



Transportation Association of Canada

Guidelines on the Use and Installation of Chevron Alignment Signs

August 2012

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| Abstract <p>The safety risks associated with horizontal curves are generally related to roadway departures. Vehicles leaving the roadway and striking fixed objects such as trees, utility poles or rockfaces typically result in high severity or fatal collisions. From a road safety perspective, failure to slow to an appropriate speed is a major cause of collisions on rural curves. Sharp curves on high speed rural roads tend to be more hazardous, as well as areas with relatively low levels of illumination during night time.</p> <p>Providing enhanced guidance for motorists is therefore important in reducing collisions at horizontal curves. Chevron alignment signs, among various traffic control devices, may be considered for improving warning and guidance where there is a change in the horizontal alignment of a roadway.</p> <p>The intent of these guidelines is to provide engineers and practitioners, across Canada, with the understanding of the key considerations in the use and installation of chevron alignment signs. The guidelines are intended to supplement the section documenting the use and installation of chevron alignment signs in the <i>Manual of Uniform Traffic Control Devices for Canada</i>.</p> <p>The provided guidance on the use of chevron alignment signs addresses rural/urban locations, road classification and network elements. The correct/incorrect placement of chevron alignment signs, hierarchy of curve delineation devices and temporary conditions are also addressed.</p> <p>Factors affecting the installation of chevron alignment signs are size, reflectivity, positioning, spacing, orientation, horizontal placement and vertical placement, as well as some other considerations. These other considerations touch upon the combination of vertical and horizontal geometry, installation in conjunction with existing delineation markers, installation along tangent approach, presence of intersecting roadways or access along a curve, maintenance and temporary conditions.</p> | | Keywords <ul style="list-style-type: none"> ○ Safety Devices Used in Transport Infrastructure ○ Traffic Control <ul style="list-style-type: none"> ● Alignment ● Bend (Road) ● Guidance ● Horizontal ● Installation ● Run Off the Road (Accid) ● Rural Area ● Traffic Sign ● Urban Area ● Warning |
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EXECUTIVE SUMMARY

The safety risks associated with horizontal curves are generally related to roadway departures. Vehicles leaving the roadway and striking fixed objects such as trees, utility poles or rockfaces typically result in high severity or fatal collisions. From a road safety perspective, failure to slow to an appropriate speed is a major cause of collisions on rural curves. Sharp curves on high speed rural roads tend to be more hazardous, as well as areas with relatively low levels of illumination during night time.

Providing enhanced guidance for motorists is therefore important in reducing collisions at horizontal curves. Chevron alignment signs, among various traffic control devices, may be considered for improving warning and guidance where there is a change in the horizontal alignment of a roadway.

The intent of these guidelines is to provide engineers and practitioners, across Canada, with the understanding of the key considerations in the use and installation of chevron alignment signs. The guidelines are intended to supplement the section documenting the use and installation of chevron alignment signs in the *Manual of Uniform Traffic Control Devices for Canada*.

The provided guidance on the use of chevron alignment signs addresses rural/urban locations, road classification and network elements. The correct/incorrect placement of chevron alignment signs, hierarchy of curve delineation devices and temporary conditions are also addressed.

Factors affecting the installation of chevron alignment signs are size, reflectivity, positioning, spacing, orientation, horizontal placement and vertical placement, as well as some other considerations. These other considerations touch upon the combination of vertical and horizontal geometry, installation in conjunction with existing delineation markers, installation along tangent approach, presence of intersecting roadways or access along a curve, maintenance and temporary conditions.



1.0 INTRODUCTION

1.1 Background

The safety risks associated with horizontal curves are generally related to roadway departures. Vehicles leaving the roadway and striking fixed objects such as trees, utility poles or rock faces typically result in high severity or fatal collisions. From a road safety perspective, failure to slow to an appropriate speed is a major cause of collisions on rural curves. Sharp curves on high speed rural roads tend to be more hazardous, as well as areas with relatively low levels of illumination during night time.

Providing enhanced guidance for motorists is therefore important in reducing collisions at horizontal curves. Chevron alignment signs, among various traffic control devices, may be considered for improving warning and guidance where there is a change in the horizontal alignment of a roadway.

In Canada, guidance on the application of chevron alignment signs is provided in Section A3.2.7 (March, 2000) of the *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC).

While the MUTCDC acknowledges the presence of site-specific conditions and the need for field investigation, the lack of more specific guidance may result in inconsistent practices across Canada.

Driver expectation may be enhanced through consistency and uniformity in the application of traffic control devices. In order to promote consistency and uniformity in the use and installation of chevron alignment signs, the Transportation Association of Canada (TAC) has commissioned the development of these guidelines.

1.2 Development of the Guidelines

The development of these guidelines involved the following:

- Review of current practices of Canadian and United States road agencies on the use and installation of chevron alignment signs;
- Review of research on human factors related to sign comprehension and interpretation, specifically at a roadway section with horizontal alignment;
- Consideration of best practices that take into account land use and the surrounding environment and other site-specific considerations, and that can be applied to various road conditions across Canada.

1.3 Outline of this Document

Section 2 of this document presents a discussion on the key considerations related to the use and installation of chevron alignment signs. The formal guidelines are presented in Sections 3 and 4 of this document.

2.0 CONSIDERATIONS FOR APPLICATION

2.1 Key Considerations Related to Use of Chevron Alignment Signs

In general, there are various traffic control devices which may be considered for improving warning and guidance where there is a change in the horizontal alignment of a roadway. Examples of such devices include:

- Curve warning signs (WA-1 to WA-6 in the MUTCDC);
- Checkerboard signs (WA-8R or WA-8L in the MUTCDC);
- Post-mounted delineation (WA-37 in the MUTCDC);
- Pavement edge lines; and,
- Raised pavement markers.

The MUTCDC provides guidance on curve warning signs (Section A3.2.1), checkerboard signs (Section A3.2.6), delineation (Section A3.4.12), pavement edge lines (Section C2.4.1) and raised pavement markers (Section C1.6.4).

The current MUTCDC and MUTCD (the United States equivalent of the MUTCDC) are consistent in the guidance that chevron alignment signs are for providing additional emphasis and guidance for a change in the horizontal alignment. By this definition, chevron alignment signs may be used in conjunction with any of the devices listed above. This in turn suggests that specific considerations, such as those related to visual conspicuity and hierarchy of implementation, may arise when using multiple curve delineation devices simultaneously.

The roadside condition along the curve is also an important consideration as it directly influences the consequence of run-off-road collisions and the need for warning and delineation against such collisions.

The considerations mentioned thus far also apply in situations where consecutive curves are present along a roadway.

For consistency in meeting drivers' expectations and to avoid the overuse and resulting potential loss of effectiveness, chevron alignment signs should **only** be used where there is relation to horizontal alignment if its characteristics meet the criteria described in these guidelines.

The general principles on the use of chevron alignment signs are described in Section 3.0 of this document. Specific issues related to the use of chevron alignment signs are also detailed in Section 3.0, which cover:

- Urban/rural considerations;
- Road classification considerations; and,
- Specific network element considerations;
- Other use considerations.

