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Introduction

Guide rail systems are designed and installed for one primary reason: to reduce the severity of a crash by preventing a vehicle from reaching a more hazardous fixed object or terrain feature. The purpose of this document is to summarize important information contained in PennDOT’s Publication 13M, Design Manual Part 2 (DM-2), Highway Design; Publication 72M, Roadway Construction Standards; and Publication 23, Maintenance Manual into a pocket guide that can be used in the field to ensure that all barrier installations are built and maintained to current standards and can be expected to perform acceptably when hit.

Questions We Must Ask Ourselves

When in the field, we need to ask ourselves the following questions:

1. Is the guide rail system more hazardous than what we are shielding?
2. Is this existing guide rail installation needed?
3. If we terminate the guide rail here – is there a possibility of a vehicle hitting the hazard?
4. If we extend the guide rail – is there another obstruction we could be shielding?
5. Are there any obstructions that are in the guide rail system’s deflection zone?
6. Are we terminating the guide rail within 200 feet of the start of another guide rail string?
7. Are we terminating the guide rail string within 200 feet of a cut slope?
8. Does the slope need any regrading?
9. Has the guide rail height been reset after an overlay?
10. Are we using the best end treatment for the field condition?
11. Are we considering guide rail in sensitive areas such as school playgrounds and reservoirs?
12. Is there adequate backup behind strong post guide rail or are longer posts required?
This document provides the information needed to answer these and other questions pertaining to installation and maintenance considerations for guide rail systems. This publication is not to be considered as a design guide. District highway design personnel should be contacted if design issues occur in the field.

Part 1 - Guide Rail Basics

Roadside Barrier Guidelines

- There are pre-determined situations or conditions where a roadside barrier is normally considered. Refer to the tables on pages 6, 7 and 8 for embankment heights and for fixed-object guidelines within the clear zone.
- These guidelines should be considered in the determination of the need for a roadside barrier rather than absolute criteria.
- They are not a substitute for engineering judgment.
- Roadside barrier guidelines are based on the premise that a roadside barrier should be installed only if it reduces the severity of potential crashes.
- There are instances where it is not immediately obvious whether the roadside barrier or the unshielded condition presents the greater undesirable situation.
- In such instances, roadside barrier guidelines may be established by using a benefit/cost analysis whereby factors such as design speed and traffic volumes can be evaluated in relation to roadside barrier need.
- Costs associated with the roadside barrier (installation costs, maintenance costs, and crash costs) are compared to similar costs associated with the unshielded condition.
- This procedure is typically used to evaluate three options:
  1. Remove or reduce the condition so that it no longer requires shielding,
  2. Install an appropriate roadside barrier, or
  3. Leave the condition unshielded.
Considerations

• Consider eliminating short lengths of guide rail since these sections are often more undesirable than no barrier at all.

• Avoid short gaps between guide rail installations by making guide rail continuous where the points of need are determined to be about 200 feet apart or less.

• Consider keeping the slope clear of fixed objects when guide rail is not required due to the height of the slope.

• Consider guide rail in sensitive areas such as school playgrounds or reservoirs even when they are outside the clear zone, which is discussed next.

Clear Zone

The term "clear zone" is defined as the total roadside border area, starting at the edge of through traveled way, available for safe use by errant vehicles. Safe use generally means the slope is flat enough and free of fixed-object hazards so a motorist leaving the road is able to stop and return to the roadway safely. The clear zone distances shown below represent minimum recommended distances and are based on limited data. The clear zone should be made as wide as economically feasible, preferably as wide as the tabulated distances.
**Since recovery is less likely on the unshielded, traversable 1V:3H slopes, consider removal of fixed objects present beyond the toe of these slopes. Determination of the width of the recovery area provided, if any, at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope.

### Minimum Clear Zone Widths (in feet)

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Design Average Daily Traffic</th>
<th>Foreslope 1V:6H or Flatter</th>
<th>1V:5H to 1V:4H</th>
<th>1V:3H</th>
<th>1V:5H To 1V:4H</th>
<th>1V:6H or Flatter</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 mph or less</td>
<td>750 – 1500</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>1500 – 6000</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>45 – 50 mph</td>
<td>750 – 1500</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>1500 – 6000</td>
<td>16</td>
<td>12</td>
<td>12</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>20</td>
<td>16</td>
<td>14</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>55 mph</td>
<td>750 – 1500</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>1500 – 6000</td>
<td>16</td>
<td>14</td>
<td>16</td>
<td>16</td>
<td>16</td>
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<tr>
<td></td>
<td>Over 6000</td>
<td>22</td>
<td>20</td>
<td>20</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>60 mph</td>
<td>750 – 1500</td>
<td>12</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1500 – 6000</td>
<td>16</td>
<td>14</td>
<td>20</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>65 – 70 mph</td>
<td>750 – 1500</td>
<td>12</td>
<td>14</td>
<td>14</td>
<td>18</td>
<td>16</td>
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<tr>
<td></td>
<td>1500 – 6000</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Over 6000</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>28</td>
<td>30</td>
</tr>
</tbody>
</table>
Barrier Requirements for Embankment Heights

<table>
<thead>
<tr>
<th>EMBANKMENT SLOPE (S=b₁:a₁)</th>
<th>EMBANKMENT HEIGHT (h)</th>
<th>AVERAGE DAILY TRAFFIC (ADT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;5000</td>
<td>5000-751</td>
</tr>
<tr>
<td>1V:1.5H</td>
<td>4.0 ft</td>
<td>6.0 ft</td>
</tr>
<tr>
<td>1V:2H</td>
<td>8.0 ft</td>
<td>10.0 ft</td>
</tr>
<tr>
<td>1V:2.5H</td>
<td>12.0 ft</td>
<td>16.0 ft</td>
</tr>
<tr>
<td>1V:3H OR FLATTER</td>
<td>GUIDE RAIL NOT REQUIRED</td>
<td></td>
</tr>
</tbody>
</table>
Guide Rail Requirements for Fixed Objects Within the Clear Zone

