Contract Report

Rumble strip effectiveness at rural intersections and railway level crossings

by *Will Hore-Lacy*

for VicRoads

VC73896-1

arrb consulting

Rumble strip effectiveness at rural intersections and railway level crossings

for VicRoads

	Reviewed
Project Leader	
Quality Manager	

VC73896-1

arrb consulting

SUMMARY

This report details a before and after study of driver behaviour in response to rumble strip installations on approaches to rural railway level crossings and the minor leg of rural road intersections.

This project is part of a larger body of work that ARRB Group has been conducting for VicRoads to investigate rumble strips as a means of improving road safety. The previous projects were:

- Transverse rumble strips literature review
  - A literature review into best practices for rumble strip use around the world.
- Rumble strip field testing
  - Field testing of the noise and vibrations for different rumble strip profiles installed using the preferred layout.
- Transverse rumble strip layout design for passive railway level crossings
  - Design advice on the preferred rumble strip layout to be installed in Victoria.
- Transverse rumble strip in-vehicle noise testing
  - A comparison of the audible and tactile feedback produced from high and low profile rumble strip in the field.

Summaries for these projects are included in Appendix C.

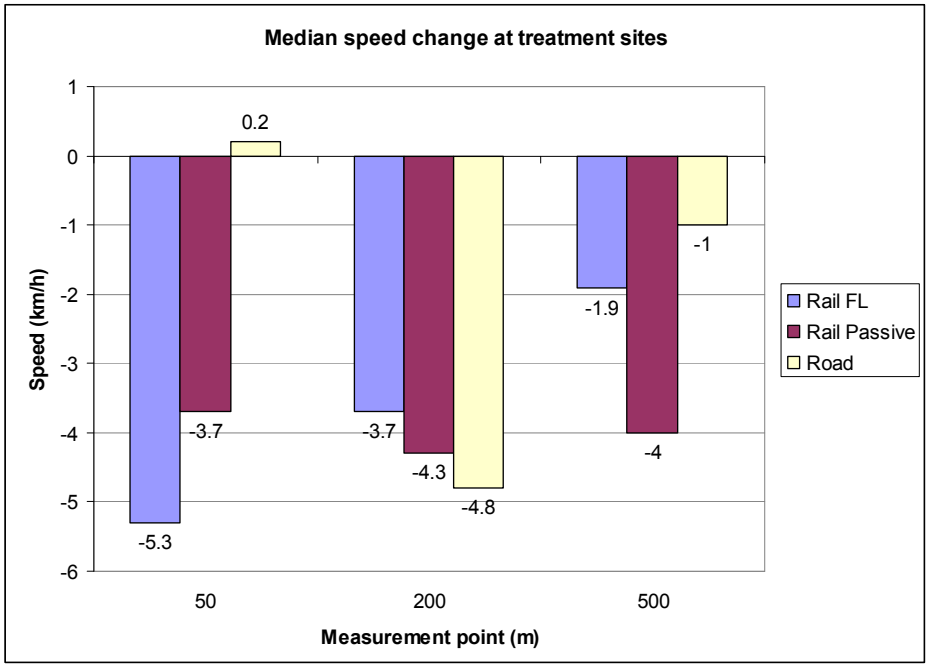
This study included 28 treatment and control sites selected by ARRB from a list of sites provided by VicRoads, with 14 for railway level crossings and 14 for road intersections. These sites were studied before and after the installation of the rumble strips using two different types of surveys:

1. surveys of vehicle behaviour using video monitoring to record braking behaviour and to detect vehicles driving around the rumble strips and a laser speed gun to obtain continuous records of vehicle speeds as they approach the railway crossing or intersection
2. speed surveys using traffic counters at three locations on the approach to the intersection or crossing over a seven day period.

The video survey results indicate earlier observed braking at most treatment sites after the installation of rumble strips. The laser speed data generally reveal slower speeds at the treatment sites after the installation of rumble strips and show a change in vehicle speed profile for some vehicles as they traverse the rumble strips. This method was very labour intensive and could only be used with a few vehicles at each site.

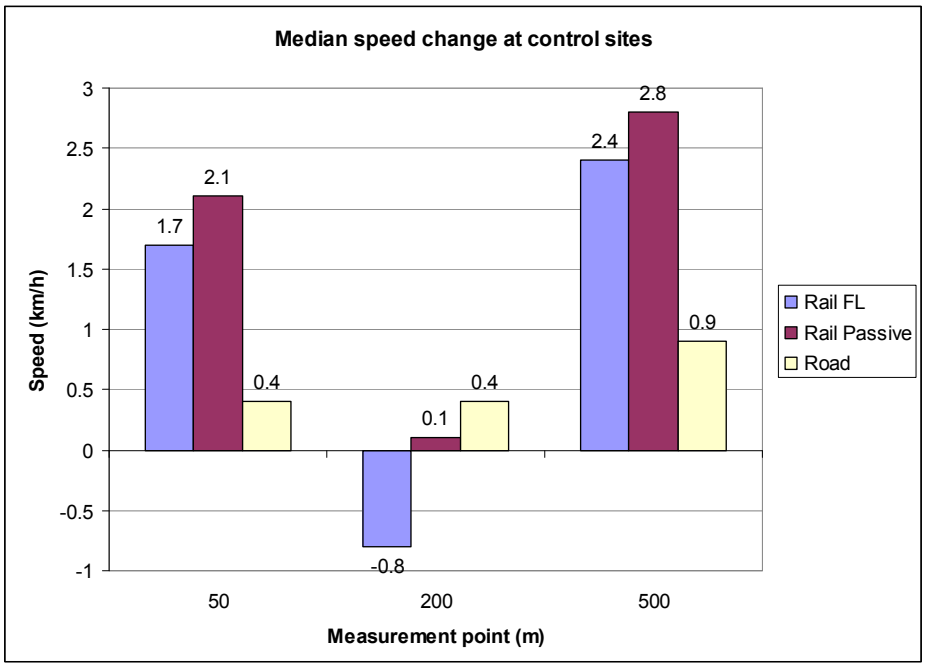
Speed surveys showed reductions in mean speed at most treatment sites, but not at the control sites. It was concluded that rumble strips proved effective in reducing speeds at all measurement points for railway level crossing approaches. It was also concluded that rumble strips were only effective in reducing the speed at the 200 m measurement point on approach to road intersections.

Figure A and Figure B show the mean speed change between the before and after 7 day speed surveys at the treatment and control sites. A negative speed change is a reduction in speed.



Note: The measurement points indicate the location of the pneumatic tube counters as distance from the stop/give way line.

Figure A: The median of the mean speed changes at the treatment sites



Note: The measurement points indicate the location of the pneumatic tube counters as a distance from the stop/give way line.

Figure B: The median of the mean speed changes at the control sites

The fact that drivers responded to the rumble strips by slowing down indicates that drivers are more alert and aware of the approaching hazards after the rumble strips have been installed.

The video surveys also showed that small numbers of vehicles went fully or partially around the rumble strip pads, usually into the oncoming traffic lane. However, in none of these cases did the driver put the vehicle at risk of a head-on collision.

arrb consulting

Contents

Tables

Figures

1 INTRODUCTION

1.1 Project Aim

As part of the Victorian Government's initiative to improve safety at railway level crossings and rural road intersections, transverse rumble strips (TRS) have been installed at selected sites around Victoria.

Pattinson et al. (2007) indicates that 'Rumble strips are intended to alert a driver to a potential hazard or a decision point', allowing them to take appropriate action with the objective of improving the safety of the roads.

The purpose of this project is to investigate the effectiveness of the preferred rumble strip layout for improving driver behaviour on approaches to railway level crossings and the minor leg of road intersections. These changes were investigated by conducting a before and after study using several different types of measurements at 28 locations around Victoria.

1.2 Rumble Strip Design and Installation

The rumble strip design was determined in previous projects ARRB had undertaken for VicRoads which included field testing of the layout and profile height. The installations were made up of three pads at decreasing spacing to encourage drivers to reduce speed. Rumble strip installations were at least 200 m from the intersection or railway crossing to avoid possible interference with braking. The exact location of the strips is determined relative to the intersection or railway crossing warning signs installed at the site as specified in AS 1742.7 – 2007 because the strips can only alert the driver, the warning signs describe the nature of the potential hazard.

The pads were designed to provide approximately half a second of noise and vibration. The noise is experienced as a distinct 'hum', with the dominant frequency determined by the spacing of the strip and the speed of the vehicle. Each pad was 12.2 m long, containing 25 rumble strips 200 mm wide at 500 mm centres with a height of 10 mm.

When approaching the intersection or railway level crossing, the first pad would start between 352 m and 402 m from the stop/give way line and the last pad would finish between 217 m and 267 m from the stop/give way line. Where the pavement was less than 5.5 m wide the strips were installed across the entire pavement width. Both a standard (Case 1) and a narrow seal (Case 2) installation designs are included in Appendix A.

2 METHOD

2.1 Site Selection

Site selection was carried out jointly by VicRoads and ARRB Group. The Murray Valley Highway, Fairley site was specified by VicRoads as it was the first installation site, but all others were selected by ARRB from lists of planned installation locations and basic site sketches provided by VicRoads. The sites were required to have at least a 550 m straight sealed approach. Sites were chosen to have high traffic volumes and long straight approaches where fatigue might be an issue, and to be as close to Melbourne as practicable.

2.2 Sites Included in Study

A summary of the groups of treatment and control sites are shown in Table 2.1.

Table 2.1: The number of treatment and control sites in each group

Approach type	Site type		
	Treatment	Control	Total
Rail crossing - Give Way - C road	2		2
Rail crossing - Give Way - Municipal road		2	2
Rail crossing - Stop - Municipal road	2	2	4[1]
Rail crossing – Flashing lights – A, B & C roads	2	2	4
Road intersection – Give way – Municipal road	1	1	2
Road intersection – Stop – C road	1	1	2
Road intersection – Stop – Municipal road	4	4	8[2]
Total	12	12	24

Details of the sites included in this study are given in Table 2.2 to Table 2.5. All installation sites had standard height strips and with a either standard or narrow seal width layouts installed. Details of these layouts are in Appendix A.

[1] An additional treatment control pairing at Tandarra-Elmore Road, Tandarra (both approaches) were scheduled however the rumble strips had not been installed at the treatment site before the after survey was conducted.
[2] An additional treatment control pairing on both approaches of Deepdene Rd to Birregurra-Forrest Rd, Birregurra were scheduled however the rumble strips had not been installed at the treatment site before the after survey was conducted.

Table 2.2: Rail installation sites in study

Pairing No.	Name	Location	Latitude/ Longitude	Type of control	Seal width
1	Murray Valley Highway (Kerang North) – north approach	Fairley	35°42'5"S 143°52'47"E	Flashing lights (active control)	Standard
2	Avenel – Nagambie Road – east approach	Nagambie	36°52'7"S 145° 9'37"E	Flashing lights (active control)	Standard
3	Dumosa - Quambatook Rd – west approach	Quambatook	35°49'6"S 143°29'29"E	Give way	Narrow
4	Patchewollock - Sea Lake Rd – east approach	Nyarrin	35°23'23"S 142°41'37"E	Give way	Narrow
5	Brislanes Rd – south approach	Murgheboluc	38° 4'55"S 144° 8'22"E	Stop	Narrow
6	Gnarpurt Rd – north approach	Lismore	37°58'10"S 143°20'30."E	Stop	Standard

Table 2.3: Rail control sites in study

Pairing No.	Name	Location	Latitude/ Longitude	Type of control	Seal width
1	Murray Valley Highway (Kerang South) – east approach	Kerang	35°45'46"S 143°56'19"E	Flashing lights (active control)	Standard
2	Midland Highway – east approach	Tatura	36°25'6"S 145°11'31"E	Flashing lights (active control)	Standard
3	Aerodrome Rd – west approach	Avenel	36°53'55"S 145°10'3"E	Give way	Narrow
4	Aerodrome Rd – east approach	Avenel	36°53'55"S 145°10'3"E	Give way	Narrow
5	Kirwans Bridge-Longwood Road – east approach	Nagambie	36°45'7"S 145°11'1"E	Stop	Narrow
6	Gnarpurt Rd – south approach	Lismore	37°58'10"S 143°20'30."E	Stop	Narrow

Table 2.4: Road intersection installation sites in study

Pairing No.	Name	Location	Latitude/ Longitude	Type of control	Seal width
8	Myers Road & Coolart Road – east approach	Bittern	38°20'19"S 145° 8'44"E	Give Way	Standard
9	Anglesea Rd & Mount Duneed Rd - east approach	Geelong	38°14'31"S 144°16'41"E	Stop	Standard
10	Myers Road & Balnarring Road – east approach	Balnarring	38°20'19"S 145° 5'49"E	Stop	Standard
11	Bittern-Dromana Road & Balnarring Road – west approach	Balnarring	38°21'13"S 145° 6'26"E	Stop	Standard
12	Churchill-Traralgon Rd & Church Rd – east approach	Morwell	38°16'16"S 146°28'12"E	Stop	Standard
13	Cape Otway Rd & Gherang Rd – south approach	Winchelsea	38°16'39"S 144° 5'11"E	Stop	Standard

Table 2.5: Road intersection control sites in study

Pairing No.	Name	Location	Latitude/ Longitude	Type of control	Seal width
8	Myers Road & Coolart Road – west approach	Bittern	38°20'19"S 145° 8'44"E	Give Way	Standard
9	Anglesea Rd & Mount Duneed Rd - west approach	Geelong	38°14'31"S 144°16'41"E	Stop	Standard
10	Myers Road & Balnarring Road – west approach	Balnarring	38°20'19"S 145° 5'49"E	Stop	Standard
11	Bittern-Dromana Road & Balnarring Road – east approach	Balnarring	38°21'13"S 145° 6'26"E	Stop	Standard
12	Churchill Traralgon Rd & Church Rd – west approach	Morwell	38°16'16"S 146°28'12"E	Stop	Standard
13	Hodgins Road & Coolart Road – east approach	Hastings	38°18'0”S 145° 8'44"E	Stop	Standard

3 SURVEYS

Two types of surveys were conducted for this project:

1. surveys of vehicle behaviour using video monitoring and a laser speed gun to obtain speed traces of vehicles
2. speed surveys using traffic counters at three locations on the approach to the intersection or crossing over a seven day period.

3.1 Individual Vehicle Surveys

This involved a two hour day-time survey using a video camera to observe driver behaviours on the approach to the intersection or crossing and a laser speed gun to record vehicle speeds at multiple points on the approaches.

To conduct the individual vehicles surveys, a car and trailer were required at the site for the duration of the survey. Where possible they were parked to the side of the road approximately 550 m from the crossing or intersection. The effect of having the vehicle and trailer at the site is discussed in Section 5.2.

The video surveys were conducted using the ARRB video trailer, which has a pneumatic mast allowing the camera to be elevated between 3 m and 12 m. When the videos were reviewed, for each vehicle it was noted when the brake lights were first observed, if the driver attempted to avoid the rumble strips or pneumatic tube detectors and if their approach was affected by an oncoming vehicle (single lane approaches) or a train at the crossing. At most survey locations it was not possible to determine where vehicles were applying brakes for the entire approach. At greater distances from the camera (closer to intersection or crossing), brake lights were often not observed when it appeared the vehicle was braking therefore a large number of unknown observations have been recorded. This will usually mean that the vehicle braked close to the crossing or intersection or did not apply brakes at all. Observations from the zones closer to the camera were clearer and will be the focus of the before and after video comparisons.

The laser speed gun provided successive measurements of vehicle speed and distances as each vehicle approached the crossing or intersection. These generally started over 500 m before the stop/give way line and continued up to the line, or past it in some cases. The measurements were made from inside or beside the parked car.

3.2 Speed Surveys

Speed surveys were also conducted at the sites indicated above to give comprehensive data across a whole week. These sites had detectors (pneumatic tube) placed at 50 m, 200 m and 500 m from the stop/give way line to monitor the speed of vehicles at these points. The detectors were connected to traffic counters which recorded the number of vehicles, and the type and speed of each vehicle.

At 500 m, the vehicle's speed should not be greatly affected by the rumble strips (unless they are already aware of them and are alert enough to react), at 200 m the vehicle has just finished traversing the rumble strips, and at 50 m the vehicle should have slowed significantly if this was required. If a vehicle is travelling over 55 km/h at the 50 m point then it would be difficult for the driver to stop the vehicle at the crossing or intersection.

The graphs from these speed surveys have been arranged so that the point closest to the intersection or crossing is on the left to match the speed trace graphs.

3.3 Survey Timing

The before and after surveys were conducted at all sites with the detailed speed and video surveys carried out during the seven day speed surveys. At the Kerang site, active advanced warning signs (AAWS) and boom gates were installed some weeks after the rumble strips. Three sets of measurements were taken for this site and its control, before, interim (after installations of the rumble strips) and after (after the AAWS and boom barriers were installed). In this study, interest is focussed on the comparison between the before and the interim results.

3.4 Statistical Analysis

ANOVA (analysis of variance) was conducted for each matched pair of control and treatment sites and also for the treatment sites which had no accompanying control site. Speed was the dependent variable and the two factors were time period (before versus after) and treatment (treatment versus control). Analysis was conducted using the univariate ANOVA procedure in the statistics software package SPSS.

The distribution of speeds for most sites was typically characterised by a tight clustering of speeds around the mean with little variance and few extreme values. Therefore, the ANOVA identified statistically significant differences when mean speeds differed between before and after and between control and treatment for nearly all sites, as can be seen by the very low p values reported in the tables in Section 4. This meant that very small changes in mean speeds were frequently identified as statistically significant. Statistical significance of main effects are reported.

Statistical significance indicates that a result is unlikely to have occurred by chance and is reported as a probability (p) where $p < 0.05$ is considered a significant result. It does not indicate the strength of the relationship between the factors and the dependent variable. The partial eta squared (η^2) value is an estimate of degree of association between the factors and the dependent variable, or the amount of total variability in the dependent variable that can be attributed to the factors in the model. So, if partial eta squared = 0.1, 10% of the variance in mean speed can be attributed to the factors in the model (i.e. before versus after, taking into account changes in both treatment and control sites). Partial eta squared can range in value between 0 and 1 where, in approximate terms, 0.2 would be considered a small effect, 0.5 a medium effect and 0.8 a large effect.

4 RESULTS

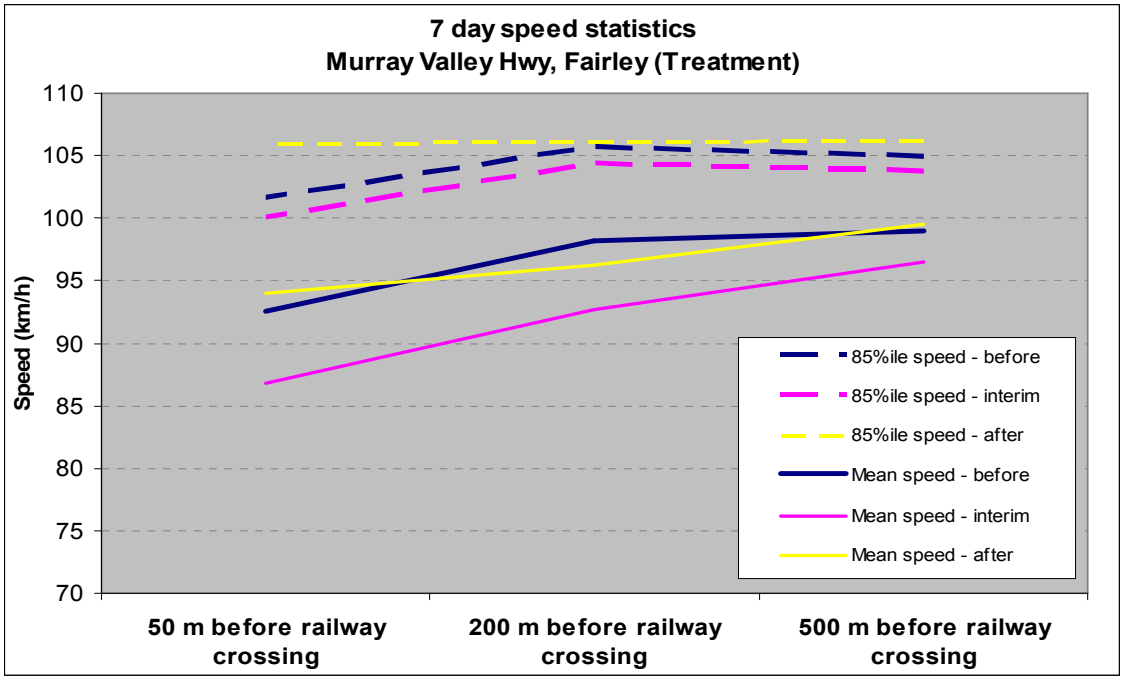
4.1 Rail Crossings

4.1.1 Active Control: Installation of Rumble Strips Followed by AAWS and Boom Barriers

Murray Valley Highway, Fairley – Treatment
Murray Valley Highway, Kerang – Control

The Murray Valley Highway, Fairley site is located north of Kerang and was the site of a major truck-train crash in 2007. Shortly after the crash the site was scheduled for upgrade by installation of rumble strips, active advanced warning signs and boom gates. This study surveyed the site three times: before any installations, after rumble strips and after the full upgrade.

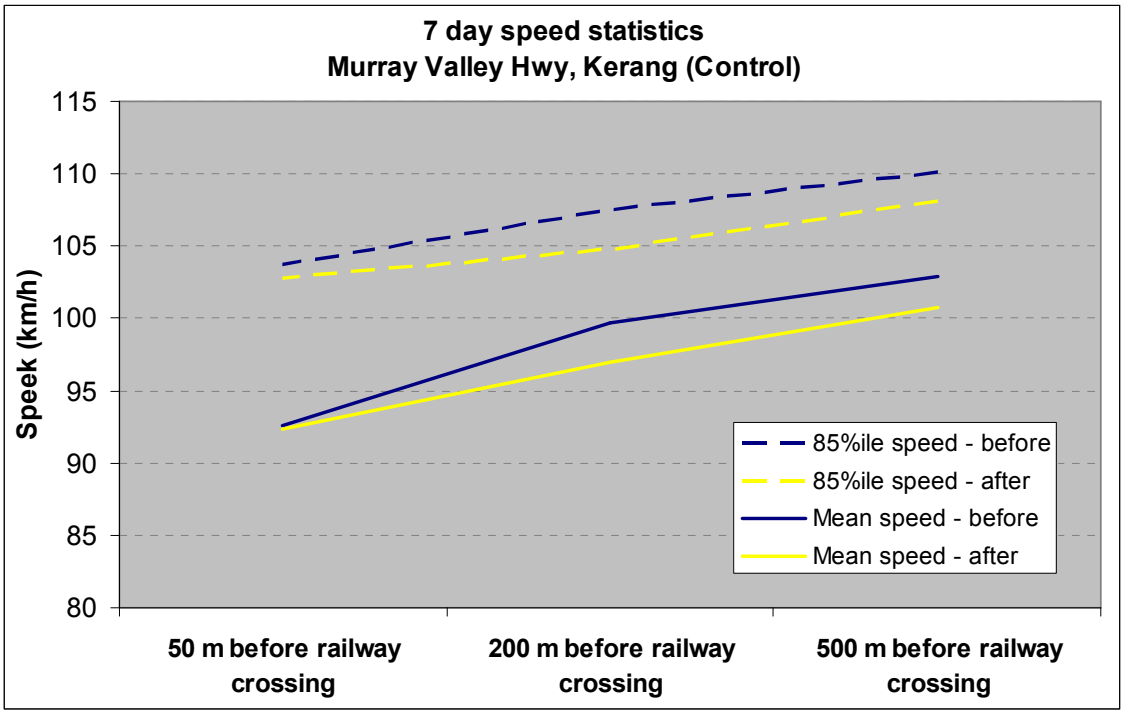
Note: 'Interim' is after rumble strips and 'After' is after active advanced warning signs and boom gates installed in addition to rumble strips.
Figure 4.1 shows that after the installation of the rumble strips (interim measurements), the mean speed was reduced at all three measurement points, 2 km/h at 500 m and 6 km/h at the other two measurement points. It should be noted that these were among the first rumble strips installed in the state and they appear to have been more aggressive (had a greater profile height) than many of the subsequent installations. As expected with an actively controlled railway level crossing, vehicles did not slow much on approach to the crossing as they would not need to slow or stop unless the signals were activated. After the installation of the boom gates and active advanced warning signs the mean speeds returned to similar level to the before survey however a 2 km/h reduction remained at the 200 m measurement point.



Note: 'Interim' is after rumble strips and 'After' is after active advanced warning signs and boom gates installed in addition to rumble strips.

Figure 4.1: 7 day speed statistics for Murray Valley Highway, Fairley (Treatment)

Figure 4.2 shows the control site had a reduction of up to 3 km/h on approach to the crossing in the after study suggesting that the reductions that occurred might have been influenced by something other than the rumble strips. This influence could in part be due to this (control) location being relatively close to the installation site and causing a behaviour change in drivers at both level crossings.



Note: 'After' is after active advanced warning signs and boom gates installed in addition to rumble strips at the Fairley treatment site.

Figure 4.2: 7 day speed statistics for Murray Valley Highway, Kerang (Control)

Table 4.1 show the results of the ANOVA conducted for these sites as described in Section 3.4. The mean speeds for each time period are shown for the treatment and control sites at the three measurement points. It also includes 'p' values and 'partial η^2' values which are a measure of the statistical significance of the results and an indication of how much the change in mean speed can be attributed to the treatment. The significance tests for these sites are only conducted between the before and after surveys.

These results show that the reduction in mean speeds is significant (p value), but the proportion of this change that can be attributed to this before after difference (partial η^2) is very small. In other words, the results are sufficiently consistent to show that this is a finding which is not likely to be due to chance fluctuations (due to the large number of observation on which it is based), but the overall effects are small (generally less than 1 km/h difference between the means). Following the discussion in Section 2.4, this can be interpreted as a sufficiently consistent reduction between the before and after conditions at the treatment site to generate a statistically significant difference, i.e. a difference that is greater than would be expected by chance. However, when all the sources of variation in the study are considered, this before after difference accounts for only a small percentage of the total variance, with much more variance being generated by the difference in speeds at the three different measuring points at 50 m, 200 m and 500 m in advance of the crossing. This pattern is consistent for most locations used in this study.

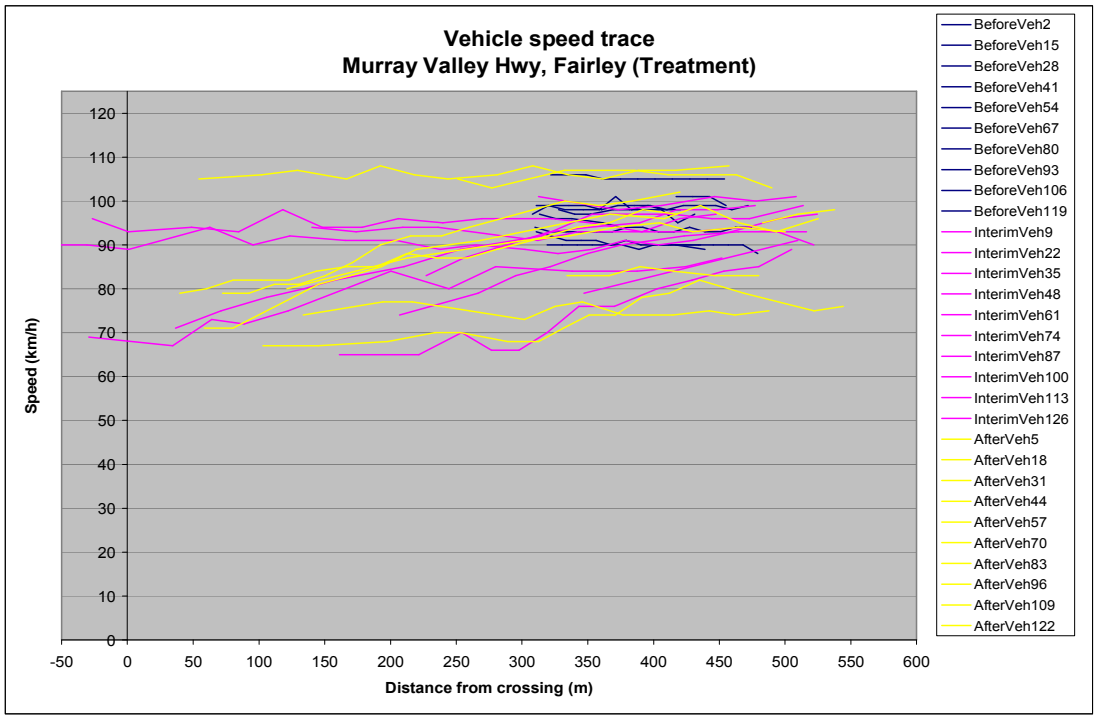
Post hoc test of mean speed comparisons (Scheffé) on the difference in mean speeds between the before survey and both the interim (rumble strips) and after (active advanced warning signs and boom barriers) surveys are significant. The change in mean between the interim survey and the after survey was also shown to be significant. This indicates that both the reduction in mean speeds that occurred with the rumble strips and the subsequent increase after the additional safety measures were installed were statistically significant.

Table 4.1: Results of the ANOVA for the Murray Valley Highway, Fairley and Kerang sites

Distance	Treatment	Before mean (km/h)	Interim mean (km/h)	After mean (km/h)	p and partial η^2
50 m	Control	92.6	N/A	92.1	
	Treatment	92.5	86.5	93.4	$p < .001$, $\eta^2 = 0.037$
200 m	Control	99.7	N/A	97.0	
	Treatment	98.2	92.5	95.8	$p < .001$, $\eta^2 = .035$
500 m	Control	103.0	N/A	103.7	
	Treatment	99.0	96.3	99.3	$p < .001$, $\eta^2 = .067$

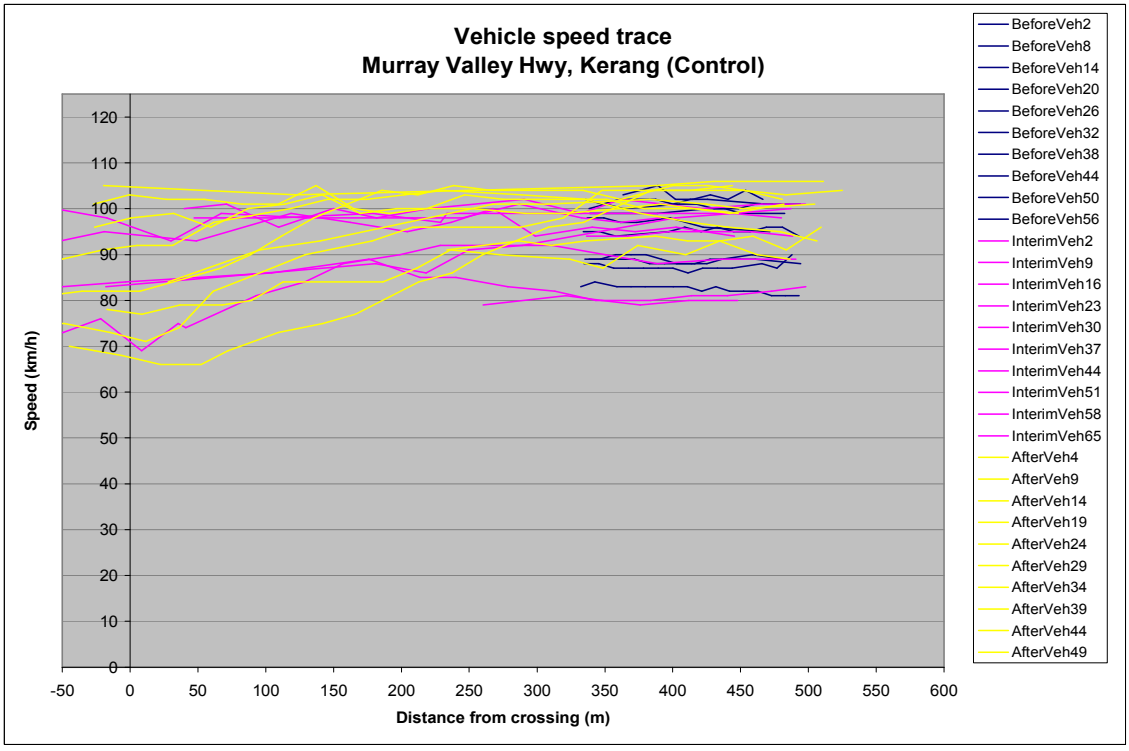
From the laser data a selection of vehicle traces was plotted to show a sample of individual vehicle speeds on the approach. The sample of ten traces was generated by specifying a starting trace number and multiplier. These were adjusted for each survey to enable coverage across the entire survey period.

The selection of vehicle traces in Figure 4.3 and Figure 4.4 does not suggest any clear conclusions, although it does show some vehicles slowing more and earlier after the treatment was installed, particularly in the interim period. Both sites show a wide range of approach speeds.



