WinSLAMM v 10.3
Media Filtering Devices

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University of Alabama

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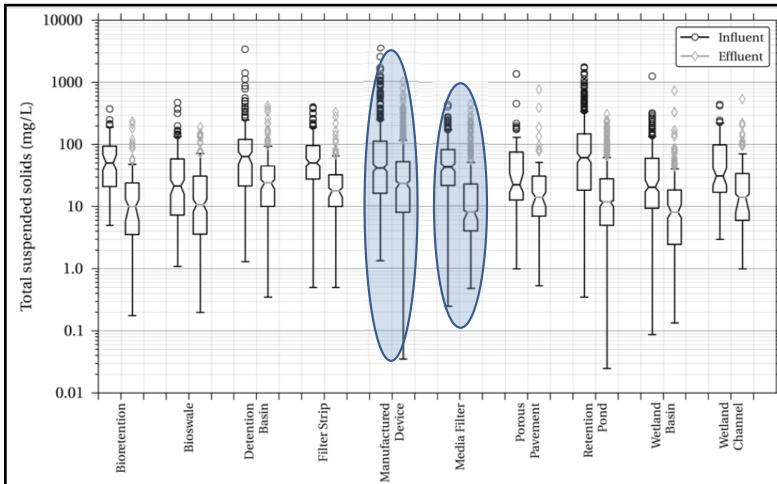
1

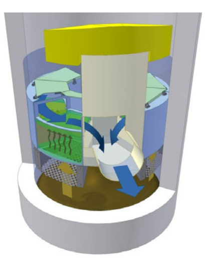


- TSS influent and effluent for different stormwater practices: International Stormwater BMP Database
- Manufactured devices (hydrodynamic devices) and media filters had about the same median influent TSS concentrations, but the media filters had substantially lower effluent TSS concentrations.

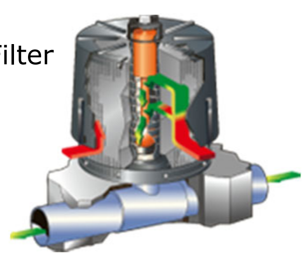
2

Stormwater Controls using Media Filtration (usually in Conjunction with Settling)

Up-Flo® Filter



StormFilter

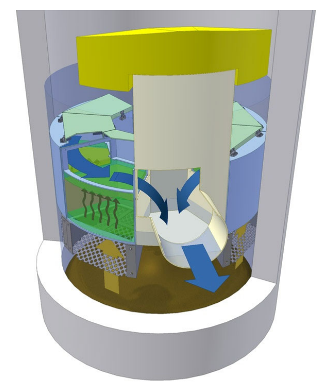


3

Up-Flo® Filter

Developed by Pitt as part of an EPA SBIR project and marketed by HydroInternational

- **Chamber** – Retains floatables and trash
- **Angled Screens** – Deflects neutrally buoyant material from media interface
- **Sump** – Stores coarse grit and gross debris
- **Filter media – high rate of flow due to partial bed expansion of contained media**:
  - Fine sediment
  - Hydrocarbons
  - Metals
  - Organics (pesticides, herbicides)
  - Nutrients (particulate phosphorus)



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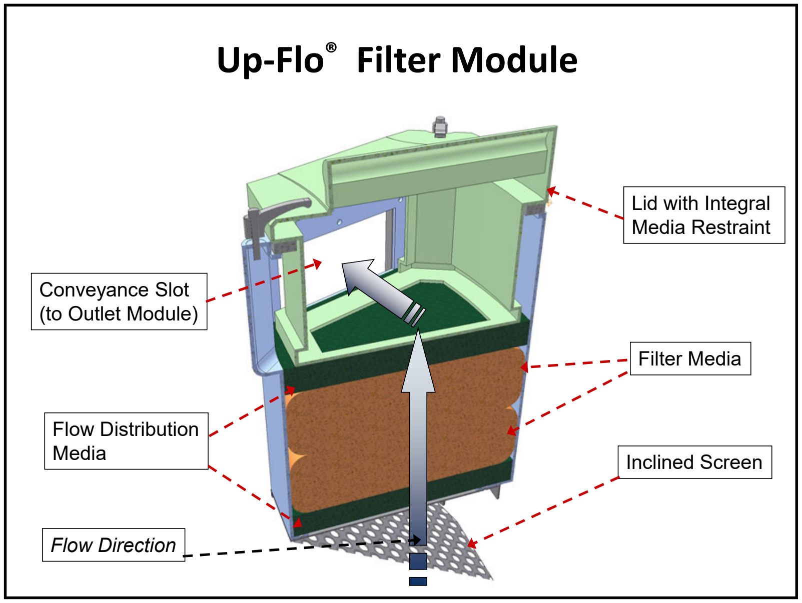
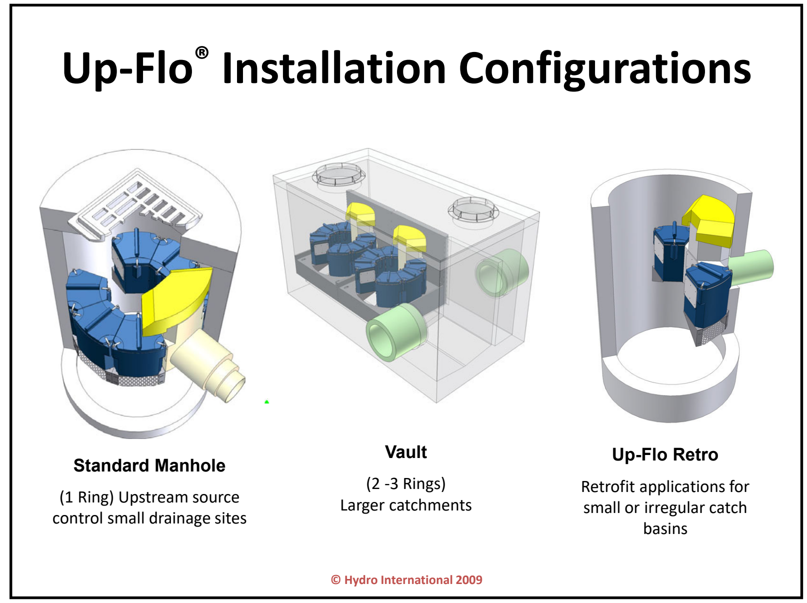

Up-Flo® Filter Module
Lid with Integral Media Restraint
Conveyance Slot (to Outlet Module)
Filter Media
Flow Distribution Media
Inclined Screen
Flow Direction

5


Up-Flo® Installation Configurations
Standard Manhole
(1 Ring) Upstream source control small drainage sites
Vault
(2 -3 Rings)
Larger catchments
Up-Flo Retro
Retrofit applications for small or irregular catch basins
© Hydro International 2009

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Current Full-Scale Monitoring in Tuscaloosa, AL
One acre, mostly paved drainage area

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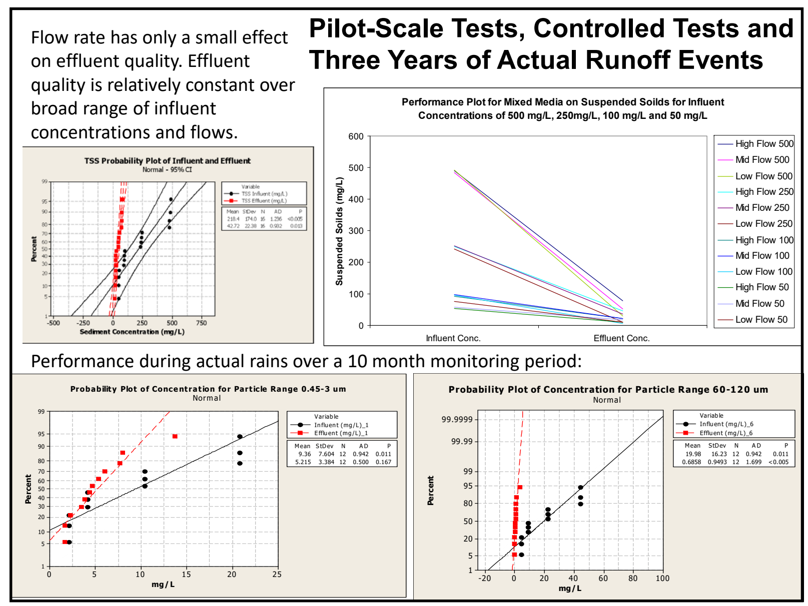
Flow rate has only a small effect on effluent quality. Effluent quality is relatively constant over broad range of influent concentrations and flows.
Pilot-Scale Tests, Controlled Tests and Three Years of Actual Runoff Events
TSS Probability Plot of Influent and Effluent
Performance Plot for Mixed Media on Suspended Soilds for Influent Concentrations of 500 mg/L, 250mg/L, 100 mg/L and 50 mg/L
Suspended Solids (mg/L)
Influent Conc.
Effluent Conc.
High Flow 500
Mid Flow 500
Low Flow 500
High Flow 250
Mid Flow 250
Low Flow 250
High Flow 100
Mid Flow 100
Low Flow 100
High Flow 50
Mid Flow 50
Low Flow 50
Performance during actual rains over a 10 month monitoring period:
Probability Plot of Concentration for Particle Range 0.45-3 um
Probability Plot of Concentration for Particle Range 60-120 um
Percent
mg/L

