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

# Water Bar 1.1 Site Specific Analysis

## I. Drainage Area

As shown, the drainage area to Water Bar 1.1 is 2.17 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 1.1 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 1.1 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 1.1 is 19 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 | 0.130 | | 0.255 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 1438.0 | 0.200 | 7.22 | 0.055 |
| CD | Waterbar | Unpaved | | | | 25.0 | 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) = | 0.312 |
| | | | | | | | | $T_c$ (min) = | 19 |

[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 16 foot long end treatment will ensure sheet flow conditions leaving Water Bar 1.1. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 1.1.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 19 | time of concentration to water bar, min |
| | A = | 2.17 | water bar drainage area, ac |
| | S = | 0.200 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 4.2 | 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 ------>*** **16 ft**

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

# Water Bar 1.2 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 1.2 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 1.2 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 1.2 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 1.2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 1.2.

**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 = | 0.530 | 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 ------>*** **0.97 fps**

# Water Bar 2 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 2 is 0.07 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 2 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 2 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 2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 2.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.07 | water bar drainage area, ac |
| | S = | 0.435 | 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 ------>*** **0.88 fps**

# Water Bar 3 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 3 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 3 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 3 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 3. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 3.

**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 = | 0.476 | 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 ------>*** **0.92 fps**

# Water Bar 4 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 4 is 0.26 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 4 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 4 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 4. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 4.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.26 | water bar drainage area, ac |
| | S = | 0.364 | 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 ------>*** **0.81 fps**

# Water Bar 5 Site Specific Analysis

**I. Drainage Area**

The drainage area to Water Bar 5 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.

**II. Runoff Coefficient**

The flowpath exiting the Water Bar 5 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 5 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 5. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 5.

**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 = | 0.260 | 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 ------>*** **0.68 fps**

# Water Bar 6 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 6 is 1.79 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 6 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 6 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 6 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 | 0.260 | | 0.223 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 853.0 | 0.225 | 7.65 | 0.031 |
| CD | Waterbar | Unpaved | | | | 78.0 | 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) = | 0.260 |
| | | | | | | | | $T_c$ (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 19 foot long end treatment will ensure sheet flow conditions leaving Water Bar 6. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 6.

| End Treatment Length Calculator | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 16 | time of concentration to water bar, min |
| | A = | 1.79 | water bar drainage area, ac |
| | S = | 0.110 | 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 ------>*** | | **19 ft** | |
| ***Velocity Check ------>*** | | **0.44 fps** | |

# Water Bar 7 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 7 is 0.68 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 7 begins as sheet flow in a HSG D meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.25.

The flowpath exiting the Water Bar 7 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 7 is 9 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 | 0.25 | | | | 100.0 | 0.290 | | 0.131 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 416.0 | 0.236 | 7.84 | 0.015 |
| CD | Waterbar | Unpaved | | | | 40.0 | 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) = | 0.149 |
| | | | | | | | | $T_c$ (min) = | 9 |

[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 7. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 7.

| End Treatment Length Calculator | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 9 | time of concentration to water bar, min |
| | A = | 0.68 | water bar drainage area, ac |
| | S = | 0.085 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 5.8 | 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 ------>*** | | **9 ft** | |
| ***Velocity Check ------>*** | | **0.39 fps** | |

# Water Bar 8 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 8 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 8 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 8 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 8. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 8.

**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 = | 0.430 | 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 ------>*** **0.88 fps**

# Water Bar 9 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 9 is 0.18 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 9 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 9 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 9. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 9.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.18 | water bar drainage area, ac |
| | S = | 0.263 | 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 ------>*** **0.69 fps**

# Water Bar 10 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 10 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.

## 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 flowpath exiting the Water Bar 10 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 10 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 | 0.19 | | | | 100.0 | 0.130 | | 0.201 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 375.0 | 0.415 | 10.39 | 0.010 |
| CD | Waterbar | Unpaved | | | | 48.0 | 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) = | 0.215 |
| | | | | | | | | $T_c$ (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 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 10. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 10.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 13 | time of concentration to water bar, min |
| | A = | 0.51 | water bar drainage area, ac |
| | S = | 0.222 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 5.0 | 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 ------>*** **6 ft**

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

# Water Bar 11 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 11 is 0.68 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 11 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 11 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 11 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 | 0.100 | | 0.211 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 335.0 | 0.287 | 8.64 | 0.011 |
| CD | Waterbar | Unpaved | | | | 79.0 | 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) = | 0.228 |
| | | | | | | | | $T_c$ (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 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 = | 14 | time of concentration to water bar, min |
| | A = | 0.68 | water bar drainage area, ac |
| | S = | 0.310 | 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 ------>*** | | **8 ft** | |
| ***Velocity Check ------>*** | | **0.74 fps** | |

# Water Bar 12 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 12 is 0.46 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 12 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 12 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 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 12. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 12.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.46 | water bar drainage area, ac |
| | S = | 0.410 | 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 ------>*** **7 ft**
***Velocity Check ------>*** **0.86 fps**

# Water Bar 13 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 13 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 13 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 13 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 13. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 13.

**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 = | 0.253 | 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 ------>*** **0.67 fps**

# Water Bar 14 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 14 is 0.19 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 14 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 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 3 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 = | 0.19 | water bar drainage area, ac |
| | S = | 0.299 | 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 ------>*** **0.73 fps**

# Water Bar 17 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 17 is 0.87 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 17 begins as sheet flow in a HSG D wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.21.

The flowpath exiting the Water Bar 17 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 17 is 10 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 | 0.21 | | | | 100.0 | 0.300 | | 0.155 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 391.0 | 0.266 | 8.32 | 0.013 |
| CD | Waterbar | Unpaved | | | | 0.0 | 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) = | 0.168 |
| | | | | | | | | $T_c$ (min) = | 10 |

[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 17. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 17.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 10 | time of concentration to water bar, min |
| | A = | 0.87 | water bar drainage area, ac |
| | S = | 0.330 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 5.3 | 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 ------>*** **11 ft**

***Velocity Check ------>*** **0.77 fps**

# Water Bar 18 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 18 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 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

A minimum time of concentration of 5 minutes was assumed for Water Bar 18 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 18. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 18.

**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 = | 0.240 | 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 ------>*** **0.66 fps**

# Water Bar 19 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 19 is 0.19 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 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

A minimum time of concentration of 5 minutes was assumed for Water Bar 19 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 19. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 19.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.19 | water bar drainage area, ac |
| | S = | 0.290 | 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 ------>*** **0.72 fps**

# Water Bar 20 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 20 is 0.36 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 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

A minimum time of concentration of 5 minutes was assumed for Water Bar 20 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 20. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 20.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.36 | water bar drainage area, ac |
| | S = | 0.290 | 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 ------>*** **0.72 fps**

# Water Bar 21 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 21 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 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 1 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 = | 0.05 | water bar drainage area, ac |
| | S = | 0.290 | 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 ------>*** **0.72 fps**

# Water Bar 22 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 22 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 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 = | 0.05 | water bar drainage area, ac |
| | S = | 0.290 | 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 ------>*** **0.72 fps**

# Water Bar 23 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 23 is 0.06 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 23 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 23 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 23. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 23.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.06 | water bar drainage area, ac |
| | S = | 0.290 | 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 ------>*** **0.72 fps**

# Water Bar 24 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 24 is 0.18 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 3 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 = | 0.18 | water bar drainage area, ac |
| | S = | 0.370 | 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 ------>*** **0.81 fps**

# Water Bar 25 Site Specific Analysis

## I. Drainage Area

As shown, the drainage area to Water Bar 25 is 1.92 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 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 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 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 | 0.200 | | 0.235 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 850.0 | 0.184 | 6.91 | 0.034 |
| CD | Waterbar | Unpaved | | | | 12.9 | 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) = | 0.270 |
| | | | | | | | | $T_c$ (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 15 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 = | 16 | time of concentration to water bar, min |
| | A = | 1.92 | water bar drainage area, ac |
| | S = | 0.230 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 4.4 | 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 ------>*** **15 ft**

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

# Water Bar 26 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 26 is 0.27 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 4 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 = | 0.27 | water bar drainage area, ac |
| | S = | 0.330 | 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 ------>*** **0.77 fps**

# Water Bar 27 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 27 is 0.68 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 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 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 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 | | | | 443.0 | 0.235 | 7.82 | 0.016 |
| CD | Waterbar | Unpaved | | | | 79.0 | 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) = | 0.241 |
| | | | | | | | | $T_c$ (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 7 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 = | 14 | time of concentration to water bar, min |
| | A = | 0.68 | water bar drainage area, ac |
| | S = | 0.330 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 4.6 | 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 ------>*** **7 ft**

***Velocity Check ------>*** **0.77 fps**

# Water Bar 28 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 28 is 0.52 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 28 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 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 ($T_c$)

As shown, the time of concentration of Water Bar 28 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 | 0.17 | | | | 100.0 | 0.160 | | 0.216 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 606.0 | 0.191 | 7.06 | 0.024 |
| CD | Waterbar | Unpaved | | | | 118.5 | 0.050 | 3.61 | 0.009 |
| | | | | | | | | | |
| | | | | | | | | | |

**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) = | 0.249 |
| | | | | | | | | $T_c$ (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 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 28. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 28.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 15 | time of concentration to water bar, min |
| | A = | 0.52 | water bar drainage area, ac |
| | S = | 0.300 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 4.6 | 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 ------>*** **6 ft**

***Velocity Check ------>*** **0.73 fps**

# Water Bar 29 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 29 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 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 1 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 = | 0.08 | water bar drainage area, ac |
| | S = | 0.290 | 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 ------>*** **0.72 fps**

# Water Bar 30 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 30 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 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 1 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 = | 0.09 | water bar drainage area, ac |
| | S = | 0.270 | 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 ------>*** **0.69 fps**

# Water Bar 31 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 31 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 31 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 31 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 31. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 31.

**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 = | 0.244 | 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 ------>*** **0.66 fps**

# Water Bar 32 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 32 is 0.11 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 32 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 32 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 32. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 32.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.11 | water bar drainage area, ac |
| | S = | 0.317 | 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 ------>*** **0.75 fps**

# Water Bar 33 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 33 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 33 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 33 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 33. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 33.

**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 = | 0.233 | 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 ------>*** **0.65 fps**

# Water Bar 34 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 34 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 34 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 34 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 34. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 34.

**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 = | 0.189 | 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 ------>*** **0.58 fps**

# Water Bar 35 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 35 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 35 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 35 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 35. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 35.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.20 | water bar drainage area, ac |
| | S = | 0.360 | 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 ------>*** **0.80 fps**

# Water Bar 36 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36 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 36 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 36 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 36. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.

**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 = | 0.263 | 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 ------>*** **0.69 fps**

# Water Bar 36.1 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.1 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 36.1 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 36.1 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 36.1. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.1.

**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 = | 0.354 | 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 ------>*** **0.80 fps**

# Water Bar 36.2 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.2 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 36.2 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 36.2 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 36.2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.2.

**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 = | 0.321 | 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 ------>*** **0.76 fps**

# Water Bar 36.3 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.3 is 0.06 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 36.3 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 36.3 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 36.3. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.3.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.06 | water bar drainage area, ac |
| | S = | 0.353 | 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 ------>*** **0.79 fps**

# Water Bar 36.4 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.4 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 36.4 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 36.4 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 36.4. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.4.

**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 = | 0.4 | 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 ------>*** **0.85 fps**

# Water Bar 36.5 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.5 is 0.22 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 36.5 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 36.5 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 36.5. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.5.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.22 | water bar drainage area, ac |
| | S = | 0.392 | 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 ------>*** **0.84 fps**

# Water Bar 36.6 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.6 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 36.6 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 36.6 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 36.6. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.6.

**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 = | 0.476 | 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 ------>*** **0.92 fps**

# Water Bar 36.7 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.7 is 0.22 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 36.7 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 36.7 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 36.7. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.7.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.22 | water bar drainage area, ac |
| | S = | 0.508 | 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 ------>*** **0.95 fps**

# Water Bar 36.8 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 36.8 is 0.15 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 36.8 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 36.8 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 36.8. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.8.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.15 | water bar drainage area, ac |
| | S = | 0.694 | 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 ------>*** **1.11 fps**

# Water Bar 37 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 37 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.

| Composite Curve Number (CN) Calculator | | | | |
|---|---|---|---|---|
| **LAND USE** | **HSG** | **CN** | **AREA (%)** | **AreaWeighted CN** |
| Impervious | D | 98 | 45% | 44 |
| Meadow | D | 78 | 55% | 43 |
| Wooded | D | 77 | 0% | 0 |
| | | | 100% | 87 |

## II. Runoff Coefficient

The drainage area for Water Bar 37 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.54 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 | D | 0.9 | 45% | 0.41 |
| Meadow | D | 0.25 | 55% | 0.14 |
| Wooded | D | 0.21 | 0% | 0.00 |
| | | | 100% | 0.54 |

**<--- Composite C**

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 37 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 37. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 37.

**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 = | 0.465 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.54 | 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 ------>*** **3 ft**

***Velocity Check ------>*** **0.91 fps**

# Water Bar 38 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 38 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 38 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 38 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 38. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 38.

**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 = | 0.200 | 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 ------>*** **0.60 fps**

# Water Bar 39 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 39 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.

## II. Runoff Coefficient

The flowpath for Water Bar 39 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 flowpath exiting the Water Bar 39 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 39 is 11 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 | 0.160 | | 0.167 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 469.0 | 0.196 | 7.14 | 0.018 |
| CD | Waterbar | Unpaved | | | | 40.0 | 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) = | 0.188 |
| | | | | | | | | $T_c$ (min) = | 11 |

[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 39. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 39.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 11 | time of concentration to water bar, min |
| | A = | 0.74 | water bar drainage area, ac |
| | S = | 0.200 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 5.1 | 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 ------>*** **9 ft**

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

# Water Bar 40 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 40 is 0.07 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 40 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 40 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 40. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 40.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.07 | water bar drainage area, ac |
| | S = | 0.270 | 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 ------>*** **0.69 fps**

# Water Bar 41 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 41 is 0.12 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 41 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 41 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 41. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 41.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.12 | water bar drainage area, ac |
| | S = | 0.217 | 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 ------>*** **0.62 fps**

# Water Bar 42 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 42 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 42 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 42 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 42. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 42.

**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 = | 0.377 | 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 ------>*** **0.82 fps**

# Water Bar 43 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 43 is 0.34 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 43 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 43 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 43. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 43.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.34 | water bar drainage area, ac |
| | S = | 0.357 | 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 ------>*** **0.80 fps**

# Water Bar 44 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 44 is 0.29 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 44 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 44 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 44. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 44.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.29 | water bar drainage area, ac |
| | S = | 0.417 | 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 ------>*** **0.86 fps**

# Water Bar 45 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 45 is 0.41 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 45 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 45 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 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 45. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 45.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.41 | water bar drainage area, ac |
| | S = | 0.240 | 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 ------>*** **6 ft**
***Velocity Check ------>*** **0.66 fps**

# Water Bar 46 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 46 is 0.26 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 | 3% | 3 |
| Turf Grass | C | 74 | 40% | 30 |
| Wooded | C | 70 | 57% | 40 |
| | | | 100% | 72 |

## II. Runoff Coefficient

The drainage area for Water Bar 46 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a and open space (turf grass), which has a runoff coefficient of of 0.24 per Table 4-5a (type C soil; 6+% slopes). Therefore, a composite C of 0.22 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 | 3% | 0.03 | |
| Turf Grass | C | 0.24 | 40% | 0.10 | |
| Wooded | C | 0.17 | 57% | 0.10 | |
| | | | 100% | 0.22 | <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 46 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 46. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 46.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.26 | water bar drainage area, ac |
| | S = | 0.351 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.22 | 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 ------>*** **3 ft**

***Velocity Check ------>*** **0.79 fps**

# Water Bar 47 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 47 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 | 7% | 7 |
| Turf Grass | C | 74 | 45% | 33 |
| Wooded | C | 70 | 48% | 34 |
| | | | 100% | 74 |

## II. Runoff Coefficient

The flowpath for Water Bar 47 begins as sheet flow in a HSG C turf grass area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.24.

The drainage area for Water Bar 47 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a and open space (turf grass), which has a runoff coefficient of of 0.24 per Table 4-5a (type C soil; 6+% slopes). 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% | 0.06 | |
| Turf Grass | C | 0.24 | 45% | 0.11 | |
| Wooded | C | 0.17 | 48% | 0.08 | |
| | | | 100% | 0.25 | <--- Composite C |

## III. Time of Concentration ($T_c$)

As shown, the time of concentration of Water Bar 47 is 11 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 | 0.24 | | | | 100.0 | 0.090 | | 0.171 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 349.0 | 0.223 | 7.62 | 0.013 |
| CD | Waterbar | Unpaved | | | | 38.0 | 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) = | 0.186 |
| | | | | | | | | $T_c$ (min) = | 11 |

[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 47. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 47.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 11 | time of concentration to water bar, min |
| | A = | 0.74 | water bar drainage area, ac |
| | S = | 0.270 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 5.1 | 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 ------>*** **9 ft**
***Velocity Check ------>*** **0.69 fps**

# Water Bar 48 Site Specific Analysis

## I. Drainage Area

As shown, the drainage area to Water Bar 48 is 1.98 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 48 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 48 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 48 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 | 0.150 | | 0.196 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 864.0 | 0.274 | 8.45 | 0.028 |
| CD | Waterbar | Unpaved | | | | 42.0 | 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) = | 0.227 |
| | | | | | | | | $T_c$ (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 17 foot long end treatment will ensure sheet flow conditions leaving Water Bar 48. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 48.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 14 | time of concentration to water bar, min |
| | A = | 1.98 | water bar drainage area, ac |
| | S = | 0.263 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 4.8 | 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 ------>*** **17 ft**

***Velocity Check ------>*** **0.69 fps**

# Water Bar 49 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 49 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 49 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 49 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 49. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 49.

**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 = | 0.250 | 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 ------>*** **0.67 fps**

# Water Bar 50 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 50 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 50 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 50 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 50. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 50.

**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 = | 0.335 | 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 ------>*** **0.77 fps**

# Water Bar 51 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 51 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 51 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 51 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 51. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 51.

**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 = | 0.385 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | assumes >6% slope, meadow (conservative) |
| ***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 ------>*** **1 ft**
***Velocity Check ------>*** **0.83 fps**

# Water Bar 52 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 52 is 0.04 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 52 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 52 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 52. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 52.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.04 | water bar drainage area, ac |
| | S = | 0.447 | 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 ------>*** **0.89 fps**

# Water Bar 53 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 53 is 0.04 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 53 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 53 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 53. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 53.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.04 | water bar drainage area, ac |
| | S = | 0.477 | 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 ------>*** **0.92 fps**

# Water Bar 55 Site Specific Analysis

## I. Drainage Area

As shown, the drainage area to Water Bar 55 is 1.7 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 55 begins as sheet flow in a HSG A wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.08.

The flowpath exiting the Water Bar 55 end treatment will be along HSG A meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.1.

**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 55 is 28 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 | 0.08 | | | | 100.0 | 0.170 | | 0.454 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 537.0 | 0.300 | 8.84 | 0.017 |
| CD | Waterbar | Unpaved | | | | 33.0 | 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) = | 0.474 |
| | | | | | | | | $T_c$ (min) = | 28 |

[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 55. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 55.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 28 | time of concentration to water bar, min |
| | A = | 1.7 | water bar drainage area, ac |
| | S = | 0.330 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 3.3 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.10 | 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 ------>*** **0.77 fps**

# Water Bar 56 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 56 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.

| Composite Curve Number (CN) Calculator | | | | |
|---|---|---|---|---|
| **LAND USE** | **HSG** | **CN** | **AREA (%)** | **AreaWeighted CN** |
| Impervious | C | 98 | 4% | 4 |
| Meadow | C | 71 | 51% | 36 |
| Wooded | C | 70 | 45% | 32 |
| | | | 100% | 72 |

## II. Runoff Coefficient

The flowpath for Water Bar 56 begins as sheet flow in a HSG A 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 56 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.22 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 | 51% | 0.11 | |
| Wooded | C | 0.17 | 45% | 0.08 | |
| | | | 100% | 0.22 | <--- Composite C |

## III. Time of Concentration ($T_c$)

As shown, the time of concentration of Water Bar 56 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 | 0.17 | | | | 100.0 | 0.280 | | 0.194 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 460.0 | 0.204 | 7.29 | 0.018 |
| CD | Waterbar | Unpaved | | | | 65.0 | 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) = | 0.217 |
| | | | | | | | | $T_c$ (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 9 foot long end treatment will ensure sheet flow conditions leaving Water Bar 56. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 56.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| *Enter Site Specific Data* | Tc = | 13 | time of concentration to water bar, min |
| | A = | 0.93 | water bar drainage area, ac |
| | S = | 0.054 | weir discharge overland slope, ft/ft |
| *Computed* | i = | 4.8 | computed from IDF, in/hr |
| *Enter Flow Parameters* | C = | 0.22 | 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 ------>*** **9 ft**
***Velocity Check ------>*** **0.31 fps**

# Water Bar 58 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 58 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 | 20% | 20 |
| Meadow | C | 71 | 30% | 21 |
| Wooded | C | 70 | 50% | 35 |
| | | | 100% | 76 |

## II. Runoff Coefficient

The drainage area for Water Bar 58 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.33 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 | 20% | 0.18 | |
| Meadow | C | 0.22 | 30% | 0.07 | |
| Wooded | C | 0.17 | 50% | 0.09 | |
| | | | 100% | 0.33 | <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 58 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 58. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 58.

**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 = | 0.200 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.33 | 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 ------>*** **3 ft**

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

# Water Bar 59 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 59 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.

| Composite Curve Number (CN) Calculator | | | | |
|---|---|---|---|---|
| **LAND USE** | **HSG** | **CN** | **AREA (%)** | **AreaWeighted CN** |
| Impervious | C | 98 | 17% | 17 |
| Meadow | C | 71 | 0% | 0 |
| Wooded | C | 70 | 83% | 58 |
| | | | 100% | 75 |

## II. Runoff Coefficient

The drainage area for Water Bar 59 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.29 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 | 17% | 0.15 | |
| Meadow | C | 0.22 | 0% | 0.00 | |
| Wooded | C | 0.17 | 83% | 0.14 | |
| | | | 100% | 0.29 | <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 59 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 59. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 59.

**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 = | 0.100 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.29 | 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 ------>*** **0.42 fps**

# Water Bar 60 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 60 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.

| Composite Curve Number (CN) Calculator | | | | |
|---|---|---|---|---|
| **LAND USE** | **HSG** | **CN** | **AREA (%)** | **AreaWeighted CN** |
| Impervious | C | 98 | 16% | 16 |
| Meadow | C | 71 | 0% | 0 |
| Wooded | C | 70 | 84% | 59 |
| | | | 100% | 74 |

## II. Runoff Coefficient

The drainage area for Water Bar 60 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.29 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 | 16% | 0.14 |
| Meadow | C | 0.22 | 0% | 0.00 |
| Wooded | C | 0.17 | 84% | 0.14 |
| | | | 100% | 0.29 |

**<--- Composite C**

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 60 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 60. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 60.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.1 | water bar drainage area, ac |
| | S = | 0.050 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.29 | 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 ------>*** **0.30 fps**

# Water Bar 61 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 61 is 0.07 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 | 25% | 25 |
| Meadow | C | 71 | 0% | 0 |
| Wooded | C | 70 | 75% | 53 |
| | | | 100% | 77 |

## II. Runoff Coefficient

The drainage area for Water Bar 61 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.35 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 | 25% | 0.23 | |
| Meadow | C | 0.22 | 0% | 0.00 | |
| Wooded | C | 0.17 | 75% | 0.13 | |
| | | | 100% | 0.35 | <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 61 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 61. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 61.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.07 | water bar drainage area, ac |
| | S = | 0.140 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.35 | 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 ------>*** **0.50 fps**

# Water Bar 62 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 62 is 0.06 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 | 45% | 44 |
| Meadow | C | 71 | 0% | 0 |
| Wooded | C | 70 | 55% | 39 |
| | | | 100% | 83 |

## II. Runoff Coefficient

The drainage area for Water Bar 62 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.5 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 | 45% | 0.41 |
| Meadow | C | 0.22 | 0% | 0.00 |
| Wooded | C | 0.17 | 55% | 0.09 |
| | | | 100% | 0.50 |

**<--- Composite C**

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 62 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 62. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 62.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.06 | water bar drainage area, ac |
| | S = | 0.140 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.50 | 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 ------>*** **0.50 fps**

# Water Bar 63 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 63 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 63 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 63 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 63. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 63.

**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 = | 0.070 | 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 ------>*** **0.35 fps**

# Water Bar 66 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 66 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 66 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 66 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 66. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 66.

**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 = | 0.320 | 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 ------>*** **0.76 fps**

# Water Bar 67 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 67 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 67 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 67 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 67. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 67.

**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 = | 0.210 | 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 ------>*** **0.61 fps**

# Water Bar 68 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 68 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 | D | 98 | 5% | 5 |
| Meadow | D | 78 | 75% | 59 |
| Wooded | D | 77 | 20% | 15 |
| | | | 100% | 79 |

## II. Runoff Coefficient

The flowpath for Water Bar 68 begins as sheet flow in a HSG D wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.21.

The drainage area for Water Bar 68 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 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 | D | 0.9 | 5% | 0.05 | |
| Meadow | D | 0.25 | 75% | 0.19 | |
| Wooded | D | 0.21 | 20% | 0.04 | |
| | | | 100% | 0.27 | **<--- Composite C** |

## III. Time of Concentration ($T_c$)

As shown, the time of concentration of Water Bar 68 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 | 0.21 | | | | 100.0 | 0.090 | | 0.195 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 364.0 | 0.176 | 6.77 | 0.015 |
| CD | Waterbar | Unpaved | | | | 78.0 | 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) = | 0.216 |
| | | | | | | | | $T_c$ (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 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 68. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 68.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 13 | time of concentration to water bar, min |
| | A = | 0.51 | water bar drainage area, ac |
| | S = | 0.190 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 5.0 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.27 | 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 ------>*** **6 ft**
***Velocity Check ------>*** **0.58 fps**

# Water Bar 69 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 69 is 0.37 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 69 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 69 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 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 69. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 69.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.37 | water bar drainage area, ac |
| | S = | 0.170 | 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 ------>*** **6 ft**
***Velocity Check ------>*** **0.55 fps**

# Water Bar 70 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 70 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 70 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 70 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 70. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 70.

**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 = | 0.360 | 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 ------>*** **0.80 fps**

# Water Bar 71 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 71 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 71 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 71 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 71. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 71.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.20 | water bar drainage area, ac |
| | S = | 0.270 | 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 ------>*** **0.69 fps**

# Water Bar 72 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 72 is 1.34 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 | 13% | 13 |
| Meadow | C | 71 | 77% | 55 |
| Wooded | C | 70 | 10% | 7 |
| | | | 100% | 74 |

## II. Runoff Coefficient

The flowpath for Water Bar 72 begins as sheet flow in a HSG A meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.1.

The drainage area for Water Bar 72 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.3 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 | 13% | 0.12 | |
| Meadow | C | 0.22 | 77% | 0.17 | |
| Wooded | C | 0.17 | 10% | 0.02 | |
| | | | 100% | 0.30 | **<--- Composite C** |

## III. Time of Concentration ($T_c$)

As shown, the time of concentration of Water Bar 72 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 | 0.10 | | | | 100.0 | 0.150 | | 0.372 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 414.0 | 0.082 | 4.62 | 0.025 |
| CD | Waterbar | Unpaved | | | | 21.0 | 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) = | 0.399 |
| | | | | | | | | $T_c$ (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 14 foot long end treatment will ensure sheet flow conditions leaving Water Bar 72. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 72.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| *Enter Site Specific Data* | Tc = | 24 | time of concentration to water bar, min |
| | A = | 1.34 | water bar drainage area, ac |
| | S = | 0.200 | weir discharge overland slope, ft/ft |
| *Computed* | i = | 3.7 | computed from IDF, in/hr |
| *Enter Flow Parameters* | C = | 0.30 | 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 ------>*** **14 ft**
***Velocity Check ------>*** **0.60 fps**

# Water Bar 74 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 74 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.

| Composite Curve Number (CN) Calculator | | | | |
|---|---|---|---|---|
| LAND USE | HSG | CN | AREA (%) | AreaWeighted CN |
| Impervious | C | 98 | 25% | 25 |
| Meadow | C | 71 | 0% | 0 |
| Wooded | C | 70 | 75% | 53 |
| | | | 100% | 77 |

## II. Runoff Coefficient

The drainage area for Water Bar 74 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.35 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 | 25% | 0.23 | |
| Meadow | C | 0.22 | 0% | 0.00 | |
| Wooded | C | 0.17 | 75% | 0.13 | |
| | | | 100% | 0.35 | <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 74 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 74. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 74.

