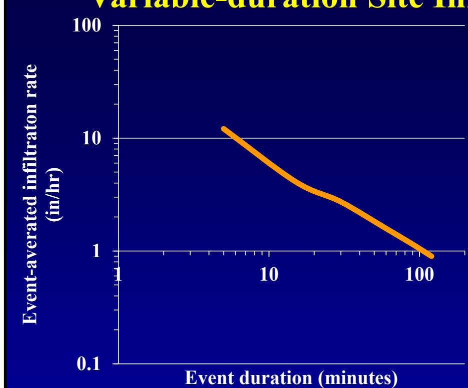
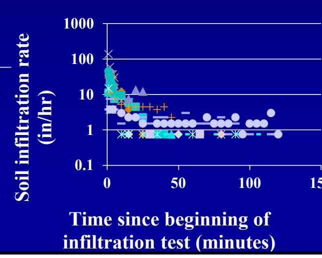
Variable-duration Site Infiltration Rates



The surface infiltration rates are less than 1 in/hr for rains about 2 hrs duration, but can be greater for shorter duration events. Subsurface measurements have indicated that infiltration rates are lower for most of the area in the drainage zones.

Must consider effects of scaling, location, and uncertainty in measured values.



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Modeling of Controls for Directly Connected Roof Runoff

This presentation focuses on the results of recent modeling efforts examining rain barrels/water tanks and rain gardens to control the annual runoff quantity from directly connected roofs. The modeling is being expanded as the curb-cut biofilter designs are finalized.

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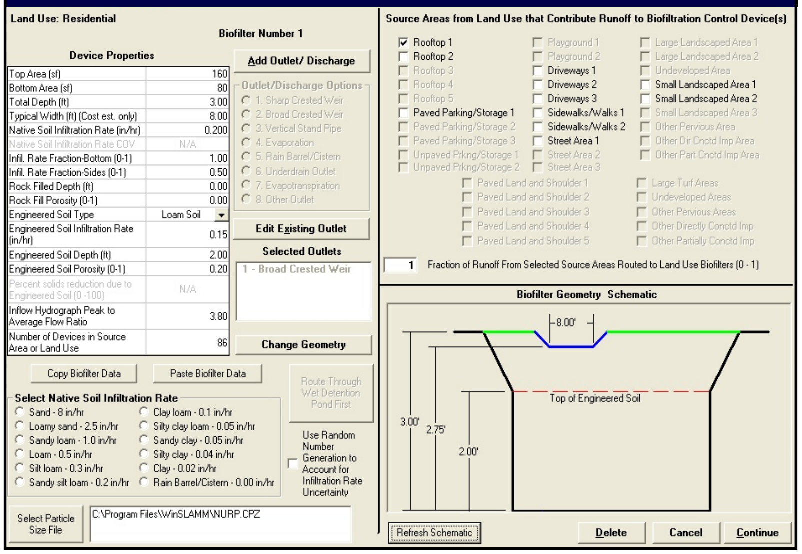
Basic Rain Garden Input Screen in WinSLAMM



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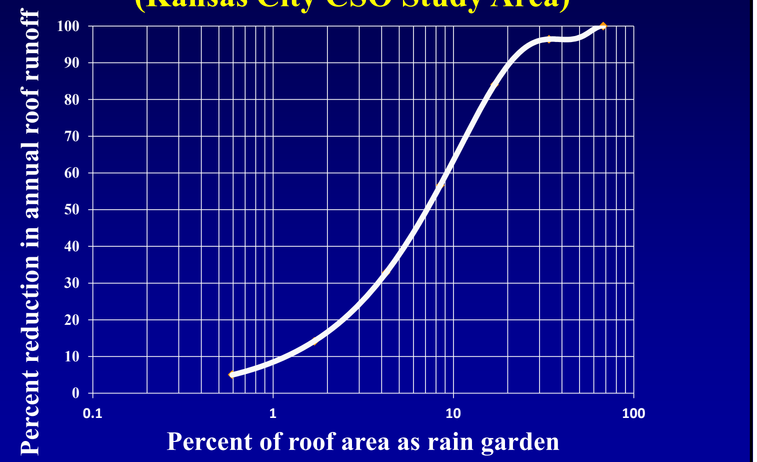
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Gardens (Kansas City CSO Study Area)



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Household water use (gallons/day/house) from rain barrels or water tanks for outside irrigation to meet ET requirements:

January	42	July	357
February	172	August	408
March	55	September	140
April	104	October	0
May	78	November	0
June	177	December	0

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Water Use Calculations in WinSLAMM

WinSLAMM conducts a continuous water mass balance for every storm in the study period.

