Acoustics Assessment

Transmission Gully Project

Technical report 12

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Prepared for

NZ Transport Agency and Porirua City Council

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F	31/03/11	Minor revisions
G	20/05/11	Minor revisions, CNVMP updated and moved, bridge numbers updated
H	26/07/11	Blasting airblast and vibration added

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Introduction

This report documents the assessment of road-traffic and construction sound and vibration for the Transmission Gully Project, including both the Main Alignment and Link Roads. For each of these acoustics topics this report provides details of: the criteria adopted, an assessment of existing and future conditions, and proposed mitigation where appropriate.

Criteria

For different aspects of the sound and vibration assessment a range of different criteria are discussed. The following standards which all contain guideline sound and vibration levels are adopted as representing good practice:

- Road-traffic sound – NZS 6806:2010
- Road-traffic vibration – NS 8176E:1995
- Construction sound – NZS 6803:1999
- Construction vibration – BS 5228-2:2009
  - Blasting – AS 2187-2:2006

In addition to these main parts of the assessment, engine braking sound has been assessed with reference to the maximum noise limit in NZS 6802:2008 and the Transit Noise Guidelines.

The conditions associated with the old designation have not been used as the assessment methodology and standards have been updated.

Existing environment

An extensive sound survey is presented including measurements at representative locations along the entire route. Near existing roads the existing sound levels are controlled by those roads, but in the more remote areas natural sounds dominate. All areas have typical sound levels for those environments. The sound from existing State highways was also modelled, and found to correlate well with measurements near those roads.

Vibration levels by State Highway 1 in Linden were measured at a range of distances from the road. Levels were found to be relatively low due to the good condition of the road surface and local geology.

Modelling

An extensive acoustics computer modelling exercise has been undertaken using an assessment year of 2031, 10 years after the planned opening of the Project. The modelling includes the scenario without the Project (do-nothing) the scenario with the Project (do-minimum) and various noise mitigation options.

Predictions of construction sound and vibration levels have been undertaken for typical construction activities anticipated at a range of representative distances.

Road-traffic vibration predictions have been made and compared to the existing measured vibration levels at Linden.

Design and mitigation

An extensive noise mitigation options assessment has been undertaken in accordance with the method set by NZS 6806. For each area of the Project a number of options have been developed and assessed by all relevant members of the project team to determine the best practicable option for noise mitigation. This process involved circulation of options and a workshop to review each team member's assessment. NZS 6806 has fundamentally changed the way in which noise mitigation measures are designed. Rather than dogmatic adherence to a specific noise limit, regardless of practicality or adverse effects such as shading by barriers, NZS 6806 promotes an integrated design process to establish the best practicable option. NZS 6806 requires significantly more design work during the acoustics assessment, and consequently the noise mitigation is more refined at this stage in the project.

For the majority of the Project no specific noise mitigation was found to be required, other than a short section of bund. Around Linden there are both low noise road surfaces and extensive noise barriers, to control road-traffic sound to within reasonable levels. In three instances building-modification mitigation is proposed.

Standard NZTA processes for road maintenance are considered to provide appropriate control of road-traffic vibration.

Construction sound and vibration requires a range of standard good practice management and control measures. These are outlined in the report and detailed in a draft management plan.

Assessment of acoustics effects

The Project has been found to increase road-traffic sound levels throughout the project area. There will be a significant change in acoustics amenity in areas remote from existing roads, but the road-traffic sound will be at reasonable levels defined by NZS 6806. This change in amenity has been signalled by the existing designation. At the interchanges with the existing State highways and local roads there will be an increase in noise levels, but with the mitigation proposed this will again be at a reasonable level defined by NZS 6806.

Engine braking sound levels on downhill gradients steeper than 4% are within the recommended limits.

Road-traffic vibration levels will increase at Linden where the road is moved slightly closer to houses, but levels will remain within the thresholds in NS 8176E.

The majority of the construction activity is remote from residential areas and while construction sound may be audible it will be controlled to within reasonable levels, defined by NZS 6803, with good practice construction noise management. This will be achieved through the use of a construction noise management plan. At Linden and other areas with houses closer to construction works there is the potential for greater construction sound and vibration effects, due to the proximity of neighbours and the likely need for some night-works. Additional control measures have been proposed such as the early construction of road-traffic noise barriers and increased communications with neighbours. Construction traffic on local roads is to be minimised by the potential programming and use of remote parking and shuttle buses for staff transport, which will be detailed in a construction traffic management plan.

Conclusions

The Transmission Gully Project has significant potential road-traffic and construction sound and vibration effects. All aspects of these potential effects have been investigated. Road-traffic noise mitigation measures have been proposed where required, and construction sound and vibration management and control measures have been identified. With the mitigation proposed, all road-traffic and construction sound and vibration should be restricted to within reasonable levels, defined by the relevant standards.

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 State Highway 1 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 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 and will be approximately 600 m long. 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 assessment

This report presents the findings of the acoustics (sound and vibration) assessment conducted by URS as part of the environmental assessment of the Project.

The purpose of the acoustics assessment was to:

- Measure existing sound levels,
- Predict and assess future road-traffic sound levels,
- Measure, predict and assess road-traffic vibration,
- Predict and assess construction sound and vibration, and
- Determine measures required to avoid, remedy or mitigate potential construction and operational noise and vibration effects.

A comprehensive study has been undertaken to address this scope and is presented in this report. The work was conducted between January 2010 and March 2011.

This acoustics assessment considers the whole project including both the Main Alignment and Link Roads, although the Main Alignment could be constructed without or prior to the Porirua Link Roads.

Without the Link Roads, there would be less traffic than modelled on the Main Alignment. This would result in slightly lower road-traffic sound levels, and therefore the assessment in this report and noise mitigation options would remain valid.

The construction periods would change if the two parts of the Project did not proceed simultaneously, but the local construction activities at any particular location within the scheme would not be significantly affected. Therefore the assessment of construction sound and vibration also remains valid regardless of the timing of the two parts of the Project.

This report is part of a suite of documents in support of the notices of requirements for designations and applications for resource consents for the Project.

Criteria

2.1 Receivers

This assessment has considered all noise sensitive locations (receivers) within certain distances of new or altered roads associated with the Project. In accordance with NZS 6806[1] these are known as Protected Premises and Facilities (PPFs), and include existing houses, schools, the marae and various other locations defined in the Standard. The distance from the road within which PPFs are considered is set in NZS 6806 as:

- Urban areas – 100 metres from the edge of the nearside traffic lane
- Rural areas – 200 metres from the edge of the nearside traffic lane

The extents of rural and urban areas are defined by Statistics New Zealand[2]. Under this definition, the Greater Wellington urban area encompasses all of the project area to the south of Battle Hill. Therefore the 100 metre distance is used in all locations other than at the north of the scheme around MacKays Crossing where the 200 metre distance is used. Outside of these areas there are no PPFs that require assessment.

These distances provide practical criteria to ensure the assessment is made at the most relevant receivers. Potential noise effects are still controlled at receivers further away by virtue of noise criteria applying at receivers nearest to the road.

The selection of receivers described above is on the basis of road-traffic noise assessment. Compared to road-traffic sound, operational and construction vibration effects are only relevant closer to the road, and therefore the same receivers are also appropriate for vibration assessment.

For construction sound the potential effects could extend further, particularly for any night-time works. While receivers within 200 metres of the road in the rural area or 100 metres of the road in urban areas still control the construction noise assessment, some more distant receivers have been considered, where there are no receivers nearer to the works.

In accordance with NZS 6806, future (unbuilt) PPFs are not considered in this assessment, unless they are consented. The Project planning consultants checked with all district councils in February/March 2011 and confirmed that there have been no building consents issued for future PPFs additional to those included in this assessment. Any new PPFs arising prior to the hearing for the Project will be addressed in acoustics evidence at the hearing.

Two structures of historic interest have been specifically identified for assessment of vibration: St Josephs Church by State Highway 58 and a brick containment vessel in the Te Puka valley.

2.2 Road-traffic sound

2.2.1 General traffic

Due to the long gestation of the Project, several criteria for road-traffic noise could be considered:

- The designation conditions from the existing Transmission Gully Project designation[3],
- Agreement between Transit and the Tawa Community Board[4],
- Transmission Gully Scheme Assessment Report (SAR)[5],

[1] NZS 6806:2010, Acoustics – Road-traffic noise – New and altered roads
[2] New Zealand: An urban/rural profile, Statistics New Zealand
[3] Decisions on commissioners' recommendations on requirements for the proposed Transmission Gully Motorway and Kenepuru Link, Transit New Zealand, 12 September 1997
[4] Agreement, Transit New Zealand, Tawa Community Board, August 2002
[5] Contract 236PN Transmission Gully: Scheme assessment, Noise assessment, Opus, February 2009

2 Criteria

- Transit Guidelines[6],
- NZS 6806:2010 Acoustics – Road-traffic noise, and
- Silverwood subdivision noise assessments[7,8].

Existing designation conditions

The existing designation conditions are relatively complex and, as discussed in detail in the SAR, they do not represent current good practice. It appears that the designation conditions were based on a specific mitigation option rather than an actual performance requirement, but they were then written as performance requirements. The conditions also give rise to anomalies due to a step change in requirements depending on existing sound levels. The conditions only apply to receivers built before 12 July 1996.

It is proposed that the Transmission Gully Project will now be authorised by a new designation and therefore the existing conditions no longer apply. Given the deficiencies identified with these conditions, they have not been used as a basis for this assessment, or for conditions proposed for the new designation.

Tawa Community Board agreement

During appeals on the existing designation an agreement was reached between Transit and the Tawa Community Board. This agreement required Transit to provide various measures such as safety barriers south of the Linden interchange, some of which have already been implemented. In addition to any performance requirements determined in this assessment, barriers in this area will need to comply with the agreement.

Scheme Assessment Report (SAR)

The SAR was written on the basis that the existing designation conditions would remain. However, recognising that this did not apply to receivers built after 12 July 1996, the SAR proposed additional targets for those locations. This approach is no longer required as for a new designation consistent criteria should be applied to all receivers. In any event, the criteria from NZS 6806 discussed below are similar to the targets proposed in the SAR.

The SAR and original designation conditions were written in terms of 'façade' sound levels. This is the sound level one metre in front of a building, including sound reflected from the building. The method for assessing road-traffic sound has been changed by NZS 6806, and now the 'free-field' sound level is used, which relates solely to the level incident on a building with no additional reflections. All sound levels in this report are given as free-field levels. For comparison with levels quoted in the SAR, the free-field levels in this report should be increased by +2.5 dB.

Transit Guidelines

The Transit Guidelines had been the basis for road noise assessment in New Zealand for over a decade. A weakness of the Guidelines was that they focus simply on achieving a specific sound level. There was little consideration required as to what mitigation is practicable in the circumstances, or of potential adverse effects from excessively high noise barriers for example. The assessment method

[6] Transit New Zealand's Guidelines for the Management of Road Traffic Noise. 1999
[7] Traffic noise assessment, Silverwood residential subdivision development stage 2, Malcolm Hunt Associates, July 2008
[8] Acoustic report – Silverwood subdivision (stage 2) Whitby, Wellington, Malcolm Hunt Associates, April 2005

2 Criteria

used by the NZTA for sound from new and altered roads changed in 2010 from the Transit Guidelines to NZS 6806:2010.

The main criterion in the Transit Guidelines was an average noise design level. However, unlike NZS 6806, the Transit Guidelines also referred to a single event noise design level of 75 dB L_{AFmax}, without a façade reflection. This criterion was designed to protect sleep. NZS 6806 explicitly excludes maximum noise criteria on the basis that peaks of sound are determined by emissions from individual vehicles, which are beyond the control of the roading authority. Therefore, this assessment does not consider single event levels, other than engine braking discussed in section 2.2.2, where the maximum value from the Transit Guidelines is used as a reference.

NZS 6806:2010

The current criteria and assessment method for road-traffic sound are set out in NZS 6806:2010. The method provides performance targets and requires assessment of a number of different options for noise mitigation (often including barriers). These options are subject to an integrated design process in which the costs and benefits are considered. For this project the following noise criteria from NZS 6806 are applicable:

Table 12-1 NZS 6806 noise criteria

Category	Criterion	Altered roads	New road
A	Primary	64 dB $L_{Aeq(24h)}$	57 dB $L_{Aeq(24h)}$
B	Secondary	67 dB $L_{Aeq(24h)}$	64 dB $L_{Aeq(24h)}$
C	Internal	40 dB $L_{Aeq(24h)}$	40 dB $L_{Aeq(24h)}$

For the Transmission Gully Project the altered road criteria apply for all receivers at the intersections with the existing State Highway 1, State Highway 58, Kenepuru Drive, Warspite Avenue and James Cook Drive. Beyond 100 metres from these intersections the new road criteria apply, other than at MacKays Crossing where the distance is 200 metres.

Noise mitigation options are to be assessed, and if practicable, the category A criterion should be achieved. If this is not practicable then mitigation should be assessed against category B. However, if it is still not practicable to comply with categories A or B then mitigation should be implemented to ensure the internal criterion in category C is achieved. Depending on the specific building, mitigation in category C could include ventilation and/or sound insulation improvements ranging from upgraded glazing through to new wall and ceiling linings. In category C there is no protection of outdoor amenity. The NZS 6806 criteria are consistent with the NZTA Environmental Plan[9].

NZS 6806 provides a procedure for assessing the benefits and costs of mitigation options to help determine the Best Practicable Option.

The criteria apply to a design year 10 to 20 years after the completion of the new or altered road. In this case the design year has been taken as 2031 and all sound predictions in this report relate to predicted traffic volumes in 2031.

[9] Environmental Plan, version 2, Transit New Zealand. June 2008

The criteria in NZS 6806 are set to be reasonable taking into account adverse health effects associated with noise on people and communities, the effects of relative changes in noise levels, and the potential benefits of new and altered roads.

Silverwood

The developers of the Silverwood subdivision entered into an agreement with the NZ Transport Agency to address potential reverse sensitivity effects. As part of this agreement there have been two acoustics assessments undertaken for different stages of the Silverwood subdivision, considering the effects of road-traffic sound from the Main Alignment. For the first stage of the subdivision the sound insulation design of houses is based on a predicted 62 dB $L_{Aeq(24h)}$ contour from road-traffic on the Main Alignment. For the second stage, rather than a contour there are (façade) sound levels predicted at specific house sites within 100 metres of the Main Alignment. For stage one the internal levels in houses are to be limited to 38 dB $L_{Aeq(24h)}$, and for stage two internal levels were to be designed to 35 dB $L_{Aeq(24h)}$ in bedrooms and 40 dB $L_{Aeq(24h)}$ in other habitable spaces.

Summary

The main criteria for road-traffic sound will be from NZS 6806. Account will be taken of the reverse sensitivity agreement with the Silverwood subdivision, and also the barriers agreed with the Tawa Community Board.

2.2.2 Engine braking

Some trucks have audible engine/exhaust brakes, which can be in the order of 10 dB louder than trucks without such brakes. This issue is generally not considered on a project basis as it requires action at a national level to influence the vehicle fleet. However, the Project has numerous sections with relatively steep gradients and therefore engine braking has been considered in this instance. An assessment has been made for all sections of the Project where road gradients are greater than 4%.

As noted above, the Transit Guidelines include a 75 dB L_{AFmax} single event noise design level. This is identical to the night-time noise limit suggested in NZS 6802[10], and has been adopted as a criterion for assessing engine braking sound in this project.

2.3 Road-traffic vibration

Vibration has not historically been assessed on many road schemes in New Zealand. There are no standardised criteria. There are International Standards that relate to vibration in general, but few that relate specifically to road-traffic vibration.

Vibration has been identified as a potential effect that requires assessment for the Project. A relevant vibration assessment Standard that has been used in New Zealand and that is referenced in the NZTA Environmental Plan is Norwegian Standard NS 8176[11]. This Standard provides methods for measuring vibration from road-traffic and also contains guideline criteria.

[10] NZS 6802:2008, Acoustics – Environmental noise
[11] NS 8176.E:2005, Vibration and shock – Measurement of vibration in buildings from landbased transport and guidance to evaluation of its effects on human beings

NS 8176 allows for vibration to be assessed as either acceleration or velocity, and, for ease of measurement, velocity has been used. The Standard also defines a procedure to determine the statistical maximum weighted velocity $v_{w,95}$, which is the parameter adopted in this report.

In Appendix B to NS 8176 there are classes of vibration criteria defined, relating to different degrees of annoyance. Class C is recommended when planning and building new transport infrastructure, and corresponds to a level where about 15% of people can be expected to be disturbed by vibration. This has been adopted for the Project and the resulting vibration criterion is $v_{w,95}$ 0.3 mm/s. However, at Linden where houses are affected by existing road-traffic vibration Class D (disturbance to 25% of people) may be appropriate which has a criterion of $v_{w,95}$ 0.6 mm/s.

For road-traffic vibration to affect buildings and cause cosmetic or structural damage the thresholds are an order of magnitude higher than the criteria for human perception, even when considering historic buildings. Therefore, consideration of the human perception limits will also address building damage.

2.4 Construction

2.4.1 Sound

There are existing designation conditions addressing construction sound, but as for road-traffic sound, these conditions do not automatically apply to the new designation. As the existing conditions reference an outdated provisional Standard, this assessment is instead based on the current construction sound Standard NZS 6803:1999[12].

NZS 6803 contains guideline noise limits which are shown in Table 12-2. However, in many instances it is not practicable to meet these limits. For certain works on the existing State highways, daytime closures will not be possible and some works will have to be conducted at night due to high traffic volumes and potential delays due to road works. It is unlikely that the guideline night-time noise limits could be achieved at nearby residential receivers. Also, where daytime works are very close to receivers there may be times when it is not practicable to comply with the limits. In such cases construction sound should still be managed to reasonable levels through construction best practice, such as reducing the sound of reversing alarms on trucks, but also greater emphasis will be needed on effective stakeholder engagement.

[12] NZS 6803:1999, Acoustics – Construction noise

2 Criteria

Table 12-2 Guideline construction noise limits

Time of week	Time period	Duration of construction work at any one location					
		less than 2 weeks		less than 20 weeks		more than 20 weeks	
		$L_{Aeq(1h)}$	L_{AFmax}	$L_{Aeq(1h)}$	L_{AFmax}	$L_{Aeq(1h)}$	L_{AFmax}
Residential							
Weekdays	0630-0730	65 dB	75 dB	60 dB	75 dB	55 dB	75 dB
	0730-1800	80 dB	95 dB	75 dB	90 dB	70 dB	85 dB
	1800-2000	75 dB	90 dB	70 dB	85 dB	65 dB	80 dB
	2000-0630	45 dB	75 dB	45 dB	75 dB	45 dB	75 dB
Saturdays	0630-0730	45 dB	75 dB	45 dB	75 dB	45 dB	75 dB
	0730-1800	80 dB	95 dB	75 dB	90 dB	70 dB	85 dB
	1800-2000	45 dB	75 dB	45 dB	75 dB	45 dB	75 dB
	2000-0630	45 dB	75 dB	45 dB	75 dB	45 dB	75 dB
Sundays and public holidays	0630-0730	45 dB	75 dB	45 dB	75 dB	45 dB	75 dB
	0730-1800	55 dB	85 dB	55 dB	85 dB	55 dB	85 dB
	1800-2000	45 dB	75 dB	45 dB	75 dB	45 dB	75 dB
	2000-0630	45 dB	75 dB	45 dB	75 dB	45 dB	75 dB
Industrial and commercial							
All days	0730-1800	80 dB	-	75 dB	-	70 dB	-
	1800-0730	85 dB	-	80 dB	-	75 dB	-

For the Transmission Gully Project, the NZS 6803 guideline limits apply where practicable. These are set as reasonable limits for construction noise, also providing protection of sleep. In cases where compliance is not practicable, alternative control methods are identified in this assessment.

Criteria for sound (airblast) from blasting rock is addressed in the following section together with vibration from blasting.

