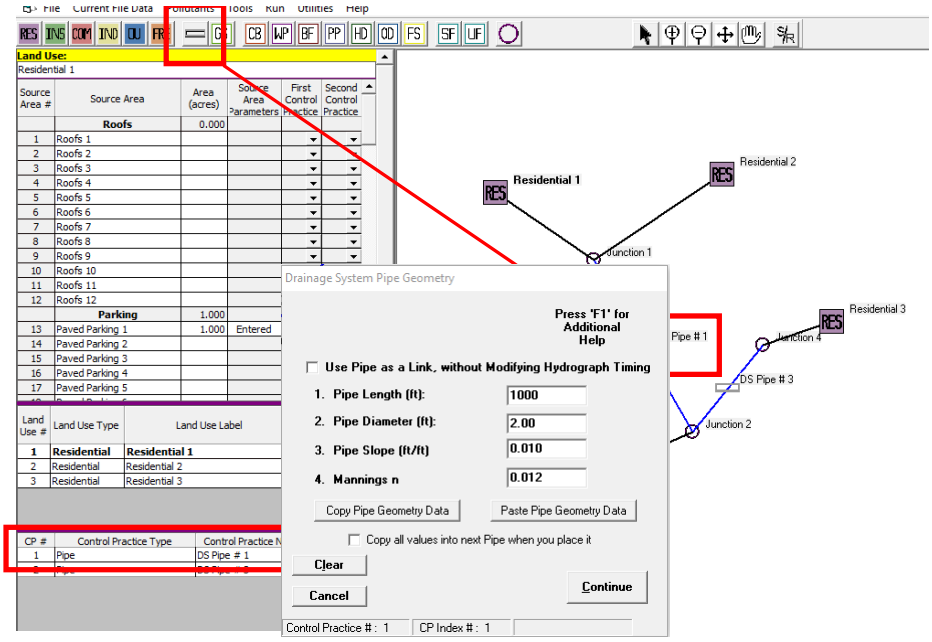
WinSLAMM v 10
Pipes, Grass Swales, and Grass Filter Strips

Tab 7a
PVA LLC
John Voorhees
January 2022

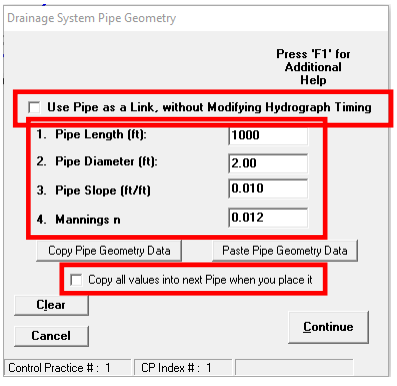
We will cover . . .

- Entering and using the Pipe Control
- Entering grass swale and grass filter strip data in WinSLAMM

Entering a Pipe in the Model



Entering a Pipe in the Model



Options

1. Use Pipe as a Link, without Modifying Hydrograph Timing
2. Modify 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)