<table>
<thead>
<tr>
<th>Fixed Objects Within the Clear Zone</th>
<th>Barrier Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sign Support (Ground Mounted)</td>
<td></td>
</tr>
<tr>
<td>• Post of Breakaway Design</td>
<td>X</td>
</tr>
<tr>
<td>• Non-Breakaway Design Sign Supports</td>
<td>X</td>
</tr>
<tr>
<td>• Concrete Base Extending 4 inches or More Above Ground</td>
<td>X</td>
</tr>
<tr>
<td>2. Lighting Poles and Supports of Breakaway Design</td>
<td>X</td>
</tr>
<tr>
<td>3. Bridge Piers and Abutments at Underpasses</td>
<td>X</td>
</tr>
<tr>
<td>4. Culvert Headwalls 4 inches or more above ground</td>
<td>X</td>
</tr>
<tr>
<td>5. Trees*</td>
<td>X</td>
</tr>
<tr>
<td>6. Utility Poles*</td>
<td>X</td>
</tr>
<tr>
<td>7. Lighting Poles with High Mast Lighting</td>
<td>X</td>
</tr>
<tr>
<td>8. Retaining Walls**</td>
<td>X</td>
</tr>
</tbody>
</table>

*Exercise sound engineering judgment and consider shielding in some special cases where such obstructions are likely to be hit due to geometric roadway conditions (outside of a curve, steep grade at beginning of a curve, etc.). Shielding should also be considered in sensitive areas such as school playgrounds and reservoirs.

**A judgment decision based on relative smoothness of wall and anticipated maximum angle of impact (refer to AASHTO Roadside Design Guide, Table 5-2).
Options (In order of preference)

- **Remove** the obstruction.
- **Redesign** the obstruction so it can be traversed safely.
- **Relocate** the obstruction to a point where it is less likely to be struck.
- **Reduce** impact severity by using an appropriate breakaway device or impact attenuator.
- **Shield** the obstruction with a longitudinal traffic barrier if it cannot be eliminated, relocated or redesigned.
- **Delineate** the obstruction if the above alternatives are not appropriate.

REMEMBER: Guide rail can also be a hazard and should only be used where the results of leaving the roadway and overturning or striking a fixed object would be more severe than the consequence of striking the barrier.

Types of Barrier

**Flexible Systems:** Weak Post W-Beam Guide Rail Types:

- 2-W (normal post spacing)
- 2-WC (close post spacing)
- 2-WCC (very close post spacing)

**Semi-Rigid Systems:** Strong-Steel Post W-Beam Guide Rail with Wood or Plastic Block Types:

- 31-S (normal post spacing)
- 31-SC (close post spacing)
- 31-SCC (very close post spacing)

**Rigid Systems:** Permanent Concrete Barrier

**Weak Post Guide Rail** (2-W, 2-WC, and 2-WCC) should be used if the minimum unobstructed distance behind the rail is available. See Deflection Table on page 18.

**Weak Post Systems** should not be used if the fill slope is steeper than 1V:2H. Weak post guide rail shall not be used around radii at intersections where it can be hit at severe impact angles.
**Strong Post Guide Rail** (31-S, 31-SC, 31-SCC) should be used when the minimum unobstructed distance behind the rail is not adequate to permit the use of a weak post system. See Deflection Table on page 18.

**Type 31 Strong Post Guide Rail**

Mixing of strong post and weak post systems in the same run of guide rail is to be used only when the proper transition treatment between systems can be provided, as shown on the Standard Drawings. Frequent transitions between strong post and weak post systems should be avoided. Refer to page 23 for more information.

**High-Tension Cable Median Barrier** is installed with a significantly greater tension in the cables than generic three-cable systems. The deflection of these systems depends on the type of system and the post spacing. The high-tension systems also result in less damage to the barrier and usually the cables remain at the proper height after an impact that damages several posts. The posts can be installed in concrete sleeves in the ground to facilitate removal and replacement. The table on page 13 presents guidelines for high-tension cable barrier systems.
High Tension Cable Median Barrier

Currently there are only proprietary systems of cable barriers which are to be used in median applications. Examples follow below. These high tension cable median barriers are compliant only with NCHRP Report 350 and are shown for illustration purposes only. The examples of high tension cable median barriers will be updated as MASH compliant systems become available.

Brifen Wire Rope Safety Fence (WRSF) by Brifen USA

Top Rope Height: 36 ½”

Deflection Distance as tested under NCHRP Report 350:

- Small car: 4' - 5 1/8" for 10' - 6" post spacing.
- Single-unit truck: 7' - 3" for 10' - 6" post spacing.
- Pick-up truck: 7' - 10 1/2" for 10' - 6" post spacing.

Foundation Type: Posts are set in tubular steel sockets contained in cylindrical concrete footings. Lower 3 cables weave between posts.

Gibraltar

Top Rope Height: 39”

Deflection Distance tested under NCHRP Report 350:

- Small car: 2' - 6" for 15' post spacing (TL-3).
- Single-unit truck: 7' for 14' post spacing (TL-4).
- Pick-up truck: 8' - 7 1/4" for 15' post spacing (TL-3).

Fourth cable is anchored. Taper the 25-inch high cable down to the bottom (20-inch) cable between the first line post and the last terminal post and connect the two cables with a series of four clamps spaced 4.5 inches apart along the 20-inch high bottom cable.

