HEGGIES

REPORT 10-7434-R1

Revision 3

M2 Motorway Upgrade Project
Environmental Assessment
Noise and Vibration
(M2U-REP-30-00-EN003A-01)

PREPARED FOR

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M2 Motorway Upgrade Project
Environmental Assessment
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EXECUTIVE SUMMARY

INTRODUCTION

The M2 Motorway spans approximately 21 km from Baulkham Hills to North Ryde and is, in several sections, in close proximity to a number of densely populated residential areas.

The current demands on the M2 Motorway are well known, with the motorway being seen to be at capacity during busy periods of the day. It is therefore proposed to widen the motorway in various sections along its length to help reduce the strain on the motorway. Associated upgrades to some of the interchanges along the route are also planned.

The purpose of this document is to provide a detailed assessment of the noise and vibration impacts associated with the construction and operation of the upgrade project.

The potential noise and vibration impacts of the M2 Upgrade Project can be broken down as follows:

- Impact on surrounding areas during the construction phase of the project due to the widening of the motorway and interchange upgrade works, including:
  - Construction noise
  - Construction vibration
  - Construction ground-borne noise from widening of the Norfolk Tunnel
- Operational impacts after project commissioning, consisting primarily of:
  - Noise emissions due to changed road traffic conditions
  - Mechanical noise emissions from the Norfolk Tunnel ventilation fan system

AMBIENT NOISE MONITORING

In order to characterise the existing noise environment adjacent to the project area and to establish the noise levels upon which to base the noise emission objectives, environmental noise monitoring was performed at a number of representative locations along the length of M2 Upgrade Project corridor.

The monitoring was completed over two separate surveys. The first of these surveys was carried out in March and April 2008 at 24 receptor locations along the motorway route; the second survey was performed in December 2008 at a further 13 locations.

CONSTRUCTION NOISE

Construction Noise Criteria

Heggies has conducted a review of guidelines and current practices for the assessment and subsequent mitigation of construction noise, and has adopted the quantitative assessment approach embodied within the Department of Environment, Climate Change and Water (DECCW) Interim Construction Noise Guideline (ICNG).

The ICNG requires the determination of *Noise Management Levels* (NMLs) for noise affected receivers consistent with current practices to deal with construction noise in a transparent and consistent way.

EXECUTIVE SUMMARY

In line with this approach, the following $L_{Aeq(15minute)}$ NMLs have been adopted for sensitive receivers:

- Daytime (7.00 am to 6.00 pm) RBL or L_{A90} Background + 10 dBA
- Evening (6.00 pm to 10.00 pm) RBL or L_{A90} Background + 5 dBA
- Night-time (10.00 pm to 7.00 am) RBL or L_{A90} Background + 5 dBA

Daytime Construction Works

Construction noise during the daytime period is generally predicted to be in line with the Noise Management Levels at most of the assessment locations. This results mainly from the relatively high daytime background noise levels which are apparent from existing traffic movements on the M2 Motorway. A number of small exceedances are predicted for the construction scenarios associated with Road Widening and Bridgeworks.

Out of Hours Works

During the evening period, exceedances of the project Noise Management Levels are apparent for most of the construction scenarios assessed. These exceedances range from minor (ie just above compliance levels) to around 15 dBA.

For the night-time period there are significant exceedances for most activities as a result of the more stringent NMLs which apply to this period.

Prior to undertaking significant “out of hours” works, justification for undertaking such works would be established, noise mitigation and management measures would be implemented (where required) to minimise the potential impacts at nearby sensitive receivers combined with extensive consultation with affected communities.

Discussion Regarding Construction Noise Exceedances

Although the assessment predicts significant exceedances at times, it is noted that the sensitive receiver noise levels predictions arise out of simulated *“worst-case”* scenarios whereby all the equipment within a particular scenario is operating concurrently, for the full 15-minute assessment period, in a location immediately adjacent to the residences of interest.

This situation, and any resulting Noise Management Level exceedances, may therefore only be apparent at a particular receiver of interest for a relatively short period of time. When all of the equipment assumed to comprise a particular construction scenario is not operating simultaneously (which will often be the case) and as plant and equipment moves along the road section of interest, the noise levels would be expected to reduce accordingly.

Notwithstanding the above, the following approach will be undertaken, in accordance with the ICNG:

- All reasonable and feasible work practices need to be applied to meet the noise goals.
- Where Noise Management Levels are likely to be exceeded (especially during the more sensitive evening and night-time periods), community liaison must be undertaken and negotiation take place to arrive at the final mitigation strategy.

The assessment indicates that in the daytime, evening and night-time periods, the higher exceedances are generally related to the use of the following items of plant:

- Concrete saws (and reinforcement cutting)
- Rockbreakers
- Jackhammers

These noise intensive activities may therefore need to be restricted where possible to daytime and evening periods.

Construction Site Compounds

The M2 Upgrade Project would require several temporary Site Compounds to be constructed along the length of the route. These compounds would be used for a variety of purposes including laydown areas, stockpiling, stores, team offices, car parking, etc.

The proposed locations of the Site Compounds are all immediately adjacent to the M2 Motorway, and as such, are already subject to reasonably high levels of ambient (road traffic) noise.

It is noted that the majority of the smaller Site Compounds are intended to be used during the daytime periods, with only the Major Compounds being used 24 hours a day.

Exceedances of Noise Management Levels are predicted where sensitive receivers are situated in proximity to Site Compounds. As such, it will be necessary to provide varying degrees of noise mitigation to minimise the impact of noise generated by the compounds.

As there are negligible existing barriers between the Site Compounds and the sensitive receivers, it is likely that some form of noise barrier would be required to be erected through dedicated and/or temporary noise walls, temporary hoardings, site sheds, etc, in locations where sensitive receivers are situated in close proximity to the proposed construction compounds. Correctly designed and constructed barriers (of solid construction using appropriate materials) would be expected to result in the following reductions in noise levels:

- Minor Barriers (hoarding of indicative height of 3 m - 4 m): 5 dBA to 10 dBA reduction
- Major Barriers (hoarding of indicative height of 6 m - 8 m): 10 dBA to 15 dBA reduction

Close liaison with the local community and a proactive information protocol (ie information on the duration and likely intensity of upcoming works) would play an important part of the management of noise emissions at these locations.

CONSTRUCTION VIBRATION

The major potential sources of construction vibration related to the M2 Upgrade Project include the use of excavators, rockbreakers and vibratory rollers.

In general, vibration produced by earthworks and road forming operations is expected to lie below structural damage criteria at the nearest sensitive receptors. Where vibration-intensive operations are being conducted in close proximity to buildings nearest to the roadworks (eg construction of the Windsor Road Ramps), judicious selection of plant and equipment will be necessary. Vibration may be perceptible for relatively short periods of time when construction activities are immediately adjacent to specific dwellings.

Finally, given the distances of the nearest residences to the proposed construction works, a review of the construction plan would be required to confirm the extent of pre-construction building condition surveys.

CONSTRUCTION IMPACTS OF WIDENING THE NORFOLK TUNNEL

During the widening of the Norfolk Tunnel both airborne and ground-borne noise will have the potential to exceed the relevant criteria at times. The potential noise impacts from the widening works which will be performed entirely within the tunnel will be mitigated with the use of acoustic sheds during the widening of the tunnel, together with an acoustic curtain at either end of tunnel at other times. The acoustic shed will only be in place for the excavation phase of the widening. All other noise generating night-time works within the tunnels will have a noise curtain in place at the portal entrances.

For the early widening works (ie adjustment to the portal transition areas and breaking out of existing concrete barriers) there would be limited mitigation measures, as the options for physical noise attenuation devices and procedural management measures (such as scheduling of activities) would be neither effective nor feasible.

It is recommended that where exceedances are indicated, suitable consultation with the affected land owners should take place to determine the appropriate feasible and reasonable management strategies, together with monitoring to confirm the predicted levels.

CONSTRUCTION NOISE AND VIBRATION MITIGATION STRATEGIES

Certain “baseline” mitigation strategies should be adopted along the route at any section where the noise goals are exceeded. The construction contractor will, where reasonable and feasible, apply best practice noise mitigation measures including:

- Erecting temporary noise walls around Site Compounds which are in proximity to residential receivers.
- Maximising the offset distance between noisy plant items and nearby noise sensitive receivers.
- Avoiding the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers whenever possible.
- Where possible, equipment with directional noise emissions should be orientated away from sensitive receivers.
- Where practical, the layout of plant and equipment at any site compounds should be developed so as to minimise noise exposure.
- Loading and unloading should be carried out away from sensitive receivers.
- The selection of site access points should take into account the proximity of noise sensitive receivers.
- Maintenance work on all construction plant should be carried out away from noise sensitive receivers and confined to standard daytime construction hours, where possible.
- Minimising consecutive works in the same locality.
- Relocate any vibration generating plant and equipment away from noise sensitive receivers in order to lower any potential vibration impacts.
- Investigate the feasibility of rescheduling the hours of operation of major vibration generating plant and equipment.
- Use lower vibration generating items of excavation plant and equipment eg smaller capacity rockbreaker hammers, wherever possible.

- Schedule a minimum respite period of at least 0.5 hour before activities commence which are to be undertaken for a continuous 4 hour period.
- Use only dampened rockbreakers and/or "city" rockbreakers to minimise the impacts associated with rockbreaking works.

The mitigation of noise impacts can often involve noise management as distinct from noise control (interpreted as simply meaning noise minimisation). For example, the scheduling of noise-intensive activities could be an effective noise management strategy in the present instance.

Specifically, time restrictions should be placed on the most noise-intensive activities, especially concrete sawing, rockbreaking and the use of jackhammers. Where there is a definite requirement for such activities to be completed out of the normal construction hours, they could be restricted to 9:00 pm to 11:00 pm for example.

A primary aim of the project should be to ensure that the local community is kept informed of the progress of the construction work in a proactive and progressive manner. This could be enabled by a combination of internet-based information, community meetings, local newsletters, leaflets, newspaper advertisements and community notice boards.

As part of the Community Liaison process a contact person would be nominated within the Construction Noise and Vibration Management Plan to directly address any noise and/or vibration complaints that the community may have during the construction phase of the project.

Noise monitoring would be carried out for assessment against the adopted construction noise goals where, subsequent to project approval, detailed construction noise impact assessments indicate significant potential exceedance at the nearest impacted noise sensitive receivers.

It is also recommended that vibration monitoring be carried out for assessment against the transient vibration guidelines (BS 7385 and DIN 4150) as a result of potential impacts on structures when working within the safe working distances for cosmetic damage as a result of vibration intensive construction activities, and where the vibration levels are greater than the maximum recommended values.

OPERATIONAL NOISE

Operational Noise Criteria

The assessment of operational noise has been performed in line with the requirements of the Environmental Criteria for Road Traffic Noise (ECRTN) and Environmental Noise Management Manual (ENMM). This document provides guidance for assessing traffic noise impacts through setting design objectives for a range of development types and provides procedures for determining noise mitigation in situations where the exceedances of the objectives occur.

The proposed M2 Upgrade Project is classified as a "Redevelopment of an Existing Freeway/Arterial Road".

The existing noise walls do not extend over the complete length of the M2 Motorway. It is noted that the opening of the M7 increased traffic volumes, particularly heavy vehicles, in the section of road between the M7 and Pennant Hills Road. An assessment of all sensitive receivers adjacent to the M2, both in sections with existing noise walls and in those sections currently without, has been undertaken with regard to the operational noise criteria for the project.

EXECUTIVE SUMMARY

Operational Noise Assessment

Noise emissions from the M2 Motorway are currently mitigated through noise walls of various heights along almost the entire length of the motorway. These range from approximately 1.8 m up to around 7.0 m in height.

The widening upgrade process of the M2 will require alterations to the existing alignment of the road corridor in many areas along the length of the motorway. These alterations include the modification of various existing cuttings, embankments and batter slopes in areas where widening works are proposed.

The widening process will therefore affect a significant number of the existing noise walls along the route of the motorway. Some of the affected noise walls are situated adjacent to the road carriageway and others are on top of embankments. All such affected noise walls will be required to taken down and re-instated as part of the project.

In all sensitive receiver locations where future exceedances of the operational noise criteria have been predicted, new or increased height noise walls have been considered where three or more exceeding properties are situated within a catchment area. As part of the design of the M2 Upgrade Project, there is also the requirement for a small number of new walls to be included in the design of the proposed widening scheme.

At some locations where the noise criteria are exceeded as a result of the project, feasibility and reasonableness considerations have concluded that the construction, or modification, of noise barriers is not feasible, reasonable or cost effective. At such locations, where residual impacts remain after all feasible and reasonable approaches have been exhausted, noise mitigation in the form of acoustic treatment for existing individual dwellings would be required.

The assessment of sensitive land use areas showed that as no exceedances of the appropriate criteria were apparent, there is no requirement to investigate additional mitigation measures at these locations.

An optimisation process (including a cost-benefit analysis) has been undertaken when designing the noise walls using the approach outlined in the RTA's ENMM. All of the noise wall designs presented within this Report therefore reflect these RTA procedures. The need for architectural treatment to address residual exceedances of the adopted noise objectives has been considered as part of the optimisation process. A total of 91 properties have been identified as requiring consideration for architectural treatment. Architectural treatment would however be subject to feedback from the community consultation process which would be performed as part of the detailed design phase of the project.

Furthermore, the final mix of the selected noise mitigation strategies will be determined after the opinions of the local affected community have been consulted. The local affected community might prefer (on aesthetic grounds) a different option mix of noise barriers and property treatment than has been proposed in this assessment. The benefits of community preferred options would then need to be considered in light of additional factors such as future noise levels in the affected area and changes in land use in the local area.

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APPENDICES

1 INTRODUCTION

In conjunction with the NSW Roads and Traffic Authority (RTA), Hills M2 and Leighton Contractors Pty Ltd, AECOM Pty Ltd and a team of specialist sub-consultants are preparing an Environmental Assessment (EA) for the proposed upgrade of the M2 Motorway.

The current demands on the M2 Motorway are well known, with the motorway being seen to be at capacity during busy periods of the day. It is therefore proposed to widen the motorway in various sections along its length to help reduce the strain on the motorway. Associated upgrades to some of the interchanges along the route are also planned.

Heggies Pty Ltd (Heggies) have been commissioned to provide a detailed assessment of the noise and vibration impacts associated with the construction and operation of the upgrade project.

1.1 Overview of the Present Study

The potential noise and vibration impacts of the M2 Upgrade Project can be broken down as follows:

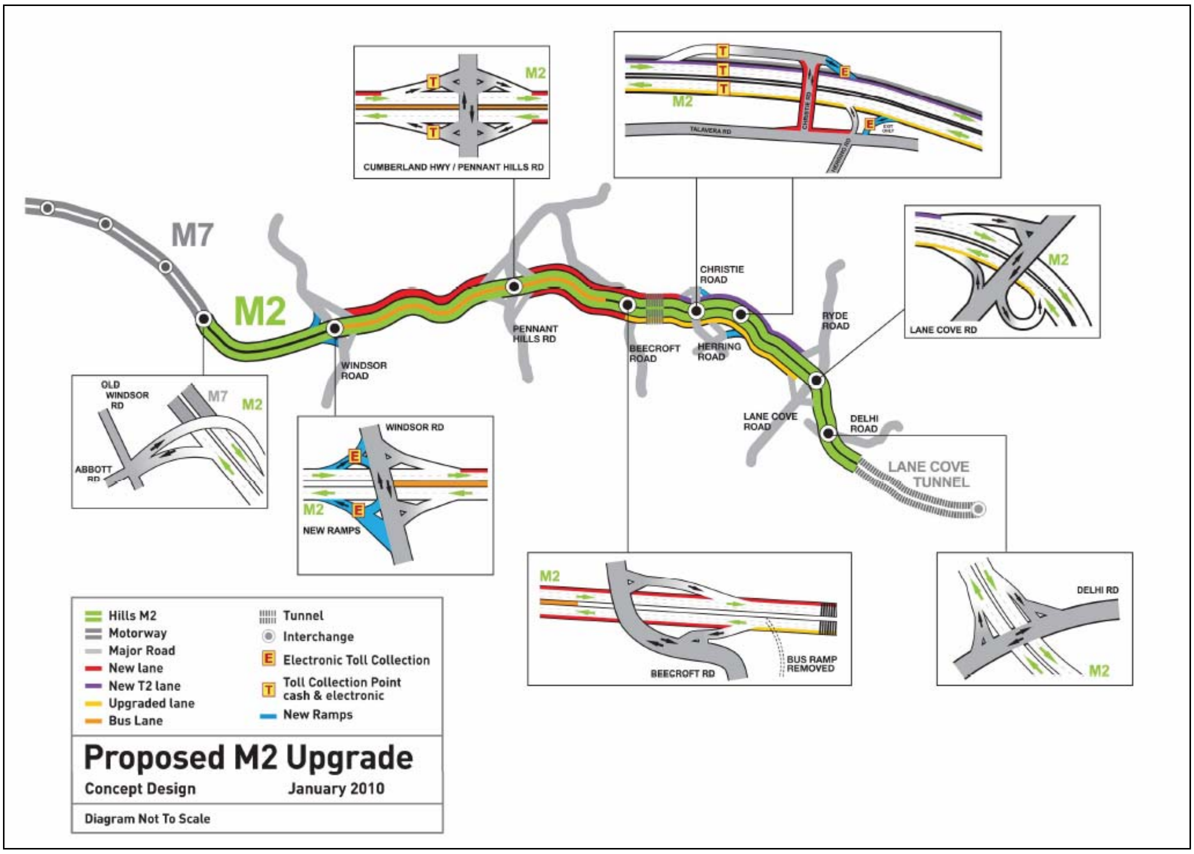
- Impact on surrounding areas during the construction phase of the project due to the widening of the motorway and interchange upgrade works, including:
  - Construction noise
  - Construction vibration
  - Construction ground-borne noise from widening of the Norfolk Tunnel
- Operational impacts after project commissioning, consisting primarily of:
  - Noise emissions due to changed road traffic conditions
  - Mechanical noise emissions from the Norfolk Tunnel ventilation fan system

2 PROJECT DESCRIPTION

2.1 General

The M2 Motorway spans approximately 21 km from Baulkham Hills to North Ryde and is, in several sections, in close proximity to a number of densely populated residential areas. The M2 Motorway Upgrade Project Area is illustrated in **Figure 1**, together with the schematic descriptions of the proposed upgrades along the route of the motorway.

Figure 1 M2 Upgrade Project Area



The proposed alterations to M2 Motorway are summarised below:

- Additional eastbound lane from Windsor Road to Pennant Hills Road
- Additional eastbound lane from Pennant Hills Road through the Norfolk Tunnel to Lane Cove Road
- Widening the westbound carriageway to provide wider lanes from Lane Cove Road to Beecroft Road
- Additional westbound lane from Beecroft Road to Pennant Hills Road
- New west-facing Windsor Road on and off-access ramps
- New Christie Road eastbound on-access ramp
- New Herring Road westbound off-access ramp

A comprehensive description of the M2 Upgrade Project is contained within **Part C – The Proposal** of the main Environmental Assessment report.

2.2 Terminology

2.2.1 Road Chainage

Consistent with the terminology adopted for other components of the Environmental Assessment of the project, road chainages for the M2 alignment are referenced to 0 km at the start of the M2 in the vicinity of Old Windsor Road at Baulkham Hills (at the junction with the M7).

2.2.2 Noise and Vibration Terminology

A detailed description of the acoustic terminology used within this report is presented within **Appendix A**.

2.2.3 Operational Assessment Years

Throughout the Operational Assessment of this document (contained in **Section 9**), reference is made to two assessment scenarios: the Future *Existing* and the Future *Design* scenarios. These are used to assess the noise impact of new and upgraded roads projects.

- The Future *Existing* scenario represents the "baseline" scenario and is used to determine the more-or-less current level of road noise, in the absence of the M2 Upgrade Project, predicted at the year of opening of the proposed project. This scenario makes use of the M2 alignment in its existing geometry, with traffic volumes extrapolated to the project opening year by applying an incremental factor to measured existing flows.
- The Future *Design* scenario represents the "assessment" scenario for the M2 Upgrade Project and uses the proposed new alignment for the project, together with future traffic volumes predicted to 10 years after the scheduled project opening year.

2.2.4 Study Area Description

The extent of works covered in this assessment starts at the western end of the M2 Motorway at the junction with the M7 Motorway (at chainage 0000), and ends to the east of the intersection of the M2 Motorway with Lane Cove Road (at chainage 18000).

It is noted that the actual widening works associated with the M2 Upgrade Project start at around chainage 3500, just west of the Windsor Road interchange, and finish at chainage 17800, just east of Lane Cove Road.

The project study area also extends out from the M2 carriageway to a distance which equates to 5 dBA below the operational noise goals for the M2 Upgrade Project, detailed in **Section 5**. Areas outside of this region have not been considered in this assessment.

3 DIRECTOR GENERAL'S REQUIREMENTS

Following receipt of the Project Application for the M2 Motorway Upgrade, Director-General's Requirements (DGRs) were issued for the Environmental Assessment on 6 April 2009.

This report has been prepared to address the DGRs that relate to potential noise and vibration impacts. The specific requirements that relate to the M2 Motorway Upgrade Project are provided below:

> ***"Operational Noise Impacts*** *– the Environmental Assessment must include an assessment of the noise impacts of the project during operation, consistent with the Environmental Criteria for Road Traffic Noise (EPA, 1999). The assessment must include specific consideration of impacts to sensitive receivers (schools, hospitals, aged care facilities), as relevant.*
>
> ***General Construction Impacts*** *– the Environmental Assessment must consider the potential impacts associated with the construction of the project, and present a management framework for construction works to ensure that impacts are mitigated, monitored and managed. The Environmental Assessment must include consideration of, and a management framework for:*
>
> - *construction noise and vibration, including a considered approach to scheduling construction works having regard to the nature of construction activities (including transport, blasting and tonal or impulsive noise-generating works, as relevant), the intensity and duration of noise and vibration impacts, the nature, sensitivity and impact to potentially-affected human receivers and structures, the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management). The Environmental Assessment must also present a strategy for monitoring and mitigating construction noise and vibration, with a particular focus placed on those activities identified as having the greatest potential for adverse noise or vibration impacts, and a broader, more generic approach developed for lower-risk activities;"*

The Operational Assessment of the M2 Upgrade Project is contained within **Section 9** of this report and the Construction Assessment is within **Section 7**.

4 CONSTRUCTION ASSESSMENT CRITERIA

4.1 Construction Noise Metrics

The three primary noise metrics used to describe construction noise emissions:

$L_{A1(1minute)}$ the "typical maximum noise level" for an event, used in the assessment of potential sleep disturbance during night-time periods. Alternatively, assessment may be conducted using the L_{Amax} or maximum noise level

$L_{Aeq(15minute)}$ the "energy average noise level" evaluated over a 15-minute period. This parameter is used to assess the potential construction noise impacts.

L_{A90} the "background noise level" in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively. The $L_{Aeq(15\ minute)}$ construction Noise Management Levels are based on the L_{A90} background noise levels.

The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (ie A-weighted).

4.2 NSW Interim Construction Noise Guideline

Heggies has conducted a review of guidelines and current practices for the assessment and subsequent mitigation of construction noise, and, for the M2 Upgrade Project, has adopted the approach laid down in the NSW Department of Environmental, Climate Change and Water (DECCW) *"Interim Construction Noise Guideline"* (ICNG), issued in July 2009.

The ICNG was developed with an emphasis on minimising construction noise impacts by implementing various work practices rather than focussing only on achieving numerical noise levels. A recurring feature of the guideline is the use of the term "feasible and reasonable" in relation to the control of construction noise impacts. The guideline recognises that construction activities are often inherently noisy but are generally of a temporary nature.

On the basis of the guideline, Heggies has adopted the following approach for the M2 Upgrade Project:

- Determine project specific **Noise Management Levels** (NMLs) for noise affected receivers consistent with current practices to deal with construction noise in a transparent and consistent way.
- Where the construction noise levels are predicted to exceed the NMLs, all **feasible** and **reasonable** work practices will be investigated to minimise noise emissions.

Consistent with this approach, the following $L_{Aeq(15minute)}$ NMLs have been adopted for sensitive receivers:

- Daytime (7.00 am to 6.00 pm) RBL or L_{A90} Background +10 dBA
- Evening (6.00 pm to 10.00 pm) RBL or L_{A90} Background +5 dBA
- Night-time (10.00 pm to 7.00 am) RBL or L_{A90} Background +5 dBA

The DECCW's Guideline also presents Noise Management Levels for areas of other sensitive land uses. These are detailed in **Table 1** below.

Table 1 Interim Construction Noise Guideline – Other Sensitive Land Uses

Land Use	Noise Management Level $L_{Aeq(15minute)}$ (applies when properties are being used)
Classrooms at schools and other educational facilities	45 dBA (internal)
Hospital wards and operating theatres	45 dBA (internal)
Places of worship	45 dBA (internal)
Active recreation areas[1]	65 dBA (external)

Note 1: Characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion.

Where internal Noise Management Levels are presented in the table above, the corresponding external noise level (which the assessments are based upon) has been determined on the assumption that a 10 dBA reduction from outside to inside noise is applicable for an openable window, with a 20 dBA reduction where mechanical ventilation has been provided.

Sleep Disturbance

The most recent guidance in relation to sleep disturbance is contained in the DECCW's *"Application Notes - NSW Industrial Noise Policy"*. The pertinent section of the DECCW's Application Notes states the following:

> *"DECC*[W] *reviewed research on sleep disturbance in the NSW Environmental Criteria for Road Traffic Noise (ECRTN) (EPA, 1999). This review concluded that the range of results is sufficiently diverse that it was not reasonable to issue new noise criteria for sleep disturbance.*
>
> *From the research, DECC*[W] *recognised that current sleep disturbance criterion of an L_{A1}, (1 minute) not exceeding the L_{A90}, (15 minute) by more than 15 dBA is not ideal. Nevertheless, as there is insufficient evidence to determine what should replace it, DECC*[W] *will continue to use it as a guide to identify the likelihood of sleep disturbance. This means that where the criterion is met, sleep disturbance is not likely, but where it is not met, a more detailed analysis is required.*
>
> *The detailed analysis should cover the maximum noise level or L_{A1}, (1 minute), that is, the extent to which the maximum noise level exceeds the background level and the number of times this happens during the night-time period. Some guidance on possible impact is contained in the review of research results in the appendices to the ECRTN. Other factors that may be important in assessing the extent of impacts on sleep include:*
>
> - *How often high noise events will occur.*
> - *Time of day (normally between 10pm and 7am).*
> - *Whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).*
> - *The LA1, (1 minute) descriptor is meant to represent a maximum noise level measured under "fast" time response. DECC*[W] *will accept analysis based on either LA1, (1 minute) or LAmax"*

Scope for Exceedances

Where predicted or measured levels exceed the Noise Management Levels the ICNG recommends that the proponent apply all "feasible and reasonable" work practices in order to minimise noise.

