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December 14, 2015

Stormwater Controls for Navy Piers
Street Cleaning,

Contents

Piers are challenging for a stormwater management perspective. They have no distinguishable drainage system to install controls, expect for placement at many separate inlets. Alternatively, street cleaning may be a suitable control practice. Previous reports have discussed pollution prevention by minimizing the use of various exposed materials (such as galvanized metals). The following are brief discussions of street cleaning along with several options that can be used at the inlets.

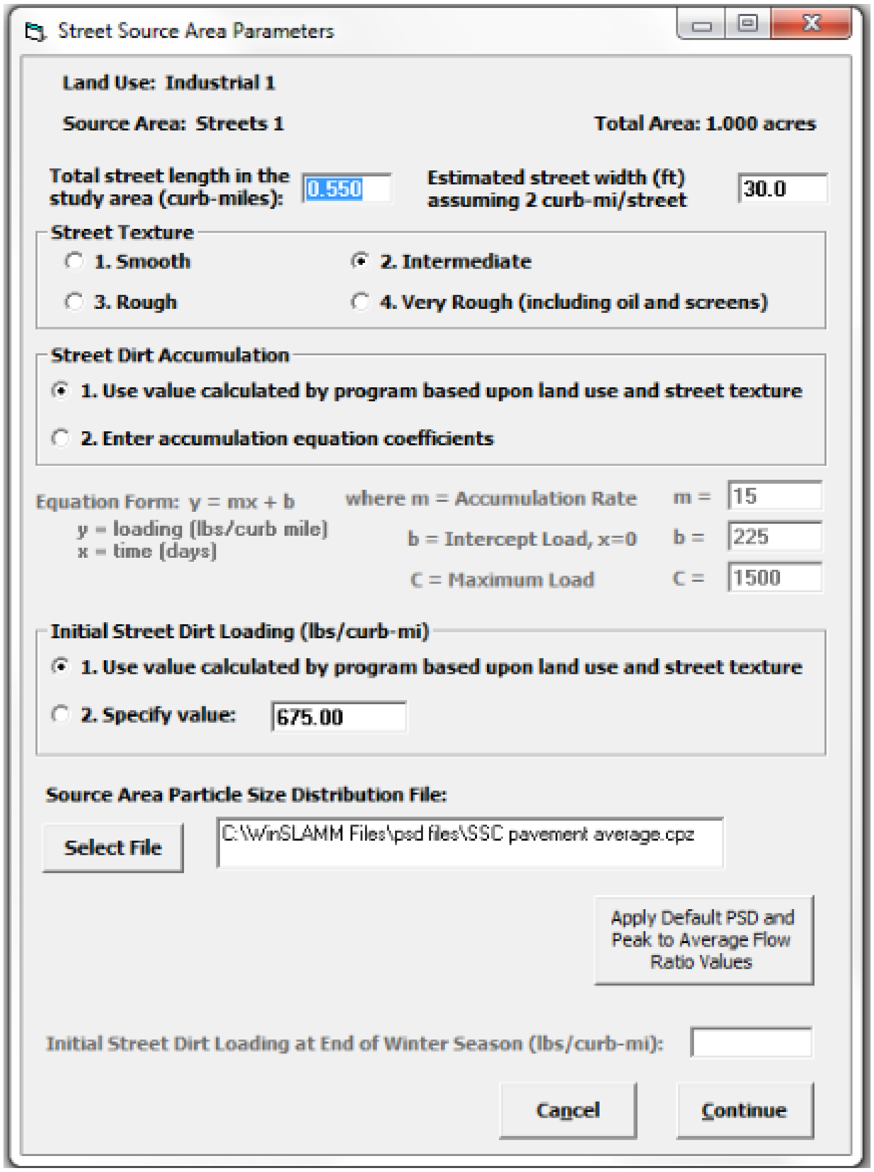
Street Cleaning

Street cleaning as a stormwater quality tool has been studied for many years as it is an easily accessible control option for most public works departments. However, there have been many misconceptions concerning street cleaning as a potential stormwater management control. Street cleaning plays an important role in most public works departments as an aesthetic and safety control measure. Street cleaning is also important to reduce massive dirt and debris buildups present in the spring in northern regions after snowmelt. Leaf cleanup by street cleaning is also necessary in most areas in the fall. However, it has been difficult to statistically demonstrate that street cleaning has a measureable benefit on outfall stormwater quality.

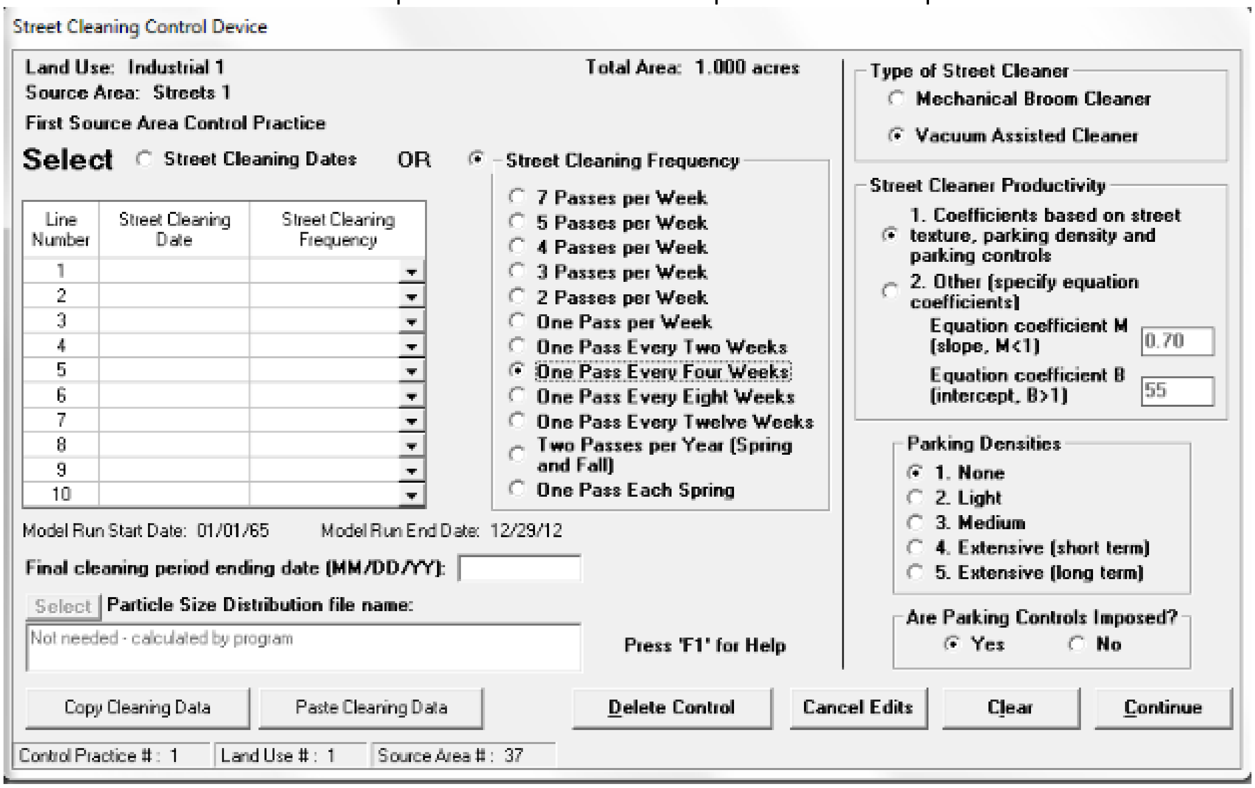
The main issues adversely affecting the benefits of street cleaners are caused by limited rain energy that preferentially removes very little of the large particles that are most effectively removed by street cleaners, and that the roads may contribute less of the total land use pollutant loads than usually assumed.

New, more efficient, street cleaners operated in locations having little other source areas are much more likely to provide water quality benefits. However, when operated in complex areas where the streets that can be cleaned make up only small portions of the stormwater pollutant discharges, street cleaning will remain limited in its water quality benefits. The use of street cleaners on paved parking and storage areas and along limited access roadways (all having drainage areas confined to the areas being cleaned) provide a greater likelihood of having measureable water quality benefits. The production functions illustrated in this discussion were developed for conditions that are expected to be most effective, such as the use of modern vacuum-assisted street cleaners at paved parking or storage areas, and where the street cleaners can operate in areas with the greatest sediment loadings with minimal interference from obstructions.

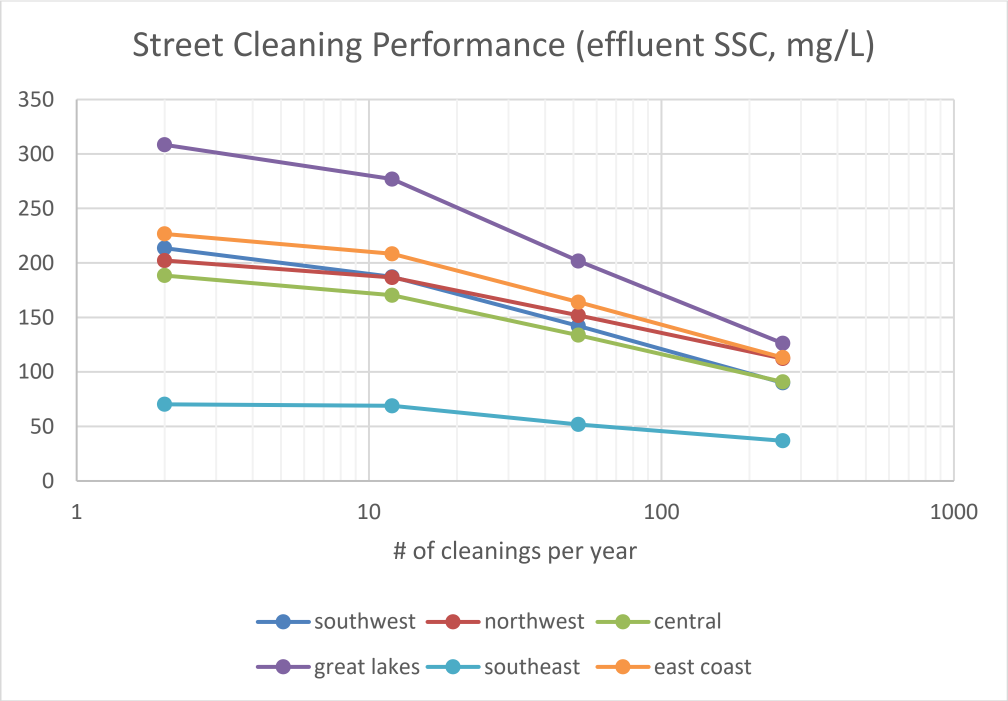
The following is a screen shot for the area being cleaned. This is shown for streets, but this has been used to obtain reasonable estimates of street cleaning in parking lots or storage areas where the street cleaners can operate in the most heavily loaded areas with minimal interference from obstructions (or parked cars).

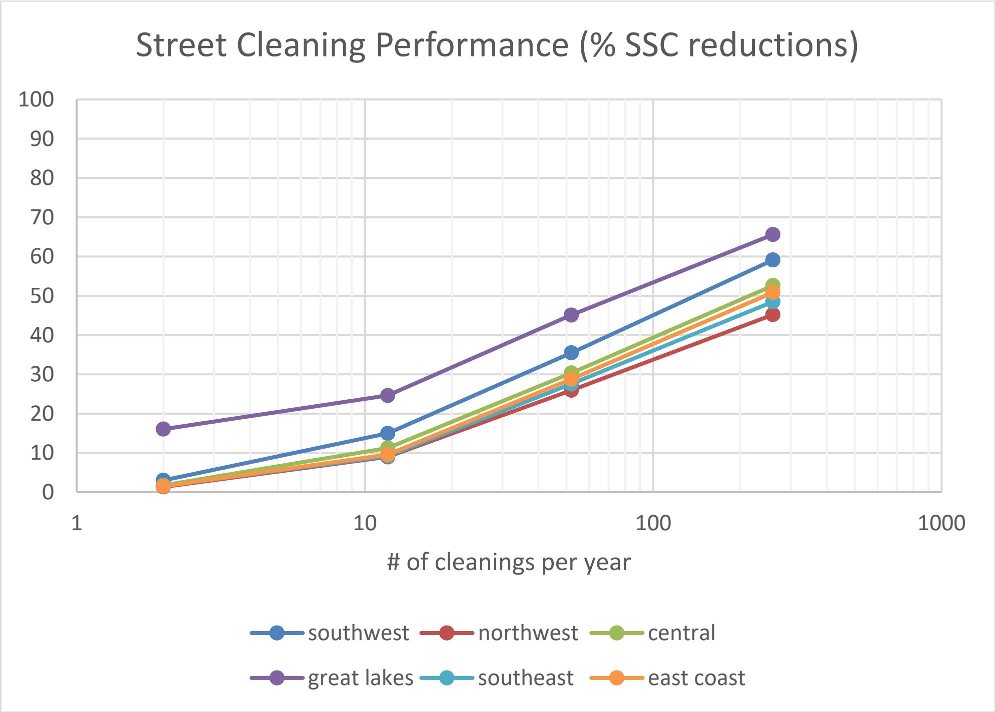


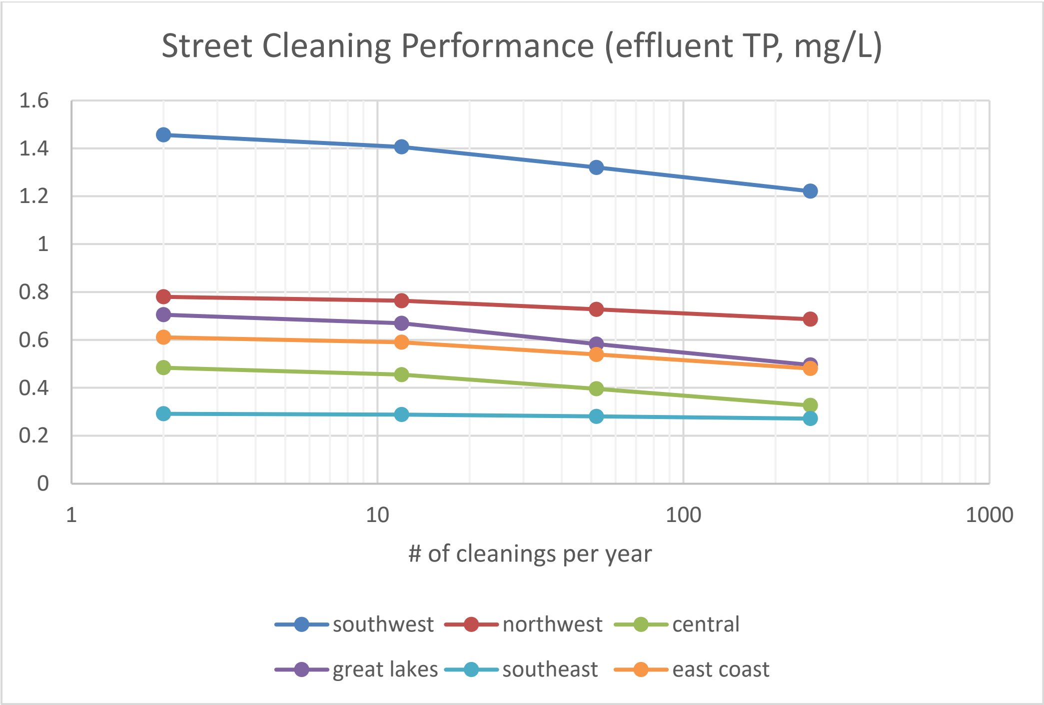
The following screen is used to describe the street cleaning operations. As noted, the high-efficiency vacuum-assisted street cleaner option was selected and no parked cars were present.

