NATURAL RESOURCES CONSERVATION SERVICE
ILLINOIS URBAN MANUAL
PRACTICE STANDARD

Rock Outlet Protection

(no.)
Code 910

Source: USDA-NRCS – Illinois

Definition

A section of rock protection placed at the outlet end of culverts, conduits, or channels.

Purpose

The purposes of this practice are to prevent scour erosion at stormwater outlets, to protect the outlet structure, and to minimize the potential for downstream erosion by reducing the velocity and energy of concentrated stormwater flows. The practice also reduces the effects of turbidity and sedimentation downstream.

Conditions Where Practice Applies

This practice applies where discharge velocities and energies at the outlets of culverts, conduits, or channels are sufficient to erode the receiving channel or area. This applies to:

1. Culvert outlets of all types
2. Pipe conduits from all sediment basins, dry and wet basin detention storm water ponds
3. New channels constructed as outlets for culverts and conduits

4. Where outflows from conduits or channels do not exceed 10 fps

The design of structurally lined aprons at the outlet of pipes and paved channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous rock linings of channels or streams.

The design of rock outlet protection depends entirely on the location. Pipe outlets at the top of cuts or on slopes steeper than 10 percent cannot be protected by rock aprons or riprap sections due to reconcentration of flows and high velocities encountered after the flow leaves the apron.

Criteria

Tailwater Depth – Depth of tailwater 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 and the receiving stream is wide enough to accept divergence of the flow, it shall be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than half the pipe diameter and the receiving stream will continue to confine the flow, it shall be classified as a Maximum Tailwater Condition. Pipes which outlet onto a flat area with no defined channel will be assumed to have a Minimum Tailwater Condition.

Apron Length – Apron length (La) shall be determined from Table 2 according to the appropriate tailwater condition and velocity out of the conduits.

Apron Width – When the pipe discharges directly into a well-defined channel, the apron shall extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank, whichever is less.

If the pipe discharges onto a flat area with no defined channels, the following criteria will be followed. Apron width will be 3 times the pipe diameter at the upstream location. The downstream width will be the pipe diameter plus the apron length for pipes with minimum tailwater conditions and the pipe diameter plus 0.4 times the apron length for pipes flowing under maximum tailwater conditions.

Bottom Grade – The outlet protection apron shall be constructed with no slope (0.0% grade) along its length. There shall be no overfall at the end of the apron. The elevation of the downstream end of the apron shall be equal to the elevation of the receiving channel or adjacent ground.

Alignment – Outlet protection apron shall be located so that there are no bends in the horizontal alignment.

Materials – Outlet protection may be done using rock riprap, concrete block or gabions.

Thickness – The maximum thickness of the riprap layer shall be 1.5 times the maximum stone diameter for d_{50} of 15 inches or less; and 1.2 times the maximum stone size for d_{50} greater than 15 inches. Table 1 lists some examples.

Stone Quality – Stone for riprap shall consist of field stone or rough unhewn quarry stone. The stone shall be hard and angular and a quality that will not disintegrate on exposure to water or weathering. The specific gravity of the individual stones shall be at least 2.5.

The median size stone for riprap shall be determined from Tables 1 and 2 for the material specified for the tailwater condition present. The placement of the riprap shall conform to Construction Specification LOOSE ROCK RIPRAP 61.

Recycled concrete equivalent may be used provided it has a density of at least 150 pounds per cubic foot, and does not have any exposed steel or reinforcing bars.

Filter Fabric – In all cases, filter fabric shall be placed between the riprap and the underlying soil to protect soil movement into and through the riprap. The material must meet or exceed requirements specified in Material Specification GEOTEXTILE 592, Table 1 or 2, Class I, II, or III.

Gabions – Shall be made of hexagonal triple twist mesh with heavily galvanized steel wire. Gabions shall be fabricated in such a manner that the sides, ends, and lid can be assembled at the construction site into mats of the specified sizes. The mats shall be a minimum of 9 inches thick.

The area on which the gabion is to be installed shall be graded as shown on the drawings. Foundation conditions shall be the same as for placing rock riprap. Where required, a cut off may be needed to prevent undermining of the main gabion structure. Gabions shall meet the requirements for installation as shown in Construction Specification WIRE MESH GABIONS 64.

Considerations

The outlets of channels, conduits and other structures are points of high erosion potential, because they frequently carry flows at velocities that exceed the allowable limit for the area downstream. To prevent scour and undermining, an outlet stabilization structure is needed to absorb the impact of the flow and reduce the velocity to non-erosive levels. A riprap-lined apron is the most commonly used practice for this purpose because of its relatively low cost and ease of installation. The riprap apron should be extended downstream until stable conditions are reached even though this may exceed the length calculated for design velocity control.

Riprap – Stilling basins or plunge pools reduce flow velocity rapidly. They should be considered in lieu of aprons where overfalls exit at the ends of pipes or where high flows would require excessive apron length. Consider other energy dissipaters such as concrete impact basins or paved outlet structures when conduits are flowing more than 10 fps. These will require a special design and Table 2 cannot be used.

Plans and Specifications

Plans and specification for installing rock outlet protection shall be in keeping with this standard and will describe the requirements for applying the practice to achieve its intended purpose. At a minimum include the following:

1. Location where the practice will be installed
2. Dimensions of the practice
3. Plan view, profile and cross section of each channel reach between the storm drain outlet under consideration and the existing publicly maintained system or the natural stream channel receiving the discharge flow
4. Rock size and thickness
5. Fabric specifications

All plans shall include the installation, inspection, and maintenance schedules with the responsible party clearly identified.

Standard Drawing PIPE OUTLET TO FLAT AREA IL-610 or PIPE OUTLET TO CHANNEL IL-611 may be used as the plan sheet.

Operation and 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.

Table 1
Rock Riprap Sizes and Thicknesses

IDOT Gradation Number	d_{50} (in.)	d_{max} (in.)	Minimum Blanket Thickness (in.)
RR-3[1]	5	10	15
RR-4	9	14	20
RR-5	12	19	28
RR-6	15	22	32
RR-7	18	27	32

[1]Concrete block may be used to replace RR-3

Table 2
Minimum IDOT Rock Sizes and Apron Length for Maximum and Minimum Tailwater Conditions

Culvert Diameter (in.)	Minimum Tailwater				Maximum Tailwater			
	5 fps[1]		10 fps[1]		5 fps[1]		10 fps[1]	
	Rock Gradation	L_a (ft.)	Rock Gradation	L_a (ft.)	Rock Gradation	L_a (ft.)	Rock Gradation	L_a (ft.)
12	No. 3	10	No. 3	12	No. 3	12	No. 3	15
18	No. 3	14	No. 4	16	No. 3	12	No. 3	16
24	No. 3	16	No. 4	20	No. 3	14	No. 4	17
30	No. 3	18	No. 4	22	No. 3	16	No. 4	20
36	No. 4	20	No. 5	24	No. 3	16	No. 4	22
48	No. 4	24	No. 6	28	No. 4	20	No. 4	24
60	No. 5	32	No. 6	36	No. 4	22	No. 5	26
72	No. 6	40	No. 6	44	No. 5	24	No. 5	29
96	No. 7	50	No. 7	54	No. 5	26	No. 5	32

[1]Maximum conduit velocity fps.

Rock Gradation source: Illinois Department of Transportation, 1997.