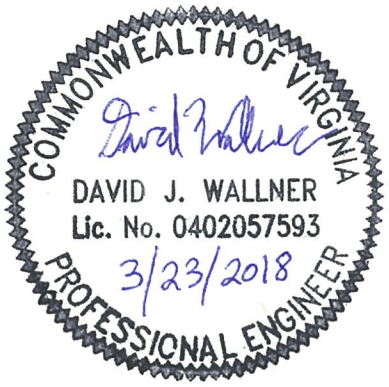
By virtue of this seal and signature, all supporting documents included in this package are accurate and support the design presented herein.



Water Bar 01 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 01 is 1.68 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 01 begins as sheet flow in a HSG B wooded area with slopes between 2-6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.11.

The flowpath exiting the Water Bar 01 end treatment will be along HSG B meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.19.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 01 is 29 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.11				100.0	0.045		0.425

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				870.7	0.093	4.92	0.049
CD	Waterbar	Unpaved				35.8	0.050	3.61	0.003

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.477
								T_c (min) =	29

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 10 foot long end treatment will ensure sheet flow conditions leaving Water Bar 01. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 01.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	29	time of concentration to water bar, min
	A =	1.68	water bar drainage area, ac
	S =	0.229	weir discharge overland slope, ft/ft
Computed	i =	3.3	computed from IDF, in/hr
Enter Flow Parameters	C =	0.19	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **10 ft**

Velocity Check ------> **0.64 fps**

Water Bar 02 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 02 is 0.51 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	31%	31
Meadow	C	71	0%	0
Wooded	C	70	69%	48
			100%	79

II. Runoff Coefficient

The flowpath for Water Bar 02 begins as sheet flow in a HSG C wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.17.

The drainage area for Water Bar 02 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.4 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	31%	0.28	
Meadow	C	0.22	0%	0.00	
Wooded	C	0.17	69%	0.12	
			100%	0.40	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 02 is 14 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.17				100.0	0.150		0.219

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				103.8	0.183	6.90	0.004
CD	Waterbar	Unpaved				77.3	0.050	3.61	0.006

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.229
T_c (min) =	14

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 9 foot long end treatment will ensure sheet flow conditions leaving Water Bar 02. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 02.

End Treatment Length Calculator

	Tc =	14	time of concentration to water bar, min
Enter Site Specific Data	A =	0.51	water bar drainage area, ac
	S =	0.208	weir discharge overland slope, ft/ft
Computed	i =	4.8	computed from IDF, in/hr
	C =	0.40	calculated composite runoff coefficient
Enter Flow Parameters	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **9 ft**

Velocity Check ------> **0.61 fps**

Water Bar 03 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 03 is 0.2 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	24%	23
Meadow	C	71	0%	0
Wooded	C	70	76%	53
			100%	77

II. Runoff Coefficient

The drainage area for Water Bar 03 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.34 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	24%	0.22
Meadow	C	0.22	0%	0.00
Wooded	C	0.17	76%	0.13
			100%	0.34 <--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 03 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 4 foot long end treatment will ensure sheet flow conditions leaving Water Bar 03. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 03.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.2	water bar drainage area, ac
	S =	0.207	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.34	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **4 ft**

Velocity Check ------> **0.61 fps**

Water Bar 04 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 04 is 0.03 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	70%	69
Meadow	C	71	30%	21
Wooded	C	70	0%	0
			100%	90

II. Runoff Coefficient

The drainage area for Water Bar 04 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.7 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	70%	0.63
Meadow	C	0.22	30%	0.07
Wooded	C	0.17	0%	0.00
			100%	0.70

<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 04 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 04. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 04.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.03	water bar drainage area, ac
	S =	0.214	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.70	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.62 fps**

Water Bar 05 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 05 is 0.51 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	7%	7
Meadow	C	71	51%	36
Wooded	C	70	42%	29
			100%	73

II. Runoff Coefficient

The flowpath for Water Bar 05 begins as sheet flow in a HSG B wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.15.