Note: 'Interim' is after rumble strips and 'After' is after active advanced warning signs and boom gates installed in addition to the rumble strip.

Figure 4.3: Selected vehicle traces for Murray Valley Highway, Fairley (Treatment)



Note: 'Interim' is after rumble strips and 'After' is after active advanced warning signs and boom gates installed in addition to rumble strips at the Fairley treatment site.

Figure 4.4: Selected vehicle traces for Murray Valley Highway, Kerang (Control)

Table 4.2 and Table 4.3 show the distance from the crossing that vehicles were observed to have applied their brakes and the number of vehicles which attempted to drive around the rumble strips. Vehicles that did not travel the entire approach were excluded.

Table 4.2 shows that after the installation of rumble strips, a number of vehicles at the treatment site were shown to apply their brakes both before and while travelling over the rumble strips where they did not do so before. Avoidance behaviour was also observed for a small number of vehicles after the installation. This included vehicles travelling entirely on the wrong side of the road to avoid the strips. Behaviour was relatively unchanged at the control site (Table 4.3).

Table 4.2: Application of brakes and rumble strip avoidance at Murray Valley Hwy – Fairley (Treatment)

	Observation of brake lights (m)					
Period	**Before 440**	**440-225**	**After 225**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	0	163	0	0
Interim	8	9	0	208	0	2
After	3	2	0	127	0	5

Note: 'Interim' is after rumble strips and 'After' is after active advanced warning signs and boom gates installed in addition to rumble strips at the Fairley treatment site.
* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.3: Application of brakes and rumble strip avoidance at Murray Valley Highway, Kerang (Control)

	Observation of brake lights (m)					
Period	**Before 440**	**440-215**	**After 215**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	3	0	1	75	0	0
Interim	0	1	0	95	0	0
After	1	0	0	74	0	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

All speed indicators for this site show that after the initial treatment of the Murray Valley Highway at Fairley, speeds on approach to the crossing were reduced. A third survey conducted after the active advanced warning signs and boom barriers were installed showed that speeds returned to a similar level to the before time period. The video observations show a few vehicles applying their brakes earlier after the installation of rumble strips (interim survey) but at a reduced level once the AAWS and boom barriers were installed.

4.1.2 Summary

- There was a small reduction in mean speeds after installation of rumble strips.
- Mean speeds returned to the before level after installation of AAWS and boom barriers.
- A few more vehicles were observed to be applying brakes earlier in the interim and after studies.

4.1.3 Active Control: Only Rumble Strips Installed

Avenel-Nagambie Road, Nagambie – Treatment
Midland Highway, Tatura – Control

This treatment site showed a reduction in mean speed of 2 km/h to 5 km/h with the greatest reduction at 50 m from the crossing as shown in Figure 4.5.

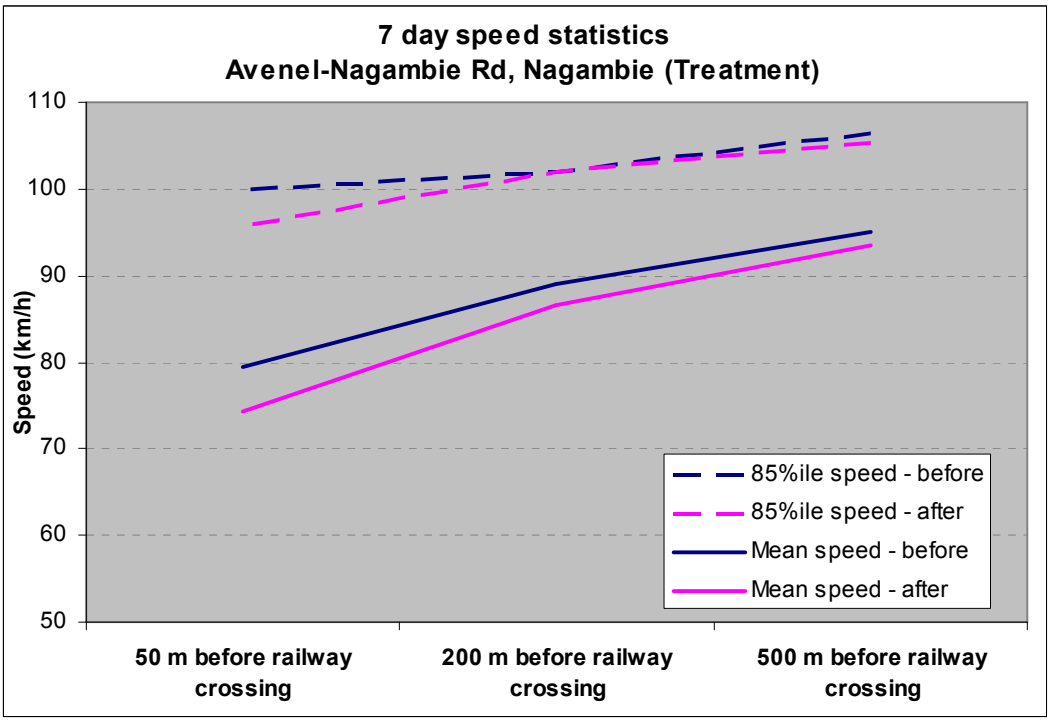


Figure 4.5: 7 day speed statistics for Avenel-Nagambie Road, Nagambie (Treatment)

The Midland Highway control site shows an increase in speeds at 50 m and 500 m and a slight decrease at 200 m. Each of these changes in the mean speed was approximately 2 km/h. These changes were the same or less than the changes that occurred at the treatment site.

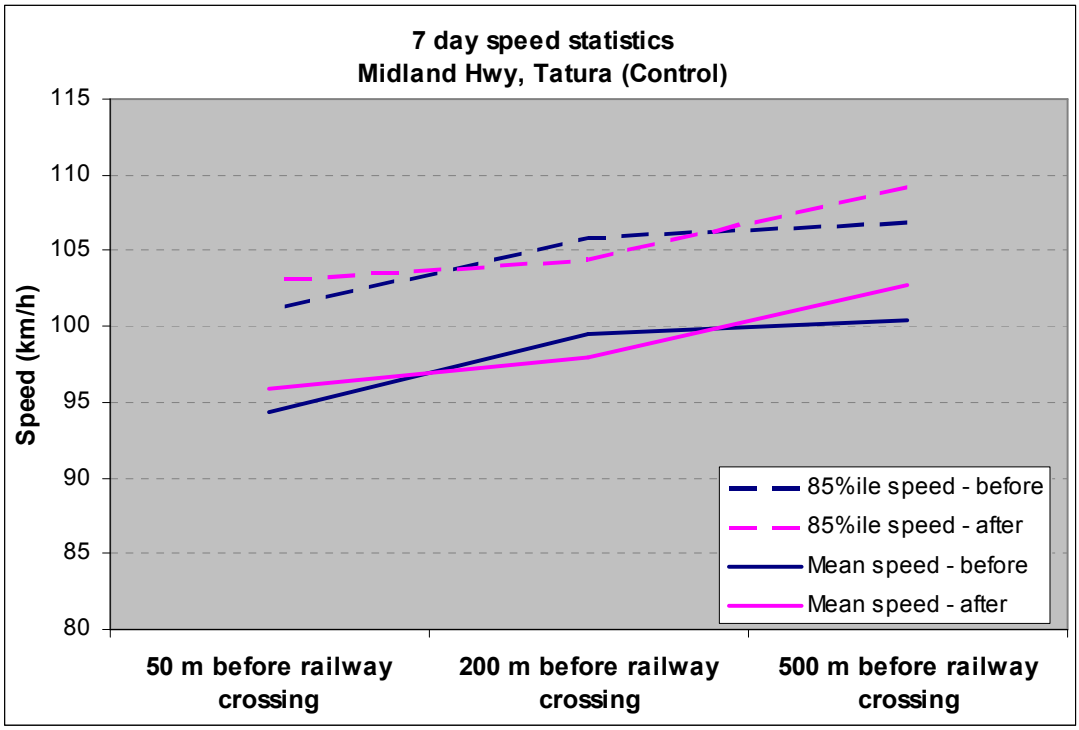


Figure 4.6: 7 day speed statistics for Midland Highway, Tatura (Control)

In this case the ANOVA shows that the largest percent reduction was at 50 m at the treatment site with a change of 5 km/h or 5.8%. Once again the change at all points is statistically significant but at 200 m the partial η^2 value of 0.104 shows that the treatment had a small effect on the speed and at 50 m the partial η^2 value of 0.240 indicates the treatment had a small to moderate effect on the speed.

Table 4.4: Results of the ANOVA for Avenel-Nagambie Road and Midland Highway

Distance	Treatment	Before mean (km/h)	Interim mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	94.4	96.1	1.7	
	Treatment	79.8	75.2	-4.6	$p < .001$, $\eta^2 = .240$
200 m	Control	99.0	98.2	-0.8	
	Treatment	89.2	87.5	-1.7	$p < .001$, $\eta^2 = .104$
500 m	Control	100.4	102.8	2.4	
	Treatment	95.1	94.1	-1.0	$p < .001$, $\eta^2 = .078$

At all measurement points, the Avenel-Nagambie Road treatment site showed a larger reduction in mean speeds than the control site. These were shown to be statistically significant. The reduction at 50 m from the crossing was shown to be the largest and the ANOVA indicates a small to moderate effect from the rumble strips.

The Avenel-Nagamabi Road site had overall slower speed speeds than Midland Highway which is likely to be because they are different classes of roads. This will influence the type and volume of traffic, they may also have different sight distances along the rail line. However this

was the best match that could be made from the sites available, given the restrictions of the site selection criteria.

The higher speeds at the Midland Highway site meant that there was greater potential for speed reductions at this site (the control site) than at the treatment site, e.g. at the 50 m measuring point a 1% reduction in speed would have been 0.84 km/h for the control site, but only 0.8 km/h at the treatment site. In the event, there were substantial reductions at all the measurement points at the treatment site, and only one small decrease in speed at the measurement points for the control site. The higher speeds at the control site did not therefore affect the significance of the results.

The before survey at Avenel-Nagamabi Road suggested that the traffic volume was not sufficient to do detailed surveys. In consultation with VicRoads it was determined that detailed after surveys would not be conducted at Avenel-Nagambie Rd or Midland Highway sites.

4.1.4 Summary

- There were reductions of 1 km/h to 4.6 km/h at the treatment site.
- ANOVA estimated that some of the reductions could be attributed to the rumble strip installation.

4.1.5 Passive: Crossing Controlled by Give Way Signs

Dumosa-Quambatook Rd, Quambatook – Treatment
Aerodrome Rd, Avenel (west) – Control

The mean speed reductions at the Quambatook site were 2 km/h, 1 km/h and 4 km/h at 50 m, 200 m and 500 m respectively as shown in Figure 4.7. Interestingly the smallest reduction in the mean speed was directly after crossing the rumble strips. The mean speed reduction was not reported at the control site because the detectors were not placed at the control site.

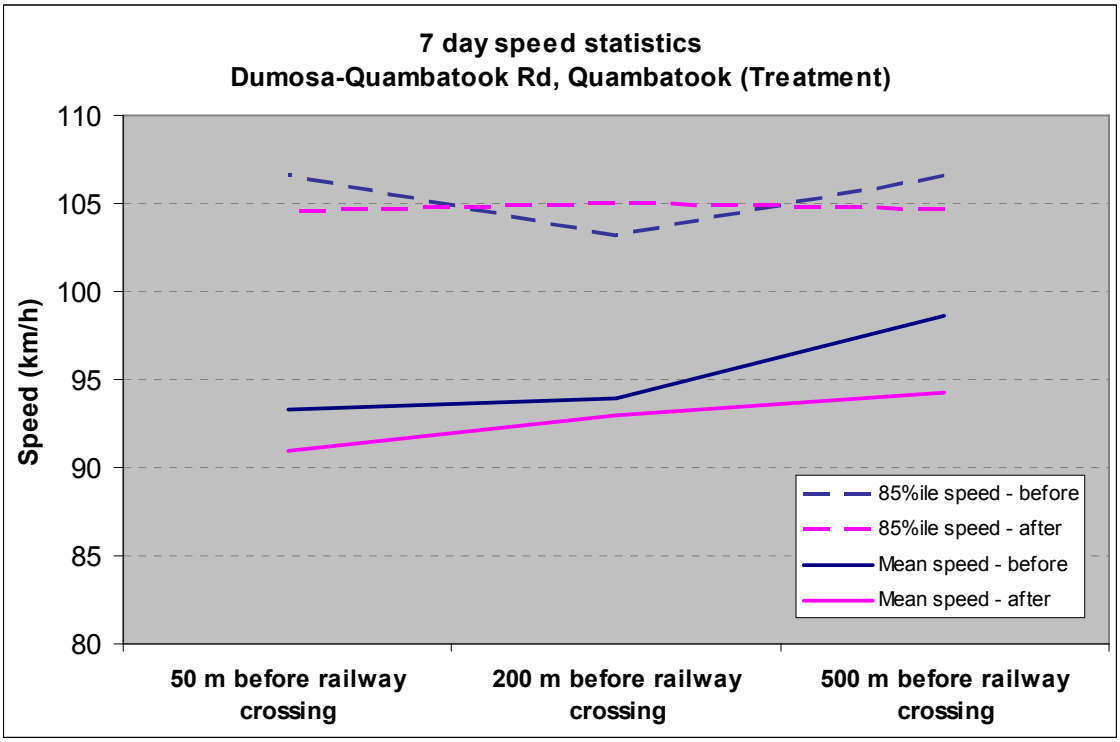


Figure 4.7: 7 day speed statistics for Dumosa-Quambatook Rd, Quambatook (Treatment)

The ANOVA shown in Table 4.5 indicates all changes in speed were significant except at 200 m from the crossing. The largest change in speeds was on the approach to the rumble strips at 500 m which is shown to be the most significant reduction however the effect of the treatment was shown to be very small.

Table 4.5: Results of the ANOVA for Dumosa-Quambatook Rd, Quambatook

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Treatment	93.5	90.8	-2.7	$p < .01$, $\eta^2 = .005$
200 m	Treatment	94.0	92.9	-1.1	$p > .05$, $\eta^2 = .001$
500 m	Treatment	98.7	94.1	-4.6	$p < .001$, $\eta^2 = .022$

The speed traces shown in Figure 4.8 indicate that most of the speed profiles are much the same before and after the rumble strip installation, i.e. there is no sudden braking, simply the after study has overall lower speeds. Note that the data points on the speed trace graphs are not always evenly distributed and that long straight lines on the graph may indicate there were no data points in that section.

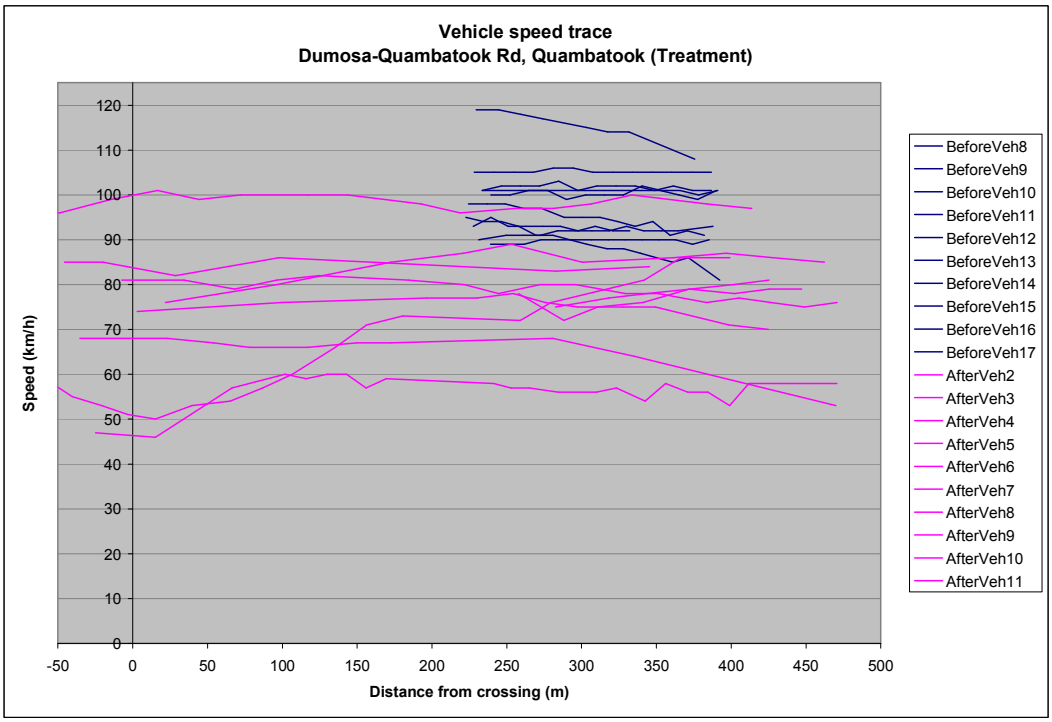


Figure 4.8: Vehicle traces for Dumosa-Quambatook Rd, Quambatook (Treatment)

The speed traces for Aerodrome Rd (west) in Figure 4.9 indicate that vehicles generally slowed more on approach to the crossing but that speeds were generally higher in the after study both on approach to and at the crossing. At both the treatment and control sites there was a large variation in vehicle approach speeds.

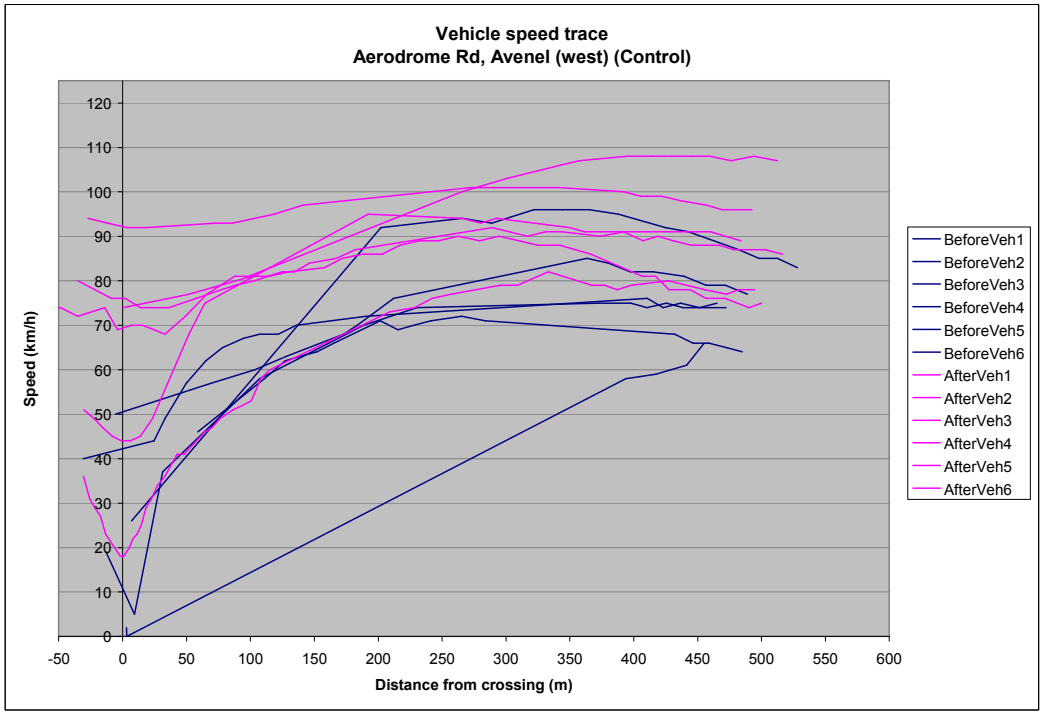


Figure 4.9: Selected vehicle traces for Aerodrome Rd, Avenel (west) (Control)

The sample of vehicles in the detailed survey is small however it does show more visible braking after rumble strips were installed and that one out of the ten vehicles attempted to avoid the rumble strips. It would also appear that drivers in this survey had the perception that the sight distance at the control site was worse than at the treatment site as vehicles generally traversed the crossing at slower speeds.

Table 4.6: Application of brakes and rumble strip avoidance at Dumosa-Quambatook Rd, Quambatook

	Observation of brake lights (m)					
Period	**Before 377**	**377-245**	**After 245**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	1	18	0	0
After	1	0	2	13	0	1

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Aerodrome Rd (west) video survey showed no obvious difference in the before and after surveys (Table 4.7), but the number of vehicles observed was very low.

Table 4.7: Application of brakes and rumble strip avoidance at Aerodrome Rd, Avenel (west)

	Observation of brake lights (m)					
Period	**Before 460**	**275-460**	**After 275**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	1	0	6	0	0
After	0	0	0	6	0	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

4.1.6 Summary

- There were small reductions in mean speed shown at the treatment site.
- Speed traces indicate an overall change in speeds as vehicles approached the rumble strips.

Patchewollock-Sea Lake Rd, Nyarrin – Treatment
Aerodrome Rd, Avenel (east) – Control

Patchewollock-Sea Lake Road showed large reductions in speeds on the approach to the crossing at all speed detector locations after rumble strips had been installed. Figure 4.10 shows that these reductions increased as vehicles approached the crossing. The mean speed reduction is not reported at the control site because the detectors were not placed at the control site.

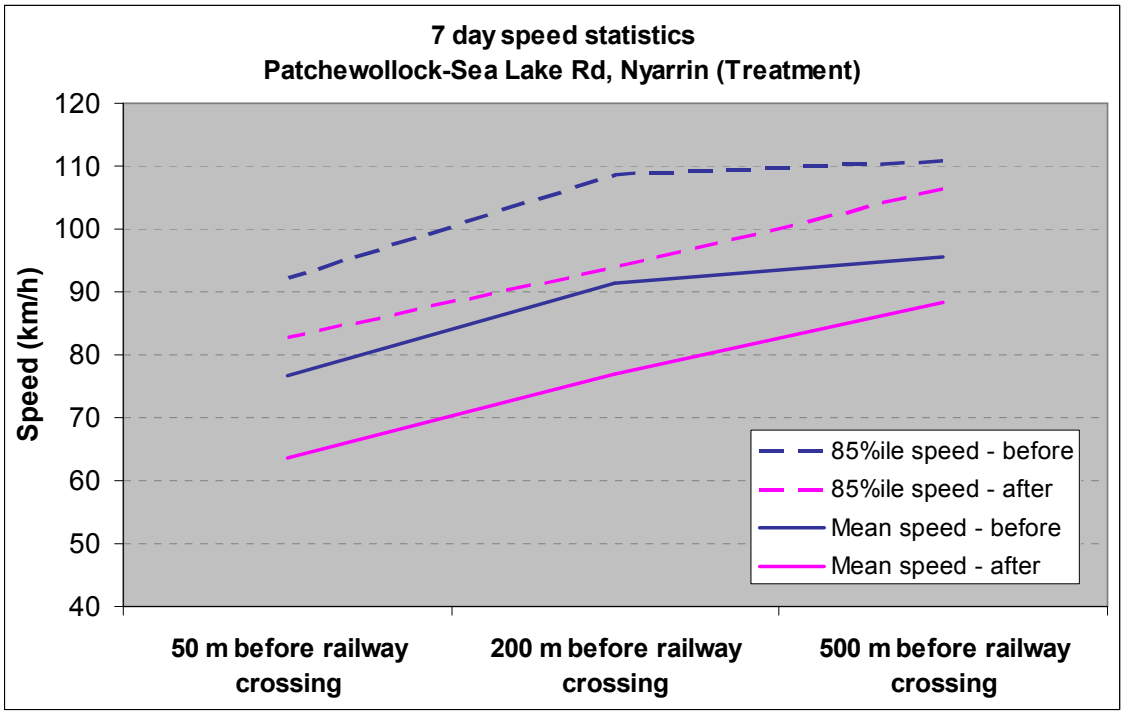


Figure 4.10: 7 day speed statistics for Patchewollock-Sea Lake Rd, Nyarrin (Treatment)

The reduction in speed after the installation of rumble strips was clear, as much as 15% or 11 km/h at 50 m from the railway crossing. However the reductions at 500 m are not statistically significant. The partial η^2 values at 50 m and 200 m still indicate that effect of the treatment was minimal.

Table 4.8: Results of the ANOVA for Patchewollock-Sea Lake Rd, Nyarrin

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Treatment	76.9	65.3	-11.6	$p < .001$, $\eta^2 = .062$
200 m	Treatment	92.1	79.6	-12.5	$p < .001$, $\eta^2 = .078$
500 m	Treatment	96.4	93.0	-3.4	$p > .05$, $\eta^2 = .005$

The speed traces in Figure 4.11 and Figure 4.12 show the treatment site to have consistently slower approach speeds after the installation while speeds at the control site are relatively consistent. However these are based on a small number of vehicles in the samples with a wide range of approach speeds.

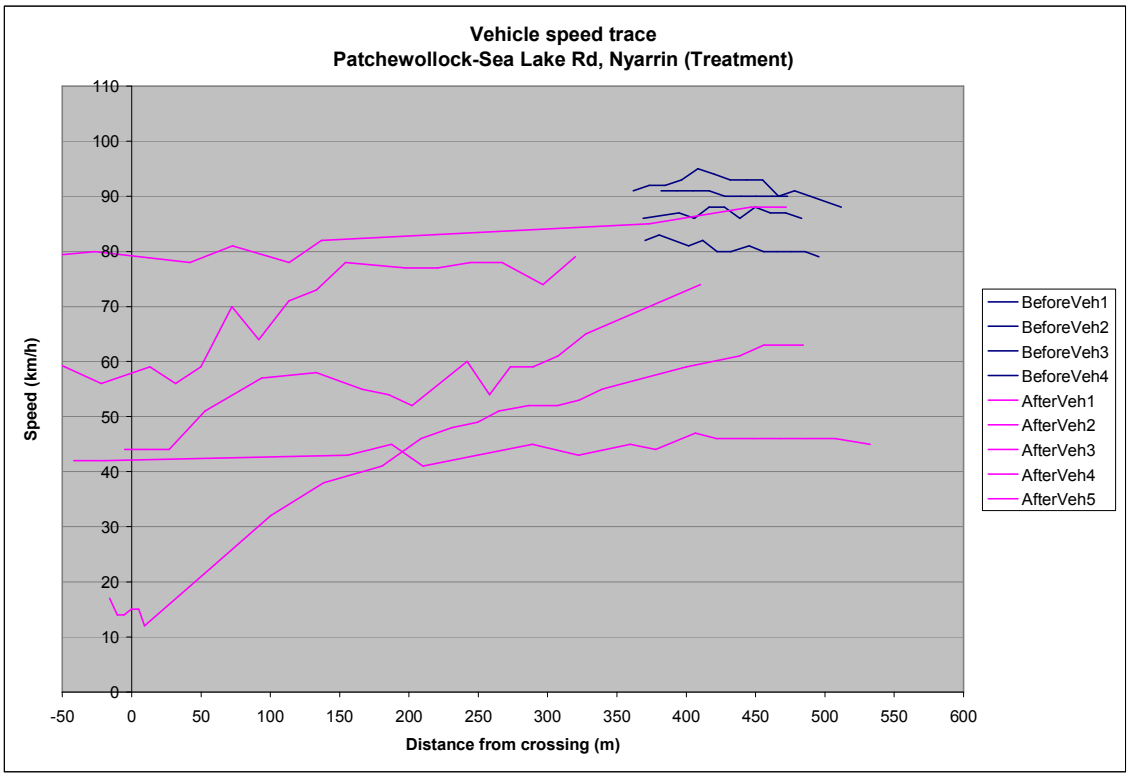


Figure 4.11: Vehicle traces for Patchewollock-Sea Lake Rd, Nyarrin (Treatment)

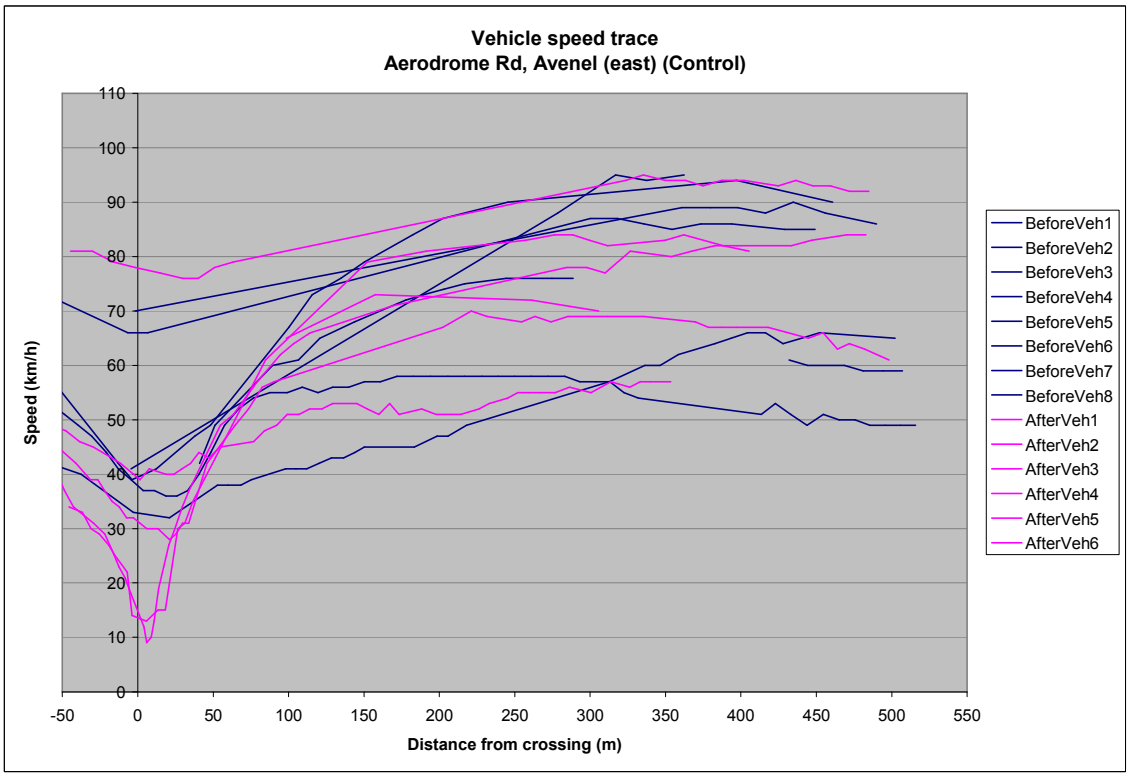


Figure 4.12: Vehicle traces for Aerodrome Rd, Avenel (east) (Control)

The video data in Table 4.9 and Table 4.10 show after the installation of rumble strips, two vehicles were observed to apply their brakes earlier with no change observed at the control site. Patchewollock-Sea Lake Rd had rumble strips installed across the entire carriageway so any avoidance would require travelling on the gravel shoulder.

Table 4.9: Application of brakes and rumble strip avoidance at Patchewollock-Sea Lake Rd, Nyarrin

	Observation of brake lights (m)					
Period	**Before 400**	**400-275**	**After 275**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	0	4	0	0
After	1	1	0	5	0	0

RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.10: Application of brakes and rumble strip avoidance at Aerodrome Rd, Avenel (east)

	Observation of brake lights (m)					
Period	**Before 470**	**470-245**	**After 245**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	0	8	0	0
After	0	0	0	6	0	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

- The speed traces for both sites show large variations in vehicle speeds on the entire vehicle approach but they are based on a very small sample size.
- The 7 day speed survey showed >10 km/h reduction at the two measurement points after the rumble strips.

4.1.7 Passive: Crossing Controlled by Stop Signs

Brislanes Rd, Murgheboluc – Treatment
Kirwans Bridge-Longwood Rd, Nagambie– Control

Brislanes Road is another low volume road that showed a noticeable drop in speeds after rumble strips were installed (Figure 4.13) compared to the control site at Kirwans Bridge-Longwood Rd where the speed profile showed almost no change (Figure 4.14).

