



Medium-term evaluation of variable speed limit signs at rural schools



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Final Report



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SUMMARY

The aim of this project was to implement and monitor the effectiveness of variable speed limit signs at rural schools in order to achieve safe speeds that are relevant to road-user behaviour at rural school road environments. Rural school road safety is of high concern to many communities as there is a conflict between high speed through traffic and the drop-off and pick-up activities associated with school commuting.

Five rural schools took part in the project. Based on analyses following focus groups with each school, permanent and variable speed limit configurations were developed for each school. Permanent 80 km/h speed limits were implemented at schools where variable 60 km/h and 40 km/h speed limits were planned, when the existing speed limit was 100 km/hr. The variable speed limits that were implemented included 70, 60 and 40 km/h.

A programme of evaluation was developed and implemented by the project team, focussing mostly on outcome measures. Measures included short (1-3 months following variable speed limit implementation) and medium-term (9-12 months following variable speed limit implementation) traffic speed, school feedback, road safety expert feedback and any immediately obvious sign operation or maintenance issues that have emerged since the implementation of the signs.

Overall, the variable speed limit signs were effective in reducing vehicle speeds during school drop-off and pick-up times. This was evident over both the short and medium-term. The signs were also perceived to be very effective in improving traffic behaviour and safety by school communities. Road safety experts had a similarly positive view of the signs' effectiveness although there was more caution related to the conditions of use and their operation.

For Kai Iwi school, the only one with a variable 70 km/h speed limit reduction within a permanent 100 km/h speed limit environment, very strong compliance was achieved with operating speed during school times generally being very close (or even slightly below in some circumstances) to this limit. This effect was maintained 12-months following the introduction of the variable speed limit signs (although reliable data only exists for the westbound direction - see Page 14). For the schools that received variable 60 km/h speed limit reductions, average traffic speed tended to reduce to approximately 70 km/h in higher speed environments and approximately 63-65 km/h in lower speed environments. In general, these effects were maintained over a 9-12 month period although at one site the speed increased slightly and at another the speed decreased relative to 3-month data. For Whenuakite School, the 40 km/h speed limit generally resulted in short-term traffic speeds of approximately 45-50 km/h in this naturally lower speed environment. Over an 11-month period the average, median and 85th percentile speeds appear to have increased; however, modal speeds appear unchanged or lower depending on the direction of travel.

Some specific recommendations from this report are:

- Continue the trial of LED variable speed limit signs for rural schools. While they appear to be effective, there are still some outstanding questions regarding their use
- Further consideration of the approach for determining the actual speed limit is needed
- Consider supporting engineering treatments where appropriate
- Explore ways of ensuring that schools and their communities take some responsibility for road safety at their school. Given the evidence presented to date, complete solutions cannot be provided solely by road controlling authorities

- Complete and implement rural school road safety guidelines taking a holistic approach and focusing on the whole of New Zealand, so that the above recommendations can be carried out in a considered and systematic way.

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INTRODUCTION

A recent report for the NZ Transport Agency (Mackie 2011¹) outlined that there appears to be two main areas of concern regarding rural school road safety for rural communities:

1. The road environment within the immediate vicinity of the school and the related pick-up and drop-off areas; and
2. Children getting to and from school buses.

The route to school is also likely to be an important consideration for road safety and may need to be considered as part of any initiatives to address rural (and urban) school road safety in the future.

This report focusses on the road environment around rural schools. More specifically, it describes a trial of variable speed limit signs at five rural schools, funded by the Road Safety Trust, as part of a programme of work which seeks to understand rural school road safety issues and provide suitable solutions. A preliminary version of this report was completed in December 2012 to share the immediate impacts of the variable speed limit signs at the schools.

The aim of this project was to implement and monitor the effectiveness of variable speed limit signs at rural schools, in order to achieve safe speeds that are relevant to road-user behaviour at rural school road environments. The trial fits within a wider move towards safer speeds that are matched to environmental conditions and impact survivability, as part of the implementation of government's Safer Journeys road safety strategy. This report describes a brief background to the trial, the implementation of the speed limit signs, the results of the project evaluation, discussion of further considerations and recommendations. More detail on the issues regarding rural school road safety can be found in the previous report for the NZ Transport Agency (NZTA) Rural School Road Safety (Mackie 2011).



Figure 1. Kai Iwi School, West of Wanganui

¹ Mackie, H.W. (2011). Rural School Road Safety. A report prepared for NZ Transport Agency by TERNZ Ltd, Final Report: September.

BACKGROUND

Rural school road safety is of high concern to many communities as there is a conflict between high speed through traffic and the drop-off and pick-up activities associated with school commuting. In recent years these concerns have been raised by a number of school communities around New Zealand.

NZTA recently carried out a project (Mackie 2011) to gain a better understanding of the road safety issues faced by rural schools. Six workshops were carried out with six separate schools (the trial process was completed by five), from which a number of key findings emerged. At all of the schools the main road user activity was private vehicles and school buses turning into and out of the school grounds within a high speed traffic environment. In some cases, there was a pedestrian presence on the highway, either crossing the road or accessing vehicles parked on the road shoulder. Although not observed during school visits, it is also understood that some children also walk or cycle along the roadside to rural schools, especially if a footpath is provided. For road safety within the immediate vicinity of rural schools, there appear to be two broad areas of concern:

- a) The highway environment near the school; and
- b) The design of drop-off/pick up areas within the school property, their interface with the highway and school procedures and systems.

Based on these two areas of concern, a joint responsibility model (Figure 2) was recommended, reflecting that most rural schools will have both highway and school property/procedural issues that need resolving, and that both road controlling authorities and schools (or Ministry of Education) will have responsibility for these different areas.

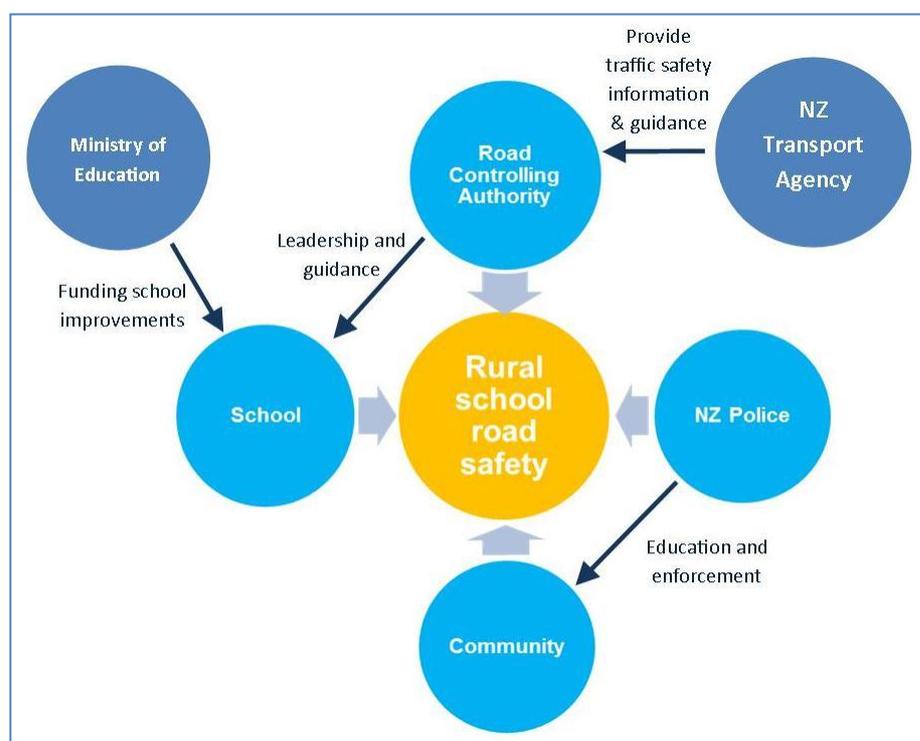


Figure 2 Joint Responsibility Model for rural school road safety (Mackie 2011)

For the highway environment near the schools, the following key issues emerged:

- The conspicuity of schools from the motorists' perspective;
- Traffic speed past schools, where significant turning and stopping occurs; and
- Overtaking near schools.

It was agreed that when addressing highway issues near rural schools, a Safe System approach to speed should be taken, matching the desired traffic speed with the risks and road user vulnerabilities that are present at each school. For rural schools, the two main risk categories are likely to be:

- Turning movements into and out of the school property where side impacts are the main risk. In these instances side impacts of no more than 50 km/h would contribute to a Safe System and therefore traffic speeds of 60-70 km/h are needed (allowing for braking); and
- Pedestrian movement across or alongside the highway. In these situations speeds of no more than 40 km/h would result in survivable impact speeds in most cases².

Therefore, it was recommended that a pilot project to implement 60 km/h and 70 km/h electronic variable signs at several schools situated in high speed environments were needed to reduce side impact vehicle risk. A potential benefit of 60 or 70 km/h signs in high speed traffic environments is likely to be that the warrant for implementing them would not include the pedestrian presence requirements that the 40 km/h signs currently include (as outlined in Traffic Note 37). This may mean that the likelihood of schools qualifying for variable speed signs would improve and in a greater number of cases funding would provide the only barrier to their implementation.

Although 40 km/h signs are allowed and are being used at a few rural locations (e.g. Ardmore School, South Auckland), more thorough monitoring of their performance, in conjunction with other speed limit options would help to determine the most appropriate sign options for rural road safety in various circumstances. For this reason, a 40 km/h variable speed limit option has been included within this initiative.

There are currently various symbolic static/active and speed advisory school sign options (Figure 3) in operation or being trialled. However, illuminated mandatory speed reduction signs are likely to be more effective than symbolic sign variations (static or active) at reducing traffic speed (Mackie 2010³), as they clearly communicate a speed which is legally required of motorists. The implementation of this trial at five rural schools will provide more concrete evidence for the effectiveness of variable speed limit signs at rural schools. Comparisons with datasets from evaluations of other signs could then be carried out to determine the relative effectiveness of various school signs.

² Although pedestrian impact speeds of 30-40 km/h are generally recommended as survivable, it is not known whether this would apply to children.

³ Mackie, H.W. (2010). Rural Intersection Active Warning Systems: Review of information and recommendations. A report prepared for NZ Transport Agency, November 2010.

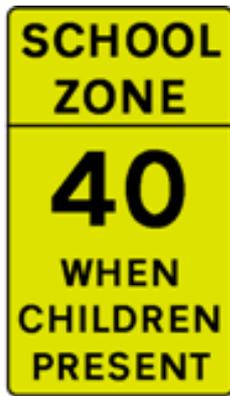


Figure 3. Other school signs in use or being trialled

TRIAL SITES

Five rural schools from around the North Island were identified by NZTA's Regional Road Safety Engineers who nominated the schools based on current road safety concerns (Figure 4). Initial workshops were carried out to identify particular issues relating to road safety at each school during drop-off and pick-up periods. The five schools that took part in the trial were Kai Iwi School (Wanganui), Opiki School (Horowhenua), Pakipaki School (Hawkes Bay), Te Uku School (Waikato), and Whenuakite School (Coromandel Peninsula). Please see the previous report (Mackie 2011) for more details regarding these workshops. Key geographical and traffic information for each school follows to set a context for the variable speed limit signs that were implemented.

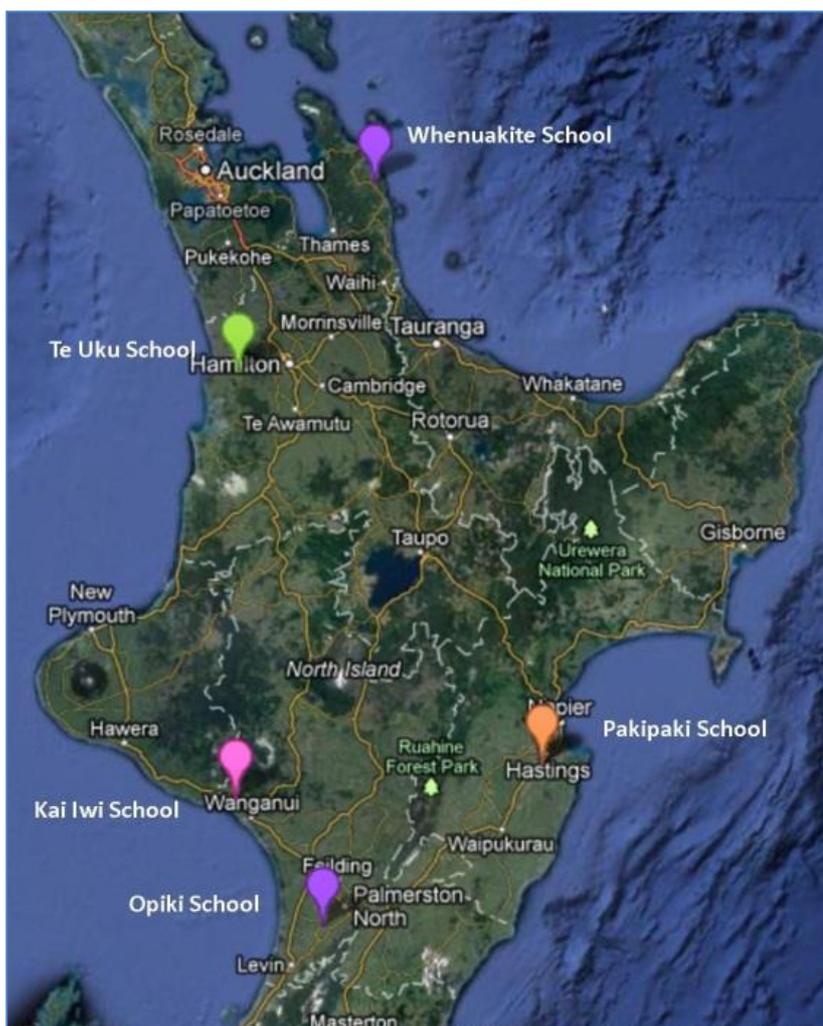


Figure 4. Locations of trial sites

Kai Iwi School, Wanganui

Kai Iwi School is located in a rural setting on State Highway 3 approximately 15km northwest of Wanganui (Figure 5).