The drainage area for Water Bar 05 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.25 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	7%	0.07	
Meadow	C	0.22	51%	0.11	
Wooded	C	0.17	42%	0.07	
			100%	0.25	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 05 is 16 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.15				100.0	0.140		0.251

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				180.0	0.190	7.03	0.007
CD	Waterbar	Unpaved				87.0	0.050	3.61	0.007

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.265
T_c (min) =	16

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 05. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 05.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	16	time of concentration to water bar, min
	A =	0.51	water bar drainage area, ac
	S =	0.142	weir discharge overland slope, ft/ft
Computed	i =	4.5	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.50 fps**

Water Bar 06 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 06 is 0.17 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	7%	7
Meadow	C	71	5%	4
Wooded	C	70	87%	61
			100%	72

II. Runoff Coefficient

The drainage area for Water Bar 06 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.23 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	7%	0.07
Meadow	C	0.22	5%	0.01
Wooded	C	0.17	87%	0.15
			100%	0.23 **<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 06 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 06. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 06.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.17	water bar drainage area, ac
	S =	0.400	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.23	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.85 fps**

Water Bar 09 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 09 is 1.37 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	22%	21
Meadow	C	71	69%	49
Wooded	C	70	9%	6
			100%	77

II. Runoff Coefficient

The flowpath for Water Bar 09 begins as sheet flow in a HSG C meadow area with slopes between 2-6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.17.

The drainage area for Water Bar 09 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.36 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	22%	0.20	
Meadow	C	0.22	69%	0.15	
Wooded	C	0.17	9%	0.02	
			100%	0.36	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 09 is 18 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.17				100.0	0.040		0.281

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				72.3	0.138	5.99	0.003
CD	Downslope	Paved				464.6	0.112	6.80	0.019
DE	Waterbar	Unpaved				2.0	0.050	3.61	0.000

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.304
T_c (min) =	18

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 19 foot long end treatment will ensure sheet flow conditions leaving Water Bar 09. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 09.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	18	time of concentration to water bar, min
	A =	1.37	water bar drainage area, ac
	S =	0.155	weir discharge overland slope, ft/ft
Computed	i =	4.2	computed from IDF, in/hr
Enter Flow Parameters	C =	0.36	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **19 ft**

Velocity Check ------> **0.53 fps**

Water Bar 10 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 10 is 1.13 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	9%	9
Meadow	C	71	86%	61
Wooded	C	70	5%	4
			100%	73

II. Runoff Coefficient

The flowpath for Water Bar 10 begins as sheet flow in a HSG B meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.19.

The drainage area for Water Bar 10 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.28 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	9%	0.08	
Meadow	C	0.22	86%	0.19	
Wooded	C	0.17	5%	0.01	
			100%	0.28	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 10 is 15 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.19				100.0	0.070		0.226

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				420.2	0.102	5.15	0.023
CD	Waterbar	Unpaved				28.6	0.050	3.61	0.002

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.251
T_c (min) =	15

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 13 foot long end treatment will ensure sheet flow conditions leaving Water Bar 10. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 10.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	15	time of concentration to water bar, min
	A =	1.13	water bar drainage area, ac
	S =	0.224	weir discharge overland slope, ft/ft
Computed	i =	4.5	computed from IDF, in/hr
Enter Flow Parameters	C =	0.28	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **13 ft**

Velocity Check ------> **0.63 fps**

Water Bar 11 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 11 is 0.74 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	4%	3
Meadow	C	71	96%	68
Wooded	C	70	0%	0
			100%	72

II. Runoff Coefficient

The flowpath for Water Bar 11 begins as sheet flow in a HSG C meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.22.

The drainage area for Water Bar 11 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.24 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	4%	0.03	
Meadow	C	0.22	96%	0.21	
Wooded	C	0.17	0%	0.00	
			100%	0.24	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 11 is 13 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.22				100.0	0.080		0.191

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				517.4	0.128	5.77	0.025
CD	Waterbar	Unpaved				16.6	0.050	3.61	0.001

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.217
T_c (min) =	13

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 8 foot long end treatment will ensure sheet flow conditions leaving Water Bar 11. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 11.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	0.74	water bar drainage area, ac
	S =	0.304	weir discharge overland slope, ft/ft
Computed	i =	4.8	computed from IDF, in/hr
Enter Flow Parameters	C =	0.24	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **8 ft**

Velocity Check ------> **0.74 fps**

Water Bar 13 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 13 is 0.63 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	15%	14
Meadow	C	71	8%	5
Wooded	C	70	78%	54
			100%	74

II. Runoff Coefficient

The flowpath for Water Bar 13 begins as sheet flow in a HSG C wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.17.

