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About 40 years working in the area of wet weather flows; effects, sources, and control of stormwater. About 100 publications, including several books.

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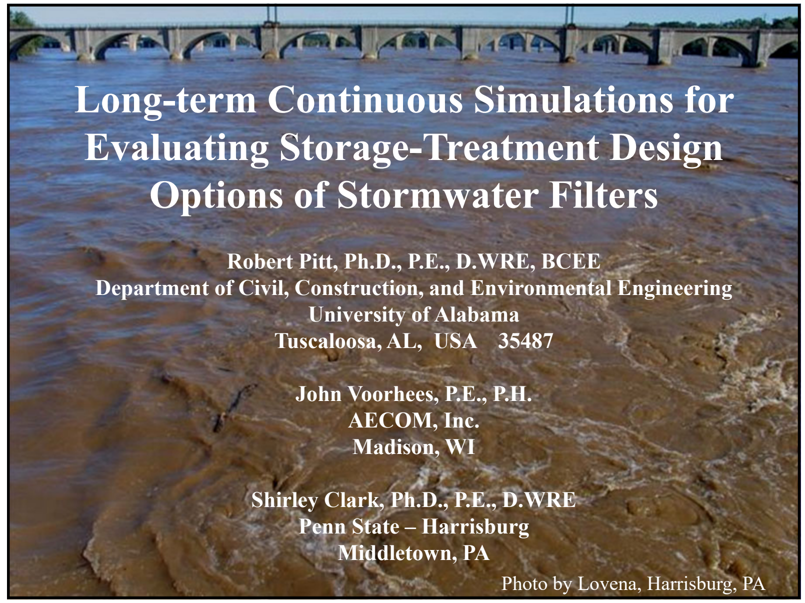

Long-term Continuous Simulations for Evaluating Storage-Treatment Design Options of Stormwater Filters

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Photo by Lovena, Harrisburg, PA

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Project Overview

- The performance of a stormwater treatment filter is dependent on the amount of the annual runoff that is treated and by the level of treatment provided.
- Most filters usually have a maximum treatment flow rate that can be utilized per filter unit to obtain the stated treatment level of the treated water.
- The use of up-gradient storage can moderate the high flows, decreasing the amount of stormwater that is bypassed without treatment.
- The sizing of this adjacent storage should be done in conjunction with a continuous model that can evaluate many storage-treatment combinations.

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Multi-Unit Examples of Stormwater Filters in Large Vaults to Handle Large Flows

The typical approach to treat large flows is to use a large number of filter units.

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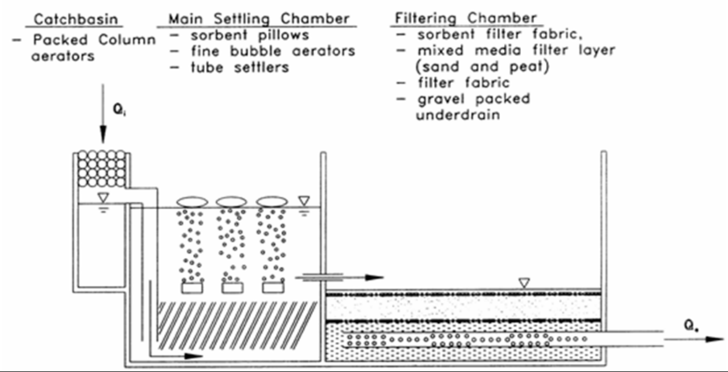
The Multi-Chambered Treatment Train (MCTT) was developed by Pitt (1999) for the EPA to provide pre-treatment of stormwater from critical source areas before infiltration. In order to handle a wide range of flows and to provide excellent treatment, storage (provided in the main settling chamber) before the filtration unit was considered a critical unit process.



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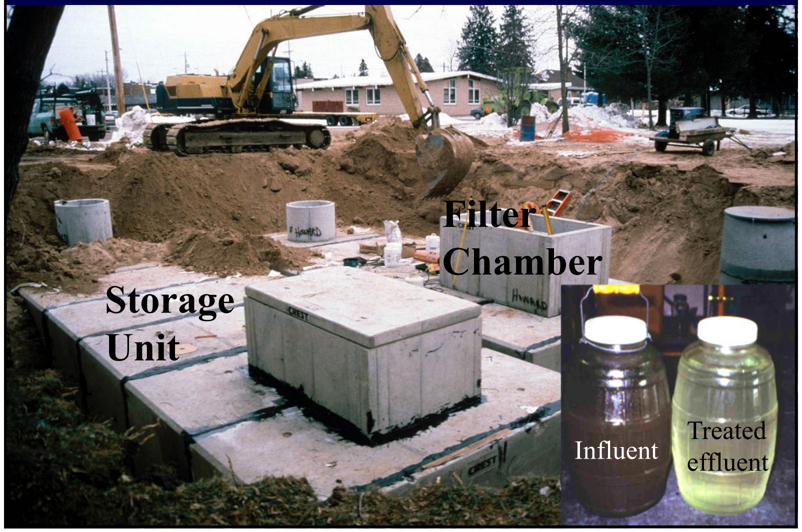
Minocqua, WI, MCTT Installation



