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Chapter 8

Safety Barriers and Roadside Furniture

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Chapter 8 Amendments – June 2005

Revision Register

Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
1	8.1	First Issue of Section 1	Steering Committee	Nov 2000
	8.2	First Issue of Section 2		May 2000
	8.3	First Issue of Section 3		
	8.4	First Issue of Section 4		June 2000
2	Figure 8.1.2	Modifications	Steering Committee	June 2000
	8.1.3.2	Modifications to 1st paragraph		
	8.1.3.3	"Example of Costing for a Collision": Total = 86,660		
	8.1.4.1	The base encroachment rate changed to 0.00030.		
	Figures 8.1.6 to 8.1.17	Modifications		
	8.1.5.2	In "Example 2": 1st paragraph modified		
	Appendix B	Appendix B added.		
	8.2.8.1	Modification to Table 8.2.7	W. Semple.	Jan 2001
	8.4.1	Sections on Single and Multiple sign supports reworded; modifications to figures; Figures 8.4.5 to 8.4.7 removed.	W. Semple.	Oct 2000
	8.4.2	Figures 8.4.8 to 8.4.14 removed; Figure 8.4.7 renumbered to 8.4.5.		
	8.4.5	Figures renumbered; "Flood Gauge Posts" replaced with "Flood Depth Indicators" and some rewording; Figure replaced and renumbered.		
	8.4.7	Renamed "Help Telephones" and reworded.		
	8.4.8	Figures 8.4.18 to 8.4.21 removed - cross reference to Standard Drawings; some rewording; remaining figures renumbered.		
3	8.1 to 8.3	Major Review	Steering Committee	Jan 2002

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Issue/ Rev No.	**Reference Section**	**Description of Revision**	**Authorised by**	**Date**
3	8.4.1	Modification to Single and Multiple Supports sections	W. Semple.	Jan 2001
	8.4.5	Modification to Flood Depth Indicators section		
4	8.4	Major Review	-	Jan 2002
5	All	Major Review and re-write. Format and layout changed.	Steering Committee	June 2005

Chapter 8
Safety Barriers and Roadside Furniture

Glossary

AADT - Annual Average Daily Traffic

Base Encroachment Rate (BER) - The rate that vehicles are expected to encroach a hypothetical length of road in a prescribed time period based on a given number of vehicles per day using the roadway. (A typical value for the BER = 0.0003 enc/km/year/vpd)

Backslope – Also known as a cut slope.

Benefit Cost Analysis - A method by which the estimated benefits to be derived from a specific course of action, are compared to the costs of implementing that action. If the estimated benefits of a specific design exceed the cost of constructing and maintaining it over a period of time, it is considered beneficial.

Benefit Cost Ratio (BCR) - the ratio of the estimated benefits to be derived from a specific course of action divided by the costs of implementing that action.

Breakaway - A device that allows an object such as a sign, or luminare, to yield or separate upon impact.

Clearance - Lateral distance from edge of travelled way to a roadside object or feature.

Clear Zone - The border area that begins at the edge of each travelled lane and is available for emergency use by errant vehicles that run off the road. This zone includes any adjoining lane/s, road shoulder, verge and batter.

Crash Cushion - Device that prevents an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle to a safe stop, or by redirecting the vehicle away from the hazard.

Crash Rate Threshold - The threshold of crashes in a given time period that warrants remedial action. Any crash rate above the threshold would warrant remedial action to address the situation. (Note: Installation of a barrier is not the only solution to a problem.)

Downstream Face - The face of the obstacle/hazard that is facing away from the oncoming traffic on the adjacent roadway.

Encroachment - When an errant vehicle departs from the travelled way.

Encroachment Rate - The number of errant vehicles that depart from the travelled way in a given time period.

End Treatment - The designed modification at the end of a roadside or median safety barrier.

Flare - The variable offset of a safety barrier to move it further from the travelled way.

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Foreslope – Also know as fill slope or embankment slope.

Frangible - A type of structure that is readily or easily broken upon impact.

Grade Adjustment Factor - A factor that is used to adjust/calculate the encroachment frequency based on the grade of the roadway that is adjacent to the section under investigation. Steep downgrades will greatly increase the encroachment frequency.

Hinge Point - The point where the extended crossfall of the verge area meets with the batter slope. This point is associated with rounding where it is applied.

Horizontal Curve Factor - A factor that is used to adjust/calculate the encroachment frequency based on the horizontal curvature of the roadway that is adjacent to the section under investigation. Tight curves greatly increase the encroachment frequency.

Impact Angle - For a longitudinal safety barrier, it is the acute angle between the tangent to the face of the safety barrier and a tangent to the vehicle's path at impact. For a crash cushion, it is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicle path at impact.

Intersecting Slope – Situations where the hazard offset from the direction of travel has both positive and negative batter slopes. For example, a drain perpendicular to the direction of travel. see Figure 8.69 in Appendix 8A.

Lateral Offset - The offset from a specified portion of the roadway. This is usually the perpendicular distance from the edge of that adjacent carriageway to the point being investigated.

Length of Need - The total length of longitudinal safety barrier needed to shield an area of concern.

Longitudinal Barrier - A safety barrier whose primary function is to prevent penetration and thereby safely redirect an errant vehicle away from a roadside or median hazard.

Median - The central strip of road not intended for use by traffic, which separates opposing traffic flows. Median width includes both adjacent shoulders.

Median Barrier - A longitudinal safety barrier used to prevent an errant vehicle from crossing the road median.

Parallel Face - The face of the roadside hazard that is closest to the adjacent roadway and is parallel to the direction of the roadway.

RISC - "Roadside Impact Severity Calculator" program.

Risk Assessment - Risk assessment is the tool that attempts to minimise risk. It is based on the philosophy of controlling potential losses by analysing costs associated with loss making situations, determining the risk of such events occurring and comparing with the cost of control.

Roadside Barrier - A safety barrier whose primary function is to prevent penetration and to safely redirect an errant vehicle away from a roadside or median hazard.

Safety barrier - a longitudinal, median or roadside barrier.

Severity Index (SI) - A SI is a number from 0 to 10 used to categorise a crash by the probability of it resulting in property damage, personal injury, or a fatality, or any combination of these outcomes. The resultant number can then be translated into a crash cost and the relative effectiveness of alternative treatments can be estimated.

Slopes

Recoverable slope - A slope on which a motorist will probably retain control of a vehicle. Slopes 1 on 4 or flatter are generally considered recoverable.

Traversable slope - A slope that is considered traversable as the errant vehicle will continue on to the bottom. Embankment slopes between 1 on 3 and 1 on 4 may be considered traversable if they are smooth and free of fixed objects.

Non-recoverable slope - A non-recoverable slope is one on which a vehicle is likely to overturn and can be considered as a hazard in itself. Embankment slopes steeper than 1 on 3 are considered non-recoverable.

Swath Width - The width between parallel lines that are at an angle to the roadway and contact with the front prominent corner and the rear prominent corner of the errant vehicle.

Transition - The joining of two different safety barrier systems to produce a gradual stiffening of the approach guardrail to prevent vehicular pocketing, snagging, or penetration at the connection. This is commonly used where a roadside barrier is connected to a bridge railing, or to a rigid object such as a bridge pier.

Travelled way - The portion of the carriageway that is assigned to moving traffic, excluding shoulders and parking lanes.

W-Beam Guardrail - A common type of steel guardrail that has a profile similar to the shape of the letter “W”. It is used with a variety of post configurations that reflect the intended performance of the safety barrier.

Upstream Face - The face of the obstacle/hazard that is facing towards the oncoming traffic on the adjacent roadway.

85th percentile speed - Eighty-fifth (85th) percentile speed is the speed at, or below, which 85% of cars are observed to travel under free flowing conditions past a nominated point. Eighty-five percent of car drivers will be equal to or slower than, and 15% will be faster than, this speed (considering only those vehicles not constrained by other vehicles, i.e. in free flowing conditions).

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8.1 Identification, prioritisation and treatment of hazardous roadside objects

8.1.1 Introduction

8.1.1.1 Purpose

The purpose of this Chapter is to reduce the frequency and severity of crashes by providing guidance in identifying and prioritising existing and potential roadside hazards for treatment using quantitative risk analysis, cost benefit techniques and qualitative evaluation. Using this guideline, together with engineering judgment, provides a rational approach to providing safety barrier installation, in a manner that will maximise the benefits to the community.

8.1.1.2 Scope

Section 8.1 provides information on the current best practice for the identification, prioritisation and treatment of roadside hazards (Table 8.1). It divides roadside hazards into three categories: embankments, rigid objects and median barriers.

Criteria and procedures outlined in this section are not a substitute for, but can assist engineering judgement. The unique circumstances of each location and the amount of funds available for road improvement must be considered when treating roadside hazards.

Typical objects included as hazards under the guidelines are as follows:

- Trees, poles and sign supports;
- Kerb and edge drop-offs;
- Roadside furniture;
- Ditches, drains and culverts; and
- Embankments and roadside barriers.

Table 8.1 Outline of evaluation procedure

Section/s	Description
8.1.2	A summary of the procedure used for identifying, assessing and prioritising the treatment of roadside hazards.
8.1.2.1, 8.1.2.2, 8.1.3	Guidance is provided on how to maximise the benefit from roadside barrier installation and identify high risk hazards and locations.
8.1.2.1, 8.1.2.2, 8.1.3.6, 8.1.4.1	Guidance is provided for identifying hazardous embankments and selecting an appropriate treatment.
8.1.2.1, 8.1.2.2, 8.1.3.7, 0	Guidance is provided for identifying hazardous objects and selecting an appropriate treatment.
8.1.2.1, 8.1.2.2, 8.1.3.8, 8.1.4.3	Guidance is provided for identifying median width hazards and selecting an appropriate treatment.
8.1.5	Guidance in the selection and prioritisation of treatments using quantitative and qualitative criteria.

8.1.1.3 Background

The current national publication by the National Association of Australian State Road Authorities (NAASRA, now Austroads) “Consideration for the Provision of Safety Barriers on Rural Roads” (NAASRA, 1987) and the **superseded** Main Roads Guideline “Engineering Note 56” (Main Roads, 1982) are generally based on the concept that a safety barrier is needed if, for a particular crash, the consequences of striking a fixed object, or running off the road, would be more serious than those associated with hitting the safety barrier. However, this method does not directly consider the probability of a crash occurring, traffic volume, road geometry or related costs.

To obtain the most cost effective outcome, a risk management approach for determining the need for safety barrier is required. This chapter adopts this approach and seeks to minimise risk while providing maximum benefit.

8.1.1.4 Application

This chapter is to be applied to the road network as shown in Table 8.2.

Table 8.2 Application of Chapter 8

Situation	Application of guideline
New construction	Applies to all new projects
Existing road network	To be applied when hazards are identified through the Road Safety Audit process, or when existing facilities are upgraded and/or maintained

8.1.2 Procedure

Figure 8.1 outlines the recommended procedure for identifying, assessing and prioritising the treatment of roadside hazards. This procedure involves four general steps as described below.

8.1.2.1 Identify the hazard

Potential hazards are identified using such variables as the clear zone, object severity and crash history (Section 8.1.3).

8.1.2.2 Determine treatment options

Establish the potential solutions for evaluation in the next phase of the process.

Based on the "Forgiving Roadside" concept, the options for treatment of roadside hazards, in order of preference, are as follows:

1. Remove the hazard.
2. Redesign the hazard so that it can be safely traversed.
3. Relocate the hazard to a point where it is less likely to be struck.
4. Reduce the impact severity by using an appropriate breakaway device.
5. Shield the hazard with an appropriately designed barrier.
6. Delineate the hazard to make it more conspicuous.

8.1.2.3 Evaluate the treatment options (Quantitative & Qualitative Assessment)

A risk assessment of the hazard and treatment options is undertaken, using quantitative measures to determine a Benefit Cost Ratio (BCR). The evaluation also includes qualitative assessment for suitability based on social, environmental and other factors. The software package named 'Roadside Impact Severity Calculator' (RISC) has been developed to perform the quantitative analysis associated with the evaluation process.

RISC requires the user to model roadside objects and potential treatment options using an array of numerical parameters. Once this is done the relative benefits and costs for different treatments are automatically calculated using an algorithm based on the AASHTO Road Design Guide. The most cost effective treatment for each hazard can be determined, and the decision-making process can continue to the next step.

8.1.2.4 Prioritise options

Each hazard reduction option is ranked using benefit cost analysis techniques and engineering judgement.

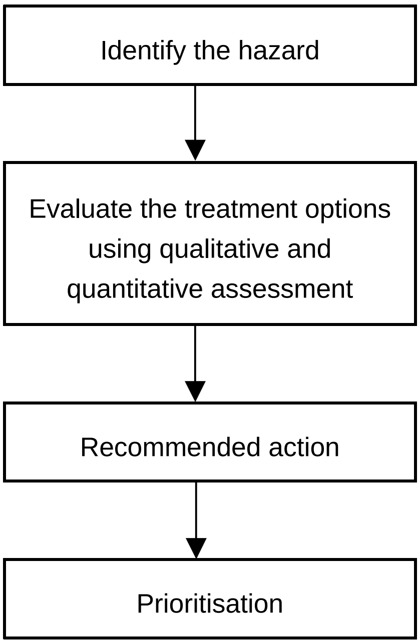

Figure 8.1 Flow chart of the four step process for identifying, assessing and prioritising the treatment of roadside hazards

8.1.3 Identify hazards

This section gives guidance to assessing the risk of impact by an errant vehicle with a roadside object. Figure 8.2 can be used in isolation or as part of the flow charts outlined later in this chapter for embankment, rigid object or median width hazards.

The two possible hazard identification outcomes are described as follows:

- The object is a potential hazard - The object possesses attributes and is located such that it is a potential hazard to errant vehicles; or
- The object is low risk - The object has low severity attributes and/or is located such that impact is unlikely. No further analysis is required for this object. Although the risk is low, this does not mean that the object is not a hazard to an errant vehicle. The level at which risk changes from being acceptable to being unacceptable is difficult to quantify and subject to debate. Therefore monitoring of the crash database and road environs should be undertaken to identify any change in circumstances.

8.1.3.1 Clear zone

If a roadside feature lies within the clear zone for a particular road segment, there is an increased probability of a collision. This probability increases as the clearance from the running lanes to the feature is reduced. Figure 8.3 depicts the relationship between vehicle speed and the probability of an errant vehicle travelling a particular lateral distance from the travelled way.

A preliminary review of Annual Average Daily Traffic (AADT) and distance-to-hazard considerations can be performed using the values depicted in Figure 8.4.

Note: The clear zone concept was first reported in Australia by Troutbeck (1983) and then adopted by VicRoads (Victoria) and the Roads and Traffic Authority (RTA - NSW). Figure 8.4 depicts the methodology outlined in the American Association of State Highway and Transportation Officials (AASHTO) "Roadside Design Guide" for the calculation of the desirable clear zone. It is important to note that these numbers are a general approximation, and the designer must keep in mind site specific conditions, design speeds, rural versus urban locations and practicality.

The designer may also choose to adjust the clear zone distance obtained in Figure 8.4

for the effects of horizontal curvature, by using the adjustment factor obtained from Figure 8.5. These adjustments are normally only made where crash histories indicate a need, or a specific site investigation shows a definitive crash potential which could be significantly lessened by increasing the clear zone width, and such increases are cost-effective.

For rigid objects the clear zone should be adjusted when positioned on non-recoverable embankment slopes. The actual offset to the rigid object is adjusted to reflect a new effective offset, taking into account the combined effect of both the embankment and the rigid object hazard. Equation 8-1 is used to calculate the adjusted offset for the object and the following two examples illustrate its application:

Equation 8-1 Adjusted offset

Adjusted offset = (E_S x offset) + (distance from edge line to hinge point)

Where:

- E_S - adjustment offset factor for slope - $E_S = 1 + \frac{s}{f}$;
- s - slope (negative for fill slope), expressed as a ratio; and
- f - braking and cornering coefficient of friction (0.4)

Equation 8-1 should only be used for slopes between 1 on 4 and 1 on 2.5.

For slopes flatter than 1 on 4, E_S should be taken as 1. For slopes steeper than 1 on 2.5, the adjusted offset distance should be taken as the distance from the edge of the trafficked way to the embankment hinge point.

The adjusted offset is calculated when the actual offset is multiplied by the adjustment factor. This results in the new adjusted offset, which is taken from the hinge point of the slope.

Example 1

If the cross section of the road between the travelled way and the object is flatter than 1 on 4, vehicles are able to recover. For this reason, the adjusted offset does not apply nor does it need to be calculated.

Example 2

If a row of light poles was located at the toe of a 1 on 3 embankment, there is an increased likelihood that an errant vehicle would reach the toe of the embankment and impact with the poles. If the offset was 4m and the distance from the travelled way to the hinge point of the slope was 1m then:

- E_S = 0.17
- Adjusted offset = (0.17 x 4) + 1 = 1.7m

If further investigation is desired to determine sensitivity of design parameters, then the RISC software should be used.

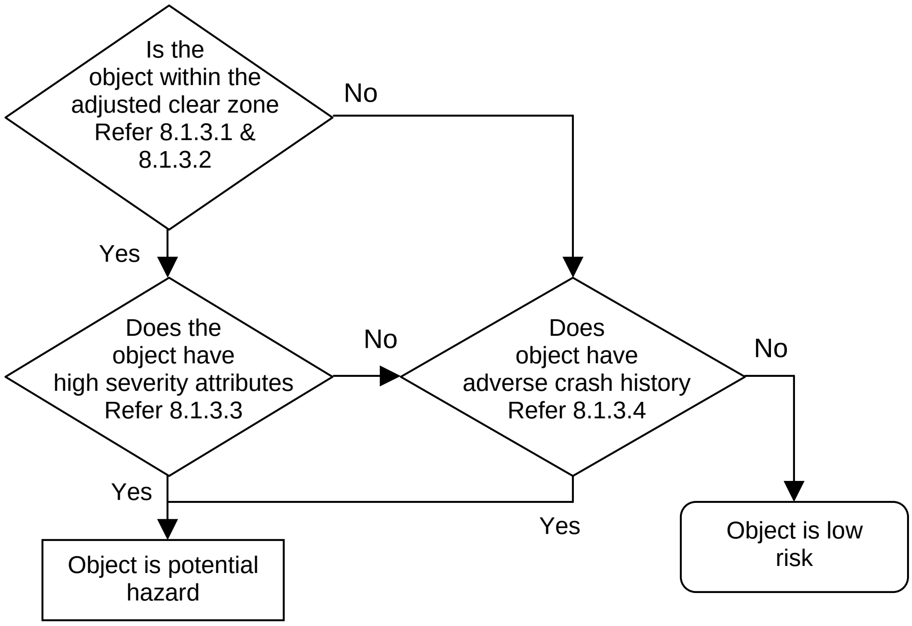

Figure 8.2 Flow chart for hazard identification

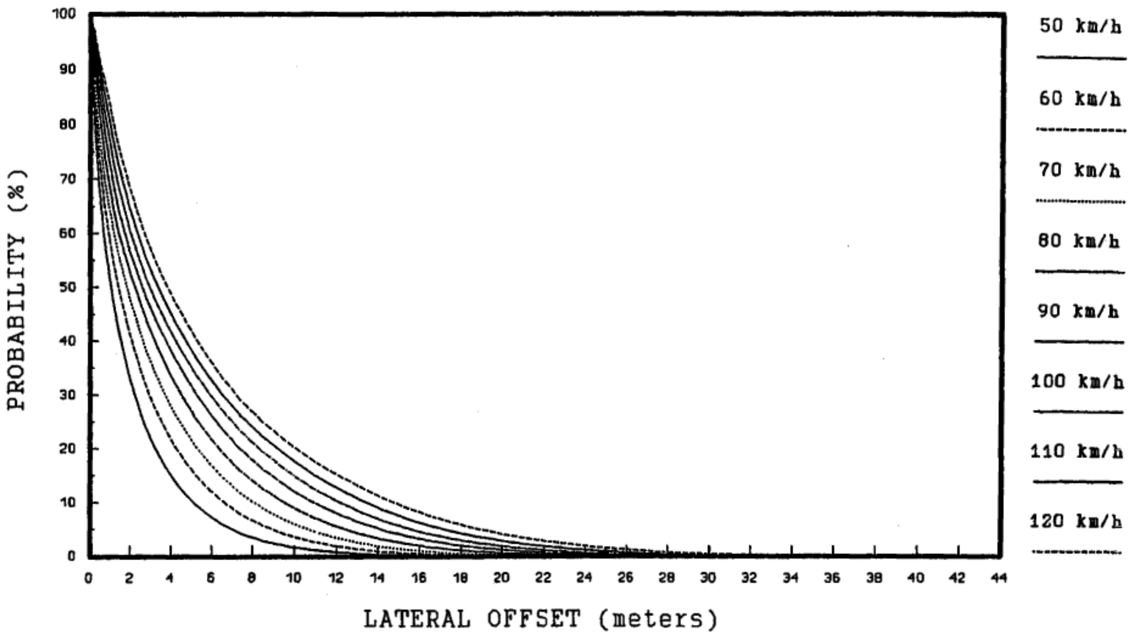

Figure 8.3 Probability encroachment curve

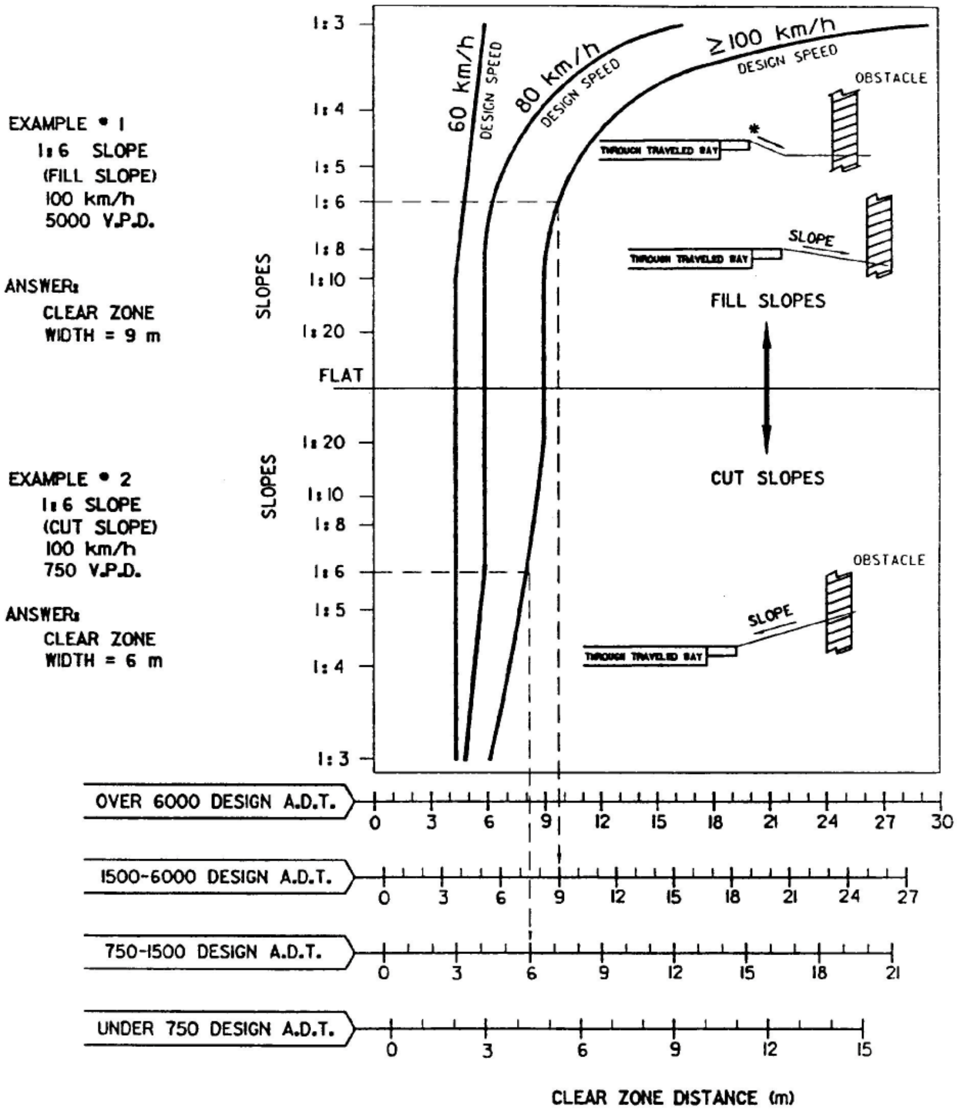

Figure 8.4 Clear zone distance curves

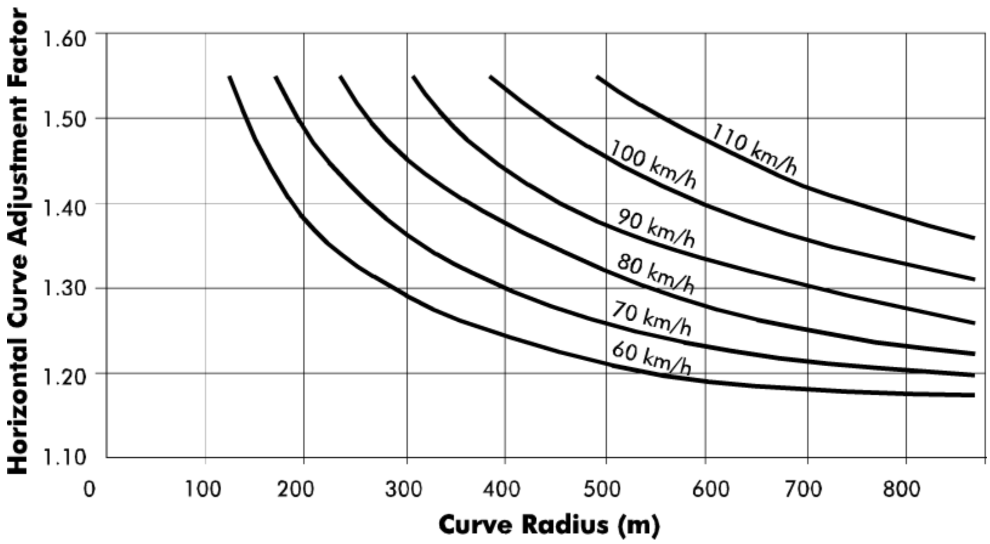

Figure 8.5 Horizontal curve adjustment

8.1.3.2 Road geometry

Horizontal and vertical curves can influence both the likelihood of a vehicle leaving the roadway and the lateral offset it will travel. When assessing objects located on the outside or inside of curves, or located on downgrades, consideration should be given to the increased number of encroachments into the clear zone and the likely distance that those vehicles might travel.

It has been well documented that road geometry can effect the probability of a vehicle leaving the road. In their Draft Road Design Guide 1996 the RTA (NSW) shows that road curvature can increase the probability by a factor of up to four when the object is on the outside of a right hand curve.

The longitudinal grade of a road can also affect the probability of a vehicle leaving the road, although this effect is not as significant as horizontal curvature effects. Where objects are located at the bottom of a grade consideration should be given to increasing the clear zone.

Figure 8.6 and Figure 8.7 provide correction/adjustment factors for the increased chance of encroachment based upon longitudinal grade and road curvature.

These factors provide an indication of the increased likelihood of vehicle encroachment from the roadway. Section 8.1.4 defines how these factors are used to modify the encroachment frequency.

8.1.3.3 Object severity

The size and fixity of an object affects both the probability and consequence of it being hit. In this chapter, objects with high severity are those likely to cause moderate to severe injuries to occupants, including death. The extent of injury is related to the speed of impact.

The term “Severity Index” (SI) is used to assign a weighted severity to an object. It is a measure of the expected severity outcome of an impact with the object; the severity index scale ranges from 0 to 10. An SI of zero anticipates a crash that involves no significant property damage or injury. At the other extreme, an SI of 10 anticipates a crash with a 100% probability of a fatality. Between these extremes, Severity Indices (SIs) reflect the relative contribution of other crash outcomes, based on the relationships outlined in Table 8.3 (2001 dollars). It is important to note that the SI represents an average severity and not a worst case impact.

Severity indices will vary with the type of vehicle involved, its speed, impact angle and the type of object impacted. The tables in Appendix 8A may be used as a guide. The selection of a SI is relatively subjective and local knowledge may be used to adjust this figure.

The relationship between SI and the type of injury is shown in Table 8.3. The costs associated with each SI are determined by the Australian Bureau of Statistics and vary (upward) each year. The defaults in the Road Impact Severity Calculator (RISC) software, for each class of incident outcome, are (in 2001 dollars):

- Fatality = $1,652,994;
- Hospitalisation = $407,990;
- Medical Treatment = $13,776;
- Minor Injury = $10,000; and
- Property Damage = $5,808.

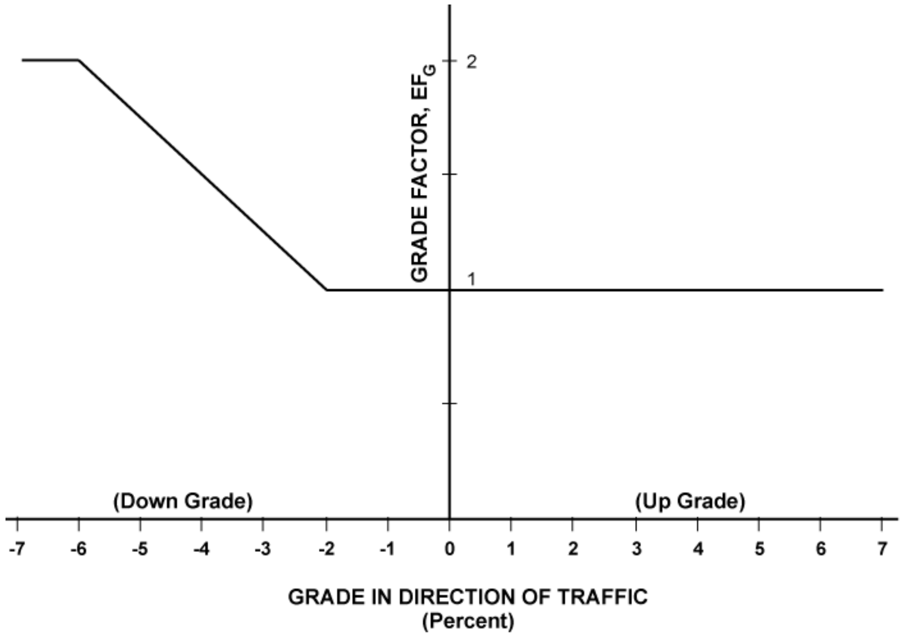

Figure 8.6 Grade correction factors (EF_g)

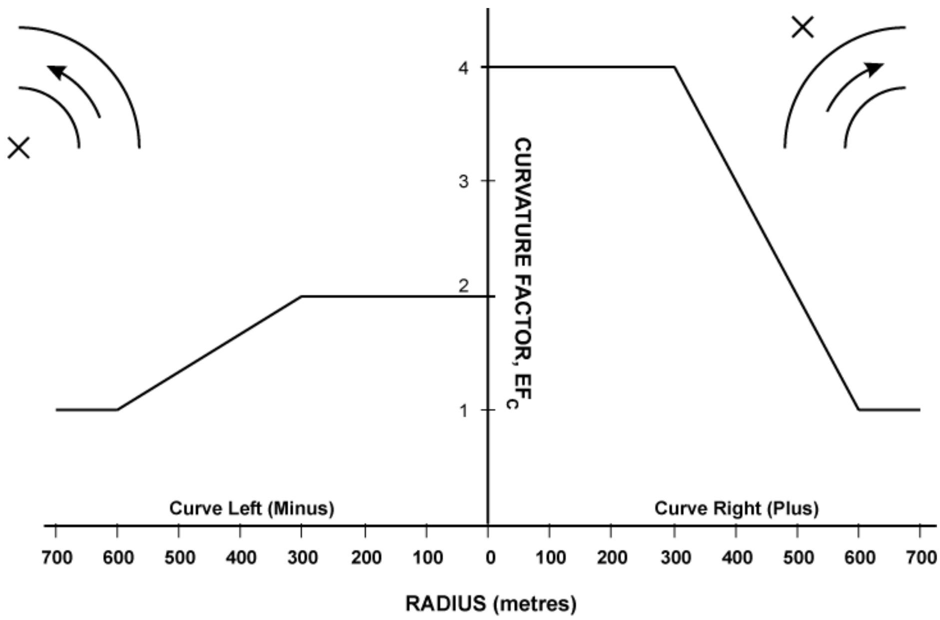

Figure 8.7 Horizontal curve adjustment factors (EF_c)

Table 8.3 Severity Index (SI) summary table

SI	Property damage (%)	Minor injury	Medical treatment	Hospitalisation	Fatal	Cost (in 2001$)
0	0	0	0	0	0	0
0.5	100	0	0	0	0	5,808
1	90.4	7.3	2.3	0	0	6,297
2	71	22	7	0	0	7,288
3	43	34	21	1	1	29,400
4	30	30	32	5	3	79,140
5	15	22	45	10	8	182,309
6	7	16	39	20	18	386,516
7	2	10	28	30	30	623,269
8	0	4	19	27	50	939,672
9	0	0	7	18	75	1,314,148
10	0	0	0	0	100	1,652,994

These crash costs are based upon Road Crash Costs in Australia, Report 102 (Bureau of Transport Economics, 2001). Users should be aware that there are currently various methods for assigning dollar values to crash severity. Please note that all dollar values in this section are to a base cost at the year 2001. These are the default values in the RISC software and allow their use to provide simple comparison BCRs for works within Queensland. Alternatively, RISC users may enter current crash values as determined by the Australian Bureau of Statistics into the RISC software under the "Tools - Options - Crash Cost" menus.

Example of costing for a collision

For a severity index of five:

- Property damage = 15% of $5,808 = $871.
- Minor Injury = 22% of $10,000 = $2,200.
- Medical Treatment = 45% of $13,776 = $6,199.
- Hospitalisation = 10% of $407,990 = $40,799.
- Fatal = 8% of $1,652,994 = $132,240.
- Total = $182,309.

8.1.3.4 Objects with pre-existing adverse crash history

For existing hazards, it is recommended that any roadside object that has had at least three crashes resulting in casualty within a three-year period, be considered for remedial treatment, regardless of other factors such as lateral offset (clear zone) and/or traffic volume.

8.1.3.5 Consistent roadside environment

Where traffic volumes are low and a consistent road environment is provided (i.e. roadside hazards are at a uniform offset), or speeds are restricted by the road alignment (e.g. mountainous terrain), these guidelines may not necessarily apply. The combination of the low number of likely encroachments, the high cost of treatment combined with driver expectations may mean that, for example, the installation of a roadside barrier cannot be justified.

Analysis of crash data from safety audits has indicated that the frequency of crashes tends to increase at the interface between varying types of road environment, or inconsistent segments. An example of this is the first tight curve after a long straight section of roadway.

Based on this experience, it is considered that the following process should be considered in consistently hazardous segments:

- Improve delineation to provide drivers with the best possible indication of the roadway alignment;
- Provide safety barrier (if justified based on embankment/hazard attributes) at the interface between varying types of road environment; and
- Monitor the crash database to identify any particular locations in which roadside barrier may be justified on crash experience.

8.1.3.6 Embankments

General

This section presents some of the necessary factors and criteria that should be considered in assessing the need to treat embankments.

Height, side slope, length and lateral offset of the embankment are factors that contribute to the severity and probability of impact, and must be considered in determining the type of treatment required.

It should also be noted that there could be roads, or sections of them, where AADT is not the main or even an appropriate guide to the level of protection required. In some cases, on low volume, high standard rural roads, the level of safety perceived or expected by drivers is higher than that indicated by traffic volume alone.

Research indicates that high severity crashes associated with embankments are primarily due to vehicle roll over. The following factors are considered to contribute to the likelihood of vehicle roll over:

- Embankment height - For embankments with a height less than 1.5m, the likelihood of vehicle roll over with a high severity outcome is considered to be low.
- Embankment slope - slopes flatter than 1 on 3 are considered to be traversable and as such do not pose a direct hazard to errant vehicles. However, if other hazardous objects are located on, or at the toe of, the embankment, consideration needs to be given to the combined effect of the hazards.
- Ground conditions on the embankment - the probability of vehicle roll-over is increased if there is a likelihood that the vehicle's tyres will dig into the ground or will strike a surface irregularity which could trip the vehicle.
- Absence of rounding at gradient changes of roadside terrain - Rounding at gradient changes provides drivers with a greater opportunity to maintain or regain control of the vehicle and decreases the likelihood of roll-over by preventing the vehicle from achieving large values of angular momentum about the roll axis.

Embankments as hazards

A preliminary review of AADT and embankment conditions can be performed using the values depicted in Figure 8.4.

Steep and high embankments are a hazardous roadside feature for errant vehicles. The height and slope characteristics have the potential to cause an errant vehicle to roll, often resulting in severe outcomes.

Embankments or fill slopes, which are parallel to the flow of traffic, are categorised as follows:

- Recoverable slope - Embankment slope of 1 on 4 or flatter. Motorists who encroach on recoverable slopes can generally stop their vehicles or slow them enough to return to the carriageway safely.
- Traversable slope - Embankment slope of between 1 on 4 and 1 on 3. A traversable slope is one on which most motorists will be unable to stop or return to the carriageway easily. As vehicles on these slopes will generally reach the toe of the slope, it is necessary to provide a clear run-out area at the base (i.e. the horizontal component of the embankment does not contribute to the clear zone distance).
- Non-recoverable slope - Embankment slope of 1 on 3 or steeper. A non-recoverable slope is one on which a vehicle is likely to overturn and is considered as a hazard in itself.

