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MINNESOTA DEPARTMENT OF TRANSPORTATION	**TRANSMITTAL LETTER NO. (20-01)**
DEVELOPED BY: Design Standards Unit	**MANUAL:** Road Design Manual
ISSUED BY: Office of Project Management and Technical Support	**DATED:** March 19, 2020
SUBJECT: Sections 2-6 and 2-8	

A list of changes is attached to this update.

INSTRUCTIONS:

1. Record this transmittal letter number, date and subject on the transmittal record sheet located in the front of the manual. The last Transmittal Letter was 19-04, dated November 19, 2019.

2. Remove from the manual: Section 2-6(1-4)
   Section 2-8(1)
   Pages 10-7(7-8) and 10-7(11-12)

3. Insert into the manual: Section 2-6(1-4)
   Section 2-8(1)
   Pages 10-7(7-8) and 10-7(11-12)

4. The Road Design Manual and associated Transmittal Letters are available online in PDF format at. http://roaddesign.dot.state.mn.us/roaddesign.aspx

5. Any technical questions regarding this transmittal should be directed to Mike Elle, Design Standards Engineer, at (651) 366-4622, or by email to DesignStandards.DOT@state.mn.us

Michael Elle

Michael Elle, P.E.
State Design Standards Engineer

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Summary of Changes
MnDOT Road Design Manual
20-01

Section 2-6 DESIGN STANDARDS

- 2-6.01 Critical Design Elements
  - Remove the number of elements in section title to avoid being over-specific
  - Clarify why they're considered critical
  - Add Ramp Length, which had been missing and is included in the HPDP write-up
  - Update number and names of the elements per FHWA revisions
  - Update applicability of all but two of the elements as only for high-speed design speeds
  - Update references to applicable design information
  - Clarify/specify that applicability of superelevation rate as a controlling criterion is as a maximum
  - Clarify that any design exceptions for these are formal exceptions
  - Clarify language regarding preservation standards and their applicability
  - Various editorial revisions for flow, information and clarity
- 2-6.02 General Design Elements
  - Update references to applicable design information as necessary
  - Remove bus turn-out bullet, as it had been removed from Chapter 11
  - Simplify and correct typical parking lane application
  - Remove specific design criteria in turn lane discussion
  - Various editorial revisions for clarity or correctness, as necessary
- 2-6.03.01 Formal Design Exceptions
  - Revise first sentence to better reflect contemporary design approach
  - Update references to federal policy and guidance (both here and in 2-8 References)
  - Clarify that Bullet 2 pertains to any individual user group
- 2-8.0 References
  - Update editions of AASHTO "Green Book" and TRB Highway Capacity Manual
  - Update title and publication date of MnDOT Bicycle Facility Design Manual

Section 10-7 TRAFFIC BARRIERS

- 10-7.02.01 Structural Plate-Beam Guardrail
  - Table 10-7.02A Estimated Working Width for Type 31 W-Beam Guardrail
    - Correct modified post spacing dimension in third row of table
    - Correct slope representation in fourth row of table
- 10-7.03 Length-of-Need
  - Figure 10-7.03A Barrier Layout for Adjacent Traffic
    - Correct figure reference for opposing traffic

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2-6.0 DESIGN STANDARDS

Highway design standards are divided into two categories: critical design elements and general design elements. The following sections define these two categories and explain how they are applied to projects. Design elements are also listed with references to specific areas of the Road Design Manual and other sources for further information.

2-6.01 Critical Design Elements

The Federal Highway Administration (FHWA) designates ten critical design elements of primary importance to geometric design due to their effects on roadway safety and traffic operation. MnDOT designates one additional critical element—Ramp Length—due to its operational effect on mainline highways. Except as noted, they are applicable only on facilities with design speeds of 50 mph [80 km/h] or higher. They are as follows:

