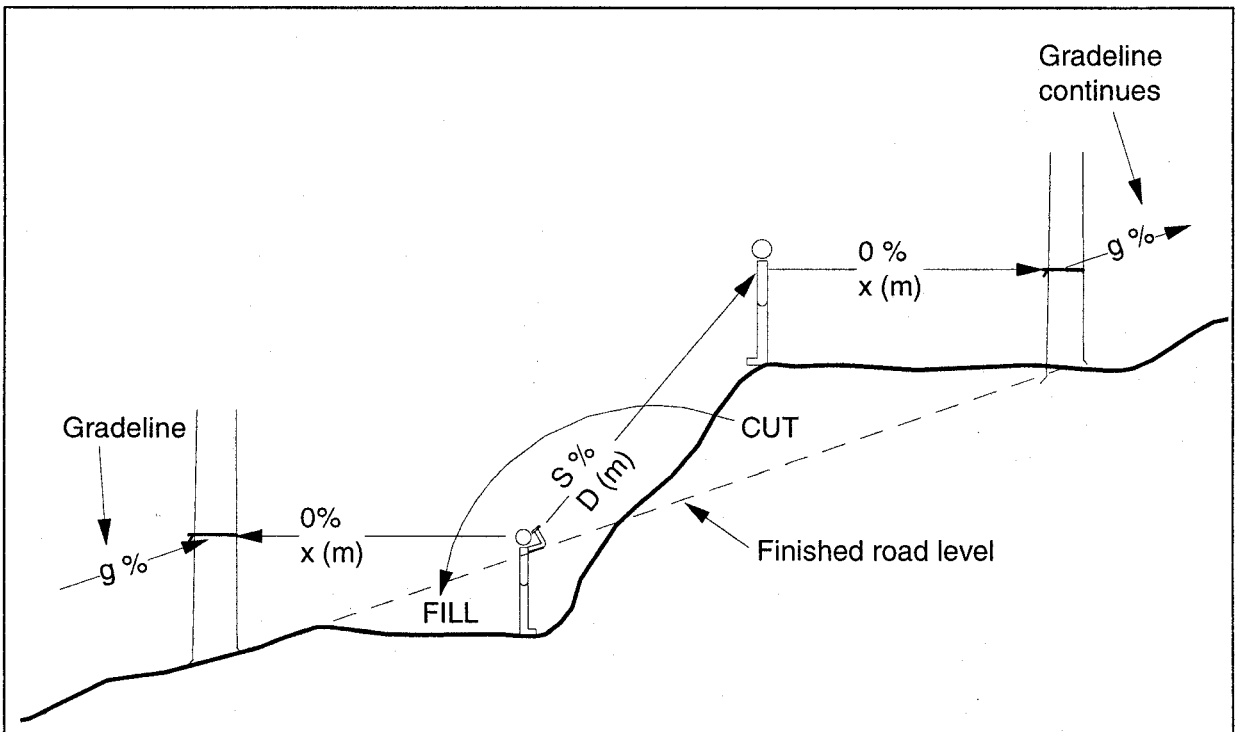
1. Intermediate Control Points

Intermediate control points are required where a small (or occasionally large) hill is inline with the new road. In this situation, rather than trying to form the road over top of a rock bluff, a box cut is made through the hill to the required grade. Refer figure 154.



1. Measure S % (slope in percent) and D (distance in metres), while g % = slope of gradeline being marked.

2. Calculate distance required at a 0% grade = x (metres), where

$$x = \frac{D(S-g)}{2g\sqrt{S^2+1}}$$

(Note: Both S and g are expressed as a decimal slope, ie. 10% = 0.1)

Figure 154 - Intermediate control points over a rock bluff.

2. Crossing Hollows or Draws

In crossing a hollow or draw, the gradeline must not be continued so far up into the hollow that construction of the minimum radius curve will materially increase the finished grade of the road. The best way to avoid this problem is to "shoot" a level grade across the hollow at a point where it is twice as far to the other side as the radius of the desired curve in the hollow.

