

# **Road Safety Study – Candia Road**

## **‘Before’ and ‘After’ Crash Study**

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### **Abstract**

During a crash reduction study in 2009 Traffic Engineering Solutions Ltd (TES) established that a substantial rural road loss-of-control crash problem existed along Candia Road (Henderson, Auckland). The reported crashes appeared particularly adverse along a southern section of the road, from Henderson Valley Road to Sturges Road; this route becoming the focus of the investigation. As a result of the investigation, crash remedial works were recommended, designed and installed along the study cordon route (early 2010). The crash remedial works were mainly focussed at two bends within the study cordon, and the works were consistent with the Safe System principles of achieving ‘*Safe Roads and Roadsides*’, ‘*Safe Speeds*’, and ‘*Safe Road Use*’.

In order to determine the effectiveness of the constructed works in terms of reducing crashes, reported crash statistics were studied in 2017 for a seven year period ‘before’ the works were installed, and a seven year period ‘after’ the works were installed. The crash monitoring study has indicated that the combined package of constructed works reduced crashes substantially. Prior to works, 45 crashes were reported along the study cordon over seven years, including 1 fatality and 9 serious injury crashes. After works, only 6 crashes were reported over seven years, with zero death/serious injury crashes (DSI), and no evidence of crash migration.

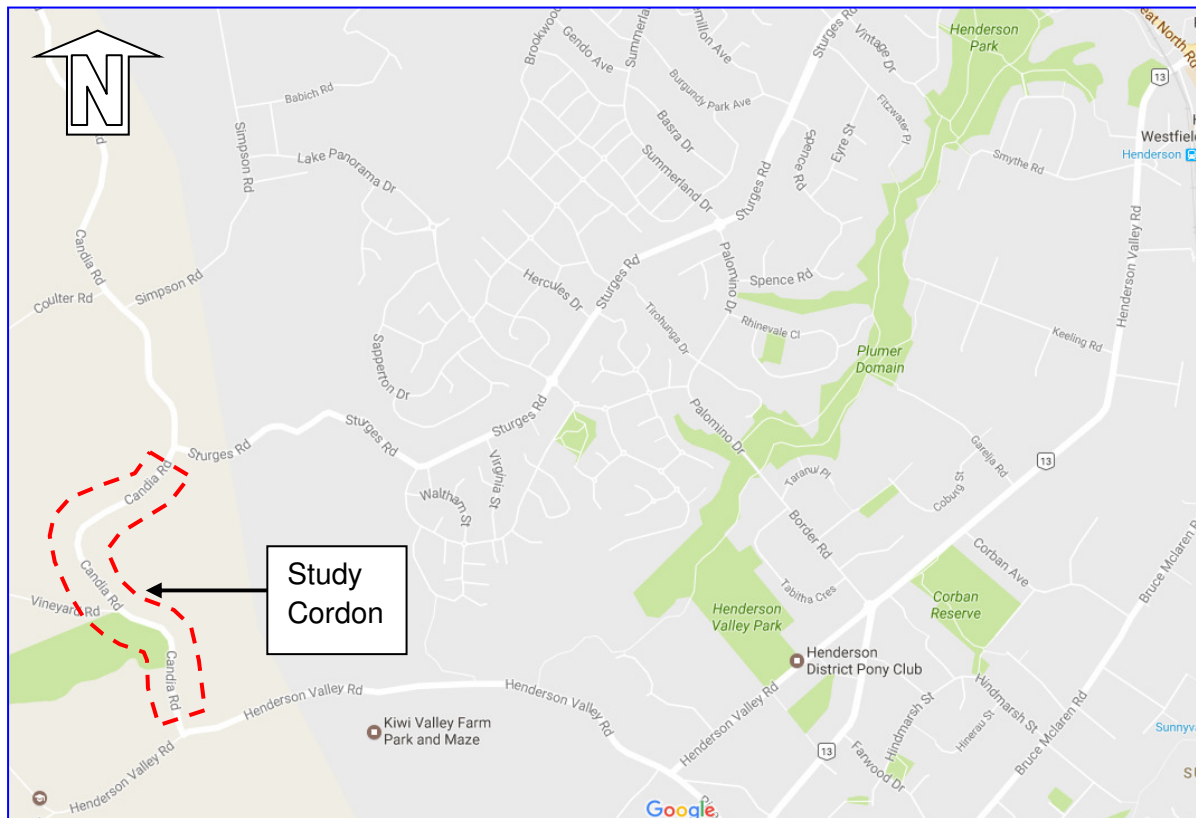
Effectively, reported crashes have reduced by 87%, with substantial lifetime crash cost savings of \$24 million (including a downward crash trend). Also, a very high Benefit Cost Ratio (19) was achieved, and an average of 1.4 DSI crashes were saved per year.

# 1. Introduction

A crash reduction study in 2009 of Candia Road (Henderson, Auckland) established that a substantial rural road loss-of-control crash problem existed between Henderson Valley Road and Sturges Road. The outcome of the study was a package of crash remedial works which were constructed in early 2010. The majority of the works were implemented at two bends within the study cordon. In order to determine the effectiveness of the works, a 'before' and 'after' study was undertaken in 2017. Reported crashes were compared for a seven-year period 'before' the works were implemented (2003 – 2009, inclusive), and a seven-year period 'after' the improvements were installed (2010 – 2016, inclusive). A seven-year analysis period was used rather than the typical five-year analysis period because the crash data was available, and a longer analysis period was considered more likely to provide significant robust results, providing no other variables change.