2.4.2 Vibration

As for road-traffic vibration, there are no standardised criteria in New Zealand for construction vibration. A German Standard (DIN 4150-3) is often referenced in New Zealand for building damage criteria, but for this assessment the criteria in British Standard BS 5228-2:2009[13] are used as they cover building damage, damage to other objects and human perception. The main issue for daytime construction vibration is building damage. Table 12-3, Table 12-4 and Table 12-5 give a summary of the BS 5228-2 criteria. Vibration levels are given as the peak particle velocity. BS 5228-2 also provides guidance for vibration affecting sensitive electronic instruments. However, there are no receivers near the Project where this is known to be relevant.

[13] BS 5228-2:2009, Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration

Table 12-3 Human response to construction vibration

Vibration level	Response
0.14 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 mm/s	Vibration might be just perceptible in residential environments.
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.
10.0 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level.

Table 12-4 Transient vibration guide values for cosmetic building damage

Building type	Peak component particle velocity in frequency range of predominant pulse, at base of building
Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4Hz and above
Unreinforced or light framed structures Residential or light commercial buildings	(maximum displacement of 0.6mm below 4 Hz) 15 mm/s at 4 Hz, 20 mm/s at 15 Hz, 50 mm/s at 40 Hz and above

*Guide values would be reduced for continuous rather than transient vibration

Table 12-5 Vibration guide levels for other structures

Structure	Peak particle velocity
Retaining walls – slender and potentially sensitive masonry walls	10 mm/s at toe 40 mm/s at crest (reduced for continuous vibration)
Underground services	30 mm/s transient vibration 15 mm/s continuous vibration

Blasting

Guideline criteria for airblast and vibration from blasting are provided in Australian Standard AS 2187-2:2006[14], which is referenced by NZS 6803.

[14] AS 2187-2:2006, Explosives – Storage and use – Use of explosives

Existing environment

3.1 Overview

Unlike previous standards, the criteria in NZS 6806 to assess road-traffic sound are not dependent on the existing sound levels. Measurements of existing levels are therefore not required to determine the criteria. However, an appreciation of the existing environment is required to judge the potential road-traffic and construction noise effects. Therefore, the existing environment has been assessed in detail through both modelling and measurements.

The Project is in a wide variety of different environments ranging from built-up to open areas. To obtain a reasonable representation of the sound environment in each of these different areas has required measurements at a large number of receivers along the route. This has included measurements at some locations over a number of days to capture temporal variations, and also spot measurements at a larger number of locations to capture spatial variations. Reference has also been made to sound monitoring conducted for the SAR.

For the existing State highways at the three intersections with the Main Alignment, acoustics computer modelling has been used to predict existing road-traffic sound levels to supplement measurements. This also forms the basis for comparisons with modelling of the Project.

The last aspect of quantifying the existing environment has been measurements of road-traffic vibration. This has been conducted in Linden where the Main Alignment will be closest to receivers. The measurements serve both to assess existing road-traffic vibration and also to validate the theoretical prediction model used for future road-traffic vibration.

3.2 Sound survey

3.2.1 Procedure

Four noise loggers were used over a period of approximately two months with each logger being located at a different receiver each week. Loggers were configured to continuously make consecutive fifteen minute measurements. A portable sound analyser was used to conduct ‘spot’ fifteen minute daytime measurements at additional positions while the loggers were being redeployed each week. During these times observations were made to identify dominant sound sources. All measurements were selected to be free-field where possible.

The measurements were conducted in general accordance with NZS 6801[15]. Measurement and calibration details required by that Standard are held on file by URS.

Equipment

The following instrumentation was used for the survey:

- Four Acoustical Research Laboratories Type EL316 noise loggers, and
- One Brüel & Kjær Type 2250 sound level analyser.

[15] NZS 6801:2008, Acoustics – Measurement of environmental sound

3 Existing environment

Meteorological conditions

During the survey, meteorological data was obtained from existing weather stations in the general area, as shown in Table 12-6.

Table 12-6 Weather stations

Location	Operator	Data
Tawa	Greater Wellington Regional Council	Wind speed, wind direction, temperature, pressure, humidity, rainfall
Seton Nossiter Park	Greater Wellington Regional Council	Rainfall
Whitby	Private	Wind speed, wind direction, temperature, pressure, humidity
Mana Island	MetService	Wind speed, wind direction, temperature, humidity, rainfall
Paraparaumu Airport	MetService	Wind speed, wind direction, temperature, pressure, humidity, rainfall

The meteorological data from all of these weather stations has been used to identify periods when conditions were likely to have been outside the meteorological restrictions in NZS 6801, and these periods have been excluded from the sound analysis. The timing of the survey from January to March, which generally coincides with favourable weather conditions in terms of reduced wind speed and rainfall, minimised the quantity of sound data that had to be excluded.

Traffic data

For measurements dominated by road-traffic sound from existing State Highways 1 and 58, to provide a level representative of the average exposure over the year, the results have been adjusted to account for the actual traffic flow during the survey. This has been done by using the daily traffic counts from the nearest permanent count station and adjusting the sound measurements to correspond to the 2009 Annual Average Daily Traffic (AADT).

Analysis

There is a natural variation in the acoustic environment throughout the day, and often significant variation between days. Areas close to traffic sources generally have a more consistent sound profile than locations dominated by natural sounds. Each day’s data was analysed and abnormal events excluded. For example, events like a neighbour mowing the lawn will result in a clear ‘spike’ in the sound levels, and while the exact source is not identifiable, it is clearly not road-traffic. The $L_{Aeq(24h)}$ was then calculated for each day where there is sufficient data after bad weather and abnormal events are excluded. For unattended logger measurements, the arithmetic average $L_{Aeq(24h)}$ over all valid days has been used. All data from each noise logger location has been averaged to obtain the $L_{Aeq(24h)}$ sound level at that location.

For spot measurements, the daily variations in sound levels at nearby noise logger locations have been used to estimate the $L_{Aeq(24h)}$ sound level.

A discussion of the measurement uncertainty is provided in section 3.2.3.

3.2.2 Results

The results of the sound survey are listed in Table 12-7, with a description of the observed environment. In the case of unattended loggers, the notes about the sound environment should only be taken as a guide, as observations were only made at the start and end of the measurement cycle.

Table 12-7 Sound survey results

Dates	Address	Type	$L_{Aeq(24h)}$	Notes
26/01/2010	306 SH1	Spot	60	Traffic (dominant), cicadas, dogs barking
26/01/2010	378 SH1	Spot	53	Traffic (dominant), cicadas, planes
26/01/2010	330 SH1	Spot	52	Cicadas (dominant), traffic
26/01/2010	516 Paekakariki Hill Road	Spot	46	Cicadas (dominant), traffic, birds
3/02/2010	347 SH1	Spot	57	Traffic (dominant), cicadas, birds
3/02/2010	370 SH1	Spot	53	Cicadas (dominant), traffic, sheep, birds, plane, dog bark
3/02/2010	SAR ref 6 SH1	Spot	56	Cicadas (dominant), traffic
3/02/2010	SAR ref 9 Paekakariki Hill Road	Spot	47	Cicadas (dominant), traffic, birds
3/02/2010	504B Paekakariki Hill Road	Spot	41	Cicadas (dominant), traffic, birds
3/02/2010	528 Paekakariki Hill Road	Spot	47	Cicadas (dominant), traffic (dominant when present), birds
11/02/2010	462 Paekakariki Hill Road	Spot	43	Birds and trees (dominant), horses, cicadas, traffic
11/02/2010	436A Paekakariki Hill Road	Spot	39	Trees (dominant), cicadas, birds, traffic
11/02/2010	436E Paekakariki Hill Road	Spot	38	Cicadas (dominant), trees, birds
15/02/2010	Adjacent 19 The Mainsail	Spot	46	Cicadas (dominant), traffic, birds
15/02/2010	247B Flightys Road	Spot	54	Cicadas (dominant), chainsaws, birds
15/02/2010	247 Flightys Road	Spot	43	Cicadas (dominant), chainsaws, birds
15/02/2010	247C Flightys Road	Spot	40	Chainsaws (dominant), birds, cicadas, plane
15/02/2010	317 Flightys Road	Spot	53	Chainsaws (dominant), trucks, cicadas, birds
15/02/2010	Opposite 66 Spyglass Lane	Spot	50	Cicadas (dominant), birds, heavy machinery
23/02/2010	412 Flightys Road	Spot	45	Cicadas (dominant), trees, birds, plane
23/02/2010	390 Flightys Road (top)	Spot	44	Cicadas (dominant), trees, birds, logging trucks
23/02/2010	390 Flightys Road (bottom)	Spot	45	Cicadas (dominant), trees, birds, logging trucks
23/02/2010	53A Paremata-Haywards Road	Spot	43	Traffic (dominant), cicadas, birds, trees
23/02/2010	75B Paremata-Haywards Road	Spot	43	Cicadas (dominant), traffic, birds, plane
23/02/2010	75E Paremata-Haywards Road	Spot	54	Cicadas (dominant), traffic, birds, plane
23/02/2010	450 Flightys Road	Spot	47	Cicadas (dominant), birds, trees
23/02/2010	350 Flightys Road	Spot	47	Cicadas (dominant), birds, trees, chainsaws

3 Existing environment

Dates	Address	Type	$L_{Aeq(24h)}$	Notes
23/02/2010	344A Flightys Road	Spot	44	Wind in trees (dominant), birds, cicadas, chainsaws, dogs
23/02/2010	328 Flightys Road	Spot	43	Cicadas (dominant), birds, trees, chainsaws
3/03/2010	Porirua Park Mungavin Avenue	Spot	53	Traffic (dominant), birds, occasional dogs, trees and planes
3/03/2010	Cheshire Street Playground	Spot	45	Cicadas (dominant), trees, birds, traffic, chainsaw
3/03/2010	Arahura Crescent Playground	Spot	45	Cicadas and birds (dominant), traffic dominant when present, occasional dogs, people, cows, music, rubbish truck and chainsaw
11/03/2010	Bluff Road Reserve	Spot	51	Cicadas (dominant), traffic, trees, birds, train, planes
11/03/2010	Opposite 9 Bluff Road	Spot	55	Traffic (dominant), lawn mower (sometimes dominant), cicadas, trees
11/03/2010	Mahoe Park	Spot	57	Traffic (dominant), cicadas, trees
11/03/2010	Arthur Carman Park	Spot	50	Traffic (dominant), cicadas, trees, plane
11/03/2010	Kowhai Park	Spot	53	Traffic (dominant), trees, cicadas, birds, plane, train dominant at 12:02-04
11/03/2010	Wall Park	Spot	53	Traffic (dominant), cicadas, trees, trains
11/03/2010	Woodman Drive Reserve	Spot	53	Traffic (dominant), birds, plane
19/03/2010	Adjacent to 38 Mexted Terrace	Spot	53	Traffic (dominant), birds, cicadas, trees
19/03/2010	Gillies Place Playground	Spot	45	Cicadas (dominant), traffic, birds, trees, plane
19/03/2010	Ernest Street Reserve	Spot	57	Birds and trees (dominant), plane, cicadas, traffic (dominant when present)
19/03/2010	Takapu Road (east end)	Spot	42	Cicadas (dominant), trees, birds
12/03/2010 – 18/03/2010	1 Raroa Terrace	Logger	53	Cicadas, traffic, trees
12/03/2010 – 18/03/2010	11 Rangatira Road	Logger	50	Cicadas, birds, horses, traffic
24/02/2010 – 02/03/2010	130 Warspite Avenue	Logger	45	Cicadas (dominant), traffic, trees
24/02/2010 – 02/03/2010	14 Carnevon Place	Logger	51	Trees, cicadas, people
16/02/2010 – 17/02/2010	18 Japonica Crescent	Logger	59	Traffic, cicadas, trees
16/02/2010 – 22/02/2010	207 Flightys Road	Logger	48	Cicadas, birds, power tools from adjacent paddock
24/02/2010 – 02/03/2010	298C Paekakariki Hill Road	Logger	55	Cicadas, birds, trees, lawn mower
12/03/2010 – 18/03/2010	30 Mexted Terrace	Logger	49	Traffic
26/01/2010 – 03/02/2010	324 SH1	Logger	54	Cicadas, traffic
04/03/2010 – 10/03/2010	34 Tremewan Street	Logger	58	Traffic, cicadas

Dates	Address	Type	$L_{Aeq(24h)}$	Notes
27/01/2010 – 02/02/2010	366 SH1	Logger	55	Cicadas, birds, traffic
16/02/2010 – 22/02/2010	394 SH1	Logger	57	Cicadas, traffic
16/02/2010 – 22/02/2010	436 East Paekakariki Hill Road	Logger	50	Cicadas, other insects
04/03/2101 – 10-03/2010	5 Bluff Road	Logger	53	Traffic, cicadas, birds, trees
19/03/2010 – 29/03/2010	500 Takapu Road	Logger	43	Cicadas, birds, trees, intermittent local traffic
04/02/2010 – 10/02/2010	504a Paekakariki Hill Road	Logger	52	Traffic, cicadas
04/02/2010 – 10/02/2010	510 Paekakariki Hill Road	Logger	46	Trees, traffic, cicadas, birds
04/02/2010 – 10/02/2010	525 SH1	Logger	52	Traffic, cows
24/02/2010 – 02/03/2010	53B Paremata-Haywards Road	Logger	53	Cicadas, trees, traffic (SH58), birds
04/03/2010 – 10/03/2010	6 Matai Street	Logger	56	Traffic (dominant), cicadas
16/02/2010 – 22/02/2010	66 Exploration Way	Logger	42	Birds, traffic
19/02/2010 – 29/03/2010	66 Tremewan Street	Logger	55	Traffic, cicadas, birds, trees
19/03/2010 – 24/03/2010	88 Ernest Street	Logger	48	Cicadas, traffic

3.2.3 Discussion

By performing a measurement, the true value of a parameter is only known to within a measurement uncertainty. An uncertainty budget is presented in Table 12-8 for the sound survey, based on the methodology proposed by Craven and Kerry[16].

It is also important to recognise the contributions of other sound sources, particularly cicadas. The sound survey was scheduled during January to March to minimise the effect of rain, however this is the peak season for cicadas. As cicada noise is predominantly high frequency, it is possible to identify sites where cicada noise was significant. Figure 12-1 shows the high-frequency contributions of the 45 spot measurements. The x-axis shows the level with high frequencies excluded (i.e. without cicadas), and the y-axis shows the increase when the high frequencies are added back on (i.e. with cicadas). From this we conclude that for the majority of sites the contribution was less than 2 dB, and for a smaller proportion, sound levels increase by over 10 dB due to high-frequency contributions. The increases in sound levels are more pronounced in areas with a lower background sound level. When considering existing levels, all measurements in an area near a receiver have been considered and the higher levels likely to be influenced by cicadas have been excluded.

[16] N.J. Craven and G. Kerry. *A good practice guide on the sources and magnitude of uncertainty arising in the practical measurement of environmental noise.* University of Salford. 2001.

Table 12-8 Measurement uncertainty budget

Source of uncertainty	Value (half width)	Conversion	Distribution	Standard uncertainty
Source				
Traffic flow	1000 in 22000	0.2 dB	Rectangular	0.11 dB
% HGV and Mean speed	5% at 90km/hr to 15% at 110km/hr	3.1 dB	Rectangular	1.8 dB
Transmission path				
Weather	3 dB	3.0 dB	Rectangular	1.7 dB
Ground	min inc in weather			
Topography	No change	0.0 dB	Rectangular	0.0 dB
Receiver				
Position	1 m in 100 m	0.9 dB	Rectangular	0.50 dB
Instrumentation	1.9 dB	1.9 dB	Rectangular	1.1 dB
Background	Minimal			
Reflective surfaces	1.25 dB	1.25 dB	Rectangular	0.72 dB
Combined uncertainty				2.9 dB
Expanded uncertainty (95% confidence)				5.7 dB

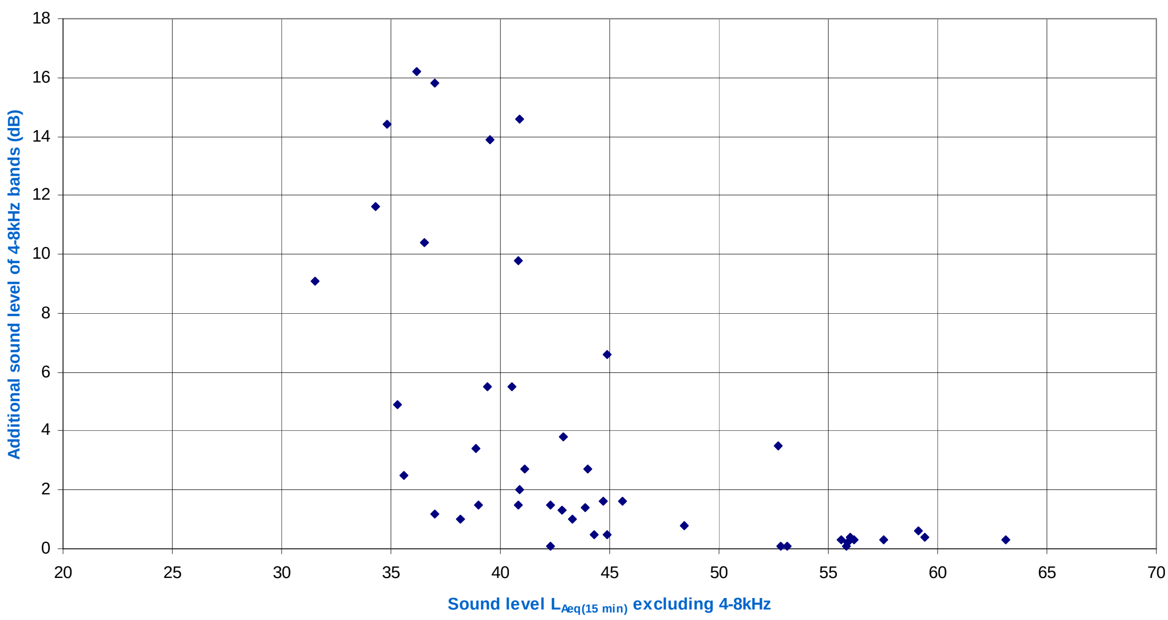

Figure 12-1 Estimated contributions of cicada sound

3.2.4 Engine braking

To provide data for an assessment of engine braking, measurements have been made of this sound source from existing roads. Locations were identified in the Wellington region with steep gradients remote from houses, where engine brakes are likely to be used. Two of these locations with the steepest gradients were selected for measurements: State Highway 1 at Ngauranga Gorge (8% gradient) and State Highway 58 at Haywards Hill (7% gradient).

Measurements of engine braking sound were conducted on 4 June 2010 with the Brüel & Kjær Type 2250 sound level analyser, 5 metres from the nearside downhill traffic lane at Ngauranga Gorge and 6 metres at Haywards Hill. An operator attended the measurements on-site, and for each downhill truck pass-by that could be isolated from general traffic, the maximum sound level (L_{AFmax}) was recorded. It was noted whether engine brakes were audible.

Over a two hour period at Ngauranga Gorge there were only three trucks recorded using audible engine brakes. The average of the maximum sound levels was 93 dB L_{AFmax}, and the sound power spectrum in Table 12-9 is from one of the measurements adjusted to the average level. These trucks were in the order of 10 dB louder than the majority of trucks not using audible engine brakes. Over a one hour period at Haywards Hill, no trucks were observed to be using audible engine brakes.

The small number of trucks using audible engine brakes at both locations reflects the changing composition of the heavy vehicle fleet in New Zealand, with fewer trucks having audible engine brakes.

Table 12-9 Engine braking sound power level spectrum

Octave band (Hz)	16	31.5	63	125	250	500	1 K	2 K	4 K	8 K
Engine braking spectra (dB)	102	106	115	118	118	113	109	103	100	95

3.3 Existing road-traffic sound

3.3.1 Modelling

Section 4 of this report describes the extensive acoustics computer modelling undertaken for road-traffic sound. One of the scenarios modelled is ‘do-nothing’, which comprises the existing roads with traffic flows predicted for 2031. For the receivers near to existing State highways where measurements have been conducted, the do-nothing model results have been adjusted for traffic volumes to give sound levels relating to the 2009 AADT.