2.2 Key Considerations Related to Installation of Chevron Alignment Signs

To enhance guidance for motorists, curve delineation devices should provide adequate visual cues from the approach to a horizontal curve through to the end of the curve, or to the end of a series of consecutive curves where they exist. The number of chevron alignment signs provided and their spacing would be influenced by conditions on the approach and along the curve. Factors which may influence the installation of chevron alignment signs include the presence of other signage or intersecting roadways and access driveways along the curve.

As with the case for other traffic signs, general guidance related to the horizontal and vertical placement of chevron alignment signs can be found in the MUTCDC. More specific guidance is also available from the TAC *Guide for Lateral and Vertical Roadside Sign Placement (2008)*. However, as horizontal curves are typically designed with superelevation, the vertical placement of chevron alignment signs may require adjustment depending on the rate of superelevation. The vertical placement may also require adjustment when a vertical curve is located in advance of the horizontal curve and the horizontal curve is not conspicuous to approaching motorists.

Other installation considerations include orientation of the sign against approaching traffic, as well as the application of an oversized sign in specific situations where extra emphasis is required.

Guidelines on the installation of chevron alignment signs are detailed in Section 4.0 of this document, which cover:

- Reflectivity;
- Orientation;
- Positioning and spacing;
- Horizontal and vertical placement; and
- Other installation considerations.

3.0 GUIDANCE ON THE USE OF CHEVRON ALIGNMENT SIGNS

General principles on the use of chevron alignment signs are as follows:

1. Chevron alignment signs are to provide additional guidance to drivers where there is a change in the horizontal alignment of the road. Chevron alignment signs **should** be used when the difference between the design speed (or posted speed if lower) on the approach and the safe speed* in the turn or curve (as shown on an advisory speed tab sign) is 35 kilometres per hour or higher. Chevron alignment signs **may** be considered if the speed difference is less than 35 kilometres per hour when collision history indicates a pattern of off-road and/or head-on collisions or truck rollover collisions, an engineering review indicates that additional curve warning is needed to make the curve more apparent to approaching motorists, or the curve is severe and driver compliance with the advisory speed limit is low.
2. In cases of road sections with multiple consecutive curves, chevron alignment signs are recommended to be placed at the specific turns or curves within the road section that meets the warrants for installation. Each curve should be individually reviewed, and should be compared to the posted speed limit.
3. Chevron alignment signs may be provided in rural and urban locations, and on all road classes or on freeway ramps only if the location possesses a horizontal curve that meets the requirements for chevron alignment signs.
4. Chevron alignment signs may be used in conjunction with other traffic control devices for improving warning and guidance only if the location possesses a horizontal curve that meets the requirements for chevron alignment signs. Chevron alignment signs should not be used if other traffic control devices are better suited.
5. Chevron alignment signs should not be used where there is no relation to horizontal alignment along a road segment.
6. Temporary conditions chevron alignment signs should be used when any of the above principles are applicable. The signs should be removed when they are no longer appropriate.

* According to the MUTCDC, "safe speed" is "determined by ball bank indicator, and is the speed shown on the Advisory Speed tab sign (WA-7S.)"

Specific considerations related to the use of chevrons alignment signs are detailed in Section 3.1 to 3.4.

Chevron alignment signs should only be used where they are justified according to these guidelines. Overuse of such signs may detract from their effectiveness. A qualified engineer or technician should review and verify the need for chevron alignment signs at each roadway location to confirm whether the signs are required, or if other devices or measures should be used instead.

3.1 Specific Urban/Rural Considerations

3.1.1 Urban Environment

Urban environments are often complex, with various features that compete for driver attention. While streetlights, buildings or other roadside features may provide indication to drivers about the change in horizontal alignment, the Guidelines recommend that chevron alignment signs should generally be considered where it is feasible for physical installation. An example is a right turning curve on a divided roadway (as shown in Figure 3.1) with a raised centre median, where chevron alignment signs are mounted on the median.



Photo taken on a multi-lane urban roadway along a divided section. Three Chevron Alignment signs are mounted on the centre median.

FIGURE 3.1 – USE OF CHEVRONS IN AN URBAN ENVIRONMENT

In an urban environment, curve warning signs and sometimes raised pavement markers are typical curve warning / delineation devices used. Where collision history or engineering judgement determines that enhanced warning or guidance is needed for a horizontal curve, chevron alignment signs may be installed in addition to these devices, such as delineation markers. However, a site review should be conducted to ensure that the physical installation is feasible given the presence of typical roadside features such as sidewalks, utility poles, fire hydrants, parking signs and meters, and other landscaping features.

Where visual clutter already exists, or the installation of chevron alignment signs may increase visual clutter, the use of the minimum size chevron alignment signs may be less effective. Larger chevron alignment signs could also be considered to increase the signs' conspicuity.

3.1.2 Rural Environment

Failure to slow to an appropriate speed due to lack of curve conspicuity is a major cause of collisions on rural curves. Sharp curves and isolated curves on high speed rural roads tend to be more hazardous for motorists. Curves or turns in rural non-illuminated areas may also pose significant safety risks to motorists during nighttime or adverse weather conditions. An example of a curve in a rural area is shown in Figure 3.2.



Photo taken on an unlit two-lane undivided rural roadway. Six chevron alignment signs are mounted on the outside of the curve. An access road to a development is located along the curve.

FIGURE 3.2 – USE OF CHEVRONS IN A RURAL ENVIRONMENT

In general, the lack of visual cues from typical urban features such as buildings and streetlights results in the need for providing site specific traffic control devices to delineate a change in road alignment in a rural environment. The Guidelines recommend that chevron alignment signs should be provided at horizontal curves on rural roads of radius less than 100 metres, or those with design speed of 50 kilometres per hour or less. Consideration of the design speed versus the posted speed limit, as well as the conspicuity of the road and curve, should also be made when determining whether the section should have chevron signs.

High speed rural roads may warrant oversized (larger than the minimum) chevron alignment signs. Specific guidance on providing oversized chevron alignment signs according to approach speeds is provided in Section 4.1.

3.2 Specific Road Classification Considerations

Chevron alignment signs may be installed on all road classes currently defined in the MUTCDC. However, it is recommended that the effectiveness of using other curve delineation devices be reviewed for urban local roads prior to using chevron alignment signs. The road classes currently listed in the MUTCDC are shown in Table 3.1.

TABLE 3.1 – MUTCDC ROAD CLASSES

| URBAN | RURAL |
|------------|-----------|
| Local | Local |
| Collector | Collector |
| Arterial | Arterial |
| Expressway | n/a |
| Freeway | Freeway |

3.3 Specific Network Element Considerations

3.3.1 Consecutive Curves

According to the MUTCDC:

- A reverse turn sign or a reverse curve sign indicates that there are two curves in opposite directions, as defined in the warrants for curve signs, which are separated by a tangent section of less than 120 metres.
- A winding road sign indicates that there is a series of five or more turns or curves (as defined in the warrants for turn and curve signs) separated by tangent distances of less than 120 metres.