Where $L_{Aeq(15minute)}$ construction noise levels are predicted to be "highly noise affected" (ie above 75 dBA) the relevant authority (consent, determining or regulatory) may require respite periods to be observed. This may include restricting the hours that the very noisy activities can occur, taking into account:

1. Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences).
2. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

The implementation of an effective community consultation and liaison programme is emphasised as being a critical tool in successfully handling adverse noise impacts from construction works.

The ICNG provides comprehensive guidance for work practices which aim to achieve *"desired environmental outcomes - there are no prescribed noise controls for construction works."*

4.2.1 Ground-borne Noise

Ground-borne construction noise is usually present on tunnelling projects when vibration from activities such as rock breaking, road heading, rotary cutting, tunnel boring and rock drilling/sawing can be transmitted through the ground and into the habitable areas of nearby buildings. Ground-borne (or regenerated) noise occurs when this vibration in the ground and/or building elements is regenerated as audible noise within areas of occupancy inside the building.

Sometimes the vibration generated by the above activities may be perceptible in nearby buildings. In such cases, the human comfort vibration goals discussed in **Section 4.3** are applicable.

As the M2 Upgrade Project includes the widening of the Norfolk Tunnel, which would be completed using roadheaders and drill rigs, there is potential for ground-borne noise impacts at the sensitive receivers situated above the tunnel.

Internal ground-borne noise goals of $L_{Aeq(15minute)}$ 40 dBA (evening) and $L_{Aeq(15minute)}$ 35 dBA (night-time) are specified within the DECCW's ICNG. These goals are only applicable when the ground-borne noise levels are higher than the airborne noise levels inside residential dwellings. During daytime periods, only the human comfort vibration goals are applicable.

4.3 Construction Vibration Assessment Criteria

Vibration targets vary primarily according to whether the particular activities of interest are continuous in nature or intermittent and whether they occur during the day or night-time. The effects of vibration in buildings can be divided into three main categories:

- Those in which the occupants or users of the building are inconvenienced or possibly disturbed, ie human disturbance;
- Those in which the integrity of the building or the structure itself may be prejudiced; and
- Those where the building contents may be affected.

Criteria which are relevant to the response of building occupants to vibration are more stringent than those relevant to building damage. This is because people are able to "feel" vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building.

This ability of people to sense vibration at relatively low magnitudes has created a widespread and strong public misconception which can cause considerable overestimation of the risk of damage associated with vibration in buildings. This is particularly the case when the source of that vibration is outside the building, visible and audible, but generally not within the occupant's control.

Many people, for example, believe that even barely perceptible levels of building vibration from say, traffic, excavation or construction works, can damage dwellings, or may affect delicate objects or other items of personal value within their homes. This largely subjective response is particularly the case when these low levels of vibration are accompanied by high noise levels, or if there are other adverse connotations or effects associated with the source of the vibration. These might include startlement, loss of privacy or perceived loss of property value, fear, inconvenience, odour, etc.

On the other hand, sources of much higher levels of vibration (eg domestic appliances, people walking on floors, slamming of doors, etc) are readily accepted due to their day-to-day familiarity or because they are "within the control" of the occupant.

It is primarily these day-to-day effects which cause the gradual, long-term fatigue-induced deterioration of most structures - considered to be normal ageing. Provided that the levels of vibration-induced structural stress from an additional source are well below those of these "normal" stress-inducing events, then the additional source of vibration is unlikely to accelerate the normal ageing process.

4.3.1 General

Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels which are well below those causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2-1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in **Table 2**.

Table 2 Peak Vibration Levels and Human Perception of Motion

Approximate Vibration Level		Degree of Perception
Peak Vibration Level	**RMS Vibration Level**	
0.10 mm/s	0.07 mm/s	Not felt
0.15 mm/s	0.1 mm/s	Threshold of perception
0.35 mm/s	0.25 mm/s	Barely noticeable
1 mm/s	0.7 mm/s	Noticeable
2 mm/s	1.4 mm/s	Easily noticeable
6 mm/s	4.2 mm/s	Strongly noticeable
14 mm/s	10 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having a frequency content in the range of 8 Hz to 80 Hz. The RMS vibration levels assume a crest factor of 1.4 for sinusoidal vibration.

Table 2 suggests that people will just be able to feel floor vibration at levels of about 0.1 mm/s (RMS) and that the motion becomes "noticeable" at a level of approximately 0.7 mm/s (RMS).

The DECCW's "*Assessing Vibration: a technical guideline*" notes that *"vibration in buildings can be caused by many different external sources, including industrial, construction and transportation activities. The vibration may be continuous (with magnitudes varying or remaining constant with time), impulsive (such as in shocks) or intermittent (with the magnitude of each event being either constant or varying with time)."*

Construction activities typically generate building vibrations that are intermittent or impulsive in nature, however vibration levels may sometimes be constant from sources such as generators or ventilation fans.

Examples of intermittent vibration events include the vibration generated by rockbreakers, vibratory rollers, drilling/piling and excavators. Examples of impulsive vibration events include the vibration generated by demolition activities, blasting or the dropping of heavy equipment.

Where vibration is intermittent or impulsive in character, the DECCW vibration guideline (and other similar guidelines) recognise that higher vibration levels are tolerable to building occupants than for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous vibration sources.

The following sections describe the applicable continuous and intermittent vibration goals for the M2 Upgrade Project construction activities.

4.3.2 Human Comfort Goals for Continuous and Impulsive Vibration

The DECCW's "*Assessing Vibration: a technical guideline*" is applicable for the M2 Upgrade Project and is based on the guidelines contained in British Standard BS 6472-1992 "*Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)*". The DECCW guideline refers only to human comfort considerations and nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers.

The criteria in the DECCW guideline are non-mandatory, "*they are goals that should be sought to be achieved through the application of all feasible and reasonable mitigation measures. Where all feasible and reasonable measures have been applied and vibration values are still beyond the maximum value, the operator would need to negotiate directly with the affected community*".

Construction vibration can be continuous, intermittent or impulsive and the DECCW's vibration guideline provides different goals for each category. The continuous vibration goals are most stringent and higher vibration levels are acceptable for intermittent and impulsive vibration on the basis of the shorter exposure times. Examples of typical vibration sources are provided in **Figure 2**.

Figure 2 Examples of Vibration (DECCW Vibration Guideline)

Examples of types of vibration

Continuous vibration	Impulsive vibration	Intermittent vibration
Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading. Blasting is assessed using ANZECC (1990).	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer this would be assessed against impulsive vibration criteria.

The applicable human comfort vibration goals for continuous, intermittent and impulsive vibration sources are provided in **Table 3**, **Table 4** and **Table 5** respectively. In all cases, the vibration goals are expressed in terms of the RMS vibration velocity level in mm/s, measured in the most sensitive direction (z-axis).

The DECCW vibration guideline notes the following in relation to the preferred and maximum vibration levels:

"There is a low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values. Activities should be designed to meet the preferred values where an area is not already exposed to vibration. Where all feasible and reasonable measures have been applied, values up to the maximum value may be used if they can be justified. For values beyond the maximum value, the operator should negotiate directly with the affected community. Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project.

In circumstances where work is short term, feasible and reasonable mitigation measures have been applied, and the project has a demonstrated high level of social worth and broad community benefits, then higher vibration values (above the maximum) may apply. In such cases, best management practices should be used to reduce values as far as practicable, and a comprehensive community consultation programme should be instituted."

Table 3 Preferred and Maximum Vibration Levels for Continuous Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.14	0.28
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

Table 4 Preferred and Maximum Vibration Levels for Intermittent Vibration (Vibration Dose Values)

Building Type	Preferred Vibration Dose Value ($m/s^{1.75}$)	Maximum Vibration Dose Value ($m/s^{1.75}$)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: For the definition of the Vibration Dose Value refer to the discussion in the following section. Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

Table 5 Preferred and Maximum Vibration Levels for Impulsive Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.1	0.2
Residential Daytime	6.0	12.0
Residential Night-time	2.0	4.0
Offices, schools, educational institutions and places of worship	13.0	26.0
Workshops	13.0	26.0

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

4.3.3 Intermittent Vibration (Vibration Dose Values)

For most construction activities that generate perceptible vibration in nearby buildings, the character of the vibration emissions is intermittent. This includes equipment such as rockbreakers, excavators, piling rigs, rock drills, vibratory rollers and heavy vehicle movements.

Intermittent vibration is defined in the DECCW vibration guideline as follows:

> *"**Intermittent vibration** can be defined as interrupted periods of continuous (e.g. a drill) or repeated periods of impulsive vibration (e.g. a pile driver), or continuous vibration that varies significantly in magnitude. It may originate from impulse sources (e.g. pile drivers and forging presses) or repetitive sources (e.g. pavement breakers), or sources which operate intermittently, but which would produce continuous vibration if operated continuously (for example, intermittent machinery, railway trains and traffic passing by). This type of vibration is assessed on the basis of vibration dose values".*

Where vibration comprises a number of events, a Vibration Dose (Dv) may be estimated for each event by the following formula using vibration measured in velocity:

$$Dv = 0.07\ V(rms) \times t^{0.25}\ m/s^{1.75}$$

Where, V (rms) = rms particle velocity (mm/s)

t = Total cumulative time (seconds) of the vibration event or period of vibration

The total vibration dose is then calculated using the following formula:

$$Dv = \left(\sum_{n=1}^{n=N} Dv_n^4 \right)^{0.25}$$

Where, Dv = Total vibration dose value for the day or night

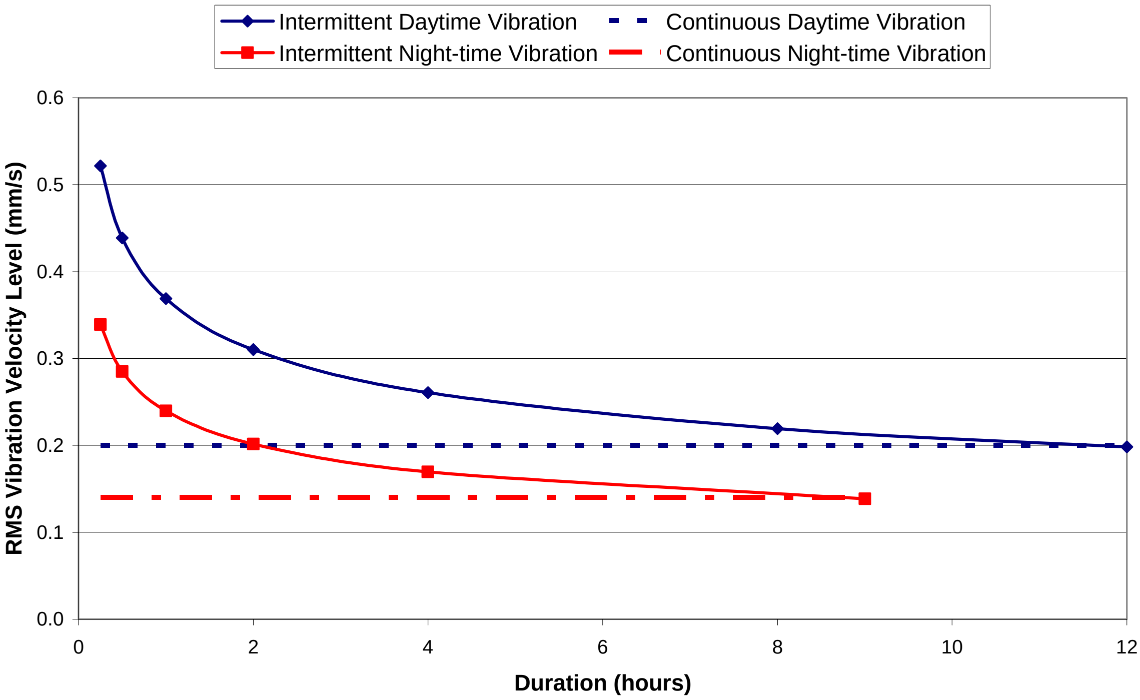
Dvn = Vibration dose value for each vibration dose event

N = Total number of vibration dose events

The permissible vibration level corresponding to the vibration dose value varies according to the duration of exposure. For example, higher vibration levels are permitted if the total duration of the vibration event(s) is small and lower vibration levels are permitted with if the total duration of the vibration event(s) is large.

This concept is illustrated graphically in **Figure 3** where the intermittent vibration curves for the daytime and night-time periods correspond to the preferred Vibration Dose Values in **Table 4**. As the total duration of the intermittent vibration sources during the daytime and night-time periods get larger, the intermittent vibration goals approach the preferred continuous vibration goals in **Table 3**.

Figure 3 Vibration Levels Corresponding to "Low Probability of Adverse Comment" for Residential Receivers - Continuous and Intermittent Vibration



4.3.4 Vibration Criteria - Surface Structures

Most commonly specified "safe" structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

British Standard 7385: Part 2 - 1993 Guidelines

In terms of the most recent relevant vibration damage goals, Australian Standard AS 2187: Part 2-2006 *"Explosives - Storage and Use - Part 2: Use of Explosives"* recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 *"Evaluation and measurement for vibration in buildings Part 2"* as they "are applicable to Australian conditions".

The Standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in **Table 6** and graphically in **Figure 4**.

Table 6 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

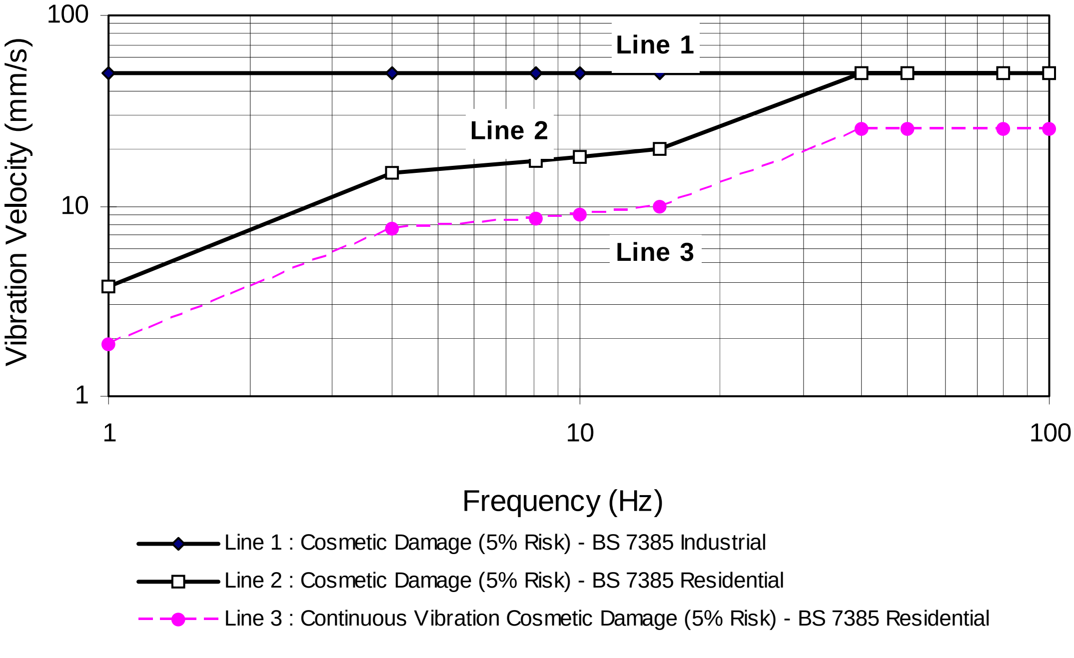
Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and Above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The Standard states that the guide values in **Table 6** relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration may give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 6** may need to be reduced by up to 50%.

Note: rockbreaking/hammering activities are considered to have the potential to cause dynamic loading in some structures (eg residences) and it may therefore be appropriate to reduce the transient values by 50%.

Figure 4 Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for building types corresponding to "Line 2" are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The Standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 6**, and major damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the Standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 6** should not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS 2187 specifies that vibration measured should be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) should be compared with the guidance curves presented in **Figure 4**.

It is noteworthy that extra to the guide values nominated in **Table 6**, the standard states that:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK."*

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

5 OPERATIONAL NOISE ASSESSMENT CRITERIA

5.1 Operational Noise Criteria

The roadway corridor for the M2 Motorway Upgrade Project runs through several areas of urban residential development. As a result the acoustical design of the project - as well as the design and management of potential residual noise impacts at dwellings in the vicinity of the motorway - introduces significant challenges with respect to achieving timely, efficient, balanced, equitable, reasonable and cost-effective outcomes for the project and the community.

Achieving a balanced acoustical design, especially in terms of feasibility and reasonableness, is guided primarily by the following two references:

- DECCW (formerly EPA), *"Environmental Criteria for Road Traffic Noise"* (ECRTN), May 1999
- RTA, *"Environmental Noise Management Manual"* (ENMM), December 2001

The original noise mitigation for the M2 Motorway was developed with reference to the Interim Noise Policy (ITNP). It is noted that the ECRTN base criteria are more stringent than those specified within the ITNP.

5.2 Environmental Criteria for Road Traffic Noise (ECRTN)

In May 1999, the NSW Environment Protection Authority (now the DECCW) issued the *"Environmental Criteria for Road Traffic Noise"* (ECRTN). This document provides guidance for assessing traffic noise impacts through setting design objectives for a range of development types and provides procedures for determining noise mitigation in situations where the exceedances of the objectives occur.

In addition to road design and development controls, the document nominates a number of other strategies which may be used to reduce the impact of traffic noise. These include:

- Governing maximum noise levels from individual vehicles
- Developing programmes to monitor and control noisy vehicles on the road system
- Controlling noise from heavy vehicle exhaust and engine brakes
- Implementing traffic management policy at local and regional levels
- Continuing encouragement of the community to use public transport and to increase the number of passengers travelling in private vehicles

The ECRTN embodies a non-mandatory performance-based approach. The proposed criteria (or objectives) are to be applied as targets, applicable to the future volumes of traffic projected to 10 years' time, however it is recognised that situations will exist where planning strategies are not feasible.

Solutions that can be reasonably applied in the short-term may not always achieve the targets. In such cases, a longer-term perspective may need to be taken to institute ongoing strategies that will minimise traffic noise impacts over time.

The ECTRN notes that there are generally limited resources to provide noise control on existing roads to meet the target criteria and that the noise minimisation strategies adopted must take into account what is reasonable and feasible. The ECTRN goes on to note that in the urban context, background noise levels are elevated and generally increase incrementally over long periods of time. This affects the level of noise mitigation that is practicably achievable.

It is recommended that the criteria in the ECRTN be referred to in the early stages of planning for new roads or modifications to existing roads. The effects of road traffic noise can then be assessed and controlled throughout the planning process. Where feasible, a new or existing road should be aligned and designed and constructed to meet the criteria. However, if this is not practicable, other initiatives such as the control of road use behaviour (including speed control), managing the use of exhaust brakes, land use planning and building design would need to be instituted to assist in minimising the impacts.

5.2.1 ECRTN Classification of the M2 Upgrade Project

The proposed M2 Upgrade Project is classified as a "Redevelopment of an Existing Freeway/Arterial Road". Based on this definition the appropriate criteria are presented in **Table 7** (refer first row of table).

The M2 Upgrade Project would also have a potential impact on a number of sensitive land usage areas. These include Model Farms High School, Winston Hills Public School, Muirfield High School, Our Lady of Lourdes Primary School and Church, the Royal Institute for Deaf and Blind Children School, Epping Heights Public School and the Macquarie University Campus. Muirfield Golf Course and Pennant Hills Golf Course are also situated in close proximity to the M2 Motorway.

The relevant ECRTN criteria for these land uses have also been included in **Table 7**.

Table 7 Operational Traffic Noise Criteria

Road Type	Daytime Criteria (7 am to 10 pm)	Night-time Criteria (10 pm to 7 am)	Guidance when the Existing Ambient Noise Already Exceeds the Base Criteria
Redevelopment of existing freeway/arterial road	LAeq(15 hr) 60 dBA	LAeq(9 hr) 55 dBA	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may be achievable only through long-term strategies, such as improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles; greater use of public transport; and alternative methods of freight haulage
Redevelopment of existing collector roads			
Places of Worship	LAeq(1 hr) 40 dBA (internal)	LAeq(1 hr) 40 dBA (internal)	The most practicable mitigation measures to achieve internal noise goals often involve building (facade) treatments. Other mitigation options include regulation of vehicle exhaust noise, limiting access of heavy vehicles during sensitive times, limitations on exhaust brake use, etc. When such treatments are not able to achieve the nominated target internal noise levels, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dB
Hospital Wards	LAeq(1 hr) 35 dBA (internal)	LAeq(1 hr) 35 dBA (internal)	
Existing School Classrooms	LAeq(1 hr) 45 dBA (internal)	-	
Active Recreation (eg Golf Courses)	Freeways and Arterial Roads: LAeq(15 hr) 60 dBA	-	

It is noted that in situations where the existing ambient noise level already exceeds the above criteria, and where all reasonable and feasible noise mitigation measures have been considered and implemented, an "allowance" criterion is applicable. For a redeveloped road this allowance criterion limits the noise increase from the project under consideration to no more than 2 dBA.

5.3 Environmental Noise Management Manual (ENMM)

The RTA's *"Environmental Noise Management Manual"* (ENMM) was issued in December 2001 and provides guidance in managing and controlling noise (and vibration) from all aspects of road traffic generated noise.

Within the ENMM, properties which are subject to noise levels exceeding 60 dBA $L_{Aeq(15hour)}$ or 55 dBA $L_{Aeq(9hour)}$ are identified as being "noise affected". These levels correspond to the ECRTN criteria detailed in **Table 7** as applying to the redevelopment of the motorway.

The ENMM recognises that the base criteria recommended by the ECTRN are not always practicable, and that it is not always feasible or reasonable to expect that they should be achieved. This is particularly relevant to existing roads in urban environments. Guidance is provided when this situation is apparent.

The ENMM also uses the term "acute". This refers to properties which are exposed to adverse levels of road traffic generated noise (ie at least 65 dBA $L_{Aeq(15hour)}$ or 60 dBA $L_{Aeq(9hour)}$). In operational road traffic noise assessments, consideration for noise mitigation treatment is given to properties that experience acute levels of noise at the project design year even when there is no change in noise level due to the project.

The ENMM notes that the most effective way of minimising noise from vehicles and traffic is to control vehicle noise at the source. Examples of such measures could include:

- Reducing traffic volumes by promotion of public transport
- Implementation of more stringent noise standards for new vehicles
- The progressive replacement of older, noisier vehicles
- Measures to ensure noise-control equipment on heavy vehicles and older cars is properly maintained
- The selection and design of road routes and alignments so as to reduce gradients and achieve smooth traffic flows
- The use of "low noise" pavements
- Restricted access to noisy vehicles
- Traffic management measures to achieve smooth traffic flows

Where the above source measures are not practical, or do not provide sufficient noise reduction, additional methods would be required to reduce levels to within acceptable margins. Such methods may include the use of noise walls or architectural treatment of properties.

Generally speaking, and for the M2 Upgrade Project, preference is given to the use of noise walls to mitigate noise levels. This is because all sensitive receivers behind a particular noise wall benefit from the resulting reduction in noise.

Architectural property treatments are utilised to mitigate adverse noise only after all of the other mitigation options noted above have been considered.

5.4 Road Traffic Noise Criteria – General Discussion

Achieving a balanced acoustical design, especially in terms of feasibility and reasonableness, is guided by the DECCW's ECRTN and the RTA's ENMM.

These documents provide guidance for optimising the at-roadway noise mitigation measures in terms of noise reduction, cost-effectiveness, urban landscape design requirements and community preferences. It is noted that where road noise affected multi-storey buildings are apparent, the use of road side noise walls to mitigate upper storeys is usually not practicable.

Guidance is also provided for determining the reasonableness of additional architectural treatments at individual dwellings where residual noise impacts may potentially remain after the optimisation process.

In addition to the tests of reasonableness for individual dwellings or specific localities, the ECRTN (and the ENMM) however recognises the need to address any unique project-wide demands and outcomes of a major project.

The ECRTN presents the NSW Government's guidelines for road traffic noise assessment. The policy document provides road traffic noise criteria for proposed road or residential developments as well as criteria for other sensitive land uses.

The noise level objectives and the processes for optimising noise mitigation for roadway projects in the ENMM are consistent with those embodied in the ECRTN.

Both the ECRTN and ENMM acknowledge that achieving the base objectives for existing roads in urban environments is sometimes not realistic. This is especially apparent in situations where the existing levels of background noise are already high and exceed the objectives.

Retrofitting of engineering-type noise controls to existing roads is also noted as having limited effectiveness. For example, increasing the height of already high noise walls provides diminishing additional noise benefit whilst the associated visual impacts, shadowing, constructability and costs can become prohibitive. These factors must be taken into account when determining appropriate and realistic noise objectives for any proposal.

5.5 M2 Upgrade Project Road Traffic Noise Objectives

The following summarises the noise objectives which have been adopted for the M2 Upgrade Project with consideration of the ECRTN and ENMM. As such, additional noise mitigation is therefore to be considered where either:

Scenario 1

- The predicted 2021 Future *Design* noise level exceeds the ECRTN base criteria for redeveloped roads *and* the noise level increase due to the project is greater than 2 dBA.

or

Scenario 2

- The predicted 2021 Future *Design* noise levels are acute (≥65 dBA $L_{Aeq(15hour)}$ or ≥60 dBA $L_{Aeq(9hour)}$) regardless of the incremental impact of the project.

5.5.1 New Windsor Road On/Off Ramps – ECRTN Noise Goals

Incorporated within the design for the proposed upgrade of the M2 Motorway is the construction of two new west-facing access ramps at the intersection of the M2 with Windsor Road. It is noted that the ECRTN criteria which is applicable to the rest of the M2 Project Area, as previously detailed in **Table 7**, is the "Redevelopment of Existing Freeway/Arterial Road" category.

To determine the appropriate criteria with which to assess the proposed Windsor Road access ramps, the following definitions have been taken from the ENMM.

Figure 5 ENMM Extract Regarding Category Definitions

'Existing road traffic noise exposure'

A site is defined as having an "existing road traffic noise exposure" if the prevailing noise level from the existing road alignment(s) under consideration is equal to or greater than 55 dB(A) $L_{eq(15hr)}$ (day) or 50 dB(A) $L_{eq\ (9hr)}$ (night).