The drainage area for Water Bar 13 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.28 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	15%	0.13	
Meadow	C	0.22	8%	0.02	
Wooded	C	0.17	78%	0.13	
			100%	0.28	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 13 is 16 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.17				100.0	0.070		0.253

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				198.2	0.151	6.27	0.009
CD	Waterbar	Unpaved				62.1	0.050	3.61	0.005

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.267
T_c (min) =	16

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 13. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 13.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	16	time of concentration to water bar, min
	A =	0.63	water bar drainage area, ac
	S =	0.517	weir discharge overland slope, ft/ft
Computed	i =	4.5	computed from IDF, in/hr
Enter Flow Parameters	C =	0.28	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **7 ft**

Velocity Check ------> **0.96 fps**

Water Bar 14 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 14 is 0.31 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	4%	4
Meadow	C	71	26%	18
Wooded	C	70	71%	49
			100%	71

II. Runoff Coefficient

The drainage area for Water Bar 14 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.21 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	4%	0.04
Meadow	C	0.22	26%	0.06
Wooded	C	0.17	71%	0.12
			100%	0.21 <--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 14 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 4 foot long end treatment will ensure sheet flow conditions leaving Water Bar 14. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 14.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.31	water bar drainage area, ac
	S =	0.202	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.21	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **4 ft**

Velocity Check ------> **0.60 fps**

Water Bar 15 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 15 is 0.14 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	7%	6
Meadow	C	71	43%	31
Wooded	C	70	50%	35
			100%	72

II. Runoff Coefficient

The drainage area for Water Bar 15 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.24 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	7%	0.06
Meadow	C	0.22	43%	0.10
Wooded	C	0.17	50%	0.09
			100%	0.24 **<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 15 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 15. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 15.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.14	water bar drainage area, ac
	S =	0.288	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.24	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.72 fps**

Water Bar 16 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 16 is 0.13 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	6%	6
Meadow	C	71	62%	44
Wooded	C	70	32%	22
			100%	72

II. Runoff Coefficient

The drainage area for Water Bar 16 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.25 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	6%	0.06
Meadow	C	0.22	62%	0.14
Wooded	C	0.17	32%	0.05
			100%	0.25 <--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 16 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 16. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 16.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.13	water bar drainage area, ac
	S =	0.100	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.42 fps**

Water Bar 17 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 17 is 0.38 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	32%	31
Meadow	C	71	69%	49
Wooded	C	70	0%	0
			100%	80

II. Runoff Coefficient

The drainage area for Water Bar 17 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.43 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	32%	0.28
Meadow	C	0.22	69%	0.15
Wooded	C	0.17	0%	0.00
			100%	0.43

<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 17 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 10 foot long end treatment will ensure sheet flow conditions leaving Water Bar 17. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 17.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.38	water bar drainage area, ac
	S =	0.188	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.43	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **10 ft**

Velocity Check ------> **0.58 fps**

Water Bar 18 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 18 is 0.59 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 18 begins as sheet flow in a HSG B meadow area with slopes between 2-6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.14.

The flowpath exiting the Water Bar 18 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 18 is 21 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.14				100.0	0.050		0.327

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				197.1	0.066	4.15	0.013
CD	Waterbar	Unpaved				15.9	0.050	3.61	0.001

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.342
								T_c (min) =	21

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 18. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 18.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	21	time of concentration to water bar, min
	A =	0.59	water bar drainage area, ac
	S =	0.026	weir discharge overland slope, ft/ft
Computed	i =	4.0	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.22 fps**

Water Bar 19 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 19 is 0.93 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 19 begins as sheet flow in a HSG B wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.15.

The flowpath exiting the Water Bar 19 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 19 is 16 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.15	100.0	0.140	0.251

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	261.8	0.252	8.10	0.009
CD	Waterbar	Unpaved	18.5	0.050	3.61	0.001

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.262
T_c (min) =	16

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 10 foot long end treatment will ensure sheet flow conditions leaving Water Bar 19. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 19.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	16	time of concentration to water bar, min
	A =	0.93	water bar drainage area, ac
	S =	0.193	weir discharge overland slope, ft/ft
Computed	i =	4.5	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **10 ft**

Velocity Check ------> **0.59 fps**

Water Bar 19.1 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 19.1 is 1.66 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 19.1 begins as sheet flow in a HSG B meadow area with slopes between 2-6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.14.

The flowpath exiting the Water Bar 19.1 end treatment will be along HSG B meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.19.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 19.1 is 24 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.14				100.0	0.030		0.361

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				581.4	0.067	4.18	0.039
CD	Waterbar	Unpaved				48.1	0.050	3.61	0.004

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.403
								T_c (min) =	24

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 11 foot long end treatment will ensure sheet flow conditions leaving Water Bar 19.1. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 19.1.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	24	time of concentration to water bar, min
	A =	1.66	water bar drainage area, ac
	S =	0.135	weir discharge overland slope, ft/ft
Computed	i =	3.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.19	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **11 ft**

Velocity Check ------> **0.49 fps**

Water Bar 20 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 20 is 1.09 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 20 begins as sheet flow in a HSG B meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.19.