In situations where the MUTCDC warrants a reverse turn sign, a reverse curve sign, or a winding road sign for a section of road containing a series of curves, chevron alignment signs are recommended to be placed only at the specific turns or curves within the road section which meet the warrants for chevron alignment signs. The safe speed for each curve within the section should be individually compared to the posted speed limit.

3.3.2 Ramps

The installation of chevron alignment signs on interchange ramps is not explicitly documented in the MUTCDC; however, if the ramp possesses a horizontal curve that meets the requirements for chevron alignment signs, it is recommended that they be installed as per the guidelines. The following should be considered in the review:

- The vehicle speeds on the approach to the ramp curve, as they may be different than the mainline posted speed limits or the ramp exit advisory speed limit; and
- The signs currently installed or recommended, in order to reduce any sign clutter that may lead to drivers needing time to interpret the signs and distract them from focusing on navigating the road.

3.4 Other Use Considerations

3.4.1 Where Chevron Alignment Signs Should Not Be Used

It is recommended that chevron alignment signs be only used in relation to horizontal alignment. Examples of where chevron alignment signs are not to be used include the purposes of:

1. marking obstructions in the roadway;
2. indicating roadway width transitions such as lane drops and approaches to narrow bridges; and,
3. marking the end of the minor street approach of T-intersections.

3.4.2 Hierarchy of Curve Delineation Devices

Consistent with the MUTCDC, the guidelines recommend that chevron alignment signs are to be used to provide additional guidance to drivers where there is a change in the horizontal alignment of the road that meets the criteria in this report. Therefore, chevron alignment signs may be used in conjunction with other curve delineation devices. Currently, some provincial road agencies provide post-mounted delineation along roads classified as freeway, expressway or highway on a routine basis.

Guidance related to the concurrent use of chevron alignment signs and other devices, including curve warning signs, delineation markers, checkerboard signs, pavement edge lines and/or raised pavement markers, is summarized in Table 3.2 below.

TABLE 3.2 – USE OF CHEVRON ALIGNMENT SIGNS WITH OTHER DEVICES

| CURVE DELINEATION DEVICE | CONSIDERATIONS |
|--|--|
| Turn and Curve Warning signs (WA-1, 2, 3, 4, 5, 6) | <p>MUTCDC guidance (Section A3.2.1): Curve warning signs are used when required by the warrants outlined in Table A3-1. An advisory speed tab sign (WA-7S) is used only where required by the warrants outlined in Table A3-1. According to Table A3-1, a curve warning sign is typically warranted when the difference between the maximum practical speed and the safe speed in turn or curve is 10 kilometres per hour or higher.</p> <p>Use of Chevron Alignment signs with a Curve Warning sign: The guidelines recommend that chevron alignment signs may be installed, regardless of whether or not there is a difference between the maximum practical speed and the safe speed in a turn or curve.</p> <p>As such, chevron alignment signs may be installed with or without a curve warning sign prior to the turn or curve.</p> <p>In situations where the MUTCDC warrants a reverse turn sign, a reverse curve sign, or a winding road sign for a section of road containing a series of curves, chevron alignment signs are recommended to be placed only at the specific turns or curves within the road section which meet the warrants for chevron alignment signs. The safe speed for each curve within the section should be individually compared to the posted speed limit.</p> |

| CURVE DELINEATION DEVICE | CONSIDERATIONS |
|--|--|
| <p>Delineation Marker (WA-37)</p> | <p><i>MUTCDC guidance (Section A.3.4.12):</i> Delineation markers (which include post-mounted delineators) are typically installed to provide visibility during periods of rain or snow when pavement markings can be obscured. They may also be installed when the road alignment at night is not apparent with the use of pavement markings alone, or where the roadway is not illuminated. As such, they are considered as guide markings and are not a substitute for a proper warning sign.</p> <p>Delineation markers may be used on both long continuous sections of highway or through short sections where there are horizontal curves. Table A3-4 outlines the spacing of the delineation markers, and includes spacing recommendations on the approach and along the curve.</p> <p>The MUTCDC recommends regular spacing where possible, and suggests that where driveways, side roads, or other obstructions inhibit this, the marker is moved no more than $\frac{1}{4}$ the normal spacing, or omitted entirely. At least five delineation markers should be seen by the driver at all times on the approach and along the curve.</p> <p>It is noted that the MUTCDC does not explicitly say that the delineation markers cannot be used in conjunction with warning signs, such as chevron alignment signs.</p> <p><i>Use of Chevron Alignment signs with Delineation Markers:</i> Chevron alignment signs are considered a higher form of guidance than delineation markers because chevron alignment signs are warning signs and command greater attention.</p> <p>If delineation markers have been installed at a location, chevron alignment signs may be considered as a supplement to the delineation markers when (a) a collision pattern of run-off-road and head-on collisions exists with the use of the delineation markers and (b) nighttime visibility is limited with the use of delineation markers.</p> <p>The use of chevron alignment signs to supplement delineation markers may have the potential to create visual clutter. An engineering site review should be conducted to determine the appropriate treatment that minimizes visual clutter while maximizing effectiveness in providing guidance and warning to motorists about the turn or curve.</p> <p>Delineation markers should be removed and substituted by chevron alignment signs if the recommended sign spacing is equal to or less than the current delineation marker spacing. The chevron alignment sign spacing details are described in Section 4.6.2.</p> <p>However, if the delineation markers are provided as a continuous system that extends before and after the curve along the tangents, it is recommended that the delineation markers be maintained and supplemented by chevron alignment signs.</p> <p>Road agencies that currently adopt the same spacing requirements for delineation markers and chevron alignment signs may consider adopting the recommended spacing in these guidelines to differentiate the spacing requirements of the two devices.</p> <p>Jurisdictional policies or procedures that govern the use of curve delineation devices should be respected if and when they are in effect.</p> |

| CURVE DELINEATION DEVICE | CONSIDERATIONS |
|--|--|
| <p>Checkerboard sign (WA-8R or WA-8L)</p> | <p>MUTCDC guidance (Section A3.2.6): The checkerboard signs (specifically WA-8R and WA-8L) indicate an abrupt change of alignment at a turn or curve. The signs should be installed at the turn or curve, and should always be located directly in line with the path of the approaching vehicle.</p> <p>Use of Chevron Alignment signs with a Checkerboard sign: Chevron alignment signs may be used as a supplement to a checkerboard sign, particularly when collision history indicates the need for enhanced curve delineation with the use of a checkerboard sign.</p> <p>Conversely, a checkerboard sign may be used to supplement chevron alignment signs in the situation of an intersecting roadway or access driveway along the curve, as described in Section 4.6.4.</p> <p>A Chevron alignment sign and a checkerboard sign should not be installed on the same post. It is recommended that the checkerboard sign be installed at an unobstructed location slightly behind the chevron alignment sign.</p> |
| <p>Pavement edge lines</p> | <p>MUTCDC guidance (Section C2.4.1): Line markings to delineate the edge of the travelled lane may be used in advance of and around sharp curves.</p> <p>Use of Chevron Alignment signs with pavement edge lines: Chevron alignment signs may be used with or without pavement edge lines.</p> |
| <p>Raised pavement markers</p> | <p>MUTCDC guidance (Section C1.6.4): Raised pavement markers may be used as positioning guides, or to supplement and enhance the visibility of pavement markings, or in some cases to substitute for other types of markings. With respect to pavement markings, MUTCDC Section C2.1 on directional dividing lines indicates that “directional dividing lines are normally applied throughout the entire length of the pavement on major provincial highways, on other major rural roads and on all major urban streets. On other rural roads and urban streets where a continuous directional dividing line is neither necessary nor practical, it is desirable to mark the following locations with a single solid yellow line 30m in advance of and beyond any curve having a radius of less than 200m or where the sight distance is less than 150m.</p> <p>Use of Chevron Alignment signs with raised pavement markers: Chevron alignment signs may be used with or without the use of raised pavement markers.</p> |

