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APPENDIX A

SECTION A-1M-GEOMETRIC DESIGN STANDARDS

INTRODUCTION

VDOT (L&D) has formally adopted the AASHTO A Policy on Geometric Design of Highways and Streets, commonly referred to as the AASHTO "Green Book", as our minimum design standards. Therefore, all design criteria must meet AASHTO minimum standards.

Highway improvement plans are based on established AASHTO geometric design standards for various elements of the roadway under design. The tables on the following pages provide the **minimum** geometric standards which are to be used for development of VDOT projects except those projects which can be developed using the Guidelines for RRR Projects located in Appendix A, Section A-4 of this manual. Note that there are no specific RRR standards for Interstate projects. If the designer has determined that Guidelines for RRR Projects do not apply to the project in question, the Geometric Design Standard Figures A-1-1M through A-1-10M should be used for project development.

The Geometric Standard tables were developed using the A Policy on Geometric Design of Highways and Streets published by the American Association of State Highway and Transportation Officials (AASHTO). These tables present basic practical guidelines compatible with traffic, topography and safety; however, due to the restrictive format, all variables could not be included. The designer is urged to refer to the above named publication and other related chapters in the Road Design Manual for further discussion of design considerations before selecting the proper design speed criteria for a given project.

THE APPLICATION OF THE CRITERIA PROVIDED IN THE GEOMETRIC DESIGN STANDARD TABLES MUST BE MADE IN RELATION TO THEIR EFFECT ON THE ROADWAY SYSTEM AND IN CONJUNCTION WITH SOUND ENGINEERING JUDGMENT TO ENSURE AN APPROPRIATE DESIGN. The economic, environmental and social factors involved in highway design shall also be considered. The designer should always attempt to provide for the highest degree of safety and best level of service that is economically feasible. The "minimum" design criteria shown in Figures A-1-1M through A-1-10M should only be used when overriding economic or environmental considerations so dictate.

ROADWAY WIDTH

Roadway width as referenced in this section is the portion of the highway, including graded shoulders, for vehicular use.

DESIGN SPEED

Design speed is defined as a speed determined for design and correlation of the physical features of a highway that influence vehicle operation - the maximum safe speed maintainable over a specified section of highway when conditions permit design features to govern.

The geometric Figures indicate a design speed range for each functional classification. The selection of the proper design speed to be used on a particular project is of primary importance in project development. The design speed selected should:

- be logical with respect to topography, anticipated operating speed, adjacent land use, and functional classification of the highway.

- be as high as practicable to attain a desired degree of safety, mobility and efficiency while under the constraints of environmental quality, economics, aesthetics and social or political impacts

- be consistent with the speed a driver is likely to expect. Drivers do not adjust their speeds to the importance of the highway, but to their perception of the physical limitations and traffic thereon.

Although the design speeds for rural highways are coupled with a terrain classification, terrain is only one of the several factors involved in determining the appropriate design speed of a highway.

Although the selected design speed establishes the minimum radius of curvature and minimum sight distance necessary for safe operation, there should be no restriction on the use of flatter horizontal curves or greater sight distances where such improvements can be provided as a part of economic design. However, if a succession of flatter curves or tangent sections would encourage drivers to operate at higher speeds, that section of highway should be designed for a higher speed and all geometric features, particularly that of sight distance on crest vertical curves and intersection sight distance should be related to it.

Table A-1-1M indicates the various speed ranges applicable to each functional classification.

EXCEPTIONS

Where it is impractical or not economical to obtain the AASHTO minimum design criteria as shown in the Geometric Standard tables, an exception shall be secured from the State Location and Design Engineer on **all** projects. On all new or reconstruction Interstate projects

deviations from AASHTO standards (desirable standards where specified) must obtain the written approval of the Federal Highway Administration regardless of funding source. For Interstate projects, other than new or major reconstruction, all deviations from minimum AASHTO standards (in place at the time of original construction of that portion of the interstate) must be given written approval of the Federal Highway Administration regardless of funding source. For projects on the National Highway System with Federal Oversight, deviation from AASHTO Design standards must be given written approval by the Federal Highway Administration.

On State funded rural projects where design constraints require that the overall design speed selected for a project is less than the design speed which would be normally selected based on terrain, a design exception is not required if the speed falls within the range of design speeds shown in Table A-1-1M for the particular class of roadway being designed. The designer must fully document the necessity for the use of a reduced design speed (or any design exception) and have it approved in accordance with Design Exception Requirements form LD-440. For additional instructions on Design Exceptions, see Instructional and informational Memorandum IIM-LD-227. The designer should exercise care to avoid selecting a speed which may be lower than the speed the average driver would expect because of impacts on traffic operations and safety which may result.

DESIGN SPEEDS FOR VARIOUS FUNCTIONAL CLASSIFICATIONS

L=Min. for Level Terrain

R=Min. for Rolling Terrain

M=Min. for Mountainous Terrain (As defined by Section 23 of the Highway Capacity Manual)

CBD=Min. for Central Business District

S=Min. for Suburban Area

D=Min. for Developing Area

ROADWAY CLASSIFICATION		SPEED (kmh) 30	50	60	80	100	110
RURAL ARTERIAL	FREEWAYS - 110 km/h MIN. 60 km/h – M MIN. 80 km/h – R			X M	X R	X L	X
RURAL COLLECTOR ROAD	ADT OVER 2000			X M	X R	X L	
	CURRENT ADT 400 TO 2000		X M	X R	X L		
	CURRENT ADT UNDER 400	X M	X R	X L			
RURAL LOCAL ROAD	CURRENT ADT OVER 400		X M	X R	X L		
	CURRENT ADT 400 OR UNDER	X M	X R	X L			
URBAN ARTERIAL	FREEWAYS MIN. 80 km/h		X CBD	X S	X	X D	X
URBAN COLLECTOR STREET			X	X	X		
URBAN LOCAL STREET		X	X				

DESIGN SPEEDS FOR VARIOUS FUNCTIONAL CLASSIFICATIONS
TABLE A - 1-1M

GEOMETRIC DESIGN STANDARDS FOR RURAL PRINCIPAL ARTERIAL SYSTEM (GS-1M)

	TERRAIN	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)	(6) STOPPING SIGHT DISTANCE (METERS)	MIN. WIDTH OF LANE	(1) MINIMUM WIDTH OF TOTAL SHOULDERS (Graded + Paved)		(2) PAVED SHOULDER WIDTH		(3) WIDTH OF DITCH (FRONT SLOPE)	(4) SLOPE	(5) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
				MIN.		FILL	CUT	RT.	LT.			
FREEWAYS	LEVEL	110	502	220	3.6 m	5.2 m	4.3 m	3.6 m	1.2 m	3.6 m	CS-4B	2 THRU LANES SAME DIRECTION = 1.5m + PAVE. WIDTH + 4.3m 3 OR MORE THRU LANES SAME DIRECTION = 4.3m + PAVE. WIDTH + 4.3m
	ROLLING	100	394	185								
	MOUNTAINOUS	80	230	130							CS-4E	
OTHER PRINCIPAL ARTERIALS	LEVEL	110	502	220	3.6 m	3.9 m	3.0 m	2.4 m	1.2 m	3.0 m	CS-4 OR 4B	UNDIVIDED & DIVIDED 3 OR MORE THRU LANES SAME DIRECTION = 3.0m + PAVE. WIDTH +3.0m
		100	394	185								
	ROLLING	100	394	185						1.8 m	CS-4 OR 4E	
		80	230	130								
	MOUNTAINOUS	80	230	130							CD-3 OR 3B	DIVIDED 2 THRU LANES SAME DIRECTION 1.5m + PAVE. WIDTH + 3.0m
		60	124	85								

GENERAL NOTES

Freeways - A design speed of 110 km/h should be used for Rural Freeways. Where terrain is mountainous a design speed of 100 km/h or 80 km/h, which is consistent with driver expectancy, may be used. All new and major reconstructed Interstate facilities will have a 110 km/h design speed unless a lower design speed is approved by the Location and Design Engineer and FHWA.

Other Principle Arterials - A design speed of 60 to 110 km/h should be used depending on terrain, driver expectancy and whether the design is constructed on new location or reconstruction of an existing facility. An important safety consideration in the selection of one of the lower design speeds in each range is to have a properly posted speed limit which is enforced during off peak hours.

Incorporated towns or other built-up areas, Urban Standard GS-5(M) may be used for design.

Standard TC-5.01R(M) superelevation based on 8% maximum is to be used for all Rural Principle Arterials.

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS							
TYPE OF TERRAIN	FREEWAYS			ARTERIALS			
	DESIGN SPEED (km/h)						
	80	100	110	60	80	100	110
	GRADES (PERCENT) *						
LEVEL	4	3	3	5	4	3	3
ROLLING	5	4	4	6	5	4	4
MOUNTAINOUS	6	6	5	8	7	6	5

Grades 1 percent steeper than the value shown may be used on Rural Freeways in extreme situations for one-way downgrades except in mountainous terrain.

Clear Zone and Recoverable Area information can be found in Appendix A(M), Section A-2(M) of the Road Design Manual.
If medians are included, see Section 2E-3 of Chapter 2D of the Road Design Manual

FOOTNOTES

(1) Shoulder widths shown are for right shoulders and independently graded median shoulders. On non-Interstate a 2.4 m graded median shoulder will be provided when the mainline is 4 lanes (both directions). For 6 or more lanes, the median shoulder provided will be the same as that shown for independent grading. On Freeways, if truck traffic is less than 250 DDHV, the minimum width of total shoulder should be 4.6 m for fills and 3.6 m for cuts.

(2) When the mainline is 6 or more lanes, the left paved shoulder width should be the same as the right paved shoulder. On Freeways, if truck traffic is less than 250 DDHV, the minimum right paved shoulder width should be 3.0 m.

(3) Ditch slopes to be 6:1 - 3.0 m and 3.6 m widths and 4:1 - 1.8 m width.

(4) Additional or modified slope criteria to apply where shown on typical sections.

(5) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m (0.3 m additional clearance required for non-vehicular overpasses).
Right shoulder may be 10' minimum when truck traffic is less than 250 DDHV.

(6) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 1M

GEOMETRIC DESIGN STANDARDS FOR RURAL MINOR ARTERIAL SYSTEM GS-2M)

TRAFFIC VOLUME	TERRAIN	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)	(8) STOPPING SIGHT DISTANCE (METERS) MIN.	MINIMUM PASSING SIGHT DISTANCE (METERS)	(2) MIN. WIDTH OF LANE	(3) MIN. WIDTH OF GRADED SHOULDERS FILL W/GR	(3) MIN. WIDTH OF GRADED SHOULDERS CUT & FILL	(4) PAVED SHOULDER WIDTH RT.	(4) PAVED SHOULDER WIDTH LT.	(5) WIDTH OF DITCH (FRONT SLOPE)	(6) SLOPE	(7) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
(1) ADT OVER 2000	LEVEL	110	502	220	730	3.6 m	3.9 m	3.0 m	2.4 m	1.2 m	3.0 m	CS-4, CS-4A OR CS-4C	3.0 m PLUS PAVEMENT WIDTH PLUS 3.0 m
		100	394	185	670								
	ROLLING	100	394	185	670								
		80	230	130	540						1.8 m		
	MOUNTAINOUS	80	230	130	540							CS-3 OR CS-3B	
		60	124	85	410								
(1) ADT 1500 TO 2000	LEVEL	110	502	220	730	3.6 m	3.3 m	2.4 m	1.8 m	1.2 m	1.8 m	CS-4, CS-4A OR CS-4C	2.4 m PLUS PAVEMENT WIDTH PLUS 2.4 m
		100	394	185	670								
	ROLLING	100	394	185	670								
		80	230	130	540	3.3 m							
	MOUNTAINOUS	80	230	130	540							CS-3 OR CS-3B	
		60	124	85	410								
ADT 400 TO 1500	LEVEL	110	502	220	730	3.6 m	3.3 m	2.4 m	1.8 m	1.2m	1.8 m	CS-4, CS-4A OR CS-4C	
		100	394	185	670								
	ROLLING	100	394	185	670								
		80	230	130	540	3.3 m							
	MOUNTAINOUS	80	230	130	540							CS-3 0R CS-3B	
		60	124	85	410								
ADT UNDER 400	LEVEL	110	502	220	730	3.6 m	2.7 m	1.8 m	1.2 m	1.2 m	1.8 m	CS-4, CS-4A OR CS-4C	1.8 m PLUS PAVEMENT WIDTH PLUS 1.8 m
		100	394	185	670								
	ROLLING	100	394	185	670								
		80	230	130	540	3.3 m							
	MOUNTAINOUS	80	230	130	540							CS-3 OR CS-3B	
		60	124	85	410								

GENERAL NOTES

Rural Minor Arterials are designed with design speeds of 80 to 110 km/h, dependent on terrain features and traffic volumes, and occasionally may be as low as 60 km/h in mountainous terrain.

In incorporated towns or other built-up areas, Urban Standard GS-6(M) may be used for design.

Standard TC-5.01R(M) superelevation based on 8% maximum is to be used for Rural Minor Arterials.

If medians are included, see Section 2E of the Road Design Manual.

Clear zone and Recoverable Area information can be found in Appendix A(M), Section A-2(M) of the Road Design Manual.

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS				
TYPE OF TERRAIN	DESIGN SPEED (km/h)			
	60	80	100	110
	GRADES (PERCENT)			
LEVEL	5	4	3	3
ROLLING	6	5	4	4
MOUNTAINOUS	8	7	6	5

FOOTNOTES

(1) Use current ADT for restoration type projects (not applicable to RRR projects) and use design year ADT for all other projects.

(2) Lane width to be 3.6 m at all interchange locations. For projects not on the National Highway System, width of traveled way may remain at 6.6 m on reconstructed highways where alignment and safety records are satisfactory.

(3) If graded median is used, the width of median shoulder is to be 2.4 m.

(4) The Paved widths shown are the widths to be used if the Materials Division recommends the shoulders be paved or stabilized. When the mainline is 4 lanes (both directions) a minimum 2.4 m wide paved shoulder will be provided on the right of traffic and a minimum 1.2 m wide paved shoulder on the median side. Where the mainline is 6 or more lanes, both right and median paved shoulders will be 2.4 m in width. If paved shoulders are not recommended by the Materials Division the mainline pavement structure will be extended 0.3 m at the same slope into the shoulder to eliminate raveling of the pavement edge.

(5) Ditch slopes to be 6:1 - 3.0 m width, 4:1 - 1.8 m width.

(6) Additional or modified slope criteria to be applied where shown on typical sections.

(7) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m (0.3 m additional clearance required for non-vehicular overpasses).

(8) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 2M

GEOMETRIC DESIGN STANDARDS FOR RURAL COLLECTOR ROAD SYSTEM (GS-3M)

DESIGN YEAR TRAFFIC VOLUME	TERRAIN	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)	(9) STOPPING SIGHT DISTANCE (METERS	MINIMUM PASSING SIGHT DISTANCE (METERS)	(2) MIN. WIDTH OF LANE	(3) (4) MIN. WIDTH OF GRADED SHOULDERS	(5) WIDTH OF DITCH	(6) RECOMMENDED SLOPE	(7) (8) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS

				MIN.			FILL W/GR	CUT & FILL	(FRONT SLOPE)		AND VERTICAL CLEARANCES
(1) ADT OVER 2000	LEVEL	100	394	185	670	3.6 m	3.3 m	2.4 m	3.0 m	CS-4, CS-4A, OR CS-4C	2.4 m PLUS PAVEMENT WIDTH PLUS 2.4m
	ROLLING	80	230	130	540						
	MOUNTAINOUS	60	124	85	410				1.8 m	CS-3 OR CS-3B	
(1) ADT 1500 TO 2000	LEVEL	80	230	130	540	3.3 m	2.7 m	1.8 m	1.8 m	CS-4, CS-4A, OR CS-4C	1.2 m PLUS PAVEMENT WIDTH PLUS 1.2 m
	ROLLING	60	124	85	410						
	MOUNTAINOUS	50	83	65	345				1.2 m	CS-3 OR CS-3B	
CURRENT ADT 400 TO 1500	LEVEL	80	230	130	540	3.3 m	2.4 m	1.5 m	1.8 m	CS-4, CS-4A, OR CS-4C	1.0 m PLUS PAVEMENT WIDTH PLUS 1.0 m
	ROLLING	60	124	85	410						
	MOUNTAINOUS	50	83	65	345	3.0 m			1.2 m	CS-3 OR CS-3B	
CURRENT ADT UNDER 400	LEVEL	60	124	85	410	3.0 m	2.1 m	0.6 m	1.8 m	CS-1	0.6 m PLUS PAVEMENT WIDTH PLUS 0.6 m
	ROLLING	50	83	65	345				1.2 m		
	MOUNTAINOUS	30	29	35	200						

GENERAL NOTES

Geometric design features should be consistent with a design speed appropriate for the conditions.

Low design speeds (60 km/h and below) are generally applicable to highways with curvilinear alignment in rolling or mountainous terrain and where environmental conditions dictate.

High design speeds (70 km/h and above) are generally applicable to highways in level terrain or where other environmental conditions are favorable.