For rain barrels/tanks, the model fills the tanks during rains (up to the maximum amount of runoff from the roofs, or to the maximum available volume of the tank).

Between rains, the tank is drained according to the water demand rate. If the tank is almost full from a recent rain (and not enough time was available to use all of the water in the tank), excess water from the event would be discharged to the ground or rain gardens after the tank fills.

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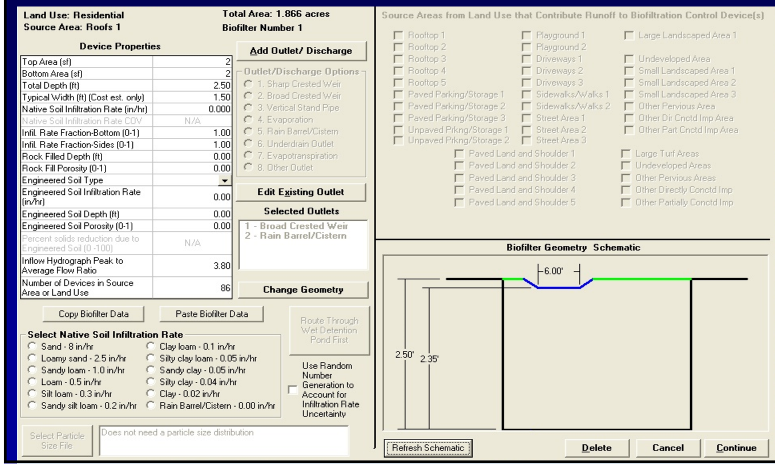
Basic Rain Barrel/Water Tank Input Screen in WinSLAMM (same as for biofilters, but no soil infiltration and with water use profile)



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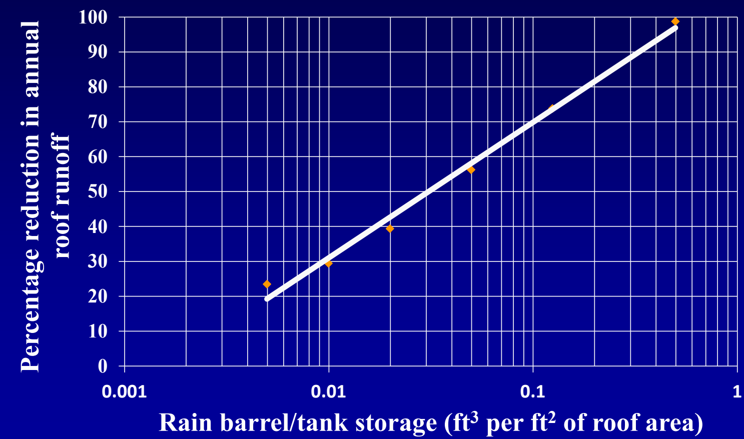
Reductions in Annual Flow Quantity from Directly Connected Roofs with the use of Rain Barrels and Water Tanks (Kansas City CSO Study Area)



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0.12 ft of storage is needed for use of 75% of the total annual runoff from these roofs for irrigation. With 945 ft² roofs, the total storage is therefore 113 ft³, which would require 25 typical rain barrels, way too many! However, a relatively small water tank (5 ft D and 6 ft H) can also be used.

rain barrel storage per house (ft³)	# of 35 gallon rain barrels	tank height size required if 5 ft D (ft)	tank height size required if 10 ft D (ft)
0	0	0	0
4.7	1	0.24	0.060
9.4	2	0.45	0.12
19	4	0.96	0.24
47	10	2.4	0.60
118	25	6.0	1.5
470	100	24	6.0

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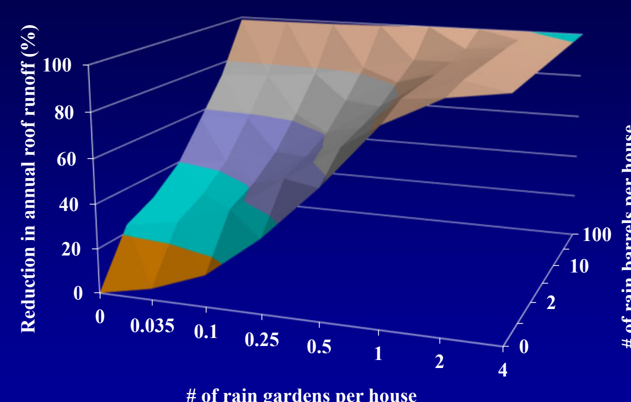
Interaction Benefits of Rain Barrels and Rain Gardens in the Kansas City CSO Study Area