3.4.3 Temporary Conditions

The temporary conditions chevron alignment signs (TC-31) should be used for temporary conditions only when the criteria described in Sections 3.1 through 3.4 warrant their use. The signs should not be used for other purposes, such as to denote detours or lane closures. The signs should be removed when they are no longer appropriate.

3.4.4 Collisions

Chevron alignment signs may be considered for enhancing guidance for horizontal curves at a location where the following is relevant:

- There is collision history that indicates a pattern of run-off-road and/or head-on collisions at a turn or curve where a checkerboard sign or post-mounted delineators are currently being used. A threshold of one correctable collision per year over three consecutive years is recommended.
- The potential consequence of a vehicle running off-road is severe due to roadside hazards in or close to the clear zone (such as steep embankment or body of water). In these situations, it may be prudent to also consider the use of roadside barriers or guardrails for protection.
- There is a history of truck rollover collisions. A threshold of one correctable collision per year over three consecutive years is recommended.

4.0 GUIDANCE ON THE INSTALLATION OF CHEVRON ALIGNMENT SIGNS

General principles on the installation of chevron alignment signs are as follows:

1. Chevron alignment signs are installed on the outside of a curve or sharp turn in the direction of travel.
2. Chevron alignment signs should be oriented to directly face each approach lane for which the signs are intended.
3. The dimension of a chevron alignment sign used in urban and rural environment shall not be less than 450mm x 600mm. All signs used at the same location shall be of the same size.
4. Oversized (larger than minimum size) chevron alignment signs may be considered when the posted speed on the approach is 70 kilometres per hour or higher, or on roads with higher road classes such as expressways and freeways. The use of oversized chevron alignment signs could also be considered where visual clutter may make the use of the minimum size chevron alignment signs less effective.
5. The number and spacing of chevron alignment signs installed should follow the recommendations in this report.
6. When chevron alignment signs are installed, a driver should always have a minimum of two signs and preferably at least three signs in view until the alignment changes.
7. When installed, at least the first two chevron alignment signs on approach to the curve should be visible for a sufficient amount of time to provide adequate time for driver perception and reaction.
8. The horizontal placement of chevron alignment signs shall be in accordance with the *Guide for Lateral and Vertical Roadside Sign Placement* (TAC, 2008).
9. Chevron alignment signs should generally be installed at a height of 1.2 m above the near edge of the nearest traffic lane to the bottom of the sign. However, as horizontal curves are typically designed with superelevation, the vertical placement of chevron alignment signs may require adjustment depending on the rate of superelevation. The height adjustment of the chevron alignment signs should follow the recommendations in this report.
10. Temporary conditions chevron alignment signs should be installed with the same considerations as the above principles. The signs should have the same design and dimensions as a standard chevron alignment signs except with an orange background.

Specific considerations related to installation of the signs are detailed in Section 4.1 to 4.6.

4.1 Size and Reflectivity

The minimum size of chevron alignment sign is 450mm x 600mm, as defined in the MUTCDC. Oversized (larger than minimum) signs have dimensions that increase from the minimum size in 150mm increments. Standard shapes and colors shall be used and standard proportions shall be retained to the extent practical. All signs used at one location should be the same size.

Oversized chevron alignment signs should be considered where the approach speed (posted speed or 85th percentile speed) is 70 kilometres per hour or higher, or on roads with higher road class (such as expressways or freeways). It is recommended that 600mm x 750mm signs be used for expressways, while 750mm x 900mm or larger signs be used for freeways. Engineering judgment should be used to determine whether oversized signs are appropriate for use and the sign size to be installed.

It is acknowledged that various larger sign sizes are already being used by Canadian road agencies based on the posted speed limit or road classification. In general, the existing usage is consistent with the above recommendations contained in this section. Examples of sign sizes and their application are shown in Table 4.1 below.

TABLE 4.1 – CHEVRON SIGN SIZES USED BY CANADIAN ROAD AGENCIES

| ROAD AGENCY | SIGN SIZES | NOTES |
|--|----------------------------|---|
| Alberta Transportation | 450 x 600 mm | no specific guidance on when and where larger signs are used |
| | 600 x 750 mm | |
| Saskatchewan Highway and Infrastructure | 450 x 600 mm | no specific guidance on when and where larger signs are used |
| | 600 x 750 mm | |
| Ontario Ministry of Transportation | 450 x 600 mm | for speed limit 60 km/h or less |
| | 600 x 750 mm (oversize) | for speed limit 70 km/h or greater |
| Ministère des Transports du Québec | 300 x 375 mm | for when approach speed is less than 50 km/h & lateral placement is less than 5m from the edge line |
| | 600 x 750 mm | for when speed is 50 km/h to 90 km/h and lateral placement is less than 15m from the edge line |
| | 900 x 1200 mm | for when speed is 80 km/h to 100 km/h and lateral placement is over 10m from the edge line |
| New Brunswick Department of Transportation and Infrastructure | 450 x 600 mm | for 80 km/h or less |
| | 600 x 750 mm | for arterial / collector |
| | 750 x 900 mm | for new 2 lane two way |
| | 900 x 1200 mm | for freeway |

The chevron alignment signs should provide a minimum retroreflectivity rating of ASTM Type III or equivalent and ideally higher with a prismatic sheeting material.

4.2 Positioning and Spacing

The recommended spacing of chevron alignment signs is shown in Table 4.2 and is based on the horizontal curve radius and the approximate corresponding design speed. A posted advisory speed for the curve may be used to estimate the radius. It is recommended that the posted or advisory speed be used to determine the sign spacing if it is found to be less than the design speed.

