1. Purpose

This note covers the design requirements for both flexible and semi-rigid Guard Fence (GF) on all arterial roads in Victoria and local roads in accordance with the relevant authority.

This Road Design Note (RDN) should be read in conjunction with the Austroads Guide to Road Design (AGRD) Part 6: Roadside Design, Safety and Barriers and VicRoads Supplement (VRS) to Part 6. Where conflicts or discrepancies occur between this note and the AGRD or VRS, this note shall take precedence.

This RDN should also be read in conjunction with Road Design Note 06-04 Accepted Safety Barrier Products, VicRoads Standard Section 708 – Steel Beam Guard Fence and relevant product specific information.

2. Performance standards

Only road safety barriers and terminal treatments accepted for use by VicRoads shall be used.

Acceptance for individual GF products will only be given if they conform to the requirements of AS/NZS 3845 Road Safety Barrier Systems and VicRoads Standard Section 708.

GF systems, including terminal treatments, accepted by VicRoads as complying with these requirements are listed in RDN 06-04. Suppliers will also be issued with a letter of acceptance by VicRoads, including after the date of issue of the latest version of RDN 06-04.

In addition, VicRoads Detail Sheets are published for all accepted products to inform users of any conditions of use, as determined through evaluation.

Proprietary products must be installed and maintained in accordance with the system supplier’s drawings, specifications and maintenance instructions. Public Domain (e.g. Type B) systems must be installed and maintained in accordance with VicRoads standard drawings and specifications.

3. Application of Guard Fence

Guard Fence (GF) is the most commonly used barrier type in Australia and refers to any barrier system with a steel w-beam or steel thrie-beam, commonly referred to as ‘guardrail’ in the U.S. market.

In recent years, the use of flexible GF has become more prevalent in comparison to semi-rigid GF, for its lower occupant injury risk during a crash.

All GF systems have been evaluated in accordance with either NCHRP 3501 or MASH2 crash testing criteria and are capable of restraining a range of passenger vehicles at various speeds. Some products are also capable of containing heavy vehicles up to 10,000 kg. Refer RDN 06-04 and Product Detail Sheets for accepted Test Levels.

W-beam barriers are typically incapable of containing heavy vehicles, such as buses or semi trailer trucks. Higher containment barriers are included in RDN 06-04. Where the proportion of heavy vehicles is high and the consequence of barrier penetration could be catastrophic (e.g. gantry or cantilever support structures on an urban freeway), then a higher performance barrier may be required. In this case a risk assessment, as detailed in AGRD Part 6, Section 6.3, should be undertaken to determine an appropriate level of protection.

GF is particularly useful in situations where the minimum offset, length or deflection of wire rope safety barrier cannot be accommodated in the available road reserve. They are also effective on roads with tight curves, where WRSB cannot be installed.

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2 Manual for Assessing Safety Hardware.
GF systems consist of the following components:

- Posts (strong or weak) – absorb some of the crash energy upon impact through post rotation in the surrounding soil. The post shape and strength will differ between products and will have the greatest influence on whether a system is considered flexible or semi-rigid;
- Blocks (only used in Type B) – positioned between the rail and post to minimise vehicle snagging, and reduce the potential for vehicles to vault over the barrier, by maintaining rail height during the initial stages of impact. Flexible GF has no block;
- Release mechanism – a critical component of all GF systems, designed to release the W-beam or thrie-beam during an impact to maintain desirable contact with the impacting vehicle;
- W-beam – longitudinal steel sections in the shape of a ‘W’, spliced together that work in tension to contact and redirect the vehicle away from the hazard;
- Thrie-beam – longitudinal steel sections in the shape of a ‘VVV’, spliced together that work in tension to contact and redirect the vehicle away from the hazard;
- End Terminals – designed to anchor the GF system and introduce the necessary characteristics required for safe vehicle impact and redirection throughout the length of need section.
- Delineator – Frangible plastic bracket with retroreflective material to alert drivers of the position of the GF system. Fastened to the top of the beam with a single bolt. Refer VicRoads Standard Section 708.11.

The W-beam or thrie-beam mounting height (measured to top of rail) and adequate post support are critical to ensure the barrier system will perform as intended.

GF may be used along the median of divided roadways and along the outer verge of roads where the warrants for the use of safety barriers are met.

Figure 3.1: Type B Guard Fence profile

Figure 3.2: Comparison of typical Guard Fence types

4. Warrants

Warrants for the use of safety barriers are based on the premise that they should only be installed if they will reduce the severity of potential crashes. That is, the consequences of an errant vehicle striking a hazard or overturning will be more severe than impacting the safety barrier itself. While safety barriers do not eliminate impact severity, they are highly effective at reducing the number of fatal and serious injuries, especially flexible systems.

Engineering judgement is required, based on the particular site conditions (context), to determine whether a safety barrier should be provided and the details of the installation. A barrier should only be used where it will be effective and where installation is economically justified, environmentally acceptable and physically practical.

The use of barriers to protect valuable roadside assets (e.g. communications equipment, gantries, etc.) should only be considered where the consequences of vehicle impact with the asset are considered greater than the impact of a vehicle with a roadside barrier.

More detailed warrants for the use of safety barriers are described in AGRD and VRS to Part 6, Sections 4 and 5.

For a summary of the common types of roadside hazards, refer AGRD Part 6, Section 4.3.

Historically, the likelihood of crashes involving roadside hazards (including steep batter) has been linked to clear zones. However, it is known that a significant portion of vehicles that leave the carriageway will travel beyond the given clear zone. Consequently, hazards beyond the clear zone must be considered when assessing the need for a safety barrier. This principle aligns with Safe System.

VicRoads Network Design Services team is currently reviewing VRS to Part 6 to provide updated advice regarding roadside safety and clear zones. For current clear zone requirements, refer to Section 4.2 of the AGRD and VRS to Part 6.
Consideration should always be given to other measures before installing a barrier, such as:

- Removing the hazard altogether;
- Modifying the hazard so that it is no longer a danger (i.e. installing a driveable end wall, flattening batters, etc);
- Reducing the impact severity of the hazard (i.e. slip base or impact absorbing lighting poles, frangible sign posts, etc);
- Relocating the hazard to a less vulnerable location; and
- Improving the alignment, cross section, surfacing and delineation to reduce the number of vehicles leaving the roadway.

