Mile High USDCM Method

Appendix C Table Riprap Arpon Sizing - East Pond Southwest Rundown

	High Mesa Trail Offsi	te
Culvert Diameter (ft)	Dc	3
Normal Depth	Yn	2.1
Design Discharge	Q	127.5
Tailwater depth	Yt	2.10
	Q/D^1.5	24.5
	Da	2.6
Riprap size	D50 (ft)	0.9
Riprap size	D50 (in)	11
	Yt/Da	0.8
	Q/Da^1.5	31

BOX HEIGHT	D	<u>₩•</u>	L
18" - 24"	1'-0"	4'	15
30" - 36"	1'-6"	6'	20
42" - 48"	2'-0"	7*	24
54" - 60"	2'-6"	8'	28
66" - 72"	3'-0"	9"	32

Figure 9-37. Low tailwater riprap basin

_	31	Q/Da^1.5	
Should be below equal or less than 6 to use figure 9-38.	12.3	Q/Da^2.5	Check:
		Type H	From Figure 9-38
		0.9	D50 (ft)
	Thickness (ft)	1.7	T
	Thickness (in)	21	T

Depth of pool = 3', at 3:1 slopes = plunge pool bottom = 9' bottom, total = 32'.

3.2.3 Rock Sizing for Riprap Apron and Low Tailwater Basin

Scour resulting from highly turbulent, rapidly decelerating flow is a common problem at conduit outlets. The following section summarizes the method for sizing riprap protection for both riprap aprons (Section 3.2.1) and low tailwater basins (Section 3.2.2).

Use Figure 9-38 to determine the required rock size for circular conduits and Figure 9-39 for rectangular conduits. Figure 9-38 is valid for $Q/D_c^{1.3}$ of 6.0 or less and Figure 9-39 is valid for $Q/WH^{1.3}$ of 8.0 or less. The parameters in these two figures are:

- 1. $Q/D^{1.5}$ or $Q/WH^{0.5}$ in which Q is the design discharge in cfs, D_c is the diameter of a circular conduit in feet, and W and H are the width and height of a rectangular conduit in feet.
- 2. Y/D_c or Y/H in which Y_c is the tailwater depth in feet. D_c is the diameter of a circular conduit in feet. and H is the height of a rectangular conduit in feet. In cases where Y_t is unknown or a hydraulic jump is suspected downstream of the outlet, use $Y_t/D_t = Y_t/H = 0.40$ when using Figures 9-38 and 9-39.
- The riprap size requirements in Figures 9-38 and 9-39 are based on the non-dimensional parametric Equations 9-16 and 9-17 (Steven, Simons, and Watts 1971 and Smith 1975).

Circular culvert:

$$d_{s0} = \frac{0.023Q}{V_1^{1/2}D_c^{0.3}}$$

Rectangular culvert:

$$d_s = \frac{0.014H^{0.5}Q}{Y,W}$$
 Equation 9-17

These rock size requirements assume that the flow in the culvert is subcritical. It is possible to use Equations 9-16 and 9-17 when the flow in the culvert is supercritical (and less than full) if the value of D_c or H is modified for use in Figures 9-38 and 9-39. Note that rock sizes referenced in these figures are defined in the Open Channels chapter. Whenever the flow is supercritical in the culvert, substitute D_c for D_c and H_a for H_a , in which D_a is defined as:

$$D_a = \frac{\left(D_c + Y_a\right)}{2}$$
 Equation 9-18

Where the maximum value of D_a shall not exceed D_c , and



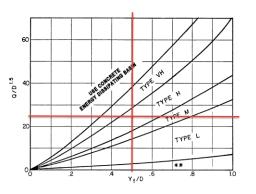


Figure 9-38. Riprap erosion protection at circular conduit outlet (valid for Q/D2.5 ≤ 6.0)

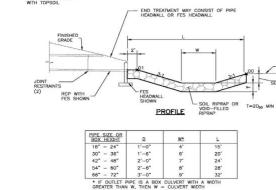


Figure 9-37. Low tailwater riprap basin



ASTM International (ASTM): D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³)).

1.04 SUBMITTALS

- CONTRACTOR shall cooperate with ENGINEER in obtaining and providing samples of all specified materials.
- B. CONTRACTOR shall submit certified laboratory test certificates for all items

PART 2 PRODUCTS

2.01 MATERIALS

A. RIPRAP

Riprap used shall be the type designated on the DRAWINGS and shall conform to Table 1.

Table 1: Riprap Gradation

Riprap Designation	% Smaller Than Given Size By Weight	Intermediate Rock Dimension (inches)	d50* (inches)
Type VL	70 - 100 50 - 70 35 - 50 2 - 10	12 9 6 2	6**
Type L	70 - 100 50 - 70 35 - 50 2 - 10	15 12 9 3	9**
Type M	70 - 100 50 - 70 35 - 50 2 - 10	21 18 12 4	12**
Туре Н	70 - 100 50 - 70 35 - 50 2 - 10	30 24 18 6	18
Type VH	70 - 100 50 - 70 35 - 50 2 - 10	41 33 24 9	24

**Mix VL, L and M riprap with 35% topsoil (by volume) and bury it with 4 to 6 inches of topsoil, all vibration compacted, and revegetate.

31 37 00 - 2

3.2.2 Low Tailwater Basin

The design of low tailwater riprap basins is necessary when the receiving channel may have little or no flow or tailwater at time when the pipe or culvert is in operation. Figure 9-37 provides a plan and profile view of a typical low tailwater friprap basin.