For example, if the radius of the curve in the hollow is to be 26 metres, the Abney man should stop setting grade when he is about perpendicular and 60 metres from one side of the hollow to the other. At that point he should set the Abney at zero and "shoot" across the hollow and make a grade mark (figure 155). He can then go across the hollow and continue setting grade at that point. This procedure will ensure that the desired grade will not have been increased.

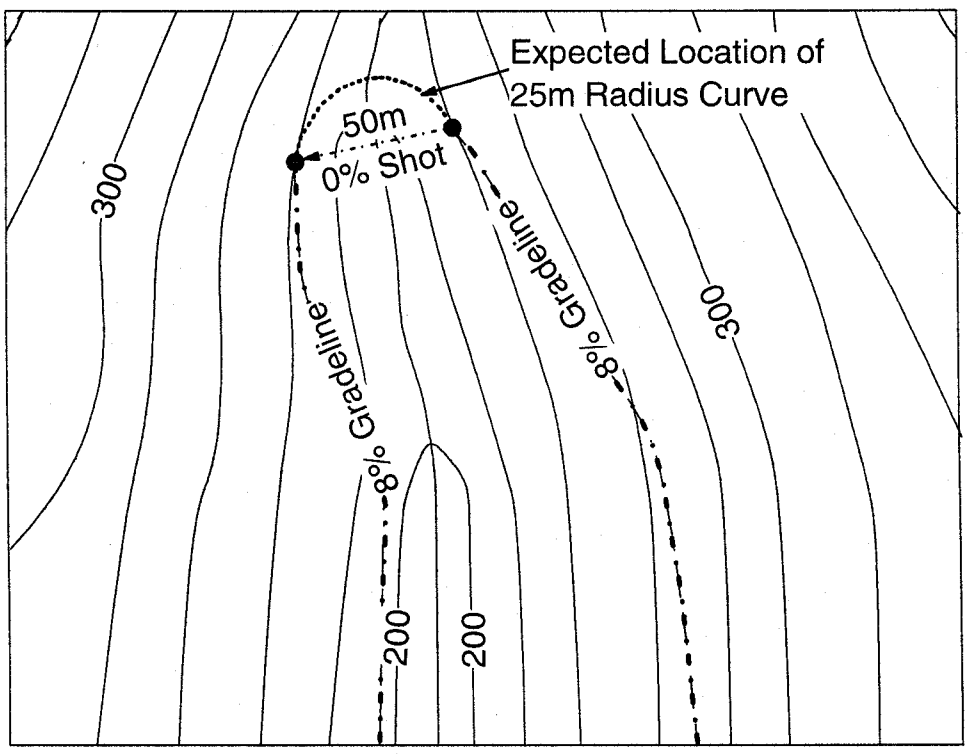


Figure 155 - Procedure of shooting 0% across hollow

If gaining every possible metre of elevation is imperative, then the shot across the hollow can be on a gradient, but it should not be more than one half of the grade being run.

3. Running Around Long Narrow Ridges

This problem is similar to crossing hollows. It is best to run around the ridge on a zero percent grade from the point where you want the curve to begin, to the point where you want it to end. At this point, the gradeline can be continued and allow construction of the desired radius curve and lower the grade around the curve. Running a continuous gradeline around the nose and constructing a larger radius curve will cause the gradient to increase and the curve would be in a through cut for nearly its entire length.

