University of Southern Queensland
Faculty of Engineering and Surveying

CLEAR ZONES IN URBAN ENVIRONMENTS

A dissertation submitted by

Mr Tony Gallagher

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ABSTRACT

Run off road accidents are global problems, with fatal and serious injuries reported for speeds of 40 km/hour and above. Frequency and severity of these injuries can be significantly impacted by providing a safe roadside environment. This can be achieved by ensuring the area adjacent to the roadside is free of obstacles, hazards and distractions and is designed to maximise drivers' opportunity to regain control of an errant vehicle. A "clear zone" is the total width from the traffic lane edge required to be clear of roadside hazards.

A variety of hazards may occur within the specified clear zone including point and continuous hazards. There is still some conjecture about the diameter size of trees and poles to be classified as hazards. A hierarchy of treatments exists with six different methods recommended. Practicalities of treatments in urban areas must be considered.

Questions arise about the classification of hazards and the inherent risks associated with their presence, including the treatment of new infrastructure versus current treatments of existing rigid objects and potential hazards in specified clear zones

To meet legal requirements, road authorities must fulfil their duty of care to road users. They must not create a foreseeable risk of harm and are obliged to take reasonable steps to remedy an existing risk within a reasonable time. The court recognises that resources are limited, including man power and funding. Road authorities need methods in place to prioritise projects to address safety issues.

Quantitative and qualitative assessments are required to prioritise and assess the engineering, environmental and social ramifications of safety concerns and proposed treatments. Designers and engineers are reluctant to make subjective decisions that may not be supported by standards. Practical treatment solutions must be 'fit for purpose'. The conclusion of this paper provides tools that designers and engineers can use to assist the evaluation process.

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ENG4111 Research Project Part 1 and
ENG4112 Research Project Part 2

Limitations of Use

CANDIDATE'S CERTIFICATION

I certify that the ideas, designs and experimental work, results, analysis and conclusions set out in this dissertation are entirely my own efforts, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Tony Gallagher

Student Number: Q8042318

Signature

Date

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
Benefit Cost Ratio (BCR)	The ratio of the estimated benefits to be derived from a specific course of action divided by the costs of implementing that action.
Breakaway	A device that allows an object such as a sign, or luminare, to yield or separate upon impact
Carriageway	The portion of the road formation, including lanes, auxiliary lanes and shoulders that is set aside for the use of vehicles, either moving or stationary.
Clear Zone	The border area that begins at the edge of each travelled lane and is available for emergency use by errant vehicles that run off the road. This zone includes any adjoining lane/s, road shoulder, verge and batter.
Distributed Objects	Known as 'continuous obstacles'. They are potential hazards which extend along a length of roadside
End Treatment	The designed modification at the end of a roadside or median safety barrier
Frangible	A type of structure that is readily or easily broken upon impact.
Gating end treatment	A gating treatment will breakaway upon collision and allow a vehicle to pass through the end treatment.
Lateral Offset	The offset from a specified portion of the roadway. This is usually the perpendicular distance from the edge of that adjacent carriageway to the point being investigated
Length of Need	The total length of longitudinal safety barrier needed to shield an area of concern
Misfeasance	Work that was conducted on a road surface, but

conducted negligently.

Non-feasance	Failing to do a task in relation to the condition of roads and roadside footpaths
Non-gating end treatment	A non-gating treatment does not allow vehicles to pass through the end treatment. The terminal re-directs the vehicle away from the barrier or be arrested by the barrier
Non-recoverable Slope	A non-recoverable slope is one on which a vehicle is likely to overturn and can be considered as a hazard in itself. Embankment slopes steeper than 1 on 3 are considered non-recoverable.
Operating Speed	Is the 85^{th} percentile speed. This is the speed at, which 85% of cars are observed to travel under free flowing conditions past a nominated point
Point Objects	Point Hazards are permanent hazards of fairly limited length
Recoverable Slope	A slope on which a motorist will probably retain control of a vehicle. Slopes 1 on 4 or flatter are generally considered recoverable.
RISC	Roadside Impact Severity Calculator program.
RSAP	Roadside Safety Analysis Program
Travelled way	The portion of the carriageway that is assigned to moving traffic, excluding shoulders and parking lanes

"Could you have avoided this tragedy?"

"Are your actions or inactions responsible?"


1. Introduction

The problem of death and serious injury resulting from road accidents is a global phenomenon. Authorities in virtually all countries are concerned about the growth in the number of people killed and seriously injured on their roads, and the resultant cost in both dollars and personal tragedy.

The relevance of single vehicle run-off-road accidents as a traffic safety issue can be demonstrated as detailed in a review of European accident data. In 1998, 33.8% of all fatalities in the European Union were attributed to single vehicle collisions (Dupre & Bisson, 2006).

Queensland Department of Main Roads reports that an unforgiving roadside environment is a major contributor to the amount of people killed or seriously injured on Queensland Roads. In the five-year period leading up to June 2005, approximately one third of fatal crashes and about 16% of the total number of people killed and seriously injured, involved vehicles which ran off the travelling way or road, and hit an unforgiving object or hazard.

The Victorian State Roads Authority states that every year there are over 800 casualty crashes in Victoria involving utility poles. Of these crashes, 80% occur at intersections. Accidents involving utility poles represent approximately 5% of all casualty crashes in Victoria. Further, *fatal* utility pole crashes represent 9%

of all fatal crashes. In the metropolitan area, while utility pole crashes represent 5% of overall casualty crashes, they represent a staggering 14% of all fatal casualty crashes (VicRoads, 2007).

The Roadside Infrastructure for Safer European Roads (RISER) accident database states that the most severe accident configurations are collisions with trees and poles. Fatal and serious injuries as a result of these collisions are reported where impact speeds are 40 km/hr and above (Dupre & Bisson, 2006).

Any road traffic system has a degree of complexity and is potentially hazardous to the health of travelling motorists. Elements of the overall system include the motor vehicles, roads and road users, and their physical, social and economic environments. To make the road system less hazardous, a "systems approach" is required; understanding the system as a whole and identifying where there is potential for intervention. In particular, it requires recognising and understanding human nature as it is. Humans are prone to lapses of concentration and making mistakes. The human body is also vulnerable to the consequences of this human error – possibly injury or death. A safe road traffic system is one that accommodates and compensates for human error and vulnerability.

Regardless of the reason for a vehicle leaving the roadway, a roadside environment free of fixed objects with stable, flattened slopes, enhances the chances of eliminating serious crashes, or at least reducing crash severity. The forgiving roadside concept provides a safer environment for errant vehicles leaving the roadway. The key is a roadside design which reduces or eliminates the likelihood of serious consequences for these incidents.

A safe roadside environment can be achieved by ensuring that an adequate area is provided adjacent to the roadside that is free of obstacles, hazards and distractions and designed in such a way that drivers have the opportunity to regain control of an errant vehicle. **A clear zone is therefore the total width from the traffic lane edge required to be clear of roadside hazards**. This width is required to enable drivers to recover and regain control of their errant vehicle in an emergency situation where the motorist has unexpectedly left the roadway. Solid objects that are located within the clear zone can often convert a loss of control situation that could otherwise have a harmless outcome, into a serious or potentially fatal crash. The clear zone width depends on a number of factors which will be investigated and documented in this paper. Factors usually considered in the determination of clear zone widths include, but are not restricted to, traffic speed, traffic volumes, batter slopes, extent and size of hazards, visibility and roadside geometry.

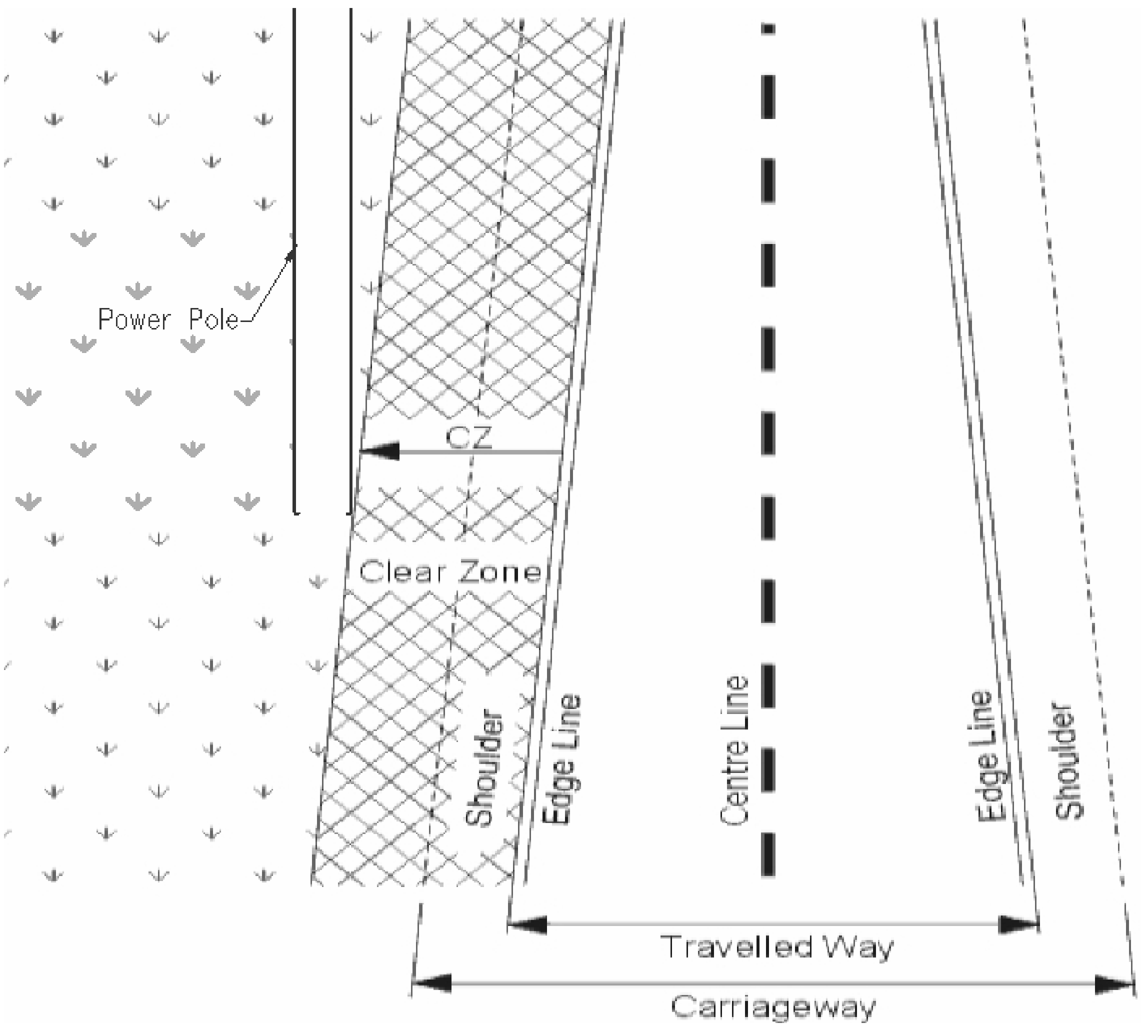

Figure 1-1 Clear Zone Definitions

There are many reasons why a vehicle could leave the travelling way and encroach on the roadside, including:

- driver fatigue or inattention;
- excessive speed;
- driving under the influence of drugs or alcohol;
- crash avoidance (with either another vehicle or an object on the travelling way);
- roadway conditions such as ice, snow or rain;
- vehicle component failure;
- poor visibility; and
- misunderstanding or misinterpreting the traffic guidance system.

The clear zone concept originated in the United States of America and has been adopted with different approaches around the world. Approaches used depend on land availability and design policy. The clear zone is usually a compromise between 3 variable and independent parameters:

- the recovery area required for an errant vehicle;
- the cost of providing that area; and
- the probability of an errant vehicle encountering a hazard.

According to the Road Hazard Management Guide of Tasmania, the ideal roadside environment would be completely free of any obstructions to the safe passage of errant vehicles. Such a roadside would drastically reduce injuries in run-off-road crashes; it would provide drivers enough capacity to recover and regain control of their vehicles. They could either stop safely, without colliding with any objects or over-turning the vehicle, or they could safely re-enter the travelling way. However, it is rarely possible or practical to construct a roadside environment completely free of hazards. There is usually a requirement for roadside guidance signage, utility poles and other roadside furniture. Further, the topography of the finished landscape often necessitates cut or fill embankments. These factors all contribute to the overall makeup of the roadside and the potential for a hazard free clear zone (Department of Infrastructure Energy & Resources Tasmania, date unknown).

Engineers and designers are continually faced with decisions regarding objects that exist or are proposed in a clear zone. The placement of new rigid objects such as street lighting poles, trees in landscaping, gantry posts and power poles regularly causes confusion. Questions arise about whether they should be classified as hazards and about the inherent risks associated with their presence. Various flow-on effects are debated, such as the need to install protective barriers, or alternatively, to provide slip base systems. The question often asked, is why new infrastructure should be treated any differently to the many existing rigid objects and potential hazards located within specified clear zones. As a result of this confusion and variance in ideas and opinions, there are increasing inconsistencies exist on our road networks. A certain post situated at one location may be protected by guardrail while others in similar situations are totally unprotected.

Usually, standards are not sufficiently clear in this regard, and often the wording used is either obscure or open to misinterpretation. This leads to implementation confusion and nervousness about legal liability issues. Decisions are often governed by the degree of risk the designer is prepared to accept. Some extracts from the various standards that could be used to justify the presence of rigid objects close to roadside environments are:

> *"Criteria and procedures outlined in this section (chapter 8) are not a substitute for, but can assist engineering judgement. The unique circumstances of each location and the amount of funds available for road improvement must be considered when treating roadside hazards."*
>
> (Queensland Main Roads Roads, 2005, chapter 8).

> *"Clear zones are intended as a guide to by which practitioners can assess sites, not a prescriptive value. Practitioners may provide a greater or lesser width depending on the risk factors applying to a particular site."*

(Department of Infrastructure Energy & Resources Tasmania, date unknown).

Although the above general statements exist in the standards, designers rarely use or rely on them to justify or defend their design decisions. Designers are more likely to be conscious and concerned about their obligations to discharge their duty, usually resulting in appropriate use of the standards. Ultimately, this produces a safe and defendable design that does not leave either the design or the relevant authority open to vicarious liability for any negligent actions. So, although the standards contain a high degree of subjectivity, human nature tends to favour the conservative side, rather than relying strictly on the standards to justify less than favourable assessments. Therefore, often engineering judgement is not used and the most costly solution is implemented. Decision makers are often unaware of how courts will react if an accident occurs.

The Austroads Urban Road Design Manual (2003) states that while the concept of clear zones is widely accepted as the most appropriate method for determining width for various road conditions it is constantly debated amongst practitioners. There needs to be further research into this area to confirm the risk associated with the differences to the clear zone widths.

Therefore, the aim of this project is to provide engineers and designers with the tools to quickly and confidently assess the risk of roadside hazards and to determine an appropriate treatment that is fit for purpose.

1.1 Methodology

The methodology employed in the research includes the following.

1. Research the background information relating to the identification and treatment of roadside hazards, and in particular the use of clear zones.
2. Research and evaluate available methods used for risk assessment of roadside hazards, particularly in an urban environment.

3. Research the protective measures used for roadside hazards, particularly those which are applicable in urban situations.
4. Determine the legal requirements and likely ramifications for a road authority when a vehicle impacts a hazard that is within a specified clear zone.
5. Determine and test a suitable procedure for the evaluation and treatment of roadside hazards in urban environments.

2. Literature Review

2.1 Hazard Identification

Main Roads Western Australia, Assessment of Roadsides Hazards (2006)

The Main Roads Department in Western Australia classifies roadside hazards into two categories; point hazards and continuous hazards.

Point Hazards are permanent hazards of fairly limited length. These types of hazards include:

- trees over 100mm in diameter;
- bridge end posts and piers;
- large planters;
- hazardous mail boxes or landscape features;
- non-breakaway signs;
- inappropriate slip bases on signs;
- protruding footings (including those for breakaway signs);
- non-traversable driveway headwalls;
- non-traversable culvert headwalls;
- fixed objects in the drain line;
- utility poles;
- end treatments to guardrails;
- walls or corners of walls; and
- hydrant bases more than 100m high.

It should be noted that while trees less than 100mm in diameter within the clear zone are not considered to be point hazards, they should still be removed from the clear zone as they can grow to become potential hazardous in the future. Multiple trees less than 100mm in diameter may also be hazardous if they are spaced less than

2.1m apart. This is relevant to existing vegetation and substantial shrubs that may be planted as part of a landscaping treatment.

Continuous hazards differ from point hazards in that they are of considerable length and therefore it is generally less practical to remove or relocate them. When located within the clear zone they are considered to be hazards. However, they may also be a significant hazard when situated beyond the clear zone. The length of the hazard increases the likelihood that an errant vehicle may collide with it, and some hazards (for example, cliffs) have a high crash severity regardless of the speed of the errant vehicle. Examples of continuous hazards include:

- dense woods;
- rows of large trees;
- steep embankments (i.e. that have a critical slope or non-recoverable slope);
- rock outcrops or boulders intermixed with trees;
- rock cuttings;
- cliffs or precipitous drop-offs;
- bodies of water, including streams and channels over 0.6m deep;
- unshielded hazards such as cliffs or bodies of water that are beyond the desired minimum clear zone, but are likely to be reached by an errant vehicle;
- protective treatment such as guardrail;
- retaining walls;
- fences with rail that can spear vehicles.

Queensland Department of Main Roads, Road Planning and Design Manual (2005)

The Queensland Department of Main Roads assigns weighted severity index to roadside objects. This index is related to the vehicles speed at impact, impact angle, size, deformability and fixity. Objects that are not considered in the high severity category are:

- sign support posts which are circular hollow section (CHS) less than 65mm diameter;

- slip base pole;
- traffic signal pole;
- trees and shrubs with ultimate truck diameter less than 80mm in diameter;
- wooden objects less than 80mm diameter.

<u>Roadside Infrastructure for Safer European Roads (RISER)</u> (Dupre & Bisson, 2006)

The RISER statistical database holds nearly 265 000 single vehicle accident cases derived from seven European countries (Austria, Finland, France, the Netherlands, Spain, Sweden and the United Kingdom). In 67% of these cases, it was known that the vehicle struck an object.

<u>Tree Impacts Only</u>

The narrowest tree diameter involved in a fatal collision was 0.3m (0.2m where no seatbelt was worn) and the largest set-back distance from the edge of the road was 6.8m (10.8m where no seatbelt was worn). All fatal accidents involved impact speeds of 70km/h or greater (where speed data was known). When serious accidents were also included, impact speeds were 40km/h or greater.

<u>Post/Pole Impacts Only</u>

In accidents involving posts and poles, posts/poles as narrow as 0.2m were impacted (0.11m where no seatbelt was worn), resulting in death or serious injury. Impact speeds in serious and fatal accidents were 40km/h or above. Fatal accidents involving posts/poles were more often side impacts than frontal impacts.

<u>Posts and Poles</u>

Posts and poles on the roadside of varying types were also considered as hazards in a number of the countries. In Great Britain and Finland, traffic sign supports with a minimum diameter of 0.09m and 0.11m respectively are considered as hazards. In

Spain, trees and poles over 0.15m diameter are hazards depending on the distance to the carriageway edge line

Point versus Distributed Objects

The objects identified in RISER databases as *hazardous* objects, are those which, when impacted, can lead to serious occupant injuries. These objects are divided into 'point' and 'distributed' objects.

Point Objects are narrow items in the roadside that could be stuck in a collision. Examples include trees, all types of bridge supports, lighting poles, utility poles, sign posts and terminations of barriers.

Distributed Objects are a known as 'continuous obstacles'. They are potential hazards which extend along a length of roadside. Examples include all types of embankments, ditches, rock face cuttings, retaining walls, safety barriers not meeting current standards, forest and closely spaced trees.

2.2 Adopted Clear Zone Widths

2.2.1. American Association of State Highway and Transportation Officials (AASHTO, 2002)

The Roadside Design Guide selection of a clear zone width is based on empirical data using traffic volumes, speed & roadside geometry. Figure 2-1 provides the clear zone distance curves developed through research by AASHTO used to determine the clear zone width.

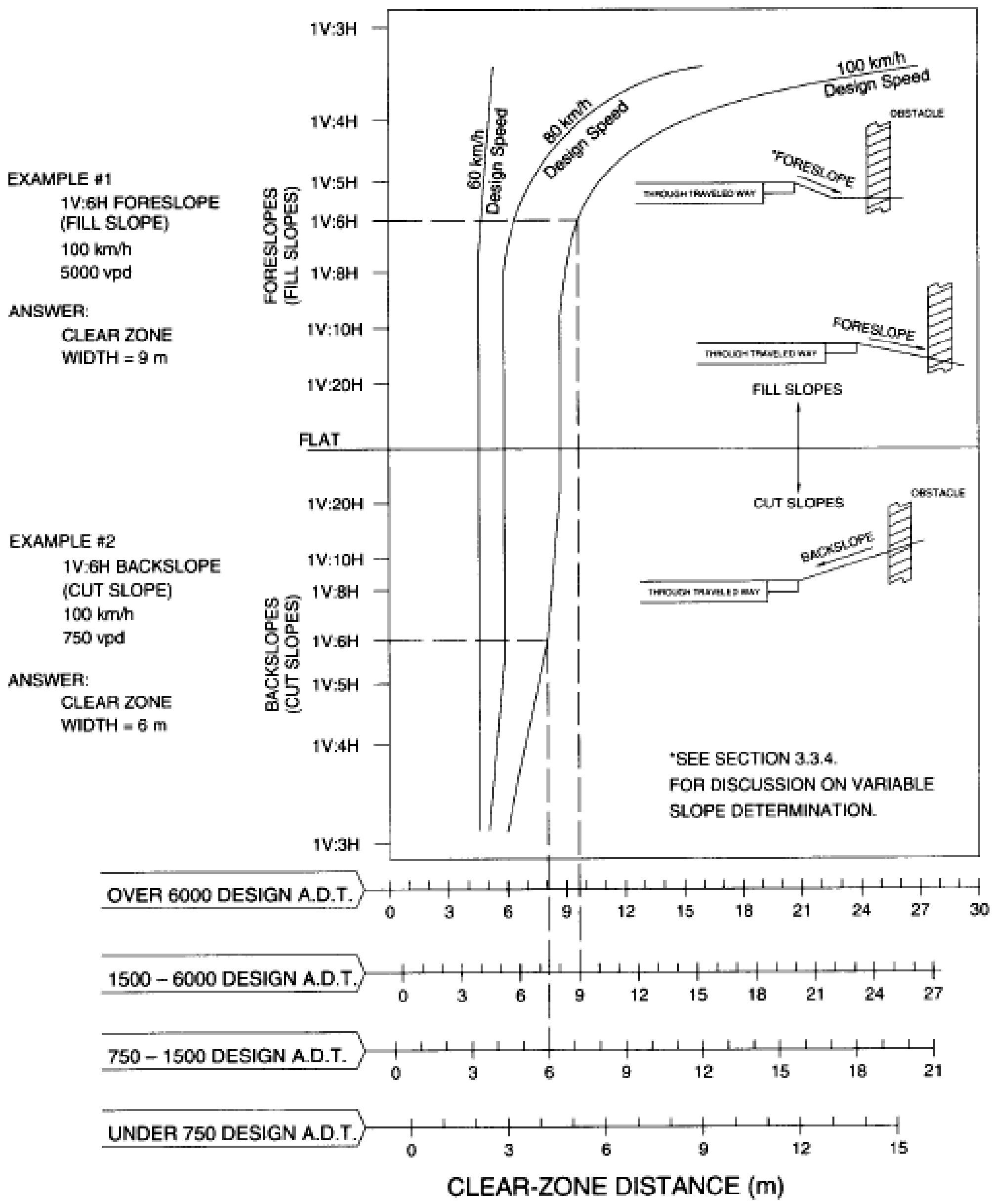

Figure 2-1 Clear Zone Distance Curves

(AASHTO, 2002)

Based on these figures, for a 60km/hr zone with a flat roadside representing a footpath, the required clear zones for various Average Annual Daily Traffic (AADTs) are shown in Table 2-1.

Table 2-1 AASHTO Clear Zone Widths

AADT	Width (m)
<750	2.0 -3.0
750 – 1500	3.0 - 3.5
1500 – 6000	3.5 – 4.5
>6000	4.5 – 5.0

(AASHTO, 2002)

The Guide suggests that from distances obtained from the figure, only the approximate centre of the range should be considered and not a precise distance to be held as absolute. The width may be modified to take into account the horizontal curvature. This modification is normally only considered when crash histories indicate a need, or when a site investigation shows a definitive crash potential. Table ?? provides the proposed adjustment required.

Table 2-2 Curve Correction Factors

(AASHTO, 2002)

K_{cz} (Curve Correction Factor) (Metric Units)

RADIUS (m)	DESIGN SPEED (km/h)					
	60	70	80	90	100	110
900	1.1	1.1	1.1	1.2	1.2	1.2
700	1.1	1.1	1.2	1.2	1.2	1.3
600	1.1	1.2	1.2	1.2	1.3	1.4
500	1.1	1.2	1.2	1.3	1.3	1.4
450	1.2	1.2	1.3	1.3	1.4	1.5
400	1.2	1.2	1.3	1.3	1.4	—
350	1.2	1.2	1.3	1.4	1.5	—
300	1.2	1.3	1.4	1.5	1.5	—
250	1.3	1.3	1.4	1.5	—	—
200	1.3	1.4	1.5	—	—	—
150	1.4	1.5	—	—	—	—
100	1.5	—	—	—	—	—

Embankment slopes are defined as:

- "recoverable" if they are flatter than 1 on 4;
- "non–recoverable" for slopes between 1 on 3 and 1 on 4; and
- "critical" for slopes greater than 1 on 3.

For slopes classified as recoverable, no adjustment to the clear zone width is required. If a slope is classified non-recoverable, vehicles will be unable to recover and rejoin the carriageway. Generally, vehicles do not roll, but continue to traverse the embankment until either coming to a stop, or reaching the toe of the embankment. In this case, a clear runout area beyond the toe of the recoverable batter slope is desired. The extent of the clear runout area is determined by subtracting from the recommended clear zone distance, the available distance from the edge of the travelled way to the start of the non-recoverable slope. The result is the desirable clear runout that should be provided beyond the toe of the batter, if practical.

2.2.2. The Queensland Department of Main Roads, Road Planning and Design Manual (2005)

The RPDM has adopted the methodology outlined by AASHTO when determining the clear zone widths. Main Roads also state that the designer may choose to adjust the clear zone width for the effect of horizontal curvature by using an adjustment factor obtained from Figure 2-2.

