Storm Drain Outlet Protection - OP

DEFINITION

Paved and/or riprapped channel treatment, placed below storm drain outlets.

PURPOSE

To reduce storm water velocity and dissipate the energy of flow leaving a storm drain before it empties into receiving channels, and to armor erodible materials.

CONDITIONS

This standard applies to all storm drain outlets, road culverts, paved channel outlets, etc., discharging into natural or constructed channels. Treatment will extend between the points where flow exits the storm drain and where flow velocity and/or flow energy from the design storm event is dissipated to the degree where there is minimal to no risk of erosion of the receiving channel.

DESIGN CRITERIA

Structurally lined aprons at the outlets of pipes and paved channel sections should be designed by professionals familiar with storm water conveyance systems and according to the following criteria:

Capacity: The structure should be designed to handle the peak storm flow (Q), in cubic feet per second (cfs), from the 25-year, 24-hour frequency storm, or the design discharge of the water conveyance structure, whichever is greater.

Tailwater Depth: The design depth of thetailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. If the tailwater depth is less than half the diameter of the outlet pipe, it should be classified as a low tailwater condition. If the tailwater depth is greater than half the pipe diameter, it should be classified as a high tailwater condition. Pipes which outlet onto flat areas with no defined channel may be assumed to have a low tailwater condition.

Materials: The apron may be lined with riprap, grouted riprap, or concrete. The median sized stone for riprap (d_{5o}) should be determined according to tailwater conditions described in Table 1. Maximum stone size is equal to 1.5 times the d_{50} value. The gradation, quality and placement of riprap should conform to the specifications in **Riprap – RR.**

Apron Length (L_A): The apron length should be determined according to tailwater conditions described in Table 1.

Apron Width (W_A): See Figure 1. If the pipe discharges directly into a well-defined channel, the apron should extend across the channel bottom and up the channel banks to an elevation one foot above the high tailwater depth or to the top of the bank (whichever is less). If the pipe discharges onto a flat area with no defined channel, the width of the apron should be determined as follows:

1. The upstream end of the apron, adjacent to the pipe, should have a width three times the diameter of the outlet pipe.
2. For a low tailwater conditions, the downstream end of the apron should have a width equal to the pipe diameter plus the length of the apron.
3. For a high tailwater conditions, the down stream end should have a width equal to the pipe diameter plus 0.4 times the length of the apron.

Bottom Grade: The apron should be constructed with no slope along its length (0.0% grade). The invert elevation of the downstream end of the apron should be equal to the elevation of the invert of the receiving channel. There should be no turbulence at the end of the apron.

Side Slope: If the pipe discharges into a well-defined channel, the side slopes of the channel should not be steeper than 2:1.

Alignment: The apron should be located so that there are no bends in the horizontal alignment.

Geotextile: Geotextiles should be used as a separator between the graded stone, the soil base, and the abutments. The geotextile will prevent the migration of soil particles from the subgrade into the graded stone. The geotextile should be placed in direct contact with the subgrade without any voids. Refer to specification **Geotextile – GE.**

Energy Dissipaters and Stilling Basins: Structural controls, generally made from precast concrete or from pour-in-place concrete, should be used whenever concrete aprons are installed. The design of the energy dissipaters and stilling basins shown in Figure 2 are discussed in the Federal Highways Administration (FHWA) publication HEC- 14, Hydraulic Design of Energy Dissipaters for Culverts and Channels.

Stilling basins are used to convert flows from supercritical to subcritical flow rates by allowing a hydraulic jump to occur. The stilling basin allows a controlled hydraulic jump to occur within the structure over a wide range of flow conditions and depths. A professional engineer using hydraulic computations must design energy dissipaters and stilling basins. A primary concern for both energy dissipaters and stilling basins is whether sediment and trash can accumulate. TDOT drawing standards include a riprap basin energy dissipater, based upon procedures in HEC- 14. The United States Bureau of Reclamation (USBR) also has developed many designs of such structures.

CONSTRUCTION SPECIFICATIONS

1. Ensure that the subgrade for the geotextile and riprap follows the required lines and grades shown in the plan. Compact any fill required in the subgrade to the density of the surrounding undisturbed material. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.
2. Geotextile - Install a geotextile liner to prevent soil movement through the

openings in the riprap. Refer to specification **Geotextile – GE**.