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Performance Summary by Particle Size

25 gallon/min Flow Rate and 500 mg/L Concentration			
Particle Size (µm)	Average Influent Concentration (mg/L)	Average Effluent Concentration (mg/L)	Average Reduction (%)
< 0.45	240	120	49
0.45 to 3	26	3.2	88
3 to 12	92	32	65
12 to 30	130	28	79
30 to 120	81	3.9	95
120 to 1180	142	0.55	100
> 1180	30	0	100
sum >0.45 µm	500	67.7	86

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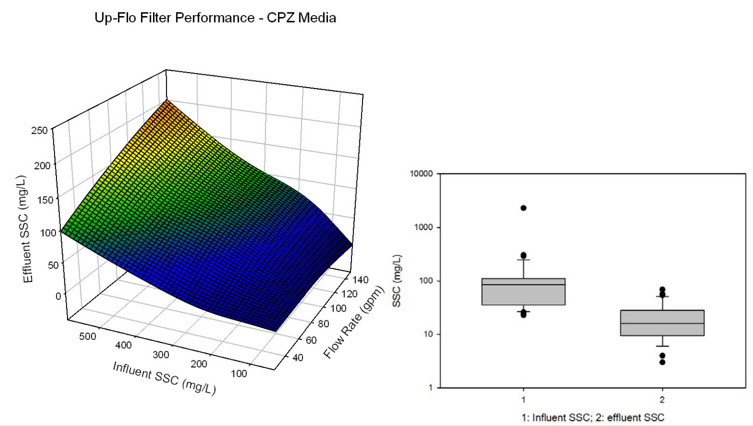
SSC Influent and Effluent Concentrations during 40 Monitored Events at Full-Scale Up-Flo® Filter Installation at BamaBelle Site, Tuscaloosa, AL



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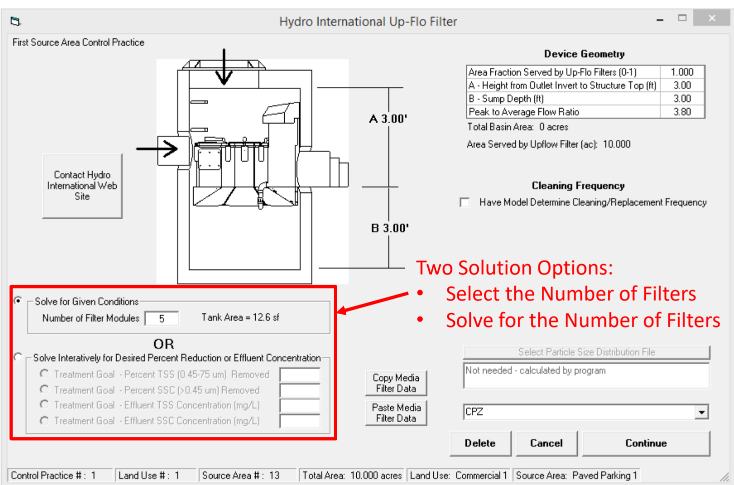
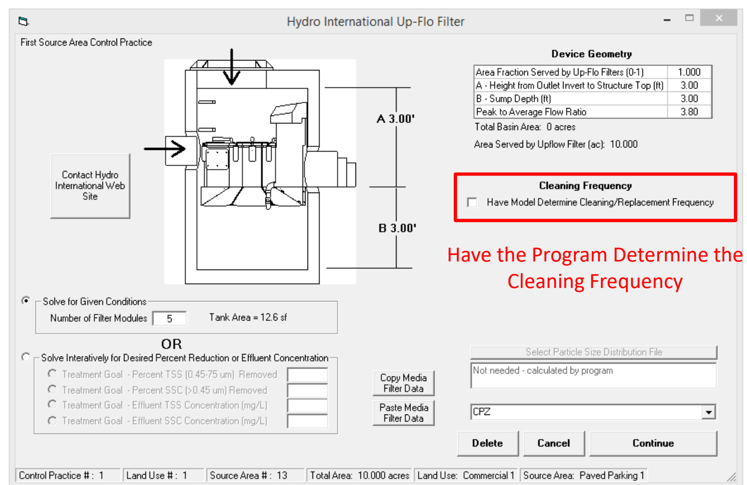
Up-flo® Filter Incorporated into WinSLAMM Version 10.3 Based on Lab and Field Tests



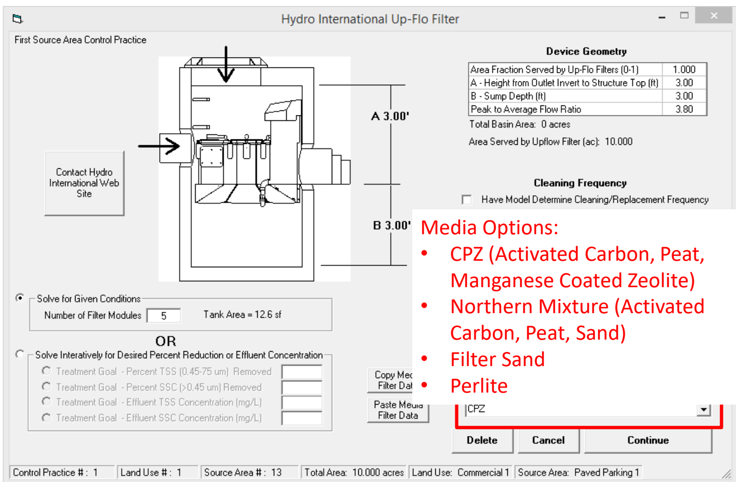
11

Up-flo® Filter Incorporated into WinSLAMM Version 10.3 Based on Lab and Field Tests



12

Up-flo® Filter Incorporated into WinSLAMM Version 10.3 Based on Lab and Field Tests



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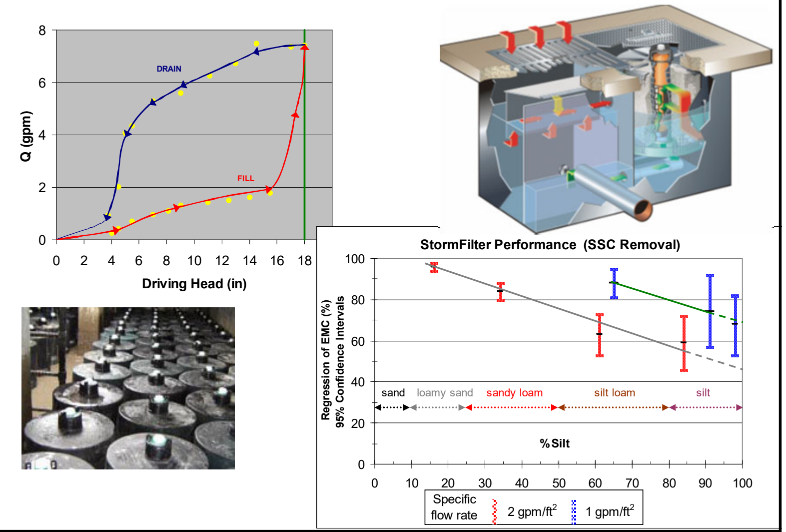
Contech's StormFilter also has substantial performance information (from both laboratory and field tests).