Embankment slopes of 1 on 4 or flatter should be provided wherever possible, as drivers who encroach onto such slopes have a greater chance of safely bringing their vehicle to a stop or controlling it down the slope. However, in order to cater for the different characteristics and performance of heavy commercial vehicles, embankment slopes flatter than 1 on 6 are desirable where this can reasonably be achieved, particularly where volumes of heavy commercial vehicles are high.

If further investigation is desired to determine sensitivity of design parameters, then the RISC software should be used.

8.1.3.7 Rigid objects

General

This section presents some of the necessary factors and criteria that should be considered in assessing the need for shielding of hazardous roadside objects.

If further investigation is desired to determine sensitivity of design parameters, then the RISC software should be used.

Rigid objects as hazards

The term ”Severity Index” is used to assign a weighted severity to roadside objects. This severity index is directly related to the speed of impact, impact angle and objects’ size, deformability and fixity. Recommended severity indices for a range of potential roadside hazards are provided in Appendix 8A.

For the purpose of this chapter, the following objects are NOT considered to be in the high severity category:

- sign support posts with a (Circular Hollow Section [CHS]) nominal bore that is less than 65mm (however, even posts of this size are not forgiving to motorcyclists, refer to Section 4.3 of Austroads GTEP Part 15 Motorcycle Safety);
- slip base poles;
- traffic signal posts;

- objects behind the "length of need" sections of a guard rail; and
- trees and shrubs with an ultimate trunk diameter that is less than or equal to 80mm;
- wooden objects less than 80mm diameter.

Examples of high severity objects (in a speed environment 100km/h) are:

- trees and shrubs with an ultimate trunk diameter that is >80mm;
- timber posts or poles greater than 80mm diameter;
- sign support posts with a Circular Hollow Section (CHS) nominal bore that is greater than 65mm;
- objects behind the leading and trailing terminals of guardrail;
- culvert ends;
- ditches/drains (depending upon ditch profile and depth of water in the ditch/drain, if applicable);
- bridge ends and piers;
- ends of retaining walls; and
- rock cuttings.

This is not an exhaustive list of high severity objects. During a field survey or safety audit, any object may be defined as "high severity" if the survey staff, using experience and judgment, considers it to have attributes that make it so. Appendix 8B provides assistance to the RISC software, relating to methods for rating objects and field data collection considerations.

8.1.3.8 Median barriers

General

This section presents some of the factors and criteria that should be considered in assessing the need for median barriers.

The California State Department of Transportation, Sacramento (1991) has shown that median barriers do not necessarily reduce the number of crashes. Their installation is often a reasonable balance between the increase in total crashes and a reduction in more severe cross-median crashes.

To date, only limited research has been performed in Queensland. This research is documented in a report titled: "An Investigation of Cross Median Accidents and the Appropriateness of Current Median Barrier Installation Guidelines" (Queensland Department of Transport, 1995).

The hazards presented within medians are cross-over crashes and rigid objects in the median. In these aspects, hazards encountered in medians are special cases of the rigid object general case. The vehicle crossing the median becomes the hazard with the speed environment altered to the closing speed of the two vehicles (e.g. if the speed limit is 80km/h, the closing speed and therefore the speed limit value entered in RISC is 160km/h). The severity of a rigid object in the median is determined similarly to that of any rigid object in the roadside environment, thus the position of object option in RISC is chosen to be that the object is in the median.

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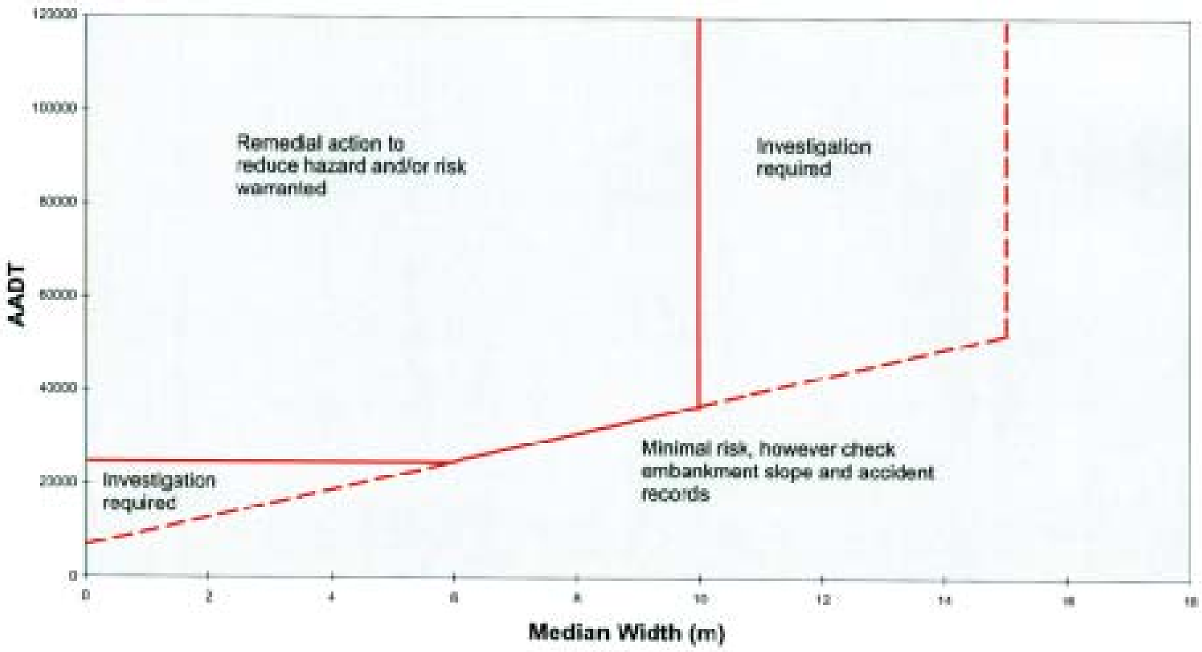

Figure 8.8 Recommended median barrier guidelines for high speed divided roads

Designers should also refer to Austroads GTEP Part 15, which identifies that any object, including posts for guardrail, is a problem for motorcyclists (and arguably cyclists, but to a lesser extent). The needs of pedestrians and cyclists may also guide one towards providing barrier in specific locations.

Design

Refer to Section 8.2.4 for design procedures.

Width and AADT

A preliminary review of AADT and median width considerations can be performed using the values depicted in Figure 8.8.

Once the Volume/Width combination indicates that an investigation is required, the following factors should be considered:

- Is the median slope non-recoverable or non-traversable?
- Is the profile of the median such that an errant vehicle is likely to be directed across the median?
- Is the median landscaped such as to reduce the speed and/or chance of an errant vehicle crossing the median?
- Is there a high percentage of heavy vehicles?
- Are there severe consequences of vehicular incursion into the opposing lanes?

If further investigation is desired to determine sensitivity of design parameters, then the RISC software should be used.

8.1.4 Treatment options

8.1.4.1 Treatment of embankments

Figure 8.9 outlines the recommended process for assessing the treatment of embankments. As depicted in the flow chart there are five possible outcomes:

1. Embankment is low risk: It has low severity attributes and/or is located such that impact is unlikely. No further analysis is required for this case. However, monitoring of the crash

database and road environs should be undertaken to identify any change in circumstances. (Refer to note below.)

2. Flatten embankment: Given that the alternative of installing safety barrier introduces a new object into the clear zone, it is desirable to modify the embankment such that it does not pose a hazard to an errant vehicle.
3. Embankment is more hazardous than roadside barrier: Installation of roadside barrier is recommended.
4. Safety barrier is more hazardous than embankment. Installing safety barrier is not recommended.
5. Apply engineering judgement and consider other options: The installation of roadside barrier may not be recommended, however a more detailed assessment may be undertaken if required. Consideration could also be given to other treatment options if available.

Note: Although the risk is low, this does not mean that the situation is not a hazard to an errant vehicle. The level at which the risk changes from being acceptable to being unacceptable is difficult to quantify and subject to debate.

The following three sub-sections outline the three decision making criteria identified in the Evaluation and Selection process shown in Figure 8.9.

Is embankment flattening an economical solution?

A preferred option to installing safety barrier is slope flattening to 1 on 3 or flatter. American research has shown that this can result in a significant reduction in the severity of vehicle run-off road accidents, which is primarily due to the reduction in probability of vehicle roll over.

Using the software package “Roadside Impact Severity Calculator” (RISC) (see Appendix 8B) various treatment options for a hazard can be compared and the expected crashes per year, the social crash costs per year and the BCRs over a specified period for each of the options proposed can be produced. The point at which embankment flattening becomes a cost effective option can be determined by comparing the BCRs for safety barrier installation versus slope flattening.

Does embankment pose a greater risk than safety barrier installation?

Guardrail, wire rope systems and concrete safety shapes should be considered and evaluated separately to determine the need for these types of safety barrier to shield embankment hazards (refer to Section 8.2).

By using the RISC software and entering the appropriate parameters (refer to Appendix 8B), a Benefit/Cost Ratio can be determined.

Depending on the outcome of the above risk assessment, engineering judgement is required to determine if the roadside barrier installation can be justified for other reasons.

If a safety barrier is installed where the overall perceived costs are greater than the benefits then it will have a negative effect upon the road system, as those funds can not be used elsewhere.

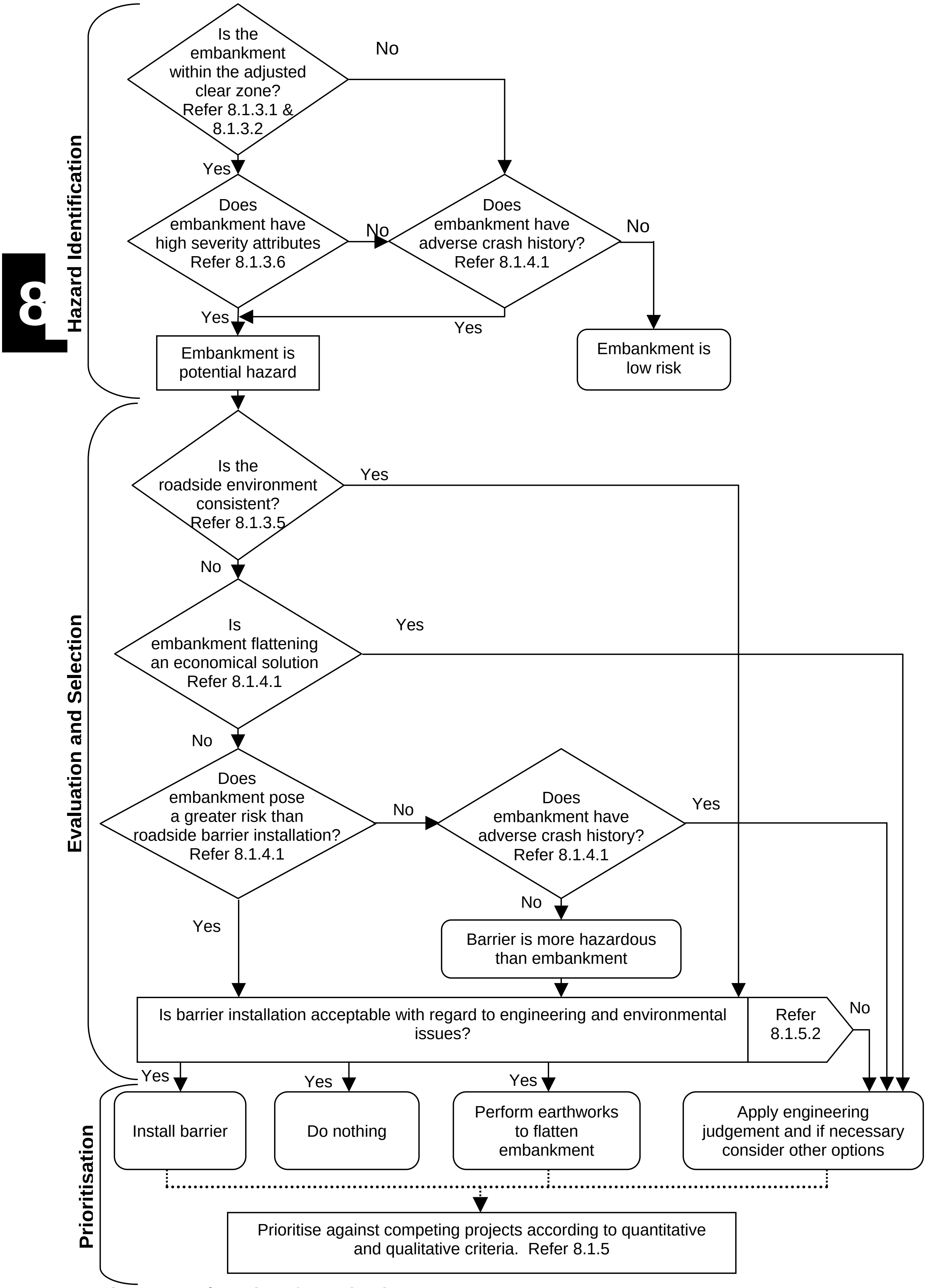

Figure 8.9 Flow chart for embankments

Does the embankment have an adverse crash history?

It is recommended that any roadside feature that has at least 3 casualty crashes within a three-year period, be considered for remedial treatment, regardless of other factors (such as lateral offset and/or traffic volume).

8.1.4.2 Treatment of rigid objects

Figure 8.10 outlines the recommended process for assessing the need to treat rigid objects as hazards.

The following options are available for managing a rigid object hazard:

- remove it;
- relocate it to a point where it is less likely to be struck;
- reduce impact severity by using an appropriate break-away or frangible device;
- redirect a vehicle by shielding the hazard with a longitudinal barrier or crash cushion; or
- delineate the hazard.

If W-Beam guardrail, wire rope systems or concrete safety shapes are considered for shielding rigid hazards, their use should be evaluated separately to determine the need for these types of safety barrier (refer to Section 8.2).

By using the RISC software and entering the appropriate parameters (refer to Appendix 8B), a Benefit/Cost Ratio (BCR) can be determined.

Using engineering judgement is also necessary when determining treatment options and practitioners are advised against using the RISC software as a "black box" without understanding the sensitivity of input and output parameters.

8.1.4.3 Treatment of median barriers

The installation of median barrier is only recommended on high speed (i.e. speed limit is 80km/h or greater), median separated carriageways. However, in low speed environments (i.e. speed limit less than 80km/hr) median barrier might be appropriate:

- where the roadways on either side of the median are graded independently resulting in a significant height difference and a steep slope across the median, and/or
- for treating sites with pre-existing adverse crash history where median barrier may reduce the severity, if not the frequency, of incidents.

Figure 8.11 outlines the recommended process for assessing the need for median barriers on high-speed divided roads.

If the median is wide enough and flat enough to accommodate the deflections of flexible or semi-rigid safety barriers, the use of these safety barriers may be appropriate. For narrow medians where RISC indicates a high enough BCR for the installation of a safety barrier, for instance on high volume roads, a rigid safety barrier type would be recommended since rigid safety barrier systems have negligible deflection on impact.

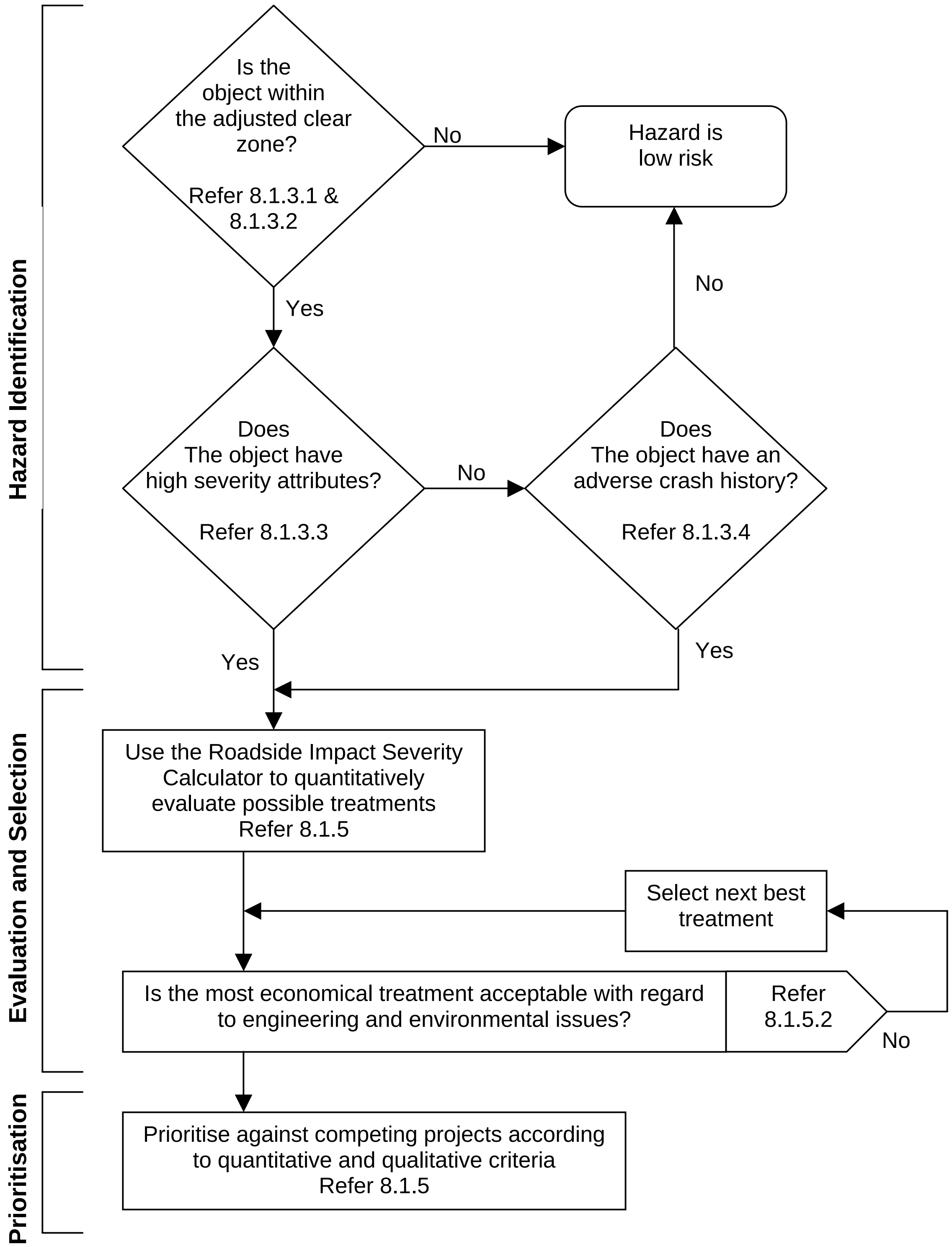

Figure 8.10 Flow chart for rigid objects

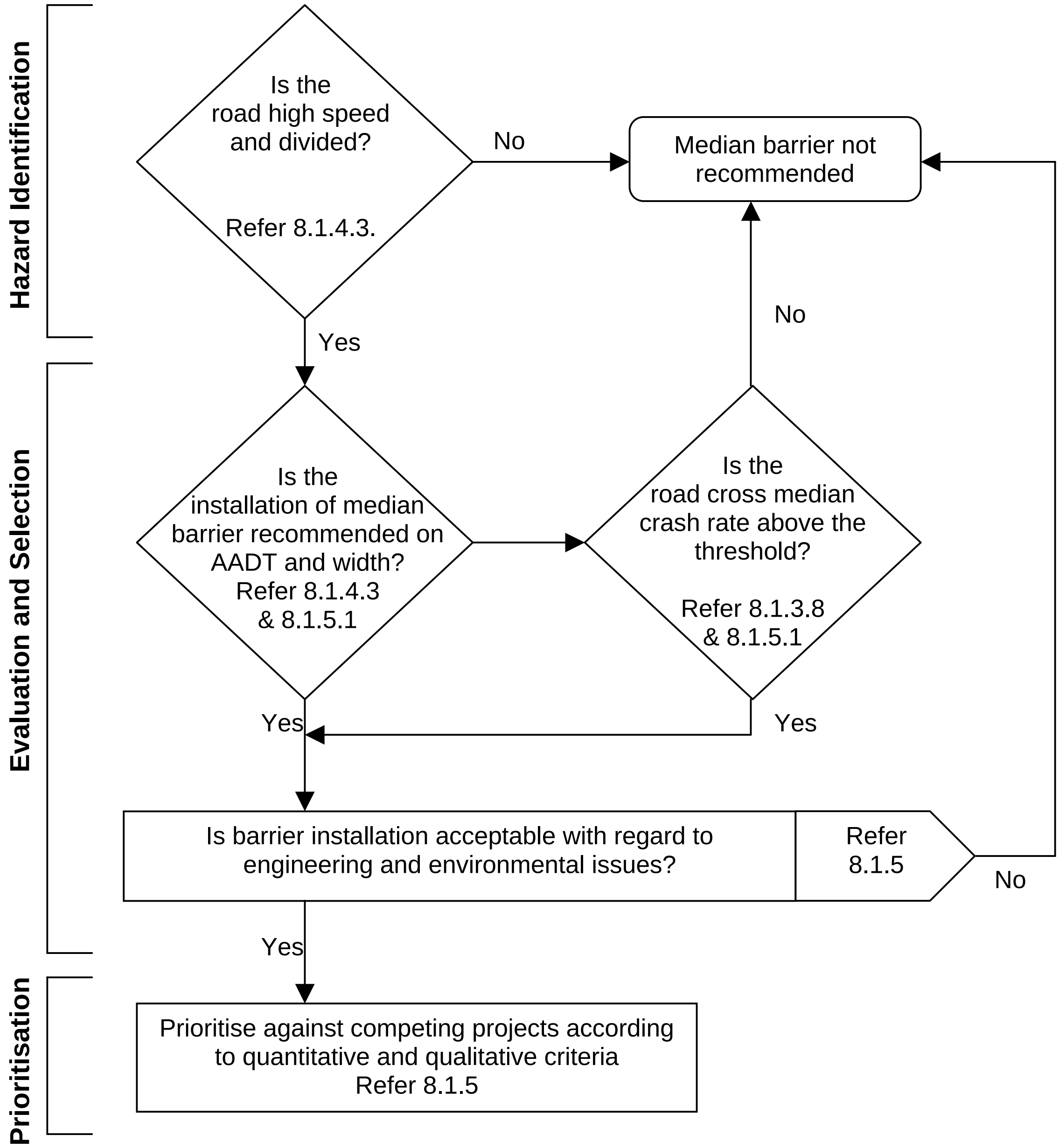

Figure 8.11 Flow chart for median barriers

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8.1.5 Option evaluation and prioritisation

8.1.5.1 Quantitative evaluation

Benefit cost analysis is a method that estimates the benefits derived from a specific course of action compared to the costs of implementing that action. If the estimated benefits of a specific design exceed the cost of constructing and maintaining that design over a period of time, the safer design may be implemented. However, simply having a benefit/cost ratio greater than one may not in itself provide justification for the construction of a roadside safety treatment. Each project must compete with others for limited safety funds. It should be noted that the accompanying "RISC software automates this process, supplying benefit to cost ratios for each treatment option.

The primary benefit obtained from selecting one design over another is the expected reduction in future crash costs. These typically include property damage costs and personal injury costs. In some cases, the total number of crashes may be reduced by a given treatment, such as providing a significantly wider roadside recovery area than previously existed. In other instances, the safety treatment may not reduce the total number of crashes but may reduce their severity (e.g. the installation of a median barrier).

A benefit/cost analysis must consider the period of time (project life) over which each alternative treatment provides a benefit. Since different treatments can have different project lives, both benefits and costs must be annualised so direct comparisons between alternative treatments can be made. To reduce total (life cycle) costs to annualised costs, discount rates must be considered. An annualised benefit/cost ratio thus compares the expected savings to society (through reduced crash costs) to the costs (construction and maintenance) incurred to provide a specific treatment.

The following is a brief summary of the basic methodology for calculating BCRs.

The BCR is defined as the Net Present Benefit (NPB) divided by the Net Present Cost (NPC) (Equation 8-2).

Equation 8-2 BCR

$$BCR = \frac{NPB}{NPC}$$

The NPB is defined as the total value of benefits due to crash reduction over a defined period based on an economic discount rate (NPB).

Equation 8-3 NPB

$$NPB = (factor) \times B$$

Where:

- (factor) is a discounting factor, for different values of rate and period; and
- B is the value of annual benefits (i.e annual reduction in road crash cost).

The NPC is defined as the cost of implementation (discounted if not undertaken in the first year).

Factors required for the determination of a BCR are:

- cost savings in crashes prevented or reduced severity (reduction in road crash cost);
- cost of implementing treatment;
- cost of maintaining treatment;
- cost of repairing treatment if hit;
- length of analysis period; and

- discount rate.

When the RISC analysis yields a BCR greater than 1.5 for rural roads and 2.5 for urban roads, installation of safety barrier may be justified. Candidates for treatment should be scheduled for implementation in priority order depending on BCR and crash history.

RISC software methodology

The modelling method can be used to determine the possible BCR achievable by comparing the treatment options available. For example, an economic comparison can be made between leaving an end-on culvert as is, installing bar grates, redesigning the culvert end wall to reduce its severity, and the installation of guardrail.

Once a roadside object is identified as a potential hazard (i.e. within the clear zones, refer to Section 8.1.3.1), the risk can be analysed. The methodology and processes adopted by the RISC software for determining the impact frequency of errant vehicles and calculating risk is outlined in the following section (the calculations following are automated somewhat when entering the data into RISC). Figure 8.12 illustrates this process.

DETERMINE ROAD ENVIRONMENT VARIABLES

Road environment variables define the roadway characteristics and are used to determine the base encroachment frequency (the number of expected encroachments per kilometre per year).

The following variables are required:

- Road type - the three general road types are divided, undivided and one-way;
- Number of lanes - the number of lanes on each carriageway;
- Width of lanes - the width of the marked lanes; and
- 85th percentile speed - if unavailable then the posted limit + 10km/h can be used.

DETERMINE TRAFFIC VOLUMES

The current traffic volume of the road can be determined from District reports and/or traffic survey counts.

The traffic volume is then divided into the number of carriageways. For example, on a two-lane two-way road, the traffic volume would remain unchanged (i.e. it is a single carriageway), whereas for a four lane divided facility, the volume is divided by two for a 50%/50% split. If a split of traffic other than 50%/50% is evident, then the traffic volumes can be apportioned to each carriageway accordingly.

DETERMINE CURVATURE AND GRADE FACTORS

Figure 8.6 and Figure 8.7 provide adjustment factors for longitudinal grade (EF_g) and road curvature (EF_c) respectively. These figures modify the encroachment frequency, due to the increased probability of a vehicle leaving the road on horizontal curves or grades (refer Section 8.1.3.2).

IDENTIFY ROADSIDE OBJECT ATTRIBUTES

These following attributes, in combination with vehicle speed and road curvature define what the probability of impact with the object will be:

- Horizontal offset of the object from the edge of the travelled way;
- Object length; and
- Object width.

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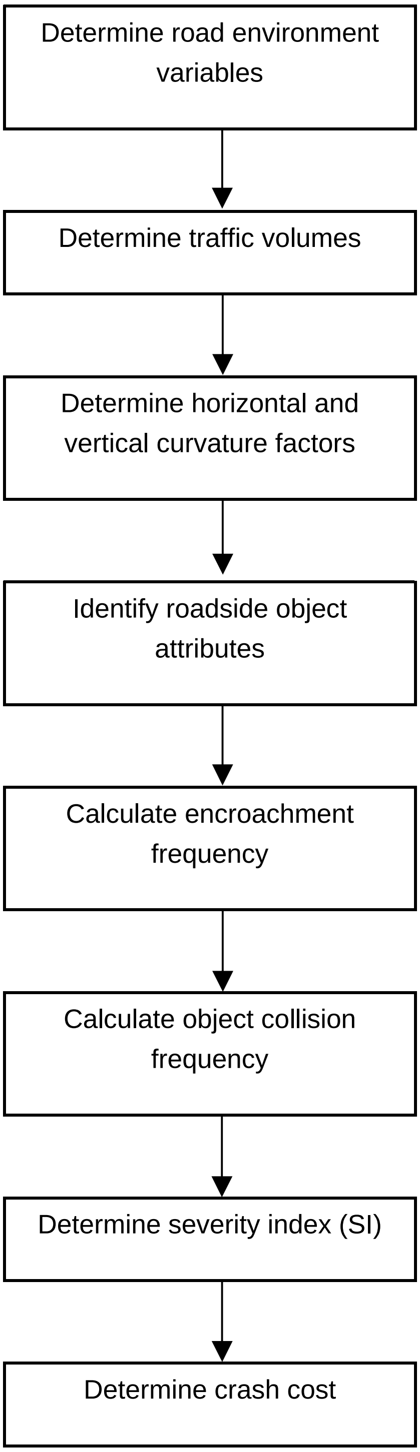

Figure 8.12 Flow chart of risk assessment process adopted by RISC (refer to Section 8.1.5.1)

CALCULATE ENCROACHMENT FREQUENCY

The likelihood of a vehicle leaving the roadway under particular circumstances is then determined using the following relationship Equation 8-1):

Equation 8-4 – Encroachment Frequency

$$EF = BER \times AADT \times EF_c \times EF_g \times EF_u$$

Where:

- EF - Encroachment Frequency (encroachments/year/km);
- BER - Base Encroachment Rate (0.00030 enc/km/year/vpd);
- AADT - Annual Average Daily Traffic;
- EF_c - Curvature factor (refer Section 8.1.3.2);
- EF_g - Grade factor (refer Section 8.1.3.2); and
- EF_u - User factor (Used at discretion of engineer to accommodate special circumstances)

The encroachment frequency is an estimation of the number of vehicles that will leave the roadway per kilometre per year. Clearly not all vehicles that leave the roadway will necessarily collide with a roadside object and variables such as the object's size and offset from the edge of the travelled way and vehicle speed (refer to the section below) influence the likelihood of impact with the object.

The base encroachment rate is based on work performed in the United States, outlined in the American Association of State Highway and Transportation Officials (AASHTO) publication 'Roadside Design Guide' (AASHTO). This rate should be adjusted when actual data at a specific location is available, or modified based on engineering judgement for non-typical conditions.

CALCULATE OBJECT COLLISION FREQUENCY

The number of impacts for any object is dependent upon the number of directions from which it can be impacted. For example, an object on the left hand side of a divided road can only be struck from one direction of travel, whereas an object in the median can potentially be struck from traffic travelling in either direction. Figure 8.13 depicts the three typical types of roadway.

Using the "calculated encroachment frequency" and the "roadside object attributes" of the object being analysed, an estimate of the number of impacts per year with the object can be determined.

To estimate the object collision frequency the impact zones of the object are divided into three areas, upstream face (Zone 1), corner (Zone 2) and parallel face (Zone 3), as shown in Figure 8.14.

For the situation where the object can only be impacted from one direction, the following cases apply:

- Collision frequency for upstream side (Zone 1);
- Collision frequency for upstream corner (Zone 2); and
- Collision frequency for parallel face (Zone 3).

Whereas, if the object can also be impacted from the opposing direction the following cases must also be calculated:

- Collision frequency downstream side (Zone 1);
- Collision frequency downstream corner (Zone 2); and
- Collision frequency for parallel face (Zone 3).

Note that, for the opposing direction, the lateral offset of the object may need to be increased given that there is at least an additional lane between the object and the travelled path.

While Equation 8-5, Equation 8-6 and Equation 8-7 are complicated, the RISC software obviates the need for time consuming normal analysis.

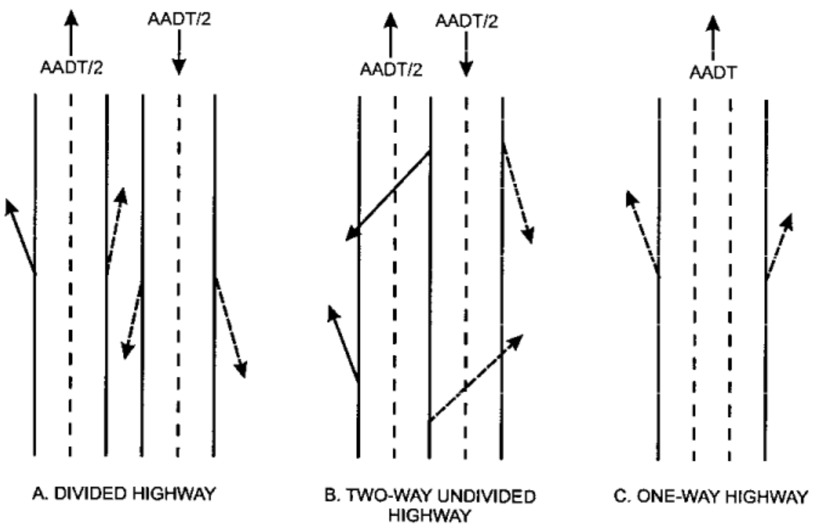

Figure 8.13 Roadway types

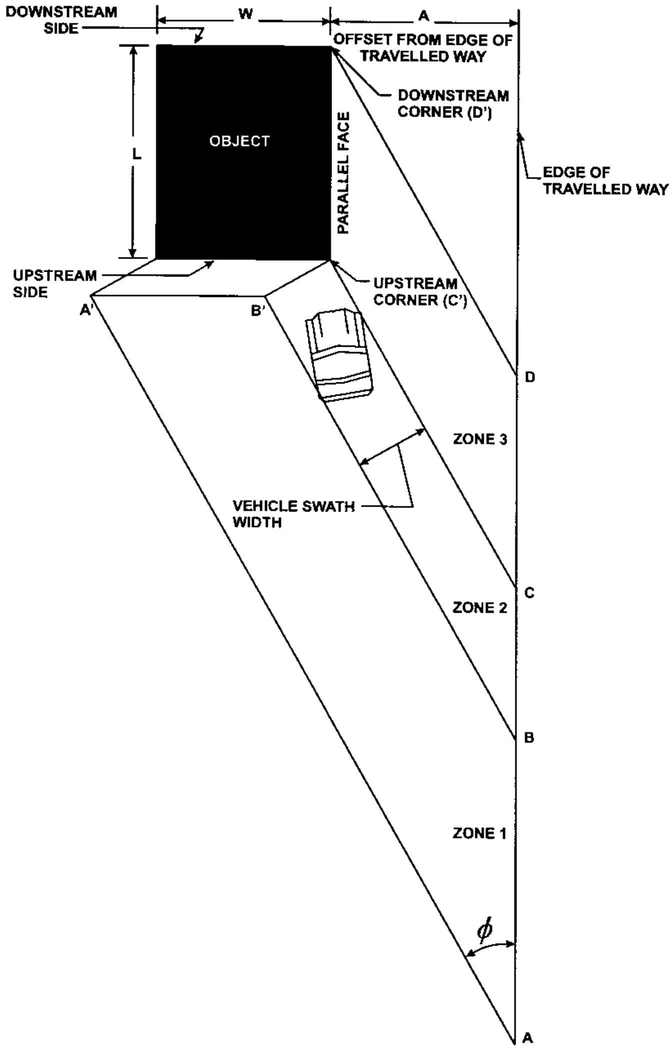

Figure 8.14 Impact sones for roadside hazards

Equation 8-5 Collision frequency for upstream side for lane closet to hazard

$$CFUS = EF \times \frac{1}{\tan\phi} \times \frac{\sum_{i=1}^{W} LEP\left(A + SW \times \cos\phi + |i-1|\right)}{1000}$$

Equation 8-6 Collision frequency for upstream side for lane closet to hazard

$$CFUC = EF \times \frac{1}{\sin\phi} \times \frac{\sum_{i=1}^{W} LEP\left(A + |i-1| \times \cos\phi\right)}{1000}$$

Equation 8-7 Collision frequency for parallel face

$$CFFA = \frac{EF \times L \times LEP \times A}{1000}$$

Where:

- CFUS = Collision frequency for the upstream side;
- CFUC = Collision frequency for the upstream corner;
- CFFA = Collision frequency for the parallel face;
- LEP = Lateral Extent Probability;
- F = Encroachment angle (degrees);
- SW = Swath Width (3.6 m);
- EF = Encroachment Frequency (enc/km/y);
- A = Lateral offset of object (m) (see below for value to use for traffic travelling in lanes other than the lane closest to the hazard); and
- W = Width of object (m)

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When determining the impacts for traffic travelling in lanes other than the lane closest to the hazard (e.g. traffic travelling in the opposite direction)**, it is important to increase the offset of the feature to reflect the increased distance to travel.** In these cases the variable "A" in Equation 8-5 and Equation 8-6 is replaced with "A+S" where:

- A = Lateral offset of object (m); and
- S = sum of adjacent lane widths.

The total number of impacts per year for the object is given by Equation 8-8.

Equation 8-8 Total number of impacts per year

Impacts/year = CFUS + CFUC + CFFA

DETERMINE SEVERITY INDEX (SI) FOR OBJECT

Once the collision frequency has been calculated for the roadside object, it is necessary to assign severity values. As discussed earlier, the SI defines the severity of the outcome of an impact with a particular roadside feature. Appendix 8A outlines suggested SIs for particular features. It is important to note that these figures are to be used as a guideline only and engineering judgment needs to be applied.

A separate SI for each impact zone of the hazard should be applied. A typical example of this would include increasing the SI for end-on impacts with guardrail. This process is automated when the RISC software is used.

The SI distribution (using 2001 dollars) is shown in Table 8.3. The costs are based on vehicle occupancy of one and the proportion of crash outcome types.

DETERMINE CRASH COSTS

Once the number of crashes that can be expected at a given location and the objects SI is known, the expected crash cost per year can be calculated using the following relationship.

