APPENDIX A

ROADSIDE BARRIER WARRANTS

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APPENDIX A
ROADSIDE BARRIER WARRANTS

A.1 INTRODUCTION

The warranting process described in this appendix was developed using the Roadside Safety Analysis Program (RSAP). A number of assumptions were made concerning factors such as roadway type, cross section elements, hazards and barrier cost. These assumptions reduced the number of variables normally considered to the following:

- Hazard type and size
- Hazard offset
- Traffic volume
- Traffic growth
- Horizontal curvature
- Grade
- Speed

Traffic volume, traffic growth, horizontal curvature and grade are taken into account by a factor termed "Adjusted Traffic Factor" (ATF). ATF is calculated by modifying the initial average daily traffic (ADT) with adjustments for traffic growth, horizontal curvature and grade. The ATF is then used in warranting tables for each hazard type. Speed and hazard offset are considered in the warranting tables.

RSAP was run using these variables to determine the ATF required to yield a benefit/cost (b/c) ratio of both 1.0 and 4.0. If the b/c was less than 1.0, a barrier is clearly not warranted. If the b/c was greater than 4.0 a barrier is warranted. The b/c of 4.0 allowed for barrier systems more expensive than the strong post w-beam (other than the concrete safety shape, stone masonry and precast concrete systems). The range of ATF that resulted in b/c of between 1.0 and 4.0 indicated that barriers are possibly warranted. Some guidelines are provided to assist in the application of engineering judgment concerning the use of barriers in this range.

A.2 STEPS IN THE WARRANTING PROCESS

The steps to determine warrants for roadside barriers on low speed and low volume roads using this procedure are:

1. Determine the needed clear zone, as described in Section 2.2.

2. Using Tables 2.3, 2.4, 2.5 and 2.6, identify hazards within the clear zone that may warrant barriers. Hazards that may warrant barriers include those in Group 2 if there is a clear crash history or if multiple hazards serve to increase the severity. All hazards in Group 3 may warrant barriers.

3. Collect the necessary data to perform the analysis. Such data include the length and width of the hazard; the offset of the hazard from the roadway; speed, present traffic volume and anticipated traffic growth factor of the road; curve radius and grade of the road, if appropriate; available crash data and other concerns such as environmental and aesthetic impacts.

4. Calculate the ATF using information from Tables A.1, A.2 and A.3 and the formula presented below. The factors in these tables adjust the initial ADT to account for expected traffic growth and the effects of horizontal curves and grade.

5. Select the warranting table or tables (summarized in Table A.5) that most closely approximate the actual hazard. Since it is impossible to anticipate all possible roadside hazards, it may be necessary to use two closely associated tables and interpolate the results.

6. Using the ATF with the warranting tables, classify possible roadside barriers as either not warranted, possibly warranted or warranted. If roadside barriers are possibly warranted, consider the factors in Table A.4 to evaluate the need for barriers at that location.

Concrete safety shape, precast concrete guardwall, and the stone masonry guardwall barrier systems are very expensive. The warranting tables do not fully take into account the expense of these systems. Usually there must be a barrier warrant based on safety to justify these systems and also an exceptional need such as aesthetics or an unusual safety concern.

A.3 CALCULATION OF THE ADJUSTED TRAFFIC FACTOR

The Adjusted Traffic Factor (ATF) used in the warranting tables is determined by the following formula:

ATF = Initial ADT * TG * HC * DG

The factors TG, HC, and DG are found in Tables A.1, A.2 and A.3 respectively.

Table A.1: Traffic Growth Adjustment Factor, TG

Annual Growth Factor	Adjustment Factor
0%	1.00
1%	1.10
2%	1.21
3%	1.34
4%	1.49
5%	1.65

Table A.2: Horizontal Curve Adjustment Factor, HC

Radius		Adjustment Factor (HC)	
Meters	Feet	Hazard on Outside of Curve	Hazard on Inside of Curve
586 or greater	1,911 or greater	1.00	1.00
441 – 585	1,431 – 1,910	1.50	1.25
351 – 440	1,151 – 1,430	2.50	1.50
291 – 350	951 – 1,150	3.50	1.75
290 or less	950 or less	4.00	2.00

Table A.3: Down Grade Adjustment Factor, DG

Percent Down Grade	Adjustment Factor (DG)
0 – 2%	1.00
2.1% – 3.0%	1.10
3.1% – 4.0%	1.40
4.1% – 5.0%	1.70
5.1% – 6.0%	1.90
6.1% and larger	2.00

For example, a road has an initial ADT of 350 and a projected annual growth factor of two percent. The hazard being analyzed is on the outside of a 500 m (1,700 ft)-horizontal curve and on a downgrade of four percent. The ATF is:

ATF = Initial ADT * TG * HC * DG

ATF = 350 * 1.21 * 1.50 * 1.40

ATF = 889

A.4 APPLICATION OF THE WARRANTING TABLES

The warranting tables will yield one of three results:

1. A barrier is not warranted.
2. A barrier is possibly warranted.
3. A barrier is warranted.

If the result is that a barrier is "possibly warranted", the decision to place barriers cannot be clearly quantified and additional considerations must be made. Table A.4 lists the considerations that might be applied in this evaluation.