3.3.2 Results

A comparison of the measured sound levels discussed in Section 3.2.2 with the results of the computer modelling using 2009 parameters is provided in Table 12-10. The comparison has been limited to unattended logger locations where several days of data have been used to estimate the daily average. It can be seen that there is good agreement for the majority of sites. For the measurement locations further from the road, the traffic component of the measured sound level becomes a smaller proportion. This results in the computer model predicting a lower sound level than measured.

NZS 6806 requires modelled results to be within ±2 dB of measurements. The CRTN method used in these predictions has previously been shown to provide the required accuracy under controlled conditions. However, in this instance, contamination of measurements by other sounds, localised screening not included in the model, and uncertainty in the acoustics performance of existing road surfaces, have led to greater differences between measured and predicted levels. The issues of contamination and road surfaces do not affect the predictions for future scenarios, and the omission of localised screening provides a conservative assessment.

Table 12-10 Comparison of measured and predicted road-traffic sound levels

Measurement location	Measured $L_{Aeq(24h)}$	Predicted $L_{Aeq(24h)}$	Difference	Comment
324 SH1	54	56	2	
366 SH1	55	40	-15	Significant setback from road. Measured levels dominated by other sources
394 SH1	57	33	-24	Significant setback from road. Measured levels dominated by other sources
525 SH1	52	56	4	
53B Paremata-Haywards Road	53	45	-8	
1 Raroa Terrace	53	56	3	
11 Rangatira Road	50	54	4	
130 Warspite Avenue	45	43	-2	
18 Japonica Crescent	59	62	3	
30 Mexted Terrace	49	53	4	Logger located amongst building with several small fences which have not been modelled individually
34 Tremewan Street	58	59	1	
5 Bluff Road	53	52	-1	
6 Matai Street	56	57	1	
66 Tremewan Street	55	58	3	
88 Ernest Street	48	45	-3	

3.4 Vibration

3.4.1 Procedure

Measurements were conducted in general accordance with the requirements of NS 8176. An Instantel Minimate Pro6 vibration monitor was used with geophones to obtain tri-axial velocity levels. At each measurement position vibration velocity levels were stored to the vibration monitor’s memory for subsequent processing. Traffic was observed and the times of at least fifteen heavy vehicle pass-bys were recorded during measurements at each position. Fifteen is the minimum number of events for analysis specified by NS 8176E. The stored vibration data was analysed to obtain the maximum weighted one-second average velocity for each of the heavy vehicle pass-bys. For each position the statistical maximum weighted velocity $v_{w,95}$ was then calculated. The vibration monitor has six channels with two triaxial geophones, so for all measurements two positions were recorded simultaneously.

Measurements were made at two houses adjacent to the existing State highway in Linden, and also in a reserve at various distances from the State highway.

3.4.2 Results

The measured vibration levels are shown graphically in Figure 12-2 for different distances from the State highway at Linden in the reserve, and a summary table is provided in Table 12-11. It can be seen that the NS 8176 criterion of $v_{w,95}$ 0.3 mm/s is achieved at a distance of less than 7 metres from the road.

Table 12-11 Vibration measurement results

Parameter	Value			
Distance from road (m)	5	7	12	15
Average velocity (mm/s)	0.21	0.14	0.06	0.06
Standard deviation (mm/s)	0.13	0.07	0.04	0.04
Statistical maximum weighted velocity $v_{w,95}$ (mm/s)	0.45	0.28	0.14	0.13

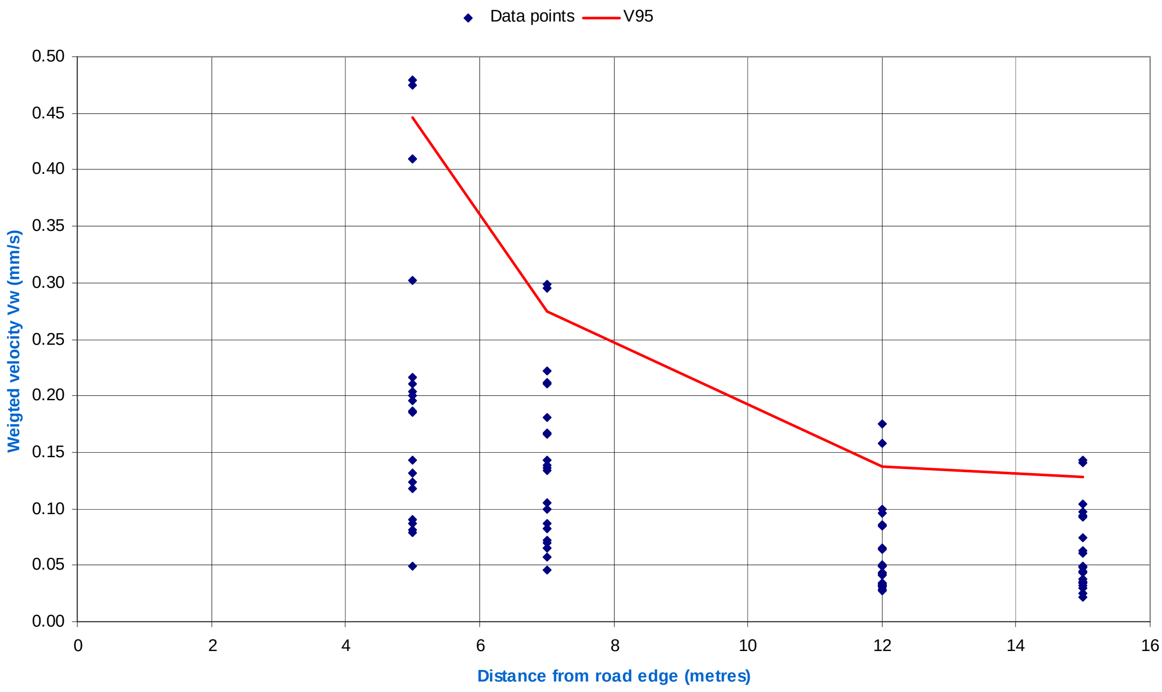

Figure 12-2 Vibration measurement results

The most recent measured surface roughness for the nearest lane to the vibration measurement location is shown in Figure 12-3. The NAASRA roughness value is approximately 20 counts/km, which is consistent with a surface in good condition with few imperfections.

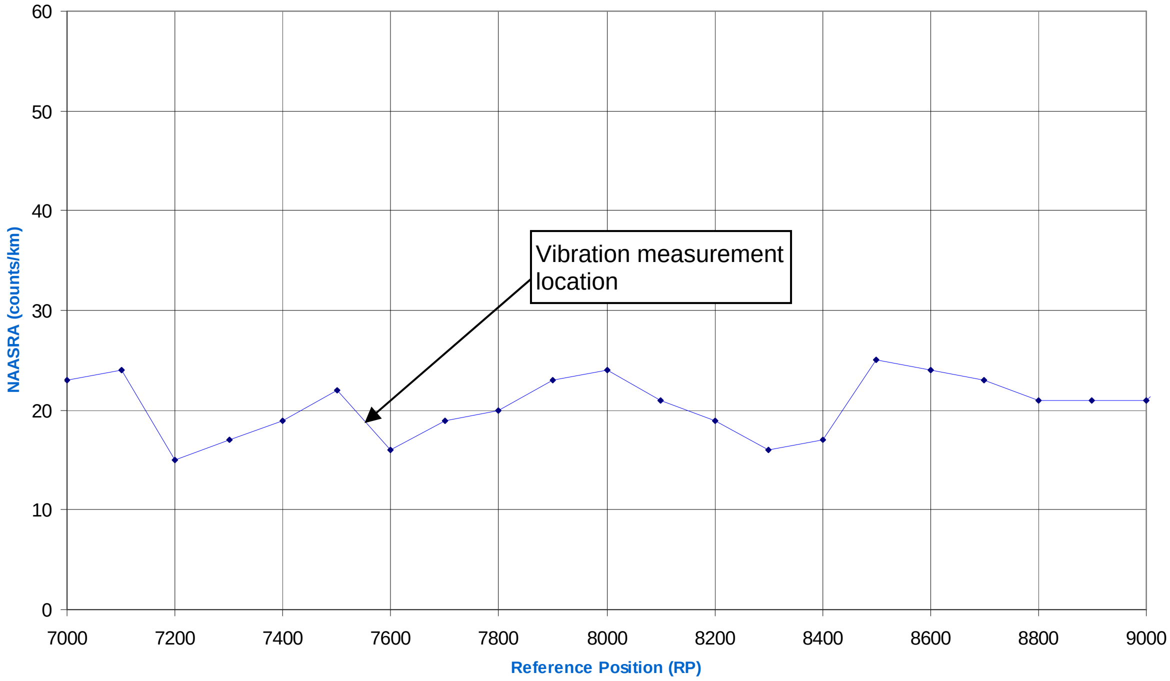

Figure 12-3 Existing State Highway 1 surface roughness

Modelling

4.1 Road-traffic sound model

The cornerstone of this assessment is acoustics modelling of road-traffic sound, which provides an objective basis to consider future activity. The modelling techniques used are well established in New Zealand and have been shown to be accurate. The discrepancies in Table 12-10 relate mainly to contamination by other sources and measurement uncertainty rather than modelling uncertainty.

4.1.1 Procedures

The first two scenarios to be modelled were:

- Do-nothing – the Project not constructed; the existing roads with 2031 traffic; and
- Do-minimum – the Project constructed; 2031 traffic; no specific noise mitigation.

The do-minimum alignment for the Project is a development of the 'preferred option' from the SAR. That option has since been adjusted to form the current do-minimum scenario as a result of further investigations and workshops. URS contributed to those workshops.

Comparison of do-nothing and do-minimum sound levels shows that the Project meets the threshold criteria to be considered as both a new and altered road in accordance with NZS 6806. Having assessed the do-minimum scenario, the Project was then considered in discrete areas, listed in Table 12-12 and shown on Figure 12-4, relating to the locations of Protected Premises and Facilities (PPFs). Three to six noise mitigation options were investigated for each area, as summarised in Table 12-13. Where no mitigation options are listed it is because all PPFs are in NZS 6806 category A in the do-minimum scenario. For each option modelled predictions were made at all individual receivers.

Table 12-12 Acoustics assessment areas

Acoustics assessment area	Protected Premises and Facilities	Project sections	
A	SH1 Paraparaumu Paekakariki Road	1	MacKays Crossing
B	(Battle Hill)	4	Battle Hill
C	Paekakariki Hill Road	4 5	Battle Hill Golf Course
D	Flightys Road	5 6	Golf Course State Highway 58
E	SH58 Paremata Haywards Road	6	State Highway 58
F	Brady Road Silverwood	6 7	State Highway 58 James Cook
G	James Cook Drive Spyglass Lane	7	James Cook
H	Warspite Avenue Corinna Street Niagara Street Loongana Street	7	James Cook
I	Takapu Road	8	Cannons Creek
J	Bluff Road	9	Linden

4 Modelling

Acoustics assessment area	Protected Premises and Facilities	Project sections	
K	Japonica Crescent Apple Terrace Huanui Street	9	Linden
L	Tremewan Street Mexted Terrace Collins Avenue Roberts Street Coates Street North Street	9	Linden
M	Rangatira Road	9	Linden
N	Little Collins Avenue Collins Avenue Allen Terrace Mahoe Street Raroa Terrace	9	Linden
O	Ranui Terrace South Street Matai Street	9	Linden

Table 12-13 Noise mitigation options

Area	Noise mitigation options
A	1. 2 m high roadside barriers 2. Open graded porous asphalt surface 3. 2 m bund, 1.5 m high wall and open graded porous asphalt surface
B	1. Grade 6 chipseal surface
C	1. Grade 6 chipseal surface 2. Open graded porous asphalt surface 3. 2 m high barrier
D	1. Grade 6 chipseal surface 2. Open graded porous asphalt surface 3. 3 m high barrier 4. 3.5 m / 4 m high barriers and grade 6 chipseal surface 5. 2.5 m high barrier and open graded porous asphalt surface 6. 2 m high bund by one PPF
E	1. Open graded porous asphalt surface (part only) 2. 1.5 m / 3 m high barriers and open graded porous asphalt surface (part only) 3. 2 m high barriers and open graded porous asphalt surface (part only) 4. 2 m / 4 m barriers and open graded porous asphalt surface (part only)
F	1. Grade 6 chipseal surface 2. Open graded porous asphalt surface 3. 3 m high barrier
G	n/a
H	(do-minimum has open graded porous asphalt surface) 1. 1 m high roadside barrier 2. 1.5 m high roadside barrier 3. 1 m high roadside barrier (part only) 4. 2.5 m high roadside barrier
I	n/a
J	n/a

Area	Noise mitigation options
K	(do-minimum has open graded porous asphalt surface) 1. 2 m high barrier at boundary 2. 3 m high barrier at boundary 3. 2 m / 2.5 m / 3 m / 3.5 m / 5 m high barriers at boundary 4. 2 m high barrier at boundary (part only) 5. 2.5 m / 3 m / 3.5 m / 5 m high barriers at boundary
L	(do-minimum has open graded porous asphalt surface) 1. 2.5 m high roadside barrier 2. 2 m high roadside barrier (part only) 3. 2 m high roadside barrier (part only)
M	n/a
N	(do-minimum has open graded porous asphalt surface) 1. 2 m high barrier at boundary 2. 3 m high barrier at boundary 3. 5 m high barrier at boundary 4. 5 m high barrier partly at roadside 5. 2 m / 2.5 m / 3 m high barriers
O	(do-minimum has open graded porous asphalt surface) 1. 1.5 m high roadside barrier 2. 2 m high roadside barrier 3. 3 m / 3.5 m high roadside barriers 4. 1.5 m / 2 m / 3 m / 3.5 m high barriers 5. 2 m / 3 m roadside barriers

At the end of the assessment of mitigation options, the selected options were combined and the entire scheme was remodelled as the final 'Notice of Requirement (NoR) scenario', with 2031 traffic. A summary matrix of all the assessment scenarios considered is provided in Table 12-14.

Table 12-14 Assessment scenarios

Scenario	Year	Assessment Area														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Existing	2009	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Do-nothing	2031	✓				✓		✓	✓		✓	✓	✓	✓	✓	✓
Do-minimum	2031	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mitigation Option 1	2031	✓	✓	✓	✓	✓	✓		✓			✓	✓		✓	✓
Mitigation Option 2	2031	✓		✓	✓	✓	✓		✓			✓	✓		✓	✓
Mitigation Option 3	2031	✓		✓	✓	✓	✓		✓			✓	✓		✓	✓
Mitigation Option 4	2031				✓	✓			✓			✓			✓	✓
Mitigation Option 5	2031				✓							✓			✓	✓
Mitigation Option 6	2031				✓											

As a visual aid, graphical sound level contours have been produced. Sound level values should not be taken directly from the contours as they are interpolated from a 20 metre grid resulting in some localised inaccuracies. Sound levels have been calculated separately at individual receivers.

Table 12-15 lists the key model settings.

4 Modelling

Table 12-15 Model settings

Parameter	Setting/source
Software	Cadna/A v4.1.137
Algorithm	CRTN[17] (NZ modified as detailed in 4.1.2) ISO 9613-2[18] (engine braking only)
Order of reflections	1
Parameter	$L_{Aeq(24h)}$ L_{AFmax}(engine braking only)
Ground absorption	1
Receiver height	1.5 m (4.5 m upper floors) – most exposed façade
Sound contour grid	1.5 m height, 20 m resolution
Receivers and grid position	free-field

The CRTN algorithm gives results in terms of the $L_{A10(18h)}$. To convert this to $L_{Aeq(24h)}$ a –3 dB adjustment has been made. This adjustment has been implemented in the software in conjunction with the road surface adjustment detailed below.

[17] Calculation of Road Traffic Noise (CRTN). UK Department of Transport and the Welsh Office. ISBN 0115508473. 1988
[18] ISO 9613-2:1996 Acoustics – Attenuation of sound during propagation outdoors. Part 2 General method of calculation.

4 Modelling

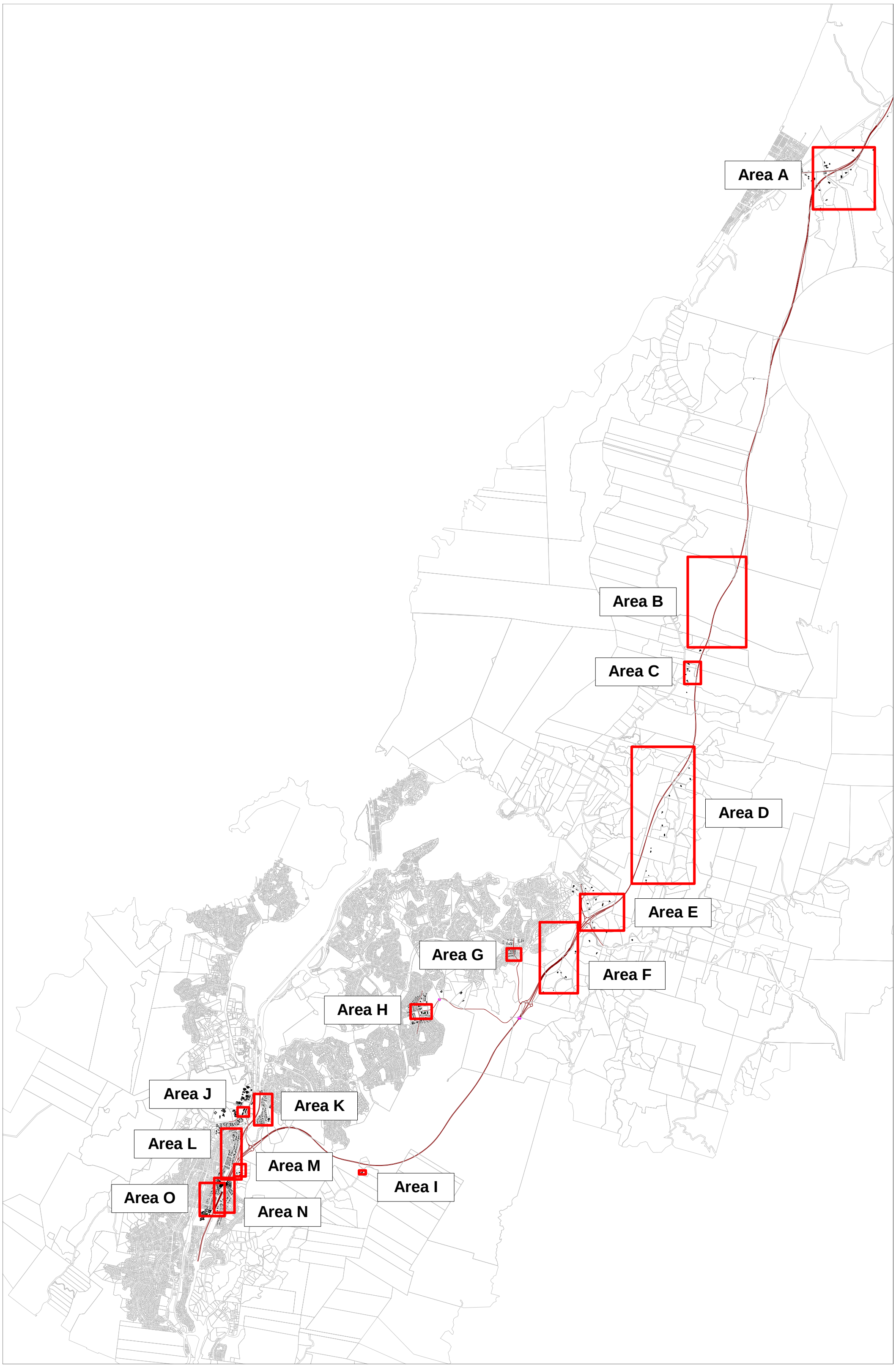

Figure 12-4 Acoustics assessment areas

4.1.2 Input data

Most data used in the acoustics model has been obtained directly from the project GIS system. However, in some instances additional data such as traffic flow and barriers have required manual entry direct into the acoustics model.

