TRANSMISSION GULLY PROJECT
ASSESSMENT OF ENVIRONMENTAL EFFECTS

TECHNICAL REPORT No.1
ROAD DESIGN PHILOSOPHY

New Zealand Transport Agency and Porirua City Council

Transmission Gully Project

Assessment of Environmental Effects

Technical Report No.1

Road Design Philosophy

July 2011

Prepared by

Mark Edwards
Roading Design Manager

Reviewed by

Tony Coulman
Principal, Transportation Engineering & Design

Opus International Consultants Limited
Wellington Office
Level 9, Majestic Centre
100 Willis Street, PO Box 12-003
Wellington, New Zealand

Telephone: +64 4 471 7000
Facsimile: +64 4 471 1397

Date: July 2011
Reference: 5C1591.20

Status: Final

Contents

List of Tables

List of Figures

1 Introduction

1.1 Overview

The Transmission Gully Project (*the Project*) consists of three components:

- The Transmission Gully Main Alignment (the Main Alignment) involves the construction and operation of a State highway formed to expressway standard from Linden to MacKays Crossing. The NZ Transport Agency (NZTA) is responsible for the Main Alignment.
- The Kenepuru Link Road involves the construction and operation of a road connecting the Main Alignment to existing western Porirua road network. The NZTA is responsible for the Kenepuru Link Road.
- The Porirua Link Roads involves the construction and operation of two local roads connecting the Main Alignment to the existing eastern Porirua road network. Porirua City Council (PCC) is responsible for the Porirua Link Roads.

1.2 Transmission Gully Main Alignment

The Main Alignment will provide an inland State highway between Wellington (Linden) and the Kapiti Coast (MacKays Crossing). Once completed, the Main Alignment will become part of State Highway 1 (SH1). The existing section of SH1 between Linden and MacKays Crossing will likely become a local road.

The Main Alignment is part of the Wellington Northern Corridor (Wellington to Levin) road of national significance (RoNS). The Wellington Northern Corridor is one of the seven RoNS that were announced as part of the Government Policy Statement on Land Transport Funding (GPS) in May 2009. The focus of the RoNS is on improved route security, freight movement and tourism routes.

The Main Alignment will be approximately 27 kilometres in length and will involve land in four districts: Wellington City, Porirua City, Upper Hutt City, and Kapiti Coast District.

The key design features of the Main Alignment are:

- Four lanes (two lanes in each direction with continuous median barrier separation);
- Rigid access control;
- Grade separated interchanges;
- Minimum horizontal and vertical design speeds of 100 km/h and 110km/hr respectively; and
- Maximum gradient of 8%;

- Crawler lanes in some steep gradient sections to account for the significant speed differences between heavy and light vehicles.

1.3 Kenepuru Link Road

The Kenepuru Link Road will connect the Main Alignment to western Porirua. The Kenepuru Link Road will provide access from Kenepuru Drive to the Kenepuru Interchange. This road will be a State highway designed to following standards:

- Two lanes (one in each direction);
- Design speeds of 50 km/h;
- Maximum gradient of 10%; and
- Limited side access.

1.4 Porirua Link Roads

The Porirua Link Roads will connect the Main Alignment to the eastern Porirua suburbs of Whitby (Whitby Link Road) and Waitangirua (Waitangirua Link Road). The Porirua Link Roads will be local roads designed to the following standards:

- Two lanes (one in each direction);
- Design speeds of 50 km/h;
- Maximum gradient of 10%; and
- Some side access will be permitted.

1.5 Purpose and Scope of this Report

This Design Philosophy Statement (DPS) has been developed to guide and inform the design development of the Transmission Gully project. Key assumptions were recorded from the outset of the project, and updated progressively as the project evolved. The assumptions have been developed into the Design Philosophy Statement to ensure there was a common understanding amongst the design team and other specialists as to the scope and standards the Transmission Gully project was to achieve.

This DPS outlines the key design standards, philosophies, assumptions and guidelines that have been adopted to inform the development of the Transmission Gully project. These have been presented to, and considered by, Transit New Zealand's Scope and Standards Review Committee, which has subsequently been replaced by the NZ Transport Agency's 'Value Assurance Committee', to ensure that nationally-consistent standards have been applied.

2 Route Security

2.1 Context

The NZ Transport Agency (NZTA) has a responsibility to proactively manage natural hazard risks to its state highway network. The Civil Defence Emergency Management Act 2002 identifies roads as a key lifeline utility, and requires operators to demonstrate they have assessed network risks, and that they have taken proactive measures to ensure that the lifelines (roads) are able to function to the fullest extent possible after a natural hazard and other events.

It is generally recognised that Wellington City will be cut off from the rest of New Zealand following a large earthquake and perhaps a large storm event, as both the existing SH1 and SH2 routes and the North Island Main Trunk rail network are vulnerable to damage and likely to be closed for many weeks. A major concern is that this transport disruption would seriously impair Wellington's ability to recover after such an event. Given the potential for large landslides and fault ruptures to close existing roads, risk mitigation for large earthquakes and significant storm events is very difficult to achieve.

Development of the Transmission Gully route presents a unique opportunity to substantially improve security of the regional and national road network - one of the key objectives for the route. Porirua City Council and the Wellington Lifelines Group both made submissions highlighting the need for improved route security when the Western Corridor options were being considered, and requested that this to be considered as part of the northern access upgrade into Wellington.

2.2 Route Security Philosophy

The following route security philosophy is proposed for Transmission Gully:

- Design year is 2026 for future traffic predictions,
- The highway is open for full access with minimum structural damage following small hazard events with a short return period,
- The highway suffers limited repairable damage in moderate hazard events, with limited access, or the highway reopens after a short period of closure, say 12 hours to three days[*],
- The highway suffers major damage but does not collapse catastrophically following large, long return period events, and limited access can be restored within a reasonable period (say 3 days to 2 weeks[†])

[*] The emergency management sector operates on the premise that people should be self-reliant for 3 days after major events, and that help should be available after that.

[†] After 2 weeks, the recovery phase will be severely impacted upon by lack of access after the immediate response phase, following a major event.

Such an approach would provide a relatively high-degree of security for the State highway network between MacKays Crossing and Linden, including access to SH58.

2.3 Natural Hazards Affecting the Transmission Gully Corridor

The key natural hazards likely to affect the corridor are:

Earthquakes

- Fault rupture (Ohariu and/or Moonshine Faults),
- Ground shaking,
- Slope failures,
- Liquefaction.

Storms

- Slope failures,
- Debris flows,
- Flooding.

Non-natural hazards including road crashes, possibly involving hazardous materials, and road maintenance work could also result in short-duration disruption.

The effects on the highway can be classified using 'resilience states' that define the three principal dimensions resulting from a hazard event:

- Damage state,
- Availability state (degree of access) – e.g. single lane access/full closure,
- Outage (duration of impairment of access) – e.g. up to 12 hours / up to 3 days / many weeks.

2.3.1 Management of Major Natural Hazards

Damage from major natural hazards can be managed to achieve the defined level of route security through the selection of an appropriate route alignment, road form and design parameters.

While avoiding active faults would provide a higher level of route security, it is generally recognised by lifeline facilities that these are features that cannot be avoided as they extend over many kilometres and are part of a network (as opposed to buildings that can be sited to avoid active faults).

2.3.2 Earthquake Fault Rupture

The Transmission Gully route crosses two active faults:

- Ohariu Fault, which has an estimated recurrence interval of 2,200 years, and is likely to result in 3m to 5m horizontal movement and smaller vertical displacements during a major seismic event. There is an associated active splinter of the Ohariu Fault south of Wainui Saddle,

- Moonshine Fault, which has an estimated recurrence interval of greater than 11,000 years.

Ohariu Fault

The number of crossings of the active fault and associated splinter faults by the Transmission Gully alignment should be minimised. Where it is necessary to cross the faults, the order of preference for earthworks-type should be:

- Embankments, where access after a rupture event (and potential 3m to 5m horizontal movement) can be reinstated within days, or

- Cuttings with the understanding that fault-rupture would likely lead to large landslides at the fault, which would probably be costly and take a few weeks to reinstate.

Crossing the Ohariu Fault on a bridge or viaduct structure should be avoided wherever possible. The expected 3m to 5m fault displacements would cause extensive structural damage, necessitating costly reinstatement work. Repair using temporary Bailey bridging could take many weeks, with permanent repairs likely to require many months or even years to complete.

Crossing the Ohariu Fault with a tunnel should also be avoided. Fault-rupture would cause the collapse and/or misalignment of part or all of any such structure, resulting in a much higher potential for fatalities than on an open highway. Tunnel reinstatement would also be very costly, taking probably many months or years to complete.

It is preferable for the Transmission Gully route to cross the Ohariu Fault on an embankment, or in a cutting, which will provide an acceptable level of route security.

Moonshine Fault

This fault has a very long recurrence interval, and hence a very low probability of rupture. The location and width of the fault zone are poorly defined, as are the characteristics and form of the fault.

This fault was therefore considered to be of lesser importance to the selection process of the Transmission Gully route and the development of scheme designs. However, as with the Ohariu Fault, large structures should be avoided in the fault-zone wherever possible.

2.3.3 Earthquake-Induced Landslides

Moderate to large earthquakes lead to slope failures in steep to very steep slopes, including cuttings, which generally are steeper than the natural hillside slopes.

The strategy used was:

- To avoid high, steep, cut slopes that could generate large amounts of slope-failure materials and take many weeks to clear,
- Keep slope-angles moderate in Wellington Greywacke where slopes are more than 10m to 15m high, e.g. to approximately 45° or flatter,
- Avoid high, moderately-steep cuttings through fault-disturbed rock,
- Provide intermediate benches and berms at the foot of cuttings to trap rockfalls and small slips in small to moderate events, and
- Avoid high cuttings where possible, for example by using split level carriageways.

2.3.4 Earthquake Liquefaction

Site investigations to-date indicate that the risk of earthquake-induced ground liquefaction is generally low. However, there is an area north of Paekakariki where ground improvement may be required.

2.3.5 Earthquake Shaking

Appropriate seismic design will mitigate the effects of ground shaking. Structures will be designed to the Transit New Zealand Bridge Manual requirements. Other measures that may be adopted include:

- Retaining walls (free-standing) designed to allow limited displacement in large earthquakes, using a displacement-based design approach,
- Embankments designed to allow controlled displacement in large earthquakes, using a displacement-based design approach, and
- Cut slopes in soil, designed to allow displacement in large earthquakes.