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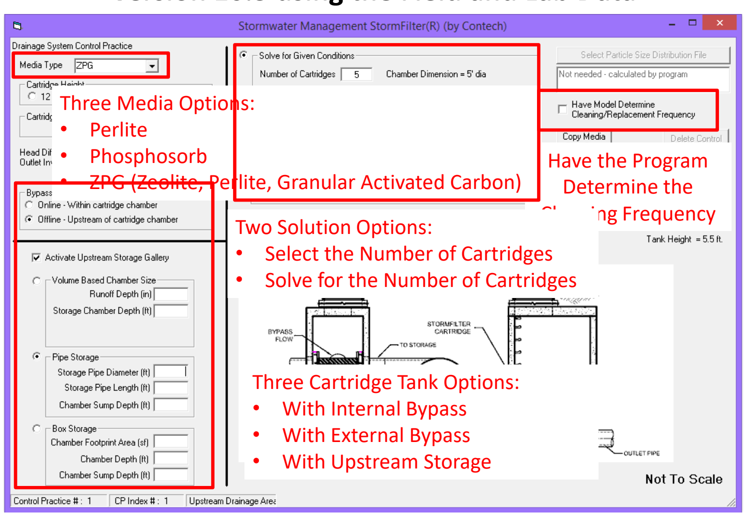
The Contech StormFilter is Incorporated into WinSLAMM Version 10.3 using the Field and Lab Data



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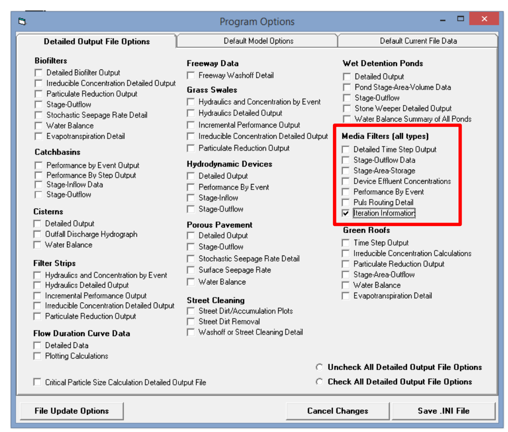
Analysis Procedure When Solving Iteratively

From the Tools menu, select "Program Options", and go to the "Detailed Output File Options"



Select the "Iteration Information" Checkbox in the Media Filters group

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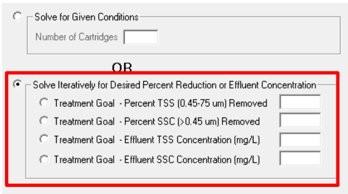
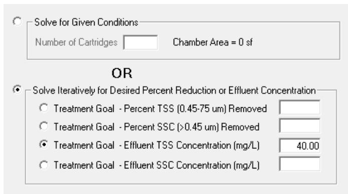
Analysis Procedure When Solving Iteratively



Two Solution Options:
- Select the Number of Filters
- Solve for the Number of Filters

Select "Solve Iteratively for Desired Percent Reduction or Effluent Concentration" then select the Treatment Goal for either TSS (0.45 to 75 um) or SSC (>0.45 um),



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Analysis Procedure When Solving Iteratively

Output from Three Model Runs with Different Final TSS Concentration Goals
File Name: [filename] SF#001 -87_Iterations.csv

Number of Iterations	Final TSS Conc.(mg/L) Goal	Number of Cartridges	Final TSS Concentration (mg/L)	Current - Previous TSS Conc. (mg/L)	Final Percent Reduction
1	40	12	43.64159	43.64159	68.81%
2	40	18	39.10429	-4.537292	
3	40	15	40.41138	1.307083	
1	30	12	43.64159	43.64159	71.70%
2	30	18	39.10429	-4.537292	
3	30	21	36.75288	-2.35141	
4	30	22	36.61931	-0.1335716	
1	20	12	43.64159	43.64159	71.70%
2	20	18	39.10429	-4.537292	
3	20	21	36.75288	-2.35141	
4	20	22	36.61931	-0.1335716	

1

1. Final iteration concentration slightly above goal, due to Iteration Tolerance of 2 mg/L (and one less cartridge may not be sufficient, so it rounds up)
   Use "Solve for Given Conditions" Option to determine Number of Cartridges needed to get below the Final TSS Concentration Goal

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Analysis Procedure When Solving Iteratively

Output from Three Model Runs with Different Final TSS Concentration Goals
File Name: [filename] SF#001 -87_Iterations.csv

Number of Iterations	Final TSS Conc.(mg/L) Goal	Number of Cartridges	Final TSS Concentration (mg/L)	Current - Previous TSS Conc. (mg/L)	Final Percent Reduction
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2	20	18	39.10429	-4.537292	
3	20	21	36.75288	-2.35141	
4	20	22	36.61931	-0.1335716	

2

2. Final iteration concentration unable to meet goal in this example because selected media unable to remove finer particles needed to reach the goal, even if all the water passed through the media filter with no bypass. Sedimentation of particulates in filter chambers (or upstream storage units) is also calculated and will affect results. However, there is a maximum number of filter units per acre recommended by the manufactures so very large systems are not considered.

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To Summarize, When Using WinSLAMM to Determine the Number of Filters:

1. Set the Detailed Output to Create the Iteration Information file.
2. Select the Desired Output Goal.
3. Run the Program.
4. Review the Iteration Information file, and/or the Stormwater Controls Summary tab, to determine detailed performance information.
5. Test the modified input using the 'Solve For Given Conditions' option in conjunction with other controls at the site.

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WinSLAMM v 10.3
Pipes, Grass Swales, and Grass Filter Strips

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We will cover . . .

- References
- Processes
- Examples of large-scale monitoring and modeling using infiltration controls
- Entering pipe, grass swale, and grass filter data in WinSLAMM

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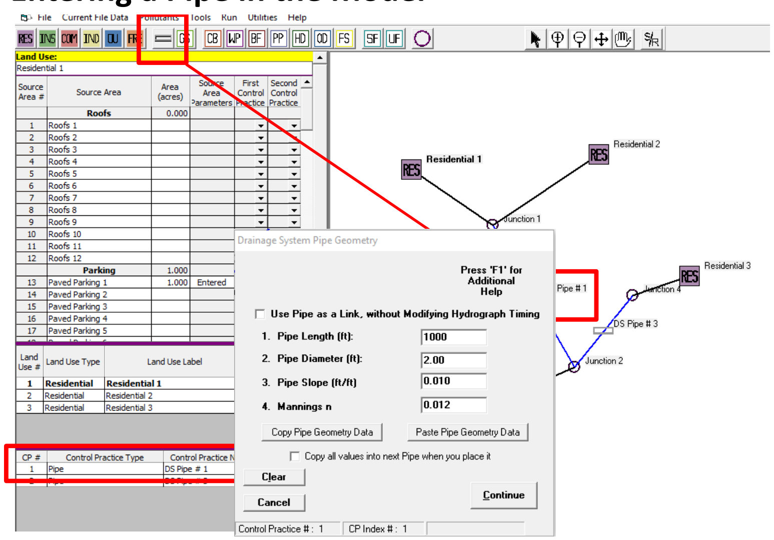
Entering a Pipe in the Model



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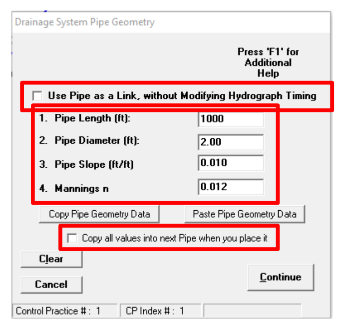
Entering a Pipe in the Model



Options

1. Use Pipe as a Link, without Modifying Hydrograph Timing
2. Modifying the Hydrograph Timing by entering in Pipe Data
3. Copy all Four Variables from selected pipe to every pipe created after the selected pipe (some modifications may be needed)

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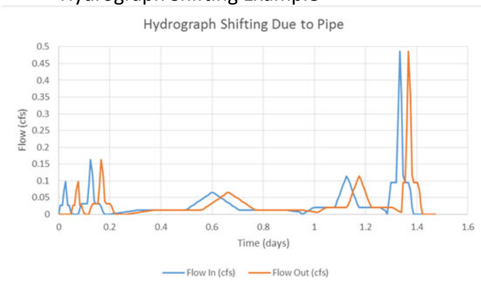
Entering a Pipe in the Model

Rain No.	Rainfall Depth (in)	Pipe No.	Avg Vel (ft/s)	Avg Depth (ft)	Travel Time (min)	Starting Increment No.	Ending Increment No.	Total No. of Incs.	Adj. No. of Increments	No. of Positive Flow Incs	No. of Incre. Shifts	Volume Shifted to Next Event (cf)	Max Flow (cfs)	Max Vel (ft/s)	Max Depth (ft)	Surcharged?
1	0.1	1	1.235059	6.71E-02	67.47315	0	10	10	0	7	7	1.562756	9.74E-02	1.619576	0.101573	#FALSE#
2	0.2	1	1.30847	7.33E-02	63.68759	11	28	17	0	14	6	0.624069	0.16368	1.89696	0.129636	#FALSE#
3	0.5	1	0.976864	4.70E-02	85.307	29	136	107	0	107	9	0.852409	6.51E-02	1.432696	8.42E-02	#FALSE#
4	0.4	1	1.16082	6.10E-02	71.78835	137	184	47	0	47	7	1.244993	0.114166	1.700002	0.10944	#FALSE#
5	0.5	1	1.823753	0.121976	45.69334	185	212	27	0	14	5	0	0.486276	2.636818	0.217113	#FALSE#

Detailed Output

1. Pipe Event Summary
2. Average Pipe Flow and Velocity
3. Maximum Pipe Flow and Velocity

Hydrograph Shifting Example



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Selected Grass Swale and Filter Strip Monitoring References