(Note: 3 cable design is shown).

Foundation Type: Line post can be driven or socketed. Posts are set on alternate sides of cables.
Safence by Gregory Highway Products

Top Rope Height: 28 3/8”
Deflection Distance as tested under NCHRP Report 350:

- Pick-up truck: 6’-10 5/8” for 13’-2 3/8” post spacing.

Fourth cable is anchored with its own connection to the concrete terminal block.
Foundation Type: Socketed

CASS by Trinity

Top Rope Height: 29”
Deflection Distance as tested under NCHRP Report 350 for CASS TL-3:

- Pick-up truck: 7’- 8 7/8” for 20’ post spacing.

A four-cable design adds a fourth cable midway between the bottom and middle cables to the CASS TL-4 system.
Foundation Type: The CASS system posts can be driven, installed in a driven sleeve, installed in a sleeve in a concrete footing (poured or pre-cast), or mounted to a concrete surface.

Nu-Cable by Nucor Marion Steel

Top Rope Height: 35”
Deflection Distance as tested under NCHRP Report 350:

- Small-car: 4’ - 7 1/8” for 20’ post spacing.
- Single-unit truck: 7’ - 6 1/8” for 20’ post spacing.
- Pick-up truck: 9’ - 6 1/8”
Foundation Type: Socketed
## Design/Location Table for High Tension Cable Barrier Systems

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>GUIDELINE</th>
</tr>
</thead>
</table>
| **Crash Requirements** (NCHRP Report 350) | • Cable Barriers: Test Level 4 (TL-4), minimum.  
• End Anchor Terminals: Test Level 3 (TL-3), minimum. |
| **Number of Cables** | • 4 cables, minimum. |
| **Post Spacing (maximum)** | • 10 ft |
| **Median Width (minimum)** | • Slopes 6:1 to 10:1 - 36 ft  
• Slopes 10:1 or Flatter - 24 ft |
| **Median Slope** | • 6:1 or flatter.  
• For median slopes 4:1 to 6:1, consult with Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section. |
| **Deflection** | • Barrier placement location needs to account for the deflection limits of the system used.  
• Deflections from a hit in any direction should not encroach into a travel lane.  
• Do not specify maximum allowable dynamic deflections greater than 8 ft. |
| **Barrier Placement (Swale Line)** | • Slopes 6:1 to 10:1 - Not within 8 ft of swale line.  
• Slopes 10:1 or Flatter - Not within 2 ft of swale line.  
• Do not locate posts or end anchors in saturated soils. |
| **Barrier Placement (Shoulder versus Center)** | • For slopes greater than 6:1, install two systems in median.  
• For 6:1 slopes or flatter, install one system in median.  
• Place high-tension cable barrier systems a minimum of 10 ft and preferably 12 ft or more from the edge of traveled way.  
• For additional guidance, see the AASHTO Roadside Design Guide, Section 6.6 (Placement Recommendations). |
| **Maximum Distance Between Anchors** | Varies by manufacturer and system. |
| **Transitions to Existing Barrier Systems** | If encountered, needs to be addressed. Examples include bridge piers, sign structures, concrete median barrier, W-beam guide rail, dual structures with barrier dikes, etc. Consult with the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section for guidance. |
| **Footings** | Contractor to provide for a design to account for the anticipated soil type and to be sealed by a Professional Engineer (P.E.) licensed in Pennsylvania. |
Length of Need (LON) is defined as the length of barrier needed in advance (upstream) of a fixed object hazard or a non-traversable terrain feature to prevent a vehicle that has left the roadway from reaching the shielded feature. It is determined by selecting the appropriate variables and using the formula on page 15 to calculate the LON (the "X" value) shown in the diagram below.

\[ X = \text{Distance from the obstruction to end of barrier need.} \]
\[ Y = \text{Distance from edge of through traveled way to end of barrier need.} \]
\[ LA = \text{Distance from edge of through traveled way to lateral extent of obstruction.} \]
\[ L_1 = \text{Tangent length of barrier upstream from obstruction.} \]
\[ L_2 = \text{Distance from edge of through traveled way to barrier.} \]
\[ L_3 = \text{Distance from edge of through traveled way to obstruction.} \]
\[ LC = \text{Distance from edge of through traveled way to outside edge of the clear zone.} \]
\[ LR = \text{The theoretical Runout Length needed for a vehicle leaving the roadway to stop.} \]
\[ a:b = \text{Flare Rate.} \]

See DM-2 Figure 12.3 and RC-54M, Sheet 3.
Length of Need Procedure:

1. Choose an appropriate $L_A$ as it is a critical part of the evaluation process. This distance should include all features or hazards that need to be shielded, up to the clear zone at each site.

2. Select a Runout Length ($L_R$) from the table below.

3. Select Tangent Length ($L_1$). If a semi rigid barrier is connected to a rigid barrier, the tangent length should be at least as long as the transition section. See page 9 for types of barrier.

4. If the barrier is flared away from the roadway, the maximum recommended flare rate shown on page 19 should not be exceeded.