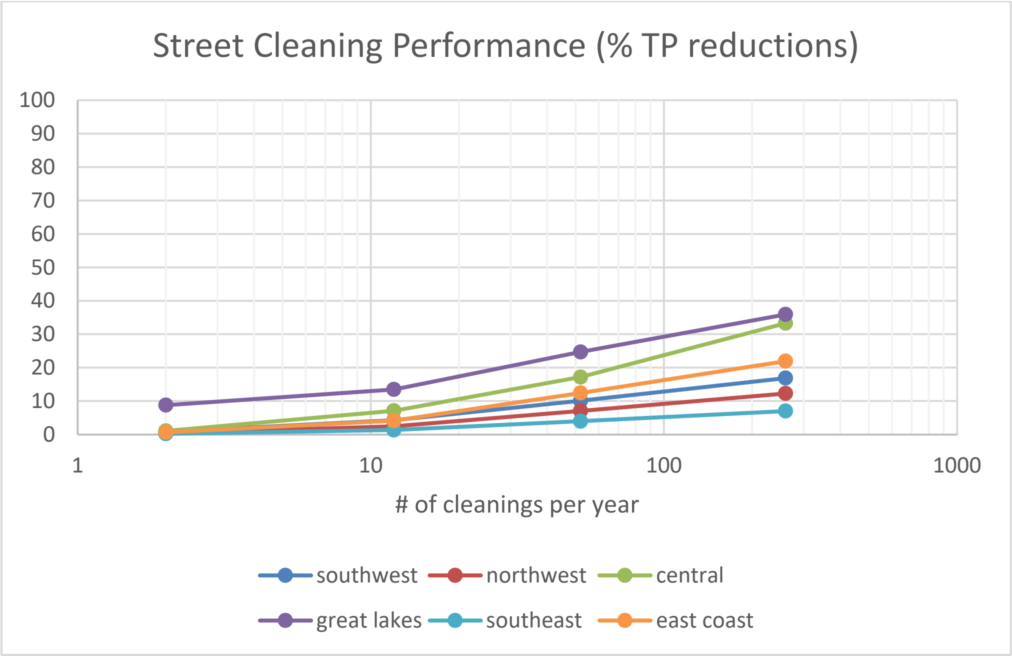


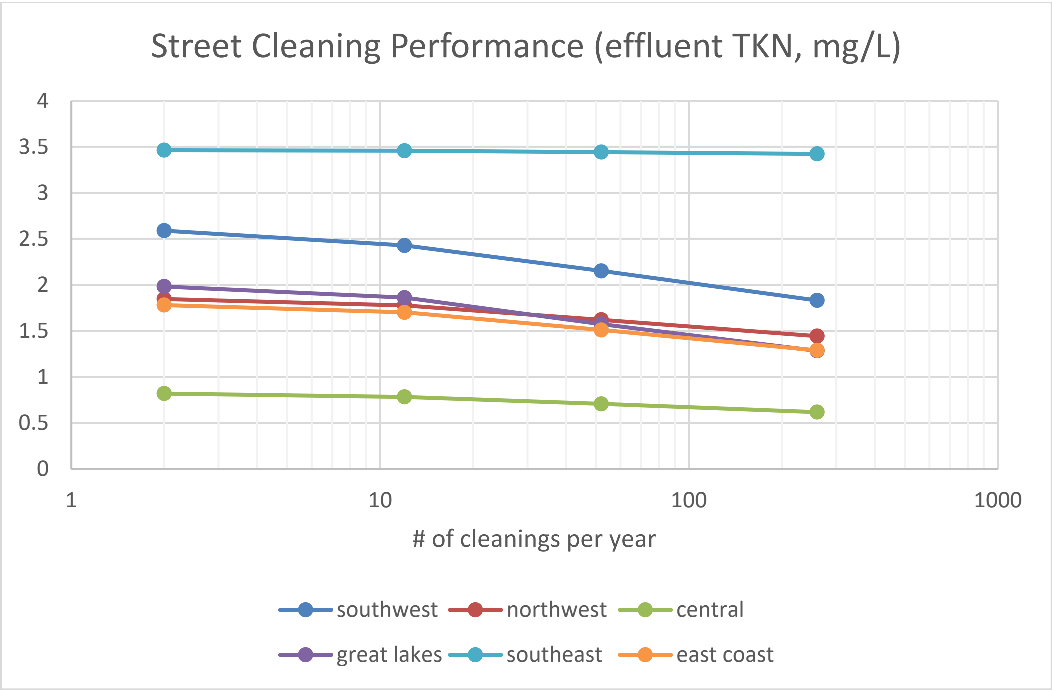
The following production functions were developed for different street cleaning frequencies: twice a year, monthly cleaning, weekly cleaning, and cleaning 5 days a week. Under all conditions, very few benefits are shown for infrequent street cleaning as it requires about weekly, or greater, cleaning to have likely measureable water quality improvements in outfall water quality.

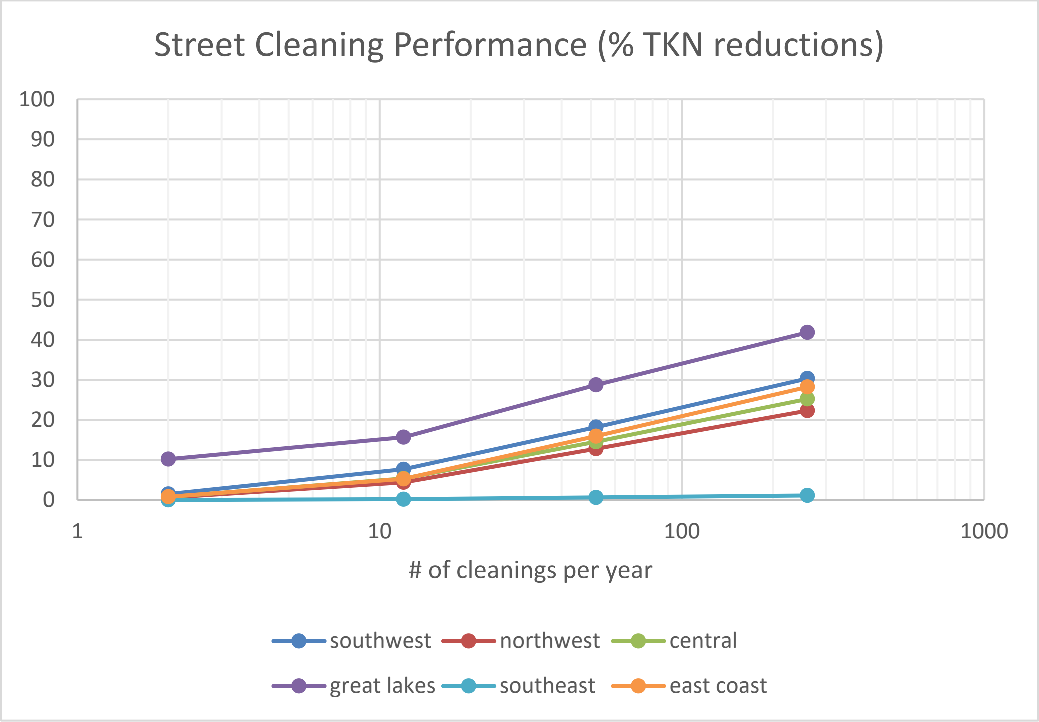

Street Cleaning Performance (effluent SSC, mg/L)
350
300
250
200
150
100
50
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast

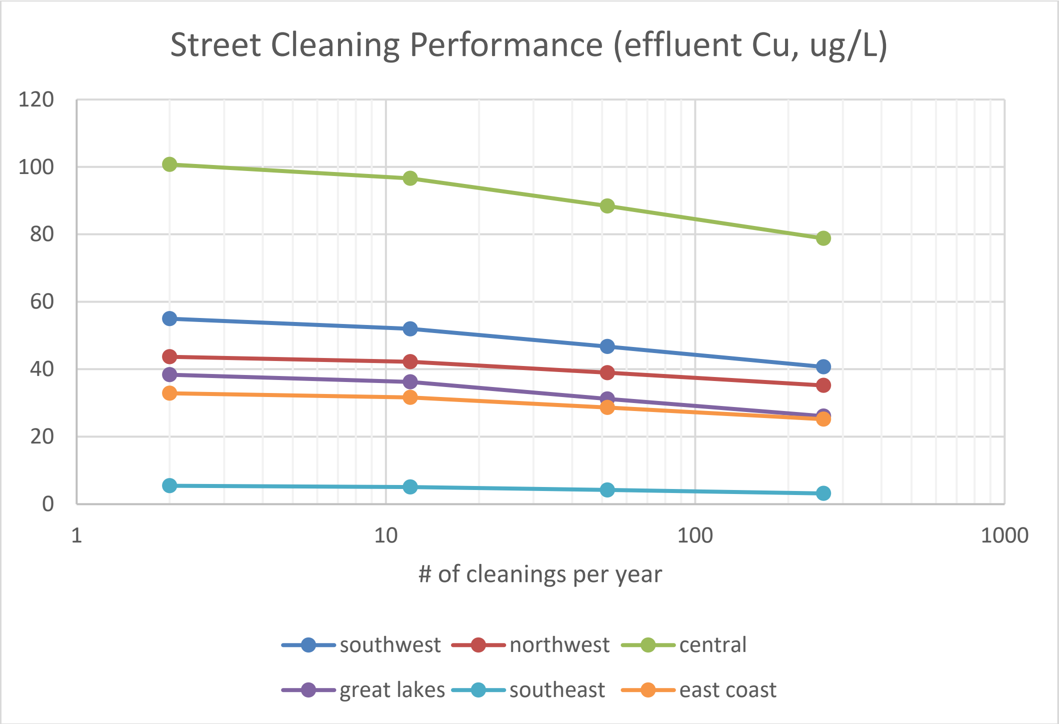

Street Cleaning Performance (% SSC reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast


Street Cleaning Performance (effluent TP, mg/L)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast

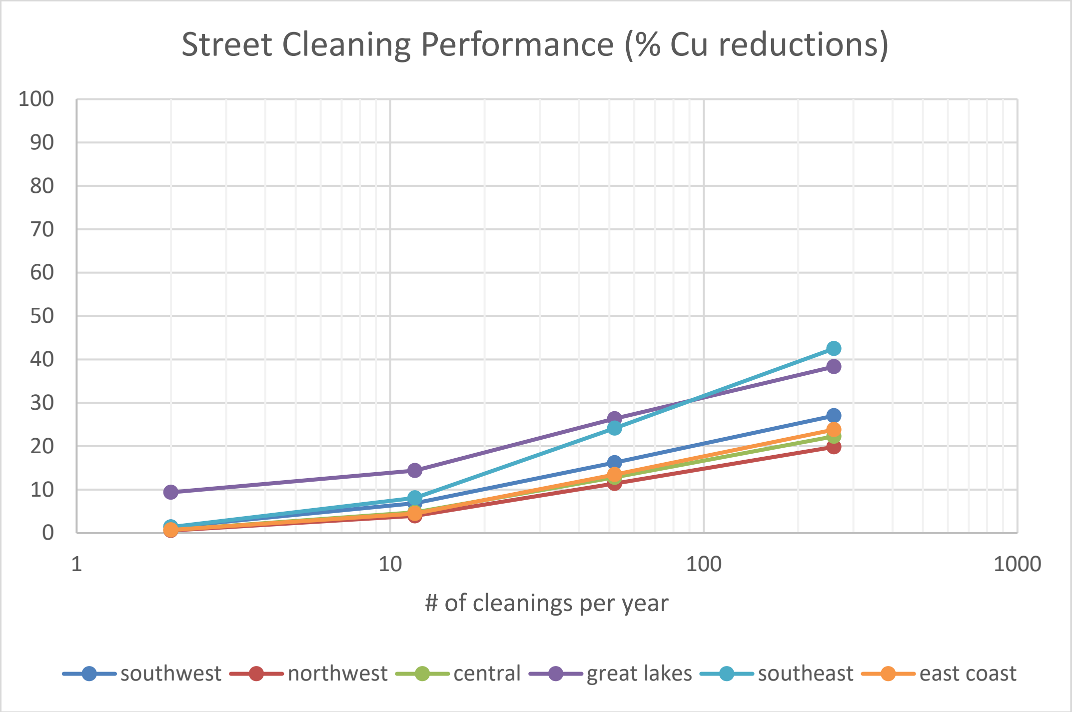

Street Cleaning Performance (% TP reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast


Street Cleaning Performance (effluent TKN, mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast

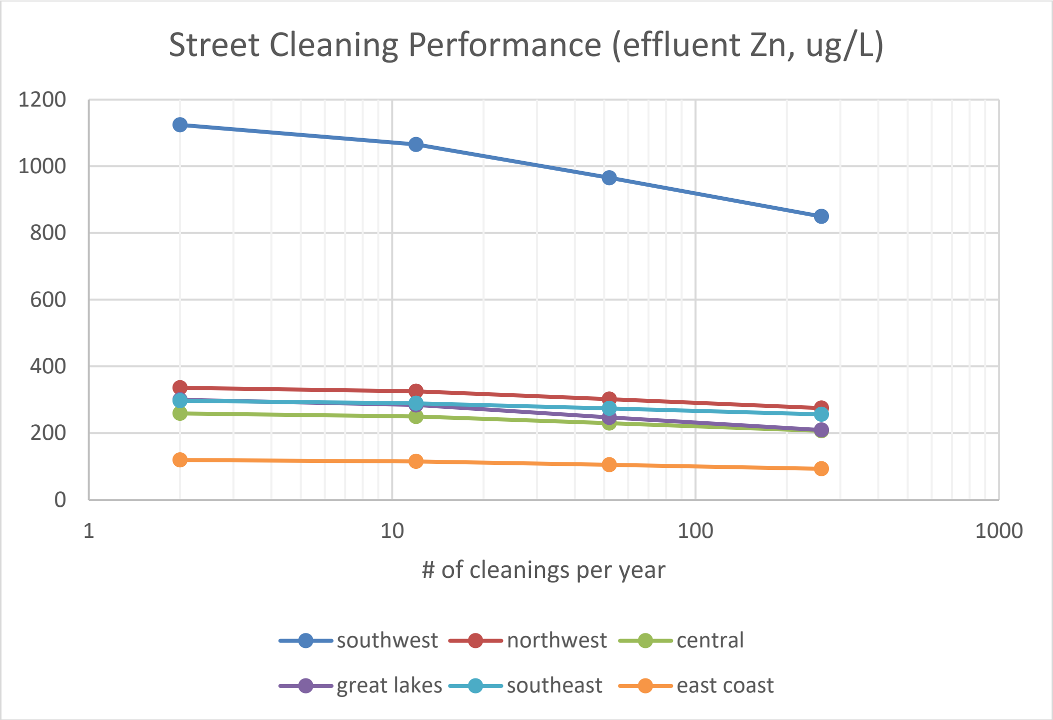

Street Cleaning Performance (% TKN reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast

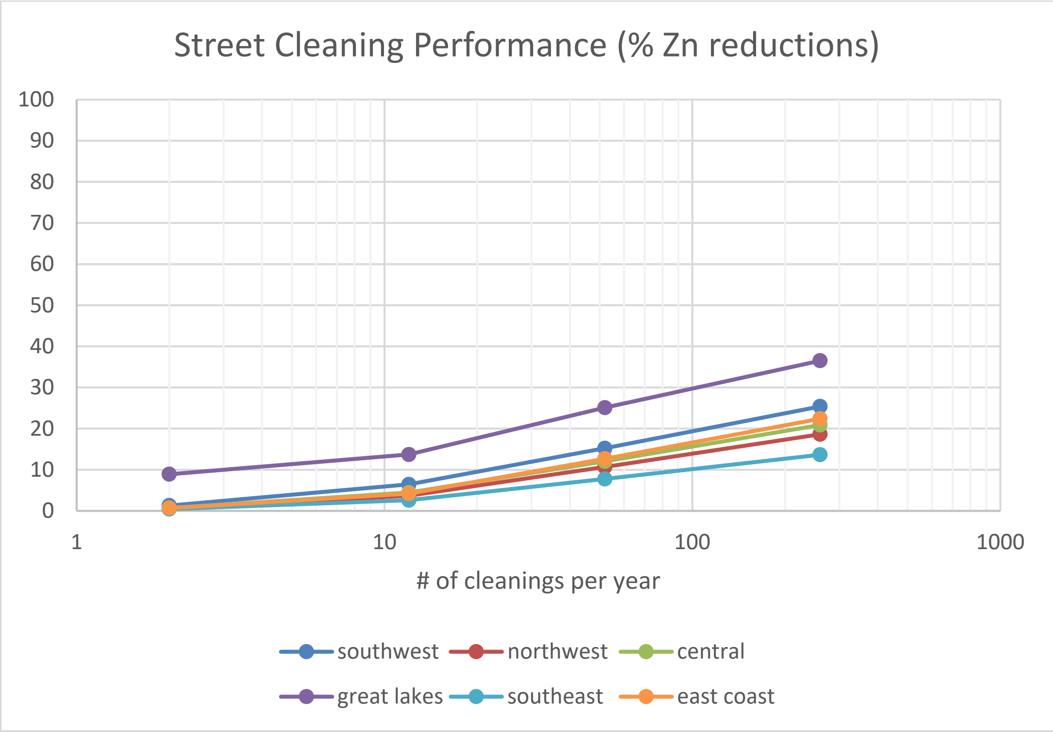


Street Cleaning Performance (effluent Cu, ug/L)
120
100
80
60
40
20
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast



Street Cleaning Performance (% Cu reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
1000
# of cleanings per year
southwest
northwest
central
great lakes
southeast
east coast





Catchbasins

Catchbasins are stormwater inlets having sumps below the outlets to retain captured sediment. If there is no sump, very little material can be retained. Field work has shown that sediment is accumulated up to about 1 ft below the outlet, above which re-suspension and scour overcome the sedimentation. The sump depth should therefore be several feet deep, with deeper sumps requiring somewhat less frequent cleaning. Sediment and retained water sampling in the sumps have shown the potential for nuisance conditions, especially mosquito activity. Their use should therefore be carefully evaluated, especially considering their rather marginal performance for most common installations.