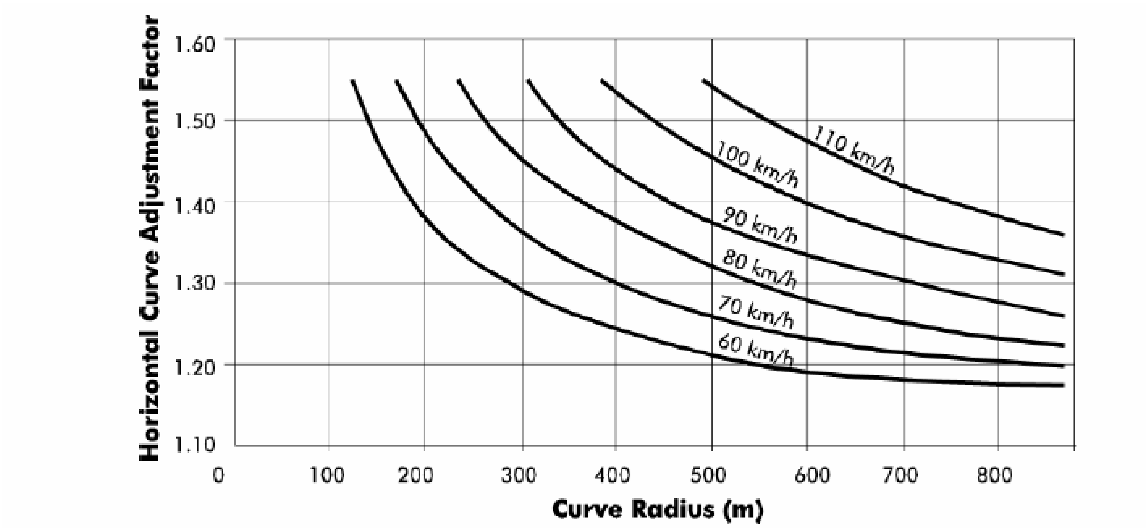

Figure 2-2 Clear Zone Adjustment Curves

(Queensland Department of Main Roads, 2005, Chapter 8)

An adjusted offset is recommended for rigid objects when positioned on non-recoverable embankment slopes. The actual offset to a rigid object is adjusted to reflect a new effective offset

Adjusted offset = (Es x offset) + (distance from edge line to hinge point)

Where:

Es	is	adjustment offset factor for slope – Es = 1 + s/f
s	is	slope (negative for fill slope), expressed as a ratio, eg. 1 on 4 = 0.25
f	is	braking and cornering coefficient of friction (0.4)

2.2.3. **Roadside Infrastructure for Safer European Roads (RISER)** (Dupre & Bisson, 2006)

A review of several European countries in RISER provided seven main criteria used to specify the dimensions for the safety zone. The main parameters of interest are:

1. Road Type – the class of road (motorway, national road, divided or non divided traffic lanes, et cetera);
2. Traffic – the volume and mix of traffic observed on the road usually expressed in Annual Average Daily Traffic (AADT) and percentage of heavy vehicles;
3. Speed – the design speed is usually the most common speed used for designing the road, but redesign of existing roads should use observed speeds unless they are less than the design speed;
4. Side Slope – the characteristics of the slopes adjacent to the roadway, typically the gradient and height of the slope;
5. Horizontal alignment – separate criteria may be considered for straight and curved sections;
6. Driving lane width – lateral width of the travel lane(s). Note that this is often associated with road type;
7. Other – many modifications of the safety zone width may result from the location of bodies of water, industrial areas, residential areas and railway lines et cetera.

Table 2-3 below lists the recommended safety zone width for the following road, speed and slope conditions.

- Coefficient Of Friction 0.3 (Wet Grass) [μ].
- Initial Manoeuvre On The Road Was Abrupt Steering.

- Vehicles Decelerate On Roadside Without Manoeuvre. For a vehicle running off the road the worst case is a friction coefficient of 0.3 for wet grass resulting in an available deceleration of 2.9 m/s^2 [a].
- Impact Velocity 40 Km/hr after Crossing Safety Zone.
- Flat Conditions (Ideal Conditions).

Table 2-3 RISER Recommended Safety Zone Width (m)

Exit Angle	**Slope**	**µ**	**a**	**Exit Speed from Carriageway (km/h)**		
(deg)			**(m/s^2)**	**50**	**60**	**70**
5	0	0.3	2.9	1	2	4
10	0	0.3	2.9	2	5	8
15	0	0.3	2.9	3	7	11
20	0	0.3	2.9	4	9	15
25	0	0.3	2.9	5	11	18
30	0	0.3	2.9	6	13	22

(Dupre & Bisson, 2006)

The angle that a vehicle leaves the road depends on road-tyre friction, travel speed, lateral position of the vehicle to the carriageway, and geometrical road properties (vertical and horizontal alignment). The theoretical safety zone calculation for 5 degrees is the recommended starting point for developing safety zone criteria.

2.2.4. Transit New Zealand State Highway Geometric Design Manual (2002)

Transit New Zealand has adopted the empirical data provided by AASHTO utilising traffic volumes, speed & roadside geometry. This guideline specifies that the AASHTO data represents straight level sections of roads only. Adjustments must be made for horizontal curvature, gradient and side slope. The largest of the adjusted distances is the clear zone required. Horizontal curvature and gradient can significantly affect roadside encroachment rates. American research has shown that the Effective Traffic Volume (ETV) can be used to relate encroachment frequency with road alignment. ETV is defined as the traffic volume on a straight flat section of road that is equivalent to the traffic volume on a section of road with horizontal curvature and/or grades and is calculated by the following formula.

$$EVT = K \times AADT$$

Where:

AADT	=	AADT in Design View
K	=	Volume Adjustment Factor

K and M factor are obtained from Figure 2-3. The clear zone width for a straight level road for AADT = ETV is obtained from AASHTO Clear Zone Distance Curves (see Figure 2-1).

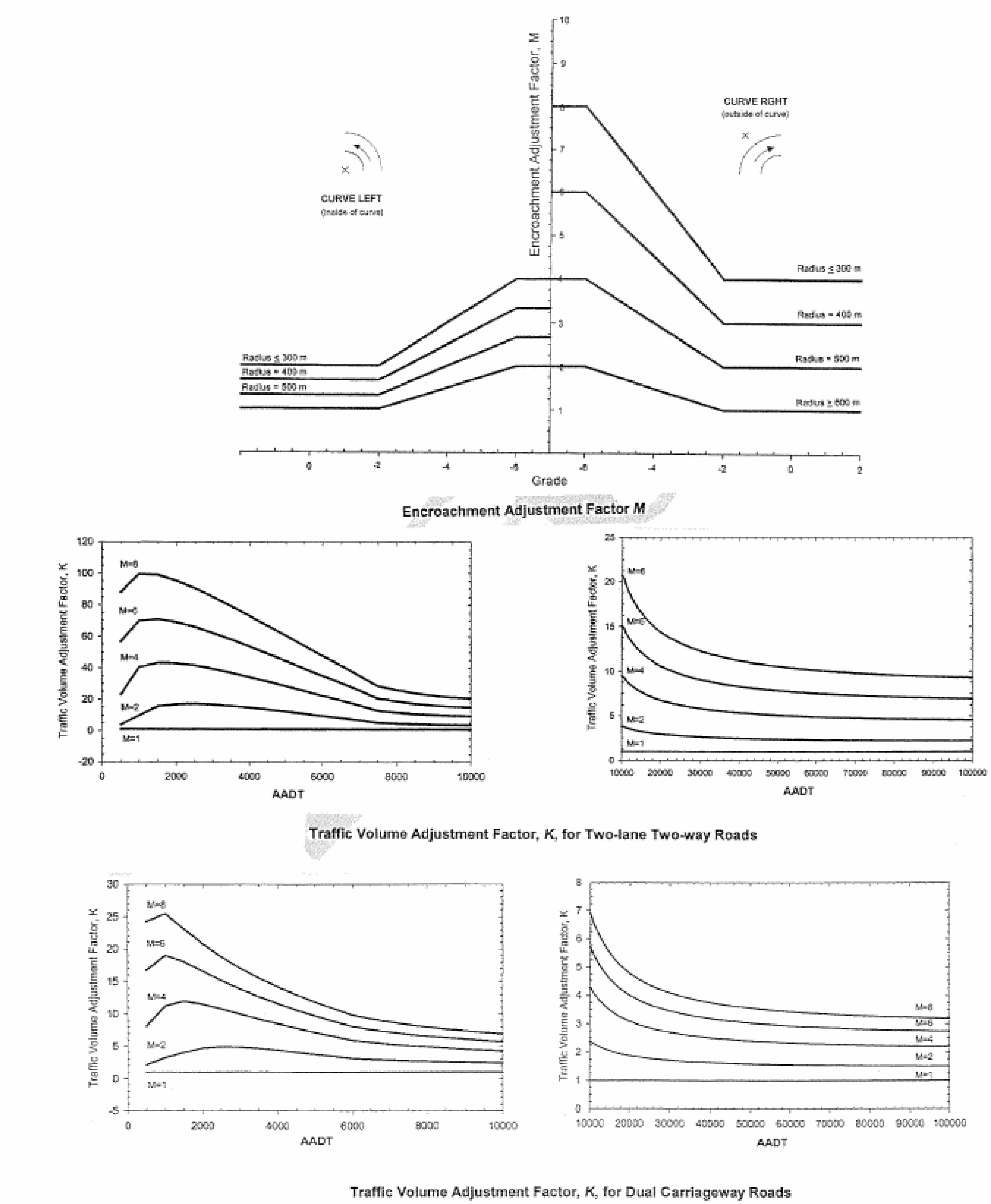

Figure 2-3 Adjustment for Road Alignment

(Transit New Zealand, 2002)

2.2.5. AustRoads Urban Road Design Manual (2003)

The Austroads clear zone method is dependent on speed, traffic volumes, batter slopes and horizontal geometry. The figure below provides clear zone distance curve produced through Austroads research. The manual states that in urban low speed environments, it is difficult to achieve the specified clear zone. Existing hazards are often within the clear zone and can be expensive or socially sensitive to relocate. Aesthetic and urban road design considerations become more predominant and it is the role of the designer to determine an appropriate compromise.

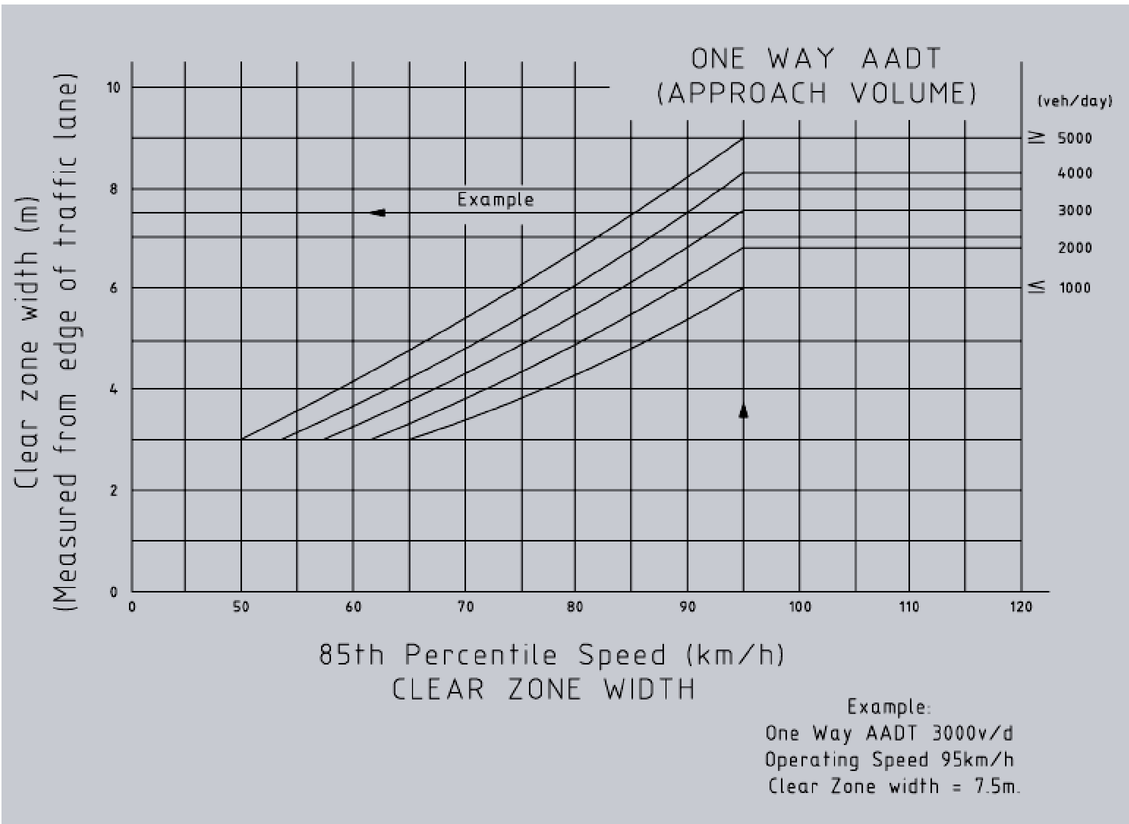

Figure 2-4 Austroads Clear Zone Distance Curve

(Austroads, 2003)

For a straight section of road and a speed of 60 km/hr, the clear zone widths for a one-way approach AADT are shown in Table 2-3.

Table 2-4 Austroads Clear Zone widths for one-way approach AADT

AADT	Width (m)
<1000	3.0
2000	3.0
3000	3.25
4000	3.7
>5000	4.2

The clear zone widths specified in Table 2-4 increases where there is sub-standard horizontal geometry or non-trafficable batter slopes present. The clear zone width on the outside of curves increases by a factor depending on the operating speed and radius which can be determined from Figure 2-5.

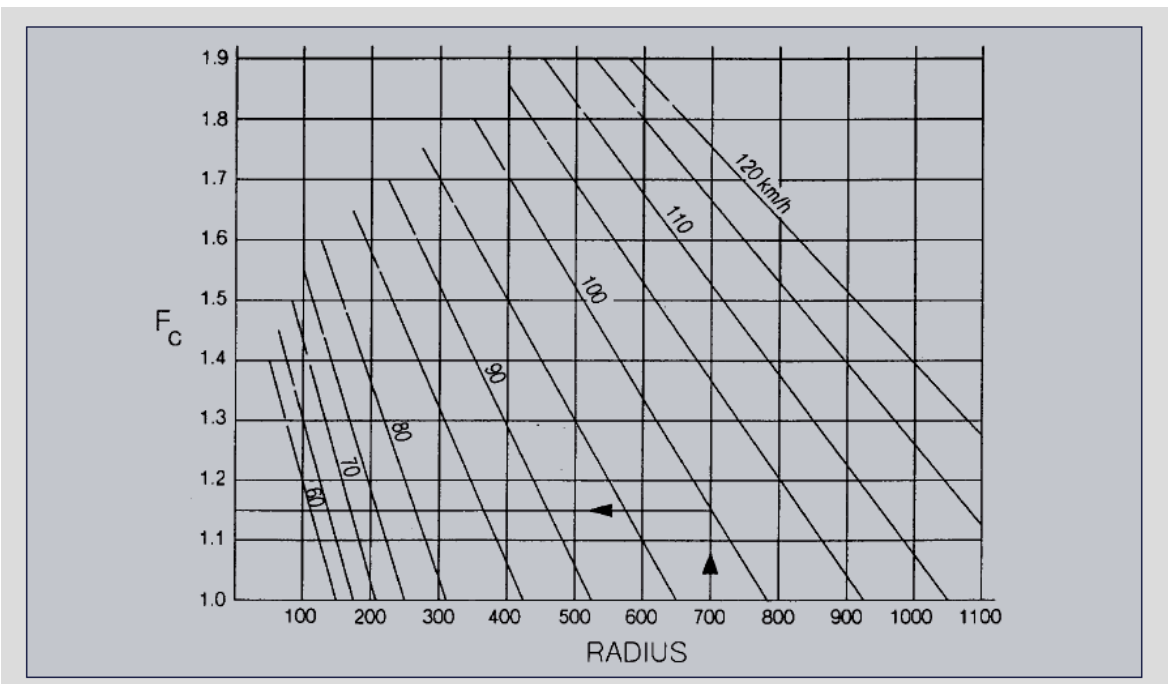

Figure 2-5 Austroads Horizontal Curve Factor

(Austroads, 2003)

An effective clear zone width is calculated depending on the grade of the batter slope and whether the batter slope is considered trafficable for a typical vehicle. Batter slopes classifications are shown below.

- Batter slopes steeper than 1 on 3.5 are considered “non-trafficable” and are not included in the calculation of the available clear zone.
- Batter slopes between 1on 3.5 and 1on 6 are considered “partially trafficable”. An errant vehicle could be brought under control, however cannot rejoint the carriageway. One half of the batter slope width can be included in the calculation of the available clear zone.
- Batter slopes flatter than 1 on 6 are considered “trafficable” and an out of control vehicle is likely to recover. In this case, the full width of the batter slope can be included in the clear zone.

2.2.6. British Columbia Ministry of Transportation and Highways (1996)

The Ministry had based the Clear Zone width based only on Design Speed and Road Classification. The Ministry had determined that this approach does not provide the optimum design. Standards have therefore been revised to reflect Design Speed and Design Traffic Volume based on the AASHTO "Roadside Design Guide". Therefore, Table 3 has been adopted as a guide to determine clear zone widths for 60km/hr.

Table 2-5 British Colombia Clear Zone Widths

AADT	Width (m)
<750	2.0
750 – 1500	3.0
1501 – 6000	4.0
>6000	5.0

(British Columbia Ministry of Transportation & Highways, 2006)

The Clear Zone used for kerb and channel designs is 2.0m from the face of the kerb or 0.5m behind the footpath, whichever is greater.

2.2.7. The Australian Standard for Street Lighting (AS/NZS 1158.1.3:1997)

This guideline is based on speed only. Rigid objects can be located no closer than 3m from the traffic lane, in speed zones less than 70km/hr. Frangible poles, for example slip base poles, are permitted 1m from the traffic lane depending on the level of pedestrian activity.

2.3 Dealing with Hazards within the Clear Zone

2.3.1. AASHTO (2002)

The recommended treatments for dealing with roadside hazards are shown below, in order of preference.

1. Remove the obstacle to eliminate the hazard.
2. Redesign the obstacle so it can be traversed safely without likelihood of impact.
3. Relocate the obstacle to a point where it is less likely to be impacted.
4. Reduce impact severity by using an appropriate breakaway device where possible.
5. Shield the obstacle with traffic barrier or impact attenuator providing the barrier is not deemed a greater hazard itself.
6. Delineate the obstacle to at least give motorists an awareness of the likely hazard.

2.3.2. Main Roads Western Australia (2006)

The Assessment of Roadside hazards recommend a Quantitative and Qualitative evaluation to determine the most appropriate treatment to a roadside safety issue.

Qualitative evaluation utilises numerical values to assess the likelihood and consequence of a crash. Consequences may be determined from modelling, experimental studies or past data. Run-off the road type crashes involve the use of encroachment factors and severity indices used with other information to quantify the events.

The severity indices are related to crash costs which are used in a cost benefit analysis. This analysis estimates the benefit derived from a proposed treatment compared to the cost of implementing. If the estimated benefit exceeds the cost of constructing and maintaining the treatment, the proposal maybe implemented. Projects must compete for funding, therefore a benefit /cost ratio greater than one may be enough to justify expenditure .The primary benefit obtained from selecting one project over another is the expected reduction in future crash costs, involving property damage, injury and fatality costs.

Qualitative evaluation involves accessing the suitability of a treatment considering environmental and engineering factors. Environmental considerations include recognition of unique vegetation, retention of water courses and visual pollution. Engineering consideration include traffic growth, vehicle/pedestrian/cyclist mix, crash history and social justice/equity.

2.3.3. <u>The Queensland Department of Main Roads (2005)</u> (Chapter 8)

The Road Planning and Design Manual states that the determination of an appropriate treatment for a hazard should be carried out by evaluating alternatives, using the Roadside Incident Severity Calculator (RISC) software to determine a Benefit/Cost ratio (BCR) for each alternative. Engineering judgement is also recommended as practitioners are warned against using the RISC software as a "black box" without understanding the sensitivity of input and output parameters. The assessment process and parameters adopted by RISC are as follows:

- consider traffic volumes;
- consider horizontal and vertical geometry of the road;
- consider roadside object attributes, for example slope, hazards, size and length, distance from traffic lane;
- assess encroachment frequency calculation;
- perform object collision frequency calculation;
- determine treatment costs and ongoing maintenance requirements;
- determine severity index; and
- determine crash cost.

The Road Planning and Design Manual recommends that when a BCR greater than 1.5 for rural roads and 2.5 for urban roads is achieved, there is generally a good basis for recommend the installation of a safety barrier or other alternative treatment. Candidates for treatment should be prioritised depending on BCR, crash history, available funding, politics and community expectations, combined with engineering judgement.

2.3.4. <u>**VicRoads Road Design Note on Roadside Utility Poles**</u> (VicRoads, 2007)

Ideally, no roadside hazard should be located in the clear zone. In practice, due to site constraints, it is sometimes difficult to satisfy clear zone requirements. A risk analysis approach has been developed for utility poles. A pole risk score is based on the multiplication of five risk factors.

- Daily Traffic Volume
- Offset factor
- Road factor
- Curve factor
- Severity factor

Risk scores above 10 000 indicate a high risk score. The Design Note suggests that a barrier system is likely to be the most cost effective solution for scores greater that 10 000. For scores greater than 50 000, underground power lines are suggested.

2.3.5. <u>Department of Infrastructure Energy & Resources Tasmania</u> (date unknown)

The Roadside Management Guide states that hazard reduction options are to be ranked according to a benefit cost analysis and engineering judgement. The guide recommends that computer software be utilised due to the complexity of the analysis. Recommended software packages include:

- Roadside Incident Severity Calculator (RISC), developed by Main Roads Queensland;
- Road Safety Risk Manager (RSRM) developed by ARRB Transport Research in association with AustRoads; and
- USA Roadside Safety Analysis Program (RSAP) (NCHRP, 2003).

2.4 Summary

Authorities agree on what on what constitutes a hazard. However, variations occur as some prefer to specify wooden objects less than 80mm diameter as a hazard, compared to a 100mm diameter.

The determination of the Clear Zone widths varies between authorities, with the various guidelines adopting different ranges. Table 2-6 shows a comparison of recommended widths based on different AADTs, for 60 km/hr, on a straight section of roadway.

Table 2-6 Recommended widths in a straight, 60 km/hour zone

AADT	Clear Zone Widths					
	AASHTO	Austroads	AS/NZS Standard	Motor Cycle Industry in Europe	British Columbia	RISER
1000	3.25	3.0	3.0	4.0	3.0	2
2000	4.0	3.0	3.0	4.0	4.0	2
3000	4.0	3.0	3.0	4.0	4.0	2
4000	4.0	3.0	3.0	4.0	4.0	2
5000	4.0	3.0	3.0	4.0	4.0	2
6000	4.0	3.25	3.0	4.0	5.0	2
8000	4.0	3.7	3.0	4.0	5.0	2
10000	4.0	4.2	3.0	4.0	5.0	2

AASHTO 2002, Austroads 2003, AS/NZS 1158.1.3:1997, The Motorcycle Industry in Europe date unknown, British Columbia Ministry of Transportation & Highways 1996, Dupre & Bisson 2006.

Notes:

- *Austroads is the only guide that specified a one-way AADT. The assumption was made that equal traffic exists on both directions for the purpose of comparison.*
- *RISER Values are for a five degree exit angle.*

Design guides agree with the AASHTO recommended treatment hierarchy for hazards, in order of preference. A quantitative and qualitative evaluation is suggested by most guides to determine the most appropriate treatment. Computer software is recommended for a quantitative evaluation to determine a Benefit/Cost Ratio. The qualitative evaluation involves engineering judgement based on environmental and engineering considerations.

3. Legal Requirements

3.1 Non-Feasance versus Mis-Feasance

In the consideration of the treatment of hazards in the clear zone, the area of law relevant to our decision is the liability of road authorities in negligence.

The law relevant to negligence concerning road authorities was dominated in the past by the "**non-feasance** principle", otherwise knows as the "highway rule". This rule of law meant road authorities <u>would not be liable for mere non-feasance or the failing to do a task</u> in relation to the condition of roads and roadside footpaths. However, road authorities <u>would be liable for **misfeasance**, referring to work that was conducted on a road surface, but conducted negligently.</u>

3.2 High Court Rulings on the Liability of Road Authorities

This distinction between misfeasance and non-feasance was swept aside in Australia by the decision of the High Court in *Brodie versus Singleton Shire Council* (201) 206 CLR 512. The circumstances involved in this claim are outlined below.

Mr Brodie drove a truck laden with pre-mix concrete weighing 22 tonnes across a 50 year old wooden bridge. The bridge collapsed and the truck fell into the creek bank below. The bridge's supporting wooden girders had been undermined by dry rot or termites. The truck was damaged and Mr Brodie suffered injuries. He claimed that the accident was caused by the negligence of the Shire Council.

The claim went before a trial judge where the collapse was found to have been caused by the failure of a particular component – the supporting girders. Evidence was provided that in recent years the council had replaced the planks on the bridge but not the girders. At trial, Mr Brodie and the truck owner were successful. The case was held to be one of misfeasance and that by only repairing the planking, the Council had negligently repaired the roadway, leaving it in a condition which was bound to deteriorate and cause a hidden danger to users of the highway.

In the first instance, the Court of Appeal reversed the decision. It was held that the action the council took in replacing the defective planks on the bridge amounted to mere superficial repairs to the surface and did not remove the case from the category of non-feasance. The cause of the collapse was the failure to repair or replace the defective girders. The Court of Appeal distinguished the issue of the replacement of the planks from that of the defective girders. The trial judge, on the other hand, did not sever what was done from what was left undone.

The High Court held 4:3 that road authorities should no longer be afforded an immunity. The slim majority of the High Court decision held that the distinction between misfeasance and non-feasance is illusory and ultimately unsustainable. In essence, the road authority is open to a finding of misfeasance if it takes any positive but inadequate action, even if they attempt to remove an existing danger. Failure to undertake an action would be non-feasance and any claim would fail due to highway immunity. The tortious liability of road authorities should be determined according to the general principals of negligence. The High Court's decision considered the duty of care with respect to both the design and construction. In effect, road authorities could no longer rely on the non-feasance principle. The could no longer avoid liability by contending that the road authority was not under a positive duty either to inspect the road surface, or maintain it, or even to undertake necessary upgrade works. Road authorities now have to take "reasonable care" that they do not create foreseeable "risk of harm". Where a design on an existing road poses a risk, the authority is obliged to take reasonable steps within a reasonable time to address that potential risk.

Although the decision of the High Court in *Brodie v Singleton Shire Council* removed the "misfeasance/non-feasance" distinction, they recognised that road authorities do not have unlimited funding. In formulating new principles for the liability of road authorities, the High Court stated that limited funding was a factor to be taken into account when assessing the liability of any road authority for a particular incident. In fact, this factor is a consistent theme the *Brodie v Singleton Shire Council* decision. The overarching principle of liability for road authorities was stated by the High Court to be as follows:

> *"[Road authorities are] obliged to take <u>reasonable</u> care that their exercise or failure to exercise those powers does not create a foreseeable risk of harm to a class of persons (road users) which includes the plaintiff. Where the state of roadway, whether from design, construction works or non-repair poses a risk to that class or persons, then, to discharge its duty of care, an authority with power to remedy the risk is obliged to take <u>reasonable steps</u>, by the exercise of its power within a <u>reasonable time</u> to address the risk."*

Importantly, the High Court accepts that the financial considerations and budgetary imperatives are relevant when determining whether the road authority has discharged its duty of care. However, it would seem that the High Court was wary about putting too much weight on this factor. Lawyers from Crown Law state that:

> *"The public resources in question are … provided in part by government grants; the prospect of irate ratepayers left to shoulder the apprehended increased burden is conjectural. Further it is implicit in the submissions of the interveners that highway authorities carry insurance…; The Attorney-*

General for Victoria submitted that it should not be assumed that road authorities would be able to "transfer….the financial burden of increased exposure to claims for compensation if their immunity for non-feasance is removed. Nor should it be assumed that they will be unable to do so."