Intermediate design speeds would be appropriate where terrain and other environmental conditions are a combination of those described for low and high speed.

The designer should strive for higher values than the minimum where conditions of safety dictate and costs can be supported.

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS						
TYPE OF TERRAIN	DESIGN SPEED (km/h)					
	30	50	60	80	100	110
	GRADES (PERCENT)					
LEVEL	7	7	7	6	5	4
ROLLING	10	9	8	7	6	5
MOUNTAINOUS	12	10	10	9	8	6

In incorporated towns or other built-up areas, Urban Standard GS-7M may be used.

Standard TC-5.01R(M) superelevation based on 8% Maximum to be used for Rural Collectors.
Maximum grades of short length (less than 150 m), on one-way downgrades and on low-volume Rural Collectors may be 2 percent steeper.

Clear zone and Recoverable Area information can be found in Appendix A(M), Section A-2(M) of the Road Design Manual.

FOOTNOTES

(1) Use current ADT for restoration type projects (not applicable to RRR projects) and use design year ADT for all other projects.

(2) Lane width to be 3.6 m at all interchange locations.

(3) Provide 1.2 m wide paved shoulders when design year ADT exceeds 2000 VPD, with 5% or more truck and bus usage. All shoulders not being paved will have the mainline pavement structure extended 0.3 m on the same slope into the shoulder to eliminate raveling at the pavement edge.

(4) When the mainline is four lanes, a minimum paved shoulder width of 1.8 m right of traffic and 0.9 m left of traffic will be provided.

(5) Ditch slopes to be 6:1 - 3.0 m width, 4:1 - 1.8 m width, 3:1 - 1.2 m width.

(6) Additional or modified slope criteria to be applied where shown on typical sections.

(7) Where the approach roadway width (traveled way plus shoulder) is surfaced, that surfaced width shall be carried across all structures if that width exceeds the width shown in this table.

(8) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m desirable and 4.45 m minimum (0.3 m additional clearance required for non-vehicular overpasses).

(9) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 3M

GEOMETRIC DESIGN STANDARDS FOR RURAL LOCAL ROAD SYSTEM (GS-4M)

TRAFFIC VOLUME	TERRAIN	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)	(9) STOPPING SIGHT DISTANCE	MINIMUM PASSING SIGHT DISTANCE	(2) MIN. WIDTH OF SURFACING OR PAVEMENT	(3)(4)(5) MIN. WIDTH OF GRADED SHOULDERS		(6) WIDTH OF DITCH (FRONT SLOPE)	(7) RECOMMENDED SLOPE	(8) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCE
				MIN.			FILL W/GR	CUT & FILL			
(1) ADT OVER 2000	LEVEL	80	230	130	550	7.2 m	3.3 m	2.4 m	1.8 m	CS-4, 4A OR 4C	APPROACH ROADWAY WIDTH
	ROLLING	60	124	85	410					CS-3, 3A OR 3B	
	MOUNTAINOUS	50	83	65	345				1.2 m		
(1) ADT 1500 TO 2000	LEVEL	80	230	130	550	6.6 m	2.7 m	1.8 m	1.8 m	CS-4, 4A OR 4C	10 m PLUS PAVEMENT WIDTH PLUS 10 m
	ROLLING	60	124	85	410					CS-3, 3A OR 3B	
	MOUNTAINOUS	50	83	65	345				1.2 m		
ADT 400 TO 1500	LEVEL	80	230	130	550	6.6 m	2.4 m	1.5 m	1.8 m	CS-4, 4A OR 4C	
	ROLLING	60	124	85	410	6.0 m				CS-3, 3A OR 3B	
	MOUNTAINOUS	50	83	65	345				1.2 m		
ADT 400 TO 250	LEVEL	60	124	85	410	5.4 m	2.1 m	0.6 m	1.8 m	CS-1	0.6 m PLUS PAVEMENT WIDTH PLUS 0.6 m
	ROLLING	50	83	65	345				1.2 m		
	MOUNTAINOUS	30	29	35	200						
ADT 250 TO 50	LEVEL	50	83	65	345	5.4 m	2.1 m	0.6 m	1.2 m	CS-1	
	ROLLING	50	83								
	MOUNTAINOUS	30	29	35	200						
ADT UNDER 50	LEVEL	50	83	65	345	5.4 m	2.1 m	0.6 m	1.2 m	CS-1	
	ROLLING	30	29	35	200						
	MOUNTAINOUS	30	29								

GENERAL NOTES

Low design speeds are generally applicable to roads with winding alignment in rolling or mountainous terrain where environmental conditions dictate.

High design speeds are generally applicable to roads in level terrain or where other environmental conditions are favorable.

Intermediate design speeds would be appropriate where terrain and other environmental conditions are a combination of those described for low and high speed.

Standard TC-5.01R(M) superelevation based on 8% maximum is to be used.

In incorporated towns or other built-up areas, Urban Standard

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS					
TYPE OF TERRAIN	DESIGN SPEED (km/h)				
	30	50	60	80	100
	GRADES (PERCENT)				
LEVEL	8	7	7	6	5
ROLLING	11	10	10	8	6
MOUNTAINOUS	16	14	13	10	--

GS-8(M) may be used.

FOOTNOTES

(1) Use current ADT for restoration type projects (not applicable to RRR projects) and use design year ADT for all other projects.

(2) Lane width to be 3.6 m at all interchange locations.

(3) In mountainous terrain or sections with heavy earthwork, the graded width of shoulder in cuts may be decreased 0.6 m, but in no case shall the shoulder width be less than 0.6 m.

(4) Minimum shoulder slope shall be 8% on low side and same slope as pavement on high side.

(5) Provide 1.2 m wide paved shoulders when design year ADT exceeds 2000 VPD, with 5% or more truck and bus usage. All shoulders not being paved will have the mainline pavement structure extended 0.3 m on the same slope into the shoulder to eliminate raveling at the pavement edge.

(6) Ditch slopes to be 4:1 - 1.8 m width, 3:1 - 1.2 m width.

(7) Additional or modified slope criteria to be applied where shown on typical sections.

(8) Vertical clearance at roadway underpasses for new and reconstructed bridges is 5.05 m desirable and 4.45 m minimum (0.3 m additional clearance required for non-vehicular overpasses).

(9) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 4M

GEOMETRIC DESIGN STANDARDS FOR URBAN PRINCIPAL ARTERIAL SYSTEM (GS-5M)

	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)		(13) STOPPING SIGHT DISTANCE (METERS)	MIN. WIDTH OF LANE	(1) MIN. WIDTH GRADED SHOULDERS		(2) PAVED SHOULDER WIDTH		(3) WIDTH OF DITCH (FRONT SLOPE)	(4) SLOPE	(7) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
		U	ULS	MIN.		FILL W/GR	CUT & FILL	RT.	LT.			
FREEWAYS	110	502	-	220	3.6 m	4.5 m	3.6 m	3.0 m	1.2 m	3.6 m	CS-4 OR CS-4B	2 THRU LANES SAME DIRECTION = 1.8 m + PAVE. WIDTH + 3.6 m
	100	394	-	185								
	80	280	-	130							CS-4 OR 4E	3 OR MORE THRU LANES SAME DIRECTION = 3.6 m + PAVE. WIDTH + 3.6 m
OTHER PRINCIPAL ARTERIAL WITH SHOULDER DESIGN	100	394	-	185	(12) 3.6 m	3.9 m	3.0 m	2.4 m	1.2 m	3.0 m	CS-4 OR CS-4E	UNDIVIDED & DIVIDED 3 OR MORE THRU LANES SAME DIRECTION = 3.6 m + PAVE. WIDTH + 3.6 m
	80	280	-	130						1.8 m		
	60	150	149	85	(5)(6)(12) 3.3 m						CS-3 OR CS-3B	2 THRU LANES (DIVIDED) SAME DIRECTION 1.8 m + PAVE. WIDTH + 3.0 m
	50	99	94	65								
	MIN. DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS) U	ULS	STOPPING SIGHT DISTANCE (METERS) MIN.	MIN. WIDTH OF LANE	(8) STANDARD CURB & GUTTER		BUFFER STRIP WIDTH		(9) MIN. SIDEWALK WIDTH	(10) SLOPE	(7) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
OTHER PRINCIPAL ARTERIAL WITH GUTTER	100	394	-	185	(12) 3.6 m	CG-7		(11)		1.5 m	2:1	SAME AS CURB TO CURB OF APPROACHES
	80	280	-	130								
	70	215	227	105								
	60	150	149	85	(5)(6)(12) 3.3 m	CG-6						
	50	99	94	65								

GENERAL NOTES

Freeways - Urban Freeways should accommodate desired safe operating speeds during non-peak hours, but should not be so high as to exceed the limits of prudent construction, right of way and socioeconomic costs due to the large proportion of vehicles which are accommodated during periods of peak flow when lower speeds are necessary. The design speeds for Freeways should never be less than 80 km/h.

On many Urban Freeways, particularly in suburban areas, a design speed of 100 km/h or higher can be provided with little additional cost above that required for 80 km/h design speed. The corridor of the mainline may be relatively straight and the character and location of interchanges may permit high speed design. Under these conditions, a design speed of 110 km/h is most desirable because the higher design speeds are closely related to the overall quality and safety of the facility.

Other Principal Arterials - Design speeds for Urban Arterials generally range from 60 to 100 km/h, and occasionally may be as low as 50 km/h. The lower (60 km/h and below) speeds apply in the central business district and intermediate areas. The higher speeds are more applicable to the outlying business and developing areas.

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS								
TYPE OF TERRAIN	FREEWAYS *			ARTERIALS				
	DESIGN SPEED (km/h)							
	80	100	110	50	60	70	80	100
	GRADES (PERCENT)							
LEVEL	4	3	3	8	7	6	6	5
ROLLING	5	4	4	9	8	7	7	6
MOUNTAINOUS	6	6	5	11	10	9	9	8

Standard TC-5.01R(M) (Rural) superelevation based on 8% maximum is to be used for all Freeways and other Principal Arterials with a design speed greater than or equal to 100 km/h.

* Grades 1 percent steeper that the value shown may be used on Urban Freeways for extreme cases in urban areas where development precludes the use of flatter grades and for one-way downgrades, except in mountainous terrain.

Standard TC-5.01U(M) (Urban) superelevation based on 4% maximum is to be used on Other Principal Arterials with a design speed less than 100 km/h.

Standard TC-5.04ULS(M) (Urban Low Speed) superelevation based on 2% maximum is to be used on Other Principal Arterials with a design speed less than or equal to 70 km/h (70 km/h = 227 m minimum radius).

Clear Zone and Recoverable Area information can be found in Appendix A(M), Section A-2(M) of the Road Design Manual.

If medians are included, see Section 2E-3 of Chapter 2E of the Road Design Manual.

A minimum 9.2 m width of surfacing or a minimum 9.2 m face to face of curb is to be used within incorporated cities or towns to qualify for maintenance payments.

For guidelines on Interchange Ramp, see Standard GS-R(M).

FOOTNOTES

(1) Shoulder widths shown are for right shoulders and independently graded median shoulders. A 2.4 m graded median shoulder will be provided when the mainline is 4 lanes (both directions). For 6 or more lanes, the median shoulder provided will be the same as that shown for independent grading. On Freeways, if truck traffic exceeds 250 DDHV, the minimum width of graded shoulder should be 5.1 m for fills and 4.2 m for cuts.
(2) When the mainline is 6 or more lanes, the left paved shoulder width should be the same as the right paved shoulder. On Freeways, if truck traffic exceeds 250 DDHV, the right paved shoulder width should be 3.6 m, and on 6 or more lane Freeways, the left paved shoulder width should also be 3.6 m if truck traffic exceeds 250 DDHV.
(3) Ditch slopes to be 6:1 - 3.0 m and 3.6 m widths and 4:1 - 1.8 m width.
(4) Additional or modified slope criteria to apply where shown on typical sections.
(5) Minimum lane width to be 3.6 m at all interchange locations.
(6) If heavy truck traffic is anticipated, an additional 0.3 m width is desirable.
(7) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m (0.3 m additional clearance required for non-vehicular overpasses).
(8) Or equivalent City or Town design.
(9) Width of 2.4 m or more may be needed in commercial areas.
(10) 3:1 and flatter slopes may be used when the right of way is behind the sidewalk (or sidewalk space) in residential or other areas where slopes will be maintained by the property owner.
(11) If a buffer strip is used between the back of curb and sidewalk, it should be 0.6 m minimum.
(12) Situations having restrictions on trucks may allow the use of lanes 0.3 m less in width.
(13) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 5M

GEOMETRIC DESIGN STANDARDS - URBAN MINOR ARTERIAL STREET SYSTEM (GS-6M)

	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS) U	MINIMUM RADIUS (METERS) ULS	(12) STOPPING SIGHT DISTANCE (METERS) MIN.	(11) MIN. WIDTH OF LANE	(3) STANDARD CURB & GUTTER		BUFFER STRIP WIDTH		(4) MIN. SIDEWALK WIDTH	(5) SLOPE	(6) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
STREETS WITH CURB & GUTTER	100	394	-	185	3.6 m	CG-7		(10)		1.5 m	2:1	SAME AS CURB TO CURB OF APPROACHES
	80	280	-	130								
	70	215	227	105		CG-6						
	60	150	149	85	(1)(2) 3.3 m							
	50	99	94	65								
	MIN. DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS) U	MINIMUM RADIUS (METERS) ULS	STOPPING SIGHT DISTANCE (METERS) MIN.	MIN. WIDTH OF LANE	(7) MIN. WIDTH OF GRADED SHOULDERS FILL W/GR	(7) MIN. WIDTH OF GRADED SHOULDERS CUT & FILL	(8) PAVED SHOULDER WIDTH RT	(8) PAVED SHOULDER WIDTH LT	(9) MIN. SIDEWALK WIDTH	(5) SLOPE	(6) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
STREETS WITH SHOULDER DESIGN	100	394	-	185	3.6 m	3.9 m	3.0 m	2.4 m	1.2 m	3.0 m	2:1	3.0 m + PAVEMENT WIDTH + 3.0 m
	80	280	-	130						1.8 m		
	60	150	149	85	(1)(2) 3.3 m	3.3 m	2.4 m	1.8 m	1.2 m			2.4 m + PAVEMENT WIDTH + 2.4 m
	50	99	94	65								

GENERAL NOTES

Design Speeds for Urban Arterials generally range from 60 to 80 km/h and occasionally may be as low as 50 km/h. The lower (60 km/h and below) speeds apply in the central business district and intermediate areas. The higher speeds are more applicable to the outlying business and developing areas.

Standard TC-5.01R(M) superelevation based on 8% maximum is to be used for 100 km/h design speed.

Standard TC-5.01U(M) (Urban) superelevation based on 4% maximum is to be used for design speeds less than 100 km/h.

Standard TC-5.04ULS(M) (Urban Low Speed) superelevation based on 2% maximum may be used for design speeds less than or equal to 70 km/h (70 km/h = 211 m minimum radius).

Clear Zone and Recoverable Area information can be found in Appendix A(M), Section A-2(M) of the Road Design Manual.

If medians are included, see Section 2E-3 of Chapter 2E of the Road Design Manual.

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS					
TYPE OF TERRAIN	DESIGN SPEED (km/h)				
	50	60	70	80	100
	GRADES (PERCENT)				
LEVEL	8	7	6	6	5
ROLLING	9	8	7	7	6
MOUNTAINOUS	11	10	9	9	8

A minimum 9.2 m width of surfacing or a minimum 9.2 m face to face of curb is to be used within incorporated cities or towns to qualify for maintenance payments.

FOOTNOTES

(1) Lane width to be 3.6 m at all interchanges or if design year ADT exceeds 2000.

(2) If heavy truck traffic is anticipated, an additional 0.3 m width is desirable.

(3) Or equivalent City or Town design.

(4) A width of 2.4 m or more may be needed in commercial areas.

(5) 3:1 and flatter slopes may be used when the right of way is behind the sidewalk (or sidewalk space) in residential or other areas where slopes will be maintained by the property owner.

(6) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m (0.3 m additional clearance required for non-vehicular overpasses).

(7) If graded median is used, the width of median shoulder is to be 2.4 m.

(8) The Paved widths shown are the widths to be used if the Materials Division recommends the shoulders be paved or stabilized. When the mainline is 4 lanes (both directions) a minimum 2.4 m wide paved shoulder will be provided on the right of traffic and a minimum 1.2 m wide paved shoulder on the median side. Where the mainline is 6 or more lanes, both the right and median paved shoulders will be 2.4 m in width. If paved shoulders are not recommended by the Materials Division, the mainline pavement structure will be extended 0.3 m at the same slope into the shoulder to eliminate raveling of the pavement edge.

(9) Ditch slope to be 6:1 - 3.0 m width and 4:1 - 1.8 m width.

(10) If a buffer strip is used between the back of curb and sidewalk, it should be 0.6 m minimum.

(11) Situations having restrictions on trucks may allow the use of lanes 0.3 m less in width.