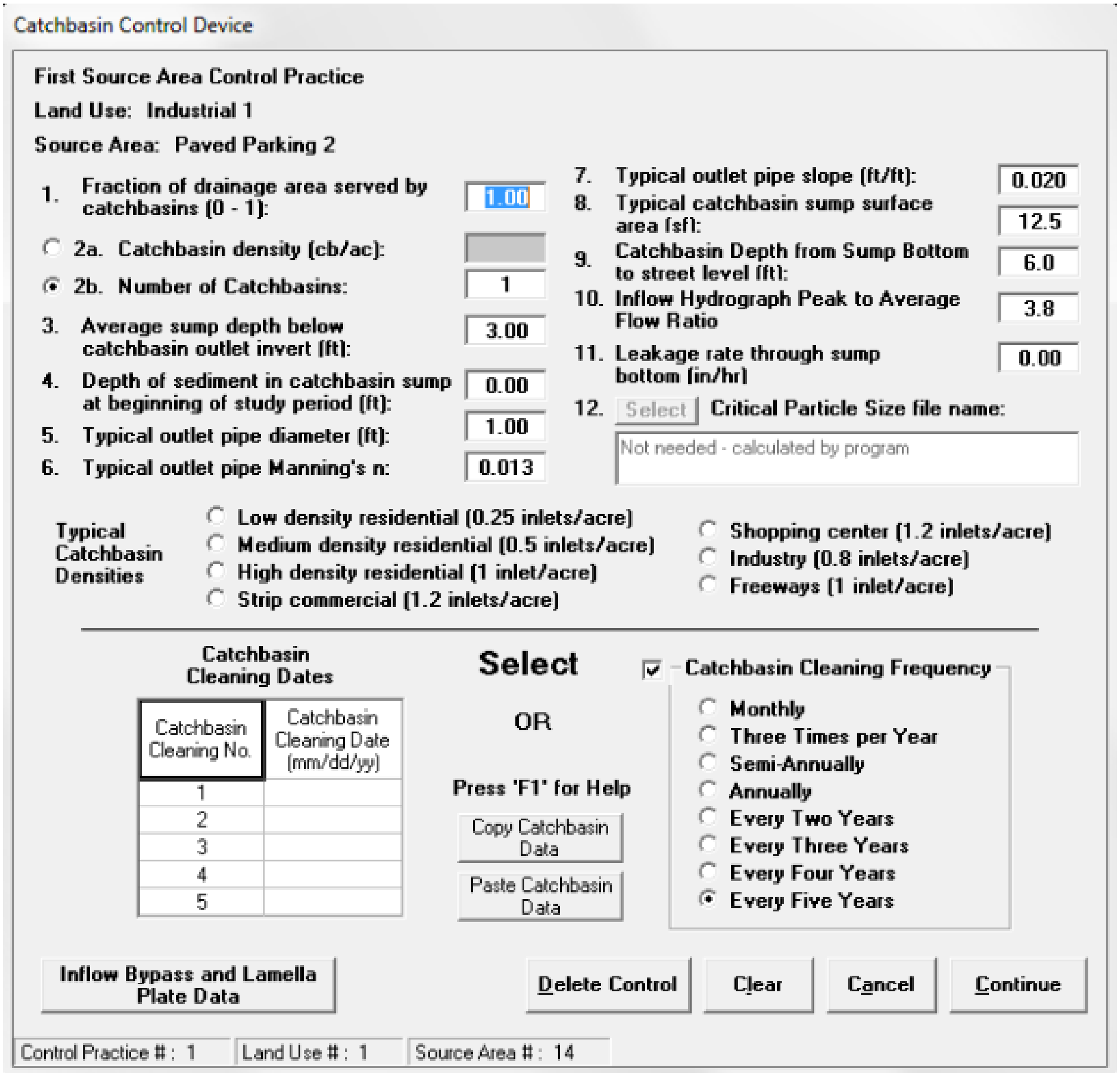
Catchbasins can be applied to either a specific source area or as part of the drainage system. Treatment is due to particle settling unless there is leakage through the bottom of the sump, which is considered as a runoff volume loss to the system. WinSLAMM calculates the portion of the total catchbasin volume that is full of captured sediment for each rainfall event, and the catchbasins and separators stop trapping sediment (scour balancing sedimentation) when the trapped material approaches the outlet. The sediment depth value is reset to zero when the catchbasin is cleaned.

Catchbasins are modelled as simple vertical walled detention basins with a pipe outlet. However, because they are small, they have negligible storage volume, so the complete storage component of the detention pond algorithm is not applied. Pipe outlet flow is calculated as the flow rate through a partially filled pipe or as orifice flow, whichever is smaller. Hydrodynamic devices can be placed at any individual source area or as a drainage system control. Hydrodynamic devices are very similar to catchbasins in the model, except that they have additional bypass capabilities and lamella plates can be added for improved performance.

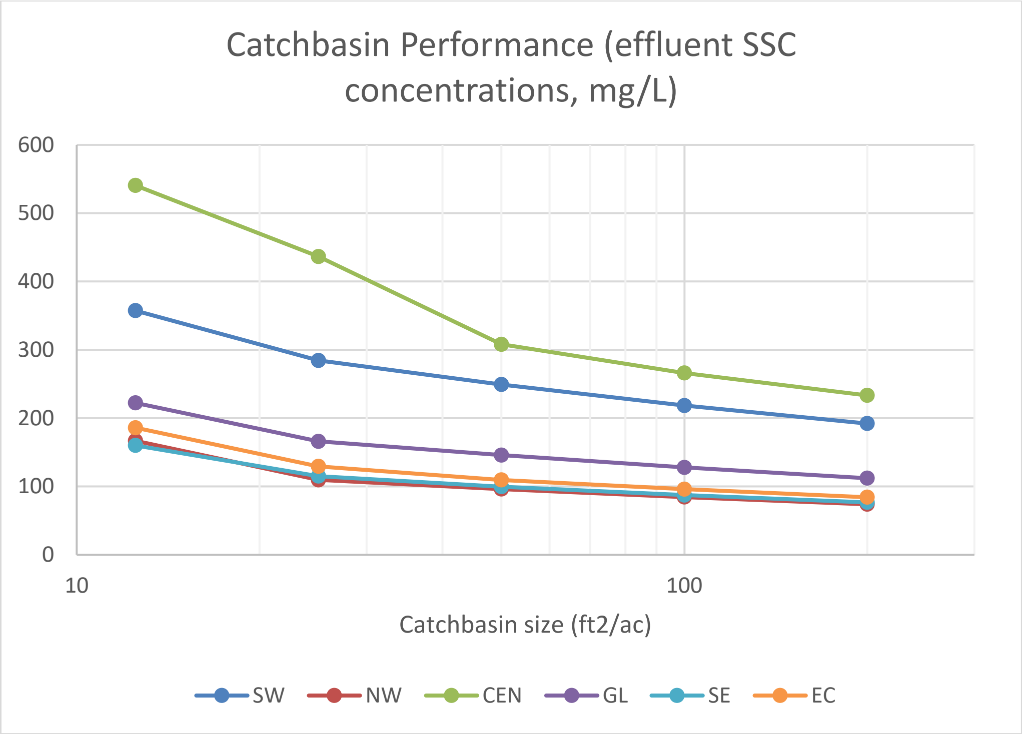
The analysis examined the number of typical catchbasins per acre of paved drainage area, with about 12.5 ft^2 (4 ft diameter) of area for each unit. The areas and numbers of catchbasins associated with some of the areas are:

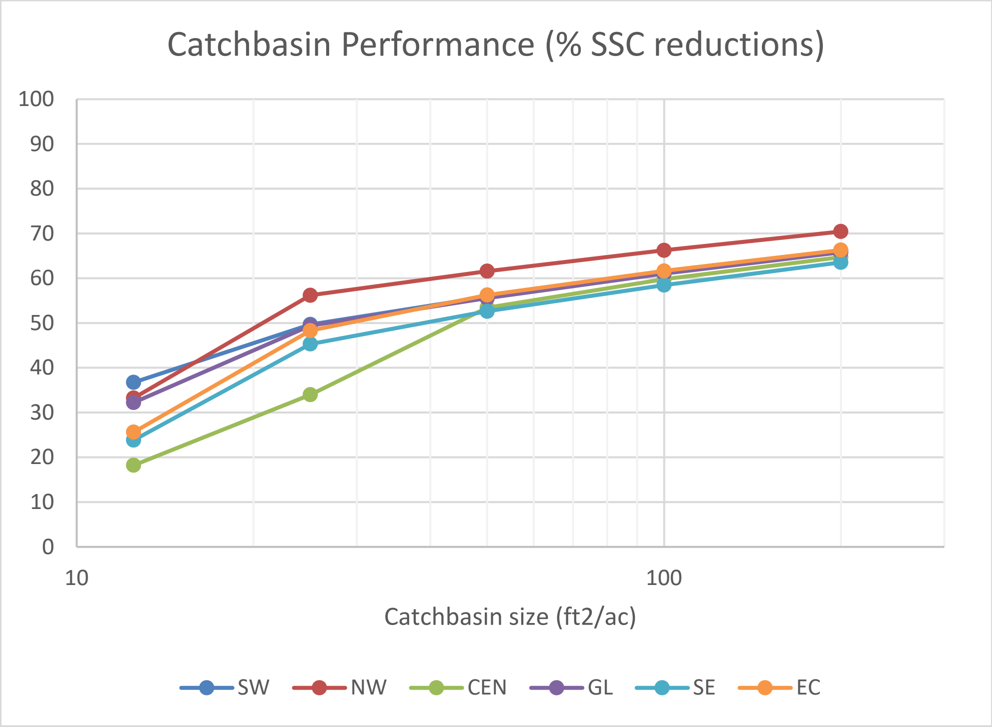
1 catchbasin/acre: 12.5 ft^2 (0.035 of paved drainage area)
2 catchbasin/acre: 25 ft^2 (0.06% of paved drainage area)
4 catchbasin/acre: 50 ft^2 (0.11% of paved drainage area)
8 catchbasin/acre: 100 ft^2 (0.23% of paved drainage area)
16 catchbasin/acre: 200 ft^2 (0.5% of paved drainage area)

Typical uses of catchbasins are relatively low, ranging from about 1 per 4 acres in low density residential areas to about 1.2 per acre in commercial areas. Industrial areas have about 0.8 per acre (based on site surveys, but these values can obviously vary). Therefore, the larger areas shown are more representative of larger vaults and not simple catchbasins, and overlap with some hydrodynamic device sizes and performance expectations. The following is the input screen for catchbasins in WinSLAMM.



The following are the calculated production functions relating effluent SSC reductions and concentrations to total catchbasin surface areas per acre of paved drainage area.





Catchbasin performance is limited due to the small settling areas used for most installations. However, field monitoring has shown about 25 to 45% SSC reductions, with most of the captured material larger than 50 µm, with very little of finer particulates when one or two are used per acre (10 to 25 ft^2 total surface area).

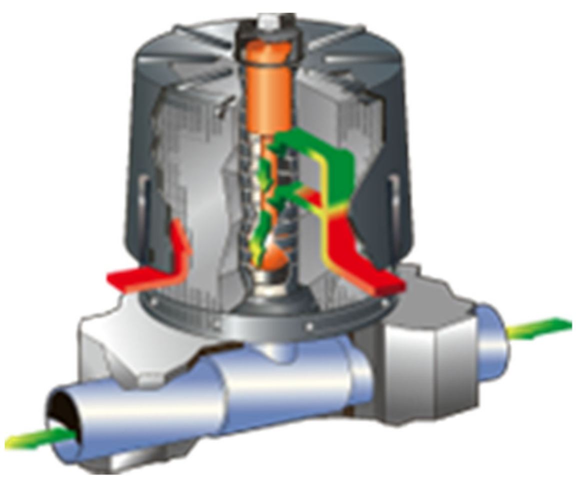
Catchbasins (with sumps) have historically been used to remove the large debris before it enters the drainage system causing cleaning problems. If installed with hoods over the outlets, catchbasins can be effective in retaining floatable materials. Larger hydrodynamic devices can be used for somewhat more effective stormwater control.

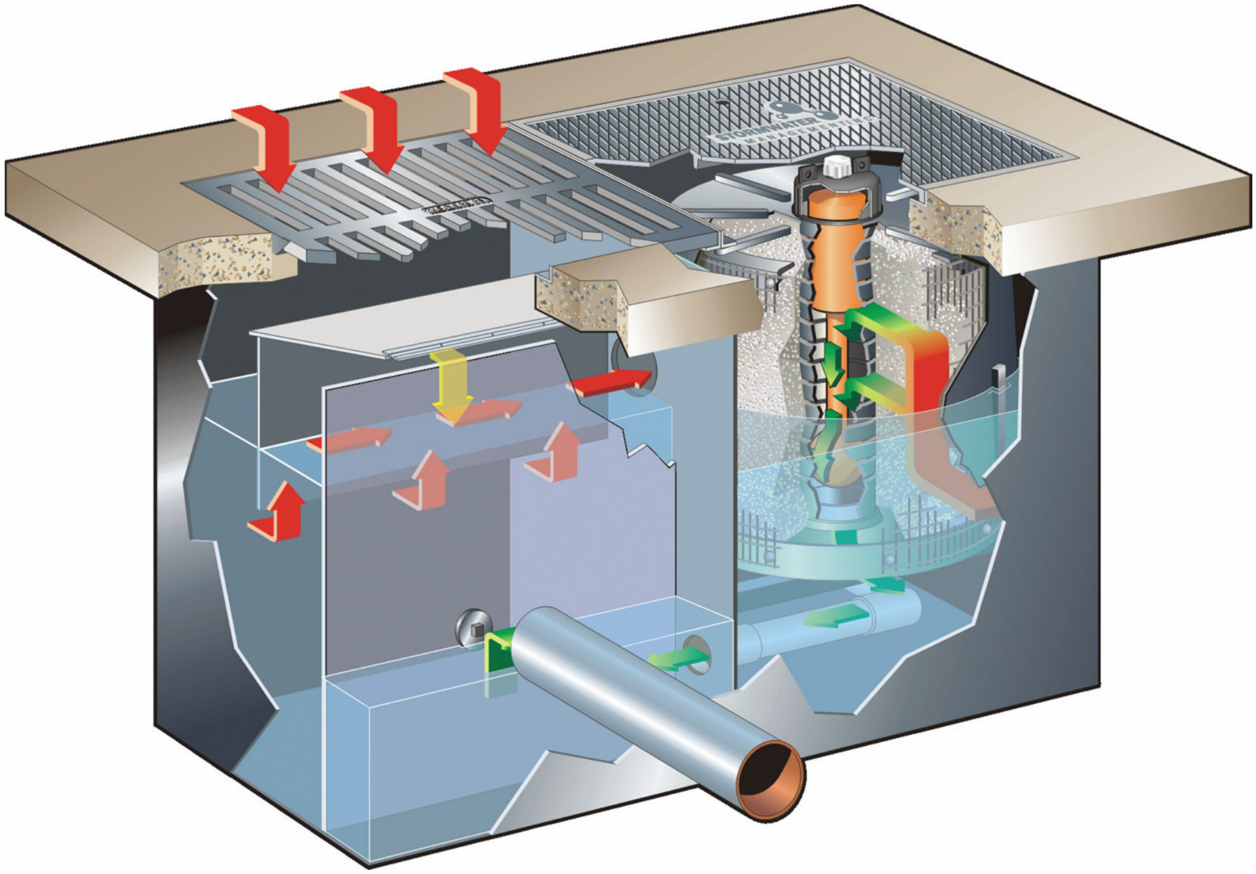
Proprietary Media Filters: Contech StormFilter™

The Contech StormFilter™ (http://www.conteches.com/Products/Stormwater-Management/Treatment/Stormwater-Management-StormFilter) has been available for many years as a proprietary stormwater treatment device incorporating various media. It has been used at many types and scales of locations, from treating runoff from small roofs to large paved areas. The StormFilter has undergone many laboratory and field evaluation performance tests for a variety of conditions, providing much performance information for its use in WinSLAMM.

