CHAPTER 5

CULVERT LOCATION

PRINCIPLES OF CULVERT LOCATION

Culvert location is defined as the selection of alignment and grade with respect to both roadway and stream. Proper location is important because it influences adequacy of the opening, maintenance of the culvert, protection from flooding of adjoining improvements, and possible washout of the roadway. Although every culvert installation is unique, the few principles set forth here apply in most cases.

A culvert is an enclosed channel serving as a continuation of and a substitute for an open stream where that stream meets an artificial barrier such as a roadway, embankment, or levee. It is necessary to consider abutting property, both as to ponding upstream and as to safe exit velocities in order to avoid undue scour or silting downstream.

An open stream is not always stable. It may be changing its channel, becoming straighter in some places and more sinuous in others. It may be scouring deeper in some places, silting in others. Change of land use upstream by clearing, deforestation, or development can change both the stability and flood flow of a stream.

Since a culvert is a fixed line in a stream, engineering judgment is necessary in properly locating the structure.

CSP installation with straight alignment.

Alignment

The first principle of culvert location is to provide the stream with a direct entrance and a direct exit. Any abrupt change in direction at either end will retard the flow and make a larger structure necessary.

A direct inlet and outlet, if not already existing, can be obtained by a channel change, a skewed alignment, or both. The cost of a channel change may be partly offset by a saving in culvert length or decrease in size. A skewed alignment requires a greater length of culvert, but is usually justified by improving the hydraulic condition and the safety of the road. See section on Pipe Length for Skew Angles at the end of this chapter.

The second principle of culvert location is to use reasonable precaution to prevent the stream from changing its course near the ends of the culvert. Otherwise the culvert may become inadequate, cause excessive ponding and possibly washout – any one of which can lead to expensive maintenance of the roadway. Steel end sections, riprap, grass, or paving will help protect the banks from eroding.

Culvert alignment may also be influenced by choice of a grade line. Methods of selecting proper alignment are illustrated in Figures 5.1 and 5.2.

At roadway intersections and private entrances, culverts should be placed in the direct line of the roadway ditch, especially where ditches are required to carry any considerable amount of storm water.

Culverts for drainage of cut-and-fill sections on long descending grades should be placed on a skew of about 45 degrees across the roadway. Thus the flow of water will not be retarded at the inlet.

Traditional CSP and Spiral Rib Pipe on highway 401 near Toronto, Ontario.

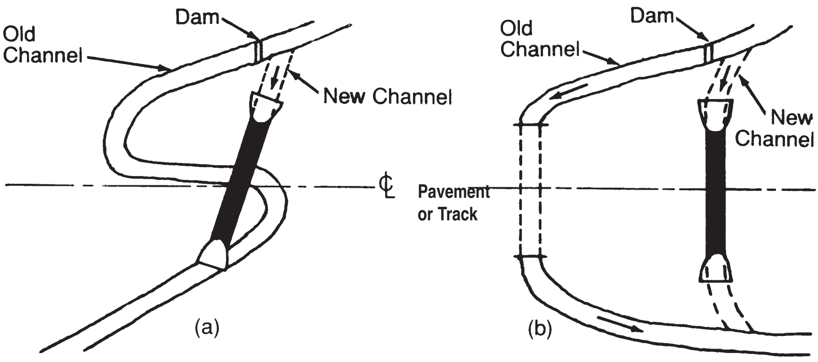

Figure 5.1 A channel change can improve alignment and provide more direct flow.