For new projects, designs should be developed to align with Safe System principles and good road safety practice.

This RDN assumes that the need for a roadside barrier has already been pre-determined, following due consideration of containment levels, aesthetics and cost-effectiveness; and that either flexible or semi-rigid GF is the preferred barrier type for the given site.

5. Design Requirements

This section provides details of design criteria to be met as part of the assessment of the suitability of GF for use at a particular site.

Design terminology

It is noted that the VicRoads Final Drawing Presentation Guidelines provides only specific line styles for GF, Wire Rope Safety Barrier (WRSB) and concrete barriers. As such, to avoid any confusion in the design, review or construction process when GF products are specified, they shall be accompanied by a note which specifies the type of GF system designed along with the Test Level. This note shall use the terminology as follows;

- “TL-# Semi-Rigid Guard Fence” for public domain, semi-rigid, Guard Fence.
- “TL-# Flexible Guard Fence” for Flexible Guard Fence products.

It is important to include the minimum test level as this is a design decision and may limit the number of suitable products that can be selected, e.g. thrie-beam products and w-beam fall under the ‘semi-rigid’ category. The ‘#’ symbol specifying test level would be filled in as appropriate by designers (e.g. TL-3 or TL-4).

Alternatively, where a proprietary system has been specifically included in a design to meet a particular need, the note can specify the system by name and optionally include the terminology “or equivalent” where an alternative may be used.

5.1. General layout

GF can be located either close to the hazard (Line A) or at edge of traffic lane or shoulder (Line B). VicRoads standard drawings SD 3511 and SD 3521 show layouts for installations at Line A and Line B respectively.

Line A is desirable where the terrain between the hazard and the roadway is driveable (typically 10:1 or flatter), or can be reshaped to make it driveable. Line A installations also provide the added benefit of minimising nuisance impacts and reducing required barrier lengths.

5.2. Barrier offset criteria

This section describes the offsets required between the barrier and:

- Adjacent traffic lanes (5.2.1)
- Kerb and channel (5.2.2)
- Roadside hazards (5.2.3)

5.2.1. Offsets to traffic lanes

It is desirable to locate GF as far from the edge of the traffic lane as site conditions permit. This maximises the chance of drivers being able to regain control of the vehicle before striking the barrier.

Larger offsets to traffic lanes also avoid nuisance impacts and subsequent increased maintenance costs, and can minimise the length of barrier required. The ability of a vehicle to stop clear of the traffic lane, either for break-down or maintenance activities is also an important factor in the provision of a wide clearance from traffic lane to barrier.

Safety barriers should also be located outside the shy line where possible, particularly for short lengths of barrier. The shy line is the distance from the edge of the traffic lane beyond which a roadside object will not be perceived as an obstacle and result in motorists changing their behaviour. For more detail regarding shy line effects and offsets refer AGRD Part 6, Section 6.3.5.

Desirable offset – 4.0m and Greater

The desirable offset of 4.0m provides a comfortable width for a vehicle to stop clear of the traffic lane and barrier, and provides space for maintenance activities and emergency services. This offset also provides a recovery area between the traffic lane and barrier for errant vehicles to maximise the opportunity to recover.

Where long lengths of safety barrier is being installed, an offset of 4.0m–6.0m from the edge line should be provided so that occupants are able to open the doors of a passenger vehicle clear of the traffic lane.

Every effort should be made to achieve the desirable offset of 4.0m–6.0m on freeways and highways.

Minimum offset – 3.0m

The minimum offset of 3.0m provides an adequate width for a passenger vehicle to stop clear of the traffic lane and barrier.

Absolute minimum offsets – <3.0m

Absolute minimum offsets are defined as any offset less than 3.0m, and can be as low as 0.6m.
The use of flexible and semi-rigid Guard Fence

Absolute minimum offsets shall only be adopted after the required approvals have been obtained, in accordance with Section 6.3.5 and Appendix VA of VRS to Part 6.

Shoulder widths appropriate to the road classification and traffic lane configuration should be maintained at all times.

When seeking approval for absolute minimum offsets in medians, details of the width available for vehicles to stop on the adjacent outer verge should be provided to assist in the assessment process. Refer Section 6.1.

Where continuous safety barrier is installed at an offset less than 3m from edge line, stopping should be discouraged by limiting the length of reduced offset and by providing advice to drivers on alternative opportunities.

Long lengths of barrier offsets at 2.0-3.0m (with sealed shoulder) should be avoided, as this invites a vehicle to pull over and occupy part of the traffic lane. This results in a hazardous situation.

5.2.2. Offsets to kerb and channel

GF is designed and tested to contain and redirect an impacting vehicle when struck with the vehicle’s centre of gravity at or near its normal position.

When a vehicle crosses kerb and channel, vehicle roll and pitch can be developed, which could lead to roadside barriers being vaulted. This risk increases significantly where vehicle speeds exceed 70km/h.

![POSSIBLE BUMPER TRAJECTORY](image)

**Figure 5.1: Bumper trajectory behind kerb**

For this reason, GF installations behind kerb and channel should be avoided as far as practicable. Where kerb and channel is unavoidable, the barrier should be positioned such that it minimises the likelihood of breach. The allowable offsets between GF and kerb are shown in Table 1.

From solely a performance perspective, the most acceptable compromise is to position the GF above line of kerb (or closest to back of kerb) irrespective of kerb type. This mitigates any trajectory influence and ensures a vehicle will contact the GF within its optimal zone. Unfortunately, this can increase the frequency of nuisance impacts, unless the combination of kerb and barrier can be offset away from the traffic lane.

The next best compromise is to place the barrier further away, where there is confidence that all vehicles have returned to the ground and collide with the barrier at the expected bumper bar height. This requires sufficient space but minimises the risk of nuisance impacts, and is considered the overall most desirable range.

The least tolerable circumstance is to position the safety barrier such that the vehicle has commenced or not quite completed the vaulting process. For GF, this is between the line of kerb and an offset of 1.0m. Performance within this range will vary from most desirable at back of kerb to least desirable at 1.0m offset, and should be balanced with other elements such offset to traffic lanes and frequency of nuisance impacts.