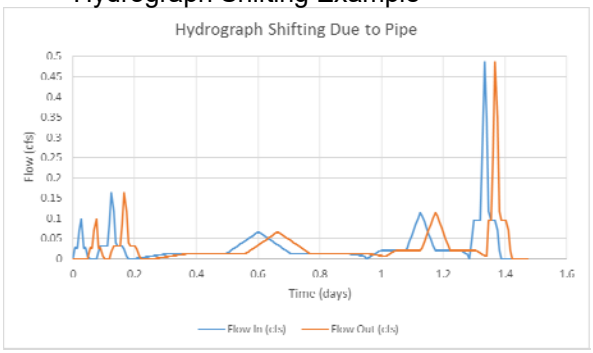
Entering a Pipe in the Model

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

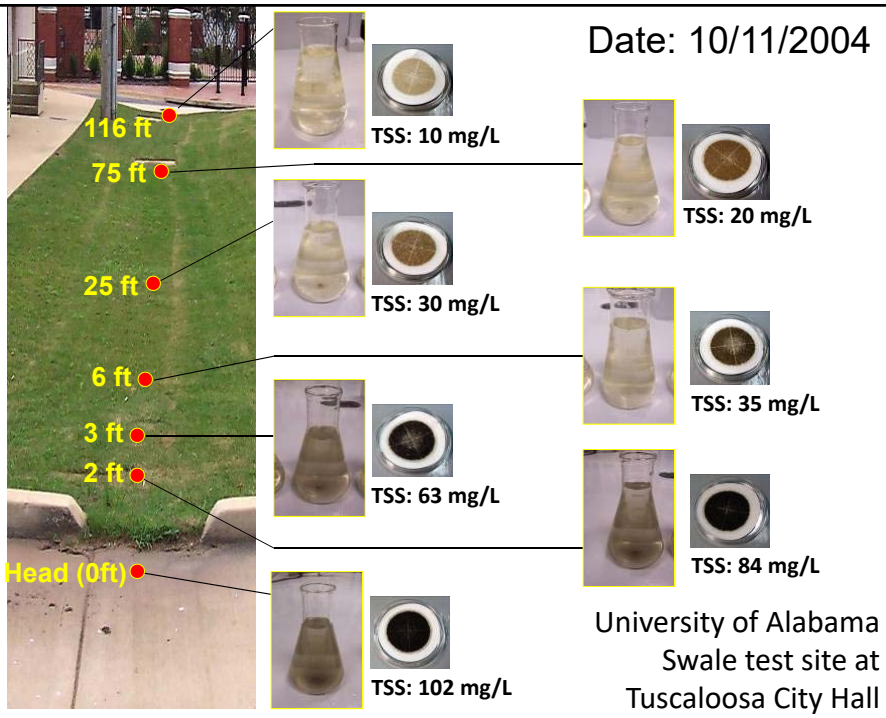
Hydrograph Shifting Example



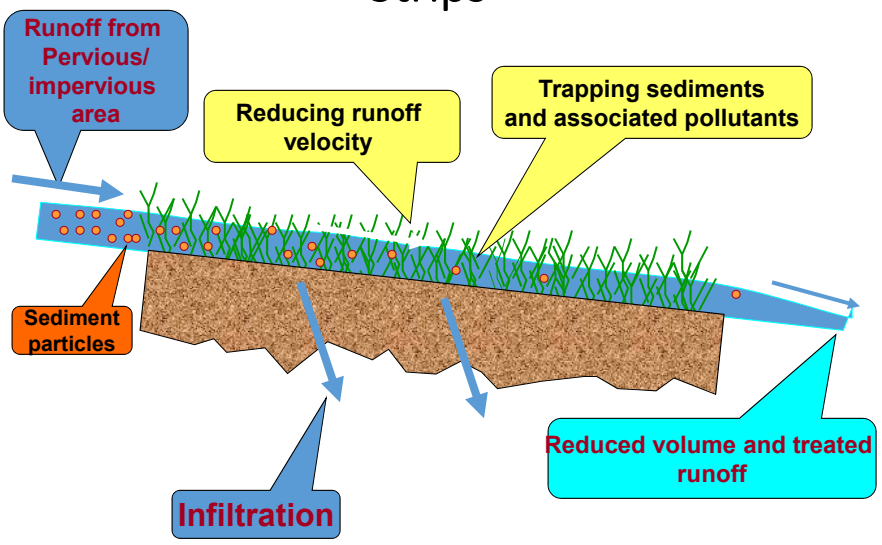
Entering and Using Grass Swales

Selected Grass Swale and Filter Strip Monitoring References

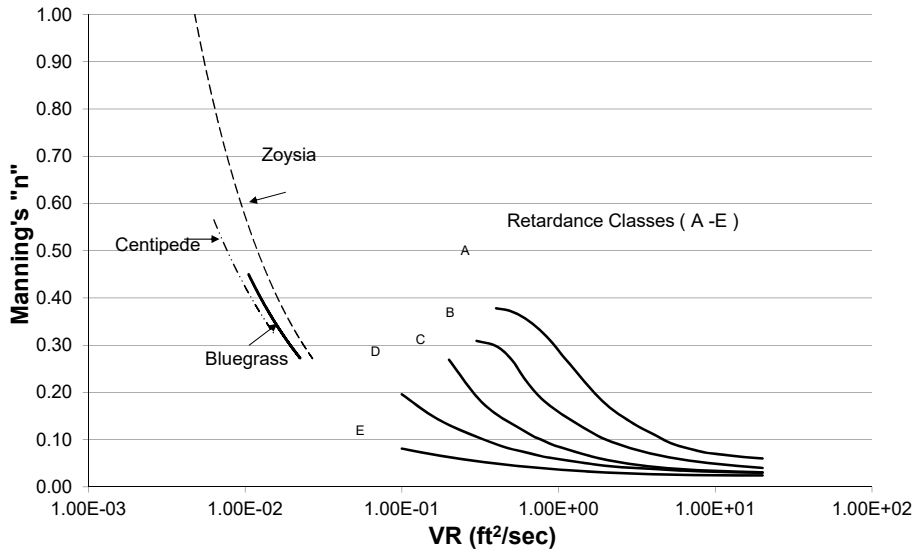
- EPA Report - Infiltration Through Disturbed Urban Soils and Compost (Pitt 1999)
- Alabama Highway Drainage Conservation Design Practices (Nara and Pitt 2005)
- HEC-15, Design of Roadside Channels with Flexible Linings, 2005
- Results of Tests on Vegetated Waterways (Cox and Palmer 1948)



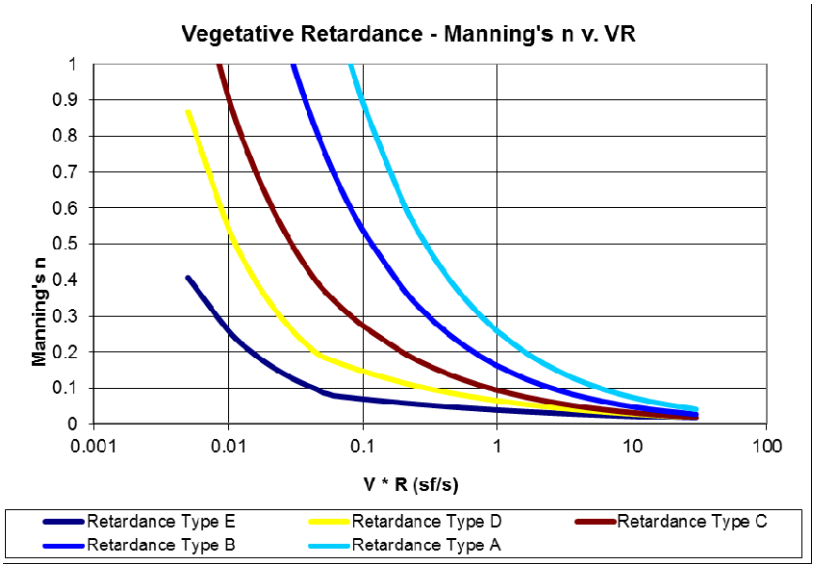
Pollutant Control in Grass Swales and Filter Strips



Extended Manning's n curves for small grass swales and grass filters

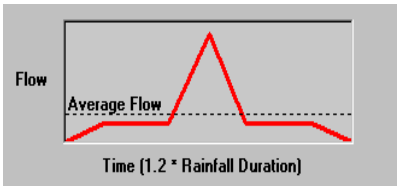


WinSLAMM Mannings n Values



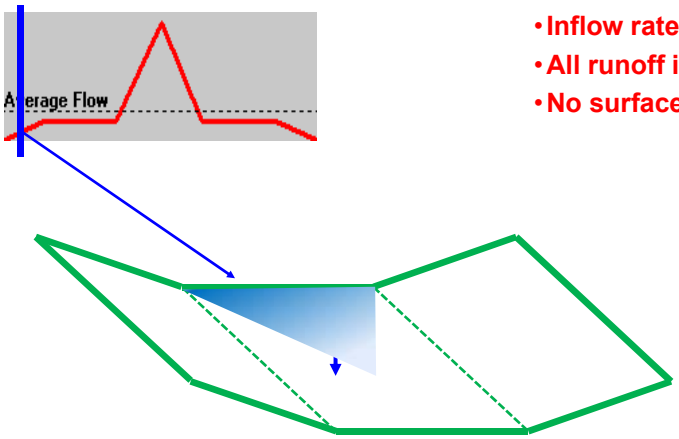
Dynamic Wetted Width Calculation

- Calculate event volume
- Convert volume to flow with:
  - Runoff duration = 1.2 times rainfall duration
  - Complex triangular hydrograph peak to average ratio = 3.8



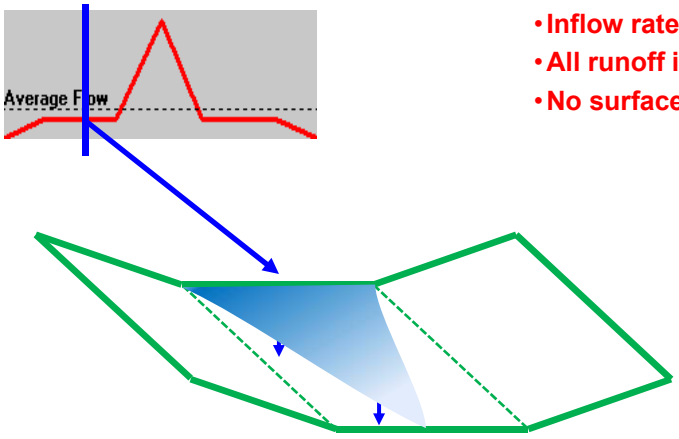
- Flow rate calculated for each time interval set by user
- Calculate the wetted width from the flow rate and swale geometry using Manning's open channel flow equation for each time step
  - Width
  - Side slope
  - Slope
  - Manning's n from Retardance Factor

