Chapter H
Roadside Design Guide

Part I – Practices, Guidelines and Processes

H1 Overview

H1.1 Introduction

Motor vehicle collisions take a tremendous toll on society within the Province. For example, in 2003, 321 fatal collisions, representing 0.3% of the total 113,357 collisions resulted in 380 deaths. And from 1999 to 2003, approximately 18,650 personal injuries occurred annually in Alberta *(Source: 2003 Alberta Traffic Collision Statistics).* The total annual societal cost of motor vehicle collisions in Alberta is conservatively estimated at $2.6 billion, based on the collision costs presented in *Alberta Infrastructure and Transportation's (INFTRA) Benefit-Cost Analysis Guide.*

While a detailed breakdown of collisions in Alberta is not available, data gathered in the United States suggests that roughly 60% of all fatal collisions involved only one vehicle. In about 70% of these collisions, the vehicle left the road surface and either overturned or collided with a fixed object within the roadside area. Some of these fixed objects were man-made, including bridges and approaches, retaining walls, overhead sign supports, utility poles, longitudinal traffic barriers, culverts, and other roadside elements. The design, position and location of these fixed objects are usually dictated by the highway agency.

Although vehicles are expected to remain on the roadway, the highway designer must recognize that vehicles may leave the roadway for a variety of reasons. These reasons can be grouped into three types: driver operation, vehicle malfunction, and roadway conditions.

Driver Operation includes:

- falling asleep
- reckless or inattentive driving
- driving under the influence of alcohol or other drugs
- excessive speed
- not driving according to weather conditions (sun, snow, rain, ice, fog)
- or when the driver deliberately attempts to avoid a collision with another motor vehicle, an animal, or an object on the road.

Vehicle malfunction includes:

- component failures such as steering or braking systems
- tire blowouts.

Roadway conditions include:

- poor alignment
- poor visibility due to weather conditions
- reduced pavement friction
- inadequate drainage
- or substandard signing, marking, or delineation.

The probability of a collision occurring within the roadside environment depends primarily on the speed and trajectory of the errant vehicle and what lies in its path. While the severity of a collision is influenced by several factors, such as the use of vehicle occupant restraint systems, the type of vehicle, and the nature of the roadside environment, the highway designer can only address the design and functionality of the roadside environment.

The forgiving roadside design philosophy emerged in the mid 1960s to reflect the fact that vehicles can run off the roadway. Most highway agencies in North America now accept that the

severity of a collision, measured in terms of personal injury and/or extent of property damage, can be reduced if a more traversable recovery area is provided. A principal objective of the forgiving roadside philosophy is to provide a generally clear traversable area adjacent to the highway—a Clear Zone area— to accommodate the occasional errant vehicle that enters the roadside. The Clear Zone should be free of non-traversable hazards, such as unyielding fixed objects or steep sideslopes.

Significant advances have been made to understand how the design and functionality of roadside features can influence the outcome of a roadside-related collision. Road agencies now have a better understanding of the performance limits of road safety hardware. This knowledge includes the average severity of collisions resulting from contact with barriers and other hazards, and the expected frequency of roadside encroachments, based on traffic volume, speed, and shoulder width. In some cases, these factors can be combined to permit a rational examination of the design options available to the designer. In other cases, design decisions must continue to be based on previous experience and/or state-of-the-art practices. Selecting the best alternative from a range of acceptable choices is the continuing challenge the highway designer must face.

Recent publications by the American Association of State Highway and Transportation Officials (AASHTO), such as the *Highway Safety Design and Operations Guide (1997)* and the *Roadside Design Guide (2002),* provide an in-depth discussion and history of the forgiving roadside concept. The reader is encouraged to review these documents.

There are several design strategies for the treatment of roadside features within the Clear Zone area. AASHTO suggests the following priority for dealing with identified roadside hazards:

- remove the hazard
- redesign the hazard so that it can be safely traversed or contacted
- relocate the hazard to reduce the probability of it being traversed or contacted
- reduce the severity of the hazard
- shield the hazard
- delineate and increase the driver's awareness of the hazard when other mitigation measures cannot be made to work.

The Clear Zone concept and the hazards that should be considered for mitigation are presented in **Section H3.2**.

H1.2 Historical Perspective

The design of the roadside environment, defined as the area from the travelled way (at the edge of the outermost roadway lane) to the right-of-way (ROW) limit, has evolved significantly over the past five decades.