- EPA Report - Infiltration Through Disturbed Urban Soils and Compost (Pitt 1999)
- Alabama Highway Drainage Conservation Design Practices (Nara and Pitt 2005)
- HEC-15, Design of Roadside Channels with Flexible Linings, 2005
- Results of Tests on Vegetated Waterways (Cox and Palmer 1948

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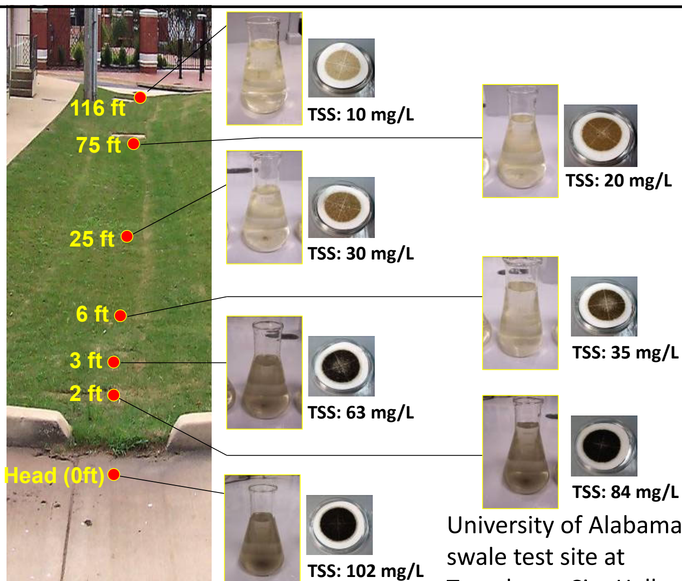

University of Alabama swale test site at Tuscaloosa City Hall

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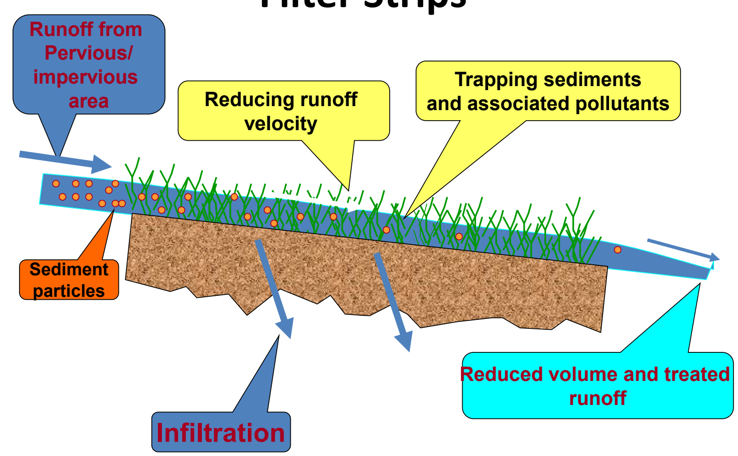
Pollutant Control in Grass Swales and Filter Strips



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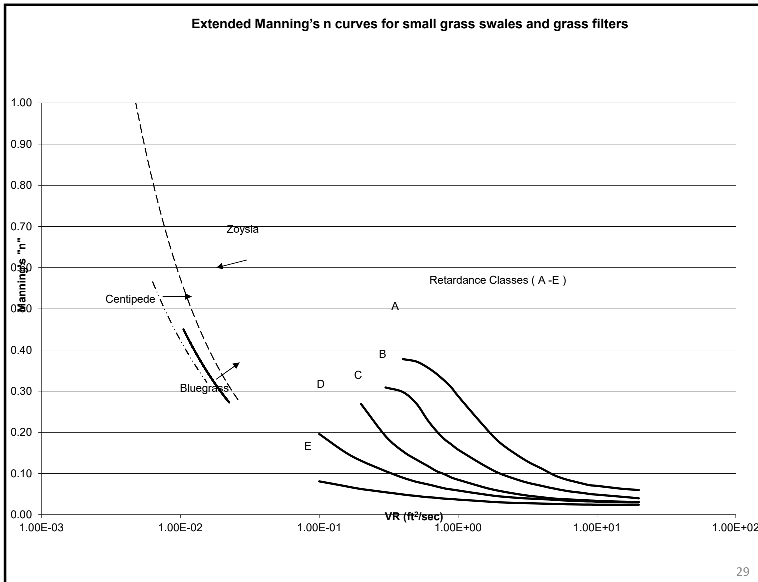

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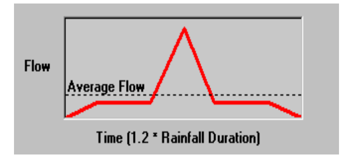
Dynamic Wetted Width Calculation

- Calculate event volume
- Convert volume to flow with:
  - Runoff duration = 1.2 times rainfall duration
  - Complex triangular hydrograph peak to average ratio = 3.8
- Flow rate calculated for each time interval set by user
- Calculate the wetted width from the flow rate and swale geometry using Manning's open channel flow equation for each time step



- Width
- Side slope
- Slope
- Manning's n from Retardance Factor

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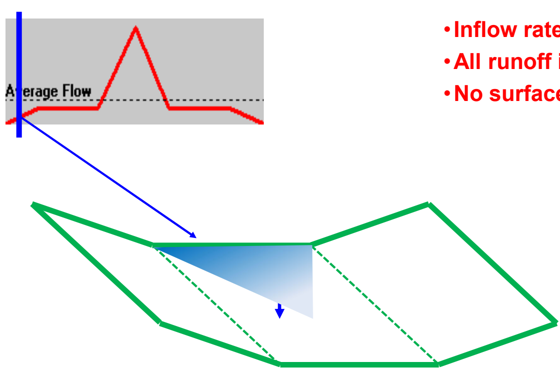
Swale Performance - Infiltration



- Inflow rate – Low
- All runoff infiltrated
- No surface discharge

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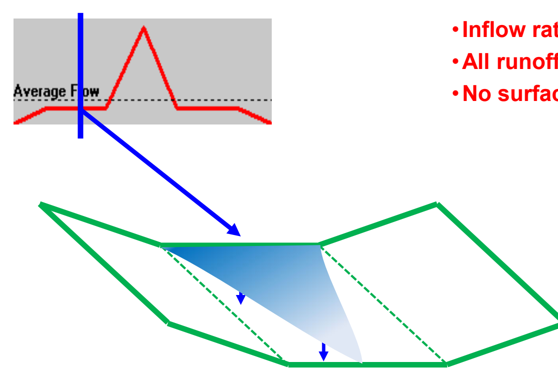
Swale Performance - Infiltration



- Inflow rate – Moderate
- All runoff infiltrated
- No surface discharge

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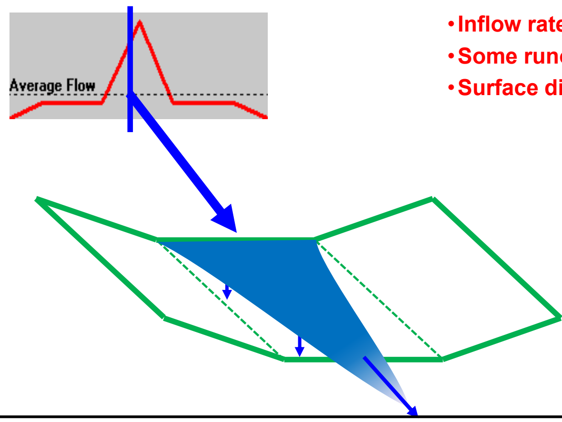
Swale Performance - Infiltration



- Inflow rate – High
- Some runoff infiltrated
- Surface discharge

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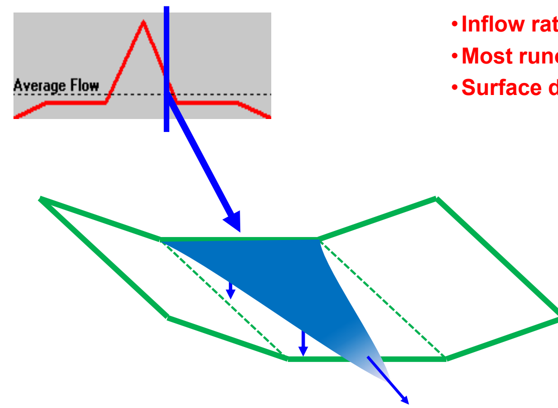
Swale Performance - Infiltration



- Inflow rate – Moderate
- Most runoff infiltrated
- Surface discharge

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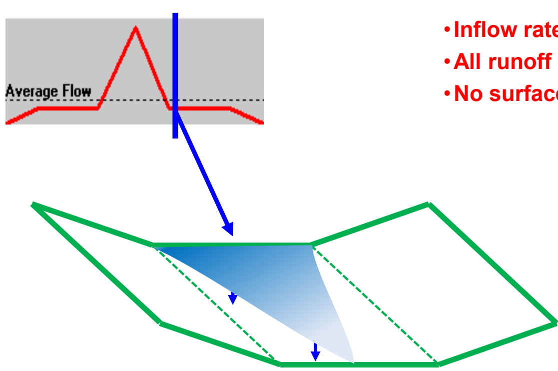
Swale Performance - Infiltration



