10

Chapter 10

Alignment Design

Table of Contents

Chapter 10 Amendments - August 2001

Revision Register

Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
1		First Issue	Steering Committee	May 2000
2	10.2.4	Paragraph added at the end of section	Steering Committee	Aug 2001
	10.3.3	Cross reference to Figure 10.7 added Figure 10.8 - title added		
	10.4.1	Corrections to references		
	New	Relationship to Other Chapters		

10

10

Chapter 10
Alignment Design

10.1 Introduction

The overall quality and appearance of a road will be determined by the quality of the alignment design (horizontal and vertical) and its relationship to the surrounding environment.

"An important concept in highway design is that every project is unique. The setting and character of the area, the values of the community, the needs of the highway users, and the challenges and opportunities are unique factors that designers must consider with each highway project. Whether the design to be developed is for a modest safety improvement or 10 miles of new-location rural freeway, there are no patented solutions. For each potential project, designers are faced with the task of balancing the need of the highway improvement with the need to safely integrate the design into the surrounding natural and human environments." (Flexibility in Highway Design (US DOT, 1997).

A holistic approach to the design is required where the various elements of the road design are considered as a whole in the context of the environment through which the road passes and the expectations of the community affected by the road. To achieve the best result, designers must consider the engineering requirements of the road in question together with the characteristics of the area in which the road is located. The designer must consider the character of the area in the context of its physical location and give proper weight to:

- Physical characteristics of the area
- Use of the corridor (destination spots, pedestrians, cyclists, rural industry, urban residential etc)
- The type and scale of the road to be designed
- Vegetation in the corridor (density, type)
- Views available, scenic values
- Historic features (including both indigenous and introduced cultural heritage)
- Features to preserve (including natural environment)

Designers need to employ imagination, ingenuity and flexibility to get the best result.

It is important that all of the necessary information on both physical constraints and community expectations is obtained early in the process. It is also important that the special expertise of landscape architects, environmental specialists and others is employed at the beginning before controlling decisions are made and changes can still be adopted.

This chapter is devoted to the design of the horizontal and vertical alignments as a coordinated whole in harmony with the landscape, the environment and the community in general.

10.2 Design Principles

10.2.1 Introduction

Design principles have to consider the entire range of factors impinging on the design - engineering, landscape, environmental, community expectations. This manual deals in detail with the engineering requirements of road design, taking into account the other factors to be addressed. For a complete treatment of the other issues, designers should refer to the respective manuals developed for the disciplines involved:

- Road Landscape Manual
- Erosion and Sediment Control Manual
- Road Project Environmental Management Processes Manual
- Road Traffic Noise Management Code of Practice

In engineering terms, road alignments have to service traffic in terms of providing a route that meets constraints imposed by vehicle dynamics, occupant comfort, and topography. This means that most road alignments are in fact complex three-dimensional splines that do not have a simple mathematical definition. This problem has historically been addressed by reducing the three-dimensional alignment to two two-dimensional alignments. In each case, the alignments are made up of geometric elements that are convenient to calculate and construct yet still ensure that vehicle dynamics constraints are met. Even with the advent of computers, this approach has still proven to be the most convenient for both design and construction. To use complex three-dimensional models would introduce unnecessary complexity into the process but it is necessary to ensure that the two alignments are properly coordinated and complement each other.

Details of the specific engineering requirements for horizontal and vertical alignment are provided in Chapters 11 and 12 of this manual. The intent of this Chapter is to put those requirements in context and emphasise the importance of the complementarity of the design of those elements.

10.2.2 Driver Perception of Roadway

Drivers use the visual information of the roadway geometry to develop their perception of the road conditions and thereby control the speed and position of their vehicles on the roadway. They need sufficient information to allow them to take the necessary decisions to safely negotiate each geometric feature.

The amount of visual information perceived by drivers is limited, however, by the following:

1. Drivers travelling for relatively long periods of time at high speed become ‘velocitised’ (losing perspective of speed of travel and physical surroundings).
2. Inadequate attention because of driver ‘day dreaming’ rather than concentrating entirely on the driving task. In this state, a driver can often become more alert at a particular point in time and not be able to recall the last few minutes of the trip.
3. Driver fatigue.
4. Driver use of drugs and alcohol.
5. Driver distraction.
6. Driving at night/dawn/dusk.
7. Driving in rain.
8. Driving in fog.

All of the above factors (except dot point 4) can affect most drivers at particular times. This results in instances where drivers have reduced perception of the roadway. For this reason, it is very important to provide drivers with as many clues as possible as to what lies ahead. This will minimise any safety problems especially during times of reduced driver perception. Roadside conditions must not be ambiguous or misleading as this provides an inadequate level of driver perception.

The provision of as many clues as possible as to what lies ahead is especially critical for geometric elements comprising a large decrease in speed i.e. high speed minor road ending at a rural intersection. Methods to achieve this are discussed in Section 8.6.

Particular aspects of geometric design which provide good/poor driver perception are discussed below.

- Co-ordinating horizontal and vertical alignments as discussed in Section 10.3 improves driver perception of the roadway.
- The smooth curving face of a cutting can provide good driver perception of the corresponding curvature in a road.

  Conversely, a fill cannot provide good driver perception if the view ahead is open to the sky where there may be no visual background of fixed objects.

  Even on flat terrain, a horizontal curve can provide poor driver perception if there is no visual background of fixed objects.

- Vegetation or other obstructions on the inside of sharper curves can provide inadequate driver perception of the tightness of the curve.
- A driver will not expect a curve if this sole cue comes from a line of service poles or trees which continue straight on, or from a deceptive gap in a line of trees on the outside of the curve.
- A crest should not obscure a potential hazard such as a narrow bridge, a railway at-grade crossing, an at-grade intersection or a horizontal curve which requires a significant reduction of speed. Even small crests can obscure important features. The visual clues presented to the driver by the view of the road surface are especially important on sections of sharp curvature.

10.2.3 Holistic Design Approach

Designers must take a holistic approach to the total road design and consider the effects of each element on the other elements of the design. The horizontal and vertical alignments must be considered together and the effect of the cross section must also be considered at this time. The approach to alignment coordination is discussed in 10.3.

An important issue is the size of the road compared to its surroundings (its scale). The cross section has the greatest effect on this - the wider the road, the greater the scale. In some environments, a large scale may fit well with the surrounds and be compatible with them. However, it is often the case that roads will have a scale too large for the environment and the design should attempt to mitigate this effect.

Some design techniques that will tend to reduce the perceived width and therefore the perceived scale include:

- Median planting
- Reducing the extent of shoulder seal
- Independent grading
- Landscaping

Using a holistic approach will mean that designers will critically examine the application of minimum requirements in the design. Combinations of the minimum requirements of complementary elements will rarely produce a satisfactory result and in many cases will produce an unsafe result. A better result will usually be achieved by adopting better than the minimum and this can often be done at the same or lower cost.

10.2.4 Aesthetics of Road Design

It is important to realise that no road can be regarded as aesthetically successful if it is not integrated with the natural and man made features that surround it. Cosmetic treatments in the form of shrubs and trees cannot overcome the aesthetic deficiencies of poor location and design.

In addition to providing a pleasant visual experience to drivers (and possibly because of it), accident rates are lower on roads with good aesthetic characteristics. Roads designed to fit the terrain and take advantage of adjacent natural features create less driving tension and weariness for the driver.

Two perspectives have to be considered in the aesthetics of a road:

- the view ***of*** the road; and
- the view ***from*** the road.

From the community perspective, the impact of the road on their outlook, or the appearance of the road from their residences, is the major factor. This perspective is helped by application of good design principles as discussed elsewhere in this Chapter but it may be necessary to provide other features such as shielding with vegetation and earth mounds to overcome the intrusion of the road into the community's landscape. This is beyond the scope of this manual.

The view from the road is within the control of the designer and application of the design principles enunciated in this manual should achieve a pleasing result.

