H3 Roadside Design Process

H3.1 Introduction

This section summarizes the design process used to determine the most appropriate and cost-effective design strategies for roadside features for a particular highway.

Selected design tools available to the highway designer, including the Roadside Safety Analysis Program (RSAP) computer software, are also discussed in this section.

H3.2 Design Process

This section provides guidance to the highway designer when selecting appropriate roadside strategies for a particular corridor, or for a specific segment of a highway.

In general, there are three steps to the design process:

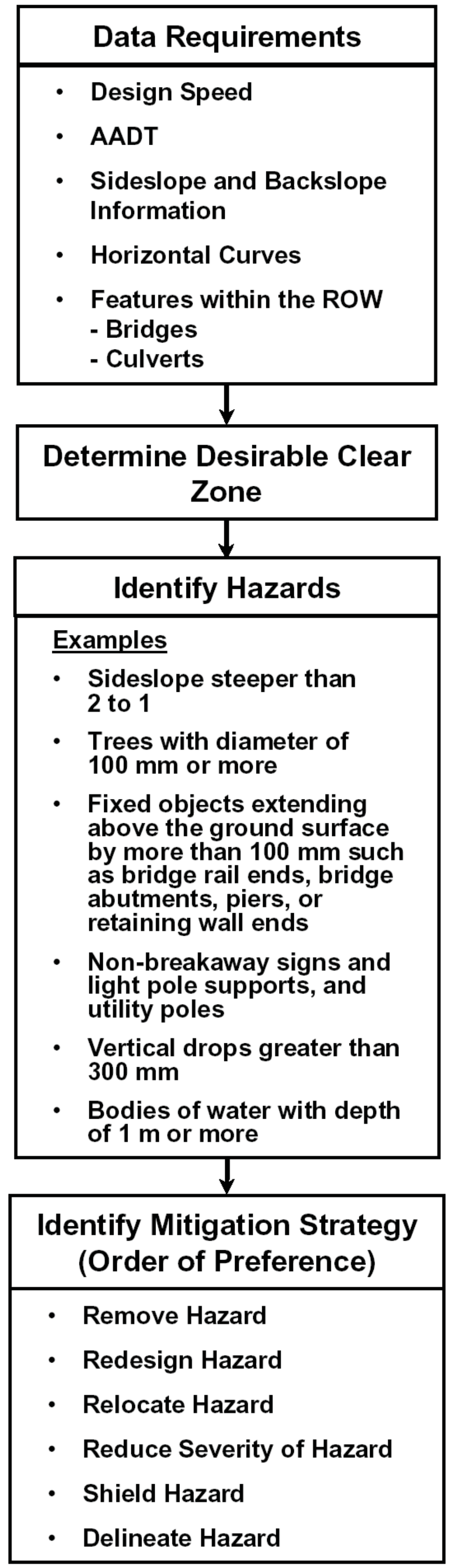
1. Identify the Clear Zone requirements.
2. Identify the hazards within or adjacent to the Clear Zone.
3. Identify the appropriate mitigation strategy for each hazard.

Figure H3.1 illustrates the overall roadside design process.

Strategies to redesign, relocate, and reduce the severity of hazards are provided in **Sections H4**, **H7, H8, H9,** and **H11** of this guide.

The purpose of delineating the hazard is to increase the driver's awareness of the hazard, if the other mitigation strategies are not feasible. The use of shoulder rumble strips may be used for the purpose of delineating hazards. **Section H4.9** provides more information on shoulder rumble strip applications.

FIGURE H3.1 Roadside Design Process



The mitigation strategy of shielding the hazard is unique because additional design features are introduced into the roadside environment.

When the strategy is to shield the hazard, the following elements need to be identified in sequence:

- the appropriate barrier system
- the appropriate end treatment
- the length of protection.

To select the appropriate barrier system, refer to **Section H3.2.3.1**.

To select the appropriate end treatment, refer to **Section H3.2.3.2**.

To select the length of protection, refer to **Section H3.2.3.3**.

H3.2.1 Clear Zone Requirements

Ideally, the highway designer should strive to provide as wide and as forgiving a roadside as possible, while still considering physical constraints and economics. In this context, a forgiving roadside is considered to be an area adjacent to the driving lane that has a relatively flat, smooth, firm surface, with no hazards, and extends laterally as far as errant vehicles are likely to encroach (travel away from the highway). For most projects, there will be isolated locations or longitudinal segments where the Clear Zone cannot be provided in accordance with the preferred design criteria. Factors such as topography, environmental features, drainage requirements, property requirements, and financial commitments will often dictate the shape and area (size) of the space available immediately adjacent to the travelled way.

The Clear Zone concept attempts to establish a balance between the safety benefit of a flat, smooth, firm surface with no hazards, and the economic and social implications related to providing this clear area, adjacent to the travelled way.

The path of an errant vehicle is difficult to predict. It depends largely on the nature of the roadside, the circumstances that first caused the vehicle to depart the roadway, driver action during encroachment, and the characteristics of the vehicle (examples include type, mechanical condition, and height).

The ideal solution is to provide a very wide traversable area adjacent to the roadway to accommodate errant vehicles. However, road authorities can rarely accomplish this because of physical, economic, or fiscal constraints. From the *GM Proving Ground Study*, we can conclude that only a few of the errant vehicles will likely travel a great distance off the highway. Consequently, the return on investment to keep the roadside clear decreases as the width of the clear area is increased. This is because the additional cost needed to provide the extended clearance generally increases with Clear Zone width, while the number of vehicles that are predicted to travel to the outer reaches of the Clear Zone area is relatively low.

The Clear Zone concept does not establish an exact area of responsibility for the road authority. It should be viewed as a desirable width for design and maintenance purposes, rather than as an absolute demarcation between safe and unsafe conditions.

Although the Clear Zone width is an attempt to balance the safety benefit against the potential constraints, the wide variety of constraints across the Province may still result in some situations where the full Clear Zone width is simply not achievable. In these cases, an attempt should first be made to address the constraints, whether it be the space available, environmental or property commitments, or funding, such that the Clear Zone can be achieved.

The roadside mitigation strategies (presented in **Section H1)** should be reviewed and considered when selecting the appropriate treatment, if the hazard or constraint cannot be eliminated. If the appropriate mitigation strategies are not practical, the designer may consider an adjustment to the Clear Zone.

The following sections describe in detail the methods used to determine the Desirable Clear Zone and the roadside mitigation strategies.

Section H3.2.1.1 provides examples of the process.

H3.2.1.1 Desirable Clear Zone

The Desirable Clear Zone (DCZ) is defined as the width of adjacent roadside border area specifically allocated for use by an errant vehicle.

This area, which may consist of paved or unpaved shoulders, shoulder rounding, recoverable or non-recoverable (or traversable) slopes, traversable features, and/or a clear runout area, may be located on the right hand side of the travel lanes of undivided highways or within the median area of divided highways.

The Desirable Tangent Clear Zone (DTCZ) distance is the value provided for a tangent segment of the highway. The DCZ may vary along the highway depending on whether the highway segment is on a tangent or on a curve. The radius of the curve and the location along the curve also potentially influence the DCZ.

The surface within this portion of the roadside should be relatively firm and free of hazards in order to promote vehicle stability and recovery.

The DCZ for a given segment is calculated using the following formula:

$$DCZ = DTCZ \times Kcz$$

where: DCZ = the Desirable Clear Zone

DTCZ = the Clear Zone for a tangent highway cross section

Kcz = curve correction factor

The DTCZ distances for various design speeds and traffic volumes are presented in **Table H3.1.** For divided highways, traffic volume in one direction is to be used to establish the Clear Zone. For undivided highways, the full (two-way)AADT is to be used.

The curve modification factors, Kcz, for a variety of radii and design speeds are presented in **Table H3.2.** The curve modification factor is applicable only on the outside of a curved segment due to expected increased encroachment on the outside of the curve.

TABLE H3.1 Clear Zone Distances (in metres from edge of driving lane)

Design Speed (Km/h)	Design AADT +	Fill Slopes			Cut Slopes		
		6:1 or Flatter	5:1 to 4:1	3:1	3:1	5:1 to 4:1	6:1 or Flatter
60 or less with barrier curb***	All	0.5	0.5	0.5	0.5	0.5	0.5
60 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	4.5 – 5.0	**	4.5 – 5.0	4.5 – 5.0	4.5 – 5.0
70 –80	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	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	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	Under 750	5.5 - 6.0	6.0 – 8.0	**	3.0 – 3.5	4.5 – 5.0	4.5 – 4.9
	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 *	10.0 – 13.0 *	**	5.0 – 6.0	6.5 – 7.5	8.0 – 8.5
	Over 6000	9.0 – 10.5 *	11.0 – 14.0 *	**	6.5 – 7.5	8.0 – 9.0	8.5 – 9.0
120 or More	750 – 1500 +	8.0 – 9.0	9.0 – 12.0	**	3.5 – 5.0	6.0 – 6.5	7.0 – 7.5
	1500 – 6000 +	9.0 – 10.0	10.0 – 14.0	**	5.5 – 6.5	7.0 – 8.0	8.0 – 9.0
	Over 6000 +	10.0 – 11.0 *	11.0 – 15.0	**	7.0 – 8.0	8.5 – 9.5	9.0 – 10.0

* Where a site specific investigation indicates a high probability of continued crashes, or such occurrences are indicated by crash history, the designer may provide Clear Zone distances greater than the suggested range shown. Clear Zones may be limited to 9 m for practicality or to provide a consistent roadway template if previous experience with the subject roadway or 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 the 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.

***On a curbed roadway, the Clear Zone distance should be measured from the edge of driving lane, e.g. on a 2-lane 10m road width from curb to curb, 3.5 m adjacent to centreline may be considered the driving lane and therefore, the curb is 1.5m from the driving lane. It is still prudent to place obstacles at least 0.5 m behind the curb.

+ The AADT used for this purpose shall be the daily volume on the roadway i.e. the full AADT on undivided highways and half of the AADT on divided highways.

TABLE H3.2 Curve Modification Factors (K_{cz})

<table>
<tr><th rowspan="2">Radius (m)</th><th colspan="6">Design Speed (km/h)</th></tr>
<tr><th>60</th><th>70</th><th>80</th><th>90</th><th>100</th><th>≥110</th></tr>
<tr><td>>1100</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>1100</td><td>1.1</td><td>1.1</td></tr>
<tr><td>900</td><td rowspan="4">1.1</td><td rowspan="2">1.1</td><td>1.1</td><td rowspan="3">1.2</td><td rowspan="2">1.2</td><td>1.2</td></tr>
<tr><td>700</td><td rowspan="3">1.2</td><td>1.3</td></tr>
<tr><td>600</td><td rowspan="4">1.2</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td></tr>
<tr><td>500</td><td rowspan="3">1.3</td></tr>
<tr><td>450</td><td rowspan="4">1.2</td><td rowspan="3">1.3</td><td rowspan="2">1.4</td><td>1.5</td></tr>
<tr><td>400</td><td rowspan="10"></td></tr>
<tr><td>350</td><td>1.4</td><td rowspan="2">1.5</td></tr>
<tr><td>300</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td><td rowspan="2">1.5</td></tr>
<tr><td>250</td><td rowspan="2">1.3</td><td rowspan="6"></td></tr>
<tr><td>200</td><td>1.4</td><td>1.5</td><td rowspan="4"></td></tr>
<tr><td>150</td><td>1.4</td><td>1.5</td><td rowspan="2"></td></tr>
<tr><td>100</td><td>1.5</td><td></td></tr>
</table>

Notes:
(1) Clear Zone correction factor is applied to outside of curves only.
(2) Curves flatter than 1,100 m do not require an adjusted Clear Zone.

The measurement of the Desirable Clear Zone is only applicable over recoverable surfaces (firm; 4:1 or flatter slopes). The presence of a non-recoverable surface (generally considered to have a slope steeper than 4:1) requires an extension of the Clear Zone distance provided. The extension (called a recovery area), equivalent to the width of the non-recoverable slope located within the Desirable Clear Zone, is provided in recognition that an errant vehicle will likely travel to the bottom of the slope.

Figures H3.2 and H3.3 illustrate the measurement of the Desirable Clear Zone over a recoverable surface and a non-recoverable surface, respectively.

FIGURE H3.2 Desirable Clear Zone (DCZ) over Recoverable Surface

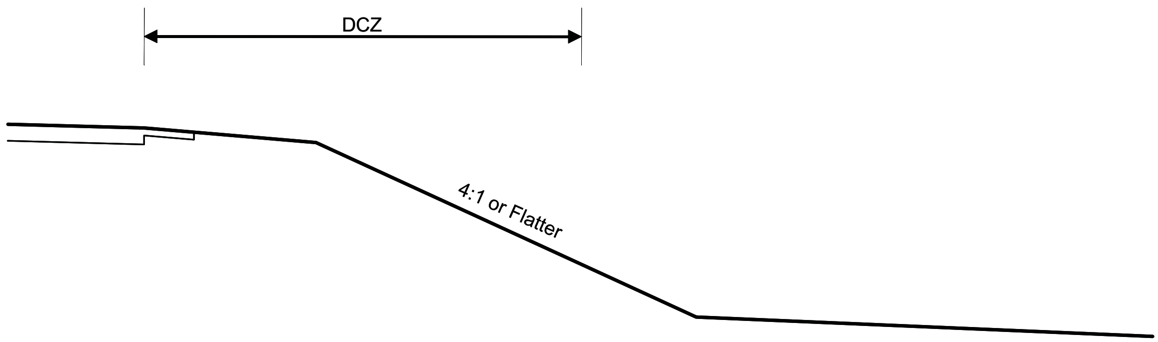
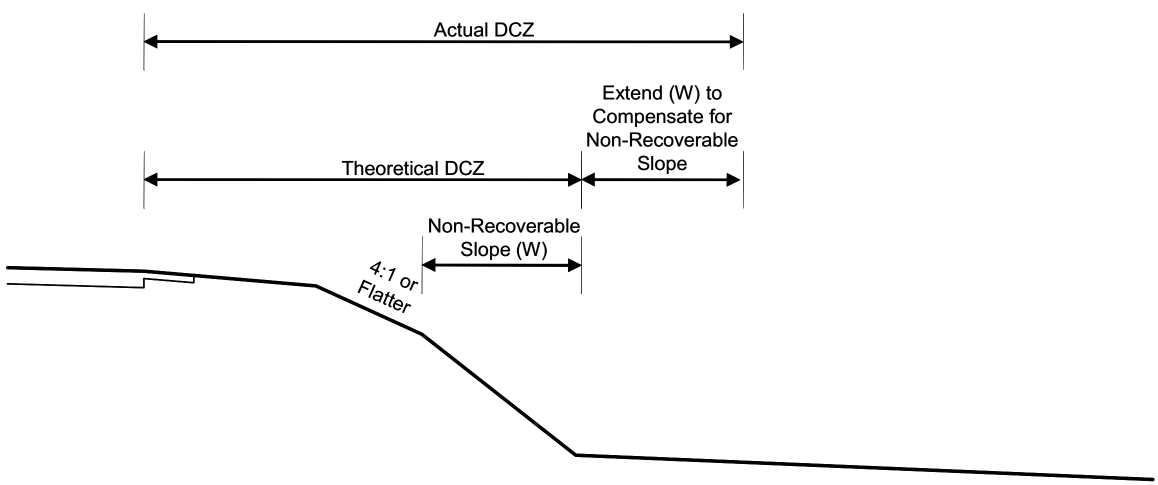


FIGURE H3.3 Desirable Clear Zone (DCZ) over Non-recoverable Surface



The Desirable Clear Zone distance should not be considered as the maximum clear distance that needs to be provided for a facility. Mitigation of hazards beyond the Desirable Clear Zone should be considered where the combination of horizontal curvature, collision experience, and severity of hazard may pose significant concerns if hit by an errant vehicle. If a cost-effective mitigation solution to provide additional width beyond the Desirable Clear Zone is achievable, then increasing the offset to further enhance the safety of the facility should be considered.

The designer should use judgement when applying the Clear Zone offsets. Consider providing some form of hazard mitigation where the cross section or slope of the terrain or horizontal curvature tends to channel errant vehicles towards a hazard outside the Clear Zone. This would also apply for critical isolated hazards, such as bodies of water, cliffs and bridge piers, just beyond the Clear Zone where the consequences of a collision may be extremely severe, even if the probability of a collision are limited. Similarly, if isolated objects such as trees, are found to be just within the Clear Zone while other trees in the immediate vicinity are outside the Clear Zone, removal of the trees inside the Clear Zone may not significantly reduce the risk to drivers. Protection or removal may not be a cost-effective solution.

H3.2.2 Hazards to be Considered

The hazards must be identified within the Desirable Clear Zone before a mitigation strategy can be formulated.

Hazards can be categorized as:

- sideslopes
- roadside obstacles
- permanent bodies of water.

H3.2.2.1 Sideslopes

High embankments may be considered as hazards because of the severe consequences related to errant vehicles leaving the roadway and travelling down the slope.

Sideslopes with a slope ratio steeper than 3:1 are considered to be a hazard since the possibility of a vehicle rollover will significantly increase.

Similarly, steep backslopes may also be considered as a hazard due to an increased possibility of a vehicle roll-over.

Figures H3.4 and **H3.5** provide the longitudinal traffic barrier warrants for fill slopes with AADT < 400 vpd and AADT ≥ 400 vpd, respectively.

Slope and height combinations on or below the curve do not warrant shielding unless they include obstacles that are within or immediately outside of the Clear Zone and present a serious hazard to the occupants of errant vehicles. If the sideslope and height of the fill relationship fall within the barrier-warranted zone, the sideslope hazard should be mitigated by either flattening out the slope or shielding it with a barrier. The preferred mitigation is flattening the sideslope versus installing a longitudinal traffic barrier, provided that the slope material is firm and that the overall height of embankment is less than 14 m. However, all slopes that are not shielded by a barrier should be free of obstacles and water hazards based on the Clear Zone criteria.

Where sideslope flattening is used to eliminate the need for a barrier on high embankments, a 4:1 sideslope is typically used. A 4:1 sideslope is generally considered satisfactory for embankment heights up to 14 m provided that the slope itself, and the area at the base of the embankment, are free of obstacles and water hazards and constructed to be firm. If the embankment height is greater than 14 m, barrier protection is suggested regardless of the sideslope ratio.

Economic analysis using the Department's guidelines has shown that for embankments up to 14 m in height, where AADT exceeds 600 vpd on an 8 m wide road or exceeds 1000 vpd on a 13.4 m wide road, it is generally more cost effective to build flatter sideslopes than it is to install a barrier.

Figure H3.6 illustrates the cost-effectiveness of a sideslope improvement versus barrier installation.

If the barrier system chosen is more expensive than the conventional W-Beam weak post system; for example, strong post or concrete barrier, then a special economic analysis can also be undertaken to determine the cost-effectiveness. A benefit-cost spreadsheet customized for this purpose is available from Technical Standards Branch. Additional discussion on benefit-cost analysis is provided in **Section H3.3**.

FIGURE H3.4 Warrants for Sideslopes with AADT < 400 vpd

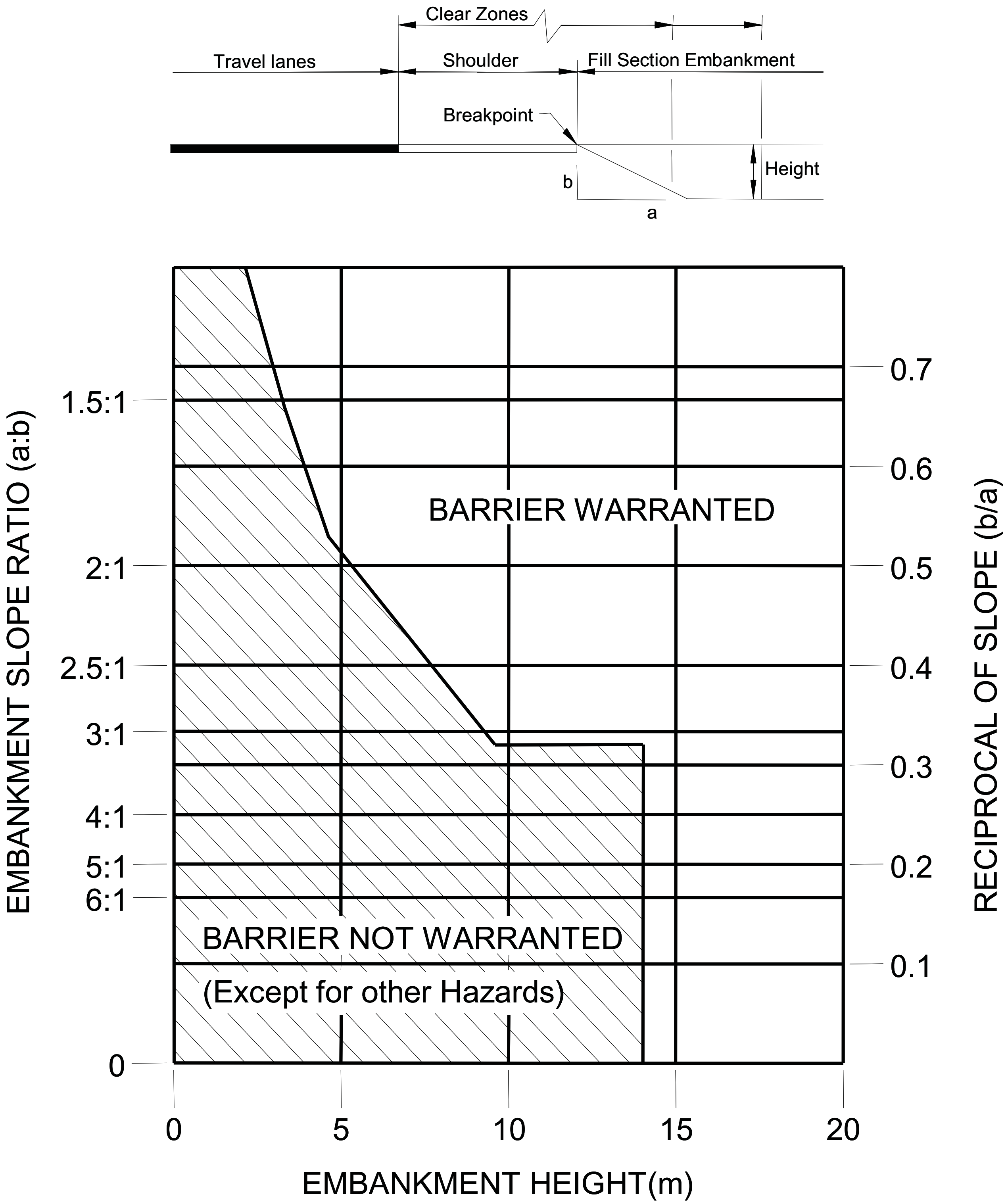


FIGURE H3.5 Warrants for Sideslopes with AADT ≥ 400 vpd

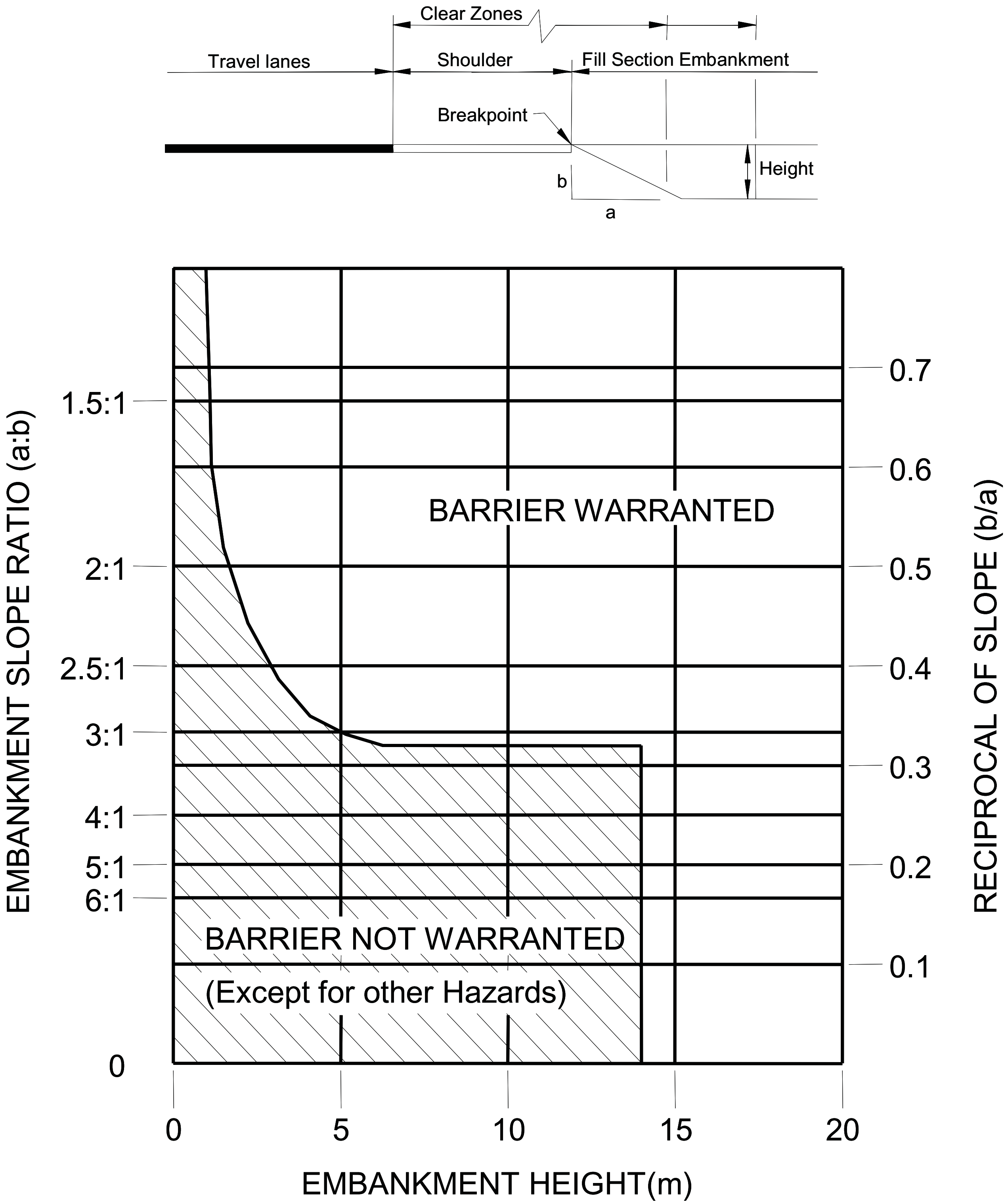
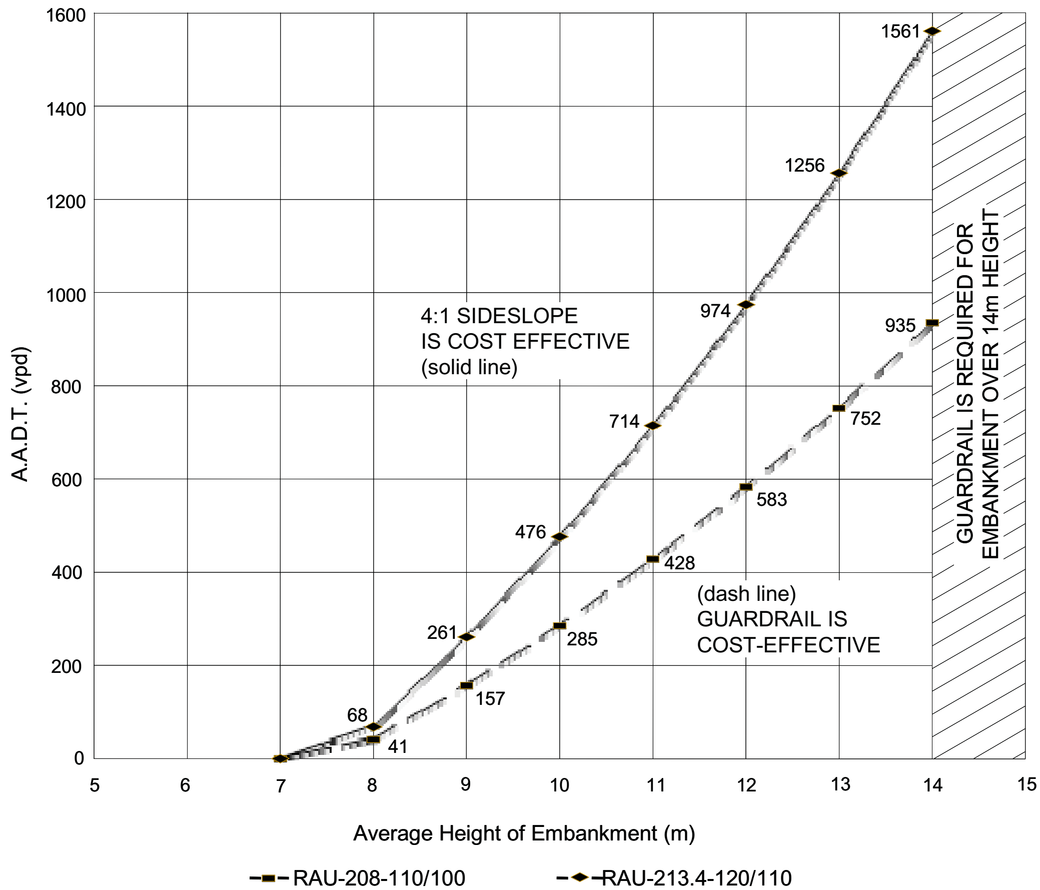


FIGURE H3.6 Sideslope Improvement Versus Barrier Installation



NOTES:

1. Guardrail is required if there are any non-traversable hazards or fixed objects on the embankment or at the base of the embankment.
2. Additional maintenance cost associated with snow clearing at guardrail installations is not included in the analysis (due to the difficulty in estimating the annual cost)

ASSUMPTIONS

1. Shoulder Encroachment Rate as per AASHTO Roadside Design Guide.
2. Severity Index of Collisions as per T.A.C.
3. Collision severity information as per Section 3.3.
4. Guardrail and Sideslope construction, installation, and maintenance costs are based on 2005 unit prices.
5. Traffic volume increases 2 % annually for first ten years and 1 % thereafter.
6. Internal Rate of Return of 4 % on investment at 20 years is satisfactory.
7. Embankment sideslope is 3:1 with guardrail installation.