The acceptance of limited displacement allows route security to be retained, particularly for emergency services access, following a major event. However, some pavement reinstatement may be required post-event.

2.3.6 Storm-Induced Landslides

The potential for storm-induced slope failures will be managed through:

- Flatter cut-slopes in overburden and completely weathered rock,
- Drainage,
- Benches and debris collection berms,
- Acceptance of small failures that can readily be reinstated.

2.3.7 Debris Flow in Storm Events

Significant debris flow hazards are present along the Transmission Gully route, as evidenced by the debris fan and alluvium deposits found in the Te Puka and Horokiri Stream valleys. However, given the rural nature of the area, the impact of these past events on the future road cannot readily be appreciated. The impact of debris flows on the existing North Island Main Trunk railway line and SH1 have therefore been utilised to better understand the potential impact on the proposed route of these debris flow events.

Debris inundations and debris flood gravel deposits have periodically affected the coastal route area. Rainfall-induced gully erosion, debris floods, and wash-outs have from 2003 to 2006 caused a succession of flooding problems in Te Puka Stream (at the northern section of the route), and to the North Island Main Trunk railway, Paekakariki Hill Road and SH1 north and south of Paekakariki settlement. Of particular note is the October 2003 event, when debris flood gravels at Paekakariki blocked SH1 and stopped trains.

There are potential debris-flow hazards in both the Te Puka and Horokiri catchments. Debris control systems, including debris channels, will be provided in these catchments. Where required, culvert structures will be sized to allow the passage of debris under the highway, and structures will be designed to allow ease of access to remove debris accumulation and carry out maintenance.

2.4 Route Security on Transmission Gully compared with the Coastal Route

Completion of the Transmission Gully project will improve route security for the Wellington region by providing an alternative, less vulnerable route north. The following table summarises differences in route security between Transmission Gully and the existing coastal route.

In addition to natural hazards, man-made hazards such as traffic accidents, spillages, and unplanned road maintenance can cause significant traffic disruption. While these types of hazards will occur on both the Transmission Gully route and the existing coastal route, the addition of an alternative route provides redundancy in the network that will significantly reduce traffic disruption. It is acknowledged that unplanned road closures hazards could occur on both routes simultaneously; however, this is likely to be very infrequent and connections between the two routes should allow through-flow for most scenarios.

Table 1.1 - Route Security Comparisons

Geological Hazard	Existing SH1 Coastal Route	Transmission Gully
Earthquakes and ground shaking	• Both routes exposed to similar levels of earthquake shaking. • High probability (>50%) of MM6 to MM8 shaking in the next 50 years, and significant probability of MM 9–10 shaking due to an earthquake on the Wellington Fault or another nearby active fault.	
Fault rupture	• Fault movement on Ohariu Fault could cause loss of or damage to the existing SH1 bridge at Paremata. • Possible damage to SH1 along the Porirua Motorway.	• Ohariu Fault crossed on earthworks (Unconstrained Alignment). Minor delays possible for reinstatement. • Moonshine Fault crossed on earthworks. Minor delays possible for reinstatement.
Earthquakes-induced landslides	• Very high, steep slope from Pukerua Bay to Paekakariki has long history of instability. • Earthquake-induced landslide susceptibility rated high to very high. • Large failure at Paekakariki in 1855 earthquake. • Reduced slope stability at rail and road cuts, and from removal of forest cover. • During MM9 &10 earthquake shaking (500-2000 year return period) large landslides are possible in several places; small-moderate landslides are likely in many places. • MM 7-8 earthquake is likely to cause smaller and fewer slides. • Debris disposal likely to be a problem; disposal into sea likely to cause concern.	• Transmission Gully slopes lower and less steep, with no history of instability except for small failures, despite loss of forest cover. • Earthquake-induced landslide susceptibility at northern end is moderate to low, with few high areas. • Rock cuts up to 30-60 m high, with overall slope of 45° or less, have low to moderate susceptibility to earthquake-induced failure. • During MM9-10 shaking, small to moderate failures are expected on natural slopes or cut slopes, depending on steepness, height of cuts and support measures used. • No large failures expected in cuts of ~45°; flatter cuts (< 35°) in weak rocks and soils will minimise slope failure potential.
Liquefaction ground damage	• During MM9-10 earthquake shaking, liquefaction potential is moderate to high on SH1 from Porirua to Plimmerton. • Significant damage to SH1 and NIMT railway likely due to lateral spreading and settlements.	• Liquefaction potential generally low. Small liquefaction-prone areas on the route at Pauatahanui can be avoided or treated. • Liquefaction damage expected to be very minor.
Tsunami hazard	• Tsunami hazard is relatively high from Pukerua Bay to Paekakariki (4.5-10.0 km of highway). • Significant damage to SH1 is possible during a	• Tsunami hazard rated as very low, with very low potential for damage along the route.

	medium to large (≥5 m run-up) tsunami (worst-case scenario).	
Rainfall-induced landslides, debris floods, debris flows	• Coastal slope from Pukerua Bay to Paekakariki has a history of storm-related landslide and debris flood events. • Effects, damage, and closure times possibly significant at several locations, but effects less than during a large earthquake.	• Relatively-minor effects from landslides and debris floods during rainstorms 2003-2006. • Effects, damage, and closure times likely to be minor if appropriate design and construction measures are used to accommodate flood water and gravel debris at stream crossings.

3 Traffic Modelling

There are a number of factors that have a bearing on the operational performance of the Transmission Gully route. These have been taken into account in the traffic modelling and assessment of alignment options. Changes in traffic demand are heavily influenced by changes in land use, car ownership, environmental conditions, operational costs, alternative travel options, improvements to the road network and the available capacity of the network. Accurately defining the network is therefore critical to understanding changes in traffic demand and network performance under different scenarios.

3.1 Treatment of the Existing State Highways

The Transmission Gully project provides significant opportunities for treatment of the existing state highway network, particularly SH1. The project is predicted to remove nearly all through-traffic from the existing SH1 and, as a result, cut traffic levels by up to 75% on some sections of the existing route.

In assessing variations in design options and connections as part of the Transmission Gully project, the assumed treatment of SH1 and other State highways in the region reflected those projects currently identified, or programmed, in the RLTS or the NZTA's 10-year programme. These projects include:

- SH1/Paekakariki Hill Road/Beach Road intersection improvement,
- SH1/Pukerua Bay safety improvements and pedestrian crossing facilities,
- SH58/SH2 grade separation, and
- SH58 safety improvements between Pauatahanui and SH2.

A number of other projects have an indirect impact on the State highway network through the provision of additional capacity and / or reduced congestion, such as rail improvements and the Grenada to Petone route. However, it is anticipated that when the Transmission Gully project and the proposed delivery timeframe have been agreed, further work will be undertaken in conjunction with Porirua City Council and Kapiti Coast District Council to define the future configuration and management of the existing state highway network.

This might include:

- Revoking the State highway status of all or part of the existing network (SH1 and SH58), with these roads transferring to local road status,
- Reducing traffic capacity to improve community amenity,
- Increasing community facilities and reducing severance,
- Reducing traffic speed limits,
- Provision of additional passenger transport, walking and cycling facilities.

3.1.1 Future Land Use

The future Wellington Region land use is addressed by a number of documents:

Wellington Regional Strategy

One of the three key sections in the Wellington Regional Strategy document is "Investment in good regional form". This section describes a number of key focus areas for development and preservation. Key areas for industrial development include Seaview/Gracefield, Grenada, Porirua/Linden and Waingawa. Potential greenfield residential and urban development sites include Waikanae North and Paraparaumu. Areas recommended for residential intensification include Petone, Upper Hutt and the Johnsonville to Wellington growth spine.

Wellington Transport Strategy Model Report

In tandem with the Transmission Gully modelling process, the Wellington Transport Strategy Model (WTSM) model has been updated for Greater Wellington Regional Council to a 2006 base. New network, land use, demographic, economic, traffic and passenger transport data has been incorporated. A report (SKM, 2008) prepared for Transmission Gully on the WTSM model, details the growth predictions included in the traffic modelling for the project. Detailed information is provided showing the increases in growth for WTSM zones. Growth in specific local authorities is estimated, with Wellington City and the Kapiti Coast District having the largest predicted population increases of approximately 20% to 23% for the period 2006 to 2026. In contrast, growth in areas such as Porirua, Masterton and Upper Hutt is predicted to be much lower at between 1% and 5%.

Kapiti Coast Growth

Kapiti Coast District Council has identified a number of key areas for future growth and intensification. Paraparaumu and Raumati are expected to experience significant future growth through infill housing intensification. Waikanae is also expected to grow significantly through a mixture of intensification and greenfield development. In addition to housing, commercial development proposals have been identified in the town centre, along with business and light industrial development associated with the airport expansion.

Porirua Development Framework

The Porirua Development Framework identifies areas for potential growth and intensification in both the short and long term. Areas for possible intensification in the short term include Titahi Bay, Eastern Porirua and the esplanade area between Mana and Plimmerton. Areas for possible future intensification include further development in Titahi Bay and Eastern Porirua, as well as in Elsdon and Paremata. Possible urban growth areas include the area north of Plimmerton and Camborne in the medium-term, with growth continuing northwards to Pukerua Bay in the long-term. Possible areas for industrial or business growth include central Porirua and Kenepuru in the medium-term, and along SH58 east of the Transmission Gully route in the long term.

WTSM Traffic Model Growth Projection

The WTSM traffic model is based on Statistics New Zealand's latest "medium growth" population projections (November/December 2007). However, the growth assumptions in WTSM represent lower growth than the aspirations of the Kapiti Coast and Porirua local authorities, meaning the modelling predictions may be conservative. It may be appropriate to test the high (and possibly low) growth scenarios in the future, in order to determine the effect of traffic demands on the network.

3.2 Travel Demand Management

Travel Demand Management (TDM) of the road network in the Wellington Region is provided by extensive train and bus networks. Railways run adjacent to the SH1 and SH2 road transport corridors. There is a concentration of bus services serving Wellington and its suburbs, as well as bus links to the Kapiti Coast and Hutt Valley. Associated with the public transport network are a growing number of park-and-ride facilities aimed at encouraging the use of public transport in preference to long-distance vehicle travel.

