Transportation Association of Canada

Synthesis of Practices for the

Implementation of Centreline Rumble Strips

July 2005

DISCLAIMER

The material presented in this text was carefully researched and presented. However, no warranty expressed or implied is made on the accuracy of the contents or their extraction from reference to publications; nor shall the fact of distribution constitute responsibility by TAC or any researchers or contributors for omissions, errors or possible misrepresentations that may result from use of interpretation of the material contained herein.

Cover photos courtesy of Dr. John Morrall

Copyright 2005 by
Transportation Association of Canada
2323 St. Laurent Blvd.
Ottawa, ON K1G 4J8
Tel. (613) 736-1350 ~ Fax (613) 736-1395
www.tac-atc.ca

ISBN 978-1-55187-208-0

TAC REPORT DOCUMENTATION FORM

Project No.	Report No.	Report Date	ITRD No.
		July 2005	

Project Manager
Michael Balsom

Title and Subtitle
Synthesis of Practices for the Implementation of Centreline Rumble Strips

Author(s)	Corporate Affiliation (s)
Geni Bahar Margaret Parkhill	iTRANS Consulting Inc.

Sponsoring/Funding Agencies and Addresses	Performing Agencies Names and Addresses
Transportation Association of Canada (TAC) 2323 St. Laurent Blvd. K1G 4J8	iTRANS Consulting Inc. 100 York Blvd., Suite 300 Richmond Hill, ON L4B 1J8

Abstract

The primary purpose of centreline rumble strips (CLRS) is to alert drivers whose vehicles are crossing roadway centrelines to avoid potential crashes with the opposing traffic or fixed objects. The noise and vibration felt by the driver when the vehicle is driven on the rumble-stripped portion of the roadway act as warning to fatigued and inattentive drivers. Rumble strips are typically milled into pavement and can be used on new, existing or reconstructed pavement.

The Synthesis of Practices for the Implementation of Centreline Rumble Strips reviews centreline rumble strip implementation in Canada and the United States. The report provides a description of where and when they should be considered and also provides design dimensions for their implementation. In general, undivided highways, where head-on and opposite-direction sideswipe collisions are frequent, are candidate areas for CLRS. Specific installations could also be considered for “no passing zones” and two to four-lane transition areas.

The report discusses safety implications of CLRS, and indicates an overall improvement in head-on and sideswipe collisions, with reductions between 15 and 25% for head-on and opposite direction collisions. Other considerations, such as noise, cost, and the effect on bicycles and motorcyclists are addressed in this synthesis, with analysis and recommendations. Issues with installation, maintenance, pavement markings, collision migration, and driver response are investigated, but show no documented evidence substantiating these concerns.

Keywords

- Road Safety Devices
- Centre
- Rumble strip
- Specifications
- Installation
- Construction method

No. of Pages	No. of Figures and Photographs	Language	Price
38 pages and three appendices	31 figures and photographs	English	

Supplementary Information

FICHE DE RAPPORT DE L'ATC

Projet nº	Rapport nº	Date du rapport	DIRR nº
		Juillet 2005	

Gestionnaire du projet

Michael Balsom

Titre et sous-titre

Synthesis of Practices for the Implementation of Centreline Rumble Strips

Auteur (s)	Affiliation (s)
Geni Bahar	iTRANS Consulting Inc.

Nom et adresse de l'organisme parrain	Nom et adresse de l'organisme exécutant
Association des transports du Canada 2323, boul. St-Laurent Ottawa K1G 4J8	ITRANS Consulting Inc. 100 York Blvd., Suite 300 Richmond Hill, ON L4B 1J8

Résumé

Le but premier des bandes d'alerte pour zone médiane (BAZM) est de prévenir les conducteurs que leur véhicule est en train de franchir la ligne médiane de la chaussée et ainsi d'éviter un accident potentiel avec un véhicule circulant en sens inverse ou encore avec des objets fixes. Le bruit et les vibrations qui se produisent à l'intérieur des véhicules circulant sur les BAZM servent à alerter les conducteurs fatigués et inattentifs. Ces bandes d'alerte sont concrètement gravées dans la chaussée, qu'il s'agisse de revêtements de chaussée nouveaux, existants ou reconstruits.

La *Synthèse des pratiques de mise en place des bandes d'alerte pour zone médiane* propose un examen de l'utilisation de cette technique de sécurité routière au Canada et aux États-Unis. Le rapport contient une description des circonstances dans lesquelles le recours aux BAZM devrait être envisagé et il fournit également les paramètres dimensionnels recommandés pour l'installation de ces dernières. En règle générale, les routes à chaussée unique – où les collisions frontales et les collisions latérales de véhicules circulant en sens inverse sont fréquentes – sont les candidates idéales pour l'installation de BAZM. Celles-ci peuvent également se révéler utiles dans les zones de dépassement interdit ainsi que dans les zones où la chaussée passe de deux à quatre voies de circulation.

Le rapport traite par ailleurs des incidences des BAZM sur la sécurité et il indique notamment que ces dernières contribuent à réduire de 15 à 25 % le nombre de collisions frontales et de collisions latérales de véhicules circulant en sens inverse, soit une amélioration globale fort notable. La synthèse s'intéresse également à d'autres questions connexes, dont le niveau de bruit des BAZM, leur coût et leurs incidences sur les cyclistes et les motocyclistes, analyse et recommandations à l'appui. Les autres préoccupations courantes entourant la mise en place de BAZM s'entendent notamment des points suivants : installation, entretien, marquage des chaussées, changements au niveau des collisions et réponse des conducteurs automobiles. Toutes ces préoccupations sont explorées dans le rapport, mais il n'existe par ailleurs aucune preuve documentée permettant de conclure à leur bien-fondé.

Mots-clés

Dispositifs de sécurité routière
Centre
Bande Bruissante
Recommandation
Montage
Methode de construction

Nombre de pages	Nombre de figures	Langue	Prix
38 pp. + annexes	31	Anglais	

Renseignements supplémentaires

Table of Contents

List of Figures

List of Tables

Project Steering Committee

This report was developed under the supervision of a project steering committee of volunteer members. The participation of the committee members throughout the project is gratefully acknowledged.

John Morrall, Chair
Consultant

Tomasz Kroman
UMA Engineering Ltd.

Sukhy Kent
Saskatchewan Highways and Transportation

Chuan Kua
City of Edmonton

Roy Biller
Infrastructure Systems Ltd.

Michael Delsey
Totten Sims Hubicki Associates

Tom Ellerbusch
City of Toronto

EXECUTIVE SUMMARY

Modelled after shoulder rumble strips, which alert drivers that they are leaving the travel lane, centreline rumble strips (CLRS) are placed between opposing lanes of traffic on an undivided roadway with the purpose of alerting drivers that they are crossing over the centreline into the path of oncoming traffic. This warning is generated in the form of increased noise inside the vehicle and a vibration of the vehicle, similar to that of shoulder rumble strips.

The target collision types for CLRS are head-on and opposite-direction sideswipe collisions due to inattentive drivers. Run-off-road-left collisions may be considered as a secondary target collision type, particularly if shoulder rumble strips are not present.

In Canada, three provinces (Alberta, Saskatchewan, and British Columbia) and Parks Canada have implemented CLRS. In 2003 in the United States, at least twenty states have installed CLRS; twelve states are “considering” CLRS, four states will “probably” install CLRS, and two states have “definite plans” to install CLRS in the near future.

Centreline rumble strips may be considered on undivided rural, two-lane, three-lane, or four-lane highways in all zones (passing or no passing) in the following cases:

- New highway sections
- When repaving, rehabilitating or reconstructing existing highway sections
- Other highway sections that are not part of a project but would benefit from the installation of CLRS in terms of safety (i.e., decreasing the number of crossover centreline crashes).

Based on a review of current literature and practices in North America and internationally, CLRS are installed on two-lane, three-lane, or four-lane undivided rural roads in the following locations:

- Where double solid painted lines currently exist (demarcating a “no passing zone”), including horizontal and low radius curves, climbing or passing lanes, and tangent “no passing” zones where the length is greater than 300 m
- Where there has been a frequent occurrence of cross-centreline or head-on collisions, including passing zones, horizontal curves and tangents
- At undivided two-lane to divided four-lane transitions
- Across the intersection of field entrances

Centreline rumble strips are generally not installed on highway sections where:

- Posted speed limit is 70 km/h or less in the vicinity of a residential or urban area
- There are curbs and gutter or a sidewalk
- Average spacing of driveways is less than 150 m and/or average spacing of intersections is less than 500 m
- A residential or urban area is within 200 m
- Intersections of side roads, commercial or residential entrances are within 60 m
- Bridge decks are within 60 m.

Similar to the recommended design approach for shoulder rumble strips, dimensions for CLRS are presented. The dimensions are within the range applied across North America. Adopting similar dimensions to those of shoulder rumble strips (SRS) is appropriate to facilitate installation (i.e., the same equipment may be used for both shoulder and centreline rumbles strips) and provide more cost effective applications.

Recommended Design Dimensions – Milled-in Centreline Rumble Strips

Dimension	Guideline	Comments
F (strip shape)	Round	Consistent with current practices in North America, most milling equipment, and TAC recommendation for SRS.
G (strip width)	300 mm typical (12 in) or 500 mm heavy trucks (20 in)	Consistent with current practices in North America and TAC recommendation for SRS. Similar to SRS, a width of 500 mm (20 in) may be considered on segments with a large proportion of heavy trucks.
H (centre-to-centre spacing of strips)	300 mm (12 in)	Consistent with current practices in North America and TAC recommendation for SRS.
I (strip depth)	8 ± 2 mm (0.3 ± 0.08 in)	Consistent with current practices in North America and TAC recommendation for SRS. This is not as deep as the designs in most U.S. states; however, testing indicates that a depth of 8 mm provides sufficient noise and vibration to drivers, and is acceptable to cyclists.
J (strip length)	175 ± 25 mm (7 ± 1 in)	Consistent with current practices in North America and TAC recommendation for SRS.

The following collision modification factors are recommended for the installation of CLRS on two-lane rural roads, with both horizontal and tangent alignments, and ADT ranging from 5,000 veh/day to 22,000 veh/day:

- 0.85 for all collision types, with injury severity
- 0.75 for head-on and opposite-direction sideswipe collisions, with injury severity
- 0.79 for head-on and opposite-direction sideswipe collisions of all severities.

Noise generated by vehicles contacting rumble strips is a valid concern, and most agencies review noise impacts prior to installing CLRS. Other common concerns regarding the implementation of CLRS, including installation, maintenance, pavement markings, collision migration, and driver response were reviewed. In general, there is no documented evidence that these concerns are substantiated.

The impacts of CLRS on bicyclist, motorcyclists, truck drivers, and emergency vehicle operators were reviewed, and no substantiated negative effects were found for bicyclists or motorcyclists. Wider rumble strips (500 mm) may be considered for segments with higher truck volumes.

SOMMAIRE

Conçues d'après les paramètres des bandes d'alerte pour accotement, lesquelles visent à prévenir les conducteurs qu'ils s'écartent de leur voie de circulation, les bandes d'alerte pour zone médiane (BAZM) sont disposées entre des voies de circulation opposées d'une route à chaussée unique. Les BAZM ont pour but d'avertir les conducteurs qu'ils s'apprêtent à franchir la ligne médiane de la chaussée et à pénétrer dans la voie de circulation en sens inverse. À l'instar des bandes d'alerte pour accotement, l'avertissement communiqué au conducteur se manifeste sous la forme d'un bruit accru et de vibrations à l'intérieur du véhicule.

Les types de collisions que les BAZM visent à éviter sont les collisions frontales et les collisions latérales de véhicules circulant en sens inverse. Ces collisions sont attribuables à l'inattention des conducteurs. Les collisions dues à des sorties de route vers la gauche peuvent être considérées comme un type secondaire d'accidents que les BAZM ont pour but d'éviter, en particulier si la chaussée n'est pas pourvue de bandes d'alerte pour accotement.

Au Canada, trois provinces (Alberta, Saskatchewan et Colombie-Britannique) de même que Parcs Canada ont aménagé des BAZM. En 2003, aux États-Unis, la situation était la suivante : au moins 20 États avaient aménagé des BAZM; 12 États examinaient la possibilité d'en faire autant; 4 États estimaient qu'ils installeraient « probablement » des BAZM et deux autres États avaient établi « des plans définitifs » d'installation prochaine de BAZM.

Les BAZM peuvent être utilisées dans toute zone (dépassement autorisé ou interdit) de routes rurales à deux, trois ou quatre voies et à chaussée unique, et plus spécifiquement dans les cas suivants :

- sur les nouveaux tronçons de route;
- lors des travaux de resurfaçage, de réfection ou de reconstruction de tronçons routiers existants;
- sur tout autre tronçon routier qui ne fait pas partie d'un projet mais où l'installation de BAZM améliorerait la sécurité (p. ex. en diminuant le nombre des accidents attribuables au franchissement de la ligne médiane de la chaussée).

À la lumière d'une analyse de la documentation et des pratiques existantes en Amérique du Nord et à l'échelle internationale, il appert que les BAZM sont notamment utilisées sur les routes rurales à deux, trois ou quatre voies et à chaussée unique dans les circonstances suivantes :

- lorsque la chaussée présente déjà une double ligne continue (zone de dépassement interdit), y compris les courbes de tracé en plan et de faible rayon, les voies pour véhicules lents ou les voies de dépassement ainsi que les zones tangentes de dépassement interdit de plus de 300 m de longueur;
- aux endroits où des collisions attribuables au franchissement de la ligne médiane sinon des collisions frontales ont fréquemment eu lieu, y compris les zones de dépassement, les courbes de tracé en plan et les zones tangentes;
- aux points de transition d'une route à deux voies et à chaussée unique à une route à quatre voies et à chaussées séparées;
- aux points d'intersection avec des voies d'accès à des terrains.

Les bandes d'alerte pour zone médiane ne sont généralement pas utilisées sur les tronçons de route où :

- la limite de vitesse affichée dans le voisinage d'un secteur résidentiel ou urbain est de 70 km/h ou moins;
- des bordures/caniveaux ou des trottoirs longent la voie de circulation;
- l'espacement moyen des entrées de cour est inférieur à 150 m, ou encore lorsque l'espacement moyen des intersections est inférieur à 500 m, ou les deux;
- un secteur résidentiel ou urbain se trouve à moins de 200 m;
- des intersections avec des routes latérales ou encore des entrées commerciales ou résidentielles se trouvent à moins à 60 m;
- des tabliers de pont se trouvent à moins de 60 m.

Les paramètres dimensionnels des BAZM sont exposés ci-après. Appliqués de façon générale à l'échelle de l'Amérique du Nord, ces paramètres se comparent à ceux recommandés pour la conception des bandes d'alerte pour accotement (BAA). L'adoption de paramètres dimensionnels analogues pour l'un et l'autre types de bandes d'alerte s'avère pertinente puisque cette pratique permet de faciliter l'installation desdites bandes (le même équipement peut être utilisé dans les deux cas) et de réaliser ainsi des gains d'efficience.

Paramètres dimensionnels recommandés – BAZM gravées dans la chaussée

Paramètres	Lignes directrices	Observations
F (forme des stries)	Arrondie	Conforme aux pratiques appliquées en Amérique du Nord, aux exigences de la plupart des équipements de fraisage des chaussées et à une recommandation de l'ATC concernant les BAA.
G (largeur des stries)	300 mm – dimension type (12 po) ou 500 mm – camions lourds (20 po)	Conforme aux pratiques appliquées en Amérique du Nord et à la recommandation de l'ATC concernant les BAA. À l'instar des BAA, une largeur de 500 mm (20 po) est considérée acceptable sur les tronçons routiers où circulent de nombreux camions lourds.
H (espacement des stries, de centre à centre)	300 mm (12 po)	Conforme aux pratiques appliquées en Amérique du Nord et à la recommandation de l'ATC concernant les BAA.
I (profondeur des stries)	8 ± 2 mm (0,3 ± 0,08 po)	Conforme aux pratiques appliquées en Amérique du Nord et à la recommandation de l'ATC concernant les BAA. Ce paramètre ne témoigne pas de la profondeur des stries pratiquées dans la majorité des États des États-Unis. Toutefois, différents essais démontrent qu'une profondeur de strie de 8 mm permet de créer suffisamment de bruit et de vibrations pour alerter les conducteurs automobiles sans pour autant incommoder les cyclistes.
J (longueur des stries)	175 ± 25 mm (7 ± 1 po)	Conforme aux pratiques appliquées en Amérique du Nord et à la recommandation de l'ATC concernant les BAA.

Les facteurs ci-après d'atténuation du nombre de collisions sont recommandés pour l'installation de BAZM sur les routes rurales à deux voies, avec alignements horizontaux et tangents, et où le DQM oscille entre 5 000 et 22 000 véhicules par jour :

- 0,85 pour tous les types de collisions avec blessures graves;
- 0,75 pour les collisions frontales et les collisions latérales de véhicules circulant en sens inverse, avec blessures graves;
- 0,79 pour les collisions frontales et latérales de véhicules circulant en sens inverse, tous types de gravité compris.

Le bruit produit par le contact des véhicules franchissant les bandes d'alerte demeure une préoccupation d'intérêt, à tel point que la majorité des administrations routières jugent opportun de procéder à des analyses des incidences ici visées avant d'aménager des BAZM. Les autres préoccupations entourant couramment la mise en place de BAZM concernent notamment les points ci-après : installation, entretien, marquage des chaussées, changements au niveau des collisions et réponse des conducteurs automobiles. Ceci dit, il n'existe ni analyses ni données permettant de conclure au bien-fondé de ces préoccupations.

Les incidences des BAZM sur les cyclistes, les motocyclistes, les conducteurs de camion et les exploitants de véhicules d'urgence ont été analysées. Les BAZM ne présentent vraisemblablement aucun effet négatif sur les cyclistes et les motocyclistes. En revanche, des bandes d'alerte plus larges (500 mm) pourraient être envisagées sur les tronçons routiers accueillant un plus grand nombre de camions.

1. INTRODUCTION

Rumble strips are raised or grooved patterns installed on the road surface to provide both an auditory warning (rumbling sound) and a physical vibration to alert drivers that they are leaving the travel lane. In addition to warning inattentive drivers, longitudinal rumble strips may help drivers maintain the travel lane during inclement weather when visibility is poor (*1*).

Shoulder rumble strips have proven to be very effective for warning drivers that they are about to drive off the road. Many studies also show very high benefit-to-cost (B/C) ratios for shoulder rumble strips (SRS), making them among the most cost-effective safety features available (*1*).

There are three types of rumble strip installations. The most common type is the continuous shoulder rumble strip; located on the road shoulder to reduce roadway departure crashes. Transverse rumble strips may be installed on approaches to intersections, toll plazas, horizontal curves, and work zones (*1*). Centreline rumble strips are applied along the centre of undivided roadways, and are generally used to prevent head-on collisions.

Centreline rumble strips (CLRS) are similar to shoulder rumble strips in design and intent. The target collision types for CLRS are head-on and opposite-direction sideswipe collisions due to inattentive drivers. Run-off-road-left collisions may be considered as a secondary target collision type, particularly if shoulder rumble strips are not present.

The objective of this assignment is to review and synthesize current literature and practices in North America and internationally, and to recommend an update to the TAC *Geometric Design Guide for Canadian Roads* (1999) with discussion on CLRS.

Section 2 of this report reviews current practices in North America and internationally, including design elements and documented issues. Conclusions based on this review are outlined in Section 3, where recommendations for design elements and application guidelines are found. Section 4 contains potential future research topics. Appendix A provides design drawings obtained from several jurisdictions. Appendix B contains the provincial and state CLRS policy documents reviewed.

Much of the information included in this paper is based on the recent work by Dr. Eugene Russell and Dr. Margaret Rys of Kansas State University for NCHRP Synthesis 34-01, which was recently published as NCHRP Synthesis 339 “Centerline Rumble Strips” (*2*). The authors wish to thank Drs. Russell and Rys for sharing the results of their survey of practices.

2. CURRENT APPLICATIONS

In North America, agencies are applying rumble strips along the centrelines of undivided two-way roads to reduce crossover collisions (*3*). However, this practice appears to be constrained at times due to a lack of published knowledge regarding design practices, site selection for installation, expected benefits, and possible detriments.

In Canada, three provinces (Alberta, Saskatchewan, and British Columbia) have implemented centreline rumble strips (CLRS) (*2*,*4*,*5*).

According to a 2003 survey conducted in the United States (*6*), twenty states have installed CLRS (Alaska, Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Kentucky, Maryland, Massachusetts, Minnesota, Nevada, New Hampshire, New Mexico, Ohio, Oregon, Pennsylvania, Virginia, Washington, Wyoming). Twelve states are "considering" CLRS, four states will "probably" install CLRS, one state (Kansas) has "definite plans" to install in the near future (*6*), and one state (New York) plans to install test applications of CLRS in each region (*7*). This indicates that 38 states have installed or might install CLRS in the near future. However, only three states reported five or more installations and nine states indicated greater than 15 mi (24 km) of CLRS installed; indicating that CLRS are not used extensively in any state at the time of the survey.

Based on a recent survey (*2*), warrants were not found for the installation of CLRS. This prompted an additional survey for that project focused on warrants. There were a total of eighteen responses to the additional survey: fourteen U.S. states (including twelve with CLRS and two that were considering CLRS), and three Canadian provinces including two with CLRS. The consultants for NCHRP 34-01 consider this response a reliable cross-section. The survey provides the following insights (*2*):

- The majority of respondents (58%) did not think CLRS warrants are appropriate. Two respondents (11%) indicated that a warrant would be appropriate, and one provided a draft warrant document (Missouri, Appendix B).
- The majority of respondents would prefer guidelines based on "engineering judgment".

Based on these results, and as outlined in the scope of work, guidelines for implementation of CLRS are provided as part of this review of current practices.

Internationally, few references to CLRS were found. One study was conducted in the Netherlands combining shoulder and centreline rumble strips (rumble strips are also referred to as "chipping strips") (*8*).

As defined in the TAC *Best Practices for the Implementation of Shoulder and Centreline Rumble Strips* (*9*), the terminology used in this report for CLRS dimensions and design parameters is illustrated in Figure 1.