Swale Performance - Infiltration



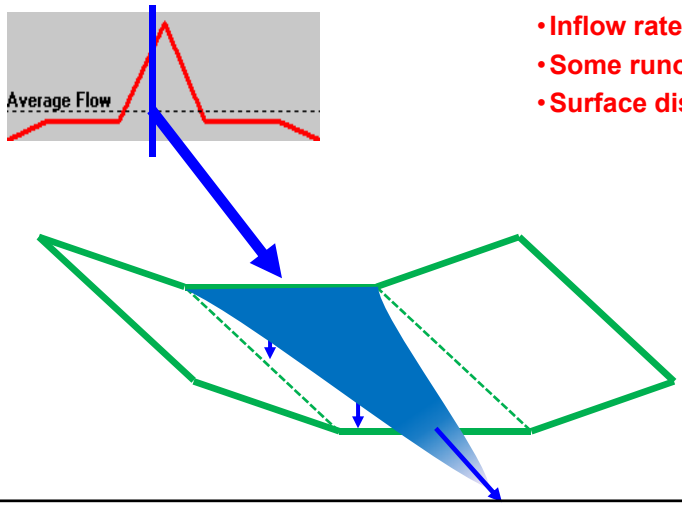
- Inflow rate – Low
- All runoff infiltrated
- No surface discharge

Swale Performance - Infiltration



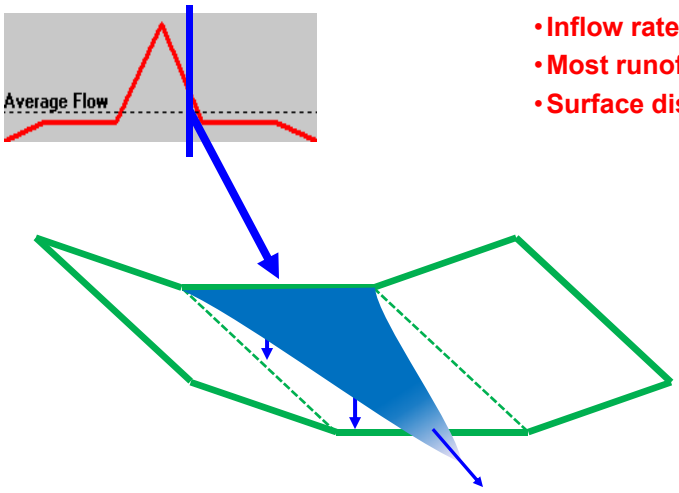
- Inflow rate – Moderate
- All runoff infiltrated
- No surface discharge

Swale Performance - Infiltration



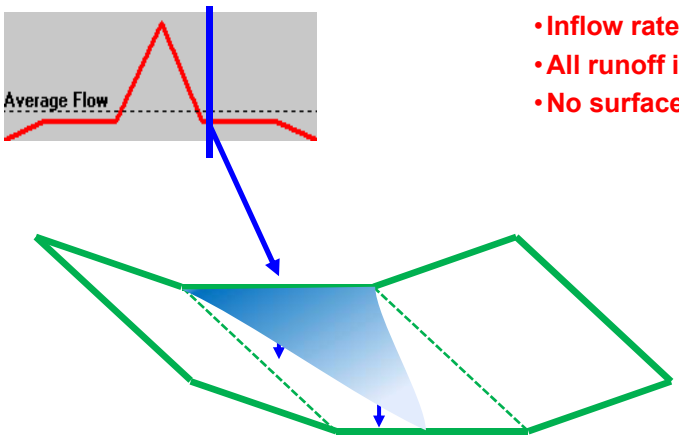
- Inflow rate – High
- Some runoff infiltrated
- Surface discharge

Swale Performance - Infiltration



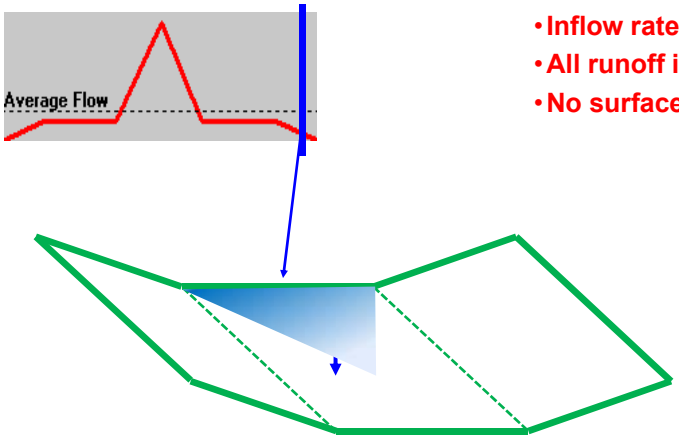
- Inflow rate – Moderate
- Most runoff infiltrated
- Surface discharge

Swale Performance - Infiltration



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

Swale Performance - Infiltration

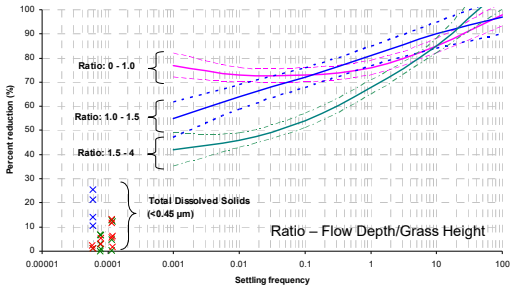


- Inflow rate – Low
- All runoff infiltrated
- No surface discharge

Swale Performance – Particulate Filtering

For each time step -

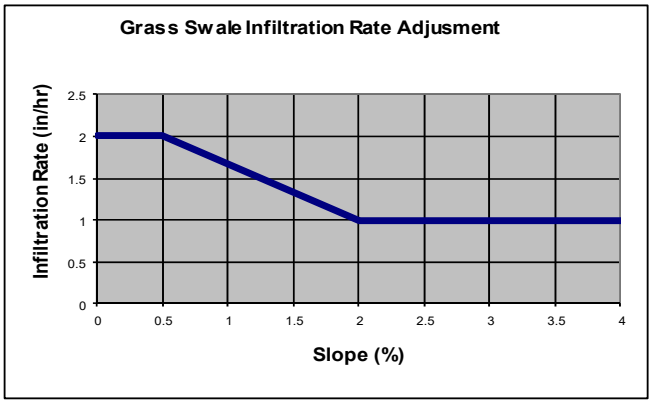
- Calculate flow velocity, settling velocity and flow depth
- Determine flow depth to grass height, for particulate reduction for each particle size increment using Nara & Pitt reference