The flowpath exiting the Water Bar 20 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 20 is 14 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.19	100.0	0.120	0.204

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	576.8	0.149	6.23	0.026
CD	Waterbar	Unpaved	2.5	0.050	3.61	0.000

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.230
								T_c (min) =	14

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 12 foot long end treatment will ensure sheet flow conditions leaving Water Bar 20. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 20.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	14	time of concentration to water bar, min
	A =	1.09	water bar drainage area, ac
	S =	0.291	weir discharge overland slope, ft/ft
Computed	i =	4.8	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **12 ft**

Velocity Check ------> **0.72 fps**

Water Bar 21 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 21 is 0.3 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 21 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 21 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 21. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 21.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.30	water bar drainage area, ac
	S =	0.092	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.41 fps**

Water Bar 22 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 22 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 22 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 22 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 22. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 22.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.195	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.59 fps**

Water Bar 23 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 23 is 2.84 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 23 begins as sheet flow in a HSG B meadow area with slopes between 2-6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.14.

The flowpath exiting the Water Bar 23 end treatment will be along HSG B meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.19.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 23 is 22 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.14	100.0	0.040	0.342

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	452.2	0.118	5.54	0.023
CD	Waterbar	Unpaved	12.7	0.050	3.61	0.001

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.365
								T_c (min) =	22

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 20 foot long end treatment will ensure sheet flow conditions leaving Water Bar 23. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 23.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	22	time of concentration to water bar, min
	A =	2.84	water bar drainage area, ac
	S =	0.130	weir discharge overland slope, ft/ft
Computed	i =	3.9	computed from IDF, in/hr
Enter Flow Parameters	C =	0.19	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **20 ft**

Velocity Check ------> **0.48 fps**

Water Bar 24 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 24 is 0.09 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 24 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 24 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 24. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 24.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.09	water bar drainage area, ac
	S =	0.062	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.33 fps**

Water Bar 25 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 25 is 1.81 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 25 begins as sheet flow in a HSG B meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.15.

The flowpath exiting the Water Bar 25 end treatment will be along HSG B meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.19.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 25 is 20 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.15				100.0	0.070		0.287

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				659.8	0.074	4.39	0.042
CD	Waterbar	Unpaved				53.2	0.050	3.61	0.004

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.333
								T_c (min) =	20

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 13 foot long end treatment will ensure sheet flow conditions leaving Water Bar 25. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 25.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	20	time of concentration to water bar, min
	A =	1.81	water bar drainage area, ac
	S =	0.090	weir discharge overland slope, ft/ft
Computed	i =	4.1	computed from IDF, in/hr
Enter Flow Parameters	C =	0.19	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **13 ft**

Velocity Check ------> **0.40 fps**

Water Bar 26 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 26 is 0.16 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 26 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 26 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 26. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 26.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.16	water bar drainage area, ac
	S =	0.119	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.46 fps**

Water Bar 27 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 27 is 0.55 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 27 begins as sheet flow in a HSG B wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.15.

The flowpath exiting the Water Bar 27 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 27 is 18 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.15	100.0	0.080	0.279

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	201.6	0.129	5.79	0.010
CD	Waterbar	Unpaved	60.5	0.050	3.61	0.005

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.294
								T_c (min) =	18

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 27. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 27.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	18	time of concentration to water bar, min
	A =	0.55	water bar drainage area, ac
	S =	0.160	weir discharge overland slope, ft/ft
Computed	i =	4.3	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.53 fps**

Water Bar 28 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 28 is 0.05 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 28 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 28 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 28. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 28.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.05	water bar drainage area, ac
	S =	0.101	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.43 fps**

Water Bar 29 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 29 is 0.28 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 29 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 29 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 4 foot long end treatment will ensure sheet flow conditions leaving Water Bar 29. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 29.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.28	water bar drainage area, ac
	S =	0.243	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **4 ft**

Velocity Check ------> **0.66 fps**

Water Bar 30 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 30 is 0.1 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 30 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 30 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 30. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 30.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.10	water bar drainage area, ac
	S =	0.305	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.74 fps**

i. New Impervious Cover: Access Roads

New impervious cover in Spread 11 includes six (6) access roads (MVP-MLV-AR-31 through -35, and PI-343). Increased volumes of stormwater runoff resulting from access roads will be controlled utilizing the methodology established in *MVP-33.1 through MVP-33.3 Gap Graded Gravel Detail for Mainline Valve Pads and Permanent Access Roads*.