Other TDM measures have recently been introduced to manage traffic and/or encourage the use of alternative transport modes. These include:

- Bus lanes - aimed at providing priority to buses, particularly in and around the Wellington CBD;
- Variable message signage (VMS) and an advanced traffic management system (ATMS), which provide information designed to improve safety and to allow drivers to make informed decisions about their travel;
- Signal co-ordination and network optimisation (SCATS) has been installed on key links and roads with signalised intersections, such as Mana Esplanade and throughout the Wellington CBD;
- Parking, pricing and enforcement strategies have been introduced in the CBDs of Wellington, Lower Hutt, Porirua and Upper Hutt in order to limit the availability of parking and reduce the attractiveness of private car usage, particularly during peak periods, and
- Travel planning aimed at providing information and facilities for employees, employers, major public attractors (sports facilities, hospitals, etc.) and educational facilities to reduce the dependence on cars and look at more sustainable means of travel.

All the key transport providers in the Wellington Region are seeking to implement TDM through specific projects and mechanisms such as changes in land use, planning processes and education.

Greater Wellington Regional Council, the local authorities and the NZTA plan to undertake a number of specific TDM schemes and measures as part of the Regional Land Transport Strategy. These include:

- Enhancing the public transport network to provide a viable alternative to travel by car;
- Increasing capacity at key traffic bottlenecks;
- Promoting alternatives to car travel;
- Travel planning and land use that reduces car dependency, for instance, encouraging new housing developments to be sited near public transport, and
- Longer-term introduction of a road-pricing system that signals the true cost of car travel.

The measures are aimed at reducing vehicle trips, particularly in peak hours, in order to optimise use of the network and to reduce emissions.

Construction of the new Transmission Gully road corridor will provide additional capacity that could be managed through the use of pricing strategies (tolls) and other mechanisms, including ramp metering and priority for specific users (Buses, High Occupancy Vehicles or HCV's). However, more importantly the Transmission Gully project should provide the ability to implement enhanced TDM measures on the existing Coastal Route, and on other local roads in the Porirua area.

These measures might include:

- The removal of vehicle lane capacity (possibly in favour of walking, cycling, and public transport provision and facilities);
- Reduction in speed environment (e.g. 100km/h to 70km/h);
- Better walking and cycle linkages (including to and from public transport facilities);
- Bus priority in the form of signal activation and bus lanes, and
- VMS and ATMS information (e.g. incident management and advice north and south of Transmission Gully to avoid bottleneck conditions on either Transmission Gully or the Coastal Route).

These measures are aimed at achieving a better balance between different road users, and improving the attractiveness of walking, cycling and public transport.

3.3 Capacity

3.3.1 Levels of Service, Capacity, and Number of Lanes

Level of Service (LOS) is a qualitative measure of the capacity of a road. The level is related to the quality of service available to a given traffic flow. Austroads (Austroads, 1988) provides a method for calculating the level of service of a road, ranging from LOS A to LOS F.

LOS A represents the best quality of service, permitting drivers to drive unimpeded at free-flow speed. LOS F represents heavily congested conditions, where queuing and delays result. LOS C represents stable flow, but with most drivers somewhat restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. With LOS C, the general level of comfort and convenience is noticeably inferior to LOS A and B. LOS D is close to the limit of stable flow, with all drivers severely restricted in their freedom to select their desired speed and manoeuvre within the traffic stream. At LOS D, the level of comfort and convenience is poor, and small increases in traffic flow are likely to result in traffic flow becoming unstable.

Level of Service C has been selected as an appropriate minimum performance level for mid-blocks for the 2026 design year, as it was considered an acceptable balance between cost and service. A higher LOS was considered inappropriate, because the associated increase in cost was not commensurate with the associated performance improvement, and would fail to meet the project objective of providing a cost-optimised route. Similarly, a lower LOS was considered inappropriate, because of the likelihood of the project failing to deliver the required safety and reliability objectives. It would also be extremely disruptive and expensive to retrofit significant lengths of the route if additional capacity was required in the future.

Predicted traffic volumes are such that, for a minimum LOS C, a total of four lanes (two in each direction) are required along the entire length of the Transmission Gully route. This will provide traffic capacity for predicted growth well beyond 2026.

3.3.2 Interchanges

Interchanges will be designed in accordance with the on-and-off ramp standard designs, as detailed in Part III of the MOTSAM (NZ Transport Agency, 2010).

The at-grade components of interchanges are likely to be either large roundabouts, or dumbbell roundabouts. These will all be designed in accordance with Austroads guidelines. Key design parameters for roundabouts are:

- Dumbbell roundabouts have a central island diameter of 40m.
- Large roundabouts have a central island diameter of between 100m and120m.
- Sensitivity analyses are undertaken to determine optimum diameters and desirable performance.
- Roundabouts will generally have 2 lanes, with a 10m circulating width, but single lane operation has also been considered.
- Approach and exit speeds have been considered to be lower than 50km/h.
- Typical gap acceptance parameters have been used.
- Ideal ramp gradients should be no more than 6%, and
- Minimum lane widths on ramps and roundabouts are to be 3.5m.

4 Geometric Design Standards

A key assumption of the Transmission Gully design philosophy, is to provide a "National State Highway" to expressway standard as defined by the Geometric Design Manual. Table 2.1 of the Geometric Design Manual defines road classification characteristics, with an expressway having the following:

- Traffic function – traffic movement is the primary consideration;
- Land access – rigid access control;
- Traffic volume – greater than 8000 vehicles per day, and
- Flow characteristics – uninterrupted flow except at signalised intersections.

The key difference between an expressway and a motorway is that no side-access is permitted to a motorway, whereas "rigid access control" is required for an expressway. Also, a motorway has completely uninterrupted flow with all intersections being fully grade-separated, while signalised intersections are permitted on an expressway.

In most respects, Transmission Gully is designed to a motorway standard - for example, all interchanges are grade-separated to the extent that there is free-flow through movements with priority to Transmission Gully traffic, and no direct access is envisaged for properties adjoining the Transmission Gully route. However, given the topographical constraints of the route, and the possibility that there may be a need for temporary access in special circumstances, for example to harvest forest where there is no possible alternative access, it was decided that an expressway standard was more appropriate than a motorway standard overall.

4.1 General

The geometric design standards for this project are based on the following standards:

- Transit Draft State Highway Geometric Design Manual (GDM) (Transit, 2001),
- Manual of Traffic Signs and Markings: Part III Motorways (MOTSAM) (New Zealand Transport Agency, 2010),
- Austroads: Guide to Traffic Engineering Practice: Part 6 – Roundabouts (Austroads, 1993),
- Austroads: Rural Road Design Guide (Austroads, 2003),
- Austroads: Urban Road Design Guide (Austroads, 2002).

4.2 Horizontal Design Speed

Section 4.8 of the Geometric Design Manual specifies minimum design speeds for dual carriageway state highways. For expressways these are 110 km/h, 100 km/h and 80 km/h in flat, rolling and mountainous terrain respectively. The manual defines rolling terrain as *"any combination of ...vertical alignment that will cause heavy vehicle speeds to be reduced substantially below those of passenger cars, but will not cause them to operate at a crawl speed for any significant length of time"*. The manual defines mountainous terrain as *"any combination of …vertical alignment that will cause heavy vehicles to operate at crawl speeds for significant distances and/or at frequent intervals"*.

Austroads (Austroads, 2009) provides information on the performance of heavy vehicles on various combinations of grades over various lengths of road. An analysis of the proposed grades on Transmission Gully shows that heavy vehicles will be at crawling speed (40km/h or slower) for between 15% and 20% of the route, and substantially below (40km/h and 70km/h) passenger car speeds for another 20% to 25% of the route. The above analysis confirms that Transmission Gully has a combination of mountainous, rolling, and flat terrain as defined by the Geometric Design Manual.

Land use adjacent to the route is predominantly rural, with some native and exotic forest areas, and some rural residential areas. The route passes through challenging terrain and environmentally-sensitive areas that constrain the horizontal alignment. A 100km/h horizontal design speed has therefore been selected as appropriate for the entire length of the main alignment excluding the link roads.

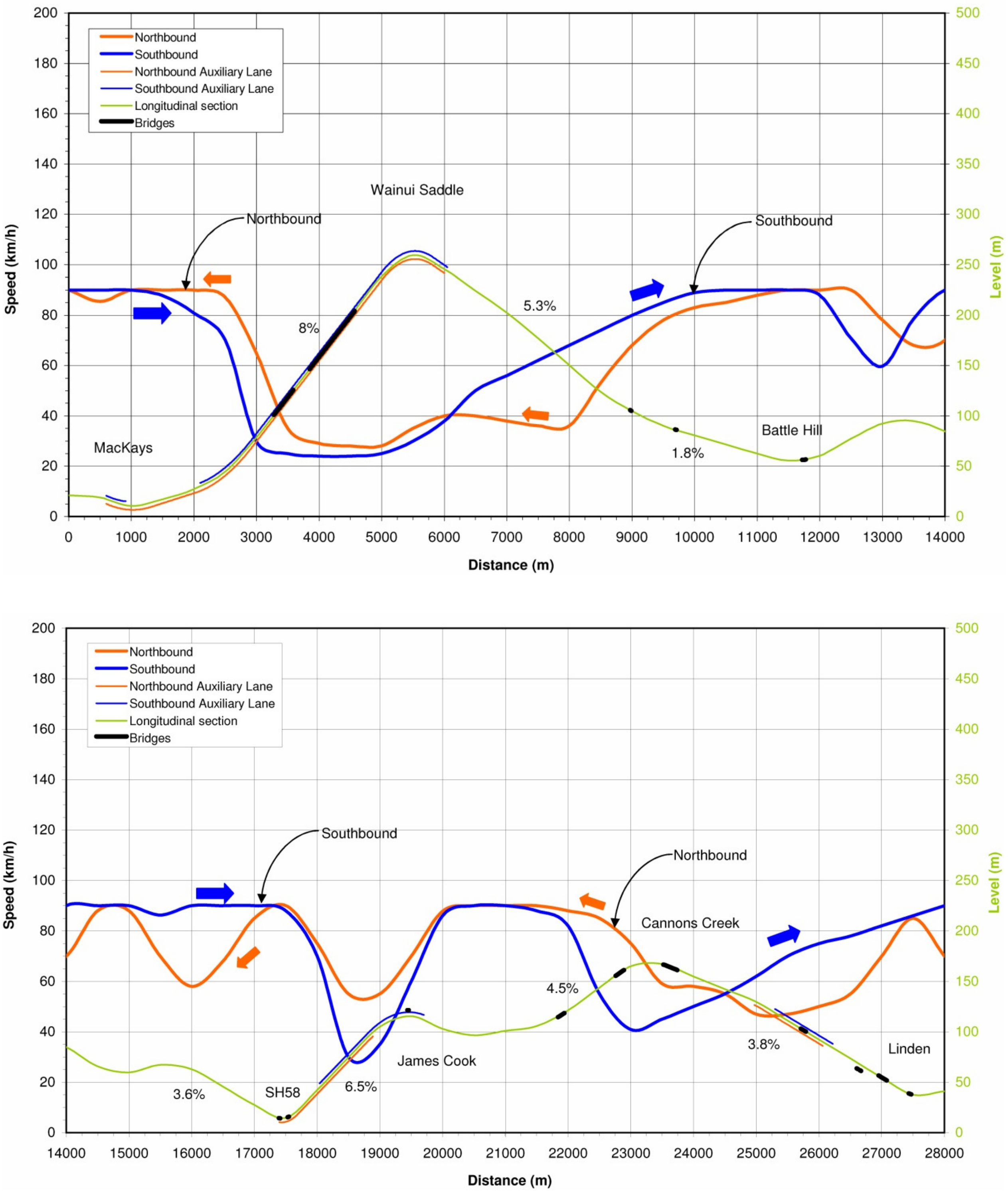

Figure 1.1 - Predicted Heavy Vehicle Speeds

4.3 Horizontal Alignment

The horizontal alignment will be based on a design speed of 100km/h. Curve radii of 650m or greater are achievable, except for one curve just north of the Kenepuru Interchange, where topographical constraints have resulted in a radius of 600m being proposed. While this curve has a smaller radius than all other curves, it is still above minimum design criteria as set out in the Geometric Design Manual.