- 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

Infiltration Adjustment

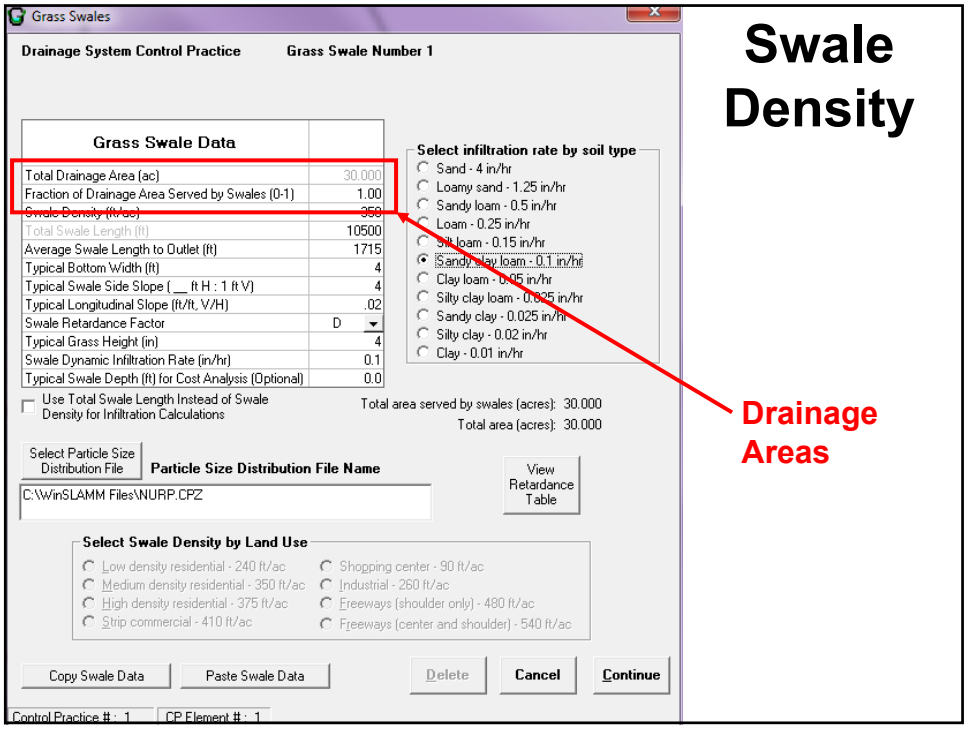
- User enters the dynamic infiltration rate, assumed to be ½ the static rate.
- WinSLAMM will adjust the infiltration rate based upon the swale slope as shown in the plot below.