The noise level contours corresponding to these day and night noise levels define the "noise catchment" for an existing road. In areas outside these contours, road traffic is unlikely to be a significant noise source.

'Significant contribution to road traffic noise exposure'

A "significant contribution to road traffic noise exposure" from a road development or upgrading proposal is defined as an increase in road traffic noise at any exposed façade of more than 2 dB(A) compared to the road traffic noise level from the existing road.

'New source of road traffic noise'

A "new road traffic noise source" can be either:

- A new road where a road of the same category (i.e. arterial, collector or local road) did not previously exist
- A new road within an existing but previously undeveloped road corridor, *or*
- An alignment or realignment producing noise at a receptor *from a different direction* which makes a "significant contribution to noise exposure", as defined above, on top of any increase in traffic noise from the same direction as at present.

It is apparent, following the background noise monitoring carried out for the project as well as preliminary noise modelling, that the residential receivers in the vicinity of the proposed access ramps have an "existing road traffic noise exposure" as these areas are currently exposed to noise levels which are greater than 55 dBA $L_{Aeq(15hour)}$ or 50 dBA $L_{Aeq(9hour)}$.

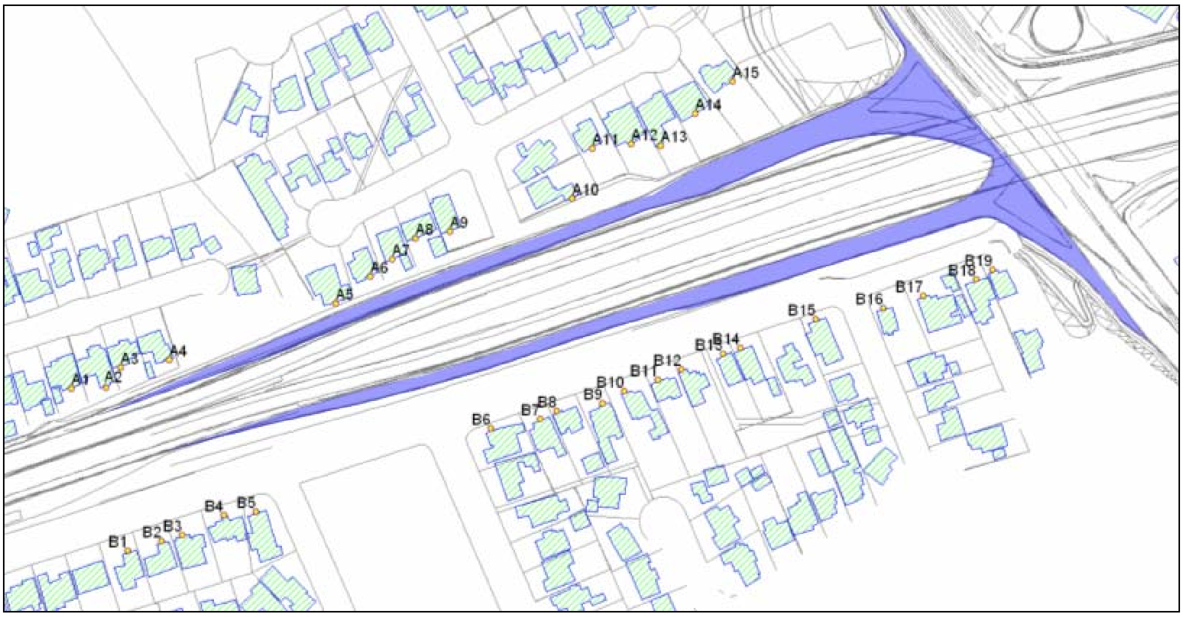
Although the proposed Windsor Road access ramps will introduce a potential "new" source of noise to the locality, in addition to the existing carriageway, the ENMM states that they would only be required to be assessed as a "New Source of Road Traffic Noise" if they provide a "significant contribution to the road traffic noise exposure" of the area. This contribution is defined as being significant if the increase in road traffic noise due to the development (ie the proposed access ramps), at any facade of any affected receiver, is found to be increased by more than 2 dBA over the existing road traffic noise.

To assess whether the contribution of noise from the proposed new on/off access ramps is "significant" at the receivers in the vicinity of Windsor Road, a noise modelling exercise was performed. The model set-up procedure and model calibration for this exercise is described in subsequent sections of this assessment.

The calibrated noise model allows the Future *Existing* and Future *Design* noise levels at all residential receivers in the vicinity of the new access ramps to be predicted, along with the stand-alone contribution of the proposed access ramps to the noise levels to be determined.

The properties at which noise levels have been calculated are illustrated in **Figure 6**, together with the location of the proposed access ramp in blue.

Figure 6 Potentially Affected Properties at the Newly Proposed Windsor Road Access Ramps



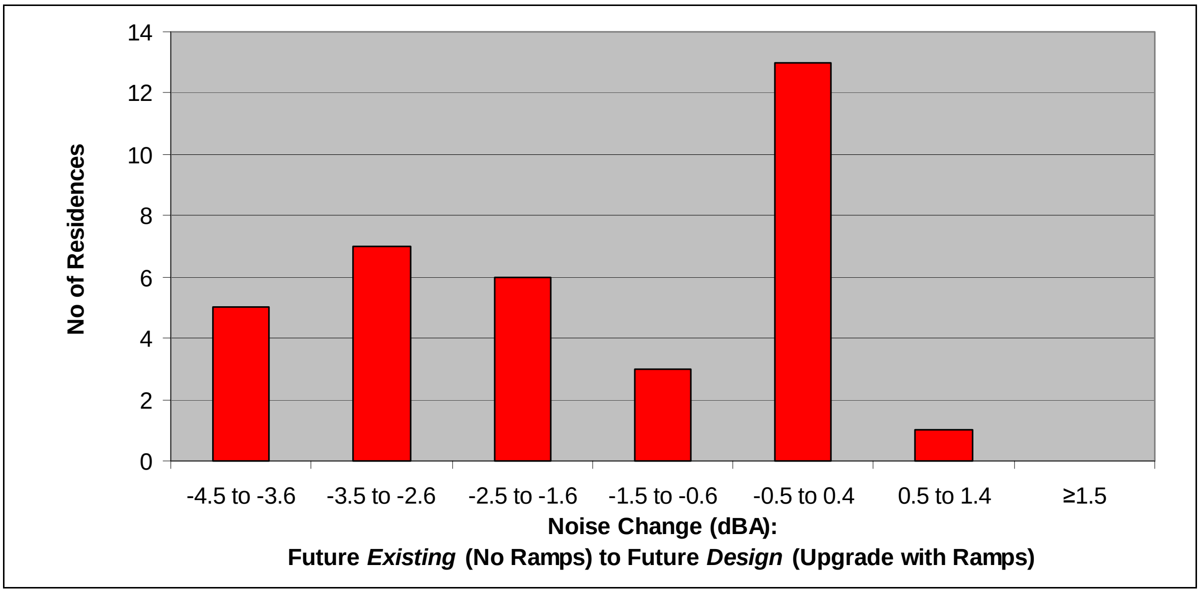
The results of the modelling exercise were found to show that, upon completion of the upgrade, the contribution of the new on/off access ramps alone were predicted to be well below the combined noise levels of both the main M2 carriageway and the proposed access ramps (around 10 dBA below, which adds 0 dBA to the total noise level).

As such, the contribution of the proposed on/off access ramps to the total noise can therefore be taken as not being significant. Accordingly, it is concluded that they do not constitute a “new” source of road traffic noise and that the ECRTN’s “Redeveloped” road noise objectives apply.

In absolute terms, the Future *Design* noise levels at almost all properties in the precinct actually reduce when compared to Future *Existing* noise levels, as is shown in **Figure 7**.

This reduction occurs as a result of the new access ramps having to rise in height to meet with Windsor Road. The access ramps therefore effectively act as noise barriers to the road traffic on the main M2 carriageway (which is the dominant source of noise) thereby resulting in less overall noise exposure for the properties situated adjacent. The small number of overall noise level increases occurs at the western end of the new ramps precinct where they merge with the main carriageway.

Figure 7 Noise Change Adjacent to New Windsor Road On/Off Ramps



5.5.2 Traffic Noise Objectives Outside of the M2 Project Area

The ECRTN and ENMM criteria which are relevant to the M2 Upgrade Project are to be applied at all locations where physical widening of M2 Motorway is occurring. The adopted criteria for the project have been previously detailed in **Section 5.5** of this report.

The widening works associated with the M2 Upgrade Project are noted as starting at chainage 3500 (which is just west of the proposed new Windsor Road access ramps) and finishing at chainage 17800 (which is just east of the Lane Cove Road Intersection).

As such, there are two sections of the M2 Motorway where no works associated with the M2 Upgrade Project are occurring. These locations are:

- From the junction of the M7 with the M2 to just west of Windsor Road (chainage 0 – 3500)
- From east of Lane Cove Road to the Lane Cove Tunnel entrance (chainage 17800 – 20200)

In these locations, where no works associated with the M2 Upgrade Project are occurring, only the incremental criterion, which limits the noise level increase as a result of the additional traffic flow from the project to 2 dBA (ie 2021 Future *Design* minus 2011 Future *Existing*), is applicable.

Properties which are outside of the extent of the upgrade works and which currently experience acute noise levels would be subject to the original conditions of approval for construction of the M2 Motorway and will be considered accordingly. This process would be performed separately to the proposed M2 Upgrade Project.

5.5.3 Sleep Disturbance and Maximum Noise Level Events

The DECCW's ECRTN and the RTA's ENMM provide guidance as to the likelihood of sleep disturbance resulting from road traffic related maximum noise level events (mainly associated with heavy vehicle movements).

The ECRTN document does not set explicit criteria for road traffic noise as no definitive quantitative correlation has been yet established between heavy vehicles noise levels and sleep disturbance. The ECRTN does however point out the following:

> *"There are no universally accepted criteria governing the likelihood of sleep disturbance. In other words, at the current level of understanding, it is not possible to establish absolute noise levels that correlate to levels of sleep disturbance (for all or even a majority of people)."*

Notwithstanding the above, the ECRTN/ENMM suggests that:

- Maximum internal noise levels below 50 dBA to 55 dBA are unlikely to cause awakening reactions.
- One or two events per night, with maximum internal noise levels of 65 dBA to 70 dBA, are not likely to affect health and wellbeing significantly.

A maximum noise event can be defined as any passby for which the difference in the L_{Amax} and $L_{Aeq(1hour)}$ noise levels is greater than 15 dBA. Furthermore, the ECRTN recommends that the assessment of sleep disturbance should include a consideration of the maximum noise level exceedances occurring during the night-time period and the emergence of these exceedances above the ambient noise level.

5.6 Noise Criteria – Operational Phase: Mechanical Services

Operational noise from mechanical services plant is assessed against different criteria to those applying to operational noise from road traffic. For the M2 Upgrade Project, items of mechanical plant are situated in the Norfolk Tunnel in the form of ventilation fans. The criteria used are taken from:

- DECCW (formerly EPA), *"Industrial Noise Policy"* (INP), January 2000

The procedures contained in the DECCW's *"NSW Industrial Noise Policy"* require a determination of the Rating Background Level (RBL) and ambient L_{Aeq} noise levels during daytime, evening and night-time periods.

The RBL is the background noise level used for assessment purposes and represents the median of the daily background noise levels during each assessment period. The L_{Aeq} noise level represents the energy-averaged noise level during each assessment period.

The assessment procedure for industrial (eg mechanical) noise sources has two components:

- Controlling the intrusive noise impacts in the short-term for residents, and
- Maintaining noise level amenity for residences and other land uses.

Intrusive Criterion

The intrusive criterion for stationary noise sources limits $L_{Aeq,15minute}$ noise emissions levels to the RBL plus 5 dBA.

Amenity Criterion

The amenity noise goal depends upon the level of ambient "industrial" L_{Aeq} noise already existing within an area and how this level compares to the acceptable noise levels specified in **Table 8**.

For example, where existing industrial L_{Aeq} noise levels already *exceed* the acceptable noise levels given in **Table 8** by 2 dBA or more, the L_{Aeq} amenity noise criterion would be set at 10 dBA *below* the existing L_{Aeq} levels in order to limit any further increase in ambient industrial noise levels. The amenity noise goal also depends upon the acoustical environment of the receivers, which in the case of the M2 Upgrade Project is "suburban" (as opposed to "rural" or "urban").

The final $L_{Aeq(15minute)}$ design noise goal applicable to stationary noise sources is then chosen as the *lower* of the intrusive and amenity goals.

Table 8 NSW Industrial Noise Policy Amenity Criteria Relevant to M2 Upgrade Project

Type of Receiver	Indicative Noise Amenity Area	Time of Day[1]	Recommended L_{Aeq} Noise Level	
			Acceptable	Recommended Maximum
Residence	Suburban	Day	55 dBA	60 dBA
		Evening	45 dBA	50 dBA
		Night	40 dBA	45 dBA
Active Recreation Area	All	When in Use	55 dBA	60 dBA
Commercial Premises	All	When in Use	65 dBA	70 dBA

Note 1: DECCW Governing Periods: Day: 7.00 am to 6.00 pm, Evening: 6.00 pm to 10.00 pm, Night: 10.00 pm to 7.00 am.

6 AMBIENT NOISE ENVIRONMENT

6.1 Noise Monitoring Locations

In order to characterise the existing noise environment adjacent to the Project Area (in relation to both the construction and operational noise assessments) and to establish the noise levels upon which to base the noise emission objectives, environmental noise monitoring was performed at a number of representative locations along the length of M2 Upgrade Project corridor.

These locations were selected based on previous monitoring surveys carried out for the motorway as well as a detailed inspection of potentially affected areas, giving consideration to other noise sources which may adversely influence the measurements, security issues for the noise monitoring devices and gaining permission for access from the resident or landowner.

The monitoring was completed over two separate surveys. The first of these surveys was completed in March and April 2008 at 24 receptor locations along the motorway route and the second survey was performed during December 2008 at a further 13 locations.

A list of the various monitoring locations, split over the two surveys, is provided in **Table 9**, whilst **Appendix B** shows their locations on the M2 Site Plan.

Unattended noise loggers were deployed adjacent to residential dwellings in order to measure the prevailing levels of road traffic noise over a minimum period of one week. The measurements were conducted at a height of 1.5 m above ground and generally at a distance of 1 m from the facade of the subject building, in accordance with the ECRTN.

All noise measurement instrumentation used in the surveys was designed to comply with the requirements of AS 1259.2-1990 *"Acoustics - Sound Level Meters. Part 2: Integrating - Averaging"* and carried appropriate and current NATA calibration certificates.

The equipment utilised for the continuous unattended noise surveys comprised of Acoustic Research Laboratories Type EL215 and Type EL316 Environmental Noise Loggers, fitted at all times with microphone wind shields.

The calibration of the loggers was checked prior to, and following, each measurement survey and the variation in calibration at any location was found to not exceed 0.5 dBA at all times.

All noise loggers were set to record statistical noise descriptors in continuous 15-minute sampling periods for the duration of their deployment.

Weather data recorded during the noise monitoring survey periods by the Sydney Bureau of Meteorology was used to assist in identifying potentially adverse weather conditions that could have a detrimental impact on the measured noise levels such as rainy periods, etc.

Table 9 Unattended Noise Logging Locations (March-April 2008 and December 2008 Surveys)

M2 Section	Survey	ID	Address	
Section 1: (Abbot Road to Windsor Road Access Ramps)	1	S1-1	13 Sierra Place	Baulkham Hills
		S1-2	89 Baulkham Hills Road	Baulkham Hills
		S1-3	24 Lambert Crescent	Baulkham Hills
		S1-4	15 Leatherwood Court	Baulkham Hills
		S1-5	108 Junction Road	Baulkham Hills
		S1-6	17 Livingston Avenue	Baulkham Hills
		S1-7	10 Murrills Crescent	Baulkham Hills
	2	S1-8	13 Leatherwood Court	Baulkham Hills
		S1-9	4 Craig Avenue	Baulkham Hills
		S1-10	10 Petrina Close	Baulkham Hills
Section 2: (Windsor Road Access Ramps to Beecroft Road)	1	S2-1	12 Mill Drive	North Rocks
		S2-2	10 Virginia Place	West Pennant Hills
		S2-3	11 Wilshire Avenue	Carlingford
		S2-4	70 Westmore Drive	West Pennant Hills
		S2-5	3 Mundon Place	West Pennant Hills
		S2-6	25 Coral Tree Drive	Carlingford
		S2-7	5 Orchard Road	Beecroft
		S2-8	24A Castle Howard Road	Cheltenham
	2	S2-9	13 Williams Road	North Rocks
		S2-10	8 Rajola Place	North Rocks
		S2-11	33 Carmen Avenue	Carlingford
		S2-12	30 Austral Avenue	Beecroft
Section 3: (Beecroft Road to Delhi Road)	1	S3-1	30 Dunmore Road	Epping
		S3-2	4 Somerset Street	Epping
		S3-3	56 Somerset Street	Epping
		S3-4	19 Woodvale Avenue	North Epping
		S3-5	6/8 Nile Close	Marsfield
		S3-6	40 Ashburton Avenue	South Turramurra
		S3-7	45/147 Talavera Road	Marsfield
		S3-8	3/3 Tasman Place	North Ryde
		S3-9	21 Epping Road	North Ryde
	2	S3-10	13 Stewart Close	Cheltenham
		S3-11	140 Crimea Road	Marsfield
		S3-12	150 Crimea Road	Marsfield
		S3-13	2/4 Nile Close	Marsfield
		S3-14	1A Busaco Road	Marsfield
		S3-15	1 Fontenoy Road	Macquarie Park

6.2 Ambient Noise Monitoring Results

The results of the ambient noise surveys are presented in tabular form in **Table 10** and **Table 11**, and are also illustrated graphically in **Appendix C** (in the form of plots which show the average 24 hour noise levels at each monitoring location for the duration each logging period).

Representative Rating Background Levels (RBL) during the DECCW's standard daytime construction hours (7.00am to 6.00pm), the evening period (6.00pm to 10.00pm) and the night-time period (10.00pm to 7.00am), as required by the NSW "*Industrial Noise Policy"* (INP), are provided in **Table 10**. These noise levels are used to set noise objectives in relation to the construction phase of the project.

To represent overall day to day variations in road traffic noise emissions for freeways, use is made of the $L_{Aeq(15hour)}$ and $L_{Aeq(9hour)}$ noise indices. These indices represent the energy-averaged noise level that prevails during the daytime (7.00 am to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods. These indices, which are used for the operational assessment, are provided in **Table 11**.

Observations of the acoustical environment at the noise monitoring locations indicate that, during some periods, the noise environment would be influenced by short-term high noise level events such as sirens, street conversations, horns, etc, as well as the prevailing road traffic. As these former noise sources are relatively short-term in nature, they would have the effect of increasing the higher order L_{Amax} and L_{Aeq} indices rather than the L_{A10} and L_{A90} levels.

The ECRTN requires that, when conducting ambient noise surveys, it is only the noise level contributions from road traffic noise that are relevant, therefore in order for the measured data to reflect the prevailing levels of road traffic noise, the data was processed taking into account the following:

- Prevailing weather conditions.
- Uncharacteristic changes in the noise indices.
- Uncharacteristic variations of the L_{Aeq} compared to the L_{A10} index.

The unattended noise logging results measured in the vicinity of the tunnel portals have been utilised to determine the existing L_{A90} background and ambient L_{Aeq} noise levels during the daytime, evening and night-time periods applicable to operational stationary noise sources.

Table 10 Summary of Unattended Noise Logging – Construction Noise Indices

Receiver ID	Address		Construction Noise Indices (RBL) (dBA)		
			Daytime Period [1]	Evening Period [2]	Night-time Period [3]
S1-1	13 Sierra Place	Baulkham Hills	44	45	38.5
S1-2	89 Baulkham Hills Road	Baulkham Hills	50	47	38
S1-3	24 Lambert Crescent	Baulkham Hills	52	47	39.5
S1-4	15 Leatherwood Court	Baulkham Hills	48.5	49	47
S1-5	108 Junction Road	Baulkham Hills	51.5	47.5	37.5
S1-6	17 Livingstone Avenue	Baulkham Hills	47.5	44	36.5
S1-7	10 Murrills Crescent	Baulkham Hills	46	43.5	38.5
S1-8	13 Leatherwood Court	Baulkham Hills	51	48	36
S1-9	4 Craig Avenue	Baulkham Hills	57.5	54	38
S1-10	10 Petrina Close	Baulkham Hills	59.5	56.5	41.5
S2-1	12 Mill Drive	North Rocks	37	38	34
S2-2	10 Virginia Place	West Pennant Hills	52	48	39.5
S2-3	11 Wilshire Avenue	Carlingford	56.5	52.5	42
S2-4	70 Westmore Drive	West Pennant Hills	53.5	50	38
S2-5	3 Mundon Place	West Pennant Hills	47	46	35.5
S2-6	25 Coral Tree Drive	Carlingford	46	49	41.5
S2-7	5 Orchard Road	Beecroft	51.5	47	36
S2-8	24A Castle Howard Road	Cheltenham	53.5	48.5	33
S2-9	13 Williams Road	North Rocks	57.5	53	38.5
S2-10	8 Rajola Place	North Rocks	58	52.5	41.5
S2-11	33 Carmen Avenue	Carlingford	57.5	54.5	37.5
S2-12	30 Austral Avenue	Beecroft	57	52.5	39
S3-1	30 Dunmore Road	Epping	58	52	46
S3-2	4 Somerset Street	Epping	52	48	35
S3-3	56 Somerset Street	Epping	49	44.5	32.5
S3-4	19 Woodvale Avenue	North Epping	54.5	50	33
S3-5	6/8 Nile Close	Marsfield	44.5	42	36.5
S3-6	40 Ashburton Avenue	South Turramurra	45.5	47	38.5
S3-7	45/147 Talavera Road	Marsfield	50	46	35
S3-8	3/3 Tasman Place	North Ryde	51	48.5	41.5
S3-9	21 Epping Road	North Ryde	53.5	51.5	41
S3-10	13 Stewart Close	Cheltenham	54	50.5	33.5
S3-11	140 Crimea Road	Marsfield	53	49	36.5
S3-12	150 Crimea Road	Marsfield	49	45	31
S3-13	2/4 Nile Close	Marsfield	47	44.5	31.5
S3-14	1A Busaco Road	Marsfield	48.5	47.5	37
S3-15	1 Fontenoy Road	Macquarie Park	54	51.5	42

Note 1: DECCW's standard construction hours: 7.00 am to 6.00 pm Monday to Friday, 8.00 am to 1.00 pm on Saturdays and no work on Sundays or Public Holidays.

Note 2: Evening hours: 6.00 pm to 10.00 pm.

Note 3: Night-time hours: 10.00 pm to 7.00 am Sunday to Friday, 10.00 pm Saturday to 8.00 am Sunday.

Table 11 Summary of Unattended Noise Logging – Road Traffic Noise Indices

Receiver ID	Address		Road Traffic Noise Indices (dBA)		
			$L_{A10(18hour)}$	$L_{Aeq(15hour)}$	$L_{Aeq(9hour)}$
S1-1	13 Sierra Place	Baulkham Hills	52.5	51.5	47
S1-2	89 Baulkham Hills Road	Baulkham Hills	58.5	56.5	52.5
S1-3	24 Lambert Crescent	Baulkham Hills	60.5	59	55
S1-4	15 Leatherwood Court	Baulkham Hills	57	55.5	55.5
S1-5	108 Junction Road	Baulkham Hills	62	59	53.5
S1-6	17 Livingston Avenue	Baulkham Hills	58	56	52
S1-7	10 Murrills Crescent	Baulkham Hills	55.5	54	50
S1-8	13 Leatherwood Court	Baulkham Hills	59.5	57.5	53.5
S1-9	4 Craig Avenue	Baulkham Hills	68	65.5	61
S1-10	10 Petrina Close	Baulkham Hills	66.5	65.5	60
S2-1	12 Mill Drive	North Rocks	48.5	51	45
S2-2	10 Virginia Place	West Pennant Hills	58	56	54
S2-3	11 Wilshire Avenue	Carlingford	61.5	59.5	56
S2-4	70 Westmore Drive	West Pennant Hills	60	58	54
S2-5	3 Mundon Place	West Pennant Hills	54	53	48
S2-6	25 Coral Tree Drive	Carlingford	55.5	53	50.5
S2-7	5 Orchard Road	Beecroft	58.5	56.5	50.5
S2-8	24A Castle Howard Road	Cheltenham	59.5	57.5	52.5
S2-9	13 Williams Road	North Rocks	63.5	61.5	58
S2-10	8 Rajola Place	North Rocks	63.5	61.5	58
S2-11	33 Carmen Avenue	Carlingford	65	63.5	59
S2-12	30 Austral Avenue	Beecroft	64	62	57
S3-1	30 Dunmore Road	Epping	64	61.5	57.5
S3-2	4 Somerset Street	Epping	59.5	57.5	52.5
S3-3	56 Somerset Street	Epping	56	53.5	48
S3-4	19 Woodvale Avenue	North Epping	61	59	54
S3-5	6/8 Nile Close	Marsfield	53	51.5	46.5
S3-6	40 Ashburton Avenue	South Turramurra	56.5	55	50
S3-7	45/147 Talavera Road	Marsfield	61.5	60	52.5
S3-8	3/3 Tasman Place	North Ryde	57	56	50.5
S3-9	21 Epping Road	North Ryde	60	58.5	53
S3-10	13 Stewart Close	Cheltenham	60	58	53.5
S3-11	140 Crimea Road	Marsfield	59	58	52.5
S3-12	150 Crimea Road	Marsfield	54.5	53.5	48
S3-13	2/4 Nile Close	Marsfield	55.5	55	48.5
S3-14	1A Busaco Road	Marsfield	56	54.5	49.5
S3-15	1 Fontenoy Road	Macquarie Park	61.5	60	55

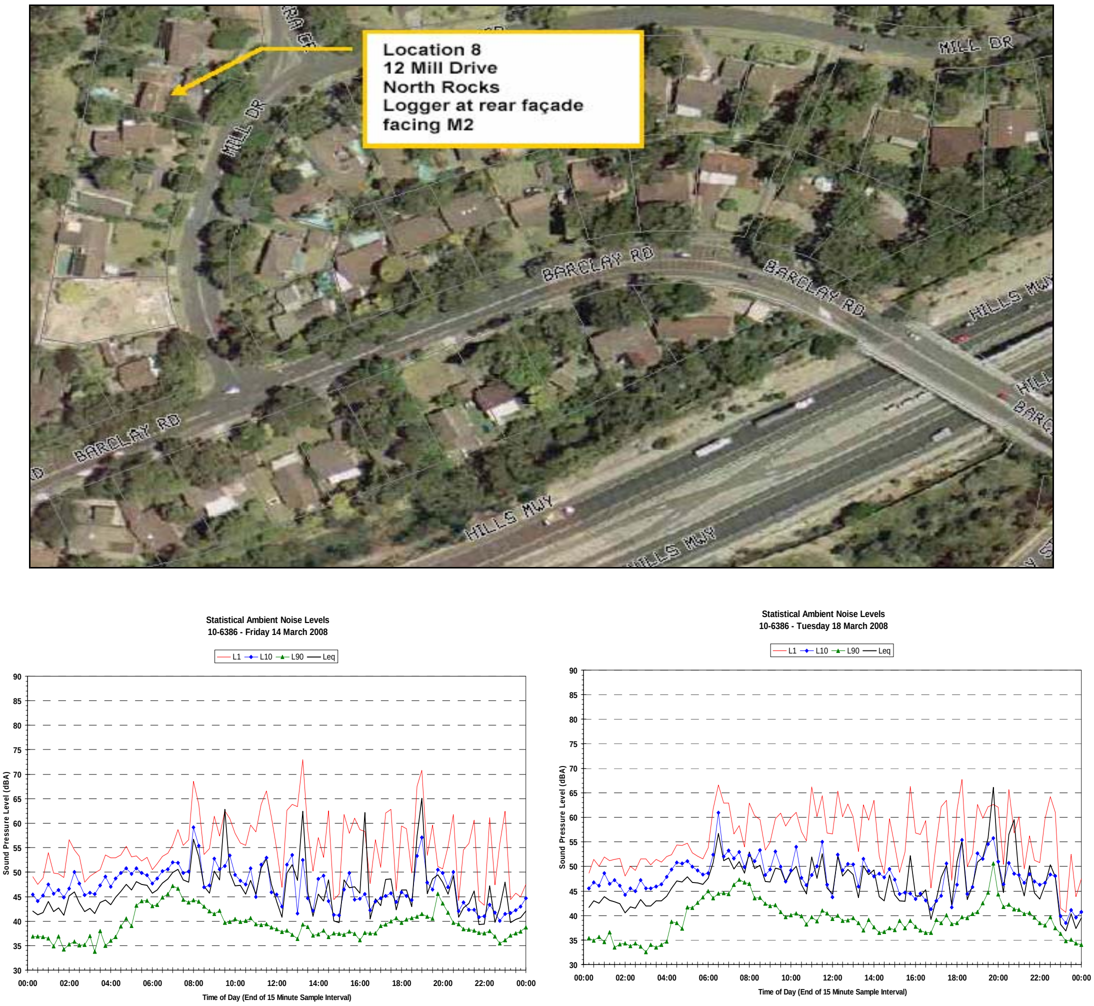
Reference to the background noise logging data contained in **Table 11** shows that where receivers are situated adjacent to the M2 Motorway and are not screened from view of the motorway by other houses, the existing levels of road traffic noise are, in the majority of cases, already above the ECRTN base criteria of 60 dBA $L_{Aeq(15hour)}$ and 55 dBA $L_{Aeq(9hour)}$.