The zone of distances in between the tolerable limits (accounting for a specific safety barrier and kerb profile) is deemed unacceptable positioning of a safety barrier.

The allowable offsets in Table 1 attempt to locate the barrier at a point where the vehicle bumper is likely to be close to its normal height above the ground when the barrier is impacted. All offsets are measured from back of kerb to face of the w-beam, unless otherwise noted.

<table>
<thead>
<tr>
<th>Kerb type</th>
<th>Design speed &lt;70km/h:</th>
<th>Design speed 70 to 80km/h:</th>
<th>Design speed &gt;80km/h:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-mountable</td>
<td>Desirable – ≥ 2.5m</td>
<td>Desirable – ≥ 3.0m</td>
<td>Not recommended</td>
</tr>
<tr>
<td></td>
<td>Minimum – 0 – 1.0m</td>
<td>Minimum – 0 – 1.0m</td>
<td></td>
</tr>
<tr>
<td>Mountable</td>
<td>No restrictions on kerb offsets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Clearance to Guard Fence from kerb

NB: Offset from back of kerb to face of barrier unless otherwise noted. These offsets can be used for both flexible and semi-rigid GF, noting that they were originally developed for semi-rigid GF.
Nesting should only be used on Type B GF required, another)

Nesting of the w-beam perpendicular to the departure end of the hazard.

When utilised, the reduced post spacing of 1.0m shall extend from a point 10m prior to the approach end of the hazard to a point perpendicular to the departure end of the hazard.

Double Nesting (Type B only)

Nesting of the w-beam (using two w-beam sections inside one another) is also designed to increase lateral stiffness where required, e.g. to achieve minimum deflection requirements. Nesting should only be used on Type B GF. The recommended treatment is to nest and splice two layers of guard fence together in a 'running bond' configuration shown in Figure 5.3.

5.2.3. Offsets to roadside hazards

Sufficient clearance must be provided between GF and the roadside hazard, to allow for the dynamic deflection of the barrier when impacted, and any roll effect of vehicles with a high centre of gravity.

For GF installations, the working width (the minimum barrier-to-hazard clearance) is the sum of the dynamic deflection and vehicle roll allowance.

Dynamic deflection

Dynamic deflection refers to the lateral displacement of a barrier when it is impacted and will be different for each system.

Dynamic deflection will depend on the Test Level of the barrier, the test criteria used (NCHRP 350 or MASH) and is typically based on a capacity impact test. Refer to detail sheets for the recommended dynamic deflection of each product.

Any comparison of dynamic deflection between products must consider the crash testing completed and capacity impact energy. For example, TL-3 MASH testing has 13% more impact energy than TL-3 NCHRP 350 testing and will generate larger deflection values.

In constrained locations where deflection cannot be accommodated, stiffening of the barrier system by reducing the post spacing to 1.0m will achieve smaller deflections. However, this stiffening of the barrier will increase the potential for vehicle occupant injury, and due consideration should be given. Practitioners must liaise with product suppliers for expected performance and deflection values.

When utilised, the reduced post spacing of 1.0m shall extend from a point 10m prior to the approach end of the hazard to a point perpendicular to the departure end of the hazard.

Figure 5.2: Kerb offset profile (applicable to flexible and semi-rigid GF)

Vehicle roll allowance

In addition to dynamic deflection, GF systems may induce vehicle roll when impacted. A vehicle roll allowance should be adopted where the hazard has sufficient vertical height to be within a vehicle roll envelope (e.g. trees, poles, sign gantries, etc).

Crash test data gives the most accuracy when determining vehicle roll allowance and is documented as 'Working Width' within product detail sheets. Where crash testing has not been done to Test Level 4 and above (i.e. using taller vehicles), Table 6.8 of AGRD Part 6 can be used to determine potential vehicle roll allowance, where there is an identified need.

Vehicle roll allowances shown in Table 6.8 range from approximately 0.5 to 1.0m based on concrete barriers. The values in this table also apply to a 710mm (approximately) w-beam barrier. For thrie-beam barriers, the values will need to be interpolated.

Some flexible GF systems are tested to a TL-4 level, meaning the ‘working width’ can be used as the vehicle roll allowance.

Where a hazard poses no additional impact risk with rolling vehicles (e.g. culverts, fill batters or non-vertical cut batters), the vehicle roll allowance can be substituted by the system width. Refer Figure 3.2.

Figure 5.3: Nested w-beam (Source: RMS NSW Standard Detail – MD.R132.F04.A.1)

The length of nested w-beam should extend at least one length either side of the identified hazard for strengthening and should not be used in conjunction with reduced post spacing.

Combinations of nesting and reduced post spacing should only be used as per technical advice in supplier detail sheets to avoid pocketing by errant vehicles.

Nesting of flexible GF will not provide measurable performance benefits, and should not be used as a method of reducing deflection.

Figure 5.4: Nested w-beam (Source: RMS NSW Standard Detail – MD.R132.F04.A.1)
5.3. Protection of vertical drops

GF shall only be used for the protection of vertical drops (including culverts) after a risk assessment has established that the containment level provided by the proposed barrier system is appropriate for the site.

Consideration should always be given to remove or reduce the hazard caused by drainage culverts. Options may include designing the culvert end to be traversable. Refer VRS to Part 6, Section 5.4.6 for further guidance regarding particular culvert sizes.

Where providing GF over culvert, the area behind the GF should be sufficient to accommodate the expected dynamic deflection of the barrier, i.e. the drop should be located outside the deflection width of the GF.

Bridge Technical Note 2009/002, Guidelines for Bridge Approach Barriers, provides guidelines for GF on approach to structures. It should also be read in conjunction with AS 5100 Bridge Design.

5.4. Horizontal and vertical alignment

Crash testing as per MASH and NCHRP 350 is generally performed on straight sections of longitudinal barrier, so the behaviour of impacted GF on curves is, to some extent, unpredictable. However, infield examples of GF have performed well on the outside of curves, even those of relatively small radius, as the concave shape supports the development of tension in the rail.

Installations on the inside of curves can be more problematic, as the convex shape can mitigate development of tension in the rail. However, this is usually only a problem for very small radii, such as those on the corners of intersections.

Options for installations at radii less than 10m should be discussed with the Manager Safe System Design, and is typically only used in constrained locations. This may occur on local roads where there is not available land to comply with recommended length of barrier requirements and in small areas that require protection, for example rest stop areas.