Figure 5. Kai Iwi School, State Highway 3 Northwest of Wanganui

The school is situated in a valley on a straight section of highway with slight to moderate curve approaches. The school side of the highway has a wide shoulder with a footpath running parallel to the road from the school grounds to the Kai Iwi Tavern 500m north-west. The opposite shoulder contains a weigh pit, suitable for heavy vehicles. The Annual Average Daily Traffic (AADT) is 4418 vehicles/day with 16.8% heavy vehicles. The existing speed limit past the school, prior to this trial, was 100 km/h at all times.

Opiki School, Horowhenua

Opiki School is located on the intersection of State Highway 56 and two local roads, Tane and Poplar Roads, 18km southwest of Palmerston North (Figure 6). The surrounding landscape is rural although there is a limited settlement surrounding the school.



Figure 6. Opiki School, State Highway 56, Southwest of Palmerston North

The school is situated on flat terrain with moderate winding curves to the north and a relatively straight long section of highway to the south of the school. Public access to the school is off Tane Road which is controlled by a Stop sign. The Annual Average Daily Traffic (AADT) on State Highway 56 is 8188 vehicles/day with 13.6% heavy vehicles. The existing speed limit on the State Highway past the school prior to the trial was 80 km/h (recently reduced from 100 km/hr).

Pakipaki School, Hastings

Pakipaki School is located on State Highway 50A, 9km southwest of Hastings (Figure 7). The surrounding landscape is rural.

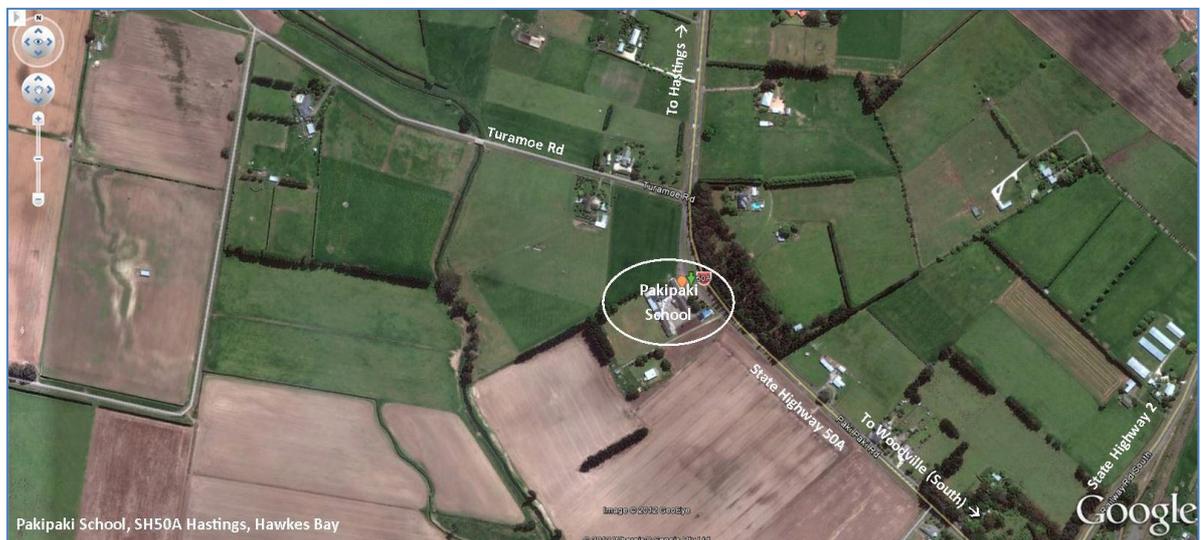


Figure 7. Pakipaki School, State Highway 50A South of Hastings

The school is located on the west side of a moderate curve on flat terrain with a straight section of highway to the north. The approach from the south passes the small settlement of Pakipaki where State Highway 50A intersects with State Highway 2. State Highway 50A is one of three southern state highway links from Hawkes Bay to Wellington. The speed limit outside school prior to the trial was 100 km/hr. The Annual Average Daily Traffic (AADT) is 4665 vehicles/day with 14.1% heavy

vehicles. The school drop off/pick up area consists of a layby area separated from the State Highway by a low level wooden railing.

Te Uku School, Waikato

Te Uku School is located on State Highway 23, 35km west of Hamilton (Figure 8). State Highway 23 is the main access road to Raglan Township and Raglan beaches.



Figure 8. Te Uku School, State Highway 23 West of Hamilton

The school is located next to a local service station and cafe on the north-eastern corner of the intersection of State Highway 23 and local roads Okete & Matakotea Roads. The school itself is set back from the highway with a large yet rough car parking area adjacent to the highway. The surrounding landscape is predominantly rural.

The westbound highway alignment is relatively straight with a gentle left-hand curve on the eastbound approach. The Annual Average Daily Traffic (AADT) is 3508 vehicles/day with 5.8% heavy vehicles. The speed limit outside school sign prior to the trial was 100km/hr, but a symbolic school sign (children) with flashing beacons was operational when the trial commenced.

Whenuakite School, Coromandel Peninsula

Whenuakite School is located on State Highway 25, 27km south of Whitianga and approximately 500 metres south of the Hot Water Beach Road intersection (Figure 9).

The highway alignment approaches to the school are through rolling undulating topography with moderate to tight curves often requiring lower vehicle speeds. The Annual Average Daily Traffic (AADT) is 2660 vehicles/day with 11.8% heavy vehicles. Prior to the trial the speed limit past the school was 100 km/hr. The school drop off/pick up area consists of a lay-by area separated from the main highway by a wide planted island. There is also a separated bus turning area.



Figure 9. Whenuakite School, State Highway 25 South of Whitianga

SIGN IMPLEMENTATION

Based on the risk analyses for each school (reported previously in Mackie 2011), Table 1 shows the speed limits that were agreed for each school, and the times that the variable speed limit signs are activated for during drop-off and pick-up periods.

Table 1 School Speed Limits & Sign Times

	Location	Original Speed Limit (pre-trial)	Reduced Speed Limit (At all times)	Proposed Speed Limits (School times only)	School Sign Times AM	School Sign Times PM
Kai Iwi School	SH 3 (West of Wanganui)	100 km/hr	100km/hr	70km/hr	8:20-8:55am	2:50-3:10pm
Opiki School	SH 56 (Horowhenua)	80km/hr	80km/hr	60km/hr	8:25-9.00am	2:50-3:10pm
Pakipaki School	SH 50A (Hastings)	100 km/hr	80km/hr	60km/hr	8.25-9:00am	2.55-3.20pm
Te Uku School	SH 23 (West of Hamilton)	100 km/hr	80km/hr	60km/hr	8.35-9.10am	2.45-3.05pm
Whenuakite School	SH 25 (South of Whitianga)	100 km/hr	80km/hr	40km/hr	8:25-9.00am	2:55-3:15pm

Figure 10 shows the layout of the variable speed limit signs used on the approaches to each school and Figure 11 shows an example of the static signs used on side roads located within the speed restricted area. For all signs only one sign was located on each approach. Please see Appendix A for the trial speed limit layout for each school.



Figure 10 School variable speed limit signs used in the trial.

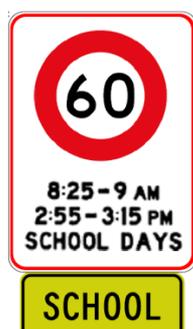


Figure 11 Static variable speed limit signs installed on side roads within variable speed limit area.

The variable speed limit signs were installed by HMI Technologies. The roundel diameter of each sign was 750mm and each sign was solar powered with a radio transmitter providing communication with a controller at each school. Various sign operation programmes were available, offering varying levels of automation. Most schools opted for a programme that required staff to activate the sign system on Monday morning and then turn it off on Friday afternoon (with the precise times of sign activation occurring automatically). Another option was for staff to turn the sign on each school day.

Regulatory requirements

Due to the current law only allowing a maximum speed of 40 km/h for any 'school zone', a Traffic Control Devices application was submitted and approved for this trial, with accompanying NZ Gazette notices, to allow the trial schools to use higher variable speed limits of 60km/h and 70km/hr.

EVALUATION APPROACH

A programme of evaluation was developed by the project team, focussing mostly on outcome measures – short and medium term traffic speed, school feedback and any immediately obvious sign operation or maintenance issues. Any issues observed from the video data that was collected plus road safety expert feedback was also collected.

Vehicle Speed

Prior to the variable speed limit signs being installed at each school, speed measurements were carried out using speed recording tube counters placed across both lanes of the state highway, at a suitable location as close as possible to each school. Data was collected over a 5-15 day period (depending on each school). Speed measurements were also carried out following the implementation of permanent 80 km/h speed limits, where applicable. Approximately one month following the installation of the school variable speed limit signs, the speed measurements were repeated, giving a set of pre/post speed data for each school, following each speed limit change that was introduced. A further data collection period was carried out 9-12 months (depending on the school) following installation, to understand the medium-term effects of the signs on traffic speed.

In order to evaluate the effectiveness of the variable speed limit signs, only the speed data captured within the sign activation times were included. This data was analysed using the following parameters:

- All data with a headway of less than 4 seconds was removed, to eliminate vehicles following another vehicle which may not provide a true representation of a driver's speed choice;
- Removal of weekend data;
- Removal of speed data outside the variable speed limit activation times; and
- Direction of travel separated and analysed.

In addition to this, general (24/7) speed profiles were also created, to provide information on the underlying speed patterns and the effects of the permanent 80 km/h speed limits where they were introduced. The general speed data was analysed using the following parameters:

- All data with a 'Headway' of less than 4 seconds was removed;
- Direction of travel separated and analysed; and
- Due to varying survey periods, all data was analysed by calculating the proportion (%) of vehicles travelling at various speeds.

Speed distribution graphs are provided in Appendix B for each school.

Descriptive statistics (provided in the next section) for each condition were calculated, including average, median, mode, 85% speeds and standard deviation. Graphs were created to show the distribution of speeds for school times for the various speed limit conditions, general speed and also raw data examples from morning and afternoon school times to show the time-series effects of the signs on speed.

School Focus Groups

Workshops involving the school principal, teachers, parents and board of trustees representatives were carried out following sign implementation to collect feedback on the operation of the signs, and the effects of the new speed limits on traffic behaviour outside the schools.

A similar format was used as the initial workshops reported by Mackie (2011), with a mixture of indoor presentations/meetings and outdoor observation of school drop off or pick up behaviour. The project team also conducted 'drive-throughs' to experience the signs first hand.

Expert feedback

A simplified 'Delphi technique' was used to establish a consensus about the effectiveness of the variable speed limit signs. Five road safety experts who have been involved with the rural school research programme (excluding the author) were invited to respond, by email to the following questions:

1. Do you have any comments about the effectiveness of the variable speed limit signs? E.g. Do they catch attention, are they easy to read and understand and is the message credible (given the contexts in which the various speed limits have been applied)? In general, do they send the right message in your view?
2. Do you have any comments on the operation of the signs by schools?
3. Do you have any comments on the time periods over which the signs are activated each day?
4. Do you have any comments about the reliability or maintenance requirements of the signs?
5. In your view, are variable speed limit signs a good solution for addressing road safety concerns at rural schools? Please explain your answer.

The responses were then distilled into key themes that represented the consensus views of the group.

Sign operational issues

Any operational issues with the signs were noted for future consideration. The effectiveness of the signs not only relates to their effect on traffic speed when they are working, but also to the signs reliability and usability. An electronic sign that is not operational potentially causes road safety risk.