1. **Design Speed**
   This criterion applies to the full range of design speeds.
   Refer to 2-5.06.01 for general information and requirements.
   This is a fundamental design control, upon which standard values for all design speed-dependent elements are based. For this reason, FHWA states that design exceptions for Design Speed "should be extremely rare." Normally, a design speed value within the specified allowable range is selected, and individual design elements not meeting the associated criteria are cited as design exceptions. There are cases, however, where classification of an entire highway corridor or segment using a nonstandard design speed value is most representative of the road, its attributes and context, and is therefore appropriate.
2. **Lane Width**
   Refer to Technical Memorandum No. 18-08-TS-06 for design requirements and general information.
3. **Shoulder Width**
   Refer to Technical Memorandum No. 17-12-TS-05 for design requirements and general information.
4. **Horizontal Curve Radius**
   Refer to Chapter 3 for general information and requirements.
5. **Superelevation Rate**
   Superelevation exceeding the maximum rates designated in Chapter 3 requires a design exception.
6. **Stopping Sight Distance**
   Refer to 2-5.08.01 for general information and requirements.
7. **Maximum Grade**
   Refer to Chapter 3 for general information and requirements.
8. **Cross Slope**
   Refer to Chapter 4 for general information and requirements.
9. **Vertical Clearance**
   Refer to MnDOT LRFD Bridge Design Manual for design requirements and general information.
10. **Design Loading Structural Capacity**
    This criterion applies to the full range of design speeds.
    For new construction/reconstruction projects, any new or existing bridge that does not meet the standard loading requires a design exception. As with Design Speed, FHWA states that exceptions to this criterion should be extremely rare. For preservation projects, any existing bridge that fits the horizontal and vertical alignment of the roadway may remain in place without any requirements for structural capacity. For improvement projects, bridges should meet the minimum inventory load requirements of the MnDOT Bridge Preservation, Improvement and Replacement Guidelines. A design exception is required if the bridge does not meet these guidelines.
11. **Ramp Length**
    This criterion applies to the full range of ramp, loop and mainline design speeds. Chapter 6 as amended by Technical Memorandum No. 19-01-TS-01 provides standard acceleration and deceleration lengths for ramps and loops.

For preservation projects, the design standards for the critical elements are the existing conditions or the new construction / reconstruction standards, whichever is less. Preservation standards are not applicable on freeways; in other words, the design standard for preservation-type projects on freeways is the new construction / reconstruction standard. The MnDOT Bridge Preservation, Improvement and Replacement Guidelines document contains the bridge preservation design standards.

Where the new construction / reconstruction or preservation standards for the critical design elements cannot be attained, a formal design exception is required. The consideration given to safety, maintenance, or other improvements as part of preservation projects should be addressed in the appropriate project documents.

2-6.02 General Design Elements

There are many general design elements that are common to most projects. These elements and the typical design values, policies, and practices that have been developed for them are referenced below.

General design elements included in new construction/reconstruction projects should normally meet the standard value for that element. Preservation projects may modify these elements as warranted to correct performance deficiencies. Although designers do not have to document design exceptions if these standards cannot be met, they must discuss any judgments and decisions in the project documents.

The following list includes some of the general design elements that are often encountered:

Alleys
For information, refer to AASHTO guidelines.
Backslopes
Refer to Chapter 4 for design guidance, requirements, and ditch traversability guidelines.
Bikeways
Refer to Chapter 11, the MnDOT Bicycle Facility Design Manual, and the Minnesota GO Statewide Bicycle System Plan for design assistance, requirements, and route designations.
Clear Zone
Refer to Chapters 4 and 10 and AASHTO's "Roadside Design Guide" for design information, guidance, and requirements.
Climbing Lanes
Refer to Chapter 3 for design guidelines and requirements.
Continuous Rumble Strips
Refer to Chapter 4 for design guidance and general information.
Curbs
Refer to Chapter 4 for design guidance and requirements.
Curb Ramps
Refer to Chapter 11 and Standard Plans .200 series for design guidance and requirements.
Drainage
Refer to Chapter 8 for design guidance.
Entrances and Driveways
Refer to Chapter 5 for design guidance and requirements.
Erosion Control
Refer to Chapter 8 for design guidance on current practices.
Frontage Roads
Refer to Chapters 4 and 6 for proper design and location of frontage roads.
Roadside Slopes
Refer to Chapter 4 for design requirements and general guidance.
Interchanges
Refer to Chapter 6 for design guidance and information.
Intersections
Refer to Chapter 5 for design criteria and general information.
Lighting
Refer to Chapter 10 and the MnDOT Traffic Engineering Manual for design information.