3. Geotextile must meet design requirements and be properly protected from punching or tearing during installation. Repair any damage by removing the riprap and placing another piece of geotextile over the damaged area. All connecting joints should overlap a minimum of 1 foot. If the damage is extensive, replace the entire geotextile liner.
4. Riprap may be placed by equipment, but take care to avoid damaging the geotextile.
5. The minimum thickness of the riprap should be 1.5 times the maximum stone diameter, but not less than 6".
6. The outlet structure must conform to the specified grading limits shown on the plans.
7. Construct the apron on zero grade with no turbulence at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.
8. Ensure that the apron is properly aligned with the receiving stream and, preferably, straight throughout its length.
9. Immediately after construction, stabilize all disturbed areas with vegetation.
10. Stone quality - Select stone for riprap from fieldstone or quarry stone. The stone should be hard, angular, and highly weather-resistant. The specific gravity of the individual stones should be at least 2.5. Refer to specification **Riprap – RR**.

MAINTENANCE

Inspect riprap outlet structures after heavy rains to see if any erosion around or below the riprap has taken place or if stones have been dislodged. Immediately make all needed repairs to prevent further damage.

Riprap Outlet Protection Specifications

This table is intended to select two parameters for the design of riprap outlet protection, based upon outlet velocities that correspond with circular culverts flowing full. Flow values less than the lowest value for the culvert size usually indicate a full-flow velocity less than 5 feet per second, for which riprap is usually not necessary. Flow values more than the highest value for the culvert size usually indicates that a concrete stilling basin or energy dissipater structure is necessary.

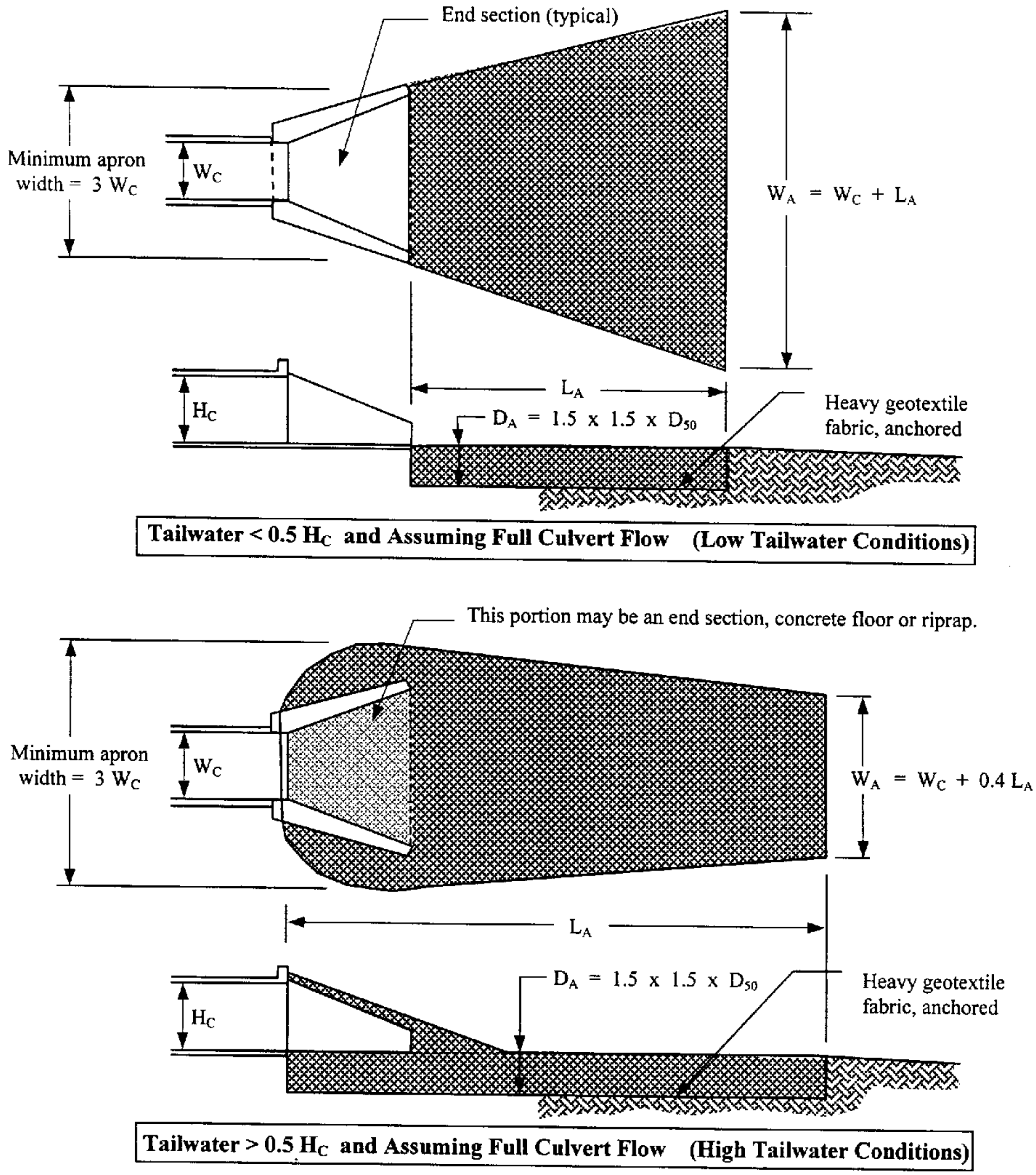
Adjust values upward if the circular culvert is not flowing full based upon outlet conditions. For noncircular pipe, convert into an equivalent cross-sectional area of circular culvert to continue design.