**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 = | 0.410 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.35 | 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 ------>*** **0.86 fps**

# Water Bar 75 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 75 is 0.12 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 | 8% | 8 |
| Meadow | C | 71 | 92% | 65 |
| Wooded | C | 70 | 0% | 0 |
| | | | 100% | 73 |

## II. Runoff Coefficient

The drainage area for Water Bar 75 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 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 | 8% | 0.07 |
| Meadow | C | 0.22 | 92% | 0.20 |
| Wooded | C | 0.17 | 0% | 0.00 |
| | | | 100% | 0.27 <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 75 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 75. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 75.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.12 | water bar drainage area, ac |
| | S = | 0.030 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.27 | 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 ------>*** **0.23 fps**

# Water Bar 76 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 76 is 0.56 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 | 93% | 66 |
| Wooded | C | 70 | 0% | 0 |
| | | | 100% | 73 |

## II. Runoff Coefficient

The flowpath for Water Bar 76 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 76 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 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 | 93% | 0.20 | |
| Wooded | C | 0.17 | 0% | 0.00 | |
| | | | 100% | 0.27 | **<--- Composite C** |

## III. Time of Concentration ($T_c$)

As shown, the time of concentration of Water Bar 76 is 12 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 | 0.070 | | 0.195 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**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 | | | | 98.0 | 0.224 | 7.64 | 0.004 |
| CD | Waterbar | Unpaved | | | | 10.0 | 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) = | 0.200 |
| | | | | | | | | $T_c$ (min) = | 12 |

[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 76. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 76.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| *Enter Site Specific Data* | Tc = | 12 | time of concentration to water bar, min |
| | A = | 0.56 | water bar drainage area, ac |
| | S = | 0.240 | weir discharge overland slope, ft/ft |
| *Computed* | i = | 5.1 | computed from IDF, in/hr |
| *Enter Flow Parameters* | C = | 0.27 | 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 ------>*** **0.66 fps**

# Water Bar 77 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 77 is 0.15 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 | 93% | 66 |
| Wooded | C | 70 | 0% | 0 |
| | | | 100% | 73 |

## II. Runoff Coefficient

The drainage area for Water Bar 77 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 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 | 93% | 0.20 |
| Wooded | C | 0.17 | 0% | 0.00 |
| | | | 100% | 0.27 <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 77 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 77. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 77.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.15 | water bar drainage area, ac |
| | S = | 0.130 | weir discharge overland slope, ft/ft |
| ***Computed*** | i = | 6.6 | computed from IDF, in/hr |
| ***Enter Flow Parameters*** | C = | 0.27 | 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 ------>*** **3 ft**

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

# Water Bar 78 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 78 is 0.06 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 | 17% | 17 |
| Meadow | C | 71 | 83% | 59 |
| Wooded | C | 70 | 0% | 0 |
| | | | 100% | 76 |

## II. Runoff Coefficient

The drainage area for Water Bar 78 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 | 17% | 0.15 | |
| Meadow | C | 0.22 | 83% | 0.18 | |
| Wooded | C | 0.17 | 0% | 0.00 | |
| | | | 100% | 0.34 | <--- Composite C |

**III. Time of Concentration ($T_c$)**

A minimum time of concentration of 5 minutes was assumed for Water Bar 78 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 78. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 78.

**End Treatment Length Calculator**

| | | | |
|---|---|---|---|
| ***Enter Site Specific Data*** | Tc = | 5 | time of concentration to water bar, min |
| | A = | 0.06 | water bar drainage area, ac |
| | S = | 0.030 | 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 ------>*** **1 ft**

***Velocity Check ------>*** **0.23 fps**

# Water Bar 79 Site Specific Analysis

## I. Drainage Area

The drainage area to Water Bar 79 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.

## II. Runoff Coefficient

The flowpath exiting the Water Bar 79 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 79 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 79. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 79.

**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 = | 0.150 | 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 ------>*** **0.52 fps**

i. New Impervious Cover: Access Roads

New impervious cover in Spread 9 includes three (3) access roads (MVP-MLV-AR-25 through -27). 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 Giles and Montgomery County design storm values of 4.70 and 5.00 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-25 | 0.28 / 0.28 | 56 / 56 | 684,148 | 13.31 / 13.31 | 50,475 / 50,475 |
| MLV-AR-26 | 0.15 / 0.12 | 60 / 67 | 3,523 | 0.14 / 0.21 | 381 / 529 |
| MLV-AR-27 | 0.33 / 0.33 | 70 / 70 | 410,321 | 20.14 / 20.14 | 69,266 / 69,266 |

| 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-25 | 0.10 / 0.10 | 78 / 78 | 19,776 | 1.69 / 1.69 | 4,088 / 4,088 |
| MLV-AR-26 | 0.10 / 0.10 | 58 / 78 | 1,263 | 0.05 / 0.12 | 123 / 285 |
| MLV-AR-27 | 0.10 / 0.10 | 73 / 85 | 16,988 | 1.35 / 1.97 | 3,223 / 4,748 |

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-25 FULL DA | Pre | 13.31 | 1.15875 | 50475 | 0 |
| | Post | 13.31 | 1.15875 | 50475 | |
| MLV-AR-25 AR ONLY | Pre | 1.69 | 0.092 | 4008 | 0 |
| | Post | 1.69 | 0.092 | 4008 | |

| | | | | | |
|---|---|---|---|---|---|
| MLV-AR-26 FULL DA | Pre | 0.14 | 0.00875 | 381 | 148 |
| | Post | 0.21 | 0.01214 | 529 | |
| MLV-AR-26 AR ONLY | Pre | 0.05 | 0.00282 | 123 | 162 |
| | Post | 0.12 | 0.00654 | 285 | |

| | | | | | |
|---|---|---|---|---|---|
| MLV-AR-27 FULL DA | Pre | 20.14 | 1.59013 | 69266 | 0 |
| | Post | 20.14 | 1.59013 | 69266 | |
| MLV-AR-27 AR ONLY | Pre | 1.35 | 0.074 | 3223 | 1525 |
| | Post | 1.97 | 0.109 | 4748 | |

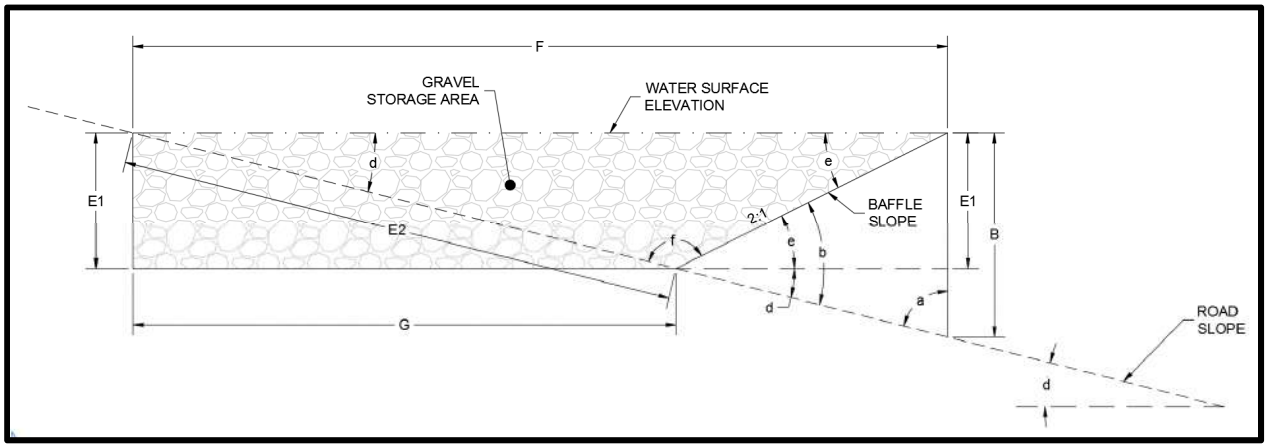
The runoff volume increase when considering only the access road is greater than the resulting runoff volume increase when considering the full drainage area. As a result, the reservoir within the access road is conservatively sized to accommodate the required volume computed using the road footprint 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-25 | 50 | 0.410 | 1 | 50 | 1 |
| | 920 | 0.120 | 1 | 920 | 1 |
| | 683 | 0.057 | 1 | 683 | 1 |
| MVP-MLV-AR-26 | 13 | 0.060 | 1 | 14 | 1 |
| | 8 | 0.240 | 1 | 8 | 1 |
| | 22 | 0.053 | 2 | 11 | 1 |
| | 7 | 0.100 | 1 | 7.5 | 1 |
| MVP-MLV-AR-27 | 17 | 0.180 | 1 | 17 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| | 200 | 0.074 | 5 | 40 | 1 |
| | 121 | 0.026 | 2 | 60 | 1 |
| | 89 | 0.099 | 2 | 44 | 1 |
| | 54 | 0.301 | 1 | 54 | 1 |
| | 253 | 0.367 | 1 | 253 | 1 |
| | 129 | 0.051 | 4 | 32 | 1 |
| | 92 | 0.028 | 2 | 46 | 1 |
| | 127 | 0.202 | 1 | 127 | 1 |
| | 200 | 0.082 | 5 | 40 | 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; $ft^2$

$a = 90 - \tan^{-1}(\text{road slope})$

$b = \tan^{-1}(\text{road slope}) + \tan^{-1}(\text{baffle slope})$

$d = \tan^{-1}(\text{road slope})$

$e = \tan^{-1}(\text{baffle slope})$

$f = 180 - b$

$A = B \times (\sin(a)/\sin(b))$

B = baffle height

$E1 = A \times \sin(e)$

$E2 = A \times (\sin(e)/\sin(d))$

$F = A \times (\sin(f)/\sin(d))$

G = F - E1/baffle slope

2. Determine the storage volume available per earthen baffle.

$$V_{available} = CSA \times W \times n$$

where $V_{available}$ = 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-25 | | |
|---|---|---|
| MUSYM | 14E | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 1.84 | [IN/HR] |
| Max Depth | 0.90 | [FT] |
| Drawdown Time | 12 | [HR] |
| MVP-MLV-AR-26 | | |
| MUSYM | 11B | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 1.28 | [IN/HR] |
| Max Depth | 1.13 | [FT] |
| Drawdown Time | 21 | [HR] |
| MUSYM | 11B | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 1.28 | [IN/HR] |
| Max Depth | 1.13 | [FT] |
| Drawdown Time | 21 | [HR] |
| MUSYM | 11B | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 1.28 | [IN/HR] |
| Max Depth | 1.13 | [FT] |
| Drawdown Time | 21 | [HR] |

| MVP-MLV-AR-27 | | |
|---|---|---|
| MUSYM | 30C | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 2.18 | [IN/HR] |
| Max Depth | 0.95 | [FT] |
| Drawdown Time | 11 | [HR] |
| MUSYM | 8E | [-] |
| HSG | C | [-] |
| $K_{SAT}$ | 0.24 | [IN/HR] |
| Max Depth | 0.95 | [FT] |
| Drawdown Time* | 48 | [HR] |
| MUSYM | 33E | [-] |
| HSG | D | [-] |
| $K_{SAT}$ | 0.7 | [IN/HR] |
| Max Depth | 0.95 | [FT] |
| Drawdown Time | 33 | [HR] |

*Note: 72-hour maximum drawdown time satisfied by reducing safety factor.

ii. New Impervious Cover: Main Line Valve Pads

New impervious cover in Spread 9 also includes four (4) main line valve sites (MVP-MLV-25 through -27 with two pads at MVP-MLV-25). 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 Giles and Montgomery County design storm values of 4.70 and 5.00 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-25 PAD 1 | 0.10 / 0.10 | 55 / 85 | 2,396 | 0.06 / 0.26 | 174 / 610 |
| MLV-25 PAD 2 | 0.10 / 0.10 | 55 / 85 | 218 | 0.00 / 0.00 | 13 / 44 |

| | | | | | |
|---|---|---|---|---|---|
| MLV-26 | 0.10 / 0.10 | 58 / 85 | 2,396 | 0.09 / 0.28 | 218 / 653 |
| MLV-27 | 0.10 / 0.10 | 58 / 85 | 2,396 | 0.09 / 0.28 | 218 / 653 |

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-25 Pad 1 | Vreq | 436 | cf |
| | Area | 2376 | sf |
| | Dreq | 0.46 | ft |
| | | | |
| | Ddesign | 8 | in |
| | Vdesign | 634 | cf |

| | | | |
|---|---|---|---|
| MLV-25 Pad 2 | Vreq | 30 | cf |
| | Area | 225 | sf |
| | Dreq | 0.33 | ft |
| | | | |
| | Ddesign | 8 | in |
| | Vdesign | 60 | cf |

| | | | |
|---|---|---|---|
| MLV-26 Pad | Vreq | 436 | cf |
| | Area | 2376 | sf |
| | Dreq | 0.46 | ft |
| | | | |
| | Ddesign | 8 | in |
| | Vdesign | 634 | cf |

| | | | |
|---|---|---|---|
| MLV-27 Pad | Vreq | 436 | cf |
| | Area | 2376 | sf |
| | Dreq | 0.46 | 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-25 PADS 1 & 2 | | |
|---|---|---|
| MUSYM | 14E | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 1.84 | [IN/HR] |
| Depth | 8 | [IN] |
| Drawdown Time | 9 | [HR] |

| MVP-MLV-26 | | |
|---|---|---|
| MUSYM | 11B | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 1.28 | [IN/HR] |
| Depth | 8 | [IN] |
| Drawdown Time | 13 | [HR] |

| MVP-MLV-27 | | |
|---|---|---|
| MUSYM | 30C | [-] |
| HSG | B | [-] |
| $K_{SAT}$ | 2.18 | [IN/HR] |
| Depth | 8 | [IN] |
| Drawdown Time | 7 | [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.

| | | Culvert Design | | | | | [1]Riprap Apron Outlet Protection Design | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Corresponding Stream | [3]Culvert Diameter, $d_o$ (in) | Culvert Material | [2]Pipe Slope (ft/ft) | Q (cfs) | Design Flow Frequency | $d_{50}$ Riprap Size, $d_{50}$ (in) | AASHTO Riprap Class | Placement Thickness per NSA Riprap Gradation, d (in) | Placement Thickness per AASHTO Riprap Gradation, d (in) | Apron Length, $L_a$ (ft) | Apron Initial Width, $W_i$ (ft) | Apron Terminal Width, W (ft) |
| 33+35.49 | S-MN32 | N/A (Box Culvert: Span=12.0-ft, Rise=8.0-ft) | Concrete | 0.0060 | 524.55 | 10-Yr | N/A - Scour protection needs to withstand tailwater velocity of 7.796 ft/s and shear stress of 2.29 psf. Suggest AASHTO Riprap Class A or equivalent. Note that scour protection should be placed within the channel from top-of-bank to top-of-bank, and extend from the culvert outlet to the limit of disturbance. | | | | | | |
| | | | | | | | | | | | | | |
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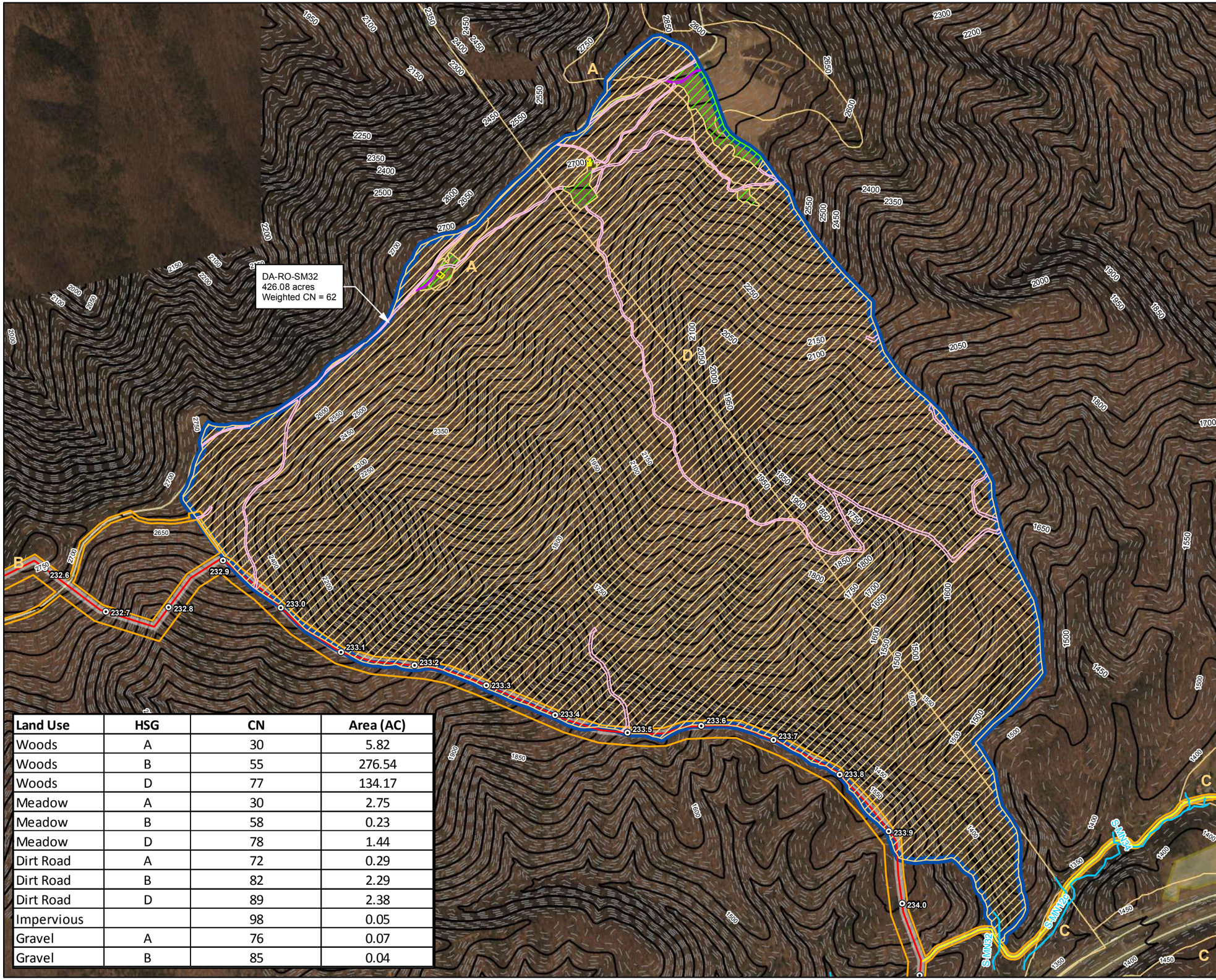
| | | | | | | | | | | | | | |

[1]Designed in accordance with VESCH Std & Spec 3.18 assuming minimum tailwater condition ($T_w < 0.5d_o$).

[2]The slope was calculated from a combination of LIDAR and field notes taken for the stream channel characteristics.

[3]Requires roadway grading (fill of 4.667 feet) to install culvert with minimum recommended cover of 2 inches.




| Land Use | HSG | CN | Area (AC) |
|---|---|---|---|
| Woods | A | 30 | 5.82 |
| Woods | B | 55 | 276.54 |
| Woods | D | 77 | 134.17 |
| Meadow | A | 30 | 2.75 |
| Meadow | B | 58 | 0.23 |
| Meadow | D | 78 | 1.44 |
| Dirt Road | A | 72 | 0.29 |
| Dirt Road | B | 82 | 2.29 |
| Dirt Road | D | 89 | 2.38 |
| Impervious | | 98 | 0.05 |
| Gravel | A | 76 | 0.07 |
| Gravel | B | 85 | 0.04 |

**Legend**

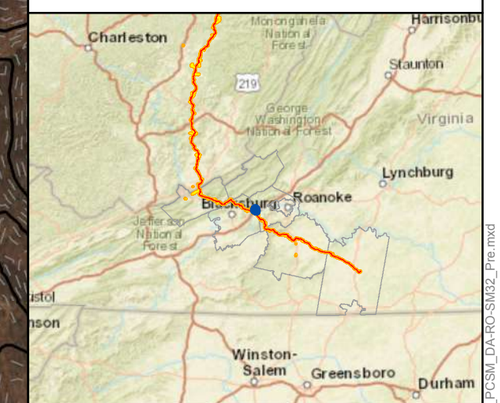
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Gravel
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S




**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

**Pre-Construction Drainage Area Map**
**DA-RO-SM32**
**Spread 9**

Figure 1
*Montgomery and Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

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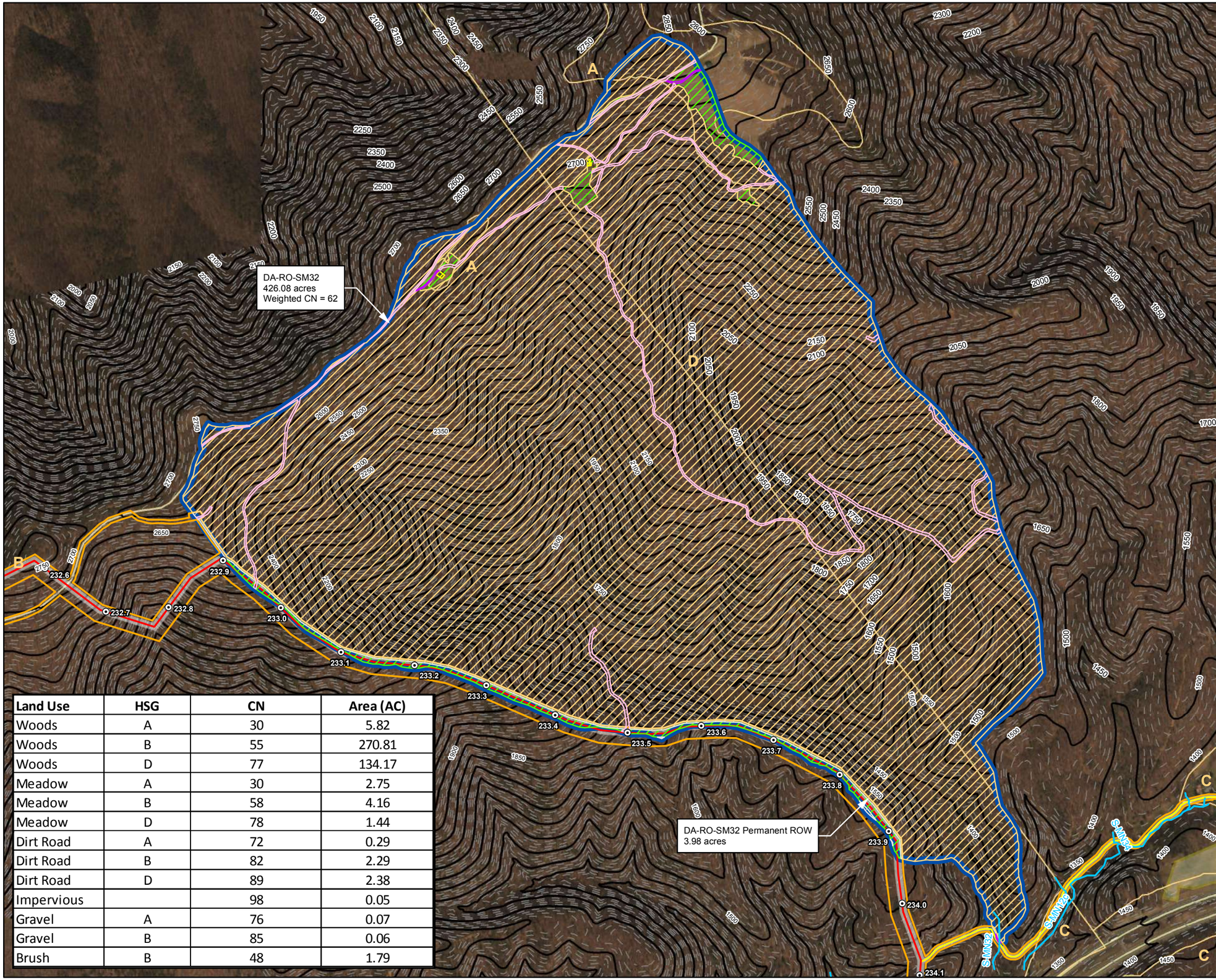



| Land Use | HSG | CN | Area (AC) |
|---|---|---|---|
| Woods | A | 30 | 5.82 |
| Woods | B | 55 | 270.81 |
| Woods | D | 77 | 134.17 |
| Meadow | A | 30 | 2.75 |
| Meadow | B | 58 | 4.16 |
| Meadow | D | 78 | 1.44 |
| Dirt Road | A | 72 | 0.29 |
| Dirt Road | B | 82 | 2.29 |
| Dirt Road | D | 89 | 2.38 |
| Impervious | | 98 | 0.05 |
| Gravel | A | 76 | 0.07 |
| Gravel | B | 85 | 0.06 |
| Brush | B | 48 | 1.79 |

**Legend**

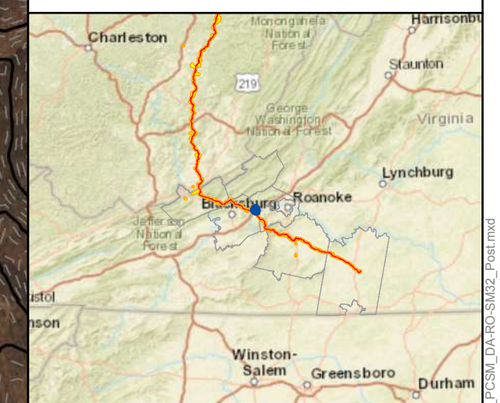
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S




# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Post-Construction Drainage Area Map
## DA-RO-SM32
## Spread 9

Figure 2

*Montgomery and Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

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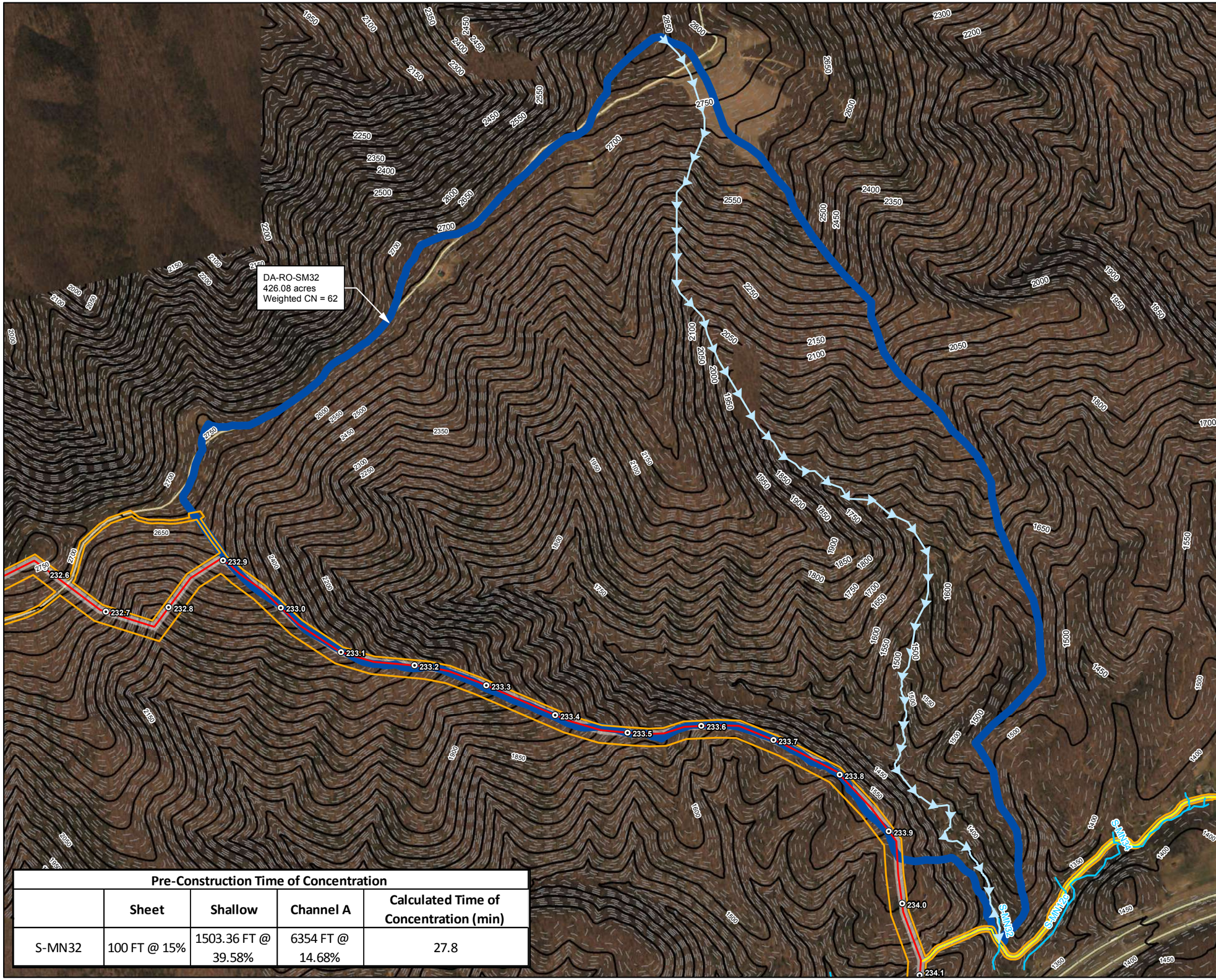



| Pre-Construction Time of Concentration | | | | |
|---|---|---|---|---|
| | Sheet | Shallow | Channel A | Calculated Time of Concentration (min) |
| S-MN32 | 100 FT @ 15% | 1503.36 FT @ 39.58% | 6354 FT @ 14.68% | 27.8 |

**Legend**

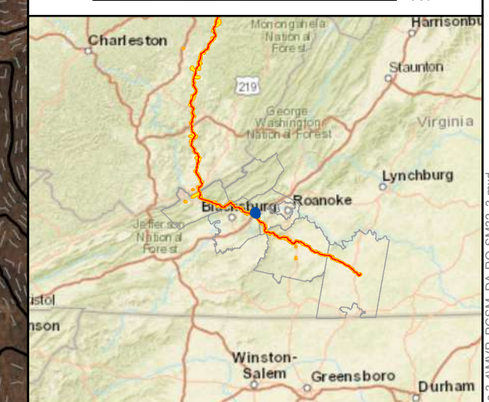
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S




**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

**Pre-Construction Drainage Area and Time of Concentration**
**DA-RO-SM32**
**Spread 9**

Figure 3
*Montgomery and Roanoke County, Virginia*
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM32_3.mxd

**Legend**

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S

**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

**Post-Construction Drainage Area and Time of Concentration**
**DA-RO-SM32**
**Spread 9**

Figure 4
*Montgomery and Roanoke County, Virginia*
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM32_4.mxd

**Post-Construction Time of Concentration**

| | Sheet | Shallow | Channel A | Calculated Time of Concentration (min) |
|---|---|---|---|---|
| S-MN32 | 100 FT @ 15% | 1503.36 FT @ 39.58% | 6354 FT @ 14.68% | 27.8 |