Mailbox Supports
Refer to Chapter 11 for design guidance and requirements.
Medians
Refer to Chapter 4 for information on medians. Refer to Chapter 5 for information on median openings.
Noise Abatements
Refer to Chapter 11 for design guidance and information.
Operational Improvements to Two-Lane Highways (Passing Lane Sections)
Refer to Chapter 3 for design guidance and general information.
Park and Ride Facilities
Refer to Chapter 11 for design information. Park and ride facilities are desirable at locations where it is beneficial for commuters to park and use public transit or ride share.
Parking Lanes
Refer to Technical Memorandum No. 17-12-TS-05 for design information. Parking lanes may be provided on low-speed urban and suburban facilities.
Pedestrian Traffic and Crossings
Refer to Chapter 11 and the MnDOT Traffic Engineering Manual for design guidance and information.
Rail Crossings
Refer to Chapter 11 for design guidance and information.
Rest Areas
Refer to Chapter 11 for design information. Rest areas are desirable on facilities with long distances between towns. Rest areas provide a safe area to recover from the effects of fatigue.
Retaining Walls
Refer to Chapter 9 for design guidance and information.
Sidewalk
Refer to Chapter 11 for widths, location, and general information.
Sight Distances
Refer to Section 2-5.08 for definitions. Refer to Chapter 3 for application to horizontal and vertical curves.
Signals
Refer to the MnDOT Traffic Engineering Manual for design guidance and general information.
Signing and Marking
Refer to the MnDOT Traffic Engineering Manual for guidance and general information.
Special Freeway Designs
Several examples exist in the AASHTO publication “A Policy on Geometric Design of Highways and Streets” including reverse-flow freeways, dual-divided freeways, collector/distributor roads, and exclusive bus and high-occupancy vehicle (HOV) lanes.
Terminals (Turn Arounds, Cul-de-Sacs, etc.)
Refer to Chapter 4 of the Road Design Manual and Chapter 5 of AASHTO’s “A Policy on Geometric Design of Highway and Streets” for design guidance and general information.
Traffic Barriers
Refer to Chapter 10 for current design guidance and requirements.
Traffic Control Devices
Refer to the MnDOT Traffic Engineering Manual for guidance and standards.
Tunnels
Refer to Chapter 9 of the Road Design Manual and Chapter 4 of AASHTO’s “A Policy on Geometric Design of Highway and Streets.”
Turf Establishment and Landscape
Refer to Chapters 8 and 11 for design guidance and requirements. Turf establishment is provided where ground cover is disturbed.
Turn Lanes
Refer to Chapter 5 for design information and requirements.
Utilities
Refer to the MnDOT Utility Accommodation & Coordination Manual.

2-6.03 Geometric Design Exceptions

When a project design includes geometric elements that fail to satisfy minimum criteria as set forth by MnDOT policy, a design exception is required. Failure of a design to meet the standard for any of the critical design elements requires approval of a *Formal Design Exception.* If the standard for any general design element is not met, an *Informal Design Exception* should be documented.

2-6.03.01 Formal Design Exceptions

MnDOT's general practice is to right-size project designs, which usually satisfies standard criteria for the critical design elements (a.k.a. controlling criteria, as defined by FHWA). However, standard values for these elements should not be strived for at all costs. On occasion, the judicious application of good design practice and engineering judgment—including balanced consideration of functional, modal, safety, economic, environmental and context-related factors—involves the use of sub-standard critical design elements to fashion an appropriate solution and achieve project goals. In these cases, formal documentation and processing of the design exceptions and their justification is required.

U.S. Federal policy on application of design standards—as well as evaluation and approval procedure for design exceptions—on the National Highway System is provided in rulemaking dated November 1, 2018 to the Code of Federal Regulations (CFR), Title 23. It states, "For most situations, there is sufficient flexibility within the range of acceptable values to achieve a balanced design. However, when this is not possible, a design exception may be appropriate. State and local agencies may consider designs that deviate from the design standards when warranted based on the conditions, context, and consequences of the proposed projects."