EVALUATION OUTCOMES

Vehicle speed

Kai Iwi School

Following installation of the 70 km/h speed limit signs, speed data collected at Kai Iwi School during school sign activation periods (70km/h speed limit) showed significant reductions in speed for westbound vehicles as shown in Table 2. The 85th percentile speed reduced by 30% from 107km/h to 75km/h and the average speed reduced by 27% from 84km/h to 61km/hr. These reductions were maintained when speed was measured again 12 months following installation, although only westbound data is available for this purpose due to a sign fault corrupting data for the eastbound direction.

The eastbound traffic showed very little change in average speed once the 70km/h speed limit was implemented (dropping by 1.3km/h) and the 85th percentile speed increased by 5 km/h to 88km/hr. However, the median and modes dropped much more significantly. Also, prior to the operation of the 70 km/h signs, the eastbound traffic was travelling well below the maximum operating speed of 100km/h during school times, which means that any large drop in speed would be unlikely. The speed distribution graphs for Kai Iwi School during school times show that a double-peak distribution has emerged following the implementation of the signs. This should be treated with caution as it may be that there are two separate sets of expectations about the appropriate speed when the sign is activated, which may not be beneficial to road safety.

Table 2. Kai Iwi School - Speed data during school times 8.20am-8.55am / 2.50pm-3.10pm

Speed Limit	Eastbound		Westbound		
	100km/h	70km/h (3 mnths)	100km/h	70km/h (3 mnths)	70km/h (12 mnths)
Count (vehicles)	1274	737	1263	544	608
Average (km/h)	74	72	84	61	62
Median (km/h)	76	69	93	65	66
Mode (km/h)	76	66	96	68	68
85th percentile (km/h)	84	88	107	75	75
Std Deviation (km/h)	11	13	27	18	16

The general speed data (Table 3) captured prior to the school signs becoming operational show that the eastbound and westbound traffic profiles are very different. This is likely due to the location of the speed tubes near the curve to the east of the school. In the westbound direction, traffic will have crossed the railway bridge and exited the curve and would have accelerated to near full speed with the straight in front of them. In the Eastbound direction traffic would be slowing, in preparation for the curves ahead.

Table 3. Kai Iwi School - General Speed Data – 24/7

	Eastbound	Westbound
Speed Limit	100km/h	100km/h
Count (vehicles)	25096	23681
Average (km/h)	76	97
Median (km/h)	78	98
Mode (km/h)	80	97
85th percentile (km/h)	85	111
Std Deviation (km/h)	10	16

Opiki School

Speed data collected at Opiki School (Table 4) show larger reductions in speed for northbound vehicles compared with southbound vehicles. Following sign installation, the 85th percentile speed slowed from 94 km/h to 82 km/h (13%) for northbound vehicles and from 93 km/h to 89 km/h for southbound vehicles. At the speed tube location, approximately 20m south of the intersection, the school variable speed limit (60 km/h) was possibly more credible in the Northbound direction where motorists would be slowing for the intersection and school zone. In the Southbound direction, motorists may be accelerating with the long straight ahead of them.

In the Northbound direction it appears that average and median speed has increased slightly relative to the 3-month data (albeit with very little change in modal speeds). It is of some concern that 85% speeds have increased by 9 km/h since the signs were installed. In the Southbound direction, traffic speeds have decreased by approximately 3 km/h, including 85% speeds.

Table 4. Opiki School - speed data during school times 8.25am-9.00am / 2.50pm-3.10pm

Speed Limit	Northbound			Southbound		
	80km/h	60km/h (3 mnths)	60km/h (12 mnths)	80km/h	60km/h (3 mnths)	60km/h (12 mnths)
Count (vehicles)	1429	624	813	1525	611	744
Average (km/h)	83	70	75	82	78	75
Median (km/h)	82	69	73	84	78	75
Mode (km/h)	81	72	73	84	76	73
85th percentile (km/h)	94	82	91	93	89	86
Std Deviation (km/h)	11	11	14	13	11	11

The Opiki settlement was already located within an 80km/h zone prior to the trial. General speed data taken prior to the school signs becoming operational show both north and southbound traffic speeds are relatively similar during all times (Table 5).

Table 5. Opiki School - general speed data – 24/7

	Northbound	Southbound
Speed Limit	80 km/h	80 km/h
Count (vehicles)	25525	28884
Average (km/h)	85	87
Median (km/h)	84	87
Mode (km/h)	81	85
85th percentile (km/h)	96	96
Std Deviation (km/h)	11	11

Pakipaki School

Speed data for Pakipaki School (Table 6) show similar reductions in average and 85% speeds between north and southbound vehicles following the speed limit reduction from 80km/h to 60km/h during school times. However, in the northbound direction, there was a greater reduction in the mode, suggesting a greater tendency for some motorists to slow to the sign-posted 60 km/h in this direction. Twelve months following sign installation there may have been further reductions in traffic speed, particularly in the southbound direction. It also appears that the permanent 80 km/h speed limit reduction had some effect on traffic speeds during school times particularly in the southbound direction, prior to the implementation of the variable signs.

Table 6. Pakipaki School - Speed data during school times 8.25am-9.00am / 2.55pm-3.20pm

Speed Limit	Northbound				Southbound			
	100km/h	80km/h	60km/h (1 mnth)	60km/h (12 mnths)	100km/h	80km/h	60km/h (1 mnth)	60km/h (12 mnths)
Count (vehicles)	806	676	569	1554	780	558	620	1616
Average (km/h)	76	76	67	67	87	82	73	70
Median (km/h)	78	77	66	66	88	82	73	70
Mode (km/h)	78	77	59	64	88	83	73	72
85th percentile (km/h)	86	85	79	78	98	90	83	80
Std Deviation (km/h)	11	10	11	10	12	9	10	10

General speed data (Table 7) taken prior to implementation of the variable signs show the average northbound speeds are approximately 10km/h slower than southbound vehicle speeds for the 100km/h speed limit, presumably due to the effects of having just travelled through Pakipaki village and negotiating an intersection. The permanent 80 km/h signs reduced speeds significantly (approximately 7 km/hr) in the southbound direction.

Table 7. Pakipaki School - general speed data – 24/7

Speed Limit	Northbound		Southbound	
	100km/h	80 km/h	100km/h	80 km/h
Count (vehicles)	15182	10961	16446	12082
Average (km/h)	80	77	89	82
Median (km/h)	80	78	89	82
Mode (km/h)	80	78	88	82
85th percentile (km/h)	89	86	100	91
Std Deviation (km/h)	10	10	11.3	9.5

Te Uku School

Traffic speeds for Te Uku School (Table 8) show that the vehicle speeds during school drop-off and pick-up times are lower than the general speed data shown in Table 9 (more so than for the previous three schools). Interestingly speeds went up in the eastbound direction in particular following the implementation of the 80 km/h signs, however, the speeds are well below the posted speed limit and there may have been varying conditions when the speeds were measured.

The variable school signs resulted in speed reductions to near the posted (60 km/hr) speed limit in both the eastbound and westbound directions. Further reductions in speed are shown 11 months following sign installation, although a slightly different location for the tube counter may have influenced the results. In particular, the 11 month results appear to be contaminated with a greater proportion of low speed or café traffic. Nevertheless, the modal speeds should still give a reasonable indication of through traffic speed and clearly traffic speed past the school that is near the posted variable speed limit of 60 km/h has been maintained.

Table 8. Te Uku School - Speed data during school times 8.30am-9.05am / 2.45pm-3.05pm

Speed Limit	Eastbound				Westbound			
	100km/h	80km/h	60km/h (2mnths)	60km/h (11mnths)	100km/h	80km/h	60km/h (2mnths)	60km/h (11mnths)
Count (vehicles)	377	578	622	643	239	370	399	629
Average (km/h)	65	70	62	57	70	70	63	56
Median (km/h)	65	73	63	59	71	71	62	57
Mode (km/h)	63	78	63	58	74	77	63	58
85th percentile (km/h)	84	85	78	78	87	84	77	77
Std Deviation (km/h)	17	16	16	20	15	14	12	20

The general speed data (Table 9) shows that the average speeds were affected very little by the 80 km/h speed limit, again perhaps reflecting a natural traffic speed that is near this speed. However, the modal speeds have decreased significantly, as has the speed variability, particularly in the westbound direction. Overall, the westbound direction is likely to provide the most reliable data as the speed tubes were placed slightly to the east of the school and therefore the traffic is less likely to be affected by other factors such as the school, cafe, intersection etc.

Table 9. Te Uku School - general speed data – 24/7

Speed Limit	Eastbound		Westbound	
	100km/hr	80 km/hr	100km/hr	80 km/hr
Count (vehicles)	4512	9444	3591	8365
Average (km/h)	78	80	80	80
Median (km/h)	82	82	83	81
Mode (km/hr)	90	84	87	80
85th percentile (km/h)	95	95	97	92
Std Deviation (km/h)	18	16	17	12

Whenuakite School

Traffic speeds at Whenuakite School (Table 10) show that the natural traffic speed during school times is significantly lower than the 100 km/h or even 80 km/h speed limits. The introduction of the 40 km/h variable speed limit signs has resulted in a 10% reduction in the 85th percentile speeds of southbound vehicles and 8% reduction in northbound vehicles (compared with 100km/h speed limit). There was a 15% reduction in the average speeds of northbound vehicles between the 80km/h and 40km/h speed limit conditions, but only a 2% reduction in southbound vehicle speeds. In the southbound direction, the sign was reported being shaded by a nearby hedge and may have meant that the sign was not working as effectively as the northbound sign. In the northbound direction, traffic speed reduced to within 3-5 km/h of the posted 40 km/h speed limit.

In general, northbound speeds increased slightly (except modal speed) 11 months following sign installation, less so in the southbound direction with modal speed decreasing slightly. In both the Northbound and Southbound directions 11-month 85% speeds increased relative to the 2-month speeds.

Table 10. Whenuakite School - speed data during school times 8.25am-9.00am / 2.55pm-3.15pm

Speed Limit	Northbound				Southbound			
	100km/h	80km/h	40km/h (2 mnths)	40km/h (11mnths)	100km/h	80km/h	40km/h (2 mnths)	40km/h (11mnths)
Count (vehicles)	298	323	287	413	391	407	360	538
Average (km/h)	52	53	45	51	58	56	52	53
Median (km/h)	54	56	44	48	58	57	50	51
Mode (km/h)	53	63	43	43	48	N/A	46	43
85th percentile (km/h)	70	70	59	69	74	69	68	72
Std Deviation (km/h)	17	16	14	16	14	13	13	16

General vehicle speeds are significantly higher than the speeds during school times only, but due to the relatively low traffic speeds at this segment of road, the 80 km/h signs have had limited effect in further reducing speed. There may have been some reduction in 85thile speeds.

Table 11. Whenuakite School - general speed data – 24/7

Speed Limit	Northbound		Southbound	
	100km/hr	80 km/hr	100km/hr	80 km/hr
Count (vehicles)	5177	4703	5434	5018
Average (km/h)	68	66	69	67
Median (km/h)	70	68	71	69
Mode (km/hr)	73	73	73	72
85th percentile (km/h)	81	78	82	80
Std Deviation (km/h)	14	13	13	13

School focus groups

The key points from the follow-up focus groups, as well as outstanding issues that were raised in the initial focus group are given in Table 12 below. Without exception, all school personnel reported a noticeable reduction in the speed of traffic past their school. People from two schools also specifically mentioned that turning into and out of the school property is now easier with the variable speed limit signs. This positive feedback supports the findings of the vehicle speed outcomes. However, almost all schools mentioned outstanding issues, mostly unrelated to the signs specifically, that may need further attention.

Table 12. Main points from follow-up school focus groups, incorporating any outstanding concerns from initial focus groups.

School	Feedback & Outstanding Concerns
Kai Iwi School	<p>Feedback</p> <ul style="list-style-type: none"> ● Vehicle speeds appear to have reduced dramatically during drop off and pick up times and traffic noise is much lower. ● Turning into and out of the school has become a lot easier. <p>Outstanding</p> <ul style="list-style-type: none"> ● Overtaking by ‘through’ traffic is still a concern and request double yellow centrelines lines are marked outside the school. ● The school would like to consider using the hall car park for parking next door but access is difficult and request improvements are made. ● Move the road sign blocking bus driver’s visibility. ● Remark no-stopping lines outside school entrance. ● Restrict use of weigh-pit. ● Improve conspicuity of the school. School investigating visual options for this.
Opiki School	<p>Feedback</p> <ul style="list-style-type: none"> ● Noticeable improvements in road safety since the signs were installed. ● The “School Ahead No Excuses” sign is very effective. ● The school lacks a presence for vehicles travelling from the north on SH56. <p>Outstanding</p> <ul style="list-style-type: none"> ● Vehicle speeds on Tane Road (side road) is a concern. ● Bus parking continues to be problematic when the area is used for school drop offs. ● Concern for children within car park. Re-design access. ● Improve conspicuity of the school. ● Investigate installing threshold signs when speed limit is gazette, to reinforce speed change ● Relocation of the recycling bin.
Pakipaki School	<p>Feedback</p> <ul style="list-style-type: none"> ● Southbound traffic is noticeably slower when signs are on. ● Turning into the school is a lot easier with the reduced speed limits. ● Road noise has reduced. <p>Outstanding</p> <ul style="list-style-type: none"> ● The school would like to extend the times the signs are activated to 8am-9am, and two afternoon periods, reactivated at 4pm for high school bus drop off. ● Improve conspicuity of the school. ● Paint “School” on the road at the northern approach to the school. ● Install a barrier around the curve and along the footpath.