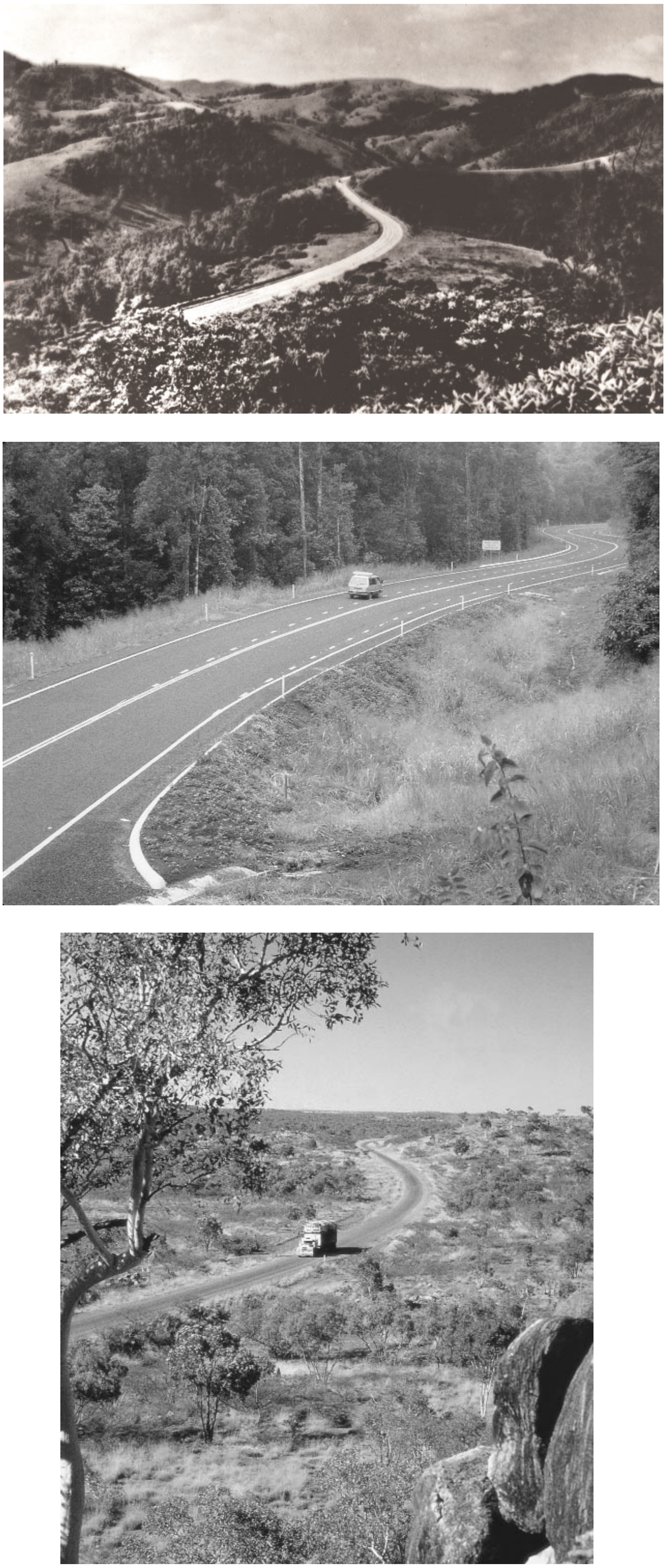


Figure 10.1 Well designed roads in harmony with their surroundings produce a pleasing appearance

It is desirable that any point of interest in the vicinity of the road (e.g. areas of high scenic value) be able to be viewed by users of the road. The sub-section titled “Development and Maintenance of Views”, Section 3.4.2 of this Manual, discusses this issue.

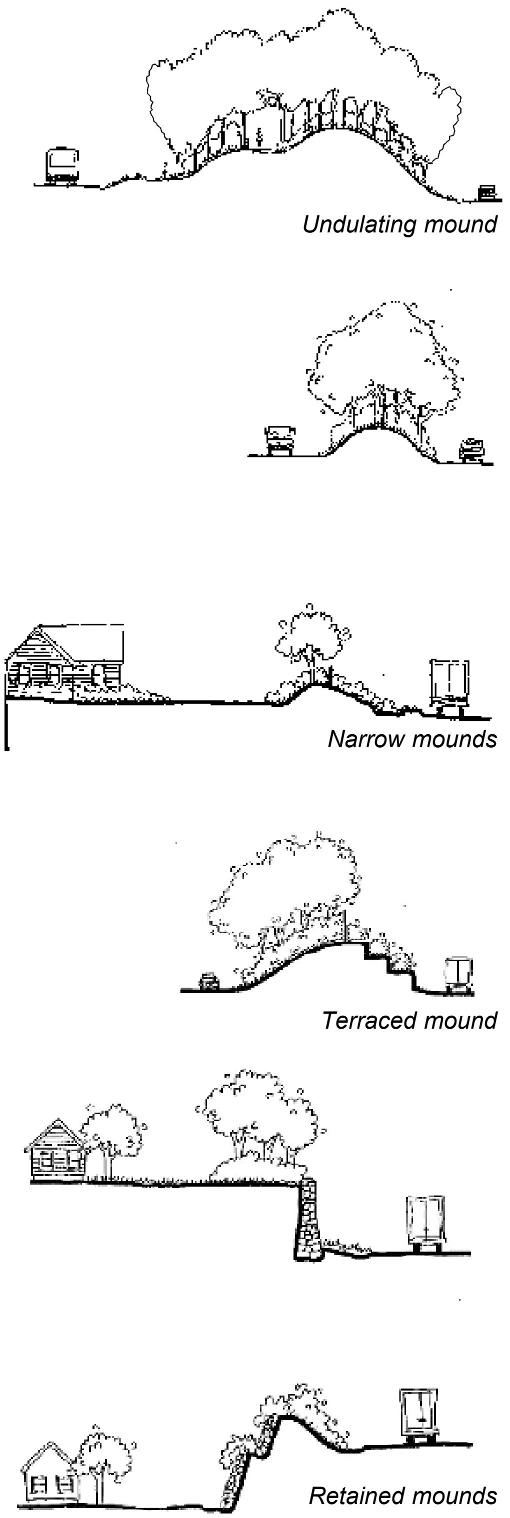


Figure 10.2 Landscape Mounding Alternatives

10.2.5 Designing for Sun Position

The impact of the sun shining directly into a driver's eyes should be considered in the location and design of a road. It is not always possible to design a road to avoid this problem in all circumstances but careful consideration should be given to it particularly when conflict situations occur. An intersection on the crest of a hill is one such case.

Judicious application of curvature, subtle changes in direction and provision of appropriate landscaping can help to alleviate some of the situations where sun glare is a problem. The different sun positions throughout the year make the analysis more complex but they have to be considered. Figures 10.3 and 10.4 provide solar charts for Queensland and provide a guide for designers in assessing the impact of sun position on a road design.

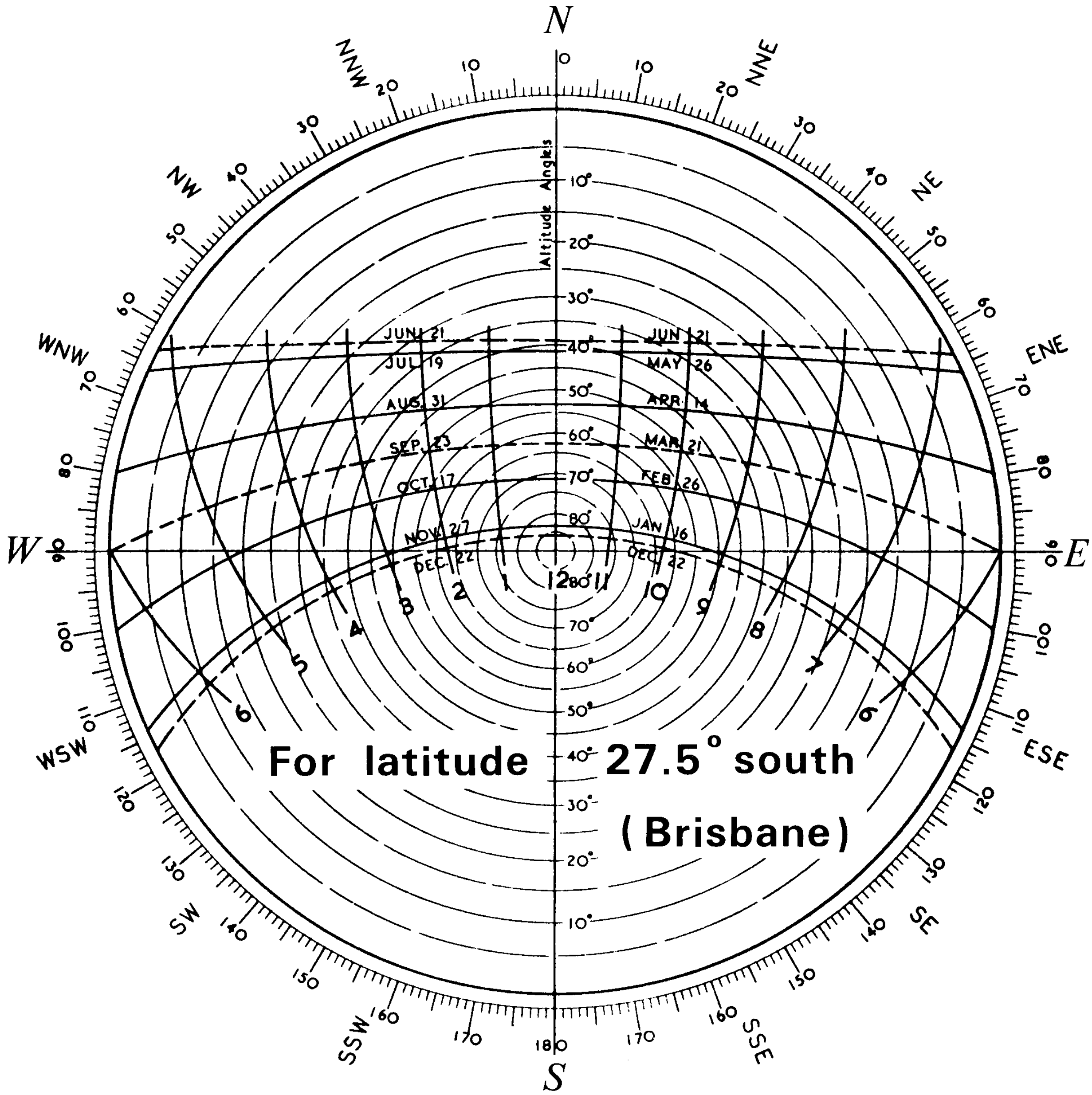
10.3 Alignment Coordination

10.3.1 General

The importance of alignment coordination cannot be over emphasised. The appearance, economy and safety of the road design depend on the successful achievement of proper coordination. Details of the individual elements of horizontal and vertical alignment design are provided in Chapters 11 and 12 - this Chapter will address their combination.