**COMPOSITE CURVE NUMBER COMPUTATION SHEET**

| S-MN32 Pre-Construction | | | | |
|---|---|---|---|---|
| **LAND USE** | **HSG** | **CN** | **AREA (AC)** | **Area Weighted CN** |
| Woods | A | 30 | 5.822 | 0.41 |
| Woods | B | 55 | 276.54 | 35.70 |
| Woods | D | 77 | 134.17 | 24.25 |
| Meadow | A | 30 | 2.749 | 0.19 |
| Meadow | B | 58 | 0.229 | 0.03 |
| Meadow | D | 78 | 1.436 | 0.26 |
| Dirt Road | A | 72 | 0.294 | 0.05 |
| Dirt Road | B | 82 | 2.293 | 0.44 |
| Dirt Road | D | 89 | 2.376 | 0.50 |
| Impervious | N/A | 98 | 0.053 | 0.01 |
| Gravel | A | 76 | 0.074 | 0.01 |
| Gravel | B | 85 | 0.043 | 0.01 |
| | | | 426.08 | 62 |

**= Composite CN**

**COMPOSITE CURVE NUMBER COMPUTATION SHEET**

| S-MN32 Post-Construction | | | | |
|---|---|---|---|---|
| **LAND USE** | **HSG** | **CN** | **AREA (AC)** | **Area Weighted CN** |
| Woods | A | 30 | 5.822 | 0.41 |
| Woods | B | 55 | 270.81 | 34.96 |
| Woods | D | 77 | 134.17 | 24.25 |
| Meadow | A | 30 | 2.749 | 0.19 |
| Meadow | B | 58 | 4.163 | 0.57 |
| Meadow | D | 78 | 1.436 | 0.26 |
| Dirt Road | A | 72 | 0.294 | 0.05 |
| Dirt Road | B | 82 | 2.293 | 0.44 |
| Dirt Road | D | 89 | 2.376 | 0.50 |
| Impervious | N/A | 98 | 0.053 | 0.01 |
| Gravel | A | 76 | 0.074 | 0.01 |
| Gravel | B | 85 | 0.056 | 0.01 |
| Brush | B | 48 | 1.790 | 0.20 |
| | | | 426.08 | 62 |

**= Composite CN**

***Table 1 – Manning's n Values for Sheet Flow***

| **Land Surface Type** | **Manning n** |
|---|---|
| **Grass:** | |
| Average Grass Cover | 0.40 |
| Poor Grass Cover, Moderately Rough Surface | 0.30 – 0.40 |
| Light Turf | 0.20 |
| Dense Turf | 0.17 – 0.80 |
| Dense Grass | 0.17 – 0.30 |
| Bermuda Grass | 0.30 – 0.48 |
| Dense Shrubbery and Forest Litter | 0.40 |
| **Natural:** | |
| Short Grass Prairie | 0.10 – 0.20 |
| Poor Grass Cover, Moderately Rough Surface | 0.30 – 0.40 |
| Sparse Vegetation | 0.05 – 0.13 |
| Oak Grasslands, Open Grasslands | 0.60 |
| Dense Cover of Trees and Bushes | 0.80 |
| Rangeland: | |
| Typical | 0.13 |
| No Debris Cover | 0.09 – 0.34 |
| 20% Debris Cover | 0.05 – 0.25 |
| Woods: | |
| Light Underbrush | 0.40 |
| Dense Underbrush | 0.80 |
| Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed) | 0.40 |

*Note:*

*Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.*

*Sources:*

*-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA*

*-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC*

## *Table 2 – Manning's n Values for Open Channel Flow*

| Channel Type | Manning n | | |
|---|---|---|---|
| | Min. | Normal | Max. |
| **1. Excavated or Dredged Channels[1]** | | | |
| ***a. Earth, Straight, and Uniform:*** | | | |
| Clean, recently completed | 0.016 | 0.018 | 0.020 |
| Clean, after weathering | 0.018 | 0.022 | 0.025 |
| Gravel, uniform section, clean | 0.022 | 0.025 | 0.030 |
| With short grass, few weeds | 0.022 | 0.027 | 0.033 |
| ***b. Earth Winding and Sluggish:*** | | | |
| No vegetation | 0.023 | 0.025 | 0.030 |
| Grass, some weeds | 0.025 | 0.030 | 0.033 |
| Dense weeds or aquatic plants in deep channels | 0.030 | 0.035 | 0.040 |
| Earth bottom and rubble sides | 0.028 | 0.030 | 0.035 |
| Stony bottom and weedy banks | 0.025 | 0.035 | 0.040 |
| Cobble bottom and clean sides | 0.030 | 0.040 | 0.050 |
| ***c. Dragline-Excavated or Dredged:*** | | | |
| No vegetation | 0.025 | 0.028 | 0.033 |
| Light brush on banks | 0.035 | 0.050 | 0.060 |
| ***d. Rock Cuts:*** | | | |
| Smooth and uniform | 0.025 | 0.035 | 0.040 |
| Jagged and irregular | 0.035 | 0.040 | 0.050 |
| ***e. Channels not Maintained, Weeds and Brush Uncut:*** | | | |
| Dense weeds, high as flow depth | 0.050 | 0.080 | 0.120 |
| Clean bottom, brush on sides | 0.040 | 0.050 | 0.080 |
| Same as above, highest stage of flow | 0.045 | 0.070 | 0.110 |
| Dense brush, high stage | 0.080 | 0.100 | 0.140 |
| **2. Main Channels[2]** | | | |
| a. Clean, straight, full stage, no rifts or deep pools | 0.025 | 0.030 | 0.033 |
| b. Same as above, but more stones and weeds | 0.030 | 0.035 | 0.040 |
| c. Clean, winding, some pools and shoals | 0.033 | 0.040 | 0.045 |
| d. Same as above, but some weeds and stones | 0.035 | 0.045 | 0.050 |
| e. Same as above, lower stages, more ineffective | 0.040 | 0.048 | 0.055 |
| f. Same as (d) with more stones | 0.045 | 0.050 | 0.060 |
| g. Sluggish reaches, weedy, deep pools | 0.050 | 0.070 | 0.080 |
| h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush | 0.075 | 0.100 | 0.150 |

*Notes:*

*[1]A Manning's n value of 0.040 was used in Hydraflow Hydrographs for roadside channels.*

*[2]A Manning's n value of 0.030 was used in Hydraflow Hydrographs for existing/natural channels.*

*Sources:*

*-ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY*

*-Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY*

# Hydraflow Table of Contents

Culvert S-MN32.gpw

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

Wednesday, 09 / 20 / 2017


**Watershed Model Schematic..... 1**

**Hydrograph Return Period Recap..... 2**

**1 - Year**

**Summary Report..... 3**
**Hydrograph Reports..... 4**
Hydrograph No. 1, SCS Runoff, Culvt S-MN32 Pre-..... 4
TR-55 Tc Worksheet..... 5
Hydrograph No. 2, SCS Runoff, Culvt S-MN32 Post-..... 6
TR-55 Tc Worksheet..... 7
Hydrograph No. 3, SCS Runoff, Culvt S-MN32 Preforested-..... 8
TR-55 Tc Worksheet..... 9

**10 - Year**

**Summary Report..... 10**
**Hydrograph Reports..... 11**
Hydrograph No. 1, SCS Runoff, Culvt S-MN32 Pre-..... 11
Hydrograph No. 2, SCS Runoff, Culvt S-MN32 Post-..... 12
Hydrograph No. 3, SCS Runoff, Culvt S-MN32 Preforested-..... 13

**IDF Report..... 14**

# Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

**Legend**

| Hyd. | Origin | Description |
|---|---|---|
| 1 | SCS Runoff | Culvt S-MN32 Pre- |
| 2 | SCS Runoff | Culvt S-MN32 Post- |
| 3 | SCS Runoff | Culvt S-MN32 Preforested- |

# Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Inflow hyd(s) | Peak Outflow (cfs) | | | | | | | | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1-yr | 2-yr | 3-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr | |
| 1 | SCS Runoff | ------ | 37.41 | ------- | ------- | ------- | 524.55 | ------- | ------- | ------- | Culvt S-MN32 Pre- |
| 2 | SCS Runoff | ------ | 37.41 | ------- | ------- | ------- | 524.55 | ------- | ------- | ------- | Culvt S-MN32 Post- |
| 3 | SCS Runoff | ------ | 37.41 | ------- | ------- | ------- | 524.55 | ------- | ------- | ------- | Culvt S-MN32 Preforested- |

# Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Peak flow (cfs) | Time interval (min) | Time to Peak (min) | Hyd. volume (cuft) | Inflow hyd(s) | Maximum elevation (ft) | Total strge used (cuft) | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SCS Runoff | 37.41 | 1 | 736 | 336,699 | ------ | ------ | ------ | Culvt S-MN32 Pre- |
| 2 | SCS Runoff | 37.41 | 1 | 736 | 336,699 | ------ | ------ | ------ | Culvt S-MN32 Post- |
| 3 | SCS Runoff | 37.41 | 1 | 736 | 336,699 | ------ | ------ | ------ | Culvt S-MN32 Preforested- |

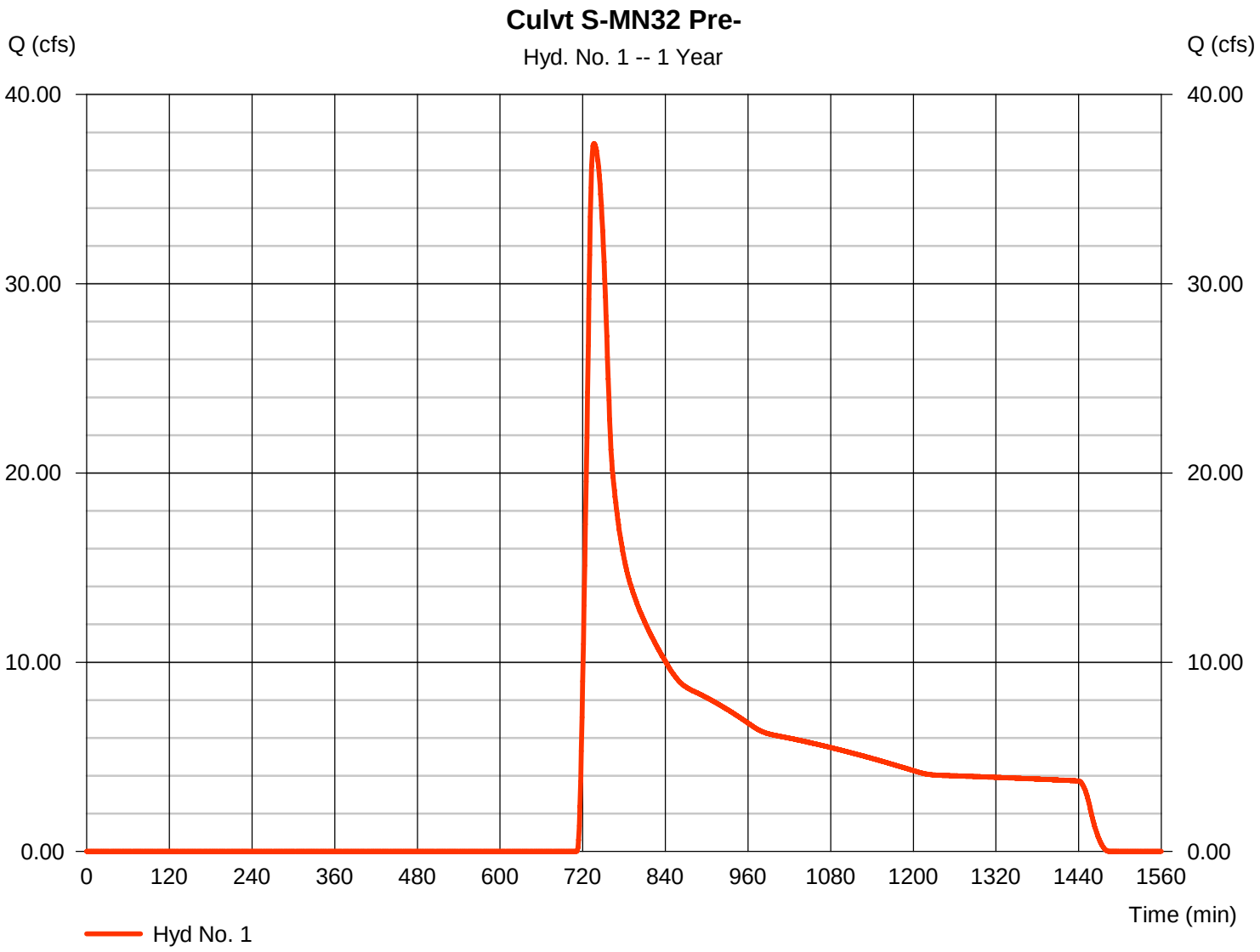
# Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 1

Culvt S-MN32 Pre-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 37.41 cfs |
| Storm frequency | = 1 yrs | Time to peak | = 736 min |
| Time interval | = 1 min | Hyd. volume | = 336,699 cuft |
| Drainage area | = 426.080 ac | Curve number | = 62 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 27.80 min |
| Total precip. | = 2.50 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |



# TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

## Hyd. No. 1

Culvt S-MN32 Pre-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.00 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 15.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 17.25** | **+** | **0.00** | **+** | **0.00** | **=** | **17.25** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 1503.36 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 39.58 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =10.15 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 2.47** | **+** | **0.00** | **+** | **0.00** | **=** | **2.47** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 5.33 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 9.33 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 14.68 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =13.08 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})6354.0 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 8.10** | **+** | **0.00** | **+** | **0.00** | **=** | **8.10** |

**Total Travel Time, Tc ..... 27.80 min**

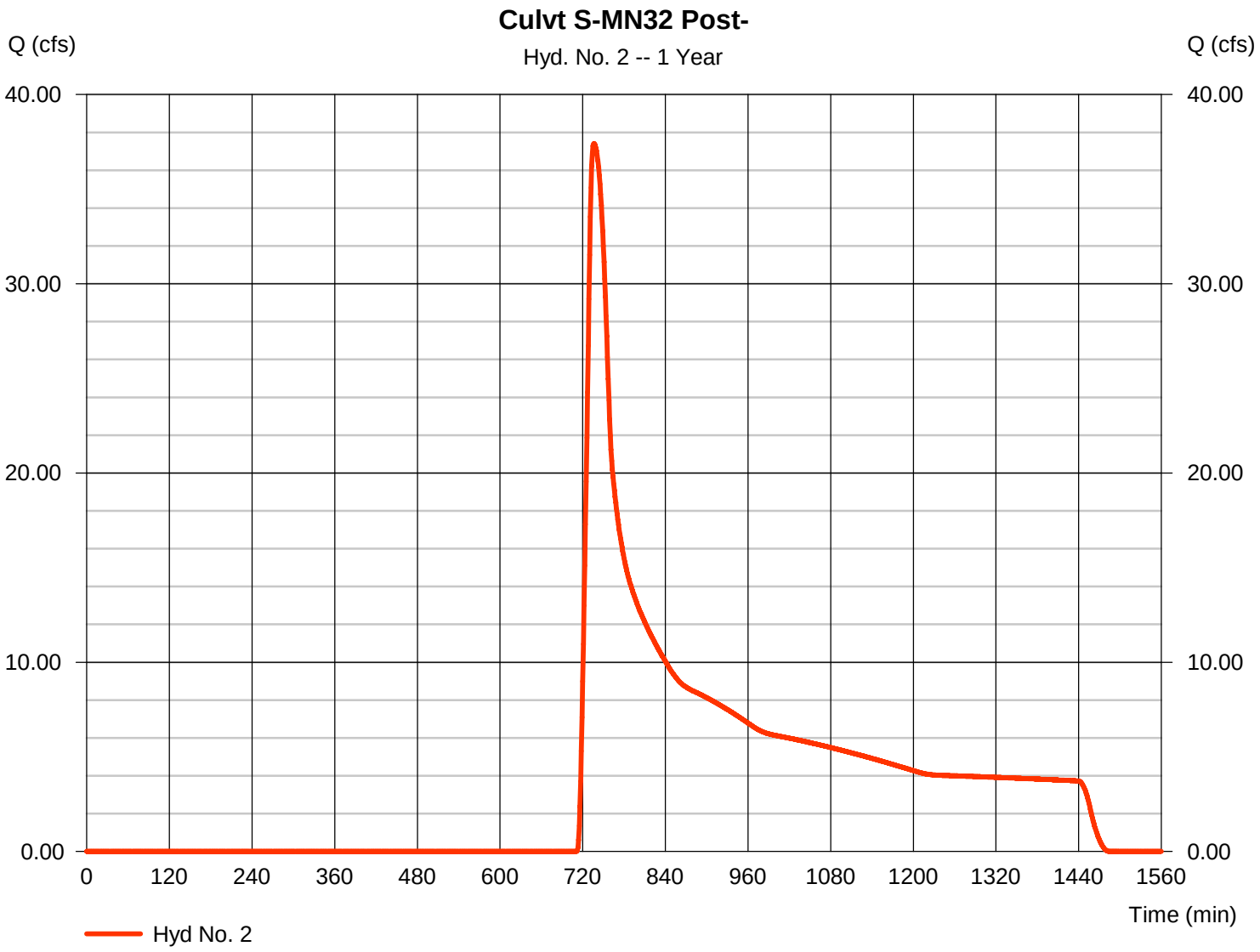
# Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 2

Culvt S-MN32 Post-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 37.41 cfs |
| Storm frequency | = 1 yrs | Time to peak | = 736 min |
| Time interval | = 1 min | Hyd. volume | = 336,699 cuft |
| Drainage area | = 426.080 ac | Curve number | = 62 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 27.80 min |
| Total precip. | = 2.50 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |



# TR55 Tc Worksheet



## Hyd. No. 2

Culvt S-MN32 Post-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.00 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 15.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 17.25** | **+** | **0.00** | **+** | **0.00** | **=** | **17.25** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 1503.36 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 39.58 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =10.15 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 2.47** | **+** | **0.00** | **+** | **0.00** | **=** | **2.47** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 5.33 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 9.33 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 14.68 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =13.08 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})6354.0 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 8.10** | **+** | **0.00** | **+** | **0.00** | **=** | **8.10** |

**Total Travel Time, Tc ..... 27.80 min**

# Hydrograph Report

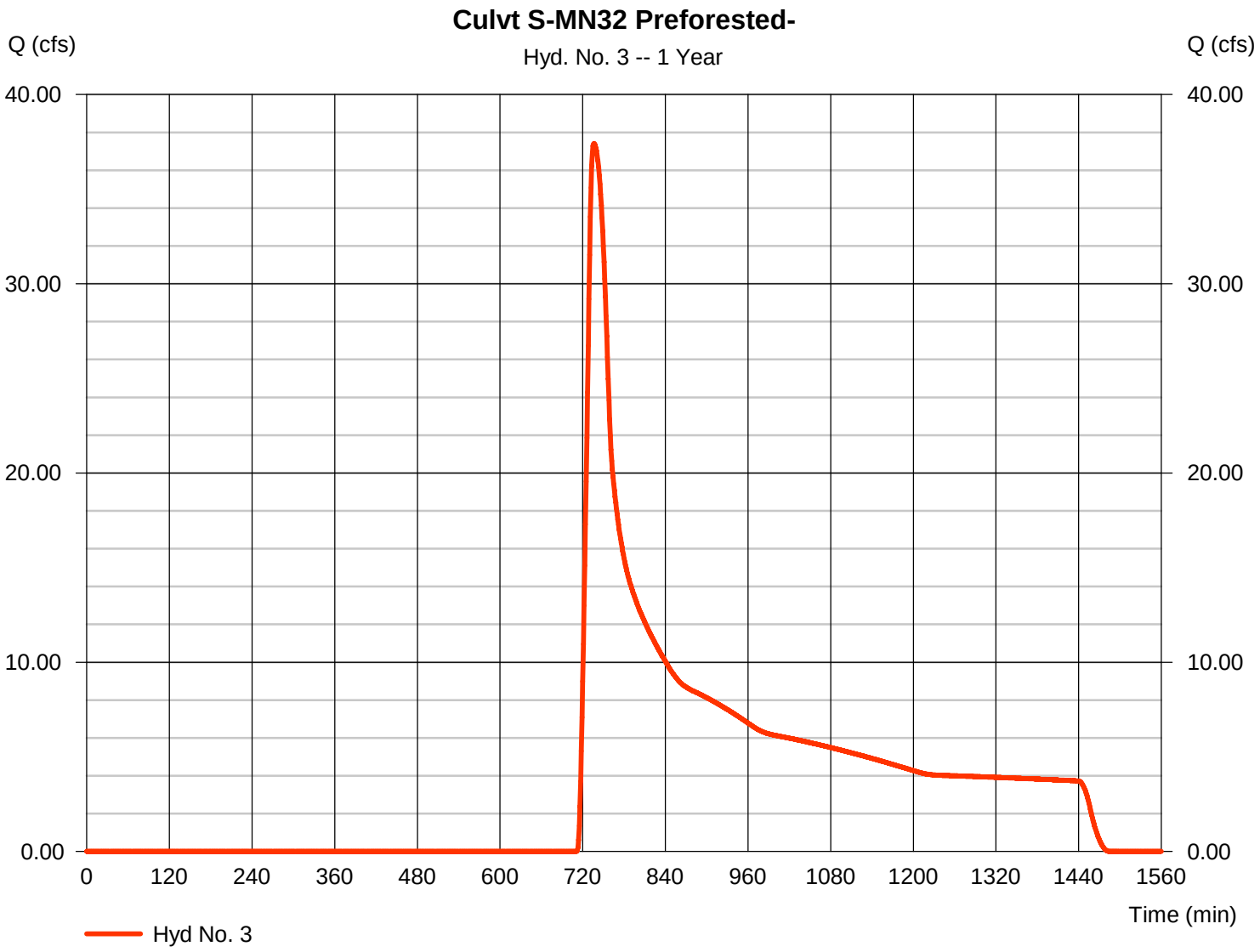
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 3

Culvt S-MN32 Preforested-

| | | | | | |
|---|---|---|---|---|---|
| Hydrograph type | = | SCS Runoff | Peak discharge | = | 37.41 cfs |
| Storm frequency | = | 1 yrs | Time to peak | = | 736 min |
| Time interval | = | 1 min | Hyd. volume | = | 336,699 cuft |
| Drainage area | = | 426.080 ac | Curve number | = | 62* |
| Basin Slope | = | 0.0 % | Hydraulic length | = | 0 ft |
| Tc method | = | TR55 | Time of conc. (Tc) | = | 27.80 min |
| Total precip. | = | 2.50 in | Distribution | = | Type II |
| Storm duration | = | 24 hrs | Shape factor | = | 484 |

* Composite (Area/CN) = [(8.980 x 30) + (279.110 x 55) + (137.990 x 77)] / 426.080



# TR55 Tc Worksheet



## Hyd. No. 3

Culvt S-MN32 Preforested-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.00 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 15.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 17.25** | **+** | **0.00** | **+** | **0.00** | **=** | **17.25** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 1503.36 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 39.58 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =10.15 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 2.47** | **+** | **0.00** | **+** | **0.00** | **=** | **2.47** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 5.33 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 9.33 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 14.68 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =13.08 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})6354.0 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 8.10** | **+** | **0.00** | **+** | **0.00** | **=** | **8.10** |

**Total Travel Time, Tc ..... 27.80 min**

# Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Peak flow (cfs) | Time interval (min) | Time to Peak (min) | Hyd. volume (cuft) | Inflow hyd(s) | Maximum elevation (ft) | Total strge used (cuft) | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SCS Runoff | 524.55 | 1 | 731 | 2,208,332 | ------ | ------ | ------ | Culvt S-MN32 Pre- |
| 2 | SCS Runoff | 524.55 | 1 | 731 | 2,208,332 | ------ | ------ | ------ | Culvt S-MN32 Post- |
| 3 | SCS Runoff | 524.55 | 1 | 731 | 2,208,332 | ------ | ------ | ------ | Culvt S-MN32 Preforested- |

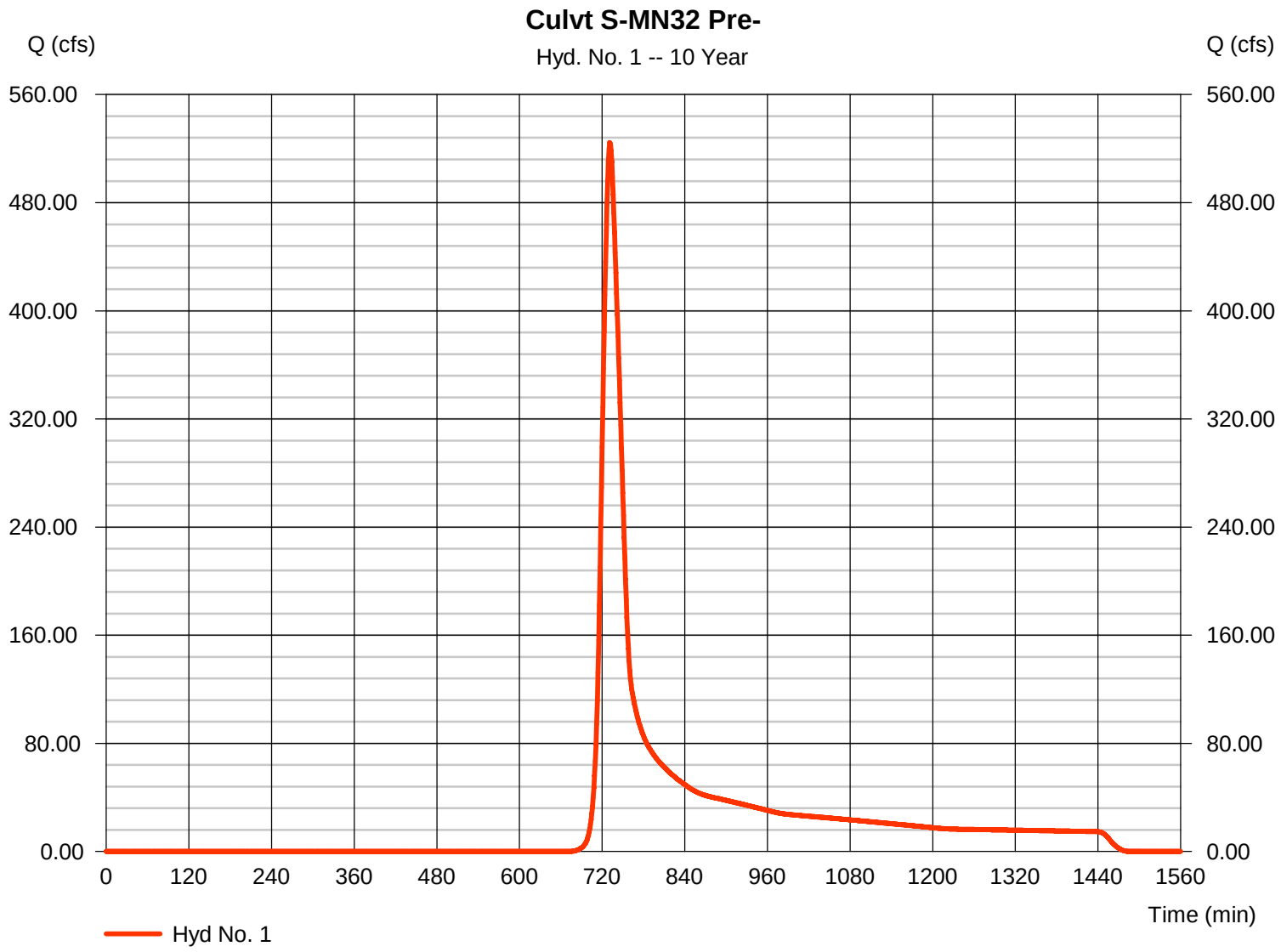
# Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 1

Culvt S-MN32 Pre-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 524.55 cfs |
| Storm frequency | = 10 yrs | Time to peak | = 731 min |
| Time interval | = 1 min | Hyd. volume | = 2,208,332 cuft |
| Drainage area | = 426.080 ac | Curve number | = 62 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 27.80 min |
| Total precip. | = 5.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |



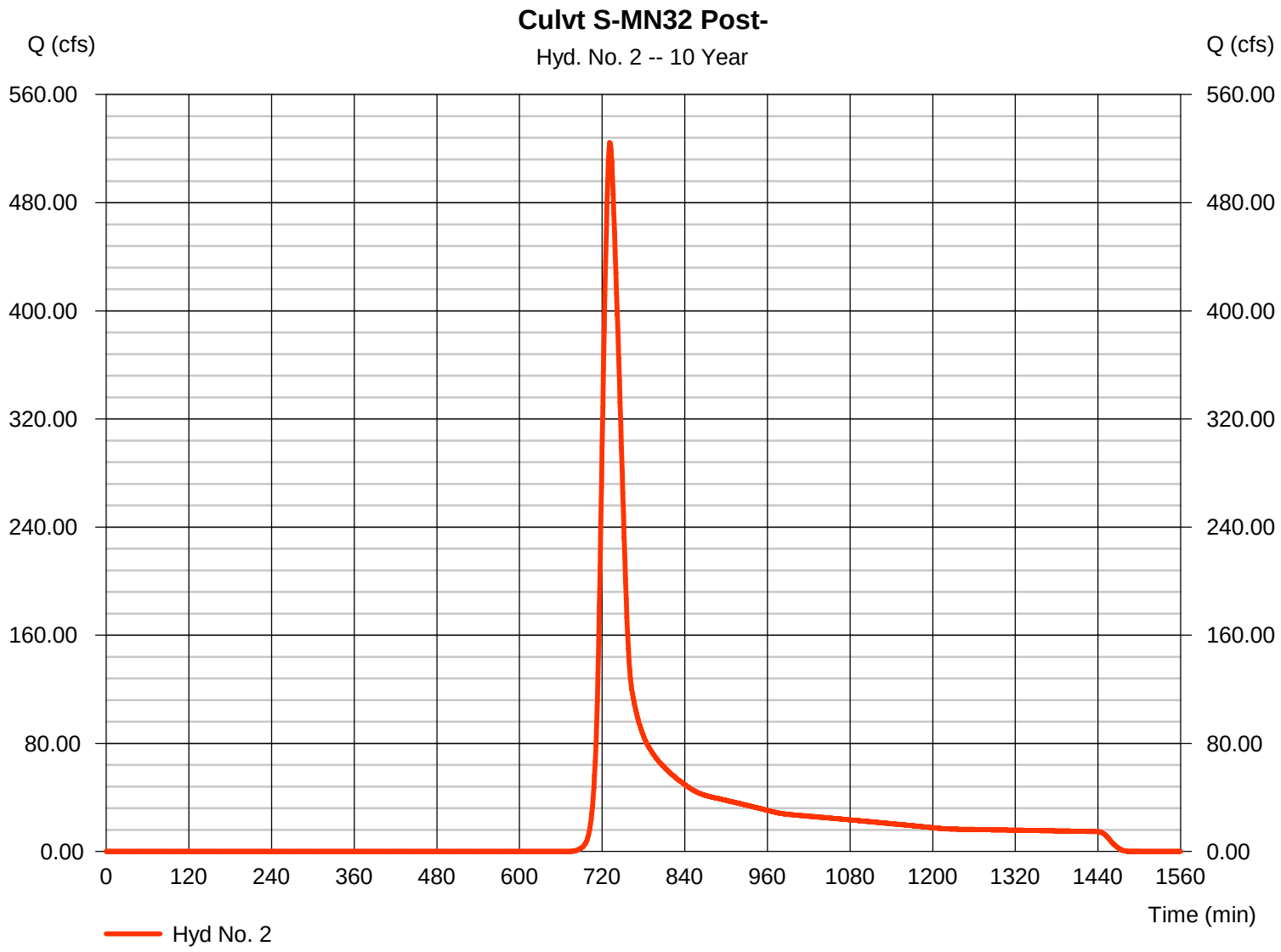
# Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 2