6.2.1 Discussion

Four of the above monitoring locations (15 Leatherwood Court, 12 Mill Drive, 3 Mundon Place and 40 Ashburton Avenue) were excluded from some of the subsequent analysis for the following reasons:

- The noise level data amassed at both 12 Mill Drive and 40 Ashburton Avenue was found to have been significantly influenced by extraneous sources present in the vicinity of the measurement locations, in both cases unrelated to road traffic noise. For example, **Figure 8** shows the location map for 12 Mill Drive (North Rocks) and two typical daily noise plots. The residence is some distance from the motorway and experiences highly variable noise levels throughout the day and night that is not related to "steady" road traffic noise.
- The L_{Aeq} noise data for 15 Leatherwood Court was found to have very little variance throughout the period of the day, with practically no difference between the daytime and night time noise levels, as can be seen in **Table 11**. As a result of this the logging at this location was deemed to be erroneous and was discounted.
- 30 Mundon Place was monitored separately to the March to April monitoring exercise and was subsequently found also to be not representative (in terms of dominant noise levels) of typical motorway operation.

Figure 8 Aerial Location Map for 12 Mill Drive, North Rocks



7 ASSESSMENT OF CONSTRUCTION PHASE

The M2 Upgrade Project represents a major infrastructure development project, constructed over two years, and as such there would be periods when impacts on the surrounding areas are expected.

As it will be necessary for the motorway to, at least partly, remain open during the daytime, works would often be required to be conducted during the less busy night-time period.

7.1 Construction Noise Modelling Procedure

The general methodology adopted for the prediction of construction noise impacts is as follows:

- A review of the construction works is undertaken to identify the various main stages of the construction process, the equipment involved and the scheduling of these activities. This leads to the distillation of the construction programme into a series of distinct construction scenarios which are fully representative of the range of activities and planned scheduling of the project – refer to **Section 7.1.2**.
- The start point for the calculations is to assign representative sound power levels to all the equipment involved in the above construction scenarios.
- To enable comparison of equipment noise emissions to the project construction noise goals, it is necessary to convert the above sound power levels to equivalent L_{Aeq} noise emissions.
- Finally, the simulated construction scenarios are "placed" in realistic configurations at representative Noise Catchment Areas along the project route to determine the impact at nearest sensitive receivers.

7.1.1 Construction Noise Modelling – SoundPLAN

In order to quantify noise emissions from the proposed construction works, noise calculations have been undertaken to predict the $L_{Aeq(15minute)}$ noise levels at the nearest sensitive receivers using the CONCAWE industrial noise algorithm within the SoundPLAN noise modelling software.

The calculations take into account the source noise levels of the anticipated equipment, the location of the nearest residential receivers, the number of items of equipment likely to be operating at any given time and the distance and topography (including existing noise barriers) between the equipment and the nearest receivers.

The upgrade works are essentially repeated along the length of the M2 Motorway, and as such, the impact of the proposed works has been assessed by examining representative receivers along the length of the Motorway in selected noise catchment areas. A map illustrating each of the construction noise catchment areas is provided within **Appendix B**.

7.1.2 Construction Scenarios, Equipment and Sound Power Levels

For the M2 Upgrade Project, a series of construction scenarios has been developed which represent the various construction phases of the upgrade process.

Table 12 details each of the critical work elements of relevance to construction impacts, together with the equipment required during each scenario and the corresponding sound power levels for each item of plant.

The expected location and duration of each of the key construction scenarios is indicated in **Table 13** together with the period of the day in which the activity will be undertaken. It is noted that not all scenarios are required at all locations along the motorway.

Table 12 Construction Scenarios and Typical Equipment Involved

Scenario	Activity	Equipment Used	Sound Power Level (dBA)	
			L_{Aeq}	L_{Amax}
1a + 1b	Road Widening	Excavator 30t	109	115
		Truck (delivery / removal)	93	97
		Concrete Truck	109	113
		Concrete Saw	114	118
		Mobile Crane	105	113
		Vibratory Roller	106	114
		(PLUS at selected locations – Scenario 1b)		
	(Scenario 1b includes the additional equipment associated with Rocksawing/breaking)	Rocksaw	114	118
		Rockbreaker	117	124
		Compressor	106	107
		Generator	100	103
2	Cross-Stitching & Temporary Median Works	Excavator 30t with Hammer	109	115
		Jack Hammer	115	117
		Truck (delivery / removal)	93	97
		Concrete Truck	109	113
		Concrete Saw	114	118
		Mobile Crane	105	113
		Vibratory Roller	106	114
3	Intelligent Transport System (ITS) Works	Excavator 30t	109	115
		Truck (delivery / removal)	93	97
		Concrete Truck	109	113
		Concrete Saw	114	118
		Reinforcement Cutting	109	118
		Mobile Crane	105	113
		Generator	100	103
		Lighting Tower	87	88
4	Re-Surfacing Asphalt Works	Asphalt Paver	104	112
		Vibratory Roller	109	114
		Tip Trucks	93	97
5	Traffic Management, Set-Up and Line Marking	Truck (delivery / removal)	93	97
		Generator	100	103
		Lighting Tower	87	88
6	Hydroblasting	Drilling Rig	104	104
		Truck (delivery / removal)	93	97
		Compressor	106	107
		Generator	100	103
		Jackhammer	115	117
		Mobile Crane	105	113
		Lighting Tower	87	88
7a	Bridgeworks (Daytime - Bored Piling, Abutments and Piers, Deck and Finishing)	Piling Rig (bored)	107	110
		Rockbreaker	117	124
		Excavator 30t	109	115
		Backhoe	106	111
		Truck (delivery / removal)	93	97
		Generator	100	103
		Compressor	106	107
		Jackhammer	115	117
		Crane (up to 70t)	109	113
		Concrete Pump	108	112
		Vibratory Roller	106	114
7b	Bridgeworks (Evening and Night-time works)	Generator	100	103
		Compressor	106	107
		Concrete Truck	109	113
		Concrete Pump	108	112
		Concrete Vibrator	105	112
		Truck (delivery / removal)	93	97
		Mobile Crane	105	113
		Boom Lift	102	108

Table 13 Key Construction Activities, Likely Duration and Scheduling Times

Chainage/Location	Duration	Period	Activity
0 – 4000 West of Windsor Road	4 months	Day	ITS Works (eg signage)
			Re-Surfacing Asphalt Works
		Night	Cross-Stitching & Temporary Median Works
			Traffic Management Set-Up and Line Marking
			Re-Surfacing Asphalt Works
Windsor Road Ramps	15 months	Day	Widening & Ramp Construction
			Bridgeworks
			Re-Surfacing Asphalt Works
		Night	Hydroblasting
			Cross-Stitching & Temporary Median Works
			ITS Works (eg signage)
			Traffic Management Set-Up and Line Marking
4000 – 6000 Windsor Road to Barclay Road	12 months	Day	Widening Works (including rockhammering)
			Re-Surfacing Asphalt Works
		Night	Cross-Stitching & Temporary Median Works
			ITS Works (eg signage)
			Traffic Management Set-Up and Line Marking
6000 – 7900 Barclay Road to Carmen Drive	14 months	Day	Widening Works (including rockhammering)
			Re-Surfacing Asphalt Works
		Night	Cross-Stitching & Temporary Median Works
			ITS Works (eg signage)
			Traffic Management Set-Up and Line Marking
7900 – 9400 Carmen Drive to Pennant Hills Road	6 months	Day	ITS Works (eg signage)
			Cabling and Trenching Works
9400 – 12000 Pennant Hills Road to Beecroft Road	10 months	Day	Widening Works (including rockhammering)
			Bridgeworks
			Re-Surfacing Asphalt Works
		Night	Cross-Stitching & Temporary Median Works
			ITS Works (eg signage)
			Traffic Management Set-Up and Line Marking
12000 – 12400 Beecroft Road to West Tunnel Portal	5 months	Day	Widening Works (including rockhammering)
			ITS Works (eg signage)
			Re-Surfacing Asphalt Works
		Night	Cross-Stitching & Temporary Median Works
			Traffic Management Set-Up and Line Marking
			Re-Surfacing Asphalt Works
12400 – 13550 Portal & Tunnel Works1	18 months	Day	Tunnel Drilling
			Widening Works (including rockhammering)
			ITS Works (eg signage)
			Re-Surfacing Asphalt Works
		Night	Tunnel Drilling
			Widening Works (including rockhammering)
			Cross-Stitching & Temporary Median Works
			Traffic Management Set-Up and Line Marking
			Re-Surfacing Asphalt Works
13550 – 15000 East Tunnel Portal to Busaco Road	16 months	Day	Widening Works (including rockhammering)
			Bridgeworks (Terry's Creek, Busaco Road)
			Re-Surfacing Asphalt Works
		Night	Cross-Stitching & Temporary Median Works
			ITS Works (eg signage)
			Traffic Management Set-Up and Line Marking
15000 – 15400 Busaco Road to Toll Plaza	12 months	Day	Widening Works (including rockhammering)
			Re-Surfacing Asphalt Works
		Night	Cross-Stitching & Temporary Median Works
			ITS Works (eg signage)
			Traffic Management Set-Up and Line Marking
15400 – 15700 Toll Plaza Works	15 months	Day	Widening Works
			ITS Works (eg signage)

Chainage/Location	Duration	Period	Activity
		Night	Cross-Stitching & Temporary Median Works
			ITS Works (eg signage)
			Traffic Management Set-Up and Line Marking
15700 – 16000 Toll Plaza to Christie Road	12 months	Day	Widening Works (including rockhammering)
			Re-Surfacing Asphalt Works
			ITS Works (eg signage)
		Night	Cross-Stitching & Temporary Median Works
			Re-Surfacing Asphalt Works
			Traffic Management Set-Up and Line Marking
16200 – 17650 Christie Road to Lane Cove Road	23 months	Day	Widening Works (including rockhammering)
			Herring Road Bridgeworks/Ramps
			Re-Surfacing Asphalt Works
			ITS Works (eg signage)
		Night	Cross-Stitching & Temporary Median Works
			Re-Surfacing Asphalt Works
			Traffic Management Set-Up and Line Marking

Note 1: The impacts from the construction works associated with the widening of the Norfolk Tunnel are discussed in detail in **Section 7.7**.

It is noted that the majority of the proposed construction works associated with the M2 Upgrade Project would be undertaken during the standard daytime construction hours. Night-time works would be completed on an as-needed basis.

Furthermore, where evening and night-time works are required, it is noteworthy that they would not be continuous at any one location for the full duration of the works within that section.

7.2 Construction Noise Predictions

Using the sound power levels in **Table 12**, construction noise levels have been predicted at the nearest receiver locations to the various Noise Catchment Areas for each of the construction scenarios detailed in **Table 13** (noting that not every scenario is apparent of each assessment location).

The resultant daytime, evening and night-time $L_{Aeq(15minute)}$ noise levels are presented in **Table 14**, **Table 15** and, **Table 16** respectively (where appropriate) and compared with the relevant Noise Management Levels.

The predicted construction noise levels will inevitably depend upon the number of plant items and equipment operating at any one time and their precise location relative to the receiver of interest. A receiver will therefore experience a range of values, representing the variation in construction noise depending upon the location of the particular construction activity and the likelihood of the equipment of interest operating simultaneously.

Where a range of values are apparent, the values presented in the assessment tables represent the predicted noise levels at several receivers within that Noise Catchment Area at various offset distances from the construction works.

It is noted that the following predictions are representative of typical construction works situated on the carriageway of M2 in the vicinity of each of the assessment locations, and that for extended periods of time, noise levels would potentially be lower than the calculated levels as predicted for the construction scenarios evaluated.

In each construction scenario, all of the equipment belonging to a particular activity is assumed to be operating concurrently for the full 15 minute period.

It is noted that the following predictions relate to when the particular plant is approximately adjacent to the residences of interest and that as plant and equipment moves along the road of concern, noise levels will reduce.

7.2.1 Daytime Construction Noise

The assessment of the impacts of construction noise during the daytime period, for each of the construction scenarios, is provided in **Table 14**.

Table 14 Construction Noise Predictions – Daytime

Noise Catchment Area (Refer to Appendix B)	Side of Motorway	Daytime NML (dBA) (RBL +10 dBA)	Predicted LAeq(15minute) Noise Level for each Scenario (dBA) (Refer to Table 12 for descriptions)							
			1a Road Widening	1b Road Widening	2 Cross Stitching	3 ITS Works	4 Re-Surfacing	5 Traffic Manage	6 Hydro-blasting	7a Bridge-works
1	North	62	-	-	-	57- 63	49- 52	-	-	-
	South	62	-	-	-	54	45	-	-	-
2	North	62	-	-	-	59	52- 54	-	-	-
3	North	61	-	-	-	51- 54	44- 48	-	-	-
	South	61	-	-	-	56	49	-	-	-
4	North	61.5	-	-	-	57	53	-	-	-
	South	61.5	-	-	-	55	49	-	-	-
5[1]	North	57.5	51- 67	53- 68	-	-	44- 54	-	-	49- 63
	South	56	54- 66	52- 67	-	-	49- 53	-	-	50- 63
6	South	69.5	54	56- 60	-	-	46- 48	-	-	-
7	North	67.5	52- 54	57- 59	-	-	48	-	-	-
	South	67.5	56	59- 60	-	-	49	-	-	-
8	North	68	50	55	-	-	45	-	-	-
	South	68	51	53	-	-	42	-	-	-
9	South	68	53	57	-	-	47	-	-	-
10	North	62	51	55	-	-	44	-	-	-
	South	66.5	43	48	-	-	38	-	-	-
11	North	63.5	47	51	-	-	42	-	-	-
	South	67.5	58- 62	67	-	-	56	-	-	-
12	South	61.5	-	-	-	61	-	-	-	-
13	North	67	59- 61	61- 64	-	-	50- 53	-	-	-
	South	61.5	52	59	-	-	49	-	-	-
14	South	61.5	48- 54	53- 57	-	-	43- 47	-	-	-
15	North	63.5	55- 60	60- 63	-	-	49- 52	-	-	59
	South	68	49- 53	54- 59	-	-	44- 47	-	-	54- 59
16	North	63.5	53- 55	59	-	-	47	-	-	-
	South	68	56- 60	60- 61	-	-	49- 51	-	-	-
17	North	62	57- 62	61- 64	-	57- 59	52	-	-	-
	South	62	57	59	-	55	48	-	-	-
	Tunnel	66	54	59	-	56	49	-	-	-
18	North	59	50- 54	57	-	51- 54	44- 47	-	-	54- 60
	South	59	52- 55	54- 58	-	51- 55	44- 49	-	-	48- 55
19	North	55.5	47	51	-	-	41	-	-	-
	South	57	57	60	-	-	51	-	-	-
20	North	58.5	46- 51	52- 55	-	-	39- 45	-	-	50- 63
	South	60	42- 51	53- 55	-	-	37- 45	-	-	56- 61
21	North	64	49- 53	63	-	59	52	-	-	-

Note 1: Location 5 presents the worst-case noise levels apparent when the existing noise walls are temporarily removed to construct the new Windsor Road access ramps.

Construction noise during the daytime period is generally predicted to be in line with the Noise Management Levels at most of the assessment locations detailed in **Table 14**. This results from the high background noise levels which are apparent from existing traffic movements on the M2 Motorway.

A number of small exceedances (less than 5 dBA) of the Noise Management Levels are predicted for the scenarios associated with Road Widening and Bridgeworks. The largest exceedance is predicted at Noise Catchment Area 5 in the vicinity of the proposed new Windsor Road access ramps. This exceedance, however, represents the worst-case noise levels subject to the nearby properties when the existing noise barrier is removed to allow construction of the new ramps.

7.2.2 Evening Construction Noise

The assessment of the impacts of construction noise during the evening period, for each of the construction scenarios, is provided in **Table 15**.

Table 15 Construction Noise Predictions – Evening

Noise Catchment Area (Refer to Appendix B)	Side of Motorway	Evening NML (dBA) (RBL +5 dBA)	Predicted LAeq(15minute) Noise Level for each Scenario (dBA) (Refer to Table 12 for descriptions)							
			1a Road Widening	1b Road Widening	2 Cross Stitching	3 ITS Works	4 Re-Surfacing	5 Traffic Manage	6 Hydro-blasting	7b Bridge-works
1	North	52	-	-	59- 65	-	49- 52	50- 55	-	-
	South	52	-	-	54	-	45	45	-	-
2	North	52	-	-	62	-	52- 54	49- 51	-	-
3	North	53	-	-	56	-	44- 48	43- 46	-	-
	South	53	-	-	59	-	49	48	-	-
4	North	52.5	-	-	61	-	53	50- 52	-	-
	South	52.5	-	-	59	-	49	46- 48	-	-
5[1]	North	49	-	-	53- 67	49- 68	-	44- 53	50- 63	38-56
	South	48.5	-	-	52- 67	49- 67	-	46- 54	51- 63	57-66
6	South	61.5	-	-	55- 57	51- 57	-	46	-	44-63
7	North	58	-	-	55- 57	52- 54	-	45- 47	-	44-69
	South	58	-	-	58	55	-	47	-	45-51
8	North	57.5	-	-	52	49- 51	-	43	-	-
	South	57.5	-	-	56	48	-	42	-	-
9	South	57.5	-	-	55	54	-	43- 45	-	44-51
10	North	53	-	-	53	51	-	42	-	-
	South	57.5	-	-	46	43	-	36	-	-
11	North	55	-	-	49	47	-	39	-	-
	South	59.5	-	-	62- 64	59- 63	-	50- 52	-	-
12	South	52	-	-	-	-	-	-	-	-
13	North	57.5	-	-	60- 62	59- 61	-	49- 51	-	52-58
	South	52	-	-	58	53	-	47	-	40-41
14	South	52	-	-	52- 56	49- 54	-	39- 44	-	60-69
15	North	53.5	-	-	58- 61	56- 59	-	47- 50	-	-
	South	57	-	-	52- 56	49- 54	-	42- 44	-	-
16	North	53.5	-	-	56	55	-	45	-	46-50
	South	57	-	-	58- 60	56	-	47- 50	-	51-57
17	North	53	57- 62	61- 64	59- 63	-	52	50	-	-
	South	53	57	59	57	-	48	45	-	-
	Tunnel	57	54	59	58	-	49	47	-	-
18	North	49.5	50- 54	57	53- 56	-	44- 47	43- 46	-	40-45
	South	49.5	52- 55	54- 58	53- 57	-	44- 49	43- 47	-	39-53
19	North	52	-	-	50	47	-	40	-	-
	South	49.5	-	-	60	57	-	49	-	-
20	North	52.5	-	-	50- 54	45- 50	-	40- 44	-	-
	South	51	-	-	50- 53	50	-	35- 44	-	-
21	North	56.5	-	-	61	-	52	50	-	41-48

Note 1: Location 5 presents the worst-case noise levels when the existing noise walls are temporarily removed to construct the new Windsor Road access ramps.

During the evening period exceedances are apparent for most of the construction scenarios assessed. Exceedance of the project Noise Management Levels in these scenarios typically range from zero (ie compliance) to around 15 dBA.

The largest exceedance (of about 20 dBA) is predicted at Noise Catchment Area 5 in the vicinity of the proposed new Windsor Road access ramps. This exceedance represents the worst-case noise levels subject to the nearby properties when the existing noise barrier is removed to allow construction of the new ramps.

It is noted that evening construction works would not be expected to be continuous at any one location for the full duration of the works within that section.

7.2.3 Night-time Construction Noise

The assessment of the impacts of construction noise during the night-time period, for each of the construction scenarios, is provided in **Table 16**.

Table 16 Construction Noise Predictions – Night-time

Noise Catchment Area (Refer to Appendix B)	Side of Motorway	Night NML (dBA) (RBL +5 dBA)	Predicted $L_{Aeq(15minute)}$ Noise Level for each Scenario (dBA) (Refer to Table 12 for descriptions)							
			1a Road Widening	1b Road Widening	2 Cross Stitching	3 ITS Works	4 Re-Surfacing	5 Traffic Manage	6 Hydro-blasting	7b Bridge-works
1	North	44.5	-	-	59- 65	-	49- 52	50- 55	-	-
	South	44.5	-	-	54	-	45	45	-	-
2	North	44.5	-	-	62	-	52- 54	49- 51	-	-
3	North	41	-	-	56	-	44- 48	43- 46	-	-
	South	41	-	-	59	-	49	48	-	-
4	North	42.5	-	-	61	-	53	50- 52	-	-
	South	42.5	-	-	59	-	49	46- 48	-	-
5[1]	North	41.5	-	-	53- 67	49- 68	-	44- 53	50- 63	38-56
	South	43.5	-	-	52- 67	49- 67	-	46- 54	51- 63	57-66
6	South	46.5	-	-	55- 57	51- 57	-	46	-	44-63
7	North	43.5	-	-	55- 57	52- 54	-	45- 47	-	44-69
	South	43.5	-	-	58	55	-	47	-	45-51
8	North	46.5	-	-	52	49- 51	-	43	-	-
	South	46.5	-	-	56	48	-	42	-	-
9	South	46.5	-	-	55	54	-	43- 45	-	44-51
10	North	44.5	-	-	53	51	-	42	-	-
	South	47	-	-	46	43	-	36	-	-
11	North	43	-	-	49	47	-	39	-	-
	South	42.5	-	-	62- 64	59- 63	-	50- 52	-	-
12	South	41	-	-	-	-	-	-	-	-
13	North	44	-	-	60- 62	59- 61	-	49- 51	-	52-58
	South	41	-	-	58	53	-	47	-	40-41
14	South	41	-	-	52- 56	49- 54	-	39- 44	-	60-69
15	North	38	-	-	58- 61	56- 59	-	47- 50	-	-
	South	51	-	-	52- 56	49- 54	-	42- 44	-	-
16	North	38	-	-	56	55	-	45	-	46-50
	South	51	-	-	58- 60	56	-	47- 50	-	51-57
17	North	40	57- 62	61- 64	59- 63	-	52	50	-	-
	South	40	57	59	57	-	48	45	-	-
	Tunnel	44	54	59	58	-	49	47	-	-
18	North	37.5	50- 54	57	53- 56	-	44- 47	43- 46	-	40-45
	South	37.5	52- 55	54- 58	53- 57	-	44- 49	43- 47	-	39-53
19	North	43.5	-	-	50	47	-	40	-	-
	South	36.5	-	-	60	57	-	49	-	-
20	North	42	-	-	50- 54	45- 50	-	40- 44	-	-
	South	40	-	-	50- 53	50	-	35- 44	-	-
21	North	47	-	-	61	-	52	50	-	41-48

Note 1: Location 5 presents the worst-case noise levels when the existing noise walls are temporarily removed to construct the new Windsor Road access ramps.

For the night-time period there are significant exceedances for many activities as a direct result of the more stringent NMLs.

It is noted that night-time construction works would not be expected to be continuous at any one location for the full duration of the works within that section.

7.2.4 Discussion on Exceedances

Although the above assessment predicts the potential for significant exceedances, at times, it is again noted that the sensitive receiver noise levels presented above are all predicted during a worst-case scenario when all of the equipment within a particular scenario is operating concurrently, for the full 15 minute assessment period, in a location immediately adjacent to the residences of interest.

This situation, and the associated higher Noise Management Level exceedances, may therefore only be apparent at a particular receiver of interest for a relatively short period of time. As the plant and equipment moves along the road of concern, the noise levels would be expected to reduce accordingly.

Certain proposed night-time works have the potential to result in noise levels well above background noise levels. As such they have the potential to impact upon adjacent sensitive receivers causing possible disturbance and nuisance.

