CHAPTER G
3R/4R GEOMETRIC DESIGN GUIDELINES

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CHAPTER G
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G.1 INTRODUCTION

3R projects generally include resurfacing, restoration or rehabilitation of existing paved roads. 4R projects include some reconstruction of existing paved roads, which generally takes place in conjunction with resurfacing, restoration or rehabilitation of the existing pavement. The purpose of the 3R/4R guidelines is to extend the service life of existing paved highways and enhance highway safety on a network basis. To accomplish this objective, the standards focus on the most safety-cost effective improvements and also encourage the use of low-cost opportunities to improve safety where major reconstruction is not cost-effective. The guidelines contained in this document are general in nature and are not a substitute for engineering judgement.

The process used to review the geometric design standards on existing paved highways under Alberta Infrastructure' jurisdiction is described below:

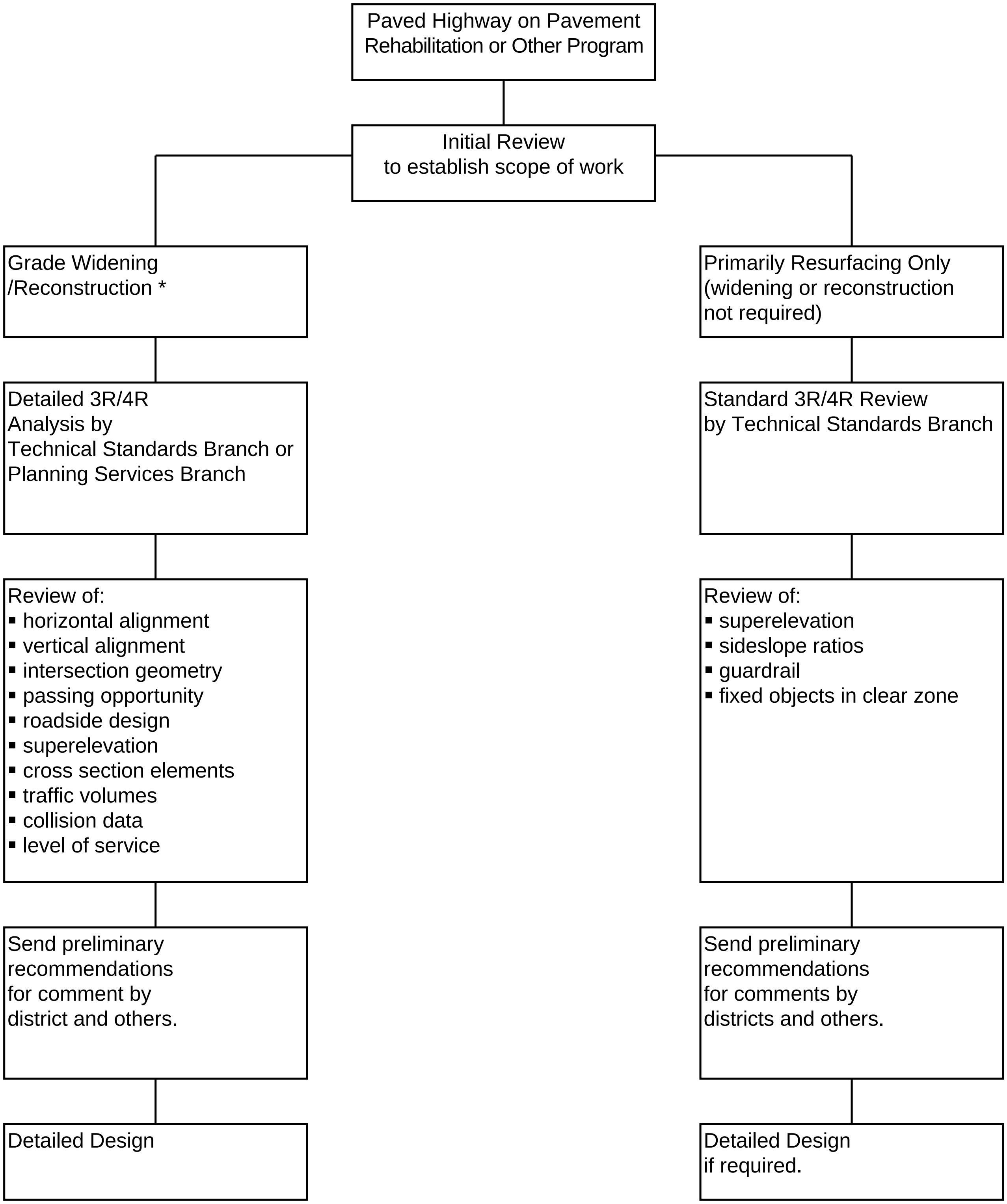
Pavements are designed with an intended life of 20 years and therefore, the first and subsequent rehabilitation will generally occur in 20-year cycles. This pattern establishes a logical timetable for the review of geometric design standards on existing paved roads. If geometric improvements are required it is generally most cost-effective to construct at the time of rehabilitation. Projects that are scheduled for pavement rehabilitation are listed on a construction program. This list is based on pavement condition and other considerations. Because approximately 15,000 km (total two-lane equivalent length as of March 1994) of Alberta's primary highway system are paved and because those pavements generally require rehabilitation every 20 years, approximately 750 km of pavement will require rehabilitation each year. An assessment of geometric design standards is made on each section of highway prior to pavement rehabilitation. It is desirable that this assessment take place several years before the scheduled rehabilitation to allow all improvement options to be considered. The first step in the geometric assessment process is an initial screening of all the projects to determine the general scope of work. This initial screening is done by a small group of experts representing the design, planning and programming functions with special input, if required, from other areas; for example, the Regional Offices (Regional Services), the Maintenance, Specifications and Traffic Engineering Section, the Highway Engineering Section of Technical Standards Branch (Planning and Technical Services) etc.

The general scope-of-work determination includes deciding whether or not grade-widening is required and deciding if selective geometric improvements or general reconstruction (perhaps to new construction standards) is appropriate.

The initial technical review is based on a summary of geometric, traffic and collision data that is readily available for each project. Generally, as part of the initial review, projects will be identified for planning study, preliminary engineering or detailed engineering work. This type of technical review may also be applied to projects listed on the Primary Highway Construction Program. This process allows projects which previously may have been unsupported by technical data to gain some technical credibility, or conversely, projects without technical merit can be identified.

The Geometric Assessment Process Flowchart (Figure G-1) shows an outline of the sequence of activities involved on a typical 3R/4R assessment.

Figure G-1 Geometric Assessment Process Flowchart



* Reconstruction may involve spot alignment improvement only

G.1.1 Guidelines for Initial Review

The following information is required for the initial technical review: project description, AADT, level of service, pavement width, sideslope, backslope, collision rate, and summary of horizontal alignment information noting radii of all curves.

When determining the scope of work for a 3R/4R project, a fundamental parameter that must be considered is pavement width. If the pavement is sufficiently wide to provide the desired service for traffic, then only the other geometric parameters need to be assessed. If grade-widening is necessary, a choice must be made between simple grade-widening (retaining existing horizontal and vertical geometry) or some degree of reconstruction.

If grade-widening is not required, the horizontal curvature should be reviewed together with the collision data to see if selective alignment improvements may be called for. If neither grade-widening or horizontal curve improvements are indicated by the initial review and there are no obvious safety concerns, the project may be given a standard 3R/4R review rather than a detailed 3R/4R analysis. Projects which are labelled as standard 3R/4R review are still reviewed for sideslope ratio, removal of fixed objects in the clear zone (for example, guardrail), etc. but will not need a full detailed geometric assessment. All other projects will undergo a detailed 3R/4R analysis which includes an assessment of horizontal alignment, vertical alignment, roadside area, intersection geometrics, superelevation and passing opportunity.

Sections G.1.2 and G.1.3 provide guidelines for establishing the minimum acceptable width and choosing between grade widening and reconstruction.

G.1.2 Minimum Lane and Shoulder Widths

Undivided Highways

Designers should refer to Figure G-1.1 (Suggested Minimum Standards for Rural Highways in Alberta).

Through reference to this figure, a designer can determine if a given roadway would be sufficiently wide after an overlay according to the existing width, AADT and functional classification. If the roadway would not be sufficiently wide, consideration should be given to grade-widening and/or reconstruction. A designer should then refer to Figure A-3.2i, Desirable Standards for Rural Highways in Alberta to determine the desirable width for the roadway. The Suggested Minimum Standards in Figure G-1.1 are shown in terms of Existing AADT while the Desirable Standards in Figure A-3.2i are shown in terms of Design AADT. A rationale for Figure G-1.1 is provided based on economic analysis and other considerations in Appendix A.

Divided Highways

On existing paved highways that are being twinned or overlaid (divided highways), the suggested minimum roadway width for each road top is 9.5m. This provides sufficient width for shoulders and lanes as follows: 0.3m, 3.7m, 3.7m and 1.8m.

Where the pavement width is greater than 9.9m (0.3m left shoulder, 2.2m right shoulder), the right shoulder should be increased to a 3.0m width before increasing the left shoulder width.

G.1.3 Grade Widening/Reconstruction Versus Overlay

Designers should refer to Section C.8.1 of this document for a discussion on the department's strategy to retain existing pavement widths. All feasible alternatives should be explored to minimize the loss of pavement width while undertaking pavement rehabilitation however inevitably there will be a need to widen or reconstruct some roadways. In choosing between full or partial grade-widening and total reconstruction, many factors must be taken into consideration. Normally, input will be required from Regions and Technical Standards Branch before that decision is made. However, the following guidelines may be useful:

1. If width after overlay will be less than that shown in Figure G-1.1, grade-widening is generally cost-effective from the point of view of collision cost reduction, assuming a provincial average collision rate for the existing width of roadway.

2. Where the existing collision rate is significantly different from the provincial average for this roadway width, this should be considered when assessing the need for grade widening. When assessing the collision history of a particular road, designers should consider the breakdown of collision types and their relationship to geometric features. For example, geometric improvements will usually have very little impact on the number of animal collisions. However, roadside improvements can significantly reduce the severity of run-off-the-road type collisions.

3. Existing geometrics should also be considered. Substandard geometrics would provide more support for grade widening or reconstruction rather than overlay.

4. Where grade-widening and horizontal or vertical alignment improvements are warranted, a designer should carefully assess the impact of doing selective alignment improvements only. Selective alignment improvements will likely be less costly than applying the desirable new construction standards throughout. However, they may result in a less balanced design; for example, a wide roadway with minimum alignment standards. Generally on grade-widening projects, improvement of sub-standard horizontal curvature is considered appropriate. However, vertical alignment improvements may be done selectively according to the 3R/4R Geometric Design Guidelines. Vehicle speeds generally increase as a result of lane and shoulder width improvements. These speed increases will offset part of the safety benefit of grade-widening because, other things being equal, collision rates increase with speed. Because the typical driver expects better alignments on wider roads and drives accordingly, it is appropriate to provide better than minimum alignment standards on roadways with wide shoulders.

Where a grade widening project requires alignment improvements over a substantial portion of its length, it is appropriate to adopt the desirable new construction standards for the entire project to ensure design consistency.

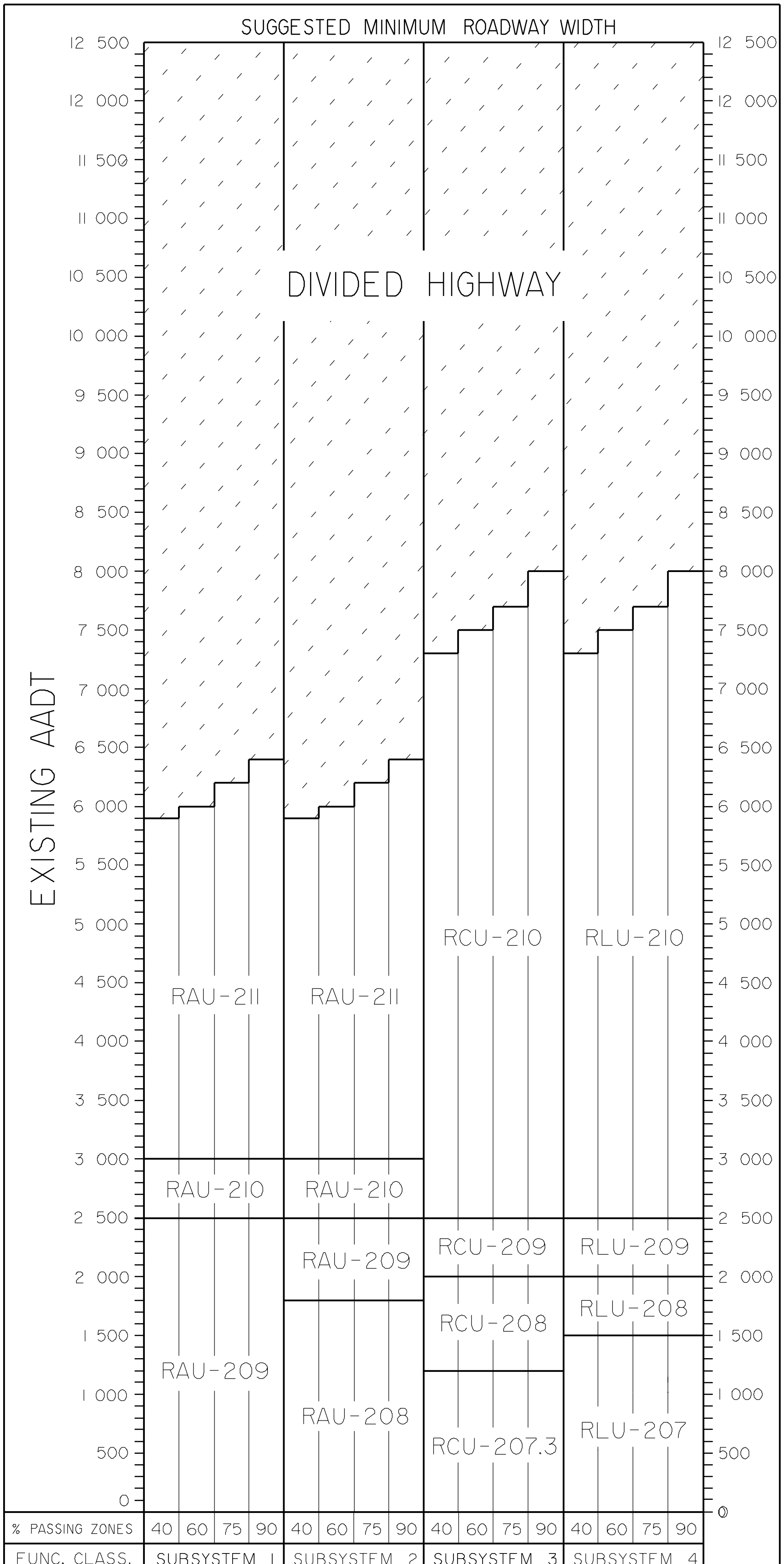
G.1.4 Acceptable Curb Heights on Existing Roadways

Acceptable curb heights on existing roadways (after overlay etc.) are dependent of curb locations, taking pedestrian safety into consideration. Table G.1.4 provides a general guideline for selecting minimum curb heights.

Table G.1.4 Minimum Acceptable Curb Heights on Existing Roadways

Curb Location	Minimum Acceptable Curb Height
Adjacent to sidewalk	75 mm
Adjacent to boulevard	50 mm
On median side	50 mm

FIGURE G-1.1 SUGGESTED MINIMUM ROADWAY WIDTH FOR RURAL HIGHWAYS IN ALBERTA (shown in terms of existing AADT)



NOTE: ON RURAL HIGHWAYS IN ALBERTA, THE TYPICAL PASSING ZONE AVAILABILITY IS 75%.

(shown in terms of existing AADT)

NOTE: This chart has been developed as a guideline to assist in deciding whether a particular roadway, which requires pavement rehabilitation, should be widened. The chart should be used as follows:

1. A geometric assessment should be conducted on all pavement rehabilitation projects. The need for, and cost-effectiveness of, grade widening will be considered as part of that assessment. This chart has been prepared to show cost-effectiveness based on generalized assumptions for construction cost, collision rate and collision severity. The collision rates have been based on design designation (roadway width) and traffic volume. Appendix B provides the background information and an example of the economic analysis. The assumptions are based on provincial averages. Where any of the major parameters related to costs or benefits, on a particular project, are significantly different from those assumed, a project specific economic analysis should be undertaken.

2. The chart shows suggested minimum widths for roadways on each subsystem, based on traffic volumes. The ranges have been established based on practical considerations, which limit the minimum widening that can be done, and the results of a life-cycle economic analysis, which includes safety benefits associated with grade widening. The existing AADT values have been obtained from the economic analysis, by determining the current traffic volume required to yield a satisfactory rate of return on construction investment, by the end of the design life. For this purpose, a 20 year design life and an average annual traffic growth rate of 2.5% (not compounded) was used. Generally, this is considered to be a good ballpark growth rate to apply to Alberta's rural, roads based on examination of traffic growth patterns for the period from 1979 to 1989. Where a more accurate 20 year traffic volume projection is available for a specific roadway, a designer may use that information to adjust the ranges shown here or run a special economic analysis to determine the cost-effectiveness of grade-widening on that particular project.

3. If the roadway after being overlayed would have a width less than that shown for the existing AADT and function, then grade widening, reconstruction, or twinning is called for. Desirable standards, as shown on Figure A-3-2ii, should generally be used on all projects which involve a significant amount of grading work.

4. if the overlayed width is greater than, or equal to, the width shown and the accident rate is normal, an overlay is appropriate.

5. Where reconstruction has been selected, it must be decided whether "new construction standards" or special "retrofit design standards" should be used. The geometric and safety record of the existing roadway, the level of access control, the desirable design speed, the design AADT, the passing demand and opportunity should all be considered in that decision.

6. The maximum AADT volumes shown for two lane roadways in each subsystem, and for each percentage of passing zone availability, have been set according to the limit of level-of-service 'D', which could be achieved at the end of the design life (20 years). If higher volumes were allowed, level-of-service 'E' would result in the design hour (30th highest hour) assuming normal traffic composition and characteristics. It has been assumed that subsystems 1 and 2 are typically rural and subsystems 3 and 4 are typically commuter for the traffic volume ranges where twinning is comtemplated. Level-of-service 'E' on two lane roadways is defined as that condition where vehicles experience delay for at least 75% of the time in the design hour. Such a condition is generally considered to be unacceptable for two lane rural roads in Alberta.

G.2 HORIZONTAL CURVATURE

Improvements should be considered at all horizontal curves on pavement rehabilitation projects. Improvements will generally be warranted only on curves which do not meet the minimum radius for new construction. Curves that exceed the minimum radius should also be considered for upgrading, based on factors such as superelevation rate, collision rate, intersections or hazards on curve, consistency with highway alignment, horizontal-vertical alignment coordination, road user savings due to lower vehicle running costs, or small deflection angles.

Designers undertaking geometric assessment generally prepare a summary of all horizontal alignment elements that should be considered for improvement for any of the reasons listed above, or for other reasons. The summary includes the curve geometric information (radius, spiral, delta, superelevation, width, length), township diagram, collision records and traffic information (AADT).

Where detailed analysis is required, use of the department's Benefit-Cost Guidelines is recommended as one tool in the analysis, the results of which will be only one of several factors which will bear upon the decision.

Because of the many site specific factors which can affect the outcome of an analysis, a project specific analysis considering all of the alignment alternatives should be undertaken. Where the realignment proposals involve more than one curve on a highway section, it is necessary to include the entire alignment (from common point to common point, which includes all the alternatives) in the analysis. The route to be used should include all expected costs that apply to the specific project. All alternatives considered must be feasible from a route location perspective.

The benefit-cost guidelines include benefits for reductions in vehicle running cost, time savings for shorter alignments or higher speeds, and potential savings in collision costs. Three factors may contribute to savings in collision cost for horizontal alignment improvements. These factors are:

1. **Length of Alignment**

   Where the length of the project is different for different alternatives, this will result in differences in total vehicle kilometres, or exposure of vehicles to collision risk, over the analysis period.

2. **Collision severity.**

   The collision severity on any particular project could be affected by horizontal alignment improvement. However, there is no data available at the present time to link these two factors. Generally, where horizontal realignment is being considered, if all other geometric features are to remain unchanged, then no change in collision severity should be assumed. The analysis should consider that other improvements (sideslope flattening or removal of obstacles such as approaches), which are often undertaken at the same time as horizontal realignment, could result in lower collision severity. In this case, a reduction in collision severity may be appropriate.

3. **Collision rate.**

   Collision rate (generally expressed as collisions per 100 million vehicle kilometres) is known to be related to the sharpness of horizontal curvature. Many models have been developed to predict the collision rate on horizontal curves and tangents of high speed rural highways. It is recommended that the Glennon Model be used to estimate the future collision rate, as described in Appendix D of the 1987 Transportation Research Board (TRB) publication Special Report 214 entitled Designing Safer Roads - Practices for Resurfacing, Restoration or Rehabilitation. The model should be calibrated using the existing collision experience on the highway section in question. An example showing the use of this model is included in Appendix B of this chapter.

On many projects where horizontal realignment is considered, cost effectiveness can be demonstrated without a significant dollar value for collision cost savings. However, on some projects the collision cost savings are crucial to the overall cost-effectiveness. In these cases, a sensitivity analysis should be performed; that is, an analysis which will show the cost-effectiveness based on a range of collision rates that may result after geometric improvement. The results of the sensitivity analysis will allow an informed decision to be made regarding realignment based on a reasonable prediction of collision rate change.

An example of a full economic analysis, including a sensitivity analysis, for horizontal alignment improvement is shown in Appendix B.

Where horizontal realignment of existing paved roads takes place, the new alignment should be projected considering desirable standards. Minimum standards are to be used for critical locations, with better standards encouraged where practical and cost-effective. Desirable standards result in lower superelevation rates, less wear and tear for vehicles and tires on curves, and generally safer and more relaxed driving conditions for all road users.

G.3 VERTICAL CURVATURE

G.3.1 Crests

Vertical crest curve reconstruction should be evaluated if any one of the following conditions exist:

1. There is a safety problem, or

2. There is a hazard in close proximity to the crest, or

3. The AADT exceeds 3000 and there is limited sight distance (that is, stopping sight distance available is substantially less than what would normally be provided under new construction standards for vehicles travelling at the average running speed of vehicles on the crest).

Although evaluation of vertical crest curves is appropriate where any of the above conditions exist, reconstruction may not be the most desirable action, due to low cost-effectiveness, physical constraints, or other reasons.