Culvt S-MN32 Post-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 524.55 cfs |
| Storm frequency | = 10 yrs | Time to peak | = 731 min |
| Time interval | = 1 min | Hyd. volume | = 2,208,332 cuft |
| Drainage area | = 426.080 ac | Curve number | = 62 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 27.80 min |
| Total precip. | = 5.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |



# Hydrograph Report

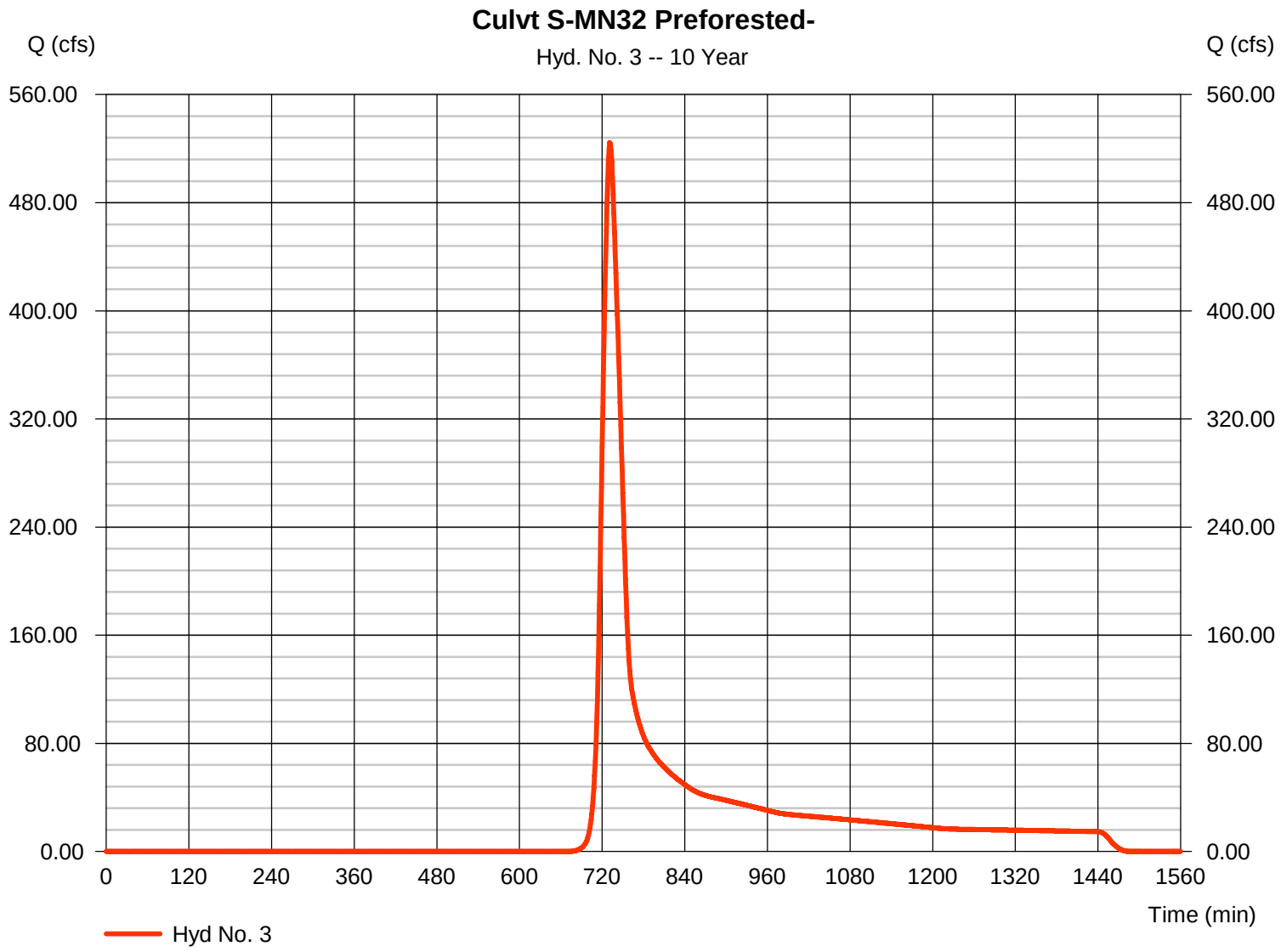
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 3

Culvt S-MN32 Preforested-

| | | | | | |
|---|---|---|---|---|---|
| Hydrograph type | = | SCS Runoff | Peak discharge | = | 524.55 cfs |
| Storm frequency | = | 10 yrs | Time to peak | = | 731 min |
| Time interval | = | 1 min | Hyd. volume | = | 2,208,332 cuft |
| Drainage area | = | 426.080 ac | Curve number | = | 62* |
| Basin Slope | = | 0.0 % | Hydraulic length | = | 0 ft |
| Tc method | = | TR55 | Time of conc. (Tc) | = | 27.80 min |
| Total precip. | = | 5.00 in | Distribution | = | Type II |
| Storm duration | = | 24 hrs | Shape factor | = | 484 |

* Composite (Area/CN) = [(8.980 x 30) + (279.110 x 55) + (137.990 x 77)] / 426.080



# Hydraflow Rainfall Report



| Return Period (Yrs) | Intensity-Duration-Frequency Equation Coefficients (FHA) | | | |
|---|---|---|---|---|
| | B | D | E | (N/A) |
| 1 | 0.0000 | 0.0000 | 0.0000 | -------- |
| 2 | 69.8703 | 13.1000 | 0.8658 | -------- |
| 3 | 0.0000 | 0.0000 | 0.0000 | -------- |
| 5 | 79.2597 | 14.6000 | 0.8369 | -------- |
| 10 | 88.2351 | 15.5000 | 0.8279 | -------- |
| 25 | 102.6072 | 16.5000 | 0.8217 | -------- |
| 50 | 114.8193 | 17.2000 | 0.8199 | -------- |
| 100 | 127.1596 | 17.8000 | 0.8186 | -------- |

File name: SampleFHA.idf

### Intensity = B / (Tc + D)^E

| Return Period (Yrs) | Intensity Values (in/hr) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 min | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.69 | 4.61 | 3.89 | 3.38 | 2.99 | 2.69 | 2.44 | 2.24 | 2.07 | 1.93 | 1.81 | 1.70 |
| 3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 6.57 | 5.43 | 4.65 | 4.08 | 3.65 | 3.30 | 3.02 | 2.79 | 2.59 | 2.42 | 2.27 | 2.15 |
| 10 | 7.24 | 6.04 | 5.21 | 4.59 | 4.12 | 3.74 | 3.43 | 3.17 | 2.95 | 2.77 | 2.60 | 2.46 |
| 25 | 8.25 | 6.95 | 6.03 | 5.34 | 4.80 | 4.38 | 4.02 | 3.73 | 3.48 | 3.26 | 3.07 | 2.91 |
| 50 | 9.04 | 7.65 | 6.66 | 5.92 | 5.34 | 4.87 | 4.49 | 4.16 | 3.88 | 3.65 | 3.44 | 3.25 |
| 100 | 9.83 | 8.36 | 7.30 | 6.50 | 5.87 | 5.36 | 4.94 | 4.59 | 4.29 | 4.03 | 3.80 | 3.60 |

Tc = time in minutes. Values may exceed 60.

rk Sladic\EQT\Project\112IC07157 MVP\Virginia Stormwater\Culvert Design - Other\Culvert S-MN32\Montgomery.pcp

| Storm Distribution | Rainfall Precipitation Table (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-yr | 2-yr | 3-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| SCS 24-hour | 2.50 | 0.00 | 0.00 | 0.00 | 5.00 | 5.50 | 0.00 | 0.00 |
| SCS 6-Hr | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-1st | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-2nd | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-3rd | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-4th | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-Indy | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Custom | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**ENERGY BALANCE METHOD**

**Inputs:**

| | 1-Yr Event | |
|---|---|---|
| | Peak Flow, Q (cfs) | Runoff Volume, RV (cf) |
| Pre-Developed Condition | 37.410 | 336,699 |
| Developed Condition | 37.410 | 336,699 |
| Pre-Developed (Forest) Condition | 37.410 | 336,699 |

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

**Calculations:**

| | | | | |
|---|---|---|---|---|
| [1] ***Check #1:*** | $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> | 37.410 | ≤ OK | 37.410 |
| ***Check #2:*** | $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> | 37.410 | ≤ OK | 37.410 |
| ***Check #3:*** | $Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> | 37.410 | *shall not* be required to be ≤ | 37.410 |

## STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

[1] Per VADEQ, the improvement factor can be waived if the road is being maintained within the current footprint.

# HY-8 Culvert Analysis Report

## Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 524.55 cfs

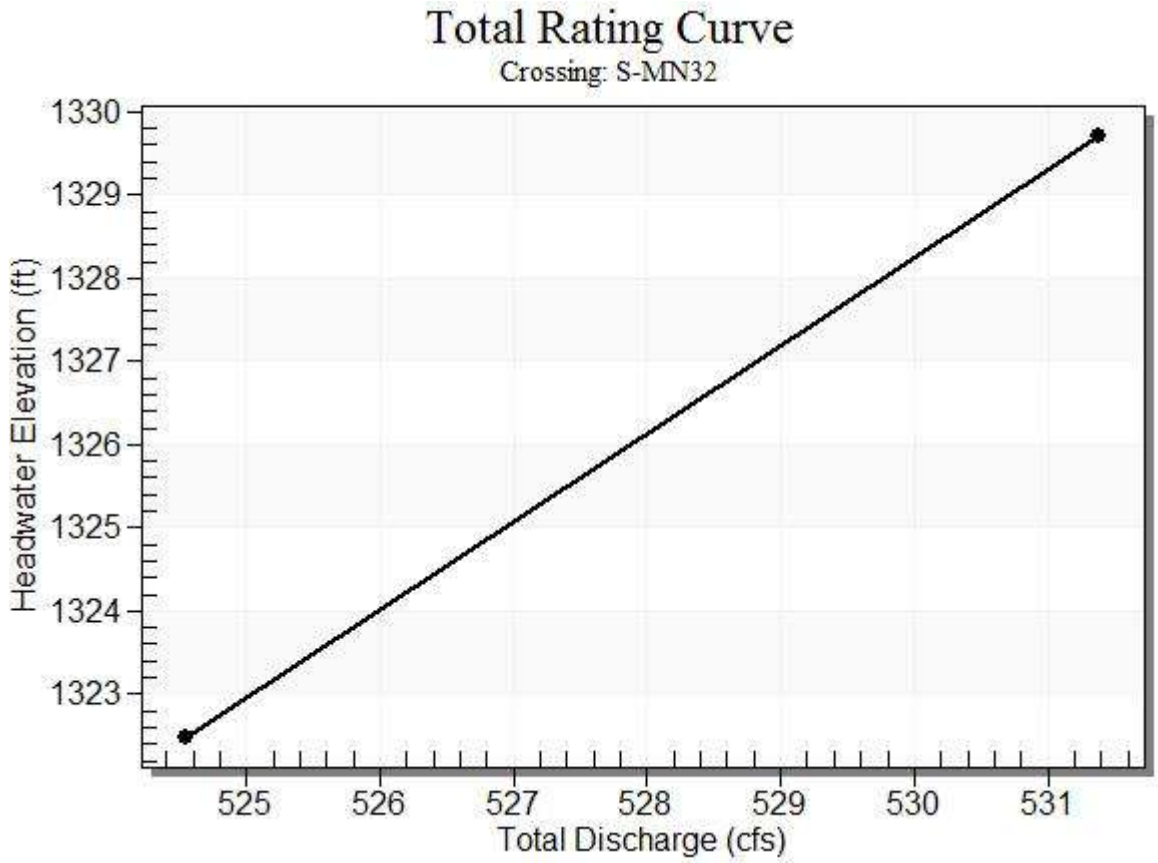
Design Flow: 524.55 cfs

Maximum Flow: 524.55 cfs

## Table 1 - Summary of Culvert Flows at Crossing: S-MN32

| Headwater Elevation (ft) | Total Discharge (cfs) | Culvert S-MN32 Discharge (cfs) | Roadway Discharge (cfs) | Iterations |
|---|---|---|---|---|
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.49 | 524.55 | 524.55 | 0.00 | 1 |
| 1322.56 | 531.38 | 531.38 | 0.00 | Overtopping |

**Rating Curve Plot for Crossing: S-MN32**



## Table 2 - Culvert Summary Table: Culvert S-MN32

| Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |
| 524.55 | 524.55 | 1322.49 | 6.460 | 7.596 | 7-M1t | 4.146 | 3.895 | 6.117 | 6.117 | 7.146 | 7.796 |

**********

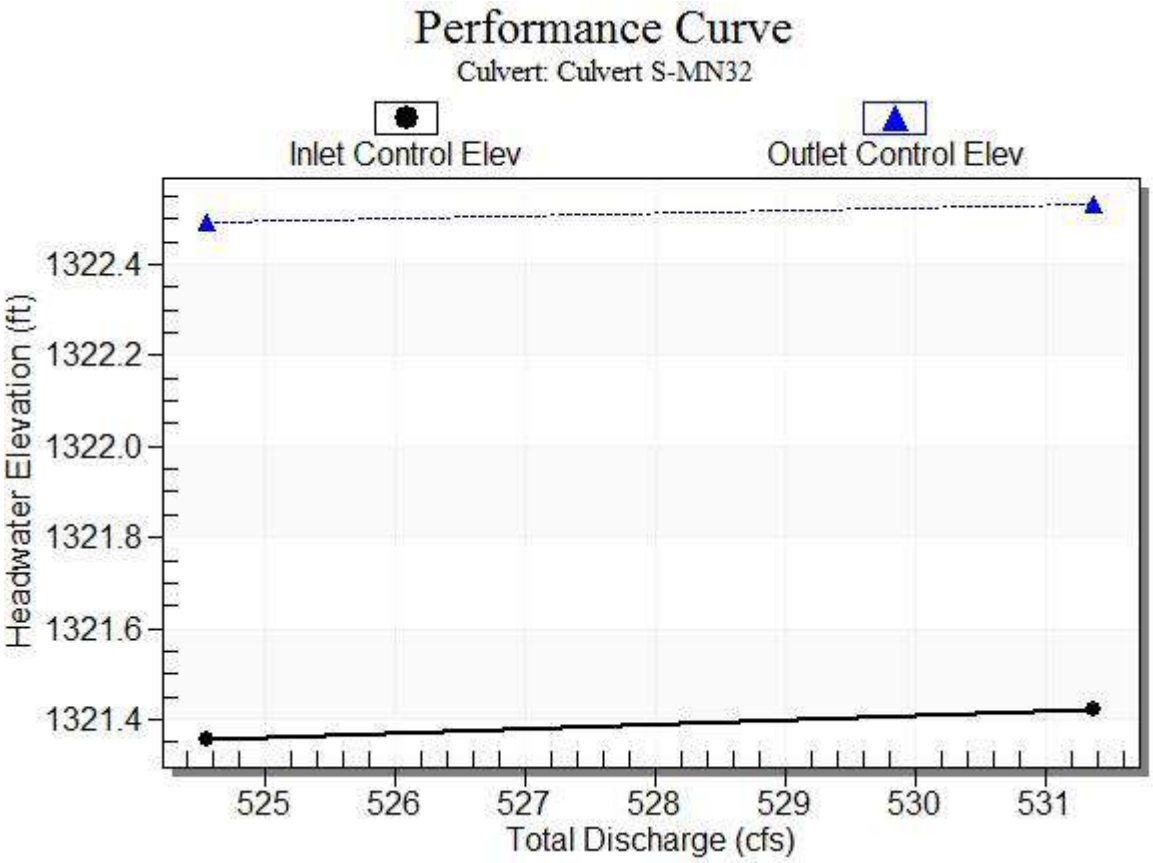
Straight Culvert

Inlet Elevation (invert): 1314.90 ft, Outlet Elevation (invert): 1314.83 ft

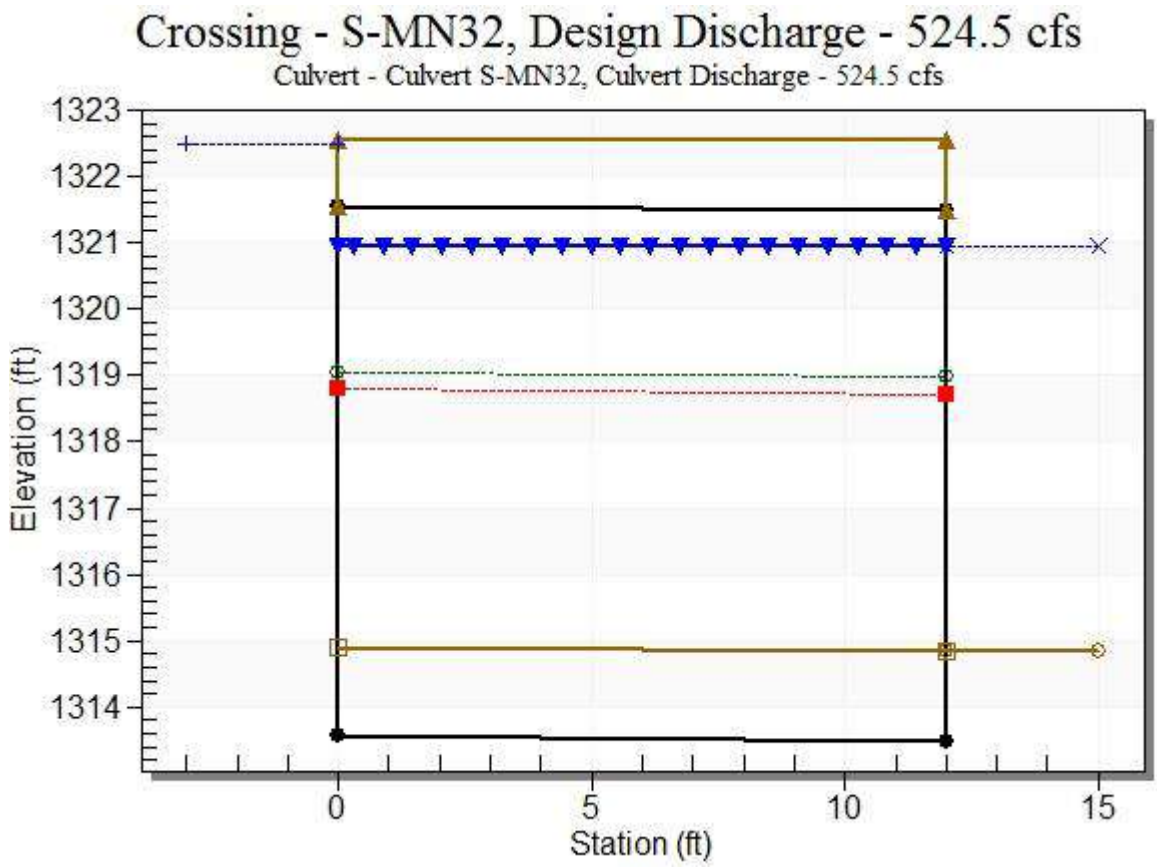
Culvert Length: 12.00 ft, Culvert Slope: 0.0057

**********

**Culvert Performance Curve Plot: Culvert S-MN32**



**Water Surface Profile Plot for Culvert: Culvert S-MN32**




**Site Data - Culvert S-MN32**

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1313.56 ft

Outlet Station: 12.00 ft

Outlet Elevation: 1313.49 ft

Number of Barrels: 1

**Culvert Data Summary - Culvert S-MN32**

Barrel Shape: Concrete Box

Barrel Span: 12.00 ft

Barrel Rise: 8.00 ft

Barrel Material: Concrete

Embedment: 16.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: NONE

## Table 3 - Downstream Channel Rating Curve (Crossing: S-MN32)

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) | Velocity (ft/s) | Shear (psf) | Froude Number |
|---|---|---|---|---|---|
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |
| 524.55 | 1320.94 | 6.12 | 7.80 | 2.29 | 0.56 |

## Tailwater Channel Data - S-MN32

Tailwater Channel Option: Rectangular Channel

Bottom Width: 11.00 ft

Channel Slope: 0.0060

Channel Manning's n: 0.0300

Channel Invert Elevation: 1314.83 ft

## Roadway Data for Crossing: S-MN32

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 1322.56 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft

| | | Culvert Design | | | | | [1]Riprap Apron Outlet Protection Design | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Corresponding Stream | [3]Culvert Diameter, $d_o$ (in) | Culvert Material | [2]Pipe Slope (ft/ft) | Q (cfs) | Design Flow Frequency | $d_{50}$ Riprap Size, $d_{50}$ (in) | AASHTO Riprap Class | Placement Thickness per NSA Riprap Gradation, d (in) | Placement Thickness per AASHTO Riprap Gradation, d (in) | Apron Length, $L_a$ (ft) | Apron Initial Width, $W_i$ (ft) | Apron Terminal Width, W (ft) |
| 25 + 83.30 | S-MN33 | N/A (Box Culvert: Span=4.0-ft, Rise=3.0-ft) | Concrete | 0.0215 | 40.40 | 10-Yr | N/A - Scour protection needs to withstand tailwater velocity of 6.60 ft/s and shear stress of 2.05 psf. Suggest AASHTO Riprap Class A or equivalent. Note that scour protection should be placed within the channel from top-of-bank to top-of-bank, and extend from the culvert outlet to the limit of disturbance. | | | | | | |
| | | | | | | | | | | | | | |
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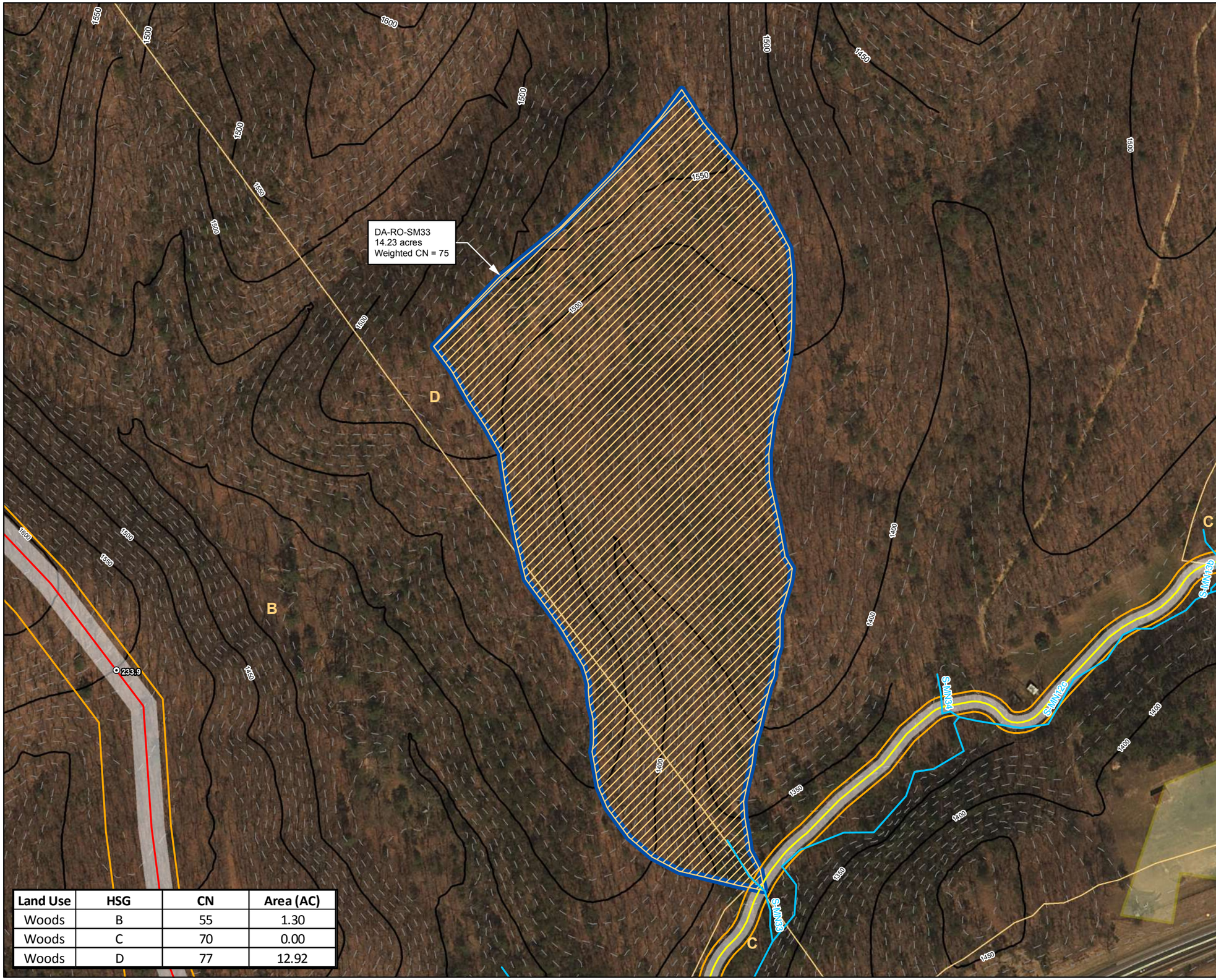
| | | | | | | | | | | | | | |

[1]Designed in accordance with VESCH Std & Spec 3.18 assuming minimum tailwater condition ($T_w < 0.5d_o$).

[2]The slope was calculated from a combination of LIDAR and field notes taken for the stream channel characteristics.