Riprap Aprons for Low Tailwater (downstream flow depth < 0.5 x pipe diameter)															
Culvert Diameter	Lowest value			Intermediate values to interpolate from									Highest value		
	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}
	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In
12"	4	7	2.5	6	10	3.5	9	131	6	12	16	7	14	17	8.5
15"	6.5	8	3	10	12	5	15	16	7	20	18	10	25	20	12
18"	10	9	3.5	15	14	5.5	20	17	7	30	22	11	40	25	14
21"	15	11	4	25	18	7	35	22	10	45	26	13	60	29	18
24"	21	13	5	35	20	8.5	50	26	12	65	30	16	80	33	19
27"	27	14	5.5	50	24	9.5	70	29	14	90	34	18	110	37	22
30"	36	16	6	60	25	9.5	90	33	15.5	120	38	20	140	41	24
36"	56	20	7	100	32	13	140	40	18	180	45	23	220	50	28
42"	82	22	8.5	120	32	12	160	39	17	200	45	20	260	52	26
48"	120	26	10	170	37	14	220	46	19	270	54	23	320	64	37
Riprap Aprons for High Tailwater (downstream flow depth > 0.5 x pipe diameter)															
Culvert Diameter	Lowest value			Intermediate values to interpolate from									Highest value		
	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}	Q	L_A	D_{50}
	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In	Cfs	Ft	In
12"	4	8	2	6	18	2.5	9	28	4.5	12	36	7	14	40	8
15"	7	8	2	10	20	2.5	15	34	5	20	42	7.5	25	50	10
18"	10	8	2	15	22	3	20	34	5	30	50	9	40	60	11
21"	15	8	2	25	32	4.5	35	48	7	45	58	11	60	72	14
24"	20	8	2	35	36	5	50	55	8.5	65	68	12	80	80	15
27"	27	10	2	50	41	6	70	58	10	90	70	14	110	82	17
30"	36	11	2	60	42	6	90	64	11	120	80	15	140	90	18
36"	56	13	2.5	100	60	7	140	85	13	180	104	18	220	120	23
42"	82	15	2.5	120	50	6	160	75	10	200	96	14	260	120	19
48"	120	20	2.5	170	58	7	220	85	12	270	105	16	320	120	20