- Inflow rate – Moderate
- All runoff infiltrated
- No surface discharge

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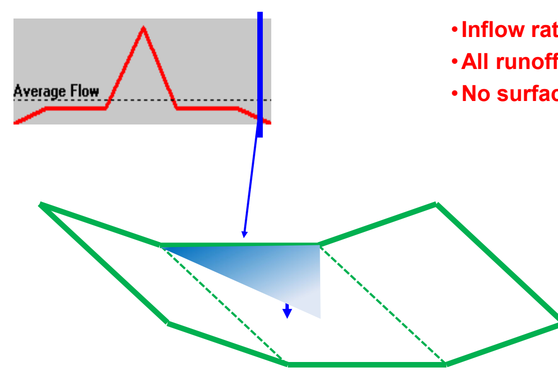
Swale Performance - Infiltration



- Inflow rate – Low
- All runoff infiltrated
- No surface discharge

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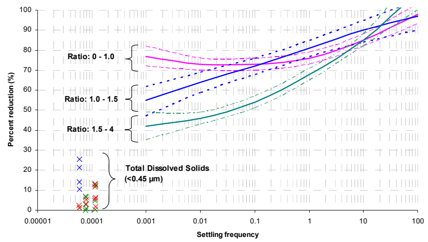
Particulate Removal Calculations

For each time step -

- Calculate flow velocity, settling velocity and flow depth
- Determine flow depth to grass height, for particulate reduction for each particle size increment using Nara & Pitt reference



- Check particle size group limits
  - Not exceed irreducible concentration value
  - No filtering for particles less than 50 microns
- Scour adjustment by
  - Flow velocity
  - Impervious area

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Modeling Grass Swales

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Five Components to Modeling Grass Swales

- Swale Density
- Swale Infiltration Rate
- Swale Geometry
- Grass Characteristics
- Runoff Particle Size Distribution

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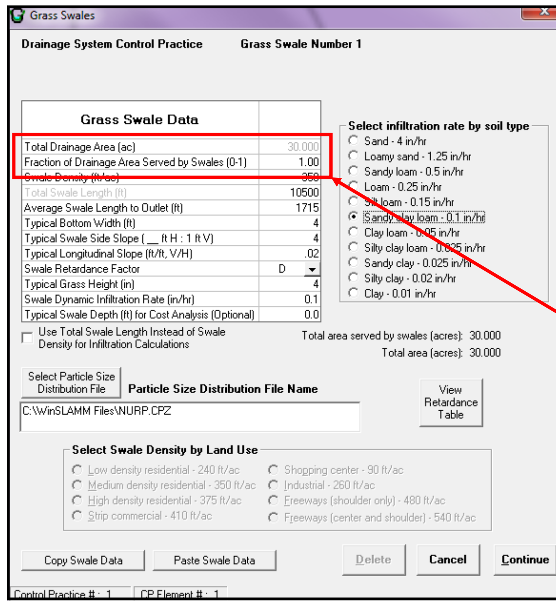
Swale Density



Drainage Areas

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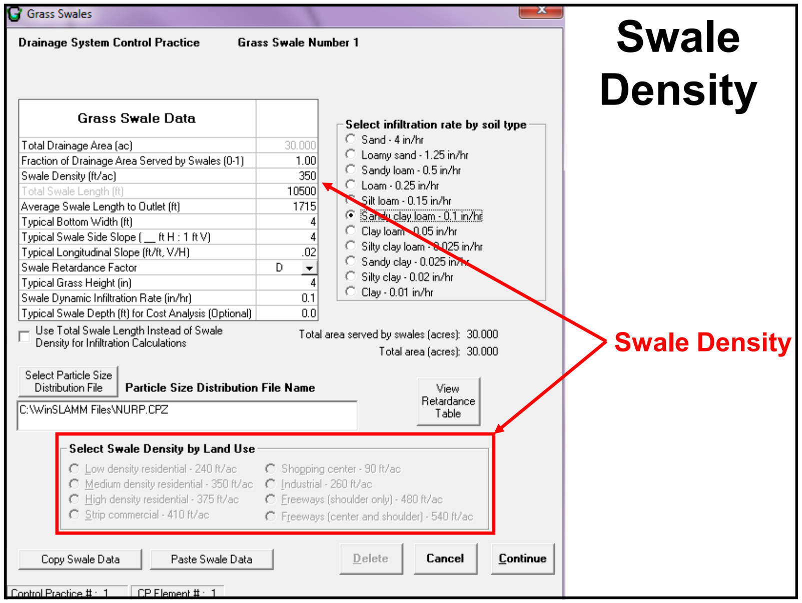
Swale Density
Grass Swales
Drainage System Control Practice
Grass Swale Number 1
Grass Swale Data
Select infiltration rate by soil type
Select Swale Density by Land Use
Swale Density

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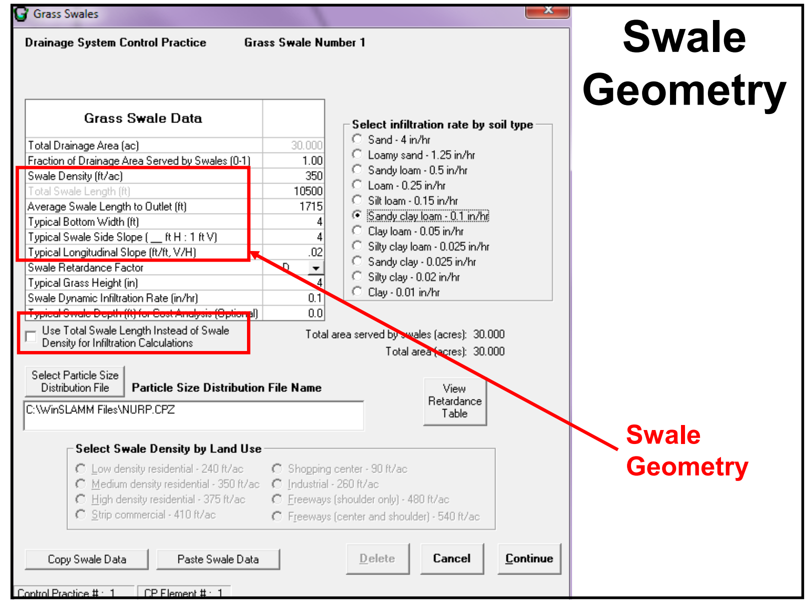
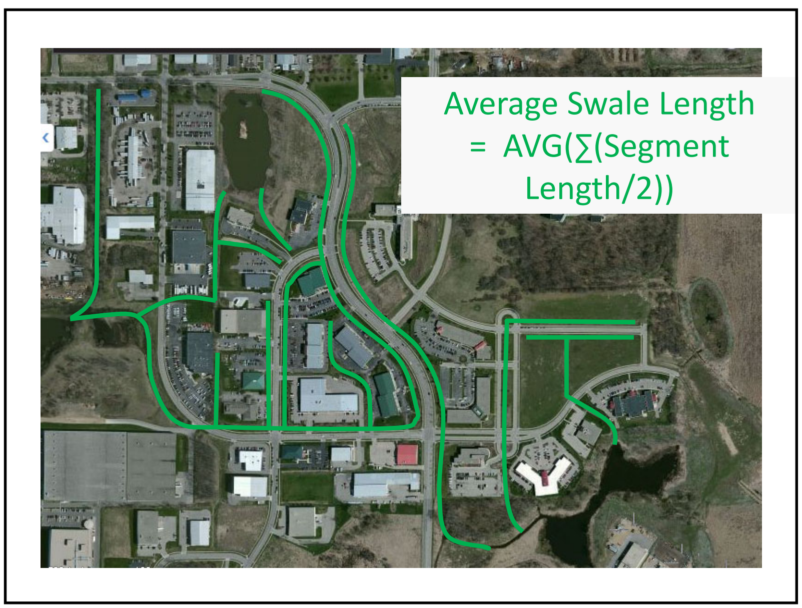

Swale Geometry
Grass Swales
Drainage System Control Practice
Grass Swale Number 1
Grass Swale Data
Select infiltration rate by soil type
Select Swale Density by Land Use
Swale Geometry

42


Average Swale Length = AVG(∑(Segment Length/2))