Design documentation requirements for projects with or without design exceptions are provided in the MnDOT Highway Project Development Process (HPDP) Handbook. Pertinent information such as functional classification, traffic volume and project description are recorded, as are tabular existing and proposed values for the critical design elements and a written justification for the exception(s).

The design exception justification should address the stated evaluation components outlined in Federal guidance on the subject. It states, "All proposed design exceptions should be thoroughly analyzed and the potential impacts understood before approval. The process to evaluate and justify design exceptions must be based on an evaluation of the context of the facility (e.g., community values), needs of all the various project users, safety, mobility (i.e., traffic performance), human and environmental impacts, project costs, and other impacts." It goes on to outline recommended documentation elements: specific design criteria that will not be met; existing roadway characteristics; alternatives considered; comparison of the performance of the roadway against various contextual and environmental factors; proposed mitigation measures; and compatibility with adjacent sections of roadway. The assembled components and supporting data should represent a compelling basis for proposed solution. A rule of thumb for successful design exception justification is that two conditions are successfully asserted:

1. No reasonable, feasible, and practical solution can be devised to provide standard values for the critical design elements in question, OR the selection of a non-standard value or values for these elements is advantageous in some way or ways and results in an overall superior design.
2. Use of non-standard values for the elements in question will not be expected to unduly degrade the safety or operational performance of the proposed facility for any users.

2-6.03.02 Informal Design Exceptions

As with critical design elements, the Department's policy for general design elements is to adhere to standard design criteria where practical, reasonable, and beneficial. In cases where substandard values for general elements are applied, some documentation of these informal design exceptions should be included in the project file. Although the level of formality and degree of justification in documenting informal exceptions will generally be less than for formal exceptions, compelling reasoning for the variance and considerations taken into account in the decision-making process should always be provided.

It is understood that not every piece of design information presented in this manual or in AASHTO publications is considered a "design standard" but would more appropriately be described as good engineering practice. The designer should exercise judgment in discerning which general elements and design attributes are deserving of documentation when compromised.

2-8.0 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 2018
2. *Highway Capacity Manual*, Transportation Research Board, 2016
3. *Design Standards for Highways—Final Rule*, Federal Register, Vol. 83, No. 212, November 1, 2018
4. *Memo: Revisions to the Controlling Criteria for Design and Documentation for Design Exceptions*, U.S. Department of Transportation, Federal Highway Administration, May 5, 2016
5. *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, AASHTO, 1977
6. *Economic Analysis for Highways*, Robley Winfrey, International Textbook Company, 1969
7. *A Guide for Achieving Flexibility in Highway Design*, AASHTO, May 2004
8. *Older Driver Highway Design Handbook*, FHWA, January 1998
9. *Application of Design Standards, Uniform Federal Accessibility Standards, and Bridges*, FHWA
10. *Highway Design and Operational Practices Related to Highway Safety*, AASHTO, 2nd Edition, June 1974
11. *Roadside Design Guide*, AASHTO, 2011
12. *Passing Sight Distance Criteria*, NCHRP Report 605, Transportation Research Board, 2008
13. *Bridge Preservation, Improvement and Replacement Guidelines*, MnDOT, 2006
14. *Geotechnical and Pavement Manual*, MnDOT
15. *LRFD Bridge Design Manual*, MnDOT
16. *Traffic Engineering Manual*, MnDOT
17. *State Aid Manual*, MnDOT
18. *Right of Way Manual*, MnDOT
19. *Bicycle Facility Design Manual*, MnDOT, February 2020

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10-7.01.05 Clear Zones

The roadside clear zone is the distance from the edge of the traveled way or traveled lane, including the shoulders, a recoverable slope and/or a clear zone runout area, which should be free of any non-traversable hazards or fixed objects. In general, hazards within the clear zone which cannot be removed, relocated or made breakaway will warrant guardrail. A detailed description of clear zones is given in Chapter 4.