## 2. Study Cordon

Candia Road is a rural road located in Henderson, West Auckland. The area is predominantly farmland and rural lifestyle blocks. The study cordon was a 1km section of Candia Road located between Henderson Valley Road and Sturges Road. This section was selected because it had a high number of reported crashes prior to the crash study, over a five-year period (2004-2008). The junctions of Henderson Valley Road and Sturges Road were excluded from the study due to crash patterns at these junctions being minor and not related to the main crash pattern (loss-of-control crashes). Candia Road carried around 2,500 vehicles per day (vpd) in 2010, and 3,500 vpd in 2016, representing a 40% increase in traffic over this time period.



**Figure 1: Location of Study Cordon**

### 3. Methodology

During the initial crash study, crash plots were prepared using the New Zealand Transport Agency (NZTA) Crash Analysis System (CAS). These plots indicated that reported crashes were predominantly loss-of-control, and these were distributed along the entire study cordoned route. However, a detailed review of individual Traffic Crash Reports revealed that most of the loss-of-control crashes on the CAS plots directly related to two major, sharper bends (to the north and south of Vineyard Road), with a relatively minor number of crashes related to a third more moderate bend (at Vineyard Road). Many of the crashes were not plotted correctly at the actual location of the bends, and there are two main reasons considered likely to explain this:

- Rural road crashes may be plotted in accordance with the final resting place of the errant vehicle, rather than at the location where the loss-of-control problem begins. In the case of loss-of-control crashes the difference can be significant, as vehicles gradually losing control can traverse a sizeable distance before coming to rest. It is important to track loss-of-control crashes back to the original location of the problem; and
- Rural roads often have few indicators to help identify an exact geographic location, and the approximate location of a crash may be estimated based on a rough distance from the nearest side road. Detailed examination of Traffic Crash Reports can provide clues to help identify the causal factor and its precise location.

Also, significant experience and expertise can be required to interpret Traffic Crash Reports correctly, especially if the available information is limited, vague, misleading or contradictory. Also, errors are more likely to arise at complex road junctions with an unclear compass bearing. In such situations cross-referencing the information can help eliminate reporting error.

Crashes are often a result of a combination of contributory factors acting simultaneously. Along the subject route the loss-of-control crash problem was considered to be aggravated by a combination of the following key factors:

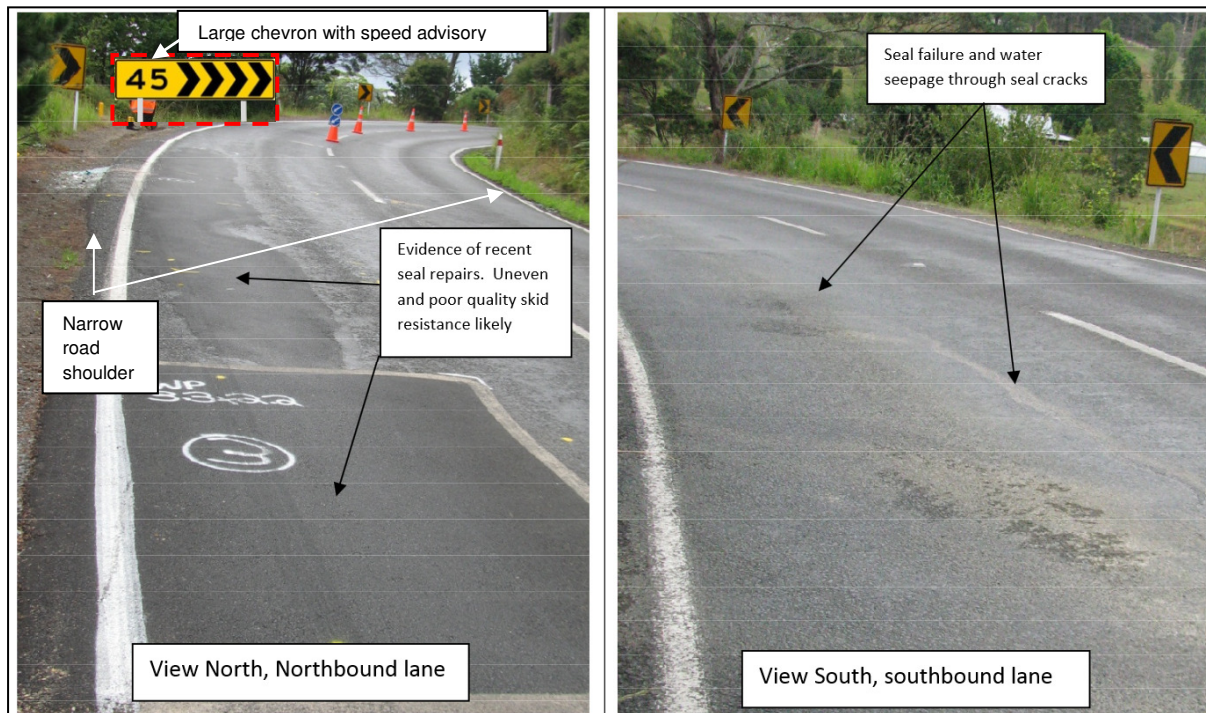
- Excessive vehicle speeds for the road environment, with two relatively sharp bends and one moderate bend on a road with a posted speed of 70km/h;
- Lack of conspicuity of curve warning signage, with the existing curve warning signage being technically correct but limited in terms of visibility (number, location, size, and obstructed by vegetation);
- Narrow and unforgiving road shoulders, reducing the space available for motorists to correct an errant vehicle;
- Ineffective road-marking delineation (faded edgeline and centreline);
- Irregular road surface condition (patch seal repairs and evidence of seal failure);
- Inconsistent super-elevation (undulating road surface);
- Insufficient road surface skid resistance (visual evidence of longitudinal cracking and flushing of seal surface).