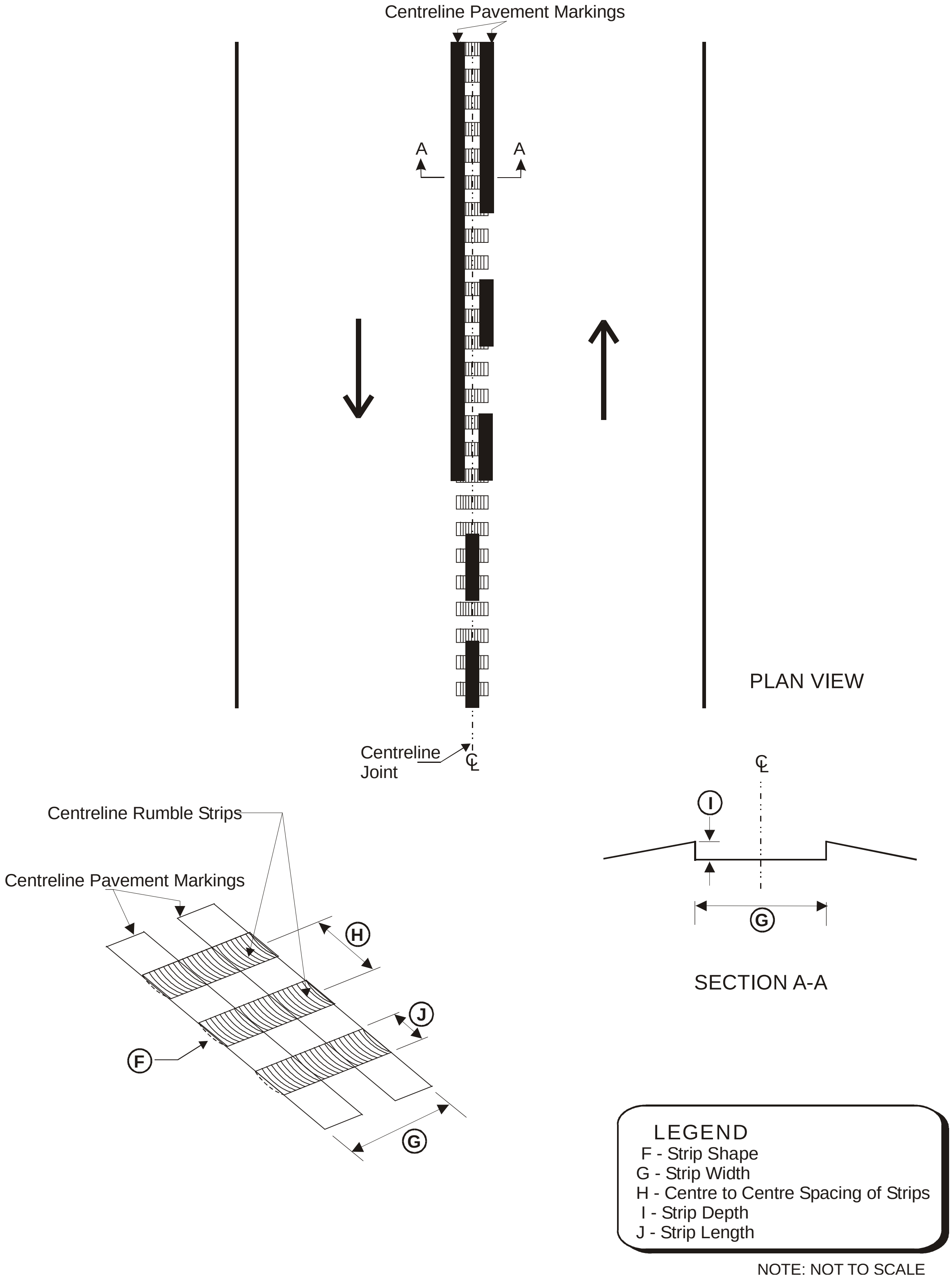


Figure 1: Centreline Rumble Strip Design Terminology

2.1 APPLICATIONS

This section summarizes the characteristics of current CLRS applications in Canada and internationally. Effectiveness and costs of various designs are discussed, along with a summary of potential concerns identified in the literature. A summary of the design elements detailed in Sections 2.1.1 to 2.1.5 is provided in Section 2.1.6.

2.1.1 Road Characteristics

In this section, a synthesis of the state of the practice is described. It provides information about the characteristics of the roadways, such as the horizontal alignment, passing areas, density and location of intersections and driveways, proximity to residential areas, width of the lanes and shoulders, etc. For some agencies, the design drawings and guidelines or policies for implementation are provided in Appendix A and Appendix B, respectively.

2.1.1.1 Canada

In Alberta, CLRS are installed only in no passing zones, preferably on horizontal curves, on rural two-lane highways with a posted speed of 100 km/h (design speed of 110 km/h) (Figure 2). Locations are usually selected based on a pattern of collisions related to horizontal curvature and/or passing in a no passing zone (e.g., three or more related collisions in the last five years).

In 1999, the province developed installation criteria for CLRS to be installed on highway segments with the following characteristics (*10*):

- Selected horizontal curves on undivided highways that have a history of collisions that could be reduced through the use of additional guidance to assist drivers in keeping within the designated lanes.
- All horizontal curves of undivided highways where there are double-barrier lines (no passing in both directions).
- All double-barrier lines at no passing zones of climbing lanes or passing lanes.
- All double-barrier lines at no passing zones at tangent sections where the length is greater than 300 m.
- Short sections of double-barrier centrelines in advance of intersections do not require rumble strips if they are on tangent (straight alignment).

CLRS are not installed within 200 m (656 ft) of residences. Temporary warning signs are installed for six to twelve months after construction to advise motorists of the installation of a new traffic control device (i.e., CLRS) (Figure 3) (*11*). Draft guidance on installing these signs is provided in Appendix A, Figure 15.

Figure 2: An example of milled CLRS in Alberta
(Photo: Dr. John Morrall; Equipment Courtesy: All West Bobcat Services)

Figure 3: A temporary warning sign used in Alberta in advance of highway section with CLRS to alert drivers to presence of rumble strips along the highway centreline (additional details in Appendix A, Figure 15)

In Saskatchewan, CLRS are a relatively new practice. During 2001, in response to local resident concerns, CLRS were installed as a pilot project at a location that experienced a high frequency of head-on collisions; however, this project was discontinued due to road surface deterioration, and a new location is pending (*4*). Guidelines, policies, or warrants regarding the installation of CLRS in general situations have not been developed to date in Saskatchewan.

CLRS have also been installed in Saskatchewan on undivided two-lane to divided four-lane transitions, specifically on the two-lane section approaching the transition. The CLRS start approximately where a “No Passing” sign is located, and stops at the gore point where the rumble strips turn into shoulder rumble strips (SRS), as illustrated in Appendix A, Figure 16) (*4*).

In British Columbia, a recent Technical Bulletin (DS04002) (*5*) states that centreline rumble strips should be considered on undivided rural two-lane, three-lane, or four-lane highways in no passing zones (i.e., a double solid painted centreline) in the following three scenarios:

1. New undivided, rural two-lane, three-lane, or four-lane highway sections.
2. When re-paving, rehabilitating, or reconstructing existing undivided rural two-lane, three-lane or four-lane highway sections.
3. Other undivided rural two-lane, three-lane, or four-lane highway sections that are not part of a project but would benefit from the installation of CLRS (to decrease the frequency of crossover centreline collisions).

The B.C. Technical Bulletin continues by stating that CLRS should not be used in urban areas, such as highway sections with any of the following (*5*):

- Speed zone of 70 km/h or less in the vicinity of a residential or urban area
- Curb and gutter or a sidewalk
- Average driveway spacing less than 150 m or average intersection spacing less than 500 m.

In addition to the above points, British Columbia has the following guidelines (*5*):

- CLRS shall begin at the start of the double solid painted centreline
- With a painted flush median < 2.0 m wide, apply CLRS in the centre of the painted median
- With a painted flush median ≥ 2.0 m, follow application guidelines for SRS
- Interrupt CLRS prior to driveways and intersections; do not need to interrupt for field entrances
- Do not install on bridge decks, overpasses, or other concrete surface structures
- Discontinue CLRS within 200 m of a residential or urban area
- Applying CLRS on lane widths less than 3.4 m requires an engineering review
- Recommended minimum depth of pavement is 50 mm.

Design guideline drawings from British Columbia are provided in Appendix A, and the full British Columbia Technical Bulletin is included in Appendix B.

Parks Canada has installed CLRS on the Icefields Parkway from the TransCanada Highway to KM-52 (52 km), as well as the following no passing zone sections of the TransCanada Highway (*12*):

- Banff National Park from Castle Junction to the British Columbia border (35 km)
- Yoho National Park (east to west boundary) (46 km)
- Glacier National Park (east to west boundary) (44 km)
- Mount Revelstoke National Park (east to west boundary) (13 km).

In addition, CLRS were installed in Fall 2004 on the TransCanada Highway, regardless of passing zone, between Castle Junction, Alberta and the Alberta/British Columbia border (Figure 4) (*12*).

Signs are posted on the roadside of the TransCanada Highway to inform drivers of the presence of rumble strips (Figure 5).

Figure 4: CLRS installed on the TransCanada Highway regardless of passing zone (Photo: Dr. John Morrall)

Figure 5: CLRS signs on the roadside of the TransCanada Highway (Photo: Dr. John Morrall)

2.1.1.2 United States

In the United States, the majority of CLRS are installed on rural two-lane highways, however, some states (e.g., Kentucky, Maryland, Oregon, Pennsylvania, and Virginia) indicate CLRS could be or have been installed on four-lane undivided roadway sections.

The cross-sections of roads with CLRS vary from state to state. Reference to the travel lane widths for the application of CLRS (*9*) include:

- Jurisdictions consistently applied CLRS on roads with travel lane widths of 3.4 m (11 ft). Many jurisdictions recommend that CLRS be applied on roads where the travel lane width ranges from 3.4 m to 3.6 m (11 to 12 ft).
- Some jurisdictions require that a paved shoulder width of 1.2 m (4 ft) be available on roads where the travel lanes are 3.4 m (11 ft) wide and CLRS are to be installed.

Based on survey results (*2*) and the literature review undertaken by iTRANS, four states install CLRS only in no passing zones (California, Washington, Massachusetts, Connecticut); and seven states indicate installations in all zones (i.e., passing and no passing) (Arizona, Colorado, Delaware, Maryland, Minnesota, Oregon, Pennsylvania) (Figure 6 to Figure 9). At this time, it is not clear if the remaining states that install CLRS in no passing zones or in all zones. Those agencies that install CLRS in passing zones reason that drivers are more likely to go to sleep on long, straight stretches (where passing is permitted) thus CLRS may be effective at these locations (*9*). Anecdotal comments from staff in Colorado indicate that CLRS in passing zones may reduce ill-advised passing and dangerous “peeking out” driver behaviour (*2*).

Figure 6: Delaware CLRS installation in passing zone (*13*) (http://www.deldot.net/static/projects/rumblestrip/index.html)

Figure 7: CLRS implemented in a Maryland passing zone (*14*)

Figure 8: CLRS implemented in a Maryland no passing zone (Photo courtesy: Thomas Hicks)

Figure 9: Centreline Rumble Strips in Minnesota (http://www.dot.state.mn.us/trafficeng/safety/rumble/index.html)

The horizontal and vertical alignment of the road is often considered in terms of the passing sight distance; two states explicitly indicate that sections with CLRS have horizontal and/or vertical curves (e.g., Colorado has installed CLRS on winding mountain roads, Massachusetts has at least one site with both horizontal curves and tangents); it can be assumed that most CLRS installations include both horizontal curves and tangents, vertical curves and level sections, due to the length of installations (up to 60 km). In addition, a recent study by Persaud et al. (*7*) reviewed CLRS data from seven states, and indicated that most sections included both horizontal curves and tangent sections.

Traffic volumes and traffic mix appears to vary from state to state. Based on reviewed literature, ADT information was found for eight states (California, Colorado, Delaware, Maryland, Michigan, Minnesota, Oregon, Washington), and ranged 5,000 to 22,000 veh/day (*7*,*15*).

Posted speed limits are typically 55 mph (90 km/h), based on information from four states (Michigan, Minnesota, Oregon, Washington) (*2*,*15*,*16*,*17*). Utah indicates a posted speed limit of 50 mph (80 km/h) or greater (*2*). Maryland notes a posted speed of at least 40 mph (65 km/h) (*14*,*18*). No information was available regarding the design speeds of roadways with CLRS implemented.

Most states are sensitive to noise issues; few have indicated a recommended minimum distance to residences from CLRS. These issues are further discussed in Section 2.2. Information signs for CLRS do not appear to be common practice in the United States., as no mention was found in publications or current practices.

There is some concern by agencies that have not implemented CLRS that the rumble strips may reduce the effective lane width available to drivers. Based on a recent survey (*2*), 19 states (out of 24 respondents) did not have to adjust lane width because of rumble strips. Consideration of rumble strip width and how far the CLRS extends into the travel lane will be considered in Section 3.

Thus, based on the literature review, all states indicate that site selection is based on a history of cross-centreline collisions, generally with high severity. Some states consider CLRS a low-cost intermediate measure until funding is available for further improvements to the road. Often, other low-cost improvements are made at the time CLRS are installed such as SRS; restriping, repainting or other delineation; adding turn lanes or other intersection improvements; signage; enforcement, and education. The most common reason for installing CLRS is high collision history; no state indicated use of CLRS exclusively to enhance centreline delineation (*6*). CLRS implementation is further discussed in Section 2.2.

2.1.1.3 International

In the Netherlands, raised CLRS were experimentally installed on 4 sections of two-lane rural roads with a posted speed of 80 km/h along with other measures intended to reduce the operational speed of the roads. No other international applications were found in current literature.

2.1.1.4 Summary

Based on current practices, centreline rumble strips may be appropriate on two-lane, three-lane, or four-lane undivided rural roads in the following locations, if noise and other considerations are satisfied (as discussed in Section 2.2):

- Where double solid painted lines currently exist (demarcating a “no passing zone”), including horizontal and low radius curves, climbing or passing lanes, and tangent “no passing” zones where the length is greater than 300 m
- Where there has been a frequent occurrence of cross-centreline or head-on collisions, including passing zones, horizontal curves and tangents
- At undivided two-lane to divided four-lane transitions
- Across the intersection of field entrances.

Centreline rumble strips are not appropriate in the following locations (*9*):

- 200 m prior to a residential or urban area
- Across the intersection of a side road, commercial, or residential entrance
- On bridge decks
- Where posted speed limit is less than 70 km/h in the vicinity of a residential or urban area.

As noted in the introduction, before recommending practice to Canadian agencies, other considerations must be examined, as described in the remainder of Section 2. The conclusions based on this review will be outlined in Section 3.

2.1.2 Design Dimensions

This section presents the state of the practice with respect to the design dimensions of milled CLRS. These dimensions comprise strip width, length, shape, depth, and spacing between stripes.

2.1.2.1 Canada

In Alberta, milled rumble strips are installed at the centreline, with a width of 300 mm (12 in), a length of 150 to 200 mm (6 in to 8 in), in a round shape with a depth of 7 ± 2 mm (0.28 to 0.35 in). Rumble strips are spaced 300 mm (12 in) apart in a continuous pattern, measured from centre to centre (*2*,*11*,*19*) (Appendix A, Figure 14). The presence of SRS does not influence site selection process for the installation of CLRS in Alberta (*11*).

Parks Canada uses the same design dimensions as Alberta (*12*).

In Saskatchewan, milled CLRS are installed directly on top of the pavement markings, with a width of 100 mm (4 in), a length of 150 mm (6 in), in a round shape with a depth of 8 to 12 mm (0.3 in to 0.5 in). Rumble strips are spaced 150 mm to 175 mm (6 in to 7 in) measured from edge to edge, or 250 mm to 275 mm (9.8 in to 10.8 in) measured from centre to centre. At undivided two-lane to divided four-lane transitions, CLRS have similar dimensions, except they are 300 mm (12 in) wide, and are spaced 150 mm to 175 mm edge to edge, or 300 mm to 325 mm (11.8 in to 12.8 in) centre to centre (*20*).

In British Columbia, milled rumble strips are installed on the centreline, or in the centre of a flush painted median less than 2.0 m wide. CLRS have a width of 300 ± 10 mm (12 ± 0.4 in), a length of 140 ± 20 mm (5.5 ± 0.8 in), a depth of 8 ± 2 mm (0.3 ± 0.08 in), are round in shape with a radius of 300 mm (12 in) radius. Rumble strips are spaced 300 mm (12 in) apart in a continuous pattern, measured from centre to centre. A lateral tolerance for placement is specified at ±10 mm (0.4 in) left or right of the outside edge of the centreline pavement marking (*5*).

Table 1: Summary of CLRS Design Dimensions used in Canada

Dimension	Range of values	Value [number of agencies]
Width (across road)	100 or 300 mm (4 or 12 in)	100 mm (4 in) [1]* 300 mm (12 in) [4]^
Length (along road)	140 to 200 mm (5.5 to 8 in)	150 to 200 mm (6 to 8 in) [2] 150 mm (6 in) [1] 140 ± 20 mm (5.5 ± 0.8 in) [1]
Depth	7 to 8 mm (0.275 to 0.31 in)	7 ± 2 mm (0.275 ± 0.08 in) [2] 8 ± 2 mm (0.31 ± 0.08 in) [1] 8 to 12 mm (0.3 to 0.5 in) [1]
Shape	N/A	Round [4]
Spacing (centre to centre)	250 to 325 mm (9.8 to 12.8 in)	300 mm (12 in) [3] 250 to 275 mm (9.8 to 10.8 in) [1]* 300 to 325 mm (11.8 to 12.8 in) [1]^

*Saskatchewan on centreline
^Saskatchewan at undivided two-lane to divided four-lane transitions

2.1.2.2 United States

In the United States, milled-in (sometimes referred to as ground-in) rumble strips are the most common type used for CLRS (Alaska, Arizona, California, Colorado, Connecticut, Delaware, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, Oregon, Pennsylvania, Utah, Virginia, Washington). Alabama, California, and Hawaii use raised rumble strips; Virginia and Oregon also use rolled rumble strips; the type used in Texas it is unclear (*2*).

Sixteen states use continuous CLRS (Alaska, Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Kentucky, Massachusetts, Minnesota, Nevada, New Hampshire, Ohio, Pennsylvania, Virginia, Washington) and New Mexico uses an intermittent pattern of approximately 2 metres of rumble strips spaced 2 metres apart (*2*). The CLRS pattern in Maryland varies by installation (*14,18*). Oregon uses two patterns, installed in either passing or no passing zones, and apply continuous CLRS in flush medians 1.2 m (4 ft) in width or greater (Appendix A) (*2*).

Table 2: Summary of CLRS Design Dimensions used in the U.S.

Dimension	Range of values	Value [number of states]
Width (across road)	100 to 450 mm (4 to 18 in)	300 mm (12 in) [4 states] 400 mm (16 in) [8 states] 450 mm (18 in) [1 state] 100 to 300 mm (4 to 12 in) [1 state] 125 to 300 mm (5 to 12 in) [1 state] 300 to 400 mm (12 to 16 in) [1 state] 350 to 450 mm (14 to 18 in) [1 state] Not specified [4 states]
Length (along road)	150 to 200 mm (6 to 8 in)	150mm (6 in) [1 state] 165 mm (6.5 in) [3 states] 180 mm (7 in) [7 states] 200 mm (8 in) [1 state] Not specified [7 states]
Depth	9.5 to 19 mm (0.375 to 0.75 in)	12.5 mm (0.5 in) [8 states] 9.5 to 12.5 mm [1 state] 12.5 to 15.7 mm (0.5 to 0.625 in) [1 state] 16 to 19 mm (0.625 to 0.75 in) [1 state] Not specified [9 states]
Shape	N/A	Round [5 states] Not specified [14 states]
Spacing (centre to centre)	300 to 1200 mm (12 to 48 in)	300 mm (12 in) [9 states] 1200 mm (48 in) [1 state] Various patterns [4 states] Not specified [5 states]

Note: Some design dimensions were found for 19 states, those that were unclear or unavailable are noted as "not specified"; some states use more than one design value and are counted more than once.
N/A = not applicable

2.1.2.3 International

In the Netherlands, the raised centreline rumble strip (or chipping strip) is 300 mm (12 in) wide (Figure 10). Other design dimensions were not published (*8*). The Netherlands uses a continuous pattern on the centreline (*8*).

Figure 10: Raised Centreline Rumble Strips in the Netherlands (*8*)

2.1.2.4 Summary

In summary, the most common design dimensions for CLRS in North America are:

- Width (across road) 300 mm or 400 mm (12 in or 16 in)
- Length (along road) 180 mm (7 in)
- Depth 12.5 mm (0.5 in)
- Shape Round
- Spacing (centre to centre) 300 mm (12 in)

2.1.3 Pavement Markings and Markers

In this section, the application of markings and markers in conjunction with centreline rumble strips is described based on the state of the practice.

In the Canadian provinces of Alberta, Saskatchewan and British Columbia, pavement markings are applied on top of the CLRS (*19,11,4,2*). In Alberta, centreline pavement markings may be applied once in each direction of travel to increase adherence and ensure visibility of the markings; however, Saskatchewan has found that, due to the uniformity of the rumble strips and the slow speed of paint application, a single pass is sufficient when marking the centreline (*4*).

Most U.S. states apply the centreline pavement markings on top of the CLRS whether a double yellow (no passing zone) or broken yellow (passing zone) (Arizona, Colorado, Connecticut, Delaware, Kansas, Massachusetts, Minnesota, Nebraska, Pennsylvania, Texas, Virginia, Washington). Maryland applies pavement markings on top of or beside CLRS; in some cases paints the yellow dashed centreline between a set of rumble strips (Figure 7). Oregon paints a double yellow centreline on either side of the CLRS (*21*) (Figure 11), or provides a 1.2 m (4 ft) painted median (*2*).

The Netherlands appear to be apply the centreline pavement marking intermittently on top of the centreline rumble areas (Figure 10) (*8*).

Only one state (California) was found to use pavement markers in conjunction with CLRS. The pavement markers were placed between the rumble strips. California also uses raised profile thermoplastic striping in conjunction with CLRS (*2*).

Information on the type of paint used was not found during the literature and practice review.

Figure 11: Oregon CLRS installed in a flush median on Mt. Hood Highway (*2*)

In summary, most jurisdictions apply pavement markings on top of CLRS after they have been installed. The use of raised pavement markers in conjunction with CLRS is not common practice.

2.1.4 Impact on Safety

The target collision types for CLRS are head-on and opposite-direction sideswipe collisions due to inattentive drivers. Run-off-road-left collisions may be considered as a secondary target collision type, particularly if SRS are not present on the roadway.

To date, Alberta, Saskatchewan, and British Columbia have not conducted formal evaluations of CLRS (*19*,*11*,*2*). However, the Insurance Corporation of British Columbia (ICBC) suggests an CMF of 0.68 (based on published results by others) for installing CLRS in no passing zones on undivided rural highways for head-on, sideswipe, run-off-road left and overtaking collisions (*5*).

Few evaluation studies have been conducted in the United States on the effectiveness of CLRS, and most of these do not account for regression-to-the-mean, as most locations are selected for implementation based on a high collision history. Fortunately, recent work completed by Persaud et al. (*7*) used an empirical Bayes approach to a cross-section of locations to estimate the impact on safety of CLRS. It should be noted that this cross-section of locations included data from seven states and a variety of CLRS designs and patterns, but it was not possible to determine the effects associated with different designs. All locations were two-lane rural roads, with both horizontal curves and tangent alignments, and ADT ranging from 5,000 to 22,000 veh/day (average of 9,000 veh/day). The average segment length was 2 km. Persaud et al. (*7*) found the following collision reductions, summarized as collision modification factors in Table 3:

- 15% reduction in all injury collisions combined (with a 95% confidence interval of 5 to 25%)
- 25% reduction in head-on and opposing-direction sideswipe injury collisions (with a 95% confidence interval of 5 to 45%)
- 21% reduction in head-on and opposing-direction sideswipe collisions of all severities (with a 95% confidence interval of 5 to 37%).

Table 3: Collision Modification Factors (CMFs) for CLRS (based on (*7*))

CMF	Collision Type	Collision Severity
0.85	All types	Injury
0.75	Head-on and opposite-direction sideswipe	Injury
0.79	Head-on and opposite-direction sideswipe	All severities

Other studies indicate a similar trend in reduced collisions after the implementation of CLRS, summarized in Table 4. Although the magnitude of collision reduction cannot be estimated with certainty (due to regression-to-mean, and the variety of CLRS designs and road characteristics included in these studies), it can be concluded that installing CLRS reduces collisions of all types and severities, reduces target collisions of all severities, and perhaps most importantly reduces fatal collisions. These findings support the results of the analysis described above by Persaud et al. (*7*).

In summary, CLRS have been found to have a positive effect on safety, particularly for the target collisions of head-on and opposite-direction sideswipe. The results of Persaud et al. (*7*) are recommended for use by agencies.