The use of traffic control devices to advise motorists of the sharp crest may be considered where a decision has been made not to improve a vertical alignment due to low cost-effectiveness, although the existing alignment is substantially below current standards. Additional low-cost measures to be considered are fixed hazard removal, shoulder widening and relocation of minor intersection.

Generally, a substantial sight distance restriction is one where the minimum stopping sight distance available is more than 20 km/h less than the 85th percentile running speed of vehicles on the crest. In Alberta, the 85th percentile running speed on two-lane highways is frequently 109 km/h. Therefore, the suggested minimum vertical crest curvature is generally based on the minimum stopping sight distance for 89 km/h.

Using current object height, eye height, perception-reaction time and friction factor, this gives a minimum stopping sight distance of 165.76 m (rounded to 166 m) or a crest K value of 51.0 (rounded to 50) for a running speed of 109 km/h. Therefore a K value of 50 is considered acceptable on existing paved undivided highways with design speed up to 110 km/h. This same value is used for divided highways which may have a higher design speed (up to 130 km/h), a higher posted speed of 110 km/h and a higher 85th percentile running speed (estimated a 116 km/h). The reason for accepting the K of 50 on divided highways is because stopping sight distance is not as critical on a roadway serving just one direction of travel. Additionally, experience from other agencies especially in the United States[1] indicates that a speed differential between running speed and stopping sight distance speed of 32.2 km/h (20 mph) is generally acceptable on existing crest curves that are under consideration for reconstruction.

Table G.3.1 shows suggested minimum vertical crest curve K values for 3R projects in Alberta based on the above criteria.

[1] Reference: Special Report 214, Practices for Resurfacing, Restoration and Rehabilitation, Transportation Research Board, National Research Council 1987.

Table G.3.1 Suggested Minimum Vertical Crest Curve K Values for 3R/4R Projects

Design Speed (Km/h)	85th Percentile Running Speed V_{85} (Km/h)	Speed Used for Minimum Vertical Crest Curves V_{85} -20 (Km/h)	Stopping Sight Distance m	K Value if SSD < LVC* object = 0.38 m		K Value if SSD > LVC*
				Exact	Rounded for Design	
110 - 130	109	89	165.75	51.00	50	Depends on the A value (refer to formulae on following page)
100	100	80	136.84	34.76	35	
90	90	70	108.90	22.02	25	
80	80	60	83.35	12.90	15	

SSD = Stopping Sight Distance
A = Algebraic Difference of Grades
* LVC = Length of Vertical Curve

Where the 85th percentile running speed is different from that shown in Table G.3.1, the formulae below can be used to determine minimum crest K values.

Use of the formulae below may also be required to determine the suggested minimum K value where the stopping sight distance exceeds the length of vertical curve *(SSD > LVC)*.

$$SSD = \frac{Vt}{3.6} + \frac{V^2}{254.f} \qquad t = 2.5 \text{ seconds}$$

$$K = \frac{SSD^2}{200(\sqrt{h_1} + \sqrt{h_2})^2} = \frac{SSD^2}{538.666} \qquad \text{if } SSD < LVC$$

$$K = \frac{2(SSD)}{A} - \frac{200(\sqrt{h_1} + \sqrt{h_2})^2}{A^2} \qquad \text{if } SSD > LVC$$

$$K = \frac{2(SSD)}{A} - \frac{538.666}{A^2}$$

$h_1 = 1.05m$ (eye)
$h_2 = 0.38m$ (object)
$V = Speed\ (km/h)$
$f =$ *friction factor for stopping* (*Table B*.2.3)

Reference: AASHTO, A Policy on Geometric Design of Highways and Streets, 1990 (Page 283)

G.3.2 Sags

It is generally not cost effective to improve vertical sag curves unless accident records indicate that the vertical curvature is causing collisions. If the existing vertical sag K value is so low that it is uncomfortable for occupants of vehicles travelling at the 85th percentile speed, consideration should be given to improvement. Where the 85th percentile running speed is 110 km/h, a sag vertical curve K value of 30 should be considered minimum. Sharper sags would be uncomfortable at this speed[1] . Table G.3.2 shows minimum sag curve K values which are suggested for various speeds.

[1] TAC Manual of Geometric Design Standards for Canadian Roads (1986), Appendix A.

Table G.3.2 Suggested Minimum Vertical Sag Curve K Values for 3R/4R Projects

Design Speed km/h	85th Percentile Running Speed km/h	Suggested Minimum Sag Curve K Value	
		Exact	Rounded for Design
60	60	9.2	10
80	80	16.4	20
100	100	25.7	25
110	109	30.6	31
120	112	32.3	33
130	116	34.6	35

The above table is based on the following:

1. Radial acceleration should not exceed 0.3 m/sec^2
2. Radial acceleration = v^2 / R
3. R is the rate of change of curvature = 100K

$$0.3 \geq \frac{v^2}{100K}$$ v in metres per second

$$K \geq \frac{V^2}{100x0.3}\left(\frac{1000}{3600}\right)^2$$ V in km/h

Therefore $K \geq \frac{V^2}{388.8}$

[1] TAC Manual of Geometric Design Standards for Canadian Roads (1986), Appendix A.

G.4 INTERSECTIONS

Annual traffic collisions statistics compiled over several years in Alberta have shown that approximately 25 percent of all casualty collisions and 28 percent of all fatal collisions occurring on the rural highway system have happened at intersections. Consequently, it is appropriate to review the functional, geometric and operational requirements of all at-grade intersections at the time of pavement rehabilitation. Designers should refer to Chapter D At-Grade Intersections to check all aspects of existing intersections, such as layout, gradients, superelevation and capacity.

To provide safe operations, intersections should be designed to accommodate all vehicles which use them on a regular basis. The available intersection sight distance in both directions for each vehicle type must be measured in the field using the eye and object heights shown in the table. Alternatively, the sight distance available may be measured from the profile if an accurate as built profile is available and there are no restrictions to the sight lines in the horizontal plane. The accident history at each intersection should also be checked before deciding if corrective measures are appropriate.

The available sight distance should be compared to the sight distance required for each design vehicle according to new construction standards and the design speed. Where this sight distance is not available, a designer should compare the available sight distance to the requirement for the posted speed at that location on the major highway.

Note: Intersection sight distance requirements are based on providing sufficient sight distance so that the design vehicle, having come to a stop on the minor road, can safely make a left turn onto the highway without being struck by a vehicle approaching at high speed from the left. A perception-reaction time of two seconds is allowed for this manoeuvre. In the new construction standard, the high speed vehicle is assumed to be approaching at design speed. However, in the 3R standard the posted speed is used.

The sight distances shown on Table G.4 are generally acceptable at existing intersections. However, more stringent criteria (longer sight distances) are generally provided at newly constructed intersections if trucks larger than the WB-15 vehicle are frequently turning at the junction. Designers should assess the turning movements and vehicle composition at an intersection to ensure that an adequate sight distance is provided.

Table G.4 Suggested Minimum Sight Distances for At-Grade Intersections on 3R/4R Projects

Design Vehicle	Eye Height (m)	Object Height (m)	Sight Distance Requirement for Left Turn onto Highway (m)										
			New Construction Standard					Minimum Acceptable for 3R Projects					
			Design Speed (km/h)					Posted speed (km/h)					
			80	100	110	120	130	60	70	80	90	100	110
WB-21	2.1	1.3	-	-	-	-	-	307	358	409	460	500	500
WB-15	2.1	1.3	313	392	430	470	510	233	272	313	330	392	430
Bus (SU type)	1.8	1.3	235	295	325	355	385	177	206	235	240	295	325
Passenger Vehicle (P type)	1.05	1.3	160	200	220	235	255	117	136	160	155	200	220

G.5 PASSING OPPORTUNITY (CLIMBING, PASSING LANES)

Projects undergoing pavement rehabilitation should be checked for passing opportunity. The passing opportunity available on a highway segment due to pavement markings, together with the passing demand (which is a function of traffic volume and speed distribution), will have a major impact on level-of-service. Designers should use the warrants and guidelines for climbing and passing lanes contained in Chapter B to determine the need for auxiliary lanes.

Care should be exercised in applying the auxiliary lane warrants to existing paved roadways. There may be cases where the addition of an auxiliary lane is not desirable even though the warrant is met. This could be due to the physical constraints of the existing roadway, presence of hazards such as intersections, or the location of no passing zones. For safety reasons on some projects, it may be necessary to include some access control in conjunction with construction of auxiliary lanes. Where this is not feasible, it may be better not to build the auxiliary lane.

G.6 ROADSIDE DESIGN

G.6.1 Definition of Clear Zone

Clear zone is the total roadside border area, starting at the edge of travelled way, available for safe use by errant vehicles. Although the movement of out-of-control vehicles is difficult to predict, a study of run-off-road incidents entitled The General Motors Proving Ground Study[8] has shown that 50 percent of errant vehicles do not go beyond five metres from the edge of roadway while a full 80 percent stray less than nine metres. Provision of a clear forgiving roadside area for the entire right of way width is desirable. However, for hazards that are located more than nine metres from the travelled way, it is more difficult to justify the cost of mitigation because of the smaller number of crashes that would be eliminated.

[8] Skeels, P.C., The Role of the Highway in a Safe Transportation System. Presented at 65th annual convention, American Road Builders Association (Feb. 1968).

To assist designers in deciding which hazards should be mitigated, the clear zone concept has been developed. The clear zone distance, used for design purposes, is a function of the design speed, sideslope and traffic volume. Other factors such as horizontal alignment, hazard type etc. should also be used where applicable. Clear zone width can be determined from Table C-5.2a. For typical Alberta rural highway conditions, the normal clear zone on tangent sections is 9 m. Generally, any hazard located within the clear zone distance should be mitigated. Sometimes major hazards are located outside of the clear zone; for example, large bodies of water which could result in severe collisions. In these cases, designers may still provide protection even though it is generally not required by the clear zone policy. Engineering judgement should be used in applying the clear zone concept, generally providing more protection against, or clearance from severe hazards, especially when volumes and speeds are higher.

G.6.2 Shoulder Rumble Strips

In general on all overlay or grade-widening projects, shoulder rumble strips should be included if the shoulder is wide enough. Generally on undivided highways, the minimum shoulder width required for rumble strips is two metres. This is to ensure that an adequate smooth pavement width is available on the shoulders for bicycle traffic. In the case of one-direction-only roads, such as divided highways or interchange ramps, the minimum shoulder width is two metres on the right hand side and 1.2m on the left hand side to allow for rumble strips. Rumble strips are not placed through urban areas or where shoulder widths are reduced due to turning lanes or for other reasons. The addition of shoulder rumble strips is expected to reduce the number of single vehicle run-off-road collisions by alerting drivers when they veer off the travel lanes.

The typical layout and details for shoulder rumble strips is shown in Figures C-3.1a, C-3.1b and C-3.1c. Some changes to the typical layout may be made in the future to allow for usage on narrower shoulders, intermittent strips or selective rumble strips where run-off-road incidents are likely to occur. Because shoulder rumble strips are a relatively new feature in Alberta, the methods used to install the strips may be modified and improved in the future. Shoulder rumble strip layouts and methods should be consistent with current practice at the time of installation.

G.6.3 Improvement to Sideslopes, Ditch and Backslopes

On any roadway where the 85th percentile running speed exceeds 100 km/h, any existing sideslopes of 3:1 or steeper should be identified as candidate locations for improvement. On projects where it is not cost effective to do sideslope improvements on the entire project (due to low traffic volumes), improvements should be considered at locations where run-off-the-road collisions are likely to occur, such as on the outside of sharp horizontal curves. Existing sideslopes of 4:1 or flatter on existing paved roads generally do not warrant improvement.

Where sideslope improvements are being undertaken, a 4:1 slope should be considered as a minimum, 5:1 desirable for moderate volumes (design AADT 1500-4000) and 6:1 desirable for higher volume two-lane roadways (design AADT>4000) and all divided highways. Where the existing ditch width is being reduced to accommodate sideslope improvements, 1.2m should be considered the minimum width. However, the designer must ensure that the ditch is sufficiently wide to provide adequate drainage and snow storage capacity.

Although backslopes are not as critical as sideslopes for an errant vehicle, it is desirable to provide 3:1 or flatter backslopes to improve the traversability of the entire roadside cross section.

The traffic volume ranges in Table G.6.3a are suggested as a guide for determining the extent of roadside improvement that is warranted at the time of pavement rehabilitation. These ranges are based on an economic analysis of the safety cost effectiveness of sideslope improvements and consideration of the new construction standards for roadways with these volumes. The economic analysis is shown in Appendix C.

G.6.4 Treatment of Approaches on

Access management, particularly the assessment of existing approaches for possible elimination, consolidation or improvement should be considered prior to all overlay, rehabilitation or widening projects.

In determining the number, location and spacing of approaches to adjacent properties or roadways serving adjacent lands, the department's Access Management Guidelines (Chpater I of the Design Guide) shall be used. These guidelines may be used as basic requirements on new construction projects and may also be used as a basis for access management plans on pavement rehabilitation projects or for consideration of development applications.

When accesses are to be retained the following guidelines should be used:

1. The geometrics of approaches shall typically be as shown in Figure D-3.3a (for main intersecting roadway) or Figure D-3.3b (for minor intersecting roadway). The geometrics of other embankments within or close to the clear zone of a highway right-of-way such as a railway embankments or irrigation canal embankments should be assessed in a similar way to roadway approaches. Because of the additional hazard posed by irrigation canals, there is a greater need to provide protection for the motorist and therefore relocation of accesses in close proximity to canal crossings may be justified in some cases. The purpose of the relocation would be to allow appropriate traffic barriers to be placed to protect highway traffic from the canal hazard and to allow for gentle slopes.

2. Where a culvert is required on a new approach or where culvert replacement is needed in an existing approach the culvert should be placed as far away from the highway as possible while still accommodating ditch drainage. Placement near the highway right-of-way boundary is desirable.

3. The slope of an approach is a key factor affecting safety. The slopes are generally variable due to the transition from highway embankment to approach embankment and due to the intersection of these slopes and therefore the slope midway between the highway shoulder and basic right-of-way boundary is used here (and illustrated in Figures D-3.3a & D-3.3b) as a criteria. In areas of high fill, the slope should be measured at a location where the slope extends to the bottom of the embankment.

   If slope is steeper than 4:1 on undivided highway or 5:1 on divided highway, improvement should be considered. If slope is steeper than 3:1, approach should be given a high priority for improvement or removal.

Where condition of existing culverts in approaches indicates that replacement is needed, approach sideslopes should be reviewed and improved to an appropriate standard where warranted.

Where improvements to existing approaches are being made or where new approaches are being installed, the desirable slopes shown in Table 1 are suggested.

4. Under special or site specific circumstances, designers are encouraged to use their engineering judgment to customize the design rather than attempt to apply the typical solution where this is impractical. Judgment could be based on the designer's knowledge of the safety and geometric information on the highway in the vicinity of the existing accesses in question, e.g., poor collision history, substandard geometric parameters, presence of bridges or irrigation canals, aesthetics and so on.
5. Accesses on the outside of horizontal curves where run-off-road incidents are more likely to occur should be given higher priority for improvement.
6. Engineering judgment should be used to determine the need for and scheduling of improvements to existing accesses. Normally a review of access management in general and access geometrics in particular would be undertaken prior to any construction operations. Minor improvements to accesses may be made in conjunction with pavement rehabilitation works however major access management initiatives are normally only undertaken as part of major upgrading projects.

Table G.6.3a Sideslope Improvement Warrants

Design AADT	Sideslope Improvements Warranted	Assumptions
0 - 200	Selective improvement at locations where run-off-road collisions are likely.	1. 85th percentile running speed exceeds 100 km / h. 2. Existing sideslope is 3:1 or steeper.
200-300		
Pavement width ≤ 8.2m	Improve sideslope to 4:1 or flatter.	
Pavement width > 8.2m	Selective improvements warranted only.	
300 - 1500	Improve sideslope to 4:1 (minimum) or flatter.	
1500 - 4000	Improve sideslope to 4:1 minimum or 5:1 (desirable)	
> 4000 (undivided) All Divided Highways	Improve sideslope to 4:1 minimum or 6:1 desirable.	

Table G.6.4 Suggested Approach Sideslopes*

Primary Highway Posted >= 100 km/h	Fill Height	Acceptable Slope on Existing Approach – Projects with Minimum Grading (see Note 1)	Acceptable Slope on Existing Approach – Projects with Major Grading Component (see Note 2)	Desirable Slope on New Approach
Undivided Highway AADT < 1,000	< 4 m fill	3:1	4:1	7:1
	> 4 m fill	2:1	3:1	4:1
Undivided Highway 1,000 < AADT < 3,000	< 4 m fill	3:1	5:1	7:1
	> 4 m fill	2:1	3:1	5:1
Undivided Highway AADT > 3,000	< 4 m fill	4:1	5:1	7:1
	> 4 m fill	3:1	4:1	6:1
Divided Highway AADT < 6,000	< 4 m fill	4:1	5:1	7:1
	> 4 m fill	3:1	4:1	7:1
Divided Highway 6,000 < AADT < 15,000	< 4 m fill	4:1	6:1	8:1
	> 4 m fill	3:1	5:1	7:1
Divided Highway AADT > 15,000	< 4 m fill	6:1	7:1	10:1
	> 4 m fill	4:1	5:1	7:1

* Approach slope to be measured at a point midway between the highway shoulder and basic right-of-way boundary as illustrated on Figures D-3.3a and D-3.3b.

Note 1: Projects with minimal grading may include pavement rehabilitation projects and projects with isolated grading work such as intersection improvements.

Note 2: Projects with major grading component include sideslope improvement, grade-widening, reconstruction etc.

G.6.5 Guardrail

All existing guardrail installations should be reviewed to determine if replacement is necessary or if some other mitigative measure is more cost effective. Because guardrail on the shoulder is a hazard of moderate severity and generally causes snow drifting when the conditions are right, it is desirable to eliminate guardrail where possible or offset the guardrail from the shoulder. Where guardrail has been installed due to a high embankment or a steep sideslope, it may be more cost effective to flatten the sideslope than to reinstall the guardrail. A design guide based on life-cycle cost-effectiveness, which is summarized in Section C.5.3.1., provides some guidance for choosing between guardrail replacement and sideslope flattening from 3:1 to 4:1. All projects should be checked for hazards in the clear zone or near the clear zone which may need to be mitigated or protected by guardrail. Refer to Section C.5.3. Hazards to be Considered for Mitigation.

G.7 SUPERELEVATION

This section is to be used when it has been determined that horizontal realignment will not take place.

The superelevation rate on an existing road should be compared to what is required by a vehicle travelling at the 85th percentile running speed on that radius according to new construction standards.

Where the existing superelevation is less than what is recommended for new construction for the 85th percentile running speed and the superelevation rate is less than the maximum allowable (0.08 m/m), consideration should be given to increasing the superelevation rate.

To decide whether or not superelevation adjustment is warranted the following steps should be taken:

1. Calculate the f_{demand} that will result on a vehicle travelling on the circular portion of the curve at the 85th percentile running speed. This value should be compared to the maximum safe side friction factor (f_{max}) of the 85th percentile running speed which is based primarily on comfort.

2. If f_{demand} exceeds f_{max} the superelevation rate should be increased to e_{max} (0.08 m/m) or e_{3R} (shown on chart on following page), whichever is lower. Where practical, it is desirable when making adjustments to superelevation to set the new cross slope at e_{design}; that is, at the recommended superelevation rate according to new construction standards.

3. If f_{demand} is less than f_{max} but $e_{existing}$ is less than e_{design}, some improvement to the superelevation should be considered as follows:

   i) If f_{demand} exceeds 0.04 and is less than f_{max}, but $e_{existing}$ is less than e_{design}, the superelevation should be set at least as high as indicated in the Superelevation Chart for 3R Projects and can be set as high as indicated by the new construction superelevation standard, which should be considered as the desirable rate. Where the existing curvature is sharper than would be allowed using the 85th percentile running speed and the 0.06 m/m maximum table, an absolute maximum 0.08 m/m superelevation may be used.

   ii) If f_{demand} is less than 0.04 (based on the 85th percentile running speed), some flexibility is allowed. Improvement of superelevation is not required even though it may be desirable. This is because it is difficult to justify expenditures on superelevation improvement which only yield a more comfortable curve. When $f_{demand} \leq 0.04$, the factor of safety against side slipping is so high that it is not a concern. The adoption of 0.04 as tolerable is supported by the policy of allowing f values up to 0.04 (approximately) on normal crown curves before applying superelevation.

The following formulae may be used to calculate R_{min} and f_{demand}:

$$R_{min} = \frac{V^2}{127(e_{max} + f_{max})}$$

R_{min} = minimum radius (m) for the design speed
V* = design speed (km/h)
e_{max} = the maximum superelevation rate used
- generally 0.06 for rural roads in Alberta
- 0.08 m/m is permitted on 3R projects

f_{max}* = the maximum allowable safe side friction factor for the design speed (Table B.3.3)

$$f_{demand} = \frac{V^2}{127R} - e$$

f_{demand} = the friction demand on a vehicle travelling at speed V (km/h) on a circular curve of radius R (m) with superelevation e

Table G.7 Suggested Minimum Radii for Superelevation Rates on 3R/4R Projects

e_{3R}	V85 60 km/h	V85 70 km/h	V85 80 km/h	V85 90 km/h	V85 100 km/h	V85 110 km/h	V85 120 km/h	V85 130 km/h
	R_{MIN} (m) f_{demand}	R_{MIN} (m) f_{demand}	R_{MIN} (m) f_{demand}	R_{MIN} (m) f_{demand}	R_{MIN} (m) f_{demand}	R_{MIN} (m) f_{demand}	R_{MIN} (m) f_{demand}	R_{MIN} (m) f_{demand}
NC	1410 (0, 0.04)	1930 (0, 0.04)	2520 (0, 0.04)	3190 (0, 0.04)	3950 (0, 0.04)	4770 (0, 0.04)	5680 (0, 0.04)	6660 (0, 0.04)
RC	570 (0.03)	775 (0.03)	1010 (0.03)	1280 (0.03)	1570 (0.03)	1900 (0.03)	2270 (0.03)	2670 (0.03)
0.03	315 (0.06)	430 (0.06)	560 (0.06)	800 (0.05)	990 (0.05)	1300 (0.043)	1620 (0.04)	1910 (0.04)
0.04	205 (0.10)	300 (0.09)	390 (0.09)	531 (0.08)	790 (0.06)	1060 (0.05)	1260 (0.05)	1480 (0.05)
0.05	170 (0.12)	230 (0.12)	315 (0.11)	425 (0.10)	570 (0.09)	800 (0.07)	940 (0.07)	1110 (0.07)
0.06	130 (0.15)	190 (0.15)	250 (0.14)	340 (0.13)	440 (0.12)	600 (0.10)	750 (0.09)	960 (0.08)
0.07	130 (0.15)	175 (0.15)	240 (0.14)	320 (0.13)	420 (0.12)	560 (0.10)	710 (0.09)	890 (0.08)
0.08	125 (0.15)	170 (0.15)	230 (0.14)	305 (0.13)	390 (0.12)	530 (0.10)	670 (0.09)	830 (0.08)

R_{min} is the suggested minimum radius for the superelevation rate and 85th percentile running speed shown.