Equation 8-9 Annual crash costs

Annual Crash Costs per Year ($) = (Impacts per Year) x (SI Crash Cost per impact)

Where:

- Impacts per year is the calculated object collision frequency (Equation 8-8); and
- SIs related to crash costs are determined by RISC, an example of which, in 2001 dollars, is given in Section 8.1.3.3.

8.1.5.2 Qualitative evaluation

Before a treatment option is selected for prioritisation and implementation, its suitability in terms of the following issues should be considered:

Environmental considerations

Environmental considerations include:

- Recognition of unique vegetation (e.g. environmentally sensitive areas or national parks);
- The retention of water courses in their natural state adjacent to the road;
- Reduction of clearing; and
- Visual pollution.

If clearing trees within the clear zone is unacceptable on environmental grounds, alternative treatment options may need to be considered.

Engineering considerations

Engineering considerations include:

- Traffic growth;
- Pedestrian traffic;
- Crash history;
- Other geometric influences;
- Social justice/equity;
- School bus routes; and
- Freight routes.

For example, sites that have a poor crash history need to be evaluated such that an appropriate priority can be assigned.

8.1.5.3 Ranking of selected treatment options for all hazards

The following procedure is recommended for ranking selected treatment options:

1. Select the optimal treatment option for each hazard identified, using quantitative and qualitative evaluation.
2. List and rank the selected treatment options for all hazards identified, according to BCRs and environmental and engineering factors.
3. Treat hazards with the highest ranking, as funds become available.

8.2 Roadside barrier systems - selection and location of permanent systems

8.2.1 Purpose

Section 8.2 of this chapter provides details of the available types and uses of safety barrier systems together with the selection process involved.

The decision to install a safety barrier system for hazardous objects should be made by a road designer and be based on sound engineering judgment, appropriate documents and design processes (refer to Section 8.1).

Section 8.2 first provides a discussion of general principles (that are common to all barrier types/systems and which) designers must consider. (Note: Where design principles relate to a particular type of barrier system, those principles are included in the description of that particular system.) This is followed by a description of design parameters and procedures. Particulars of barrier types, end treatments, transitions and testing are then outlined.

Appendix 8C provides practical applications and highlights lessons from actual experience. Incorrect practices are discussed and practical examples and guidance are provided.

8.2.2 General principles

Once a barrier system has been determined to be necessary (refer to Section 8.1), the correct system needs to be chosen. Section 8.2.2 provides general advice common to all barrier systems. Main Roads has adopted AS3845 and the National Cooperative Highway Research Program (NCHRP) test standards for crash testing of barriers and end treatments. Those existing barriers that have met the requirements of the policy are considered to be operational. New barrier systems will have to be tested under these guidelines before they are classed as operational. However, some barriers that are currently in use have not been crash tested but are deemed to be acceptable by way of continued satisfactory performance in the field, as allowed under AS3845.

8.2.2.1 Proximity of barriers to traffic

The underlying principle when designing the layout of a roadside barrier is to provide the largest possible distance between the barrier and the running lane. This distance:

- Provides a driver an opportunity to regain control of the vehicle before striking the barrier;
- Allows the driver to avoid colliding with the barrier in minor encroachments;
- Provides some space to reduce speed before impact in major encroachments;
- Ensures better sight distance at intersections, accesses and around horizontal curves;
- Allows vehicles to stand clear of the adjacent traffic lane after impact; and
- Provides an opportunity for disabled vehicles to stop clear of the running lanes.

8.2.2.2 Installations in proximity to kerbing

Kerbs should not be placed in proximity to barrier systems, particularly in environments with speed limits above

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70km/h. Kerbs in front of barrier systems will have a significant effect on the performance of the vehicle as it approaches the barrier with potentially hazardous consequences. It is essential that the barrier system should be located and designed to ensure that the errant vehicle does not:

- vault over the barrier; or
- go under the barrier causing snagging of the barrier supports and other problems.

The decision about location is made more difficult by the wide range of factors influencing the behaviour and trajectory of errant vehicles (e.g. suspension stiffness, vehicle weight, speed of impact, angle of impact). Locating kerbs in front of barriers makes it more difficult to ensure that the two conditions above are achieved.

Further, on high speed facilities, placing kerbs close to the travelled way introduces an additional hazard with little benefit for the traffic stream. They:

- do not influence driver behaviour prior to the deviation of the vehicle;
- do not redirect errant vehicles after impact with them;
- do not redirect vehicles at highway speeds (AASHTO);
- may cause a driver to lose control after impact with them; and
- may cause the vehicle to leave the ground after impact with them thereby changing the trajectory of the exit path.

When a vehicle strikes a kerb, its trajectory depends upon several variables including:

- •the size and suspension characteristics of the vehicle;
- its impact speed and angle; and
- the height and shape of the kerb.

The Roads and Traffic Authority (RTA) of New South Wales (NSW) has documented the trajectory characteristics of a car following an impact with a kerb, for various kerb types at various speeds. The data indicates that the trajectory path of a car's front bumper is a function of the impact angle, vehicle speed, and type of kerb. Based on this data, RTA has defined that a barrier should not be located within 0.2m of the edge of the kerb. This 0.2m requirement is the desirable offset distance for placement of a semi-rigid barrier behind a kerb taking into consideration the overhang dimension of a vehicle, as depicted in Figure 8.15.

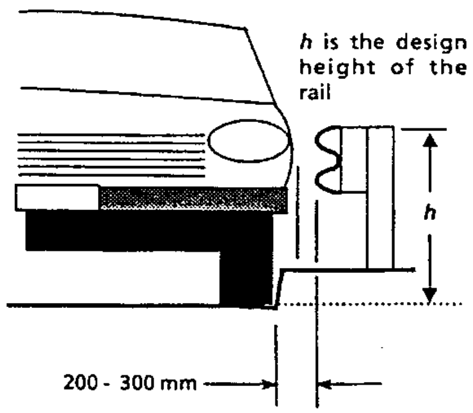

Figure 8.15 Offset required from face of kerb (for semi-rigid barrier) (RTA, 1996).

For higher speeds and higher impact angles, the length and height of the trajectory path increases. Because of this, the American Association of State Highway and Transportation Officials (AASHTO) specifically indicates the use of guardrail behind a kerb should be discouraged where high-speed, high-angle crashes are likely, but suggests if no other feasible alternative exists, the use of a kerb no higher than 100mm or stiffening of the guardrail to reduce its deflection is a satisfactory solution.

AASHTO further suggests that if a particular guardrail/kerb combination is to be used extensively, the system should be crash tested to assess the barrier performance under typical impact scenarios.

At those locations where a kerb might be considered an appropriate solution (e.g. for drainage or delineation), alternative treatments should be considered particularly when a safety barrier system is to be installed. In particular, where a rigid barrier is to be installed, a kerb will impart a vertical force to the vehicle, the dynamic effect of which could adversely affect the performance of the barrier. If drainage control is required in this area, another solution should be used.

Where a decision to install safety barrier systems in proximity to kerbing is made, the following should be considered (RTA, 1996):

- At the simplest level for design assumptions, all kerbing can be treated as Type 5 barrier kerbing (refer to Main Roads Standard Drawing Number 1033) and, at impact speeds, the suspension of the errant vehicle absorbs the difference in surface level between the road and the median, shoulder or verge for values of offset between approximately 1.5m and 2m.
- A safety barrier should not be located closer than 0.2m to the edge of the kerb except where the speed limit is 70km/h or lower in which case the barrier face may be aligned with the face of the kerb. 0.2m is the desirable offset distance for placement of a semi-rigid barrier behind a kerb, taking into consideration the overhang dimension of a vehicle as shown in Figure 8.15 (RTA,).
- Where kerbing is unavoidable in the design and the safety barrier system is installed further than 300mm from the kerb but closer than 1.5m to it, the design height as recommended by the Standard Drawings and/or manufacturer is measured using the road surface as the datum.
- Where kerbing is unavoidable in the design and the barrier system is installed 1.5m or further from the kerb the design heights as recommended by the Standard Drawings and/or manufacturer are to be measured using the finished surface of the median, shoulder or verge adjacent to the barrier as the datum.

AS3845 provides slightly more sophisticated guidance on this matter, but is only valid for impact angles up to 15°.

The presence of kerb and slope features must also be addressed with regard to end treatment installations. The Standard Drawings show the limitations of sloping shoulders and batters in relation to public domain end treatments such as the Modified Eccentric Loader Terminal (MELT).

Where new crash cushions are being installed existing kerbs should be removed to ensure the performance of the end treatment is not affected. For new construction, kerbs should not be located where crash cushions are to be installed (RTA).

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8.2.2.3 Installations in proximity to batters

Barriers should not be installed on batters with transverse slopes steeper than 1 on 10. If a barrier is to be installed on batters with slopes steeper than steeper1 on 10 they are to be positioned either between the traffic and the batter or beyond the batter altogether.

In some situations, where the slope is steeper than 1 on 10, flattening of the barrier slope in front of the barrier to 1 on 10 or flatter will be required.

Similar to crashes involving kerbing, a wide range of factors will influence the behaviour and trajectory of errant vehicles as they traverse batters (e.g. suspension stiffness, vehicle weight, speed of impact, angle of impact).

Consequently there is uncertainty about where to position barriers so that:

- the vehicle does not vault over the barrier; or
- the vehicle does not go under the barrier with consequent snagging on the barrier supports and other problems.

This uncertainty makes it difficult to position barriers on batters such that their effective operation is assured.

8.2.2.4 Compatibility

Where possible, continuity of a barrier type should be maintained along a road section. New installations should be compatible with existing lengths of barrier and capable of having suitable transition devices to connect them to existing installations. The type of barrier installed must also be compatible with the selected end treatments. Refer to Section 8.2.6 for further details.

8.2.2.5 Culverts

For culvert locations where it is possible to install posts, typical flexible and semi-rigid systems may be used. W-beam posts with a grouted foot may be installed onto the top of the culvert; specialist advice should be sought in this case.

For the situation where posts cannot be installed and where the culvert is less than 6m in length:

- w-beam without intermediate posts can be used - Figure 8.16; or
- two box beams attached behind a w-beam guardrail (South Australian Department of Transport) may be used - Figure 8.17. Reinforced posts at the culvert ends should be provided for this type of installation.

For situations where the culvert is greater than 6m in length, specialist advice from the Traffic Engineering and Road Safety (TERS) section of Main Roads Traffic and Road Use Management (TRUM) Division should be sought.

8.2.2.6 Posts conflicting with existing structures or Public Utility Plant (PUP)

For locations where a post conflicts with an existing structure or PUP, it is possible to delete the post and install a nested double rail (i.e. two w-beam rails) including a blockout over this section.

The use of multiple blockouts is **not** appropriate, as this affects the height of the rail due to rotation about the post during a crash.

Alternatively, for multiple post conflicts, a post and base plate assembly similar to that shown on Main Roads Standard Drawing Number 1478 may be used. (Note that an appropriately designed rigid surface is required for this option.)

8.2.2.7 Site considerations

Other site conditions should be considered relative to each barrier and type of end treatment. These additional factors may result in the initial barrier selection being inappropriate for the site.

The prevailing site conditions (such as turnouts from driveways) might require the barrier to be installed in segments thereby creating short gaps between adjacent lengths. This practice is not recommended.

If the designer, using sound engineering judgement, chooses to use a configuration where gaps exist between adjacent lengths then:

- the number of such discontinuities is to be minimised so that the number of ends is reduced to as few as possible;
- the downstream rail end along each turnout should be flared properly; and
- (the upstream rail end of each gap should be equipped with an appropriate end treatment.

Barriers should be located so drivers' visibility is not restricted, especially in the vicinity of intersections.

Barrier aesthetics may also need to be considered, depending on the location of the barrier.

8.2.2.8 Costs

Life cycle costs

The initial cost of a barrier will certainly influence the final decision when choosing between barrier systems. The initial cost of a system is proportional to its strength and inversely proportional to its operational costs (AASHTO).

Operational costs are those costs associated with maintaining the barrier systems to ensure they remain operational following impact; they include ongoing maintenance costs.

Typically, the systems covered in this document will require little routine maintenance apart from periodic checking of structural components. AS3845 provides guidance for maintenance of barrier system installations and post-crash rectification decisions.

For the conditions found in the Queensland roadside environment (e.g. the presence of termites) life cycle costs have dictated the choice of steel posts over wooden posts for guardrail installations. Treatment of frangible wooden posts of end treatments also creates an environmental issue when disposal is required after crashes, again dictating the choice of steel posts as shown in Main Roads' Standard Drawings.

In addition to the initial cost of the barrier and the routine and collision maintenance costs, consideration should also be given to materials and labour costs. Specifically, the availability of materials and expertise particular to the barrier type should be addressed as design considerations.

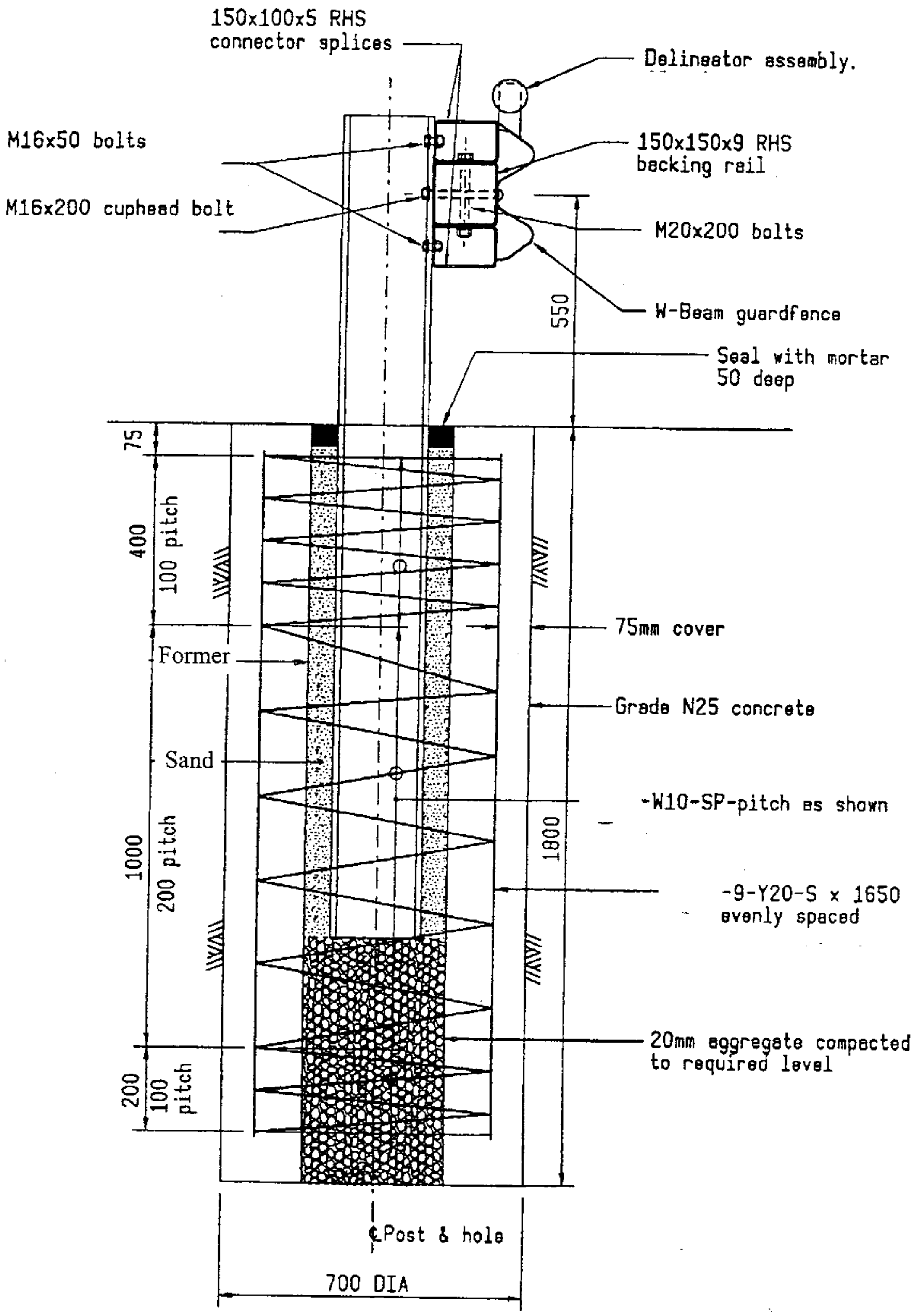

Figure 8.16 W-beam without intermediate posts over culverts with increased footing depth (gap length <6m)

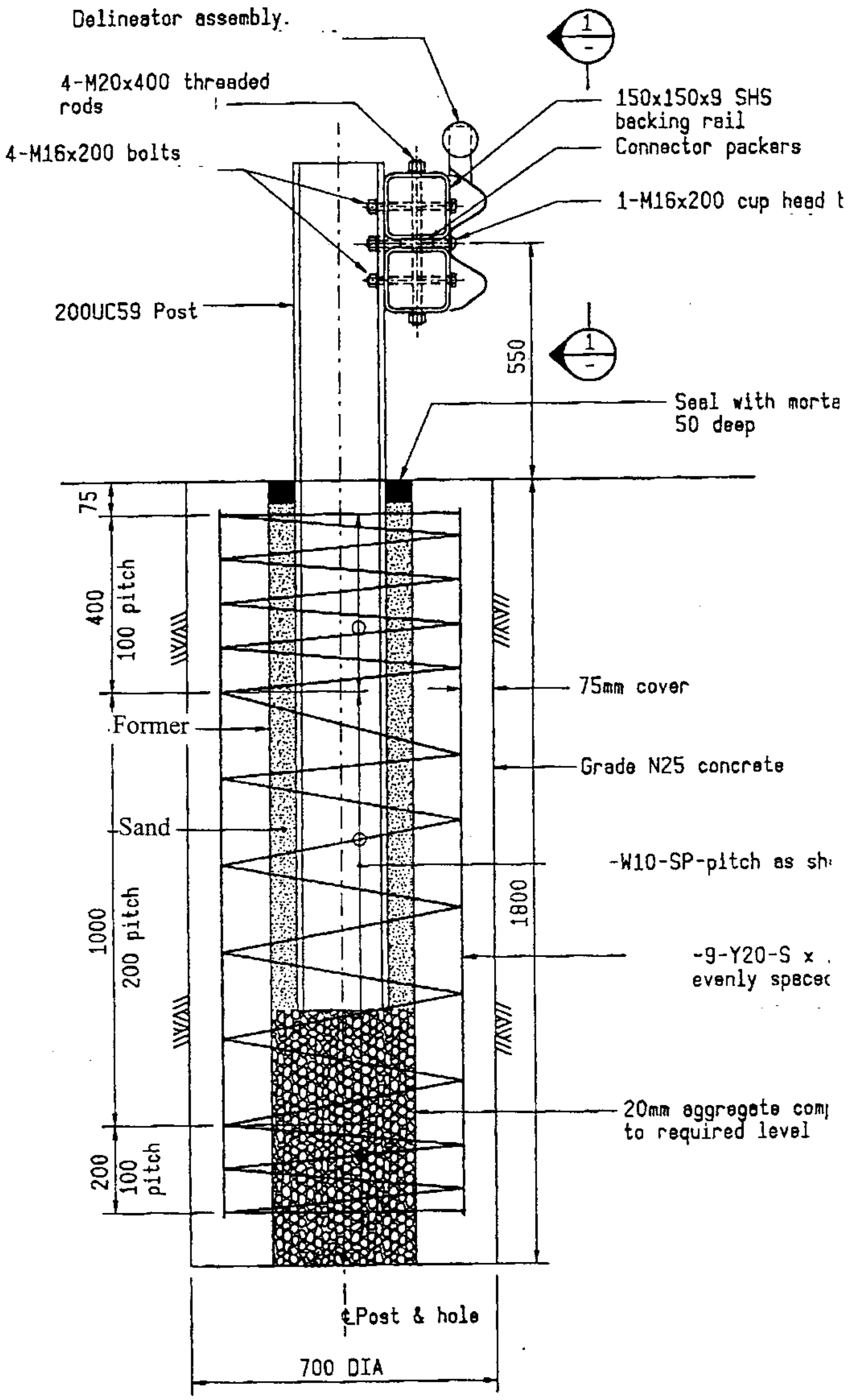

Figure 8.17 Two box beams attached behind w-beam over culverts (gap length <6m)

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Maintenance costs

ROUTINE MAINTENANCE COSTS

These costs are attributable to those maintenance activities undertaken on a routine basis to ensure the operation of the barrier is not compromised. These activities may include periodic mowing and removal of vegetation around the barrier, and checking of structural attachments, particularly for semi-rigid systems. Vegetation maintenance costs around barriers can be significantly reduced or eliminated by appropriate treatment of the surface around the installation.

As with the selection process defined for longitudinal barriers, the cost and maintenance aspects of an end treatment require detailed consideration.

Analysis of more than one treatment may be appropriate. However, the systems outlined in this chapter should incur low maintenance costs.

COLLISION MAINTENANCE COSTS

Collision maintenance costs will be a function of the frequency of impact. The number of crashes that will occur along a particular installation depends upon a number of factors including traffic speed and volume, roadway alignment and the distance between the edge of the running lane and the barrier itself (AASHTO). Consideration of these factors will aid in assessing the collision maintenance costs of the selected barrier.

These costs may be quite high if the end treatment is subject to a high impact frequency or if the cost of replacement parts is high.

For installations with a high frequency of crashes with the end treatments, consideration should be given to the use of re-useable end treatments (AASHTO. Alternatively, a complete redesign of the situation might be appropriate in some cases.

If nuisance crashes are relatively common, a crash cushion with redirection capability should reduce or eliminate the maintenance effort required for minor repairs or partial replacement of an end treatment system (AASHTO).

The cost and availability of replacement parts will influence the type of system implemented.

Spare parts must be available to ensure the system is repaired within the shortest time. If they are not available, a temporary safety barrier should be installed and both spares and temporary safety barriers should be a design consideration.

Barriers requiring minimal collision maintenance reduce the risk to maintenance crews, especially on high speed, high volume roads.

Further details are given in the later sections that deal with each type of barrier system.

8.2.2.9 Barrier systems for motorcycles

Safety barriers are effective in redirecting design vehicles (Refer to Table 8.4). However the design vehicles currently used for safety barriers do not include some vehicle types such as motorcycles, and thereby reducing injury to the occupants of those vehicles. The effects of safety barriers on the safety of other road user groups, especially motorcyclists, remain unclear (Duncan, et al., 2000).

Safety barrier testing with the objective of determining motorcyclist protection has not yet been performed, mainly because a valid test procedure has not yet been agreed upon. The objective of designing a safety barrier in areas where motorcycle impacts are likely is different from that where vehicular crashes are concerned.

In motorcycle crashes, injuries result from the rider and/or pillion passenger contacting the barrier system. The primary objective of barriers in motorcycle crash incidents is to prevent the rider (or pillion) from coming into contact with the support structure (posts) of the barrier system and the hazard that the barrier was installed to shield in the first place. This is different from passenger vehicle crashes where a well-designed barrier system comes into contact with and deforms/re-directs only the errant vehicle, not the occupants.

Field experience with flexible wire rope barriers, as documented in Austroads Guide to Traffic Engineering Practice Part 15, has shown that the majority of injuries to motorcyclists (or pillions) occur from contact with the support posts and not, as was first believed, from the ropes.

At locations where motorcycle involvement in "run-off-the-road" crashes is high, consideration should be given to installing a barrier system which results in reduced likelihood of a rider coming into contact with the support posts. A semi-rigid guardrail configuration similar to that in Figure 8.18 has been tested experimentally by INRETS and shown to prevent a test "body" from hitting the posts of a steel beam system. Alternatively, a thrie-beam guardrail mounted at a similar height to that shown in Figure 8.18 should also present fewer discontinuities to a motorcyclist (or pillion) than a standard installation. Continuous concrete barrier may offer the potential for least injury to motorcyclists, but cost precludes its widespread use. End treatments also present a problem. Main Roads has developed a 'rubbing rail' for select use where a high incidence of motorcycle/barrier interaction is a concern. Specialist advice from the TERS Section of Main Roads TRUM division should be sought for further details.

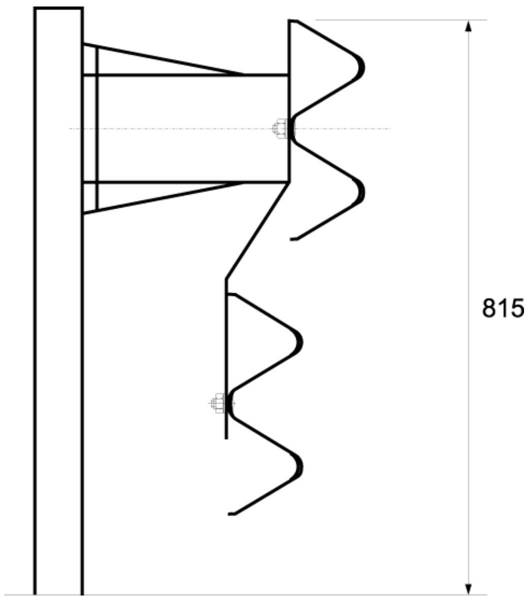

Figure 8.18 Modified w-beam barrier configuration for motorcyclist protection

8.2.2.10 Field experience

Monitoring the performance of barriers in the field is the best way to determine the performance of a barrier under particular situations. These observations will identify any problems that may occur with the system, allowing improvement to be made to ensure optimal performance of future installations.

When investigating crashes into barrier systems, AS3845 states that, as a minimum,

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the following questions should be asked and answered:

- Did the system function as designed?
- Should the system be restored to its pre-crash status?
- If not, which upgrade measures should be carried out to improve the safety of the hazard?

Australian Standard AS3845 suggests that part of an action plan for maintenance of safety barrier systems should include these assessment criteria.

Appendix 8C provides examples of barrier systems in practice and some of the pitfalls to be avoided.

8.2.3 Design parameters

8.2.3.1 Overview

Specific design parameters must be used by the designer of the barrier and include the following:

- design vehicle;
- containment level (AS3845);
- type of barrier system;
- length of need;
- lateral offset from the edge of the running lane;
- consideration of slope effects; and
- flare rate.

To a certain extent the design vehicle will influence the choice of barrier system and, furthermore, most of the above factors are interrelated. The following sections provide the starting point for selecting the most appropriate barrier type for either a roadside or median barrier, based on the above selection criteria.

Where a median barrier is being designed, also refer to the specific requirements outlined in Sections 8.1.3.8, 8.1.4.3 and 8.2.4.3.

Where appropriate, tables have been devised to aid with the selection process.

Further clarification of the performance of a particular barrier system can be found in the various references at the end of this Chapter. In addition, Section 8.2.8 discusses some results from past testing of various systems.

8.2.3.2 Test level and design vehicle

AS3845 defines test levels for barrier systems determined by speed, impact angle and vehicle mass.

Table 8.4 summarises the AS3845 criteria.

The appropriate test level should be selected for the design vehicle using the road being designed.

Designers need to be aware that:

- there are no steel systems (e.g. wire rope, thrie beam and w-beam) which can meet the criteria for redirection of Test Levels 5 or 6;
- rigid concrete barrier systems can meet all test levels if designed to do so. Concrete barriers as shown in Main Roads Standard Drawings meet test level 4 but special designs will be required if the design vehicle exceeds any parameters of test levels above this;
- thrie beam is the only steel system which meets test level 4; and
- vehicles of greater mass than test level 6 will require the use of a special barrier system to contain them. Reference to specialist structural

designers and the provisions of AS3845 is recommended in this case.

In addition to assessing a barrier's capability of containing a vehicle, engineering judgment may provide justification for barriers with high performance characteristics in areas with high traffic volumes and speeds, or at locations with poor road geometry (e.g. sharp curves on mountainous routes carrying high volumes of commercial vehicles).

Table 8.4 Vehicle criteria

Test level	Vehicle mass and type	Speed (km/h)	Impact angle (degrees)
0	820kg small car	50	20
	1,600kg small car	50	25
1	820kg small car	50	20
	2,000kg utility	50	25
2	820kg small car	70	20
	2,000kg utility	70	25
3	820kg small car	100	20
	2,000kg utility	100	25
4	820kg small car	100	20
	8,000kg rigid chassis truck	80	15
5	820kg small car	100	20
	36,000kg van type semi-trailer	80	15
6	820 kg small car	100	20
	36,000kg tanker type semi-trailer	80	15

Clearances and deflection values

Given that a barrier has been deemed necessary to reduce the risk of a roadside hazard to an errant vehicle, it is essential that the distance between the barrier and the object is sufficient to avoid a vehicle snagging on the hazard. This snagging could occur if a vehicle with a high centre of gravity crashes into the barrier, resulting in the vehicle vaulting the barrier system even if the appropriate deflection distance exists (AASHTO).

Consideration of such an event occurring will influence the decision on which barrier would be appropriate, given the barrier-to-hazard distance.

Note: Noise barriers constitute a hazard within the roadside environment and designers should treat them as they would any other roadside hazard.

Table 8.5 gives a guide to initial selection of barrier systems in 100km/h situations.

Table 8.5 Guide to initial barrier selection (100km/h)

Min. distance (m) (from face of barrier system to hazard)	Suitable barrier System
1.5 or more	Flexible Semi-Rigid Rigid
0.5 to 1.0	Semi-Rigid Rigid
0 to 0.5	Rigid

If post spacings for wire rope systems are reduced, the minimum barrier system to hazard distance may also be reduced (refer to manufacturer's recommendations).

Barriers with higher performance parameters may be required for areas with high traffic volumes and speeds, or at locations with poor road geometry (e.g. sharp curves).

Flexible systems exhibit larger values of dynamic deflection when compared with semi-rigid and rigid barrier types. Therefore, it is important to ensure

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sufficient distance is available between the barrier and the hazard to accommodate the lateral deflection.

Typical deflection characteristics for semi-rigid longitudinal barrier types available in Australia are provided in the Table 8.6.

Table 8.6 Deflection characteristics of semi-rigid barrier systems (RTA, 1996)

Type	Maximum Deflection (m) (recorded from full scale crash tests)
W-Beam Blocked Out (strong post)	0.6 to 0.9
Thrie-Beam Blocked Out (strong post)	0.5 to 1
Modified Thrie Beam	0.9

Typical deflection characteristics for wire rope barrier types available in Australia are provided in Table 8.7.

Nine factors should be considered (AASHTO) when selecting roadside barriers. The general principle is that the most desirable system is the one which offers the required degree of shielding at the lowest "whole of life" cost (AASHTO). These selection criteria are shown in Table 8.8.

Once an initial choice has been made, more detailed guidance is outlined in the appropriate section of this chapter.

The aim of the foregoing is not to single out a particular barrier type, but to provide an initial listing of appropriate barriers that will perform satisfactorily for the traffic composition of the road section requiring a longitudinal barrier.

A flow chart (Figure 8.19 is provided as an overall guide for barrier system selection.

8.2.4 Design procedures

A distinction has been made in the following sections between edge-of-the-road (roadside) barriers and median barriers. The requirements for median barriers are the same as those for roadside barriers plus additional requirements nominated specifically for median barrier in the associated sections. A worked example is shown in Appendix 8D.

The number of choices available, the infinite number of real-world situations, the multitude of variables and the lack of objective criteria complicate the selection process. The following sections give general guidance for initial selection, remembering that the best solution is one that provides the required degree of shielding at the lowest "whole of life" cost (AASHTO).

Designers should refer to Section 8.2.8 to obtain an appreciation of the performance of a barrier with regard to containment of vehicles.

Table 8.7 Deflection values for wire rope type barrier systems

Barrier type	Post spacing (m)	Post width (mm)	Design speed (≥ 85th percentile speed measured or predicted at the site being considered)											
			60 km/h		70 km/h		80 km/h		90 km/h		100 km/h		110 km/h	
			Y	Z	Y	Z	Y	Z	Y	Z	Y	Z	Y	Z
BRIFEN (4 wire)	2.4	140	1.2	2.2	1.3	2.4	1.4	2.6	1.5	2.8	1.6	3.0	1.7	3.2
	1.2	140	1.0	1.8	1.1	2.0	1.2	2.2	1.3	2.4	1.4	2.6	1.5	2.8
	1.0	140	0.9	1.6	1.0	1.8	1.1	2.0	1.2	2.2	1.3	2.4	1.4	2.6
BHP FLEX-FENCE (3 wire)	2.5	80	0.9	1.7	1.0	1.9	1.1	2.1	1.2	2.3	1.3	2.5	1.4	2.7
BHP FLEX-FENCE (4 wire)	2.5	80	0.9	1.7	1.0	1.9	1.1	2.1	1.2	2.3	1.3	2.5	1.4	2.7
Y = minimum distance from the hazard to the traffic face of the barrier. (Y = barrier deflection + post width.) Z = minimum median width (including 0.5m minimum shoulders) required for barrier performance only, for the speed zone (barrier in centre of the median). Reference must also be made to Chapter 7 for minimum widths for medians. Z = post width + twice barrier deflection.														

Table 8.8 Selection criteria for roadside barriers

Criteria	Comments
1. Performance Capability	Barrier must possess sufficient structural integrity to contain and redirect vehicles.
2. Deflection	Expected deflection of barrier should not exceed available room to deflect.
3. Site Conditions	Slope approaching the barrier and distance from the carriageway may preclude use of some barrier types.
4. Compatibility	Barrier must be compatible with planned end anchor and capable of having transition segments installed to join to other barrier systems (such as bridge railing)
5. Cost	Standard barrier systems are similar in cost, but high-performance barriers can cost significantly more.
6. Maintenance	
A. Routine	Few systems require a significant amount of routine maintenance.
B. Collision	Generally, flexible systems require significant repair after a collision, semi-rigid systems have fewer repair requirements and rigid systems or high performance railings require an even smaller amount of repair, sometimes nil.
C. Material Storage	The fewer different systems used, the fewer inventory items and the less storage space required.
D. Simplicity	Simpler designs, besides costing less, are more likely to be constructed and repaired properly by field personnel.
7. Aesthetics	Occasionally, barrier aesthetics is an important consideration in its selection.
8. Field Experience	The performance and maintenance requirements of existing systems should be monitored to identify problems, especially those that could be lessened or eliminated by using a different barrier type.
9. Environmental Impact	Detriment to barrier or fauna may be a consideration as well as preservatives in wooden barrier elements.

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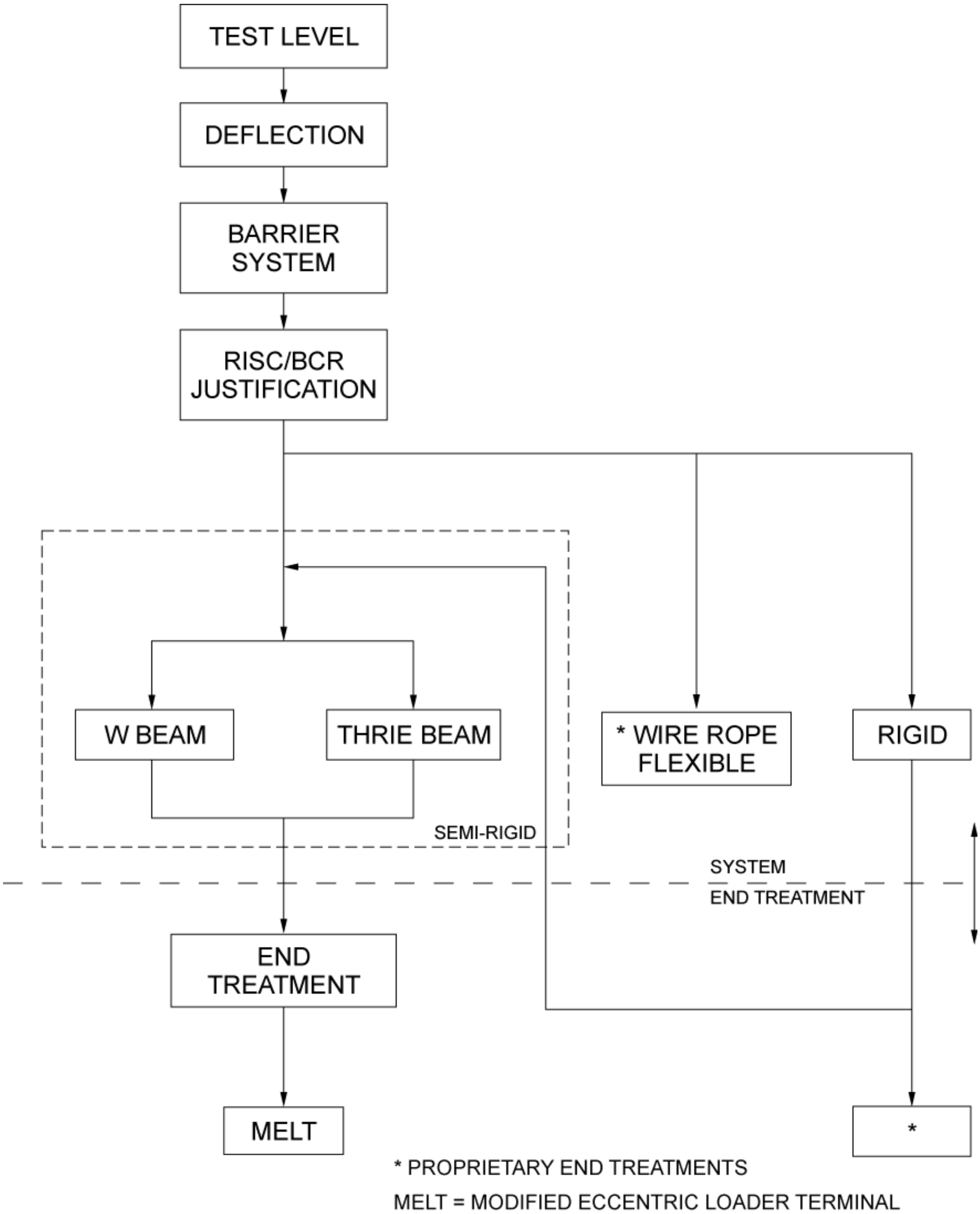

Figure 8.19 Guide to barrier system selection

8.2.4.1 Longitudinal barriers

General

The following section defines the steps to be taken to design a roadside barrier system. This follows on from the initial barrier selection process and the determination of the design vehicle and test level the barrier is required to meet.