<p>Te Uku School</p>	<p>Feedback</p> <ul style="list-style-type: none"> ● The 60km/h signs have reduced speeds. ● Marking out the coffee shop car park has made an improvement. ● The school requests a right turning bay into the school. <p>Outstanding</p> <ul style="list-style-type: none"> ● Remove the 'Temporary' plates on the 80km/h signs. ● Repair pot holes outside school, and longer-term redesign and rebuild drop-off and parking area ● Electronic signs to be turned on weekly instead of daily. ● Investigate pedestrian access/safety past coffee shop. ● Look at trimming hedge west of Okete Rd. ● Look at small fence outside School along State Highway, to prevent heavy vehicles parking there. ● Mark the school car park entry & exit.
<p>Whenuakite School</p>	<p>Feedback</p> <ul style="list-style-type: none"> ● Sign operation times are good. ● Vehicles are slowing down and are a lot less impatient. ● There is a lot less overtaking outside the school. ● Power cuts affect the operation of the signs. ● Northern electronic sign is shaded (solar power) and does not always work. <p>Outstanding</p> <ul style="list-style-type: none"> ● Trees blocking sunlight to signs (solar panel) need to be trimmed. ● NZTA to investigate installing additional batteries as back-up.

Road safety expert feedback

Five road safety experts responded to the questions about the variable speed signs. Their summarised responses are outlined below.

1. Do you have any comments about the effectiveness of the variable speed limit signs? E.g. Do they catch attention, are they easy to read and understand and is the message credible (given the contexts in which the various speed limits have been applied)? In general, do they send the right message in your view?

Yes the signs are effective – they catch attention, are easy to read and are credible and the school sign helps with credibility, although the “School” sign might be larger for greater effect. It will be important to develop specifications that manufacturers comply with for these signs in the longer term. Their effectiveness suggests that gated signs are not required. It appears that a small number of more extreme drivers still don’t comply with them.

2. Do you have any comments on the operation of the signs by schools?

There is some concern about the operation procedures. Some feel that a high level of automation is needed to remove human variability from the system, others feel that they should continue to be operated by schools and flexibility is needed. The operating system may need some attention.

3. Do you have any comments on the time periods over which the signs are activated each day?

Any system needs to ensure that the operation times are reliable and consistent, each day and throughout the year. The operation times also need to be credible and matched to school travel activities. There have been many requests to adjust the timing of the sign, often with longer operation periods requested. On the other hand, the times may need to be kept short to maximise credibility.

4. Do you have any comments about the reliability or maintenance requirements of the signs?

Generally sign reliability seems ok although in one area, two signs have required repair recently. It is important that communication between schools, RCAs and the sign manufacturers is effective to ensure good response times to faults.

5. In your view, are variable speed limit signs a good solution for addressing road safety concerns at rural schools? Please explain your answer.

Variable speed limit signs at schools appear to be a very useful tool, to be used when the right mix of risk factors exist at rural schools. They should be considered alongside other intervention options both on the highway and on school property, but they can also be considered as a cost effective option when other more expensive road engineering solutions might be cost prohibitive.

Sign operational issues

The following issues regarding sign operation were noted during the trial:

Shading by nearby trees. Although not completely verified, at Whenuakite School, a nearby hedge tended to shade one of the electronic signs, which may have temporarily affected its performance. Some of the vegetation was cut back to allow more sunlight on the solar panel.

Sign operation times. The actual time that the signs are operational seems to depend on a number of factors including the agreed time periods during programming, the type of programme that is used for the controller and also the reliability of school staff in turning the signs on and off. One school preferred the daily sign operation (turn on manually each day) but variability in the sign operation seemed to be related to when the responsible staff member arrived at school to turn the sign on. More consistency around sign operation would be useful, although the varying needs of each school need to be considered, including school start and finish times, bus run times and the time over which parents arrive at and leave the school. More instruction and perhaps an easier to use controller might help. At least one school mentioned that a longer sign operation time (especially in the afternoon) might be useful given the extended nature of commuting activity at that school.

Usability of the controller. Some school staff reported that they found it difficult to first understand how to use the controller, or they thought the signs were not working properly when the problem may have been their understanding of the controller. The need to adjust the controller for daylight saving time is something that could be made more obvious to school staff and a reminder may be needed when times change.

Sign failure/damage. Since the variable speed limit signs have been installed, there has been damage to one of the signs at Opiki and a technical failure at one of the Kai Iwi signs. While maintenance and repair issues are inevitable it is important that any signs that are not functioning

are repaired or replaced as soon as possible to prevent any road safety risk. Lines of communication for reporting faults and then agreed response times may be important considerations for future installations.

DISCUSSION

Overall, it would be reasonable to conclude that the variable speed limit signs at rural schools have been successful in significantly reducing vehicle speeds during school drop-off and pick-up times. The signs resulted in significant reductions in speed and they were perceived to be very effective in improving traffic behaviour and safety by school communities. Furthermore, these speed reductions have been sustained over an extended period (up to 12 months post installation). This positive finding from the longer-term data is important as a long-term evaluation of variable speed limit signs in New Zealand has never been carried out. The findings suggest that these signs, in school environments, do not generally suffer from the initial novelty effect that is often associated with various other signs. One minor observation that should be investigated further with future school variable speed limit evaluations is the possible tendency for 85% speeds to creep back upwards over the longer term, with modal speeds often unchanged. This may suggest that while most motorists continue to respond to the signs over time, those who prefer to driver faster become desensitised to the signs. However, much more analysis is required before any more definite statement can be made in this regard. This phenomenon was only observed at two sign locations (across two of the five schools).

For Kai Iwi school, the only one with a 70 km/h speed limit reduction, very strong compliance was achieved with operating speed during school times generally being very close to this limit. For the schools that received 60 km/h speed limit reductions, average traffic speed tended to reduce to approximately 70 km/h in higher speed environments and approximately 63-65 km/h in lower speed environments. For Whenuakite, the 40 km/h speed limit generally resulted in traffic speeds of approximately 45-50 km/h in this naturally lower speed environment.

In a previous report (Mackie 2010), investigating the likely speed responses to electronic variable speed limit signs as part of the development of a Rural Intersection Active Warning System (RIAWS), a graph of sign-posted vs actual speeds for various previous trials was presented. In Figure 12 below, the typical findings from this school sign trial are overlaid onto this graph as a comparison (with the latest NZ RIAWS example included). It appears that the speeds from the present trial were consistently lower than those presented from other variable speed limit trials, although there was a similar high level of compliance for both the rural school and RIAWS 70 km/h examples. Some of this may be due to the naturally lower speed of some of the roads in the present trial, although it does also seem that the signs in the present trial were particularly effective. This trend may be explained by a high degree of credibility associated with the current signs, reinforced by the fact that many motorists slow down past rural schools during these times, to some degree, even without a lower variable speed limit.

The relatively high level of compliance with these signs suggests that it may be possible to aim for lower speed limits than one might normally consider acceptable, while still maintaining credibility and compliance by motorists – depending on the natural operating speed of the road and the presence of other cues that indicate why slowing down is necessary (such as a visible school environment with relevant commuter activity).

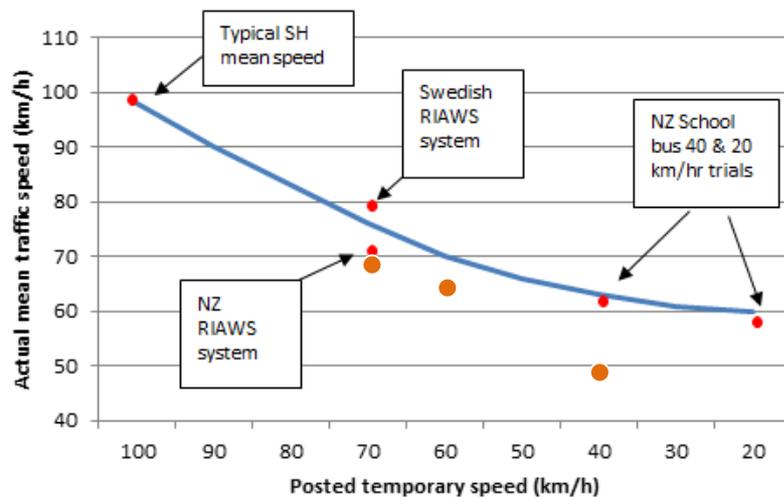


Figure 12. Typical operating speed responses to various variable speed limit systems, with the typical rural school variable speed limits from the present trial overlaid (orange dots).

Aside from the signs, it is clear from the focus group and expert feedback that variable speed limit signs are unlikely to be a comprehensive solution for schools, as at most schools a number of other outstanding issues have been raised or reconfirmed. Many of these issues related to school property and procedures, and this reinforces the need for a joint responsibility model for any road safety improvements. It does seem that the likelihood of school property related issues being addressed is less likely than for highway improvements, no doubt due to the limited resources available to schools. However, given that resources are limited for most agencies in the present climate, a 'road safety contract' could be developed between schools and RCAs to ensure that both highway and school property issues are addressed. For example, such a contract might insist that if variable speed limit signs are installed, then the school must improve (or enforce) procedures for picking up and dropping off students. Whatever the solution, it would seem fair that the responsibility for road safety investment at rural schools rests, not only with the RCA.

Systems for operating the signs need to be considered further including school training, design of the controller, instructions and operation programmes available. From the trial schools it does seem that the weekly programme is superior to a daily operation programme as there is less room for operator error. However, it also appears that different schools have different requirements in terms of when the signs need to operate and often flexibility is also needed.

There is also a need to ensure a rapid response to sign failures and a maximum acceptable 'out time' could be specified in variable speed limit standards.

As mentioned earlier, other school signs are also in use or are being trialled, including a more substantial version including gated signs and associated road marking, planned by Auckland Transport (Figure 13).



Figure 13. Variable speed limit configuration soon to be trialled by Auckland Transport

It would be useful to compare the evaluation findings from these various trials so that collectively, an understanding of the relative effectiveness (and costs) of the various sign/marking options can be considered. This would help to inform a more consistent and cost effective approach to addressing rural school road safety in the future.

In order to achieve consistency, to reduce the burden on RCAs and to make the process of addressing community concerns clearer and more transparent, rural school road safety guidelines are currently being developed. Such guidelines will focus on the whole of New Zealand and are being developed in partnership with NZTA, Ministry of Education, local road controlling authorities and school communities among other stakeholders.

RECOMMENDATIONS

Some specific recommendations from this report are:

- Continue the trial of LED variable speed limit signs for rural schools. While they appear to be effective, there are still some outstanding questions regarding their use
- Further consideration of the approach for determining the actual speed limit is needed
- Consider supporting engineering treatments where appropriate
- Explore ways of ensuring that schools and their communities take some responsibility for road safety at their school. Given the evidence presented to date, complete solutions cannot be provided solely by road controlling authorities
- Complete and implement rural school road safety guidelines taking a holistic approach and focusing on the whole of New Zealand, so that the above recommendations can be carried out in a considered and systematic way.

