Petone to Grenada Project Evaluation

September 2017

FINAL VERSION

NZ TRANSPORT AGENCY
WAKA KOTAHI

New Zealand Government

More information

NZ Transport Agency
Published [month and year]

ISBN [number]

If you have further queries, call our contact centre on 0800 699 000 or write to us:

NZ Transport Agency
Private Bag 6995
Wellington 6141

This document is available on the NZ Transport Agency's website at www.nzta.govt.nz

INTRODUCTION

Evaluation scope

This Petone to Grenada (P2G) project evaluation has been carried out as part of the ongoing investigations phase of the P2G project. The purpose of the evaluation is to provide an independent assessment against the project objectives and with consideration of the wider transport system context. This is an internal quality assurance step at the Detailed Business Case stage and will be reported to the Transport Agency Board.

The physical scope of the evaluation is necessarily contained to the P2G project area as currently conceived. In order to keep the scope of work manageable, the evaluation has not sought to reopen or reconsider the strategic transport options at the wider network level, although some whole-of-system implications and opportunities are considered. In particular, the evaluation has not looked for a new east-west connection corridor, it has not considered in detail the options that could be pursued on SH2/ Ngauranga/SH1 as an alternative, and it has not considered in detail a SH58 upgrade as an alternative.

A lot of work has been done over a number of years on the wider strategic context (for example the Ngauranga Triangle Strategic Study, 2010[1]), and it is left to that work to speak to the wider options in detail. It is enough to simply note here that P2G was pursued in accordance with and based on the findings of that earlier work.

Evaluation team

A small evaluation team of subject matter experts was assembled, each being independent of the project team:

- Geometrics, safety and engineering options: Keith Weale, Stantec
- Geotechnical and resilience: Charlie Price, Stantec
- Cost estimation and engineering options: Morgan Pheloung and David Jewell, Bond CM
- Consenting: Belinda Peterson, NZTA
- Evaluation lead: Shane Avers, NZTA

Separately, peer review of the non-traditional economics (wider economic benefits) was provided by Anthony Byett.

Keith, Charlie, Morgan and David all worked on and/or are currently still engaged in the Transmission Gully project for the Transport Agency, giving them direct experience in the closest and most current major roading project in the region. This is particularly relevant to the geotechnical/resilience and cost assessments. Morgan and David both have long experience working in the Wellington region, including recently the Mackays to Pekapeka project. David led oversight for the contractor on the complex Dowse to Petone upgrade, which is located very near the project and included for further work as part of the proposed scheme. Belinda is a highly experienced planner both in the public and private sectors and has lead roles in several of the Transport Agency's major projects at a scale comparable to and larger than P2G.

In addition, a number of people were consulted from within the project team (both NZTA internal and the project consultants, Opus) and from a range of discipline and subject areas across the Transport

[1] https://www.nzta.govt.nz/resources/ngauranga-triangle-strategy-study/

Agency (including, safety, consenting, communications, other related and interconnected projects that are currently under investigation, and the Wellington network context). The project team has been very helpful in providing project information.

The evaluation team held a day-long workshop to bring together the individual discipline findings, look for connections across these findings, and brainstorm options. Site visits were made by all team members except geotechnical.

Structure of this report

This evaluation report is set out as follows.

The first part contains an examination of the existing proposed P2G scheme, an assessment of the cost, scope and performance against the project objectives, and the potential for cost refinement and performance improvement, in sections 1 to 9:

1. Overview of the project context
2. The proposed scheme
3. Summary of 2016 multi-criteria analysis
4. Consenting strategy
5. Geometrics and safety of the proposed scheme
6. Cost estimates for the proposed scheme
7. Resilience performance of the proposed scheme
8. Potential resilience improvements within the proposed scheme
9. Conclusion on the proposed scheme

The second part considers possible alternatives in section 10 and tests how the outcomes might be achieved differently and better in section 11.

The report concludes with a set of recommended next steps in section 12.

1. OVERVIEW OF THE PROJECT CONTEXT

1.1 Historical investigations

The project is mentioned in planning documents as far back as 1975 and the Transport Agency (and predecessors) has had the P2G project under investigation since at least 1995. The timeline of these investigations is:

- 1995 Petone – Grenada Link Study (Beca). Included consultation with the potentially affected communities.
- 2010 Project Feasibility Report (SKM)
- Project investigations phase begins in 2012 (Opus as consultants)
- 2014 Scoping Report (Opus)
- 2015 Assessment of alternatives (Opus), including multi-criteria analysis (MCA) of alternative alignments and interchange options.
- 2016 MCA of the then preferred alignment against five further alignments and interchange options. The currently proposed scheme was selected from this process and interchange options subsequently developed further.

The community and stakeholders have been engaged throughout the investigations phase.

1.2 Resilience context

The project would perform an important resilience role within the Wellington network. It would provide two forms of resilience:

1. Network resilience – P2G would improve redundancy and route alternatives within the Wellington transport network in the case of network closure due to incidents or storm events.
2. Route resilience – P2G would provide an access lifeline following a major seismic event.

The Wellington network is vulnerable to short-term closure and disruption. For example, a recent slip in the Ngauranga gorge and recent flood events have resulted in road closures that caused delays and cut off access to and from Wellington city.

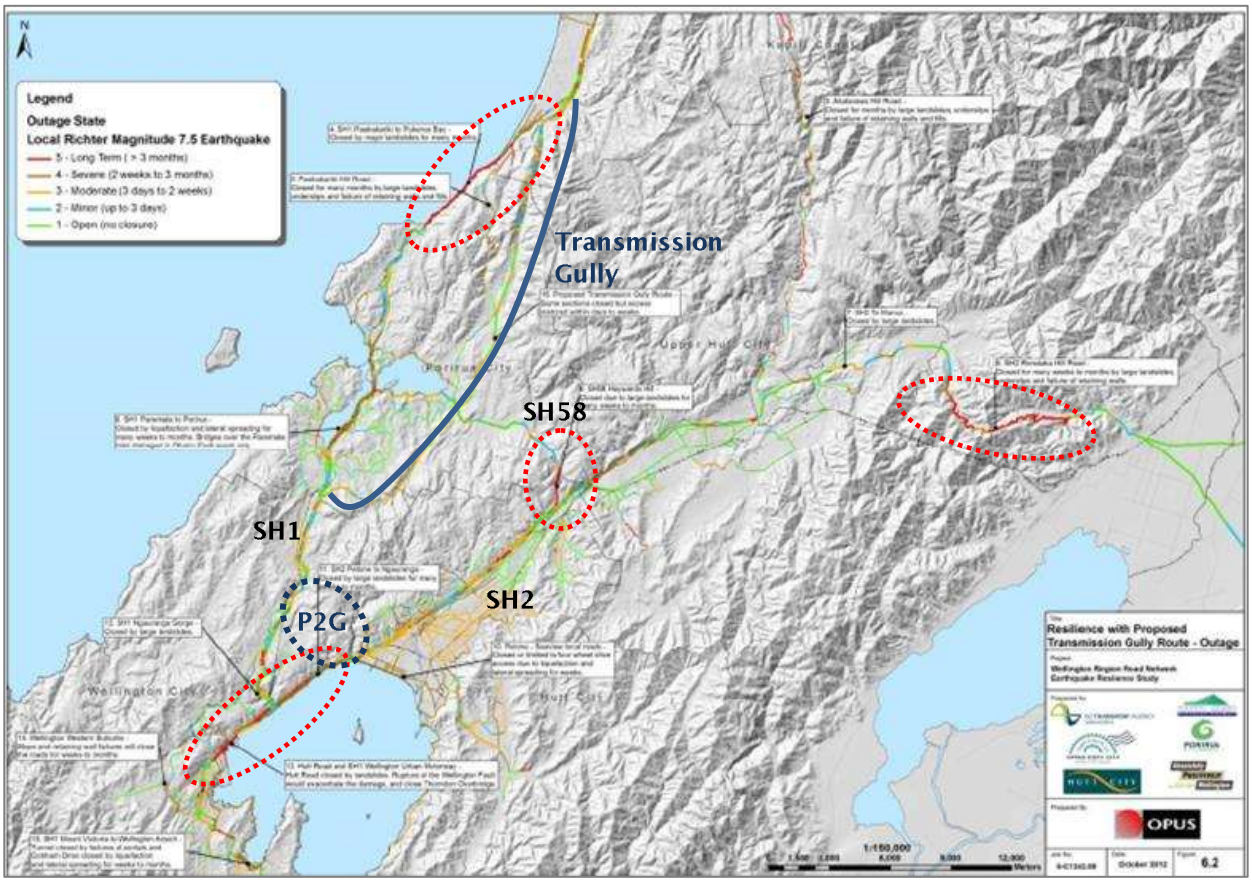
Wellington is built in a seismically active region with fault lines subject to major rupture events in excess of magnitude 7.5. Figure 1 shows the expected outage periods for sections of the Wellington transport network following a magnitude 7.5 earthquake. Sections coloured red are expected to suffer long-term outages of greater than 3 months.

From a regional access perspective, the current network is vulnerable to long-term closure and isolation at the four red circled locations: SH1 Paekakariki, SH2 between Ngauranga and Petone, SH58 near SH2, and SH2 Rimutaka hill.

For Wellington city, the western suburbs and Porirua, the source of long-term vulnerability to isolation following a major earthquake is a major landslide on the Paekakariki section of SH1. A resilience lifeline is currently being built in the form of Transmission Gully which will help relieve this vulnerability.

However, no such lifeline exists for the Hutt valley, which would be cut off in all three directions. Petone to Grenada is a possible solution by providing a resilient lifeline connecting the valley to SH1 and on to the Transmission Gully access to the north.

Figure 1 Outage of Wellington region transport network after a large earthquake



Notes: Red circled sections are vulnerable to long-term closure in the event of a major earthquake and are of particular significance from an access perspective. Resilience lifelines are in blue; The blue line is the Transmission Gully route, the blue circle is the Petone to Grenada study area.

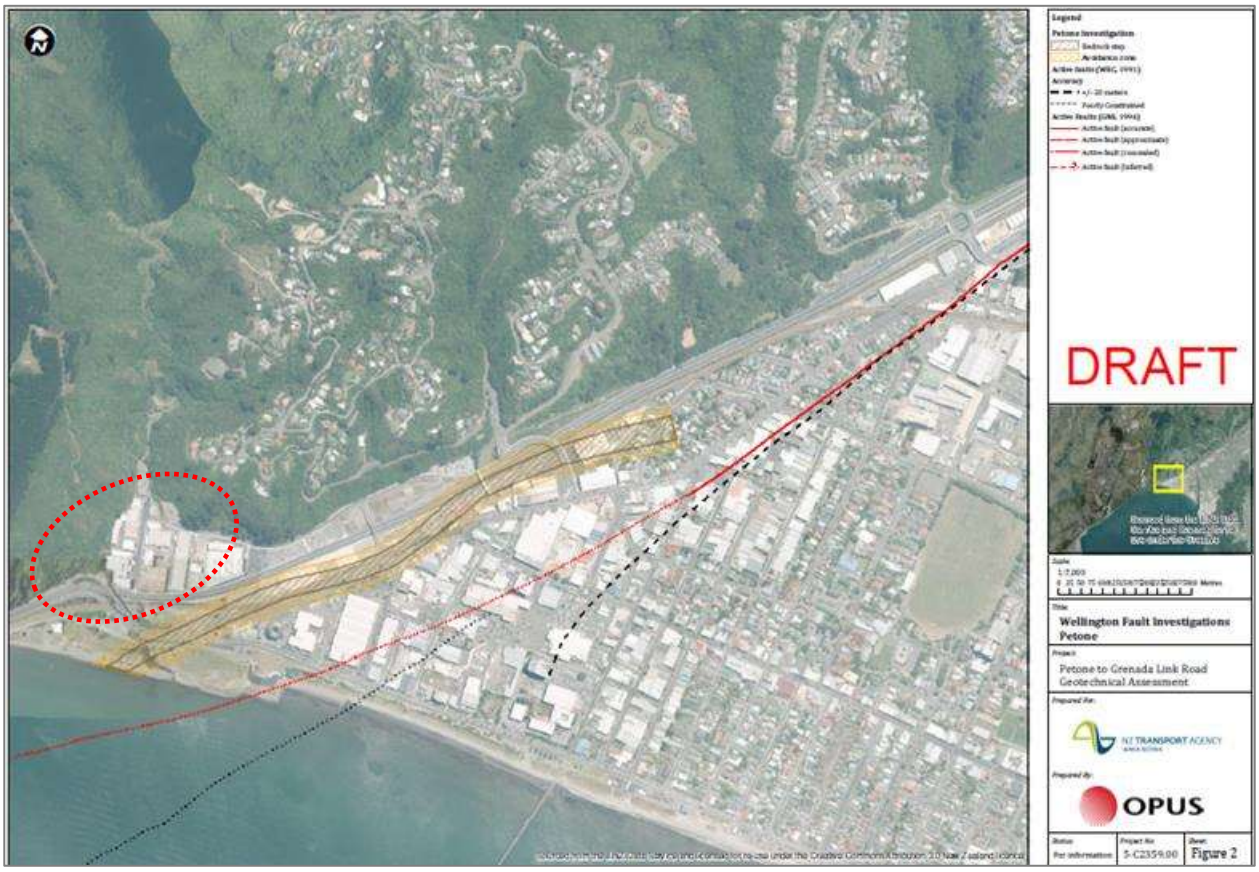
Source: Petone to Grenada Link, Natural Hazards and Resilience of Options, Opus, 2016

As discussed, lifeline alternatives to P2G are outside of the scope of this evaluation and have previously been considered by other studies. SH58 is a natural alternative east-west link, given that there is existing infrastructure there. However, it is thought that an offline solution would be required there also and there would be consequential down-stream network impacts for SH2. Another option is to improve the resilience of SH2 along the foreshore between Petone and Ngauranga.

For further context, Figure 2 shows the location of fault lines in the vicinity of Petone. The existing Petone interchange and the general location of the proposed new Petone interchange are in the circled area.

The Wellington fault runs roughly along the seaward side of SH2, which is itself built on a shelf thrust up by the last significant rupture of the fault. The P2G investigations have discovered a previously unknown splinter fault in the vicinity of the proposed Petone interchange.

Figure 2 Estimated active fault locations at Petone



Source: Memo: "Active fault hazards for the Petone to Grenada interchange in Petone", Opus, January 2017. The area within the dashed red oval is the location of the existing and proposed Petone interchanges.

Figure 2 shows how tightly constrained the transport corridor is along the western Hutt valley and Petone and how little space is available for an interchange. An interchange will contain a number of structures and these should not straddle the fault line. Furthermore, the valley floor is subject to liquefaction, flooding and tsunami risk, which must be designed for. The currently proposed location, within the marked circle at the opening of the Korokoro valley, clearly provides the greatest space between the constraints posed by the escarpment, the sea, and the fault lines.

At its western end the alignment crosses the extrapolated position of another fault line (the Moonshine fault). This has a lower return period (lower risk) than the Wellington fault. However, the location of this fault is not well known and any of the structures in the proposed Tawa interchange may overlie part of the fault. There is a risk that bridge structures may need to be moved at a future design stage once the location of the fault is better understood.

1.2.1 Recent changes to the legislative and regulatory environment related to resilience

Two changes have been made in the legislative and regulatory environment since the P2G MCA was carried out:

- Amendment of Section 6 (Matters of National Importance) of the Resource Management Act (RMA), April 2017. The Act now says, "…all persons exercising functions and powers under [the Act]…shall recognise and provide for the following matters of national importance:… **(h) the management of significant risks from natural hazards**".
- Draft Government Policy Statement (GPS) on transport 2018/19–2027/28 has made resilience a priority with the inclusion of a Resilience Objective. It has a particular focus on economically and socially critical locations including those vulnerable to low probability high impact events.

The GPS also takes a 'whole of system' view for cost effective mitigation or adaptation to resilience risks.

Given their timing, these recent changes have not been taken into account in the current scheme selection or design.

1.3 Current project objectives

The project objectives, as stated in the 2016 MCA, are as follows:

1. To enhance local, regional and national economic growth and productivity for people and freight;

2. To improve connectivity between the lower Hutt Valley and Johnsonville and Porirua;

3. To reduce journey times and improve journey time reliability between the lower Hutt Valley, Ngauranga and Porirua, and on the Wellington State highway network;

4. To enhance safety of travel on the Wellington State highway network;

5. To enhance **resilience** of the Wellington State highway network;

6. To manage the immediate and long term social, cultural, land use and other **environmental impacts** of the Project on the Wellington region and its communities by so far as practicable avoiding, remedying or mitigating any such effects through route and alignment selection, expressway design and conditions;

By developing and constructing a **cost efficient** new road alignment to **expressway standards** between SH2 in the lower Hutt Valley and SH1 north of Ngauranga.

The first four of these could be grouped together as things that would necessarily follow from building a "new road alignment to expressway standards between SH2 and SH1".

This leaves resilience, environmental, and cost as the project's key differentiating objectives.

It is worth taking note that the starting point for the project's investigation has been an expressway standard. As discussed later, this is significant in the context of the extremely challenging topography. It is also interesting to note that the original project scope was not expressway. The expressway requirement was added later.

It is also worth noting that there is no prioritisation set out among the objectives, so they provide no guidance to evaluators and designers if there are natural trade-offs among resilience, environment or cost. Furthermore, the objectives have not been updated to reflect recent changes to the legislative environment or following recent natural disaster events such as the Kaikoura earthquakes.

1.4 Stakeholders

The project is supported by all directly affected Councils. It is a committed project in Greater Wellington Regional Council's Regional Land Transport Programme where it is ranked third highest priority for its economic, safety and resilience benefits. The project would provide access to the last major greenfield development site in the Wellington City Council area, known as Lincolnshire Farms, and as such is a crucial enabler of this development.

The Lincolnshire Farms area is primarily owned by a single developer. A Lincolnshire Farms Structure Plan (LFSP) was prepared in 2006 and shows P2G. Since then, investigations have shown that the

alignment and layout of P2G as shown in the LFSP is not viable in the topography. The P2G project would necessitate a Structure Plan change.

The Councils have each recently expressed a growing focus on resilience, in the wake of earthquake events in the past few years.

The Hutt City Council has aspirations to reconfigure and improve its arterial road network serving the industrial centre in the east (Seaview) and to refocus the Petone Esplanade away from being a freight and commuter route and toward local amenity. Known as the Cross Valley Link project, a Strategic Business Case was prepared in 2016 in partnership with the Transport Agency. The outcomes sought by Cross Valley Link and the scheme design for P2G (particularly the Petone interchange with a direct connection to the Petone Esplanade) are currently not well aligned.

Major communities along the alignment include Korokoro at the Petone end, Horokiwi in the centre, and newly established housing in the Grenada area (particularly on Havana Rise and Mark Avenue). The Horokiwi community consists of approximately 70 households (around 140–210 residents), many of which are on lifestyle blocks. Both the Horokiwi and Korokoro communities are actively engaged and organised.

The project affects two Iwi and there are Māori landholdings near Petone at the reserve on Petone Esplanade and an area of land on the escarpment known as Korokoro North Block, which would be affected by the proposed scheme. There are a number of properties that would be required in the Petone area, several of which have been acquired in anticipation of the project on a willing buyer willing seller basis.

The Petone rail station would be affected by the scheme, which would see the rail line re-aligned and the station rebuilt.

Belmont Regional Park, owned and administered by the Greater Wellington Regional Council (GWRC), extends in a narrow finger down the Korokoro valley (Figure 3). The proposed scheme would encroach into the corner of the park here at its most southerly end near the Cornish Street entrance (roughly in the area of the circled yellow triangle). The park is large, extending across to the western side of the escarpment where it is traversed, primarily through farmland, by Transmission Gully (designation shown as thick red line). The Korokoro Environmental Group is an active stakeholder in relation to the valley.

Figure 3 Map of the Belmont Regional Park, showing the Korokoro valley near Petone (bottom left)

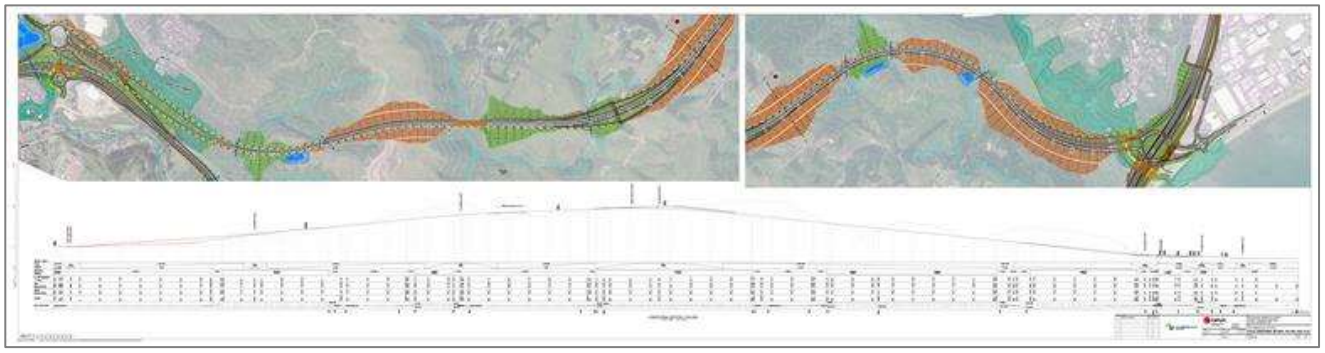
2. THE PROPOSED SCHEME

The current scheme alignment (known as MC01) was selected from the 2016 multi-criteria analysis (MCA). The major components of the scheme would be:

- Approximately 6.5km link road between Petone in the east and Grenada and Tawa in the west
- Three interchanges, being Petone (SH2), Tawa (SH1), and a mid-block interchange at Horokiwi
- Approximately 1.5km of additional works along existing SH1 and SH2, to accommodate the Petone interchange (SH2 widening to Dowse) and safety improvements on SH1 (re-aligning the 'Tawa curves')
- Two lanes plus a crawler lane in both directions for the full length (road carriageway width of approximately 32m, excluding walking and cycling)
- Walking and cycling facilities for the full length, including on both sides in the steep sections
- A local road bridge across the alignment to reinstate severance of Horokiwi Road and access for the local community (the Horokiwi community bridge). This bridge has been discussed with the community, although a final selection among three options has not yet been made.

The long section is shown in Figure 4. The project is an east-west traverse of the Wellington escarpment. The vertical alignment is effectively 'up and down', climbing from near sea level at Petone to a summit at around 280m and descending to Tawa. Horokiwi interchange is located near the summit. The gradient is 10% on the Petone side and 9-10% on the Tawa side.

Figure 4 Long section roll plot of the P2G current scheme alignment (MC01)



Notes: Petone IC is at the right, Tawa IC at the left, and Horokiwi IC (diamond) near the centre. The full extent of SH2 widening to Dowse and of the Tawa curves realignments is not shown. The three major cuttings from left to right are: Petone, Horokiwi (centre), and Havana Rise. The up-and-down profile is clear from the long section at the bottom of the image.

Both the Petone and Tawa interchanges are existing and would be completely reconstructed as part of the project.

The safety issues created by the steep downgrade on the approach to the narrow perpendicular shelf of land at Petone has driven the form of the Petone interchange.

The Petone interchange is a significant structure that would interconnect SH2 (north and south) and the Petone Esplanade with P2G (ie, 4 directions). The major transport corridor there includes rail and the Transport Agency is currently developing a cycleway that would need to be accommodated within the interchange. It is sited very near to the Wellington fault.

The Petone interchange scheme design is for a three-level signalised roundabout configuration consisting of 13 bridge structures with a free-flow system ramp connection from P2G to SH1 north. To support the traffic capacity that would be added by this free-flow connection the scheme includes widening of the Petone to Dowse section of SH2 for approximately 1.5km. The scale of the roundabout itself supports the requirement for stacking at the interchange, but has resulted in an increase in the cut volume.

The area is highly constrained between the sea and the steep hillside and the SH2 corridor carries around 65,000 vehicles per day. As such, the Petone interchange presents significant complexities for traffic management during construction.

Figure 5 shows the existing situation at Petone, looking south from the Hutt valley in the direction of SH1 toward Wellington city. The Wellington escarpment is the large hillside and the Korokoro valley is visible running perpendicular away from SH1 and the cluster of light industrial buildings at the centre of the image. The Petone Esplanade can be seen at the bottom left and Hutt Road runs beside the railway line.

Figure 6 shows the proposed Petone interchange and the P2G road running through a large cutting in the escarpment. The rail line has been realigned to the West (shifted rightward in the image). The cutting would remove land held in trust by a group of Iwi owners.

The Tawa interchange would also be a complex node within the road network. It would join SH1 (north and south), the local road to Tawa, the local road to the Takapu valley, and P2G (effectively 5 directions). The scheme design is a double at-grade roundabout configuration. The interchange is sited on one of the Tawa curves, which are a series of three out of context curves on the existing SH1 motorway. The scheme design includes the realignment of all three curves over a section of 2.5km of existing SH1 (from existing 300m radius to 550m radius).

Figure 7 shows the existing situation at Tawa, looking South along SH1 toward Wellington. Tawa is to the right of the image, the Grenada north housing development is to the upper left, and Takapu road is visible at the bottom left.

Figure 8 shows the proposed Tawa interchange and P2G running parallel with SH1 for around 700m before rising toward the east in a cutting. Four south facing ramps and two north facing ramps are visible, along with the connection to Takapu road. The large roundabout is in cutting to reduce property take from the light industrial and warehousing buildings.

Figure 5 Artist's impression of existing Petone interchange (looking south), showing Wellington escarpment and Korokoro valley

Figure 6 Artist's impression of P2G scheme showing Petone interchange and large Petone cut

Figure 7 Artist's impression of existing Tawa interchange (looking south)

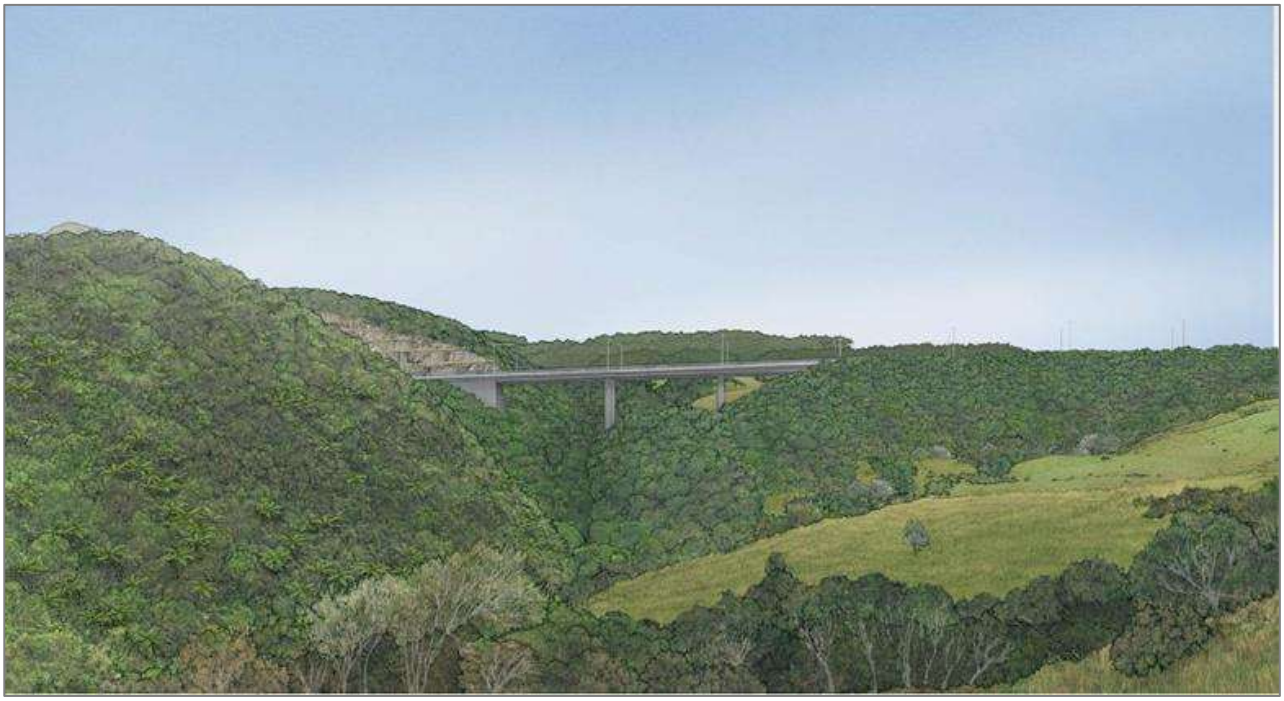
Figure 8 Artist's impression of P2G scheme showing Tawa interchange with connections to P2G and SH1

The project team considered widening of SH1 from Tawa to Transmission Gully (Linden) but opted for a managed motorway approach in this section. This avoids the need for capital investment there. However, this requirement is now being revisited within the wider Wellington network context.

Horokiwi interchange is a simple diamond arrangement. It would connect to a new local arterial that would run through a large new property development to connect to the existing Grenada interchange.

Slightly west of the Horokiwi interchange the alignment crosses the Belmont Gully, which contains mature native bush. The scheme bridges this gully (the Belmont bridge) as shown in Figure 9.

Figure 9 Artist's impression of the Belmont gully bridge, giving a sense of the topography



The alignment effectively goes through the escarpment, cutting at right angles to several major ridgelines. As a result, the scheme contains three major cuttings that are up to 85m high. The scheme is mostly in cut, resulting in both a very large cut volume of approximately 13 million cubic metres (13Mm^3) and a large cut-to-fill imbalance due to there being a need for only 3Mm^3 of fill within the project. By comparison, the nearby Transmission Gully, which is considered a major earthworks job and is 27.5km long (3-4 times longer than P2G), has 6.5Mm^3 cut and is roughly in balance within the project designation.

Figure 10 shows the both the challenging terrain and the scale of these cuts in the landscape. Also visible in Figure 10 is the border of the Belmont Regional Park (dashed white line).

The fill disposal strategy relies primarily on fill placement onto the Lincolnshire Farms development area, which is at the western end of the project. Much of the surplus would need to be hauled up the steep hill to this site.

The presence of the Wellington fault at the eastern end means the rock there is particularly fractured. The Petone cut, the first cut travelling east to west, goes through this fractured rock. This 700m cutting alone contains approximately 5Mm^3 and reaches the full 85m height. This cutting would be visible to the Hutt Valley and Wellington harbour. It can be seen above the Petone interchange in the artist's impressions in Figure 6 above and Figure 10 below.

Figure 10 Aerial impression showing the P2G Petone interchange, large Petone cut, Horokiwi cut and Horokiwi interchange (distant), Belmont Regional Park outline, and the Korokoro valley

The proposed large cuts are similar in scale and geology to the existing cut faces in the nearby Horokiwi quarry (near top left in Figure 10). A recent photograph of one of these cuts is shown in Figure 11 with earthmoving equipment visible at its base showing proportion.

A view of the escarpment where the cut and interchange would be is shown in Figure 12. This is taken from the Petone foreshore recreation reserve, beside the Petone Esplanade (at a location slightly outside of the bottom frame in Figure 10). Most of the hillside in the centre of the picture would be cut. The Petone interchange would be ten meters in the air, roughly at the top of the existing distant light poles. The opening to the Korokoro valley is visible in the right of the picture. The view can be married with Figure 10 via the hilltop stand of pine, the remains of which are visible at the top of the cut in Figure 10.

Figure 11 Existing cut face in Horokiwi quarry (approximately similar height as proposed P2G cuttings)

Figure 12 View to site of Petone cut and Petone interchange from the Petone foreshore reserve

2.1 Project economics

P2G's economic benefits are dominated by high travel time savings and high agglomeration benefits. The project's particularly high wider economic benefits (WEBs) reflect its unique characteristics in significantly improving the transport connection between two urban areas.

The project's economic benefits are summarised in Table 1 below. The traditional project economic benefits were updated in June 2017 to reflect revised transport modelling.

Table 1 Summary of P2G project economic benefits

Category	Benefit type	Benefit (NPV $M)
Conventional economic benefits	Travel time savings	358
	Congestion relief	50
	Vehicle operating costs (VOC)	1
	Crash costs	27
	Vehicle emissions reductions	0.04
	Total conventional benefits	**436.04**
Wider economic benefits (WEBs)	Imperfect competition	22
	Agglomeration	440
	Labour supply	14
	Labour demand	15
	Total WEBs	**491**
Resilience benefits	Reduced delay – major incidents	**65**
Total economic benefits (NPV)		**$992M**

The net present value (NPV) of the project costs including maintenance were assessed as $752M, giving a project BCR of 1.3.

Sensitivity testing at 6% discount rate gave a BCR range of 1.0 – 1.5.

Given the scale of WEBs in this project, an independent evaluation of the WEBs assessment was commissioned. This concluded that, although the analysis had been conducted in accordance with the EEM, the agglomeration effects may have been overstated and a conservative value in the order of $300-400M may be more appropriate. This would reduce the BCR to a range between 1.1 – 1.3.

The evaluation noted that the ratio of WEBs to conventional benefits (approximately 110%) is very high. In the UK, a rule of thumb maximum typical WEBs/conventional benefits ratio is 50%. While this does not rule out the possibility of high relative WEBs on a project-by-project basis it does highlight the uncertainty present in WEBs analysis and the importance of a clear and robust narrative explaining why the WEBs might be so high for P2G. Further work might be done to evaluate the conventional benefits against the WEBs in greater detail (including to ensure alignment of basic assumptions). In general, in recognition of the uncertainty in the non-conventional economic analysis, WEBs might best be thought of as part of the strategic case for a project.

The evaluation also noted the observed attenuation effect on WEBs, being that WEBs tend to decrease as distance increases. This suggests that the same level of WEBs may not be found for a longer east-west route, such as for SH58.

3. SUMMARY OF THE 2016 MULTI-CRITERIA ANALYSIS

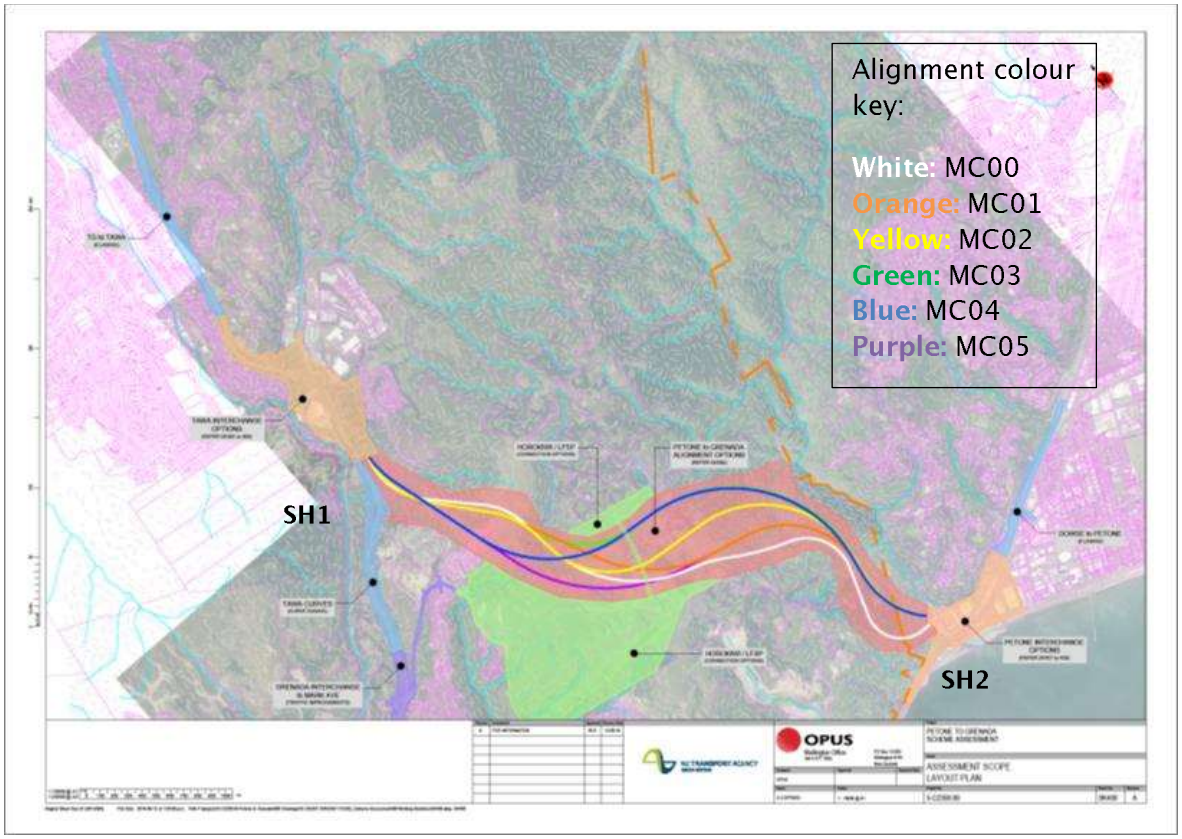
3.1 Methodology

The October 2016 multi-criteria analysis (MCA) updated the 2015 MCA, from which alignment MC00 had been selected. In 2016, MC00 was tested against a further five alternative alignments (MC01-MC05), which notably all removed the tight radius curves on the MC00 approach to Petone. The MCA alignment options are shown in Figure 13.

The 2016 MCA considered 15 criteria, all of which were the same as for 2015 except for the addition of crime prevention through environmental design (CPTED) as a distinct criterion. The criteria were rated against the six project objectives (see section 1.3) for each discipline on an eight point scale from 'Significant Positive' (score of +3) through to 'Significant negative' (-3) or 'Fatally Flawed' (F). No option was rated fatally flawed. Scores were given as unmitigated (the base score, taking account of any mitigation already allowed for in the 2015 MCA) or mitigated (where further mitigation options existed). The mitigation was specifically intended to assist with Objective 6 (Environmental).

The summary below focuses on the alignment MCA. The interchanges were also subject to MCA but they are not considered as fundamental to the project objectives and the interchange forms are addressed later in this evaluation report.

Figure 13 The 6 alignment options for 2016 MCA (orange line is selected option MC01)



Notes: The 2014 scoping report alignment is the white line, known as MC00. The other 5 alignments are all variations on MC00. It is notable that all 5 alternatives are on the same alignment near Petone (removing the tight MC00 approach curves), all tie-in to SH1 at Tawa, and the differences along the way are the north-south spreads that cut through ridgelines at different heights and encroach into Lincolnshire Farms (shaded green) and the Horokiwi area to greater or lesser extents.

3.2 Summary of MCA results

The 2016 MCA found that all alignment options had consenting challenges, with all having significant social, environmental and cultural effects (albeit to varying degrees).

The MCA served two purposes: to test the previously preferred alignment MC00 against alternatives and to select from among those alternatives. The clearest result was that MC00 was least preferred and should be dropped in favour of an alternative. However, there was far less differentiation among the alternatives to suggest which should be selected.

Of the 15 criteria, the alternative alignments scored equally on all but two: urban design and resilience. That is, **the only differentiating factors between the MCA alternatives were urban design and resilience.**

Table 2 shows MCA scores for the two differentiators and illustrates how, with various weightings applied, the MCA results increasingly favour urban design over resilience. Urban design related particularly to the impact on the Lincolnshire Farms Structure Plan, although this plan would have to be changed for any P2G alignment. The strongest alignment from a resilience perspective (MC03) is favoured only when the transport category (containing resilience and transport) is weighted with half of the overall points. This is despite urban design being only one of four elements within the built and human environment category and resilience being a standalone objective of the project.

Table 2 Resilience and urban design scores under different MCA scenarios

MCA Scenario	Differentiator	Weight	MC01	MC03	Spread (MC03–MC01)
Unweighted criteria scores	Resilience	1	1	2	1
	Urban Design	1	2	-2	-4
	Total score (all criteria)		**-2**	**-5**	**-3**
Categories weighted equally	Resilience	5	5	10	5
	Urban Design	2.5	5	-5	-10
	Total score (all criteria)		**8**	**3**	**-5**
Categories weighted according to workshop agreed weightings	Resilience	9	9	18	9
	Urban Design	16	16	-16	-32
	Total score (all criteria)		**-13**	**-36**	**-23**
Transport category weighting scenario	Resilience	25	25	50	25
	Urban Design	2.5	5	-5	-10
	Total score (all criteria)		**68**	**83**	**15**
Human and built environment category weighting scenario	Resilience	5	5	10	5
	Urban Design	12.5	25	-25	-50
	Total score (all criteria)		**18**	**-27**	**-45**

Notes: the 15 MCA categories were bundled into categories: resilience is one of two in the transport category, and urban design is one of four in the built and human environment category. Since scores for all 13 other categories were equal they had no bearing on the total score in the scenarios and are not shown here. In the single category weighted scenarios, one category is given 50% of the overall points.

The alignments were also assessed against the project objectives (Table 3), resulting in very slight differences in the overall scores.

Table 3 Overall scores of assessment against project objectives

	MC00	MC01	MC02	MC03	MC04	MC05
Overall score against objectives	9	13	13	12	12	13
Ranking	6th	1st	1st	2nd	2nd	1st

The slight differences between 1st and 2nd rankings reflected differentiation on the environmental objective. Strangely, all alignments were given the same assessment against the project's resilience objective despite there being a clear preference for MC03 and MC04 on this criterion.

3.3 MCA differentiators: Resilience and Urban design

The outcome of the MCA assessment was that MC01 was selected over MC03. It is worth considering the two differentiating factors in more depth.

MC01 has the highest cuts in all zones of high ground (three cuts of 65m, 80m and 85m high). The MCA **resilience assessment** concluded that[2]:

- For MC01, landslides (in large earthquakes and storms) would likely close the route "from many weeks to months", and judged it "Slightly consistent" with project objectives.
- For MC03, landslides (in large earthquakes and storms) would likely close the route for "few to many weeks", and judged it "Moderately consistent" with project objectives and "Very consistent" if a tunnel was added at the Petone end.

The **urban design** expert assessment report notes the following[3]:

> "Compatibility with the future development pattern of the LFSP [Lincolnshire Farms Structure Plan] is the key matter for urban design assessment for this section of the Project." (p22)

The urban design assessment favoured MC01 because:

- MC03 and MC04 run through a lower density residential area of the Lincolnshire Farms Structure Plan (LFSP) while MC01 avoids this and is assessed as enabling higher density development under the LSFP, and
- MC03 and MC04 create greater severance for the Horokiwi community.

It is notable that the urban design scoring essentially reflects the relative impact on a structure plan that was drawn in 2006, before the geometric and geotechnical feasibility of P2G had been considered in any depth, and which would have to be changed under any option. It also reflects the impact on the Horokiwi community.

Ecology was also a differentiator in the base position, with MC01, MC03 and MC04 all scoring equal and highest. However, with mitigation there was no differentiation among the alternatives (all scored minor negative).

3.4 Other points to note from the MCA

It is interesting to note the outcome of the MCA visual effects assessment. The MCA summary report notes:

> "At the southern junction at Petone, the physical landscape is identified as very precipitous and highly visible, with the proposed link road having to traverse the scarp face which surrounds the harbour. This is identified as the most dominant and most visible landscape feature on the route… The finding of the assessment is that the effect on the landscape of the project is significantly negative regardless of which options are preferred due to the extent of excavation, cut faces and fill areas." (pp63-64)

[2] See report "Natural Hazards and Resilience of Options, MCA 2016", Opus, 26 October 2016

[3] "Multi-criteria assessment: Urban design for the Petone to Grenada project", Issue 07: 16th December 2016; Brewer Davidson

However,

> **"The option with the lesser degree of significant negative effect is MC03."** (p64)

As mentioned, no fatal flaws were found in any aspect of the alternatives. This includes for the Belmont Gully, which has subsequently had a bridge added to the scope to avoid embankment.

The project costings used at the MCA stage are significantly lower than the current updated estimates (approximately one third of current costs). As a result, actual expected cost cannot be said to have been fully taken into account in the MCA.

As discussed earlier (section 1.2.1), recent changes to the RMA related to natural hazards were not taken into account in the MCA. The MCA RMA weighted scenario favours MC01 and MC05. It is worth asking if this would still be the case if the new emphasis on natural hazard risk was taken into account. Following the RMA change the project team has acknowledged that "the proposed new s6 clause would certainly elevate the weighting with respect to natural hazards, including resilience."[4]

3.5 Conclusion from the evaluation of the MCA process

In selecting MC01 as the preferred alignment the 2016 MCA prioritised urban design over resilience. In essence, this decision favoured a small community and an outdated structure plan over the seismic resilience of a key transport lifeline that would serve the entire Hutt valley. For a distant observer working only from the reports of the process, it is difficult to reconcile this decision making with the core objectives of the project.

This highlights a potential shortcoming, being that the priority of the objectives was not (and is not) clear and did not provide enough direction to the MCA assessors. One way to test the priority is to ask the following two questions:

1. If, once built, the project failed to satisfy all parties with its urban design outcomes, could the project still be considered a success?
2. If, once built, the project was found not to be resilient following a major earthquake and failed in its role as a lifeline to the population of the Hutt valley, could the project still be considered a success?

If success is more associated with resilience than urban design then there is cause to reconsider the MCA result and further consider MC03.

However, it must also be noted that the lack of differentiation among the alternatives reflects their similarity. While another of the alignments might be reconsidered it would still only be a variation on a common theme. If the theme itself is unable to fully satisfy the objectives, then a more fundamental alternative may need to be considered.

[4] Opus email of 16 February 2017.

4. CONSENTING STRATEGY

A consenting strategy was prepared in January 2016 based on the previous preferred alignment (MC00). This is a two stage process that would follow the Council consenting path.

The strategy has not yet been updated for the newly proposed alignment or the further design detail. However, the January 2016 strategy identified the significant issues or effects and these remain directly relevant. These include:

- Potentially serious landscape and visual impacts, particularly from the Petone interchange to the crest, and from filling of gullies on the western sector;
- Potential for erosion and sedimentation during construction, water quality and hydrological changes associated with construction and operation of the road. The significance of these issues has also increased with the notification of the proposed Natural Resources Plan and its focus on water quality, stream bed reclamation and Iwi issues;
- Ecological effects, including terrestrial, freshwater and marine;
- Social and community impacts, particularly property acquisition or impacts, effects on neighbourhood character;
- At the Petone interchange, displacement of all the business between SH2 and the coastal escarpment;
- Noise impacts from the construction and operation of the road;
- Recreation impacts, mainly in relation to recreational access;
- Potential effects on sites and resources of significance to tangata whenua, and on streams and Maori-owned sites; and
- Archaeological effects, and particularly due to impacts on the original site of the Britannia Flour Mill and the Wellington Woollen Mill near the mouth of the Korokoro Stream, and potential impacts on the Takapu to Korokoro track used during pre-European times.

The consenting strategy would be updated to reflect changes in the statutory environment as noted earlier. It may be beneficial to do this now to reflect the more current alignments. In particular, the inclusion of natural hazards as a Part 2 RMA matter of national importance should be reflected in the assessment of alternatives and in the further design process. At a more detailed level, the ongoing development of the PNRP will influence consenting status and mitigation requirements for the final route.

The current scheme includes offset mitigation for the environmental effects. Primary mitigations are the Beach to Bush cycle and walking path, the Belmont Gully bridge, Horokiwi community bridge and intended off-site mitigation that is not yet fully detailed.

Beach to bush would reconnect the Petone foreshore with the Belmont Regional Park via paths that would pass under the Petone interchange following the daylighted Korokoro stream (the stream is currently in culvert under SH2 and light industrial buildings). This change from culvert to bridges adds to the cost of the interchange. Beach to bush is considered a key indirect mitigation for the visual effects of the Petone cut.

The Belmont Gully bridge was added to the project in place of an embankment to avoid effects on the native bush in the gully. Some preliminary work has been done on the feasibility of using daylight shafts to light culverts if an embankment was built.

From a consenting point of view, an embankment will certainly be more difficult to consent than a bridge. As mitigation, the work to date has already identified potential opportunities such as land swap with higher quality vegetation to add to Belmont Regional Park (BRP) and development of a Seton Nossiter Park – Horokiwi – BRP pedestrian and cycle link. The potential costs associated with these opportunities would need to be reflected in the cost estimates for a bridged option. A potential

option may be to seek consent for an embankment, and to revert to a bridge if the embankment was strongly opposed. Alternatively, consents could be sought for both.

The Horokiwi community bridge is proposed to help mitigate the severance of the community.

There are likely to be a wide range of options for offset mitigation outside of the alignment, in particular using the BRP. The Transmission Gully project includes extensive offset mitigation within the park and much of the opportunity for stream mitigation and mass planting has already been taken by Transmission Gully. However, large areas of BRP are transitioning from farmland and is covered in relatively low ecological value scrub. There may be mitigation opportunities in regenerating scrublands through diversification planting. This would need to be explored with Greater Wellington Regional Council.

5. GEOMETRICS AND SAFETY OF THE PROPOSED SCHEME

In accordance with the project objectives the proposed scheme has been designed to expressway standards: no at-grade intersections; wide horizontal curve radii such that the alignment takes a relatively direct path; a wide carriageway including six lanes, median separation, and shoulders; and an 80kph design speed. The geometry has necessitated the very deep cuts and resulted in a less resilient road.

5.1 Geometric design philosophy

The geometric design has tried to marry three desired outcomes that are in conflict in the P2G context:

- Expressway standard.
- Self-explaining road, and
- 80kph downhill speed limit for safety.

The expressway standard has resulted in the adoption of a 100kph vertical design speed and the introduction of crawler lanes for the full length. Recognising that in such an environment drivers will tend to drive over the design speed, the designers have sought to make the road more self-explaining by adopting an 80kph horizontal design speed. This implied operating speed marries with the expressway speed.

However, each carriageway is three lanes wide and would look and feel like a motorway with large radii curves while also having long downhill sections at 10% gradient. As a result, although the design has achieved a self-explaining environment on the horizontal alignment, having been boxed in by the required expressway standard the design effectively concedes that a self-explaining road cannot achieve safe speeds in the approach to the interchange.

The proposed solution to these conflicting objectives is to post the road at an 80kph speed limit in order to control for safety and to use active speed limit enforcement.

A similar issue, albeit to a lesser extent, applies to the 7% gradient approach to the Tawa interchange.

5.1.1 Cross-section selection

The cross-section (six lanes, median separated etc) was selected to provide:

- Capacity for the 2000 passenger vehicles and 75 heavy commercial vehicles forecast for the 2031 peak hour;
- Expressway level of service (LOS C); and
- Safety on long steep upgrades where heavy vehicles may block both lanes and slow operating speeds to 20kph for all vehicles.

The first two of these lead to two lanes in each direction, and the third leads to the adoption of crawler lanes. The cross-section is completed with median and shoulder widths as per expressway standards.

The geometric evaluator considered each of the above to be reasonable given the starting premises of an expressway standard and that demand will be as forecast.

However, both of these premises can be challenged. In addition to questioning whether the road needs to be an expressway, the scheme does not appear to have considered any demand management options or tools or modal alternatives beyond cars.

5.1.2 Maximum longitudinal gradient

10% was set as the maximum gradient for the project. From a geometrics perspective, a lesser gradient would be preferred in the context of a sustained long downgrade approaching an interchange. However, a lower gradient would only be possible on the chosen alignment by further deepening the cuts.

5.1.3 Downstream impacts: enlarged Petone interchange

The most significant downstream design effect of the steep gradients is the changed and enlarged form of the Petone interchange. The safety issues associated with vehicles approaching an interchange on a 10% gradient have necessitated a large, complex arrangement that includes 13 structures and a northbound system ramp that in turn requires widening of SH2 toward Dowse. This has increased the cost of this interchange, as discussed in the next section.

The evaluation team found that the scale and form of the proposed Petone interchange is a necessary response to the unique safety concerns raised by the scheme alignment and expressway standard.

5.1.4 Walking and cycling

The form of the walking and cycling facilities is also governed by safety concerns given the steep downgrades. This has resulted in two design choices: that the facilities are physically separated from the traffic lanes, and that downhill cyclists are separated from pedestrians and uphill cyclists by providing the facility on both sides of the alignment.

These design choices have naturally extended the carriageway beyond what it would have been had cycling been provided on shoulder or if it could have been provided on only one side.

5.2 Geometrics of the MCA alternative alignments

All of the 2016 MCA alignments suffer the same 10% gradient problem, with common implications for the interchange designs, and are otherwise similar in their vertical alignments. All alignment alternatives to MC00 have the same horizontal design parameters.

The MCA alternatives demonstrate some scope for reducing earthworks through alignment changes north of the summit. There is little opportunity for improvement to the south.

The evaluation team concluded that among the MCA alignments MC01 and MC03 are the best geometrically. However, there is no 'silver bullet' from a cost perspective among these options.

6. COST ESTIMATES FOR THE PROPOSED SCHEME

6.1 High-level cost review of the proposed scheme

The project team's most recent cost estimate for the proposed scheme, as described above, is $723m for physical works and approximately $1.2bn including contingency and risk (ie, at the 95th percentile).

The evaluation team has carried out a high-level review of this estimate. Given time and scope considerations this was not a full parallel estimate but rather an independent due diligence exercise. The results are summarised in Table 4.

Table 4 P2G scheme cost estimate and high-level evaluation review (2017 costs)

	Project ($M)	Evaluation review	% difference
NZTA managed costs	166	158	-5%
Physical works	723	797	10%
Base	889	955	7%
Contingency allowance	20%	25%	
Expected	**1,067**	**1,194**	**12%**
Risk allowance	10%	20%	
95th	1,173	1,433	22%

The evaluation found higher costs in all bottom line cost categories except NZTA managed costs. The key drivers of these differences are:

- Higher allowance for traffic management costs, particularly in relation to the highly complex task of constructing the Petone interchange under live traffic.
- Higher P&G and MSQA allowances, reflecting recent large NZTA contracts (P&G), albeit lower than recent due to efficiencies from the earthworks scale, and the likely complexities of seismic design and geotechnical issues (MSQA).
- Higher extraordinary costs to allow for requirements of spoil placement on Lincolnshire farms.
- Higher allowances for contingency and risk to reflect the stage of design development and uncertainties related to geotechnical and seismic risk, particularly near the Wellington fault at Petone.

It is clear that the project is both of a very large cost and, naturally at this stage in the project development, there remains considerable uncertainty in the cost.

The very high cost of the project is illustrated by comparison to other recent large NZTA projects, two of which are located near P2G. Table 5 shows these costs and the per kilometre cost for P2G, which is more than three times higher than the nearest comparator project.

Table 5 Comparison of P2G per kilometre cost against other major earthworks projects

	Project length	Physical works cost (approx.)	Cost per km
Mackays to Peka Peka	18km	$630M	$35M
Transmission Gully	27.5km	$775M	$28M
Pūhoi to Warkworth	18.5km	$700M	$38M
Petone to Grenada	**8km**	**$995M**	**$125M**

The cost breakdown between the three main components of the P2G project are shown in Table 6 below. The main alignment physical works contains earthworks of $192M and the Petone interchange works include $74M of bridges.

Table 6 Evaluation review cost breakdown by major project component

	Tawa interchange	Petone interchange	Main alignment (MC01)	Combined project ($M)
Total NZTA managed costs	18	77	63	158
Total physical works	107	261	432	797
Base	125	338	492	955
Contingency	44	116	79	239
Expected	**169**	**454**	**571**	**1,194**
Risk	51	134	54	239
95th	220	588	625	1,433

Clearly, the Petone interchange is a significant project in its own right, with an expected cost of nearly half a billion dollars.

6.2 Potential for incremental cost savings via scope reduction

The current scheme has had several scope elements added since the alignment was selected, including:

- Crawler lanes in both directions for the full length
- Fully separated walking and cycling facilities on both sides
- The Horokiwi community bridge
- The Belmont gully bridge
- Widening SH2 to Dowse
- Realignment of the SH1 Tawa curves

The evaluation has considered cost savings that might be available if these elements were able to be removed from the project scope. These results are presented in Table 7 below for the expected costs (including contingency).

Interestingly, the October 2016 safety workshop (attended by Transport Agency safety experts) concluded that the downhill crawlers were not necessary. Given the nature of the gradients and current cyclist numbers, the walking and cycling facilities are unlikely to be supported by a benefit cost ratio.

The scale of the Petone interchange has changed significantly from the project scoping stage. However, this is not scope that can be removed without consequential changes to the alignment itself. Changes to the Petone interchange are considered in a later section.

Table 7 Estimated savings in expected cost through scope reductions

Scope item to be removed	Notes	Estimated saving in expected cost ($M)
Crawler lanes	Saves 5 metres of road width	24
Walking and cycling	Each saves 3 metres of carriageway width	47
Horokiwi bridge	No specific design available at this stage	46
Belmont bridge	Replace with culvert, provides spoil site	54
Widening to Dowse	Subject to a number of assumptions	42
Tawa curves	Subject to a number of assumptions	25
Total estimated saving in expected cost		**238**
Expected scheme cost after scope reductions		$951M
Potential saving (approx. %)		**20%**

Note: Crawler lanes are associated with narrowed shoulders, hence saved road width is less than saved lane widths; Limited schedule information available for Dowse and Tawa estimates.

6.3 Potential for cost savings via changes to design parameters

The vertical alignment and design speed can affect the level of earthworks and cost. However, the P2G crest vertical curves do not coincide with the deep cuttings, and are therefore not determining factors in the earthworks volumes. The determining design parameter for P2G earthworks is the maximum gradient of 10% coupled with the alignment itself (which cuts at right angles through the ridgelines). As a result, relaxing the proposed crest curve (k-value of 60) via a reduced vertical design speed (currently 80kph) would have a limited effect on the earthworks volumes, even for a reduction to a k-value of 30.

The horizontal design speed was set to 80kph to improve safety on the downhill gradients and interchange approaches. It is not clear why this was applied to the entire alignment. However, a reduction of the horizontal design speeds *within the existing alignment* is unlikely to reduce costs, since tighter radius curves would require widened cuts to provide stopping sight distances.

To achieve cost savings via tighter radius curves at a lower design speed the alignment itself would need to be changed so as to allow it to better follow the natural curves of the landscape.

6.4 Summary of cost estimate review for the proposed scheme

The currently proposed scheme has a very high cost relative to other major recent Transport Agency projects. This is driven by the nature of the terrain and the chosen alignment (cutting through a large escarpment) and the consequential costs for the major interchanges. The Petone interchange in particular is a significant project in its own right.

The evaluation review considered the accuracy of the cost estimate and found that it is appropriate for a project at this stage, but suggested that additional risk and contingency should be allowed.

The evaluation also considered opportunities to reduce project cost by removing scope items that might be considered optional. This provides approximately 20% cost saving, but the overall project cost remains significant. It should be noted that in practice it may not be possible to make all of these scope reductions, after considering the safety and consentability implications.

7. RESILIENCE PERFORMANCE OF THE PROPOSED SCHEME

7.1 Source of resilience risks

In terms of major seismic and storm events, the main resilience risk to the project is from road closure due to material on the road from cut slope failures and landslides. This risk is affected by:

- Very high cut slopes – higher slopes are at greater risk of failure and collapse.
- Strength of the material – fractured and highly weathered material is at greater risk of failure.
- Ability to access the failure points in order to clear material from the road.
- Carriageway width – extent and length of road closure depends on the quantity of material on the road and the capacity of the carriageway to 'store' the material while leaving some lanes unaffected.

The current scheme has very high cuts in three locations (plus another large cut). The material is fault fractured, particularly at the Petone end, and highly weathered near the surface. In the event of a major earthquake, if all high cut slopes suffered failure and completely blocked the road it would not be possible to access each failure from both sides, because of the limited access nature of P2G. Clearance would have to work in from one side, making the clearance and reinstatement much slower. Having said this, the carriageway width is very wide (six lanes plus median, shoulder, walking and cycling facilities), which is a positive from a resilience perspective as it is less likely that the carriageway would be completely blocked.

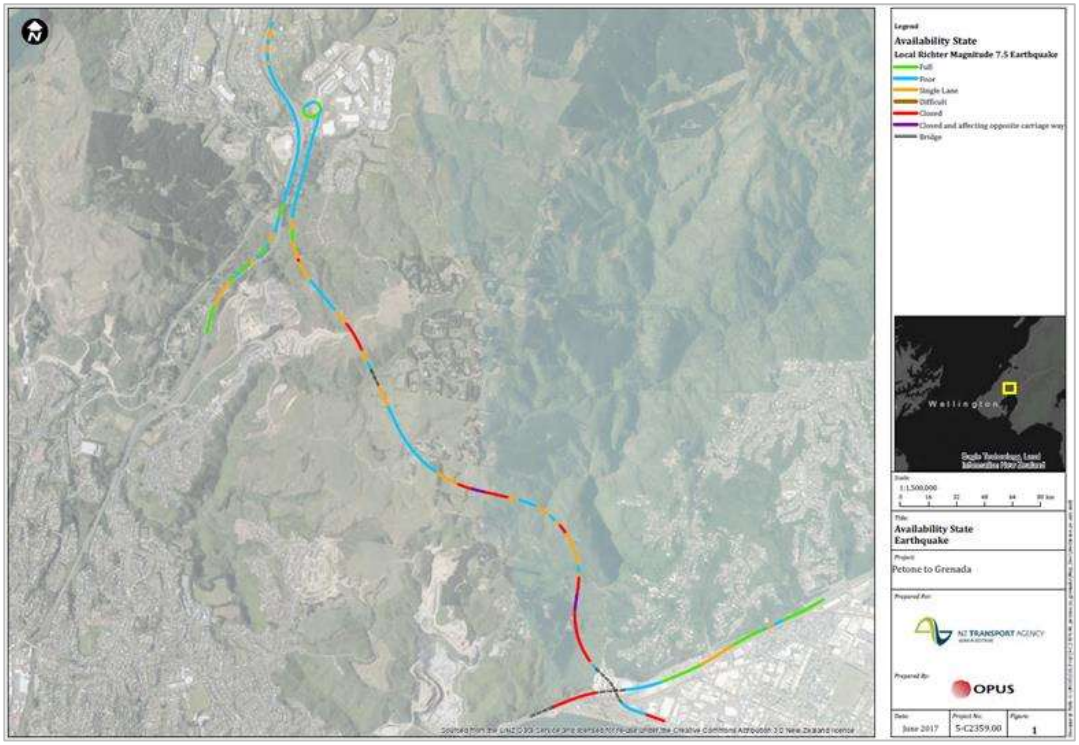
The proposed scheme typical cross sections currently do not show catch berms or rock fall fences or barriers to prevent small landslides or fretting of the cut face from spilling onto the carriageway.

7.2 Resilience assessments of MCA alignment options

Further resilience analysis of MC01[5] found that following a major seismic event limited access (middle lanes with controlled access) could be provided within 30 to 50 days (3 to 7 weeks), as illustrated in Figure 14 and Figure 15.

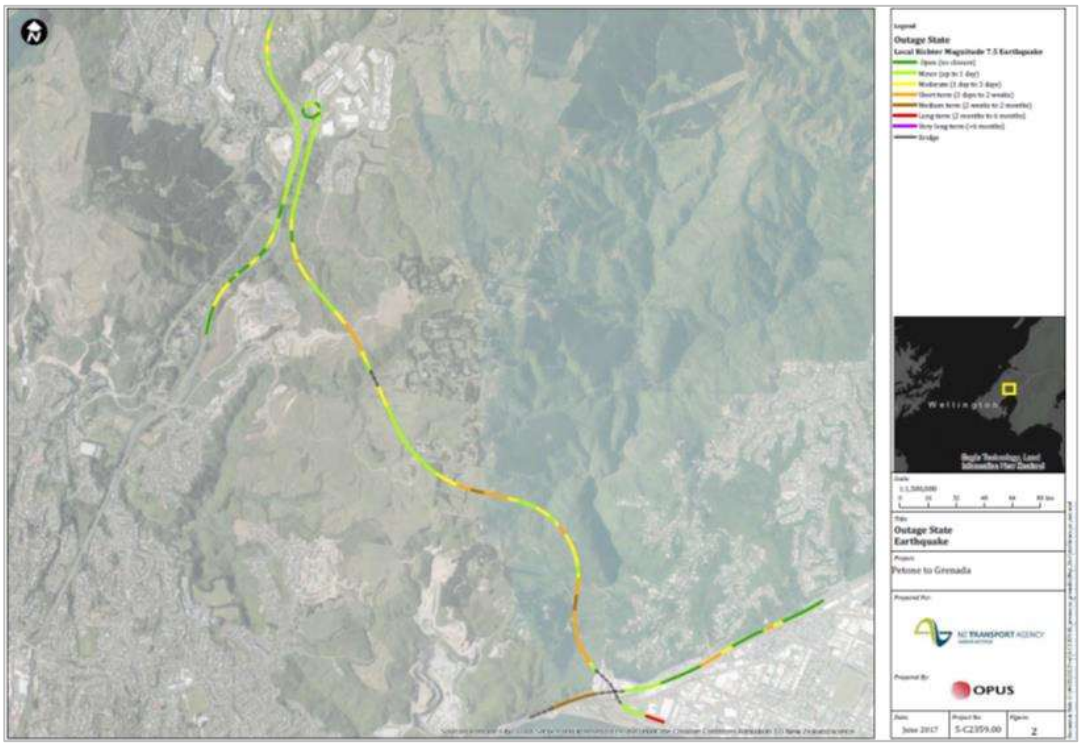
Although these estimates are subject to uncertainty at this stage, the expected closure period for the proposed P2G alignment is only slightly better than that for existing SH2 and SH58. There would be small resilience benefit from P2G under the proposed scheme. The MCA analysis recommended the MC03 alignment as being superior to MC01, at no additional cost. However, it noted that MC03 would also have resilience problems at Petone and proposed a tunnel to resolve this. The resilience of alternative MCA alignments are discussed further in sections 7 and 8.

Figure 14 Expected availability state for MC01 following a 7.5M earthquake



[5] See working paper, "Resilience of Petone to Grenada Link", Opus, 6 June 2017

Figure 15 Expected outage state for MC01 following a 7.5M earthquake



Of the other alignments considered in the MCA, MC03 and MC04 have lower cuts at Horokiwi and Havana Rise (but the same cut at Petone). The MC03 and MC04 alignments are shown in Figure 13 (green and blue lines respectively). These alignments differ from MC01 in the mid-section where they both take a more northerly route. In so doing they cut through lower points in the ridgelines, resulting in lower cuts and improved resilience. Table 8 summarises the cut height differences among the three alignment options.

Table 8 Major cut heights among MC01 and the most resilient MCA alignment options

Major cut	MC01 cut heights	MC03 cut heights	MC04 cut heights
Petone cut	85m high (750m long)	85m high (750m long)	85m high (750m long)
Horokiwi cut	80m	50-55m	50-55m
Havana Rise cut	65m	65m	40m

Both the MCA resilience expert and the evaluation team resilience expert concluded that MC01 is less resilient than these other two routes. However, the cuts on the other two alignments are still high and the vulnerability at Petone remains. As a point of comparison, the Petone cut is a significantly higher cut than the highest final design cut heights on Transmission Gully, which are 75m (310m long) and 65m (585m long).

MC04 is probably the most resilient of the MCA alternatives. MC04 achieves the lowered cut at its western end by going through Havana Rise, a newly established residential street, at a location that is both further down the hillside (allowing the lower cut) but also the site of several newly built and under-construction homes.

MC03 avoids this part of Havana Rise, but encroaches further into the Horokiwi community (in common with MC04).

8. POTENTIAL RESILIENCE IMPROVEMENTS WITHIN THE PROPOSED SCHEME

As discussed above, MC01 was assessed as having relatively poor resilience due to the very high cuttings and fractured rock conditions. Two options have been considered by the evaluation team for improving resilience within the scope of the 2016 MCA alternatives:

1. Change to a more resilient alignment: either MC03 or MC04, and
2. Replace the most vulnerable cut (Petone) with a tunnel.

8.1 Use alternative MCA alignments MC03 or MC04

MC03 and MC04 each bring improved resilience and potentially lower cost compared with the current scheme. The MCA chose MC01 over these alignments primarily because MC01 had a stronger urban design outcome, thereby prioritising urban design over resilience. If the project's core purpose is to provide improved resilience to the Wellington transport network then this MCA conclusion should be revisited.

Each of MC03 and MC04 is expected to have a lower earthworks volume than MC01, which allows cost to be reduced. The estimated cost comparisons for the three alignment options are shown in Table 9 below.

Table 9 Cost comparison for more resilient MCA alignments

Option	MC01	MC03	MC04
Base – $M	955	824	809
Expected – $M	1194	1030	1012
95th – $M	1433	1236	1214

These alignments provide improved resilience and a saving of approximately $150–200M. However, it should be noted that because MC03 and MC04 were not selected at the MCA stage their earthworks volumes have not been further refined and are likely to be subject to more uncertainty than for MC01. This uncertainty applies also to the potential cost savings.

It is also important to note that MC03 and MC04 both have greater community and property impacts (particularly MC04), and therefore greater stakeholder risk.

Although they are relatively more resilient than MC01, neither of these alternative alignments is particularly resilient in their own rights. This is especially so at the Petone end where all three alignments are common, but also in the other remaining large cuts.

8.2 Use a tunnel to replace Petone cut

All of the MCA options are on the same alignment at the Petone end: they all go through a very deep cutting in fractured rock where the natural slopes are steepest (>50°). The MCA expert evaluation identified this cut as the least resilient and suggested that a tunnel would improve resilience there. Tunnels tend to perform well in seismic resilience terms, as long as they don't cross a fault line (which this tunnel would not do). A tunnel would also improve the environmental and consenting outcome and significantly reduce the project's earthworks spoil.

The evaluation team arrived at a high-level assessment of the potential tunnel cost (assuming 3 lanes) of $300–400M, after allowing for the avoided earthworks cost.

It is worth noting that this cost estimate assumes both 3 lanes and a bored tunnel. The geotechnical assessment suggests that the rock could be suited to a roadheader, which was the methodology used in Wellington's Terrace tunnel, as well as boring machine. In particular, the geotechnical assessment indicates that the rock may be relatively low strength and that fracture spacings are very small, which would serve to improve penetration rates (although this may be offset by a need for additional support and grippers). Further work would be required to test actual potential costs.

However, a Petone tunnel could not avoid the very steep gradient (10%), which is considered unsafe in a tunnel due to (for example) fire risk and egress limitations. This means it could also not avoid the consequential requirement for a large and complex solution at the Petone interchange.

The evaluation team briefly considered a full alignment tunnel. This would avoid the gradient problem (as the rise to the Grenada side is within acceptable gradient tolerance), completely avoid the resilience problems associated with cuttings, and avoid environmental impacts. However, given the likely cost this option was not considered further in any depth. The project team also considered a full length tunnel and discounted it for similar reasons, and because it would be very difficult to provide an interchange for Horokiwi.

8.3 Conclusions on within-scheme resilience improvement options

In relation to resilience within the scope of the existing scheme, the evaluation finds that:

- Resilience could be improved using an alternative alignment (MC03 or MC04) for a roughly 10% cost saving on the current scheme, but with increased stakeholder risks;
- Resilience could be further improved by adding a tunnel to one of these alignments for a roughly 10% overall cost increase on the current scheme, with the same stakeholder risks and a likely worsened safety outcome. This option is estimated (at a high level) to add around $150-250M to the net overall project cost;
- None of these options (including the existing scheme) provides a very high quality resilience solution.

9. CONCLUSION REGARDING THE CURRENT PROPOSED SCHEME

The evaluation concludes that the current scheme:

- Is very expensive relative to other major projects in New Zealand (albeit for a BCR comparable to other major projects);
- Has significant environmental impacts that may not be possible to directly mitigate;
- Does not meet a core project objective, being resilience;
- Could be made more resilient but for additional cost and new risks; and
- Even with improvements, overall resilience would remain uncertain and may not meet the project's resilience objective.

Given this finding, the evaluation next stepped outside of the confines of the existing scheme concept (but remaining within the existing scheme area) to ask how/if the project could be reconceived to provide a set of desired outcomes at lower cost and with a similar or smaller environmental impact. This is discussed in the remainder of this report.

10. ALTERNATIVES

The evaluation has looked for solutions within the existing P2G area that could:

- Achieve a more tolerable project cost;
- Deliver resilience, a core project objective;
- Deliver the project's transport benefits;
- Avoid or manage, as much as possible, the project's environmental impacts.

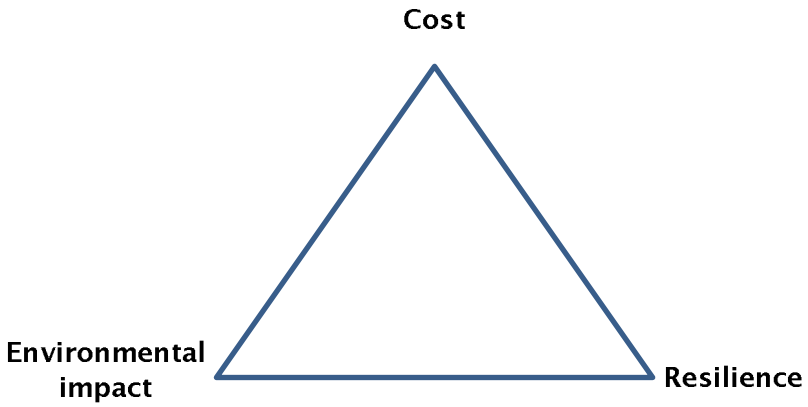
Possible alternatives to the current proposed scheme are discussed below.

The current approach contains constraints and assumptions that tie the project up and severely limit the possible solution. The result, as shown in the first part of this report, is that it is not possible to meet the above aims within the current proposal.

To find possible alternative solutions these constraints and assumptions must be challenged and loosened. Specifically:

- The project's objectives should be reconsidered and clearly prioritised. The position of resilience within the objectives should be made explicit (eg, as against other outcomes, such as urban design);
- The requirement for an expressway standard should be challenged and relaxed;
- The assumed vehicular traffic demand should be challenged and reconsidered holistically taking account of not just an infrastructure supply response but also a demand response;
- The required level of service should be challenged for its realism and appropriateness within a modern urban transport network;
- The solution set should be widened from only a capital solution (ie, a major physical engineering exercise) to a capital and network operational solution;
- The project should be deliberately and actively integrated with related projects within the wider network context, working with other Transport Agency projects and with our local government partners;
- The alignment should be fundamentally reconsidered by revisiting specific options in the scoping report.

Every solution is a trade-off among three points on a triangle: impact on the environment, cost and resilience. The conclusion reached by this evaluation is that the current proposed scheme fails on all three of these points.



No matter how it is looked at, the Petone to Grenada project contains difficult challenges and there is no obvious solution that avoids them all. If it is to improve P2G's performance against the three points, the Transport Agency will need to be bold and honest with the affected communities and with

its partners. It will need to be very clear on its objectives, explain the project's challenges and complexities, and share a vision for what it is trying to achieve within these confines and constraints.

This presents an opportunity. Petone to Grenada can be reframed as a project of the future: a whole-of-system solution that demonstrates the Transport Agency's serious intent to integrate across transport modes, make efficient and smart choices between capital and operational investments, to work with the environment and landscape, and to anticipate and leverage likely transport futures.

11. CHALLENGING THE ASSUMPTIONS TO FIND AN IMPROVED OUTCOME

The current proposal suffers from:

- Very high cost;
- Poor resilience:
- Significant environmental impact.

These outcomes are fundamentally the result of five underlying drivers:

- The physical location – road must traverse the coastal escarpment;
- Requirement for expressway standard;
- Assumed traffic volume of (approximately) 30,000vpd;
- Assumptions of minimum acceptable interchange spacing;
- Environmental impacts.

For this evaluation the physical location is taken as given (ie, the evaluation scope is constrained to the P2G area). The physical conditions obviously cannot be changed, but they can be better worked with.

The other four fundamental drivers are assumptions that can be changed.

11.1Expressway standard vs. arterial link road

It is not clear why the road must be to expressway standard. P2G is a major arterial link road between two motorways – it is not a motorway and does not need to be a motorway to fulfil its objectives. In fact, requiring expressway standard (and associated level of service) is causing the scheme to fail against the objectives.

To meet expressway standard the road must be fairly straight. As a result:

- It goes through hills and ridgelines resulting in massive cuts and poor resilience
- The approach gradients to Petone interchange (in particular) are too steep
- The operating speeds are too high, particularly on the approach to Petone
- The Petone interchange has to be made safe through scale and complexity, and the scheme has to spill over to widen toward Dowse.

It is interesting to note that the 1991, 1995 and 2010 concepts were all either 2- or 4-lane roads with tighter geometric alignments (lower speeds) and crawler lanes only if and where needed. Between then and now the road has changed to an expressway standard with much larger radii curves and six lanes.

The expressway standard (and environmental goals, discussed below) results in deeper cuts, poor resilience, and a large and complex interchange at Petone.

11.2 Passively meeting traffic demand vs. active demand management

To date the traffic demand assumption has simply been taken as given. As a result, the road is considered on the borderline between needing two and three lanes to meet peak capacity. The current scheme is based on the argument that it is better to build the third lanes rather than face the extremely difficult and costly task of adding them in the future. While this is a fair line of reasoning, it is fundamentally flawed if demand is not 30,000vpd.

To provide for the assumed demand:

- The scheme is designed with three lanes and has huge interchanges at either end that allow for stacking
- As a result, the expressway cross-section becomes even wider, exacerbating the operating speed problem and reinforcing the cost outcome at Petone.

The traffic modelling is based on assumed occupancy of around 1.3-1.6 people per vehicle. This assumption appears not to have been challenged.

While the potential for public transport (buses) on the route was acknowledged in the 2016 MCA process, it was considered out of scope and given no further consideration. In fact, the existing low public transport usage between Porirua and Hutt catchments is discussed as indicating low customer demand for public transport. Currently, to travel by public transport involves a transfer in Wellington city and is clearly incomparable to a with-P2G public transport scenario.

Finally, the underlying single occupancy vehicle philosophy takes no account of potential future developments around more efficient vehicle usage via ride sharing. In this sense, the scheme cannot be said to be future-proofed or fit for purpose.

11.3 Traditional high-speed motorway design vs. network management and braided ramps

The 2014 Scoping Report proposed connection options to SH1 at the existing Grenada interchange and at a new interchange between Tawa and Grenada (Figure 16).

The Grenada option was thought not to provide sufficient connectivity to capture traffic and balance flows from the north. The new mid-block interchange option was discounted as it violated the minimum interchange spacing allowed under common motorway design standards. The Option B plan shown in Figure 16 has the south facing Tawa ramps deleted for this reason, which further degraded the assessed viability of this option. However, variants of these options may deserve further consideration.

Figure 16 Connection options to SH1, from 2014 Scoping Report

Notes: These are Options A (left) and B from the 2014 Scoping Report. Option A would connect to existing Grenada interchange via Grenada Drive (an existing three lane local road). Option B would connect at a new interchange, and would traverse a landfill (blue shaded area), as well as having a connection to Grenada Drive. Both options were discarded in favour of the Tawa interchange. Interchange spacings under Option B were considered too close.

The Grenada option would use existing Grenada Drive, which is currently a three lane road and could be relatively easily widened to accommodate a repurposed P2G. The interchange would need some upgrade.

The required minimum interchange spacing rests on the assumption that the motorway is flowing at its maximum speed. In reality SH1 is highly congested and speed restricted at the Tawa curves. A relaxation of the design standards to allow closer spacing could be achieved, if it were accompanied by ramp braiding to remove the weave[6].

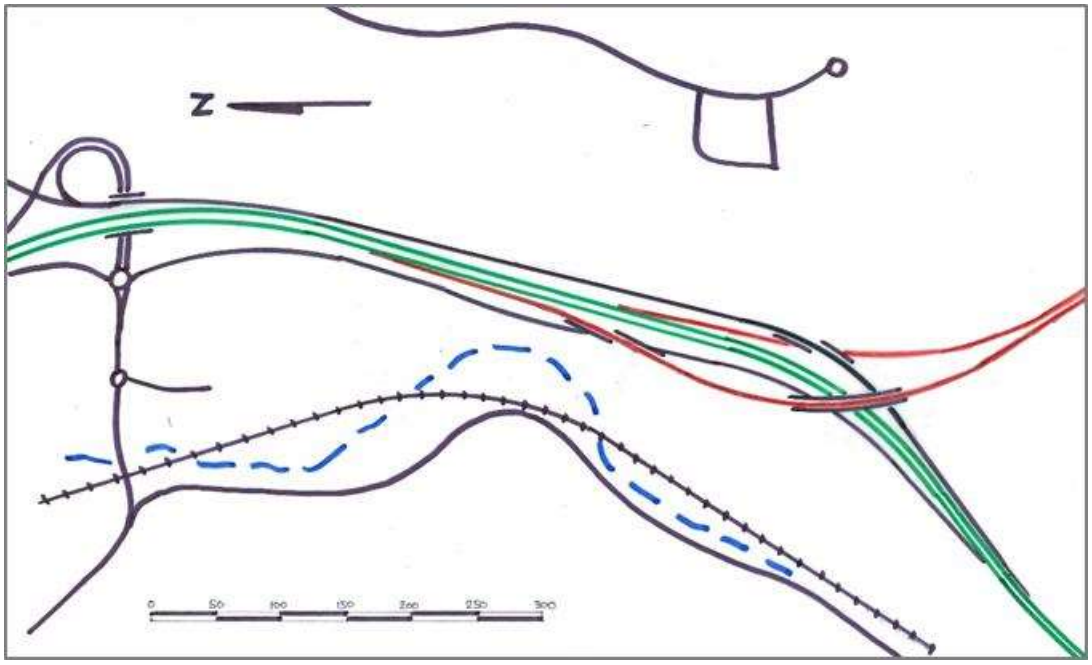
Ramp braiding is a possible answer to unsafe and operationally undesirable weaving between successive entrance and exit ramps of closely spaced interchanges. With two interchanges placed as close together as in Figure 16 the ramp for the second interchange would be 'braided' over or under the ramp of the first interchange so that the close entries and exits are reversed and thereby removed. As an illustration, this concept is shown in Figure 17 (this is conceptual only and its practicalities and cost have not been tested).

A new mid-block interchange would allow the Tawa interchange to be left untouched aside from the extension of its ramps, avoiding the large and complex current scheme design. The south facing ramps of the Tawa interchange would be extended to about 700m long, which is the same length as the south facing ramps of the Constellation Drive or Upper Harbour Highway interchanges in Auckland. South facing connectivity would not need to be provided at the P2G interchange, which would simplify it, if there was a connection to P2G from Grenada via Grenada Drive, as envisioned in the scheme design.

A P2G interchange would likely need to be located far enough north to avoid the landfill shown in Figure 16, as the variable and unstable landfill 'ground' would pose multiple challenges from construction, engineering, settlement and contaminant perspectives. Cursory consideration suggests that a more northerly alignment might be possible, but further investigation would be required to properly assess its viability.

[6] A network operational solution might also be considered (eg, ramp metering to manage the weave, as with Kyber Pass and Gilles Ave interchanges in Auckland).

Figure 17 Conceptual layout of possible braided ramps at Tawa and a new P2G interchange



11.4 Environmental impacts: the Korokoro valley vs. the Petone cut

In any form P2G would have significant impacts on the environment and local communities. The project team has rightly taken these impacts seriously and has tried to manage or mitigate them. However, it is appropriate now to ask how successful this has been and to reconsider alternatives.

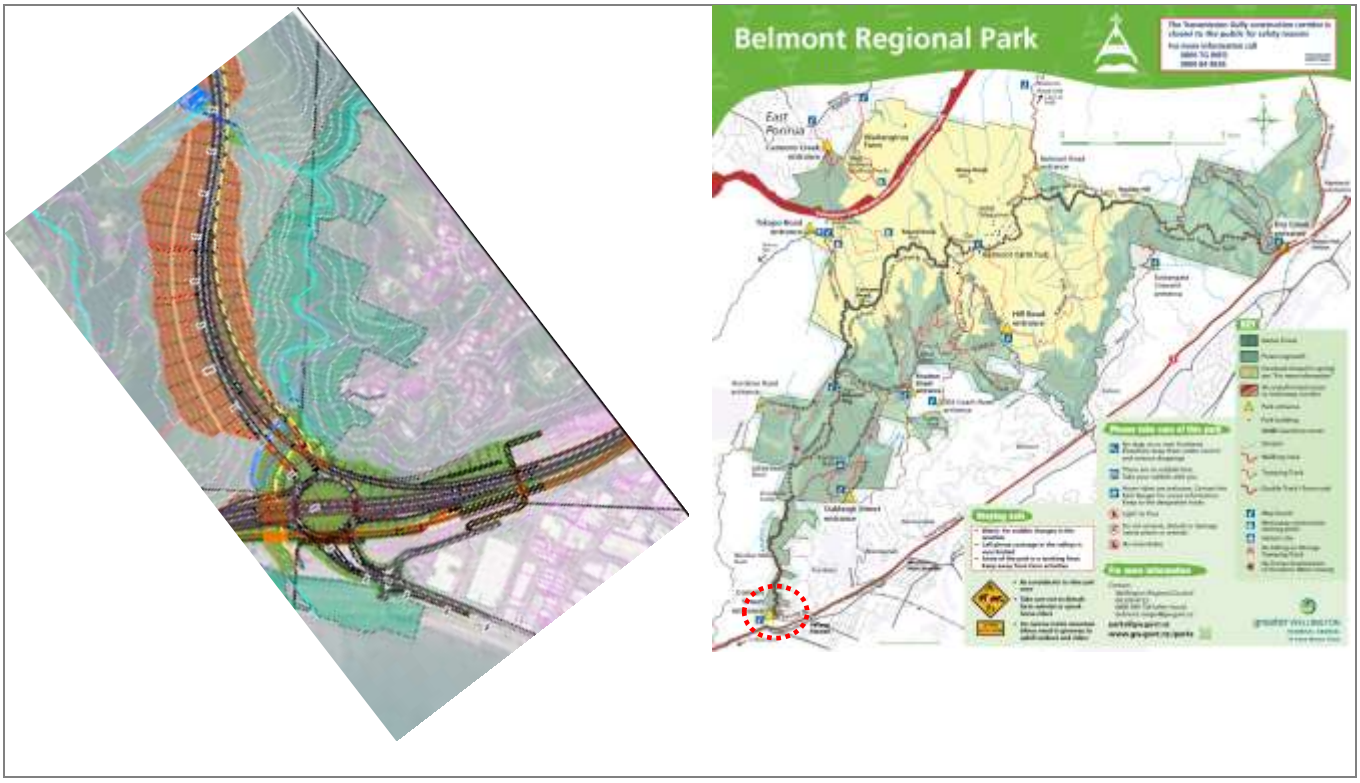
Given the topography it is not surprising that every P2G study from 1995 to 2014 initially proposed an alignment that followed and worked with the landscape rather than cutting through it. Most of the Wellington roading network in hilly terrain has developed in this way, sinuously flowing around the landscape. Both the 1991 and 1995 Grenada Link Road concepts were in the Korokoro valley.

From an engineering perspective the natural alignment from Petone is to follow the Korokoro valley, rising with it toward the escarpment summit and making cuts only where necessary to climb out of the valley. Coming out of the 2014 Scoping Report, MC00 (precursor to MC01) was selected from four alignment options, two of which went up the Korokoro valley. These two alignments, shown in Figure 18, were assessed as being significantly more resilient, having far less earthworks and providing flatter approach gradients to Petone. The proposed scheme alignment through the regional park is shown in Figure 19 along with the BRP map for context.

Figure 18 Alignment options in the Korokoro valley, from 2014 Scoping Report

Notes: These are alignment options P2 (left) and P3 which were discarded at the 2015 MCA. Belmont Regional Park is outlined in orange. Both alignments would turn up the first tributary valley (in box cut), after approximately 400m.

Figure 19 MC01 alignment from Petone and map of the Belmont Regional Park for context



Notes: MC01 is in a very large cut through the western side of the lower Korokoro valley, but encroaches less into the Belmont Regional Park. The affected area of the park is ringed in red.

The problem is that the valley is part of the Belmont Regional Park and contains native flora and fauna and (in its higher reaches) historical sites. It has environmental and cultural value to the community. Various P2G studies therefore concluded that the Korokoro was not viable from an environmental perspective and charted a different alignment.

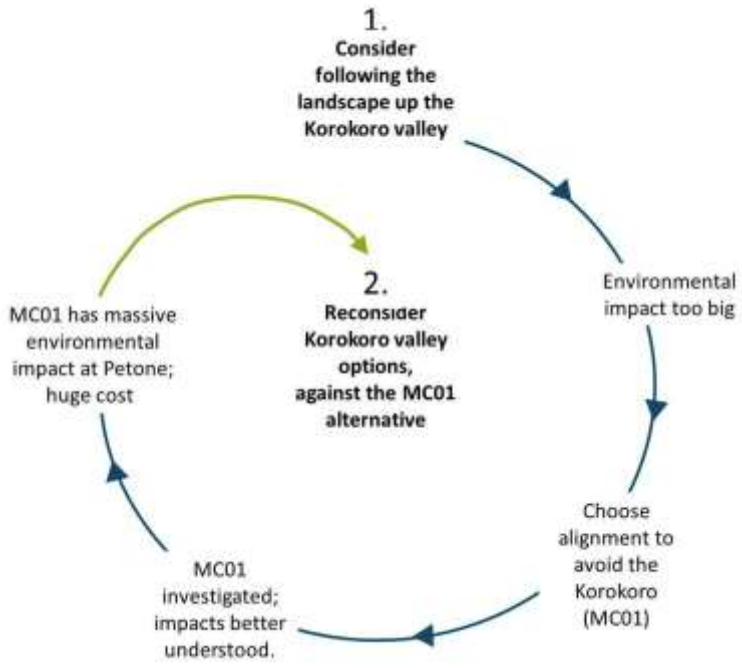
The proposed scheme would leave a large scar in the Petone landscape (Figure 6). The irony is that in trying to avoid an environmental (ecological) impact on the Korokoro the scheme would create a lasting environmental (visual) impact on the Hutt valley and Wellington harbour. The earthworks scale

is also expected to present dust and erosion and sediment control challenges during construction, which are likely to impact consent conditions. There is further irony in the urban design focus of the 2016 MCA (focused on the Lincolnshire Farms end), given how considerable the visual and urban design impacts necessarily are from the scheme's Petone interchange.

These ironies bring us full-circle (Figure 20). It was right to consider alternatives to impacting the Korokoro valley. Now that we have done this and have fuller knowledge of what form that alternative would have to take, what it would cost, what it would look like and its resilience performance, it is appropriate to come back to the Korokoro and reassess the options there.

We should ask whether an alternative would be possible in the Korokoro that could avoid the problems with MC01 while being acceptable from an environmental perspective.

Figure 20 Coming full-circle with environmental impacts at Korokoro and Petone



The valley is shown in the artist's impression in Figure 10 and its location in the regional park is shown in Figure 3 and Figure 19. There is a tributary valley approximately 400m in and another tributary a similar distance on from this.

The evaluation team visited the Korokoro valley as part of its site visit. Access to the valley and the regional park is currently not pleasant, being from a small car park in a cluster of light industrial buildings and along a poorly maintained track. Although part of the regional park, the valley has been heavily modified over the years, as shown in Figure 21 below. This includes an existing one lane, partly paved access road that runs up the valley and fords the stream in places. The stream has a steel framed stop-fence built across it to protect the downstream culvert during flood and there is man-made material (concrete and steel) strewn around.

The valley opens at the southern end from a relatively narrow mouth, which affords it visual seclusion not available to the Petone cut. Beyond this the valley is relatively wide. There are no houses on the western side (where MC01 would partially cut) and few on the east.

Figure 21 Korokoro valley looking north showing existing access road and other modification

As an alternative to the cut and fill embankment methodologies of the 2014 Scoping Report options (P2 and P3), a viaduct could be considered for the valley section. This would disturb the environment less, requiring construction works only at the pier footings (using the existing unsealed road for construction access). Viaduct construction in sensitive ecological locations elsewhere in New Zealand has demonstrated how effective this approach can be.

The 2015 MCA landscape effects peer review suggested that, although there would be significant negative effects from an alignment in the valley, there is potential to obscure it within the landscape (through a combination of embankment location and design and using planting) and to directly mitigate the effects by reinstating the valley entrance at Petone. The 2015 MCA did not take account of mitigation in this sense. In conversation with the evaluation team, the peer reviewer has indicated that, had a more holistic mitigation strategy been available as part of the MCA analysis, the landscape effects assessment may have favoured the valley alignment.

The evaluation team has conducted a very preliminary assessment of the viability of a valley option from a gradient perspective and found that the gradient could be reduced substantially for the approach to Petone. However, if the road turned up the first tributary it would be in box cut and this may still be deep. Combinations of increased gradient in the cut or on the approach could be tested.

It may be that geometrically and for resilience it would be better to go up the second tributary. However, this would bring with it further potential disturbance to the valley, including potentially greater disturbance to cultural and heritage sites.

From a consenting perspective the second tributary option is considered more difficult. Depending on design, the Korokoro valley option would likely result in moderate and potentially significant adverse

effects. Potential mitigation and off-setting of significant adverse effects would need to be an integral component of the assessment.

Having said this, there may be greater scope to mitigate or off-set some of the effects in the valley compared to the significant landscape and visual effects associated with the Petone cut, and the landscape, visual and urban design effects associated with the considerable scale of the proposed scheme's Petone interchange.

From a resilience perspective, an option that sidles the northern side of the valley (2014 option P3) offers the best performance among the cut-fill embankment options (compared to option P2, which was on the southern side). However, an alignment that went up the first tributary would need to manage risk from a possible block slide there. P3, which would have a shallower cutting, is again preferred as it is more resilient in this sense than P2.

12. ALTERNATIVE FOR FURTHER INVESTIGATION: OPTION B

It is beyond the scope of this evaluation to assess alternatives in depth. However, it is appropriate that the evaluation highlight alternatives that may be worthy of further investigation as a next step. The main alternative, Option B, is enabled by the following changes to the project philosophy:

1. Restate the project objectives to be clear that resilience is a requirement: a P2G road that is not resilient is not a success.
2. Agree on an acceptable outage status for P2G in a 7.5M event. What is the longest tolerable road closure after such an event?
3. Consider using probabilistic analysis to assess geotechnical risk, rather than relying on deterministic assessment;
4. Remove the requirement for expressway standard and relax the geometric requirements; allow tighter curves that follow the landscape by allowing lower design and operational speed (eg, 60kph). This will enable smaller cuttings and allow the form of the Petone interchange to change, reducing cost and improving resilience.
5. Take a whole-of-system view and reshape the project as a freight, public transport and high-occupancy vehicle corridor. Use active demand management, including differential tolling to encourage efficient travel choices along with improved public transport options. This allows a smaller road footprint, reduces cost, and is better attuned to desires of local Councils. Aim to move customers and freight, not steel.
6. Reduce carriageway width by removing the third lanes, providing shoulder running for very slow trucks and consider enforcing left-lane only for freight vehicles.
7. Revisit the Korokoro valley alignments but as well as cut and fill embankments investigate a viaduct design to minimise the environmental footprint. Auckland's Northern Gateway (ALPURT B2) provides examples of viaduct construction that were able to tread very lightly on an ecologically sensitive landscape (Otanerua EcoViaduct, Nukumea viaduct, Waiwera viaduct).
8. A Korokoro valley alignment may allow the gradient to be reduced, and the extent and viability of this opportunity should be investigated. The avoided cost of the Petone cut and the saved cost on the Petone interchange and Dowse widening should be assessed and compared with the cost of the viaduct option.
9. Build on the environmental mitigation package developed by the project team (beach to bush) by further restoring the Korokoro stream (currently in culvert covered by light industrial buildings) and providing the community with a gateway to the Belmont Regional Park. Restore the heavily modified Korokoro valley and improve recreational walking and cycling tracks. Explore other mitigation opportunities in the BRP, such as diversification planting in scrublands.
10. Engage with Greater Wellington Regional Council on options to redevelop the Petone rail station into a public transport interchange connecting Hutt to Wellington rail with the intersecting Porirua to Hutt bus lines on P2G. Engage Councils on how P2G can integrate with local feeder public transport services. Recognise that public transport forms part of the solution to P2G (it enables avoided capex spend) and support it as a system-level intervention.
11. Continue engagement with Wellington City Council and Lincolnshire Farms to agree alteration to the structure plan to accommodate an optimised P2G, noting that the development cannot proceed in absence of P2G. Potentially consider whether a more sympathetic integration is possible if the road is no longer expressway. Consider options for public transport connections and improved direct walking and cycling connections.
12. Ensure coordination among Transport Agency projects and with local road and other Council projects. (eg, Petone Esplanade and foreshore vision, cross valley link, Melling interchange, SH2 cycleway projects).
13. If necessary for safety and to protect the asset, gazette P2G as limited access (even if it is not expressway).
14. Consider making Horokiwi interchange an at grade intersection (enabled by relaxation of the expressway requirement).

15. Reconsider the need for walking and cycling on both sides of the carriageway, depending on how much the gradient can be flattened through changes to the alignment.
16. Reconsider the Tawa interchange, investigating the design impact of reducing the carriageway from six to four lanes.
17. More fundamentally, reconsider whether the Grenada interchange could accommodate the P2G connection (enabled by the move away from expressway standard) or if a new mid-block interchange with braided ramps could be accommodated between Tawa and Grenada. Both would avoid around 800m of new road parallel to existing SH1 and complete reconstruction of Tawa interchange.
18. Include, within a total system view, consideration of how the network is managed. Consider a network management solution as well as or in place of a capital investment solution (further building on the potential of public transport to result in avoided capex).
19. The project economics will need to be updated to reflect changes to the project (particularly the travel time benefits). The non-conventional benefits should also be reviewed at a holistic level to ensure they fit within a broad strategic narrative.

12.1 Other options outside of the scope of this evaluation

Beyond the P2G area considered in this evaluation the obvious other options that might be considered are:

- Enhancing the Ngauranga to Petone corridor with greater capacity (widening) and improved resilience
- Upgrading (four laning) SH58 to provide for east-west movements
- A combination of both of the above.

These options have been considered in previous studies, most notably the Ngauranga Triangle Strategic Study and the Petone to Grenada, SH58 Scoping/PFR Report (2013). These studies have concluded that P2G was both the most economic option and strategically preferred as providing the better connectivity between the western corridor and the Hutt valley.

From an economics perspective, the SH58 option is likely to have lower non-traditional economic benefits than the P2G route, due to its greater length.

However, the above study was predicated on previous estimates of cost. That the estimates for P2G are no longer valid suggests that the comparisons against these other options might be revisited. Naturally, the uncertainty in the P2G cost applies to these other options also, and it may be that on closer re-examination the costs of the other options are found to be higher also.