Two 35 gal. rain barrels plus one 160 ft² rain garden per house can reduce the total annual runoff quantity from directly connected roofs by about 90%

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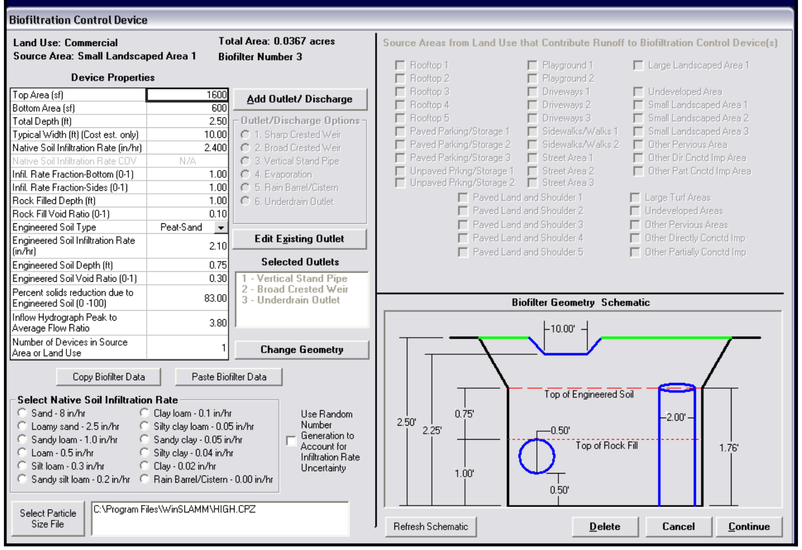
Biofilter Design with multiple layers and outlet options



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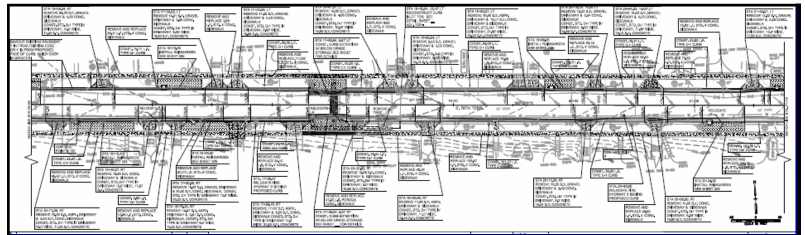
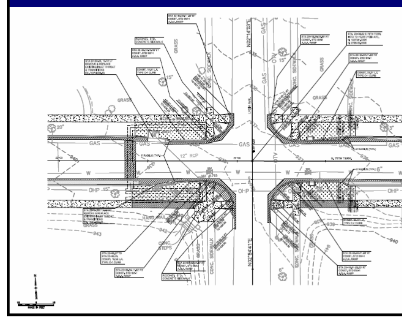
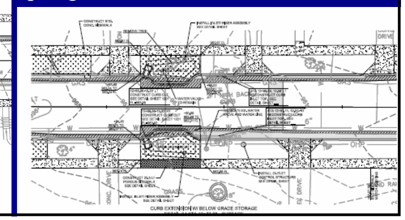


Examples from "65%" plans prepared by URS for project streets. Plans reviewed and modeled by project team, and construction will occur in spring and summer of 2011.





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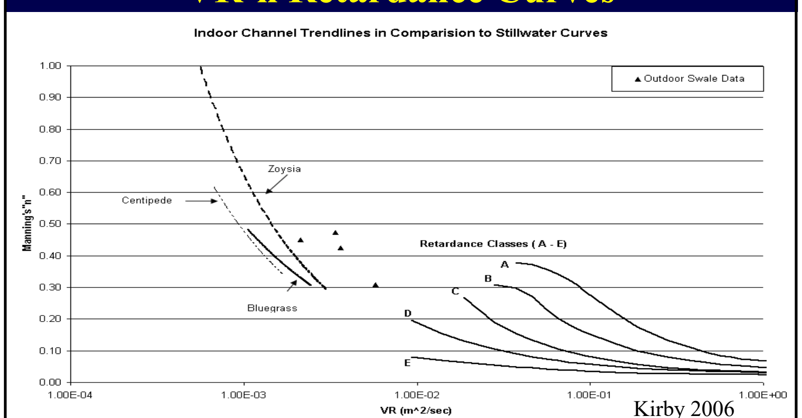
Low Flow vs. Historical Stillwater, OK, VR-n Retardance Curves



Swale and grass filter hydraulic characteristics can be predicted on the basis of flow rate, cross sectional geometry, slope, and vegetation type.