Straight sections of w-beam can be used to form a radius of 45m or greater. For radii less than 45m, w-beams are required to be factory curved. Consideration should be given to likely impact angles on curved barrier installations, as the maximum impact angle tested under NCHRP 350 and MASH is 25°. Vehicle impacts at angles greater than 25° can therefore be expected to have more severe consequences than those encountered in controlled crash tests. Most flexible GF is crash tested under the MASH system (Test Level 3) at a maximum impact angle of 25°.

There are no vertical alignment limitations for GF installations.

5.5. Flaring

A barrier is flared when it is not parallel to the edge of the traffic lane. A flared installation (typically Line A) maximises the offset between the traffic lane and the barrier, increases the likelihood of the driver being able to regain control, and minimises nuisance impacts.

Motorists are less likely to perceive barriers as a risk/hazard if the terminal gradually flares away from the approaching traffic. It should be noted that some terminals do need to be installed parallel to the roadway.

Refer Table 6.5 of AGRD Part 6.5 for maximum flare rates. Caution should be used in applying flaring as GF is designed to work best with a low angle impact. The flare rates applied should not enable impacts with the GF to occur at an angle greater than 25 degrees.

For flare rates for proprietary terminals, refer to the system supplier’s product manuals and VicRoads standard drawing SD 3545.
5.6. Length of redirection

The length of redirection is the length of GF required to redirect an errant vehicle and shield the driver from a roadside hazard. It is a requirement that the GF be positioned so that the extremities of the length of redirection (points of redirection) are aligned with the hazard required to be protected (points of need).

Consideration needs to be given to the length of redirection for both adjacent and opposing traffic if the identified hazard is at risk of being impacted by opposing traffic.

Figure 5.6: Barrier length of redirection
(Source: AGRD Part 6, Fig 6.21)

The run-out length method shall be used to determine hazard points of need in Victoria. The run-out length is the theoretical distance needed for a vehicle that has left the roadway to come to a stop. It is measured along the roadway from the point at which the vehicle leaves the running lane, although the actual distance travelled is along the departure path. This method has been used to determine lengths of redirection shown on VicRoads standard drawings SD 3511 and SD 3521.

Curved sections

The above method and standard drawings are only applicable to straight sections of road. For barrier designs on the outside of horizontal curves, it is assumed that a vehicle’s exit path from the road will follow a tangential run out path. Therefore, rather than using the theoretical run out length, a line from the outside edge of the hazard to a tangent point on the curve should be used to determine the appropriate point of need for the hazard.

Figure 5.7: Length of redirection on outside of curve
(Source: AGRD Part 6, Fig 6.24)

For barrier designs on the inside of curves, the length of redirection is based on the theoretical run out length projected from the edge of the traffic lane to the rear of the hazard. Refer to Table 6.9 of the AGRD Part 6 for the theoretical run out lengths.

Figure 5.8: Length of redirection on inside of curve
(Source: AGRD Part 6, Fig 6.25)

The length of redirection has traditionally excluded GF terminals, however all current VicRoads approved approach-side GF terminals now have some re-directive capabilities, which help to reduce overall GF installation lengths. The points of redirection vary between each product, and designers should refer to the system supplier’s drawings and specifications for further details. VicRoads standard drawing SD 3545 provides a comparison of accepted GF terminals, and their respective points of redirection.

The application of terminal flaring, as per Section 5.5, can help to minimise the required barrier length of redirection. However, note that some GF terminals can only be installed tangentially (refer Section 8).

5.7. Minimum barrier length

In order to perform satisfactorily, GF systems must have sufficient length to enable the strength to be developed through the system and into the posts as impact occurs.

As a general guide, to effectively redirect an errant vehicle on high speed roads, a minimum length of 30m of semi-rigid GF (including terminals) is recommended. For flexible GF, a minimum length of approx. 56m (plus terminals) is recommended. Refer product Detail Sheets.

Regardless of whether the necessary length of redirection is provided (refer Section 5.6), a minimum of a single span of GF (i.e. 5m) must be installed between approved G.R.E.A.T TL3 approach and departure terminals.

A minimum of two spans of GF (i.e. 10m) must be installed between an approved G.R.E.A.T TL3 approach terminal and the Trailing Terminal.

5.8. Sight distance

All barriers should be considered non-transparent for assessing sight distance or sight lines.

The effect of GF on sight distances, particularly on horizontal curves and in the vicinity of intersections and driveways, shall be considered when selecting barrier offsets. The presence of vertical geometry should also be considered in conjunction with the horizontal geometry and the location of the safety barrier.

Safety barriers installed in narrow centre medians should allow for the median to be widened on curves, allowing better stopping sight distance for vehicles that need to stop in the
case of a hazard on the road (e.g. debris). Refer to Section 5.5 and Appendix G, AGRD Part 3.

The typical mounting height from the top of the steel beam to ground surface level for GF is between 730-740mm for w-beam products and 980mm for thrie-beam.

Consideration may need to be given to raising driveways to provide sight distance over the top of a barrier, where the need for GF is unavoidable.

Safe Intersection Sight Distance (SISD), as described in Chapter 3 of the AGRD Part 4A and VRS to Part 4A, should be maintained at all times. As a general rule, sight distances will not be compromised if the offset from barrier to traffic lane is 3m or more.

**5.9. Grading requirements on batters**

It is desirable to locate GF where the approach slope from the pavement is essentially flat. GF has been designed for level terrain conditions and performs most effectively when installed on slopes of 10:1 or flatter. If GF is placed on slopes steeper than 10:1, studies have shown that for certain encroachment angles and speeds, the barrier may not perform as intended.

Ideally GF should be placed as close to the hazard as possible and the area between the edge of verge and GF should be made flat and obstacle free, with a cross slope not steeper than 10:1. If this is not achievable, the following steps should be considered:

**Batter slope flatter than 5:1**

Place the GF as close as possible to the hazard and create an obstacle free area at least 2m wide with a slope not steeper than 10:1 in front of the GF.

The batter slope from edge of verge to the flat area should be maintained at 5:1 or flatter.

The 2m wide flat area in front of the GF provides adequate space for the four wheels of an errant vehicle to be in contact with a level surface when impacting the GF.