UNIT PRICES (2005)

1.	Borrow excavation	$ 2.72/cu m.
2.	Overhaul	$ 0.75/cu m/km.
3.	Guardrail installation (including material cost)	$ 74/m (2005 unit price).
4.	Guardrail re-installation (including removal and new material cost)	$ 89/m (2005 unit price).
5.	Guardrail maintenance	$ 500/km/yr.

H3.2.2.2 Roadside Obstacles

Roadside obstacles may be non-traversable hazards or fixed objects and may be either man-made or natural features.

Hazards that should normally be considered for mitigation include:

- wood poles or posts with a cross sectional area greater than 10,000 mm^2 (100x100 mm) which do not have breakaway features
- trees having a diameter of 100 mm or more
- fixed objects extending above the ground surface by more than 100 mm, such as boulders, bridge rail ends, bridge abutments, piers, retaining wall ends, and bridge headwalls
- intersecting roadways and cross slopes
- non-breakaway signs or light pole supports
- non-breakaway utility poles
- vertical drops greater than 300 mm
- mailboxes with 100 mm wood posts or 50 mm steel posts and greater
- drainage structures, such as culvert and pipe ends without tapered end sections or traversable grates.

The decision on the use of a longitudinal traffic barrier should be based on the size, shape and location of the hazard.

These hazards should be mitigated based on the order of preference provided in **Section H3.2.3.**

H3.2.2.3 Permanent Bodies of Water

Bodies of water with a depth of one metre or more located within the Clear Zone should be considered a hazard. Longitudinal traffic barrier systems are typically used to mitigate this type of hazard.

Where the bodies of water are seasonal in nature, or where the depth of water varies based on the season, the designer should use engineering judgement to determine if shielding is warranted based on traffic exposure, offset from roadway, duration of hazard, length of hazard, and severity of the hazard.

H3.2.3 Mitigation Strategies

It is recognized that the Province will not always be able to incorporate safety improvements into its work program, due to physical, environmental, and/or fiscal priorities and constraints. However, the highway designer is encouraged to be proactive in improving safety, where possible. The intent of providing a clear area adjacent to the highway is to minimize the severity of roadside collisions resulting from an errant vehicle leaving the roadway.

The ideal time to consider the appropriate mitigation strategy is at the grading design stage. Generally, hazards located in the Clear Zone should be mitigated.

Ideally, the designer should strive towards providing the widest area that can be reasonably afforded, fully considering physical and economic constraints, and stakeholder expectations. However, provision of a completely clear roadside is not always possible. In such circumstances, a mitigation strategy must be employed to reduce the severity potential of a roadside hazard.

As indicated in **Section H1.1**, for each hazard identified the following strategies listed in priority of preference will be considered to determine the appropriate roadside mitigation:

- remove the hazard
- redesign the hazard so that it can be safely traversed or contacted
- relocate the hazard to reduce the probability of it being traversed or contacted
- reduce the severity of the hazard
- shield the hazard
- delineate and increase the driver's awareness of the hazard, if the other

mitigation measures cannot be made to work.

The Length of Need and the selection of the appropriate longitudinal traffic barrier system, end treatments, and crash cushions need to be determined to shield the hazard properly.

H3.2.3.1 Longitudinal Traffic Barrier System Selection

The choice of longitudinal traffic barrier system is generally governed by the traffic volume (AADT), traffic speed (posted and/or design), facility type, and design deflection requirements (working area of the system). Other considerations include the stiffness required for connections to other features (such as bridges and retaining walls), severity of the hazard, aesthetics, special maintenance conditions (such as prevailing snow drifting problems) and other constraints or considerations.

All longitudinal traffic barrier systems must meet the test levels as specified in *NCHRP Report 350*. The six *NCHRP Report 350* performance test levels (TL-1 to TL-6) are discussed in **Section H1.3**.

The following table provides the minimum test level requirements for longitudinal traffic barriers:

TABLE H3.3
Barrier Test Level Requirements

Design Speed (km/h)	Test Level
> 70	TL-3
> 50 to ≤ 70	TL-2
≤ 50	TL-1

Test Level TL-3 is the basic level of performance desired for roadside hardware. Lower test levels are generally cost-effective for lower speed, lower volume highways. Higher test levels (TL-4, TL-5, or TL-6) are desirable for median applications and where the hazard is very severe and/or the exposure is very high.

Longitudinal traffic barrier systems that are more forgiving are preferred because they may reduce injuries and fatalities when crashes occur, provided that suitable operating space is, or can be made, available.

In general, the longitudinal traffic barrier systems listed below may be used on Alberta highways. The list is presented in order of most forgiving to the most rigid and indicates the *NCHRP Report 350* test level (TL):

- High Tension Cable System* (TL-4)
- Alberta Weak Post W-Beam** (Not tested under *NCHRP Report 350*, but assumed to be functionally equivalent to TL-3)
- Weak Post Box Beam (TL-3)
- Strong Post W-Beam with Plastic posts (TL-3)
- Strong Post W-Beam with Wood or Steel posts (TL-3)
- Modified Thrie Beam (TL-4)
- Precast Single Slope or F-Shape Concrete Barrier (TL-3)
- Cast-in-place or extruded F-Shape or Single Slope Concrete Barrier (TL-4 or TL-5).

* At the time of writing, "High Tension Cable Barrier" systems are considered "Introductory" by INFTRA because their use on Alberta highways has just commenced. Products are normally evaluated under in-service conditions for a period of two years prior to being accepted as "Approved Products". Consequently, although this product may be identified as the preferred product for many applications, permission to use it must still be obtained from INFTRA.

** The Alberta Weak Post W-Beam system has exhibited satisfactory in-service performance over many years and will continue to be used, where appropriate.

The New Jersey Concrete Barrier (TL-4) may only be used when connecting to or replacing a small segment of existing New Jersey Concrete Barrier.

Barrier systems not identified in this guide may only be used when authorized by Alberta Infrastructure and Transportation.

Standard drawings for the various longitudinal traffic barriers are provided in **Appendix B** of this guide.

Roadside Applications

Roadside longitudinal traffic barrier systems are designed to be impacted on only one side.

For roadside applications, Weak Post Box Beam and concrete barriers are generally not used unless the designer has provided site-specific justification such as matching an existing system.

INFTRA has also specified certain longitudinal traffic barrier systems for specific highways under its jurisdiction.

Table H3.4 identifies the preferred barrier systems on Alberta highways.

Additional information pertaining to roadside barrier systems is provided in **Section H5.2**.

TABLE H3.4 Preferred Longitudinal Traffic Barrier Systems on Alberta Highways

Location	Minimum Acceptable Test Level	Preferred Longitudinal traffic barrier System	Additional Information
Anthony Henday Drive	TL-4	High Tension Cable system or Modified Thrie Beam system on steel posts	
Calgary Ring Road including Stoney Trail, Highway 22X, East Freeway	TL-4	High Tension Cable system or Modified Thrie Beam system on steel posts	
Deerfoot Trail and Deerfoot Extension	TL-4	High Tension Cable system or Modified Thrie Beam system on steel posts	
Other divided highways with Design Speed > 70 km/h	TL-3	Strong Post W-Beam system with wood, plastic or steel posts	Spacer blocks must be either wood or plastic.
Undivided highways with AADT > 2500 and Design Speed ≥ 100 km/h	TL-3	Strong Post W-Beam system with wood, plastic or steel posts	Spacer blocks must be either wood or plastic.
Undivided highways with AADT ≤ 2500	TL-3	Alberta Weak Post W-Beam system with no spacer blocks[1]	
Divided and undivided highways with Design Speed > 50 km/h and ≤ 70 km/h	TL-2	Alberta Weak Post W-Beam system with no spacer blocks[1]	
Divided and undivided highways with Design Speed ≤ 50 km/h	TL-1	Alberta Weak Post W-Beam system with no spacer blocks[1]	

1. System not tested under *NCHRP Report 350*. It is considered acceptable for use on Alberta highways based on past performance and is assumed to have an equivalent TL-3 rating. Review design deflection to confirm appropriateness.

Median Applications

There are two reasons to provide a longitudinal traffic barrier system in the median:

- to shield a hazard (similar to the roadside application)
- to prevent cross-median crashes.

A median longitudinal traffic barrier system is normally designed to be impacted on both sides if it is within or near the Clear Zone of both roadways.

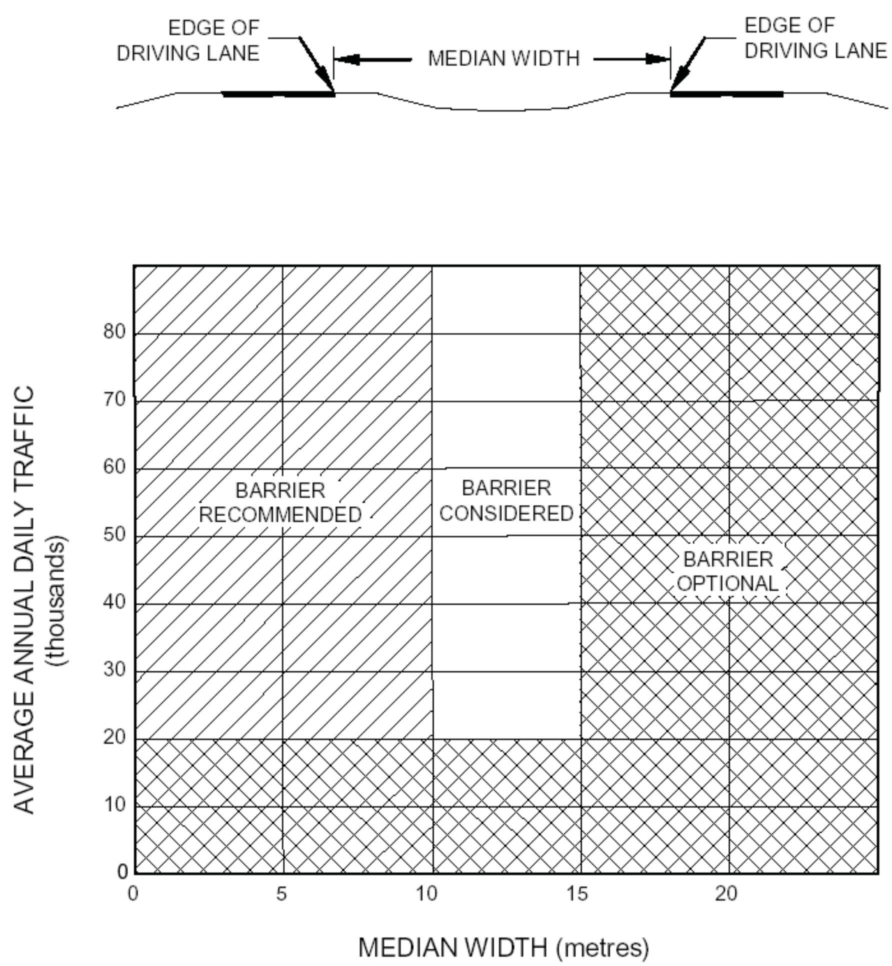
A longitudinal traffic barrier system can be used within medians that are wide enough to ensure that the barrier system will be outside of the Desirable Clear Zone for opposing traffic.

The appropriateness of the selected barrier system should be reviewed to confirm that the design deflection can be accommodated at the hazard location.

Median longitudinal traffic barrier systems are typically used to prevent cross-median crashes, although some systems are provided just to control access to adjacent lands.

Figure H3.7 illustrates the median barrier warrant.

FIGURE H3.7 Median Barrier Warrant



Source: Fig. 6.1, AASHTO Roadside Design Guide, 2002

In addition to the normal warrant which is used for medians less than 15 m wide, the following warrant, based on collision experience, is used to evaluate wider medians with very high traffic volumes. The collision rate calculation requires a minimum of three crashes within a five-year period. A median barrier is required if one of the following conditions* is met:

- 0.310 cross-median crashes of any severity per kilometre per year
- 0.075 fatal crashes per kilometre per year.

** Criteria based on CalTrans crash study warrant*

Crash data for the various highways may be obtained from Alberta Infrastructure and Transportation.

There are six types of median barrier systems that may be used in Alberta. These are listed in order of most forgiving to most rigid.

- High Tension Cable Barrier System (TL-4)
- Weak Post Box Beam (TL-3)
- Strong Post W-Beam (TL-3)
- Precast Single Slope or F-Shape Concrete Barrier (TL-3)
- Modified Thrie Beam (TL-4)
- Cast-in-place or extruded F-Shape Concrete Barrier (TL-4 or TL-5)
- Cast-in-place or extruded Single Slope Concrete Barrier (TL-4 or TL-5).

The preferred approach is to use the most forgiving barrier system that can be accommodated, assuming that no other design requirements or any other overriding considerations exist. Additional discussion of median barrier systems is provided in **Section H5.3**.

Alberta Weak Post W-Beam, Strong Post W-Beam and Modified Thrie Beam may be used in the median if the median width is wider than the required DCZ and if the selected barrier system does not dynamically deflect into the opposing traffic lanes when impacted.

A Single Slope concrete barrier is considered the standard application when a concrete barrier is warranted.

A Cast-in-place and/or extruded type concrete barrier is preferred versus a precast barrier.

Precast concrete barriers may be considered for permanent installations if the barrier system needs to be removed in the near future. Applicable scenarios might include additional construction anticipated within the next few years or when median crossovers or lane shifts in the median are required during construction. In these situations it would be more cost effective to provide precast concrete barriers. The precast concrete barriers may also be embedded 50 mm into the pavement to control dynamic deflection, provided that the effective barrier height above pavement meets the requirements of the desired test level.

Precast concrete barriers are considered TL-3 systems (with or without 50 mm embedment into pavement), while cast-in-place or Extruded Concrete Barriers of the same dimension are rated as TL-4 due to their greater rigidity.

The High Tension Cable System may be used where significant accumulations of snow are expected to occur, such as on north-south highway systems where other systems may act as a barrier to snow drift resulting in more extensive snow removal operations.

Weak Post Box Beam barrier systems are not generally used as a median barrier except in special circumstances where the designer has provided site-specific justification.

Modified Thrie Beam barrier systems may also be used as a median barrier for short segments in the vicinity of overland flow routes or flood plains versus a concrete barrier to provide flood relief during a major storm event. Additional discussion of this modification is provided in **Section H4.7**.

The New Jersey Concrete Barrier (TL-4) may only be used when connecting to or replacing short segments of existing New Jersey Concrete Barrier.

Design Deflection

The design deflection of a barrier system is the distance that a particular longitudinal traffic barrier system will shift laterally when impacted by an errant vehicle. It must be fully considered when selecting the appropriate barrier system.

The design deflection of a barrier system defines the minimum offset between the barrier system and the hazard that is being shielded. If the system is placed too close to the hazard, the impacting vehicle may deflect the barrier into the hazard. This may allow the vehicle to interact with the hazard and negate the purpose of the barrier system.

If the hazard cannot be relocated beyond the design deflection area for the barrier system, then a different system with a lower design deflection should be selected to ensure that the hazard will not be inadvertently contacted during a collision.

Table H3.5 provides the design deflection for the various systems.

TABLE H3.5
Barrier Design Deflection

Barrier System	Design Deflection (m)
High Tension Cable Systems (TL-4)	As per manufacturer/ supplier specifications (2.1 to 2.4)
Alberta Weak Post W-Beam with no spacer blocks (TL-3) [1]	2.5
Precast Concrete Barrier (TL-3)	Up to 1.8
Weak Post Box Beam (TL-3)	1.5
Strong Post W-Beam with Plastic Post (TL-3)	1.5
Strong Post W-Beam with Wood or Steel Post (TL-3)	0.9
Modified Thrie Beam (TL-4)	0.9
Standard Thrie Beam (TL-3)	0.6
Concrete Barrier (TL-4 or TL-5)	0.0

1. System not tested under *NCHRP Report 350*. It is considered acceptable for use on Alberta highways based on past performance and is assumed to have an equivalent TL-3 rating.

For additional information such as restrictions and installation requirements for the barrier systems, refer to **Section H5**.

H3.2.3.2 Barrier End Treatment Selection

The selection of an end treatment is dependent on the type of barrier system, type of facility, location of the end treatment, topography, geometrics, and many other factors.

TL-3 end treatments are recommended because there are no crash tested end treatments available for the TL-4 or TL-5 test levels.

End treatments not included in this guide must be authorized by INFTRA.

In this guide, the term "end treatment" refers to both End Treatments and Crash Cushions.

Additional discussion on end treatments is provided in **Section H6**.

The following tables provide the recommended end treatments for the various barrier systems.

High Tension Cable Systems

TABLE H3.6
End Treatments for TL-4 High Tension Cable Systems

Applications	End Treatments
Roadside or median	Proprietary End Terminal

Alberta Weak Post W-Beam

TABLE H3.7
End Treatments for TL-3 Alberta Weak Post W-Beam

Applications	End Treatments
Roadside or median – leaving end treatment on a divided highway	Wing End* (TEB 3.03)
Roadside or median	Turn Down (TEB 3.12)

* Located outside clear zone in direction of on-coming traffic.

Weak Post Box Beam

TABLE H3.8
End Treatments for TL-3 Weak Post Box Beam

Applications	End Treatments
Roadside or median if AADT < 10,000	Turn Down End Treatment (TEB 3.37)
Roadside or median requiring TL-3 end treatment	Bursting Energy Absorbing Terminal (BEAT)

Strong Post W-Beam

TABLE H3.9
End Treatments for TL-3 Strong Post W-Beam

Applications	End Treatments
Roadside or median – leaving end treatment on a divided highway	Wing End* (TEB 3.03)
Roadside or median if AADT < 10,000 or Design Speed ≤ 70 km/h	Turn Down (TEB 3.12)
Roadside application requiring TL-3 end treatment, or AADT ≥ 10,000 and Design Speed > 70 km/h	Flared Energy Absorbing Terminal (FLEAT) – **preferred** (RDG-B1.5)
	ET-Plus (RDG-B1.4)
Median application requiring TL-3 end treatment, or AADT ≥ 10,000 and Design Speed > 70 km/h	FLEAT-MT – **preferred** (RDG-B1.6)
	CAT-350 (RDG-B1.7)

* Located outside clear zone in direction of on-coming traffic.

Modified Thrie Beam

TABLE H3.10
End Treatments for TL-4 Modified Thrie Beam

Applications	End Treatments
Roadside or median – leaving end treatment on a divided highway	Wing End* (RDG-B5.1)
Roadside application	Flared Energy Absorbing Terminal (FLEAT) – **preferred** (RDG-B1.5)
	ET-Plus (RDG-B1.4)
Median application	FLEAT-MT – **preferred** (RDG-B1.6)
	CAT-350 (RDG-B1.7)

* Located outside clear zone in direction of on-coming traffic.

All TL-3 end treatments identified are designed to connect with a Strong Post W-Beam barrier system. A transition from the Modified Thrie Beam to a Strong Post W-Beam is required for the installation of a TL-3 end treatment. This is shown in standard drawing RDG-B5.5 in **Appendix B5**.

Concrete Barrier

TABLE H3.11
End Treatments for TL-4 or TL-5 Concrete Barrier

Applications	End Treatments
Roadside or median when posted speed is 60 km/h or less or outside clear zone	Flared and Tapered Down (3.0 m long)
Roadside or median requiring TL-3 end treatment	TRACC (RDG-86.8) CAT-350 (RDG-B6.12, RDG-B6.13, RDG-B1.7)
	QuadGuard (when AADT > 50,000)
Leaving end not exposed to opposing traffic	Full length barrier at end (blunt end)

The TRACC system is the preferred end treatment for concrete barriers on highways with 50,000 or less AADT where system impacts are less likely to occur. For highways with more than 50,000 AADT, the QuadGuard system is preferred.

Flared and Tapered Down end sections may be considered an acceptable TL-3 end treatment provided that the Turn Down section of the concrete barrier is located outside of the Desirable Clear Zone for traffic in both directions. For downstream treatments, the Tapered Down section only needs to be located outside of the Desirable Clear Zone for opposing traffic.

H3.2.3.3 Length of Need

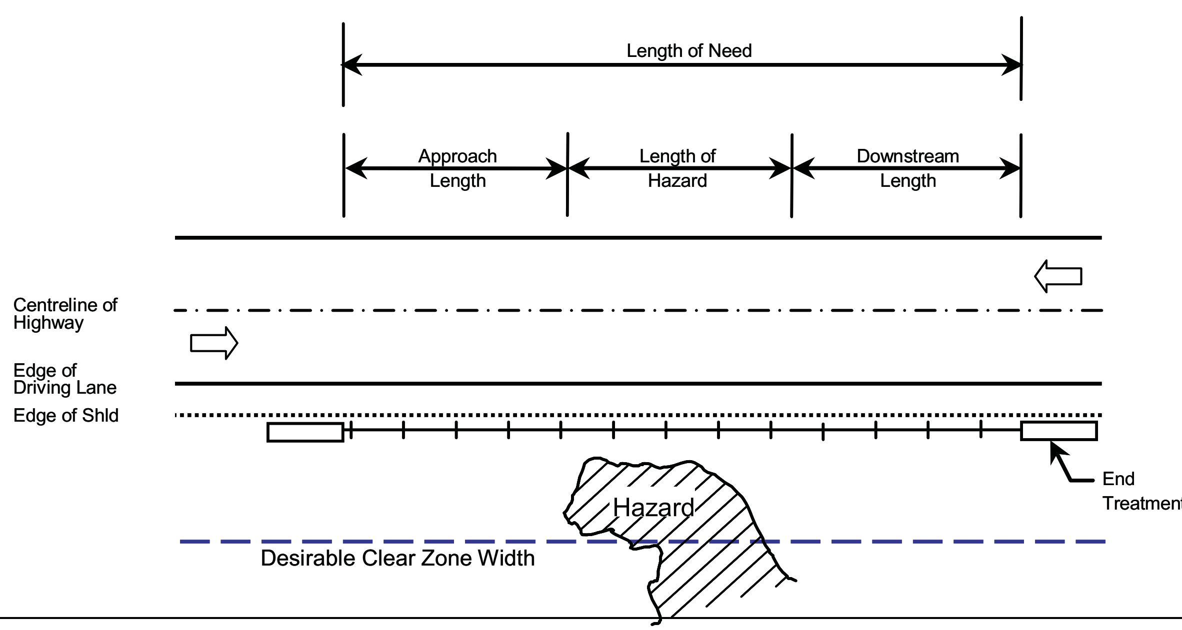
The Length of Need (LON) is defined as the length of barrier system required to provide protection at any obstacle or hazard. A portion of the end treatment may be considered in the LON as shown in the relevant standard drawings (also see Table 3.14).

The length is separated into three elements:

- approach length to the hazard
- length of the hazard
- downstream length after the hazard.

Figure H3.8 illustrates the Length of Need elements.

FIGURE H3.8 Length of Need Elements



The Length of Need is a function of the distance to the hazard from the edge of the driving lanes, the location of the barrier system in relation to the hazard and the edge of the driving lanes, and the design speed of the highway segment. The basis for the Clear Zone concept is that an errant vehicle leaving the roadway will travel for a distance before coming to a stop. Road safety researchers have not developed an accepted path for errant vehicles to date. For simplicity, the path of the errant vehicle is assumed to be straight. This distance, referred to as the Runout Length (L_R), depends on the design speed of the highway.

Protection should be provided to shield to the back of the hazard whenever possible to minimize the opportunity for an errant vehicle to strike the hazard. In some instances, such as a continuous hazard that extends far beyond the highway, protection to the back of the obstacle is not possible. When this situation occurs, protection should be provided to the Desirable Clear Zone distance.

When determining the Length of Need, one of the key steps is to identify the length of the hazard. In some instances, multiple hazards may be in close proximity to each other and, as a result, the length of hazards may overlap or result in a small separation (less than 50 m) between the two protection lengths. It may be necessary to consider these hazards as one continuous, combined hazard.

An exception to this situation is acceptable where an opening between the multiple hazards is required such as an entrance for a residence or to access utilities. If an opening is required, the
For a barrier system used to shield a hazard on a divided highway, the downstream of the barrier system is extended beyond the length of the hazard to provide barrier stability. The length of extension is dependent on the type of selected barrier system. **Table H3.13** provides the extension length for the various barrier systems.

location of the opening should be provided to minimize the potential of an errant vehicle striking the hazards. In addition, an appropriate end treatment or crash cushion may also be required to protect an errant vehicle from striking the end of the downstream barrier system.

The Length of Need for a barrier system may be calculated as shown in **Figure H3.9** or may be determined graphically as shown in **Figures H3.10** and **H3.11**.

The mathematical calculation method may only be used on tangent sections of the highway, as the method to determine the Length of Need is based on a similar triangle methodology. Similar triangles will not properly yield the appropriate Length of Need on spiral or curved segments of the highway. In this case, the Length of Need should be determined graphically.

In addition to providing the Length of Need to shield the hazard, the minimum length required for the selected guardrail system (see **Tables H5.1** and **H5.2** for roadside and median barrier systems, respectively) should be reviewed to ensure that the minimum guardrail length is provided to ensure stability of the system.

Table H3.12 provides the minimum runout length based on the AADT and design speed of the highway.

TABLE H3.12 Minimum Runout Length (L_R)

Design Speed (km/h)	Traffic Volume (AADT) [1]							
	>6,000	6,000 to 2,000	2,000 to 800	800 to 400	400 to 200	200 to 100	100 to 50	<50
	Runout Length L_R (m)							
≥ 110	150	135	120	110	60	30	15	Barrier only as required on site-specific basis as directed by the Engineer
100	120	110	100	90	45	22	11	
90	110	100	90	80	40	20	10	
80	100	90	80	70	35	20	10	
70	85	80	70	65	35	20	10	
60	75	70	60	55	30	15	10	

Note:
1. The AADT used for this purpose shall be the daily volume on the roadway i.e. the full AADT on undivided highways and half of the AADT on divided highways.
2. The values shown in this table are suggested minimums. These values may be exceeded where appropriate. To address areas of higher risk or relatively higher exposure, end treatments are normally provided outside of the Length of Need unless the end section is able to provide the same test level as the system.

TABLE H3.13 Minimum Barrier Extension Length for the Downstream End on a Divided Highway

Barrier System Type	Extension Length
Alberta Weak Post W-Beam Barrier	11.43 m
High Tension Cable	10 m
Strong Post W-Beam Barrier	3.81 m*
Precast Single Slope or F-Shape Concrete Barrier	9 m
Modified Thrie Beam Barrier	3.81 m*
Cast-in-place or Extruded Concrete Barrier	3 m

*Anchored with a cable anchor terminal.

To calculate the Length of Need on tangent sections of roads where the hazard is adjacent to the travelled lane, use the following formulae (refer to **Figure H3.9**):

$$\text{Length of Need} = X_1 = \frac{LH_1 + \frac{L_1}{f} - L_2}{\frac{1}{f} + \frac{LH_1}{L_R}}$$

If $L_1 = 0$, then Length of Need $= X_1 = \dfrac{LH_1 - L_2}{\frac{1}{f} + \frac{LH_1}{L_R}}$

The barrier offset $= Y_1 = LH_1 - \left(\dfrac{LH_1}{L_R}\right)X_1$

where:

X_1 = Length of need for adjacent traffic

Y_1 = Barrier offset at beginning of end treatment (adjacent traffic)

L_1 = the tangent length of barrier measured from the hazard to the point of flare for adjacent traffic.

L_2 = Distance from the edge of adjacent traffic travelled way to the tangent section of the barrier.

L_3 = Distance from the edge of adjacent traffic travelled way to the hazard.

L_R = Runout Length (refer to **Table H3.12**)

LH_1 = Distance from the left edge of adjacent traffic travelled way to the backside of the hazard or clear zone (whichever is less).

f = flare rate

To calculate the Length of Need on tangent sections of roads where the hazard is from the opposing direction, use the following formulae (refer to **Figure H3.9**):

$$\text{Length of Need} = X_2 = \frac{LH_2 + \frac{L_4}{f} - L_5}{\frac{1}{f} + \frac{LH_2}{L_R}}$$

If $L_4 = 0$, then Length of Need $= X_2 = \dfrac{LH_2 - L_5}{\frac{1}{f} + \frac{LH_2}{L_R}}$

Barrier Offset $Y_2 = LH_2 - \left(\dfrac{LH_2}{L_r}\right)X_2$

Where:

X_2 = Length of Need for Opposing Traffic

Y2 = Barrier offset at beginning of end treatment (Opposing Traffic).

L_2 = Distance from the edge of adjacent traffic travelled way to the tangent section of the barrier.

L_4 = The tangent length of barrier measured from the hazard to the point of flare for opposing traffic.