(12) For intersection sight distance requirements, see Appendix C, Table C-1-5

FIGURE A - 1 - 6M

GEOMETRIC DESIGN STANDARDS FOR URBAN COLLECTOR STREET SYSTEM (GS-7M)

		MINIMUM	STOPPING	(1) (2)	(3)	BUFFER	(4)	(5)	(8) (9)

	DESIGN SPEED (km/h)	RADIUS (METERS)		SIGHT (11) DISTANCE (METERS)	MIN. WIDTH OF LANE	STANDARD CURB & GUTTER	STRIP WIDTH	MIN. SIDEWALK WIDTH	SLOPES	NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
		U	ULS	MIN.						
STREETS WITH CURB & GUTTER	80	280	--	130	3.3 m	CG-7	(10)	1.5 m	2:1	SAME AS CURB TO CURB OF APPROACHES
	70	215	227	105		CG-6				
	60	150	149	85						
	50	99	94	65						
	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)		STOPPING SIGHT DISTANCE (METERS)	(1) (2) MIN. WIDTH OF LANE	(7) MINIMUM WIDTH OF GRADED SHOULDERS		(6) WIDTH OF DITCH (FRONT SLOPE)	(5) SLOPES	(8)(9) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
		U	ULS	MIN.		FILL W/GR.	CUT & FILL			
STREETS W/ SHOULDER DESIGN	80	280	--	130	3.3 m	3.3 m	2.4 m	1.8 m	2:1	2.4 m + PAVEMENT WIDTH + 2.4 m
	60	150	149	85						
	50	99	94	65		2.1 m	1.2 m	1.2 m		1.2 m + PAVE. WIDTH + 1.2 m

GENERAL NOTES

A minimum design speed of 50 km/h or higher should be used for collector streets, depending on available right of way, terrain, adjacent development and other area controls.

In the typical street grid, the closely spaced intersections usually limit vehicular speeds and thus make the effect of design speed of less significance. Nevertheless, the longer sight distances and curve radii commensurate with design speeds higher than the value indicated result in safer highways and should be used to the extent practicable.

Standard TC-5.01U(M) (Urban) superelevation based on 4% maximum.

Standard TC-5.04ULS(M) (Urban-Low Speed) superelevation based on 2% maximum may be used with a design speed of 70 km/h or less (70 km/h = 211 m minimum radius).

A minimum 9.2 m width of surfacing or a minimum 9.2 m curb to curb is to be used within incorporated cities or towns to qualify for maintenance payments.

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS				
TYPE OF TERRAIN	DESIGN SPEED (km/h)			
	50	60	70	80
	GRADES (PERCENT)			
LEVEL	9	9	8	7
ROLLING	11	10	9	8
MOUNTAINOUS	12	12	11	10

Clear zone and Recoverable Area information can be found in Appendix A(M), Section A-2(M) of the Road Design Manual.

Maximum grades of short lengths (less than 150 m) and one-way down grades may be 2% steeper.

FOOTNOTES

(1) 3.6 m if ADT exceeds 2000. Where feasible, lanes should be 3.6 m wide in industrial areas; however, where available or attainable right of way imposes severe limitations, 3.0 m lanes can be used in residential areas and 3.3 m lanes can be used in industrial areas.

(2) Lane width to be 3.6 m at all interchange locations.

(3) Or equivalent City or Town Design.

(4) A width of 2.4 m or more may be needed in commercial areas.

(5) 3:1 and flatter slopes may be used when right of way is behind the sidewalk (or sidewalk space) in residential or other areas where the slopes will be maintained by the property owner.

(6) Ditch slopes to be 4:1 - 1.8 m width and 3:1 - 1.2 m width.

(7) When Design year ADT exceeds 2000VPD, with greater than 5% total truck and bus usage:
Provide 1.2 m wide paved shoulders when the graded shoulder is 1.5 m wide or greater or provide 1 m wide paved shoulders when the graded shoulder is 1.2 m wide. All shoulders not being paved will have the mainline pavement structure extended 0.3 m, on the same slope, into the shoulder to eliminate raveling at the pavement edge.

(8) Where the approach roadway width (traveled way plus shoulder) is surfaced, that surfaced width shall be carried across all structures if that width exceeds the width shown in this table.

(9) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m desirable and 4.45 m minimum (0.3 m additional clearance required for non-vehicular overpasses).

(10) If a buffer strip is used between the back of curb and sidewalk, it should be 0.6 m minimum.

(11) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 7M

GEOMETRIC DESIGN STANDARDS FOR URBAN LOCAL STREET SYSTEM (GS-8M)

	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)		(1) MAX. PERCENT OF GRADE	(11) STOPPING SIGHT DISTANCE (METERS)	(2) MIN. WIDTH OF LANE	(3) STANDARD CURB & GUTTER	(4) BUFFER STRIP WIDTH	(5) MIN. SIDEWALK WIDTH	(6) SLOPE	(9) (10) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
		U	ULS								
STREETS WITH CURB & GUTTER	50	99	94	15	58m	3.0m	CG-6	(10)	1.5m	2:1	SAME AS CURB TO CURB OF APPROACHES
	30	34	24		30m						

	DESIGN SPEED (km/h)	MINMUM RADIUS (METERS)		(1) MAX. PERCENT OF GRADE	STOPPING SIGHT DISTANCE (METERS)	(2) MIN. WIDTH OF LANE	(7) MIN. WIDTH GRADED SHOULDERS		(8) WIDTH OF DITCH (FRONT) SLOPE	(6) SLOPE	(9) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS AND VERTICAL CLEARANCES
		U	ULS				FILL W/GR.	CUT & FILL			
STREETS WITH SHOULDER DESIGN	50	99	94	15	58m	3.0m	2.1 m	1.2 m	1.2 m	3:1	1.2 m + PAVEMENT WIDTH +1.2 m
	30	34	24		30m						

GENERAL NOTES

Design Speeds is not a major factor for local streets. For consistency in design elements, design speeds ranging from 30 to 50 km/h may be used, depending on available right of way, terrain, adjacent development and other area controls.

In the typical street grid, the closely spaced intersections usually limit vehicular speeds, making the effect of a design speed of less significance.

Design speeds exceeding 50 km/h in residential areas may require longer sight distances and increased curve radii, which would be contrary to the basic function of a local street.

Standard TC-5.01U(M) (Urban) superelevation based on 4% maximum.

Standard TC-5.04ULS(M) (Urban Low Speed) superelevation based on 2% maximum may be used with a design speed of 70 km/h or less (70 km/h = 227 m minimum radius).

A minimum 9.2 m width of surfacing or a minimum 9.2 m curb to curb is to be used within incorporated cities or towns to qualify for maintenance payments.

FOOTNOTES

(1) Grades in commercial and industrial areas should be less than 8 percent; desirably, less than 5 percent.

(2) Where feasible, lanes should be 3.3 m wide and in industrial areas should be 3.6 m wide; however, where available or attainable right of way imposes severe limitations, 2.7 m lanes can be used in residential areas and 3.3 m lanes can be used in industrial areas.

(3) Or equivalent City or Town design.

(4) The minimum buffer strip width with no sidewalk or sidewalk space is to be 1.5 m.

(5) Widths of 2.4 m or more may be needed in commercial areas.

(6) 3:1 and flatter slopes may be used when the right of way is behind the sidewalk (or sidewalk space) in residential or other areas where slopes will be maintained by the property owner.

(7) When Design year ADT exceeds 2000 VPD, with greater than 5% total truck and bus usage:
Provide 1.2 m wide paved shoulders when the graded shoulder is 1.5 m wide or greater or provide 1 m wide paved shoulders when the graded shoulder is 1.2 m wide. All shoulders not being paved will have the mainline pavement structure extended 0.3 m, on the same slope, into the shoulder to eliminate raveling at the pavement edge.

(8) Ditch slopes to be 3:1 - 1.2 m width.

(9) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m desirable and 4.45 m minimum (0.3 m additional clearance required for non-vehicular overpasses).

(10) If a buffer strip is used between the back of curb and sidewalk, it should be 0.6 m minimum.

(11) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 8M

GEOMETRIC DESIGN STANDARDS FOR SERVICE ROADS (GS-9M)

(1) DEAD END SERVICE ROADS UNDER 25 VPD									
PROPERTIES SERVED	DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)	STOPPING SIGHT DISTANCE (METERS)	MINIMUM PASSING SIGHT DISTANCE (METERS)	(2) MINIMUM TRAVELED WAY WIDTH	MINIMUM WIDTH OF SHOULDER		(3) WIDTH OF DITCH (FRONT SLOPE)	SLOPES
						FILL W/GR.	CUT & FILL		
1	20	10	40	-	3.6m	1.2m	0.6m	0.9m	(4)
OVER 1	30	29	70	20	4.2m	1.5m			

GENERAL NOTES

The minimum design speed for service roads should be 30 km/h except for one lane service roads serving one property which may have a minimum design speed of 20 km/h.

Standard TC-5.01R(M) superelevation based on 8% maximum to be used (See 2001 AASHTO "Green Book").

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEEDS				
TYPE OF TERRAIN	DESIGN SPEED (km/h)			
	20	30	50	60
	GRADES (PERCENT)			
LEVEL	8	8	7	7
ROLLING	12	11	10	9
MOUNTAINOUS	18	16	14	12

FOOTNOTES

(1) For through service roads and dead end service roads with over 25 VPD, use Standards shown for Local Roads and Streets.

(2) Under adverse conditions, intermittent shoulder sections or turnouts for passing may be required (see page 411, 2004 AASHTO "Green Book").

(3) Ditch slope to be 3:1.

(4) Slopes to be same as mainline when service road is parallel to or otherwise visible from the mainline. For other cases slopes should be in accordance with standards for Local Roads and Streets.

FIGURE A - 1 - 9M

GEOMETRIC DESIGN STANDARDS FOR INTERCHANGE RAMPS (GS-RM)

	RAMP DESIGN SPEED (km/h)	MINIMUM RADIUS (METERS)	(6) STOPPING SIGHT DISTANCE (METERS)	(1) MINIMUM RAMP PAVEMENT WIDTHS	MINIMUM WIDTH OF SHOULDER					(5) WIDTH OF DITCH (FRONT SLOPE)	(4) NEW AND RECONSTRUCTED MINIMUM BRIDGE WIDTHS
					RIGHT OF TRAFFIC		LEFT OF TRAFFIC				
					GRADED WIDTH	(2)(3) PAVED WIDTH	GRADED WIDTH		(2) (3) PAVED WIDTH		
			MIN.				FILL W/GR.	CUT & FILL			
INTERCHANGE RAMPS	100	394	185	4.8m	3.3m	2.4m	2.7m	1.8m	1.2m	3.0m	1.8 m PLUS PAVEMENT WIDTH PLUS 2.4 m
	80	230	130								
	60	124	85								
	50	83	65								
	40	51	50	5.4m							
	30	29	35								
AUXILIARY LANES											AUXILIARY LANE SHOULDER WIDTHS ARE TO BE THE SAME AS MAINLINE THROUGH LANES

GENERAL NOTES

The determination of the proper design speed for any particular ramp should be made using guidelines shown in Exhibit 10-56 of the 2004 AASHTO "Green Book".

Standard TC-5.01R(M) is to be used. Maximum ramp superelevation to be 8% (See 2001 AASHTO "Green Book").

Clear Zone and Recoverable Area information

RELATIONSHIP OF MAXIMUM GRADES TO DESIGN SPEED			
DESIGN SPEED (km/h)			
20 - 30	40 - 50	60	70 - 80
GRADES (PERCENT)			
6 - 8	5 - 7	4 - 6	3 - 5

can be found in Appendix A(M), Section A-2(M) of the Road Design Manual.

Where topographic conditions dictate, grades steeper than desirable may be used. One-way descending gradients on ramps should be held to the same general maximums, but in special cases they may be 2 percent greater.

FOOTNOTES

(1) Interchange ramp widths shown are for one lane traffic. For two lane or other conditions see Exhibit 10-67 in the 2004 AASHTO "Green Book"..

(2) Shoulder widths on ramps with a design speed of 40 mph or less may be reduced to 1.8 m right, or 0.9 m left, when justifiable. However, the sum of the right and left shoulder shall not be less than 3.0 m. See 2004 AASHTO "Green Book", page 838.

(3) On ramps with a radius of less than 150 m, consider (depending on radius and percent of trucks) the extension of the full pavement structure (on the same slope as the pavement) through the inside paved shoulder area to eliminate raveling of the pavement edge.

(4) Vertical clearance at roadway underpasses for new and reconstructed bridges is to be 5.05 m desirable and 4.42 m minimum (0.3 m additional clearance required for non-vehicular overpasses).

(5) Ditch slopes to be 6:1.

(6) For intersection sight distance requirements, see Appendix C, Table C-1-5.

FIGURE A - 1 - 10M

SECTION A-2M-CLEAR ZONE GUIDELINES

INTRODUCTION

If practicable, a traversable recovery area for errant vehicles should be provided beyond the edge of the traveled way (edge of mainline pavement) in order to improve highway safety. Ideally this recovery area or "clear zone" should be free of obstacles such as unyielding sign and luminaire supports, non-traversable drainage structures, utility poles and steep slopes. It must be noted that clear zone roadside design involves a series of compromises between "absolute" safety and "engineering, environmental and economic constraints." The following clear zone guidelines were developed using the AASHTO Roadside Design Guide.

The recommended width of clear zone as discussed in the Roadside Design Guide is influenced by the traffic volume, speed, and embankment slope (see TABLE A-2-1M). The Roadside Design Guide will be used as reference for determination of clear zones for Freeways; Rural and Urban Arterials (with shoulders); and Rural and Urban Collectors (with shoulders) with design speeds of 80 kph or greater and with design year ADT volumes greater than 2000. For Rural and Urban collectors with design speeds less than 80 kph and with a design year ADT less than 2000 and for Local Roads, no minimum required clear zone width will be specified; however, the designer should strive to provide as much clear zone as possible with a minimum 3.0 meter width being desirable. Projects such as RRR, intersection improvements, etc., would not normally be provided with recoverable areas due to the intent of the project to provide minimal improvements and extend the service life of an existing highway for a fraction of the costs of reconstruction or to provide necessary interim improvements.

When adequate right of way is available, urban projects should be designed with shoulders in lieu of curbs (unless city ordinances require otherwise) and they should have clear zone widths consistent with their design speeds, traffic volumes, and embankment slopes as noted in TABLE A-2-1M.

In urban and suburban areas where curb is utilized with a design speed of 70 kph or less, a 2.3 meter desirable and 1.8 meter minimum clear zone beyond the curb face is to be provided (see FIGURE A-2-1M). It is policy to place utility poles or other fixed objects outside the clear zone (beyond the sidewalk space or behind the curb in the case of a raised median). However, in rare instances this may be impractical due to prevailing limitations or conditions (example - relocation of utility poles to another corridor may not be economically feasible). When this occurs, an absolute minimum horizontal clearance of 0.5 meters beyond the face of curb is to be provided (per Roadside Design Guide Section 3.4.1 page 3-14) and 2004 AASHTO “Green Book”, page 319. The justification for not providing the 2.3 meter desirable or 1.8 meter minimum clear zone width beyond the curb face is to be documented in the project file (e.g. - F.I. Report, memorandum from R/W Division Utility Section, etc.). When mountable curb is used in urban areas it is desirable to provide the same clear zone as would be provided for with a rural condition. However, if those values cannot be obtained, the clear zone widths for 70 kph or less should be utilized.

DESIGN SPEED	DESIGN ADT	FORESLOPES			BACKSLOPES		
		6:1 or Flatter	5:1 to 4:1	3:1	3:1	5:1 to 4:1	6:1 or Flatter
60 km/h or less	Under 750	2.0-3.0	2.0-3.0	**	2.0-3.0	2.0-3.0	2.0-3.0
	750-1500	3.0-3.5	3.5-4.5	**	3.0-3.5	3.0-3.5	3.0-3.5
	1500-6000	3.5-4.5	4.5-5.0	**	3.5-4.5	3.5-4.5	3.5-4.5
	Over 6000	4.5-5.0	5.0-5.5	**	4.5-5.0	4.5-5.0	4.5-5.0
70-80 km/h	Under 750	3.0-3.5	3.5-4.5	**	2.5-3.0	2.5-3.0	3.0-3.5
	750-1500	4.5-5.0	5.0-6.0	**	3.0-3.5	3.5-4.5	4.5-5.0
	1500-6000	5.0-5.5	6.0-8.0	**	3.5-4.5	4.5-5.0	5.0-5.5
	Over 6000	6.0-6.5	7.5-8.5	**	4.5-5.0	5.5-6.0	6.0-6.5
90 km/h	Under 750	3.5-4.5	4.5-5.5	**	2.5-3.0	3.0-3.5	3.0-3.5
	750-1500	5.0-5.5	6.0-7.5	**	3.0-3.5	4.5-5.0	5.0-5.5
	1500-6000	6.0-6.5	7.5-9.0	**	4.5-5.0	5.0-5.5	6.0-6.5
	Over 6000	6.5-7.5	8.0-10.0*	**	5.0-5.5	6.0-6.5	6.5-7.5
100 km/h	Under 750	5.0-5.5	6.0-7.5	**	3.0-3.5	3.5-4.5	4.5-5.0
	750-1500	6.0-7.5	8.0-10.0*	**	3.5-4.5	5.0-5.5	6.0-6.5
	1500-6000	8.0-9.0	10.0-12.0*	**	4.5-5.5	5.5-6.5	7.5-8.0
	Over 6000	9.0-10.0*	11.0-13.5*	**	6.0-6.5	7.5-8.0	8.0-8.5
110 km/h	Under 750	5.5-6.0	6.0-8.0	**	3.0-3.5	4.5-5.0	4.5-5.0
	750-1500	7.5-8.0	8.5-11.0	**	3.5-5.0	5.5-6.0	6.0-6.5
	1500-6000	8.5-10.0*	10.5-13.0	**	5.0-6.0	6.5-7.5	8.0-8.5
	Over 6000	9.0-10.5*	11.5-14.0*	**	6.5-7.5	8.0-9.0	8.5-9.0

TABLE A-2-1M CLEAR ZONE DISTANCES
(In meters from edge of driving lane)

* Where a site specific investigation indicates a high probability of continuing accidents, or such occurrences are indicated by accident history, the designer may provide clear zone distances greater than 9 meters as indicated. Clear zones may be limited to 9 meters for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high speed vehicles that encroach beyond the edge of shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right of way availability, environmental concerns, economic factors, safety needs, and accident histories. Also, the distance between the edge of the travel lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of slope. While the application may be limited by several factors, the fill slope parameters which may enter into determining a maximum desirable recovery area are illustrated in FIGURE A-2-4M .