Table A.4: Barrier Warrant Considerations For "Possibly Warranted" Conditions

Consideration	Barrier is more warranted if:	Barrier is less warranted if:
Adjusted Traffic Factor	ATF is at the high end of range	ATF is at the low end of range
Roadway cross section	Section elements are more severe than assumed	Section elements are less severe than assumed
Size of hazard does not fit the assumption	Hazard is larger	Hazard is smaller
Hazard does not fit the description in the warrant table	Hazard is more severe	Hazard is less severe
Expected cost of barrier	Expected costs will be low	Expected costs will be high
Multiple hazards exist at the site	Many additional hazards	
Operating speed	Likely to exceed design speed	At or below design speed
Crash history	Clear crash pattern	No crash pattern
Aesthetic impacts		Serious concerns
Environmental impacts		Serious concerns

It is difficult to quantify the considerations outlined in Table A.4 if more than one consideration is applicable. This table is intended to aid in the necessary exercise of professional judgment.

A.5 WARRANTING TABLES

The tables in this section were developed using RSAP. The following assumptions were made in the analyses:

- Costs. A life cycle of 20 years and a discount of four percent were assumed. Costs for roadside barriers were assumed to be $68.40 per m ($18.00 per ft), plus $2,000.00, to account for end treatments.

- Roadway characteristics. Two-lane, two-way rural collector roads were assumed, with 3.4 m (11 ft) lanes and 0.6 m (2 ft) shoulders. Truck volumes of ten percent were also assumed.

- Segments were assumed to be 600 m (2,000 ft) long, with no grade and no curvature (the ATF accounts for grade and curvature).

- Several hazards from Group 3 (discussed in Section 2.3) were analyzed at varying offsets and sizes.

- Guardrail lengths were estimated using minimal lengths of need. Length of need was calculated to the appropriate clear zone for the speed and ADT. All lengths were rounded to the nearest 3.81 m (12.5 ft) section. Guardrail offsets were assumed to be 0.6 m (2 ft) from the hazard for speeds of 50 km/h (30 mph) and less, 1.0 m (3 ft) for speeds of 55 km/h to 70 km/h (35 to 44 mph), and 1.2 m (4 ft) for speeds of 80 km/h (50 mph) and greater, with a maximum offset of 3.0 m (10 ft).

The warranting tables are based on benefit/cost (b/c) ratios of both 1.0 and 4.0. Considering the assumptions if conditions do not result in a b/c of at least 1.0, then a roadside barrier is clearly not warranted. If a b/c of 4.0 or greater is found, then a barrier is clearly warranted. At conditions between 1.0 and 4.0 a barrier may be warranted, and is designated as "possibly warranted."

These tables are appropriate only for rural two-lane roads with speeds of 80 km/h (50 mph) or less and initial traffic volumes less than 2,000 vehicles per year. If the tables are used for other conditions, the results will not be dependable.

Table A.5: Key to Warranting Tables

Hazard	Table
Fixed object, 1.2 m (4 ft) X 1.2 m (4 ft)	A.6
Fixed object, 1.2 m (4 ft) X 3.0 m (10 ft)	A.7
Vertical headwall, 1.0 m (3 ft) high	A.8
Headwall with flared wing walls, 1.2 m (4 ft) high	A.9
1V: 2H foreslopes, 4m (13 ft) high	A.10
1V: 2H foreslopes, 14m (46 ft) high	A.11
Vertical foreslope, 4m (13 ft) high	A.12
Group of trees, 30 m (100 ft) long	A.13
Water, 1 m (3 ft) deep	A-14

In the warranting tables, length is measure parallel to the road and width is perpendicular to the road.

Table A.6: Barrier Warrants for Fixed Object 1.2 X 1.2 meters

Metric Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 3.5 m	0 – 249	250 – 999	1,000 (+)
	3.6 – 4.9 m	0 – 249	350 – 1,399	1,400 (+)
	5.0 – 6.0 m	0 – 499	500 – 2,399	2,400 (+)
	6.1 – 6.6 m	0 – 1,199	1,200 (+)	
	6.7 – 7.2 m	0 – 2,999	3,000 (+)	
	7.3 (+) m	All		
60 km/h	1.0 – 2.3 m	0 – 299	300 – 1,399	1,400 (+)
	2.4 – 4.9 m	0 – 399	400 – 1,899	1,900 (+)
	5.0 – 6.0 m	0 – 799	800 – 4,999	5,000 (+)
	6.1 – 7.2 m	0 – 1,299	1,300 (+)	
	7.3 (+)	All		
50 km/h	0.6 – 1.7 m	0 – 799	800 – 4,999	5,000 (+)
	1.8 – 2.9 m	0 – 999	1,000 (+)	
	3. 0 – 3.5 m	0 – 1,199	1,200 (+)	
	3.6 – 4.2 m	0 – 1,299	1,300 (+)	
	4.3 (+) m	All		
30 km/h	All	All		

Note: This is the most appropriate table to use for an unprotected end of a bridge wall.