V_{85} is the 85th percentile running speed recorded in daylight and good road conditions.

f_{demand} is the friction demand on a vehicle travelling on the circular portion of the curve given the speed and superelevation rate shown.

1. The desirable superelevation rates are shown in the new construction standards, Table B.3.6a.
2. Values shown in this table are the suggested minimum superelevation values that should result from pavement rehabilitation projects.
3. Existing superelevation rates which are higher than the design superelevation rate for new construction should normally not be altered unless they are greater than 0.08 m/m (which is the absolute maximum) or more than 0.02 m/m higher than the recommended rate for new construction. In this case they should be lowered.
4. The minimum radii for each superelevation rate and running speed as shown in this table have been calculated using an allowable friction demand which is higher than that used for each superelevation rate on new construction projects. The friction demand is, however, always less than the maximum allowable safe side friction factor for each design speed.
5. The ball-bank indicator test may be used to determine the need for speed advisory tabs on signs at horizontal curves.
6. The rationale used to develop this table is explained in Appendix D.

APPENDIX A

ECONOMIC ANALYSIS FOR GRADE-WIDENING

This appendix presents the economic analysis that is the basis for Figure G.1.1. Suggested Minimum Roadway Width for Rural Highways in Alberta. The appendix is divided into the following sections:

G.A.1. Background Information: Basis of Economic Analysis
G.A.2. Calculation of Costs
G.A.3. Calculation of Benefits
G.A.4. Summary of Results
G.A.5. Rationale for Figure G.1.1.

G.A.1 Background Information: Basis of Economic Analysis

The economic analysis used to justify the suggested traffic volumes ranges required to warrant grade-widening as shown on Figure G-1.1, is based on the principles set out in the Benefit-Costs Analysis, Summary, Guide and User Manual prepared by K. E. Howery, P.Eng. and Applications Management Consulting Ltd. for Alberta Infrastructure, distributed in 1992. Because the above document is general in nature, some additional investigation into collision rates, collision severity, construction costs, etc. was required for this economic analysis. The values adopted as a result of the investigation are documented in this appendix.

Alberta Infrastructure' benefit-cost analysis guidelines suggest that an Internal Rate of Return (IRR) of at least four percent must be produced in the design life of an improvement for it to be considered cost effective. The IRR is an indicator of the economic viability of any project. The IRR is the discount rate at which the present value of benefits equals the present value of costs. As in any investment, the higher the rate of return, the better. However, any rate higher than the discount rate (four percent being generally used) shows economic feasibility.

The IRR for any proposed improvement is calculated based on incremental costs and benefits that would result from the improvement. For example, on an existing paved highway which is scheduled for pavement rehabilitation, the very minimum amount of work that may be required could be a pavement overlay. The pavement overlay will result in certain costs and benefits. The proposed improvement may be realignment, grade-widening or something else. The improvement will result in some costs and benefits which should be calculated over the life of the improvement. The costs and benefits that are used in the analysis are the net values resulting from the improvement; that is, the additional construction costs, the reduced road user costs and other additional benefits to society. The stream of costs and benefits used in the analysis may be extended to 50 years. However, the key indicator of economic feasibility is the IRR at the end of the design life of the improvement. This is generally the twentieth year, or sooner in some cases.

G.A.2 Calculation of Costs

The incremental costs for grade-widening on existing paved roads are calculated based on the current practice for treatment of those projects. Current practice is to first determine if grade-widening or other geometric improvements are required. If no major improvements are required, the existing sideslope ratio is checked for adequate slope using the 3R/4R Geometric Design Guidelines. Generally if the existing sideslope is 3:1 or steeper, the slope will be improved to 4:1 if the AADT is at least 300 or flatter where appropriate for higher volumes. On some projects even where the existing slope is 4:1, it may be necessary or desirable to include sideslope improvement in the overlay project to preserve the pavement surface width and provide a flat roadside area that is appropriate for the traffic volume.

Based on the above considerations, the cost of an overlay without grade-widening is calculated. This is the base case or do-nothing alternative (alternative 1) for economic analysis purposes. The cost for grade-widening (alternative 2) which includes overlay, sideslope improvement, etc. is then calculated. An average cost for grade-widening to both sides and one side is used in the analysis.

The costs for each alternative are all inclusive project costs i.e. including engineering, materials, right of way, contract, etc. For each alternative, a stream of capital costs is developed for each year, starting from the year of construction and extending to year 50 (or longer if necessary). This is necessary because the grade-widening may result in higher capital costs in future years due to the wider pavement that will need to be overlayed in 20-year cycles (approximately).

The capital cost difference for each year is calculated by comparing the costs for alternatives 1 and 2. This is easily done using a standardized Lotus spreadsheet, a copy of which is shown in this appendix.

G.A.3 Calculation of Benefits

The benefits used in this economic analysis for grade-widening are based on safety only. In particular the benefits are calculated based on a reduced collision rate that can be expected after widening, and a reduced collision severity for run-off-road collisions that should result due to the flatter sideslope, wider ditch and flatter backslope. The change in collision severity is used only if the sideslope ratio is different in one alternative compared to the other.

Frequently, other geometric improvements such as improvements to horizontal or vertical alignment or intersections, are included with grade-widening. However, because the additional costs associated with those improvements are not included here, the benefits are also not included.

The collision rate for each roadway used in this analysis has been based on the average collision experience on Alberta primary highways from 1986 to 1990. The information has been obtained from collision records compiled by Motor Transport Services and is summarized in Figure G-A.3. The average collision rates computed over the five-year period for each shoulder width were plotted based on traffic volumes. The initial plots for each roadway width produced a set of points. A smooth curve was interpolated to represent each set of points. The interpolation was not strictly scientific, but rather was based on application of engineering judgement to the data available for each volume and width.

A collision severity index scale has been developed for run-off-road collisions in Alberta to determine the benefits that may occur due to the flattening of sideslopes and other improvements to the roadside area that are generally undertaken as part of grade-widening projects.

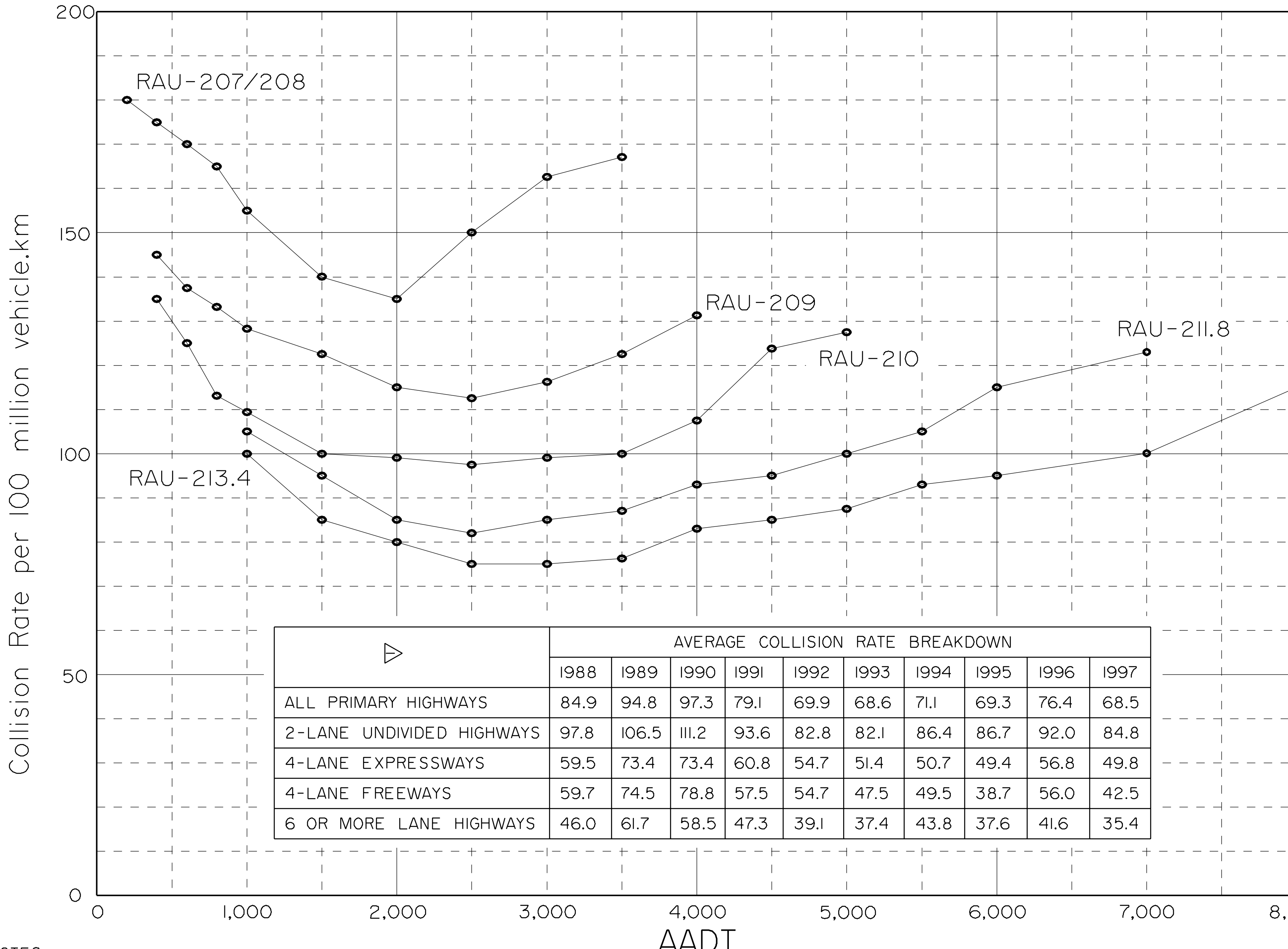
The typical severity indices have been established using the Alberta Collision History Information and the typical differences between severity indices as published by the U.S. Federal Highway Administration (FHWA) for collisions occurring in 3:1, 4:1 and 5:1 sideslopes at 70 mph. It is assumed that the severity of a typical run-off-road collision in Alberta is representative of a collision occurring on a 4:1 sideslope. Although some slopes are steeper and some are flatter, the average severity is likely a good typical value to use for a 4:1 slope which is very common in Alberta. The severity indices for 3:1, 5:1 and 6:1 slopes were selected based on the typical differences in severity between those slopes and a 4:1 slope as reported by FHWA; that is, the Alberta severity indices are not the same as FHWAs (because it was found that Alberta's run-off-road collisions are generally less severe than predicted by FHWA). However, the scale developed by Alberta and shown in Table G.A.3.a is consistent with FHWA in terms of the relative severity of various slopes.

Table G.A.3.a Alberta Severity Indices for Run-off-Road Collisions

			Breakdown of Collision Types (% of Total)		
Embankment Sideslope	**Severity Index (name)**	**Severity Index (value)**	**Fatal**	**Injury**	**Property Damage Only**
3:1	$SA_{3:1}$	4.8	3.2	45.0	51.8
4:1	$SA_{4:1}$	4.0	1.585	34.315	64.100
5:1	$SA_{5:1}$	3.8	1.385	32.095	66.520
6:1	$SA_{6:1}$	3.0	0.5283	23.2717	76.2000

Using the severity indices to predict the breakdown of collision type after grade-widening and the average cost per collision of each type, the net benefits may be calculated.

FIGURE G-A.3 TYPICAL COLLISION RATES ON ALBERTA TWO-LANE UNDIVIDED HIGHWAYS



⚠1	AVERAGE COLLISION RATE BREAKDOWN									
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
ALL PRIMARY HIGHWAYS	84.9	94.8	97.3	79.1	69.9	68.6	71.1	69.3	76.4	68.5
2-LANE UNDIVIDED HIGHWAYS	97.8	106.5	111.2	93.6	82.8	82.1	86.4	86.7	92.0	84.8
4-LANE EXPRESSWAYS	59.5	73.4	73.4	60.8	54.7	51.4	50.7	49.4	56.8	49.8
4-LANE FREEWAYS	59.7	74.5	78.8	57.5	54.7	47.5	49.5	38.7	56.0	42.5
6 OR MORE LANE HIGHWAYS	46.0	61.7	58.5	47.3	39.1	37.4	43.8	37.6	41.6	35.4

NOTES

⚠1
1. THIS FIGURE IS BASED ON COLLISION DATA FOR ALL UNDIVIDED ALBERTA HIGHWAYS FROM 1986 TO 1990. THE CURVES WERE INTERPOLATED BASED ON THE ORIGINAL DATA (A SET OF POINTS). THE TOTAL LENGTH OF HIGHWAY USED WAS 11,500 km.
2. THE DESIGNATIONS SHOWN ABOVE ARE EXPLAINED AS FOLLOWS: RAU-213.4 = RURAL ARTERIAL UNDIVIDED, 2 LANE, 13.4m SURFACE WIDTH ETC.
3. COLISION REPORTING LIMIT WAS CHANGED FROM $500 TO $1000 IN JANUARY 1991.

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The total societal cost of fatalities, injuries and property damage resulting from collisions in Alberta has been tabulated as follows (in the Benefit-Cost Analysis Guide):

Fatality	770,465	$/Death *
Serious Injury	515,721	$/Injury
Moderate Injury	5,042	$/Injury
Property Damage	2,011	$/Collision

* 1992 dollars

The costs per fatal and injury collision are calculated as follows:

Fatal Collision

For each crash that includes a fatality, on average:

- 1.35 people die
- 0.57 are seriously injured
- 0.69 are moderately injured.

Including property damage, an average cost per fatal collision is valued at:

1.35 x 770,465 + 0.57 x 515,721 + 0.69 x 5,042 + 2,011 **= $1,339,578 per fatal collision**

Injury Collision

For an average non-fatal crash that includes an injury:

- 0.26 victims are seriously injured and
- 1.43 receive moderate injury.

The average cost per injury collision, including property damage, is as follows:

515,721 x 0.26 + 5,042 x 1.43 + 2,011 **= $143,309 per injury collision**

Therefore, the average cost per collision is as follows:

Fatal Collision	$ 1,339,535
Injury Collision	$ 143,309
Property Damage Only Collision	$ 2,011

Based on the above, and knowing that, of all accident types in Alberta, two percent are fatal, 25 percent are injury and 73 percent are property damage only, an average cost for all collisions (C_p) may be calculated:

C_p = 0.02 x 1,339,578 + 0.25 x 143,309 + 0.73 x 2,011
= 26,792 + 35,827 + 1,468 = **$64,087 per collision** (this is an average for all collision types)

Similarly the average cost per run-off-road collision on various sideslopes may be calculated using the information in Table G.A.3.a:

Sideslope	Average Cost per Collision	$ (1992)
3:1	0.032 (1,339,578) + 0.450 (143,309) + 0.518 (2011) =	108,397
4:1	0.01585 (1,339,578) + 0.34315 (143,309) + 0.64100 (2011) =	71,698
5:1	0.01385 (1,339,578) + 0.32095 (143,309) + 0.66520 (2011) =	65,886
6:1	0.005283 (1,339,578) + 0.232717 (143,309) + 0.762000 (2011) =	41,960

Therefore the percentage reduction of run-off-road collision cost resulting from sideslope flattening is shown in Table G.A.3.b.

Table G.A.3.b
Percentage Reduction of Run-off-Road Collision Cost Resulting from Sideslope Flattening

Sideslope ratio on existing road	Unit coll. cost $ per accident (C_{ssl})	% Reduction in cost as a result of sideslope flattening to 4:1	% Reduction in cost as a result of sideslope flattening to 5:1	% Reduction in cost as a result of sideslope flattening to 6:1
3:1	C 3:1 = 108,399	33.9	39.2	61.3
4:1	C 4:1 = 71,698	-	8.1	41.5
5:1	C 5:1 = 65,886	-	-	36.3
6:1	C 6:1 = 41,960	-	-	-

The total number of accidents per km of highway per year (A_t) can be calculated from the following formula:

$$A_t = (CR \times AADT \times 365.25 \times 1km) / (100 \times 10^6)$$

Where A_t = total number of accidents / km / year
AADT = average annual daily traffic
CR = existing collision rate expressed in collisions per 100 million vehicle km.

The provincial average percentage of total collisions that are run-off-road type, based on the records from 1987 to 1991, is used to establish a reasonable breakdown.

Percent of all collisions that are run-off road type	
1991	34.07
1990	32.40
1989	34.60
1988	33.50
1987	36.10
5 Year Average	34.13

The average distribution of collisions may be expressed as follows:

$$A_t = 0.659 \times A_t + 0.341 \times A_t$$

with 0.341 x A_t representing the number of run-off-road collisions.

Total accident cost per km per year on a given roadway is:

$$C_t = C_a \times 0.659 \times A_t + C_{ssl} \times 0.341 \times A_t$$

Where C_t = collision cost / km / year
C_{ssl} = average cost per run-off-road collision on a given sideslope
C_a = provincial average cost per accident

$$C_t = \left[(CR \times AADT \times 365.25 \times 1) / \left(100 \times 10^6\right)\right] \times \left(C_a \times 0.659 + C_{ssl} \times 0.341\right)$$

Using the above formula together with information from Figure G-A.3 and Table G.A.3b, the collision-reduction benefits that can be expected from a grade-widening project may be calculated for any value of AADT.

In the case of a project-specific analysis, knowledge of the collision experience on the existing highway may be used to calculate the collision cost without improvement. For this generic economic analysis, the results of which will be used throughout the province, average values are used.

The calculations described above may be done on a Lotus spreadsheet.

G.A.4 Summary of Results

The economic analysis involved a series of calculations using various values for existing pavement width and proposed pavement width together with the costs and benefits defined in previous sections. For each case, (each combination of pavement width before and after) a series of calculations was run using a range of AADT values to determine the lowest traffic volume that would justify grade-widening. The criteria used to justify grade-widening was an internal rate of return of four percent at year 20. In all cases it was assumed that the traffic volume would grow at a rate of two percent for the first 10 years and one percent per annum for future years. These growth rates are not compounded. These estimated growth rates are based on historical records for Alberta.

The proposed pavement widths used in the analysis are the standard design designations used for grade-widening and new construction (10m, 11.8m and 13.4m). For each proposed pavement width, a series of existing pavement widths were used as required for development of Figure G-1.1, Suggested Minimum Roadway Width for Rural Highways in Alberta.

The existing and proposed widths used were as follows:

Proposed Pavement Width (m)	10	11.8	13.4
Existing Pavement Width (m)	7.9, 7.3, 7.0, 6.7	9.8, 9.5, 9.0, 8.5, 7.9, 7.1	11.0, 10.0, 9.0

Because many of the existing narrow pavements in the province have 3:1 sideslopes and, therefore, would warrant sideslope improvement which affects construction costs, additional analyses were run for these conditions.

The results of the economic analysis are summarised in Table G.A.5.1 below.

Table G.A.5.1
Existing AADT Required to Justify Grade-Widening

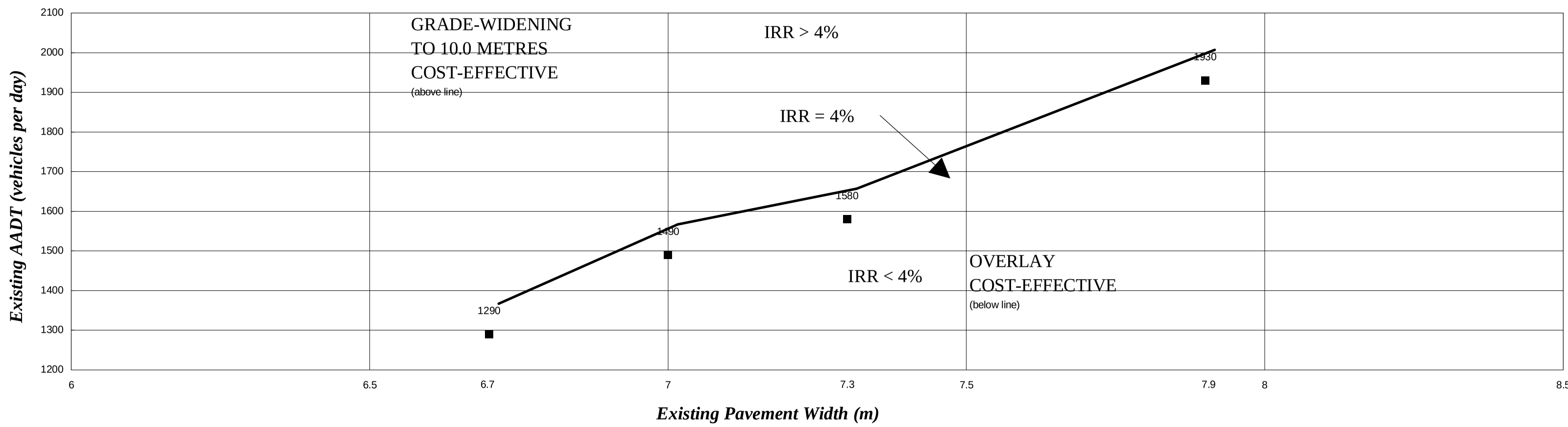
			Proposed Pavement Width (m)		
			10.0	11.8	13.4
Existing Pavement Width	Existing Sideslope 4:1	6.7	1570		
		7.0	1620		
		7.1		1782	
		7.3	1780		
		7.9	2080	1925	
		8.5		1980	
		9.0		2145	2300
		9.5		2420	
		9.8		2500	
		10.0			2670
		11.0			2875
	Existing Sideslope 3:1	6.7	1290		
		7.0	1490		
		7.1		1720	
		7.3	1580		
		7.9	1930	1810	
		8.5		1875	
		9.0		1980	
		9.5		2210	
		9.8		2370	

These results are shown graphically in Figures G-A.5.1 through G-A.5.5. Two sample Lotus spreadsheet summaries are also included to illustrate the computations.

