

## CHAPTER 5

### EROSION CONTROL AND RIPRAP PROTECTION

#### 5-1 PLANNING AND DESIGN CONSIDERATIONS

5-1.1 Hydraulic structures discharging into open channels will be provided with riprap protection to prevent erosion. Two general types of channel instability can develop downstream from a culvert and storm drain outlet. The conditions are known as either gully scour or a localized erosion referred to as a scour hole. Distinction between the two conditions of scour and prediction of the type to be anticipated for a given field situation can be made by a comparison of the original or existing slope of the channel or drainage basin downstream of the outlet relative to that required for stability.

5-1.2 Gully scour is to be expected when the Froude number of flow in the channel exceeds that required for stability. It begins at a point downstream where the channel is stable and progresses upstream. If sufficient differential in elevation exists between the outlet and the section of stable channel, the outlet structure will be completely undermined. Erosion of this type may be of considerable extent depending upon the location of the stable channel section relative to that of the outlet in both the vertical and downstream directions.

5-1.3 A scour hole or localized erosion is to be expected downstream of an outlet even if the downstream channel is stable. The severity of damage to be anticipated depends upon the conditions existing or created at the outlet. In some instances, the extent of the scour hole may be insufficient to produce either instability of the embankment or structural damage to the outlet. However, in many situations flow conditions produce scour of the extent that embankment erosion as well as structural damage of the apron, end wall, and culvert are evident.

5-1.4 The results of research conducted at U.S. Army Engineer Waterways Experiment Station to determine the extent of localized scour that may be anticipated downstream of culvert and storm-drain outlets has also been published. Empirical equations were developed for estimating the extent of the anticipated scour hole based on knowledge of the design discharge, the culvert diameter, and the duration and Froude number of the design flow at the culvert outlet. These equations and those for the maximum depth, width, length and volume of scour and comparisons of predicted and observed values are discussed in Section 4-2.4.3. Examples of recommended application to estimate the extent of scour in a cohesionless soil and several alternate schemes of protection required to prevent local scour downstream of a circular and rectangular outlet are illustrated in Practical Guidance for Design of Lined Channel Expansions at Culvert Outlets, Technical Report H-74-9.

## 5-2 RIPRAP PROTECTION

5-2.1 Riprap protection should be provided adjacent to all hydraulic structures placed in erosive materials to prevent scour at the ends of the structure. The protection is required on the bed and banks for a sufficient distance to establish velocity gradients and turbulence levels at the end of the riprap approximating conditions in the natural channel. Riprap can also be used for lining the channel banks to prevent lateral erosion and undesirable meandering. Consideration should be given to providing an expansion in either or both the horizontal and vertical direction immediately downstream from hydraulic structures such as drop structures, energy dissipators, culvert outlets or other devices in which flow can expand and dissipate its excess energy in turbulence rather than in a direct attack on the channel bottom and sides.

5-2.2 There are three ways in which riprap has been known to fail: movement of the individual stones by a combination of velocity and turbulence; movement of the natural bed material through the riprap resulting in slumping of the blanket; and undercutting and raveling of the riprap by scour at the end of the blanket. Therefore, in design, consideration must be given to selection of an adequate size stone, use of an adequately graded riprap or provision of a filter blanket, and proper treatment of the end of the riprap blanket.

5-3 **SELECTION OF STONE SIZE.** There are curves available for the selection of stone size required for protection as a function of the Froude number. (See Figures 4-21 through 4-23). Two curves are given, one to be used for riprap subject to direct attack or adjacent to hydraulic structures such as side inlets, confluences, and energy dissipators, where turbulence levels are high, and the other for riprap on the banks of a straight channel where flows are relatively quiet and parallel to the banks. With the depth of flow and average velocity in the channel known, the Froude number can be computed and a stone size determined from the appropriate curve. Curves for determining the riprap size required to prevent scour downstream from culvert outlets with scour holes of various depths are also available. The thickness of the riprap blanket should be equal to the longest dimension of the maximum size stone or 1.5 times the stone diameter (50 percent size), whichever is greater. When the use of very large rock is desirable but impractical, substitution of a grouted reach of smaller rock in areas of high velocities or turbulence maybe appropriate. Grouted riprap should be followed by an ungrouted reach.

5-4 **RIPRAP GRADATION.** A well-graded mixture of stone sizes is preferred to a relatively uniform size of riprap. In certain locations the available material may dictate the gradation of riprap to be used. In such cases the gradation should resemble as closely as possible the recommended mixture. Consideration should be given to increasing the thickness of the riprap blanket when locality dictates the use of gradations with larger percents of small stone than recommended. If the gradation of the available riprap is such that movement of the natural material through the riprap blanket would be likely, a filter blanket of sand, crushed, rock, gravel, or synthetic cloth

must be placed under the riprap. The usual blanket thickness is 6 in., but greater thickness is sometimes necessary.

5-5        **RIPRAP DESIGN.** An ideal riprap design would provide a gradual reduction in riprap size until the downstream end of the blanket blends with the natural bed material. This is seldom justified. However, unless this is done, turbulence caused by the riprap is likely to develop a scour hole at the end of the riprap blanket. It is suggested that the thickness of the riprap blanket be doubled at the downstream end to protect against undercutting and unraveling. An alternative is to provide a constant-thickness rubble blanket of suitable length dipping below the natural streambed to the estimated depth of bottom scour.