The crash severity was considered to be exacerbated by the road's narrow width, increasing the likelihood of head-on collisions. Also, a steep embankment existed on the outside of two bends, with no guardrails, increasing risk of Run-off and Roll-over (R&R) crashes.

Figures 2 and 3 are photographs taken before any works were implemented, illustrating typical issues that existed along the route.



**Figure 2: Visibility of Advance Warning signs obstructed by vegetation (view southwards towards Vineyard Road)**



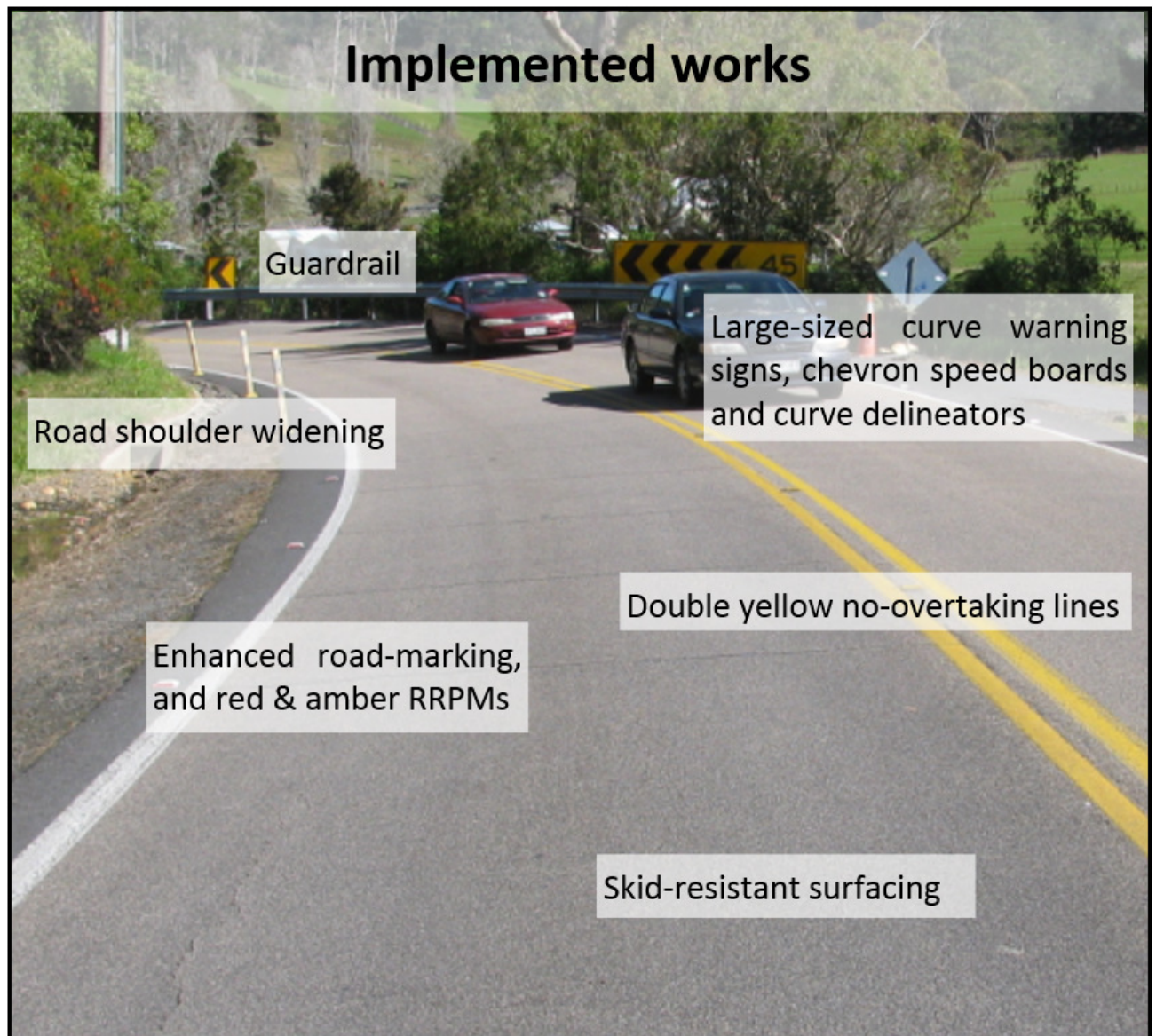
**Figure 3: Signage and Road surface issues at the bend north of Vineyard Road**