The stormwater treatment performance of the StormFilter is affected by many different factors, specifically including drainage area/rainfall characteristics and particle size distributions of the particulate solids, along with the fraction of the pollutants in filterable forms. The StormFilter system reduces particulate solids through both sedimentation in the cartridge chambers and by filtering in the cartridges themselves. The detailed program outputs illustrate the removals of the particulates by the different unit processes. The Contech StormFilter is described in WinSLAMM using many different options and routines. Great care was taken to simplify the input requirements for the user by coding in standard dimensions and only showing available choices.

The following are illustrations (from Contech) showing the treatment flow path in a single filter cartridge along with installations showing the use of single and many cartridges in different treatment systems.

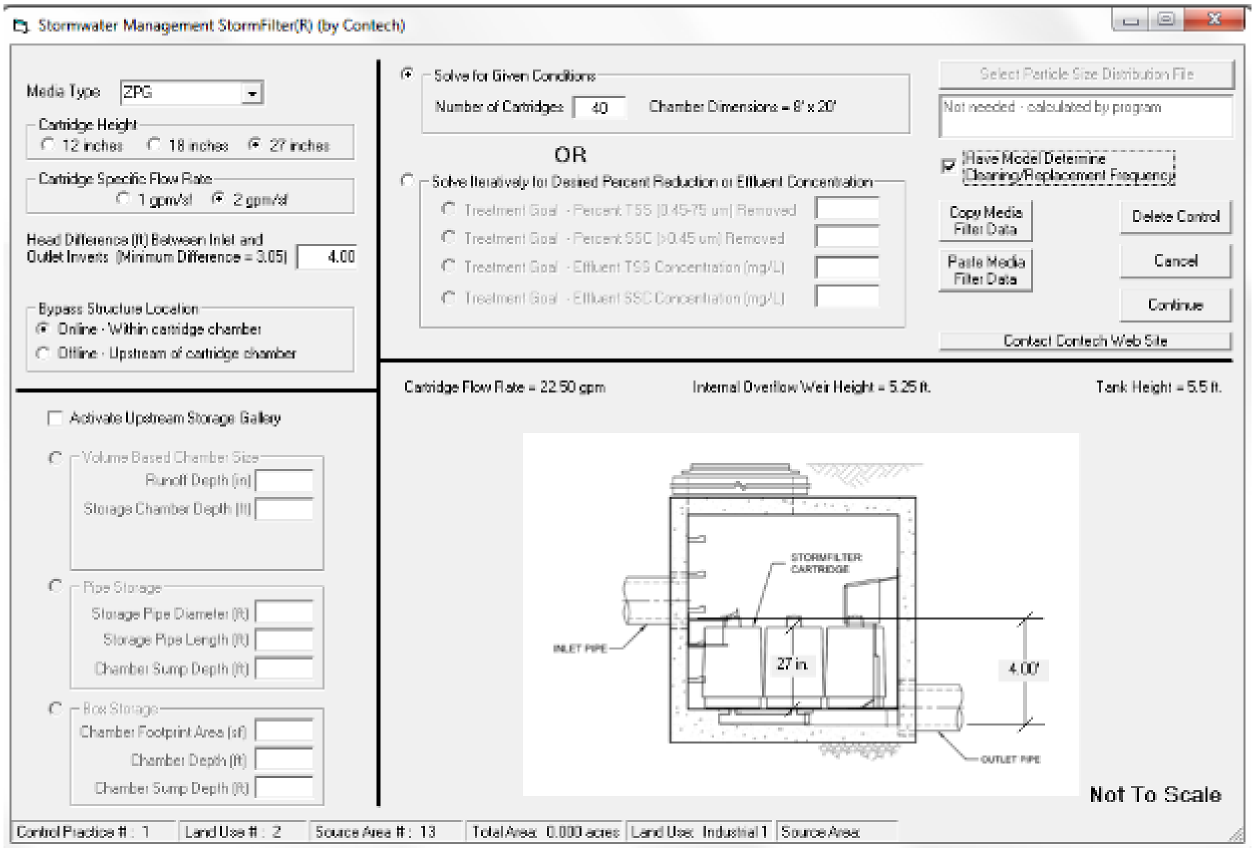




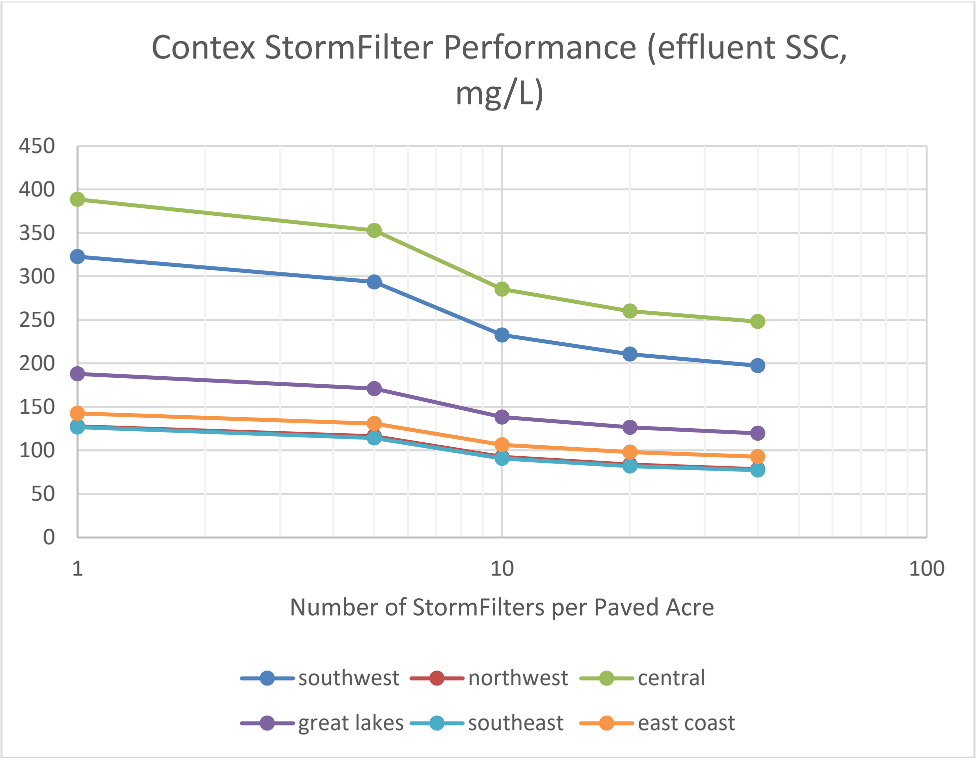
CatchBasin StormFilter inlet unit with pre-settling vault at McKinleyville, CA, school district bus yard, showing underflow floatables trap and overflow rectangular weir for bypassing large flows.

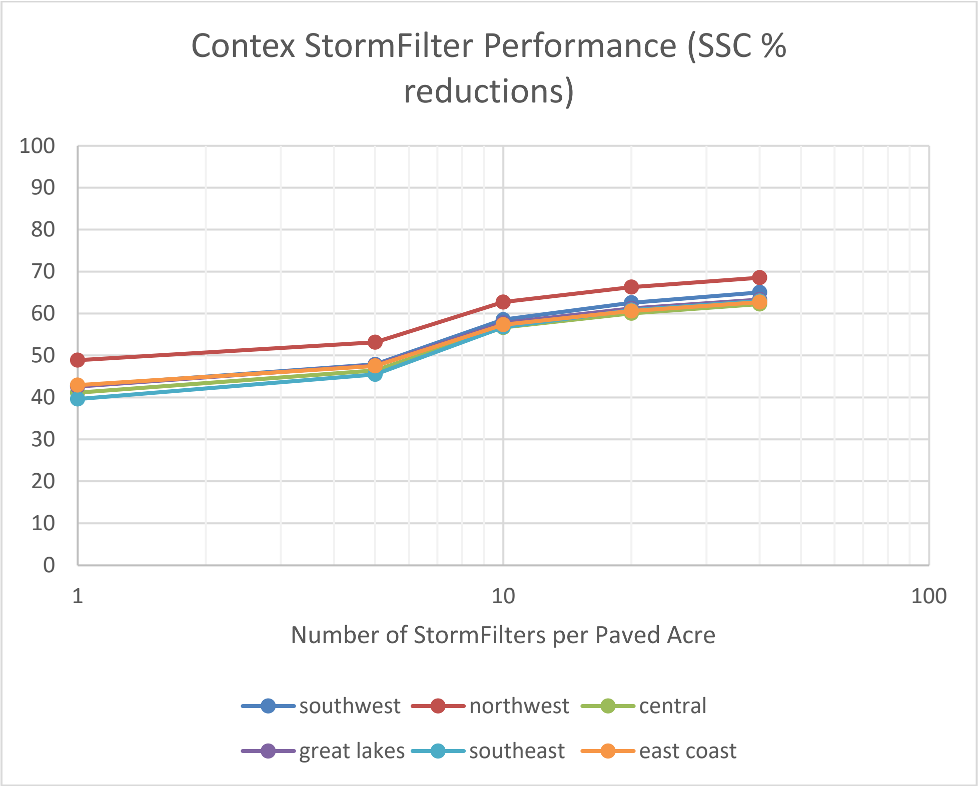
The following is the input screen for the StormFilter in WinSLAMM. For the production function calculations, the ZPG media was selected in 27 inch cartridges having 2 gpm/ft^2 flow rates. The model determined the cleaning frequency based on the accumulated sediment material in the vaults (The filter vault was cleaned before the sediment interfered with the filter operation). The following table shows the range of cartridges examined (per acre), along with typical corresponding chamber sizes.

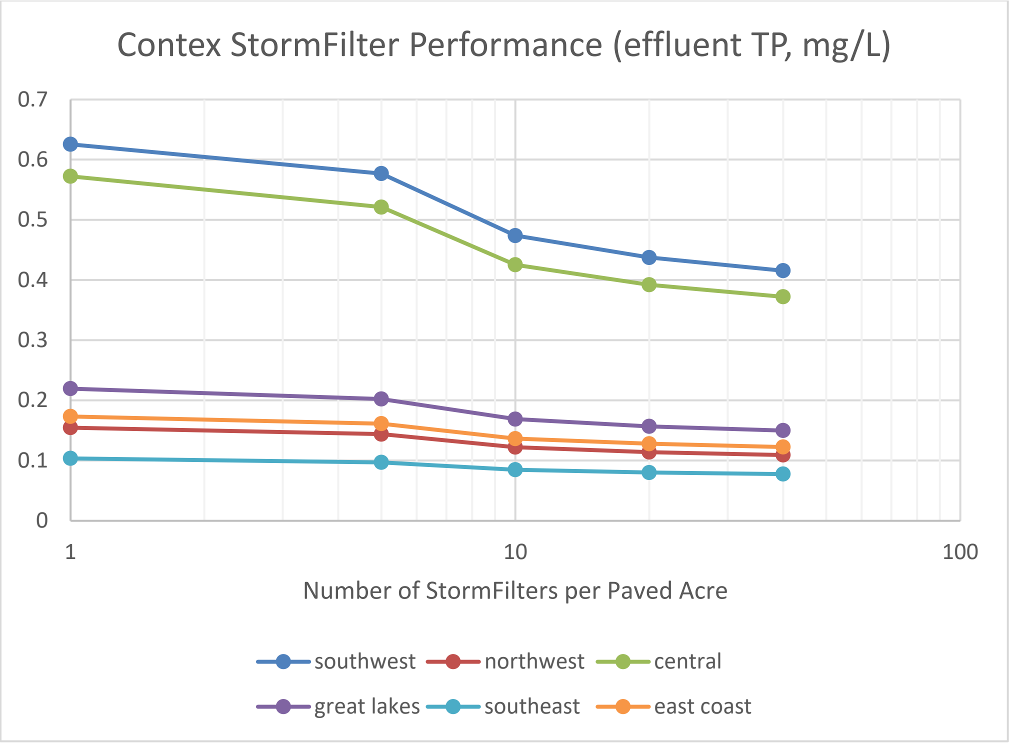
# of cartridges per paved acre	1/ac	5/ac	10/ac	20/ac	40/ac
corresponding tank size	4 ft D = 12.5 ft^2	5 ft D = 20 ft^2	72 ft^2	112 ft^2	160 ft^2
tank size as a % of paved drainage area	0.03%	0.046%	0.17%	0.26%	0.37%

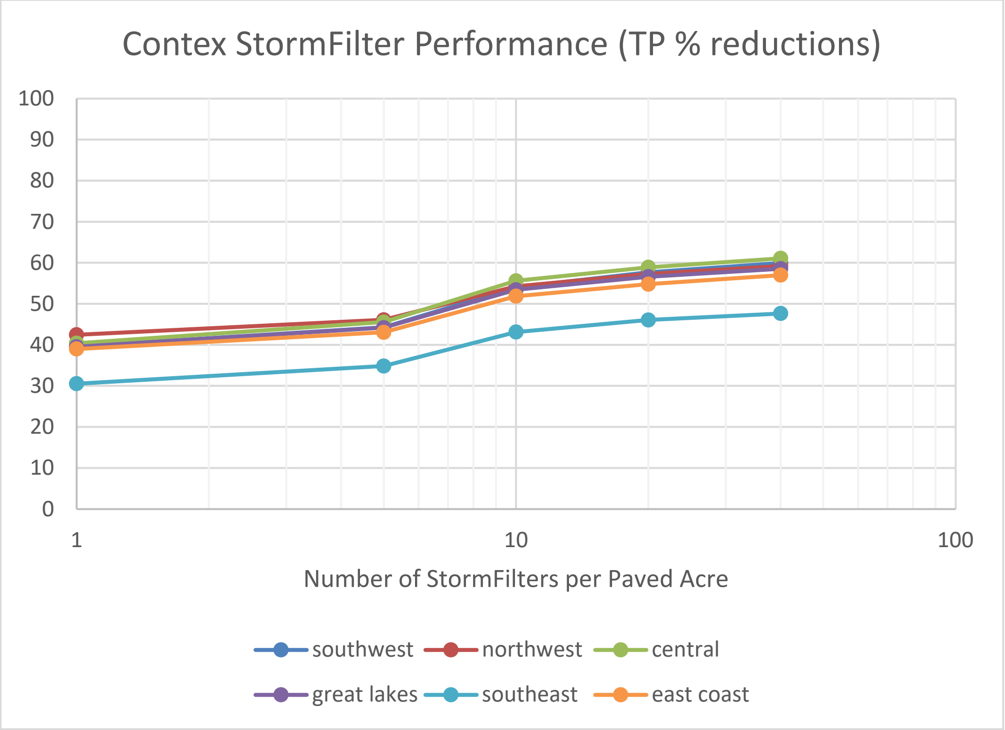


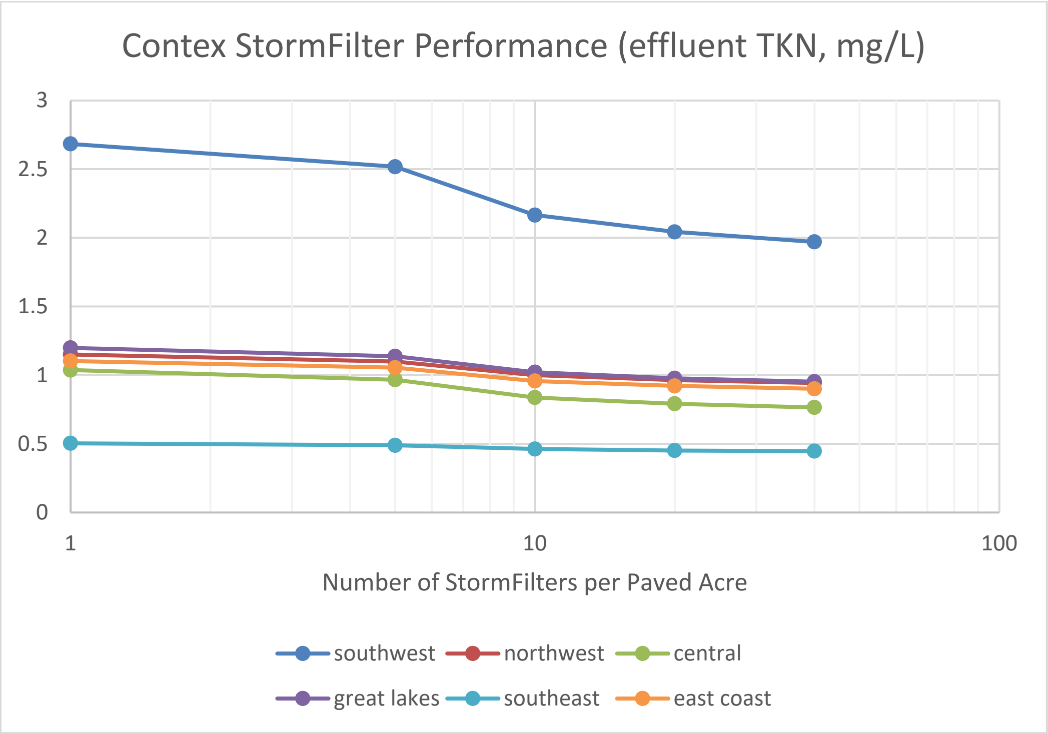
The following production functions illustrate the calculated performance of the StormFilters for SSC, total phosphorus, Total Kjeldahl nitrogen, total copper, and total zinc. These are shown both for the expected treated effluent concentrations and the percentage removals. The model examined the StormFilters for one acre of paved parking/storage areas in industrial areas (without unusual activities in the area). As stated previously, these are long-term average performance expectations and do not illustrate the storm-to-storm highly variable conditions.