Initial GIS data was imported and used for the analysis of noise mitigation options. During that time the overall Project design was developed in response to the noise mitigation and numerous other factors. Therefore, once the GIS data was frozen at the end of the process, the do-minimum and NoR scenarios were remodelled to verify that the analysis remained valid. In practice, most of the more significant developments to the design occurred in areas where there are no PPFs, so the acoustics analysis was unaffected.

Contours

Topographic contours have been imported directly from the project GIS. High resolution contours at 1 metre intervals have been used within 50 metres of the roads where the new landform is likely to influence the predicted sound levels. For the area within 500 metres of the road, where all PPFs are located, contours at 5 metre intervals have been used. Finally, up to 2 kilometres from the roads, contours at 20 metre intervals have been used purely for visual purposes so that sound contours display realistically.

Two sets of topographic contours have been used:

- Do-nothing contours of the existing landform without the Project, and
- Do-minimum contours of the new landform with the Project.

All of the mitigation options and final NoR scenario are based on the do-minimum topographic contours.

Buildings

The footprints for all buildings within 200 metres of the roads have been imported into the acoustics model from the project GIS. All buildings have been modelled as 5 metres uniform height for single storey buildings and 7.5 metres uniform height for known two storey buildings. Buildings have been modelled as reflective, with a 2 dB reflection loss.

Road alignments

Road alignments have been imported from the project GIS as centrelines and road widths. Each two-lane carriageway has been modelled as a separate road. Gradients have been calculated by the acoustics software, and have been manually disabled for downhill sections. Where there is a third lane (e.g. crawler lane, or exit lane) this has been modelled as a separate road. Link roads only have one lane in each direction so these have each been modelled as a single road.

Road surfaces

Surfaces of existing roads have been modelled as the current surfaces recorded by the NZTA. For the do-minimum scenario it has been assumed that intersections will be stone mastic asphalt, the Linden area will be open graded porous asphalt, but all other parts of the road will be a coarse chip seal. In investigating mitigation options alternative surfaces have been tested in the acoustics model for some sections.

The procedure used to incorporate different road surfaces in the model is as follows:

- In accordance with Transit Research Report 28[19], a -2 dB adjustment has been made for a reference asphaltic concrete road surface,
- Surface corrections relative to asphaltic concrete have been in accordance with LTNZ Research Report 326[20]. The combination of surface corrections for cars and heavy vehicles have been made using the equation on the NZTA Transport Noise website[21], and
- The combined correction has been entered in the modelling software as a road surface correction. This has also included the adjustment from $L_{A10(18h)}$ to $L_{Aeq(24h)}$.

Safety barriers

Solid (e.g. concrete) safety barriers have been manually entered in the acoustics model as 0.81 m high barriers for the do-minimum scenario, on the basis of barriers detailed in the SAR preferred option. These have been tested and then removed from the model if they do not alter the predicted noise levels at any PPF by more than 2 dB and do not cause any PFF to be in a lower NZS 6806 category. In places, the barriers subsequently proposed for noise mitigation options could be integrated with alternative safety barriers. In area A (MacKays Crossing) there are earth bunds in the design for safety purposes, which have been included in the do-minimum scenario.

Bridges

All bridges have been configured to be ‘self-screening’ roads, which blocks the sound of that road passing through them. To represent the kerb and channel on bridges a 150 mm high vertical barrier has been modelled along the edges of the bridges.

Traffic data

Traffic data has been provided for all roads as the Annual Average Daily Traffic (AADT), percentage of heavy vehicles and speed. This has been provided separately for each carriageway and separately for crawler lanes. All traffic data has been provided for the design year of 2031, which is ten years after the assumed opening year of 2021.

The CRTN model has been developed based on 18-hour traffic. However, this has been entered as the 24-hour daily traffic (AADT), which results in modelling in the order of +0.2 dB conservative.

[19] Research Report 28. Traffic noise from uninterrupted traffic flows, Transit, 1994
[20] Research Report 326: Road surface effects on traffic noise: Stage 3 – Selected bituminous mixes. Land Transport New Zealand, 2007
[21] NZTA Transport Noise website, www.acoustics.nzta.govt.nz, accessed 5 March 2010

Table 12-16 Road details

Road section	Existing road (2009)	Do nothing (2031)	Do minimum (2031)
SH1, north of MacKays Crossing interchange	24,420 vpd (7% HV) 80 km/h Chipseal	24303 vpd (24% HV) 100 km/h Chipseal	27,948 vpd (21% HV) 100 km/h Chipseal
Existing SH1, south of MacKays Crossing interchange	24,420 vpd (7% HV) 80 km/h Chipseal Asphaltic concrete south of 350 SH1	24303 vpd (24% HV) 100 km/h Chipseal 80km/h, Asphaltic concrete south of 350 SH1	5,553 vpd (47% HV) 80 km/h Asphaltic concrete
Main Alignment (SH1) – MacKays Crossing to SH58	-	-	22,395 vpd (15% HV) 96-100 km/h Chipseal
SH58	18,090 vpd (6% HV) 50 km/h Chipseal	16,671 vpd (11% HV) 49-50 km/h Chipseal	10,651 vpd (18% HV) 40-50 km/h Chipseal
SH58 interchange roundabout	-	-	8,809 vpd (18% HV) 50 km/h Stone mastic asphalt
Main Alignment (SH1) – SH58 to James Cook interchange	-	-	20,232 vpd (15% HV) 98-100 km/h Chipseal
James Cook Interchange roundabout	-	-	2,973 vpd (20% HV) 50 km/h Stone mastic asphalt
Main Alignment (SH1) – James Cook interchange to Kenepuru interchange	-	-	19,104 vpd (13% HV) 98-99 km/h Chipseal
James Cook Drive	1,923 vpd (12% HV) 48-50 km/h Asphaltic concrete	1,862 vpd (16% HV) 37 km/h Asphaltic concrete	3,118 vpd (18% HV) 37 km/h Asphaltic concrete
Whitby link road	-	-	3,118 vpd (18% HV) 37 km/h Asphaltic concrete
Warspite Avenue	6,070 vpd (5% HV) 50 km/h Asphaltic concrete	7,028 vpd (9% HV) 50 km/h Asphaltic concrete	7,292 vpd (10% HV) 45 km/h Asphaltic concrete
Waitangirua link road	-	-	7,519 vpd (10% HV) 37-50 km/h Chipseal
Main Alignment (SH1) – Kenepuru interchange to Linden interchange	-	-	18,678 vpd (13% HV) 80-98 km/h OGPA
Kenepuru interchange Roundabout	-	-	8,661 vpd (7% HV) 50 km/h Stone mastic asphalt

Kenepuru Drive	14,840 vpd (3% HV) 50 km/h Slurry seal	15,474 vpd (4% HV) 50 km/h Asphaltic concrete	15,384 vpd (4% HV) 49 km/h Asphaltic concrete
Kenepuru link road	-	-	12,994 vpd (7% HV) 45-47 km/h OGPA
Existing SH1 – North of Linden interchange	23,533 vpd (5% HV) 91-94 km/h OGPA-14, 20% voids	59,126 vpd (15% HV) 90-91 km/h OGPA-14, 20% voids	45,146 vpd (14% HV) 95-96 km/h OGPA
SH1 – South of Linden interchange	23,533 vpd (5% HV) 91-94 km/h OGPA-14, 20% voids	59,126 vpd (15% HV) 90-91 km/h OGPA-14, 20% voids	63,824 vpd (14% HV) 90-96 km/h OGPA

4.2 Road-traffic sound results

4.2.1 Scenarios

Predicted road-traffic sound level contours for the following scenarios are shown on the drawings in the plan set listed in Table 12-17. For the NoR scenario only the sheets with mitigation measures are included; for all other areas the NoR scenario is the same as the do-minimum scenario.

Table 12-17 Road-traffic sound level contour drawings

Scenario	Drawings
Do-nothing	NA01-02, NA13-15, NA20-21
Do-minimum	NB01-21
NoR	NC10, NC15, NC20-21

4.2.2 Mitigation

Road-traffic sound level predictions have been made for all the mitigation options listed in Table 12-13. The process of assessing these options and selecting the NoR option is described in Section 5.2. Summary figures of the selected options are shown in Section 5.2. Similar figures and detailed predictions were produced for each individual option and circulated to the project team conducting the options assessment. This data is held on file by URS.

4.2.3 Engine braking

As described in Section 2.2.2, sound level predictions have been made for all parts of the Project with a downhill gradient of 4% or greater. This occurs near PPFs at:

- Linden
- Kenepuru Link Road
- Takapu Road
- Waitangirua Link Road
- Whitby Link Road
- Bradey Road
- SH58 interchange

- Flightys Road
- Paekakariki Hill Road
- MacKays Crossing interchange

The do-minimum acoustics model for the Project has been used to predict the sound level from engine braking at PPFs by each of these areas. Point sources have been placed on these sections of the road at 100-200 metre intervals approximately aligned with the nearest PPFs, 4 metres above the road surface and 1 metre from the edge of the nearside downhill lane. Each point source was assigned sound power levels derived in Section 3.2.4.

All of the predicted engine braking sound levels are below 75 dB L_{AFmax}, with the majority below 60 dB L_{AFmax}.

4.3 Road-traffic vibration

4.3.1 Method

Road-traffic vibration has been assessed in the Linden area where there are receivers close to the Main Alignment. On the basis of the assessment in this area, predictions have not been made for other areas where receivers are further from the Project.

Two approaches have been taken to predicting road-traffic vibration levels. The first has been to use an empirical model detailed by TRRL Research Report 246[22] and Watts[23]. This model includes the ground conditions and a peak displacement input, such as from an imperfection in the road surface. Soil conditions are described in the Scheme Assessment Report[24], and on this basis both London clay and sand/gravel which are reference ground types in the prediction model have been considered to approximate local conditions for the Project. The empirical model provides a vibration estimate in the form of Peak Particle Velocity (PPV). This has been divided by 1.4 to provide an approximation of the weighted velocity, v_w, being used in this assessment.

The second approach has been to use measurements of actual vibration levels at a range of distances from the existing State highway in Linden to estimate the levels from the Main Alignment on the basis of the change in distance to receivers, assuming similar ground conditions, road structure and surface.

4.3.2 Results

The empirical model assumes that vibration levels are directly proportional to the height of the roughness profile. That is, a doubling of displacement will result in a doubling of vibration at the receivers. The test measurements originally used to develop the model were over a section with a 25 mm high profile, and this displacement has been used in our assessment. Vibration levels have been predicted at a number of distances for the two different soil conditions, with the results shown in Figure 12-5. It can be seen that the vibration levels are significantly in excess of the 0.3 mm/s project criterion at locations close to the road. This model is not consistent with the vibration measurements reported in Section 3.4.

[22] Traffic induced vibrations in buildings. TRRL Research Report 246, 1990
[23] Watts. G. The generation and propagation of vibration in various soils produced by the dynamic loading of road pavements. Journal of Sound and Vibration 156(2), 1992
[24] Transmission Gully Scheme assessment report, Volume 2, Section 4 – Site description, 2008

4 Modelling

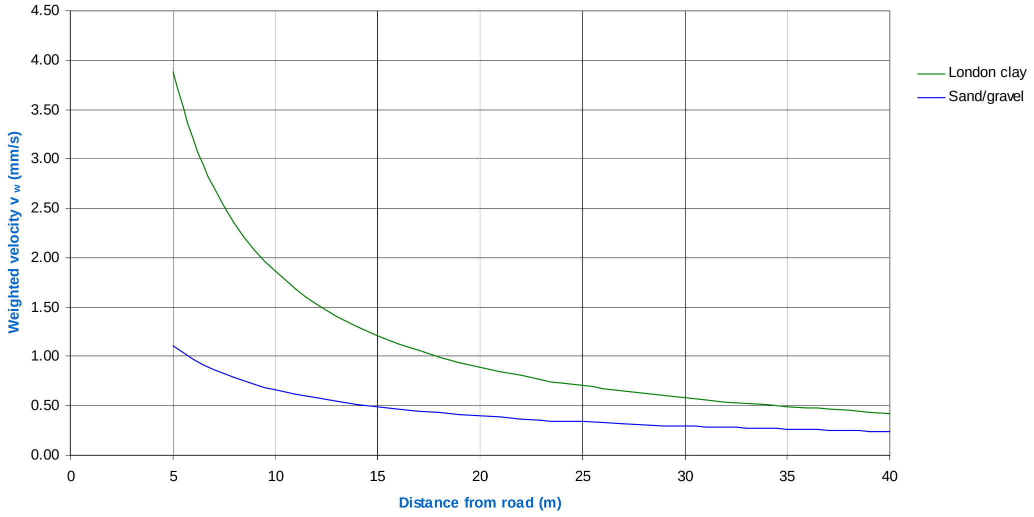

Figure 12-5 Road-traffic vibration (25 mm displacement)

To reconcile the model with the vibration measurements conducted at Linden, the calculations have been repeated with a 2 mm rather than 25 mm peak displacement, representing a smoother road surface. The results for a 2 mm displacement are shown in Figure 12-6 together with the measured levels from Figure 12-2. This shows good agreement between the adjusted model and the measurements. As discussed in Section 3.4.2, State Highway 1 has a low NAASRA count, which would be consistent with a profile height significantly less than 25 mm.

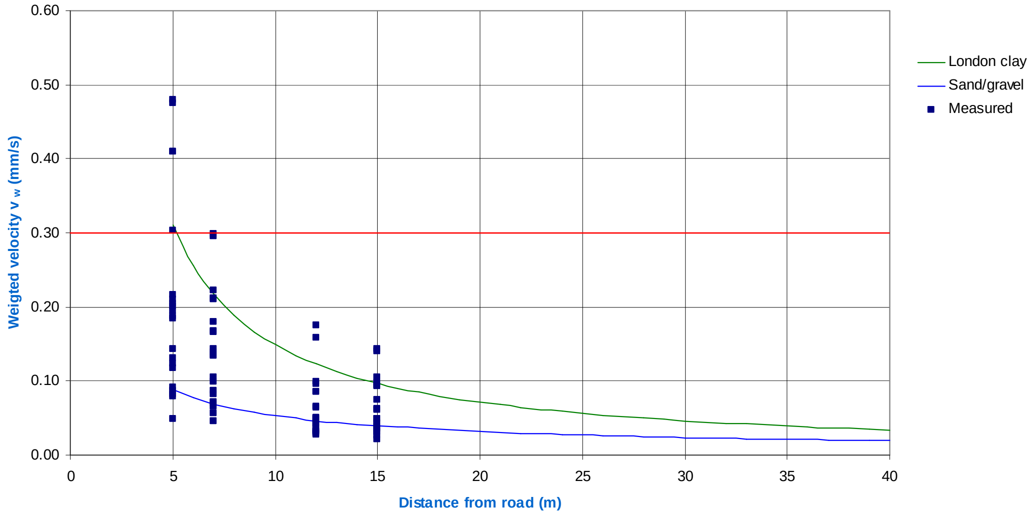

Figure 12-6 Road-traffic vibration (2 mm displacement)

From the vibration modelling and measurements it is concluded that provided the road surface is kept in good condition, vibration from road-traffic would be within the $v_{w,95}$ 0.3 mm/s criterion at all buildings more than 7 metres from the road edge, and within the $v_{w,95}$ 0.6 mm/s criterion at buildings closer to the road. The distance of PPFs from the road can be seen in the plan set.

4.4 Construction sound

4.4.1 Method

The project team has identified an indicative construction methodology. As a result of comments by URS, this indicative methodology incorporates measures to control construction sound, such as the sequencing of events and access points to the site. From the types of equipment and duration of works envisaged an assessment has been made for typical activities using the construction sound calculator on the NZTA Transport Noise website (www.acoustics.nzta.govt.nz). From these calculations, buffer distances required from construction activities to comply with guideline noise limits in NZS 6803 have been determined. Where this is not practicable, noise mitigation measures have been investigated in more detail.

Construction works have been summarised into the activities listed in Table 12-18, with a description of the activities and typical equipment. A draft construction noise and vibration management plan has been prepared. This provides more detail on the construction activities and timeline.

Table 12-18 Construction activities

Activity	Description
Roadworks - Earthworks	3 earthworks crews will be used in parallel to form a front. It has been assumed that all soil will be rippable with a dozer. Short-haul earth movements will be performed with a scraper, and long-haul movements will be using trucks.
Roadworks - Pavement	Spreading fill, chip sealing. Rolling and compaction. Paving
Roadworks - Finishing	Roadside furniture, linemarking, restorations. Vehicle movements
Bridgeworks	Extensive earthworks will be required to reach the required formation level in many instances. Equipment similar to roadworks. Bridgework will involve pre-cast elements and concrete fabrication at the site. There is no need for 24-hour pours. An 80 tonne pile rig will be used, but there will be no driven piling.
Crushing	A mobile crushing plant will be located in areas along the alignment where excavated material is processed for reuse.
SH58 main compound	The main site compound is proposed to be located near the interchange with SH58. The exact location is yet to be determined. The concrete batching plant is expected to be a major noise source, as will vehicle movements in general.
Laydown areas	8 laydown areas have been considered along the site. Several vehicles will be operational in the area at once, along with generators etc.
Vehicle movements along Main Alignment	Passenger vehicles Long haul truck Fuel tanker Waste truck
Night works at the SH1 tie-ins	Demolition, earthworks, pavement, kerbing, noise barrier installation

4.4.2 Results

Sound levels have been predicted for each construction activity listed in Table 12-18 at three different distances, with results provided in Table 12-19. It can be seen that compliance with the long-term guideline daytime construction noise limit (70 dB $L_{Aeq(1h)}$) will be achieved for most activities with a separation distance of 50 to 100 metres.

Table 12-19 Predicted construction sound levels

Activity	Items	Noise level at 50 m	Noise level at 100 m	Noise level at 200 m
Roadworks - Earthworks	3 × excavator 3 × scrapers 1 × long haul truck	79 dB	73 dB	67 dB
Roadworks - Pavement	Dozer Spreading / chipping fill. Roller Paving	71 dB	65 dB	59 dB
Bridgeworks	Auger Truck mounted concrete pump Crane / winch Generator	72 dB	66 dB	60 dB
Crushing	Mobile crushing plant Articulated loader	74 dB	68 dB	62 dB
Batching plant at site base		75 dB	69 dB	63 dB
Laydown areas	3 × excavator 3 × scrapers 1 × long haul truck Generator Water truck filling Repairing activities (grinder etc)	75 dB	69 dB	63 dB
Vehicle movements	Haul truck passbys (25%)	63 dB	57 dB	51 dB
Night works at the SH1 tie-ins	Excavator Road roller Asphalt paver	85 dB @ 10m (75 dB with 3m high barrier)	80 dB @ 20m (70 dB with 3m high barrier)	74 dB @ 20m (64 dB with 3m high barrier)

The guideline noise limits will not be achievable at the State Highway 1 tie-in at Linden where night works will be required. Adverse noise effects of construction sound at properties in this area will require pro-active management and consultation, as detailed in the draft construction noise and vibration management plan.

The house at 51 Paremata Haywards Road is adjacent to the site compound and it is not practicable to comply with the noise limits at that location. For the purposes of construction of the Project, that house has been included within the designation footprint and will not be occupied for unrelated residential use during construction.

4.5 Construction vibration

4.5.1 Method

The method for construction vibration is similar to construction sound. The same typical construction activities have been assumed. In the case of vibration, only certain activities likely to generate significant vibration have been assessed. The predictions of construction vibration have been made using the methods in BS 5228-2[25] and TRL Research Report 429[26].

4.5.2 Results

Vibratory compaction is the main source of construction vibration with the potential for adverse effects. Appendix E of BS 5228 provides a method for calculating three different probabilities of exceedance of a given vibration level. Predicted vibration levels are shown in Table 12-20 for different distances, with commentary provided on the resultant effects on the basis of the criteria in Section 2.4.2. For all works closer than 50 metres to receivers, regular communication with residents is required to minimise annoyance. This has been addressed in the draft construction noise and vibration management plan.