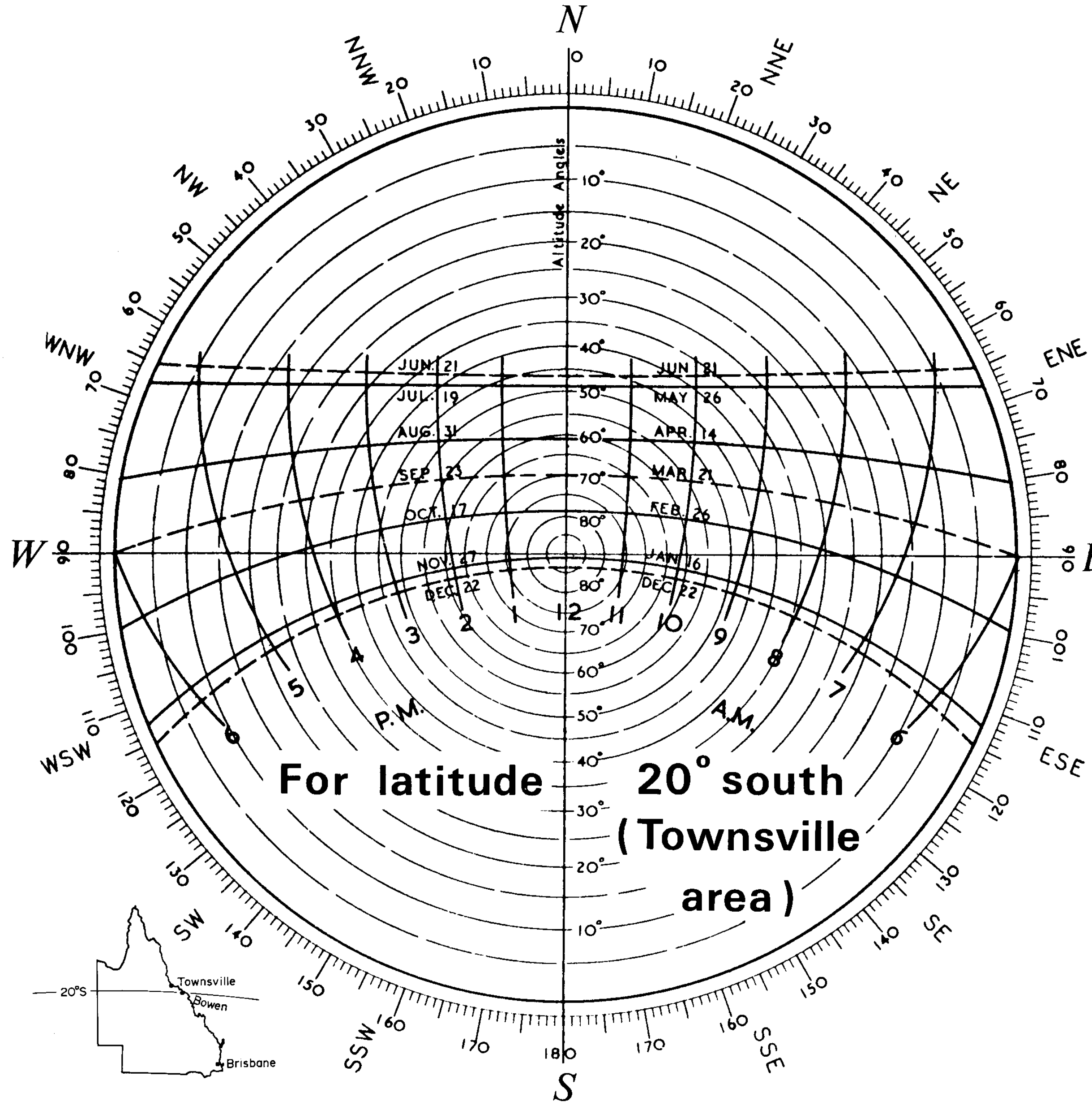
Coordination of alignment and profile should not be left to chance but should begin at the concept stage, during which adjustments can readily be made. The designer should study long, continuous stretches of highway in both plan and profile and visualize the whole in three dimensions. (See AASHTO, 1994).

If long lengths are not considered, it is possible to produce discontinuities in appearance even though the shorter lengths, taken in isolation, are satisfactory. (See upper photograph in Figure 10.11).



The centre of the diagram represents the observer's position. The heavy curved lines represent the sun's path for selected dates and latitude 27.5° South and are crossed by lines indicating hours. To find the sun's position for the required conditions, select the point where the appropriate lines intersect. The sun's altitude (in degrees above the horizontal plane) is shown by the relation of this point to the concentric circular lines within the diagram. The direction of the sun's rays is shown by a line drawn through this point from the outer graduated circle towards the centre.

Figure 10.3 Solar Chart for South Queensland



The centre of the diagram represents the observer's position. The heavy curved lines represent the sun's path for selected dates and latitude 20° South and are crossed by lines indicating hours. To find the sun's position for the required conditions, select the point where the appropriate lines intersect. The sun's altitude (in degrees above the horizontal plane) is shown by the relation of this point to the concentric circular lines within the diagram. The direction of the sun's rays is shown by a line drawn through this point from the outer graduated circle towards the centre.

Figure 10.4 Solar Chart for North Queensland

Further emphasis of the importance of these elements of the design process is given in US DOT, 1997 as follows:

"The interrelationship of horizontal and vertical alignment is best addressed in the route location and preliminary design phases of the project. At this stage, appropriate trade-offs and balances between design speed and the character of the road - traffic volume, topography and existing development - can be made. …

Because they must be complementary, horizontal and vertical geometry must be designed concurrently. Uncoordinated horizontal and vertical geometry can ruin the best parts and accentuate the weak points of each element. Excellence in the combination of their designs increases efficiency and safety, encourages uniform speed, and improves appearance - almost always without additional cost."

It is therefore essential that the designer establish these elements of the design in the concept stage, confirm them in the planning stage and properly detail them in the design stage. They must be addressed in the earliest stages of any new road development proposal, and maintained throughout the planning and design process.

10.3.2 Principles of Co-ordination

Users see the road as a constantly changing three-dimensional continuum, and unless designers take account of this fact, they may not appreciate how the finished design will appear to road users. Thus, horizontal and vertical alignments must not be considered in isolation.

The driver sees a foreshortened and, thus, distorted view of the road, and unfavourable combinations of horizontal and vertical curves can result in apparent discontinuities in the alignment, even though the horizontal and vertical designs each comply separately with the provisions of Chapters 11 and 12.

The main principle of obtaining good co-ordination between horizontal and vertical alignments is given below:

Ideally vertical elements should be superimposed on horizontal ones in such a way that the intersection points practically coincide with the horizontal slightly in advance of the vertical, and the horizontal and vertical curves are of similar lengths.

When horizontal and vertical curves are superimposed, the combination of superelevation and vertical profile may cause distortion in the outer pavement edges which could confuse drivers at night ie. give poor driver perception. Computer packages are available which enable a designer to view the roadway from the drivers perspective. The use of these packages can enable a designer to identify such distortions in the outer pavement edges.

Figure 10.5 shows examples of ideal and acceptable co-ordination of horizontal and vertical curves.

10.3.3 Specific Co-ordination Issues

Some situations in which poor coordination of vertical and horizontal alignment occurs are discussed in the following paragraphs.

The vertical curve overlaps one end of the horizontal curve

If a vertical crest curve overlaps either the beginning or the end of a horizontal curve, drivers have little time to react to the horizontal curve once it comes into view. This is a particularly unsafe practice if there is a decrease in 85th percentile speed at the start of the horizontal curve. An example of this is shown in the upper diagram of Figure 10.6.