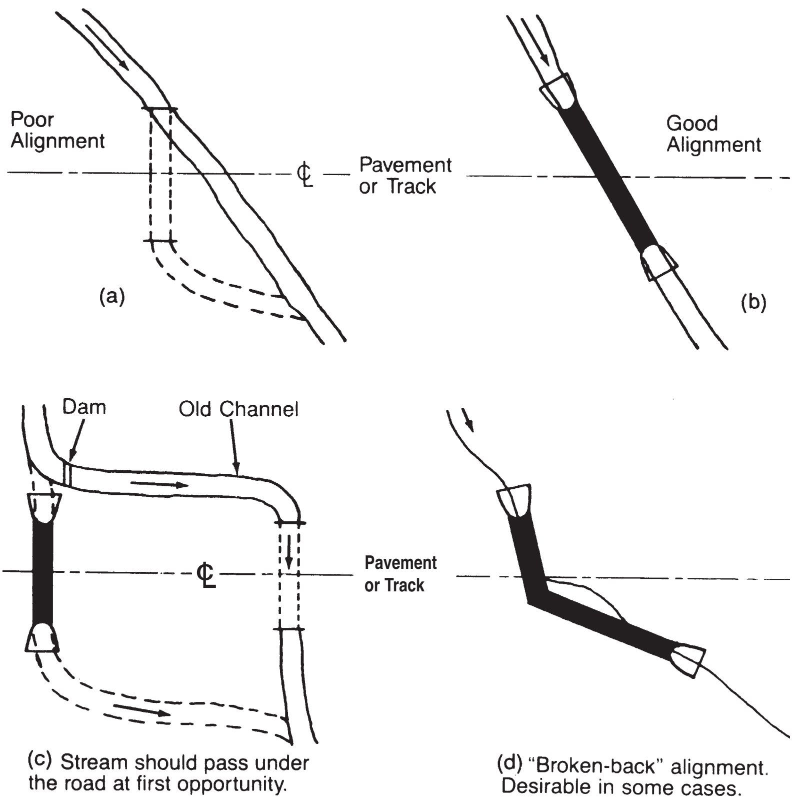

Figure 5.2 Various methods of obtaining correct culvert alignment.

A broken alignment under a roadway may be advisable on long culverts. Consideration should be given to entrance and exit conditions. Also, consider increasing the size of the structure to facilitate maintenance and removal of debris that the stream may carry during flood periods.

Changes in alignment may be accomplished by welded miter cuts for bends, either in profile or alignment. When the designer has determined the radius of curvature, the angle of the miter cut can then be determined. Gradual change in alignment can be accomplished by small angle changes at the joints or by field sweeping the coupled lengths of pipe.

Grade

The ideal grade line for a culvert is one that produces neither silting nor excessive velocities and scour, one that gives the shortest length, and one that makes replacement simplest (Figure 5.3).