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Knowledge of Site Hydrology is Critical in the Design of Stormwater Treatment Systems

- Continuous simulations allow evaluations to consider highly varying flow rates and antecedent conditions.
- Critical flow characteristics vary for different regions and for different development characteristics.
- This example is for commercial paved areas, common locations for stormwater filters.
- A typical five year period used by the state of Wisconsin for stormwater quality evaluations was used in the evaluations.

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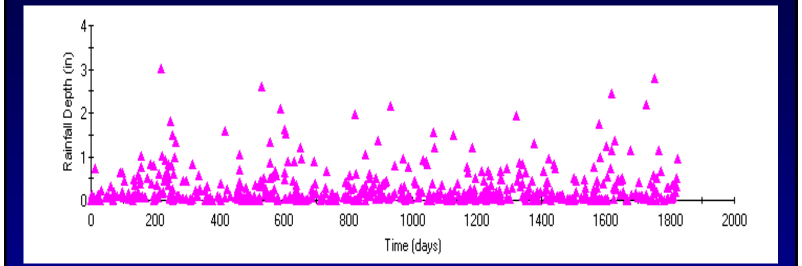
Five year plot of Madison, WI total rain depths (1980 through 1985)



This period was selected by the WI DNR and the USGS to be representative of typical long-term conditions, and not to contain any unusually large rains. The largest rains in this period were about three inches in depth. A treatment system designed to treat 100% of the resultant flows from these events may bypass some limited flows every several years, depending on the frequency of very large drainage-class storm events.

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Flow Rate Distribution Calculations

- WinSLAMM was used to calculate cumulative flow rate distribution plots for all events in the 5-year study period. These flows were calculated on 6-minute increments, then exported to Excel, sorted and summed to prepare the fraction of time associated with any flow rate, or less.
- Another plot was created showing how adjacent storage and controlled releases could reduce these flows.

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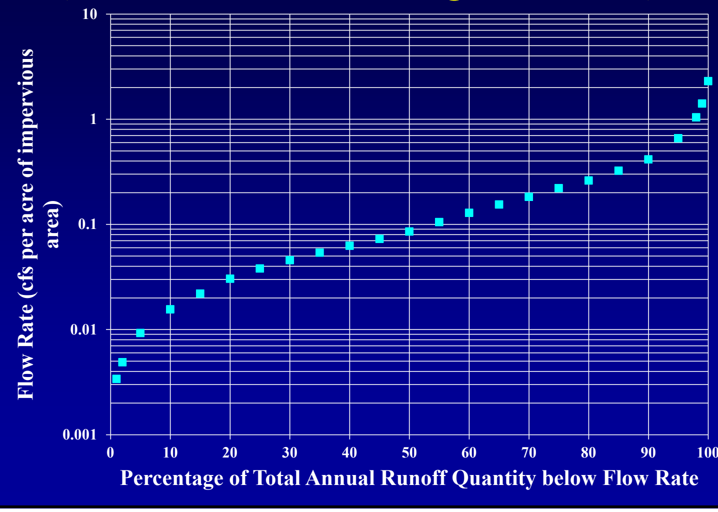
Annual Cumulative Flow Rate Distributions (Madison, WI, 1980 through 1985 rains)