Table 4: Summary of Studies on Effectiveness of CLRS in the U.S. and Internationally (various CLRS designs and road characteristics)

State[1]	Effectiveness of CLRS	Comments
California (*17*)	58% reduction in all collisions 90% reduction in fatal collisions	38 km (23.5 mi) route, regression-to-the-mean is likely present, and other measures were implemented in parallel with the CLRS
Colorado (*22*,*2*)	34% reduction in head-on collisions 36.5% reduction in sideswipe opposite direction collisions Overall reduction of 35% for target collisions	Regression-to-the-mean is likely present as the site was selected based on high collision frequency
Delaware (*13*)	95% reduction in head-on 60% reduction in "drove left of centre" collisions 100% reduction in fatal collisions (though injury and PDO collisions increased by 4% and 13% respectively)	Regression-to-the-mean is likely present as the site was selected based on high collision frequency
Massachusetts (*6*,*2*)	62.5% reduction in all fatal collisions 8 and 25% reduction in target collisions at 2 locations; 70% increase in target collisions at 1 location; Total collisions increased by 7% with a standard deviation of 47%	It is unclear how treated sites were selected Overall, authors feel that CLRS were effective in reducing severity of collisions.
Minnesota (*16*)	29% reduction in all collisions 29% reduction in sideswipe passing 57% reduction in sideswipe opposite 64% reduction in run-off-road left 25% increase in head-on	Unsure how volumes changed over time period; 3 years before and after frequencies
Oregon (*2*)	13 to 100% reduction in all collisions Overall reduction of 69.5% in all collisions	Regression-to-the-mean is likely present as the sites were selected based on high collision frequency
The Netherlands (*8*)	20% reduction in all collisions 36% reduction in injury collisions	Other measures were implemented simultaneously including shoulder rumble strips
Persaud et al. (*7*)	15% reduction in all injury collisions combined (95% CI = 5 to 25%) 25% reduction in frontal and opposing-direction sideswipe injury collisions (95% CI = 5 to 45%) 21% reduction in frontal and opposing-direction sideswipe collisions of all severities (95% CI = 5 to 37%)	CI = confidence interval
Summary	All collisions: from -69.5% to +7% All fatal collisions: from -100% to -62.5% Target injury collisions: from -5% to -45% All target collisions: from -95% to -8%	The results of Persaud et al. (*7*) are recommended for use by agencies.

[1]No formal evaluations performed to date in Canada

2.1.5 Costs

Based on the literature review, the cost of centreline rumble strips is found to vary by location and by year. The values found per linear metre (and linear ft) are summarized in Table 5. Note that these values are in American and Canadian dollars, depending on the jurisdiction, and often include a variety of other road improvements, construction traffic control, and replacement of pavement markings. The cost per metre of installation may decrease as length of project area increases, or if several projects are combined in one contract.

Factors that may influence the cost of installing CLRS include (*2*):

- Speed at which CLRS can be milled (e.g., pattern dimension and complexity, and strip length and cut depth increase milling time)
- Type of roadway surface (concrete takes more time than asphalt)
- Volume of traffic at installation site (amount of traffic control or accommodation during work zone, unexpected delays in installation)
- Overall size of installation (mobilization costs)
- Flexibility for contractor in timing of installation.

Table 5: Cost to install CLRS in Canada (CN$) and the United States (US$)

Province/State	**Cost per linear m (per linear ft)**	**Comments**
Alberta (*11*)	$1.60 ($0.49)	CLRS have a much higher unit price due to the discontinuity of the installation, the fact that segments are generally shorter, traffic control during construction is more difficult, and there is a requirement to paint the centreline in both directions after installation (2004).
Parks Canada (*12*)	$0.75 ($0.23)	Based on a 30 km contract. Excludes re-painting the lines after installation. May want to use more conservative price as other contractors were about double = $1.50 ($0.46) (2004) (*12*)
Saskatchewan (*20*)	$0.40 ($0.12)	Estimated cost is $400/km (2005)
British Columbia[1]	$0.80 to $1.00 ($0.24 to $0.30)	Approximate costs $800 to $1000 / linear km, may be reduced as implementation becomes more common, at this time only one contractor in Province installs CLRS. Cost is higher than shoulder rumble strips due to additional safety vehicle required behind milling machine (2004)
California (*17*) [2]	$20.86 ($6.35)	Total cost of project (rumble strips, pavement markers, raised thermoplastic striping) in January 1996
Colorado (*22*,*2*)	$2.85 ($0.87)	Includes all work zone traffic control and replacement of pavement marking material (1998)
Delaware (*13*)	$0.66 to $2.00 ($0.20 to $0.60)	Depends on length of installation, does not include traffic control (1994 or 2002)
Kansas (*2*)	$0.26 to $0.85 ($0.08 to $0.26)	(2001)
Survey by Massachusetts (*6*,*2*)	$0.66 to $9.84 ($0.20 to $3.00)	Includes a range generated from a survey of 14 states in 2003 (Hawaii was most expensive)
Pennsylvania (*23*)	$5.74 ($1.75)	Based on pilot installations, includes work zone traffic control and maintenance (2002)
Virginia (*14*)	$1.25 to $1.31 ($0.38 to $0.40)	Short project, expect lower cost per length for larger projects (year unknown)
Summary[2]	$0.26 to $9.84 ($0.08 to $3.00)	1995 to 2003

[1]Personal communication with Darwin Tyacke of B.C. Ministry of Transportation
[2]California was excluded from the summary due to number of other improvements that were included in the cost

2.1.6 Summary of Applications

Based on current practices, CLRS are installed on two-lane, three-lane, or four-lane undivided rural roads in the following locations, if noise and other considerations are satisfied:

- Where double solid painted lines currently exist (demarcating a “no passing zone”), including horizontal and low radius curves, climbing or passing lanes, and tangent “no passing” zones where the length is greater than 300 m
- Where there has been a frequent occurrence of cross-centreline or head-on collisions, including passing zones, horizontal curves and tangents
- At undivided two-lane to divided four-lane transitions
- Across the intersection of field entrances.

Centreline rumble strips are not appropriate in the following locations:

- 200 m prior to a residential or urban area
- Across the intersection of a side road, commercial, or residential entrance
- On bridge decks
- Where posted speed limit is less than 70 km/h in the vicinity of a residential or urban area.

In summary, the most common design dimensions for CLRS in North America are:

▪ Width (across road)	300 mm or 400 mm (12 in or 16 in)
▪ Length (along road)	180 mm (7 in)
▪ Depth	12.5 mm (0.5 in)
▪ Shape	Round
▪ Spacing (centre to centre)	300 mm (12 in)

Generally, pavement markings are applied on top of CLRS after installation and pavement markers are not used in conjunction with CLRS.

The overall impact of CLRS on safety is positive, and CMFs are available from work done by Persaud et al. (Table 3).

Cost per linear metre ranges from $0.26 to $9.84 in North America ($CN and $US), and varies depending mainly on the jurisdiction, size of installation, and availability of contractors who can perform the work.

2.2 DOCUMENTED ISSUES

Based on the literature review, and a review of the survey responses to NCHRP Project 34-01 (*2*), the following issues and concerns have been discussed by various agencies: noise, installation, maintenance (winter /debris and standing water, pavement marking service life (visibility /retroreflectivity), collision migration, special road users, bridges, and overuse. At the end of this section, a summary of the issues and conclusions / recommendations for each topic is stated.

2.2.1 Noise Concerns

Although the noise produced by centreline rumble strips would be intermittent as vehicles will not continually encounter them, Alberta Transportation has received some complaints about noise where the ambient noise level is very low; some residents claim to be able to hear the noise from up to 2 km away from the CLRS installation (*2*). Most agencies (including Alaska, Colorado, Delaware, Pennsylvania, and Saskatchewan) suggest the consideration of noise impacts before implementing CLRS (*2*). Maryland considers noise from rumble strips prior to installing, however, noise is considered second to safety (*18*). Alaska suggests that more research on noise is needed (*2*).

Gupta (*24*) measured the noise levels of vehicles passing over grooved rumble strips and found that rumble strips increase noise levels from 6 dB to 8 dB (for this study noise measurements were taken 3 m from the edge of the roadway). The amount of noise created by rumble strips relates to the rumble strip dimensions, type of vehicle, and speed at which the strips are being traversed.

An analysis of various milled rumble strip designs conducted in Alberta (*25*) found that:

- A change in speed from 80 km/h to 120 km/h has little effect on the outside sound level when the vehicle is in the normal driving lane (75 dBA to 82 dBA), but when driving on rumble strips the sound level is greatly affected (88 dBA to 102 dBA)
- The sound level outside the vehicle increases linearly with vehicle speed
- The majority of sound created by rumble strips dissipates at approximately 100 m
- For tractor-trailer units, a minimum rumble strip depth of 8 mm is required to produce an increase in sound within the cab.

Studies show that rumble strips that are terminated 200 m prior to residential or urban areas produce tolerable noise impacts on residences. At an offset of 500 m, the noise from rumble strips is negligible (*9*). These findings are supported by NCHRP Report 191, which found that most agencies adopted policies against the use of [shoulder] rumble strips in residential areas; that [shoulder] rumble strips are more appropriate in rural, commercial, and industrial areas (*26*).

The FHWA Rumble Strip website notes that SRS could be placed farther from the travel lane to reduce the number of vehicles who contact the rumble strip and produce noise; however, the website also notes that this gives less time and distance for an errant driver to react and guide the vehicle back to the travel lane (*1*). Consideration of CLRS width and extension into the travel lane will be discussed further in Section 3.

In summary, noise concerns are valid, and most agencies are conscious of the need to evaluate potential noise impacts on residential areas prior to implementing CLRS.

2.2.2 Installation

Two different types of CLRS are currently in use, milled and raised (*9*):

1. Milled CLRS are installed using the same milling technique for milled SRS
2. Raised CLRS typically consist of inverted, thermoplastic markers or striping and raised plastic reflectors that adhere to new or existing pavement.

Raised CLRS are reflective to define the centreline of the road at night and in poor weather. However, raised CLRS are applied on top of the pavement, and are therefore usually restricted to warm climates that do not require snow removal (*9*).Little information was found about the raised CLRS installations. Milled CLRS are the focus of the text below.

Effective construction techniques are needed to minimize the amount of lane closure time needed to install rumble strips (*26*). Colorado notes that the milling machine moves at about 2 km/h (1.25 mph) (
Figure 12); this relatively rapid installation means less danger to the equipment and operators/road users and less inconvenience to the public. In addition, milling rumble strips allows for greater accuracy in placement and dimension (*9*).

Figure 12: Dustrol Inc. Milling Machine (*2*)

Some agencies mill [shoulder rumble strips] on imperfect pavement; before milling any surface, the agency must answer two questions (*27*):

1. "Can the pavement hold up if rumble strips are installed here?"
2. "What is the safety consequence of not providing a rumble strip on this roadway, both this year and in the foreseeable future?"

British Columbia indicates that a minimum depth of pavement required is 50 mm, and that CLRS are not to be installed if pavement deterioration or cracking is evident. Pavement should be in sufficiently good condition to accept the milling process without ravelling or deteriorating, otherwise the pavement should be upgraded prior to milling CLRS (*5*).

Milled CLRS are cut into the road surface; therefore they are equally effective on new, existing, or reconstructed surfaces, both asphalt and concrete pavement (*13*). The milled-in process is also used to ensure accuracy in placement and dimension of the CLRS, an important consideration in the installation process. To date it has been found that the milling-in process does not affect the structural integrity of either asphalt or concrete roads (*9*).

Milled rumble strips are equally suited for both asphalt and concrete roadway surfaces, with two possible exceptions (*2*):

1. Thickness of most recent (topmost) overlay of asphalt should exceed the depth of rumble strips to maintain integrity of overlay seal; and
2. Avoid milling roadway joints of concrete.

An advantage of milled rumble strips over other types is that they produce a louder noise and more vehicle vibration, which increases the potential for alerting a drowsy or distracted driver (*27*).

In summary, milling is the most popular method of installing CLRS, and appears to provide accurate yet rapid installation of rumble strips. Milled rumble strips are equally effective on new, existing, or reconstructed surfaces, both asphalt and concrete pavement surfaces. The roadway surface condition and planned improvements along the segment should be considered prior to installing CLRS.

2.2.3 Maintenance

No concerns related to drainage patterns and CLRS were found in the literature.

The implementation of rumble strips may limit the flexibility of temporarily realigning travel lanes during construction (*26*). However, as noted by the FHWA Rumble Strips website, "For long-term rehabilitation projects on asphalt pavements, most road agencies simply fill in the rumble strips by milling a trench along the shoulder of the rumble strip and filling the trench with asphalt. Once construction is complete, the shoulder is resurfaced and new rumble strips are milled into the new asphalt overlay." (*1*).

In general, most jurisdictions note that little or no maintenance of milled-in CLRS is required to maintain their effectiveness (based on subjective measures of effectiveness).

2.2.3.1 Rumble Strip Service Life

Most agencies expect the same service life for rumble strips as the service life of the pavement. Agencies that have installed raised rumble strips note that they tend to wear down and need to be maintained or reapplied periodically. Milled transverse rumble strips tend to wear at the edges of the groove and close up gradually over time, but since shoulder (and centreline) rumble strips are not travelled continuously, it is assumed that they both should perform adequately until roadway resurfacing (*26*).

2.2.3.2 Pavement Deterioration

Most jurisdictions that have implemented milled-in rumble strips noted that the milling-in process did not affect the structural integrity of either asphalt or concrete roads (*9*). One state (Minnesota) has documented concern from focus group studies that potholes are developing where CLRS were installed. However, this has not been validated (*2*).

The FHWA rumble strip website indicates concern that heavy traffic would cause shoulder pavements with rumble strips to crumble faster. This concern has proven to be unfounded (*1*).

Some agencies indicate concern that milling the rumble strip on the longitudinal joint of asphalt may accelerate deterioration of the joint. Alberta, Saskatchewan, and British Columbia install CLRS generally on the longitudinal pavement joint (*2*,*4*,*5*) and have not indicated any increase in the rate of pavement deterioration.

2.2.3.3 Snow, Debris, and Standing Water

Winter maintenance vehicles may scrape raised rumble strips off the road surface, so this type of rumble strip is usually restricted to use in areas that do not contend with snow removal (*1*).

Focus group studies conducted in Minnesota with snowplough operators documented some concern that CLRS cause problems with the snow and ice removal process, specifically that additional passes of snowploughs were required. Also, the snowplough operators reported some damage to the under body of snowploughs. However, the participants in the focus group also felt that CLRS may improve safety of highway and were not opposed to their installation (*2*).

Colorado has found that milled rumble strips fill somewhat with sand and debris in winter months, which covers the pavement markings at the bottom of groove. However, the action of traffic over time eventually clears out the debris, and based on subjective evaluations inside a passenger car, there does not appear to be a reduction in the effectiveness of noise and vibration generated by rumble strips when debris is present (*22*). Water does not appear to stand in the grooves or accelerate the deterioration of the asphalt at the bottom of the groove (*22*).

The FHWA rumble strip website indicates that preliminary concerns that the freeze-thaw cycle of water collecting in the grooves would crack the pavement have proven to be unfounded (*1*). This fact is supported by Alberta where no problems with snow, ice, water or debris accumulating in rumble strips were found (*2*).

In summary, milled rumble strips are more appropriate than raised rumble strips for Canadian weather conditions. Snowplough drivers need to be informed of routes with CLRS in order to increase their awareness of and potentially modify their approach to snowploughing those routes. Overall, agencies that have noted debris or water standing in the grooves have found no reduction in the effectiveness of the CLRS, while the installations in Alberta did not encounter problems with water or debris accumulating in the grooves.

2.2.3.4 Pavement Marking Service Life (Visibility, Retroreflectivity)

Alberta installations have not experienced any difficulties or adverse wear of pavement markings after the installation of CLRS. Alberta Transportation staff have observed that the pavement marking in the groove of the rumble strip may actually experience less wear and tear from snowploughs and vehicles as the paint is protected from the surface (*9*). Conversely, Colorado notes a potential increase in pavement marking deterioration on the flat section between the rumble strips (*22*) based on visual inspection only. Most American jurisdictions that currently use CLRS have noted no problems with the rumble strip visually affecting the night time retroreflectivity of the yellow painted lines (*9*).

In Alberta, the highway agency repaints the centreline markings on the top of the rumble strips following their installation. This painting is done to increase the visibility of the centreline, although the centreline is still quite visible after the milling process. The practice in Alberta is that the marking must be repainted in both directions to ensure that effectiveness of the marking is the same for both directions of travel (*9*).

A 2003 survey found that some states report decreased visibility and retroreflectivity of centreline markings under night time conditions due to snow, salt, sand or debris collecting in the grooves (*6*), as discussed in Section 2.2.3.3. The same survey found that some states have modified their paint trucks to place centreline markings on either side of CLRS as opposed to on top of the rumble strips.

A study conducted in Michigan compared edge line pavement markings applied on top of SRS to edge line pavement markings applied to a flat pavement surface. The study found that wet-night visibility of the pavement markings was much greater on rumble strips than on flat pavement. The authors state that placing pavement markings on top of the rumble strip may increase the service life of the marking due to reduced contact from vehicles and snowploughs (*15*).

In Texas, pavement markings applied over rumble strips were found to maintain their visibility during rainy night time conditions, while markings on flat pavement "seem to disappear" (*28*). Similarly, Saskatchewan Highways and Transportation staff note a loss of reflectivity of the centreline marking during wet conditions, but no reduction in night time visibility of markings painted on top of rumble strips. One location was selected for CLRS installation based on a frequent lack of visibility due to fog; CLRS were found to enhance centreline delineation at that site (*2*). Conversely, a focus group study in Minnesota found that some participants felt that the painted centreline striping is less visible at night, particularly under wet-night conditions. Minnesota paints the centreline on top of the rumble strips (*2*).

In summary, there is no certain evidence if painting on top of CLRS increases or decreases pavement marking visibility or retroreflectivity. Further research is necessary to determine actual measurements of the contrast and retroreflectivity levels under different conditions.

2.2.4 Collision Migration

An Arizona district engineer suggests that CLRS should be applied to all two-lane roads if funding is available, not just on horizontal curves, as "drivers are more likely to go sleep on long straight stretches" (*2*). Delaware notes that a head-on collision pattern may be transferred downstream of the CLRS installation to segments that do not have CLRS (*13*). No studies were found about quantified collision migration, further research is necessary to determine if this is an issue for consideration.

2.2.5 Road Users

The following sections provide an overview of vehicle driver response to CLRS, and potential impacts to special road users: bicyclists, motorcyclists, truck drivers, and emergency vehicle operators.

2.2.5.1 Driver Response

Rumble strips are a relatively new measure, and CLRS are somewhat uncommon in North America. Several agencies have indicated concern that drivers may not understand what a rumble strip is as they drive over it, and may believe there is a mechanical problem with their vehicle (*26*). Others suggest that drivers may be conditioned to correct to the left when they contact rumble strips due to their experience with SRS, and therefore may move in the incorrect direction upon contact with CLRS. A simulator study done in Massachusetts found that about 27% of drivers corrected to the left improperly upon encountering CLRS (*6*). Despite this finding, safety evaluation studies have indicated a reduction in the target crashes (Section 2.1.4).

States that are currently using CLRS in passing zones have not reported any driver reaction problems to CLRS (e.g., Minnesota, Pennsylvania, Washington) (*14*). A Colorado district traffic engineer notes that CLRS in both passing and no passing zones may reduce “high risk” passing and “peeking out” manoeuvres (*2*).

A focus group study in Minnesota found that most personal travellers believe CLRS will save lives particularly for inattentive or drowsy drivers, and are also useful as guidance to locate the centreline in poor weather conditions (e.g., heavy fog, blowing snow). Focus group participants also felt that CLRS would deter unsafe passing. There was concern that unaware drivers may overreact; however, overall, the focus groups concluded that CLRS are a valuable safety enhancement to the highway (*2*).

A similar conclusion was reached by the maintenance staff in Saskatchewan who commented that on two-lane undivided to four-lane divided transitions, where rumble strips are applied on the approach to and through the transition, signs located in the gore area are hit less frequently after the installation of the CLRS (*2*). In Pennsylvania, members of the public have commented that CLRS are useful in winter driving conditions to assist drivers in locating the centreline of the road (*2*). Both findings imply that drivers generally understand the message that the CLRS convey.

Since this treatment is relatively new, there may be a need for public information campaigns to explain the function of CLRS; this may also provide an opportunity to address concerns of local cycling or motorcycling groups (*14*). The FHWA Rumble Strips website (*1*) suggests providing “Rumble Strip” or “Rumble Strips Ahead” signs to notify road users of the presence of rumble strips. As noted in Section 2.1.1, Alberta is currently implementing temporary warning signs for 6 to 12 months after implementing CLRS (Figure 3).

There is no clear evidence that drivers respond to CLRS in undesired ways.

2.2.5.2 Bicyclists

Most studies regarding the impact of rumble strips on bicyclists investigate shoulder or transverse, but not CLRS. Both Alberta and Saskatchewan have received no response from the cycling community regarding CLRS installations in those provinces.

A cyclist group, Bicycle Colorado, notes a range of opinions on the implementation of CLRS on mountainous roads (http://bicyclecolo.org/site/). The concern is generally that motorists will not provide sufficient passing distance to cyclists in order to avoid contact with CLRS. Other cyclists feel that motorists do not hesitate to encounter the CLRS when passing cyclists, and find the noise of CLRS is a disadvantage. One cyclist suggests that cyclists should ride briefly on rumble strips prior to riding on a busier road with rumble strips (centreline or shoulder) in order to become accustomed to the “feel” in case they encounter rumble strips occasionally or in a traffic situation.

A recent study by Torbic et al. (2001) evaluated rumble strip patterns on non-freeway roads to establish which design dimensions were the most effective for motorists and the most friendly for bicyclists (*29*). Two alternatives are recommended:

1. 127 mm wide strips, 178 mm edge to edge between cuts, 10 mm deep, for operating speeds of 88 km/h
2. 127 mm wide strips, 178 mm edge to edge between cuts, 6.3 mm deep, for operating speed of 72 km/h.

Agencies may wish to consider these design dimensions in areas that are known to be popular to cyclists.

2.2.5.3 Motorcyclists

Testing in Alberta of SRS with motorcycle drivers found that no adverse handling conditions were experienced when driving on 8 mm (0.3 in) deep rumble strips, except for some reduction in deceleration performance. However, it was determined to be of no major concern since it was unlikely that deceleration would occur entirely within the rumble strip zone (*9*). Alberta has had no negative response from the motorcycle community regarding CLRS installations in that province (*2*). Similarly, in Saskatchewan, although no response has be formalized from the motorcycle community, a crew foreman that installs CLRS also rides with a motorcycle club, and has personally “tested” riding on CLRS many times with no noted problems (*2*).

A survey conducted in 2003 noted that some states have indicated concern for motorcyclists that encounter CLRS (*6*), but no specific data were evaluated. A focus group in Minnesota felt that motorcyclists would be less likely to pass other vehicles in order to avoid contact with CLRS (*2*). A literature search as part of NCHRP 34-01 found no identified issues regarding motorcyclists and CLRS (*2*).

In summary, although there is intuitive concern for motorcyclists who encounter CLRS, there have been no quantified or recorded incidents of negative experience.

2.2.5.4 Truck Drivers

NCHRP Report 191 notes that truck drivers may be less likely to detect rumble strips (*26*). Testing in Alberta found that a rumble strip depth of 8 mm is required to create any noticeable effect on tractor-trailers, and that width of 500 mm is more effective on roadways with a large proportion of heavy vehicles (*9*).

A focus group in Minnesota of professional truck drivers noted personal experiences in which CLRS were perceived to have prevented collisions (*2*). This focus group found CLRS useful during adverse weather conditions such as blowing snow and fog, and did not experience manoeuvring problems or loss of control due to contact with CLRS (*2*).

In summary, no adverse experiences of truck drivers and CLRS were found in the literature or in survey responses, and wider rumble strips (500 mm) may be considered for segments with higher truck volumes.

2.2.5.5 Emergency Vehicle Operators

Very limited information was found in current literature documenting potential issues of rumble strips with police, fire, or emergency medical service vehicles. A focus group study noted the following responses from participants (*2*):

- Police & State Patrol: CLRS may be unsafe during high speed pursuits, however if CLRS can be shown to improve overall safety then patrolling of highways with CLRS may be adapted to account for their presence
- EMS: it can be "difficult and troublesome" to drive an ambulance on CLRS, however if CLRS save lives, then they are of value.

No evidence of perceived negative effects on emergency vehicles was found. It is recommended that the impact of rumble strips on emergency vehicles be tested to better understand any potential difficulties

2.2.6 Damage to Vehicles

As noted in Section 2.2.5.1, some drivers may be confused when they encounter rumble strips with their vehicles, and believe that there is a mechanical malfunction with the vehicle. However, this does not appear to be a common reaction (*26*), and with the increased application of rumble strips (shoulder, centreline, and transverse), it is likely that driver confusion will become less of a concern. No instances of vehicle damage were found in the reviewed literature.

