2. Roadside Design Policies, Standards and Guidelines

2.1 Introduction

Policies, standards and guidelines used for the design of the roadside environment on provincial highway projects are provided in this chapter. Deviations from policies and standards in Chapter 2 should be justified and documented in the Design Criteria. Deviations may also be documented as applicable in other design report(s), including but not limited to the Project Scope and Cost Report (SCR), Preliminary Design Report (PDR), Project Assessment Report (PAR), or Corridor Investment Plan (CIP).

Policies are clearly stated in bold text under the heading "Policy". Each policy defines when they are applicable on a provincial highway project. Standards are referenced in each policy as required. Design guidance is provided in the preceding text before each policy, and additional design guidance and details are provided in Chapters 3, 4 and 5.

Highway design and roadside safety practices have evolved over time as research projects and updated roadside safety features, practices, and hardware have been developed, tested, implemented and evaluated. As such, an existing highway can exhibit a broad range of design treatments and roadside safety hardware over the length of a corridor, reflecting the era of initial construction, reconstruction or rehabilitation.

The roadside environment, including medians, on Major Capital Expansion projects as defined in Table 2-1 should be designed according to the applicable policies and standards in Chapter 2 unless otherwise justified and documented within the applicable design report(s).

On Major Capital Rehabilitation projects and Major Capital Reconstruction projects as defined in Table 2-1, explicit benefit/cost evaluations should be used to determine whether applicable policies and standards in Chapter 2 including desirable roadside safety or median improvements are cost beneficial for inclusion with the project, or whether such improvements should be deferred to a future rehabilitation, reconstruction or expansion project. Decisions should be justified and documented within the applicable design report(s).

Roadside design decisions should be consistent with the applicable Corridor Investment Plan and Project Scope and Cost Report.

Category of work for Capitalization Purposes	Category of work for Programming Purposes	Characteristics of Work for Design Purposes
Operating/Maintenance (expensed)	Emergency Maintenance Work	• Work that requires immediate repairs – unforeseen or unplanned hazards.
	Maintenance	• Work that must be done on a periodic basis to eliminate actual or potential safety hazards. • Work that is identified in the Maintenance Quality Standards.
Minor Capital Work (capitalized)	Holding	• An action taken when an asset does reach the trigger (threshold) value but a full rehabilitation/reconstruction is not undertaken. This work will maintain acceptable levels of functionality or safety and prolongs the life of the asset.
	Preventive	• Work is done before the asset reaches the trigger (threshold) value. Planned strategies that extend the life of the asset or enhance its service potential. • Work undertaken to a small section or component of an asset to be consistent with the overall asset.
Major Capital (capitalized)	Rehabilitation	• Renews the life of an asset. • Activities performed when the trigger value has been achieved, at the end of the anticipated service life. This work restores serviceability and improves an existing asset to a condition of structural or functional adequacy.
	Reconstruction	• Activities may be performed at the end of the anticipated service life, but typically after two or three rehabilitation cycles. Generally the complete or major removal and replacement of an existing asset.
	Expansion	• Capital improvement that improve the asset's performance or capacity either as part of a reconstruction of an existing asset or a green field project.

Table 2-1: Category of Work

2.2 Design Procedures and Roadside Safety Hardware

Roadside design procedures, design treatments, and roadside safety hardware selected for use on provincial highway projects are presented in this manual. However, new procedures and concepts are continually being developed along with new or modified roadside safety hardware. Design, installation, maintenance and repair guides are available from roadside safety hardware manufacturers to provide supplemental detailed information for products used on provincial highway projects.

It is important to ensure that the design processes and roadside safety hardware selections used across the province on provincial highway projects are consistent for similar situations. The application of other procedures, other roadside design treatments, and modifications to roadside safety hardware should be reviewed with the ~~Design and Contract Standards~~Highway Design Office prior to being used on provincial highway projects.

POLICY: **On Provincial Highway Projects, only roadside design procedures authorized by the ~~Design and Contract Standards~~Highway Design Office should be used for design of roadside environments**

2.3 Roadside Design

2.3.1 Desirable Clear Zone

It is recognized that some vehicles will run off the road, regardless of the design of the roadway. It is desirable for errant vehicles that have departed the travelled way to have an opportunity to stop or slow down within the roadside before encountering obstacles. This is intended to reduce the number of fatality and injury crashes that can occur within the roadside environment. As described in Section 1.3, test track experience and full scale testing at the GM Proving Grounds in the 1950s established a basic understanding of encroachment distance relationship and geometry of the roadside environment.

A significant number of serious collisions, and the severity of injuries sustained during encroachments onto the roadside environment, can be reduced if a clear zone is provided adjacent to the travelled way. The clear zone selected and provided within the right-of-way to accommodate the path of most errant vehicles should be traversable, and be free of obstacles, such as unyielding landscaping, bridge piers, sign supports, light poles, non-traversable ditches, rigid drainage features, and steep slopes. When obstacles or areas of concern cannot be eliminated, relocated, or made traversable or breakaway within the selected clear zone, barrier systems or crash cushions should be considered and evaluated to determine if they would be a cost effective design treatment to shield the obstacle or area of concern from errant vehicles.

Vehicle impacts with barrier systems, crash cushions and breakaway systems will likely involve vehicle damage and may result in occupant injury, dependent on the physical characteristics of the errant vehicle, and on the angle, speed, and orientation of the errant vehicle at point of impact. The severity of an impact for a vehicle interacting with a barrier system or crash cushion should be less severe than the severity of interacting with the obstacle(s) being shielded. Designers should strive to eliminate the need for barrier systems and crash cushions by providing desirable clear zones wherever practical and cost beneficial. Roadside safety is enhanced by providing a forgiving roadside.

The desirable clear zone values provided in Table 2-2 and the horizontal curve adjustment factors provided in Table 2-3 are modified and based on suggested clear zone distances and adjustment factors from the AASHTO Roadside Design Guide. These distances were based on limited empirical data that was extrapolated to provide values for a wide range of conditions. The values should be considered as approximate and not a precise value to be held as absolute.

POLICY: On Major Capital Expansion Projects, all obstacles within the desirable clear zone according to Table 2-2 and Table 2-3 that cannot be removed, relocated or made breakaway, should be shielded by a barrier system or crash cushion.

On Major Capital Reconstruction Projects, all obstacles within the desirable clear Zone according to Table 2-2 and Table 2-3 should be evaluated to determine whether alternative roadside mitigation treatments are cost beneficial and should be included with the project or deferred to a future rehabilitation, reconstruction or expansion project.

On Capital Rehabilitation Projects, when obstacles are identified and prioritized as areas of concern through on-going operational and collision reviews, alternative mitigation treatments should be evaluated to determine whether the treatments are cost beneficial and should be included with the project or deferred to a future rehabilitation, reconstruction or expansion project.

Design decisions should be documented in the project's Design Criteria.

Design Speed Km/h	AADT	Negative Foreslope (Fill)			10H:1V or flatter	Positive Foreslope		
		3H:1V	4H:1V to 5H:1V	6H:1V or flatter		6H:1V or flatter	5H:1V to 4H:1V	3H:1V
≥ 110	**≥ 6,000**	Note 1	14	10.5	9.5	9	9	7.5
	≥ 1,500	Note 1	13	10	9	8.5	7.5	6
	≥ 750	Note 1	11	8	7	6.5	6	5
	< 750	Note 1	8	6	5.5	5	5	3.5
100	**≥ 6,000**	Note 1	13.5	10	9	8.5	8	6.5
	≥ 1,500	Note 1	12	9	8.5	8	6.5	5.5
	≥ 750	Note 1	10	7.5	7	6.5	5.5	4.5
	< 750	Note 1	7.5	5.5	5.5	5	4.5	3.5
90	**≥ 6,000**	Note 1	10	7.5	7.5	7.5	6.5	5.5
	≥ 1,500	Note 1	9	6.5	6.5	6.5	5.5	5
	≥ 750	Note 1	7.5	5.5	5.5	5.5	5	3.5
	< 750	Note 1	5.5	4.5	4	3.5	3.5	3
70 to 80	**≥ 6,000**	Note 1	8.5	6.5	6.5	6.5	6	5
	≥ 1,500	Note 1	8	5.5	5.5	5.5	5	4.5
	≥ 750	Note 1	6	5	5	5	4.5	3.5
	< 750	Note 1	4.5	3.5	3.5	3.5	3	3
≤ 60	**≥ 6,000**	Note 1	5.5	5	5	5	5	5
	≥ 1,500	Note 1	5	4.5	4.5	4.5	4.5	4.5
	≥ 750	Note 1	4.5	3.5	3.5	3.5	3.5	3.5
	< 750	Note 1	3	3	3	3	3	3

Note 1: Errant vehicles encroaching onto non-recoverable slopes (parallel foreslopes steeper than 4H:1V) likely will not be able to stop or return to the roadway easily, and typically can be expected to encroach beyond the toe of slope. Fixed objects should not be present in the vicinity of the toe of non-recoverable slopes. Determination of the width of recovery area at the toe of slope should take into consideration right-of-way availability, width of shoulder, environmental constraints, collision history, and slope beyond toe of slope. Desirable width of recovery area at toe of slope when slope beyond toe of slope is relatively flat should be the applicable desirable clear zone value for 10H:1V slope or flatter, minus width of shoulder and half width of rounding, and should not be less than 3m.

Note 2: Positive foreslopes at bridge abutments up to 2H:1V do not require protection.

Table 2-2: Desirable Clear Zone Values

Table modified from AASHTO Roadside Design Guide.

<table>
<tr><th rowspan="2">Radius (m)</th><th colspan="6">Design Speed (km/h)</th></tr>
<tr><th>60</th><th>70</th><th>80</th><th>90</th><th>100</th><th>≥110</th></tr>
<tr><td>900</td><td rowspan="4">1.1</td><td rowspan="2">1.1</td><td>1.1</td><td rowspan="3">1.2</td><td rowspan="2">1.2</td><td>1.2</td></tr>
<tr><td>700</td><td rowspan="3">1.2</td><td>1.3</td></tr>
<tr><td>600</td><td rowspan="5">1.2</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td></tr>
<tr><td>500</td><td rowspan="3">1.3</td></tr>
<tr><td>450</td><td rowspan="4">1.2</td><td rowspan="3">1.3</td><td rowspan="2">1.4</td><td>1.5</td></tr>
<tr><td>400</td><td></td></tr>
<tr><td>350</td><td>1.4</td><td rowspan="2">1.5</td><td></td></tr>
<tr><td>300</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td><td rowspan="2">1.5</td><td></td></tr>
<tr><td>250</td><td rowspan="2">1.3</td><td></td><td></td></tr>
<tr><td>200</td><td>1.4</td><td>1.5</td><td></td><td></td><td></td></tr>
<tr><td>150</td><td>1.4</td><td>1.5</td><td></td><td></td><td></td><td></td></tr>
<tr><td>100</td><td>1.5</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Note: Horizontal Curve Adjustment Factors should only be applied to the outside of horizontal curves with radii of 900 m or less.

Table 2-3: Horizontal Curve Adjustment Factors

Table based on AASHTO Roadside Design Guide

2.3.2 Slopes

Parallel slopes along a roadway perform two essential functions within the roadside environment. Foreslopes (includes frontslopes and sideslopes in cut and fill sections respectively) provide structural support for the roadway, and in conjunction with backslopes (in cut) provide a transition between the roadway and original ground. Slopes are typically described by the ratio of horizontal to vertical change in slope (eg., a 4H:1V is a slope that changes 1 m vertically for every 4 m measured horizontally).