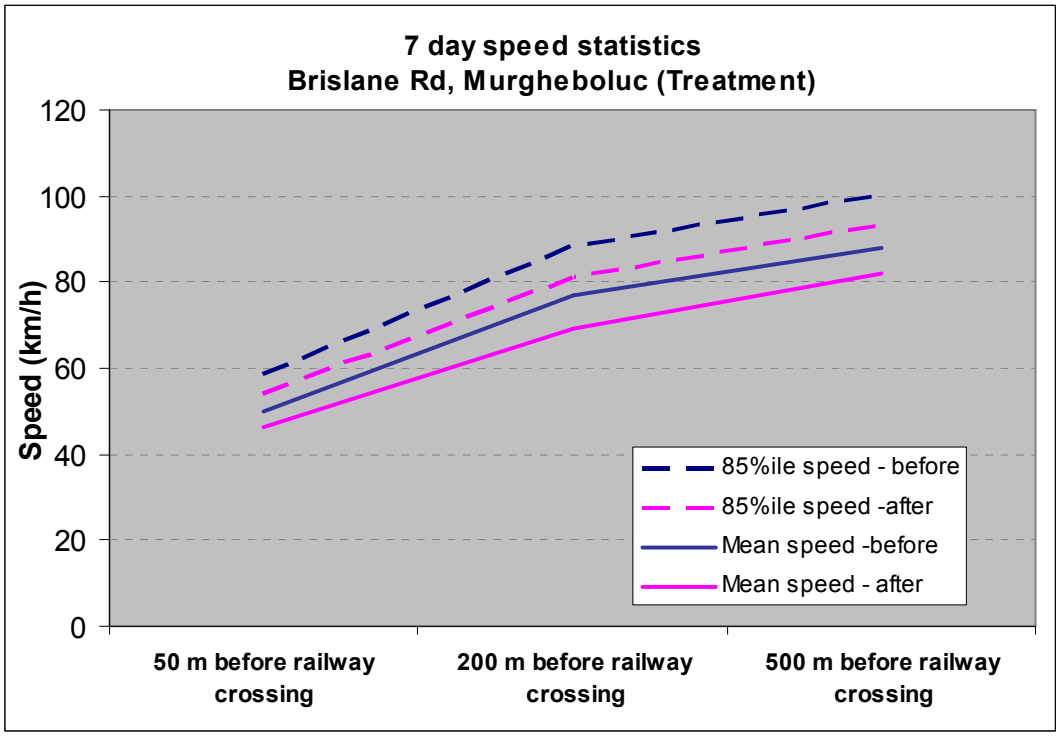


Figure 4.13: 7 day speed statistics for Brislanes Rd, Murgheboluc

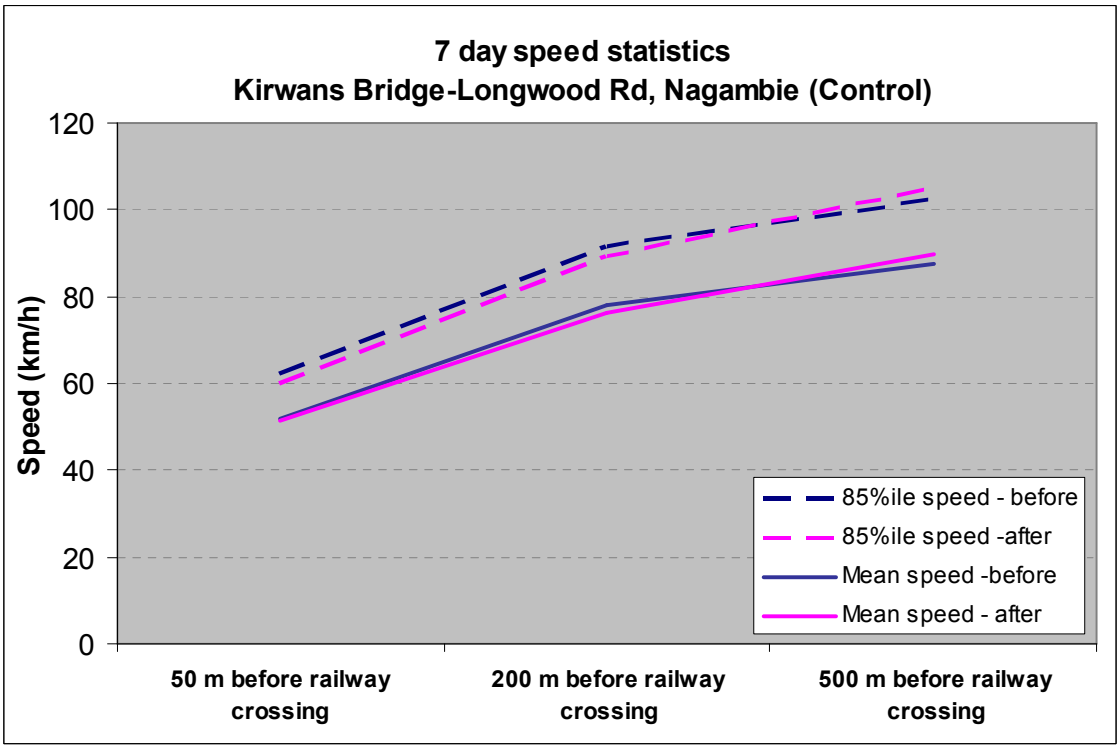


Figure 4.14: 7 day speed statistics for Kirwans Bridge-Longwood Rd, Nagambie (Control)

Table 4.11 shows that while large percentage reductions in mean speed were statistically significant in all cases, the partial η^2 value does not indicate the effect was from the rumble strips.

Table 4.11: Results of the ANOVA for Brislanes Rd and Kirwans Bridge-Longwood Rd

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	51.4	52.1	0.7	
	Treatment	50.5	45.9	-4.6	$p < .001$, $\eta^2 = .038$
200 m	Control	77.7	76.7	-1.0	
	Treatment	77.3	71.2	-6.1	$p < .001$, $\eta^2 = .026$
500 m	Control	87.1	90.0	2.9	
	Treatment	87.8	83.0	-4.8	$p < .001$, $\eta^2 = .022$

The speed trace for Brislanes Rd in Figure 4.15 indicates a reduction in the high speed vehicles however most vehicles had similar speeds 500 m from the crossing. The speeds at the control site did not change but there were very few vehicles (Figure 4.16). Both sites show generally good compliance with the stop sign as most vehicles were travelling less that 10 km/h at the crossing.

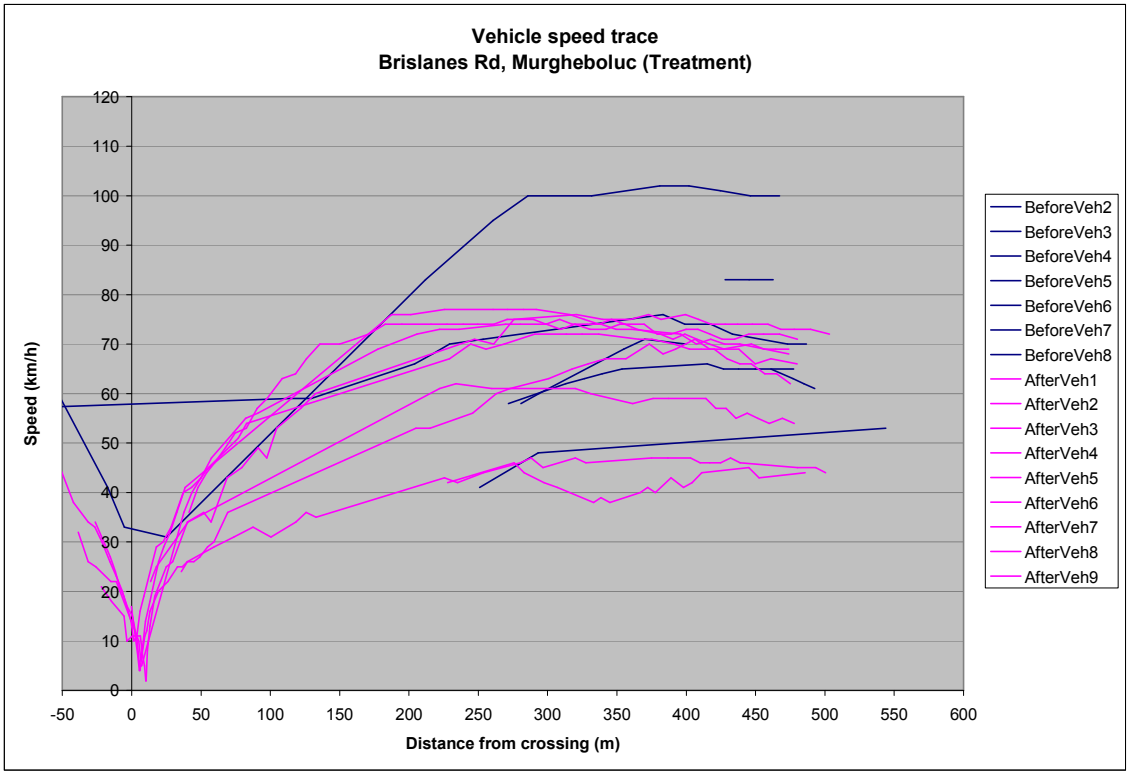


Figure 4.15: Vehicle traces for Brislanes Rd, Murgheboluc (Treatment)

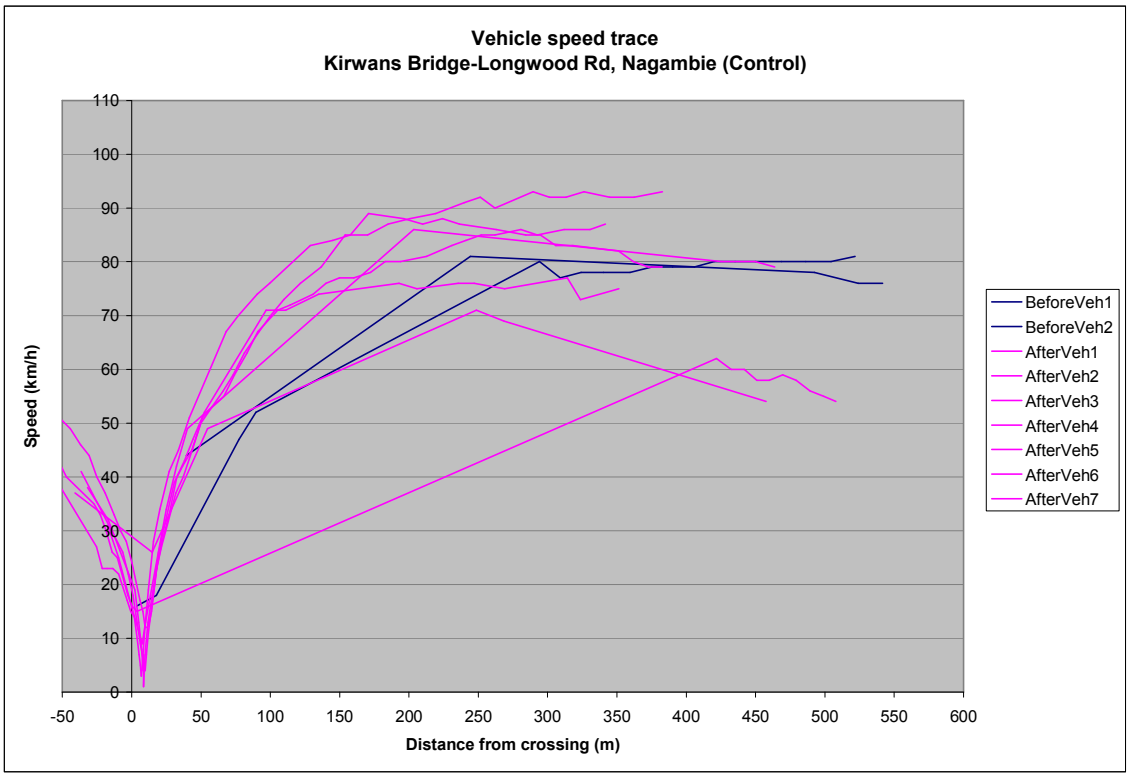


Figure 4.16: Vehicle traces for Kirwans Bridge-Longwood Rd, Nagambie (Control)

The video survey showed very little difference in the before and after surveys at both locations (Table 4.12 and Table 4.13). Brislanes Rd had rumble strips installed across the entire carriageway so any avoidance would require travelling on the gravel shoulder.

Table 4.12: Application of brakes and rumble strip avoidance at Brislanes Rd, Murgheboluc

	Observation of brake lights (m)					
Period	**Before 500**	**200-500**	**After 200**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	0	9	0	0
After	0	0	1	7	0	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.13: Application of brakes and rumble strip avoidance at Kirwans Bridge-Longwood Rd, Nagambie

	Observation of brake lights (m)					
Period	**Before 470**	**225-470**	**After 225**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	1	2	0	0
After	0	0	1	5	0	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.
** This shows a different number of vehicles to the trace graph (Figure 4.16) because two vehicles were recorded with the laser after the video was stopped.

4.1.8 Summary

- The 7 days speed count showed a reduction in mean speeds at all measurement points.
- The detailed survey at these sites are not clear due to very small sample sizes.

Gnarpurt Rd, Lismore (north) – Treatment
Gnarpurt Rd, Lismore (south) – Control

Figure 4.17 shows a very small reduction in mean speeds on approach to the railway level crossing for the treatment site. For the same period the control site showed a slight increase in speeds.

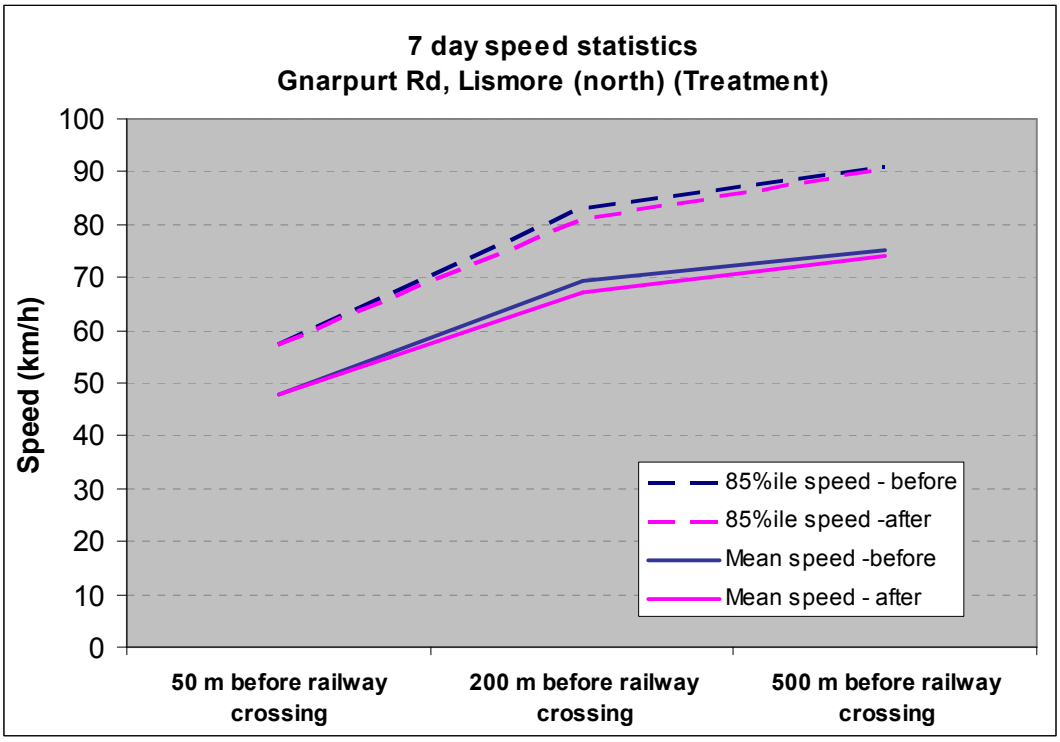


Figure 4.17: 7 day speed statistics for Gnarpurt Rd, Lismore (north) (Treatment)

Figure 4.18 shows a slight increase in speed between the before and after study. When compared to the slight decrease at the treatment site, it becomes more apparent there was a shift to lower speeds as a result of the treatment.

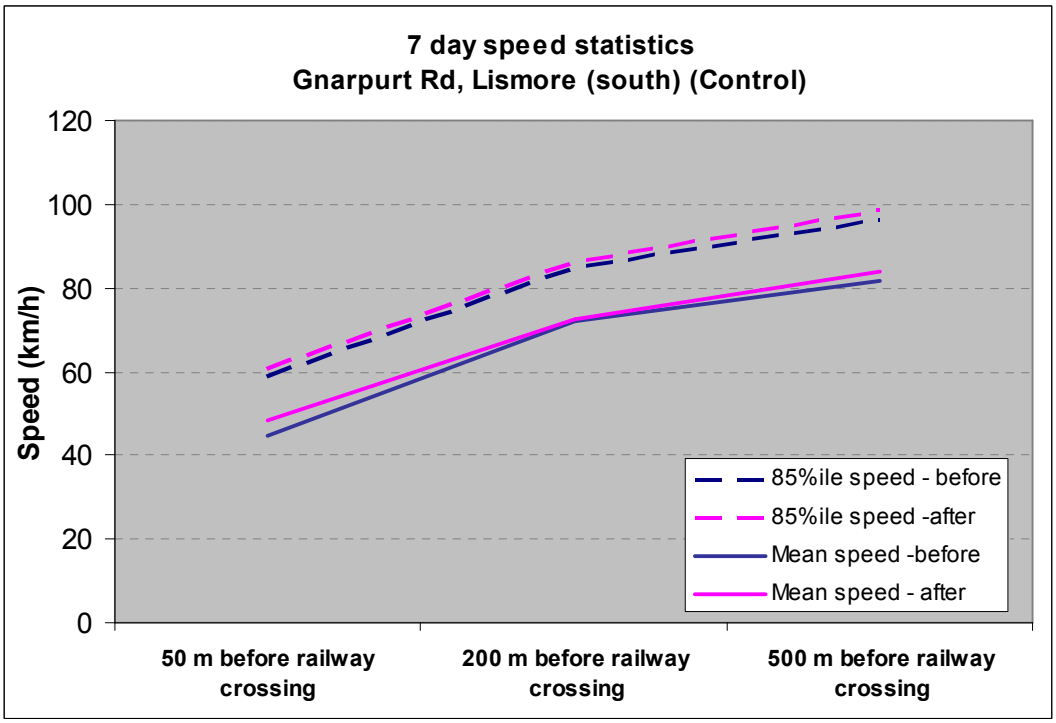


Figure 4.18: 7 day speed statistics for Gnarpurt Rd, Lismore (south) (Control)

Both the increase for the control and decrease at the treatment are small but statistically significant with the largest reduction recorded directly after the rumble strips at 200 m (Table 4.14). However the ANOVA estimated the rumble strips did not contribute to this change at any measurement point.

Table 4.14: Results of the ANOVA for Gnarpurt Rd north and south approaches

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	44.4	47.9	3.5	
	Treatment	47.7	47.3	-0.4	$p < .001$, $\eta^2 = .012$
200 m	Control	72.0	73.1	1.1	
	Treatment	68.7	66.3	-2.4	$p < .001$, $\eta^2 = .032$
500 m	Control	81.8	84.4	2.6	
	Treatment	74.2	76.0	1.8	$p < .001$, $\eta^2 = .061$

The speed traces for the treatment site (Figure 4.19) indicate a very similar profile after the treatment is installed apart from one vehicle which approached at very high speed during the before measurements. The control site shows very little difference in the before and after surveys (Figure 4.20). Compliance with the stop sign at both of these sites does not appear to be as good as at the other stop sign controlled level crossings included in this project which may be due to local factors at this site.

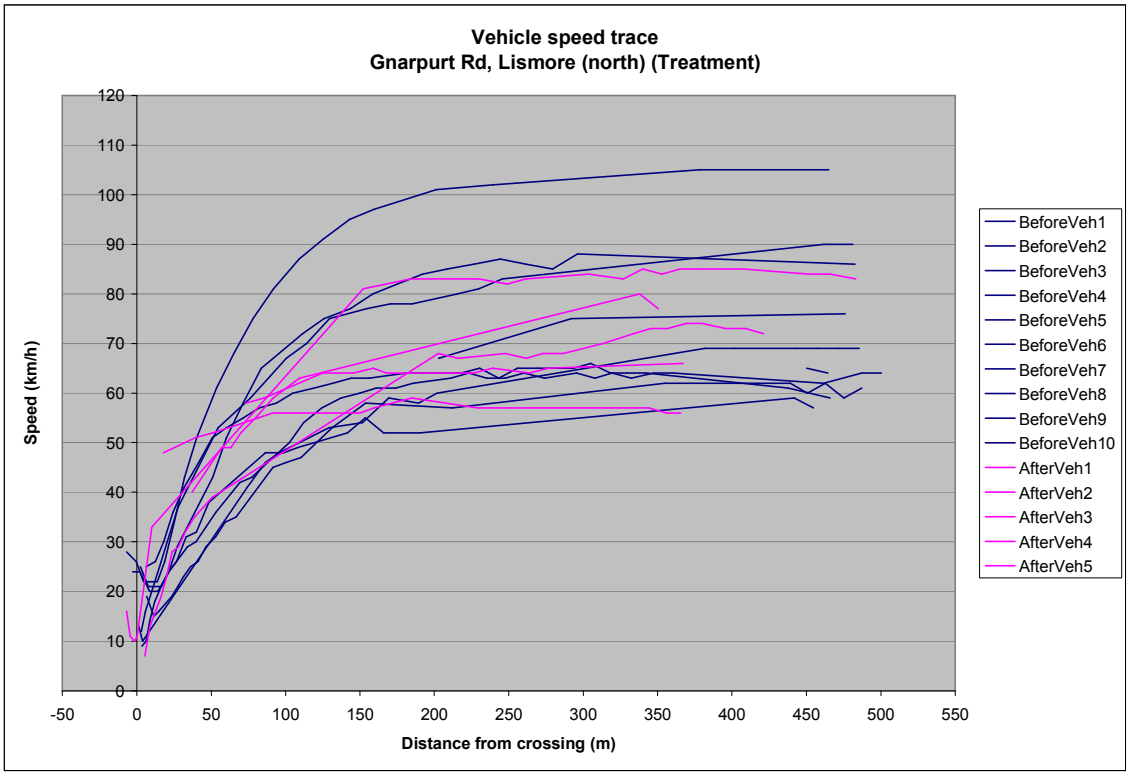


Figure 4.19: Vehicle traces for Gnarpurt Rd, Lismore (north) (Treatment)

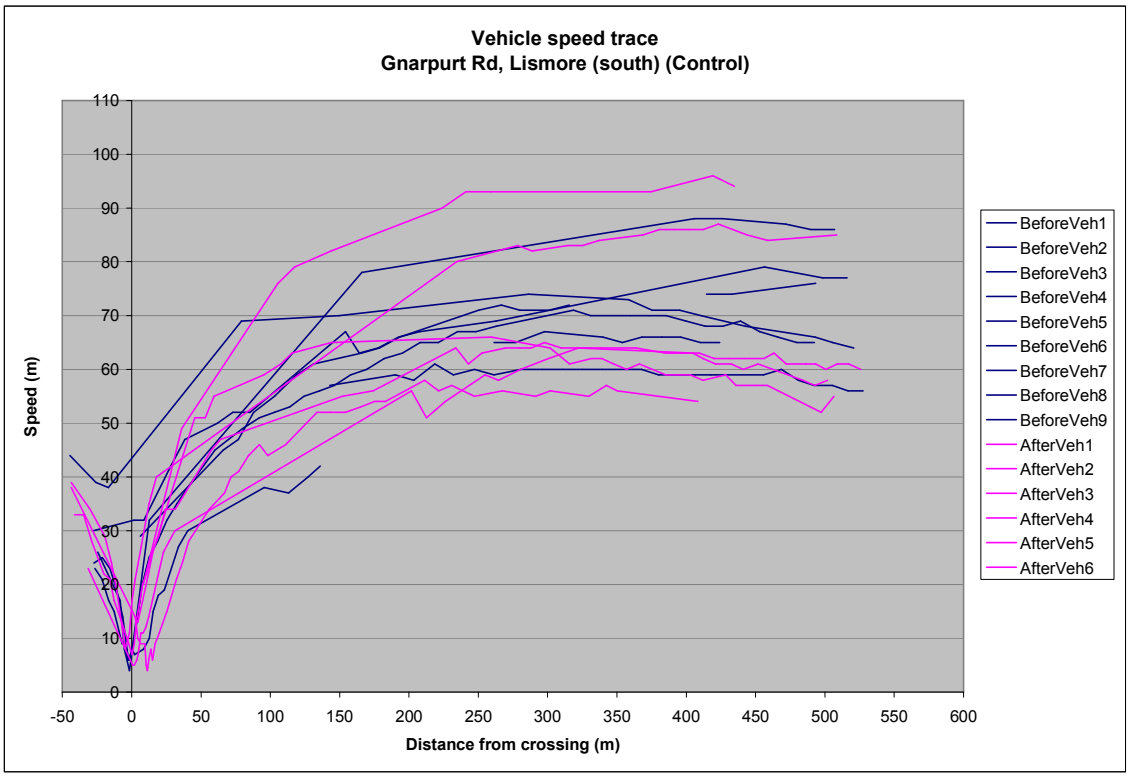


Figure 4.20: Vehicle traces for Gnarpurt Rd, Lismore (south) (Control)

The video observations in Table 4.15 and Table 4.16 show very little except that one vehicle drove around the rumble strips at the treatment site. Note that this was one vehicle out of a total of four observations.

Table 4.15: Application of brakes and rumble strip avoidance at Gnarpurt Rd, Lismore (north)

	Observation of brake lights (m)					
Period	**Before 500**	**250-500**	**After 250**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	0	10	0	0
After	0	0	0	4**	0	1

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.
**This shows a different number of vehicles to the trace graph (Figure 4.19) due to a brief failure of the video camera during this survey.

Table 4.16: Application of brakes and rumble strip avoidance at Gnarpurt Rd, Lismore (south)

	Observation of brake lights (m)					
Period	**Before 500**	**265-500**	**After 265**	**Total vehicles observed**	**Train**	**RS or detector avoidance***
Before	0	0	2	9	0	0
After	0	0	2	6	0	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

4.1.9 Summary

- This treatment site showed the least reduction out of all the level crossings surveyed for this project.
- The largest reduction was at the measurement site directly after the rumble strips.

4.2 Road Intersections

The road intersection sites used in this study were intersections of 'C' and local roads with more major roads, generally 'B' or 'C' class roads, in rural areas. When viewing the speed trace results it should be noted that the 'zero' distance is the intersection control sign, usually located approximately 10 metres before the stop/give way line.

4.2.1 Give Way Controlled Intersections

Myers Road & Coolart Road, Bittern (east) – Treatment
Myers Road & Coolart Road, Bittern (west) – Control

The 7 day speed counts for Myers Rd and Coolart Rd showed a reduction in mean speeds at all measurement points at the treatment site (Figure 4.21) with almost no change at the control site (Figure 4.22).

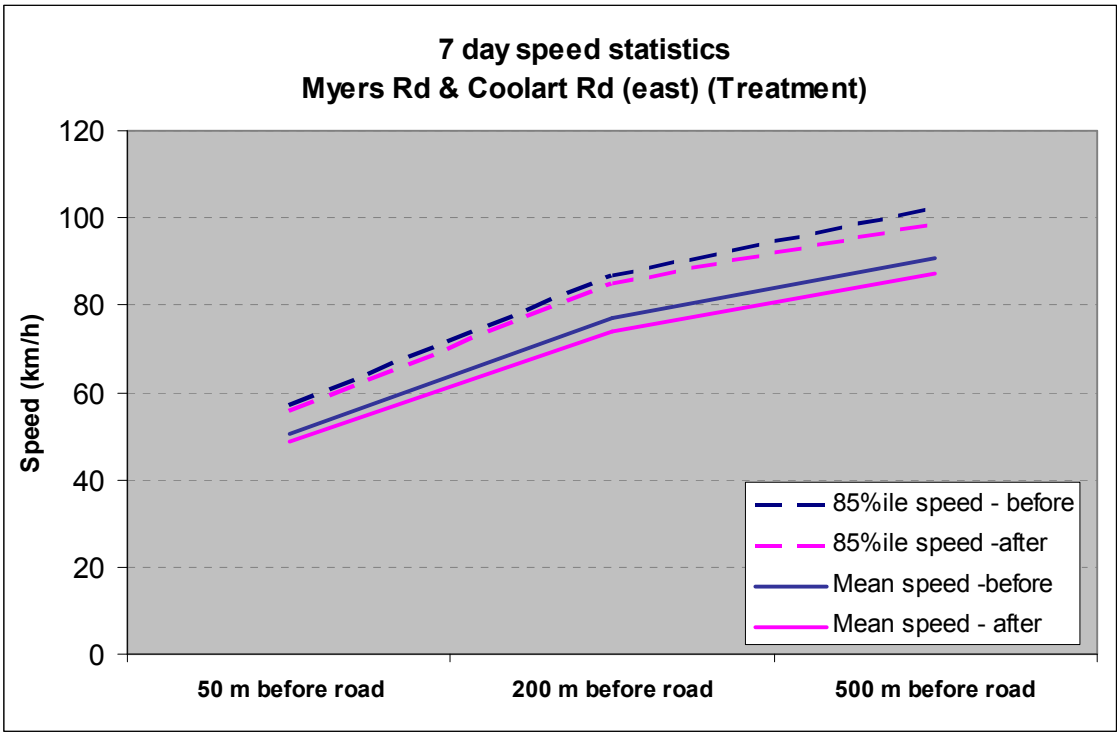


Figure 4.21: 7 day speed statistics for Myers Road & Coolart Road, Bittern (east) (Treatment)

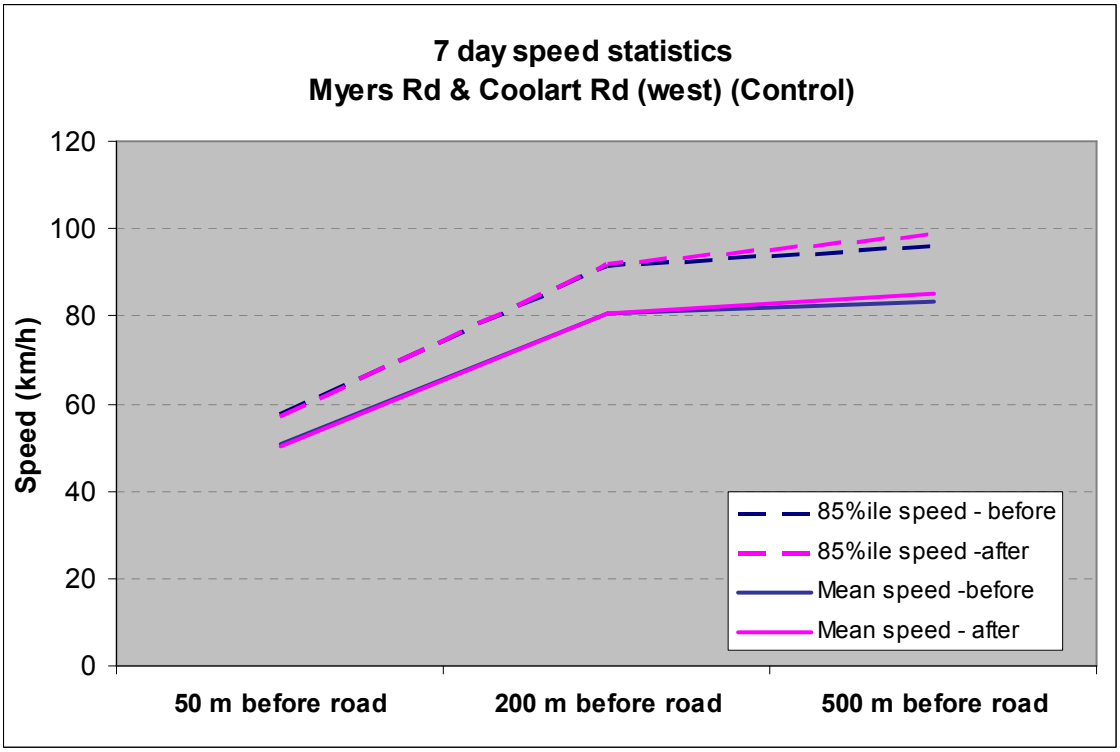


Figure 4.22: 7 day speed statistics for Myers Road & Coolart Road, Bittern (west) (Control)

Table 4.17 shows that statistically significant reductions occurred at all measurement points with the largest being at the 200 m and 500 m points. However the η^2 statistic is small indicating that according to this analysis, the rumble strips may have had little effect on the observed change in mean speed.

Table 4.17: Results of the ANOVA for Myers Rd & Coolart Rd east and west approaches

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	50.6	50.5	-0.1	
	Treatment	50.6	48.8	-1.8	$p < .001$, $\eta^2 = .011$
200 m	Control	80.6	80.7	0.1	
	Treatment	77.2	73.8	-3.4	$p < .001$, $\eta^2 = .046$
500 m	Control	83.1	85.3	2.2	
	Treatment	90.6	87.2	-3.4	$p < .001$, $\eta^2 = .053$

The speed traces from the treatment site shown in Figure 4.23 show little change in average speeds and profile shapes however it appears that several high speed outliers present in the before period did not occur in the after period. From the selection of speed traces shown in Figure 4.24 it would appear the control site had slower vehicle speeds in the after survey. However the averaged speed trace in the appendix (Figure B 14) does not show this trend when all vehicles in the detailed survey are included therefore it appears to be a result of the sample. It should be noted that despite this being a give way controlled intersection, most vehicles appear to have stopped at the intersection.