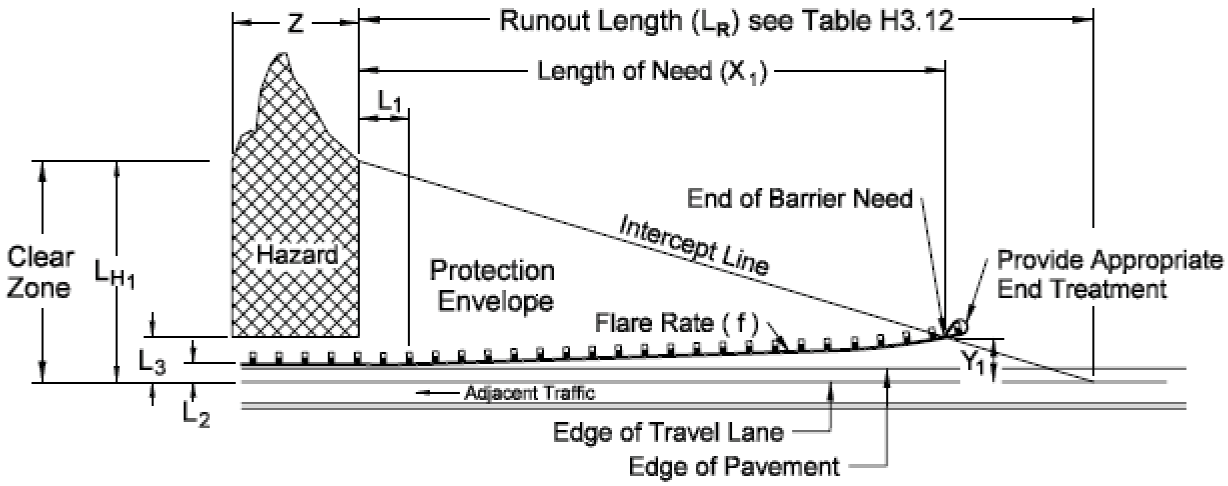
L_5 = Distance from left edge of opposing traffic travelled way to the tangent section of barrier.

L_R = Runout Length (refer to **Table H3.12**)

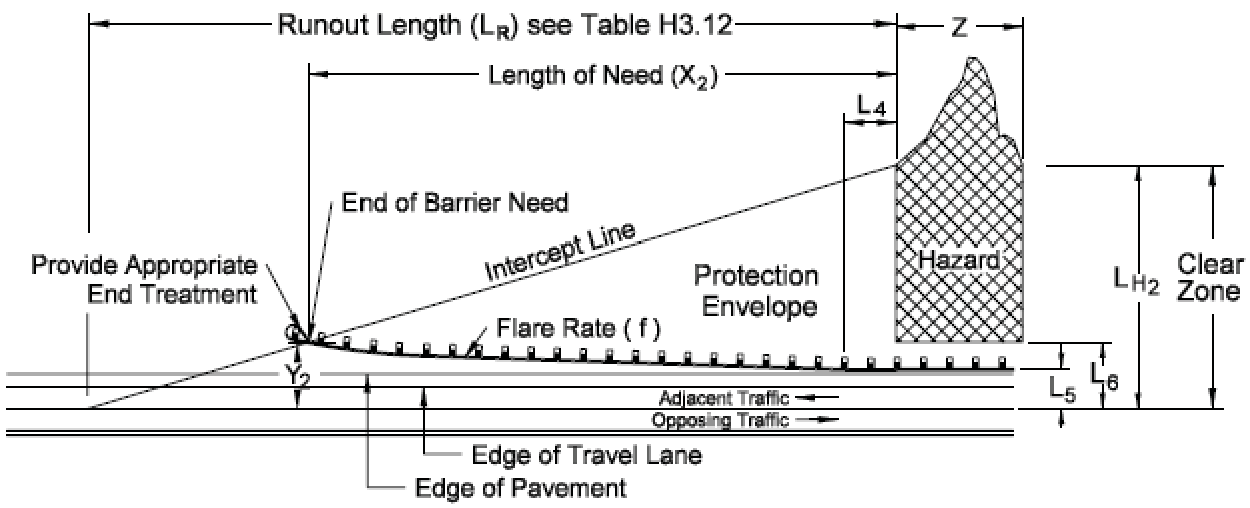
LH_2 = Distance from the left edge of opposing traffic travelled way to the backside of the hazard or clear zone (whichever is less).

f = flare rate

FIGURE H3.9 Traffic Barrier Length of Need



ADJACENT TRAFFIC



OPPOSING TRAFFIC

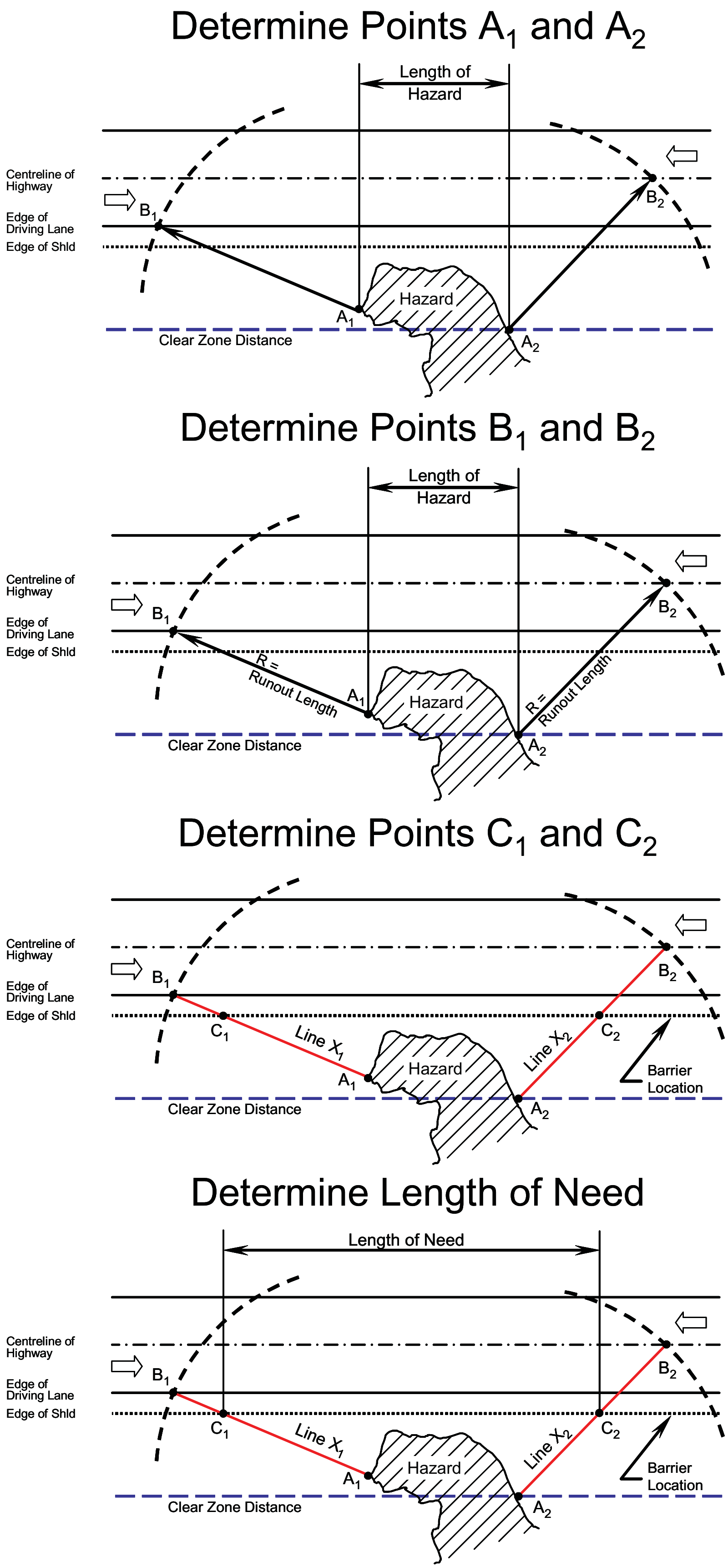
The following procedures outline the steps to determine the Length of Need graphically for both undivided and divided highways on tangent and curved segments of the road where the similar triangles methodology cannot be applied.

<u>Undivided Highways</u>

Figure H3.10 illustrates this method graphically.

- Select the Runout Length (L_R) based on the design speed and AADT (from **Table H3.12**)
- Determine the length of the hazard based on the following criteria:
  - The beginning of the hazard is the first point encountered (Point A1) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone distance offset, whichever is encountered first, measured perpendicular to the highway
  - The end of the hazard is the last point encountered (Point A2) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone distance offset, whichever is encountered last, measured perpendicular to the highway.
  - Draw arcs with a radius equal to the Runout Length (L_R) from Point A1 and A2
  - Locate Point B1 at the intersection of the encroachment arc with the edge of the driving lane on the same side in the direction of travel
  - Locate Point B2 as the intersection of the encroachment arc with the centre line of the highway
  - Draw Lines X1 and X2 from Points B1 and B2 to the centre of the encroachment arcs (Points A1 and A2) respectively, and draw either the proposed barrier location, or the offset of the flared end treatment that may be considered as part of the Length of Need, whichever is furthest away from the edge of the driving lane
  - Locate Intersection Points C1 and C2 at the intersections of Lines X1 and X2 with either the proposed barrier location, or the offset of the flared end treatment that may be considered as part of the Length of Need
  - Length of Need is determined as the distance between Points C1 and C2 measured along the proposed alignment of the barrier system.

FIGURE H3.10 Determine Length of Need for Undivided Highways

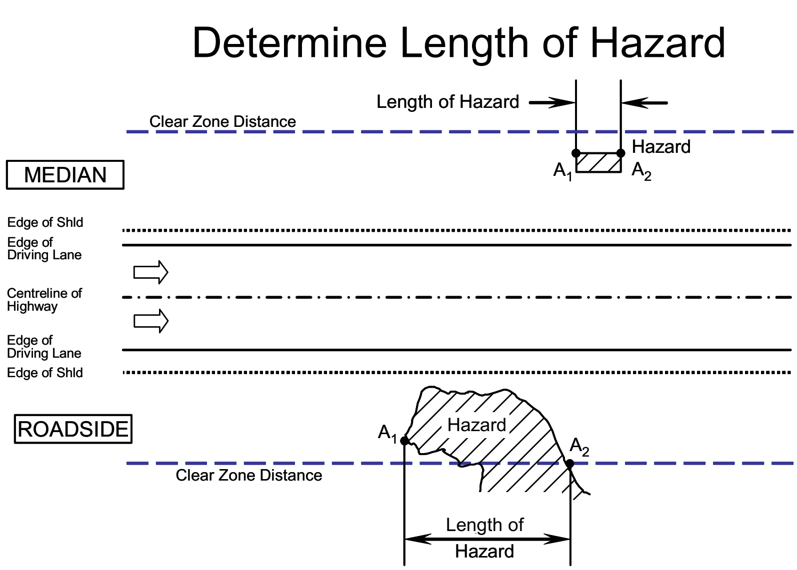


Divided Highways

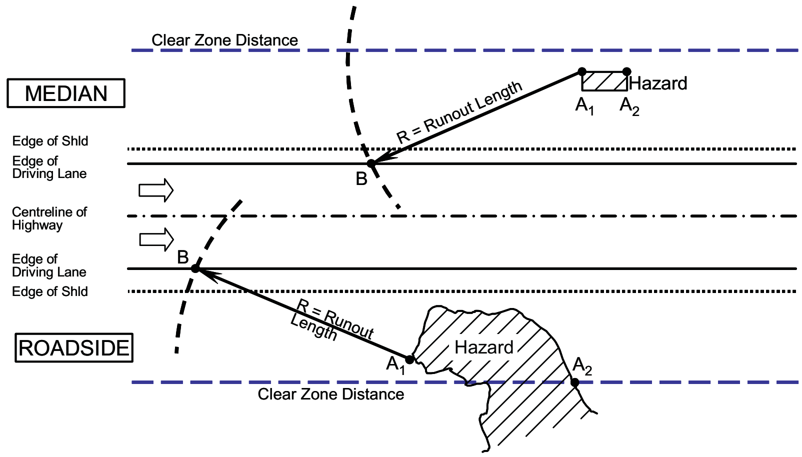
Figure H3.11 illustrates this method graphically.

- Select the Runout Length (L_R) based on the design speed and AADT from **Table H3.12**
- Determine the length of the hazard based on the following criteria:
    - o The beginning of the hazard is the first point encountered (Point A1) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone distance offset, whichever is encountered first, measured perpendicular to the highway
    - o The end of the hazard is the last point encountered (Point A2) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone distance offset, whichever is encountered last, measured perpendicular to the highway.
    - o Draw an arc with a radius equal to the Runout Length (L_R) from Point A1
    - o Locate Point B at the intersection of the encroachment arc with the edge of the driving lane on the same side in the direction of travel
    - o Draw Line X from Points B to the centre of the encroachment arc (Point A1)
    - o Draw the line showing either the proposed barrier location, or the flared end treatment that may be considered as part of the Length of Need, whichever is furthest away from the edge of the driving lane
    - o Locate Intersection Point C at the intersection of Line X with either the proposed barrier location, or the flared end treatment that may be considered as part of the Length of Need
    - o Length of Need is determined as the distance from Intersection Point C to the end of the hazard, plus the minimum system extension indicated in **Table H3.13**.

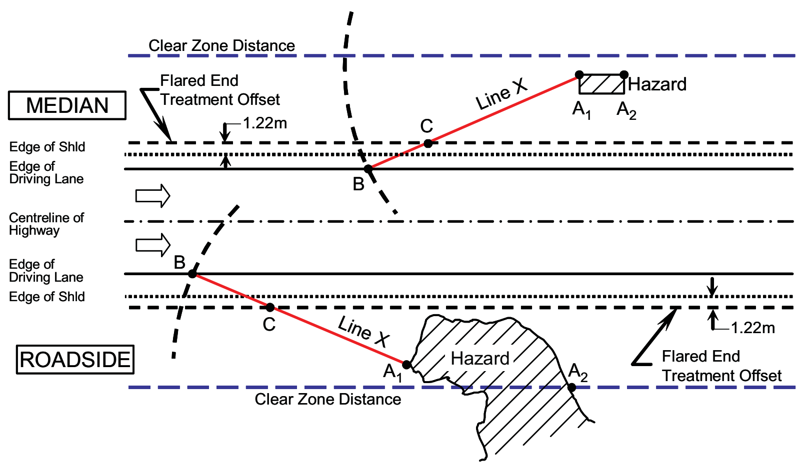
FIGURE H3.11 Determine Length of Need for Divided Highways



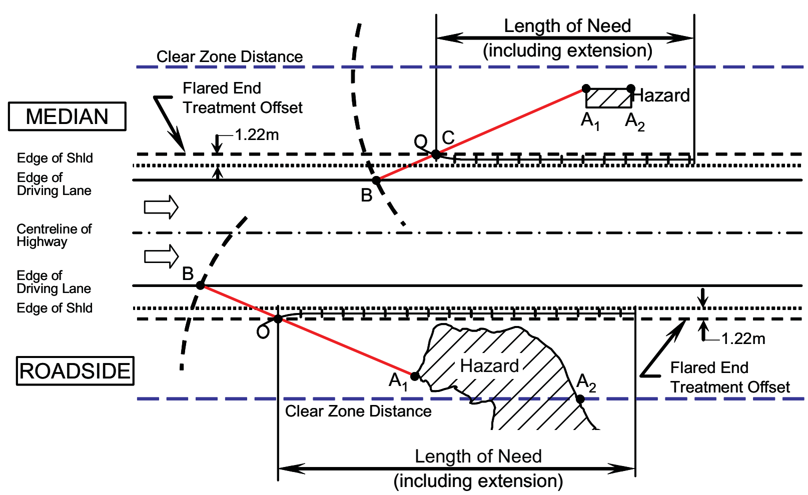
Determine Point B



Determine Point C



Determine Length of Need



A portion of the length of selected end treatment systems such as the FLEAT or the ET-Plus may be used to satisfy the required Length of Need, particularly for W-Beam and Modified Thrie Beam systems. **Table H3.14** provides the applicable lengths of end treatments that may be considered as part of the Length of Need requirements. Consult the manufacturer to confirm the specific length that may be considered part of the Length of Need requirements for end treatments not listed.

TABLE H3.14
Length of End Treatments Considered as Part of the Length of Need Requirements

End Treatments	System Length
Turn Down	0 m
Flared Energy Absorbing Terminal (FLEAT)	7.6 m
ET-Plus	11.4 m
CAT-350	0 m

H3.2.3.4 Examples

Example 1 – Determine the Desirable Clear Zone distance on a 4:1 sideslope.

Information provided:

- Design Speed = 110 km/h
- Sideslope Ratio = 4:1
- AADT = 5500 vpd
- Radius = 750 m.

Using **Table H3.1**, the Desirable Tangent Clear Zone distance is 13.0 m:

TABLE H3.1 Clear Zone Distances (in metres from edge of driving lane)

Design Speed (Km/h)	Design AADT +	Fill Slopes			Cut Slopes		
		6:1 or Flatter	5:1 To 4:1	3:1	3:1	5:1 To 4:1	6:1 or Flatter
60 or less with barrier curb***	All	0.5	0.5	0.5	0.5	0.5	0.5
60 or Less	Under 750 750 – 1500 1500 – 6000 Over 6000	2.0 – 3.0 3.0 – 3.5 3.5 – 4.5 4.5 – 5.0	2.0 – 3.0 3.5 – 4.5 4.5 – 5.0 4.5 – 5.0	** ** ** **	2.0 – 3.0 3.0 – 3.5 3.5 – 4.5 4.5 – 5.0	2.0 – 3.0 3.0 – 3.5 3.5 – 4.5 4.5 – 5.0	2.0 – 3.0 3.0 – 3.5 3.5 – 4.5 4.5 – 5.0
70 –80	Under 750 750 – 1500 1500 – 6000 Over 6000	3.0 – 3.5 4.5 – 5.0 5.0 – 5.5 6.0 – 6.5	3.5 – 4.5 5.0 – 6.0 6.0 – 8.0 7.5 – 8.5	** ** ** **	2.5 – 3.0 3.0 – 3.5 3.5 – 4.5 4.5 – 5.0	2.5 – 3.0 3.5 – 4.5 4.5 – 5.0 5.5 – 6.0	3.0 – 3.5 4.5 – 5.0 5.0 – 5.5 6.0 – 6.5
90	Under 750 750 – 1500 1500 – 6000 Over 6000	3.5 – 4.5 5.0 – 5.5 6.0 – 6.5 6.5 – 7.5	4.5 – 5.5 6.0 – 7.5 7.5 – 9.0 8.0 – 10.0 *	** ** ** **	2.5 – 3.0 3.0 – 3.5 4.5 – 5.0 5.0 – 5.5	3.0 – 3.5 4.5 – 5.0 5.0 – 5.5 6.0 – 6.5	3.0 - 3.5 5.0 – 5.5 6.0 – 6.5 6.5 – 7.5
100	Under 750 750 – 1500 1500 – 6000 Over 6000	5.0 – 5.5 6.0 – 7.5 8.0 – 9.0 9.0 – 10.0 *	6.0 – 7.5 8.0 – 10.0 * 10.0 – 12.0 * 11.0 – 13.5 *	** ** ** **	3.0 – 3.5 3.5 – 4.5 4.5 – 5.5 6.0 – 6.5	3.5 – 4.5 5.0 – 5.5 5.5 – 6.5 7.5 – 8.0	4.5 – 5.0 6.0 – 6.5 7.5 – 8.0 8.0 – 8.5
110	Under 750 750 – 1500 1500 – 6000 Over 6000	5.5 - 6.0 7.5 – 8.0 8.5 – 10.0 * 9.0 – 10.5 *	6.0 – 8.0 8.5 – 11.0 * 10.0 – 13.0 * 11.0 – 14.0 *	** ** ** **	3.0 – 3.5 3.5 – 5.0 5.0 – 6.0 6.5 – 7.5	4.5 – 5.0 5.5 – 6.0 6.5 – 7.5 8.0 – 9.0	4.5 – 4.9 6.0 – 6.5 8.0 – 8.5 8.5 – 9.0
120 or More	750 – 1500 + 1500 – 6000 + Over 6000 +	8.0 – 9.0 9.0 – 10.0 10.0 – 11.0 *	9.0 – 12.0 10.0 – 14.0 11.0 – 15.0	** ** **	3.5 – 5.0 5.5 – 6.5 7.0 – 8.0	6.0 – 6.5 7.0 – 8.0 8.5 – 9.5	7.0 – 7.5 8.0 – 9.0 9.0 – 10.0

Table reproduced from Section H3.2.1.1

Using **Table H3.2**, the curve adjustment factor (K_{cz}) is 1.3 for a radius of 750 m using a conservative approach:

TABLE H3.2 Curve Modification Factors (Kcz)

<table>
<tr><th rowspan="2">Radius (m)</th><th colspan="6">Design Speed (km/h)</th></tr>
<tr><th>60</th><th>70</th><th>80</th><th>90</th><th>100</th><th>≥110</th></tr>
<tr><td>>1100</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>1100</td><td>1.1</td><td>1.1</td></tr>
<tr><td>900</td><td rowspan="4">1.1</td><td rowspan="2">1.1</td><td>1.1</td><td rowspan="3">1.2</td><td rowspan="2">1.2</td><td>1.2</td></tr>
<tr><td>700</td><td rowspan="3">1.2</td><td>1.3</td></tr>
<tr><td>600</td><td rowspan="5">1.2</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td></tr>
<tr><td>500</td><td rowspan="3">1.3</td></tr>
<tr><td>450</td><td rowspan="4">1.2</td><td rowspan="3">1.3</td><td rowspan="2">1.4</td><td>1.5</td></tr>
<tr><td>400</td><td></td></tr>
<tr><td>350</td><td>1.4</td><td rowspan="2">1.5</td><td></td></tr>
<tr><td>300</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td><td rowspan="2">1.5</td><td></td></tr>
<tr><td>250</td><td rowspan="2">1.3</td><td></td><td></td></tr>
<tr><td>200</td><td>1.4</td><td>1.5</td><td></td><td></td><td></td></tr>
<tr><td>150</td><td>1.4</td><td>1.5</td><td></td><td></td><td></td><td></td></tr>
<tr><td>100</td><td>1.5</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table reproduced from Section H3.2.1.1

To determine the Desirable Clear Zone (DCZ) at R-750 location, the formula is:

DCZ = DTCZ × Kcz

where:

DCZ	=	the Desirable Clear Zone
DTCZ	=	the Clear Zone for a tangent highway cross section
Kcz	=	curve correction factor

DCZ with R-750 = 16.9 m

<u>Results:</u>

Desirable Clear Zone distance on the inside of an R-750 curve and tangent segment = 13.0 m (because the curve correction factor is not applied on the inside of a curve).

Desirable Clear Zone distance on the outside of an R-750 curve = 16.9 m.

Example 2 – Determine the Desirable Clear Zone distance on a 3:1 sideslope.

Information provided:

- Design Speed = 90 km/h
- Sideslope Ratio = 3:1
- AADT = 4000 vpd
- Radius = 1100 m
- Slope beyond toe of sideslope = 5%
- Shoulder width = 2.2 m.

When the sideslope ratio is steeper than 4:1, the surface is considered to be non-recoverable. For a sideslope ratio of 3:1, the surface is considered to be traversable. As a result, the Desirable Clear Zone distance is applied from the toe of the fill slope instead of from the edge of driving lane.

Using the slope beyond the toe of the sideslope (5% or 20:1) and **Table H3.1** with a sideslope ratio of 6:1 or flatter, the Desirable Clear Zone distance on Tangent is 6.5 m.

Using **Table H3.2**, the curve adjustment factor (Kcz) is 1.0 for a radius of 1100 m.

The Desirable Clear Zone distance is calculated using the following formula:

$$DCZ = DTCZ \times Kcz$$

where:	DCZ	=	the Desirable Clear Zone
	DTCZ	=	the Clear Zone for a tangent highway cross section
	Kcz	=	curve correction factor

Results:

Desirable Clear Zone on Tangent, and on the inside and outside of an R-1100 m curve = 6.5 m (applied beyond the toe of the sideslope).

Therefore, the Clear Zone includes all of the 3:1 sideslope plus an additional 4.3 m width (6.5 m minus the shoulder width of 2.2 m) applied at the toe of sideslope to provide the needed recovery width.

Example 3 – Determine the Desirable Clear Zone distance on a 2:1 sideslope.

Information provided:

- Design Speed = 80 km/h
- Sideslope Ratio = 2:1
- AADT = 700 vpd
- Tangent segment
- Slope beyond toe of sideslope = 10%
- Shoulder width = 1.0.

When the sideslope ratio is steeper than 4:1, the surface is considered to be non-recoverable. However, a sideslope ratio steeper than 3:1 is also considered to be non-traversable. Preferably the sideslope should be flattened to a minimum sideslope ratio of 3:1.

The Desirable Clear Zone distance is applied from the toe of the flattened fill slope (3:1) instead of from the edge of driving lane.

Using the slope beyond the toe of the sideslope (10% or 10:1) and **Table H3.1** with a sideslope ratio of 6:1 or flatter, the Desirable Tangent Clear Zone distance is 3.0 m.

Alternatively, if the sideslope cannot be flattened to accommodate a sideslope ratio of 3:1 or flatter, then a guardrail system should be considered to shield the 2:1 sideslope.

The installation of the guardrail system may be eliminated and the existing sideslope retained if a benefit-cost analysis confirms that maintaining the existing condition (the steeper sideslope) outweighs the societal benefit of reducing the collision severity at the site.

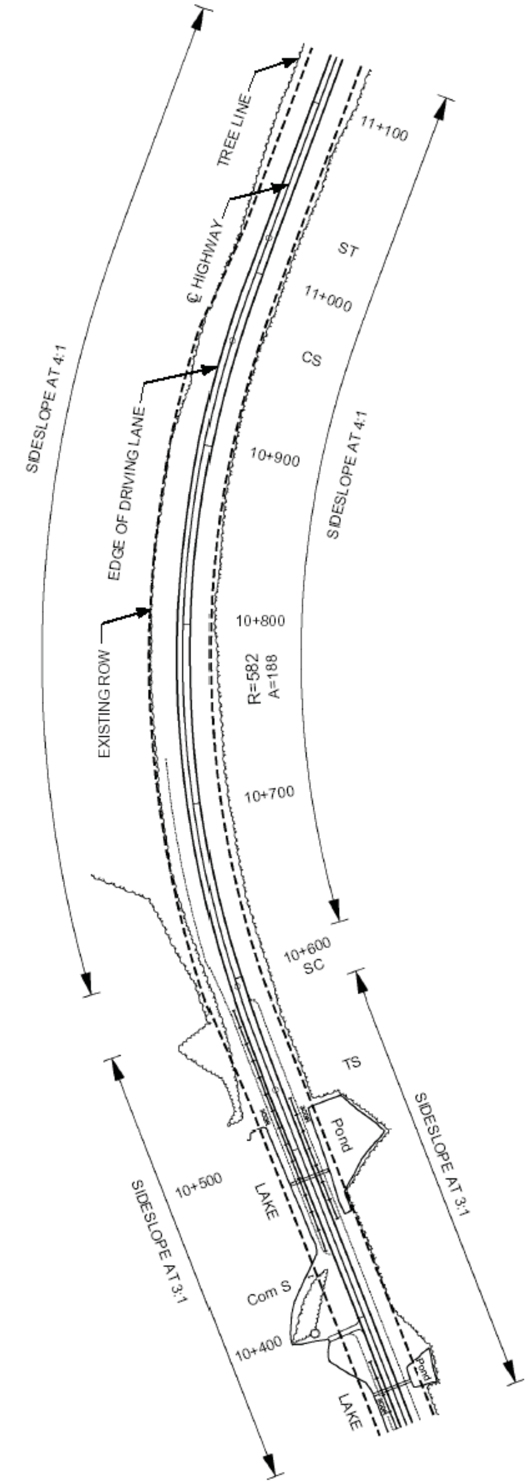
Results:

Desirable Tangent Clear Zone is 2.0 m (3.0 m minus the shoulder width of 1.0 m) applied at the toe of the flattened sideslope with a minimum sideslope ratio of 3:1.

Example 4 – Determine Appropriate Roadside Safety Treatments

Information provided:

- Design Speed = 110 km/h
- Sideslope = 3:1 or 4:1 as identified
- AADT = 800 vpd
- Radius = 580 m
- Slope beyond toe of sideslope = 10%.
- Shoulder width = 3.0 m



EXISTING CONDITIONS

The surface of the 3:1 sideslope is considered to be non-recoverable. The Desirable Clear Zone distance is applied from the toe of the sideslope instead of from the edge of driving lane.

The surface of the 4:1 sideslope is considered to be recoverable. The Desirable Clear Zone distance is applied from the edge of the driving lane.