Table 1

Source: Knoxville Engineering Department

Riprap Outlet Protection



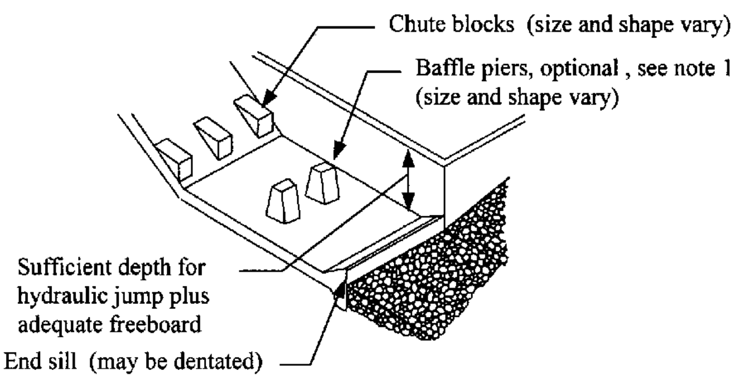
NOT TO SCALE

H_C = height of culvert
W_C = width of culvert
L_A = length of riprap apron
W_A = width of riprap apron at end
D_{50} = median riprap size
D_{MAX} = maximum size of riprap = 1.5 D_{50}
D_A = depth of riprap apron = 1.5 D_{MAX}

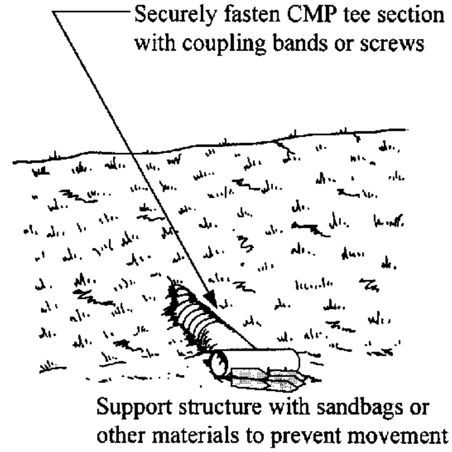
Figure 1

Source: Knoxville Engineering Department

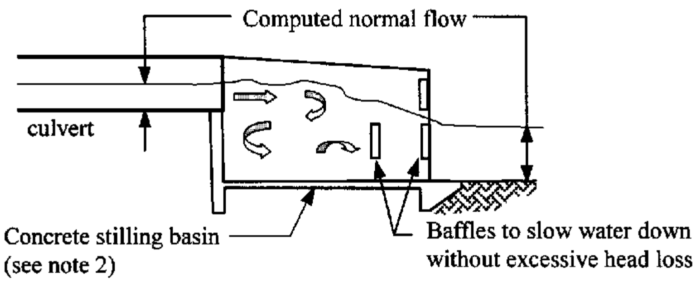
Various Energy Dissipaters and Stilling Basins



Typical Stilling Basin At End of Paved Flume or Chute



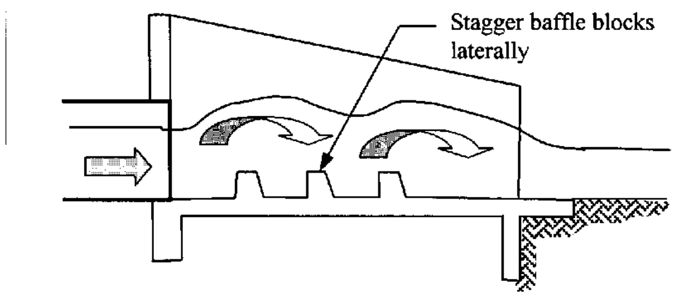
Temporary CMP Energy Dissipator



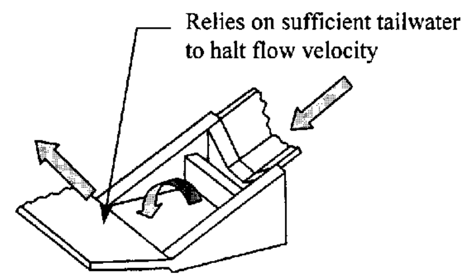
Typical Stilling Basin Using Baffles and Elevation Drop

Notes:

1. This is the basic format for several types of stilling basins. USBR Type II basin does not contain baffle piers, but does have a dentated end sill. USBR Type III basin has baffle piers and a smooth undentated end sill. See HEC-14 for detailed design of concrete structures.
2. Concrete stilling basin should be approximately as wide as the downstream channel. Design baffles to retain sufficient stormwater to act as a plunge pool for a wide range of flow values.



Typical Energy Dissipator – Baffle Blocks Within Headwall



Typical Impact Energy Dissipater (Virginia DOT)

Figure 2

Source: Knoxville Engineering Department