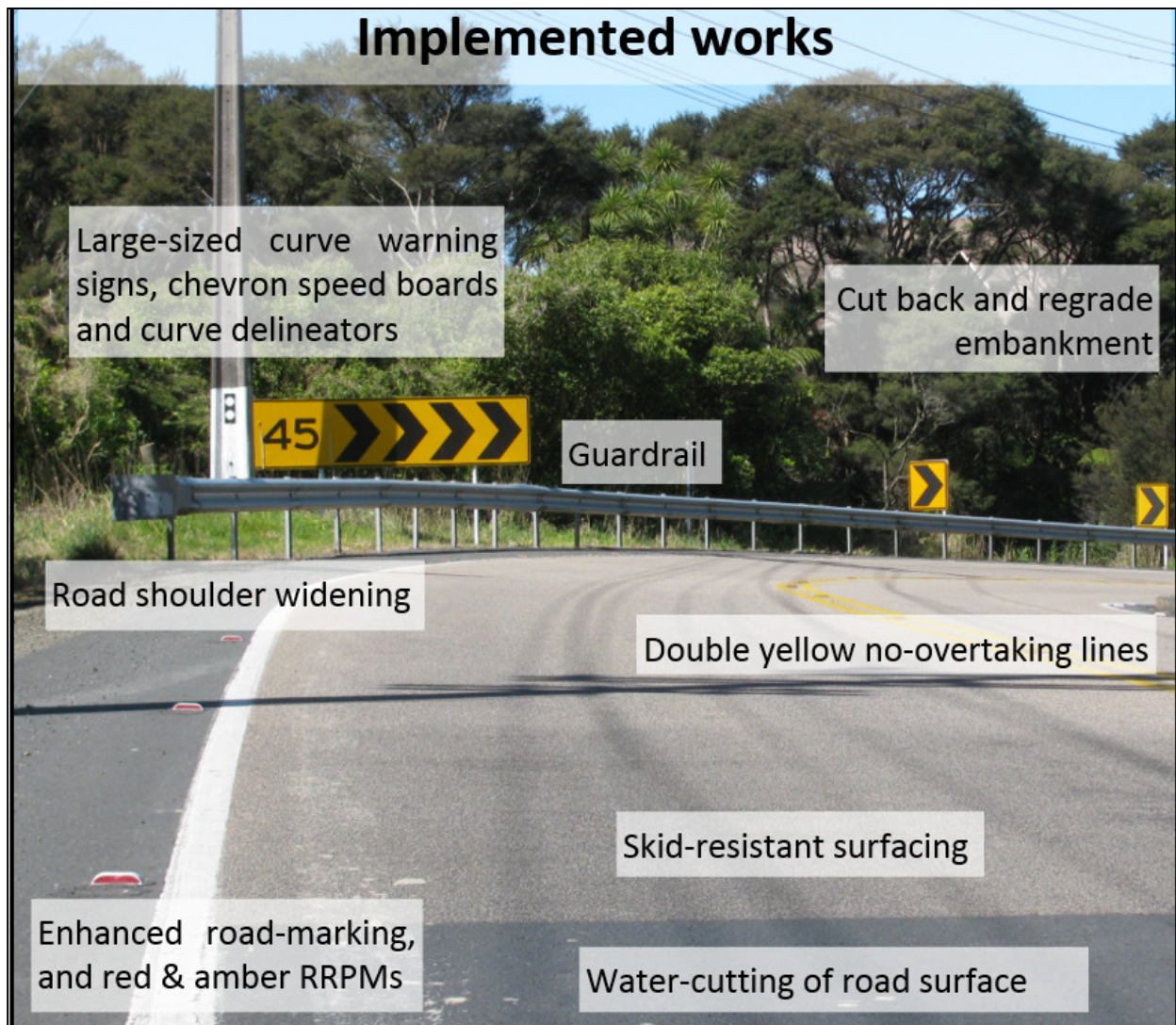
A package of crash remedial measures was proposed (TES 2009), with reference to general recommendations in technical guidelines (Austroads, 2009a; Austroads, 2009b; Transit New Zealand, 2009). The works were focussed mainly at the two sharper bends, and the following works were considered (illustrated in Figures 4 and 5):

- **Curve warning signage and chevrons:** Upgrade quantity, size, visibility and double-gate;
- **Embankment:** Cut-back embankment to improve forward visibility on the inside of one bend;
- **Road shoulders:** Widen and seal road shoulders, to provide a more forgiving roadside and more opportunities for errant motorists to correct their vehicle if starting to lose control;
- **Shape correction:** To provide a smooth road surface and consistent super-elevation around the bends;
- **Skid resistant surface:** A highly skid-resistant road surface (Polished Stone Value > 70) at two bends, reducing likelihood of loss-of-control at the bends;
- **Water-cutting:** Water-cut the road surface on the approaches to the bends, to reduce the likelihood of loss-of-control crashes on the approaches to the bends, but with reduced expenditure (as opposed to skid resistant surfacing);
- **Guardrail:** Install guardrail, to prevent errant vehicles from R&R down an embankment on the outside of two bends;
- **No Overtaking:** Install thermoplastic double yellow 'No-Overtaking' lines, to discourage overtaking and speeding, and to reduce the visual appearance of the road's width;
- **Thermoplastic road-marking:** Install thermoplastic road-marking for durability;
- **Raised Reflective Pavement Markers (RRPM's):** Upgrade RRPM's, with red and amber reflective faces for edgeline and double yellow 'No-Overtaking', respectively;
- **Edge marker posts:** Maintain posts and install additional posts, for improved delineation, particularly at night;
- **Vegetation trimming:** To improve forward visibility of existing and proposed signage;
- **Street-lighting:** Being a rural road, only flag-lighting of junctions was required. The junction at Vineyard Road had no crash problem and adequate flag-lighting;
- **Raised profile road-marking:** This was recommended for edgelines and centrelines, for enhanced visibility and audible warning should a motorist start to deviate. However, it is understood that this recommendation was deleted from the final plans due to concerns about the possible effect of associated noise on local residents.

The proposed crash remedial works did not include special provisions for pedestrians and cyclists, since vulnerable road users weren't significant in the reported crash statistics, and pedestrian / cyclist volumes were observed to be low. Figures 4 and 5 illustrate the proposed works as photographed after implementation.