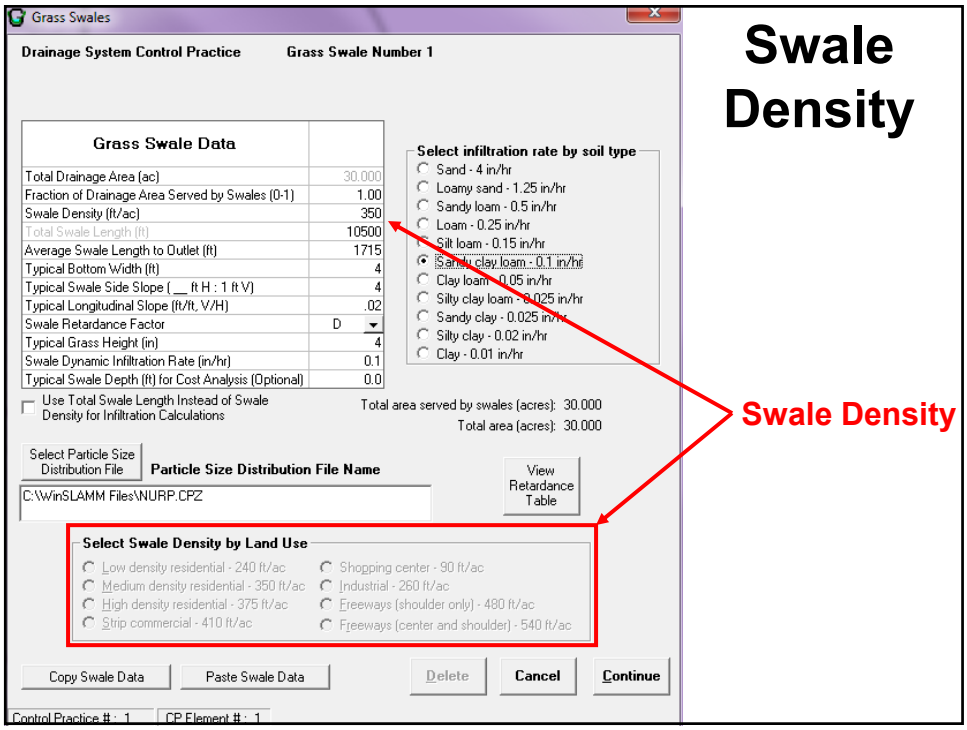


Modeling Grass Swales

Five Components to Modeling Grass Swales

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


Grass Swales
Drainage System Control Practice
Grass Swale Number 1
Grass Swale Data
Total Drainage Area (ac) 30.000
Fraction of Drainage Area Served by Swales (0-1) 1.00
Swale Density (ft/ac) 350
Total Swale Length (ft) 10500
Average Swale Length to Outlet (ft) 1715
Typical Bottom Width (ft) 4
Typical Swale Side Slope (__ ft H : 1 ft V) 4
Typical Longitudinal Slope (ft/ft, V/H) .02
Swale Retardance Factor D
Typical Grass Height (in) 4
Swale Dynamic Infiltration Rate (in/hr) 0.1
Typical Swale Depth (ft) for Cost Analysis (Optional) 0.0
Use Total Swale Length Instead of Swale Density for Infiltration Calculations
Select infiltration rate by soil type
Sand - 4 in/hr
Loamy sand - 1.25 in/hr
Sandy loam - 0.5 in/hr
Loam - 0.25 in/hr
Silt loam - 0.15 in/hr
Sandy clay loam - 0.1 in/hr
Clay loam - 0.05 in/hr
Silty clay loam - 0.025 in/hr
Sandy clay - 0.025 in/hr
Silty clay - 0.02 in/hr
Clay - 0.01 in/hr
Total area served by swales (acres): 30.000
Total area (acres): 30.000
Select Particle Size Distribution File
Particle Size Distribution File Name
C:\WinSLAMM Files\NURP.CPZ
View Retardance Table
Select Swale Density by Land Use
Low density residential - 240 ft/ac
Medium density residential - 350 ft/ac
High density residential - 375 ft/ac
Strip commercial - 410 ft/ac
Shopping center - 90 ft/ac
Industrial - 260 ft/ac
Freeways (shoulder only) - 480 ft/ac
Freeways (center and shoulder) - 540 ft/ac
Copy Swale Data
Paste Swale Data
Delete
Cancel
Continue
Control Practice # : 1
CP Element # : 1
Swale Density
Drainage Areas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Particle Size Distribution File Name
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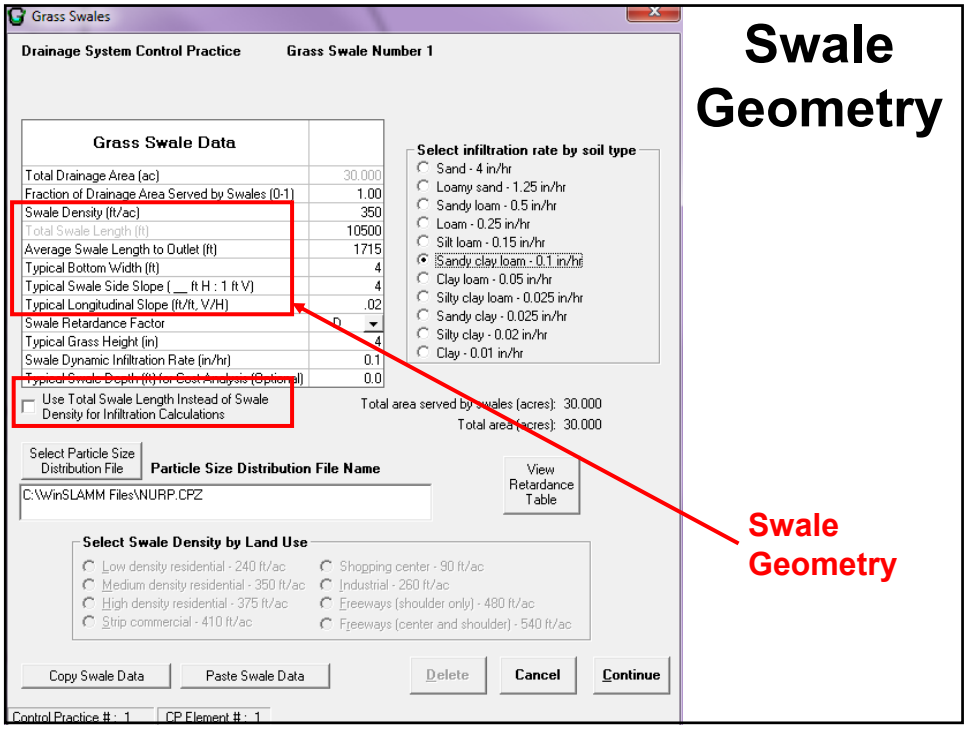
Copy Swale Data
Paste Swale Data
Delete
Cancel
Continue
Control Practice # : 1
CP Element # : 1
Swale Density
Swale Density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Silty clay - 0.02 in/hr
Clay - 0.01 in/hr
Total area served by swales (acres): 30.000
Total area (acres): 30.000
Select Particle Size Distribution File
Particle Size Distribution File Name
C:\WinSLAMM Files\NURP.CPZ
View Retardance Table
Select Swale Density by Land Use
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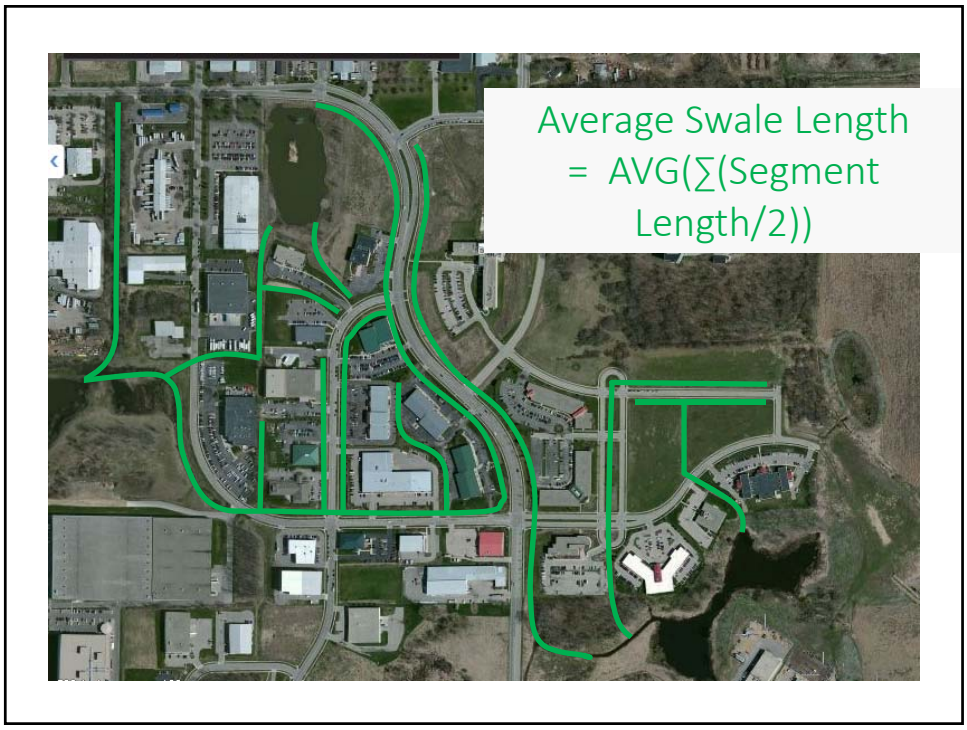
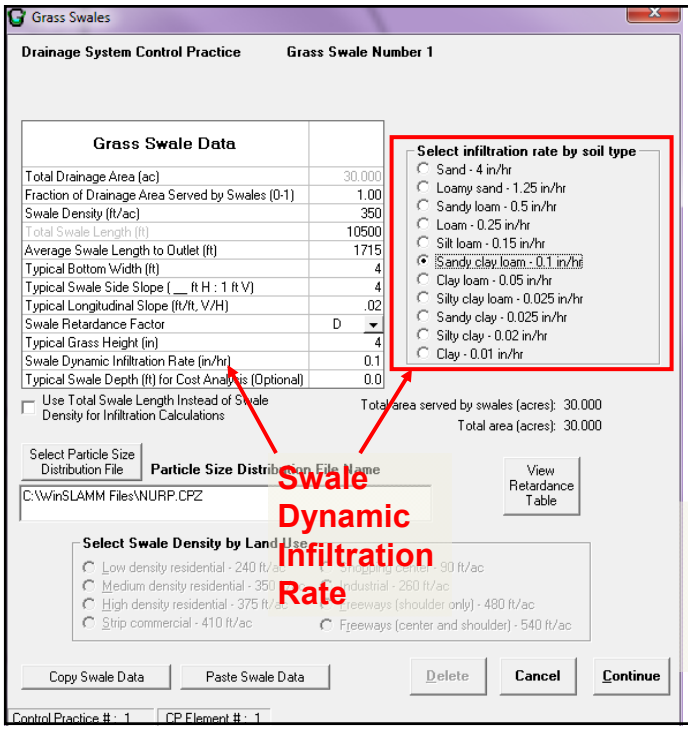
Industrial - 260 ft/ac
Freeways (shoulder only) - 480 ft/ac
Freeways (center and shoulder) - 540 ft/ac
Copy Swale Data
Paste Swale Data
Delete
Cancel
Continue
Control Practice # : 1
CP Element # : 1
Swale Geometry
Swale Geometry