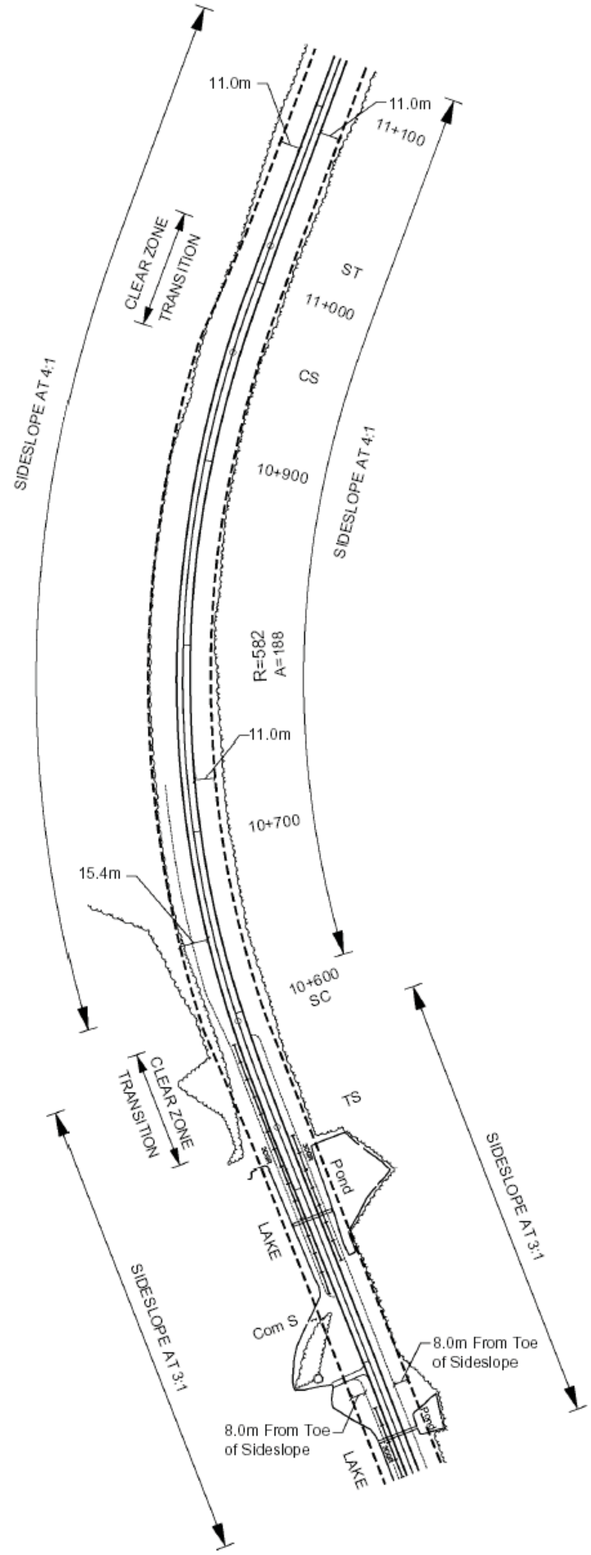
Using **Table H3.1**, the Desirable Tangent Clear Zone distance is 11.0 m for the 4:1 sideslope.

Using **Table H3.2**, the curve adjustment factor (K_{CZ}) is 1.4 for an R-580 m curve.

The Desirable Clear Zone distances for the section of highway are:

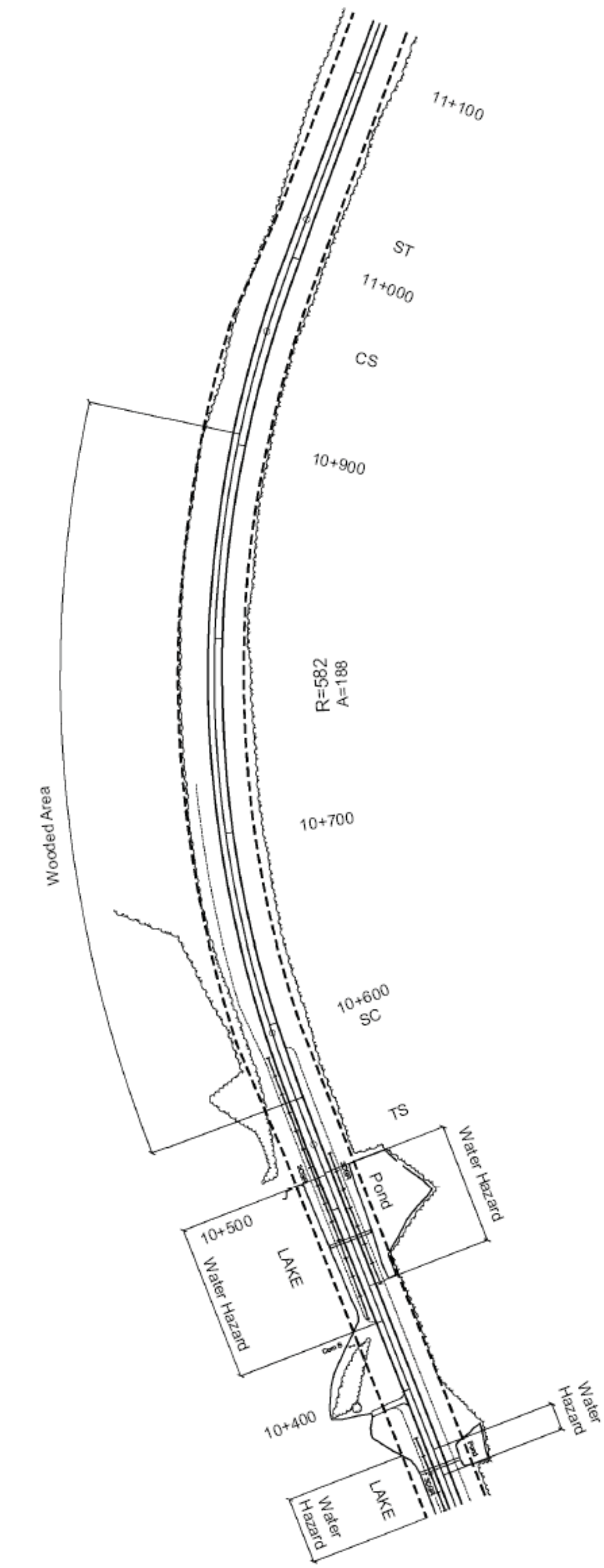
- on tangent segments with a 3:1 sideslope, 8.0 m (11.0 m minus the shoulder width of 3.0 m) applied from the toe of the sideslope
- on tangent and inside curved segments with a 4:1 sideslope, 11.0 m applied from the edge of the driving lane
- on outside curved segments with 4:1 sideslope, 15.4 m (11.0 m X 1.4) applied from the edge of the driving lane.

Using the Desirable Clear Zone distance for the highway segment, the following hazards have been identified.



SIDESLOPE HAZARDS

Using the desirable Clear Zone distance for the highway segment, the following hazards have been identified:



OTHER HAZARDS

For each of the obstacles, the following mitigation strategies are listed in order of preference:

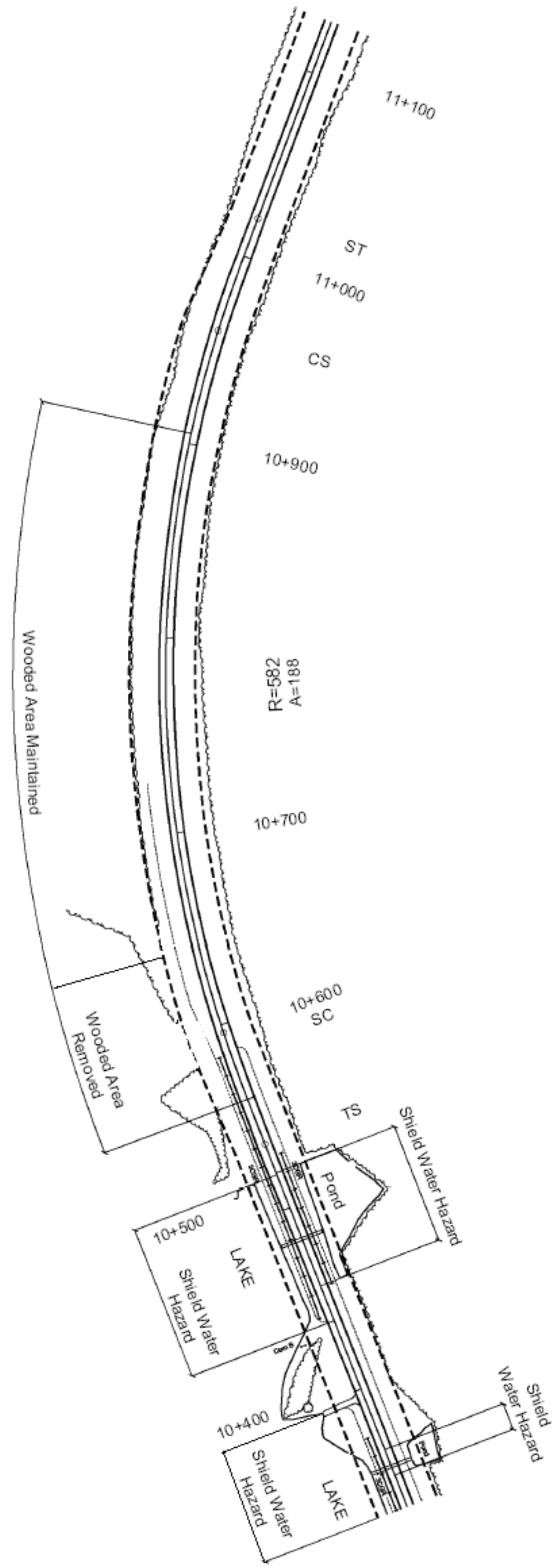
- remove the hazard
- redesign the hazard so that it can be safely traversed or contacted
- relocate the hazard to reduce the probability of it being traversed or contacted
- reduce the severity of the hazard
- shield the hazard.

A review was undertaken to determine if there were opportunities to relocate the hazards as far away from the Desirable Clear Zone distance as possible.

Results:

- Shield water bodies within the Desirable Clear Zone Distance
- Maintain wooded area encroaching less than 2 m within the Desirable Clear Zone Distance
- Remove wooded area encroaching 2 m or greater within the Desirable Clear Zone Distance to the Desirable Clear Zone limit.

The following illustrates the recommended treatment for this segment of the highway.

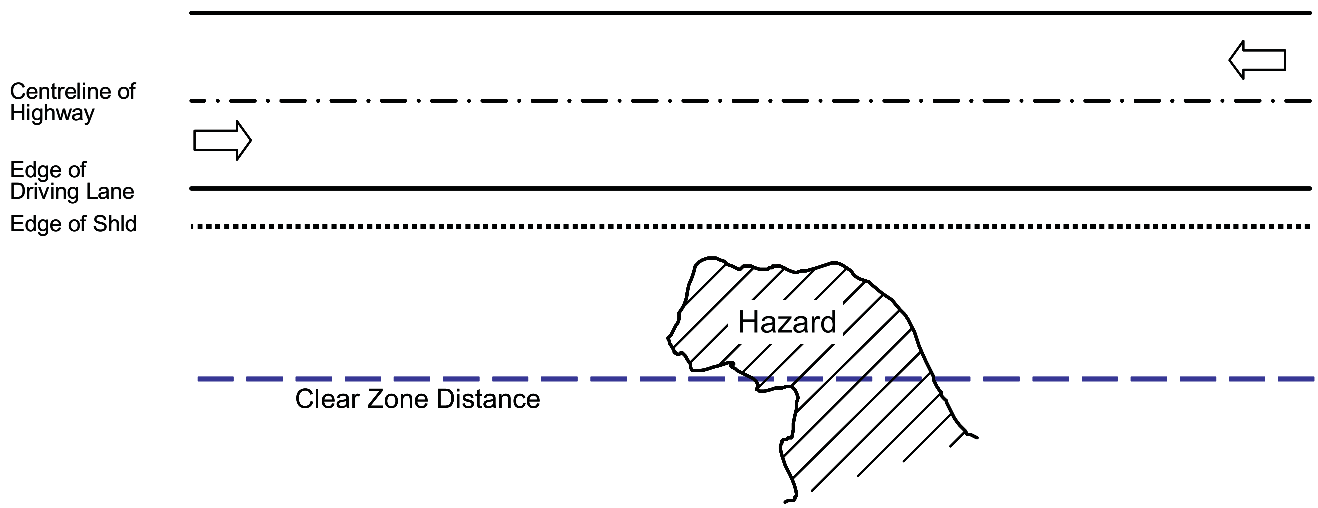


RECOMMENDED MITIGATION MEASURES

Example 5 – Determine the Length of Need for a guardrail on a tangent highway segment with non-flare end treatment.

Information provided:

- Undivided Highway
- Design Speed = 110 km/h
- AADT = 8,000 vpd.



Using **Table H3.12**, the minimum runout length (L_R) is 150 m.

TABLE H3.12 Minimum Runout Length (L_R)

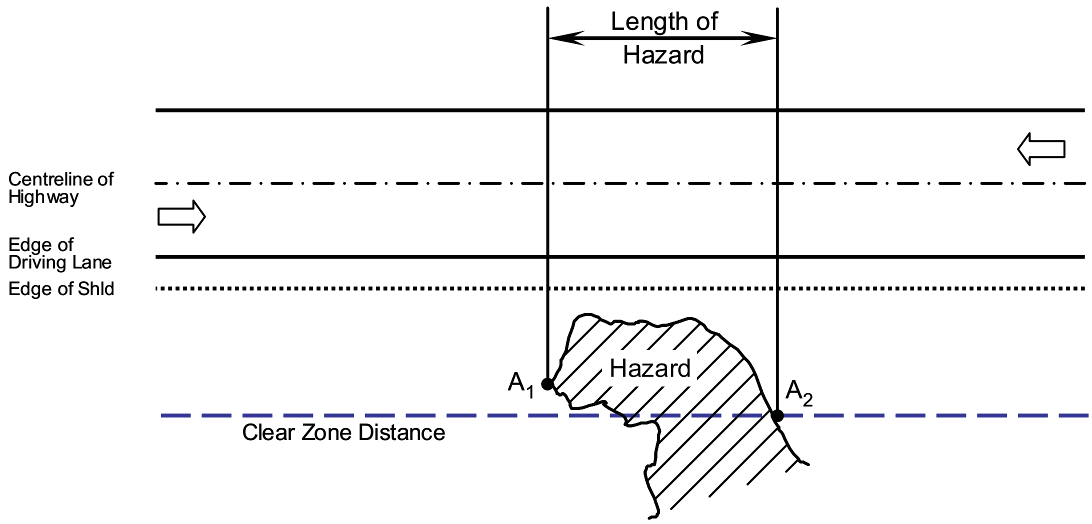
Design Speed (km/h)	Traffic Volume (AADT)[1]							
	>6,000	6,000 to 2,000	2,000 to 800	800 to 400	400 to 200	200 to 100	100 to 50	<50
	Runout Length L_R (m)							
≥ 110	150	135	120	110	60	30	15	Barrier only as required on site-specific basis as directed by the Engineer
100	120	110	100	90	45	22	11	
90	110	100	90	80	40	20	10	
80	100	90	80	70	35	20	10	
70	85	80	70	65	35	20	10	
60	75	70	60	55	30	15	10	

Table reproduced from Section H3.2.3.3.

Step 1: Determine the Length of Hazard

The length of the hazard is determined based on the following criteria:

- The beginning of the hazard is the first point encountered (Point A1) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone distance offset, whichever is encountered first, measured perpendicular to the highway.
- The end of the hazard is the last point encountered (Point A2) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone distance offset.

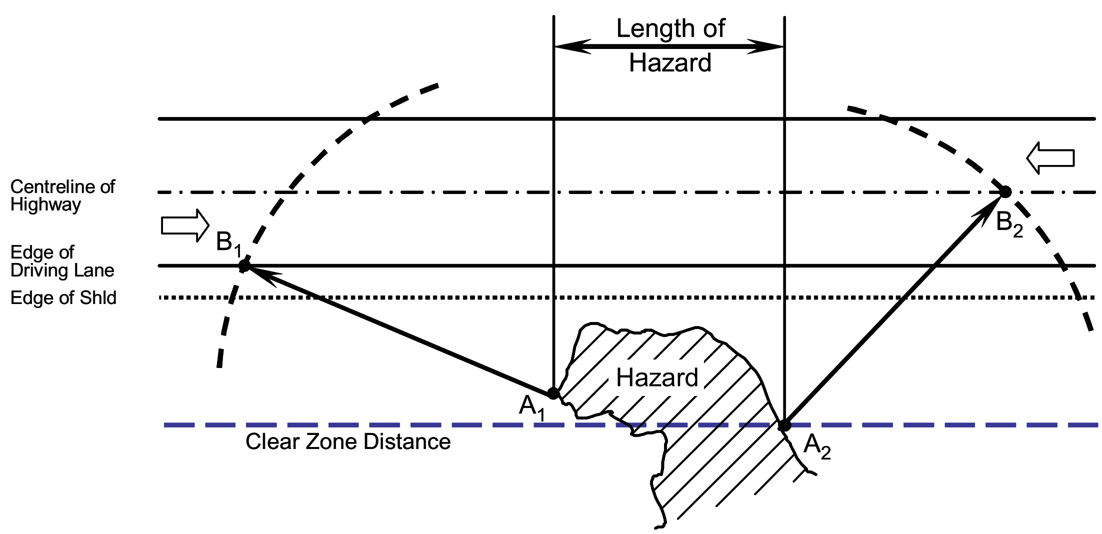


Step 2: Determine Intersection Points B1 and B2

Draw arcs with a radius equal to the Runout Length (L_R) from Point A_1 and A_2.

Locate Point B_1 at the intersection of the encroachment arc with the edge of the driving lane on the same side in the direction of travel.

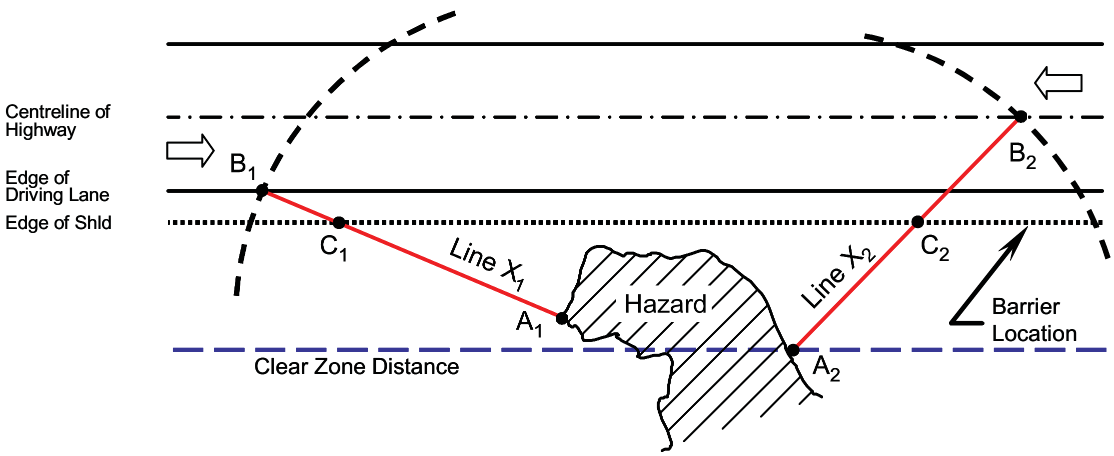
Locate Point B_2 as the intersection of the encroachment arc with the centre line of the highway.



Step 3: Determine Intersection Points C1 and C2

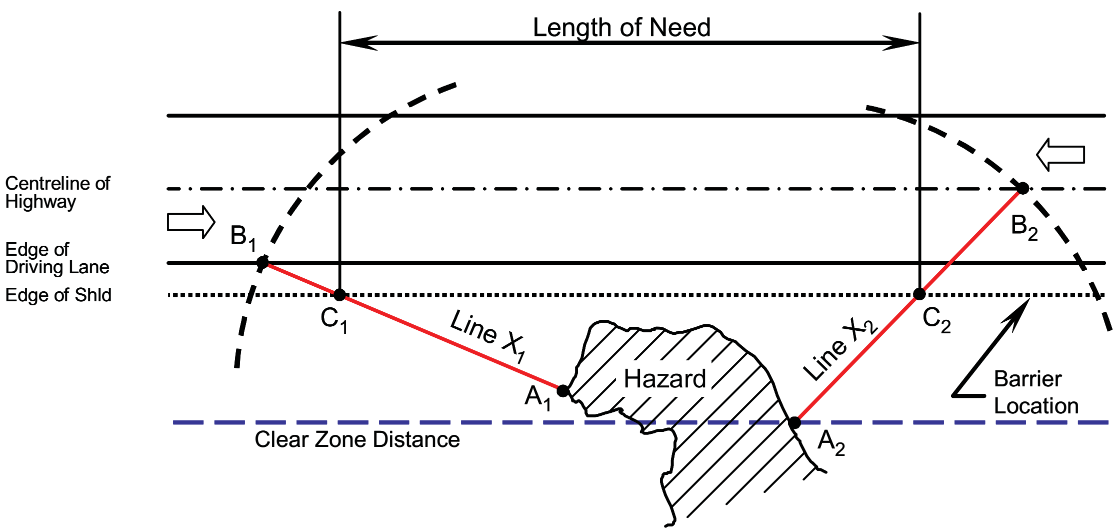
Draw Lines X_1 and X_2 from Points B_1 and B_2 to the centre of the encroachment arcs (Points A_1 and A_2), respectively, and draw the line of the proposed barrier.

Locate Intersection Points C_1 and C_2 at the intersections of Lines X_1 and X_2 with the proposed barrier location.



Step 4: Determine the Length of Need

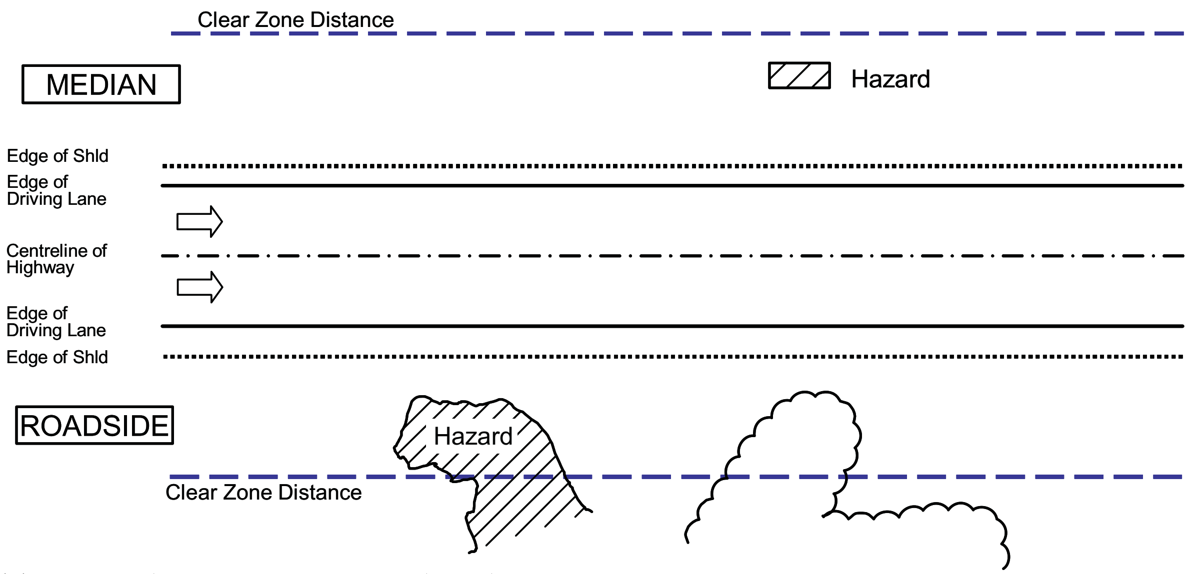
The Length of Need is the distance between Points C_1 and C_2 measured along the proposed alignment of the barrier system.



Example 6 – Determine Length of Need for multiple hazards on tangent section with flared end treatment

Information provided:

- Divided Highway
- Design Speed = 100 km/h
- AADT = 4,000 vpd
- Barrier system = Strong Post W-Beam
- End treatment = FLEAT 350.



Using **Table H3.12**, the minimum runout length (L_R) is 110 m.

TABLE H3.12 Minimum Runout Length (L_R)

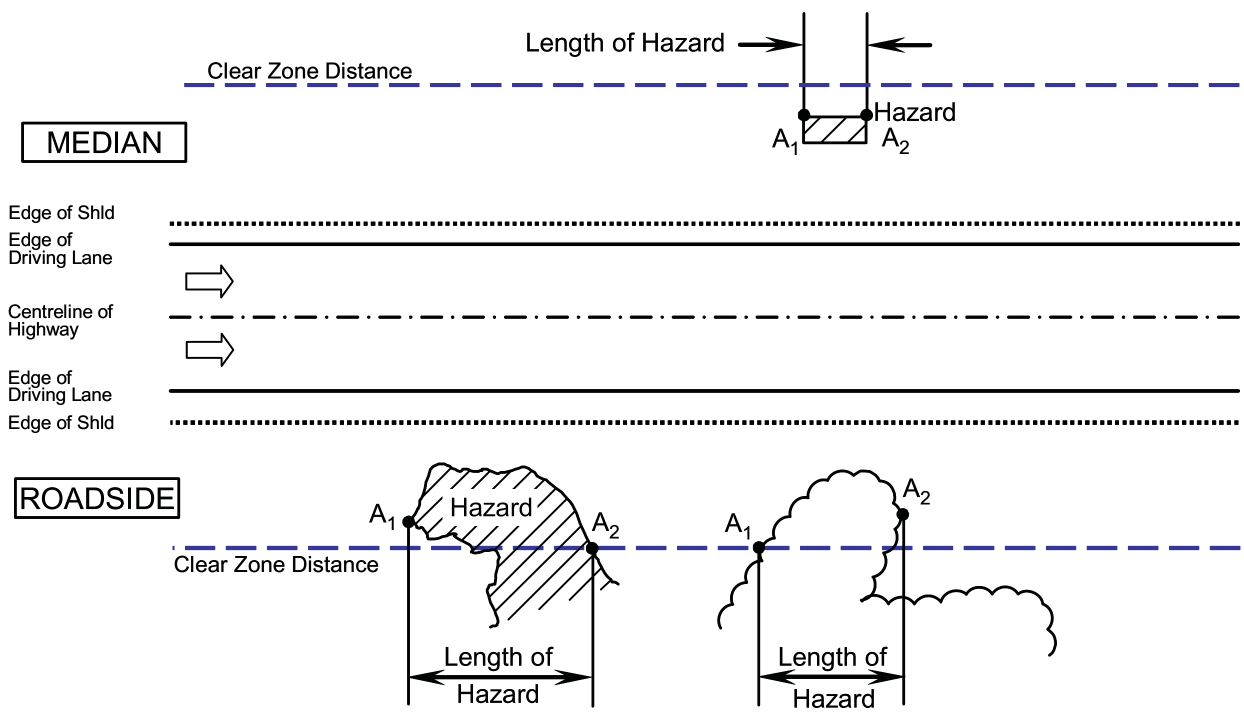
Design Speed (km/h)	Traffic Volume (AADT)[1]							
	>6,000	6,000 to 2,000	2,000 to 800	800 to 400	400 to 200	200 to 100	100 to 50	<50
	Runout Length L_R (m)							
≥ 110	150	135	120	110	60	30	15	Barrier only as required on site-specific basis as directed by the Engineer
100	120	110	100	90	45	22	11	
90	110	100	90	80	40	20	10	
80	100	90	80	70	35	20	10	
70	85	80	70	65	35	20	10	
60	75	70	60	55	30	15	10	

Table reproduced from Section H3.2.3.3.

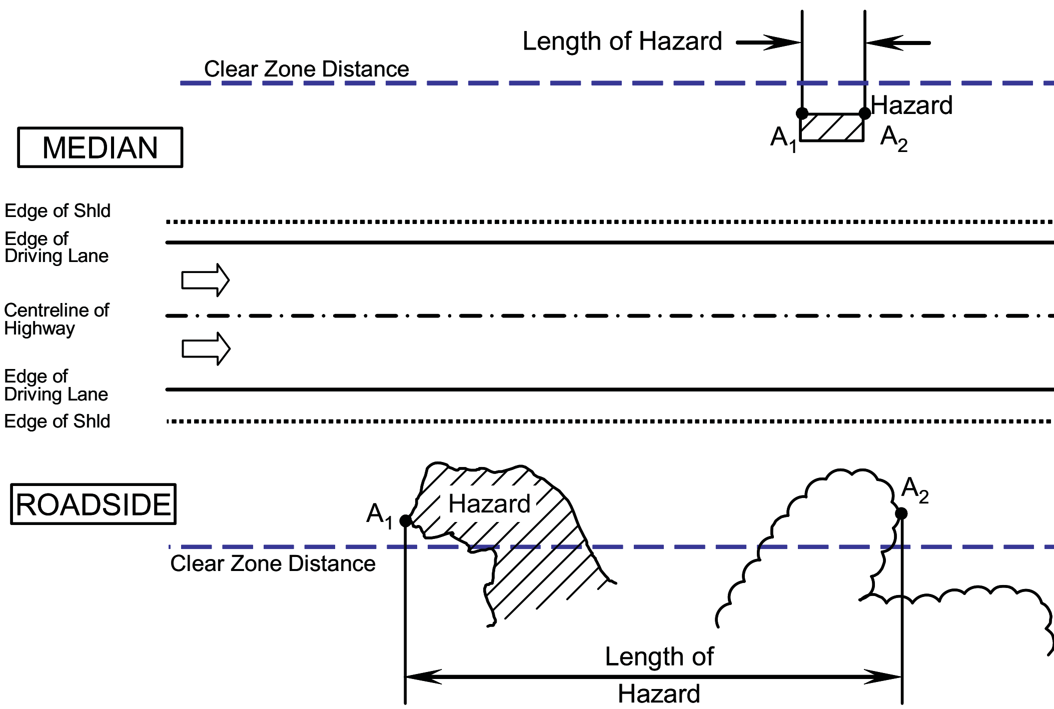
Step 1: Determine the Length of Hazard

The length of each hazard is determined based on the following criteria:

- The beginning of the hazard is the first point encountered (Point A1) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone offset, whichever is encountered first, measured perpendicular to the highway.
- The end of the hazard is the last point encountered (Point A2) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone offset.