[3]Requires roadway grading (fill of 0.750 feet) to install culvert with minimum recommended cover of 2 inches.




| Land Use | HSG | CN | Area (AC) |
|---|---|---|---|
| Woods | B | 55 | 1.30 |
| Woods | C | 70 | 0.00 |
| Woods | D | 77 | 12.92 |

**Legend**

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

N W E S

## Mountain Valley Pipeline Project

Mountain Valley PIPELINE

**Pre-Construction Drainage Area Map**
**DA-RO-SM33**
**Spread 9**

Figure 1
*Montgomery and Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

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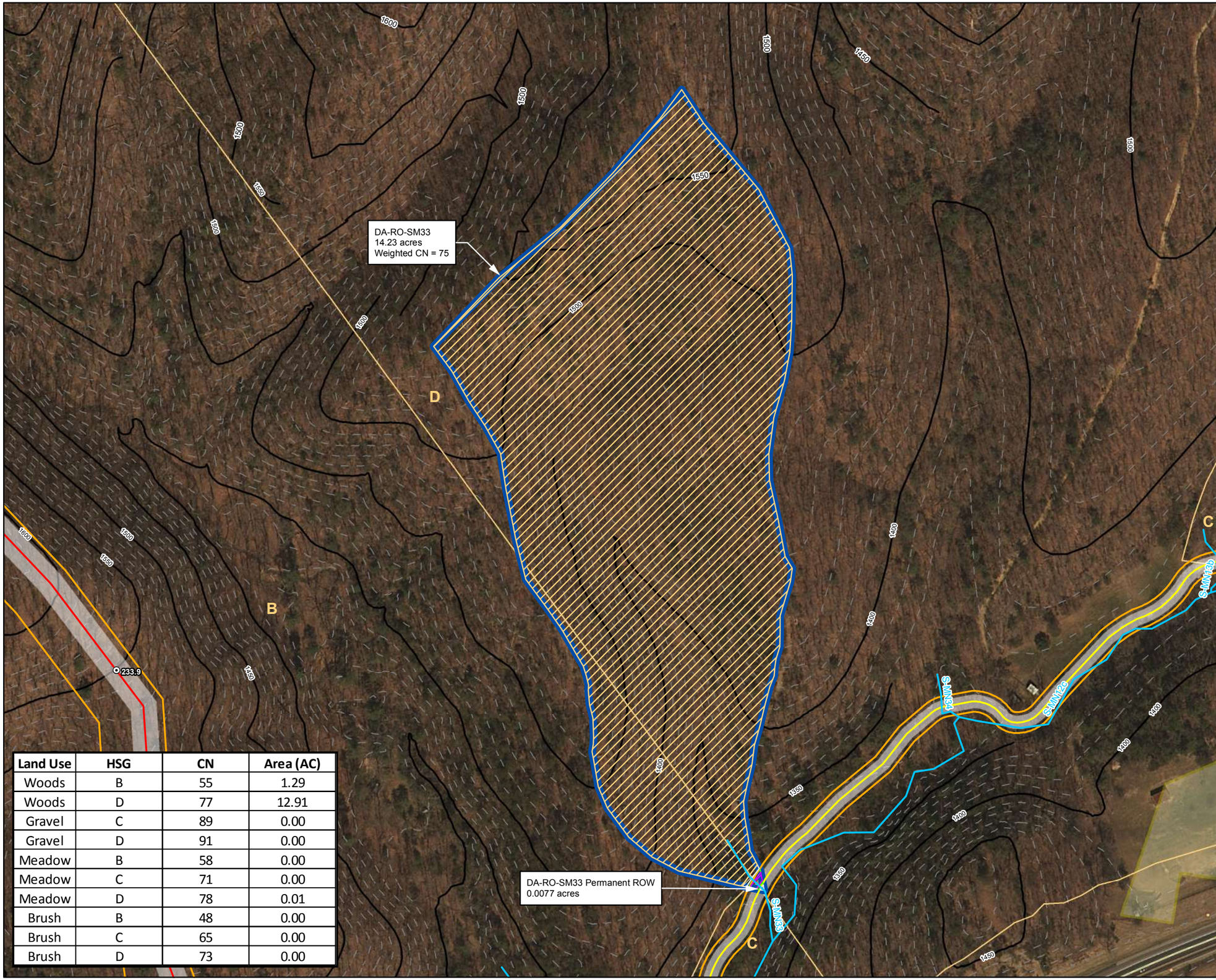


| Land Use | HSG | CN | Area (AC) |
|---|---|---|---|
| Woods | B | 55 | 1.29 |
| Woods | D | 77 | 12.91 |
| Gravel | C | 89 | 0.00 |
| Gravel | D | 91 | 0.00 |
| Meadow | B | 58 | 0.00 |
| Meadow | C | 71 | 0.00 |
| Meadow | D | 78 | 0.01 |
| Brush | B | 48 | 0.00 |
| Brush | C | 65 | 0.00 |
| Brush | D | 73 | 0.00 |

**Legend**

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Gravel
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

N W E S

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

## Post-Construction Drainage Area Map
## DA-RO-SM33
## Spread 9

Figure 2

*Montgomery and Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

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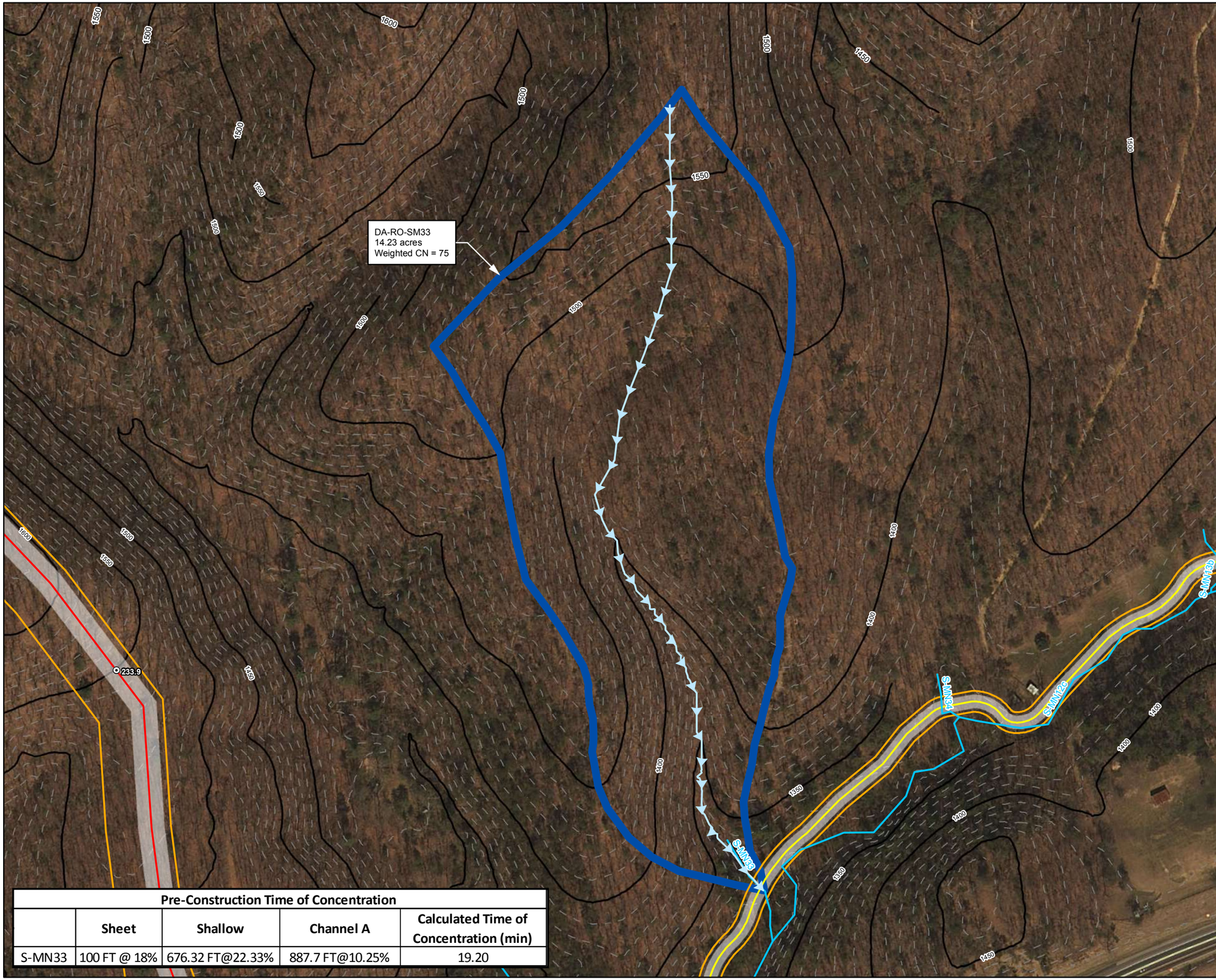


| Pre-Construction Time of Concentration | | | | |
|---|---|---|---|---|
| | Sheet | Shallow | Channel A | Calculated Time of Concentration (min) |
| S-MN33 | 100 FT @ 18% | 676.32 FT@22.33% | 887.7 FT@10.25% | 19.20 |

**Legend**

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

N W E S

**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

**Pre-Construction Drainage Area and Time of Concentration**
**DA-RO-SM33**
**Spread 9**

Figure 3
*Montgomery and Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

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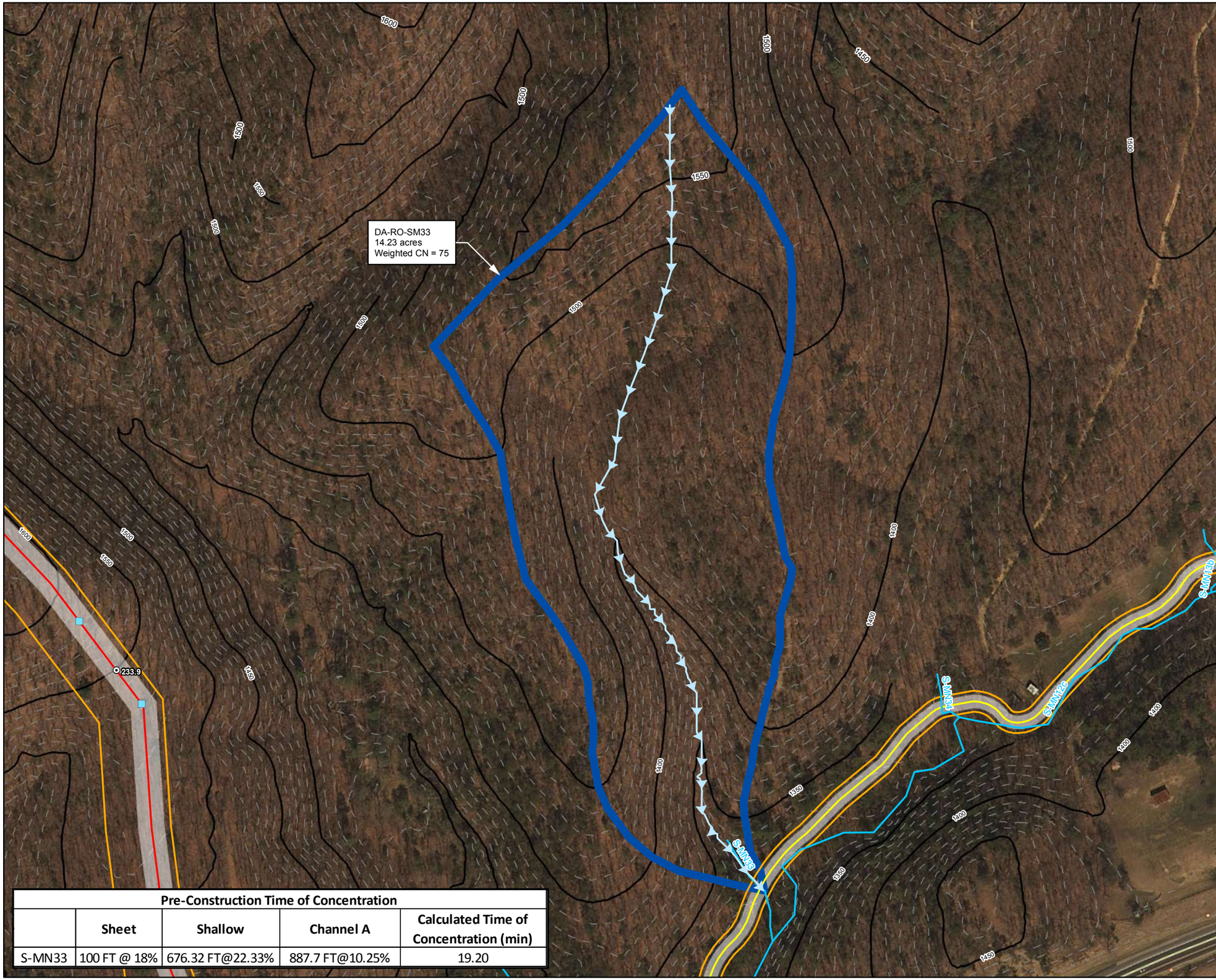



| Pre-Construction Time of Concentration | | | | |
|---|---|---|---|---|
| | Sheet | Shallow | Channel A | Calculated Time of Concentration (min) |
| S-MN33 | 100 FT @ 18% | 676.32 FT@22.33% | 887.7 FT@10.25% | 19.20 |

**Legend**

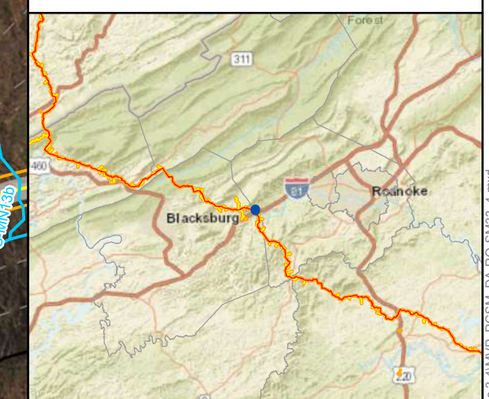
- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

N W E S




**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

**Post-Construction Drainage Area and Time of Concentration**
**DA-RO-SM33**
**Spread 9**

Figure 4
*Montgomery and Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

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**COMPOSITE CURVE NUMBER COMPUTATION SHEET**

| S-MN33 Pre-Construction |
|---|
| See calculation in Hydraflow report |

| S-MN33 Post-Construction | | | | |
|---|---|---|---|---|
| **LAND USE** | **HSG** | **CN** | **AREA (AC)** | **Area Weighted CN** |
| Woods | B | 55 | 1.295 | 5.00 |
| Woods | D | 77 | 12.91 | 69.86 |
| Gravel | C | 89 | 0.003 | 0.02 |
| Gravel | D | 91 | 0.005 | 0.03 |
| Meadow | B | 58 | 0.002 | 0.01 |
| Meadow | C | 71 | 0.001 | 0.01 |
| Meadow | D | 78 | 0.005 | 0.03 |
| Brush | B | 48 | 0.004 | 0.01 |
| Brush | C | 65 | 0.000 | 0.00 |
| Brush | D | 73 | 0.005 | 0.03 |
| | | | 14.23 | 75 |

**= Composite CN**

***Table 1 – Manning's n Values for Sheet Flow***

| **Land Surface Type** | **Manning n** |
|---|---|
| **Grass:** | |
| Average Grass Cover | 0.40 |
| Poor Grass Cover, Moderately Rough Surface | 0.30 – 0.40 |
| Light Turf | 0.20 |
| Dense Turf | 0.17 – 0.80 |
| Dense Grass | 0.17 – 0.30 |
| Bermuda Grass | 0.30 – 0.48 |
| Dense Shrubbery and Forest Litter | 0.40 |
| **Natural:** | |
| Short Grass Prairie | 0.10 – 0.20 |
| Poor Grass Cover, Moderately Rough Surface | 0.30 – 0.40 |
| Sparse Vegetation | 0.05 – 0.13 |
| Oak Grasslands, Open Grasslands | 0.60 |
| Dense Cover of Trees and Bushes | 0.80 |
| Rangeland: | |
| Typical | 0.13 |
| No Debris Cover | 0.09 – 0.34 |
| 20% Debris Cover | 0.05 – 0.25 |
| Woods: | |
| Light Underbrush | 0.40 |
| Dense Underbrush | 0.80 |
| Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed) | 0.40 |

*Note:*

*Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.*

*Sources:*

*-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA*

*-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC*

## *Table 2 – Manning's n Values for Open Channel Flow*

| Channel Type | Manning n | | |
|---|---|---|---|
| | Min. | Normal | Max. |
| **1. Excavated or Dredged Channels[1]** | | | |
| ***a. Earth, Straight, and Uniform:*** | | | |
| Clean, recently completed | 0.016 | 0.018 | 0.020 |
| Clean, after weathering | 0.018 | 0.022 | 0.025 |
| Gravel, uniform section, clean | 0.022 | 0.025 | 0.030 |
| With short grass, few weeds | 0.022 | 0.027 | 0.033 |
| ***b. Earth Winding and Sluggish:*** | | | |
| No vegetation | 0.023 | 0.025 | 0.030 |
| Grass, some weeds | 0.025 | 0.030 | 0.033 |
| Dense weeds or aquatic plants in deep channels | 0.030 | 0.035 | 0.040 |
| Earth bottom and rubble sides | 0.028 | 0.030 | 0.035 |
| Stony bottom and weedy banks | 0.025 | 0.035 | 0.040 |
| Cobble bottom and clean sides | 0.030 | 0.040 | 0.050 |
| ***c. Dragline-Excavated or Dredged:*** | | | |
| No vegetation | 0.025 | 0.028 | 0.033 |
| Light brush on banks | 0.035 | 0.050 | 0.060 |
| ***d. Rock Cuts:*** | | | |
| Smooth and uniform | 0.025 | 0.035 | 0.040 |
| Jagged and irregular | 0.035 | 0.040 | 0.050 |
| ***e. Channels not Maintained, Weeds and Brush Uncut:*** | | | |
| Dense weeds, high as flow depth | 0.050 | 0.080 | 0.120 |
| Clean bottom, brush on sides | 0.040 | 0.050 | 0.080 |
| Same as above, highest stage of flow | 0.045 | 0.070 | 0.110 |
| Dense brush, high stage | 0.080 | 0.100 | 0.140 |
| **2. Main Channels[2]** | | | |
| a. Clean, straight, full stage, no rifts or deep pools | 0.025 | 0.030 | 0.033 |
| b. Same as above, but more stones and weeds | 0.030 | 0.035 | 0.040 |
| c. Clean, winding, some pools and shoals | 0.033 | 0.040 | 0.045 |
| d. Same as above, but some weeds and stones | 0.035 | 0.045 | 0.050 |
| e. Same as above, lower stages, more ineffective | 0.040 | 0.048 | 0.055 |
| f. Same as (d) with more stones | 0.045 | 0.050 | 0.060 |
| g. Sluggish reaches, weedy, deep pools | 0.050 | 0.070 | 0.080 |
| h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush | 0.075 | 0.100 | 0.150 |

*Notes:*

*[1]A Manning's n value of 0.040 was used in Hydraflow Hydrographs for roadside channels.*

*[2]A Manning's n value of 0.030 was used in Hydraflow Hydrographs for existing/natural channels.*

*Sources:*

*-ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY*

*-Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY*

# Hydraflow Table of Contents

Culvert S-MN33.gpw

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

Wednesday, 09 / 20 / 2017


**Watershed Model Schematic..... 1**

**Hydrograph Return Period Recap..... 2**

**1 - Year**

**Summary Report..... 3**
**Hydrograph Reports..... 4**
Hydrograph No. 1, SCS Runoff, Culvt S-MN33 Pre-..... 4
TR-55 Tc Worksheet..... 5
Hydrograph No. 2, SCS Runoff, Culvt S-MN33 Post-..... 6
TR-55 Tc Worksheet..... 7
Hydrograph No. 3, SCS Runoff, Culvt S-MN33 Preforested-..... 8
TR-55 Tc Worksheet..... 9

**10 - Year**

**Summary Report..... 10**
**Hydrograph Reports..... 11**
Hydrograph No. 1, SCS Runoff, Culvt S-MN33 Pre-..... 11
Hydrograph No. 2, SCS Runoff, Culvt S-MN33 Post-..... 12
Hydrograph No. 3, SCS Runoff, Culvt S-MN33 Preforested-..... 13

**IDF Report..... 14**

# Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

## Legend

| Hyd. | Origin | Description |
|---|---|---|
| 1 | SCS Runoff | Culvt S-MN33 Pre- |
| 2 | SCS Runoff | Culvt S-MN33 Post- |
| 3 | SCS Runoff | Culvt S-MN33 Preforested- |

# Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Inflow hyd(s) | Peak Outflow (cfs) | | | | | | | | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1-yr | 2-yr | 3-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr | |
| 1 | SCS Runoff | ------ | 9.713 | ------- | ------- | ------- | 40.40 | ------- | ------- | ------- | Culvt S-MN33 Pre- |
| 2 | SCS Runoff | ------ | 9.713 | ------- | ------- | ------- | 40.40 | ------- | ------- | ------- | Culvt S-MN33 Post- |
| 3 | SCS Runoff | ------ | 9.713 | ------- | ------- | ------- | 40.40 | ------- | ------- | ------- | Culvt S-MN33 Preforested- |

# Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Peak flow (cfs) | Time interval (min) | Time to Peak (min) | Hyd. volume (cuft) | Inflow hyd(s) | Maximum elevation (ft) | Total strge used (cuft) | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SCS Runoff | 9.713 | 1 | 726 | 33,603 | ------ | ------ | ------ | Culvt S-MN33 Pre- |
| 2 | SCS Runoff | 9.713 | 1 | 726 | 33,603 | ------ | ------ | ------ | Culvt S-MN33 Post- |
| 3 | SCS Runoff | 9.713 | 1 | 726 | 33,603 | ------ | ------ | ------ | Culvt S-MN33 Preforested- |

# Hydrograph Report

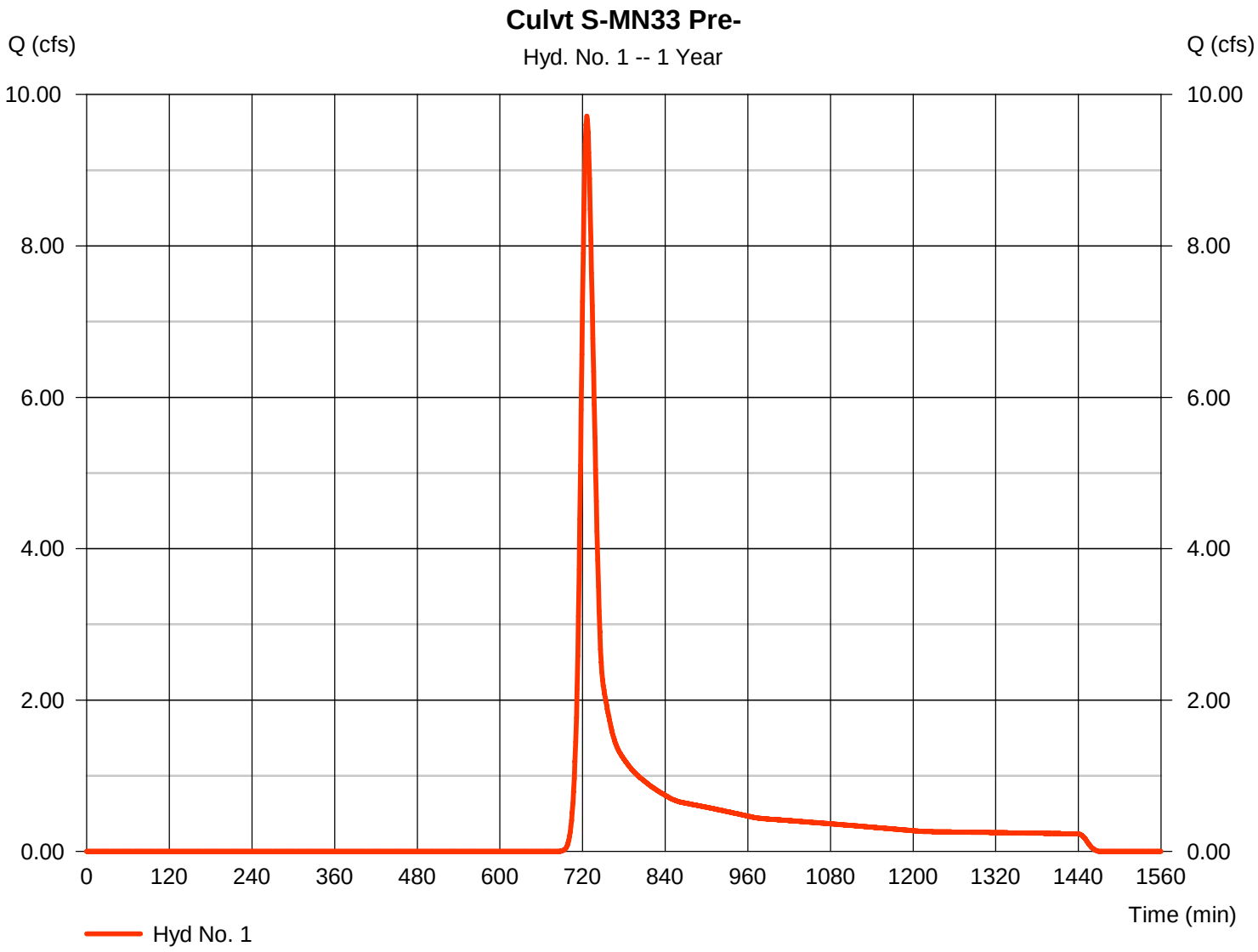
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 1

Culvt S-MN33 Pre-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 9.713 cfs |
| Storm frequency | = 1 yrs | Time to peak | = 726 min |
| Time interval | = 1 min | Hyd. volume | = 33,603 cuft |
| Drainage area | = 14.230 ac | Curve number | = 75* |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 19.20 min |
| Total precip. | = 2.50 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230



# TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

## Hyd. No. 1

Culvt S-MN33 Pre-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.00 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 18.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 16.03** | **+** | **0.00** | **+** | **0.00** | **=** | **16.03** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 676.32 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 22.33 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =7.62 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 1.48** | **+** | **0.00** | **+** | **0.00** | **=** | **1.48** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 2.00 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 5.00 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 10.25 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =8.61 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})887.7 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 1.72** | **+** | **0.00** | **+** | **0.00** | **=** | **1.72** |

**Total Travel Time, Tc ..... 19.20 min**

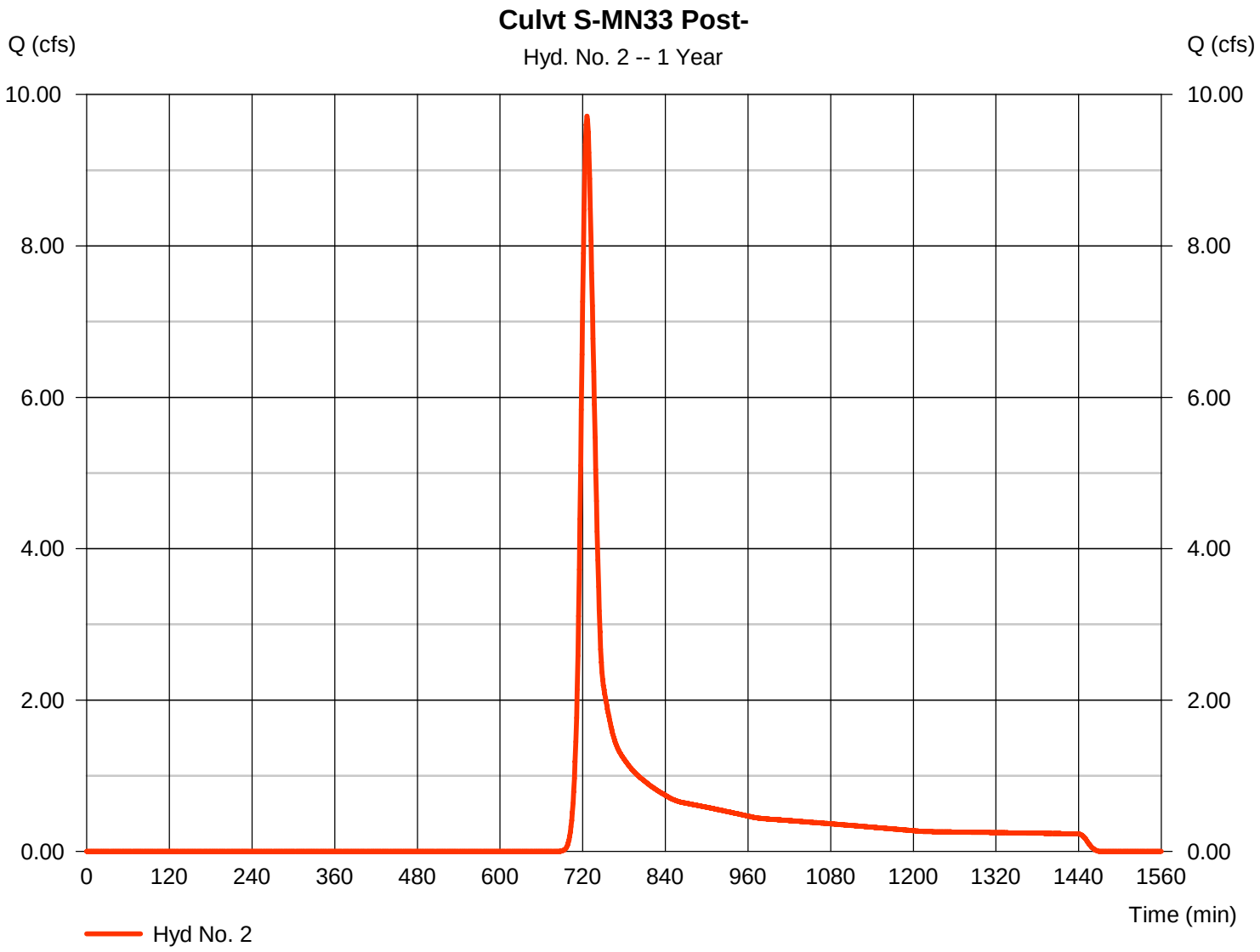
# Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 2

Culvt S-MN33 Post-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 9.713 cfs |
| Storm frequency | = 1 yrs | Time to peak | = 726 min |
| Time interval | = 1 min | Hyd. volume | = 33,603 cuft |
| Drainage area | = 14.230 ac | Curve number | = 75 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 19.20 min |
| Total precip. | = 2.50 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |



# TR55 Tc Worksheet



## Hyd. No. 2

Culvt S-MN33 Post-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.00 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 18.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 16.03** | **+** | **0.00** | **+** | **0.00** | **=** | **16.03** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 676.32 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 22.33 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =7.62 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 1.48** | **+** | **0.00** | **+** | **0.00** | **=** | **1.48** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 2.00 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 5.00 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 10.25 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =8.61 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})887.7 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 1.72** | **+** | **0.00** | **+** | **0.00** | **=** | **1.72** |

**Total Travel Time, Tc ..... 19.20 min**

# Hydrograph Report

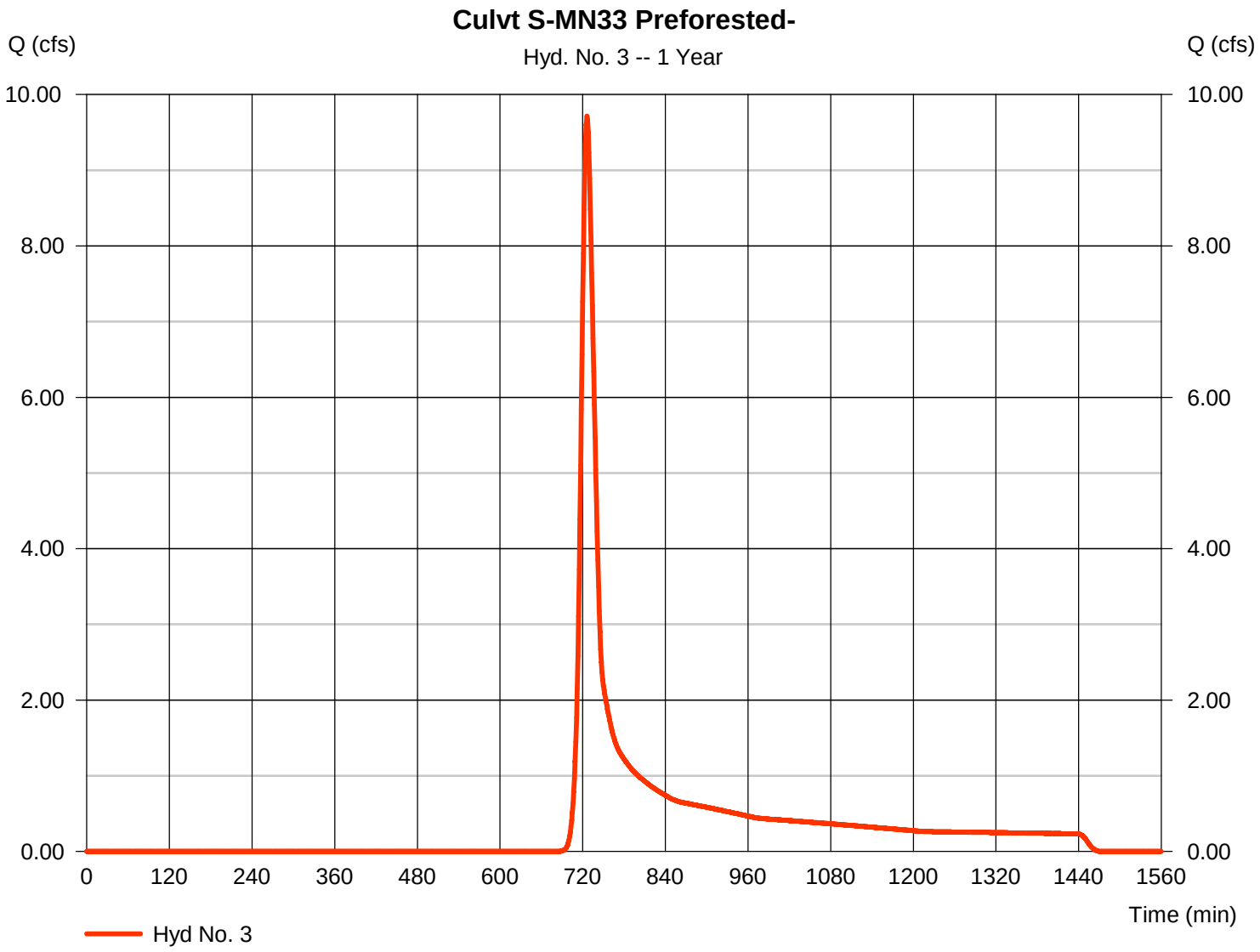
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 3