Table A.7: Barrier Warrants for Fixed Objects 4 Feet X 4 Feet

Continued, U.S. Customary Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 11 ft.	0 – 249	250 – 999	1,000 (+)
	12 – 15 ft	0 – 249	350 – 1,399	1,400 (+)
	16 – 19 ft	0 – 499	500 – 2,399	2,400 (+)
	20 – 21 ft	0 – 1,199	1,200 (+)	
	22 – 23 ft	0 – 2,999	3,000 (+)	
	24 (+) ft	All		
40 mph	3 – 7 ft	0 – 299	300 – 1,399	1,400 (+)
	8 – 15 ft	0 – 399	400 – 1,899	1,900 (+)
	16 – 19 ft	0 – 799	800 – 4,999	5,000 (+)
	20 – 23 ft	0 – 1,299	1,300 (+)	
	24 (+) ft	All		
30 mph	2 – 5 ft	0 – 799	800 – 4,999	5,000 (+)
	6 – 9 ft	0 – 999	1,000 (+)	
	10 – 11 ft	0 – 1,199	1,200 (+)	
	12 – 13 ft	0 – 1,299	1,300 (+)	
	14 ft (+)	All		
20 mph	All	All		

Note: This is the most appropriate table to use for an unprotected end of a bridge wall.

Table A.8: Barrier Warrants for Fixed Object 1.2 meters Wide X 3.0 meters Long

Metric Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 3.5 m	0 – 149	150 – 599	600 (+)
	3.6 – 4.8 m	0 – 199	200 – 949	950 (+)
	4.9 – 6.0 m	0 – 399	400 – 1,699	1,700 (+)
	6.1 – 6.6 m	0 – 999	1,000 (+)	
	6.7 – 7.2 m	0 – 2,499	2,500 (+)	
	7.3 (+) m	All		
60 km/h	1.0 – 2.3 m	0 – 199	200 – 899	900 (+)
	2.4 – 4.8 m	0 – 249	250 – 1,099	1,100 (+)
	4.9 – 6.0 m	0 – 699	700 – 4,799	4,800 (+)
	6.1 – 6.6 m	0 – 1,149	1,150 (+)	
	6.7 (+) m	All		
50 km/h	0.6 – 1.7 m	0 – 599	600 – 3,599	3,600 (+)
	1.8 – 2.9 m	0 – 799	800 (+)	
	3. 0 – 3.6 m	0 – 949	950 (+)	
	3.7 – 4.2 m	0 – 1,049	1,050 (+)	
	4.3 – 4.8 m	0 – 1,749	1,750 (+)	
	4.9 – 5.4 m	0 – 2,499	2,500 (+)	
	5.5 (+) m	All		
30 km/h	0.6 – 1.1 m	0 – 4,999	5,000 (+)	
	1.2 (+) m	All		

Table A.9: Barrier Warrants for Fixed Object 4 Feet Wide X 10 Feet Long

Continued, U.S. Customary Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 11 ft.	0 – 149	150 – 599	600 (+)
	12 – 15 ft	0 – 199	200 – 949	950 (+)
	16 – 19 ft	0 – 399	400 – 1,699	1,700 (+)
	20 – 21 ft	0 – 999	1,000 (+)	
	22 – 23 ft	0 – 2,499	2,500 (+)	
	24 (+) ft	All		
40 mph	3 – 7 ft	0 – 199	200 – 899	900 (+)
	8 – 15 ft	0 – 249	250 – 1,099	1,100 (+)
	16 – 19 ft	0 – 699	700 – 4,799	4,800 (+)
	20 – 21 ft	0 – 1,149	1,150 (+)	
	22 (+) ft	All		
30 mph	2 – 5 ft	0 – 599	600 – 3,599	3,600 (+)
	6 – 9 ft	0 – 799	800 (+)	
	10 – 11 ft	0 – 949	950 (+)	
	12 – 13 ft	0 – 1,049	1,050 (+)	
	14 – 15 ft	0 – 1,749	1,750 (+)	
	16 – 17 ft	0 – 2,499	2,500 (+)	
	18 (+) ft	All		
20 mph	2- 3 ft	0 – 4,999	5,000 (+)	
	4 (+) ft	All		