A bridge barrier is one object that cannot be removed or relocated outside of the clear zone. A bridge barrier normally warrants guardrail. The standard plate-beam guardrail approach treatment used at bridges is detailed in the Standard Plans Manual, series 600. These designs should normally be used for approach ends of bridges on divided highways and both ends of bridges on two-way highways, see Figure 10-7.01C, unless the bridge is located at a site that meets all the following criteria:

1. The bridge is located within the limits of a municipality.
2. The bridge site is located where design speeds are less than 40 mph.
3. The roadway is either an urban section with curbs and sidewalk berm or a rural section in which the bridge width equals or exceeds the width of the roadway inclusive of shoulders.

Wherever semi-rigid barrier joins a rigid bridge barrier, a crash worthy transition is needed. This produces a gradual stiffening of the approach to the bridge barrier to protect against vehicle pocketing, snagging or penetration of the system and is accomplished by double-nesting of the guardrail and gradually reducing the post spacing.

Crash-worthy transitions are required at all new bridges, as well as at bridges on which the bridge barriers are reconstructed, when the design speed is 40 mph or greater. For preservation projects, consult TM 17-07-TS-02 "W-Beam Guardrail Upgrade Considerations for Preservation Projects" for guidance on evaluating the existing transition. Approved transitions are shown in the Standard Plans Manual, series 600.

Bridges in high-speed locations with pedestrian traffic require special consideration. If possible, where positive separation of pedestrians and vehicles is provided, the pedestrian traffic should be routed away from the guardrail terminal. If rerouting pedestrian traffic is not possible, a non-extruding end treatment should be considered.

Guardrails should also be provided at approaches to barrier walls that are within the clear zone. The criteria used for design is the same as that used in providing guardrails at bridge approaches.

10-7.01.06 Roadside Hazards

Roadside hazards are non-traversable features usually flanking the roadway for some distance and are potentially damaging for out-of-control vehicles. Examples are rough rock cuts, large boulders, permanent water of 2 ft or more in depth. Guardrail should be provided along the shoulder or off the shoulder and closer to the hazard whenever such hazards are located within the clear zone. Where such parallel hazards exist in the proximity of the roadway but outside of the clear zone, guardrail may be warranted if the relative risk is high, such as being a hazard located on the outside of a curve.

10-7.02 Selection of Barrier Type

Certain types of barrier are selected for specific purposes. The standard types in use by MnDOT and their general areas of application are discussed below.

10-7.02.01 Structural Plate-Beam Guardrail

The W-beam is the most commonly used plate-beam guardrail or barrier in Minnesota and the rest of the nation. It derives its name from the shape of the plate beam. W-beam guardrail is a semi-rigid system on steel posts. In this type of system, impact is resisted by a combination of bending and tension of the rail acting with the posts and limiting lateral deflections. Reduced deflections can be achieved by methods such as nesting of the rail, which consists of two stacked pieces of plate beam, and/or reduced post spacing. (See Table 10-7.02A).

The Type 31 Guardrail System (MGS) is a non-proprietary steel post, W-beam guardrail system that has been successfully crash tested per MASH TL-3 criteria. The Type 31 Guardrail System uses a typical W-beam guardrail with:

- 31 in. top of rail mounting height with a 2 in. up tolerance and a 1 in. down tolerance.
- 6 ft long W6 × 9 steel posts.
- 6 in. × 12 in. routed or non-routed wood blockouts or composite blockouts.
- 12-gauge rail with rail splices at the center of the span location.

Table 10-7.02A ESTIMATED WORKING WIDTH *
FOR
TYPE 31 W-BEAM GUARDRAIL

Type 31 with 6 ft-3in. post spacing	5 ft.
Modified 3 ft-1½ in. post spacing	3 ft-7 in.
Modified 1 ft-6¾ in. post spacing	3 ft.
Type 31 with 6 ft-3 in. post spacing at the break point of the 1V:2H slope and 9 ft long posts.	5 ft-3 in.

*Working width is defined in MASH as the distance between the traffic side of the guardrail before the impact and the maximum lateral position of any major part of the guardrail system or vehicle after impact.

Thrie beam is another type of structural plate beam that has one corrugation in addition to those of the W-beam. It is currently only used in bullnose crash cushion and transition design in Minnesota. For further details about the thrie beam guardrail, check the *Roadside Design Guide*.