Each access road consists of a geogrid, underlain by a 2-inch layer of clean-washed choker stone, geotextile fabric, an open-graded subbase reservoir, and compacted earthen baffles to detain water within the access road. The access road surface will consist of two gravel tracks, with a center aisle top-dressed with soil and seeded with a meadow seed mix per *MVP-ES11.2 Upland Meadow Seed Mix and Application Rates* or *MVP-ES11.3 Upland Steep Slope Seed Mix and Application Rates*.

Pre- and post-construction runoff volumes for the 10-year 24-hour storm were calculated using the Franklin and Pittsylvania County design storm values of 5.70 and 5.20 inches, respectively, per *PSS&S Section 4.2.2 Design Storms*. Runoff volumes were calculated for both the drainage area to each gap graded gravel access road and for the access road footprint alone. Results are shown below.

10-YEAR STORM DATA FULL RUN-ON DRAINAGE AREA					
SITE	TIME OF CONCENTRATION (PRE / POST) [HR]	CURVE NUMBER (PRE / POST)	DRAINAGE AREA [FT^2]	Q_{10} PEAK FLOW (PRE / POST) [CFS]	Q_{10} VOLUME (PRE / POST) [FT^3]
MLV-AR-31	0.13 / 0.10	60 / 66	5,061	0.28 / 0.39	726 / 933
MLV-AR-32	0.13 / 0.13	62 / 63	71,529	4.32 / 4.52	11,227 / 11,712
MLV-AR-33	0.21 / 0.21	55 / 58	7,621	0.28 / 0.34	853 / 995
MLV-AR-34	0.10 / 0.10	64 / 72	2,185	0.13 / 0.18	310 / 426
MLV-AR-35	0.36 / 0.25	62 / 67	2,323	0.08 / 0.12	299 / 372
PI-343	0.32 / 0.31	56 / 63	86,795	2.15 / 3.45	8,234 / 11,772

10-YEAR STORM DATA ACCESS ROAD FOOTPRINT					
SITE	TIME OF CONCENTRATION (PRE / POST) [HR]	CURVE NUMBER (PRE / POST)	DRAINAGE AREA [FT^2]	Q_{10} PEAK FLOW (PRE / POST) [CFS]	Q_{10} VOLUME (PRE / POST) [FT^3]
MLV-AR-31	0.10 / 0.10	58 / 78	1,498	0.08 / 0.17	194 / 409
MLV-AR-32	0.10 / 0.10	58 / 78	3,441	0.18 / 0.40	456 / 961
MLV-AR-33	0.10 / 0.10	57 / 78	1,410	0.07 / 0.16	174 / 385
MLV-AR-34	0.10 / 0.10	56 / 79	915	0.03 / 0.10	87 / 218
MLV-AR-35	0.10 / 0.10	55 / 78	523	0.02 / 0.05	48 / 122

PI-343	0.10 / 0.10	56 / 79	12,840	0.92 / 2.67	2,439 / 6,360

Increases in run-off volumes for both the drainage area and access road only are further summarized below.

		Peak Flow (cfs)	Hydrograph Volume (ac-ft)	Hydrograph Volume (ft^3)	Required Treatment Volume (ft^3)
MLV-AR-31 FULL DA	Pre	0.28	0.01667	726	207
	Post	0.39	0.02142	933	
MLV-AR-31 AR ONLY	Pre	0.08	0.00445	194	215
	Post	0.17	0.00939	409	
MLV-AR-32 FULL DA	Pre	4.32	0.25774	11227	485
	Post	4.52	0.26887	11712	
MLV-AR-32 AR ONLY	Pre	0.18	0.01047	456	505
	Post	0.4	0.02206	961	
MLV-AR-33 FULL DA	Pre	0.28	0.01958	853	142
	Post	0.34	0.02284	995	
MLV-AR-33 AR ONLY	Pre	0.07	0.00399	174	211
	Post	0.16	0.00884	385	
MLV-AR-34 FULL DA	Pre	0.13	0.00712	310	116
	Post	0.18	0.00978	426	
MLV-AR-34 AR ONLY	Pre	0.03	0.002	87	131
	Post	0.1	0.005	218	
MLV-AR-35 FULL DA	Pre	0.08	0.00686	299	73
	Post	0.12	0.00854	372	
MLV-AR-35 AR ONLY	Pre	0.02	0.0011	48	74
	Post	0.05	0.0028	122	
MVP-PI-343 FULL DA	Pre	2.15	0.18903	8234	3538
	Post	3.45	0.27025	11772	
MVP-PI-343 AR ONLY	Pre	0.92	0.056	2439	3920
	Post	2.67	0.146	6360	