All horizontal curves will have transitions. Generally, the proportion of transition length to circular curve will be between 1.5:1 to 1.3:1. This is preferred on aesthetic grounds, and where the majority of a circular curve can be seen by approaching drivers.

4.4 Super-elevation

The maximum effective super-elevation proposed is 6.5%. On curves where the radius exceeds 3,000m, normal camber will be used. Super-elevation will be increased on horizontal curves on steep down-grades, as recommended in Section 4 of the Geometric Design Manual.

4.5 Vertical Design Speed

The vertical design speed cannot be considered in isolation, and must relate to the horizontal geometric design. The Geometric Design Manual states that it is good design practice for the vertical design speed to be at least 10km/h higher than the horizontal design speed, i.e. 110km/h.

Under the current Geometric Design Manual recommendations, a vertical design speed of 110km/h can be achieved in all locations, except at Wainui Saddle.

4.5.1 Vertical Alignment

The main Transmission Gully route will have a maximum gradient of 8%. On at least one of the link roads into Porirua the gradient will be up to 10%, although this may be able to be reduced during the next phase of design investigation. The link road to Kenepuru Drive will be posted at 50km/h, and will have a maximum gradient of 8%.

The crest curves will be designed for a speed of 110km/h, which equates to a K value of 102. At Wainui Saddle the proposed K value will be 62, which equates to a design speed of about 100km/h.

The adoption of a new Austroads sight-distance model provides a relaxation of the current standards used above, such that the K value proposed for the crest curve at Wainui Saddle is now appropriate for a design speed of 110km/h. This has been approved by Transit's Scope and Standards Review Committee (see Section 6.18).

Sag curves at interchanges will have a minimum K value of 40, which significantly exceeds the normal comfort requirement for a 100km/h design speed. Elsewhere on the main route, which will not be illuminated, a K value of 150 will be used for sag vertical curves, in accordance with the Geometric Design Manual.

4.5.2 Vertical Clearances

A 6m vertical clearance will be provided to the undersides of all structures at interchanges. Connections under the route for landowner access will have a nominal 5m vertical clearance.

4.6 Stopping Sight-Distances

Three key stopping sight-distances (SSD) will be provided in the design as follows:

- Around the inside of a horizontal curve, as required for a 100km/h design speed;
- From driver's eye height to a 0.2m object on the main route, as required for a 100km/h design speed;
- Four times the main route stopping sight-distance at the beginning of interchange off-ramps.

In some cases the SSD will not be fully achievable on the inside of curves, either in the median or at the back of shoulders. Achieving the SSD is also problematic on the southbound off-ramp at the James Cook Interchange. This has been approved to Transit's Scope and Standards Review Committee.

4.7 Crawler and Auxiliary Lanes

Transmission Gully will have gradients of between 3% and 8% over sections of the route up to 4 km long. Heavy vehicles on these grades could have impact on the safety and capacity of other traffic, as well as degrading the level of service because of the speed differential between the heavy and light vehicles. The need for crawler lanes and auxiliary lanes has therefore been considered.

For the purposes of this report, crawler lanes are defined as additional lanes provided for slow moving vehicles where their speed has been reduced because of a steep grade. Auxiliary lanes are defined as extensions to on or off ramps where the grades are such that slow moving vehicles are not able to accelerate to their normal operating speed within the traffic stream, or where they must decelerate early from their normal operating speed.

Austroads (Austroads, 2003) provides guidance that crawler and/or auxiliary lanes should be considered where:

- There are long grades over 8%;
- Heavy trucks enter the traffic stream from a side connection on the upgrade;
- The level of service falls two levels below that on the approach to the up-grade, or to level E; and
- Crashes attributed to the effects of slow moving trucks are significant.

Transmission Gully has 8% grades only on the southbound approach to Wainui Saddle. In all other locations, except for on and off ramps, grades are typically less than 5%, apart from a 6.5% up-grade for southbound traffic to the south of SH58. The primary locations where heavy vehicles enter the traffic stream on an up-grade from an intersection are at SH58 (north and southbound), and northbound at Kenepuru.

Calculations (Austroads, 1988) indicate that the southbound approach to Wainui Saddle would be operating at a level of service of E in the 2026 morning peak hour. In all other cases, the Level of Service will be C or better.

In the flat country north of MacKays Crossing, the level of service (LOS) is calculated to be between A and B. Southbound traffic approaching Wainui Saddle will therefore experience a drop of up to three levels of service, and on this basis, the Austroads guide suggests crawler lanes should be considered. On other sections of Transmission Gully the drop in LOS is not as significant.

The safety audit raised concerns about the safety implications of the predicted speed differential between heavy and light vehicles on steep grades. The audit recommended the inclusion of crawler lanes for both the ascending and descending carriageways on the north side of Wainui Saddle, such that there are three lanes in each direction.

At this stage of the project, it is considered appropriate to include the crawler and auxiliary lanes to provide an acceptable LOS and a safe environment.

4.8 Escape Ramps

Where long steep down-grades occur, it is desirable to provide emergency escape ramps to allow an out-of-control vehicle to stop. The Austroads rural road design guide (Austroads, 2003) provides details of different types of escape ramp. The ramps incorporate arrestor beds, which transfer a vehicle’s kinetic energy through the displacement of aggregate in the bed. Properly designed beds will stop vehicles under controlled conditions without significant damage to the vehicle.

Details of three forms of escape ramps incorporating arrestor beds are provided in the Austroads design guide:

- A descending grade layout (parallel to the traffic lanes and on the same vertical grade);
- A horizontal grade layout, whereby there is zero gradient on the escape ramp;
- An ascending grade ramp which uses an uphill gradient to assist in slowing a vehicle.

The ascending grade ramp is preferable because it will be the shortest, but all three of the above types could be suitable for Transmission Gully depending on the required ramp location and site topography. The design guide recommends escape ramps should be provided on routes with a gradient steeper than 6%, where the number of trucks exceeds 150 per day. Guidance is provided on the location of ramps relative to a summit, with summit-to-ramp distances decreasing as gradients increase, e.g. for gradients between 6% and 10% the approximate distance from a summit to a ramp should be 3km.

Vehicles that enter an arrestor bed will have to be retrieved, as it is unlikely they will be able to extract themselves. Either an appropriate service/access road is required adjacent to the ramp, or anchorage blocks can be provided to winch the vehicle free. Although the anchor block option may be cheaper to construct, there may be additional operational costs to retrieve vehicles and to maintain the arrestor bed. These issues will be resolved with more detailed design in the next phase of the project.

The descent northbound from Wainui Saddle has a gradient of approximately 8% and a right hand curve towards the bottom of the descent. The curve starts approximately 2700m downhill from the Saddle.

It is proposed that an emergency escape ramp be provided for northbound vehicles prior to the right hand curve, i.e. approximately 2.7 km from the summit, at a location which will provide adequate forward sight distance and enable the driver of an out-of-control vehicle to make a decision in adequate time to use the escape ramp. If practicable, an ascending grade ramp with arrestor bed should be provided.

No other locations are considered to warrant construction of an escape ramp.

4.9 Brake Check & Brake Rest Areas

A brake check area is an area set aside for trucks at the top of a steep descent, while a brake rest area is an area provided part way down, or at the bottom of a descent. The Austroads rural design guide (Austroads, 2003) recommends these facilities should be provided on routes that have long steep downgrades and truck numbers of upwards of 100 vehicles per day.

Drivers using these facilities should be able to begin a descent starting from a standstill and in a low gear, which could make the difference between a controlled and an out-of-control descent. Brake check areas also provide the opportunity to display information about the grade ahead, escape-ramp locations, and maximum safe descent speeds. These areas need to be large enough to hold several trucks according to the predicted arrival rate, and to have good visibility together with acceleration and deceleration tapers. Adequate signage is also required to provide advance notice of the facility.

Brake check and brake rest areas would be desirable on the Transmission Gully route. The longest steep grade is that for northbound vehicles descending from Wainui Saddle. Although northbound trucks will approach the summit slowly because of the ascent to the Saddle, this is the obvious location for a brake check area and room may be available just to the south of the summit.

4.10 Over-Dimension and Over-Weight Route

The Transmission Gully route will be designed to cater for over-dimension and over-weight vehicles. This is considered to be a prudent design objective, given that the project is a new–build, 27km-long project that will bypass existing coastal communities.

5 Earthworks

5.1 General

Cut slope and fill batter design will be based upon geotechnical advice derived from site investigations.

5.2 Rock Cut Slopes

5.2.1 Philosophy

Rock cut slopes in Wellington Greywacke rock will be designed to achieve the factors of safety and performance criteria set out in Table 1.2

Table 1.2 - Rock Slope Design Criteria

Design Case	Conditions Performance or Design Criteria
Normal	Factor of safety > 1.5 or precedent cut slope angle.
Storm and Construction	Accept some small wedge / block failures in modest storms, and larger slope failures in 100 year storm, consistent with route security philosophy.
Earthquake	Limited failures acceptable in moderate to large earthquakes consistent with route security philosophy.

