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Posted Speed Limit Study

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Document prepared by:

Aurecon New Zealand Limited
Level 4, 139 Carlton Gore Road
Newmarket Auckland 1023
PO Box 9762
Newmarket Auckland 1149
New Zealand

T +64 9 520 6019
F +64 9 524 7815
E auckland@aurecongroup.com
W aurecongroup.com

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Name	**R Lauren**	Name	**J Hind**
Title	**Technical Officer**	Title	**Technical Director**

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Executive Summary

Purpose

As part of the Western Ring Route (WRR) Project NZTA are making significant alterations to the existing motorway network creating a new system interchange at Waterview forming a connection between SH16 and SH20. This work will not only add additional complexity to the driving environment but will increase volumes and weaving movements.

This report investigates the suitability of the existing 100km/h posted speed limit along the SH16 North-Western Motorway between the Central Motorway Junction (CMJ) and Te Atatu Interchange. Based on the analysis of the geometric conditions, existing vehicle speeds, crash rates and predicted vehicle volumes a new speed restriction may be warranted for all or part of the study length.

Comparisons have been made to other sections of the Auckland motorway network to aid in the prediction of how the proposed motorway layout will function and the corresponding implications of a lower speed restriction.

Analysis Results

Operating Speeds	For 100km/h zones the operating speed is approximately 98km/h In 80km/h zones the operating speed is approximately 85km/h. Speed restrictions on motorways result in a 40-65% reduction; i.e. a speed limit reduction of 20km/h will reduce vehicle speeds by 8 to 13km/h.
Road Geometry	The existing road is being upgraded to 110km/h for most of the length with isolated reductions to 85km/h in some constrained areas. The Great North Road Interchange becomes more out of context with a design speed of 70-80km/h.
Ramp Spacing	Ramp separation is less than desirable however similar to most other parts of the network.
Shy-Lines	Generally suited for 110km/h with the exception of parts of the Great North Road Interchange which are more suited for 60km/h and can expect a 5% reduction in lane capacity.
Weaving	Extremely high weaving volumes are expected westbound between the St Lukes Road on-ramp and the Great North Road off-ramp. Based on traffic volumes flow breakdown will be inevitable in the outer lanes whilst the median lanes will be flowing more freely. This will likely result in high speed differentials between vehicles and therefore increased crash severity. In the eastbound direction high flows from the Great North Road on-ramp are expected to cause flow break down.
Crash Data	High numbers of weaving related crashes occur in comparison to other parts of the network. This high number of crashes is seen to be caused by high levels of congestion on the outer lanes resulting in high speed differentials. The number 'loss of control' type crashes are likely to reduce due to the geometric upgrades with the exception of the Great North Road interchange which largely remains unchanged.

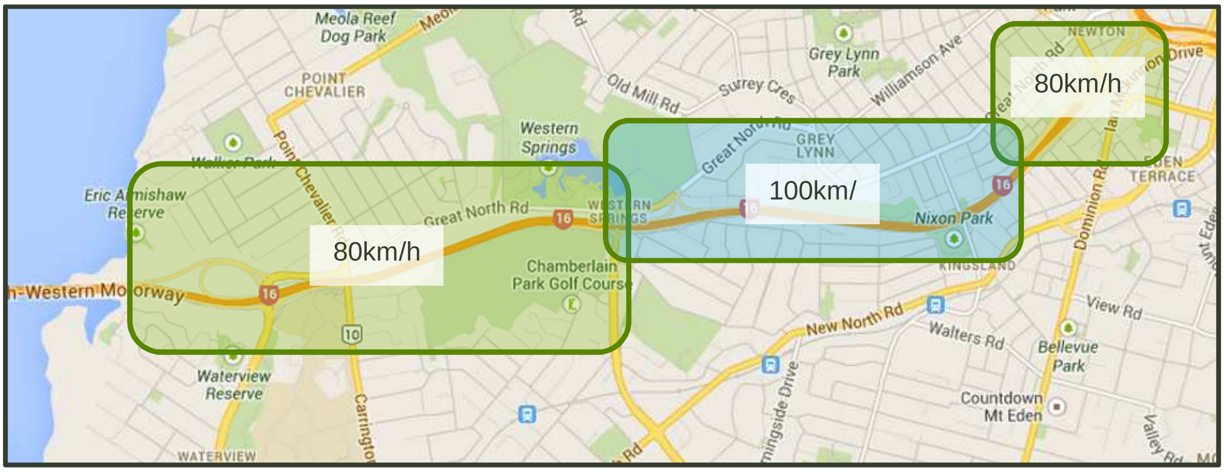
Proposal

The analysis results show that the Great North Road interchange has a number of existing issues such as low geometric standards and a comparatively high number of 'loss of control' type crashes. With the introduction of the SH20 connections and the upgrading of the adjacent sections of motorway these existing deficiencies will become more pronounced and with the increased complexity and traffic volumes it will ultimately be unsafe to be operated at a 100km/h posted speed.

In addition to this the high weaving volumes between St Lukes Road and the Great North Road off-ramp are likely to result in flow break down and unlike other locations, such as Khyber Pass Rd to Gillies Ave where all the traffic lanes are saturated, the through lanes will be flowing more freely resulting in high differential speeds resulting in increased crash severity.

It is recommended that a speed restriction of 80km/h be put in place from St Lukes Road to the SH16 causeway. It is expected that by posting an 80km/h speed restriction that vehicle speeds will reduce to approximately 90km/h, in order to increase the reduction it is recommended some form of threshold be created to enhance compliance.

On its own the 80km/h speed is seen to be appropriate for this section of road on a general basis however during heavy peak or unbalanced flows this is still not likely to be sufficient for safe operation due to the geometric and weaving constraints. During the congested and unbalanced situations a 60km/h speed limit may be more appropriate and therefore further consideration should be given to the implementation of a variable speed limit, or a peak time temporary speed limit.



Proposed Speed Restrictions

1 Introduction

Purpose of the Report

As part of the Western Ring Route (WRR) project, the New Zealand Transport Agency (NZTA) is constructing a new motorway tunnel linking the current northern end of SH20 at Maioro St with the Northerwestern Motorway (SH16) by the existing Great North Road interchange.

With this new connection a large system interchange is to be constructed over the top of the existing service interchange at Great North Road which is expected to greatly change the character of the existing road alignment as well as introducing new decisions for users to process.

In addition to providing this new connection the NZTA is also upgrading SH16 from St Lukes interchange through to the Lincoln Road interchange. These upgrades are to provide increased capacity for both the future demand and the new movements introduced by the SH20 tunnel. As part of this work NZTA is also upgrading the geometric condition of the existing motorway to be more in line with current design standards.

The changing character and geometric condition of the road has prompted a review of the posted speed limit to determine what would be suitable for the safe operation of the road post construction. This report will also investigate how any such speed limits should be posted so as to ensure uniform adherence.

Land Transport Rule 54001

Setting of Speed Limits road controlling authorities may set enforceable speed limits on roads within their jurisdictions. The purpose of the procedures is to ensure that the risk to public safety is minimised and that the freedom of road users to travel on NZ roads at speeds that are reasonable and appropriate is protected through checks and balances on the actions of road controlling authorities. This is achieved through the Director of Land Transport Safety setting standards and auditing and monitoring the application of the rule by road controlling authorities. The power to set a speed limit is limited to road controlling authorities that have power to make bylaws concerning the use of roads under the Local Government Act 2002.

Assessment Criteria

To determine a suitable permanent speed limit the following information was collated and assessed as outlined in the *Land Transport Rule 54001: Setting of Speed Limits*:

- The existing speed limits;
- The character of the surrounding land environment;
- The function of the road;
- Detailed roadside development data;
- The number and nature of side roads;
- Carriageway characteristics;
- Vehicle, cycle and pedestrian activity;
- Crash data; and
- Speed survey data.

The above rules pertain to all road types. As such some details are not considered to be applicable to the SH16 corridor under consideration. The following Section sets out the structure of the report covering the prudent points relating to speed limit selection along the SH16 corridor.

2 Existing Conditions

Extents

The brief for this review implies the expectation that an 80km/h speed limit may be extended through to the western side of the Great North Road interchange. However, for the purposes of a robust review the extent of the analysis included within this report considers the wider area from the Central Motorway Junction (CMJ) through to Te Atatu Interchange. Through this section the motorway is both wide and generally flat presenting a consistent environment to drivers. Heading further west towards Lincoln and Royal Road interchanges and motorway narrows and features some tight vertical geometry.

The SH20 Tunnel has gone through its own process to determine the safe operating speed limit and as such will not be investigated further in this report. The integration of the tunnel speed limit with the adjoining motorway network will however be taken into account.

Existing Speed Limits

2.1.1 Existing Motorway

Currently the motorway network is posted at 100km/h with the exception of the CMJ which has an 80km/h posted speed limit that runs from the northern end of the harbour bridge through to the northern end of the Newmarket Viaduct on SH1. There is currently a temporary 80km/h speed limit posted over the Newmarket Viaduct which NZTA is looking to have formalised. On SH16 there is a short 80km/h section that runs from the CMJ to the Newton Road on/off-ramps as shown in Figure 2-1.

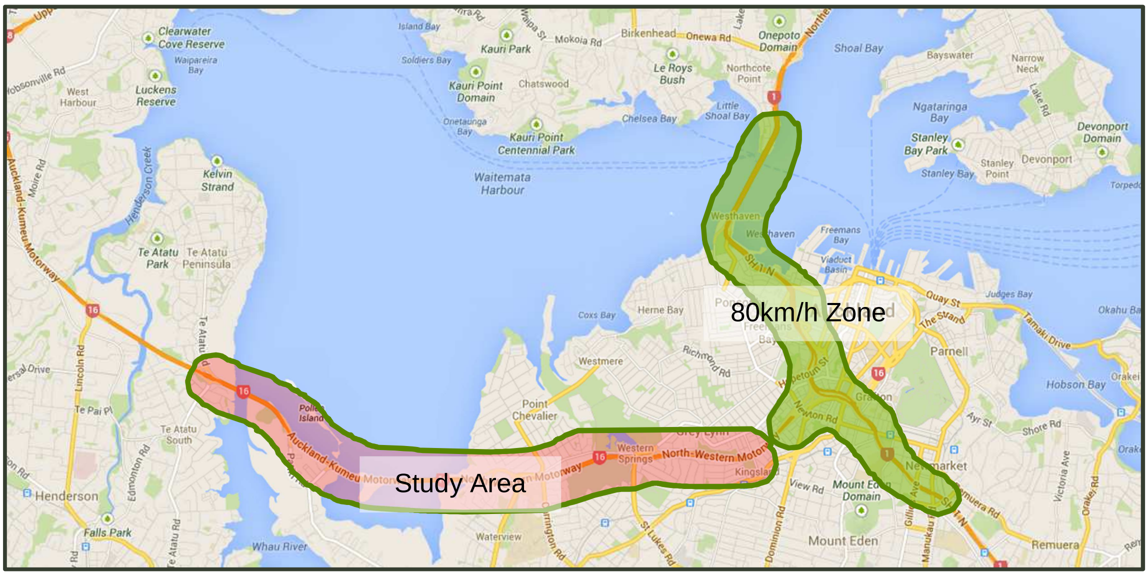


Figure 2-1 Existing Speed Restriction

2.1.2 SH20 Tunnel

The SH20 Tunnel that is currently under construction is to have a posted speed limit of 80km/h. This speed limit has been set due to both the tight cross section of the tunnel and the high consequences of any accidents within the tunnel.

Existing Operating Speeds

2.1.3 Observed Vehicle Speeds

Speed profiles have been obtained from the Auckland Motorway Alliance (AMA) which contains statistical representations of vehicle speeds over a 24 hour period. The data used was the 4th quarter data set from 2012 (October to December). This period was used due to difficulties in obtaining complete sets of data for the entire network as gaps in the collection data often arise due to maintenance and construction.

This information clearly shows considerable reductions in speed during both the morning and evening peak periods. In order to obtain the free flow driver speed these peak periods have been excluded resulting in reasonably consistent vehicle speeds.

The following three tables contain the speed profile data for the inner sections of the Northern, Southern and Northwestern Motorways.

	Westbound	Eastbound
	85th percentile	85th percentile
St Lukes	98	96
Great North	98	95
Te Atatu	95	91

Table 2-1 Existing SH16 Northwestern Motorway Vehicle Speed (October to December 2012)

	Northbound (km/h)	Southbound (km/h)
	85th percentile	85th percentile
CMJ	85	83
Gillies Ave	74	85
Greenlane	92	100
Mt Wellington	95	100
Papatoetoe	95	98

Table 2-2 Existing SH1 Southern Motorway Vehicle Speed (October to December 2012)

	Northbound (km/h)	Southbound (km/h)
	85th percentile	85th percentile
St Mary's Bay	82	84
Esmonde Road	100	100
Northcote Road	98	100
Tristram Ave	97	98
Constellation Dr	94	101

Table 2-3 Existing SH1 Northern Motorway Vehicle Speed (October to December 2012)

2.1.4 Perceived Vehicle Speeds

Table 2-1 above states the actual vehicle speeds recorded at 3 locations on the motorway network, these values however are unlikely to be what is presented to the driver.

Although vehicles originating from different parts of the world are built to different standards, in general most are in rough accordance with the European Union requirements which are as follows.

- The indicated speed must never be less than the actual speed
- The indicated speed must not be more than 110% of the true speed plus 4km/h

In effect, although most of the speeds above are in the range of 95km/h the actual driver may be under the impression they are traveling at 110km/h which although in excess of the legal speed limit is on the tolerance margin.

2.1.5 Adherence to Non-Standard Speed Limits

For the New Zealand road network there are two general speed limits, 50km/h for urban roads and 100km/h for motorways and rural roads.

Road Controlling Authorises (RCA's) can implement alternative speed limits at intervals of 10km/h however these need to be regularly signed to ensure drivers are aware the road has a non-standard speed limit.

By having these two standard speed limits drivers develop their own feel for the environment which can result in either deliberate or accidental noncompliance with the posted speed limit. This may be slower or faster than the posted speed limit with both presenting a safety hazard due to the differential speed difference between complying and noncomplying vehicles.

Table 2-4 below shows the impact of a 70km/h speed limit through the Lincoln Road interchange. This section of road is currently under reconstruction and as such it has a number of adverse factors which should reduce vehicle speeds, these include;

- Narrow lane
- No shoulders
- Poor road surface

Due to their being a notable difference between the AM and PM 85% speeds both the upper and lower values have been shown.

Westbound (km/h)		Eastbound (km/h)	
Upper 85%	Lower 85%	Upper 85%	Lower 85%
90	85	85	80

Table 2-4 Lincoln Road Interchange Vehicle Speeds

By comparing the Lincoln Road construction site with vehicle speeds along the remaining sections of SH16 there is roughly a 10km/h reduction in vehicle speeds when the posted reduction is 30km/h (100 less 70 km/h).

In addition to poor adherence with the reduced speed limit the Lincoln Road site appears to show a greater range of vehicle speeds than other sections of motorway. For the Te Atatu, GNR and St Lukes sections the speed variance between the 5% and 95% is in the range of 6km/h, for Lincoln Road this increases to roughly 10km/h.

Road Geometry

2.1.6 Designed Conditions

Figure 2-2 below graphically depicts the minimum level of sight distance available to the road user as they travel westbound along the designed SH16 alignment after the construction of the 3 upgrade projects at St Lukes, Great North Road, along the causeway and through the Patiki Rosebank Peninsula.

Horizontal curve radii, superelevation and vertical curve values have not been shown as these are generally of a suitable standard to not influence a driver's speed to a significant degree.

For the purposes of making the figure the following criteria have been used;

- Target design speed – 120km/h (305m)
- Optimal design speed – 100km/h (225m)
- Minimum design speed – 80km/h (155m)
- Direction – westbound carriageway only
- Lane – left lane on left hand curves right lane on right hand curves
- Eye height - 1.1m
- Target height – 0.2m

The trend line shown on the graph is a 5th order polynomial and shows the general feel of the road alignment from the driver's perspective. What the trend line shows is that although there are some isolated reductions in sight distance only suitable for 80-85 km/h, once away from the CMJ the long straights result in an environment for over 100km/h.

Refer to Appendix B for a more detailed chart.

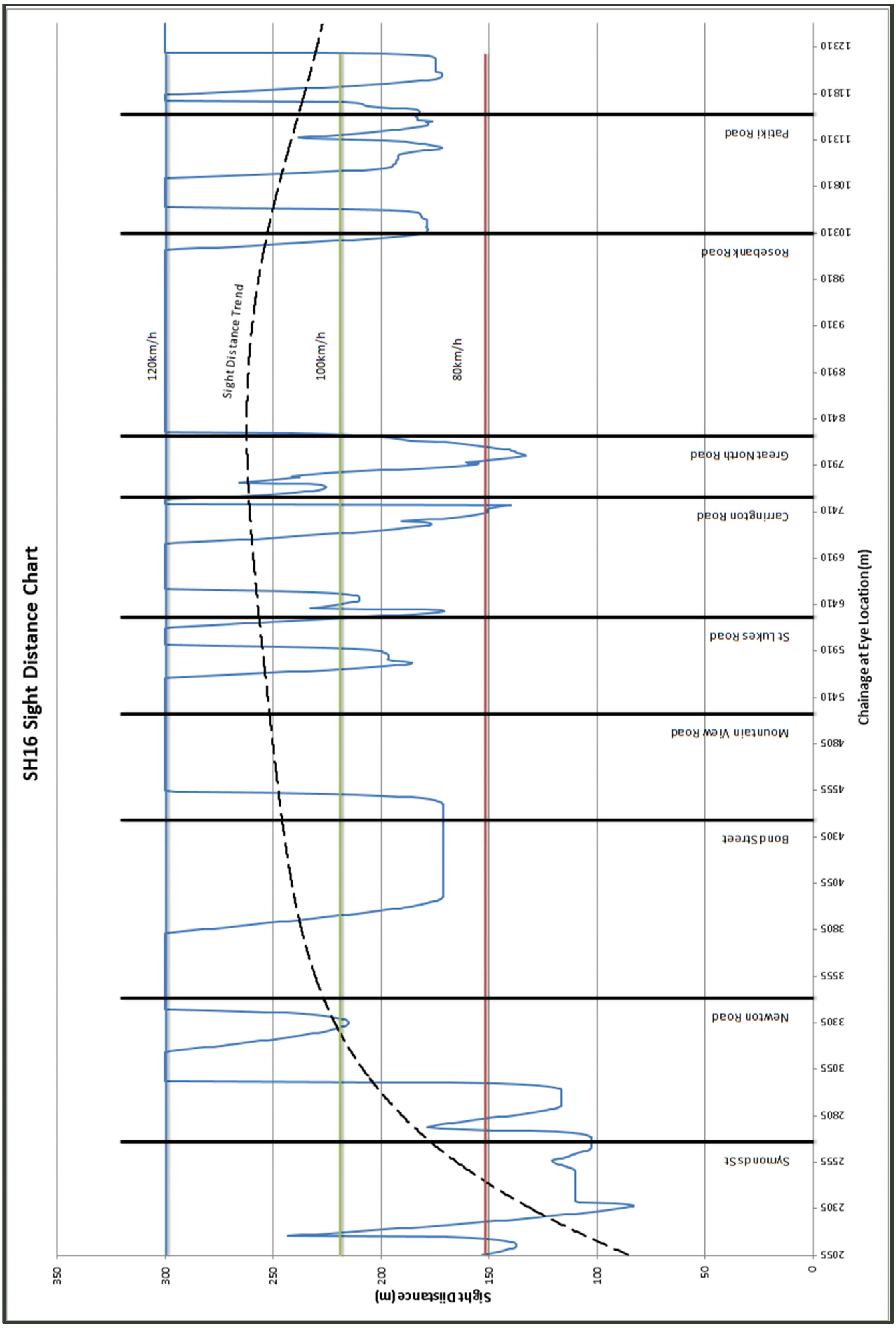


Figure 2-2 Sight Distance Chart (Khyber Pass Road to Te Atatu Road)

Refer to Appendix C for detailed chart

2.1.7 Changes from Existing

Using the detailed Sight Distance Chart in Appendix C, 3 locations have been shown where the road geometry has been notably improved from that of existing as shown by the dashed boxes. This is most evident in two locations, St Lukes interchange going past the golf course and the Patiki / Rosebank Peninsula.

Table 2-5 below notes the existing sight distance available and the currently proposed values at 3 key locations.

Location	Existing SSD	Existing Design Speed (km/h)	Proposed SSD (m)	Proposed Design Speed (km/h)
St Lukes (1)	115m	65	165	85
Rosebank (2)	115	65	175	85
Patiki (3)	110	65	175	85

Table 2-5 Improvements on Existing

Traffic Performance

2.1.8 Ramp Spacing

One of the concerns with the new route is that the section between St Lukes and Great North Road will experience a significant amount of weaving and be mentally challenging to the driver with multiple ramps and potential destinations.

Based on Austroads Traffic Management Part 6, successive on/off-ramps should be separated by different amounts depending on the number of lanes on the motorway. This separation is based on providing for the turbulence associated with on/off-ramps and the additional weaving required on wider roads. Table 2-6 lists the ideal separations.

Number of Through Lanes	Ideal Minimum Ramp Spacing
2 Lanes	900m
3 Lanes	1,200m
4 Lanes	1,500m

Table 2-6 Ideal Ramp Spacing

In order to assess the proposed SH16 configuration the ramp spacing has been compared with other parts of the motorway network. The following tables list the ramp spacing for the Southern, Northern and proposed North-western motorways heading away from the CBD.

2.1.8.1 Northern Motorway

Northern Motorway - Northbound		
On-Ramp	Off-Ramp	Separation (m)
Onewa (4 lanes)	Esmode	850
Esmode (4 lanes)	Northcote	750
Northcote (4 lanes)	Tristram	1150
Tristram (3 lanes)	Upper Harbour	1650
Upper Harbour (2 lanes)	Greville	1050
Greville (2 lanes)	Oteha Valley	1300

Table 2-7 Northern Motorway Ramp Spacing

As shown in Table 2-7 above, the Northern Motorway has a number of ramps with sub-standard spacing's, particularly between Onewa and Tristram Ave. In this section an auxiliary lane is provided between each interchange which helps mitigate the weaving issues generated from closely spacing ramps.

2.1.8.2 Southern Motorway

Southern Motorway - Southbound		
On-Ramp	Off-Ramp	Separation (m)
Green Lane (3 lanes)	Tecoma St	500
Tecoma St (3 lanes)	Ellerslie	700
Ellerslie (3 lanes)	South Eastern	2000
Mt Wellington (3 lanes)	Princess St	1450
Princess St (3 lanes)	Highbrook Drive	900
Highbrook Drive (3 lanes)	East Tamaki	1000
East Tamaki (3 lanes)	Te Irirangi	2300

Table 2-8 Southern Motorway Ramp Spacing

The Southern Motorway is characterised by groups of closely spaced ramps which are followed by long separations, in some cases this has been caused by placing an additional interchange between two generously spaced interchanges.

Between Market Road and the Ellerslie Panmure highway the ramps are roughly 1/3rd of the desirable spacing and unlike the Northern Motorway each ramp is a standard merge or diverge with no auxiliary lanes. The operating speed of this section of motorway reduces to approximately 40km/h in both the morning and evening peaks.

2.1.8.3 North-Western Motorway

North-Western Motorway - Westbound		
On-Ramp	Off-Ramp	Separation (m)
Newton (4 lanes)	St Lukes	1900
St Lukes (4 lanes)	Great North	750
SH20 (5 lanes)	Rosebank	1400
Patiki (4 lanes)	Te Atatu	1100
Te Atatu (3 lanes)	Lincoln	1400
Lincoln (2 lanes)	Royal	1750

Table 2-9 North-Western Motorway Ramp Spacing

For the proposed works on the North-Western Motorway 3 sections between the CMJ and Royal Road will have sub-standard spacing's. The two areas of most concern are the section between St Lukes and Great North Road and the section between the Patiki on-ramp and Te Atatu.

Neither of these sections has an auxiliary lane however the section between St Lukes and Great North Road has intentionally been designed to incorporate an auxiliary lane and only requires signage and line-marking changes to open it.

2.1.9 Shy Lines and Shoulder Width

The existing shoulder widths vary greatly through the study length however the proposed works are adopting a standard width of 2.5m. The one exception to this is going through the Great North Road interchange where the shoulder is expected to reduce to 0.5m.

The issue with narrow shoulders in front of barriers is that drivers can tend to shy away from the barrier, slow down or in some cases change lane. Table 2-10 lists the required offsets as to avoid adversely influencing a driver's behavior. It is noted that Austroads provides a single value for both sides of the road whereas the State Highway Geometric Design Manual (SHGDM) provides lesser values for on the off-side.

Design Speed (km/h)	Shy Line Offset (m)	SHGDM Off-Side Values (m)
80	2.0	1.0
90	2.2	1.5
100	2.4	2.0
110	2.8	2.0
120	3.2	2.0

Table 2-10 Shy Line Offset Values (Austroads 2009)

It is noted that shy line values are more relative when comparing against discrete objects near the road side rather than a continuous object like a barrier. Table 2-11 below shows the general reduction in lane capacity from having objects placed within the shy line.

In the case of a median barrier it is when there are discrete reductions in width that the lane capacity reduces. For long continuous sections, or where the narrowing is done with a gentle taper, the impact can be negligible.

Clearance to Fixed Object (m)	% of Normal Lane Capacity
1.8	100
1.2	98
0.6	95
0.0	88

Table 2-11 Shy Line Impact on Lane Capacity for Median Divided Road (TNZ SHGDM)

The shoulder widths provided through the Great North Road Interchange here are not uncommon with other parts of the network such as the southern motorway however they are quite out of context with the adjoining sections of motorway. Based on the above values from Table 2-10 & Table 2-11 a change in driver behavior can be expected through this section with a potential reduction in lane capacity of 5%.

A lower speed limit through this section would aid in reducing the effects of the narrow shoulders however the degree to which the shoulder narrows would require an approximate 60km/h speed limit to fully offset the shy line affect.

2.1.10 Lane Allocation

As shown in Table 2-9 above, the separation between St Lukes Road and Great North Road is half of the desirable value of 1.5km. Compounding this is the high demand for the Great North Road off-ramp and the SH20 ramp which is located some 600m further west.

The predicted traffic volumes per lane are shown below in Figure 2-3.

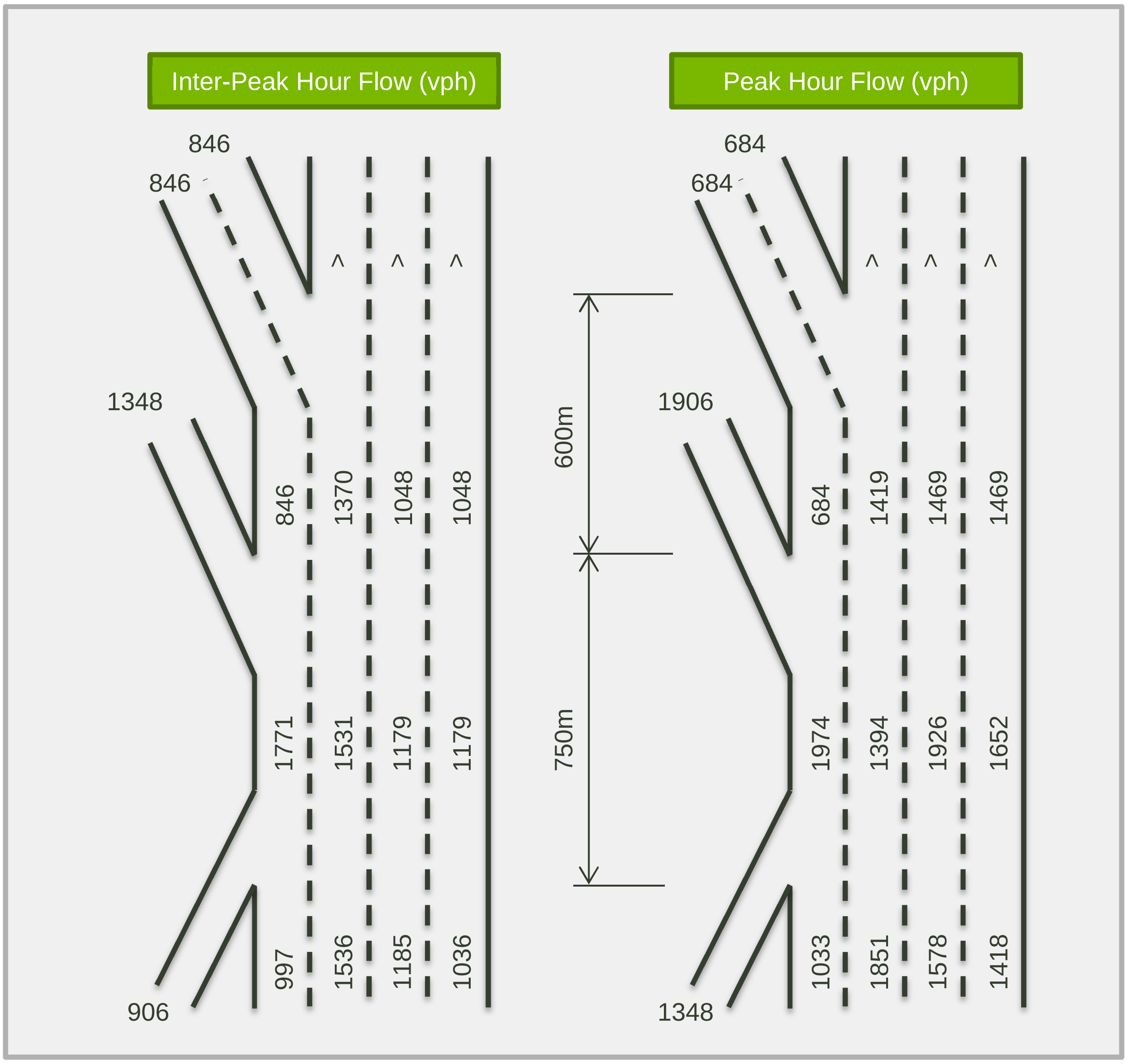


Figure 2-3 Lane by Lane Forecast for Design Year 2026

Lane allocation data sourced from Waterview Connection Project Stage 2 Traffic Engineering Report (400-RPT-00036)

2.1.11 St Lukes to Great North Road Weaving

Weaving Analysis

As seen in Figure 2-3 above, during both peak and inter-peak periods the heavy demand for the Great North Road off-ramp results in lane saturation in the outer most lane; with 1,800vph being the desirable maximum and 2,000vph being the absolute maximum.

In addition to the heavy use of the outer lanes a significant amount of weaving is expected to occur between St Lukes and the Great North Road on-ramp. Based on the values from Figure 2-3 above an indicative weaving diagram has been created and is shown in Figure 2-4.

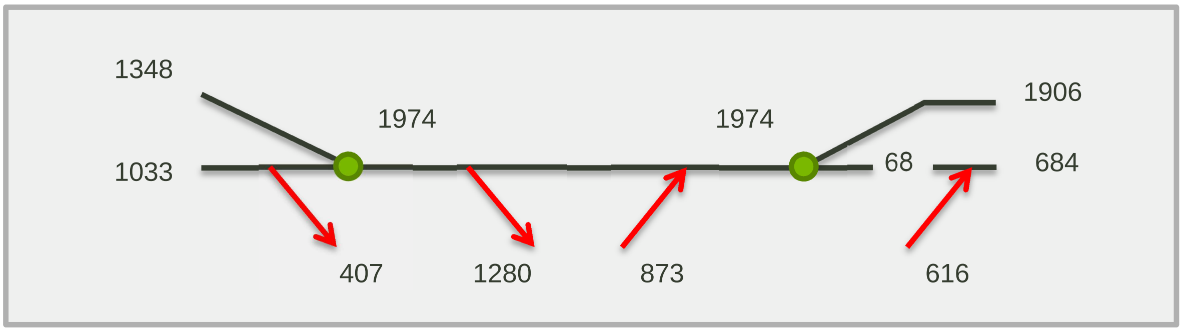


Figure 2-4 St Lukes to Great North Road Weaving

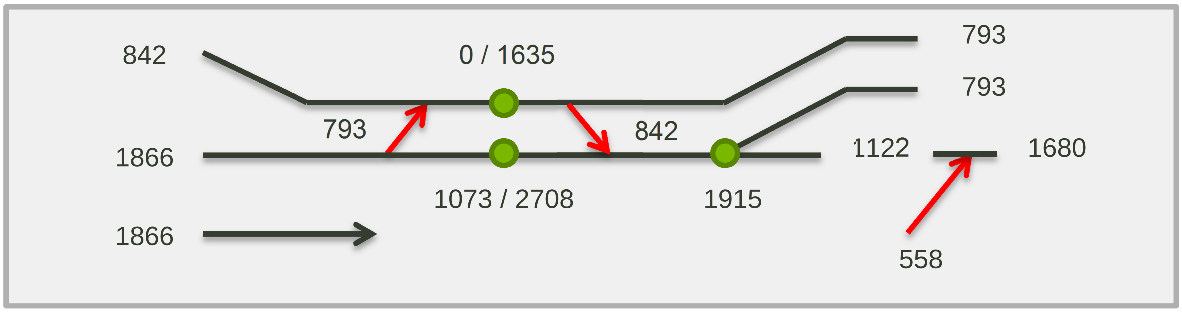


Figure 2-5 Kyber Pass Rd to Gillies Ave Comparison

As can be seen in Figure 2-4 above there are a number of weaving issues which are generated by the conflicting user destinations. The primary conflict here is the 1,348vph coming on the St Lukes Road westbound on-ramp who need to weave through 1,906vph on SH16 wanting to take the Great North Road off-ramp.

An anomaly is presented in this data being that 97% of the vehicle in the left most lane are said to be going to Great North Road, this implies that only 5% of people coming on at St Lukes would be wanting to head into the SH20 tunnel even though 27% of the total motorway flow is taking this route.

A situation that could result from these numbers is that the Great North Road off-ramp becomes over capacity and stationary vehicles back onto the motorway, this would cause any users wanting to take the SH20 tunnel to stay away from the left most lane and then weave across under Carrington Road.

A comparison has been made between the proposed St Lukes to Great North Road layout and the existing Kyber Pass Rd to Gillier Ave weave. Although the traffic volumes on SH16 are less than that on SH1 providing more space for lane changing, the conflicting movements are actually greater on SH16 with 3254 weave movements being required as opposed to 1635 on SH1.

Based on these figures two undesirable conditions arise:

- Stationary vehicles in the left lane between St Lukes and Great North Road
- High levels of weaving on the substandard section of road under Carrington Road.

Weaving Mitigation

Auxiliary Lane

In order to address the weaving issues mentioned above the St Lukes upgrade project is building the pavement wide enough so that an auxiliary lane can be installed if deemed required.

Although the auxiliary lane will not remove the conflicting destinations it will add additional lane capacity which will aid in reducing the need for vehicles to weave into the central lanes of the motorway to avoid traffic coming on and off the St Lukes and Great North Road ramps respectively.

Speed Limit

Although revising the speed limit will not reduce the volumes of the conflicting movements a reduced speed limit would increase the effective travel time and therefore decision time through the weaving section. This is known to increase the capacity of a weaving section of fixed length reducing the likelihood of flow break down.

It is noted, with the volumes involved, that flow break down would be inevitable at times; however the reduced speed limit would delay the onset of this. In addition the difference is vehicle speed between weaving vehicles and straight through traffic would be reduced resulting in greater safety margins.

As noted in the assessment of the Lincoln Road interchange temporary speed limit the adherence to the quoted value was poor, it is therefore unlikely a reduced speed limit alone would provide the potential benefits mentioned above.

2.1.12 Great North Road to St Lukes

Lane Allocation

For the weaving movements between Great North Road and St Lukes no “Lane by Lane” was provided in the Traffic Engineering Report. Using hourly flows a rough lane allocation diagram has been created that averages out the vehicle volumes over the traffic lane and this is shown in Figure 2-6 below.

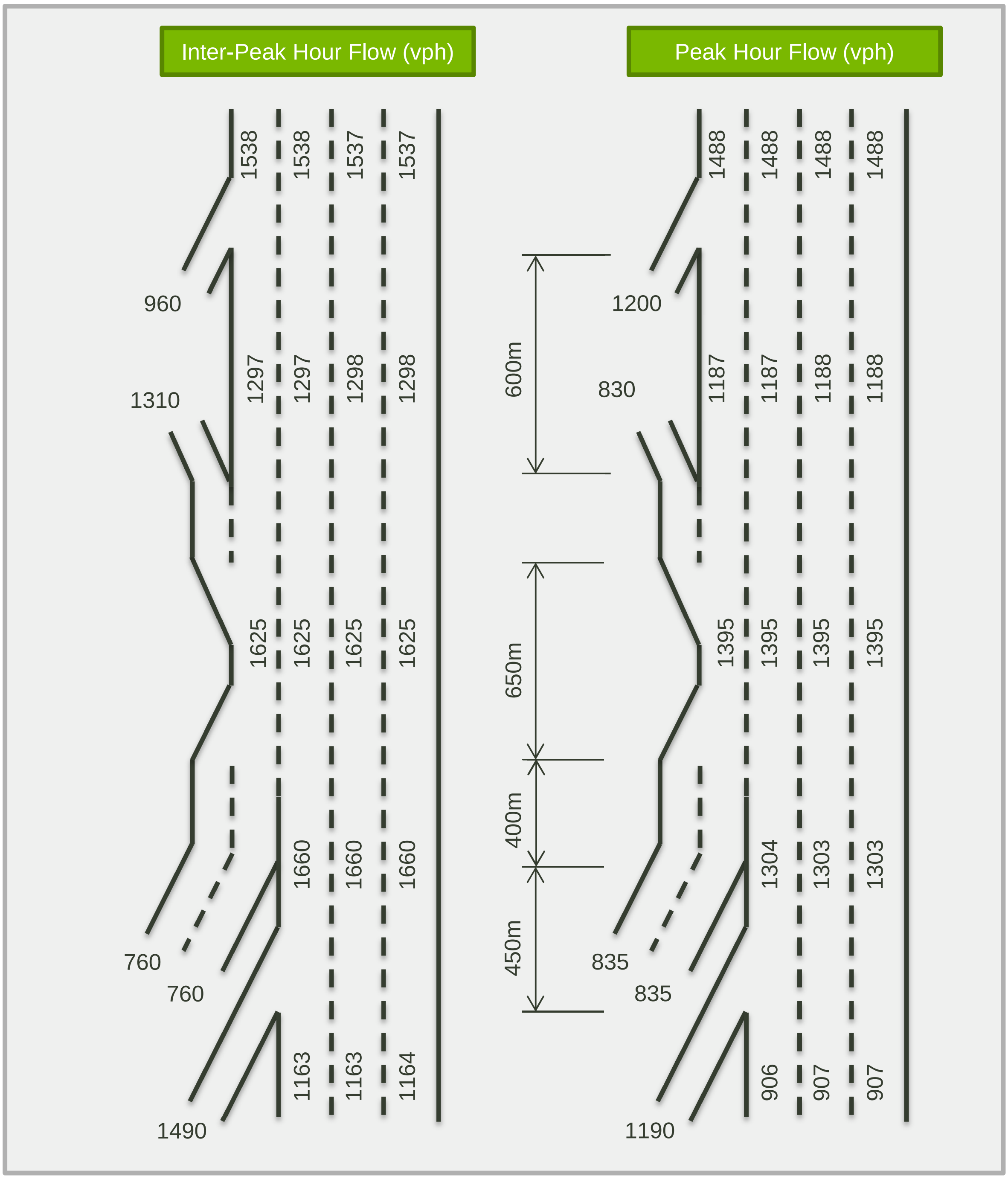


Figure 2-6 Great North Road to St Lukes Lane Allocation

Great North Road On-Ramp

Using the volumes from Figure 2-6 above it is clear that the Great North Road eastbound on-ramp will push the outer most traffic lane over capacity. The 1490vph coming from the on-ramp combined with the 1163vph on the outer lane creates 2653vph of demand in this lane, in general terms 1800vph is treated as the maximum capacity of a traffic lane. This issue will be mitigated slightly by vehicles using the Great North Road eastbound off-ramp however in the range of 800vph will be required to move out of the outer lane in order to accommodate the on-ramp flows.

SH20 to St Lukes Off-Ramp Weave

Without having the origin and destination volumes through this section it is hard to know what weaving issues will exist. Normally an assumption could be made that most vehicles coming on at one on-ramp would not be exiting at the next, however in this case one of the on-ramps is coming from SH20 where the last off-ramp was 7km previous. Therefore is can be expected that a moderate amount of users would want to exit the motorway at St Lukes. Based on the 1310vph using the St Lukes off-ramp and the 6500vph passing through this section, if an equal split is assumed between the SH16 and SH20 traffic the St Lukes off-ramp will attract 1004vph from SH16 and 306vph from SH20.

These approximated weaving volumes are shown in Figure 2-7 below. As shown, the outer most lane is likely to reach capacity due to vehicles from SH16 trying to cross over the SH20 traffic to reach the St Lukes off-ramp. This will result in underutilisation of the outer lane going through the St Lukes interchange which is shown to have 490vph, this will assist with reducing the impacts of the eastbound on-ramp flows from St Lukes.

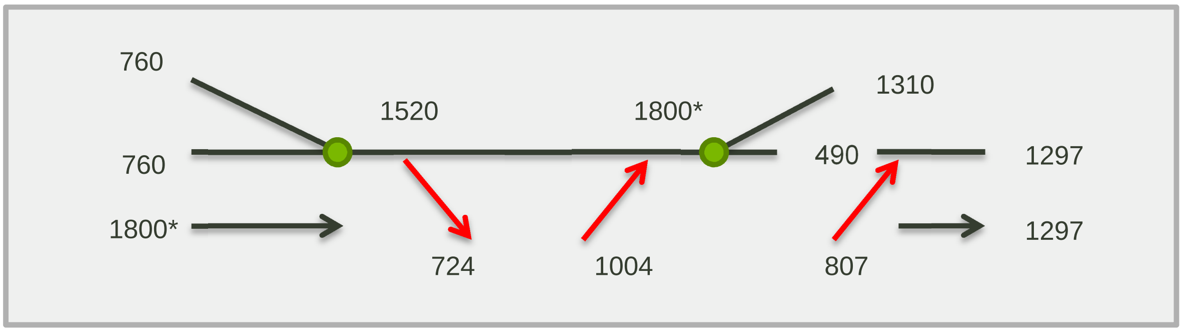


Figure 2-7 Approximated SH20 to St Lukes Weave Volumes

*Assumed maximum lane capacity of 1800vph.

Crash Data

2.1.13 Data Collection

Crash information has been extracted from the NZTA Crash Analysis System (CAS) over a 5 year period using the following criteria.

- Crash Years – 2008 to 2012
- Crash Type – All injury type accidents.
- Extents – Te Atatu interchange through to the Newton Road over-bridge.

2.1.14 Crash Sections

Due to the length of the analysis area and the number of accidents the results have been broken down into 6 sections as shown in Figure 2-8.

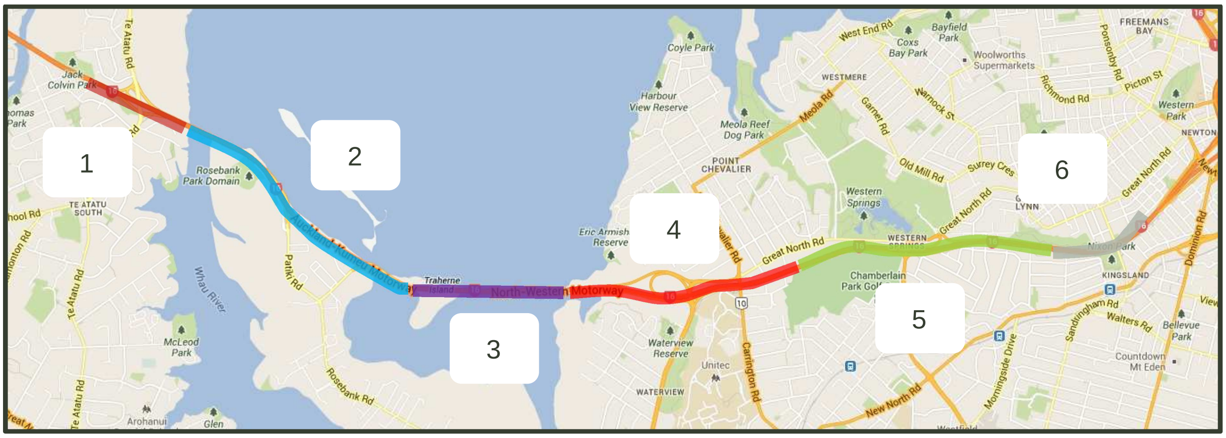


Figure 2-8 Crash Study Sections

Each crash study section represents a unique portion of SH16 in terms of geometry and layout as follows: Crash Diagrams for these sections are provided in Appendix B.

- Section 1 – Te Atatu Interchange
- Section 2 – Patiki and Rosebank Peninsula
- Section 3 – Causeway straight
- Section 4 – Great North Road Interchange
- Section 5 – St Lukes Interchange
- Section 6 – St Lukes approach

2.1.15 Crash Results

General Results and Speed Related Accidents

The total number of crashes on each section is shown in the Table 2-12 below; in addition both the number of ‘loss of control’ type accidents and the AADT is also shown.

Although ‘loss of control’ type accidents are not necessarily caused by excessive speed alone, higher speeds in general can result in inattention or other minor factors resulting in ‘loss of control’ crashes. As such this is an important factor to consider when assessing the consequences of changing the posted speed limit.

Section	Eastbound	Westbound	Loss of Control *	AADT (2012)
1	20	25	7 (0.9)	96,000
2	26	39	27 (3.3)	81,000
3	6	7	3 (0.3)	91,000
4	17	29	17 (1.7)	102,000
5	20	36	14 (1.4)	102,000
6	27	14	8 (0.7)	121,000

Table 2-12 Total Cashes and Speed Related Crashes.

**Values in brakets represents the number of accidents loss of control accidents for every 10,000 vehicles.*

Section 2 Defects

As shown in Table 2-12 above, the number of loss of control type crashes varies significantly between the different sections. In Section 3 going across the straight part of the causeway the 'loss of control' type crashes occur at a rate of 0.3 per 10,000 vehicles whereas going over the Rosebank and Patiki peninsula there are 10 times as many occurring at 3.3 crashes per 10,000 vehicles.

Currently the sight distance through this section is suitable for a 65km/h design speed however as shown in Table 2-5 this is being improved to 85km/h and should result in a reduction in crashes through this section.

Sections 4 & 5 Defects

For the Great North Road and St Lukes sections the crash rates are 1.7 and 1.6 per 10,000 vehicles respectively. Similar to the Patiki and Rosebank, these sections have existing substandard geometric features with the existing sight distance being limited to 115m (65km/h). As shown in Table 2-5 the St Lukes section has the geometry upgraded for an 85km/h design speed however the Great North Road section is to be left as per the existing layout.

Due to the upgrade works through the St Lukes section a reduction in crashes can be expected.

For the Great North Road section there is potential for an increase in crashes due to the increased traffic volumes, the added complexity of the new SH20 and the retention of the existing substandard alignment.

Congestion Related Accidents

As can be expected on an urban motorway the predominant types of crashes are either 'rear end' or 'side swipe' type crashes. These are generally caused by the high volumes of traffic in combination with flow turbulence created at each on/off ramp. Although lower speeds would mitigate the severity of these types of crashes they are still a common feature on busy low speed urban roads.

In order to establish the impact of the road geometry on the occurrence of 'rear end' and 'side swipe' type crashes they have been looked at in both peak and off peak scenarios. This is shown in Table 2-13 below using the following peak periods:

- Westbound – 4pm to 6pm
- Eastbound – 7am to 9am

Section	Eastbound	Westbound	Peak	Off-Peak
1	15	19	26%	74%
2	16	21	32%	68%
3	4	6	30%	70%
4	10	19	48%	52%
5	12	30	29%	71%
6*	24	9	39% (55%)	61% (45%)

Table 2-13 Rear End and Side Swipe Type Crashes

**Due to the character of the CMJ Section 6 has PM peak flows in both the eastbound and westbound direction.*

Based on Table 2-13 there are two sections that appear to have issues with weaving and side swipe crashes that are not solely related to peak hour congestion. These are Great North Road (section 4) and the St Lukes Approach (section 6) through Newton Gully.

Great North Road

For the Great North Road section, 13 (68%) of the westbound crashes occur on the approach to the Great North Road off-ramp as SH16 passes under Carrington Road. In the eastbound direction 4 (40%) of the crashes occur on the Great North Road on-ramp and further 4 (40%) within 400m of the end of the merge.

As shown in Appendix C this is one of the few sections of SH16 that is not being upgraded and retains the existing substandard geometry more suited for a 65km/h design speed.

In addition to the high crash rate and the substandard geometry this section is also expected to have high volumes of conflicting weaving movements in both the westbound and eastbound direction as shown in Figure 2-4 and Figure 2-7.

It is seen that a lower posted speed limit would go some way towards addressing the safety issues through this section by effectively increasing the weaving lengths provided for the various ramp merges and diverges in this area. In addition to this a lower speed limit would be more in context with the road geometry which is notably lower through the Great North Road interchange than on the adjoining sections.

St Lukes Approach (Newton Gully)

For the Newton Gully section the 73% of the weaving related accidents are in the eastbound direction. In addition to this the eastbound direction experiences an increased number of crashes during the morning and evening peak, 24% and 16% of total crashes respectively.

It is important to note that the crash analysis only extends as far as the Newton Road on/off-ramps and so most of the CMJ ramps are not included in these results.

There are two main issues that contribute to this high crash rate which are as follows:

- The high number of potential movements with the SH16 motorway splitting into 5 separate ramps.
- Unbalanced ramp capacity at the CMJ

The high number of potential movements is inherent of the CMJ's function and although physically demanding for user, is thought to be the lesser of the two main issues. In part the confusion of the multiple destinations is mitigated by having each lane with a single destination; however this results in very high demand on some lanes and very low demands on others.

In terms of the unbalanced capacity, the SH16 eastbound approach to the CMJ is dominated by two flows, the SH16 to Hobson St / north and SH16 to south. During the evening peak all of the flows reduce however the unbalance remains as shown in Figure 2-9.

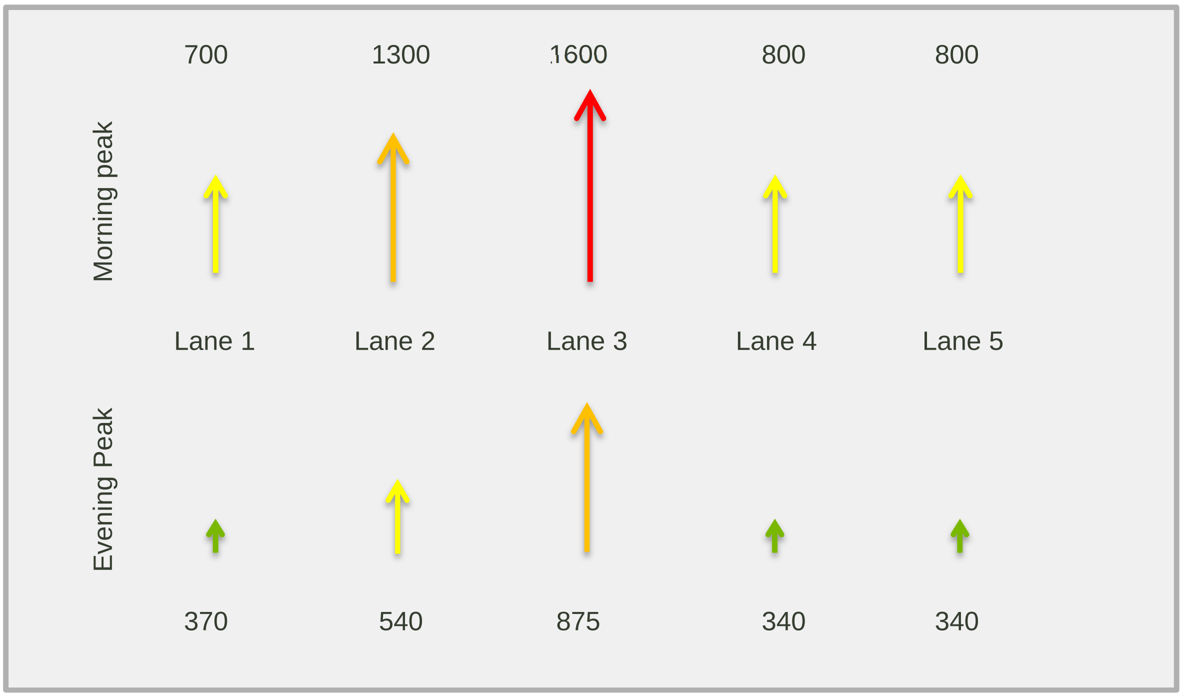


Figure 2-9 SH16 Eastbound Approach and Demand Lane Balance

As shown in Figure 2-9 the two highest demands are located in Lanes 2 & 3, with low volumes in Lanes 1, 4 & 5. A common observation through this section is that vehicles with the intention of heading to lane 3 tend to capitalise on the low utilisation of lanes 4 & 5 in order to advance ahead of the queue. This results in users making dangerous merge manoeuvres very close to the ramp nose.

What is not reflected in Figure 2-9 is that based on typical driving mentality users with the desire to use lanes 1 & 2 at the CMJ may approach from the west in lanes 3 and 4, conversely users with the intention of departing on lanes 4 & 5 may approach on lanes 1 & 2 from the St Lukes Interchange. What this means is that although the approach flow and demand of lane 3 is less than 1,800 vph weaving movements through this lane could push it well over this threshold.

For example; the PM peak from the St Lukes Road on-ramp is 1,390vph, if 1/3rd of these vehicles were to head to lanes 4 & 5 that would push lane 3 up to 1,338vph, 3 to 4 times greater than the adjacent lanes.

In regards to speed, very high speed differentials can be experienced through this section with Lane 3 often being in stop/start conditions with the remaining lanes and in particular Lanes 4 & 5 are free flowing. Ideally the difference in speed between adjacent lanes of traffic should not be more than 20-30km/h however on this section of SH16 the difference can often be in the range of 50-60km/h.

In relation to mitigating this issue through the use of a lower speed limit it is seen that a very low speed limit, in the range of 50-60km/h, would be required to fully mitigate the concern. Based on the current observed speeds it is noted that users do not reduce their speed significantly through this part of the current 80km/h restriction with the eastbound inter peak speed being 95km/h and the westbound inter peak speed being 100km/h.

A further issue arises that the length of the queue in lane 3 is highly variable, on occasions it can extent back some 1.5km whereas at other times of the day it can be non-existent. Based on the crash data obtained there are a high number of crashes caused by congestion at this 1.5km extent.

St Lukes to Great North Road

In order to gauge the impact on crashes of closely spaced on/off-ramp a comparison has been made using two similar locations in Auckland as follows:

- Northcote to Esmonde Road = 750m
- Kyber Pass Road to Gillies Ave = 350m
- St Lukes to Great North Road = 750m

The total number of weaving related crashes has been compared against both the AADT and the total number of movements and is shown in Table 2-14 below. The volumes of weave movements have been calculated by combining the total number of vehicles coming onto the motorway with the total number coming off the motorway. In addition to this the percentage of ideal capacity that is used is also shown, as this value approaches 100% motorway speeds reduce and the occurrence of flow breakdown becomes more likely.

On-Ramp	AADT	Capacity %	Weave movements	Crashes	Crashes / 10k vehicles	Crashes / 10k weaves
Northcote	57,248	85%	14,767	7	1.2	4.7
Kyber	103,826	92%	30,361	8	0.8	2.6
St Lukes (2013)	51,573	76%	26,184	19	3.7	7.3

Table 2-14 Crashes rates based on AADT and weaving volumes

Although the above data set is too small to make any definitive conclusions, a trend is seen that as the capacity of the roadway approaches its limits the number of injury type crashes reduces. This is a previously established trend as when a road becomes congested speeds reduce the chance of injury becomes less likely in a crash.

In the case of the St Lukes to Great North Road section the 76% capacity figure in combination with the high weave volumes suggests that the lanes on the edge of the motorway can become heavily congested whilst the through lanes remain relatively free flowing creating high differential speeds. The potential impacts of traffic volumes on the St Lukes to Great North Road section is shown in Table 2-15 below.

What isn't apparent from the above figures is any effect on safety from the short weaving length. When comparing Northcote to St Lukes both weaving lengths are the same however Northcote has a better safety record per weave (however Northcote also has a lower number of weaves in total and it could be its weave volumes are more suited to the weave length provided).

- Northcote = 2.0k weaves per 100m
- St Lukes = 3.5k weaves per 100m

Capacity Loading	AADT	Capacity %	Weave movements	Crashes (volume)	Crashes (weave)
None	84,600	-	34,800	31	25
Balanced	-	96%	-	5	7
Traffic Model	-	92%	-	7	11

Table 2-15 Extrapolated crash volumes post upgrade based on 2026 volumes.

3 Potential Speed Limit

Introduction

Based on other sections of roadway of similar geometric condition either a 100km/h or 80km/h speed limit could be considered. Another option is 90km/h, however this is a rarely used limit and may not be sufficiently different from the standard 100km/h to provide any real benefit in the context of this motorway.

Summary of Operational Issues on SH16

Area of Assessment	Identified Issues	Impact of Lower Speed Limit
Operating Speed	Vehicles tend to operate 2km/h under the posted speed limit when set at 100km/h. In 80km/h sections vehicles tend to operate 5km/h over the posted speed limit.	Average vehicle speed reduces by 40-65% of the posted reduction. Greater speed differentials between vehicles may be generated with likely reduction in safety.
Road Geometry	Normalised sight distance provides for 100-110km/h. Sight distance reduces to 85k/h in some locations. Great North Road interchange remains out of context being more suited for 70km/h.	For the majority of the project length a reduced sight distance will have little impact on the crash types presented. The exception is through the Great North Road interchange where “loss of control” type crashes could be expected.
Ramp Spacing	Ramp spacing generally less than desirable.	A reduced speed limit would aid in mitigating the short ramp spacing increasing travel time between ramps.
Shy-Lines	Generally suited for 110km/h with the exception of the Great North Road Interchange which is more suited for 60km/h and can expect a reduction in lane capacity of 5%.	A reduced speed limit would aid in mitigating the impacts of substandard shy-line through the Great North Road Interchange however a 60km/h speed limit would be required to totally negate it.
St Lukes to Great North Road	Extremely high weaving movements expected with flow breakdown highly likely.	A reduced speed limit would aid in mitigating the high weaving movements however at peak times a posted speed in the range of 60km/h may be required to have any measurable effect. The ideal solution would be to

		grade separate these movements.
Great North Road On-Ramp	Heavy on-ramp flows resulting in flow breakdown.	A reduced speed limit would help this merge function, however an ideal solution would be to have the on-ramp form a lane gain or a long auxiliary lane.
Crash Data	A high number of congestion related crashes were identified. In addition some locations also had “loss of control” type crashes however these sections have had suitable geometric upgrades.	A reduced posted speed limit would likely reduce congestion and therefore the occurrence of congested related crashes, in addition it will tend to reduce crash severity.

Table 3-1 Summary of Operational Issues on SH16

Potential Speed Values

3.1.1 100km/h

Retaining the existing speed limit would leave the SH16 motorway in context with the rest of the motorway network and would avoid the potential for confusion and reduce deferential speeds between users.

The primary issue maintaining a 100km/h speed limit for the length of SH16 is that the geometry and complexity of the road through the Great North Road interchange is being reduced from the existing situation which would have the likely consequence of increasing the crash rate through this section. It is noted that this section already has a relatively high number of “loss of control” type crashes in comparison to the adjoining sections of SH16.

3.1.2 80km/h

A comprehensive 80km/h speed limit would holistically fit well with the current 80km/h speed limit in the CMJ and the proposed 80km/h speed limit for the SH20 tunnel as it would create one seamless section of motorway.

Once taking appreciation of the road environment however the 80km/h speed limit will appear out of place between the CMJ and Great North Road as the road geometry is suited for normal operating speeds in the range of 100km/h. This would likely result in a greater variance of vehicle speeds which as highlighted in Section 0 is one of the reasons for the high number of crashes on this section of motorway in comparison to others.

Despite this, the Great North Road interchange itself is of a lower standard than the two adjoining sections of motorway. The end result will be similar to that of the Esmonde Road interchange on the Northshore. Both the northbound and southbound approaches to this interchange are suited for 110km/h however the through route of the motorway under Esmonde Road is more suited for 65km/h. Attempting to address a single out of context element on a wide urban motorway is not a simple task and potentially reducing the operating speed of the entire motorway would be the most effective way to mitigating the issues at this location.

3.1.3 60km/h

As highlighted in Table 3-1 there are a number of traffic related issues that would be improved through having a lower speed limit. The primary benefit would be traffic flow which would be greatly improved with the occurrence of flow break down being reduced and the effective weaving lengths between ramps being almost doubled.

An additional benefit would be the reduced speed differentials between free flowing lanes and congested lanes. This reduced speed differential would reduce the risk of injury crashes improving the operational reliability of the motorway.

However, a 60km/h speed limit is not seen as a practicable full time speed limit for an urban motorway as ultimately the issues such a speed limit would address only exist for a few hours each day. Therefore, although a 60km/h speed limit would deliver the greatest benefits in terms of operation and safety, it could only really be used as a “Temporary” speed limit during peak conditions.

3.1.4 Variable Speed Limit

While this may provide the best solution, this is considered beyond the scope of this study as it is not currently in use on the New Zealand motorway network. Further consideration of this option however may be applicable for this section of the motorway network.

3.1.5 CO^2 Emissions

Another aspect closely related to vehicle speed is vehicle efficiency and most importantly greenhouse gas emission. Based on NZTA figures 44% of New Zealand’s CO^2 emissions come from transport with 90% of that coming from road transport.

For a typical vehicle the most efficient operating speed is 70-80km/h, speeds above this attract too much wind resistance whereas speeds below this run the engine inefficiently. By maintaining a vehicle at these speeds a reduction in CO^2 emissions of approximately of 15% can be achieved.

In the case of an 80km/h posted speed limit CO^2 reductions would be achieved through two ways, more efficient vehicle operation and less turbulent flow resulting in reduced braking and accelerating.

4 Proposed Speed Limit

Proposed Speed Value

Based on the analysis conducted a number of aspects support a reduced speed limit in order to improve traffic performance and to reduce the severity of crashes. These savings could be claimed by reducing the speed limit on any section of road and are not overly specific to the studied section of SH16.

Based on the geometrics of the proposed motorway and the observed driver behaviour through similar sections most of the study length is suited to a 100km/h speed limit with the exception of the Great North Road Interchange which, due to is reduced standard and added complexity, does warrant a reduced speed limit. This limit could be extended through to the St Lukes Interchange to incorporate the west facing ramps which would create a reduced speed limit environment that is in context and therefore likely to have a higher level of compliance.

The debatable section however is from the CMJ through to St Lukes being a 2km length with little side friction and few geometric constraints. A reduced speed limit through this section would likely feel unwarranted which would result in a high level of non-compliance. It is noted that the minimum length of a 100km/h speed limit is 2km and therefore this section of road would fit within those parameters to be posted differently from the Great North Road interchange and the CMJ.

To this extent it is proposed that the section of SH16 between the CMJ and the Great North Road Interchange be split into 3 sections as shown in Figure 4-1.

In order to gain the intended benefits of a lower speed restriction an effective implementation method is required for which for which some guidance is provided in Appendix A.

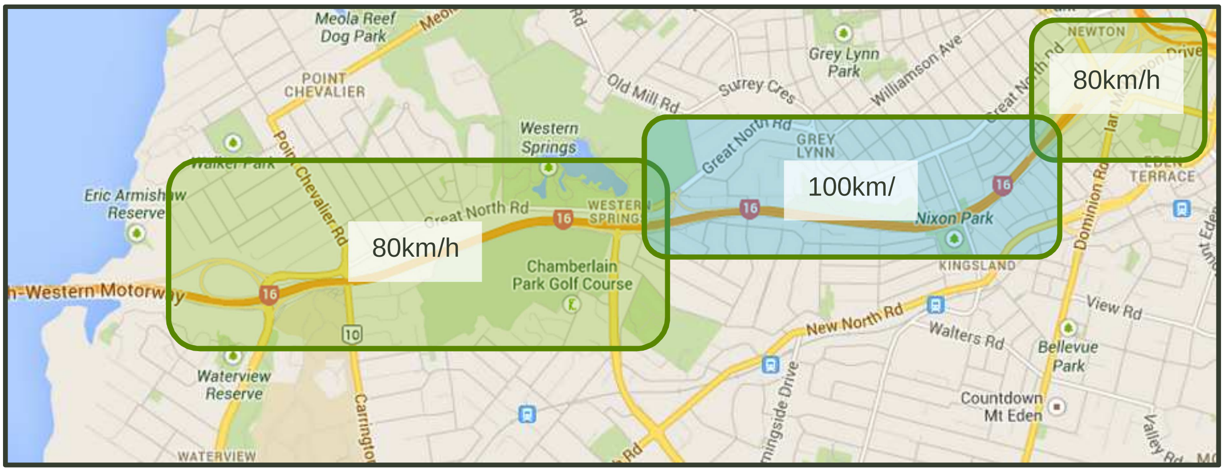


Figure 4-1 Proposed Speed Limits

Appendix A
Implementation Method

Appendix A
Implementation Method

Implementation Method

1.1 Existing Treatments

Currently the sections of motorway that are posted at 80km/h have the standard gated RG-1 Speed Limit signs as shown in Figure 1 and Figure 2. These signs are often located on wide complex sections of motorway with a significant amount of large overhead signage leaving the speed limit signs notably inconspicuous and often not seen by drivers.

For the SH16 eastbound approach to the CMJ the speed limit threshold is not seen to be overly effective in slowing vehicles down prior to the CMJ however the very tight geometry of the CMJ ramps effectively force users to slow down.

For the SH1 southbound approach to the Harbour Bridge the speed limit threshold is again notably inconspicuous however the 5% uphill grade, narrow lanes and no shoulders generally results in low vehicle speeds on the incline with a wide variety of speeds observed on the down grade and through St Marys Bay.

Figure 1 SH16 Eastbound Speed Limit Change

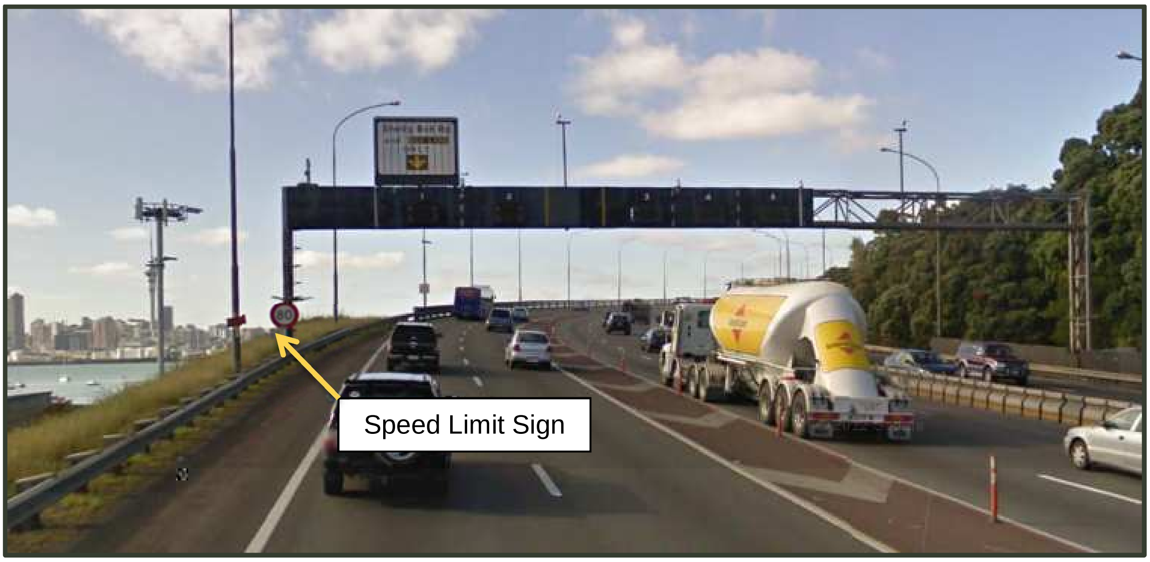


Figure 2 SH1 Southbound Speed Limit Change

1.2 Existing Guidelines

The general concept when making a speed limit change is to create a threshold that provides a visual cue to the drivers that they are entering a new environment and need to adjust their speed. Traditionally a motorway is a uniform section of road where the speed limit doesn't change and the only locations where is does change are on the on/off ramps or when entering and leaving the city limits.

Although not common in New Zealand, in both the USA and Australia rural expressways tend to be posted 10-20km/h higher than urban motorways. When these changes occur there are generally a number of visual elements that change such:

- Reduced median width
- Concrete median barrier rather than wire-rope
- Additional traffic lanes
- Edge barriers rather than clear zones
- Greater frequency of interchange
- Greater intensity of roadside development.

The above elements all work together to encourage the driver to reduce their speed and generally provide a buffer from where the reduced speed is actually needed for safety reasons.

In New Zealand the typical speed change threshold occurs on two-lane, two-way roads however the principles behind their effectiveness remain the same. RTS 15 Guidelines for urban-rural speed thresholds provides and number of examples and explains some of the principles behind effective thresholds as follows:

- Location
- Roadway narrowing
- Lighting
- Conspicuity
- Changes in pavement surface
- Landscaping and roadside verge treatment

1.2.1 Location

The initial governing factor in determining the location of a speed threshold is the location of the warranted speed restriction. In this case the analysis conducted in Section 2 has determined the sections of road that warrant a speed restriction and the precise location is yet to be determined. To this extent the location of the speed limit change has a degree of flexibility to ensure the other criteria are appropriately meet.

The second factor to consider when locating the threshold is the sight distance available to the threshold and the implication it has on any other roadside features such as on/off-ramps. Ideally the threshold should be located on a straight however a large radius curve can also be used provided the threshold remains within the drivers cone of vision.

1.2.2 Roadway Narrowing

Carriageway Width

In order to create an effective threshold where users are encouraged to reduce speed a "pinch point" needs to be created through the horizontal and vertical elements. A simple cross section from RTS 15 is shown in Figure 3.

In a motorway environment there is reduced scope to narrow the road however there is ample scope to reduce the edge shoulders. As part of the SH16/20 interchange works a number of shoulder reductions are being adopted for various constraints, generally these are limited to 1m in width with one section reduced to 0.5m. In order to ensure the threshold is effective a similar width shoulder in the range of 0.5 to 1.0m could be used through the threshold through either “hard” measures such as barrier or “soft” measures such as “safe hit” posts.

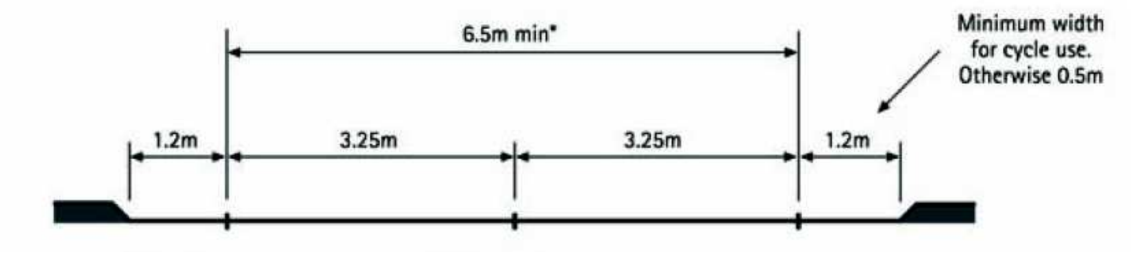


Figure 3 LTSA RTS 15 (2002)

Height to Width Ratio

One important element is height with research indicating drivers travel at a reduced speed where the height of the vertical features is greater than the width of the roadway as shown in Figure 4. For a motorway achieving this balance is not be practicable due to the number of traffic lanes required, for example a 4 lane motorway with 2m shoulders would require the vertical elements to be over 18m in height however it is still an important factor to take into account.

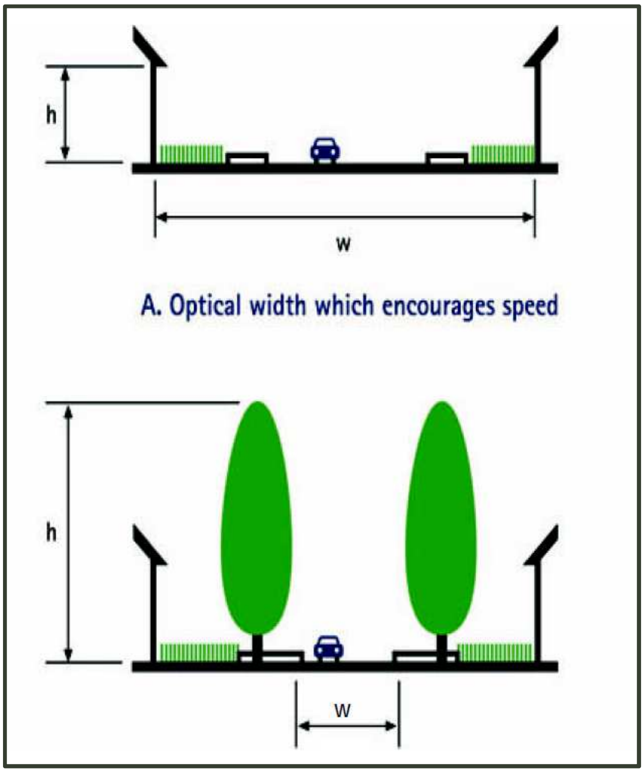


Figure 4 LTSA RTS 15 (2002)

1.2.3 Conspicuity

A key requirement for any threshold is that it stands out and is seen by drivers. As shown in Figure 1 and Figure 2 the existing speed thresholds blend in with their surroundings making them less effective at reducing vehicle speeds.

Along with providing adequate visibility and the reduced carriageway width other measures than can enhance the conspicuity and therefore effectiveness of a threshold are as follows.

- Landscaping that contrasts in colour with the surrounding landscape.
- Coloured paving materials through the pinch point
- Size of the speed limit sign and backing board.

- RRPM's and enhanced street lighting

1.2.4 Landscaping and Roadside Verge Treatment

For thresholds on standard two-lane two-way roads planting can be an effective tool for creating the narrow feel of the road, however in a motorway environment with a narrow median there is no real potential to gate this treatment. Although there may be some locations where the median width is wide enough to provide central landscaping maintenance aspects would likely require any such planting to be low and easy to maintain.

1.3 Proposed Layout and Location

1.3.1 Proposed Layout

Cross Section

A similar threshold concept was used at the end of the SH16 north-western motorway where it was required to transition from the 100km/h motorway environment into an 80km/h rural highway as shown in Figure 5. For this location the motorway shoulders were reduced in width to 0.7m and additional barrier was added on the left hand side of the carriageway even though there were not significant hazards in need of protection.

For the SH16 threshold the narrowing of the motorway shoulders was done at a rate of 1:50 which presents a very gentle taper rate that is normally used to ease the driver into a narrower area. The result of this is a safer layout in terms of reducing barrier strikes and erratic driving; however there is a reduction in the "pinch point" effect on the driver.

In order to enhance the "pinch point" effect a shorter taper rate could be used similar to that of barrier flare rates. In order to ensure the safe operation of the barrier a taper rate of 1:15 should be treated as the minimum for a 110km/h design speed with longer taper rates of up to 1:30 to reduce the shy line effect on drivers.

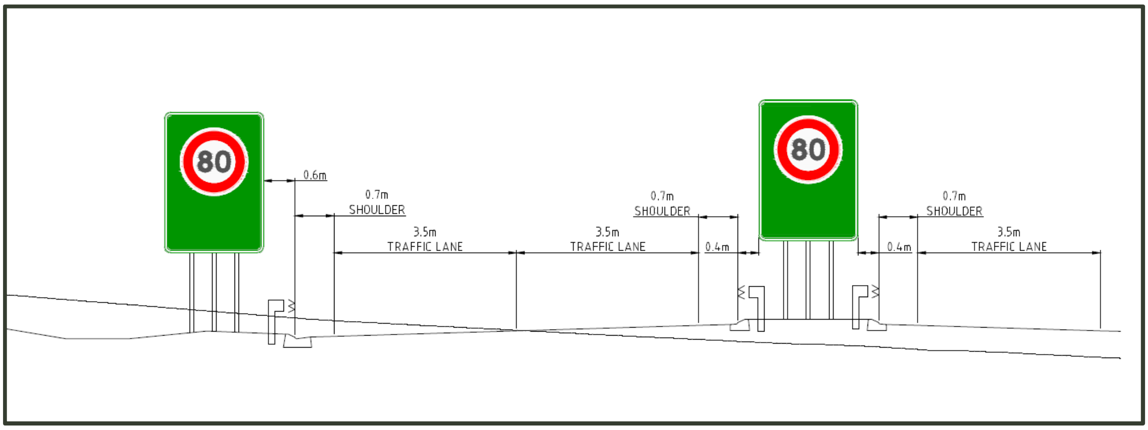


Figure 5 SH16 North-Western Motorway Termination Threshold

Plan Layout

In the case of the study area the motorway is 4 lanes in either direction and therefore two of the traffic lanes will not be influenced by this reduction in shoulder width and therefore other options may need to be investigated. One such option will be the narrowing of lanes through the use of chevrons to ensure all 4 lanes of the motorway have some physical encouragement to slow down. Figure 6 shows what could be done by reducing the traffic lanes to 3.25m for a 20m length which would in turn enable the forming of a 0.5m wide chevron section, in addition to the narrow lanes the figure also shows how "safe hit:" posts at 2m centres with 1:15 tapers would appear over the same section.

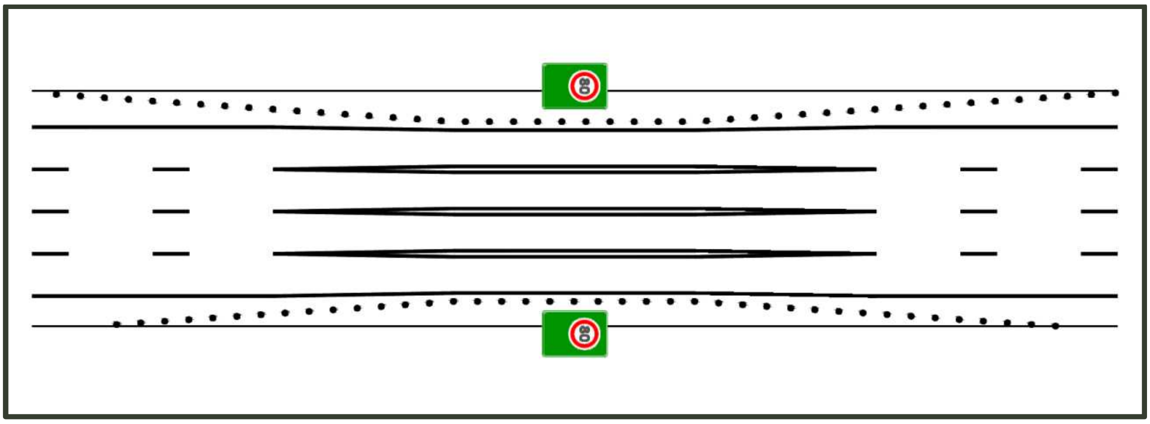


Figure 6 SH16 Pinch Point Concept

1.3.2 Proposed Threshold Locations

Based on Section 4 two new thresholds are required to be created on SH16 with an additional one on SH20 prior to entering the tunnel.

SH16 Westbound

For the westbound threshold the proposed location is as the SH16 alignment passes under St Lukes Road as shown in Figure 4-1**Error! Reference source not found.**. The combination of the large overhead structure and use of appropriate signage makes this location ideal.

This location places the change in speed limit 370m before the westbound St Lukes Road on-ramp providing adequate time for vehicles to slow down.

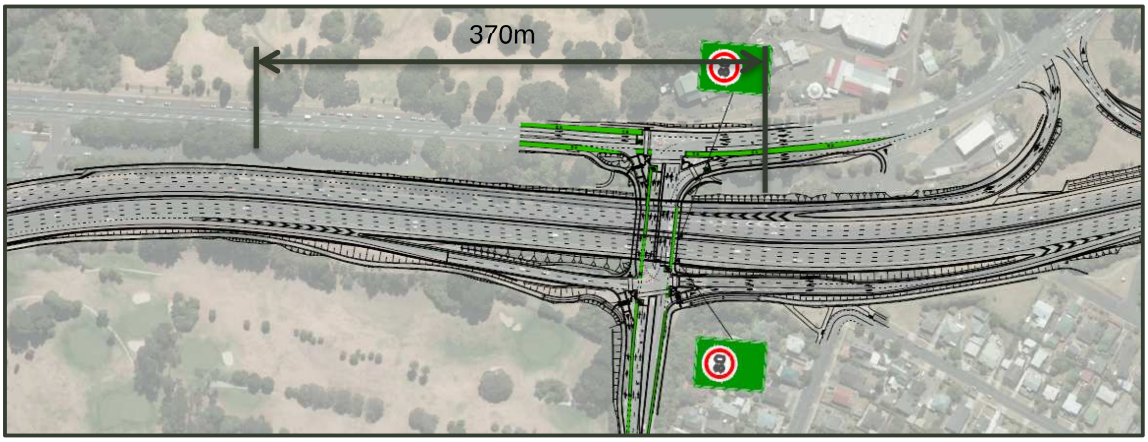


Figure 7 Westbound Threshold at St Lukes Road

SH16 Eastbound

For eastbound traffic on SH16 the threshold has been located 650m from the end of the bifurcation of SH16 and SH20 as shown in Figure 8. This location has been selected as it is located midway between two motorway gantries and therefore reduces sign clutter as much as practicable.

This places the change in speed limit 1km before the most demanding section of the interchange giving drivers additional time to slow down from the free flowing alignment on the SH16 causeway.

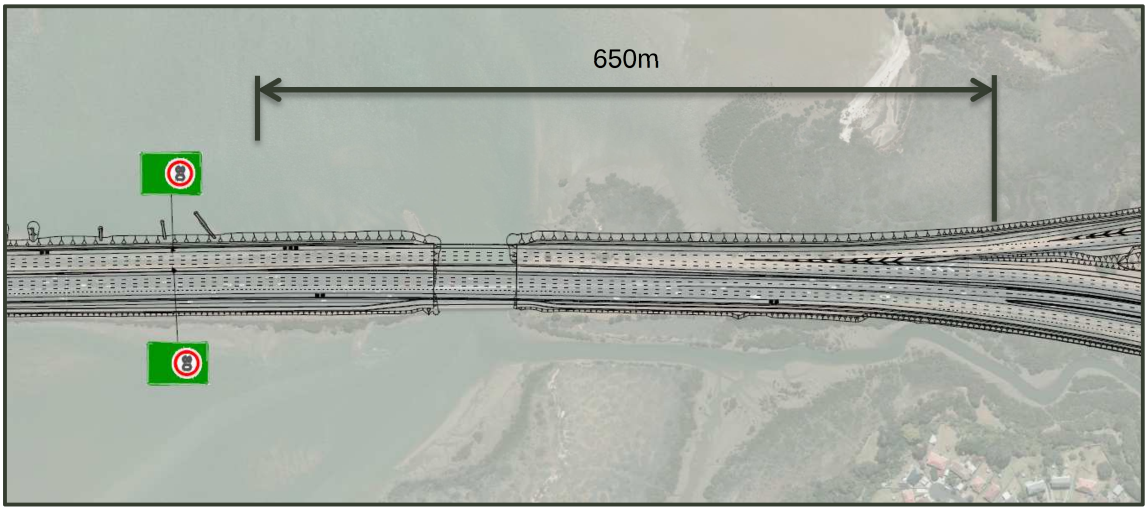


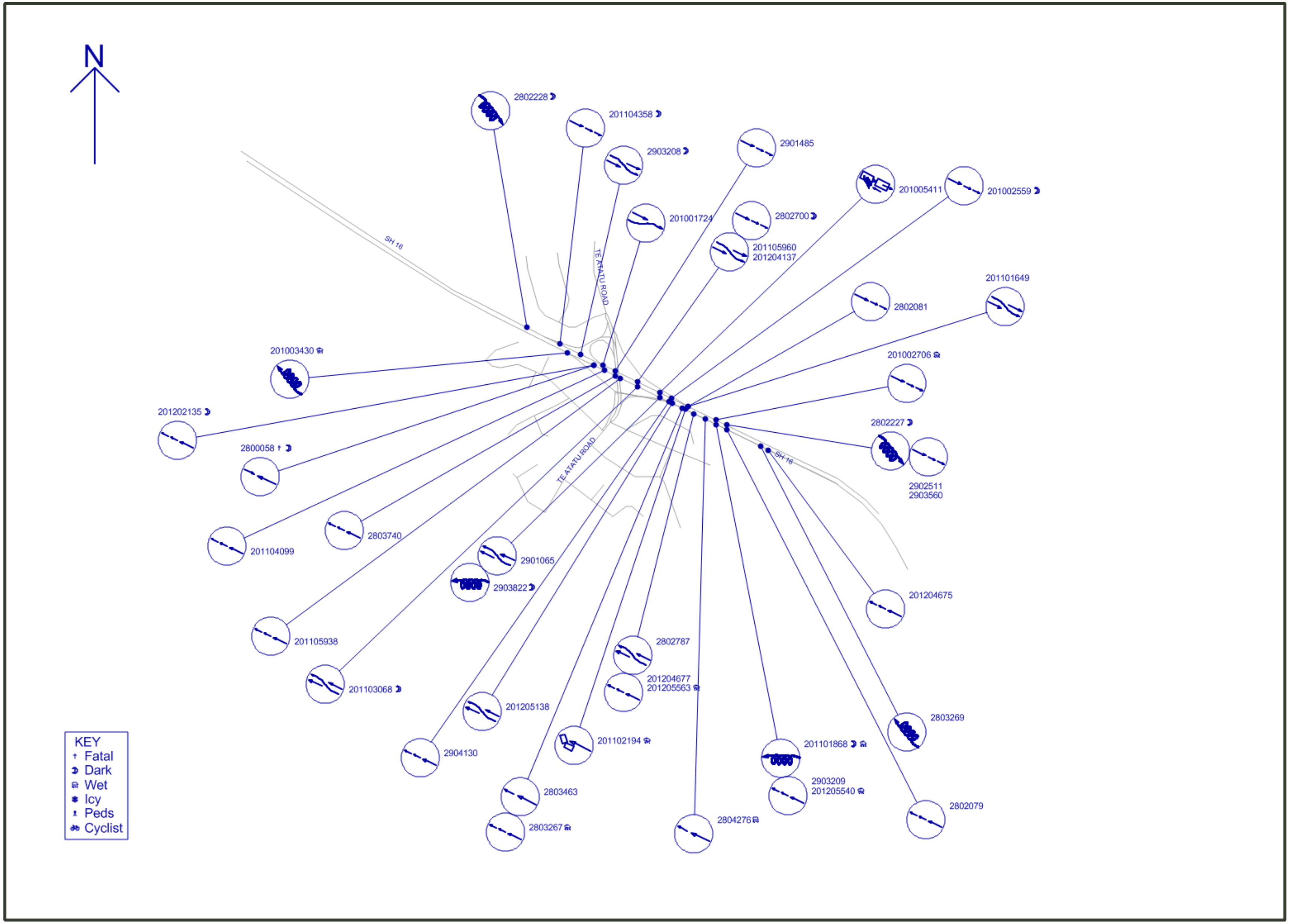
Figure 8 Eastbound Threshold on Causeway

SH20 South

For traffic heading northbound on SH20 towards the tunnel it is proposed to apply the threshold where Maioro Street passes above SH20. This will place the change in speed limit 1.4km prior to the tunnel and will have vehicles slowing down prior to the lower geometry section of SH20 through Hendon Park where vehicles are required to get in lane before the descent into the tunnel.

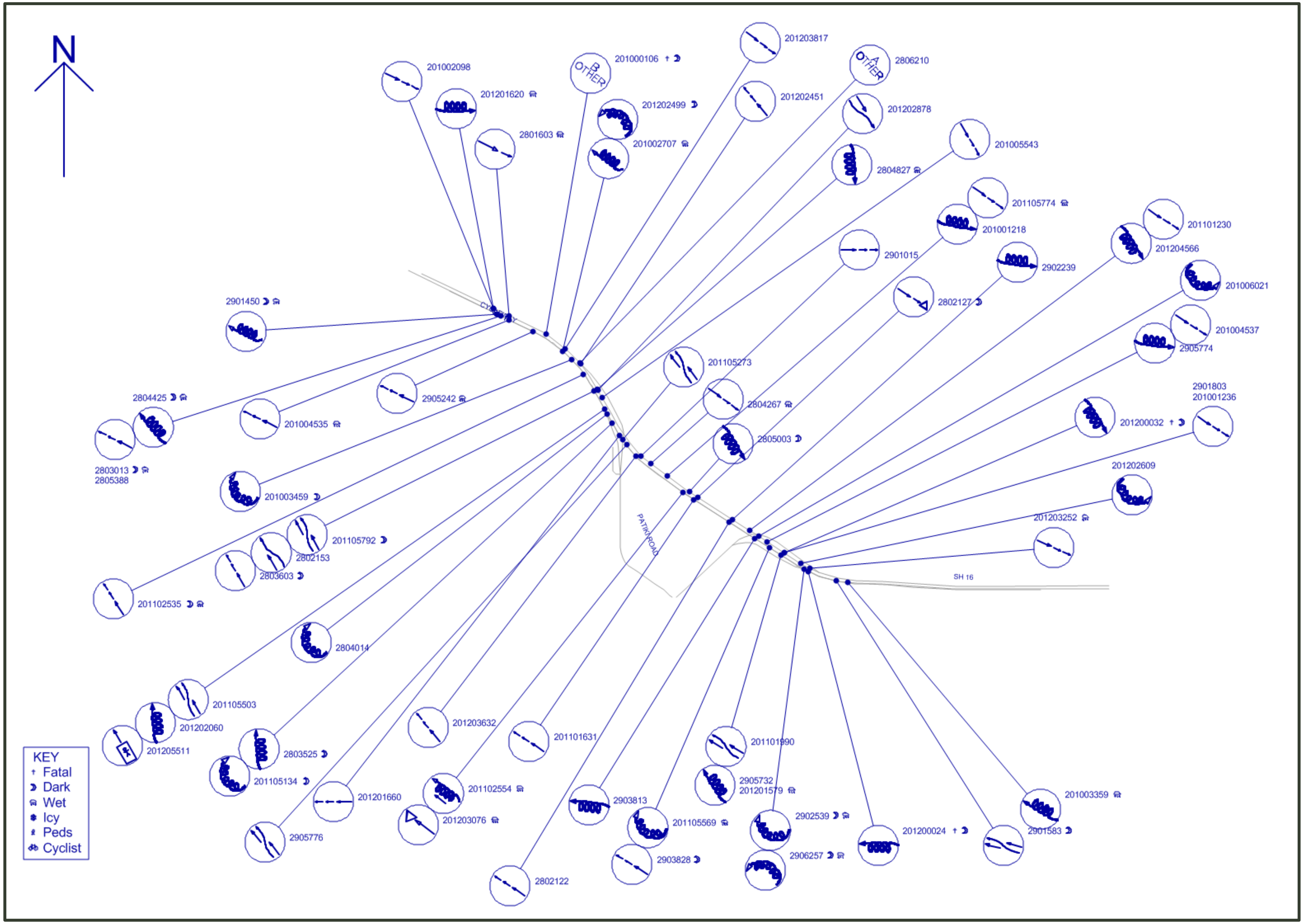
Appendix B
Crash Diagrams

Appendix B
Crash Diagrams



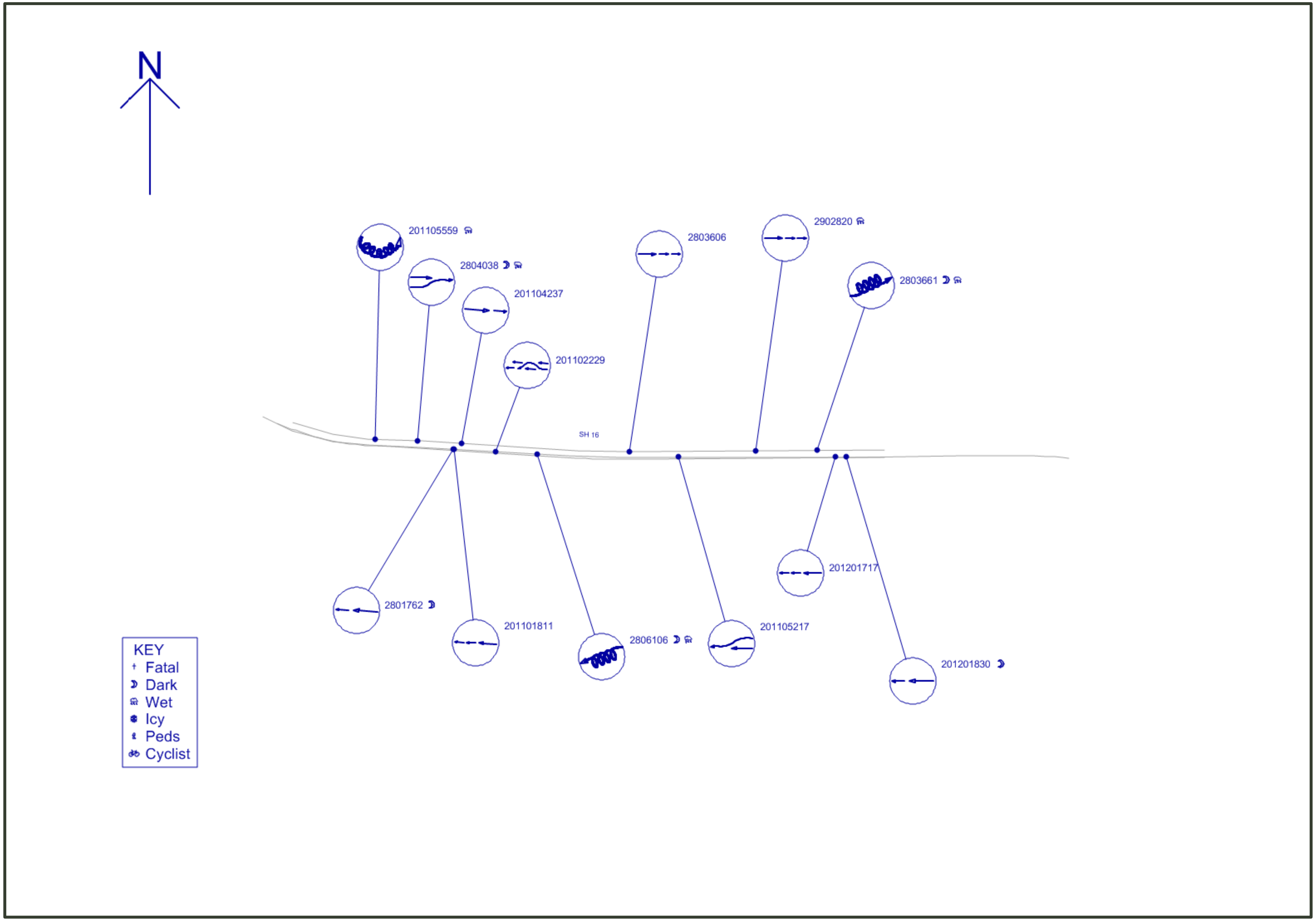
Section 1

Te Atatu Interchange



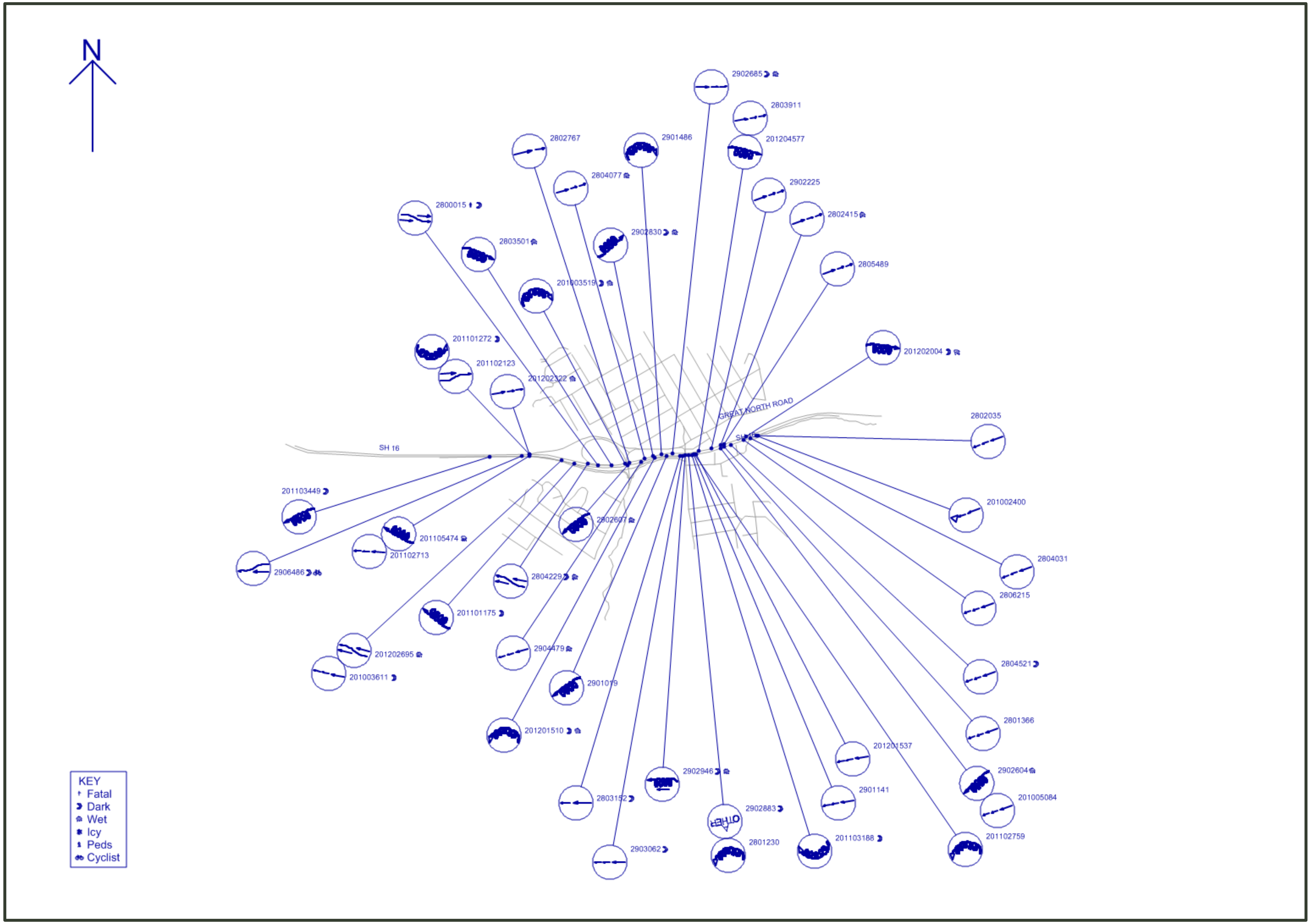
Section 2

Patiki Rosebank Peninsular



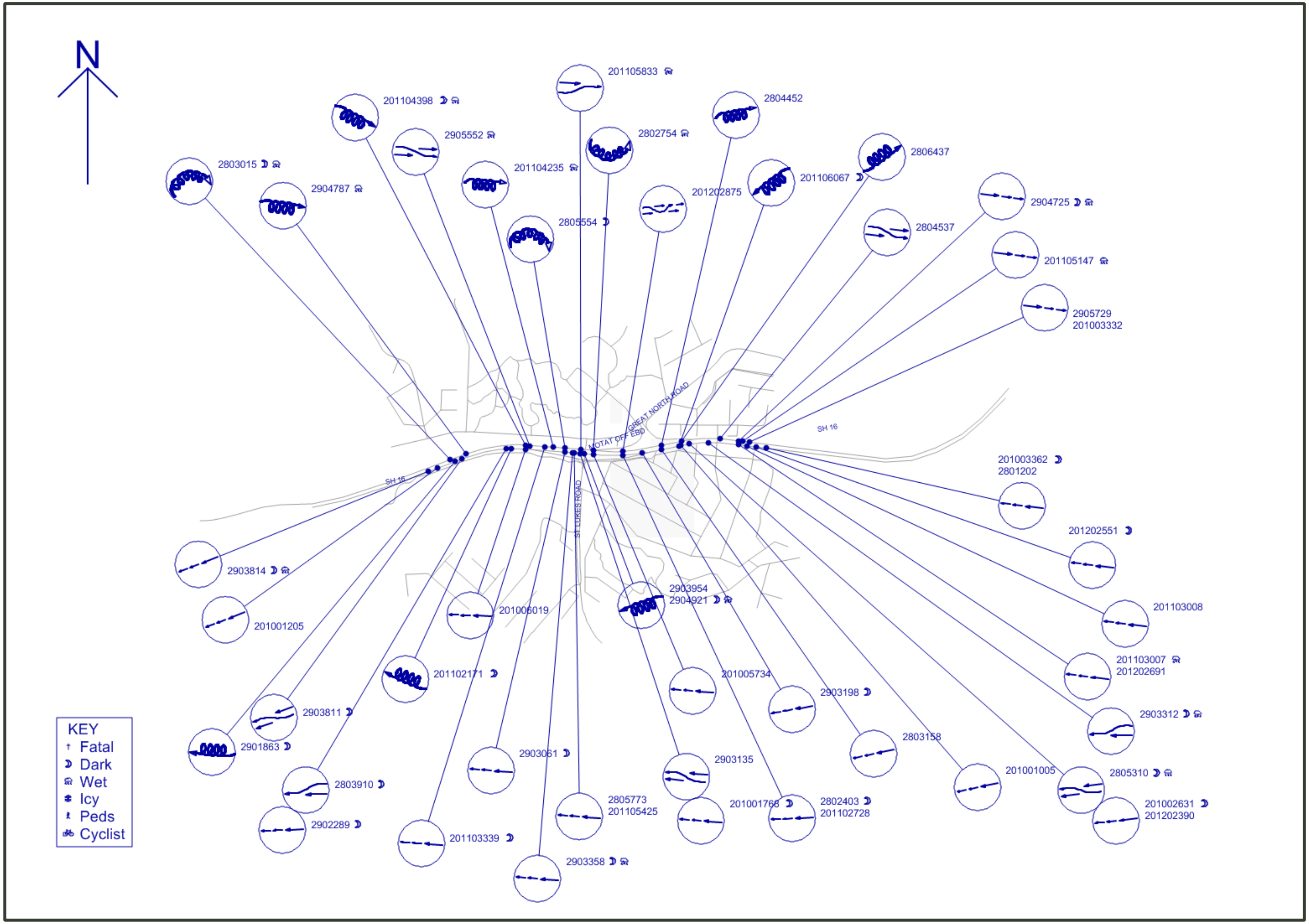
Section 3

Causeway Straight



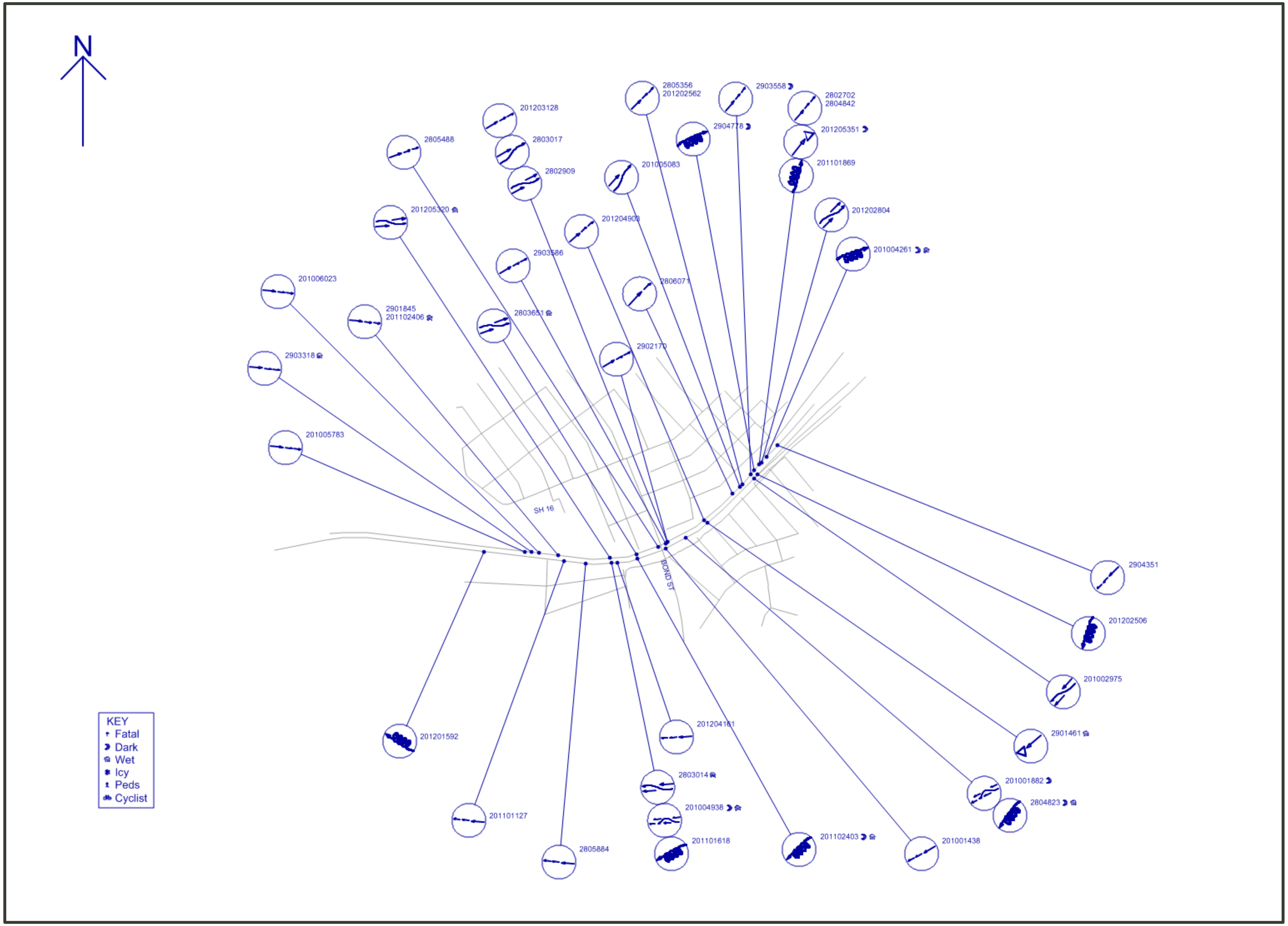
Section 4

Great North Road Interchange



Section 5

St Lukes Interchange

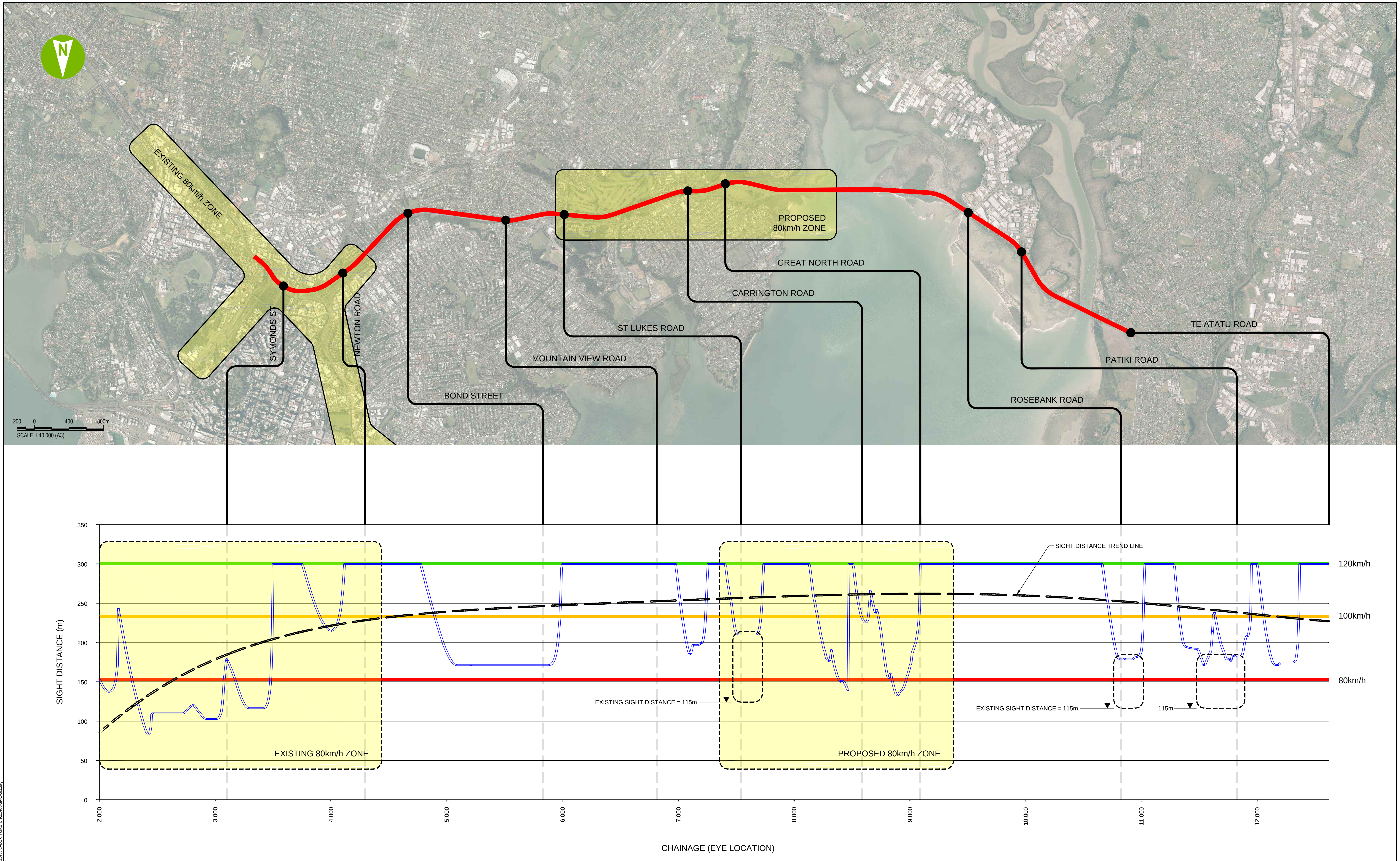


Section 6

St Lukes Approach

Appendix C
Site Distance Chart

Appendix C
Site Distance Chart



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CLIENT

NZ TRANSPORT AGENCY
WAKA KOTAHI

REV	DATE	REVISION DETAILS	APPROVED

DRAWN | DESIGNED

CHECKED

APPROVED

DATE

PROJECT

WESTERN RING ROUTE - SPEED LIMIT STUDY

TITLE

PROJECT No.
225938

SCALE | SIZE
A1

DRAWING No. | REV

Aurecon New Zealand Limited
Level 4, 139 Carlton Gore Road
Newmarket Auckland 1023
PO Box 9762
Newmarket Auckland 1149
New Zealand

T +64 9 520 6019
F +64 9 524 7815
E auckland@aurecongroup.com
W aurecongroup.com

Aurecon offices are located in:
Angola, Australia, Botswana, China, Ethiopia, Hong Kong, Indonesia, Lesotho, Libya, Malawi, Mozambique, Namibia, New Zealand, Nigeria, Philippines, Singapore, South Africa, Swaziland, Tanzania, Thailand, Uganda, United Arab Emirates, Vietnam.