Source: The 2002 AASHTO Roadside Design Guide and errata August 2001- February 2003.

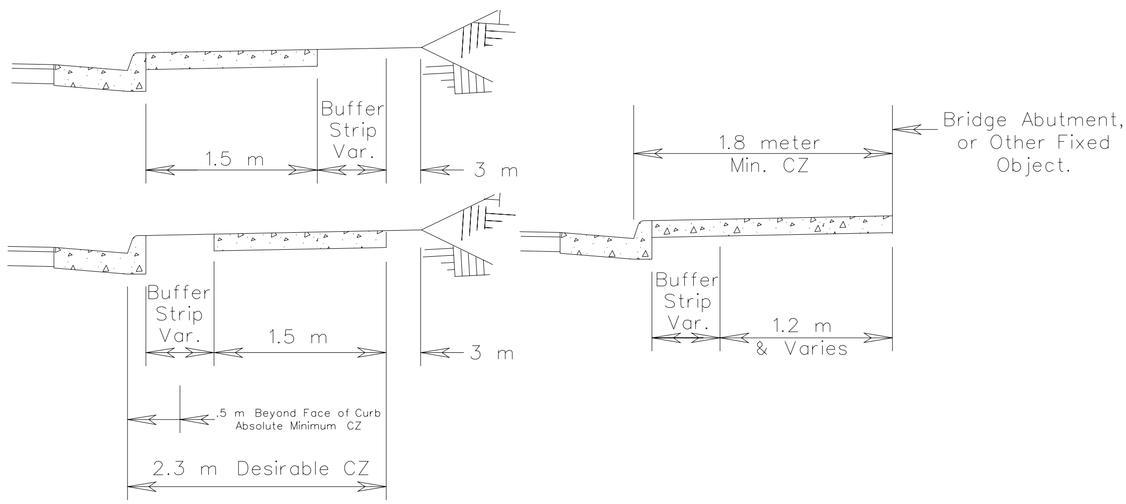


FIGURE A-2-1M
URBAN CLEAR ZONE WIDTH GUIDELINES

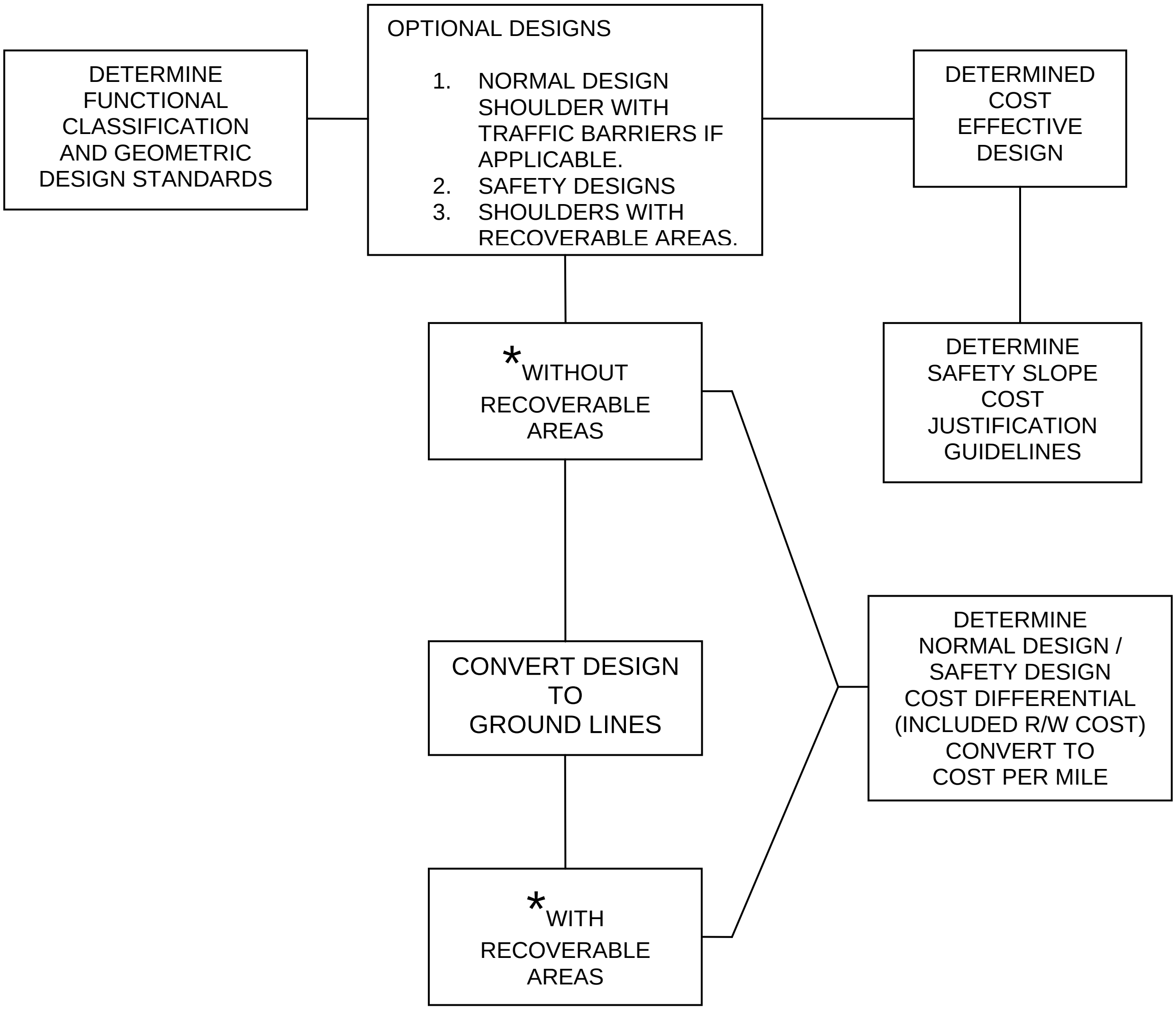
CLEAR ZONE COST-EFFECTIVENESS ANALYSIS

For projects where the clear zone widths from the AASHTO Roadside Design Guide are under consideration, Freeways; Rural and Urban Arterials (with shoulders); and Rural and Urban Collectors (with shoulders) with design speeds of 80 kph or greater and with a design year ADT greater than 2000, an early cost-effectiveness analysis is required to determine the feasibility of providing the recoverable areas to meet the clear zone requirements shown in TABLE A-2-1M. This analysis should be done during the preliminary plan development process and should involve determining the additional construction and R/W costs to provide the desired clear zone. Refer to AASHTO's Roadside Design Guide, Appendix A, for "A Cost-Effective Selection Procedure". Any other procedure which will provide this cost is acceptable as long as it is documented in the project files. After the additional cost to provide the recoverable area is determined, it should be compared to the estimated accident cost without the recoverable area. This cost comparison along with good engineering judgment should be used to determine the feasibility of providing the recoverable areas through the project and should be documented on the Project Scoping Form LD-430 or SR-1 as applicable.

Prior to establishing the additional construction and R/W cost estimate, the developed areas that would involve heavy R/W damages and/or relocations or environmental restrictions such as park properties, historic areas or wetlands should be noted and where practicable horizontal and vertical alignment adjustments are to be made to provide the desired recoverable areas and clear zones. In these situations alternate designs may include elimination of ditches and/or median width reductions with possible incorporation of raised medians or median barrier to reduce required R/W.

A suggested procedure is shown in FIGURE A-2-2M to develop the difference in cost between the typical section based on the project's functional classification and proper Geometric Design Standards and the typical section with the desired recoverable areas. Any other procedure which will provide this cost is acceptable as long as it is documented in the project files. After the additional cost to provide the recoverable area is determined, it should be compared to the estimated accident cost without the recoverable area as determined from FIGURE A-2-3M. This cost comparison along with good engineering judgment should be used to determine the feasibility of providing the recoverable areas through the project and should be documented on the Project Scoping Form LD-403 or SR-1 as applicable.

FIGURE A-2-2 M



* GEOPAK
DESIGN CROSS SECTION LISTING
EARTHWORK VOLUME COMPUTATIONS

COST EFFECTIVE SELECTION PROCEDURES

Note: Upon receipt of normal design and safety design earthwork quantities, a cursory review may indicate that the cost per side for the earthwork alone far exceeds the cost per mile for safety slopes, thereby eliminating the need to determine the other additional costs such as drainage extensions, right of way, etc.

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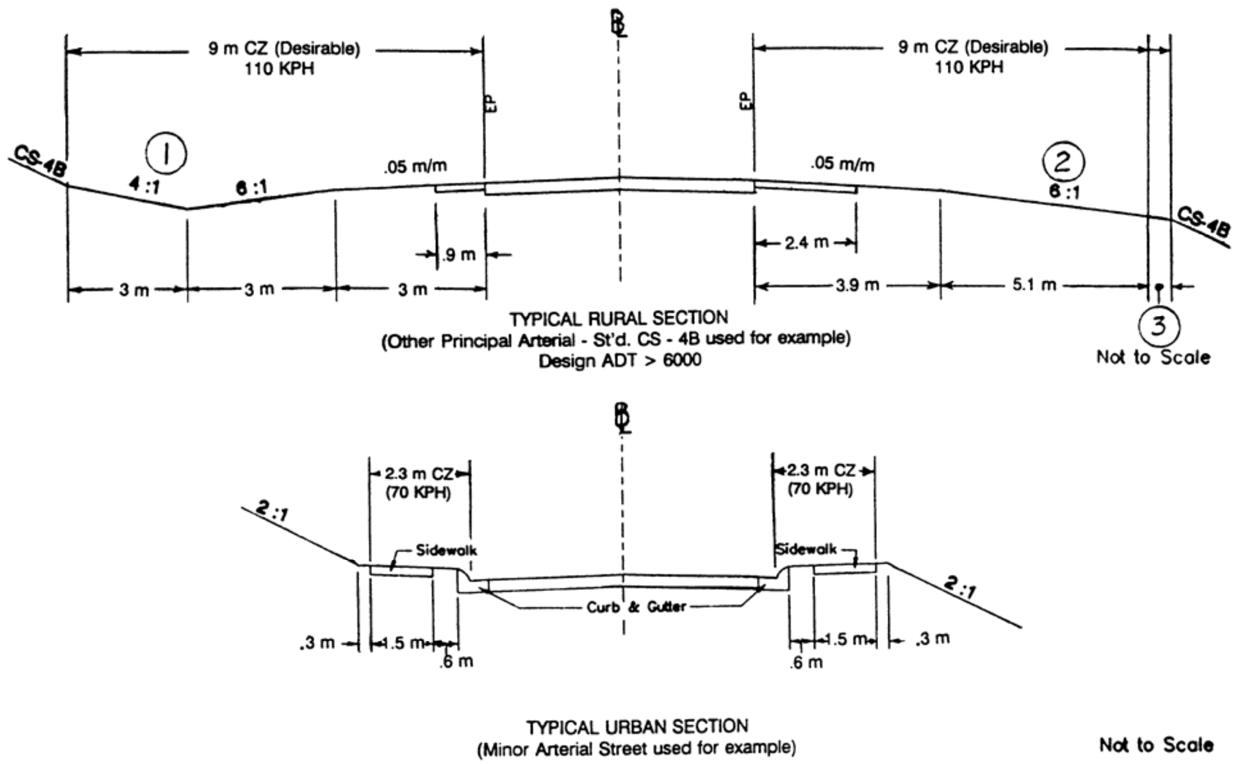
SHOWING CLEAR ZONES ON TYPICAL SECTIONS

The clear zone width(s) is to be clearly shown on the project typical sections if traversable slopes are being provided so that other divisions will be aware of the desirable clear zones for a project. When varying clear zone widths occur, furnish station to station breakdown. Following are typical methods of showing clear zone data on typical sections.



TYPICAL METHOD
OF SHOWING CLEAR ZONE DATA
ON TYPICAL SECTIONS

NOTES:

1. If the front slope of ditch is 6:1, the back slope should be 4:1, and if the front slope is 3:1, the back slope should be flat.

2. The preferred slope for recoverable areas with fills is 6:1 or flatter.

3. Recoverable area width to be increased 1 meter if GR-3 or 8 guardrail is required.

DETERMINING CLEAR ZONE WIDTH

The following is a guide and should be supplemented with sound engineering judgment:

Clear zone (CZ) is defined as the roadside border area, starting at the edge of the traveled way (edge of mainline pavement), available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope 4:1 or flatter, a non-recoverable slope between 4:1 and 3:1, and/or a clear run-out area. Previously, 9 m was considered to be the standard clear zone, but current guidelines, as shown in TABLE A-2-1M, give values greater or less than 9 m, depending on the roadside slopes, design speeds, and traffic volumes. These values should suggest only the approximate center of a range to be considered and not a precise distance to be held as absolute.

TABLE A-2-1M is to be used by the designer and may be modified by the values shown in TABLE A-2-2M. See the AASHTO Roadside Design Guide for further details.

Embankment slopes must have a relatively smooth and firm surface to be truly recoverable or traversable.

Fill slopes between 3:1 and 4:1 are non-recoverable slopes, defined as one which is traversable, but from which most motorists will be unable to stop or to return to the roadway easily. Vehicles on such slopes typically can be expected to reach the bottom. Since a high percentage of encroaching vehicles will reach the toe of these slopes, the recovery area cannot logically end on the slope. Fixed obstacles should not be constructed along such slopes and a clear runout area (3 m min.) at the base is desirable. Figure A-2-4M on page A-40 (Metric) provides an example of a clear zone computation for non-recoverable slopes.

Any non-traversable hazards or fixed objects, including but not limited to those listed in TABLE A-3-1M, page A-44 (Metric) which are located within the clear zone as determined from TABLE A-2-1M, should preferably be removed, relocated, made yielding, or as a last resort, shielded with a barrier.

HORIZONTAL CURVE ADJUSTMENTS

These modifications are normally only considered where accident histories indicate a need, or a specific site investigation shows a definitive accident potential which could be significantly lessened by increasing the clear zone width and such increases are cost effective.

TABLE A-2-2M

(K_{cz}) (Curve Correction Factor)

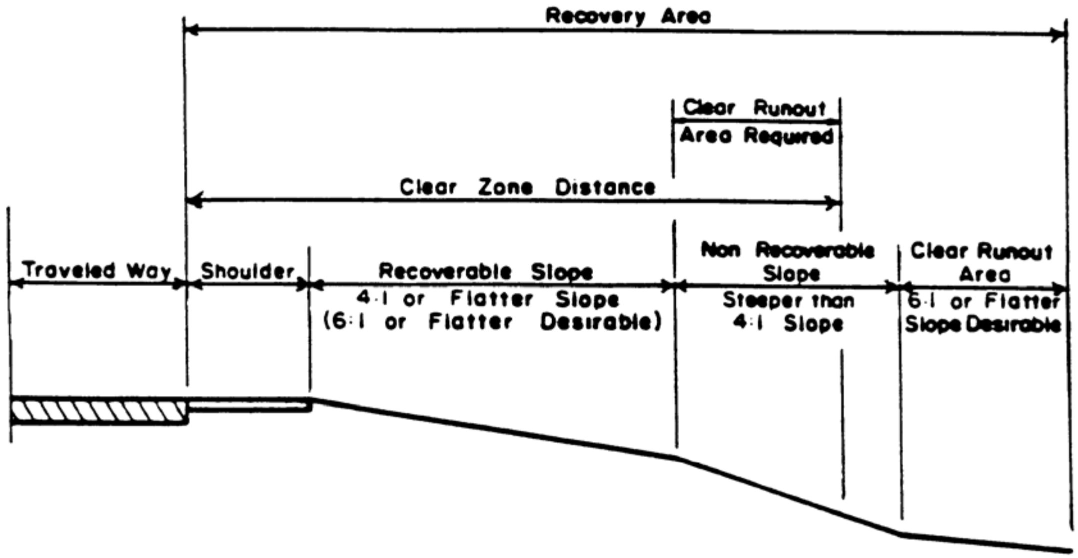
CURVE RADIUS (METERS)	DESIGN SPEED					
	60	70	80	90	100	110
900	1.1	1.1	1.1	1.2	1.2	1.2
700	1.1	1.1	1.2	1.2	1.2	1.3
600	1.1	1.2	1.2	1.2	1.3	1.4
500	1.1	1.2	1.2	1.3	1.3	1.4
450	1.2	1.2	1.3	1.3	1.4	1.5
400	1.2	1.2	1.3	1.3	1.4	1.4
350	1.2	1.2	1.3	1.4	1.5	
300	1.2	1.3	1.4	1.5	1.5	
250	1.3	1.3	1.4	1.5		
200	1.3	1.4	1.5			
150	1.4	1.5				
100	1.5					

$CZ_c = (L_c)\ (K_{cz})$ K_{cz} = curve correction factor

Where CZ_c = clear zone on outside of curvature, ft.
L_c = clear zone distance ft., Table A-2-1M

Note: Clear zone correction factor is applied to outside of curves only. Curves with radius greater than 875 meters don't require an adjusted clear zone.