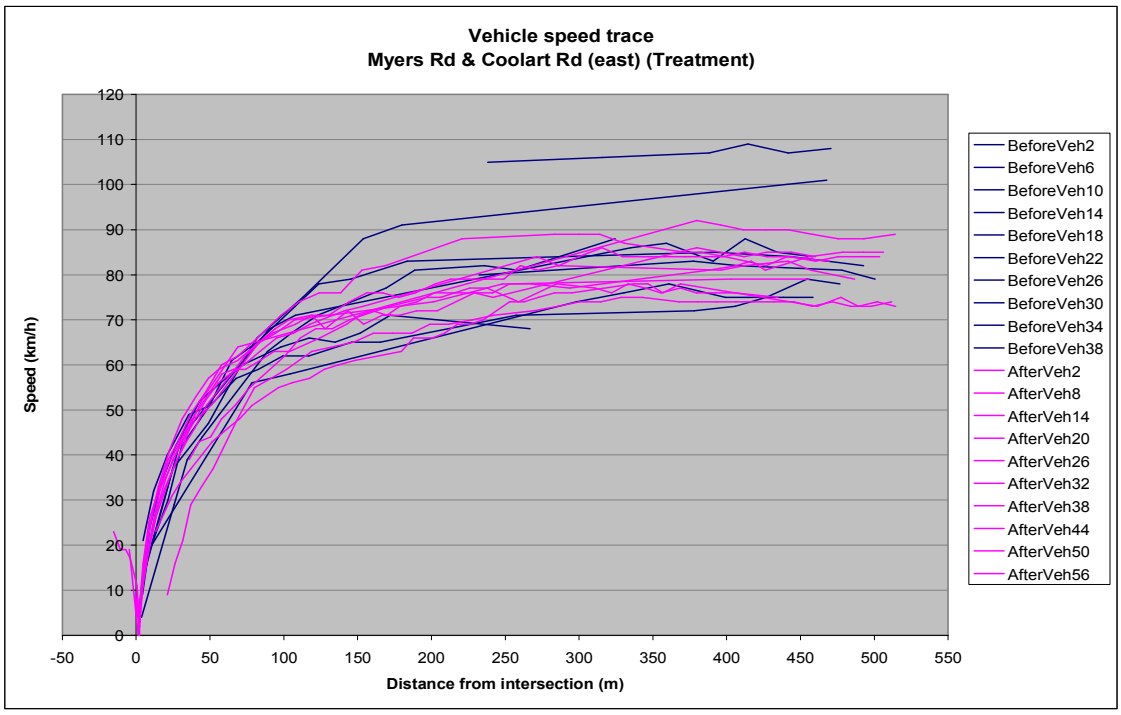


Figure 4.23: Selected vehicle traces for Myers Road & Coolart Road, Bittern (east) (Treatment)

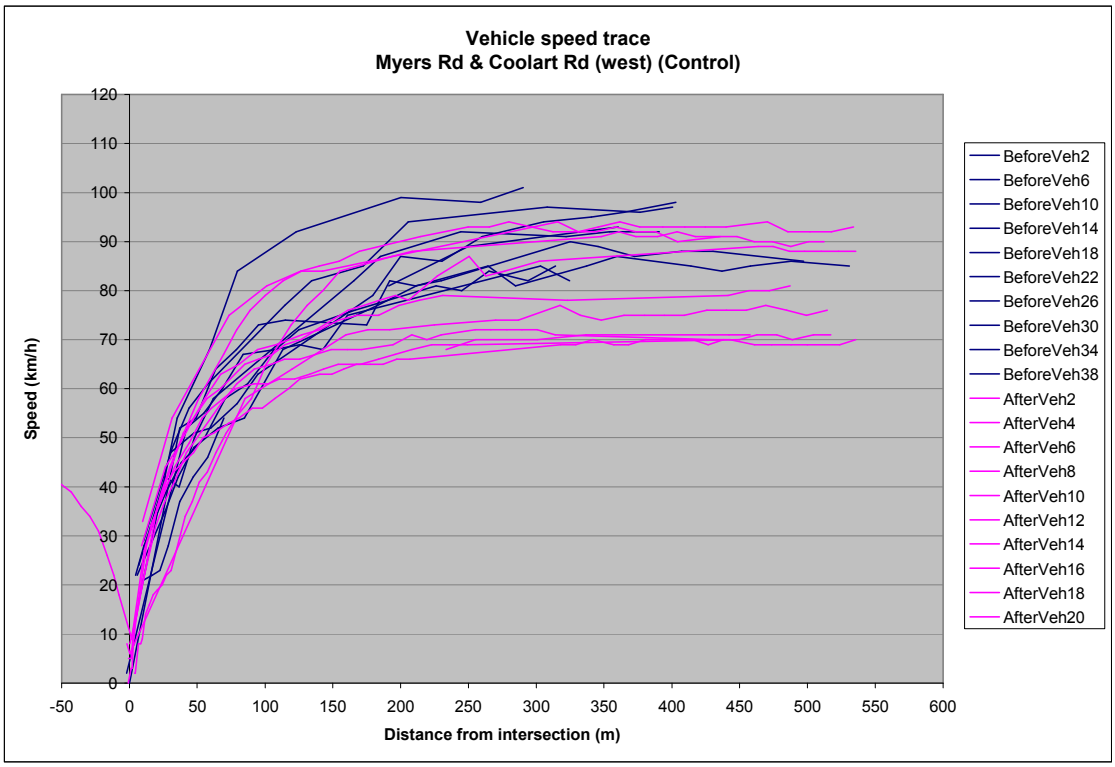


Figure 4.24: Selected vehicle traces for Myers Road & Coolart Road, Bittern (west) (Control)

The detailed video survey noted a large number of vehicles braking earlier in the after survey at the treatment site (Table 4.18), while the control site generally showed similar braking locations in the before and after study (Table 4.19). It should also be noted that several vehicles exhibited rumble strip avoidance behaviour at the treatment site.

Table 4.18: Application of brakes and rumble strip avoidance at Myers Road & Coolart Road, Bittern (east)

	Observation of brake lights (m)				
Period	**Before 485**	**200-485**	**After 200**	**Total vehicles observed**	**RS or detector avoidance***
Before	0	0	1	53	0
After	3	5	14	67	3

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.19: Application of brakes and rumble strip avoidance at Myers Road & Coolart Road, Bittern (west)

	Observation of brake lights (m)				
Period	**Before 500**	**250-500**	**After 250**	**Total vehicles observed**	**RS or detector avoidance***
Before	0	4	17	53	0
After	1	3	5	32	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Mean speed reductions at this site were shown to be small after rumble strips were installed, however the video survey indicates that some drivers applied brakes further from the intersection after installation.

4.2.2 Summary

- There were small reductions in mean speeds observed in 7 day speed surveys at the treatment site.
- More vehicles were observed to apply brakes earlier at the treatment site in the after survey.

4.2.3 Stop Controlled Intersections

Anglesea Rd & Mount Duneed Rd (east) – Treatment
Anglesea Rd & Mount Duneed Rd (west) – Control

The after survey at the Mt Duneed Rd treatment site showed consistent reductions in mean speeds with the greatest reduction occurring 200 m before the intersection (Figure 4.25). At the control site there was a large reduction in mean speed at the 500 m measurement point (Figure 4.26) but little change at the other points.

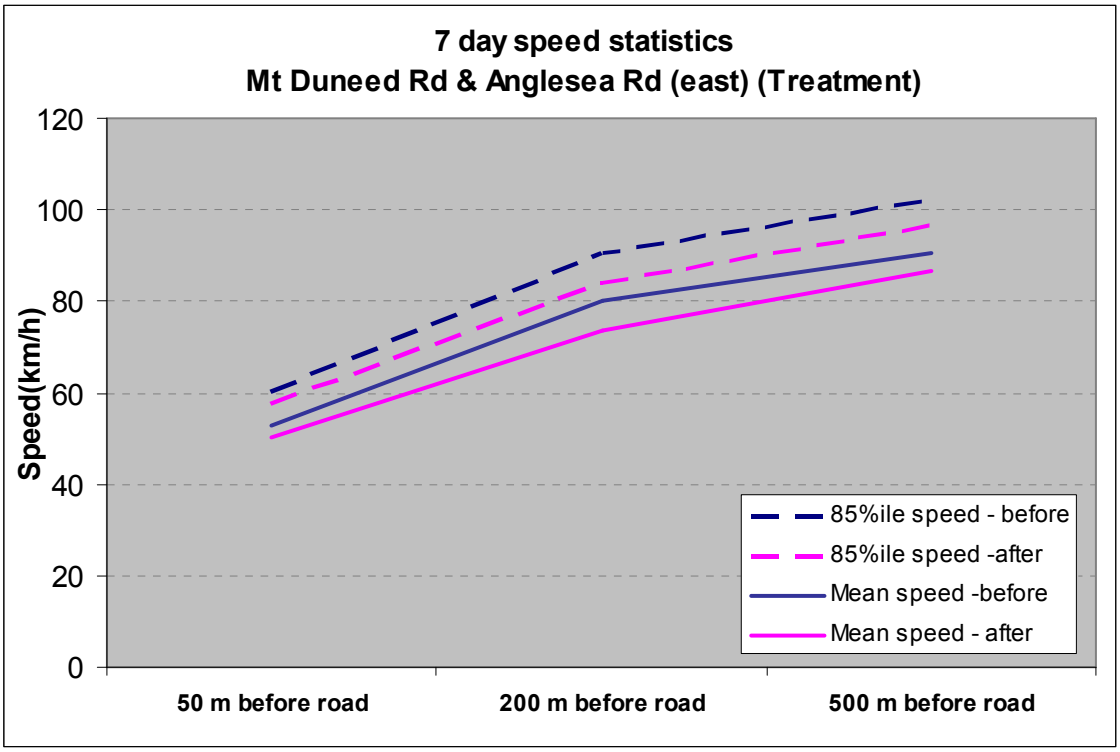


Figure 4.25: Day speed statistics for Anglesea Rd & Mount Duneed Rd (east) (Treatment)

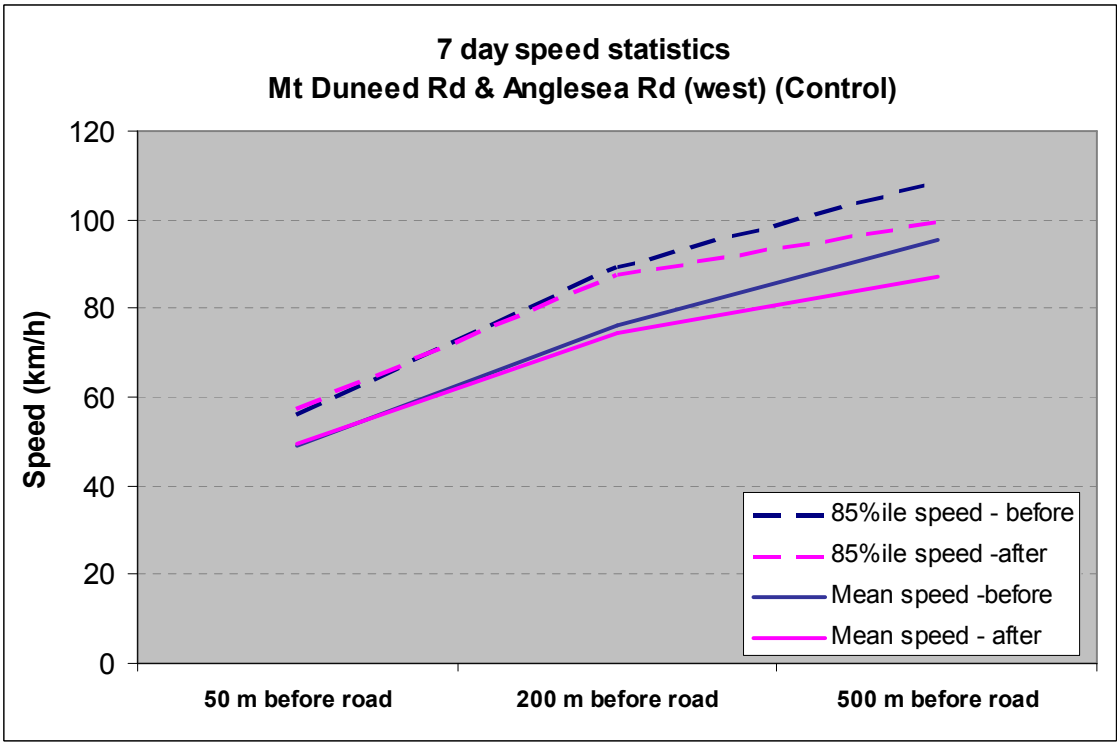


Figure 4.26: Day speed statistics for Anglesea Rd & Mount Duneed Rd (west) (Control)

The largest reduction was at the 500 m measurement point for the control site which appears to be somewhat of an anomaly since the other measurement points are relatively unchanged at the control site. The treatment site had consistent reductions at all measurement points, the largest was at the 200 m point. The ANOVA shows that all reductions in speed were statistically significant however the effect of the rumble strips was minimal (Table 4.20).

Table 4.20: Results of the ANOVA for Anglesea Rd & Mount Duneed Rd east and west approaches

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	48.9	49.6	0.7	
	Treatment	52.9	50.4	-2.5	$p < .001$, $\eta^2 = .047$
200 m	Control	76.2	74.3	-1.9	
	Treatment	80.1	73.5	-6.6	$p < .001$, $\eta^2 = .046$
500 m	Control	95.3	87.3	-8.0	
	Treatment	90.7	86.5	-4.2	$p < .001$, $\eta^2 = .053$

The speed traces in Figure 4.27 and Figure 4.28 show an overall reduction in speeds at the installation site with no obvious change shown at the control site. However there was more variation in entrance speeds at the control site.

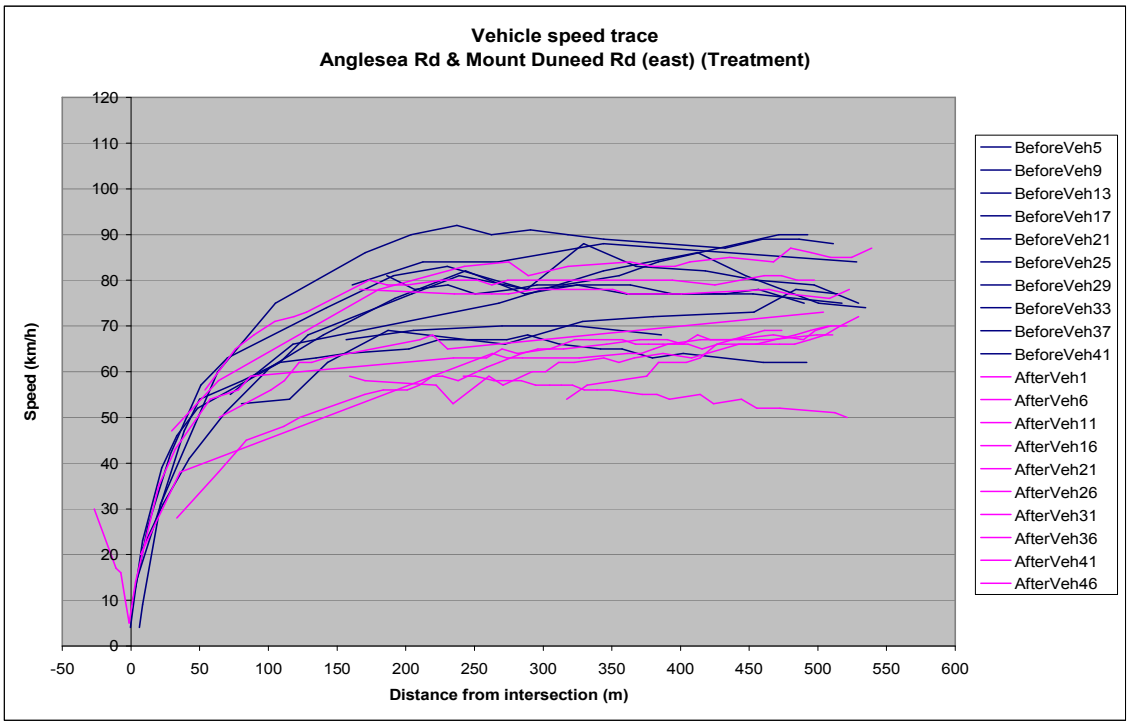


Figure 4.27: Selected vehicle traces for Anglesea Rd & Mount Duneed Rd (east) (Treatment)

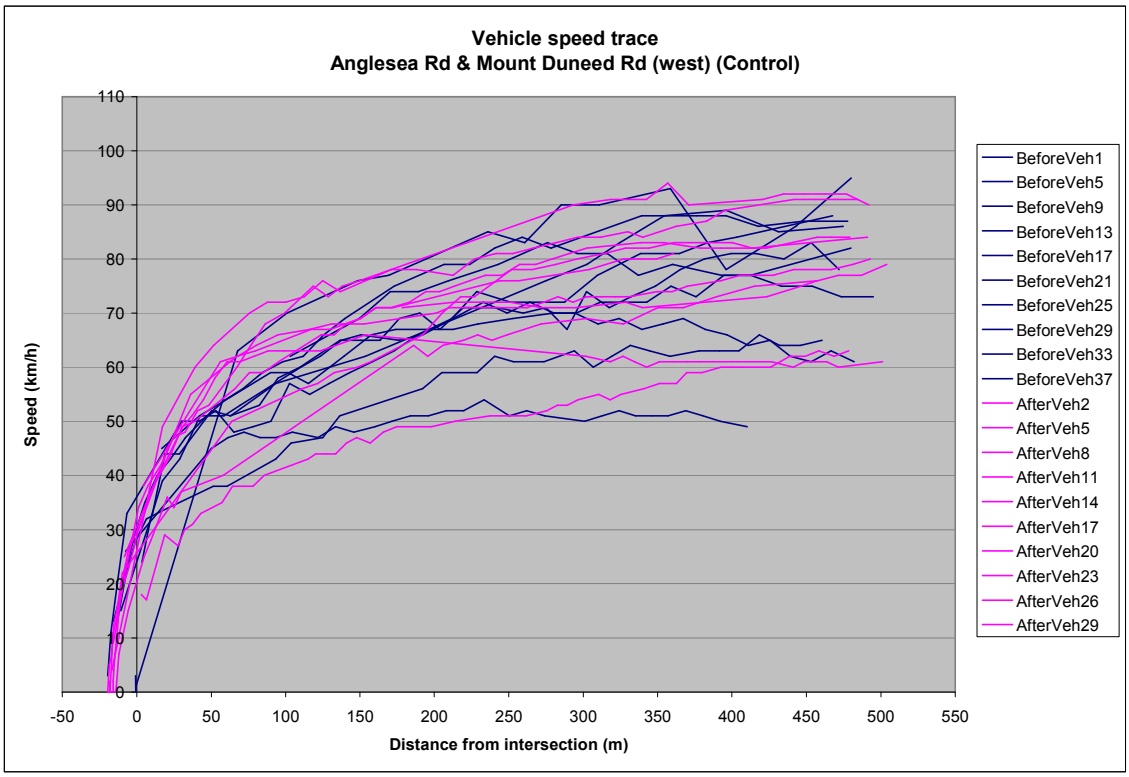


Figure 4.28: Selected vehicle traces for Anglesea Rd & Mount Duneed Rd (west) (Control)

The video survey observations are not as easy to interpret at the control site however there appears to be minimal change (Table 4.22). The slight shift in braking behaviour may in part be due to a slightly different location of the video trailer. At the treatment site there is a clearer trend of vehicles braking earlier (Table 4.21).

Table 4.21: Application of brakes and rumble strip avoidance at Anglesea Rd & Mount Duneed Rd (east)

	Observation of brake lights (m)				
Period	**Before 500**	**345-500**	**After 345**	**Total vehicles observed**	**RS or detector avoidance***
Before	2	0	0	55	0
After	6	3	34	61	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.22: Application of brakes and rumble strip avoidance at Anglesea Rd & Mount Duneed Rd (west)

	Observation of brake lights (m)				
Period	**Before 480**	**480-330**	**After 330**	**Total vehicles observed**	**RS or detector avoidance***
Before	1	5	22	43	0
After	3	1	16	39	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

4.2.4 Summary

- Speed reductions were observed in the 7 day speed survey at all measurement points at the treatment site.
- The vehicle traces also showed similar reductions.

Myers Rd & Balnarring Rd, Balnarring (east) – Treatment
Myers Rd & Balnarring Rd, Balnarring (west) – Control

The 7 day speed counts for Myers Rd and Balnarring Rd showed a slight increase at every measurement point for both sites (Figure 4.29 and Figure 4.30) except the 200 m measurement point at the treatment site which had a large (9.7 km/h) reduction in mean speed between the before and after studies. It also shows a large change of speed profile in the section of road containing rumble strips. In the before study the mean speed increased by 2 km/h between the 500 m and 200 m points while in the after study there was an 11 km/h decrease in this zone.

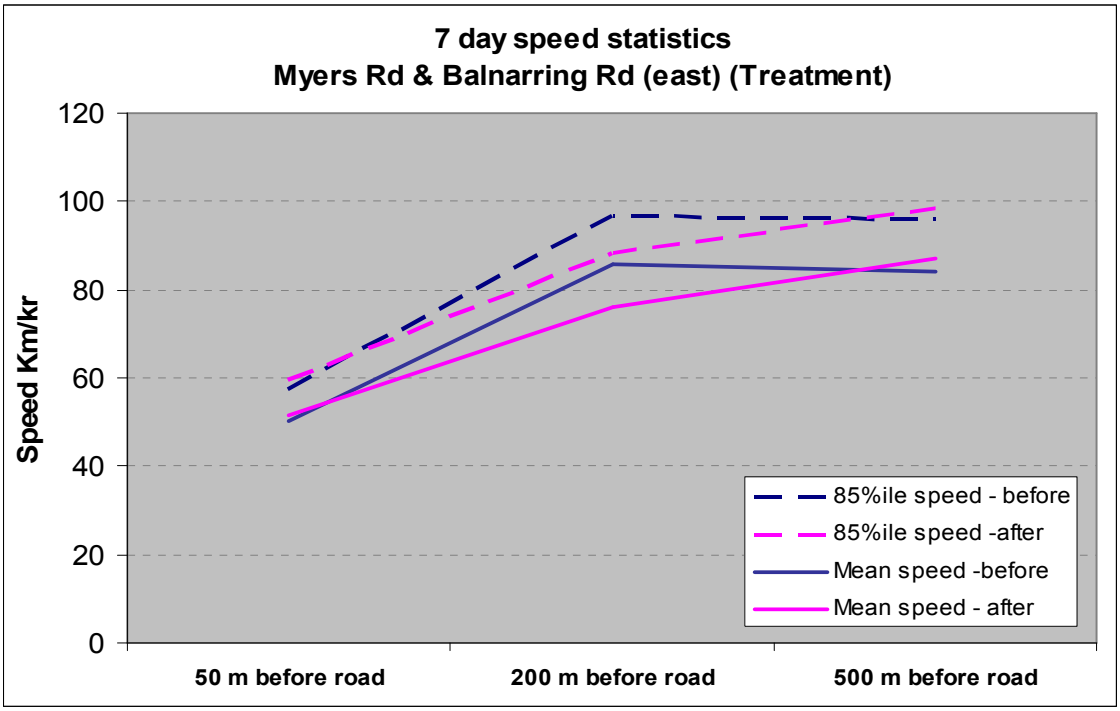


Figure 4.29: 7 day speed statistics for Myers Rd & Balnarring Rd, Balnarring (east)

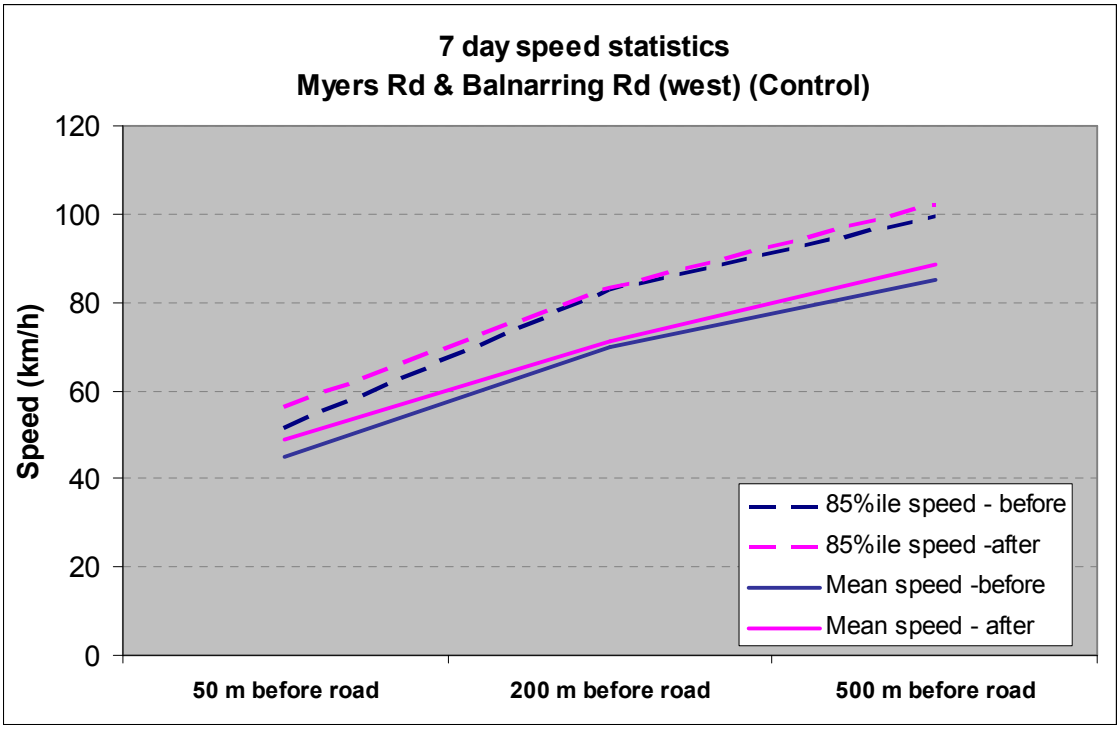


Figure 4.30: 7 day speed statistics for Myers Rd & Balnarring Rd, Balnarring (west)

As stated above, the only large change in mean speed was at the 200 m measurement point for the treatment site. The ANOVA (Table 4.23) shows that this change in speed was significant with a small percentage (24%) of that change being attributed to the rumble strips.

Table 4.23: Results of the ANOVA for Myers Rd & Balnarring Rd east and west approaches

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	44.9	48.7	3.8	
	Treatment	50.4	51.5	1.1	$p < .001$, $\eta^2 = .096$
200 m	Control	70.0	71.1	1.1	
	Treatment	85.8	76.1	-9.7	$p < .001$, $\eta^2 = .240$
500 m	Control	85.3	88.6	3.3	
	Treatment	83.9	87.2	3.3	$p < .001$, $\eta^2 = .015$

The speed trace shown in Figure 4.31 revels a concentration of vehicles traversing the rumble strip zone travelling between 60 km/h and 70 km/h that was not present in the before study. This also has an effect on the speed profile in the section between 150 m and 50 m from the intersection because drivers are not required to decelerate as quickly. The control site (Figure 4.32) shows very similar speed profiles in the before and after surveys with a larger variation of speeds however there is a slight reduction in speeds between 50 m and 125 m from the intersection.

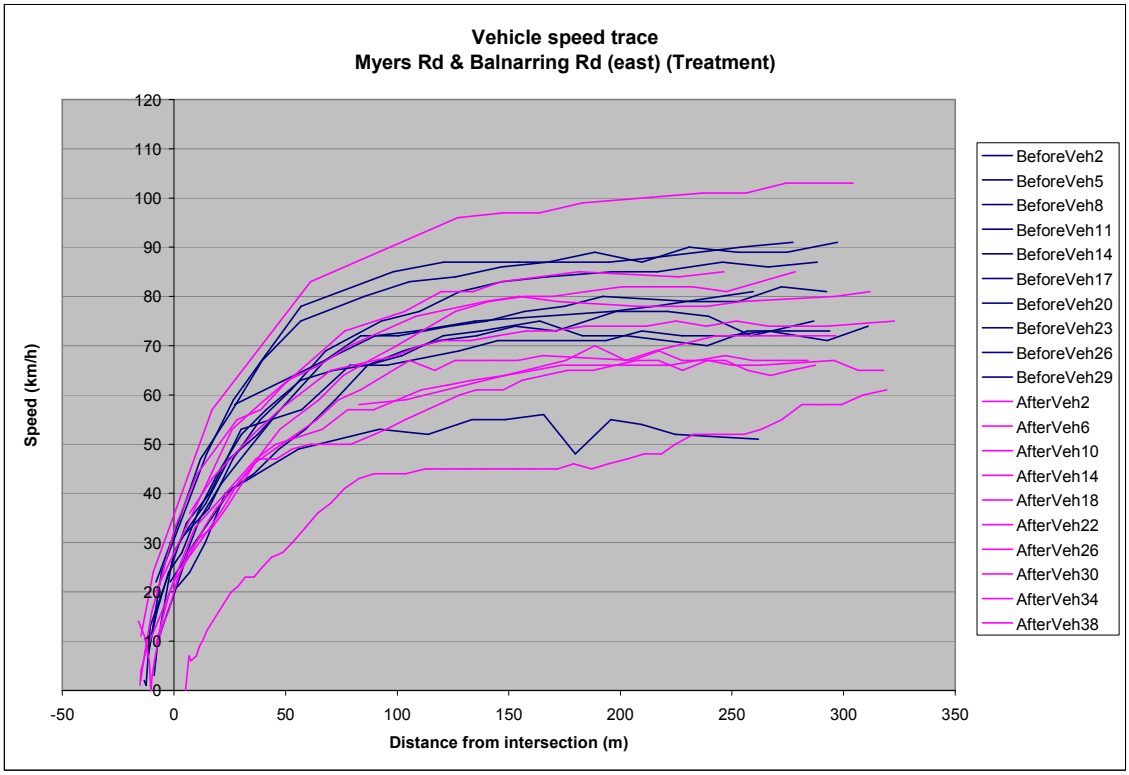


Figure 4.31: Selected vehicle traces for Myers Rd & Balnarring Rd, Balnarring (east) (Treatment)

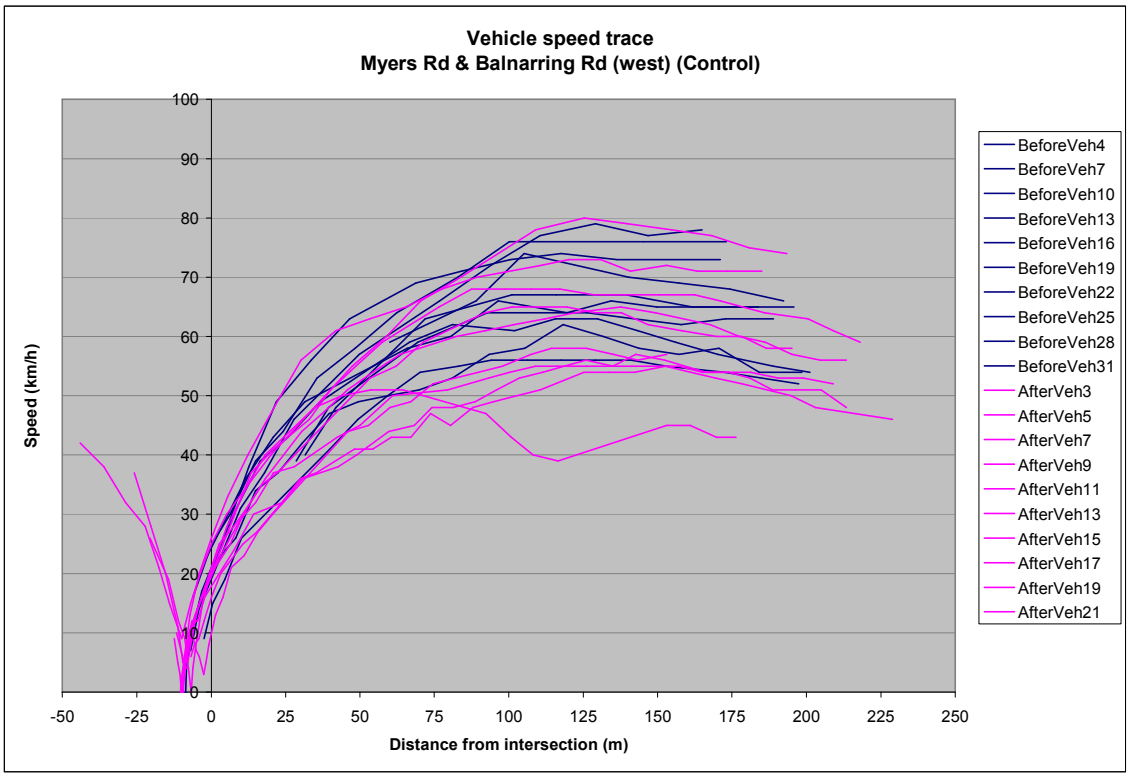


Figure 4.32: Selected vehicle traces for Myers Rd & Balnarring Rd, Balnarring (west)

Table 4.24 shows a slight shift in the zones that brakes were applied at the treatment site, in the after study it would appear that they were applied earlier. There is a large shift in the number of recorded brake light observations for the control site shown in Table 4.25. This is likely to be due to different camera locations in the before and after surveys.