2.2.7 Bridges

Of those agencies with CLRS policies or guidelines, some discourage implementation on bridge decks. For example:

- British Columbia's guidance document instructs that CLRS are to be discontinued in advance of bridges, 60 m from the deck joint (Appendix A)
- Kentucky's design specification states "do not install centreline rumble strips on bridge decks" (Appendix A)
- Pennsylvania's policy states that CLRS are not to be installed on bridge decks (Appendix B).

No instances of CLRS applied on bridge decks were found, and installation is not recommended.

2.2.8 Overuse

There is some concern that overuse of rumble strips could reduce their effectiveness. That is, drivers may adapt or become accustomed to the noise. As noted by others, this concern is primarily for transverse rumble strips (*26*), as drivers must drive over the rumble strips placed across the lane. However, for shoulder or centreline rumbles strips, this is likely not an issue, as drivers will contact the rumble strips only if they are leaving their lane.

2.2.9 Summary of Documented Issues

Noise concerns for CLRS are valid, and most agencies are aware of the need to evaluate potential noise impacts on residential areas prior to implementing CLRS.

Based on the literature reviewed, nineteen states reported that lane width was not adjusted when CLRS were applied. Milling is the most popular CLRS installation method, and appears to provide accurate and rapid installation of rumble strips; milled rumble strips are equally effective on new, existing, or reconstructed surfaces, for both asphalt and concrete pavement surfaces. The roadway surface condition and planned improvements along the segment should be considered prior to installing CLRS. British Columbia specifies a recommended minimum depth of pavement of 50 mm.

In general, most jurisdictions note that little or no maintenance of milled-in CLRS is required to maintain their effectiveness (based on subjective measures of effectiveness). CLRS are generally installed on the longitudinal pavement joint, and jurisdictions have not documented an increased rate of pavement deterioration. CLRS are not installed on bridge decks.

Milled rumble strips are more appropriate for Canadian application due to snowplough activity. Overall, agencies that have noted debris or water standing in the milled grooves have found no reduction in the effectiveness of the CLRS. No damages to vehicles have ever been recorded based on the sources of information.

Most jurisdictions have experienced no difficulties or adverse wear of pavement markings after the installation of CLRS. Subjective evaluations indicate that the pavement marking in the CLRS groove may actually experience less wear and tear. There is, however, no certain evidence that painting on top of CLRS increases or decreases pavement marking visibility and/or retroreflectivity.

No studies were found quantifying collision migration, nor any measured negative impacts on vehicles delivering of emergency services.

There is no clear evidence that drivers respond to CLRS in undesired ways. There is some concern if CLRS are implemented on routes with high bicycle volumes drivers may move away from the centreline and closer to cyclists, but there is no factual evidence to substantiate this concern. Although there is intuitive concern for motorcyclists who encounter CLRS, there have been no quantified or recorded incidents of negative effects. No adverse experiences of truck drivers and CLRS were found in the literature; wider rumble strips may be considered for segments with higher truck volumes.

3. RECOMMENDED PRACTICE

3.1 RECOMMENDED DESIGN

Modelled after shoulder rumble strips (SRS), which alert drivers that they are leaving the travel lane, centreline rumble strips (CLRS) are placed between opposing lanes of traffic on an undivided roadway with the purpose to alert drivers that they are crossing over the centreline into the path of oncoming traffic. This warning is generated in the form of increased noise inside the vehicle and a vibration of the vehicle, similar to that of shoulder rumble strips.

Similar to the recommended design approach for shoulder rumble strips, recommended dimensions for CLRS are presented here (Table 6). The dimensions are within the range of dimensions currently applied across North America. Adopting similar dimensions to those of SRS is appropriate to facilitate installation (i.e., the same equipment may be used for both shoulder and centreline rumbles strips) and provide more cost effective applications.

Table 6: Recommended Design Dimensions – Milled-in Centreline Rumble Strips

Dimension	**Guideline**	**Comments**
F (strip shape)	Round	Consistent with current practices in North America, most milling equipment, and TAC recommendation for SRS.
G (strip width)	300 mm typical (12 in) or 500 mm heavy trucks (20 in)	Consistent with current practices in North America and TAC recommendation for SRS. Similar to SRS, a width of 500 mm (20 in) may be considered on segments with a large proportion of heavy trucks.
H (centre to centre spacing of strips)	300 mm (12 in)	Consistent with current practices in North America and TAC recommendation for SRS.
I (strip depth)	8 ± 2 mm (0.3 ± 0.08 in)	Consistent with TAC recommendation for SRS. This is not as deep as the designs in most states; however, testing by Alberta indicates that a depth of 8 mm provides sufficient noise and vibration to alert drivers without creating excessive noise in the surrounding area, and is acceptable to cyclists.
J (strip length)	175 ± 25 mm (7 ± 1 in)	Consistent with current practices in North America and TAC recommendation for SRS.

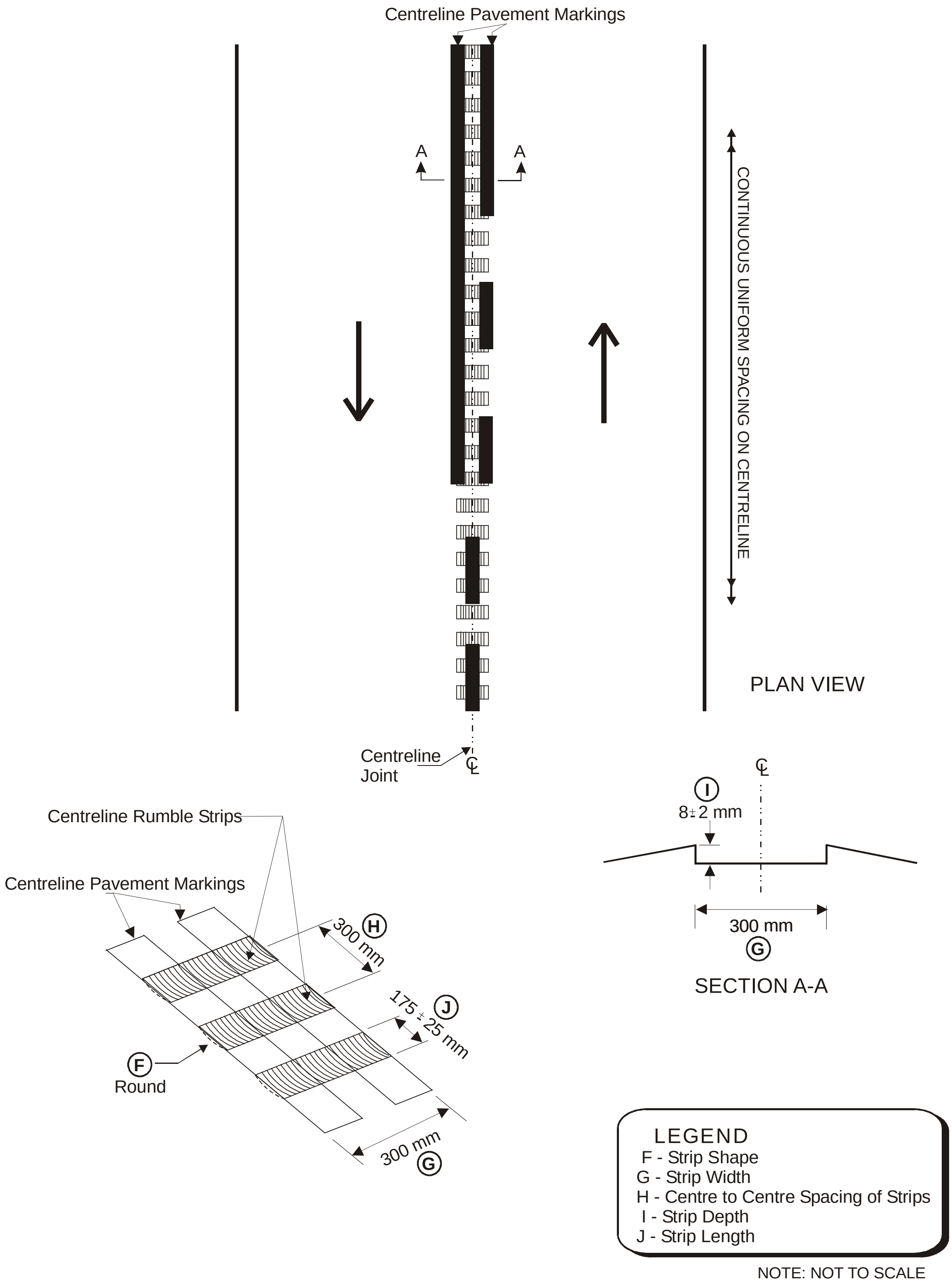


Figure 13: Recommended Centreline Rumble Strip Design

3.2 APPLICATION GUIDELINES

The intent of centreline rumble strips is to alert drivers that they are crossing the centreline of an undivided road. The target collision types of head-on, opposite direction sideswipe, and run-off-road-left can occur in both "no passing" zones and where passing is permitted. Therefore, it is recommended that the TAC Geometric Design Guide provide flexible application guidelines that jurisdictions may implement in both passing and no passing zones.

This section describes the guidelines intended for implementation on rural two-lane and multi-lane undivided highways with centreline pavement markings, in no passing and passing-permitted zones.

3.2.1 General Guidelines

Centreline rumble strips may be considered on undivided, rural two-lane, three-lane, or four-lane highways in all zones (passing or no passing) in the following cases:

- New highway sections
- When repaving, rehabilitating or reconstructing existing highway sections
- Other highway sections that are not part of a project but would benefit from the installation of CLRS in terms of safety (i.e., to decrease the number of crossover centreline crashes).

Consideration may also be given for implementation of CLRS in situations that meet the requirements for directional dividing lines, as defined in Section C2.1.1 of the Manual of Uniform Traffic Control Devices for Canada (MUTCDC) (*30*), such as:

- Approaches to the crest of a hill where clear view ahead is less than 150 m
- 30 m in advance of and beyond any curve having a radius of less than 200 m or where the sight distance is less than 150 m.

CLRS are not recommended for installation if the section is scheduled for repaving, rehabilitation, or reconstruction within 3 years.

The recommended minimum depth of pavement is 50 mm. Prior to installation, visual inspection for pavement deterioration or cracking may be conducted to determine if the pavement is in sufficiently good condition to accept the milling process without ravelling or deteriorating, otherwise the upgrading the pavement surface should be considered prior to applying CLRS.

Consideration should be given to traffic line painting operations to ensure that new centreline pavement markings are applied within a short period of time after CLRS installation, on top of the rumble strips as shown in Figure 13. By using similar width for CLRS as for the centreline pavement marking, lane width will not be diminished with CLRS installation. Good painting practices are required to ensure adequate adhesion to the roadway surface after CLRS application.

Centreline rumble strips should not be used on highway sections where:

- Posted speed limit is 70 km/h or less in the vicinity of a residential or urban area
- There are curbs and gutter or a sidewalk
- Average spacing of driveways is less than 150 m and/or average spacing of intersections is less than 500 m.

It is recommended that CLRS be discontinued 60 m in advance of the pavement edge of a crossing roadway, commercial, or residential entrance. The distance may vary based on the proximity of residences and the nature of the surroundings. For example, if there are raised medians at the intersection, the CLRS would not be implemented alongside the median. It is acceptable to continue CLRS across a field entrance.

Centreline rumble strips should be discontinued 60 m in advance of the deck joint of a bridge, and CLRS should not be installed on bridges.

3.2.2 Machinery Requirements

The installation of CLRS does not require different machinery than the type used for installation of milled-in shoulder rumble strips.

Milling machines should be equipped with an integral sweeping device mounted directly behind the cutter otherwise; a separate sweeping operation should be conducted as construction of the rumble strips progresses within the signed construction zone. After milling, the contractor should pick up and dispose of all debris created from the milling operation (*9*).

3.2.3 Temporary Traffic Control

The installation of centreline rumble strips is a mobile operation and, typically, the highway can be kept open for traffic during the installation (*9*). The application of CLRS can typically be completed at a rate of about 2 km/h (1.25 mph) (*9*).

Appropriate temporary traffic control measures, consistent with local policies and guidelines for temporary traffic control in mobile work zones, are suitable for the safety of the construction workers and road users during the centreline rumble strip installation procedures (*9*). The reader is referred to the Manual of Uniform Traffic Control Devices for Canada (MUTCDC) for appropriate measures.

3.3 MAINTENANCE GUIDELINES

Maintenance issues specific to CLRS were not identified by highway agencies. At present, all jurisdictions with CLRS appear to follow regular highway maintenance practices.

4. FUTURE RESEARCH

Based on the review of current literature, there are some gaps in knowledge, and opportunities for research on other measures, such as:

- Additional analysis of the safety benefits of CLRS in Canada
- Additional research of the impact on motorcyclists, bicyclists, and emergency vehicle operators
- Optimum spacing between rumble strips for cost effectiveness
- The impact of snow, ice, and debris build-up on pavement marking visibility and rumble strip effectiveness
- Scientific evaluation in a controlled setting of retroreflectivity of pavement markings applied on top of rumble strips. To date most jurisdictions report only subjective evaluations
- Research on the use of “lane line” or “edge line” rumble strips, which are applied between lanes of the same direction
- Research on the use of “mid-lane” rumble strips, which are applied along the centre of a travel lane, parallel to the direction of travel.

DEFINITIONS AND ACRONYMS

AADT	Annual Average Daily Traffic (vehicles / day).
B/C	Benefit / Cost ratio.
CLRS	Centreline rumble strips.
CMF	Collision Modification Factor – Used to estimate the safety impacts of countermeasures, it indicates the reduction (or increase) in the frequency and severity of collisions after the implementation of the countermeasure.
dB	Noise level (decibels) measured on a logarithmic scale.
dBA	Noise level (effective decibels) measured using the A-scale on a standard sound level meter. The A-scale most closely correlates to human reaction to sound.
SRS	Shoulder rumble strips.
TRS	Transverse rumble strips.

REFERENCES

1. "Rumble Strips Website." http://safety.fhwa.dot.gov/programs/rumble.htm (8-3-2004)

2. Russell, E. R. and Rys, M. J., "NCHRP Synthesis 339: Centerline Rumble Strips." *ISSN 0547-5570/ISBN 0-309-07020-1*, Washington, D.C., Transportation Research Board, (2005)

3. "Kansas Joins Growing List of States to Implement Centerline Rumble Strips." *The Urban Transportation Monitor*, Vol. 17, No. 15, (2003) pp. 7-7.

4. Hunt, P., "Centreline Rumble Strips in Saskatchewan." (9-7-2004)

5. British Columbia Ministry of Transportation, "Centreline Rumble Strips: Technical Circular and Bulletin." *DS04002*, (5-17-2004)

6. Noyce, D and Elango, V., "Safety Evaluation of Centerline Rumble Strips: A Crash and Driver Behavior Analysis." *83rd Annual Meeting of the Transportation Research Board*, Washington, D.C, (2004)

7. Persaud, B., Retting, R., and Lyon, C., "Crash Reduction Following Installation of Centerline Rumble Strips on Rural Two-Lane Roads." (2003)

8. van der Horst, R., "Speed-Reducing Measures for 80 Km/h Roads." *International Cooperation of Theories and Concepts in Traffic Safety*, Vol. 9th ICTCT Workshop, (2004) pp. 1-12.

9. Transportation Association of Canada, "Best Practices for the Implementation of Shoulder and Centreline Rumble Strips." (2001)

10. Alberta Transportation & Utilities, "Briefing Note: Milled Shoulder Rumble Strips and Centre Line Rumble Strips Projects." (1999)

11. Kenny, B., "Centreline Rumble Strips in Alberta." (8-27-2004)

12. Chambefort, P., "Parks Canada Centreline Rumble Strips." (10-1-2004)

13. Delaware Department of Transportation, "Centerline Rumble Strips The Delaware Experience." (2003)

14. NCHRP and Transportation Research Board, "Guidance for Implementation of the AASHTO Strategic Highway Safety Plan - Volume 4: A Guide for Addressing Aggressive-Head-on Collisions (NCHRP Report 500)." (2003)

15. Filcek, M., Oulevski, V., Morena, J., Long, D., and Maleck, T, "Investigation of the Dry/Wet-Night Retroreflectivity and Durability of Pavement Markings Placed

in Milled Rumble Strips." *83rd Annual Meeting of the Transportation Research Board*, Washington, D.C., (2004)

16. Engstrom, D., "Rumble Strip Applications." (11-16-2000)

17. Fitzpatrick, K., Balke, K., Harwood, D. W., and Anderson, I. B., "Accident Mitigation Guide for Congested Rural Two-Lane Highways." *440*, Washington, D.C., Transportation Research Board, (2000)

18. Maryland Department of Transportation, "DRAFT Directive and Guidance on the Use of Longitudinal Rumble Strips." (1997)

19. Alberta Transportation & Utilities, "A Review of Practices for Use of Rumble Strips on Alberta's Rural Highways." (1998)

20. Hunt, P., "Centreline Rumble Strips in Saskatchewan." (1-24-2005)

21. Davis, D., "Small Investment, Dramatic Dividends - Saving Lives in "Blood Alley"." *Public Roads*, Vol. March/April 2002, (2002)

22. Outcalt, W., "Centerline Rumble Strips." *CDOT-DTD-R-2001-8*, Denver, CO, Colorado Department of Transportation, (2001)

23. Hood, M., "Centerline Rumble Strips Counter Head-On Crashes." *LTAP Technical Information Sheet*, Vol. 94, (2002) pp. 1-4.

24. Gupta, J., "Development of Criteria for Design, Placement and Spacing of Rumble Strips." (1994)

25. Alliant Engineering & Consulting Ltd., "Report on Milled Rumble Strip Performance Testing." (2000)

26. Harwood, D. W., "Use of Rumble Strips to Enhance Safety." *NCHRP*, Vol. 191, (1993)

27. Morena, D. A., "Rumbling Toward Safety." *Public Roads*, Vol. 9, (2003)

28. Hawkins, G., "Choosing the Right Pavement Markings can Serve as a Wake-Up Call for Motorists." *Roads and Bridges*, Vol. 7, (2004)

29. Torbic, D. J., Elefteriadou, L., and El-Gindy, M., "Development of More Bicycle-Friendly Rumble Strip Configurations." *80th Transportation Research Board Annual Meeting*, (2001)

30. "Manual of Uniform Traffic Control Devices for Canada." Ottawa, Canada, Transportation Association of Canada, (1998)

APPENDIX A: DESIGN DRAWINGS FROM PROVINCES AND STATES

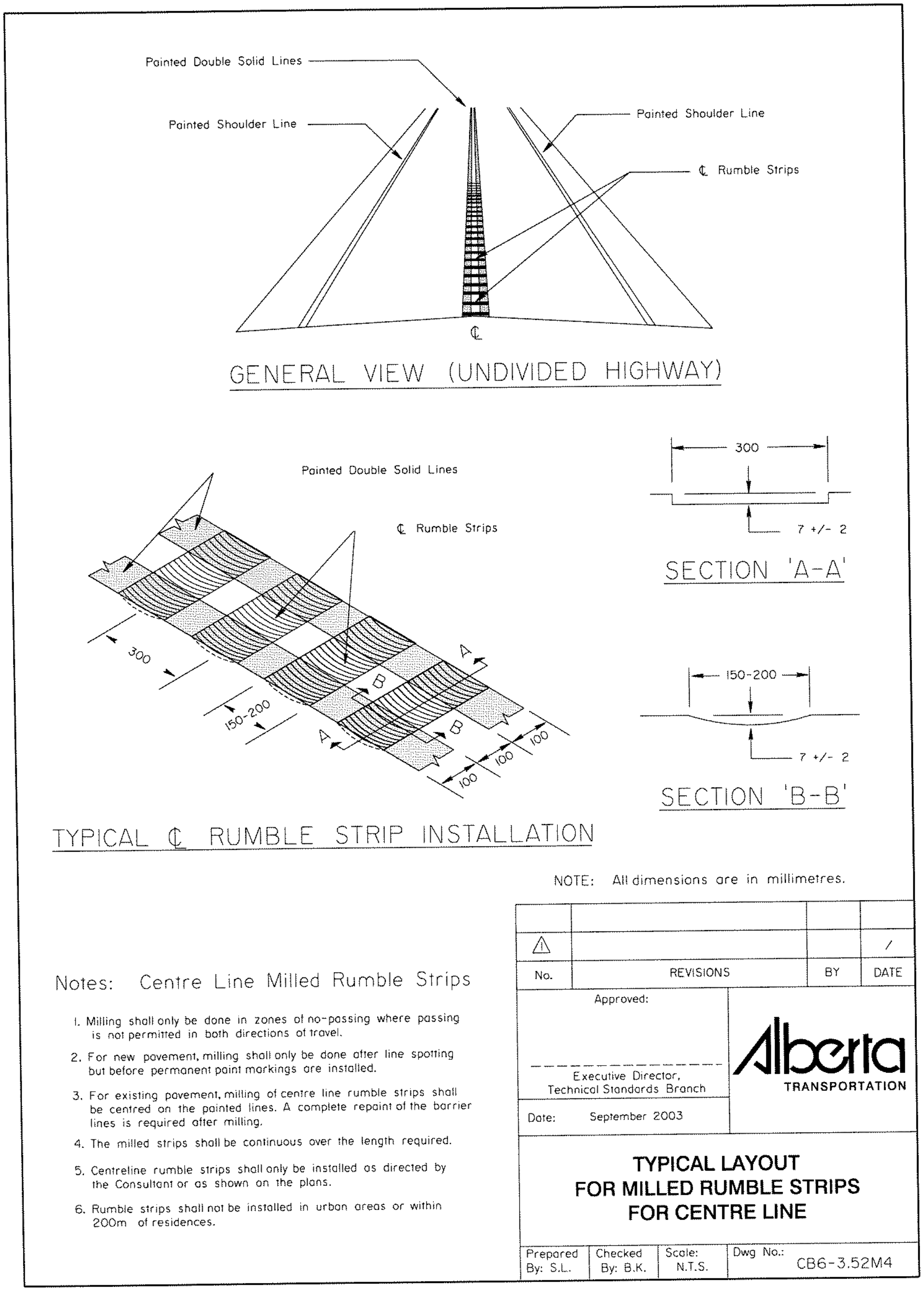


Figure 14: Alberta Typical Layout for Milled Centreline Rumble Strips

General

Favourable experience with the effectiveness of the centreline rumble strips (CRS), has allowed for the application of the devices along sections of highways marked with the yellow solid double line.

The application of the CRS has been continuously expanded to include many newly constructed, higher classes of highways. There is also a growing demand to install the CRS along the existing highways.

Since the CRS are relatively new to our highway network system, many drivers may not be completely familiar with this new function of the rumble strips.

A warning CENTRELINE RUMBLE STRIPS sign may be installed in advance of the highway section marked with the CRS to alert the drivers to the presence of the rumble strips along the highway centreline.

Standard

The CENTRELINE RUMBLE STRIPS (WA-106) sign is a warning sign and has black lettering on a yellow background.

WA-116	900 mm x 900 mm	
Colour	Message and border Background	Black Yellow
Sheeting	ASTM, Type III	

The sign is supplemented with a standard distance tab:

WA-500-T-O	750 mm x 450 mm	
Colour	Message and border Background	Black Yellow
Sheeting	ASTM, Type III	

DRAFT

DRAFT

Guidelines for Use

The purpose of the CENTERLINE RUMBLE STRIPS sign is to inform the drivers that the CRS are placed along the upcoming section of a highway.

The sign should be installed at locations where the CRS have been newly introduced along the highway.

After an introductory period, usually 6 to 12 months, the sign should be removed. This period may be extended based on the local experience.

Guidelines for Placement

The CENTERLINE RUMBLE STRIPS sign should be installed 50 to 150 metres in advance of a highway section marked with the CRS. The sign is installed on the right side of the highway for both directions of travel.

Long highway sections marked with the CRS may have supplementary CENTERLINE RUMBLE STRIPS signs installed every 20 to 30 kilometres. The signs may be introduced after each major junction along the route.

Before supplementary signs can be placed along the highway, several factors should be considered, including: traffic volumes, roadway class, collision history and familiarity of the drivers with the function of the centreline rumble strips.