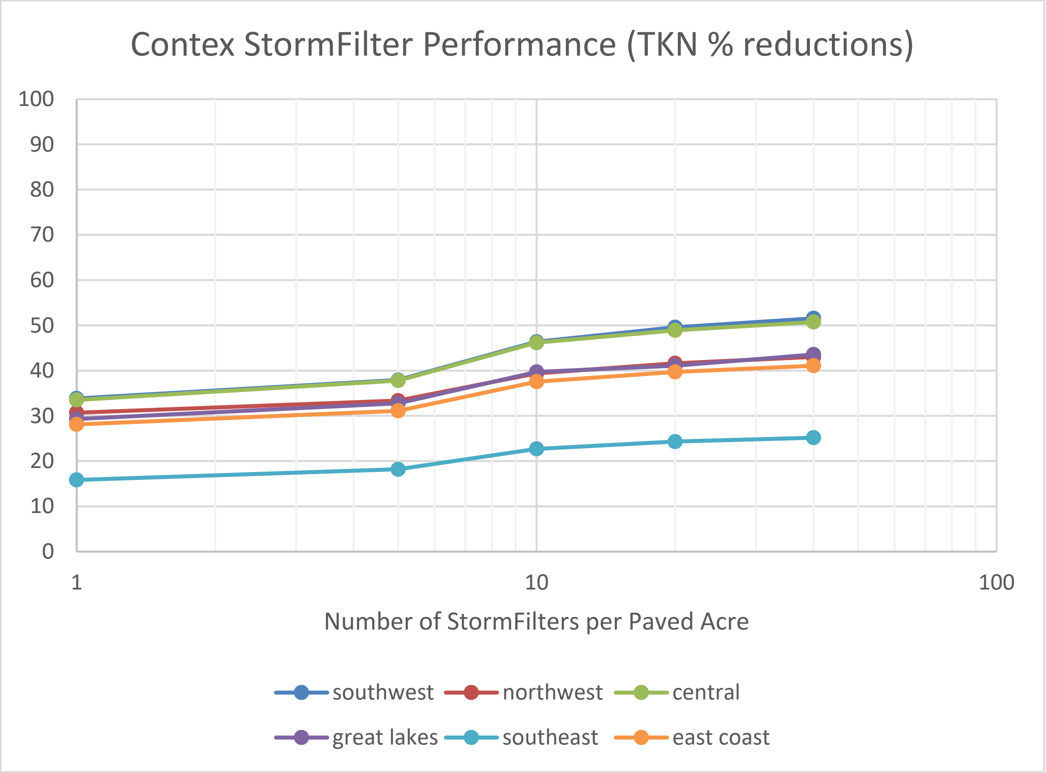

Contex StormFilter Performance (effluent SSC, mg/L)
450
400
350
300
250
200
150
100
50
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast

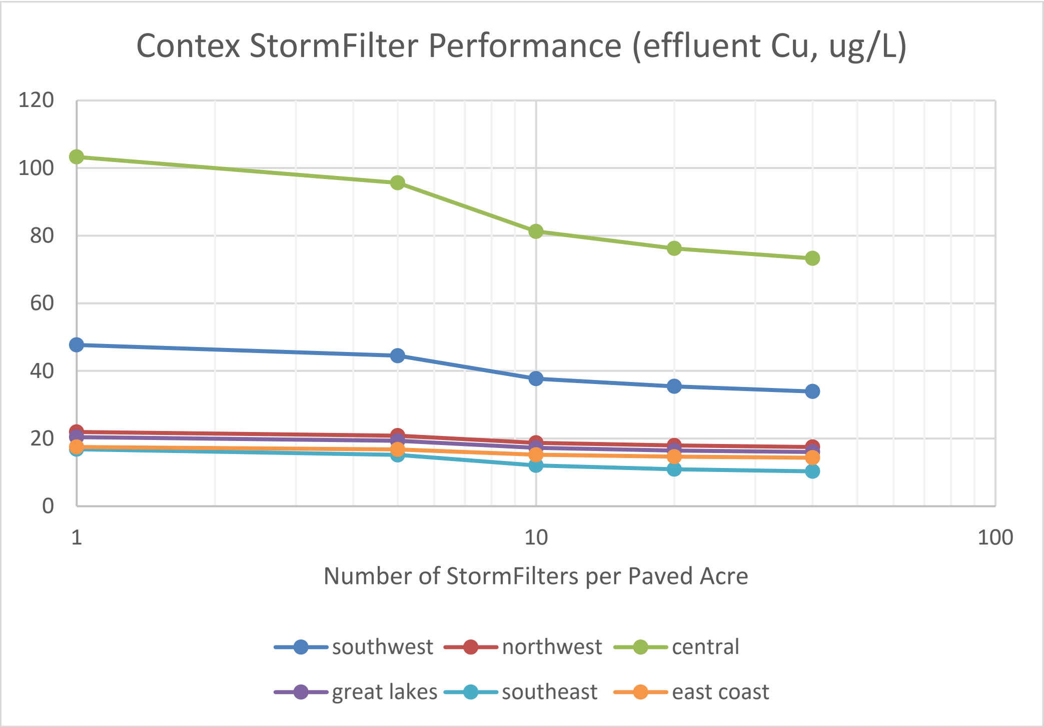

Contex StormFilter Performance (SSC % reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast

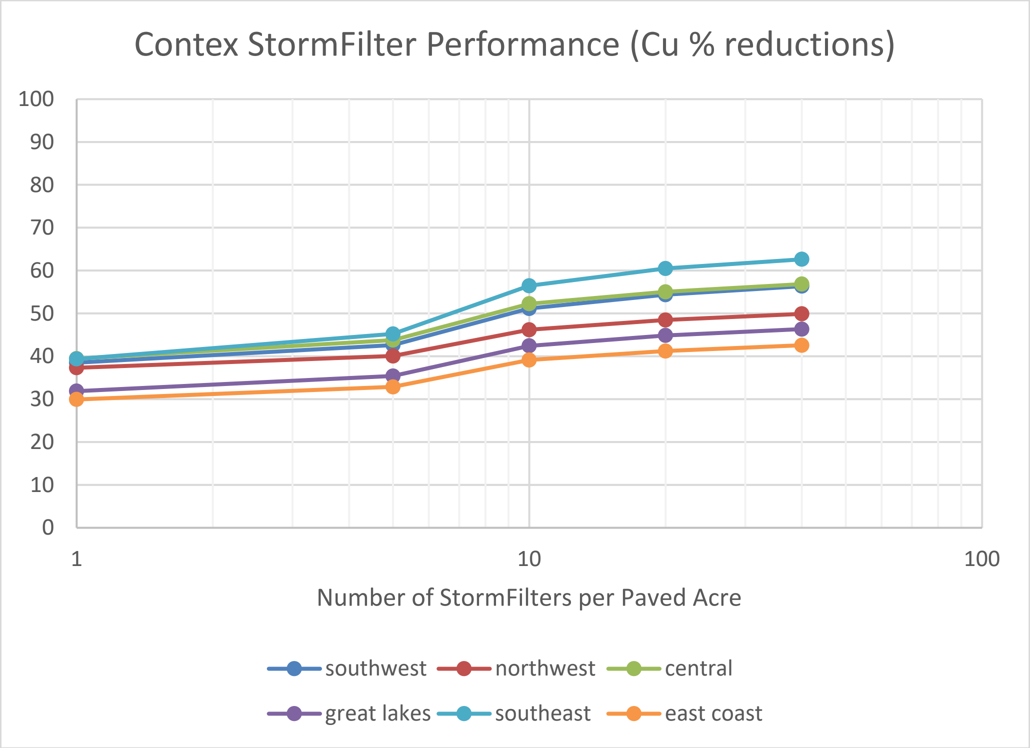

Contex StormFilter Performance (effluent TP, mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast

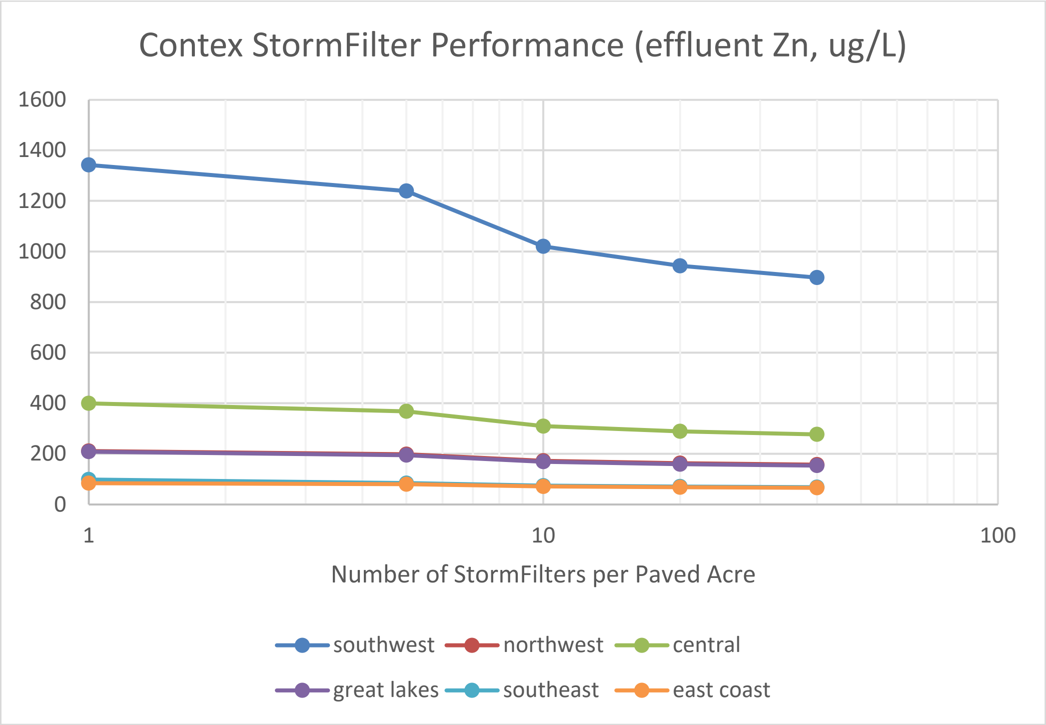

Contex StormFilter Performance (TP % reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast

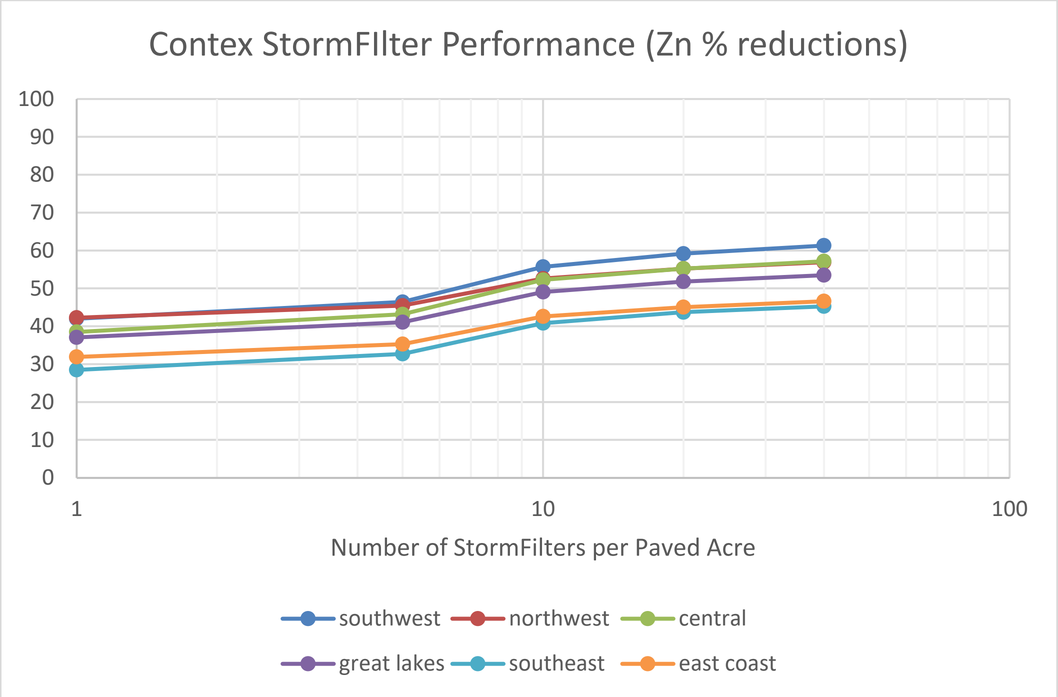

Contex StormFilter Performance (effluent TKN, mg/L)
3
2.5
2
1.5
1
0.5
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast


Contex StormFilter Performance (TKN % reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast


Contex StormFilter Performance (effluent Cu, ug/L)
120
100
80
60
40
20
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast

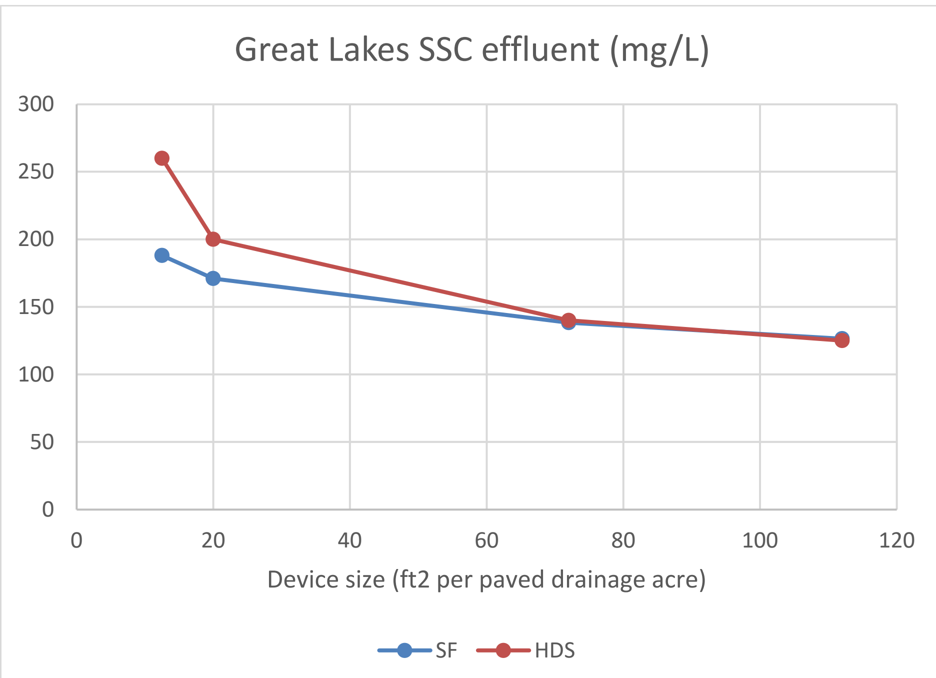

Contex StormFilter Performance (Cu % reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of StormFilters per Paved Acre
southwest
northwest
central
great lakes
southeast
east coast





These plots show that about 10 cartridges per paved drainage area are approaching the maximum levels of control. This is likely affected by the particle size distribution used in these calculations. The performance calculated are within the range of the levels of performance stated by the manufacture and certified by regulatory agencies.