For a safety barrier to re-direct errant vehicles away from roadside hazards, the barrier needs to develop longitudinal strength in tension during a collision. Figure 8.20 shows the mechanism of w-beam barrier operating correctly in a crash.

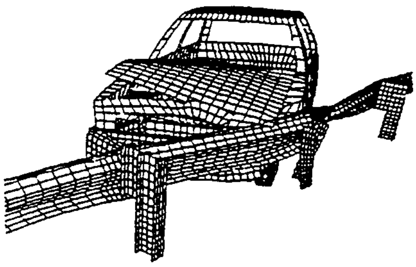

Figure 8.20 Wire frame model showing correct operation of w-beam barrier in a crash

This strength cannot be developed unless each end of the barrier is anchored properly to the ground. In the case of concrete barriers the effective operational anchorage in a crash is the footings in the vicinity of the impact area. For w-beam, thrie beam and wire rope barriers, the effective operational anchorages will be at both ends of the barrier; these may be in the order of hundreds of metres from the crash area.

It is important that designers, constructors and maintainers note that w-beam, thrie-beam and wire rope barriers will deflect when hit by errant vehicles. The mechanism of deflection reduces the severity of crashes on occupants. Refer to Table 8.5 for indicative deflections at 100km/hr for various barrier systems.

Section 8.2.3 and Table 8.5, Table 8.6 and Table 8.7 define the dynamic deflection and the minimum barrier-to-obstruction distance of various barrier types, for application as a roadside or median barrier at various design speeds.

Table 8.9 designer in the design of w-beam and thrie-beam safety barriers, and is supplemented by the information provided in the rest of this Chapter.

Step 1 – Determine the lateral distance of the barrier from the edge of the road

The lateral offset and details of the features of any kerb (e.g. slope) will be required.

The lateral offset criterion is based on the shy line offset principle as described in Chapter 7 of this manual.

Design shy line offset distances for different speed environments are shown in Table 8.10. In general however, the following guidelines should be applied:

- for relatively short, isolated sections of barrier the barrier should be located beyond the shy line offset;
- for long, continuous lengths of barrier, the shy line distance is not considered critical if the barrier is first installed beyond the shy line offset and gradually introduced nearer (i.e. tapered closer) to the travelled way.

Deflection and barrier-to-obstruction distances, as discussed elsewhere in this Chapter, also require consideration when determining the lateral offset of the barrier.

When shielding an embankment, a minimum distance of 0.5m should be provided between the back of the barrier posts and the embankment edge.

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Table 8.9 Selected w-beam and thrie-beam characteristics

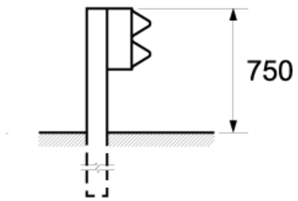
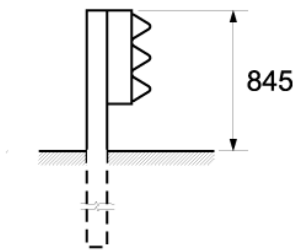
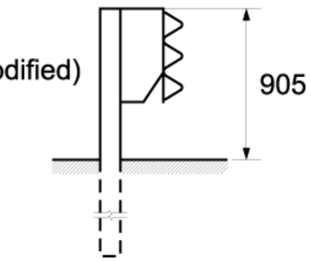
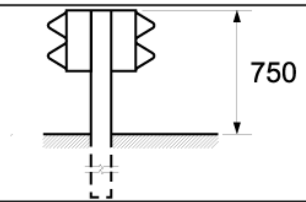
Type	Post spacing (m)	Dynamic deflection (m)	Remarks
G4 	2.0	1.0 (2000 kg vehicle at 100 km/h; and 25°)	(a) W-beam steel rail system (b) Anchored terminals are essential (c) Mounting height 40 mm greater than AS3845 allows for 1 overlay (lift course) without alteration
G9 	2.0	0.6 (2000 kg vehicle at 100 km/h; and 25°)	(a) W-beam steel rail system (b) Can be used with G4 system with W-thrie transition beam (c) Anchored terminals are essential (d) Mounting height 40 mm greater than AS3845 allows for 1 overlay (lift course) without alteration
G9 (Modified) 	2.0	1.0 (8000 kg vehicle at 100 km/h; and 15°)	(a) Thrie-beam steel rail system with modified blockout (b) Can be used with G4 system with W-thrie transition beam (c) Anchored terminals are essential (d) Mounting height 40 mm greater than AS3845 allows for 1 overlay (lift course) without alteration
MB4 	2.0	0.5 (2000 kg vehicle at 100 km/h; and 25°)	(a) W-beam steel rail median system (b) Anchored terminals are essential (c) Mounting height 40 mm greater than AS3845 allows for 1 overlay (lift course) without alteration

Table 8.10 Shy line distances

85th Percentile Speed (km/h)	Shy Line Distance (m)	
	Nearside (Left)	Offside (Right)
≤ 70	1.5	1
80	2	1
90	2.5	1.5
≥100	3	2

When considering the lateral distance of the barrier from the edge of the road the designer should also consider vehicle trajectory characteristics resulting from collision with a kerb or slope. Generally barrier systems should not be installed in proximity to kerbs and should only be installed on slopes that are 1 on 10 or flatter (refer to Sections 8.2.2.2 and 8.2.2.3).

Should these features be considered to pose a potential problem, flattening of the slope to 1 on 10 may be required.

Step 2 - Determine the barrier length of need

AASHTO and the RTA have different methods for determining the length of need. **The AASHTO Method is the preferred design procedure and recommended for use in determining the length of need of safety barrier.** . The AASHTO method uses geometrical approach to determining the barrier length.

The formulae used in the AASHTO method considers the distance from the road edge before leaving the travelling lane but the distance of the hazard from the edge of the road is not explicitly included. The latter variable is addressed implicitly as the distance from the edge of the running lane to the far side of the hazard is considered (instead). Given that a safety barrier is going to be installed, AASHTO start with the design assumption that it is the edge of the hazard farthest from the road that will determine the length of need.

AASHTO METHOD (PREFERRED AND RECOMMENDED)

Using the distance of the barrier from the road edge and the dimensions of the hazard, the barrier length of need may be determined using Table 8.10 and Table 8.11, and Figure 8.21, Figure 8.22 and Figure 8.23.

The influence of slopes on the design may be deduced by completing this procedure on a scaled plan, highlighting the hazard and indicating contour lines.

For straight sections of road, determine the following parameters as defined in Figure 8.21:

- L_R, = The Runout Length. The definition of this parameter, as defined by AASHTO, is the theoretical distance needed for a vehicle that has left the roadway to come to a stop. It is measured from the upstream extent of the obstruction along the roadway to the point at which a vehicle is assumed to leave the roadway (AASHTO). Table 8.11 indicates the runout length decreases as speed and/or traffic volumes decrease.
- L_A, = The Lateral Extent of the Area of Concern. This is the distance from the edge of the running lane to the far side of the fixed object or to the outside edge of the clear zone (i.e. outside edge of L_C, (refer Figure 8.21 and Figure 8.22) of an embankment or a fixed object that extends beyond the clear zone.
- L_1 = is the tangent length of the barrier upstream from the Area of Concern. This length is chosen by the designer.

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For the situation where a semi-rigid railing is connected to a rigid barrier, AASHTO suggest the tangent length should be at least as long as the transition section. This measure reduces the possibility of pocketing at the transition and increases the likelihood of smooth redirection if the guardrail is struck immediately adjacent to the rigid barrier (AASHTO).

- L_2 = The barrier's lateral distance from the edge of the running lane.

If the Area of Concern extends well beyond the appropriate clear zone (eg. a river) the designer may choose to shield only that portion that lies within the clear zone by setting L_A equal to L_C.

For determination of barrier length of need, all lateral dimensions are measured from the edge of the running lane as shown in Figure 8.21, Figure 8.22 and Figure 8.23.

It should be noted that the 'barrier length of need' does **not** include the end terminal treatments. In cases where it is not possible (e.g. due to site restrictions) to provide the full length of need and/or the appropriate end treatments, specialist advice should be sought from the TERS Section of Main Roads' TRUM Division.

The barrier length then becomes a function of the distance it is located from the edge of the running lane and can most readily be obtained geometrically by drawing the "length of need" chord from the edge of the running lane at L_R to the rearmost point of the hazard. The barrier should cross this chord (refer to the worked example in Appendix 8D).

This method to determine barrier length is only relevant to straight sections of road.

For horizontally curved road sections, assume that a vehicle's exit path from the road will follow a tangential runout path (Figure 8.23 - AASHTO).

The barrier length of need is determined using the tangent line from the curve to the edge of the hazard, or to the clear zone if a non-traversable feature is being shielded (Figure 8.23).

The barrier length then becomes a function of the distance it is located from the edge of the driving lane and can most readily be obtained geometrically by drawing the "length of need" chord from the tangent of the running lane to the rearmost point of the hazard. A flare is not generally used on a horizontal curve (AASHTO).

Table 8.11 Suggested runout lengths for barrier design

Design Speed (km/h)	Runout Length, L_R, (m) for a AADT of:			
	>6000	2000 to 6000	800 to 2000	< 800
110	145	135	120	110
100	130	120	105	100
90	110	105	95	85
80	100	90	80	75
70	80	75	65	60
60	70	60	55	50
50	50	50	45	40

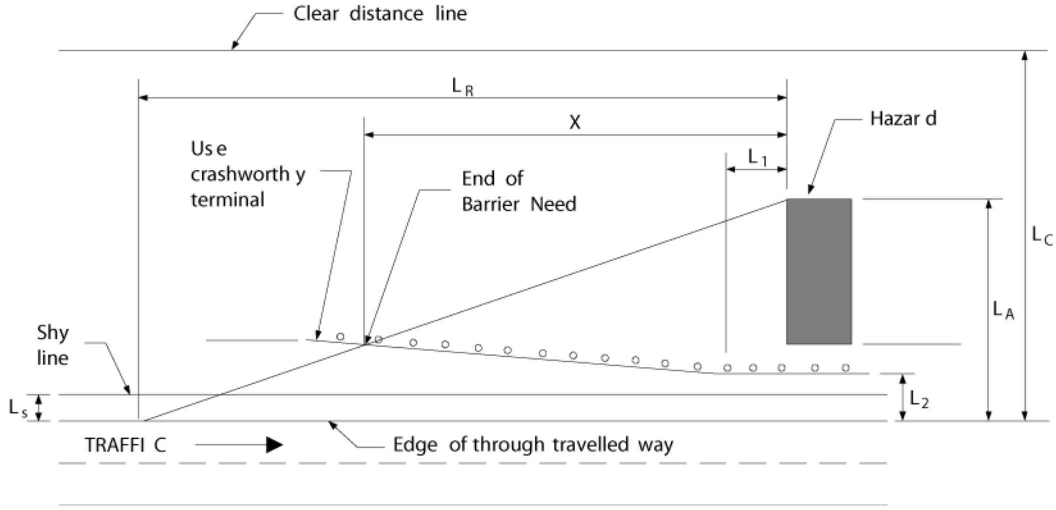

Figure 8.21 Approach barrier layout variables

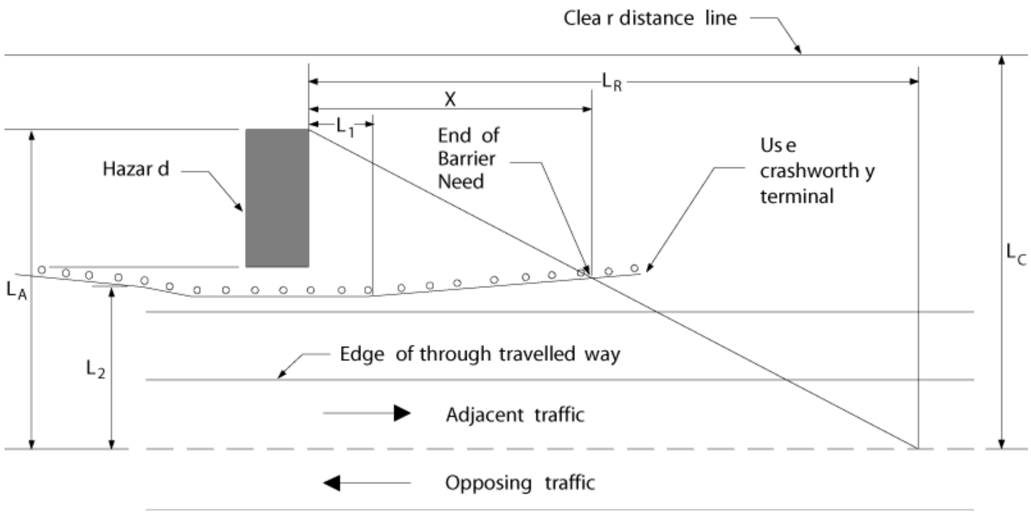

Figure 8.22 Approach barrier for opposing traffic

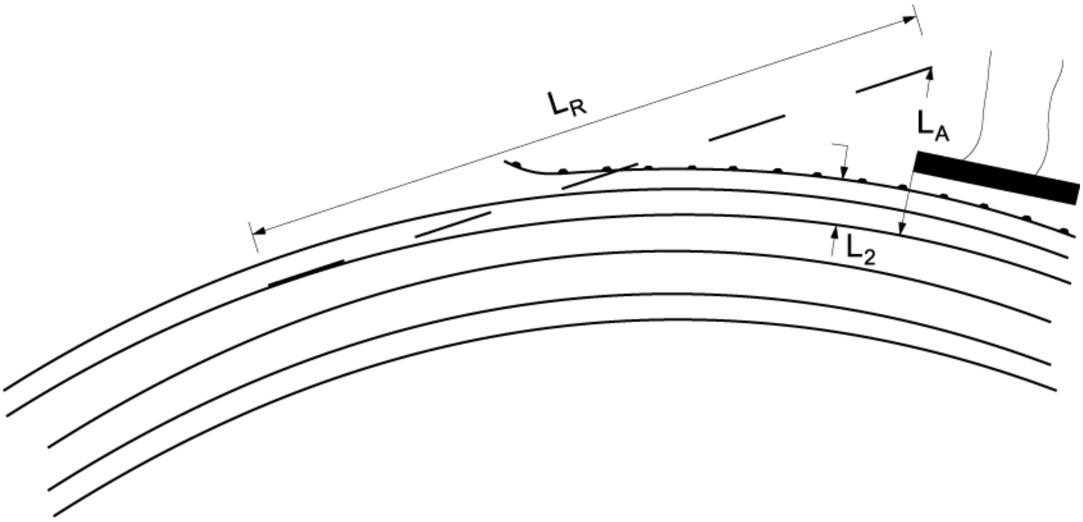

Figure 8.23 Determination of length of need on horizontal curves

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Step 3 - Check that the length of need can be justified using the BCR

Refer to Section 8.1 and determine whether the value of the BCR for the design is above the given thresholds. If so, proceed to Step 4. If not, either exercise engineering judgment and use length of need as determined in Step 2 or use minimum lengths as shown in Main Roads' Standard Drawings. Note that using a reduced length will not be fully effective and this approach should be adopted with caution.

Step 4 - Select an appropriate end treatment

Refer to the Section 8.2.6 to determine the most appropriate end treatment for the chosen barrier design.

Step 5 - Determine the flare rate

It is important that a motorist does not perceive roadside barriers to be a hazard. Motorists are less likely to perceive roadside barriers to be a hazard if they are introduced gradually to the roadside environment through the use of flares.

A barrier is considered to be flared when it is not parallel to the edge of the carriageway.

The flare rate is the ratio of the length of flared part of the barrier to the barrier offset and is equal to the cotangent of the flare angle.

Flared sections of barriers are also used as transitions to barrier sections closer to the road, to shield isolated objects such as bridge parapets, and to reduce the total length of barrier needed.

Disadvantages of flaring sections of barriers can include:

- increased severity of crashes because the impact angle is greater leading to higher severity accidents, particularly for rigid and semi-rigid barriers;
- increased likelihood of a vehicle being redirected back onto the roadway following an impact with the flared section; and
- increased need for flattening the slope in the area between the roadway and the barrier.

For barrier layouts that require flared sections, the flare angle for various design speeds is obtained from Table 8.11 and Table 8.12.

The flare angles are different for semi-rigid and rigid barriers. Flare angles also vary depending on whether the barrier is located within or beyond the shy line.

Flare angles for rigid and semi-rigid barriers located within and beyond the shy line offset, for various design speeds, are given in AS3845 and summarised in Table 8.12. These values indicate a smaller flare angle for both types of barrier when located inside the shy line. Smaller flare angles should be used where extensive grading would be required to ensure a low-angle approach to the barrier from the carriageway (AASHTO).

Table 8.12 Suggested flare rates (AS3845)

Design Speed Flare Rate for Flare Rate for Barrier beyond Shy Line (km/h)	Flare Rate for Barrier inside Shy Line (b:1)	Flare Rate for Barrier beyond Shy Line	
		Maximum flare rate for rigid barrier systems (a:1)	Suggested maximum flare rate for semi-rigid systems (a:1)
110	30:1	20:1	15:1
100	30:1	18:1	15:1
90	25:1	15:1	10:1
80	20:1	15:1	10:1
70	15:1	10:1	10:1
60	15:1	10:1	10:1
50	15:1	10:1	10:1

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8.2.4.2 Height of barrier openings

Figure 8.24 defines restrictions on barrier openings (AS3845). Openings as shown are undesirable. Vehicle sheet metal and mechanical components disturbed during impact may penetrate openings and cause the vehicle to snag on the barrier support structure. This may lead to unacceptably high decelerations for the occupants and may also create the conditions for vehicle instability.

8.2.4.3 Design of median barriers

General

In addition to the requirements for roadside barrier system design given in Sections 8.2.4.1 and 8.2.4.3, further consideration of terrain effects (e.g. kerbing, side slope) must be considered when designing the median barrier layout.

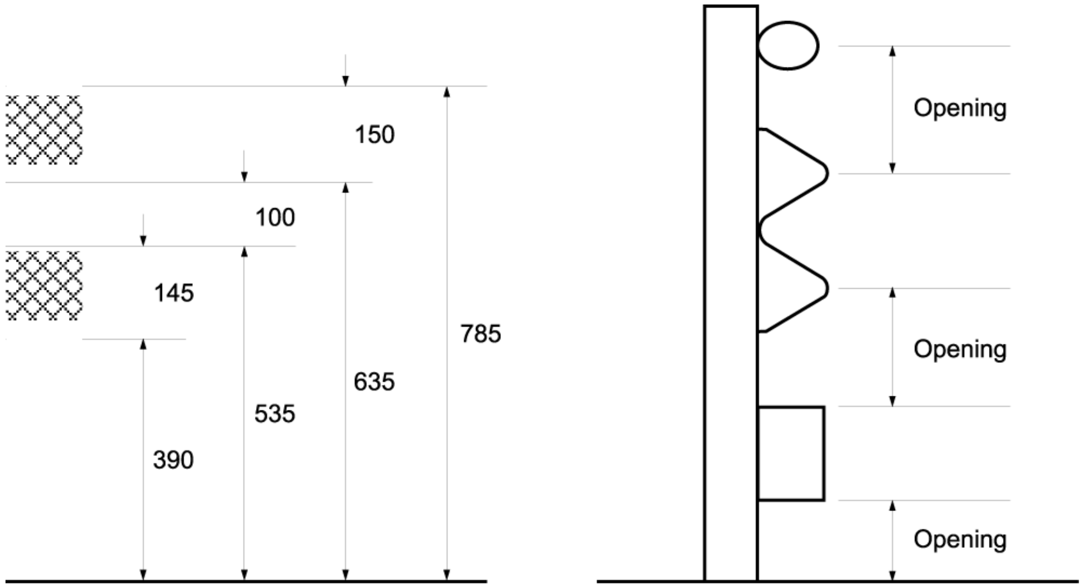
Median barriers may be warranted to protect vehicles from isolated rigid objects located within the median, such as bridge piers or sign supports.

Once the decision has been made to install a barrier at these locations, the required degree of shielding needs to be determined. The main concern is whether the shielding is necessary for one or both directions.

For the situation when shielding is required for both directions of travel, wire rope barriers, semi-rigid barriers with crash cushions or rigid barriers with crash cushions could be used. Figure 8.25 details how a bridge pier may be protected.

Design procedures

The following defines the steps to be taken to design a median barrier system. This discussion follows on from the initial barrier selection process and determination of the design vehicle and test level the barrier is required to meet and is given below to assist the designer in the barrier design. The following procedure is supplemented by the information provided in the rest of this Chapter.



(a) Avoid openings in areas cross hatched

(b) Definition of an opening

Figure 8.24 Restrictions to and classification of barrier openings.

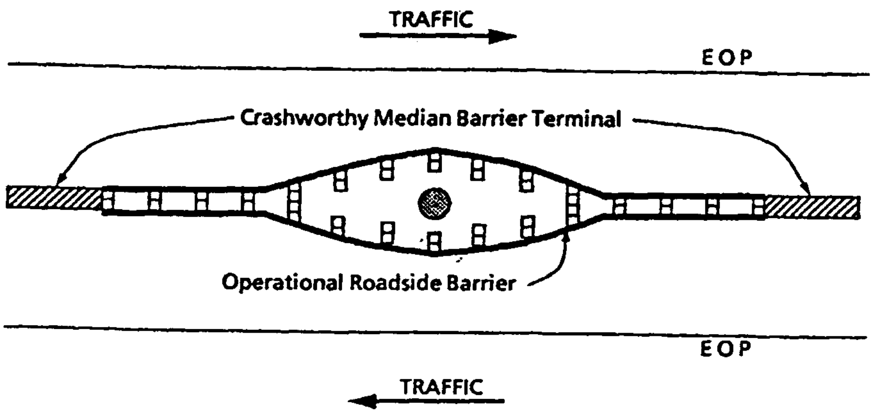


Figure 8.25 Suggested layout for shielding a rigid object in a median

STEP 1 - DETERMINE THE TYPE OF MEDIAN BARRIER

From Table 8.5, select the barrier type most applicable to the median location in question and the barrier locations in relationship to the hazard.

STEP 2 - DETERMINE THE LATERAL DISTANCE OF THE BARRIER FROM THE EDGE OF THE ROAD

As with roadside barriers, designers should consider the lateral offset, kerb and slope features.

The shy line offset distance, L_S, refer Figure 8.21 and Figure 8.22) for various design speeds can be obtained from Table 8.10.

When considering the lateral distance of the barrier from the edge of the road the designer should also take account of vehicle trajectory characteristics resulting from collisions with kerbs. Flattening of the slope to 1 on 10 and/or deleting the kerb may be required.

STEP 3 - DETERMINE THE FLARE RATE

The flare rates used for design of median barriers are the same as those for roadside barriers.

For barrier layouts requiring flared sections, the flare angle for various design speeds is obtained from Table 8.12.

Note that the flare angles are different for semi-rigid and rigid barriers, and also depend on whether they are located within or beyond the shy line.

STEP 4 - SELECT AN APPROPRIATE END TREATMENT

Refer to the Section 8.2.6 to determine the most appropriate end treatment for the chosen barrier design.

Further design considerations for median barrier systems

Along with the above design process, further consideration of the following details is required when median barrier systems are to be designed and installed.

Access

Consideration should be given to access across medians for emergency vehicles and maintenance procedures. Details of treatments for median cross-overs are given in Chapter 13 of this manual.

Where an emergency cross-over passes through a median barrier, a lift out section of barrier must be provided.

Sloped medians

The most desirable median is one that is relatively flat (i.e. with slopes of 1 on 10 or less), free of hazards and is at least as wide as the clear zone (refer also Chapter 7 of this manual). When this ideal condition is not available the following placement guidelines are to be observed. Figure 8.27 (AASHTO, 2002) illustrates three types of median configurations.

Considering Figure 8.27:

- Type 1 illustrates application in depressed medians or medians with a ditch.
- Type 2 illustrates application in stepped medians or medians that separate carriageways with significant differences in elevation.
- Type 3 illustrates application in raised medians, or median berms.

TYPE 1

Illustrations 1 and 2 of Figure 8.27 indicate barrier locations for shielding steep slopes. The barriers should be either a wire rope, semi-rigid or rigid type and be installed near to the shoulder. In addition, for the situation described in Illustration 1 of Figure 8.27, barriers may be required to be placed on both sides of the median. Illustration 3 of Figure 8.27 requires a barrier to be located at or near the centre of the median. The deflection of the barrier used at this location should not be greater than half the median width. This application is specific to relatively flat slopes.

TYPE 2

Median barriers should be installed adjacent to the shoulder to shield the sorts of embankments shown in Illustrations 4 and 5 of Figure 8.27. For non-traversable medians, barriers should be placed adjacent to both carriageways.

TYPE 3

Research has shown that if this cross section type is high enough and wide enough, vehicles may be redirected if the angle of impact is relatively shallow.

If, however, it is considered that this will not occur, a semi-rigid median barrier may be placed at the apex of the cross section. For non-traversable slopes, a barrier should be placed near the shoulders of both carriageways. If retaining walls are used adjacent to each carriageway, it is recommended that the base of the wall be contoured to the exterior shape of a standard concrete barrier, and that the wall be designed to withstand vehicular impacts.

In addition to the above:

- the most desirable median barrier placement is in the middle of a flat median; and
- the same barrier type should be used over the complete length.

Figure 8.26 illustrates the recommended placement of the barriers upstream and downstream of the stepped median. In this situation, the median barrier is "split". Most median barriers can be split this way.

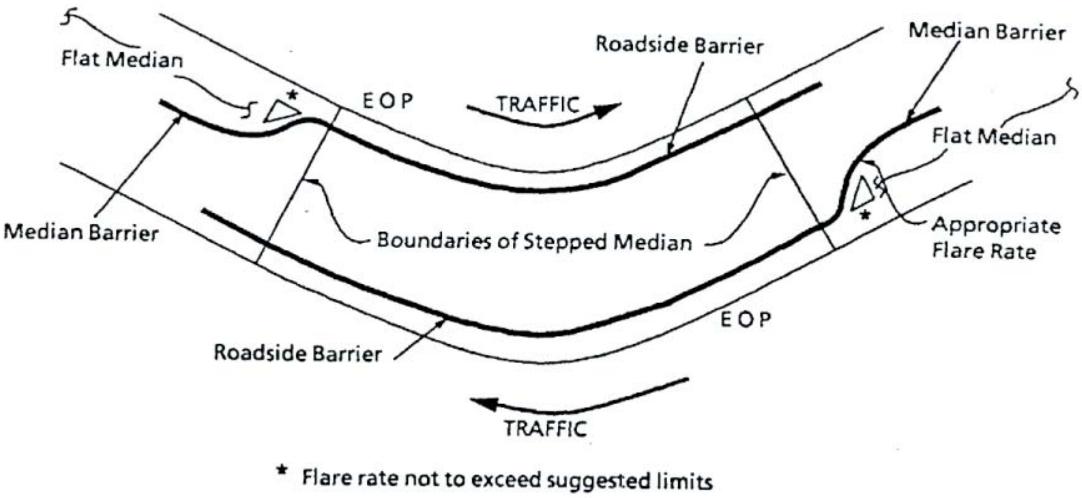


Figure 8.26 Example layout of barrier for a split median

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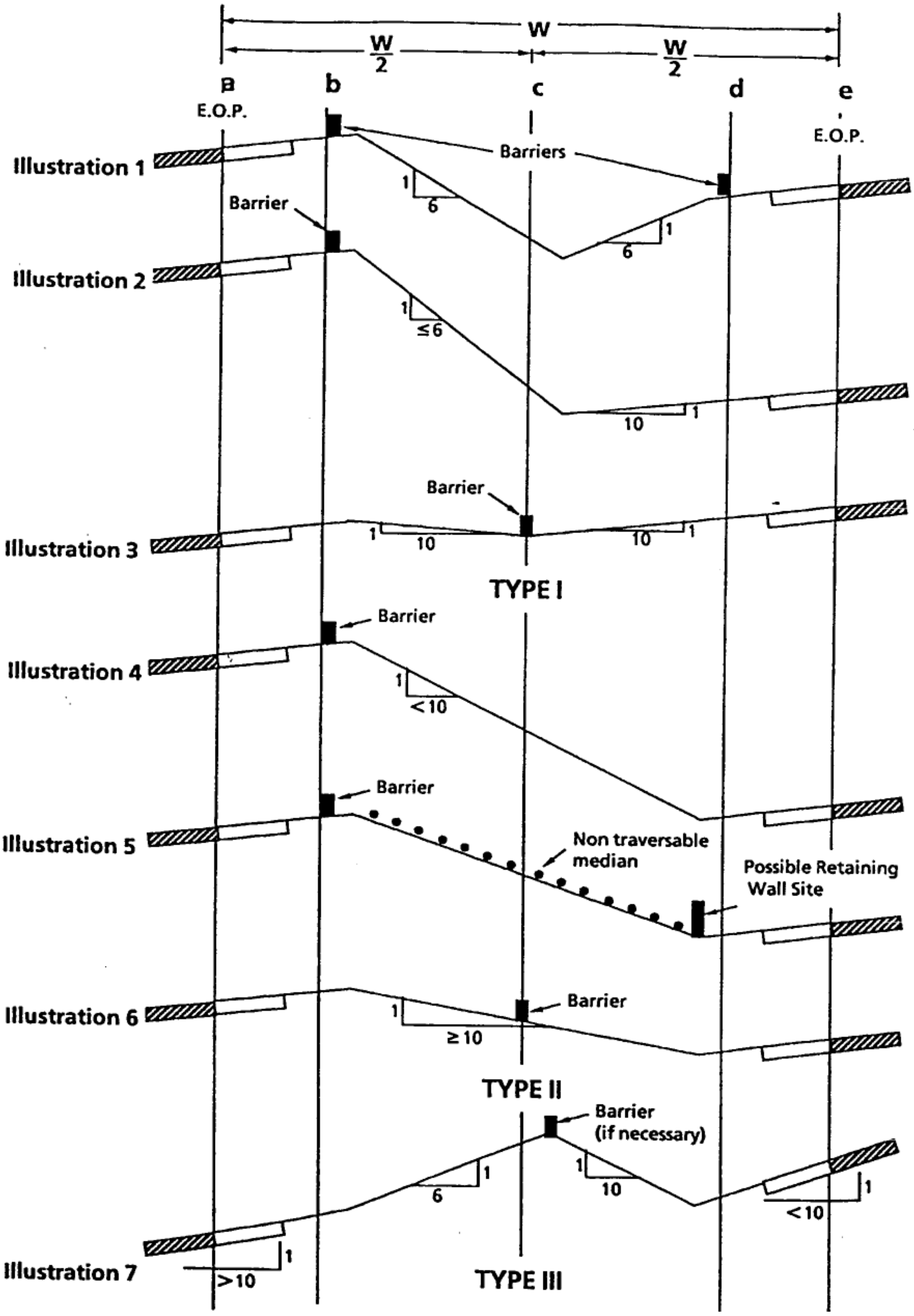

Figure 8.27 Recommended barrier placement for various median configurations

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8.2.5 Barrier types

8.2.5.1 Rigid (concrete barrier)

Rigid barriers include:

- Precast concrete barriers;
- Cast in situ reinforced concrete parapets;
- Extruded concrete barrier; and
- Combinations of the above.

Rigid barrier systems exhibit very little, if any, deflection on impact. They also allow for greater strength and rigidity to be designed into the barrier system to deflect high mass design vehicles (AS3845). During collisions, energy is dissipated by raising and lowering the vehicle and by deformation of the vehicle body and mechanical components rather than by deflection of the system. Rigid barriers are therefore used at locations where there is limited scope for barrier deflection, where the design vehicle exceeds the test level for steel systems, where the hazard is close to the running lane or in narrow medians.

Rigid barrier should be the type of safety barrier used in high volume traffic areas where a significant portion (10% or greater) of the traffic is articulated commercial vehicles (semi-trailers). They may also be considered in areas where the incidence of motorcycle accidents is high.

In order for the barrier to be effective, the barrier must be able to resist the impact load through a combination of moment and shear loads. To achieve this, a minimum length of barrier is required (Table 8.13). Achieving this minimum length depends on the method of anchorage of the barrier and the detail of the connections between elements of the system. The following advice is subdivided into temporary and long term systems.

Temporary installations

The only feasible temporary concrete barrier system is a precast (portable) concrete barrier. A suitable temporary connection system consists of two angle connectors per joint (Main Roads Standard Drawing Number 1473). It is assumed that temporary systems will only be in position for a number of months.

Permanent installations

Permanent installations could consist of a suitable system connecting any combination of precast, in situ or extruded systems (Table 8.14). Permanent installations require a 40 year design life.

MINIMUM LENGTH OF BARRIER TO RESIST VEHICLE IMPACT

The structural integrity of concrete barriers requires a minimum length of connected barrier to provide the gross mass to resist the impact load of an errant vehicle. The length is dependent on the means of restraint used to support the barrier.

The following sub-sections apply to road sections with speed environments that are ≥80km/h and where the angle of attack does not exceed 15 degrees.

OVERLAYS, CORRECTOR COURSES, ETC

Overlays (or lift or corrector) courses placed after initial construction of the barrier may reduce the relative/residual height of barriers and/or their profile. Designers should make provision for such future treatments when designing a barrier. (Refer to Main Roads Standard Drawing Numbers 1460 and 1468 respectively for details of the minimum upstand height for Type “F” barrier and the minimum total height for single slope barrier). Specialist advice should be sought from the TERS Section of Main Roads' TRUM Division in cases where overlays or other treatments have resulted/will result in barriers with non-complying relative/residual heights and/or their profiles.

Table 8.13 Minimum length of rigid (concrete) barrier.

Barrier Restraining System	Min length (m)	Deflection of barrier after impact (mm)
Temporary Concrete barrier sitting on pavement and/or mortar seating	30	175
Permanent Concrete barrier sitting on pavement and/or mortar seating	30	175*
Concrete barrier restrained by 25mm thick asphalt on both sides of barrier	25	0
Concrete barrier anchored with dowels in accordance to AS 3845	20	0
Concrete barrier embedded 200 mm into compacted pavement or fill in accordance with AS 3845	20	0

*No test data available. Temporary test data used as worst case deflection answer.
Smaller lengths of barrier could be obtained by using piles incorporated into the barrier system to provide the restraining system. However, specialist structural advice is required.
The barrier system used shall take into account the deflection of the barrier and the implication of the movement.

Table 8.14 Connection systems

System	Detail
Portable concrete barrier	Reinforced concrete infill in accordance with Main Roads Standard Drawing No. 1473
Reinforced and extruded systems	Refer to Standard Drawings 1460 to 1644 and 1468. (Dowels bars 1.0m long placed with 500mm in each end, with one end de-bonded, are required at expansion joints.)

Note: Angle connectors were not included in any testing program.

END DETAIL FOR PERMANENT BARRIER

The termination of a concrete barrier is usually achieved by the attachment of a w-beam or thrie beam end treatment or other equivalent collapsible system (e.g. MELT, GREAT system).

The attachment of this less rigid termination system to the concrete barrier requires the use of a reinforced concrete barrier terminal section. The minimum length of the terminal section is 3.0m.

In order to achieve continuity of the concrete barrier, the terminal section must be positively connected to the other section of the barrier.

In permanent installations, it will often be necessary to cut precast portable concrete barrier systems to form the gaps required for light poles or where required for other reasons.

Using the shorter cut lengths of portable concrete barrier resulting from this is permitted when it is possible to join the adjacent two portable concrete barrier sections together using reinforced concrete infill in accordance with Main Roads Standard Drawing No 1473.

Logically this means it may be possible to use the two end sections off one portable concrete barrier. The remaining interior section would have to be discarded because it does not have the recess for the concrete infill necessary to achieve the continuity connection.

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Main Roads' rigid barrier systems are illustrated in Figure 8.28 and Figure 8.29. Single slope barriers (Figure 8.29) are recommended for all new designs with the exception of short lengths of barrier, which join with existing 'F' type barrier. 'F' type barrier (Figure 8.28) is not recommended except where it is necessary to join a short length of new rigid barrier to an existing 'F' type barrier. 'F' type barrier is not recommended because small, front wheel drive vehicles have a tendency to "barrel roll" when hitting 'F' type barriers, particularly at speeds approaching 80km/h. Consequently, only single slope concrete barriers are to be used where speed limits are 80km/h or above.

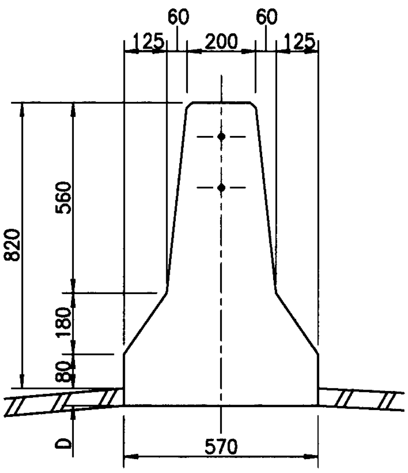

Figure 8.28 Concrete rigid (concrete) barrier shapes - 'F' type

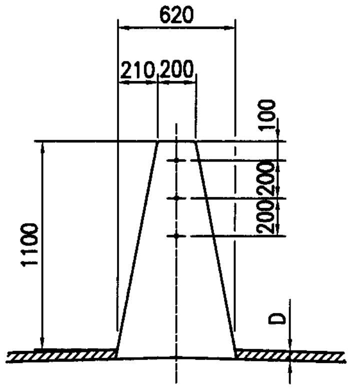

Figure 8.29 Concrete rigid (concrete) barrier shapes - single slope

Rigid barriers are designed and tested to operate with flat terrain approaches. Kerbing placed on the approaches to the barrier will impart a vertical force to the vehicle, the dynamic effect of which could adversely affect the operation of the barrier (VicRoads).