However, evening and night-time works are only proposed for specific works on the motorway or on the major roads that intersect with the motorway. Undertaking these works during the daytime would have the potential to cause significant traffic disruption both directly at the works location and also extending out widely into the surrounding road networks. Due to the large number of people potentially affected by such works, it is therefore considered that night-time works are appropriate in these instances.

Working on busy roads can pose safety risks to both construction personnel and the users of the roads if appropriate measures are not put in place. Construction works associated with roads often require temporary modification to existing lane alignments and other traffic control measures which are different to the usual conditions experienced by road users at these locations. This increases the potential for traffic incidents that could affect the safety of construction personnel and other the road users. As such, certain activities are proposed at night-time to address these safety concerns. Some of these works involve short-term activities such as making appropriate changes to the lane alignment and other intersection features to create safer daytime working environments for both construction personnel and road users.

In summary, whilst the noise associated with the proposed night-time work activities may have the potential to impact upon the amenity of adjacent sensitive receivers, their justification is based on significant safety considerations and the potential for widespread traffic disruption.

On the basis of the above, the following approach would be undertaken, in accordance with DECCW's Interim Construction Noise Guideline:

- All reasonable and feasible work practices need to be applied to meet the noise goals.
- Where Noise Management Levels are likely to be exceeded (especially during the more sensitive evening and night-time periods), community liaison must be undertaken and negotiation take place to arrive at the final mitigation strategy.

Suitable methods for mitigating the impact of construction noise (and vibration) are discussed in more detail in **Section 8**.

It is noteworthy that in the above assessment of the daytime, evening and night-time periods, the higher exceedances are generally related to the use of the following items of plant:

- Concrete saws (and reinforcement cutting)
- Rockbreakers
- Jackhammers

7.2.5 Sleep Disturbance

The assessment of the predicted sensitive receiver LAmax noise levels during the night-time period is presented in **Table 17**. The corresponding Sleep Disturbance Screening Criterion (RBL +15 dBA) for each assessment location is also presented.

Table 17 Construction Noise Predictions – Sleep Disturbance

Location (Refer to Appendix B)	Side of Motorway	Sleep Disturbance Screening Criterion (dBA) (RBL +15 dBA)	Predicted LAmax Noise Level for each Scenario (dBA) (Refer to Table 12 for descriptions)							
			1a Road Widening	1b Road Widening	2 Cross Stitching	3 ITS Works	4 Re-Surfacing	5 Traffic Manage	6 Hydro-blasting	7b Bridge-works
1	North	54.5	-	-	60- 65	-	54- 57	54- 62	-	-
	South	54.5	-	-	57	-	51	50	-	-
2	North	54.5	-	-	64	-	56- 59	56- 58	-	-
3	North	51	-	-	56- 58	-	50- 52	48- 51	-	-
	South	51	-	-	61	-	55	53	-	-
4	North	52.5	-	-	63- 66	-	58	58	-	-
	South	52.5	-	-	61	-	55	52- 54	-	-
5[1]	North	51.5	-	-	57- 68	56- 71	-	50- 62	52- 59	45-61
	South	53.5	-	-	63- 72	63- 75	-	58- 61	55- 67	64-71
6	South	56.5	-	-	58- 61	58- 62	-	50- 52	-	50-67
7	North	53.5	-	-	58- 60	58- 60	-	53	-	51-73
	South	53.5	-	-	60	61	-	52	-	52-57
8	North	56.5	-	-	57	57	-	48	-	-
	South	56.5	-	-	56	58	-	49	-	-
9	South	56.5	-	-	56- 59	59	-	47- 50	-	50-55
10	North	54.5	-	-	57	57	-	48	-	-
	South	57	-	-	49	50	-	43	-	-
11	North	53	-	-	53	53	-	44	-	-
	South	52.5	-	-	63- 67	69	-	57- 59	-	-
12	South	51	-	-	66	-	-	-	-	-
13	North	54	-	-	60- 63	68	-	52- 55	-	58-63
	South	51	-	-	59- 61	65- 67	-	55	-	45-47
14	South	51	-	-	52- 57	58- 60	-	45- 49	-	65-72
15	North	48	-	-	62	54- 58	-	52- 54	-	-
	South	61	-	-	56- 61	62- 65	-	48- 50	-	-
16	North	48	-	-	58	56- 61	-	49	-	50-54
	South	61	-	-	61- 64	59	-	53- 55	-	55-61
17	North	50	64- 68	69	64- 67	-	57	55- 58	-	-
	South	50	63	65	63	-	54	52- 54	-	-
	Tunnel	54	60	65	60	-	54	52	-	-
18	North	47.5	57- 60	63	57- 59	-	49- 52	51	-	47-50
	South	47.5	58- 61	60- 64	56- 61	-	49- 54	49- 52	-	45-57
19	North	53.5	-	-	52	54	-	46- 49	-	-
	South	46.5	-	-	61- 63	64	-	54	-	-
20	North	52	-	-	54- 57	52- 58	-	48- 50	-	-
	South	50	-	-	55- 57	52- 56	-	48	-	-
21	North	57	-	-	64	-		55	-	48-52

Note 1: Location 5 presents the worst-case noise levels when the existing noise walls are temporarily removed to construct the new Windsor Road access ramps.

Exceedance of the project Sleep Disturbance Screening Criteria ranges from zero (ie compliance) to around 20 dBA.

The largest exceedance is predicted at Assessment Location 5 which is in the vicinity of the proposed new Windsor Road access ramps. This exceedance represents the noise levels subject to the nearby properties when the existing noise barrier is removed to allow construction of the new ramps.

Again, the higher exceedances of the Sleep Disturbance Screening Criteria are generally related to the use of the following items of plant:

- Concrete saws (and reinforcement cutting)
- Rockbreakers
- Jackhammers

7.3 Construction Noise - Sensitive Land Uses

The assessment of the impact of construction noise on other sensitive land used is provided in **Table 18** and **Table 19.**

Table 18 Assessment of Existing Educational Facilities

Location	NML (dBA)	Predicted $L_{Aeq(15minute)}$ Noise Level for each Scenario (dBA) (Refer to Table 12 for descriptions)							
		1a Road Widening	1b Road Widening	2 Cross Stitching	3 ITS Works	4 Re-Surfacing	5 Traffic Manage	6 Hydro-blasting	7a Bridge-works
Model Farms High School	55 (external)[1]	-	-	-	40	33	-	-	-
Winston Hills Public School		-	-	-	51	45	-	-	-
Our Lady of Lourdes Primary School		47	55	-	-	40	-	-	39
Murfield High School		42	46	-	-	35	-	-	-
Royal Institute for Deaf and Blind Children School		43	48	-	-	37	-	-	-
Epping Heights Public School		55- 63	56- 64	-	-	47- 51	-	-	50- 57
Macquarie University		46	52	-	-	42	-	-	44

Note 1: Based on an internal NML of 45 dBA and a 10 dBA reduction from external to internal noise levels for openable windows.

The above assessment concludes that at the existing educational facilities, the majority of the predicted construction noise levels are below the Noise Management Levels. The only exception is at Epping Heights Public School, where exceedances of around 9 dBA are predicted for a number of the scenarios.

It is however noted that the ambient noise monitoring results, as presented in **Table 10**, show existing daytime background (L_{A90}) noise levels measured in the vicinity of Epping Heights Public School of 58 dBA (measured on Dunmore Road).

Table 19 Assessment of Places of Worship

Location	NML (dBA)	Predicted L_{Amax} Noise Level for each Scenario (dBA) (Refer to Table 12 for descriptions)							
		1a Road Widening	1b Road Widening	2 Cross Stitching	3 ITS Works	4 Re-Surfacing	5 Traffic Manage	6 Hydro-blasting	7a Bridge-works
Our Lady of Lourdes Church	55 (external) [1]	52	60	44	40	42	45	49	48

Note 1: Based on an internal NML of 45 dBA and a 10 dBA reduction from external to internal noise levels for openable windows.

Exceedances of the Noise Management Level at Our Lady of Lourdes Church are predicted when the Road Widening works are in proximity to the church.

7.4 Construction Site Compounds

The M2 Upgrade Project would require several temporary Site Compounds to be constructed along the length of the route. These compounds, which are located within the existing RTA Lease Boundary, would be used for a variety of purposes including laydown areas, stockpiling, stores, team offices, car parking, etc.

The location of each the Site Compounds is illustrated on aerial photographs in **Part C – The Proposal, Section 7 - Project Description** of the main EA. A discussion of the main Site Compound activities which are considered to be potentially noise generating is provided below.

Stockpiling, Stores, Laydown areas, etc

The majority of the Site Compounds would be used for the stockpiling and storing of materials and equipment. Noise from these activities would be expected to be generated by the movement of materials and equipment around the site.

Equipment Mobilisation

Most of the Site Compounds would also be used at times to store and mobilise items of construction plant prior to moving out onto the M2 carriageway.

Bridge Construction Compounds

A number of the Site Compounds are situated in close proximity to bridges which are required to be modified as part of the M2 Upgrade Project. In these compounds, equipment and plant related to the construction of the bridgeworks would be stored and mobilised, and concrete trucks, concrete pumps, cranes, and piling rigs would be made use of, as necessary.

The assessment of construction works associated with bridgeworks has previously been performed within **Section 7.2** of this report.

Major Compounds (TIDC Compound)

The TIDC Compound, which is likely to be used as the Main Site Compound, is located within a commercial area. Residential receivers are however situated to the south of the site, across Epping Road, at a distance of around 170 m. It is noted that the TIDC Compound has previously been used as one of the main site compounds during the construction of the Epping to Chatswood Rail Line.

The location of the various compounds, together with their size, intended use and points of access, are presented in **Table 20**.

It is noted that the majority of the smaller Site Compounds are intended to be made use of during the daytime periods, with the Major Compounds being used 24 hours a day. There may however be a requirement for some of the smaller Site Compounds to occasionally support some activities undertaken during the evening and night-time periods.

Table 20 Construction Site Compound Details

Compound	Location	Approx. Size (m^2)	Proposed Use	Proposed Access	Average Daily Traffic Movements[1]	
					Light	Heavy
Windsor Road (24 hour)	Windsor Road, North of M2	5,800	Bridge construction Team office Laydown Area	Torrs Street, onto Windsor Road	85	40
Darling Mills Creek	East of existing Windsor Road ramps	4,000	Bridge Construction Welfare Laydown Area	Windsor Road ramps	38	24
Barclay Road (Not in constant use)	Between Barclay Road, Perry Street & M2	6,600	Stockpile Rehandling Area Bridge Crew	Perry Street	26	24
Devlins Creek (Not in constant use)	Under bridge	16,000	Bridge Construction Welfare Laydown Area	Allerton Road (Bridge Construction Traffic Only)	36	24
Barombah Road	West of Beecroft Road	3,500	Stockpile Rehandling Area	Barombah Road	38	24
Beecroft Road (24 hour)	Old Bus Ramp, adjacent to Derby Street	1,460	Bridge Construction Welfare Laydown Area	Beecroft Road and W/B off ramp	38	24
Sutherland Road (Tunnelling – 24 hour)	North of M2, adjacent to Sutherland Road	3,800	Tunnel Construction Welfare Laydown Area	E/B, through existing Noise Wall and Sutherland Road	46	24
Somerset Road – Terrys Creek	Small strip at end of Somerset Street	2,850	Bridge Construction Welfare Laydown Area	Crimea Road	26	24
Terrys Creek	Long strip adjacent to W/B access at Crimea	20,500	Bridge Construction Welfare Laydown Area	Crimea Road (Bridge Construction Traffic Only)	36	24
Vimiera Road (Not in constant use)	South of M2, at end of Vimiera Road	8,200	Stockpile Rehandling Laydown Area	W/B, with suitable ramps (Light vehicle off Vimiera Road)	60	36
Busaco Road	Corner of Busaco/ Talavera Road	1,300	Bridge Works	Corner of Busaco and Talavera Road	38	24
Toll Plaza (24 Hour)	East of E/B Toll Plaza	2,200	Stockpile Rehandling Laydown Area	Toll Plaza Exit onto E/B	38	24
Christie Road (24 hour)	Western corner of Christie Road and Talavera Road	7,000	Bridgeworks	Talavera Road	46	24
Macquarie Park (24 hour)	North of M2	49,800	Stockpile Rehandling Laydown Area Subcontractor yards	E/B carriageway	124	64
TIDC Compound (24 hour)	South of M2, immediately off Delhi Road W/B On-ramp	35,000	Main Office, Welfare, Canteen, Laboratory, Traffic Management, Stores, Main Car Park	Delhi Road, W/B on-Ramp and Wicks Road feeding onto Epping Road	800	184
North Ryde Station	Behind North Ryde Station	11,500	Car Park	Delhi Road	580	52

Note 1: Average vehicle movements relate to round trips (ie one movement relates to a particular vehicle arriving at and departing from a particular Site Compound).

7.4.1 Construction Compounds - Noise Impact Assessment

The assessment of the potential noise impacts from the M2 Upgrade Project Site Compounds is presented below.

Smaller Site Compounds - Daytime

The proposed locations of the Site Compounds are all immediately adjacent to the M2 Motorway, and as such, are already subject to reasonably high levels of ambient (road traffic) noise.

Reference to the unattended noise logging data detailed in **Section 6.2** concludes that the following typical ambient RBL noise levels were measured during the daytime period at monitoring locations in close proximity to the M2 carriageway:

- Daytime Period (RBL): 50 dBA – 55 dBA

These RBL levels have been used to set the sensitive receiver Noise Management Levels for the daytime operations of the smaller Site Compounds.

The following table details the assessment of the potential noise impacts from the anticipated activities at the various smaller Site Compounds.

The predicted construction noise levels will inevitably depend upon the number of plant items and equipment operating at any one time within a particular compound and their precise location relative to the receiver of interest. A receiver will therefore experience a range of values, representing the variation in construction noise depending upon the location of the particular activity and the likelihood of the equipment of interest operating simultaneously.

It is noted that the following predictions are representative of typical Site Compound works, at a variety of offset distances, and that for extended periods of time, noise levels would potentially be lower than the calculated levels.

In each construction scenario, all of the equipment belonging to a particular activity is assumed to be operating concurrently for the full 15 minute period.

Table 21 Construction Compounds - Noise Impact Assessment (Daytime)

Site Compound Activity	Indicative Equipment	Daytime NML (dBA) (RBL +10 dBA)	Predicted $L_{Aeq(15minute)}$ Noise Level (dBA)[1]		
			5 – 10 m	10 – 20 m	20 – 50 m
Stockpile, Laydown Area, Stores, etc	Pickup Truck Bobcat Hand Held Tool	60 – 65	83 - 77	77 - 71	71 - 63
Equipment Mobilisation	Front End Loader Crane Concrete Truck		91 - 85	85 - 79	79 - 71

Note 1: The range of noise levels represents items of plant working at different distances

Smaller Site Compounds – Night-time

A number of the smaller Site Compounds are proposed to be made use of on a 24 hour basis. These include the Windsor Road, Beecroft Road Old Bus Ramp, Beecroft Road, Christie Road and Macquarie Park compounds.

These compounds are required to be operational 24 hours per day as they would be used to support the previously outlined construction activities that need to occur outside of standard construction hours. This is to ensure the safety of road users and construction personnel, and to minimise any potential traffic implications.

Although these compounds are intended to be used during the more sensitive night-time periods, it is however noted that during these periods no major noise intensive activities would be likely to be carried out on a regular basis.

The night-time uses would typically be related to:

- Traffic management launch areas
- Storage and laydown areas
- Welfare and supervision area

Reference to the unattended noise logging data detailed in **Section 6.2** concludes that the following typical ambient RBL noise levels were measured during the night-time period at monitoring locations in close proximity to the M2 carriageway:

- Night-time Period (RBL): 39 dBA – 44 dBA

These RBL levels have been used to set the sensitive receiver Noise Management Levels for the night-time operations of the smaller Site Compounds.

The following table details the assessment of the potential noise impacts from the anticipated activities at the various smaller Site Compounds.

Table 22 Construction Compounds - Noise Impact Assessment (Night-time)

Site Compound Activity	**Indicative Equipment**	**Night-time NML (dBA)** (RBL +5 dBA)	**Predicted $L_{Aeq(15minute)}$ Noise Level (dBA)[1]**		
			5 – 10 m	**10 – 20 m**	**20 – 50 m**
Stockpile, Laydown Area, Stores, etc	Pickup Truck Bobcat	44 – 49	83 - 77	77 - 71	71 - 63

Note 1: The range of noise levels represents items of plant working at different distances

The Macquarie Park and Christie Road compounds are noted as being situated at sufficiently large distances from any surrounding sensitive receivers so as to ensure that noise impacts at these locations are not likely.

TIDC Compound

The TIDC Compound is likely to be used as the Main Site Compound for the M2 Upgrade Project. As it would support all construction activities, including those that would need to be undertaken during evening and night-time periods due to safety risks and potential traffic implications, it is proposed to be used on a 24 hour basis. The following table presents the potential noise impacts at the nearest residential receivers.

It is noted that although all of the TIDC compound would be used by the M2 Upgrade Project, it is however proposed to only use the northern portion of the site for noise generating activities. This area is outlined in red in **Figure 9**.

Figure 9 Location of TIDC Compound

The majority of the sensitive receivers on Epping Road are shielded from the TIDC Site by large existing commercial buildings. A small number of receivers do however have a line of sight to the proposed TIDC Site. These receivers are situated to the south of the site, across Epping Road, at a distance of around 170 m.

The ambient noise data measured at 21 Epping Road, North Ryde, has been used to establish the various Noise Management Levels in **Table 23**.

Table 23 TIDC Construction Compound - Noise Impact Assessment

Site Compound Activity	Equipment	NML (dBA) (day/eve/night)	Predicted $L_{Aeq(15minute)}$ Noise Level[1]
Stockpile, Laydown Area, Stores, etc	Pickup Truck Bobcat Hand Held Tool	64/57/46	52
Equipment Mobilisation	Front End Loader Crane Concrete Truck		60

Note 1: Noise levels are predicted at the nearest sensitive receivers situated at a distance of 170 m from the southern extent of the noise generating activities

Based on the above assessment of the TIDC Compound, it is recommended that all site sheds associated with this compound be located along the southern boundary site to provide additional noise attenuation to the receivers on Epping Road, and that all noise intensive activities be completed towards the northern end of the site.

Noise Mitigation

Exceedances of the Noise Management Levels are predicted where sensitive receivers are situated in proximity to the Site Compounds. As such, it will be necessary to provide some form of noise mitigation to minimise the impact of noise generated by the compounds.

As there are negligible existing barriers between the Site Compounds and the sensitive receivers, it is likely that some form of noise barrier would be required to be erected (through dedicated and/or temporary noise walls, temporary hoardings, etc) in locations where sensitive receivers are situated in close proximity to the proposed construction compounds.

Correctly designed and constructed barriers (of solid construction using appropriate materials) would be expected to result in the following reductions in noise levels:

- Minor Barriers (hoarding of indicative height of 3 m - 4 m): 5 dBA to 10 dBA reduction
- Major Barriers (hoarding of indicative height of 6 m – 8 m): 10 dBA to 15 dBA reduction

7.4.2 Construction Traffic Impacts

It is intended that the TIDC Compound will have a large staff/visitor car parking area, with another large Workforce Parking Area located in the North Ryde Station Compound.

The majority of the car parking facilities are provided at the Main Compound so as to minimise light vehicle parking in other compound areas along the Project Area. Light Vehicle Works buses (15 – 20 seaters) would then be used to ferry the workforce from the Main Compound areas to the various work sites.

The EPA (now part of DECCW) published the "*Environmental Criteria for Road Traffic Noise"* (ECRTN) which is appropriate for assessing road traffic noise. The criteria for arterial, collector and local roads are set out in **Table 24**.

Table 24 DECCW Road Traffic Noise Criteria

Development	Day (7.00 am to 10.00 pm)	Night (10.00 pm to 7.00 am)
Land use development with potential to create additional traffic on existing freeways / arterials	$L_{Aeq(15hour)}$ 60 dBA	$L_{Aeq(9hour)}$ 55 dBA
Land use development with potential to create additional traffic on collector roads	$L_{Aeq(1hour)}$ 60 dBA	$L_{Aeq(1hour)}$ 55 dBA
Land use development with potential to create additional traffic on local roads	$L_{Aeq(1hour)}$ 55 dBA	$L_{Aeq(1hour)}$ 50 dBA

Where existing L_{Aeq} noise levels already exceed the above targets, the objective is then to limit any increase in noise level which may result from construction traffic movements. As changes in noise levels of around 2 dBA are not noticeable, mitigation measures are not required to be implemented where the increase in overall traffic noise is below this level.

However, when the contribution of construction traffic related noise increases the existing noise level by more than 2 dBA, feasible and reasonable noise mitigation measures are required to be applied to limit potential impacts to the general acoustic amenity of the area.

The majority of Site Compounds are proposed to be accessed from the M2 carriageway, and as such, the impact of light and heavy vehicle movements associated with these sites would be negligible over the existing ambient noise climate.

Where possible, construction traffic will utilise major roads, including the M2, Epping Road, Lane Cove Road, however to access some of the Site Compounds, it is likely that construction vehicles will, at times, need to travel short distances on local roads.

Local Roads - Light Vehicles

The potential noise impact of construction related light vehicle movements on local roads at the smaller Site Compound is considered to be negligible when considering the relatively small number of daily movements to these compounds. It is likely that the noise from these vehicles will be perceived as part of the general road traffic.

The Main Compound (TIDC Compound) which has large car parking facilities would be accessed from Lane Cove Road and Epping Road. As both of these road are major arterial routes, which are already subject to high daily volumes of traffic, the additional construction traffic that the M2 Upgrade Project would create is not expected to create any additional noise impacts.

Local Roads - Heavy Vehicles

Heavy vehicle movements on collector and arterial roads are likely to be perceived as part of the general road traffic, however once they move onto the local roads immediately adjacent to the Site Compounds, the community is likely to associate these heavy vehicle movements with the M2 Upgrade Project construction works.

The Site Compounds which require heavy vehicle access via local roads are detailed in **Table 25**, together with the expected number of hourly movements.

For the smaller Site Compounds it is anticipated that during the worst-case hour, four heavy vehicle movements would occur during the daytime in busy periods, with lower numbers during quieter periods. No night-time movements to these sites are expected along local roads.

For the TIDC Compound, the expected daytime and night-time worst-case hourly heavy vehicle movements are detailed in **Table 25**.

Table 25 Construction Traffic Impacts on Local Roads – Heavy Vehicles

Construction Compound	Accessed From	Expected Maximum Hourly Heavy Vehicle Movements	
		Daytime	Night-time
Windsor Road	Torrs Road, off Windsor Road	4	-
Devlins Creek	Allerton Road	4	-
Terrys Creek	Crimea Road	4	-
Culloden Road	Talavera Road/Culloden Road	4	-
TIDC	Wicks Road (onto Epping Road)	18	4

It is noted that the heavy vehicle movements associated with the TIDC Compound would be accessed from local roads with no residential receivers, and as such, there are anticipated to be no adverse impacts from heavy vehicles travelling to this Site Compound.

A summary of the predicted noise contribution of heavy vehicle movements to the Smaller Site Compounds, at various offset distances, is presented in **Table 26**. Only daytime values are presented in the table as night-time heavy vehicle movements are not anticipated at the Smaller Worksites.

Table 26 Predicted Off Site Heavy Vehicle Noise – Small Worksites

Distance	$L_{Aeq(1hour)}$ Sound Pressure Level (dBA)	
	Criteria (Daytime) [1]	Predicted (Daytime)[2]
10 m	55	55
20 m	55	53
30 m	55	51
40 m	55	49
50 m	55	48

Note 1 ECRTN local road criteria as shown in **Table 24**.

Note 2 Four trucks per hour are assumed for the daytime scenario, with no night-time movements anticipated.

The following mitigation measures are recommended in order to minimise the impact of exceedances of the criteria at residential receiver locations:

- All trucks to have mufflers and any other noise control equipment in good working order.
- Truck drivers are to avoid heavy acceleration and braking as far as is practicable.
- Truck drivers are to avoid compression braking as far as is practicable.
- Speed is to be minimised as far as is practicable.
- Truck movements are to be restricted to the daytime period to the furthest extent possible.

Noise from idling trucks near construction sites can also impact on amenity in some instances. For this reason, it is recommended that any queuing of trucks awaiting entry to the site outside normal construction hours should be restricted to locations away from residences and that if trucks are required to queue in such locations during construction hours, engines should be shut down.

The finalised construction traffic arrangements will be reviewed during the detailed design phase of the project.

7.4.3 Site Compounds - Noise Mitigation

The key control strategies involved for mitigating noise from the Site Compounds would include:

- Noise walls (enclosures) surrounding any continuously operating plant (ie generators)
- Truck management (eg limiting of “queuing” adjacent to residential areas)
- Temporary noise barriers (through temporary noise walls, hoardings, etc) wherever feasible to protect residents adjacent to the relevant sites, especially surrounding maintenance work areas.

Additional construction compound site hoardings and noise barriers (eg provided by site buildings) wherever feasible and practical could provide further shielding and reduce noise at the nearest relevant receivers.

Close liaison with the local community and a proactive information protocol (ie information on the duration and likely intensity of upcoming works) would play an important part of the management of noise emissions at these locations.

Assessment of the noise impacts from Site Compounds would be performed in more detail during the detailed design phase, when the specifics of each site would be known. Specific noise management strategies for each compound would also be developed at that time.

7.5 Construction Vibration

The major potential sources of construction vibration related to the M2 Upgrade Project include the use of excavators, rockbreakers and vibratory rollers.

Bulldozers/Excavators

Typical ground vibration levels from bulldozers range from 1 mm/s to 2 mm/s at a distance of approximately 5 m. At distances greater than 20 m, vibration levels are usually below 0.2 mm/s.

Hydraulic Rockbreakers

Table 27 sets out the typical ground vibration levels at various distances from a large rockbreaker operating in hard sandstone.

Table 27 Typical Rockbreaker Vibration Levels (mm/s) versus Distance

Operation	Vibration Level (mm/s) at Given Distance					
	5 m	**10 m**	**20 m**	**30 m**	**40 m**	**50 m**
Heavy Rockhammering	5	1.5	0.50	0.20	0.15	0.10

Use of light rock hammers is therefore recommended during construction near the closest buildings on the project, some of which may be in the order of 5 m from the works. At these residences, there may be occasions when vibration is perceptible during rock breaking immediately adjacent to the residences.

Vibratory Rollers

Levels of ground vibration caused by vibratory rollers can be up to 1.5 mm/s at 25 m. The highest levels of vibration usually occur as the roller is brought to rest and the frequency of the centrifugal forces passes through resonance with the natural frequency of the roller/ground structure.