(Sammon, 2007).

The Judgement of the High Court also makes no reference to the effect of nationally accepted standards, such as those made by AustRoads. What the High Court did say, consistent with the recognition of limited funds (at paragraph 155) is:

"Different roads will serve different purposes and need not be constructed to the same standard. Thus, one would not expect all country roads to be sealed. The cost and practicality of an alternative and safer design, if one be available, may be weighed against the funds available to the construction authority. This may involve striking a balance between competing designs or methods of construction."

The High Court emphasised that the question of whether there is a duty of care is a question separate from whether a breach of duty has been established. Authorities with powers to design, construct and maintain roadways are obliged to take reasonable care that their exercise or, now, failure to exercise those powers does not create a foreseeable risk of harm to road users. In considering whether there has been a breach of duty, the factors below are relevant.

1. The magnitude of the risk.
2. The degree of probability the risk will occur.
3. The expense, difficulty and inconvenience in taking the steps described to alleviate the danger.
4. The existence of competing or conflicting responsibilities of the authority.

These considerations make it apparent that much will turn on the facts of each case. The *nature* of the defect is more significant that the question of whether it arose by action or neglect.

3.3 Liability of Road Authorities in Queensland

The effect of the *Brodie v Singleton Shire Council* decision has been partially modified in Queensland by an Act of Parliament, namely the *Civil Liability Act 2003* (QLD). This Act partially revives the "Highway Rule". Under Section 37 of the Act, a road authority is not liable for failure to repair a road, keep a road in repair, or to inspect the road for the purposes of determining the *need* to repair a road or keep the road in repair.

Section 37 of the *Civil Liability Act 2003* (QLD) states:

> ***Restriction on liability of public or other authorities with functions of road authorities:***
>
> ***(1)*** *A public or other authority is not liable in any legal proceeding for any failure by the authority in relation to any function it has as a road authority-*
>
> *a. To repair a road or to keep a road in repair; or*
>
> *b. To inspect a road for the purpose of deciding the need to need to repair the road or to keep the road in repair.*
>
> ***(2)*** *Subsection (1) does not apply if at the time of the alleged failure the authority had actual knowledge of the particular risk the materialisation of which resulted in the harm.*
>
> ***(3)*** *In this section-*
>
> ***"road"*** *see the Transport Operations (Road Use Management) Act 1995, schedule 4.*
>
> ***"road authority"*** *means the entity responsible for carrying out any road work.*

As well as partially reinstating the old "Highway Rule", Parliament actually endorsed some of the principles set out by the High Court in *Brodie v Singleton Shire Council*

(201) 206 CLR 512. In section 35 of the *Civil Liability Act,* the Act picks up the recognition of limited funding by the High Court in *Brodie v Singleton Shire Council* (201) 206 CLR 512, and applies this more broadly to "public authorities".

Section 35 of the Act reads as follows:

Principles concerning resources, responsibilities etc. of public or other authorities.

The following principles apply to a proceeding in deciding whether a public or other authority has a duty or has breached a duty-

(a) the functions required to be exercised by the authority are limited by the financial and other resources that are reasonably available to the authority for the purpose of exercising the functions;

(b) the general allocation of financial or other resources by the authority is not open to challenge;

(c) the functions required to be exercised by the authority are to be decided by reference to the broad range of its activities (and not merely by reference to the matter to which the proceeding relates);

(d) the authority may rely on evidence of it <u>compliance with</u> its general procedures and <u>any applicable standards</u> for the exercise of its functions as evidence of the proper exercise of its functions in the matter to which the proceeding relates.

3.3.1. Advice from Crown Law for Main Roads Queensland

Main Roads Queensland has sought advice from Crown Law regarding the application of legal principles to Road Safety Risk Management methodologies used by the department. Advice from Gerard Sammon, Principal Lawyer for Crown Solicitor is:

> *"In my opinion, there is a sense in which the methodology as you have described it to me is consistent with section 35 of the Civil Liability Act, especially if the methodology is adopted by Main Roads as a recognised tool, as a matter of policy. For example, section 35(a) recognises the limited funding available to road authorities and in particular, section 35(b) provides that the allocation of financial resources is not open to challenge.*

This is consistent with the methodology, which analyses road projects in terms of comparative cost/benefit outcomes.

In my opinion, therefore, the methodology and in particular, analysis produced by it would be accepted by a court as a methodology under which a road authority might properly allocate priority to competing projects. In my opinion also, the products of the methodology may be accepted as evidence by a court that the risk factors inherent in a particular section of road have been improved on and overall basis when compared to the previous position.

I should also add that I would expect that a court would not allow the results of analysis produced by the methodology to definitively answer whether a road authority is negligent, since this is the very function of the court. In many cases, however, the result produced by the methodology would be accepted as evidence by the court

I would also wish to sound a word of warning. Like any program or methodology, the result is only as good as the information put into it. If important information is left out, then the value of any assessment done by the methodology will be therefore diminished."

(Sammon, 2007).

Main Roads also sought advice from Crown Law on two matters related to clear zones.

1. Installation of traffic signal posts within the Clear Zone.
2. Liability resulting from trees planted by the road authority in the Clear Zone.

Advice from Crown Law on these matters is:

1. Installation of traffic signals within the Clear Zone.

A plaintiff may collide with a traffic signal post and claim that the decision to install it was negligent. I agree that there is some rising of the level of *risk by installing an immovable object such as a traffic signals pole in the road reserve. However, the overall benefit of traffic signals, in regulating and controlling traffic, clearly outweighs the slight raising of the level of risk caused by the immovable pole. The methodology would help to demonstrate this, although I would expect that the balancing of factors is something that a court would accept intuitively.*

2. Liability resulting from trees planted by the road authority in the Clear Zone.

Every traffic incident leading to litigation in court will be analysed on the merits of the incident and its specific causation. In almost every case, the fact that a vehicle collides with a tree will be due to negligence of someone other than the road authority; for example, negligent driving of vehicles on the road. Put another way, vehicles should not strike trees which are off the trafficked road surface unless there has been negligence by someone on the road (including, in some cases, the road authority where the road surface is defective).

However, the fact that the vehicle strikes a tree does not mean that the road authority responsible for planting the tree will never be liable in negligence for at least some aspect of the vehicle striking the tree. A claim could be made by an injured person in the vehicle that strikes the tree, that if the tree had not been located so close to the trafficked surface, then either the person would not have sustained injury or the injuries would not have been as severe as they were. It is therefore possible for there to be a claim in negligence against the road authority which plants trees too close to the trafficked surface, on the basis that the placement of the trees was negligent, even if the cause of the vehicle hitting the trees was not the fault of the road authority.

A court will ask why trees were planted too close to the trafficked road surface, when there is no discernable benefit to traffic safety from the presence of the trees themselves. In this regard, a court will look at the *function of trees differently from that of a traffic signals pole. A court will readily accept that traffic signals can improve road safety overall, even if their introduction does introduce a measure of risk, due to the new presence of an immovable object in the road reserve. The planting of trees can make no such claim to some benefit to traffic safety. Main Roads would not be able to rely upon any benefit from section 35(d) of the Civil Liability Act set out above, because Main Roads will have failed to follow its own standards.*

An argument that the planting of trees adds to the aesthetics of the roads surrounds will not impress a court, against the risk that they pose to road safety with no discernable benefit to road safety. A court will ask, if aesthetics was the goal, then was it not possible to plant soft shrubs, which would not pose a threat to vehicles, and could in fact even cushion the blow from a vehicle collision. A court will ask why it was necessary to plant solid trunk trees which do pose a risk to vehicles which collide with them.

3.4 Net Reduction of Risk

Road Authorities are charged with a duty of care to reduce risks and not to create foreseeable risk of harm to road users. The allowance of some hazards in a clear zone as a trade off with the removal of others does not meet duty of care requirements. An example would be allowing trees to be planted in the centre median, because the power poles which were located in the clear zone have been removed or relocated. Duty of care does not work on a system of credits.

When a court comes to look at the liability of a road authority for placing trees, in the opinion of the court, too close to the trafficked surface, <u>in my opinion a court is not likely to look</u> at balancing the overall benefits of the project which led to the planting of the trees. Instead, in my opinion, a court will focus on the feature of the road landscape that is the subject of the claim against the road authority. In other words, a court will focus on why trees have been planted too close to the trafficked surface, (against Main Road's usual standards) and <u>will not weigh up the overall benefit to</u>

road safety, of the project that involved the planting of the trees. (Sammon, 2007).

4. Method of Treatment

Design options for reducing roadside obstacles are listed below, in order of preference.

1. Remove the hazard.
2. Redesign the hazard so it can be safely traversed without likelihood of impact.
3. Relocate the hazard to a point where it is less likely to be impacted.
4. Reduce impact severity by using an appropriate breakaway device where possible.
5. Shield the hazard with an appropriate longitudinal traffic barrier designed for redirection, or use a crash cushion providing the treatment is not deemed a greater hazard itself.
6. If the above alternatives are not appropriate, delineate the hazard to at least give motorists an awareness of the likely hazard.

4.1 Remove the hazard

Eliminating the hazard is clearly the first strategy which should be investigated, however there are a number of issues that must be considered. Examples could include:

- Possibility of community backlash about removing and old and significant tree of interest.
- Moving a power line underground may cause clashes with other services. If the power line is high voltage, cables will have to be spaced appropriately and the depth of the trench will also be a factor.
- Removing a street light will affect the required light intensities in design areas.

4.2 Redesign the hazard

Hazards may be redesigned to enable an errant vehicle to negotiate the hazard safely. Examples where hazards could be redesigned include:

- Redesigning a culvert endwall can significantly improve its safety. A vertical, concrete endwall is a significant hazard to vehicles that run off the road. Installing a sloping endwall allows errant vehicles to ride up the face of the endwall. Figure 4-1 below pictures an example of a sloping endwall under a property entrance.

- Embankment slopes can be flattened so that the slope is a maximum of 1 on 4. This will allow vehicles that run off the road to safely traverse the slope and recover. Slopes greater than 1 on 4 are not included in clear zone width calculations.

Figure 4-1 Photo of sloping end wall on culvert

4.3 Relocate the hazard

This treatment is often used for trees, power poles, street lights and culvert endwalls.

In regard to this treatment, there are a number of considerations.

- If a power pole is to be relocated, power authorities need to be consulted regarding the maximum span between poles, the maximum angle in wires and the attributes of the pole, such as a sub-station.

- Underground services may be in conflict with the proposed new location.

- Light intensities will need to be reassessed when relocating street lights.
- Trees may hold either heritage or community sentiment.
- Culvert flows and possible downstream effects may need to be reassessed when relocating culvert headwalls.

4.4 Providing Breakaway Supports

The installation of signposts and light poles with frangible bases is becoming increasingly common. Due to the function of the street light or sign, to perform their duty properly, they cannot be placed too far from the travelled way. Thus frangible poles are an acceptable method of providing a forgiving roadside. Common pole types are listed below.

- Wooden frangible posts.
- Aluminium frangible assemblies.
- Steel frangible posts.
- Impact absorbing poles.
- Slip base poles.

Wooden frangible posts have holes drilled at the base creating a plane of weakness that allows the post to break at impact. The Aluminium frangible assemblies collapse due to a shear pin action. The Steel frangible poles break on impact as a result of shear plane failure. Impact absorbing poles crumple and bend around a vehicle on impact. The slip base poles consist of a support connection which shears on impact.

Circumstances where a breakaway design may not be appropriate are listed below.

- Locations where regular parking or other slow speed activity may result in accidental dislodgement of the poles.
- Narrow medians where the falling pole would not fall clear of the running lanes.
- Areas where the fall of the pole would foul overhead electricity conductors.

- Areas with high pedestrian activity.
- Areas where it is difficult or impossible to provide underground power to those lights.

4.5 Shielding hazard

Safety barriers are installed to protect vehicles from hazards that cannot be removed, relocated or made more forgiving. Design parameters which must be considered include:

- the design vehicle;
- the containment level specified in AS3845:1999;
- the type of barrier;
- the length of need ;
- lateral offset from the edge of the running lane;
- side slopes;
- flare rates;
- deflection angle; and
- clearance from hazard to barrier to allow for deflection or deformation of barrier.

A guardrail installation is in itself a hazard and care should be taken to ensure that the guardrail does not present a higher safety concern than the hazard it is protecting. The underlying principle that needs to be taken into account in the design is to get the largest possible distance between the barrier and the running lane. Maximising this distance will provide a driver with:

- maximum opportunity to regain control before striking the barrier;
- maximum opportunity to avoid collision in minor encroachments;
- space to reduce speed before impact;

- better sight lines at intersections, accesses and around horizontal curves;
- a clear area for the vehicle to stand after impact; and
- an opportunity for disabled vehicles to stop clear of the running lane.

There are three main types of barriers used.

- Wire rope.
- Steel Beam Guardrail (W-Beam and Thrie Beam).
- Concrete safety barrier.

AS3845:1999 defines test level for barriers based on speed, impact angle and vehicle mass. The appropriate level should be selected for the design vehicle using the road. For example wire rope and steel beam meet the standards for test level 2 for 70km/hr, impact angle of 25 degrees using a pick up truck of 2000 kg. Standard height concrete barriers and Thrie beam have passed the test for level 4 involving a 820kg car at 100km/hr , impact angle of 20degrees or 8000 kg rigid truck travelling at 80km/hr, impact angle 15 degrees.

The distance of the hazard behind the safety barrier is a major consideration regarding the selection of which type to install. There must be sufficient space for the safety barrier to deflect during a crash without contacting the hazards placed behind the system.

The length of barrier required for the purposes of this report will be determined by the method set down by AASHTO (2002) and recommended by The Queensland Department of Main Roads (2005, Chapter 8). There are two main parameters to consider:

1. On a straight section of road a runout length parameter has been defined by AASHTO and represents the theoretical distance needed for a vehicle that has left the roadway to come to a stop. The runout length is a function of speed and AADT.

2. The lateral extent of area of concern is the distance from the running lane to the far side of the hazard or the outside edge of the clear zone in the case of hazard such as a creek or river.

The barrier length becomes a function of the chord drawn through the lateral distance of the hazard linking to the back to the runout length measured along the edge of the travelled way. Figures 4-2 and 4-3 demonstrate how the barrier length is determined.

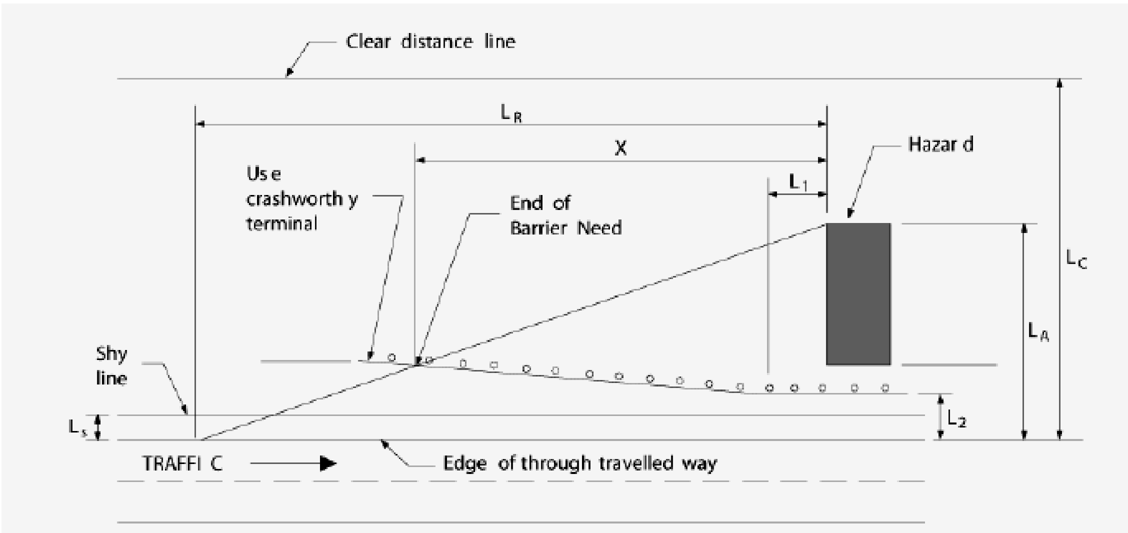

Figure 4-2 – Calculation of required guardrail length for adjacent lane

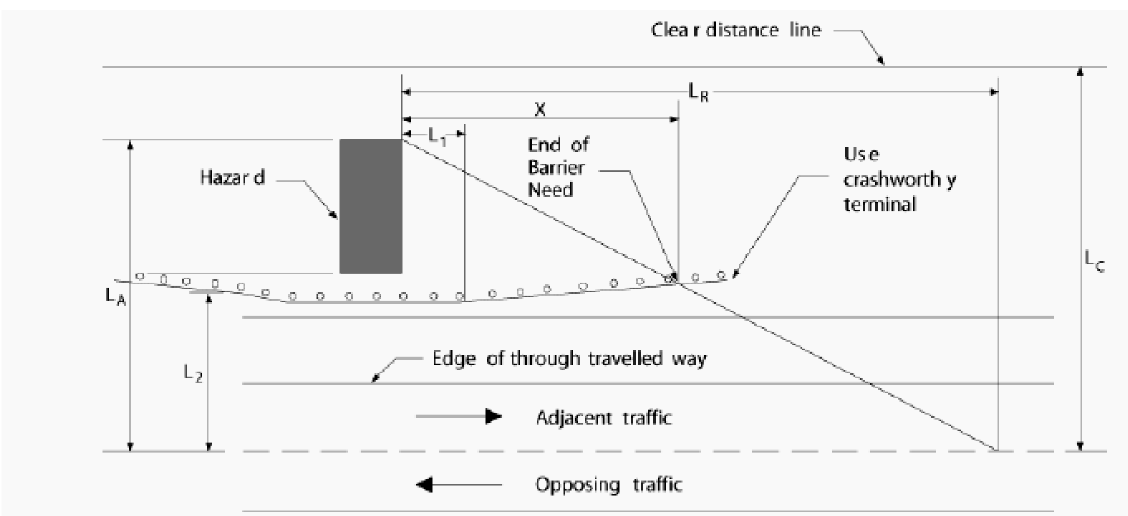

Figure 4-3 – Calculation of required guardrail length for opposing lane

- L_R represents the runout length obtained from Table 4-1. It is the theoretical distance needed for a vehicle that has left the road to stop.
- L_A is the lateral extent of the area of concern. This is the distance from the edge of the travelled way to the far side of the hazard or to the outside edge of the clear zone.
- L_1 is the tangent length of the barrier upstream of the area of concern.
- L_2 is the barrier's lateral distance from the edge of the travelled way.

Table 4-1 provides suggested runout lengths for the barrier design from the Queensland Department of Main Roads Road Planning and Design Manual (2005).

Table 4-1 Suggested Run-out Lengths for Barrier Design

(Queensland Department of Main Roads, 2005, Chapter 8)

Design Speed (km/h)	Runout Length, L_R, (m) for a AADT of:			
	>6000	2000 to 6000	800 to 2000	< 800
110	145	135	120	110
100	130	120	105	100
90	110	105	95	85
80	100	90	80	75
70	80	75	65	60
60	70	60	55	50
50	50	50	45	40

For horizontally curved sections, the vehicle path is assumed to exit tangentially. The required length is determined by using a tangent line from the curve to the edge of hazard, or to edge of clear zone.

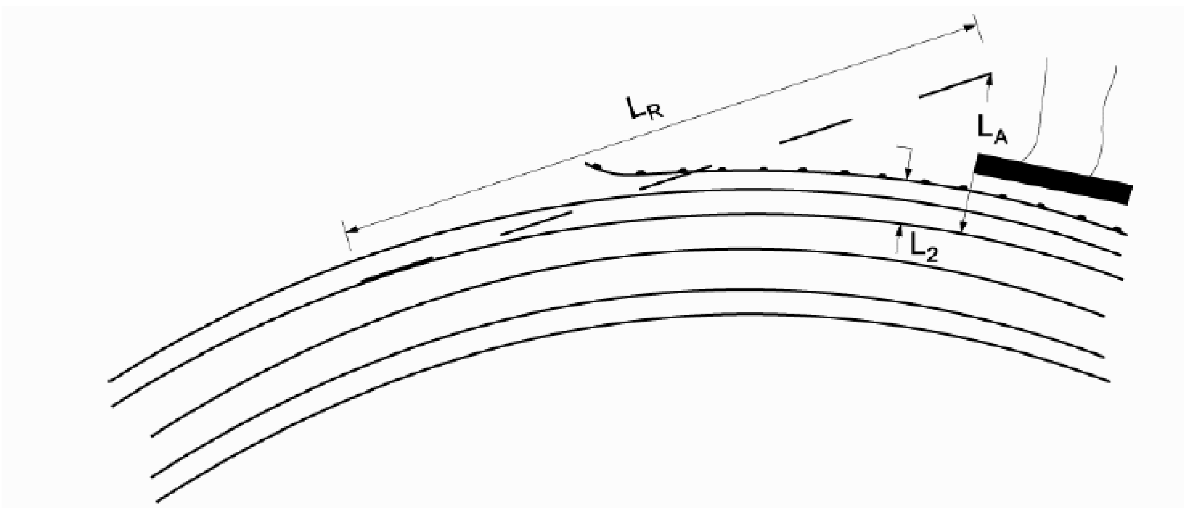

Figure 4-4 – Calculation of required guardrail length on horizontal curves

The lateral offset of the guardrail is based upon a shy line offset principal. When roadside features such as roadside safety barriers are located too close to traffic, drivers in the adjacent traffic lane tend to reduce speed, drive off-centre in the lane, or move into another lane. The distance from the edge of the traffic lane beyond which a roadside object will not be perceived as an obstacle and result in motorists changing their behavior is called the shy line. The shy line distance for up to 70 km/hr has been determined as 1.5m for the nearside or to the left of the vehicle and 1.0 m for the offside or right of vehicle. For relatively short, isolated sections of barrier, the barrier should be located outside the shy line offset. For long continuous lengths of the barrier the shy line distance is not as critical, if the barrier is started outside the shy line and gradually tapers closer to the running lane.

According to the European Best Practice for Roadside Design, experience has shown that typical problems associated with safety barriers are:-

- Insufficient length of systems to shield hazards
- Installations shielding hazards neglect neighbouring hazards

- Insufficient free distances behind the system
- Inappropriate end terminals for barrier

4.5.1. Wire Rope

The Wire rope systems are a flexible barrier which relies on a degree of tensile strength to enable them to restrain vehicles sufficiently.

During impact the cables which are restrained by end anchors, wrap around the bumper and front fender of the vehicle. The cables deflect and stretch with large tensile forces developed in the cable and lateral components of those tensile forces redirect the vehicle. Therefore a certain minimum length is required in order to develop sufficient tension. A barrier that is too short will not deform around an errant vehicle without breaking off its posts. Manufacturers should be contacted regarding the minimum required length. A 24m minimum length of barrier at full height is not to be less than 24m is a standard from manufacturer of BRIFEN and Ingal FLEXFENCE.

The wire rope deflects on average 2m; therefore this clearance is required from the hazard. Different manufactures may be able to reduce deflection by providing decreased post spacing. The advantages of a wire rope system are listed below.

- Installation costs are lower than other systems.
- Easier to repair following vehicle impact.
- Minimises sand, snow, flood water and debris build up.
- Does not obstruct sight lines.
- More aesthetical pleasing in urban areas.

The limitations of a wire rope system are listed below.

- On horizontal curves when the horizontal curve radius is less than 600m. The manufacturers should be consulted for design guidance.
- The system should not be installed on sag vertical curves less than Radius 3000m.

- At connections to other barriers or bridge parapets, the wire rope system should not be used. The wire rope design cannot assure that vehicles upon collision will be redirected safely due to cable deflection.

- The approach terrain to the barrier should be as level as possible. Ingal civil products recommend that a slope of 1in 20 is preferable, while a slope of 1in 10 is the maximum. Steeper slopes can result in vehicles impacting the barrier at other than the design height.

- Where motor cyclists represent a high percentage of users, there have been concerns raised about the friendliness of wire rope to errant riders, although no resulting deaths to riders are known.

Figure 4-5 Example of a wire rope installation

4.5.2. Steel Beam Guardrail

Steel Beam Guardrail is classified as semi-rigid and therefore deflects less than the flexible wire rope system. The steel w - beam guardrail typically deflects around 1.0m. Deflection values are given in AS3845:1999. Where excessive deflections are undesirable, the distance between posts may need to be decreased or thrie-beam installed.

Thrie-beam is stiffer than w-beam guardrail because of the increased depth of the beam element. Queensland Department of Main Roads recommends (2005, Chapter 8) that a modified version of the thrie-beam is the minimum standard of barrier used in high volume traffic areas where a significant portion (10% or higher) of traffic is heavy vehicles.

According to Main Roads Standard Drawing 1474 (Queensland Department of Main Roads, 2006), Steel Beam Guardrail requires a minimum length of 28m for a 2 lane roads and 20m for 1 lane road.

Figure 4-6 Typical steel beam guardrail installation

4.5.3. Concrete Barriers

This rigid barrier system exhibits very little, if any deflection on impact. These barriers are therefore used at locations where there is limited scope for barrier deflection. Rigid barriers should also be considered in the following situations.

- In a high volume traffic area with a significant portion (10% or greater) of articulated commercial vehicles.
- Where there is a high incidence of motorcycle accidents.
- Where the hazard is close to the running lane or in narrow medians. The minimum clearance from the running lane should be 0.5m to allow for vehicle overhang.
- Where separating opposing traffic lanes would be beneficial.

The rigid barrier must be able to resist the impact of vehicles through the combination of momentum and sheer loads. The minimum length of barrier is variable, depending on the method of anchorage and the connections between elements of the system. The minimum length varies between 20m to 30m.

When installing concrete barriers it is important that sight distances have not been compromised and pavement drainage is not affected.

Figure 4-7 Example of a concrete barrier installation

4.5.4. End Treatments

A crashworthy end treatment must be installed at the beginning and end of a barrier system.

The end treatment performs these two functions:

- anchoring the barrier system so the longitudinal strength is developed in a crash; and
- ensuring that the treatment will not cause injury if hit front on by an errant vehicle.

The end treatment should redirect an errant vehicle away from the hazard during and after impact. Therefore end treatments have been designed to either redirect vehicles or allow vehicles to pass through the end treatment, but redirect vehicles away from the hazard. End treatments are defined as being either gating or non-gating.

A gating treatment will breakaway upon collision and allow a vehicle to pass through the end treatment. It is important that a hazard free area exists beyond the treatment of level terrain. This terminal type is not suitable in locations where it is possible for an errant vehicle to pass through the end treatment and enter into a hazard or opposing traffic. Australian Standard AS3845:1999 states that a hazard free zone 22.5m long and 6m wide needs to be created behind the end treatment.

A non-gating treatment does not allow vehicles to pass through the end treatment. The terminal re-directs the vehicle away from the barrier or be arrested by the barrier. The treatments are designated as crash cushions or impact attenuators and as they do not require a clear level area behind the barrier, this treatment is suitable for:

- attachments to median barriers;
- protecting barrier ends;
- shielding ramp gore areas;
- isolated fixed objects; and
- shielding bridge piers and rail ends.