Table 12-20 Vibration levels from vibratory compactor

	Exceedence probability			
Distance from source	50%	33%	5%	Comment
5 metres	6 mm/s	11 mm/s	21 mm/s	Structural and cosmetic damage possible. Careful assessment required if any buildings are this close to final alignment
10 metres	3 mm/s	5 mm/s	9 mm/s	Cosmetic damage is possible. High level of annoyance expected. Assessment based on chosen equipment advisable.
20 metres	1 mm/s	2 mm/s	4 mm/s	Vibration to be clearly perceptible and may cause annoyance. No risk of structural or cosmetic damage
50 metres	0.3 mm/s	0.5 mm/s	1.0 m/s	Vibration to be perceptible at times, but annoyance should be minimal.

The other construction activity with potential for vibration is the bored piles for bridgework; however the setbacks to residences will be significantly greater than general surfacing work. No model for this activity is provided in BS 5228, however an assessment has been performed based on vibratory piling, which is expected to generate greater vibration levels than bored piles. At 20 metres from the source, the 5% exceedance level is 5 mm/s (well below damage threshold) and at 50 metres from the source, the 50% exceedance level is approaching the threshold of perception in a residential setting. On this basis we do not expect vibration from bored piling activities to have a significant effect.

4.5.3 Blasting

Blasting may be used in the Wainui Saddle area. This is well over 1 kilometre from any receivers, and is screened from the nearest receivers by the terrain. In this situation the airblast and vibration guideline criteria from AS 2187-2 will be achieved with normal practices, and therefore no further analysis has been conducted.

[25] BS 5228-2:2009, Code of practice for noise and vibration control on construction and open sites – Part 1: Vibration
[26] Ground-borne vibration caused by mechanised construction works, TRL Report 429, 2000

Design and mitigation

5.1 Alignment

The horizontal and vertical alignment of a road can significantly influence the sound levels at PPFs. Therefore, substantial acoustics gains can be made in the planning stage of a project. In this instance, the fundamental route has been determined through previous processes as documented in the SAR. In general, both the existing designation and the preferred alignment from the SAR do minimise road-traffic sound levels as the route is generally well separated from PPFs.

The current project team has made further refinements to the alignment, mainly to the north of State Highway 58, and primarily resulting from ecological considerations. While URS has contributed to development of the alignment, in general there are no PPFs nearby and the changes have a neutral acoustics effect. Two areas where acoustics has been a consideration in refining the alignment during the current phase of the Project are:

- MacKays Crossing. The Main Alignment is further from some PPFs than the existing State Highway 1, but closer to others. The current location provides a balance in providing reasonable separation from all these PPFs.
- Battle Hill. The alignment has been moved closer to gas-line ridge (refer to plan set). This is beneficial as gas-line ridge now provides slightly more effective acoustics screening of the road from the main visitor areas at Battle Hill.

5.2 Mitigation options

The acoustics assessment areas and mitigation options evaluated are detailed in Section 4.1.1. For any areas where the NZS 6806 category A criteria was exceeded (Table 12-1), a number of mitigation options were tested. For each mitigation option tested, URS ran the acoustics computer model to predict road-traffic sound levels at each PPF.

The mitigation options for each area were assessed by URS on the basis of:

- compliance with NZS 6806 criteria,
- attenuation provided by structural (barriers and low noise surfaces) mitigation,
- need for building-modification (ventilation/sound insulation) mitigation, and
- value-for-money (using the benefit-cost ratio (BCR) calculation from NZS 6806).

The acoustics assessment by URS was documented in a separate options matrix for each area, which was then circulated to the project team for other factors to be assessed. With the assessment matrix, each option was described and presented graphically as illustrated in Figure 12-7. For each option the following issues were considered by the appropriate project team members:

- Compliance with relevant safety standards and guidelines,
- Constructability/technical feasibility,
- Availability of sufficient land for construction and maintenance and the extent to which the NZTA/PCC would need to acquire land, or interests in land,
- Potential effects on known heritage or cultural values,
- The extent to which the mitigation option promotes integration and establishes visual coherence and continuity in form, scale and appearance of structures and landscape proposals along the route,
- Road users' views to the surrounding landscape and key features/ locations in particular,
- Maintenance or enhancement of visual amenity for surrounding residents,

- Utilisation of materials that reflect the character of the location,
- Maintenance or enhancement of the convenience and attractiveness of pedestrian and cycle networks,
- Maintenance or enhancement of safe routes to school,
- Impacts (land take, amenity and usability) on community facilities (reserve, school, playground, playing field, etc),
- Public access to the coastal marine area, rivers, or lakes,
- Public safety and security,
- Potential effects on areas of significant indigenous vegetation and significant habitats of indigenous fauna,
- Natural character of the coastal environment, wetlands, lakes, rivers, and their margins,
- Potential effects on coastal processes,
- Potential flooding effects, and
- On-going maintenance of the mitigation options and surrounding area.

Each discipline rated these assessment criteria using a seven point scale (+++, ++, +, o, -, --, ---), and provided commentary explaining the rating. The completed options matrices were then circulated to the project team and considered at the noise mitigation workshop.

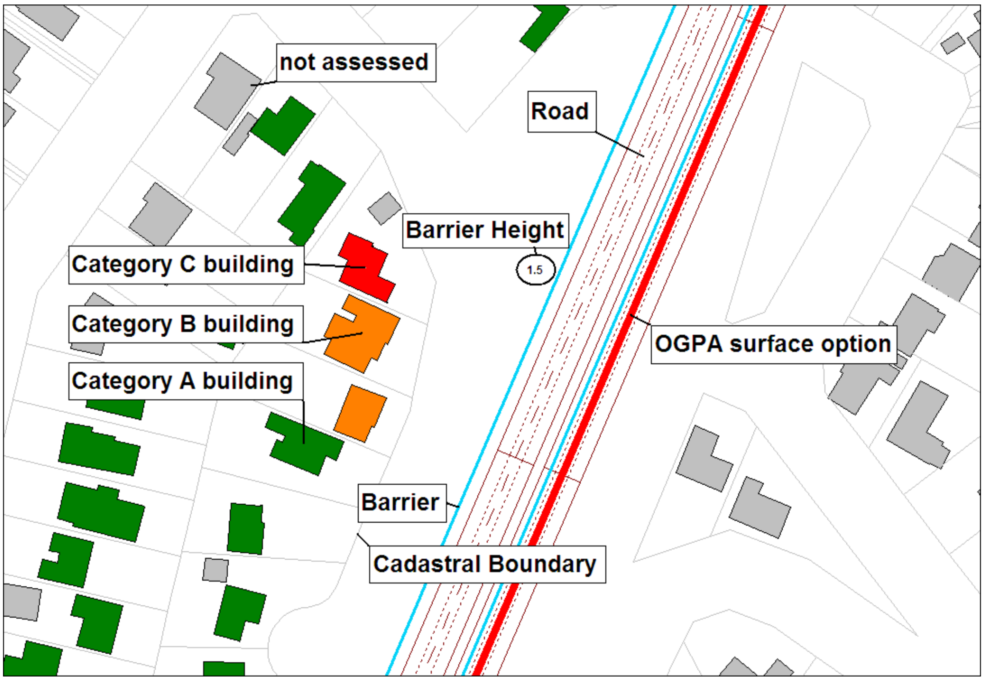

Figure 12-7 Mitigation option figures key

Workshop

The noise mitigation workshop was held on 9 June 2010, with a follow-up meeting on 10 June 2010. The following people contributed to the workshop:

- NZTA project staff
- Consultant team: acoustics, planning, social, roading, structures, visual/landscape, urban design, construction, ecology
- NZTA national office: acoustics, urban design

- NZTA regional office: planning, maintenance

The RATAG/EPA acoustics expert (Malcolm Hunt) attended the workshop as an observer.

Each of the acoustics assessment areas and the options matrices completed by all disciplines were reviewed at the workshop. In each case an option was selected as providing the Best Practicable Option (BPO). In some instances this was subject to confirmation following further modelling. In all cases there was consensus achieved at the workshop as to the selected options. However, if there had been greater tension between different considerations, then the planning consultant was responsible for balancing the constraints and determining the BPO.

A brief commentary on the design issues for each acoustics assessment area is provided below, with the reasons for the selected options.

Consultation

Following the workshop the lead acoustics engineer and a member of the planning team met individually or in small groups with all property owners where it was proposed to locate a barrier on the property boundary. As well as numerous residents, this included the Maraeroa Marae, Linden Primary School and He Huarahi Tamariki Teen Parent Unit.

In several cases, minor changes were made to the selected noise mitigation options, within the envelope of the BPO determined by the project team, to accommodate the preferences of the neighbours. This generally involved slight increases to the height of noise barriers. Also, inspection of three houses revealed that the proposed noise barriers would not be effective as high windows would overlook the barriers. It is therefore proposed to use building-modification mitigation in those cases.

Area A - MacKays Crossing

In this area, the Main Alignment passes over the existing road alignment and then has south facing slip lanes to connect with the existing State Highway 1 coastal route. The Main Alignment is elevated above some PPFs, although others towards the Te Puka stream overlook the Main Alignment. This is classified as a rural area and therefore the ten PPFs within 200 metres of the alignment have been considered. Those within 200 metres of the existing road have been assessed using the altered road targets from NZS 6806, whereas the three PPFs overlooking Te Puka stream further from the existing road have been assessed against the NZS 6806 new road targets.

Road-traffic is predicted to more than double in this location by 2031, and there will be a greater percentage of heavy vehicles. These factors lead to a significant increase in the road-traffic sound levels compared to the existing scenario. The Project moves the main traffic closer to some PPFs but further from others and the sound levels vary accordingly.

Options tested include use of a low noise road surface and roadside barriers. All options were found to have relatively poor benefit-cost ratios due to the large extent of works required to benefit a small number of PPFs.

At the workshop the do-minimum option (Figure 12-8) was selected. This has a grade 2/4 chip seal surface and no noise barriers, although safety barriers and bunds are included. The main reasons for selecting this option are:

- All PPFs are in Categories A or B except one PPF in category C which is owned by the NZTA and will be demolished,

- The BCR for options with low noise road surfaces is poor as a long length of the Main Alignment is required to be treated to benefit a small number of PPFs, and
- The barriers tested do not provide significant benefit due to the topography, and create adverse visual effects.

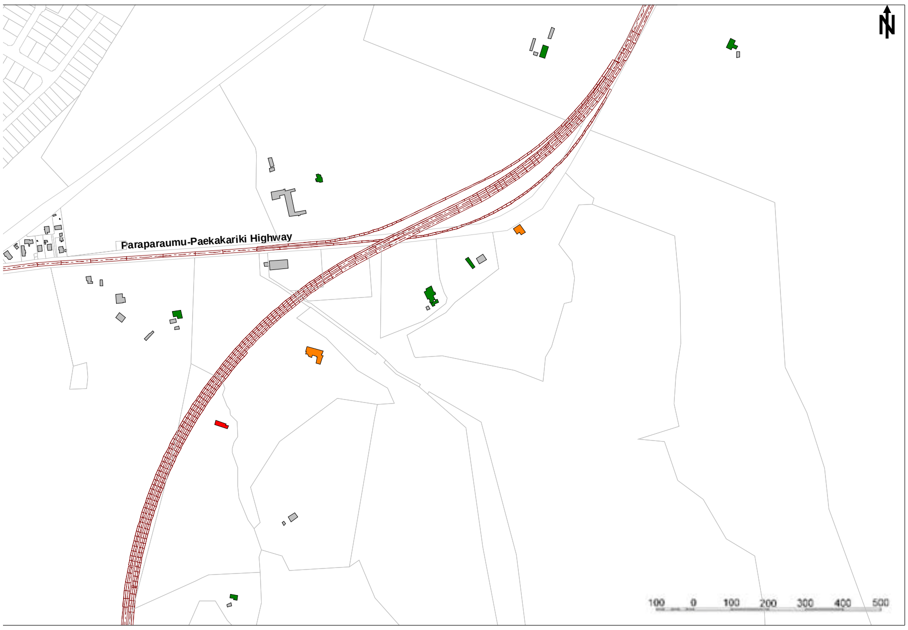

Figure 12-8 Area A - MacKays Crossing – selected option

Area B - Battle Hill

Battle Hill is not defined as a noise receiver under NZS 6806 (or under the old Transit Guidelines), as it is a rural area with no PPFs (e.g. houses) within 200 metres of the road. However, as there are potential noise effects for recreational users, a mitigation option has been tested using a smaller road surface chip size (grade 6). At the workshop, it was decided to maintain the do-minimum option of a grade 2/4 chip seal and no acoustics barriers/bunds, as:

- There will be a significant change in acoustics amenity in the valley (Transmission Gully), but using a low noise road surface would not fundamentally alter the effect of that change,
- The valley floor, which is most affected, is not a primary picnic type area, and
- Gas-line ridge provides effective screening of the Battle Hill visitor centre regardless of road surface.

As there are no PPFs at Battle Hill, Figure 12-9 shows road-traffic sound level contours rather than buildings coloured according to NZS 6806 categories.

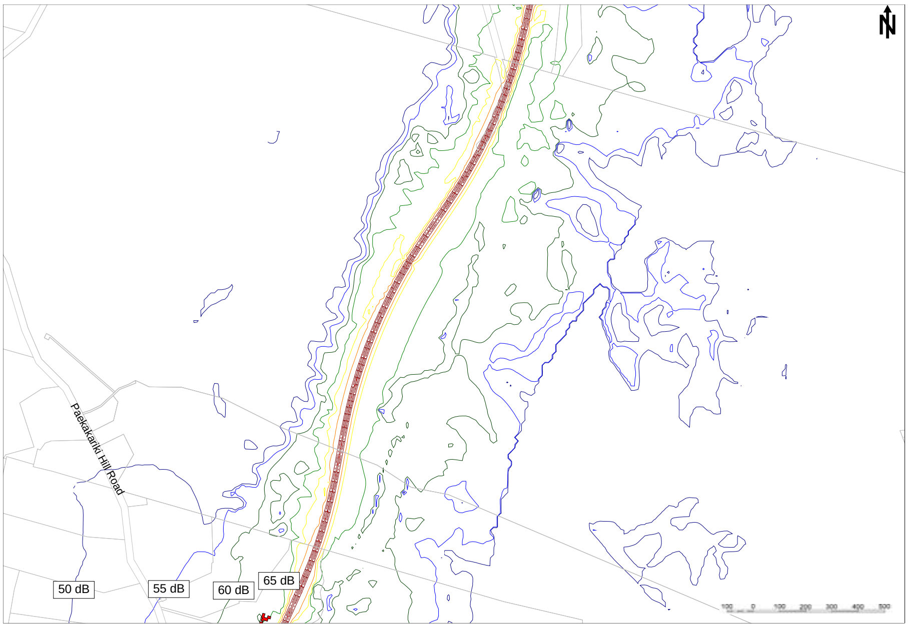

Figure 12-9 Area B - Battle Hill – selected option

Area C - Paekakariki Hill Road

At the closest point there are four residences on Paekakariki Hill Road near the Main Alignment. However, all of them are outside the 100 metre zone specified by NZS 6806. However, as these locations were included in the SAR, noise mitigation options have been considered.

Options tested include low noise road surfaces and barriers (assumed to be earth bunds). The surfaces tested are a fine chip seal (grade 6) and open graded porous asphalt (OGPA). Due to the topography and distance from the road the effect of the barrier is limited. The effect of the low noise road surfaces is also limited by noise from adjoining sections of road.

Again, at the workshop it was decided to maintain the do-minimum option of a grade 2/4 chip seal and no acoustics barriers/bunds, as:

- NZS 6806 does not apply as all PPFs are more than 100 metres from the Main Alignment,
- All PPFs are in NZS 6806 categories A and B,
- A barrier (bund) has limited effectiveness and creates adverse visual effects blocking views from the road, and
- Low noise road surfaces have limited effectiveness unless significantly extended.

Despite the limited performance, bunds may be provided if fill disposal is required in this area, or if it is desired to replace safety barriers.

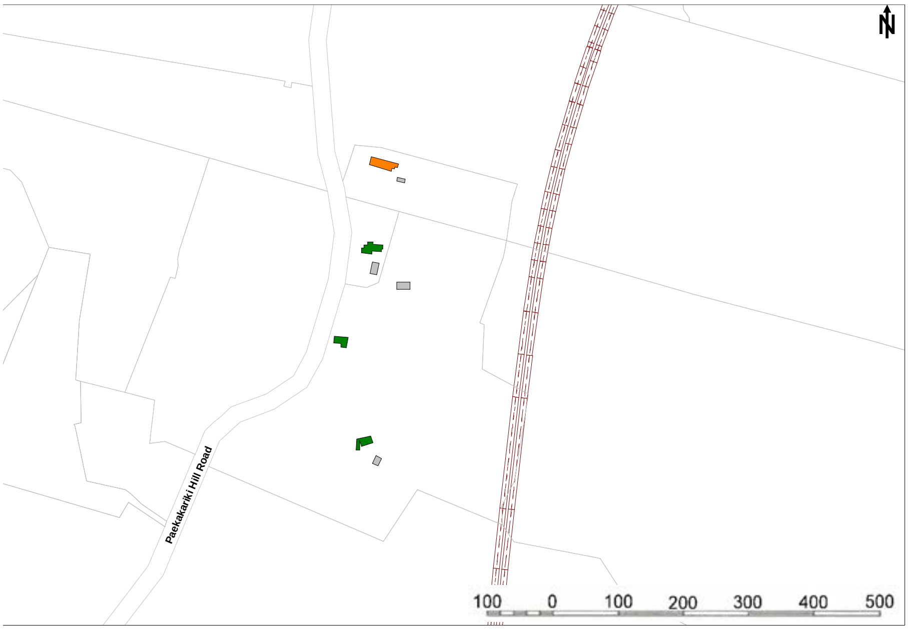

Figure 12-10 Area C - Paekakariki Hill Road – selected option

Area D - Flightys Road

This part of the Main Alignment runs north from State Highway 58 to the west of the residential properties on Flightys Road, for approximately 7 kilometres. The Main Alignment is a new road in this area. There are only two PPFs within 100 metres of the road that should be considered under NZS 6806. However, a further nine properties extending as far as 235 metres from the road have been included in the analysis. One of these is a new house at 350 Flightys Road, which is not shown on the diagram, but is approximately 120 metres from the road and close to the house at 344A Flightys Road.

Options tested include low noise road surfaces, barriers (assumed to be earth bunds) and combinations of the two. The surfaces tested include both a fine chip seal (grade 6) and open graded porous asphalt. The bunds modelled stop where the road goes into deep cuts.

At the workshop a modified option was selected. This is option 6 which has a 2 metre high bund by one PPF (390 Flightys Road), and no mitigation by other PPFs. Figure 12-11 shows this barrier as a green line to denote a noise bund rather than a noise wall. The reasons for selecting this option were:

- NZS 6806 only applies to two PPFs as all others are more than 100 metres from the road,
- All PPFs are in Categories A and B in the do-minimum scenario apart from 390 Flightys Road,
- Due to the topography and distance from the road, the effect of barriers is limited,
- The BCR for low noise road surfaces is poor as a long length is required to benefit a small number of PPFs, and
- A bund has been chosen rather than a wall/fence, as it will fit better in this environment. The bund requires a steep slope from road to keep the crest close to the road for acoustics screening.

Following a meeting with residents in this area the height of the bund in the final design has been raised to approximately 3 metres above the road. For noise mitigation the minimum height is still shown as 2 metres.