FIGURE A-2-4M EXAMPLE OF A PARALLEL EMBANKMENT SLOPE DESIGN



Source: The AASHTO Roadside Design Guide.

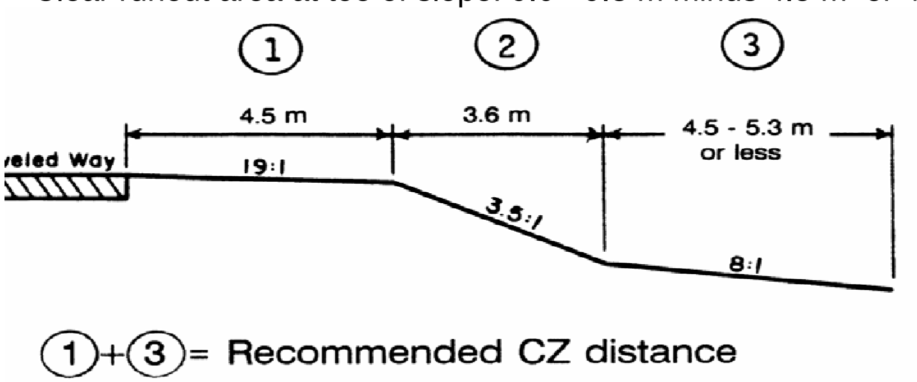
This figure illustrates a recoverable slope followed by a non-recoverable slope. Since the clear zone distance extends onto a non-recoverable slope, the portion of the clear zone distance on such a slope may be provided beyond the non-recoverable slope if practical. This clear runout area would then be included in the total recovery area. The clear runout area may be reduced in width based on existing conditions or site investigations. Such a variable slope typical section is often used as a compromise between roadside safety and economics. By providing a relatively flat recovery area immediately adjacent to the roadway, most errant motorists can recover before reaching the steeper slope beyond. The slope break may be liberally rounded so an encroaching vehicle does not become airborne. It is suggested that the steeper slope be made as smooth as practical and rounded at the bottom.

NON-RECOVERABLE PARALLEL SLOPES

Embankment slopes from 3:1 up to 4:1 are considered traversable if they are smooth and free of fixed object hazards. However, since many vehicles on slopes this steep will continue on to the bottom, a clear run-out area beyond the toe of the slope is desirable. The extent of this recovery area could be determined by first finding the available distance between the edge of the traveled way and the breakpoint of the recoverable slope to the non-recoverable slope. This distance is then subtracted from the total recommended clear zone distance based on the slope that is beyond the toe of the non-recoverable slope. The result is the desirable clear run-out area. The following example illustrates this procedure:

EXAMPLE

Design ADT: 7000
Design Speed: 100 kph
Recommended clear zone distance for the 8:1 slope: 9 - 9.8 m (from TABLE A-2-1)
Recovery distance before breakpoint of slope: 4.5 m
Clear runout area at toe of slope: 9.0 - 9.8 m minus 4.5 m or 4.5 - 5.3 m

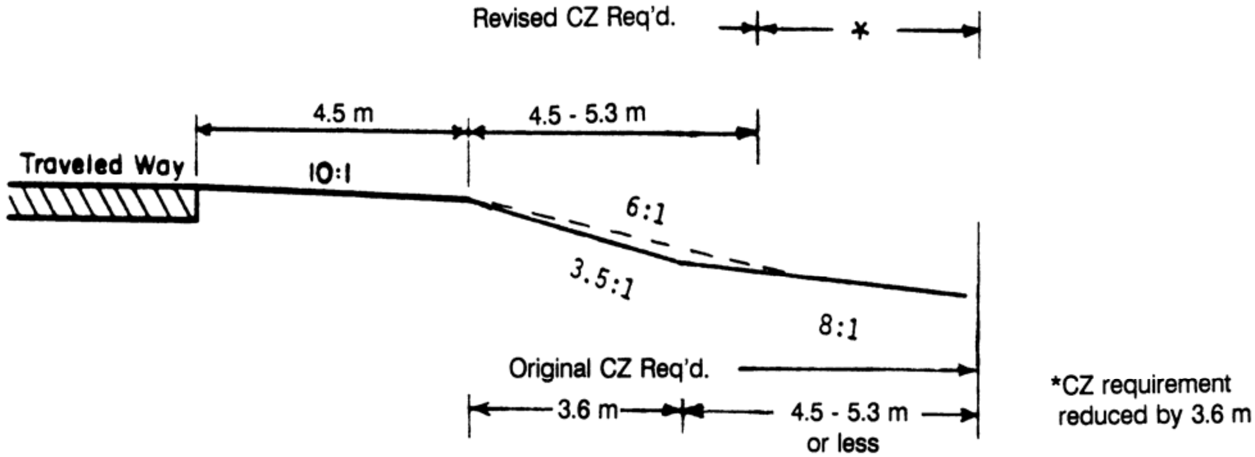


(For Example of Alternate Design to reduce CZ requirement, see below)

Discussion: Using the steepest recoverable slope before or after the non-recoverable slope, a recovery distance is selected from Table A-2-1M. In this example, the 8:1 slope beyond the base of the fill dictates a 9.0 - 9.8 m recovery area. Since 4.5 m are available at the top, an additional 4.5 - 5.3 m could be provided at the bottom. All slope breaks may be rounded and no fixed objects would normally be built within the upper or lower portions of the clear zone or on the intervening slope.

The designer may find it safe and practical to provide less than the entire 4.5 - 5.3 m at the toe of the slope. A smaller recovery area could be applicable based on the rounded slope breaks, the flatter slope at the top, or past accident histories. A specific site investigation may be appropriate in determining an appropriate recovery area at the toe of the slope.

Example of Alternate Design (incorporating minor slope adjustment) to reduce total clearance requirement.



When traffic barriers must be provided because hazardous conditions can not be eliminated, see Section A-3-Barrier Installation Criteria.

SECTION A-3M-TRAFFIC BARRIER INSTALLATION CRITERIA

INTRODUCTION

Traffic Barriers should only be used where the result of striking a fixed object hazard or leaving the roadway would be more severe than the consequence of striking the barrier. Where guardrail needs are indicated by warrants see the current AASHTO Roadside Design Guide. The roadway should be examined to determine the feasibility of adjusting site features so that the barrier will not be required (i.e. flattening a fill slope, removing a hazardous object, such as a drainage headwall, etc.) The initial cost to eliminate the guardrail may appear excessive; however, the fact that a barrier installation will require maintenance costs for many years should not be overlooked.

GUARDRAIL WARRANTS

The determining warrants for Traffic Barriers on VDOT projects are (1) Embankment Heights (see below) and (2) Fixed and Hazardous Objects Within the Clear Zone (see TABLE A-3-1M).

SYSTEM CLASSIFICATION		TRAFFIC VOLUMES	FILLS OVER 2.3 m	FILLS OVER 4.6 m	AT OBVIOUS NEEDS SUCH AS BRIDGES, LARGE END WALLS, PARALLEL WATER HAZARDS, ETC., AND FILLS WHERE RECOMMENDED DURING FIELD INSPECTION
INTERSTATE - PRIMARY AND ARTERIAL	FILLS WITHOUT RECOVERABLE AREAS	ALL	√		√
	FILLS WITH RECOVERABLE AREAS				√
SECONDARY AND FRONTAGE ROADS		ADT OVER 1000	√		√
		ADT 1000 - 250		*√	√
		ADT LESS THAN 250			√
URBAN		ALL			√

* Exception - Bristol, Salem, and Staunton Districts. Traffic barriers are to be provided only at obvious needs such as bridges, large endwalls, parallel water hazards, etc., and fills where recommended at field inspection.

When fill slopes are 3:1 or flatter, a barrier is not required unless there are hazardous obstacles within the clear zone limits. This may include the clear runout area if the fill slope is between 3:1 and 4:1 (see Fig. A-2-4M).

DETERMINING WARRANTS FOR ROADSIDE BARRIERS

Fixed and Hazardous Objects Within The Clear Zone	Guardrail Required	
	YES	NO
1. Sign Support (ground mounted): (A) Post of breakaway design (a)		X
(B) Post not meeting breakaway criteria (b)(c)(d)	X	
2. Lighting/Signal Poles and Towers (A) Breakaway design		X
(B) Not meeting breakaway design (b)(c)(g)(h)	X	
3. Bridge parapet ends, piers and abutments at underpasses	X	
4. Retaining walls and culvert headwalls	X	
5. Trees with a diameter of 100 mm or greater (e)	X	
6. Utility Poles (f)		X
7. Above ground utilities (telephone pedestals, etc.) (i)	X	
8. Rough rock cuts and large boulders	X	
9. Streams or permanent bodies of water more than 0.6 m deep (h)	X	

NOTES

(a) Multiple post installations where the spacing between posts is less than the minimum spacing required for breakaway shall be replaced or shielded by guardrail.
(b) Every effort should be made to convert non-breakaway to breakaway.
(c) Where these devices exist and cannot be converted to breakaway, relocated or removed, the choice of guardrail should be in accordance with the deflection shown in Table A-3-2M.
(d) Wood posts larger than 150 mm x 200 mm nominal size do not meet the breakaway requirements even if drilled.
(e) Every effort should be made to remove the tree rather than shield it with guardrail.
(f) Guardrail will not normally be used to shield a line of utility poles. However, where guardrails are used in front of utility poles for other reasons, the choice of guardrail should be in accordance with the deflection shown in Table A-3-2M.
(g) Pedestal poles, except for those used for power supply, should be converted to breakaway standards where possible.
(h) A field review and evaluation should be made to determine if guardrail is suitable for protecting motorists from these roadside hazards.
(i) Consideration should be given to placing utilities underground.

TABLE A-3-1M

BARRIER TYPE SELECTION

When it has been determined that a barrier is required, a determination must be made as to the type of barrier that is to be used. Although the process is complicated by the number of variables and the lack of objective criteria, there are guidelines that can be used in making a barrier system selection. In general, the most desirable system is one that offers the lowest accident severity at the least cost and is consistent with the given constraints. The Standard GR-8 Weak Post System is to be used only when speeds are $\leq$ 70 km/h.

The AASHTO Roadside Design Guide presents eight items which must be considered before a system selection is made. In taking all eight items into account, the deflection, strength, and safety requirements should never be compromised. Table A-3-2M groups the Standard types of guardrail by three systems: flexible, semi-rigid and rigid. The table includes barrier height, maximum dynamic deflection, minimum offset from hazardous object, post spacing, and typical terminal treatment for each Standard. The Road and Bridge Standards provide transition designs for use in various situations.

TABLE A-3-2M - TYPICAL BARRIER/GUARDRAIL SELECTION AND PLACEMENT

SYSTEM	STANDARD	MINIMUM BARRIER HEIGHT	MAXIMUM DYNAMIC DEFLECTION (a)	MINIMUM OFFSET FROM HAZARD (c)	POST SPACING	DIVIDED ROADWAY **OR ONE-WAY TRAFFIC**		**UNDIVIDED ROADWAY** OR TWO-WAY TRAFFIC	
						RUN-ON TERMINAL TREATMENT	RUN-OFF TERMINAL TREATMENT (d)	RUN-ON TERMINAL TREATMENT	RUN-OFF TERMINAL TREATMENT
FLEXIBLE (WEAK POST OR CABLE)	GR-3	685	3.3	3.3	4.9	GR-3	GR-3	GR-3	GR-3
	GR-8(I)	760	2.1	2.1	3.81	GR-6, 7 ,9 (h)	GR-8,Ty.II	GR-6, 7 ,9 (e) (h)	GR-6, 7 ,9 (e) (h)
	GR-8A	760	1.5	1.5	1.905	GR-6, 7, 9 (h)	GR-8,Ty.II	GR-6, 7 ,9 (e) (h)	GR-6, 7 ,9 (e) (h)
	GR-8B	760	1.2	1.2	0.952	GR-6, 7, 9 (h)	GR-8,Ty.II	GR-6, 7 ,9 (e) (h)	GR-6, 7 ,9 (e) (h)
	GR-8C	760	1.4	1.4	1.27	GR-6, 7, 9 (h)	GR-8,Ty.II	GR-6, 7 ,9 (e) (h)	GR-6, 7 ,9 (e) (h)
	MB-5 (f)	760	2.1	2.1	8.81	IMPACT ATT.	IMPACT ATT.	N/A	N/A
	MB-5 (f)	760	1.5	1.5	1.905	IMPACT ATT.	IMPACT ATT.	N/A	N/A
	MB-5 (f)	760	1.2	1.2	0.952	IMPACT ATT.	IMPACT ATT.	N/A	N/A
SEMI-RIGID (STRONG POST)	GR-2	685	0.9	0.9	1.905	GR-6,7,9 (h)	W BEAM END SECTION	GR-6,7,9 (h)	GR-6,7,9 (h)
	GR-2A	685	0.6 (b)	0.6 (b)	0.952	GR-6,7,9 (h)		GR-6,7,9 (h)	GR-6,7,9 (h)
	MB-3 (g)	685	0.9	0.9	1.905	IMPACT ATT.	IMPACT ATT.	N/A	N/A
RIGID (CONCRETE BARRIER)	MB-7D,7E, 7F,12A,12B, & 12C (k)	810	0'	0'	N/A	IMPACT ATTENUATOR (i)	N/A	IMPACT ATTENUATOR (i)	IMPACT ATTENUATOR (i)

NOTES:

(a) The deflection zone of all rail systems must be totally clear of any obstacles in order to assure that the rail will perform as tested.

(b) No test data available.

(c) Minimum offset from back of post to hazardous object.

(d) The noted terminal treatments apply when the terminal is installed outside the clear zone for opposing traffic. If a run-off terminal is installed within the clear zone of opposing traffic, see note "e".

(e) Transition from weak post system to terminal must be provided in accordance with St'd. GR-INS drawings to protect opposing traffic from impacting the opposite end of the terminal when it falls within clear zone.

(f) For use in wide flat medians (>9m).

(g) For use in narrow medians (approximately 3 m - 9 m).
(h) If more than a 60 m extension of standard guardrail is necessary to tie into the slope with a St'd. GR-6 use a St'd. GR-7 or GR-9 terminal. For St'd. GR-6 installations, St'd. GR-2 must be installed from the terminal to the beginning of the flare before introducing St'd. GR-8.
(i) Concrete turned down terminals may be used for locations outside clear zone.
(k) For use in medians 0 - 9 m wide.
(l) GR-8 is not acceptable on projects with design speeds greater than 70 km/h.

GUARDRAIL INSTALLATION IN URBAN SETTINGS

In Urban settings with speeds of 70 km/h or less that include curb or curb and gutter, the use of guardrail is not recommended. Standard CG-2 or CG-6 (150 mm high curb) is usually used for speeds of 70 km/h or less in urban and suburban areas and is referred to as "barrier curb" because it has a 150 mm vertical face and is intended to discourage motorists from deliberately leaving the roadway. Even when CG-3 or CG-7 (100 mm high mountable curb) is used in Urban settings, it is impractical to install guardrail in an attempt to protect pedestrians walking along sidewalks due to the lack of accessibility caused when placing guardrail and terminals adjacent to accessible routes.

When curbed sections do not include sidewalk or sidewalk space and hazards exist that warrant guardrail, St'd. GR-2 (Strong Post) guardrail (which includes a blockout) should be installed with the face of the rail aligned with the face of the curb. This decreases the possibility of an errant vehicle striking the curb before impacting the guardrail or from snagging the guardrail posts. St'd. GR-8 (Weak Post) guardrail should not be used adjacent to asphalt or concrete curb.