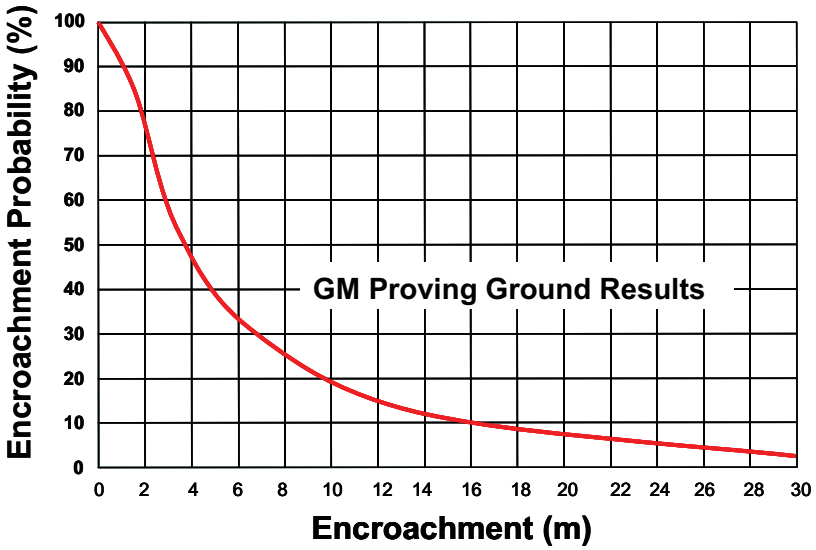
Early field testing, performed during the *General Motor Proving Grounds Study* by P.C. Skeels in the late 1950s, established a basic understanding of the relationship between encroachment probability and encroachment distance. The study revealed that a high percentage of the vehicles leaving the travelled way will only travel, or encroach, into the roadside area a short distance. Researchers also learned that a very low percentage of errant vehicles will travel a great distance into the roadside area. This encroachment probability/distance relationship, graphically illustrated in **Figure H1.1**, still influences the design philosophy of the roadside today.

In the late 1960s, road authorities throughout North America began to concentrate on the design of the roadside environment to improve road safety. Field studies conducted in the mid 1960s and 1970s enhanced the understanding of encroachment patterns for run-off-the-road (ROR) collisions. Several studies have also been undertaken to gain a better understanding of the path and stability of errant vehicles when they traverse the roadside.

From these studies, it was determined that vehicle behaviour depends largely on the characteristics of the roadside, vehicle speed, the contributing circumstances that caused the loss of control, and the performance characteristics of the vehicle. On traversable roadside terrain, the driver may be able to regain partial control of the vehicle after the speed of the vehicle has been reduced.

The design of the roadside has also evolved over time. Road embankments were initially constructed with steep sideslopes to reduce the amount of grading required. The steepness of the slope was typically governed by the loading requirements to support vehicular traffic and to ensure embankment stability. As traffic volumes and speeds increased, the incidence of roadside collisions also increased. It is now understood that providing wider and flatter areas adjacent to the travelled way can reduce the severity of roadside collisions. Many road authorities have adopted the practice of providing flatter open areas adjacent to their roadways.

FIGURE H1.1 GM Proving Ground Encroachment Relationship



H1.3 Testing Procedures for Roadside Hardware

The design of roadside hardware, consisting of longitudinal traffic barrier systems, end treatments, and crash cushions, has evolved over the past 50 years. Extensive research is conducted annually to support initiatives to refine the performance of the hardware. While controlled tests cannot always faithfully replicate in-service conditions, they offer the best perspective as to what might happen in the field during a collision involving roadside hardware.

The need for comprehensive testing procedures for roadside hardware to confirm how devices would function during a collision was recognized quite some time ago. Research conducted in the 1970s by the Transportation Research Board (TRB) in the United States yielded an early attempt to define how roadside hardware should perform during service conditions (in-service). The National Cooperative Highway Research Program (*NCHRP) Report 350 – Recommended Procedures for the Safety Performance Evaluation of Highway Features (1993)*, presents the most current guidelines to evaluate the performance of roadside hardware.