5 Design and mitigation

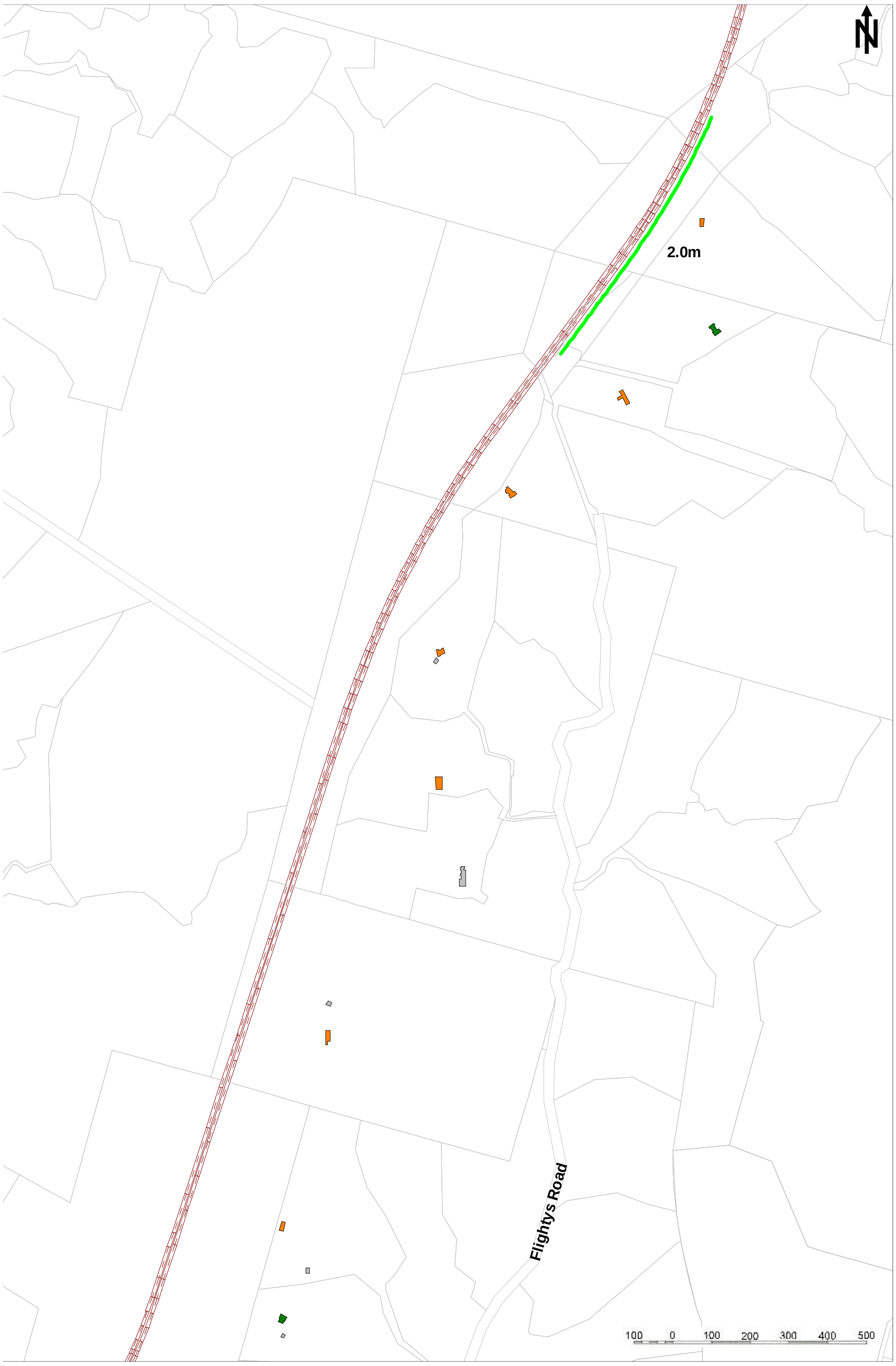

Figure 12-11 Area D - Flightys Road – selected option

Area E - SH58 Interchange

There are 5 PPFs in this area all accessed from State Highway 58. There are numerous other ancillary buildings. The Project is treated as an altered road project for three of these PPFs near State Highway 58, but for the two PPFs furthest from State Highway 58, the Main Alignment is treated as a new road.

Options tested include low noise road surfaces, barriers and combinations of the two. The surface tested is open graded porous asphalt, although it may be that stone mastic asphalt (SMA) would be required in some areas such as the roundabouts for engineering reasons.

At the workshop it was decided to maintain the do-minimum option of a grade 2/4 chip seal and no acoustics barriers/bunds, as:

- All PPFs are in Categories A and B in the do-minimum scenario, and
- Options with a low-noise road surface have a poor BCR due to the limited number of PPFs that benefit from them.

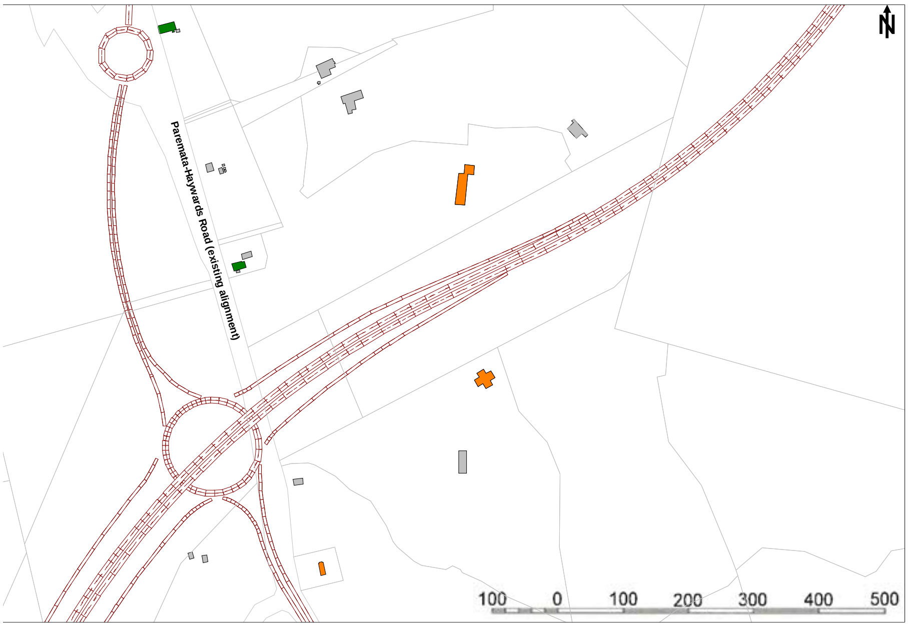

Figure 12-12 Area E - State Highway 58 Interchange – selected option

Area F - Silverwood

In this area the Silverwood subdivision is to the west of the Main Alignment, and a few houses on Bradey Road are to the east. The nearest parts of Silverwood are on a hillside overlooking the Main Alignment, whereas houses on Bradey Road are partially screened by the terrain. The houses on Bradey Road are in category A of NZS 6806 in the do-minimum scenario (as shown on Figure 12-13), and therefore no mitigation is required for those houses.

The Silverwood subdivision is subject to an agreement between the developers and the NZTA (see Section 2.2.1). Road-traffic sound levels have previously been predicted for the developers, but the results of current modelling show higher sound levels. It is understood that the agreement requires buildings in the subdivision to be constructed to mitigate future road-traffic sound levels, and therefore the do-minimum scenario has been selected. The old predictions were in terms of façade sound levels which are 2.5 dB higher than sound levels in Figure 12-13.

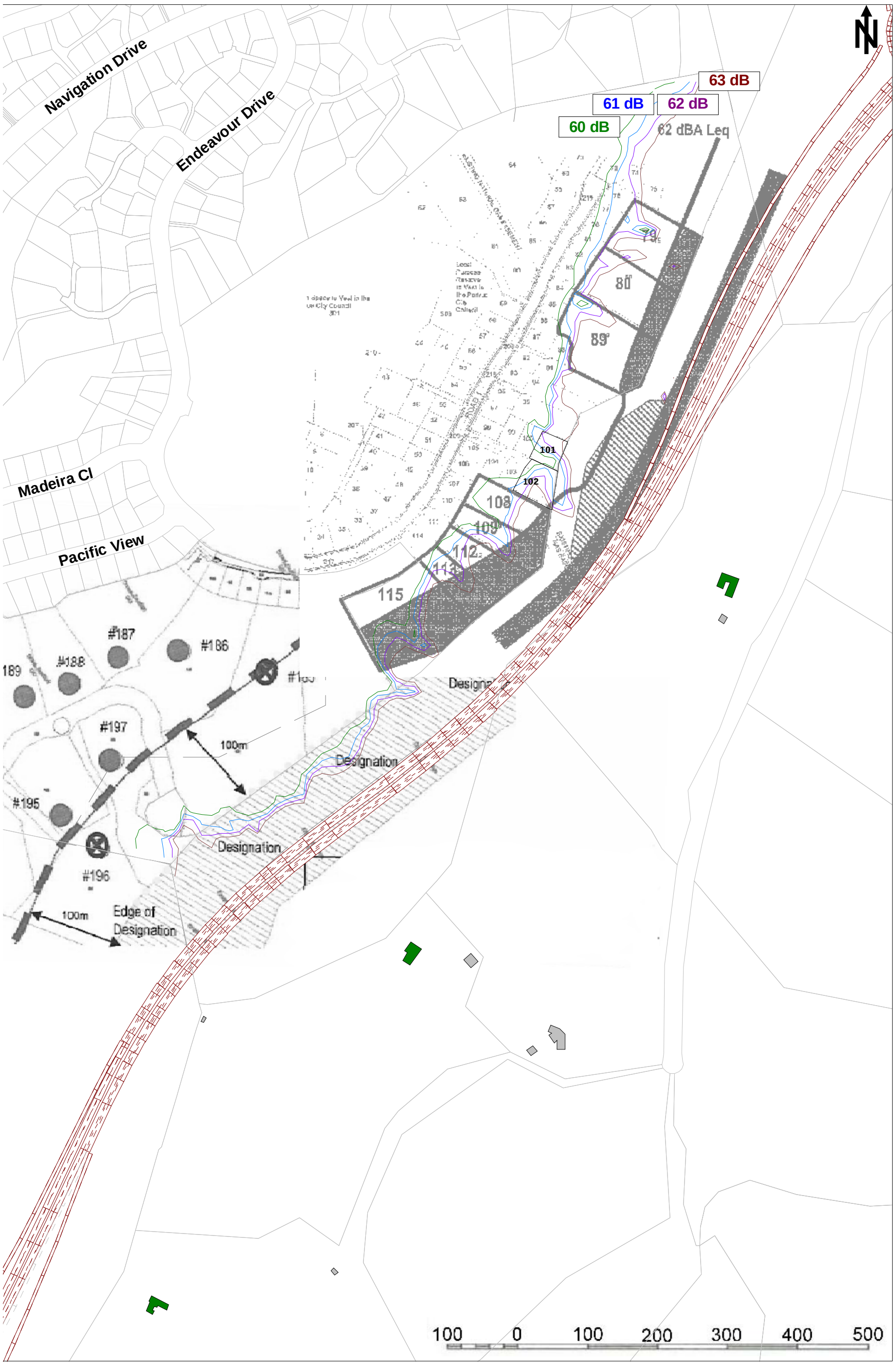

Figure 12-13 Area F - Silverwood – selected option

Area G - Whitby link

No mitigation options have been investigated as all PPFs are in NZS 6806 category A in the do-minimum scenario. In this area there are several recently built PPFs and some with building consent that have not yet been constructed. For these new PPFs the building outlines used in the acoustics model are indicative only.

Figure 12-14 Area G - Whitby link – selected option

Area H - Waitangirua link

On one side of the link road is a church and commercial premises, and on the other side is a marae and associated buildings. There are then various residential properties slightly further away. For most buildings which are within 100 metres of Warspite Avenue, this is treated as an altered road project. However, for the residential buildings at the back of the marae the link road is treated as a new road.

The link road has an open graded porous asphalt surface in the do-minimum scenario, and the options tested are various barriers adjacent to the marae. The road is on an embankment so the barriers have been modelled at the roadside where they would be most effective.

At the workshop it was decided to maintain the do-minimum option of open graded porous asphalt and no acoustics barriers/bunds, as:

- All PPFs are in category A except units at the rear of marae in category B, and
- Barriers would have to be elevated above the marae and could cause adverse visual effects.

However, it was determined that as any barriers would be primarily for the benefit of the units at the rear of the marae, and this is where adverse visual effects would be experienced, the marae and landowner (PCC) should be consulted. Following consultation, in consideration of the views of the marae a 2 metre high roadside barrier by the link road is proposed as the selected option.

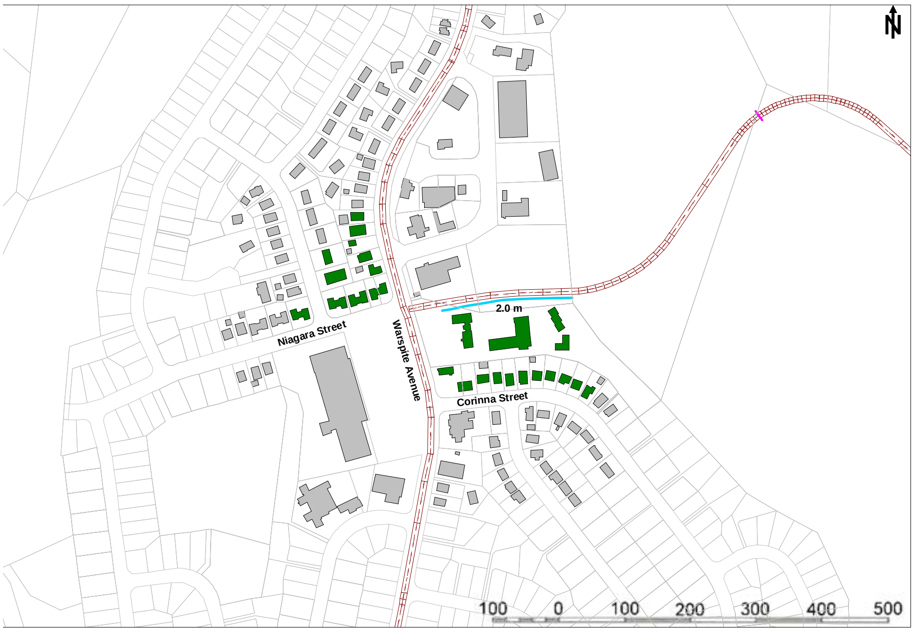

Figure 12-15 Area H - Waitangirua link – selected option

Area I - Takapu Road

No mitigation options have been investigated as the single PPF is in NZS 6806 category A in the do-minimum scenario. The Main Alignment is in a deep cutting at this location.

Figure 12-16 Area I - Takapu Road – selected option

Area J - Bluff Road

No mitigation options have been investigated as all PPFs are in NZS 6806 category A in the do-minimum scenario.

Figure 12-17 Area J - Bluff Road - selected option

Area K - Ranui Heights

Houses on Japonica Crescent, Apple Terrace and Huanui Street are on a hill above the existing State Highway 1, just north of the Main Alignment tie-in at Linden. There are 43 PPFs within 100 metres of the existing SH1, on the east side. There are some minor modifications being undertaken to the existing State Highway 1 in this location including raising the height of the road and increasing the radii of two curves.

Road-traffic is predicted to more than double in this location by 2031, and there will be a greater percentage of heavy vehicles. These factors lead to a significant increase in the road-traffic sound levels from the existing State Highway 1 for the do-nothing scenario compared to the existing scenario. The Project fractionally decreases the sound levels at most PPFs as it reduces the traffic volume on the existing State Highway 1 coastal route. However, the do-minimum levels remain above existing levels.

A low noise road surface is already in use here, so the five mitigation options tested are for barriers. The barriers have been located on the designation boundary above the road. However, there are some places where houses still overlook barriers, which reduces the effectiveness.

At the workshop, option 4 was selected, which has a 130 metre long, 2 metre high barrier on part of the designation boundary. The reasons for selecting this option were:

- Three PPFs were in category C, but are moved into category B by this option,
- With option 4 all PPFs are in categories A and B, and

- Barriers to achieve a significant acoustics benefit at other PPFs would be impractical and have significant adverse visual and shading effects.

Consultation was conducted with individual property owners by the proposed barrier. At the north end of the barrier the ground height significantly lowers relative to the houses, and it was requested that the barrier height be raised. The barrier has therefore been raised to be 3 metres high at the north end.

Figure 12-18 Area K - Ranui Heights - selected option

Area L - Linden

This area is to the west of State Highway 1 in Linden, at the Main Alignment tie-in. The road corridor is significantly widened in this area and the road realigned to accommodate the Main Alignment merging with the existing State Highway 1. Several PPFs on Tremewan Street are owned by the NZTA and will be removed. Three of these have been removed from this assessment, but others may be subsequently removed. There are concrete safety barriers on the bridges and medians in the do-minimum scenario.

Road-traffic is predicted to more than double in this location by 2031, and there will be a greater percentage of heavy vehicles. This causes a significant increase in the road-traffic sound levels compared to the existing scenario. To the north the Project fractionally reduces traffic and therefore sound levels, but at the tie-in and to the south it causes a slight further increase in traffic and sound.

A low noise road surface is already in use here, so the three mitigation options tested are for barriers. The barriers have been located on the designation boundary or the highest point between the boundary and road, where they will be most effective.

At the workshop option 3 was selected, which has a 70 metre long 2 metre high barrier between the road and the designation boundary. Following development of the road alignment in this area, there is sufficient space created so that the barrier will be formed as an earth bund. Figure 12-19 also shows several concrete safety barriers. The reasons for selecting this option were:

- With the selected option all PPFs are in NZS 6806 category A, and
- There are no significant benefits from extending the barrier.

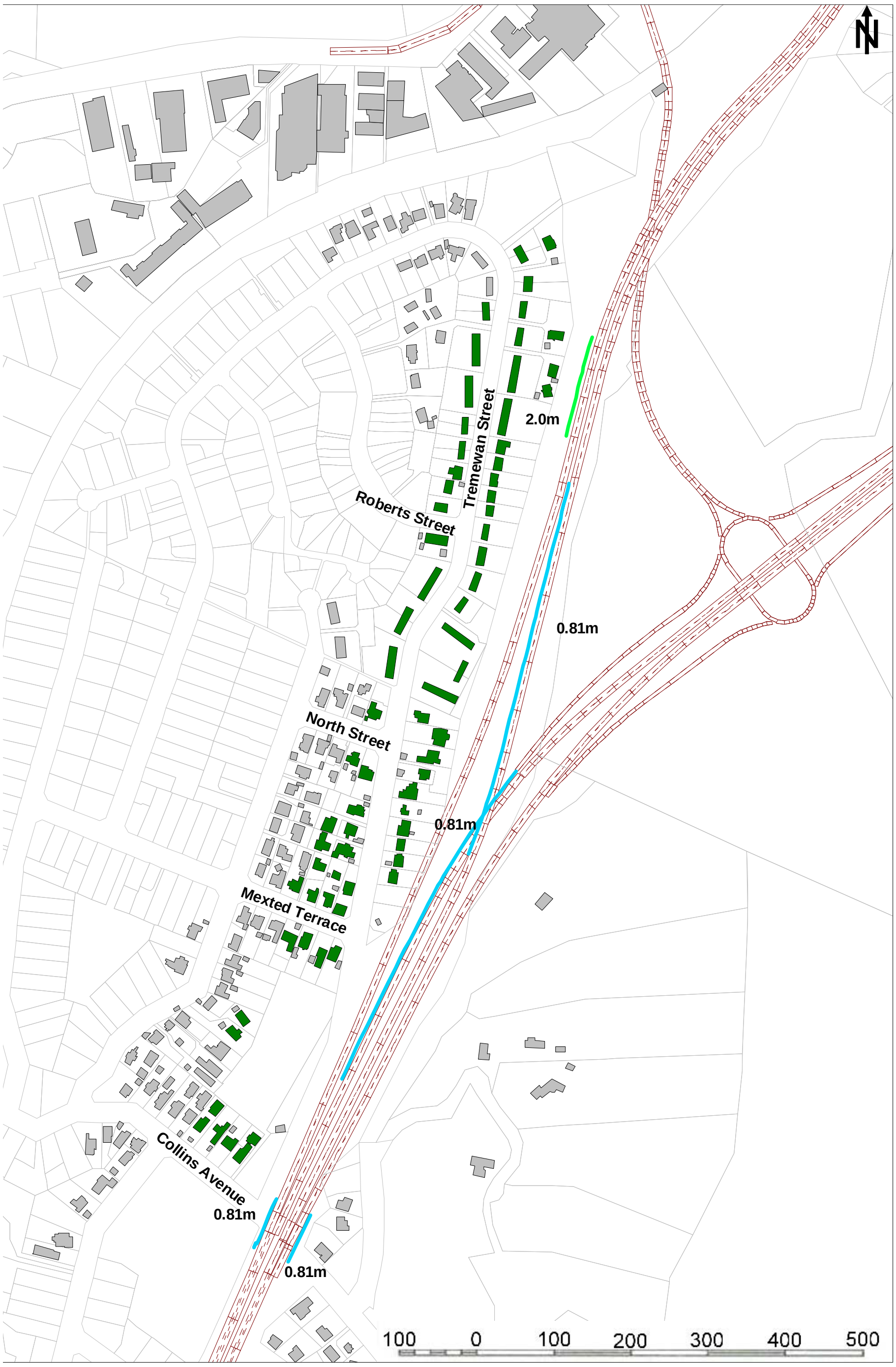

Figure 12-19 Area L - Linden - selected option

Area M - Rangatira Road

No mitigation options have been investigated as both PPFs are in NZS 6806 category A in the do-minimum scenario. Figure 12-20 still includes the concrete safety barriers that are part of the do-minimum scenario.

