

amount in order that financial interests may determine whether it would be profitable to make the investment or not. In these mountainous districts the earthwork is often the largest item of cost and the final construction work should show an improvement or a smaller volume of earthwork than the preliminary estimate. As it often occurs that the final yardage is greatly in excess of that originally estimated, and as in some cases financial difficulties have followed which have threatened the continuation of the work, it is proper that special precaution and care be exercised to eliminate constantly recurring errors which invariably produce deficient quantities, and which in special cases may affect the total materially.

Of course, in comparatively level country, the transverse surface slope is generally not of sufficient importance to be given special consideration, but it often happens that at river crossings or along stream bluffs there are surprisingly steep transverse slopes which should certainly justify attention. There is no place where error is more likely to creep in than in those locations where the usual conditions justify the practice of ignoring small errors, but which errors may

mate and the more accurate method is to use a diagram for sloping ground."

There has been a number of diagrams for earthwork in which the slope of the ground has been considered, among which those of Wellington and Trautwine are perhaps best known. These diagrams as well as the tables which consider transverse slopes are made on a basis of angle of slope in degrees. This requires that either the angle be measured in the field or calculated from other data. The latter method is most generally employed and frequently involves a considerable amount of computation. It has appeared that the work could be done more efficiently by the use of diagrams based on a contour slope-distance instead of angle in degree. The data may then be taken directly from the contour map and profile and applied to the diagram from which the volume of earthwork may be read. Standard diagrams similar to those shown herewith may be made for any roadbed dimensions and used efficiently in the field or office. In case reference was to be made to tables on the angle basis a curve as shown herewith would save time in changing from one system to the other. In fact all computation work

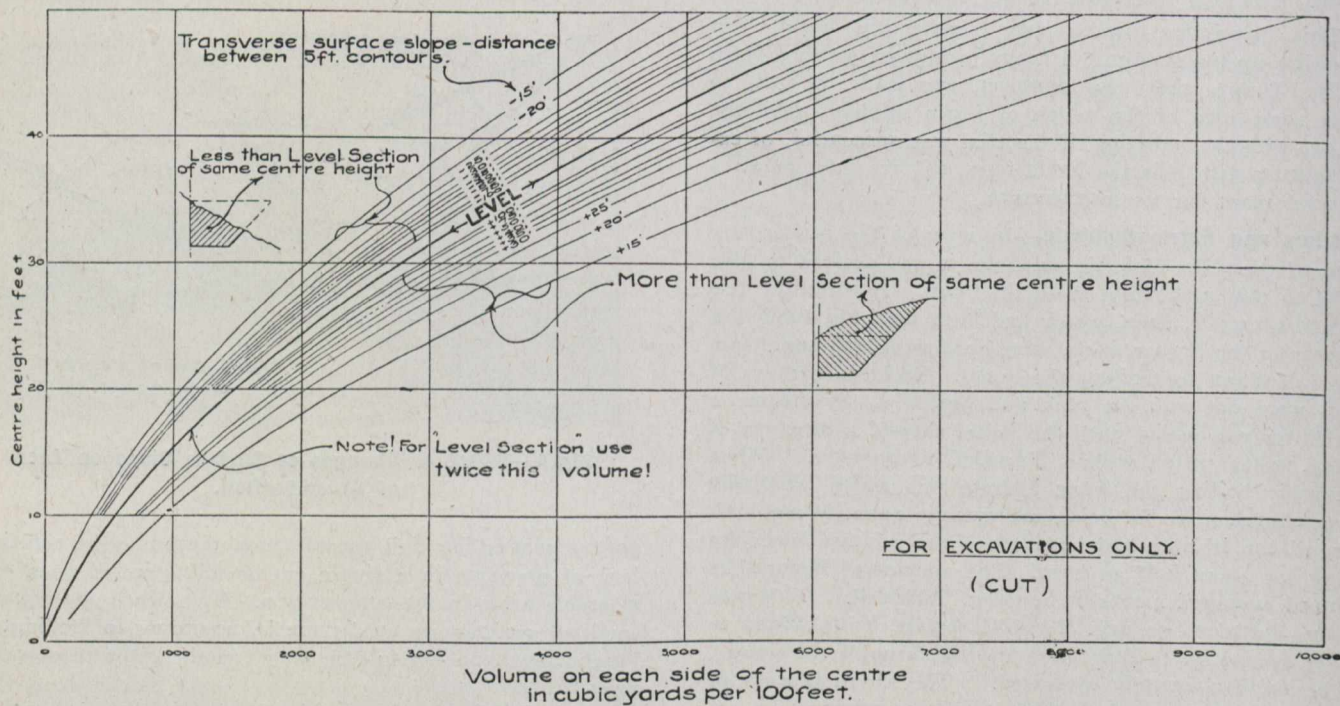


Fig. B—Effect of Changes of Surface Slope on Volume of Earthwork. Base 20 ft.; Slope 1 to 1.

at unusual places introduce large inaccuracies in the estimates. It is certainly evident that there is inconsistency in the practice of taking into full account small quantities on the level ground and then disregarding the effect of surface slope at some river bank where that effect may produce an error in yardage larger than any item that had previously been considered.

The effect of a slope of 30 deg. upon a 5 ft. cut is given by Raymond in his Elements of Railroad Engineering as amounting to an increase in volume of 60 per cent. He further suggests that "what sections may be considered level across may be determined by remembering that a cross slope of one in ten will be erroneously calculated by the level-section method by about 2 per cent., the truth being in excess, and a slope of one in five will be erroneously calculated by about 8 per cent." Steeper slopes increase this more rapidly, as they become very steep and may give rise to errors of over 60 per cent. as mentioned above. Raymond suggests, however, that "these values are roughly approxi-

involved in transferring data on the contour-distance basis to the angle-of-slope basis may be eliminated by the use of this diagram.

Many of the tables given for surface slope correction give quantities for equal increments to extreme angles of slope, and do not take into account the fact that in these extreme cases a change of 1 deg. may alter the total by a large quantity. It appears that when the surface-slope is very steep the cross-section should be taken approximately at least, if the quantity is to be estimated with a consistent degree of accuracy. On one of the western roads the following rule has been used:

"Where the transverse surface slope is steep and the 5-ft. contours are less than 15 ft. apart, cross-sections must be taken."

This limits the slope to one in three for the application of graphical methods and requires constantly that necessary data be taken for extreme cases. Since it cannot be expected that the contours on a topographical map are located cor-