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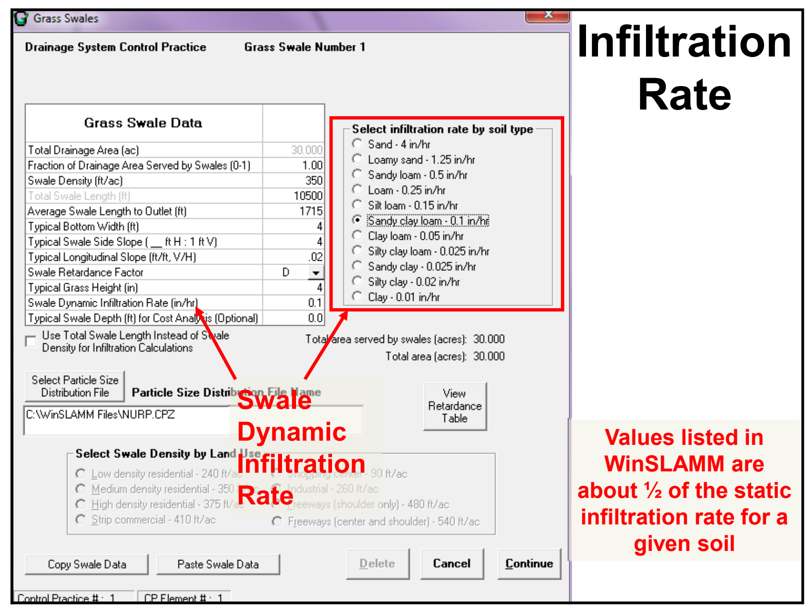
Infiltration Rate
Grass Swales
Drainage System Control Practice
Grass Swale Number 1
Grass Swale Data
Select infiltration rate by soil type
Swale Dynamic Infiltration Rate
Values listed in WinSLAMM are about ½ of the static infiltration rate for a given soil

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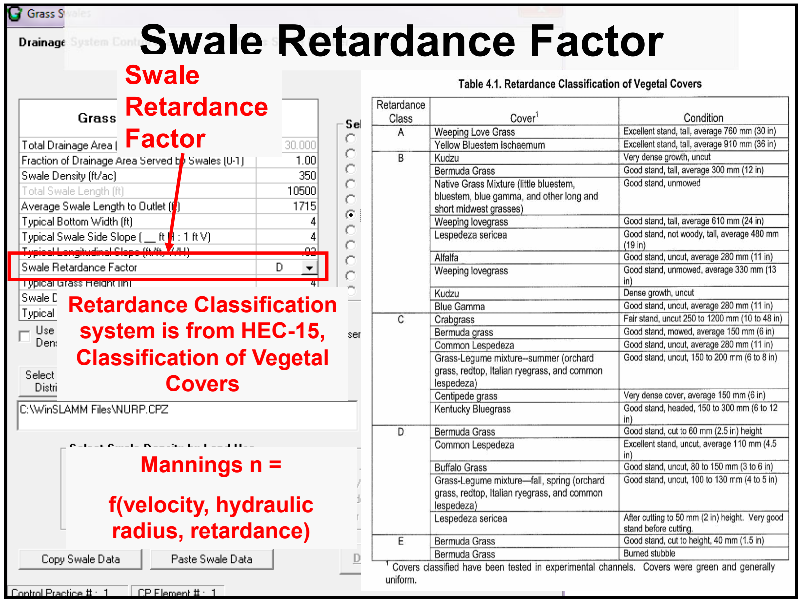

Table 4.1. Retardance Classification of Vegetal Covers

Retardance Class	Cover[1]	Condition
A	Weeping Love Grass	Excellent stand, tall, average 760 mm (30 in)
	Yellow Bluestem Ischaemum	Excellent stand, tall, average 910 mm (36 in)
B	Kudzu	Very dense growth, uncut
	Bermuda Grass	Good stand, tall, average 300 mm (12 in)
	Native Grass Mixture (little bluestem, bluestem, blue gamma, and other long and short midwest grasses)	Good stand, unmowed
	Weeping lovegrass	Good stand, tall, average 610 mm (24 in)
	Lespedeza sericea	Good stand, not woody, tall, average 480 mm (19 in)
	Alfalfa	Good stand, uncut, average 280 mm (11 in)
	Weeping lovegrass	Good stand, unmowed, average 330 mm (13 in)
	Kudzu	Dense growth, uncut
	Blue Gamma	Good stand, uncut, average 280 mm (11 in)
C	Crabgrass	Fair stand, uncut 250 to 1200 mm (10 to 48 in)
	Bermuda grass	Good stand, mowed, average 150 mm (6 in)
	Common Lespedeza	Good stand, uncut, average 280 mm (11 in)
	Grass-Legume mixture--summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 150 to 200 mm (6 to 8 in)
	Centipede grass	Very dense cover, average 150 mm (6 in)
	Kentucky Bluegrass	Good stand, headed, 150 to 300 mm (6 to 12 in)
D	Bermuda Grass	Good stand, cut to 60 mm (2.5 in) height
	Common Lespedeza	Excellent stand, uncut, average 110 mm (4.5 in)
	Buffalo Grass	Good stand, uncut, 80 to 150 mm (3 to 6 in)
	Grass-Legume mixture—fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 100 to 130 mm (4 to 5 in)
	Lespedeza sericea	After cutting to 50 mm (2 in) height. Very good stand before cutting.
E	Bermuda Grass	Good stand, cut to height, 40 mm (1.5 in)
	Bermuda Grass	Burned stubble

[1] Covers classified have been tested in experimental channels. Covers were green and generally uniform.

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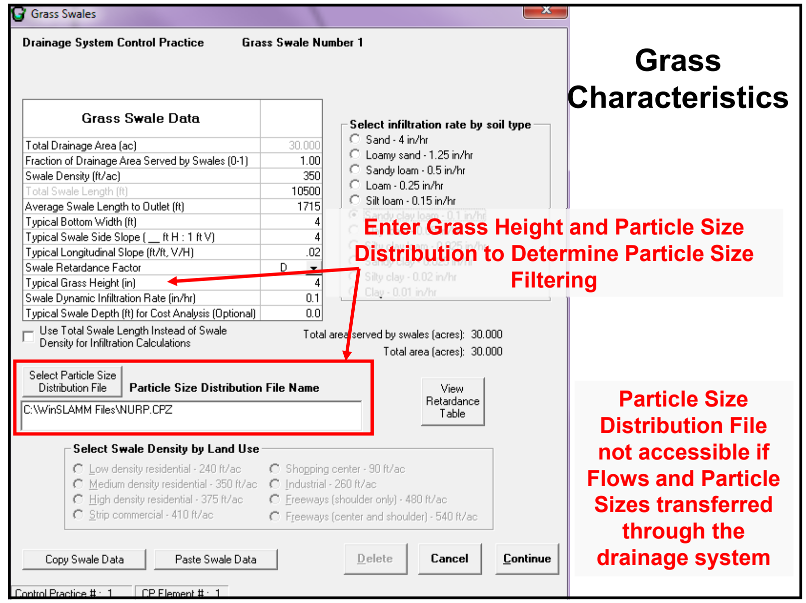

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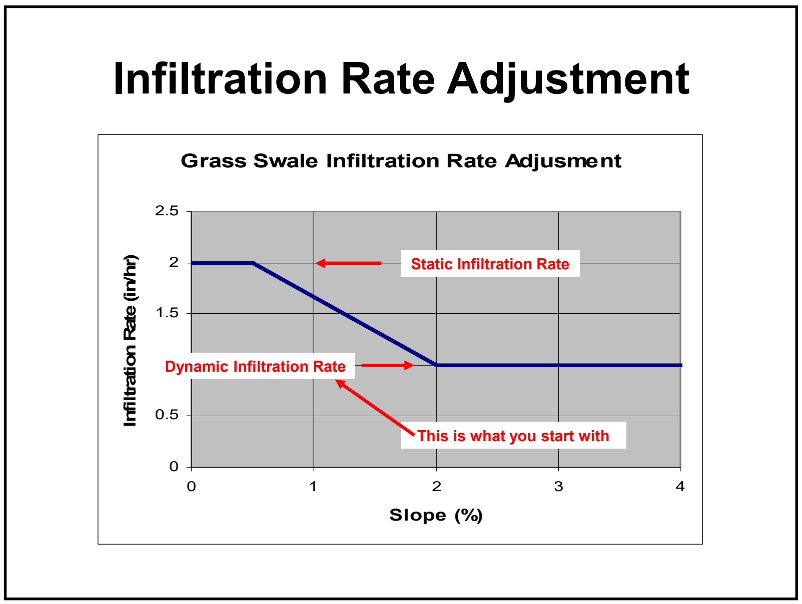