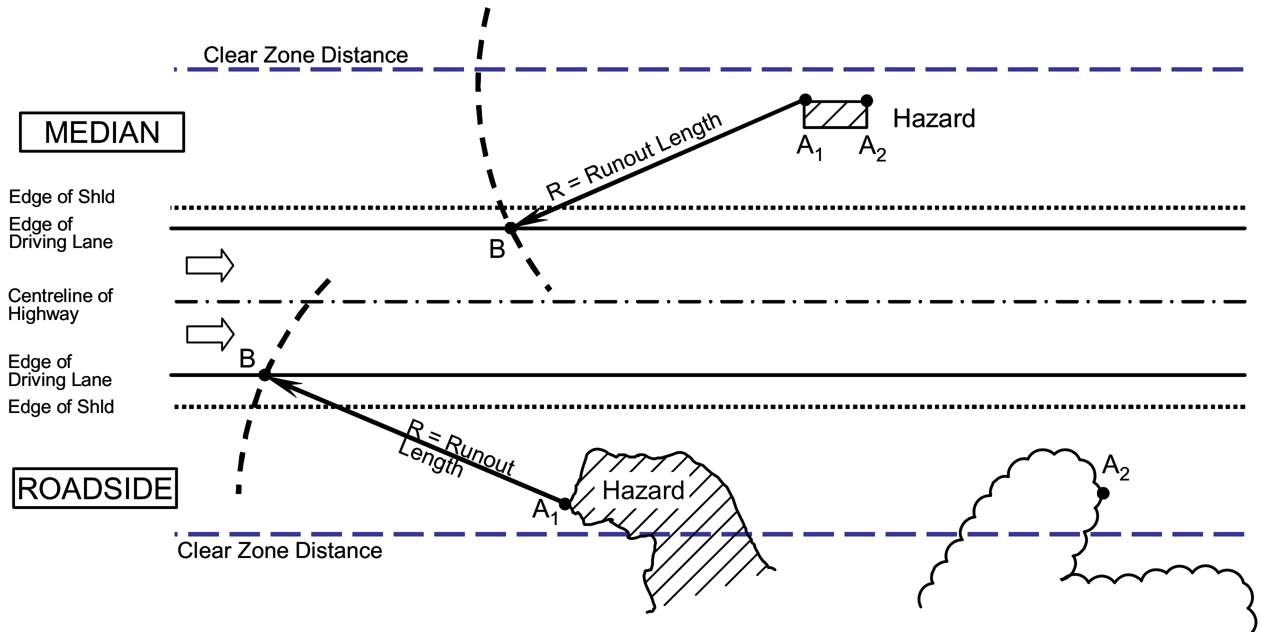
Due to the close proximity of the two hazards, the barrier protection for the hazards will overlap. As a result, the two hazards may be considered as one single hazard.



<u>Step 2: Determine Intersection Point B</u>

Draw arcs with a radius equal to the Runout Length (L_R) from Point A_1.

Locate Point B at the intersection of the encroachment arc with the edge of the driving lane on the same side in the direction of travel.

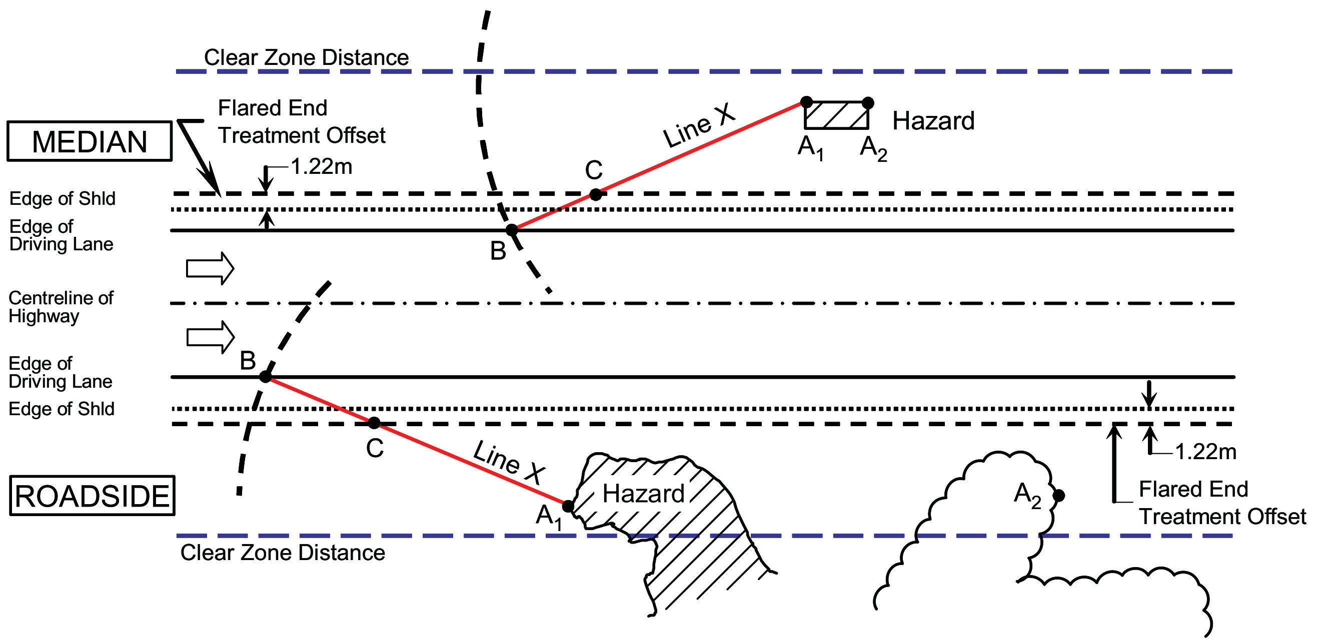


Step 3: Determine Intersection Point C

Draw Lines X from Points B to the centre of the encroachment arcs (Points A_1).

Draw the line showing the offset of the flared end treatment as provided in the end treatment drawing that may be considered part of the Length of Need. For instance, the FLEAT 350 end treatment as illustrated in standard drawing RDG-B1.5 in **Appendix B1** provides flare offset between 0.76 m and 1.22 m. For this example, an offset of 1.22 m is selected.

Locate Intersection Point C at the intersection of Line X with the offset of the flared end treatment that may be considered part of the Length of Need.



Step 4: Determine Length of Need

Using **Table H3.13**, the minimum extension length for the Strong Post W-Beam is 3.81 m.

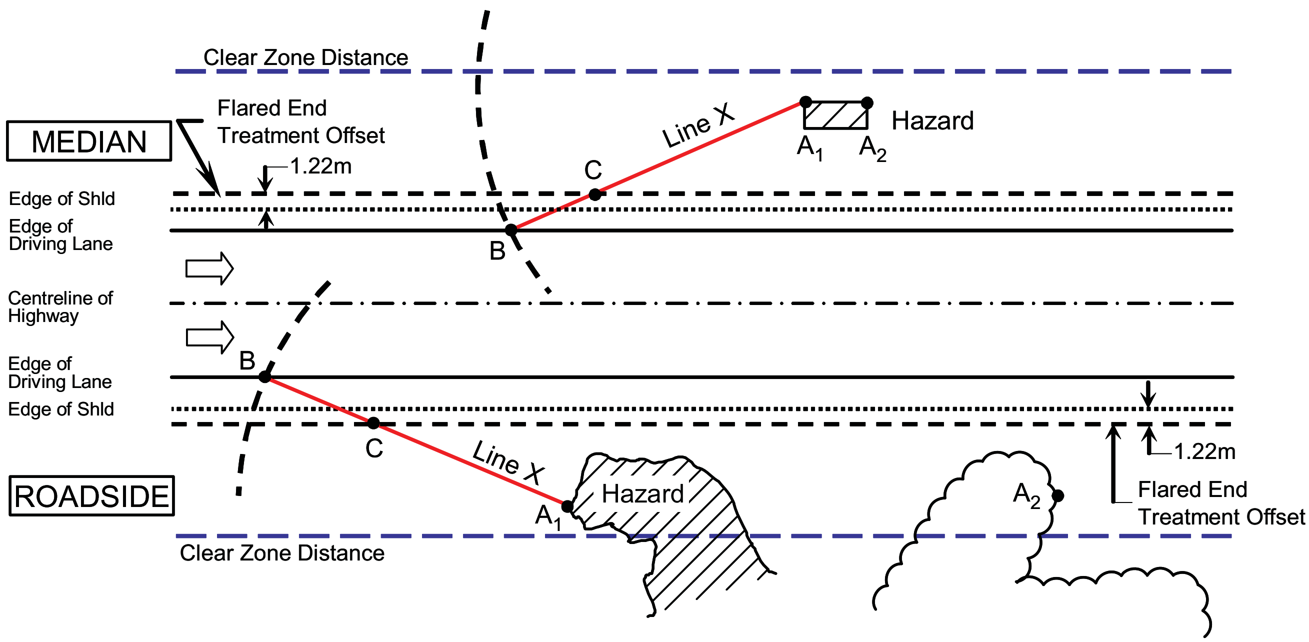
The extension length is the standard length required from the end of the treatment to the effective length. This is needed for anchorage of the system so that the system will perform as intended throughout the entire Length of Need.

TABLE H3.13 Minimum Barrier Extension Length for the Downstream End on a Divided Highway

Barrier System Type	Extension Length
Alberta Weak Post W-Beam Barrier	11.43 m
High Tension Cable	10 m
Strong Post W-Beam Barrier	3.81 m*
Precast Single Slope or F-Shape Concrete Barrier	9 m
Modified Thrie Beam Barrier	3.81 m*
Cast-in-place or Extruded Concrete Barrier	3 m

*Anchored with a cable anchor terminal. Table reproduced from Section H3.2.3.3.

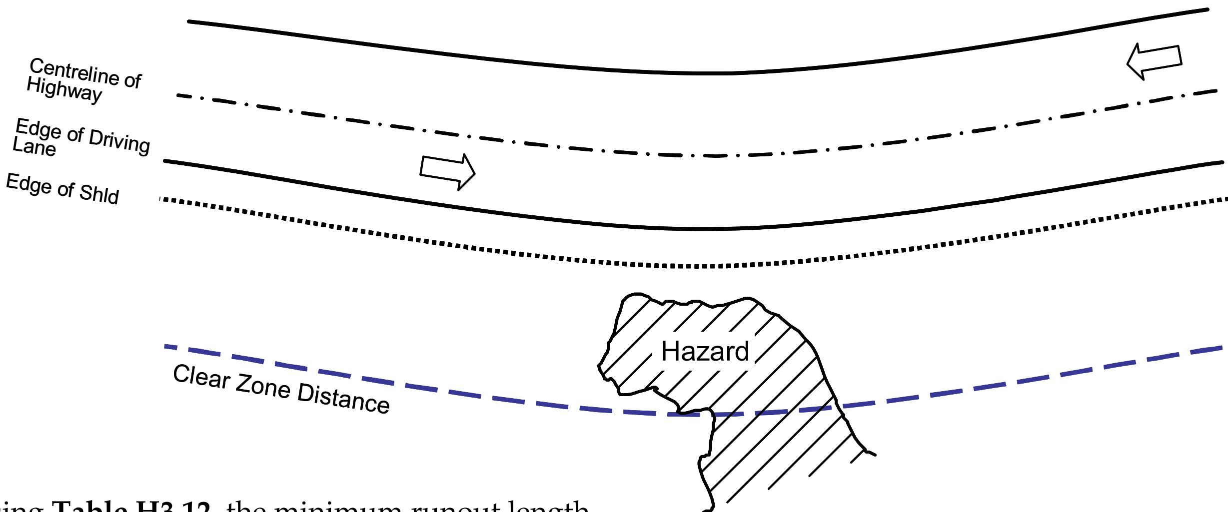
Length of Need is the distance between Point C and A_2, measured along the proposed alignment, plus the minimum extension beyond the hazard.



Example 7 – Determine Length of Need for Curved/Spiral section with flared end treatment

Information provided:

- Undivided Highway
- Design Speed = 90 km/h
- AADT = 4,000 vpd
- Barrier system = Strong Post W-Beam
- End Treatment = FLEAT 350.



Using **Table H3.12**, the minimum runout length (L_R) is 100 m.

TABLE H3.12 Minimum Runout Length (L_R)

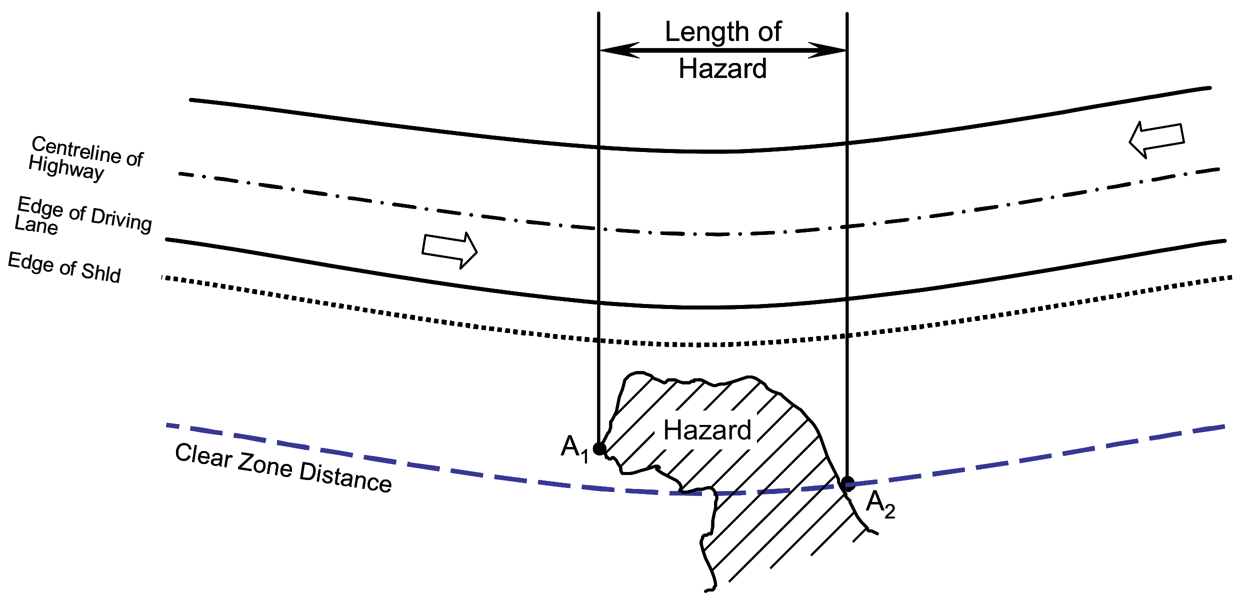
Design Speed (km/h)	Traffic Volume (AADT)[1]							
	>6,000	6,000 to 2,000	2,000 to 800	800 to 400	400 to 200	200 to 100	100 to 50	<50
	Runout Length L_R (m)							
≥ 110	150	135	120	110	60	30	15	Barrier only as required on site-specific basis as directed by the Engineer
100	120	110	100	90	45	22	11	
90	110	100	90	80	40	20	10	
80	100	90	80	70	35	20	10	
70	85	80	70	65	35	20	10	
60	75	70	60	55	30	15	10	

Table reproduced from Section H3.2.3.3.

Step 1: Determine the Length of Hazard

The length of the hazard is determined based on the following criteria:

- The beginning of the hazard is the first point encountered (Point A1) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone offset, whichever is encountered first, measured perpendicular to the highway.
- The end of the hazard is the last point encountered (Point A2) of the hazard on the same side of the highway in the direction of travel, or the intersection of the hazard at the Clear Zone offset.

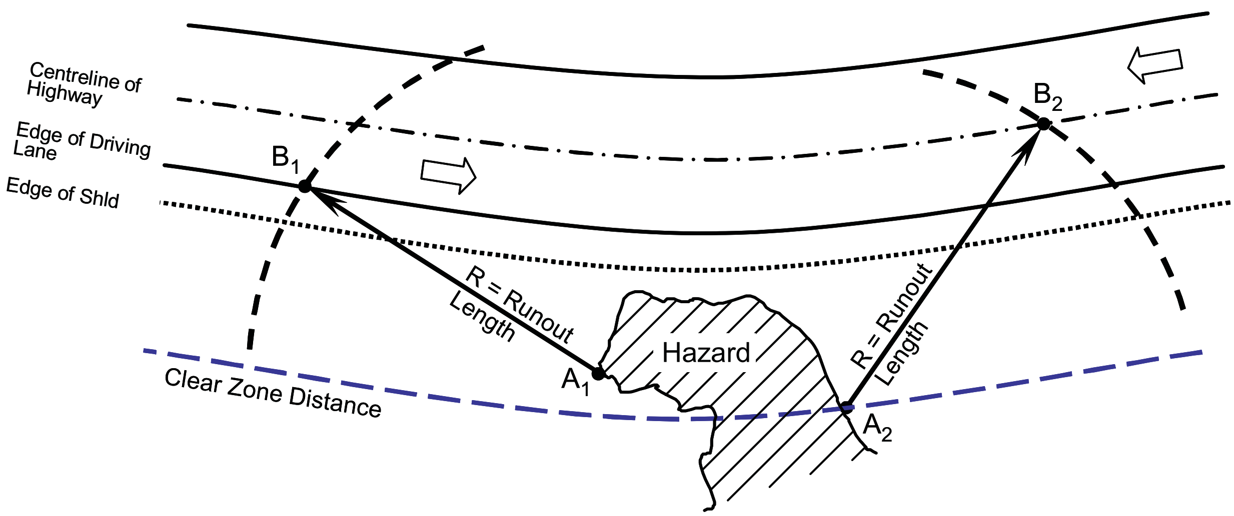


Step 2: Determine Intersection Points B1 and B2

Draw arcs with radii equal to the Runout Length (L_R) from both Points A_1 and A_2.

Locate Point B_1 at the intersection of the encroachment arc with the edge of the driving lane on the same side in the direction of travel.

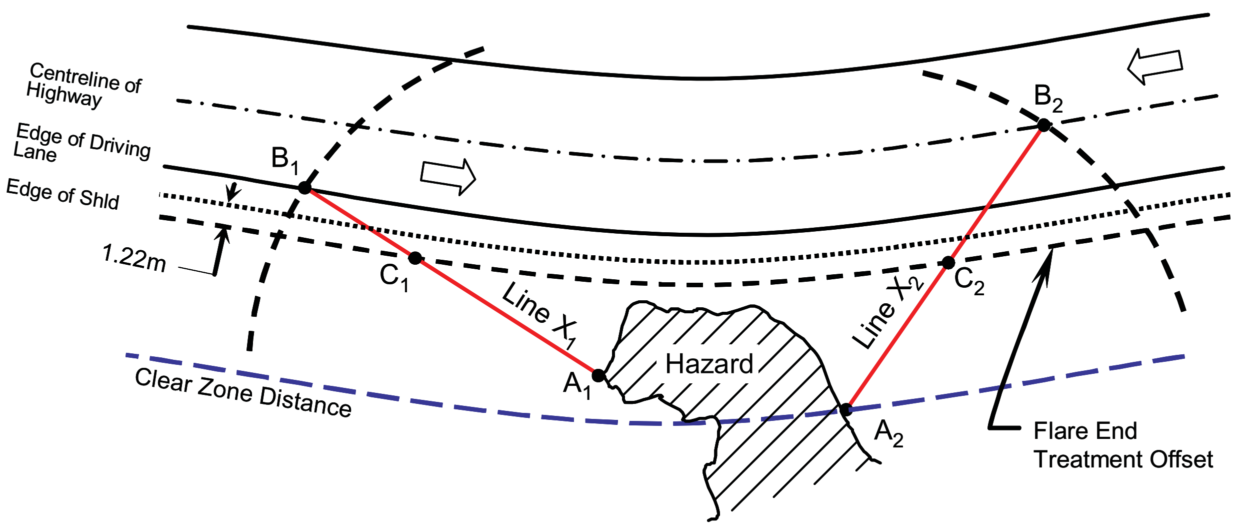
Locate Point B_2 as the intersection of the encroachment arc with the centreline of the highway.



Step 3: Determine Intersection Points C_1 and C_2

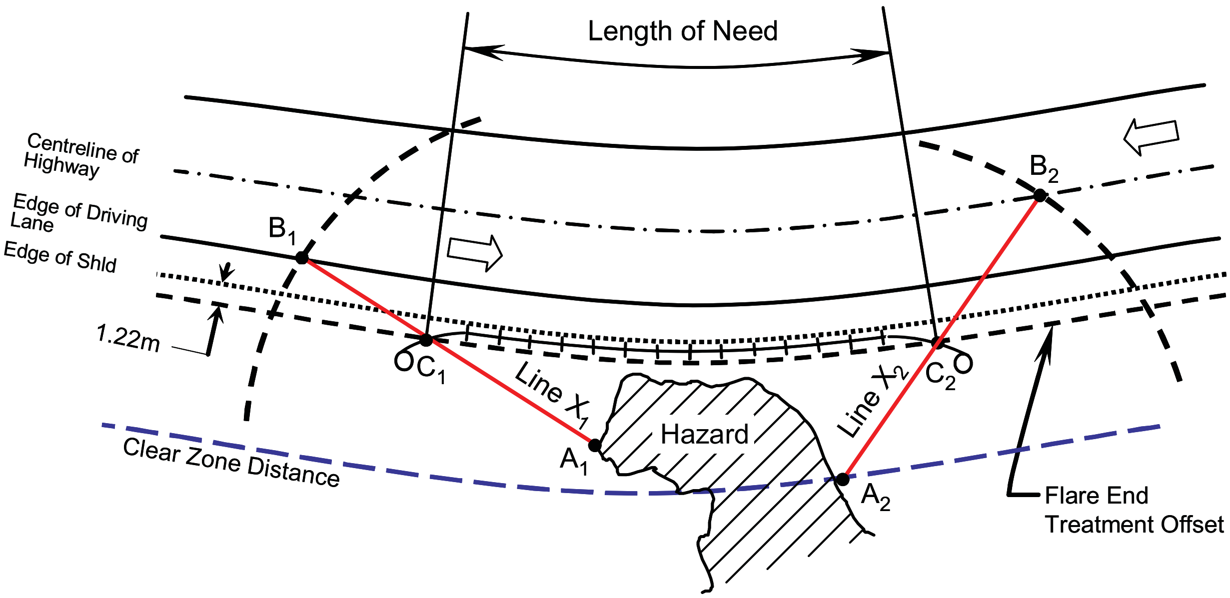
Draw Lines X_1 and X_2 from Points B_1 and B_2 to the centre of the encroachment arcs (Points A_1 and A_2), respectively, and draw the line of the flared end treatment that may be considered part of the Length of Need. For FLEAT 350 end treatment, as illustrated in standard drawing RDG-B1.5 in **Appendix B1**, the maximum offset for the end treatment flare is between 0.76 m and 1.22 m. An offset of 1.22 m is selected since the additional grading can be accommodated along the highway.

Locate Intersection Points C_1 and C_2 at the intersections of Lines X_1 and X_2 with the offset of the flared end treatment that may be considered part of the Length of Need.



Step 4: Determine the Length of Need

The Length of Need is the distance between Points C_1 and C_2 measured along the proposed alignment of the barrier system.



H3.3 Economic Analysis

The economic analysis of roadside treatments is based on a comparison of estimated benefits and costs. Societal benefits are the avoided costs due to a collision that would have been sustained by society if a design treatment was not provided. Societal costs include healthcare and insurance costs, loss of income, and legal and government costs. Implementation costs include the capital and maintenance expenditures required to provide and maintain the serviceability of the roadside treatment.

Societal benefits are calculated by estimating the encroachment rate, collision rate and average severity of collisions.

Implementation costs are determined from one-time and annualized costs.

Economic factors, such as the life-cycle period, discount rate and traffic growth rate must be established to perform the economic analysis.

Existing collision information, together with a reasonable estimate of the future collisions anticipated, may be used as the basis for an estimate of annual collision cost savings for a particular roadside treatment. The Roadside Safety Analysis Program (RSAP), when calibrated for local conditions, may be used to estimate future annual collision costs.

Economic Factor Selection

The following economic factors should be used for the analysis:

- Analysis Period. The analysis period is always 20 years, however, the life of the improvement may be greater or less than the analysis period and each cost and benefit is discounted based on the year it occurs. Although the project costs and benefits are extended to 50 years, the economic evaluation of each design alternative is based only over the first 20 years.
- A 4% annual discount rate is to be used. An Internal Rate of Return (IRR) of 4% at year 20 is considered economically beneficial. Higher rates of return are more beneficial and may be used to rank several proposals or projects against each other. A 4% rate of returen is considered acceptable for INFTRA investments.
- Traffic Growth Rate. An annual traffic growth rate of 2% should generally be used unless another rate can be applied based on historical traffic growth and/or future needs of the project.

H3.3.1 RSAP – Roadside Safety Analysis Program

The Roadside Safety Analysis Program (RSAP) was developed by AASHTO in the 1990s to:

- model multiple roadside features
- incorporate real-world collision data
- be compatible with the MS Windows operating system
- use a stochastic method based on the Monte Carlo simulation technique (random chance simulation).

RSAP has been the subject of numerous technical reviews by a variety of academic, transportation, and safety agencies. *NCHRP Report 492: Roadside Safety Analysis Program – Engineers Manual*, provides an overview and discussion of this analysis software and a review of its features, methodologies, and the assumptions used in the program.

The Monte Carlo technique simulates one encroachment at a time. The conditions associated with each encroachment are randomly generated from built-in distributions of encroachment scenarios, and including the following:

- encroachment location, including segment, location within segment, travel direction,

departure lane, and encroachment direction (right or left)
- encroachment speed and angle combination
- vehicle type
- vehicle orientation.

RSAP uses a random number generator to select its collision scenarios. Designers will typically let RSAP select this seed number randomly. However, if a series of runs are to be performed, **it is preferable to use the same seed number for the subsequent runs.** This ensures that the same collision characteristics are being used for each of the alternatives.

Additional information related to the Monte Carlo simulation technique is provided in *NCHRP Report 492*.

Determining Encroachment Frequencies

RSAP uses the Cooper encroachment data as prepared by B.C. Research in 1980. This research focused on the investigation of wheel markings off the edge of the shoulder for various types of highways (both undivided and divided) along relatively straight and flat sections of highway.

Although this information was collected about 25 years ago (on highways in five provinces in Canada), it still represents the best available data of this type. However, there are certain limitations with respect to this data. One limitation is that the Cooper encroachment rates are for encroachments off the edge of the paved roadway and do not include encroachments off the travelled lane onto the shoulder only. Another limitation is that it includes encroachments of all types - both controlled and uncontrolled.

The encroachment frequency curves used by the RSAP program are based on a modified version of the Cooper encroachment rates. They have been adjusted by a set of factors to obtain 1) the encroachments beyond the edge of the travelled lane, and 2) to obtain the frequency of encroachments that are uncontrolled.

Figure H3.12 illustrates the encroachment prediction data used by the RSAP program for divided and undivided roadways. The same encroachment data is presented in *AASTHO's Roadside Design Guide 2006*.

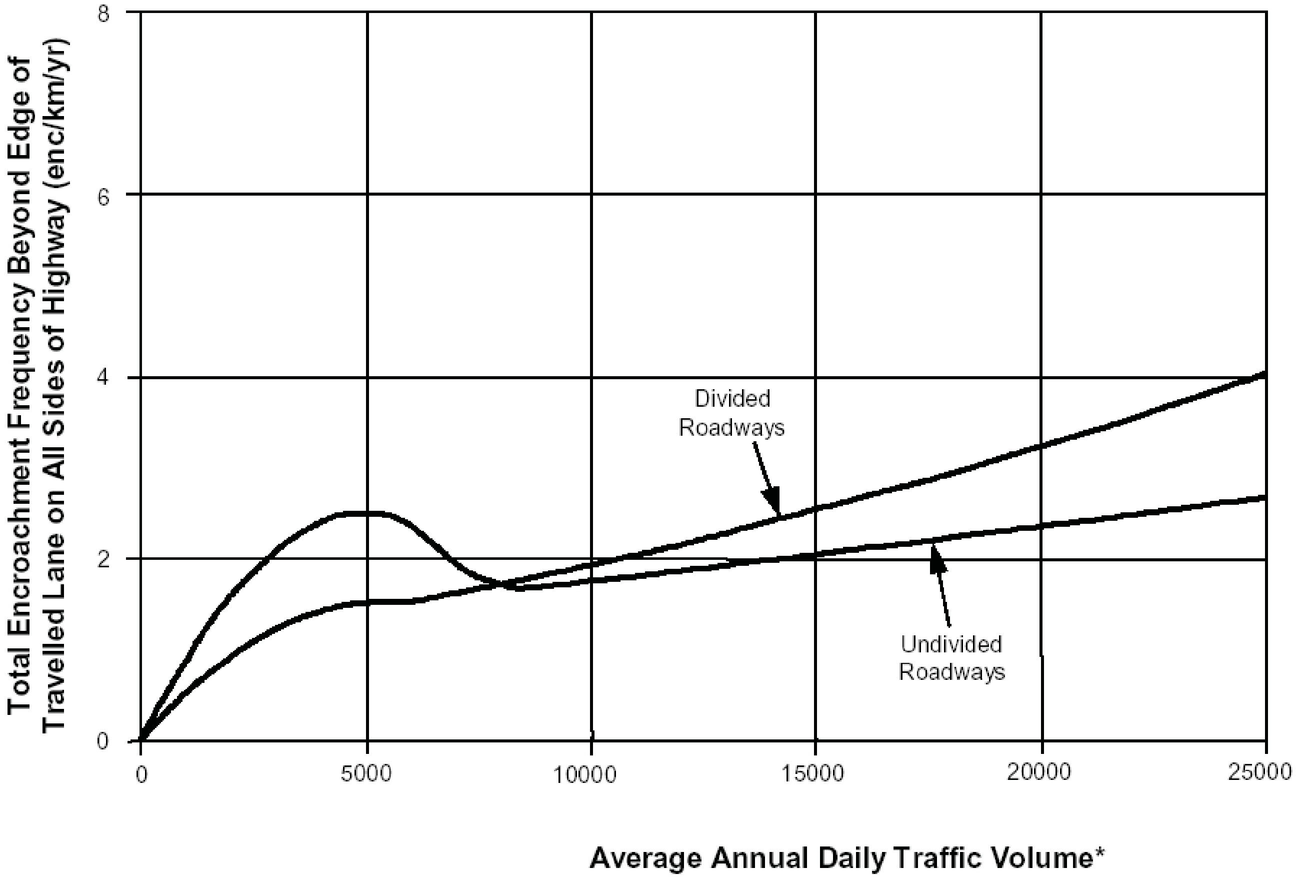
The encroachment frequencies illustrated in **Figure H3.12** are estimates of uncontrolled encroachments beyond the edge of the travelled lane on all sides of the highway. For example, on divided highways the encroachment frequency is an estimate of all encroachments beyond the edge of travelled lane on both sides of the highway as well as the median.