The exact location of the signs may be adjusted in field to ensure adequate signs visibility along the highway.

Safety Issues

Due to the increasing number of the centreline rumble strips along the highway, warning signs should be used at locations where they are most needed. Such selective approach to signing helps to optimize the use of signs along the highway increases their effectiveness and reduces the drivers' information load.

Figure 15: Draft Guidance for CLRS warning signs in Alberta

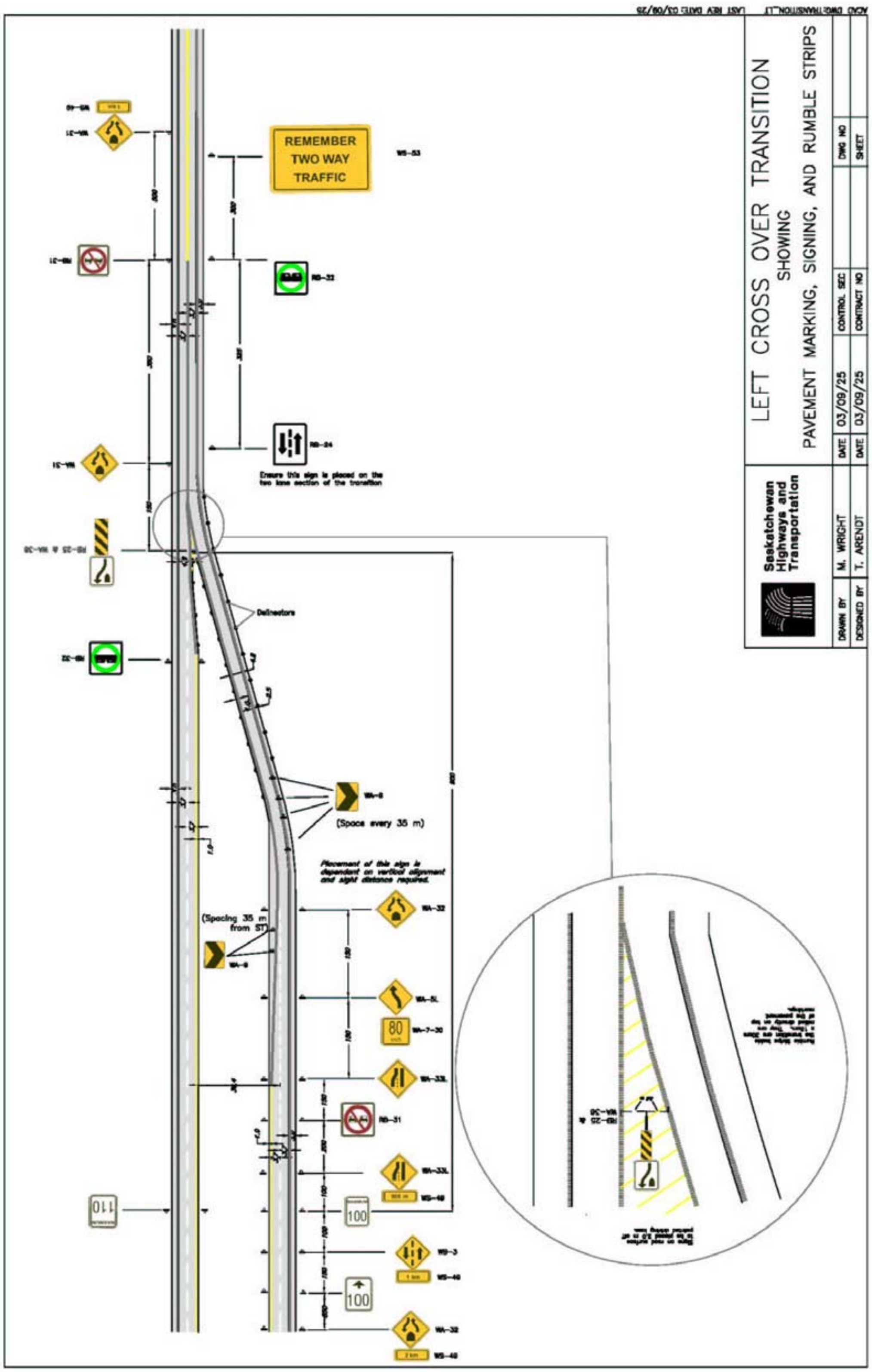


Figure 16: Saskatchewan CLRS at undivided two-lane to divided four-lane transition

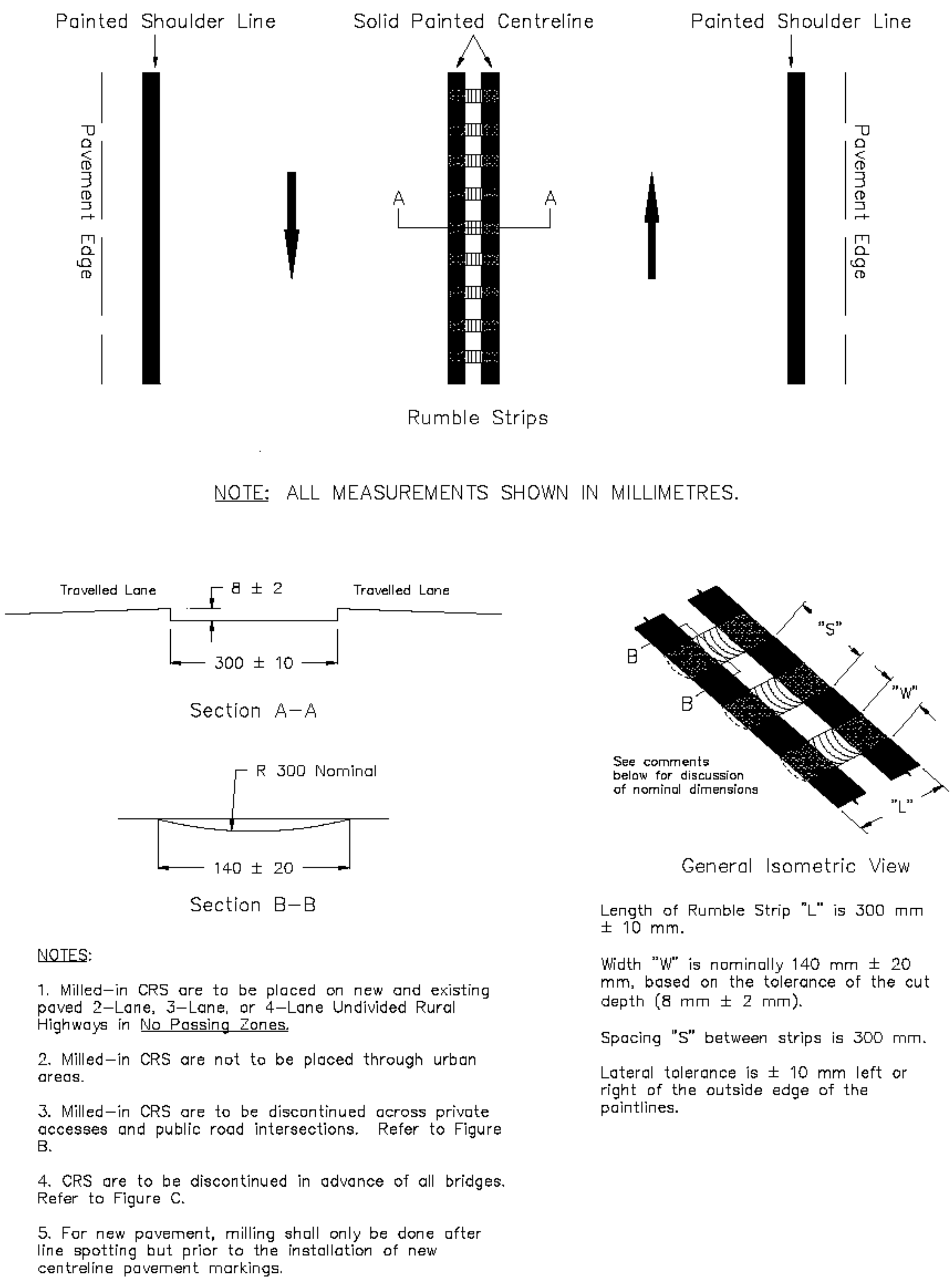


Figure 17: British Columbia Milled Centreline Rumble Strips (*5*)

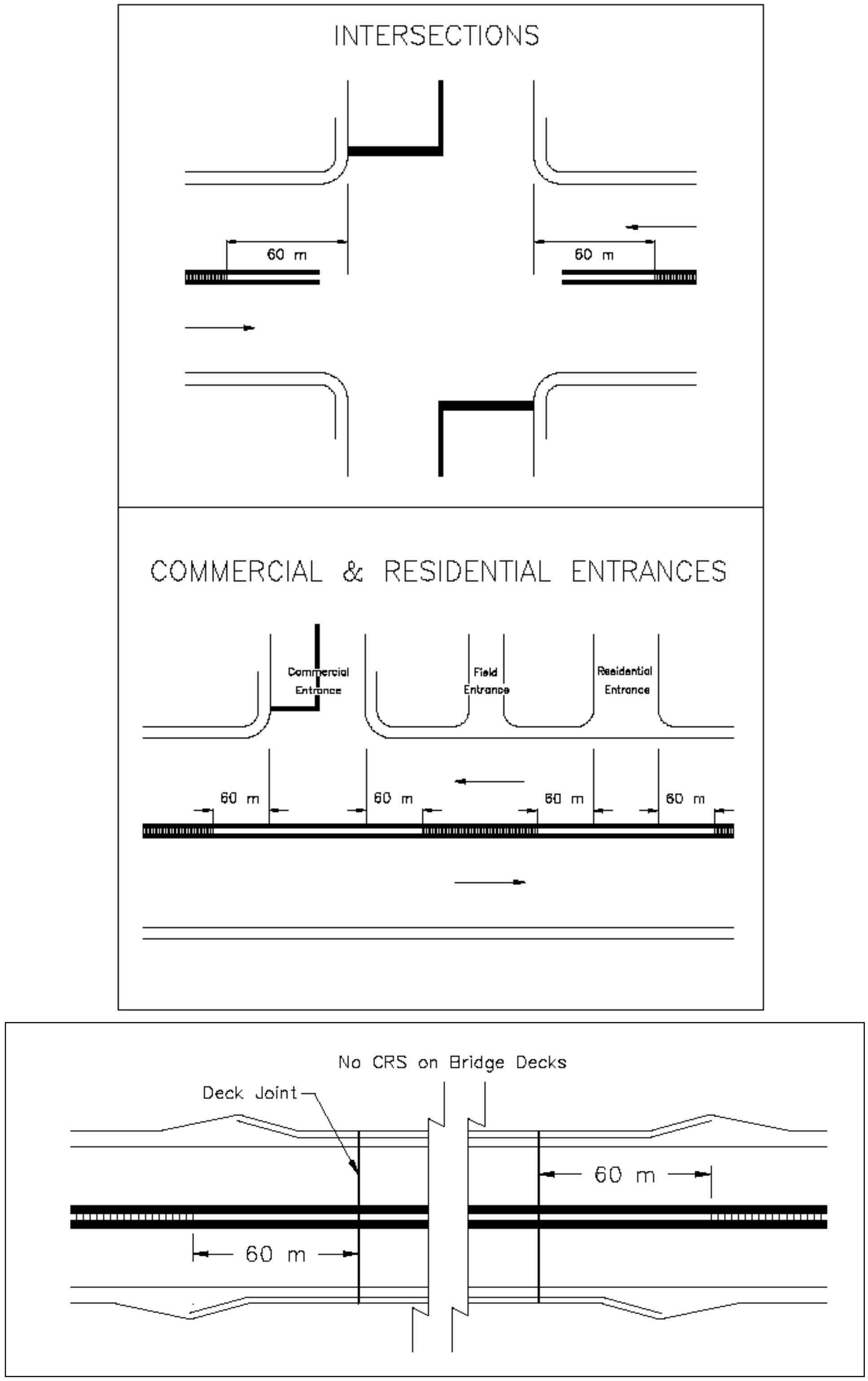


Figure 18: British Columbia CLRS Interruptions at Intersections, Driveways, and Bridge Decks (*5*)

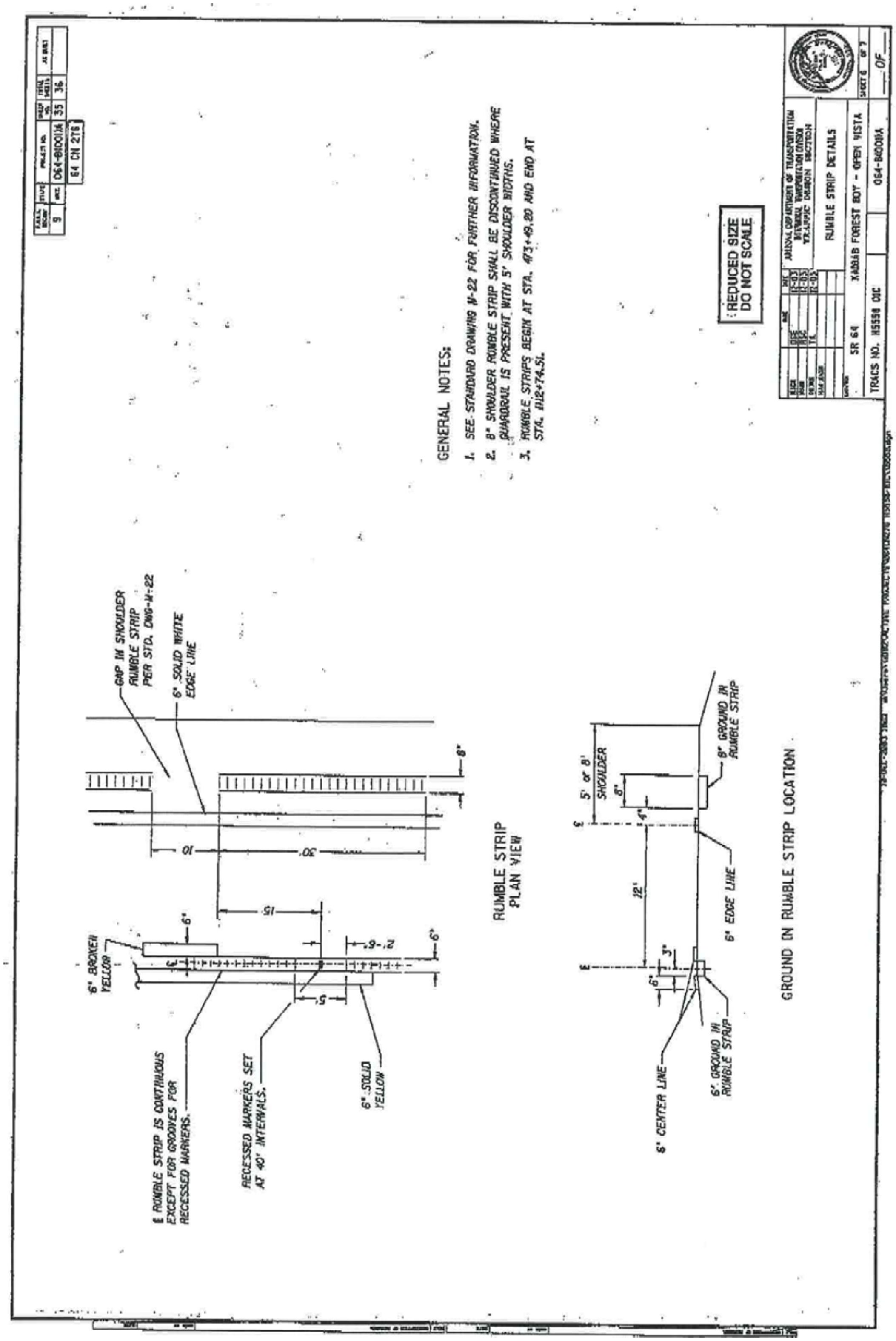


Figure 19: Arizona Rumble Strip Details

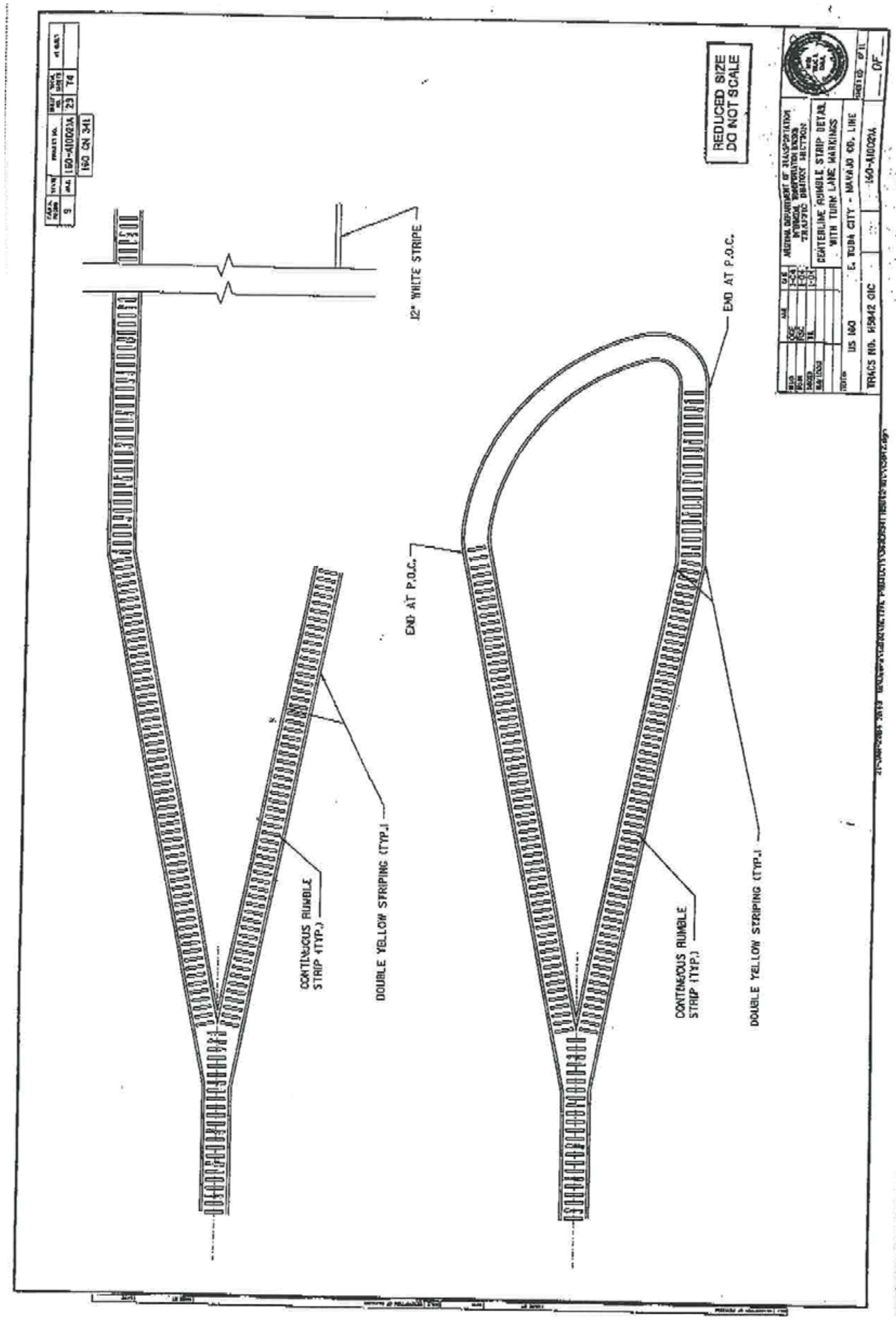


Figure 20: Arizona Centreline Rumble Strip Detail with Turn Lane Markings

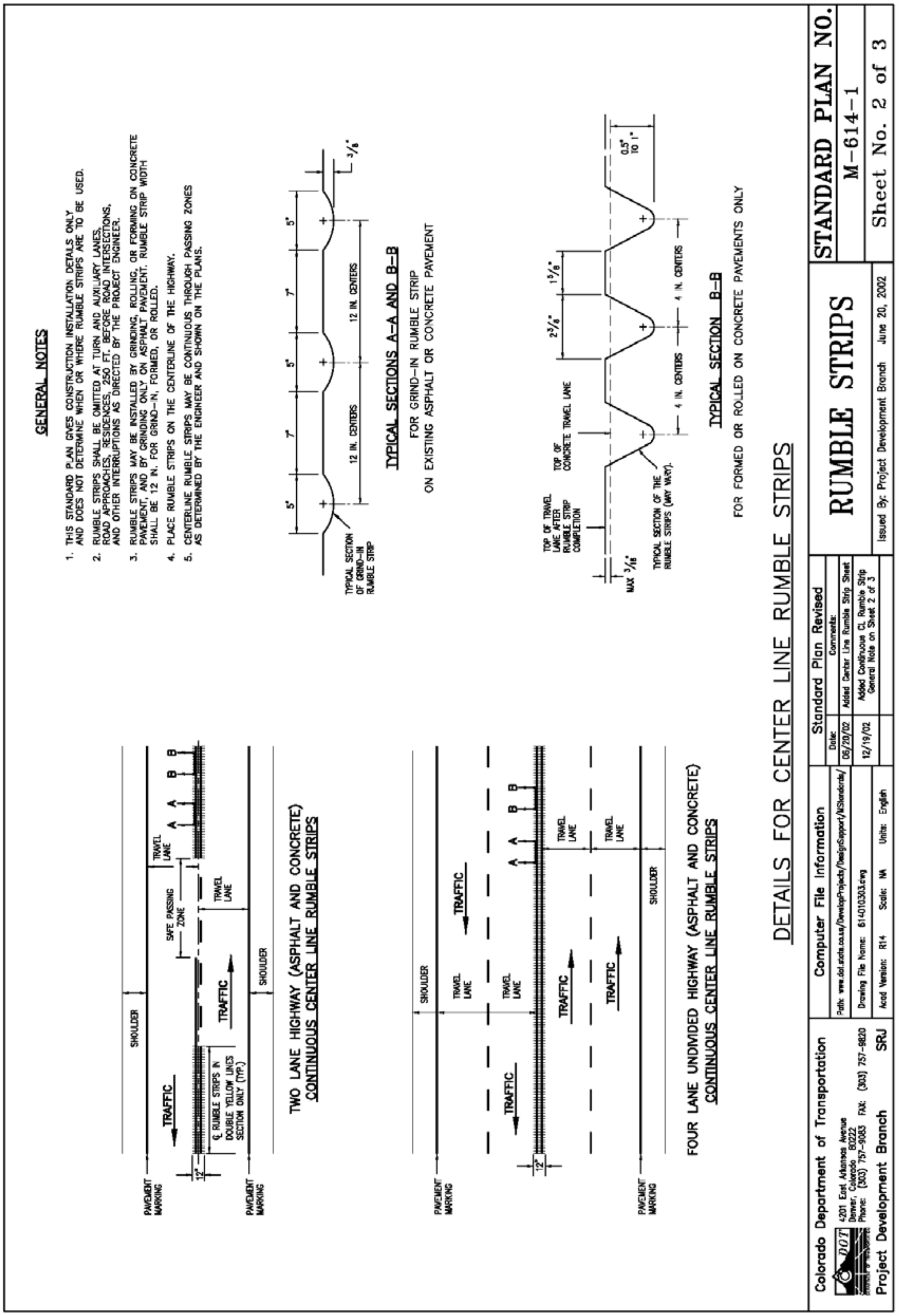


Figure 21: Colorado Centreline Rumble Strip Details

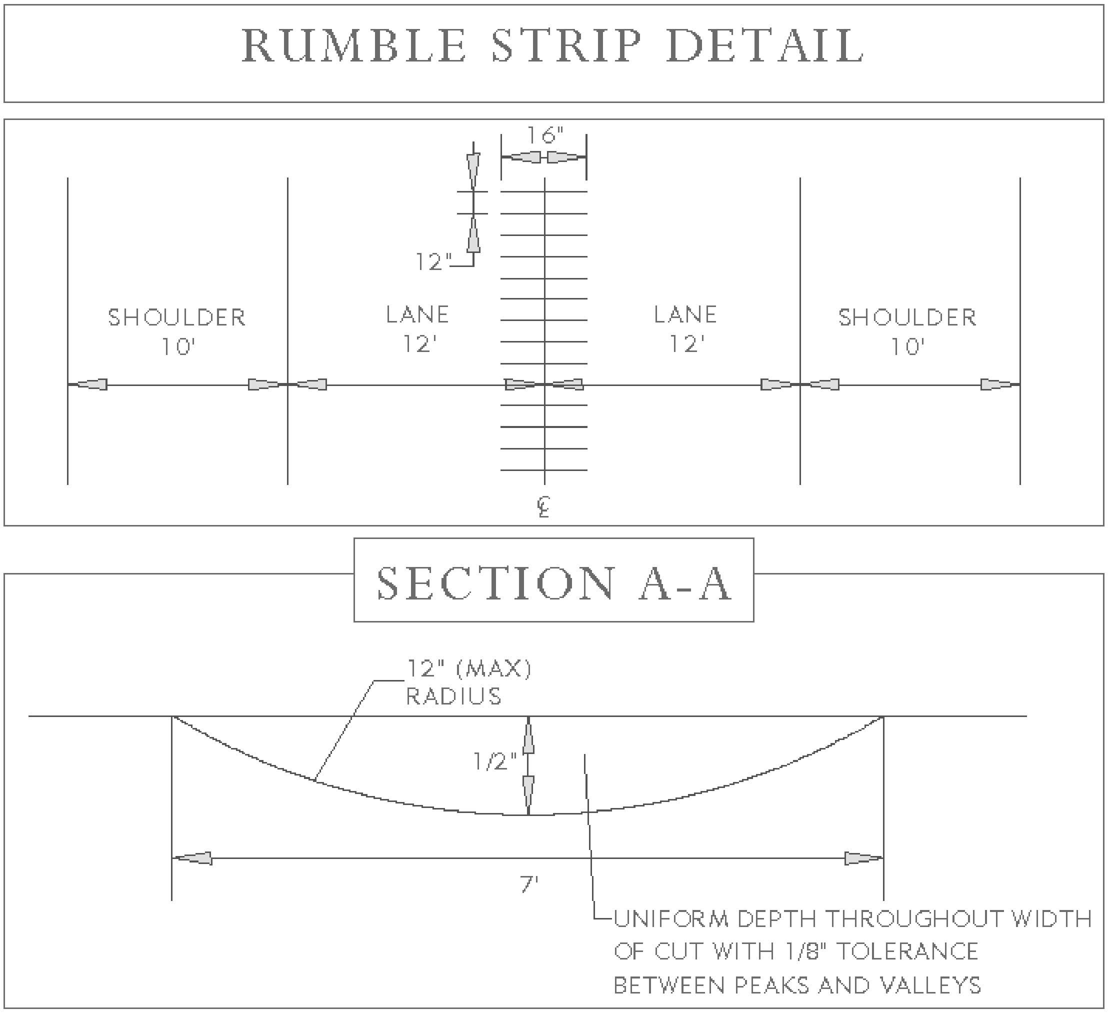


Figure 22: Delaware Rumble Strip Detail (*13*)
(http://www.deldot.net/static/projects/rumblestrip/index.html)