The following figure illustrates the complementary benefits of sediment trapping in the StormFilter chambers by both plain sedimentation (as illustrated by the hydrodynamic settling device curve) and the trapping in the filters themselves (the StormFilter curve includes both sedimentation plus filter trapping). When the filter chambers are less than about 70 ft^2 (associated with about 10 cartridges per acre of paved drainage area), both processes are important, with the StormFilter providing much greater benefits than plain sedimentation alone. The cartridges are always responsible for the treatment of filtered pollutants (and smallest particles) in the stormwater which are beyond the capability of sedimentation, even with very large chambers.



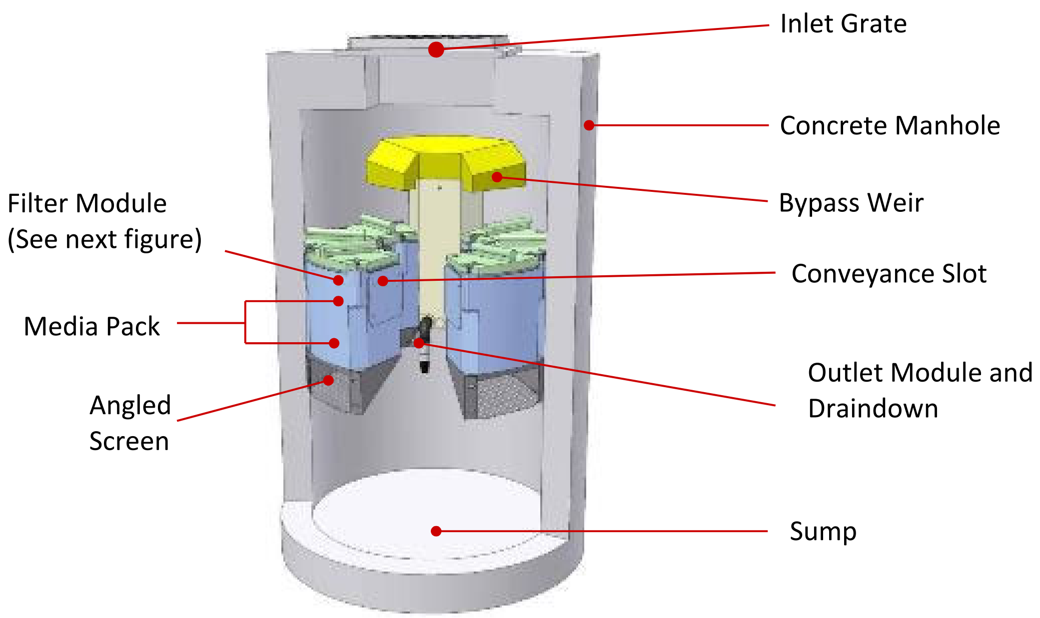
Proprietary Media Filters: HydroInternational UpFlo™ Filter

The UpFlo™ filter was developed by stormwater researchers at the University of Alabama under the support of EPA Small Business Innovative Research (SBIR) grants. As part of the SBIR process, the UpFlo™ filter was further developed and commercialized by HydroInternational. The following UpFlo™ filter descriptions are summarized from HydroInternational material.

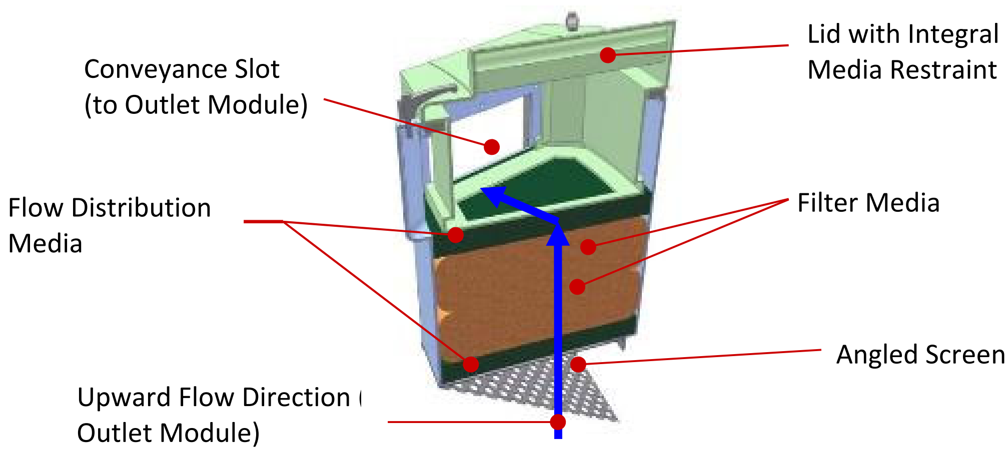
The Up-Flo™ filter is a modular subsurface filtration system that can be installed into 4-ft diameter catchbasins or large precast concrete vaults (for larger drainage areas). It incorporates a combination of treatment processes including sedimentation of settleable gross sediments, coarse screening of floatable materials, and upflow filtration through a treatment media mixture incorporating physical filtration along with ion exchange and sorption. Overall, much finer stormwater particulates can be removed compared to sedimentation processes alone at the design treatment flow rates. Each UpFlo™

filter system installed in the 4 ft diameter chambers can usually have up to six filter modules, depending on the desired treatment flow rate from the drainage area. Large areas can contain several systems located in treatment vaults for larger drainage areas. Each filter module has a design hydraulic loading rate of about 25 gallons per minute (gpm) at maximum stage, so a single 4 ft chamber with six cartridges can treat about 150 gpm.

The following figures are a schematic and a cross section of the UpFlo™ filter showing the major components of a typical six-module configuration.



Up-Flo® Filter Components



Filter Module Components

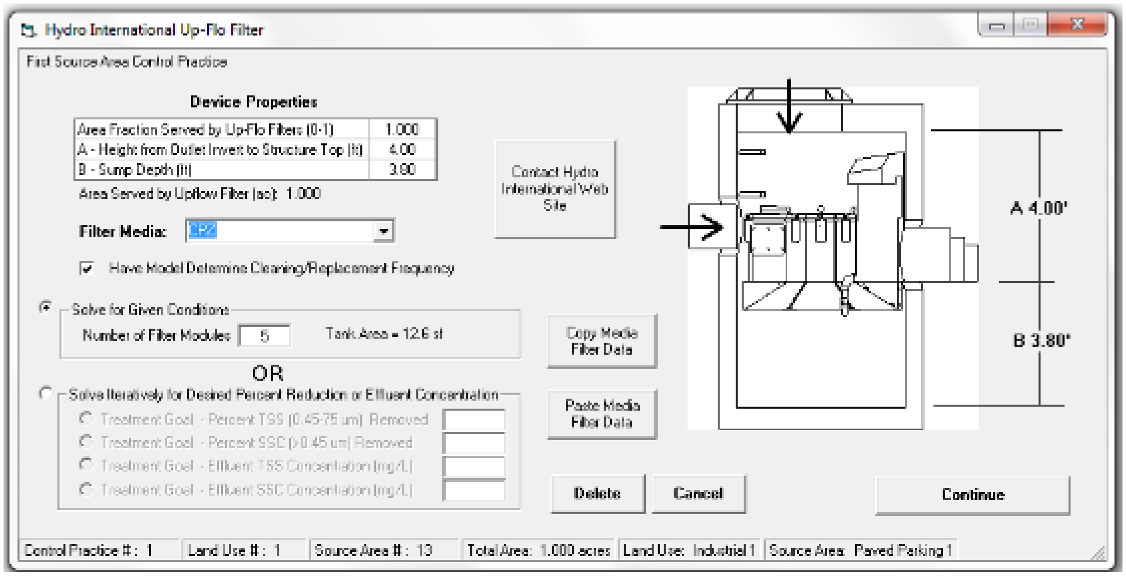
Inlet Grate, Sump and Angled Screening. Stormwater runoff is conveyed into the sump by flowing around the installed filter modules from a surface inlet or directly from the drainage system's pipe network. The stormwater head in the chamber above the filter media causes upward filtration through the bottom of the media in the filter module. The angled screens are designed to capture the floatable materials in the sump, minimizing the chance of ragging and blinding the bottom of the filter by protecting the filter module from the direct path of the upward flow.

Filter Module. The filter module has two filter media bags, distribution metalla layers, and a restraining lid with a conveyance slot designed as the main outlet weir for the treated flow. Several types of proprietary filter media mistures are available, including standard mix CPZ™ (a combination of activated carbon, spganum peat moss, and manganese coated zeolite), and the winter mix CPS™ (activated carbon, spganum peat moss, and filter sand). The treatment flow rate through each filter module generally ranges from 10 to 25 GPM, depending on the height of the water column above the filter media, but can also be regulated by adjusting the type of media. The distribution metalla material, which is a polyethylene fiber web material, is used to distribute the upward flow evenly across the filter media bags, to support and baffle the filter media, and provides expansion volume upon compression during high flows, and prevents damage and breaking of filter media bags during the high flow conditions.

Outlet Module, Draindown and Bypass. The outlet module is where the draindown and bypass controls are installed and where the flow mixture (comprised of blended treated and partially treated flows) exits the filter system. During a storm event, the treated flow is discharged by the conveyance slot from the filter modules, while the partially treated flow is discharged from the draindown port and the bypass. The draindown (with screening inside) is designed to ensure that the water stage in the sump between storm events is lower than the level of filter media, minimizing the development of anaerobic condition and the risk of degradation of filter media, as well as preventing leaching of captured pollutants from the media. The overflow bypass is siphon-activated and directly discharges the excess flow to the outlet module with partial treatment associated with sedimentation in the catchbasin sump. The hood on the top of the outlet module is also designed to prevent the floatable trash and deris from escaping along with the bypass flow. The bypass flows are mixed with the media treated flows as they exit the filter system.

During a rain event, the stormwater enters the filter chamber and the sump water level rises. Larger particles settle to the bottom of the sump and the gross debris and floatables are separated by the angled screens placed below the upflow filter modules. The flow continues to rise and moves through the screens into the filter module. This rising water column in the sump provides a driving head and differential pressure between the sump and filter module water levels so that the upward flow can go through the restrained filter media. Runoff treatment with high flow rates is accomplished by controlled fluidization of the filter media in the media bags so that fine particulates are captured throughout the surface area and the depth of the media bags. During peak rainfall periods, the flow may exceed the treatment capacity, with the excess bypass flow discharged to the outlet directly from the siphon-activated bypass, while the filter module still keeps treating and the large sediment is captured in the sump due to gravitational settling. Following a storm event, the elevated water column drains down slowly through the depth of the filter media bags through the draindown outlet. During this period, a slight backwashing effect occurs with some of the captured particulates washed from the filter bags into the sump, helping to minimize clogging and prolonging media life. The sump water continues to drain to the standing water level below the level of the media by the draindown port, thereby allowing the media to drain completely and remain aerated between rains. At the same time, the screened trash and debris on the angled screens are also released by the downward flow of the water and then settle into the sump.

The following is the UpFlo^{TM} filter input screen used in WinSLAMM showing the information used in these analyses. Most of the necessary information is already contained in the model code, except for the depth dimensions and the number of filter modules being used. The model can calculate the benefits of the UpFlo^{TM} filter by selecting a specific number of filters, or it can alternately determine the number of filter modules needed to meet specific effluent or treatment objectives. The model can also determine (and apply) the recommended cleaning frequency, based on the accumulated depth of material captured in the sump.



The following output summary indicates some of the features of a specific model run (5 filter modules for southeast conditions).

Land Uses | Junctions | Control Practices | Outfall

Runoff Volume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L)

Data File: C:\WinSLAMM Files\Example Files\Boeing toolbox\SE Hydro UF.mdb
Rain File: AL Birmingham 5978.RAN
Date: 11-20-15 Time: 16:05:19
Site Description:

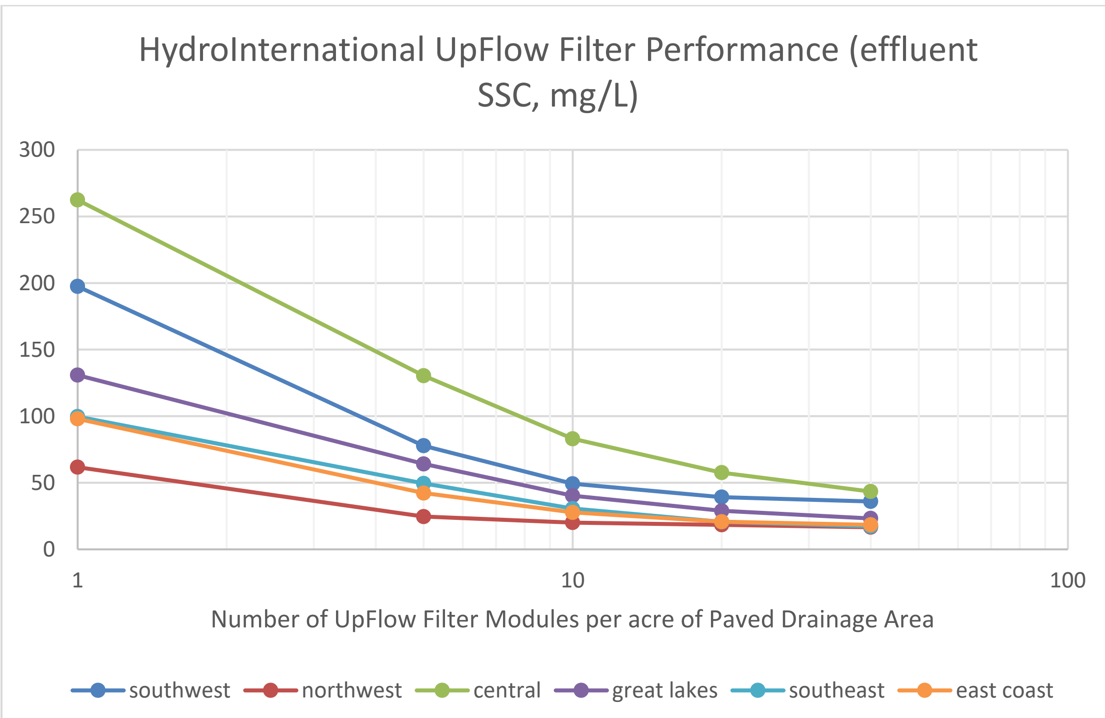
Col. #	2	3	4	5	6	7	8	9	10	11	12	13	14
Control Practice No.	Control Practice Type	Control Practice Name or Location	Total Inflow Volume (cf)	Total Outflow Volume (cf)	Percent Volume Reduction	Total Influent Load (lbs)	Total Effluent Load (lbs)	Percent Load Reduction	Flow Weighted Influent Conc (mg/L)	Flow Weighted Effluent Conc (mg/L)	Percent Conc. Reduction	Influent Median Part. Size (microns)	Effluent Median Part. Size (microns)
1	Upflo Filter	SA Device, LU# 1 ,SA# 13	3.897E+06	3.903E+06	-1.540E-01	51148	12054	76.43	210.2	49.47	76.468	40.00	8.10