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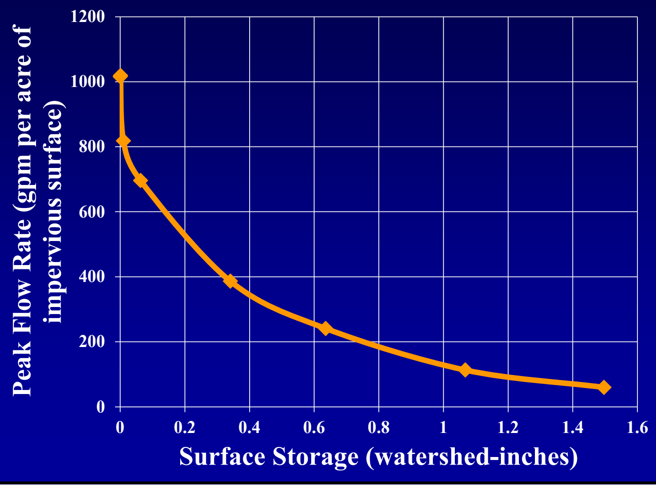
Effects of Storage on Peak Flow Rates (Madison, WI)



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Treatment Flow Rates and Fraction of Total Flow Treated

- The 6-minute calculated flows were used to determine treatment flow rate effects.
- A number of treatment flow rates were subtracted from all of the calculated site runoff rate values. The excessive flows not treated for each flow increment were then summed and compared to the total flow quantity. These excessive flow sums for each treatment flow rate were then plotted to indicated how much of the total period flow would be treated, if different treatment flow rates were available.

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Treatment Flow Rates and Fraction of Total Flow Treated (cont.)

- This was repeated using the adjusted 6-minute flow rate distributions associated with different storage volumes. These results were also plotted to indicate the benefits of storage and treatment flow rates on the amount of the total flow able to be treated.

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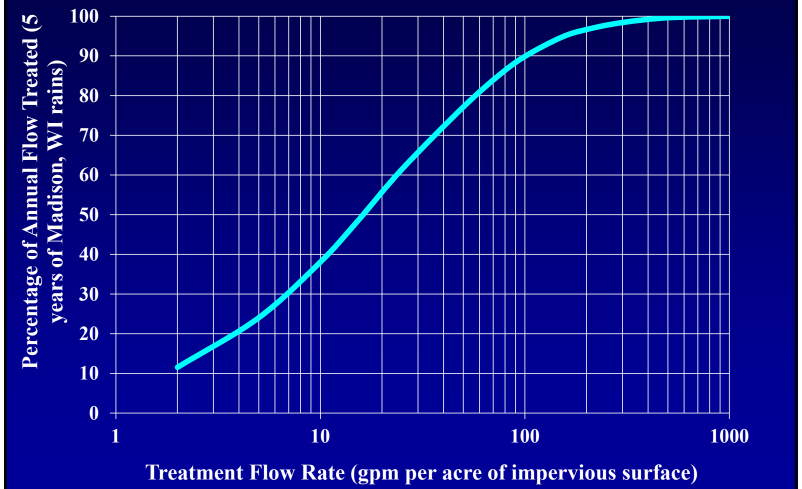
Percentage of Annual Flows Treated for Different Treatment Flow Rates (no storage)



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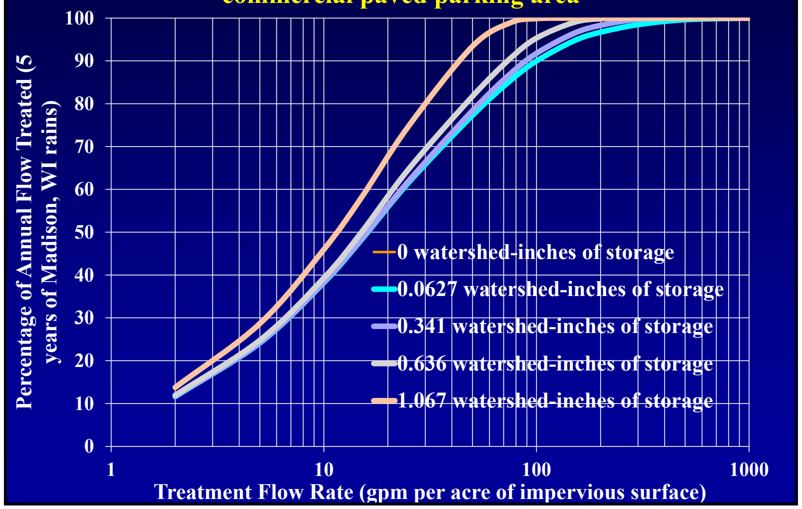
Effects of treatment flow rate and storage on percentage of annual flow treated, 1980 through 1985 Madison, WI rains and one acre commercial paved parking area



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- As an example, about 45 gpm per acre of impervious area can provide 90% treatment of the total period flows, if about 1.1 inches of storage was available.
- Very little benefit is available for storage amounts up to about 0.34 inches.