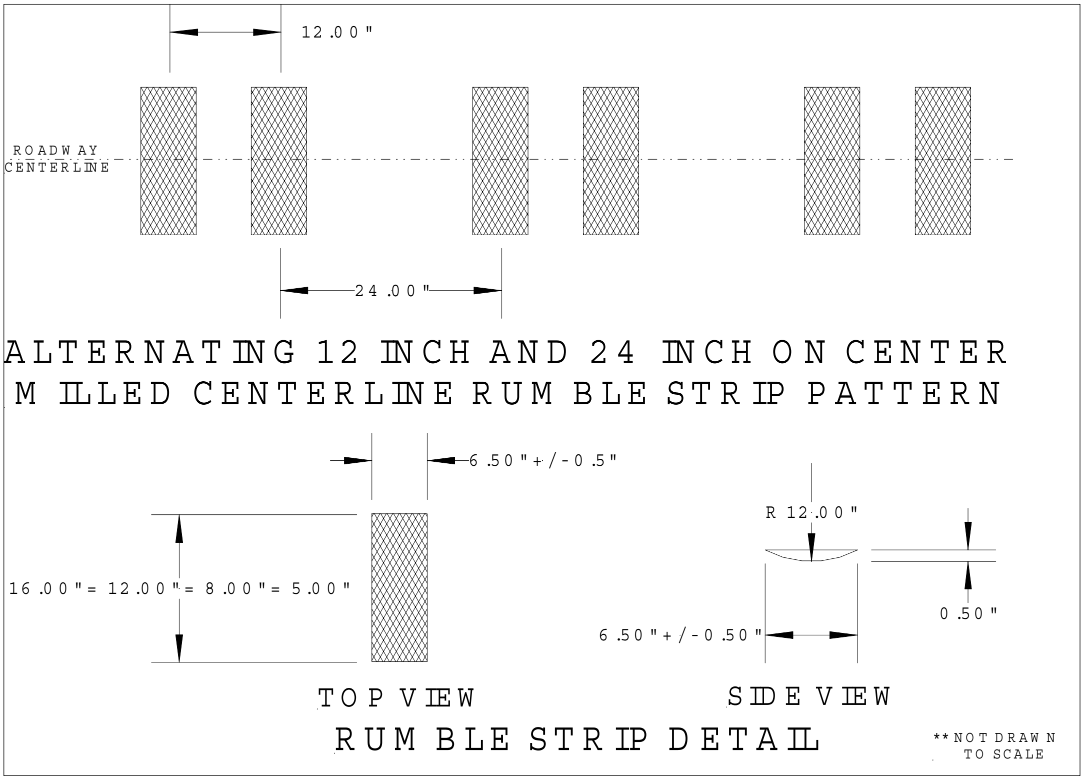


Figure 23: Kansas Blueprint of Alternating 12 and 24-inch Pattern (*2*)

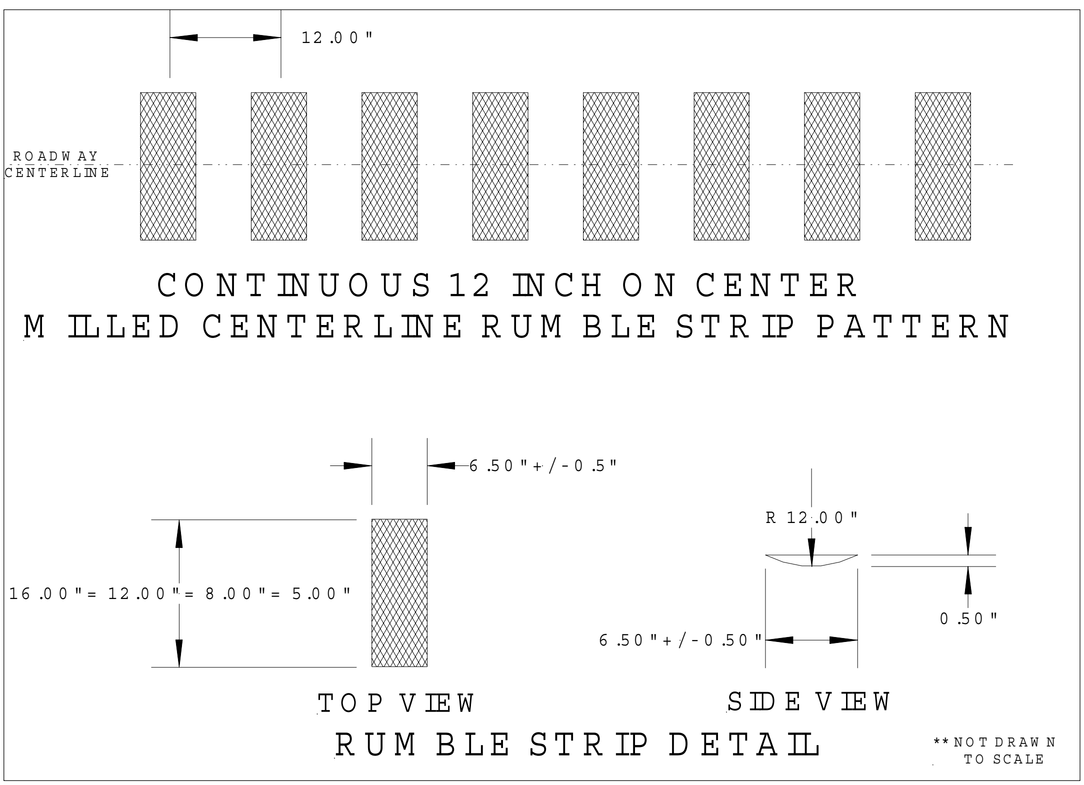


Figure 24: Kansas Blueprint of Continuous 12-inch Pattern (*2*)

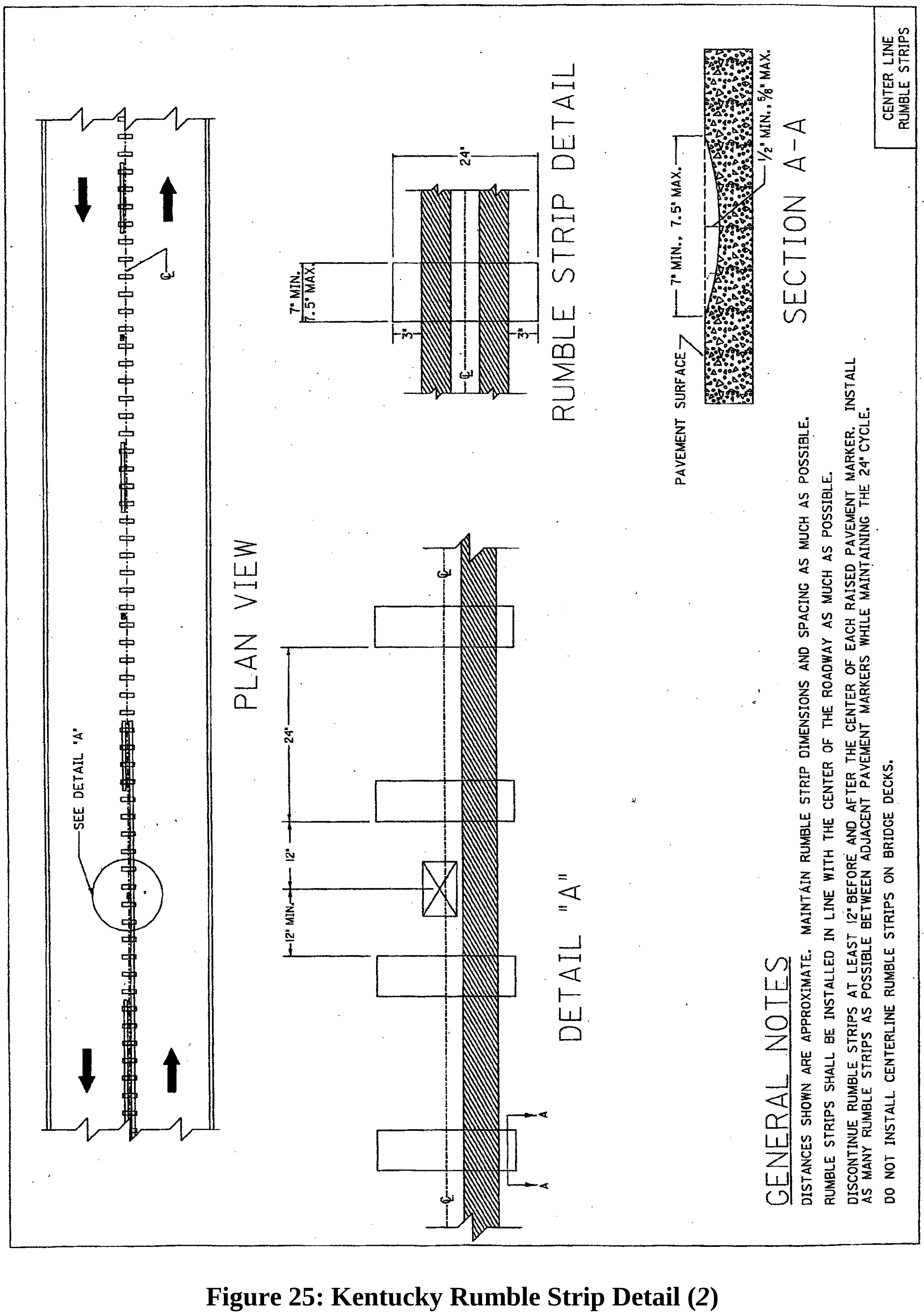


Figure 25: Kentucky Rumble Strip Detail (*2*)

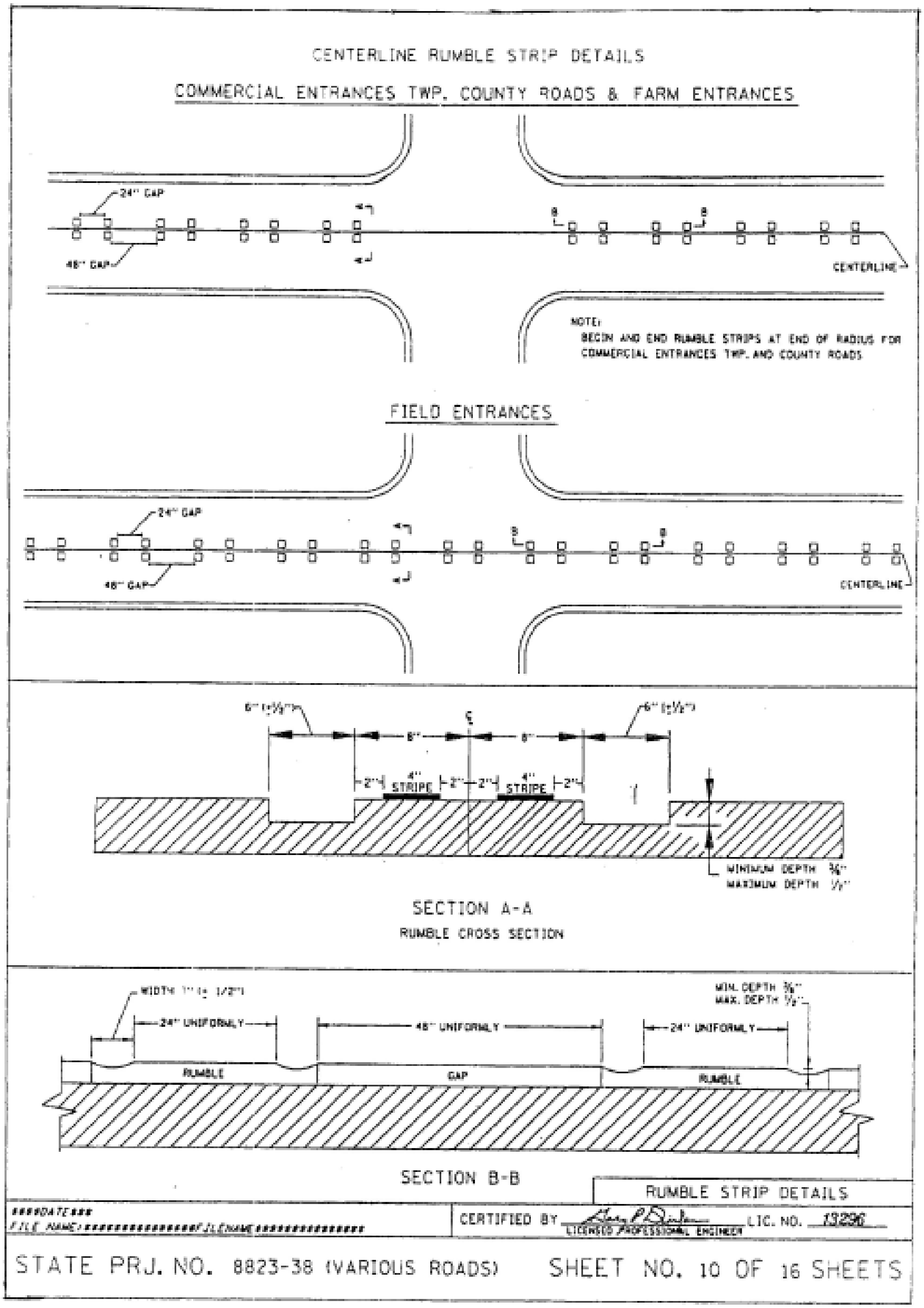


Figure 26: Minnesota Centreline Rumble Strip Details (*2*)

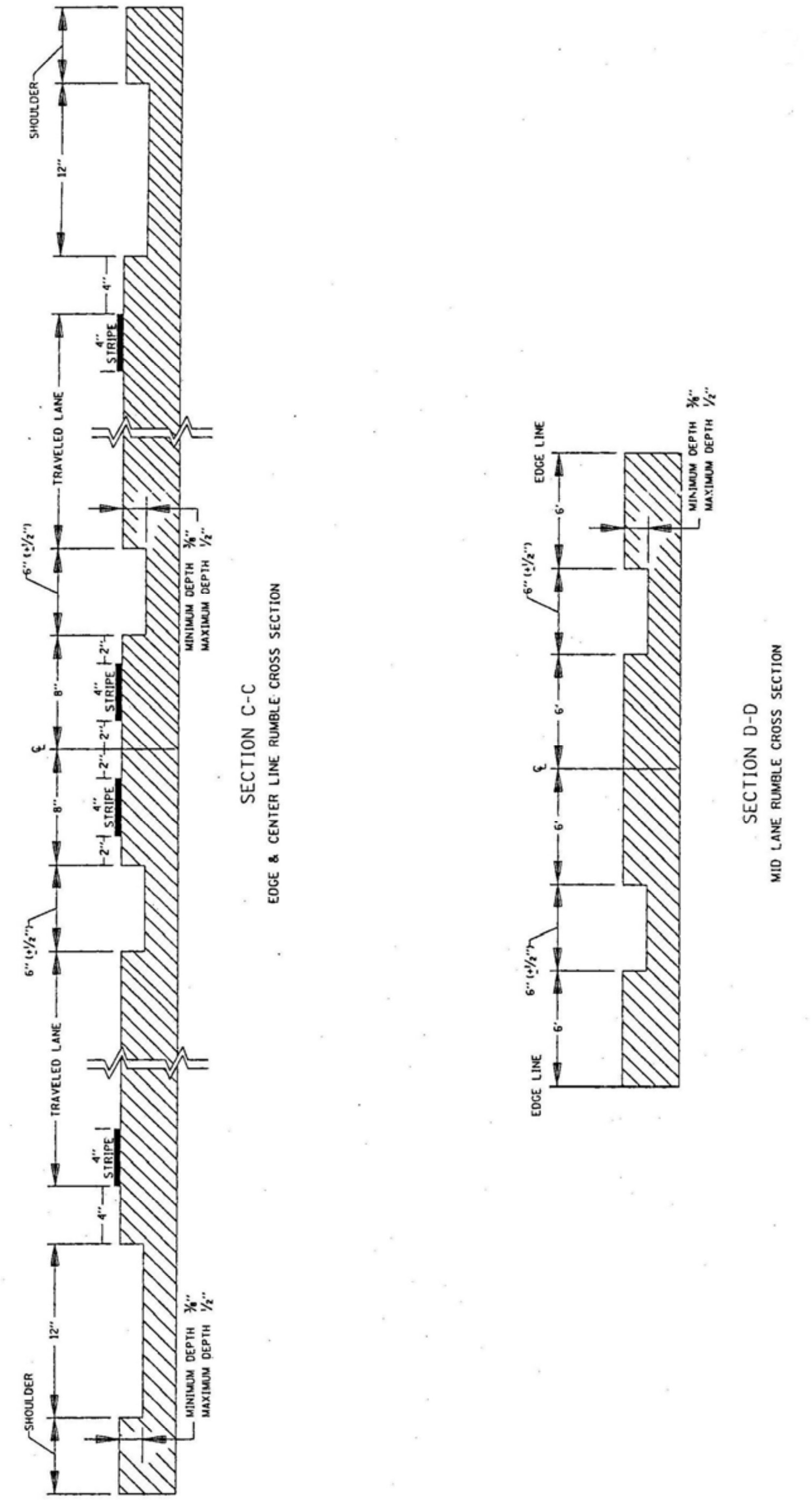


Figure 27: Minnesota Redesigned Centreline Rumble Strips (*2*)

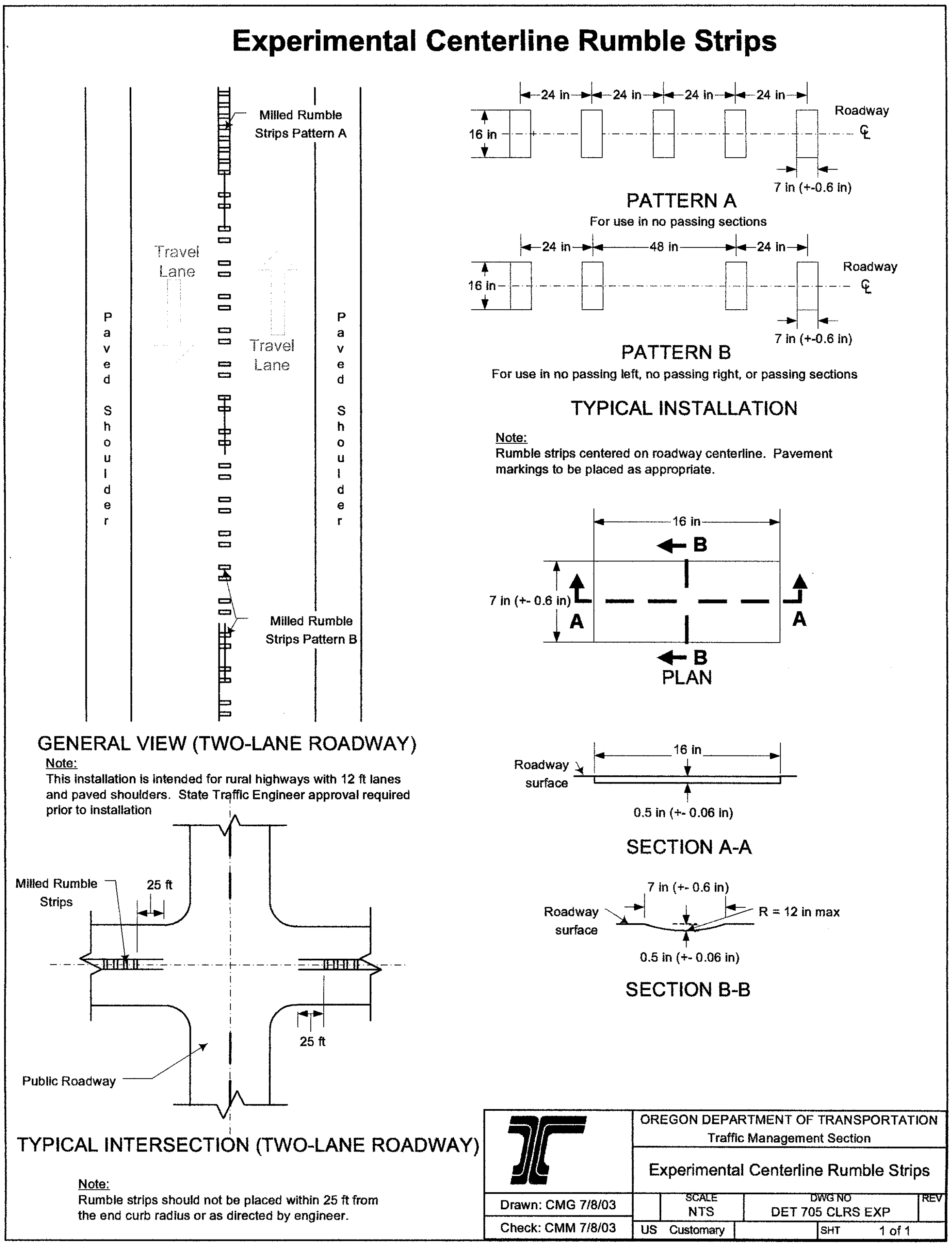


Figure 28: Oregon Experimental CLRS Pattern Details (*2*)