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

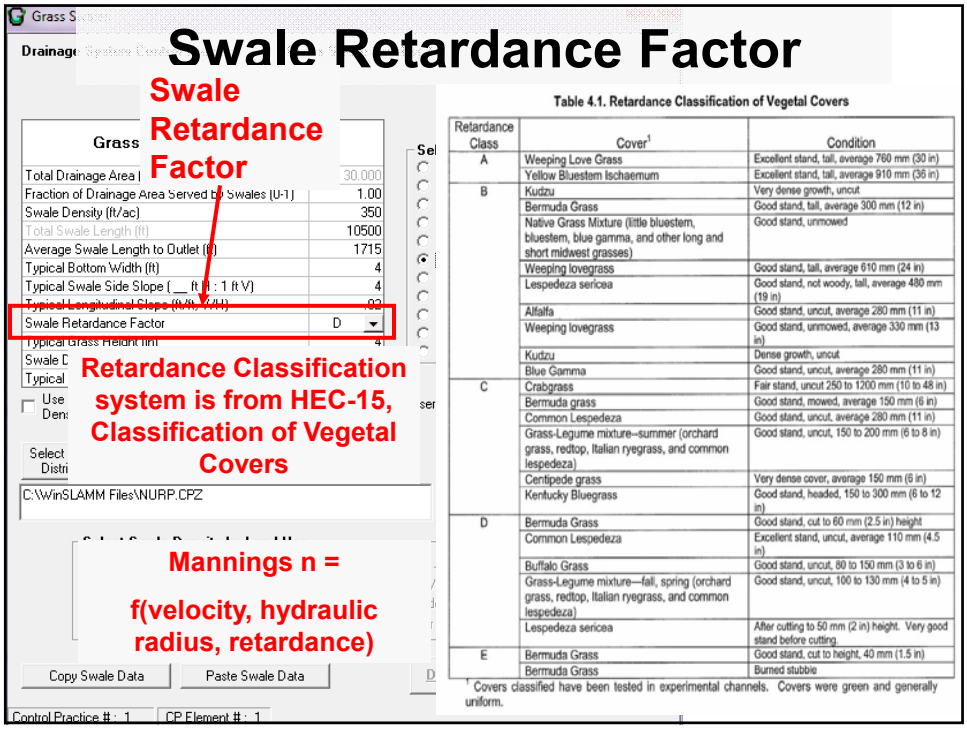
Average Swale Length = AVG(∑(Segment Length/2))

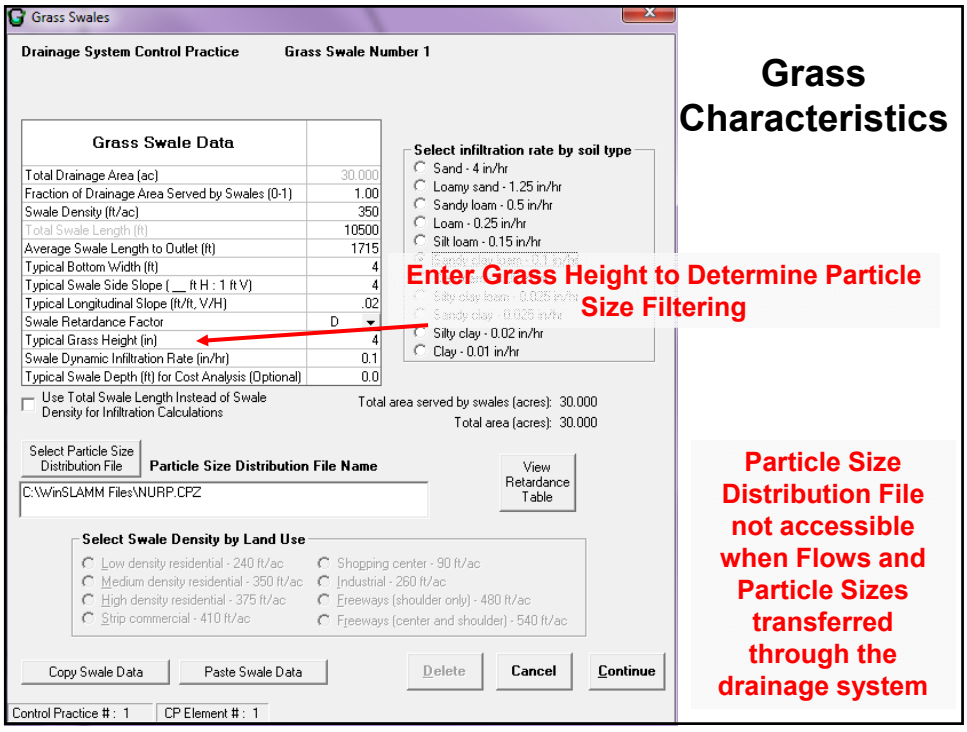
...or
Use the Default:
1.5 x SqRoot of the Drainage Area



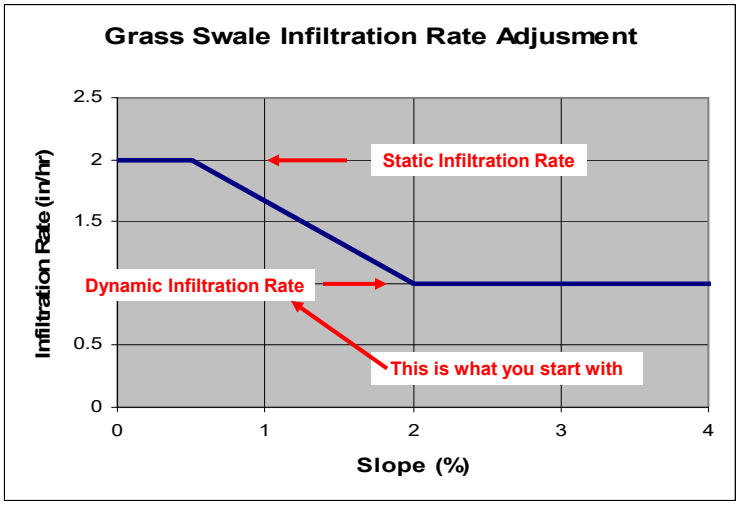
Infiltration Rate

Values listed in WinSLAMM are about ½ of the static infiltration rate for a given soil


Swale Retardance Factor
Swale Retardance Factor
Retardance Classification system is from HEC-15, Classification of Vegetal Covers
Mannings n =
f(velocity, hydraulic radius, retardance)
Table 4.1. Retardance Classification of Vegetal Covers
Retardance Class
Cover
Condition
Copy Swale Data
Paste Swale Data