5.10. **Post depths on narrow verges**

When GF is used to shield embankments and the full width of dynamic deflection cannot be provided, consideration needs to be given to the provision of adequate ground support as, over time, softening of the verge may occur. Adequate post support is critical to ensure the barrier system will perform as intended.

A 500mm minimum clearance from the rear of the post to the embankment hinge point should be provided, although this may vary due to soil conditions, batter slope and post depth. Desirably the hinge point of batters steeper than 4:1 should be located outside the deflection width of the barrier.

If posts are placed closer to the hinge point than the minimum, it is recommended that the post embedment depth is increased to provide sufficient lateral support in semi-rigid systems.

Note some barrier suppliers have crash tested and/or analysed the performance of their proprietary systems at a clearance of less than 500mm away from the batter hinge point. 500mm is the minimum clearance and anything less than this should only be implemented in a constrained location with risk assessment and design non-conformance. Documented evidence should be sought from the supplier to support any option assessment and decision making.

As a guide, additional post embedment depth of 1000/a mm should be provided for semi-rigid GF, where the embankment is ah:1V (refer Figure 5.10), limited to a maximum slope 2:1.

Alternatively, 2.4m posts (600mm additional depth) are commonly used on narrow verges. Consideration of the appropriate barrier system for containment on steeper slopes should also be given. For flexible GF, the plastic deformation of the post occurs at ground level. However, in weaker soils some suppliers recommend a longer 1770mm or 1860mm post, to provide sufficient lateral support during impact and facilitate the yielding action of the post.

Adoption of increased embedment depth as above should only be adopted on existing roads with constrained formation widths. Adequate formation width should be provided on all Greenfields projects and high risk retrofit projects.

![Figure 5.9: Slopes in front of Guard Fence on embankment](Source: VicRoads Supplement to AGRD Part 6, Fig V6.1)

**Batter slope steeper than 5:1**

Place the GF adjacent to the traffic lane or shoulder (Line B) according to offset criteria described in Section 5.2.

![Figure 5.10: Narrow verge post depths](Source: Department of Transport and Main Roads, Queensland, standard drawing SD 1474)
6. Design Considerations

6.1. Provision for stopping

Roadside stopping is expected and therefore must be considered where lengths of safety barrier are installed so that vehicles can safely pull off the road in the event of an emergency.

Where the road has two lanes or less in each direction, provision for stopping can be managed entirely within the LHS roadside. If the road has three lanes or more in each direction, adequate provision for stopping should be considered for both the LHS and median of the carriageway.

Where long lengths of GF are being considered, and the barrier offset to the traffic lane is less than 3m, provision for stopping should be carefully managed. Stopping should be discouraged in high risk areas and opportunities for stopping clear of traffic should be provided at a maximum spacing of 1km.

In the case of elective/discretionary stopping (e.g. the driver has an element of choice and will stop at a location which they perceive as safe), it is desirable that opportunities are available off the main carriageway where the speed environment is low. Where existing off-road opportunities are not available, it is recommended that Emergency Stopping Bays (ESBs) are provided at least every 1km-4km to give drivers additional space to stop further from the traffic lane.

Emergency Stopping Bays should be designed in accordance with VicRoads RDN 06-02 Appendix E, which includes a barrier offset of 5m-6m from the edge line of the road and a length of 55m (absolute minimum length 30m). EABs should have advanced signing and may be more frequent in high risk stopping sections such as steep grades.

Provision for heavy vehicles (HV) stopping should be considered where the percentage of HV is high. It may be provided less frequently, however the layout of an ESB should be modified to allow for the additional length and width of these vehicles.

6.2. Allowing for access

It may be necessary to consider breaks in GF at locations where pedestrians cross the road, or where intersections, property accesses or median breaks exist.

Access for emergency services should also be a consideration, particularly on rural or mountainous roads in high fire/flood risk areas. The provision of breaks should be reviewed along the whole length of a project and minimised as appropriate.

Where breaks are necessary, approved end treatments must be provided and barriers should be overlapped (refer section 8.4). Any unprotected hazards located in close proximity to the break in GF (i.e. outside of the length of redirection) must be reviewed for removal, relocation or alternative protection.

Consideration may include staggering of the GF lengths to minimise the risk of an errant vehicle entering the gap.

Consultation with the relevant VicRoads Regional Operations area should be undertaken to determine an appropriate access width for maintenance purposes. In general, 3 to 5m should be provided between overlapping barriers. Refer AGRD Part 6 Commentary 14 for an example diagram of a barrier access arrangement.

If a longitudinal break is required between GF terminals for property access, consideration should be given for service vehicles, such as garbage trucks, to stop clear of the adjacent traffic lane. A nominal 18m should be considered between end terminals at driveway locations, subject to other requirements within this RDN being met.

6.3. Vulnerable road users

Consideration for vulnerable road user requirements, such as for pedestrians, cyclists and horse riders should be given when determining GF layouts.

The rear side of posts and w-beam should be considered accordingly as a possible hazard for pedestrians and cyclists. Refer AGRD Part 6A and VRS to Part 6A for required path clearances and further guidance.

Consideration should also be given for appropriate end terminals located adjacent to paths. Some terminals are designed to gate, curve or kink the w-beam away from the impacting vehicle extending into the area behind the barrier system. These terminal types should be avoided where pedestrians and/or cyclists will be regularly accessing the area around the terminal.

While GF is seldom justified for the protection of pedestrians and cyclists alone, Safe System principles suggest we separate vulnerable road users from the road and from general traffic. Refer AGRD Part 6, Section 6.5.2 for further guidance.

6.4. Motorcyclists

Most motorcyclist collisions into safety barriers will occur in one of two ways: a) the motorcyclist impacts the barrier while riding in an upright position, or b) the motorcyclist is sliding along the road surface and may have separated from their motorcycle before impact.

In both impact scenarios, it is typically the posts on a GF system that present the most risk of injury, whereas the w-beam provides a smooth contact surface.

While the overall frequency of motorcyclist impacts into safety barriers is low in comparison to other road users, it is important to select the most suitable GF product on popular motorcycle routes in Victoria. Seek VicRoads guidance for the latest list.