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Storage-Treatment Examples

- The following examples examine several treatment objectives and show how interactions of storage and treatment can be used to select the most cost-effective combination.
- Typical filter and storage costs are shown on the following tables and are used in conjunction with the previous performance curves to determine the costs of the different treatment and storage options.

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Example Filter Costs

	Cost for Filters	Total Treatment Flow Rate (gpm)	Total Storage in Basic Unit (ft^3)
small vault and 3 filter cartridges	$14,500	22.5	72
plus another 3 filter cartridges (total of 6)	$19,000	45	72
large vault with 9 filter cartridges	$33,500	67.5	360
plus another 3 filter cartridges (total of 12)	$38,000	90	360
plus another 3 filter cartridges (total of 15)	$42,500	112.5	360

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Example Storage Volumes and Costs

Total Storage Volume (ft^3)	Number of Each Type of Storage Tank (200 ft^3/1,000 ft^3/6,000 ft^3)	Total Cost for Storage
200	1/0/0	$5,000
400	2/0/0	10,000
1,000	0/1/0	15,000
2,000	0/2/0	30,000
6,000	0/0/1	40,000
12,000	0/0/2	80,000

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Example Cost and Performance Scenarios

- The following plots examine a series of different combinations of storage and filtration capacity. Each example uses a different set of conditions that are able to meet the performance objectives.
- For each option, a combination of filters and storage volume was determined to meet the performance objective. The costs for each of these components are plotted separately for each option, along with the total costs for both components. The least cost option that can meet the performance objective is then easily identified.

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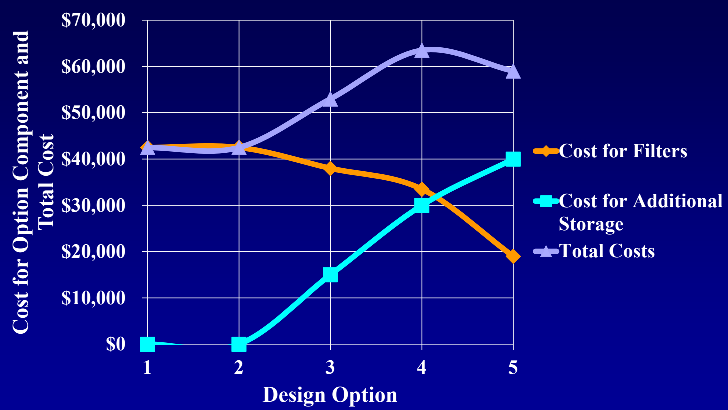
1) Goal is to treat 90% of the annual runoff



The most cost-effective solution is to use the basic filter only option with 15 filter cartridges (total cost of $42,500) for the acre of impervious area, without any additional storage.

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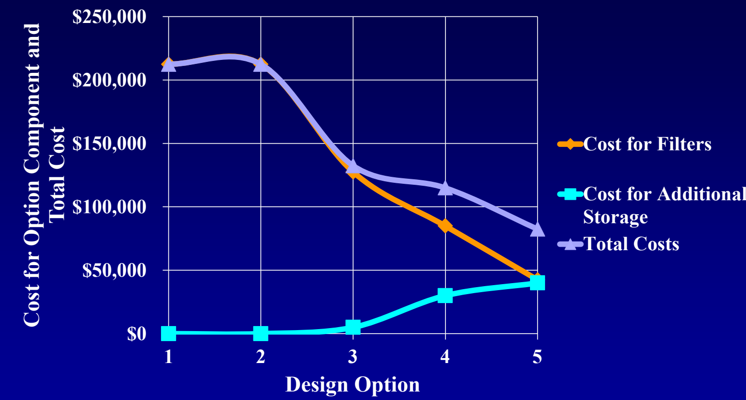
2) Goal is to treat 100% of the annual runoff (which is becoming common now with numeric standards in stormwater permits)



The most cost-effective solution is to use the largest amount of storage (total cost of about $82,500). About 70 cartridges are needed to treat the 500 gpm peak flow rate. The cost to treat 100% of the peak expected flows is about two times the cost of treating 90% of the total runoff volume.

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3) Goal is to treat the total annual runoff at 40, 60, or 80% SSC reduction levels in order to meet TMDL requirements.