The data in **Figure H3.12** is based on multiplying the original Cooper encroachment data by a factor of 2.466 for two lane undivided highways and 1.878 for multi-lane highways. The effect of multiplying the original Cooper encroachments by these two factors is to convert the encroachment frequencies from the edge of paved roadway (i.e. the Cooper encroachments) to the edge of the travelled lane. Therefore designers wishing to estimate off-road encroachments need to adjust the values shown in **Figure H3.12** accordingly.

In addition, **Figure H3.12** data has also been adjusted by multiplying the original Cooper encroachment data by a factor of 0.60 to eliminate the 40% of all encroachments that are assumed to be controlled.

In comparison, the encroachment frequencies presented in *NCHRP Report 492* are based on the original unmodified encroachment rates from the original Cooper study, and do not account for the adjustment factors included in **Figure H3.12**.

FIGURE H3.12 Encroachment Frequency Curves



* Average Annual Daily Traffic Volume is based on total traffic in both directions

The encroachment module uses a number of inputs such as horizontal and vertical curve geometrics and traffic growth data. Previous research has suggested that an increase in collisions should be expected on downgrades (Grade > 2%) and on curves (Radii < 580 m). *AASHTO's Roadside Design Guide 2006* currently only considers increased collisions on the outside of curves, collision adjustments for downgrades and inside of curves are not considered. The RSAP program takes the influence of grades on crash frequency into account.

<u>Severity</u>

The most recent North American severity index (SI) tables were published in *Appendix A* of *AASHTO Roadside Design Guide 1996 (RDG 1996)*. These SI values are included in **Appendix A** of this guide.

RSAP includes many of the RDG 1996 roadside features and associated severity indices in the pull-down menus of the software. However, not all features are provided. While RSAP permits user-defined features to be modelled (the user must define the SI characteristics), the program does not provide any guidance into the selection of the SI values. The SI values included in RSAP will typically be suitable for the majority of analysis scenarios. Some specific SI values not provided with RSAP, such as the Alberta Weak Post Barrier system. For the Alberta Weak Post Barrier system, use the SI values found in **Appendix A**. Some of the SI values are illustrated in **Table H3.15**.

The crash (collision) prediction module is used to determine the vehicle swath and the roadside features that might be affected. Although RSAP contains a number of very sophisticated algorithms, a vehicle's behaviour must still be simplified with the following assumptions, which may or may not be realistic:

- the errant vehicle maintains a constant encroachment angle throughout the event
- the errant vehicle maintains a constant orientation throughout the event
- the errant vehicle's speed remains essentially unchanged.

RSAP uses a number of speed and angle (S/A) distribution tables when simulating collisions. At this time, RSAP has only five S/A tables to estimate collision performance on the ten (10) standard AASHTO functional classes of highway. It will be necessary to determine which classifications best fit the highways under investigation.

The severity prediction model uses an assessment of occupant risk during specified crash events. At this time, RSAP must still essentially rely on the standard severity tables found in *RDG 1996*. As noted earlier, the software does permit the user to enter user-defined roadside features, including the associated severity index values. This flexibility is useful when analyzing features that are not included on RSAP's standard lists.

TABLE H3.15 Alberta-Specific RSAP Inputs

Feature	SI Value at 110 km/h Design Speed [2,3]	Average Repair Cost of System per Impact [1]
Alberta Weak Post W-Beam Barrier	3.3	$950
Alberta Weak Post W-Beam Turn Down End Treatment	4.3	$250
Weak Post Box Beam non-*NCHRP Report 350* Turn Down End Treatment	4.3	$400
Concrete Barrier Flared and Tapered Down End Treatment	4.6	$250

1. Values based on 2005 dollar value.
2. SI values based on Table HA.8 in Appendix A of this guide.
3. For RSAP inputs, the Impact Speed at 100 km/h is generally consistent with a Design Speed of 110 km/h.

Societal Costs

RSAP requires a number of project-specific inputs which are generally easy to enter. Alberta uses different values than the default values set in RSAP (based on *RDG 2002*). For RSAP applications, use the following societal values for the three collision classes - fatal, injury, and property damage for Alberta highways:

- Fatal class collision $1,345,068 *
- Injury class collision $100,000 *
- PDO class collision $12,000 *.

**Values based on 2000 dollar value.*

The costs assigned to the various types of collisions, including fatalities, are not intended to represent the value of a human life and/or injury. The cost estimates represent the typical direct and indirect costs to society caused by a motor vehicle collision, such as medical expenses, wages lost, and insurance administration costs.

Understanding How RSAP Works

RSAP is a user-friendly program. However, care needs to be exercised when using the software to ensure that the results generated are appropriate for the situation being modelled.

The designer will initially input the basic information that RSAP needs to complete the analysis, including the project description, seed number (for random number generation), societal cost information (crash costs), vehicle mix, and reporting instructions. Selection of the analysis units (metric units preferred) and the economic factors is also done upfront.

The user then goes on to input the needed data related to costs, the general highway conditions, specific details of the highway segment(s) being studied, and finally the features located within the segments. Segments can vary in length but must have common characteristics. Features existing in a segment can be one-of-a-kind or repeated throughout the segment.

RSAP is intended to analyze fixed features (such as slopes and objects) and is not appropriate to use for modelling dynamic features or events such as opposing traffic or a specific collision.

The software determines the total collision cost of a feature by aggregating the costs of many collisions, based on the encroachment data, injury probabilities, and collision severity. Costs are only applied to the features modelled. Flat surfaces typically do not warrant modelling because they do not generate meaningful collision costs.

H3.3.2 INFTRA's Benefit-Cost Worksheet

One economic analysis tool currently available for general use in Alberta is the benefit-cost worksheet prepared by INFTRA.

The worksheet provides the Internal Rate of Return information based on the comparison of construction and societal costs between the two competing alternative treatments.

INFTRA's Benefit-Cost Analysis Manual provides more detailed guidelines and procedures on this worksheet.

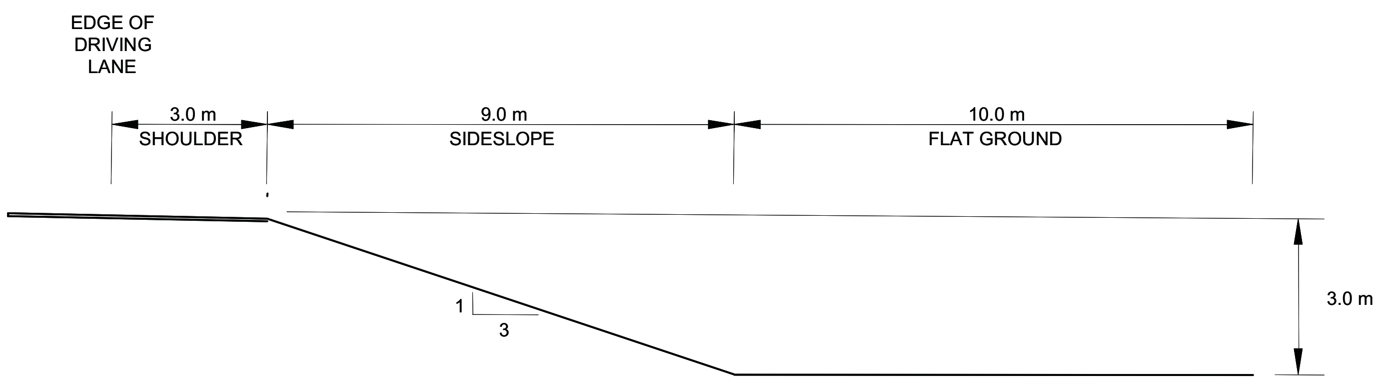
The benefit-cost worksheet is available from INFTRA's Technical Standards Branch.

H3.3.3 Examples

Example 1 – Determine the Annual Crash Cost for the cross section (shown below) using the RSAP Program.

Information provided:

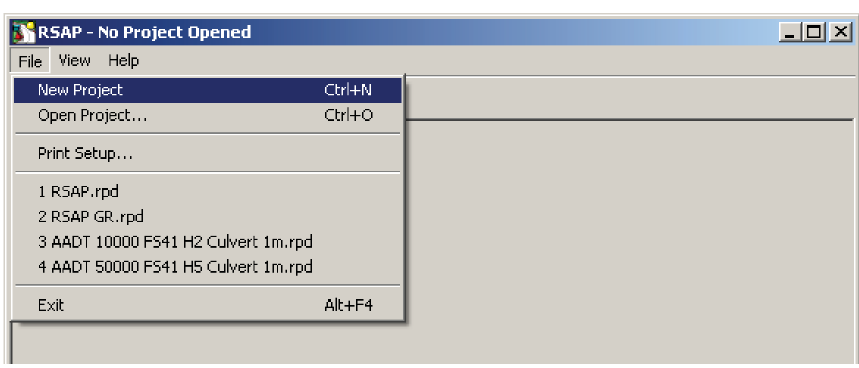
- Rural, Two-Way Undivided Highway
- Segment Length = 500 m
- Number of Lanes = 2
- Lane Width = 3.7 m
- Shoulder Width = 3.0 m
- Speed Limit = 100 km/h
- ADT Volume = 10,000 vpd
- Truck Percentage = 10%
- Traffic Growth Rate = 2% per year
- Sideslope = 3 m height with 3:1 slope.



Note: The screen capture images were prepared using RSAP V2.0.3 2001. Later versions of RSAP may employ slightly different data entry formats.

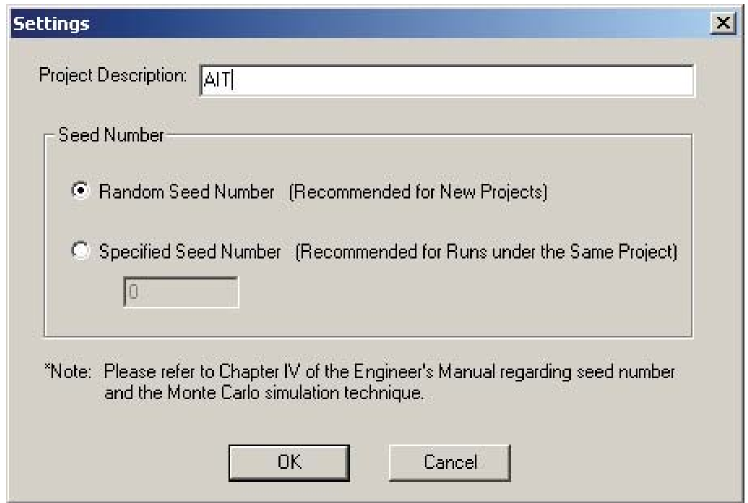
Step 1:

Using the RSAP software, from the File drop down menu, select a New Project to start a new analysis.



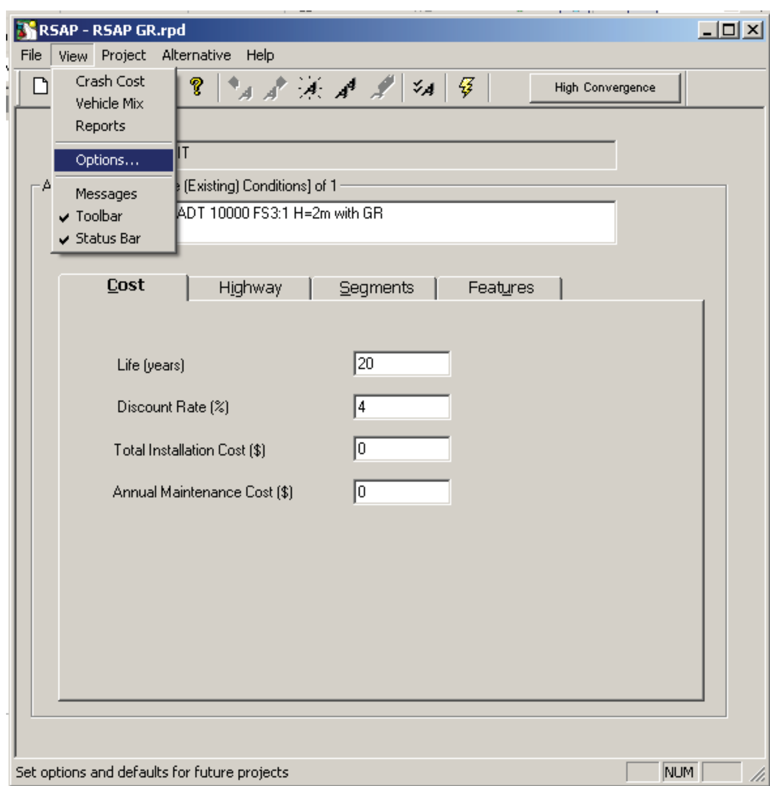
Step 2:

Enter the project description. For the first analysis, maintain the seed number as the random seed number.



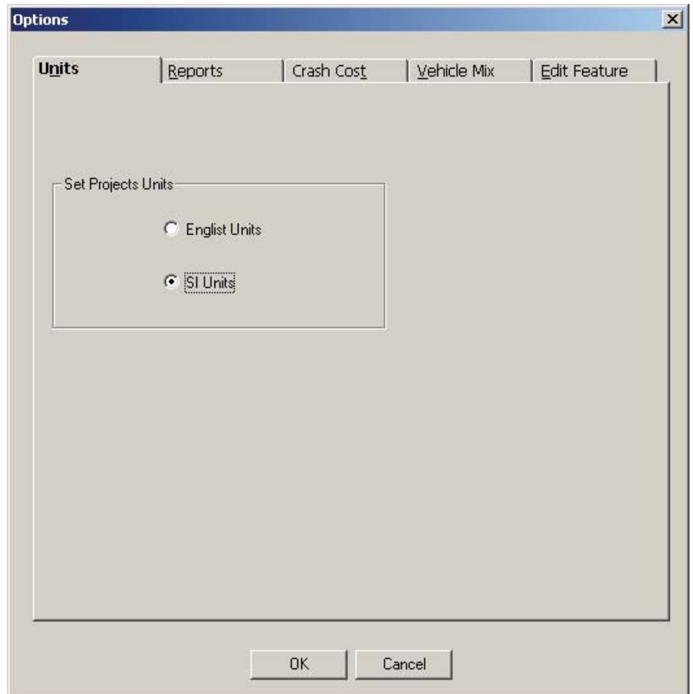
Step 3:

On the View menu, select Options to set or confirm all initial settings.



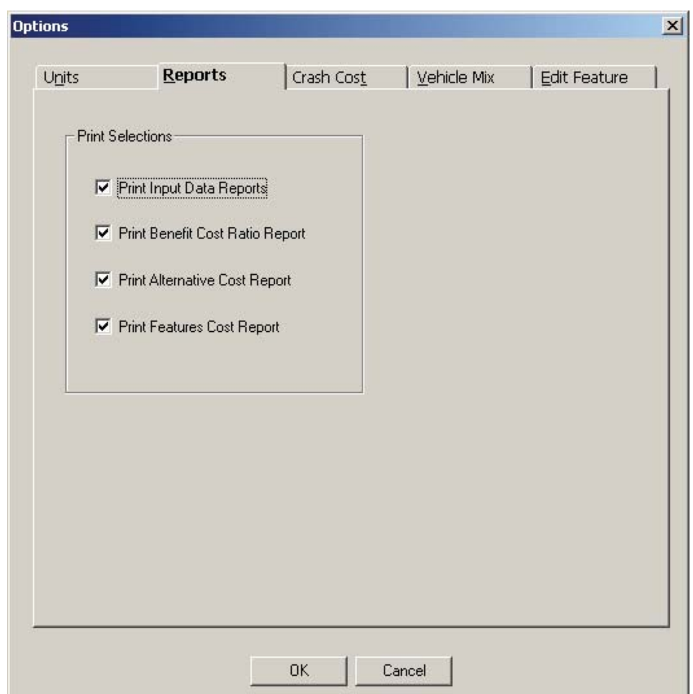
Step 4:

On the Units tab, for metric units, set Project Units to SI Units.



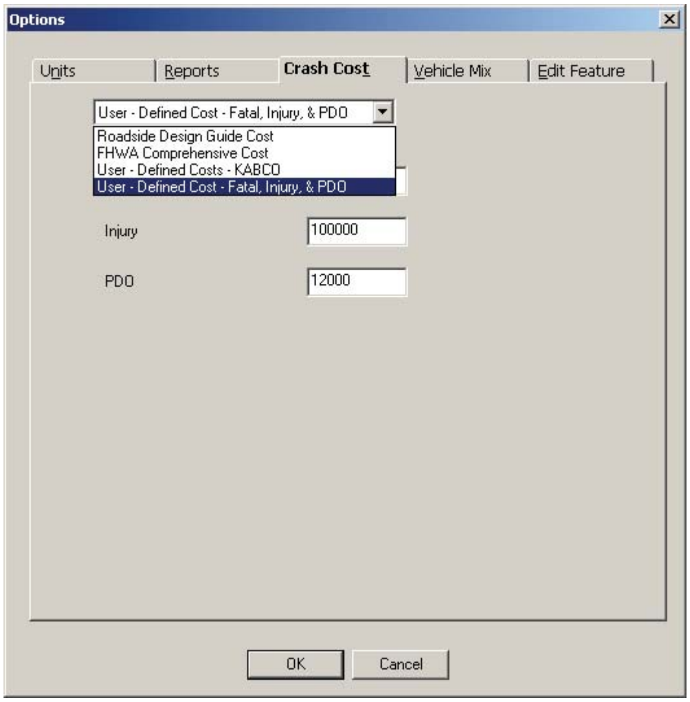
Step 5:

On the Reports tab, ensure all Printing Selection settings are checked on.

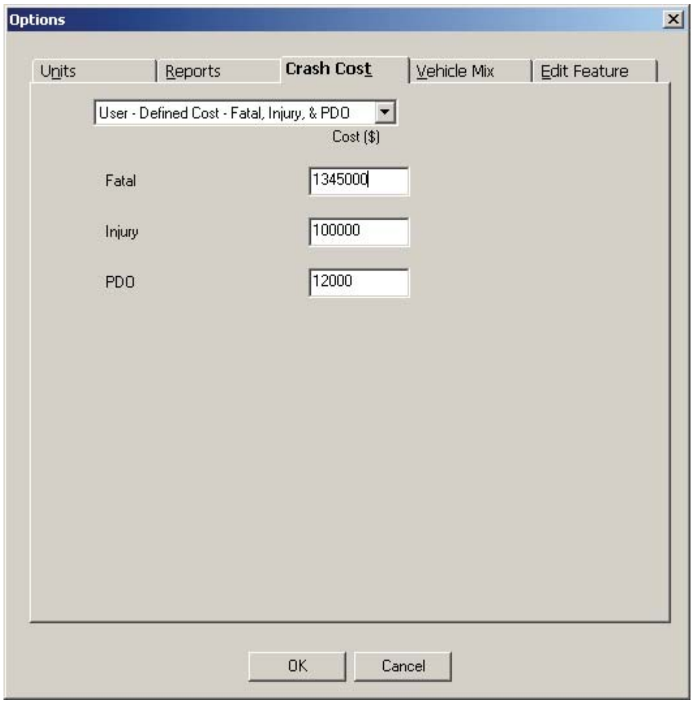


Step 6:

On the Crash Cost tab, select User-Defined Cost-Fatality, Injury and PDO then enter user-defined crash costs.



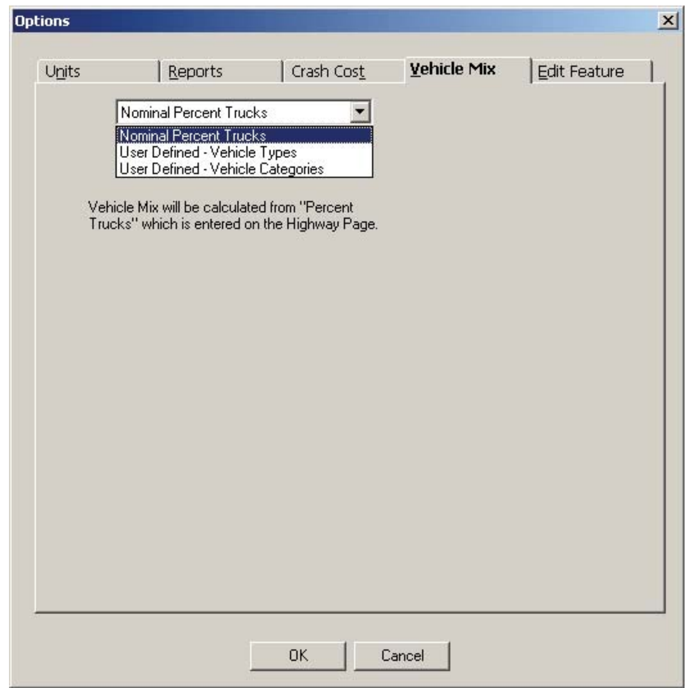
The current INFTRA severity crash costs are $1,345,068, $100,000, and $12,000 for Fatality, Injury, and Property Damage Only (PDO), respectively.



Step 7:

On the Vehicle Mix tab, select Nominal Percent Trucks unless site-specific information is available.

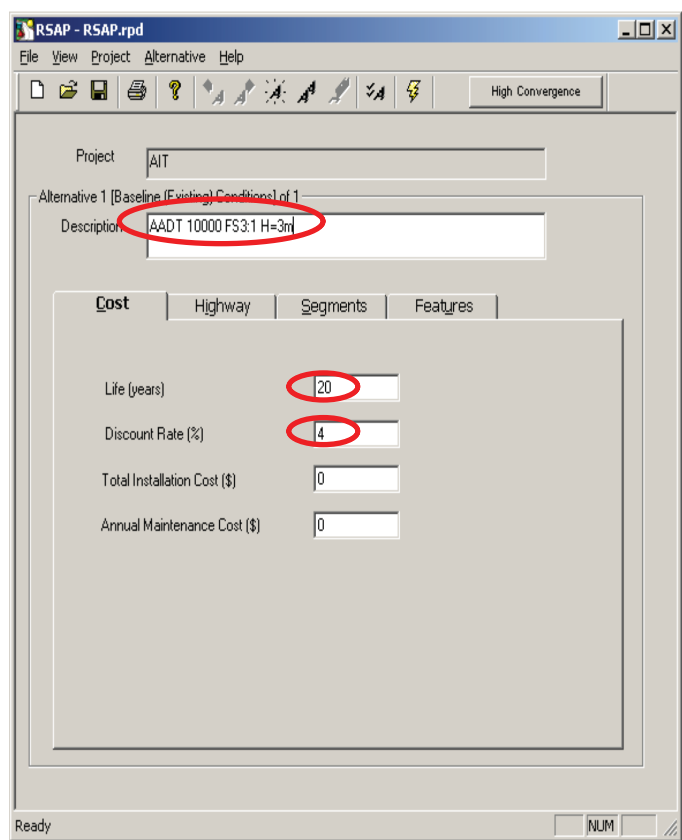
Once all information has been entered, select "OK" to exit the Options Window.



Step 8:

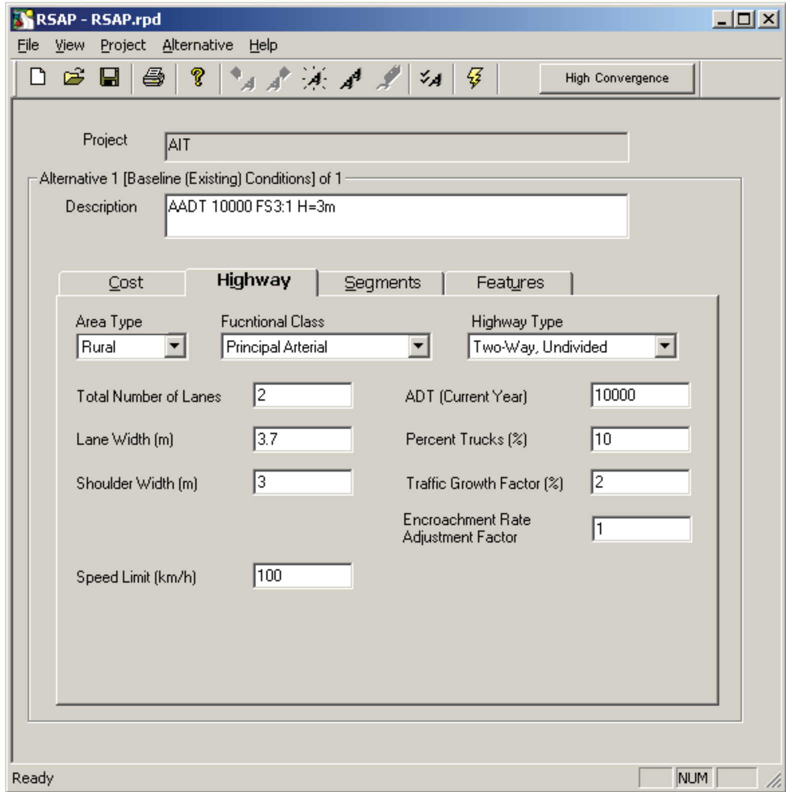
Enter the description of the analysis.

On the Cost tab, enter the analysis period (20 years) and discount rate (4%).



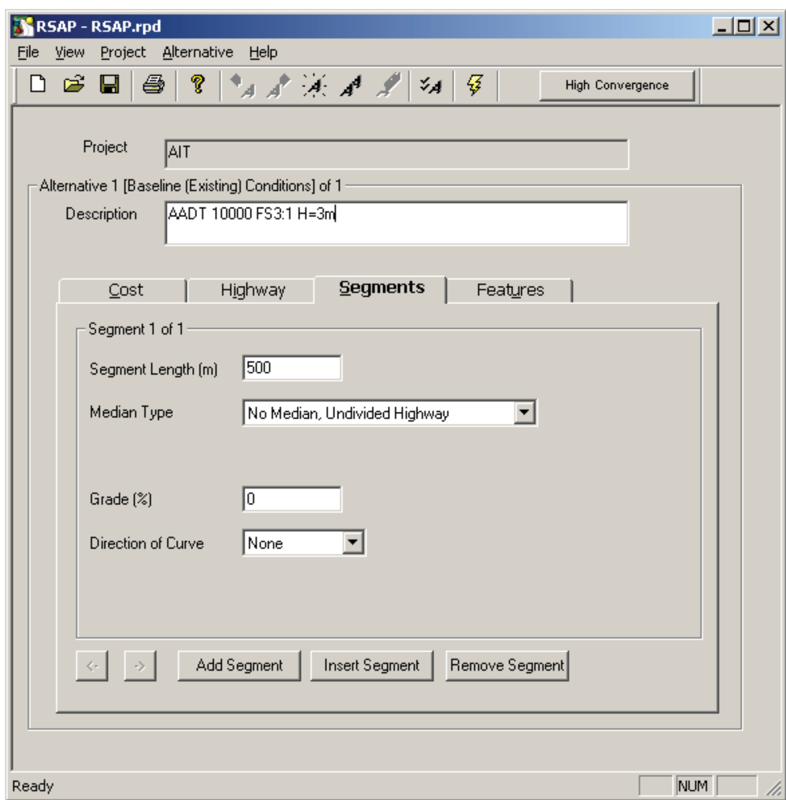
Step 9:

On the Highway tab, enter the basic highway information.



Step 10:

On the Segments tab, enter the following information.



Step 11:

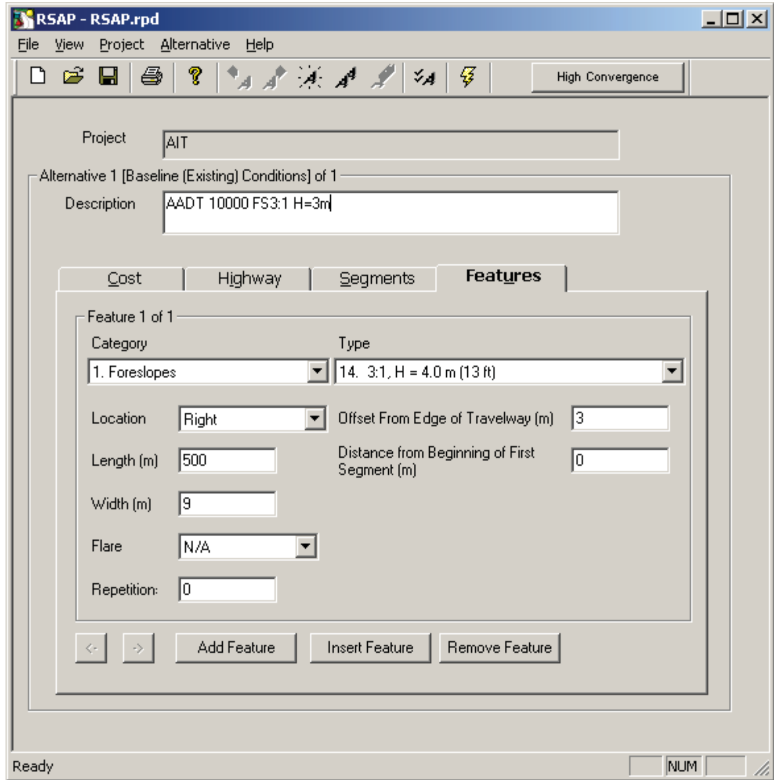
On the Features tab, enter the various features (such as slope or object) within the roadside environment one at a time. When finished, each feature description will include a feature type, location, length, width, offset from the edge of the travelled way, flare, and repetition (along the highway segment).