The defect may be corrected in both cases by completely separating the curves. If this is uneconomic, the curves must be adjusted so that they are coincident at both ends, if the horizontal curve is of short radius. If the horizontal curve is of longer radius, they need be coincident at only one end.

The vertical curve overlaps both ends of the horizontal curve

If a vertical crest curve overlaps both ends of a sharp horizontal curve, a hazard may be created because a vehicle has to undergo a sudden change of direction during passage of the vertical curve while sight distance is reduced. This creates the same problems as discussed above.

The corrective action is to make the curves coincident at one end so as to bring the crest on to the horizontal curve.

Insufficient separation between the curves

If there is insufficient separation between the ends of the horizontal and vertical curves, a false reverse curve may appear on the outside edge-line at the beginning of the horizontal curve, or on the inside edge-line at the end of the horizontal curve. This is a visual defect and is illustrated in the middle diagram of Figure 10.6.

Corrective action consists of increasing the separation between the curves.

Dissimilar length horizontal and vertical geometric elements

A short movement in one plane should not be placed within a large movement in the other. A particular instance where this can lead to safety problems is when a small depression in the vertical alignment results in a ‘hidden dip’. An example of a hidden dip is shown in the upper diagram of Figure 10.9. (See also Figure 10.7.) Large depressions such as those shown in the lower diagram of Figure 10.5 are not deemed to be hidden dips.

Corrective action consists of making both ends of horizontal and vertical curves coincident, thus producing similar length curves. An alternative treatment is to completely separate the curves.

Figures 10.9 and 10.10 show examples of grossly dissimilar lengths of both horizontal and vertical geometric elements where short movements in one plane are combined with large movements in the other.

Long Flat Grades

Long straights with flat grades make it difficult for drivers to judge the distance and speed of approaching vehicles leading to overtaking accidents. An approaching vehicle more than 2500m away on a straight seems to be standing still but the same situation on a large curve provides the driver with a changing perspective allowing some judgement of speed and distance. This situation is exacerbated at night.

Roller Coaster Grading

Long straight sections are prone to “roller coaster” grading (see Figure 10.7) with the added potential for hidden dips. Designers should take care that these features are not incorporated into the design by using appropriate curvature in both planes and checking lines of sight for hidden dips.

Optical Summit

Figure 10.8 illustrates a phenomenon known as “Optical Summit” brought about by the combination of vertical and horizontal alignments. The horizontal curve does not overlap the two vertical curves and the vertical curves are too small for the large movements in the other plane. The appearance has been improved considerably by the adjustments to both alignments as shown in the figure. The horizontal curve has been lengthened to encompass both of the sag vertical curves and the sag curves have been lengthened to be more in keeping with the scale of the other movements.

This example also illustrates the benefit of using perspective views during the design process to highlight potential problems while they can still be corrected at minimal cost.

10.4 Fitting the Road to the Terrain

10.4.1 General

A visually attractive and physically unobtrusive road will be one that integrates well with the environment through which it passes.

"A general rule for designers is to achieve a flowing line, with a smooth and natural appearance in the land, and a sensuous, rhythmic continuity for the driver. This effect results from following the natural contours of the land, using graceful and gradual horizontal and vertical transitions, and relating the alignment to permanent features such as rivers and mountains." (Aesthetics in Transportation, US DOT, 1980).

10

The opposite of this occurs with designs using a combination of long tangents with short curves whether in the horizontal or vertical plane. Figures 10.10 and 10.11 illustrate examples of the results achieved.

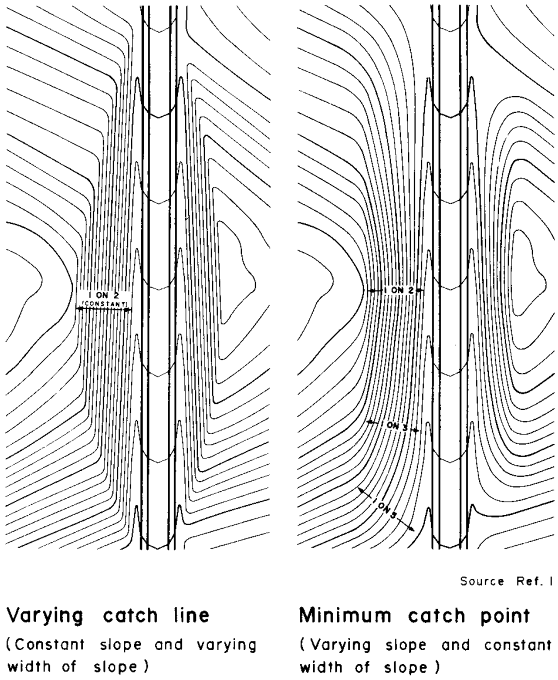
In urban areas, the type of surroundings will depend on the land use of the areas through which the alignment passes. The hard lines of an industrial area will be complemented more by a design which incorporates features such as retaining walls and other structures more in keeping with that urban form. The urban form of the area being traversed will dictate the detail of the design whatever that form. A length of urban road may call for several changes in the design concept as the road passes from one form to another.

Split carriageways in urban setting

In other areas it will be rare that the terrain precisely matches the speed that must be used for the design of the alignment elements. Earthworks will be needed to mould the road into the terrain but careful attention to the principles in this Chapter will minimise the intrusion caused by this.

It was pointed out in Section 6.1 that drivers will adopt a speed related to the horizontal alignment and the terrain. If the horizontal alignment can be designed to match the terrain, the road will be consistent with driver expectations, aesthetically pleasing and economical. Figure 10.12 shows two alignments through the same hill, one generally following the contours and producing a more pleasing result than the other at a much lower cost in earthworks.

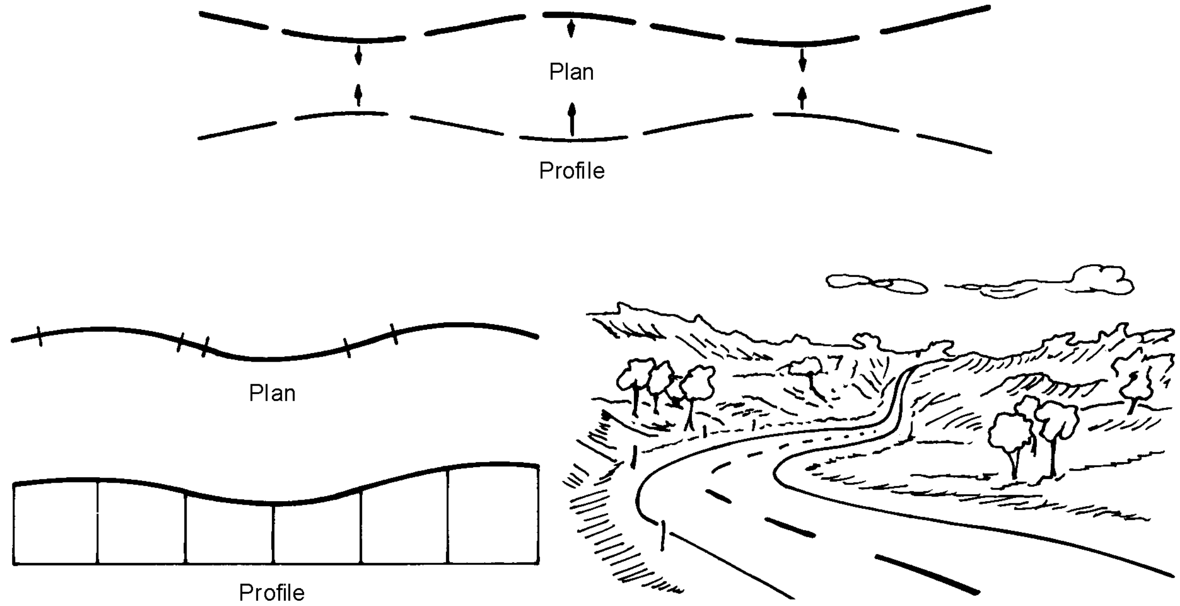
The use of continuous liberal curves is preferred to long tangent, short curve design. An example of this is shown in Figure 10.5.



Varying the width and slope of batters

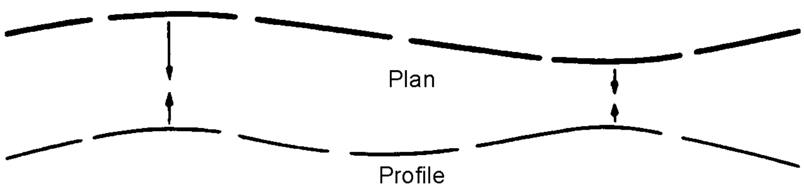
In flat open terrain, long straight road sections are common, but generally there is advantage in avoiding excessive lengths of straight road. A gentle curvilinear design (consisting of large radii horizontal curves) always helps to keep the operating conditions 'under control' and at the same time, affords scope for far more sympathetic fitting of the road to the terrain.