There are two types of crash cushion mechanisms currently in use, namely the compression crash cushion and inertial barriers. AASHTO (2002) advises that a compression crash cushion absorbs the kinetic energy of the vehicle using crushable energy absorbing materials. A rigid system is required, usually in the form of a ground anchor to resist the collision force

Inertial barriers are designed to transfer the momentum of a colliding vehicle to an expendable material, usually sand. No rigid backup is required, since the energy is not absorbed but transferred to other masses.

Wire rope barrier end systems do not have a special end treatment as the end posts will collapse under the impact of an errant vehicle.

4.5.5. Barrier Kerb

Placing barrier kerbs close to the travelled way to shield hazards provides little benefit and introduces an additional hazard to the traffic stream.

Barrier Kerbs:-

- Do not influence driver behaviour prior to the deviation of the vehicle:
- Do not redirect errant vehicles after impact with them;
- May cause a driver to lose control after impact with them;
- May cause the vehicle to leave the ground after impact with them;
- May cause the vehicle to leave the ground after impact with them thereby changing the trajectory of the exit path.

4.5.6. Delineating hazard

The last in order of preference as this treatment does not provide any physical protection is to delineate the hazard to make it more conspicuous. This action is the last resort as the treatment does not provide any protection from the hazard. Delineation of hazard usually involves one of the following options:-

- Provide Width makers as indicated in Figure 4-8 The Manual of Uniform Traffic Control Devices (Queensland Department of Main Roads, 2003) states that width makers may be erected singly on utility poles or other vertical obstructions which are so close to the roadway as to be a hazard.
- Place additional Road edge guide posts in front of the hazard to provide additional delineation. For example extra guideposts can be located at large culvers or in front of trees.
- Edge lines can be provided with raised, traverse bars of thermoplastic material. The edge line then provides an audible and tactile warning whenever a vehicle tyre runs over them. The intention is to alert drivers of the fact their vehicle is drifting from the edge of the travelled way. Audiotactile edge lines should be

considered where there is a history of fatigue related crashes and on roads prone to fog. It should be noted that this noise from this treatment will cause annoyance to nearby residents. Refer to Figure 4-9 for an example of its installation.

- Shoulder rumble strip are a thermoplastic or grooved markings with slight vertical profile which is designed to provide audible and tactile warning by use of the ribs. It is normally located between hard shoulder and nearside travel lanes of carriageways.
- Raised pavement markers can be used in conjunction with line marking. The benefits are the markers are not obscured at night under wet conditions as the retro-reflective panels sit above the surface.

Figure 4-8 Example of delineation of power poles

Figure 4-9 Example of audible line marking

5. Treatment Evaluation

Funding available to road authorities is limited therefore treatments need to be evaluated to determine if the proposed benefit outweighs the cost of installation and maintenance. The treatment will also have to be evaluated to determine its affect on the environment and society. Low volume roads equate to low risk, but we cannot justify retaining a safety deficiency due to low volume. The deficiency must be assessed on technical merit. Therefore determination for a proposed treatment requires a quantitative and qualitative evaluation by an experienced operator.

5.1 Quantitative Evaluation.

A quantitative evaluation uses numerical values for both the likelihood of a crash occurring and the consequence of the crash. This evaluation involves a benefit cost analysis that measures the benefit derived from a specific treatment compared to the cost of implementing remedial treatment. If the estimated benefits exceed the cost of constructing and maintaining the proposed treatment, then the treatment maybe justified. Each project however, must compete with others for limited funding.

The primary benefit from selecting one treatment over another is the expected reduction in future crash costs. Typically these include property damage costs and personal injury costs. Therefore the analysis must consider the period of time which each alternative provides benefit. Since different proposed treatments can have different project lives, both the benefits and the costs must be annualised so that direct comparisons between proposed treatments can be made. Discount rates are applied to convert total costs to annualise.

The BCR is defined as the Net Present Benefit (NBP) divided by the Net Present Cost (NPC). The NPB is defined as the total value of benefits due to crash reduction over a defined period based on an economic discount rate. The NPC is the cost of implementation (discounted if not undertaken in the first year).

Quantitative analysis can be complex due to the number of variables; therefore computer programmes have been developed to assist in comparing options. Three well known packages are:

- Roadside Incident Severity Calculator (RISC) developed by Main Roads Queensland;
- Road Safety Risk Manager (RSRM) developed by ARRB Transport Research in association with Austroads (2003); and
- USA Roadside Safety Analysis Program (RSAP) (NCHRP, 2003).

This report compares the functionality and results from two of these software packages. Packages analysed are the Roadside Incident Severity Calculator (RISC) and Roadside Safety Analysis Program (RSAP).

5.1.1. RISC

The software package RISC was developed to perform the quantitative analysis associated with the evaluation process. The program requires users to model roadside objects and potential treatment options using an array of numerical parameters. The relative benefits and costs for different treatments are automatically calculated using algorithm based on the AASHTO Road Design Guide.

The following variables are input into the main screen shown in Figure 5-1 to set up the existing conditions or the base case.

- Road environmental variables including the road type, number of lanes, width of lanes, the operating speed, traffic volume, curvature and grade.
- Roadside object attributes including the horizontal offset of the object from the running lane, object width, object length and object type.

Treatments are then included with the input of treatment type, installation cost and maintenance cost.

In the determination of a BCR the RISC program calculates the following.

- The probability of impact using object attributes, vehicle speed and road curvature.

- The encroachment frequency, which is an estimate of the number of vehicles that will leave the roadway per kilometre per year. Not all vehicles that leave the roadway will collide with a roadside object, variables such as object size, offset and speed influence the likelihood of impact with object.
- Object collision frequency, which is an estimate of the number of impacts with an object per year. This estimate is determined by using the calculated encroachment frequency and the roadside object attributes.
- Severity Index of the object, which defines the severity of the impact with a particular roadside feature. Severity index for different objects can be found in appendix A of Chapter 8 of QDMR Road Planning and Design Manual
- Annual crash costs (impacts per year multiplied by the severity index crash cost per impact).

Queensland Main Roads recommends that the installation of safety barrier may be justified for BCR greater than 1.5 for rural roads and 2.5 on urban roads

Figure 5-1 is the main screen of RISC used to set up the existing conditions. The same screen is then used for proposed treatments and associated installation and maintenance costs.

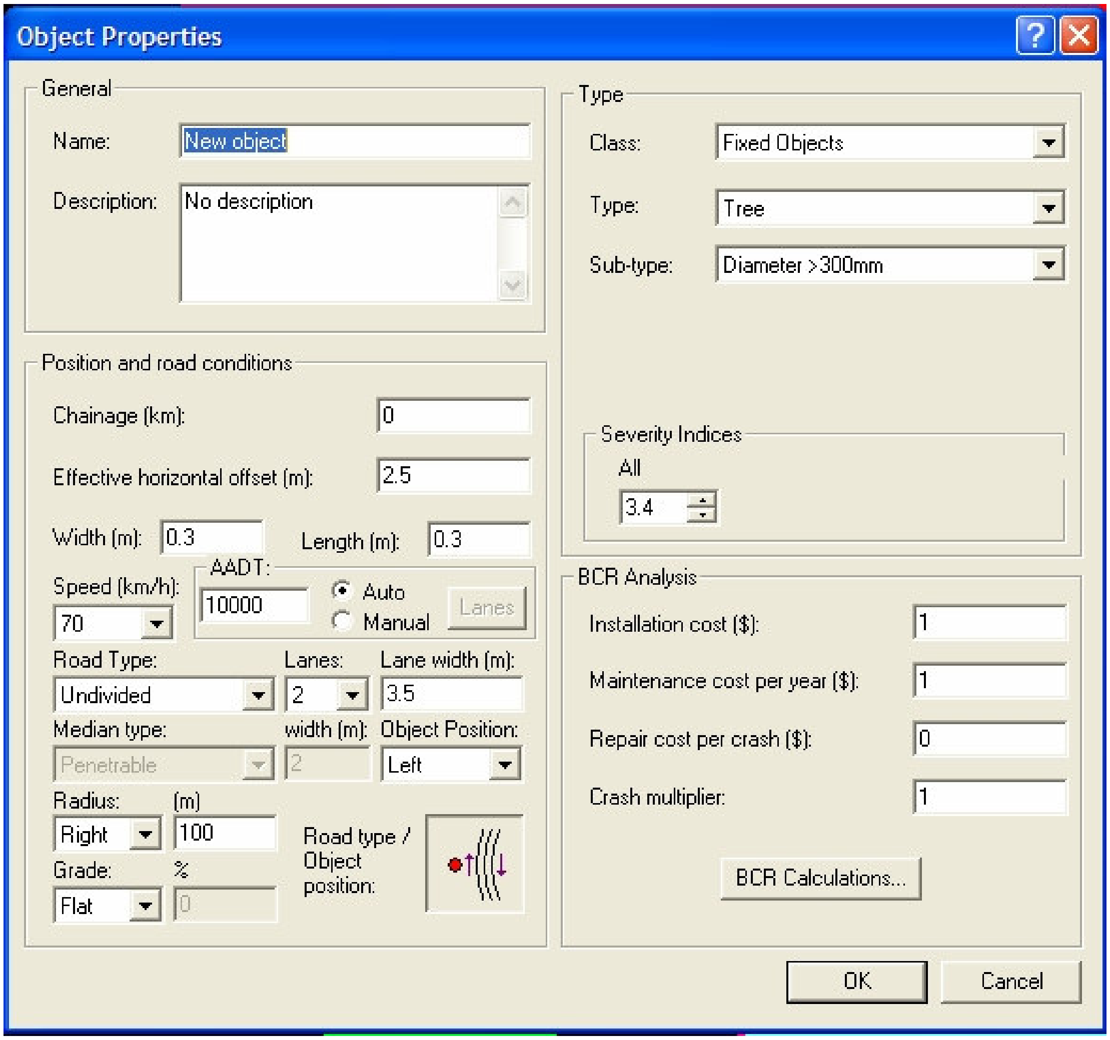

Figure 5-1 Main Screen of RISC Program

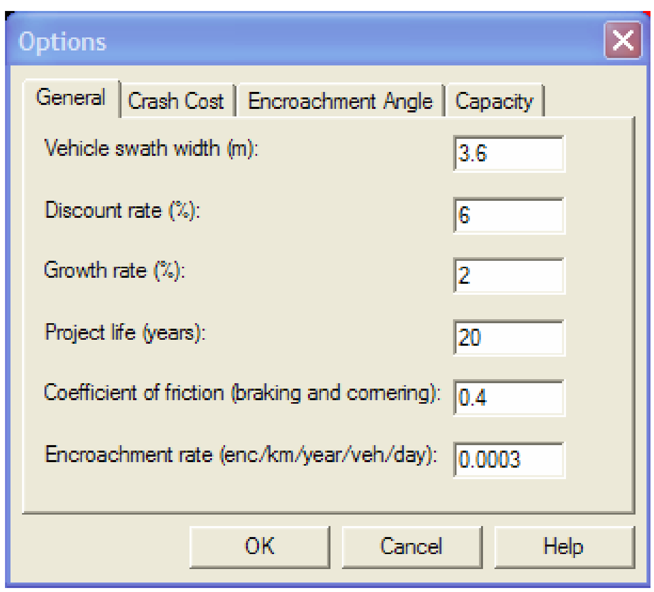

Figure 5-2 General Data Input for RISC

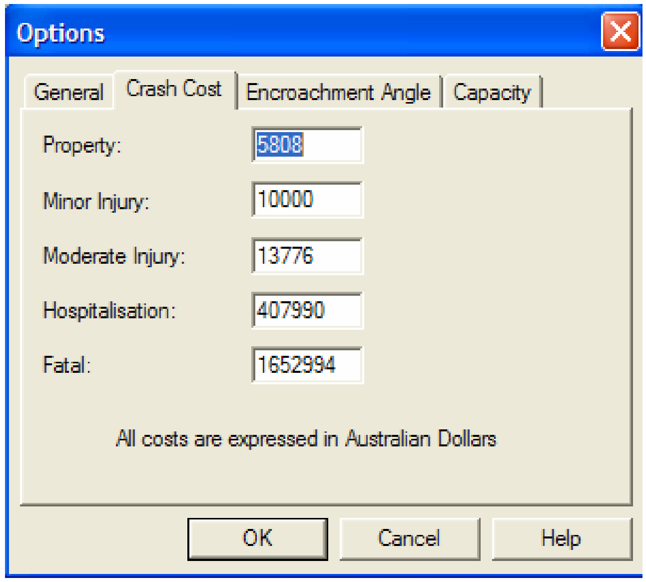

Figure 5-3 Crash Cost Data Input for RISC

5.1.2. RSAP

The cost effectiveness procedure incorporated into RSAP is based on the concept of incremental benefit/cost (B/C) ratio. The B/C ratio is the ratio of reduction in crash costs compared to increase in direct costs between alternatives. There are four basic modules associated with the cost-effectiveness procedure.

1. The Encroachment Module uses roadway and traffic information to estimate the expected encroachment frequency.
2. The Crash Prediction Module assesses if the encroachment would result in a crash.
3. The Severity Prediction Module uses severity index/impact speed relationship developed for each roadside feature or hazard.
4. The Benefit/Cost Analysis Module involves the estimated crash severity converted to crash costs using accident cost figures.

The same variables as RISC are input into the RSAP program shown in figures 5-4, 5-5, 5-6 and 5-7. The existing conditions or the base case is set up with:

- Road environmental variables including the road type, number of lanes, width of lanes, the operating speed, traffic volume, curvature and grade.
- Roadside object attributes including the horizontal offset of the object from the running lane, object width, object length and object type.

Alternative treatments are then tested with the input of treatment type, installation cost and maintenance cost.

According to the user manual the RSAP programme incorporates a stochastic solution method using the Monte Carlo simulation technique. Vehicle encroachments are simulated one at a time to determine if the crash would occur, the resulting severity and the associated crash cost. As a result of the stochastic solution method, the logic incorporated into RSAP is somewhat different than other encroachment probability based models. Conditions associated with each encroachment, including speed, angle, vehicle type, vehicle orientation, and encroachment location, are randomly generated from built-in distributions of encroachment scenarios for these parameters. The program determines if an encroaching vehicle's path will lead to impact. If impact is predicted, the type and severity of impact is identified and crash costs estimated. The probability that the vehicle will stop or be brought back into control is also estimated, and the estimated crash cost is reduced accordingly. Another encroachment event will be randomly generated and the process repeated. This process will continue until a stable average encroachment cost is reached.

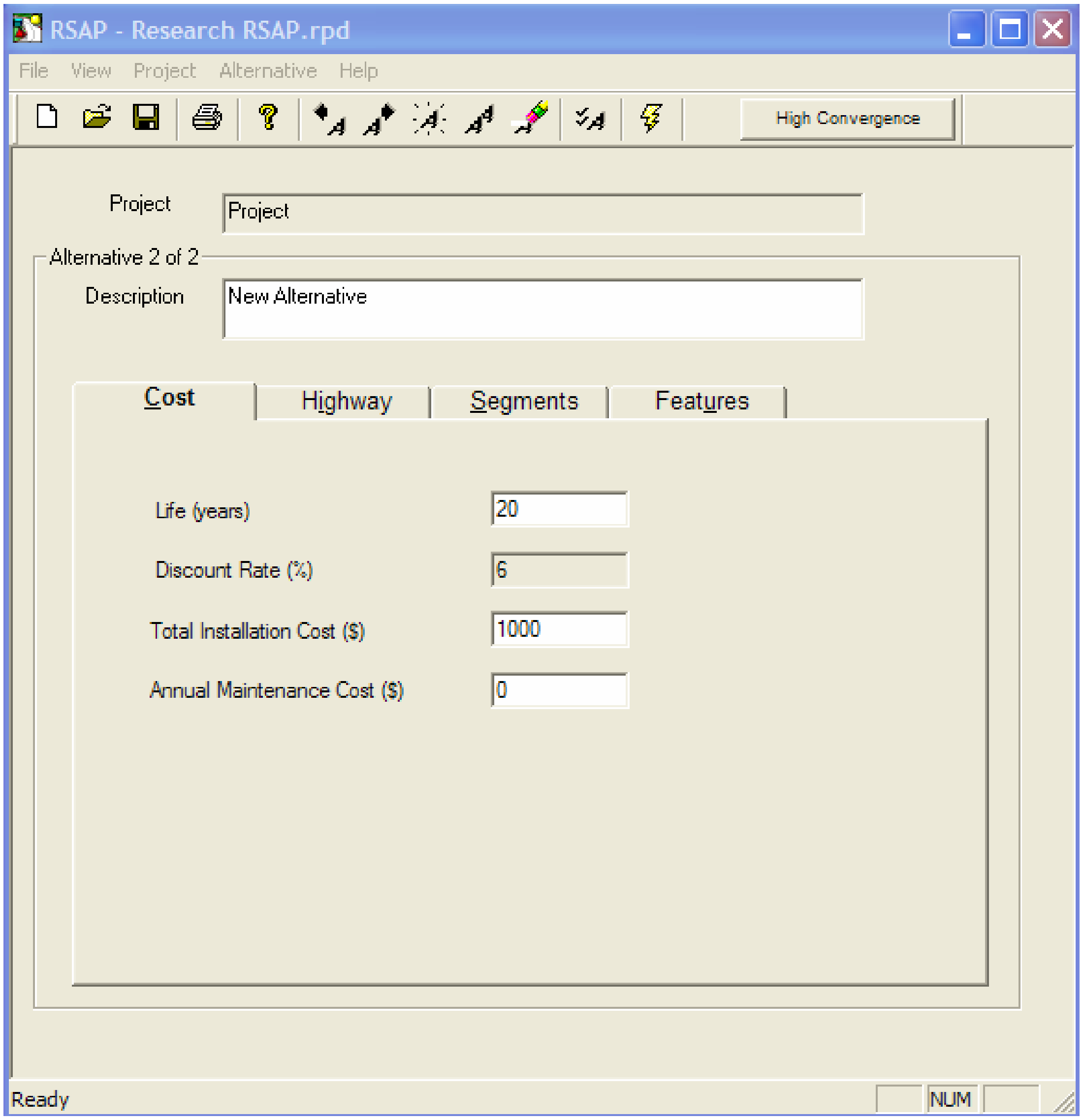

Figure 5-4 Cost Data Input for RSAP

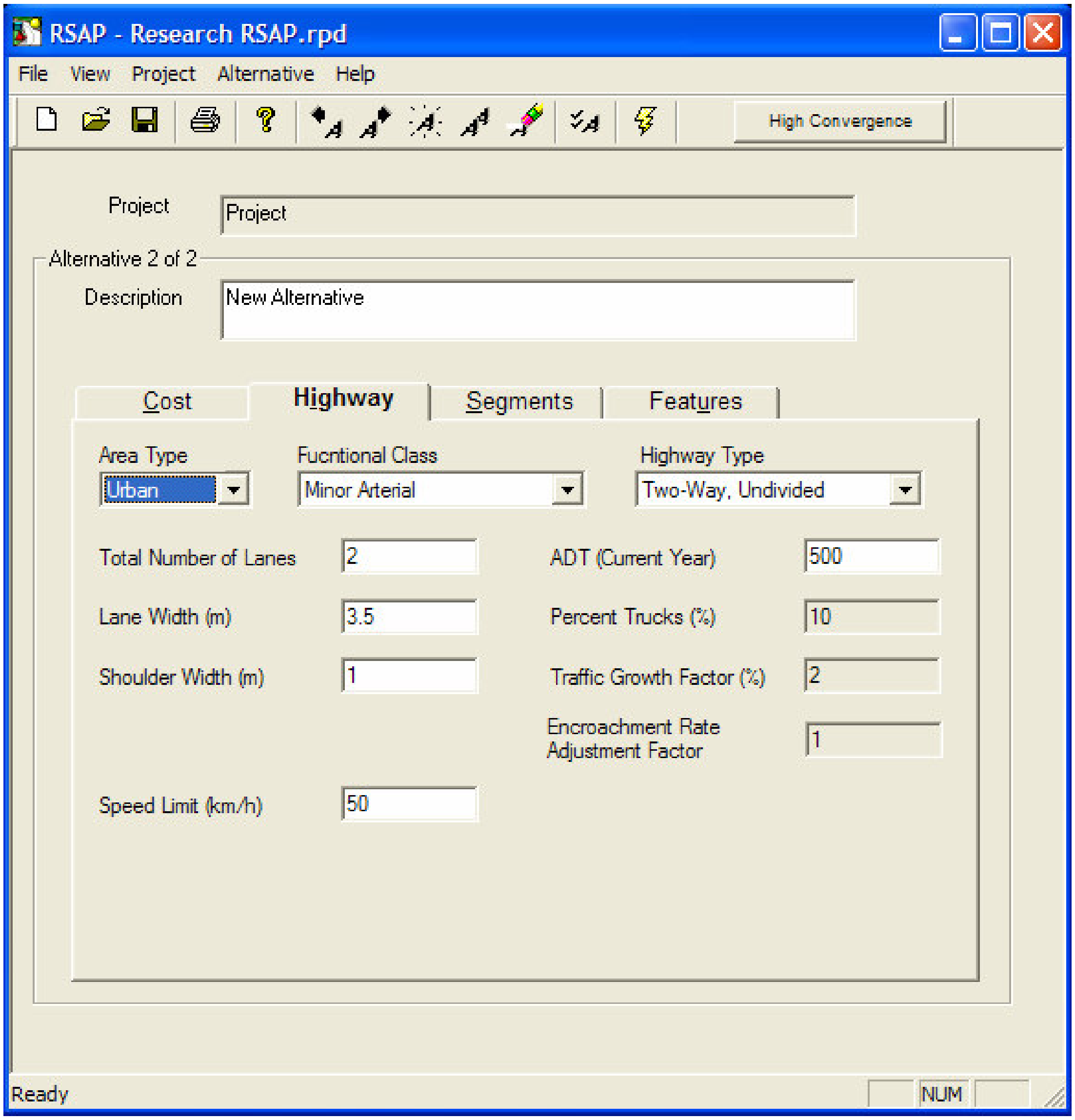

Figure 5-5 Highway Data Input for RSAP

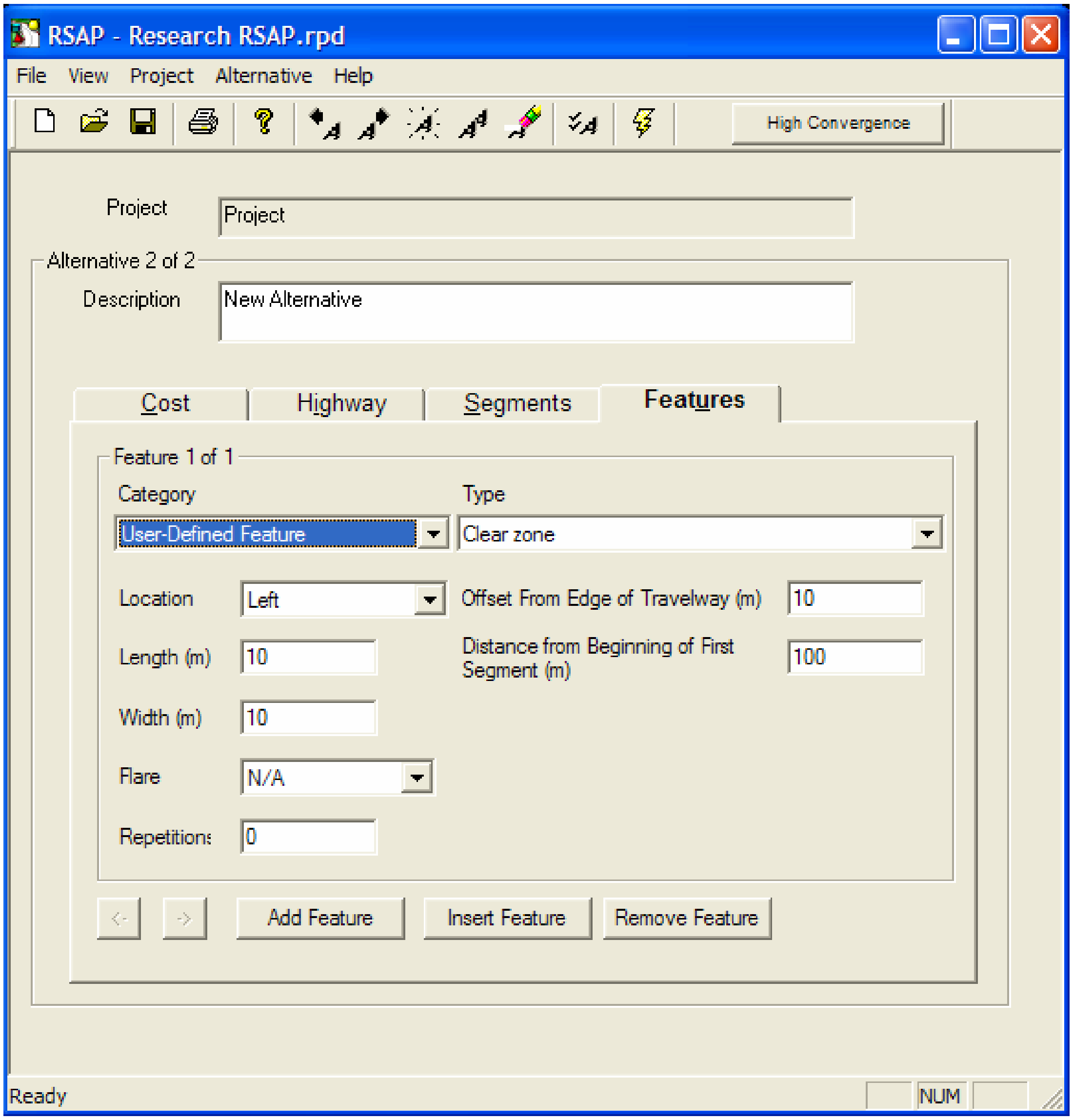

Figure 5-6 Features Data Input for RSAP

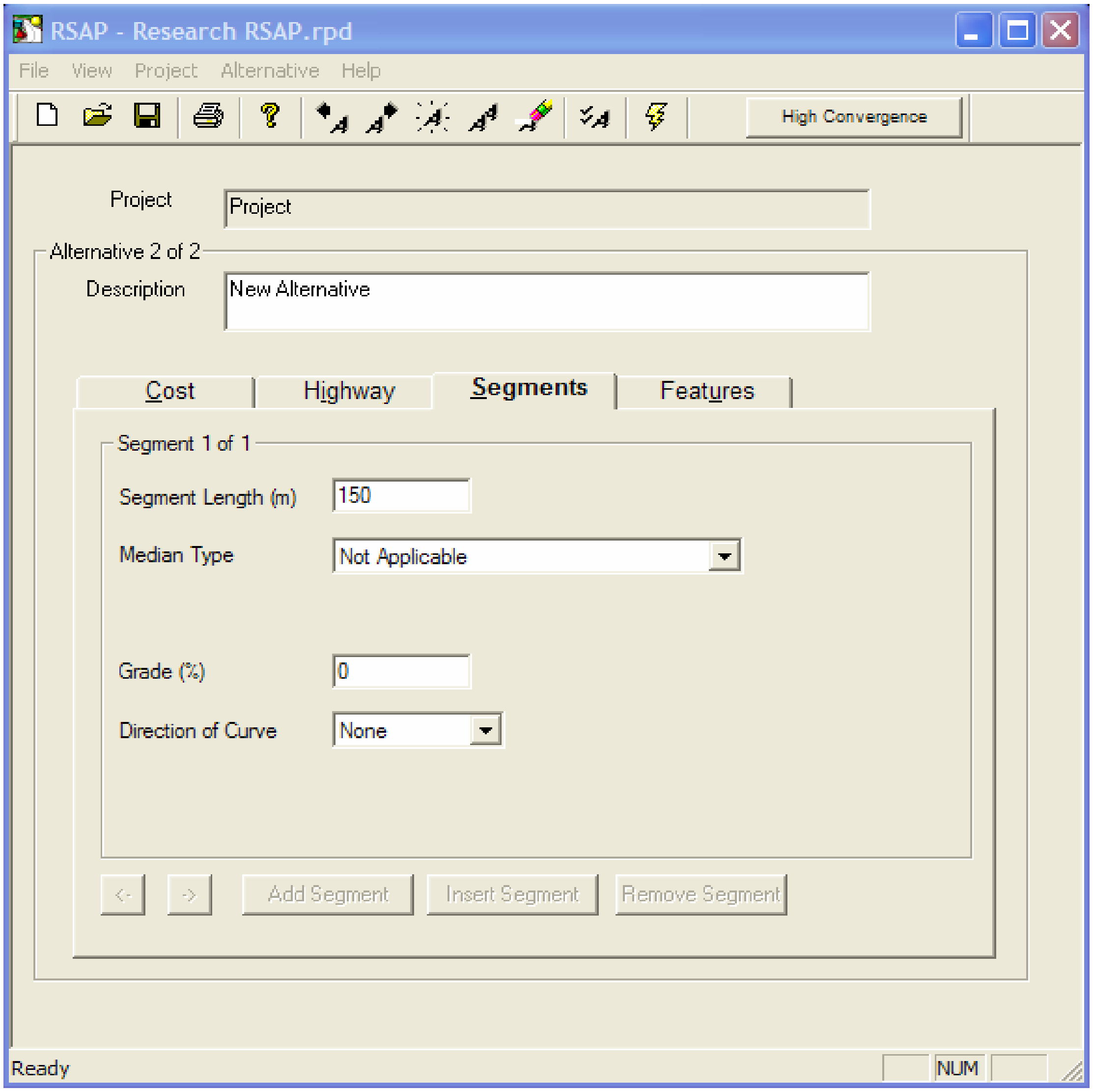

Figure 5-7 Features Segment Input for RSAP

5.1.3. Software Results

The results of the various runs of the RISC and RSAP programmes are included in Appendix B and Appendix C. The following variables were used as "set up base cases" to determine the Benefit Cost Ratios for the removal of a hazard from the clear zone:-

- AADTs 500, 1000, 5000, 10 000, 20 000
- Treatment costs $1000, $5000, $10 000, $20 000, $50 000
- Alignment Straight , R 100, R 500
- Hazard location Inside of curve, Outside of curve
- Grade Flat, 5% downgrade, 5% Upgrade

The results of the BCR analysis are consistent with what you would expect with increases in AADT and speed improving the BCR score, while increasing the offset lowers the BCR score. The geometry with the highest resultant BCR is on the outside of the radius 100 curve, on a down grade. Treatment costs and BCRs are very dependant on the variables of AADT, speed, offset and geometry.