The aim is to provide stable cut slopes through the selection of appropriate cut slope angles and geometry, while accepting some failures in large storm or earthquake events consistent with the route security philosophy. Provision will also be made for implementing localised stabilisation measures during construction.

Three important issues influence the selection of cut slopes in rock:

- Stability under normal conditions;
- Stability and route security under large hazard events, e.g. earthquakes and storms;
- Rock fall hazard mitigation.

An integrated approach, considering all three issues, has been used in the selection of appropriate cut slope designs. This approach has been fundamental to the achievement of a robust and cost-efficient solution.

The stability of cut slopes has been considered using four approaches:

- Precedent cut slopes;
- Behaviour of slopes in historical earthquakes;
- Rock defect analyses, and

- Rock mass stability analyses.

5.2.2 Precedent Cut Slopes

Experience in the design, construction and observation of the performance of cut slopes, particularly for state highways in the region, provides background knowledge of stable cut slopes and common stability issues affecting large cuttings in Wellington Greywacke.

This has been supplemented by a survey by geotechnical engineers of cut slopes in greywacke in the region - predominantly of state highway cuttings (SH1, SH2 and SH58), but also of some local road and quarry cuttings. The following information was recorded:

- Cut slope angle (using compass clinometer, laser survey, or in occasional instances visual estimation);
- Slope height (laser survey or visual estimation);
- Rock weathering and rock mass conditions, and
- Observed stability of cuttings.

5.2.3 Earthquake Stability

Historical landslides provide valuable information on the susceptibility of slopes to earthquake-induced landslides. Historical regional landslides have been considered to understand the potential for earthquake-induced landslides along the Transmission Gully route.

An earthquake-induced slope failure hazard study for the Wellington Region was completed for Greater Wellington Regional Council in 1994. This indicated that the natural slopes along the Transmission Gully route near the Te Puka and upper Horokiri Streams have moderate susceptibility, with some small areas of high susceptibility. This is consistent with the generally lower overall slope angle and lack of deep-seated landslides along the Transmission Gully route. However, construction of the road would result in cuts with a higher susceptibility than the natural slopes.

Using a methodology developed to predict susceptibility of slopes to earthquake-induced slope failure, it is considered that 50m high cuts at an average 45° slope would have a moderate susceptibility to earthquake-induced slope failure. Moderate slope failure susceptibility would give rise to a minor slope failure potential in a MM 7 to 8 ground shaking, and severe slope failure potential in a MM 9 to 10 shaking intensity. The minor slope failure potential implies small (100 cubic metre to 10,000 cubic metre) failures, and the severe slope failure potential implies large (> 10,000 cubic metres) failures. However, very large failures (>100,000 cubic metres) are not expected.

Failures in the order of 10,000 cubic metres can be cleared in a few days to a week or so, and hence such failures are consistent with the route security philosophy proposed for the project.

5.2.4 Rock Defect Analysis

Wellington Greywacke rock is generally closely to very closely jointed. However, the joints generally have a very low persistence, and joint orientations vary considerably. This would suggest that the rock would behave as a "homogeneous", closely jointed rock mass. There are also, however, numerous faults, shear surfaces and crush zones present in the rock, and these are generally much more persistent (tens of metres) than the joints, and have the potential to have a significant influence.

Detailed consideration of these defects using data from the geotechnical investigations, has concluded that overall formation of the cuttings at a cut slope of approximately 45° to 50° will minimise the potential for planar failures, due to approximately 80% of the shear surfaces being steeper than 45° to 50°. Approximately 15% of the shear zones that dip at between 20° and 45° could give rise to some failures in the west-northwest-facing cut slopes on the eastern flanks of the Te Puka and Horokiri Valleys, particularly those that dip towards the west-northwest. Actual failures will depend on the shear strength of the shear surfaces and crush zones.

5.2.5 Rock Mass Stability Analyses

Consideration has been given to the possibility of circular failures in cuttings through a homogeneous jointed rock mass. Analyses have been undertaken based on rock mass strength parameters derived from the geotechnical investigations. These indicate that the average 45° slopes most likely to be encountered in the rock will have a factor of safety of at least 1.5 under static conditions, assuming average groundwater levels. In some areas, the rock quality is such that a 50° slope will give a factor of safety of at least 1.5.

5.2.6 Combined Rock Mass and Defect Analyses

The potential presence of dominant defects has been considered. Analysis of slopes with dominant defects (such as shear zones) and a closely jointed rock mass indicates this situation is likely to be critical. The likely presence of dominant defects in individual slopes and the influence of combined failures will require careful consideration.

5.2.7 Cut Slope Design and Effect on Rock Fall Hazards

The cut slope configuration has a significant effect on rock fall hazards associated with road cuttings. Rocks tend to stay close to the face and land near the toe of the slope for slope angles steeper than 75°. Such slopes will not be applicable to cuttings for Transmission Gully.

For slope angles between approximately 55° and 75°, falling rocks are likely to bounce and spin, with the result that they can land some distance from the toe.

Where slope angles are between approximately 40° and 55°, rocks will tend to roll down the face to the toe. Therefore, cut slope angles in this range will effectively minimise rock fall hazards to the highway, and minimise, or avoid, the need for rock fall management measures such as catch-fences or ditches requiring significant volumes of additional excavation.

Slope angles less than 40° would further reduce rock fall risk, but these are not practical on much of the Transmission Gully route because of the steep natural slopes present.

Rocks which dislodge typically tend to break up. Rock fall materials in greywacke are typically less than 200 mm in size.

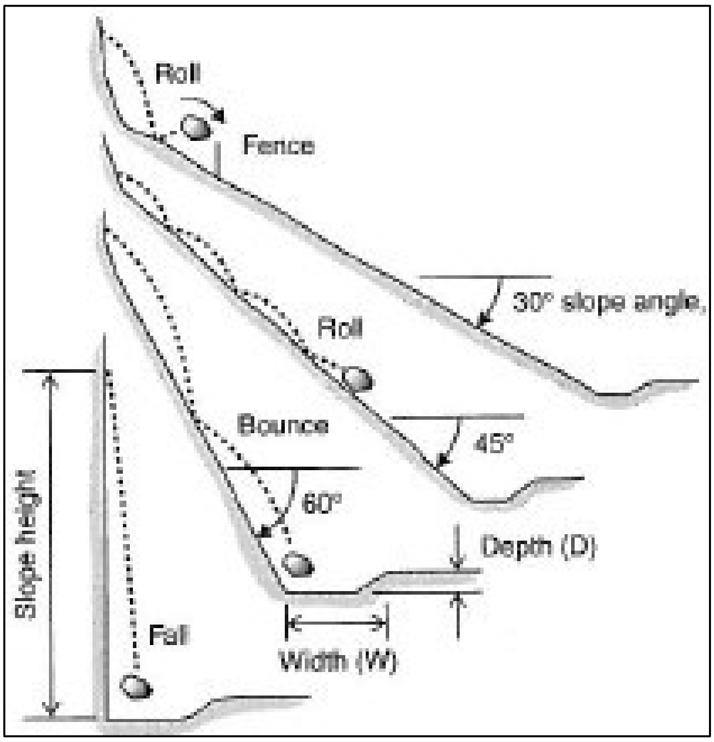

Figure 1.2: Rock Fall Behaviour on Slopes

5.2.8 Summary of Cut Slope Design Philosophy

Further investigation and assessment will be required for major cut slopes along the route during future stages of the project. This will provide better definition of rock mass properties, particularly the significant shear zone features.

Work to date indicates that cut slopes of the order of 45° to 50° are appropriate for cut slopes up to 50m high. Flatter slopes are appropriate in weaker, fault-disturbed materials such as at the Wainui Saddle, where 35° to 45° slopes are likely to be more suitable.

In terms of earthquake performance, it is considered that cut slopes of 45° would have a moderate susceptibility to failures - in the order of 10,000 cubic metre in a large (MM[‡] 9 – 10) earthquake shaking.

Rock fall hazards can be better managed if the faces of cut slopes are kept within the range 40° to 55°, leading to rock fragments rolling rather than bouncing, and thereby limiting rock travel.

[‡] MM # Modified Mercalli intensity scale for measuring earthquake intensity.

Considering the above issues, and with a view to a cost-effective solution, a slope of approximately 45° is considered appropriate for the majority of the cut slopes along Transmission Gully.

The cut slope configuration proposed for Transmission Gully, and widely adopted in Wellington Greywacke rocks, uses 3m-wide benches at about 10 m height intervals. This has provided excellent performance of cut slopes, and has helped manage rock fall hazards, minimise erosion, and the establishment of vegetation to provide an attractive landscape in the medium to long term.

5.3 Soil Cut Slopes

5.3.1 Design Philosophy

Soil slopes will be designed for expected ground and groundwater conditions, and the assessed design strengths of the soils.

Soil slopes will be designed to the factors of safety and performance criteria set out in Table 1.3.

Table 1.3 – Soil Slope Design Criteria

Design Case	Conditions Performance or Design Criteria
Normal	Factor of safety > 1.5
Storm and Construction	Factor of safety > 1.25
Earthquake	Factor of safety > 1, or displacement <300mm in 1,000 year return period event

Preliminary design recommendations have been developed to provide stable cut slopes in soil through the selection of appropriate cut slope angles and geometry. Provision has been made to implement localised stabilisation measures during construction, and to accept some failures in large storm or earthquake hazard events.

Three important issues influence the selection of cut slopes in soil:

- Stability under normal conditions,
- Route security for storm events,
- Route security for large earthquake events.

The stability of cut slopes has been considered using three approaches:

- Precedent cut slopes;
- Behaviour of slopes in historical earthquakes;
- Stability analyses.

5.3.2 Precedent Cut Slopes

Experience in the design, construction and observation of cut slope performance, particularly for State highways in the region, provides knowledge of cut slope stability and common issues affecting large cuttings in soil.

The most relevant recent information comes from the SH2 Kaitoke to Te Marua realignment project. This project was constructed through Pre-Holocene deposits (Kaitoke Gravels and Pakuratahi deposits), and is relevant given the presence of similar Pre-Holocene deposits along parts of the Transmission Gully route, particularly in Sectors 2, 5 and 6. Information has also been gained from the Silverwood subdivision, constructed between 2006 and 2008, immediately to the south of SH58, and west of the Transmission Gully alignment.

5.3.3 Behaviour in Historical Earthquakes

There is no precedent information on soil cut slopes that have exhibited significant failures in large earthquakes.