The structural support function of the foreslope can often be achieved with slopes as steep as 1H:1V or even vertical slopes, dependent on the material used to construct the slope. However, the transitional function of the foreslope influences errant vehicle stability, and hence safety. Flatter slopes on high speed roadways are desirable because they result in less abrupt transitions between adjacent surfaces, decrease the risk of vehicle roll-over and tend to reduce the lateral distance away from the road that an errant vehicle will travel.

On freeways and high speed arterial roads with reasonably wide roadsides, foreslopes and backslopes should be designed to provide a reasonable opportunity for recovery of errant vehicles. Foreslopes of 6H:1V or flatter can be negotiated by a vehicle with a reasonable chance of recovery and should therefore be provided where practical and cost beneficial. Foreslopes of 4H:1V or flatter are recoverable where height is moderate. Foreslopes of 3H:1V or flatter and steeper than 4H:1V are traversable where the height is moderate. Foreslopes steeper than 3H:1V are considered critical as there is a higher probability of errant vehicles overturning, and may justify shielding with a barrier dependent on height, length, and uniformity of the critical slope, which should be evaluated using MTO’s Roadside Evaluation Manual and MTO’s Roadside.xlsx program.

Further flattening of slopes may be considered dependent on availability of material and property. Flat and well rounded slopes simplify the establishment of vegetative ground cover and its subsequent maintenance. Slopes 3H:1V or flatter are desirable for maintenance reasons, and usually vegetative ground cover can be readily established on slopes as steep as 2H:1V.

Figure 2-1 provides desirable section for medians separating low speed interchange ramps.

POLICY: On Major Capital Expansion Projects, desirable foreslopes and backslopes should be according to Tables 2-4 through 2-7. At locations where barrier systems are required, foreslopes and backslopes may be steeper dependent on the functional foundation requirements of the selected barrier system.

On Major Capital Reconstruction Projects, desirable foreslopes and backslopes should be according to Tables 2-4 through 2-7 when cost beneficial.

On Major Capital Expansion and Reconstruction Projects, medians separating low speed interchange ramps should be minimum 10 m wide with 3H:1V foreslopes and backslopes. At locations where barrier systems are required, foreslopes and backslopes may be steeper dependent on the functional foundation requirements of the selected barrier system.

Appendix A provides severity indices for various surfaces, foreslopes, and backslope configurations for a range of design speeds.

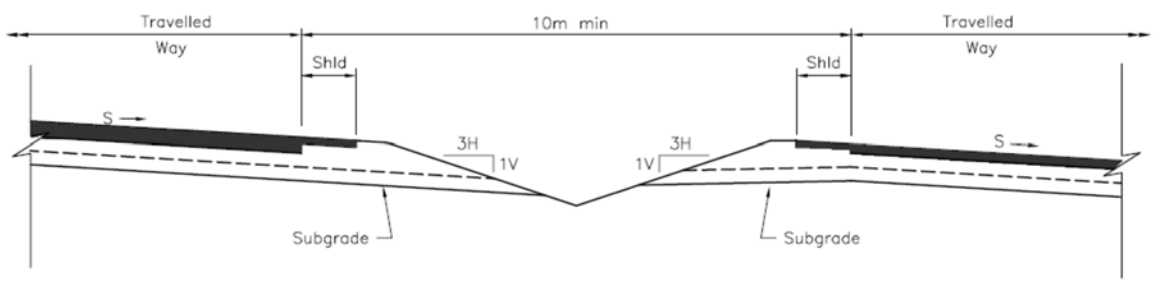


Figure 2-1: Desirable Grading Section for Medians Separating Low-Speed Interchange Ramps.

Note 1: Distance should be 1.5 m minimum when ditch not required.

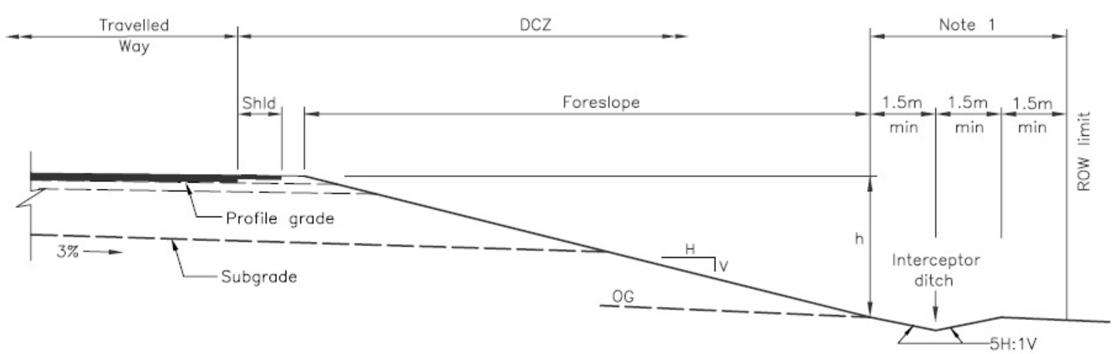


Figure 2-2: Earth/Shale Fill Sections
To be used with Table 2-4

Functional Classification	Design Speed (km/h)	Height: h (m)	Design Year AADT	Foreslope Ratio
Freeway	All	h ≤ 3	All	6H:1V
		3 ≤> h ≤≥ 4.5	All	5H:1V
		4.5 ≤> h ≤≥ 6	All	4H:1V
		h > 6	All	2H:1V Note 1
Interchange Ramp	≥ 100	h ≤ 3	All	6H:1V
		3 ≤> h ≤≥ 6	All	4H:1V
		h > 6	All	2H:1V Note 1
	70 to 100	h ≤ 6	All	4H:1V
		h > 6	All	2H:1V Note 2
	< 70	h ≤ 6	All	3H:1V
		h > 6	All	2H:1V Note 2
Arterial	≥ 70	h ≤ 2	All	6H:1V
		2 ≤> h ≤≥ 4	> 20,000	6H:1V
			≤ 20,000	4H:1V
		4 ≤> h ≤≥ 5	All	4H:1V
		5 ≤> h ≤≥ 6	> 20,000	4H:1V
			≤ 20,000	2H:1V Note 2
		h > 6	All	2H:1V Note 2
	< 70	h ≤ 2	All	4H:1V
		2 ≤> h ≤≥ 4	All	3H:1V
		h > 4	All	2H:1V Note 2
Collector and Local	≥ 70	h ≤ 2	All	4H:1V
		2 < h ≤≥ 6	All	3H:1V
		h > 6	All	2H:1V Note 2
	< 70	h ≤ 6	All	3H:1V
		h > 6	All	2H:1V Note 2

Note 1: Roadside barrier recommended with 4H:1V foreslope above subgrade.
Note 2: Roadside barrier recommended with 3H:1V foreslope above subgrade.

Table 2-4: Desirable Earth and Shale Fill Foreslopes

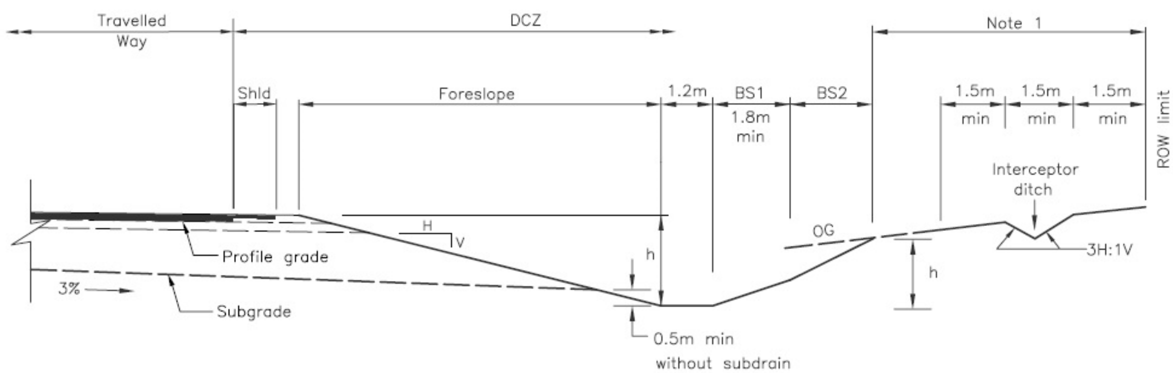
To be used with Figure 2-2

Functional Classification	Design Speed (km/h)	Height: h (m)	Design AADT	Foreslope Ratio	Backslope Ratio	
					BS1	BS2
Freeway	All	h ≤ 3	All	6H:1V	3H:1V	2H:1V
		h > 3	All	4H:1V	4H:1V	2H:1V
Interchange Ramp	≥ 100	h ≤ 2	All	6H:1V	3H:1V	2H:1V
		h > 2	All	4H:1V	4H:1V	2H:1V
	70 to 100	h ≤ 2	All	6H:1V	3H:1V	2H:1V
		h > 2	All	4H:1V	4H:1V	2H:1V
	<70	h ≤ 2	All	3H:1V	3H:1V	2H:1V
		h > 2	All	3H:1V	2H:1V	2H:1V
Arterial	≥70	h ≤ 2	All	6H:1V	3H:1V	2H:1V
		h > 2	All	4H:1V	4H:1V	2H:1V
	<70	h ≤ 3	All	3H:1V	3H:1V	2H:1V
		h > 3	All	3H:1V	2H:1V	2H:1V
Collector and Local	≥70	h ≤ 1	All	4H:1V	4H:1V	2H:1V
		h > 1	All	3H:1V	3H:1V	2H:1V
	<70	All	All	3H:1V	2H:1V	2H:1V

Note 1: Dependent on local soil conditions, Backslope-2 may need to be flatter.

Table 2-5: Desirable Earth and Shale Cut Slopes

To be used with Figure 2-3



Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-3: Earth/Shale Cut Sections

To be used with Table 2-5

Functional Classification	Design Speed (km/h)	Height: h (m)	Design AADT	Foreslope Ratio
Freeway	All	h ≤ 2	All	6H:1V
		2 > h ≤≥ 4	> 15,000	6H:1V
			≤ 15,000	4H:1V
		h > 4	All	1.25H:1V Note 1
Interchange Ramp	≥ 100	h ≤ 3	All	6H:1V
		3 <> h ≤≥ 6	All	4H:1V
		h > 6	All	1.25H:1V Note 1
	70 to 100	h ≤ 6	All	4H:1V
		h > 6	All	1.25H:1V Note 1
	< 70	h ≤ 6	All	3H:1V
		h > 6	All	1.25H:1V Note 2
Arterial	≥ 70	h ≤ 2	All	6H:1V
		2 <> h ≤≥ 4	> 25,000	6H:1V
			≤ 25,000	4H:1V
		4 <> h ≤≥ 5	All	4H:1V
		5 <> h ≤≥ 6	> 25,000	4H:1V
			≤ 25,000	1.25H:1V Note 1
		h > 6	All	1.25H:1V Note 1
	< 70	h ≤ 2	All	4H:1V
		2 <> h ≤≥ 4	All	3H:1V
		h > 4	All	1.25H:1V Note 2
Collector and Local	All	h ≤ 2	All	4H:1V
		2 <> h ≤≥ 3	> 1000	4H:1V
			≤ 1000	3H:1V
		h > 3	All	1.25H:1V Note 2

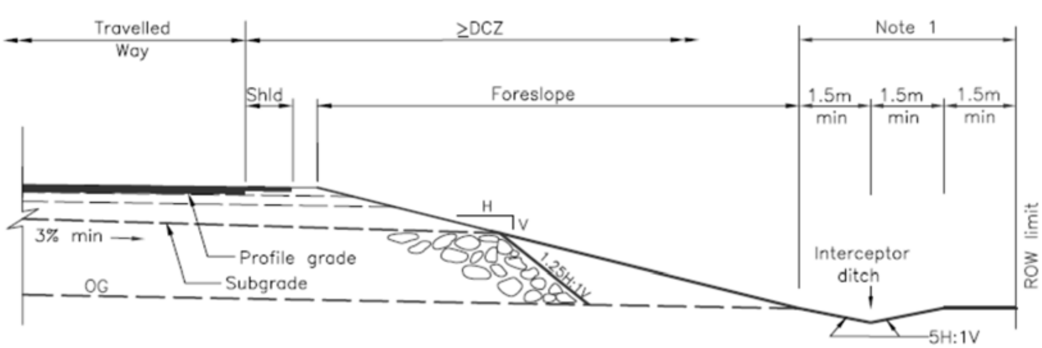
Note 1: Roadside barrier recommended with 4H:1V foreslope above subgrade.
Note 2: Roadside barrier recommended with 3H:1V foreslope above subgrade.