In addition, safety is enhanced by making the drivers more aware of their speed, by allowing them to make better assessment of the distances and speeds of other vehicles, by reducing headlight or sun glare in appropriate circumstances, and by reducing boredom and fatigue.

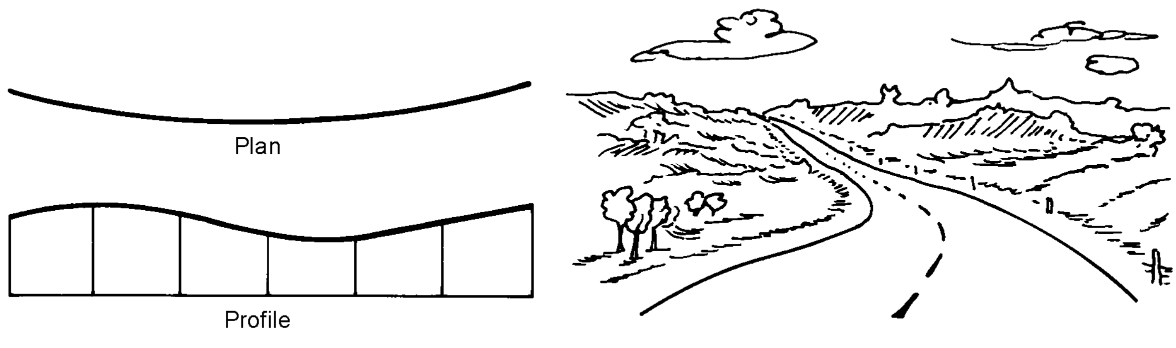


The ideal combination. A smooth flowing appearance results when vertical and horizontal curves coincide. Ideally, horizontal curves should slightly overlap the vertical.

IDEAL CO-ORDINATION



A legitimate case of coordination: one phase is skipped in the horizontal plane, but vertices still coincide. The long tangent in plan is softened by vertical curvature.

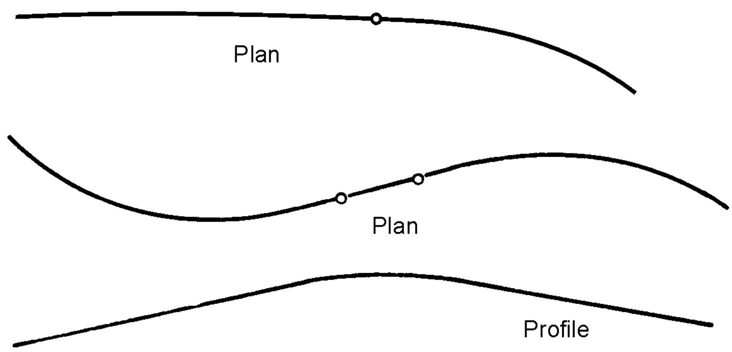


If the horizontal scale is large and the vertical scale relatively small, it may be satisfactory to include two vertical movements on one long horizontal curve.

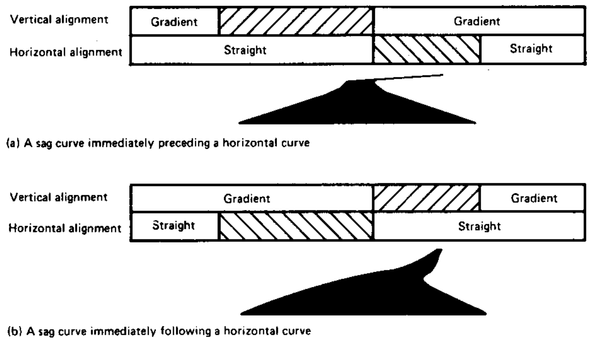
ACCEPTABLE CO-ORDINATION

Figure 10.5 Ideal and Acceptable Co-ordination of Vertical and Horizontal Alignments

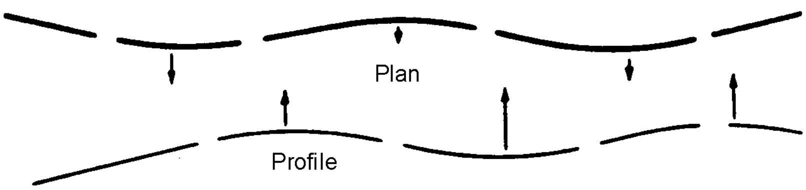
10



VERTICAL CURVE OVERLAPS ONE END OF THE HORIZONTAL CURVE



INSUFFICIENT SEPARATION BETWEEN CURVES



NON-COORDINATED HORIZONTAL AND VERTICAL ALIGNMENTS
(ALIGNMENTS OUT BY HALF A PHASE)

