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Executive Summary

The Waitarere Beach Road Curves project (the Project) is part of the Otaki to North of Levin (O2L) section of the Wellington Northern Corridor Road of National Significance (RoNS).

The project development has been driven by the project objectives which, in relation to SH1 north of Levin, are to:

- enhance inter-regional and national economic growth and productivity;
- improve journey times on the state highway network;
- enhance safety of travel on the state highway network;
- appropriately balance the needs of both inter-regional traffic and local road users; and
- to achieve all the above objectives in a cost effective manner.

The Waitarere Beach Road curves section of SH1 has witnessed a high number of on-going fatal and serious crashes. Of particular concern are the run-off-road and cross-centreline crashes, due to the severe nature of such crashes. The occurrence and severity of these crashes is exacerbated by existing problems with the road environment including low radii curves, no median or edge protection and narrow road width.

The Project will address the existing safety issues, by (amongst other provisions):

- easing the curves and improving the road geometry;
- providing a wider carriageway with plenty of space on the road shoulder;
- installing wire rope median and edge barrier;
- consolidating or improving private access ways and intersections;
- improving turning facilities at Poroutawhao School.

As a result of these changes, approximately 7 deaths and serious injury crashes can be saved every 5 years. The changes will also result in the KiwiRAP Star Rating[1] for the Project area shifting from a 2-Star road to a 4-Star road.

In addition, the Project's benefits also include:

- improved provision for agricultural vehicles, cyclists, pedestrians, equestrians and slower moving local traffic and improved separation of it from regional and national traffic, by providing 3m shoulders;
- improved route security and resilience in the event of road crashes, or other disruptions through providing a wider road corridor;
- journey time savings and improved journey time reliability for regional and national traffic, in particular freight, by reducing through traffic travel time by 18 seconds per vehicle;
- alignment with the Otaki to North of Levin section of the Wellington Northern Corridor RoNS and the Wellington Northern Corridor RoNS as a whole; and
- enabling future roading upgrades (i.e. north bound passing lanes to the south and north of the Project area) as planned for this section of SH1.

1 KiwiRAP is New Zealand's joint agency Road Assessment Programme. The Ministry of Transport, the Transport Agency, Police, ACC and AA developed the programme to assess the risk of New Zealand roads and targeted it at decision makers and the wider public. It classifies roads from 1-Star (very high risk) to 5-Star (very low risk).

NZ Transport Agency
Waitarere Beach Road Curves

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

1.1 Roads of National Significance

The Wellington Northern Corridor is one of seven State highway Roads of National Significance (RoNS) projects the New Zealand Government has nominated as essential to increasing New Zealand's prosperity. The Transport Agency is tasked with substantially completing these state highway projects within a ten year period. The Wellington Northern Corridor is shown in Figure 1-1 below, with the Otaki to the North of Levin segment coloured purple at the northern extent of the corridor.

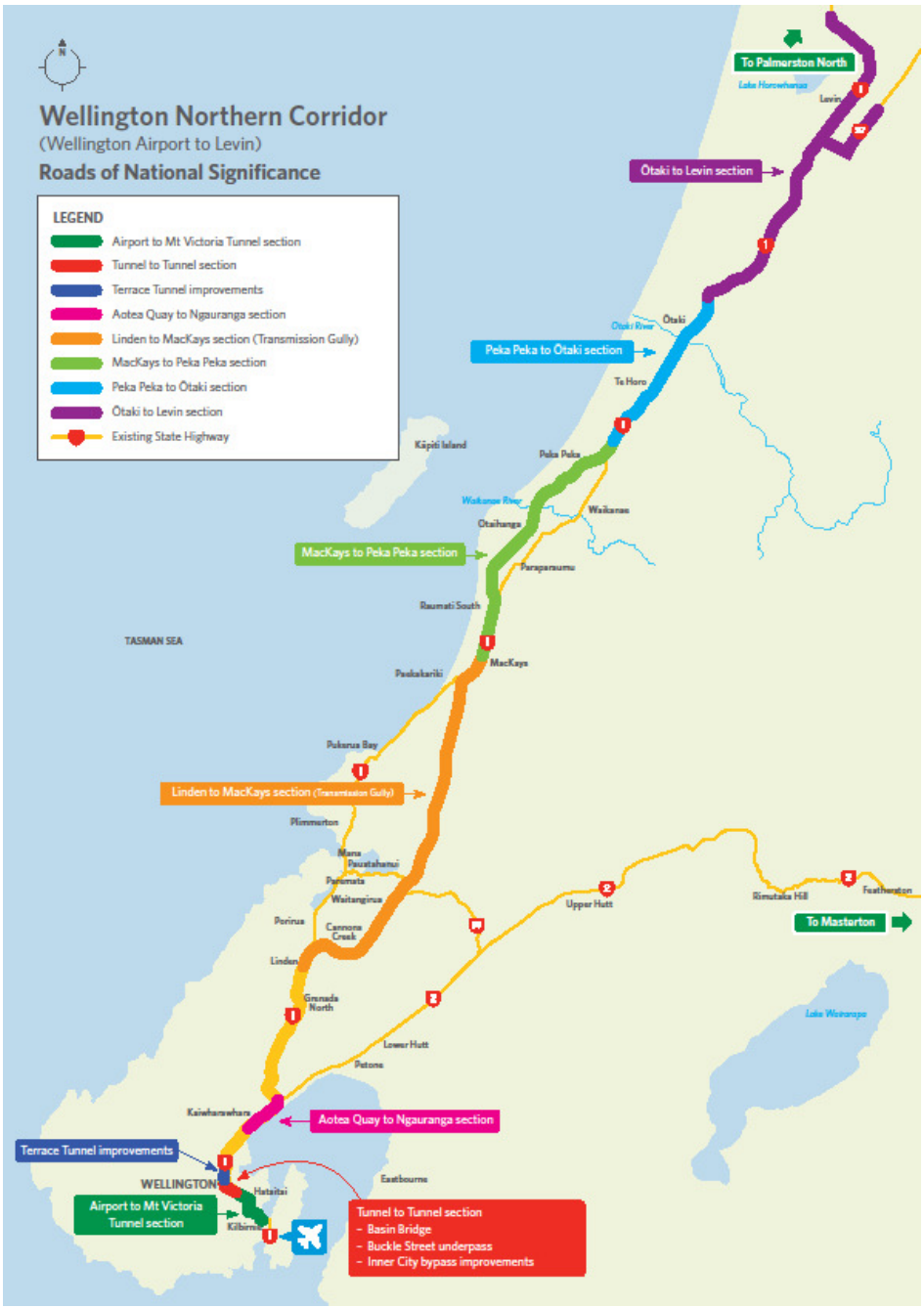

Figure 1-1: Wellington Northern Corridor Road of National Significance

The segment of the RoNS corridor located immediately to the south (known as Peka Peka to Otaki) is due to commence construction in 2016/17. Further to the south Mackays to Peka Peka and

Transmission Gully are already under construction and are due for completion in 2016 and 2020 respectively. To the north, Whirokino Trestle and Manawatu Bridges are currently being investigated and on current programme will be replaced in 2016/17.

Within the Otaki to Levin segment, safety improvements have just been completed at the Manakau and Ohau townships.

1.2 Background

1.2.1 Otaki to North of Levin

The Waitarere Beach Road Curves improvement project (the Project) is part of the Otaki to North of Levin section of the Wellington Northern Corridor RoNS. The Project seeks to improve the safety and efficiency of a substandard length of SH1, located to the north of Levin within the context of the overall project objectives (see section 2.2).

In mid-2012 the Otaki to North of Levin Scoping Report[2] presented options for expressway alignments between North of Otaki to North of Levin. Based on the outcomes of this report, the NZ Transport Agency (the Transport Agency) decided that the most appropriate strategy between North of Otaki and North of Levin was to progressively upgrade the existing highway to create 2+1 and 4 lane sections with intersection and safety improvements that will achieve the RoNS objectives of delivering a suitable level of travel time, safety and capacity improvement appropriate to future demands of this section of the Wellington RoNS.

As a result of that decision, the current strategy for Otaki to North of Levin is as follows (and as shown in Figure 1-2 below):

SHORT TERM

- Safety improvements at priority locations: Ohau and Manakau (construction underway).

MEDIUM TERM

- South of Levin: improvements to the connection between SH1 and SH57 (which also delivers the southern section of bypass of Levin) as well as safety improvements from Taylors Road through to Manakau (Forest Lakes plus potential additional enhancements between Forest Lakes and Manakau)
- Levin: accommodate growth and traffic on SH1 and SH57 [these investigations are now being undertaken with Horowhenua District Council].
- North of Levin: targeted safety improvement at Waitarere Beach Road Curves. Complementary safety improvements and passing opportunities.

LONG TERM

- 4 lane expressway
- Northern bypass of Levin

[2] MWH, July 2012

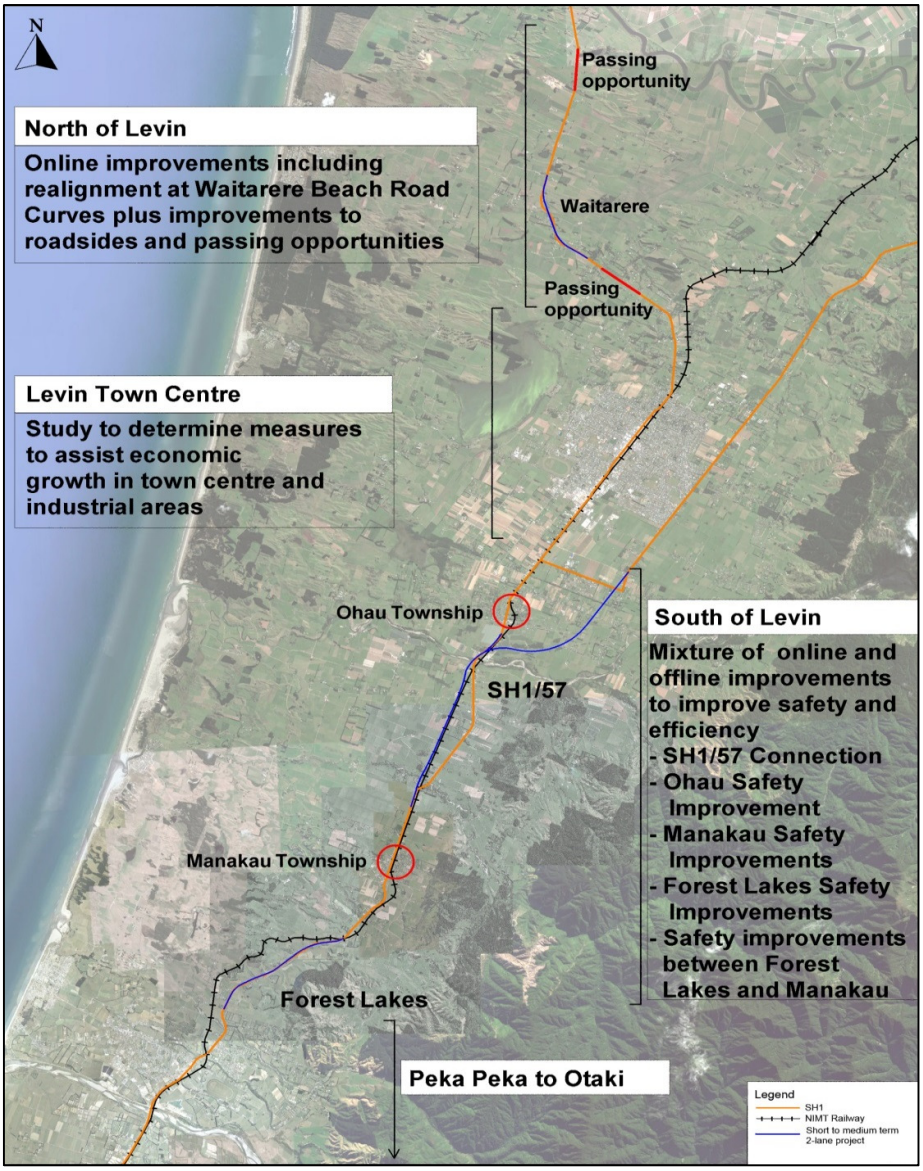

Figure 1-2: Otaki to north of Levin - Short and medium term improvements

1.2.2 North of Levin

The north of Levin improvements have been considered together in a Programme Business Case. The Programme Business Case considered what improvements are needed for the SH1 corridor between Levin and the Manawatu River Bridge and recommended a programme of activities that together will achieve the objectives of the corridor.

Four programmes were developed and assessed against the project objectives. The preferred programme includes the following individual projects:

- Waitarere Beach Road Curves
- Poroutawhao School Improvements
- Northbound passing lane north of Levin
- Northbound passing lane north Waitarere Beach Road
- Widening and edge barrier work for the entire corridor
- Minor Safety Improvements at Lindsay Road (immediately north of Levin)

- Vertical curve improvements near Lindsay Road

The investigation determined that the Poroutawhao School improvements should be progressed before, or with, the Waitarere Beach Road Curves project. Also, the Waitarere Beach Road Curves project should be progressed prior to the northbound passing lane north of Levin. All other improvements can be implemented independently.

The outcomes from implementing the preferred programme for the north of Levin section are estimated to be:

- A reduction of 31 deaths and serious injuries over a 10 year period
- An increase in the KiwiRAP Star Rating for the corridor from 2.9 Stars to a 3.5 Star minimum.
- A 32% increase in passing opportunities
- A reduction in state highway travel time of 71 vehicle hours per day.

The investigation into the Waitarere Beach Road curves is primarily concerned with the study area shown overleaf.

Figure 1-1: Location Plan

2 Outcomes

2.1 Strategic Outcomes

The investigation and statutory approval processes for the Otaki to North of Levin section are undertaken within a series of objectives for the RoNS Wellington Northern Corridor objectives. These are as follows:

- to enhance inter-regional and national economic growth and productivity;
- to improve access to Wellington's CBD, key industrial and employment centres, port, airport and hospital;
- to provide relief from severe congestion on the state highway and local road networks;
- to improve the journey time reliability of travel on the section of SH1 between Levin and the Wellington Airport; and
- to improve the safety of travel on state highways.

2.2 Project Objectives

The project objectives define the outcomes wanted by the proposed work. The project objectives are:

In relation to SH1 north of Levin to:

- *enhance inter-regional and national economic growth and productivity;*
- *improve journey times on the state highway network;*
- *enhance safety of travel on the state highway network;*
- *appropriately balance the needs of both inter-regional traffic and local road users; and*
- *to achieve all the above objectives in a cost effective manner.*

3 Context

3.1 Traffic Data

3.1.1 Traffic Volumes

The latest traffic count data for SH1 and the intersecting local roads, sourced from the Transport Agency's Traffic Monitoring System (TMS) and RAMM[3]/CAS[4] data, in the vicinity of the Waitarere Curves is outlined in Table 3-1below.

Table 3-1: Summary of Traffic Volumes

Description	Location	AADT[5] (year if applicable)	% Heavies
SH1 Whirokino (ID:01N00964) North of Waitarere Beach Road	RP[6] 967/9.79 (SH1 North)	7,300 (2013)	13%
SH1 North of Levin (ID:01N00979) South of Waitarere Beach Road	RP 967/11.66 (SH1 South)	9,350 (2013)	11%
Waitarere Beach Road	RP 967/5.90	2,400	-
Paeroa Road	RP 967/6.27	70	-
Clay Road	RP 967/7.48	unknown[7]	-

The Otaki to north of Levin SATURN[8] base network model outputs[9] shows that link and intersection Levels of Service (LoS) for 2011 and 2041 for both SH1 and the intersection of SH1 and Waitarere Beach Road are expected to be A/B (a very good level of service). Therefore long term, the level of service for Waitarere Beach Road intersection suggests that a layout similar to that which currently exists will deliver the required performance in terms of delays.

3.1.2 Traffic Growth

The historic 10 year growth rate was -0.5% and the historic 20 year growth rate was recorded at 1% for the closest telemetry site, located at Ohau, south of Levin. The nearest non-continuous count site to Waitarere Beach Road is located approximately 6 km to the south (North Levin - Kawiu Rd); historic growth shows similar trends to Ohau with -1.4% growth in the last 10 years and 0.3% growth in the last 20 years, as shown in Figure 3-1 below.

3 Road Assessment and Maintenance Management software

4 NZ Transport Agency's Crash Analysis System

5 Annual Average Daily Traffic (vehicles per day)

6 Route Position

7 There was no traffic data available for Clay Road based on HDC records/RAMM; however, it is estimated that the ADT would be similar or slightly more than Paeroa Road. In addition to a number of residential dwellings, Clay Road also has a Marae, refer Section 2.2.2 for further details.

8 Network analysis software produced by ATKINS (SATURN = Simulation and Assignment of Traffic to Urban Road Networks)

9 See Otaki to north of Levin Scoping Report

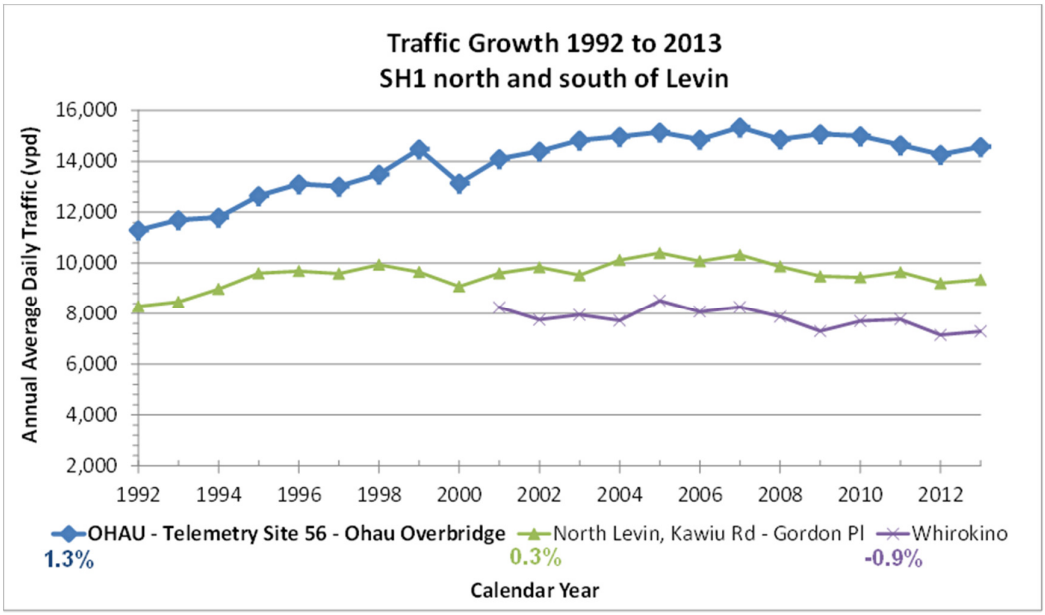

Figure 3-1: Traffic Growth 1992 to 2013

The Wellington Northern Corridor RoNS is expected to result in increased development in this part of the country. Accordingly, a slightly higher growth rate has been adopted than would otherwise have been the case based on historic data.

Based on a 0.5% growth rate, the traffic flow in 2041 is expected to be approximately 10,600 vehicles per day.

Growth in heavy vehicle traffic is currently higher than growth in light vehicle traffic. In addition, the replacement of the Whirokino Trestle and Manawatu River Bridge will also allow larger vehicles to use this route, which could add another 40 heavy vehicles per day[10], although there may be suppressed demand in which case a higher number could be expected.

3.1.3 Travel Speed

Travel speed data has been collected and validated using the following three sources:

- Car following travel time surveys[11] undertaken in July 2014 along the project extent.
- Design speed estimates for the existing situation based on RAMM High Speed Data and Out of Context Curve tables.
- Design speed estimates for the existing situation using geometric model data.

The average southbound and northbound travel speeds from the passenger car following survey were recorded as 87.1 km/h and 86.4 km/h respectively, with a combined average speed of 86.8 km/h.

The geometric model and RAMM based existing length weighted mean speed was estimated at 86.1 km/h and 86.7 km/h respectively, showing close correlation with the car-following survey estimate of 86.8 km/h.

10 Whirokino Trestle and Manawatu River Bridge Scheme Assessment Report, BBO, February 2015

11 These surveys involved following another vehicle, at approximately the same speed, along the project extent and recording the travel time and distance travelled. This was repeated five times in each direction.

4 Problems, Opportunities and Constraints

4.1 Waitarere Beach Road Curves

The section of SH1 in the vicinity of Waitarere Beach Road had curve easing prior to the mid-1970s; nevertheless this section has witnessed a high number of on-going fatal and serious crashes. Of particular concern are the run-off-road and cross-centreline crashes, due to the severe nature of such crashes.

Key safety and geometric deficiencies for the Waitarere Beach Road Curves, determined through site inspections, are numerous:

- Out of context curves - the curves between Clay Road and Waitarere Beach Road are below the standard required for a 100 km/h highway;
- No median barrier - Austroads and Transport Agency guidance indicates that a median barrier should be provided when there is a high percentage, or high average daily number of heavy vehicles, or severe consequences for vehicles crossing the centreline;
- Inconsistent clear zone and a large number of accesses with resultant side friction concerns;
- The highly trafficked Waitarere Beach Road intersection is within the deficient curve section;
- Substandard combinations of vertical and horizontal curves;
- Narrow sealed shoulder;
- Lack of passing opportunities to the north and south; and
- Safety concerns at the intersections of Paeroa Road and Clay Road.

The above deficiencies are considered to have contributed to the significant number of high severity injury crashes within the project area.

The existing curves within the project extents are defined as follows;

- Curve at Waitarere Beach Road - 300m radius, 6% superelevation, 440m length;
- Curve at Paeroa Road - 360m radius, 6% superelevation, 290m length;
- Curve between Paeroa Road and Clay Road - 340m radius, 7% superelevation, 390m length; and
- Large radius curve north of Clay Road - 1000m radius, 3% superelevation, 210m length.

All of these curves have curve radii less that that recommended in the Roads of National Significance Design Standards and Guidelines of 1100m, and three of them are less than the minimum radius of 720m.

These are considered to have contributed to the significant number of high severity injury crashes on this section of highway. Furthermore, the existing road environment is considerably below the standard required to meet Safe System principles. The project extent is shown in Figure 1-1.

4.2 Economic

The section of State Highway 1 which runs through the study area is part of the Wellington Northern Corridor RoNS. Justification of the Wellington Northern Corridor RoNS is contained within the Wellington RoNS Business Case (Transport Agency, November 2009). This document outlines how the programme of projects contributes to economic growth and productivity in the region and nationally.

SH1 through the study area provides access for both people and freight between Wellington (and the South Island) and a major part of the remainder of the North Island. It connects locations of national economic significance as well as connecting local economic centres such as Levin and Whanganui.

The particular area around Waitarere Beach Road is mostly farm land with dairy farming the predominant land use. Waitarere Beach Road also provides access to multiple farms and also a number of rural commercial businesses as well as some residential property. All of these properties and land uses access the highway either directly or indirectly.

4.3 Transport

In addition to the overall issues presented in Section 4.1 above, the following issues have also been identified.

All Poroutawhao school pupils generally get to school either by bus or private car. There is a concern in relation to the safety of the school access as there are no turning facilities for right turning vehicles. Drivers typically pull to the left and wait for a gap in the traffic stream. This can result in a few cars (and maybe a school bus) all waiting on the shoulder.

There is a stakeholder concern about safety at the right turn for buses from Waitarere Beach Road to SH1 for travel to Levin schools.

There are currently no dedicated pedestrian or cycle facilities along this section of SH1, which is common for this type of rural highway with very low pedestrian and cycle volumes. Pupils do not walk to school due to safety concerns, nor is this encouraged by the school (pupils are not allowed to cross SH1).

The right-turn movement into and from Clay Road is a safety concern, especially when a Tangi occurs at Matau Marae. This is due to a lack of dedicated turning facilities and limited visibility.

The current road width is of concern with agricultural machinery using the shoulders of SH1 in this area as land is used primarily for farming.

4.4 Maintenance

The existing maintenance regime includes typical road routine maintenance. Since the 1996/1997 financial year, $87,055 has been spent on routine maintenance including; shoulder maintenance, minor levelling, emergency work, in-situ stabilisation, surfacing defects repair, stormwater structure maintenance, digouts, edge marker post maintenance, environmental clean-up and surface water channel maintenance.

The current alignment has no formalised stormwater system, resulting in higher maintenance costs after storm events. There are numerous large trees or hedges that require routine trimming to maintain adequate sight lines. Sight rails are located at Waitarere Beach Road / SH1 intersection and require routine painting to maintain level of service. Lighting is present at Waitarere Beach Road / SH1 intersection requiring routine maintenance.

The forward works programme shows a section of SH1 is programmed for maintenance reseal in 2016-2017, with a further section resealed in 2018-2019. The local roads and SH1 are currently maintained by the Horowhenua District Council and Transport Agency respectively.

4.5 Crash History and Crash Risk

A full review of the crash history for this 2.5 km section of SH1 (RP 967/5.1 to RP 967/7.69) has been analysed. For the five-year period from January 2009 to December 2013 a total of 16 crashes occurred (four high severity crashes resulting in eight DSi). The predominant fatal crashes that have occurred here have all involved vehicles crossing the centreline.

Undivided state highways with over 6,000 vpd generally have higher numbers of deaths and serious injuries as a result of head-on than run-off road crashes[12]. This site is not an exception with five fatalities and one serious injury from head-on crashes, and one serious injury from run-off road crashes in the five year period[13].

Although lack of passing opportunities is acknowledged as a problem, particularly by the local community[14], there have been no crashes within the Project extent recorded as being associated with passing manoeuvres in the last 5 years.

[12] Figures 3-6 and 3-7, High Risk Rural Roads Guide, NZ Transport Agency

[13] The eighth DSi is from a vehicle crossing movement at the Waitarere Beach Road intersection.

[14] Some members of the community identified a number of intersections and other locations between Levin and the Manawatu River where they have observed unsafe passing manoeuvres.(Provided in memo compiled by Lloyd Shearman dated 17 July 2015.)

There has been an average of more than one death or serious injury per injury crash. The DSi per high severity crashes for head-on is 3.0 which is well above the national average of 1.6. Run-off road, intersection and other high severity crashes are all below the national average based on the High-Risk Rural Roads Guide.

Based on the published 2012 KiwiRAP risk map, this section of SH1 has a medium personal risk and a high collective risk. Therefore this section of SH1 is classified as a high risk rural road signifying a 'Safe Systems Transformation Works' treatment strategy[15].

Figure 4-1 displays the existing Road Protection Score (RPS), which is calculated in 100m sections. The dark blue line is the average RPS and the light blue line displays the equivalent Star rating for the entire section. These scores relate only to this specific section of SH1 as bounded by the Route Position (RP) values. The high RPS scores are at the intersection locations. The section with Waitarere Beach Road scores highest due to this being a relatively major intersection and has a high number of turning movements. The RPS score for Paeroa Road is due to low sight distance and no left or right turning facilities. Clay Road is reported as adequate sight distance and no left or right turning facilities.

The graph shows that the stretch of SH1 to which this project pertains is only a 2-Star road.

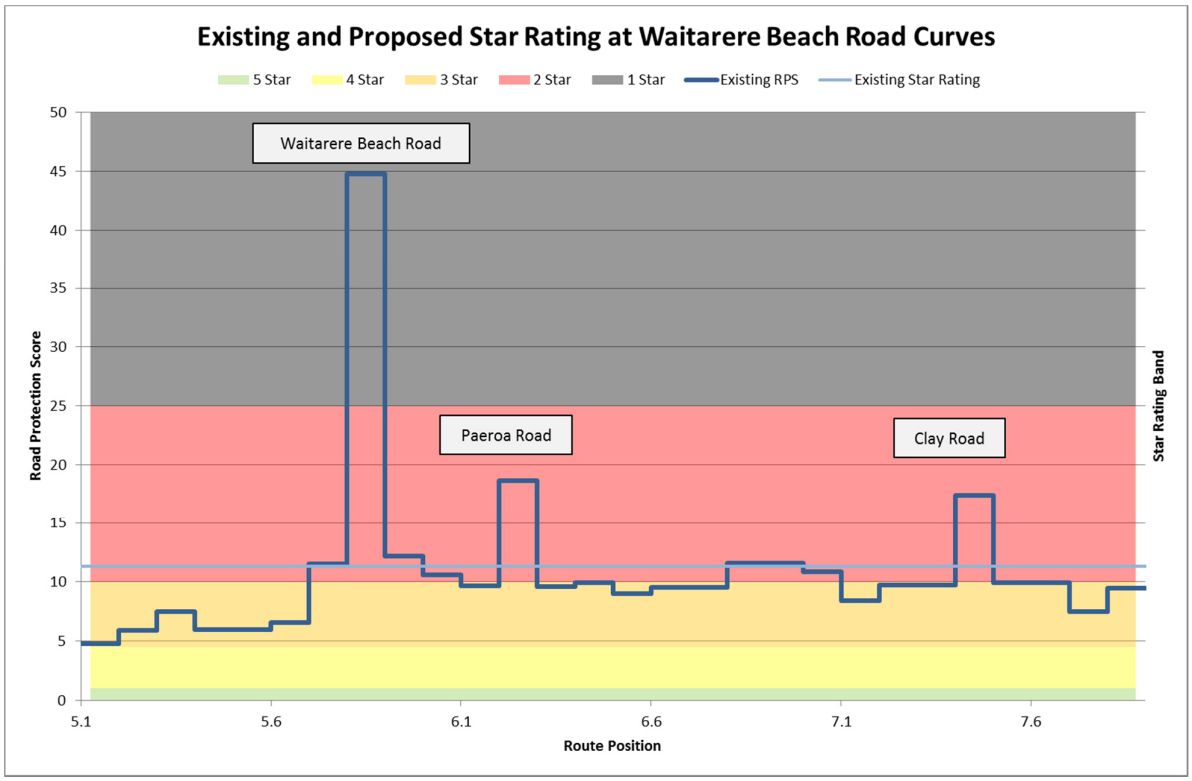

Figure 4-1: KiwiRAP Risk Worm for Waitarere Beach Road Curves[16]

[15] As defined within the NZ Transport Agency High-Risk Rural Roads Guide (2011)

[16] The data from which this table is produced has been edited to better match the actual road hierarchy. Currently KiwiRAP data has Waitarere Beach Road incorrectly defined as a local road, while Paeroa and Clay Roads are incorrectly defined as minor roads. Actual traffic data means Waitarere Beach Road should be classified as a minor road and the other two roads should be classified as unsealed roads, as they have an AADT below the necessary 260 vehicles per day to be classed as local roads.

5 Preferred Option

5.1 Scope

Details of how the options were developed and assessed leading to selection of a preferred option is provided in full within the Consideration of Alternatives Technical Report provided as part of the overall NoR documentation. This section does not replicate the findings of that report but instead focuses on the key aspects of transportation design that underpin the intended outcomes of the proposed work.

The Project Feasibility Reports[17] in 2013 and the North of Levin Programme Business Case in 2015 identified that safety improvements are required at the curves at Waitarere Beach Road, as well as passing lanes, passing opportunities and edge treatments to the north and south of this location.

It is noted that the most significant component of the North of Levin Programme is the proposed works in the vicinity of Waitarere Beach Road.

The recommended project option for Waitarere Beach Road Curves was based on the RoNS Standard Curve realignment (Option 8-3) of the previous PFR stage. This option has been developed further for the Detail Business Case and the details of the recommended project option are described below.

5.2 Geometry and Cross Section

An improved cross section is proposed for the full length of the project (excluding the tapers back to the existing alignment at the north and south extents). The improved cross section is a safer design to that previously proposed during earlier PFR investigations, as a result of providing RoNS and Safe System standards.

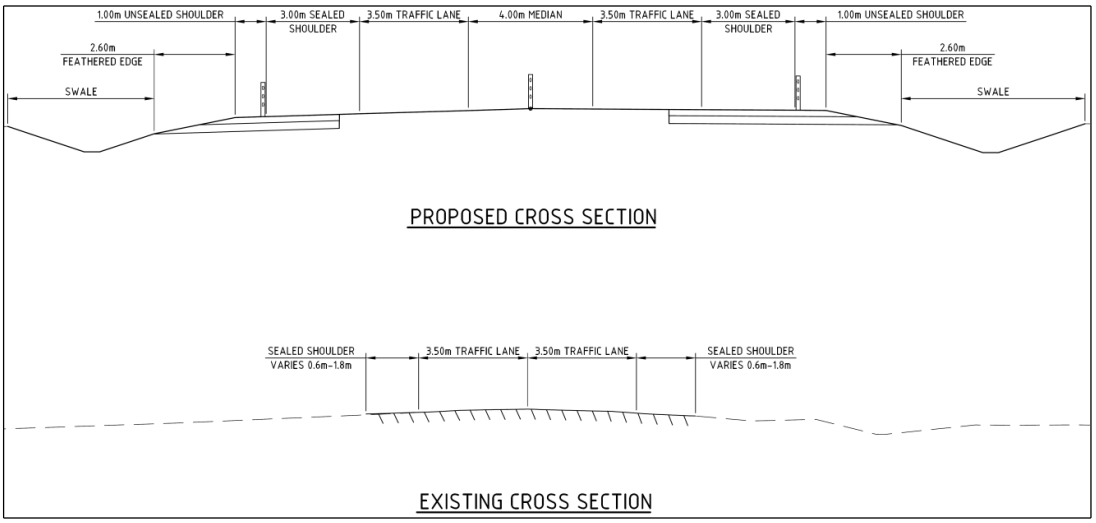

Figure 5-1: Existing and Proposed Cross Sections

The preferred cross section includes a single 3.5m wide traffic lane in each direction, 3.0m sealed shoulders, 1.0m unsealed shoulders and a 4.0m median. Full barrier protection is provided, including wire rope barrier in the central median and edge protection wire rope barrier (on the edge of the 3.0m sealed shoulder) along the full length of the realignment (except across accessways). The preferred cross section and barrier provision are the minimum requirements necessary to meet the RoNS design guidelines.

The preferred option realigns the section of SH1, removing the back to back out of context curves. The realignment results in two proposed 800m left hand radii curves separated by a new straight section of highway. There is also a 2000m radius horizontal curve at the southern end of the project near Clay

[17] Project Feasibility Report: Route Improvements Report (February 2013) (http://www.nzta.govt.nz/projects/otaki-to-north-of-levin/docs/pfr-11-route-improvements.pdf)

Project Feasibility Report: Waitarere Beach Road Curves (February 2013)

(http://www.nzta.govt.nz/projects/otaki-to-north-of-levin/docs/pfr-08-waitarere-curves.pdf)

Road. These new 800m radii curves meet the minimum requirements of the RoNS Standards and Guidelines.

The alignment has been selected on the basis of providing a high standard geometric solution within the context of known cultural constraints together with limiting the number of parcels and quantities of private land required as much as practicable. These matters are set out in greater detail in the Alternatives Report.

Cyclists are provided for by way of the wide 3.0m sealed shoulders[18]. No other specific measures for cyclists are proposed, as it is not considered necessary for the limited number of cyclists observed.

5.3 Wire Rope Median Barrier

Wire rope median barrier is proposed to address the high number of fatal and serious cross-centreline crashes.

Wire rope median barrier is recommended by the Transport Agency for high risk rural roads and also for projects proposed as part of the RoNS. It will eliminate the high numbers of cross centreline crashes which are happening on this section of road. Cross centreline crashes have the highest risk of fatal and serious injuries.

These cross centreline crashes are likely to reduce once geometric improvements are made, but not significantly. Figure 5-2 below shows that over two-thirds of head on casualties occur on straight roads or easy curves.

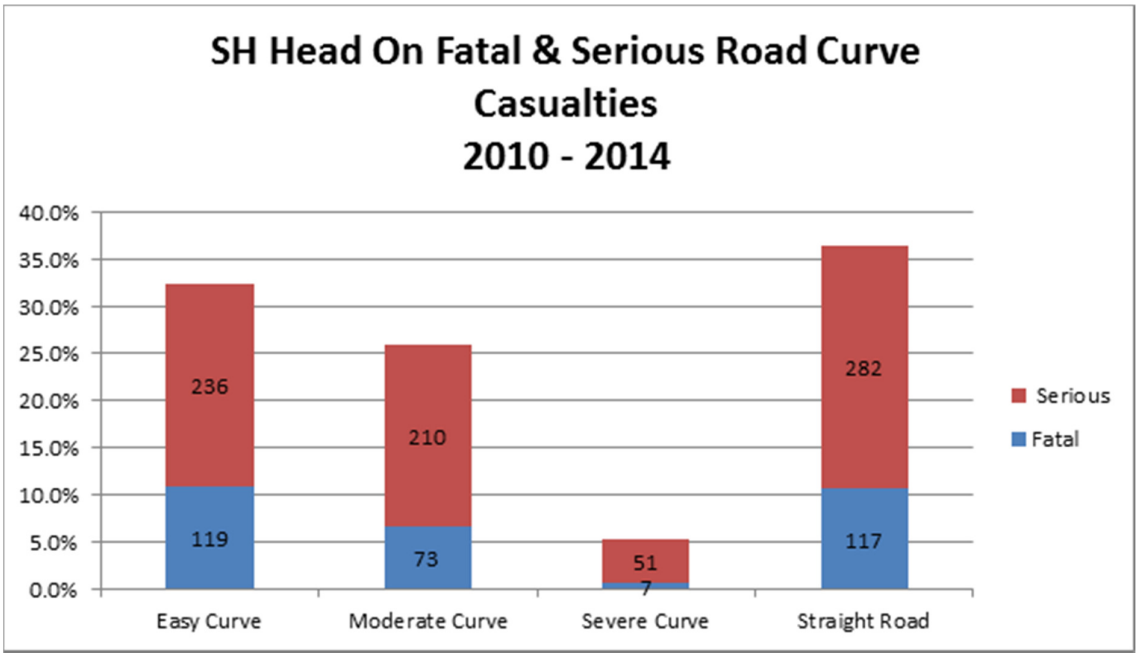

Figure 5-2: Head On Curve Casualties

Two examples of projects where wire rope barrier has been installed are presented below.

- Centennial Highway, SH1 north of Porirua. Prior to median barrier installation; 10 fatal or serious crashes in 5 years. After installation; no fatal or serious crashes in 5 years.
- Rangiriri, north of Hamilton. Prior to median barrier installation; 12 fatal or serious crashes in 5 years. After installation; no fatal crashes but four serious crashes in 4 years (only one head on crash and this did not result in injury).

From these and other examples, there is a lot of evidence to show that providing wire rope barrier significantly reduces the numbers of deaths and serious injuries on stretches of road which it is installed.

[18] Meets the requirements of Austroads Guide to Road Design Part 3: Geometric Design

Providing the median barrier without geometric improvements would not result in a good safety outcome as the wire rope barrier would restrict visibility around the tight curves in an environment with regular intersections and accessways.

It is acknowledged that there have been concerns raised by local landowners in regard to the impact that the wire rope barrier will have on their access.

Based on this concern, further investigation was undertaken specifically to determine the benefits, impacts and costs with and without the median barrier.

The Waitarere Beach Road Curves project was assessed in three different ways.

- **Full Scheme**: Includes wire rope median barrier and turn around areas
- **Variant A**: Safe Hit Posts (or wide centreline) instead of the wire rope median barrier, but still including the turnaround areas
- **Variant B**: Safe Hit Posts (or wide centreline), no turn around areas and Paeroa Road would connect directly to SH1 in a similar way to the current situation.

The impact of the wire rope median barrier on some of the key outcomes are presented in the table below and expanded upon in Section 6.1.2.

Table 5-1: Impact of Wire Rope Median Barrier

	No Median Barrier, no turn around area (Variant B)	No Median, with turn around area (Variant A)	Full scheme
Reduction in deaths and serious injuries per 5 years	2.7	2.9	7
Published KiwiRAP Star Rating	3	3	4
Increase in affected resident/business travel time	0	0	An average of 41 seconds per affected round trip movement. Total 1.5 hrs per day for all movements.
Average % increase in round trip travel time	0	0	5% to Levin 5% to Foxton
BCR	1.2	1.2	1.4
Incremental BCR[19]	-	1.8	13

As each option includes some form of median (i.e. wide centreline or space for a median barrier), the road width and footprint for the main state highway alignment would not materially change.

Based on economic analysis undertaken in accordance with the Transport Agency's Economic Evaluation Manual, the 'Full scheme' option is likely to save 7 deaths and serious injuries every 5 years, but the variants are only likely to save between 2.7 and 2.9.

The KiwiRAP rating for no median barrier was assessed as being 3 stars, compared to a 4 star road with the median barrier.

[19] Incremental BCR is a way of determining the economic efficiency of proceeding with a higher cost option over a lower cost option. It is calculated as being the increase in benefits divided by the increase in cost. For a scheme with a BCR between 1 and 2, an incremental BCR of greater than 1 means that the higher cost option should be progressed. As Variant A has an incremental BCR of 1.8 compared to Variant B, and the Full Scheme option has an incremental BCR of 13 over Variant A, the Full Scheme should be progressed.

There will be an effect in terms of resident and business travel time, and this is discussed further in Section 6.1.3; however, based on the safety benefits presented above, wire rope median barrier is a key part of the benefit delivered by the Project.

5.4 Intersections

There are four local road intersections within the project extents:

- **Waitarere Beach Road**: This is the main intersection within the project extents, carrying the largest volume of traffic of the intersecting roads to SH1 (approximately 3,000 vpd). The intersection provides the only access to the Waitarere Beach community which includes residential properties as well as commercial and leisure facilities. This intersection will continue to operate as a priority T-intersection where all movements are permitted as per the existing situation.
- The preferred option provides a high standard left turn slip lane for northbound traffic turning into Waitarere Beach Road. This facility will also be utilised by local residents who live on both sides of the proposed alignment, either by western residents who wish to head south to Levin or for eastern residents to access their properties when coming from the south. The slip lane forms a priority controlled T-junction with Waitarere Beach Road. From here, road users turn right and then exit south via the Waitarere Beach Road / SH1 intersection, utilising the break in the wire rope barrier.
- The sight distance to the south and north is much improved when exiting Waitarere Beach Road, due to the straightened realignment of SH1. It has also reduced the high super elevation which exiting right turning vehicles had to cross when heading southbound.
- Closure of right turn movements at this intersection and provision of a mid-block ('P-turn') facility further north of Waitarere Beach Road was not considered; this is because this intersection already exhibits a good crash history (and is being improved). Waitarere Beach Road is used by around 2,500 vpd which would all be required to undertake left in / left out movements and use 'P- turn' facilities to the north and south. This is not considered necessary.
- This layout does mean that there are four property accessways north of the Waitarere Beach Road curve that do not have turning facilities. These are all located on the eastern side of SH1. The access to these properties for northbound vehicles will require turning at Koputaroa Road which is 2km north of the end of the wire rope barrier. This will be the safest turnaround location, however there will be other opportunities to turn past the wire rope barrier; for example the Poroutawhao School entrance will be sealed.
- **Clay Road**: This intersection serves a small number of properties (on the east side) and Matau Marae. It currently operates as priority T-intersection with all movements permitted and will remain so under the preferred option. However, the intersection will be improved, with a slight extension of Clay Road to connect into the realigned SH1. This allows the intersection limit line to be pushed further south which removes the visibility issues at the current location in the cutting, whilst also providing a slightly improved approach angle. The intersection is further improved with the provision of a right turn bay on SH1 and wider sealed shoulders for SH1 left turn in traffic.
- This intersection also provides a left turn slip lane, this time to facilitate southbound turn around movements. This facility will be utilised in particular by people leaving the Whare Rongopai and Hill residential properties wanting to travel north.
- **Paeroa Road**: The current intersection of Paeroa Road will be closed at the intersection with SH1. Access will be provided by a newly created link, running between Paeroa Road and a new intersection at Hinaupiopio (the curve 1200m north of the access to Huia Marae). This is positive (for safety and efficiency) as it removes a number of accessways onto the state highwayand consolidates them into a single point which will be of a high standard.
- **Hinaupiopio** (the curve 1200m north of the access to Huia Marae): A new intersection will be constructed at this location to consolidate accessways and to provide turn around movements. This facility will provide access to all properties on the western side of the highway between, and including, Huia Marae and Paeroa Road. This facility will also allow southbound vehicles to safely perform a U-turn movement and turn back north. This facility is necessary due to the median wire rope barrier preventing right turns along the Project length.

5.5 Poroutawhao School

North of the main project area, it is proposed to install a right turn bay into Poroutawhao School to cater for the peak turning movements at this location.

In conjunction with this work, other safety improvements will also be progressed including lighting, improved signage for the school and double yellow lines to prevent overtaking.

5.6 Access

Access is a key consideration for the project. Whilst the benefits of a median wire rope barrier are clearly known and accepted, for the barrier to be effective, it must be provided in continuous lengths to prevent cross centreline crashes.

Therefore, the inclusion of a median wire rope barrier affects access along the corridor, except for where the wire rope is interrupted, at Waitarere Beach Road and Hinaupiopio.

Access for properties along the length of the route will therefore be reduced to left in / left out only, with no right turns possible either into or out of accessways.

The effect of the wire rope and detour length has been assessed for every property along the corridor. Further discussion on the effects of this barrier is presented in Section 6.1.3.

5.7 Signage and Road Markings

The drawings provided have included indicative road markings. These will need to be fully considered at detailed design stage. Nevertheless the drawings provide a reasonable level of detail to demonstrate how the road markings could be used within the proposed layout.

Signage has not been included at this stage of the investigation. Signage plays an important safety role in providing driver information and will be an important aspect of detailed design, particularly given the changed road layouts and turning restrictions.

5.8 Bus Provision

There is an existing bus service that runs along SH1 through the project area and stops at Waitarere Beach Road morning and evening. This bus service and the associated drop off and pick up often result in numerous cars being parked on Waitarere Beach Road in close proximity to the intersection with SH1.

Discussions with the bus operator, Horizons Regional Council, have revealed that this stop forms part of a daily bus service running return from Levin to Palmerston North. The bus arrives at the intersection around 7:00 am heading north, and returns (travelling south back to Levin) at around 6:05pm. It is understood that up to 12 people may board and exit the bus at this location.

Whilst this is not an official bus stop, it has been confirmed that the car parking around the intersection is related to a bus which stops to pick up and drop off passengers on SH1 in close proximity to Waitarere Beach Road.

The current situation, whilst it has not been witnessed, is expected to result in pedestrian movements across SH1 (primarily in the evening when the bus is travelling south). This is highly undesirable.

A number of treatments are possible to provide a suitable facility for the bus, which provides a safe and convenient solution for the bus operator and passengers and does not impact the overall state highway operation.

A facility that provides for pick-up and drop-off of passengers away from the highway is considered most appropriate, provided some parking can be provided. However, it is recognised that further assessment will need to be undertaken, for example to understand whether any of the existing seal (which will become redundant) can be utilised for vehicle parking and bus turnaround due to the existing superelevation. Any decision will need to be based on cost, convenience and safety. A conceptual layout for this option is shown below in red.

If this facility is wanted by Horizons or by the national bus service supplier (for example the naked bus or InterCity buses) then it can be advanced discretely and separately to the Project, i.e. this work is not required to be delivered as part of the Project but rather is an opportunity that is able to be realised in the future. This matter can be considered during the pre-implementation phases.

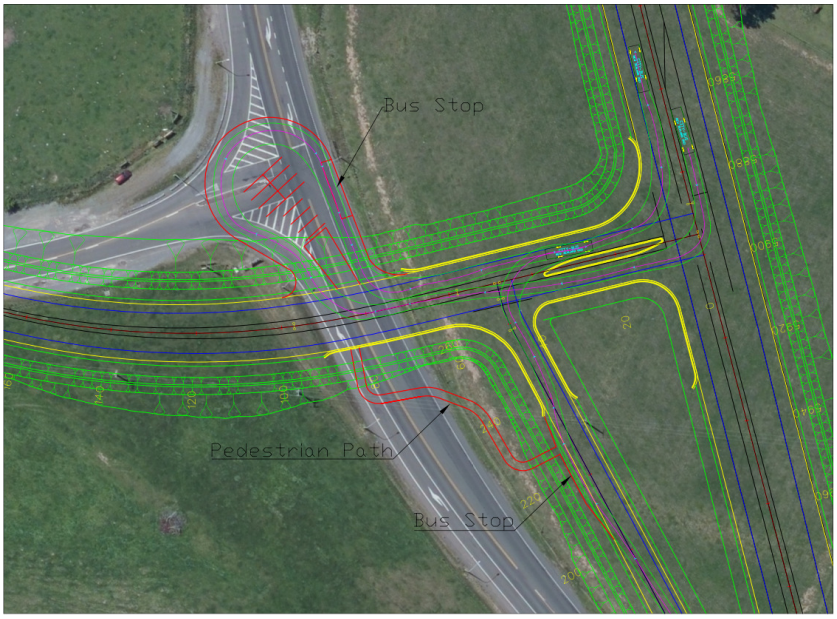

Figure 5-3: Potential Bus Stop Layout at Waitarere Beach Road

6 Recommended Option – Assessment

6.1 Project Objectives

The project objectives are defined in Section 2.2. The manner in which this project contributes to the objectives are discussed below.

6.1.1 Improve journey times on the state highway network

As outlined in Section 3.1.3, the Do-Minimum mean speed through the project length is estimated to be 87 km/h. The realignment increases the mean speed by providing a significantly improved highway alignment replacing the existing out of context curves with large 800m and 2000m radii curves. The SH1 proposed option mean speed has been estimated as 100km/h.

In addition the SH1 realignment results in a reduction in route length of 80m, reducing both travel time and vehicle operating costs.

This means that travel times through this section will reduce by approximately 18 seconds per vehicle. For the traffic volumes through the project site, this gives a saving of approximately 43 hours per day.

Based on the NZ Transport Agency's Economic Evaluation Manual procedures, the reduced journey time for these road users equates to approximately $460,000 of travel time benefits per annum.

6.1.2 Enhance safety of travel on the state highway network;

This project improves the safety of the area in a number of ways.

The realignment removes the existing series of deficient double S curves. These three geometrically deficient curves are replaced with two 800m radii curves with a 110 km/h design speed and higher design standard. Secondly a large portion of the realignment will have roadside edge and median wire rope barriers. This will help to further reduce the likelihood of the fatal or serious crashes where vehicles have strayed outside their lane either into oncoming traffic or running off the road. The cross section is more forgiving than the existing arrangement, with a 2.0m wide median either side of the central barrier (4.0m total median width) and a 3.0m sealed shoulder to the edge barrier. Therefore, there is an increased area for drivers to recover their vehicle if they were momentarily to lose control.

There is no recorded crash problem at the Waitarere Beach Road intersection, but after the realignment takes place, it will remain as the most likely location where a severe crash could occur within the section. Allowing full intersection movements results in numerous conflict points, hence the continued risk (particularly given the high volumes of traffic using the intersection). So while there is confidence in that fatal and serious crashes will reduce in number, there is still a possibility that they might occur at this intersection due to the traffic conflicts. That said, the intersection operates safely now, with a good crash history. Given it is being improved (geometrically - resulting in a higher standard intersection layout and improved visibility) as part of the upgrade works, then the existing crash risk will be reduced.

Ultimately the Project's effectiveness will be measured by the crash history record after the proposed alignment has been opened. A successful project would involve no fatal or serious injury crashes occurring within the project length, over the following ten year period. However, by providing breaks in the central wire rope barrier to facilitate turning movements at Waitarere Beach Road and Hinaupiopio, it means that the possibility remains for a fatal or serious injury crash to occur in the future. This risk can only be eliminated through construction of a grade separated intersection, which is not appropriate due to the high cost of such a facility as well as the increased cultural and environmental effects.

6.1.2.1 KiwiRAP assessment

The KiwiRAP Risk Worm profile (as presented in Figure 4-1) was updated to reflect the proposed design, graphically showing the improvements gained in Figure 6-1. The dark purple line represents the proposed RPS for the project, which shows a marked improvement. The Waitarere Beach Road intersection retains a high RPS score of 34 because the intersection remains priority controlled. The reduction in RPS is due the improved alignment and sight distance visibility.

The introduction of wire rope median and side barriers has reduced the RPS for the majority of the project to a score of just above zero. This would result in the highway as a whole for the project extent becoming a KiwiRAP 4-Star road.

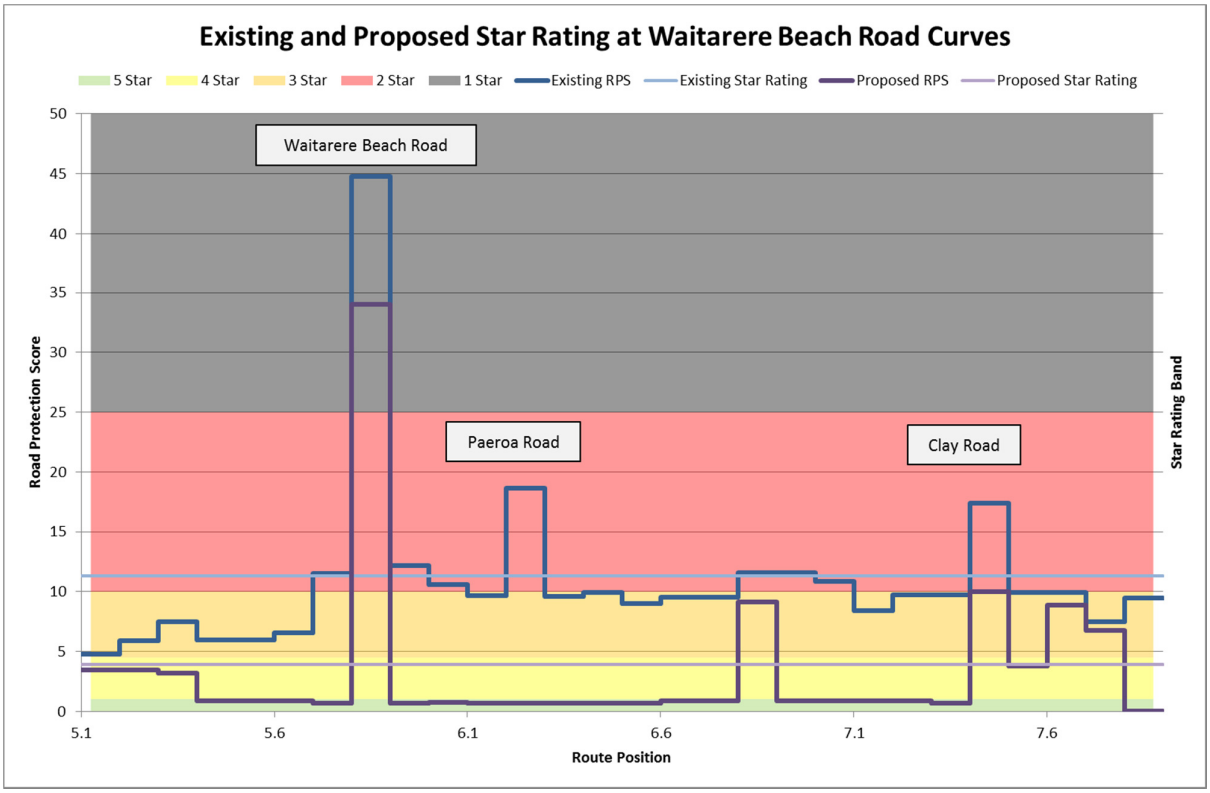

Figure 6-1: Proposed KiwiRAP Risk Worm Profile

6.1.3 Appropriately balance the needs of both inter-regional traffic and local road users

The needs of inter-regional traffic are addressed by improving travel time and safety though the area.

In terms of local road users, the safety through the area will also be improved. However, it is acknowledged that some local road users will be disadvantaged as the wire rope median barrier will result in them needing to travel longer distances to and/or from their properties.

Approximately 23 properties (which contain 14 dwellings) which currently have a SH1 frontage will have increased journeys due to the provision of a wire rope median barrier along the project length. In addition, Paeroa Road is also affected as it will be realigned to link to Hinaupiopio, which will intersect with the state highway to allow all turning movements. Paeroa Road currently has approximately 10 properties (containing 4 dwellings) in addition to those that front SH1.

The tables below outline the impact that the wire rope barrier will have on journeys to and from Levin and Foxton.

Table 6-1: Journey Time Impact of Wire Rope Median Barrier on Journeys to Levin

Journey time per return trip to Levin	Number of properties
No impact (typical journey time is 18 minutes)	53 properties (31 dwellings)
Up to a 30 second increase in journey time	3 properties (1 dwelling)
Up to a 60 second increase in journey time	7 properties (4 dwelling)
Up to a 90 second increase in journey time	2 properties (0 dwellings)
Up to a 120 second increase in journey time	3 properties (2 dwelling)

Table 6-2: Journey Time Impact of Wire Rope Median Barrier on Journeys to Foxton

Increased journey time per return trip to Foxton	Number of properties (dwellings)
No impact (typical journey time is 20 minutes)	40 properties (23 dwellings)
Up to a 30 second increase in journey time	4 properties (2 dwelling)
Up to a 60 second increase in journey time	10 properties (5 dwellings)
Up to a 90 second increase in journey time	2 properties (2 dwellings)
Up to a 120 second increase in journey time	3 properties (2 dwellings)

The proposed breaks within the median barrier have been considered at length to ensure they are the most appropriate on balance, but recognising that a level of inconvenience (and therefore concern from some residents) is inevitable. The current layout has been developed after significant consultation with local residents, iwi and community representatives.

The full scheme results in an average of 41 seconds per affected round trip for dwelling movements. In terms of travel times to the key destinations of Levin and Foxton, the average increase in round trip travel time is 5%.

Based on the NZ Transport Agency's Economic Evaluation Manual procedures, the additional journey time for these local road users equates to approximately $18,000 of travel time dis-benefits per annum.

Some landowners have raised a concern that road users will be exposed to a higher risk when larger vehicles in particular have to turn left out of their property and perform a turn-around manoeuvre at a turning facility, rather than just turning right out of their property. Whilst the longer period of time on the road does result in higher risk, it is considered to be outweighed by the removal of the right turn out manoeuvre[20]. In any event the proposed arrangement is considerably safer than the current layout, as the proposed project improves sight distances and provides a wider road with wide shoulders better allowing these movements to occur than at present.

6.1.4 Achieve all the above objectives in a cost effective manner.

Overall this project achieves a BCR of 1.4, which means that the benefits outweigh the costs. The incremental BCR of the median barrier and turn around areas also show that these aspects are excellent value for money.

This project is also part of the wider Wellington Northern Corridor RoNS, which has a BCR of 1.6

6.2 Wider Project Impacts

6.2.1 Improved provision for different types of vehicles

The Horowhenua has a large farming industry, particularly horticultural, and therefore there are often large agricultural vehicles driving on the highway. The current narrow width of the highway means that these slow moving vehicles drive in the traffic lane, often holding up the free flow of other vehicles on the highway. This either results in queues forming or drivers attempting unsafe overtaking manoeuvres.

However, the improved cross section, including wider shoulders and a median will mean that the slower vehicles can run on the shoulder and other vehicles can pass with ease.

The wider shoulders will also benefit cyclists, pedestrians, equestrians and slower moving local traffic in the same manner.

6.2.2 Route Security

The alternative route when crashes do happen on this stretch of road adds approximately 10 to 15 minutes to a through journey.

[20] High Risk Intersection Guide (HRIG), NZTA, July 2013, outlines that right turning crashes (Type J and Type L) account for a third of all deaths and serious injuries at rural intersections based on data from 2006-2010. For rural priority T intersections, crossing/turning and right turn against crashes contribute up to 60% of the total intersections deaths and serious injuries.

The reduced number and severity of road crashes due to the road improvements including the median barrier will result in improved route security and resilience as the highway will be closed less often.

This is due both to the reduced number of crashes, but also due to the wider cross section and median barrier meaning that often only one side of the highway will need to be closed. In addition, emergency services will be able to lower the median barrier if necessary.

6.2.3 Enabling future roading upgrades

The programme business case report outlined that the northbound passing lane between Levin and Waitarere Beach Road should not be progressed until the improvements at Waitarere Beach Road Curves are undertaken. This is primarily because installing the passing lane will lead to increase speeds northbound and increasing speeds into these curves is likely to lead to an increase in the number of fatal and serious crashes at this site and possibly beyond. Therefore this Project enables other future improvements to the SH to occur, in accordance with RoNS objectives.

7 Recommended Option - Economic Analysis

7.1 Economic Summary of Recommended Project Option

The Project forms part of the Wellington Northern Corridor RoNS Project which has a programme BCR of 1.6 (not allowing for wider economic impacts) and has an assessment profile of HHL; high strategic fit, high effectiveness and low economic efficiency. If wider economic impacts are included then the programme BCR is 1.8 (excluding the benefits of Petone to Grenada project).

In order to test how the proposed work contributes towards the overall project, the BCR of the project has also been calculated as if it were a standalone project. An economic evaluation has been carried out in accordance with modified full procedures of the Economic Evaluation Manual (EEM, July 2013). The recommended option was analysed against the Do minimum option.

A summary of the economic evaluation is presented in the table below.

Table 7-1: Economic Evaluation Outcomes

Present Value Costs	$10.7M
Present Value Benefits	$15.0M
Travel Time Benefits	$5.5M
Vehicle Operating Cost Benefits	-1.8M
Crash Cost Benefits	$11.4M
Benefit Cost Ratio	1.4

7.2 Crash Benefits

For the purposes of crash analysis, the study length was divided into the following sections:

- **Waitarere Beach Road intersection**: crashes within a 50m radius of the Waitarere Beach Road and SH1 intersection.
- **Midblock crashes**: The crashes occurring along the project length, excluding crashes within 50m of the Waitarere Beach Road intersection. Crash modelling was not undertaken for the Paeroa Road/SH1 intersection, Clay Road/SH1 intersection and the new intersection at Hinaupiopio due to a combination of very low side road volumes and no intersection related crash movements within 50m of either of the existing intersections.

7.2.1 Waitarere Beach Road Intersection

In the five year period from 2009-2013 there were four reported crashes within 50m of the intersection, including one serious crossing turning crash and three non-injury crashes.

Method C (weighted accident procedure) was adopted for the Do Minimum as there has only been one injury crash in the latest five year period. The injury crash rate for the intersection was determined using the EEM 'General high speed cross and T intersections >=80km/h' crash model with the output from the model weighted based on the single injury crash that has occurred in the last five year period. Injury crash costs for both the Do Minimum and option were determined from EEM Table A6.22 for a priority T intersection, adjusted for the Do Minimum and option mean speed.

Method B (accident rate analysis) was adopted for the option due to fundamental change as a result of the completely new intersection being provided, with significant alignment/ sight distance improvements compared to the existing intersection. The injury crash rate for the intersection was determined using

the EEM 'General high speed cross and T-intersections >=80km/h' crash prediction model. A crash reduction factor for intersection sight distance improvements of 30%[21] was applied to the model.

7.2.2 Midblock

In the five year period from 2009-2013 there were 11 reported crashes along the project midblock extent (RP 967/5.10 to RP 967/7.69), excluding crashes within 50m of the Waitarere Beach Road intersection. The midblock section included two fatal crashes, one serious crash, two minor injury crashes and six non-injury crashes.

As there has been greater than one high severity crash per kilometre, Method A (accident by accident) analysis was adopted for the Do Minimum. The analysis considered the movement type of each crash separately with costs determined from EEM Table A6.21, adjusted for the Do Minimum mean speed of 87km/h.

Method B, accident rate analysis, was adopted for the option due to fundamental change as a result of the highway realignment, wider 17m carriageway and central median and edge safety barrier provision. The injury crash rate for the midblock section was determined using the EEM 'Rural two-lane roads >=80km/h' exposure crash model. Crash reductions factors for guardrail provision of 25%[22] and wire rope median barrier provision of 30%[23] were applied to the model, as both these treatments are not included in the typical two-lane rural road model. Injury crash costs for the option were determined from EEM Table A6.22 for midblock crashes for a 100km/h near rural speed limit area.

7.2.3 Crash Migration

A potential effect of undertaking a significant highway realignment, can be crash migration from the project site to nearby site(s). However, as the project extent has long straights of greater than 2 km in either direction of the improvement works, crash migration is considered to be unlikely.

It is also noted that the Otaki to North of Levin RoNS (of which Waitarere Beach Road curve improvements is a part) also includes overall route improvements comprising; consistent seal width, safer roadsides, vertical profile improvements and additional passing lanes in the vicinity of the Waitarere Beach Road curves realignment. These route improvements are considered to further reduce the risk of crash migration.

7.3 Travel Time and Vehicle Operating Costs

For the purposes of Travel Time Cost (TTC) and Vehicle Operating Cost (VOC) analysis, the study length was divided into the following sections:

- **Highway realignment**: The SH1 realignment results in a reduction in route length of 80m, reducing both travel time and vehicle operating costs. In addition, the realignment increases the mean speed by providing a significantly improved highway alignment replacing the existing out of context curves with large 800m and 2000m radii curves.
- **Wire Rope Median Barrier effects**: Travel time and vehicle operating dis-benefits relating to the wire rope median barrier have been assessed based on the additional delays introduced from turning restrictions (i.e. direct accesses LILO[24]).
- **Waitarere Beach Road Intersection**: Since the proposed intersection layout is almost identical to the existing layout apart from the addition of a left turn slip lane, it was considered that the travel time and vehicle operating costs associated with the intersection operation would be minimal and therefore no modelling was undertaken. In addition, as the left turn slip for northbound would reduce delays marginally for SH1 northbound traffic, this assumption is considered conservative.

21 NZTA, High Risk Intersection Guide July 2013, Intersection Improvements - Sight distance improvements, IS3, pg. 111.

22 NZTA, EEM (July 2013), Crash Model #11 Rural two lane road >=80km/h, Effects of crash barriers, pg. 5-309.

23 NZTA, High Risk Rural Roads Guide, Appendix D, Table D1 - Median Barriers, pg. 92. This applies to all injury crashes, although it is expected that higher severity crashes will reduce by a much larger percentage.

24 Left In and Left Out movements only

7.3.1 Highway Realignment

As outlined above, the SH1 highway realignment to remove the out of context curves will result in a shortened route (80 m) at a higher design speed. This will provide travel time benefits for vehicles travelling on SH1.

The highway realignment also has a significant impact on vehicle operating costs (VOC) and CO2 emissions. The reduction in route length of the option results in VOC savings, however the increase in travel speed results in an increase in VOC. For this project, the VOC benefits from the route shortening and a more uniform operating speed are outweighed by the increase in travel speed, resulting in negative VOC benefits.

The following assumptions were made in the calculation of VOC and travel time costs/benefits:

- As outlined in Section 3.1.3, the Do-Minimum mean speed through the project length is assessed as 87 km/h. The mean speed for the Waitarere Beach Road section was estimated at 70 km/h.
- The SH1 proposed option mean speed has been estimated as 100km/h with the option speed for Waitarere Beach Road increasing to 80km/h due to the improved alignment.
- Traffic growth of 0.5% was adopted as the Wellington Northern Corridor RoNS is expected to result in increased development in this part of the region. Waitarere Beach Road growth was estimated at 0% based on modelling outputs[25].

7.3.2 Wire Rope Median Barrier effects

The provision of central median wire rope barrier has implications for movements at intersections and property accessways.

An assessment was carried out to determine both the additional distance travelled and additional travel time incurred from the restriction of right turning movements. The key assumptions of the assessment included:

- Existing side road right in or right out turning delays will be equivalent to the introduced right in/right out delays at the nearest intersection. This is based on the fact that traffic volumes along SH1 are relatively consistent, resulting in similar side road gap acceptance. Left turn delays were assumed to be negligible.
- Where right turn in/out movement is restricted, distances were measured to the nearest intersection/ turnaround facility. The turnaround facilities provided as part of the proposed option are Waitarere Beach Road intersection in the north (where the median wire rope barrier is broken to allow all movements) and the new intersection at Hinaupiopio. Where appropriate, additional manoeuvring time was added to account for u-turning movements.
- A 10.4 vpd trip generation rate for a dwelling was adopted in accordance with Appendix 5B of the Transport Agency Planning and Policy Manual.

Paeroa Road is the only intersection that will be affected by the median wire rope barrier; traffic on Paeroa Road will be diverted to the new intersection at Hinaupiopio where all movements are permitted.

In addition to the Paeroa Road properties, approximately 14 dwellings which currently have direct access to SH1 will be affected (restricted to LILO) by the provision of a wire rope median barrier along the project length.

The analysis revealed that there will be approximately $18,000 of travel time dis-benefits per annum, $16,000 of vehicle operating cost dis-benefits per annum.

7.4 Maintenance Costs

The Do-minimum future maintenance costs were based on the future works programme, noting that there is no significant pavement rehabilitation works planned along the project extent in the near future.

The recommended option will result in an increase in maintenance cost due to the following:

25 Even if higher growth was assumed for Waitarere Beach Road, the proposed design of the intersection would not need to change as it could adequately cater for an increase in development.

- Significant increase in carriageway width from approximately 24,000m^2 to 43,000m^2, which increases the cost of both annual maintenance and renewals.
- Maintenance costs attributed to both the side protection (3.1 km total) and median (1.7 km) wire rope barrier were included. These costs were factored based on the actual RAMM maintenance costs for a similar state highway site (SH58 RP 0/1.4-2.3).

7.5 Wider Economics Benefits

The Project is part of the Otaki to Levin RoNS, which in turn is part of the Wellington Northern Corridor RoNS. It is noted that analysis of wider economic benefits (WEBs) was assessed as part of the economic evaluation of the entire Wellington Northern Corridor, but WEBs have not been included in the economic evaluation for Waitarere Beach Road Curves Project.

7.6 Sensitivity Analysis

A number of sensitivity tests were undertaken to determine the impact on the BCR if some of the key assumptions changed. Some of the key outcomes are presented below.

- If the construction cost increased to the 95%ile estimate, the BCR would drop to 1.1
- If an additional fatal head on crash occurred in the five year crash history, the BCR would increase to 3.2.
- If traffic volumes were to grow at 1% per annum, rather than 0.5%, the BCR would increase to 1.6.
- If a 4% discount rate was used rather than 6%, then the BCR increase to 1.8.

Further sensitivity testing was undertaken into the effect of the construction start timing on the BCR. The construction timing affects the impact the existing situation (Do-Minimum) will have on the economics, with delaying construction increasing the impact of the Do-Minimum. Delaying construction start to 2021 reduced the BCR slightly, while bringing construction forward to 2016 increased the BCR slightly, however in both cases the BCR remained at 1.4.

The results of the sensitivity testing show the BCR ranges from 1.1, when using the 95th percentile cost estimate, to 3.2 when including the effect of an additional fatal head-on crash.

The first year rate of return (FYRR) did not significantly alter from the base of 13%, with the exception of testing the effect of additional high severity crashes occurring in the future (17% FYRR with an additional serious head-on crash to 31% FYRR with an additional fatal head-on crash)