Table A.10 Barrier Warrants for Vertical Headwall 1.0 Meter High X 2.4 Meters Long

Metric Units

Speed	Hazard Offset	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 2.3 m	0 – 299	300 – 1,199	1,200 (+)
	2.4 – 3.6 m	0 – 349	350 – 1,499	1,500 (+)
	3.7 – 4.8 m	0 – 399	400 – 1,899	1,900 (+)
	4.9 – 5.4 m	0 − 999	1,000 (+)	
	5.5 – 6.0 m	0 – 1,799	1,800 (+)	
	6.1 (+) m	All		
60 km/h	1.0 – 2.3 m	0 – 599	600 – 3,199	3,200 (+)
	2.4 – 3.6 m	0 – 699	700 – 4,999	5,000 (+)
	3.7 – 4.8 m	0 – 899	900 (+)	
	4.9 – 5.4 m	0 – 2,999	3,000 (+)	
	5.5 (+) m	All		
50 km/h	0.6 – 1.7 m.	0 – 1,700	1,800(+)	
	1.8 – 2.3 m	0 – 1,999	2,000 (+)	
	2.4 – 2.9 m	0 – 2,199	2,200 (+)	
	3.0 – 3.6 m	0 – 2,399	2,400 (+)	
	3.7 (+) m	All		
30 km/h	All	All		

Table A.11: Barrier Warrants for Vertical Headwall 3 Feet High X 8 Feet Long

Continued, U.S. Customary Units

Speed	Hazard Offset	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 7 ft.	0 – 299	300 – 1,199	1,200 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 399	400 – 1,899	1,900 (+)
	16 – 17 ft	0 – 999	1,000 (+)	
	18 – 19 ft	0 – 1,799	1,800 (+)	
	20 (+) ft	All		
40 mph	3 – 7 ft.	0 – 599	600 – 3,199	3,200 (+)
	8 – 11 ft	0 – 699	700 – 4,999	5,000 (+)
	12 – 15 ft	0 – 899	900 (+)	
	16 – 17 ft	0 – 2,999	3,000 (+)	
	18 (+) ft	All		
30 mph	2 – 5 ft.	0 – 1,700	1,800(+)	
	6 – 7 ft	0 – 1,999	2,000 (+)	
	8 – 9 ft	0 – 2,199	2,200 (+)	
	10 – 11 ft	0 – 2,399	2,400 (+)	
	12 (+) ft	All		
20 mph	All	All		

**Table A.12: Barrier Warrants for Headwall with Flared Wing Walls 1.2
Meters High X 2.0 Meters Long X 2.4 Meters Wide**

Metric Units

Speed	Hazard Offset	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 1.7 m	0 – 599	600 – 3.599	3,600 (+)
	1.8 – 2.3 m	0 – 649	650 – 3,799	3,800 (+)
	2.4 – 3.6 m	0 – 699	700 (+)	
	3.7 – 4.2 m	0 − 899	900 (+)	
	4.3 (+) m	All		
60 km/h	1.0 – 2.3 m	0 – 1,099	1,100 (+)	
	2.4 – 3.6 m	0 – 1,399	1,400 (+)	
	3.7 – 4.2 m	0 – 1,999	2,000 (+)	
	4.3 (+) m	All		
50 km/h	All	All		
30 km/h	All	All		

Table A.13: Barrier Warrants for Headwall with Flared Wing Walls 4 Feet High X 6 Feet Long X 8 Feet Wide

Continued, U.S. Customary Units

Speed	Hazard Offset	Effective ADT		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 5 ft.	0 – 599	600 – 3.599	3,600 (+)
	6 – 7 ft	0 – 649	650 – 3,799	3,800 (+)
	8 – 11 ft	0 – 699	700 (+)	
	12 –13 ft	0 − 899	900 (+)	
	14 (+) ft	All		
40 mph	3 – 7 ft.	0 – 1,099	1,100 (+)	
	8 – 11 ft	0 – 1,399	1,400 (+)	
	12 – 13 ft	0 – 1,999	2,000 (+)	
	14 (+) ft	All		
30 mph	All	All		
20 mph	All	All		

Table A.14: Barrier Warrants for 1V: 2H Foreslopes 4 Meters High X 30 Meters Long

Metric Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 2.3 m	0 – 549	550 – 2,999	3,000 (+)
	2.4 – 3.6 m	0 – 599	600 – 3,599	3,600 (+)
	3.7 – 4.8 m	0 – 749	750 – 4,999	5,000(+)
	4.9 – 5.4 m	0 – 1,399	1,400 (+)	
	5.5 – 6.0 m	0 – 3,999	4,000(+)	
	6.1 (+) m	All		
60 km/h	1.0 – 3.4 m	0 – 949	950(+)	
	2.4 – 3.6 m	0 – 1,049	1,050 (+)	
	3.7 – 4.2 m	0 – 1,249	1,250 (+)	
	4.3 – 4.8 m	0 – 1,499	1,500 (+)	
	4.9 – 5.4 m	0 – 3,199	3,200 (+)	
	5.5 (+) m	All		
50 km/h	0.6 – 2.3 m	0 – 2,149	2,150 (+)	
	2.4 – 2.9 m	0 – 2,349	2,350 (+)	
	3.0 – 3.6 m	0 – 3,399	3,400 (+)	
	3.7 (+) m	All		
30 km/h	All	All		