Figure 10.6 Poor Co-ordination of Vertical and Horizontal Alignments

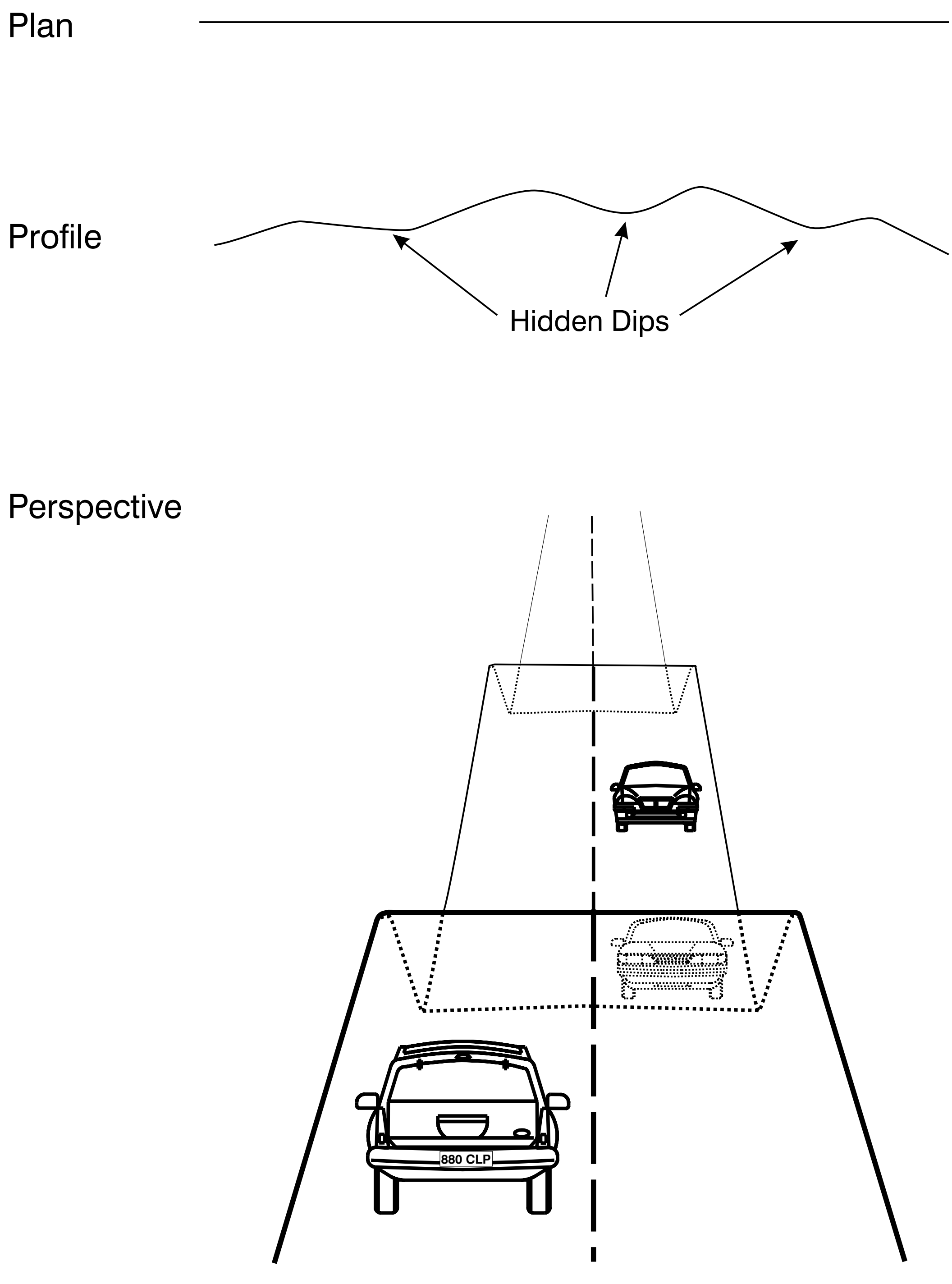


Figure 10.7 Roller Coaster Grading resulting in hidden dips

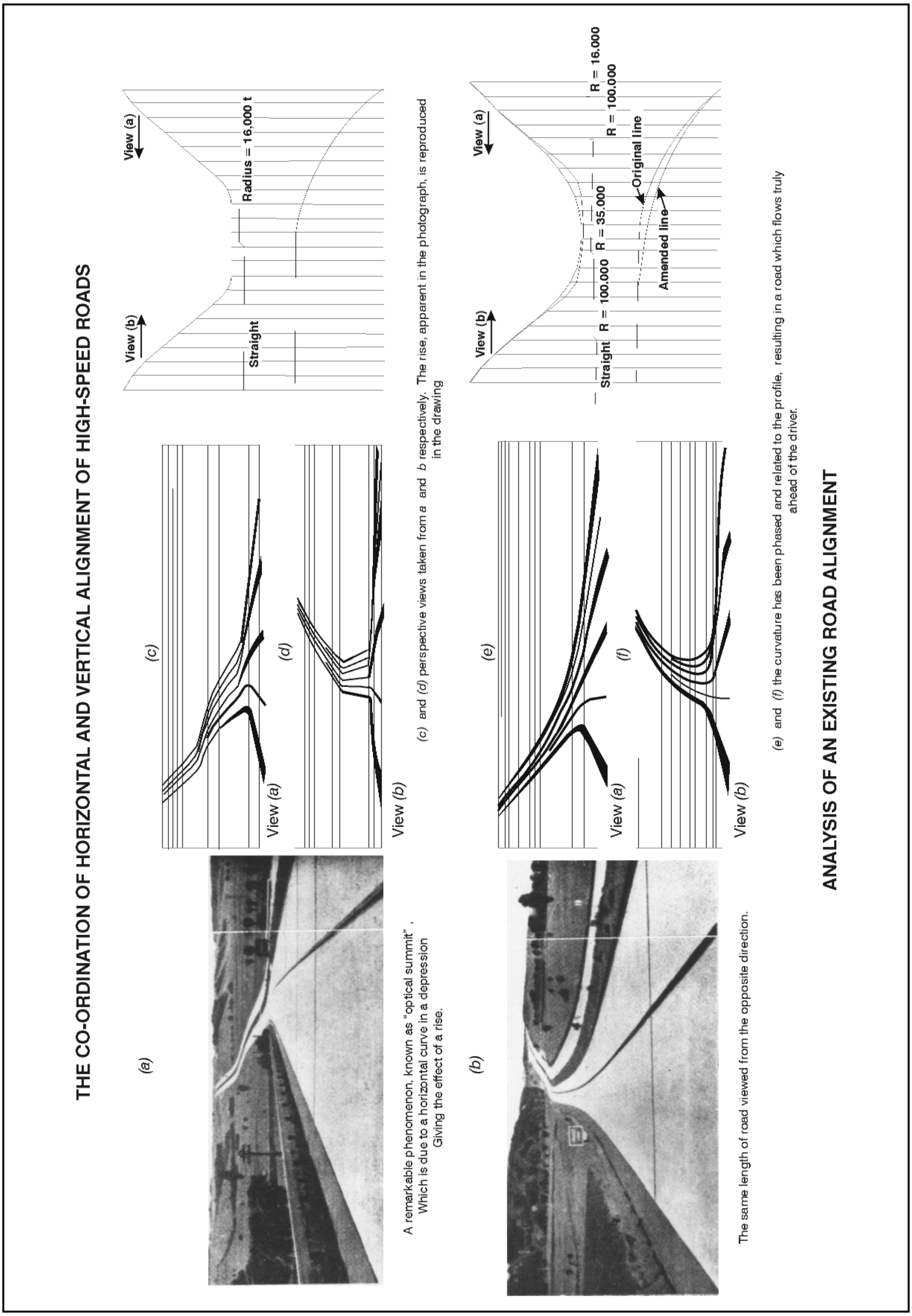


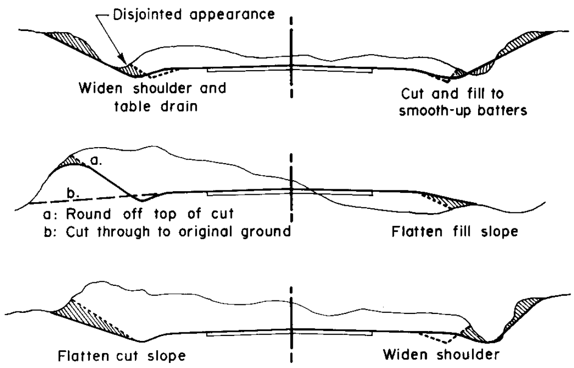
Figure 10.8 The "Optical Summit" Effect

For additional information on curvilinear alignment design in flat terrain, refer Section 10.11.

10.4.2 Approaches to Design

Designers have to exercise their creativity and ingenuity as well as their knowledge and skill in road design to produce the most effective results. Some of the ways in which they can improve the likelihood of more pleasing and effective designs are discussed below.

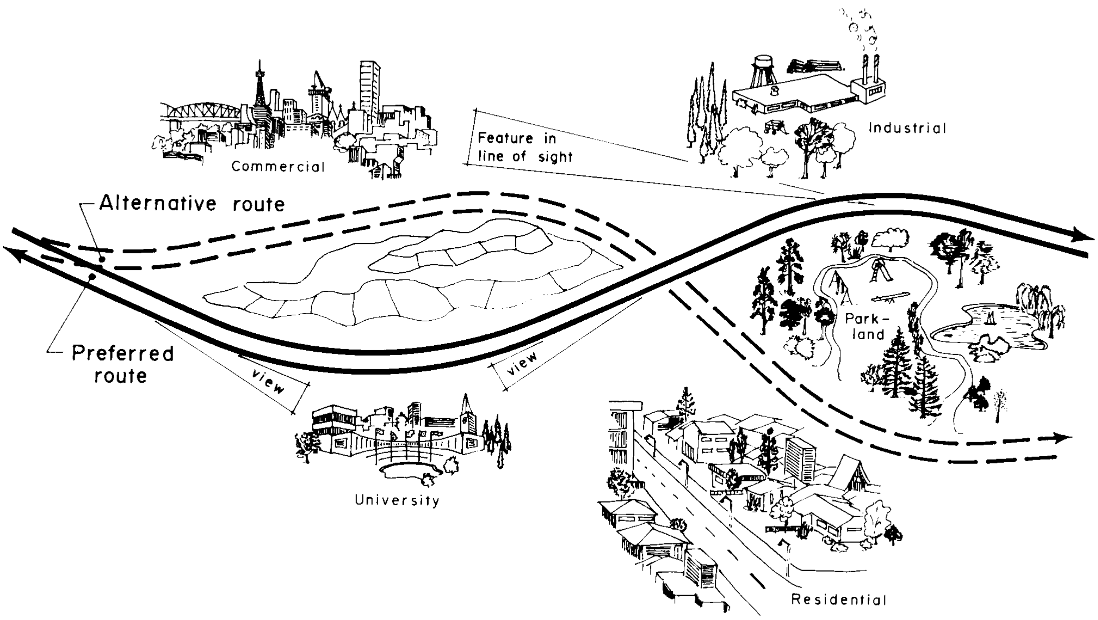
- Careful attention to detail will alert the designer to potential improvements in the design -
  - Minor alignment shifts
  - Rounding of batters, shoulders and table drains
  - Flattening fill and cut batters, particularly where they are small (may also be able to avoid the use of guard rail)
  - Adopting constant minimum batter catch points to transition from cut to fill
  - Using independent alignment and grading for each direction of traffic
  - Cut and cover tunnels to overcome both urban and rural problems of separation



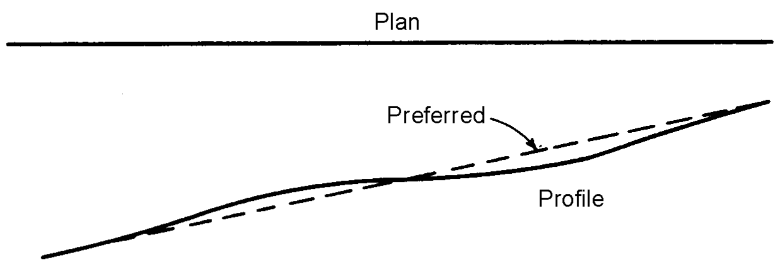
Blending batters with the roadside

- Use of a multidisciplinary team will assist the designer to reach the right conclusions. The team must be in place at the start of the process to achieve the best result (see 10.1 above). For the most complex designs, in addition to the road designer, the team may include -
  - Landscape Architect
  - Urban Designer/ Architect
  - Environmental Scientist
  - Town Planner
  - Structural Engineer
  - Road Engineers (drainage, pavement, geotechnical)

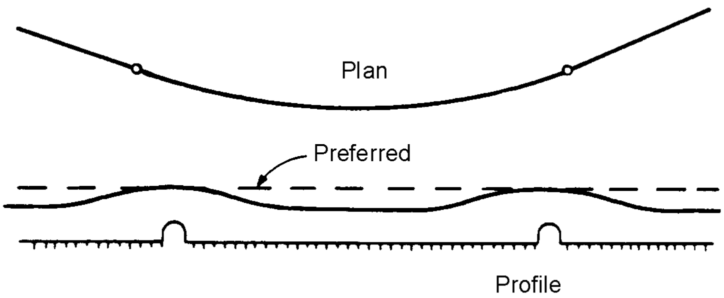
10



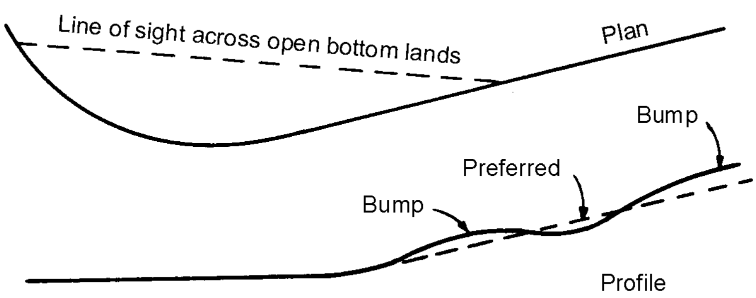
Location principles - choice of alignment



Avoid designing little local dips in an otherwise long, uniform grade. These usually result from zeal to balance cut and fill exactly and reduce overhaul.