Sometimes hazards that need to be shielded exist on urban projects with sidewalk/sidewalk space. In situations like this, guardrail can be placed behind the sidewalk and in front of the hazard. Examples of such hazards are ponds, steep embankments, etc. When these situations arise, sound engineering judgment should be used in deciding whether/where to place the guardrail. If the hazard is within the clear zone, a barrier would be warranted. The hazards that are outside the clear zone are the items that require an engineering decision based on evaluation of all the elements within the design site.

GUARDRAIL LOCATIONS ON FIELD INSPECTION PLANS

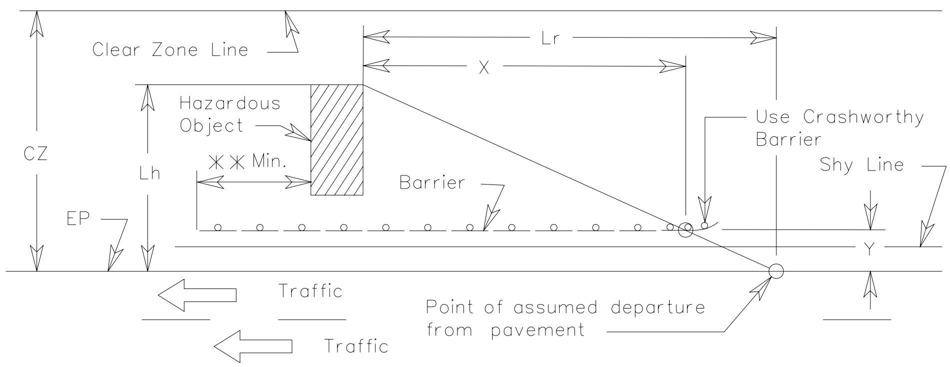
The approximate locations of barriers should be shown on field inspection plans and discussed at the field inspection. If the locations are not shown, the type, terminals, and placement should be generally discussed. Maintenance of areas protected by barriers should also be discussed at this time.

DETERMINING LOCATION OF THE ENDS OF GUARDRAIL

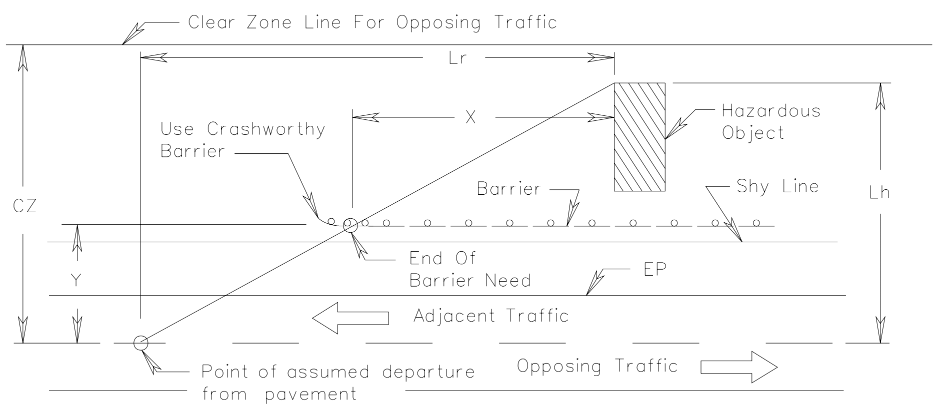
Figure A-3-1M and Table A-3-3M give a method to determine the location of the end of guardrail systems. Appropriate terminals shall be placed at this point.

FIGURE A-3-1M - BARRIER LENGTH OF NEED DETERMINATION

Condition showing hazard for adjacent traffic



Condition showing hazard for opposing traffic



$$X = \left(1 - {}^{Y}/_{L_h}\right) L_r$$

X = Length of Need	** = 7.6 m for GR-2
CZ = Clear Zone Width	= 3.8 m for GR-2A
Lh Max. = CZ	= 7.6 m plus a Type II for GR-8
Lr = Runout length (See table A-3-3M)	= 0.3 m for MB-7C
LS = Shyline	

TABLE A-3-3M
DESIGN PARAMETERS FOR ROADSIDE BARRIER LAYOUT

DESIGN SPEED (km/h)	DESIGN TRAFFIC VOLUME (ADT) OVER 6000 RUNOUT LENGTH Lr (m)	2000-6000 RUNOUT LENGTH Lr (m)	800-2000 RUNOUT LENGTH Lr (m)	UNDER 800 RUNOUT LENGTH Lr (m)	SHY* LINE (m)	FLARE RATE BEYOND SHY LINE GR-2, 3 & 8 MB-3	BEYOND SHY LINE MB-7D, 7E, 7F, 12A, 12B & 12C	INSIDE SHY LINE ALL
110	145	135	120	110	2.8	15:1	20:1	30:1
100	130	120	105	100	2.4	14:1	18:1	26:1
90	110	105	95	85	2.2	12:1	16:1	24:1
80	100	90	80	75	2.0	11:1	14:1	21:1
70	80	75	65	60	1.7	10:1	12:1	18:1
60	70	60	55	50	1.4	8:1	10:1	16:1
50	50	50	45	40	1.1	7:1	8:1	13:1

- Shy line is measured from the adjacent edge of pavement and is a distance beyond which a roadside object will not be perceived as a threat by a driver. In other words, a driver will not react to an object beyond the shy line offset. If possible, the roadside barrier should be placed beyond the shy line offset.

Source: The 2002 Roadside Design Guide Tables 5.5, 5.7 & 5.8.

SLOPES FOR APPROACH BARRIERS

As a general rule, a roadside barrier should not be placed on an embankment if the slope of the embankment is steeper than 10:1; however, in special cases, such as "barn roof" ("recoverable area") slopes, it is acceptable to place semi-rigid barrier on slopes as steep as 6:1. When semi-rigid barrier is used on 6:1 slopes, a 3.0 m rounding should be included between the shoulder and slope. Where it is not feasible for the entire graded median in the area of the hazard to be on a 10:1 slope, an acceptable alternative is to provide the 10:1 slope between the edge of pavement and the approach barrier (See Fig. A-3-2M). A clear run-out path should also be provided behind the terminal.

When recoverable areas are less than 4.3 m in width and guardrail is required, the guardrail is to be placed on a fill with guardrail (W/GR) shoulder and the recoverable area is not to be provided.

Although not encouraged, guardrail is permitted on 6:1 slopes if located beyond 3.6 m of the shoulder hinge point.

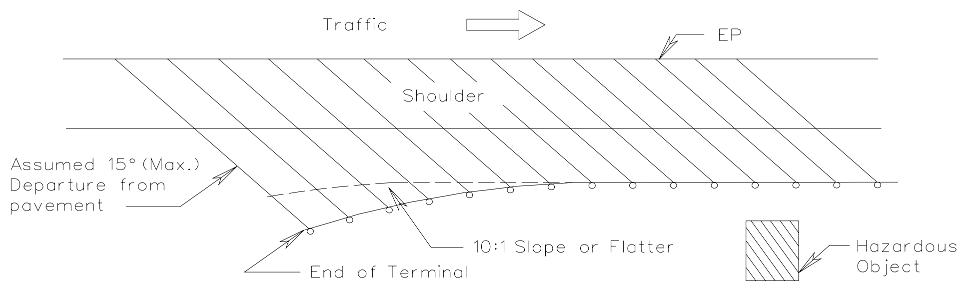


FIGURE A-3-2M - SUGGESTED SLOPES FOR APPROACH BARRIERS

FIXED OBJECTS WITHIN DEFLECTION AREA

No fixed objects, regardless of their distances from the edge-of-pavement, will be allowed within the deflection zone of the guardrail system to assure that the barrier system will perform as designed. This will include overhead sign supports, walls, drainage structures, bridge piers, signal supports, utility poles, trees, etc. Additionally, the deflection zone must be free of breakaway signs, signals, and luminaire supports since their performance when struck by deflecting guardrail is unknown and untested. If a sign or luminaire support must remain within the deflection zone, it must be a breakaway design.

When it is impractical to locate these obstacles outside of the deflection zone of a particular type of guardrail (e.g., GR-8 = 2.1 m, GR-8B = 1.2 m), it will be necessary to strengthen the guardrail to decrease deflection or use a different type of guardrail or barrier which has less deflection so the object is shielded within the clear zone.

Methods of stiffening the rail include decreasing post spacing and double nesting of rail elements. Each stiffening method typically halves the deflection. The stiffening method should begin 5.4 m in advance of the hazard and continue at least to the end of the hazard. Plans fitting these criteria are to be submitted to the Engineering Services Section for review, approval, and details.

Table A-3-2M (Typical Barrier/Guardrail Selection and Placement) specifies the minimum offset distance required from "hazardous objects" to meet deflection requirements of the different types of barrier systems.

FIXED OBJECT ATTACHMENT/TRANSITIONS POLICY

A transition section is needed where flexible (weak-post) roadside guardrail must join a rigid bridge railing, concrete barrier, retaining wall, etc. The transition design produces a gradual stiffening of the overall approach protection system so vehicular pocketing, snagging, or penetration can be reduced or avoided at any position along the transition.

A transition is also needed when a GR-6, GR-7, or GR-9 terminal is used on the run-off end of a flexible (weak-post) guardrail system on undivided roadways with two-way traffic to protect opposing traffic from impacting the opposite end of the terminal. The Road and Bridge Standards include details on guardrail transitions.

A rub rail is provided in Standards GR-FOA-1, -2, and -4 to help prevent potential vehicular snagging at the immediate upstream end of the rigid bridge railing. The rub rail is not necessary on the Special Design GR-FOA-3 as it is attached to a flared terminal wall that has a transitioned face to prevent snagging. Special Design GR-FOA-3 will be retained for use only on bridges that have been designed with the flared terminal wall.

ENTRANCES OR CONNECTIONS ADJACENT TO A BRIDGE

When entrances or connections cannot be relocated or eliminated and are located adjacent to a bridge on low-volume rural roads or in areas with dense entrance locations, it is necessary to install radial guardrail around the entrances or connections. Plans fitting this criteria are to be submitted to the Engineering Services Section for review, approval and details.

GUARDRAIL OVER CULVERT IN FILLS

Standard GR-10, Type I, II or III, is the preferred method of installing guardrail over culverts where fills are less than 1090 mm above the culvert top slab.

Type I is adaptable to culverts with a perpendicular width of 3.2 m or less. A 7.6 m section is used with the rail doubled and one post omitted. Type II is adaptable to culverts with a perpendicular width of 5.1 m. A length of 11.4 m is used with the rail doubled and two posts omitted. Type III is for use with a perpendicular width of 7 m. A length of 30.5 m is used with the rail doubled and three posts omitted.

In situations where the use of Standard GR-10 is not feasible, an allowable alternative may be the TEXAS T-6 (BGR-01) for speeds $\leq$ 70 km/h.

SHORT GAPS

Short gaps between barrier installations should be avoided. When the areas of concern are less than 60 m apart, the barrier protection shall be made continuous.

PONDS OR OTHER BODIES OF WATER

Barrier is to be constructed on all functional classifications at ponds or other bodies of water over 0.6 m in depth.

TERMINAL REQUIREMENTS

Guardrail/barrier terminals are to be provided for all installations regardless of "Functional Classification". Terminals develop the necessary tension at the end of the system in order to redirect a vehicle and, if hit, minimize the damage to a vehicle and its occupants. The termini of guardrail/barrier must be designed and located so there are no exposed rail element ends within the clear zone that a vehicle could impact.

(1) Flexible (Weak Post or Cable) Guardrail Installations -

Cable guardrail should normally be used only on Limited Access projects that provide “Recoverable Areas” exceeding 4.3 m in width. Cable guardrail should be introduced when the height of fill slopes exceeds 6.0 m. This height is based on the hinge point between 6:1 slopes and 2:1 slopes. If the introduction of cable guardrail is in close proximity to an adequate cut section, it should be extended and terminated in the back slope of the cut ditch. (Use 15:1 transition for Design Speeds of 110 km/h or 13:1 transition for Design Speeds of 100 km/h or less). Standard GR-3 (Cable Guardrail) is terminated on both the run-on and run-off ends with an anchor assembly as detailed in St'd. GR-3.

When using GR-8 Weak Post Guardrail, the preferable run-on terminal is St'd. GR-6 which buries the end of the guardrail into a cut slope and anchors the terminal with a concrete block. This terminal treatment requires enough right of way to extend the guardrail a minimum of 3.8 m beyond the ditch line. The guardrail should terminate a minimum of 300 mm below the ground elevation of the backslope. The rail preceding the GR-6 terminal is to maintain a consistent height (760 mm) from the ground elevation to the top of the rail to prevent errant vehicles from impacting at an improper height. A total length of St'd. GR-8 Weak Post Guardrail based on the appropriate flare for the design speed shown on the standard drawing should be used adjacent to the St'd. GR-6 terminal. If more than a 60 m extension of St'd. GR-8 guardrail is necessary to tie into the slope with a Std. GR-6 terminal, it would not be cost effective. If the GR-8, Type II, terminal installation is not feasible, a St'd. GR-7 (Breakaway Cable Terminal) or GR-9 (Strong Post Alternate Breakaway Cable Terminal) including appropriate transitions should be used.

For run-off terminal treatment with St'd. GR-8 (weak post guardrail), the St'd. GR-8, Type II terminal is acceptable only for divided roadways or one-way traffic situations. When two-way traffic on an undivided facility would introduce the possibility of opposing traffic impacting an intended run-off terminal for another lane, a GR-6, 7, or GR-9 terminal must be used. Because the possibility would then exist for opposing traffic to impact the opposite end of the terminal, a transition (in accordance with the Road and Bridge Standards) must be used to join the St'd. GR-6, 7 or GR-9 terminal and the weak post guardrail system (GR-8) to minimize any possible impacts.

(2) Semi-Rigid (Strong Post) Guardrail Installations -

With Standard GR-2 (Strong Post Guardrail), the preferred run-on terminal treatment on divided and undivided roadways is to bury the end of the guardrail into a cut slope, using St'd. GR-6 terminal, even if the guardrail must be extended 60 m to accomplish this. If more than a 60 m extension of St'd. GR-2 (Strong Post Guardrail) is necessary to tie a St'd. GR-6 terminal into the back slope, cost-effectiveness would justify use of a St'd. GR-7 (Breakaway Cable Terminal) or GR-9 (Alternate Breakaway Cable Terminal). Run-off terminals for use with undivided roadways with two-way traffic are handled in the same manner. However, for the run-off terminal on a divided roadway or with one-way traffic, a W-Beam End Section treatment in accordance with St'd. GR-HDW details is sufficient to terminate the St'd. GR-2.

(3) Rigid (Concrete Barrier) Installations -

St'd. MB-7D, 7E, 7F, 12A, 12B and 12C Concrete Median Barriers are considered rigid installations, thus requiring special attention to the terminal treatment to minimize the hazard if impacted. For run-on treatment outside the clear zone and all run-off treatment, a concrete turned down terminal can be used to terminate concrete barrier.

A Standard Insertable Sheet is available in the CADD Insertable Sheet directory for a 3.6 m section of the turned down terminal. A special design Impact Attenuator must be requested for all sites within the clear zone where concrete median barrier must be terminated.

TERMINAL INSTALLATION

(1) GR-8, Type II, Terminal Treatment Installation:

The St'd. GR-8, Type II, terminal is used only as a means of anchoring the run-off end of GR-8 (Weak Post) guardrail on divided or one-way roadways when installed outside the clear zone for opposing traffic. The guardrail is to be flush with the concrete anchor throughout the length of the anchor assembly in order for the installation to function properly without shearing the bolts.

(2) GR-6 Terminal Treatment Installation:

The St'd. GR-6 terminal is used as a means of terminating run-on or run-off ends of St'd. GR-2 or GR-8 guardrail on divided or undivided roadways by burying the end of the guardrail into the cut slope.

(3) GR-7 Breakaway Cable Terminal Installation:

When using the St'd. GR-7 terminals on standard shoulders, the 1.2 m flare as specified in the standard drawing or manufacturer's specifications must be provided for the installation to function as tested. This is considered essential to proper performance for end-on impacts to eliminate the potential of spearing. In consideration of the 1.2 m flare requirement to construct the terminal treatment for St'd. GR-7, the shoulder in the terminal area must be widened sufficiently to accommodate site preparation for the terminal. The terminal should be located, or the barrier may need to be extended as needed, to provide a clear run-out path behind the terminal.

On bridge replacement projects and other projects (involving guardrail updates) on which existing shoulders are of insufficient width and for which there are no provisions for widening such shoulders, additional fill material is required to be placed to ensure that the flare can be correctly installed. Typical installation details are shown in Standard GR-SP with a tabulation of the applicable widths. (Projects with paved shoulders - Details are shown on Special Design Drawing No. 2154-A, Asphalt Paving Under Guardrail).

When this situation occurs for the GR-7 terminals on projects without normal grading operations, a pay item [Guardrail Terminal site preparation (GR-) - Item Code 13349 with pay unit of Each] is to be used to cover the required embankment, benching and reseeding.

(A Special Provision Copied Note is available for use in contracts involving this pay item.)

New construction projects provide the necessary shoulder widening for the required guardrail terminals; therefore, the separate pay item for site preparation is not applicable.