APPENDIX A – TRIALS SITES SIGN LAYOUT & PHOTOS

Kai Iwi School, State Highway 3, Wanganui



Figure 14 Kai Iwi School - Trial Signs Location & Layout



Figure 15 70km/h LED Mandatory Speed Sign Installed - Left: Eastbound, Right: Westbound

Opiki School, State Highway 56, Manawatu



Figure 16 Opiki School - Trial Signs Location & Layout



Figure 17 (i&ii) 60km/h LED Mandatory Speed Sign Installed - Left: Northbound, Right: Southbound

Pakipaki School, State Highway 50A, Hawkes Bay



Figure 18 Pakipaki School - Trial Signs Location & Layout



Figure 19 60km/h LED Mandatory Speed Sign Installed - Southbound



Figure 20 Pakipaki School - Side Road Warning Signs on Turamoe Road

Te Uku School, State Highway 23, Waikato

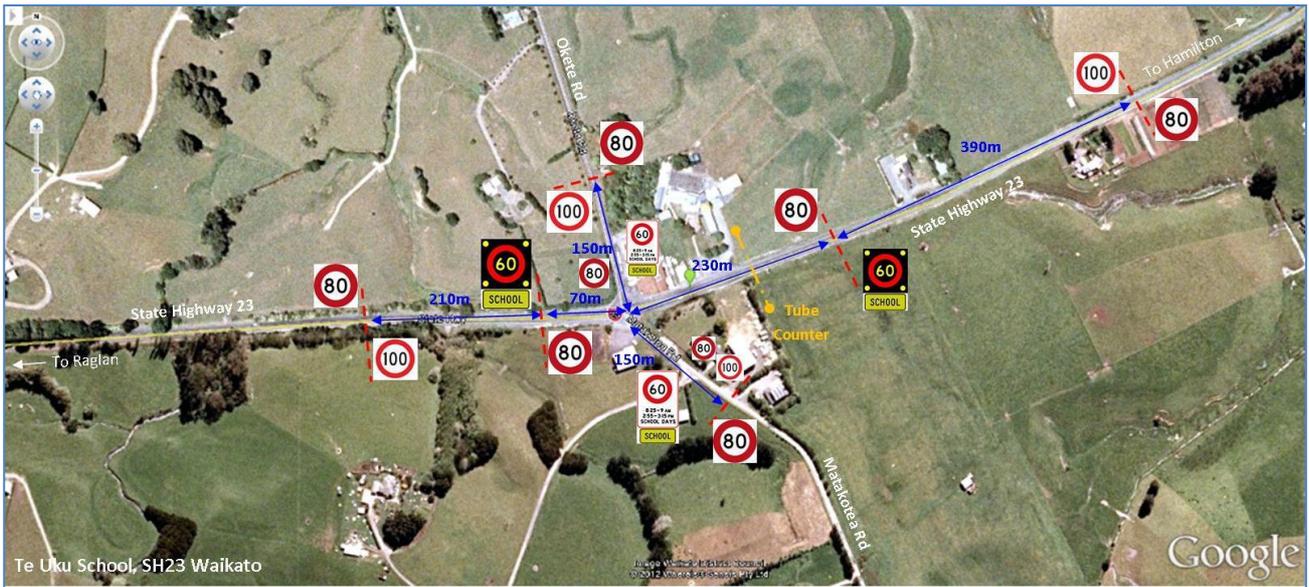


Figure 21 Te Uku School - Trial Signs Location & Layout



Figure 22 (i&ii) 60km/h LED Mandatory Speed Sign Installed - Left: Westbound, Right: Eastbound



Figure 23 (i&ii) Te Uku School - Side Road Warning Signs on Okete Rd (left) and Matakotea Road (right).

Whenuakite School, State Highway 25, Coromandel Peninsula

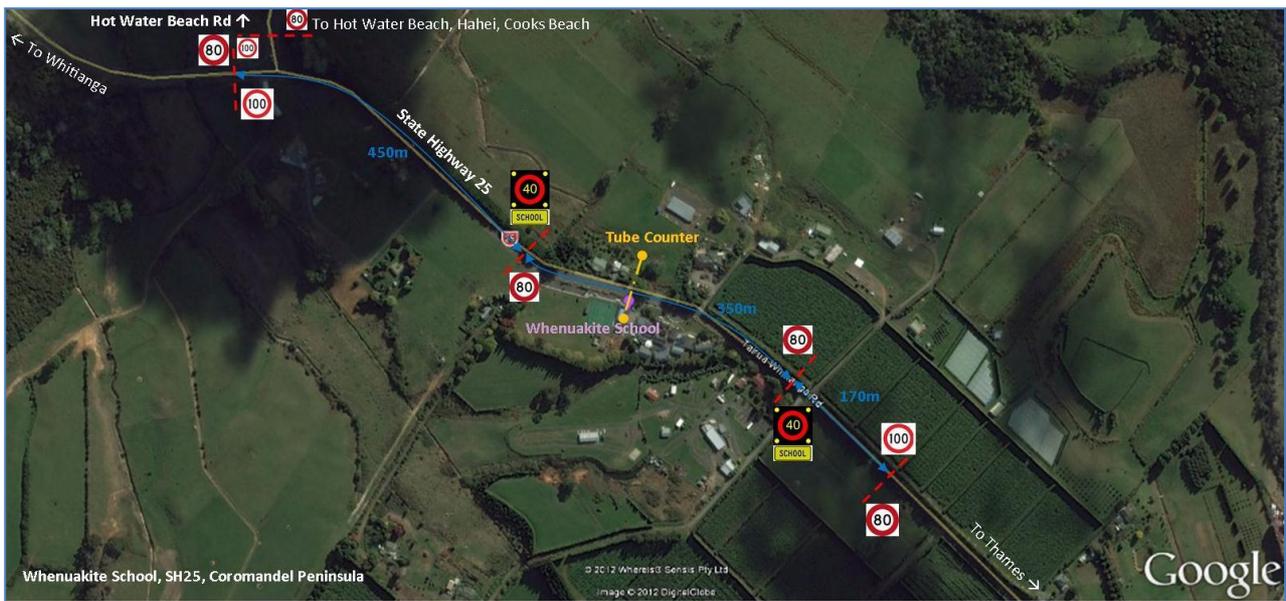


Figure 24 Whenuakite School - Trial Signs Location & Layout

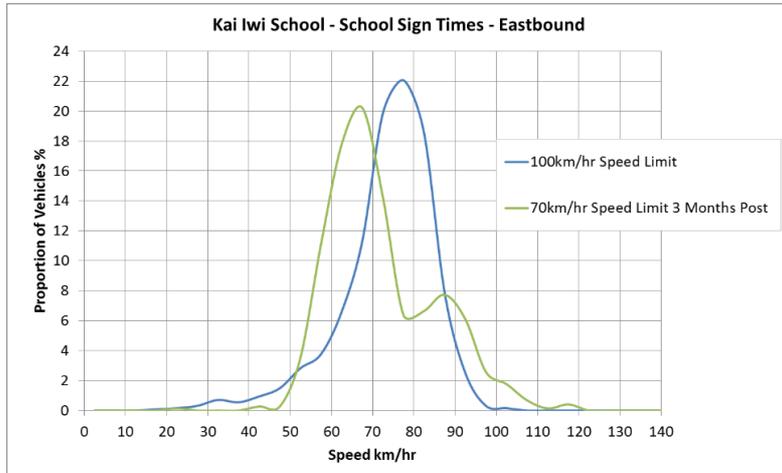


Figure 25 (i&ii) 40km/h LED Mandatory Speed Sign Installed - Left: Northbound, Right: Southbound

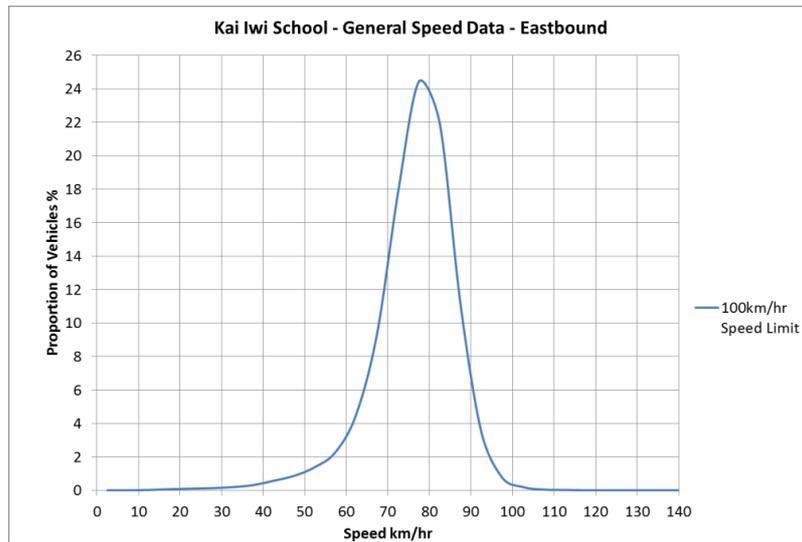
APPENDIX B – SPEED DATA GRAPHS

Kai Iwi School – Eastbound

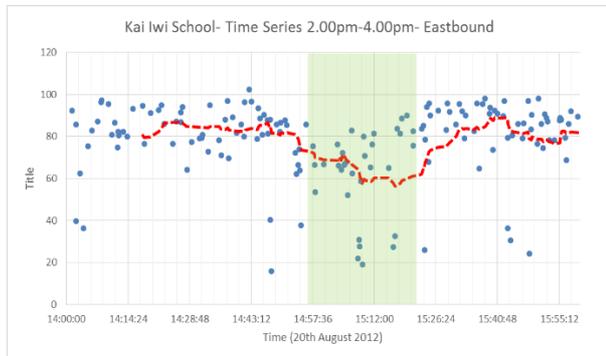
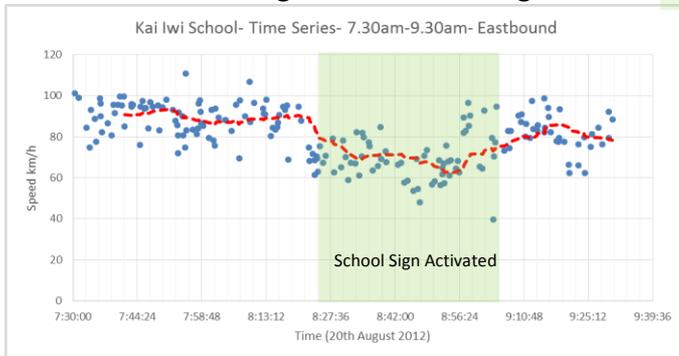
School Sign Times – 8.20am-8.55am / 2.50pm-3.10pm



General Speed Data

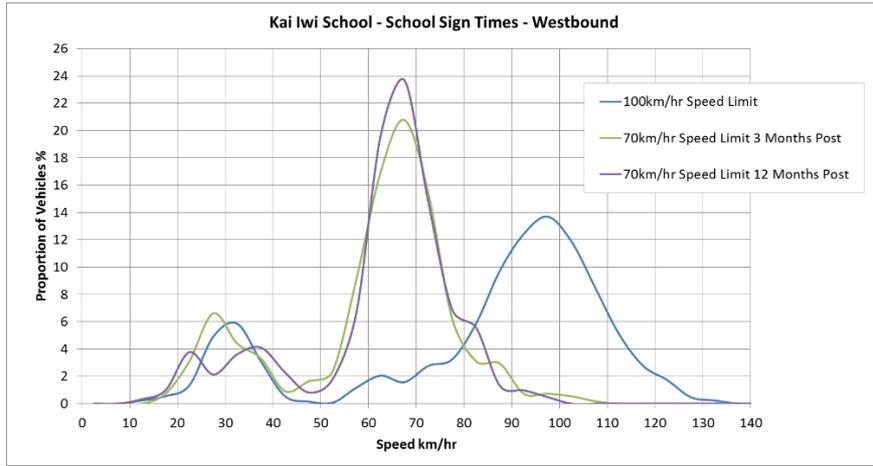


Time Series - School Sign Installed – 20 August 2012

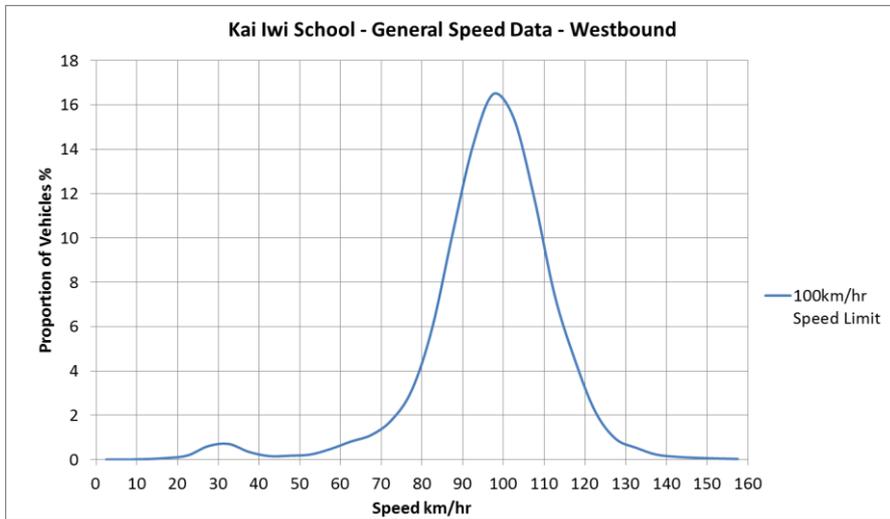


Kai Iwi School – Westbound

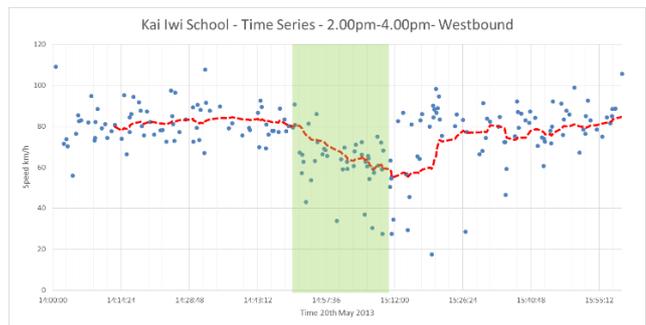
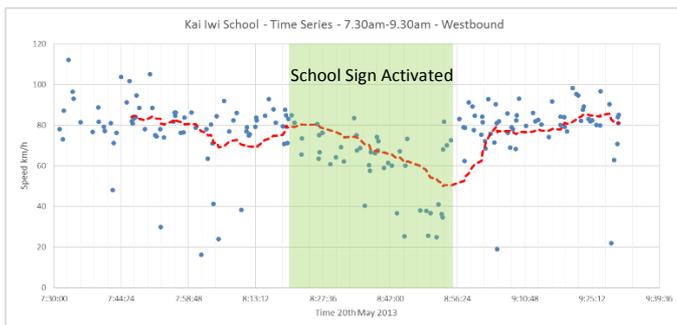
School Sign Times – 8.20am-8.55am / 2.50pm-3.10pm