The use of accepted under mounted rails, such as steel rail, can greatly reduce the risk of injury and should be considered in high risk locations on both flexible and semi-rigid GF systems. Refer to RDN 06-04 for accepted motorcycle-friendly products.
Flexible GF is also considered a more forgiving option for motorcyclists that slide across the top of the w-beam rail, because the posts sit below the top of the rail. Semi-rigid GF posts sometimes protrude above the top of w-beam rail and may cause snagging.

Care should be taken to avoid sharp or broken edges, potential snagging points, or unnecessary protrusions or added devices. Reflectors used for delineation purposes need to be flexible or frangible in case motorcyclists slide along the top of the w-beam. Plastic post caps are also available to provide a more forgiving profile of the top of the Type B post/block combination.

6.5. Underground assets

Where drainage or underground services are required at the GF location it is important that the drainage design and services strategy is coordinated with the barrier design. Items affected may include the location and depth of pipes/conduits and location of pits. Installations of GF along the invert of table drains should be avoided for maintenance, durability and barrier performance reasons.

Where barriers are required across culverts or other underground services and two or more consecutive standard driven GF posts cannot be used, strengthening of the w-beam and/or omission of posts may be considered as follows.

6.5.1 Barrier strengthening

Options to strengthen include reducing post spacing on the approach and departure sides of a culvert (refer to Section 5.2.3) or asset, utilising bored pile post foundations on either side of the culvert or asset, or provision of a reinforced concrete ground beam with posts mounted on base plates.

The provision of bored pile foundations or ground beams require structural design and proof engineering by a VicRoads prequalified design consultant and approval by the Superintendent.

Some Flexible GF systems have surface mount variants installed on concrete foundation pavements. These variants must be installed in accordance with all supplier requirements and should be constrained to the area of need only, and not the entire length of barrier.

Attaching posts (flexible and semi-rigid) directly to a culvert structure also requires structural advice and approval by the Superintendent.

6.5.2 Post omission

Where necessary, a single flexible or semi-rigid GF post only can be omitted to avoid a lateral underground asset, resulting in an isolated post spacing of up to 5m.

Post omission within Type B GF must also be nested to provide additional strength. Nesting of the w-beam is designed to increase lateral stiffness to compensate for the missing post and provide continuity of stiffness for vehicles, thereby minimising pocketing. Refer Section 5.2.3 for double nesting configuration for strengthening only.

The recommended Type B post omission treatment is to nest and splice two layers of w-beam together in a 'running bond' configuration shown below (Figure 6.1). The length of nested GF should extend at least one w-beam length either side of the omitted post and should not be used in conjunction with reduced post spacing.

If factory drilled nested w-beam sections are not available, the additional holes required for bolting of the nested w-beam should only be formed by drilling. No holes shall be formed or enlarged using oxy-acetylene equipment (“gas-axe”) or similar flame cutting methods. Once formed, the holes should be filed to remove any rough edges and painted with a single pack zinc-rich primer that meets AS/NZS 3750.9. Source NZTA TM-2003: Nesting of semi-rigid guardrail.

Combinations of nesting and reduced post spacing should only be used as per technical advice to avoid pocketing.

Figure 6.1: Nested semi-rigid GF and omitted post (Source: NZTA Standard Detail – RSB-4 rev2)
6.5.3 Use of twin blockouts (Type B only)
Where isolated individual (i.e. single) GF posts cannot be installed due to underground services, twin blockouts are acceptable on Type B to allow the post to be setback further from the w-beam. More than two stacked blockouts has the potential to lift the w-beam as the post rotates back during an impact and therefore should not be installed.

6.6. Median installations
Where guard fence is installed within the median, care must be taken to ensure that the exposed posts cannot be impacted by opposing traffic.

Terminals specifically used for median installations are available and can be found in RDN 06-04.

Back-to-back (double sided) blocked out Type B GF should not be used as a median barrier.

Some flexible GF products have variants for ‘back-to-back’ installations. Practitioners must consider maintenance and repair requirements, such as any impact damage into the surrounding foundations and repair methodology. Refer to VicRoads Detail Sheets for product variants.

Where traffic volumes are high and the median is narrow, rigid concrete barrier is generally desirable. The maintenance for concrete barrier is considerably less than a GF; because it will survive major collisions without needing to be replaced. Further guidance on narrow median options can be found in Section 5.4.3 of VRS to Part 6 and Section 4.7 of VRS to Part 3.

6.7. System specific design
Where a particular need is identified outside the current guidelines; the system supplier may be sought for advice and guidance of a barrier system’s performance in a non-standard installation. System specific designs shall be:

- based on valid crash testing data;
- supported with evidence from the supplier;
- documented with correspondence from the owner;
- specified on the safety barrier design drawings;
- certified by a VicRoads prequalified designer, and;
- approved by the contract Superintendent.

Any alterations made to the system specific design shall be endorsed by the original designer and supplier, and approved by the Superintendent. Approved suppliers of each Guard Fence system can be found in RDN 06-04.

7. Installation Considerations

7.1. Barrier beam height
The height of GF is critical to its satisfactory performance and it is essential that this be maintained at the correct level throughout the life of the installation.

As of September 2017, the standard height of Type B GF in Victoria is 740mm to the top of w-beam (shown in VicRoads standard drawing SD 3661). This height is to be adopted for all future installations of Type B GF, where existing Type B GF is within the Limit of Works of a funded infrastructure project, or where maintenance is required on impacted Type B GF.

Where existing Type B GF installations are below standard height, lifting of the w-beam can be achieved with proprietary Abraham Blocks (pictured below).

![Figure 7.1: Abraham block](image)

Some flexible GF products can also be lifted retrospectively to be compliant with installation height requirements. Please refer to product manuals to see the accepted lifting components that can be used.

Where the face of GF is erected within 1m of the back of kerb, the barrier height shall be measured from the lip of the kerb. Where the face of GF is erected within 1.5m from the edge of pavement without kerbing, the barrier height shall also be measured from that edge of pavement. For distances beyond 1.5m, the barrier height shall be measured from the nominal ground surface at the GF location.

7.2. Provision of paving adjacent to GF
Where GF is proposed adjacent to unsealed shoulders, the shoulders should be sealed in conjunction with the barrier installation. This may not be necessary if the GF is located sufficiently clear of the existing pavement to accommodate maintenance activities (e.g. mowing) in between the barrier and pavement.
In general, paving should be provided where the full width between GF and the edge of the traffic lane is less than or equal to 3m.