5. Calculate the Length of Need ($X$) from the following equation and round the calculated value up to the nearest 12.5-foot or 25-foot rail segment:

$$X = \frac{L_A + \left(\frac{b}{a}\right)(L_1) - L_2}{\left(\frac{b}{a}\right) + \left(\frac{L_A}{L_R}\right)}$$

6. For parallel installations i.e. no flare rate, the previous equation becomes:

$$X = \frac{L_A - L_2}{\left(\frac{L_A}{L_R}\right)}$$

Runout Lengths

<table>
<thead>
<tr>
<th>DESIGN SPEED (mph)</th>
<th>DESIGN TRAFFIC VOLUME (ADT)</th>
<th>800 &amp; UNDER</th>
<th>801 - 2000</th>
<th>2001 - 6000</th>
<th>OVER 6000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L_R^*$</td>
<td>$L_R^*$</td>
<td>$L_R^*$</td>
<td>$L_R^*$</td>
<td>$L_R^*$</td>
</tr>
<tr>
<td>70</td>
<td>360</td>
<td>395</td>
<td>445</td>
<td>475</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>330</td>
<td>345</td>
<td>400</td>
<td>425</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>280</td>
<td>315</td>
<td>345</td>
<td>360</td>
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<tr>
<td>50</td>
<td>245</td>
<td>260</td>
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<td>45</td>
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<tr>
<td>30</td>
<td>130</td>
<td>150</td>
<td>165</td>
<td>165</td>
<td></td>
</tr>
</tbody>
</table>

*L_r = Runout Length in feet
See DM-2 Table 12.9
Length of Need for Opposing Traffic

- X is determined using the same equation.
- All lateral dimensions are measured from the centerline for a two-lane roadway. See the layout at the bottom of this page.
- Three ranges of clear zone width, $L_C$, that deserve special attention:
  1. If the barrier is beyond the appropriate clear zone for opposite direction traffic, no additional barrier and no crashworthy end treatment is needed. (NOTE: an appropriate barrier anchor remains necessary to ensure proper containment and redirection for near-side impacts).
  2. If the barrier is within the appropriate clear zone but the area of concern is beyond it, no additional barrier is needed; however, a crashworthy end treatment should be used.
  3. If the area of concern extends well beyond the appropriate clear zone (e.g., a river), an option may be to shield only that portion which lies within the clear zone, by setting $L_A$ equal to $L_C$.

Approach Barrier Layout for Opposing Traffic

See DM-2 Figure 12.4 and RC-54M
Length of Need (LON) Field Check

A straightforward method to verify correct LON in the field is to stand on the roadway edge directly opposite the shielded feature, and then pace off the appropriate runout length from the Runout Lengths Table on page 15. At that point, turn and look at the shielded area. If the proposed (or actual) guide rail installation crosses that line of sight, then the area is adequately covered. (NOTE: if the terrain makes it impossible for a vehicle to reach the hazard from that point, the installation may be too long. On the other hand, if the intervening terrain is also hazardous or if there are other significant obstacles in the immediate vicinity, it may be desirable to extend the barrier to shield all of the dangerous conditions.)

Additional Considerations

Although it is critical that the correct LON be installed, there are several other placement considerations essential to good barrier performance. These placement considerations are discussed below.

Design Deflection Distance is based on the results of 62-mph impacts into the barrier at a 25° impact angle by the two-wheel drive, four-door, half-ton pickup truck used in the Manual for Assessing Safety Hardware (MASH) procedures. In the field, actual deflections can be much greater (or less) depending on actual impact conditions.
## Deflection Table
*(Minimum Unobstructed Distance)*

<table>
<thead>
<tr>
<th>Type</th>
<th>Deflection (ft)</th>
<th>Post Spacing (ft-in)</th>
<th>Mounting Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-W</td>
<td>9</td>
<td>12' - 6&quot;</td>
<td>32&quot;</td>
</tr>
<tr>
<td>2-WC</td>
<td>6.5</td>
<td>6' - 3&quot;</td>
<td></td>
</tr>
<tr>
<td>2-WCC</td>
<td>5.5</td>
<td>3' - 1 ½&quot;</td>
<td></td>
</tr>
<tr>
<td>Semi-Rigid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31-S</td>
<td>4</td>
<td>6' - 3&quot;</td>
<td>31&quot;</td>
</tr>
<tr>
<td>31-SC</td>
<td>3</td>
<td>3' - 1 ½&quot;</td>
<td></td>
</tr>
<tr>
<td>31-SCC</td>
<td>1.5</td>
<td>1' - 6 ¾&quot;</td>
<td></td>
</tr>
<tr>
<td>Rigid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Barrier</td>
<td>0</td>
<td>-</td>
<td>32&quot; or 50&quot;</td>
</tr>
</tbody>
</table>

*Measured from the rear face of the guide rail post to the front face of the obstruction.

### Height Measurement
The minimum height of strong post w-beam guide rail (31-S) is 31 inches, measured as shown below or from the gutter line when set above a curb. For optimum performance refer to the graphic in the section "Barrier Placement on Slopes."
Guide Rail Flare Rates

- A roadside barrier is considered flared when it is not parallel to the edge of traveled way.
- The flare is normally used to locate the barrier terminal farther from the roadway and/or to reduce the total length of barrier needed.
- Disadvantages are it increases the angle of impact when struck and may require extensive site grading to ensure a flat approach.

Flare Rates for Barrier

<table>
<thead>
<tr>
<th>Design Speed (mph)</th>
<th>Maximum Flare Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concrete Barrier</td>
</tr>
<tr>
<td>70</td>
<td>20:1</td>
</tr>
<tr>
<td>65</td>
<td>19:1</td>
</tr>
<tr>
<td>60</td>
<td>18:1</td>
</tr>
<tr>
<td>55</td>
<td>16:1</td>
</tr>
<tr>
<td>50</td>
<td>14:1</td>
</tr>
<tr>
<td>45</td>
<td>12:1</td>
</tr>
<tr>
<td>40</td>
<td>11:1</td>
</tr>
<tr>
<td>35</td>
<td>10:1</td>
</tr>
<tr>
<td>30</td>
<td>8:1</td>
</tr>
</tbody>
</table>