General Speed Data

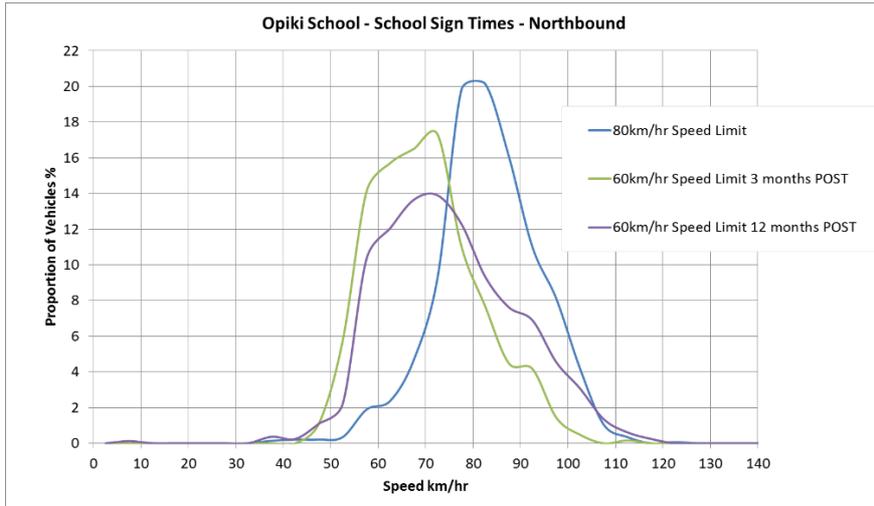


Time Series - School Sign Installed – 20th May 2013

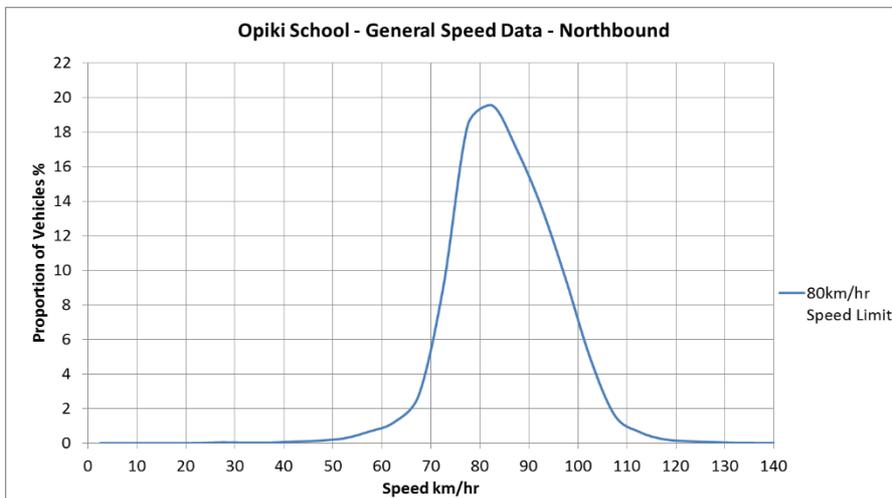


Opiki School – Northbound

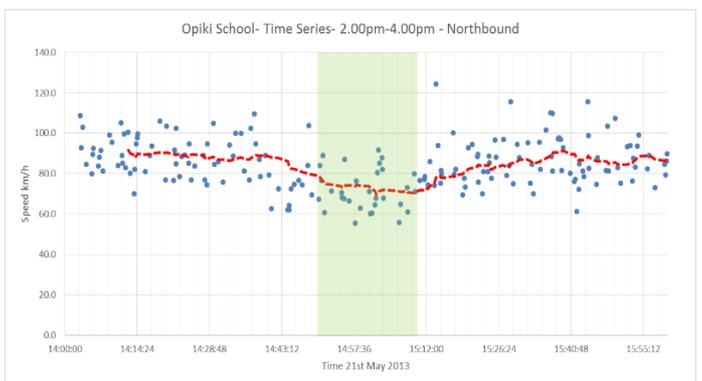
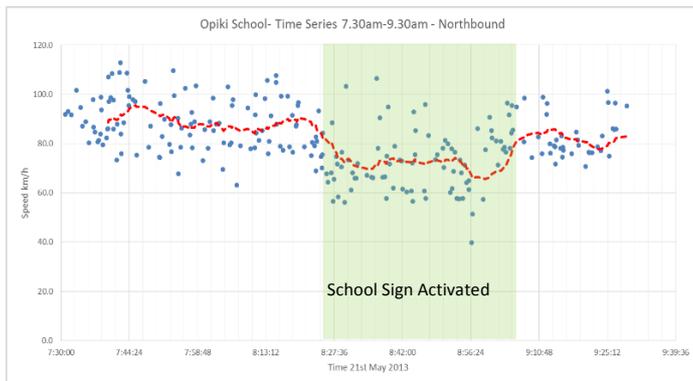
School Sign Times – 8.25am-9.00am / 2.50pm-3.10pm



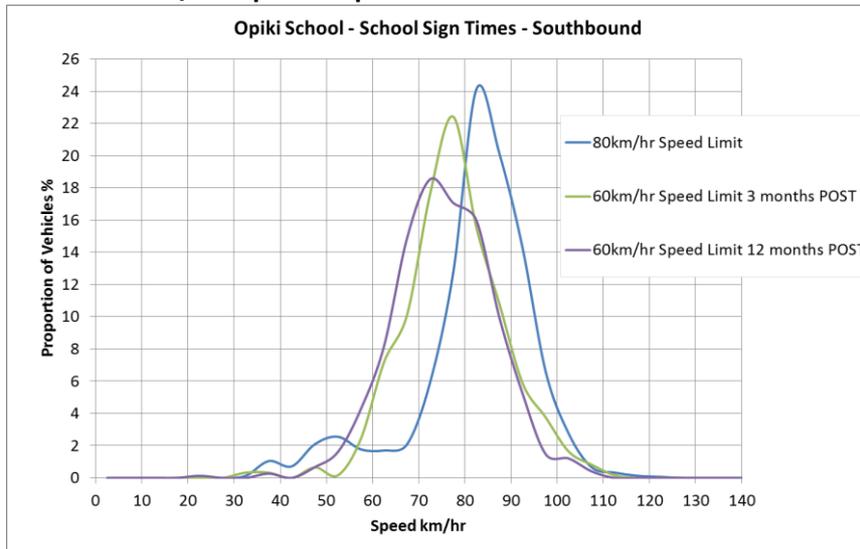
General Speed Data



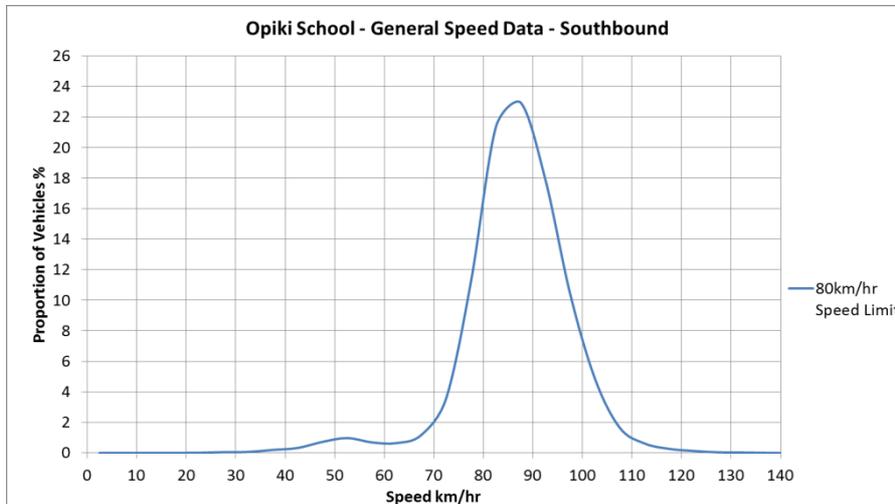
Time Series - School Sign Installed – 21 May 2013



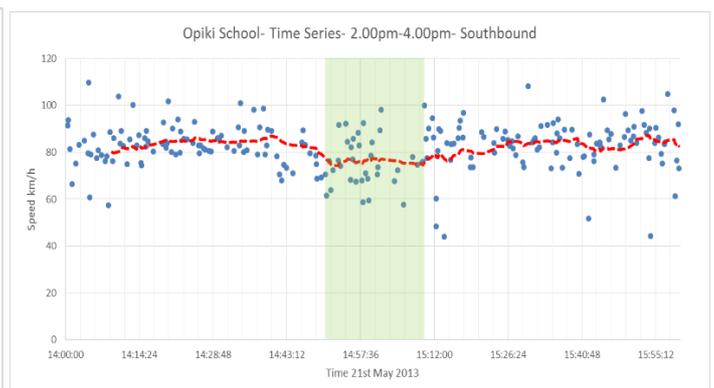
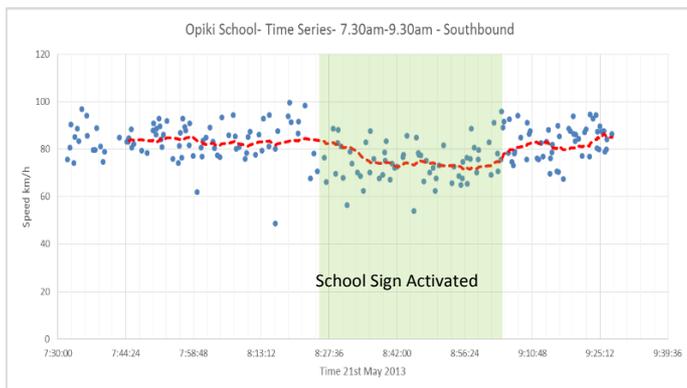
Opiki School – Southbound
School Sign Times – 8.25am-9.00am / 2.50pm-3.10pm



General Speed Data

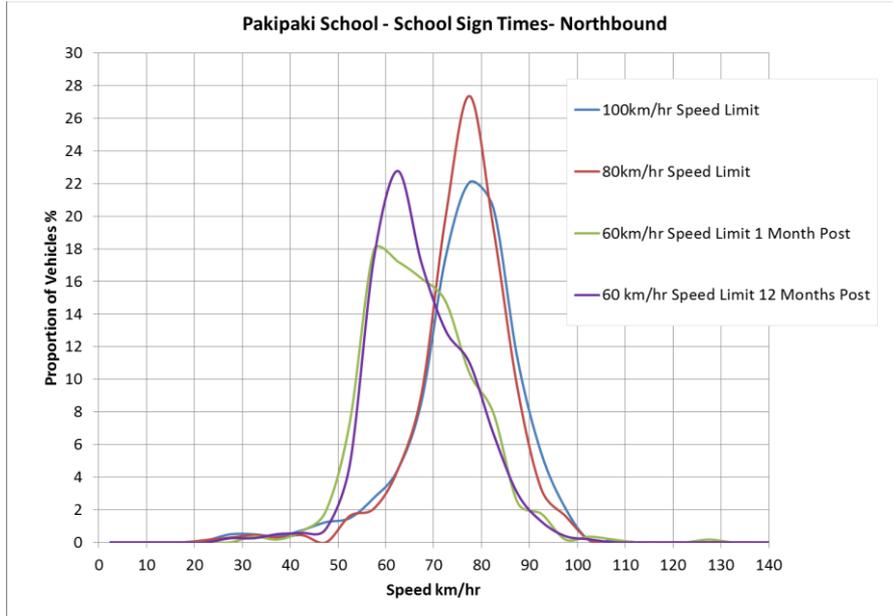


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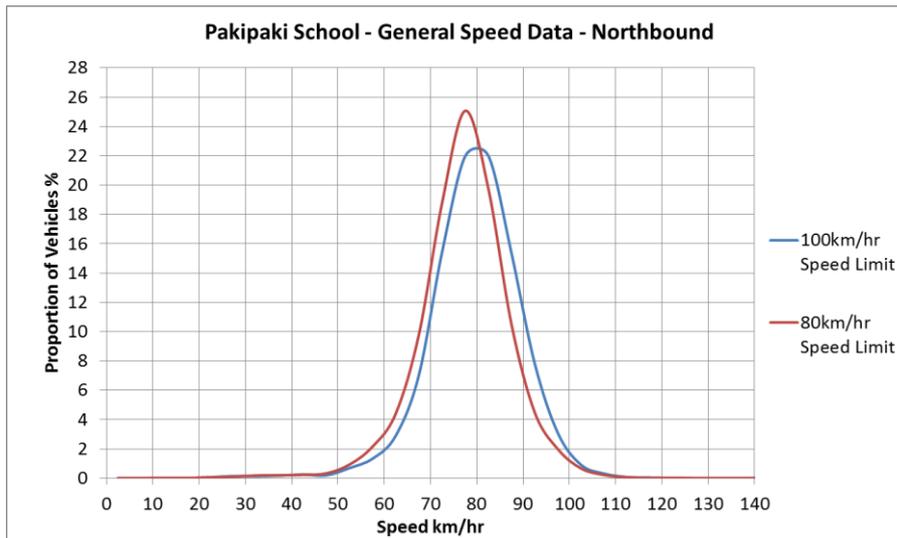