Grass Swales
Drainage System Control Practice
Grass Swale Number 1
Grass Swale Data
Select infiltration rate by soil type
Enter Grass Height to Determine Particle Size Filtering
Particle Size Distribution File not accessible when Flows and Particle Sizes transferred through the drainage system
Grass Characteristics
Select Particle Size Distribution File
Particle Size Distribution File Name
View Retardance Table
Select Swale Density by Land Use
Copy Swale Data
Paste Swale Data
Delete
Cancel
Continue

Infiltration Rate Adjustment



Additional Output

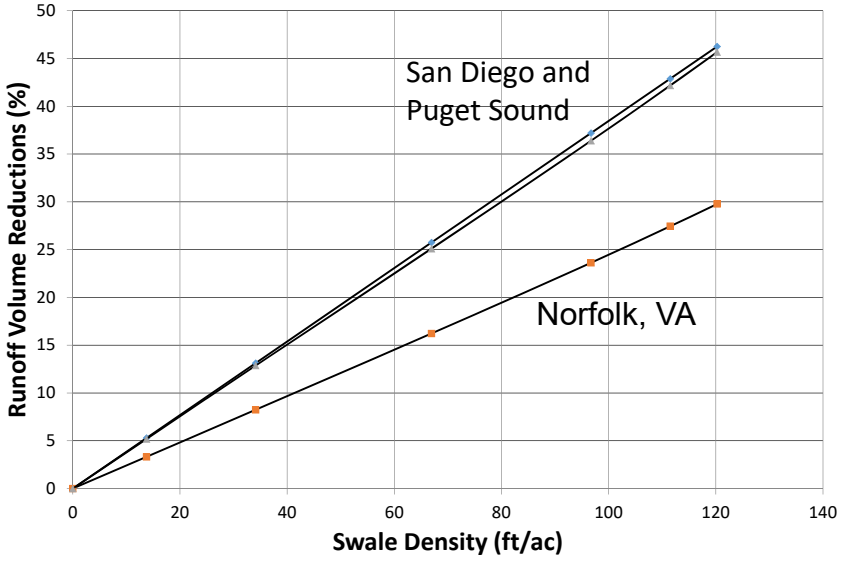
Rain No.	Rainfall Depth (in)	Step Count	QIn	QCalc	Diff	h	Wetted Perimeter	Swale Vol Reduction	Runoff Vol Before Swales	Runoff Vol After Swales
39	0.21	1	0.659558	15.88515	15.22559	0.5				
39	0.21	2	0.659558	3.332024	2.672466	0.25				
						0.125				
						5625				
						5313				
						4141				
						3623				
						6975				
						4116				
							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

Detailed Hydraulics By Time Step
Hydraulics And Concentration By Event
Incremental Performance
Irreducible Concentration
Particulate Reduction by Particle Size

Iterative calculation to determine swale height and wetted perimeter for each runoff event

SwaleQ = 1.486 / n * (h * BottomWidth + SideSlope * h ^ 2) ^ (5 / 3) / (BottomWidth + h * Sqr(SideSlope * SideSlope + 1) * 2) ^ (2 / 3) * Sqr(LongSlope)

Grass Swale Production Functions for US Navy (San Diego, Puget Sound, and Norfolk)

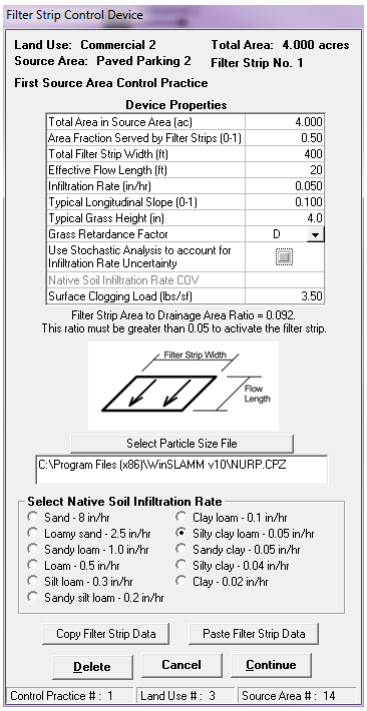


Modeling Filter Strips

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



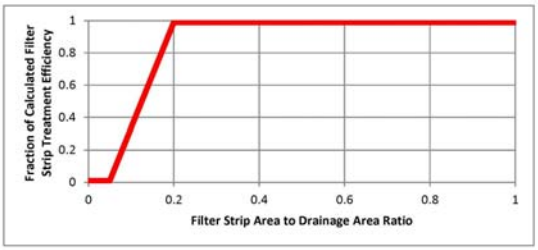
Four Components to Modeling Filter Strips

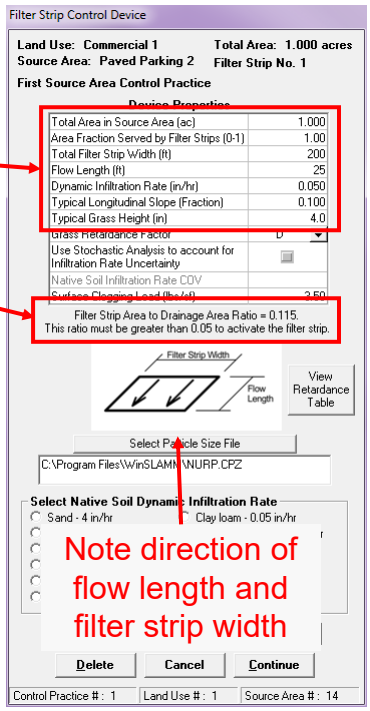
- Infiltration Rate
- Geometry
- Grass Characteristics
- Clogging and Runoff Particle Size Distribution