See RC-54M
Barrier Placement on Slopes
Barrier, regardless of type, performs best when an impacting vehicle is stable when contact is first made. Since vehicles running off the road at high speeds tend to become airborne and are likely to override barrier placed on a slope, the following guideline should be followed:

For Optimum Performance

Guidelines for Barrier on Slopes

- Do not place guide rail on slopes steeper than 1V:6H.
- W-beam systems can be placed anywhere on 1V:10H or flatter slopes.
- When the slopes are between 1V:10H and 1V:6H, the face of the barrier must not be between 2 to 12 feet beyond the grade hinge point.
- Strong post systems need 2 feet of soil support behind the rail for support. When 2 feet is not obtainable, strong posts that are a minimum of 1 foot longer shall be provided.
- Cable barrier can be placed on a 1V:6H slope or flatter, so long as it is not within the specified distances of a swale line (see table on page 13). Most proprietary systems can be placed on 1V:4H slopes, but manufacturers' recommendations must be followed.
Guide Rail and Curb

Curbs do not have a significant redirection capability and can have the same type effect on vehicle trajectory as slopes, i.e., wheel impact with a curb can cause a vehicle to vault over a barrier placed above or beyond it. The following guidelines apply:

• Curb is not recommended for high speed (45 mph and higher) roadways.
• When guide rail/curb installation is unavoidable, keep curb height to a maximum of 4 inches and use strong post guide rail.
• If the curb exceeds 4 inches, follow these guidelines:
  1. Type 31-SC guide rail should be used.
  2. Stiffen the guide rail
     o Add a rubrail or
     o Double nest the rail or
     o Bolt a W-beam to back of the posts
  3. Curb must be flush with the face of guide rail.
  4. The guide rail height is measured from the gutter line to the top of rail when the guide rail is placed in front of or at the face of the curb.
Guide Rail and Trees

- Generally, guide rail should not be used to shield a line of utility poles or trees.
- Where guide rail is used in front of poles or trees due to other obstructions, use the Deflection Table on page 18.
- Consider removing trees where they are an obstruction and in locations where they are likely to be hit.
- Use crash history at similar sites, scars indicating previous crashes or field views to determine removable trees.
- Tree removal is usually a preferred option but an assessment regarding its expense and effectiveness should be considered.
- Roadways through wooded areas with heavy nighttime traffic volumes, frequent fog and narrow lanes should be well delineated.
- Pavement markings and post mounted delineators are among the most effective and least costly improvements that can be made to a roadway.
Guide Rail Transitions

If a transition is not used or is not properly placed, a vehicle may deflect the more flexible system and pocket or snag on the stiffer section.

- When guide rail approaches an obstacle that requires a stiffer, stronger system, introduce 25-foot increments of stronger guide rail systems for a gradual increase in strength.

- Frequent transitions between strong post and weak post systems should be avoided.

For example, a transition from weak post guide rail to an obstruction with 1 foot, 6 inches of deflection distance consists of the following:

- Type 2-W (12’-6” post spacing) to
- 25 feet of Type 2-WC (6’-3” post spacing) to
- 25 feet of Type 2-WCC (3’-1 ½” post spacing) to
- 25 feet of Type 31-S (6’-3” post spacing) to
- 25 feet of Type 31-SC (3’-1 ½” post spacing) to
- Type 31-SCC (1’-6 ¾” post spacing) in front of the obstruction

NOTE: The number and types of transitions depend upon the obstruction's deflection distance.

See RC-50M and RC-54M for more information.
Connections to Bridge Barriers

Since there are numerous bridge barrier types currently in place on Pennsylvania highways, the attachment details shown in the RC Standards for new construction and reconstruction will not always be directly applicable for every project. However, crashworthy systems can be developed if three concerns are met: an adequate transition between the bridge end and the approach guide rail; an adequate attachment to the bridge barrier itself; and the elimination of any potential snag points at the bridge end.

- A transition is simply a gradual stiffening of the approach guide rail at the bridge end so the rail cannot deflect enough to result in a vehicle "pocketing" when it reaches the rigid bridge barrier. Acceptable transitions for some specific existing bridge barriers are shown in DM-2, Chapter 12, Appendix A.

- A structurally adequate attachment of the guide rail to the bridge barrier is shown on the transition details as well. This detail is needed to prevent the approach railing from pulling free from the bridge barrier. In some cases, the existing bridge barrier itself may not be structurally adequate to support such a connection. For many such structures, extending the guide rail across the structure eliminates the need for a structural connection at the bridge end and may increase the capacity of the bridge barrier itself.

- Finally, if the bridge barrier is significantly higher than the approach railing, a truck or SUV impacting the approach railing could lean over the railing far enough to snag on the end of the bridge barrier. Also, if no rubrail is used, a vehicle's tire could fold under the guide rail and snag on the bottom edge of the bridge parapet.
Part 2 - Special Cases

Omitted Post(s)
These configurations can be used when site conditions do not permit standard spacing of guide rail posts. Typical situations are locations where barrier must be continuous over a low-fill culvert, span a buried utility line, or where isolated rock prevents driving a post.

The RC Standards (RC-51M, Type 31 Strong Post Guide Rail) depicts three long-span systems where strong posts are omitted across culverts and small structures:

- One omitted post (i.e., 12-foot, 6-inch long span)
- Two omitted posts (i.e., 18-foot, 9-inch long span)
- Three omitted posts (i.e., 25-foot, 0-inch long span)
Nested Panels

Semi-rigid systems such as guide rail can be stiffened locally by reinforcing the W-beam or thrie-beam rail element with a nested rail. A nested rail uses a double section of W-beam (or thrie-beam), where one W-beam (or thrie-beam) is nested inside the other. W-beam and thrie-beam rail elements are typically nested as part of transitions, including guide rail to bridge barrier transitions (refer to RC-50M).