Pakipaki School – Northbound

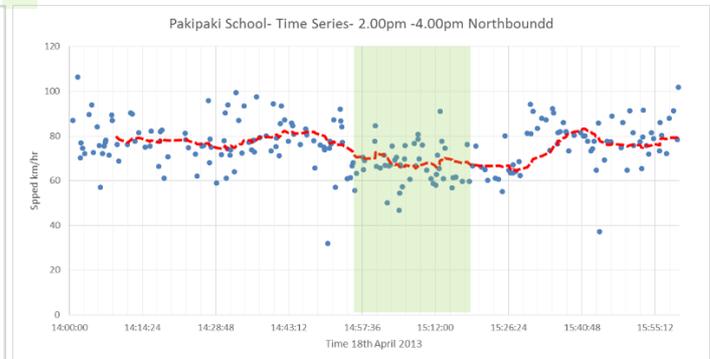
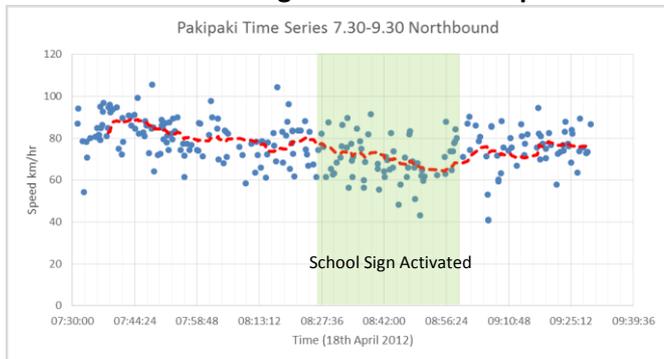
School Sign Times – 8.25am-9.00am / 2.55pm-3.20pm



General Speed Data

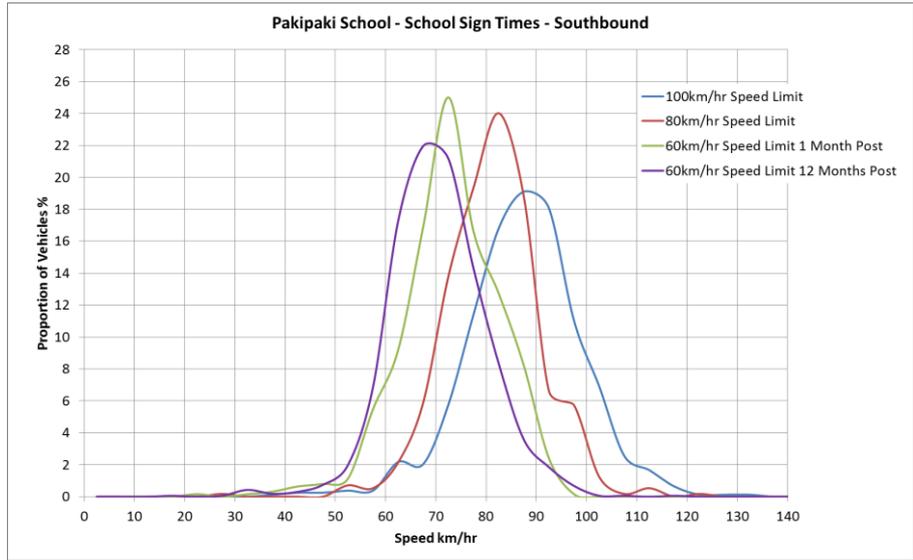


Time Series - School Sign Installed – 18th April 2013

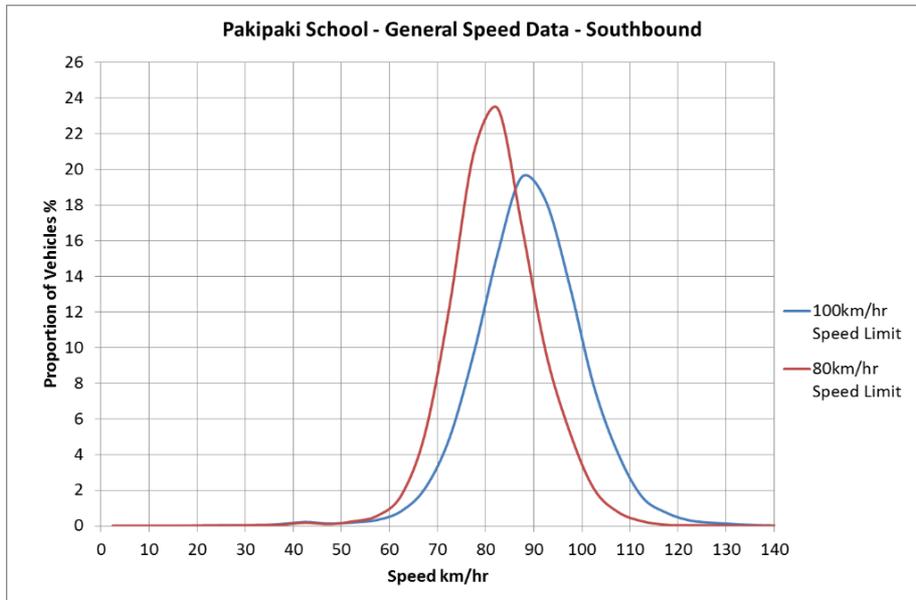


Pakipaki School – Southbound

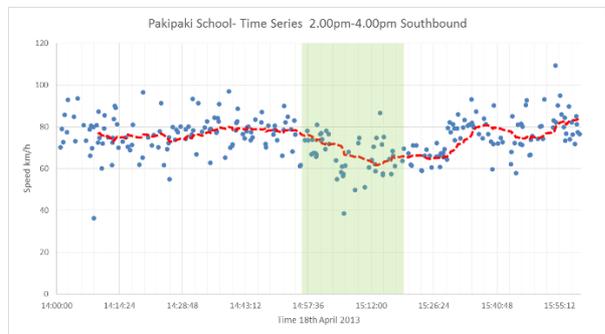
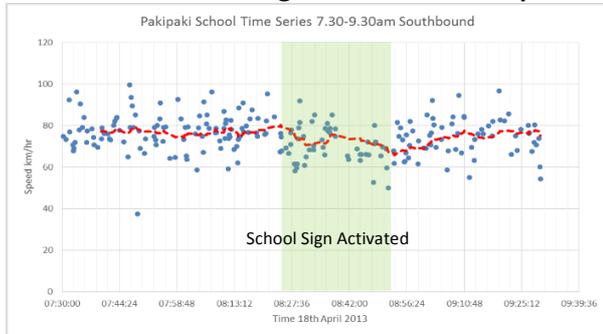
School Sign Times – 8.25am-9.00am / 2.55pm-3.20pm



General Speed Data

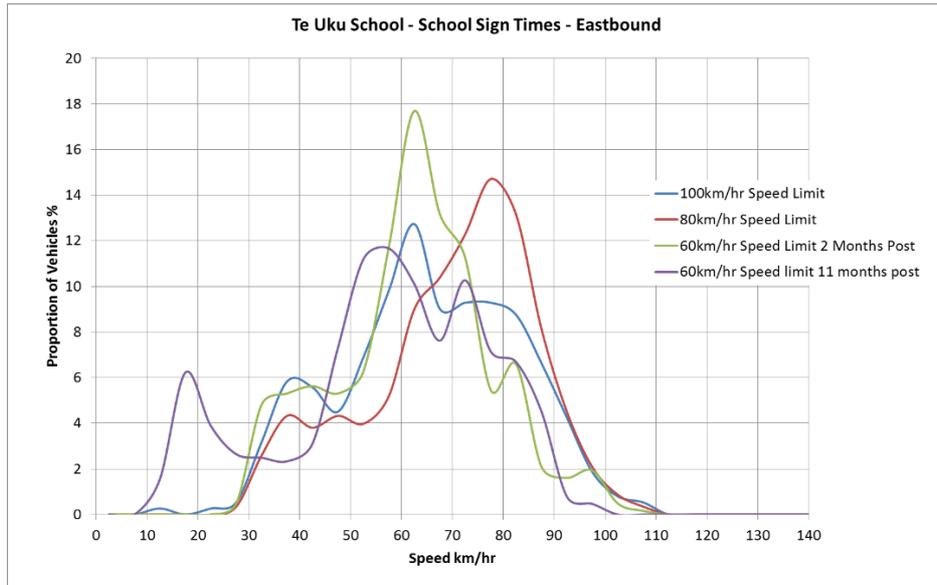


Time Series - School Sign Installed – 18th April 2013

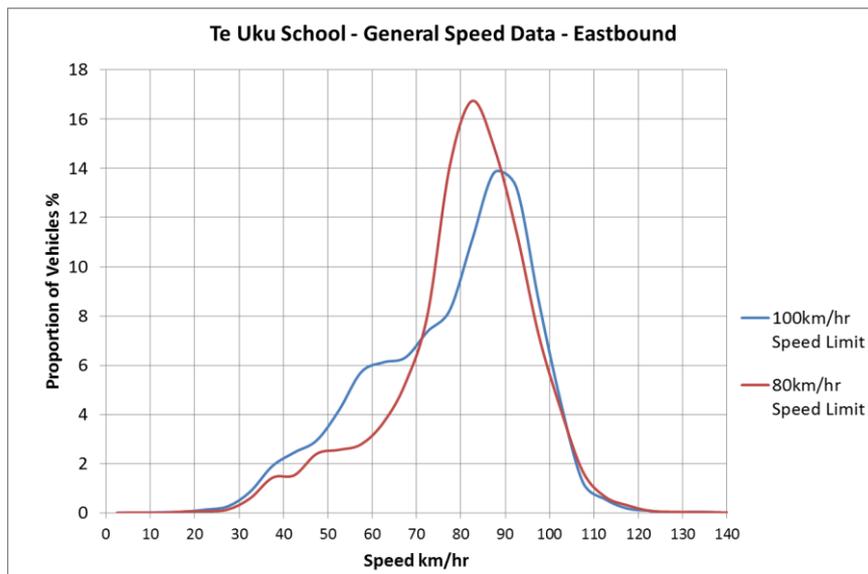


Te Uku School – Eastbound

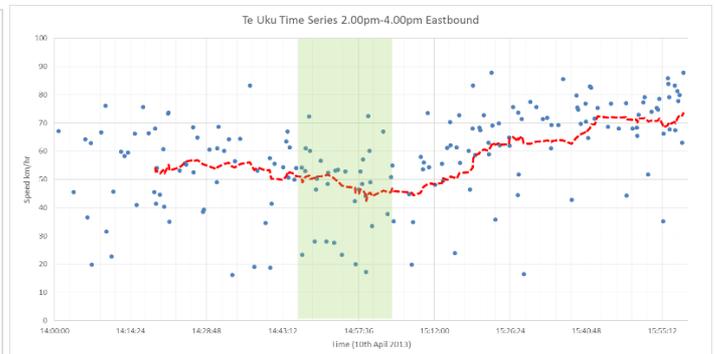
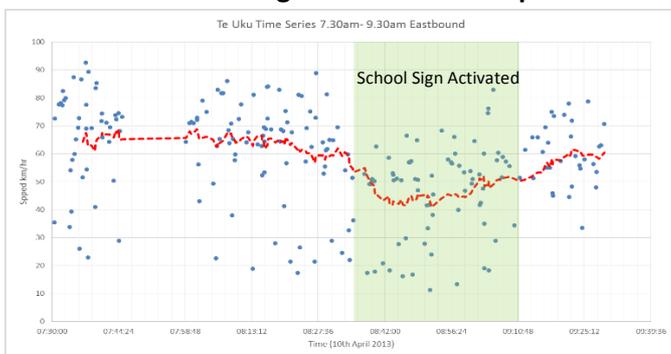
School Sign Times – 8.35am-9.10am / 2.45pm-3.05pm