5.3.4 Stability Analyses

Stability analyses have been carried out (Figure 1.3) assuming 15m to 30m high 35° slopes, with 3m-wide benches at 10m vertical intervals, in the Pre-Holocene alluvium in Sectors 5 and 6, and completely weathered greywacke in Sector 8. The groundwater level profile was at 5m to 10m deep, based on observations and representative soil parameters, which were chosen based on laboratory test results. This indicated that the commonly accepted factor of safety of 1.5 would be achieved under normal static conditions.

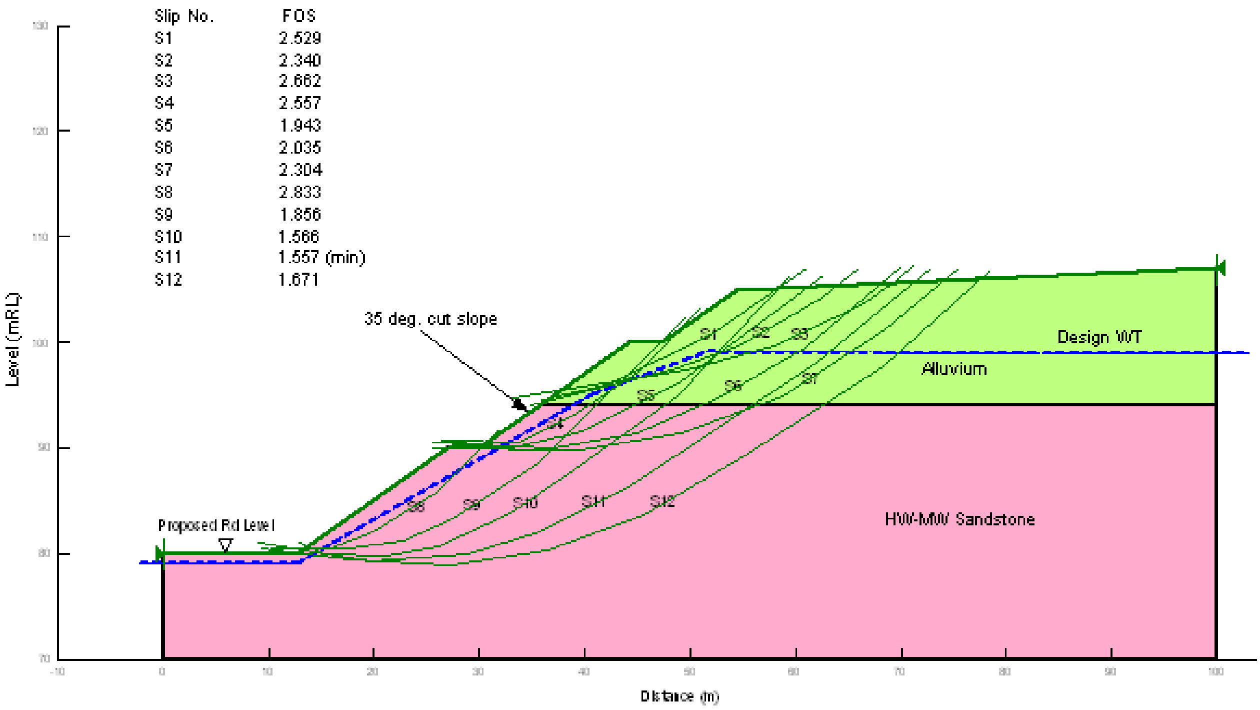

Figure 1.3: Typical Slope Stability Analysis of Cut Slopes in Soil

Should the groundwater level rise to a 3 m depth under wet or storm conditions, the factor of safety drops to slightly less than 1.5 for the most critical surfaces. This is considered acceptable, based on the proposed design philosophy.

Cut slopes appropriate for the different soils encountered along the Transmission Gully route have been developed based on precedent cut slopes in the region, and representative stability analyses based on soil properties from laboratory tests on samples obtained during the geotechnical investigations.

Table 1.4 – Proposed Cut Slopes

Soil Type	Location	Slope
Dune Sand (Paekakariki)	Sector 1	20° to 25°
Coarse Alluvium (Te Puka Terrace)	Sector 2	40°
Colluvium, fine Pre-Holocene Alluvium	Sectors 5 & 6	25° to 35°
Completely weathered greywacke	Sectors 8 & 9	35°

Existing landslides in Sector 6 confirm the potential for slope failure, which is likely to have been triggered by high groundwater conditions. The creation of drainage holes and sub-soil drains at the toe of slopes, and in some cases at intermediate levels, is therefore considered to be important to maintain stability. It may also be necessary to form some cuttings to a shallower 25° slope where weaker soils are encountered, or where cut slopes greater than 30 m are proposed.

Erosion protection measures should include surface drains to redirect surface flows away from the cut slopes, and provision of geotextile erosion matting to protect erodible materials such as dune sands, loess, and fine alluvium.

Rock fall draped netting protection may be appropriate for cut slopes in coarse alluvium with cobble and boulders, such as at the Te Puka terrace immediately south of SH1 at Paekakariki.

5.4 Embankments

5.4.1 Philosophy

Preliminary embankment design recommendations have been developed to provide stable embankments through selection of appropriate slope angles and geometry, and acceptance of some limited displacement in large storm or earthquake events.

Three important issues influence the selection of embankment slopes:

- Stability under normal conditions;

- Route security for storm events;
- Route security for large earthquake events.

Stability of embankment slopes has been considered using three approaches:

- Precedent embankment slopes;
- Behaviour of slopes in historical earthquakes;
- Stability analyses.

5.4.2 Precedent Embankment Slopes

The most relevant recent information on the behaviour of embankment slopes in the region comes from the SH 2 Kaitoke to Te Marua realignment project. This project involved the construction of embankments up to 30m high, with 26° slopes formed with 3m wide berms at 10m to 15m vertical intervals. The embankment slopes have performed as expected and similar configurations have been adopted for embankments on stable ground on other State highway projects in the region.

There is no precedent information on the performance of embankment slopes in the Wellington Region in large earthquake events. It is known from experience in the United States that fill slopes do experience settlement and associated cracking during large earthquakes, with the magnitude of settlement being dependent on the materials and standard of compaction. The standard of compaction should be high for Transmission Gully, and so settlement is expected to be less than 100mm, which is consistent with the route security philosophy.

Fill Materials

The probable embankment fill materials for the Transmission Gully project will vary, depending on the materials available from cuttings in the general location of the fill embankment.

5.4.3 Stability Analyses

Stability analyses have been carried out (Figure 1.4) assuming 20m to 40m high embankments formed at 25° slope, with 3m-wide benches at 10m vertical intervals, using the fill materials derived from the Pre-Holocene alluvium in Sectors 5 and 6, and from completely weathered Greywacke. Soil parameters have been based on laboratory test results.

The analyses indicate that a factor of safety of 1.5 would be achieved under normal static conditions.

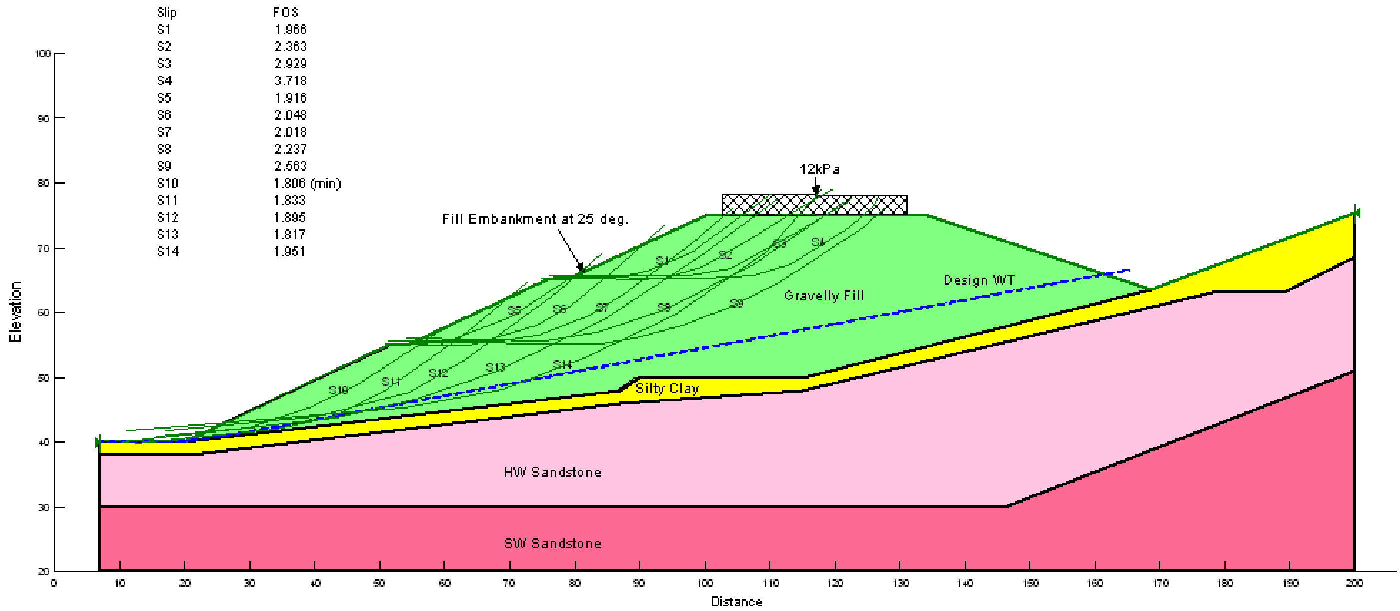

Figure 1.4: Typical Slope Stability Analysis of Soil Embankment

5.4.4 Behaviour in Historical Earthquakes

Stability analyses were undertaken under earthquake conditions, using a peudo-static approach, to derive the critical horizontal acceleration to reduce the factor of safety of the cut slope to unity. These analyses indicate slope displacements of less than 100mm in a 1000 year return-period earthquake event (0.52g peak ground acceleration), and up to 200mm displacement in a larger earthquake event, giving a peak ground acceleration of 0.75g, with an 84 percentile level of confidence. Such limited displacements in large earthquakes are considered to be acceptable.

5.4.5 Settlement

Embankments founded on competent ground, or on foundation levels undercut to competent ground, are proposed, to ensure that settlements are small.

The soft peat in the low-lying areas in Sector 1 should be undercut to the competent underlying dense sandy gravel and sand. If there are some residual peat layers or compressible clay/silt layers at depth, preloading will minimise post-construction settlements to less than 50mm. Similarly soft ground may be encountered along the Kenepuru link adjacent to the stream, and possibly along the link to James Cook Drive.