Geometry

Geometry

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



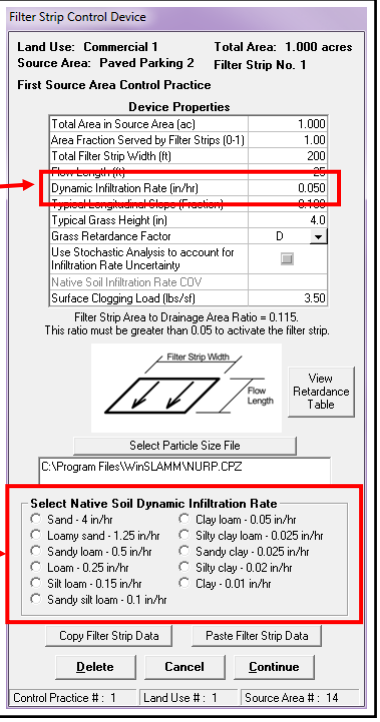


Infiltration Rate

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

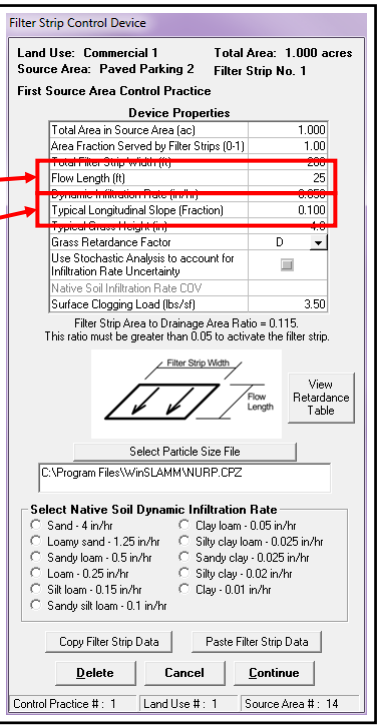


Effective Flow Length

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

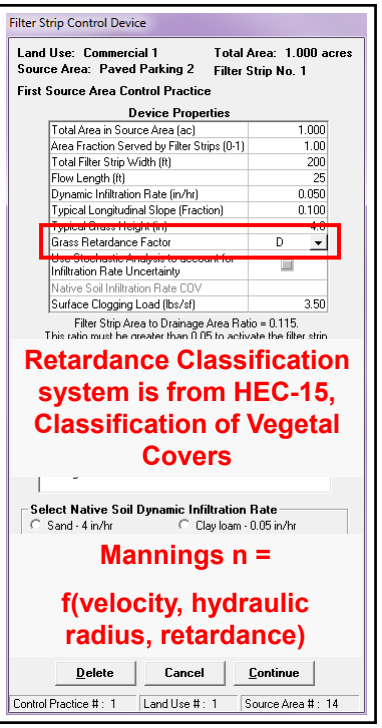


Retardance

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.



Surface Clogging

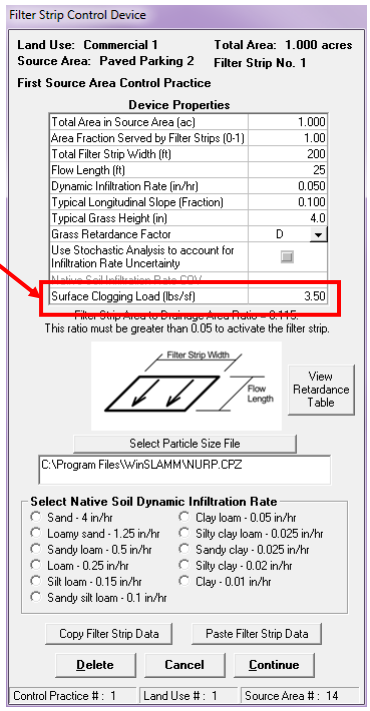
Surface Clogging

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

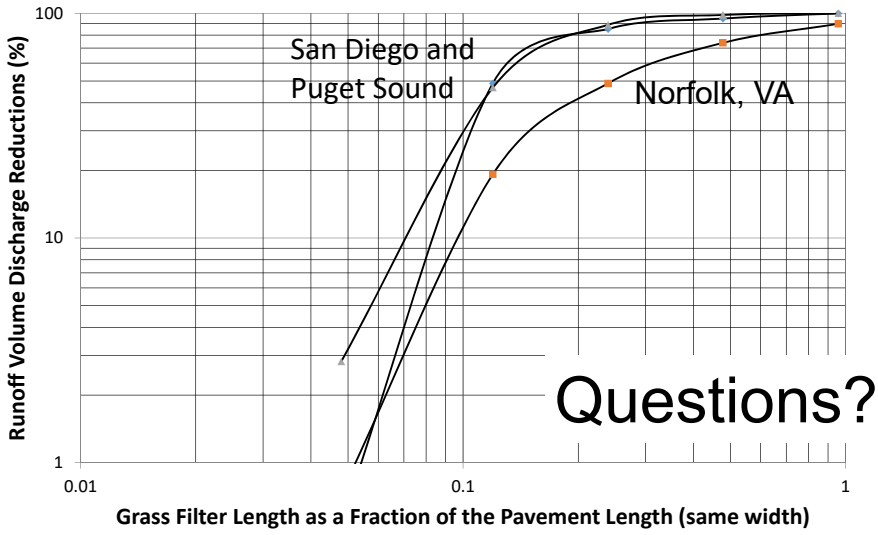


Additional Output

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)	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	0.01	1	3.22707	3.22707	0	3.229954	0	0	130	0.0000	0.0446	0.108969	15	0	0.02619	0.0000	0.0000	0.0050	0.0027	0.0051
41	0.01	1	3.22707	3.22707	0	3.229957	0	0	130	0.0000	0.0446	0.108969	15	0	0.02619	0.0000	0.0000	0.0051	0.0028	0.0052
42	0.01	1	3.22707	3.22707	0	3.229948	0	0	130	0.0000	0.0446	0.108969	15	0	0.02619	0.0000	0.0000	0.0051	0.0028	0.0052
43	0.33	1	735.6448	735.6448	0	169.7649	565.9003	565.9003	130	0.0002	0.0446	0.108969	19.28059	31.34552	5.97022	1.1074	0.0006	0.0235	0.0276	0.0516
44	0.07	1	106.7271	106.7271	0	86.29122	20.43898	20.43898	130	0.0002	0.0445	0.108969	15	27.53138	0.866157	0.0351	0.0007	0.0109	0.0087	0.0162
45	0.43	1	1013.367	1013.367	0	269.4128	743.9595	743.9595	130	0.0004	0.0445	0.108969	17.9533	30.16286	8.224113	1.4009	0.0016	0.0221	0.0252	0.0471
46	2.59	1	8609.945	8609.945	0	318.1631	8291.851	8291.851	130	0.0020	0.0445	0.108969	40.80983	50.52875	69.87511	26.1559	0.0070	0.0497	0.0847	0.1586
47	0.34	1	762.9528	762.9528	0	103.7634	659.2626	659.2626	130	0.0022	0.0445	0.108969	21.70889	33.50921	6.191841	1.3791	0.0076	0.0292	0.0383	0.0717
48	0.32	1	708.6318	708.6318	0	103.519	605.1809	605.1809	130	0.0023	0.0445	0.108969	21.58258	33.39666	5.750992	1.2617	0.0082	0.0284	0.0366	0.0686
49	0.51	1	1239.519	1239.519	0	239.1143	1000.422	1000.422	130	0.0026	0.0444	0.108969	20.72677	32.63411	10.05948	2.0381	0.0092	0.0253	0.0308	0.0577
50	0.13	1	236.219	236.219	0	97.26946	138.9721	138.9721	130	0.0027	0.0444	0.108969	15	27.53138	1.917065	0.2389	0.0094	0.0183	0.0189	0.0355
51	0.24	1	503.1494	503.1494	0	35.03768	468.561	468.561	130	0.0028	0.0444	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

Grass Filter Production Functions for US Navy (San Diego, Puget Sound, and Norfolk)



Questions?