Culvt S-MN33 Preforested-

| | | | | | |
|---|---|---|---|---|---|
| Hydrograph type | = | SCS Runoff | Peak discharge | = | 9.713 cfs |
| Storm frequency | = | 1 yrs | Time to peak | = | 726 min |
| Time interval | = | 1 min | Hyd. volume | = | 33,603 cuft |
| Drainage area | = | 14.230 ac | Curve number | = | 75* |
| Basin Slope | = | 0.0 % | Hydraulic length | = | 0 ft |
| Tc method | = | TR55 | Time of conc. (Tc) | = | 19.20 min |
| Total precip. | = | 2.50 in | Distribution | = | Type II |
| Storm duration | = | 24 hrs | Shape factor | = | 484 |

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230



# TR55 Tc Worksheet



## Hyd. No. 3

Culvt S-MN33 Preforested-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.00 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 18.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 16.03** | **+** | **0.00** | **+** | **0.00** | **=** | **16.03** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 676.32 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 22.33 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =7.62 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 1.48** | **+** | **0.00** | **+** | **0.00** | **=** | **1.48** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 2.00 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 5.00 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 10.25 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =8.61 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})887.7 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 1.72** | **+** | **0.00** | **+** | **0.00** | **=** | **1.72** |

**Total Travel Time, Tc ..... 19.20 min**

# Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Peak flow (cfs) | Time interval (min) | Time to Peak (min) | Hyd. volume (cuft) | Inflow hyd(s) | Maximum elevation (ft) | Total strge used (cuft) | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SCS Runoff | 40.40 | 1 | 725 | 126,517 | ------ | ------ | ------ | Culvt S-MN33 Pre- |
| 2 | SCS Runoff | 40.40 | 1 | 725 | 126,517 | ------ | ------ | ------ | Culvt S-MN33 Post- |
| 3 | SCS Runoff | 40.40 | 1 | 725 | 126,517 | ------ | ------ | ------ | Culvt S-MN33 Preforested- |

# Hydrograph Report

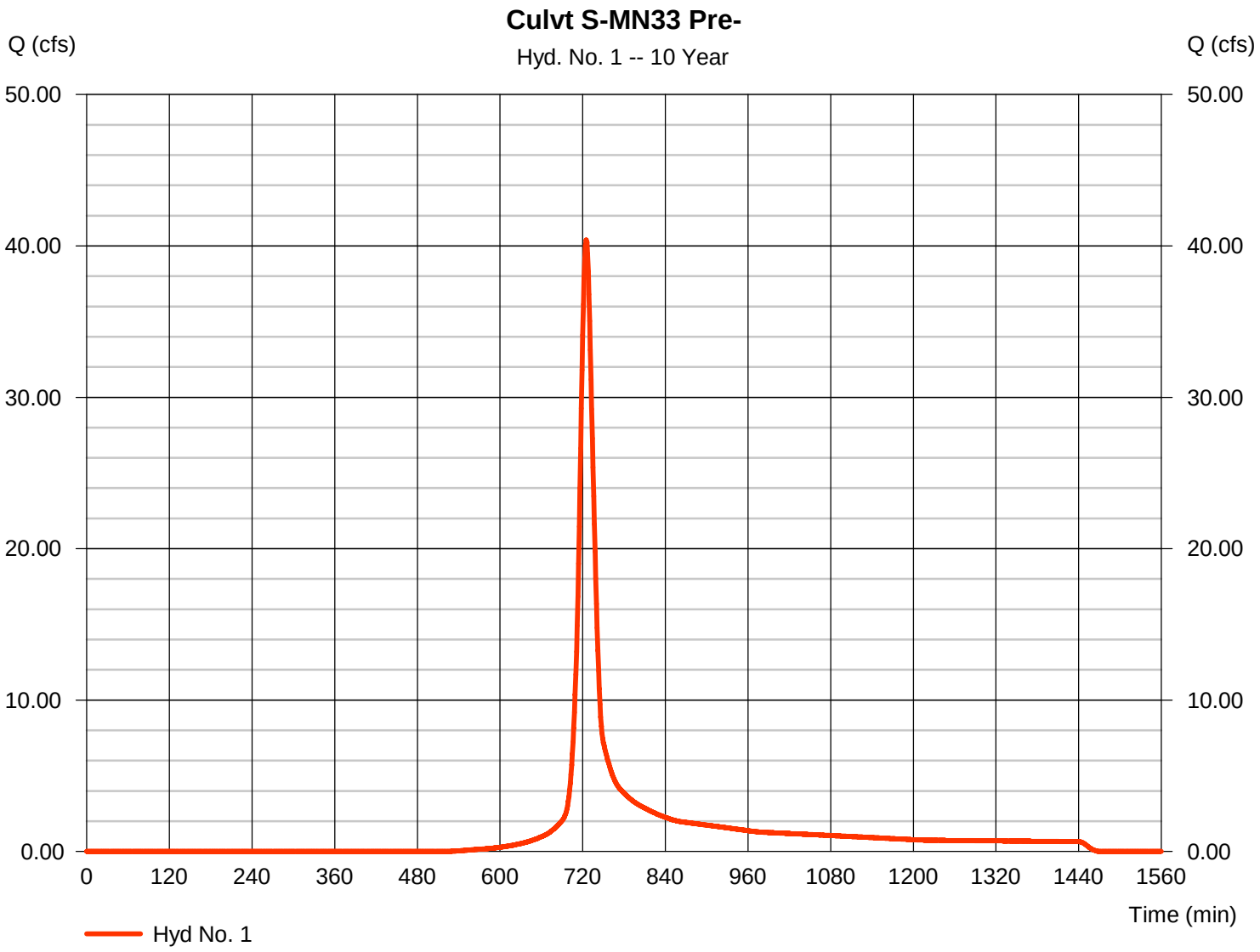
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 1

Culvt S-MN33 Pre-

| | | | | | |
|---|---|---|---|---|---|
| Hydrograph type | = | SCS Runoff | Peak discharge | = | 40.40 cfs |
| Storm frequency | = | 10 yrs | Time to peak | = | 725 min |
| Time interval | = | 1 min | Hyd. volume | = | 126,517 cuft |
| Drainage area | = | 14.230 ac | Curve number | = | 75* |
| Basin Slope | = | 0.0 % | Hydraulic length | = | 0 ft |
| Tc method | = | TR55 | Time of conc. (Tc) | = | 19.20 min |
| Total precip. | = | 5.00 in | Distribution | = | Type II |
| Storm duration | = | 24 hrs | Shape factor | = | 484 |

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230



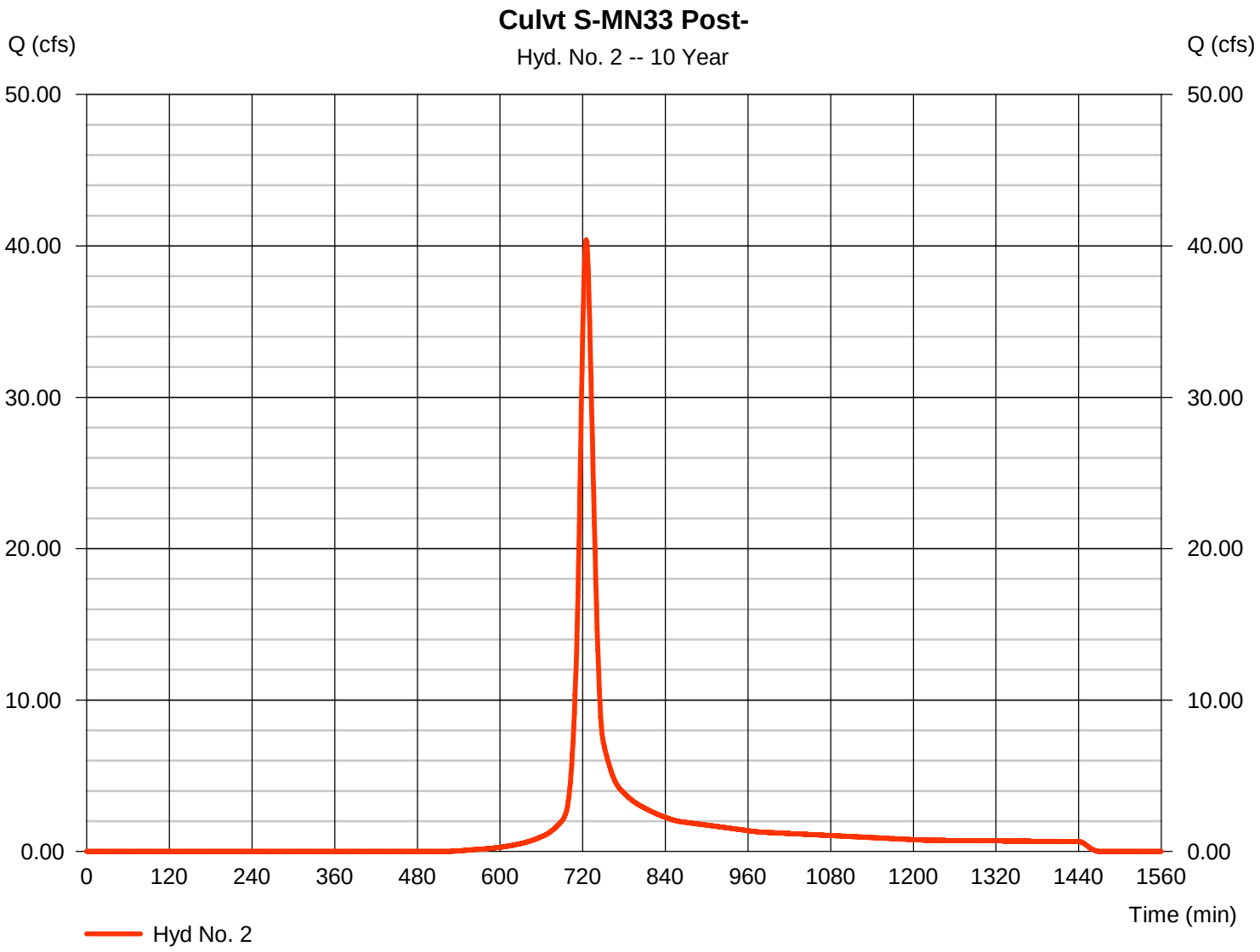
# Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 2

Culvt S-MN33 Post-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 40.40 cfs |
| Storm frequency | = 10 yrs | Time to peak | = 725 min |
| Time interval | = 1 min | Hyd. volume | = 126,517 cuft |
| Drainage area | = 14.230 ac | Curve number | = 75 |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 19.20 min |
| Total precip. | = 5.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |



# Hydrograph Report

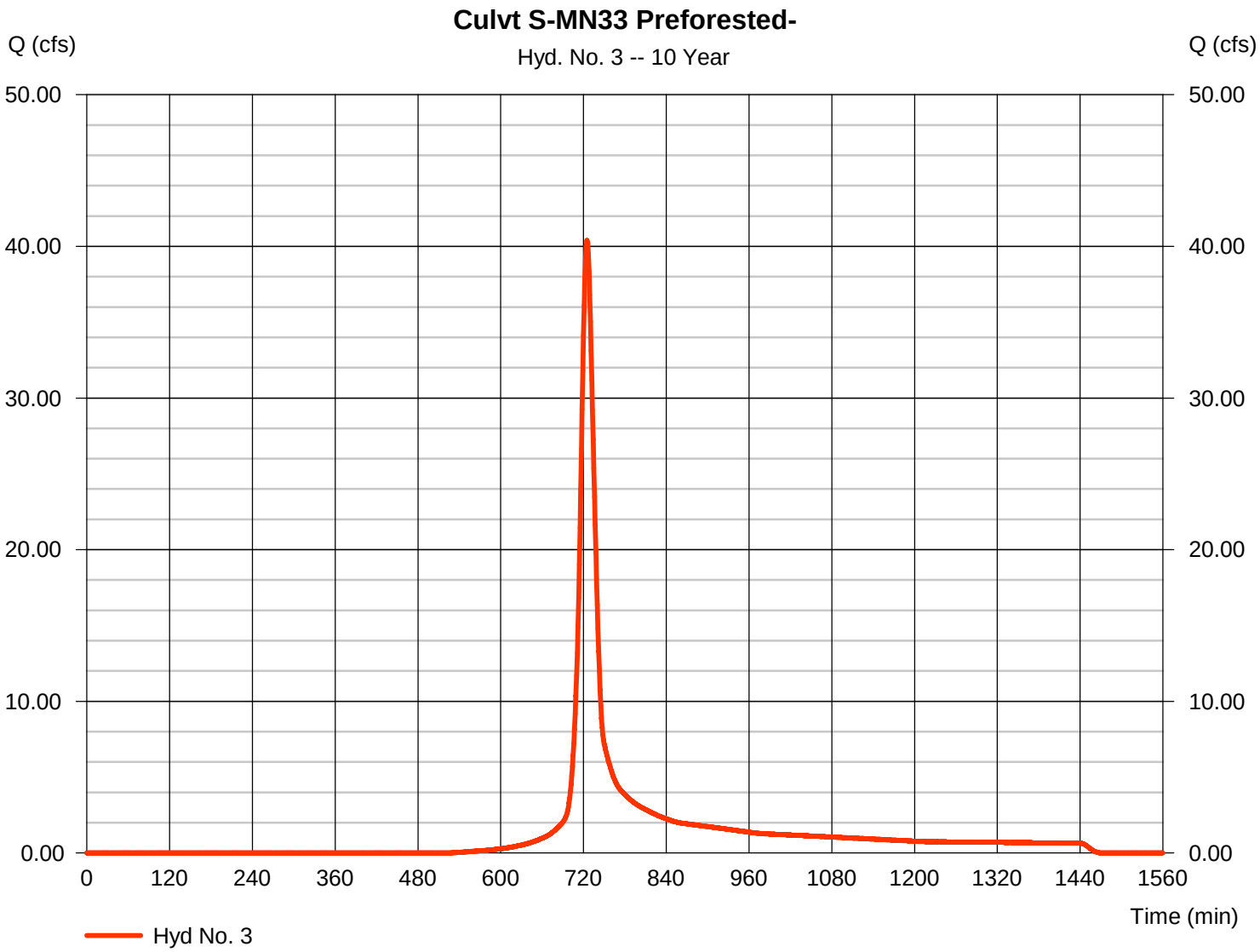
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 3

Culvt S-MN33 Preforested-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 40.40 cfs |
| Storm frequency | = 10 yrs | Time to peak | = 725 min |
| Time interval | = 1 min | Hyd. volume | = 126,517 cuft |
| Drainage area | = 14.230 ac | Curve number | = 75* |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 19.20 min |
| Total precip. | = 5.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230



# Hydraflow Rainfall Report



| Return Period (Yrs) | Intensity-Duration-Frequency Equation Coefficients (FHA) | | | |
|---|---|---|---|---|
| | B | D | E | (N/A) |
| 1 | 0.0000 | 0.0000 | 0.0000 | -------- |
| 2 | 69.8703 | 13.1000 | 0.8658 | -------- |
| 3 | 0.0000 | 0.0000 | 0.0000 | -------- |
| 5 | 79.2597 | 14.6000 | 0.8369 | -------- |
| 10 | 88.2351 | 15.5000 | 0.8279 | -------- |
| 25 | 102.6072 | 16.5000 | 0.8217 | -------- |
| 50 | 114.8193 | 17.2000 | 0.8199 | -------- |
| 100 | 127.1596 | 17.8000 | 0.8186 | -------- |

File name: SampleFHA.idf

### Intensity = B / (Tc + D)^E

| Return Period (Yrs) | Intensity Values (in/hr) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 min | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.69 | 4.61 | 3.89 | 3.38 | 2.99 | 2.69 | 2.44 | 2.24 | 2.07 | 1.93 | 1.81 | 1.70 |
| 3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 6.57 | 5.43 | 4.65 | 4.08 | 3.65 | 3.30 | 3.02 | 2.79 | 2.59 | 2.42 | 2.27 | 2.15 |
| 10 | 7.24 | 6.04 | 5.21 | 4.59 | 4.12 | 3.74 | 3.43 | 3.17 | 2.95 | 2.77 | 2.60 | 2.46 |
| 25 | 8.25 | 6.95 | 6.03 | 5.34 | 4.80 | 4.38 | 4.02 | 3.73 | 3.48 | 3.26 | 3.07 | 2.91 |
| 50 | 9.04 | 7.65 | 6.66 | 5.92 | 5.34 | 4.87 | 4.49 | 4.16 | 3.88 | 3.65 | 3.44 | 3.25 |
| 100 | 9.83 | 8.36 | 7.30 | 6.50 | 5.87 | 5.36 | 4.94 | 4.59 | 4.29 | 4.03 | 3.80 | 3.60 |

Tc = time in minutes. Values may exceed 60.

rk Sladic\EQT\Project\112IC07157 MVP\Virginia Stormwater\Culvert Design - Other\Culvert S-MN33\Montgomery.pcp

| Storm Distribution | Rainfall Precipitation Table (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-yr | 2-yr | 3-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| SCS 24-hour | 2.50 | 0.00 | 0.00 | 0.00 | 5.00 | 5.50 | 0.00 | 0.00 |
| SCS 6-Hr | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-1st | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-2nd | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-3rd | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-4th | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-Indy | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Custom | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**ENERGY BALANCE METHOD**

**Inputs:**

| | 1-Yr Event | |
|---|---|---|
| | Peak Flow, Q (cfs) | Runoff Volume, RV (cf) |
| Pre-Developed Condition | 9.713 | 33,603 |
| Developed Condition | 9.713 | 33,603 |
| Pre-Developed (Forest) Condition | 9.713 | 33,603 |

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

**Calculations:**

| | | | | | |
|---|---|---|---|---|---|
| [1] ***Check #1:*** | $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> | 9.713 | ≤ OK | 9.713 |
| ***Check #2:*** | $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> | 9.713 | ≤ OK | 9.713 |
| ***Check #3:*** | $Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> | 9.713 | *shall not* be required to be ≤ | 9.713 |

## STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

[1] Per VADEQ, the improvement factor can be waived if the road is being maintained within the current footprint.

# HY-8 Culvert Analysis Report

## Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 40.4 cfs

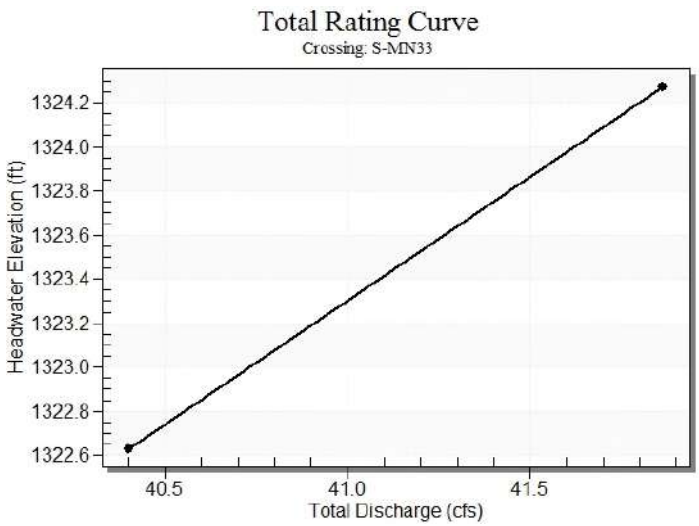
Design Flow: 40.4 cfs

Maximum Flow: 40.4 cfs

## Table 1 - Summary of Culvert Flows at Crossing: S-MN33

| Headwater Elevation (ft) | Total Discharge (cfs) | Culvert S-MN33 Discharge (cfs) | Roadway Discharge (cfs) | Iterations |
|---|---|---|---|---|
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.63 | 40.40 | 40.40 | 0.00 | 1 |
| 1322.74 | 41.86 | 41.86 | 0.00 | Overtopping |

## Rating Curve Plot for Crossing: S-MN33



## Table 2 - Culvert Summary Table: Culvert S-MN33

| Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |
| 40.40 | 40.40 | 1322.63 | 2.637 | 2.291 | 5-S2n | 1.261 | 1.459 | 1.313 | 1.530 | 7.496 | 6.603 |

**********

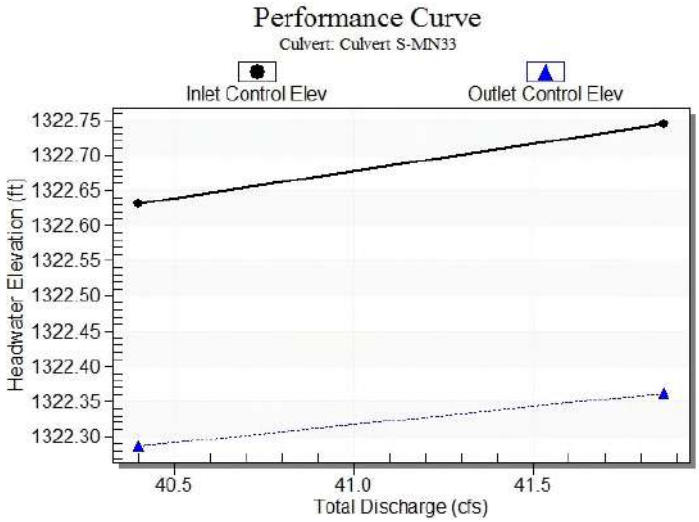
Straight Culvert

Inlet Elevation (invert): 1319.99 ft, Outlet Elevation (invert): 1319.74 ft

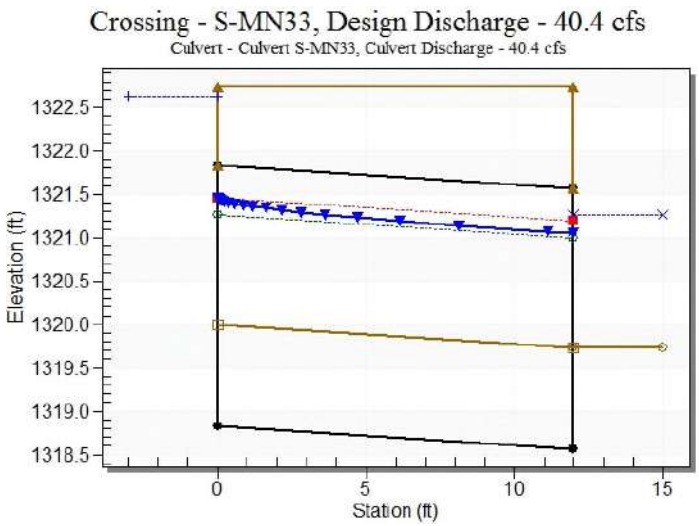
Culvert Length: 12.00 ft, Culvert Slope: 0.0215

**********

## Culvert Performance Curve Plot: Culvert S-MN33



## Water Surface Profile Plot for Culvert: Culvert S-MN33




## Site Data - Culvert S-MN33

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1318.83 ft

Outlet Station: 12.00 ft

Outlet Elevation: 1318.57 ft

Number of Barrels: 1

## Culvert Data Summary - Culvert S-MN33

Barrel Shape: Concrete Box

Barrel Span: 4.00 ft

Barrel Rise: 3.00 ft

Barrel Material: Concrete

Embedment: 14.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

## Table 3 - Downstream Channel Rating Curve (Crossing: S-MN33)

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) | Velocity (ft/s) | Shear (psf) | Froude Number |
|---|---|---|---|---|---|
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |
| 40.40 | 1321.27 | 1.53 | 6.60 | 2.05 | 0.94 |

### Tailwater Channel Data - S-MN33

Tailwater Channel Option: Rectangular Channel

Bottom Width: 4.00 ft

Channel Slope: 0.0215

Channel Manning's n: 0.0300

Channel Invert Elevation: 1319.74 ft

### Roadway Data for Crossing: S-MN33

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 1322.74 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft

| | | Culvert Design | | | | | [1]Riprap Apron Outlet Protection Design | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Corresponding Stream | Culvert Diameter, $d_o$ (in) | Culvert Material | [2]Pipe Slope (ft/ft) | Q (cfs) | Design Flow Frequency | $d_{50}$ Riprap Size, $d_{50}$ (in) | AASHTO Riprap Class | Placement Thickness per NSA Riprap Gradation, d (in) | Placement Thickness per AASHTO Riprap Gradation, d (in) | Apron Length, $L_a$ (ft) | Apron Initial Width, $W_i$ (ft) | Apron Terminal Width, W (ft) |
| 20 + 88.96 | S-MN34 | N/A (Box Culvert: Span=9.0-ft, Rise=6.0-ft) | Concrete | 0.070 | 278.12 | 10-Yr | N/A - Scour protection needs to withstand tailwater velocity of 15.6 ft/s and shear stress of 9.03 psf. Suggest grouted riprap or equivalent. Note that scour protection should be placed within the channel from top-of-bank to top-of-bank, and extend from the culvert outlet to the limit of disturbance. | | | | | | |
| | | | | | | | | | | | | | |
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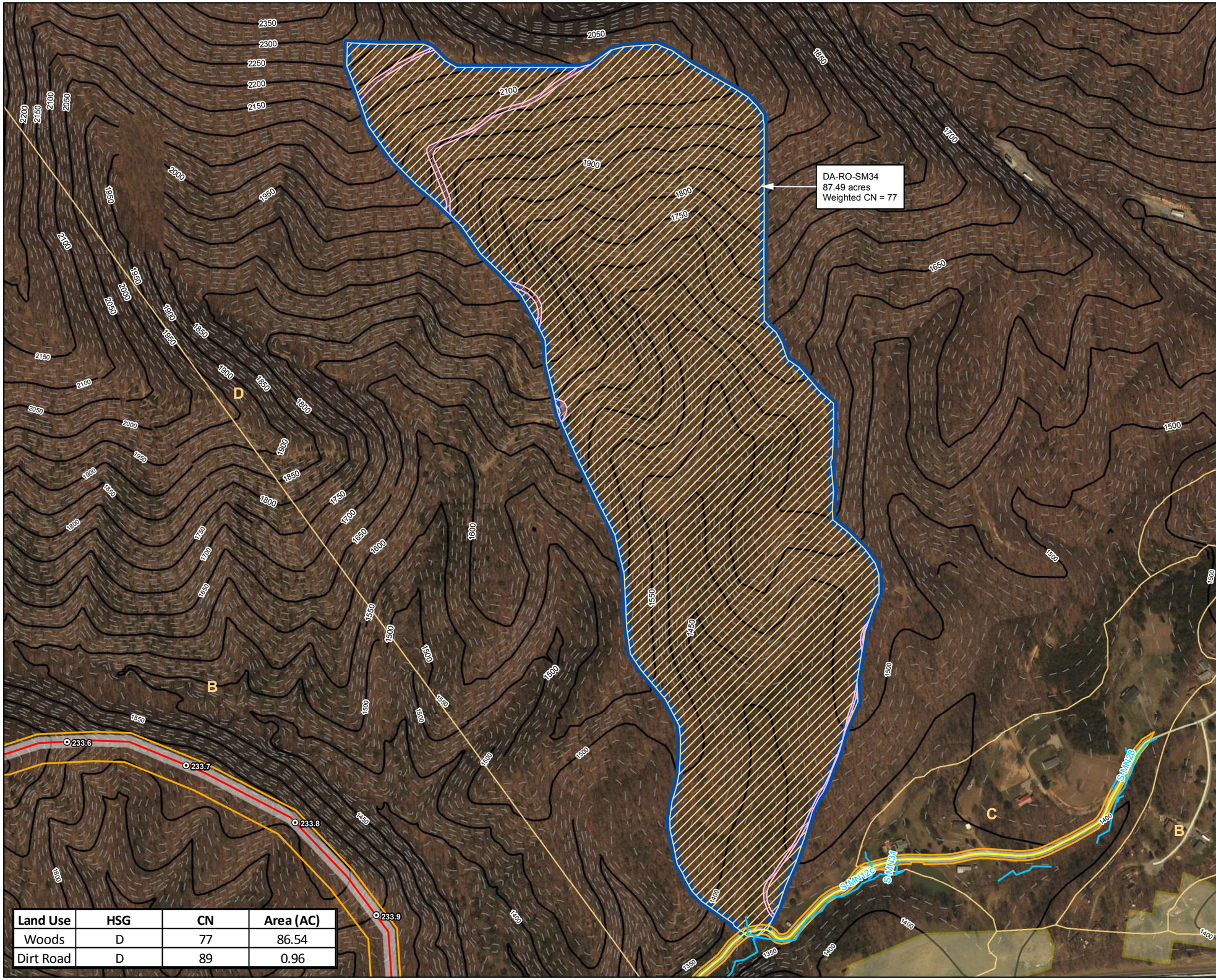
| | | | | | | | | | | | | | |

[1]Designed in accordance with VESCH Std & Spec 3.18 assuming minimum tailwater condition ($T_w < 0.5d_o$).