For the example, begin with the sideslope as the first feature under the Feature tab. The sideslope is identified as Foreslope.

For a sideslope height of 3.0 m, select the next available height (4.0 m).

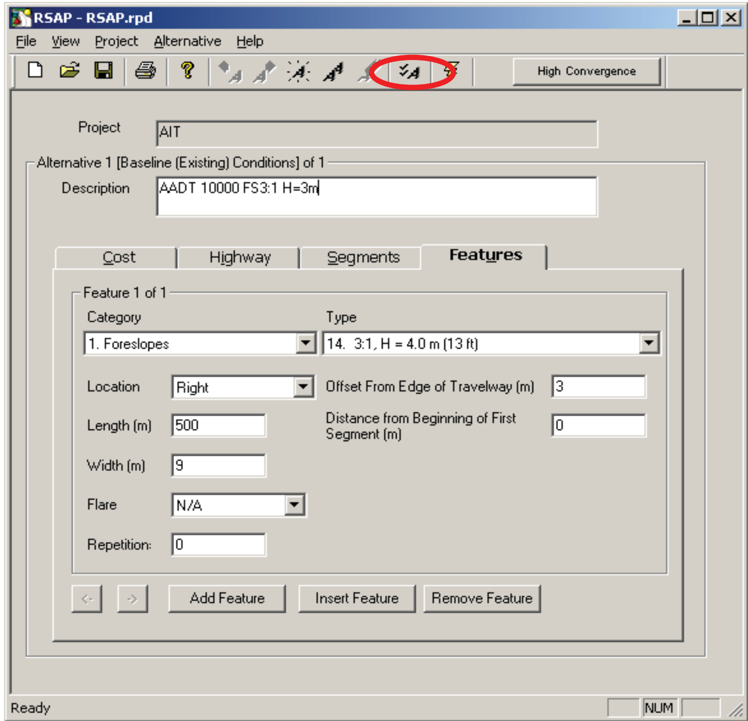
Enter the Offset From Edge of Travelway (3.0 m), Feature Length (500 m), and Width of the feature (9.0 m).

The next feature (10 m flat ground) does not need to be modelled because RSAP does not assign any meaningful collision cost to it since its SI is negligible.



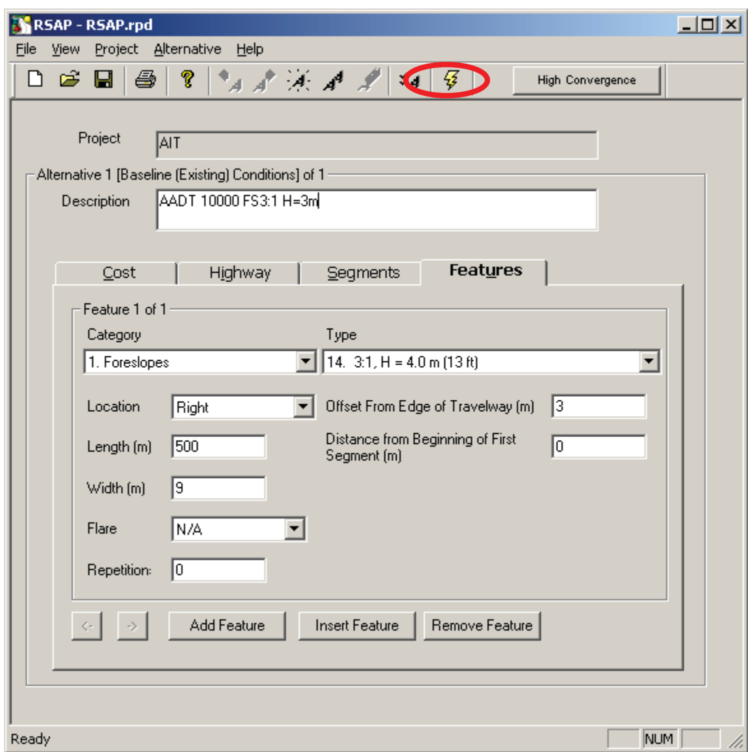
Step 12:

Once all features have been entered, select Pre-Calc Check to ensure there are no errors.



Step 13:

Select Analyze to analyze the features.



The annual crash cost information is generated on page 2 of the report.

Roadside Safety Analysis Program Version 2.0.3

Date: May 15, 2007

Alternative Cost Report

File Name: RSAP Example 1.rpd
Project Description: AIT

Alternative	Description
1	AADT 10000 FS3:1 H=3m

Alternative	Expected Crash Frequency (Acc/Yr)	Annual Crash Cost ($)	Annual Installation Cost ($)	Annual Maintenance Cost ($)	Annual Repair Cost ($)
1	0.177463	12251.93	0.00	0.00	0.00

<u>Results</u>

Annual crash cost is $12,251.93 for the cross section.

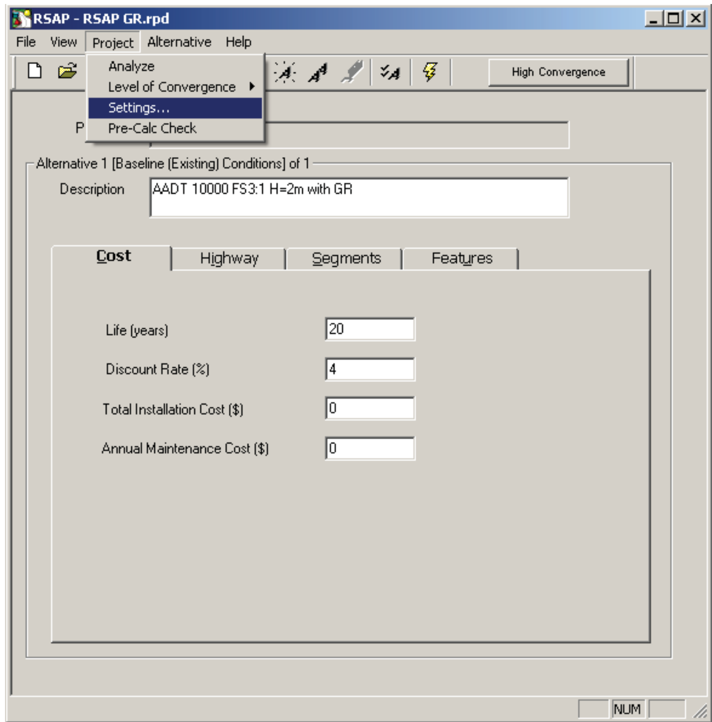
Note that a subsequent analysis run would return a slightly different answer if a new random seed number was selected.

To maintain the same seed number for subsequent analysis, the following procedures are provided.

If an additional analysis is required, the seed number should be locked using the following procedure:

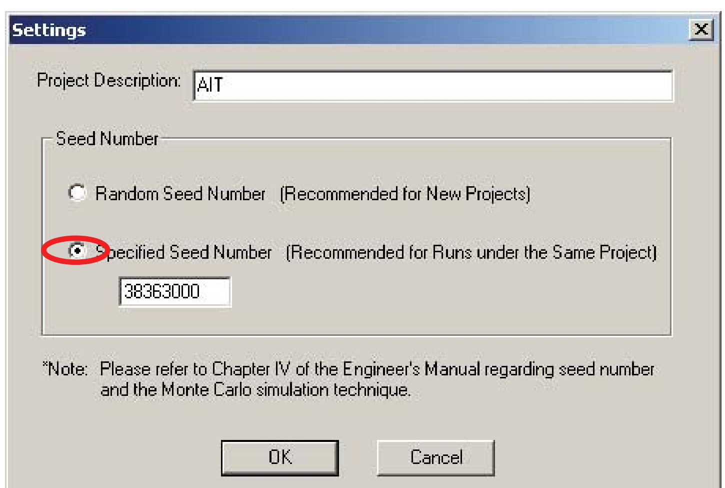
Step 1:

Under the Project menu, select Settings to open the setting menu.



Step 12:

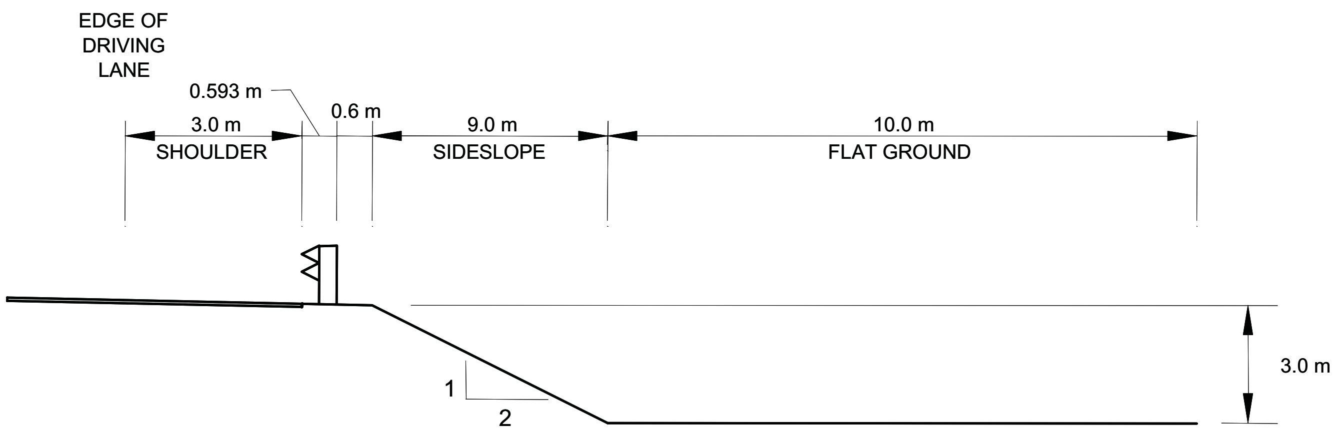
Select Specified Seed Number to lock the seed number for subsequent analysis.



Example 2 – Determine the Annual Crash Cost of a cross section with a guardrail system using the RSAP program.

Information provided:

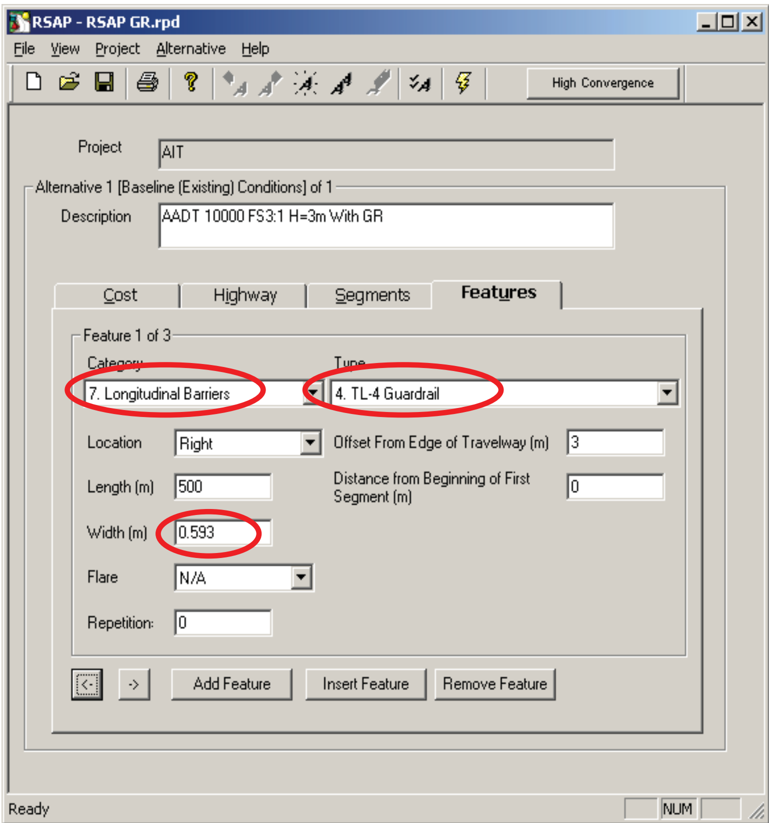
- Rural, Divided Freeway
- Segment Length = 500 m
- Number of Lanes = 2
- Lane Width = 3.7 m
- Shoulder Width = 3.0 m
- Speed Limit = 110 km/h
- ADT Volume = 10,000 vpd
- Traffic Growth Rate = 2% per year
- Guardrail = Modified Thrie Beam (TL-4)
- Guardrail Length = 500 m
- Sideslope = 3 m height with 3:1 slope.

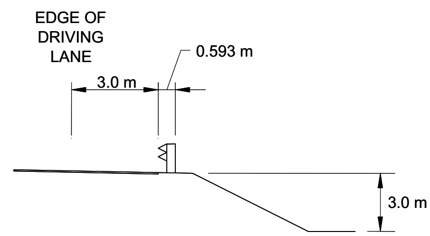


Follow Steps 1 to 10 from Example 1 to enter or confirm initial setup, Cost information, Highway information, and Segment information.

Step 11:

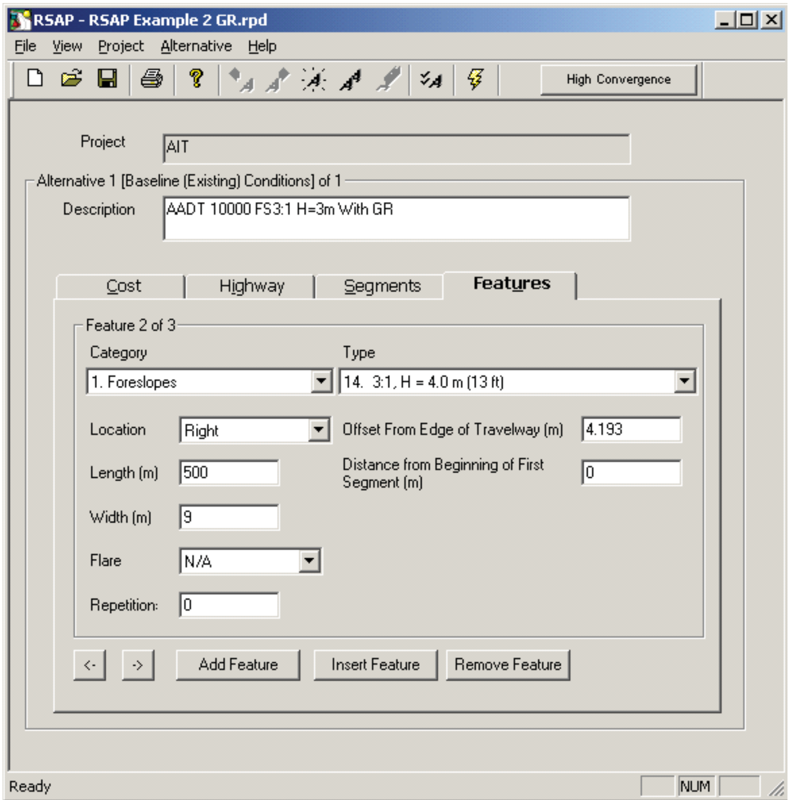
Enter the first feature (Modified Thrie Beam) in the Features tab including the width of the feature. Note that Modified Thrie Beam is classified as a TL-4 longitudinal traffic barrier. This type of guardrail is 593 mm wide.

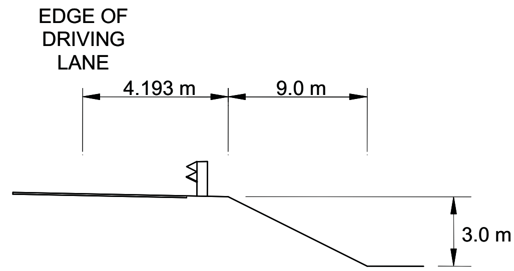




Step 12:

Enter the remaining feature, 3:1 Sideslope, by selecting the Add Feature.





Steps 13 and 14:

Once all features have been entered, select Pre-Calc Check to ensure there are no errors.

Select Analyze to analyze the features.

The annual crash cost information is generated in page 2 of the report.

Roadside Safety Analysis Program Version 2.0.3

Date: May 11, 2007

Alternative Cost Report

File Name: RSAP Example 2 GR.rpd
Project Description: AIT

Alternative	Description
1	AADT 10000 FS3:1 H=3m With GR

Alternative	Expected Crash Frequency (Acc/Yr)	Annual Crash Cost ($)	Annual Installation Cost ($)	Annual Maintenance Cost ($)	Annual Repair Cost ($)
1	0.344933	26690.44	0.00	0.00	267.40

The annual crash cost information for each of the features individually is provided in page 3 of the report.

Roadside Safety Analysis Program Version 2.0.3

Date: May 11, 2007

Feature Cost Report

File Name: RSAP Example 2 GR.rpd
Project Description: AIT

Alternative: 1
Description: AADT 10000 FS3:1 H=3m With GR

Feature	Distance From Beginning Of First Segment	Expected Crash Freq (Acc/Year)	Average Severity	Annual Crash Cost ($)	Category	Type
1.1	0.0	0.326482	3.23	25080.65	Longitudinal Barriers	TL-4 Guardrail
2.1	0.0	0.018451	4.27	1609.79	Foreslopes	3:1, H = 4.0 m (13 ft)

<u>Results</u>

The annual crash cost for the cross section with guardrail system is $26,690.44.

Example 3 – Determine Annual Crash Cost using the RSAP program of cross section with User Define Feature

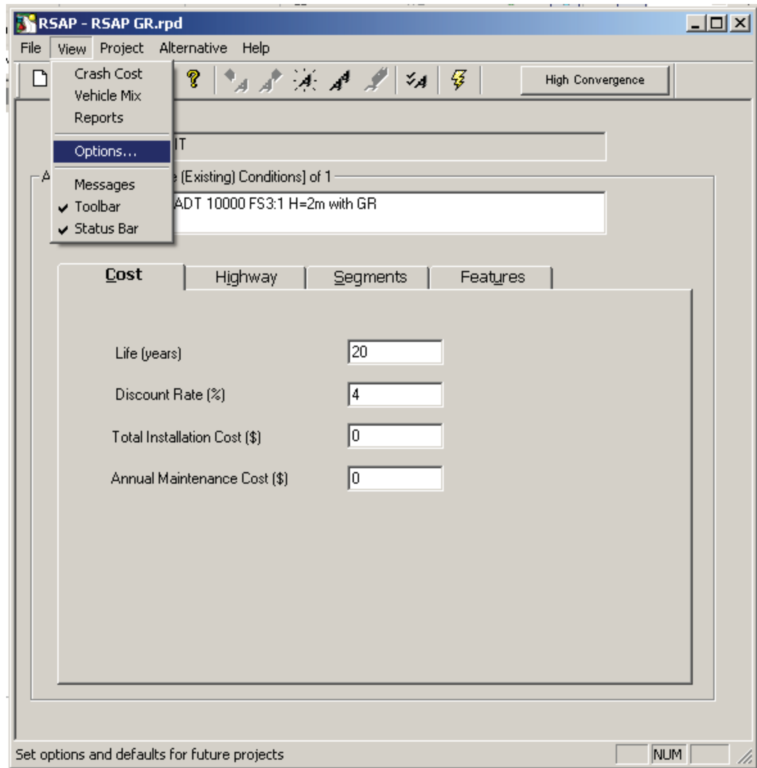
Information provided:

- Rural, Two-Way Undivided Highway
- Segment Length = 500 m
- Number of Lanes = 2
- Lane Width = 3.7 m
- Shoulder Width = 3.0 m
- Speed Limit = 100 km/h
- AADT Volume = 1,000 vpd
- Traffic Growth Rate = 2% per year
- Guardrail = Alberta Weak Post W-Beam
- Length of Guardrail = 232 m
- End Treatment = Alberta Weak Post W-Beam Turn Down End Treatment
- Sideslope = 2 m height of fill with 3:1 slope.

Follow Steps 1 to 10 from Example 1 to enter/confirm initial setup, Cost information, Highway information, and Segment information.

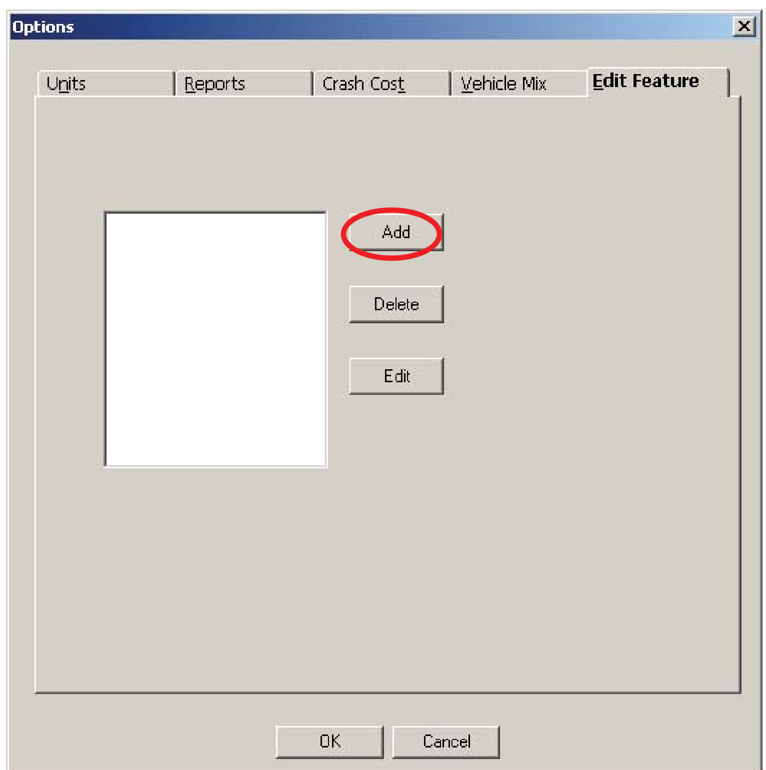
Step 11:

To add User-Defined Features, from the View drop down menu select Options then the Edit Feature tab.



Step 12:

Select Add to add the user-defined features.



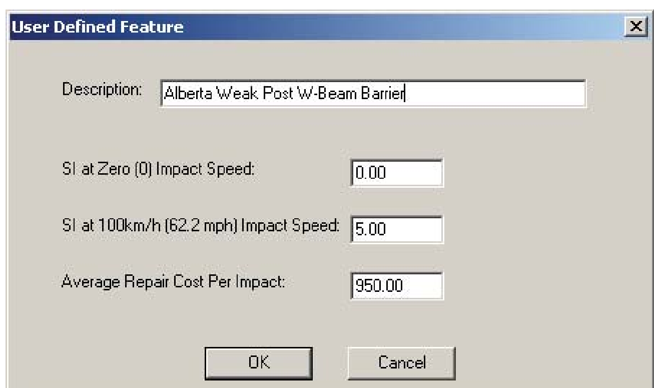
<u>Step 13:</u>

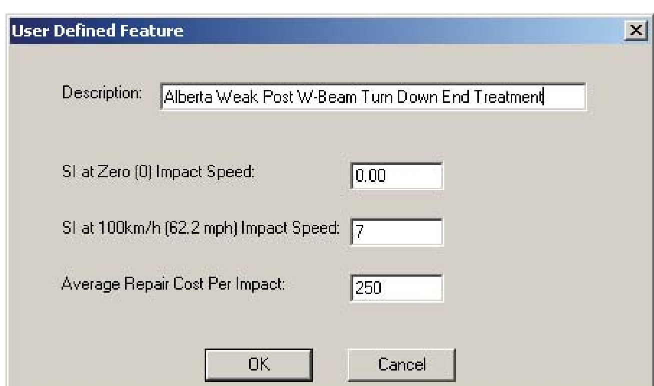
For Alberta Weak Post W-Beam and Turn Down End Treatment, enter the SI Values and Average Repair Cost per Impact information as provided in **Table H3.15**.

TABLE H3.15 Alberta-Specific RSAP Inputs

Feature	SI Value at 0 km/h Impact Speed	SI Value at 100 km/h Impact Speed	Average Repair Cost per Impact
Alberta Weak Post W-Beam Barrier	0	5.0	$950
Alberta Weak Post W-Beam Turn Down End Treatment	0	7.0	$250
Weak Post Box Beam non-*NCHRP Report 350* Turn Down End Treatment	0	5.0	$400
Concrete Barrier Flared and Tapered Down End Treatment	0	5.0	$250

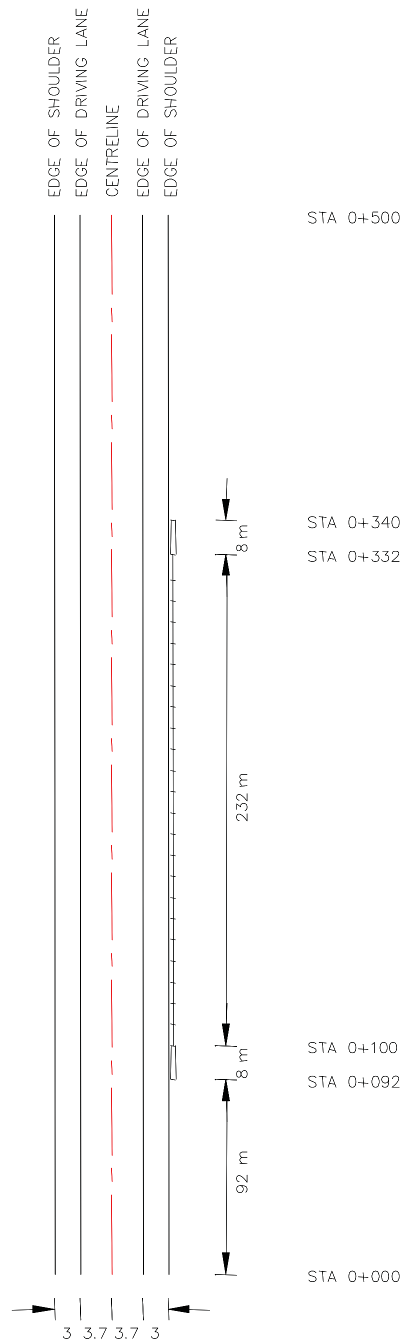
Table reproduced from Section H3.3.1



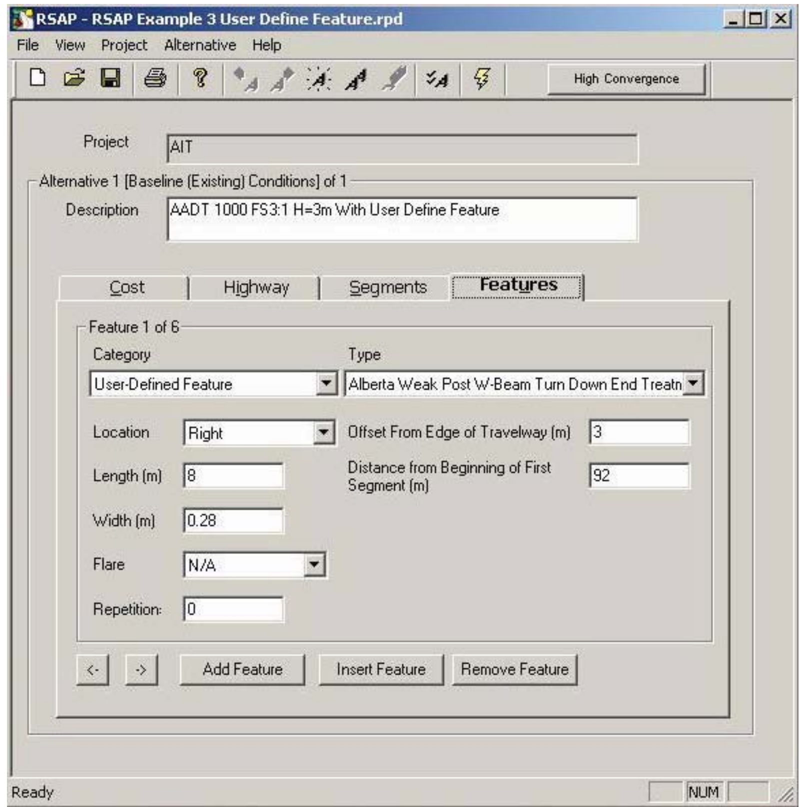


Step 14:

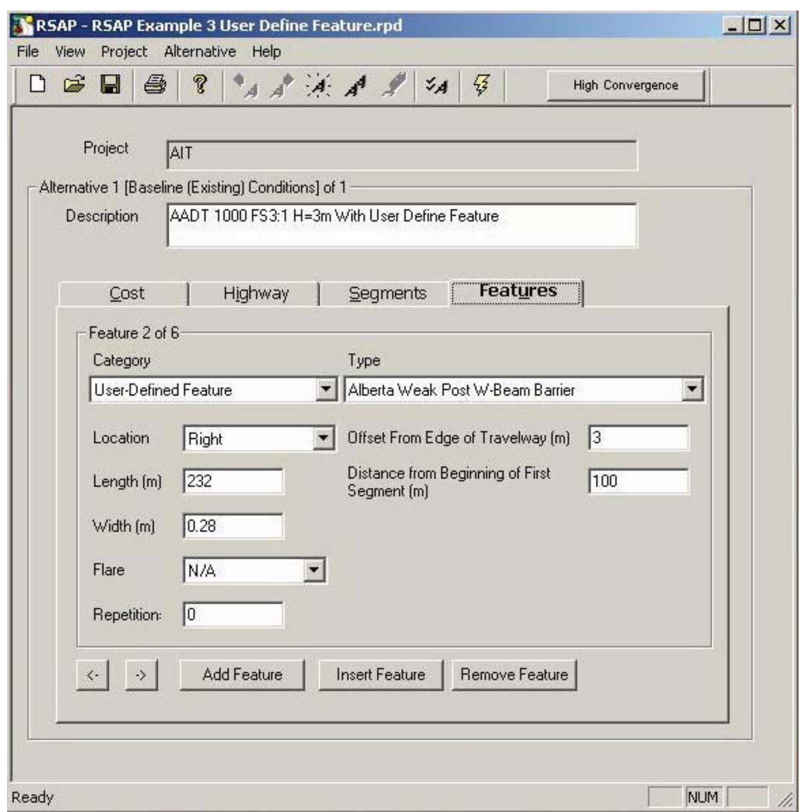
Enter the Approach End Treatment as the first feature, Guardrail as the second feature, Downstream End Treatment as the third feature, and the Sideslope as the fourth feature.