Table 4.24: Application of brakes and rumble strip avoidance at Myers Rd & Balnarring Rd, Balnarring (east)

	Observation of brake lights (m)				
Period	**Before 350**	**170-350**	**After 170**	**Total vehicles observed**	**RS or detector avoidance***
Before	2	3	11	43	0
After	5	7	3	51	1

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.25: Application of brakes and rumble strip avoidance at Myers Rd & Balnarring Rd, Balnarring (west)

	Observation of brake lights (m)			
Period	**Before 160**	**After 160**	**Total vehicles observed**	**RS or detector avoidance***
Before	16	22	40	0
After	5	3	28	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

4.2.5 Summary

- There was a 9.7 km/h speed reduction at the 200 m measurement point between the before and after survey.
- A large change of speed profile was observed in the 7 day speed surveys for the section of road containing rumble strips

Bittern-Dromana Road & Balnarring Rd, Balnarring (west) – Treatment
Bittern-Dromana Road & Balnarring Rd, Balnarring (east) – Control

Both the treatment and control sites at Bittern-Dromana Rd & Balnarring Rd showed very little difference in mean speeds (Figure 4.33 and Figure 4.34). These changes were shown to be statistically significant in the ANOVA due to the very large sample size. However the partial η^2 shows that the rumble strips did not influence this change (Table 4.26).

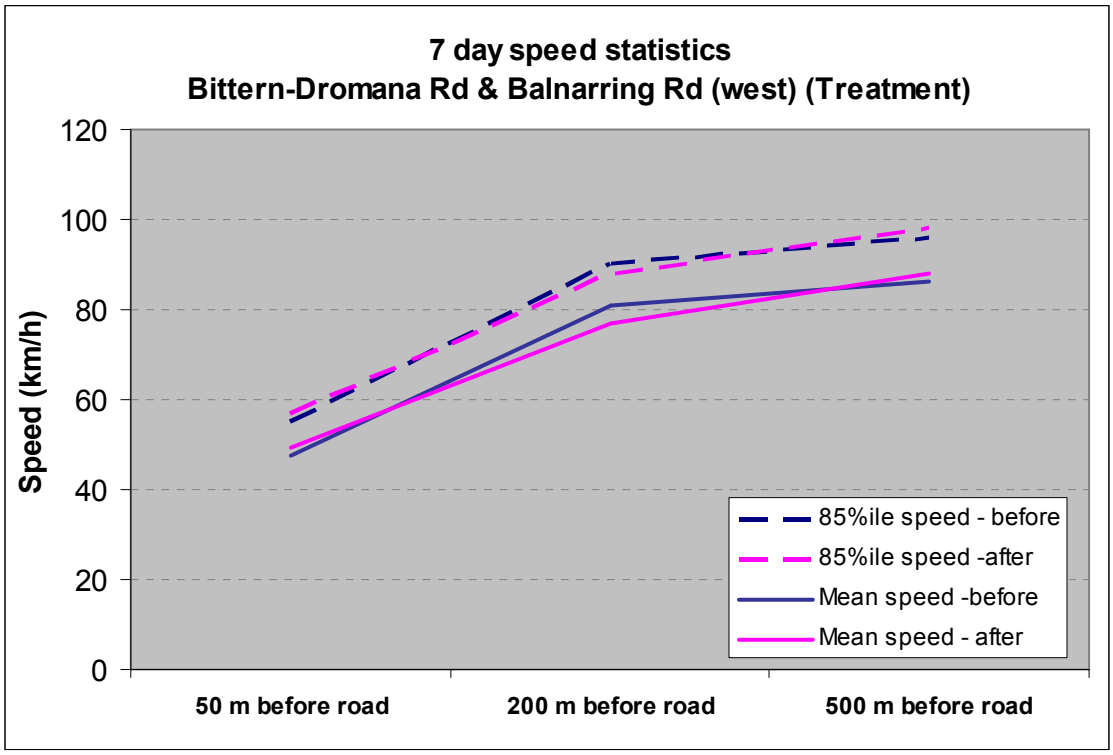


Figure 4.33: 7 day speed statistics for Bittern-Dromana Road & Balnarring Rd, Balnarring (west) (Treatment)

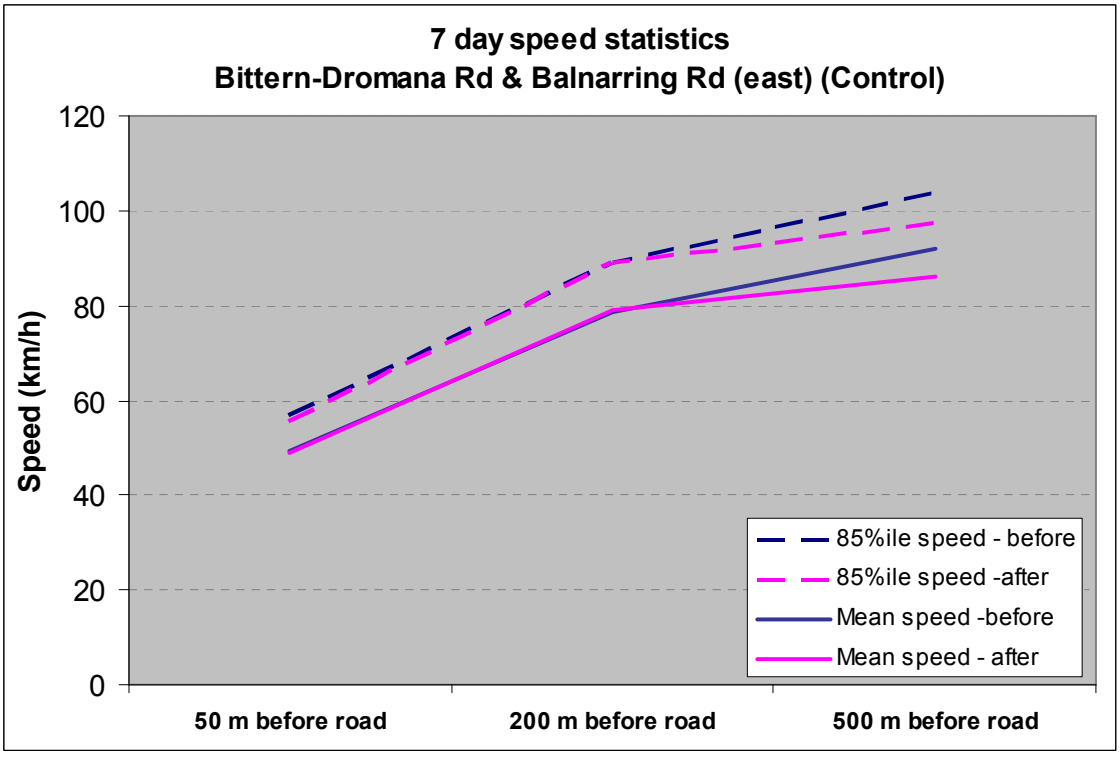


Figure 4.34: 7 day speed statistics for Bittern-Dromana Road & Balnarring Rd, Balnarring (east) (Control)

Table 4.26: Results of the ANOVA for Bittern-Dromana Road & Balnarring Rd west and east approaches

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	49.5	48.8	-0.7	
	Treatment	47.6	49.2	1.6	$p < .001$, $\eta^2 = .012$
200 m	Control	78.5	79.1	0.6	
	Treatment	80.7	76.9	-3.8	$p < .001$, $\eta^2 = .016$
500 m	Control	91.8	86.0	-5.8	
	Treatment	86.4	87.8	1.4	$p < .001$, $\eta^2 = .045$

The speed trace for the treatment site shows two distinct groups of drivers (Figure 4.35). There was a higher speed group with a similar speed trace to those in the before study and a lower speed group that further reduced speed in the rumble strip zone and maintained a slower speed until approximately 100 m from the intersection when all speed profiles were similar. Figure 4.36 shows similar speed profiles for the before and after surveys at the control site. Note that there appears to be some discrepancy in reference points for the before and after surveys. The error could not be clearly found so they have been reported with this discrepancy rather than introducing an approximate correction factor.

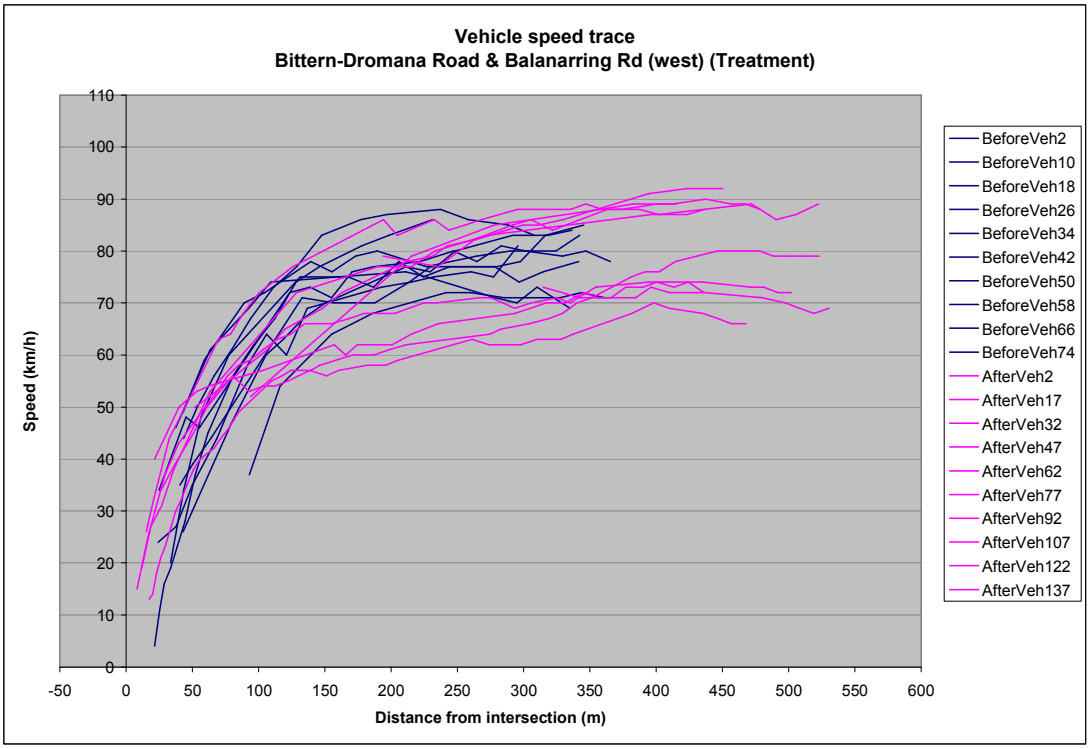


Figure 4.35: Selected vehicle traces for Bittern-Dromana Road & Balnarring Rd, Balnarring (west) (Treatment)

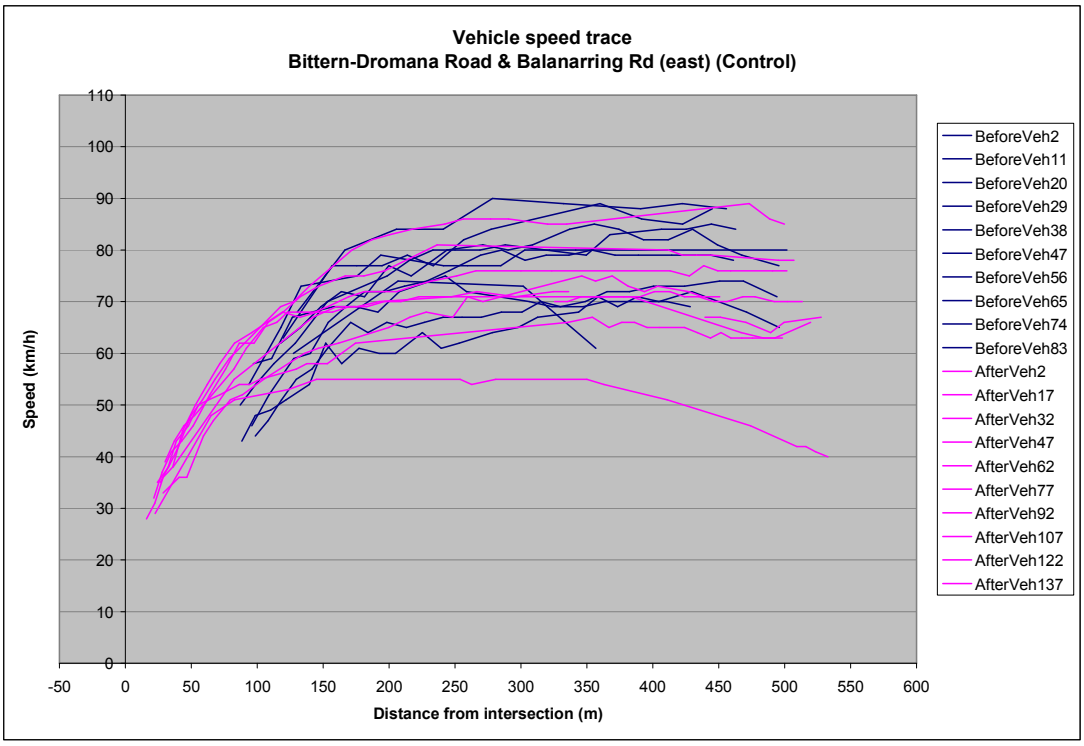


Figure 4.36: Selected vehicle traces for Bittern-Dromana Road & Balnarring Rd, Balnarring (east) (Control)

Table 4.27 shows an increase in driver braking before the rumble strip zone, which are the most accurate observations due to their proximity to the camera. Table 4.28 shows some large variations in brake light observations with a shift towards vehicles braking closer to the intersection in the after study.

Table 4.27: Application of brakes and rumble strip avoidance at Bittern-Dromana Road & Balnarring Rd, Balnarring (west)

	Observation of brake lights (m)				
Period	**Before 380**	**190-380**	**After 190**	**Total vehicles observed**	**RS or detector avoidance***
Before	1	8	49	269	0
After	5	2	10	199	1

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.28: Application of brakes and rumble strip avoidance at Bittern-Dromana Road & Balnarring Rd, Balnarring (east)

	Observation of brake lights (m)				
Period	**Before 500**	**200-500**	**After 200**	**Total vehicles observed**	**RS or detector avoidance***
Before	15	7	64	153	0
After	3	21	84	154	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

4.2.6 Summary

- There was very little change in mean speed at the treatment site.
- The speed traces indicate two different driver reactions, those approaching at higher speeds continued as normal, those at lower speeds slowed in or before the rumble strip zone.

Churchill-Traralgon Rd & Church Rd, Morwell (east) – Treatment
Churchill-Traralgon Rd & Church Rd, Morwell (west) – Control

The Churchill-Traralgon Rd and Church Rd treatment site showed some reductions in speed at the 500 m and 200 m measurement points while other points at the treatment and control sites remain very similar (Figure 4.37 and Figure 4.38).

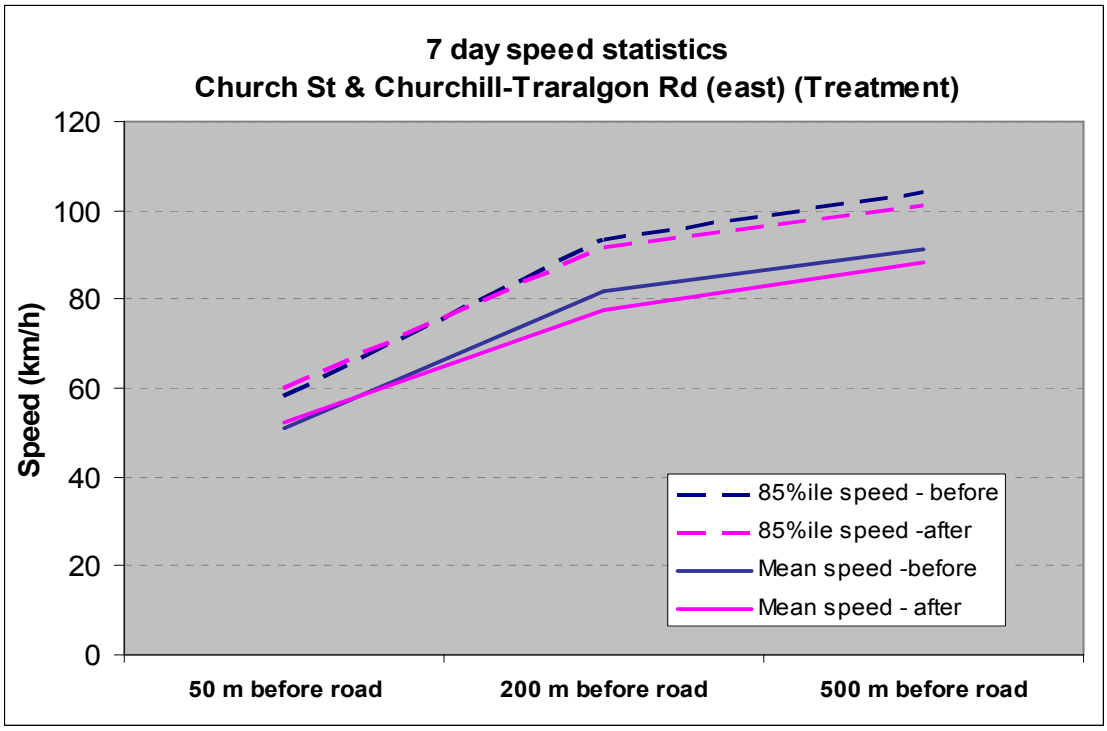


Figure 4.37: 7 day speed statistics for Churchill-Traralgon Rd & Church Rd, Morwell (east) (Treatment)

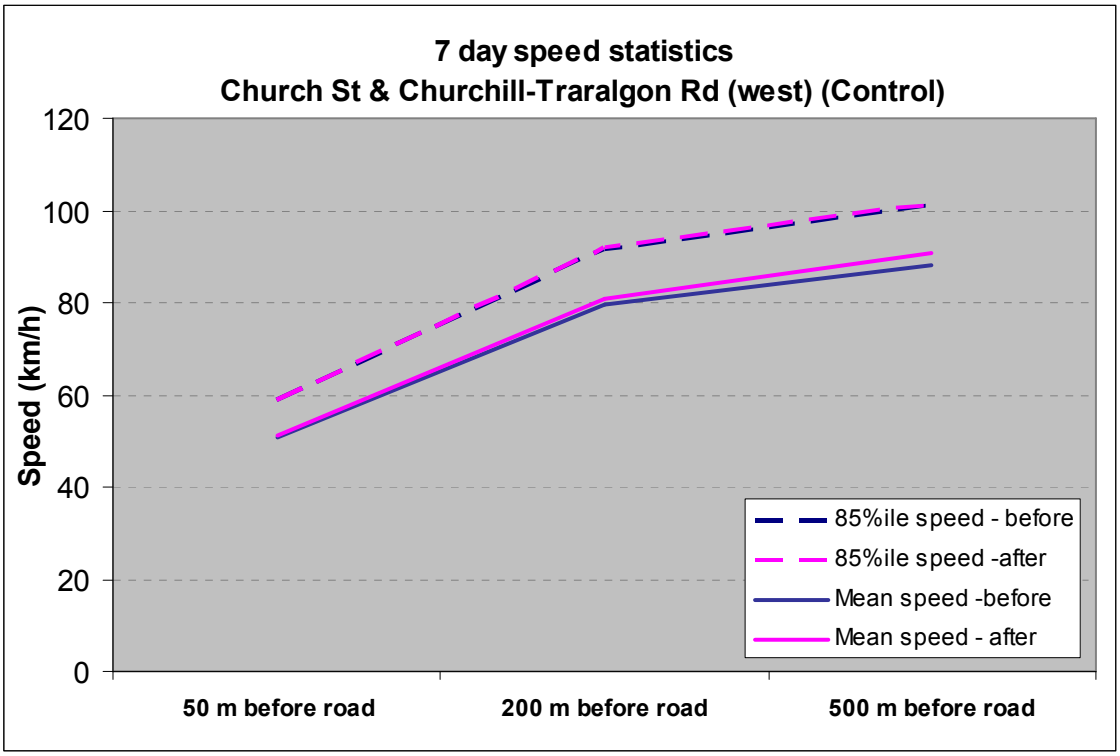


Figure 4.38: 7 day speed statistics for Churchill-Traralgon Rd & Church Rd, Morwell (west) (Control)

The ANOVA (Figure 4.29) indicated the differences in mean speed were all statistically significant but estimated that only a small proportion of the change was due to the rumble strips.

Table 4.29: Results of the ANOVA for Churchill-Traralgon Rd & Church Rd east and west approaches

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	51.0	51.0	0.0	
	Treatment	51.1	52.1	1.0	$p < .001$, $\eta^2 = .002$
200 m	Control	79.7	81.0	1.3	
	Treatment	81.9	77.8	-4.1	$p < .001$, $\eta^2 = .011$
500 m	Control	88.4	90.6	2.2	
	Treatment	91.3	88.3	-3.0	$p < .001$, $\eta^2 = .009$

The speed traces for the treatment site (Figure 4.39) show a very large variation in entrance speeds in the before and after surveys. These variations continue across the entire approach until approximately 100 m from the intersection. The drivers that have entered at slower speeds seemed to slow down further in the rumble strip zone while the drivers that entered fast did not appear to react. Overall vehicles in the after study were slower on approach to the intersection until around the 100 m point.

The control site showed less variation in approach speeds and the before and after traces were very similar (Figure 4.40).

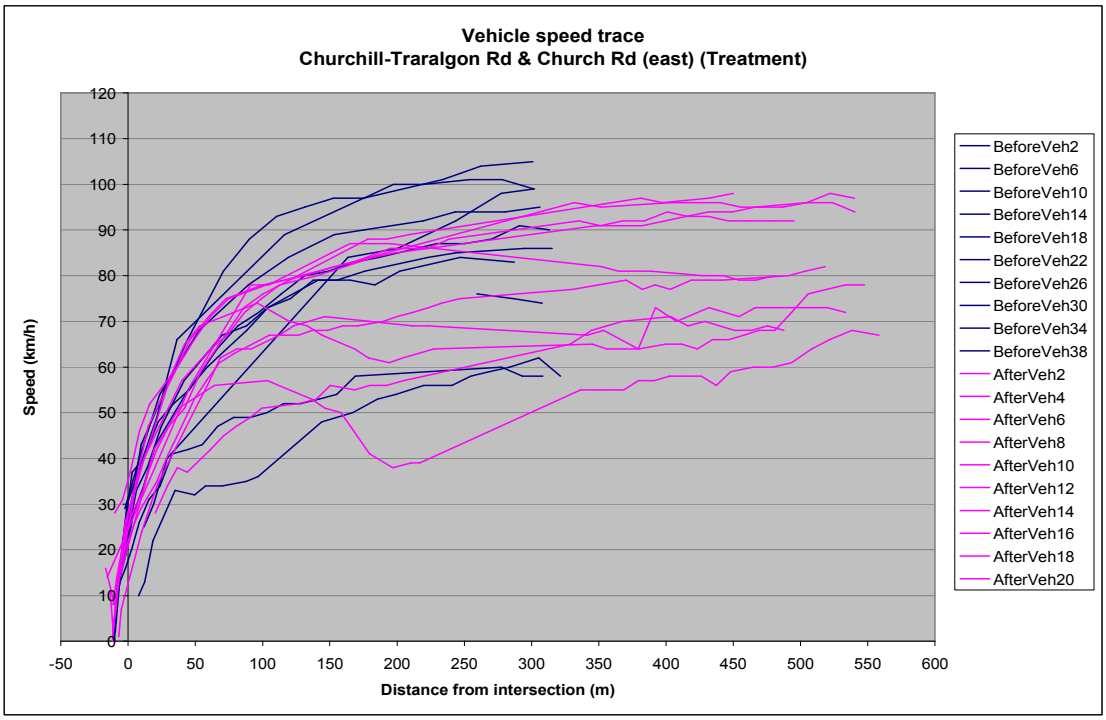


Figure 4.39: Selected vehicle traces for Churchill-Traralgon Rd & Church Rd, Morwell (east) (Treatment)

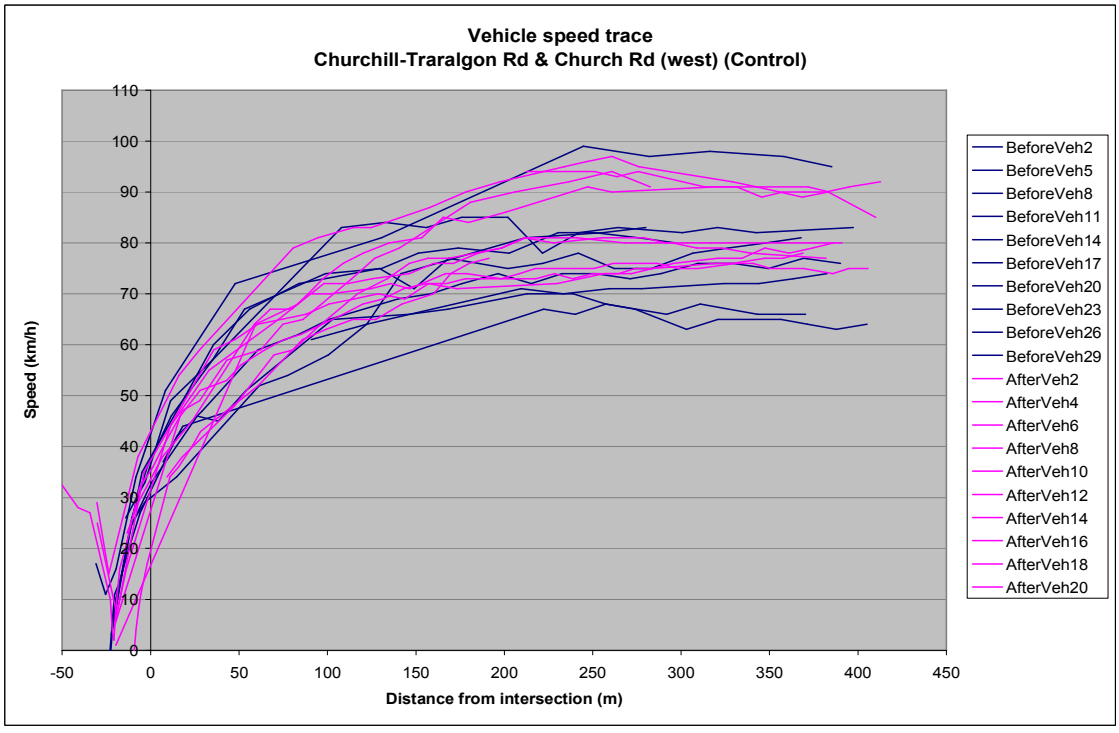


Figure 4.40: Selected vehicle traces for Churchill-Traralgon Rd & Church Rd, Morwell (west) (Control)

Table 4.30 indicates many people applied brakes before 250 m or in the rumble strip zone in the after study. This may be because the rumble strips are slightly hidden due to undulations in the

road (hence the break in the laser speed data in the after survey) and may mean they come as more of a surprise making people more likely to react to them

The change at the control site is largely due to different camera locations in the before and after survey, the after survey location did not allow braking close to the intersection to be observed (Table 4.31).

Table 4.30: Application of brakes and rumble strip avoidance at Churchill-Traralgon Rd & Church Rd, Morwell (east)

	Observation of brake lights (m)			
Period	**Before 250**	**After 250**	**Total vehicles observed**	**RS or detector avoidance***
Before	2	40	42	0
After	14	4	24	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.31: Application of brakes and rumble strip avoidance at Churchill-Traralgon Rd & Church Rd, Morwell (west)

	Observation of brake lights (m)				
Period	**Before 260**	**190-260**	**After 190**	**Total vehicles observed**	**RS or detector avoidance***
Before	0	1	26	36	0
After	0	0	0	21	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

4.2.7 Summary

- There was a small reduction in mean speeds at the treatment site.
- The video observations indicated some drivers braking earlier after the rumble strips were installed.

Cape Otway Rd & Gherang Rd, Winchelsea – Treatment
Hodgins Rd & Coolart Rd, Hastings – Control

Both the Cape Otway Rd & Gherang Rd site and the Hodgins Rd & Coolart Rd site showed minimal changes in mean speed (Figure 4.41 and Figure 4.42). Reductions at both sites were seen at the 200 m measurement point and were of a similar order. The ANOVA for these sites indicated that the rumble strips had very little effect on the changes in mean speed (Table 4.32).

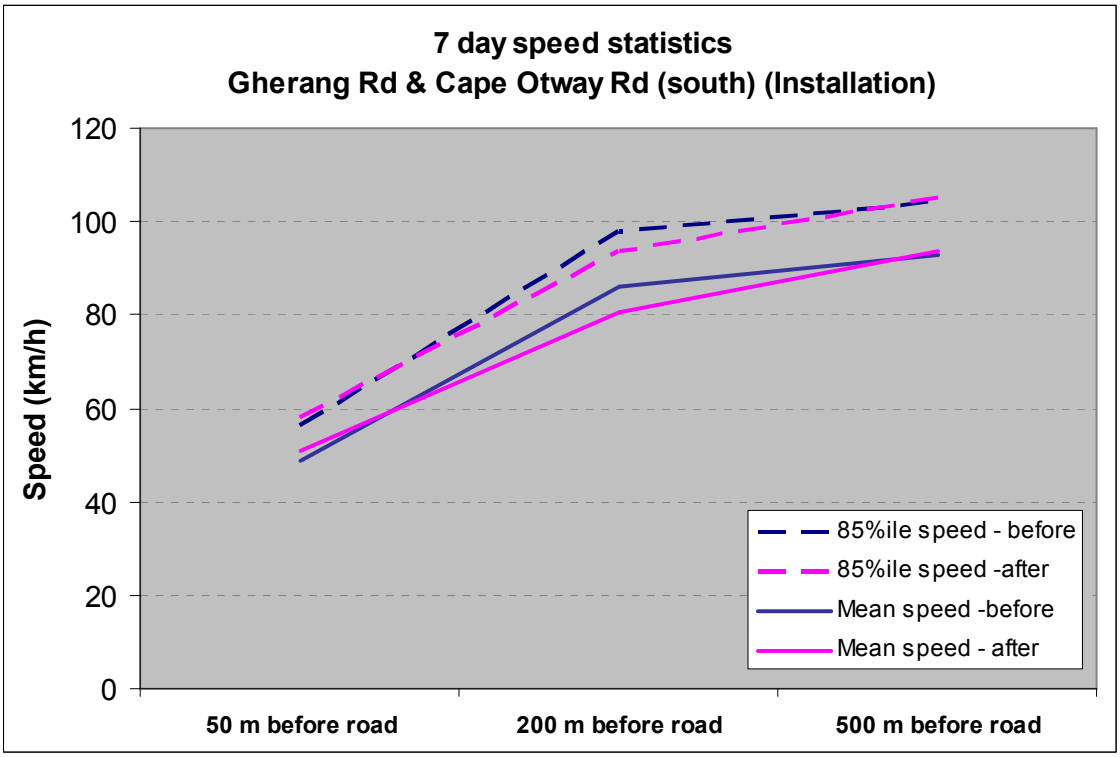


Figure 4.41: 7 day speed statistics for Cape Otway Rd & Gherang Rd, Winchelsea (Treatment)

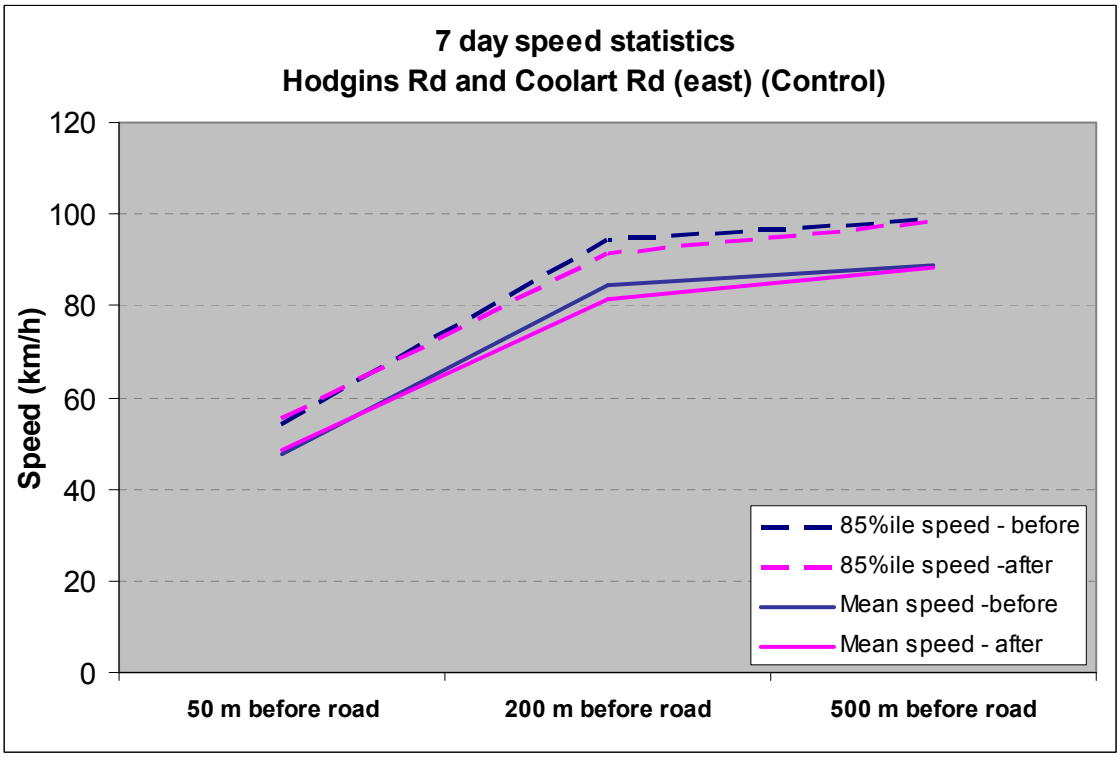


Figure 4.42: 7 day speed statistics for Hodgins Rd & Coolart Rd, Hastings (Control)

Table 4.32: Results of the ANOVA for Cape Otway Rd & Gherang Rd and Hodgins Rd & Coolart Rd approaches

Distance	Treatment	Before mean (km/h)	After mean (km/h)	Difference (km/h)	p and partial η^2
50 m	Control	47.5	48.6	1.1	
	Treatment	49.0	50.7	1.7	$p < .001$, $\eta^2 = .009$
200 m	Control	84.5	81.4	-3.1	
	Treatment	86.0	80.5	-5.5	$p < .001$, $\eta^2 = .021$
500 m	Control	88.9	88.4	-0.5	
	Treatment	92.8	93.9	1.1	$p < .001$, $\eta^2 = .014$

The speed traces for the treatment site (Figure 4.43) show little reduction in speed however they do have less variation in approach speed. It also shows one extreme reaction to the rumble strips with a vehicle slowing from 80 km/h to 50 km/h to traverse the rumble strips.