Table 2-6: Desirable Rock Fill Foreslopes
To be used with Figure 2-4

Functional Classification	Design Speed (km/h)	Height: h (m)	Design AADT	Foreslope Ratio	Backslope Ratio	
					BS1	BS2 Note 1
Freeway	All	h ≤ 4	All	6H:1V	3H:1V	2H:1V
		h > 4	All	6H:1V	0.25H:1V	NA
Interchange Ramp	≥ 100	h ≤ 4	All	6H:1V	3H:1V	2H:1V
		h > 4	All	6H:1V	0.25H:1V	NA
	70 to 100	h ≤ 3	All	4H:1V	4H:1V	2H:1V
		h > 3	All	4H:1V	0.25H:1V	NA
	< 70	h ≤ 2	All	4H:1V	4H:1V	2H:1V
		h > 2	All	3H:1V	0.25H:1V	NA
Arterial	≥ 70	h ≤ 3	All	6H:1V	3H:1V	2H:1V
		h > 3	All	6H:1V	0.25H:1V	NA
	< 70	h ≤ 3	All	4H:1V	3H:1V	2H:1V
		h > 3	All	4H:1V	0.25H:1V	NA
Collector And Local	All	h ≤ 2	All	4H:1V	4H:1V	2H:1V
		h > 2	All	4H:1V	0.25H:1V	NA

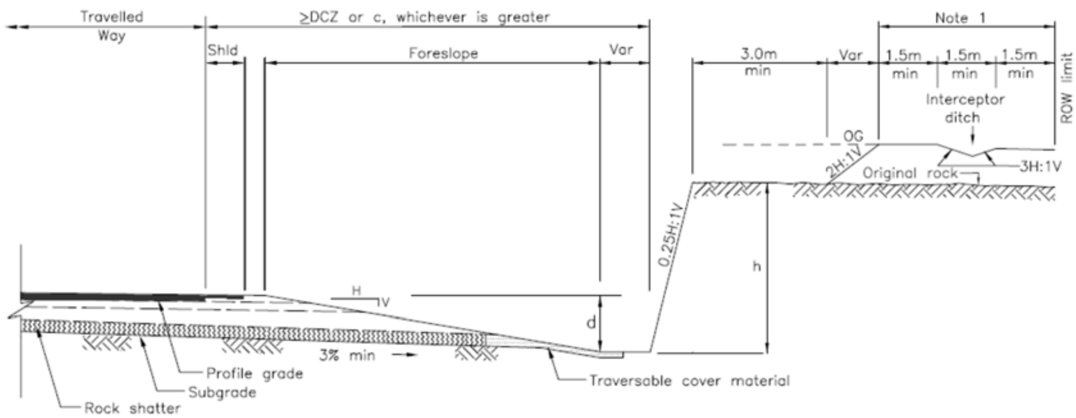
Note 1: Dependent on local conditions including location of DCZ and depth of ditch for rock fall, 2H:1V Backslope-2 may be as steep as 0.25H:1V.

Table 2-7: Desirable Rock Cut Foreslopes and Backslopes
To be used with Figure 2-5 and 2-6



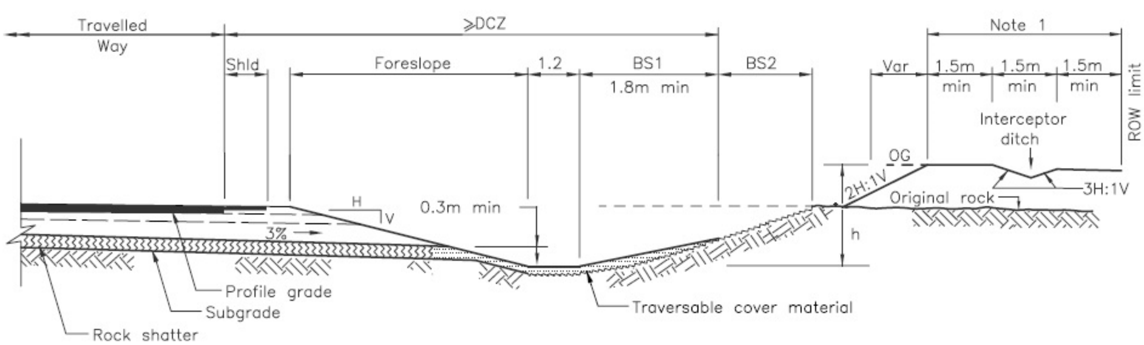
Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-4: Rock Fill Sections
To be used with Table 2-6



Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-5: Rock Cut Sections: 0.25H:1V Rock Face
To be used with Table 2-7



Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-6: Rock Cut Sections: Buried Backslope
To be used with Table 2-7

2.3.3 Shoulder Rounding

Shoulder rounding is the transition between the shoulder cross-fall and the foreslope. It provides additional material beyond the edge of shoulder to provide lateral support of the shoulder and to provide a relatively smooth transition to the foreslope for an errant vehicle departing the roadway. Rounded slopes reduce the probability of an errant vehicle at sharper encroachment angles from becoming airborne, therefore potentially reducing the severity of the encroachment and affording the driver more opportunity for control of the vehicle with tires still in contact with the ground.

Shoulder rounding is also required to provide lateral stability for barrier systems that use posts to support cables or beams, and provide lateral stability for embedded roadside concrete barrier systems.

At least half of the rounding width may also be used by drivers during an emergency stop on the shoulder to increase offset to moving traffic in the adjacent travel lanes.

Providing desirable rounding widths on Major expansion and Reconstruction Projects should accommodate future increases in top of pavement grade due to pavement overlays and/or pavement recycling, therefore minimizing subsequent need to reduce shoulder widths. The proposed pavement rehabilitation strategy should be reviewed to determine if rounding widths larger than desirable values below are required.

Design Speed (km/h)	Desirable (m)	Minimum (m)
≥ 100	1.5	1.0
< 100	1.0	0.5

Table 2-8: Desirable and Minimum Rounding Widths

POLICY: On Major Capital Expansion Projects, desirable rounding widths should be according to Table 2-8. At locations where barrier systems are required, rounding widths are dependent on the functional foundation requirements of the selected barrier system and the steepness of the adjacent foreslope.

Chapter 4 provides functional foundation requirements for each barrier system.

2.3.4 Drainage Ditches

The primary function of a roadside drainage ditch is to collect and convey water along the highway right-of-way until it can be drained away from the subgrade of the roadway, and in most cases along the right-of-way. Ditches are designed to carry the design run-off and to accommodate excessive storm water flows with minimal flooding or damage. However ditches should also be designed, built and maintained with consideration for roadside safety.

For high speed roadways, desirable foreslope and backslope configurations for V-ditches and Trapezoidal ditches are provided in Figures 2-7 and 2-8.

POLICY: On Major Capital Expansion Projects, desirable traversable roadside ditch configurations on high speed arterial roads and freeways should be according to Figures 2-7 and 2-8. At locations where roadside barrier systems are proposed, ditch configurations may be based solely on hydraulic and maintenance requirements.

On Major Capital Reconstruction Projects, desirable traversable roadside ditch configurations on high speed arterial roads and freeways should be according to Figures 2-7 and 2-8 when cost beneficial. At locations where roadside barrier systems are proposed, ditch configurations may be based solely on hydraulic and maintenance requirements.

Appendix A provides severity indices for various ditch depth and shape configurations including surface types for a range of design speeds.

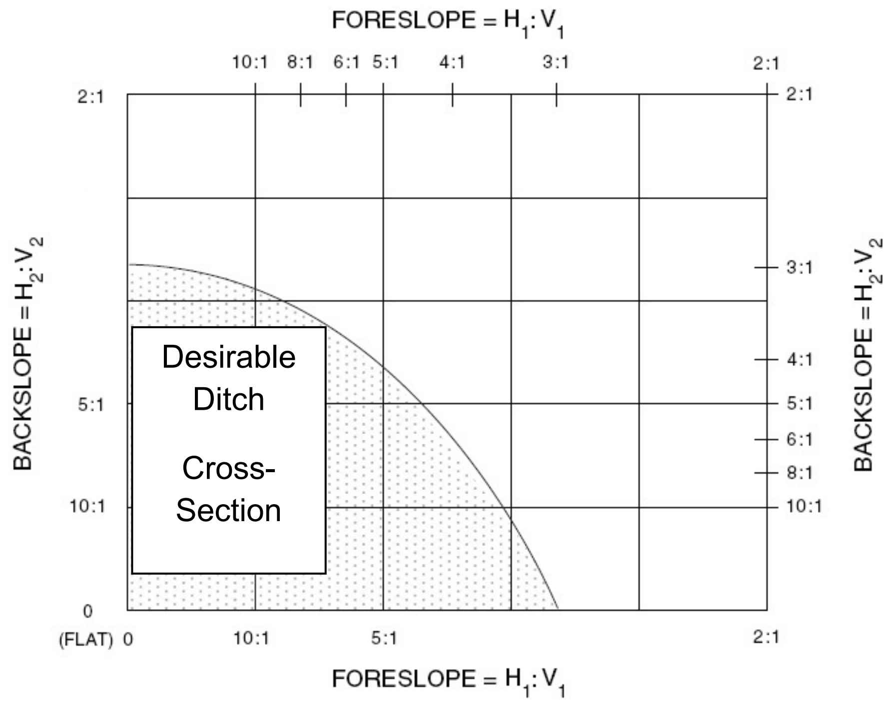


Figure 2-7: Desirable Cross-Section for 'V' Ditches on High Speed Roads

Figure based on AASHTO Roadside Design Guide.

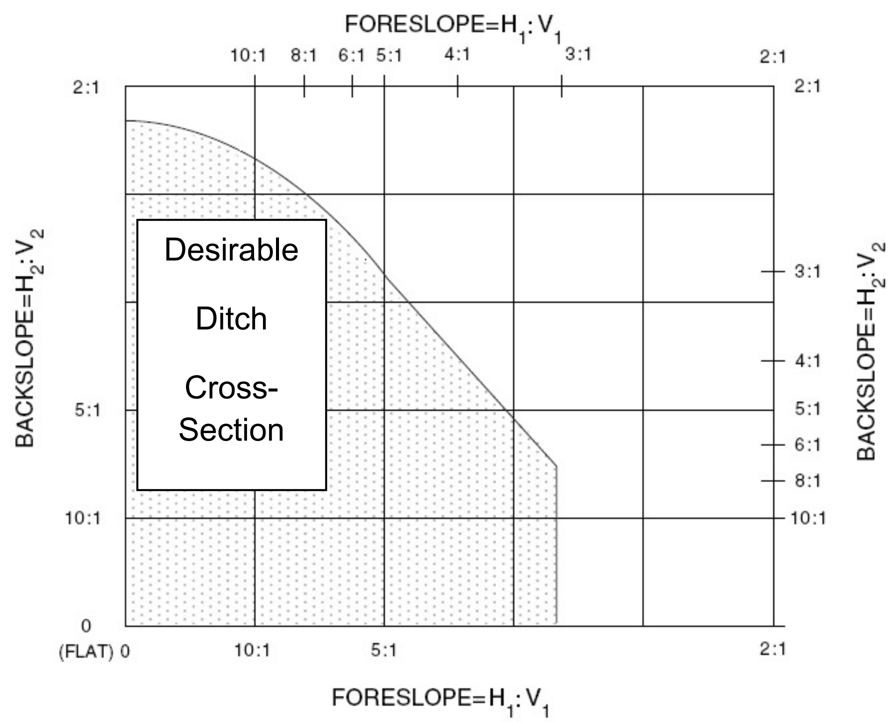


Figure 2-8: Preferred Cross-Section for Trapezoid Ditches on High Speed Roads

Bottom Width of Ditch ≥ 1.2 m

Figure based on AASHTO Roadside Design Guide.