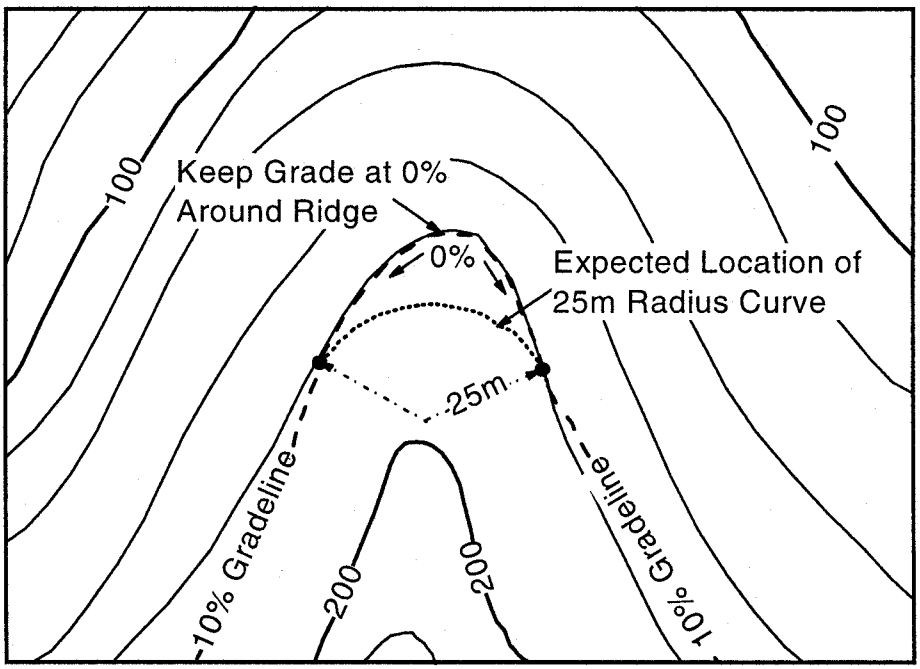


Figure 156 - Running around the nose on a zero percent grade.

Walk around the ridge on a zero percent grade and estimate where the curve will end to begin the next gradeline section.

4. Switchback Layout

In most cases, the slope of the ground in the switchback area will be greater than the gradient that is being run. The problem then, is how to modify the gradeline to allow construction of the desired grade around the switchback.

For example, let us assume that the switchback area has a side slope of 30% and you wish to build a switchback with an 26 meter radius on a 6% grade, and that the road grade on the straights is 10%. If the switchback is a full half circle, then the elevational distance on the ground between the beginning and the end of the switchback is 16 metres (2 x 26 x 0.3), and the length of the switchback is 79 metres (26 x Π).

If the switchback is to be built to 6% it will only use 4.74 metres (79 x 0.06) of the elevational difference between the beginning and end of the switchback. The difference between 16 metres on the ground and the 4.74 metres used in the construction must be compensated for. This can be done by cutting half of the difference $\left(\frac{16-4.74}{2}=5.13m\right)$ on the uphill side of the switchback, and filling the same amount on the downhill side of the switchback.

To be a continuous grade, the cutting and filling must start beyond the beginning and ending of the switchback. This distance is provided for by laying out a 0% grade for 51.3 metres up to the beginning of the curve, and for 51.3 metres beyond the end of the curve (51.3 x 0.1 = 5.13). In this case, the field procedure would be to run the 10% grade to within 51.3 metres of the beginning of the curve, run A 0% grade for 51.3 metres, layout a half circle with an 26 metre radius, run 0% for 51.3 metres, and then continue the gradeline at 10%.

Considering the impact of steep ground on switchback construction costs, it becomes obvious that locating suitable switchback areas is very important. In some situations they can be the most important control point on the entire road.

Use the table and figures below to aid in the calculations required for gradeline setout.

	Symbols	Example
Side Slope (%/100)	S	0.3
Road Grade (%/100)	G	0.1
Curve Radius (m)	R	25
Grade on Curve (%/100)	g	0.06
Elevational Diff (m)	E = (2xRxS)	2 x 25x 0.3 = 15
Curve Deflection (degrees)	θ	180
Curve Length (m)	C = (R×Π×θ/180)	25 x 3.142 x 180/180 = 79
Elevation gained on curve (m)	H = C x g	79 x 0.06 = 4.74
Cut and Fill Depth (m)	D = (E - H)/2	15 x 4.74/2 = 5.13
Dist at 0% Grade Before Curve (m)	X = D/G	5.13/0.1 = 51.3
Dist on ground from A to B (m)	$F = \sqrt{(2R)^2 + (E)^2}$	$\sqrt{(2\times25)^2 + (15)^2} = 52.2$