Also, W-beam and thrie-beam rail elements may be nested for stiffening as a last resort. For example, nesting for stiffening may be considered to shield isolated fixed objects located near the rail. Nesting may provide stiffening and thus reduces deflections, if needed, and if no other reasonable options are available.

When nested guide rail is specified, provide at least 200 feet of Type 31-S Guide Rail between nested runs.

Typical Nested Panel

NOTE: Two sections of W-beam rail element, one set inside the other. Splice connection shown.
Guide Rail at Intersections and Driveways

W-beam strong post guide rail is often considered for installation between a main highway and an intersecting roadway or driveway. Typically, the W-beam guide rail is parallel with the main highway and is connected to curved W-beam guide rail, along a short radius, at the intersecting roadway or driveway.

**Type 31 Strong Post In-Line Anchor:**
Along the main highway, the W-beam strong post guide rail needs to be in tension, so impacting vehicles will be contained and redirected. Tension may be accomplished by providing a Type 31 Strong Post In-Line Anchor. This anchor adds a cable anchorage, with the anchor located at the post before the guide rail radius begins. The Type 31 Strong Post In-Line Anchor should be used at intersections and driveways, except when less than 25 ft from a bridge or other anchorage.

The Type 31 Strong Post In-Line Anchor may be used in conjunction with the following:

- Curved W-Beam Guide Rail at Intersections (see page 30), with long breakaway timber posts
- Treatment at Intersections and Driveways (see page 29)

RC-54M provides construction details of a Type 31 Strong Post In-Line Anchor along the main highway.

**Guide Rail with Short Radius:**
The guide rail with a short radius may be considered for installation at the following locations:

- Treatment at Intersections. A roadway may approach and intersect with a main highway, coming to a stop condition. In this situation, the following treatments may be considered:
  1. A Terminal Section, Single, flared with a 4-foot offset, may be used for local and minor collector roadways coming to a stop condition, excluding signals, with an Average Daily Traffic (ADT) ≤ 2,000 vehicles per day and cannot be used beyond the immediate intersection.
2. A Type 31 Strong Post End Treatment or "turndown" may be used on non-NHS highways coming to a stop condition when all of the following apply:
   a. The posted speed limit is ≤ 45 mph.
   b. The ADT is ≤ 2000 vehicles per day.
   c. The turndown is not in a high crash location.
3. Install an impact attenuating device on all NHS highways and in high crash locations. Impact attenuating devices may be used in all situations if deemed appropriate.
   • Curved W-Beam Guide Rail at Intersections. This installation extends from the strong post guide rail along the main highway along a radius ≤ 35 feet to an intersecting roadway. Page 30 provides construction details. The curved W-beam guide rail is to be bolted to long breakaway timber posts. The area behind the curved W-beam guide rail should desirably be maintained free of fixed objects or hazards.
   RC-54M provides construction details for guide rail with a short radius.
Provide type and length of guide rail and end treatment beyond the intersection radii as indicated on the construction drawings and determined by design.

Intersecting Side Road

Tie-in to Existing Guide Rail

R=17'-0" MIN.

Type 31 Strong Post
In-line anchor* (See Note 7)

R=8'-6" MIN.

Guide rail may be terminated here (outside the clear zone if possible) with proper end treatment (See Note 4).

End treatment or terminal section, single

*See RC-51M, Sheets 4 thru 7 of details and hardware for Type 31 strong post in-line anchor.

**May possibly decrease to 8'-6" in future DM-2 updates.

Treatment at Intersections and Driveways

Notes:

1. On the 8’-6” radius system in the curved W-beam guide rail at intersections detail, the rail is not to be bolted to the center post.

2. Radius panels must be shop bent only.

3. Do not use any washers on the rail side of the long breakaway posts.

4. For guide rail terminated on the main highway, use a proper end treatment in place of an in-line anchor.

5. A terminal section, single may be used for local and minor collector roadways coming to a stop condition, excluding signals, with an average daily traffic (ADT) ≤ 2000 vehicles per day and cannot be used beyond the immediate intersection.

6. A Type 31 strong-post end treatment or *turndown* may be used on non-nhs highways coming to a stop condition when all of the following apply:
   a. The posted speed limit is ≤ 45 MPH.
   b. The ADT is ≤ 2000 vehicles per day.
   c. The turndown is not in a high crash location.

7. Long breakaway timber posts are not needed at intersections with guide rail radius > 35’.

See RC-54M
CURVED W-BEAM GUIDE RAIL AT INTERSECTIONS

<table>
<thead>
<tr>
<th>GUIDE RAIL RADIUS</th>
<th>TYPICAL NUMBER OF LONG BREAKAWAY TIMBER POSTS</th>
<th>MIN. DESIRED AREA FREE OF FIXED OBJECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8&quot; - 6&quot;</td>
<td>5</td>
<td>25&quot; x 15&quot;</td>
</tr>
<tr>
<td>17&quot; - 6&quot;</td>
<td>6</td>
<td>30&quot; x 15&quot;</td>
</tr>
<tr>
<td>25&quot; - 6&quot;</td>
<td>9</td>
<td>40&quot; x 20&quot;</td>
</tr>
<tr>
<td>35&quot; - 6&quot;</td>
<td>11</td>
<td>50&quot; x 20&quot;</td>
</tr>
</tbody>
</table>