The control sites showed little change in the before and after studies (Figure 4.44).

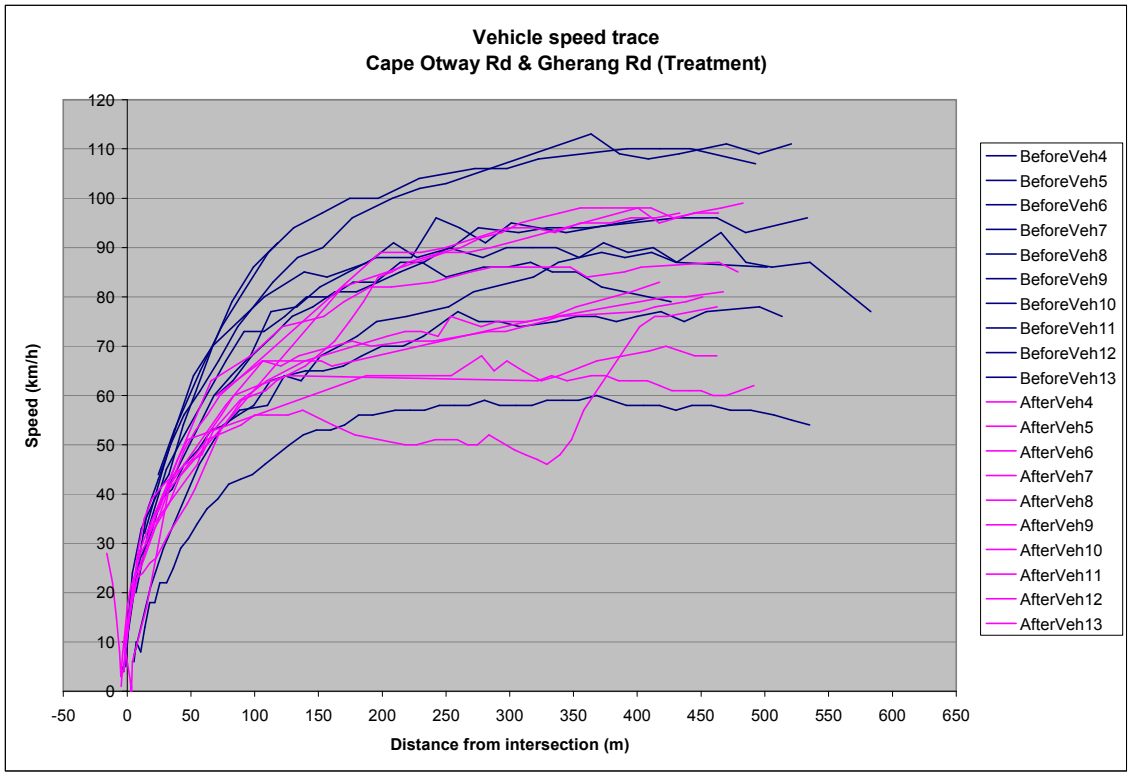


Figure 4.43: Selected vehicle traces for Cape Otway Rd & Gherang Rd, Winchelsea (Treatment)

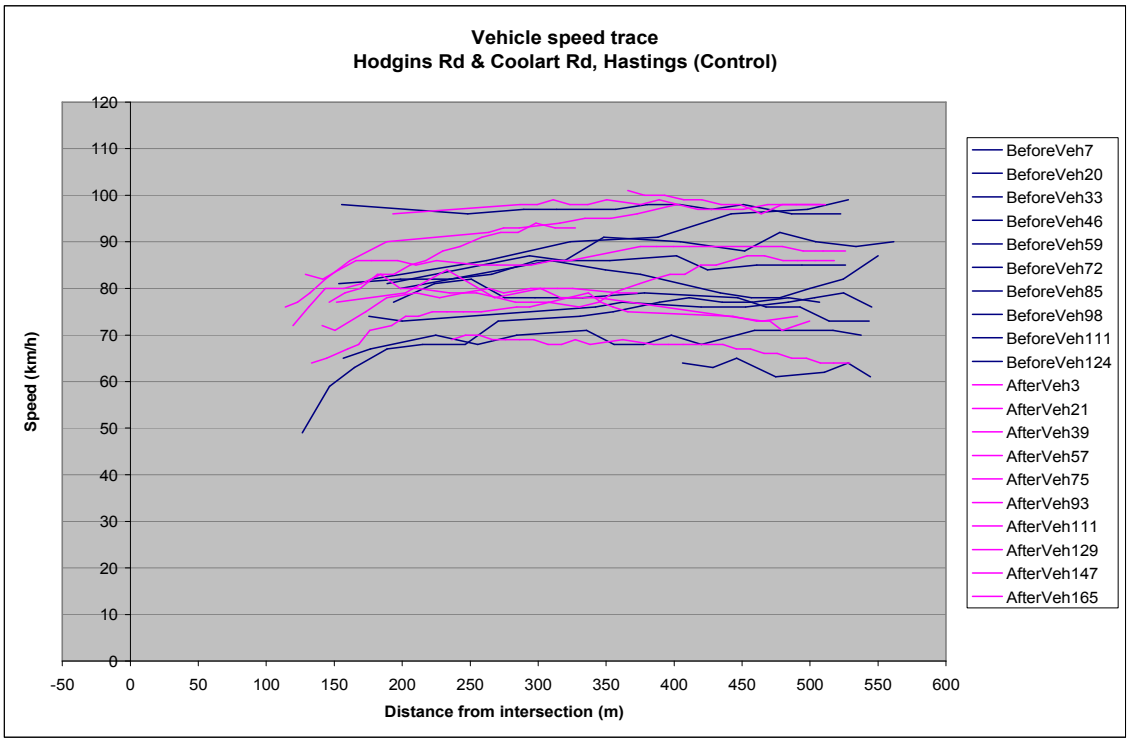


Figure 4.44: Selected vehicle traces for Hodgins Rd & Coolart Rd, Hastings (Control)

The video observations for Cape Otway Rd & Gherang Rd do not show any improvement in the after survey while the increase in early braking observations at Hodgins Rd and Coolart Rd is likely to be due to the fact that the after survey was conducted later in the day and had more peak hour traffic.

Table 4.33: Application of brakes and rumble strip avoidance at Cape Otway Rd & Gherang Rd, Winchelsea

	Observation of brake lights (m)				
Period	**Before 500**	**200-500**	**After 200**	**Total vehicles observed**	**RS or detector avoidance***
Before	0	1	16	18	0
After	0	1	3	15	1

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

Table 4.34: Application of brakes and rumble strip avoidance at Hodgins Rd & Coolart Rd, Hastings

	Observation of brake lights (m)				
Period	**Before 420**	**200-420**	**After 200**	**Total vehicles observed**	**RS or detector avoidance***
Before	2	1	158	233	0
After	4	11	132	248	0

* RS or detector avoidance = Number of vehicles that showed rumble strip or pneumatic tube detector avoidance behaviour.

4.2.8 Summary

- There was a mean speed reduction at treatment site at the 200 m measurement point however reduction at control was almost as large.
- The speed traces showed a slight reduction in speeds on the approach and includes a more extreme reaction to rumble strips.

4.3 Speed Reduction Summary

Table 4.35 and Table 4.36 show a summary of the change in mean speed observed in the 7 day speed surveys at the treatment sites after rumble strips had been installed.

Table 4.35: Summary of mean speed reductions at railway level crossing sites

		Range by measurement site (km/h)			Median by measurement site (km/h)		
Site control	**Site type**	**50 m**	**200 m**	**500 m**	**50 m**	**200 m**	**500 m**
Flashing lights	Treatment	-4.6 to -6	-1.7 to -5.7	-1 to -2.7	-5.3	-3.7	-1.9
	Control	N/A	N/A	N/A	1.7	-0.8	2.4
Give way	Treatment	-2.7 to -11.6	-1.1 to 12.5	-3.4 to -4.6	-7.2	-6.8	-4
	Control	N/A	N/A	N/A	N/A	N/A	N/A
Stop	Treatment	-0.4 to -4.6	-2.4 to -6.1	1.8 to -4.8	-2.5	-4.3	-1.5
	Control	3.5 to 0.7	1.1 to -1	2.9 to 2.6	2.1	0.1	2.8

Table 4.36: Summary of mean speed reductions at road intersection sites

		Range by measurement site (km/h)			Median by measurement site (km/h)		
Site control	**Site type**	**50 m**	**200 m**	**500 m**	**50 m**	**200 m**	**500 m**
Give way	Treatment	N/A	N/A	N/A	-1.8	-3.4	-3.4
	Control	N/A	N/A	N/A	-0.1	0.1	2.2
Stop	Treatment	1.7 to -2.5	-3.8 to -9.7	3.3 to -4.2	1	-5.5	1.1
	Control	3.8 to -0.7	1.3 to -3.1	3.3 to -8	0.7	0.6	-0.5

- At all types of railway level crossing control, greater reductions in speed were reliably seen at sites with rumble strips for all measurement distances.

- At the give way controlled intersections there was a greater reduction in speed at the site with rumble strips than at the site without, but note that this is based on one treatment/control pair.
- At the stop sign controlled intersections, speed reductions at sites with rumble strips were only evident at the 200 m measurement locations.

4.4 Rumble Strip Avoidance Summary

Table 4.37 and Table 4.38 show a summary of the rumble strip avoidance behaviour observed in the video surveys at the treatment sites after rumble strips had been installed.

Table 4.37: Summary of rumble strip avoidance behaviour for railway level crossing sites

Treatment Location	No. Vehicles	No. avoiding rumble strips
Murray Valley Highway (Kerang North) – North approach	i: 208 / a:127*	i: 2 / a: 5*
Patchewollock - Sea Lake Rd – east approach	5	0
Dumosa - Quambatook Rd – west approach	13	1
Brislanes Rd – South approach	7	0
Gnarpurt Rd – North approach	4	1

*i = interim survey period, a = after survey period

Table 4.38: Summary of rumble strip avoidance behaviour for road intersection sites

Treatment Location	No. Vehicles	No. avoiding rumble strips
Churchill-Traralgon Rd & Church Rd - east	24	0
Anglesea Rd & Mount Duneed Rd - east approach	61	0
Myers Road & Coolart road – east approach	67	3
Myers Road & Balnarring Road – east approach	51	1
Bittern-Dromana Road & Balnarring Road – west approach	199	1
Cape Otway & Gherang Rd – South approach	15	1

In the video surveys, rumble strip avoidance behaviour was only observed for cars and one motorcycle. Out of the 15 recorded cases only three involved the vehicle moving onto the shoulder, while all others involved putting at least one wheel onto the double lines or into the opposing traffic lane. Only one vehicle was observed avoiding rumble strips on a narrow seal (full road width) installation (Dumosa – Quambatook Rd). Due to the site selection criteria all sites had good visibility of oncoming traffic and no collisions or near misses were observed from vehicles crossing into the oncoming lane.

Avoidance behaviour does occur, but at low levels (1.7%). The video survey did not reveal an instance where a driver put the vehicle at risk of a head-on collision to avoid the rumble strips.

5 DISCUSSION

5.1 Limitations of the Study

Vehicle volumes at most passive railway level crossing sites were too small for the detailed surveys, despite efforts to select the highest volume sites that fitted the selection criteria. The selection criteria were designed to select sites that would be both possible to survey and sites that would be most likely to benefit from rumble strips. The difficulties encountered by the project team in finding these sites make it clear that there are very few passive railway level crossings in Victoria that have long straight approaches and large traffic volumes.

Various site conditions often made it impossible to position the research team's vehicle and video trailer in the ideal locations to conduct the survey. These included:

- narrow shoulder
- vertical curves
- environmental obstructions (overhanging trees and long grass)
- overhead powerlines
- property or minor road entrances.

These conditions meant that in some cases it was not possible to view traffic for the entire 500 m approach at all sites, resulting in missing laser and video data.

Because the surveys were conducted by different operators and some site conditions may have changed, a better position to survey from was found, or the weather conditions changed. Not all the before and after video or laser surveys were located in exactly the same place, and the camera height and field of view will not always be the same. This means that not every before and after survey will have the same coverage. This proved to be a greater issue when the video was located 550-600 m before the crossing or intersection since it was sometimes not possible to determine if the brake lights came on in last 150~200 m.

In the first group of railway level crossing detailed surveys there was a problem with the laser speed gun that did not allow measurements to be take at distances greater than approximately 200 m.

Measurement were taken approximately 1 month after the rumble strips has been installed. It is entirely possible that the substantial speed reductions detected will diminish over time as drivers become accustomed to the rumble strips. Further speed surveys should be conducted to ensure that the rumbles strips continue to deliver benefits in the longer term.

5.2 Effect of Survey Equipment on Results

The degree to which the video trailer and survey car parked beside the road at survey sites affected driver behaviour is hard to determine but because they were present in all surveys, any effects should at least be consistent. What can be seen in some of the speed traces and the averaged speed traces (Appendix B) is that the first few readings taken with the speed gun show vehicles accelerating and then returning to a 'normal' speed profile. This suggests that after the vehicles had passed the survey vehicle and trailer it had a minimal effect on their behaviour.

Tube detectors on the road can also often be mistaken as a measurement device for speed enforcement and produce erratic behaviour. It is hard to judge if this was an issue in this trial because they were present at all sites surveyed. However the video observations looked for drivers avoiding either the tube detector or rumble strips and the only sites at which avoidance behaviour was observed also had rumble strips.

6 CONCLUSION

6.1 Rumble Strips Alone

The original aim of rumble strips was to increase the alertness of drivers approaching a hazard. Drivers slowing down at all, even by a small amount, would indicate that they are aware of the change in the road environment.

At active railway crossings, median speeds were significantly reduced at all three measurement points on the approach to the crossing. The smallest reduction (1.9 km/h) was at the measurement point 500 m from the crossing; the next largest reduction (3.7 km/h) was at 200 m from the crossing; and the largest reduction (5.3 km/h) was 50 m from the crossing. At the control site median speeds increased by 1.7 km/h and 2.4 km/h at the 50 m and 500 m measurement points and reduced slightly (0.8 km/h) at the 200 m measurement point. It may therefore be concluded that the rumble strips have been effective in reducing vehicle speeds on the approaches to crossings with flashing lights.

At passive railway level crossings, significant reductions in speed were found at all measurement points on the approach, although the reductions were more uniform. At the 500 m measurement point the median reduction was 4.0 km/h, at 200 m the reduction was 4.3 km/h, and at 50 m 3.7 km/h. At the control site median speeds increased by 2.1 km/h and 2.8 km/h at the 50 m and 500 m measurement points with a negligible increase of 0.1 km/h at the 200 m measurement point. It may therefore be concluded that the rumble strips have been effective in reducing vehicle speeds on the approaches to passive controlled railway crossings.

At the road intersections, significant reductions were achieved only at the 200 m measurement point (directly after the rumble strips), where a 4.8 km/h reductions was achieved. The reduction at 500 m was only 0.95 km/h, while speed increased marginally (by 0.2 km/h) at the 50 m measurement point. The control sites remained relatively unchanged with speed increases between 0.4 km/h and 0.9 km/h at all measurement points. It may therefore be concluded that the rumble strips at the road intersection sites slow the drivers down quite considerably at the point on the approach where they should be scanning the intersection and identifying other vehicles approaching the intersection, but appear to have little other effect.

The other practical measure of alertness was braking behaviour established from the video surveys. While at most sites there were very few vehicles in the sample, some earlier braking occurred consistently at the treatment sites after the installation of rumble strips. The earlier braking suggests earlier awareness of the crossing or intersection.

Another issue to be drawn out of the video survey is the rumble strip avoidance behaviour when a vehicle attempted to go fully or partially around the rumble strip pads, in most cases moving into the oncoming traffic lane. While crossing double lines is a traffic infringement and is likely to need policing, it is clear that these motorists have seen the rumble strips and are reacting to them. Major problems may come where a driver is alert enough to react but not enough to ‘think through’ their reaction. However this behaviour was observed at low levels (1.7%) and did not reveal any instance where a driver put the vehicle at risk of a head-on collision to avoid the rumble strips.

6.2 Rumble Strips and Additional Safety Treatments

Murray Valley Highway, Fairley was the only site included in this study that was surveyed three times, the third with additional railway level crossing features installed in addition to the rumble strips. The results from the 7 day count and the averaged speed trace data showed that while

there was a reduction in speed after the rumble strips were installed, when the site was surveyed for the third time (with the addition safety treatments), speeds were back at a similar level to the before study. This leads to two possible conclusions, one that the rumble strips become less effective over time as people become accustomed to their presence or two, that the additional warning devices give drivers confidence to approach the intersection at higher speeds when they are not warning of an approaching train. Because no comparable sites with only rumble strips have been surveyed at a later date after installation it is not possible to determine which scenario is more likely.

6.3 Further Work

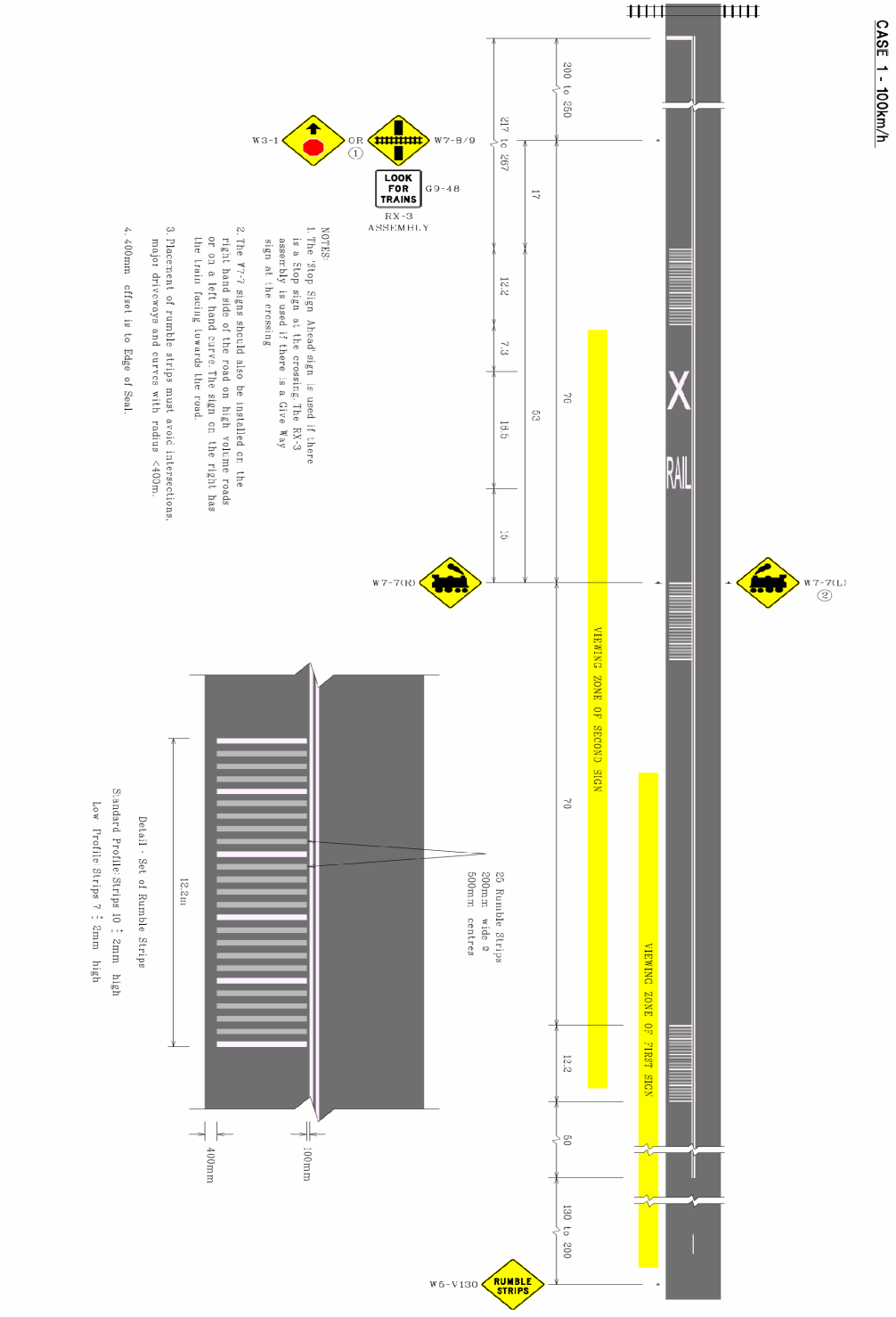
Because the after survey was conducted soon after installation of the rumble strips it is recommended that further surveys are conducted to determine if the rumbles strips continue to deliver benefits in the longer term.

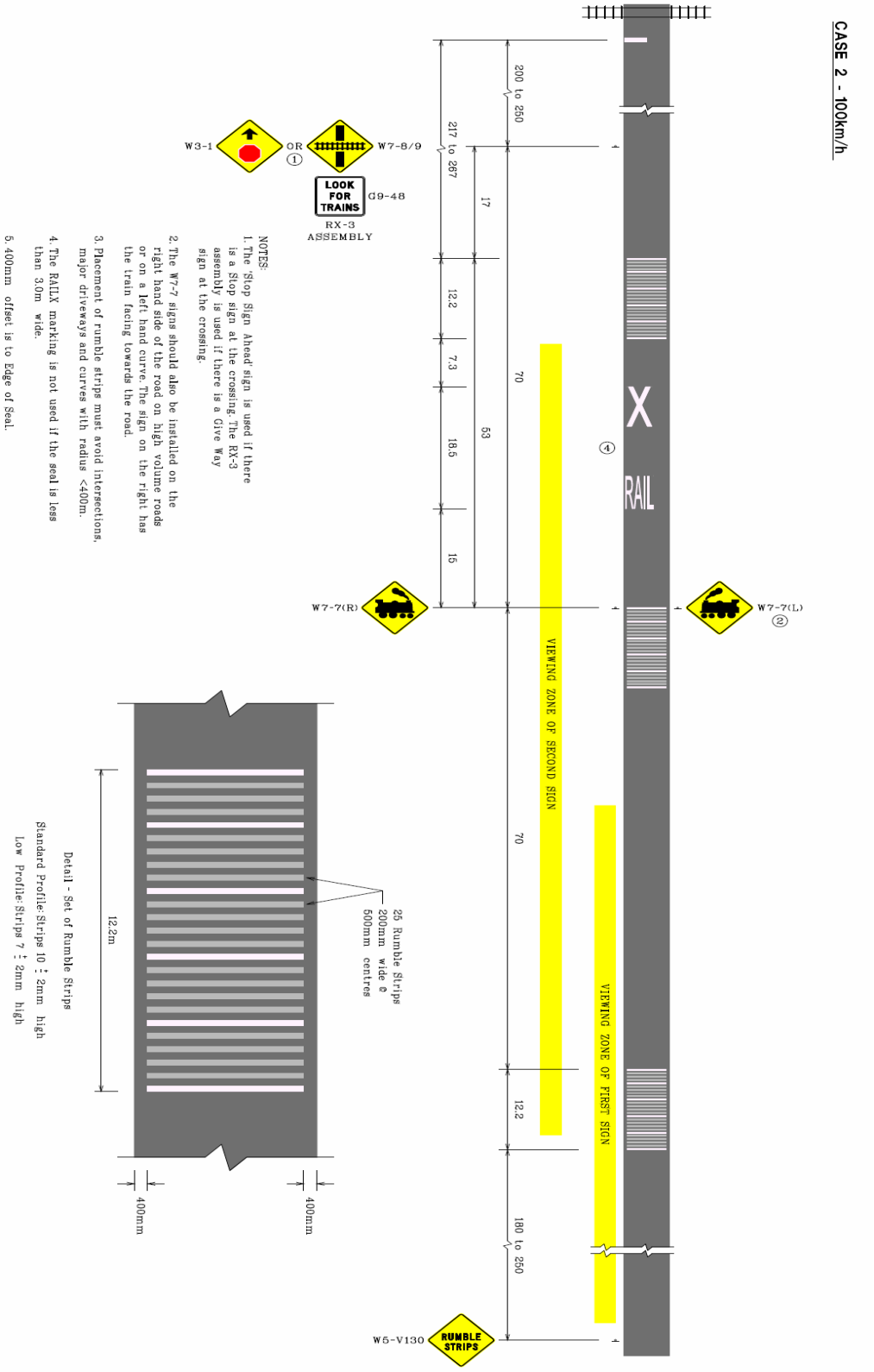
REFERENCES

Pattinson W, Hore-Lacy W & Jones D 2007, *Transverse Rumble TRS Literature Review*, contract report VC73238 for Vicroads, ARRB Group Ltd, Vermont South, Vic.

Standards Australia 2007, Manual of uniform traffic control devices, Part 7: Railway crossings, AS 1742.7-2007, Standards Australia, Sydney.

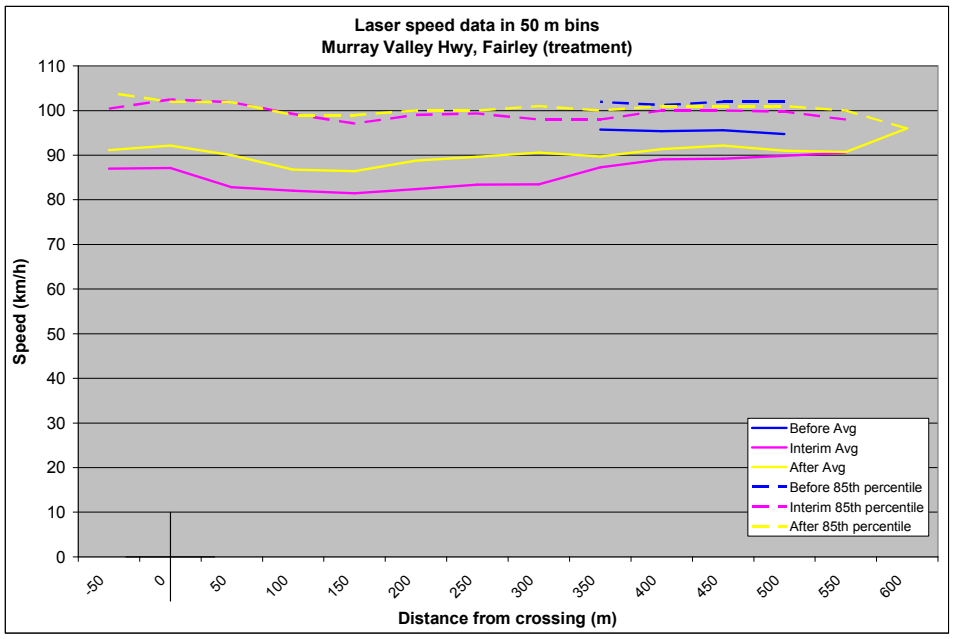
APPENDIX A RUMBLE STRIP DESIGN AND LAYOUT




CASE 2 - 100km/h
W3-1
OR
①
W7-8/9
LOOK FOR TRAINS
G9-48
RX-3 ASSEMBLY
200 to 250
217 to 267
17
12.2
7.3
18.5
15
70
53
X
RAIL
④
W7-7(R)
W7-7(L)
②
VIEWING ZONE OF SECOND SIGN
VIEWING ZONE OF FIRST SIGN
70
12.2
180 to 250
W5-V130
RUMBLE STRIPS
NOTES:
1. The 'Stop Sign Ahead' sign is used if there is a Stop sign at the crossing. The RX-3 assembly is used if there is a Give Way sign at the crossing.
2. The W7-7 signs should also be installed on the right hand side of the road on high volume roads or on a left hand curve. The sign on the right has the train facing towards the road.
3. Placement of rumble strips must avoid intersections, major driveways and curves with radius <400m.
4. The RAILX marking is not used if the seal is less than 3.0m wide.
5. 400mm offset is to Edge of Seal.
Detail - Set of Rumble Strips
Standard Profile Strips 10 ± 2mm high
Low Profile Strips 7 ± 2mm high
12.2m
25 Rumble Strips 200mm wide @ 500mm centres
400mm
400mm

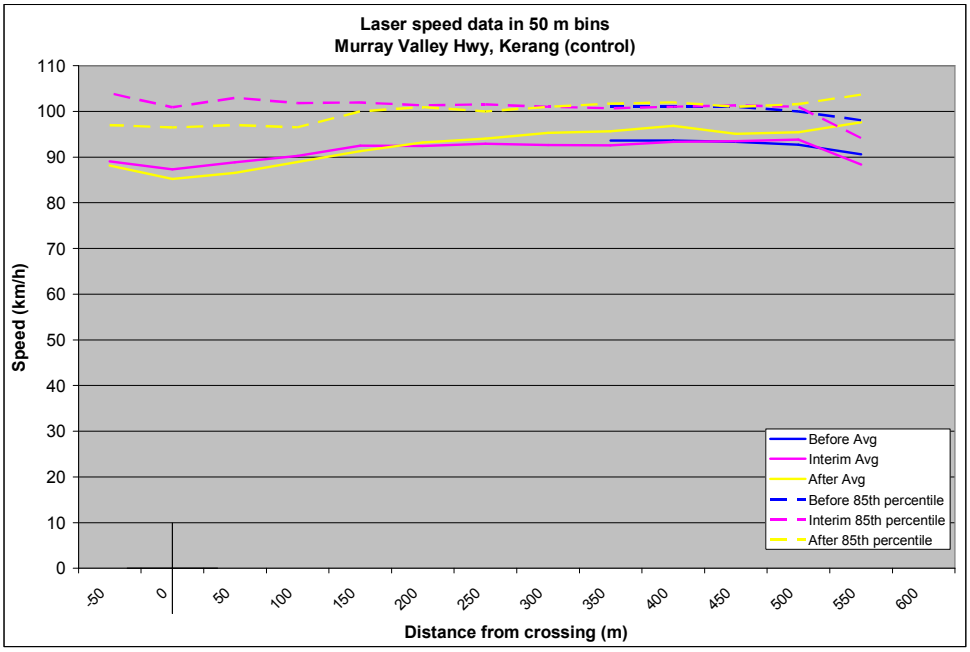
APPENDIX B ADDITIONAL GRAPHS OF LASER DATA

Murray Valley Highway, Fairley – Treatment
Murray Valley Highway, Kerang – Control



Note: 'Interim' is after rumble strips and 'After' is after active advanced warning signs and boom gates installed in addition to rumble strips

Figure B 1: Laser speed data in 20 m bins for Murray Valley Highway, Fairley (Treatment)



Note: 'Interim' is after rumble strips and 'After' is after active advanced warning signs and boom gates installed in addition to rumble strips at the Fairley site.

