8.7 Erosion, Sedimentation, and Debris Control

8.7.1 Introduction

Natural streams and manmade channels are subject to the forces of moving water. Pressure, velocity, and centrifugal forces can be significant depending on the depth of flow, and the slope and sinuosity of the watercourse. An evolutionary process is the result with the continuous occurrence and dynamic interplay of erosion, sedimentation, and debris movement. This process, referred to as fluvial geomorphology, is accelerated during storm events when stream depths and velocities are high. Inserting a culvert into this dynamic environment requires special attention to the effects of these natural phenomena on the culvert and the effects of the culvert on the stream channel. Past experience has shown significant problems, including erosion at the inlet and outlet, sediment buildup in the barrel, and clogging of the barrel with debris.

8.7.2 Scour at Inlets

A culvert barrel normally constricts the natural channel, thereby forcing the flow through a reduced opening. As the flow contracts, vortices and areas of high velocity flow impinge against the upstream slopes of the fill and may tend to scour away the embankment adjacent to the culvert. In many cases, a scour hole also forms upstream of the culvert floor as a result of the acceleration of the flow as it leaves the natural channel and enters the culvert.

Upstream slope paving, riprap protection, headwalls, wingwalls, and cutoff walls help to protect the slopes and channel bed at the upstream end of the culvert.

8.7.3 Scour at Outlets

Scour at culvert outlets is a common occurrence. The natural channel flow is usually confined to a lesser width and greater depth as it passes through a culvert barrel. An increased velocity results with potentially erosive capabilities as it exits the barrel. Turbulence and erosive eddies form as the flow expands to conform to the natural channel. However, the velocity and depth of flow at the culvert outlet and the velocity distribution upon reentering the natural channel are not the only factors which need consideration. The characteristics of the channel bed and bank material, velocity and depth of flow in the channel at the culvert outlet, and the amount of sediment and other debris in the flow are all contributing factors to scour potential. Due to the variation in expected flows and the difficulty in evaluating some of these factors, scour prediction is subjective.

Scour in the vicinity of a culvert outlet can be classified into two separate types. The first type is called local scour and is typified by a scour hole produced at the culvert outlet. This is the result of high exit velocities, and the effects extend only a limited distance downstream. Coarse material scoured from the circular or elongated hole is deposited immediately downstream, often forming a low bar. Finer material is transported further downstream. The dimensions of the scour hole change due to sedimentation during low flows and the varying erosive effects of storm events. The scour hole is generally deepest during passage of the peak flow. Methods for predicting scour hole dimensions are found in HEC No. 14, "Hydraulic Design of Energy Dissipators for Culverts and Channels." The second type of scour is classified as general stream degradation. This phenomenon is independent of culvert performance. Natural causes produce a lowering of the streambed over time. The identification of a degrading stream is an essential part of the original site investigation. Both types of scour can occur simultaneously at a culvert outlet.

Protection against scour at culvert outlets varies from limited riprap placement to complex and expensive energy dissipation devices. At some locations, use of a rougher culvert material or a flatter slope alleviates the need for a special outlet protection device. Preformed scour holes, approximating the configuration of naturally formed holes, dissipate energy while providing a protective lining to the streambed. Riprapped channel expansions and concrete aprons protect the channel and redistribute or spread the flow. Barrel outlet expansions operate in a similar manner. Headwalls and cutoff walls protect the integrity of the fill. When outlet velocities are high enough to create excessive downstream problems, consideration should be given to more complex energy dissipation devices. These include hydraulic jump-basins, impact basins, drop structures, and stilling wells. Design information for the general types of energy dissipators is provided in HEC No. 14. Riprap is the most common element for outlet protection in Connecticut. Design guidelines for smaller culverts can be found in Chapter 11, Section 11.13. Outlet protection for larger culvert is discussed in Chapter 7.

8.7.4 Sedimentation

The companion problem to erosion is sedimentation. Most streams carry a sediment load and tend to deposit this load when their velocities decrease. Therefore, barrel slope and roughness are key indicators of potential problems at culvert sites. Other important factors in sedimentation processes are the magnitude of the discharge and the characteristics of the channel material.

Culverts which are located on and aligned with the natural channel generally do not have a sedimentation problem. A stable channel is expected to balance erosion and sedimentation over time; a culvert resting on such a channel bed behaves in a similar manner. In a degrading channel, erosion, not sedimentation, is a potential problem. However, a culvert located in an aggrading channel may encounter some sediment accumulation. Stream channel aggradation and degradation, and characteristics of each type of stream are discussed in HEC 20. Fortunately, storm events tend to cleanse culverts of sediment when increased velocities are experienced. Helical corrugations tend to promote this cleansing effect if the culvert is flowing full.

Certain culvert installations may encounter sedimentation problems. The most common of these are multibarrel installations and culverts built with depressions at the entrance. Culverts with more than one barrel may be necessary for wide shallow streams and for low fills. It is well documented the one or more of the barrels will accumulate sediment, particularly the inner barrel in a curved stream alignment. It is desirable for these installations to be straight and aligned with the upstream channel. Culverts built with an upstream depression possess a barrel slope which is less than that of the natural channel. Sedimentation is the likely result, especially during times of low flow. However, self-cleansing usually occurs during periods of high discharge. Both design situations should be approached cautiously with an increased effort in the field investigation stage to obtain a thorough knowledge of stream characteristics and bed-bank materials.

8.7.5 Assessment of Erosion Potential

A field investigation of all proposed outlet locations or existing outlets to be used in a drainage design of a proposed project should be conducted to determine the erosion resistance of the soils at the outlet, the character of the downstream flow path, and any other site constraints that must be addressed by the proposed design.

Barring any unusual conditions, as determined during the field investigation, the criteria outlined in Section 11.13 should be used to determine the type of outlet protection required. When severe conditions are present, it is the responsibility of the designer to provide outlet protection as needed to safeguard against erosion damage.