FIGURE G-A.5.1

EXISTING SSL = 3:1 OR STEEPER

Cost-Effectiveness of Grade-Widening to 10.0 m
VS
Overlay on Existing Paved Roadways
Based on life-cycle benefits and costs considering total societal impact



ASSUMPTIONS

1. *A one kilometre length of roadway is used in the analysis (vertical and horizontal geometry are not taken into account).*
2. *Two alternatives are considered in the analysis: Overlay and Sideslope Improvements versus Grade-Widening*
3. *20 year pavement cycle is assumed in the analysis, therefore, rate of return in the 20 th year is assumed.*
4. *Calculation of user cost is based on the collision rate and provincial average cost per collision.*
5. *Benefits for grade-widening are derived from the reduction in collision cost as a result of a predicted decrease in collision rate.*

UNIT PRICES

Overlay Cost:
6.7, 7.0, 7.3 m - $ 42,000 / km (80mm ACP)
7.9 m - $ 44,000 / km (80 mm ACP)
10.0 m - $ 78,000 / km (100 mm ACP)

Grade-Widening Cost:
6.7 m - $ 235,043 / km
7.0 m - $ 225,797 / km
7.3 m - $ 216,577 / km
7.9 m - $ 203,792 / km

Sideslope Improvement Cost: *$ 20,000 / km*

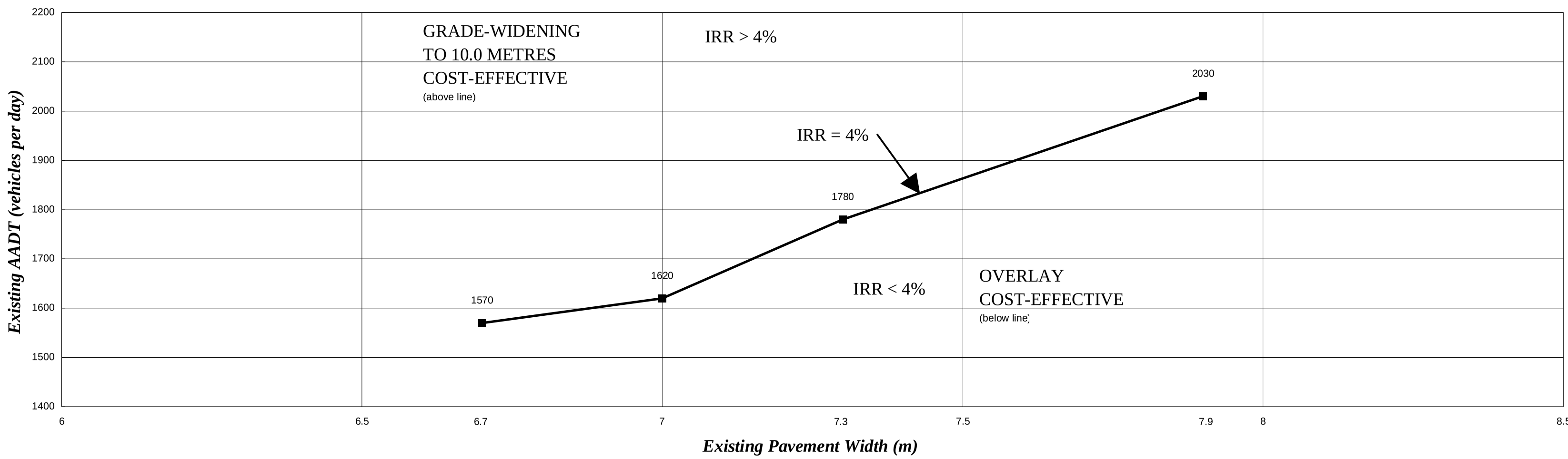
NOTE

IRR = Internal Rate of Return for proposed improvement at the end of design life

FIGURE G-A.5.2

EXISTING SSL = 4:1 OR FLATTER

Cost-Effectiveness of Grade-Widening to 10.0 m
VS
Overlay on Existing Paved Roadways
Based on life-cycle benefits and costs considering total societal impact



ASSUMPTIONS

1. *A one kilometre length of roadway is used in the analysis (vertical and horizontal geometry are not taken into account).*
2. *Two alternatives are considered in the analysis: Overlay and Sideslope Improvements versus Grade-Widening*
3. *20 year pavement cycle is assumed in the analysis, therefore, rate of return in the 20 th year is assumed.*
4. *Calculation of user cost is based on the collision rate and provincial average cost per collision.*
5. *Benefits for grade-widening are derived from the reduction in collision cost as a result of a predicted decrease in collision rate.*

UNIT PRICES

Overlay Cost:
6.7, 7.0, 7.3 m - $ 42,000 / km (80mm ACP)
7.9 m - $ 44,000 / km (80 mm ACP)
10.0 m - $ 78,000 / km (100 mm ACP)

Grade- Widening Cost:
6.7 m - $ 235,043 / km
7.0 m - $ 225,797 / km
7.3 m - $ 216,577 / km
7.9 m - $ 203,792 / km

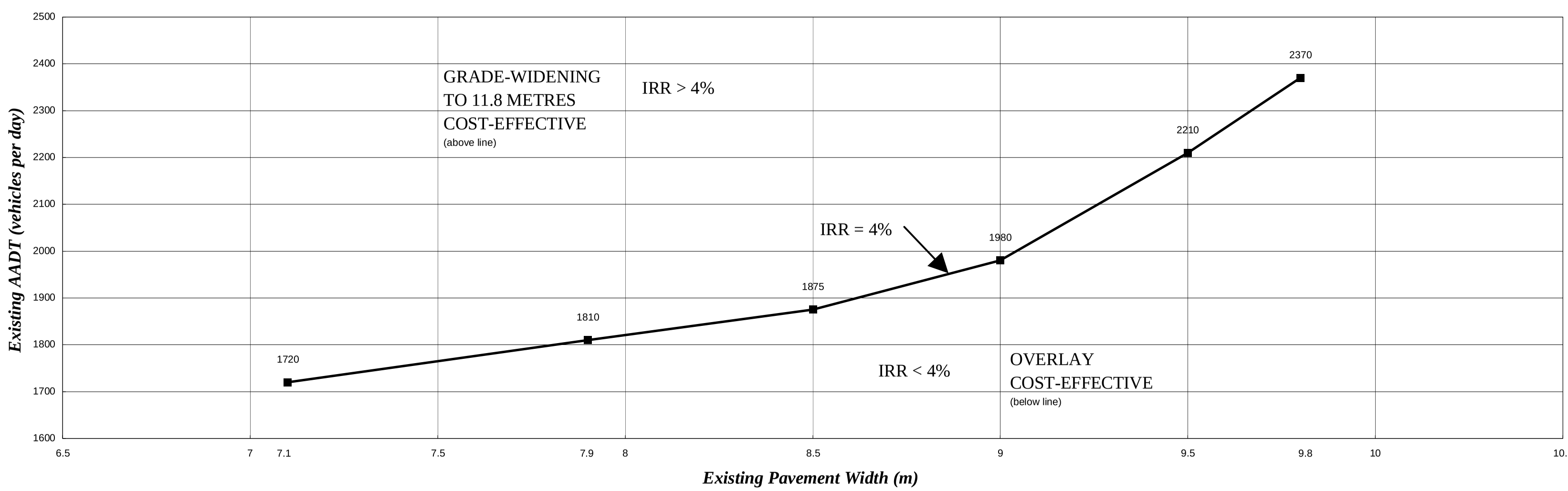
NOTE

IRR = Internal Rate of Return for proposed improvemnets at the end of design life

FIGURE G-A.5.3

EXISTING SSL = 3:1 OR STEEPER

Cost-Effectiveness of Grade-Widening to 11.8 m
VS
Overlay and Sideslope Improvements on Existing Paved Roadways
Based on life-cycle benefits and costs considering total societal impact



ASSUMPTIONS

1. *A one kilometre length of roadway is used in the analysis (vertical and horizontal geometry are not taken into account).*
2. *Two alternatives are considered in the analysis: Overlay and Sideslope Improvement versus Grade-Widening*
3. *20 year pavement cycle is assumed in the analysis, therefore, rate of return in the 20 th year is assumed.*
4. *Benefits for grade-widening are derived from the reduction in collision cost as a result of a predicted decrease in collision rate and reduced severity of accidents due to sideslope flattening from 4:1 to 5:1.*

NOTE

IRR = Internal Rate of Return for proposed improvement at the end of design life

UNIT PRICES

Overlay Cost:

7.1 m - $ 42,000 / km (80 mm ACP)
7.9 m - $ 44,000 / km (80 mm ACP)
8.5 m - $ 56,000 / km (100 mm ACP)
9.0 m - $ 68,000 / km (100 mm ACP)
9.5 m - $ 73,000 / km (100 mm ACP)
9.8 m - $ 78,000 / km (100 mm ACP)
11.8 m - $ 88,000 / km (100 mm ACP)

Grade-Widening Cost:

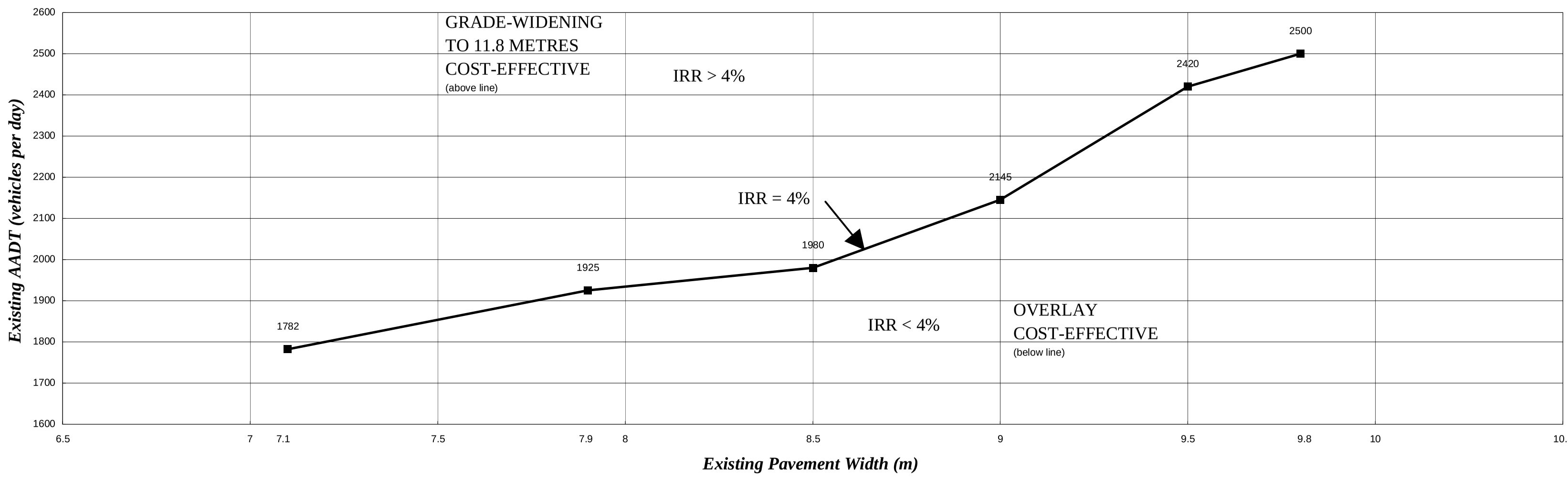
7.1 m - $ 311,687 / km
7.9 m - $ 285,720 / km
8.5 m - $ 266,554 / km
9.0 m - $ 266,554 / km
9.5 m - $ 244,202 / km
9.8 m - $ 230,791 / km

Sideslope Improvement Cost: *$ 20,000 / km (both sides)*

FIGURE G-A.5.4

EXISTING SSL = 4:1 OR FLATTER

Cost-Effectiveness of Grade-Widening to 11.8 m
VS
Overlay on Existing Paved Roadways
Based on life-cycle benefits and costs considering total societal impact



ASSUMPTIONS

1. *A one kilometre length of roadway is used in the analysis (vertical and horizontal geometry are not taken into account).*
2. *Two alternatives are considered in the analysis: Overlay versus Grade-Widening*
3. *20 year pavement cycle is assumed in the analysis, therefore, rate of return in the 20 th year is assumed.*
4. *Benefits for grade-widening are derived from the reduction in collision cost as a result of a predicted decrease in collision rate and reduced severity of accidents due to sideslope flattening from 4:1 to 5:1.*

UNIT PRICES

Overlay Cost:

7.1 m - $ 42,000 / km (80 mm ACP)
7.9 m - $ 44,000 / km (80 mm ACP)
8.5 m - $ 56,000 / km (100 mm ACP)
9.0 m - $ 68,000 / km (100 mm ACP)
9.5 m - $ 73,000 / km (100 mm ACP)
9.8 m - $ 78,000 / km (100 mm ACP)
11.8 m - $ 88,000 / km (100 mm ACP)

Grade-Widening Cost:

7.1 m - $ 311,687 / km
7.9 m - $ 285,720 / km
8.5 m - $ 266,554 / km
9.0 m - $ 266,554 / km
9.5 m - $ 244,202 / km
9.8 m - $ 230,791 / km

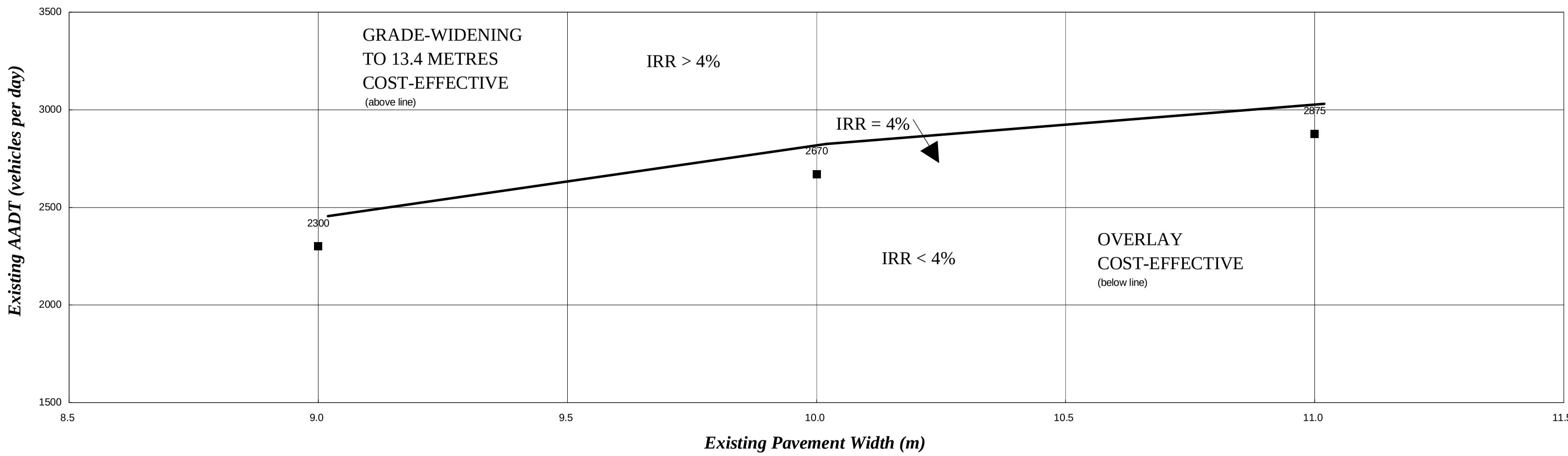
NOTE

IRR = Internal Rate of Return for proposed improvement at the end of design life

FIGURE G-A.5.5

EXISTING SSL = 4:1 OR FLATTER

Cost-Effectiveness of Grade-Widening to 13.4 m
VS
Overlay on Existing Paved Roadways
Based on life-cycle benefits and costs considering total societal impact



ASSUMPTIONS

1. *A one kilometre length of roadway is used in the analysis (vertical and horizontal geometry are not taken into account).*
2. *Two alternatives are considered in the analysis: Overlay versus Grade-Widening*
3. *20 year pavement cycle is assumed in the analysis, therefore, rate of return in the 20 th year is assumed.*
4. *Benefits for grade-widening are derived from the reduction in collision cost as a result of a predicted decrease in collision rate and reduced severity of accidents due to sideslope flattening from 4:1 to 6:1.*

UNIT PRICES

Overlay Cost:

9.0 m - $ 68,000 / km (100 mm ACP)
10.0 m - $ 78,000 / km (100 mm ACP)
11.0 m - $ 82,300 / km (100 mm ACP)

Grade-Widening Cost:

7.1 m - $ 311,687 / km
7.9 m - $ 285,720 / km
8.5 m - $ 266,554 / km

NOTE

IRR = Internal Rate of Return for proposed improvement at the end of design life

Table G.A.5.2

ECONOMIC ANALYSIS - GRADE-WIDENING vs OVERLAY

22-Jul-96 15:07

EXISTING ROADWAY WIDTH - 7.0 M 3:1 SIDESLOPE
IMPROVED ROADWAY WIDTH - 10.0 M 4:1 SIDESLOPE (RAU-210-110)
NOTE: All costs reported in thousands of 1993 dollars unless otherwise noted

CAPITAL & MAINTENANCE

ALTERNATIVE I

overlay
in the first year ($/km) - **42000**
sideslope improvements
both sides, 1 km ($/km) - **20000**
Total cost ($/km) - **62000**
overlay every 20 years - **42000**

ALTERNATIVE II

grade-widening of the existing highway
(both sides)
Capital Cost:
grade-widening - **225797** $ per km
20% contingencies - **45159** $ per km
Total capital cost: **270956** $ per km
overlay every 20 years - **78000** $ per km
Grade-widening costs include:
GRADING, GBC, ACP (50 mm), ACP (80 mm)

BENEFITS

ALTERNATIVE I - Road User Cost:

Collision Rate, CR **139**
AADT **1490**
Provincial average cost per collision ($ per acc.):
(excluding run-off-road type) - **64086**
Average cost per run-off-road collision ($ per acc.):
on a 4:1 sideslope - **71676**
Total collision cost per km per year:
[(CR x AADT x 365.25 x 1)/(100 x 10^6)] x (64,086 x 0.659 + 71,676 x 0.341)

ALTERNATIVE II -Road User Cost:

Collision Rate, CR **101**
AADT **1490**
Provincial average cost per collision ($ per acc.):
(excluding run-off-road type) - **64086**
Average cost per run-off-road collision ($ per acc.):
on a 4:1 sideslope - **71676**
Total collision cost per km per year:
[(CR x AADT x 365.25 x 1)/(100 x 10^6)] x (64,089 x 0.659 + 71676 x 0.341)

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES (IN 1000 $)			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
		ALTERNATIVE I		ALTERNATIVE II							(guess)
No.	Year	CAP.	R.U.C.	CAP.	R.U.C.	CAP. COST DIFF.	R.U.C. SAVINGS	COST+R.U.C VALUES	CAPITAL	TOTAL	30.00%
0	1993	62,000	0	270,956	0	(208,956)	0	(208,956)	(208,956)	(208,956)	
1	1994	0	50,437	0	36,648	0	13,789	13,789	(208,956)	(195,698)	-93.40%
2	1995	0	51,698	0	37,565	0	14,133	14,133	(208,956)	(182,631)	-70.49%
3	1996	0	52,959	0	38,481	0	14,478	14,478	(208,956)	(169,760)	-50.89%
4	1997	0	54,220	0	39,397	0	14,823	14,823	(208,956)	(157,090)	-36.95%
5	1998	0	55,481	0	40,313	0	15,167	15,167	(208,956)	(144,623)	-27.09%
6	1999	0	56,742	0	41,230	0	15,512	15,512	(208,956)	(132,364)	-19.97%
7	2000	0	58,003	0	42,146	0	15,857	15,857	(208,956)	(120,314)	-14.69%
8	2001	0	59,263	0	43,062	0	16,202	16,202	(208,956)	(108,476)	-10.68%
9	2002	0	60,524	0	43,978	0	16,546	16,546	(208,956)	(96,851)	-7.57%
10	2003	0	61,785	0	44,894	0	16,891	16,891	(208,956)	(85,440)	-5.10%
11	2004	0	63,046	0	45,811	0	17,236	17,236	(208,956)	(74,244)	-3.13%
12	2005	0	64,307	0	46,727	0	17,580	17,580	(208,956)	(63,263)	-1.51%
13	2006	0	65,568	0	47,643	0	17,925	17,925	(208,956)	(52,498)	-0.19%
14	2007	0	66,829	0	48,559	0	18,270	18,270	(208,956)	(41,947)	0.92%
15	2008	0	68,090	0	49,475	0	18,615	18,615	(208,956)	(31,611)	1.85%
16	2009	0	69,351	0	50,392	0	18,959	18,959	(208,956)	(21,489)	2.64%
17	2010	0	70,612	0	51,308	0	19,304	19,304	(208,956)	(11,579)	3.32%
18	2011	0	71,873	0	52,224	0	19,649	19,649	(208,956)	(1,880)	3.90%
19	2012	0	73,134	0	53,140	0	19,993	19,993	(208,956)	7,610	4.40%
20	2013	42,000	74,395	78,000	54,056	(36,000)	20,338	(15,662)	(225,386)	462	**4.03%**
21	2014	0	75,655	0	54,973	0	20,683	20,683	(225,386)	9,538	4.49%
22	2015	0	76,916	0	55,889	0	21,028	21,028	(225,386)	18,411	4.89%
23	2016	0	78,177	0	56,805	0	21,372	21,372	(225,386)	27,082	5.24%
24	2017	0	79,438	0	57,721	0	21,717	21,717	(225,386)	35,555	5.54%
25	2018	0	80,699	0	58,638	0	22,062	22,062	(225,386)	43,830	5.81%
26	2019	0	81,960	0	59,554	0	22,406	22,406	(225,386)	51,912	6.05%
27	2020	0	83,221	0	60,470	0	22,751	22,751	(225,386)	59,802	6.26%
28	2021	0	84,482	0	61,386	0	23,096	23,096	(225,386)	67,504	6.44%
29	2022	0	85,743	0	62,302	0	23,440	23,440	(225,386)	75,021	6.61%
30	2023	0	87,004	0	63,219	0	23,785	23,785	(225,386)	82,354	6.76%
31	2024	0	88,265	0	64,135	0	24,130	24,130	(225,386)	89,508	6.89%
32	2025	0	89,526	0	65,051	0	24,475	24,475	(225,386)	96,484	7.01%
33	2026	0	90,787	0	65,967	0	24,819	24,819	(225,386)	103,287	7.12%
34	2027	0	92,047	0	66,883	0	25,164	25,164	(225,386)	109,919	7.22%
35	2028	0	93,308	0	67,800	0	25,509	25,509	(225,386)	116,383	7.31%
36	2029	0	94,569	0	68,716	0	25,853	25,853	(225,386)	122,683	7.39%
37	2030	0	95,830	0	69,632	0	26,198	26,198	(225,386)	128,821	7.46%
38	2031	0	97,091	0	70,548	0	26,543	26,543	(225,386)	134,801	7.53%
39	2032	0	98,352	0	71,464	0	26,888	26,888	(225,386)	140,625	7.59%
40	2033	42,000	99,613	78,000	72,381	(36,000)	27,232	(8,768)	(232,885)	138,799	7.57%
41	2034	0	100,874	0	73,297	0	27,577	27,577	(232,885)	144,322	7.63%
42	2035	0	102,135	0	74,213	0	27,922	27,922	(232,885)	149,699	7.68%
43	2036	0	103,396	0	75,129	0	28,266	28,266	(232,885)	154,933	7.72%
44	2037	0	104,657	0	76,046	0	28,611	28,611	(232,885)	160,027	7.76%
45	2038	0	105,918	0	76,962	0	28,956	28,956	(232,885)	164,985	7.80%
46	2039	0	107,179	0	77,878	0	29,301	29,301	(232,885)	169,808	7.83%
47	2040	0	108,439	0	78,794	0	29,645	29,645	(232,885)	174,500	7.86%
48	2041	0	109,700	0	79,710	0	29,990	29,990	(232,885)	179,065	7.89%
49	2042	0	110,961	0	80,627	0	30,335	30,335	(232,885)	183,504	7.92%
50	2043	0	112,222	0	81,543	0	30,679	30,679	(232,885)	187,821	7.94%