**Figure 4: Constructed works on the northern approach to the bend north of Vineyard Road. Similar works were implemented on the southern approach to this bend.**



**Figure 5: Constructed works on the northern approach to the bend south of Vineyard Road. Similar works were implemented on the southern approach to this bend.**

## 4. Results

Figure 6 illustrates a CAS plot of reported crash statistics 'before' the crash remedial measures were installed. The position of most crashes has not been edited, and the crashes appear to be distributed along the entire route.

Figure 7 illustrates the same crashes as Figure 6, but Traffic Crash Reports have been analysed in detail and the exact nature, position and direction of each crash re-plotted. Correct interpretation of Traffic Crash Reports can require significant experience and technical expertise. This further analysis results in crash patterns being much stronger and more evident. This enables the causal factors to be identified more accurately, and any proposed remedial works to be focussed on the main issues.

Figure 8 illustrates a CAS plot of reported crash statistics 'after' the crash remedial measures were installed. In this case the Traffic Crash Reports were not analysed for accuracy of the crashes' positions and directions, as it is evident that there have been significant crash savings achieved, and the exact nature of the crash patterns are less relevant at this stage of the analysis.

The works were installed in early 2010. Hence, for the crash monitoring, the 'before' analysis encompassed a seven-year period from 2003 to 2009 (inclusive), and the 'after' analysis encompassed a seven-year period from 2010 to 2016 (inclusive).