The *NCHRP Report 350* states that a performance goal is to provide hardware systems that will safely do one of the following:

- contain or redirect an errant vehicle away from a hazardous area
- decelerate the vehicle to a stop over a relatively short distance
- readily break away, fracture, or yield
- allow a controlled penetration
- be traversed

without causing serious injuries to the vehicle's occupants or to other motorists, pedestrians, or work zone personnel.

Six test levels (TL-1 to TL-6) are defined in the *NCHRP Report 350* to benchmark roadside hardware. The tests, defined in terms of test vehicle characteristics (type and mass), impact speed, and impact angle, are used to quantify the impact severity of various performance conditions.

The test conditions for longitudinal traffic barriers are summarized in **Table H1.1**.

The *NCHRP Report 350* testing criteria considers two basic aspects of the longitudinal traffic barrier: Length of Need and transition. The Length of Need section is the portion of the longitudinal traffic barrier that is designed to redirect or contain an errant vehicle. The transition section is the portion at the end of the longitudinal traffic barrier that connects with features of varying rigidity.

A similar test matrix dealing with end treatments and crash cushions can be found in *NCHRP Report 350*. The test conditions for end treatments and crash cushions are summarized in **Table H1.2**.

TABLE H1.1
Test Conditions for Longitudinal Barriers

Test Level	Test Vehicle(s) Used	Impact Angles	Impact Speeds
1	820 kg car	20°	50 km/h
	700 kg car	20°	
	2000 kg pickup truck	25°	
2	820 kg car	20°	70 km/h
	700 kg car	20°	
	2000 kg pickup truck	25°	
3	820 kg car	20°	100 km/h
	700 kg car	20°	
	2000 kg pickup truck	25°	
4	820 kg car	20°	100 km/h
	700 kg car	20°	
	2000 kg pickup truck	25°	
	8000 kg single-unit truck	15°	80 km/h
5	820 kg car	20°	100 km/h
	700 kg car	20°	
	2000 kg pickup truck	25°	
	36000 kg tractor trailer	15°	80 km/h
6	820 kg car	20°	100 km/h
	700 kg car	20°	
	2000 kg pickup truck	25°	
	36000 kg tanker truck	15°	80 km/h

Alberta Infrastructure and Transportation has adopted the crash performance criteria documented in *NCHRP Report 350*. With the exception of the Alberta Weak Post W-Beam system, all barrier systems must meet the test levels as specified in *NCHRP Report 350*.

The Alberta Weak Post W-Beam system has been accepted for use on Alberta's highways based on many decades of satisfactory in-service performance in the Province.

In general, the basic test level requirement for high speed arterial highways is TL-3. TL-4 is used on specially designated highways as shown in **Table H3.4** and is expected to satisfy the majority of the high volume freeways and expressways close to and through major urban centres. TL-5 and TL-6 are used for special site conditions (normally dictated by Bridge Code CAN/CSA-S6-06 requirements) with high truck exposure and/or special hazards. TL-3 is also used for most local roads but TL-2 may be considered for low traffic volume locations with favourable site conditions and for work zones with reduced speeds.

Bridgerail performance levels are selected in accordance with a procedure in the *Canadian Highway Bridge Design Code* based on considerations of multiple factors. The performance levels are discussed in **Section H7.2.**

The reader is encouraged to review the *NCHRP Report 350 – Recommended Procedures for the Safety Performance Evaluation of Highway Features* document for additional background and discussion regarding the specific testing requirements of roadside hardware.

Current research is underway to update the testing guidelines and the results will likely be presented in a future NCHRP report. The updated testing guidelines may be adopted by INFTRA in the future.

TABLE H1.2 Test Conditions for End Treatments and Crash Cushions

Test Level	Feature	Devices	Test Vehicle(s) Used	Nominal Angles	Nominal Speeds
1	Terminals and Redirective Crash Cushions	Gating/ Non-Gating	820 kg car	0°/15°	50 km/h
			700 kg car		
			2000 kg pickup truck		
		Gating/ Non-Gating	2000 kg pickup truck	20°	
	Non-redirective Crash Cushions	Gating	820 kg car	0°/15°	
			700 kg car		
			2000 kg pickup truck		
		Gating	2000 kg pickup truck	20°	
2	Terminals and Redirective Crash Cushions	Gating/ Non-Gating	820 kg car	0°/15°	70 km/h
			700 kg car		
			2000 kg pickup truck		
		Gating/ Non-Gating	2000 kg pickup truck	20°	
	Non-redirective Crash Cushions	Gating	820 kg car	0°/15°	
			700 kg car		
			2000 kg pickup truck		
		Gating	2000 kg pickup truck	20°	
3	Terminals and Redirective Crash Cushions	Gating/ Non-Gating	820 kg car	0°/15°	100 km/h
			700 kg car		
			2000 kg pickup truck		
		Gating/ Non-Gating	2000 kg pickup truck	20°	
	Non-redirective Crash Cushions	Gating	820 kg car	0°/15°	
			700 kg car		
			2000 kg pickup truck		
		Gating	2000 kg pickup truck	20°	