Refer VicRoads Standard Section 708 for further details of paving requirements between GF and existing pavements. VRS to Part 6 also includes further guidance in relation to sealing between GF and adjacent roadside furniture, and also between overlapping barriers.

### 7.3. Maintenance

In accordance with Section 28 of the OH&S Act 2004, designers shall consider the OH&S implications of maintenance and repair of safety barriers.

The on-going maintenance of the areas on both sides of the barrier as discussed within this RDN should be taken into account when considering the installation of GF. The cost, practicality and the OH&S implications of the maintenance of these areas needs to be considered.

Maintenance factors to be considered are:
- routine maintenance;
- impact repair;
- effect of barrier on adjacent road and roadside maintenance;
- having the correct equipment available to fix the barrier.

Concrete maintenance strips below GF can be considered in accordance with VicRoads Standard Section 708.

The concrete maintenance strip can be placed parallel to the GF, such that it extends a minimum of 300mm clear of the rear of the post and 300mm clear from the face of the w-beam. Refer to VicRoads standard drawing SD 3503 for further information.

### 7.4. W-beam overlap

GF steel rails are spliced together at alternate posts using eight bolts (six bolts for thrie-beam), with the rails overlapped so that the exposed ends face away from nearside approaching traffic. That is the upstream section overlays the downstream section. This is to avoid the possibility of the impacting vehicle snagging on the end of the overlapping w-beam.

For proprietary end terminals, refer to VicRoads standard drawing SD 3545 and supplier product manuals for the appropriate overlaps, as they may vary from the requirement above for terminals located on the trailing end.

### 7.5. Delineation

Delineators are to be installed to the top of the w-beam, at 15m spacing, in accordance with VicRoads Standard Section 708.

In general, delineators should only be installed on tangential sections of GF, when the offset to the nearest traffic lane is ≤ 4m.

### 7.6. Cutting posts

GF posts shall not be cut under any circumstances. Refer VicRoads Standard Section 708 for installation details where posts cannot be driven.

### 8. Terminals & end treatments

Once the GF has been located to accommodate the length of redirection and lateral deflection, suitable approach and departure end terminal treatments must be selected for use. These may include GF terminal products or transitions into other barriers or structures (e.g. bridge end posts).

### 8.1. Terminals

Appropriate terminals need to be provided so that the end of the GF will not spear or snag an errant vehicle, causing it to overturn or vault the barrier. In addition, an appropriate terminal will ensure that vehicle decelerations will not exceed the recommended limits.

Provision of a crash-tested terminal, in accordance with RDN 06-04 is mandatory where the GF termination is likely to be hit end on by an errant vehicle.

As of January 2014, only Gating Redirective Energy-Absorbing Terminals (G.R.E.A.Ts) can be used for new installations of approach terminals in Victoria. Breakaway Cable Terminals (BCTs) are no longer accepted for use and should be considered for replacement when a) within the limit of works of a funded project or b) repair is required. BCTs should be replaced with a Trailing Terminal only when applicable. Refer Section 7.8.2.

Thrie-beam barrier systems do not have directly compatible terminals, but may be transitioned to w-beam guard fence or concrete barriers, which have their own accepted end terminals.

Refer to RDN 06-04 for accepted GF terminal systems and the relevant product manuals.

![Figure 8.1: ET 2000 Plus terminal](image-url)
All GF terminals are designed to have a location at which the length of redirection begins (i.e. Point of Need). This position could be a particular post, or distance from a post, at which the redirective capabilities of the barrier system begins and the terminal is no longer “gating”.

The component length of the terminal that “gates”, or breaks away when struck, is the underlying difference with all terminals, and can significantly influence product selection when site constraints are tight (e.g. close to driveways or intersecting roads). Provided that the terminal Point of Need and GF point of redirection are horizontally aligned, the barrier system will provide the same redirective capabilities regardless of the terminal selected.

The Trailing Terminal is not crashworthy when impacted from the reverse direction and therefore can only be used when there is no practical chance of being impacted by opposing traffic (e.g. on a divided carriageway, or at sufficient offset to opposing traffic lanes, or is shielded from approach traffic by another barrier).

Table 2: G.R.E.A.T Point of need & flare widths

<table>
<thead>
<tr>
<th>Terminal (Total length)</th>
<th>Location of PoN</th>
<th>Distance from impact head to PoN</th>
<th>Allowable flare</th>
</tr>
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<tbody>
<tr>
<td>X-Tension TL3 (13.03m)</td>
<td>600mm from first post</td>
<td>2.20m</td>
<td>max offset 1200mm</td>
</tr>
<tr>
<td>ET 2000 Plus TL3 (15.86m)</td>
<td>Post 3</td>
<td>4.43m</td>
<td>max offset 600mm</td>
</tr>
<tr>
<td>SKT SP TL3 (15.24m)</td>
<td>Post 3</td>
<td>4.6m</td>
<td>max offset 600mm</td>
</tr>
<tr>
<td>FLEAT SP TL3 (11.43m)</td>
<td>Post 3</td>
<td>4.6m</td>
<td>offset between 760mm &amp; 1220mm</td>
</tr>
<tr>
<td>Trend 350 TL3 (11.43m)</td>
<td>Post 3</td>
<td>4.24m</td>
<td>max offset 450mm</td>
</tr>
</tbody>
</table>

8.1.3 Short radius curve terminal

Short radius curve treatment for semi-rigid GF can be used at intersecting highways, minor roads and accesses at constrained locations. For details of VicRoads accepted arrangement of a short radius curve terminal treatment, refer VicRoads standard drawing SD 4092. A radius of 2.5m only is accepted. Minimum lengths of GF from radius to point A, point B and C as specified within standard drawing SD 4092 shall be provided to develop the required tension in the w-beam and prevent pocketing. Semi-rigid GF can transition to flexible GF at point B, as seen in VicRoads standard drawing SD 4092.

VicRoads recommends the use of short radius curves on 70km/h roads or less (NCHRP 350 Test Level 2).
Consideration for use in high speed constrained situations may be acceptable where a documented risk assessment is completed and after due consideration of alternative conforming systems.