Table 36 - Calculating switchback layout

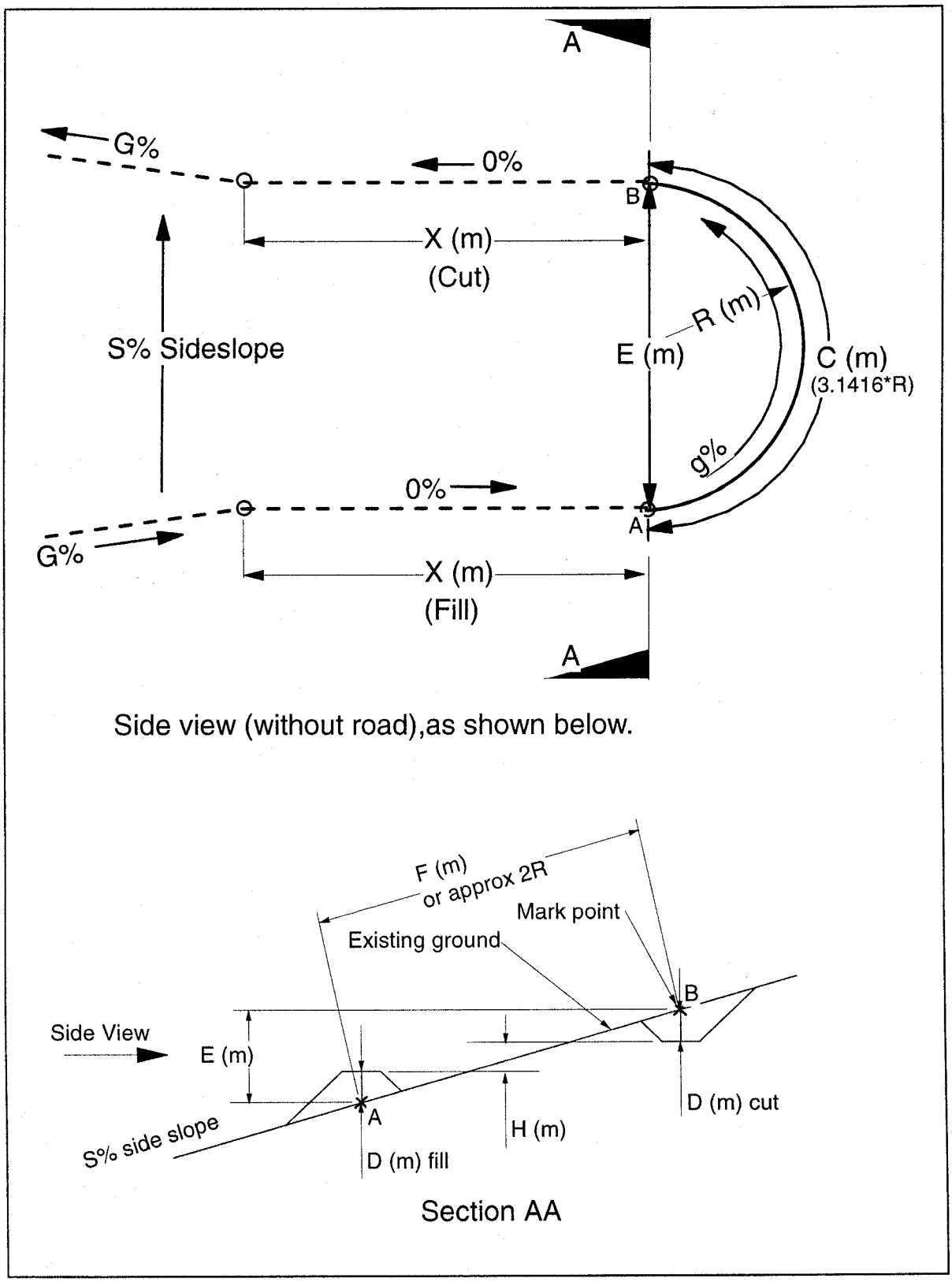


Figure 157 - Switchback layout.