Adopting the Queensland Main Roads recommended minimum BCR of 2.5 on an urban road as a guide for acceptable interventions; the analysis indicates the following characteristics.

- In urban areas the low speed environments make it very hard to get a adequate BCR.
- For low AADTs of around 1000 it is very hard to justify a treatment based on BCR where the treatment costs are greater than $1000.
- On straight alignments it is very hard to get the required BCR with treatment costs greater than $1000, even with a high AADT of 20000 vehicles per day.
- A low speed environment makes it difficult to achieve an adequate BCR.
- Curvature and grade has a large influence on scores

Results show that an appropriate BCR is hard to achieve. An assessment based solely on BCR would not justify an appropriate treatment. Therefore a qualitative assessment is required in conjunction with a quantitative assessment.

Qualitative Evaluation

Before a treatment option is selected for implementation or prioritisation, a number of issues must be considered. The impact of the following considerations must be evaluated, to determine the suitability of a recommended treatment.

5.1.4. Environmental considerations

Environmental considerations include the following factors.

- Recognition of the preservation of unique vegetation such as ornamental trees. The clearing of trees within the clear zone maybe unacceptable due to environmental or public concerns; an alternative treatment option will have to be considered.
- Retention of water courses in their natural state adjacent to the road.
- The installation of a treatment may result in visual pollution.

5.1.5. Engineering considerations

Engineering considerations include the following factors.

- The likely traffic growth at the site.
- The frequency and severity of crashes that have occurred.
- The effect on public transport, school bus routes and freight routes.
- Interaction of pedestrians and cyclists with proposed treatments.
- Social justice/equity issues.

6. Prioritisation Methods used in Queensland

The High Court decision in Brodie and Queensland's Civil Liability Act 2003 recognised that resources available to a road authority might dictate the pace and priority at which work is implemented. For this reason the road authority must be able to show that it has implemented a reasonable system of prioritisation of works. The process must take into account the magnitude of risk and the likelihood of injury or damage, to indicate to a court that it has met its duty of care.

An aspect of prioritisation is the ability to achieve "fitness for purpose". One view of fitness for purpose is to produce a strategy to reduce the overall system wide risks to road users by building roads to a level of service that is often lower than that by optimum engineering standards to any one length of road. This view of what fitness for purpose means shifts the focus from the question of 'what is the best road we could build here with the available funds?' to the question of 'what service level across the network will achieve the best safety overall outcomes?' This has the effect of shifting the focus from project level outcomes to system level outcomes.

6.1 Road Safety Audits

A road safety audit is a formal examination of an existing or proposed road upgrade project. The audit is a proactive means of accident prevention, seeking to ensure that, as far as practicable, road and traffic scheme are safe and fit for the purpose for which it was intended. The main objective of an audit is to minimise the risk of a crash and to enhance the importance of road safety audits when constructing and designing roads.

Audits can be conducted at the following stages:-

- Stage 1: Concept Design involves influencing fundamental issues such as route choice, standard, impact on and continuity with exiting adjacent network, and intersection or interchange provision.
- Stage 2: Draft design typically involves consideration of the horizontal and vertical alignment, intersection layouts and land acquisition requirements.
- Stage 3: Detailed Design typically involves consideration of geometric layout, line marking, signage, delineation, traffic signals, lighting, intersection details,

clearance to roadside objects, landscaping and provision for vulnerable road users.

- Stage 4: Pre-Opening to traffic involves a detailed inspection of the newly completed road prior to the opening to traffic.
- Stage 5: Existing road audit aims to ensure that the safety features of the road are compatible with the intended purpose of the road, and to ensure that these are at an appropriate level of safety.

The road safety auditor/team is responsible for checking the safety elements at each stage of a scheme to identify any road safety problems. It is not the road safety auditor's role to redesign the scheme, or to implement changes. The road safety auditor is responsible for reporting and recommending on safety related matters. The road safety audit process and checklists are included in the Austroads Road Safety Audit Guide (Austroads, 2002).

6.2 Federal Government

The Australian Government contributes funds to treat identified high casualty crash areas or black spot sites. Federal Funding for Queensland for this project currently runs at $8.9M annually. Program Development and Performance Department acts as secretariat for the National Black Spot Program in Queensland. Projects can be nominated by key road stakeholders such as Queensland Transport, Queensland Police, RACQ, local governments, Bicycle Queensland and road transport agencies, as well as the general public. Department of Main Roads districts have established mechanisms whereby key stakeholders are encouraged to nominate and have input into proposed treatments for projects.

A Black Spot database has been developed to receive nominations. The database contains fields such as location, federal/state electorates, crash history, treatments, estimate costs and construction start/end dates. Based on the information provided to the database, projects will be assessed for eligibility. The use of the database ensures uniformity of assessment on projects. Nominations are considered by the Queensland Black Spot Consultative Panel made up of key stakeholders. The consultative panel will determine a program of projects, based on available funds.

The program is sent for approval by the federal Minister for Transport and Regional Services.

The Black Spot Program is only open to state-controlled and local government controlled roads. For discrete sites, projects are deemed eligible based on a minimum casualty rate of 3 in a 5 year period and achieve a BCR greater than 2.0. On a length of road there needs to be a minimum average of 0.2 casualty crashes per kilometre per annum over a 5 year period or the length must be amongst the top 10% of sites identified in each state which have an identified higher crash rate than other roads combined with a BCR greater than 2.0. Department of Main Roads districts and Local Governments are encouraged to contribute towards the cost of projects. Their contributions are taken into account by the consultative panel.

6.3 State Government

The Queensland State Government initiated the Safer Roads Sooner (SRS) program to achieve its commitment outlined in The Queensland Road Safety Strategy (QRSS) of less than 5.6 fatalities per 100 000 population by 2011. The SRS program targets low cost, high benefit projects that address killed and serious injury (KSI) crashes on the state controlled network.

The SRS program consists of reactive and proactive components. The primary focus of the program is the reactive component known as Targeted Road Safety Initiative (TRSI). This component relies on the identification of sites with high KSI history and a Benefit Cost Ratio of 1.0 or higher. In urban areas, KSI eligibility criteria require five identified high severity crashes involving fatality or hospitalisation in the past five years. In rural areas, the eligibility criteria require three identified high severity crashes involving fatality or hospitalisation in the past 5 years. Treatments must provide maximum value in terms of safety improvement (accident reduction) for the SRS funding applied.

The proactive part of the program aims to prevent crashes before they occur by applying treatments to potentially dangerous sites on the state controlled network.

There are currently two elements aligned with two Queensland 2006 Road Safety Summit initiatives. These two initiatives began in the 2006-07 year.

1. Installation of 1000 km of audio-tactile lines over a three year period.
2. Implementation of fatigue counter-measures involving vegetation clearing, rest stops and the installation of crash barriers over a three year period.

Projects are submitted by Queensland Main Roads district offices through a nomination process via the Safer Roads Sooner Targeted Road Safety Initiative database. The database is open to districts for submission of candidate projects for a period of approximately two months every year. Projects are then assessed by the Safer Roads Sooner Technical Committee (SRSTC), which consists of representatives from engineering and administrative sections of Main Roads and Queensland Transport. This committee ensures that SRS funds are targeted towards a priority list of projects for the most critical safety concerns across the whole state. The final product of the SRSTC assessment is to produce a preliminary list of recommended projects that is then passed to the Safer Roads Sooner Advisory Committee (SRSAC).

The SRSAC includes representatives from both within Queensland Government, private transport and road industry related organisations. The committee reviews the recommended short list to ensure that SRS funding is best directed towards low cost, high safety benefit solutions. Finally, the SRSAC endorses a final list of recommended SRS projects to seek Ministerial approval for. Through the SRSAC the Department of Main Roads is accountable to the Minister for the development and delivery of the SRS program.

6.4 Local Authorities

Projects are identified on the “local roads of regional significance” (LRRS) network and are submitted to the Regional Road Group (RRG) for prioritization. Local roads of regional significance include low order roads on the state controlled network and high order roads on the council network. The Regional Road Group consists of a number of shires that have been grouped together. In the Toowoomba area the group includes Toowoomba City, Millmerran Shire, Cambooya Shire, Pittsworth Shire, Crows Nest Shire, Jondaryan Shire and Rosalie Shire. The shires enter projects on the Road Network Safety Tool which ranks projects. The Regional Road Group then decides which projects are worthy to be progressed further.

6.5 Planning and Design Projects

Projects that are in the process of planning or design are constrained by set budgets. Decisions are constantly faced by designers concerning hazards that fall within designated clear zones. Decisions upon treatment are based on benefit cost ratio score, crash history and community concerns. Prioritisation is performed within project teams by the project manager and where necessary referred to higher management. This process provides the most uncertainty to designers and engineers as they fear legal ramification if expensive treatments are not implemented.

7. Conclusion

Run off the road accidents are recognised as global problems, with fatal and serious injuries reported for speeds of 40 km/hr and above. The adoption of a clear zone concept is seen as a major contributor to the reduction of this type of accident, as the probability of a collision decreases if a sufficient width is provided for a errant vehicle to regain control. The width of the clear zone measured from the edge of the travelled way is treated differently by various standards and road authorities. In urban areas the width most standards agree on is 3.0m for AADT up to 1000 vehicles per day increasing to 4.0m for higher traffic volumes.

A mix of hazards may occur within the specified clear zone both point and continuous hazards. There is still some conjecture about the diameter size of trees and poles which are classified as hazards. Trees with trunk diameter 80mm and above are considered a potential hazard risk. Steel poles with a diameter of 65mm and above, in particular those poles used for sign support are considered a safety risk and should be installed with a break away support.

To meet legal requirements road authorities must fulfil their duty of care to road users. To achieve this they must not create a foreseeable risk of harm and are obliged to take reasonable steps to remedy an existing risk within a reasonable time. The court recognises that resources are limited in terms of both man power and funding. Therefore road authorities need to have in place, methods, to prioritise projects that have been identified to address a safety issue. Prioritisation ensures that the areas with the highest benefit are treated first, thus making best use of available resources. All levels of government in respect to Queensland have set up a system for prioritising projects. Crash history and the benefit cost ratio results are the main criteria used in the prioritisation process.

A hierarchy of treatments exist with six different methods recommended. Practicalities of treatments in urban areas must be considered. Relocating power poles outside a clear zone cannot often be achieved due to property boundaries, footpaths and underground utility services. Guardrail is rarely installed in built up urban environments due to aesthetics, pedestrian paths, property assesses and the physical space required catering for the guardrail and deflection upon impact.

A quantitative evaluation is relatively easy to undertake as there are computer programs specially designed to determine a benefit cost ratio score for a proposed treatment to a site. The benefit cost ratio is very sensitive to traffic volumes, geometry and treatment costs. A benefit cost ratio score high enough to justify a treatment is often very difficult to achieve. Low traffic volumes equate to low risk, but to dismiss a low benefit cost ratio score on a low volume road does not fulfil our requirements with duty of care. Risk assessment programs are a useful means to quickly assess a site, however it is often the only method employed.

A qualitative evaluation or reality check is also required to assess engineering, environmental and social ramifications of safety concern and proposed treatments. Designers and engineers are reluctant to make subjective decisions that may not be backed up by standards. Training is required in carrying out qualitative assessment to give designers and engineers the tools and understanding to reality test proposed treatments. Practical treatment solutions need to be determined that are ‘fit for purpose’. The High Court recognised that different roads serve different purposes and need not be constructed to the same standard.

The procedure that should be adopted for assessment and determination and prioritisation of treatments is shown below.

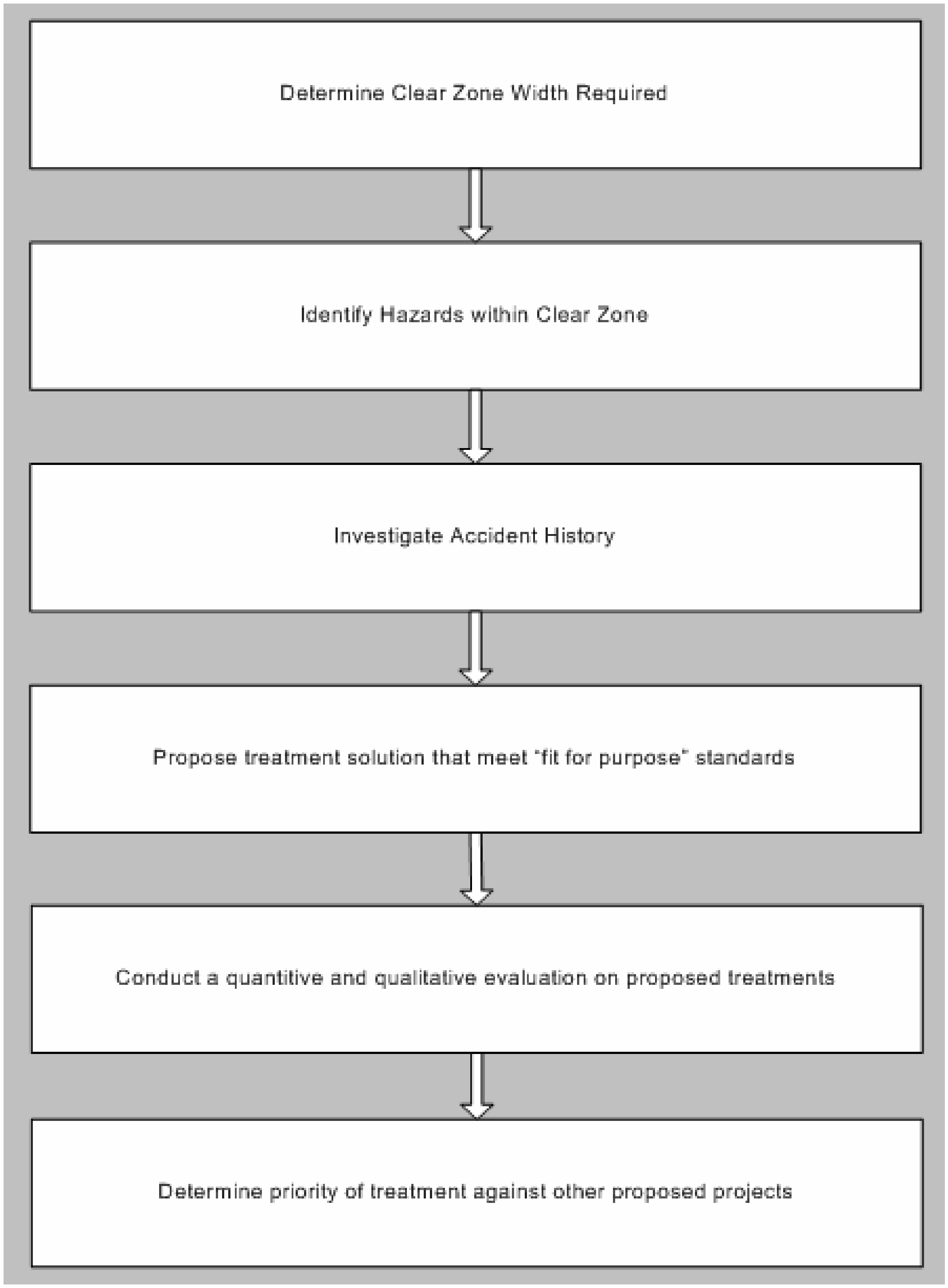

Figure 7-1 Proposed Assessment and Prioritisation Procedure

A list of considerations has been developed to assist designers and engineers to address all aspects in relation to the hazard, clear zone width and treatment selection. The checklist should be kept as documented evidence of compliance with duty of care responsibilities. See Figure 7-2 on next page.

CLEAR ZONE HAZARD TREATMENT CONSIDERATIONS	Addressed
• Has the correct operating speed been determined? (Note: This is not the post speed). • Does the clear zone width need to be adjusted for side slopes or horizontal geometry? • Have you performed a benefit cost ratio assessment? • Has the accident history, including frequency and severity of crashes, been determined? • Does the treatment suit the site? • Have you considered the treatment's affect on pedestrian paths? • Will the public react negatively to the proposed treatment? • Does the treatment effect public transport routes? • Will there be any adverse effects on the environment? • Will the treatment provide a risk greater than the hazard? • Has barrier deflection widths been taken into account? • Has the shy line been considered in the placement of guardrail? • Does the treatment conflict with property assesses or sight lines? • Does the treatment effect public transport or school bus routes? • Has the need of gating or non-gating end treatments been determined? • Has the effect on required light intensity been considered when relocating street lights • Has the proximity of overhead power lines been considered when recommending slip base poles for street lights? • Has the amount of heavy vehicles been considered in the select of barrier type? • Has manufacturers' stated barrier limitations been taken into account in relation to side slope and minimum horizontal and vertical curves?	

Figure 7-2 Clear Zone Hazard Treatment Considerations

A hazard treatment evaluation score card has also been developed, to use in conjunction with the checklist. This score card assists in the final selection of the most appropriate treatment. It also provides evidence of the methodology that has been followed.

Figure 7-3 Hazard Treatment Evaluation Score Card

HAZARD TREATMENT EVALUATION SCORE CARD	
Treatment	**Score**
Accident History	
Benefit Cost Ratio Score	
Horizontal Geometry	
Severity of Accident	
Vertical Geometry	
Treatment Impact	
Total	

Legend

• Score of greater than 10	Treatment should be implemented as soon as possible.
• Score of 7-10	Treatment is a priority.
• Score of less than 7	Funds better utilised elsewhere.

Accident History	
3	> 3 accidents over 3 years
2	2-3 accidents over 3 years (adopt for design)
1	1 accident over 3 years
0	<1 accident

Benefit Cost Ratio Score	
3	> 2.5
2	1.2 – 2.5
1	0.8 – 1.2
0	< 0.8

Horizontal Geometry	
3	Hazard located on outside of curve less than R200
2	Hazard located on outside of curve greater than R200
1	Hazard located on inside of curve
0	Straight

Severity of worst accidents that have occurred	
4	Fatal
3	Hospitalisation (adopt for design)
2	Medical attention
1	Property damage

Vertical Geometry	
3	Downgrade greater than 8%
2	Downgrade 5-8%
1	Downgrade 2-5%
0	Downgrade less than 2%

Treatment Impacts	
The public will react negatively to the proposed treatment, for example, removal of significant trees.	-1
The treatment will impact on public and school bus routes.	-1
There will be a negative impact on the environment, for example, trees and watercourses.	-1
The treatment will have a major impact on pedestrians.	-1

8. Test Cases

Two test cases have been selected to test the findings from this research paper:-

- An existing untreated site
- Proposed treatment for landscaping in the design process.

8.1 Existing Site

The site under consideration consists of a row of timber power poles which are located in the centre median, as indicated in sigure 8-1 and 8-2. The power poles are located 1.0m from the traffic lane and extend over a distance of 900m at an interval of 30m. The median width is 3.0m. The AADT is 23737 vehicles with an annual approximate growth rate of 2%, with 11.5% heavy vehicles. The operating speed in this section is 62 km/hr. The geometry is straight with a downgrade of 2%

The clear zone for this area with the above criteria requires a width of 4.2m.

An analysis of the accident history reveals that there have been 3 accidents where a vehicle has struck a power pole over the past 15 years. The 3 accidents consisted of 2 requiring medical attention and the other admission into hospital.

The possible treatment scenarios are:-

1) Remove the hazard by placing the power line underground. Treatment cost for this would be around $400 000
2) Relocation of the power line to the side of the road however this would be an unlikely option as there are conflicts with light poles, trees, underground services and pedestrian footpath.
3) Providing guardrail as an option requires the power poles to be relocated to the centre of the median and steel beam guardrail placed on both sides of the median. Treatment cost for this would be around $250 000 to relocate the poles and $270 000 to install the guardrail.

From the three options investigated, Option 1 would be the only likely treatment to be considered further based on cost, practicality and derived benefit.

A quantitative evaluation of treatment 1 using the Queensland Main Roads RISC program gives a Benefit Cost Ratio of 0.

The accident history shows that the poles represent a low risk. Taking the AADT of the closest carriageway of 9896 vehicles, over 15 years 52844640 vehicles have past the power poles with only 3 recorded accidents. This represents a very low probability of an accident occurring. The accidents were not severe with only 1 accident requiring hospitalisation.

Table 8-1 Evaluation Score Card for Existing Site

HAZARD TREATMENT EVALUATION SCORE CARD

Accident History	1
Benefit Cost Ratio Score	0
Horizontal Geometry	3
Severity of Accident	1
Vertical Geometry	0
Treatment Impact	0
Total	**5**

The score card gives a score of five which reflects that funds would be better utilised elsewhere. Therefore the recommendation is that the treatment cost is too high to warrant action. The site should be placed on a list for prioritisation with other projects, but it is very doubtful if it would ever get funding ahead of more urgent or higher risk projects.

Figure 8-1 Existing Site – Photo 1

Figure 8-2 Existing Site – Photo 2

8.2 Proposed Treatment in Design Process

The site under consideration involves controlling the right turn movements by the installation of a centre median. The council want to plant Red Ceder trees in the median for aesthetic reasons. The trunks of these trees will grow to greater than 80mm in diameter. As indicated in Figure 8-3? the trees will be located 2.6 m from the traffic lane and planted at an interval of approximately 10m. The median width is 4.2m. The AADT is 22349 vehicles with an annual growth rate of 2%, with 3% heavy vehicles. The operating speed in this section is 58 km/hr. The geometry is straight with a flat grade.

The clear zone for this area with the above criteria requires a width of 4.2m.

The possible treatment scenarios are:-

1) Plant frangible shrubs instead of the proposed trees. The council prefer the trees to provide more of an aesthetic impact leading into the city centre.
2) Providing barrier to shield the trees on both sides of the median. Wire rope is the preferred barrier treatment.

   Treatment cost would be around $50 000 for 406m of wire rope installed in two sections.

From the two options proposed, only Treatment 2 would be considered further based on cost, practicality and derived benefit.

A quantitative evaluation of treatment 2 using the Queensland Main Roads RISC program gives a Benefit Cost Ratio of 0.

Questions that need to be considered in this situation are:-

- Do you install the guardrail as soon as the trees are planted?

  The guardrail will present more of a hazard then the tree until the trees have matured. The risk is will the wire rope be installed when it is needed in the future.

- Will the guardrail have an adverse impact on pedestrian paths across the road?

The guardrail should have little impact on Pedestrians as there are break at intersections.

- Is the median wide enough to cater for guardrail deflection?

  The median is 4.2m wide, installing the wire rope 0.5m from the kerb face, will leave 1.55m for the wire rope to deflect if the tree trunks grow to 100mm in diameter. The manufactures will have to be consulted to achieve a post spacing that will achieve this deflection.

Table 8-2 Evaluation Score Card for Proposed Site

HAZARD TREATMENT EVALUATION SCORE CARD

Accident History	2
Benefit Cost Ratio Score	0
Horizontal Geometry	3
Severity of Accident	0
Vertical Geometry	0
Treatment Impact	0
Total	**5**

The score card gives a score of five which reflects that funds would be better utilised elsewhere. Therefore the recommendation is that the treatment cost is too high to warrant action and funds would be better served elsewhere. The site should be placed on a list for prioritisation against other projects and monitored to see if vehicles are impacting the young trees.