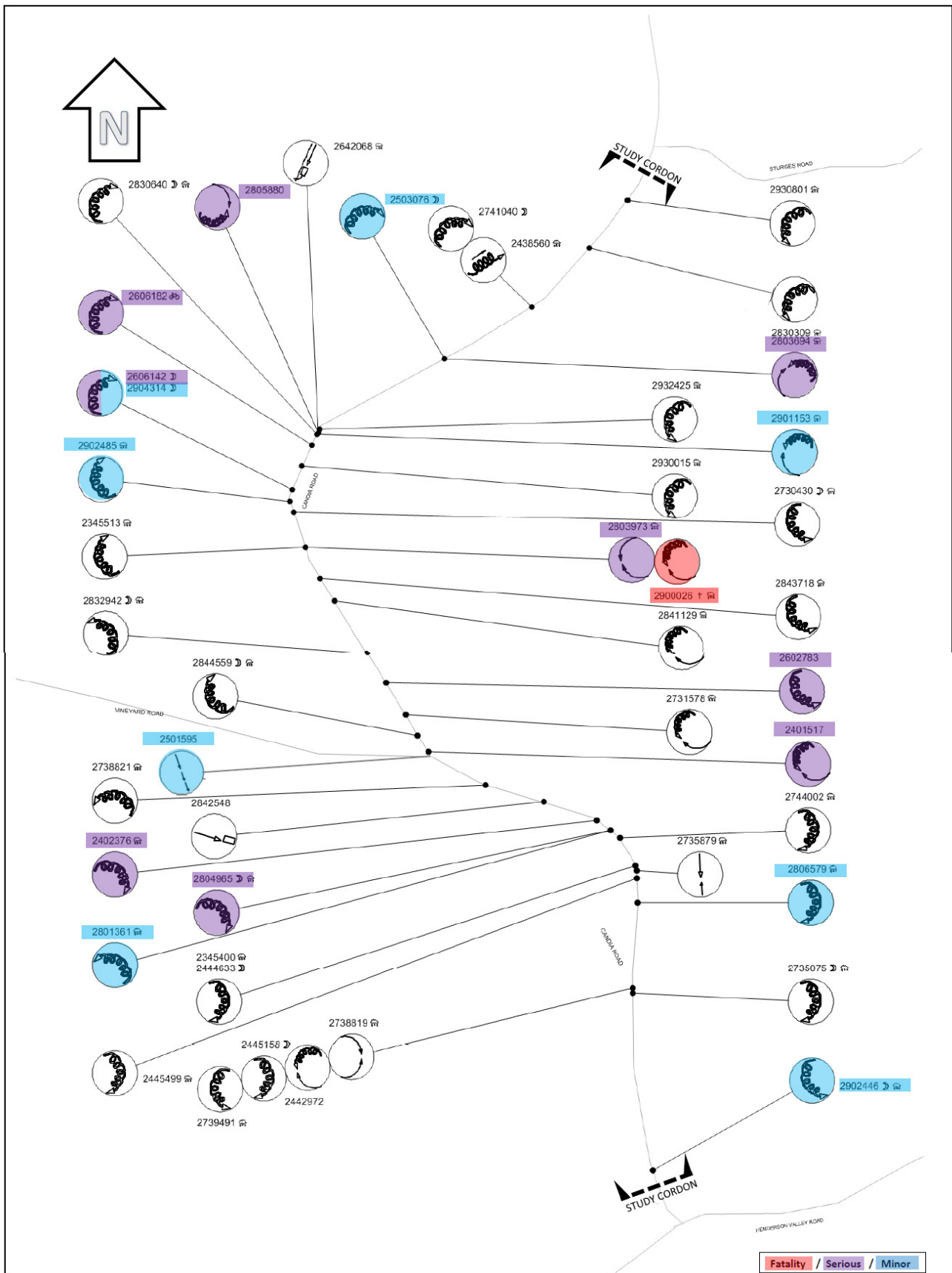
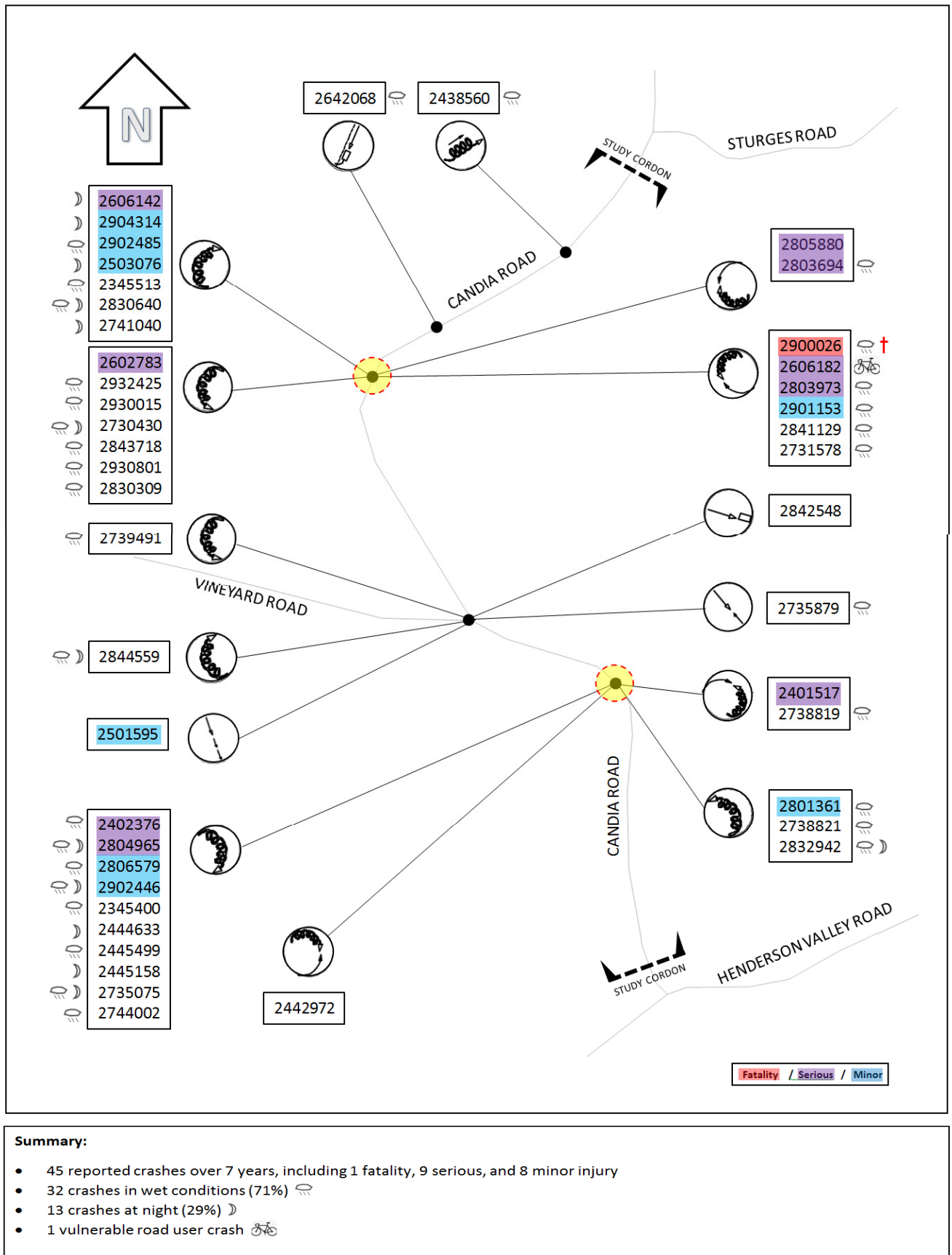
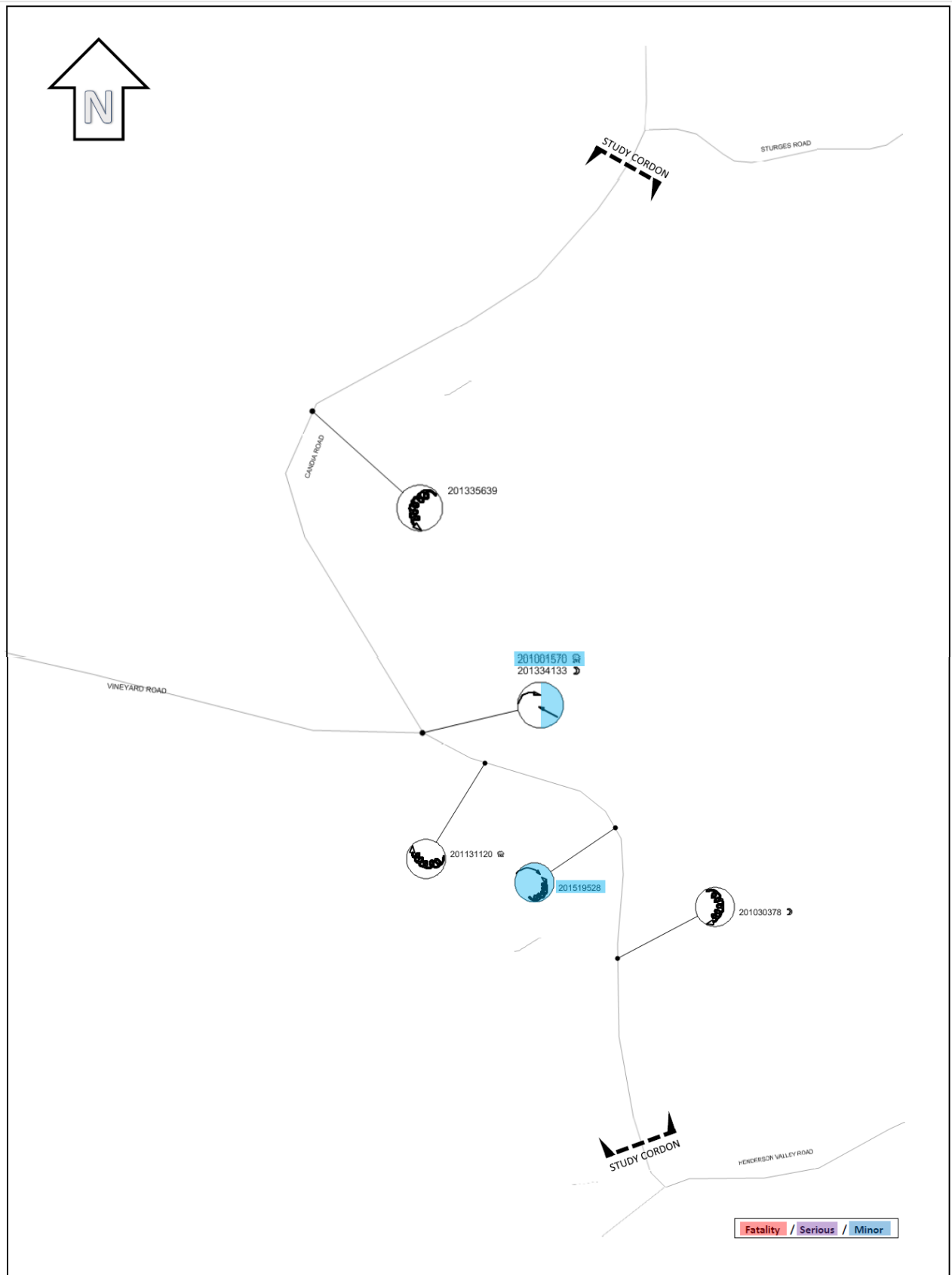