By providing a low tailwater basin at the end of a storm drain conduit or culvert, the kinetic energy of the discharge dissipates under controlled conditions without causing scour at the channel bottom.

Low tailwater is defined as being equal to or less than 1/2 of the height of the storm drain, that is:

$$y_i \le \frac{D}{3}$$
 or $y_i \le \frac{H}{3}$

 y_i = tailwater depth at design flow (feet)

D = diameter of circular pipe (feet)

H = height of rectangular pipe (feet)

Rock Size
The procedure for determining the required riprap size downstream of a conduit outlet is in Section 3.2.3. After selecting the riprap size, the minimum thickness of the riprap layer, T, in feet, in the basin is defined

$$T = 2D_{so}$$
 Equation 9-15

Basin Geometry
Figure 9-37 includes a layout of a standard low tailwater riprap basin with the geometry parameters
provided. The minimum length of the basin (L) and the width of the bottom of the basin (W1) are
provided in a table at the bottom of Figure 9-37. All slopes in the low tailwater basin shall be 3(H): {V},
minimum.

Other Design Requirements

Extend riprap up the outlet embankment slope to the mid-pipe level, minimum. It is recommended that riprap that extends more than 1 foot above the outlet pipe invert be installed 6 inches below finished grad and buried with topsoil.

Provide pipe end treatment in the form of a pipe headwall or a flared-end section headwall. See Section 3.1 for options.

Mile High USDCM Method

Appendix C Table Riprap Arpon Sizing - East Pond South Rundown

High Mesa Trail Offsite		
Culvert Diameter (ft)	Dc	1.5
Normal Depth	Yn	0.85
Design Discharge	Q	14.8
Tailwater depth	Yt	0.85
	Q/D^1.5	8.1
	Da	1.2
Riprap size	D50 (ft)	0.37
Riprap size	D50 (in)	5
	Yt/Da	0.7
	O/D=44 F	10

BOX HEIGHT	D	<u>W*</u>	L
18" - 24"	1'-0"	4'	15'
30" - 36"	1'-6"	6'	20
42" - 48"	2'-0"	7*	24
54" - 60"	2'-6"	8*	28'
66" - 72"	3'-0"	9"	32'



Should be below equal or less than 6 to use figure 9-38.

Figure 9-37. Low tailwater riprap basin

Check:	Q/Da^2.5	9.9
From Figure 9-38	Type L	
D50 (ft)	0.4	
T	0.7	Thickness (ft)

Depth of pool = 1', at 3:1 slopes = plunge pool bottom = 4' bottom, total = 10'.

3.2.3 Rock Sizing for Riprap Apron and Low Tailwater Basin

Scour resulting from highly turbulent, rapidly decelerating flow is a common problem at conduit outlets. The following section summarizes the method for sizing riprap protection for both riprap aprons (Section 3.2.1) and low tailwater basins (Section 3.2.2).

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- The riprap size requirements in Figures 9-38 and 9-39 are based on the non-dimensional parametric Equations 9-16 and 9-17 (Steven, Simons, and Watts 1971 and Smith 1975).

Circular culvert:

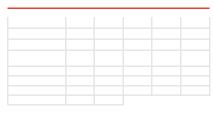
$$d_{\rm N} = \frac{0.023 Q}{\gamma_{\rm f}^{12} D_{\rm c}^{0.1}} \label{eq:deltaN}$$
 Equation 9-16

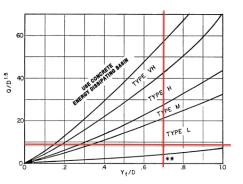
$$d_n = \frac{0.014 H^{0.5} Q}{Y_i W}$$
 Equation 9-17

These rock size requirements assume that the flow in the culvert is subcritical. It is possible to use Equations 9-16 and 9-17 when the flow in the culvert is supercritical (and less than full) if the value of D_c or H is modified for use in Figures 9-38 and 9-39. Note that rock sizes referenced in these figures are defined in the Open Channels chapter. Whenever the flow is supercritical in the culvert, substitute D_c for D_c and H_c for H_c in which D_c is defined as:

$$D_{u} = \frac{\left(D_{c} + Y_{n}\right)}{2}$$
 Equation 9-18

Where the maximum value of D_a shall not exceed D_c , and





Use D_a instead of D whenever flow is supercritical in the barrel. **Use Type L for a distance of 3D downstream.

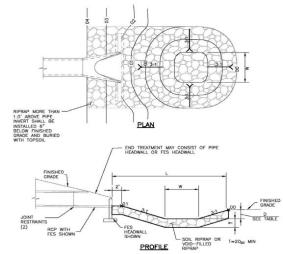


Figure 9-37. Low tailwater riprap basin

Figure 9-38. Riprap erosion protection at circular conduit outlet (valid for Q/D2.5 $\leq 6.0)$



ASTM International (ASTM): D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³)).

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 y_t = tailwater depth at design flow (feet)

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H = height of rectangular pipe (feet)

Rock Size The procedure for determining the required riprap size downstream of a conduit outlet is in Section 3.2.3.

After selecting the riprap size, the minimum thickness of the riprap layer, T, in feet, in the basin is defined

$$T=2D_{\rm S0} \hspace{1.5cm} {\rm Equation} \hspace{0.1cm} 9\text{-}15$$

Basin Geometry
Figure 9-37 includes a layout of a standard low tailwater riprap basin with the geometry parameters
provided. The minimum length of the basin (L) and the width of the bottom of the basin (W1) are
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Provide pipe end treatment in the form of a pipe headwall or a flared-end section headwall. See Section 3.1 for options.