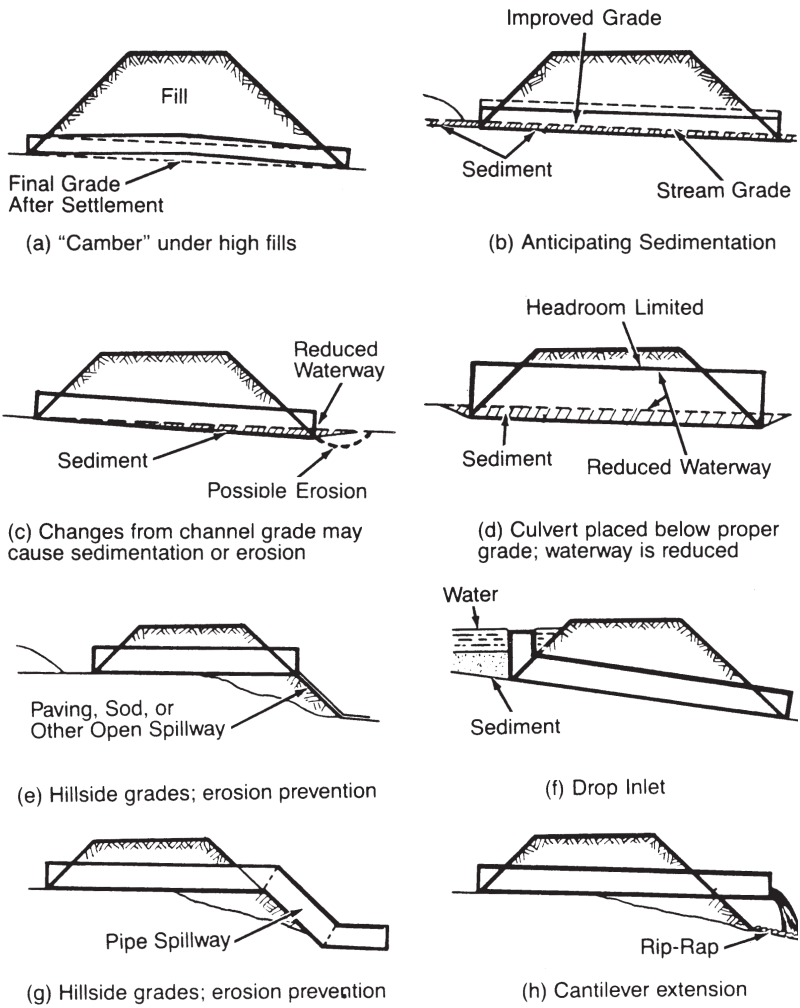

Figure 5.3 Proper culvert grades are essential to safe functioning of the structure.

Excessive velocities cause destructive scour downstream and to the culvert structure itself unless protected. Safe streambed velocities are given in Table 4.3 and 4.4, page 136.

Capacity of a culvert with a free outlet (not submerged) is not increased by placement on a slope steeper than its critical slope. (About 1 percent for a 2400 mm pipe.) The capacity is controlled by the amount of water that can get through the inlet.

On the other hand, the capacity of a pipe on a very slight gradient and with a submerged outlet is influenced by the head (difference in elevation of water surface at both ends). In this case, the roughness of the culvert interior, in addition to the velocity head and entrance loss, is a factor.

A slope of 1 to 2 percent is advisable to give a gradient equal to or greater than the critical slope, provided the velocity falls within permissible limits. In general, a minimum slope of 0.5 percent will avoid sedimentation.

In ordinary practice the grade line coincides with the average streambed above and below the culvert. However, deviation for a good purpose is permissible.

Spiral rib steel pipe stream diversion installation.

Culvert Length

The required length of a culvert depends on the width of the roadway or roadbed, the height of fill, the slope of the embankment, the slope and skew of the culvert, and the type of end finish such as end section, headwall, beveled end, drop inlet or spillway.

A culvert should be long enough so that its ends do not clog with sediment or become covered with a settling, spreading embankment.

A cross-sectional sketch of the embankment and a profile of the streambed is the best way to determine the required length of culvert needed. Lacking such a sketch, the length of a simple culvert under an embankment can be determined as follows:

CSP stream diversion.

To the width of the roadway (and shoulders) add twice the slope ratio times the height of fill at the center of the road. This is illustrated in Figure 5.4 in terms of the variables in the figure, B=C x H/V. The height of fill, C, should be measured to the flow line if headwalls are not to be used, and to the top of the culvert if headwalls or end sections are to be installed.

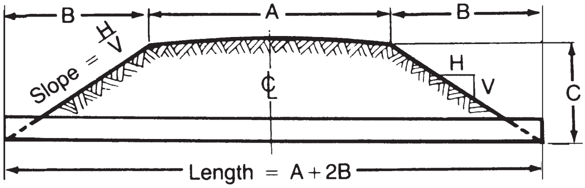

Figure 5.4 Computation of culvert length when flow line is on flat grade.

Example: A roadway is 12 m wide, has, two to one side slopes, and at the center of the road the height of fill to flow line is 2 m. The culvert length at the flow line is then 12 + 2[2(2/1)] = 20 m.

If the culvert is on a slope of 5 percent or more, it may be advisable to compute the sloped length in the manner shown in Figure 5.5.

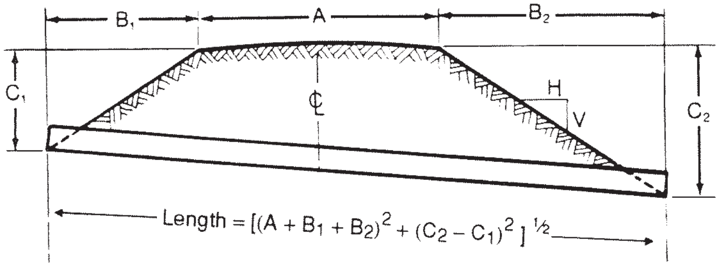

Figure 5.5 Determining culvert length on a steep grade.