Figure B 2: Laser speed data in 50 m bins for Murray Valley Highway, Kerang (Control)

Midland Highway, Tatura – Control

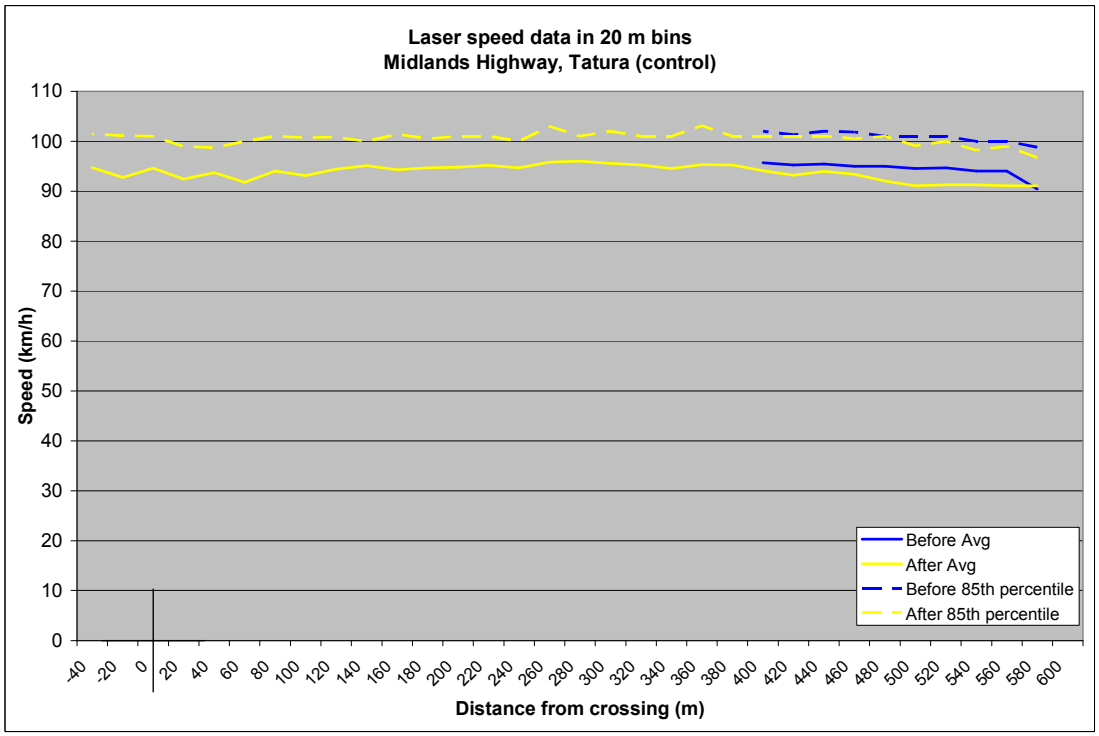


Figure B 3: Laser speed data in 20 m bins for Midland Highway, Tatura (control)

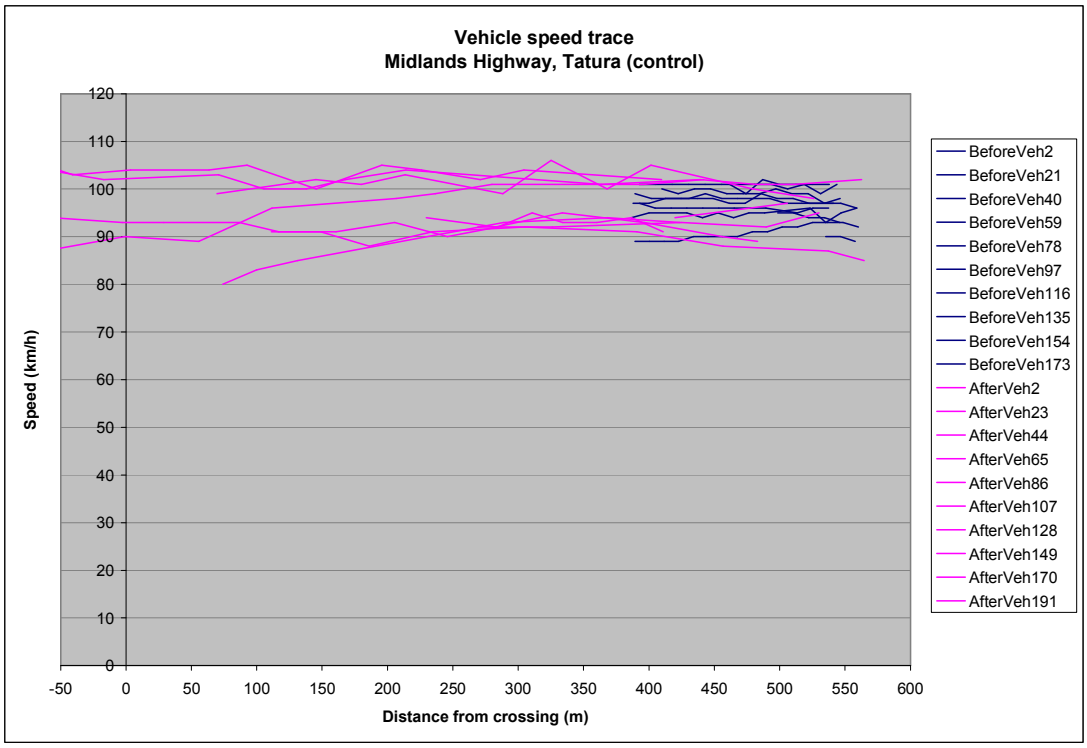


Figure B 4: Selected vehicle traces for Midland Highway, Tatura (Control)

Dumosa-Quambatook Rd, Quambatook – Treatment
Aerodrome Rd, Avenel (west) – Control

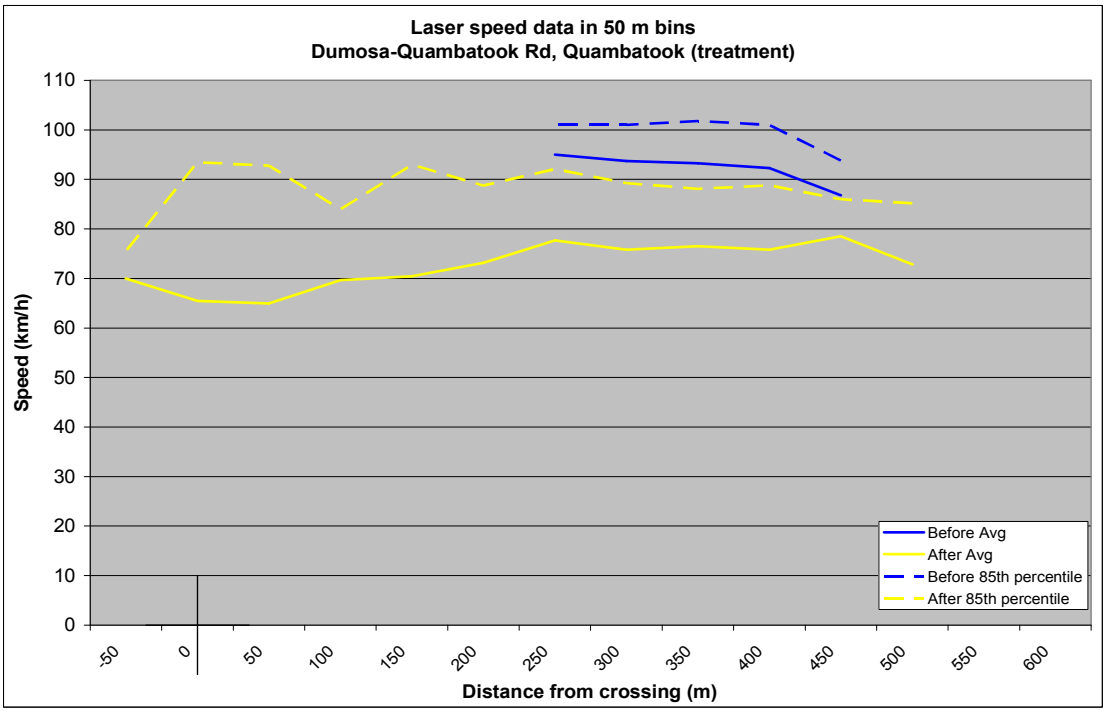


Figure B 5: Laser speed data in 50 m bins for Dumosa-Quambatook Rd, Quambatook (treatment)

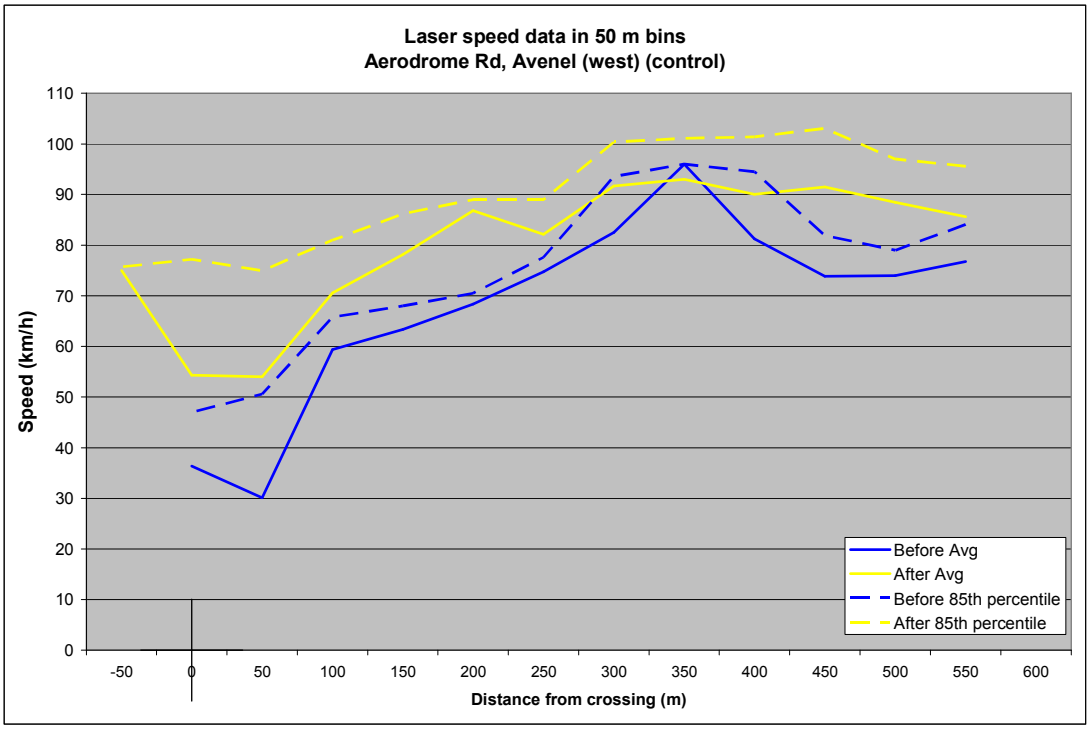


Figure B 6: Laser speed data in 50 m bins for Aerodrome Rd, Avenel (west) (control)

Patchewollock-Sea Lake Rd, Nyarrin – Treatment
Aerodrome Rd, Avenel (east) – Control

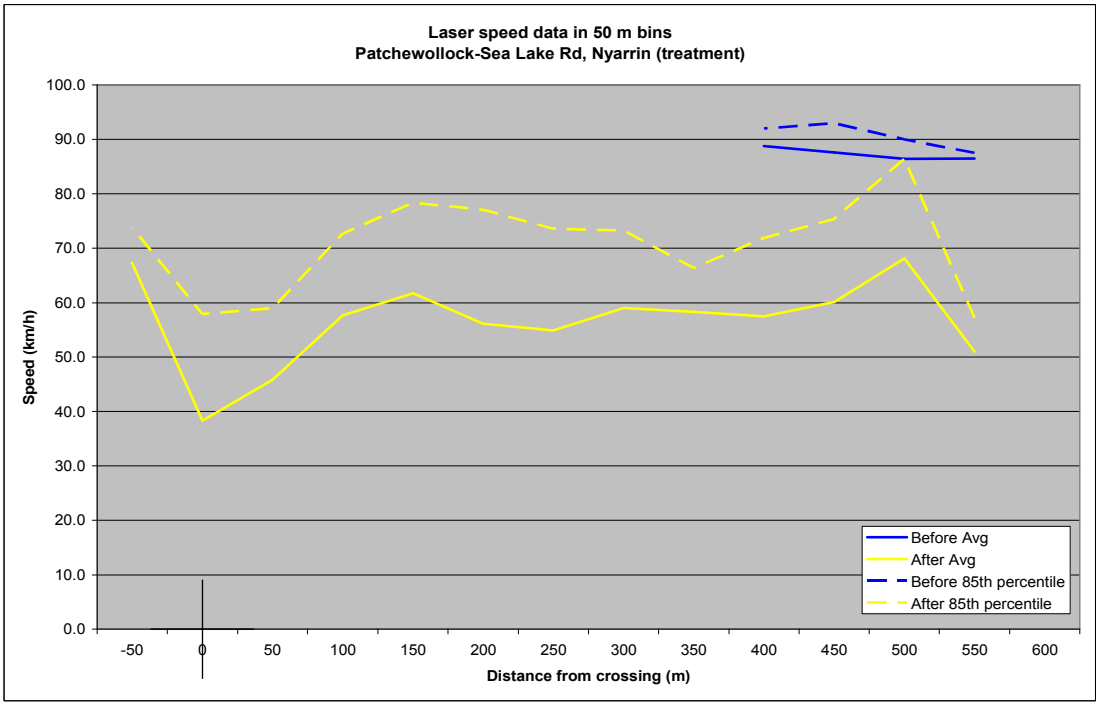


Figure B 7: Laser speed data in 50 m bins for Patchewollock-Sea Lake Rd, Nyarrin (treatment)

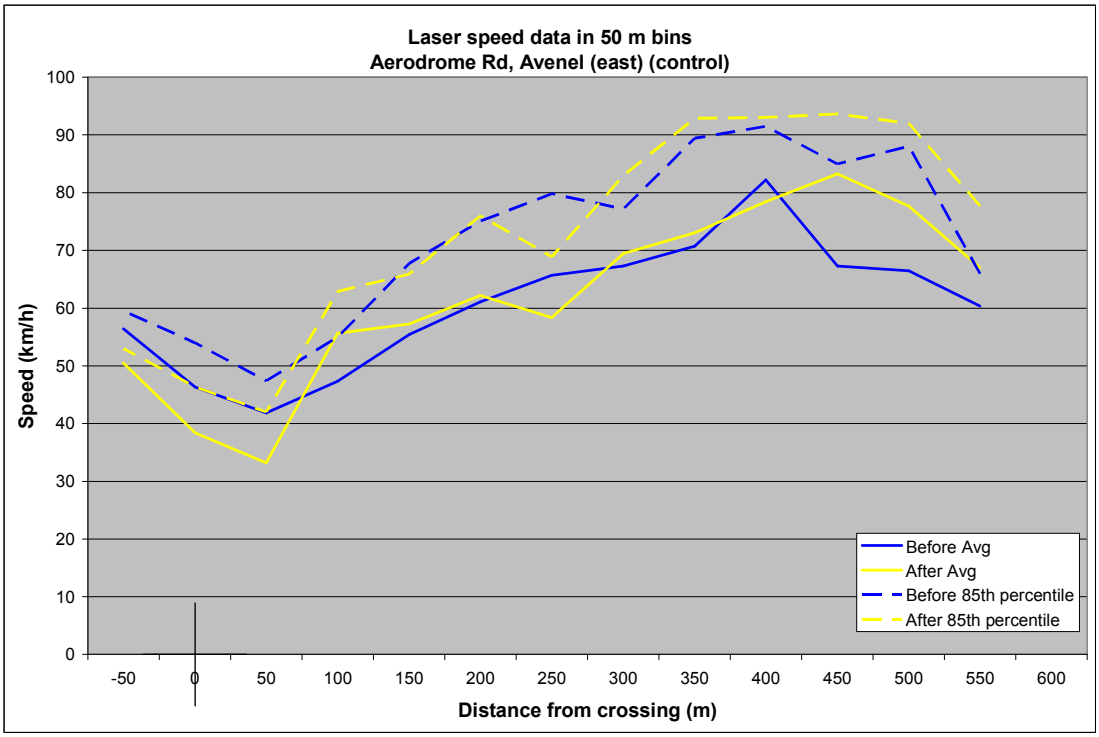


Figure B 8: Laser speed data in 50 m bins for Aerodrome Rd, Avenel (east) (control)

Brislanes Rd, Murgheboluc – Treatment
Kirwans Bridge-Longwood Rd, Nagambie – Control

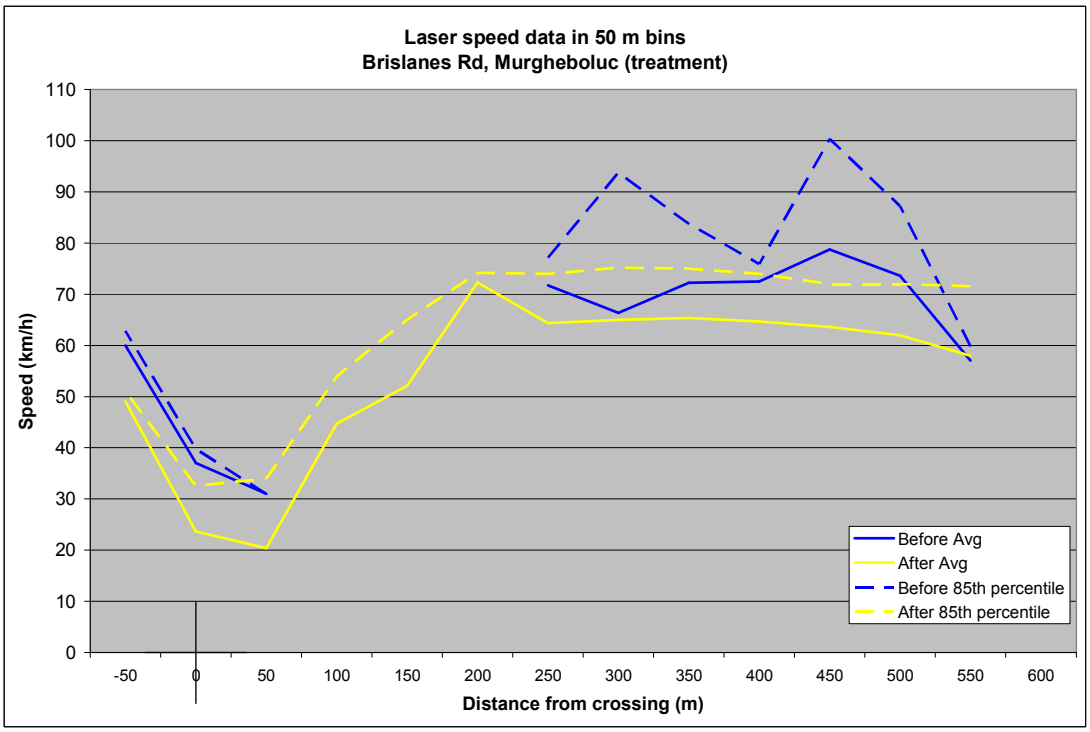


Figure B 9: Laser speed data in 50 m bins for Brislanes Rd, Murgheboluc (treatment)

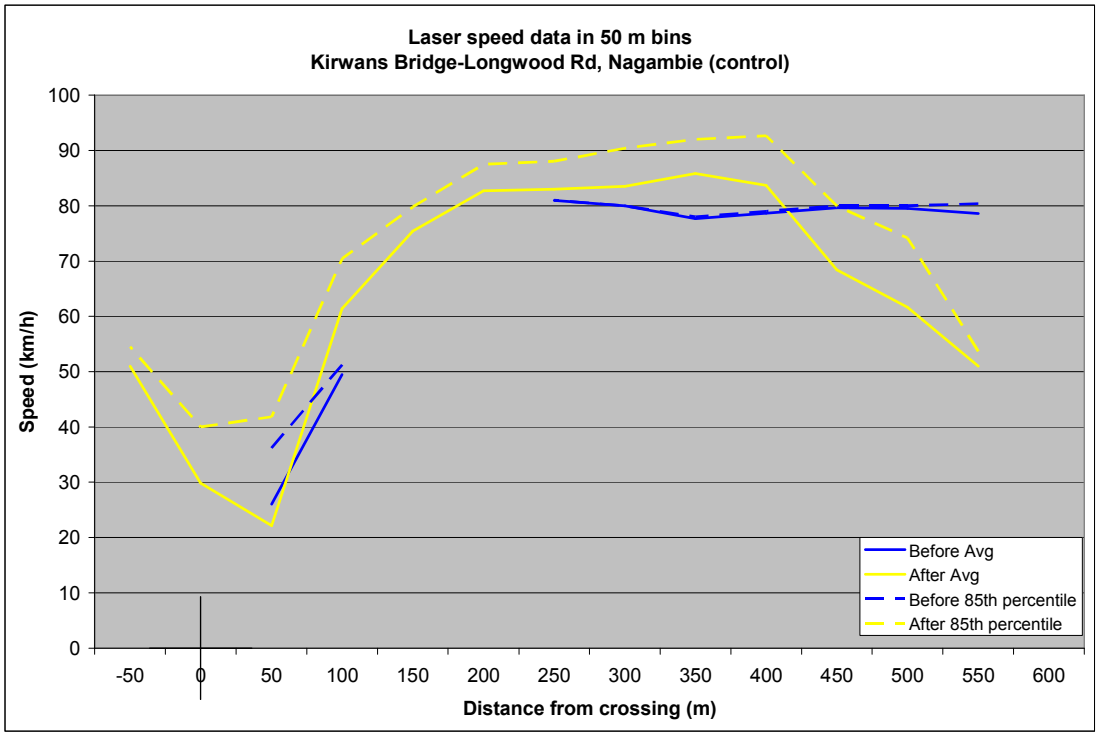


Figure B 10: Laser speed data in 50 m bins for Kirwans Bridge-Longwood Rd, Nagambie (control)

Gnarpurt Rd, Lismore (north) – Treatment
Gnarpurt Rd, Lismore (south) – Control

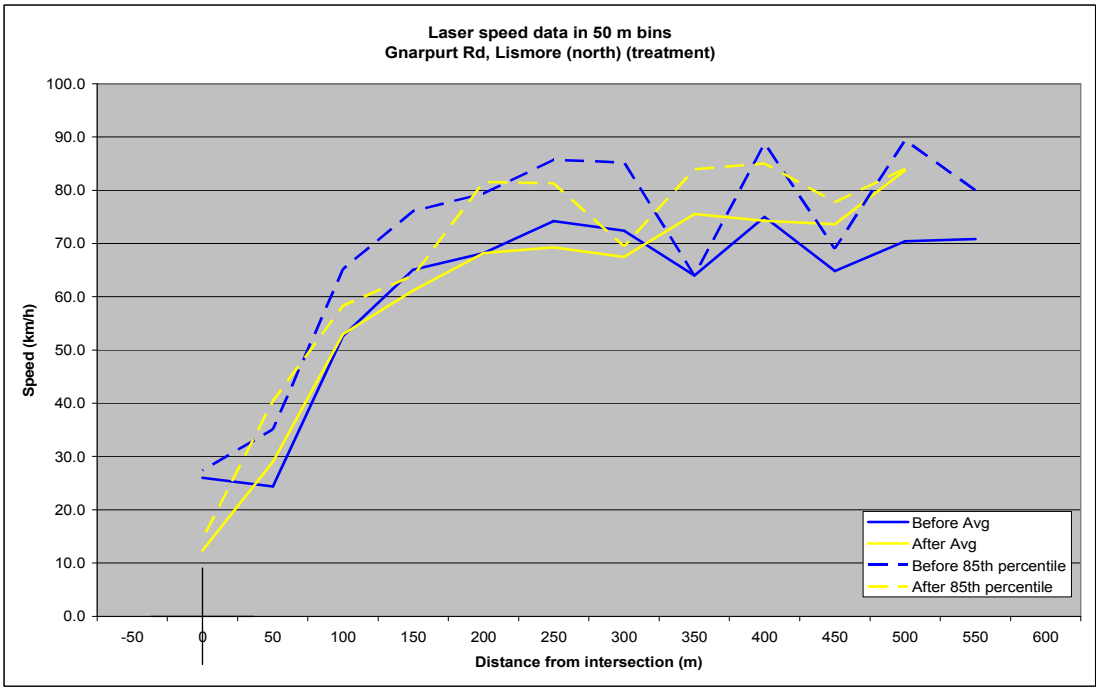


Figure B 11: Laser speed data in 50 m bins for Gnarpurt Rd, Lismore (north) (treatment)

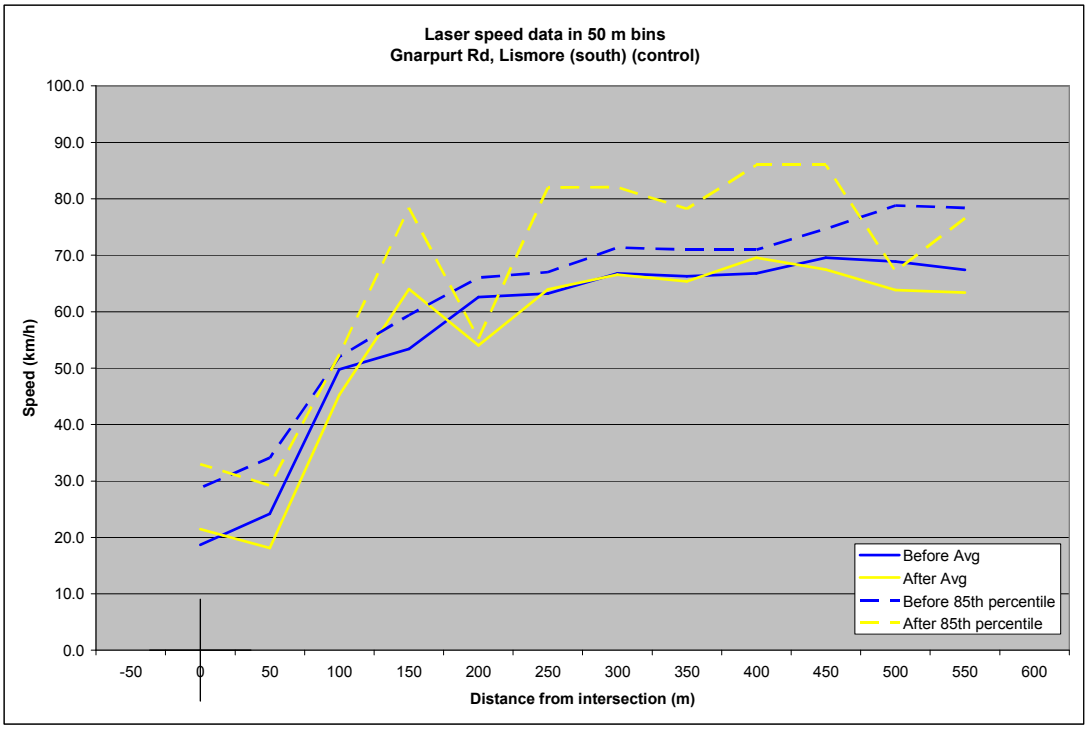


Figure B 12: Laser speed data in 50 m bins for Gnarpurt Rd, Lismore (south) (control)

Myers Road & Coolart Road, Bittern (east) – Treatment
Myers Road & Coolart Road, Bittern (west) – Control

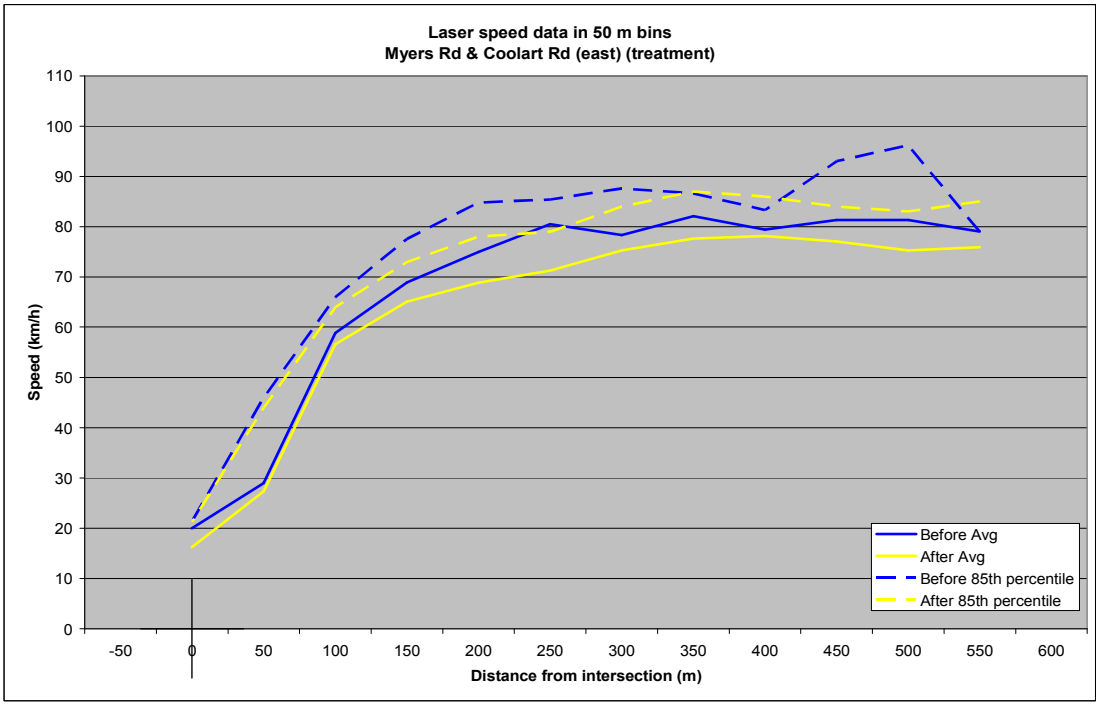


Figure B 13: Laser speed data in 50 m bins for Myers Road & Coolart Road, Bittern (east) (treatment)

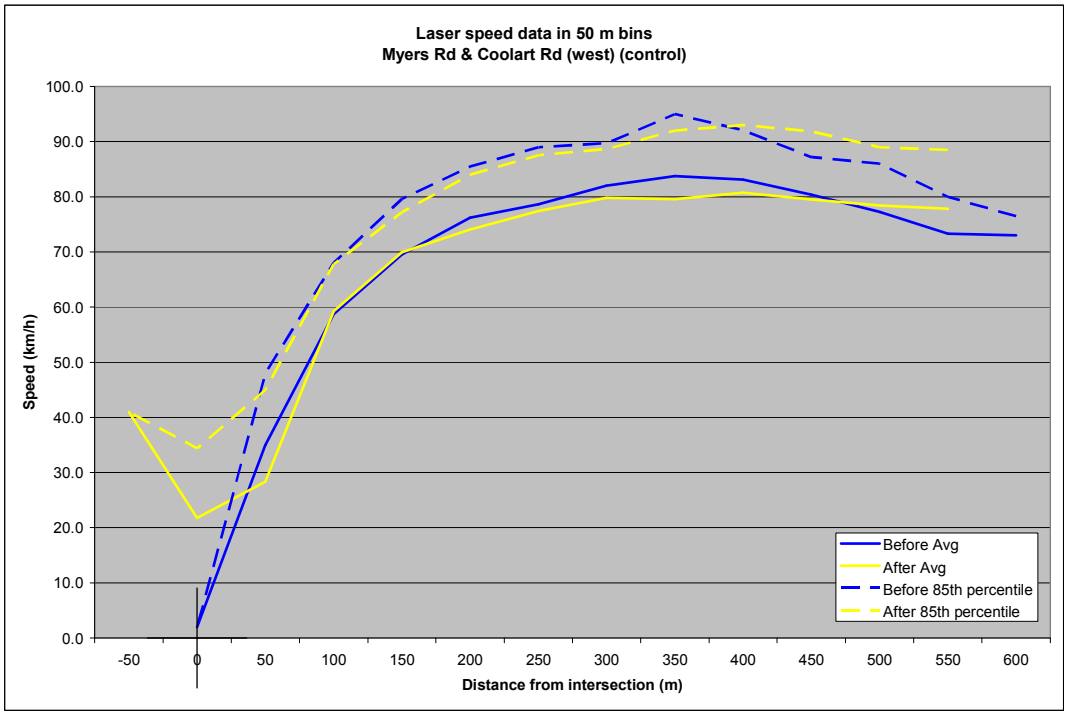


Figure B 14: Laser speed data in 50 m bins for Myers Road & Coolart Road, Bittern (west) (control)

Anglesea Rd & Mount Duneed Rd (east) – Treatment
Anglesea Rd & Mount Duneed Rd (west) – Control