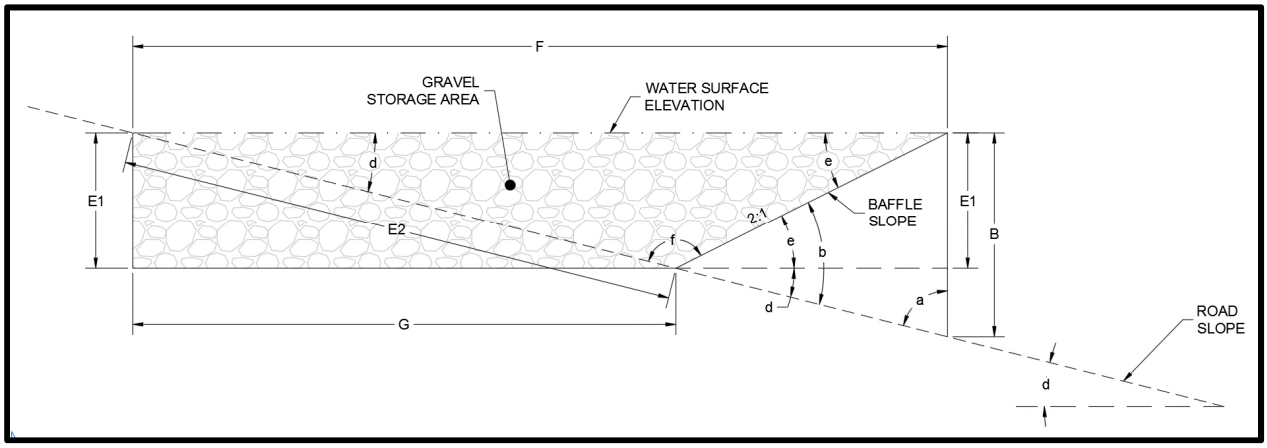
The runoff volume increase when considering only the access road is greater than the resulting runoff volume increase when considering the full drainage area. As a result, the reservoir within the access road is conservatively sized to accommodate the

required volume computed using the road footprint only. Any increase in runoff volume from pre- to post-construction condition must be stored within the gap graded gravel to meet flood protection requirements per 9VAC25-870-66.C.2.

A site-specific analysis was performed for all access roads to determine the number of earthen baffles, earthen baffle spacing and subbase reservoir depth required to detain the increased volume from the 10-year storm, and allow the excess stormwater to infiltrate into the underlying soil. Details of the analysis are provided below.

Site	Road Length (ft)	Road Slope (ft/ft)	# of Baffles	Baffle Spacing (ft)	Baffle Height (ft)
MVP-MLV-AR-31	125	0.100	6	20	1
MVP-MLV-AR-32	10	0.038	0	0	0
	30	0.069	1	30	1.5
	31	0.022	1	31	0.5
	27	0.023	1	27	0.5
	27	0.004	0	0	0
	21	0.031	1	21	0.5
	15	0.040	1	15	0.5
	75	0.026	1	75	1
	53	0.014	1	53	0.5
MVP-MLV-AR-33	33	0.012	1	32	0.25
	38	0.032	2	18	1
	27	0.008	0	0	0
	14	0.038	1	14	0.25
MVP-MLV-AR-34	6	0.028	0	0	0
	35	0.055	2	17	0.75
	36	0.075	2	18	1
MVP-MLV-AR-35	8	0.007	0	0	0
	33	0.019	1	33	1
MVP-PI-343	90	0.002	0	0	0
	437	0.05	10	43	1
	416	0.009	3	138	1
	270	0.052	5	54	1
	228	0.026	1	228	1
	75	0.187	1	75	1
	51	0.12	1	51	1
	75	0.046	1	75	1
	200	0.013	1	200	1
	186	0.045	1	186	1
	103	0.0098	1	103	1

Because the slopes of the access roads vary significantly, storage calculations were performed for each, using the following methodology:



1. Determine the cross-section area (CSA) of storage behind each baffle, assuming a triangle based on bottom slope.

$$CSA = 0.5 \times A \times F \times \sin(e) + 0.5 \times E1 \times E2 \times \sin(a)$$

where CSA = Cross-sectional area; ft^2

$a = 90 - \tan^{-1}(\text{road slope})$	$A = B \times (\sin(a)/\sin(b))$
$b = \tan^{-1}(\text{road slope}) + \tan^{-1}(\text{baffle slope})$	B = baffle height
$d = \tan^{-1}(\text{road slope})$	$E1 = A \times \sin(e)$
$e = \tan^{-1}(\text{baffle slope})$	$E2 = A \times (\sin(e)/\sin(d))$
$f = 180 - b$	$F = A \times (\sin(f)/\sin(d))$
	G = F - E1/baffle slope

2. Determine the storage volume available per earthen baffle.

$$Vavailable = CSA \times W \times n$$

where Vavailable = Storage volume per earthen baffle; ft^3
W = Stone width (12 ft)
n = Stone porosity (0.40)

3. Determine the number of baffle cells needed by dividing the storage volume per earthen baffle into the required treatment volume. Because it is necessary to round up to the next integer, the baffle design volume will always exceed the required treatment volume.

4. Determine the baffle cell spacing by dividing the number of baffles needed into the access road length.

To ensure the roads drain with the 72-hour maximum drawdown time, the design volumes were divided by the most conservative saturated hydraulic conductivity (Ksat) of the underlying soils. Each calculated drawdown time used the maximum depth of each triangular CSA and was multiplied by a Safety Factor of 2, resulting in the following drawdown times (all less than the 72-hour maximum). Note that several access roads span more than one different soil types with different Ksat rates.

MVP-MLV-AR-31		
MUSYM	7C	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Max Depth	0.83	[FT]
Drawdown Time	16	[HR]

MVP-MLV-AR-32		
MUSYM	11A	[-]
HSG	B	[-]
K_{SAT}	1.30	[IN/HR]
Max Depth	1.32	[FT]
Drawdown Time	24	[HR]
MUSYM	11A	[-]
HSG	B	[-]
K_{SAT}	1.30	[IN/HR]
Max Depth	1.32	[FT]
Drawdown Time	24	[HR]
MUSYM	11A	[-]
HSG	B	[-]
K_{SAT}	1.30	[IN/HR]
Max Depth	1.32	[FT]
Drawdown Time	24	[HR]
MUSYM	11A	[-]
HSG	B	[-]
K_{SAT}	1.30	[IN/HR]
Max Depth	1.32	[FT]
Drawdown Time	24	[HR]

MVP-MLV-AR-33		
MUSYM	27C	[-]
HSG	B	[-]

K_{SAT}	1.28	[IN/HR]
Max Depth	0.94	[FT]
Drawdown Time	18	[HR]
MUSYM	27C	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Max Depth	0.94	[FT]
Drawdown Time	18	[HR]
MUSYM	27C	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Max Depth	0.94	[FT]
Drawdown Time	18	[HR]

MVP-MLV-AR-34		
MUSYM	5B3	[-]
HSG	B	[-]
K_{SAT}	1.78	[IN/HR]
Max Depth	0.87	[FT]
Drawdown Time	12	[HR]
MUSYM	5B3	[-]
HSG	B	[-]
K_{SAT}	1.78	[IN/HR]
Max Depth	0.87	[FT]
Drawdown Time	12	[HR]
MUSYM	5B3	[-]
HSG	B	[-]
K_{SAT}	1.78	[IN/HR]
Max Depth	0.87	[FT]
Drawdown Time	12	[HR]

MVP-MLV-AR-35		
MUSYM	4B	[-]
HSG	B	[-]
K_{SAT}	1.47	[IN/HR]
Max Depth	0.72	[FT]
Drawdown Time	12	[HR]

MVP-PI-343

MUSYM	23B	[-]
HSG	B	[-]
K_{SAT}	2.44	[IN/HR]
Max Depth	0.98	[FT]
Drawdown Time	10	[HR]
MUSYM	23C	[-]
HSG	B	[-]
K_{SAT}	2.44	[IN/HR]
Max Depth	0.98	[FT]
Drawdown Time	10	[HR]
MUSYM	9B	[-]
HSG	D	[-]
K_{SAT}	0.63	[IN/HR]
Max Depth	0.95	[FT]
Drawdown Time	36	[HR]

ii. New Impervious Cover: Main Line Valve Pads

New impervious cover in Spread 11 also includes five (5) main line valve sites (MVP-MLV-31 through -35). Increased volumes of stormwater runoff resulting from the main line valve pads will be controlled utilizing the methodology established in *MVP-33.1 through MVP-33.3 Gap Graded Gravel Detail for Mainline Valve Pads and Permanent Access Roads*. All pads will be located on relatively flat ground. The runoff volume increase when considering only the pad is greater than the resulting runoff volume increase when considering the full drainage area. As a result, the reservoir within the gap graded gravel pad is conservatively sized to accommodate the required volume computed using the pad footprint only.