Based on recommendations used by the NSW Roads and Traffic Authority, **Table 28** sets out safe working distances for the use of vibratory rollers adjacent to buildings.

Table 28 Safe Working Distances for Vibratory Rollers [1]

Roller Class	Weight Range	Centrifugal Force Range	Distance from Building	
			A	**B**
I - Very Light	Less than 1.25 tonnes	10 - 20 kN	3 m	No effect
II - Light	1 to 2 tonnes	20 - 50 kN	5 m	No effect
III - Medium	2 to 4 tonnes	50 - 100 kN	6 m	12 m
IV - Medium Heavy	4 to 6 tonnes	100 - 200 kN	12 m	24 m
V - Heavy	7 to 11 tonnes	200 - 300 kN	25 m	50 m
V- Very Heavy	12 tonnes and over	Over 300 kN	25 m	50 m

A Values suggested to prevent damage to buildings.
B Values suggested to minimise strongly adverse comment from residents.

Note: Source of data: ARRB Special Report No.11, *"Ground Vibrations: Damaging Effects to Buildings"*.

To minimise the vibration impact during use of the vibratory roller, **Table 28** recommends the use of a roller class "II Light" when operating as close as 5 m from the closest buildings on the project.

Expected Vibration Impacts

In general, vibration produced by earthworks and road forming operations is expected to lie below structural damage criteria. Where vibration-intensive operations are being conducted in close proximity to the buildings nearest to the roadworks (eg construction of the Windsor Road Ramps), judicious selection of plant and equipment will be necessary as outlined above.

Given the distances of the nearest residences to the proposed construction works, a review of the construction plan would be required to confirm whether pre-construction building condition surveys would be required.

Vibration may be perceptible for relatively short periods of time when construction activities are immediately adjacent to specific dwellings.

It is recommended that the construction methodology, plant and equipment, management of vibration impacts and community consultation protocol be reviewed prior to commencing construction. This should be addressed as part of the Construction Noise and Vibration Management Plan for the project.

7.6 Windsor Road Access Ramps and Intersection Re-Alignment

As has been previously detailed in **Section 7.2**, the potential impacts from the construction of the proposed Windsor Road Access Ramps are likely to be significant. This is especially apparent for the eastbound off-access ramp, where the existing properties are situated as close as approximately 5 m from the proposed construction works.

Similar impacts would also exist during the construction of the westbound on-access ramp, however the sensitive receivers on this side of the carriageway are noted as being situated further away from the construction works at a distance of around 15 m to 20 m away.

The potential impacts at both locations are likely to be most apparent when heavy plant, such as excavators and vibratory rollers, are situated in close proximity to the affected receivers. It is noted that there would also be the requirement to remove the existing noise walls (which are currently located at the edge of the outer carriageway) to allow the proposed ramps to be constructed.

It is however also noted that the proposed access ramps would be generally built up at this location and that widening of the road will typically not require cutting into virgin ground. As such, the use of rocksaws/rockbreakers at this location, which typically make a significant contribution to overall noise levels, will therefore be very minimal.

As part of the Windsor Road upgrade works, it is also proposed to widen the northbound side of Windsor Road from Woodlands Street up to the new on-access ramp to the M2. This will provide a more efficient flow of traffic at the intersection when the new access-ramps are built. The construction works associated with this phase of the project would be as close as approximately 5 m to 10 m from the nearest sensitive receivers on Windsor Road and as such, the impacts from the operation of heavy plant would be expected to potentially be significant at times.

Is it noteworthy that the majority of the noise intensive activities construction works associated with the upgrade of Windsor Road are proposed to be undertaken during the less sensitive daytime period, except for where a specific requirement for out of hours works exists.

7.7 Norfolk Tunnel Widening

As part of the M2 Upgrade Project three 3.5 m wide running lanes and a 2.5 m wide breakdown lane are proposed in each direction in the Norfolk Tunnel. This will require the removal of sandstone bedrock to widen the existing eastbound and westbound tunnel tubes together with modifications to the eastern and western tunnel portals. Other related works include the installation of rock bolts.

These works are expected to generate potentially significant noise and vibration which may affect nearby properties.

7.7.1 Sensitive Receivers

A number of residential properties are situated in close proximity to the Norfolk Tunnel. The location of the nearest receivers is illustrated in **Figure 10**.

Figure 10 Norfolk Tunnel

Image courtesy of Google Earth

It is noted that a number of newly built properties are now situated near the eastern portal of the tunnel, highlighted in red in **Figure 10**.

Reference to the above figure concludes that the properties which are in the vicinity of either tunnel portals are likely to be potentially affected by airborne noise from the construction works associated with the widening of the Norfolk Tunnel and tunnel portals.

Properties which are situated above the tunnel may also be potentially affected by ground-borne noise from the construction works.

The potentially affected properties are listed in **Table 29**.

Table 29 Properties Potentially Affected by Norfolk Tunnel Construction Works

Eastern End of Tunnel	Western End of Tunnel
2 Gillard Way, North Epping	59 Norfolk Road, North Epping
4 Gillard Way, North Epping	61 Norfolk Road, North Epping
6 Gillard Way, North Epping	27 Somerset Street, North Epping
8 Gillard Way, North Epping	29 Somerset Street, North Epping
10 Gillard Way, North Epping	31 Somerset Street, North Epping
12 Gillard Way, North Epping	1 Callistemon Close, North Epping
14 Gillard Way, North Epping	3 Callistemon Close, North Epping
16 Gillard Way, North Epping	3A Callistemon Close, North Epping
2 Sunden Way, North Epping	
3 Sunden Way, North Epping	
4 Sunden Way, North Epping	
5 Sunden Way, North Epping	
6 Sunden Way, North Epping	
7 Sunden Way, North Epping	
8 Sunden Way, North Epping	
9 Sunden Way, North Epping	
10 Sunden Way, North Epping	
11 Sunden Way, North Epping	
12 Sunden Way, North Epping	
13 Sunden Way, North Epping	

The effects of both airborne and ground-borne noise are discussed in more detail in the following sections.

7.7.2 Widening Methodology

The construction activities associated with the widening of the Norfolk Tunnel and supporting works, including haulage of spoil to disposal, are proposed to occur continuously (24 hours a day, six days a week) over certain periods.

Full possession of the tunnel tubes would be required to facilitate preliminary works associated with the tunnel widening. Services relocations, rock bolt installation to support the additional tunnel span and the construction of a proposed barrier to isolate the work areas from the trafficable portions of the M2 Motorway could not be completed with live traffic operating within the same tunnel tube without significant safety risks to road users and construction personnel.

Similarly, the contra-flow traffic arrangements required to maintain traffic flow in both directions along the motorway during a full tunnel tube possession could only occur safely during times of low traffic volumes. As such, full possession of a tunnel tube could only occur in the evening and night-time periods generally between 8.00 pm and 5.00 am when traffic volumes are low.

A key challenge associated with the proposed tunnel widening is maintaining the structural integrity of the tunnel. Excavation works within the Norfolk Tunnel are proposed on a 24 hours a day, six days a week basis for approximately four to six months in each tunnel tube.

For safety reasons during tunnelling operations it is necessary to stabilise the newly cut surface as soon as possible to maintain ground stability. Stabilisation is achieved through the installation of rock bolts, shotcrete and other devices.

A continuous tunnelling process (24 hours a day, six days a week) would reduce the duration between excavation and stabilisation and ensure tunnel integrity. This is required to enable the works within the tunnel to be completed within the proposed two year construction period and to minimise safety risks to motorists and the construction workforce.

The proposed methodology of the widening works is detailed in **Table 30**.

Table 30 Tunnel Widening Works

Stage	Works	Period	Duration	Proposed Mitigation
0 Early Works	Surveys, installation of Traffic Management, adjustment of portal transition areas (using excavator with hammer).	Night-time	4 Months	Limited potential for mitigation of works at portals.
1 Eastbound Tube	Service relocation, installation of new service trench and barrier (using excavator with hammer) within tunnel and at each portal. Installing rockbolts in tunnel.	Night-time	2.5 Months	Acoustic curtain at each end of tunnel, limited potential for mitigation of works at portals.
2 Eastbound Tube	Completion of service relocations and installation within tunnel and at each portal.	Night-time	1 Month	Acoustic curtain at each end of tunnel.
	Widening the existing rock batters at portals (using line drilling, excavators with hammers).	Daytime	1 Month	Limited potential for mitigation of works at portals.
3 Westbound Tube	Service relocation, installation of new service trench and barrier (using excavator with hammer) within tunnel and at each portal, installing rockbolts in tunnel.	Night-time	2.5 Months	Acoustic curtain at each end of tunnel, limited potential for mitigation of works at portals.
4 Westbound Tube	Completion of service relocations and installation within tunnel and at each portal, erection of separation barrier and Acoustic sheds in tunnel.	Night-time	1 Month	Acoustic curtain at each end of tunnel.
	Widening the existing rock batters at portals (using line drilling, excavators with hammers).	Daytime	1 Month	Limited potential for mitigation of works at portals.
5 Westbound Tube	Actual widening of the tunnel using S300 roadheader, rock drill and shotcrete rigs. Spoil removed by tipper truck.	24 hours, 6 days a week.	4.5 Months	Acoustic shed/curtain at each end of tunnel.
6 Westbound Tube	Removal of separation barrier and acoustic sheds. Installation of new drainage, barriers, wall lining, and profiling of new carriageway.	Night-time	1 Month	Acoustic curtain at each end of tunnel.
7 Eastbound Tube	Erection of separation barrier in tunnel and acoustic sheds at each portal.	Night-time	1 Month	Limited potential for mitigation of works at portals.
8 Eastbound and Westbound Tubes	Eastbound - Actual widening of the tunnel using S300 roadheader, rock drill and shotcrete rigs. Spoil removed by tipper truck.	24 hours, 6 days a week.	4.5 Months	Acoustic shed/curtain at each end of tunnel.
	Westbound - Completion of services and instrumentation and commissioning. Forming of new concrete portal.	Night-time		Limited potential for mitigation of works at portals.
9 Eastbound Tube	Removal of separation barrier and acoustic sheds. Installation of new drainage, barriers, wall lining, and profiling of new carriageway. Completion of services and instrumentation and commissioning. Forming of new concrete portal.	Night-time	2.5 Month	Acoustic curtain at each end of tunnel, limited potential for mitigation of works at portals.

7.7.3 Airborne Noise

Airborne noise will potentially affect receivers that are situated in proximity to the Norfolk Tunnel portals.

The potential noise impacts from the widening works which will be performed entirely within the tunnel will be mitigated with the use of acoustic sheds during the excavation of the tunnel, together with an acoustic curtain at either end of tunnel at other times.

The acoustic shed will only be in place for the excavation phase of the widening. All other night-time works within the tunnels will have a noise curtain in place at the portal entrances.

It is also noted that some works will be undertaken immediately outside of the portals at night-time (such as deluge diversion and cable pit works). Noise mitigation measures for these activities are limited.

For the early widening works (ie adjustment to the portal transition areas and breaking out of existing concrete barriers) there would also be limited mitigation measures, as the options for physical noise attenuation devices and procedural management measures (such as scheduling of activities) would either not be effective or are not feasible.

An assessment of the potential impacts from widening of the Norfolk Tunnel has been completed, and is detailed in **Table 31**. Noise levels have been predicted at the nearest affected sensitive receivers to both tunnel portals.

The Noise Management Levels are based on the unattended noise logging data measured at 56 Somerset Street, Epping. It is noted that the receivers which overlook the Norfolk Tunnel portals would be subject to higher ambient noise environment than was measured at this location, and would subsequently have higher Noise Management Levels. The assessment is therefore considered to represent a worst-case situation.

Noise levels have been predicted for the three scenarios, these being:

- Early widening construction works outside the portals – no mitigation
- Widening construction works at the tunnel portals – mitigation from acoustic shed only
- Widening construction works within the tunnels – mitigation from acoustic shed and curtain

Table 31 Norfolk Tunnel – Potential Noise impacts

Activity	Equipment	Proposed Mitigation	Predicted Noise Level LAeq(15min) (dBA)[1]	Noise Goals (dBA)	
				Time Period Noise Management Level (Day/Eve/Night)	Sleep Disturbance LA1(60sec)
A – Outside Portal Works	Excavator with hammer, rock drill	n/a	62	59/49.5/37.5	47.5
B – Widening Works at Tunnel Portal	Roadheader, rock drill, shotcrete rig	Acoustic Shed only	51		
C – Widening Works Entirely Within Tunnel	Roadheader, rock drill, shotcrete rig	Acoustic Shed and Acoustic Curtain	39		

Note 1: The predicted noise levels include a -5 dBA correction for the effect of the existing noise walls.

It is noted that the above noise levels have been predicted at the nearest potentially affected receivers to the construction works, and therefore represent the worst-case levels. Properties which are situated further away would be subject to lower levels of noise as a result of the increased separation distance.

The above assessment indicates that significant exceedances of the Evening and Night-time Noise Management Levels are predicted for the construction works which are required outside of the tunnel portals. It is not possible to apply any noise mitigation measures to these activities, although other impact minimisation strategies would be considered prior to commencement of these works.

Exceedances are also predicted when the widening works are at the tunnel portals, when the acoustic shed has been constructed but the acoustic curtain has not.

Grid Noise Map Predictions

As significant exceedances of the Noise Management Levels are likely to be apparent during some of the construction works associated with the Norfolk Tunnel, there is potential to restrict the activities to the following periods to ensure the impacts from the works are minimised:

- Activity A – Outside Portal Works: Daytime only
- Activity B – Widening Works at Tunnel Portal: Daytime and Evening only
- Activity C – Widening Works Entirely Within Tunnel: No restrictions.

To illustrate the potential exceedances with relation to the above activities, the following grid noise maps have been generated. All three maps, calculated at 1.5 m above the local ground level, indicate where potential exceedances of the appropriate Noise Management Levels (coloured in red) may occur for that phase of works.

Figure 11 Activity A – Outside Westbound Portal (Daytime 59 dBA NML) – No Mitigation

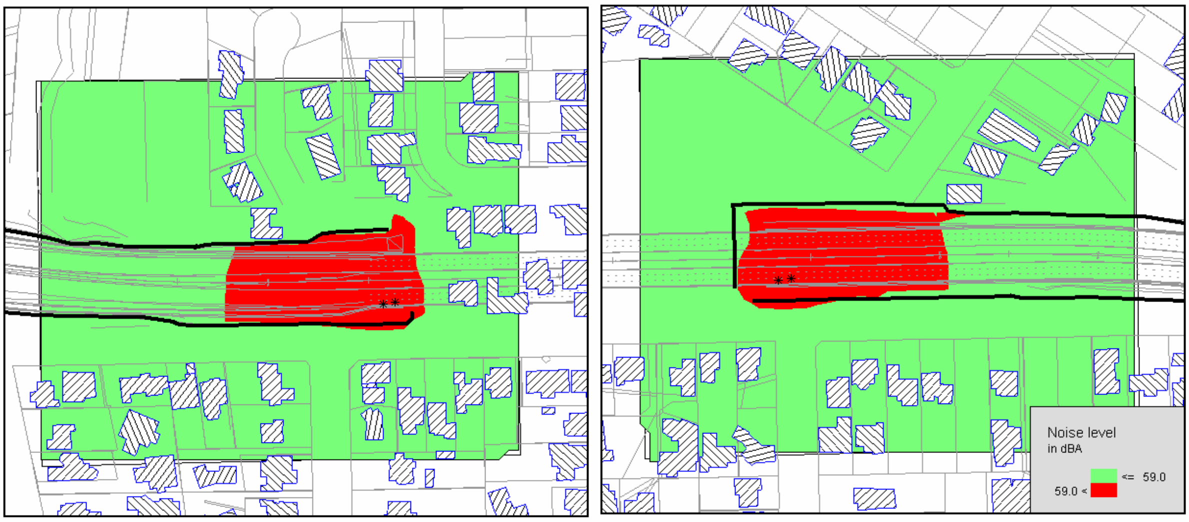


Figure 12 Activity B – Widening Westbound Portals – Shed Only (Evening 49.5 dBA NML)

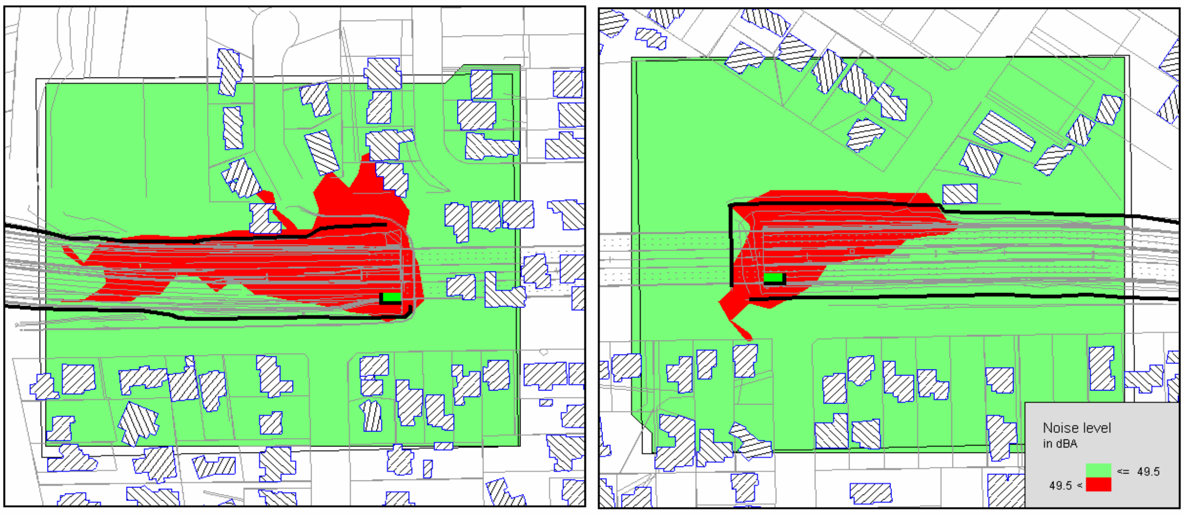
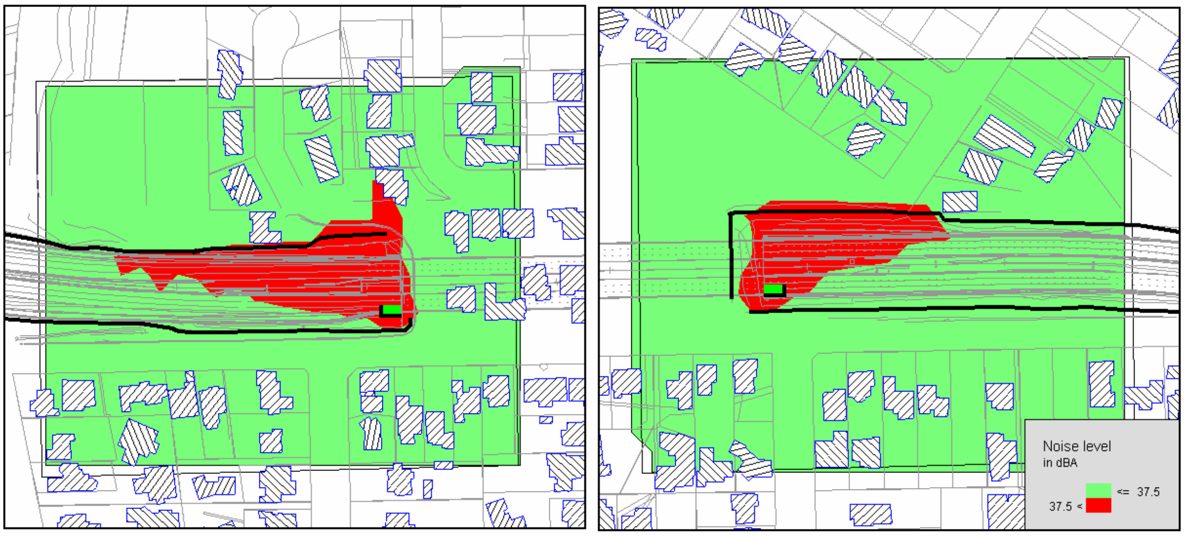


Figure 13 Activity C – Widening within Westbound Tunnel (Night-time 37.5 dBA NML) – Shed and Curtain in Place



Noise Mitigation

As discussed above, noise mitigation is proposed to be provided by the construction of a purpose built acoustic shed and an acoustic curtain at either end of the tunnel being widened. Both of these items are proposed to be constructed from 25 mm thick timber.

To ensure the noise attenuation of the acoustic shed and curtain is maximised it is vital that they are constructed and appropriately sealed, with air gaps being minimised. As doors would be required in both structures to allow access, it is also important that these form a good seal with the rest of the facade. Suitable operational procedures would also be required to be implemented to minimise the duration that the doors are required to be open, or manage the timing of when the doors are opened when tunnel excavation is in progress.

As a result of the potential exceedances it will also be vital that the local community is kept well informed of the constructions works. Where the higher exceedances are apparent, suitable consultations should take place with the affected land owners to determine the appropriate feasible and reasonable management strategies, together with monitoring to confirm the predicted levels.

7.7.4 Ground-borne Noise - Roadheaders

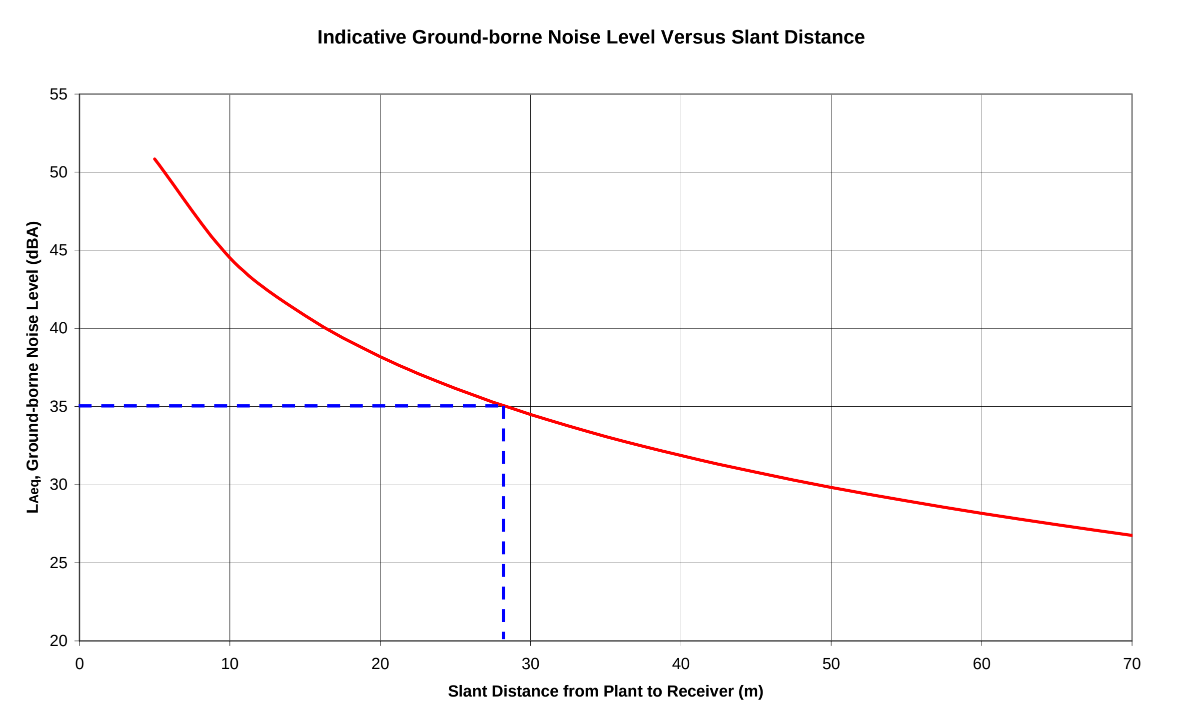
Ground-borne noise in buildings is caused by the transmission of ground-borne vibration rather than the direct transmission of noise through air. Vibration may be generated by construction equipment and can be transmitted through the ground into the adjacent building structures. After entering a building, this vibration may cause the walls and floors to faintly vibrate and hence to radiate noise. This type of ground-borne vibration and noise can occur due to the excavation of rock using roadheaders.

Attenuation with distance occurs due to the geometric spreading of the wave front and due to other losses within the ground material known as “damping”. In addition, losses occur with the transfer of vibration from floor-to-floor within buildings (typically 2 dBA per floor).

Reference to **Figure 10** shows that the impacts from ground-borne noise would be expected to be greatest when the roadheader is working at either end of the tunnel. The residential properties in these locations (ie directly above) would be situated approximately 15 m to 20 m above the works.

Figure 14 presents indicative ground-borne noise levels for roadheaders. As the figure demonstrates, ground-borne noise levels reduce as the distance between plant and the receivers increase.

Figure 14 Indicative Ground-borne Noise Levels from Roadheaders (Sydney Measured)



Reference: Tunnelling Noise and Vibration Management - Australian Acoustical Society, Technical Meeting, Dec 2003

The ground-borne noise impacts would be greatest when the roadheader is situated immediately below the property in question. As the roadheader moves along the tunnel, the impact from ground-borne noise would reduce. It is anticipated that the roadheader would be underneath a particular receiver location for around 10 to 12 days.

Reference to **Figure 14** concludes that at the nearest affected receivers, with a slant distance of around 15 m, the $L_{Aeq(15minute)}$ 35 dBA night-time noise goal would potentially be exceeded by around 5 dBA.