H1.4 Contents of this Guide

This document provides guidance for the cost-effective design of the roadside environment for highways in Alberta. The guide will also serve as a rudimentary reference for designers wishing to increase their knowledge in roadside design.

Section H1 outlines the general philosophy and principles of roadside design. Roadside design is not performed in isolation from other design activities. The relationship between roadside design and other design processes is presented along with a glossary of roadside design terms.

Section H2 presents INFTRA's current practices and guidelines governing roadside design activities.

Section H3 presents the design process for roadside design treatments. A set of decision charts is included to guide the designer through the design process to select the most appropriate design treatment for the specific situation under consideration.

Sections H4 to **H11** present the characteristics and design aspects of various roadside features in Alberta:

H4	Grading and drainage
H5	Roadside and median barrier systems
H6	Barrier end treatments and crash cushions
H7	Bridges
H8	Signs, supports, and poles
H9	Other roadside features
H10	Work Zone considerations
H11	Urban and restricted environment

Section H12 documents other resources available to the designer to increase their knowledge of roadside design.

Appendix A provides severity indices for roadside features, barriers and fixed objects for use in detailed design (predicting the safety implications of design choices).

Appendix B has standard drawings which are used for design and construction.

Appendix C provides guidelines to upgrade existing bridgerails.

Appendix D provides guidelines to upgrade existing bridge approach rail transitions for bridge approaches.

H1.5 Relationship to Other Design Documents

This *Roadside Design Guide* should be used and read in conjunction with other design-governing documents used in Alberta including:

- *Highway Geometric Design Guide*
- *Design Bulletins*
- *Benefit-Cost Analysis Manual*
- *Standard Drawings (CB6 Manual and TEB)*
- *Bridge Standard Drawings*
- *Canadian Highway Bridge Design Code.*

H1.6 Glossary of Roadside Design Terms

This section presents a selected glossary of roadside design terms used in this guide. Additional terms described in the documents listed in **Section H1.5** may also be useful to the designer.

Average Annual Daily Traffic (AADT) is the total traffic (either measured or estimated) over an entire year divided by the number of days in that year. Values are for total two-way traffic.

Backslopes are parallel surface planes located beyond the ditch that slope up from the bottom

of the ditch to the natural or original ground elevation.

Barricade is a device which provides a visual indicator of a hazardous location or the desired path a motorist should take. It is not intended to physically contain or redirect an errant vehicle.

Barrier *see* longitudinal traffic barrier.

Breakaway is a design feature which allows a device such as a sign, light pole, or traffic signal support to yield or separate upon impact to reduce the severity of impact with a roadside feature. The release mechanism may be a slip plane, plastic hinges, fracture elements, or combination of these.

Bridge Railing is an integral barrier or device fastened on a bridge intended to prevent an errant vehicle from going over the side of the bridge structure.

Bullnose Thrie Beam Median Barrier is an end treatment using Thrie Beam barrier elements to shield hazards, such as bridge piers and light poles in the median.

Clearance is the lateral distance from the edge of the travelled way to a roadside feature.

Clear Zone is the total roadside border area adjacent to the travelled way provided for use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear runout area. The desired width is dependent upon traffic volumes and speed, and on the roadside geometry.

Cost-Effectiveness is a measure of tangible benefits produced by the resources allocated and is generally expressed with standard terms and predefined parameters.

Crash Cushion is an impact attenuating device designed to bring an errant vehicle of a particular size range, at a given speed and angle of impact, to a safe stop by gradually decelerating the vehicle or redirecting the vehicle away from the hazard.

Crash Tests are vehicular impact tests used to determine the structural and safety performance of roadside barriers and other highway appurtenances. The tests may be grouped into three criteria:

- structural adequacy
- impact severity
- post-impact vehicular trajectory.