Figure 6: NZTA CAS Plot: Candia Road – All Reported Crashes 2003 – 2009. In total, 45 reported crashes over seven years, including 1 fatality, 9 serious injury, and 8 minor injury crashes. Crashes plotted along the route, similar to the original CAS plot.



**Figure 7: NZTA CAS Plot: Candia Road – All Reported Crashes 2003 – 2009.** In total, 45 reported crashes over seven years, including 1 fatality, 9 serious injury, and 8 minor injury crashes. Traffic Crash Reports analysed and crashes re-plotted and grouped accurately.



**Figure 8: NZTA CAS Plot: Candia Road – All Reported Crashes 2010 – 2016. In total, 6 reported crashes over seven years, including 2 minor injury crashes. These crashes are in the locations provided by the Crash Analysis System.**

Overall, the crash savings achieved along the route for the combined package of constructed works were substantial, and far exceeded expectations and crash reduction savings typically expected and generated. The results are summarized as follows:

- From 2003 to 2009, 45 crashes were reported within the study cordon. Only 6 crashes were reported from 2010 to 2016. Thus, reported crashes along the study cordon have reduced 87%. This result achieves statistical chi-squared significance greater than 99.9%. Also, over the intervening time periods, traffic volumes on Candia Road were estimated to have increased by around 40%;
- Analysis of all reported loss-of-control crashes on roads in the Auckland area (the 'control group') over the same time periods shows a 22% reduction in loss-of-control crashes. Thus, over the same time periods, the reduction in reported crashes within the study cordon has far exceeded the 'control group' crash trend. The percentage crashes saved taking into account the crash trend is 83%;
- Reported crashes were reviewed on nearby rural roads over the same time periods, and this established that reported crashes had decreased in the surrounding area. Hence, there was no evidence of crash migration, and addressing crashes along the study cordon did not result in crashes relocating elsewhere;
- The 45 reported crashes before works included 1 fatality, 9 serious injury and 8 minor injury crashes. The 6 crashes after works included only 2 minor injury crashes. The average number of death/serious injury crashes saved per year is 1.4; and
- The estimated cost of construction of all the works was around \$1 million, and reverse discounted to present value would be around \$1.3 million. Based on economic analysis (NZTA, 2016), Present value life-time crash cost savings were around \$24 million (including the 22% downward crash trend), resulting in a Benefit Cost Ratio (BCR) of approximately 19.

It is noted that regression to the mean analysis of the crash statistics was considered unnecessary due to the long period of crash analysis (7 years) and the substantial results that were 99.9% chi-squared significant.

Also, it is acknowledged that land-use patterns are more likely to change over a longer period of analysis. However, over the analysis period the only identified variable was vehicle volumes, which increase by around 40% over the analysis period, increasing the merit of the results. Other variables such as nearby road geometrics, driver behaviour, posted speed limits, or police enforcement (speed/alcohol) were not identified to have changed.



The crash remedial works were **innovative** for the following reasons:

- The key causal factors relating to the crash patterns (excessive speed and loss of control at the two main bends) were precisely identified by reading all the available Traffic Crash Reports, with most of the reported crashes re-positioned and re-plotted (Figure 7). The initial crash plot (Figure 6) indicated crashes distributed relatively evenly along the route, which was misleading, and necessitated preparation of Figure 7. Also, non-injury crashes were considered important to help identify crash patterns/locations;
- A large number of complementary crash remedial measures were implemented simultaneously at specific sites, focusing on the key issues, yet achieving a route-long Safe System crash saving;
- The package of works that were implemented exceeded crash remedial works generally recommended in technical guidelines to address similar issues, but were justified by the results, showing that significantly better outcomes can be achieved by doing more than the required minimum improvements.