It is assumed that the filter unit can reduce the SSC at the 85% level under all flow conditions considered. The treatment flow options therefore vary for each level of control desired:

Control Option	Fraction of Total Annual Flow that Must be Treated, Assuming Constant 85% Reductions by the Filters
40% SSC Load Reductions	48%
60% SSC Load Reductions	71%
80% SSC Load Reductions	95%

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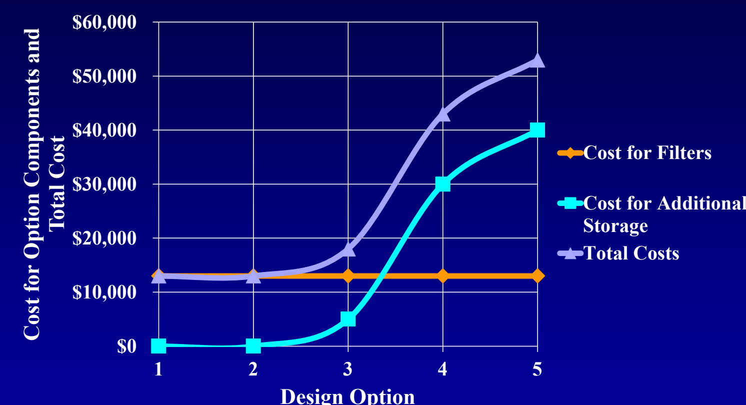
Costs for different storage-treatment options for 40% SSC load reductions



Only the smallest vault with two cartridges is needed. No additional storage is needed. The expected cost is about $13,000 per acre of impervious acre.

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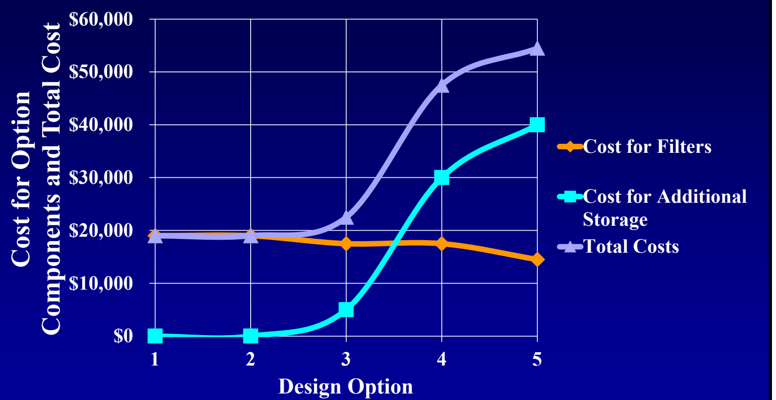
Costs for different storage-treatment options for 60% SSC load reductions



Only the smallest vault with 5 filter cartridges is needed to provide the least cost option, with no additional storage. The expected total cost is about $19,000 per acre of impervious acre.

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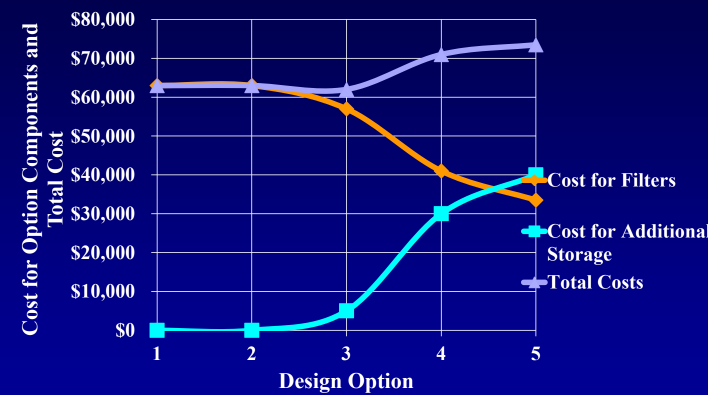
Costs for different storage-treatment options for 80% SSC load reductions



An intermediate control option is slightly more cost-effective. This option uses the large vault with 15 filter cartridges, plus the small vault with 3 more cartridges, at about $62,000 per impervious acre.

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Conclusions

- The procedures described in this paper can be effectively used to predict performance and to prepare design curves that assist in sizing stormwater filters for specific areas.
- Continuous simulations produce cumulative flow rate plots that can be used in evaluating different treatment flow rate objectives. It is possible to determine the treatment flow rates needed to treat different fractions of the total long-term flows.
- These examples, using WinSLAMM, show how dramatically the treatment flow rate is dependent on treatment objectives and how storage can be used in many cases to reduce the overall expected costs of the treatment systems, in a similar manner as used in many other fields of the water and wastewater treatment industry.

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