Satisfactory performance of rigid systems is achieved when impact angles are less than 15°.

Higher impact angles will occur with increasing distance from the edge of road to the face of the barrier.

For straight sections, impact angles for various offsets can be determined from the examples described in Appendix 8C. A correction for horizontal curves may also be calculated by using the figures contained in Appendix 8C. If the distance from the edge of the running lane to the barrier location is too great, a rigid barrier type may not be suitable.

The minimum clearance to the safety barrier should be 0.5m to allow for vehicle overhang. Clearance may need to be more than 0.5m; designers should check clearance to the barrier is adequate for the design (or check) vehicle using its swept path.

Specific to rigid median barrier installations, the type of barrier used should be compatible with other median features, such as luminare supports, sign supports and bridge piers.

When using rigid barrier, designers must check sight distances, especially sight distances around horizontal curves, at intersections and at accesses, to be checked for adequacy.

Drainage should be checked and drains installed from the high side of superelevated sections to prevent ponding.

8.2.5.2 Semi-rigid barrier

General

The deflection of semi-rigid barriers is less than that of flexible systems, but more than rigid systems. The barrier redirects colliding vehicles by some of the collision forces being transferred to the support posts of the barrier, which either break away or bend on impact, and to tension in the barrier rails, which redirect the vehicle.

Because these systems have stiffer rails than flexible systems, resistance is achieved through the combined flexure and tensile strength of the rail. The undamaged adjacent posts provide support.

The tension in the rails is dependent on the correct installation of the end anchorages so attention needs to be directed to this aspect when installing these systems.

An increase in the number of posts will reduce the deflection on impact. Increasing the number of posts will strengthen and stiffen the barrier to reduce deflection for the situation when an isolated hazard is near a semi-rigid barrier.

Deflection values for semi-rigid barrier systems are given in AS 3845. The following discussion provides information on semi-rigid barrier systems used in Australia. Obsolete and superseded systems and those not complying with the provisions of AS 3845 (such as box-beam guardrail) are not covered as use of non-AS 3845 systems is not recommended.

W-beam blocked out (strong post)

W-beam guardrail is a commonly used roadside and median barrier.

A w-beam rail (Figure 8.30) is supported by a blockout attached to steel posts. The grade and the thickness of the steel are specified in AS 3845 and in Main Roads Standard Drawings and Specifications.

The blockout moves the point of impact away from the plane of the posts, thereby reducing vehicle snagging.

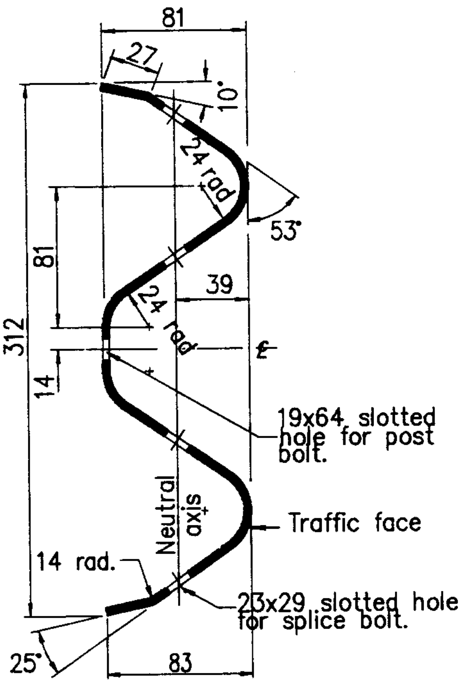

Figure 8.30 W-beam profile

The likelihood of vehicle vaulting over the barrier is also reduced because of the rail height being maintained during the initial stages of post deflection during impact.

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Rail to blockout bolt washers should not be installed for this system, as they are not necessary for strength over the normal operating range of crashes. However, they will cause the rail to ride down during severe impact, leading to the possibility of vaulting by colliding vehicles. Omitting these washers keeps rail heights relatively constant during severe crashes, thus ensuring the system operates more effectively than if rail to blockout bolt washers were present.

The standard w-beam post spacing is 2m as defined in AS 3845.

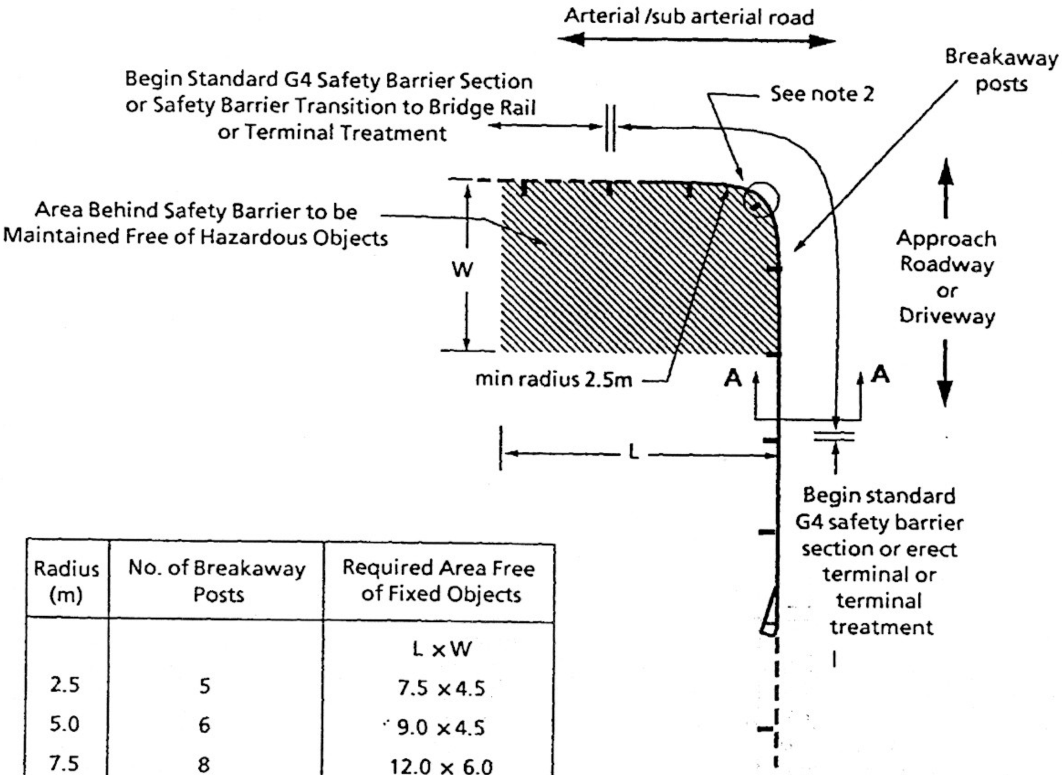
There is an issue of w-beam guardrail achieving the required tension for collisions where the guardrail is on the inside of a curve. Where the barrier simply follows the curvature of the roadway, most crashes on the inside of the curve are from overcorrection from drivers who run off the outside of the curve. Such collisions are usually high impact, non-tracking collisions where some deflection is useful in reducing collision severity.

Where excessive deflection would be undesirable, the distances between posts may need to be decreased or thrie-beam may be used instead.

For installations of reduced radius and for installations on the inside of curves, guidance can be obtained from Figure 8.31 and Figure 8.32. Although these figures pertain to bridges in proximity to intersecting roads, the small radii of curvature given in the figures, as well as the positioning of guardrail on the inside of the curve, give indicative treatments for non-bridge applications (RTA).

Posts need to be buried to sufficient depth in order to achieve the required stiffness to redirect vehicles in a crash. Sometimes this depth cannot be achieved because other underground features (eg. gully pits, PUP) conflict with where the posts should be installed. In these situations, a plate and post assembly may be fixed to the concrete upper portion of the pit or other feature. This treatment should be for only one post in any given length of barrier. Plate and post assembly details are shown on Main Roads' Standard Drawing Number 1478.

When using semi-rigid barrier, designers must check barrier require sight distances to be checked for adequacy, especially sight distances around horizontal curves, at intersections and at accesses.



Radius (m)	No. of Breakaway Posts	Required Area Free of Fixed Objects
		L x W
2.5	5	7.5 x 4.5
5.0	6	9.0 x 4.5
7.5	8	12.0 x 6.0
10.0	11	15.0 x 6.0

NOTES:

1. No washers are to be used on the mushroom headed bolts connecting the rail to the blockout pieces.
2. The rail is not bolted to the post at the centre of the nose as shown.
3. The curved guardrail section shall be precurved by the manufacturer.
4. Timber blockout pieces are 150 x 200 x 360 (nominal)
5. Breakaway posts are 150 x 200 x 1800 (nominal) oregon, or treated radiata pine, or steel posts with slip base.
6. Posts are spaced at 2000
7. AS3845 gives details of G4 configuration

Figure 8.31 Curved safety barrier detail on a main road at an approach roadway using 2.5 to 10m radius treatment

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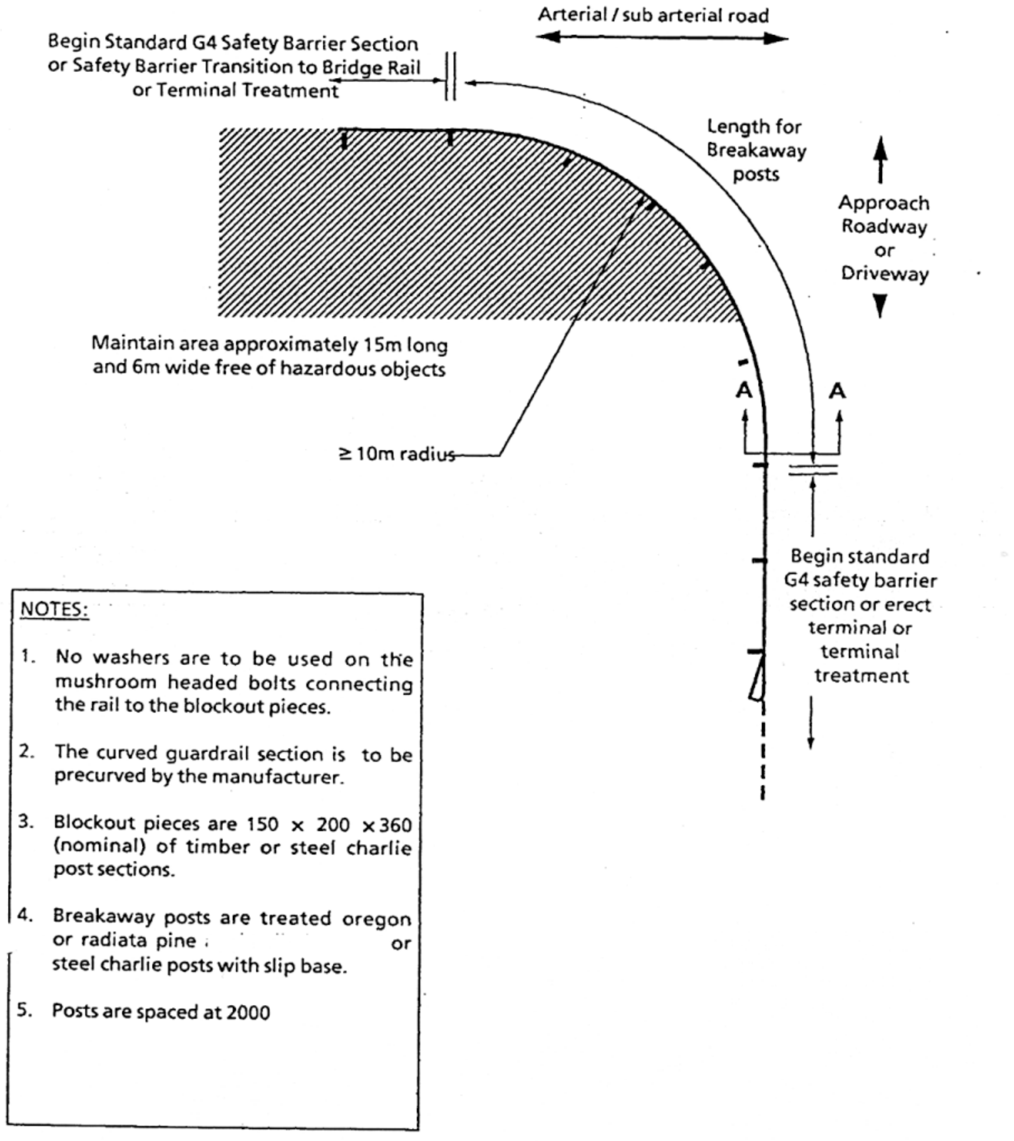

Figure 8.32 Curved safety barrier detail on a main road at an approach roadway using 10m or greater radius treatment

Thrie-beam blocked out (strong post)

Thrie-beam guardrail is stiffer than w-beam guardrail because of the increased depth of the beam element. This type of rail has two indentations (Figure 8.33), compared with the one indentation possessed by the w-beam (Figure 8.30). The blockouts enhance the performance of the barrier for crashes involving heavy vehicles and this barrier is particularly suitable for use at locations where there is a high frequency of crashes, particularly if these involve heavy vehicles.

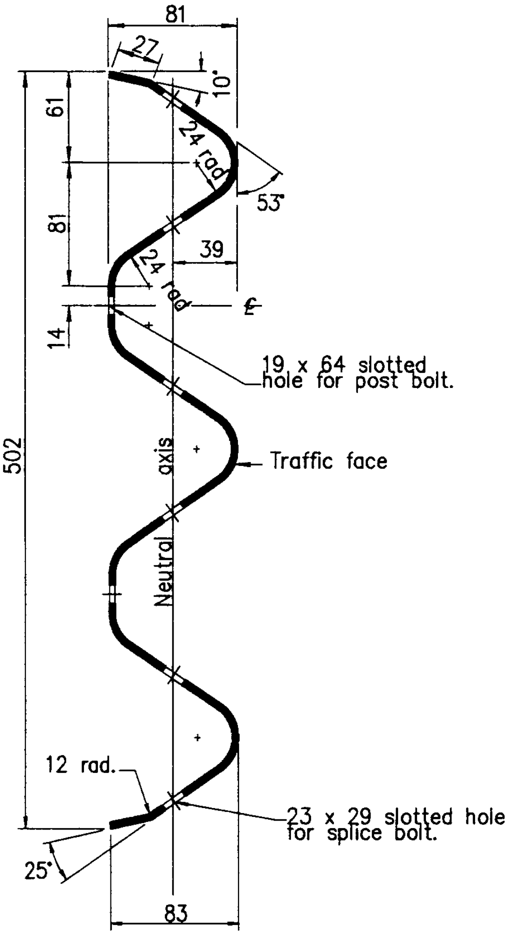

Figure 8.33 Thrie-beam profile

To reduce twisting of the rail, the rail to blockout bolts should alternate between the top and the bottom indentations.

Rail to blockout bolt washers should not be installed for this system, as they are not necessary for strength over the normal operating range of crashes. However, they will cause the rail to ride down during severe impact, leading to the possibility of vaulting by colliding vehicles. Omitting these washers keeps rail heights relatively constant during severe crashes, thus ensuring the system operates more effectively than if rail to blockout bolt washers were present.

When using semi-rigid barrier, designers must check barrier require sight distances to be checked for adequacy, especially sight distances around horizontal curves, at intersections and at accesses.

Transition pieces are available for connection to w-beam. AS 3845 and Main Roads Standard Drawings give details of such transitions.

The standard post spacing for thrie-beam blocked-out (strong post) should be at 2m as per AS3845.

Modified thrie-beam blocked out (strong post)

Thrie beam guardrail meets Test Level 4 (Table 8.4) and AS3845 nominates that it is suitable for redirection of vehicles of up to 8000kg at speeds of 100km/h and crash angles of up to 15°.

The modified thrie-beam is an improved version of the thrie-beam guardrail and should be the minimum standard for barrier used in high volume traffic areas where a significant portion (10% or greater) of the traffic is heavy vehicles.

A spacer block, with a triangular notch cut from its web, allows the lower portion of the thrie-beam and the flange of the spacer block to bend when hit and results in small vehicles being redirected less severely in collisions. This characteristic is ideal for guardrail situations on high volume roads carrying a mix of heavy vehicle through traffic and local passenger vehicle traffic (eg highways approaching regional centres).

Upon impact, the rail remains nearly vertical in the collision area and the posts are pushed backwards.

Rail to blockout bolt washers should not be used (refer to the above comments on Thrie-Beam Blocked Out [Strong Post]).

AS3845 provides more information on these semi-rigid systems.

Further notes on semi-rigid systems

Following a minor impact, semi-rigid systems should still be functional, providing no structural damage has occurred. Consequently, they do not require immediate repair. Large crashes, however, require repair reasonably promptly.

A height of 750mm to the top of the rail for w-beam barriers provides satisfactory protection against under ride and vaulting. The 750mm value supersedes the previous Departmental standard of 700mm to the top of the beam.

The height of any semi-rigid system should not be allowed to fall below 700mm as w-beam guardrail will not develop adequate torsional stiffness and vehicles may ramp over it. Ramping occurs when heights are ≤600mm.

Successive overlays (or lift or corrector courses) may reduce the relative height of barriers. Abraham blockouts (refer to Main Roads Standard Drawing Number 1478) with slotted bolt holes and an offset web allow rails to be repositioned at the correct heights after overlays without re-installing posts.

Refer to relevant Main Roads Standard Drawings for overall construction tolerances.

8.2.5.3 Flexible barrier

General

At present there are several types of wire rope barrier systems available that meet AS3845, according to their manufacturers, and are currently in use in Australia. They are the BRIFEN wire rope barrier system, the Ingal FLEXFENCE and CASS wire rope barrier systems, and the Saferoads ARMOURWIRE tensioned three strand cable barrier.

There are many products that have been tested to the European CEN 1713 requirements, however until such time as the harmonization between standards is clarified, all systems must comply with AS3845 and NCHRP350.

All proprietary systems that have been recognized for suitable use in Queensland must be designed and installed in accordance with the manufacturer's specification/s.

The following discussion has been included for guidance and reflects current manufacturers' literature.

Following an average impact, the maintenance activities and costs associated with repairing wire rope barriers are minimal. It is only the damaged posts that need to be replaced. The wire does not need to be re-tensioned. These flexible systems are suitable for either roadside or median applications (provided there are adequate clearances to account for their deflection).

These systems have particular application in floodway areas as minimal debris is caught on the system during flood events due to its reduced cross-sectional area. Wire rope barrier systems also reduce driver visibility problems, especially at intersections.

Designers and installers need to be mindful of the deflections exhibited when these types of systems are involved in collisions. Because these systems exhibit larger deflections than other barrier types, adequate clearance must be provided within the median and between the barrier and the hazard for roadside applications.

Wire rope barriers have been designed for, and tested primarily using, passenger cars. For further information regarding deflection and performance for heavy vehicles refer to the literature referenced in Sections 8.2.3 and 8.2.8.

Location guidance

The leading and trailing "points of need" are the second and second-last posts of the length of barrier that has all wires at full height (refer to Figure 8.34).

Table 8.7 is a guide to determining if a wire rope barrier system is suitable at specific locations; it gives minimum deflection values for 1.5t passenger vehicles. (Note: Larger offsets should be used whenever possible as the range of vehicles using the roads in Queensland regularly exceeds this mass.)

For flexible barrier systems the lateral deflection distance may be reduced to some extent by decreasing the post spacing.

Although alternative post spacings are given in Table 8.7, any variation in standard spacing will require further reference to manufacturers' specifications to ensure the correct post spacing/deflection relationship is maintained for the particular wire rope fence type.

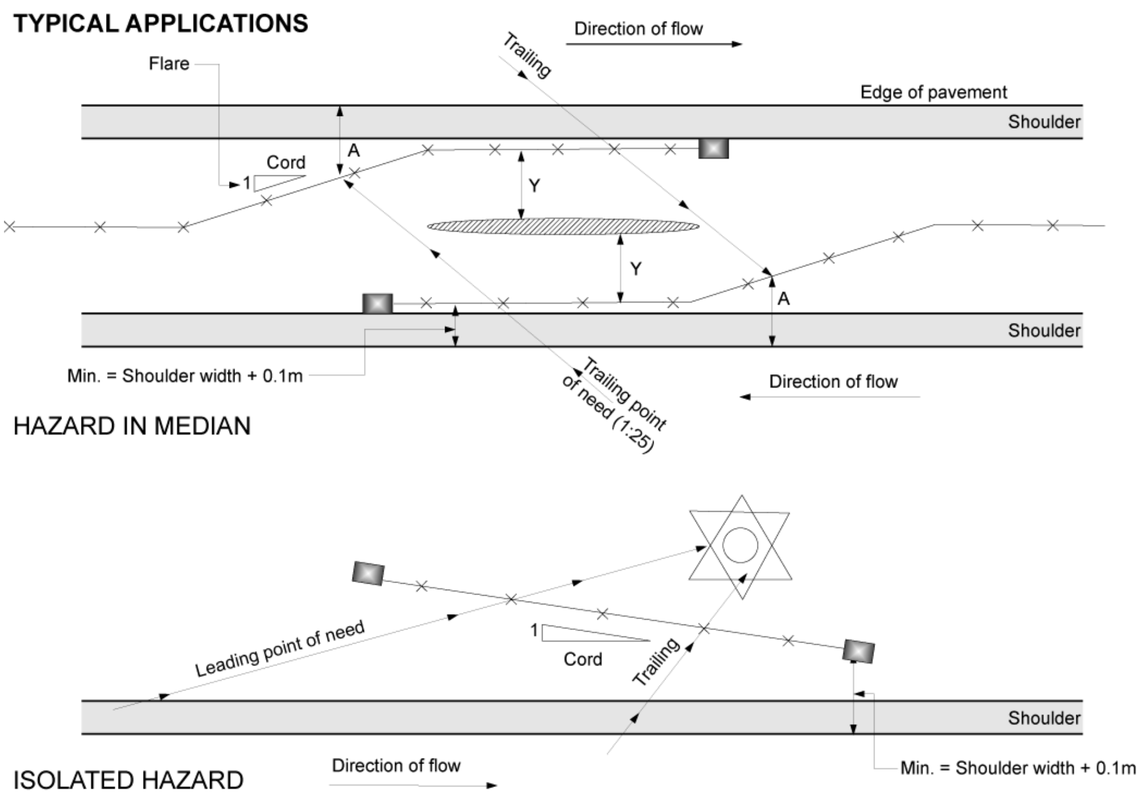

Figure 8.34 Determination of points of need for flexible barrier.

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Limitations of flexible barrier

The maximum lateral slope on which wire rope fence should be installed is typically 1 on 10. The designer is advised to consult with the manufacturer when it is desired to install wire rope barrier systems in situations outside this limit, or for each installation if there is any uncertainty with regard to the proposed installation.

Flexible barrier systems, particularly the wire rope types, require immediate repair following an impact, since the remaining posts/barrier are/is not functional.

In addition to the deflection values given in Table 8.7 and the consequent clearance required between the wire rope barrier fence and the hazard, operational constraints for each of the following situations should be considered when deciding to whether to use a wire rope barrier system:

- Wire rope systems should not be installed on horizontal curves when the horizontal curve radius is less than 600m and manufacturer's standard post spacing are used. The designer is advised to consult with the manufacturer when it is desired to install wire rope barrier systems in such situations, or for each installation if there is any uncertainty with regard to the proposed installation. The required rope tension and height will not be maintained during or after an impact. The re-directive forces exerted on the vehicle by the wire ropes may be too great for the occupants of the vehicle and tension problems may occur. This advice is based on information from the RTA. Whilst not designed specifically for the containment of heavy vehicles, refer to the Section 8.2.8 for details of results of heavy vehicle impact testing. Note that heavy vehicle crashes result in larger deflections than those expected from crashes by passenger vehicles.
- The systems should not be installed on sag vertical curves where the vertical curve radius is less than 3000m. This is because the tension in the ropes may cause the posts at the bottom of the dip to lift out especially in cold weather. This, combined with the possibility of the suspension of an errant vehicle being compressed at the bottom of such a vertical sag, may lead to an occurrence where the vehicle body passes under the ropes, instead of being caught on them. The ropes may then encroach into the turret of the vehicle, causing injury to the occupants.
- The systems should not be installed to connect to any other barriers or bridge parapets. The deflection inherent in the design cannot assure that vehicles colliding in the transition area between the rope barrier system and another system will be redirected safely.

Installation in proximity to rigid and semi-rigid barrier installations

Wire rope safety fences are not designed to be connected to other safety barriers or bridge ends. However, these barrier types may be installed in proximity to other barrier types. The following figures, Figure 8.35 and Figure 8.36 give examples of how this may be achieved via an overlap (not transition). A general arrangement of an overlap length is also shown in Figure 8.37. Details of such overlaps, including overlap lengths, are discussed in Section 8.2.7.6.

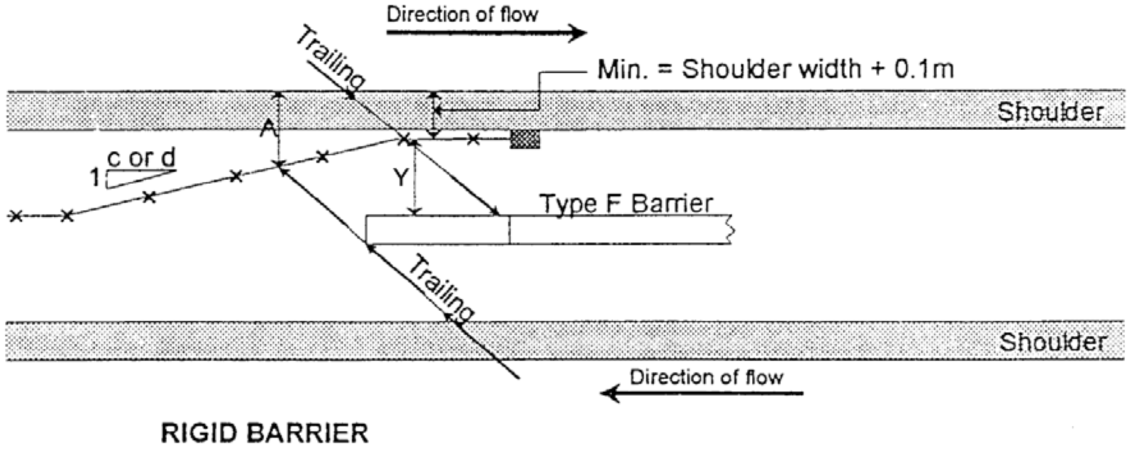

Figure 8.35 Overlap of flexible barrier and rigid barrier

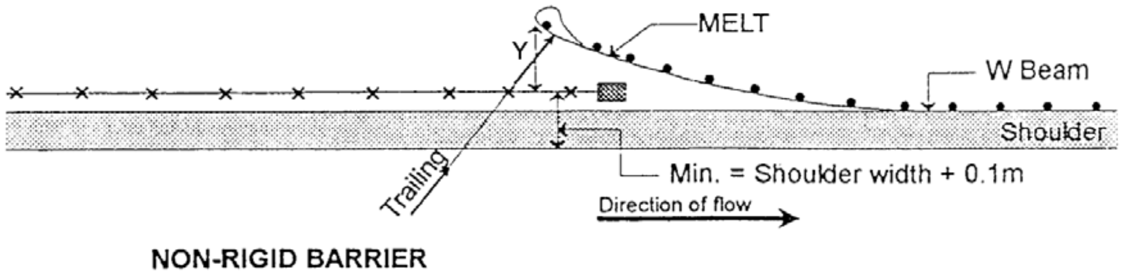

Figure 8.36 Overlap of flexible barrier and semi rigid barrier

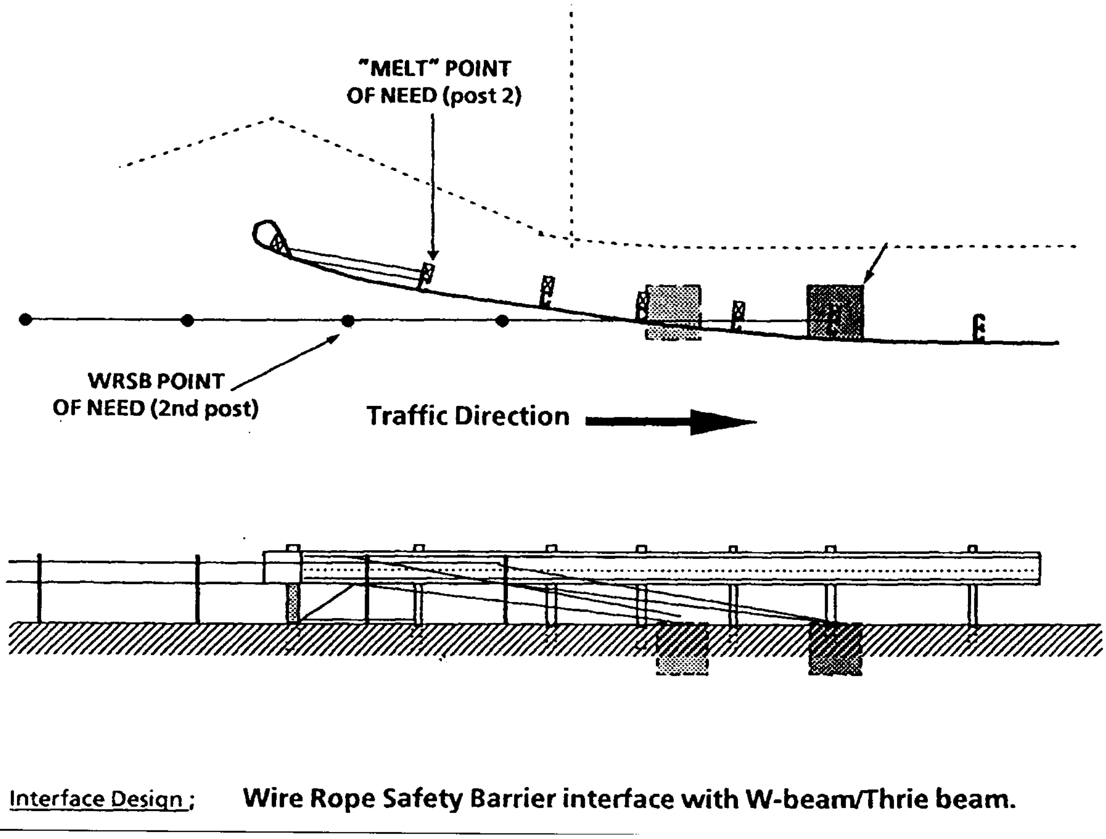

Figure 8.37 Wire rope safety barrier interface with w-beam/thrie beam

8

Unusual installations

The designer is required to consult with the manufacturer for any proposed installations that approach or exceed the constraints or associated constraint values given above. Wire rope barrier manufacturers have advised that, by the use of decreased post spacings, radii less than 600m may be achieved but it is recommended that the specific instance be referred to the particular manufacturer for validation before finalising the design.

Installation length

The specification for BRIFEN (as detailed in the manufacturer's documentation) states that it must be installed with the maximum span from end anchor to end anchor of 1385m with intermediate anchors a minimum of 60m apart to achieve the deflection nominated in the literature. In addition, tension rigging screws are to be provided at locations no greater than 154m apart. The minimum length of BRIFEN barrier at full height is not to be less than 24m.

It is recommended that Ingal FLEXFENCE, if chosen, be restricted to installations having a maximum length of 1000m between end anchorages.

BRIFEN

The BRIFEN system consists of four tensioned galvanised steel wire ropes supported by steel posts. The steel posts sit in concrete sockets that allow easy withdrawal when damaged. Two parallel ropes, vertically displaced from each other, are located in a plumb groove at the top of each post. A second pair of ropes is installed below the top pair. The second pair is at the same height as each other, is crossed over in the horizontal plane from one support post to the next and is held in position by hooks on each side of each post. The fence is supported by two end anchor arrangements, one at each end of each rope.

The standard post spacing is 2.4m. Recent testing of the system at 3.2m post spacing has recorded larger rope deflections, but the manufacturer has stated that this has not affected the performance of the system. Consequently, 3.2m spacings are becoming more common.

The installation height of a wire rope safety fence is an important consideration. The design height of the BRIFEN fence post is 680mm. The height to the top of the post is measured from the pavement edge level if the barrier is located within 1.5m of the edge of carriageway. For those situations when the barrier is a distance of 1.5m or greater from the edge of the carriageway, the height of the post is measured from the ground level at the base of the post.

Cable Safety System (CASS) Wire Rope Safety Barrier

CASS consists of three steel cables supported by steel posts. Post spacings of 2m, 3m and 5m have been tested, and the system passed NCHRP350 Test Level 3 requirements.

The system can be supplied with the option of using driven posts, concrete footings or steel sleeves.

It is recommended that the system be only used adjacent to embankments with a maximum slope of 1 on 6.

ARMORWIRE tensioned three strand cable barrier

The ARMORWIRE system consists of three steel cables supported by U-channel steel posts at 2m centres, and has passed the NCHRP350 Test Level 3 requirements.

Deflections between 1.99m and 3.6m can be expected depending on the post spacing used.

Ingal FLEXFENCE

The Ingal FLEXFENCE system consists of three or four tensioned galvanised steel wire ropes supported by steel posts. The steel posts sit in concrete sockets that allow easy withdrawal when damaged.

The typical installation height of the Ingal FLEXFENCE post is 775mm. The height to the top of the post is measured from the pavement edge level if the barrier is located within 1.5m of the edge of carriageway. For those situations when the barrier is a distance of 1.5m or greater from the edge of the carriageway, the height of the post is measured from the ground level at the base of the post.

The standard post spacing is 2.5m, but installations have been completed using a 3.0m post spacing. Tension rigging screws, however, should be located at spacings no greater than 300m. The minimum length of barrier at full height recommended by the manufacturer is 24m.

8.2.6 End treatments

8.2.6.1 General

To complete the design of the barrier, a crashworthy end treatment must be applied to the beginning and end of the barrier length.

An end treatment is required to perform two functions, namely:

- to anchor the barrier system such that longitudinal strength is developed in a crash; and
- to be weak enough that, if hit by an errant vehicle, it will not cause the vehicle's occupants to suffer injury or death by severe deceleration or spearing of the passenger compartment of the vehicle.

In w-beam barrier systems the longitudinal strength requirement is provided by the use of cable anchor assemblies on each end. In wire rope systems the longitudinal strength requirement is provided by the use of cable anchor assemblies on each end and intermediate anchor assemblies. To achieve the desired weakness in w-beam barriers, the system uses frangible elements, such as slip base posts, at either end. Figure 8.38 shows the desired failure mechanism for a w-beam end treatment.

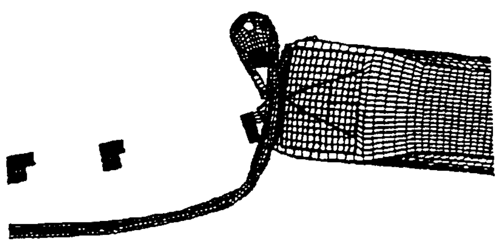

Figure 8.38 A wire frame model illustrating in plan view, the desired failure mechanism for a w-beam end treatment

Wire rope barrier end designs are their own end treatment, the end posts collapsing under the impact of an errant vehicle. Figure 8.77 in Appendix 8C shows an example.

End treatments should redirect an errant vehicle away from the hazard during and after impact. In achieving this goal, some end treatments redirect vehicles along the travelled way; others allow the vehicles to pass through the end treatment but re-direct vehicles away from the hazard whilst doing so. Based on this characteristic, end treatments are defined as being either **gating** or **non-gating**.

The purpose of an end treatment is to reduce the hazard posed to an errant vehicle from the end of the barrier system that is a hazard in itself if not dealt with properly.

Part of the testing associated with meeting AS 3845 requires that errant vehicles encountering the end treatment must remain stable during and after an angular or head-on collision and be directed away from the hard part of the safety barrier and the hazard the safety barrier was designed to protect. If this occurs during crash testing then the terminal has performed properly and is considered to have met the vehicular parameters of crashworthiness. Other parameters include occupant deceleration values, which need to be below bodily damage thresholds. As with barriers, crashworthy end treatments have been subject to tests defined in AS 3845 that evaluate structural adequacy, occupant risk and vehicle trajectory characteristics.

It should be noted that all end terminal tests are conducted in a controlled environment on level terrain with an obstruction/hazard free run-out area behind the test item.

Since these conditions may not be present in the majority of actual road environments, it is critical that prevailing site conditions be considered when deciding which end terminal to use (AASHTO).

A crashworthy barrier end treatment is essential if:

- the barrier terminates within the clear zone; and/or
- the barrier is in an area where it is likely to be hit head-on by an errant vehicle.

In addition, for flexible and semi-rigid barrier types, end treatments must be properly anchored so that the design operational requirements are achieved in practice (AASHTO). Any re-directional capability required by the design will only be achieved by the end treatment developing the same full tensile strength as the barrier upon impact.

The most appropriate crashworthy end treatment for a barrier should be selected following consideration of:

- its gating characteristics (refer 8.2.6.3);
- its re-directive characteristics;
- the speed environment;
- the space available for installation of the terminal;
- its capacity to absorb nuisance crashes;
- its compatibility with barrier type; and
- cost and maintenance factors.