10-7.02.02 3-Cable Guardrail (Low Tension)

This is a flexible system with either weak wood posts or steel posts. With this system, impact is resisted by cable tension and end anchorage. The posts and cable hook bolts are designed to give way under impact conditions and not interfere with the redirection of the colliding vehicle. Deflections of 10 ft or greater can be expected within the contact area; for design purposes, use 11 ft. This type of guardrail may be used for installations where the design deflection is not a constraint. Cable guardrail should not be installed along embankments steeper than 1:2, around the inside of a curve greater than 4 degrees, or any place where the installation does not develop tension in the cable upon impact.

10-7.02.03 High-Tension Cable Guardrail

This is a flexible system with steel posts. These systems are generally used in median applications, but can also be used as roadside barriers. High-tension cable guardrail is installed with significantly more tension than a low-tension system, thus the deflection of this system is reduced to 6 to 10 ft, dependent on post spacing. All available systems are proprietary. Technical Memorandum 15-08-TS-04 includes design guidance for the systems currently available.

10-7.02.04 Box Beam Guardrail

Box beam guardrail is a semi-rigid system consisting of a rectangular box beam mounted on steel posts. The typical installation consists of a 6 in. x 6 in. steel tube mounted on S3 x 5.7 steel posts on 6 ft centers.

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

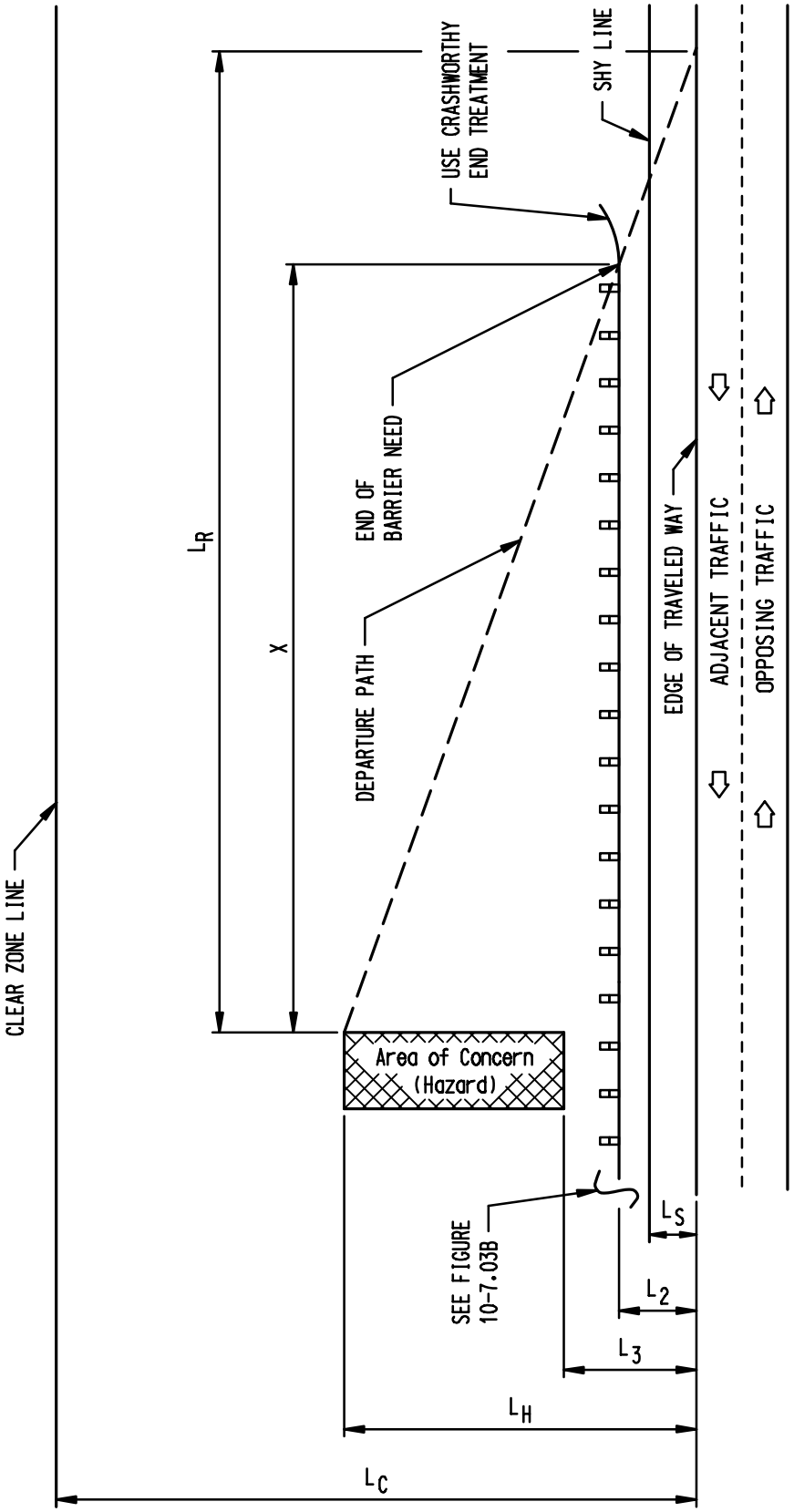
Figures 10-7.03A and B indicate the variables involved in the determination of the layout of a required guardrail installation. Table 10-7.03A gives the design parameters for roadside barrier layout based upon design speed. The variables are explained below:

L_C = Clear zone width (see Figure 4-6.04A)
L_H = Distance from edge of the through lane to the far side of the hazard or the outside edge of the clear zone. This is a critical element of the design and requires some judgment on the part of the designer.
L_2 = Distance from the edge of the through lane to the barrier.
L_3 = Distance from the edge of the through lane to the near edge of the hazard.
L_R = Run-out length or theoretical distance needed for a vehicle that has left the roadway to come to a stop before hitting the hazard (see Table 10-7.03A).
X = Distance from the hazard to the end of the barrier (length-of-need).
L_S = Shy line offset (distance beyond which a roadside object will not be perceived by the driver as a threat, guardrail should be placed outside shy line offset) (see Table10-7.03A).

Normally, the barrier is placed as far from the edge of the traveled lane as possible, L_2, while maintaining the required deflection distance between the barrier and the hazard, L_3-L_2. The deflection distance between the barrier and the hazard influences the designer's selection of barrier type. On roadways with side slopes steeper than 1:10, this lateral placement may need to be adjusted to prevent a vehicle from striking the face of the barrier at a point too high or too low, which can cause vaulting or snagging. See Figure 10-7.01B for proper placement.

Table 10-7.03A
DESIGN PARAMETERS FOR ROADSIDE BARRIER LAYOUT

Design Speed mph (km/h)		Runout Length (L_R) Given Traffic Volume (ADT) ft (m)								Shy Line Offset L_S ft (m)	
		Over 10,000 vehicles/day		5,000 to 10,000 vehicles/day		1,000 to 5,000 vehicles/day		Under 1,000 vehicles/day			
80	(130)	470	(143)	430	(131)	380	(116)	330	(101)	12	(3.7)
75	(120)	420	(127)	380	(116)	340	(102)	290	(89)	10	(3.2)
70	(110)	360	(110)	330	(101)	290	(88)	250	(76)	9	(2.8)
65	(105)	330	(101)	290	(89)	250	(76)	230	(69)	8.5	(2.6)
60	(100)	300	(91)	250	(76)	210	(64)	200	(61)	8	(2.4)
55	(90)	270	(81)	220	(67)	190	(57)	180	(54)	7	(2.2)
50	(80)	230	(70)	190	(58)	160	(49)	150	(46)	6.5	(2.0)
45	(70)	200	(60)	160	(49)	140	(42)	130	(38)	6	(1.7)
40	(60)	160	(49)	130	(40)	110	(34)	100	(30)	5	(1.4)
35	(55)	140	(42)	110	(34)	100	(29)	90	(26)	4.5	(1.3)
30	(50)	110	(34)	90	(27)	80	(24)	70	(21)	4	(1.1)



BARRIER LAYOUT FOR ADJACENT TRAFFIC
Figure 10-7.03A