TABLE 4.2 – RECOMMENDED CHEVRON SIGN SPACING

| CURVE RADIUS (m) | APPROXIMATE DESIGN SPEED OF CURVE (km/h)* | | RECOMMENDED SPACING (m) |
|---------------------|---|-----------------|----------------------------|
| | Rural or High-Speed Urban | Low-Speed Urban | |
| 30 | 25 to 30 | 35 to 40 | 13 |
| 40 | 30 to 35 | 35 to 40 | 16 |
| 50 | 35 to 40 | 40 to 45 | 20 |
| 60 | 40 to 45 | 40 to 45 | 22 |
| 70 | 40 to 45 | 45 to 50 | 24 |
| 80 | 45 to 50 | 45 to 50 | 27 |
| 90 | 45 to 50 | 45 to 50 | 29 |
| 100 | 50 to 55 | 50 to 55 | 30 |
| 125 | 55 to 60 | 50 to 55 | 35 |
| 150 | 60 to 65 | 55 to 60 | 38 |
| 175 | 65 to 70 | n/a** | 42 |
| 200 | 70 to 75 | n/a | 45 |
| 225 | 75 to 80 | n/a | 48 |
| 250 | 75 to 80 | n/a | 51 |
| 275 | 80 to 85 | n/a | 53 |
| 300 | 85 to 90 | n/a | 56 |
| 350 | 85 to 95 | n/a | 61 |
| 400 | 90 to 100 | n/a | 65 |
| 450 | 95 to 105 | n/a | 69 |
| 500 | 100 to 110 | n/a | 73 |
| 550 | 105 to 115 | n/a | 77 |
| 600 | 105 to 115 | n/a | 80 |
| 700 | 110 to 125 | n/a | 87 |
| 800 | 115 to 130 | n/a | 93 |
| 900 | 120 to 140 | n/a | 98 |

* Posted or advisory speed used to determine the sign spacing if it is found to be less than the design speed or if the design speed is unknown.

** corresponding design speed greater than 60 km/h

When installed, at least the first two chevron alignment signs on approach to the curve should be visible for a sufficient amount of time to provide adequate time for driver perception and reaction. On a single-lane approach, the first chevron alignment sign (the leading sign) should be placed directly in front of the driver on the approach. For a multi-lane approach, the leading signs should consist of a chevron alignment sign directly in front of all approach lanes. All subsequent signs should be spaced from the last leading sign as recommended in Table 4.2.

The chevron alignment signs should be placed so that a driver should always have a minimum of two signs and preferably at least three signs in view while navigating the curve until the change in alignment eliminates the need for the signs. To achieve this, chevron alignment signs should be provided along the entire curve section until the alignment changes and the vehicle is in a tangent section of the road.

The number of chevron alignment signs used at a location should be based on the required spacing. Should chevron alignment signs also be placed on the approach to curve, the number of signs required would also increase. The recommended procedure is documented in Section 4.6.3.

Special treatments are required when an intersecting road or access driveway is located along the curve. The recommended procedure is described in Section 4.6.4.

The recommended placement of the chevron alignment signs for single- and multi-lane approaches is illustrated in Figure 4.1.

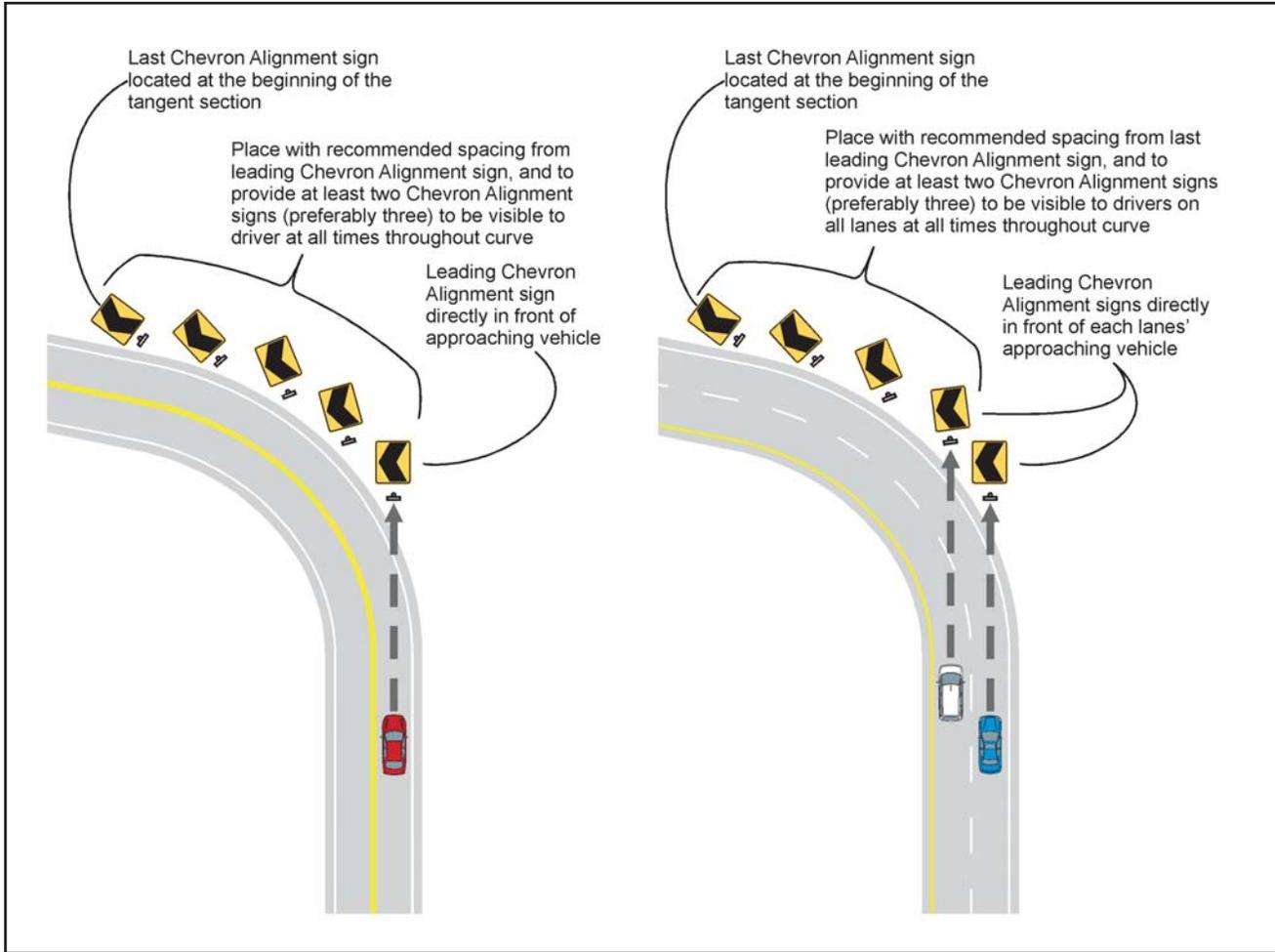


FIGURE 4.1 – RECOMMENDED CHEVRON PLACEMENT FOR SINGLE-AND MULTI-LANE APPROACHES

4.3 Orientation

Chevron alignment signs should be installed in line with and at approximately a right angle to approaching traffic for which the signs are intended. The signs should be visible for a sufficient distance to provide the road user with adequate time to react to the change in alignment.

4.4 Horizontal Placement

Chevron alignment signs should be installed on the outside of a turn or curve.

As for other roadside signs, the lateral placement of chevron alignment signs needs to take into consideration clear zone and maintenance requirements. Ideally, chevron alignment signs should be located outside of the clear zone to reduce the potential for collisions with the sign supports. Signs placed within the clear zone should have breakaway supports or be placed behind barrier protection. Maintenance operations, particularly snowplow operations, have the potential to damage or obstruct roadside signs. While signs may be moved further away from the edge of the travel lane to accommodate maintenance operations, engineering judgement should be used to consider the implications to sign visibility, especially at night when sign visibility may depend on headlight illumination.