2.3.5 Rock Cuts

Desirable rock face offset requirements for rock fall catchment purposes, as measured from the edge of the travelled way, is related to the rock cut height. Tables 2-9 and 2-10 provides the desirable rock face offset requirements and desirable ditch depth requirements to reduce the potential of rock fall material landing or coming to rest on the highway travelled way.

Rock Cut Height: h (m)	Desirable Rock Face Offset for Rock Fall Catchment: c (m)
10 to 12	5.0 to 6.0
> 12 to 14	6.5 to 7.0
> 14 to 16	8.5
> 16 to 18	10.0
> 18 to 20	11.0
> 20 to 22	12.0
> 22 to 24	13.0
> 24 to 26	14.0
> 26	15.0

Table 2-9: Desirable Rock Face Offsets

Rock Cut Height: h (m)	Desirable Ditch Depth for Rock Fall Catchment: d (m)
10 to 18	0.75
>18 to 20	1.0
>20 to 22	1.25
>22 to 24	1.5
>24 to 27	1.75
>27	2.0

Table 2-10: Desirable Ditch Depth at Rock Cut

Rock Cut Height (h) is the maximum height of the rock cut and measured vertically from bottom of ditch to top of rock cut as shown in Figure 2-5.

Desirable rock face offset for rock fall catchment (c) is the distance measured horizontally from the edge of the travelled lane or auxiliary lane to the toe of the rock face as shown in Figure 2-5.

Desirable ditch depth for rock fall catchment (d) is the depth of the ditch measured vertically from bottom of ditch to the outside edge of shoulder.

POLICY: **On Major Capital Expansion Projects desirable rock face offset and desirable ditch depth for rock fall catchment on high speed arterial roads and freeways should be according to Tables 2-9 and 2-10.**

On Major Capital Reconstruction Projects desirable rock face offset and desirable ditch depth for rock fall catchment on high speed arterial roads and freeways should be according to Tables 2-9 and 2-10 when cost beneficial.

2.3.6 Freeway Medians

New freeways are desirably designed with a depressed median of sufficient width with 6H:1V slopes to allow the roadbed to drain into the median and provide separation between opposing directions of travel. The minimum width of medians on new 4 lane or 6 lane freeways and freeway extensions is ~~22.5m~~23 m as shown in Figure 2-9. The desirable width on new 4 lane freeways and freeway extensions is 30~~.0~~ m as shown in Figure 2-10. A 30 m width can accommodate future staged widening into the median for 6 lanes with minimal or no impact on interchanges or flyovers or adjacent land use. These widths should be adjusted upward to account for future buffer zones between high occupancy vehicle lanes and general lanes if the ultimate configuration includes high occupancy vehicle or other managed lanes. On new highways, or highways being widened on the inside, freeway medians narrower than 23~~2.5~~ me~~tres~~ shall have either parallel runs of single-sided barrier or a single run of high-tension ~~median~~ cable median barrier adjacent to one platform.

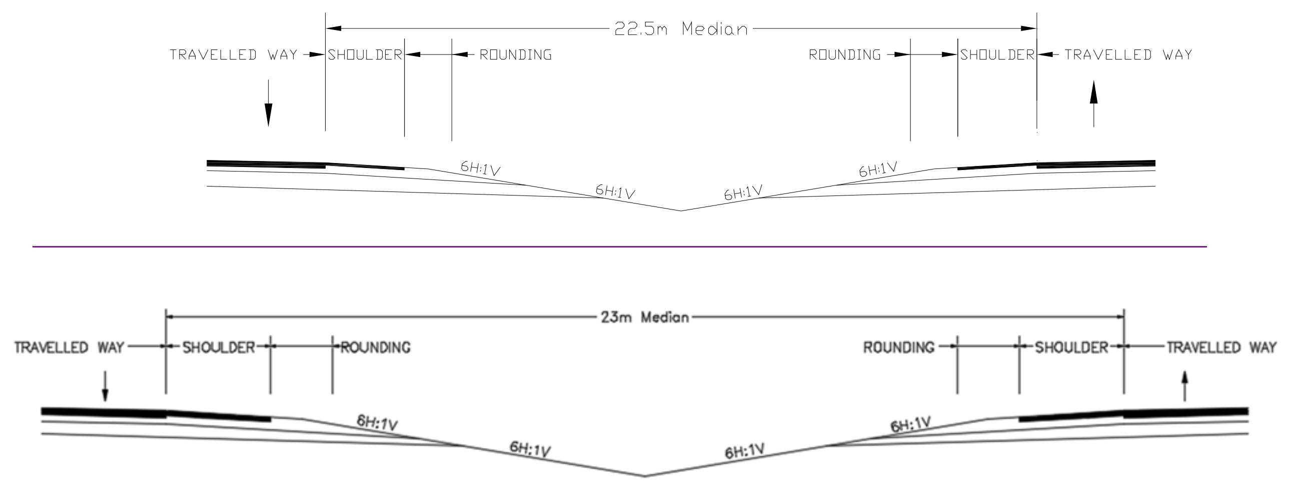


Figure 2-9: ~~Standard~~ Minimum Median Configuration

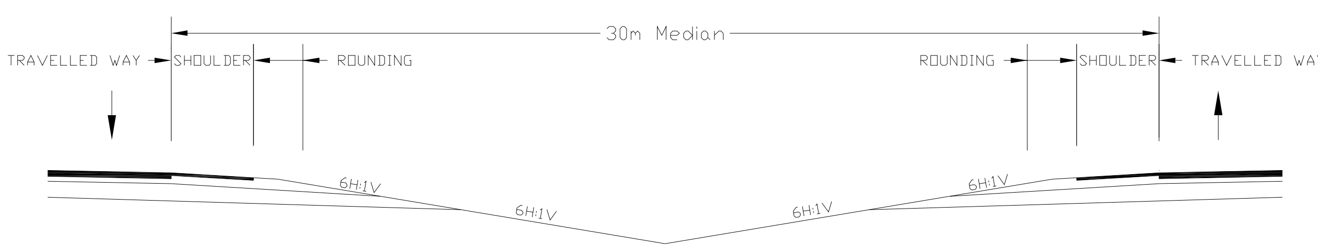


Figure 2-10: Desirable Median Configuration

Where it is necessary to minimize the footprint on new 4 lane or 6 lane freeways and freeway extensions in specific locations due to significant environmental constraints, the minimum width of median is 7.5 m as shown in Figure 2-11. The 7.5 m width includes a TL-5 tall wall median concrete barrier and provides 3.35 m wide median shoulders, which can be reduced to a minimum width of 2.5 m at bridge piers, high mast lighting poles, or overhead signs.

Where the terrain is extremely rolling, the adjacent land is not environmentally sensitive/significant, and acquisition of additional right-of-way is not a significant constraint, a wide variable median with a minimum width of 45 m should be considered as shown in Figure 2-12. The additional median width permits the use of independent roadway alignments, both horizontally and vertically, to its best advantage in blending the freeway into the natural topography. The remaining median width beyond the desirable clear zone may be left in its natural state of vegetation, trees, and rock outcroppings to reduce maintenance costs and add scenic interest to passing motorists. Staged construction of additional lanes in the median or on the outside should be considered during the Route Selection stage to ensure initial grading will accommodate future widening to the ultimate lane configuration and sufficient right-of-way is acquired.

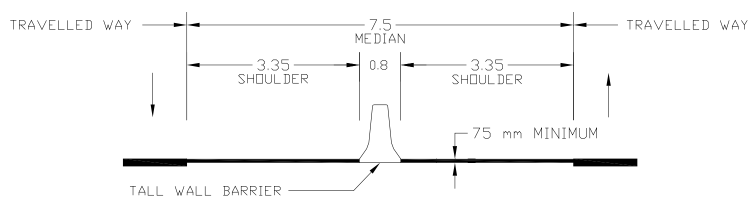


Figure 2-11: Minimum Narrow Median Configuration

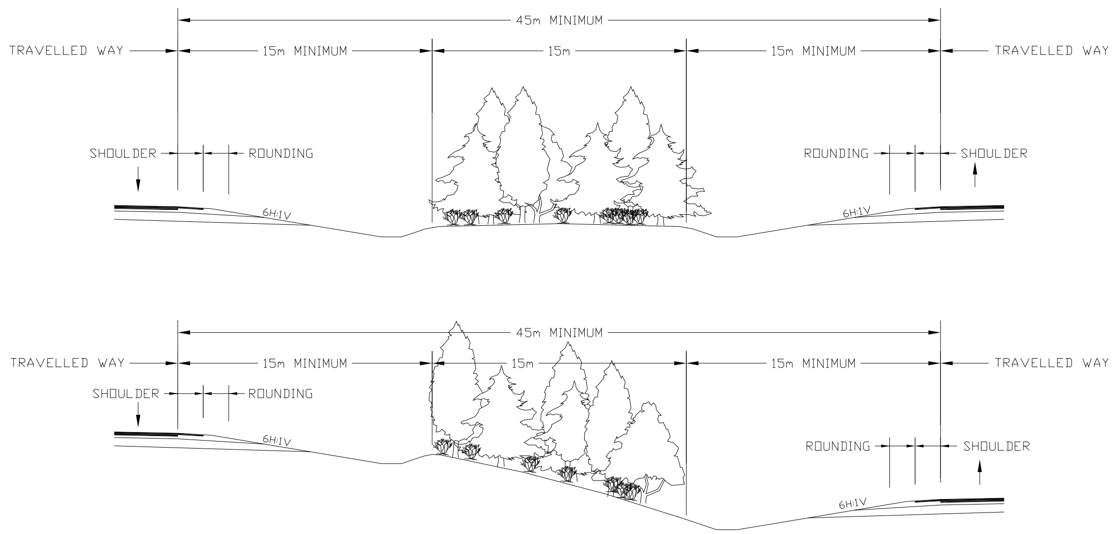


Figure 2-12: Independent Alignment Median Configuration

Median shoulder widths should not exceed the width of the adjacent through lane by more than one increment of 0.25 m.

Barrier system(s) may be installed in existing medians between opposing lanes of traffic on divided highways (in the ~~center~~ centre median) and between parallel roads, such as collector lanes, ramps, and frontage (service) roads (in the outer median). The primary function of a barrier system in a median is to separate traffic and to contain and redirect errant vehicles. Dependent on width of the median, a median barrier system may be used which is designed to be impacted from either side of median, or roadside barrier systems may be used on each side of the median which are designed to be impacted from only one side.

Installation of median barriers should greatly reduce the number of serious cross-median collisions between vehicles travelling in opposite directions. However, installation of median barriers will generally result in significant increases in reported collisions, especially during winter storm events. This is primarily due to the reduction of the recoverable area that the relatively wide depressed median provided for errant vehicles.