Details of the re-directive characteristics of each treatment are covered under the description of that system.

Splayed ends (fishtail ends) are not used.

The minimum departure end treatment for w-beam barrier should be as shown on Main Roads Standard Drawing Number 1474.

The Australian Standard AS 3845 gives further details on these systems.

For back-to-back w-beam median treatments, non-proprietary end treatments may be used as shown in Figure 8.39, Figure 8.40 and Figure 8.41. Note that these figures are sketches showing indicative shapes only and do not detail actual layouts.

8.2.6.2 Types of end treatment available

General

The end treatments in this section have been tested in accordance with NCHRP230 and/or NCHRP350 to determine their crashworthiness and found to perform satisfactorily. Further, AS3845 nominates NCHRP350 as the applicable test standard but "deems" that systems with adequate prior operational performance are acceptable. Some NCHRP230 tested systems, whilst not necessarily meeting the updated criteria under NCHRP350 will fall into the "deemed to comply" classification of AS3845.

In areas of roadway cut section, or where the road is transitioning from cut to fill, it is sometimes possible to terminate a traffic barrier in the cutting or backslope. (See "concrete terminal block' in Standard Drawing 1484)

A w-beam guardrail anchored in the backslope has been successfully crash tested to NCHRP Report 350 Test Level 3.

When properly designed and located, this type of anchor provides full shielding for the identified hazard, eliminates the possibility of an end-on impact with the barrier terminal and minimises the likelihood of a vehicle passing behind the rail. It is considered a non-gating terminal.

Key design considerations include:

1. maintaining a uniform rail height relative to the roadway grade until the barrier crosses the table drain;
2. using a flare rate within the clear zone that is appropriate for the design speed;
3. adding a rub-rail for w-beam guardrail installations; and
4. using an anchor that is capable of developing the full tensile strength of the w-beam rail.

Also, the foreslopes on the approach should be no steeper than 1 on 4. If a barrier cannot be terminated in the backslope without violating any of these principles, a different type of end treatment may be more appropriate (AASHTO, 2002),

End treatments are defined as being either gating or non-gating.

When a vehicle collides with either the end or the side of a gating end treatment, the system will break away and allow the vehicle to pass through. The energy dissipated in this process slows the vehicle and directs it away from the hazard (i.e. the hard end of the barrier).

Non-gating end treatments do not allow the vehicle to pass through the terminal but redirect the vehicle along the travelled way. They are specifically designated as crash cushions and are used for the protection of median ends and hard parts of barrier systems. They are also applicable to shielding isolated fixed objects.

For each type of end treatment, the re-directive characteristics should be noted; these will vary according to material, construction etc. It should also be noted that some treatments nominated as "gating" will not always "gate" but will sometimes redirect the errant vehicle, depending on the impact point.

Wire rope safety barrier end treatments are to be provided in accordance with the relevant manufacturer's specification. The end anchors are frangible, detaching from the anchor block when hit and thus wire rope barriers have their end treatment as an integral part of this system. Safety ropes are provided to ensure the uncoupled wire ropes are not a hazard to adjacent traffic.

The following section gives indicative advice from manufacturer's documentation; further details should be requested from manufacturers, if/as required.

8.2.6.3 Gating end treatments

General

When using these gating end treatment systems it is important an area of level terrain that is clear (of hazards) is provided beyond the end treatment to ensure a vehicle will not encounter any further hazards, should the terminal allow the vehicle through.

For this reason, gating terminals need a hazard free, rectangular-shaped run-out area beyond the terminal (parallel to the rail) and behind the rail (refer to Section 8.2.8 if more details of this are required). Some treatments, such as the "Brakemaster", need less space than others.

Designers should be aware these systems do not protect the area behind the end treatment, hence they are nominated as "gating".

These terminal types are not suitable for use where the potential for an errant vehicle to travel through the end treatment and into a hazard or into opposing traffic lanes is highly likely (e.g. narrow medians).

The Australian Standard AS3845 gives further details on some of these systems. It also defines that, for all gating systems, a hazard-free zone of 22.5m long and 6m wide needs to be created behind the end treatment, allowing colliding vehicles to pass behind the end treatment.

Gating end treatments acceptable under AS3845 and available in Australia include:

- Modified Eccentric Loader Terminal (MELT);
- Departure End Terminal (DET);
- QuadTrend 350;
- Sand filled barrels;
- Sequential Kinking Terminal (SKT);
- Flared Energy Absorbing Terminal (FLEAT);
- ET2000 Plus; and
- Thrie-beam bull nose.

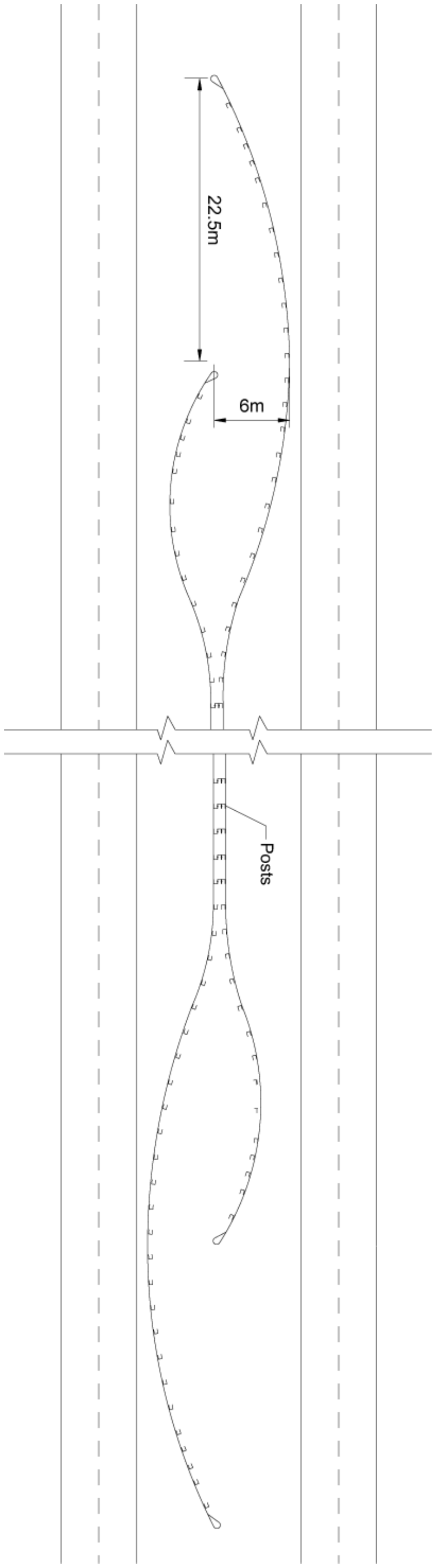

Figure 8.39 Non-proprietary end treatment(s) for back to back guardrail installation (e.g. wide median treatment)

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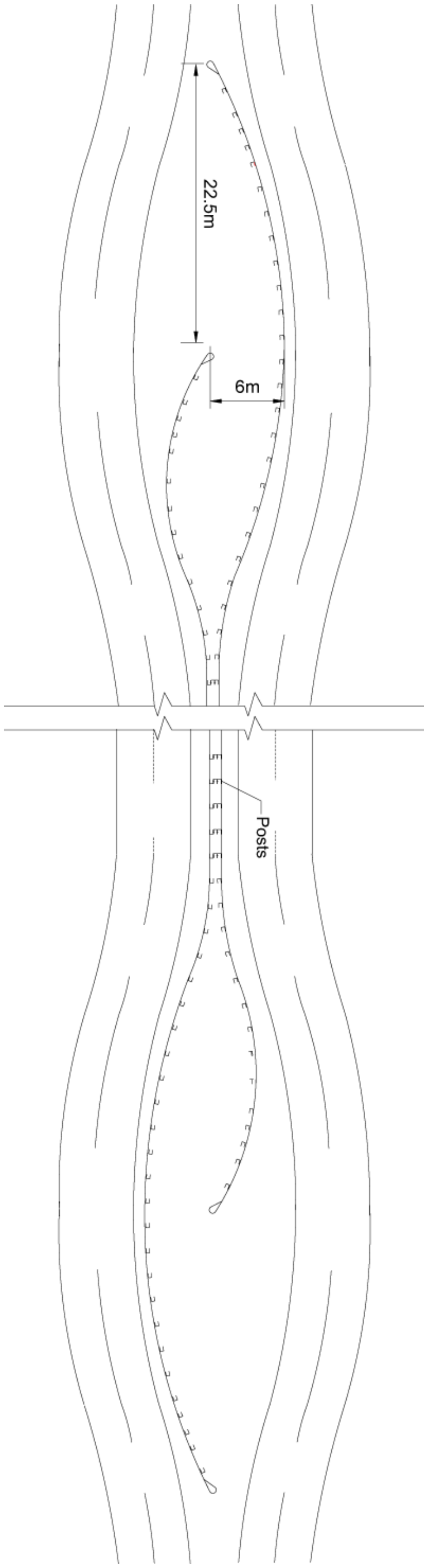

Figure 8.40 Non-proprietary end treatment(s) for back to back guardrail installation (e.g. narrow median treatment)

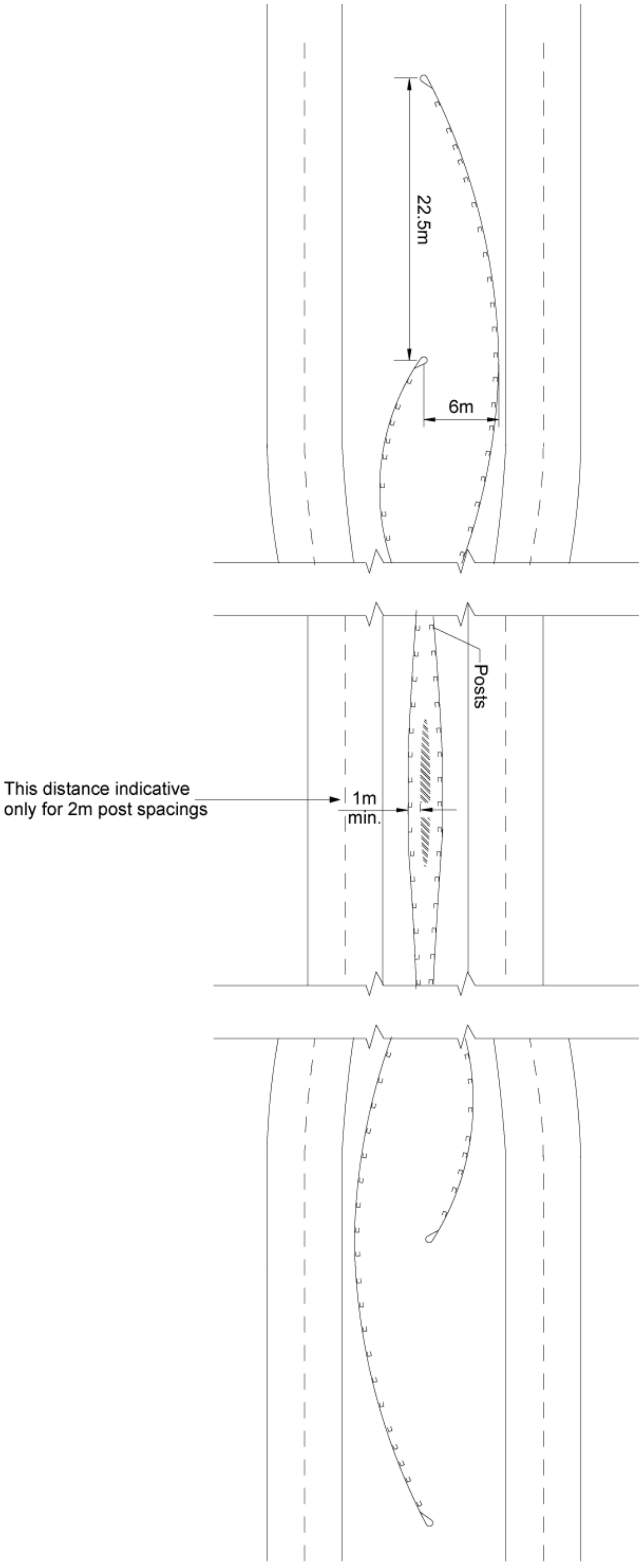

Figure 8.41 Protection around median hazard(s) (eg. gantry, pier) using guardrail.

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Modified Eccentric Loader Terminal (MELT)

This end treatment is used where the Breakaway Cable Terminal (BCT) was used previously and incorporates the latest US operational experience that is particularly relevant to the smaller Australian passenger car.

The design of the BCT had been tested successfully with vehicles with mass 1020kg and 2000kg. Testing with vehicles of 820kg mass, however, has shown that the BCT was too stiff to buckle readily under reduced energy crashes from this class of vehicle. The vehicles of smaller mass did not develop sufficient kinetic energy to activate the pivoting mechanism and testing showed that this class of vehicle was more susceptible to rotational forces than the larger mass vehicles. The BCT is therefore no longer used.

The MELT needs a hazard free area 22.5m beyond the terminal (parallel to the rails) and 6m behind the rails (Figure 8.42).

Its standard length is 8m and the maximum slope in the departure area should not be steeper than 1 on 10.

The MELT should be used with a parabolic flare that has a minimum offset of 1.2m. Any value of offset flare smaller than 1.2m may result in there not being enough kinetic energy in collisions by smaller vehicles, as mentioned above, to ensure that the terminal's pivot mechanism will activate for all collision angles.

Redirection along the travelled way for a side impact begins at the 3rd post from the approach end. It is at this point that the "length of need" chord may cross the MELT (refer to Section 8.2.4).

Concrete Footings for MELT Installations

Main Roads Standard Drawings and MRS11.14 do not currently provide for the use of concrete footings for MELT installations. However, Main Roads Standard Drawing Number 1474 details an alternative concrete footing for slip base posts. If such a footing is used the scheme documents should adequately specify Main Roads requirements (e.g. include a supplementary specification).

For steel beam guardrail installations, MRS11.14 indicates that steel posts should be driven or installed by the excavation and backfilling of a post hole. Slip base posts shall be erected strictly in accordance with the details shown on Main Roads Standard Drawing Numbers 1474 and 1476. Where posts are to be installed into a cement-stabilised pavement layer, in an asphalt pavement or in concrete, refer to MRS11.14.

The six steel posts of the terminal Type 1 MELT have slip bases. It is appropriate for the bottom of the slip base posts to be installed in a concrete footing (i.e. posts one to six as shown on Main Roads Standard Drawing Number 1474). Furthermore, the first two posts of this terminal have soil plates. In the case of the slip base posts being set in a concrete footing, these soil plates can be omitted.

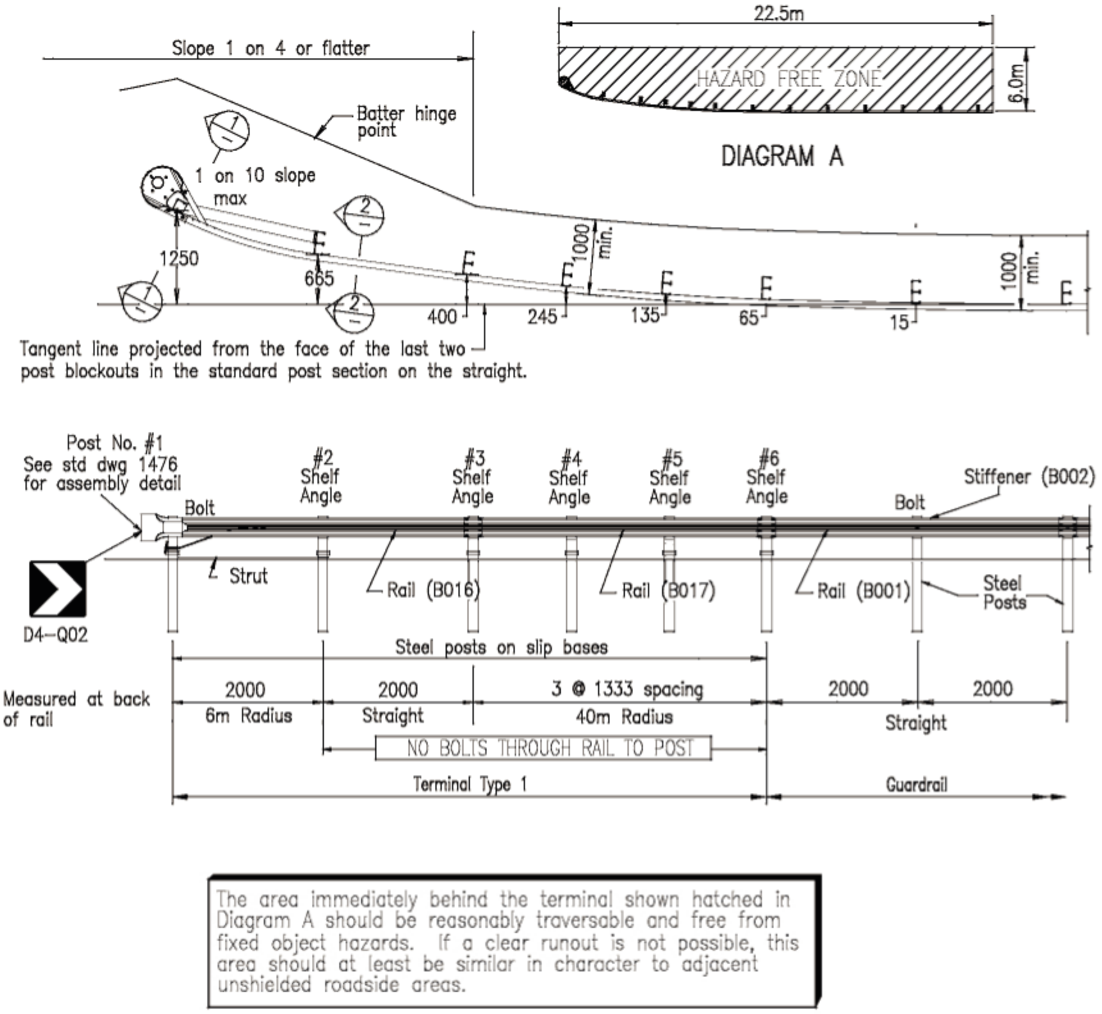

Figure 8.42 General arrangement Modified Eccentric Loader Terminal (MELT)

The concrete footing for each slip base post should have a minimum diameter of 450mm and minimum depth of 1100mm (i.e. the full length of the post), and use N25/20 concrete.

For departure end treatments (for one-way traffic) where posts do not have slip bases, a concrete footing cannot be used. The installation of these shall be in accordance with Main Roads Standard Drawing Number 1474 and the soil plate must be installed.

DEPARTURE END TREATMENT

One way traffic departure end treatments are to be used on safety barriers only when there is no possibility of opposing traffic impacting them. They are not to be used within the clear zone of opposing traffic. The trailing terminal end anchorage assembly shown in Figure 8.43 may be used in these cases. For all other installations, use of a MELT is recommended.

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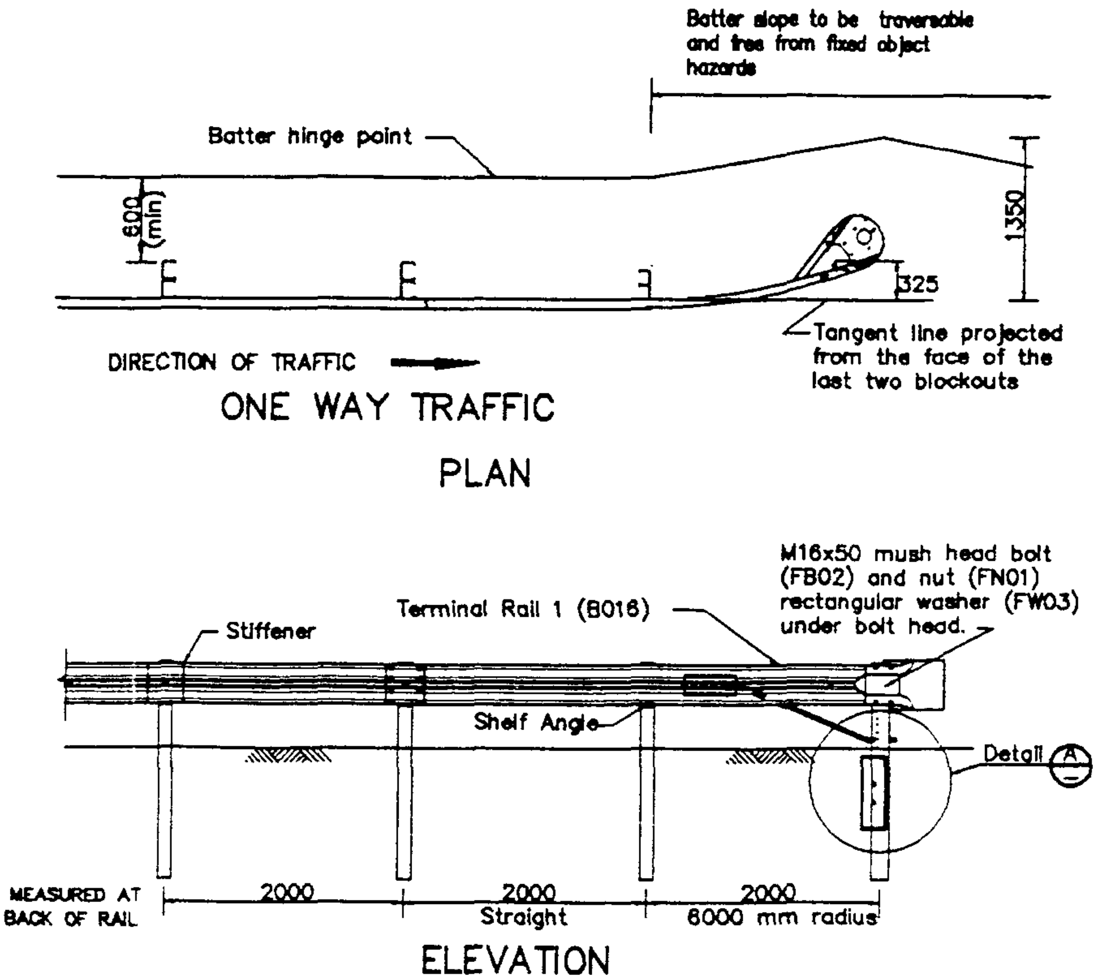


Figure 8.43 Trailing terminal end and anchorage assembly (note one way traffic only)

Sand-filled barrels - Energite and Fitch systems

These systems, whilst different, use similar mechanisms so they will be treated together in this Chapter. An example of the "Energite" system is depicted in Figure 8.44.

These systems use sand filled modules that transmit the energy of the impact to the weights of sand in the barrels, thus dissipating the collision energy based on the principle of conservation of momentum.

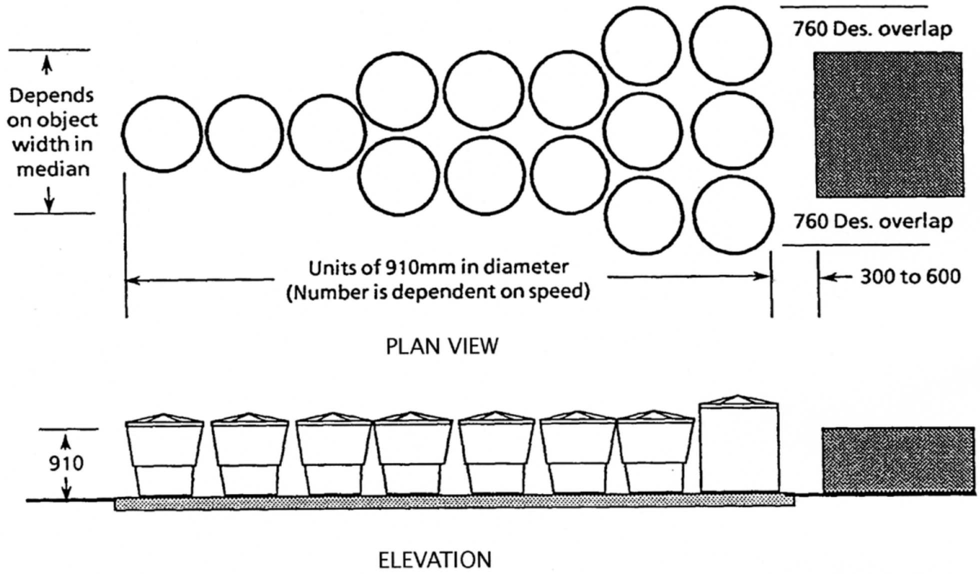
Damaged modules must be replaced after each impact.

The force of impact is not transmitted through the barrels so backup structures or walls are not required for these systems.

These systems can be used as either a crash cushion or a barrier end treatment.

These systems will not redirect some side crashes, particularly those occurring toward the rear of the installation. If pocketing between the rear of the sand barrel array and the structure being protected is a concern, designers should use more barrels in a wider arrangement.

Nearside and Offside Leading Terminal where width of cover required is variable.



Terminal;	**Patented "ENERGITE" Sand filled barrels.**
Application;	This system can be hit end on, or it can be hit from either side. It has been specifically designed to protect objects of all widths, located in medians. It can be used both in nearside and offside applications and has particular application in gore areas. It uses sand filled modules, which are replaced after a collision.
Design;	Design and installation procedures are specified by the manufacturer.
Site Considerations;	The area where the barrels are to be located must be no steeper than 5% and carry a concrete or asphalt foundation pad.
Speed Zone;	Can be used in all speed zones up to 110 km/h (additional length and barrel units required above 100 km/h).

Figure 8.44 End treatment – "Energite" sand filled barrels

These systems protect hazards of any width. They are particularly suited to gore areas.

Designers should note that the water content (typically 3%) in the sand might freeze if cold weather continues for several days, however freezing is typically not applicable for Queensland conditions. In this situation, the system will not work as designed. Mixing rock salt (5% to 25% by volume) with the sand will help ameliorate the possibility of errant vehicles hitting barrels of frozen sand.

The site must be well compacted and be able to accommodate a concrete or asphalt foundation pad.

The transverse slope should not exceed 1 on 20 for "Energite" and be level for "Fitch" systems.

The site grading is important for "Fitch" systems. At least 7m in advance of the installation as well as the site itself must be level and well compacted.

These systems can be used in nearside or offside situations.

They must be designed and installed according to the relevant manufacturer's specifications.

8

QuadTrend 350 system

The QuadTrend 350 System (Figure 8.45) is an end treatment that can be attached directly to concrete barriers, bridge rails and abutments located on the side of the roadway. The system consists of a series of steel panels, support posts with slip bases and sand-filled plastic containers. All posts and major components are above ground for ease of installation and refurbishment. The system meets NCHRP350, Test Level 3 as a re-directive, gating attenuator. Note that this treatment requires a clear zone, in accordance with the manufacturer's specifications, behind the system.

This system can be used where short lengths of end treatment are required (e.g. 8m). The manufacturer should be consulted for actual installation details.

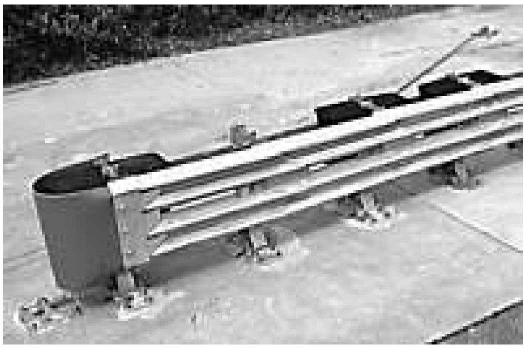


Figure 8.45 QuadTrend 350 system

Sequential Kinking Terminal (SKT), Flared Energy Absorbing Terminal (FLEAT) and ET2000 Plus

These systems will be treated together as their operation differs only in the detail. Figure 8.46, Figure 8.47 and Figure 8.48 show an example of each of the three systems.

The systems use a steel shoe mounted at the end of the last rail of the end treatment. On impact, the shoe is pushed along the rail, causing the rail to deform and curl around, thus dissipating the collision energy. All three systems require a hazard free area 22.5m beyond the terminal (parallel to the rails) and 6m behind the rails. **Each of the systems described require a hazard free zone** (Figure 8.49).

SKT for Test Level 3 (100km/h) is approximately 16m long and the FLEAT for Test Level 3 (100km/h) is 11m long making them a valid alternative to the MELT. The SKT is well suited to situations where the shoulder width is limited and a flared end treatment cannot be accommodated.

Figure 8.46 Example of SKT installation

Figure 8.47 Example of FLEAT installation

Figure 8.48 Example of ET2000 Plus installation

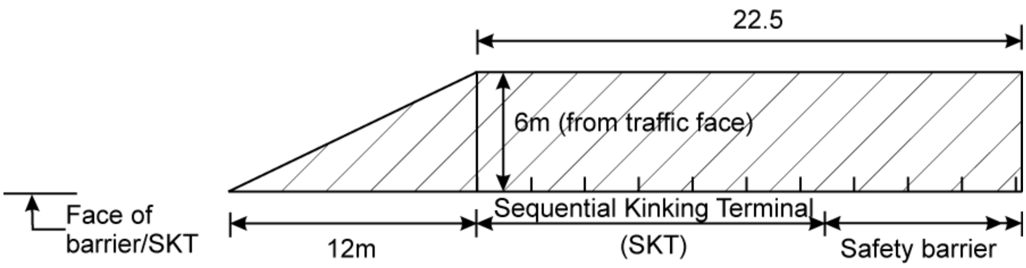


Figure 8.49 Hazard free zone required for SKT, FLEAT and ET2000 systems (SKT shown)

Thrie beam bullnose

The Thrie-beam Bullnose is a non-proprietary system, originally developed by the US Minnesota Department of Transport, adapted for use in Queensland (Figure 8.50 and Figure 8.51).

The Thrie Beam Bullnose can be used in either median or gore area applications with radii of 2.5m and widths greater than 5m, and has been tested to meet NCHRP350 Test Level 3 requirements.

The system consists of a weakened section (of slotted thrie-beam and slip based posts) that essentially captures the errant vehicle, and requires a hazard free zone 19m long. (This hazard free zone should be reasonably traversable and free from non-frangible objects. If it is not possible to provide a clear run out area, this area should be at least be similar in character to adjacent unshielded roadside areas. (Refer to Main Roads Standard Drawing Numbers 1488 and 1489.)

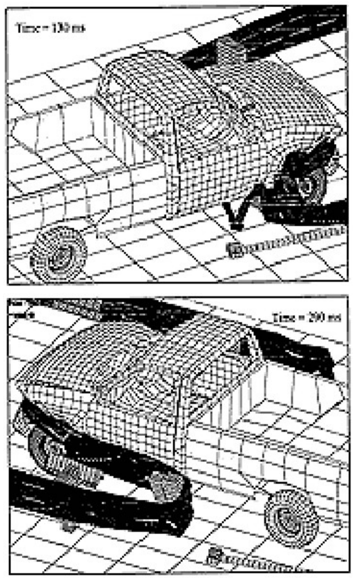


Figure 8.50 Thrie beam bullnose tests

Figure 8.51 Thrie beam bullnose installation

8.2.6.4 Non-gating end treatments - crash cushions

Non-gating end treatments are also known as crash cushions or impact attenuators.

Non-gating terminals do not allow a colliding vehicle to pass behind the terminal. On collision with the end of the terminal, the vehicle will be redirected away from the barrier or be arrested by the barrier.

Because non-gating end treatments do not require a clear, level area behind the barrier, their application is suited to:

- median barrier ends where it is important to prevent colliding vehicles encroaching onto the opposite carriageway; or

- where a run-out area is not available, thus precluding the use of a gating terminal.

Non-gating end terminals are appropriate for:

- attachment to median barriers;
- protecting barrier ends;
- shielding exit ramp gore areas;
- shielding fixed objects located within the clear zone;
- shielding bridge rail ends; and
- shielding piers.

Systems tested satisfactorily and available in Australia include:

- Brakemaster;
- QuadGuard;
- QuadGuard Wide;
- QuadGuard Elite;
- Rubber Crash Cushion;
- React 350;
- TRACC; and
- TAU II.

In addition to protecting barrier ends, crash cushions may also be used to protect vehicles from colliding with isolated fixed objects at locations where these objects cannot be removed or relocated and where the use of a longitudinal barrier cannot be achieved.

The two crash cushion mechanisms that are currently in use are:

- compression crash cushions; and
- inertial barriers.

When hit end-on, AASHTO advises that a compression crash cushion absorbs the kinetic energy of the colliding vehicle using crushable energy-absorbing materials. Some of the energy is also dissipated by the crushing of the front end of the colliding vehicle. A rigid system is required to resist the collision force of the vehicle causing the material deformation and this is usually in the form of a ground anchor or other linkage to a rigid backup (such as part of the barrier), or both.

Inertial barriers (which may or may not be gating) have been designed to transfer the momentum of a colliding moving vehicle to an expendable material, usually sand, located in the vehicle’s path when hit. No rigid backup is required for this type, since the energy of the vehicle is not absorbed but transferred to other masses (AASHTO).

Both the compression crash cushions and inertial barriers are designed to decelerate a colliding vehicle to a safe stop.

Compression crash cushions can also redirect vehicles if hit on the side at shallow angles.

All crash cushion systems available at present are patented products and must be designed and installed in accordance with the relevant manufacturer’s specification.

The following describes the main features of the systems and the most appropriate applications.

Brakemaster system

This system uses w-beam guardrails, a cable-brake assembly and an anchor assembly that dissipates the energy of the impact through a braking mechanism and the nesting of the guardrails (Figure 8.52).

This system can be used as either a crash cushion or a barrier end treatment and redirects vehicles following side crashes. This system can be used for protection of narrow hazards (such as median barriers in wide medians), bridge piers or semi-rigid guardrail, particularly for low-frequency impact occurrences. It can be used in front of a rigid barrier providing a suitable transition section is installed to prevent pocketing. Since the fender panels of this system can flare out to 3m wide during a design impact, **installations in medians narrower than 5m are not recommended**.

The site must be able to accommodate a concrete anchorage system installed at the nose of the device. The transverse slope should not exceed 8%. The system can be used in nearside or offside situations. **It must be designed and installed according to manufacturers specifications.**

Up to 40% of the system elements may be recoverable and re-useable after a design impact and this system is characterised by its short repair times after impact.

Field experience has shown that nuisance crashes do not affect this system's ability to perform satisfactorily in subsequent design crashes.

QuadGuard cushion

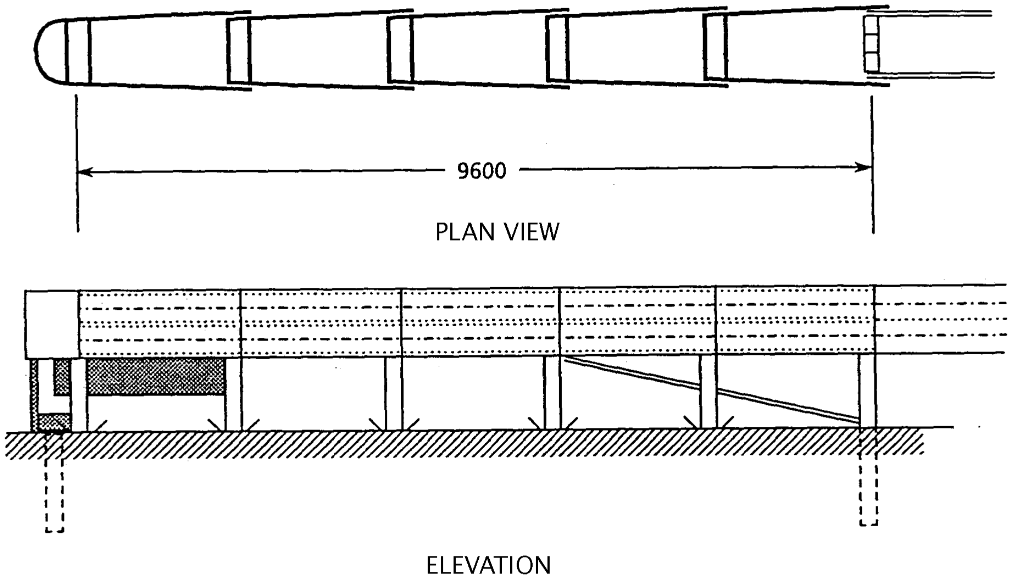
This system uses crushable cartridges that dissipate the energy of the impact (Figure 8.53). These cartridges contain a stiff hexagonal matrix filled with polyurethane foam and are held in place within a guidance frame, the whole being contained within steel rails. Any cartridges damaged during impact must be replaced after each impact.

This system can be used as either a crash cushion or a barrier end treatment and will redirect vehicles following side crashes for impact angles of up to 20°. This system was designed specifically for protection of narrow hazards up to 1000mm wide, such as type "F" rigid barrier. It can also be used for narrow hazards (such as median barriers in wide medians), bridge piers or semi-rigid guardrail, particularly for low-frequency impact occurrences. It is particularly suited to gore areas. A chart is available from the manufacturer for use in selecting the appropriate type of QuadGuard cushion for use in a particular installation. It should be noted that the length of the cushion is proportional to the speed environment.

The site must be able to accommodate a concrete anchorage system used to pin the frame to the road surface. The transverse slope should not exceed 8%. The system can be used in nearside or offside situations. It must be designed and installed according to manufacturers specifications.

Following design crashes, 75 to 80% of the system may be re-used. Field experience has shown that nuisance crashes do not affect this system's ability to perform satisfactorily in subsequent design crashes.