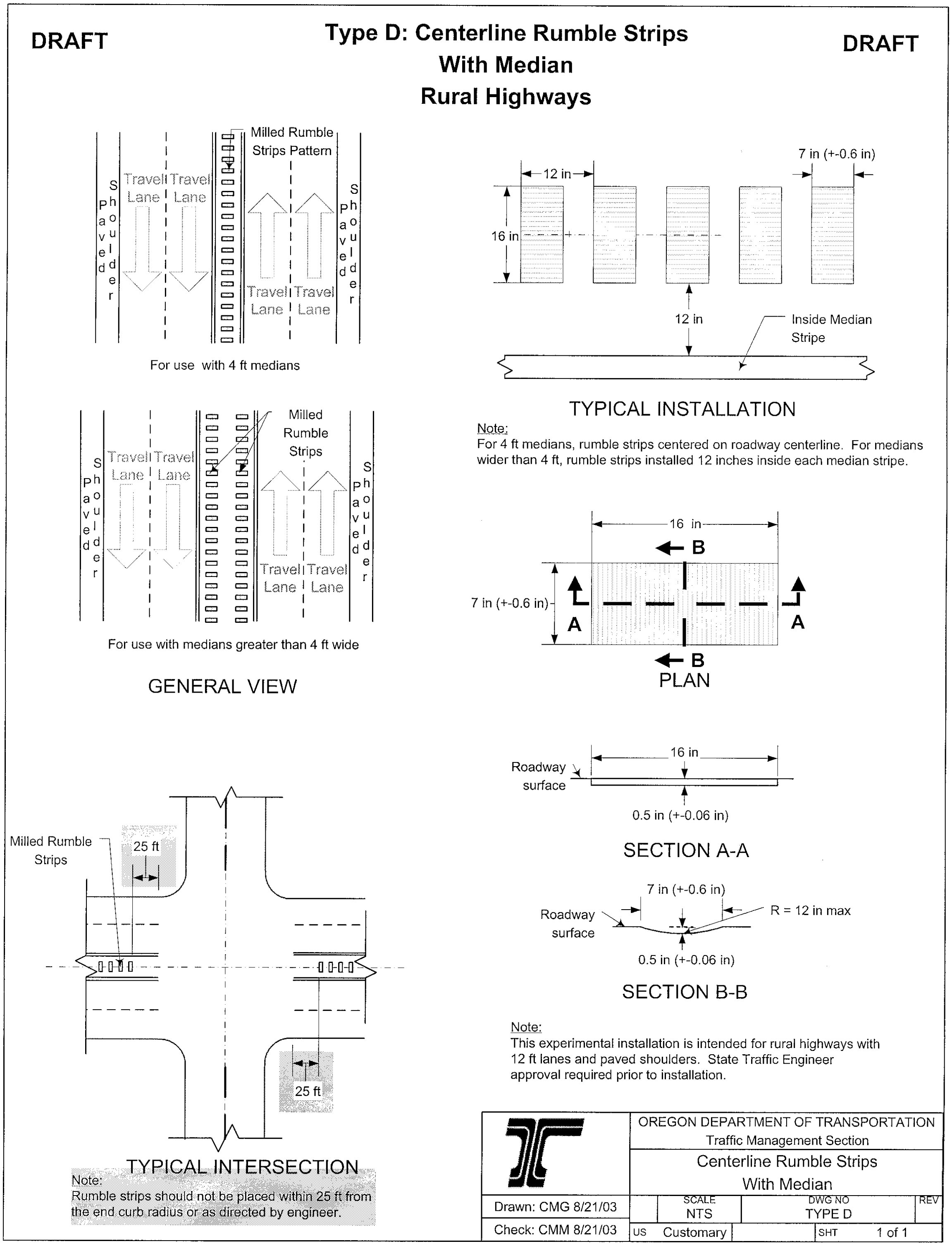


Figure 29: Oregon median pattern details (*2*)

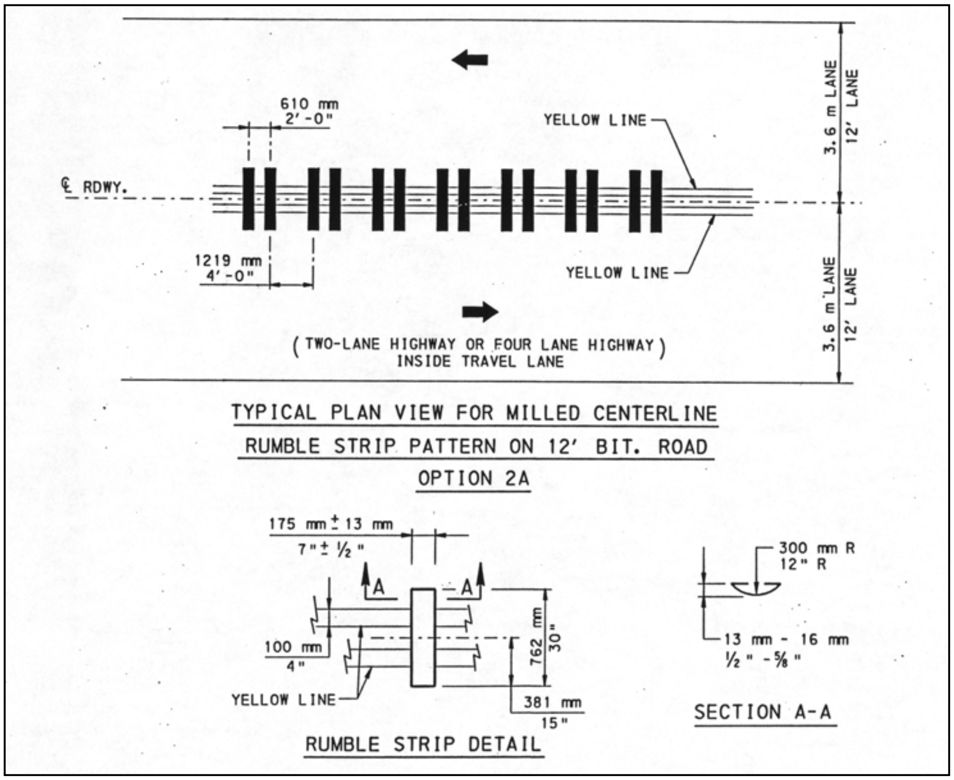


Figure 30: Pennsylvania Blueprint Example 1 (*2*)

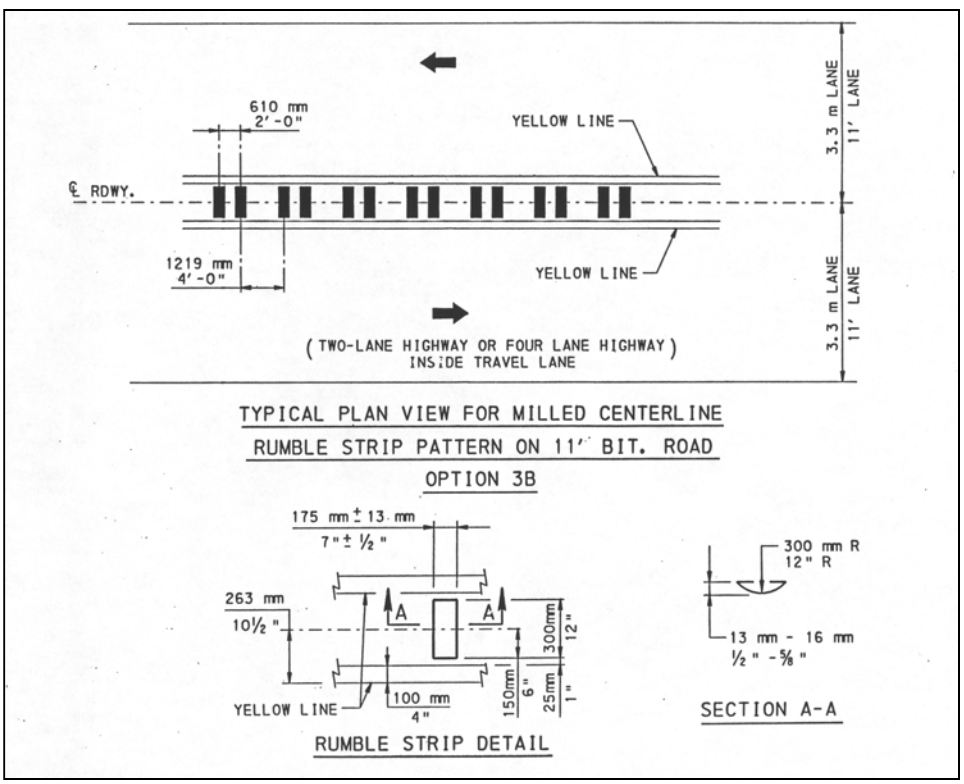


Figure 31: Pennsylvania Blueprint Example 2 (*2*)

APPENDIX B: PROVINCIAL AND STATE CENTRELINE RUMBLE STRIP POLICIES

BRITISH COLUMBIA

BRITISH COLUMBIA

Ministry of Transportation
TECHNICAL BULLETIN

ENGINEERING BRANCH
DESIGN GUIDELINES
BULLETIN NUMBER:
DS04002

Subject: Centreline Rumble Strips	
Date: May 17, 2004	**Author**: Janelle Yardley, EIT
Bulletin Number: DS04002 **Bulletin Type**: New Standard	**Action Required**: Immediate **Effective Date**: May 17, 2004
Contacts	**Standards Affected**
Richard Voyer, P.Eng. Senior Geometric Standards and Design Engineer Engineering Branch, Victoria (250) 387-7761 Darwin Tyacke, AScT Senior Geometric Standards Technologist Engineering Branch, Victoria (250) 356-7928	None

1. Background:

Centreline Rumble Strips (CRS) have started being used by an increasing number of highway agencies over the last few years. CRS are used as a means to counter the frequency of crossover centreline crashes due to driver fatigue, inattention, error and/or impairment. Early studies have shown noteworthy safety improvements. Based on these published results, ICBC estimates that installing CRS in no passing zones on undivided rural highways could reduce the number of head-on, sideswipe, off-road-left and overtaking crossover crashes by 32%. It is believed that the investment in CRS will bring benefits through crash reduction that far exceed the cost of installation.

2. Considerations:

- Centreline Rumble Strips should be considered on undivided, rural two-lane, three-lane, or four-lane highways in no passing zones (i.e. a double solid painted centreline) in the following cases:
  1. New undivided, rural two-lane, three-lane, or four-lane highway sections;
  2. When re-paving, rehabilitating or reconstructing existing undivided, rural two-lane, three-lane, or four-lane highway sections;
  3. Other undivided, rural two-lane, three-lane, or four-lane highway sections that are not part of a project but would benefit from the installation of CRS in terms of decreasing the number of crossover centreline crashes. To assist Regions, a prioritized list of highway corridors prone to crossover crashes is attached, identifying possible candidate locations; however, it does not limit CRS to only those locations. Funding and other resources for these stand-alone CRS projects are subject to availability and should be considered in the larger context of all safety initiatives.
- CRS should not be used in urban areas. Good indications of urban highway sections are:
  1. Speed Zone of 70 km/h or less in the vicinity of a settlement;
  2. Highway section with curb and gutter or a sidewalk;
  3. The average spacing is less than 150 metres for driveways and 500 metres for intersections.

BC SUPPLEMENT TO TAC
GEOMETRIC DESIGN GUIDE

Page 1 of 1

- The minimum centreline depth of pavement required is 50 mm. CRS are not to be installed if pavement deterioration or cracking is evident. Pavement should be in sufficiently good condition to accept the milling process without ravelling or deteriorating, otherwise the pavement should be upgraded prior to milling centreline rumble strips.
- CRS are not to be installed if pavement is to be overlaid within 3 years.
- Milling of CRS should be coordinated with traffic line painting operations to avoid milling newly applied traffic lines and to ensure that new yellow centrelines are installed within a short period of time after completion of the milling of the centreline rumble strips.
- All projects that involve CRS should be submitted for ICBC Cost-Sharing evaluation.

3. Application Guidelines:

The layout for Milled-in CRS is shown in Figure A.

- CRS should be installed on the centreline, for undivided, rural two-lane, three-lane, or four-lane highways in no passing zones.
- For application of CRS on lane widths less than 3.4 m, an engineering review is required.
- On rural two-lane, three-lane, or four-lane undivided highways, CRS should be installed in the following manner:
  a) 300 mm CRS installed over the double solid painted centreline.
  b) CRS installation shall begin at the start of the double solid painted centreline.
- On highways with a painted flush median, CRS should be installed in the following manner:
  a) For painted flush median < 2.0 m – apply CRS in the centre of the painted median;
  b) For painted flush median ≥ 2.0 m – refer to Technical Bulletin DS04001 and follow application guidelines for Shoulder Rumble Strips.

4. CRS Interruptions:

- CRS are to be interrupted prior to driveways and intersections, as shown in Figure B.
- CRS shall not be installed on bridge decks, overpasses or other concrete surface structures, as shown in Figure C.
- CRS should be discontinued within 200 m of a residential or urban area.

5. Action:

- Insert this Technical Bulletin at the back of Tab 6 of the BC Supplement to the TAC Geometric Design Guide along with the following two attachments:
  1. Prioritized Highway Corridors for Cost-Effective CRS Implementation
  2. Sample Special Provisions Wording – "Milled Centreline Rumble Strips"

CALIFORNIA

Program Procedure and Guidelines for 2-3 Lane Highway Cross-Centerline Collision Monitoring

A program element was created and attached to the Highway Safety Improvement Program (HB1) in a joint memorandum from Jim Borden and Jim Nicholas on October 08, 1996. This program was initiated out of a study done by a committee of Caltrans engineers. Its purpose is to reduce fatal cross centerline collisions on 2 and 3 lane facilities. Using this program, Caltrans intends to initiate improvements to reduce the number and the severity of collisions. The procedures to accomplish this program are discussed below.

A) Each year a statewide TASAS Selective Collision Retrieval (TSAR) report will be requested with the following criteria:
1) The access control is conventional or expressway,
2) A minimum of one vehicle from each opposing direction involved in a collision,
3) Severity is fatal,
4) 5 calendar years of data, and
6) Left turn and U-turn collisions are excluded.

B) The resultant TSAR data file will be evaluated for collision concentration locations. A roadway segment will be considered to have a concentration if there are 3 or more cross centerline fatal collisions and a cross centerline fatal collision rate of 0.12 or greater fatal acc/mi/yr. Identified locations will be tabulated and high-lighted to indicate a cross centerline fatal collision concentration or remain blank. The action that the district performs for each of these identified locations is explained below in section (E) through (H).

C) The following point system is then applied to each cross centerline fatal collision concentration:

Number of Fatal Collisions	**Value**
Less Than 4	5
4 - 5	10
6 - 8	20
9 - 11	28
12+	35

Number of Deaths	**Value**
Less than 4	2
4 - 5	5
6 - 8	10
9 - 12	15
13 - 14	20
15+	25

Fatal Collision Rate (fat.acc./mile/year)	**Value**
Less than 0.15	2
0.15 - 0.249	5
0.25 - 0.749	10
0.75+	15

Death Rate (deaths/mile/year)	**Value**
Less than 0.25	2
0.25 - 0.499	5
0.50 - 0.999	10
1.00+	15

Total Collisions / Mile	**Value**
Less than 10	2
10 - 19.99	4
20 - 29.99	6
30 - 49.99	8
50+	10

D) Each location will then receive a total weighted value by summing up the values in the five categories (Section C).

E) Each location in which a fatal cross-centerline collision occurred in the year of 1998 (marked by a * on both lists) and received a total weighted value of 40 or more will prompt a Headquarters (HQ) request for an investigation study of the site is done. These locations are marked with a symbol ( ) on the Cross Centerline Collision List and the Summary and Weighted Value List shows a **'REPORT'** required for the given concentration location. Following this study, the investigating district sends a memorandum outlining its observations, recommendations and proposals to the HQ Highway Safety Improvement Program. Please consider the history of this location in your study as it pertains to this monitoring program as well (i.e. if the location has seen an increase/decrease in cross-centerline collisions etc.).

F) Those locations with a weighted value less than 40 and a fatal cross-centerline collision occurring in the year of 1998 will be marked with a box ( ) on the Cross Centerline Collision List and the Summary and Weighted Value List will have a **'REVIEW SITE**'. These locations will be for the Districts information and no report to Headquarters is necessary. However, the District may pursue the development of a **Minor B** safety improvement project for these locations. Districts are encouraged to implement incremental improvements through low-cost roadway betterment that may reduce cross centerline collisions.

G) Those locations without a **'REPORT**' or **'REVIEW SITE**' are locations that had previous concentrations but the location did not experience a cross-centerline fatal collision in the year of 1998. These locations are maintained as monitored locations and do not require a study done by the districts.

Low cost improvements should be tried first. They include barrier striping, restriping with raised profile thermoplastic traffic stripe, rumble strips on the outside paved shoulder, centerline buffer zones, rumble strips on a centerline buffer zone, surface mounted channelizers on a centerline buffer zone, black raised pavement markers on the centerline, and other innovative devices and applications.

MINNESOTA

Note that this Draft Guideline has not been adopted by Mn/DOT. This draft Guideline has been posted on-line for information purposes only.
http://www.dot.state.mn.us/trafficeng/safety/rumble/index.html

DRAFT Centerline Rumble Strip (CLRS) Guideline – July, 2002

Based upon research conducted by the Office Traffic, Security, and Operations (OTSO), it is estimated that an effective collision reduction factor for head-on and crossing centerline collisions of up to 40% could be achieved with the installation of CLRS. It is recommended that districts consider installation of CLRS on new rural 2-lane and 4-lane undivided projects where sufficient collision history dictates. Existing concrete pavements must have 2.5” or greater overlays in order to be eligible under this guideline. Guidelines below detail specific locations that are eligible for CLRS installation under this guideline.

Guidelines for Use

1. The purpose of milled CLRS is to reduce the occurrence of head-on and/or across the centerline sideswipe collisions on undivided 2-lane or 4-lane highways. These types of collisions are often severe and are referred to as “correctable” by CLRS in this guideline.
2. Consider CLRS on the following rural locations and under the following conditions:

Draft

Roadway Description	CLRS Installation Recommended?*
2-lane or 4-lane undivided with 12’ or 11’lanes, with or without paved shoulders	YES
2-lane or 4-lane undivided with 10’ or less lanes, with paved shoulders	YES – if min. 10’ driving lane can be maintained by “borrowing” width from shoulder; otherwise, NO
2-lane or 4-lane undivided with 10’ or less lanes, without paved shoulders	NO

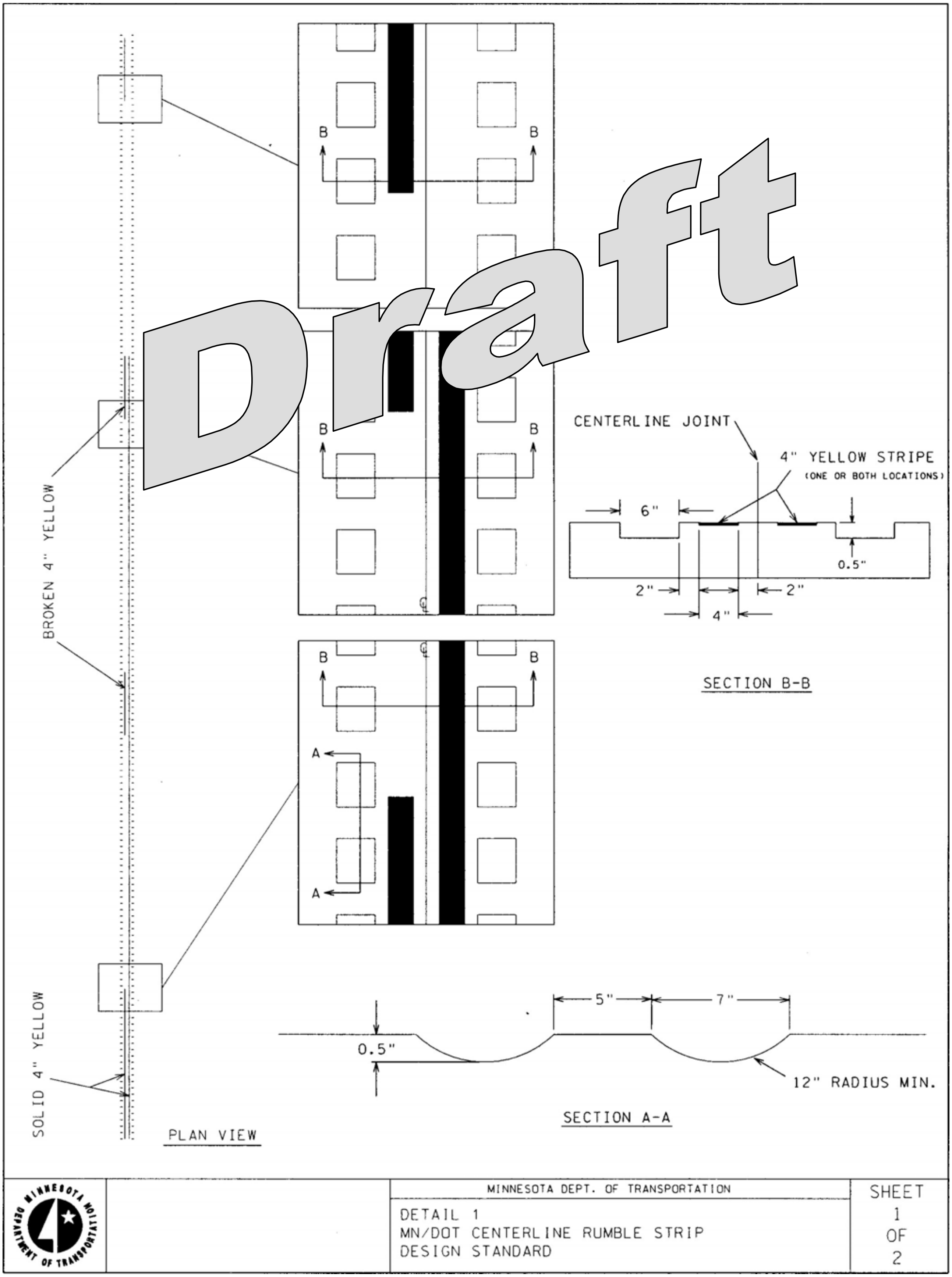
* For YES, see Details 1 and 2 for design specification.

3. Qualification for shoulder rumble strips (SRS) and CLRS are independent of each other. That is, both shoulder rumble strips and CLRS should be used if a cross section meets the criteria for both installations. If both installations are recommended but not possible based on cross section dimensions, engineering judgment based on collision history should be used to determine whether SRS or CLRS should be installed.
4. Milled CLRS are for use on bituminous pavement, or on bituminous over concrete pavements that have a minimum 2.5” bituminous overlay.
5. If it is desired to retrofit CLRS on existing pavement, the pavement should be in sufficiently good condition, as determined by the district, to effectively accept the

milling process without raveling or deteriorating. Otherwise the pavement needs to be upgraded prior to milling any desired CLRS.