Access points which cannot be relocated and that must remain open to traffic often prevent the installation of fully effective or compliant safety barrier installations. In such cases, it is critical to provide the most effective barrier installation practical, effectively shielding the primary hazard while adjusting the design to address secondary concerns to the extent practical. In general, short radius curve treatments are considered a better alternative than providing no treatment and less severe for the occupants than, for example, that of a bridge drop off.

A short radius curve treatment aims to redirect a vehicle where possible or absorb the energy of a vehicle impacting at a high angle. To achieve this, it requires frangible (timber) posts to break away, allowing the GF to wrap around the front of a vehicle and bring it to a stop. High angle impacts will deflect significantly allowing the vehicle to travel into a run-out area behind the barrier, refer Figure 8.4. The required run out area is clearly shown on the standard drawings and shall be provided.

Figure 8.4: Short radius curve deflection

Without a run-out area or breakaway posts, the vehicle will essentially be hitting a very stiff system at high speed and at a high angle, resulting in the vehicle to either under-ride the w-beam causing a large amount of occupant ride-down forces, or vault over the barrier into whatever hazard may be behind. In addition, double nesting shall not be provided as this would make the system even more rigid.

Following investigation into the work done by the FHWA (USA), short radius treatments have been successfully crash tested to NCHRP350 Test Level 2: 70km/h and are largely ineffective at higher speeds. Impact speeds above this can cause the vehicle to override or under-ride the barrier and could become more severe for the occupant than the hazard.

Due consideration must be given to the hazard, including consideration of the severity of the hazard, the likelihood of an impact, traffic speed and other appropriate available protection options. The same level of protection could be achieved with an extended barrier and flared crash tested terminal without the concerns from a high speed impact.

### 8.1.4. Terminating motorcycle protection rail

GF products can be retrofitted with motorcycle protection rails to provide protection for riders that slide into the posts following an incident.

As of October 2017, there are three currently approved ‘Motorcycle Safety Products’ available for use in Victoria. The rails need to be terminated appropriately, as to not expose riders to additional risk. Each of the three accepted systems has their own terminals, which may or may not be compatible in configuration with the end terminal on the GF itself.

Polybuffer is the only proprietary system that is accepted for use on barrier terminals. It fits underneath the rail with no bracket connection.

### 8.2. Run out areas

A run out area, beginning at the terminal head and extending a minimum of 18m past the terminal Point of Need and 6m wide, should be provided behind the GF system, as per VicRoads standard drawing SD 3571.

This area should be reasonably traversable and free from fixed object hazards, to allow an errant vehicle that has passed through the “gating” component of the terminal to come to a safe stop, without rollover or subsequent impact with a fixed object.

Designers should endeavour to ensure a run out area is available, including consideration of extending earthworks and providing additional drainage infrastructure to remove any fixed hazards or non-traversable terrain.

Where the desirable run out area cannot reasonably be achieved, a compromised solution may be acceptable. The provision of a run out area, whilst desirable, must never be considered a substitute for providing adequate length of redirection, nor should the desire to provide a run out area affect the choice of GF offsets to hazards, kerbs and traffic lanes.

Desirably the slope of the approach and run out areas should be 10:1 or flatter. Where this is deemed impractical, refer to VicRoads standard drawing SD 3571 for minimum run out area grading details.

A documented risk assessment should be prepared whenever a minimum run out area cannot be provided.

### 8.3. Transition to other safety barrier systems

When connecting GF to a rigid barrier or structure, specially designed transitions are required to effectively and gradually transition the lateral stiffness of the GF, and reduce the potential for vehicle pocketing and snagging at the connection.

Semi-rigid GF can be transitioned to a concrete barrier by decreasing the post spacing and double nesting the w-beams. VicRoads standard drawing SD 4084 and SD 4081 details a standard semi-rigid w-beam GF transition and connection to a bridge end post.

Flexible GF and thrie-beam systems must be transitioned to semi-rigid GF before being transitioned to a rigid barrier (e.g. concrete) in the approach direction. However, a rigid barrier can be transitioned straight to a flexible or semi-rigid barrier on the departure side. Accepted transitions can be found in supplier product manuals.
The use of flexible and semi-rigid Guard Fence

GF cannot be transitioned into wire rope safety barrier (WRSB), and can only be “interfaced” by overlapping the barrier systems.

8.4. Overlapping barriers
When GF systems overlap with WRSB, the interface between the systems must have sufficient clearance between them to ensure neither barrier adversely affects the performance of the other. The leading and trailing points of need for each barrier length should be longitudinally aligned to prevent exposure of any adjacent roadside hazards.

Figure 8.5: Overlapping barriers

9. Design Philosophy
This section describes the approach that should be taken when designing GF installations. The primary aim of a GF design should be to maximise the offset of the barrier from the traffic lane, while providing adequate clearance behind the GF to allow it to deflect on impact.

Ideally a GF installation will provide the desirable offsets to hazards, kerbs and traffic lanes described in Section 5.2. Where site constraints do not permit an ideal installation, the order of preference for reducing offsets and barrier design parameters is as follows:

1. Reduce offset from the traffic lane to GF to a minimum of 3.0m.
2. Adopt minimum offset requirements for barrier deflection (as low as 0.5m for Type B GF) and provide reduced post spacing and/or double nesting as appropriate (refer Section 5.2.3 & Section 6.5).
3. Reduce offset from the traffic lane to GF to an absolute minimum (down to 0.6m) with relevant approvals.
4. Consider the use of alternative terminal products that may provide for a greater length of redirection within the length of terminal.
5. Consider the use of a more rigid barrier system.
6. Undertake an appropriate risk assessment and reconsider removal or relocation of the hazard.

References
Supersedes: RDN 06 – 08 A SEPTEMBER 2015
VicRoads Supplement to AGRD Part 6 – Sections 4.2 to 6.0.
VicRoads Standard Drawings – Guard Fences and Barriers.
VicRoads Standard Section 708 – Steel Beam Guard Fence.
VicRoads Road Design Note 06-04 – Accepted Safety Barrier Products.

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Road Design Notes are subject to periodic review and may be superseded.

Road Design Note 06-08 – Revision Summary

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<td>Major update. Updated to include flexible GF and thrie-beam.</td>
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