5.4.6 Ground Improvements

Ground improvement for embankments should generally comprise of:

- Undercut of soft, compressible, organic materials at foundation level;

- Construction of a minimum 500mm-thick drainage blanket wrapped in geotextile, with outlet sub-soil drains;
- Benching into the natural ground interface to remove loose, soft or organic materials, and keying the new embankment fill into competent natural ground;
- Construction of sub-soil drains along the interface between natural ground and the fill embankment;
- Construction of drainage layers within the embankment fill where the fill is fine-grained soils, and particularly where the fill may be wet and of optimum moisture content.

Additional ground improvement measures may be required where there are significant thicknesses of soft compressible layers below foundation level, which cannot be practically or economically excavated and removed. These areas should be preloaded, with wick drains installed to accelerate settlement if necessary, to minimise post-construction settlements.

Ground improvement may also be required where there is a potential for liquefaction, which may affect route security or the performance of adjacent structures such as bridges and retaining walls.

5.4.7 Fill Slope Configuration

Where berms are provided they should slope outwards to shed rain water and reduce the risk of gully erosion. Any surface water from the road should be collected, and either piped or run down lined cascade drains to minimise embankment erosion

Table 1.5 – Proposed Fill Slopes

Fill Source	Embankment Fill Materials	Description	Performance	Additional Stabilisation Measures
Sector 1	Dune Sand	Fine to medium sand	22° - No berms given low height embankments	Erosion protection matting, topsioling and revegetation to minisise erosion
Sector 2	Pre-Holocene Gravel	Sandy Gravel with cobble, boulders	25° - 3m wide benches at 10m vertical intervals	Rockfall netting unlikely to be required
Sectors 3 & 4	Wellington Greywacke derived fill	Silty sandy Gravel	25° - 3m wide benches at 10m vertical intervals 45° - Reinforced soil embankment	None envisaged
Sectors 3 & 4	Fault disturbed Wellington	Gravelly sandy Silt and Clay	25° - 3m wide benches at 10m vertical intervals	Possibly intermediate coarse gravel / rock fill

	Greywacke derived fill			layers to ensure drainage during construction
Sectors 5 & 6	Pre-Holocene Alluvium	Clayey and sandy silt	25° - 3m wide benches at 10m vertical intervals	Intermediate coarse gravel / rock fill layers to ensure drainage during construction
Sectors 8 & 9	Wellington Greywacke derived fill including completely weathered Greywacke	Silty sandy Gravel and Silty and Sandy Clay	25° - 3m wide benches at 10m vertical intervals 45° - Reinforced soil embankment	May require granular layers to ensure drainage, if fill is completely weathered

5.5 Reinforced Soil Embankments

5.5.1 Concept

Reinforced soil embankments (RSE) up to 35m high are proposed to reduce the footprint of the earthworks, to minimise encroachment into the Te Puka and Horokiri Streams and other natural features.

Reinforced soil embankments have been chosen as construction will be similar to normal embankments, but with the inclusion of geogrid reinforcement layers. They avoid the need for temporary or permanent facing, which is a significant consideration both in terms of cost and appearance.

The RSEs may be located close to or possibly straddling both the Ohariu fault and the splinter fault south of Wainui Saddle. The reinforced soil block is expected to perform as a "rigid" block and accommodate displacement without significant damage.

RSEs of this height have not been commonly constructed in New Zealand, and careful construction quality control will be required.

5.5.2 Reinforcement

It is proposed that high density polyethylene (HDPE) (such as Tensar) geogrids will be used, which will provide a relatively low cost and durable reinforcement for the embankment fill. These are more robust than polyethylene geogrids and less susceptible to damage. The geogrids are predicted to have a design life exceeding 100 years.

Reinforcement requirements will vary depending on ground conditions, configuration, and fill materials, as well as earthquake performance requirements. The earthquake design philosophy will be to allow controlled displacement of reinforced embankments, without failure through the reinforced soil block. Some excavation into the natural hillside may be required to achieve an adequate reinforcement length.

5.5.3 Fill Materials

For all heights of up to 35m in the upper reaches of the Te Puka and Horokiri Stream valleys, selected granular fill materials sourced from cuttings are proposed. The proposed fill should be competent slightly to highly weathered Greywacke rock, i.e. silty sandy gravel, to provide the required strength properties and drainage characteristics.

5.5.4 Stability Analyses

Stability analyses have been undertaken (Figure 1.5) using reinforced slope stability assessment software, to determine the preliminary configuration and to assess stability of the reinforced soil embankments.

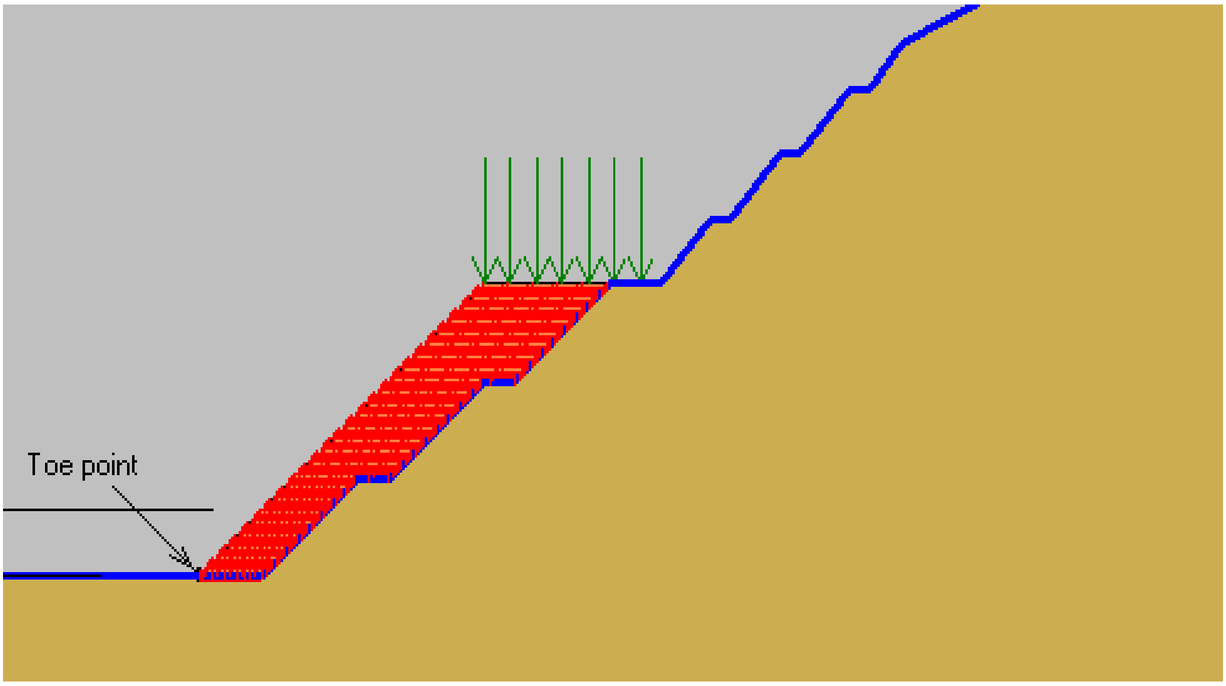

Figure 1.5: Typical Analysis of a Reinforced Soil Embankment

5.5.5 Landscaping and Re-vegetation

It is important that the RSE slopes are vegetated as soon as possible after construction, and the vegetation maintained during the life of the RSE. Vegetation is usually grass and other low vegetation to provide protection to the slope surface. Large trees could destabilise the slope, and should be avoided.

5.6 Earthworks and Construction Materials

5.6.1 Unsuitable Foundation Materials

Excavation and replacement of unsuitable material below all structure foundations, retaining walls, and embankments (both conventional and reinforced) is proposed. In some instances, the materials may be suitable for reuse once recompacted.

It may be impractical to remove all the soft peat in Sector 1, and possibly elsewhere, and it may be necessary to undertake pre-loading for soil strengthening.

5.6.2 Excavation Characteristics

The excavation characteristics of cut materials along the route have been considered.

Sector 1

This has sand dune materials that can be easily excavated using earthmoving machinery, without the need for any ripping.

Sector 2

This has very dense Pre-Holocene gravel materials with cobble and boulders, and may require light ripping to facilitate excavation.

Sectors 3 and 4

These are comprised of predominantly rock materials, which are closely jointed and, given the proximity of the Ohariu fault, generally have shear and crush zones. It is likely that the majority of the materials could be excavated by ripping, although blasting may be required for an alignment on the eastern flank south of the Wainui Saddle.

Sectors 5 and 6

Excavation will predominantly be in Pre-Holocene soil deposits that are mostly fine grained, with some gravelly sandy silts. These soils can be easily excavated by earthmoving machinery. Some light ripping may be required in the gravelly materials and in localised areas of rock.

Sector 7

There are no cuttings requiring excavation in this sector.

Sector 8

This sector is comprised predominantly of rock materials, with completely to highly weathered rock near the surface. The rock is closely jointed, and it is likely that the majority of materials can be excavated by ripping. Some localised heavy ripping or blasting may be required. The completely weathered rock materials may be wet and may require some drying.

Sector 9

Excavation in this sector will predominantly be in rock. North of Cannons Creek the rock will likely be able to be excavated by ripping, with blasting possibly required near the base of the box cutting. The area south of Cannon's Creek includes more competent bedrock material, although this is still closely jointed. Ripping and some blasting may be required, particularly between Cannons Creek and the Gun Club.

5.6.3 Embankment Fill Materials

Soils and rock excavated on-site will generally be reusable as fill. However, some of the material from the soils in Sectors 5 and 6 may not be suitable for fill, primarily because the natural moisture content is higher than the optimum moisture content, and drying may be time-consuming. Also, some of the rock cutting materials from near the Wainui Saddle fault-zone and adjacent areas may be too cohesive, or wet, and it may be preferable to dispose of them and use more suitable materials for fill.

The reinforced soil embankments and walls will require selected fill materials. These can be derived from the rock cuttings, but may need to be hauled some distance, as locally available materials may not be suitable.

5.6.4 Compaction Characteristics

The soils in Sector 6 are generally 5% to 15% wetter than optimum, and would require significant drying for use in embankments. It will be important to construct this section of the project during seasons where drying is possible.