Table A.15: Barrier Warrants for 1V: 2H Foreslopes 13 Feet High X 100 Feet Long

Continued, U.S. Customary Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 7 ft.	0 – 549	550 – 2,999	3,000 (+)
	8 – 11 ft	0 – 599	600 – 3,599	3,600 (+)
	12 – 15 ft	0 – 749	750 – 4,999	5,000(+)
	16 – 17 ft	0 – 1,399	1,400 (+)	
	18 – 19 ft	0 – 3,999	4,000(+)	
	20 (+) ft	All		
40 mph	3 – 7 ft	0 – 949	950(+)	
	8 – 11 ft	0 – 1,049	1,050 (+)	
	12 – 13 ft	0 – 1,249	1,250 (+)	
	14 – 15 ft	0 – 1,499	1,500 (+)	
	16 – 17 ft	0 – 3,199	3,200 (+)	
	18 (+) ft	All		
30 mph	2 – 7 ft	0 – 2,149	2,150 (+)	
	8 – 10 ft	0 – 2,349	2,350 (+)	
	10 – 11 ft	0 – 3,399	3,400 (+)	
	12 (+) ft	All		
20 mph	All	All		

Table A.16: Barrier Warrants for 1V: 2H Foreslopes 14 Meters High X 30 Meters Long

Metric Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 2.3 m	0 – 149	150 – 649	650 (+)
	2.4 – 3.6 m	0 – 199	200 – 749	750 (+)
	3.7 – 4.8 m	0 – 249	250 – 899	900 (+)
	4.9 – 6.0 m	0 – 399	400 – 1,599	1,600 (+)
	6.1 – 7.2 m	0 – 899	900 (+)	
	7.3 (+)	All		
60 km/h	1.0 – 2.3 m	0 – 249	250 – 949	950 (+)
	2.4 – 3.6 m	0 – 299	300 – 1,249	1,250 (+)
	3.7 – 4.8 m	0 – 349	350 – 1,599	1,600 (+)
	4.9 – 5.4 m	0 – 549	550 – 3,149	3,150 (+)
	5.5 – 6.0 m	0 – 1,299	1,300 (+)	
	6.1 (+)	All		
50 km/h	0.6 – 2.3 m	0 – 599	600 – 3,199	3,200 (+)
	2.4 – 3.6 m	0 – 749	750 (+)	
	3.7 – 4.2 m	0 – 799	800 (+)	
	4.3 (+) m	All		
30 km/h	0.6 – 2.3 m	0 – 3,799	3,800 (+)	
	2.4 (+) m	All		

Table A.17: Barrier Warrants for 1V: 2H Foreslopes 46 Feet High X 100 Feet Long

Continued, U.S. Customary Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 7 ft.	0 – 149	150 – 649	650 (+)
	8 – 11 ft	0 – 199	200 – 749	750 (+)
	12 – 15 ft	0 – 249	250 – 899	900 (+)
	16 – 19 ft	0 – 399	400 – 1,599	1,600 (+)
	20 – 23 ft	0 – 899	900 (+)	
	24 (+) ft	All		
40 mph	3 – 7 ft.	0 – 249	250 – 949	950 (+)
	8 – 11 ft	0 – 299	300 – 1,249	1,250 (+)
	12 – 15 ft	0 – 349	350 – 1,599	1,600 (+)
	16 – 17 ft	0 – 549	550 – 3,149	3,150 (+)
	18 - 19 ft	0 – 1,299	1,300 (+)	
	20 (+) ft	All		
30 mph	2 – 7 ft.	0 – 599	600 – 3,199	3,200 (+)
	8 – 11 ft	0 – 749	750 (+)	
	12 – 13 ft	0 – 799	800 (+)	
	14 (+) ft	All		
20 mph	2 – 7 ft.	0 – 3,799	3,800 (+)	
	8 (+) ft	All		

Table A.18: Barrier Warrants for Vertical Foreslopes 4 Meters High X 30 Meters Long