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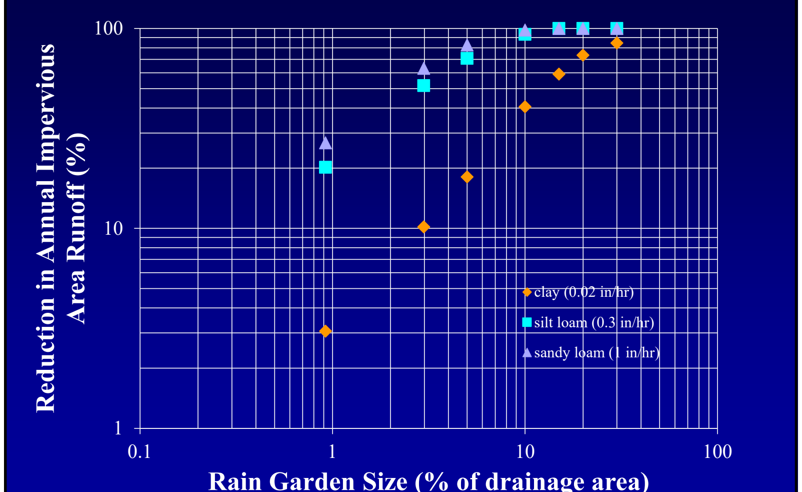
Annual Runoff Reductions from Paved Areas or Roofs for Different Sized Rain Gardens for Various Soils



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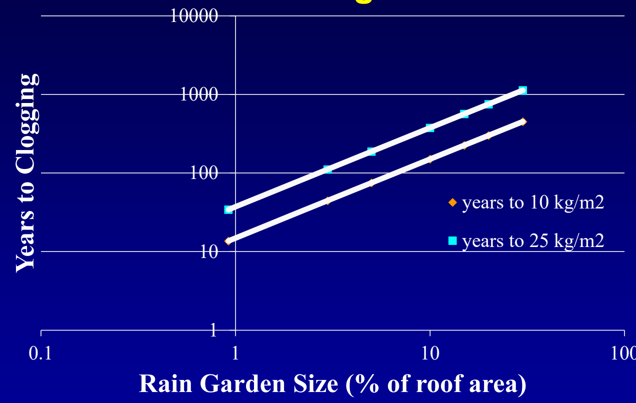
Clogging Potential for Different Sized Rain Gardens Receiving Roof Runoff



Clogging not likely a problem with rain gardens from roofs

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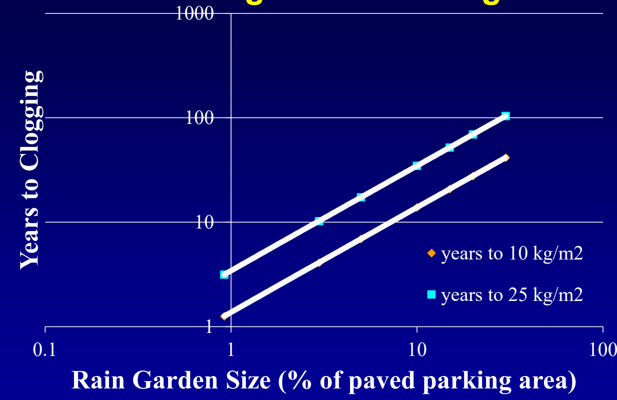
Clogging Potential for Different Sized Rain Gardens Receiving Paved Parking Area Runoff



Rain gardens should be at least 10% of the paved drainage area, or receive significant pre-treatment (such as with long grass filters or swales, or media filters) to prevent premature clogging.

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Conclusions

- Extensive use of biofilters and other practices is needed in order to provide significant benefits to the combined sewer system.
- Placement and design of these controls is very critical. Roof runoff rain gardens located at disconnected roofs are less than 10% as effective compared to directly connected roofs.
- Critical hydrologic and hydraulic processes for small flows and small areas are not the same compared to large events and large systems.
- Detailed site surveys are needed to determine actual flow paths; remote sensing is limited for these details.
- The weight-of-evidence provided by independent evaluations decreases the uncertainty of complex decisions.

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