~~The median widths provided in Figure 2-13 are modified and based on guidelines for median barriers in the AASHTO Roadside Design Guide. These widths were based on limited empirical data that was extrapolated to provide values for a wide range of conditions. The widths should be considered as approximate and not a precise value to be held as absolute.~~

POLICY: **On Major Capital Expansion and Reconstruction Projects, median configurations on freeways should be according to ~~Figure 2-13~~Table 2-11.**

Median Width (W)	Freeway Median Configuration
W <= 10 m	TL-5 (tall wall or equivalent) median barrier required. A lower test-level barrier system may be considered if existing and projected truck traffic volumes are low
10 m < W <= 15 m	TL-3 barrier required, either parallel runs of single-sided barrier or a single run of high-tension cable median barrier (Note 1)
15 m < W <= 23 m	TL-3 barrier required, either parallel runs of single-sided barrier or a single run of high-tension cable median barrier (Note 2)
23 m < W	Median barrier not normally considered

Note 1: A benefit/cost evaluation and an engineering study should be conducted to determine the type of barrier(s) to be installed. The evaluation should include the following factors: traffic volumes, vehicle classifications, median crossover collision history, vertical and horizontal alignment relationships, and median/terrain configurations. Potential prioritized locations may be on horizontal curves, long grades, or within limits of interchanges.

Note 2: For locations on existing highways with median widths greater than 15 m and history of higher than provincial average cross-median crashes, a benefit/cost evaluation and an engineering study should be conducted to determine the type of barrier(s) to be installed. The evaluation should include the following factors: traffic volumes, vehicle classifications, median crossover history, crash incidents, vertical and horizontal alignment relationships, and median/terrain configurations. Potential prioritized locations may be on horizontal curves, long grades, or within limits of interchanges. New highways constructed with medians less than 23 m should have a median barrier.

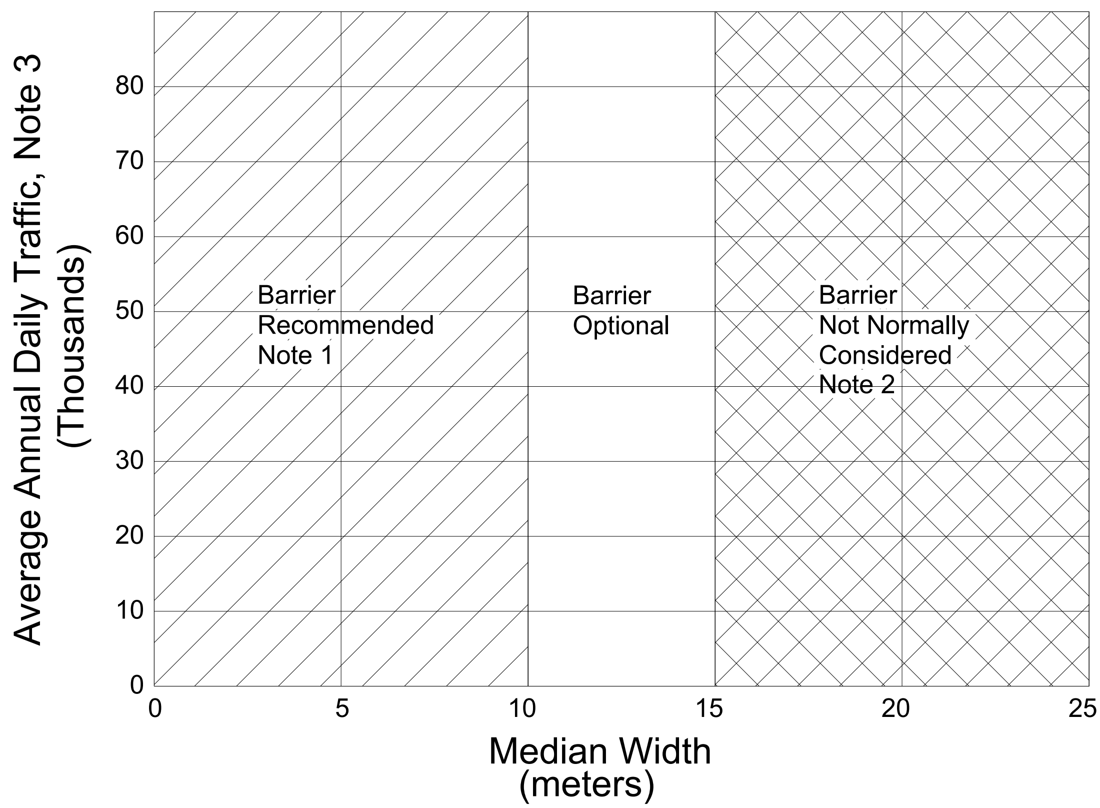
Table 2-11 – Freeway Median Configurations

~~**Barrier Recommended:** For existing locations with median widths less than 10 m, tall wall concrete median barriers are recommended.~~

~~**Barrier Optional:** For locations with existing median widths greater than 10 m but less than 15 m, a benefit/cost evaluation and an engineering study should be conducted to determine if barrier(s) should be installed. The evaluation should include the following factors in the evaluation: traffic volumes, vehicle classifications, median crossover collision history, vertical~~

~~and horizontal alignment relationships, and median/terrain configurations. Potential prioritized locations may be on horizontal curves, long grades, or within limits of interchanges.~~

~~**Barrier Not Normally Considered:** For existing locations with median widths wider than 15 m, barrier system(s) in median are not normally considered. However, consideration should be given to designing the median to accommodate future installation of barrier(s) in the median. For locations with median widths greater than 15m with history of higher than provincial average cross-median crashes, a benefit/cost evaluation and an engineering study should be conducted to determine if barrier(s) should be installed. The evaluation should include the following factors in the evaluation: traffic volumes, vehicle classifications, median crossover history, crash incidents, vertical and horizontal alignment relationships, and median/terrain configurations. Potential prioritized locations may be on horizontal curves, long grades, or within limits of interchanges.~~



~~Note 1: TL-5 median barrier recommended unless existing and projected truck traffic volumes are low.~~

~~Note 2: When number of through lanes exceeds 3 lanes in both directions with centre median width less than 23 m, TL-3 barrier(s) recommended in median.~~

~~Note 3: Average Annual Daily Traffic based on 10-year projection after scheduled construction start.~~

~~**Figure 2-13 – Freeway Median Configurations**~~

~~Figure based on AASHTO Roadside Design Guide.~~

2.3.7 Freeway Median Crossovers and Openings

To avoid extreme adverse travel for emergency and law-enforcement vehicles, emergency crossovers on freeways with depressed medians are normally provided where interchange spacing exceeds 8 km. Maintenance crossovers may be required at one or both ends of interchange facilities, depending on interchange type, for the purpose of snow removal and de-icing operations, and at other locations to facilitate maintenance operations. When required, maintenance or emergency crossovers should not be located closer than 450 m to the end of the speed-change lane of a ramp or to any structure. Crossovers should be located only where desirable stopping sight distances are provided and should not be located on superelevated curves. Median crossovers are unacceptable on freeways with narrow medians less than 15 m wide.

The width and surface of the crossover should be sufficient to accommodate and support the turning movements of the maintenance equipment used on it. The crossover should be depressed below shoulder level to be inconspicuous to traffic and should have 10H:1V or flatter foreslopes perpendicular to traffic to minimize effect to errant vehicles. Where parallel culvert(s) are required under the crossover to convey drainage in median ditch through the crossover, the foreslope perpendicular to traffic may be steepened to 6H:1V to accommodate safety slope treatments on the culvert(s). Alternatively, ditch inlet(s) or cross culverts could be considered to convey drainage under one side of highway to outlet in a roadside ditch, eliminating need for parallel culvert(s) under the crossover. Shifting proposed location of crossover to coincide with a crest curve or near a high point in median ditch grade could eliminate need for culvert(s) at the crossover.

Median barrier systems are provided to separate traffic and to redirect errant vehicles. In most cases, the traffic is travelling in opposite directions at a high rate of speed, particularly on freeway facilities.

An opening in the median barrier system for emergency services or other purposes violates driver expectations and could result in a serious collision as emergency vehicles (or illegal users) change speeds or turn to make the crossover manoeuvre. The provision of openings in median barriers in narrow medians significantly increases the risk to the travelling public, results in a discontinuity in TL-5 median protection, and would likely exceed the benefits attributable to such an opening.

For medians wider than 15 m with TL-3 median barriers or roadside barriers on both sides of median, providing openings in the median barrier for crossovers is not desirable for reasons mentioned above. While the wider median can be configured to accommodate median crossovers, there will be a gap in median protection between each end of the median barrier on either side of the crossover. These crossovers should only be provided when formally requested by emergency services and by maintenance for winter operations.

POLICY: **On Provincial Highway Projects, openings in median barrier systems on freeways with medians less than 15 m wide should not be permitted. Openings in median barrier systems on freeways with medians wider than 15 m may be permitted when formally requested by emergency services or by maintenance for winter operations supported by a documented engineering analysis.**

2.3.8 Ramp Bullnoses

The bullnose exit from a freeway or arterial road represents a critical area for the driver. The grading requirements in this area are unique due to the intersection of the foreslopes supporting the freeway or arterial roadway and the foreslopes supporting the ramp. A relatively flat, firm, and smooth traversable surface with foreslopes 6H:1V or flatter is desirable beyond the bullnose within the area defined by the overlap of the desirable clear zone for the freeway or arterial roadway and the desirable clear zone for the ramp, and for a distance equivalent to the encroachment length provided in Table 2-1~~1~~2 measured from the gore bifurcation point as shown in Figure 2-13~~4~~.

Design Speed Of Through Roadway (km/h)	60	80	100	110	120	130
Gore Encroachment Length (m)	45	75	105	135	160	200

Table 2-12~~1~~: Encroachment Length in Gores at Exits

In some cases, the relatively flat surface will not be practical, due to the presence of other obstacles, such as signs, piers, abrupt slope transitions, or extreme topography. A barrier system or crash cushion should be provided to shield these obstacles if the desirable grading cannot be accommodated.

Curb at bullnoses on high speed roadways is discouraged and only mountable curb is permitted if required for drainage purposes.

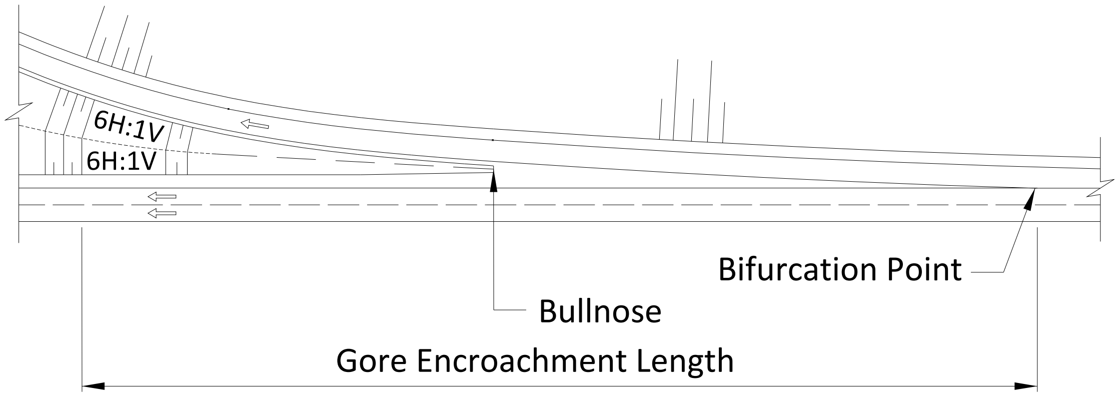


Figure 2-134: Clear Traversable Area Beyond Ramp Bullnose

POLICY: **On provincial Highway Projects, the area beyond the exit ramp bullnose from high speed roadways should be traversable and free of obstacles for a distance according to Table 2-12~~1~~ measured from the bifurcation point, or protected by a barrier system or crash cushion.**

2.3.9 Curbs

Curbs are commonly used to control drainage and reduce maintenance operations. They are classed as either ~~barrier, semi-mountable, or mountable~~Type I, Type II or Type III with Type I being the tallest and Type III the shortest. These were formerly referred to as barrier, semi-mountable and mountable curb respectively. Although they are undesirable on high speed roadways, they cannot be completely avoided either on high speed or low speed roadways.