The package of remedial works was **cost effective**, as evidenced by the substantial benefit-cost ratio achieved by the crash savings.

The package of remedial works **stands out beyond traditional activities** in terms of the extremely high percentage of crash savings (87%), proven to have been achieved over a long period of time (seven years).

Table 1 tabulates the crash savings typically expected from implementing the individual crash remedial measures.

No.	Problem	Solution	Safe System Action				Conservative Assumed Crash Savings Benefit*
			Roads	Speeds	Vehicles	Road Use	%
1	Loss of control crashes at bends along route	Install/upgrade advance curve warning signage, advisory speed signage, chevron speed boards, and curve indicators. Rationalise and remove signage not justified. Maintain existing signage, and improve forward visibility of existing signage.	✓	✓		✓	15% of all LOC along route
2	Loss of control and R&R	Install crash barrier around the outside of two bends.	✓				5% of all crashes at 2 bends
3	Uneven road surface	Shape correction and resurfacing to provide even surface, consistent super-elevation, and improved skid resistance.	✓				10% of all crashes at 2 bends
4	Low skid resistance	Install highly skid-resistant road surface (PSV>70) on both traffic lanes around two bends.	✓	✓		✓	20% of LOC at 2 bends
5	Narrow road Shoulders	Widen, smooth and seal road shoulders at 2 bends, taking into account existing topography and adjacent embankments.	✓				10% of LOC at 2 bends
6	Visibility on inside of bend	Cut-back embankment and roadside vegetation on the inside of one bend.	✓				10% of all crashes
7	Faded road-marking	New white thermoplastic centreline, edgeline, and double-yellow 'No Overtaking' lines.	✓	✓		✓	
8	Superfluous roadside furniture	Remove redundant roadside traffic signs.	✓			✓	
9	Edge marker post maintenance	Maintain and install additional edge marker posts along route in a consistent manner complying with MOTSAM.	✓	✓		✓	
10	Centreline RRPM	Install bi-directional amber RRPM's along the new double yellow 'No Overtaking' lines, exceeding MOTSAM specifications.	✓	✓		✓	
11	Edgeline RRPM maintenance	Maintain and replace existing red Edgeline RRPMs and install additional red mono-directional RRPM's on left-side of road on edgelines on sharp bends with crashes.	✓	✓		✓	
12	Vegetation and visibility	Trim vegetation at locations where visibility is restricted of signs or on the inside of bends.	✓	✓			

\* Crash savings were based on (1) iRap Road Safety Toolkit - [toolkit.irap.org](http://toolkit.irap.org), (2) Austroads Road Safety Engineering Toolkit - [www.engtoolkit.com.au](http://www.engtoolkit.com.au), (3) Auckland City Council Black Spot Monitoring Report, 1998, (4) North Shore City Council Black Spot Monitoring Report, 2009, (5) NZTA EEM, and (6) U.S. Dep. of Transportation - Federal Highway Administration, ITE, Toolbox of Countermeasures, 2007.

**Table 1: Crash remedial measures and typically predicted crash savings**

Relating to Table 1 the following is noted:

- If a large number of individual crash remedial works are combined, then the crash saving benefit attributable to each individual remedial measure may need to be lowered below that recommended in technical guidelines, if the total summated crash savings exceeds that considered reasonable.
- If the crash savings benefit attributable to each crash remedial measure in Table 1 were to be summated, then the predicted benefit from the combined package of works would be around 70% of reported crashes. Such a crash saving prediction far exceeds that generally considered reasonable in technical guides, but was less than the saving achieved (87%).

In relation to the Safe Systems principles (Safer Journeys, 2010), the works addressed the following areas:

- **Safe Roads and Roadsides:** The works made the road and roadside safer by installing a combination of effective crash remedial measures, including skid-resistant road surfacing, water-cutting of the road surface, consistent super elevation, shoulder widening, berm cutback, vegetation cutback, and guardrail;
- **Safe Speeds:** The works encouraged slower and safer vehicle speeds through a combination of advisory speed signage and conspicuous road-marking; and
- **Safe Road Use:** Safer road use was encouraged with enhanced road-marking delineation, including thermoplastic edgeline, 'No Overtaking' centreline, and raised reflective pavement markers.



Figure 9: NZTA Safe System Approach

## 5. Conclusions

In summary, crash studies can achieve substantial crash savings with very high BCR far exceeding typical expectations by using several techniques, such as:

- Precisely locating and plotting crashes by analysing all available Traffic Crash Reports. This is particularly important for rural roads, as geographical references are often unavailable, or distant;
- Using all available crash data (including non-injury and minor injury crashes), in order to establish stronger crash patterns, identify causal factors, and determine correct locations of crashes. Examining only severe injury and fatal crashes can lead to weaker crash patterns and less evidence of specific causal factors;
- Focus the crash remedial works at the locations where most crashes have been reported, while applying the 'Safe Systems' approach to the remainder of the route; and
- Designing a large package of complementary remedial works, focussed at key locations along routes, as determined by the in-depth crash analysis. Incorporating additional countermeasures can result in crash savings far greater than that typically predicted or achieved.

## 6. References

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## 7. Acknowledgements

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