Pipe Length for Skew Angles

When a culvert crosses the roadway at other than a right angle, the increased bottom center line length should be computed as follows:

First determine the length at right angles to the roadway (Figure 5.4 or 5.5). Then divide by the cosine of the angle between the normal and skewed direction (the skew angle).

Example: Assume a normal length of 20 m and an angle of 20 degrees skewed from the normal.

$$\text{Skew length} = \frac{20}{0.940} = 21.284 \text{ m} = L_S$$

Next, if skewed ends are required on the pipe, determine L' (Figure 5.6) by multiplying the pipe diameter by the tangent of the angle between the normal length and skew length and add this to the increased bottom center line length.

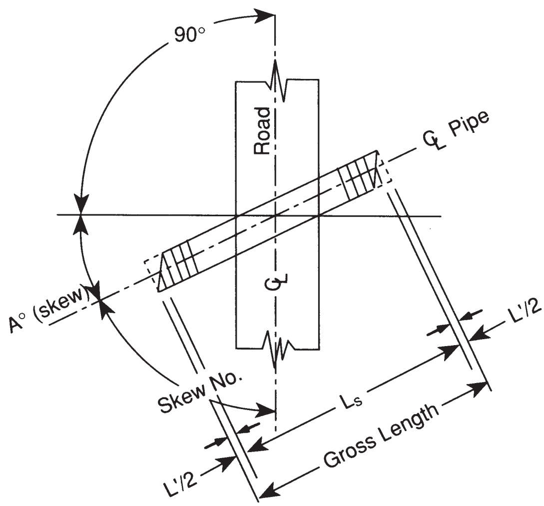

Figure 5.6 Determine gross length of pipe required from which to fabricate skewed pipe crossing.

Example: Assume pipe in previous example is 0.9 m diameter.

L' = 0.9 (0.364) = 0.328 m

Gross Length = 21.3 + 0.3 = 21.611 m

The required length of pipe is 21.6 m.

Under certain conditions, as in the previous example, the ends of the structure may be cut to make them parallel to the center line of the road. For correct fabrication of corrugated steel culverts it is essential to specify the direction of flow as well as the skew angle or skew number (Figure 5.7).

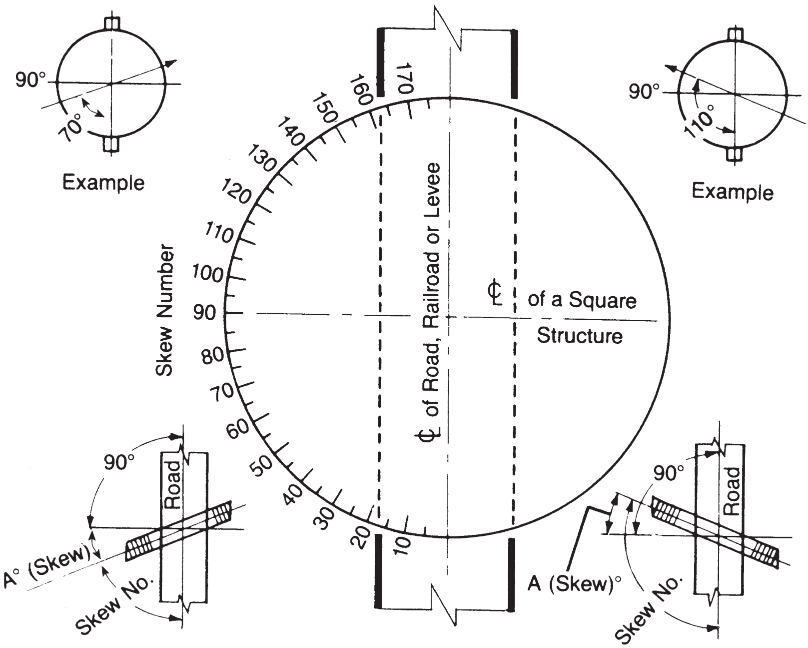

Figure 5.7 Diagram for method of properly specifying skewed culverts. The direction of flow should also be indicated for fabrication as a left or right.

DCSP box for a short span bridge.

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