Table G.A.5.3

ECONOMIC ANALYSIS - GRADE-WIDENING vs OVERLAY

22-Jul-96 15:11

EXISTING ROADWAY WIDTH- 11.0 M **4:1 SIDESLOPE**
IMPROVED ROADWAY WIDTH- 13.4 M **6:1 SIDESLOPE (RAU-213.4)**
NOTE: All costs reported in thousands of 1993 dollars unless otherwise noted

CAPITAL & MAINTENANCE

ALTERNATIVE I

overlay
in the first year ($/km) - **82300**
sideslope improvements
both sides, 1 km ($/km) - **0**
Total cost ($/km) - **82300**
overlay every 20 years - **82300**

ALTERNATIVE II

grade-widening of the existing highway
(both sides)
Capital Cost:
grade-widening - **316040** $ per km
20% contingencies - **63208** $ per km
Total capital cost: **379248** $ per km
overlay every 20 years - **120000** $ per km

BENEFITS

ALTERNATIVE I - Road User Cost:

Collision Rate, CR **91**
AADT **2875**
Provincial average cost per collision ($ per acc.):
(excluding run-off-road type) - **64086**
Average cost per run-off-road collision ($ per acc.):
on a 4:1 sideslope - **71676**
Total collision cost per km per year:
[(CR x AADT x 365.25 x 1)/(100 x 10^6)] x (64,089 x 0.659 + 71,676 x 0.341)

ALTERNATIVE II -Road User Cost:

Collision Rate, CR **75**
AADT **2875**
Provincial average cost per collision ($ per acc.):
(excluding run-off-road type) - **64086**
Average cost per run-off-road collision ($ per acc.):
on a 6:1 sideslope - **42000**
Total collision cost per km per year:
[(CR x AADT x 365.25 x 1)/(100 x 10^6)] x (64,089 x 0.659 + 42,000 x 0.341)

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES (IN 1000 $)			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
		ALTERNATIVE I		ALTERNATIVE II							(guess)
No.	Year	CAP.	R.U.C.	CAP.	R.U.C.	CAP. COST DIFF.	R.U.C. SAVINGS	COST+R.U.C VALUES	CAPITAL	TOTAL	30.00%
0	1993	82,300	0	379,248	0	(296,948)	0	(296,948)	(296,948)	(296,948)	
1	1994	0	63,713	0	44,541	0	19,172	19,172	(296,948)	(278,513)	-93.54%
2	1995	0	65,306	0	45,654	0	19,651	19,651	(296,948)	(260,344)	-70.84%
3	1996	0	66,899	0	46,768	0	20,131	20,131	(296,948)	(242,448)	-51.33%
4	1997	0	68,491	0	47,881	0	20,610	20,610	(296,948)	(224,831)	-37.39%
5	1998	0	70,084	0	48,995	0	21,089	21,089	(296,948)	(207,497)	-27.53%
6	1999	0	71,677	0	50,108	0	21,569	21,569	(296,948)	(190,451)	-20.39%
7	2000	0	73,270	0	51,222	0	22,048	22,048	(296,948)	(173,696)	-15.09%
8	2001	0	74,863	0	52,335	0	22,527	22,527	(296,948)	(157,236)	-11.05%
9	2002	0	76,455	0	53,449	0	23,007	23,007	(296,948)	(141,072)	-7.92%
10	2003	0	78,048	0	54,562	0	23,486	23,486	(296,948)	(125,206)	-5.44%
11	2004	0	79,641	0	55,676	0	23,965	23,965	(296,948)	(109,638)	-3.45%
12	2005	0	81,234	0	56,789	0	24,444	24,444	(296,948)	(94,371)	-1.82%
13	2006	0	82,827	0	57,903	0	24,924	24,924	(296,948)	(79,402)	-0.48%
14	2007	0	84,420	0	59,017	0	25,403	25,403	(296,948)	(64,732)	0.64%
15	2008	0	86,012	0	60,130	0	25,882	25,882	(296,948)	(50,361)	1.58%
16	2009	0	87,605	0	61,244	0	26,362	26,362	(296,948)	(36,286)	2.38%
17	2010	0	89,198	0	62,357	0	26,841	26,841	(296,948)	(22,507)	3.06%
18	2011	0	90,791	0	63,471	0	27,320	27,320	(296,948)	(9,021)	3.65%
19	2012	0	92,384	0	64,584	0	27,800	27,800	(296,948)	4,174	4.15%
20	2013	82,300	93,976	120,000	65,698	(37,700)	28,279	(9,421)	(314,154)	(126)	**4.00%**
21	2014	0	95,569	0	66,811	0	28,758	28,758	(314,154)	12,494	4.44%
22	2015	0	97,162	0	67,925	0	29,237	29,237	(314,154)	24,831	4.83%
23	2016	0	98,755	0	69,038	0	29,717	29,717	(314,154)	36,888	5.17%
24	2017	0	100,348	0	70,152	0	30,196	30,196	(314,154)	48,668	5.47%
25	2018	0	101,941	0	71,265	0	30,675	30,675	(314,154)	60,175	5.73%
26	2019	0	103,533	0	72,379	0	31,155	31,155	(314,154)	71,412	5.96%
27	2020	0	105,126	0	73,492	0	31,634	31,634	(314,154)	82,384	6.17%
28	2021	0	106,719	0	74,606	0	32,113	32,113	(314,154)	93,093	6.35%
29	2022	0	108,312	0	75,719	0	32,593	32,593	(314,154)	103,543	6.52%
30	2023	0	109,905	0	76,833	0	33,072	33,072	(314,154)	113,740	6.67%
31	2024	0	111,498	0	77,946	0	33,551	33,551	(314,154)	123,687	6.80%
32	2025	0	113,090	0	79,060	0	34,030	34,030	(314,154)	133,387	6.92%
33	2026	0	114,683	0	80,173	0	34,510	34,510	(314,154)	142,846	7.03%
34	2027	0	116,276	0	81,287	0	34,989	34,989	(314,154)	152,068	7.12%
35	2028	0	117,869	0	82,400	0	35,468	35,468	(314,154)	161,056	7.21%
36	2029	0	119,462	0	83,514	0	35,948	35,948	(314,154)	169,815	7.29%
37	2030	0	121,054	0	84,627	0	36,427	36,427	(314,154)	178,350	7.37%
38	2031	0	122,647	0	85,741	0	36,906	36,906	(314,154)	186,664	7.44%
39	2032	0	124,240	0	86,855	0	37,386	37,386	(314,154)	194,763	7.50%
40	2033	82,300	125,833	120,000	87,968	(37,700)	37,865	165	(322,006)	194,797	7.50%
41	2034	0	127,426	0	89,082	0	38,344	38,344	(322,006)	202,477	7.55%
42	2035	0	129,019	0	90,195	0	38,823	38,823	(322,006)	209,953	7.60%
43	2036	0	130,611	0	91,309	0	39,303	39,303	(322,006)	217,231	7.64%
44	2037	0	132,204	0	92,422	0	39,782	39,782	(322,006)	224,314	7.68%
45	2038	0	133,797	0	93,536	0	40,261	40,261	(322,006)	231,207	7.72%
46	2039	0	135,390	0	94,649	0	40,741	40,741	(322,006)	237,913	7.75%
47	2040	0	136,983	0	95,763	0	41,220	41,220	(322,006)	244,437	7.78%
48	2041	0	138,576	0	96,876	0	41,699	41,699	(322,006)	250,784	7.81%
49	2042	0	140,168	0	97,990	0	42,179	42,179	(322,006)	256,956	7.84%
50	2043	0	141,761	0	99,103	0	42,658	42,658	(322,006)	262,959	7.86%

G.A.5 Rationale for Figure G-1.1 Suggested Minimum Roadway Width for Rural Highways in Alberta (Based on updated, Economic Analysis, November 1994)

Subsystem 1:

Because of the function of Subsystem 1, a minimum acceptable shoulder of 1.0m is considered reasonable. If the roadway width is less than nine metres, grade widening is required regardless of economic analysis. To consider the cost effectiveness of widening roadways that are in the nine metre range, it is reasonable to use 8.5m as a benchmark as roadways within 0.5m of the suggested minimum are not significantly different from the minimum. The economic analysis shows that:

- widening of an 8.5m roadway to 11.8m is justified at AADT 1980
- widening of an 8.5m roadway to 13.4m is justified at AADT 2100.

Consequently (because the desirable standard width is 13.4m for AADT exceeding 2400 and 11.8 for lower volumes), it is appropriate to use nine metres as the suggested minimum width for AADT up to 2400, 10m for AADT 2400-2900, and 11m for AADT exceeding 2900. It is feasible to construct a widening project that increases the width from nine metres to 11.8m, or from 10m to 13.4m. However, widening from 10m to 11.8m is generally impractical. Widening from 11m to 13.4m is justified by safety benefits for AADT's exceeding 2900.

Subsystem 2:

Based on function, a minimum acceptable shoulder of 0.5m is considered reasonable. If the roadway is less than eight metre, grade widening is required regardless of economic analysis. To consider the cost-effectiveness of widening roadways that are in the eight metre range, widening to 10m, 11.8m or 13.4m may be considered. The economic analysis shows:

- widening of an eight metre roadway to 10m is justified at AADT 2000
- widening of an eight metre roadway to 11.8m is justified at AADT 1930 (existing 4:1 slope), or 1820 (existing 3:1 slope)
- widening of an eight metre roadway to 13.4m is justified at AADT 2100.

Based on the above, it is appropriate to use nine metres as the suggested minimum roadway width for AADT above 1800 (where 11.8 is the desirable width), 10m for AADT above 2700 (where 13.4 is the desirable width), and 11m for AADT above 2900. This will ensure cost effectiveness and practicality in this zone.

Subsystem 3:

Based on the knowledge that grade widening of two metres or less is impractical and that the desirable standard on Subsystem 3 is nine metres or less for AADT of 700 or less (for 75 percent passing zones), the minimum acceptable width in this zone is 7.3m. This will allow for two, 3.5m lanes plus an additional 0.15m on each side to provide some lateral support for the shoulder and reduce damage to the pavement edge by heavy vehicles.

For volumes from 700-1300 AADT where RCU-210 is the desirable standard, although it is possible to widen to 10m, the volume is too low to justify the cost. Therefore, 7.3m should be the suggested minimum. For volumes greater than 1300, it is reasonable to adopt eight metres as a suggested minimum width, even though widening of a 7.3m roadway cannot be justified based on the economic analysis, because of the typically high running speeds and high percentage of trucks experienced in Alberta. For AADT greater than 2000, a suggested minimum of nine metres is supported by economic analysis. Similarly for AADT greater than 2500, the suggested minimum is 10m.

Subsystem 4:

Because of the lower function on Subsystem 4, and therefore the probability of less truck traffic and shorter trip length, a minimum acceptable pavement width of seven metres is suggested. This value applies to the zone where the desirable width is nine metres; that is, up to AADT 1000 for 75 percent passing zones.

For the zone where RLU-210 is the desirable standard (AADT 1000-1700) and for volumes up to 2000, grade-widening cannot be justified based on the general economic analysis. However, it is generally believed that a seven metre road is inadequate to carry high volumes. Therefore 1500 AADT is suggested as a compromise value, based on a combination of engineering judgement and economic analysis, where seven metres is the minimum acceptable for volumes up to 1500 and 8.0m is the minimum for volumes between 1500-2000 in general in Subsystem 4.

For volumes between 2000-2500, the suggested minimum is 9m and for volumes above 2500, the suggested minimum is 10m based on economic analysis and practical considerations for grade-widening.

The rationale above is strictly based on the results of the economic analysis. For design purposes an AADT of 2500 for widening of nine metre roads and 3000 for widening of 10m roads have been adopted. This decision provides greater consistency across the subsystems and ensures a higher economic return on widening projects.

Note: Traffic volumes above are shown in terms of existing AADT.

APPENDIX B

EXAMPLE OF ECONOMIC ANALYSIS FOR HORIZONTAL CURVE IMPROVEMENTS

This appendix presents an example of an economic analysis for a horizontal curve improvement on a particular project. The 3R/4R Geometric Design Guidelines suggest that a project specific analysis be undertaken to determine the cost effectiveness of any proposed horizontal realignments. This example is provided to illustrate the process required.

This appendix is divided into the following sections:

G.B.1. Data Collected for the Analysis
G.B.2. Construction and Maintenance Costs for Both Alternatives (do nothing versus alignment improvement)
G.B.3. Calculation of Collision Rates for Both Alternatives
G.B.4. Calculation of Road User Costs for Existing and Proposed Alignment
G.B.5. Economic Analysis using Lotus Module Benefit-Cost.

G-B.1 DATA COLLECTED FOR THE ANALYSIS

The existing highway is paved and has an alignment as shown in Figure G-B.1 which is lower than current standards for the design speed.

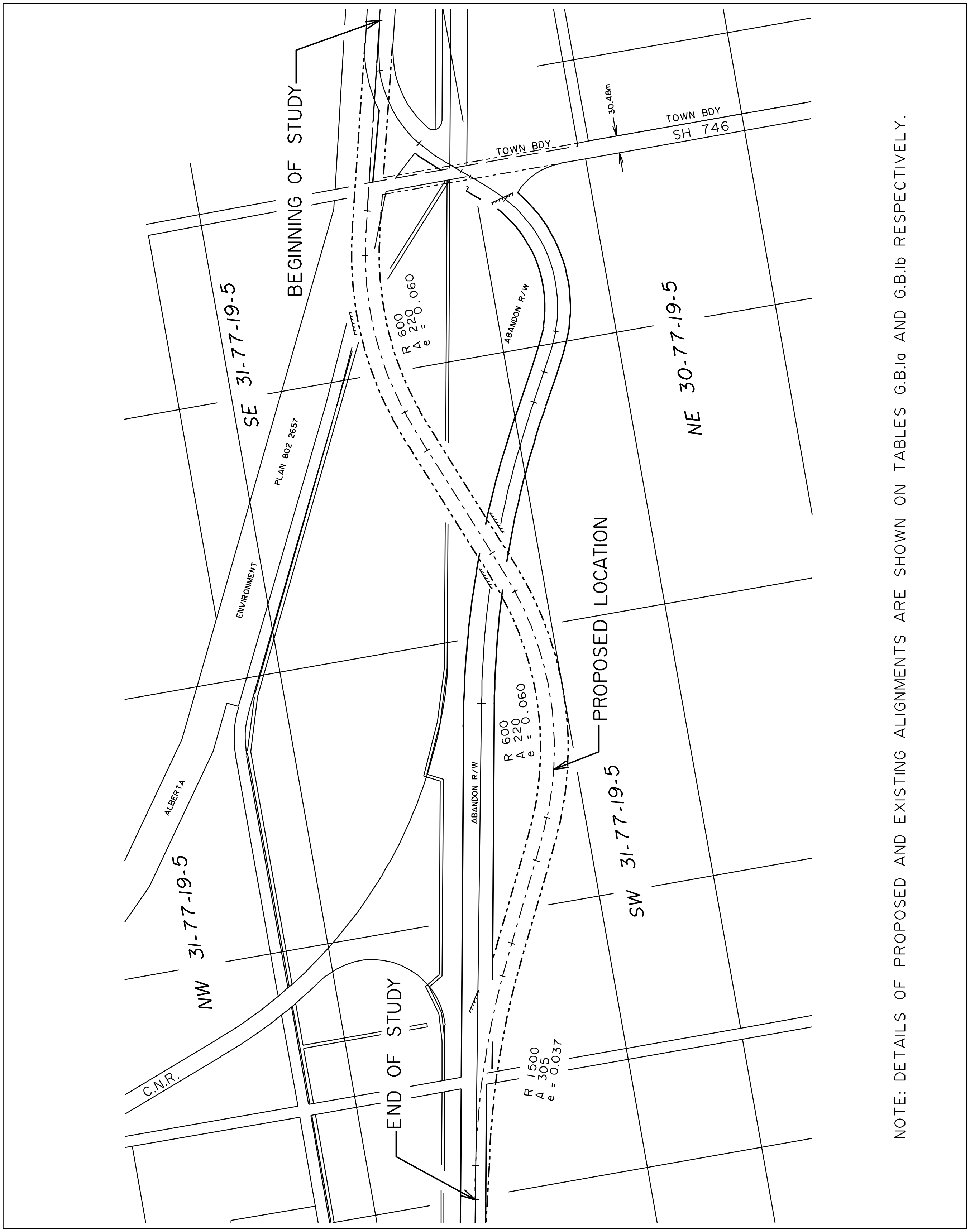


FIGURE G-B.1 DATA COLLECTED FOR ANALYSIS: HWY. 2 AT McLENNAN, ALBERTA

Table G.B.1.a Proposed Alignment Information for Project

Proposed Alignment (Metric Stations)			Glennon's Formula Length *		
	Station	Length (m)	Tangent Length (m)	Curve Length (m)	NOTES
START	0+000				Δ = 35°57'45"
T.S.	0+346.026		346.026		R = 600
		80.667		80.667	A = 220
S.C.	0+426.693				
		295.932		295.932	
C.S.	0+722.625				
		80.667	80.667		
S.T.	0+803.292				
		219.689	219.689		
T.S.	1+022.981				
		80.667		80.667	Δ = 48°04'30"
S.C.	1+103.648				R = 600
		422.773		422.773	A = 220
C.S.	1+526.421				
		80.667	80.667		
S.T.	1+607.088				
		155.838	155.838		
T.S.	1+762.926				
		62.118		62.118	Δ = 15°37'35"
S.C.	1+825.044				R = 1500
		346.980		346.979	A = 305
C.S.	2+172.023				
		62.118	62.118		
S.T. (END)	2+234.1416				
				880.039 @ R = 600	
			945.005	409.097 @ $ = 1500	
		Total Lengths	945.005 (tangent)	1289.136 (curves)	
		Grand Total		= 2,234.141 m	

Table G.B.1.b Existing Alignment Information for Project

Existing Alignment (Imperial Stations) (ft)			Length (ft)	(m)	Glennon's Formula Length*		NOTES Curve Info etc.
					Tangent Length (m)	Curved Length (m)	
START	Sta. T.S.	391+82.9					Curve #1
			300'	91.44	—	91.44	Δ = 64°03'00"
	S.C.	388+82.9					D_c = 8°00'
Curve #1			500.7'	152.61	—	152.61	R = 218.297m
	C.S.	383+82.2					L_s = 91.44m
			300'	91.44	91.44		e = 8%
	S.T.	380+82.2					
			63.1'	19.23	19.23		
	T.S.	380+19.1					
			250'	76.2			Curve #2
	S.C.	377+69.1					Δ = 79°20'00"
Curve #2			883.3'	269.23			D_c = 7°
	C.S.	368+85.8				76.2	R = 249.482m
			250'	76.2		269.23	L_s = 76.2m
	S.T.	366+35.8					e = 8%
			158.2'	48.22	48.22		
	T.C.	364+77.6					Curve #3
Curve #3			1888.3'	575.55		575.55	Δ = 18°53'00"
	C.T	345+89.3					D_c = 1°
			2818.4'	889.528	889.528		R = 1746.376m
Common Point (END)		316+70.9				Summary R = 218.3m L = 244.05 R = 249.48m L = 345.43m R = 1746.376m L = 575.55	
			Total		1,124.618m	1,165.03m	
			Grand Total		2,289.648m		

* <u>Glennon's Formula Length</u>
In the case of spiral curves, the L_C value used in the Glennon Formula (see Section G.B.3) is based on the length of the circular position plus one spiral length. To compensate, the length of tangent is considered to include one spiral. The degree of curve (as used in the Glennon Formula) is based on the controlling radius i.e. the circular curve radius in the case of both simple and spiral curves.

Table G.B.1.c
Conversion Chart

Degree of Curve per 100 feet	Radius (m)
0.2	8,731.85
0.4	4,365.92
0.6	2,910.62
0.8	2,182.96
1	1,746.37
1.2	1,455.31
1.4	1,247.41
1.5	1,164.00
1.6	1,091.48
1.8	970.21
2	873.19
2.2	793.80
2.4	727.65
2.6	671.68
2.8	623.70
3.0	582.13
3.2	545.74
3.4	513.64
3.6	485.10
3.8	459.57
4.0	436.59
4.2	415.80
4.4	396.90
4.5	388.08
4.6	379.65
4.8	363.83
5.0	349.27
6.0	291.06
8.0	218.30
10.0	174.64
11.0	158.76
12.0	145.53
14.0	124.74
16.0	109.15
20.0	87.32
40.0	43.66

This chart may be used to convert from Degree of Curve per 100 feet to radius in metres.