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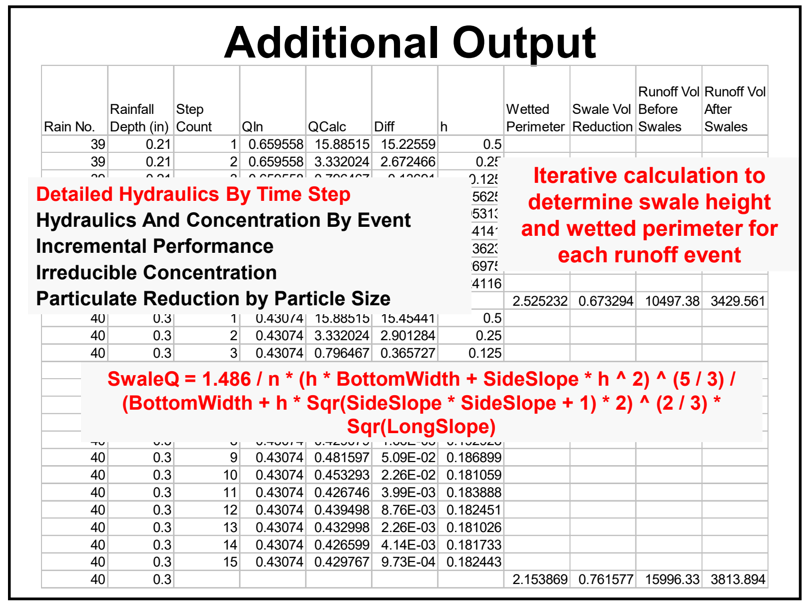

Rain No.	Rainfall Depth (in)	Step Count	QIn	QCalc	Diff	h	Wetted Perimeter	Swale Vol Reduction	Runoff Vol Before Swales	Runoff Vol After Swales
39	0.21	1	0.659558	15.88515	15.22559	0.5				
39	0.21	2	0.659558	3.332024	2.672466	0.25				
							2.525232	0.673294	10497.38	3429.561
40	0.3	1	0.43074	15.88515	15.45441	0.5				
40	0.3	2	0.43074	3.332024	2.901284	0.25				
40	0.3	3	0.43074	0.796467	0.365727	0.125				
40	0.3	9	0.43074	0.481597	5.09E-02	0.186899				
40	0.3	10	0.43074	0.453293	2.26E-02	0.181059				
40	0.3	11	0.43074	0.426746	3.99E-03	0.183888				
40	0.3	12	0.43074	0.439498	8.76E-03	0.182451				
40	0.3	13	0.43074	0.432998	2.26E-03	0.181026				
40	0.3	14	0.43074	0.426599	4.14E-03	0.181733				
40	0.3	15	0.43074	0.429767	9.73E-04	0.182443				
40	0.3						2.153869	0.761577	15996.33	3813.894

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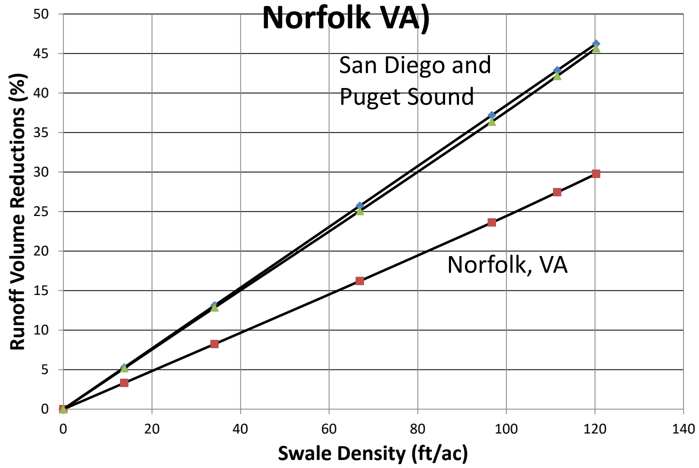
Grass Swale Production Functions for Three US Locations (San Diego CA, Puget Sound WA, and Norfolk VA)



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Modeling Filter Strips

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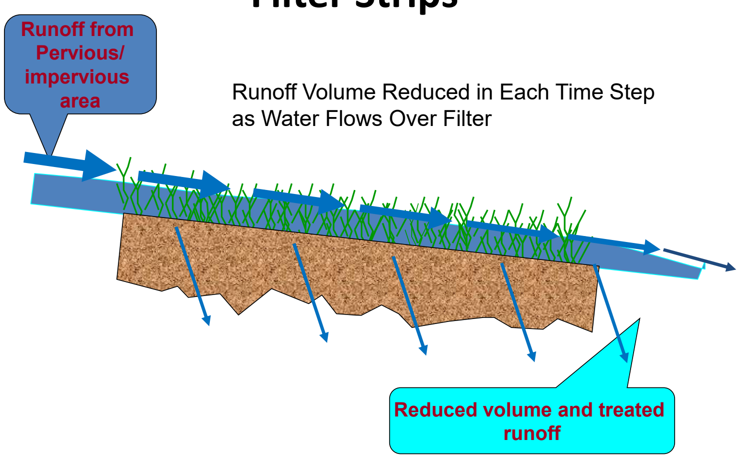
Runoff Volume Reduction in Filter Strips



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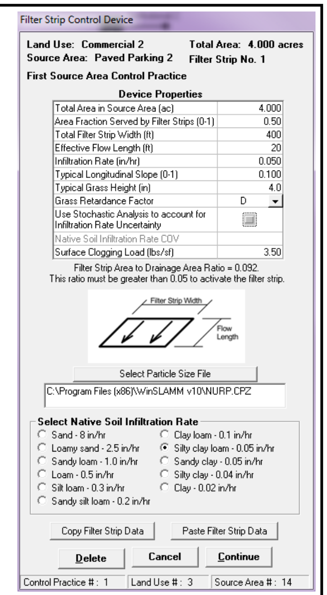
Grass Filter Strips

Assumptions:

- Flow over surface modeled as sheet flow
- All particle sizes are treated
- Effective treatment length reduced based upon slope
  - <0.02 ft/ft – 3 ft reduction
  - >0.05 ft/ft – 10 ft reduction
  - else – 6 ft reduction
- Irreducible concentration a function of particle size



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Five Components to Modeling Filter Strips

- Infiltration Rate
- Geometry
- Grass Characteristics
- Clogging and Runoff Particle Size Distribution

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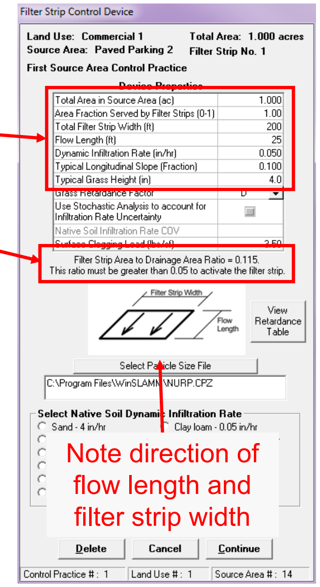
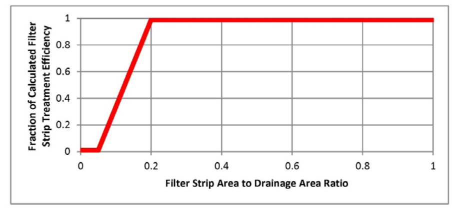
Geometry

Geometry

The filter strip area to drainage area ratio must be greater than 0.05





Note direction of flow length and filter strip width

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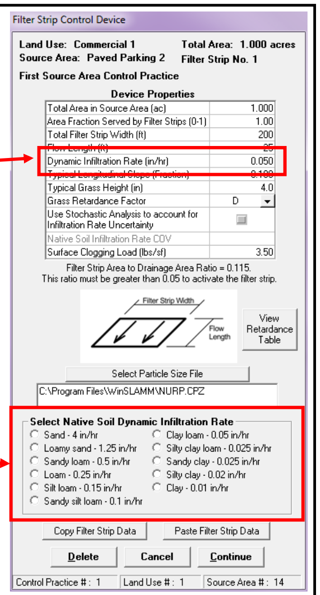
Infiltration Rate

Infiltration Rate

Depth of Water in Filter Strip	Infiltration Rate (in/hr)
<= 0.015 ft	Entered Rate x 2 (Static Infiltration Rate)
> 0.015 and < 0.03 ft	Interpolated Between the Two Rates
>= 0.03 ft	Entered Rate (Dynamic Infiltration Rate)

Listed native soil infiltration rates based upon field double ring infiltrometer measurements



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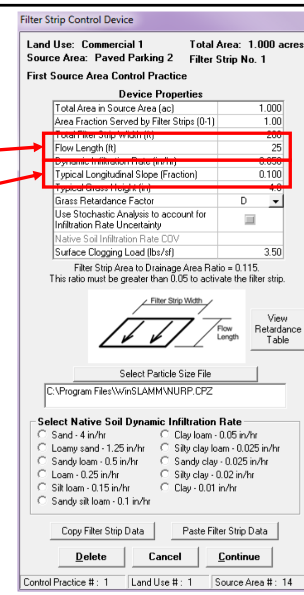
Effective Flow Length