Crashworthy is a term used to describe a feature that has been proven acceptable for use under specified conditions, either through crash testing or in-service performance.

Design AADT is the AADT projected for the design year. For new construction projects, the design year is normally considered to be 20 years after the year of construction because the design life is typically 20 years in duration. The Design AADT can be estimated using the current AADT and a projected annual growth rate.

Design Speed is the speed selected and used for correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favourable that the design features of the highway govern. The design speed should be used in determining Clear Zone and set-back of hazards, etc. When selecting longitudinal traffic barrier systems and related hardware, the design speed may not be directly related to the crash test speed. The crash test speed/impact angle/vehicle size combinations for each test level is considered to represent fairly severe collisions.

Design Vehicle is a selected motor vehicle used to establish highway design controls to accommodate the specific weight, dimensions, and operating characteristics of a designated type of vehicle.

Ditches are normally located between the sideslope and backslope planes and are intended to collect and channel surface and subsurface water. Most highways in Alberta have a rounded flat bottom or a ditch that slopes gradually away from the highway.

Drainage Features are roadside items that are designed to adequately accommodate roadway drainage. Examples include curbs, culverts, ditches, and drop inlets.

Driving Lane is the portion of the roadway designed for the movement of vehicles, excluding shoulders. A driving lane may have different surfaces including concrete, asphalt, or granular.

End Treatment is a design modification of a longitudinal traffic barrier system or an added device at the end of the barrier system intended to reduce the severity of impact.

Flare is the variable offset distance of a barrier system to locate it further from the travelled way.

Frangible Base or Structure is a structure or component especially designed to readily break upon impact.

Gating is the performance characteristic of an end treatment or crash cushion allowing a vehicle impacting the nose and/or end segment of the system to pass through the device.

Guardrail is a flexible to semi-rigid form of longitudinal traffic barrier used to mitigate vehicles from striking a more severe hazard located on the roadside or in the median, or to mitigate against crossover median collisions. It is intended to contain or redirect an errant vehicle of a particular size range, at a given speed and angle of impact. Common types of guardrail systems used in Alberta include:

- High Tension Cable Guardrail
- Alberta Weak Post W-Beam Barrier
- Strong Post W-Beam Barrier
- Modified Thrie Beam Barrier.

Gore Point is the decision point on an exit ramp or the convergent point of an entrance ramp with the mainline.

Hazard is any non-breakaway or non-traversable roadside feature located within the roadside environment that is greater than 100 mm in diameter or thickness or that protrudes more than 100 mm that can increase the potential for personal injury and/or vehicle damage when struck by an errant vehicle leaving the travelled portion of the roadway.

Hinge is the weakened section of a sign post designed to allow the post to rotate upward when impacted by a vehicle.

Impact Angle is the angle between a tangent to the face of the barrier system and a tangent to the vehicle's path at impact. For crash cushions, the impact angle is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicle's path at impact.

Length of Need is the total length of a longitudinal traffic barrier needed to shield a hazard by containing or redirecting the errant vehicle away from the hazard.

Longitudinal Traffic Barrier is the generic term for a device used to mitigate vehicles from striking a more severe hazard located on the roadside or in the median, or to mitigate against crossover median collisions. It is intended to contain or redirect an errant vehicle of a particular size range, at a given speed and angle of impact. Common types of longitudinal traffic barrier systems used include:

- High Tension Cable Guardrail
- Alberta Weak Post W-Beam Barrier
- Strong Post W-Beam Barrier
- Modified Thrie Beam Barrier
- Concrete Barrier.

Median is the portion of a divided highway separating the travelled ways for traffic going in opposite directions.

Median Barrier System is a longitudinal traffic barrier designed to be impacted on both sides.

Modified Thrie Beam Barrier is a TL-4 guardrail system with a three-rib steel beam element, longer posts, and wide offset blocks.

Non-Recoverable Slope is a slope that is considered to be traversable although errant vehicles will generally continue to the bottom of these slopes with little chance for recovery. Embankment slopes between 3:1 and 4:1 may be considered traversable, but non-recoverable, if they are smooth and free of hazards.

Offset is the distance between the travelled way and a roadside barrier or other hazard.

Offset Block is an element of strong post guardrail systems that positions the beam away from the post to reduce the potential for wheel snags on the post during impact. Offset blocks for Strong Post W-Beam guardrail systems are made of either solid wood or plastic. Offset blocks for Modified Thrie Beam systems are made from standard structural steel (I-Beam) modified to provide a triangular cutout in the web.