(4) GR-9 Alternate Breakaway Cable Terminal Installation:

If the 1.2 m offset cannot be achieved to properly install the Standard GR-7 terminal, evaluate using a St'd. GR-9 or request a special design terminal treatment from the Engineering Services Section. The GR-9 terminal treatment should only be used after an analysis including additional right of way costs indicates it is more cost effective than providing the proper site preparation to install a St'd. GR-7 or to extend the guardrail (60 m maximum) to provide a St'd. GR-6 terminal.

The GR-9 terminal is intended solely for use on the end of a w-beam installation with no flare. The guardrail is anchored in a manner similar to the standard breakaway cable terminal and redirects side-impacting vehicles. For an "end-on" hit, the terminal essentially flattens and slides backward, absorbing crash energy.

The total length of the terminal is 15.2 m. The length of need begins 3.8 m from the first post. The maximum deflection for the terminal along the length of need is 1.2 m. For GR-9 installations used to terminate GR-8 (weak post guardrail), an additional 15.2 m transition of St'd. GR-2 (wood posts only) is required.

(5) W-Beam End Section Installation:

For run-off treatment on a divided or one-way roadway, St'd. GR-2 (Strong Post) guardrail can be terminated with a W-Beam End Section in accordance with the Standard GR-HDW details as long as the installation is outside the clear zone for opposing traffic. The "flared" or "rounded" treatment may be used if installed outside the clear zone for opposing traffic. Payment is length of St'd. GR-2 guardrail.

IMPACT ATTENUATORS (CRASH CUSHIONS)

During the preliminary design stages for new construction and for rehabilitation or reconstruction of existing highways, the need for and space requirements of crash cushions to shield non-removable fixed objects should be considered. This will ensure compatibility with the final design and the crash cushion that is to be installed. Since these devices are expensive to install and maintain, the hazard must be studied to determine if elimination is possible or its inherent hazard potential can be economically reduced to tolerable limits by less drastic safety treatments, such as guardrail, breakaway supports, set-back, safety shape, etc. Present procedure requires that the proposed site be selected by the roadway designer and reviewed by the Special Design section for the type of crash cushion to be used. When requesting the review and installation details from the Special Design section, submit a print of the plans with a transmittal slip giving the project number, activity number, roadway design speed and advertisement date. In no case will attenuation devices be designed for placement behind curbed locations. For additional data, refer to the AASHTO's Roadside Design Guide.

In 1993 the National Cooperative Highway Research Program (NCHRP) published NCHRP Report 350. As a result of that report the FHWA issued a requirement that all permanent safety hardware systems included in Federal Aid projects after August 1998 meet NCHRP 350. VDOT extended that requirement to include state funded projects as well.

Devices subjected to traffic speeds greater than 70 km/h must meet NCHRP 350 Test Level 3.

Devices subjected to traffic speeds of 70 km/h and less must meet NCHRP 350 Test Level 2.

For a list of approved devices see Instructional and Informational Memorandum LD-222.

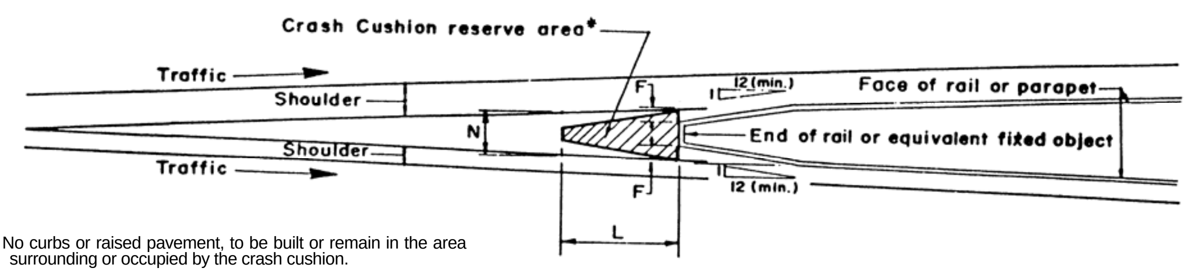
Fixed roadside hazards vary in size and shape, and in the degree of danger they present. The traffic passing by varies as well in volume, speed and density. For these reasons a selection from various types of crash cushions can be designed to meet the special requirements of a particular hazard site.

Figure A-3-3M suggests the area that should be made available for crash cushion installation. Although it depicts a gore location, the same recommendations will generally apply to other types of fixed object hazards that require shielding. The unrestricted conditions represent the minimum dimensions for all locations except for those sites where it can be demonstrated that the increased costs for obtaining these dimensions (as opposed to those for restricted conditions) will be unreasonable. The preferred condition dimensions should be considered optimum. The space provided by these dimensions will seldom be fully used by a crash cushion. These dimensions are recommended so there will be additional space available should experience dictate the need for a device capable of slowing larger vehicles than originally considered or for producing lower deceleration forces. In the meantime, the unoccupied space provides valuable motorist recovery area. Site conditions may dictate the type of attenuator needed. For example, fixed objects such as barrier ends which are less than 1 meter wide should be shielded by a narrow crash cushion. Similarly, wide hazards, e.g., those greater than 4.9 meters, can be effectively shielded best a wide impact attenuator or approved sand barrier arrays.

These dimensions are recommended so there will be additional space available should experience dictate the need for a device capable of slowing larger vehicles than originally considered or for producing lower deceleration forces. In the meantime, the unoccupied space provides valuable motorist recovery area. Site conditions may dictate the type of attenuator needed. For example, fixed objects such as barrier ends which are less than 3 feet wide should be shielded by a narrow crash cushion. Similarly, wide hazards, e.g., those greater than 3 feet, can be effectively shielded best by a wide impact attenuator or approved sand barrier arrays.

Design Speed on Main line (km/h)	Dimensions for Crash Cushion, Reserve Area (meters)								
	Minimum						Preferred		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
50	2	2.5	0.5	2.5	3.5	1	3.5	5	1.5
80	2	5	0.5	2.5	7.5	1	3.5	10	1.5
110	2	8.5	0.5	2.5	13.5	1	3.5	17	1.5
130	2	11	0.5	2.5	17	1	3.5	21	1.5

Source: The errata August 2001-February 2003 of the 2002 AASHTO Roadside Design Guide.



Σ No curbs or raised pavement, to be built or remain in the area surrounding or occupied by the crash cushion.

FIGURE A-3-3M

Source: The 1988 AASHTO Roadside Design Guide.

BRIDGES

When the proposed design calls for the utilization of an existing bridge having the older type parapet walls or rails, an appropriate detail showing the "Recommended Method for Attaching Guardrail to Bridge Rails" is to be obtained from the Engineering Services Section for inclusion in plans. Prints of the existing bridge rail should accompany the request. The method of measurement and basis of payment is for "Special Design Guardrail Bridge Attachment, (B or Str. No.), Lump Sum" which price bid shall include all materials, labor, tools, equipment, and incidentals necessary to complete the work connecting all segments of rail to one bridge.

When the use of guardrail on depressed medians is being planned to shield bridge piers, the designer should also consider the use of a Special Design Impact Attenuator Bull Nose Barrier. This design has been used for several years with excellent performance. The design utilizes a 1.5 m radius W-beam guardrail and wooden breakaway posts; therefore, a 3.0 m wide median would be the minimum. A similar design of the "Bull Nose Barrier" is shown in the AASHTO Roadside Design Guide. (Pay Item - Bull Nose Barrier-Each - Computer Est. No. 13601.) Installation layout details will be furnished by the Engineering Services Section for each Bull Nose Barrier location for inclusion in the plans. Bull nose barriers must not be used behind or on top of curbs or raised medians.

SECONDARY PROJECTS

See Section A-1-Geometric Standards (Metric), GS-3, GS-4, GS-7 and GS-8 for additional widths to be added to the normal shoulders on secondary roads when guardrail is required.

SAFETY/MAINTENANCE PROJECTS

When developing details for a Safety or Maintenance project, care must be taken to ensure proper barrier installation/maintenance/replacement to upgrade any outdated locations. There may be locations on a project where the guardrail has not been hit, but the installation may not be the safest that can currently be provided if an errant vehicle impacted the guardrail. Attention should be given to the following factors in evaluating these locations:

(1) Location of barrier:
- relative to hazard
- relative to pavement
- relative to shoulder break point
- relative to fixed objects (such as bridges); face of guardrail should be aligned with bridge rail, not closer to the roadway

(2) Type of guardrail used (Strong Post or Weak Post):
- no longer use Weak Post guardrail adjacent to curb
- cable guardrail normally used only on Limited Access facility with recoverable area exceeding 4.3 m
- sufficient space for maximum deflection for type used

(3) Terminals (need, type, proper installation, etc.):

- end treatment needed on both ends of a run of barrier
- terminals used with strong post guardrail
- terminals used for run-on treatment with weak post guardrail
- terminal treatment used as anchor for run-off end of weak post guardrail when not subject to two-way traffic
- proper flare, anchor, post placement for terminal to effectively decrease damage caused to impacting vehicle

- substandard terminals such as GR-5 (old turndown terminal), old standard GR-7 (those with 0.6 m diameter concrete footings for first two posts), etc., should be replaced with approved terminals.
- at bridges/walls, guardrail terminals should not be located closer to the roadway than the bridge rail or wall (fixed object attachment should be installed instead of separate units)

(4) Shoulder width and site preparation:
- provide sufficient width for site preparation
- provide additional fill if necessary for proper flare installation
- provide clear run-out area behind terminal installation

(5) Fixed object attachments:
- proper attachments to fixed objects (such as bridges/walls) to reduce possibility of snagging vehicles that impact the attachment
- align guardrail with face of bridge rail so that the end of the bridge with the fixed object attachment will not become an additional hazard
- include proper transition to gradually stiffen the overall approach

SECTION A-4M-VIRGINIA RRR GUIDELINES

OBJECTIVE

The objective of the Virginia RRR Guidelines is to provide guidance in the selection of projects where, with minimal improvements, the service life of the existing highway can be extended for a fraction of the cost of complete reconstruction.

Resurfacing, restoration, and rehabilitation (RRR) projects primarily involve work on an existing roadway surface and/or subsurface. In addition to extending the service life of the roadway, the purpose of RRR projects includes providing additional pavement strength, restoring or improving the existing cross section, decreasing noise characteristics, improving the ride of the roadway, improving bridges, and enhancing safety through the implementation of appropriate safety improvements, bridge improvements and preventive maintenance of bridges on appropriate Federal-aid roadways. Highway Bridge Replacement and Rehabilitation Program (HBRRP) Funds may be utilized for preventative maintenance (PM) for the purpose of system preservation activities on Federal-aid roadways except for those classified as local roads or rural minor collectors. Routine maintenance remains the responsibility of VDOT and/or locality.

Section 309 of the National Highway System Designation Act of 1995 (23 USC 116) states: "A preventive maintenance activity shall be eligible for Federal assistance under this title if the State demonstrates through the use of a systematic process, such as a Bridge Management System, to the satisfaction of the Secretary that the activity is a cost-effective means of extending the useful life of a Federal-aid highway."

The scope of a RRR project is influenced by many factors. Factors include roadside conditions, environmental concerns, changing traffic and land use patterns, surface deterioration rate, accident rates, funding constraints and scenic/historic areas.

Although RRR type improvements are normally accomplished within the existing right of way, the acquisition of additional right of way may be necessary. Horizontal and vertical alignment modifications, when required, are generally minor.

AUTHORITY

The Transportation Research Board's Special Report 214, Designing Safer Roads, Practices for Resurfacing, Restoration, and Rehabilitation, 1987, was the result of a study on safety cost-effectiveness of highway geometric design standards for RRR projects. Virginia has developed and adopted this guideline for non-NHS RRR projects.

In the planning and design of any Secondary System improvements in rural areas, Virginia's RRR Guidelines shall be utilized to the extent possible. On secondary projects that have a 15 year traffic projection of 750 vehicles per day or less, the RRR guidelines shall be the design concept of choice. Reconstruction under AASHTO design guidelines should be proposed on these projects only when the preliminary study report documents either;

1. The needed improvement is ineligible for development under the RRR concept.
   or
2. Extenuating circumstances preclude the use of the RRR Design concept.

Virginia RRR Guidelines may be utilized in improvements to urban streets for which the localities receive maintenance payments.

DEFINITIONS

These definitions apply to RRR projects and are not an attempt to be all-inclusive of other related activities.

Maintenance - This work is directed toward preservation of the existing roadway and related appurtenances as necessary for safe and efficient operation. Design mprovements are not normally the intent of maintenance operations. Seal coats, overlays less than 18 mm thick, crack sealing, etc., are considered maintenance items, and are not RRR activities.

Resurfacing - The addition of a layer, or layers, of paving material to provide additional structural integrity or improved serviceability and rideability.

Restoration - Work performed on pavement, or bridge decks, to render them suitable for an additional stage of construction. This may include supplementing the existing roadway by increasing surfacing and paving courses to provide structural capability, and widening up to a total of 3 meters. Restoration will generally be performed within the existing right of way.

Rehabilitation - Similar to "Restoration", except the work may include restoring structural integrity or correcting major safety defects of bridges, reworking or strengthening the base or subbase, recycling or reworking existing materials to improve their structural integrity, adding underdrains, improving or widening shoulders, and shifts in both vertical and horizontal alignment. Rehabilitation may require acquisition of additional right of way.

Reconstruction - This type of project is not considered RRR activity. A reconstruction project is designed in accordance with AASHTO design guidelines for new and major reconstruction projects and may include significant changes in cross section and shifts in both vertical and horizontal alignment. Reconstruction may require acquisition of additional right of way and may include all items of work usually associated with new construction.

PROJECT SELECTION

Projects are identified and selected based on a variety of factors with the pavement condition and environmental impact being of utmost importance. The pavement condition itself will not have a significant effect on the extent of geometric improvements included in the project. Geometric improvements will be initiated to fulfill traffic

Logical project termini are to be set; and, at no time, are project exceptions for segments of roadway or bridge, etc., to be established within the project termini due to excessive cost to provide the required improvements.

ELIGIBILITY

Improvements to Existing Roadway:

Eligible Items of Work *

- Minor alterations to vertical and/or horizontal alignment.
- Minor lane and/or shoulder widening.
- Pavement structure and joint repair.
- Resurfacing (non-maintenance activities).
- Removal or protection of roadside obstacles.
- Repairs to restore bridge structural integrity, installation of deck protective systems and upgrading substandard bridge rail.
- Culvert Extensions.

  Repair or replace culverts.

* Some RRR-type projects may be funded with either regular Federal-aid or separate categorical aid.

Examples:

Bridge rehabilitation project - RRR funding or the bridge replacement and rehabilitation program.

Roadside hazard removal and guardrail installation - RRR funding or hazard elimination program funds.

Ineligible Items of Work

Projects in the National Highway System (NHS).

New or additional through lanes.

New curbs and gutters, raised medians, storm sewers, and other new urban type improvements.

ACCIDENT RECORDS

Evaluation of accident records often reveals problems requiring special attention. In addition, relative accident rates can be an important factor in establishing both the priority and the scope of RRR projects.

The Residency Administrator or Project Manager should request from the Traffic Engineering Division that the accident history for the project area be compiled and compared to the statewide average accident rate for the same type of road. This data review is integral part of the RRR project development process so that feasible safety modifications should incorporated into the project as necessary.

The accident analysis should be completed prior to the Initial Field Review.

BRIDGE REHABILITATION OR REPLACEMENT SELECTION POLICY

Existing bridges shall be evaluated and the necessary work shall be determined in accordance with the following provisions:

Bridges with overall deck area exceeding 1860 square meters shall be evaluated and any necessary work shall be determined by the Structure and Bridge Engineer on a case-by-case basis.

All other bridges shall be replaced, rehabilitated, or allowed to remain in existing condition in accordance with the following:

(1) Bridges shall be replaced under any one or more of the following conditions unless otherwise approved by the Structure and Bridge Engineer. The new replacement structure shall meet the current requirements of the Virginia Department of Transportation's Road and Bridge Standards. RRR guidelines may only be used for the total replacement of a bridge when the 15-year traffic projection is 750 vehicles per day or less.

a) If the estimated cost for rehabilitating the existing structure exceeds 65% of the estimated cost of a new structure.

b) If the existing or rehabilitated structure is overstressed under the loading specified in the AASHTO Manual for Maintenance Inspection of Bridges (i.e., if the bridge is to be posted for less than the legal load).

c) If the usable width of the existing or the rehabilitated bridge will be less than the minimum acceptable values for usable width of bridges on RRR projects shown in the table below, and it is not economically feasible to provide that width.

(2) Bridges shall be rehabilitated as required or remain in the existing condition, if conditions in A, B, or C above do not prevail. The usable width of the existing or the rehabilitated bridge shall meet or exceed the minimum acceptable values for usable width of bridges on RRR projects shown in the Table hereinafter.