1. $R(ft) = \frac{100 \times 360}{D(ft) \times 2\pi}$

2. $R(m) = \frac{R(ft)}{3.28084}$

Where D(ft) = Degree of Curve per 100 ft. length

The following additional geometric, traffic and road user cost information is compiled:

- Pavement width is 8.5 metres
- Vertical grades are between 0 and one percent
- Traffic Information: (information is obtained from the Highway Network Planning, Land and Aggregates, Planning Services Branch)
  - Existing AADT = 1670 vehicles per day
  - Growth Factor (GF) is 1.55 over a period of 20 years (2.75% per annum, not compounded)
  - Traffic Composition:

Passenger Vehicles	91.7%	1531 vehicles per day
Recreational Vehicles	1.9%	32 vehicles per day
Buses	0.2%	4 vehicles per day
Single Unit Trucks	3.0%	50 vehicles per day
Tractor-Trailer Combinations	3.2%	53 vehicles per day

- percentage of automobiles with drivers on business trips: 62.5%
- percentage of automobiles with drivers on pleasure / other trips: 37.5%

- occupancy rate for automobiles on:
  - business trips 1.81 passengers / vehicle
  - pleasure / other trips 2.25 passengers / vehicle

- occupancy rate for:
  - recreational vehicles 2.25 passengers / vehicle
  - trucks 1.13 passengers / vehicle

The following values for time are assumed: (as indicated in the Benefit-Cost Analysis Summary)

- truck drivers MTR 24.25 / person / hour
- business people MAB 13.25 / person / hour
- all others MAP, MRV 6.00 / person / hour

The weighted average cost per accident is estimated based on the distribution of accident types and their unit costs as follows:

In Alberta, of all accidents, two percent are fatal, 25 percent cause injury, and 73 percent cause property damage only.

A fatal collision involves on average:
1.35 people who die*,
0.57 people who are seriously injured*, and
0.69 people who are moderately injured*
total cost per fatal collision - $1,339,578

An injury collision involves on average:
0.26 people who are seriously injured*
1.43 people who are moderately injured*
total cost per injury collision - $143,309

Average cost per property damage collision is $2,011

Average cost of all collisions = 0.02(1,339,578) + 0.25(143,309) + 0.73(2,011) = $64,087

G.B.2 Construction and Maintenance Costs for Both Alternatives

a. Do-Nothing scenario: Alternative I
It is assumed that an overlay will be required in the first year and every 20 years.

Overlay cost: $68,000/km x 2.36 km	$ 160,480		

b. Proposed Alignment: Alternative II

- Right of way (50m basic)	$ 6,000		
25 acres - 13 acres (return for existing) = 12 acres at $500/acre including severance	$ 15,000		
Subtotal	$ 21,000	→	$ 21,000
- Construction (RAU 211.8)			
Grading: 2.3 km × $140,000/km	$ 322,000		
Granular base course (320mm): 2.3 km × $130,000/km	$ 299,000		
Double seal coat (34mm): 2.3 km × $22,000/km	$ 51,000		
Pavement (ACP 100mm): 2.3 km × $90,000/km	$ 207,000		
Reclamation of Highway 2: 2.7 km × $10,000/km	$ 27,000		
Subtotal	$ 906,000	→	$ 906,000
- S.H. 746 extension (RAU 209) 0.35 km × $175,000/km	$ 60,000	→	$ 60,000
- Railway crossing cost (Highway 2)	$ 170,000	→	$ 170,000
Total			$ 1,157,000
Contingencies (10 percent)			$ 116,000
Grand Total			$ 1,273,000
			= 1.3 million (rounded)
Overlay cost $88,000/km × 2.3 km	$ 202,400		every 20 years

G.B.3 Calculation of Collision Rates for Both Alternatives

Accident rates for each horizontal curve are calculated using the Glennon Formula, as indicated in the FHWA Special Report 214, Appendix D. According to the Glennon Formula, below, the number of accidents on a curve per year is calculated as follows:

$$A_C = AADT \times 10^{-8} \times 365 \left[CR_T (L_C) + 33.6D\right] \qquad \text{(Glennon Formula)}$$

Where
- A_c = number of accidents per year on a curve
- CR_T = collision rate per 100 million vehicle kilometres
- L_c = length of curve in km
- D = degree of curve per 100 feet

The table on page G-43 should be used to find a degree of curve for a particular radius.

Using number of accidents obtained from the Glennon Formula, collision rate on a curve can be calculated using the following equation:

$$CR_C = \frac{\text{number of accidents on curve}}{\text{total veh.km on curve}} = \frac{A_C \times 10^8}{AADT \times 365 \times L_C}$$

Where CR_c = a collision rate per 100 million vehicle kilometres on a curve
A_c = number of accidents on a curve per year
AADT = annual average daily traffic volume
L_c = length of curve in km

The final formula that should be used for horizontal alignment improvement projects combines the two equations into one as follows:

$$CR_C = \frac{AADT \times 10^{-8} \times 365 \left[CR_T(L_C) + 3.36D\right] \times 10^8}{AADT \times 365 \times L_C} \Rightarrow CR_C = CR_T + \left[\frac{3.36D}{L_C}\right]$$

Note: The collision rate, rather than number of accidents, is used in the Lotus spreadsheet module RUC.

Collision rates are calculated as follows:

<u>Existing Alignment</u> (Alternative 1)

Posted speed on curve is 60 km / h

Because the Glennon Formula does not apply to urban conditions, it is assumed that the collision rate on the curve will be the same as elsewhere on the alignment; that is, 59 accidents per 100 million vehicle.km.

Spiral Curve #1 (C_{e1}) R = 218m, L = 244.05m, D = 8 / 100 feet

$$CR_{e1} = 59 + \left[\frac{3.36 \times 8}{0.24405}\right] = 169 \text{ accidents} / 10^8 \text{ vehicle. km}$$

Spiral Curve #2 (C_{e2}) R = 250m, L = 345.43m, D = 7 / 100 feet

$$CR_{e2} = 59 + \left[\frac{3.36 \times 7}{0.34545}\right] = 127 \text{ accidents} / 10^8 \text{ vehicle. km}$$

Simple Curve #3 R = 1746m, L= 575.6, D = 1 / 100 feet

$$CR_{e3} = 59 + \left[\frac{3.36 \times 1}{.5756}\right] = 65 \text{ accidents} / 10^8 \text{ vehicle. km}$$

Tangent Section

$$CR_T = 59 \text{ acc.}/10^8 \text{ vehicle. km}$$

This is based on records of the collision rate on tangent sections of the adjacent highway.

<u>Proposed Alignment</u> (Alternative 2)

Spiral Curve #1 (C_{p1}) R = 600m, L = 376.6m, D = 2.91 / 100 feet

$$CR_{p1} = 59 + \left[\frac{3.36 \times 2.91}{0.3766}\right] = 85 \text{ accidents} / 10^8 \text{ vehicle. km}$$

Spiral Curve #2 (C_{p2}) R = 600m, L_c = 503.44m, D = 2.91 / 100 feet

$$CR_{p2} = 59 + \left[\frac{3.36 + 2.91}{0.50344}\right] = 78 \text{ accidents} / 10^8 \text{ vehicle. km}$$

Spiral Curve #3 (C_{p3}) R = 1500m, L_c = 409.1m, D = 1.16 / 100 feet

$$CR_{p3} = 59 + \left[\frac{3.36 + 1.16}{0.4091}\right] = 70 \text{ accidents} / 10^8 \text{ vehicle. km}$$

Tangent Portion

$CR_T = 59$ accidents / 10^8 vehicle. km — based on the collision rate on the adjacent tangent.

The above collision rates are required as input in the road user cost evaluation.

G.B.4 Calculation of Road User Costs for Existing and Proposed Alignment

This calculation is done on a Lotus spreadsheet using a pre-prepared module known as RUC. The module is available from Planning Services Branch, AI. Figures G-B.4.1 through G-B.4.8 show printouts from that module. Eight calculations are required for this project because of different speeds and collision rates that are used for portions of the project on the existing and proposed alignment.

The input parameters are identified on the printout by a shaded background. Whenever a parameter such as AADT, speed or collision rate changes, an additional calculation must be run. The road user costs include costs for collisions, time, and vehicle operation. A full explanation of the considerations and instructions for use of the RUC module are included in AIs Benefit-Cost Analysis User Manual.

The parameters that varied in this analysis are listed below in Table G.B.4.

Table G.B.4 Input Parameters for Analysis

Proposed Alignment		
Collision Rate	Design Speed Surface Type	Length (m)
85	97.3 paved	376.6
78.5	97.3 paved	503.44
70	97.3 paved	409.1
59	97.3 paved	945.0
	Total	2234.14 m

Existing Alignment		
Collision Rate	Design Speed Surface Type	Length (m)
59	60 paved	244.05
127.1	85 paved	345.43
65	97.3 paved	575.6
59	97.3 paved	1124.62
	Total	2289.7 m

In this example, the Road User Costs for each alignment are calculated as a sum of four RUC calculations representing each segment.

FIGURE G - B.4.1

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT II 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	97.3	paved

TIME $:

TRK DRVR	TRK PASS	WK/BUS	OTHER
24.25	13.25	13.25	6.00

TRIP PURPOSE:	PASSENGER VEHS. % W/B	PASSENGER VEHS. % OTHER	REC. VEHS. % W/B	REC. VEHS. % OTHER	BUSES % W/B	BUSES % OTHER
	62.5	37.5	0	100	100	0

VEH.OCC.	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
FACTORS	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:

RATE	%FATAL	%INJURY	%PDO
85	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	0.38	100.14	297.67	274.89	58.95	5.99	5.53	70.47
1	0.00	100.68	301.93	251.40	0.00	0.00	0.00	0.00
2	0.00	102.02	278.34	246.62	0.00	0.00	0.00	0.00
3	0.00	103.14	317.23	290.60	0.00	0.00	0.00	0.00
4	0.00	104.75	347.55	334.09	0.00	0.00	0.00	0.00
5	0.00	104.99	379.59	384.49	0.00	0.00	0.00	0.00
6	0.00	109.28	414.28	437.69	0.00	0.00	0.00	0.00
7	0.00	117.57	450.79	499.79	0.00	0.00	0.00	0.00
8	0.00	128.54	490.22	572.86	0.00	0.00	0.00	0.00
TOT. LEN.	0.38							

TOTAL DAILY RUNNING COST FOR GRADES 70.47

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
250	0.080	0.00	196.5	2183.2	4141.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
748	0.058	0.00	3.0	69.7	135.8	0.00	0.00	0.00	0.00
600	0.060	0.38	13.1	179.7	344.3	7.71	3.62	6.93	18.25
873	0.047	0.00	1.9	57.8	113.3	0.00	0.00	0.00	0.00
1500	0.049	0.00	0.0	0.0	0.0	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 18.25

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	88.84	0.00	10.41	0.31	99.57
other	13.50	13.50		18.25	30.01	1.66		0.00	31.66

TOTAL DAILY TIME COSTS FOR ROUTE 131.23

COLLISION COSTS:

collision severity	unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2 % fatal	933930	262086	1032	7500	1204548	24090.95
25 % injury		119548	2138	6750	128436	32108.96
73 % pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00053	
TOTAL DAILY COLLISION COSTS		31.57
TOTAL DAILY ROAD USER COSTS		251.52
TOTAL ANNUAL ROAD USER COSTS		91,867.86

FIGURE G - B.4.2

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT II 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	97.3	paved

TIME $:	TRK DRVR	TRK PASS	WK/BUS	OTHER
	24.25	13.25	13.25	6.00

TRIP PURPOSE:	PASSENGER VEHS. % W/B	PASSENGER VEHS. % OTHER	REC. VEHS. % W/B	REC. VEHS. % OTHER	BUSES % W/B	BUSES % OTHER
	62.5	37.5	0	100	100	0

VEH.OCC. FACTORS	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:	RATE	%FATAL	%INJURY	%PDO
	78.5	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	0.50	100.14	297.67	274.89	78.80	8.01	7.40	94.21
1	0.00	100.68	301.93	251.40	0.00	0.00	0.00	0.00
2	0.00	102.02	278.34	246.62	0.00	0.00	0.00	0.00
3	0.00	103.14	317.23	290.60	0.00	0.00	0.00	0.00
4	0.00	104.75	347.55	334.09	0.00	0.00	0.00	0.00
5	0.00	104.99	379.59	384.49	0.00	0.00	0.00	0.00
6	0.00	109.28	414.28	437.69	0.00	0.00	0.00	0.00
7	0.00	117.57	450.79	499.79	0.00	0.00	0.00	0.00
8	0.00	128.54	490.22	572.86	0.00	0.00	0.00	0.00
TOT. LEN.	0.50							

TOTAL DAILY RUNNING COST FOR GRADES 94.21

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
250	0.080	0.00	196.5	2183.2	4141.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
748	0.058	0.00	3.0	69.7	135.8	0.00	0.00	0.00	0.00
600	0.060	0.50	13.1	179.7	344.3	10.30	4.83	9.26	24.40
873	0.047	0.00	1.9	57.8	113.3	0.00	0.00	0.00	0.00
1500	0.049	0.00	0.0	0.0	0.0	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 24.40

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	118.77	0.00	13.91	0.42	133.10
other	13.50	13.50		18.25	40.11	2.22		0.00	42.33

TOTAL DAILY TIME COSTS FOR ROUTE 175.43

COLLISION COSTS:

	collision severity	unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2	% fatal	933930	262086	1032	7500	1204548	24090.95
25	% injury		119548	2138	6750	128436	32108.96
73	% pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00066	
TOTAL DAILY COLLISION COSTS		38.97
TOTAL DAILY ROAD USER COSTS		333.01
TOTAL ANNUAL ROAD USER COSTS		121,630.64

FIGURE G - B.4.3

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT II 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	97.3	paved

TIME $:	TRK DRVR	TRK PASS	WK/BUS	OTHER
	24.25	13.25	13.25	6.00

TRIP PURPOSE:	PASSENGER VEHS. % W/B	PASSENGER VEHS. % OTHER	REC. VEHS. % W/B	REC. VEHS. % OTHER	BUSES % W/B	BUSES % OTHER
	62.5	37.5	0	100	100	0

VEH.OCC.	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
FACTORS	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:	RATE	%FATAL	%INJURY	%PDO
	70	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	0.41	100.14	297.67	274.89	64.04	6.51	6.01	76.55
1	0.00	100.68	301.93	251.40	0.00	0.00	0.00	0.00
2	0.00	102.02	278.34	246.62	0.00	0.00	0.00	0.00
3	0.00	103.14	317.23	290.60	0.00	0.00	0.00	0.00
4	0.00	104.75	347.55	334.09	0.00	0.00	0.00	0.00
5	0.00	104.99	379.59	384.49	0.00	0.00	0.00	0.00
6	0.00	109.28	414.28	437.69	0.00	0.00	0.00	0.00
7	0.00	117.57	450.79	499.79	0.00	0.00	0.00	0.00
8	0.00	128.54	490.22	572.86	0.00	0.00	0.00	0.00
TOT. LEN.	0.41							

TOTAL DAILY RUNNING COST FOR GRADES 76.55

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
250	0.080	0.00	196.5	2183.2	4141.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
748	0.058	0.00	3.0	69.7	135.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
873	0.047	0.00	1.9	57.8	113.3	0.00	0.00	0.00	0.00
1500	0.037	0.41	0.0	0.0	0.0	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 0.00

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	96.51	0.00	11.31	0.34	108.16
other	13.50	13.50		18.25	32.60	1.80		0.00	34.40

TOTAL DAILY TIME COSTS FOR ROUTE 142.56

COLLISION COSTS:

collision severity	unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2 % fatal	933930	262086	1032	7500	1204548	24090.95
25 % injury		119548	2138	6750	128436	32108.96
73 % pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00048	
TOTAL DAILY COLLISION COSTS		28.24
TOTAL DAILY ROAD USER COSTS		247.35
TOTAL ANNUAL ROAD USER COSTS		90,343.61

FIGURE G - B.4.4

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT II 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	97.3	paved

TIME $:	TRK DRVR	TRK PASS	WK/BUS	OTHER
	24.25	13.25	13.25	6.00

TRIP PURPOSE:	PASSENGER VEHS.		REC. VEHS.		BUSES	
	% W/B	% OTHER	% W/B	% OTHER	% W/B	% OTHER
	62.5	37.5	0	100	100	0

VEH.OCC. FACTORS	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:	RATE	%FATAL	%INJURY	%PDO
	59	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	0.95	100.14	297.67	274.89	147.92	15.03	13.88	176.83
1	0.00	100.68	301.93	251.40	0.00	0.00	0.00	0.00
2	0.00	102.02	278.34	246.62	0.00	0.00	0.00	0.00
3	0.00	103.14	317.23	290.60	0.00	0.00	0.00	0.00
4	0.00	104.75	347.55	334.09	0.00	0.00	0.00	0.00
5	0.00	104.99	379.59	384.49	0.00	0.00	0.00	0.00
6	0.00	109.28	414.28	437.69	0.00	0.00	0.00	0.00
7	0.00	117.57	450.79	499.79	0.00	0.00	0.00	0.00
8	0.00	128.54	490.22	572.86	0.00	0.00	0.00	0.00
TOT. LEN.	0.95							

TOTAL DAILY RUNNING COST FOR GRADES 176.83

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
250	0.080	0.00	196.5	2183.2	4141.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
748	0.058	0.00	3.0	69.7	135.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
873	0.047	0.00	1.9	57.8	113.3	0.00	0.00	0.00	0.00
1500	0.037	0.00	0.0	0.0	0.0	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 0.00

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	222.94	0.00	26.12	0.79	249.84
other	13.50	13.50		18.25	75.30	4.16		0.00	79.46

TOTAL DAILY TIME COSTS FOR ROUTE 329.30

COLLISION COSTS:

collision severity	unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2 % fatal	933930	262086	1032	7500	1204548	24090.95
25 % injury		119548	2138	6750	128436	32108.96
73 % pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00093	
TOTAL DAILY COLLISION COSTS		54.98
TOTAL DAILY ROAD USER COSTS		561.11
TOTAL ANNUAL ROAD USER COSTS		204,945.17

FIGURE G - B.4.5

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT I 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	60	paved

TIME $:	TRK DRVR	TRK PASS	WK/BUS	OTHER
	24.25	13.25	13.25	6.00

	PASSENGER VEHS.		REC. VEHS.		BUSES	
TRIP PURPOSE:	% W/B	% OTHER	% W/B	% OTHER	% W/B	% OTHER
	62.5	37.5	0	100	100	0

VEH.OCC.	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
FACTORS	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:	RATE	%FATAL	%INJURY	%PDO
	59	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	0.24	92.20	292.43	247.02	35.17	3.81	3.22	42.21
1	0.00	93.20	294.44	234.71	0.00	0.00	0.00	0.00
2	0.00	93.88	299.48	261.21	0.00	0.00	0.00	0.00
3	0.00	95.09	339.83	304.98	0.00	0.00	0.00	0.00
4	0.00	98.21	366.70	345.80	0.00	0.00	0.00	0.00
5	0.00	107.10	395.38	390.90	0.00	0.00	0.00	0.00
6	0.00	109.95	426.59	445.20	0.00	0.00	0.00	0.00
7	0.00	115.27	460.61	508.67	0.00	0.00	0.00	0.00
8	0.00	120.90	497.16	581.22	0.00	0.00	0.00	0.00
TOT. LEN.	0.24							

TOTAL DAILY RUNNING COST FOR GRADES 42.21

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
218	0.080	0.24	6.2	104.6	202.0	2.37	1.36	2.63	6.37
600	0.060	0.00	0.0	0.0	0.1	0.00	0.00	0.00	0.00
748	0.058	0.00	0.0	9.4	21.5	0.00	0.00	0.00	0.00
600	0.060	0.00	0.0	0.0	0.1	0.00	0.00	0.00	0.00
873	0.047	0.00	0.0	0.3	4.3	0.00	0.00	0.00	0.00
1500	0.049	0.00	0.0	32.7	65.7	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 6.37

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	93.37	0.00	10.94	0.33	104.63
other	13.50	13.50		18.25	31.53	1.74		0.00	33.28

TOTAL DAILY TIME COSTS FOR ROUTE 137.91

COLLISION COSTS:

	collision severity	unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2	% fatal	933930	262086	1032	7500	1204548	24090.95
25	% injury		119548	2138	6750	128436	32108.96
73	% pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00024	
TOTAL DAILY COLLISION COSTS		14.20
TOTAL DAILY ROAD USER COSTS		200.69
TOTAL ANNUAL ROAD USER COSTS		73,301.38

FIGURE G - B.4.6

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT I 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	85	paved

TIME $:	TRK DRVR	TRK PASS	WK/BUS	OTHER
	24.25	13.25	13.25	6.00

	PASSENGER VEHS.		REC. VEHS.		BUSES	
TRIP PURPOSE:	% W/B	% OTHER	% W/B	% OTHER	% W/B	% OTHER
	62.5	37.5	0	100	100	0

VEH.OCC.	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
FACTORS	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:	RATE	%FATAL	%INJURY	%PDO
	127.1	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	0.35	93.93	282.70	265.51	50.72	5.22	4.90	60.84
1	0.00	94.42	286.76	240.12	0.00	0.00	0.00	0.00
2	0.00	95.39	277.38	247.82	0.00	0.00	0.00	0.00
3	0.00	96.12	322.47	290.86	0.00	0.00	0.00	0.00
4	0.00	98.06	351.47	332.44	0.00	0.00	0.00	0.00
5	0.00	103.14	382.19	379.54	0.00	0.00	0.00	0.00
6	0.00	106.60	415.49	432.40	0.00	0.00	0.00	0.00
7	0.00	113.59	450.96	493.17	0.00	0.00	0.00	0.00
8	0.00	122.23	489.21	565.05	0.00	0.00	0.00	0.00
TOT. LEN.	0.35							

TOTAL DAILY RUNNING COST FOR GRADES 60.84

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
250	0.080	0.35	87.5	992.1	1884.1	47.23	18.31	34.78	100.32
600	0.060	0.00	0.8	45.6	90.2	0.00	0.00	0.00	0.00
748	0.058	0.00	0.0	5.0	13.3	0.00	0.00	0.00	0.00
600	0.060	0.00	0.8	45.6	90.2	0.00	0.00	0.00	0.00
873	0.047	0.00	0.0	5.3	13.7	0.00	0.00	0.00	0.00
1500	0.049	0.00	0.0	0.0	0.0	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 100.32

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	93.28	0.00	10.93	0.33	104.54
other	13.50	13.50		18.25	31.51	1.74		0.00	33.25

TOTAL DAILY TIME COSTS FOR ROUTE 137.79

COLLISION COSTS:

	collision severity	unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2	% fatal	933930	262086	1032	7500	1204548	24090.95
25	% injury		119548	2138	6750	128436	32108.96
73	% pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00073	
TOTAL DAILY COLLISION COSTS		43.29
TOTAL DAILY ROAD USER COSTS		342.24
TOTAL ANNUAL ROAD USER COSTS		125,003.30