Metric Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 2.3 m	0 – 249	250 – 1,099	1,100 (+)
	2.4 – 3.6 m	0 – 349	350 – 1,499	1,500 (+)
	3.7 – 4.8 m	0 – 449	450 – 1,999	2,000(+)
	4.9 – 6.0 m	0 – 2,999	3,000 (+)	
	6.1 (+) m	All		
60 km/h	1.0 – 2.3 m	0 – 249	250 – 1,099	1,100 (+)
	2.4 – 3.6 m	0 – 349	350 – 1,499	1,500 (+)
	3.7 – 4.8 m	0 – 449	450 – 1,999	2,000(+)
	4.9 – 5.4 m	0 – 2,999	3,000 (+)	
	5.5 (+) m	All		
50 km/h	0.6 – 2.3 m	0 – 249	250 – 1,099	1,100 (+)
	2.4 – 3.6 m	0 – 349	350 – 1,499	1,500 (+)
	3.7 – 4.8 m	0 – 449	450 – 1,999	2,000(+)
	4.9 (+) m	All		
30 km/h	0.6 – 2.3 m	0 – 249	250 – 1,099	1,100 (+)
	2.4 – 3.6 m	0 – 349	350 – 1,499	1,500 (+)
	3.7 (+) m	All		

Table A.19: Barrier Warrants for Vertical Foreslopes 13 Feet High X 100 Feet Long

Continued, U.S. Customary Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 7 ft.	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 449	450 – 1,999	2,000(+)
	16 – 19 ft	0 – 2,999	3,000 (+)	
	20 (+) ft	All		
40 mph	3 – 7 ft.	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 449	450 – 1,999	2,000(+)
	16 – 17 ft	0 – 2,999	3,000 (+)	
	18 (+) ft	All		
30 mph	2 – 7 ft.	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 449	450 – 1,999	2,000(+)
	16 (+)	All		
20 mph	2 – 7 ft.	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 (+)	All		

Table A.20: Barrier Warrants for Group of Trees 2.4 Meters Wide X 30 Meters Long

Metric Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 2.3 m	0 – 149	150 – 549	550 (+)
	2.4 – 3.6 m	0 – 199	200 – 749	750 (+)
	3.7 – 4.8 m	0 – 249	250 – 899	900 (+)
	4.9 – 6.0 m	0 – 349	350 – 1,499	1,500 (+)
	6.1 – 7.2 m	0 – 749	750 (+)	
	7.3 (+)	All		
60 km/h	1.0 – 2.3 m	0 – 249	250 – 999	1,000 (+)
	2.4 – 3.6 m	0 – 299	300 – 1,249	1,250 (+)
	3.7 – 4.8 m	0 – 349	350 – 1,649	1,650 (+)
	4.9 – 5.4 m	0 – 599	600 – 3,199	3,200 (+)
	5.5 – 6.0 m	0 – 799	800 (+)	
	6.1 (+)	All		
50 km/h	0.6 – 2.3 m	0 – 449	450 – 2,149	2,150 (+)
	2.4 – 3.6 m	0 – 599	600 – 2,999	3,000 (+)
	3.7 – 4.2 m	0 – 799	800 (+)	
	4.3 (+) m	All		
30 km/h	0.6 – 2.3 m	0 – 2,599	2,600 (+)	
	2.4 – 2.9 m	5,000 (+)		
	3.0 (+) m			

Table A.21: Barrier Warrants for Group of Trees 8 Feet Wide X 100 Feet Long

Continued, U.S. Customary Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 7 ft.	0 – 149	150 – 549	550 (+)
	8 – 11 ft	0 – 199	200 – 749	750 (+)
	12 – 15 ft	0 – 249	250 – 899	900 (+)
	16 – 19 ft	0 – 349	350 – 1,499	1,500 (+)
	20 – 23 ft	0 – 749	750 (+)	
	24 (+) ft	All		
40 mph	3 – 7 ft.	0 – 249	250 – 999	1,000 (+)
	8 – 11 ft	0 – 299	300 – 1,249	1,250 (+)
	12 – 15 ft	0 – 349	350 – 1,649	1,650 (+)
	16 – 17 ft	0 – 599	600 – 3,199	3,200 (+)
	18 - 19 ft	0 – 799	800 (+)	
	20 (+) ft	All		
30 mph	2 – 7 ft.	0 – 449	450 – 2,149	2,150 (+)
	8 – 11 ft	0 – 599	600 – 2,999	3,000 (+)
	12 – 13 ft	0 – 799	800 (+)	
	14 (+) ft	All		
20 mph	2 – 7 ft.	0 – 2,599	2,600 (+)	
	8 – 9 ft	5,000 (+)		
	10 (+)			