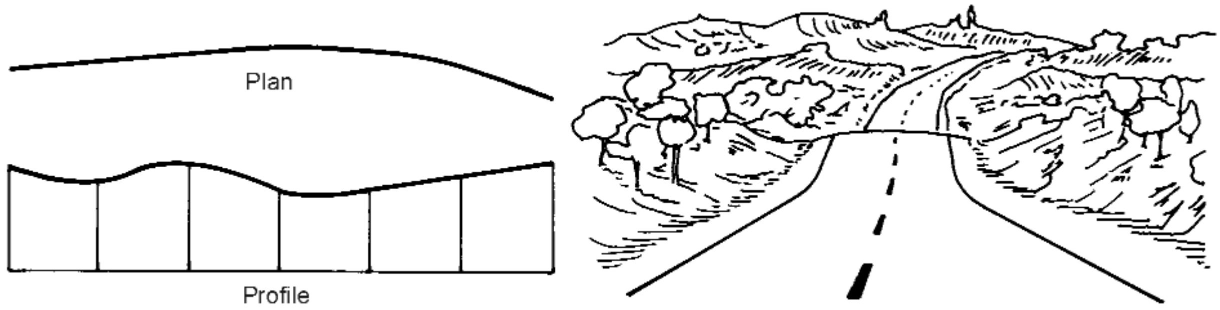


Short humps in the grade should be avoided.

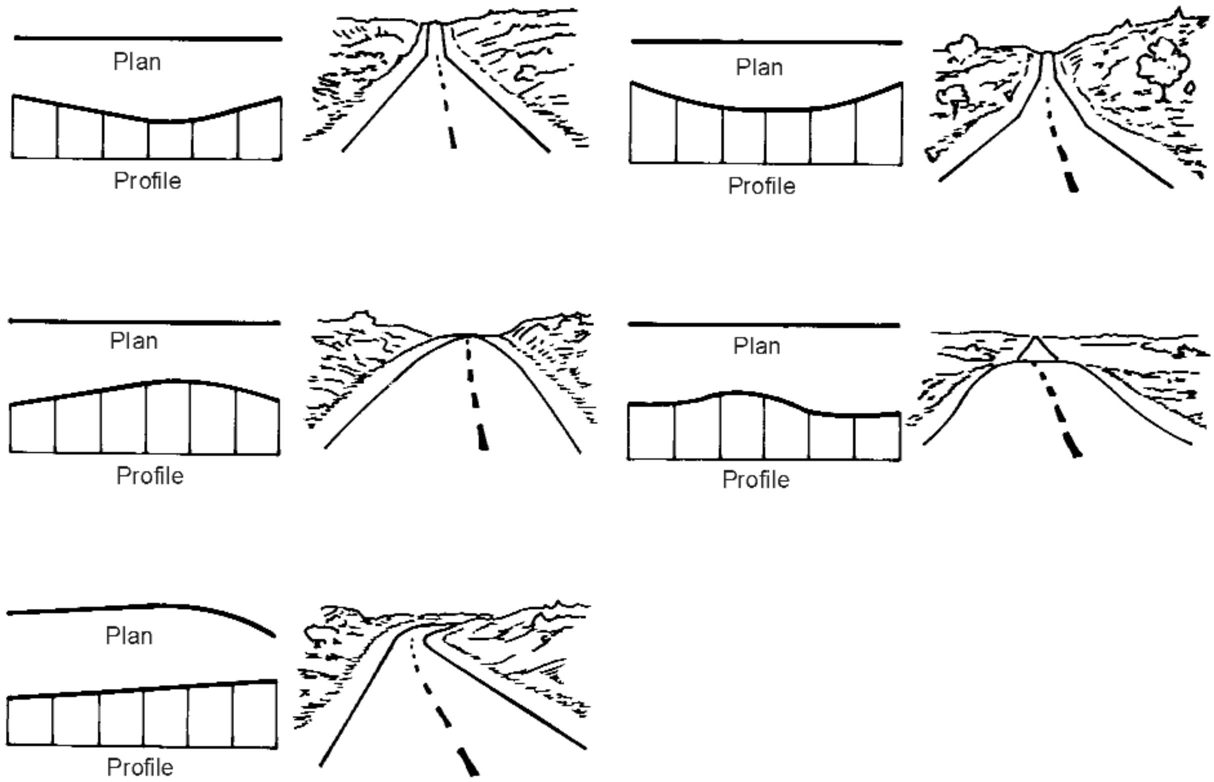


A distant side view of a long grade on tangent will reveal every bump on it

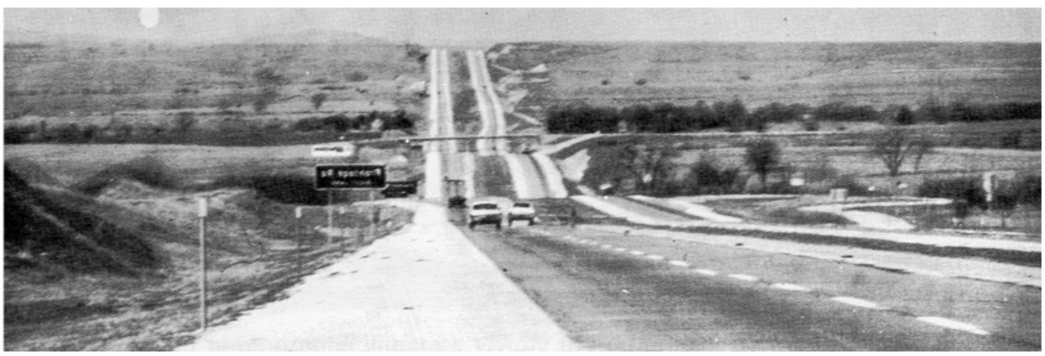
Figure 10.9 Poor Co-ordination of Alignments



An example of visually poor alignment with unrelated horizontal and vertical curves, and broken backed horizontal curves



A short movement in one plane should not be placed within a large movement in the other



Long straight grades combined with short vertical curves on a straight alignment produce a visually poor result

Figure 10.10 Poor Co-ordination of Alignments

A road which is not well fitted to the terrain. The use of long tangent, short curve design creates this lack of relationship with the generally gently rolling countryside.

A road well fitted to the terrain. This has been achieved by the use of continuous liberal curves.

Figure 10.11 Fitting the Road to the Terrain

For smaller projects, the size and expertise of the team would have to be tailored to the needs of that project. However, most projects will need to have input from many of these specialists in any case and the designer should ensure that the appropriate questions are put to them and suitable solutions generated.

- Preservation of / Integration with natural and man made features can enhance the fit of the road to the landscape and capture notable points of interest for the driver and passengers of the vehicles using the road. And it will reduce the intrusion of the road into the landscape. These features can often create an "aiming point" to justify a change in direction of the road thereby introducing interest into what may otherwise be a boring vista. Such features include -
  - Unique rock formations
  - Isolated hills / hills of interesting shapes
  - Patches of rain forest
  - Feature trees (or clumps of trees)
  - Streams and lakes
  - Man made features (historic building; isolated property buildings; windmills)

Figure 10.12 illustrates examples where the road has been designed sympathetically with the landscape compared with the alternatives which ignored the impact on the landscape.

10.5 Curvilinear Design in Flat Terrain

The traditional approach to the design of roads on extensive flat plains has been to use long tangents with relatively short horizontal curves between them. In some cases, this has created exceptionally long lengths of straight resulting in monotonous driving conditions.

While the straight sections provide some orientation, the road is uninteresting as it is totally predictable. The constant sameness of view makes driving monotonous and fatiguing leading to the driver losing all sense of pace, time and real speed with the distinct possibility of the driver falling asleep.

This can be explained by considering the effect of speed on perception and vision. As speed increases -

- concentration increases;
- the point of concentration recedes;
- peripheral vision diminishes;
- foreground detail begins to fade; and
- space perception becomes impaired.