FIGURE G - B.4.7

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT I 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	97.3	paved

TIME $:	TRK DRVR	TRK PASS	WK/BUS	OTHER
	24.25	13.25	13.25	6.00

TRIP PURPOSE:	PASSENGER VEHS. % W/B	PASSENGER VEHS. % OTHER	REC. VEHS. % W/B	REC. VEHS. % OTHER	BUSES % W/B	BUSES % OTHER
	62.5	37.5	0	100	100	0

VEH.OCC. FACTORS	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:	RATE	%FATAL	%INJURY	%PDO
	65	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	0.58	100.14	297.67	274.89	90.10	9.16	8.46	107.71
1	0.00	100.68	301.93	251.40	0.00	0.00	0.00	0.00
2	0.00	102.02	278.34	246.62	0.00	0.00	0.00	0.00
3	0.00	103.14	317.23	290.60	0.00	0.00	0.00	0.00
4	0.00	104.75	347.55	334.09	0.00	0.00	0.00	0.00
5	0.00	104.99	379.59	384.49	0.00	0.00	0.00	0.00
6	0.00	109.28	414.28	437.69	0.00	0.00	0.00	0.00
7	0.00	117.57	450.79	499.79	0.00	0.00	0.00	0.00
8	0.00	128.54	490.22	572.86	0.00	0.00	0.00	0.00
TOT. LEN.	0.58							

TOTAL DAILY RUNNING COST FOR GRADES 107.71

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
250	0.080	0.00	196.5	2183.2	4141.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
748	0.058	0.00	3.0	69.7	135.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
873	0.047	0.00	1.9	57.8	113.3	0.00	0.00	0.00	0.00
1746	0.038	0.58	0.0	0.0	0.0	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 0.00

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	135.79	0.00	15.91	0.48	152.18
other	13.50	13.50		18.25	45.86	2.53		0.00	48.40

TOTAL DAILY TIME COSTS FOR ROUTE 200.57

COLLISION COSTS:

collision severity		unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2	% fatal	933930	262086	1032	7500	1204548	24090.95
25	% injury		119548	2138	6750	128436	32108.96
73	% pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00062	
TOTAL DAILY COLLISION COSTS		36.89
TOTAL DAILY ROAD USER COSTS		345.18
TOTAL ANNUAL ROAD USER COSTS		126,076.08

FIGURE G - B.4.8

ROAD USER COST EVALUATION

PROJECT: CURVE FLATTENING PROJECT - SIMPLE CURVE 0.3 KM W OF McLennan ALT: ALT I 06-Apr-95

ROAD USER COST INPUT DATA:

AADT	%PV	%RV	%BUS	%SU	%TRT	DES. SP/	SUR. TYPE
1670	91.7	1.9	0.2	3	3.2	97.3	paved

TIME $:	TRK DRVR	TRK PASS	WK/BUS	OTHER
	24.25	13.25	13.25	6.00

TRIP PURPOSE:	PASSENGER VEHS.		REC. VEHS.		BUSES	
	% W/B	% OTHER	% W/B	% OTHER	% W/B	% OTHER
	62.5	37.5	0	100	100	0

VEH.OCC. FACTORS	PV W/B	PV OTH	RV W/B	RV OTH	TRUCKS	BUS W/B	BUS OTHER
	1.81	2.25	0.00	2.25	1.13	1.00	0.00

COLLISION DATA:	RATE	%FATAL	%INJURY	%PDO
	59	2	25	73

	#FATALS	#SER.INJ	#MOD.INJ
FATAL COLLISIONS	1.35	0.57	0.69
INJURY COLLISIONS	-	0.26	1.43

	FATALS	SER.INJ	MOD.INJ	P.D.O.
SOC.+DIR.COSTS	691800	459800	1495	300
PROPERTY DAMAGE	7500	6750	6750	3600

GRADIENT COSTS:

grade	length	unit cost for grades PV	SU	TRT	running costs on grades PV	SU	TRT	total cost for grades
0	1.12	100.14	297.67	274.89	176.04	17.89	16.52	210.45
1	0.00	100.68	301.93	251.40	0.00	0.00	0.00	0.00
2	0.00	102.02	278.34	246.62	0.00	0.00	0.00	0.00
3	0.00	103.14	317.23	290.60	0.00	0.00	0.00	0.00
4	0.00	104.75	347.55	334.09	0.00	0.00	0.00	0.00
5	0.00	104.99	379.59	384.49	0.00	0.00	0.00	0.00
6	0.00	109.28	414.28	437.69	0.00	0.00	0.00	0.00
7	0.00	117.57	450.79	499.79	0.00	0.00	0.00	0.00
8	0.00	128.54	490.22	572.86	0.00	0.00	0.00	0.00
TOT. LEN.	1.12							

TOTAL DAILY RUNNING COST FOR GRADES 210.45

CURVATURE COSTS:

radius	superelev	length	unit cost for curves PV	SU	TRT	running costs on curves PV	SU	TRT	total cost for curves
250	0.080	0.00	196.5	2183.2	4141.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
748	0.058	0.00	3.0	69.7	135.8	0.00	0.00	0.00	0.00
600	0.060	0.00	13.1	179.7	344.3	0.00	0.00	0.00	0.00
873	0.047	0.00	1.9	57.8	113.3	0.00	0.00	0.00	0.00
1500	0.049	0.00	0.0	0.0	0.0	0.00	0.00	0.00	0.00

TOTAL DAILY RUNNING COST FOR CURVES 0.00

TIME COSTS:

trip purpose	unit cost for time PV	RV	TRUCK	BUS	vehicle time costs PV	RV	TRUCK	BUS	total cost
wrk/bus	23.98	0.00	25.97	24.25	265.31	0.00	31.08	0.94	297.33
other	13.50	13.50		18.25	89.61	4.95		0.00	94.56

TOTAL DAILY TIME COSTS FOR ROUTE 391.89

COLLISION COSTS:

	collision severity	unit cost for collision FATALITY	SER. INJ	MOD. INJ	DAMAGE	SUB TOTAL	% x COST
2	% fatal	933930	262086	1032	7500	1204548	24090.95
25	% injury		119548	2138	6750	128436	32108.96
73	% pdo				3900	3900	2847.00

AVERAGE COST PER COLLISION	59046.91	
AVERAGE # COLLISIONS PER DAY	0.00111	
TOTAL DAILY COLLISION COSTS		65.43
TOTAL DAILY ROAD USER COSTS		667.76
TOTAL ANNUAL ROAD USER COSTS		243,899.93

G.B.5 Economic Analysis using Lotus Module Benefit-Cost

The economic analysis for horizontal alignment improvement is performed using a Lotus module known as Benefit-Cost which is available from Planning Services Branch (AI). A printout for the analysis on the example project is shown in Table G.B.5. The input values and theory used in the Benefit-Cost module are fully explained in the Benefit-Cost Analysis User Manual. A brief description follows:

A stream of costs and benefits for year 0 through to year 50 are input. The costs and benefits include construction, maintenance and road user costs for each alternative. In this case, the do nothing alternative is compared to the alignment improvement alternative. The annual differences in costs and benefits between the two alternatives are compared to yield a net annual undiscounted value for the improvement for each year of the analysis. These values are used to generate a column of figures representing each year entitled sum of present worth @ four percent discount rate. These figures are in turn used to determine the Internal Rate of Return (IRR) for each year of the analysis. The IRR is defined as the discount rate at which the present value of benefits equals the present value of costs. The IRR is the key indicator of economic feasibility for the project. For comparison purposes between various proposals or between various projects, the IRR at the end of the design life of an improvement is generally used. A project should be considered economically feasible if the IRR exceeds four percent at the end of the design life.

In the case of this example, where the IRR is 2.48 percent at year 20, the horizontal alignment improvement should be considered not economically feasible. A detailed treatment on how to assess the feasibility of a proposal is available in the Benefit-Cost Analysis Guide.

Table G.B.5

ECONOMIC ANALYSIS - HORIZONTAL ALIGNMENT IMPROVEMNETS

NOTE: All costs reported in thousands of 1993 dollars unless otherwise noted

CAPITAL & MAINTENANCE

ALTERNATIVE I
Overlay cost:
68,000 x 2.29 = $155,700 every 20 years
beginning the first year

ALTERNATIVE II
Construction cost:
$1,237,000

Overlay cost
88,000 x 2.23 = $196,604 every 20 years

ASSUMPTIONS:
- AADT and road user cost increase 2%
for first ten years and 1% annually thereafter.
- 1993 AADT = 1670

BENEFITS

ROAD USER COST SAVINGS
AS CALCULATED USING LOTUS MODULE RUC

ALTERNATIVE I - Road User cost	
- travel time cost	317095
- running cost on grades	153847
- excess running cost on curves	38969
- collision cost	58371
Total cost	$568,282

ALTERNATIVE II - Road User cost	
- travel time cost	284354
- running cost on grades	152696
- excess running cost on curves	15578
- collision cost	56161
Total cost	$508,790

Road User Savings: 568,282 - 508,790
= $59,492

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
		EXISTING		ALT P-1 CR 110							(guess)
No.	Year	CAP.	R.U.C.	CAP.	R.U.C.	CAP. COST DIFF.	R.U.C. SAVINGS	COST+R.U.C VALUES	CAPITAL	TOTAL	20.00%
0	1993	156	0	1,237	0	(1,081)	0	(1,081)	(1,081)	(1,081)	
1	1994	0	568	0	509	0	59	59	(1,081)	(1,024)	-94.50%
2	1995	0	580	0	519	0	61	61	(1,081)	(968)	-73.40%
3	1996	0	591	0	529	0	62	62	(1,081)	(913)	-54.51%
4	1997	0	602	0	539	0	63	63	(1,081)	(859)	-40.73%
5	1998	0	614	0	549	0	64	64	(1,081)	(806)	-30.83%
6	1999	0	625	0	560	0	65	65	(1,081)	(755)	-23.60%
7	2000	0	636	0	570	0	67	67	(1,081)	(704)	-18.17%
8	2001	0	648	0	580	0	68	68	(1,081)	(654)	-14.02%
9	2002	0	659	0	590	0	69	69	(1,081)	(606)	-10.76%
10	2003	0	671	0	600	0	70	70	(1,081)	(558)	-8.17%
11	2004	0	682	0	611	0	71	71	(1,081)	(512)	-6.08%
12	2005	0	688	0	616	0	72	72	(1,081)	(467)	-4.37%
13	2006	0	693	0	621	0	73	73	(1,081)	(424)	-2.96%
14	2007	0	699	0	626	0	73	73	(1,081)	(381)	-1.79%
15	2008	0	705	0	631	0	74	74	(1,081)	(340)	-0.80%
16	2009	0	710	0	636	0	74	74	(1,081)	(301)	0.05%
17	2010	0	716	0	641	0	75	75	(1,081)	(262)	0.77%
18	2011	0	722	0	646	0	76	76	(1,081)	(225)	1.39%
19	2012	0	727	0	651	0	76	76	(1,081)	(189)	1.93%
20	2013	156	733	197	656	(41)	77	36	(1,100)	(172)	2.16%
21	2014	0	739	0	661	0	77	77	(1,100)	(138)	2.60%
22	2015	0	744	0	667	0	78	78	(1,100)	(105)	2.98%
23	2016	0	750	0	672	0	79	79	(1,100)	(74)	3.32%
24	2017	0	756	0	677	0	79	79	(1,100)	(43)	3.62%
25	2018	0	761	0	682	0	80	80	(1,100)	(13)	3.89%
26	2019	0	767	0	687	0	80	80	(1,100)	16	4.13%
27	2020	0	773	0	692	0	81	81	(1,100)	44	4.34%
28	2021	0	779	0	697	0	82	82	(1,100)	71	4.54%
29	2022	0	784	0	702	0	82	82	(1,100)	98	4.71%
30	2023	0	790	0	707	0	83	83	(1,100)	123	4.86%
31	2024	0	796	0	712	0	83	83	(1,100)	148	5.01%
32	2025	0	801	0	717	0	84	84	(1,100)	172	5.13%
33	2026	0	807	0	722	0	84	84	(1,100)	195	5.25%
34	2027	0	813	0	728	0	85	85	(1,100)	217	5.36%
35	2028	0	818	0	733	0	86	86	(1,100)	239	5.45%
36	2029	0	824	0	738	0	86	86	(1,100)	260	5.54%
37	2030	0	830	0	743	0	87	87	(1,100)	280	5.62%
38	2031	0	835	0	748	0	87	87	(1,100)	300	5.70%
39	2032	0	841	0	753	0	88	88	(1,100)	319	5.77%
40	2033	156	847	197	758	(41)	89	48	(1,108)	329	5.80%
41	2034	0	852	0	763	0	89	89	(1,108)	347	5.86%
42	2035	0	858	0	768	0	90	90	(1,108)	364	5.91%
43	2036	0	864	0	773	0	90	90	(1,108)	381	5.96%
44	2037	0	869	0	778	0	91	91	(1,108)	397	6.01%
45	2038	0	875	0	784	0	92	92	(1,108)	413	6.05%
46	2039	0	881	0	789	0	92	92	(1,108)	428	6.09%
47	2040	0	887	0	794	0	93	93	(1,108)	443	6.13%
48	2041	0	892	0	799	0	93	93	(1,108)	457	6.16%
49	2042	0	898	0	804	0	94	94	(1,108)	471	6.19%
50	2043	0	904	0	809	0	95	95	(1,108)	484	6.22%

APPENDIX C

SUMMARY
OF ECONOMIC ANALYSIS FOR SIDESLOPE FLATTENING

The effect of slope combinations on safety during traversal by an errant vehicle is an important consideration in designing the roadside. It is this consideration which has been addressed by the following analysis.

The economic analysis was performed to determine the daily traffic volume (AADT) which would justify flattening an existing 3:1 sideslope to 4:1 with standard trapezoidal ditch cross section at the time of overlay, based on the reduction in collision severity (and collision cost) that should result from such an improvement..

Alberta collision history indicates that run-off-road collisions represent approximately 34.1 percent of all collisions on undivided rural highways.

The current proportion of collisions resulting in fatalities, injuries and property damage in Alberta is summarized in the table below:

	Fatal Collisions	*Injury Collisions*	*Property Damage Collisions*
Run-off-Road Collisions on 4:1 sideslope *	***1.585 %***	***34.3 %***	***64.1 %***
Run-off-Road Collisions on 3:1 sideslope **	***3.2 %***	***45.0 %***	***51.8 %***
All Collisions including Run-off-Road type ***	***2.0 %***	***25.0 %***	***73.0 %***

* *These figures are a 5-year provincial average (1986-1990) for undivided primary highways (it was assumed that the existing sideslope is 4:1)*

** *These figures were selected based on the typical difference in collision severity for 3:1 slopes versus 4:1 slopes used by FHWA for 70 mph (Roadside Cross- Section Improvements, January, 1994).*

*** *These figures are 1990 provincial averages for undivided primary highways included in the Benefit Cost Analysis User Manual, AT&U, 1992.*

The severity index concept was introduced in the analysis to provide a means of comparing the relative severity of collisions on various side-slopes. These distributions for run-off-road collisions on 4:1 and 3:1 slopes in Alberta are called Alberta Severity Indices $SA_{4:1}$ and $SA_{3:1}$, respectively.
Based on the above distributions, average costs per run-off-road collisions on 4:1 and 3:1 slopes were calculated using Alberta average costs for each collision type.

A summary of those calculations is shown below.

VALUES OF COLLISIONS IN ALBERTA ESTIMATED IN 1992 DOLLARS:	***$ PER COLLISION***
Fatal Collision	***1,339,578***
Injury Collision	***143,309***
Property Damage	***2,011***
CALCULATED AVERAGE COST PER RUN-OFF-ROAD COLLISION:	***$ PER COLLISION***
Collision Cost on 4:1 sideslope $\frac{1.585(1{,}339{,}578)+34.3(143{,}309)+64.1(2{,}011)}{100}=$	***71,698***
Collision Cost on 3:1 sideslope $\frac{3.2(1{,}339{,}578)+45.0(143{,}309)+51.8(2{,}011)}{100}=$	***108,397***
Collision Cost Average (all collisions including Run-off-Road type) $\frac{2.0(1{,}339{,}578)+25(143{,}309)+73(2{,}011)}{100}=$	***64,087***

The AASHTO Model as presented in the Roadside Design Guide, Appendix A, was used to calculate the number of run-off-road collisions for four pavement widths: 7.3m, 7.9 m, 8.5m and 9.8 metres before and after an overlay.

The capital cost for improving the roadside cross-section was assumed based on the average 1993 cost for one kilometre of roadside cross-section improvement (flattening sideslope to 4:1 and restoration of existing ditch to the standard configuration). The cost included borrow excavation, extension of culverts, and placing of top soil.

The internal rate of return method as described in the Benefit Cost Analysis Summary was used to evaluate the cost effectiveness of the proposed improvement for four pavement widths: 7.3 m, 7.9 m, 8.5 m, and 9.8 metres. See the attached Benefit-Cost analysis calculation sheets, Tables G.C.1 through G.C.4. An internal rate of return of four percent at the end of design life (20 years) of the improvement was considered to be the minimum satisfactory return when flattening to a 4:1 sideslope is recommended. This means that the net present value of costs for the improvement plus discounted benefits, using a four percent discount rate, considering 20 years of operation of the roadway, is equal to zero.

The benefit for each year is the difference in cost for collisions on 3:1 sideslopes versus 4:1 sideslopes. The results of the analysis show that roadside cross-section improvements are cost effective on roadways with 3:1 sideslopes, if the AADT exceeds approximately 200 for pavement widths of 7.3 metres and 7.9 metres and on roadways with AADT exceeding approximately 300 for pavement widths of 8.5 metres and 9.8 metres.

Detailed documentation on the accident prediction models, Alberta collision rates, severity indices, assumptions used in the economic analysis, etc., is available in a report entitled Economic Analysis for Sideslope Flattening, prepared by the Technical Standards Branch.

Table G.C.1

ECONOMIC ANALYSIS - ROADSIDE IMPROVEMENT

Existing pavement width = 7.3 metres **170 AADT**
Reduced pavement width = 7.0 metres

Existing ditch configuration:	3:1 sideslope, 3:1 or 2:1 backslope, 3.0 metre ditch	**SI = 4.3**
Improved ditch configuration:	4:1 sideslope, 3:1 backslope, 3.5 metre trapezoidal ditch	**SI = 3.5**
Capital cost :	$ 20,000 per kilometer (both sides)	
Collision cost (for existing condition):	$108,396 per accident	
Collision cost (for improved condition):	$71,676 per accident	

Benefits accrued are reduction in collision costs and increase annually at the same rate as traffic (2% for first 10 years and 1% thereafter)

ANNUAL COSTS						NET ANNUAL UNDISC. VALUES			SUM OF P.W. @4% DISCOUNT RATE		IRR
No.	Year	3:1 SSL, 3.5:1 BSL CAP.	3:1 SSL, 3.5:1 BSL COLL $.	4:1 SSL, 3.5:1 BSL CAP.	4:1 SSL, 3.5:1 BSL COLL $.	CAP. COST DIFF.	R.U.C.	COST+RUC VALUES	CAPITAL	TOTAL	(guess) 30.00%
0	1992			20,000		(20,000)	0	(20,000)	(20,000)	(20,000)	
1	1993		2,451		1,145	0	1,305	1,305	(20,000)	(18,745)	-93.47%
2	1994		2,500		1,168	0	1,332	1,332	(20,000)	(17,514)	-70.73%
3	1995		2,549		1,191	0	1,358	1,358	(20,000)	(16,307)	-51.25%
4	1996		2,598		1,214	0	1,384	1,384	(20,000)	(15,124)	-37.37%
5	1997		2,647		1,237	0	1,410	1,410	(20,000)	(13,965)	-27.56%
6	1998		2,696		1,260	0	1,436	1,436	(20,000)	(12,830)	-20.46%
7	1999		2,745		1,283	0	1,462	1,462	(20,000)	(11,719)	-15.19%
8	2000		2,794		1,306	0	1,488	1,488	(20,000)	(10,632)	-11.19%
9	2001		2,843		1,329	0	1,514	1,514	(20,000)	(9,568)	-8.08%
10	2002		2,892		1,352	0	1,540	1,540	(20,000)	(8,527)	-5.62%
11	2003		2,916		1,363	0	1,553	1,553	(20,000)	(7,518)	-3.65%
12	2004		2,941		1,374	0	1,567	1,567	(20,000)	(6,539)	-2.06%
13	2005		2,966		1,386	0	1,580	1,580	(20,000)	(5,591)	-0.75%
14	2006		2,990		1,397	0	1,593	1,593	(20,000)	(4,671)	0.33%
15	2007		3,015		1,409	0	1,606	1,606	(20,000)	(3,779)	1.25%
16	2008		3,039		1,420	0	1,619	1,619	(20,000)	(2,915)	2.02%
17	2009		3,064		1,432	0	1,632	1,632	(20,000)	(2,077)	2.68%
18	2010		3,088		1,443	0	1,645	1,645	(20,000)	(1,266)	3.24%
19	2011		3,113		1,455	0	1,658	1,658	(20,000)	(479)	3.73%
20	2012		3,137		1,466	0	1,671	1,671	(20,000)	284	4.15%
21	2013		3,162		1,478	0	1,684	1,684	(20,000)	1,023	4.52%
22	2014		3,186		1,489	0	1,697	1,697	(20,000)	1,739	4.85%
23	2015		3,211		1,500	0	1,710	1,710	(20,000)	2,433	5.13%
24	2016		3,235		1,512	0	1,723	1,723	(20,000)	3,105	5.39%
25	2017		3,260		1,523	0	1,736	1,736	(20,000)	3,757	5.61%
26	2018		3,284		1,535	0	1,749	1,749	(20,000)	4,387	5.81%
27	2019		3,309		1,546	0	1,762	1,762	(20,000)	4,999	5.99%
28	2020		3,333		1,558	0	1,775	1,775	(20,000)	5,591	6.15%
29	2021		3,358		1,569	0	1,788	1,788	(20,000)	6,164	6.29%
30	2022		3,382		1,581	0	1,802	1,802	(20,000)	6,720	6.42%
31	2023		3,407		1,592	0	1,815	1,815	(20,000)	7,258	6.54%
32	2024		3,431		1,604	0	1,828	1,828	(20,000)	7,779	6.64%
33	2025		3,456		1,615	0	1,841	1,841	(20,000)	8,283	6.74%
34	2026		3,480		1,626	0	1,854	1,854	(20,000)	8,772	6.82%
35	2027		3,505		1,638	0	1,867	1,867	(20,000)	9,245	6.90%
36	2028		3,529		1,649	0	1,880	1,880	(20,000)	9,703	6.97%
37	2029		3,554		1,661	0	1,893	1,893	(20,000)	10,146	7.03%
38	2030		3,578		1,672	0	1,906	1,906	(20,000)	10,576	7.09%
39	2031		3,603		1,684	0	1,919	1,919	(20,000)	10,991	7.15%
40	2032		3,627		1,695	0	1,932	1,932	(20,000)	11,394	7.20%
41	2033		3,652		1,707	0	1,945	1,945	(20,000)	11,783	7.24%
42	2034		3,676		1,718	0	1,958	1,958	(20,000)	12,160	7.28%
43	2035		3,701		1,730	0	1,971	1,971	(20,000)	12,525	7.32%
44	2036		3,725		1,741	0	1,984	1,984	(20,000)	12,879	7.35%
45	2037		3,750		1,752	0	1,997	1,997	(20,000)	13,221	7.39%
46	2038		3,774		1,764	0	2,010	2,010	(20,000)	13,552	7.42%
47	2039		3,799		1,775	0	2,023	2,023	(20,000)	13,872	7.44%
48	2040		3,823		1,787	0	2,037	2,037	(20,000)	14,182	7.47%
49	2041		3,848		1,798	0	2,050	2,050	(20,000)	14,482	7.49%
50	2042		3,872		1,810	0	2,063	2,063	(20,000)	14,772	7.51%