**NOTES**

1. ON THE 8" - 6" RADIUS SYSTEM IN THE CURVED W-BEAM GUIDE RAIL AT INTERSECTIONS DETAIL, THE RAIL IS NOT TO BE BOLTED TO THE CENTER POST.
2. RADIUS PANELS MUST BE SHOP BENT ONLY.
3. DO NOT USE ANY WASHERS ON THE RAIL SIDE OF THE LONG BREAKAWAY POSTS.
4. FOR GUIDE RAIL TERMINATED ON THE MAIN HIGHWAY, USE A PROPER END TREATMENT IN PLACE OF AN IN-LINE ANCHOR.
5. A TERMINAL SECTION, SINGLE MAY BE USED FOR LOCAL AND MINOR COLLECTOR ROADWAYS COMING TO A STOP CONDITION, EXCLUDING SIGNALS, WITH AN AVERAGE DAILY TRAFFIC (ADT) < 2000 VEHICLES PER DAY AND CANNOT BE USED BEYOND THE IMMEDIATE INTERSECTION.
6. A TYPE 31 STRONG-POST END TREATMENT OR "TURNIDOWN" MAY BE USED ON NON-HHS HIGHWAYS COMING TO A STOP CONDITION WHEN ALL OF THE FOLLOWING APPLY:
   a. THE POSTED SPEED LIMIT IS < 45 MPH.
   b. THE ADT IS < 2000 VEHICLES PER DAY.
   c. THE TURNIDOWN IS NOT IN A HIGH CRASH LOCATION.
7. LONG BREAKAWAY TIMBER POSTS ARE NOT NEEDED AT INTERSECTIONS WITH GUIDE RAIL RADIUS > 35".

See RC-54M
Crashworthy End Terminals

Crashworthy end treatments prevent errant vehicles from impacting fixed objects by either gradually decelerating the vehicle to a stop when hit head-on, or by redirecting it away from the shielded object or terrain feature when the barrier is struck on the traffic face near the terminal.

Acceptable crashworthy end treatments include:

- **Type I** - Anchored in Backslope Terminal
- **Type II** - Energy Absorbing Terminals
- **Type III** - Non-Energy Absorbing Terminals
- **Type IV** - Gating Systems for Two-Way Traffic
- **Type V** - Non-Gating Systems for Two-Way Traffic
- **Type VI** - Gating, Non-Redirective Crash Cushions

For proprietary terminals, field personnel should obtain or consult the manufacturer's field installation manuals.

**Classifications:**

- **Energy Absorbing** terminals stop vehicles safely in relatively short distances in end-on impacts (usually 50 feet or less depending on type of terminal).
- **Non-Energy Absorbing** systems will allow an unbraked vehicle to travel 150 feet or more behind and parallel to guide rail installation or along the top of the barrier when struck head-on at high speeds.

**Flared:** A 4-foot parabolic (curved) offset at the approach end, which requires a larger area for placement.

**Tangent:** Installed parallel to the shoulder with a 2-foot offset over the first 50 feet of length.

**NOTE:**

- At the trailing end of guide rail, a distance of 50 feet beyond the end treatment is to be kept clear of all roadside obstructions.
- This "downstream clear zone" is intended to minimize the likelihood that a vehicle may be directed into an obstruction by the barrier.
• On two-lane highways with two-way traffic, both the adjacent traffic and opposing traffic could impact the guide rail ends. Therefore, if either of the ends are within the clear zone and/or likely to be hit by an errant vehicle, a crashworthy end treatment is required with the exception of the "turndown" or Terminal Section, Single as described on page 27 in the section "Guide Rail with Short Radius". Regardless, if crashworthy end treatments are required, both guide rail ends still require approved end treatments in order to anchor the system.

• On divided highways, crashworthy end treatments are not required on the trailing end of the guide rail if the end is outside the clear zone of opposing traffic and/or unlikely to be hit by an errant vehicle.

All ends of weak post guide rail must have an appropriate transition to reduce deflection when a more rigid end treatment is used.

Crashworthy End Treatments by Type

For a listing of prequalified materials that are eligible for use on Department construction projects, refer to PennDOT Publication 35, Qualified Products List for Construction (Bulletin 15).

Crashworthy terminals are classified as non-gating or gating by design. A nongating system will gradually stop or redirect a vehicle away from a fixed object, while a gating terminal allows a vehicle to pass through after impact when the tension in the system is released.
Type I – Anchored in Backslope Terminal

- The most desirable method to terminate guide rail is to bury the end in a back slope that is a minimum of 1V:3H, but preferably steeper.
- Must maintain full height of guide rail in relation to roadway. If the distance from the bottom of the rail to the ground exceeds 18 inches, a second W-beam rail must be added.
- Should also be used when the barrier system's LON would normally end downstream of a cut slope if the cut slope is within 200 feet and there is not a large runout area (200 feet x 50 feet) available.

See RC-54M

Note that the height of the guide rail is held constant.
Type II – Energy Absorbing Terminals and 
Type III – Non-Energy Absorbing Terminals

- Used for single runs of strong post*
- Redirection begins beyond the third post

See pages 38-39 for grading details.

MASH Approved Type II Terminals (Tangent)
- MAX-Tension End Terminal (MAX-Tension)
- MASH Sequentially Kinking Terminal (MSKT)

MASH Approved Type II Terminals (Flared)

MASH Approved Type III Terminals

As of the date of the issuance of this publication, Bulletin 15 does not list any approved terminals in these categories. Refer to Bulletin 15 for updates.
Type IV – Gating Systems for Two-Way Traffic
• Used for double-faced strong post* guide rail, and concrete median barrier
• Minimum width of 10 feet needed
• Redirection varies for each device
• Can be permanent or temporary

*Must have appropriate transition to Type 31-S Guide Rail before installing Types II, III or IV end treatments.