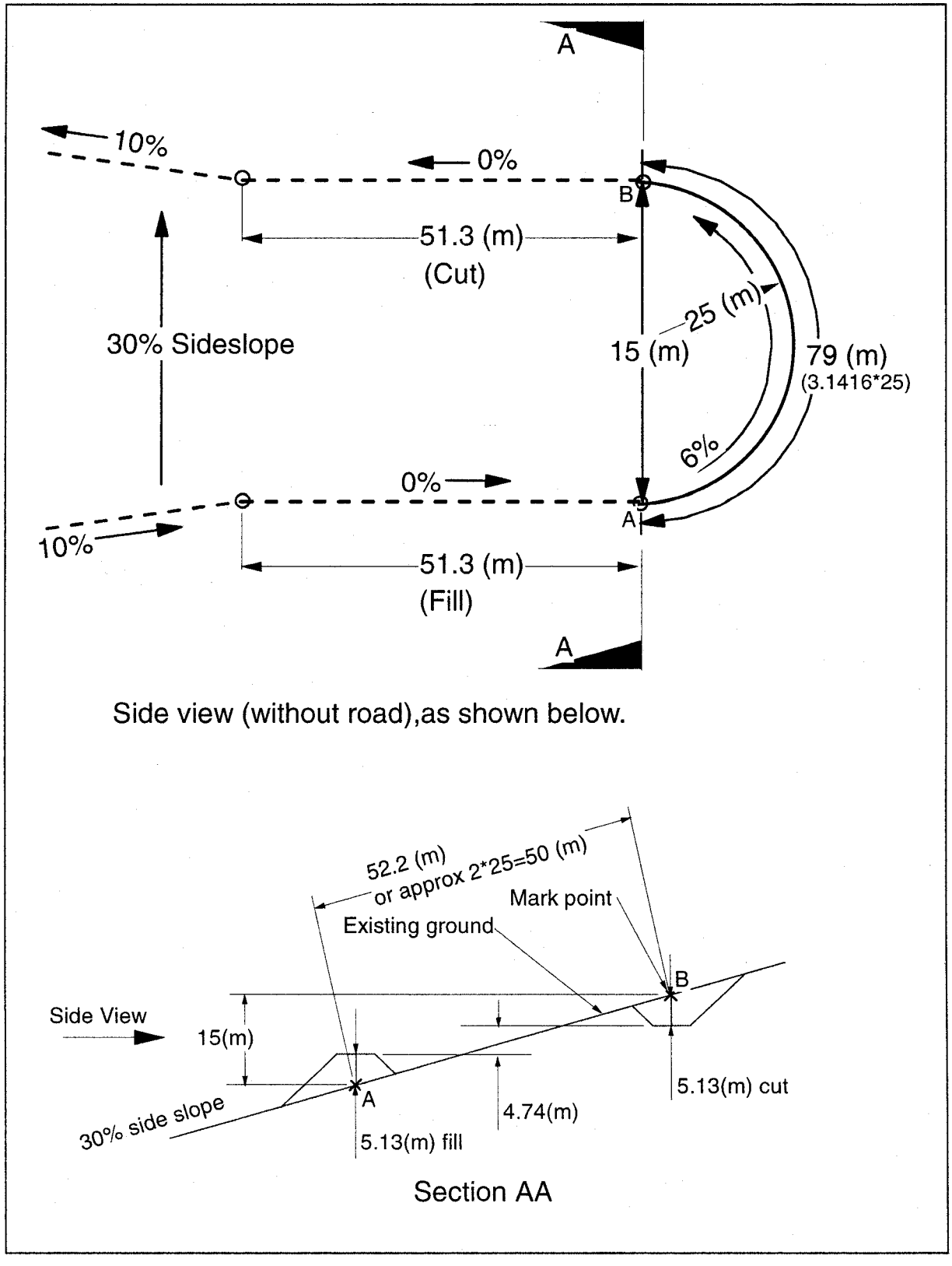


Figure 158 - Switchback layout example.