General Speed Data

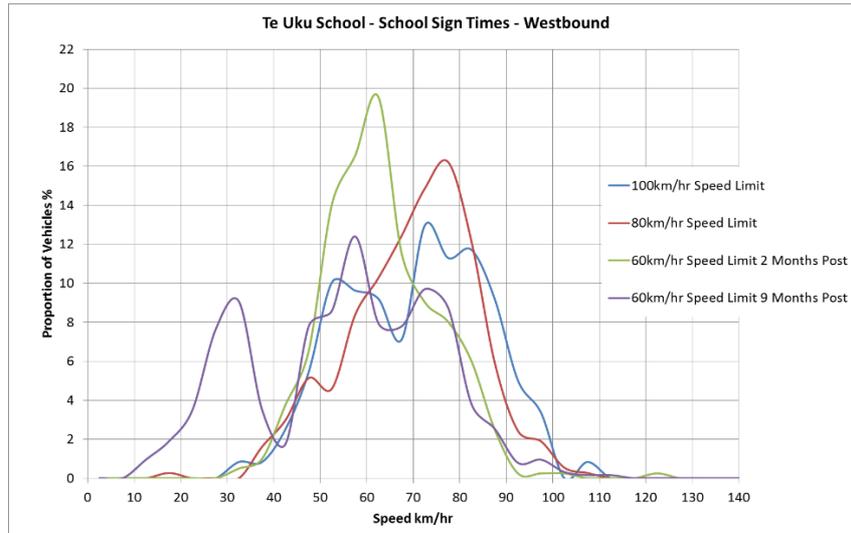


Time Series - School Sign Installed – 10th April 2013

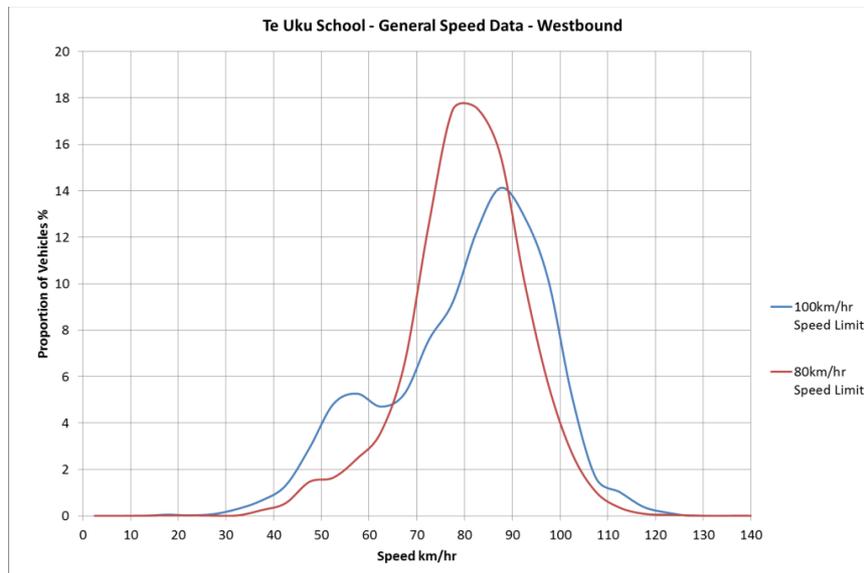


Te Uku School – Westbound

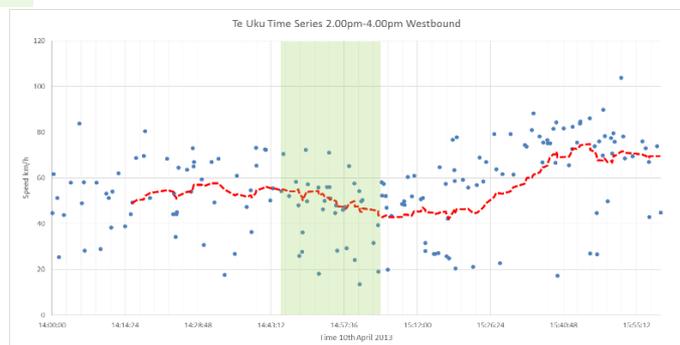
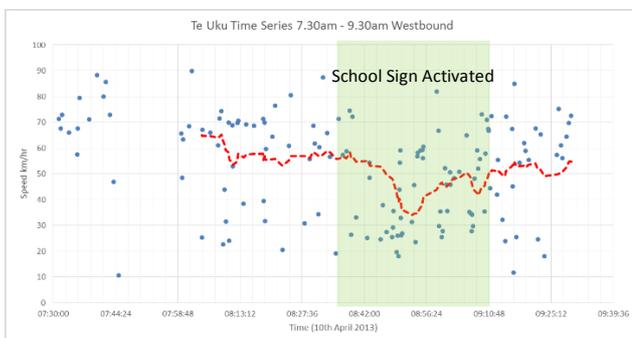
School Sign Times – 8.35am-9.10am / 2.45pm-3.05pm



General Speed Data

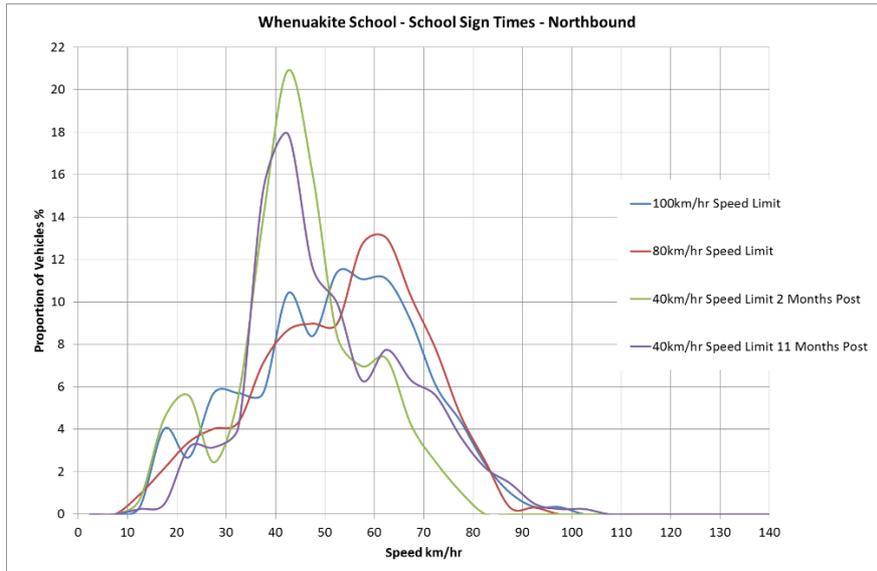


Time Series - School Sign Installed – 10th April 2013

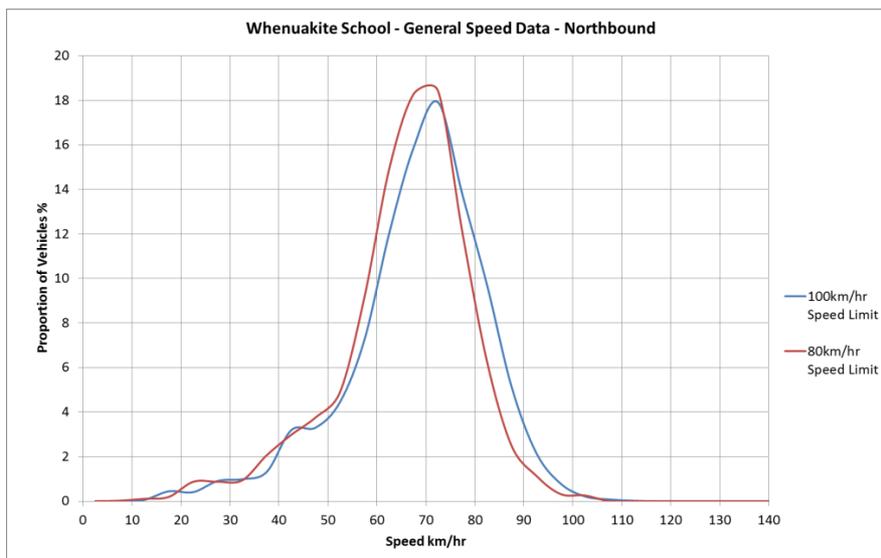


Whenuakite School – Northbound

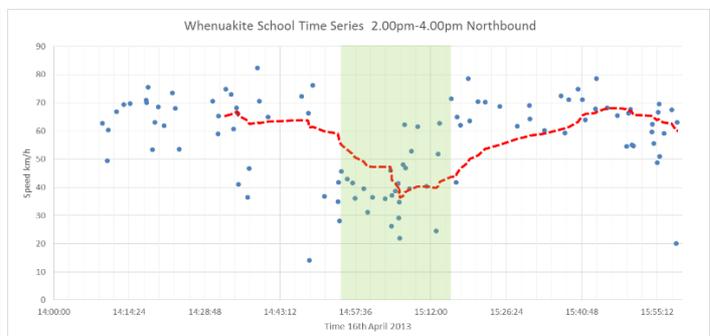
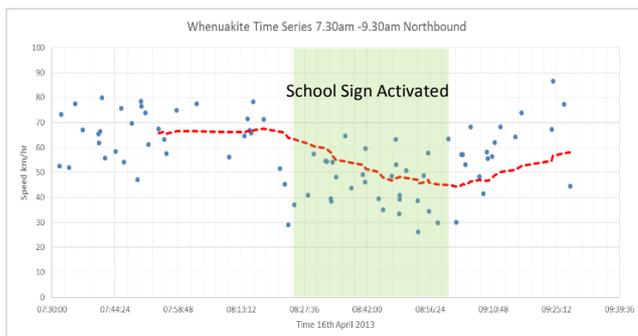
School Sign Times – 8.25am-9.00am / 2.55pm-3.15pm



General Speed Data

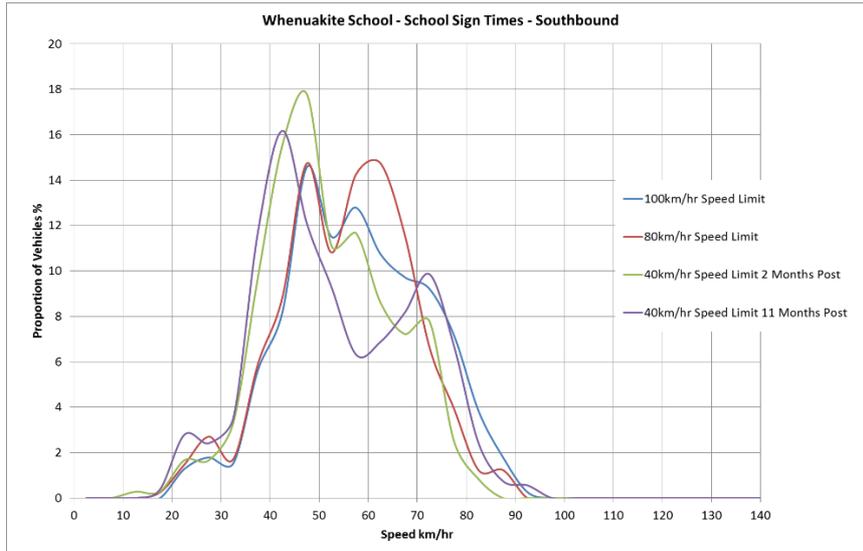


Time Series - School Sign Installed – 16th April 2013

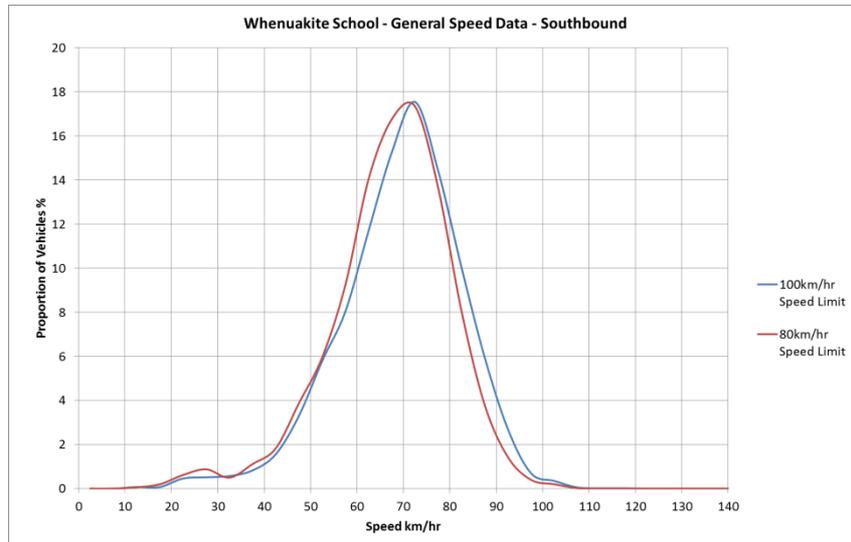


Whenuakite School – Southbound

School Sign Times – 8.25am-9.00am / 2.55pm-3.15pm



General Speed Data



Time Series - School Sign Installed – 16th April 2013