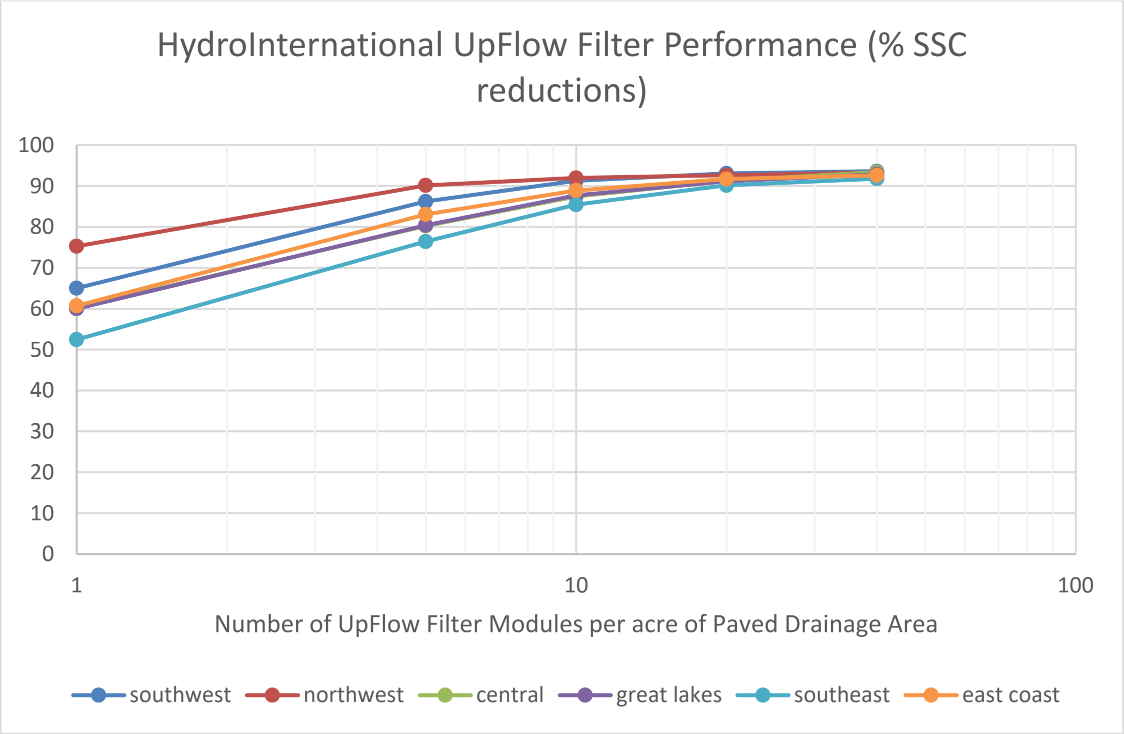
Junctions | Control Practices | Outfall

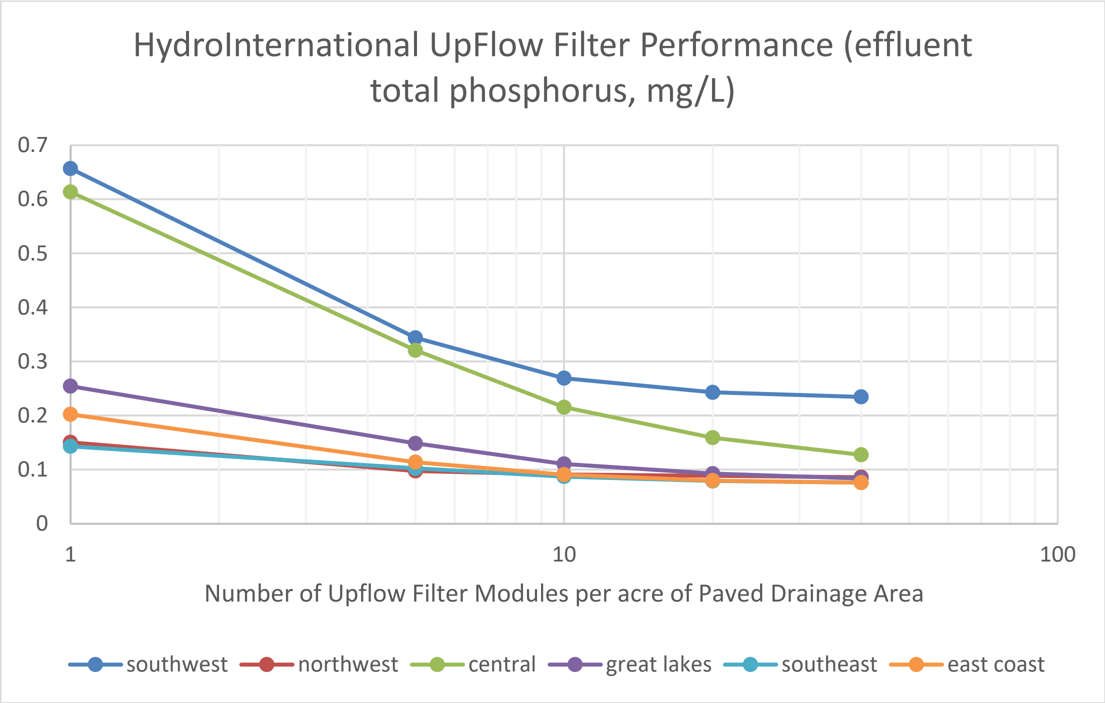
lume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L)

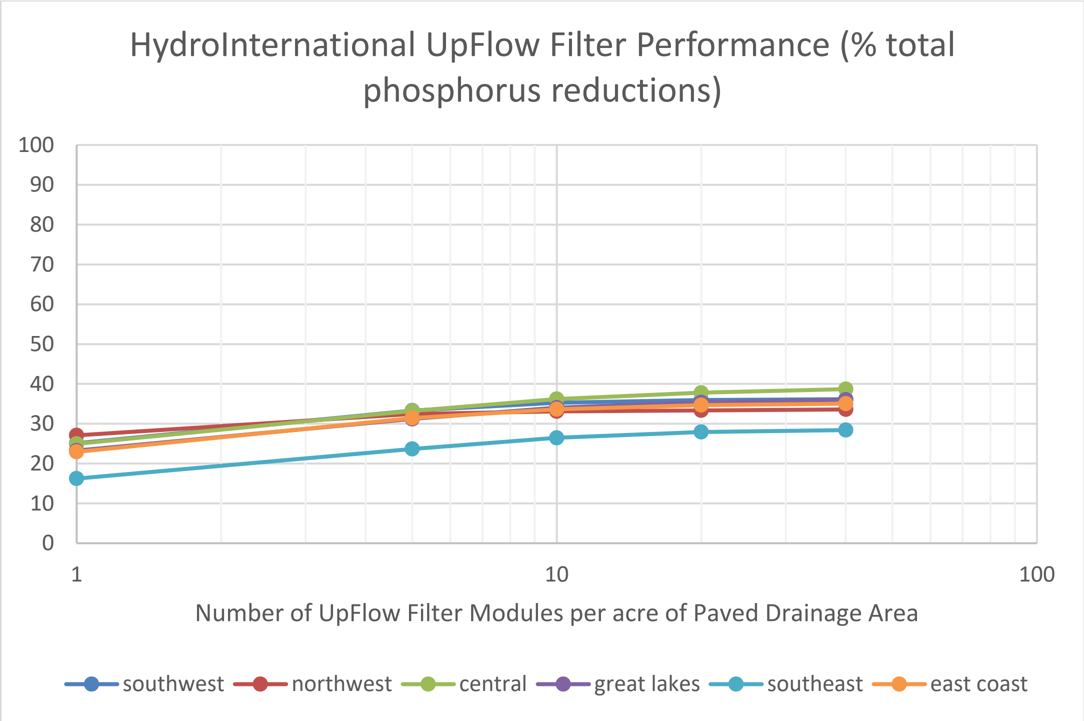
18	24	40	41	42	43	44	45	46	47	48	49	50	51	52	54
Maximum Stage (ft)	Number of Cartridges	Number of Tank Overflows (Count)	Number of Tank Height Exceedance	Bypass Volume (cf)	Bypass Conc. (mg/L)	Bypass Mass (lbs)	Overflow Volume (cf)	Overflow Conc. (mg/L)	Overflow Mass (lbs)	Cartridge Flow Volume (cf)	Cartridge Effluent Conc. (mg/L)	Cartridge Effluent Mass (lbs)	Final Sump Sediment Depth (ft)	Average Cleaning Frequency (yrs)	Residence Time in Media (hrs)
9.93		5#> 6.63' = 32	#> 9.8' = 1	364	205.00	4.66	143643	149.91	1344.29	3759958	45.62	10704.80	0.19	0.31	0.009

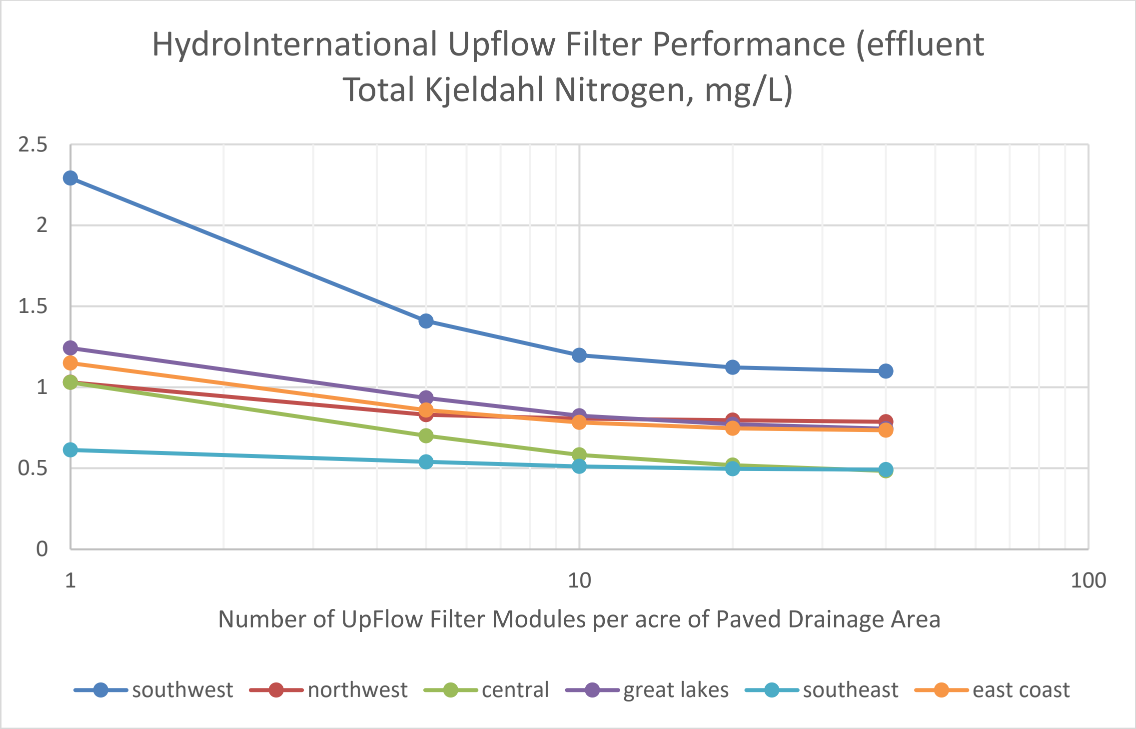
The following are the calculated production functions for the UpFlo^{TM} filter for 1 to 40 filter modules per paved drainage acre and for the six geographical areas:

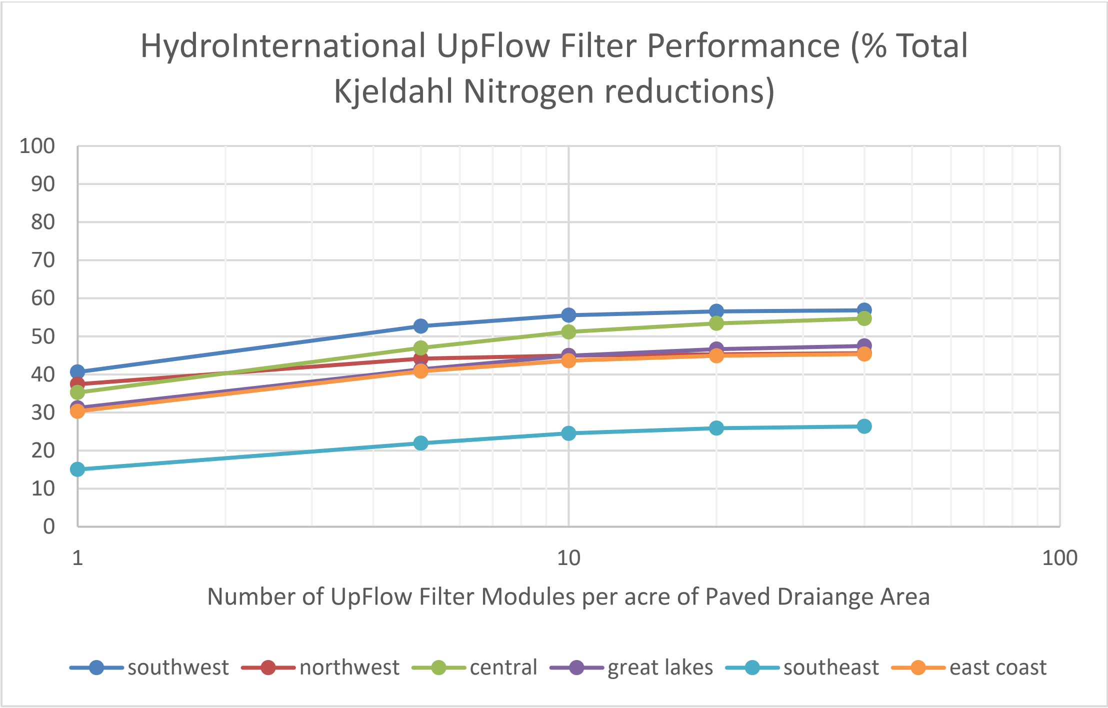


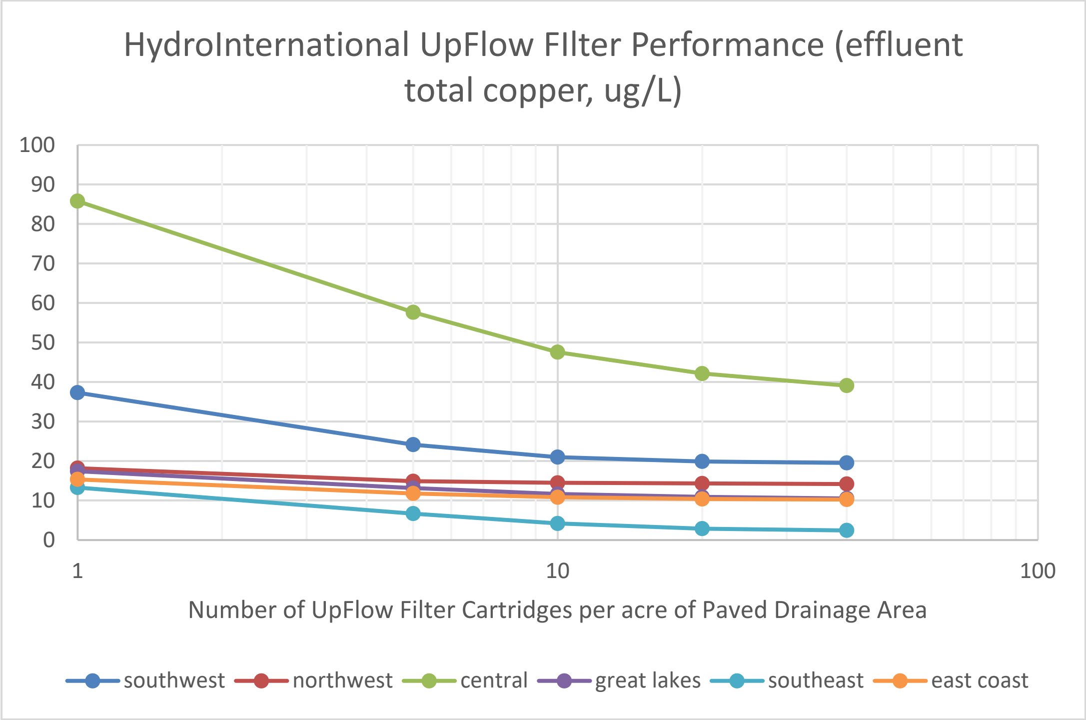

HydroInternational UpFlow Filter Performance (% SSC reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of UpFlow Filter Modules per acre of Paved Drainage Area
southwest
northwest
central
great lakes
southeast
east coast

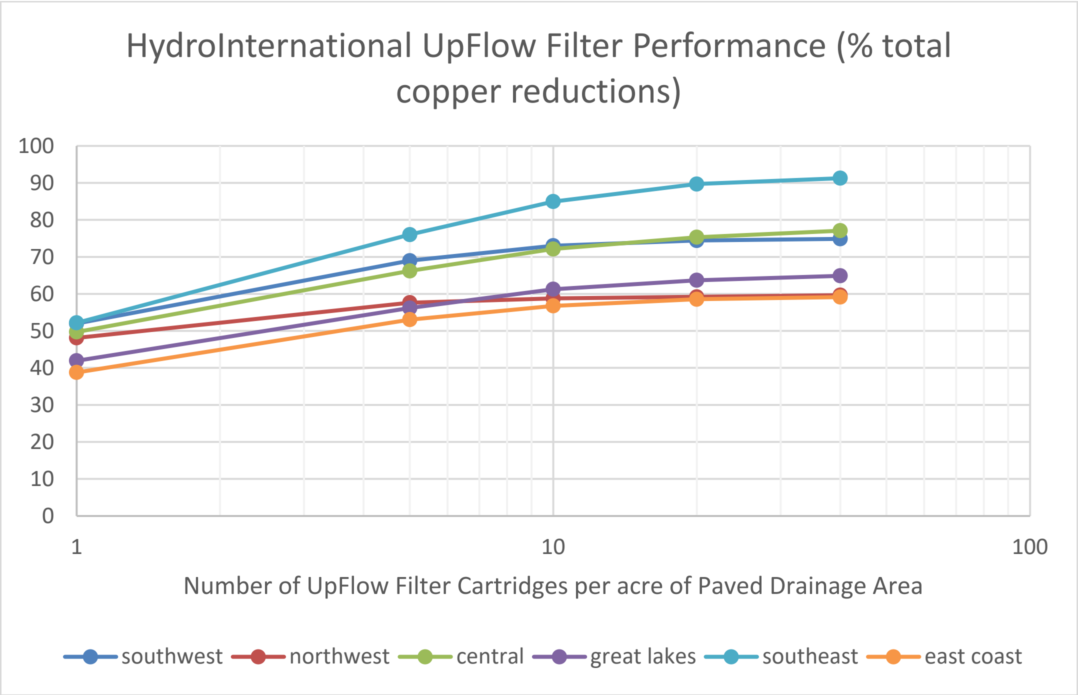

HydroInternational UpFlow Filter Performance (effluent total phosphorus, mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
Number of Upflow Filter Modules per acre of Paved Drainage Area
southwest
northwest
central
great lakes
southeast
east coast