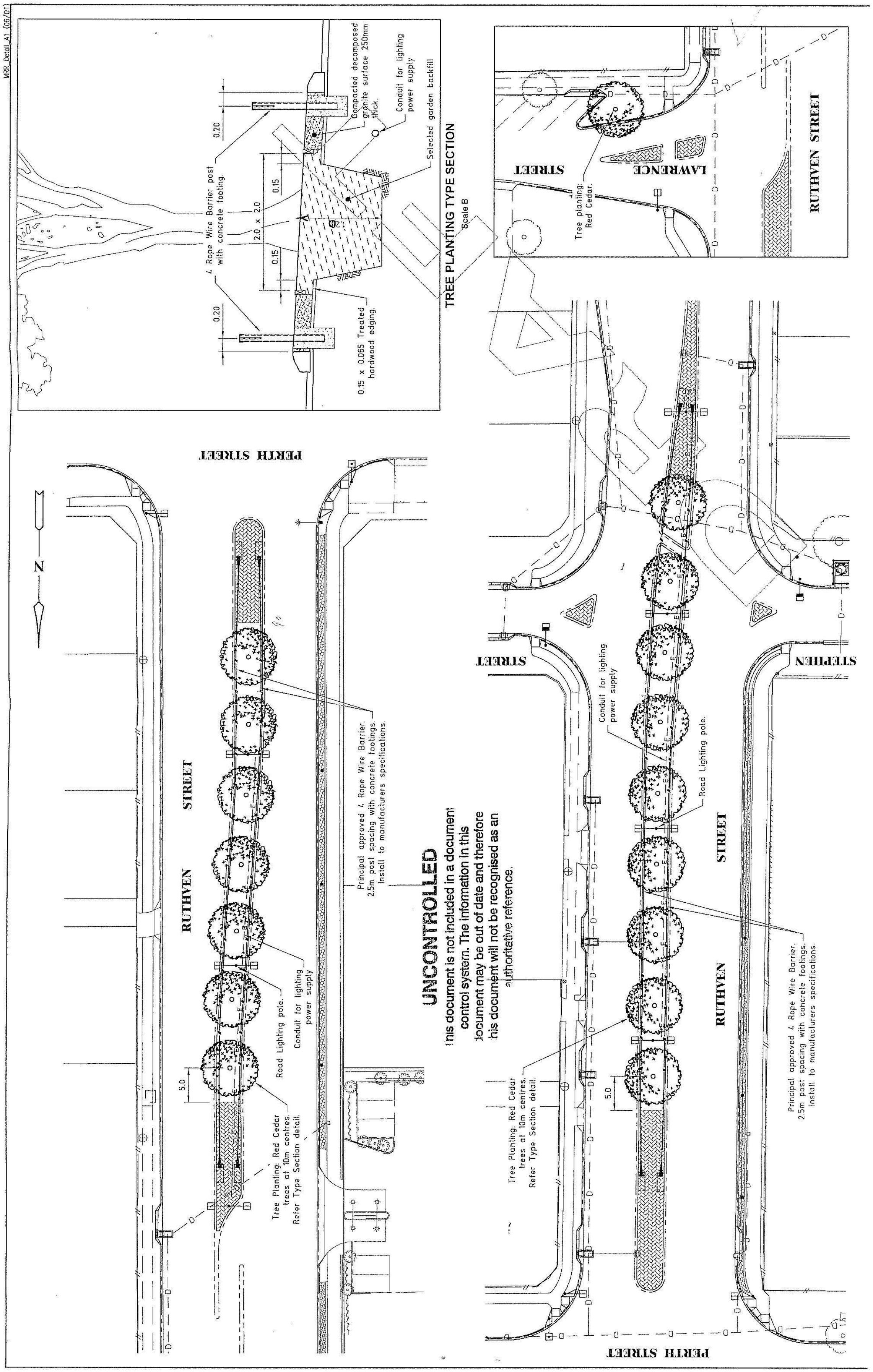

Figure 8-3 Plan for Test Case Two

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APPENDIX A – Project Specification

University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/2 Research Project
PROJECT SPECIFICATION

FOR: **Tony Gallagher**

Topic: **<u>Roadway Clear Zones in Urban Environments</u>**

Supervisor: Associate Professor Ron Ayers

Sponsorship: Queensland Department of Main Roads

Project Aim: This project aims to provide engineers and designers guidance in the selection of an appropriate treatment for hazards located close to the travel path of road vehicles.

Programme: **<u>Issue A, 17 March 2007</u>**

1. Research the background information relating to the identification and treatment of roadside hazards, and in particular the use of use of clear zones.
2. Research and evaluate available methods used for risk assessment of roadside hazards and determine an appropriate method to be used in an urban environment.
3. Research the protective measures used for roadside hazards, particularly those which are applicable in urban situations.
4. Determine the legal requirements and likely ramifications for a road authority when a vehicle impacts a hazard that is within a specified clear zone.
5. Analyse vehicle crash rates in urban areas relating to roadside hazards.
6. Explore the concepts of :-
    - Net reduction of risks
    - Risk acceptance of hazards providing a social or environmental benefit.
7. Determine and test a suitable procedure for the evaluation and treatment of roadside hazards in urban environments.
8. Provided the required written and oral presentations of the project work.

As time permits

9. Extend the investigation to rural, high speed environments

Agreed ……………………………(Student) ……………………………………(Supervisor)

Dated 30/3/07

Appendix B – RISC Reports

Offset 0.5 (50)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.4	0.6	0.4	1.4	2.3	1.6	0.7	1.1	0.8	0.7	1.1	0.8	0.5	0.7	0.5
$5,000	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$10,000	0	0	0	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.7	1.1	0.8	2.9	4.6	3.3	1.4	2.3	1.6	1.4	2.3	1.6	0.9	1.5	1.1
$5,000	0.1	0.2	0.1	0.4	0.7	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2
$10,000	0.1	0.1	0.1	0.3	0.5	0.3	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.1
$20,000	0	0.1	0	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.6	5.7	4.1	14.4	23	16.5	7.2	11.5	8.2	7.1	11.3	8.1	4.8	7.6	5.5
$5,000	0.5	0.8	0.6	2.1	3.3	2.4	1	1.6	1.2	1	1.6	1.2	0.7	1.1	0.8
$10,000	0.4	0.6	0.4	1.4	2.3	1.7	0.7	1.1	0.8	0.7	1.1	0.8	0.5	0.8	0.5
$20,000	0.2	0.3	0.2	0.7	1.1	0.8	0.4	0.6	0.4	0.4	0.6	0.4	0.2	0.4	0.3
$50,000	0.1	0.1	0.1	0.3	0.5	0.3	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.1

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	7.1	11.5	8.2	28.7	46	33.1	14.3	23	16.5	14.2	22.6	16.3	7.2	11.5	8.3
$5,000	1	1.6	1.2	4.1	6.6	4.7	2.1	3.3	2.4	2	3.2	2.3	1	1.6	1.2
$10,000	0.7	1.1	0.8	2.9	4.6	3.3	1.4	2.3	1.7	1.4	2.3	1.6	0.7	1.1	0.8
$20,000	0.4	0.6	0.4	1.4	2.3	1.7	0.7	1.1	0.8	0.7	1.1	0.8	0.4	0.6	0.4
$50,000	0.1	0.2	0.2	0.6	0.9	0.7	0.3	0.5	0.3	0.3	0.5	0.3	0.1	0.2	0.2

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	14.4	23	16.5	57.5	92	66.1	28.7	46	33	28.3	45.3	32.6	19.1	30.6	22
$5,000	2.1	3.3	2.4	8.2	13.1	9.5	4.1	6.6	4.7	4	6.5	4.7	2.7	4.4	3.1
$10,000	1.4	2.3	1.7	5.8	9.2	6.6	2.9	4.6	3.3	2.8	4.5	3.3	1.9	3.1	2.2
$20,000	0.7	1.1	0.8	2.9	4.6	3.3	1.4	2.3	1.7	1.4	2.3	1.6	1	1.5	1.1
$50,000	0.3	0.5	0.3	1.1	1.8	1.3	0.6	0.9	0.7	0.6	0.9	0.7	0.4	0.6	0.4

Offset 0.5 (60)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.5	0.7	0.6	1.9	3	2.3	1	1.5	1.1	0.9	1.5	1.1	0.6	1	0.7
$5,000	0.1	0.1	0.1	0.3	0.4	0.3	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1
$10,000	0	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0.1	0	0.1	0.1	0	0	0
$50,000	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.9	1.5	1.1	3.8	6	4.5	1.9	3	2.3	1.9	2.9	2.2	1.3	2	1.5
$5,000	0.1	0.2	0.2	0.5	0.8	0.6	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.3	0.2
$10,000	0.1	0.1	0.1	0.4	0.6	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.1
$20,000	0	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	4.7	7.4	5.6	19	29.8	22.5	9.5	14.9	11.2	9.4	14.6	11.1	6.3	9.9	7.5
$5,000	0.7	1.1	0.8	2.7	4.2	3.2	1.4	2.1	1.6	1.3	2.1	1.6	0.9	1.4	1.1
$10,000	0.5	0.7	0.6	1.9	3	2.3	0.9	1.5	1.1	0.9	1.5	1.1	0.6	1	0.7
$20,000	0.2	0.4	0.3	1	1.5	1.1	0.5	0.7	0.6	0.5	0.7	0.6	0.3	0.5	0.4
$50,000	0.1	0.1	0.1	0.4	0.6	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.1

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	9.5	14.8	11.2	37.9	59.4	44.9	19	29.7	22.5	18.7	29.2	22.2	13	19.8	14.9
$5,000	1.4	2.1	1.6	5.4	8.5	6.4	2.7	4.2	3.2	2.7	4.2	3.2	1.8	2.8	2.1
$10,000	0.9	1.5	1.1	3.8	5.9	4.5	1.9	3	2.3	1.9	2.9	2.2	1.3	2	1.5
$20,000	0.5	0.7	0.6	1.9	3.1	2.3	0.9	1.5	1.1	0.9	1.5	1.1	0.6	1	0.7
$50,000	0.2	0.3	0.2	0.8	1.2	0.9	0.4	0.6	0.5	0.4	0.6	0.4	0.3	0.4	0.3

AADT 20000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	19	29.7	22.5	76.1	119	90.2	37.9	59.4	45	37.4	58.6	44.5	25	39.5	29.9
$5,000	2.7	4.2	3.2	10.9	16.9	12.9	5.4	8.5	6.4	5.3	8.4	6.3	3.6	5.6	4.3
$10,000	1.9	3	2.2	7.6	11.9	9	3.8	5.9	4.5	3.7	5.8	4.4	2.5	3.9	3
$20,000	0.9	1.5	1.1	3.8	5.9	4.5	1.9	3	2.3	1.9	2.9	2.2	1.3	2	1.5
$50,000	0.4	0.6	0.4	1.5	2.4	1.8	0.8	1.2	0.9	0.7	1.2	0.9	0.5	0.8	0.6

Offset 0.5 (70)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.6	0.9	0.7	2.4	3.6	2.9	1.2	1.8	1.4	1.2	1.8	1.4	0.6	0.9	1.2
$5,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.1	0.2
$10,000	0.1	0.1	0.1	0.2	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1
$50,000	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.2	1.4	1.8	4.7	5.7	7.3	2.4	2.9	3.6	2.3	2.8	3.6	1.6	1.9	2.4
$5,000	0.2	0.2	0.3	0.7	0.8	1	0.3	0.4	0.5	0.3	0.4	0.5	0.2	0.3	0.3
$10,000	0.1	0.1	0.2	0.5	0.6	0.7	0.2	0.3	0.4	0.2	0.3	0.4	0.2	0.2	0.2
$20,000	0.1	0.1	0.1	0.2	0.3	0.4	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0.1	0.1	0	0.1	0.1	0	0	0

AADT 5000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	5.9	7.1	9.1	23.6	28.6	36.4	11.7	14.3	18.2	11.6	14.1	17.9	7.8	9.5	12.1
$5,000	0.8	1	1.3	3.4	4.1	5.2	1.7	2	2.6	1.7	2	2.6	1.1	1.4	1.7
$10,000	0.6	0.7	0.9	2.4	2.9	3.6	1.2	1.4	1.8	1.2	1.4	1.8	0.8	1	1.2
$20,000	0.3	0.4	0.5	1.2	1.4	1.8	0.6	0.7	0.9	0.6	0.7	0.9	0.4	0.5	0.6
$50,000	0.1	0.1	0.2	0.5	0.6	0.7	0.2	0.3	0.4	0.2	0.3	0.4	0.2	0.2	0.2

AADT 10000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	11.8	14.3	18.2	47.4	57.1	72.6	23.6	28.5	36.3	23.2	28.2	35.8	15.6	19	24.2
$5,000	1.7	2	2.6	6.8	8.2	10.4	3.4	4.1	5.2	3.3	4	5.1	2.2	2.7	3.4
$10,000	1.2	1.4	1.8	4.7	5.7	7.3	2.4	2.9	3.6	2.3	2.8	3.6	1.6	1.9	2.4
$20,000	0.6	0.7	0.9	2.4	2.9	3.6	1.2	1.4	1.8	1.2	1.4	1.8	0.8	1	1.2
$50,000	0.2	0.3	0.4	0.9	1.1	1.5	0.5	0.6	0.7	0.5	0.6	0.7	0.3	0.4	0.5

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	23.6	28.5	36.3	94.3	94.1	145.1	47.3	57.3	72.7	46.6	56.5	71.6	31.4	37.9	48.4
$5,000	3.4	4.1	5.2	13.5	13.5	20.8	6.8	8.2	10.4	6.7	8.1	10.2	4.5	5.4	6.9
$10,000	2.4	2.9	3.6	9.5	9.5	14.6	4.7	5.7	7.3	4.7	5.7	7.2	3.1	3.8	4.8
$20,000	1.2	1.4	1.8	4.7	4.7	7.3	2.4	2.9	3.6	2.3	2.8	3.6	1.6	1.9	2.4
$50,000	0.5	0.6	0.7	1.9	1.9	2.9	0.9	1.1	1.5	0.9	1.1	1.4	0.6	0.8	1

Offset 1.0 (50)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.3	0.3	0.5	1.2	1.3	1.9	0.6	0.7	0.9	0.9	0.7	0.9	0.4	0.4	0.6
$5,000	0	0	0	0.2	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$10,000	0	0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.6	0.7	0.9	2.3	2.7	2.3	0.7	0.9	3.7	1.1	1.3	1.8	0.8	0.9	1.2
$5,000	0.1	0.1	0.1	0.3	0.4	0.3	0.1	0.1	0.5	0.2	0.2	0.3	0.1	0.1	0.2
$10,000	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.4	0.1	0.1	0.2	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	1	0.2	0.1	0.1	0.1	0	0	0.1
$50,000	0	0	0	0	0.1	0	0	0	0.1	0	0	0	0	0	0

AADT 5000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.9	3.4	4.6	11.6	18.6	13.4	5.8	9.3	6.7	5.7	9.1	6.6	3.9	6.2	4.5
$5,000	0.4	0.5	0.7	1.7	2.7	1.9	0.8	1.3	1	0.8	1.3	0.9	0.6	0.9	0.6
$10,000	0.3	0.3	0.5	1.2	1.9	1.3	0.6	0.9	0.7	0.6	0.9	0.7	0.4	0.6	0.4
$20,000	0.1	0.2	0.2	0.6	0.9	0.7	0.3	0.5	0.3	0.3	0.5	0.3	0.2	0.3	0.2
$50,000	0.1	0.1	0.1	0.2	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1

AADT 10000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	5.8	9.3	6.7	23.3	9.3	26.8	11.6	18.5	13.4	11.4	18.2	13.2	7.7	12.3	8.9
$5,000	0.8	1.3	1	3.3	1.3	3.8	1.7	2.7	1.9	1.6	2.6	1.9	1.1	1.8	1.3
$10,000	0.6	0.9	0.7	2.3	0.9	2.7	1.2	1.9	1.3	1.1	1.8	1.3	0.8	1.2	0.9
$20,000	0.3	0.5	0.3	1.2	0.5	1.3	0.6	0.9	0.7	0.6	0.9	0.7	0.4	0.6	0.4
$50,000	0.1	0.2	0.1	0.5	0.2	0.5	0.2	0.4	0.3	0.2	0.4	0.3	0.2	0.2	0.2

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	11.6	18.6	13.4	46.6	74.3	53.8	23.3	37.1	26.9	22.9	36.6	26.5	15.5	24.7	17.9
$5,000	1.7	2.6	1.9	6.6	10.6	7.7	3.3	5.3	3.8	3.3	5.2	3.8	2.2	3.5	2.5
$10,000	1.2	1.9	1.3	4.7	7.4	5.4	2.3	3.7	2.7	2.3	3.7	2.7	1.5	2.5	1.8
$20,000	0.6	0.9	0.7	2.3	3.7	2.7	1.2	1.9	1.3	1.1	1.8	1.3	0.8	1.2	0.9
$50,000	0.2	0.4	0.3	0.9	1.5	1.1	0.5	0.7	0.5	0.5	0.7	0.5	0.3	0.5	0.4

Offset 1.0 (60)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.4	0.6	0.5	1.6	2.5	1.9	0.8	1.3	1	0.8	1.2	0.9	0.5	0.8	0.6
$5,000	0.1	0.1	0.1	0.2	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$10,000	0	0.1	0	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$50,000	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.8	1.3	1	3.2	5	3.8	1.6	2.5	1.9	1.6	2.5	1.9	1.1	1.7	1.3
$5,000	0.1	0.2	0.1	0.5	0.7	0.5	0.2	0.4	0.3	0.2	0.4	0.3	0.2	0.2	0.2
$10,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1
$20,000	0	0.1	0	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	4	6.3	4.8	16.1	25.1	19.1	8	12.5	9.5	7.9	12.4	9.4	5.3	8.3	6.3
$5,000	0.6	0.9	0.7	2.3	3.6	2.7	1.1	1.8	1.4	1.1	1.8	1.3	0.8	1.2	0.9
$10,000	0.4	0.6	0.5	1.6	2.5	1.9	0.8	1.3	1	0.8	1.2	0.9	0.5	0.8	0.6
$20,000	0.2	0.3	0.2	0.8	1.3	1	0.4	0.6	0.5	0.4	0.6	0.5	0.3	0.4	0.3
$50,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	8	12.5	9.6	32.2	50.2	38.2	16.1	25.1	19.1	15.9	24.7	18.9	10.7	16.7	12.7
$5,000	1.1	1.8	1.4	4.6	7.2	5.5	2.3	3.6	2.7	2.3	3.5	2.7	1.5	2.4	1.8
$10,000	0.8	1.3	1	3.2	5	3.8	1.6	2.5	1.9	1.6	2.5	1.9	1.1	1.7	1.3
$20,000	0.4	0.6	0.5	1.6	2.5	1.9	0.8	1.3	1	0.8	1.2	0.9	0.5	0.8	0.6
$50,000	0.2	0.3	0.2	0.6	1	0.8	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.3	0.3

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	16	25	19.1	64.3	100.4	76.4	32.1	50.1	38	31.5	49.3	37.6	21.2	33.2	25.2
$5,000	2.3	3.6	2.7	9.2	14.3	10.9	4.6	7.2	5.4	4.5	7.1	5.4	3	4.8	3.6
$10,000	1.6	2.5	1.9	6.4	10	7.6	3.2	5	3.8	3.2	4.9	3.8	2.1	3.3	2.5
$20,000	0.8	1.3	1	3.2	5	3.8	1.6	2.5	1.9	1.6	2.5	1.9	1.1	1.7	1.3
$50,000	0.3	0.5	0.4	1.3	2	1.5	0.6	1	0.8	0.6	1	0.8	0.4	0.7	0.5

Offset 1.0 (70)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.5	0.8	0.6	2.1	3.2	2.5	1	1.6	1.2	1	1.6	1.2	0.7	1	0.8
$5,000	0.1	0.1	0.1	0.3	0.5	0.4	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1
$10,000	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0
$50,000	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1	1.6	1.2	4.1	6.3	5	2.1	3.2	2.5	2	3.1	2.5	1.4	2.1	1.7
$5,000	0.1	0.2	0.2	0.6	0.9	0.7	0.3	0.5	0.4	0.3	0.4	0.4	0.2	0.3	0.2
$10,000	0.1	0.2	0.1	0.4	0.6	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2
$20,000	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	5.1	7.9	6.2	20.6	31.6	25	10.3	15.8	12.5	10.1	15.6	12.3	6.8	10.5	8.3
$5,000	0.7	1.1	0.9	2.9	4.5	3.6	1.5	2.3	1.8	1.4	2.2	1.8	1	1.5	1.2
$10,000	0.5	0.8	0.6	2.1	3.2	2.5	1	1.6	1.2	1	1.6	1.2	0.7	1	0.8
$20,000	0.3	0.4	0.3	1	1.6	1.2	0.5	0.8	0.6	0.5	0.8	0.6	0.3	0.5	0.4
$50,000	0.1	0.2	0.1	0.4	0.6	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	10.2	15.8	12.4	41.1	63.2	50	20.5	31.6	25	20.3	31.1	24.7	13.6	21	16.6
$5,000	1.5	2.2	1.8	5.9	9	7.1	2.9	4.5	3.6	2.9	4.4	3.5	1.9	3	2.4
$10,000	1	1.6	1.2	4.1	6.3	5	2.1	3.2	2.5	2	3.1	2.5	1.4	2.1	1.7
$20,000	0.5	0.8	0.6	2.1	3.2	2.5	1	1.6	1.2	1	1.6	1.2	0.7	1	0.8
$50,000	0.2	0.3	0.2	0.8	1.3	1	0.4	0.6	0.5	0.4	0.6	0.5	0.3	0.4	0.3

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	20.5	31.5	24.9	82.3	126.4	100	41.1	63.2	49.9	40.6	62.3	49.4	27.3	42	33.1
$5,000	2.9	4.5	3.6	11.7	18	14.3	5.9	9	7.1	5.8	8.9	7.1	3.9	6	4.7
$10,000	2	3.1	2.5	8.2	12.6	10	4.1	6.3	5	4.1	6.2	4.9	2.7	4.2	3.3
$20,000	1	1.6	1.2	4.1	6.3	5	2.1	3.2	2.5	2	3.1	2.5	1.4	2.1	1.7
$50,000	0.4	0.6	0.5	1.6	2.5	2	0.8	1.3	1	0.8	1.2	1	0.5	0.8	0.7

Offset 2.0 (50)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.2	0.3	0.2	0.8	1.2	0.9	0.4	0.6	0.4	0.4	0.6	0.4	0.3	0.4	0.3
$5,000	0	0	0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0
$10,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$20,000	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.4	0.6	0.5	1.6	2.5	1.8	0.8	1.2	0.9	0.8	1.2	0.9	0.5	0.8	0.6
$5,000	0.1	0.1	0.1	0.2	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$10,000	0	0.1	0	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.9	3.1	2.3	7.8	12.4	9.1	3.9	6.2	4.5	3.8	6.1	4.5	2.6	4.1	3
$5,000	0.3	0.4	0.3	1.1	1.8	0.3	0.6	0.9	0.6	0.5	0.9	0.6	0.4	0.6	0.4
$10,000	0.2	0.3	0.2	0.8	1.2	0.9	0.4	0.6	0.5	0.4	0.6	0.4	0.3	0.4	0.3
$20,000	0.1	0.2	0.1	0.4	0.6	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2
$50,000	0	0.1	0	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.9	6.2	4.5	15.6	24.9	18.1	7.8	12.4	9	7.7	12.2	8.9	5.2	8.3	6
$5,000	0.6	0.9	0.6	2.2	3.6	2.6	1.1	1.8	1.3	1.1	1.7	1.3	0.7	1.2	0.9
$10,000	0.4	0.6	0.5	1.6	2.5	1.8	0.8	1.2	0.9	0.8	1.2	0.9	0.5	0.8	0.6
$20,000	0.2	0.3	0.2	0.8	1.2	0.9	0.4	0.6	0.5	0.4	0.6	0.4	0.3	0.4	0.3
$50,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1

AADT 20000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	7.8	12.4	9	31.3	49.8	36.2	15.6	24.9	18.1	15.4	24.5	17.9	10.4	16.6	12
$5,000	1.1	1.8	1.3	4.5	7.1	5.2	2.2	3.5	2.6	2.2	3.5	2.6	1.5	2.4	1.7
$10,000	0.8	1.2	0.9	3.1	5	3.6	1.6	2.5	1.8	1.5	2.4	1.8	1	1.7	1.2
$20,000	0.4	0.6	0.5	1.6	2.5	1.8	0.8	1.2	0.9	0.8	1.2	0.9	0.5	0.8	0.6
$50,000	0.2	0.2	0.2	0.6	1	0.7	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.3	0.2

Offset 2.0 (60)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.3	0.5	0.3	1.2	1.8	1.4	0.6	0.9	0.7	0.6	0.9	0.7	0.4	0.6	0.5
$5,000	0	0.1	0	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$10,000	0	0	0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0
$20,000	0	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.6	0.9	0.7	2.3	3.6	2.8	1.2	1.8	1.4	1.2	1	1.4	0.8	1.2	0.9
$5,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.1
$10,000	0.1	0.1	0.1	0.2	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0
$50,000	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.9	4.5	3.5	11.7	18.2	13.9	5.8	9.1	7	5.7	8.9	6.9	3.9	6	4.6
$5,000	0.4	0.6	0.5	1.7	2.6	2	0.8	1.3	1	0.8	1.3	1	0.6	0.9	0.7
$10,000	0.3	0.5	0.3	1.2	1.8	1.4	0.6	0.9	0.7	0.6	0.9	0.7	0.4	0.6	0.5
$20,000	0.1	0.2	0.2	0.6	0.9	0.7	0.3	0.5	0.3	0.3	0.4	0.3	0.2	0.3	0.2
$50,000	0.1	0.1	0.1	0.2	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	5.8	9.1	6.9	23.3	36.4	27.8	11.6	18.1	13.8	11.4	17.8	13.7	7.6	12.1	9.2
$5,000	0.8	1.3	1	3.3	5.2	4	1.7	2.6	2	1.6	2.6	2	1.1	1.7	1.3
$10,000	0.6	0.9	0.7	3.3	3.6	2.8	1.2	1.8	1.4	1.1	1.8	1.4	0.8	1.2	0.9
$20,000	0.3	0.5	0.3	1.2	1.8	1.4	0.6	0.9	0.7	0.6	0.9	0.7	0.4	0.6	0.5
$50,000	0.1	0.2	0.1	0.5	0.7	0.6	0.2	0.4	0.3	0.2	0.4	0.3	0.2	0.2	0.2

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	11.6	18.1	13.9	46.7	72.8	55.7	23.3	36.4	27.8	23	35.8	27.5	15.5	24.2	18.5
$5,000	1.7	2.6	2	6.7	10.4	8	3.3	5.2	4	3.3	5.1	3.9	2.2	3.5	2.6
$10,000	1.2	1.8	1.4	4.7	7.3	5.6	2.3	3.6	2.8	2.3	3.6	2.7	1.5	2.4	1.8
$20,000	0.6	0.9	0.7	2.3	3.6	2.8	1.2	1.8	1.4	1.1	1.8	1.4	0.8	1.2	0.9
$50,000	0.2	0.4	0.3	0.9	1.5	1.1	0.5	0.7	0.6	0.5	0.7	0.5	0.3	0.5	0.4

Offset 2.0 (70)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.4	0.6	0.5	1.6	2.4	1.9	0.8	1.2	1	0.8	1.2	0.9	0.5	0.8	0.6
$5,000	0.1	0.1	0.1	0.2	0.3	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$10,000	0	0.1	0	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.8	1.2	1	3.2	4.8	3.8	1.6	2.4	1.9	1.6	2.4	1.9	1	1.6	1.3
$5,000	0.1	0.2	0.1	0.4	0.7	0.5	0.2	0.3	0.3	0.2	0.3	0.3	0.1	0.2	0.2
$10,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1
$20,000	0	0.1	0	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.9	6	4.8	15.8	24.2	19.2	7.9	12.1	9.6	7.8	11.9	9.5	5.2	8	6.3
$5,000	0.6	0.9	0.7	2.2	3.4	2.7	1.1	1.7	1.4	1.1	1.7	1.4	0.7	1.1	0.9
$10,000	0.4	0.6	0.5	1.6	2.4	1.9	0.8	1.2	1	0.8	1.2	0.9	0.5	0.8	0.6
$20,000	0.2	0.3	0.2	0.8	1.2	1	0.4	0.6	0.5	0.4	0.6	0.5	0.3	0.4	0.3
$50,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	7.8	12	9.5	31.5	48.3	38.3	15.7	24.1	19.1	15.5	23.8	18.9	10.4	16	12.7
$5,000	1.1	1.7	1.4	4.5	6.9	5.5	2.2	3.4	2.7	2.2	3.4	2.7	1.5	2.3	1.8
$10,000	0.8	1.2	1	3.1	4.8	3.8	1.6	2.4	1.9	1.6	2.4	1.9	1	1.6	1.3
$20,000	0.4	0.6	0.5	1.6	2.4	1.9	0.8	1.2	1	0.8	1.2	0.9	0.5	0.8	0.6
$50,000	0.2	0.2	0.2	0.6	1	0.8	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.3	0.3