Curbs do not have significant redirectional capability above speeds of approximately 10 km/h~~, especially on high speed roads~~. If an errant vehicle is spinning or slipping sideways, an impact with a curb may cause the vehicle to become airborne, or cause the vehicle to trip and roll over. The distance over which a vehicle may be airborne and the height above or below normal bumper height attained after traversing a curb may become critical if secondary crashes occur with barrier systems not designed for use adjacent to curbs.

It is often necessary, especially in urban environments to use curbs for drainage or for delineation. They are also used in low speed urban environments to discourage drivers from deliberately departing a roadway. An erosion problem may develop if surface water is allowed to drain from the roadway down the embankment. A curb may be required to channel the runoff into a catch basin, gutter outlet/spillway, or other drainage structure. Where curb is necessary on high speed roadways, ~~mountable~~ Type III curb is desirable.

Curbs should not be placed adjacent to concrete barriers, since the proper performance of the concrete barrier depends on a smooth approach area between the roadway and the concrete barrier.

POLICY: On Provincial Highway Projects, ~~barrier~~ Type I curb should not be installed on high speed roadways and ramps with posted speeds of 70km/h and higher, with the following exceptions:

- **Approaches to bridges with raised sidewalks;**
- **Narrow median islands with traffic signal poles, and;**
- **In conjunction with applicable barrier systems designed for use with barrier curbs at specified offsets.**

2.3.10 Water Bodies

Water bodies, as defined in the MTO Best Management Practices Manual for Fisheries, with a normal-water-level depth of 1 metre or more located within the desirable clear zone are considered to be areas of concern.

POLICY: On Major Capital Expansion and Reconstruction Projects, water bodies with a normal-water-level depth of 1.0m or more located within the desirable clear zone according to Table 2-2 and Table 2-3 should be shielded with a barrier system.

2.3.11 Culvert Ends

Exposed crossing culvert ends projecting beyond foreslopes within the desirable clear zone along roadways are considered to be obstacles. Errant vehicles encroaching onto recoverable slopes and non-recoverable slopes can come to abrupt stops or rollover when encountering exposed crossing culvert ends or parallel culvert ends. Various grading design and safety end treatment alternatives are available to minimize probability of impacts by locating culvert ends beyond the desirable clear zone or modifying ends to make them traversable. These options should be considered and evaluated early during hydraulic design of culverts prior to finalizing the length of new culverts and culvert extensions to determine if alternative grading options and safety end treatments can result in a cost beneficial design without having to specify a barrier system to shield the culvert end.

POLICY: On Major Capital Expansion and Reconstruction Projects, new culverts, replacement culverts, and culvert extensions on high speed roadways should be designed with end treatments as follows based on a benefit cost evaluation:

1. **Parallel culverts and exposed crossing culvert ends and sides projecting from foreslopes should be located fully beyond the desirable clear zone according to Table 2-2 and Table 2-3;**
2. **Crossing culvert ends located within the desirable clear zone should match the slope of the foreslope and be traversable with safety slope end treatments;**
3. **Safety slope end treatments for crossing culverts on foreslopes with openings greater than 750 mm should include longitudinal safety bars;**
4. **Safety slope end treatments for parallel culverts within the desirable clear zone should include transverse safety bars with 6H:1V slopes; or**
5. **Shielded with a barrier system**

2.3.12 Poles, Sign Supports and Other Roadside Equipment

Roadside poles, sign supports and other equipment (like traffic signal controller cabinets) are considered obstacles, and should be evaluated and protected according to the procedures described throughout this manual.

2.3.12.1 Luminaire Supports, Signal Poles and High Mast Poles

Luminaire and high-mast lighting supports are considered obstacles, and should be evaluated and protected according to the procedures described throughout this manual.

Luminaire supports should be located according to the clear zone guidance for the maximum AADT category (≥6,000) regardless of design traffic volume and a minimum of 3.0 metres from any lane, including auxiliary lanes. Poles located within the desirable clear zone should have breakaway bases.

Traffic signal and railway crossing poles are obstacles that are generally exempt from desirable clear zone values, as the traffic control benefits they provide outweigh the risk of having poles within the clear zone, including poles in median islands. Traffic signal poles cannot generally be equipped with frangible bases or breakaway devices as any pole strike would pose a greater risk to surrounding pedestrians and vehicular traffic.

Temporary signal and lighting poles (e.g., poles for detours, construction staging, etc) should have efforts made to locate them or protect them in accordance with the policy for their permanent counterparts, however it is recognized that this may not always be possible and engineering judgement by the designer is required.

POLICY:

1. **Luminaire supports should be located beyond the desirable clear zone in accordance using the maximum AADT criteria (AADT ≥ 6000) or have breakaway bases. Luminaire supports within the desirable clear zone shall be located a minimum of 3.0m measured from the edge of any through or auxiliary lane.**
2. **Where breakaway devices (i.e. frangible bases) are used on luminaire supports, they should be located in accordance with guidance in the ministry's Electrical Engineering Manual.**
3. **Traffic signal pole locations are to follow guidance in the ministry's Electrical Engineering Manual.**
4. **High mast lighting poles should be located in accordance with guidance in the ministry's Electrical Engineering Manual.**

2.3.12.2 Sign Supports

Sign supports of all sizes are considered obstacles, and should be evaluated and protected according to the procedures described throughout this manual.

POLICY:

1. **Where small, medium and large ground-mounted signs cannot be relocated out of the clear zone, they should be installed on breakaway posts or similar devices according to standards active in MTO's Contract Preparation System.**
2. **Cantilever, monotube and truss sign supports for large overhead signs should be protected behind barrier or mounted on top of concrete barrier where required.**

2.3.12.3 Utility Poles and Other Roadside Equipment

Utility poles and other equipment mounted within the highway corridor, such as traffic signal controller cabinets, are obstacles and should be located outside the clear zone where practical or shielded with a barrier as appropriate. Consideration for driver sight lines should also be given to the location of this equipment and the impact of any shielding or barriers and an assessment of the benefits made during design. Consideration should also be made to ensure maintenance personnel can safely access the equipment.

2.4 Roadside Safety Hardware

2.4.1 New Roadside Safety Hardware Installations

This policy covers requirements for new roadside safety hardware that should be met prior to being specified for use on provincial highway projects.

Crash testing guidelines and procedures are used to evaluate the impact performance of permanent and temporary roadside safety features. Performance is evaluated in terms of risk of injury to occupants of the impacting vehicle, the structural adequacy of the safety feature, the exposure of workers or pedestrians that may be behind a barrier or in the path of debris resulting from impact with a safety feature, and the post impact behaviour of the impact vehicle. MTO continues to specify roadside safety hardware that meets the crash test acceptance criteria of National Cooperative Highway Research Program (NCHRP) Report 350, "Recommended Procedures for the Safety Performance Evaluation of Highway Features" (1993), and has started to implement new roadside safety hardware that meets AASHTO

Manual for Assessing Safety Hardware (MASH) (2009 and 2016). MASH supersedes NCHRP Report 350, which superseded NCHRP Report 230 “Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances“ (1981).

It is important to note that new roadside safety hardware systems that meet MASH are not automatically accepted and specified for use by MTO on provincial highway projects. Unless standard drawings for roadside safety hardware in OPSD or MTOD format along with construction specifications have been implemented in MTO’s Contract Preparation System, or have been issued by the ~~Design and Contract Standards~~Highway Design Office for pilot installations on specific projects, they should not to be used on provincial highway projects.

Both NCHRP Report 350 and MASH define six performance test levels (TL-1 to TL-6) that are used to evaluate impact performance of permanent and temporary roadside safety hardware and roadside features. The test levels vary in terms of vehicle characteristics (mass, centre-of-gravity, and structural properties), approach speed, approach angle, and test evaluation criteria. A brief summary of the test levels for crash testing of longitudinal barrier systems are provided in Table 2-13~~2~~ and 2-14~~3~~. More detailed information about crash testing procedures and acceptance criteria are available in NCHRP Report 350 and MASH.

The ongoing need for updated crash test acceptance criteria every seven to eighteen years is primarily based on changes to the vehicle fleet that continue to change each year along with increased knowledge gained from crash testing experience and in-service evaluations. MASH is the culmination of over 50 years of crash testing experience and collective judgement and expertise of professionals in the field of roadside safety design.

The parameters used for NCHRP Report 350 and MASH crash testing include impact speed, impact angle, test vehicle mass, and impact location. Each parameter represents a “worst practical conditions” for roadside safety hardware. Traditionally, impact speed and impact angle have been set at the 85th percentile level. Crash test design vehicles are normally selected based upon body style and mass. Mass selected typically approximates the 2nd and 90th percentile for passenger vehicles, which are represented in MASH by the small 1,100 kg car and the 2,270 kg quad-cab pick-up truck. Impact locations on roadside safety hardware are typically selected to represent a critical impact point that provides the greatest probability of failure during a crash test. The combination of all these updated parameters in MASH are believed to represent a “worst practical condition” - impact speed and impact angle combination represents approximately the 93rd percentile of real-world crashes. It is implicitly assumed that if roadside safety hardware performs acceptably during crash testing with the two design passenger vehicles at the specified impact angles and speed, the system should work acceptably for all impact conditions in between.

Roadside safety hardware that had been previously crash tested and accepted under NCHRP Report 350 remains acceptable for manufacture and installation on provincial highway projects and will not have to be retested under MASH. However, after January 1, 2011, the Federal Highway Administration (FHWA) in the U.S. no longer issued eligibility letters for new or revised roadside safety hardware systems crash tested according to NCHRP Report 350. Therefore since 2010, modifications to roadside safety hardware designs by manufacturers that previously met NCHRP Report 350, or new designs being developed, should have been crash tested in accordance with the revised acceptance requirements of MASH.

Since 2018, MTO has been a member of the Texas Transportaton Institution's MASH Roadside Safety Pooled Fund. This program, which is administered by the Washington State Department of Transportation, contracts TTI to develop and crash test non-proprietary roadside hardware including guiderails, temporary barriers, bridge rails and breakaway hardware. MTO's membership allows for participation in the development of problem statements and voting on projects for prioritization.

In the United States on December 22, 2015, AASHTO and FHWA established an implementation schedule for roadside safety hardware, requiring new permanent installations and full replacement installation of roadside safety hardware on the National Highway System (NHS) after specified dates to meet the crash test acceptance requirements of the latest edition of MASH. This implementation schedule was subsequently amended in August 2018. The original intent was for all new roadside safety system installations to be MASH compliant by December 31, 2019. Due to limited or non-existent development of MASH compliant systems in some categories, FHWA modified its policy in November 2019 allowing the use of MASH-2009 or NCHRP Report 350 systems if MASH-2016 versions are not available. MTO is also following a similar approach and has been implementing standards for MASH systems when able. Implementation dates set in the United States for installations on the NHS along with implementation dates set by MTO for installations on provincial highways for various categories of roadside safety hardware are summarized in Table 2-15~~4~~.