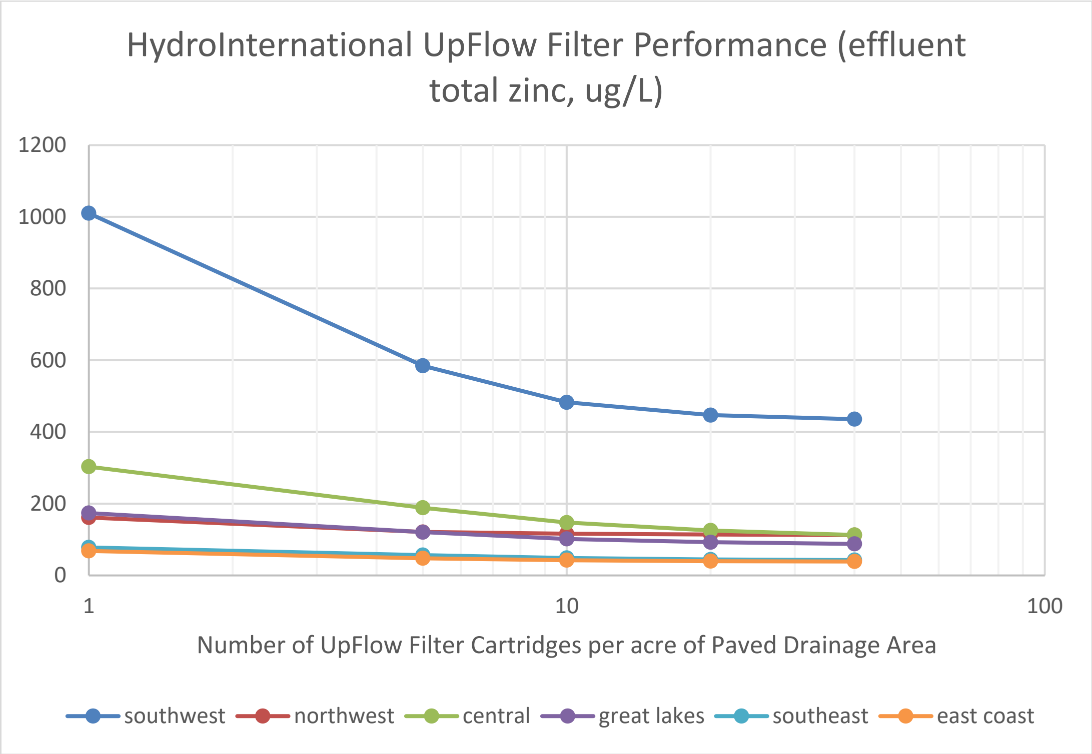

HydroInternational UpFlow Filter Performance (% total phosphorus reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of UpFlow Filter Modules per acre of Paved Drainage Area
southwest
northwest
central
great lakes
southeast
east coast

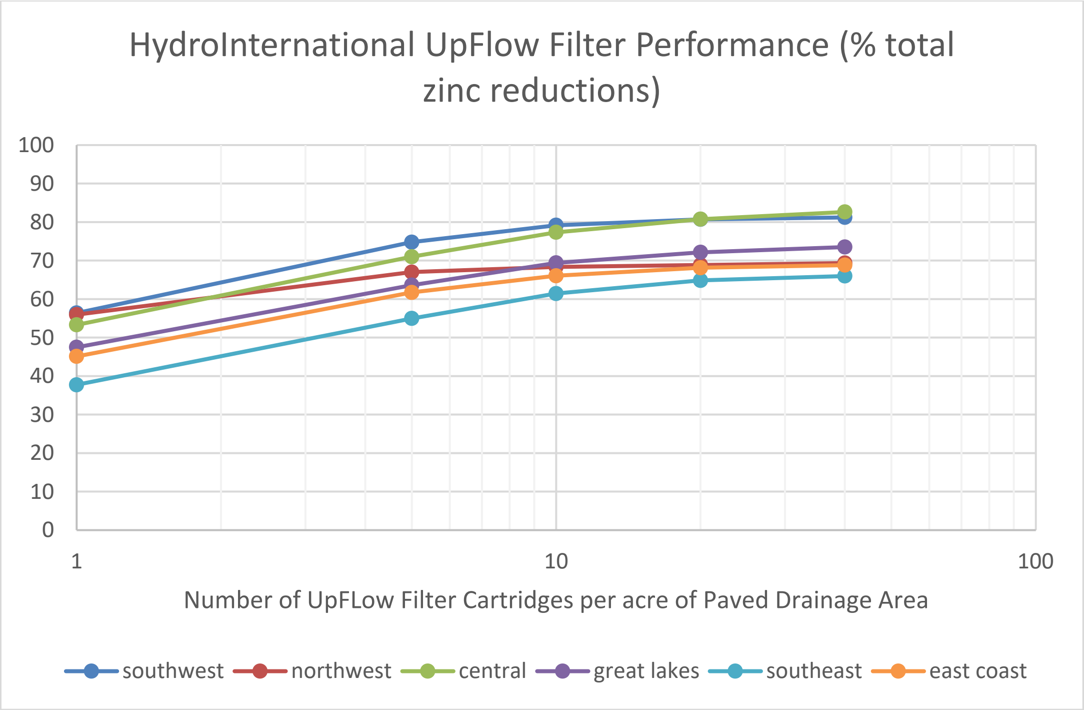

HydroInternational Upflow Filter Performance (effluent Total Kjeldahl Nitrogen, mg/L)
2.5
2
1.5
1
0.5
0
1
10
100
Number of UpFlow Filter Modules per acre of Paved Drainage Area
southwest
northwest
central
great lakes
southeast
east coast


HydroInternational UpFlow Filter Performance (% Total Kjeldahl Nitrogen reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of UpFlow Filter Modules per acre of Paved Draiange Area
southwest
northwest
central
great lakes
southeast
east coast


HydroInternational UpFlow FIlter Performance (effluent total copper, ug/L)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of UpFlow Filter Cartridges per acre of Paved Drainage Area
southwest
northwest
central
great lakes
southeast
east coast


HydroInternational UpFlow Filter Performance (% total copper reductions)
100
90
80
70
60
50
40
30
20
10
0
1
10
100
Number of UpFlow Filter Cartridges per acre of Paved Drainage Area
southwest
northwest
central
great lakes
southeast
east coast


HydroInternational UpFlow Filter Performance (effluent total zinc, ug/L)
1200
1000
800
600
400
200
0
1
10
100
Number of UpFlow Filter Cartridges per acre of Paved Drainage Area
southwest
northwest
central
great lakes
southeast
east coast

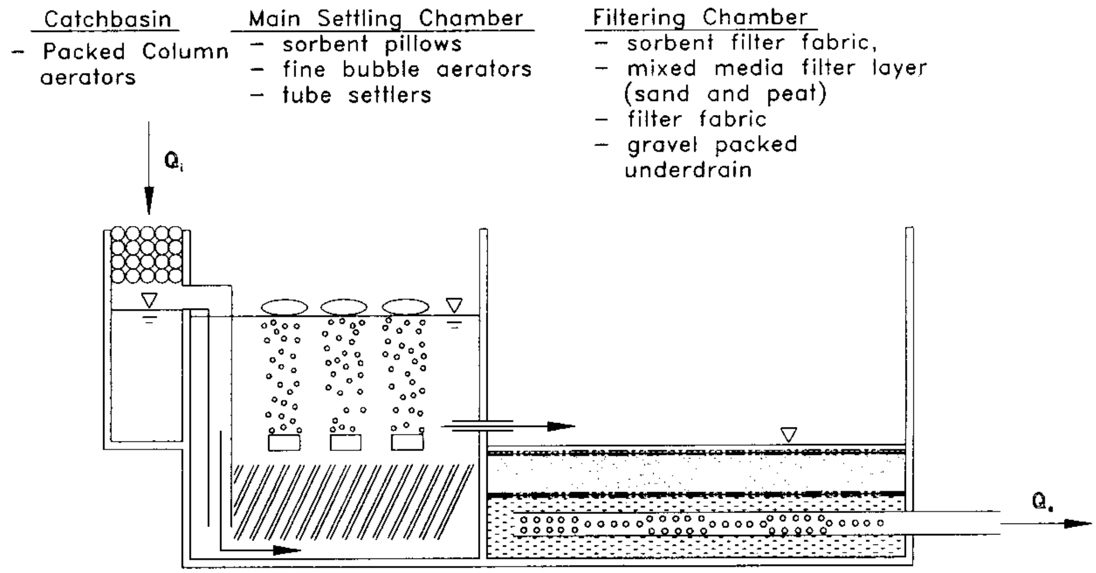


About 5 to 10 filter cartridges per paved acre of the drainage area provide close to maximum benefits, but that also depends on the particle size distributions of the particulate-bound material and the filterable fraction of the pollutants.

Multi-Chambered Treatment Train (MCTT)

The Multi-Chambered Treatment Train (MCTT) was developed to control toxicants in stormwater from critical source areas. The MCTT is most suitable for use at relatively small areas, about 0.1 to 1 ha in size, such as vehicle service facilities, convenience store parking areas, equipment storage and maintenance areas, and salvage yards, although it has been used in much larger areas. The MCTT is normally installed underground and is typically sized between 0.5 to 1.5 percent of the paved drainage area. It is comprised of three main sections, an inlet having a conventional catchbasin with litter traps, a main settling chamber having lamella plate separators and oil sorbent pillows, and a final chamber having a mixed sorbent media (usually peat moss and sand). During monitoring, the MCTT provided median reductions of >90% for toxicity, lead, zinc, and most organic toxicants. Suspended solids were reduced by more than 80% and COD was reduced by 60%. Effluent concentrations at monitored installations were all very low for these constituents.

The following figure shows a cross section of the MCTT. The catchbasin functions primarily as a protector for the other two units by removing large, grit-sized material. The setting chamber is the primary treatment chamber for removing settleable solids and associated constituents. The sand-peat filter is for final polishing of the effluent, using a combination of sorption and ion exchange for the removal of soluble pollutants.



MCTT cross section.

The final MCTT chamber is a mixed media filter (sorption/ion exchange) device. It receives water previously treated by the grit and the main settling chambers. The initial designs used a 50/50 mix of sand and peat moss, while later units used a 33/33/33 mixture of sand, peat moss, and granulated activated carbon. The MCTT can be easily modified to contain any mixture of media in the last chamber. However, care must be taken to ensure an adequate hydraulic capacity. As an example, peat moss alone is not effective because it compresses quickly, preventing water from flowing through the media. However, when mixed with sand, the hydraulic capacity is much greater and doesn't change rapidly with time. Bench-scale and field tests found that sand by itself (especially if recently installed) does not permanently retain the stormwater toxicants (which are mostly associated with very fine particles and which were mostly washed from the sand during later events). The sand-peat filter possesses ion exchange, adsorption, and filtration reduction mechanisms. As the media ages, the performance of these processes will change. Ion exchange capacity and adsorption sites, primarily associated with the peat moss, will be depleted. Filtration, primarily associated with the sand, however, increases, especially for the trapping of smaller particles. Replacement of the media in an MCTT is expected to be necessary about every 3 to 5 years.

A complete MCTT for a one acre paved area in southern California includes a standard 4 ft diameter catchbasin with a sump and debris screening, followed by a main settling chamber of 200 ft^2 and a filter chamber of 120 ft^2, for a total footprint area of about 350 ft^2, or 0.8% of the paved area. This is much smaller than biofilters alone or wet detention facilities alone, and also provides very high reductions in stormwater metals and organic toxicants in both filterable and particulate-bound forms.

Selection of Media for Treatment Devices

Pitt and Clark (2010) reviewed many media available for the removal of heavy metals and organics to very low levels. Critical aspects of these advanced treatment methods include using sufficient pre-treatment for the removal of fine particulates to minimize silting of the treatment media and also to provide sufficient contact time of the water being treated with the media.

The effectiveness of ion exchange decreases as the valence charge approaches zero and as the size of the complex increases. Clark and Pitt (2011) found that zeolites can be effective for removal of metals in the +2 valence state. However, the overall effectiveness of zeolites, and potentially other ion-exchange media such as oxide-coated sands, is likely reduced because a substantial fraction of the metals likely exist in valence forms other than +2 due to complexation with inorganic ions and organic matter.

Organic compounds and larger, less charged complexes of metals, can be chemically bonded with a media having strong sorption capacities. The octanol-water coefficient (K_{OW}) is an indication of the preference for the molecule to attach to an organic media (peat, compost, GAC) versus remaining in the stormwater runoff. The solubility coefficient (K_S) indicates the likelihood that the organic compound will remain dissolved in solution. The removal of some inorganic anions is difficult because most stormwater treatment media specifications stress high cation exchange capacities (CEC). High CEC media typically have low anion exchange capacities (AEC). CEC and AEC provide an estimate of the potential for exchanging a less-desirable compound with a pollutant whose chemical characteristics are more favorable. The following table lists some of the organic and metallic pollutants of concern in stormwater runoff and potential treatment media options, based on their chemical properties and the results of laboratory, pilot-scale, and full-scale treatment tests.

Selecting Treatment Technologies for Stormwater Organic and Metallic Pollutants (summarized from Clark and Pitt 2012)

Organics and Pesticides		
PAHs/Oil and Grease (O&G)/Dioxin	Sedimentation or filtration, possibly followed with chemically-active media.	These compounds have high K_{OW} and low K_S and are strongly associated with particulates. Sedimentation's effectiveness is a function of particle size association. Preferential sorption to organic media, such as peat, compost, and soil. Some O&G components can be microbially degraded in filter media. Reductions to very low levels with filtration may be difficult if parent material is contaminated. If low numeric permit limits exist, may have to use clean manufactured material, such as GAC.
Organic Acids and Bases	Chemically-active filtration	Tend to be more soluble in water than PAHs and more likely to be transported easily in treatment media. Need media with multiple types of sorption sites, such as peat, compost and soil. GAC possible if nonpolar part of molecule interacts well with GAC or if GAC has stronger surface active reactions than just van der Waals strength forces.
Pesticides	Chemically-active filtration	Tend to be soluble in water and need multiple reaction sites to be removed. Breakdown time in biologically-active filtration media is compound-dependent. Breakdown has the potential to restore surface-active sites, and may result in more soluble daughter products, which may or may not be more toxic. Organic media such as peat, compost, soil, GAC likely to be most effective since size of pesticide compounds will exclude substantial removal in ion-exchange resins such as zeolites.
Lead	Ion-exchange Chemically-active media filtration	Lead attaches strongly to solids. Substantial removal by sedimentation and/or physical filtration of solids to which lead is attached. • Lead < 0.45 mm may be ionic and could be removed using ion-exchange with zeolites, but filtered, ionic lead is usually at very low concentrations and it would be unusual to require treatment. • Lead complexes with hydroxides and chlorides to a certain extent. Removed in media with variety of binding sites (peat, compost, soil).
Copper, Zinc, Cadmium	Chemically-active filtration	These metals can attach to very small particles, with attachments being a function of the particulate organic content, pH, and oxidation-reduction conditions (filterable fractions vary from 25 to >75%). Physical filtration may be limited depending on size association of the pollutants. These metals complex with a variety of organic and inorganic ligands to create soluble complexes of varying valence charges (-2 to +2). Small amount of ionic species (metal as +2 ion only) reduces ion-exchange effectiveness. Complexes require variety types of sorption/exchange sites. Organic complexes may be removed by GAC. Peat, compost and soil will remove most inorganic and organic complexes. Concern about contamination of media with captured metals.