Flow Length

Longitudinal Slope

Longitudinal Slope	Effective Flow Length (ft)
<= 0.02	Flow Length minus 3.0 ft
>= 0.02 and < 0.05	Flow Length minus 6.0 ft
>= 0.05	Flow Length minus 10.0 ft



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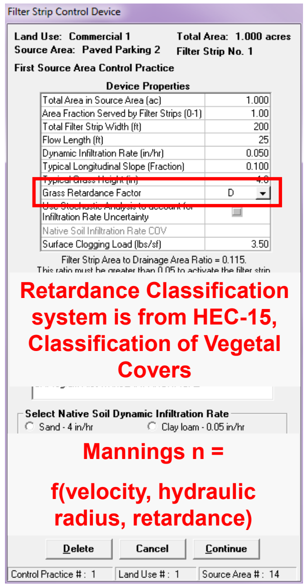
Retardance

Table 4.1. Retardance Classification of Vegetal Covers

Retardance Class	Cover[1]	Condition
A	Weeping Love Grass	Excellent stand, tall, average 760 mm (30 in)
	Yellow Bluestem Ischaemum	Excellent stand, tall, average 910 mm (36 in)
B	Kudzu	Very dense growth, uncut
	Bermuda Grass	Good stand, tall, average 300 mm (12 in)
	Native Grass Mixture (little bluestem, bluestem, blue gamma, and other long and short midwest grasses)	Good stand, unmowed
	Weeping lovegrass	Good stand, tall, average 610 mm (24 in)
	Lespedeza sericea	Good stand, not woody, tall, average 480 mm (19 in)
	Alfalfa	Good stand, uncut, average 280 mm (11 in)
	Weeping lovegrass	Good stand, unmowed, average 330 mm (13 in)
	Kudzu	Dense growth, uncut
	Blue Gamma	Good stand, uncut, average 280 mm (11 in)
C	Crabgrass	Fair stand, uncut 250 to 1200 mm (10 to 48 in)
	Bermuda grass	Good stand, mowed, average 150 mm (6 in)
	Common Lespedeza	Good stand, uncut, average 280 mm (11 in)
	Grass-Legume mixture--summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 150 to 200 mm (6 to 8 in)
	Centipede grass	Very dense cover, average 150 mm (6 in)
	Kentucky Bluegrass	Good stand, headed, 150 to 300 mm (6 to 12 in)
D	Bermuda Grass	Good stand, cut to 60 mm (2.5 in) height
	Common Lespedeza	Excellent stand, uncut, average 110 mm (4.5 in)
	Buffalo Grass	Good stand, uncut, 80 to 150 mm (3 to 6 in)
	Grass-Legume mixture—fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 100 to 130 mm (4 to 5 in)
	Lespedeza sericea	After cutting to 50 mm (2 in) height. Very good stand before cutting.
E	Bermuda Grass	Good stand, cut to height, 40 mm (1.5 in)
	Bermuda Grass	Burned stubble

[1] Covers classified have been tested in experimental channels. Covers were green and generally uniform.



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Surface Clogging

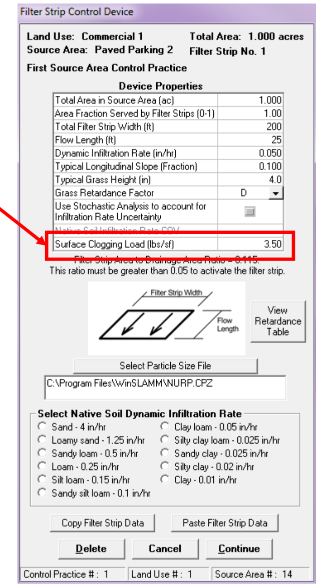
Surface Clogging

Surface clogging due to source area loading, accumulates over time.

Infiltration rate clog adjustment = Trapped Mass/Clogging Load

If the swale does not clog after 10 years, assume:

- It will not clog
- Maintain the 10 year adjusted infiltration rate



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Additional Output

Rain No.	Rainfall Depth (in)	Filter Strip No.	SA/LU Runoff Volume (cf)	Runoff Volume to FS (cf)	Runoff Volume Bypassing FS (cf)	Runoff Volume Infiltrated (cf)	FS Effluent Volume (cf)	Total Effluent Volume (cf)	Influent Conc (mg/l)	Infil. Rate Clogging Adj. Factor (Fraction)	Adj. Infil. Rate (in/hr)
40	0.01	1	3.22707	3.22707	0	3.229954	0	0	130	0.0000	0.0446
41	0.01	1	3.22707	3.22707	0	3.229957	0	0	130	0.0000	0.0446
42	0.01	1	3.22707	3.22707	0	3.229948	0	0	130	0.0000	0.0446
43	0.33	1	735.6448	735.6448	0	169.7649	565.9003	565.9003	130	0.0002	0.0446
44	0.07	1	106.7271	106.7271	0	86.29122	20.43898	20.43898	130	0.0002	0.0445
45	0.43	1	1013.367	1013.367	0	269.4128	743.9595	743.9595	130	0.0004	0.0445
46	2.59	1	8609.945	8609.945	0	318.1631	8291.851	8291.851	130	0.0020	0.0445
47	0.34	1	762.9528	762.9528	0	103.7634	659.2626	659.2626	130	0.0022	0.0445
48	0.32	1	708.6318	708.6318	0	103.519	605.1809	605.1809	130	0.0023	0.0445
49	0.51	1	1239.519	1239.519	0	239.1143	1000.422	1000.422	130	0.0026	0.0444
50	0.13	1	236.219	236.219	0	97.26946	138.9721	138.9721	130	0.0027	0.0444
51	0.24	1	503.1494	503.1494	0	35.03768	468.561	468.561	130	0.0028	0.0444

Rain No.	TSS Eff Conc Reduct. Ratio	Effluent Conc Before Ratio Adj.	Final Effluent Conc (mg/l)	Influent Load (lbs)	Effluent Load (lbs)	Cum. Clogging Load (lbs/sf)	Maximum Velocity (ft/s)	Maximum Depth (ft)	Maximum Shear (lb/sf)
40	0.108969	15	0	0.02619	0.0000	0.0000	0.0050	0.0027	0.0051
41	0.108969	15	0	0.02619	0.0000	0.0000	0.0051	0.0028	0.0052
42	0.108969	15	0	0.02619	0.0000	0.0000	0.0051	0.0028	0.0052
43	0.108969	19.28059	31.34552	5.97022	1.1074	0.0006	0.0235	0.0276	0.0516
44	0.108969	15	27.53138	0.866157	0.0351	0.0007	0.0109	0.0087	0.0162
45	0.108969	17.9533	30.16286	8.224113	1.4009	0.0016	0.0221	0.0252	0.0471
46	0.108969	40.80983	50.52875	69.87511	26.1559	0.0070	0.0497	0.0847	0.1586
47	0.108969	21.70889	33.50921	6.191841	1.3791	0.0076	0.0292	0.0383	0.0717
48	0.108969	21.58258	33.39666	5.750992	1.2617	0.0082	0.0284	0.0366	0.0686
49	0.108969	20.72677	32.63411	10.05948	2.0381	0.0092	0.0253	0.0308	0.0577
50	0.108969	15	27.53138	1.917065	0.2389	0.0094	0.0183	0.0189	0.0355
51	0.108969	31.2251	41.98845	4.083373	1.2282	0.0098	0.0384	0.0576	0.1079

Hydraulic Details by Time Step
Incremental PSD and Concentration
Particulate Reduction by Particle Size
Irreducible Concentration
Hydraulics and Concentration By Event

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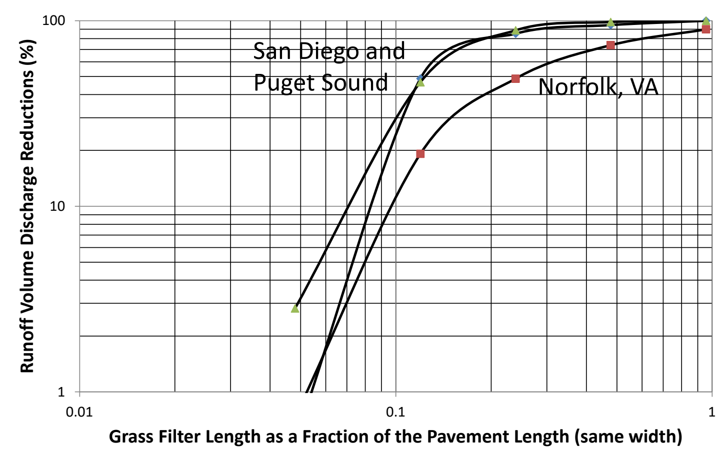
Grass Filter Production Functions for Three US Locations (San Diego CA, Puget Sound WA, and Norfolk VA)



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