In 2019 MTO implemented a policy in PEM-DCSO 2019-06 governing the implementation of new crashworthy roadside systems. The policy formalizes historical acceptance practice and provides a process for evaluation and acceptance of systems both with and without FHWA eligibility letters. The policy requires all new systems to have been crash tested according to MASH 2016 however if no such systems exist in a particular category then crash testing according to MASH 2009 or NCHRP Report 350 may be acceptable.

POLICY: On Provincial Highway Projects, only barrier systems, terminal systems, end treatments, transitions, crash cushions and small sign supports described in this manual

with active standards implemented in the Contract Preparation System should be used for new installations, unless otherwise authorized by the ~~Design and Contract Standards~~Highway Design Office.

On high-speed roads with posted speed limit of 70 km/h or higher, all new installed roadside systems shall be a minimum TL-3.

Test Level	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight (kg)	Speed (km/h)	Angle (deg.)
1	820C (Passenger Car) 2000P (Pickup Truck)	820 2,000	50 50	20 25
2	820C (Passenger Car) 2200P (Pickup Truck)	820 2, 000	70 70	20 25
3	820C (Passenger Car) 2000P (Pickup Truck)	820 2, 000	100 100	20 25
4	820C (Passenger Car) 2000P (Pickup Truck) 8000S (Single Unit Truck)	820 2, 000 8,000	100 100 80	25 25 15
5	820C (Passenger Car) 2000P (Pickup Truck) 36000V (Tractor-Van Trailer)	820 2,000 36,000	100 100 80	20 25 15
6	820C (Passenger Car) 2000P (Pickup Truck) 36000T (Tractor-Tank Trailer)	820 2,000 36,000	100 100 80	205 25 15

Table 2-132: NCHRP Report 350 Test Level Matrix for Barrier Systems

Test Level	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg	Speed km/h	Angle (deg.)
1	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 2,270	50 50	25 25
2	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 2,270	70 70	25 25
3	1100C (Passenger Car) 2270P (Pickup Truck)	1,100 2,270	100 100	25 25
4	1100C (Passenger Car) 2270P (Pickup Truck) 10000S (Single Unit Truck)	1,100 2,270 10,000	100 100 90	25 25 15
5	1100C (Passenger Car) 2270P (Pickup Truck) 36000V (Tractor-Van Trailer)	1,100 2,270 36,000	100 100 80	25 25 15
6	1100C (Passenger Car) 2270P (Pickup Truck) 36000T (Tractor-Tank Trailer)	1,100 2,270 36,000	100 100 80	25 25 15

Table 2-143: MASH Test Matrix for Barrier Systems

Roadside Safety Hardware	**MTO**	**FHWA/AASHTO**
W-Beam	May 27/16	Dec 31/17
Cast-in-place Concrete Barrier	Dec 31/17	
W-Beam Terminals	Sept 1/16	June 30/18
Crash Cushions	Dec 31/18	Dec 31/18
Cable Barriers - Roadside	Dec 31/16	When Available
Cable Barriers - Median	When Available	
Cable Barrier Terminals	When Available	
Bridge Rails	When Available	
Transitions	When Available	
All Other Longitudinal Barriers	When Available	
All Other Terminals	When Available	
Sign Supports	When Available	
All Other Breakaway Hardware	When Available	
Temporary Work Zone Devices	When Available	When Available

Table 2-154: MASH Implementation Schedules

2.4.2 Existing Roadside Hardware Installations

Existing roadside hardware installations on provincial highways providing acceptable in-service safety performance and system condition should continue to perform as originally intended until the end of their service life.

On Major Rehabilitation and Major Reconstruction Projects, existing steel beam guide rail and cable guide rail installations should be reviewed and evaluated according to procedures provided in Chapter 3. Justification for new installations and replacement of existing systems should be documented in a Guide Rail Evaluation Report.

POLICY: **On Major Capital Reconstruction and Rehabilitation Projects, a Guide Rail Evaluation Report should be prepared to justify new barrier installations, barrier replacements (including replacement in-kind), and/or barrier extensions.**

2.4.3 Barrier System Length of Need

The runout length is the distance from the obstacle or area of concern being shielded to the location where an errant vehicle departs from the travelled way. The methodology provided in Figure 2-1~~5~~4 should be used to determine the recommended approach length of a barrier system in advance of an obstacle or area of concern being shielded. Table 2-16~~5~~ provides the recommended runout lengths to be used for calculating length of need.

Length of Need is the total length of barrier recommended to shield an obstacle or area of concern. It includes the approach length upstream of the obstacle (La), and for undivided roadways, the length of the obstacle or area of concern (Lh), and the approach length downstream of the obstacle for opposing traffic (La'). For divided highways and one way ramps, leaving end treatments (LET) are required downstream of the obstacle.

DESIGN SPEED (Km/h)	**TRAFFIC VOLUME – DESIGN YEAR AADT**			
	> 10,000	**5,000 TO 10,000**	**1,000 TO 5,000**	**< 1,000**
	E (m)	E (m)	E (m)	E (m)
130	143	131	116	101
120	127	116	102	89
110	110	101	88	76
100	91	76	64	61
90	81	67	57	54
80	70	58	49	46
70	60	49	42	38
60	49	40	34	30
≤ 50	34	27	24	21

Table 2-16~~5~~: Runout Lengths

Modified from 2011 AASHTO Roadside Design Guide

POLICY: On Provincial Highway Projects, recommended length of need for new barrier installations should be calculated based on methodologies contained in this manual. Calculations should identify the size and severity of the obstacle or area of concern being shielded, and be retained in the project file(s).

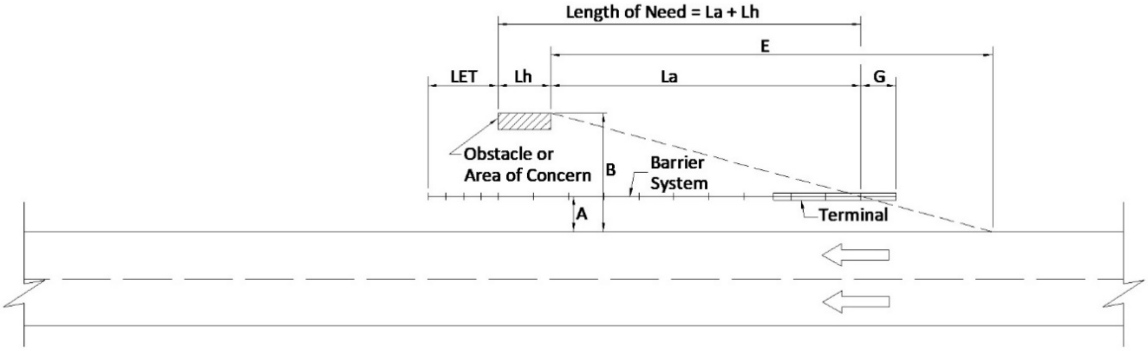


Figure 2-154: Length of Need – Divided Highway

For Divided Highway: Barrier Length of Need = La + Lh

La = E (1 - A/B) where: La = Approach Length of Barrier for Approaching Traffic
A = Distance from Edge of Travel Way to Face of Barrier.
B = Distance from Edge of Travel Way to Back of Obstacle or Area of Concern. B should not exceed Desirable Clear Zone according to Table 2-2
G = Gating length of terminal
E = Runout Length according to Table 2-165

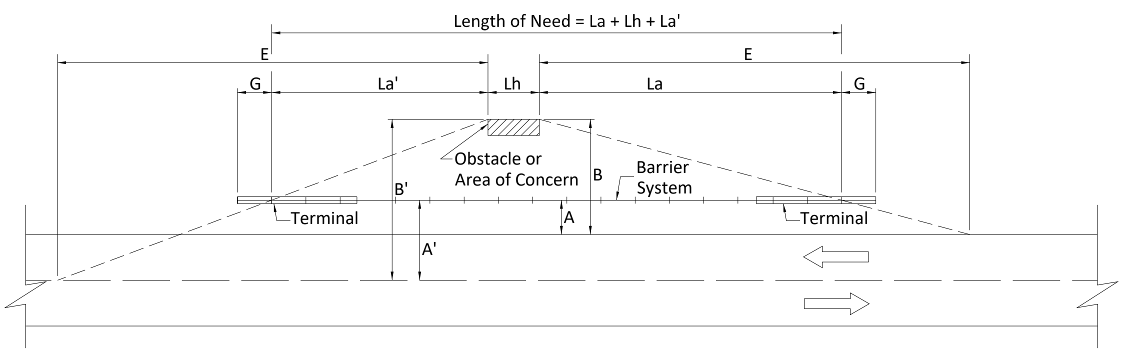


Figure 2-165: Length of Need – Undivided Highway

For Undivided Highway: Barrier Length of Need = La + Lh + La’

La’ = E (1 – A’/B’) where:La, Lh and G according to above example
La’ = Approach Length of Barrier for Opposing Traffic
A’= Distance from Centreline to Face of Barrier
B’ = Distance from Centreline to Back of Obstacle or Area Concern. B’ should not exceed Desirable Clear Zone according to Table 2-2
E = Runout Length according to Table 2-165

2.4.4 Barrier System Transitions and Connections

Barrier connections include semi-rigid Steel Beam Guide Rail transitions and connections to rigid barriers on structures, and transitions between different barrier system types. Properly designed and crash tested transitions from one type of barrier system to another are recommended to ensure continuity of protection for errant vehicles.

A proper transition design requires that the adjoining systems are compatible for deflection upon vehicle impact and that there is structural continuity in the system for distribution of impact forces and impact energy. Where deflection characteristics are significantly different between the connected systems, a gradual change in deflection stiffness is required. Risks associated with improper transition designs include pocketing (abrupt vehicle deceleration upon system impact), redirection of the vehicle back into traffic lanes and system failure due to vehicle penetration. All approved transition designs have been crash-tested or have provided many years of satisfactory in-service experience. Barrier cross-section dimensions are also considered so that snag points are not created which may pocket a vehicle and lead to rapid deceleration. Some standard transitions are intended for traffic in one direction only and exposure to opposite direction vehicle impacts would lead to problems.

No modifications should be made to any existing standard connection or transition designs. For specialized design requirements, authorization should be obtained from the ~~Design and Contract Standards~~Highway Design Office.

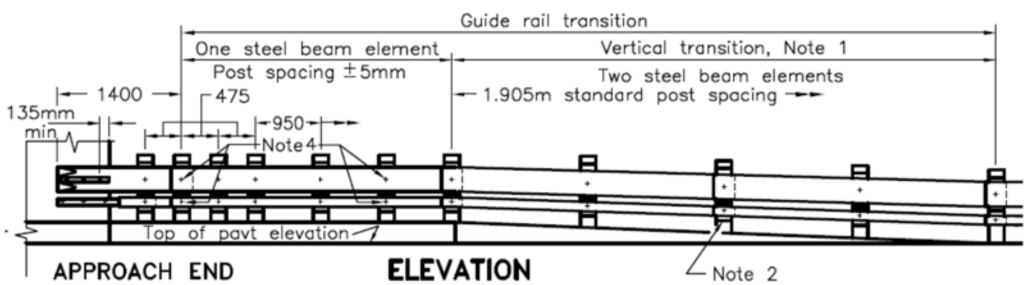


Figure 2-16~~7~~: Standard SBGR Connection to Rigid Barrier (OPSD 912.430)

POLICY: **On Provincial Highway Projects, standard barrier system transitions and connections active in the Contract Preparation System should be used for new installations, unless otherwise authorized by the ~~Design and Contract Standards~~Highway Design Office.**

On Major Capital Rehabilitation Projects, on high speed roadway approaches to structures, steel beam guide rail transitions and connections to rigid bridge rails not according to OPSD 912.430 should be replaced with barrier system transitions and connection standards active in the Contract Preparation System.