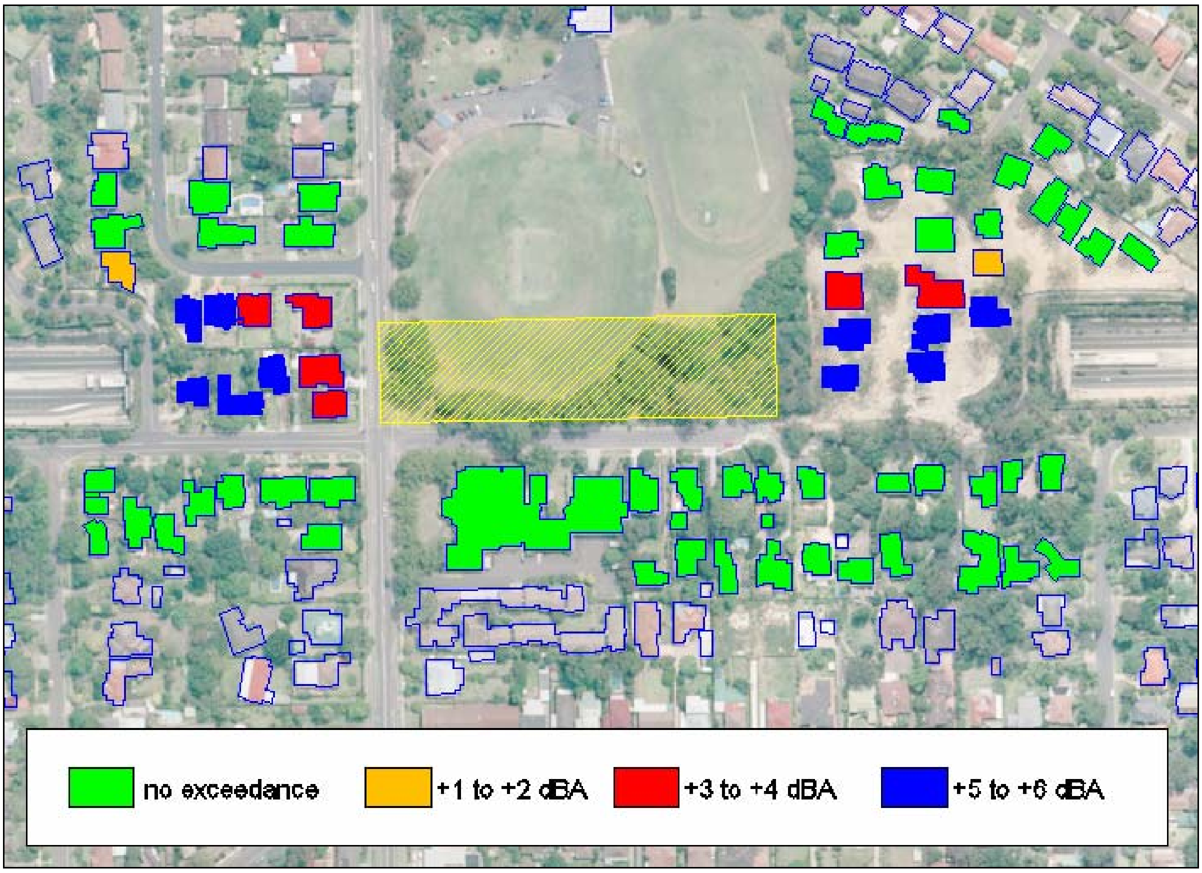
The graph also illustrates that properties which are less than 29 m away from the widening works would potentially experience night-time exceedances, up to a maximum of around 5 dBA, for a period of approximately two weeks (10-12 working nights).

It is however noted that the sensitive receiver ground-borne noise from the operation of the roadheader would be neither impulsive nor intermittent, and as such, the potential for sleep disturbance at sensitive receivers in these locations during the night-time period is considered to be low.

Notwithstanding the above, **Figure 15** presents the predicted extent of the exceedances of the $L_{Aeq(15minute)}$ 35 dBA night-time ground-borne noise goal for properties which are located above the tunnel widening works.

It should be noted that the figure illustrates the predicted worse-case ground-borne noise level when the roadheader is in the tunnel tube which is immediately below, or adjacent to, the residence in question. As the tunnel widening works proceed, or move to the other tunnel tube, the distance between the roadheader and the residence would increase and the ground-borne noise levels would noticeably reduce.

Figure 15 Potential Ground-borne Noise Impacts when Roadheader Immediately Below



Note 1: The yellow hatched area indicates where tunnel widening works could potentially occur with negligible exceedances of the night-time sensitive receiver ground-borne noise goal.

Although potential exceedances of the night-time goals are predicted, the vibration levels associated with the use of roadheaders at the Norfolk Tunnel would be expected to be below the levels required to cause structural damage to the properties situated above.

The options for mitigating ground-borne noise, such as noise resulting from the operation of a road header, are limited as physical attenuation devices are not available and procedural management measures are not feasible. Where exceedances are indicated, suitable consultation with the affected residents would be required regarding the nature of the works, the need for continuous (24 hour) tunnelling and the likely extent and duration of the predicted exceedances of NMLs.

Options such as the potential relocation of affected residents for the duration of the exceedance should also be considered.

8 CONSTRUCTION NOISE AND VIBRATION MITIGATION STRATEGIES

8.1 General Comments

The construction scenario predictions have been examined to evaluate (i) potential means for noise and/or vibration mitigation, and (ii) alternative methods to carry out specific construction activities.

In many instances the options available for reducing noise emissions are limited, given the limited range of plant and equipment able to carry out the tasks required. Furthermore, the mobility of much of the equipment limits the use of enclosures which are often very effective in reducing noise emissions from fixed noise sources.

8.2 Noise Control

Certain "baseline" mitigation strategies should be adopted along the route at any section where the noise goals are exceeded.

The construction contractor will, where reasonable and feasible, apply best practice noise mitigation measures including:

- Erecting temporary hoardings or other noise mitigation measures at Site Compounds which are in proximity to residential receivers, where practicable as determined by detailed assessment of each location.
- Maximising the offset distance between noisy plant items and nearby noise sensitive receivers.
- The coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers should be avoided, where practicable.
- Where possible, equipment with directional noise emissions should be orientated away from sensitive receivers.
- Where practical, the layout of plant and equipment at any site compounds should be developed so as to minimise noise exposure.
- Loading and unloading should be carried out away from sensitive receivers, where practicable.
- The selection of site access points should take into account the proximity of noise sensitive receivers.
- Maintenance work on all construction plant with the potential to generate noise impacts should be carried out away from noise sensitive receivers and confined to standard daytime construction hours, where possible.
- Minimising consecutive works in the same locality, where practicable.

In order to minimise noise impacts during the works, the construction contractor will make use of reasonable and feasible measures to mitigate noise effects.

The contractor will also take reasonable steps to control noise from all plant and equipment. Examples of appropriate noise control include efficient silencers and low noise mufflers.

Operators of construction equipment should be made aware of potential noise issues and of techniques to minimise noise emission through a continuous process of operator education. For example:

- Large waste material should be *placed* into dump trucks as far as practical (rather than dropped in from a height).

- Where vehicle and equipment queuing is required close to sensitive receivers, engines should be shut down if queuing for extended periods, where practicable.
- Warming up of vehicles should be carried out as far away as possible from noise sensitive receivers.
- Reversing of equipment should be minimised so as to prevent nuisance caused by reversing alarms.
- Horn signals should be kept to as low a volume as possible, given appropriate OH&S considerations.

8.2.1 Discussion of Mitigation Strategies

Construction Noise and Vibration Management Plan and CNISs

To ensure the adequacy of the noise and vibration mitigation measures for the actual design and construction method, detailed Construction Noise and Vibration Impact Statements (CNISs) will be prepared for major noise-intensive construction activities, prior to and for inclusion into the Construction Noise and Vibration Management Plan (CNVMP) for that stage/activity. Both the CNVMP and individual supporting CNISs will be revised as required.

Source Noise Control Strategies

Engines and exhausts, which are often the dominant noise sources on mobile plant, should be fitted with residential class mufflers. Wherever feasible, silenced air compressors, fitted with noise labels indicating a maximum (L_{Amax}) sound pressure level of not more than 75 dBA at 7 m should be used on site.

Equipment Selection and Maintenance

The contractor carrying out the construction works should select equipment taking into account noise and vibration emissions, eg smaller equipment options or rubber-tracked equipment where equipment is fit-for-purpose and economically feasible, equipment to be provided with residential grade mufflers, etc.

All equipment should be maintained and operated in an efficient manner, as per manufacturer's specifications, to reduce the potential for adverse noise impacts.

Concurrent Activities

There is some, albeit limited, scope for a proactive scheduling of equipment tasks to avoid "clustering" of equipment close to sensitive receivers. This applies to the equipment within the individual construction crews.

Reversing Alarms

The potential noise impact of reversing alarms should be recognised and addressed via a combination of proactive driver/operator training and operational procedures. The following mitigation strategies will be undertaken, taking into account that WorkCover OH&S requirements would need to be satisfied with respect to safety surrounding construction vehicles.

- The primary means for minimising reversing alarm noise should be through a dedicated effort on the part of all construction equipment drivers to minimise, wherever feasible, the amount of reversing of their vehicles.
- Wherever feasible, turning circles should be created at the end points of vehicle work legs, which would allow trucks, compactors, water carts, etc, to turn and avoid the need for reversing.

- Emphasis should be placed during driver training and site induction sessions on the potential adverse impact of reversing alarms and the need to minimise their use.

Noise Monitoring Plan during Critical Work Phases

A targeted noise (and vibration if necessary) monitoring plan at nearest residential and sensitive receivers based, at least initially, on the predictions provided in this report, will assist in ensuring that planned mitigation controls are being implemented during critical stages of work.

Equipment Noise Compliance Checks

Regular checks of equipment noise levels should be made to ensure that noise levels do not increase as a result of poor maintenance practice or say the replacement of individual items of equipment with alternatives which have higher noise emissions.

Noise (and Vibration) Monitoring

A well-planned, noise monitoring programme will assist in confirming and controlling the site-specific potential for disturbance at particularly sensitive localities as the works progress. Mitigation measures, including changes in work sequences or selection of smaller items of equipment, can then be put in place before significant disturbance occurs. The programme could include:

- Initial (ie pre-construction background) noise monitoring.
- Ongoing monitoring of emissions at residences and other sensitive receivers during critical phases of the work.
- Ongoing compliance checks of all critical plant and equipment.
- Investigation of complaints and follow-up monitoring to assess the effectiveness of adopted control strategies.

Temporary Construction Noise Walls

Wherever practicable, the proposed new noise walls will be constructed prior to the existing walls being taken down. However, in a number of areas the existing noise walls (or part of the existing wall) will have to be demolished before the new wall can be erected due to access restrictions and the limited availability of space required for the proposed work at that location.

In such situations a detailed assessment will be undertaken to determine the reasonable and feasible noise mitigation measures. Options such as the use of temporary noise walls would be considered and implemented where appropriate. Where required, temporary noise walls would be erected as soon as practicable after the existing walls are removed to ensure minimal impact on receivers in the area.

Moveable (Temporary) Noise Barriers

Many activities associated with the Project will involve large-sized plant moving along the Motorway, eg carrying out milling and asphalt laying. Temporary barriers for such activities are not generally practical.

The most noise-intensive activities associated with the project, namely concrete sawing, rockbreaking and the use of jackhammers, will be highly localised. Based on the outcomes of detailed assessments of each work location and scenario, the use of temporary and moveable noise barriers, eg loaded vinyl “curtains” around such sites, or at least between such sites and the nearest receivers, would be considered and made use of where reasonable and feasible. Such barriers could produce noticeable decreases in the associated noise emissions, even if these are restricted to limited hours (say 9:00 pm to 11:00 pm).

Limiting of Hours

The assessment of the potential impacts from construction noise for the M2 Upgrade Project found that the higher exceedances of the Noise Management Levels were generally associated with use of:

- Concrete Saws (and reinforcement cutting)
- Rockbreakers
- Jackhammers

There is therefore scope to reduce the potential noise impacts during the more sensitive periods by restricting such activities, where sensitive receivers are likely to be adversely affected, to daytime and evening periods, where feasible and reasonable.

Noise Management Versus Noise Control

The mitigation of noise impacts can often involve noise management as distinct from noise control. For example, the scheduling of noise-intensive activities could be an effective noise management strategy in the present instance.

Specifically, time restrictions should be placed on the most noise-intensive activities, especially concrete sawing, rockbreaking and the use of jackhammers in the vicinity of sensitive receivers, as discussed above. For example, where there is a definite requirement for such activities to be completed out of the normal construction hours, they could be restricted to 9:00 pm to 11:00 pm where reasonable and feasible.

Similarly, with respect to the activities located at any one section of the Motorway in the vicinity of sensitive receivers, advanced notice of high noise activities should be provided and respite periods employed, eg no two consecutive evenings in the same area where concrete saws are being used, where reasonably and feasibly practicable

An important component therefore of the noise management of the proposed works is comprehensive community consultation which should continue through all major stages of the construction programme.

The community would be kept informed as to the nature, timing and duration of impending works, the nearest sensitive receivers likely to be affected and the monitoring programme associated with the impending works.

Community Liaison

A primary aim of the project would be to ensure that the local community is kept informed of the progress of the construction work in a proactive and progressive manner. A combination of internet-based information, community meetings, local newsletters, leaflets, newspaper advertisements and community notice boards would be used as appropriate.

As part of the Community Liaison process a contact person would be nominated within the Construction Noise and Vibration Management Plan to directly address any noise and/or vibration complaints that the community may have during the construction phase of the project.

The community liaison process would be progressively "fine-tuned" to meet the specific requirements of the particular works under consideration. In this manner, equipment selections and work activities can be continuously coordinated and modified where necessary to minimise disturbance to neighbouring communities, and to ensure prompt response to complaints and other issues of concern, should they arise.

8.3 Vibration Control

The following "baseline" vibration mitigation measures will be implemented by the construction contractor where reasonably and feasibly practicable:

- Relocate any vibration generating plant and equipment to areas within the site in order to lower the vibration impacts.
- Investigate the feasibility of rescheduling the hours of operation of major vibration generating plant and equipment.
- Use lower vibration generating items of excavation plant and equipment eg smaller capacity rockbreaker hammers.
- Minimise consecutive works in the same locality (if applicable).
- Schedule a minimum respite period of at least 0.5 hour before activities commence which are to be undertaken for a continuous 4 hour period.
- Use only dampened rockbreakers and/or "city" rockbreakers to minimise the impacts associated with rockbreaking works.
- The use of a roller class "II Light" when operating as close as 5 m from the closest buildings.

8.4 Construction Monitoring Requirements

Noise monitoring would be undertaken as required for assessment against the adopted construction noise goals where, subsequent to project approval, detailed construction noise impact assessments indicate significant potential exceedance at the nearest impacted noise sensitive receivers.

It is also recommended that vibration monitoring be carried out for assessment against the transient vibration guidelines (BS 7385 and DIN 4150) as a result of potential impacts on structures when working within the safe working distances for cosmetic damage as a result of vibration intensive construction activities, and where the vibration levels are greater than the maximum recommended values.

9 OPERATIONAL NOISE ASSESSMENT OF THE M2 UPGRADE PROJECT

9.1 General Approaches to Controlling Road Traffic Noise

A range of noise mitigation options are available to reduce the effect of road traffic noise on the surrounding community. The general methods available are listed below.

Low Noise Road Surfaces: Such as Open Graded Asphaltic Concrete (OGAC) or Stone Mastic Asphalt (SMA). Such surfaces can produce noise level decreases of up to about 4 dBA when compared to standard road surface materials.

A full re-sheeting of the existing M2 road surface within the boundaries of the proposed Upgrade works will take place concurrently with the upgrade proposal.

Road Maintenance: Maintaining the running surface condition of a road can be important in lessening the incidence of sleep disturbance, eg where pot holes are allowed to remain for extended periods of time without repair.

Traffic Management: Such as limiting vehicle speed, speed humps, signage, etc. These methods can generate noise level improvements of up to 5 dBA, depending upon the carriageway of interest, however they are more suited to local roads than motorways. Compression brakes can be an important factor in the noise environment of roads used by heavy vehicles. While there are currently no statutory powers to limit the use of compression brakes, some success has been achieved on certain major arterial routes via the use of signage to promote awareness of their use in residential areas. In cases where inappropriate driving behaviour is identified as a significant source of annoyance (eg excessive use of compression brakes), vehicle driver education strategies should be considered.

Traffic Re-Routing: This option is particularly useful when applied to heavy vehicles using local and secondary roads in predominantly residential areas.

Noise Barriers: Noise walls gain their effectiveness by extending the path length of noise over and around the barrier between the source and the receiver. Barriers are usually most effective where both the source and receiver are at a similar elevation.

Increasing the height of already high noise walls provides diminishing additional attenuation. Noise walls are also ineffective when receivers are located at significantly elevated positions, as would be the case for upper levels of a residential apartment building overlooking a noise source.

The potential for using noise walls also depends upon other factors, including access to property, aesthetic impacts, daylight access, overshadowing, drainage, driver line-of-sight around sections of curved carriageway, maintenance access and safety (particularly for drivers and pedestrians).

Architectural Treatment of Buildings: This method involves the upgrading of property glazing for windows and sliding doors, and the upgrading of access doors if they are found to be weak points for noise access into a particular building. Double glazing, for example, can reduce internal noise levels by up to 10 dBA or more compared to a standard residential grade window. Property treatments may also include the provision of mechanical ventilation if the closure of windows and other facade openings is used as a means of managing internal noise levels in selected spaces.

9.2 Factors Affecting the Choice of M2 Upgrade Noise Mitigation Options

The specific measures adopted to seek to achieve the target noise goals would vary for a particular road in terms of the practicality and feasibility of their implementation and the sensitivity of the land use.

The noise strategies chosen would typically be found to involve a mix of the options cited in **Section 9.1**. Details of what noise mitigation measures would be feasible and reasonable to apply are typically only possible to identify at the detailed design stage of a road project. This is because site specific details are important in selecting the final mix of noise mitigation measures and the detailed design phase may require small changes to project specifics (such as the level of the road way). The process of obtaining feedback from the community may also identify a preference for a certain type of noise mitigation. During the design phase of the project the M2 Upgrade Project Team would be required to assess all available noise options.

It has already been noted that, in parallel with the M2 Upgrade Project, the motorway will be re-sheeted with low-noise Open Grade Asphalt Concrete. The primary noise mitigation options that are feasibly available for use (separate to the re-sheeting) are noise walls and/or architectural treatment of individual buildings.

The final mix of selected strategies will be based on a number of competing factors. For example, an analysis based on cost-effectiveness might yield a mix of a certain height noise wall combined with a certain degree of window upgrading of selected properties. However, the local affected community might prefer (on aesthetic grounds) a different option mix of noise barriers and property treatment. The benefits of community preferred options would then need to be considered in light of additional factors such as future noise levels in the affected area and changes in land use in the local area.

Shading and potential loss of direct solar access may be factors affecting the implementation of noise barriers located in close proximity to residential areas.

In general, noise walls and other noise source related treatments (eg quieter road pavements, traffic control, etc) are preferred to architectural treatments, where feasible and reasonable, as a result of both external and internal noise levels being reduced. However, in all instances, the opinions of the local affected community would be sought in determining the final mix of noise amelioration treatments.

Factors which impact on the potential for employing upgraded glazing include maintaining provision for natural ventilation when the glazing is closed and glazing disturbance for special buildings, eg heritage buildings. The performance of the remainder of the building envelope must also be investigated for its suitability to house upgraded glazing units.

Finally, it is noted that many sections of the M2 Motorway are protected by existing, and in some cases quite high, noise barriers. Where the proposed upgrade works will result in demolition of these existing barriers and construction of new barriers, the design of such barriers can proceed using the standard ENMM-based cost-effectiveness guidelines.

Where existing barriers are to remain, analysis of the possibility of extending their height to accommodate increased noise levels associated with the upgrade works would have additional feasibility and reasonableness considerations associated with refurbishment, foundation upgrading, etc.

9.3 Airborne Road Traffic Noise Assessment Methodology

Operational Road Traffic Scenarios

In **Section 5.2**, it was noted that the assessment of the impact of airborne noise during the Operational Phase of the M2 Upgrade Project is made using the guidance contained with the DECCW's ECRTN.

This document requires noise levels to be assessed based on traffic volumes which are projected to 10 years after the opening of the project. Accordingly, as the proposed project is scheduled to open in 2011, the future assessment year applicable to the project is taken to be 2021.

The impact assessment of the M2 Motorway Upgrade Project has therefore been performed by considering the following two assessment scenarios:

- Future *Existing* (2011) - ie the future road traffic noise that would have occurred at the proposed year of opening of the upgraded roadway assuming a "do-nothing" case.
- Future *Design* (2021) - which incorporates the alterations as a result of the proposed project and 10-year post-opening traffic levels.

A third "base" scenario (2008) has also been modelled to allow for validation of the noise model against the ambient noise surveys carried out in 2008.

Governing Criterion

The ECRTN stipulates 15-hour (daytime) and 9-hour (night-time) L_{Aeq} noise criteria of 60 dBA and 55 dBA respectively.

To determine the more stringent of the two criteria, a comparative exercise was performed using all baseline monitoring data to assess the difference between the daytime energy averaged noise level ($L_{Aeq,15hr}$) and the night-time energy averaged noise level ($L_{Aeq,9hr}$). This exercise showed that:

Average daytime $L_{Aeq(15hour)}$ noise level = Average night-time $L_{Aeq(9hour)}$ noise level + 4.8 dBA

The night-time criterion has therefore been taken as being the governing criterion as it set at 5 dBA less than the daytime criterion.

Changes in road traffic noise levels associated with the project have therefore been calculated by considering the traffic conditions for the following scenarios:

- 2011 Future *Existing* – Night-Time $L_{Aeq(9hour)}$ – refer results shown in **Appendix D**
- 2021 Future *Design* – Night-Time $L_{Aeq(9hour)}$ – refer results shown in **Appendix E**

In the above scenarios, all significant road traffic noise sources have been taken into account, ie M2 road traffic PLUS major arterial/secondary roads.

For each of the above scenarios the facade maps predict noise levels at every facade of each floor of all buildings along the length of the motorway.

All facade noise levels are evaluated at a distance of 1.0 m from the centre of the facade in question, at a height of 1.5 m for ground floor storeys and 4.3 m (1.5 m plus 2.8 m for a typical floor to floor height) for first floor storeys.

Noise levels have only been evaluated at ground and first floor storeys as is the general convention for assessments of the impacts from road traffic noise.

9.4 Calculation Procedure and Modelling Inputs

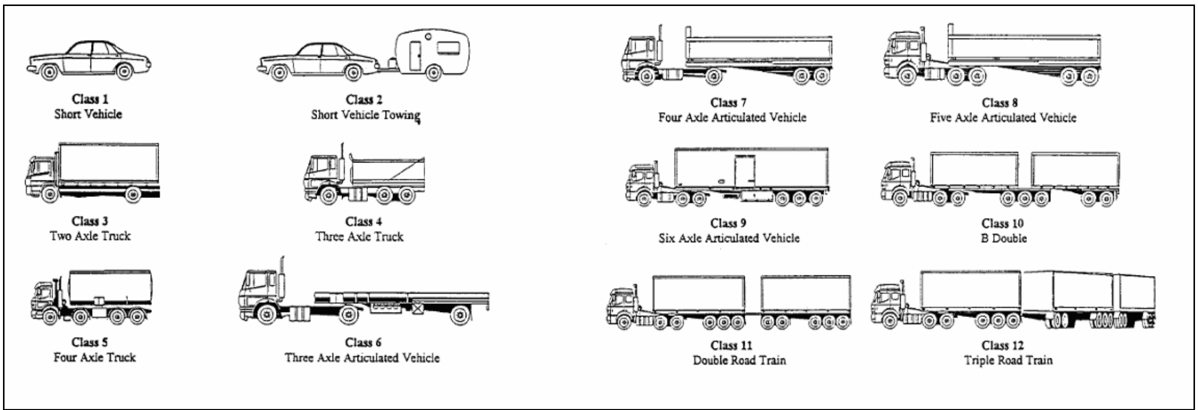
The noise modelling has been carried out using the SoundPLAN V6.5 suite of acoustics software using the Calculation of Road Traffic Noise (CORTN) prediction model for all calculations.

Road traffic noise levels were predicted using RTA and DECCW recommended procedures, as detailed in the CORTN methodology. The input data required for each section of road for these calculations includes the total traffic count, the percentage of heavy vehicles within total traffic flow and vehicle speed.

Vehicle Classification

Traffic has been split between cars and trucks based on Austroads vehicle classification system, as shown in **Figure 16**. For the purposes of the noise model, cars are considered Class 1 & 2 vehicles, and trucks are considered to be Class 3 and above.

Figure 16 Austroads Vehicle Classification System



2008 Base Year Traffic Figures

For the 2008 Base Year scenario, the traffic volumes and speeds along the various sections of the motorway were derived from traffic counts conducted in conjunction with the baseline ambient monitoring described in **Section 6**. These figures, along with representative vehicle speeds measured at the same time as the traffic counts, are presented in **Table 32**.

Table 32 2008 Base Traffic Volumes for M2 Motorway

Location	Direction	Speed (kph)	LA10(18hour) Traffic Volumes	
			Cars	Heavy Vehicles
M7 Carriageway West of M2	Eastbound	94	14597	2766
	Westbound	98	15327	3049
Old Windsor Road	Eastbound	76	7482	494
	Westbound	82	9655	712
Windsor Road Access Ramps	Eastbound	72	7279	319
	Westbound	83	7217	284
Carriageway East of Windsor Road	Eastbound	87	29227	3571
	Westbound	100	32262	4305
Pennant Hills Road On Ramps	Eastbound	79	7285	302
	Westbound	91	10640	2199
Pennant Hills Road Off Ramps	Eastbound	71	9919	2088
	Westbound	82	7350	444
Beecroft Road Access Ramps	Eastbound	76	3389	132
	Westbound	67	2420	113
Carriageway West of Toll Gates	Eastbound	84	28180	2026
	Westbound	80	31805	2971
Christie Road Access Ramps	Eastbound	63	2732	114
	Westbound	67	3078	189
Lane Cove Road Access Ramps	Eastbound	83	7101	766
	Westbound	76	1504	152
Lane Cove Loop Road	Westbound	58	5282	795
Delhi Road Access Ramps	Eastbound	84	6710	450
	Westbound	77	7607	642

Traffic volumes along the major intersections of the motorway are presented in **Table 33**. These have been sourced from the RTA's *Traffic Volume Data* from 1999 to 2007.

Table 33 RTA Traffic Volumes for Local Roads

Local Road	Intersection	LA10(18hour) Traffic Volumes	
		Cars	Heavy Vehicles
Lane Cove Road	Talavera Road	57344	6372
Beecroft Road	Copeland Road	32790	1726
Beecroft Road	Carlingford Road	45376	2388
Pennant Hills Road	Copeland Road	65519	11562
Pennant Hills Road	North Rocks Road	50980	8996
Windsor Road	Cook Street	54119	2848
Windsor Road	Churchill Drive	43150	2271

An assumed speed of 50 kph has been utilised for all surrounding local roads that are included in the noise model.

2011 and 2021 Future Traffic Figures

All traffic data, in 18 hour format, used within the modelling of the future years was supplied to Heggies by Hills M2 and is based on the traffic figures in the Transport and Traffic Impact Assessment undertaken as part of the M2 Upgrade Project Environmental Assessment. This included both M2 carriageway volumes along with data for the major surrounding arterial/secondary roads, and is presented in **Table 34**, **Table 35** and **Table 36**.