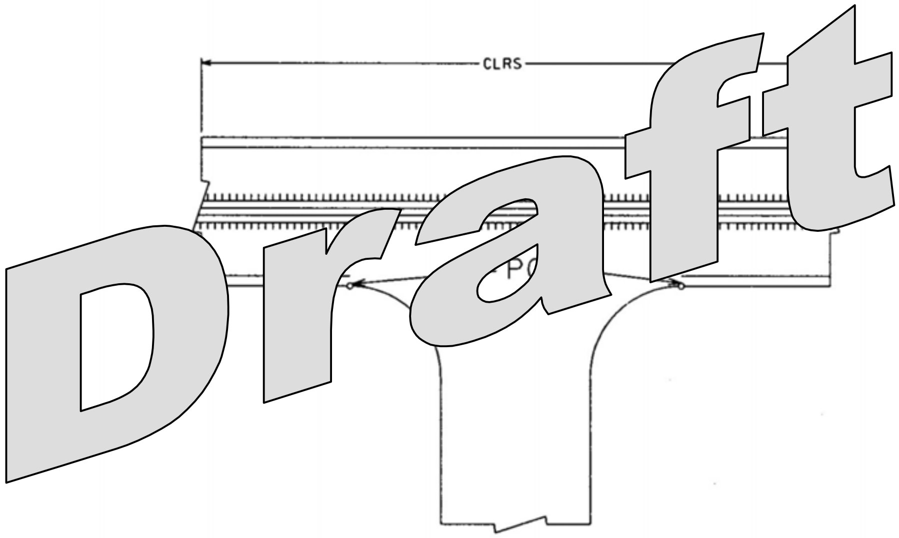
6. CLRS should not be installed on bridge decks.
7. The posted speed limit should be at least 50 m.p.h. in order to qualify under this guideline, unless a high correctable collision history exists. In this case, CLRS may be installed under any posted speed limit with appropriate documentation.
8. CLRS should be installed in passing zones and no passing zones alike. CLRS may be omitted in passing zones where noise pollution is an issue and there is no appreciable correctable collision history for the section in question. Engineering judgment should be used and documented in these cases.
9. CLRS are to be broken for intersections. Also consider breaking for driveways according to engineering judgment. When breaking CLRS pattern, discontinue CLRS 25 feet from the point of curvature of any such highway or driveway (refer to Detail #2); however, if the roadway with CLRS has left turn lanes at an intersection, the CLRS are to be broken at the beginning the turn lane or the beginning of the taper for the turn lane.
10. Coordinate the milling of CLRS with all necessary project phases. Do not mill the CLRS until all appropriate construction phases are completed.
11. Consult OTSO before installing CLRS on highways with travel lane widths that are less than 10 feet.
12. Take into consideration potential noise impacts when contemplating the installation of CLRS in residential or urban areas.

Draft

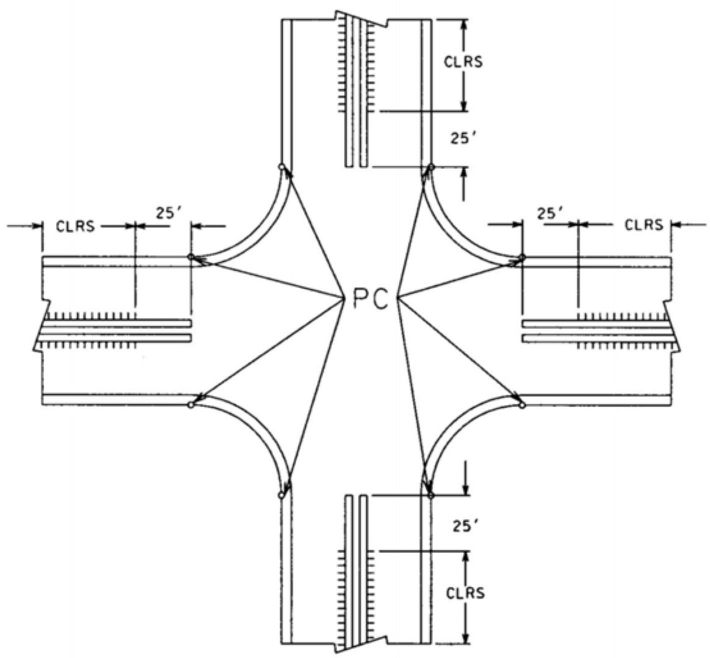

B
B
CENTERLINE JOINT
4" YELLOW STRIPE
(ONE OR BOTH LOCATIONS)
6"
0.5"
2"
2"
4"
BROKEN 4" YELLOW
SECTION B-B
A
A
5"
7"
0.5"
12" RADIUS MIN.
SECTION A-A
SOLID 4" YELLOW
PLAN VIEW
MINNESOTA DEPARTMENT OF TRANSPORTATION
MINNESOTA DEPT. OF TRANSPORTATION
DETAIL 1
MN/DOT CENTERLINE RUMBLE STRIP
DESIGN STANDARD
SHEET
1
OF
2

Draft

Draft



TYPICAL DRIVEWAY DETAIL



TYPICAL INTERSECTION DETAIL

MINNESOTA DEPT. OF TRANSPORTATION

DETAIL 2
MN/DOT CENTERLINE RUMBLE STRIP
TREATMENT AT INTERSECTIONS / DRIVEWAYS

SHEET 2 OF 2

MISSOURI
Draft Warrant

CENTERLINE RUMBLE STRIPS. Centerline rumble strips (CRS) should be included on projects with new or resurfaced roadways that meet the following conditions:

- The design speed or existing posted speed limit (whichever is higher) is at least 50 mph.
- On rural two-lane roadways.
- AADT is greater than or equal to 3500. **(PROACTIVE)**
- AADT is less than 3500, and there is a cross centerline crash rate of at least 10 per hundred million vehicle miles traveled. **(REACTIVE)** The cross centerline crashes should include only those crashes that a centerline rumble strip could influence (distracted drivers, sleepy drivers, etc.). A crash that qualifies as a cross centerline crash is any crash that begins with a vehicle encroaching on the opposing lane. It does not include crashes that begin by running off the right-side of the road and overcorrecting and then crossing the centerline or crashes that begin by a vehicle losing control prior to crossing the centerline (due to wet pavement, snow, ice or roadway alignment).
- The roadway width is at least 24 ft. [7.2 m]. For roadway widths less than 24 ft. [7.2 m] and greater than or equal to 20 ft. [6.1 m], a design exception is required. Include in the design exception submittal a thorough traffic crash analysis which reviews the cross centerline crashes and the ran-off-road-right crashes.
- The surface is concrete or the total thickness of bituminous material is at least 3-3/4 in. [95 mm], including thickness of existing bituminous material.
- Centerline rumble strips are not to be placed on bridges or within the limits of an intersection with left turn lanes. The limits of the intersection are defined by the beginning of the tapers for the left turn lanes.

OREGON

Center Line Rumble Strips (CLRS)

Head-on collisions that didn't occur at intersections account for almost 20% of fatal collisions of each year on Oregon highways. The purpose of center line rumble strips is to keep vehicles in their lane and prevent head-on and sideswipe meeting collisions where a median barrier was not feasible. ODOT has installed CLRS on rural highways in both a 4-16 foot (1.2-4.9 m) striped median. ODOT has also experimented with placing rumble strips on centerline pavement markings in both passing and no passing zones when a median cannot be added. While a median is desirable because of the separation of opposing traffic is it not always feasible.

The effectiveness of SRS in reducing road departure collisions led many states to apply the same principle between opposing travel lanes. Experience by other states indicates that CLRS are effective at reducing head-on and sideswipe meeting collisions. The primary concern with the installation is the effect on a driver making a legal passing maneuver or attempting to pass in the area where the rumble strips are installed. ODOT’s initial experimental application was only in no passing zones. In the summer of 2003, CLRS we placed in a passing zone with a modified standard SRS spacing in attempt to limit the impact to driver’s legally crossing the center line in passing areas. In altering the traditional continuous shoulder rumble strip design, it is important to monitor that there will still be enough noise and vibration to alert the driver.

Centerline rumble strips will not eliminate all cross-over collisions especially those caused by excessive speed, loss of control, and most weather related collisions. Because they are intended to alert drivers "drifting" over the center, rumble strips should be used where collision data indicate that type of driver error is prevalent. In addition to CLRS, some head-on collisions may be mitigated by improvements to the shoulder since many head-on collisions are a result of a driver overcorrecting after their vehicle has departed the roadway to the right.

The use of either CLRS is still considered experimental. ODOT will monitor our existing installations with a before-and-after collision study as well as national studies on the topic to better understand their effectiveness. To be approved for experimental installation, Region Traffic must submit an investigation to the State Traffic Engineer that documents a safety problem correctable with the use of milled-in centerline rumble strips. All guidelines below must be met, or a justification for deviation included.

Guidelines for CLRS installation on rural highways with medians - Type D

1) State Traffic Engineer's approval is required for installation.
2) Collision history indicates a large number of head-on or sideswipe meeting collisions that would be treatable with CLRS.
3) Milled-in centerline rumble strips (CLRS) can be used on new or existing bituminous pavement. To retrofit CLRS on existing pavement, the pavement should be in sufficiently good condition to effectively accept the milling process without raveling or deteriorating. Otherwise the pavement should upgraded prior to milling any desired CLRS.
4) The design and installation of the center line rumble strip is shown in drawing "Type D" in Appendix H. Specifications may be adapted from Section 00865 of the Oregon's 2002 Standard Specifications. There is
no standard detail or drawing for this installations as yet.
5) A minimum median width of 4 feet (1.2 m) is needed for this rumble strip installation. For medians 4 feet (1.2 m) in width, place the rumble strips in the center of the median. For medians greater than 4 feet (1.2 m) in width, place the rumble strips 12 inches (300 mm) inside of each median stripe.
6) Do not install CLRS on
   a) Bridge decks;
   b) In the area of intersections with public roads. Stop CLRS 650 feet (200 m) in advance of intersections or 330 feet (100 m) in advance of left turn taper if one exists;
   c) CLRS should not be placed in areas with short distances between access points.
7) For maintenance reasons, consider the use of durable striping in conjunction with milled-in rumble strips. Some of the equipment that ODOT owns for painting has difficulty in areas where the milled-in rumble strips exist because the wheel track of the sprayer hits the rumble strips. Please contact the Region Traffic Manager or Striping Supervisor to verify the striping equipment available.
8) No deletion shall be considered unless there is a clear and documented problem. Inform the Region Traffic Manager and State Traffic Engineer of decisions to delete existing rumble strip installations.

Guidelines for CLRS installation on rural highways without medians - Type E

1) State Traffic Engineer's approval is required for installation.
2) Collision history indicates a large number of head-on or sideswipe meeting collisions that would be treatable with CLRS.
3) If installed in a passing section, consider the noise impacts to residential areas nearby.
4) Milled-in centerline rumble strips (CLRS) can be used on new or existing bituminous pavement. To retrofit CLRS on existing pavement, the pavement should be in sufficiently good condition to effectively accept the milling process without raveling or deteriorating. Otherwise the pavement should upgraded prior to milling any desired CLRS.

5) The design and installation of the shoulder rumble strip is shown in drawing "Type E" in Appendix H. For installation in areas where passing is allowed, a spacing of 2'-4'-2' on center shall be used. In no passing sections, a continuous 2' spacing will be used. Specifications may be adapted from Section 00865 of Oregon's 2002 Standard Specifications. There is no standard detail or drawing for this installations as yet.

6) Do not install CLRS on

- a) Bridge decks;
- b) In the area of intersections with public roads. Stop CLRS 650 feet (200 m) in advance of intersections or 330 feet (100 m) in advance of left turn taper if one exists;
- c) CLRS should not be placed in areas with short distances between access points.

7) For maintenance reasons, consider the use of durable striping in conjunction with milled-in rumble strips. Some of the equipment that ODOT owns for painting has difficulty in areas where the milled-in rumble strips exist because the wheel track of the sprayer hits the rumble strips. Please contact the Region Traffic Manager or Striping Supervisor to verify the striping equipment available.

8) No deletion shall be considered unless there is a clear and documented problem. Inform the Region Traffic Manager and State Traffic Engineer of decisions to delete existing rumble strip installations.

PENNSYLVANIA

MILLED CENTERLINE RUMBLE STRIPS
(For Non-Interstate and Non-Expressways Use)

Responsibilities:
District Safety Engineer is the process Owner.

Guidelines for Use:
1. The purpose of milled Center Line Rumble Strips (CLRS) is to reduce the occurrence of head-on and/or sideswipe collisions on undivided two-lane or four-lane highways.

2. Consider CLRS on the following locations and under following conditions:

Roadway Description	Typical Drawing Detail
Roadway with 12 feet or greater lane width and minimum of 3 feet of paved shoulder.	Detail # 1
Roadway with 11 feet lane width and minimum of 3 feet of paved shoulder.	Detail # 1 or Detail # 2
Roadway with 11 feet lane width and less than 3 feet of shoulder or no shoulder	Detail # 2
Roadway with 10 feet lane width with or without shoulder.	Detail # 2
Roadway with less than 10 feet lane width	Consult BHSTE

3. Milled centerline rumble strips (CLRS) are for use on bituminous pavement.

4. Installing CLRS on bituminous pavement requires an ID-2 or ID-3 surface with BCBC base or better.

5. If it is desired to retrofit CLRS on existing pavement, the pavement should be in sufficiently good condition, as determined by the District, to effectively accept the milling process without raveling or deteriorating. Otherwise the pavement needs upgraded prior to milling any desired CLRS.

6. CLRS should not be installed on existing concrete pavements with overlay less than 2 ½" in depth.

7. Do not install CLRS on bridge decks.

8. CLRS may be installed in passing zones where deemed appropriate by District safety personnel. Consider reducing depth of cut to 3/8" in areas where passing is permitted. If CLRS are being discontinued for a passing zone, use engineering judgment as to where to terminate CLRS in advance of a passing zone.
9. CLRS are to be broken for intersections. Also consider breaking for driveways according to engineering judgment. When breaking CLRS pattern, discontinue CLRS 25

feet from the Point of Curvature of any such highway or driveway (refer to Typical Detail #3).

10. Coordinate the milling of CLRS with all necessary project phases. Do not mill the CLRS until all appropriate construction phases are completed.

11. Co-ordinate the milling of CLRS with traffic line painting operations a) to avoid milling newly applied traffic lines and b) to install new yellow centerlines within two weeks of CLRS completion.

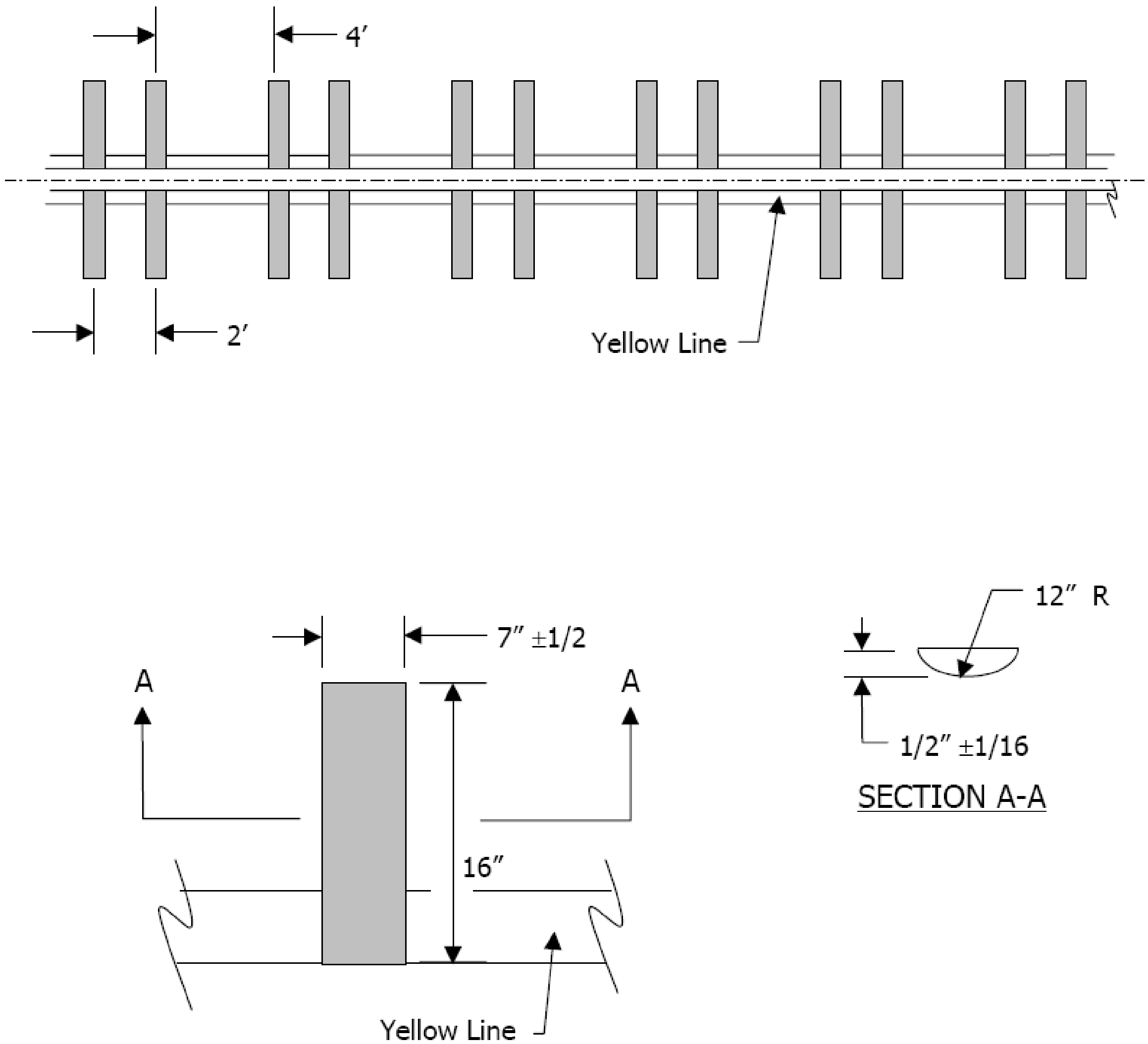
12. Consult the Bureau of Highway Safety & Traffic Engineering before installing CLRS on highways with travel lane widths that are less than 10 feet.

13. Take into consideration potential noise impacts when contemplating the installation of CLRS in residential or urban areas.

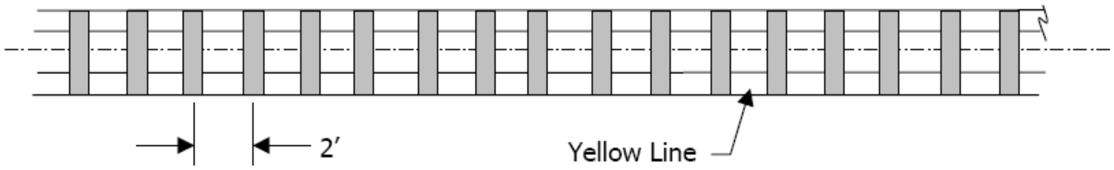
DESIGN DEVIATION

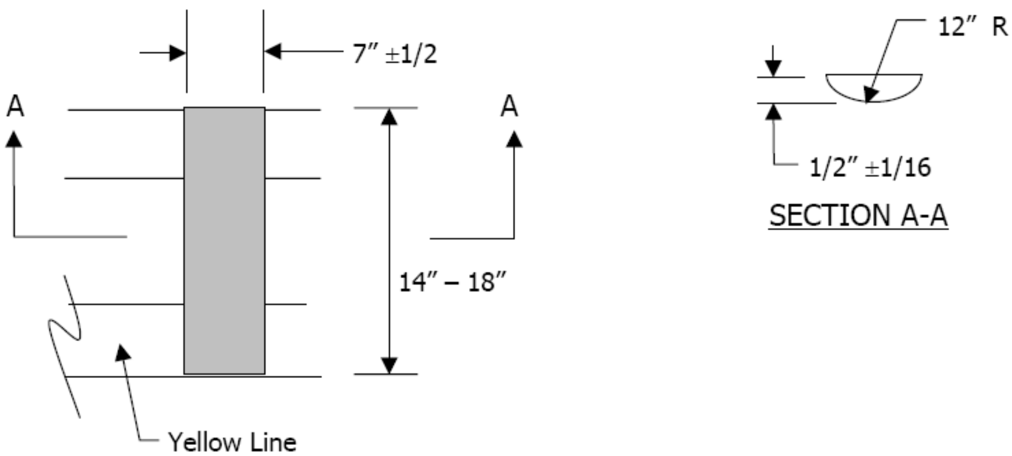
Deviation from the above specifications and guidelines may be considered by the district; however, they must be approved by the Bureau of Highway Safety & Traffic Engineering prior to being implemented.

Milled Centerline Rumble Strips
Typical Drawing Detail # 1

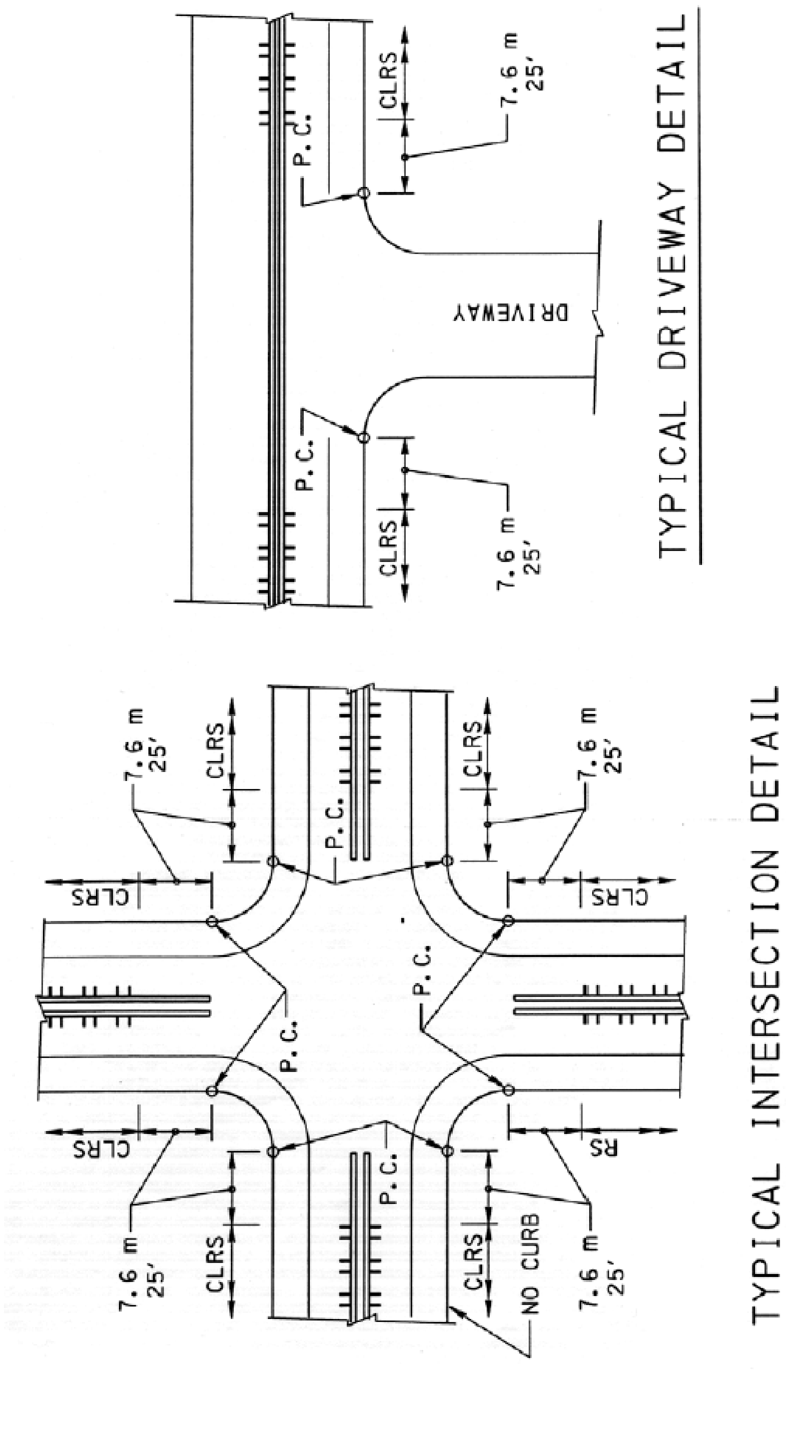


Milled Centerline Rumble Strips
Typical Drawing Detail # 2





**Milled Centerline Rumble Strips
Typical Drawing Detail # 3**



UTAH

Centerline Rumble Strips may be installed on State highways meeting the following criteria:

1. On highways with experience of high cross over head-on collisions or high potential for head-on collisions
2. On highways where the posted speed limit is 50 mph or greater,
3. In the following typical undivided highway applications:
   (a) Two-way with no passing zones;
   (b) Two-way with passing permissive in one direction;
   (c) Two-way with passing permissive in both directions; and
   (d) Two-way with painted median.