Table A.22: Barrier Warrants for Water 1.0 Meters Deep X 30 Meters Long

Metric Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
80 km/h	1.2 – 2.3 m	0 – 249	250 – 1,099	1,100 (+)
	2.4 – 3.6 m	0 – 349	350 – 1,499	1,500 (+)
	3.7 – 4.8 m	0 – 449	450 – 1,999	2,000(+)
	4.9 – 6.0 m	0 – 2,999	3,000 (+)	
	6.1 (+) m	All		
60 km/h	1.0 – 2.3 m	0 – 249	250 – 1,099	1,100 (+)
	2.4 – 3.6 m	0 – 349	350 – 1,499	1,500 (+)
	3.7 – 4.8 m	0 – 449	450 – 1,999	2,000 (+)
	4.9 – 5.4 m	0 – 2,999	3,000 (+)	
	5.5 (+) m	All		
50 km/h	0.6 – 2.3 m	0 – 599	600 – 3,199	3,200 (+)
	2.4 – 3.6 m	0 – 749	750 (+)	
	3.7 – 4.2 m	0 – 799	800 (+)	
	4.3 (+) m	All		
30 km/h	0.6 – 2.3 m	0 – 3,799	3,800 (+)	
	2.4 (+) m	All		

Table A.23: Barrier Warrants for Water 3 Feet Deep X 100 Feet Long

Continued, U.S. Customary Units

Speed	Hazard Offset From Edge of Travel Way	Adjusted Traffic Factor (ATF)		
		Not Warranted	Possibly Warranted	Warranted
50 mph	4 – 7 ft.	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 449	450 – 1,999	2,000(+)
	16 – 19 ft	0 – 2,999	3,000 (+)	
	20 (+) ft	All		
40 mph	3 – 7 ft.	0 – 249	250 – 1,099	1,100 (+)
	8 – 11 ft	0 – 349	350 – 1,499	1,500 (+)
	12 – 15 ft	0 – 449	450 – 1,999	2,000 (+)
	16 – 17 ft	0 – 2,999	3,000 (+)	
	18 (+) ft	All		
30 mph	2 – 7 ft.	0 – 599	600 – 3,199	3,200 (+)
	8 – 11 ft	0 – 749	750 (+)	
	12 – 13 ft	0 – 799	800 (+)	
	14 (+) ft	All		
20 mph	2 – 7 ft.	0 – 3,799	3,800 (+)	
	8 (+) ft	All		

A.6 SAMPLE PROBLEMS

The following are example applications of the warranting process described in this Appendix.

Problem 1.   This problem is the same as Problem 1 of Chapter 2.

Roadway data: A two-lane road, with 3.6 m (12 ft) lanes and 1.2 m (4 ft) paved shoulders. There is a tangent section and a 46 m (150 ft)-long horizontal curve on a 240 m (800 ft) radius. The whole section is on a 3 percent downward grade.

Traffic data: 400 present ADT with a 3 percent annual growth factor. Design speed is 50 km/h (30 mph). On the tangent section actual speeds may exceed the design speed.

Hazard data: The hazard is a 1V: 2H foreslope 18 m (60 ft) high, offset 1.8 m (6 ft) from the edge of travel way on the outside of the horizontal curve. The slope is 150 m (500 ft) parallel to the road, including both the horizontal curve and the tangent section. There are some scattered trees and small boulders on the slope.

Other issues: Because of the remote location, barrier construction is expected to be costly. There are no crash data available. There are no aesthetic or environmental issues.

Solution:

1. The hazard is at an offset of 1.2 m (6 ft). From Table 2.1, the clear zone range is 1.0 - 2.0 m (3 - 7 ft). From Table 2.2, the horizontal curve adjustment factor is 1.2. The higher end of the range is selected as the desired clear zone because of the seriousness of the hazard. Therefore, the slope is within the clear zone in both the tangent and curved sections. The slope is outside the clear zone for opposing traffic.

2. From Table 2.5, the slope is a Category 3 hazard so a barrier should be considered.

3. The following ADT adjustment factors were obtained from Tables A.1, A.2 and A.3:

    TG = 1.34
    HC = 1.00 for the tangent section and 4.00 for the curved section.
    DG = 1.10

4. The Adjusted Traffic Factor (ATF) for the tangent section is:

    ATF = ADT * TG * HC * DG

    AFT = 400 * 1.34 * 1.00 * 1.10

    ATF = 590

5. The Adjusted Traffic Factor (ATF) for the curved section is:

    ATF = ADT * TG * HC * DG

    ATF = 400 * 1.34 * 4.00 * 1.10

    ATF = 2,358

6.   From Table A.11, guardrail is possibly warranted on the tangent section and is clearly warranted on the curved section.

7. For the curved section, the following issues from Table A.4 are considered in determining to place a roadside barrier:

    Reasons to use a barrier:

    a. The hazard is larger than assumed in Table A.11.
    b. The hazard is more severe than assumed in Table A.11.
    a. There are multiple hazards, although only a few.
    b. Actual speeds may exceed the design speed.

    Reasons to not use a barrier:

    c. The roadway cross section elements are less severe than assumed.
    d. The barrier will probably cost more than assumed.