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	15.7	24.1	19.1	63	96.7	76.7	31.4	48.3	38.3	31	47.6	37.9	20.9	32.1	25.4
$5,000	2.2	3.4	2.7	9	13.8	10.9	4.5	6.9	5.5	4.4	6.8	5.4	3	4.6	3.6
$10,000	1.6	2.4	1.9	6.3	9.7	7.7	3.1	4.8	3.8	3.1	4.8	3.8	2.1	3.2	2.5
$20,000	0.8	1.2	1	3.1	4.8	3.8	1.6	2.4	1.9	1.6	2.4	1.9	1	1.6	1.3
$50,000	0.3	0.5	0.4	1.3	1.9	1.5	0.6	1	0.8	0.6	1	0.8	0.4	0.6	0.5

Offset 2.5 (50)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.2	0.3	0.2	0.6	1	0.7	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.3	0.2
$5,000	0	0	0	0.1	0.1	0.14	0	0.1	0.1	0	0.1	0.1	0	0	0
$10,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$20,000	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.3	0.5	0.4	1.3	2.1	1.5	0.6	1	0.7	0.6	1	0.7	0.4	0.7	0.5
$5,000	0	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$10,000	0	0.1	0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.6	2.6	1.9	6.4	10.3	7.5	3.2	5.1	3.7	3.2	5	3.7	2.1	3.4	2.5
$5,000	0.2	0.4	0.3	0.9	1.5	1.1	0.5	0.7	0.5	0.5	0.7	0.5	0.3	0.5	0.4
$10,000	0.2	0.3	0.2	0.6	1	0.7	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.3	0.2
$20,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.1
$50,000	0	0.1	0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.2	5.1	3.7	12.8	20.5	14.9	6.4	10.2	7.4	6.3	10.1	7.3	4.2	6.8	4.9
$5,000	0.5	0.7	0.5	1.8	2.9	2.1	0.9	1.5	1.1	0.9	1.4	1.1	0.6	1	0.7
$10,000	0.3	0.5	0.4	1.3	2	1.5	0.6	1	0.7	0.6	1	0.7	0.4	0.7	0.5
$20,000	0.2	0.3	0.2	0.6	1	0.7	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.3	0.2
$50,000	0.1	0.1	0.1	0.3	0.4	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	6.4	10.2	7.4	25.8	41	29.9	12.9	20.5	14.9	12.7	20.1	14.7	8.5	13.6	9.9
$5,000	0.9	1.5	1.1	3.7	5.9	4.3	1.8	2.9	2.1	1.8	2.9	2.1	1.2	1.9	1.4
$10,000	0.6	1	0.7	2.6	4.1	3	1.3	2	1.5	1.3	2	1.5	0.9	1.4	1
$20,000	0.3	0.5	0.4	1.3	2	1.5	0.6	1	0.7	0.6	1	0.7	0.4	0.7	0.5
$50,000	0.1	0.2	0.1	0.5	0.8	0.6	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.3	0.2

Offset 2.5 (60)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.2	0.4	0.3	1	1.6	1.2	0.5	0.8	0.6	0.5	0.8	0.6	0.3	0.5	0.4
$5,000	0	0.1	0	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1
$10,000	0	0	0	0.1	0.2	0.1	0	0.1	0.1	0	0.1	0.1	0	0.1	0
$20,000	0	0	0	0	0.1	0.1	0	0	0	0	0.1	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.5	0.8	0.6	2	3.1	2.4	1	1.6	1.2	1	1.5	1.2	0.7	1	0.8
$5,000	0.1	0.1	0.1	0.3	0.4	0.3	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1
$10,000	0	0.1	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.2	0.1	0	0.1	0.1	0	0.1	0.1	0	0.1	0
$50,000	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.5	3.9	3	10	15.6	11.9	5	7.8	6	4.9	7.7	5.9	3.3	5.2	4
$5,000	0.4	0.6	0.4	1.4	2.2	1.7	0.7	1.1	0.9	0.7	0.1	0.8	0.5	0.7	0.6
$10,000	0.2	0.4	0.3	1	1.6	1.2	0.5	0.8	0.6	0.5	0.8	0.6	0.3	0.5	0.4
$20,000	0.1	0.2	0.1	0.5	0.8	0.6	0.2	0.4	0.3	0.2	0.4	0.3	0.2	0.3	0.2
$50,000	0	0.1	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	5	7.8	5.9	20	31.1	23.9	10	15.6	11.9	9.8	15.3	11.8	6.6	10.3	7.9
$5,000	0.7	1.1	0.8	2.9	4.4	3.4	1.4	2.2	1.7	1.4	2.2	1.7	0.9	1.5	1.1
$10,000	0.5	0.8	0.6	2	3.1	2.4	1	1.6	1.2	1	1.5	1.2	0.7	1	0.8
$20,000	0.2	0.4	0.3	1	1.6	1.2	0.5	0.8	0.6	0.5	0.8	0.6	0.3	0.5	0.4
$50,000	0.1	0.2	0.1	0.4	0.6	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	9.9	15.5	11.9	40	62.3	47.7	20	31.1	23.8	19.7	30.7	23.6	13.3	20.7	15.8
$5,000	1.4	2.2	1.7	5.7	8.9	6.8	2.8	4.4	3.4	2.8	4.4	3.4	1.9	3	2.3
$10,000	1	1.6	1.2	4	6.2	4.8	2	3.1	2.4	2	3.1	2.4	1.3	2.1	1.6
$20,000	0.5	0.8	0.6	2	3.1	2.4	1	1.6	1.2	1	1.5	1.2	0.7	1	0.8
$50,000	0.2	0.3	0.2	0.8	1.2	1	0.4	0.6	0.5	0.4	0.6	0.5	0.3	0.4	0.3

Offset 2.5 (70)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.3	0.5	0.4	1.4	2.1	1.7	0.7	1.1	0.8	0.7	1	0.8	0.5	0.7	0.6
$5,000	0	0.1	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$10,000	0	0.1	0	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0.1	0	0.1	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.7	1.1	0.8	2.8	4.2	3.4	1.4	2.1	1.7	1.4	2.1	1.7	0.9	1.4	1.1
$5,000	0.1	0.2	0.1	0.4	0.6	0.5	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2
$10,000	0.1	0.1	0.1	0.3	0.4	0.3	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1
$20,000	0	0.1	0	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0

AADT 5000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	4.2	5.3	4.2	13.8	21.2	16.8	6.9	10.6	8.4	6.8	10.4	8.3	4.6	7	5.6
$5,000	0.6	0.8	0.6	2	3	2.4	1	1.5	1.2	1	1.5	1.2	0.7	1	0.8
$10,000	0.4	0.5	0.4	1.4	2.1	1.7	0.7	1.1	0.8	0.7	1	0.8	0.5	0.7	0.6
$20,000	0.2	0.3	0.2	0.7	1.1	0.8	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.4	0.3
$50,000	0.1	0.1	0.1	0.3	0.4	0.3	0.1	0.2	0.2	0.1	0.2	0.3	0.1	0.1	0.1

AADT 10000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	6.8	10.5	8.3	27.6	42.4	33.6	13.8	21.2	16.8	13.6	20.9	16.6	9.1	14.1	11.1
$5,000	1	1.5	1.2	3.9	6.1	4.8	2	3	2.4	1.9	3	2.4	1.3	2	1.6
$10,000	0.7	1.1	0.8	2.8	4.2	3.4	1.4	2.1	1.7	1.4	2.1	1.7	0.9	1.4	1.1
$20,000	0.3	0.5	0.4	1.4	2.1	1.7	0.7	1.1	0.8	0.7	1	0.8	0.5	0.7	0.6
$50,000	0.1	0.2	0.2	0.6	0.8	0.7	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.3	0.2

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	13.7	21.1	16.7	54.9	84.4	66.9	27.2	42	33.4	27.1	41.5	33.1	18.1	28	22.2
$5,000	2	3	2.4	7.9	12.1	9.6	3.9	6	4.8	3.9	6	4.7	2.6	4	3.2
$10,000	1.4	2.1	1.7	5.5	8.5	6.7	2.8	4.2	3.4	2.7	4.2	3.3	1.8	2.8	2.2
$20,000	0.7	1.1	0.8	2.8	4.2	3.4	1.4	2.1	1.7	1.4	2.1	1.7	0.9	1.4	1.1
$50,000	0.3	0.4	0.3	1.1	1.7	1.3	0.6	0.8	0.7	0.5	0.8	0.7	0.4	0.6	0.4

APPENDIX B – RISC Reports

Offset 0.5 (50)

AADT 500

	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.31	0.44	0.44	0.39	0.53	0.51	0.17	0.26	0.22	0.5	0.68	0.65	0.25	0.32	0.32
$5,000	0.06	0.09	0.09	0.08	0.11	0.1	0.03	0.05	0.04	0.1	0.14	0.13	0.05	0.06	0.06
$10,000	0.03	0.04	0.04	0.04	0.05	0.05	0.02	0.03	0.02	0.05	0.07	0.06	0.03	0.03	0.03
$20,000	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.02	0.02
$50,000	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01

AADT 1000

	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.62	0.85	0.63	0.69	1	0.99	0.33	0.45	0.45	0.91	1.24	1.27	0.46	0.63	0.61
$5,000	0.12	0.17	0.13	0.14	0.2	0.2	0.07	0.09	0.09	0.18	0.25	0.25	0.09	0.13	0.12
$10,000	0.06	0.08	0.06	0.07	0.1	0.1	0.03	0.04	0.04	0.09	0.12	0.13	0.05	0.06	0.06
$20,000	0.03	0.04	0.03	0.03	0.05	0.05	0.02	0.02	0.02	0.05	0.06	0.06	0.02	0.03	0.03
$50,000	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.03	0.01	0.01	0.01

AADT 5000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.32	1.82	1.82	1.53	2.11	2.08	0.7	0.96	1.01	1.94	2.55	2.7	0.95	1.32	1.29
$5,000	0.26	0.36	0.36	0.31	0.42	0.42	0.14	0.19	0.2	0.39	0.51	0.54	0.19	0.26	0.26
$10,000	0.13	0.18	0.18	0.15	0.21	0.21	0.07	0.1	0.1	0.19	0.25	0.27	0.09	0.13	0.13
$20,000	0.07	0.09	0.09	0.08	0.11	0.1	0.03	0.05	0.05	0.1	0.13	0.14	0.05	0.07	0.06
$50,000	0.03	0.04	0.04	0.03	0.04	0.4	0.01	0.02	0.02	0.04	0.05	0.05	0.02	0.03	0.03

AADT 10000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.08	1.51	1.43	1.27	1.77	1.7	0.59	0.8	0.81	1.65	2.11	2.15	0.77	1.12	1.1
$5,000	0.22	0.3	0.29	0.25	0.35	0.34	0.12	0.16	0.16	0.33	0.42	0.43	0.15	0.22	0.22
$10,000	0.11	0.15	0.14	0.13	0.18	0.17	0.06	0.08	0.08	0.17	0.21	0.21	0.08	0.11	0.11
$20,000	0.05	0.08	0.07	0.06	0.09	0.08	0.03	0.04	0.04	0.08	0.11	0.11	0.04	0.06	0.06
$50,000	0.02	0.03	0.03	0.03	0.04	0.03	0.01	0.02	0.02	0.03	0.04	0.04	0.02	0.02	0.02

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.51	2.1	2.09	1.82	2.48	2.39	0.87	1.24	1.14	2.2	3.08	3.14	1.12	1.55	1.5
$5,000	0.3	0.42	0.42	0.36	0.5	0.48	0.17	0.25	0.23	0.44	0.62	0.63	0.22	0.31	0.3
$10,000	0.15	0.21	0.21	0.18	0.25	0.24	0.09	0.12	0.11	0.22	0.31	0.31	0.11	0.16	0.15
$20,000	0.08	0.11	0.1	0.09	0.12	0.12	0.04	0.06	0.06	0.11	0.15	0.16	0.06	0.08	0.08
$50,000	0.03	0.04	0.04	0.04	0.05	0.05	0.02	0.02	0.02	0.04	0.06	0.06	0.02	0.03	0.03

Offset 0.5 (60)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.58	0.81	0.79	0.69	0.96	0.97	0.32	0.45	0.46	0.89	1.27	1.24	0.43	0.59	0.61
$5,000	0.12	0.16	0.16	0.14	0.19	0.19	0.06	0.09	0.09	0.18	0.25	0.25	0.09	0.12	0.12
$10,000	0.06	0.08	0.08	0.07	0.1	0.1	0.03	0.04	0.05	0.09	0.13	0.12	0.04	0.06	0.06
$20,000	0.03	0.04	0.04	0.03	0.05	0.05	0.02	0.02	0.02	0.04	0.06	0.06	0.02	0.03	0.03
$50,000	0.01	0.2	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.02	0.01	0.01	0.01

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.14	0.85	0.86	1.28	1.54	0.96	0.61	0.99	0.47	1.64	0.44	1.23	0.81	0.47	0.6
$5,000	0.23	0.17	0.17	0.26	0.31	0.19	0.12	0.2	0.09	0.33	0.09	0.25	0.16	0.09	0.12
$10,000	0.11	0.08	0.09	0.13	0.16	0.1	0.06	0.1	0.05	0.16	0.04	0.12	0.08	0.05	0.06
$20,000	0.06	0.04	0.04	0.06	0.08	0.05	0.03	0.05	0.02	0.08	0.02	0.06	0.04	0.02	0.03
$50,000	0.02	0.02	0.02	0.03	0.03	0.02	0.01	0.02	0.01	0.03	0.01	0.02	0.02	0.01	0.01

AADT 5000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.44	3.28	3.26	2.69	4.02	3.72	1.32	1.84	1.83	3.49	5.08	4.7	1.78	2.43	2.31
$5,000	0.49	0.66	0.65	0.54	0.8	0.74	0.26	0.37	0.37	0.7	1.02	0.94	0.36	0.49	0.46
$10,000	0.24	0.33	0.33	0.27	0.4	0.37	0.13	0.18	0.18	0.35	0.51	0.47	0.18	0.24	0.2
$20,000	0.12	0.16	0.16	0.13	0.2	0.19	0.07	0.09	0.09	0.17	0.25	0.24	0.09	0.12	0.12
$50,000	0.05	0.07	0.07	0.05	0.08	0.07	0.03	0.04	0.04	0.07	0.1	0.09	0.04	0.05	0.05

AADT 10000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2	2.68	2.72	2.34	3.31	3.27	1.11	1.59	1.43	2.84	4.23	3.9	1.53	2.02	1.98
$5,000	0.4	0.54	0.54	0.47	0.66	0.65	0.22	0.32	0.29	0.57	0.85	0.78	0.31	0.4	0.4
$10,000	0.2	0.27	0.27	0.23	0.33	0.33	0.11	0.16	0.14	0.28	0.42	0.39	0.15	0.2	0.2
$20,000	0.1	0.13	0.14	0.12	0.17	0.16	0.06	0.08	0.07	0.14	0.21	0.19	0.08	0.1	0.1
$50,000	0.04	0.05	0.05	0.05	0.07	0.07	0.02	0.03	0.03	0.06	0.08	0.08	0.03	0.04	0.04

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.86	3.81	3.72	3.33	4.42	4.46	1.55	2.05	2.01	4.18	5.31	5.63	2.02	2.66	2.79
$5,000	0.57	0.76	0.74	0.67	0.88	0.89	0.31	0.41	0.4	0.84	1.06	1.13	0.4	0.53	0.56
$10,000	0.29	0.38	0.37	0.33	0.44	0.45	0.15	0.21	0.2	0.43	0.53	0.56	0.2	0.27	0.28
$20,000	0.14	0.19	0.19	0.17	0.22	0.22	0.08	0.1	0.1	0.21	0.27	0.28	0.1	0.13	0.14
$50,000	0.06	0.08	0.07	0.07	0.09	0.09	0.03	0.04	0.04	0.08	0.11	0.11	0.04	0.05	0.06

Offset 0.5 (70)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.94	1.27	1.31	1.11	1.44	1.51	0.5	0.66	0.69	1.36	1.93	1.82	0.69	0.93	0.94
$5,000	0.19	0.25	0.26	0.22	0.28	0.3	0.1	0.13	0.14	0.27	0.39	0.36	0.14	0.19	0.18
$10,000	0.09	0.13	0.13	0.11	0.14	0.15	0.05	0.07	0.07	0.14	0.19	0.18	0.07	0.09	0.09
$20,000	0.05	0.06	0.07	0.06	0.07	0.08	0.03	0.03	0.03	0.07	0.1	0.09	0.03	0.05	0.05
$50,000	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.01	0.01	0.03	0.04	0.04	0.01	0.02	0.02

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.73	2.39	2.38	2.12	2.8	2.81	0.95	1.31	1.4	2.48	3.48	3.62	1.27	1.79	1.77
$5,000	0.35	0.48	0.48	0.42	0.56	0.56	0.19	0.26	0.28	0.5	0.7	0.72	0.25	0.36	0.35
$10,000	0.17	0.24	0.24	0.21	0.28	0.28	0.1	0.13	0.14	0.25	0.35	0.36	0.13	0.18	0.18
$20,000	0.09	0.12	0.12	0.11	0.14	0.14	0.05	0.07	0.07	0.12	0.17	0.18	0.06	0.09	0.09
$50,000	0.03	0.05	0.05	0.04	0.06	0.06	0.02	0.03	0.03	0.05	0.07	0.07	0.03	0.04	0.04

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.89	5.15	5.15	4.32	6.21	6.14	2.02	2.74	2.66	5.33	7.54	7.42	2.71	3.79	3.8
$5,000	0.78	1.03	1.03	0.86	1.24	1.23	0.4	0.55	0.53	1.07	1.51	1.48	0.54	0.76	0.76
$10,000	0.39	0.52	0.52	0.43	0.62	0.61	0.2	0.27	0.27	0.53	0.75	0.74	0.27	0.38	0.38
$20,000	0.19	0.26	0.26	0.22	0.31	0.31	0.1	0.14	0.13	0.27	0.38	0.37	0.14	0.19	0.19
$50,000	0.08	0.1	0.1	0.09	0.12	0.12	0.04	0.05	0.05	0.11	0.15	0.15	0.05	0.08	0.08

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.24	4.32	4.17	3.57	5.07	5.02	1.67	2.35	2.23	4.74	6.21	6.57	2.34	3.11	3.3
$5,000	0.65	0.86	0.83	0.71	1.01	1	0.33	0.47	0.45	0.95	1.24	1.31	0.47	0.62	0.66
$10,000	0.32	0.43	0.42	0.36	0.51	0.5	0.17	0.23	0.22	0.47	0.62	0.66	0.23	0.31	0.33
$20,000	0.16	0.22	0.21	0.18	0.25	0.25	0.08	0.12	0.11	0.24	0.31	0.33	0.12	0.16	0.16
$50,000	0.06	0.09	0.08	0.07	0.1	0.1	0.03	0.05	0.04	0.09	0.12	0.13	0.05	0.06	0.07

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	4.36	5.95	6.01	5.04	7.13	7.52	2.28	3.16	3.22	6.83	8.93	8.8	3.3	4.52	4.76
$5,000	0.87	1.19	1.2	1.01	1.43	1.5	0.46	0.63	0.64	1.37	1.79	1.76	0.66	0.9	0.95
$10,000	0.44	0.59	0.6	0.5	0.71	0.75	0.23	0.32	0.32	0.68	0.89	0.88	0.33	0.45	0.48
$20,000	0.22	0.3	0.3	0.25	0.36	0.38	0.11	0.16	0.16	0.34	0.45	0.44	0.16	0.23	0.24
$50,000	0.09	0.12	0.12	0.1	0.14	0.15	0.05	0.06	0.06	0.14	0.18	0.18	0.07	0.09	0.1

Offset 1.0 (50)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.27	0.37	0.37	0.3	0.42	0.41	0.15	0.21	0.22	0.37	0.56	0.53	0.2	0.27	0.27
$5,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.04	0.04	0.07	0.11	0.11	0.04	0.05	0.05
$10,000	0.03	0.04	0.04	0.03	0.04	0.04	0.01	0.02	0.02	0.04	0.06	0.05	0.02	0.03	0.03
$20,000	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.01	0.01
$50,000	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0.01	0.01	0.01	0	0.01	0.01

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.5	0.69	0.68	0.59	0.83	0.84	0.28	0.4	0.4	0.75	1.06	1.03	0.37	0.53	0.52
$5,000	0.1	0.14	0.14	0.12	0.17	0.17	0.06	0.08	0.08	0.15	0.21	0.21	0.07	0.11	0.1
$10,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.04	0.04	0.08	0.11	0.1	0.04	0.05	0.05
$20,000	0.02	0.03	0.03	0.03	0.04	0.04	0.01	0.02	0.02	0.04	0.05	0.05	0.02	0.03	0.03
$50,000	0.01	0.01	0.01	0.01	4	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.07	1.49	1.48	1.27	1.68	1.7	0.57	0.87	0.79	1.61	2.18	2.12	0.83	1.08	1.16
$5,000	0.21	0.3	0.3	0.25	0.34	0.34	0.11	0.17	0.16	0.32	0.44	0.42	0.17	0.22	0.23
$10,000	0.11	0.15	0.15	0.13	0.17	0.17	0.06	0.09	0.08	0.16	0.22	0.21	0.08	0.11	0.12
$20,000	0.05	0.07	0.07	0.06	0.08	0.09	0.03	0.04	0.04	0.08	0.11	0.11	0.04	0.05	0.06
$50,000	0.02	0.03	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.03	0.04	0.04	0.02	0.02	0.02

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.91	1.22	1.26	1.07	1.43	0.7	0.54	0.75	1.46	1.32	1.42	1.81	0.68	0.67	0.89
$5,000	0.18	0.24	0.25	0.21	0.29	0.14	0.11	0.15	0.29	0.26	0.28	0.36	0.14	0.13	0.18
$10,000	0.09	0.12	0.13	0.11	0.14	0.07	0.05	0.07	0.15	0.13	0.14	0.18	0.07	0.07	0.09
$20,000	0.05	0.06	0.06	0.05	0.07	0.04	0.03	0.04	0.07	0.07	0.07	0.09	0.03	0.03	0.04
$50,000	0.02	0.02	0.03	0.02	0.03	0.01	0.01	0.01	0.03	0.03	0.03	0.04	0.01	0.01	0.02

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.28	1.7	1.81	1.49	2.1	2.01	0.73	0.98	0.99	1.75	2.56	2.61	0.95	1.33	1.27
$5,000	0.26	0.34	0.36	0.3	0.42	0.4	0.15	0.2	0.2	0.35	0.51	0.52	0.19	0.27	0.25
$10,000	0.13	0.17	0.18	0.15	0.21	0.2	0.07	0.1	0.1	0.17	0.26	0.26	0.1	0.13	0.13
$20,000	0.06	0.08	0.09	0.07	0.1	0.1	0.04	0.05	0.05	0.09	0.13	0.13	0.05	0.07	0.06
$50,000	0.03	0.03	0.04	0.03	0.04	0.04	0.01	0.02	0.02	0.03	0.05	0.05	0.02	0.03	0.03

Offset 1.0 (60)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.49	0.66	0.66	0.56	0.77	0.82	0.26	0.38	0.38	0.7	1.08	0.97	0.36	0.52	0.51
$5,000	0.1	0.13	0.13	0.11	0.15	0.16	0.05	0.08	0.08	0.14	0.22	0.19	0.07	0.1	0.1
$10,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.04	0.04	0.07	0.11	0.1	0.04	0.05	0.05
$20,000	0.02	0.03	0.03	0.03	0.04	0.04	0.01	0.02	0.02	0.03	0.05	0.05	0.02	0.03	0.03
$50,000	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.99	1.35	1.37	1.11	1.55	1.62	0.57	0.76	0.73	1.48	2.07	1.96	0.71	1.07	0.99
$5,000	0.2	0.27	0.27	0.22	0.31	0.32	0.11	0.15	0.15	0.3	0.41	0.39	0.14	0.21	0.2
$10,000	0.1	0.14	0.14	0.11	0.15	0.16	0.06	0.08	0.07	0.15	0.21	0.2	0.07	0.11	0.1
$20,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.04	0.04	0.07	0.1	0.1	0.04	0.05	0.05
$50,000	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.01	0.03	0.04	0.04	0.01	0.02	0.02

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.1	2.8	2.85	2.4	3.2	3.36	1.27	1.59	1.62	3.1	4.25	4.42	1.6	2.04	2.18
$5,000	0.42	0.56	0.57	0.48	0.64	0.67	0.25	0.32	0.32	0.62	0.85	0.88	0.32	0.41	0.44
$10,000	0.21	0.28	0.28	0.24	0.32	0.34	0.13	0.16	0.16	0.31	0.42	0.44	0.16	0.2	0.22
$20,000	0.1	0.14	0.14	0.12	0.16	0.17	0.06	0.08	0.08	0.15	0.21	0.22	0.08	0.1	0.11
$50,000	0.04	0.06	0.06	0.05	0.06	0.07	0.03	0.03	0.03	0.06	0.08	0.09	0.03	0.04	0.04

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.77	2.37	2.47	1.96	2.65	2.76	0.97	1.44	1.26	2.54	3.37	3.55	1.27	1.76	1.81
$5,000	0.35	0.47	0.49	0.39	0.53	0.55	0.19	0.29	0.25	0.51	0.67	0.71	0.25	0.35	0.36
$10,000	0.18	0.24	0.25	0.2	0.27	0.28	0.1	0.14	0.13	0.25	0.34	0.36	0.13	0.18	0.18
$20,000	0.09	0.12	0.12	0.1	0.13	0.14	0.05	0.07	0.06	0.13	0.17	0.18	0.06	0.09	0.09
$50,000	0.04	0.05	0.05	0.04	0.05	0.06	0.02	0.03	0.03	0.05	0.07	0.07	0.03	0.04	0.04

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.49	3.33	3.3	2.97	3.92	4.08	1.38	1.83	1.82	3.55	4.97	4.98	3.69	2.46	2.49
$5,000	0.5	0.67	0.67	0.59	0.78	0.82	0.28	0.37	0.36	0.71	0.99	1	0.74	0.49	0.5
$10,000	0.25	0.33	0.34	0.3	0.39	0.41	0.14	0.18	0.18	0.36	0.5	0.5	0.37	0.25	0.25
$20,000	0.12	0.17	0.17	0.15	0.2	0.2	0.07	0.09	0.09	0.18	0.25	0.25	0.18	0.12	0.12
$50,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.04	0.04	0.07	0.1	0.1	0.07	0.05	0.05