Nearside and Offside Terminals to flexible and semi-rigid systems



Terminal ; **Patented "BRAKEMASTER" System**

Application; This system protects narrow hazards in low frequency impact areas such as bridge piers, double sided guardfence and narrow hazards in a wide median . It can be used in both nearside and offside applications. It can be attached to a rigid barrier using a suitable transition.

Design; Design and installation procedures are specified by the manufacturer.

Site Considerations; The transverse slope at the site should not exceed 8%. A concrete anchorage at the front is required, so the site must be able to accommodate such a feature.

Speed Zone; Can be used in all speed zones up to 100 km/h.

Figure 8.52 End treatment - "Brakemaster system"

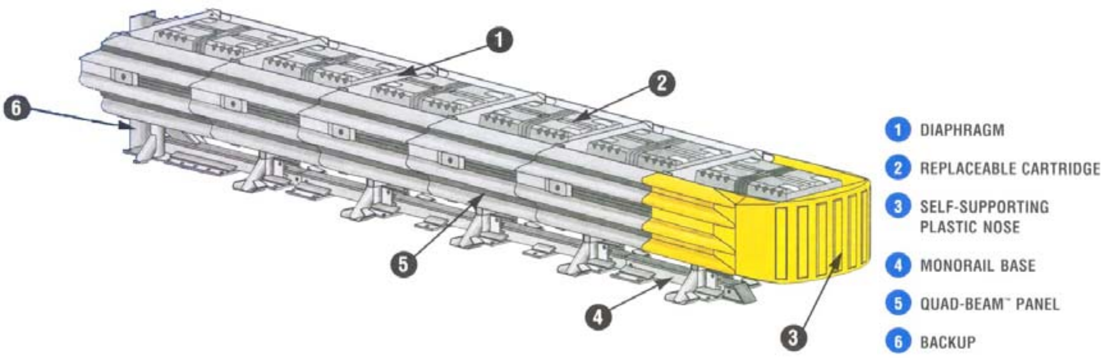


Figure 8.53 End treatment - "QuadGuard Cushion" system

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QuadGuard Wide

This system uses the same principles and construction as QuadGuard Cushion but can be used to shield wide hazards up to 2.25m wide (Figure 8.54).

QuadGuard Elite

This system uses the same principles as QuadGuard Cushion but uses high density polyethylene elements which absorb the energy of the crash without permanent deformation (Figure 8.55). After a crash, the manufacturer's documentation states that more than 99% of the system can be re-used, resulting in a cost saving compared with the cost associated with replacing the cartridges and/or frangible elements used in other systems. This cost saving must be balanced against a higher initial cost than, say standard Quadguard. It may be configured for hazards with widths of between 610mm and 2250mm.

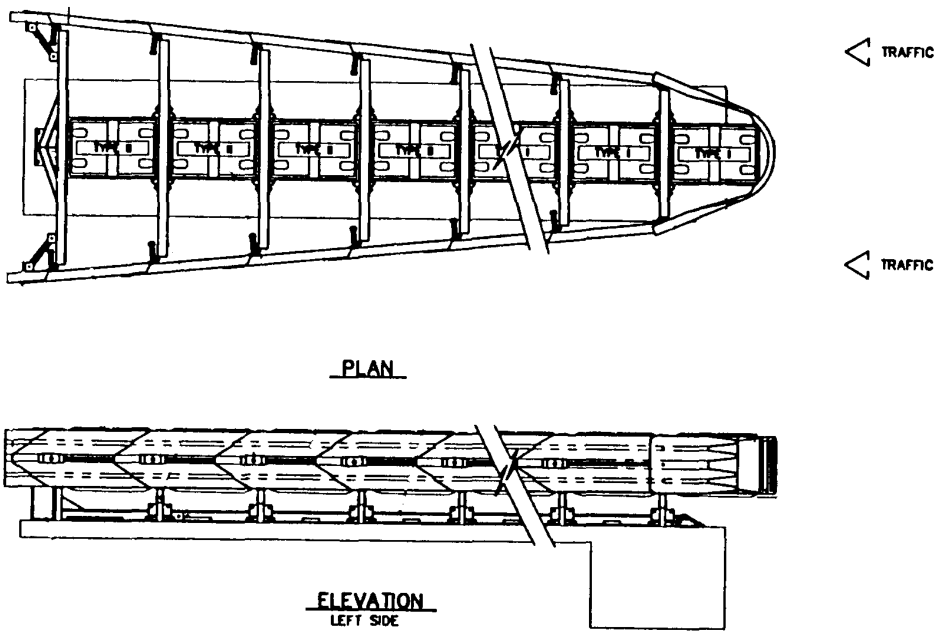


Figure 8.54 End treatment - "Quad Guard Wide"

Figure 8.55 End treatment – "QuadGuard Elite" system

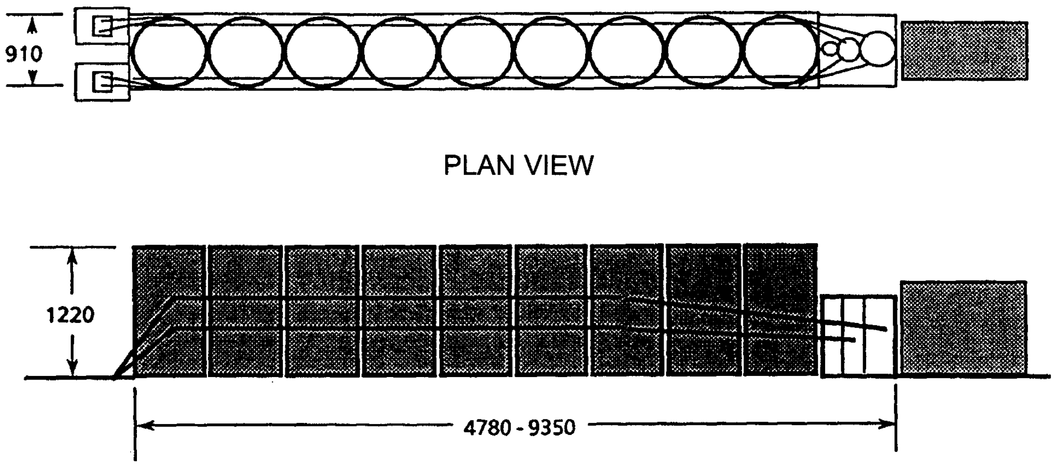
React 350

This system uses from four to a maximum of nine (depending on design speed) crushable high density polyethylene cylinders as cells which dissipate the energy of the impact (Figure 8.56). The cells are usually not damaged beyond re-use after each crash, regaining their shape with some simple activities carried out by repair crews (e.g. towing the installed arrangement back into shape). If cells are damaged after impact, they must be replaced but this would be in only the most severe collisions.

This system can be used as either a crash cushion or a barrier end treatment and will redirect vehicles following side crashes for impact angles up to 20^0. This system was designed specifically for protection of narrow hazards, such as rigid barrier. It can also be used for protection of narrow objects such as bridge piers or semi-rigid guardrail and is particularly suited to installation in median areas. The site must be able to accommodate a concrete anchorage system used as an anchor for the steel rails and steel guide cables. The transverse slope should not exceed 8%.

The system can be used in nearside or offside situations. It must be designed and installed according to manufacturers specifications.

Nearside and Offside Leading Terminal where width of cover required is less than 1000.



ELEVATION

Terminal ;	**Patented "REACT 350"**
Application;	REACT 350 consists of 4 to 9, reusable high density polyethylene cyclinders of various wall thicknesses. This system can be hit end on. It can also be hit from either side, redirecting an errant vehicle during impacts of up to 20°. It has been specifically designed to protect narrow objects (such as a rigid "Type F" barrier) and can be used both in nearside and offside applications. Has particular application in median areas.
Design;	Design and installation procedures are specified by the manufacturer.
	This system has successfully passed NCHRP Test Level 3.
Site Considerations;	Concrete anchorage of galvanised steel rails and guide cables is required, so the site must be able to accommodate such a feature.
Speed Zone;	Can be used in speed zones up to 100 km/h.

Figure 8.56 End treatment - "React 350"

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TRACC

This system uses sacrificial steel ripping plates within a telescoping steel frame to dissipate crash energy (Figure 8.57). It is approximately 800mm wide. This system can be used for shielding narrow hazards, such as rigid barrier ends.

This end treatment may be installed on either an existing or a new concrete or asphalt pad. It is useful where a short crash cushion is required as it is approximately 6.5m long.

TAU II

This system uses energy absorbing cartridges within a telescoping steel frame (Figure 8.58). It is approximately 800mm wide and is a re-directive, non-gating end treatment. This system can be used for shielding narrow hazards, such as rigid barrier, poles, and lane separation devices at toll plazas. The TAU II Universal can also be configured for hazards up to 2.6m

The site must be able to accommodate a concrete anchorage system for the steel mounting frame. The system can be used in nearside or offside situations. It must be designed and installed according to manufacturer's specifications.

Figure 8.57 End treatment - "TRACC"

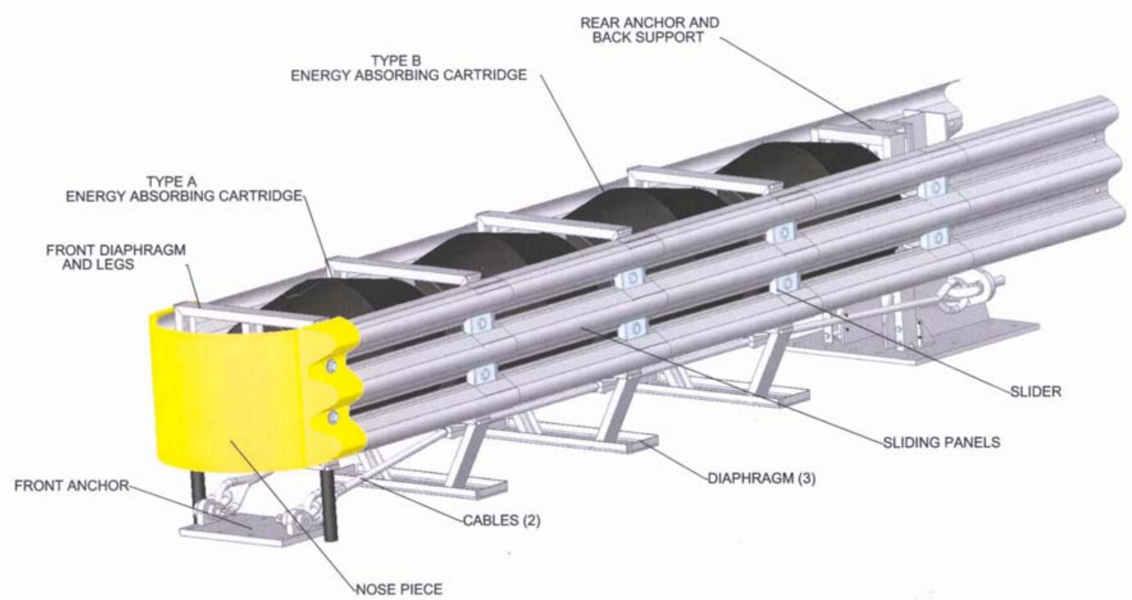

Figure 8.58 End Treatment - "TAU II"

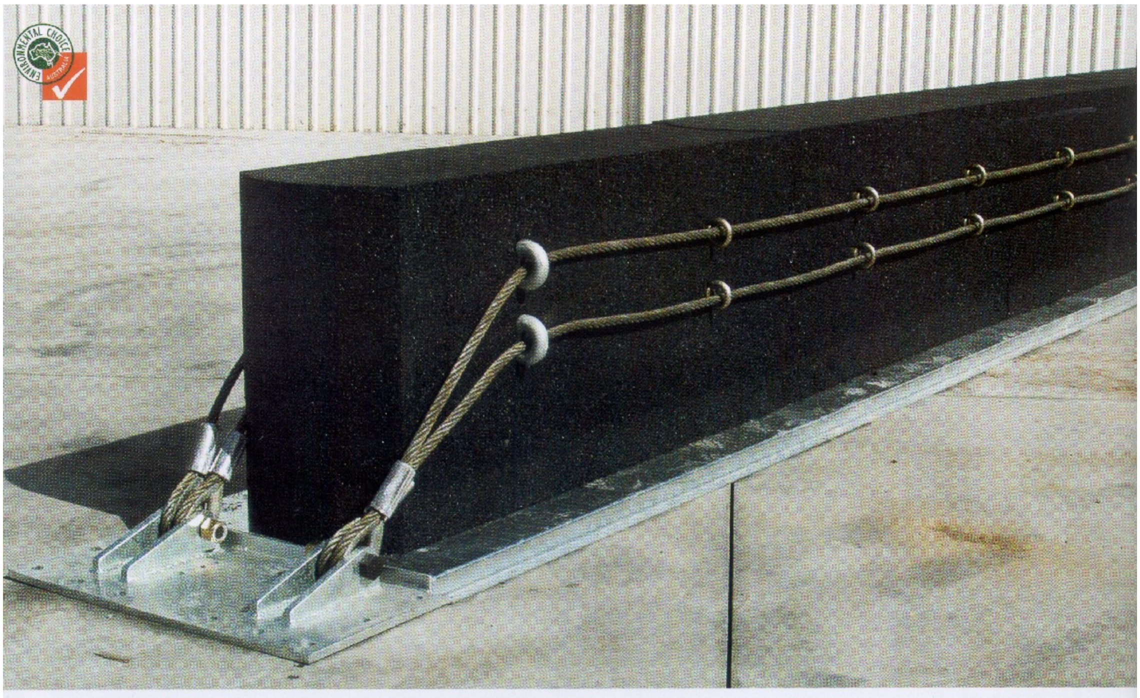

Figure 8.59 End treatment - "Rubber Crash Cushion"

Rubber crash cushion

This system consists of recycled car tyres, specially moulded into linked modular units (Figure 8.59).

It has been tested to NCHRP350 Test Level 2 as a re-directive crash cushion, and is suitable for connection to rigid barriers.

The system does not require spare parts following design impacts and does not need ongoing maintenance.

Applications include connection to concrete barriers, toll plazas and other narrow rigid ends. The site must be able to accommodate a concrete anchorage for the steel mounting frame.

It must be designed and installed according to manufacturers specifications.

8.2.6.5 Guidelines for selection of end treatments

Design speed

The end treatments and crash cushions covered have been tested for different speeds. The selected barrier end should be suitable for speed limits as shown in Table 8.15 (where a proprietary system is shown, the manufacturer has supplied that data).

Space available

The space available for the end treatment will also influence the type to be installed. For instance, in narrow medians, a QuadGuard crash cushion is more appropriate than a QuadGuard Wide system and the use of the MELT end treatment requires a large run-out area and space to flare the end.

Consideration may be given to selecting a physically smaller system on the basis that a smaller size will reduce the number of

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crashes, especially nuisance crashes, thereby reducing the maintenance that must be completed following an incident.

Table 8.15 Speed limits for end treatments

End Treatment	Speed Limit (km/h)
MELT	100
Brakemaster	100
QuadGuard	110
QuadGuard Wide	110
QuadGuard Elite	110
QuadGuard High Speed (HS)	110 (standard)
React 350	100
Sand Filled Barrels	110
TRACC	100
TAU II	100
Rubber Crash Cushion	80
QuadTrend	100
Sequential Kinking Terminal	100
Flared Energy Absorbing Terminal	100
Thrie-beam Bullnose	100
Note: Crash cushions may be made acceptable by increasing the length and frangible elements. Manufacturers of proprietary systems should be consulted for further details if the speed environment in the area of the installation is greater than that shown above.	

For a complete list of AS3845 compliant products and manufacturers details, contact the TERS Section of Main Roads' TRUM Division.

Susceptibility to nuisance crashes

Like any part of a barrier, end treatments and crash cushions are susceptible to nuisance crashes.

The chosen system should be capable of performing satisfactorily following a number of these minor crashes, without requiring repair.

Therefore, it is reasonable to suggest that a non-gating system would perform better than a gating system under these conditions.

Compatibility with barrier type

Table 8.16 details the barrier types with which some of the available end treatments are compatible. The manufacturer/s should be consulted for situations not included in Table 8.16.

In some instances a transition section will be required to ensure adequate stiffness is provided at the connection of the end treatment and the barrier. This stiffness is required to minimise vehicle snagging and pocketing of the barrier, and to limit the change in deflection occurring between the barrier and the end treatment.

8.2.7 Bridge barriers and transitions

8.2.7.1 General

This section addresses the different requirements for bridge barriers and roadside safety barriers, and provides information on appropriate transitions between the different barrier types.

8.2.7.2 Bridge barriers

A bridge railing is a longitudinal barrier intended to prevent a vehicle from running off the edge of a bridge or culvert.

Most bridge barriers differ from roadside safety barriers, in that the bridge barrier is an integral part of the structure (physically connected) and are usually designed to have virtually no deflection when struck by an errant vehicle.

For design of bridge barriers on all new bridges, Australian Standard AS5100 is to be used.

High level Bridge Barriers are regarded as rigid systems and as such require appropriate transition to Semi-rigid systems such as via a Thrie-beam barrier.

Pre-existing bridge barriers which are not designed to meet AS5100, require specialist advice on the ability to either;

1. Upgrade with longitudinal barrier (continuous Thrie-beam / W-beam); or
2. Implement standard Transitions to roadside barriers (Refer to Section 8.2.7.4).

Any upgrading or retrofitting of existing bridge railing requires specialist advice with regard to the following issues:

1. Strength of the railing required;
2. Longitudinal continuity of the system;
3. Effects of kerbs or walkways; and
4. Snagging potential.

A decision to remove, replace, upgrade or retrofit exiting bridge barrier should be based on a risk based analysis approach, using appropriate benefit /cost calculations such as the RISC program.

8.2.7.3 Transitions

Transition sections are used to join two different barrier types.

A barrier transition section will be required when joining a semi-rigid barrier to a rigid bridge railing, or to interface between flexible and semi-rigid barriers.

The purpose of a transition section is to produce a gradual stiffening of the overall approach section so vehicular pocketing, snagging or penetration can be reduced or avoided at any position along the transition (AASHTO).

Table 8.16 End treatment and barrier compatibility

End Treatment	Barrier Applications	Transition Required
MELT	W-beam	No
	Thrie-beam	Yes
SKT	W-beam	No
	Thrie-beam	Yes
FLEAT	W-beam	No
	Thrie-beam	Yes
Thrie – Bullnose	Gore Area Median	Yes
Brakemaster	Concrete Safety Barrier	Yes
	W-beam	No
	Thrie-beam	Yes
Quad Guard, Quad Guard Wide, Quad Guard Elite, Quad Guard High Speed and React 350	Concrete Safety Barrier	No
	W-beam	No
	Thrie-beam	No
Sand Filled Barrels	Concrete Safety Barrier	No
	W-beam	No
	Thrie-beam	No
Quad Trend	Concrete Safety Barrier	Yes
TAU II and TRACC	Concrete Safety Barrier	Yes
	W-beam	Yes
	Thrie-beam	Yes
Rubber Crash Cushion	Concrete Safety Barrier	No

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8.2.7.4 Design criteria

The following criteria are important (AASHTO) when designing a transition section:

- The connection point of the two systems must be as strong as the approach barrier to ensure the connection will not fail on impact by pulling out. (The use of a cast in place anchor or through-bolt connection is recommended).
- It must be designed to minimise the likelihood of snagging an errant vehicle, especially one from the opposing lane on a two-way facility.
- When providing a transition section to a bridge railing end, it is highly desirable to taper the bridge railing end behind the approach transition.
- The length of the transition should be long enough to minimise any significant changes in deflection.
- The transition length should be 10 to 12 times the difference in the lateral deflection of the two systems in question.
- The change in stiffness from the less rigid barrier to the more rigid barrier, over the transition length, should increase with a high degree of continuity. This may be achieved by reducing the post spacing, increasing the post size, strengthening the rail element or a combination of two or all of these techniques.
- Kerb and slope features should be treated as discussed in Section 8.2.2.2.

8.2.7.5 Bridge railing end transition sections at intersections

The protection of a bridge end in proximity to an intersection requires specific attention.

To protect vehicles on the side road as they approach the bridge (AASHTO):

- close the intersecting road;
- relocate the intersecting road; or
- install an approach barrier with a transition section.

If an approach barrier is to be installed, the designer must ensure approaching errant vehicles will not travel behind, through or over the barrier.

Figure 8.31 shows recommended layouts for specific barrier details for curved roadways and intersections near bridge ends where there is a horizontal curve with a radius of 2.5m to 10m. These designs are specific to the intersection of major arterial/sub-arterial roads with minor approach roads.

Figure 8.32 shows recommended layouts for specific barrier details for curved roadways and intersections near bridge ends where there is a horizontal curve with a radius of 10m or greater. These designs are specific to the intersection of major arterial/sub-arterial roads with minor approach roads.

The following criteria (RTA and FHWA) are to be adopted for bridge railing transition sections at intersections:

- Breakaway posts (without block outs) are used within the curved section. No washers are provided under the post-to-rail bolt (to minimise the rotation of the rail during impact). On the 2.5m layout there is no post to rail bolt in the centre of the nose.

- The impact height is critical, so vehicle trajectory checks must be carried out. This slope in front of the installation should be as flat as possible (maximum 1 on 10).
- The hinge point of the embankment batter is to be at least 600mm behind the back of the posts and the batter slope not to be steeper than 1 on 15.
- Because of the large deflections involved, the area shown cross hatched is to be kept clear of hazards (Figure 8.31 and Figure 8.32).
- When used in proximity to a bridge, sufficient space (i.e. minimum length of 8m) is to be provided to allow installation of a crash tested transition from the w-beam to the rigid bridge barrier.
- Design should only use full lengths of rail. Some modifications to the radius to achieve the requirement are permissible (particularly when the intersection angle is not at right angles).

8.2.7.6 Transition section designs

Two transition section designs are provided here for information and guidance:

1. Blocked out w-beam/thrie-beam, to bridge end using thrie-beam and reducing post spacing is shown in Standard Drawing 1475. The use of a thrie-beam joining a bridge railing end is better matched geometrically to a bridge railing end than a w-beam (AASHTO). The thrie-beam is also stronger than the w-beam. This added strength should decrease the maintenance activities following minor crashes. The treatment in Main Roads Standard Drawing Number 1475 reduces the approach barrier spacing within approximately 6m of the bridge railing end. Post spacing is such that two spaces at 0.5m centres are provided closest to the bridge rail end, with the previous five spaces being at 1m centres.
2. Wire rope safety barrier interface with w-beam.

<u>Overlap between wire rope barriers and w-beam</u>

Indicative deflection of barrier systems are (AS3845 and manufacturer's documentation):

- W-beam -0.9m.
- BRIFEN - 1.7m.
- Ingal - 1.4m.
- CASS - 1.2m to 3.0m (depending on post spacing).
- AMORWIRE - 1.9m to 3.6m (depending on post spacing).

Using the AASHTO determination that the transition length should be 10 to 12 times the difference in the lateral deflection of the two systems, overlap lengths become:

- 8.8m for a w-beam to BRIFEN transition; and
- 5.5m for a w-beam to Ingal transition.

Main Roads Standard Drawing Numbers 1495 and 1497 show typical details for overlap between wire rope barriers and w-beam guardrail.

The overlap length must be measured in the redirection zone of the barrier (i.e. for wire rope barriers, the leading and trailing "points of need" are the second and second-last posts where all wires are full height; for w-beam barrier, it is the 3rd post of the MELT).

Figure 8.36 and Figure 8.37 illustrate the arrangements for wire rope overlaps.

Overlaps between wire rope and rigid concrete barriers are also possible. The relevant wire rope barrier manufacturer must be consulted for the exact details as this is a proprietary product and is warranted for correct operation by the manufacturers only. (Reference should also be made to Main Roads Standard Drawing Number 1497.)

8.2.8 Testing

Roadside safety barriers are required to comply with AS3845, which calls up the American NCHRP350 document regarding testing requirements.

The majority of barriers in use today have been subjected to full-scale crash tests to determine the structural adequacy of the barrier itself, the risk to a vehicle's occupants when the barrier is hit and the vehicle's trajectory characteristics following a collision. These performance goals form the basis of the American NCHRP230 and NCHRP350 "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances". The NCHRP350 document is the latest release of the evaluation procedures.

The majority of the barriers in use today, and so considered operational, were developed and tested with the intention of containing and redirecting passenger vehicles with masses of up to 2000kg. The summary tables documenting the various barrier types have included crash test results indicating the performance limit of the barrier with respect to vehicle size.

The modified thrie-beam system has been successfully crash tested for a 14,500kg bus (i.e. Test Level 4).

The RTA states that a 1067mm high concrete safety barrier has been successfully tested using a 36,000kg truck colliding at an angle of 15° and a speed of 86km/h (i.e. Test Level 5).

Main Roads' standard for w-beam barrier height has been revised from 700mm to 750mm to the top of the beam. The 700mm height was derived from full-scale testing where ramping occurred at +600mm heights. Testing has shown that, at installation heights below 700mm, w-beam will have inadequate torsional stiffness and the vehicle may ramp over it.

Full-scale collision tests in 1967 on various blocked out w-beam barrier systems confirmed that 685mm was the optimum height for this type of barrier, without a rubbing rail. At a height of 760mm, a rubbing rail was required even though the vehicle did not under-ride or override the barrier. However, the report states that the 760mm beam "provides added insurance against vehicle rollover or penetration, particularly where uneven or sloping terrain could cause a vehicle to vault immediately in advance of the impact". Heights less than 685mm resulted in vehicles vaulting or rolling following the impact.

Further testing (Ray, Engstrand, et al., 1984) reviewed height standards for light post traffic beams and suggested that a minimum rail height of 750mm for w-beam barriers provides satisfactory protection against under ride and vaulting. The analysis was completed using a more modern vehicle fleet, including vans and light trucks, compared with the 1967 report. This result has been adopted for the current Main Roads Standard Drawings for w-beam barrier. The maximum and minimum height tolerances for this barrier type were determined to be 838mm and 686mm, respectively, for roadside and median installations.

Furthermore, the RTA specifies that "the height of the system is not to vary by more than ± 50mm with respect to the colliding vehicle". Therefore, it would be reasonable to assess the trajectory profiles of a colliding vehicle along the exit path to ensure the barrier is installed at the correct height.

For gating end treatments, the requirement for the terminal to use a hazard free, rectangular-shaped run-out area extending a minimum of 22.5m beyond the terminal (parallel to the rail) and 6m behind the rail, is "based on results of 97km/h impact test, FHWA (United States Department of Transportation Federal HighWay Administration)". The FHWA also notes that the run-out area of this size may not necessarily accommodate all crashes that might occur.

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8.3 Roadside barrier systems - selection and location of temporary systems

8.3.1 Introduction

The issue of worker safety is a topic that Main Roads takes very seriously. The environment in which our road workers find themselves is becoming more hazardous because of increasing traffic volumes, the presence of larger vehicles and speeding traffic. It is necessary to protect the workplace as far as is practicable. Separating the traffic from the workplace is one way of doing this.

This separation can be achieved by the consistent and appropriate usage of crash barriers on work sites. Appropriate standards, education and training of the people that are responsible for the erection and maintenance of the barriers is necessary to ensure proper usage of barriers on work sites.

The guidelines set out in Section 8.3 cover:

- types of safety barriers currently available; and
- how and when they should be used to enhance safety and productivity of workers and traffic at trafficked worksites.

Section 8.4 discusses the design requirements for temporary roads and the need for appropriate geometric design to control speeds through work sites.

8.3.2 General requirements

AS3845 “Road Safety Barrier Systems” defines temporary crash barriers to be those which:

- are designed to provide worker protection;
- will prevent penetration into the work or maintenance area by an errant vehicle; and
- have vehicle re-directive properties.

To provide for the safety of both workers and road users at roadwork sites, the planning and management of worksite traffic must be carried out in accordance with Part 3 of the (Manual of Uniform Traffic Control Devices (MUTCD) and Chapter 4 of this Manual.

In addition to these requirements, safety barriers can also be used to:

- enhance site safety and job productivity; and
- to reduce road user delays where it is considered that traffic volumes, traffic speeds, the nature of the work, worksite/traffic separation and duration of the works, indicate that it is both desirable and practicable to provide such additional protection.

8.3.3 Purpose of safety barriers at roadwork sites

Safety barriers are used to contain and redirect errant vehicles to prevent them from leaving the roadway and or entering the worksite. They should only be used if they reduce the severity and adverse consequences of potential accidents, since they are a hazard in themselves.

Their use may be for the following reasons:

- to provide positive protection for workers from errant vehicles entering the worksite;

- to protect critical construction works such as bridge falsework from vehicle impact;
- to protect traffic from entering work areas where hazards such as trenches and material stockpiles could endanger road users;
- to separate opposing traffic where temporary traffic diversions have the potential to cause vehicle conflict; and/or
- to minimise road user delays by negating the need for worksite speed limits.

In determining whether safety barriers should be used, the following factors should be taken into account:

- Can the speed of vehicles be maintained at such a value through the work site that in combination with worker/roadside hazard clearance and the quality of the traffic arrangements (traffic control, road surface/alignment), the risk of injury to either workers or road users is consistent with good practice and the requirements of the Workplace, Health and Safety Act?
- Bearing in mind the duration of the particular works and the space available to locate safety barriers, is it practical to install safety barriers?
- Is the consequential effect of a vehicle striking construction features (e.g. bridge falsework) such that positive protection must be provided?
- In view of the nature and duration of the particular work, the speed of vehicles through the site and the clearance between such traffic and workers/roadside hazards, would the use of safety barriers improve the safety of both workers and road users and should they therefore be provided?

8.3.4 Operational requirements for the use of barriers at roadwork sites

It is recommended that barrier systems not be installed in proximity to kerbing or on batters with slopes steeper than 1 on 10.

When barriers are used at roadwork sites the following issues are to be addressed.

8.3.4.1 Connection of individual barrier units (precast concrete, portable steel barrier and water filled plastic systems)

For all barrier units to act as a safety barrier they must be properly connected to adjacent units for the whole installation to provide barrier continuity. This resists displacement, and ensures that differential movement at the joints between units does not occur. Such movement could cause snagging and/or pocketing of impacting vehicles.

The method of connection will vary for the particular type of safety barrier but would generally consist of steel pins, concrete keys or a combination of steel pins and cables.

Barriers of different profiles and materials are not to be used in the same installation as 'pocketing' could occur due to the differences in stiffness and/or shape.

Installations of unconnected units do not form a safety barrier in any way. If impacted, individual units will either topple over or slide creating considerable risk to nearby workers, and become a major hazard to the impacting vehicle and following road users.

Proprietary end treatments for Portable Concrete Barriers (PCBs), and Portable Steel Barriers are available, but these require site specific consideration in consultation with Main Roads Traffic and Road Use Management (TRUM) division to ensure the appropriate (tested) system is applied.

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8.3.4.2 Safety barrier foundation

Temporary concrete and plastic safety barriers will generally be free standing (i.e. not anchored). Portable Steel Barriers are generally anchored at each end. Sufficient clearance must therefore be provided between the back of the barrier and the work area to allow for sliding of the barrier. This sliding can be minimised for concrete barriers where clearances are minimal, by placing fill behind the barrier or by suitably anchoring the barriers.

Barriers need to be founded on a base that enables proper alignment and is capable of supporting the barrier and other loads created. This requirement is even more critical when barriers are adjacent to trenches, foundation excavations, etc.

8.3.4.3 Minimum length

The length of temporary barrier required is to be determined from the length of need for the particular site plus the additional lengths necessary to provide for end treatments.

The minimum length, however, of all types of unanchored safety barrier (excluding terminals) is to be 30m.

8.3.4.4 Barrier lateral location

Offset between barrier and work area/hazard

The following sections provide details of the desirable clearances between temporary safety barriers and the work area/hazard to allow for barrier deflection when hit.

Concrete barrier

For properly designed barriers that have all adjacent units connected and the end unit suitably anchored, a minimum clearance of 1m should be provided. This particularly applies to “Tric Bloc” and other types of PCBs.

Portable steel barrier (Anchored)

For properly designed systems that have all adjacent units connected and anchored at the ends, a minimum design deflection of 1.5m should be allowed. (Deflections will be less depending on speed, weight and angle of impact of an errant vehicle, Refer to Table 8.17 for details.)

Table 8.17 performance of portable steel barriers - anchored

Design Speed (km/h)	Test Level	Vehicle mass (kg)	Deflection* (m)
100	4	8000	1.5
100	3	2000	1.5
80	-	-	0.960
70	2	2000	0.735
60	-	-	0.540
50	1	2000	0.375
40	-	-	0.240
* Note: Deflections for an impact angle of 25 degrees.			

Water filled plastic barrier

The clearances required for these barriers, when they have been filled as specified and properly connected, depends on the length of barrier installed and the speed, weight and angle of impact of the errant vehicle. Table 8.18 provides some general guidance on the deflections and movements to be expected with these installations.

Table 8.18 Performance of water filled plastic barrier

Length of barrier (m)	Angle of Impact (°)	Point of Impact	Deflection* (m)
100	10	Mid Point	0.8
100	20	Mid Point	2.6
30	10	Mid Point	0.9
30	20	Mid Point	3.1
All	25	8m from Depart. End	8
All	15	8m from Depart. End	2.7
* Note: Deflections for an impact speed of 70km/h.			

The shallower impact angles may be more applicable to a construction site as traffic may be more constrained through the use of various signing devices. However, each site should be assessed and barrier requirements evaluated in accordance with the manufacturer's design criteria.

Offset between barrier and traffic

Safety barriers placed parallel to the pavement should not be located more than 5m from the edge of the travelled lane to reduce the potential angle of impact. However the minimum clearance should not be less than 500mm.

For driver comfort, and to maintain traffic flow conditions, when temporary barriers are installed on both sides of traffic, it is desirable that the beginnings of the barriers be staggered a minimum of 30m.

8.3.4.5 Delineation

To provide acceptable night time visibility retro-reflective devices should be mounted along the safety barrier, generally perpendicular to the direction of traffic, to provide delineation.

It is recommended that barriers have delineation installed. This will aid in guiding road users through the work site and also alerts road users of the presence of a barrier. The latter is quite important, as barriers at road works sites frequently become covered in mud and dirt splattered from site activities.

Retro-reflective delineators such as Class 1 adhesive tape are easy to apply and, whilst their performance is diminished by dirt, they will generally reflect sufficient light from headlights to allow road users to see the shape of the path ahead. Regular cleaning before nightfall also enhances night-time safety in general and in particular if work is being carried out at night.

Some brands of plastic temporary crash barrier have integral fittings for retro-reflectivity, such as Class 1A or Corner Cube reflectors (as per AS1906). Requirements of the MUTCD are that delineators should comprise red delineators on the left and white delineators on the right.

In urban areas, acceptable visibility may be achieved through the public lighting system, which will require that the barrier is a light colour.

In order to also achieve suitable daytime visual effect, safety barriers should be arranged with contrasting colours between successive units.

In addition, a solid edge line may be placed along the pavement adjacent to the barrier to improve delineation.

8.3.4.6 Drainage

Drainage of the uphill side of barriers needs to be provided to avoid ponding against and/or concentrating flows at the ends of the barrier, both of which can create a hazard to road users (e.g. aquaplaning).

8.3.4.7 Operational monitoring

Monitoring the performance of barriers in the field is the best way to determine the performance of a barrier in particular situations. These observations will identify any problems that may occur with the system, ensuring optimal performance for future installations.

The Australian Standard on crash barriers (AS3845) requires that post-crash evaluations be carried out. After crashes into barrier systems, the following considerations, as a minimum, should be addressed:

- Did the system function as designed?
- Should the system be restored to the condition it was pre-crash?
- If not, which upgrade measures should be carried out to improve the safety of the hazard?

AS3845 suggests that part of an action plan for maintenance of safety barrier systems should include the above assessment criteria.

8.3.5 Types of temporary safety barriers

Work site safety barriers can be permanent type installations, or temporary ones to enable more speedy relocation. However whichever type is used, they must comply with the appropriate requirements of NCHRP350 (or equivalent) unless specified otherwise. Sections 8.3.5.1 and 8.3.5.2 outline some of the barrier systems available, but it is not exhaustive. Other barrier systems are available or are under development.

Safety barriers that may be applicable to roadwork sites are:

- Conventional blocked out steel w-beam barrier with either timber or steel posts;
- Precast concrete barrier including “Tric Bloc” units;
- PCBs;
- Portable Steel Barriers;
- Water filled plastic barriers; and
- Sand Filled Barrels.

Note: Most known plastic barriers at this time DO NOT satisfy the requirements of NCHRP350 (or equivalent), and hence are not to be used as safety barriers (i.e. for the purpose of containing and redirecting vehicles). The only known plastic barriers on the Australian market at time of writing which meet the requirements of NCHRP350, provided they are filled/installed in accordance with manufacturer’s requirements for NCHRP350 protection, are the Triton, the Guardian, the Roadliner S and the Aqua StopMark 1 brands of plastic block barriers. Other plastic barriers are used as delineation only.

8.3.5.1 Types of temporary longitudinal barrier

Triton barrier

Figure 8.60 shows one type of plastic block system which can be used as temporary crash barrier, the Triton® Level 3 system.

Figure 8.60 The Triton® barrier (Test Level 3)

The Triton® Barrier meets NCHRP350 Test Level 3 performance standards if optional hardware is installed.

The Triton barrier's design consists of a number of interlocking, 2m barrier sections made of polyethylene plastic. Each empty barrier section weighs 64 kg and can be unloaded and positioned by two workers without the need for cranes or special equipment. Once in place the barrier sections are pinned together and positioned correctly in and around work areas by swivelling the units as required. The sections are then filled with water to the level indicated on the unit.