Other soils along the route are generally 2% to 4% wetter than optimum, and are more readily dried if the earthworks are undertaken during appropriate seasons. An exception may be the materials along the splinter fault south of the Saddle, which may be wet. This area may require prior drainage by the drilling of drainage holes to drain the area.

Comparatively, fill from the excavated rock and coarse gravels from the Te Puka terrace east of SH1 at Paekakariki are likely to require wetting to facilitate compaction. These materials are generally able to be placed and compacted across a much longer construction season.

5.6.5 Sub-Base and Basecourse

Materials from some rock cuttings are likely to provide suitable sub-base and basecourse, and possibly concrete aggregate. Quality materials may be sourced from cuttings to the south of Cannons Creek.

5.6.6 Borrow Areas

There are a number of areas where selected materials could be borrowed from if required. Since the Greywacke along the route will be suitable for a number of purposes, both environmental and engineering considerations will determine the most appropriate borrow areas.

As noted above, the Greywacke south of Cannons Creek has potential for use as basecourse, and possibly concrete aggregate. It may be prudent to further investigate and consider forming a cutting with shallower slopes to win good quality rock.

5.7 Fill Sites

5.7.1 Disposal Philosophy

The philosophy proposed is to use surplus fill and unsuitable materials primarily for landscaping by:

- Disposing of surplus materials through placement on the flanks of fill embankments beyond the recommended structural fill envelope, to provide a more natural landscape;
- Utilising nearby fill sites to create landscape features;
- Identifying disposal areas close to the alignment, which can be developed and used without creating a hazard to either the highway, land owners or natural features such as watercourses, and where possible to create land suitable for farming or subdivision.

Alternatively, off-site disposal could be used where necessary, including offering materials for use by landowners where they have consent to fill.

It is considered that disposal on the flanks of the formation should be more fully considered during the next stage of project design.

6 Pavements

6.1 Sub-grade Characteristics

There are two types of pavement sub-grade:

- In-situ sub-grade, where the road formation is in-cut.
- Compacted fill sub-grade, where the road pavement is on a road embankment.

Where low in-situ California Bearing Ratio (CBR) values are predicted, there is the opportunity to undercut the weak materials and use gravel fill derived from Greywacke rock to improve subgrade strength and performance. Similarly, where fill materials have low subgrade strength; the upper 2m of a fill embankment can be formed in Greywacke rock gravel. These decisions will be based on the relative strengths of pavement materials, and the availability of good fill from borrow areas with the associated haul distances. Final design decisions will be a balance between cost and quality.

The in-situ CBR properties have been estimated from laboratory testing, materials type and properties, and experience. Representative preliminary CBR values are provided in Table 1.6 for the various materials likely to be encountered along the route.

Table 1.6 – Representative Pavement Subgrade CBR Values

Fill Sector	Embankment Fill Materials	Description	In Situ CBR (%)	Compacted CBR (%)
1	Dune Sand	Fine to medium sand	4	10
2	Pre-Holocene Gravel	Sandy Gravel with cobble, boulders	10	10
3 & 4	Wellington Greywacke / derived fill	Silty sandy Gravel	10	15
3 & 4	Fault disturbed Wellington Greywacke / derived fill	Gravelly sandy Silt and Clay	2 - 5	NA (not used for subgrade)
5 & 6	Pre-Holocene Alluvium	Clayey and sandy silt	2 - 5	9
8 & 9	Wellington Greywacke derived fill - completely weathered Greywacke	Silty sandy Gravel and Silty and Sandy Clay	4	7
8&9	Wellington Greywacke / derived fill	Silty sandy Gravel	10	15

6.2 Drainage

Pavement drainage is fundamental to the satisfactory performance of road pavements. Subsoil drains will be used to ensure pavements are drained and free of groundwater. This will be particularly important in areas of cut, where the groundwater level in the cutting could be high. A minimum subsoil drain depth of 1.5m would be appropriate.

6.3 Design

Pavement design will consider pavement construction alternatives. It may be appropriate to design the pavement for a limited number of in-situ CBR values, and to deal with local variability with undercuts, use of stronger subgrade layers, or use of subgrade improvement layers.

Pavement design will be based on the Austroads Pavement Design Manual 2004 (Austroads, 2004), its accompanying supplement for light traffic, and the 2007 Transit New Zealand supplement to the Austroads Pavement Design Manual (Transit, 2007).

The following assumptions have been made regarding traffic loading:

- Only heavy vehicles are considered; it is assumed that light vehicles do not make a significant contribution to pavement deterioration;
- Traffic growth is constant over the design period, at 0.7% per annum;
- Traffic composition remains constant over the design period, and HCVs are assumed to be 8.3% of total traffic volume;
- Total traffic volume is assumed to be 21,680 with a 50/50 directional split;
- The design period is assumed to be 25 years.

Based on the above assumptions, the design loading for the pavement is 6.54 million design-equivalent standard axles.

Typical compacted California Bearing Ratios (CBRs) for various sub-grades are shown in Table 1.6, and range from 7% to 15%. For the purposes of preliminary pavement design and costing, a sub-grade CBR of 8% has been assumed. This simplification will require more detailed design work at a later stage, when further materials information is available following additional geotechnical investigations.

The assumed 8% CBR and traffic loading characteristics result in a required overall unbound granular pavement depth of 370mm. If the assumed CBR is decreased to 7%, the pavement depth would increase to 400mm. If the assumed CBR is increased to 9%, the pavement depth would decrease to 350mm.

6.4 Surfacing

Surfacing design takes into account the following issues:

- Predicted traffic volumes and proportion of heavy vehicles;
- Predicted seal design life;
- Type of pavement being sealed;
- Predicted road noise generation and likely noise mitigation requirements;

- Existing road surface types where Transmission Gully connects to the existing network, and
- On-going maintenance and renewal.

Seal design is based on surfacing a flexible granular pavement in a 100km/h rural road setting. Predicted traffic volumes of up to 25,000 vehicles per day distributed over 4 traffic lanes indicate that a chip seal type surface is most appropriate as the default seal design. Exceptions to this are:

- Where high turning stresses occur on interchange roundabouts;
- Where there noise-sensitive environments require mitigation;
- Where short lengths of different pavement surfaces would provide a more consistent surface friction and surface appearance.

A two-coat chip seal surface has been assumed as the first coat seal. A seal life of between 2 to 4 years can be expected for this first coat. The second coat seal will depend on the performance of the first coat seal and subsequent detailed design. A single second coat seal may be suitable over much of the new road length.

Sections of Transmission Gully are on steep grades of up to 8%. These sections generally include crawler lanes for heavy vehicles. They are not expected to have excessively high stresses applied to the seal, because large radius horizontal curves have been used in the design. A chip seal surface will therefore be appropriate in these sections, with the possibility of using a modified bitumen binder, provided the final seal design takes the steep grade into account.

High stresses will occur at interchange roundabouts due to turning, and on connecting ramps from braking and acceleration. In these cases a structural asphaltic concrete surface is proposed.

Where noise-sensitive environments are identified, mitigation may be required to reduce noise to reasonable levels, in accordance with Transit's Noise Guidelines and Environmental Plan. A range of mitigation options are available, including quiet road surfacing. Where quiet road surfaces are required a single coat chip seal or open-graded porous asphalt (OGPA) will be considered.

The existing section of SH1 at Linden has an OGPA surface. This surface has been selected in part to minimise noise for nearby residents, and also because this road carries a high traffic volume. OGPA will be maintained over the length where Transmission Gully merges with SH1.

There is a relatively short distance between the merge/diverge point on SH1 and the Kenepuru Interchange. Because of this relatively short distance in a noise-sensitive area, and the desire to avoid short lengths of different seal types, the OGPA surface has been assumed to continue to the north side of the Kenepuru Interchange. Similarly an OGPA surface has been assumed for the Kenepuru Interchange ramps and the link road to Kenepuru Drive.

7 Traffic Services

7.1 Signage

Signage will be in accordance with MOTSAM Parts I and III (Transit New Zealand, 2004). Destination and lane-selection signage will be a combination of overhead gantries, flag signs and ground-mounted signs, with map signs used at major intersections.

7.2 Lighting

Lighting design will comply with AS/NZS 1158:2005 (Standards New Zealand and Standards Australia, 2005) to a V3 category, which is appropriate for expressways with no property access carrying high volumes of traffic at high speeds.

Lighting has been allowed for at interchanges and between closely spaced interchanges as follows:

- MacKays Crossing south to the ramps connecting to the existing SH1 near Paekakariki;
- Between SH58 and the James Cook Interchange;
- Between the Kenepuru Interchange and the connection to the existing SH1 at Linden.

7.3 Barrier Protection

All barrier design, end treatments and transitions will be in accordance with the latest versions of the following documents:

- Transit M/23:2000 Guide for Road Safety Barrier Systems;
- NZS 3114:1987 Concrete Surface Finishes;
- AS/NZS 3845:1999 Road Safety Barrier Systems;
- NCHRP Report 350 - Recommended Procedures for the Safety and Performance Evaluation of Highway Features (NCHRP 350);
- State Highway Geometric Design Manual (SHGDM);
- Transit Bridge Manual, September 2004 Revision.

Central median barriers will be wire rope to NCHRP Report 350 Test Level 3 (TL3) or NJB concrete barriers (or similar) to TL4 as specified in Transit M/23.

Test Level 5 side barriers will be concrete barriers of the “F” type, to a height of 810mm, with a tubular rail to provide a total barrier height of 1260mm.

Test Level 3 Side Barriers will be of the W-Section guardrail type.

8 References

Civil Defence Emergency Management (CDEM) Act. (2002).

SKM. 2008. Wellington Transport Strategy Model (WTSM) Update 2006 Baseline Forecasting Report.

NZ Transport Agency. (2010). Manual of Traffic Signs and Markings (MOTSAM) Part I Traffic Signs and Part III Motorways and Expressways.

Transit New Zealand. (2001). Draft State Highway Geometric Design Manual. (GDM).

Austroads (1988). Austroads Guide to Traffic Engineering Practice Part 2 – Roadway Capacity.

Austroads. (1993). Manual of Traffic Signs and Markings Guide to Traffic Engineering Practice: Part 6 – Roundabouts.

Austroads. (2003). A Guide to the Geometric Design of Rural Roads.

Austroads. (2002). Urban Road Design Guide.

Austroads. (2004). Austroads Pavement Design Manual.

Transit New Zealand. (2007). Supplement to Austroads Pavement Design Manual.

Standards Australia and Standards New Zealand. (2005). AS / NZS 1158 Road lighting

OPUS