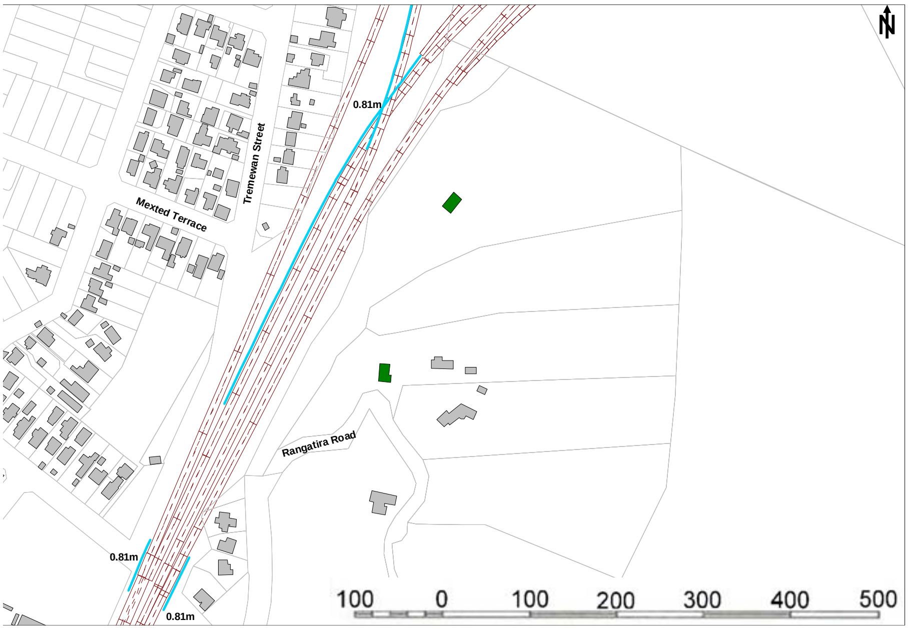

Figure 12-20 Area M - Rangatira Road - selected option

Area N - Greenacres

This area is to the east of State Highway 1, just south of the Main Alignment tie-in where traffic is merging from three lanes to two lanes. The PPFs nearest to State Highway 1 are generally above the road, but there are some areas where the road is on an embankment above houses which are set further back. State Highway 1 is widened in this area to accommodate three lanes in each direction (for merging and diverging traffic) as opposed to two existing lanes in each direction. The existing relatively wide median strip is reduced and a concrete safety barrier added. The remainder of the widening is on this east side of State Highway 1. Road-traffic is predicted to more than double in this location by 2031, and there will be a greater percentage of heavy vehicles. These factors lead to a significant increase in the sound levels compared to the existing scenario, and the Project causes a slight further increase.

A low noise road surface is already in use here, so the five mitigation options tested are for barriers. The barriers have generally been placed on the designation boundary as this is elevated above the road, where they will be most effective. However, at the Mahoe Street reserve the most effective location for the barrier is at the roadside as the highway is on an embankment.

At the workshop option 5 was selected, which has a 700 metre long 2 metre high barrier with one 2.5 metre high and one 3 metre high section. There are also concrete safety barriers. The reasons for selecting this option were:

- All PPFs were in categories A and B other than one in category C at 2 Little Collins Street,
- Greater than 2 metre barrier height could have adverse visual and shading effects,

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- Ventilation and acoustics insulation to be provided to the PPF in category C as alternatives would require higher barriers across the Collins Avenue bridge (BSN26) which is deemed to cause a significant adverse visual effect,
- The short 2.5 metre and 3 metre high sections were required to prevent two PPFs falling into category C, and
- The barrier location allows space for Wellington City Council to establish a formal walkway between Collins Avenue and Raroa Terrace.

This area has complex topography and during consultation with property owners following the workshop, the position of houses relative to the proposed barrier was verified. In three cases it was found that windows would in fact overlook the proposed barrier and it would not be feasible to increase the height of the barrier sufficient to screen those windows:

- 2 Raroa Terrace – The living space and bedrooms are above the garage and are elevated such that they would overlook the barrier. Furthermore, the residents highly value the view to the west from the garden and would prefer not to have a barrier. The selected option has therefore been adapted to stop the barrier in this location and provide building-modification mitigation.
- 2a Raroa Terrace – This is a relatively new house built at the top of a sloping section overlooking an existing tall boundary fence to the State highway. The house already has a ventilation system and well sealed windows. The selected noise mitigation option has been adapted to stop the barrier in this location, unless it is required for visual continuity. This was to be the 3 metre high section of barrier. Building-modification mitigation would not be required due to the modern construction of the house.
- 8 Allen Terrace – One bedroom of the house is close to the property boundary by the State highway overlooking the proposed barrier. In this instance the 2.5 metre high barrier will remain, but building-modification mitigation for that one bedroom will also be required.

For all houses needing building-modification mitigation a detailed assessment of the ventilation and acoustic insulation requirements would be determined at the time of construction.

In response to consultation, the 2.5 metre high section of barrier has been continued to 6 Allen Terrace as well as 8 Allen Terrace. Also, from the site inspection it was found that the barrier cannot extend south of 8 Allen Terrace without interfering with a public footpath, and in any event a section of barrier by 10 Allen Terrace would have provided less than 1 dB benefit, so it has been omitted from the selected option.

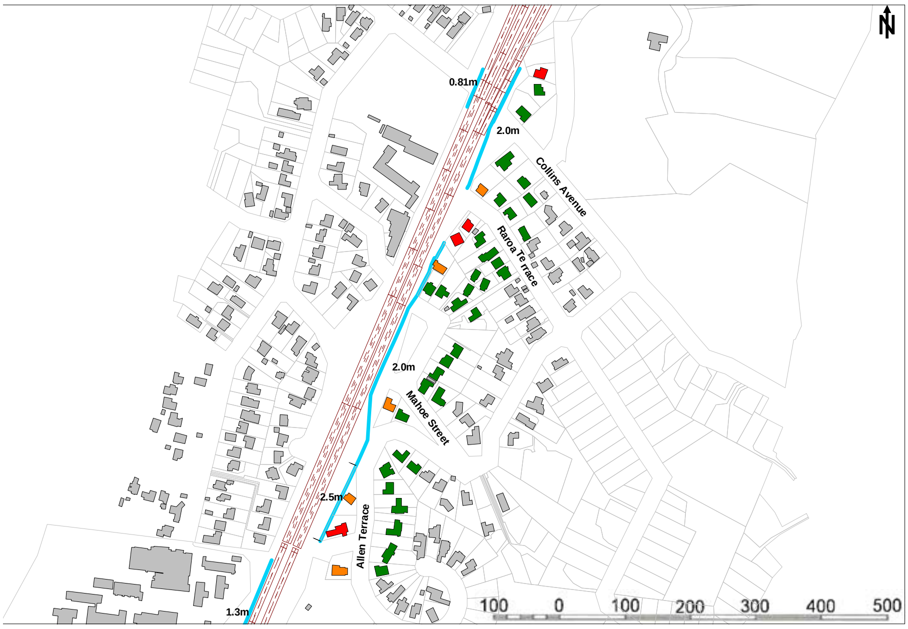

Figure 12-21 Area N - Greenacres - selected option

Area O - Tawa

This area is to the west of State Highway 1, just south of the Main Alignment tie-in where traffic is merging from three lanes to two lanes, opposite area N. It includes Linden School, Tawa Intermediate College and He Huarahi Tamariki Complex. The PPFs nearest to State Highway 1 are generally level with or below the road. State Highway 1 is widened in this area to accommodate three lanes in each direction as opposed to two existing lanes in each direction. The existing relatively wide median strip is reduced and a concrete safety barrier added. The remainder of the widening is on the opposite (east) side of State Highway 1.

Road-traffic is predicted to more than double in this location by 2031, and there will be a greater percentage of heavy vehicles. These factors lead to a significant increase in the sound levels compared to the existing scenario, and the Project causes a slight further increase.

A low noise road surface is already in use here, so the five mitigation options tested are for barriers. The barriers have been placed on the designation boundary or the highest point between the boundary and road, where they will be most effective.

At the workshop, option 5 was selected, which has a 600 metre long, 2 metre and 3 metre high barrier. There are also concrete safety barriers. The reasons for selecting this option were:

- All PPFs are in NZS 6806 categories A and B,
- Higher barriers would create adverse visual effects,

From site inspection and consultation with property owners it was found that to be effective the section of barrier by 24 South Street and 12, 14, 16 and 18 Ranui Terrace would need to increase in height in places:

- From 24 South Street to 14 Ranui Terrace the selected option has been modified by increasing the barrier to 2.5 metres height as the ground level lowers.

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- At 12 Ranui Terrace the selected option has been modified by increasing the barrier to 3 metres height as the ground level lowers, and the barrier has been extended as far as the pedestrian underpass.

Figure 12-22 Area O - Tawa - selected option

5.2.2 Road-traffic noise mitigation summary

The mitigation detailed for each of the selected options is summarised in Table 12-21 for road surfaces, Table 12-22 for barriers and Table 12-23 for building-modification to be offered to residents.

Table 12-21 NoR scenario - road surfaces

Location	Surface
Main Alignment SH1, 00000 m – 25300 m	Chipseal
Main Alignment SH1, 25300 m – 28090 m	Open graded porous asphalt
MacKays Crossing slip lanes	Chipseal
SH58 interchange roundabout	Stone mastic asphalt
SH58 and interchange slip lanes	Chipseal
James Cook interchange roundabout	Stone mastic asphalt
James Cook interchange slip lanes	Chipseal
Whitby link road	Asphaltic concrete
Waitangirua link road 0000 m – 0500 m	Open graded porous asphalt
Waitangirua link road 0500 m – 2480 m	Chipseal
Kenepuru interchange roundabout	Stone mastic asphalt
Kenepuru link road and interchange slip lanes	Open graded porous asphalt
Existing SH1 Linden	Open graded porous asphalt

Table 12-22 NoR scenario - barriers

Location	Side	Type	Length (m)	Height (m)
13680 m – 14240 m	East	Bund	378	2
27490 m – 27540 m	East	Safety barrier	53	0.81
27470 m – 27640 m	East	Wall	152	2
27680 m – 28060 m	East	Wall	380	2-2.5
27000 m – 27350 m	West	Safety barrier	284	0.81
27480 m – 27530 m	West	Safety barrier	48	0.81
27530 m – 27730 m	West	Wall	201	3
27750 m – 27940 m	West	Wall	188	2
27940 m – 28120 m	West	Wall	183	2-3
28100 m – 28460 m	West	Safety barrier	360	1.3
Existing SH1 at Linden underpass - northbound	Centre	Safety barrier	377	0.81
37 Apple Terrace - 56A Huanui Street	East	Wall	151	2-3
86 - 92 Tremewan Street	West	Bund	100	2

Table 12-23 NoR scenario – building-modification mitigation

PPF
2 Little Collins Street
2 Raroa Terrace
8 Allen Terrace (one bedroom)

With the structural mitigation detailed in Table 12-21 and Table 12-22 the total number of PPFs in each of the NZS 6806 categories are shown in Table 12-24

Table 12-24 Number of PPFs in NZS 6806 categories

Category A	Category B	Category C
261 PPFs	25 PPFs	5 PPFs

These totals exclude a number of PPFs that were considered in the assessment areas but are beyond the 100 m distance from the road specified by NZS 6806. The totals include PPFs owned by the NZTA.

5.3 Road-traffic vibration

The vibration predictions and measurements are on the basis of a well maintained road surface in Linden where neighbouring properties are and will be nearest to State Highway 1. The current road surface has been maintained to a high standard which results in relatively low vibration levels. The NZTA has systems to monitor and maintain road surfaces. In the NZTA Statement of Intent[27], road surface condition is a key performance indicator which is desired to be stable or improving. This is addressed in the State Highway Asset Management Plan[28] and given effect to by network management and maintenance contracts. This process is also informed by the annual State Highway National Pavement Condition Report. These systems provide an established and comprehensive system for monitoring and control of road surfaces to a minimum standard. The surface of the existing State Highway 1 in Linden is currently better than this minimum, and the vibration levels measured and predicted would be closer to the criteria if the surface were at the minimum standard. It is therefore considered that additional project controls would be unnecessary and inappropriate.

Two structures of historic interest have been considered with respect to road-traffic vibration: St Josephs Church by State Highway 58 and a brick containment vessel in the Te Puka valley. Both structures are over 20 metres from the nearest traffic lane. Unlike Linden, in both locations the road surface is chipseal, but Figure 12-5 shows that even with a large discontinuity representative of a poorly maintained or rough surface, vibration levels would be below 1 mm/s beyond a distance of 20 metres. In the case of St Josephs Church, State Highway 58 is moved slightly further away and is resurfaced so any existing vibration is expected to reduce. For both structures, road-traffic vibration resulting from the Project is predicted to be well below criteria for cosmetic or structural damage.

[27] NZTA, Statement of Intent 2009-2012
[28] NZTA, Interim State Highway Asset Management Plan 2009/10

5.4 Construction sound and vibration

5.4.1 Mitigation

The predictions in Section 4.4.2 show that due to the reasonable separation distance of most parts of the Project from neighbours, construction sound and vibration can generally be managed through normal good practice. This conclusion relies on adherence to such practice in the operation of the construction site, which is proposed to be addressed through a management plan as discussed in Section 5.4.4. The most sensitive area is considered to be Linden due to the close proximity of neighbours to the works, and this is discussed in Section 5.4.2.

5.4.2 Linden

Given the proximity of construction to neighbours in the Linden area, the issues of communication addressed by the management plan (Section 5.4.4) will be particularly pertinent here.

There are significant noise barriers proposed in this area for road-traffic sound as detailed in Section 5.2. These should be installed at the start of the construction programme so that they also provide protection from construction sound. There are several houses on Tremewan Street that will be removed to make space for the new road, but these should be vacated and left in place for as much of the construction period as possible as they will provide some screening for the houses behind.

Due to the existing high traffic volumes, night works will be required for certain works both for safety and to prevent excessive traffic disruption. The main controls for these works will be to restrict their duration, schedule them for the early part of the night where possible, and ensure equipment is selected and attenuated to minimise sound levels. Individual assessment will be required for each night-time activity once the detailed methodology is known. Specific communication will be undertaken with neighbours for all night works.

Where construction vibration sources are operating adjacent to neighbours, building condition surveys will be undertaken before and after the works and any cosmetic damage caused by the works will be repaired. Neighbours will be forewarned of vibration generating activities to limit annoyance from perception of vibration. Vibration will be minimised through use of bored rather than driven piles where practicable, and also through limiting the size of vibratory compactors operating near residents.

5.4.3 Access

As a key part of good practice management of construction noise effects, it is important to minimise construction traffic using local roads. URS has worked with the project team to establish ways in which the majority of construction traffic could access the site directly from the three intersections with State highways. However, there are areas where access from local roads is still likely to be required:

Paekakariki Hill Road.

There are numerous bridges on the section of the Main Alignment between State Highway 58 and MacKays Crossing, which control the timing of the works. To access this section only from the ends and construct bridges sequentially, would cause the programme to be substantially extended. Furthermore, if starting only from the ends it is not practicable to achieve a reasonable balance of earthworks cut and fill, which would result in significantly greater haulage throughout the project area.

Therefore, a midway access point has been included from Paekakariki Hill Road. This access would be used for up to three years, and probably only two years. Initially the indicative methodology was that this access could be used for four years, but the time can be reduced by making a connection to State Highway 58 as early as practicable.

Traffic using Paekakariki Hill Road would initially comprise delivery of earthworks equipment over a short duration, and then roading materials, bridge components, fuel, water and other supplies over a longer period. There would also be traffic associated with the construction workforce. Opportunities for reducing heavy vehicle movements using Paekakariki Hill Road are limited. However, it is proposed that light vehicles using Paekakariki Hill Road can be minimised by using the main compound at State Highway 58 for staff parking and using minibuses to transport staff to the Paekakariki Hill Road access.

Flightys Road

Flightys Road may be required for access to construct Bridge BSN12.

Bradey Road

Bridge BSN15 (refer to plan set) is required over the Pauatahanui Stream at State Highway 58 to form the Main Alignment. In order to construct the southern abutment of the bridge and access areas to the south of BSN15, temporary access via the Bradey Road bridge is required for approximately one year until BSN15 is completed, which will then provide the main access route.

Takapu Road

Takapu Road may be required for access to construct the Cannons Creek bridge (BSN20) and other bridges.

Ranui Heights

Access to this end of the Project will be made from the existing State Highway 1 at an early stage. However, to make this connection, temporary access is required to allow earthworks crews to access the network of forestry tracks around the site of the Kenepuru interchange in order to form the track down to State Highway 1. There is also a need to clear the existing pine plantation in this area.

Temporary access to this area will be through the Ranui Heights residential area. The forestry will be cleared with access through Ranui Heights, but logs will be stockpiled on site to avoid logging trucks travelling through Ranui Heights. The logs will subsequently be removed through the State Highway 1 access when it has been formed.

The earthworks crews will access the Kenepuru interchange through Ranui Heights for up to one year until the State Highway 1 access has been made. During this time, staff transport will be minimised through proposed use of a remote parking area and a minibus shuttle in the same manner proposed for Paekakariki Hill Road.

5.4.4 Historic structures

St Josephs Church by State Highway 58 is over 20 metres from the works. Section 4.5.2 shows that for most activities there should be no risk of structural or cosmetic damage from construction vibration at this distance. However, given the historic interest of this building it is recommended that in addition to condition surveys before and after construction, there should be monitoring of vibration levels when works are conducted within 50 metres of the Church.

While the alignment is also over 20 metres from the brick containment vessel in the Te Puka valley, earthworks will be required approximately 10 metres away. Section 4.5.2 shows that cosmetic damage is possible at this distance from compaction. It is recommended that all equipment operating within 20 metres of the brick containment vessel should be subject to individual vibration assessment, and compaction equipment should be selected to minimise vibration. Again, in addition to condition surveys before and after construction, there should be monitoring of vibration levels when works are conducted within 50 metres of the vessel.

5.4.5 Draft management plan

A construction noise and vibration management plan should detail consultant and contractor obligations during construction and maintenance, and encourage proactive management. It should also provide a framework for detailed assessment of individual activities and areas once the final construction methodology is known. A draft management plan has been prepared for the Project. The draft management plan includes specific good practice noise control and management measures proposed for each activity.

Assessment of acoustics effects

6.1 Road-traffic sound

NZS 6806

NZS 6806 sets reasonable criteria for road-traffic sound levels, taking into account health issues associated with noise and other matters. On this basis, it is considered that road-traffic sound levels in compliance with NZS 6806 category A would generally result in no more than minor adverse noise effects. Depending on the existing environment, compliance with category B may also give rise to no more than minor adverse effects. Particularly for the new road criteria where category B is the same road-traffic sound level as category A for altered roads.

Area A - MacKays Crossing

There will be an increase in traffic volumes and road-traffic sound levels at this location regardless of the Project. The Main Alignment actually moves the traffic away from the most affected PPFs, reducing the road-traffic sound levels, but increases the levels at other PPFs. The increases in road-traffic sound levels are greatest for three PPFs furthest from the existing State Highway 1, although the most affected PPF is owned by the NZTA and is to be removed. At all other PPFs the road-traffic sound levels remain within NZS 6806 categories A and B.