[2]The slope was calculated from a combination of LIDAR and field notes taken for the stream channel characteristics.

[3]Requires roadway grading (fill of 4.313 feet) to install culvert with minimum recommended cover of 2 inches.




| Land Use | HSG | CN | Area (AC) |
|---|---|---|---|
| Woods | D | 77 | 86.54 |
| Dirt Road | D | 89 | 0.96 |

**Legend**

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

N W E S

## Mountain Valley Pipeline Project

Mountain Valley PIPELINE

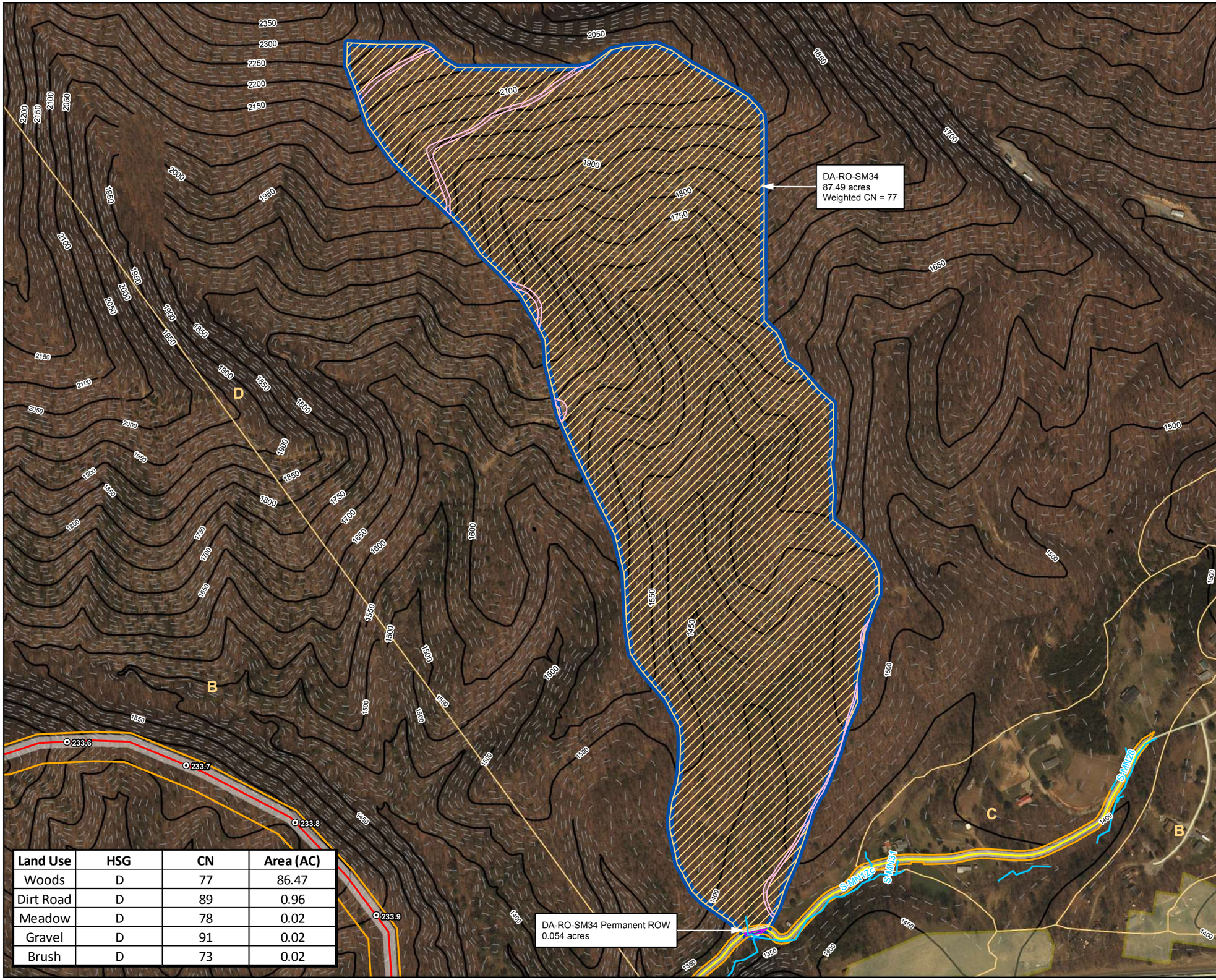
**Pre-Construction Drainage Area Map**
**DA-RO-SM34**
**Spread 9**

Figure 1
*Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM34_Pre.mxd




| Land Use | HSG | CN | Area (AC) |
|---|---|---|---|
| Woods | D | 77 | 86.47 |
| Dirt Road | D | 89 | 0.96 |
| Meadow | D | 78 | 0.02 |
| Gravel | D | 91 | 0.02 |
| Brush | D | 73 | 0.02 |

**Legend**

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

N W E S

# Mountain Valley Pipeline Project

Mountain Valley PIPELINE

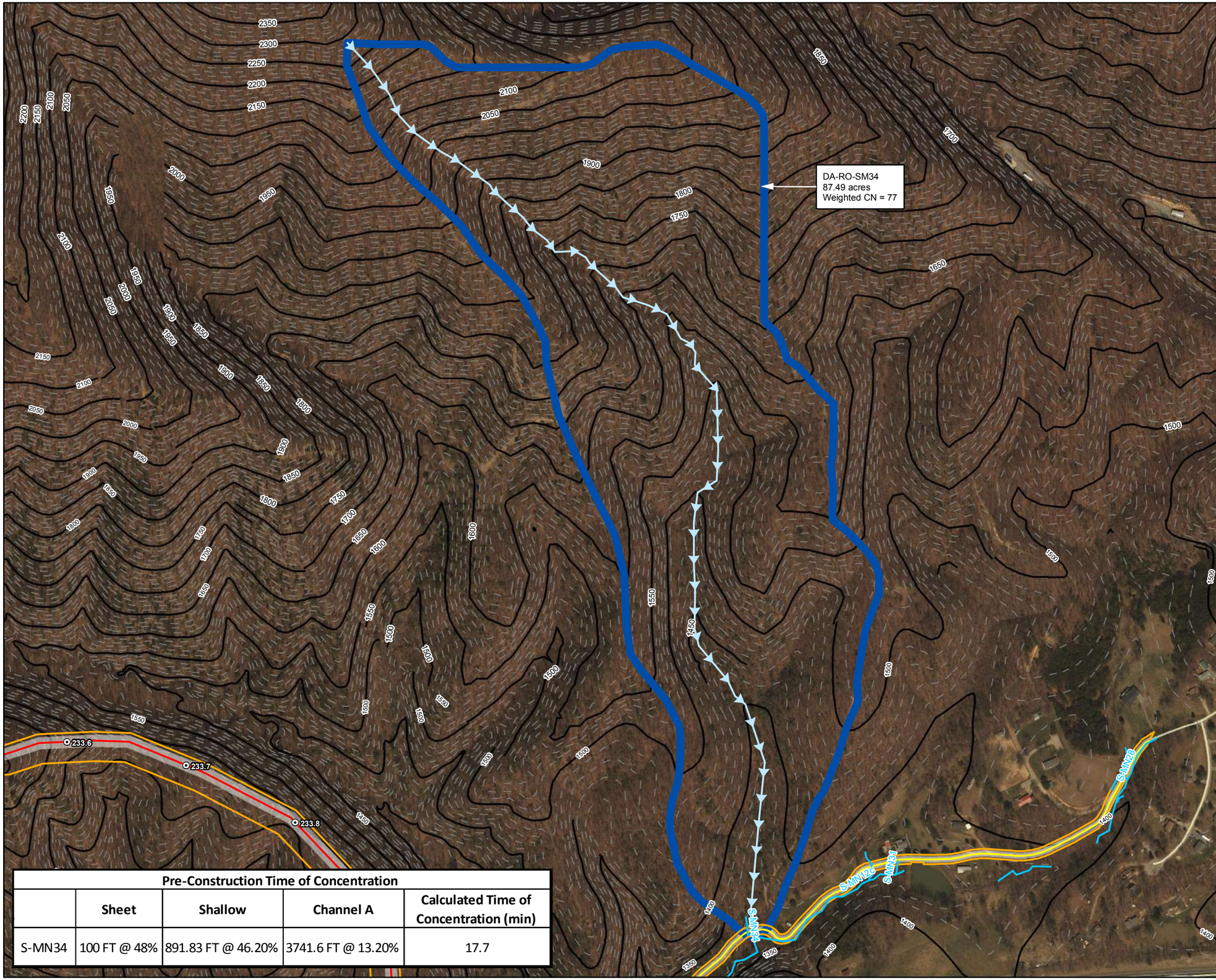
## Post-Construction Drainage Area Map
## DA-RO-SM34
## Spread 9

Figure 2
*Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford Univeristy DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM34_Post.mxd




| Pre-Construction Time of Concentration | | | | |
|---|---|---|---|---|
| | Sheet | Shallow | Channel A | Calculated Time of Concentration (min) |
| S-MN34 | 100 FT @ 48% | 891.83 FT @ 46.20% | 3741.6 FT @ 13.20% | 17.7 |

**Legend**

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

N W E S

**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

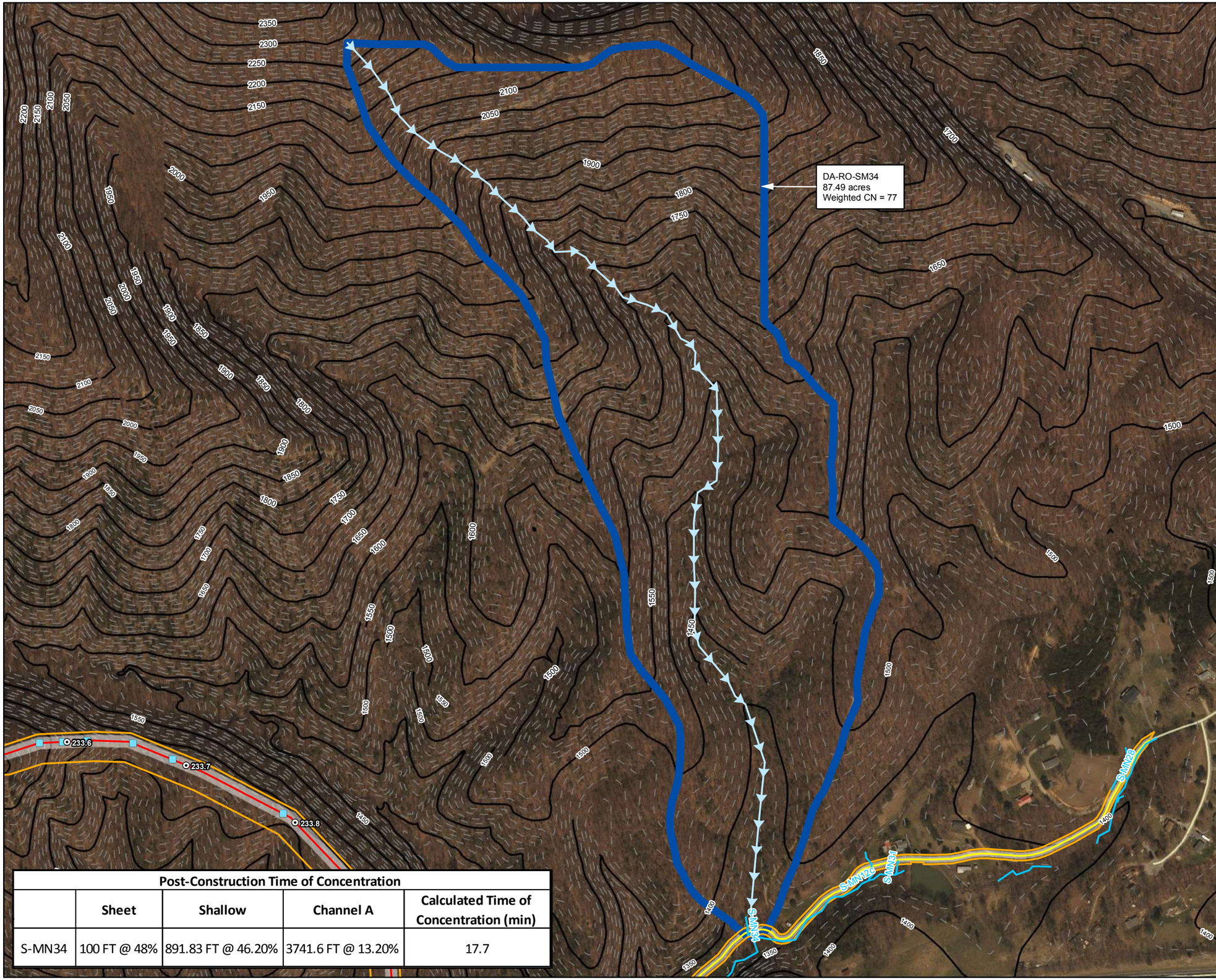
**Pre-Construction Drainage Area and Time of Concentration**
**DA-RO-SM34**
**Spread 9**

Figure 3
*Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford Univeristy DEMs.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM34_3.mxd




| Post-Construction Time of Concentration | | | | |
|---|---|---|---|---|
| | Sheet | Shallow | Channel A | Calculated Time of Concentration (min) |
| S-MN34 | 100 FT @ 48% | 891.83 FT @ 46.20% | 3741.6 FT @ 13.20% | 17.7 |

**Legend**

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

N W E S

**Mountain Valley Pipeline Project**

Mountain Valley PIPELINE

**Post-Construction Drainage Area and Time of Concentration**
**DA-RO-SM34**
**Spread 9**

Figure 4
*Roanoke County, Virginia*

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford Univeristy DEMs.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM34_4.mxd

***Table 1 – Manning's n Values for Sheet Flow***

| **Land Surface Type** | **Manning n** |
|---|---|
| **Grass:** | |
| Average Grass Cover | 0.40 |
| Poor Grass Cover, Moderately Rough Surface | 0.30 – 0.40 |
| Light Turf | 0.20 |
| Dense Turf | 0.17 – 0.80 |
| Dense Grass | 0.17 – 0.30 |
| Bermuda Grass | 0.30 – 0.48 |
| Dense Shrubbery and Forest Litter | 0.40 |
| **Natural:** | |
| Short Grass Prairie | 0.10 – 0.20 |
| Poor Grass Cover, Moderately Rough Surface | 0.30 – 0.40 |
| Sparse Vegetation | 0.05 – 0.13 |
| Oak Grasslands, Open Grasslands | 0.60 |
| Dense Cover of Trees and Bushes | 0.80 |
| Rangeland: | |
| Typical | 0.13 |
| No Debris Cover | 0.09 – 0.34 |
| 20% Debris Cover | 0.05 – 0.25 |
| Woods: | |
| Light Underbrush | 0.40 |
| Dense Underbrush | 0.80 |
| Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed) | 0.40 |

*Note:*

*Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.*

*Sources:*

*-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA*

*-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC*

## *Table 2 – Manning's n Values for Open Channel Flow*

| Channel Type | Manning n | | |
|---|---|---|---|
| | Min. | Normal | Max. |
| **1. Excavated or Dredged Channels[1]** | | | |
| ***a. Earth, Straight, and Uniform:*** | | | |
| Clean, recently completed | 0.016 | 0.018 | 0.020 |
| Clean, after weathering | 0.018 | 0.022 | 0.025 |
| Gravel, uniform section, clean | 0.022 | 0.025 | 0.030 |
| With short grass, few weeds | 0.022 | 0.027 | 0.033 |
| ***b. Earth Winding and Sluggish:*** | | | |
| No vegetation | 0.023 | 0.025 | 0.030 |
| Grass, some weeds | 0.025 | 0.030 | 0.033 |
| Dense weeds or aquatic plants in deep channels | 0.030 | 0.035 | 0.040 |
| Earth bottom and rubble sides | 0.028 | 0.030 | 0.035 |
| Stony bottom and weedy banks | 0.025 | 0.035 | 0.040 |
| Cobble bottom and clean sides | 0.030 | 0.040 | 0.050 |
| ***c. Dragline-Excavated or Dredged:*** | | | |
| No vegetation | 0.025 | 0.028 | 0.033 |
| Light brush on banks | 0.035 | 0.050 | 0.060 |
| ***d. Rock Cuts:*** | | | |
| Smooth and uniform | 0.025 | 0.035 | 0.040 |
| Jagged and irregular | 0.035 | 0.040 | 0.050 |
| ***e. Channels not Maintained, Weeds and Brush Uncut:*** | | | |
| Dense weeds, high as flow depth | 0.050 | 0.080 | 0.120 |
| Clean bottom, brush on sides | 0.040 | 0.050 | 0.080 |
| Same as above, highest stage of flow | 0.045 | 0.070 | 0.110 |
| Dense brush, high stage | 0.080 | 0.100 | 0.140 |
| **2. Main Channels[2]** | | | |
| a. Clean, straight, full stage, no rifts or deep pools | 0.025 | 0.030 | 0.033 |
| b. Same as above, but more stones and weeds | 0.030 | 0.035 | 0.040 |
| c. Clean, winding, some pools and shoals | 0.033 | 0.040 | 0.045 |
| d. Same as above, but some weeds and stones | 0.035 | 0.045 | 0.050 |
| e. Same as above, lower stages, more ineffective | 0.040 | 0.048 | 0.055 |
| f. Same as (d) with more stones | 0.045 | 0.050 | 0.060 |
| g. Sluggish reaches, weedy, deep pools | 0.050 | 0.070 | 0.080 |
| h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush | 0.075 | 0.100 | 0.150 |

*Notes:*

*[1]A Manning's n value of 0.040 was used in Hydraflow Hydrographs for roadside channels.*

*[2]A Manning's n value of 0.030 was used in Hydraflow Hydrographs for existing/natural channels.*

*Sources:*

*-ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY*

*-Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY*

# Hydraflow Table of Contents

Culvert S-MN34.gpw

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

Wednesday, 09 / 20 / 2017


**Watershed Model Schematic..... 1**

**Hydrograph Return Period Recap..... 2**

**1 - Year**

**Summary Report..... 3**
**Hydrograph Reports..... 4**
Hydrograph No. 1, SCS Runoff, Culvt S-MN34 Pre-..... 4
TR-55 Tc Worksheet..... 5
Hydrograph No. 2, SCS Runoff, Culvt S-MN34 Post-..... 6
TR-55 Tc Worksheet..... 7
Hydrograph No. 3, SCS Runoff, Culvt S-MN34 Preforested-..... 8
TR-55 Tc Worksheet..... 9

**10 - Year**

**Summary Report..... 10**
**Hydrograph Reports..... 11**
Hydrograph No. 1, SCS Runoff, Culvt S-MN34 Pre-..... 11
Hydrograph No. 2, SCS Runoff, Culvt S-MN34 Post-..... 12
Hydrograph No. 3, SCS Runoff, Culvt S-MN34 Preforested-..... 13

**IDF Report..... 14**

# Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

## Legend

| Hyd. | Origin | Description |
|---|---|---|
| 1 | SCS Runoff | Culvt S-MN34 Pre- |
| 2 | SCS Runoff | Culvt S-MN34 Post- |
| 3 | SCS Runoff | Culvt S-MN34 Preforested- |

# Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Inflow hyd(s) | Peak Outflow (cfs) | | | | | | | | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1-yr | 2-yr | 3-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr | |
| 1 | SCS Runoff | ------ | 110.12 | ------- | ------- | ------- | 278.12 | ------- | ------- | ------- | Culvt S-MN34 Pre- |
| 2 | SCS Runoff | ------ | 110.12 | ------- | ------- | ------- | 278.12 | ------- | ------- | ------- | Culvt S-MN34 Post- |
| 3 | SCS Runoff | ------ | 110.12 | ------- | ------- | ------- | 278.12 | ------- | ------- | ------- | Culvt S-MN34 Preforested- |

# Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Peak flow (cfs) | Time interval (min) | Time to Peak (min) | Hyd. volume (cuft) | Inflow hyd(s) | Maximum elevation (ft) | Total strge used (cuft) | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SCS Runoff | 110.12 | 1 | 725 | 336,284 | ------ | ------ | ------ | Culvt S-MN34 Pre- |
| 2 | SCS Runoff | 110.12 | 1 | 725 | 336,284 | ------ | ------ | ------ | Culvt S-MN34 Post- |
| 3 | SCS Runoff | 110.12 | 1 | 725 | 336,284 | ------ | ------ | ------ | Culvt S-MN34 Preforested- |

# Hydrograph Report

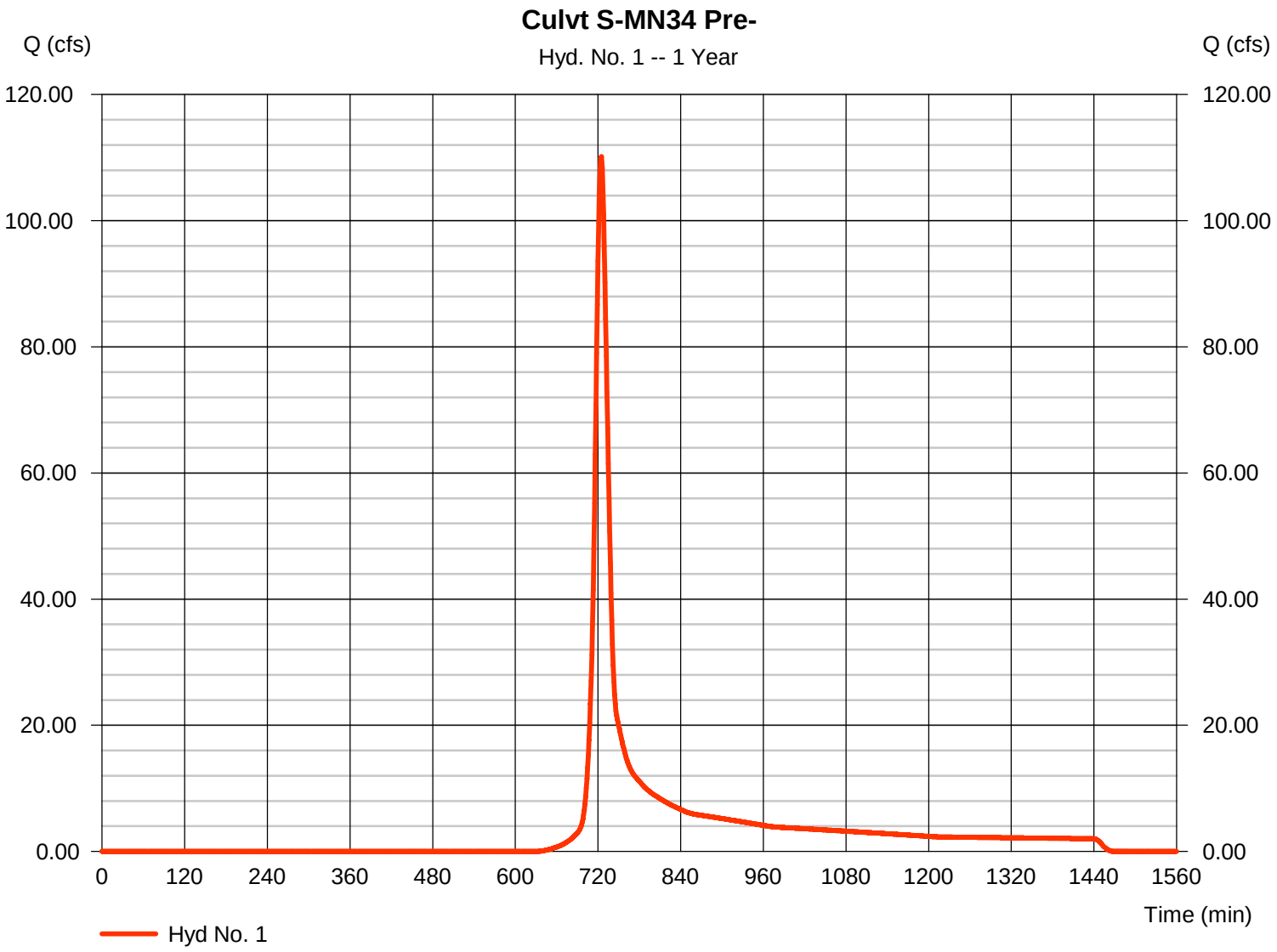
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 1

Culvt S-MN34 Pre-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 110.12 cfs |
| Storm frequency | = 1 yrs | Time to peak | = 725 min |
| Time interval | = 1 min | Hyd. volume | = 336,284 cuft |
| Drainage area | = 87.490 ac | Curve number | = 77* |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 17.70 min |
| Total precip. | = 3.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

* Composite (Area/CN) = [(86.537 x 77) + (0.957 x 89)] / 87.490



# TR55 Tc Worksheet



## Hyd. No. 1

Culvt S-MN34 Pre-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.50 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 48.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 10.03** | **+** | **0.00** | **+** | **0.00** | **=** | **10.03** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 891.83 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 46.20 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =10.97 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 1.36** | **+** | **0.00** | **+** | **0.00** | **=** | **1.36** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 2.25 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 5.50 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 13.20 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =9.91 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})3741.6 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 6.29** | **+** | **0.00** | **+** | **0.00** | **=** | **6.29** |

**Total Travel Time, Tc ..... 17.70 min**

# Hydrograph Report

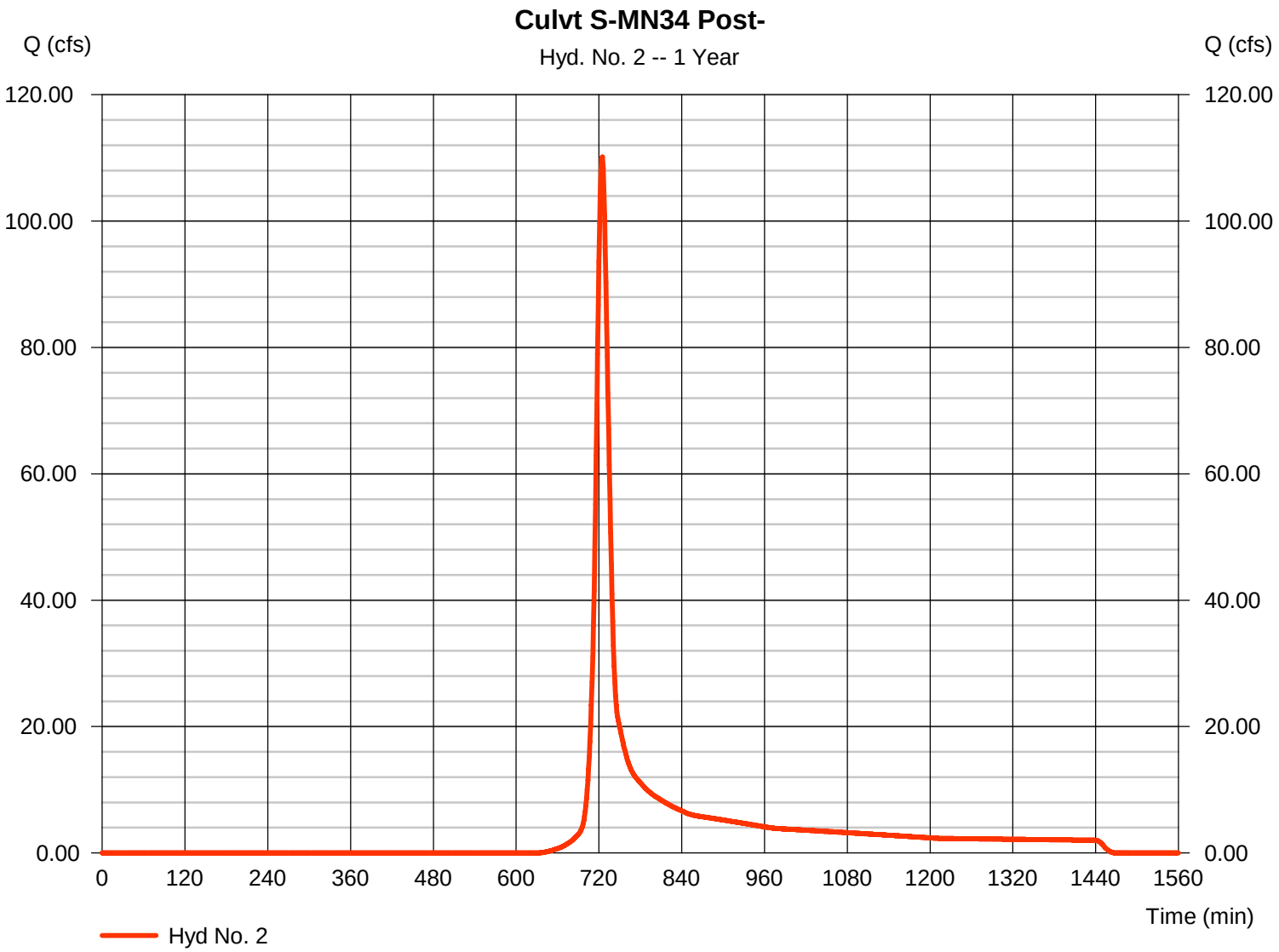
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 2

Culvt S-MN34 Post-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 110.12 cfs |
| Storm frequency | = 1 yrs | Time to peak | = 725 min |
| Time interval | = 1 min | Hyd. volume | = 336,284 cuft |
| Drainage area | = 87.490 ac | Curve number | = 77* |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 17.70 min |
| Total precip. | = 3.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

* Composite (Area/CN) = [(86.466 x 77) + (0.957 x 89) + (0.024 x 78) + (0.023 x 91) + (0.023 x 73)] / 87.490