Consistent with the *Guide for Lateral and Vertical Roadside Sign Placement* (TAC,2008), the recommended lateral placement of chevron alignment signs is between 0.3 and 6.0 metres from the edge of the travel lane to the near sign edge for posted speed limit of 60 kilometres per hour or lower, and between 4.0 and 6.0 for posted speed limit of 70 kilometres and higher.

4.5 Vertical Placement

The MUTCDC specifically indicates that chevron alignment signs be installed at a height of 1.2 metres above the near edge of the nearest traffic lane to the bottom of the sign.

Noting that these chevron alignment signs are along curves, typically with superelevation, further adjustment is made to the installation height. Accounting for the lateral distance from the road in Section 4.4, the adjustments in height are shown in Table 4.3, and the installation considerations are shown graphically in Figure 4.2. An on-site review of the signs during low lighting or nighttime conditions should be made with a passenger vehicle with low-beam headlights to ensure that the signs are visible.

TABLE 4.3 – CHEVRON ALIGNMENT SIGN HEIGHT INSTALLATION ADJUSTMENTS BY DISTANCE TO LANE EDGE AND SUPERELEVATION

| DISTANCE FROM LANE EDGE* (m) | | SIGN HEIGHT BY SUPERELEVATION (m) | | | | |
|---|-----|-----------------------------------|------|------|------|------|
| | | 0.00 | 0.02 | 0.04 | 0.06 | 0.08 |
| 60 km/h or lower, with curb, urban | 0.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| | 0.5 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| | 1.0 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 |
| | 1.5 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 |
| | 2.0 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 |
| 60 km/h or lower, with curb, rural | 2.5 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 |
| | 3.0 | 1.2 | 1.3 | 1.3 | 1.4 | 1.4 |
| | 3.5 | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 |
| 60 km/h or lower, without curb, infrequent or no snow | 4.0 | 1.2 | 1.3 | 1.4 | 1.4 | 1.5 |
| | 4.5 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| 60 km/h or lower, without curb, regular snow | 5.0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| | 5.5 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| | 6.0 | 1.2 | 1.3 | 1.4 | 1.6 | 1.7 |
| 70 km/h or higher, infreq. or no snow, urban | 4.0 | 1.2 | 1.3 | 1.4 | 1.4 | 1.5 |
| | 4.5 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| 70 km/h or higher, infrequent or no snow, rural | 5.0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| | 5.5 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| 70 km/h or higher, regular snow | 5.0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| | 5.5 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| 70 km/h or higher, regular snow | 5.0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| | 5.5 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| 70 km/h or higher, regular snow | 5.0 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |
| | 5.5 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |

* Lane edge is defined as the nearest edge of the nearest travel lane to the outside of the curve.

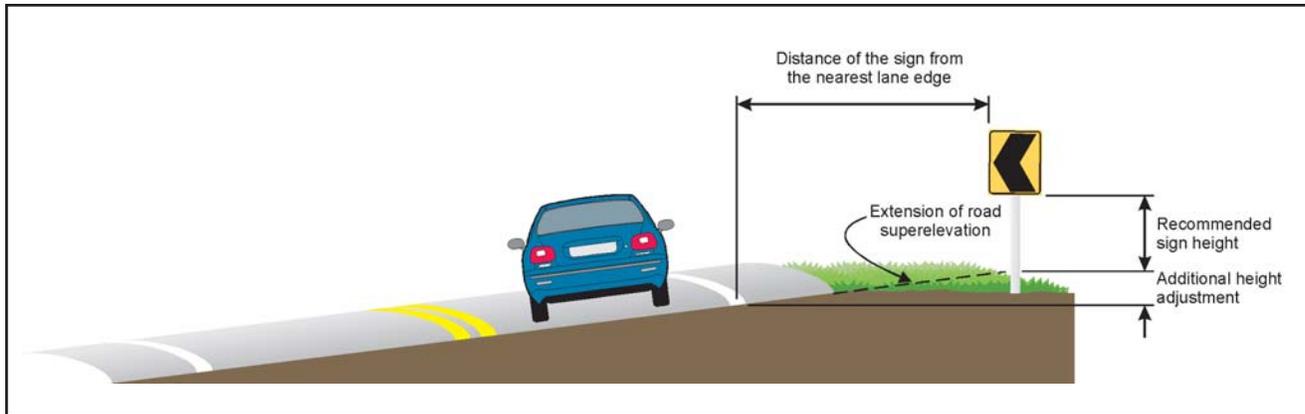


FIGURE 4.2 – CHEVRON ALIGNMENT SIGN HEIGHT INSTALLATION ADJUSTMENTS

4.6 Other Installation Considerations

4.6.1 Combination of Vertical and Horizontal Geometry

Where a vertical curve precedes a horizontal curve, and chevron alignment signs are warranted for the horizontal curve based on these guidelines or engineering judgement, the chevron alignment signs may be placed higher or lower so that they are illuminated by low beam headlights.

In general, the presence of a vertical sag curve preceding a horizontal curve would require the chevron alignment signs to be placed lower; the presence of a vertical crest curve preceding a horizontal curve would require the chevron alignment signs to be placed higher.

An engineering site review should be conducted during both daytime and nighttime conditions to verify that the visibility of the chevron alignment signs is optimized.

4.6.2 Installation in Conjunction with Existing Delineation Markers

Locations where delineation markers are currently provided may warrant chevron alignment signs. Providing the chevron alignment signs while leaving the existing delineation markers in place could provide additional guidance, but may also create visual clutter. Because delineation markers are considered to be guide markings instead of warning devices, it is important that their appearance does not interfere with the chevron alignment signs. As well, should the spacing between chevron alignment signs be less than that of the delineation markers, the provision of the markers is redundant. Therefore if the recommended chevron alignment sign spacing is equal to or less than the existing delineation marker spacing, it is recommended that the delineation markers be removed or relocated to provide the same spacing as the chevron alignment signs. An engineering site review should be conducted to determine the appropriate treatment that minimizes visual clutter while maximizing effectiveness in providing guidance and warning to motorists about the turn or curve.

Chevron alignment signs and delineation markers should not be installed on the same pole or support device to ensure that they are distinctive and do not interfere with each other.

4.6.3 Installation along Tangent Approach

In addition to the signs along the curve section, chevron alignment signs along the tangent approach have been installed previously by various road agencies. These signs may be considered after an on-site review if:

- the road geometry prevents the first two chevron alignment signs from being visible upon approach; and/or
- the horizontal curve is along a rural section where due to lack of visual cues, additional guidance may be required.

Similar to delineation markers, the spacing for these chevron alignment signs is relative to the sign spacing around the curve. The spacings to the 1st, 2nd, and 3rd chevron alignment signs are 1.85, 3, and 6 times the recommended chevron alignment sign spacing around the curve (shown as “a”), respectively, as shown in Figure 4.3.