Area B - Battle Hill

The Project will significantly change the acoustics amenity of part of Battle Hill Farm Forest Park. As gas-line ridge provides acoustics screening and there is reasonable separation from the Main Alignment, the road-traffic sound levels heard in the main visitor area of the park will be unobtrusive and will not interfere with any activities. However, as visitors pass through the valley (Transmission Gully) to access the tracks beyond, the experience will be significantly changed.

Any acoustics mitigation in this area would need to be extensive to have any effect, and even then the basic change in acoustics amenity created by the Project would remain.

Area C - Paekakariki Hill Road, Area D - Flightys Road

At these PPFs there will be a significant change in acoustics amenity, and constant road-traffic sound will become a new part of the environment. At all PPFs the road-traffic sound will be at reasonable levels, as determined by the criteria in NZS 6806. At these locations the old Transmission Gully Project designation signals to residents that road-traffic sound could reasonably be expected in this environment.

Acoustics mitigation has been investigated in these areas including low noise road surfaces and barriers, but no practicable options have been identified that would significantly reduce the sound levels to alter these conclusions.

Area E - SH58 Interchange

The situation at State Highway 58 is similar to MacKays Crossing. There is an increase in traffic volumes and road-traffic sound levels regardless of the Project. The Main Alignment causes a further increase at some PPFs, but decreases sound levels for those PPFs by State Highway 58. For the PPF furthest from State Highway 58, the increase in road-traffic sound levels is significant. At all PPFs the road-traffic sound levels remain within categories A and B of NZS 6806.

6 Assessment of acoustics effects

Acoustics mitigation has been investigated for this interchange, but again, no practicable options have been identified.

Area F - Silverwood

Road-traffic will be audible at times at PPFs on Bradey Road, but within category A of NZS 6806.

The formal agreement between the Silverwood developers and the NZTA is clear that road-traffic sound from the Main Alignment will be part of the environment. The nearest PPFs in the subdivision are required to be built with appropriate sound insulation. Given that the subdivision has proceeded on this basis any adverse noise effects from the Project should be acceptable.

Area G - Whitby link

Traffic volumes and sound levels will increase but remain within category A of NZS 6806.

Area H - Waitangirua link

With the proposed noise barrier by the marae, road-traffic sound levels will increase but remain within category A of NZS 6806 at all PPFs.

Area I - Takapu Road

Road-traffic will be audible at times at the PPF on Takapu Road, but within category A of NZS 6806.

Area J - Bluff Road

The Project gives rise to an increase in the order of only 1 dB at the PPFs in Bluff Road, which is not significant. The levels are within category A of NZS 6806.

Area K - Ranui Heights

Without the Project, road-traffic sound levels would increase by in the order of 5 dB through general traffic growth. There would be no mitigation and several PPFs would be in NZS 6806 category C. However, with the Project the increase in sound levels will be fractionally less at most PPFs as there will be less traffic on the existing State Highway 1 coastal route. With the Project, mitigation is to be provided to maintain all PPFs in NZS 6806 categories A and B. The Project therefore provides an improvement in this area.

Area L - Linden

Without the Project, road-traffic sound levels would increase in the order of 5 dB through general traffic growth. With the Project the increase will be slightly higher and lower at different PPFs. Mitigation is to be provided to maintain all PPFs in NZS 6806 category A.

Area M - Rangatira Road

Road-traffic sound levels will increase at these two PPFs but remain within category A of NZS 6806.

Area N - Greenacres

Without the Project, road-traffic sound levels would increase in the order of 5 dB through general traffic growth, and several PPFs will be in category C of NZS 6806. With the Project mitigation is provided to reduce the sound levels so that most PPFs are in categories A and B. Three PPFs would be offered building-modification mitigation to achieve the internal Category C criterion.

Area O - Tawa

Without the Project, road-traffic sound levels would increase in the order of 5 dB through general traffic growth. Linden School and He Huarahi Tamariki Complex would be in NZS 6806 category C. With the Project the increase will be slightly higher, but mitigation is provided to reduce the sound levels so that all PPFs are in categories A and B.

Summary

At the interchanges there will be an increase in road-traffic sound levels, but these remain within reasonable criteria set by NZS 6806, and the adverse noise effects are considered to be minor. In other areas such as Flightys Road, the road-traffic sound levels will also be within reasonable criteria, but as a new road the Main Alignment will cause a significant change in acoustics amenity. However, given that there is already a designation in place, such a change in amenity has previously been signalled. All PPFs are in NZS 6806 categories A and B except three that will be offered building-modification mitigation as required to achieve the internal category C criteria, one that already has effective glazing and ventilation, and one owned by the NZTA which will be demolished.

6.1.2 Engine braking

The sound of engine braking on sections of the Project with steep gradients has been predicted to be within the guideline maximum noise level limit in NZS 6802 and the Transit Guidelines. Furthermore, during two surveys in the Wellington area, it was found that the majority of trucks do not use audible engine/exhaust brakes. On this basis the potential adverse noise effect of engine braking is considered to be minor.

6.2 Road-traffic vibration

Vibration from road-traffic would only be felt close to the road. In this instance, measurements have demonstrated at the closest point to State Highway 1 in Linden, the levels are within the new road criteria beyond approximately 7 metres from the road. There are a small number of properties already close to State Highway 1 that become even closer as a result of the Project widening the road. The nearest property with the Project will be approximately 10 metres from the road. In this instance the vibration levels would still be within both the $v_{w,95}$ 0.3 mm/s criterion, and the $v_{w,95}$ 0.6 mm/s criterion for existing roads. The criteria have been derived through research into human perception and annoyance. On this basis, the adverse effects of road-traffic vibration will be minor.

There is no road-traffic vibration effect predicted on the structures of St Josephs Church or the brick containment vessel in the Te Puka valley.

6.3 Construction

The Project is for significant infrastructure requiring construction over several years. There are corresponding potential adverse construction sound and vibration effects. These have been considered in this report and control mechanisms are detailed in the draft management plan.

6.3.1 Sound

The majority of the construction is separated from neighbours and while it will be audible at many places, it will remain within reasonable limits determined by NZS 6803, using standard noise management controls. The main works will only be conducted between 0630h and 2000h Monday to Saturday, with noisy activities further limited to between 0730h and 1800h. With effective communication with neighbours, these works should not unduly interfere with normal domestic activities. There are also other specific activities at some places that could potentially be affected by construction sound such as golfing and equestrian activities. In both cases the activities could continue with appropriate management and communication about construction activities.

At the interchanges, and at Linden in particular, there will be works closer to neighbours and there will also be some works at night. Even in these instances most works will still comply with the NZS 6803 guideline noise limits and should cause only a minor adverse noise effect. In cases where the construction sound cannot reasonably comply with the guideline noise limits at night, measures will be implemented as detailed in the draft management plan to manage adverse effects. With such controls the adverse noise effect should remain minor.

6.3.2 Vibration

There are no adverse vibration effects predicted for most of the route. For areas such as Linden where there are neighbours close to vibration sources, there is the potential for cosmetic damage to buildings (such as cracking) and annoyance from perception of vibration. Any cosmetic damage due to the Project will be detected through condition surveys before and after construction and will be repaired. Annoyance will be addressed by accurately communicating the time and duration of vibration in advance, and this will generally only be during the daytime. With these controls the adverse effects of construction vibration should be minor.

Detailed assessment of specific construction equipment and vibration monitoring has been recommended when works are close to St Josephs Church and the brick containment vessel in the Te Puka valley. Works would be stopped if measured levels were near to the criteria (Section 2.4.2), and therefore construction vibration should not have an adverse effect on these structures.

If blasting is used in the Wainui Saddle area it may be audible as a ‘thud’ at the nearest receivers, but airblast and vibration levels will be within the AS 2187-2 guideline limits.

Conditions

7.1 Road-traffic sound

The new assessment method from NZS 6806, which has been used in this project, has fundamentally changed the way in which noise mitigation measures are designed. Rather than dogmatic adherence to a specific noise limit, regardless of practicality or adverse effects such as shading by barriers, NZS 6806 promotes an integrated design process to establish the best practicable option.

NZS 6806 requires significantly more design work during the acoustics assessment, and consequently the noise mitigation is more refined at this stage in the Project.

It is not possible to assign a simplistic performance standard such as a noise limit to the NZS 6806 process or the results of the process. The best practicable option is determined by following the correct process and not by achieving an absolute limit.

To support the introduction of NZS 6806, the NZTA has commissioned its legal panel to prepare designation conditions that encapsulate the NZS 6806 process. The conditions provide certainty in the noise mitigation outcome to be provided, while allowing for development during normal detailed design processes. It is recommended that this form of conditions should be used for road-traffic sound.

7.2 Road-traffic vibration

The assessment has shown that there is no requirement for additional controls of road-traffic vibration. The NZTA has an established and comprehensive national system to monitor and maintain road surface conditions. Therefore, no project specific designation conditions related to road-traffic vibration are recommended.

7.3 Construction sound and vibration

For construction sound and vibration it is critical that effective management processes are followed and this should be specified by designation conditions. There should also be noise limits to provide a framework for assessment, but allowance needs to be made for activities that cannot comply with the standard values. This frequently occurs for roading projects where night-works cannot be avoided. Again, the NZTA has recently developed standard designation conditions for road construction sound and vibration that are recommended for this project.

Specific conditions are recommended for monitoring vibration at St Josephs Church and the brick containment vessel in the Te Puka valley.

Conclusions

8.1 Road-traffic sound

There are several different road-traffic noise criteria that could be applied to this project. It is considered that best practice and the most appropriate criteria is that contained within the new Standard NZS 6806:2010.

The Project has been assessed in accordance with NZS 6806. For each area where there are Protected Premises and Facilities (PPFs) near the road, the best practicable option for noise mitigation has been determined through an integrated assessment process.

It has been found that for the majority of the Project there is no specific noise mitigation required, other than a short section of bund. At the southern end of the Project around Linden there are both low noise road surfaces and extensive noise barriers, to control road-traffic sound to within reasonable levels. In three instances building-modification mitigation is proposed.

The Project will cause an increase in road-traffic sound levels. In areas remote from existing State highways, the Project will give rise to a significant change in acoustics amenity, but the sound levels will be within reasonable limits. This change in amenity has been signalled for some time by the existing designation. In areas near to State highways there will be an increase in levels, but again within reasonable limits. Without the Project there would still be an increase in sound levels at Linden, but no mitigation would be provided.

8.2 Road-traffic vibration

The Norwegian Standard NS 8176E:2005 has been adopted for the assessment of road-traffic vibration. The nearest neighbours to the State highway are in Linden both before and after the Project. Measurements of vibration from the existing State highway in Linden show vibration levels are below the thresholds in NS 8176. In some instances the road is moved closer to neighbours, but on the basis of these measurements the vibration levels will remain within the recommended limits. While the road surface condition will change over time, the NZTA has robust procedures in place to maintain road surfaces to a reasonable standard that will control vibration effects.

8.3 Construction sound and vibration

NZS 6803:1999 has been adopted for the assessment of construction sound and British Standard BS 5228-2:2009 has been adopted for the assessment of construction vibration. For most of the Project, the sound and vibration will be kept in compliance with the guideline limits, through the use of good practice construction noise and vibration management. This will be achieved through the use of a construction noise and vibration management plan, and a draft of that plan has been prepared as part of this assessment.

Construction traffic on local roads is to be minimised by using the State highway interchanges for construction access where practicable. Where use of local roads is unavoidable, staff vehicle movements are to be minimised through the proposed use of remote parking and shuttle buses.

At Linden there is the potential for greater construction sound and vibration effects, due to the proximity of neighbours and the likely need for some night-works. Measures have been proposed in this area such as the early construction of road-traffic noise barriers, and increased communication with neighbours that will mitigate the potential effects.

Limitations

URS New Zealand Limited (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of the NZ Transport Agency and Porirua City Council in connection with the designation of the Project. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Acoustics Scope dated 22 September 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between January 2010 and July 2011 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix 12A Glossary

Abbreviation	Meaning
AADT	Annual average daily traffic (number of vehicles travelling in both directions per twenty-four hours)
AEE	Assessment of effects on the environment
AS	Australian Standard
BCR	Benefit-cost ratio
BPO	Best practicable option
BS	British Standard
CMP	Construction management plan
CNMP	Construction noise management plan
CRTN	Calculation of road traffic noise
dB	Decibels
EEM	Economic Evaluation Manual
EPA	Environmental Protection Authority
GIS	Geographic information system
HV	Heavy vehicle
Hz	Hertz
km	Kilometre
km/h	Kilometres per hour
mm/s	Millimetres per second
NAASRA	National Association of Australian State Road Authorities
NoR	Notice of requirement for designation
NS	Norwegian Standard
NZS	New Zealand Standard
NZTA	NZ Transport Agency
OGPA	Open graded porous asphalt
PCC	Porirua City Council
PPF	Protected premises and facilities
PPV	Peak particle velocity
RATAG	Regulatory Authorities Technical Advisory Group
RoNS	Road of national significance
SAR	Scheme assessment report
SH1	State Highway 1
SH2	State Highway 2
SH58	State Highway 58
TRRL	Transport and Road Research Laboratory
WHO	World Health Organisation
vpd	Vehicles per day

Appendix 12A

Term	Definition
Alignment	The horizontal or vertical geometric form of the centre line of the carriageway.
Amenity values	Defined in section 2 of the RMA as: “those natural or physical qualities and characteristics of an area that contribute to people’s appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes.”
Annual average daily traffic	The total volume of traffic passing a roadside observation point over the period of a calendar year, divided by the number of days in that year (365 or 366 days). Measured in vehicles per day.
Benefit-cost ratio	The ratio that compares the benefits accruing to land transport users and the wider community from implementing a project or providing a service, with that project’s or service’s costs.
Best practicable option	Defined in section 2 of the RMA as: “in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to - (a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and (b) the financial implications, and the effects on the environment, of that option when compared with other options; and (c) the current state of technical knowledge and the likelihood that the option can be successfully applied.”
Bridge	A structure designed to carry a road or path over an obstacle by spanning it. This includes culverts with a cross-sectional area greater than or equal to 3.4 square metres.
Carriageway	That portion of the road devoted particularly to the use of travelling vehicles, including shoulders.
Centreline	The basic line, at or near the centre or axis of a road or other work, from which measurements for setting out or constructing the work can conveniently be made.
Chip seal	A wearing course consisting of a layer or layers of chips originally spread onto the pavement over a film of freshly sprayed binder and subsequently rolled into place.
Clear zone	An area adjacent to a road carriageway that is clear of fixed objects and other hazards, providing a recovery zone for vehicles that have left the carriageway.
Conditions	Conditions placed on a resource consent (pursuant to section 108 of the RMA) or conditions of a designation (pursuant to subsection 171(2)(c) of the RMA).
Construction management plan	A site or project specific plan developed to ensure that appropriate management practices are followed during the construction phase of a project.
Cross-section	A vertical section, generally at right-angles to the centreline showing the ground. On drawings it commonly shows the road to be constructed, or as constructed.
Deceleration lane	A speed-change lane provided to allow vehicles to decrease speed.
Designation	Defined in section 166 of the RMA as: “a provision made in a district plan to give effect to a requirement made by a requiring authority under section 168 or section 168A or clause 4 of schedule 1.”

Appendix 12A

Term	Definition
Effect	Defined in section 3 of the RMA as: "(a) Any positive or adverse effect; (b) Any temporary or permanent effect; (c) Any past, present, or future effect; (d) Any cumulative effect which arises over time or in combination with other effects – Regardless of the scale, intensity, duration, or frequency of the effect and also includes – (e) Any potential effect of high probability; and (f) Any potential effect of low probability, which has a high potential impact."
Embankment	A construction work (usually of earth or stone) that raises the ground (or formation) level above the natural surface.
Environment	Defined in section 2 of the RMA and includes: "(a) Ecosystems and their constituent parts, including people and communities; (b) All natural and physical resources; (c) Amenity values; and (d) The social, economic, aesthetic and cultural conditions which affect the matters stated in paragraphs (a) to (c) of this definition or which are affected by those matters."
Expressway	A road mainly for through traffic, usually dual carriageway, with full or partial control of access. Intersections are generally grade separated.
Footpath	That portion of the road reserve set aside for the use of pedestrians only.
Free-field (Acoustics)	Description of a location which is at least 3.5 metres from any significant sound reflecting surface other than the ground.
Guard rail	A rail erected to restrain vehicles from physically leaving the road, including wire-rope barriers.
Hertz	Unit of frequency, used for sound and vibration.
Interchange ramp	A carriageway within an interchange providing for travel between two arms (legs) of the intersecting roads.
Interchange	A grade separation of two or more roads with one or more interconnecting carriageways.
Intersection	A place at which two or more roads cross at grade or with grade separation.
Kenepuru Link Road	A proposed State highway from the Kenepuru Interchange to Kenepuru Drive. This road will provide vehicular access to the Main Alignment across the NIMT and existing SH1 for traffic from western Porirua.
$L_{Aeq(24h)}$	Time-average sound level over a twenty-four hour period, measured in dB.
$L_{Aeq(1h)}$	Time-average sound level over a one hour period, measured in dB.
L_{AFmax}	Maximum sound level, measured in dB.
Local road	A road (other than a State highway) in the district, and under the control, of a territorial authority, as defined in Section 5 of the Land Transport Management Act 2003.
Median barrier	A device used on multi-lane roads to keep opposing traffic within their prescribed carriageways.
Noise	Noise may be considered as sound that serves little or no purpose for the exposed persons and is commonly described as 'unwanted sound'.
Notice of requirement for designation	A notice given to a territorial authority (under section 168 of the RMA) or by a territorial authority (under section 168A of the RMA) of a requirement for land, water, subsoil or airspace to be designated.

Appendix 12A

Term	Definition
Outline plan	A plan of the public work, project, or work to be constructed on designated land provided to a territorial authority, pursuant to section 176A of the RMA, prior to the work being undertaken.
Porirua Link Roads	Refers collectively to the Whitby Link Road and the Waitangirua Link Road.
Ramp	Carriageway within an interchange providing for travel between two arms (legs) of the intersecting roads.
Retaining wall	A wall constructed to resist lateral pressure from the adjoining ground or to maintain in position a mass of earth.
Reverse sensitivity	The vulnerability of an established activity to objection from a new sensitive land use.
Road	An area formed for vehicular traffic to travel on. The term ‘road’ describes the area between kerbs or surface water channels and includes medians, shoulders and parking areas.
Road reserve	A legally described area within which facilities such as roads, footpaths and associated features may be constructed and maintained for public travel.
Roundabout	An intersection where all traffic travels in one direction around a central island.
Sound	Sound (pressure) levels are an objective measure of changes in pressure levels that may be heard by humans. Unwanted sound can be considered as noise.
Traffic flow	The number of vehicles passing a given point during a specified period of time.
Traffic lane	A portion of the carriageway allotted for the use of a single line of vehicles.
Traffic volume	The number of vehicles flowing in both directions past a particular point in a given time (e.g. vehicles per hour, vehicles per day).
Transmission Gully Main Alignment (*the Main Alignment*)	A proposed 27km expressway between Linden (Wellington City) and MacKays Crossing (Kapiti Coast).
Transmission Gully Project (*the Project*)	Refers collectively to the Transmission Gully Main Alignment, the Kenepuru Link Road and the Porirua Link Roads.
$v_{w,95}$	Statistical maximum weighted velocity, used in the assessment of road-traffic vibration
Vehicles per day	The number of vehicles observed passing a point on a road in both directions for 24 hours.
Waitangirua Link Road	A proposed local road from the James Cook Interchange to the intersection of Warspite Avenue and Niagara Street in Waitangirua. This proposed road will have a design speed of 50 km/h.
Whitby Link Road	A proposed local road from the Waitangirua Link Road to the intersection of James Cook Drive and Navigation Drive in Whitby. This proposed road will have a design speed of 50 km/h.

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