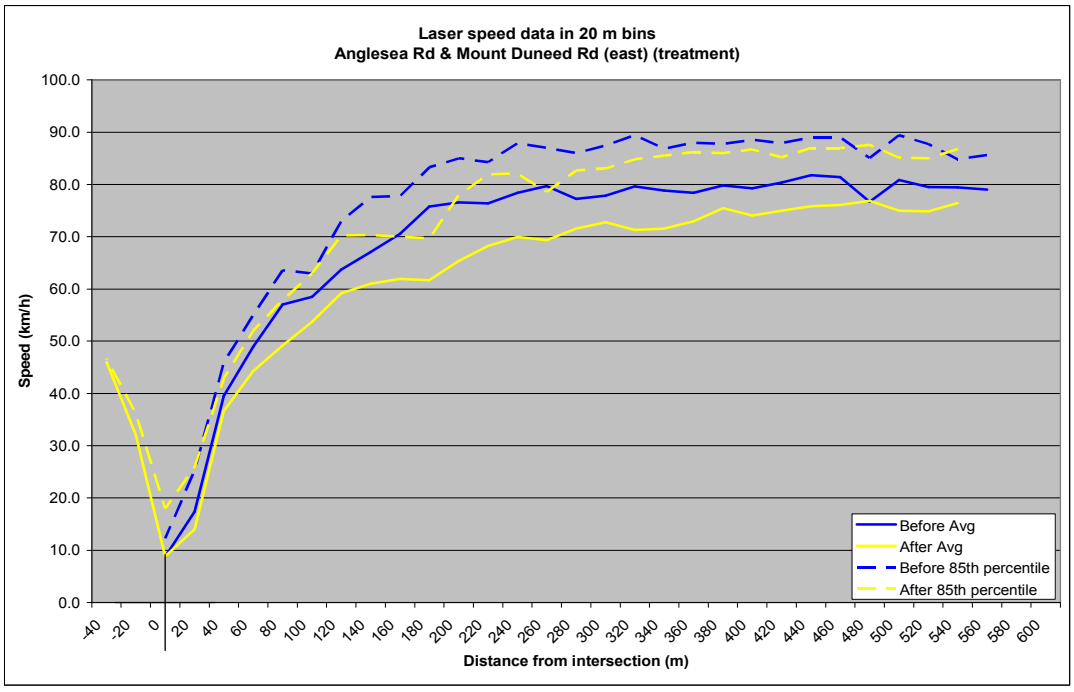


Figure B 15: Laser speed data in 20 m bins for Anglesea Rd & Mount Duneed Rd (east) (treatment)

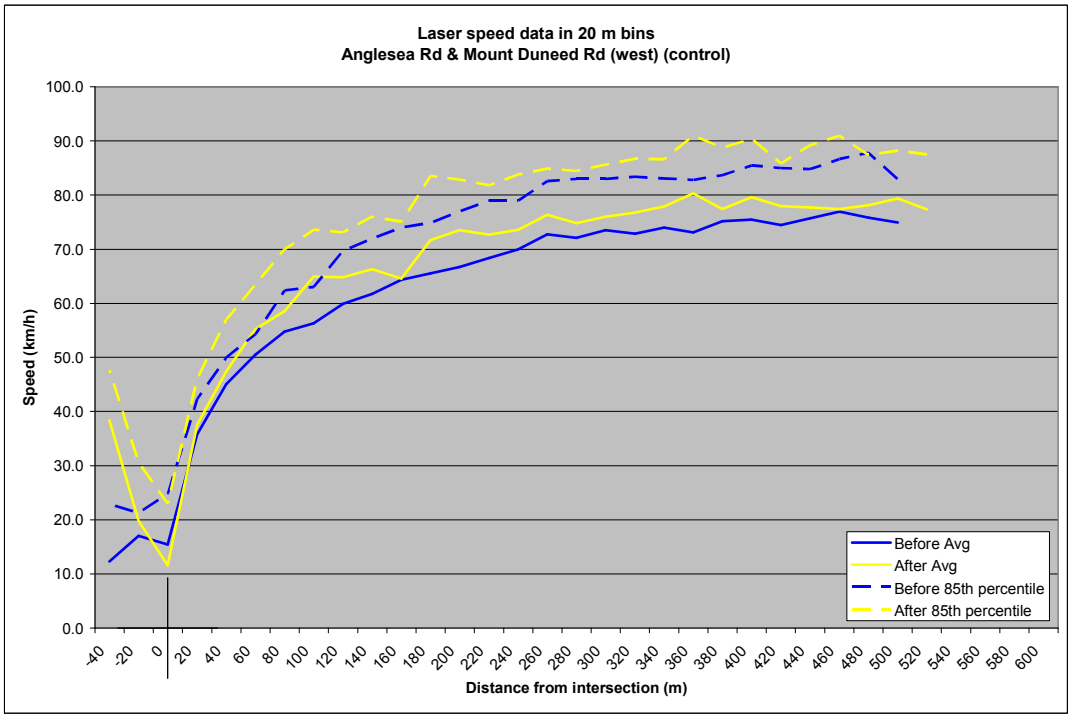


Figure B 16: Laser speed data in 20 m bins for Anglesea Rd & Mount Duneed Rd (west) (control)

Myers Rd & Balnarring Rd, Balnarring (east) – Treatment
Myers Rd & Balnarring Rd, Balnarring (west) – Control

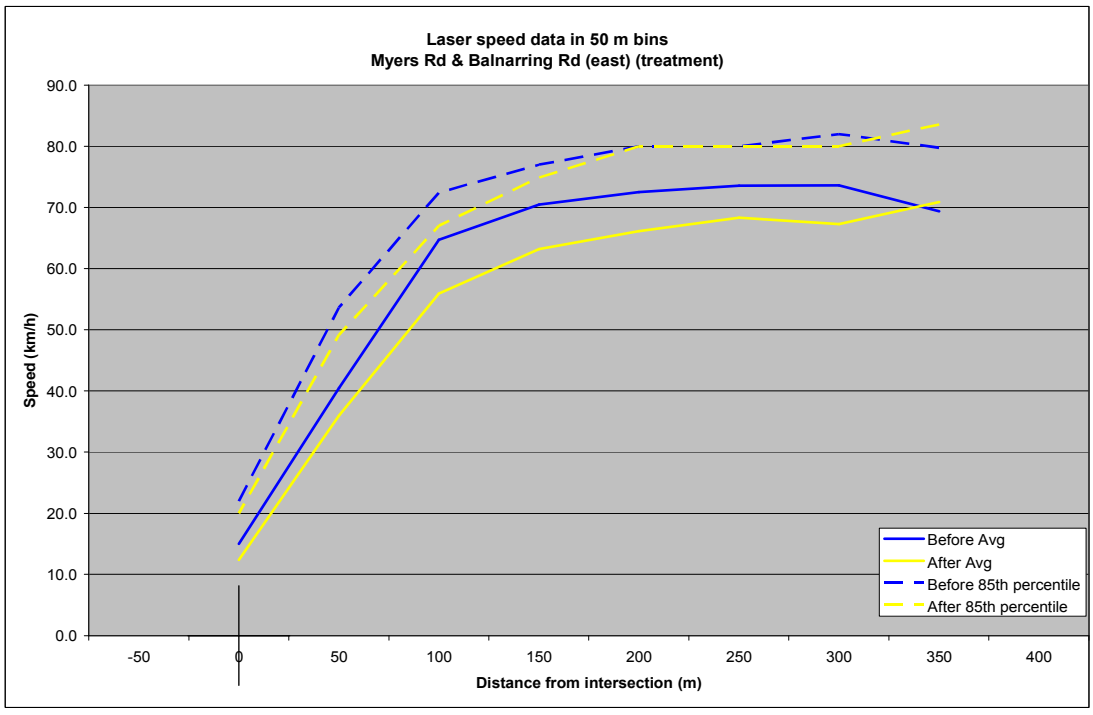


Figure B 17: Laser speed data in 50 m bins for Myers Rd & Balnarring Rd, Balnarring (east) (treatment)

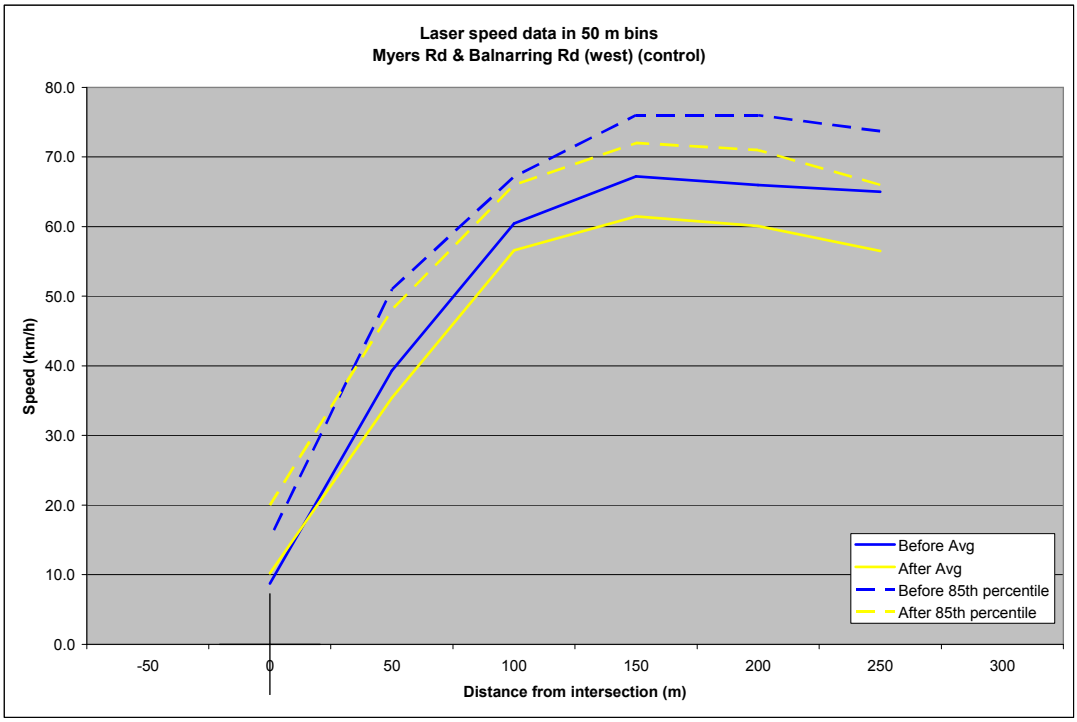


Figure B 18: Laser speed data in 50 m bins for Myers Rd & Balnarring Rd, Balnarring (west) (control)

Bittern-Dromana Road & Balnarring Rd, Balnarring (west) – Treatment
Bittern-Dromana Road & Balnarring Rd, Balnarring (east) – Control

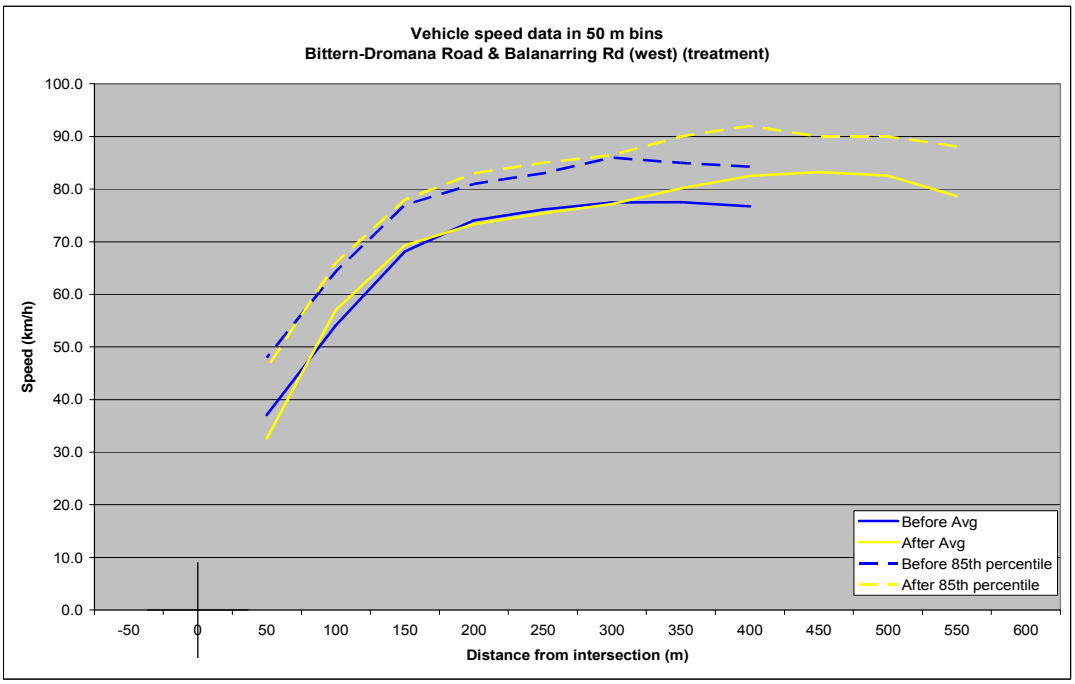


Figure B 19: Laser speed data in 50 m bins for Bittern-Dromana Road & Balnarring Rd, Balnarring (west) (treatment)

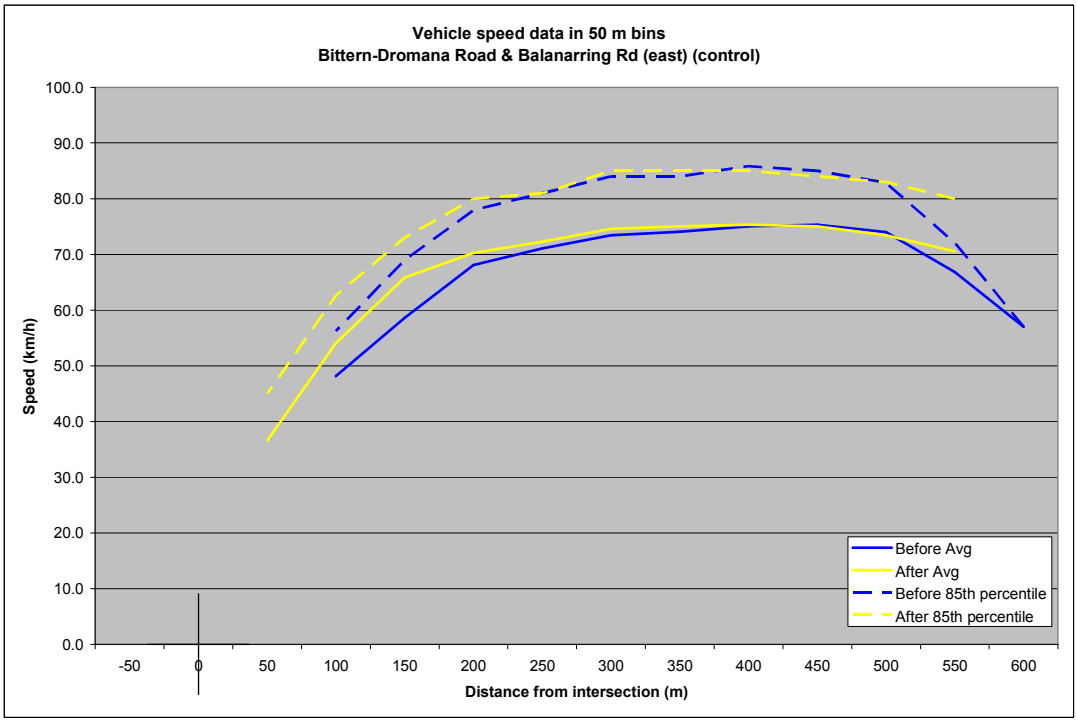


Figure B 20: Laser speed data in 50 m bins for Bittern-Dromana Road & Balnarring Rd, Balnarring (east) (control)

Churchill-Traralgon Rd & Church Rd, Morwell (east) – Treatment
Churchill-Traralgon Rd & Church Rd, Morwell (west) – Control

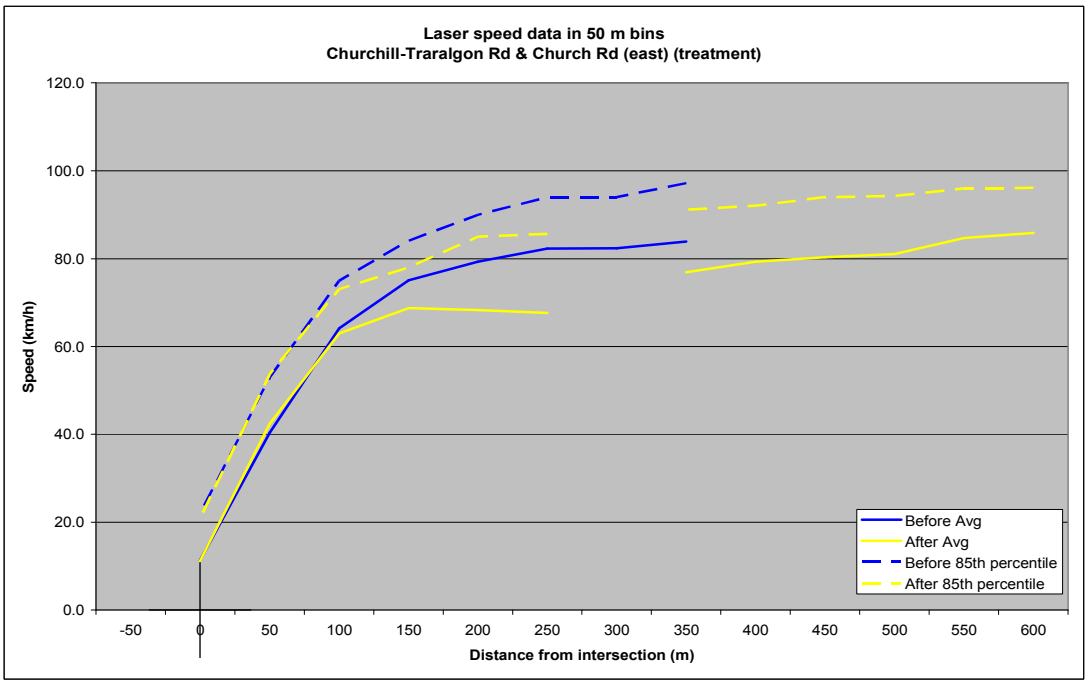


Figure B 21: Laser speed data in 50 m bins for Churchill-Traralgon Rd & Church Rd, Morwell (east) (treatment)

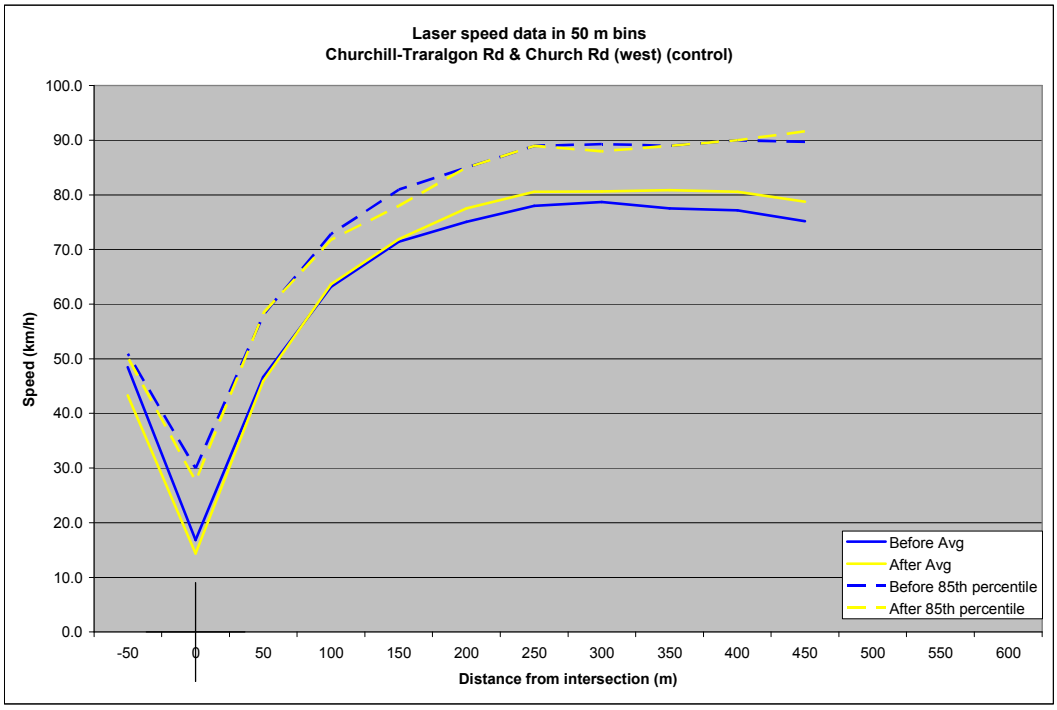


Figure B 22: Laser speed data in 50 m bins for Churchill-Traralgon Rd & Church Rd, Morwell (west) (control)

Cape Otway Rd & Gherang Rd, Winchelsea – Treatment
Hodgins Rd & Coolart Rd, Hastings – Control

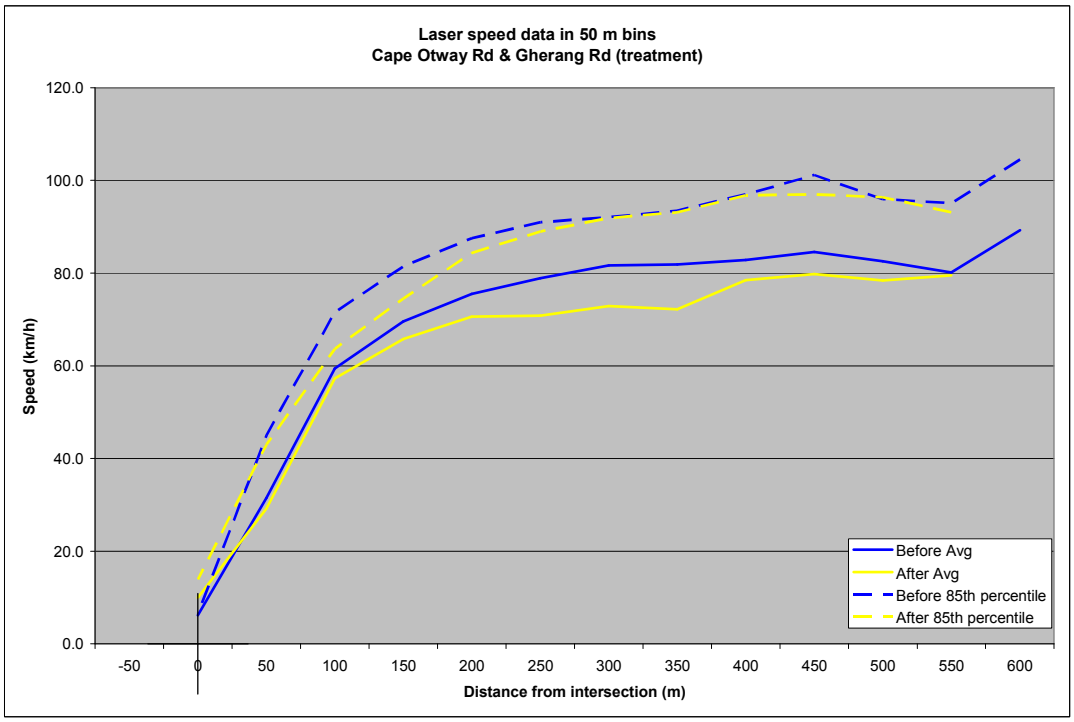


Figure B 23: Laser speed data in 50 m bins for Cape Otway Rd & Gherang Rd, Winchelsea (treatment)

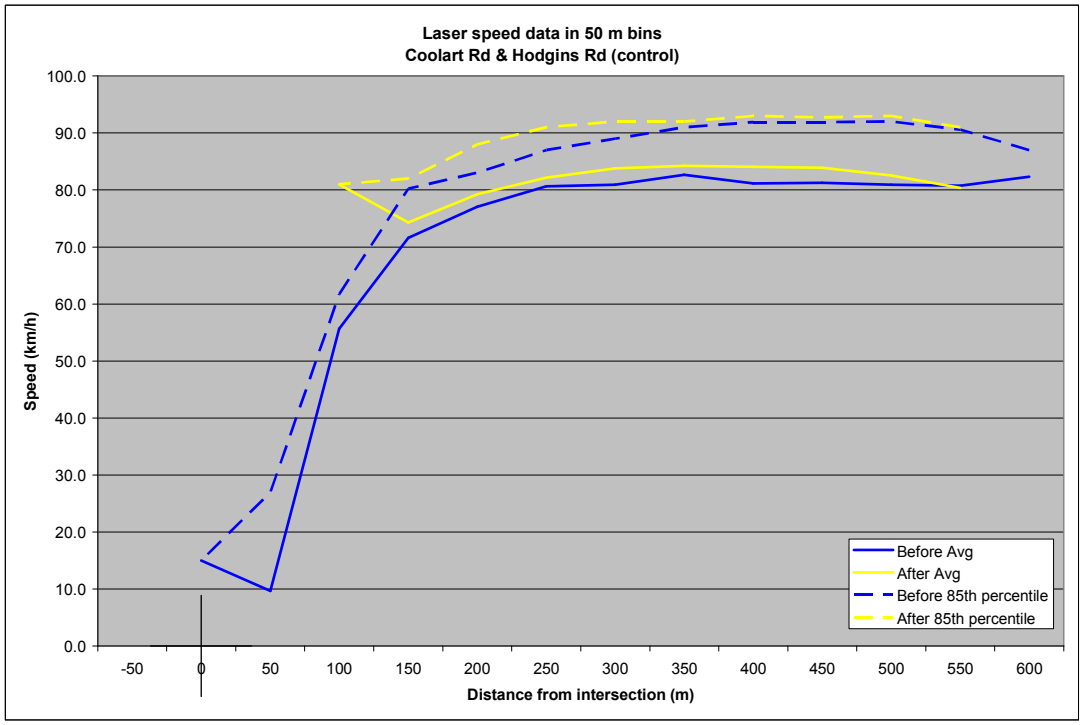


Figure B 24: Laser speed data in 50 m bins for Hodgins Rd & Coolart Rd, Hastings (control)

APPENDIX C SUMMARIES OF PREVIOUS RUMBLE STRIP WORK

C.1 Transverse rumble strips literature review – Summary

Pattinson W, Hore-Lacy W & Jones D 2007, 'Transverse Rumble TRS Literature Review', contract report VC73238 for Vicroads, ARRB Group Ltd, Vermont South, Vic.

The literature shows that there are two main reasons why transverse rumble strips (TRS) have been installed:

- to reduce speeds
- to alert the driver as they approach a potential hazard.

Both have the objective of creating a safer road environment (and reducing crashes).

The two broad types of rumble strips are raised strips (above the pavement surface), and grooved strips (depression in the road surface). With the majority of sealed rural roads in Victorian using thin sprayed bitumen and stone chip seals, raised strips will be the only viable option at most locations on rural roads. The most common type of rumble strip in the USA and Canada is the grooved strip (cut into cement or bituminous concrete pavements). Rumble grooves are more durable, are compatible with snow ploughs and are considered by some to be more effective than raised strips.

While there are some conflicting results in the various studies, generally rumble strips have been found to be:

- ineffective in reducing speeds
- effective in alerting drivers of hazards
- usually effective in reducing the number of crashes.

There are however few comprehensive studies. Even less compare profiles or layouts, or reach conclusions about their effectiveness. Most of the studies reviewed did not have enough data to draw statistically significant conclusions.

Harwood (1993) concluded that transverse rumble strips appear to be effective in reducing the number of collisions at intersections. It was found that they can provide up to a 50% reduction in the types of accidents most susceptible to correction, with results in studies varying from 14 to 100%. However this report expressed concerns regarding the validity of almost all the evaluations reviewed including why particular sites were selected, the quality (or absence) of the statistical analysis, whether there was a control group, the number of sites evaluated and 'before' and 'after' traffic volumes.

Rumble strips appear to make some drivers decelerate earlier and more rapidly when approaching an intersection or hazard. Harwood notes that the variance in speeds increases, but in a study that observed this there were no corresponding increases in crashes from higher variances in individual vehicle speeds (e.g. rear-end collisions). Some of the studies also contradict each other, perhaps reflecting local conditions and standards.

The use of TRS would appear to be best trialled and evaluated as part of treatment packages for specific locations, consisting of rumble strips, line marking and warning and regulatory signs. Variations are likely to be required to reflect the speed environment and pavement lane widths.

C.2 Rumble strip field testing – Summary

Ritzinger A, George R & Hore-Lacy W 2007, 'Rumble strip field testing', contract report VC73587 for Vicroads, ARRB Group Ltd, Vermont South, Vic.

Victoria's State Government is presently working to improve safety at road intersections and railway crossings. As part of this undertaking, VicRoads proposes to install transverse rumble strips (TRS) to alert road users of potential hazards they are approaching. TRS aim to provide road users with a combined visual, audible and tactile warning system. TRS achieve audible and tactile warnings via the noise and vibration generated in the vehicle during travel over the TRS.

VicRoads commissioned ARRB Group Ltd (ARRB) to conduct field testing of a heavy vehicle and motorcycle for the purposes of assessing the effectiveness of TRS. Qualitative assessment of the effectiveness of the TRS was obtained via evaluation forms which were completed by the driver of the heavy vehicle and the rider of the motorcycle. Quantitative assessment of the effectiveness of the TRS was obtained via the following:

- the audible feedback provided by measuring in-vehicle sound levels
- the tactile feedback provided by measuring in-vehicle vibrations.

Effectiveness was also investigated by varying TRS height construction material, and varying vehicle travel speed.

The following conclusions were drawn:

- Thermoplastic TRS was more effective at providing levels of visual, tactile and audible feedback than bitumen TRS.
- Thermoplastic TRS at 8 mm high was sufficient to provide visual, tactile and audible warnings to motorcyclists and heavy vehicle drivers.

However, it was noted by the rider of the motorcycle that thermoplastic TRS offered significantly reduced levels of grip when compared to the bitumen TRS, and that this represented a significant safety concern.

The investigation concluded that thermoplastic TRS at 8 mm high offers the highest levels of visual, tactile and audible feedback and therefore represent the preferred road treatment. However due to safety concerns bitumen TRS at 14 mm high should be used as the preferred road treatment until the levels of skid resistance of thermoplastic strips can be confirmed.

C.3 Transverse rumble strip layout design for passive railway level crossings – Summary

Hore-Lacy W & Pattinson W 2007, 'Transverse rumble strip layout design for passive railway level crossings', contract report VC73631 for Vicroads, ARRB Group Ltd, Vermont South, Vic.

Prior to installing transverse rumble strips at some 200 railway level crossings in Victoria controlled by stop or give way signs ('passive controls') a safe and effective layout was needed that: was based on the most promising overseas design; was consistent with AS 1742.7 – 2007; and that would fit with existing signs and line markings used in Victoria.

The options outlined in this report are based on the Transport Association of Canada's (TAC) design recommended in Pattinson et al. (2007). They were adapted to fit the Australian Standards for warning signs and pavement markings as well as to fit with local sign installations as advised by VicRoads.

In discussion with VicRoads, the recommended design, a modified TAC design with single sets of rumble strips was developed to suit Victorian conditions (option 4 shown in Appendix A).

A low profile variation for moderate curves (>400 m R) was also developed, in consultation with VicRoads.

A design option that may warrant further consideration is Option 3 Hybrid, which may be a useful treatment on approaches after long straight sections if driver drowsiness appears to be a severe problem (paired sets of rumble strips may be more effective for such drivers).

Monitoring of a sample of installations is recommended to assess driver responses and to determine if changes in driver behaviour can be observed.

C.4 Transverse rumble strip in-vehicle noise testing – Summary

Ritzinger A & Patrick S 2008, 'Transverse rumble strip in-vehicle noise testing', contract report VC74406 for Vicroads, ARRB Group Ltd, Vermont South, Vic.

Victoria's State Government is presently working to improve safety at road intersections and railway crossings. As part of this undertaking, VicRoads is upgrading a selection of these types of intersections in rural/regional Victoria by installing signage and transverse rumble strips (TRS) to alert road users of the potential hazards they are approaching.

The TRS comprise raised bitumen strips constructed on top of the existing road surface, and aim to provide road users with a combined visual, audible and tactile warning system. TRS provide visual warning via the application of painted markings, and audible and tactile warnings via the noise and vibration generated in the vehicle during travel over the TRS.

In recent months, VicRoads has installed TRS at a number of locations throughout rural/regional Victoria. VicRoads commissioned ARRB Group Ltd (ARRB) to conduct instrumented testing of a heavy vehicle to assess the effectiveness of installed TRS. A total of four sites located in north-western Victoria were investigated by ARRB.

This report outlines the sites investigated, details the layout of the TRS at each site, details the vehicles and instrumentation used in the investigation and an assessment of the performance of TRS at each site based on data recorded during the testing program.

The findings of the field tests based on qualitative assessments conducted by the engineers during the test program, and the results of the quantitative field testing are summarised below.

- All sites provided good visual warnings through roadside signs and painted markings.
- TRS layout comprising 25 strips at 10 mm high (Sites 1 and 2) provides the highest levels of audible and tactile feedback.
- TRS layout comprising 25 strips at 5 mm high (Site 3 eastbound, Site 4 westbound) provides reduced audible and tactile feedback when compared to the same layout at 10 mm high, but is still noticeable.
- TRS layout comprising 5 strips at 5 mm high (Site 3 westbound, Site 4 eastbound) provides almost no audible or tactile feedback.