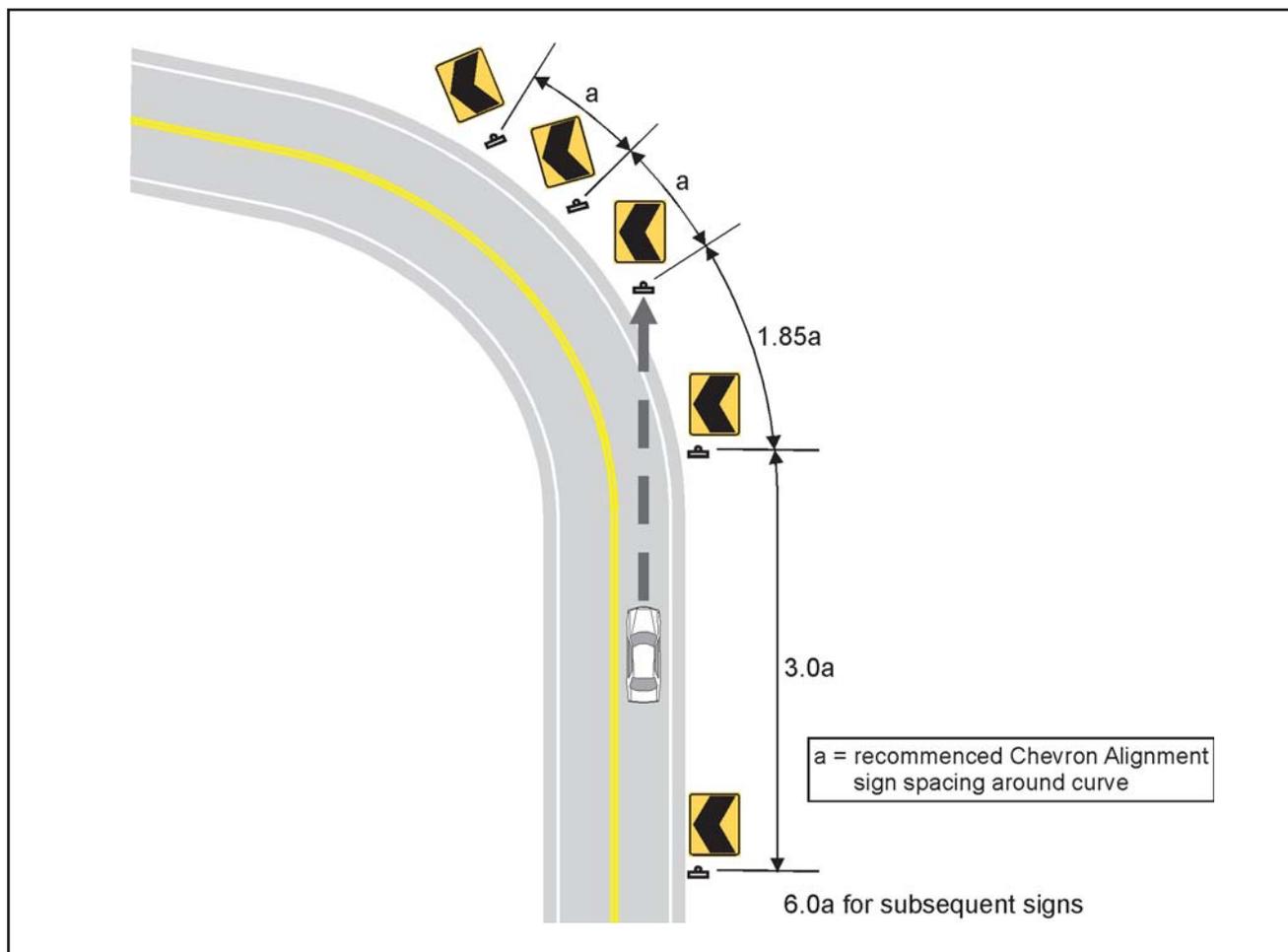


FIGURE 4.3 – RECOMMENDED CHEVRON PLACEMENT ALONG TANGENT APPROACH

4.6.4 Presence of Intersecting Roadways or Access along Curve

It is sometimes necessary to adjust the spacing of chevron alignment signs when an intersecting roadway or access is present along a curve. In these circumstances, it is recommended that an engineering site review be conducted to assess the impact of removing the affected sign(s) from the series of chevron alignment signs based on the spacing requirements.

The chevron alignment sign that is located directly in the path of approaching vehicles is considered to be the most critical. Should an intersecting roadway or access interfere with the installation of this particular sign, the following procedure is recommended:

- Review the potential to relocate the roadway or access;
- Install the chevron alignment sign in line with approaching vehicles if relocation of the roadway or access is viable;
- If the roadway or access cannot be relocated, install the first chevron alignment sign at the nearest edge of the roadway or access and ensure that the spacing (as defined in Section 4.3) is maintained between this sign and all subsequent chevron alignment signs provided;
- Consider the use of a checkerboard sign (specifically WA-8L and WA-8R) to supplement the chevron alignment signs. The checkerboard sign may be installed at the edge of the roadway or access that would optimize its visibility for approaching motorists. A checkerboard sign should not be installed on the same post as a chevron alignment sign, and should be slightly behind the chevron alignment sign as to not obstruct sightlines between vehicles on the intersecting roadway and the mainline.

4.6.5 Maintenance

The chevron alignment signs along a single curve section are intended to work together as a group. Maintenance practice to maintain consistency in the signs' appearance is important. This includes sign replacement if any of the signs are damaged or after the expected sign life has been exceeded. Therefore it is recommended that all the chevron alignment signs used at one location:

- should be replaced at the same time in order to have a consistent retro-reflectivity; and
- should be the same size.

4.6.6 Temporary Conditions

Temporary conditions chevron alignment signs (TC-31) should be installed with the same considerations as regular conditions if possible. The signs should be removed when they are no longer appropriate.

Temporary conditions chevron alignment signs should have the same design and dimensions as a standard chevron alignment signs except with an orange background.