Table G.C.2

ECONOMIC ANALYSIS - ROADSIDE IMPROVEMENT

Existing pavement width = 7.9 metres **195 AADT**
Reduced pavement width = 7.3 metres

Existing ditch configuration: 3:1 sideslope, 3:1 or 2:1 backslope, 3.0 metre ditch **SI = 4.3**
Improved ditch configuration: 4:1 sideslope, 3:1 backslope, 3.5 metre trapezoidal ditch **SI = 3.5**
Capital cost : $ 20,000 per kilometer (both sides)
Collision cost (for existing condition): $108,396 per accident
Collision cost (for improved condition): $71,676 per accident
Benefits accrued are reduction in collision costs and increase annually
at the same rate as traffic (2% for first 10 years and 1% thereafter)

ANNUAL COSTS						NET ANNUAL UNDISC. VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR
No.	Year	3:1 SSL, 3.5:1 BSL CAP.	COLL $.	4:1 SSL, 3.5:1 BSL CAP.	COLL $.	CAP. COST DIFF.	R.U.C.	COST+RUC VALUES	CAPITAL	TOTAL	(guess) 30.00%
0	1992			20,000		(20,000)	0	(20,000)	(20,000)	(20,000)	
1	1993		2,558		1,258	0	1,300	1,300	(20,000)	(18,750)	-93.50%
2	1994		2,609		1,283	0	1,326	1,326	(20,000)	(17,524)	-70.80%
3	1995		2,660		1,308	0	1,352	1,352	(20,000)	(16,322)	-51.33%
4	1996		2,711		1,333	0	1,378	1,378	(20,000)	(15,144)	-37.46%
5	1997		2,763		1,359	0	1,404	1,404	(20,000)	(13,990)	-27.64%
6	1998		2,814		1,384	0	1,430	1,430	(20,000)	(12,860)	-20.54%
7	1999		2,865		1,409	0	1,456	1,456	(20,000)	(11,754)	-15.27%
8	2000		2,916		1,434	0	1,482	1,482	(20,000)	(10,671)	-11.26%
9	2001		2,967		1,459	0	1,508	1,508	(20,000)	(9,611)	-8.15%
10	2002		3,018		1,484	0	1,534	1,534	(20,000)	(8,575)	-5.68%
11	2003		3,044		1,497	0	1,547	1,547	(20,000)	(7,570)	-3.72%
12	2004		3,070		1,510	0	1,560	1,560	(20,000)	(6,596)	-2.12%
13	2005		3,095		1,522	0	1,573	1,573	(20,000)	(5,651)	-0.81%
14	2006		3,121		1,535	0	1,586	1,586	(20,000)	(4,735)	0.28%
15	2007		3,146		1,547	0	1,599	1,599	(20,000)	(3,847)	1.19%
16	2008		3,172		1,560	0	1,612	1,612	(20,000)	(2,987)	1.97%
17	2009		3,198		1,573	0	1,625	1,625	(20,000)	(2,152)	2.63%
18	2010		3,223		1,585	0	1,638	1,638	(20,000)	(1,344)	3.19%
19	2011		3,249		1,598	0	1,651	1,651	(20,000)	(560)	3.68%
20	2012		3,274		1,610	0	1,664	1,664	(20,000)	199	4.11%
21	2013		3,300		1,623	0	1,677	1,677	(20,000)	935	4.48%
22	2014		3,325		1,635	0	1,690	1,690	(20,000)	1,648	4.80%
23	2015		3,351		1,648	0	1,703	1,703	(20,000)	2,339	5.09%
24	2016		3,377		1,661	0	1,716	1,716	(20,000)	3,009	5.34%
25	2017		3,402		1,673	0	1,729	1,729	(20,000)	3,657	5.57%
26	2018		3,428		1,686	0	1,742	1,742	(20,000)	4,286	5.77%
27	2019		3,453		1,698	0	1,755	1,755	(20,000)	4,894	5.95%
28	2020		3,479		1,711	0	1,768	1,768	(20,000)	5,484	6.11%
29	2021		3,504		1,723	0	1,781	1,781	(20,000)	6,055	6.25%
30	2022		3,530		1,736	0	1,794	1,794	(20,000)	6,608	6.38%
31	2023		3,556		1,749	0	1,807	1,807	(20,000)	7,144	6.50%
32	2024		3,581		1,761	0	1,820	1,820	(20,000)	7,663	6.60%
33	2025		3,607		1,774	0	1,833	1,833	(20,000)	8,165	6.70%
34	2026		3,632		1,786	0	1,846	1,846	(20,000)	8,652	6.79%
35	2027		3,658		1,799	0	1,859	1,859	(20,000)	9,123	6.86%
36	2028		3,684		1,812	0	1,872	1,872	(20,000)	9,579	6.93%
37	2029		3,709		1,824	0	1,885	1,885	(20,000)	10,020	7.00%
38	2030		3,735		1,837	0	1,898	1,898	(20,000)	10,448	7.06%
39	2031		3,760		1,849	0	1,911	1,911	(20,000)	10,862	7.11%
40	2032		3,786		1,862	0	1,924	1,924	(20,000)	11,263	7.16%
41	2033		3,811		1,874	0	1,937	1,937	(20,000)	11,651	7.21%
42	2034		3,837		1,887	0	1,950	1,950	(20,000)	12,026	7.25%
43	2035		3,863		1,900	0	1,963	1,963	(20,000)	12,390	7.29%
44	2036		3,888		1,912	0	1,976	1,976	(20,000)	12,742	7.32%
45	2037		3,914		1,925	0	1,989	1,989	(20,000)	13,082	7.35%
46	2038		3,939		1,937	0	2,002	2,002	(20,000)	13,412	7.38%
47	2039		3,965		1,950	0	2,015	2,015	(20,000)	13,731	7.41%
48	2040		3,990		1,962	0	2,028	2,028	(20,000)	14,039	7.44%
49	2041		4,016		1,975	0	2,041	2,041	(20,000)	14,338	7.46%
50	2042		4,042		1,988	0	2,054	2,054	(20,000)	14,627	7.48%

Table G.C.3

ECONOMIC ANALYSIS - ROADSIDE IMPROVEMENT

Existing pavement width = 8.5 metres **310 AADT**
Reduced pavement width = 7.9 metres

Existing ditch configuration:	3:1 sideslope, 3:1 or 2:1 backslope, 3.0 metre ditch	**SI = 4.3**
Improved ditch configuration:	4:1 sideslope, 3:1 backslope, 3.5 metre trapezoidal ditch	**SI = 3.5**
Capital cost :	20,000 $ per kilometer (both sides)	
Collision cost (for existing condition):	$108,396 per accident	
Collision cost (for improved condition)	$71,676 per accident	

Benefits accrued are reduction in collision costs and increase annually
at the same rate as traffic (2% for first 10 years and 1% thereafter)

ANNUAL COSTS						NET ANNUAL UNDISC. VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR
No.	Year	3:1 SSL, 3.5:1 BSL CAP.	3:1 SSL, 3.5:1 BSL COLL $.	4:1 SSL, 3.5:1 BSL CAP.	4:1 SSL, 3.5:1 BSL COLL $.	CAP. COST DIFF.	R.U.C.	COST+RUC VALUES	CAPITAL	TOTAL	(guess) 30.00%
0	1992			20,000		(20,000)	0	(20,000)	(20,000)	(20,000)	
1	1993		3,256		1,955	0	1,301	1,301	(20,000)	(18,749)	-93.50%
2	1994		3,321		1,994	0	1,327	1,327	(20,000)	(17,522)	-70.78%
3	1995		3,386		2,033	0	1,353	1,353	(20,000)	(16,319)	-51.32%
4	1996		3,451		2,072	0	1,379	1,379	(20,000)	(15,140)	-37.44%
5	1997		3,516		2,111	0	1,405	1,405	(20,000)	(13,986)	-27.62%
6	1998		3,582		2,151	0	1,431	1,431	(20,000)	(12,855)	-20.52%
7	1999		3,647		2,190	0	1,457	1,457	(20,000)	(11,747)	-15.26%
8	2000		3,712		2,229	0	1,483	1,483	(20,000)	(10,664)	-11.25%
9	2001		3,777		2,268	0	1,509	1,509	(20,000)	(9,603)	-8.13%
10	2002		3,842		2,307	0	1,535	1,535	(20,000)	(8,566)	-5.67%
11	2003		3,875		2,326	0	1,548	1,548	(20,000)	(7,560)	-3.70%
12	2004		3,907		2,346	0	1,561	1,561	(20,000)	(6,585)	-2.11%
13	2005		3,940		2,366	0	1,574	1,574	(20,000)	(5,640)	-0.80%
14	2006		3,972		2,385	0	1,587	1,587	(20,000)	(4,723)	0.29%
15	2007		4,005		2,405	0	1,600	1,600	(20,000)	(3,835)	1.20%
16	2008		4,037		2,424	0	1,613	1,613	(20,000)	(2,973)	1.98%
17	2009		4,070		2,444	0	1,626	1,626	(20,000)	(2,139)	2.64%
18	2010		4,103		2,463	0	1,639	1,639	(20,000)	(1,329)	3.20%
19	2011		4,135		2,483	0	1,652	1,652	(20,000)	(545)	3.69%
20	2012		4,168		2,502	0	1,665	1,665	(20,000)	215	4.12%
21	2013		4,200		2,522	0	1,678	1,678	(20,000)	951	4.49%
22	2014		4,233		2,542	0	1,691	1,691	(20,000)	1,665	4.81%
23	2015		4,265		2,561	0	1,704	1,704	(20,000)	2,356	5.10%
24	2016		4,298		2,581	0	1,717	1,717	(20,000)	3,026	5.35%
25	2017		4,330		2,600	0	1,730	1,730	(20,000)	3,676	5.58%
26	2018		4,363		2,620	0	1,743	1,743	(20,000)	4,304	5.78%
27	2019		4,396		2,639	0	1,756	1,756	(20,000)	4,913	5.96%
28	2020		4,428		2,659	0	1,769	1,769	(20,000)	5,503	6.12%
29	2021		4,461		2,678	0	1,782	1,782	(20,000)	6,075	6.26%
30	2022		4,493		2,698	0	1,795	1,795	(20,000)	6,629	6.39%
31	2023		4,526		2,717	0	1,808	1,808	(20,000)	7,165	6.51%
32	2024		4,558		2,737	0	1,821	1,821	(20,000)	7,684	6.61%
33	2025		4,591		2,757	0	1,834	1,834	(20,000)	8,187	6.71%
34	2026		4,624		2,776	0	1,847	1,847	(20,000)	8,674	6.79%
35	2027		4,656		2,796	0	1,860	1,860	(20,000)	9,145	6.87%
36	2028		4,689		2,815	0	1,873	1,873	(20,000)	9,602	6.94%
37	2029		4,721		2,835	0	1,886	1,886	(20,000)	10,044	7.01%
38	2030		4,754		2,854	0	1,899	1,899	(20,000)	10,471	7.07%
39	2031		4,786		2,874	0	1,912	1,912	(20,000)	10,886	7.12%
40	2032		4,819		2,893	0	1,925	1,925	(20,000)	11,287	7.17%
41	2033		4,851		2,913	0	1,938	1,938	(20,000)	11,675	7.21%
42	2034		4,884		2,933	0	1,952	1,952	(20,000)	12,051	7.26%
43	2035		4,917		2,952	0	1,965	1,965	(20,000)	12,415	7.29%
44	2036		4,949		2,972	0	1,978	1,978	(20,000)	12,767	7.33%
45	2037		4,982		2,991	0	1,991	1,991	(20,000)	13,107	7.36%
46	2038		5,014		3,011	0	2,004	2,004	(20,000)	13,437	7.39%
47	2039		5,047		3,030	0	2,017	2,017	(20,000)	13,756	7.42%
48	2040		5,079		3,050	0	2,030	2,030	(20,000)	14,065	7.44%
49	2041		5,112		3,069	0	2,043	2,043	(20,000)	14,364	7.46%
50	2042		5,144		3,089	0	2,056	2,056	(20,000)	14,654	7.49%

Table G.C.4

ECONOMIC ANALYSIS - ROADSIDE IMPROVEMENT

Existing pavement width = 9.8 metres **340 AADT**
Reduced pavement width = 9.2 metres

Existing ditch configuration: 3:1 sideslope, 3:1 or 2:1 backslope, 3.0 metre ditch **SI = 4.3**
Improved ditch configuration: 4:1 sideslope, 3:1 backslope, 3.5 metre trapezoidal ditch **SI = 3.5**
Capital cost : 20,000 $ per kilometer (both sides)
Collision cost (for existing condition): $108,396 per accident
Collision cost (for improved condition) $71,676 per accident
Benefits accrued are reduction in collision costs and increase annually
at the same rate as traffic (2% for first 10 years and 1% thereafter)

ANNUAL COSTS						NET ANNUAL UNDISC. VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR
No.	Year	3:1 SSL, 3.5:1 BSL CAP.	3:1 SSL, 3.5:1 BSL COLL $.	4:1 SSL, 3.5:1 BSL CAP.	4:1 SSL, 3.5:1 BSL COLL $.	CAP. COST DIFF.	R.U.C.	COST+RUC VALUES	CAPITAL	TOTAL	(guess) 30.00%
0	1992			20,000		(20,000)	0	(20,000)	(20,000)	(20,000)	
1	1993		3,206		1,901	0	1,305	1,305	(20,000)	(18,745)	-93.48%
2	1994		3,270		1,939	0	1,331	1,331	(20,000)	(17,515)	-70.73%
3	1995		3,334		1,977	0	1,357	1,357	(20,000)	(16,308)	-51.26%
4	1996		3,398		2,015	0	1,383	1,383	(20,000)	(15,126)	-37.38%
5	1997		3,462		2,053	0	1,409	1,409	(20,000)	(13,967)	-27.56%
6	1998		3,527		2,091	0	1,436	1,436	(20,000)	(12,833)	-20.47%
7	1999		3,591		2,129	0	1,462	1,462	(20,000)	(11,722)	-15.20%
8	2000		3,655		2,167	0	1,488	1,488	(20,000)	(10,635)	-11.20%
9	2001		3,719		2,205	0	1,514	1,514	(20,000)	(9,571)	-8.08%
10	2002		3,783		2,243	0	1,540	1,540	(20,000)	(8,531)	-5.62%
11	2003		3,815		2,262	0	1,553	1,553	(20,000)	(7,522)	-3.66%
12	2004		3,847		2,281	0	1,566	1,566	(20,000)	(6,544)	-2.07%
13	2005		3,879		2,300	0	1,579	1,579	(20,000)	(5,596)	-0.76%
14	2006		3,911		2,319	0	1,592	1,592	(20,000)	(4,676)	0.33%
15	2007		3,943		2,338	0	1,605	1,605	(20,000)	(3,785)	1.24%
16	2008		3,975		2,357	0	1,618	1,618	(20,000)	(2,921)	2.01%
17	2009		4,008		2,376	0	1,631	1,631	(20,000)	(2,084)	2.67%
18	2010		4,040		2,395	0	1,644	1,644	(20,000)	(1,272)	3.24%
19	2011		4,072		2,414	0	1,657	1,657	(20,000)	(485)	3.72%
20	2012		4,104		2,433	0	1,670	1,670	(20,000)	277	4.15%
21	2013		4,136		2,452	0	1,683	1,683	(20,000)	1,016	4.52%
22	2014		4,168		2,471	0	1,697	1,697	(20,000)	1,732	4.84%
23	2015		4,200		2,490	0	1,710	1,710	(20,000)	2,425	5.13%
24	2016		4,232		2,509	0	1,723	1,723	(20,000)	3,097	5.38%
25	2017		4,264		2,528	0	1,736	1,736	(20,000)	3,748	5.61%
26	2018		4,296		2,547	0	1,749	1,749	(20,000)	4,379	5.81%
27	2019		4,328		2,566	0	1,762	1,762	(20,000)	4,990	5.99%
28	2020		4,360		2,585	0	1,775	1,775	(20,000)	5,582	6.14%
29	2021		4,392		2,604	0	1,788	1,788	(20,000)	6,155	6.29%
30	2022		4,424		2,623	0	1,801	1,801	(20,000)	6,710	6.42%
31	2023		4,456		2,642	0	1,814	1,814	(20,000)	7,248	6.53%
32	2024		4,488		2,661	0	1,827	1,827	(20,000)	7,769	6.64%
33	2025		4,520		2,680	0	1,840	1,840	(20,000)	8,273	6.73%
34	2026		4,553		2,699	0	1,853	1,853	(20,000)	8,762	6.82%
35	2027		4,585		2,718	0	1,866	1,866	(20,000)	9,235	6.90%
36	2028		4,617		2,737	0	1,879	1,879	(20,000)	9,693	6.97%
37	2029		4,649		2,756	0	1,892	1,892	(20,000)	10,136	7.03%
38	2030		4,681		2,775	0	1,905	1,905	(20,000)	10,565	7.09%
39	2031		4,713		2,794	0	1,918	1,918	(20,000)	10,981	7.14%
40	2032		4,745		2,813	0	1,931	1,931	(20,000)	11,383	7.19%
41	2033		4,777		2,832	0	1,944	1,944	(20,000)	11,772	7.24%
42	2034		4,809		2,852	0	1,958	1,958	(20,000)	12,149	7.28%
43	2035		4,841		2,871	0	1,971	1,971	(20,000)	12,514	7.32%
44	2036		4,873		2,890	0	1,984	1,984	(20,000)	12,867	7.35%
45	2037		4,905		2,909	0	1,997	1,997	(20,000)	13,209	7.38%
46	2038		4,937		2,928	0	2,010	2,010	(20,000)	13,540	7.41%
47	2039		4,969		2,947	0	2,023	2,023	(20,000)	13,860	7.44%
48	2040		5,001		2,966	0	2,036	2,036	(20,000)	14,170	7.46%
49	2041		5,033		2,985	0	2,049	2,049	(20,000)	14,470	7.49%
50	2042		5,065		3,004	0	2,062	2,062	(20,000)	14,760	7.51%

APPENDIX D

RATIONALE FOR TABLE G.7
SUGGESTED MINIMUM RADII FOR SUPERELEVATION RATES ON 3R/4R PROJECTS

This table was developed based on the following principles:

1. On flatter curves and curves of medium radius; that is, where the superelevation rate for new construction is less than 0.04m / m, the factor of safety against side-slip is high and f_{demand} at design speed is relatively low. Therefore, a 0.02m / m tolerance in the superelevation rate is allowed.

2. On sharper curves, where the superelevation rate for new construction is between 0.04m / m and 0.06m / m, the allowable variance from design superelevation is gradually reduced as the radius is decreased. At e=0.06m / m (which is the minimum radius for new construction) the superelevation rate suggested on 3R projects is the same as that required on new construction. This is because f_{demand} at this radius is equal to the theoretical maximum safe-side friction factor for this speed (based primarily on comfort considerations).

3. On curves that are sharper than the R_{min} used for new construction, it is important to restrict the f_{demand} to f_{max} (the maximum safe-side friction factor) where possible. Therefore, the superelevation rate is increased up to 0.08m / m as required for sharper curves.

4. Because 0.08m / m is considered a practical maximum for superelevation on Alberta highways, e is not increased beyond this point. However, because it is recognized that existing curves with radii below the R_{min} for new construction can provide good service and have reasonable safety records, a lower R_{min} is suggested for existing paved roads. Even the R_{min} suggested for 3R projects should not be interpreted as an absolute minimum radius but rather as a benchmark value. Radii below the benchmark value should routinely be evaluated for realignment. However, in many cases especially on lower volume highways, realignment may not be cost effective. Overlay of the existing alignment even with curves sharper than R_{min}, possibly with the addition of speed advisory signs where warranted should not be ruled out. This may be the most viable alternative in some cases when all factors, including construction costs, road user costs and collision costs are considered. The following recommendation is published in the U.S. Transportation Research Board's (TRB) Special Report 214 Highway agencies should evaluate reconstruction of horizontal curves when the design speed of the existing curve is more than 15 m.p.h. (24 km / h) below the running speed of approaching vehicles (assuming improved superelevation cannot reduce this difference to less than 15 m.p.h.) and the average daily traffic volume is greater than 750 vehicles per day. Alberta's guideline differs from TRBs in that no speed differential is used and because all highways with sharp curvature are recommended for evaluation, not just those with volumes exceeding 750 vehicles per day.

The following summary lists the rules used to set up the values for R_{min} for each superelevation rate for V_{85} = 110 km / h. Similar rules were used for the other speeds.

e_{3R} for V85 = 110 km/h (85th percentile speed)

NC allowed until f_{demand}	= 0.02±e, (f=0.04 for 0.02+e, f=0.00 for 0.02-e)
RC allowed until f_{demand}	= 0.03 R=1900
e = 0.03 allowed until f_{demand}	= 0.043 R=1300
e = 0.04 allowed until f_{demand}	= 0.05 R=1060
e = 0.05 allowed until f_{demand}	= 0.07 R=800
e = 0.06 allowed until f_{demand}	= 0.10 R=600 (f_{max}) new construction
e = 0.07 allowed until f_{demand}	= 0.10 R=560
e3R = 0.08 allowed until fdemand	= 0.10 R=530