Advantages of this concept include:

- low or nil maintenance;
- easy repositioning (compared with fixed barrier) when it is desired to alter traffic flow or allow equipment access;
- a continuous barrier face is presented to errant vehicles;
- colour differential for high visibility in adverse weather;
- impact force is transmitted longitudinally throughout the interlocked system; and
- versatility of use either as a delineator device for traffic guidance or, if installed as such, a temporary barrier.

The Triton barrier's alternating white and orange sections provide visual stimulation for motorists in both day and night conditions. To enhance night time visibility, lights or reflective material can be attached to the barrier.

The Triton® Barrier is also available in a configuration which meets the requirements of AS3845 Test Level 0 (50km/h, 1600kg, 25 degrees) performance standards. If construction site speeds are reduced to 50km/h and installation is in accordance to manufacturer's specification, this barrier offers construction site managers a barrier which is comparable to non-compliant plastic blocks but which will redirect errant vehicles matching this test level (Figure 8.61).

Guardian barrier

Similarly, the Guardian® Barrier (Figure 8.62) meets the requirements of NCHRP350 Test Level 2 and is similar to the Triton.

Aqua Stop Mark 1

The Aqua Stop Mark 1® meets the requirements of AS3845 Test Level 0 and is similar to the Triton Test Level 0 system.

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Figure 8.61 The Triton® barrier (Test Level 0)

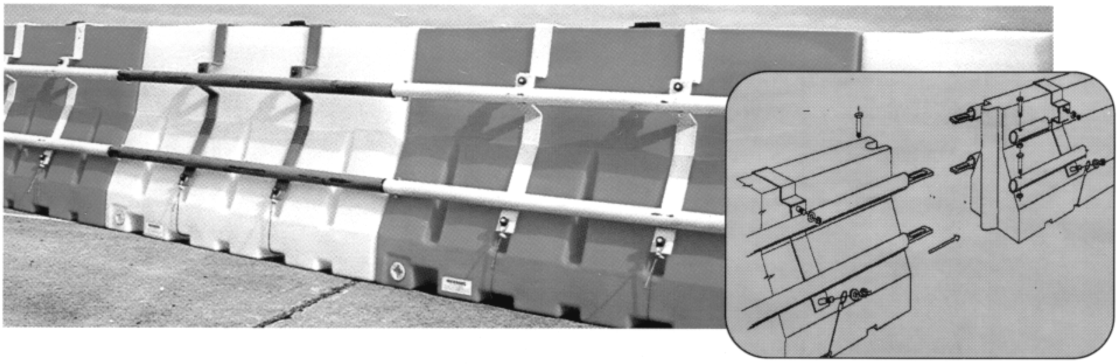

Figure 8.62 Guardian barrier (Test Level 2)

Roadliner 2000 S

The Roadliner 2000S ® meets the requirements of AS3845 Test Level 0 and is similar to the Triton (Figure 8.63).

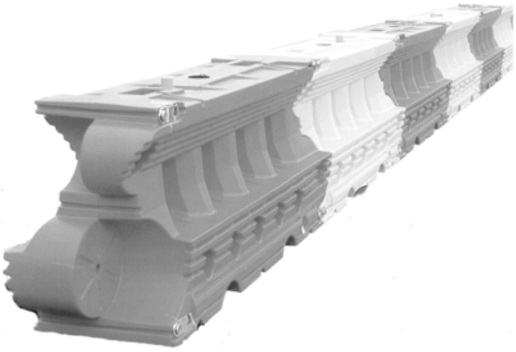

Figure 8.63 Roadliner 2000 S (Test Level 0)

BarrierGuard 800

The BarrierGuard 800 barrier meets the requirements of NCHRP Report 350 Test Level 4.

This system is an anchored Portable Steel Barrier consisting of 12m (2 x 6 m units) interlocking sections made from galvanised steel. The system is installed by linking each section together via a 'quicklink'. The system also features components to enable 30m radii and also opening gate sections for emergency access.

Figure 8.64 BarrierGuard 800 (Test Levels 3 and 4)

Advantages of this concept include:

- containment and redirection of high energy impacts with low deflection;
- remains functional after impact;
- transportable at up to 200m/truck;
- erection of up to 200m/hour by a trained three person crew;
- steel pads allow free flowing under-drainage;
- smooth profile for motorcyclists.

8.3.5.2 End treatments for temporary barrier systems

The ends of safety barriers must be appropriately treated, as they can be a major hazard to road users if they are struck end on. Sloped end sections are not recommended for barriers as they can launch vehicles that impact the barrier end on.

The most appropriate crashworthy end treatment for a barrier should be selected following consideration of:

- crash cushion characteristics;
- re-directive characteristics;
- design speed of the road;
- space available for installation of the terminal;
- capacity to absorb nuisance crashes;
- compatibility with barrier type; and
- cost and maintenance factors.

The options discussed below are preferred where site conditions allow their use.

Conventional w-beam MELT terminal

MELT terminal treatments as detailed in Section 8.2.6.3 are suitable for w-beam guard fence safety barriers, and for concrete barriers where a suitable transition is provided between the concrete barrier and the w-beam terminal. That is, for concrete barriers a transition is to be provided that includes:

- a concrete unit with a tapered profile from vertical at the w-beam connection to the profile of the concrete barrier; or
- a bridge type anchorage as set out in Main Roads Standard Drawings that provides for increasing stiffness between the standard post spacing of the MELT and the concrete barrier unit.

Flared and ramped ends

Ramped ends are required for temporary rigid safety barriers that can be suitably flared so that the exposed end is located outside the clear zone. If this is not possible, an appropriate end treatment is required.

Flared ends for temporary installations are to be installed on transverse slopes no steeper than 1 on 10 for all speed zones. For permanent installations, however, this flare rate may not be applicable, as each site needs to be assessed individually.

In determining the clear zone width, the speed value selected must be consistent with the 24 hour operation of the road and not to just satisfy temporary daytime speed zones employed. These speed zones must also be consistent with the physical restrictions and general driving environment of the site.

Energy attenuators

Where a flared end or MELT treatment cannot be achieved, an energy absorbing crash cushion appropriate to the barrier system is needed.

Suitable crash cushions are QuadGuard terminals, now available in a Construction Zone form that simplifies relocation, and some crash tested plastic units and barrel types such as the Fitch System. The latter however require considerable space and have problems if struck other than end on (refer to Section 8.2.6).

With plastic units, the manufacturer generally attests that the end unit is a crashworthy end treatment in itself, but this should be verified before installation. Other end treatments designed specifically for roadwork sites are available, such as the proprietary Quadguardcz® and the NEAT®.

As with barriers, crashworthy end treatments have been subject to tests defined in NCHRP350, evaluating structural adequacy, occupant risk and vehicle trajectory characteristics.

QUADGUARDCZ®

QuadGuardcz® uses crushable hex-foam cartridges that dissipate the energy of the impact (Figure 8.65). Any cartridges damaged during impact must be replaced after each impact. This system can be used as either a crash cushion or a barrier end treatment.

It was designed specifically for protection of narrow hazards up to 1000 mm wide, such as the unfinished ends of concrete rigid barrier in construction zones. It can also be used for:

- narrow hazards (such as median barriers in wide medians);
- bridge piers or semi-rigid guardrail, particularly for low-frequency impact occurrences; and
- protection of the ends of unfinished barriers in construction zones.

The transverse slope should not exceed 8%.

The system can be used in nearside or offside situations.

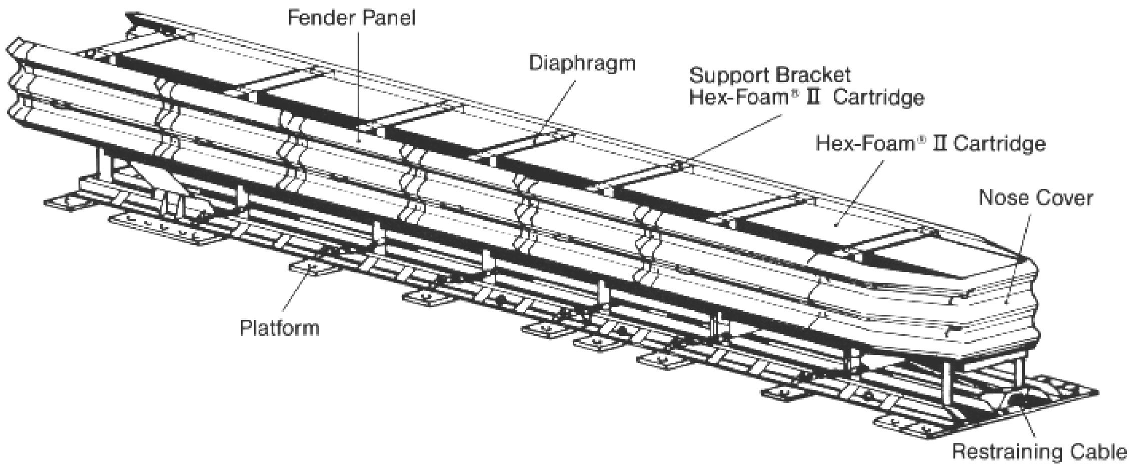

Figure 8.65 End treatment – "QuadGuardcz"

It must be designed and installed according to manufacturer's specifications.

Following design crashes, 75% to 80% of the system may be re-used.

Field experience has shown that nuisance crashes do not affect this system's ability to perform satisfactorily in subsequent design crashes.

SAND FILLED BARRELS

This system is a not a re-directive crash cushion consisting of a number of sand filled polyethylene plastic modules that are installed in arrays in front of wide hazards (Figure 8.66).

Sand barrels come in a variety of barrel sizes, depending on the application. The cone inserts serve two purposes: firstly they adjust the sand capacities of each module and secondly they ensure that the centre of gravity is at the proper elevation to ensure safe impact performance for various types of errant vehicles. Each module also includes a lid that seals each unit to restrict moisture penetration.

Sand barrels act as sacrificial crash cushions that break apart upon impact. As the impacting vehicle passes through the array, its speed is slowed by the gradual transfer of its kinetic energy to the sand, allowing for safe deceleration. When properly designed for a given site, sand barrel systems can safely decelerate vehicles with masses of up to 2000kg and travelling up to 110km/h during head on impact for a standard barrel configuration, as recommended by the manufacturers. Higher speeds or increased mass for design vehicles are accommodated by the addition of more barrels to the array and manufacturers should be consulted if a particular site has these needs.

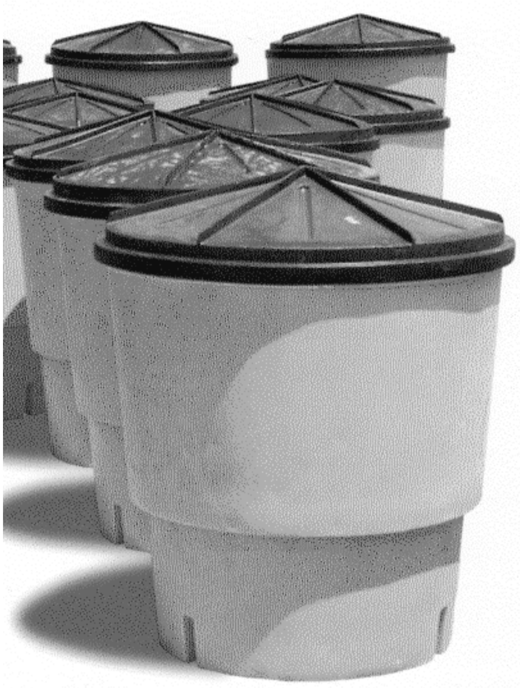

Figure 8.66 Sand filled barrels

8.3.6 Selection of safety barrier type for worksite

In considering what type of safety barrier to use, the following approach should be adopted:

8.3.6.1 Concrete barriers and anchored portable steel barriers

These barriers should be used at sites where the consequence of errant vehicles striking critical construction works (e.g. bridge false work) could have major flow-on effects. In addition, concrete barriers and anchored portable steel barriers provide a higher level of protection and would generally continue to remain functional after being struck. This latter feature is an important factor for critical sites as during out of work-hours operation it would be most undesirable to maintain traffic flow without site protection.

At these critical sites, the traffic volume and mix of commercial vehicles, particularly where these comprise heavy articulated vehicles, might require a more substantial rigid barrier.

8.3.6.2 Water filled plastic barrier

The lightweight, modular design of these barriers make them very portable (as empty units weigh between 25kg and 60 kg, depending on manufacturer) and are therefore able to be lifted and positioned by two workers without the need for cranes or special equipment.

Only those water filled plastic barrier that have satisfied the requirements for the appropriate test level of NCHRP350 (or equivalent) for redirection, occupant risk and velocity should be used as safety barriers (i.e. for the purposes of containing and redirecting vehicles).

These units have particular application in the protection of road workers by preventing the penetration of vehicles into the work site. Care needs to be exercised, in the selection of suitable sites, to ensure that provision is made for the speed range limitations and deflection requirements of this barrier.

Attention also needs to be given to emptying the units as wetting of the pavement could create a slippery surface and therefore an unexpected hazard to road users. If the units cannot be emptied and the water drained from the site then the water may be siphoned or pumped out or the units moved by fork lift to another location for emptying.

8.3.7 Further information

More specific information on types of barriers and their application, end treatments, and clear zones is available from Traffic Engineering and Road Safety (TERS) Branch, TRUM Division of Main Roads.

8.4 Roadside furniture

8.4.1 Signs

8.4.1.1 General

One of the principal elements of roadside furniture is the signing infrastructure. Signs are an essential element of the road system but their supports can represent a potential hazard depending on their size, location and configuration/design. (Note: All sign posts may be a potential hazard to motorcyclists, irrespective of size.) When positioning signs, consideration should be given to any adverse effects on views from the roadway (e.g. in areas of high scenic value). Chapter 3 of this manual provides further advice on this subject.

Sign sizes vary to the extent that they can be supported by one or more supports. Overhead signs are supported on a gantry spanning the road with substantial supporting legs, or on a cantilever over the road supported on a substantial post.

Details of signing requirements, clearances to sign faces and sign design are included in the MUTCD and Main Roads Signface Design Specification.

Manufacturing and construction details are included in the relevant Main Roads Standard Drawings.

Section 8.4 discusses whether signs and/or their supports are a roadside hazard and what treatments are available if they are hazardous.

If barrier is required, adequate clearance, commensurate with the barrier type, between the sign supports and the barrier must be provided.

8.4.1.2 Single supports

Single supports may or may not be a hazard to cars and larger vehicles, depending on the size of the support and the material from which it is made. Sign supports in the clear zone should be frangible or break away.

They must be designed in accordance with the "Design Guide for Roadside Signs" (Main Roads).

Standard Drawing 1368 provides details of both the slip and fixed base for single traffic sign supports.

Supports for overhead signs must be treated as fixed obstructions (refer to Section 8.4.1.4 below).

8.4.1.3 Multiple supports

Design of signs requiring multiple supports must be in accordance with Main Roads "Design Guide for Roadside Signs". The post sizes for such signs will often be of a size where they should be made breakaway. Main Roads' Standard Drawing Numbers 1363, 1364 and 1365 provides details for multiple traffic sign supports.

Main Roads' Standard Drawing Numbers 1366 and 1367 provide details for signs with truss type supports.

Main Roads' Standard Drawing Numbers 1450 and 1451 provide details for signs with timber supports.

In all cases locating the signs outside of the clear zone is preferred.

8.4.1.4 Gantries

Gantries are required to support signs erected above the carriageway and are substantial structures in their own right. The supports for gantries cannot be made breakaway so an alternative treatment is required to shield traffic from them. The clearance to the support is to be in accordance with Section 8.1 and Chapter 7 of this Manual.

If roadside barrier is installed for another reason, the gantry supports can be located behind that barrier. If necessary, the barrier should be extended to accommodate the sign supports if the location of the gantry cannot be moved to suit the barrier. The design of the barrier is to be in accordance with Sections 8.1 and 8.2.

In some circumstances, the supports may be adequately shielded with an energy absorbing device or safety barrier. The design of these devices must be in accordance with Section 8.2.

8.4.2 Street lighting poles

Lighting design is covered in Chapter 17 of this Manual. This section discusses details of the lighting poles as roadside furniture, details of the poles are also provided. Standard Drawing 1370 shows the range of types of poles used in various applications for roadway lighting.

Street lighting poles are provided to facilitate the provision of a lit road environment in accordance with the relevant Australian Standards for road lighting and Chapter 17 of this manual. Lighting poles therefore contribute to a safer road environment by their support of luminares. Lighting poles also present a roadside hazard and their location and design must take account of this. To obtain efficient use of the lighting installation, the luminares must be placed in accordance with the lighting design in accordance with the relevant Australian Standard for road lighting. Once fixed in space, the luminares must then be supported by lighting poles. The placement of these poles as a result of the road lighting design process might place the poles within the roadside clear zone. The poles may therefore become hazards.

Sometimes the road lighting design requires that poles be placed in high risk zones such as gore areas and splitter islands at roundabouts, off ramps and intersections. If locations with lower risks are available that still satisfy the road lighting design, they should be used. Such designs will reduce the incidence of crashes and will therefore reduce maintenance costs and lower the probability of outages resulting from crashes.

If safety barrier is installed for some other reason, the lighting poles should be placed behind the safety barrier, thereby affording motorists the necessary level of protection required. In these cases, fixed base installations may be used provided the barrier is a permanent one. Poles shall not be placed in the hazard-free zone required by gating end treatments such as the MELT (refer to Section 8.2).

Where no crash barriers are present and the pole is in the clear zone, the poles should be made breakaway using a slip base, or a frangible pole should be installed (refer to the Main Roads Standard Drawing 1370 for further details).

If safety barrier is required, adequate clearance, commensurate with the barrier type, between the poles and the barrier must be provided.

The issue of slip base poles being installed in proximity to pedestrian areas is easily resolved. If there is a possibility that an errant vehicle could dislodge a slip base lighting pole then the vehicle itself poses a hazard to pedestrians. In high pedestrian activity areas the probability of pedestrians being hit by falling poles is less than the probability of errant vehicles hitting pedestrians because not every errant vehicle will hit a lighting pole but errant vehicles will almost certainly hit pedestrians. In short, the approach of choosing fixed base lighting poles because of high pedestrian traffic assumes that fixed base lighting poles are installed to catch errant vehicles; clearly they are not. If there is an issue of pedestrian traffic in proximity to vehicular traffic then the issue needs to be addressed outside the context of slip base poles falling on pedestrians.

High mast lighting systems reduce the number of poles required and therefore improve the safety of the roadside. Slip base poles can be used for these installations and this option provides the safest situation for drivers. In some cases, the size of the pole will be too large to allow the use of the slip base and the pole will have to be shielded in some other way as described in Section 8.2.

To reduce the number of poles beside the road, it is often convenient to use the lighting poles to carry the required traffic signals at intersections. The signal head may be mounted directly onto the lighting pole ("joint use"), or a combination Traffic Signals mast arm and lighting pole can be used, depending on the requirements at the intersection.

The location of lighting poles should be in accordance with Section 8.4.4.

Placing slip base poles on batters often results in the slip base being too high or too low to perform as designed. In addition, providing sufficient room for maintenance vehicles to stop clear of the through traffic lanes can be an issue. To overcome these problems, it may be appropriate to provide a 1m wide flat area beyond the poles for the full extent of the lighting installation.

8.4.3 Traffic signals

Details of Traffic Signal requirements are included in Chapter 18 of this Manual. The location of, and clearances to, the signal pedestals are also provided in that Chapter. Since traffic signals are usually located at intersections, there is usually no opportunity to shield them from the traffic stream. Nor is it practicable to make the pedestals breakaway or frangible.

It is therefore important that the clearances stated in Chapter 18 of this manual are achieved. Shared pole positions (refer to Section 8.4.2) are desirable in reducing the number of poles required to meet the various intersection needs.

8.4.4 Poles

Poles of various types are erected in road reserves and beside roads. Lighting poles are an essential part of the road infrastructure and their location is defined by the technical requirements of the lighting design. Poles such as overhead electricity poles are placed in the road reserve for the convenience of the electricity utility and their location must be determined by the safety requirements of the road.

No unnecessary poles should be erected in the road reserve. Those that are necessary should be located as far from the travelled way as possible and at least outside the clear zone unless located behind a roadside barrier erected for another reason. Section 8.1.3.1 defines suitable clear zone widths.

In urban areas on kerbed roads, poles should be placed as far behind the kerb as possible. If it can be achieved, poles should be located on the property side of the footpath rather than the past practice of just behind the kerb.

Non-yielding poles without barrier protection should not be erected at locations where they may be more vulnerable such as the following:

- adjacent to horizontal curves with a speed value less than 80% of the 85th percentile speed of the element;
- on most traffic islands (particularly small ones) at intersections;
- on narrow medians;
- adjacent to road pavements that may become slippery under adverse conditions; and
- in gore areas adjacent to off ramps (poles in gore areas should be avoided).

When a pole must be erected in the road reserve, the options for treatment are, in order of preference:

- locate the pole outside the clear zone;
- make the pole a breakaway or frangible design where appropriate;
- provide a suitable roadside barrier (Section 8.2).

If barrier is required, adequate clearance, commensurate with the barrier type, between the sign supports and the barrier must be provided.

Circumstances where a breakaway design may not be appropriate are:

- in locations where regular parking or other slow speed activity may result in accidental dislodgement of the poles;
- in narrow medians where the falling pole would not fall clear of the running lanes; and/or
- in areas where the fall of the pole would foul overhead electricity conductors.

8.4.5 Roadside delineation

8.4.5.1 Road edge guide posts

Road edge guideposts are provided to delineate the edge of the carriageway and to provide guidance to drivers particularly during hours of darkness. They are usually located on the outside edge of the shoulder and may be made of steel, timber or plastic materials. Main Roads' Standard Drawing Number 1356 illustrates road edge guidepost requirements. Flexible materials usually present a lower risk to motorcyclists.

Details of the location and spacing of road edge guideposts are included in the MUTCD.

8.4.5.2 Maintenance marker posts

Standard Drawing 1358 illustrates the typical maintenance marker post. They are used to indicate the position of:

- any item requiring regular maintenance (e.g. sub soil drainage outlet); and
- any object that may be damaged by the operation of maintenance machinery (e.g. table drain block, public utility service installation, bench mark).

The posts should be placed as close as practicable to the object being marked. If the marker post at the object is not readily visible from the pavement, a secondary marker post should be placed at the edge of the formation. Where a secondary post is used, a delineator should be placed on the post similar to those on normal road edge guideposts.

Marker posts are made of tubular steel or timber. (Note: Such posts may be a hazard to motorcyclists.)

8.4.5.3 Hazard markers

Hazard markers are used to warn drivers of the presence of a rigid object adjacent to the travelled way. Details of their design and placing are included in the MUTCD.

8.4.5.4 Flood depth indicators

Flood depth indicators are provided on floodways and their approaches to indicate to drivers the maximum depth of water on the floodway. It is essential that the gauge provide an accurate assessment of the depth of water so that the driver can make an informed decision about whether to proceed.

Depth indicators must indicate to drivers the maximum depth of floodwaters across the road. The depth indicator must be displayed so as to be clearly visible to drivers before reaching the flooded part of the road. Where necessary, separate indicators should be provided on each approach. The zero mark should be set at the lowest pavement level on the section of road liable to flooding. Where flood depths in excess of 1.8m or 3.8m are expected, the indicators are erected on progressively higher ground (refer to Standard Drawing Number 1170 for details).

8.4.6 Noise barriers

Noise barriers are important features of roads where there are noise affected sites. Details of noise barrier requirements are provided in the Queensland Main Roads "Road Noise Management Code of Practice".

If safety barrier is required, adequate clearance, commensurate with the safety barrier type, between the noise barrier and the safety barrier must be provided.

In addition, if safety barrier is installed in proximity to noise barriers, it is to be no closer than 1m from the noise barrier (measured from the back of the safety barrier system).

8.4.7 Help telephones

Help telephones are provided on major limited access roads where drivers do not have access to nearby services to contact emergency service providers. They are sometimes provided on isolated sections of highly trafficked roads with no other means for drivers to contact these services in the event of an accident or breakdown.

Requirements for help telephones are detailed in Main Roads Traffic and Road Use Management Manual.

8.4.8 Fencing

The purpose of fencing a road is to contribute to safe traffic movement. It is used for one or more of the following purposes:

- to discourage pedestrians and animals from accessing the roadway;
- to reduce the risk of pedestrian/cyclist injury from contact with the back of a safety barrier;
- to guide pedestrian movements at traffic signals;
- to reduce the risk of pedestrian/cyclist injury from contact with the safety barrier;
- to discourage vehicles from entering or leaving the roadway at unauthorized places; and/or
- to provide some security for private property.

8

Security fencing will usually be required around urban and semi-urban motorways but may or may not be required on major arterial roads. Where practicable, pedestrians and cyclists should be provided with facilities within the right of way on Motorways outside the security fencing. In these cases, the security fence will be required between the pedestrian/cyclist path and the motorway to prevent encroachment onto the motorway pavements (refer Figure 8.67and Figure 8.68).

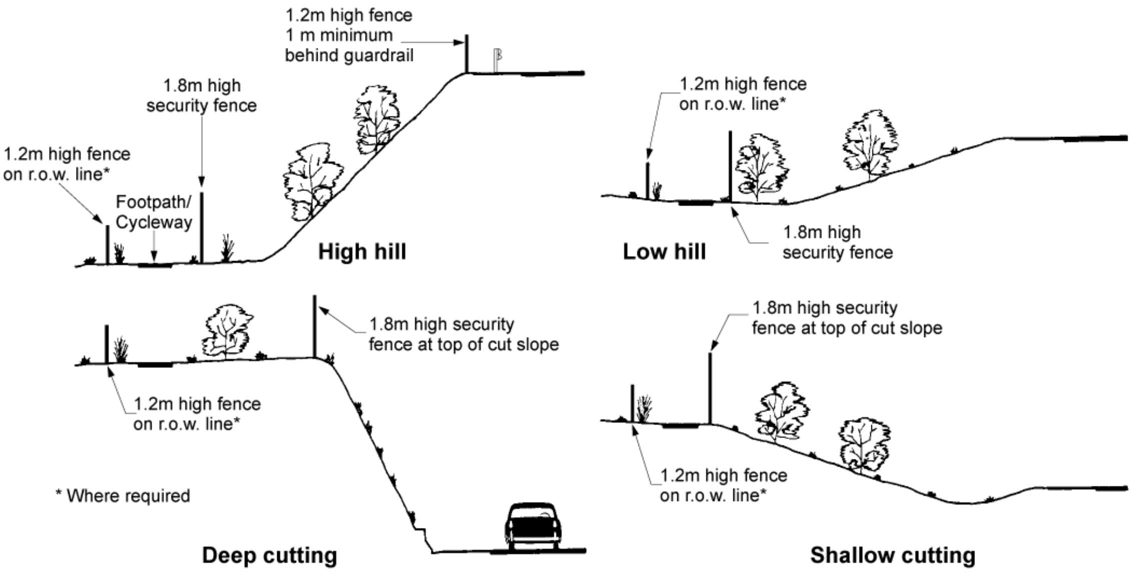

Figure 8.67 Location of security fences for motorways

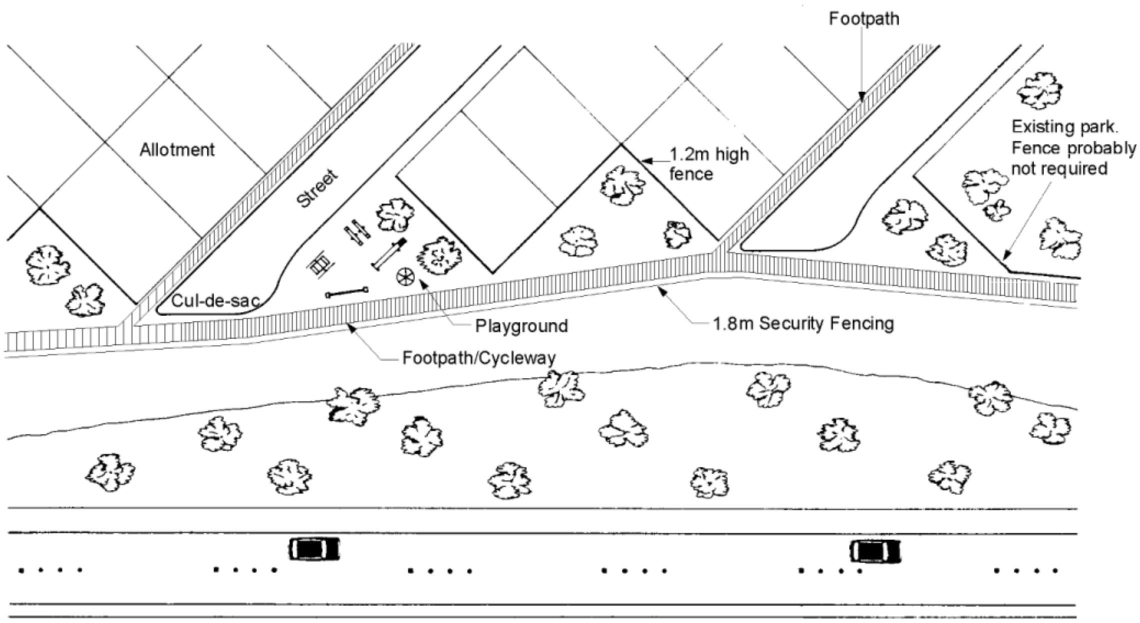

Figure 8.68 Pedestrian/cyclist access to right - of - way area

Security fencing consists of a 1.8m high, vinyl coated galvanised steel chain wire fence with the top of the chain wire exposed. This type of fencing, or a combination of wall and fence with a combined height of 1.8m, is required where pedestrian access has to be controlled. (Note: A total height of 1.8m may be required on both sides of the fence line.)

On rural roads (including motorway style roads) fences are normally required to define the property boundaries and where appropriate, prevent the straying of stock on to the roadway. On limited access roads, fences also provide a barrier to unauthorized access to and from the roadway.

Types of fencing include:

- wire mesh for controlling pedestrians and animals;
- three and four wire fences, including barbed wire as is appropriate, for rural properties;
- special cases where post and rail, stone, masonry, screen or hedges may be satisfactory;
- vermin and dog fences as required by the Rural Lands Protection Board.

The height of fence will depend on its function and the potential hazards involved. A 1.2m fence is usually required along the right of way unless other arrangements are made with property owners. Where security fencing is required, or it is important to discourage pedestrian access, a 1.8m high fence is required.

In general, it is the responsibility of the property owner to fence the property boundary unless resumption has occurred. Replacing the fencing is then required as accommodation works. Security fencing is the responsibility of Main Roads.

Fencing with horizontal rails must not be used within the clear zone or in any location where there is the possibility of impaling an impacting vehicle.

Where safety barrier is erected adjacent to a bicycle path (i.e. the path behind the barrier), measures to protect pedestrians and cyclists from any sharp edges of barrier posts are to be installed. This is to minimise the risk of catching pedals and clothing on the sharp posts resulting in cyclists/pedestrians falling against and/or over the guardrail. Section 8.2, Appendix 8C (Figure 8.125) and Chapters 5 and 7 of this manual provide detail on how this can be achieved. In providing this protection, it is essential that the operation of the guardrail, in particular that of the end treatment, is not affected (e.g. practices such as welding pipe to the back of the posts is prohibited as it is a spearing hazard,).

If fencing behind barrier is required, adequate clearance, commensurate with the barrier type, between the fence and the barrier must be provided.

8.4.9 Motor grids

Motor grids are required where a road cuts a fence line in areas where the road is not fenced along its length. These fence lines may be property boundaries, boundaries of paddocks within a property or vermin/dog fences (where they exist). The grid must retain the integrity of the fence line as well as providing a smooth and safe crossing for the vehicles on the road. If bicycles are prevalent on the road in question, special modifications are required to make the grid passable to the cycle.

Full design details have been developed and are included in Main Roads Standard Drawings. The grid rails may be fabricated from either standard railway lines (22.3kg/m) or from Rectangular Hollow Sections (RHS) in accordance with Main Roads Standard Drawings (Numbers 1351, 1352, 1353, 1354, 1355, 1448 and 1449) and Main Roads Standard Specifications.

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Relationship to other chapters

This Chapter sets out the overall philosophy adopted by the Main Roads for the design of safety barriers and roadside furniture in Queensland. It therefore relates to all of the other Chapters of this manual, which have to be read in conjunction with and applied in light of, the philosophy espoused here. Particularly relevant chapters are:

- Chapter 4 describes the standards to be applied to roads of different types.
- Chapter 5 describes the particular requirements of various road users:
  - Pedestrians;
  - Cyclists;
  - Road users with a disability; and
  - Motorcyclists; plus
  - Chapter 5 defines the dimensions of the various design vehicles.
- Chapter 6 - Design speed affects the clear zone dimensions as well as the selection, design and location of safety barriers and roadside furniture. The converse is also true.
- Chapter 7 provides guidance with respect to cross sections. A road's cross section can affect the selection, design and location of safety barriers and roadside furniture. The converse is also true. Chapter 7 is therefore closely related to Chapter 8 and they must be read in conjunction with each other.
- Chapter 9 provide guidance regarding required sight distances. Safety barriers and roadside furniture may affect/limit sight distance. The selection, design and location of safety barriers and roadside furniture should therefore take account of the guidance offered in Chapter 9.
- Chapters 13 and 14 deal with intersections and roundabouts respectively. They give sight distance requirements additional to those given in Chapter 9. The selection, design and location of safety barriers and roadside furniture should these additional sight distance models.
- Chapter 22 deals with bridges, retaining walls and tunnels. The selection, design and location of safety barriers and roadside furniture in vicinity of these structure require special consideration and attention and specialist advice should be sought in these cases (e.g. from the Structures Division of The Road System Engineering Group of Main Roads or a suitably qualified structural engineer.

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Appendix 8A: Suggested Severity Indices

Figure 8.69 defines intersecting slopes; the term "intersecting slopes" is used in some of the tables in this Appendix.

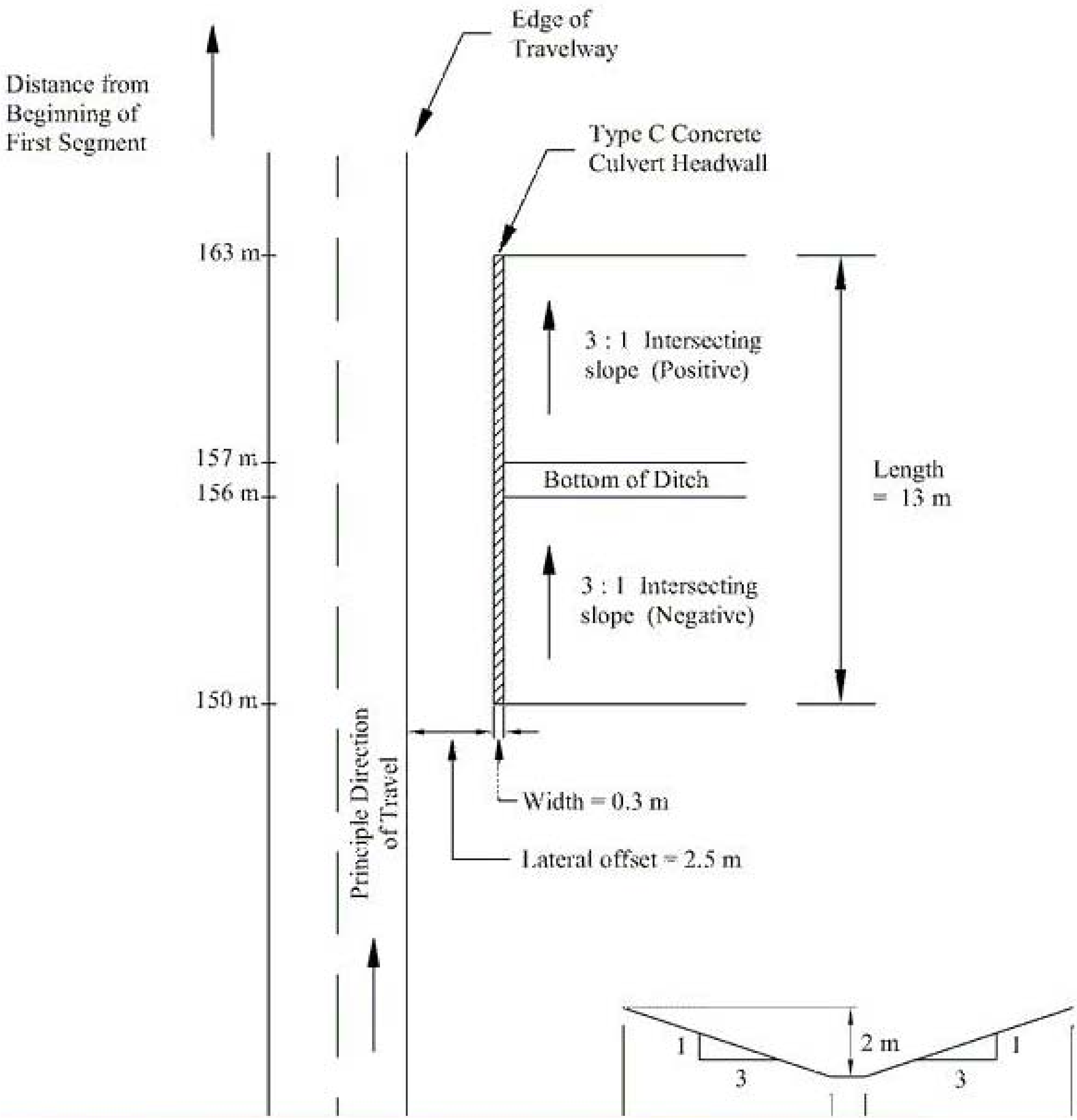

Figure 8.69 Illustration of intersecting slopes