Offset 1.0 (70)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.81	1.16	1.12	0.96	1.27	1.32	0.47	0.63	0.62	1.23	1.63	1.66	0.61	0.84	0.81
$5,000	0.16	0.23	0.22	0.19	0.25	0.26	0.09	0.13	0.12	0.25	0.33	0.33	0.12	0.17	0.16
$10,000	0.08	0.12	0.11	0.1	0.13	0.13	0.05	0.06	0.06	0.12	0.16	0.17	0.06	0.08	0.08
$20,000	0.04	0.06	0.06	0.05	0.06	0.07	0.02	0.03	0.03	0.06	0.08	0.08	0.03	0.04	0.04
$50,000	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.02	0.02

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.55	2.03	2.14	1.84	2.41	2.34	0.89	1.2	1.18	2.21	3.17	3.18	1.15	1.53	1.66
$5,000	0.31	0.41	0.43	0.37	0.48	0.47	0.18	0.24	0.24	0.44	0.63	0.64	0.23	0.31	0.33
$10,000	0.16	0.2	0.21	0.18	0.24	0.23	0.09	0.12	0.12	0.22	0.32	0.32	0.12	0.15	0.17
$20,000	0.08	0.1	0.11	0.09	0.12	0.12	0.04	0.06	0.06	0.11	0.16	0.16	0.06	0.08	0.08
$50,000	0.03	0.04	0.04	0.04	0.05	0.05	0.02	0.02	0.02	0.04	0.06	0.06	0.02	0.03	0.03

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.16	4.45	4.47	3.83	5.3	5.33	1.9	2.49	2.6	4.9	6.61	6.62	2.45	3.39	3.38
$5,000	0.63	0.89	0.89	0.77	1.06	1.07	0.38	0.38	0.52	0.98	1.32	1.32	1.49	0.68	0.68
$10,000	0.32	0.45	0.45	0.38	0.53	0.53	0.19	0.25	0.26	0.49	0.66	0.66	0.25	0.34	0.34
$20,000	0.16	0.22	0.22	0.19	0.26	0.27	0.09	0.12	0.13	0.25	0.33	0.33	0.12	0.17	0.17
$50,000	0.06	0.09	0.09	0.08	0.11	0.11	0.04	0.05	0.05	0.1	0.13	0.13	0.05	0.07	0.07

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.7	3.68	3.75	3.03	4.3	4.31	1.51	2.12	2.18	4.08	5.71	5.47	2.13	2.8	2.66
$5,000	0.54	0.74	0.75	0.61	0.86	0.86	0.3	0.42	0.44	0.82	1.14	1.09	0.43	0.56	0.53
$10,000	0.27	0.37	0.38	0.3	0.43	0.43	0.15	0.21	0.22	0.41	0.57	0.55	0.21	0.28	0.27
$20,000	0.13	0.18	0.19	0.15	0.22	0.22	0.08	0.11	0.11	0.2	0.29	0.27	0.11	0.14	0.13
$50,000	0.05	0.07	0.08	0.06	0.09	0.09	0.03	0.04	0.04	0.08	0.11	0.11	0.04	0.06	0.05

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	3.88	5.38	5.38	4.52	5.95	6.07	2.25	3.18	3.04	5.8	7.86	7.61	2.86	4	3.97
$5,000	1.06	1.06	1.08	0.9	1.19	1.21	0.45	0.64	0.61	1.16	1.57	1.52	0.57	0.8	0.79
$10,000	0.39	0.53	0.54	0.45	0.6	0.61	0.22	0.32	0.3	0.58	0.79	0.76	0.29	0.4	0.4
$20,000	0.19	0.27	0.27	0.57	0.3	0.3	0.11	0.16	0.15	0.29	0.39	0.38	0.14	0.2	0.2
$50,000	0.08	0.11	0.11	0.09	0.12	0.12	0.04	0.06	0.06	0.12	0.16	0.15	0.06	0.08	0.08

Offset 2.0 (50)

AADT 500

	Straight			R 100			R 100			R 500			R 500		
				Hazard outside curve			Hazard inside curve			Hazard outside curve			Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.23	0.3	0.3	0.24	0.33	0.35	0.13	0.18	0.18	0.29	0.4	0.4	0.17	0.23	0.24
$5,000	0.05	0.06	0.06	0.05	0.07	0.07	0.03	0.04	0.04	0.06	0.08	0.08	0.03	0.05	0.05
$10,000	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.02	0.03	0.04	0.04	0.02	0.02	0.02
$20,000	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01
$50,000	0	0.01	0.01	0	0.01	0.01	0	0	0	0.01	0.01	0.01	0	0	0

AADT 1000

	Straight			R 100			R 100			R 500			R 500		
				Hazard outside curve			Hazard inside curve			Hazard outside curve			Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.21	0.57	0.56	0.47	0.64	0.64	0.25	0.34	0.34	0.55	0.75	0.82	0.32	0.44	0.42
$5,000	0.04	0.11	0.11	0.09	0.13	0.13	0.05	0.07	0.07	0.11	0.15	0.16	0.06	0.09	0.08
$10,000	0.04	0.06	0.06	0.05	0.06	0.06	0.02	0.03	0.03	0.06	0.08	0.08	0.03	0.04	0.04
$20,000	0.01	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.02	0.03	0.04	0.04	0.02	0.02	0.02
$50,000	0	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01

AADT 5000															
	Straight			R 100			R 100			R 500			R 500		
				Hazard outside curve			Hazard inside curve			Hazard outside curve			Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.4	1.23	1.24	1.01	1.36	1.37	0.49	0.74	0.69	1.19	1.62	1.66	0.65	0.92	0.93
$5,000	0.08	0.25	0.25	0.2	0.27	0.27	0.1	0.15	0.14	0.24	0.32	0.33	0.13	0.18	0.19
$10,000	0.04	0.12	0.12	0.1	0.14	0.14	0.05	0.07	0.07	0.12	0.16	0.17	0.06	0.09	0.09
$20,000	0.02	0.06	0.06	0.05	0.07	0.07	0.02	0.04	0.03	0.06	0.08	0.08	0.03	0.05	0.05
$50,000	0.01	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.02	0.02

AADT 10000															
	Straight			R 100			R 100			R 500			R 500		
				Hazard outside curve			Hazard inside curve			Hazard outside curve			Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.71	1	1.03	0.88	1.17	1.14	0.43	0.59	0.61	0.98	1.42	1.44	0.56	0.76	0.79
$5,000	0.14	0.2	0.21	0.18	0.23	0.23	0.09	0.12	0.12	0.2	0.28	0.29	0.11	0.15	0.16
$10,000	0.07	0.1	0.1	0.09	0.12	0.11	0.04	0.06	0.06	0.1	0.14	0.14	0.06	0.08	0.08
$20,000	0.04	0.05	0.05	0.04	0.06	0.06	0.02	0.03	0.03	0.05	0.07	0.07	0.03	0.04	0.04
$50,000	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.02	0.02

AADT 20000															
	Straigh t			R 100			R 100			R 500			R 500		
				Hazard outside curve			Hazard inside curve			Hazard outside curve			Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.03	1.44	1.48	1.17	1.64	1.6	0.58	0.92	0.86	1.42	1.92	1.95	0.7	1	0.92
$5,000	0.21	0.29	0.3	0.23	0.33	0.32	0.12	0.18	0.17	0.28	0.38	0.39	0.14	0.02	0.18
$10,000	0.1	0.14	0.15	0.12	0.16	0.16	0.06	0.09	0.09	0.14	0.19	0.2	0.07	0.1	0.09
$20,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.05	0.04	0.07	0.1	0.1	0.03	0.05	0.05
$50,000	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.02	0.03	0.04	0.04	0.01	0.02	0.02

Offset (2.0 (60)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.42	0.56	0.53	0.47	0.67	0.65	0.24	0.32	0.33	0.55	0.76	0.72	0.3	0.43	0.42
$5,000	0.08	0.11	0.11	0.09	0.13	0.13	0.05	0.06	0.07	0.11	0.15	0.14	0.06	0.09	0.08
$10,000	0.04	0.06	0.05	0.05	0.07	0.07	0.02	0.03	0.03	0.06	0.08	0.07	0.03	0.04	0.04
$20,000	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.02	0.03	0.04	0.04	0.02	0.02	0.02
$50,000	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.74	1.02	1.01	0.91	1.13	1.24	0.45	0.62	0.59	1.06	1.38	1.42	0.59	0.81	0.79
$5,000	0.15	0.2	0.2	0.18	0.23	0.25	0.09	0.12	0.12	0.21	0.28	0.28	0.12	0.16	0.16
$10,000	0.07	0.1	0.1	0.09	0.11	0.12	0.05	0.06	0.06	0.11	0.14	0.14	0.06	0.08	0.08
$20,000	0.04	0.05	0.05	0.05	0.06	0.06	0.02	0.03	0.03	0.05	0.07	0.07	0.03	0.04	0.04
$50,000	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.02	0.02

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.58	2.23	2.26	1.85	2.57	2.63	0.97	1.35	1.32	2.3	2.98	2.88	1.2	1.72	1.63
$5,000	0.32	0.95	0.45	0.37	0.51	0.53	0.27	0.27	0.26	0.46	0.6	0.58	0.24	0.34	0.33
$10,000	0.16	0.22	0.23	0.19	0.26	0.26	0.13	0.13	0.13	0.23	0.3	0.29	0.12	0.17	0.16
$20,000	0.08	0.11	0.11	0.09	0.13	0.13	0.07	0.07	0.07	0.11	0.15	0.14	0.06	0.09	0.08
$50,000	0.03	0.04	0.05	0.04	0.05	0.05	0.03	0.03	0.03	0.05	0.06	0.06	0.02	0.03	0.03

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.57	1.62	1.61	1.53	2.24	2.2	0.81	1.11	1.16	1.79	2.43	2.55	1.03	1.45	1.44
$5,000	0.31	0.32	0.32	0.31	0.45	0.44	0.16	0.22	0.23	0.36	0.49	0.51	0.21	0.29	0.29
$10,000	0.16	0.06	0.16	0.15	0.22	0.22	0.08	0.11	0.12	0.18	0.24	0.25	0.1	0.14	0.14
$20,000	0.08	0.08	0.08	0.08	0.11	0.11	0.04	0.6	0.06	0.09	0.12	0.13	0.05	0.07	0.07
$50,000	0.03	0.03	0.03	0.03	0.04	0.04	0.02	0.2	0.02	0.04	0.05	0.05	0.02	0.03	0.03

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.87	2.54	2.69	1.64	2.93	3.05	1.16	1.59	1.53	2.43	3.75	3.5	1.43	2.02	2.02
$5,000	0.37	0.51	0.54	0.33	0.59	0.61	0.23	0.32	0.31	0.49	0.75	0.7	0.29	0.4	0.4
$10,000	0.19	0.25	0.27	0.08	0.29	0.31	0.12	0.16	0.15	0.27	0.38	0.35	0.14	0.2	0.2
$20,000	0.09	0.13	0.13	0.05	0.15	0.15	0.06	0.08	0.08	0.12	0.19	0.18	0.07	0.1	0.1
$50,000	0.04	0.05	0.05	0.03	0.06	0.06	0.02	0.03	0.03	0.05	0.08	0.07	0.03	0.04	0.04

Offset 2.0 (70)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.4	0.6	0.5	1.6	2.4	1.9	0.8	1.2	1	0.8	1.2	0.9	0.5	0.8	0.6
$5,000	0.1	0.1	0.1	0.2	0.3	0.3	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
$10,000	0	0.1	0	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$20,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.8	1.2	1	3.2	4.8	3.8	1.6	2.4	1.9	1.6	2.4	1.9	1	1.6	1.3
$5,000	0.1	0.2	0.1	0.4	0.7	0.5	0.2	0.3	0.3	0.2	0.3	0.3	0.1	0.2	0.2
$10,000	0.1	0.1	0.1	0.3	0.5	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1
$20,000	0	0.1	0	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
$50,000	0	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.46	3.44	3.54	3.02	4.11	4.04	1.5	2.19	2.21	3.57	4.68	4.72	1.91	2.69	2.62
$5,000	0.49	0.69	0.71	0.6	1.82	0.81	0.3	0.44	0.44	0.71	0.94	0.94	0.38	0.54	0.52
$10,000	0.25	0.34	0.35	0.3	0.41	0.4	0.15	0.22	0.22	0.36	0.47	0.47	0.19	0.27	0.26
$20,000	0.12	0.17	0.18	0.15	0.21	0.2	0.08	0.11	0.11	0.18	0.23	0.24	0.1	0.13	0.13
$50,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.04	0.04	0.07	0.09	0.09	0.04	0.05	0.05

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.2	2.83	2.85	2.49	3.31	3.41	1.22	1.75	1.72	2.99	4.02	4.13	1.66	2.24	2.27
$5,000	0.44	0.57	0.57	0.5	0.66	0.68	0.24	0.35	0.34	0.6	0.8	0.83	0.33	0.45	0.45
$10,000	0.22	0.28	0.28	0.25	0.33	0.34	0.12	0.17	0.17	0.3	0.4	0.41	0.17	0.22	0.23
$20,000	0.11	0.14	0.14	0.12	0.17	0.17	0.06	0.09	0.09	0.15	0.2	0.21	0.08	0.11	0.11
$50,000	0.04	0.06	0.06	0.05	0.07	0.07	0.02	0.03	0.03	0.06	0.08	0.08	0.03	0.04	0.05

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.88	4.12	3.94	3.34	4.67	4.67	1.75	2.44	2.47	4.27	5.35	5.47	2.28	3.09	3.13
$5,000	0.58	0.82	0.79	0.67	0.93	0.93	0.35	0.49	0.49	0.85	1.07	1.09	0.46	0.62	0.63
$10,000	0.29	0.41	0.39	0.33	0.47	0.47	0.18	0.24	0.25	0.43	0.53	0.55	0.23	0.31	0.31
$20,000	0.14	0.21	0.2	0.17	0.23	0.23	0.09	0.12	0.12	0.21	0.27	0.27	0.11	0.15	0.16
$50,000	0.06	0.08	0.08	0.07	0.09	0.09	0.04	0.05	0.05	0.09	0.11	0.11	0.05	0.06	0.06

Offset 2.5 (50)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.2	0.3	0.2	0.6	1	0.7	0.3	0.5	0.4	0.3	0.5	0.4	0.2	0.3	0.2
$5,000	0	0	0	0.1	0.1	0.14	0	0.1	0.1	0	0.1	0.1	0	0	0
$10,000	0	0	0	0.1	0.1	0.1	0	0.1	0	0	0.1	0	0	0	0
$20,000	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
$50,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.22	0.32	0.3	0.19	0.25	0.26	0.13	0.16	0.17	0.33	0.47	0.45	0.16	0.23	0.23
$5,000	0.04	0.06	0.06	0.04	0.05	0.05	0.03	0.03	0.03	0.07	0.09	0.09	0.03	0.05	0.05
$10,000	0.02	0.03	0.03	0.02	0.02	0.03	0.01	0.02	0.02	0.03	0.05	0.04	0.02	0.02	0.02
$20,000	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01
$50,000	0	0.01	0.01	0	0	0.01	0	0	0	0.01	0.01	0.01	0	0	0

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.48	0.65	0.66	0.4	0.52	0.53	0.26	0.36	0.37	0.71	0.98	0.97	0.37	0.49	0.49
$5,000	0.1	0.13	0.13	0.08	0.1	0.11	0.05	0.07	0.07	0.14	0.2	0.19	0.07	0.1	0.1
$10,000	0.05	0.06	0.07	0.04	0.05	0.05	0.03	0.04	0.04	0.07	0.1	0.1	0.04	0.05	0.05
$20,000	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.02	0.02	0.04	0.05	0.05	0.02	0.02	0.02
$50,000	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.41	0.58	0.55	0.35	0.43	0.47	0.21	0.3	0.31	0.6	0.83	0.88	0.29	0.41	0.39
$5,000	0.08	0.12	0.11	0.07	0.09	0.09	0.04	0.06	0.06	0.12	0.17	0.18	0.06	0.08	0.08
$10,000	0.04	0.06	0.06	0.03	0.04	0.05	0.02	0.03	0.03	0.06	0.08	0.09	0.03	0.04	0.04
$20,000	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.04	0.04	0.01	0.02	0.02
$50,000	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.57	0.81	1.3	1.05	1.45	1.46	0.58	0.78	0.77	1.2	1.66	1.62	0.71	0.98	0.96
$5,000	0.11	0.16	0.26	0.21	0.29	0.29	0.12	0.16	0.15	0.24	0.33	0.32	0.14	0.2	0.19
$10,000	0.06	0.08	0.13	0.1	0.14	0.15	0.06	0.08	0.08	0.12	0.17	0.16	0.07	0.1	0.1
$20,000	0.03	0.04	0.06	0.05	0.07	0.07	0.03	0.04	0.04	0.06	0.08	0.08	0.04	0.05	0.05
$50,000	0.01	0.02	0.03	0.02	0.03	0.03	0.01	0.02	0.02	0.02	0.03	0.03	0.01	0.02	0.02

Offset 2.5 (60)

AADT 500	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.34	0.51	0.48	0.41	0.61	0.52	0.22	0.3	0.28	0.47	0.66	0.62	0.27	0.37	0.36
$5,000	0.07	0.1	0.1	0.08	0.12	0.1	0.04	0.06	0.06	0.09	0.13	0.12	0.05	0.07	0.07
$10,000	0.03	0.05	0.05	0.04	0.06	0.05	0.02	0.03	0.03	0.05	0.07	0.06	0.03	0.04	0.04
$20,000	0.02	0.03	0.02	0.02	0.03	0.03	0.01	0.02	0.01	0.02	0.03	0.03	0.01	0.02	0.02
$50,000	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

AADT 1000	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.66	0.94	0.92	0.8	1.09	1.05	0.4	0.54	0.53	0.84	1.15	1.2	0.53	0.71	0.73
$5,000	0.13	0.19	0.18	0.16	0.22	0.21	0.08	0.11	0.11	0.17	0.23	0.24	0.11	0.14	0.15
$10,000	0.07	0.09	0.09	0.08	0.1	0.11	0.04	0.05	0.05	0.08	0.12	0.12	0.05	0.07	0.7
$20,000	0.03	0.05	0.05	0.04	0.05	0.05	0.02	0.03	0.03	0.04	0.06	0.06	0.03	0.04	0.04
$50,000	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.45	1.92	2.04	1.71	2.31	2.08	0.85	1.12	1.18	1.84	2.63	2.55	1.1	1.49	1.52
$5,000	0.29	0.38	0.41	0.34	0.46	0.42	0.17	0.22	0.24	0.37	0.53	0.51	0.22	0.3	0.3
$10,000	0.15	0.19	0.2	0.17	0.23	0.21	0.09	0.11	0.12	0.18	0.26	0.26	0.11	0.15	0.15
$20,000	0.07	0.1	0.1	0.09	0.12	0.1	0.04	0.06	0.06	0.09	0.13	0.13	0.05	0.07	0.08
$50,000	0.03	0.04	0.04	0.03	0.05	0.04	0.02	0.02	0.02	0.04	0.05	0.05	0.02	0.03	0.03

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.21	1.59	1.68	1.42	1.9	1.91	0.76	0.99	1.02	1.56	2.15	2.1	0.95	1.29	1.28
$5,000	0.24	0.32	0.34	0.28	0.38	0.38	0.15	0.2	0.2	0.31	0.43	0.42	0.19	0.26	0.26
$10,000	0.12	0.16	0.17	0.14	0.19	0.19	0.08	0.1	0.1	0.16	0.22	0.21	0.1	0.13	0.13
$20,000	0.06	0.08	0.08	0.07	0.1	0.1	0.04	0.05	0.05	0.08	0.11	0.1	0.05	0.06	0.06
$50,000	0.02	0.03	0.03	0.03	0.04	0.04	0.02	0.02	0.02	0.03	0.04	0.04	0.02	0.03	0.03

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.66	2.31	2.26	1.9	2.75	2.55	1.02	1.42	1.54	2.21	2.95	3.05	1.26	1.7	1.77
$5,000	0.33	0.46	0.45	0.38	0.55	0.51	0.2	0.28	0.31	0.44	0.59	0.61	0.25	0.34	0.35
$10,000	0.17	0.23	0.23	0.19	0.28	0.26	0.1	0.14	0.15	0.22	0.29	0.31	0.13	0.17	0.18
$20,000	0.08	0.12	0.11	0.1	0.14	0.13	0.05	0.07	0.08	0.11	0.15	0.15	0.06	0.09	0.09
$50,000	0.03	0.05	0.05	0.04	0.06	0.05	0.02	0.03	0.03	0.04	0.06	0.06	0.03	0.03	0.4

Offset 2.5 (70)

AADT 500															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.51	0.7	0.71	0.56	0.81	0.8	0.29	0.39	0.37	0.64	0.89	0.92	0.37	0.52	0.53
$5,000	0.1	0.14	0.14	0.11	0.16	0.16	0.06	0.08	0.07	0.13	0.18	0.18	0.07	0.1	0.11
$10,000	0.05	0.07	0.07	0.06	0.08	0.08	0.03	0.04	0.04	0.06	0.09	0.09	0.04	0.05	0.05
$20,000	0.03	0.03	0.04	0.03	0.04	0.04	0.01	0.02	0.02	0.03	0.04	0.05	0.02	0.03	0.03
$50,000	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01

AADT 1000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	0.98	1.3	1.33	0.98	1.43	1.46	0.56	0.71	0.72	1.34	1.69	1.77	0.71	0.97	0.96
$5,000	0.2	0.26	0.27	0.2	0.29	0.29	0.11	0.14	0.14	0.27	0.34	0.35	0.14	0.19	0.19
$10,000	0.1	0.13	0.13	0.1	0.14	0.15	0.06	0.07	0.07	0.13	0.17	0.18	0.07	0.1	0.1
$20,000	0.05	0.06	0.07	0.05	0.07	0.07	0.03	0.04	0.04	0.07	0.08	0.09	0.04	0.05	0.05
$50,000	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.01	0.01	0.03	0.03	0.04	0.01	0.02	0.02

AADT 5000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.11	2.85	2.74	2.18	3.06	3.21	1.14	1.53	1.54	2.54	3.55	3.5	1.42	2.16	1.95
$5,000	0.42	0.57	0.55	0.44	0.61	0.64	0.23	0.31	0.31	0.51	0.71	0.7	0.28	0.43	0.39
$10,000	0.21	0.28	0.27	0.22	0.31	0.32	0.11	0.15	0.15	0.25	0.36	0.32	0.14	0.22	0.2
$20,000	0.11	0.14	0.14	0.11	0.15	0.16	0.06	0.08	0.08	0.13	0.18	0.17	0.07	0.11	0.1
$50,000	0.04	0.06	0.05	0.04	0.06	0.06	0.02	0.03	0.03	0.05	0.07	0.07	0.03	0.04	0.04

AADT 10000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	1.81	2.25	2.39	1.94	2.6	2.71	0.96	1.29	1.3	2.27	2.96	2.75	1.19	1.74	1.8
$5,000	0.36	0.45	0.48	0.39	0.52	0.54	0.19	0.26	0.26	0.45	0.59	0.55	0.24	0.35	0.36
$10,000	0.18	0.22	0.24	0.19	0.26	0.27	0.1	0.13	0.13	0.23	0.3	0.27	0.12	0.17	0.18
$20,000	0.09	0.11	0.12	0.1	0.13	0.14	0.05	0.06	0.07	0.11	0.15	0.14	0.06	0.09	0.09
$50,000	0.04	0.04	0.05	0.04	0.05	0.05	0.02	0.03	0.03	0.05	0.06	0.05	0.02	0.03	0.04

AADT 20000															
	Straight			R 100 Hazard outside curve			R 100 Hazard inside curve			R 500 Hazard outside curve			R 500 Hazard inside curve		
Treatment	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade	Flat	Down-grade	Upgrade
$1,000	2.42	3.39	3.32	2.77	3.77	3.64	1.33	1.76	1.92	3.04	4.29	4.26	1.76	2.38	2.37
$5,000	0.48	0.68	0.66	0.55	0.75	0.73	0.27	0.35	0.38	0.61	0.86	0.85	0.35	0.48	0.47
$10,000	0.24	0.34	0.33	0.28	0.38	0.36	0.13	0.18	0.19	0.3	0.43	0.43	0.18	0.24	0.24
$20,000	0.12	0.17	0.17	0.14	0.19	0.18	0.07	0.09	0.1	0.15	0.21	0.21	0.09	0.12	0.12
$50,000	0.05	0.07	0.07	0.06	0.08	0.07	0.03	0.04	0.04	0.06	0.09	0.09	0.04	0.05	0.05

APPENDIX D – Clear Zone Hazard Considerations (Template)

CLEAR ZONE HAZARD TREATMENT CONSIDERATIONS	Addressed
• Has the correct operating speed been determined? (Note: This is not the post speed). • Does the clear zone width need to be adjusted for side slopes or horizontal geometry? • Have you performed a benefit cost ratio assessment? • Has the accident history, including frequency and severity of crashes, been determined? • Does the treatment suit the site? • Have you considered the treatment's affect on pedestrian paths? • Will the public react negatively to the proposed treatment? • Does the treatment effect public transport routes? • Will there be any adverse effects on the environment? • Will the treatment provide a risk greater than the hazard? • Has barrier deflection widths been taken into account? • Has the shy line been considered in the placement of guardrail? • Does the treatment conflict with property assesses or sight lines? • Does the treatment effect public transport or school bus routes? • Has the need of gating or non-gating end treatments been determined? • Has the effect on required light intensity been considered when relocating street lights • Has the proximity of overhead power lines been considered when recommending slip base poles for street lights? • Has the amount of heavy vehicles been considered in the select of barrier type? • Has manufacturer's stated barrier limitations been taken into account in relation to side slope and minimum horizontal and vertical curves?	

APPENDIX E – Hazard Treatment Evaluation Score Card

HAZARD TREATMENT EVALUATION SCORE CARD	
Treatment	**Score**
Accident History	
Benefit Cost Ratio Score	
Horizontal Geometry	
Severity of Accident	
Vertical Geometry	
Treatment Impact	
Total	

<u>Legend</u>

• Score of greater than 10	Treatment should be implemented as soon as possible.
• Score of 7-10	Treatment is a priority.
• Score of less than 7	Funds better utilised elsewhere.

Accident History	
3	> 3 accidents over 3 years
2	2-3 accidents over 3 years (adopt for design)
1	1 accident over 3 years
0	<1 accident

Benefit Cost Ratio Score	
3	> 2.5
2	1.2 – 2.5
1	0.8 – 1.2
0	< 0.8

Horizontal Geometry	
3	Hazard located on outside of curve less than R200
2	Hazard located on outside of curve greater than R200
1	Hazard located on inside of curve
0	Straight

Severity of worst accidents that have occurred	
4	Fatal
3	Hospitalisation (adopt for design)
2	Medical attention
1	Property damage

Vertical Geometry	
3	Downgrade greater than 8%
2	Downgrade 5-8%
1	Downgrade 2-5%
0	Downgrade less than 2%

Treatment Impacts	
The public will react negatively to the proposed treatment, for example, removal of significant trees.	-1
The treatment will impact on public and school bus routes.	-1
There will be a negative impact on the environment, for example, trees and watercourses.	-1
The treatment will have a major impact on pedestrians.	-1