5.0 BIBLIOGRAPHY

- Alaska Department of Transportation and Public Facilities, Alaska Sign Design Specifications, 2006.
- Alaska Department of Transportation and Public Facilities, Alaska Traffic Manual Supplement, 2005.
- Alberta Infrastructure and Transportation, Turn and Curve Signs Recommended Practices, 2006.
- Arizona Department of Transportation, Arizona Supplement to the 2003 Manual on Uniform Traffic Control Devices, 2004.
- Arizona Department of Transportation, Traffic Engineering Manual of Approved Signs, <http://www.azdot.gov/Highways/traffic/MOASStds.asp>, accessed 2009.
- Bhatanger, Y.S., Observations on the Use of Chevron Alignment Markers, 17th ARRB Conference, 1994.
- Bonneson, J., Pratt, M., Carlson, P., Horizontal Curve Signing Handbook, Texas Transportation Institute, 2007.
- Campbell, John L., Richard, Christian M., Graham, Jerry, NCHRP Report 600B Human Factors Guidelines for Road Systems Collection B: Chapters 6, 22 (Tutorial 3), 23 (Updated), Transportation Research Board of the National Academies, 2008.
- British Columbia Ministry of Transportation and Highways, Manual of Standard Signs & Pavement Markings, 2000.
- Carlson, Paul J., Rose, Elisabeth R., Chrysler, Susan T., Bischoff, Austin L., Simplifying Delineator and Chevron Applications for Horizontal Curves, Texas Transportation Institute, 2004.
- Center for Transportation Research and Education (CTRE), Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties, Iowa State University, 2001.
- Charlton, Samuel, G., "The role of attention in horizontal curves: A comparison of advance warning, delineation, and road marking treatments", Elsevier Accident Analysis and Prevention 39 pp. 873-885, 2007.
- Colorado Department of Transportation, The Colorado Supplement to the Federal Manual on Uniform Traffic Control Devices 2003, 2004.
- Connecticut Department of Transportation, Connecticut State Traffic Commission Regulations.
- Dorrestyn, Kym, The Signing of Sub-standard Curves – A Credibility Problem Exists!, AITPM National Conference, 2002.
- Fisher, J., Testing the Effect of Road Traffic Signs' Informational Value on Driver Behaviour, Human Factors Society, 1992.
- Gates, Tim J., Carlson, Paul J., Hawkins, H. Gene Jr., "Field Evaluations of Warning and Regulatory Signs with Enhanced Conspicuity Properties", Transportation Research Record: Journal of the Transportation Research Board, No. 1862, TRB, National Research Council, pp 64-76, 2004.
- Idaho Transportation Department, Rules Governing Traffic Control Devices, Idaho Administrative code IDAPA 39.03.41, 2009.
- Idaho Transportation Department, Sign Chart, 2009.
- Idaho Transportation Department, Traffic Manual, 2009.

Illinois Department of Transportation Division of Highways, Illinois Supplement to the National Manual on Uniform Traffic Control Devices, 2004.

Iowa Department of Transportation Office of Traffic & Safety, Traffic and Safety Manual, 2004.

Iowa Department of Transportation, Standard Road Plan SI-175 CHEVRONS, 2009.

Kanellaidis, George, Factors Affecting Drivers' Choice of Speed on Roadway Curves, Journal of Safety Research Vol. 26 pp. 49-56, 1995.

Kansas Department of Transportation, Kansas State University, Handbook of Traffic Control Practices for Low Volume Rural Roads, 2005.

Manitoba Infrastructure and Transportation Traffic Engineering, Chevron Spacing on Typical Curves.

Manitoba Transportation and Government Services, Polypost Delineator SB-9, 1996.

Manitoba Transportation and Government Services, Specification Number DP-3, 2003.

Maryland State Highway Administration, Maryland Manual on Uniform Traffic Control Devices for Streets and Highways, 2006.

Maryland Department of Transportation State Highway Administration, Standard Sign Book, http://www.marylandroads.com/businesswithsha/bizStdsSpecs/desManualStdPub/publicationsonline/ooots/internet_signbook.asp?IR=5, accessed 2009.

Massachusetts Highway Department, The Massachusetts Amendments to the Manual on Uniform Traffic Control Devices 2003 Edition and the Standard Municipal Traffic Code, 2006.

Michigan Department of Transportation, 2005 Michigan MUTCD, 2005.

Milleville-Pennel, Isabelle, Jean-Michel, Hoc, Elise, Jolly, "The use of hazard road signs to improve the perception of severe bends", Elsevier Accident Analysis and Prevention 39 pp. 721-730, 2007.

Milosevic, Stanisa, Milic, Jovan, "Speed Perception in Road Curves", Journal of Safety Research Vol. 21 pp. 19-23, 1990.

Missouri Department of Transportation, Engineering Policy Guide, http://epg.modot.mo.gov/index.php?title=903.6_Warning_Signs#903.6.11_Chevron_Alignment_Sign_.28W1-8.29_.28MUTCD_Section_2C.10.29, accessed 2009.

Nebraska, State of, Supplement to the Manual on Uniform Traffic Control Devices, 2005.

Nebraska, State of, Nebraska Standard Highway Signs, <http://www.nebraskatransportation.org/traffeng/mutcd/w1-9signs.pdf>, accessed 2009.

New Brunswick DOT MAINT TRAFFIC, Warning Signs, 1996.

New York Department of Transportation, New York State Supplement to the National Manual on Uniform Traffic Control Devices, 2008.

Newfoundland and Labrador, 2008 Spec Book, 2008.

North Carolina Department of Transportation, 2004 North Carolina Supplement to the Manual on Uniform Traffic Control Devices, 2004.

Ontario Ministry of Transportation, Ontario Traffic Manual Book 6 Warning Signs, 2001.

Ontario Ministry of Transportation, Ontario Traffic Manual Book 11 Pavement, Hazard and Delineation Markings, 2000.

Oregon Department of Transportation, Oregon Supplement to the Manual on Uniform Traffic Control Devices 2003 Edition, 2005.

Pennsylvania Department of Transportation, Handbook of Approved Signs, 2008.

Pennsylvania, Commonwealth of, Department of Transportation, Traffic Engineering Manual, 2008.

Prince Edward Island Capital Projects, Provincial Sign Manual (title unknown), 2009.

Rose, Elisabeth, R., Carlson, Paul, J., "Spacing Chevrons on Horizontal Curves", Transportation Research Record: Journal of the Transportation Research Board, No. 1918, Transportation Research Board of The National Academies, pp 84-91, 2005.

Saskatchewan Highways and Infrastructure, Design Manual, 1991.

Saskatchewan Highways and Infrastructure, Saskatchewan Traffic Control Devices Manual, 2004.

Saskatchewan Highways and Infrastructure, Traffic Control Devices Manual, 1998.

Shinar, D., The effects of changes in driver perception on rural curve negotiation, Ergonomics Research Society, 1980.

Texas Department of Transportation, Texas MUTCD Manual on Uniform Traffic Control Devices, 2006.

Transportation Association of Canada, Manual of Uniform Traffic Control Devices for Canada Fourth Edition, 1998.

Transports Québec, MTQ Standards Volume V – Traffic Control Devices, 2009.

U.S. Department of Transportation Federal Highway Administration, Low-Cost Treatments for Horizontal Curve Safety, 2006.

U.S. Department of Transportation Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways 2003 Edition, 2003.

Vest, Adam, Stmatiadis, Nikiforos, "Use of Warning Signs and Markings to Reduce Speeds on Curves", 3rd International Symposium on Highway Geometric Design, 2005.

Virginia Department of Transportation, List of Significant Changes in the Manual on Uniform Traffic Control Devices for Streets and Highways, 2005.

Washington State Department of Transportation, 2003 MUTCD 2003 Modifications for Washington State, 2005.

West Virginia Department of Transportation, Traffic Engineering Directives, 2005.

Wisconsin Department of Transportation, Wisconsin Manual on Uniform Traffic Control Devices Supplement To The Manual On Uniform Traffic Control Devices, 2005.

Zwahlen, Helmut T., Park, Jin Young, "Curve Radius Perception Accuracy as Function of Number of Delineation Devices (Chevrons)", Transportation Research Record 1495 pp 99-106, 1995.