Type V – Non-Gating System for Two-Way Traffic
• Used for concrete median barrier, double-faced strong post guide rail, and other obstructions
• Used in narrow or wide roadway medians
• Redirection begins at approach end
• Can be permanent or temporary
Type VI – Gating, Non-Redirective Crash Cushions

- Does not redirect vehicles
- Sand is used to shield wide obstructions up to 13 feet
- Water is used in non-redirection and not in medians with opposing traffic

Non-Crashworthy Terminals

Non-crashworthy terminals include the following:

- Type 31 Strong Post Anchor Terminals
- Turndowns
- Terminal Section, Single

Type 31 Strong Post Anchor Terminals

- Can be used at the trailing end of Type 31 Strong Post Guide Rail on divided highways when located outside the clear zone of opposing traffic and/or is unlikely to be struck by an errant vehicle of opposing traffic.
- Can be used at the trailing end of Type 31 Strong Post Guide Rail on one-way roadways if it is unlikely to be struck by intersecting traffic (such as intersections).

Refer to details in RC-51M.

Turndowns

- For highways on the National Highway System (NHS), can be used only on the trailing end of guide rail on divided highways when opposing traffic will not be able to impact the trailing end of the guide rail system.
• For non-NHS, divided highways, can be used on the trailing end of guide rail when opposing traffic will not be able to impact the trailing end of the guide rail system.

• For non-NHS, non-divided highways, can be used when all of the following apply:
  (1) The posted speed limit is ≤ 45 mph.
  (2) The current traffic volume is ≤ 2,000 vehicles per day.
  (3) The turndown is not in a high crash location.

Refer to details in DM-2, RC-51M (Type 31 Strong Post End Treatment) and RC-53M (Type 2 Weak Post End Treatment).

**Terminal Section, Single**

• May be used at driveways and access points.

• May be used as flared with a 4-foot offset for local and minor collector roadways coming to a stop condition, excluding signals, with an Average Daily Traffic (ADT) volume ≤ 2,000.

**Terminal Grading Details**

A barrier terminal is most likely to perform best when a vehicle is stable at the moment of impact and there is a traversable runout area immediately behind the terminal. Whenever practical, a barrier should be extended until these conditions can be met.

When a grading platform must be built, it is critical that it be built to blend with the original embankment and not cause instability in a vehicle before, during, or after a crash into the terminal. The following drawings show minimum grading requirements for parallel and flared terminals, respectively.
Grading Requirements for Terminals

For further details see RC-54M
Grading Requirements for Terminals

For further details see RC-54M
Guide rail systems must be kept in good working condition (near to "as-built condition") if they are to contain and redirect impacting vehicles. Some deterioration will occur as a result of crash damage and environmental degradation. Much of this damage can be considered "cosmetic" and will not measurably affect barrier performance. However, some kinds of damage may seriously degrade performance such as those listed below in the Longitudinal Barrier Damage and Terminal Damage sections. Repairs to these kinds of noted damage should be given priority.

The Department's Publication 23, Maintenance Manual, states, "Inspections should be made at least twice a year, in the spring after the snow season is over, and in the fall prior to the snow season. These inspections should be concerned with alignment, appearance and general condition. Any sections in need of repairs or maintenance should be noted and scheduled for repair by the County Manager."

On interstates/expressways particular emphasis is to be placed on completing necessary springtime guide rail system repairs following the winter maintenance season by the date specified in Publication 23, Maintenance Manual, especially those repairs that could not physically be made over the winter months.

In general, subsequent damage to guide rail that follows completed springtime repairs should also be repaired in a timely manner throughout the year. This includes completing appropriate repairs or replacements before the winter season begins and the ability to address them is lost until the following spring.

Note, while it is not practical to quantitatively define "in a timely manner," each identified, damaged barrier site needs to be assessed, prioritized and scheduled for repairs based upon risk exposure (highway type, kind of barrier/terminal damage, potential for being restruck in the interim, etc.).
Longitudinal Barrier Damage

The following examples of guide rail damage can result in inadequate structural and redirection performance:

- Vertical tears in the W-beam rail that begin at the top or bottom edge. These are likely to result in rail separation in a crash.
- Similarly, holes in the rail resulting from damage or deterioration that reaches the top or bottom of a rail or one hole with a height greater than 1 inch or several holes with a height less than 1 inch within a 12.5-foot length of rail.
- More than 1 missing or ineffective splice bolt.
- More than 9 inches of lateral deflection over a 25-foot length of rail.
- Top rail height more than 2 inches lower than the original rail height.
- Rail flattening that increases the W-beam section width from its original 12 inches to 18 inches or more.

Terminal Damage

The following examples of guide rail terminal damage can result in inadequate end anchorage and engineered design performance:

- Broken or damaged end post.
- Missing or very slack rail-to-end post cable.
- Missing bearing cable plate at end post.
- Impact head not properly aligned with W-beam rail element.
- W-beam rail element not properly seated in impact head.
- W-beam rail damage within the length of the terminal that may cause malfunction of the terminal during impact.
Repair/Upgrade/Remove

When a guide rail or terminal is damaged to the point where repairs are needed, several questions should be asked before the damaged hardware is simply replaced in-kind:

- Is the barrier needed or could it be removed?
- Does the barrier meet current design standards or should it be upgraded?
- Is the terminal an acceptable crash-tested design? (NOTE: the Breakaway Cable Terminal (BCT) should be replaced).
- If crashworthy, is the terminal the most appropriate type for the location? (NOTE: Non-energy absorbing terminals require a significant traversable runout area behind and parallel to the rail; energy absorbing terminals require less runout distance).
- Is the terminal acceptable where it is being used? (Refer to pages 36-37 for Terminal Section, Single or turndown).
Guide Rail References