2.4.5 Barrier System Terminals and End Treatments

The ends of the barrier system, if left unprotected, could result in serious collisions if impacted by an errant vehicle. This is because the blunt end might penetrate into the passenger cabin, cause the vehicle to ride-over or roll over, or cause a very sudden deceleration of the vehicle. Early design attempts to address this problem included turning down and burying the end or twisting the end of the barrier system. This created other problems related to vehicles vaulting the barrier system by travelling up the sloped system element or tripping and rolling over lower parts of the end.

The development of barrier system end treatments and crash cushions addressed many concerns related to unprotected ends. While the end treatments and crash cushions vary in terms of design and configuration, most are intended to dissipate some kinetic energy and safely decelerate the errant vehicle for end-on impacts. All barrier system terminals and end-treatments are designed to redirect an errant vehicle, provided that the initial impact point is sufficiently downstream of the approach end of system.

There are two types of end treatments – gating and non-gating. They differ in how impacts near the approach end of the end treatment is accommodated. Gating end treatments permit vehicles impacting the approach end of system to pass through the end treatment to the area behind and beyond the system. Non-gating end treatments do not permit the vehicle to pass (gate) through the system after being impacted near the approach end of the terminal, but slow the vehicle by attenuating collision energy. Some end treatments will either gate or attenuate collision energy, depending on the orientation and impact angle of the errant vehicle.

POLICY: **On Provincial Highway Projects, approach ends of all new barrier system installations should be terminated and anchored by a terminal or crash cushion standard active in the Contract Preparation System.**

2.4.6 Leaving Ends of Barrier Systems

The requirement to shield the leaving end of barrier systems is dependent upon whether the highway is divided or undivided. The risk of errant vehicles impacting barrier leaving ends beyond the desirable clear zone for opposite direction traffic on divided highways is minimal especially at twin bridges where there is roadside barrier approaching the bridge on the opposite side of median. This is also true for ramps or where parallel roads are located beyond the desirable clear zone for any opposite direction traffic.

All new barrier installations on undivided highways should include a standard end treatment or crash-cushion active in the Contract Preparation System, regardless of whether the end treatment is within the desirable clear zone for opposite direction traffic.

For leaving ends of new steel beam guide rail (SBGR) that are not required to be protected by a standard treatment or crash-cushion active in our Contract Preparation System, a leaving end treatment (LET) is required. The leaving end treatment will anchor the system to resist tension forces in the SBGR resulting from vehicle impacts.

POLICY: On Provincial Highway Projects, the leaving ends of all new barrier system installations on undivided highways should be terminated and anchored by a terminal or crash cushion described in this manual.

On divided highways, a leaving end treatment should be used for steel beam guide rail installations when the leaving end is located beyond the desirable clear zone according to Table 2-2 for opposing traffic.

On divided highways, the leaving end of concrete barriers or bridge rails may be left blunt when they are located beyond the desirable clear zone according to Table 2-2 for opposing traffic.

2.4.7 Barrier Systems on Overland Flow Routes and Flood Plains

In some situations, the highway is designed to permit stormwater to overtop and flow over the driving surface during extreme storm events. This is done in the vicinity of the low-point of sag vertical curves and is referred to as relief flow. It may be appropriate where storm event flow cannot be economically or physically conveyed under the highway through a culvert or a bridge structure. The highway acts as a weir when the overtopping occurs and influences flood lines, both upstream and downstream. Permitting relief flow potentially safeguards the bridge or culvert from being washed away during a major storm event.

Barrier systems installed in relief flow locations shall permit sufficient flow at elevations close to the road surface. Impermeable, or solid-barriers such as concrete barriers would effectively act as a weir. This could result in deeper water on the highway, washout of the waterway structure and increased flooding upstream of the highway.

POLICY: **On Provincial Highway Projects, impermeable barrier systems should not extend across an overland flow route where relief flow is required across a roadway during flood events.**

2.4.8 Sign Support Systems

Signs can be classified into three groups with respect to their sizes and use of supports; these are:

- Overhead Signs
- Large Signs
- Small Signs, and
- Small Signs on Concrete Median Barrier

Overhead signs, including cantilevered signs, generally require massive support systems which cannot be made breakaway, due to load carrying requirements. Where possible, overhead signs should be installed on, or relocate to, nearby overpasses or other structures. All overhead sign supports located within the Desirable Clear Zone should be shielded with a barrier system or crash cushion. If a barrier system is used, the sign support should be located sufficiently beyond the design deflection distance of the barrier, to ensure that the barrier will function as intended when struck by an errant vehicle. Design guidance for overhead signs is found in the Sign Support Manual.

Large signs typically range in sizes from 1200mm (height) x 2400mm (width) to 2700 mm x 6000 mm (2.88m^2 to 16.2m^2). Large ground mounted signs are typically installed on two to four supports, generally of wood or steel, which may be made breakaway. If sign is installed on non-breakaway supports and is located within the Desirable Clear Zone, it should be shielded with a barrier system or crash cushion. If a barrier system is used, the sign support should be located sufficiently beyond the design deflection distance of the barrier, to ensure that the barrier will function as intended when struck by an errant vehicle. Design guidance for large signs is found in Ontario Traffic Manual Book 3.

Intermediate signs typically range in sizes from 3.6m^2 up to 7.2m^2, with sign sizes up to 3000 mm (height) by 2400 mm (width). Intermediate signs are installed using the Slip-Safe Supreme system consisting of two steel breakaway posts.

Small signs typically have a sign panel area not greater than 3.6m^2 and sign sizes range up to 1500 mm (height) x 2400 mm (width). Although not usually perceived as an obstacle, on high speed highways small signs can cause significant damage to errant vehicles during impacts. Small sign supports are manufactured using wooden or steel posts, and are available in either breakaway or non-breakaway configurations. Small signs with a sign panel area not greater than 1.35 m^2 (up to 0.9m wide by 1.5m high) may be mounted on the top of concrete median barrier using a sliding base and chute design.

POLICY: **All new small and intermediate sign support system installations on high speed roadways located within the desirable clear zone according to Table 2.2 on provincial highway projects should be breakaway**.

All new small sign support systems installations on top of concrete median barrier with top width less than 1.0 m shall use the sliding base and chute design.

2.4.9 Anti-Glare Screens

Glare from the headlights of traffic travelling in the opposite direction may be a concern on sections of divided highway with relatively narrow medians and/or high traffic volumes. This situation can also occur when parallel frontage and service roads are located close to the highway. Tall Wall Concrete Median Barrier systems often have sufficient height to reduce the glare from the majority of oncoming vehicles. For other barrier systems, anti-glare screens or vanes which fasten to the top of the barrier system have been developed. At edges of right-of-way, anti-glare screens are available that attach to chain link fence

The various anti-glare screens available are usually expensive, often exceeding the cost of the barrier system itself. Damage can result from incidental contact by vehicles or by snow and ice thrown by snow plows. For these reasons anti-glare screens should only be considered on a retrofit basis to address existing operational problems.

On new facilities, potential glare problems should be addressed by appropriate horizontal and vertical alignment design, or by appropriate barrier system selection.

On temporary concrete barriers, anti-glare screens should not be added as they may affect safety performance of the temporary concrete system during impacts by errant vehicles.

POLICY: **On Provincial Highway Projects, glare screens should be provided to improve visibility where identified operational problems with headlight glare are documented, are cost beneficially justified, and standards are active in the Contract Preparation System.**

2.5 Temporary Construction Barrier Systems in Work Zones

For construction work zones where temporary construction barrier systems are required to provide positive protection between vehicular traffic and the work area and workers, Chapter 5 provides design guidance for selection and installation of acceptable temporary construction barrier systems and terminals for use on provincial highway projects. Installations of these temporary systems also need to comply with guidance provided in OTM Book 7 and according to the Ontario Occupational Health and Safety Act.

POLICY: **On Provincial Highway Projects, only temporary construction barrier systems, transitions, restraint systems, and terminals described in this manual with standards active in the Contract Preparation System should be used for temporary installations in work zones unless otherwise authorized by the ~~Design and Contract Standards~~Highway Design Office.**

2.5.1 Temporary Construction Barrier Adjacent to Excavations and Roadway Protection Systems

Ontario Regulation 213/91 Section 233(1) of Part III, Excavations, General Requirements, states "a level area extending at least one metre from the upper edge of each wall of an excavation shall be kept clear of equipment, excavated soil, rock and construction material".

Temporary construction barrier (TCB) systems are designed and crash tested for placement on paved surfaces, and paved surfaces should extend at least one metre beyond the back of unrestrained TCB systems. For restrained TCB systems, the level paved surface should be such that the barrier will perform adequately when impacted. Requirements for each barrier configuration are provided in standard drawings.

For TCB installations adjacent to roadway protection systems (support systems), a level paved area extending at least one metre from the back side of the TCB to back side of the protection system should be provided to accommodate deflection of the system when impacted. For restrained TCB systems, this paved surface width may be reduced according to applicable standards in CPS to provide adequate clearance between the back side of the TCB and back side of the protection system. For Type X TCB systems on low speed single lane installations controlled by temporary traffic signals resting in red and regulatory posted speed limits less than 70 km/h, the paved surface width may be reduced to provide at least 0.4 m clearance between the back side of the TCB and back side of the protection system.

Permanent steel beam guide rail systems may be installed as temporary barrier systems on gravel shoulders or detours as an alternative to TCB systems which also require a level area extending at least one metre from back side of the system to edge of excavation or back side of a roadway protection system.

POLICY: **On Provincial Highway Projects, when a temporary construction barrier system is specified adjacent to an excavation, a level area extending at least one metre from the upper edge of each wall of the excavation should be provided behind the backside of the temporary construction barrier system.**

In constrained areas where it is necessary to reduce the width of the level area behind the temporary construction barrier system to the upper edge of each wall of an excavation, during detailed design a Professional Engineer shall develop and specify staging plans and operational constraints according to Ontario Regulation 213/91 Section 3 of Part I, General Alternative Methods and Materials that will

afford protection for the health and safety of workers that is at least equal to the protection that would otherwise be given.

During development of the staging plans and operational constraint, a stability analysis for each excavation not supported by a roadway protection system shall be carried out to evaluate slope stability in order to specify appropriate construction procedures, temporary construction barrier system type and configuration, time restrictions, and inspection requirements. The evaluation shall be documented in a report and memorandum sealed by a Professional Engineer for use during construction.

2.5.2 Temporary Construction Barrier Adjacent to Edge of Structures and Scaffolding

Temporary Concrete Barrier and Temporary Steel Barrier systems are designed and crash tested for placement on paved surfaces, and paved surfaces should extend at least one metre beyond the back of unrestrained TCB systems to edges of bridge decks or scaffolding. For restrained TCB systems, paved surfaces according to applicable standards active in the Contract Preparation System to edges of bridge decks or scaffolding should be provided.

POLICY: **On Provincial Highway Projects, a level paved area extending at least one metre from the backside of the temporary barrier system to the edge of a bridge deck or scaffolding should be provided.**

In constrained areas on bridge decks, low deflection temporary construction barriers should be specified according to applicable standards active in the Contract Preparation System.

In constrained areas on low speed single lane installations on bridge decks controlled by temporary traffic signals resting in red with regulatory posted speed limits reduced to less than 70 km/h, a level paved area extending at least 0.4 m from the backside of a Type X temporary concrete barrier system should be specified according to applicable standards active in the Contract Preparation System.