In this case a roadside barrier is recommended for the horizontal curve and not for the tangent sections. Client agency desires and budget concerns should be considered before a final decision is made.

Problem 2. This is the same as Problem 2 in Chapter 2.

Roadway data: A two-lane road, with 3.6 m (11 ft) lanes and 0.6 m (2 ft) paved
                       shoulders. This is a flat and tangent section. The roadway
                       approaches a bridge across a river. On the approach the road
                       leaves a cut section with a 1V: 6H foreslope to a ditch, and then
                       approaches the bridge on a fill with 1V: 3H side slopes. The slope
                       break for the fill is 0.6 m (2 ft) from the edge of the shoulder. The
                       fill is approximately 2.4 m (8 ft) high. On the far side a similar fill
                       extends 60 m (200 ft) where the fill flattens to 1V: 4H. There are
                       no pavement markings on the road or the bridge.

Traffic data: 1,100 present ADT with a 1 percent annual growth factor. Design
                       speed is 70 km/h (45 mph).

Hazard data: An 8.5 m (28 ft) wide bridge crosses a river with water depths of
                       approximately 1.5 m (5 ft). The bridge rail is a vertical concrete
                       wall.

Other issues: This roadway is in a park with serious aesthetic concerns.

Solution:

1. Table 2.1 shows the clear zone range is 4.5 - 5.0 m (14 - 16 ft). Assuming 3.3 M
    (11 ft) lanes on the bridge, the bridge rail is located 1.0 m (3 ft) from the traveled
    way and is in the clear zone. The bridge rail on the opposing traffic side is
    outside the clear zone. The 1V: 3H slope is traversable but not recoverable, so
    the approach clear zone is (using the mid-point of the range):

    a.   + (3 * 2.4) = 11.9 m

         or 15 + (3 * 8) = 39 ft.

    The river is also in the clear zone.

2. Tables 2.3 and 2.6 indicate that both the bridge rail and the river are Category 3
    hazards so a barrier should be considered.

3. The following ADT adjustment factors were obtained from Tables A.1, A.2 and
    A.3:

    TG = 1.10
    HC = 1.00
    DG = 1.00

4. The Adjusted Traffic Factor (ATF) for the tangent section is:

    ATF = ADT * TG * HC * DG

    ATF = 1,100 * 1.10 * 1.00 * 1.00

    ATF = 1,210

5. Table A.6 provides the closet description of the hazard. Interpolating between 80 km/h (50 mph) and 60 km/h (40 mph), a barrier is warranted at an ATF of at least 1,200. A barrier is recommended for the bridge rail.

Barrier is recommended for both approach sides to the bridge. Barrier is not needed on the far sides because the bridge rails are outside the opposing traffic clear zones.

Problem 3.

Roadway data: A two-lane road, with 3.6 m (11 ft) lanes and .4 m (2 ft) paved shoulders.   The section being studied for roadside safety improvements is approximately 16 km (10 miles) long, with many horizontal curves of varying radii. There are no grades steeper than 2.0 percent.

Traffic data: 500 present ADT with a 1 percent annual growth factor. Design speed is 60 km/h (40 mph).

Hazard data: The primary hazards present are 1V: 1.5H side slopes from 9 m (30 ft) to 12 m (40 ft) high. The slopes are from 1.2 m (4 ft) to 2 m (6 ft) from the edge of travel way. These slopes are intermittent but occur on both sides of horizontal curves.

Warrant Issue: What curves warrant shielding with barriers?

Solution:

            Table A.11 is for 1V: 2H foreslopes, 14 m (46 ft) high. The actual hazard is slightly steeper and lower than this table. Table A.11 indicates that:

                    Barriers are not warranted at an Adjusted Traffic Factor (ATF) below 250.
                    Barriers are possibly warranted at ATFs from 250 to 949.
                    Barriers are warranted at an ATF of 950 and above.

        The ATF is:

                    ATF = Initial ADT * TG * HC * DG

                    ATF = 500 * 1.10 * HC * 1.00

Barriers warranted if the ATF is 950 or above. Therefore, the horizontal curve factor that will result in barriers being warranted is:

950 = 500 * 1.10 * HC * 1.00

HC = 1.73 or greater

From Table A.2 for hazards on the outside of the curve, the first HC greater than 1.73 is 2.50, for curves with a radius smaller than 440 m (1,430 ft). For hazards on the inside of the horizontal curve, the first HC greater than 1.73 is 1.75, for curves smaller than 350 m (1,150 ft).

Therefore, on this project, barriers are warranted for the following conditions:

Slopes on the outside of horizontal curves with a radius smaller than 440 m (1,430 ft).
Slopes on the inside of horizontal curves with a radius smaller than 350 m (1,150 ft).

Using the same process, barriers for 1V: 1.5H slopes at all other locations are possibly warranted on this project so should be considered.