Pre- and post-construction runoff volumes for the 10-year 24-hour storm were calculated using the Franklin and Pittsylvania County design storm values of 5.70 and 5.20 inches respectively, per *PSS&S Section 4.2.2 Design Storms*.

10-YEAR STORM DATA					
SITE	TIME OF CONCENTRATION (PRE / POST) [HR]	CURVE NUMBER (PRE / POST)	DRAINAGE AREA [FT^2]	Q_{10} PEAK FLOW (PRE / POST) [CFS]	Q_{10} VOLUME (PRE / POST) [FT^3]
MLV-31	0.10 / 0.10	58 / 85	2,396	0.12 / 0.33	305 / 784
MLV-32	0.10 / 0.10	58 / 85	2,396	0.12 / 0.33	305 / 784
MLV-33	0.10 / 0.10	55 / 85	2,396	0.10 / 0.33	261 / 784
MLV-34	0.10 / 0.10	58 / 85	2,396	0.10 / 0.29	261 / 697
MLV-35	0.10 / 0.10	55 / 85	2,396	0.08 / 0.29	218 / 697

Any increase in runoff volume from pre- to post-construction condition must be stored within the gap graded gravel to meet flood protection requirements per 9VAC25-870-66.C.2. The calculated treatment volume required was then divided by the pad footprint and 40% void space to determine the depth of gravel required to store the 10-year 24-hour storm event. In this instance, calculated gravel depths for all pads were less than the 8-inch minimum required per *MVP-33.1 through MVP-33.3 Gap Graded Gravel Detail for Mainline Valve Pads and Permanent Access Roads*. Therefore, gravel depths for all pads are 8 inches, providing storage beyond the 10-year 24-hour storm event.

MLV-31 Pad	Vreq	479	cf
	Area	2376	sf
	Dreq	0.50	ft
	Ddesign	8	in
	Vdesign	634	cf

MLV-32 Pad	Vreq	479	cf
	Area	2376	sf
	Dreq	0.50	ft
	Ddesign	8	in
	Vdesign	634	cf

MLV-33 Pad	Vreq	523	cf
	Area	2376	sf
	Dreq	0.55	ft
	Ddesign	8	in
	Vdesign	634	cf

MLV-34 Pad	Vreq	436	cf
	Area	2376	sf
	Dreq	0.46	ft
	Ddesign	8	in
	Vdesign	634	cf

MLV-35 Pad	Vreq	479	cf
	Area	2376	sf
	Dreq	0.50	ft
	Ddesign	8	in
	Vdesign	634	cf

To ensure the gravel pads drain with the 72-hour maximum drawdown time, the design volumes were divided by the most conservative saturated hydraulic conductivity (Ksat) of the underlying soils. Each calculated drawdown time was multiplied by a Safety Factor of 2, resulting in the following drawdown times, all less than the 72-hour maximum.

MVP-MLV-31		
MUSYM	7C	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Depth	8	[IN]
Drawdown Time	13	[HR]

MVP-MLV-32		
MUSYM	11A	[-]
HSG	B	[-]
K_{SAT}	1.30	[IN/HR]
Depth	8	[IN]
Drawdown Time	12	[HR]

MVP-MLV-33		
MUSYM	27C	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Depth	8	[IN]
Drawdown Time	13	[HR]

MVP-MLV-34		
MUSYM	5B3	[-]
HSG	B	[-]
K_{SAT}	1.78	[IN/HR]
Depth	8	[IN]

Drawdown Time	9	[HR]

MVP-MLV-35		
MUSYM	4B	[-]
HSG	B	[-]
K_{SAT}	1.47	[IN/HR]
Depth	8	[IN]
Drawdown Time	11	[HR]

Results show the 10-year 24-hour storm event will be stored within the gravel layer with no overtopping, and with reasonable drawdown times before the next storm event.