MINIMUM BRIDGE WIDTHS ON RRR PROJECTS SHALL BE AS FOLLOWS:

DESIGN YEAR VOLUME ADT	* USABLE BRIDGE WIDTH (FACE-TO-FACE OF CURB) (METERS)
0 - 750	WIDTH OF APPROACH LANES
751 - 2000	WIDTH OF APPROACH LANES + 0.6 m
2001 - 4000	WIDTH OF APPROACH LANES + 1.2 m
OVER 4000	WIDTH OF APPROACH LANES + 1.8 m

NOTE:See DRAINAGE DESIGN ELEMENTS (page A-58 Metric) Bridge Restoration and Bridge Rehabilitation for hydraulic conditions that are to be evaluated.

* If lane widening is planned as part of the RRR project, the usable bridge width should be compared with the planned width of the approaches after they are widened.

ENVIRONMENTAL CONSIDERATIONS

An environmental evaluation and documentation thereof, is required on all RRR Federal participation projects in accordance with current guidelines.

Prints are transmitted to the Environmental Engineer via Form LD-252.

ACCESS CONTROL

Generally, a RRR project will not be designated as a limited access highway due to the project being along an existing corridor with access provided to adjoining properties.

The elimination of existing access to properties is beyond the scope of work for RRR projects.

Existing limited access roadways may qualify as a RRR project.

PROJECT DEVELOPMENT

It is desirable that these projects be designed to meet the standards for new construction. If meeting these standards is not practical, due to limited funding, right of way and/or environmental restrictions, etc., improvements in roadway widths should still be considered.

The minimum roadway and travelway widths are shown under GEOMETRIC DESIGN CRITERIA, TABLE A-4-1M. Lane and shoulder width requirements are provided for roadways with 10% or more trucks and for roadways with less than 10% trucks.

The design should not decrease the existing geometrics. Widths selected should be consistent throughout a given section. Minor lane and shoulder widening is acceptable. While additional new continuous traffic lanes are an ineligible type of work, the existing pavement may be widened up to a total of 3 meters.

ROADWAY AND TRAVELWAY WIDTHS

Wide lanes and shoulders provide motorists with increased separation between overtaking and meeting vehicles and an opportunity for safe recovery of vehicles leaving the road.

Additional safety benefits include reduced interruption of the traffic flow as the result of emergency stopping and road maintenance activities, less pavement and shoulder damage at the lane edge, and improved sight distance for horizontal curves.

FUNCTIONAL CLASSIFICATION

The highway system in Virginia has been functionally classified as Principal Arterial, Minor Arterial, Collector and Local Service. The American Association of State Highway and Transportation Officials (AASHTO) utilizes, as presented in the publication: A Policy on Geometric Design of Highways and Streets, referred to as The AASHTO Book, a similar functional classification system. The designations used are: Freeway, Arterial, Collector, and Local Roads and Streets. Relationships between these two classification systems have been generally developed. Principal and Minor Arterial Highways provide direct service between cities and larger towns and are high speed, high volume facilities. Collector highways serve small towns directly, connecting them and local roads to the arterial system. Any questions concerning the functional classification of any transportation facility should be addressed to the State Transportation Planning Engineer.

DESIGN TRAFFIC VOLUMES

Traffic projections should be checked to assure that:

The anticipated traffic being used is correct and that the roadway and travelway needs will be properly accommodated for the service life of the improvement.

The project service life for RRR projects should be from 8 to 12 years.

Turning movements are obtained at signalized and problem intersections and at major traffic generators.

Future traffic generators that are anticipated to be established during the service life should be considered.

DESIGN SPEED

The design speed designated for a RRR project should be logical with respect to the character of terrain and type of highway and should be as high as practicable.

It is also important to consider the geometric conditions of adjacent sections of roadway when considering a RRR project. A uniform design speed should be maintained for a significant section of highway.

The design speed is a determining factor for required land and shoulder widths.

The following two methods may be used to determine the project design speed:

(1) Select an overall project design speed that equals or exceeds the posted or regulatory speed on the section of highway being improved.

(2) The average running speed throughout the project based on the "low volume" off peak hour traffic.

Average running speed is the speed of a vehicle over a specified section of highway, being the distance traveled divided by the running time (the time the vehicle is in motion).

An equivalent average running speed can be obtained on an existing facility where flow is reasonably continuous by measuring the spot speed.

The average spot speed is the arithmetic mean of the speeds of all traffic at a specified point.

For short sections of highway on which speed characteristics do not vary materially, the average spot speed may be considered as being representative of the average running speed.

On longer stretches of rural highway, spot speeds measured at several points, where each represents the speed characteristics pertinent to a selected segment of highway, may be averaged (taking relative lengths into account) to represent the average running speed.

TERRAIN

Terrain is a significant factor which must be given strong consideration when establishing design criteria for a highway project. High design speeds (80 km/h and greater) can generally be achieved on flat terrain, and lower design speeds (60 km/h and lower) are generally dictated by rolling and mountainous terrain, (depending upon road classification). Intermediate design speeds are determined by a combination of these factors.

While terrain is an important factor to be considered when designing a new project, RRR projects must be designed considering all existing constraints, and held within RRR parameters. That is to say that eligible RRR elements, due to terrain and other constraints upon the original design, may not allow the desired speed and safety enhancements.

SAFETY

All safety elements of the project are to be given specific consideration. Accidents, accident types, and accident rates for the project length shall be examined and documented.

The documentation may indicate deficiencies in one or more of the following areas, however, each should be examined:

- Horizontal and vertical alignment
- Cross-sectional geometrics
- Traffic control
- Access
- Railroad crossings
- Pedestrian facilities
- Bridges that remain in place
- Illumination
- Signing
- Channelization
- Intersections
- Pavement edge drop offs
- Pavement surface condition
- Maintenance of traffic
- Bicycle facilities

Improvements to the roadway surface may result in increased operating speeds. Geometrics should be examined and modified, if necessary, to maintain an acceptable level of operational safety.

Horizontal and vertical curvature and stopping sight distance are directly related to the speed of vehicles and major deviations from the desirable design may cause serious problems. These geometric characteristics can be the most difficult and costly to improve. Although every sight distance restriction can create a potential hazard, improvement on that basis alone may not be practical on every RRR project.

If curvature is shown to be the cause of numerous accidents, some corrective action should be taken. This corrective action can range from some form of positive guidance, which may include placement of additional warning signs and markings, to reconstruction.

Alignment improvements should be undertaken when accident experience is high, and if previously installed warning signs, markings, or other devices have not proven effective. In many cases, under both rural and urban conditions, existing horizontal and vertical alignments may be retained if a careful analysis indicates they can be adequately signed and marked.

If the calculated design speed for a particular horizontal or vertical curve is within 25 km/h of the design speed of the adjacent sections and the location is not an identified high accident location, (facilities with ADT < 750 vehicles per day), proper signs and markings informing drivers of the condition may be used in lieu of reconstruction to meet standards for the assumed design speed. When the difference is over 25 km/h or the design speed of the horizontal or vertical curve is less than 30 km/h, (facilities with ADT > 750 vehicles per day), corrective action must be considered and should be undertaken unless cost or other factors make the improvement impractical. If improvement is not possible, appropriate signs, markings and other provisions should be used to provide for proper speed transition.

Sight distance on horizontal curves, and at intersections, can often be improved by minor cut slope flattening, selective clearing or both. If such work is done, the actual sight distance must be measured, the maximum safe speed determined, and the location signed and marked accordingly.

Grades generally do not need to be flattened on RRR projects. Steep grades and restricted horizontal or vertical curvature in combination, however, may warrant corrective action.

A completed roadside hazard review is required. This will provide information regarding areas of potential concern relating to safety.

For safety, it is desirable to provide a roadside recovery area that is as wide as practical, but because of existing topographic features and right of way limitations associated with RRR work, considerable judgment must be used. The clear zone must be given particular attention at identified high roadside accident locations (fixed object and run-off-the-road accidents). An evaluation should be made to determine the consistency of the clear zone throughout the project limits.

Widening to provide more clear distance through short sections of rock cuts should be considered. In longer rock cuts, protrusions should be cut back or shielded if warranted. A review of accident data will help to define dangerous obstructions. Good engineering judgment, cost effectiveness, and consideration of community impact may also influence decisions.

Under urban conditions the minimum setback for any obstructions should be as close to the right of way line as possible or 0.5 m behind the curb. Where sidewalks are to be included, it is desirable to locate all obstructions behind the sidewalk.

Safety items for reducing the severity of run-off-the-road accidents include traffic barriers (including bridge rails), flattening slopes to eliminate the need for either existing barrier or contemplated barrier placement, crash cushions, breakaway or yielding sign supports, and breakaway luminaire supports.

The priority for action relative to roadside hazards is to:

- Remove or redesign
- Relocate
- Make breakaway
- Redirect by using appropriate barrier
- Delineate

To enhance safety, all RRR projects should provide the following:

Evaluation of existing traffic barrier and end treatments to determine whether they are necessary and meet applicable guidelines and standards. The extent to which the barrier must be upgraded should be consistent.

Appropriate transition and connection of approach rail to bridge rail.

Mitered end sections for both parallel and cross-drain structures located in the clear zone.

Relocating, shielding, or providing breakaway features for sign supports and luminaires.

Protection for exposed bridge piers and abutments.

Drop inlets with traversable grates that are not a hazard to be used within the clear zone.

GEOMETRIC DESIGN CRITERIA

The design criteria in Table A-4-1M for Minor Arterial, Collector and Local Road projects are based on the general approach in the "AASHTO Book" regarding functional classification and corresponding appropriate design volumes and also recommendations presented in TRB special Report 214, Practices for Resurfacing, Restoration, and Rehabilitation.

GEOMETRIC DESIGN CRITERIA
TABLE A-4-1M

MINIMUM LANE AND SHOULDER WIDTH VALUES								
ARTERIAL/ COLLECTOR/ LOCAL ROAD AND STREET SYSTEMS								
DESIGN TRAFFIC VOLUME	DESIGN SPEED MPH	10% OR MORE TRUCKS (d)			LESS THAN 10% TRUCKS (d)			DITCH WIDTH 3:1 SLOPE
		LANE WIDTH		SHOULDER WIDTH (c)	LANE WIDTH		SHOULDER WIDTH (c)	
ADT		C&G	W/SHLD		C&G	W/SHLD		
(a)	(b)	(Meters)	(Meters)	(Meters)	(Meters)	(Meters)	(Meters)	(Meters)
1 - 750	< 80	3.3(e)	3.0 (e)	0.6 (i)	3.0	2.7	0.6 (i)	1.0 (h)
	≥ 80	3.3	3.0	0.6 (i)	3.3	3.0	0.6 (i)	1.0 (h)
751 - 2000	< 80	3.3	3.3 (f)	0.6 (I)	3.3	3.0	0.6 (I)	1.0
	≥ 80	3.6	3.6 (g)	0.9 (i)	3.3	3.3	0.9 (i)	1.0
2001 - 4000	ALL	3.6	3.6	1.8	3.3	3.6	1.8	1.2
4001 - OVER	ALL	3.6	3.6	1.8	3.6	3.6	1.8	1.2

(a) Design traffic volume is between 8 and 12 years from completion.

(b) Highway segments should be classified as "Under 80" only if most vehicles have an average running speed of less than 80 km/h over the length of the segment.

(c) Cut shoulder width may be reduced by 0.3 m in mountainous terrain.

(d) Trucks are defined as heavy vehicles with six or more tires.

(e) Use 2.7 m lane width for Local Road System with ADT of 1 - 250.
(2.7 m lane width is equal to new construction standards for Rural/Local Road System)
Use 3.0 m lane width for Curb and Gutter for Urban with ADT 1-250 (3.0 m lane width is equal to new construction standards)

(f) Use 3.0 m lane width for Collector Road and Local Road System in mountainous terrain. (3.0 m lane width is equal to new construction standards.)

(g) Use 3.3 m lane width for Collector Road and Local Road System in level terrain. (3.3 m lane width is equal to new construction standards.)

(h) Use 0.6 m ditch width with pavement depths (excluding cement stabilized courses) of 0.2 m and less.

(i) Minimum width of 1.2 m if roadside barrier is utilized (minimum 0.6 m from edge of pavement to face of G.R.).

NOTE: PAVEMENT AND SHOULDER WIDTHS NOTED ARE MINIMUMS FROM A DESIGN CRITERIA STANDPOINT. UNDER NO CIRCUMSTANCES SHALL THE EXISTING PAVEMENT OR SHOULDER WIDTHS BE REDUCED TO CONFORM TO THESE MINIMUM STANDARDS.

NOTE: FOR VALUES NOT SHOWN, SEE APPROPRIATE GEOMETRIC DESIGN STANDARD FOR THE FUNCTIONAL CLASSIFICATION OF ROADWAY (METRIC GS-2M, GS-3M OR GS-4M) CONTAINED IN THE VDOT ROAD DESIGN MANUAL, VOL. 2, APPENDIX A, SECTION A-1 (Metric).

NOTE: ROADSIDE HAZARDS AND PRIORITY FOR RELATIVE ACTION ARE COVERED ON PAGE A-28 (Metric).

CLEAR ZONES AND SLOPES

Wherever possible, existing side slopes should not be steepened when widening lanes and shoulders. When the initial slopes are relatively flat, however, the slope can be steepened to 6:1 with little effect, and steepening to 4:1 may be reasonable.

Consideration should be given to flattening side slopes of 3:1 or steeper at locations where run-off-the-road type accidents are likely to occur (e.g. on the outside of horizontal curves). Accident data should be used (when available) to substantiate run-off-the-road accident locations.

Removing, relocating or shielding of isolated roadside obstacles should be evaluated in accordance with the Clear Zone and Traffic Barrier Guidelines contained in the Road Design Manual, Vol. 2, Appendix A, Sections A-2 and A-3 (Metric).

GRADES

Grades generally do not need to be flattened on RRR projects. Steep grades and restricted horizontal or vertical curvature in combination, however, may warrant corrective action.

CREST VERTICAL CURVES

An existing vertical curve may be retained as is, without further evaluation, if the existing design speed provides the stopping sight distance within 25 km/h of the overall project design speed and the average daily traffic volume is less than 750 vehicles per day.

Reconstruction of crest vertical curves is to be evaluated when the above speed and traffic volumes are exceeded and the vertical curve hides major hazards from view. Major hazards include, but are not limited to intersections or entrances, sharp horizontal curves and narrow bridges.

SAG VERTICAL CURVES

Substandard sag vertical curves should be investigated to ensure that potential hazards do not exist, especially ones that become apparent when weather conditions, or darkness, reduces visibility.

STOPPING SIGHT DISTANCES

Guidelines for determining the existing sight distances of vertical and horizontal curves are as follows:

- Existing road data to be determined from survey plan and profile sheets and/or old plans obtained from the plan library.

- Road and Bridge Standards SD-3 and SD-4 and may be used to determine the sight distances using the following methods:

  Vertical curves - Determine algebraic differences of grades in percent and length of vertical curve in meters from the survey plans, or old project plans, and the sight distance may be obtained from Standard SD-4 (Metric).

  Horizontal curves - Determine the existing degree of curve and the middle ordinate or radial distance from centerline of inside lane to obstruction to view and the sight distance may be obtained from Standard SD-3 (Metric).

- Vertical and horizontal curve sight distances may be scaled from the plans using the following heights of driver's eye and object:

Sight Distance	Hgt. of Eye	Hgt. of Object
Stopping	1.08 m	0.6 m
Passing	1.08 m	1.80 m

HORIZONTAL CURVES

An existing horizontal curve may be retained as is, without further evaluation, if the existing curve design speed, with correct superelevation provided, corresponds to a speed that is within 25 km/h of the running speeds of approaching vehicles and the average daily traffic volume is less than 750 vehicles per day.

Reconstruction of horizontal curves should be considered and evaluated when the above speed and/or volume criteria are exceeded.

When a roadway segment consists of a series of reverse curves or curves connected by short tangents, the succession of curves shall be analyzed as a unit rather than as individual curves.

The first substandard curve in a series should receive special attention because this change in alignment prepares the driver for the remaining curves in the series.

Any intermediate curve in a series of substandard curves that is significantly worse than the others in the series should be analyzed individually.

These controlling curves can be used to determine the safety and/or other mitigation measures to apply throughout the series.

PAVEMENT CROSS SLOPE

Pavement resurfacing or rehabilitation will be accomplished such that the finished pavement on tangent sections will be crowned in accordance with new construction standards.

SUPERELEVATION REQUIREMENTS

Standard superelevation will be provided on all curves to comply with the project design speed unless the following conditions exist:

Excessive cost to provide superelevation.
Excessive property damage.

Superelevations may be provided for design speeds up to a maximum of 25 km/h less than the project design speed for current traffic volumes of 750 vehicles per day or less, if the above conditions exist, with appropriate signing:

Advisory curve signs and speed limit signs will be erected.

PAVEMENT EDGE DROP

Pavement edge drops usually are caused by resurfacing of pavement without regrading the existing shoulder or erosion of gravel, turf, or earth shoulder materials.

This hazard shall be eliminated or mitigated by utilizing one or more of the following practices:

Paving the full top width between shoulder breaks.

Selectively paving shoulders at points where vehicle encroachments are likely to create pavement edge drops, such as on the inside of horizontal curves.