Thus the higher the speed, the further ahead the driver focuses and the more concentrated the angle of vision becomes. This restriction of vision (sometimes called "tunnel view") is the process used to induce hypnosis and sleep. Unless the point of concentration is made to move around laterally by means of a curvilinear layout of the road, driving will become hypnotic causing the driver to fall asleep.

To achieve space perception, it is necessary to have a lateral component of movement to allow the driver to assess relative changes in the size and position of objects. This enables the driver to discern movement and its direction. Horizontal curves provide this lateral component, the rate of movement depending on the radius of the curve.

The concept of a continuously curving alignment with constant, gradual and smooth changes of direction evolved and the curvilinear alignment concept of long flat circular curves joined by spiral transitions was born. Inherent in this concept was the idea that curves would vary up to 30,000m radius. If the curve radii are confined within the limits of 10,000m to 30,000m, the need for transitions disappears.

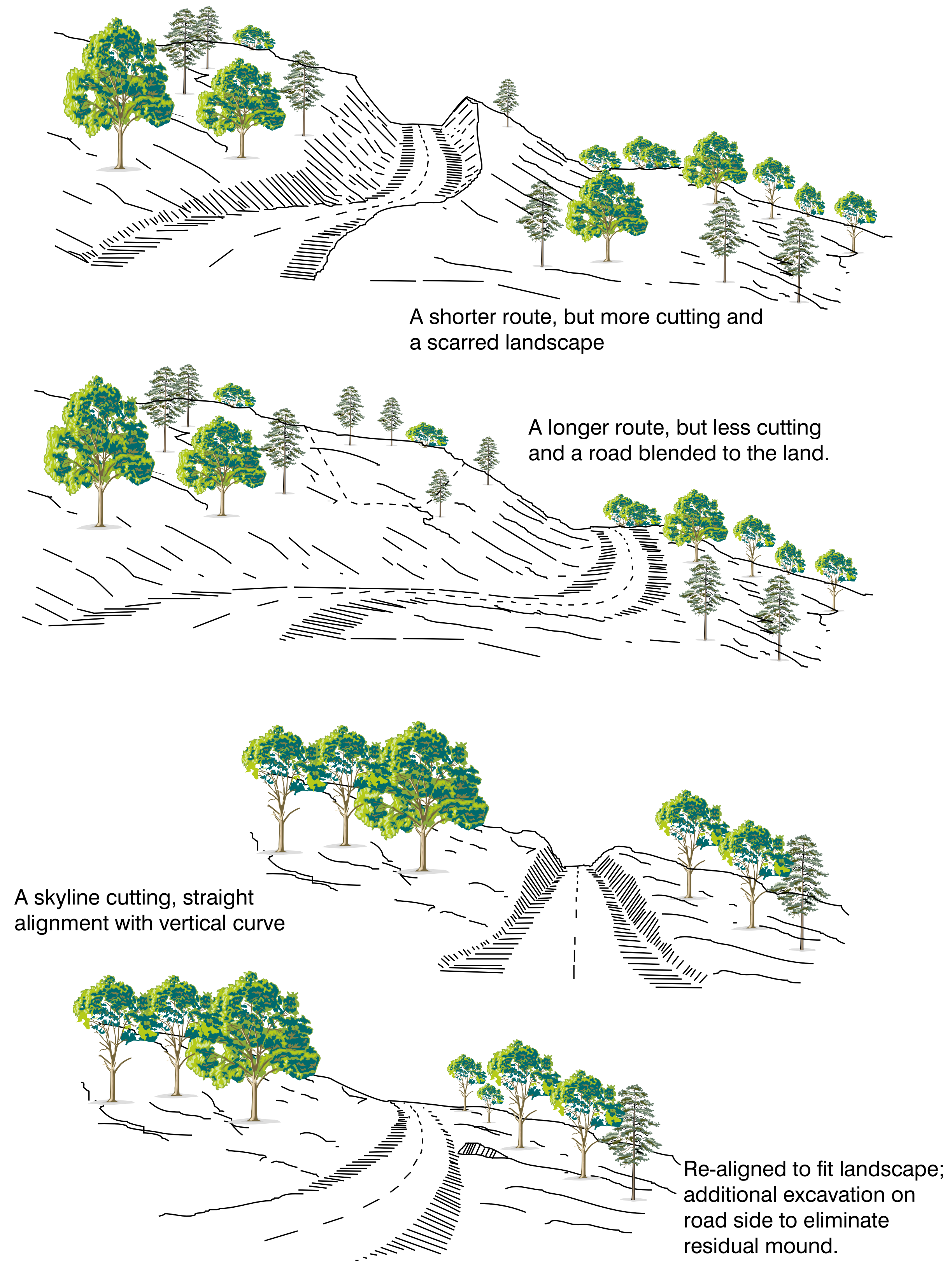


Figure 10.12 Examples of Road-landscape Compromise

Curvilinear alignment from the driver's viewpoint

Typical long tangent from the driver's viewpoint

The radius to use depends on several factors including the type of topography and the driver's desired speed of travel, the preferred radius depending on how far ahead the driver can see the road. At high speeds, the driver looks from 300m to 600m ahead and a curve should be at least this long to be visually significant when the driver is on it. A curve ceases to be visually significant if the visible part of the curve does not accomplish a turn of more than two degrees (e.g. for a curve of radius of 15,000m, the visible length of roadway should be at least 524m).

It is desirable to adopt a three-degree deflection angle as a minimum resulting in curve radii between 3000m and 30,000m. Where extensive flat plains occur, it is desirable that overtaking sight distance is provided on as much of the road as possible. This can be achieved on a 15 000m radius curve, and an alignment with this radius as a minimum will have continuous overtaking sight distance.

The larger the radius, the closer the alignment becomes to a straight line and the less the advantages of the curve become. There is little point in using radii larger than 30 000m for this reason.

10

Table 10.1 Curvilinear Alignment - Minimum Requirements Summary

Factor	Value
Radius	• Min. 3000m; Max. 30,000m
Deflection	• Min. 2° for visible part of the curve (e.g. for 15,000m radius, a length of 524m is required). • Desirable 3° (requires curves from 3000m to 30,000m radius). • Over 30,000m, the road appears straight - there is no point in using curves of larger radius than this.
Overtaking Sight Distance	• 15,000m radius curves provide continuous overtaking sight distance.

The advantages of a curvilinear alignment are:

- driving is more pleasant as the road unfolds itself smoothly with no unexpected checks;
- judging distance to an approaching vehicle is easier for the driver and therefore better decisions on overtaking manoeuvres can be made;
- the view ahead is constantly changing;
- monotony can be reduced by directing the road towards interesting features of the countryside for short periods; and
- night driving is more comfortable in that the approaching headlight glare is significantly reduced. On long straights, headlights become visible and annoying from a long distance away

(up to 15km), but on a curvilinear alignment, the glow of the approaching headlights becomes visible before the lamps become visible, the rate of approach can be better judged and the disability glare is significantly delayed.

Where the road passes through a forested area, the curvature of the road creates a continuous backdrop of trees providing excellent conditions for detecting the continuing angular change. The larger radii alignments have worked well in these cases. On treeless plains, some of the effect of the curvilinear alignment is lost. In these circumstances, the smaller radii would be more effective.

New large radius curvilinear alignment adjacent to old, long tangent/short curve alignment

In more undulating topography, the combination of the vertical curvature with the large radius horizontal curves becomes important and the principles discussed in 10.3 above must be applied. For example, short sag vertical curves may be accentuated by the large radius horizontal curves creating the appearance of a kink. It may be necessary to adopt a vertical alignment with significantly larger radius curves to avoid the appearance of kinks. Radii in both dimensions will have to be tailored to meet the circumstances, based on the extent of the driver's vision of the road ahead.

The principles of curvilinear alignment can be applied in a wide range of circumstances using a wide range of curve radii together with spirals. The vast plains of the inland lend themselves to this approach and roads designed on these principles provide an improved result for the users.

References

AASHTO (1994): "A Policy on the Geometric Design of Highways and Streets".

MacPherson, R.A. and L.J. Louis (1976): "Curvilinear Alignment Design in the South Western Plains" - Queensland Roads.

Tunnard, C. and B. Pushkarev (1963): "Man Made America: Chaos or Control".

U.S. Department of Transportation (US DOT) (1980): "Aesthetics in Transportation".

U.S. Department of Transportation (US DOT) (1997): "Flexibility in Highway Design".

Relationship to Other Chapters

- Closely related to Chapters 11 and 12 – they provide the details, this chapter provides the guidelines for putting them together;
- The cross section and how it interacts with the horizontal and vertical alignments also affects the operation and aesthetics (Chapter 7);
- The principles of this chapter have to be considered in planning – Chapter 2;
- Alignment issues arise in Chapters 4, 13, 14, 15, 16, 20 and 22.