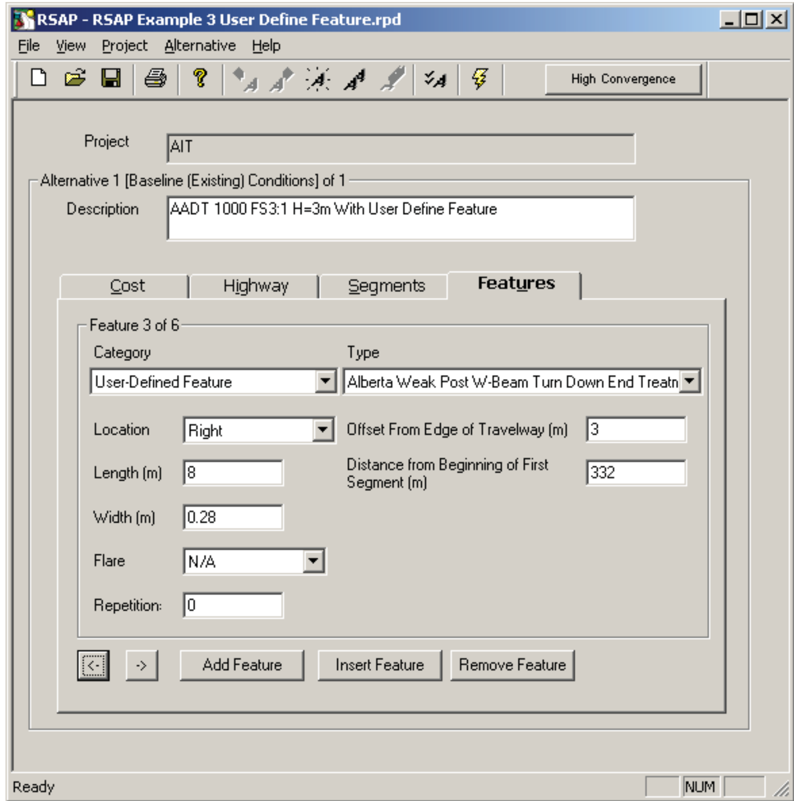
For the Approach End Treatment, enter the Offset From Edge of Travelled way (3.0 m), Length of the end treatment (8 m), Distance from Beginning of First Segment (Distance of approach End Treatment from Sta. 0+000), and Width of the system (0.28 m).



For the Guardrail system, enter the Offset From Edge of Travelled way (3.0 m), Length of the guardrail system (232 m), Distance from Beginning of First Segment (Distance of the beginning of the guardrail system from Sta. 0+000), and Width of the system (0.28 m).



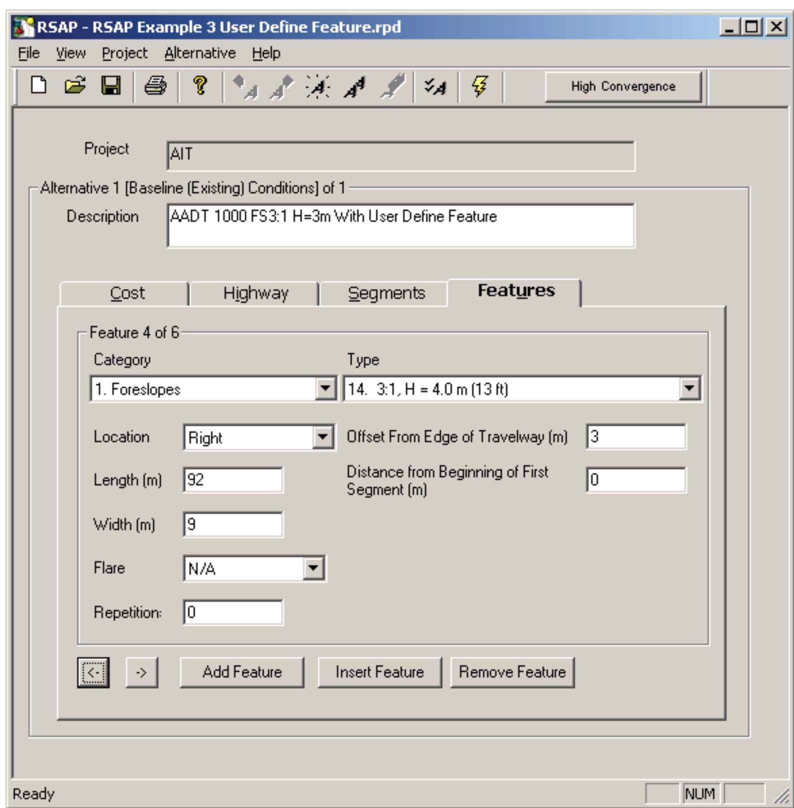
For the Downstream End Treatment, enter the Offset From Edge of Travelled way (3.0 m), Length of the end treatment (8 m), Distance from Beginning of First Segment (Distance of the downstream End Treatment from Sta. 0+000), and the Width of the system (0.28 m).



Step 15:

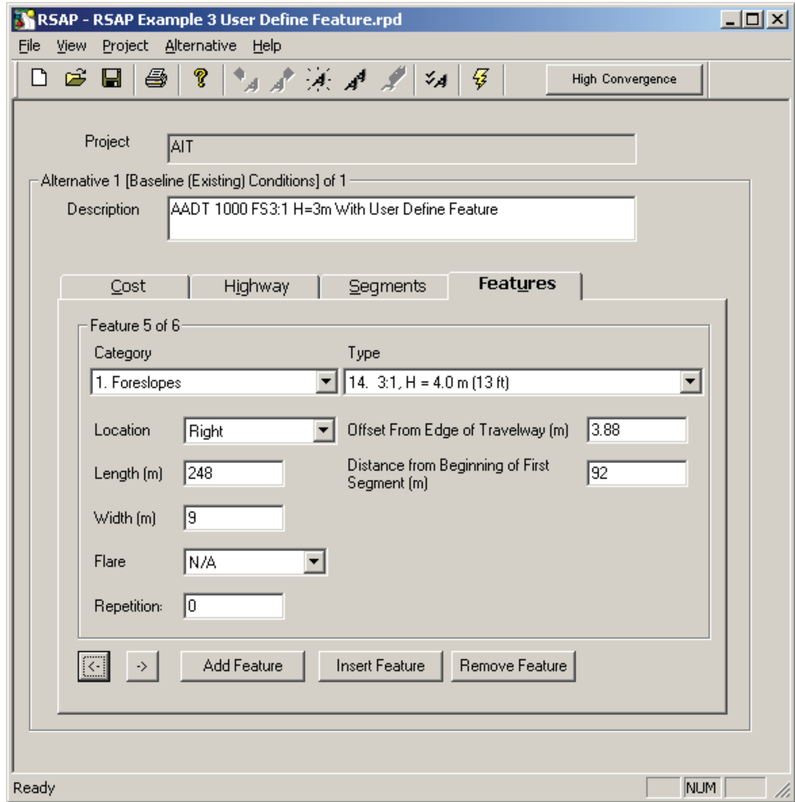
Enter the remaining feature, 3:1 Sideslope.

Enter sideslope (92 m) in advance of guardrail system.

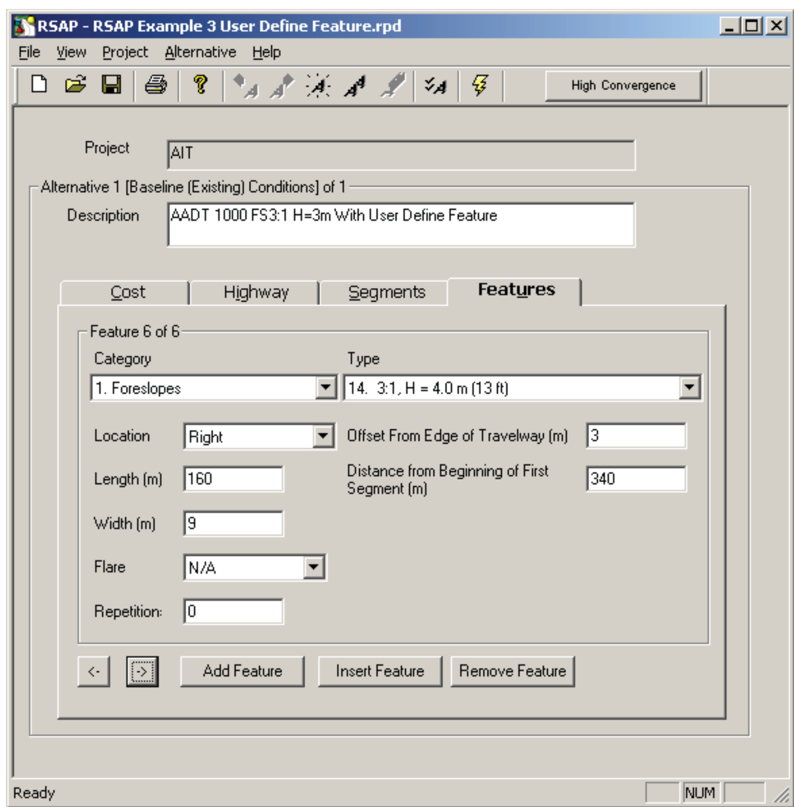


Enter sideslope adjacent to the guardrail system including end treatments (248 m).

The value for Offset from Edge of Travelway is 3.88 m (with 3.0 m shoulder width, 0.28 m guardrail system width, and 0.6 m shoulder width behind the guardrail).



Enter sideslope (160 m) after the guardrail system.



Steps 16 and 17:

Once all features have been entered, select Pre-Calc Check to ensure no errors. Select Analyze to analyze the features.

The annual crash cost information is provided on page 2 of the report.

Roadside Safety Analysis Program Version 2.0.3

Date: May 15, 2007

Time: 15:04:44PM

Page: 2

Alternative Cost Report

File Name: RSAP Example 3 User Define Feature.rpd
Project Description: AIT

Alternative	Description
1	AADT 1000 FS3:1 H=3m With User Define Feature

Alternative	Expected Crash Frequency (Acc/Yr)	Annual Crash Cost ($)	Annual Installation Cost ($)	Annual Maintenance Cost ($)	Annual Repair Cost ($)
1	0.118643	6803.38	0.00	0.00	17.32

The annual crash cost information for each of the features is provided in page 3 of the report.

Roadside Safety Analysis Program Version 2.0.3

Date: May 15, 2007

Time: 15:04:44PM

Page: 3

Feature Cost Report

File Name: RSAP Example 3 User Define Feature.rpd
Project Description: AIT

Alternative: 1
Description: AADT 1000 FS3:1 H=3m With User Define Feature

Feature	Distance From Beginning Of First Segment	Expected Crash Freq (Acc/Year)	Average Severity	Annual Crash Cost ($)	Category	Type
1.1	100.0	0.045360	3.26	81.99	User-Defined Feature	Alberta Weak Post W-Beam Barrier
2.1	92.0	0.003453	4.52	705.96	User-Defined Feature	Alberta Weak Post W-Beam Turn Down End Treatment
3.1	332.0	0.003482	4.62	631.01	User-Defined Feature	Alberta Weak Post W-Beam Turn Down End Treatment
4.1	0.0	0.016155	3.93	1225.53	Foreslopes	3:1, H = 4.0 m (13 ft)
5.1	92.0	0.024424	3.94	2479.88	Foreslopes	3:1, H = 4.0 m (13 ft)
6.1	340.0	0.025769	3.92	1679.01	Foreslopes	3:1, H = 4.0 m (13 ft)

Result

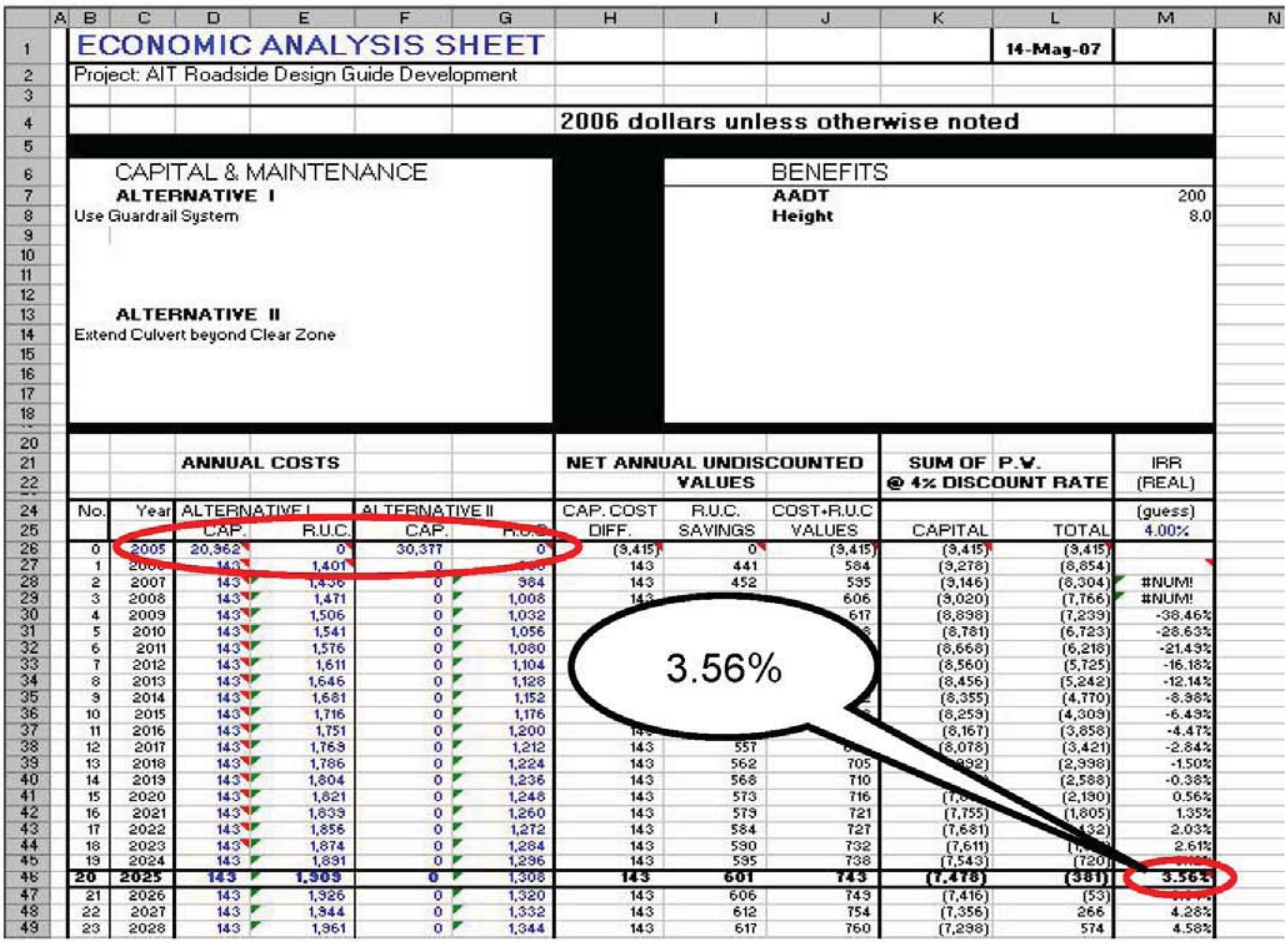
The annual crash cost for the cross section with Alberta W-Beam Weak Post Guardrail and Turn Down End Treatment is $6,803.38.

Example 4 – Benefit-Cost Analysis of Culvert Extension versus Barrier

Information provided:

- Length = 1 km
- AADT Volume = 200 vpd
- Speed Limit = 120 km/h
- Guardrail Installation
- Sideslope = 8 m height with 3:1 sideslope
- Construction Cost = $20,962
- Annual Collision Cost at Year 1 using RSAP = $1,401
- Annual Maintenance Cost = $142.50.
- Slope Flattening with Culvert Extension
- Sideslope = 8 m height with 4:1 sideslope
- Construction Cost = $30,371
- Annual Collision Cost at Year 1 using RSAP = $960.

Enter the construction, maintenance, and collision cost information, for the two alternatives into the spreadsheet.



ANNUAL COSTS						NET ANNUAL UNDISCOUNTED VALUES			SUM OF P.V. @ 4% DISCOUNT RATE		IRR (REAL)
No.	Year	ALTERNATIVE I CAP.	ALTERNATIVE I R.U.C.	ALTERNATIVE II CAP.	ALTERNATIVE II R.U.C.	CAP. COST DIFF.	R.U.C. SAVINGS	COST+R.U.C VALUES	CAPITAL	TOTAL	(guess) 4.00%
0	2005	20,962	0	30,377	0	(9,415)	0	(9,415)	(9,415)	(9,415)	
1	[illegible]	143	1,401	0	[illegible]	143	441	584	(9,278)	(8,854)	
2	2007	143	[illegible]	0	984	143	452	595	(9,146)	(8,304)	#NUM!
3	2008	143	1,471	0	1,008	143	[illegible]	606	(9,020)	(7,766)	#NUM!
4	2009	143	1,506	0	1,032	[illegible]	[illegible]	617	(8,898)	(7,239)	-38.46%
5	2010	143	1,541	0	1,056	[illegible]	[illegible]	[illegible]	(8,781)	(6,723)	-28.63%
6	2011	143	1,576	0	1,080	[illegible]	[illegible]	[illegible]	(8,668)	(6,218)	-21.49%
7	2012	143	1,611	0	1,104	[illegible]	[illegible]	[illegible]	(8,560)	(5,725)	-16.18%
8	2013	143	1,646	0	1,128	[illegible]	[illegible]	[illegible]	(8,456)	(5,242)	-12.14%
9	2014	143	1,681	0	1,152	[illegible]	[illegible]	[illegible]	(8,355)	(4,770)	-8.98%
10	2015	143	1,716	0	1,176	[illegible]	[illegible]	[illegible]	(8,259)	(4,309)	-6.49%
11	2016	143	1,751	0	1,200	[illegible]	[illegible]	[illegible]	(8,167)	(3,858)	-4.47%
12	2017	143	1,769	0	1,212	143	557	[illegible]	(8,078)	(3,421)	-2.84%
13	2018	143	1,786	0	1,224	143	562	705	[illegible]	(2,998)	-1.50%
14	2019	143	1,804	0	1,236	143	568	710	[illegible]	(2,588)	-0.38%
15	2020	143	1,821	0	1,248	143	573	716	[illegible]	(2,190)	0.56%
16	2021	143	1,839	0	1,260	143	579	721	(7,755)	(1,805)	1.35%
17	2022	143	1,856	0	1,272	143	584	727	(7,681)	[illegible]	2.03%
18	2023	143	1,874	0	1,284	143	590	732	(7,611)	[illegible]	2.61%
19	2024	143	1,891	0	1,296	143	595	738	(7,543)	(720)	[illegible]
20	**2025**	**143**	**1,909**	**0**	1,308	**143**	**601**	**743**	**(7,478)**	**(381)**	**3.56%**
21	2026	143	1,926	0	1,320	143	606	749	(7,416)	(53)	[illegible]
22	2027	143	1,944	0	1,332	143	612	754	(7,356)	266	4.28%
23	2028	143	1,961	0	1,344	143	617	760	(7,298)	574	4.58%

<u>Result</u>

The internal rate of return is less than the required 4% in 20 years therefore, a guardrail is a better treatment than a culvert extension.

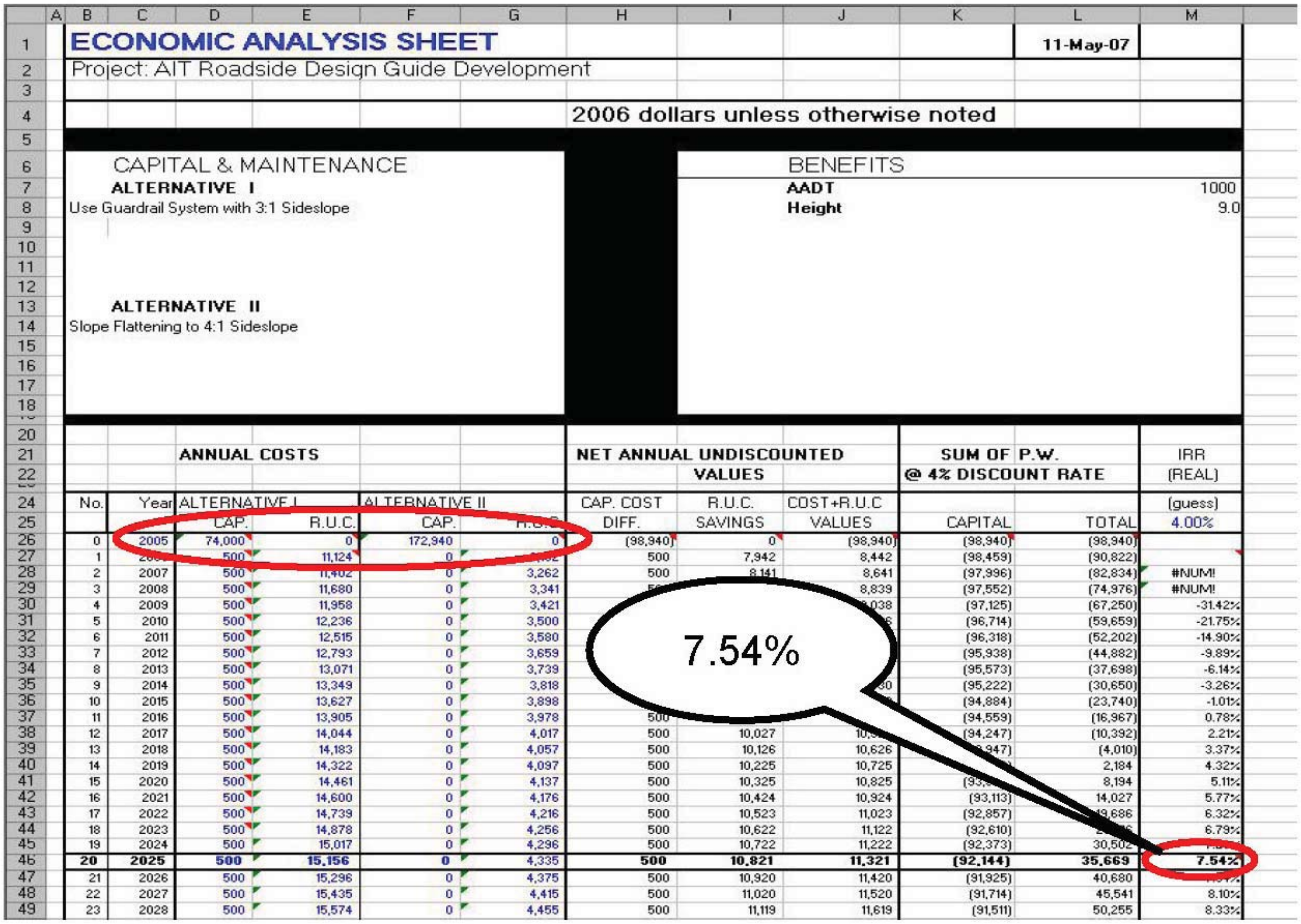
For additional benefit-cost information, refer to *INFTRA's Benefit-Cost Manual*.

Example 5 – Benefit-Cost Analysis of Slope Flattening versus Barrier for High Fill Embankment

Information provided:

- Length = 1 km
- AADT Volume = 1,000 vpd
- Speed Limit = 80 km/h
- Guardrail Installation
- Sideslope = 9 m height with 3:1 sideslope
- Construction Cost = $74,000
- Annual Collision Cost at Year 1 using RSAP = $11,124
- Annual Maintenance Cost = $500.00.
- Slope Flattening
- Sideslope = 9 m height with 4:1 sideslope
- Construction Cost = $172,940
- Annual Collision Cost at Year 1 using RSAP = $3,182.

Enter the construction, maintenance, and collision cost information, for the two alternatives into the spreadsheet.



ECONOMIC ANALYSIS SHEET 11-May-07

Project: AIT Roadside Design Guide Development

2006 dollars unless otherwise noted

CAPITAL & MAINTENANCE

ALTERNATIVE I
Use Guardrail System with 3:1 Sideslope

ALTERNATIVE II
Slope Flattening to 4:1 Sideslope

BENEFITS

AADT 1000
Height 9.0

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
No.	Year	ALTERNATIVE I		ALTERNATIVE II		CAP. COST	R.U.C.	COST+R.U.C			(guess)
		CAP.	R.U.C.	CAP.	R.U.C.	DIFF.	SAVINGS	VALUES	CAPITAL	TOTAL	4.00%
0	2005	74,000	0	172,940	0	(98,940)	0	(98,940)	(98,940)	(98,940)	
1	[illegible]	500	11,124	0	[illegible]	500	7,942	8,442	(98,459)	(90,822)	
2	2007	500	11,402	0	3,262	500	8,141	8,641	(97,996)	(82,834)	#NUM!
3	2008	500	11,680	0	3,341	[illegible]	[illegible]	8,839	(97,552)	(74,976)	#NUM!
4	2009	500	11,958	0	3,421	[illegible]	[illegible]	[illegible]	(97,125)	(67,250)	-31.42%
5	2010	500	12,236	0	3,500	[illegible]	[illegible]	[illegible]	(96,714)	(59,659)	-21.75%
6	2011	500	12,515	0	3,580	[illegible]	[illegible]	[illegible]	(96,318)	(52,202)	-14.90%
7	2012	500	12,793	0	3,659	[illegible]	[illegible]	[illegible]	(95,938)	(44,882)	-9.89%
8	2013	500	13,071	0	3,739	[illegible]	[illegible]	[illegible]	(95,573)	(37,698)	-6.14%
9	2014	500	13,349	0	3,818	[illegible]	[illegible]	[illegible]	(95,222)	(30,650)	-3.26%
10	2015	500	13,627	0	3,898	[illegible]	[illegible]	[illegible]	(94,884)	(23,740)	-1.01%
11	2016	500	13,905	0	3,978	500	[illegible]	[illegible]	(94,559)	(16,967)	0.78%
12	2017	500	14,044	0	4,017	500	10,027	[illegible]	(94,247)	(10,392)	2.21%
13	2018	500	14,183	0	4,057	500	10,126	10,626	[illegible]	(4,010)	3.37%
14	2019	500	14,322	0	4,097	500	10,225	10,725	[illegible]	2,184	4.32%
15	2020	500	14,461	0	4,137	500	10,325	10,825	[illegible]	8,194	5.11%
16	2021	500	14,600	0	4,176	500	10,424	10,924	(93,113)	14,027	5.77%
17	2022	500	14,739	0	4,216	500	10,523	11,023	(92,857)	[illegible]	6.32%
18	2023	500	14,878	0	4,256	500	10,622	11,122	(92,610)	[illegible]	6.79%
19	2024	500	15,017	0	4,296	500	10,722	11,222	(92,373)	30,502	[illegible]
20	**2025**	**500**	**15,156**	**0**	4,335	**500**	**10,821**	**11,321**	**(92,144)**	**35,669**	**7.54%**
21	2026	500	15,296	0	4,375	500	10,920	11,420	(91,925)	40,680	[illegible]
22	2027	500	15,435	0	4,415	500	11,020	11,520	(91,714)	45,541	8.10%
23	2028	500	15,574	0	4,455	500	11,119	11,619	(91,511)	50,255	8.33%

For additional benefit-cost information, refer to *INFTRA's Benefit-Cost Manual*.

<u>Result</u>

The internal rate of return is greater than the required 4% in 20 years, therefore, slope flattening is preferred over a guardrail.

H3.4 Documentation Requirements

Documentation of the Clear Zone distance, the Length of Need, and the length of barrier systems should be provided as part of a traceable design process for future reference. In addition, documentation of economic analyses should also be provided, if used.

H3.4.1 Clear Zone Documentation

The Clear Zone documentation should be included in the project-specific Design Criteria. The information should include the Tangent Clear Zone distance and the Desirable Clear Zone distance used along the highway.

H3.4.2 Length of Need and Length of Barrier System Documentation

The Length of Need documentation should include the following information:

- highway location (preferably by station reference)
- Clear Zone limit
- hazard limit lines
- barrier system location and end treatment configuration
- encroachment lines
- downstream length (if applicable).

H3.5 References

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

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

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

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

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

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

American Association of State Highway and Transportation Officials, *Roadside Design Guide 2002*, Washington, DC, 2002.

California Department of Transportation, *Traffic Safety Systems Manual*, Chapter 7, May 1998, 31pp.

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

Mak, King, and Dean .L. Sicking, *National Cooperative Highway Research Program Report 492: Roadside Safety Analysis Program (RSAP) – Engineer's Manual*, Transportation Research Board, National Research Council, Washington, DC, 2003. 153pp.

THIS PAGE LEFT BLANK INTENTIONALLY