# TR55 Tc Worksheet



## Hyd. No. 2

Culvt S-MN34 Post-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.50 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 48.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 10.03** | **+** | **0.00** | **+** | **0.00** | **=** | **10.03** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 891.83 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 46.20 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =10.97 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 1.36** | **+** | **0.00** | **+** | **0.00** | **=** | **1.36** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 2.25 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 5.50 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 13.20 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =9.91 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})3741.6 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 6.29** | **+** | **0.00** | **+** | **0.00** | **=** | **6.29** |

**Total Travel Time, Tc ..... 17.70 min**

# Hydrograph Report

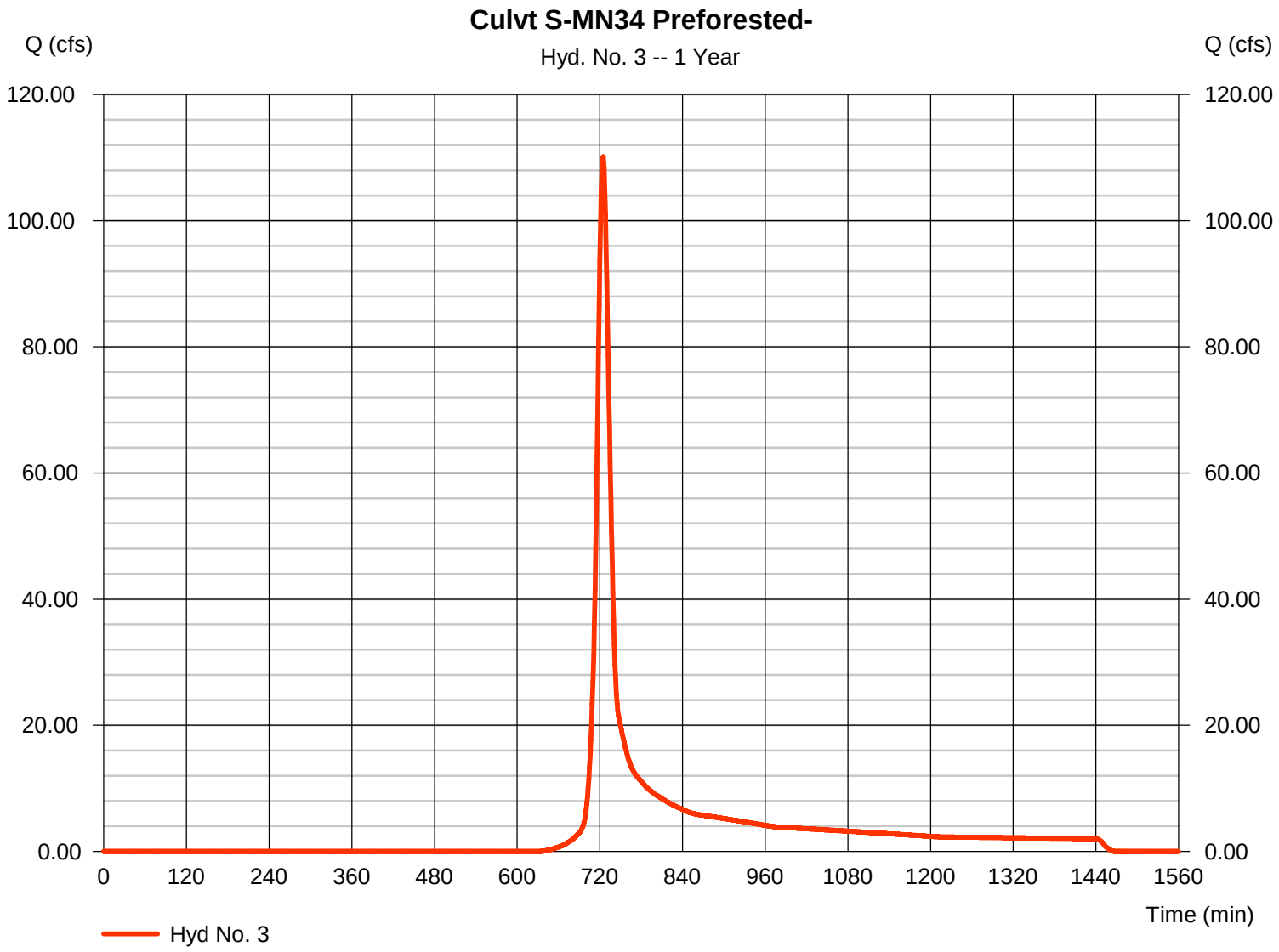
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 3

Culvt S-MN34 Preforested-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 110.12 cfs |
| Storm frequency | = 1 yrs | Time to peak | = 725 min |
| Time interval | = 1 min | Hyd. volume | = 336,284 cuft |
| Drainage area | = 87.490 ac | Curve number | = 77* |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 17.70 min |
| Total precip. | = 3.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

* Composite (Area/CN) = [(87.493 x 77)] / 87.490



# TR55 Tc Worksheet



## Hyd. No. 3

Culvt S-MN34 Preforested-

| Description | A | | B | | C | | Totals |
|---|---|---|---|---|---|---|---|
| **Sheet Flow** | | | | | | | |
| Manning's n-value | = 0.800 | | 0.011 | | 0.011 | | |
| Flow length (ft) | = 100.0 | | 0.0 | | 0.0 | | |
| Two-year 24-hr precip. (in) | = 3.50 | | 0.00 | | 0.00 | | |
| Land slope (%) | = 48.00 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 10.03** | **+** | **0.00** | **+** | **0.00** | **=** | **10.03** |
| **Shallow Concentrated Flow** | | | | | | | |
| Flow length (ft) | = 891.83 | | 0.00 | | 0.00 | | |
| Watercourse slope (%) | = 46.20 | | 0.00 | | 0.00 | | |
| Surface description | = Unpaved | | Unpaved | | Paved | | |
| Average velocity (ft/s) | =10.97 | | 0.00 | | 0.00 | | |
| **Travel Time (min)** | **= 1.36** | **+** | **0.00** | **+** | **0.00** | **=** | **1.36** |
| **Channel Flow** | | | | | | | |
| X sectional flow area (sqft) | = 2.25 | | 0.00 | | 0.00 | | |
| Wetted perimeter (ft) | = 5.50 | | 0.00 | | 0.00 | | |
| Channel slope (%) | = 13.20 | | 0.00 | | 0.00 | | |
| Manning's n-value | = 0.030 | | 0.015 | | 0.015 | | |
| Velocity (ft/s) | =9.91 | | | | | | |
| | | | 0.00 | | | | |
| | | | | | 0.00 | | |
| Flow length (ft) | ({0})3741.6 | | 0.0 | | 0.0 | | |
| **Travel Time (min)** | **= 6.29** | **+** | **0.00** | **+** | **0.00** | **=** | **6.29** |

**Total Travel Time, Tc ..... 17.70 min**

# Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

| Hyd. No. | Hydrograph type (origin) | Peak flow (cfs) | Time interval (min) | Time to Peak (min) | Hyd. volume (cuft) | Inflow hyd(s) | Maximum elevation (ft) | Total strge used (cuft) | Hydrograph Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | SCS Runoff | 278.12 | 1 | 724 | 823,566 | ------ | ------ | ------ | Culvt S-MN34 Pre- |
| 2 | SCS Runoff | 278.12 | 1 | 724 | 823,566 | ------ | ------ | ------ | Culvt S-MN34 Post- |
| 3 | SCS Runoff | 278.12 | 1 | 724 | 823,566 | ------ | ------ | ------ | Culvt S-MN34 Preforested- |

# Hydrograph Report

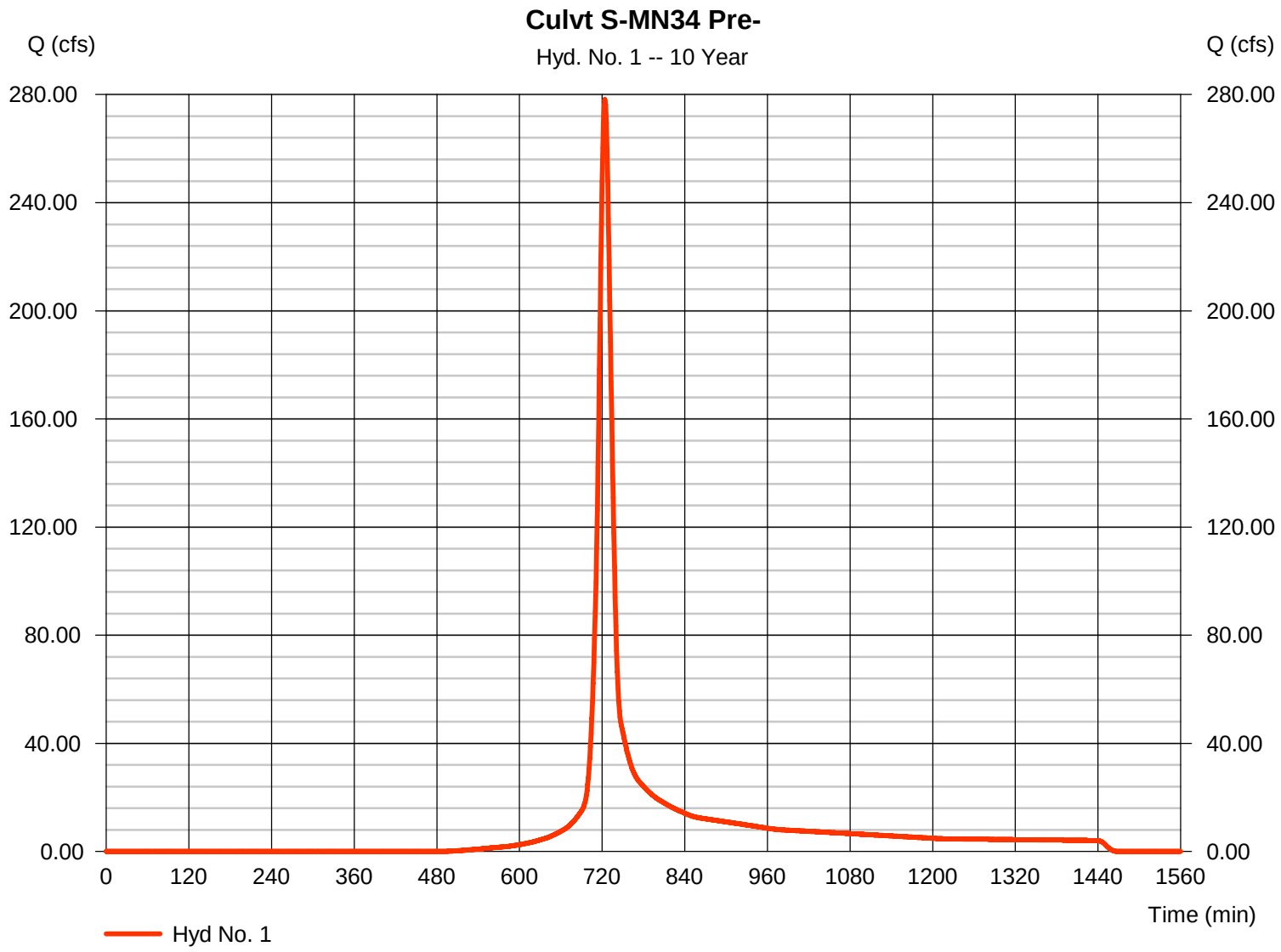
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 1

Culvt S-MN34 Pre-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 278.12 cfs |
| Storm frequency | = 10 yrs | Time to peak | = 724 min |
| Time interval | = 1 min | Hyd. volume | = 823,566 cuft |
| Drainage area | = 87.490 ac | Curve number | = 77* |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 17.70 min |
| Total precip. | = 5.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

* Composite (Area/CN) = [(86.537 x 77) + (0.957 x 89)] / 87.490



# Hydrograph Report

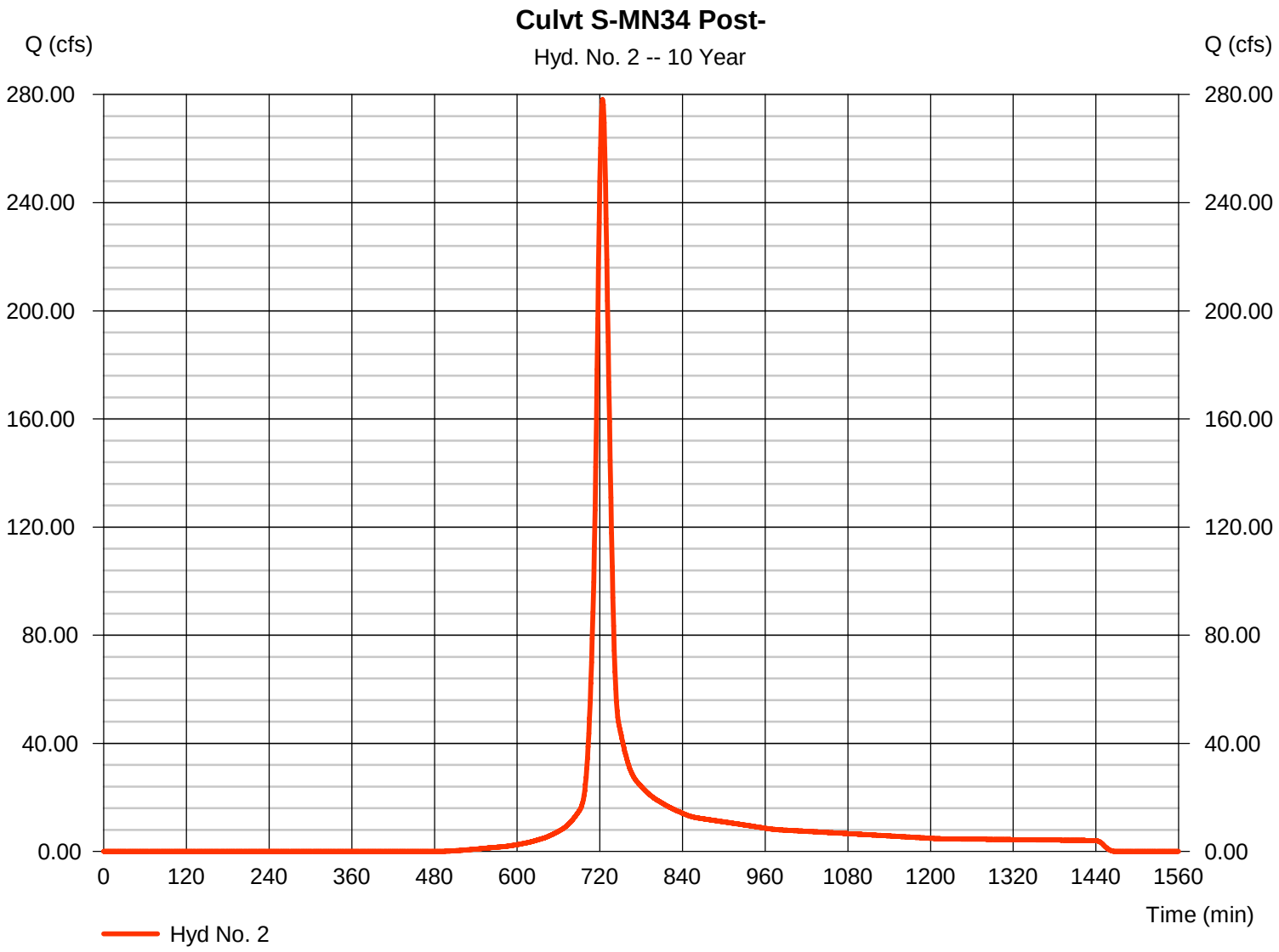
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 2

Culvt S-MN34 Post-

| | | | |
|---|---|---|---|
| Hydrograph type | = SCS Runoff | Peak discharge | = 278.12 cfs |
| Storm frequency | = 10 yrs | Time to peak | = 724 min |
| Time interval | = 1 min | Hyd. volume | = 823,566 cuft |
| Drainage area | = 87.490 ac | Curve number | = 77* |
| Basin Slope | = 0.0 % | Hydraulic length | = 0 ft |
| Tc method | = TR55 | Time of conc. (Tc) | = 17.70 min |
| Total precip. | = 5.00 in | Distribution | = Type II |
| Storm duration | = 24 hrs | Shape factor | = 484 |

* Composite (Area/CN) = [(86.466 x 77) + (0.957 x 89) + (0.024 x 78) + (0.023 x 91) + (0.023 x 73)] / 87.490



# Hydrograph Report

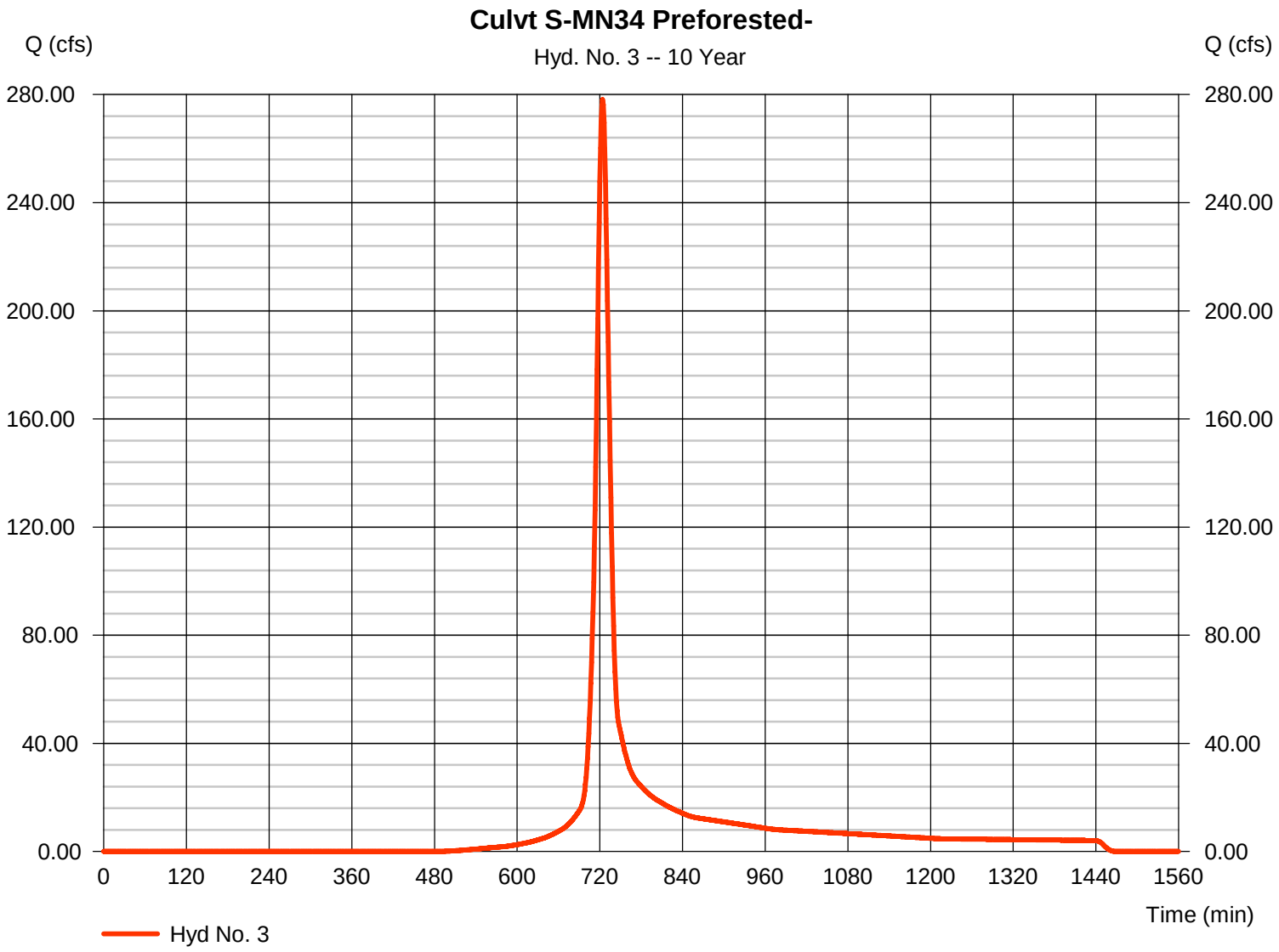
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11 Wednesday, 09 / 20 / 2017

## Hyd. No. 3

Culvt S-MN34 Preforested-

| | | | | | |
|---|---|---|---|---|---|
| Hydrograph type | = | SCS Runoff | Peak discharge | = | 278.12 cfs |
| Storm frequency | = | 10 yrs | Time to peak | = | 724 min |
| Time interval | = | 1 min | Hyd. volume | = | 823,566 cuft |
| Drainage area | = | 87.490 ac | Curve number | = | 77* |
| Basin Slope | = | 0.0 % | Hydraulic length | = | 0 ft |
| Tc method | = | TR55 | Time of conc. (Tc) | = | 17.70 min |
| Total precip. | = | 5.00 in | Distribution | = | Type II |
| Storm duration | = | 24 hrs | Shape factor | = | 484 |

* Composite (Area/CN) = [(87.493 x 77)] / 87.490



# Hydraflow Rainfall Report



| Return Period (Yrs) | Intensity-Duration-Frequency Equation Coefficients (FHA) | | | |
|---|---|---|---|---|
| | B | D | E | (N/A) |
| 1 | 0.0000 | 0.0000 | 0.0000 | -------- |
| 2 | 69.8703 | 13.1000 | 0.8658 | -------- |
| 3 | 0.0000 | 0.0000 | 0.0000 | -------- |
| 5 | 79.2597 | 14.6000 | 0.8369 | -------- |
| 10 | 88.2351 | 15.5000 | 0.8279 | -------- |
| 25 | 102.6072 | 16.5000 | 0.8217 | -------- |
| 50 | 114.8193 | 17.2000 | 0.8199 | -------- |
| 100 | 127.1596 | 17.8000 | 0.8186 | -------- |

File name: SampleFHA.idf

### Intensity = B / (Tc + D)^E

| Return Period (Yrs) | Intensity Values (in/hr) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 min | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.69 | 4.61 | 3.89 | 3.38 | 2.99 | 2.69 | 2.44 | 2.24 | 2.07 | 1.93 | 1.81 | 1.70 |
| 3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 6.57 | 5.43 | 4.65 | 4.08 | 3.65 | 3.30 | 3.02 | 2.79 | 2.59 | 2.42 | 2.27 | 2.15 |
| 10 | 7.24 | 6.04 | 5.21 | 4.59 | 4.12 | 3.74 | 3.43 | 3.17 | 2.95 | 2.77 | 2.60 | 2.46 |
| 25 | 8.25 | 6.95 | 6.03 | 5.34 | 4.80 | 4.38 | 4.02 | 3.73 | 3.48 | 3.26 | 3.07 | 2.91 |
| 50 | 9.04 | 7.65 | 6.66 | 5.92 | 5.34 | 4.87 | 4.49 | 4.16 | 3.88 | 3.65 | 3.44 | 3.25 |
| 100 | 9.83 | 8.36 | 7.30 | 6.50 | 5.87 | 5.36 | 4.94 | 4.59 | 4.29 | 4.03 | 3.80 | 3.60 |

Tc = time in minutes. Values may exceed 60.

- Mark Sladic\EQT\Project\112IC07157 MVP\Virginia Stormwater\Culvert Design - Other\Culvert S-MN34\Roanoke.pcp

| Storm Distribution | Rainfall Precipitation Table (in) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-yr | 2-yr | 3-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| SCS 24-hour | 3.00 | 0.00 | 0.00 | 0.00 | 5.00 | 6.00 | 0.00 | 0.00 |
| SCS 6-Hr | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-1st | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-2nd | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-3rd | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-4th | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Huff-Indy | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Custom | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**ENERGY BALANCE METHOD**

**Inputs:**

| | 1-Yr Event | |
|---|---|---|
| | Peak Flow, Q (cfs) | Runoff Volume, RV (cf) |
| Pre-Developed Condition | 110.120 | 336,284 |
| Developed Condition | 110.120 | 336,284 |
| Pre-Developed (Forest) Condition | 110.120 | 336,284 |

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

**Calculations:**

[1] ***Check #1:*** $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 110.120 ≤ 110.120 OK

***Check #2:*** $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 110.120 ≤ 110.120 OK

***Check #3:*** $Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 110.120 *shall not* be required to be ≤ 110.120

## STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

[1] Per VADEQ, the improvement factor can be waived if the road is being maintained within the current footprint.

# HY-8 Culvert Analysis Report

## Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 278.12 cfs

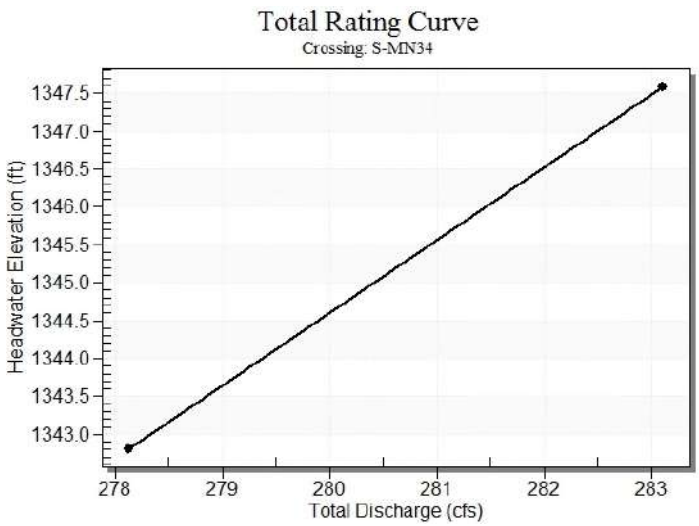
Design Flow: 278.12 cfs

Maximum Flow: 278.12 cfs

## Table 1 - Summary of Culvert Flows at Crossing: S-MN34

| Headwater Elevation (ft) | Total Discharge (cfs) | Culvert S-MN34 Discharge (cfs) | Roadway Discharge (cfs) | Iterations |
|---|---|---|---|---|
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.81 | 278.12 | 278.12 | 0.00 | 1 |
| 1342.90 | 283.11 | 283.11 | 0.00 | Overtopping |

## Rating Curve Plot for Crossing: S-MN34



## Table 2 - Culvert Summary Table: Culvert S-MN34

| Total Discharge (cfs) | Culvert Discharge (cfs) | Headwater Elevation (ft) | Inlet Control Depth (ft) | Outlet Control Depth (ft) | Flow Type | Normal Depth (ft) | Critical Depth (ft) | Outlet Depth (ft) | Tailwater Depth (ft) | Outlet Velocity (ft/s) | Tailwater Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |
| 278.12 | 278.12 | 1342.81 | 5.230 | 3.820 | 5-S2n | 1.805 | 3.089 | 2.266 | 2.065 | 13.287 | 15.602 |

**********

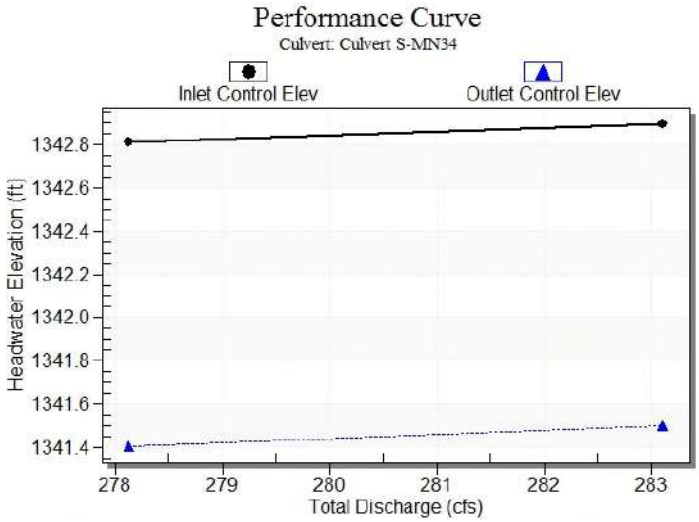
Straight Culvert

Inlet Elevation (invert): 1337.58 ft, Outlet Elevation (invert): 1336.74 ft

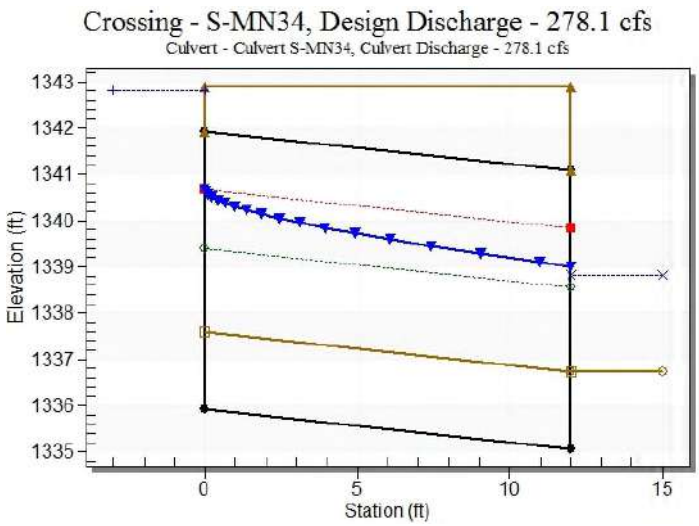
Culvert Length: 12.03 ft, Culvert Slope: 0.0701

**********

## Culvert Performance Curve Plot: Culvert S-MN34



## Water Surface Profile Plot for Culvert: Culvert S-MN34




## Site Data - Culvert S-MN34

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1335.92 ft

Outlet Station: 12.00 ft

Outlet Elevation: 1335.08 ft

Number of Barrels: 1

## Culvert Data Summary - Culvert S-MN34

Barrel Shape: Concrete Box

Barrel Span: 9.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 20.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: None

## Table 3 - Downstream Channel Rating Curve (Crossing: S-MN34)

| Flow (cfs) | Water Surface Elev (ft) | Depth (ft) | Velocity (ft/s) | Shear (psf) | Froude Number |
|---|---|---|---|---|---|
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |
| 278.12 | 1338.81 | 2.07 | 15.60 | 9.03 | 2.33 |

### Tailwater Channel Data - S-MN34

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.50 ft

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0701

Channel Manning's n: 0.0300

Channel Invert Elevation: 1336.74 ft

### Roadway Data for Crossing: S-MN34

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 1342.90 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft