

PART E: CONSIDERATION OF ALTERNATIVES

9. Assessment of alternatives

Overview

A consideration of alternatives is required in two contexts for the Project; in relation to the NoRs and in relation to some aspects of the activities for which resource consent is sought.

An extensive option evaluation exercise was undertaken during the scheme assessment phase and this resulted in some fundamental alignment decisions that provide environmental (particularly ecological) benefits over the existing designated alignment. In particular, through the Te Puka and Horokiri valleys and Battle Hill, the road alignment was shifted to the west to reduce the impact on streams and terrestrial habitat. During the scheme assessment, the location of the interchange to connect to eastern Porirua (via the Porirua Link Roads) was also moved to enable an additional local road connection from Whitby (rather than just from Waitangirua).

During the more recent E&EA phase, further design refinements have been made. Relatively minor alignment changes have resulted in avoiding the loss of some features, such as a significant area of native bush through the Wainui Saddle and a heritage feature at the bottom of the Te Puka valley.

9.1 Introduction

This chapter provides a summary of the key aspects of alternatives considered in the development of the Project.

Section 9.3 outlines the design and option evaluation process undertaken through phases 1 and 2 of the Project. Phase 1 involved the consideration of key road alignment alternatives, while Phase 2 involved the refinement of this alignment to arrive at the preferred alignment identified (i.e. the road alignment for which designations and resource consents are being sought).

Although this chapter provides a summary of alternatives considered, a number of the topic chapters in Part G also discuss particular options and alternatives in relation to environmental effects.

9.2 Scope and purpose of assessment

As stated in Chapter 3, a consideration of alternatives is required for two reasons:

- Firstly, in relation to the NoRs, particular regard must be had to whether there has been adequate consideration of alternative sites, routes and methods of undertaking the work; and

- Secondly, the Fourth Schedule requires possible alternative locations or methods for undertaking the activity to be described where it is likely that an activity will result in any significant adverse effect on the environment.

With respect to section 171(1)(b), neither the NZTA nor PCC have an interest in all of the land needed for their respective projects. As of July 2011, the Crown owns approximately 49% of the land required for the NZTA Project and PCC owns approximately 0.6% of the land required for the PCC Project. As such, a consideration of alternative sites, route and methods must be undertaken.

The alternatives to be considered by the NZTA are those that are within its powers (i.e. the purpose for which it is approved as a requiring authority) and will assist in undertaking 'the work' (as stated in the NZTA's objectives for its project). The alternatives to be considered by the PCC are those that are within its powers (under the Local Government Acts) and will assist it to undertake 'the work' (as stated in the PCC's objectives for its project).

In respect of the resource consents, Schedule 4 to the RMA requires alternative locations or methods of undertaking an activity to be described where it is likely that an activity will result in any significant adverse effects. Section 105 also requires decision makers considering applications for discharge permits to have regard to "*any possible alternative methods of discharge, including discharge into any other receiving environment*". These resource consent alternatives are constrained by the project for which designations are sought. That is, it is not appropriate to consider alternatives that will not enable the work for which a designation is sought to be undertaken. For example, it would not be appropriate to describe alternative locations for undertaking diversion activities if the NZTA could not also notify a requirement for a designation to authorise other aspects of the project in that alternative location. In this sense, the alternatives to be considered in relation to both the designations and resource consents must align.

9.2.1 NZTA Project

The NZTA has been approved as a requiring authority:

*"for its particular network utility operation being the construction and operation (including the maintenance, improvement, enhancement, expansion, realignment and alteration) of any State highway or motorway, pursuant to the [Transit New Zealand Act 1989]."*⁷³

73. Resource Management (Approval of Transit New Zealand as Requiring Authority) Notice 1994, notified in the Gazette on 3 March 1994. Under clause 29 of Schedule 2 of the Land Transport Management Amendment Act 2008, the NZTA replaced Transit New Zealand as the requiring authority approved under this Gazette Notice. Under section 47(1)(c) of the Land Transport Management Amendment Act 2008, from 1 July 2008 the Transit New Zealand Act 1989 is to be called the Government Roadway Powers Act 1989.

As such, the following options are not alternatives to be considered in relation to the NZTA Project:

- an upgrade of existing SH1 between Linden and MacKays Crossing (as this would not achieve one of the NZTA Project's objectives which is to provide an alternative strategic link for Wellington); or
- improvements in public transport between Wellington City and the Kapiti Coast (as the provision of public transport is not within the scope of NZTA's requiring authority approval). As discussed in Chapter 2, the Project itself is part of the Western Corridor Plan which involves a package of transport measures along the Western Corridor, including substantial improvement to public transport along this corridor.

9.2.2 PCC Project

PCC (as a local authority) is a requiring authority under section 166 of the RMA. PCC is constrained in its consideration of alternatives by its functions and powers under the LGA. This includes having particular regard to the contribution that network infrastructure (which includes roads) makes to its community⁷⁴.

PCC's objectives for the PCC Project are focused on maximising the benefits of the NZTA Project to the Porirua community.

9.3 Option evaluation and design process (Phases 1 and 2)

As discussed in Chapter 2, following the Western Corridor Study and the inclusion of an Inland Route for SH1 between Linden and MacKays Crossing in the WCP and the RLTS by GWRC, the NZTA (then Transit NZ) commenced investigations for a State highway within the Inland Corridor. This has involved two stages of investigation:

- scheme assessment (Phase 1); and
- engineering and environmental assessment (E&EA) (Phase 2).

The scheme assessment was focused on fundamental road alignment options, while the E&EA phase involved refinements to the design based on environmental and engineering considerations.

Two key terms are used throughout this chapter in relation to various alignment options considered:

- 'In-Designation Alignment' refers to a road alignment contained within the existing designations⁷⁵; and
- 'Unconstrained Alignment' refers to a road alignment unconstrained by the existing designations.

74. Sections 11A and 197 of the LGA.

75. The In-Designation Alignment consists of the following designations: D0103 in the KCDP; TNZ4 in the UHCP; K0405 and K0406 [Kenepuru Link Road] in the PCDP; and H5 in the WCDP.

The In-Designation Alignment effectively formed the starting point at the beginning of the Phase 1 investigations. It also provides a useful reference point, indicating where key design changes have been made along the route.

The process and key decisions made in identifying the Preferred Alignment are set out. This covers:

- key alignment decisions made during the scheme assessment (Phase 1); and
- minor refinements to the alignment made during the preliminary design (Phase 2).

The options evaluation and design process is shown generally in Figure 9.1.

The aim of the scheme assessment phase was to identify the preferred road alignments within the Inland Corridor. It was decided early on that in order to identify the best possible alignment, alignment options should not be limited by the existing designations.

Identification of the optimal design involved a process of option development, evaluation and refinement. This process involved experienced road and bridge designers who worked in conjunction with traffic engineers, planning, environmental and geotechnical specialists to identify options, which were subsequently assessed in workshops attended by experts in relevant fields. Workable options were then carried forward and developed as the amount and level of information has increased.

For the option alignment process, the Main Alignment corridor was divided into nine sections, as previously set out⁷⁶. Section divisions were determined largely on the basis of “pinch points” (e.g. at Wainui Saddle), changes in topography and where connections with the existing road network are proposed. Sections were selected such that any alignment option identified in one section could be connected to any other option in the neighbouring section.

Option identification workshops

Option identification involved a series of workshops attended by experts from the Project team, and representing a range of disciplines. These disciplines included road design, bridge design, planning, environment, landscape, traffic engineering, geotechnical, and cost estimating. All participants attended a pre-workshop drive-over of the Inland Corridor.

Alignment options were devised for each of the nine route sections in turn. The workshops identified potential options that appeared to offer benefits over the In-Designation Alignment. Initially, the team sketched possible options on contoured plans. The options considered to have merit were then modelled using MX Roads to superimpose earthworks designs on aerial photographs.

Each identified option was recorded in a register, and given a unique identifier and a description. The status of each option was also recorded, i.e. options failing to meet the Project objectives were given a closed status, options perceived as having merit were assigned a Tier 1 status, while inferior options were rated as Tier 2.

76. For the road alignment evaluation during the scheme assessment phase, the Kenepuru Link Road was included as part of Section 9 (Linden).

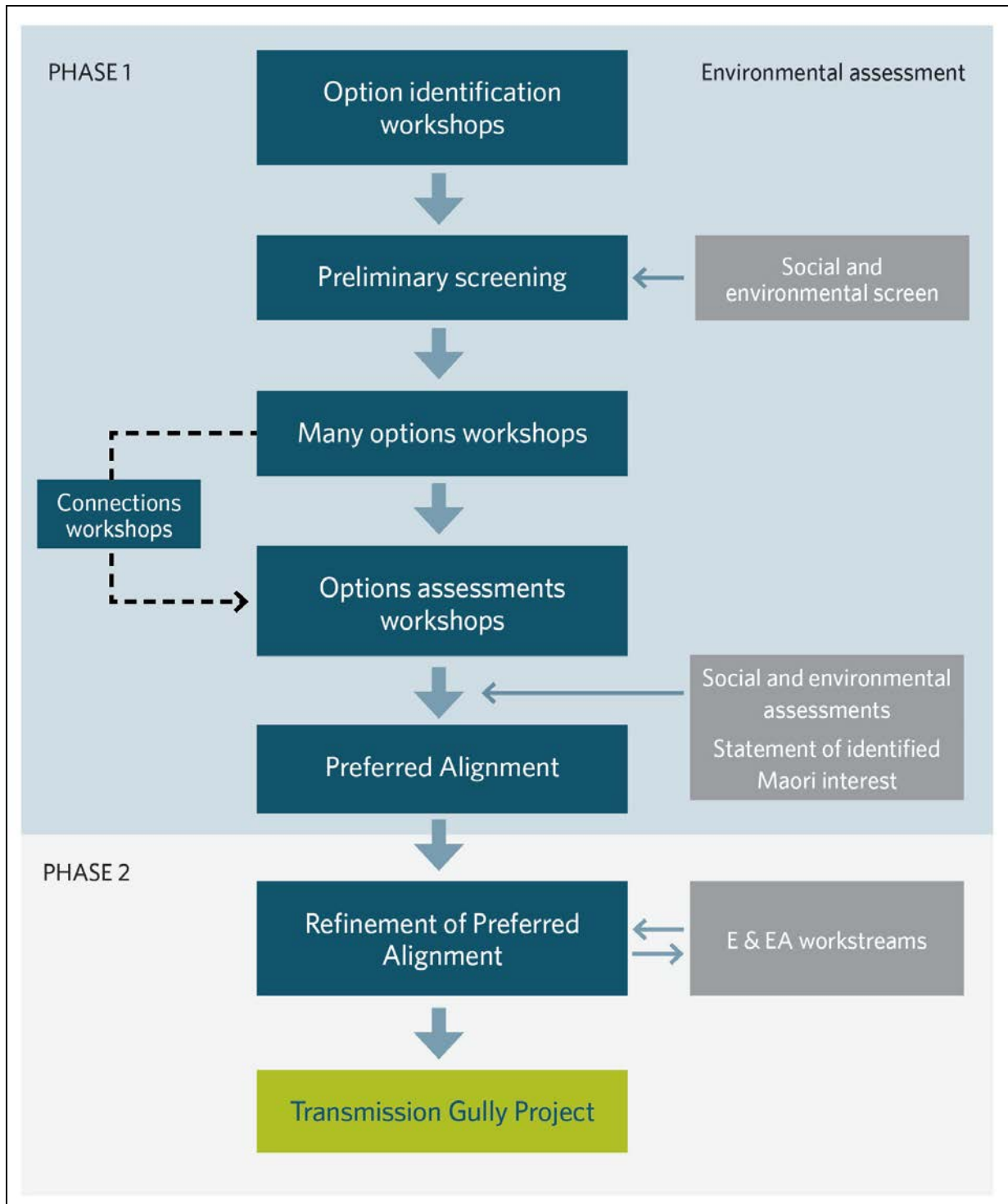


Figure 9.1: Road alignment evaluation process

Preliminary screening

Preliminary screening of alignment options was carried out in a number of workshops attended by experts from the Project team. The preliminary screening process helped to identify any non-viable options, and to provide an initial understanding of the opportunities and constraints of the various design alternatives.

Each option was initially tested against two aspects:

- Does the option contribute to the Project objectives?
- Does the alternative have any fatal flaws?

This step considered the feasibility of gaining consents for an option, and whether it could be constructed within known financial, geotechnical, ecological, cultural, and legal constraints. It was assumed there were no fatal flaws where none were known.

Every option that passed these two tests was then evaluated within respect to the criteria listed in Table 9.1.

Table 9.1: Evaluation criteria for the preliminary screening

Objective	Description
Network security	The extent to which the alternative is expected to be limited in traffic capacity due to a partial or full road closure, for example as a result of a slip during a storm event.
Safety	The likely crash rate for the alternative
Capacity	The level of service provided by the alternative, i.e. congestion related effects.
User benefits	Predicted variation in tangible benefits in EEM terms, i.e. travel time and vehicle operating cost effects.
Property effects	Predicted variation in property severance and property acquisition.
Cost	Predicted cost differential including risk for the alternative
Freight movement	The likely variation in the use of the route by heavy commercial vehicles.
Coastal route	The split in traffic between inland and the coastal routes.
Environmental / social	The likely environmental and social impact of the alternative. This includes but is not limited to ecological, stormwater, noise, visual landscape, urban design, community accessibility, social severance, and cultural or heritage issues.
Adjacent effects	Predicted benefit or disbenefit the alternative will have on neighbouring areas.

Options within each section were ranked according to their potential benefits. This allowed those options with the greatest potential to be investigated first.

In total, the initial option identification and screening process identified 34 different viable options in the 9 Project sections. This number excludes variations in forms of intersections which were considered at a subsequent connections workshop.

Many options workshop

A 'Many options workshop' was held in October 2007⁷⁷. Its primary purpose was to corroborate the outcomes of the option identification and preliminary screening processes. The objective was not to decide which options to take forward, or discard, but to identify the information required to enable robust decisions to be made on these issues during subsequent phases of the Project. Workshop participants were asked to:

- agree on the preliminary screening of each option;
- agree the ranking of the options within each section; and
- identify work required for each option.

Alignments were ranked by workshop participants in order of greatest merit.

Connections workshop

Identifying where and how the Main Alignment and the Kenepuru Link Road should connect with the existing road network formed the next stage of the options identification and development process. A connections workshop was held on 24 October 2007 to review these issues. A wide range of options had been identified prior to the workshop, including such details as interchange form and initial cost estimates. Traffic assessments had also been prepared for connections at the following locations:

- SH1 at MacKays Crossing and Paekakariki;
- SH58 at Pauatahanui;
- James Cook Drive and/or Waitangirua;
- Warspite Avenue;
- Kenepuru Drive; and
- SH1 at Linden.

At the workshop the range of intersection arrangements for each connection were considered. Workshop participants were provided with relative costs and an initial assessment of traffic benefits for each concept.

77. This workshop was attended by NZTA staff and consultants from a variety of engineering and environmental disciplines.

Options assessment workshop

An options assessment workshop was held in March 2008⁷⁸. The purpose of the workshop was to identify and agree on two optimal alignment options from MacKays Crossing to Linden, based on the data developed by the Project team.

The workshop process involved splitting attendees into groups, with each group assigned specific sections of the Project to assess. Groups selected their favoured 'In-Designation' route option, and their preferred option unconstrained by the designation, for each section.

Each of the options was assessed with respect to five key criteria:

- cost;
- network flexibility;
- physical environmental impacts;
- social environmental impacts, and
- timeliness.

Each group then presented their options to the larger workshop for final discussion and agreement. Having selected route options within each section, it was a relatively simple matter to arrive at the "In-Designation Alignment" and the "Un-constrained Alignment" by combining the preferred options for each section.

At the end of Phase 1, the Preferred (Un-constrained) Alignment was taken forward to Phase 2.

9.4 Summary of key options selected during Phase 1

This section describes some of the key alignment decisions made during Phase 1. Although the evaluation of alignment options was not constrained by the existing designation, the existing designation does still provide a useful reference in areas where fundamental changes to the road alignment were made. The alignment options selected in the following key areas are described:

- at MacKays Crossing;
- the Te Puka Stream valley;
- the Horokiri Stream valley;
- through Battle Hill; and
- potential interchange locations for local road connections to eastern Porirua.

78. This workshop ran for three days and was attended by staff from the Transit NZ, Land Transport NZ, GWRC, KCDC, UHCC, HCC, PCC, WCC and selected consultants from a variety of engineering and environmental disciplines.

9.4.1 MacKays Crossing

There were a number of issues considered for alignment options for the northern tie-in at MacKays Crossing. These included:

- potential effects on the nearby wetlands;
- potential effects on adjacent properties ;
- the landslip area and the Ohariu fault, to the east of existing SH1;
- electricity transmission lines and a local electricity substation;
- connections to existing SH1; and
- using as much as possible of the recently upgraded MacKays Crossing Interchange.

Quite a different tie-in option to the designated Alignment was selected to avoid impacts on the wetland and avoid the hazard posed by the landslip area and fault line. The alignment provides a good connection (in terms of road geometry) to the existing MacKays Crossing Interchange.

9.4.2 Te Puka Stream valley

The In-Designation Alignment ran down the eastern side of the Te Puka Stream valley. The alignment was shifted to the western side of the valley for a number of reasons including:

- The previously designated route generally followed the Ohariu Fault at the northern end and crossed the Ohariu Fault twice, on structures, and had considerable lengths of viaducts down the eastern, forested flanks of the Te Puka stream.
- Allowing lower cut heights than the alternative earthworks options previously considered.
- By following the flatter western slopes the risk of landslide debris material coming down over the State highway is reduced.
- With fewer structures the risk of debris build-up and scour damage as a result of a major rainfall event was reduced.
- The adverse ecological effects on the indigenous forest can be largely avoided.
- It allows a series of escape ramps and an arrestor bed to be constructed on the long, steep descent from Wainui Saddle to Paekakariki, providing the ability for an out-of-control vehicle to stop safely.

Technical Report 3 provides further details about the consideration of geotechnical factors in the design of the Project through Te Puka Stream valley.

9.4.3 Horokiri Stream valley

South of the Wainui Saddle, down the Horokiri Stream valley the Designated Alignment ran down the eastern side of the Te Puka Stream valley. The alignment was shifted to the western side of the valley to minimise degree of stream modification required and provide for greater use of bridges (as opposed to culverts) for a number of stream crossings, which has ecological benefits.

9.4.4 Battle Hill

The In-Designation Alignment is elevated approximately 20m above the Horokiri Valley floor through the Battle Hill Farm Forest Park and would have involved removal of vegetation on the eastern flanks. The alignment was shifted to the west onto the valley floor for a number of reasons including:

- The existing designation cuts across the ends of a number of ridges, and relatively steep sided greywacke slopes, and across the eastern tributaries of the Horokiri.
- The large cut faces needed to construct the highway as currently designated would be visible from a much greater area of the park including the main buildings associated with the Park, and from the Paekakariki hill road.
- Significantly less risk of sediment entering the Horokiri stream as a result of construction activities.
- Increased space available to implement erosion and sediment control measures.
- Reduced direct noise effects.
- Construction would be considerably simpler with fewer structures and less earthworks reducing the cost and time to construct this section.

Of these, the ecological and environmental improved outcomes were seen as the most significant advantage of moving the alignment.

9.4.5 Connections into eastern Porirua

The In-Designation Alignment included two interchanges, the Warspite Interchange which would have provided for a local road connection to Waitangirua, and a separate connection into James Cook Drive.

Based on the evaluation at the connections workshop it was considered that combining the two interchanges, and providing a new interchange at its current proposed location (north of the original James Cook Drive connection) would allow improved access to both Waitangirua (the Waitangirua Link Road) and Whitby (the Whitby Link Road). This change had the combined advantages of completely eliminating a proposed interchange from within Belmont Regional Park, and better aligning with the desire for travel from eastern Porirua (Whitby / Waitangirua to Wellington / the Hutt Valley etc.).

This proposed interchange is referred to as the James Cook Interchange.

9.5 Summary of key options selected during Phase 2

The option evaluation and design process for Phase 2 focused on refinement and optimisation of the Preferred Alignment identified through the scheme assessment. Any changes to the road alignment were much more minor than had been undertaken during Phase 1. Design changes in Phase 2 were more focused on:

- minimisation of earthworks;
- stream crossings;

- treatment of fill and cut slopes, including the form of retaining walls; and
- interchange and road connections;

The Phase 2 design and option evaluation process involved a high degree of collaborative design between the various engineering and environmental assessment teams. As discussed further in Chapter 12, an important aspect of Phase 2 was the close integration of the environment assessment work with the design process. In many cases this has resulted in potential adverse effects being reduced or completely avoided by making changes to the design. Avoidance of potential adverse effects is always preferable to remedying, mitigating or offsetting adverse effects.

The iterative and dynamic nature of this process means it is impossible to completely document all outcomes from this process entirely in this AEE report. However, where key design changes were made based on their likely environmental effects, these changes are described in this chapter and/or within the relevant topic assessment chapters in Part G.

9.5.1 Addressing issues raised during consultation

Phase 1 investigations (draft scheme assessment) for the Project were completed in mid 2008. Immediately following the Phase 1 investigations, a public consultation process was undertaken to gauge public views on the preferred alignment for the Project that had been identified during Phase 1.

The consultation process confirmed broad support for the Preferred Alignment and also identified a number of specific items that warranted further investigation during Phase 2, namely:

- pull off and vehicle inspection areas;
- property impacts at Paekakariki;
- parks and reserves / farming operations;
- bulk water mains;
- access to existing properties at SH58;
- the Whitby and Waitangirua Link roads; and
- the Kenepuru link Road.

9.5.1.1 Pull off and vehicle inspection areas

A number of consultation respondents identified the need for additional shoulder width at a few locations to allow drivers of heavy vehicles to safely pull off the carriageway and inspect their vehicles or check loads.

Discussions between the Project team and the NZ Road Transport Association identified that the main area where brake check / vehicle inspection areas would be desirable is adjacent to the Wainui Saddle, to allow heavy vehicle drivers to check their brakes and/or loads before descending (or after ascending) the 3km long 8% gradient between Wainui Saddle and Paekakariki.

Brake check / vehicle inspection areas have now been provided in both directions south of the Wainui Saddle (at approximately 5,500m). Brake check areas are not considered necessary at any other locations because the interchanges at SH58, James Cook and Kenepuru will provide regularly spaced opportunities for heavy vehicles to leave the Main Alignment to stop if necessary.

9.5.1.2 Property impacts around Paekakariki

During the scheme assessment it was identified that the alignment would have a significant land take impact on two properties⁷⁹ at Paekakariki. Consultation feedback and further alignment investigation identified opportunities to revise and reduce land take. As a result, the alignment was shifted east by approximately 30m, reducing and avoiding effects on one property. The alternative alignment also ties in more effectively with the newly constructed MacKays Crossing. The change also reduces earthworks effects on the margins of the MacKays Crossing wetland (KCDC eco-site K106).

The design was altered to accommodate the extra width of an earth bund on the northbound verge. The bund provides an alternative form of side protection barrier to a concrete or steel barrier for vehicles travelling northbound down the Te Puka descent. This also improves the protection for KCDC's water infrastructure at the bottom of Te Puka valley.

9.5.1.3 Parks and reserves and farming operations

Both the existing designated route and the Preferred Alignment pass through a number of parks and reserves. Whilst the overall physical, environmental and social impact of the preferred alignment is less than the route within the existing designation, respondents have identified specific impacts which need to be considered in detail. At Battle Hill Farm Forest Park, the potential impact of the Preferred Alignment on the viability of the existing farming operation needed to be considered. Similarly at Belmont Regional Park further consideration needed to be given to access tracks, stock routes, fence lines and yards to ensure farming operations would still be viable.

The Project team and GWRC met to discuss the Battle Hill Farm Forest Park Management Plan and agreed an approach to ensure that the Project can be effectively integrated into the operational management of the Park. The agreed approach is to consider exchanging the land within the Battle Hill park that is required for the Project with areas of Crown owned land adjacent to Battle Hill which was purchased specifically for that purpose) to avoid adversely affecting the Park's farming operation.

9.5.1.4 Bulk water main

GWRC identified that the Preferred Alignment affects its ability to access the bulk water main for inspections and maintenance. The Project team met with GWRC and identified those areas directly affected by the Project and investigated potential options for realigning the water main, including providing a series of culverts and new access tracks to allow for future inspections and maintenance. Even though the potential options are only at concept stage, the Project team and the relevant GWRC

79. Property 4 (Pt Lot 4 DP 714) and Property 5 (Pt Lot 4 DP 4269).

officers agree that the concepts are workable and that this issue will be satisfactorily resolved as the Project progresses.

9.5.1.5 Access from SH58

Access to and from a number of existing properties via a private road / right of way off SH58 adjacent to the proposed SH58 Interchange was originally proposed to be directly onto the interchange roundabout, which was raised as a significant safety concern by the safety auditors. In discussion with the affected land owners, the need was identified for further design work to ensure that access to the properties could be provided safely.

The SH58 Interchange has been subtly re-designed to enable adjacent properties to have access (via their existing private road and the existing SH58 carriageway) onto the realigned SH58 carriageway east of the interchange roundabout, rather than directly onto it.

9.5.1.6 Porirua Link Roads

Discussions with land owners, tenants and with PCC identified opportunities to enhance the proposed design to provide better integration with the existing land boundaries as well as a more favourable solution for proposed developments in the area. A number of land owners, particularly at the western end of the Waitangirua Link Road, offered alternate solutions which needed further consideration.

As part of the urban design workshops and consultation on the Waitangirua Link Road, the proposed intersection with Warspite Avenue was changed from a roundabout to a signalised intersection to improve pedestrian safety at this intersection. This will be a busy intersection in the future, particularly with the recently redeveloped Waitangirua Mall close by.

Two alternative alignment options were investigated for the Whitby Link Road. One option was through the Silverwood property and the other was through Whitby Coastal Estates land. These alternatives were considered with regard to the alignment's proximity to and potential impacts on Duck Creek. The Whitby Coastal Estates option was selected as it avoids earthworks encroachment into the stream. It also reduces the cut volumes, and height of cuts in poor quality material.

9.5.1.7 Kenepuru Link Road

The scheme road safety audit highlighted a concern with the vertical alignment of this road. In particular, the safety auditors were concerned about the steep downhill grade on the approach to the intersection with Kenepuru Drive. The Project team have made significant changes to both the vertical and horizontal alignment of the link road to address the road safety auditors' concerns.

This has included taking the Kenepuru Link Road under existing SH1, rather than over the top of it, as originally intended.

9.5.2 Further Phase 2 design refinements

Throughout Phase 2, the Preferred Alignment was refined on the basis of further, more detailed environmental and engineering investigations. Many relatively minor alignment changes were made to the design but the most important changes are described, namely:

- though Battle Hill;
- though the Wainui Saddle;
- down the Te Puka valley; and
- avoiding a historic structure (a WWII brick fuel tank).

9.5.2.1 Battle Hill

While the decision to shift the road alignment from the eastern ridge to the lower Horokiri valley floor through Battle Hill was made during the scheme assessment phase, further refinements to integrate the road into the landscape in this area were investigated during the E&EA phase. This involved moving the alignment further west which had two main benefits:

- it followed the natural topography better and meant that Gas line ridge screened to road from the western side of BHFFP; and
- it moved the alignment further from Horokiri Stream which has ecological benefits.

9.5.2.2 Wainui Saddle

During the ecological assessment, an area to the east at the Saddle was identified as of high ecological value. As a result an alternative option was assessed that moved the alignment to the west by 10 metres to reduce impacts on the identified area of ecological value.

9.5.2.3 Te Puka valley

The Te Puka valley section of the Main Alignment is the most vulnerable to natural hazards, in particular earthquakes, and has the potential to reduce the security of the route.

The geotechnical assessment identified risks associated with retaining walls on steep slopes in Te Puka and the vulnerability of bridges directly adjacent to steep slopes due to earthquake induced landslides. The Project's lead geotechnical engineer (P. Brabhakaran) was part of the New Zealand Society for Earthquake Engineering (NZSEE) Learning from Earthquakes team which visited the earthquake damaged areas of China in November 2008⁸⁰. Extensive landslides, in somewhat similar steep terrain to the Te Puka Valley, were observed to have led to closures of many highways in Sichuan. As a result it was recommended to reconsider the options for the Main Alignment through the Te Puka valley.

80. This team observed damage to infrastructure, particularly transport links as a result of the Wenchuan Earthquake that devastated areas of the Sichuan Province of China on 12 May 2008.

Options assessed to address these issues included:

- 25m high vertical retaining walls;
- 45 degree reinforced soil embankments (RSE);
- 51 degree earth embankments;
- 63 degree stepped walls.

The options were discussed with the roading, structures, hydrology and ecology teams. It was agreed that the option of using RSE was the preferred option, because it gives a higher level of route security, and because the stream impacts can be mitigated by additional stream works, without overall additional costs to the Project (additional stream works costs would be more than offset by savings in costs due to elimination of the viaducts and vertical walls).

9.5.2.4 Brick fuel tank

The alignment was shifted east by approximately 20m at the base of the Te Puka Valley in order to avoid impacting on the historic brick blast retention structure. This structure was built by the NZ Public Works Department for the US Army during WWII for storage of fuel and has been recognised by the Historic Places Trust as a feature of significance. It is hoped that public access can be provided to this historic structure as part of the Project.