Performance Level is the degree to which a bridge barrier, is designed for containment and redirection of different types of vehicles. Performance level ratings PL-1, PL-2, and PL-3 are used in the 2006 edition of the *Canadian Highway Bridge Design Code (CSA-S6-06)* to define bridge barrier requirements for structural adequacy.

Recoverable Slope is a slope on which a motorist may, to a greater or lesser extent, retain or regain control of an errant vehicle. Slopes 4:1 or flatter, are generally considered recoverable.

Roadside is the area between the outside shoulder edge and the right-of-way limits.

Roadside Barrier System is a longitudinal traffic barrier designed to be impacted on only one side.

Roadside Hardware is the collective term used to describe longitudinal traffic barrier systems, end treatments, and crash cushions.

Roadway is the portion of a highway, including shoulders, designated for vehicular use.

Rounding is the smooth transition between two surface planes or slopes to minimize the abrupt slope change, and to allow a vehicle to traverse such slopes without bottoming out or vaulting.

Severity Index (SI) is a number from zero to ten used to categorize collision by the probability of their resulting in property damage, personal injury, or a fatality, or any combination of these possible outcomes. The resultant number can be translated into a collision cost and the relative effectiveness of alternate safety treatments can be estimated.

Shielding is the introduction of a longitudinal traffic barrier system, end treatment, or crash cushion, between the vehicle and a hazard or area of concern to reduce the severity of impacts of errant vehicles.

Sideslopes are parallel surface planes located immediately adjacent to the edge of the travelled way. Sideslopes generally slope down and away from the shoulder of the highway.

Slip Base is a structural element at or near the bottom of a post or pole which will allow the post to release from its base upon impact but is still capable of resisting wind loads.

Standard Thrie Beam is a longitudinal barrier system used for bridge transitions or as part of the Thrie Beam Bullnose System. The Standard Thrie Beam uses wood or plastic offset blocks, rather than the modified structural steel elements used with the Modified Thrie Beam System.

Test Levels are the performance benchmarks for roadside hardware as outlined in *National Cooperative Highway Research Program (NCHRP) Report 350 – Recommended Procedures for the Safety Performance Evaluation of Highway Features*.

Temporary Longitudinal Traffic Barriers are used to prevent vehicular access into construction or maintenance work zones and to redirect errant vehicles to minimize damage to the vehicles, to reduce occupant and construction worker injuries, and to provide work zone area protection.

Transitions incorporate a gradual stiffening of one roadside hardware system to match the stiffness of an adjacent system where they connect to prevent or mitigate vehicular pocketing, snagging, or penetration at the connection.

Traversable Slope is a slope on which a motorist will be unlikely to steer back to the roadway but may be able to slow and stop or reach the bottom of the slope safely. Slopes between 4:1 and 3:1 generally fall into this category.

Warrants are the criteria governing the need to provide a safety treatment or improvement.

H1.7 References

The following documents were used during the development of this section:

Alberta Infrastructure and Transportation, *Benefit-Cost Analysis Manual*, Edmonton, AB, 1991.

Alberta Infrastructure and Transportation, *Highway Geometric Design Guide*, Edmonton, AB, 1999.

Alberta Infrastructure and Transportation, *Highway Guide and Information Sign Manual*, October 2006.

Alberta Infrastructure and Transportation, *Traffic Accommodation in Work Zones*, Edmonton, AB, 2001

Alberta Infrastructure and Transportation, *Traffic Accommodation in Work Zones – Urban Areas*, Edmonton, AB, 2003

Alberta Infrastructure and Transportation, *Traffic Control Standards Manual*, Edmonton, AB, 1995.

American Association of State Highway and Transportation Officials, *Highway Safety Design and Operations Guide*, Washington, DC, 1997.

American Association of State Highway and Transportation Officials, *Roadside Design Guide 2006*, Washington, DC, 2006.

Canadian Highway Bridge Design Code (CSA-S6-06)

Transportation Research Board, *National Cooperative Research Program Report 230 - Recommended Procedures for the Safety Performance Evaluation of Highway Features*, Washington, DC, 1980.

Transportation Research Board, *National Cooperative Research Program Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features*, Washington, DC, 1993.

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