Table 34 Future Traffic Figures (M2 Carriageway)

Location	Direction	LA10(18hour) Traffic Volumes		
		2011 Future *Existing*	2021 Future *Design*	%HGV
Old Windsor - Windsor Road	Eastbound	29750	37480	17%
Windsor - Pennant Hills Road		38780	48360	14%
Pennant Hills - Beecroft Road		34140	44290	8%
Beecroft - Christie Road		38250	49190	8%
Christie - Lane Cove Road		34260	45300	8%
Lane Cove - Delhi Road		25250	35130	7%
Delhi - Lane Cove Road	Westbound	26550	34390	7%
Lane Cove - Herring Road		35360	46060	9%
Herring - Beecroft Road		39940	49840	9%
Beecroft - Pennant Hills Road		36940	46690	9%
Pennant Hills - Windsor Road		42390	50430	13%
Windsor - Old Windsor Road		32140	41170	16%

Table 35 Future Traffic Figures (M2 Access Ramps)

Location	Direction	LA10(18hour) Traffic Volumes		
		2011 Future *Existing*	2021 Future *Design*	%HGV
Western end of M2	Eastbound	19390	23220	21%
Western end of M2	Westbound	20700	23320	20%
M2 Abbott Road Exit and Entrance	Eastbound	10360	14260	8%
M2 Abbott Road Exit and Entrance	Westbound	12680	18070	8%
Windsor Road - Off-Ramp	Eastbound	n/a	3910	8%
Windsor Road - On-Ramp	Westbound	n/a	3910	8%
Windsor Road - On-Ramp	Eastbound	9030	14790	5%
Windsor Road - Off-Ramp	Westbound	10250	13170	4%
Pennant Hills Road - Off Ramp	Eastbound	13280	15590	23%
Pennant Hills Road - On Ramp	Westbound	14140	15040	22%
Pennant Hills Road - On Ramp	Eastbound	8640	11520	5%
Pennant Hills Road - Off Ramp	Westbound	8690	11300	6%
Beecroft Road - On Ramp	Eastbound	4110	4900	4%
Beecroft Road - Off Ramp	Westbound	3000	3150	5%
Christie Road Off Ramp	Eastbound	3990	6520	4%
Herring Road On Ramp	Westbound	4580	7390	6%
Herring Road On Ramp	Eastbound	n/a	2630	4%

Herring Road Off Ramp	Westbound	n/a	3610	3%
Lane Cove Road - Off Ramp	Eastbound	9010	10170	12%
Lane Cove Road - On Ramp	Westbound	1980	4250	10%
Lane Cove Road - Loop On Ramp	Westbound	6830	7420	15%

Table 36 Future Traffic Figures (Intersecting Roads)

Road	LA10(18hour) Traffic Volumes		
	2011 Future *Existing*	**2021** Future *Design*	**%HGV**
Windsor Road	52578	59793	5%
Pennant Hills Road	72433	73864	18%
Beecroft Road	50253	51524	5%
Herring Road	20739	29391	5%
Talavera Road (East of Herring Road)	12860	21902	5%
Talavera Road (West of Herring Road)	9936	15874	5%
Talavera Road (West of Christie Road)	7156	9598	5%
Lane Cove Road	85422	93534	11%

Multiple Height Source Methodology

All of the noise models used in the assessment of the M2 Motorway Upgrade Project make use of a Three Height Source noise modelling methodology. This method employs three separate noise sources, at varying heights above ground, to represent the main contributors of noise from vehicles.

The three sources and their associated heights are detailed in **Table 37**.

Table 37 Three Height Source CORTN Procedure

Source	Height Above Road Surface (m)
Heavy Vehicle/Car Tyre	0.0
Heavy Vehicle Engine	1.0
Heavy Vehicle Exhaust	3.0

Ground Topography

The topography of the area along the M2 Motorway was imported in 3-dimensional format into the noise model and was sourced as follows:

- Topography for the land surrounding the project area was provided by the project team, sourced from Sinclair Knight Merz Pty Ltd, in 2 m contour steps;
- Road design levels and road corridor data for the M2 Motorway was derived from surveyed data, where available.

Facade Reflection

A facade correction of +2.5 dBA has been incorporated into the predicted noise levels throughout this report, where appropriate, in accordance with DECCW/RTA procedures.

L_{A10} to L_{Aeq} Conversions

A conversion of -6.4 dBA has been used to convert the (CORTN) $L_{A10(18hour)}$ level to the $L_{Aeq(9hour)}$ governing night-time criterion required.

This figure was derived from the average difference (before rounding) between the L_{A10} and L_{Aeq} indices of measured noise data, as presented in **Section 6**.

Existing Noise Walls used in Model

The surveyed data described above contained top-of-noise-wall height information for the majority of the M2 Motorway. This data was extracted from the survey information and directly imported in to the noise model.

In areas where no survey data was available, aerial photography, supplemented with a walk-by visual site inspection, was used to determine the appropriateness of any barriers to be included in the model.

This data was also correlated against the as-built noise wall chainages and heights provided to Heggies by the M2 Motorway project team.

M2 Upgrade Proposed Design

All design information (altered road corridor, carriageway levels, new access ramps, etc) in areas where upgrade works are proposed was supplied to Heggies in 3 dimensional format by the M2 Motorway Project Team.

Road Way Surface

The baseline CORTN noise prediction model employed within SoundPLAN includes no correction factor for the road way surface.

M2 Road Surface Re-Sheeting

The proposed upgrade of the M2 Motorway will take place concurrently with a full re-sheeting of the existing road surface.

“Low noise” pavements are able to provide noise reductions of up to 4.5 dBA relative to the expected behaviour for dense graded asphalt (DGA). It is understood that the future road surface for the M2 will be open graded asphalt concrete (OGA).

Guidance as to the likely noise reduction that can be expected from the various surface types is provided in the ENMM. This is summarised in **Table 38**.

Table 38 ENMM Table 3.1 Surface Corrections Extract

Table 3.1

Road surface noise corrections, relative to dense graded asphaltic concrete

Surface type (regularly trafficked)	Noise level variation, dB(A)		
	Traffic noise	Individual vehicles pass-by noise	
		Cars	Trucks
14 mm chip seal	+ 4.0	+ 4.0	+ 4.0
Portland cement concrete: tyned and dragged	0 to + 3.0	+ 1.0 to + 3.5	– 1.0 to + 1.0
Cold overlay	+ 2.0	+ 2.0	+ 2.0
Portland cement concrete: exposed aggregate	– 0.5 to – 3.0	– 0.1	– 6.7
Stone mastic asphalt	– 2.0 to – 3.5	– 2.2	– 4.3
Open graded asphaltic concrete	0 to – 4.5	– 0.2 to – 4.2	– 4.9

The road surface correction applied depends on the road surface's porosity, macrotexture, depth and wavelength, the percentage of heavy vehicles and vehicle speeds.

Open graded asphalt concrete is noted as providing a correction of between 0 dBA and -4.5 dBA.

The re-sheeting of the M2 Motorway road surface with OGA is expected to provide a significant noise benefit over the existing cracked and substantially degraded surface.

Under normal circumstances (and consistent with the guidance provided in the ENMM) a correction factor of -2.5 dBA would typically be applied to OGA low-noise pavement types. However, as there is potential for degradation of the M2 Motorway road surface over time, and to ensure a conservative assessment is achieved, the standard -2.5 dBA OGA correction factor has been **entirely omitted** from all calculations.

This means that the noise benefit of the M2 re-sheeting currently being undertaken on the existing carriageways and on/off ramps, together with re-sheeting of the remaining section of the M2 Motorway which would form part of the proposed Upgrade works has **NOT** been taken into account in either the Future *Existing* 2011 or Future *Design* 2021 noise modelling scenarios.

9.5 Noise Modelling Validation

The validation of the noise model was performed by comparing the 2008 base $L_{Aeq(15hour)}$ and $L_{Aeq(9hour)}$ noise level predictions with the results from the ambient noise monitoring surveys presented in **Section 6**.

Small variations between measured and predicted values are to be expected within any noise model. This is due to the dependence of measured noise levels on road surface characteristics near the specific measurement sites, the incidence of vehicles changing gears near the site, the use of brakes in downhill sections, the bias in use of multiple lanes during different periods of the day, the effects of local screening (eg fences, sheds), etc.

Comparison of measured and predicted levels has been performed by undertaking single point receiver calculations at noise model locations coinciding with the ambient monitoring locations.

The CORTN algorithms are only valid for predicting noise levels up to a distance of 300 m. As a result of this, the monitoring location at 10 Virginia Place has been discounted from the validation process as it is situated at a distance of approximately 350 m from the M2 carriageway.

The comparison of the daytime noise levels is shown in **Table 39** and **Figure 17**. It is noted that monitoring locations S1-04, S2-01, S3-01, S3-06 and S3-07 have also been excluded from the validation process for the reasons discussed in **Section 6.2.1**.

Table 39 Comparison of Measured and Predicted Noise Data (Base 2008)

No.	Address	Measured		Predicted		Predicted MINUS Measured	
		LAeq(15hour)	LAeq(9hour)	LAeq(15hour)	LAeq(9hour)	LAeq(15hour)	LAeq(9hour)
S1-1	13 Sierra Place	51.7	47.1	53.4	48.6	1.7	1.5
S1-2	89 Baulkham Hills Road	56.7	52.7	55.7	50.9	-1.1	-1.8
S1-3	24 Lambert Crescent	59.0	55.1	59.9	55.1	0.9	0.0
S1-5	108 Junction Road	59.1	53.6	59.6	54.8	0.4	1.2
S1-6	17 Livingston Avenue	56.1	51.9	57.5	52.7	1.3	0.8
S1-7	10 Murrills Crescent	53.8	49.8	55.2	50.4	1.4	0.5
S1-8	13 Leatherwood Court	57.6	53.4	59.0	54.2	1.4	0.8
S1-9	4 Craig Avenue	65.5	61.0	67.2	62.4	1.7	1.4
S1-10	10 Petrina Close	65.5	59.9	64.9	60.1	-0.6	0.2
S2-3	11 Wilshire Avenue	59.7	55.8	60.1	55.3	0.4	-0.5
S2-4	70 Westmore Drive	58.2	53.9	60.4	55.6	2.1	1.7
S2-5	3 Mundon Place	53.1	48.1	52.8	48.0	-0.3	-0.1
S2-6	25 Coral Tree Drive	53.1	50.5	56.6	51.8	3.4	1.3
S2-7	5 Orchard Road	56.5	50.5	59.1	54.3	2.6	3.7
S2-8	24A Castle Howard Road	57.6	52.5	58.6	53.8	1.0	1.3
S2-9	13 Williams Road	61.4	57.8	61.1	56.3	-0.3	-1.5
S2-10	8 Rajola Place	61.6	57.9	61.8	57.0	0.2	-0.9
S2-11	33 Carmen Avenue	63.6	59.0	65.0	60.2	1.4	1.2
S2-12	30 Austral Avenue	61.8	56.8	64.7	59.9	2.9	3.1
S3-2	4 Somerset Street	57.5	52.3	56.3	51.5	-1.2	-0.9
S3-3	56 Somerset Street	53.7	48.2	55.5	50.7	1.7	2.5
S3-4	19 Woodvale Avenue	59.2	53.9	60.2	55.4	0.9	1.5
S3-5	6/8 Nile Close	51.5	46.5	53.7	48.9	2.2	2.4
S3-8	3/3 Tasman Place	55.9	50.4	56.1	51.3	0.2	0.8
S3-9	21 Epping Road	58.4	53.0	60.8	56.0	2.4	3.0
S3-10	13 Stewart Close (1st)	64.5	60.1	65.2	60.4	0.7	0.3
S3-11	140 Crimea Road	57.9	52.7	59.1	54.3	1.2	1.6
S3-12	150 Crimea Road	53.4	47.9	54.8	50.0	1.4	2.1
S3-13	2/4 Nile Close	55.0	48.3	54.1	49.3	-0.9	1.0
S3-14	1A Busaco Road	54.7	49.5	54.6	49.8	-0.1	0.3
S3-15	1 Fontenoy Road	60.2	55.0	62.3	57.5	2.1	2.5
	Average { PREDICTED – MEASURED } Difference =					**+1.0 dBA**	**+1.0 dBA**

Figure 17 Validation Process – Predicted versus Measured Noise Levels - LAeq(15hr) and LAeq(9hr)

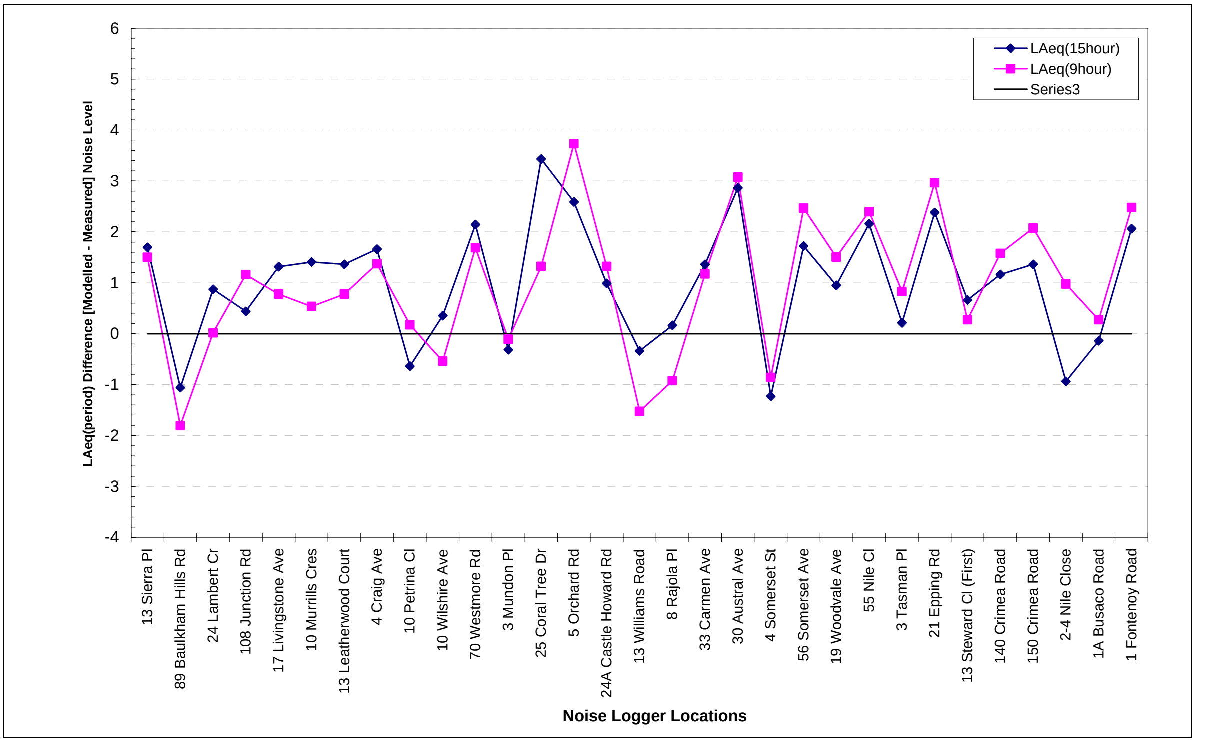


Figure 17 and **Table 39** show that the predicted noise levels provide a consistent, and slightly conservative, estimate of measured levels, with an average difference of +1.0 dBA for predicted versus measured levels.

It can also be seen that the predicted noise levels are within +3.4 dBA and -1.2 dBA of the measured noise levels for the LAeq(15hour) parameter, and +3.7 dBA and -1.8 dBA for the LAeq(9hour). These results are within acceptable tolerances for road traffic noise predictions.

Figure 18 shows the distribution of validation points in Predicted Noise Level minus Measured Noise Level bands for LAeq(15hour). It can be seen that an essentially normal distribution is apparent, with the majority of the results centred around the average of +1.0 dBA.

To assess the model performance as a function of the absolute magnitude of noise level, the same has been reproduced in **Figure 19**, showing the Measured Noise Level against the difference between the Predicted and Measured Noise Level at each of the validation points.

Figure 19 shows a relatively uniform and slightly conservative (more points above the “0” line than below) distribution of points. The trend line of the scatter results shows a modest downward tendency, implying that as the predicted noise level increases, the model becomes slightly more accurate. This is of interest given the relative significance normally applied to the provision of noise mitigation to “acute” noise-impacted properties.

Figure 18 Bar Chart Showing the Distribution of Validation Points - LAeq(15hour)

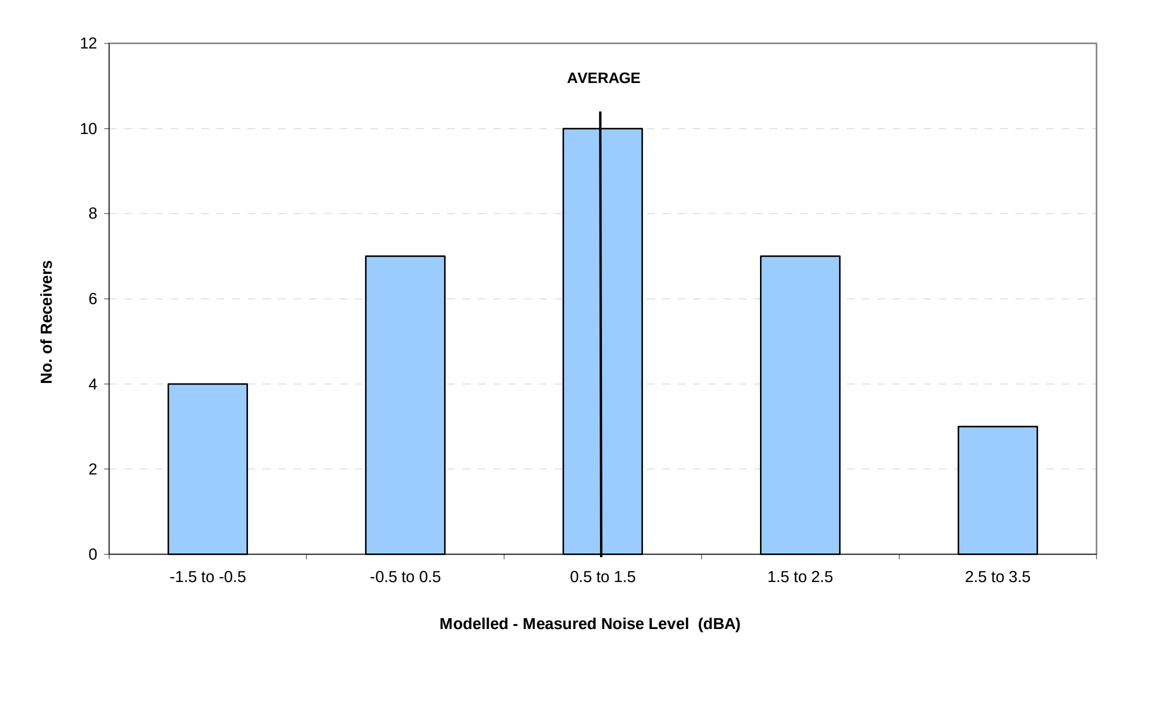
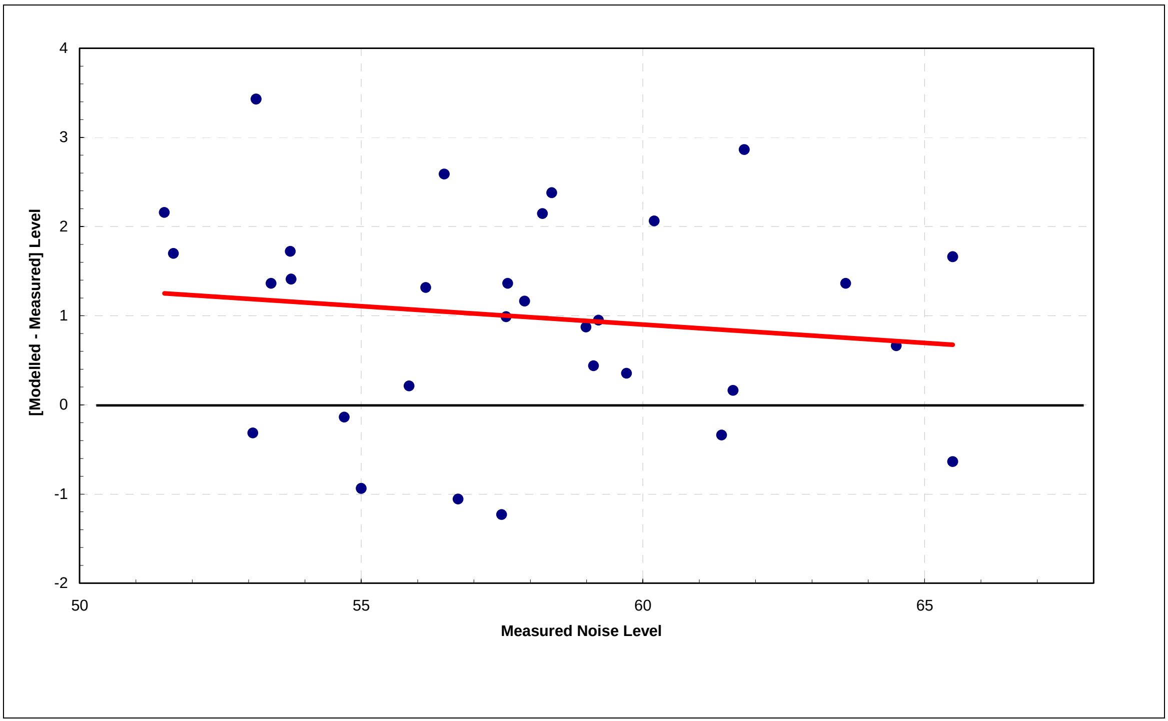


Figure 19 Scatter Graph of Predicted Minus Measured Noise Level Versus Measured Noise Level - LAeq(15hour)



On the basis of the comparison of M2 model predictions with baseline measurement results and the above discussion, it is concluded that the M2 noise model provides results which enable a reliable assessment of the proposed upgrade works and associated noise mitigation treatments.

9.6 Road Traffic Noise Associated with Intersecting Roads

The M2 Motorway is intersected at various points by a number of existing arterial/secondary roads. Residential receivers which are located close to these intersections are therefore exposed to road traffic noise from both the M2 and the roads in question. These include, Old Windsor Road, Windsor Road, Pennant Hills Road, Beecroft Road, Lane Cove Road and Delhi Road.

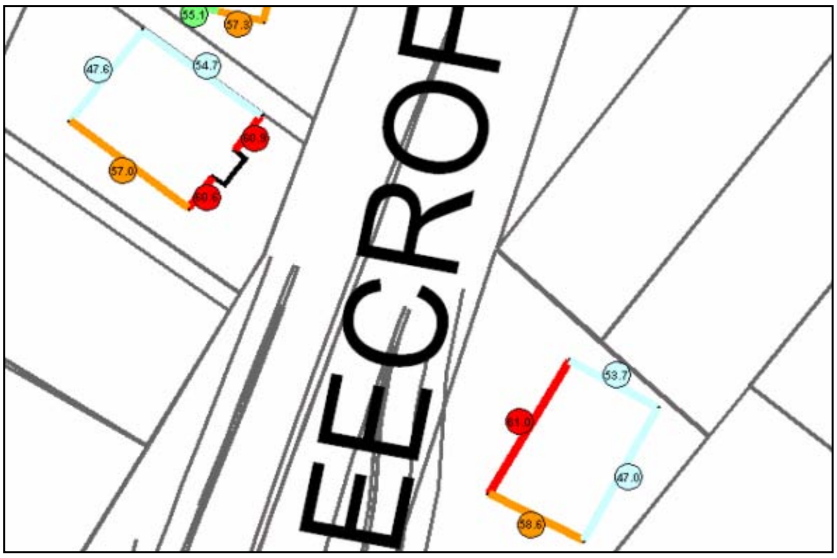
Where this situation is apparent, and an exceedance of the relevant criteria is predicted, a detailed inspection of the particular receiver in question has been performed to determine which facade(s) and hence which road source was the cause of the exceedance. An example of this is illustrated in **Figure 20**.

Furthermore, inherent within the noise model is the ability to determine the relative contributions to a particular noise level at a single facade from the various sources in the vicinity. Where an exceedance of the noise criteria is apparent near to multiple sources (ie at motorway junctions with secondary roads) this process is used to determine the dominant contribution to that particular noise level.

The facade maps in **Appendix D** and **Appendix E** represent the traffic noise levels from M2 operations combined with all major secondary roads within the M2 Project area. Residential and other sensitive receivers which are deemed to be exceeding the relevant operational criteria as a result of the noise generated by the secondary roads are highlighted on the facade maps in **Appendix E**.

Accordingly, only those residential receivers which exceed the nominated criteria as a direct result of noise generated by the M2 carriageway, M2 on/off access ramps and all associated upgrade works are included within the subsequent assessment of noise mitigation.

Figure 20 Sample Detailed Facade Noise Level Analysis (Indicative Only)



As part of the M2 Upgrade Project it is also proposed to widen a number of the roads which intersect or feed on to the M2. These include Windsor Road (north of Woodlands Street to the M2), Christie Road (M2 Exit ramp to Talavera Road) and Talavera Road (access to the School of Management to Alma Road). Of these, only Windsor Road has residential development fronting on to the road.

9.7 Noise Assessment and Mitigation

9.7.1 2011 Future Existing Scenario and Existing Noise Barriers

Noise emissions from the M2 Motorway are currently mitigated through noise walls along almost the entire length of the motorway of various heights. These range from approximately 1.8 m up to around 7.0 m in height. The noise walls are generally located either at the side of the carriageway or at the crest of cuttings, depending on which location provides the optimal noise benefit for the sensitive receivers situated behind.

The existing noise walls do not extend over the complete length of the M2 Motorway. The opening of the M7 increased traffic volumes, particularly heavy vehicles, in the section of road between the M7 and Pennant Hills Road. An assessment of all sensitive receivers adjacent to the M2, both in sections with existing noise walls and in those sections currently without, has been undertaken with regard to the operational noise criteria for the project.

The 2011 Future *Existing* facade plots in **Appendix D** show that several residential precincts along the route of the motorway are subject to noise levels exceeding ECRTN base criteria. This is confirmed by the unattended ambient noise survey detailed in **Table 11**.

9.7.2 2021 Future Design Scenario Assessment and Mitigation

Operational Noise Criteria Action Levels for Noise Treatment

The operational noise criteria for the M2 Upgrade Project have been previously defined in **Section 5.5** of this report. However, they are provided again below for reference.

Scenario 1

- The predicted 2021 Future *Design* noise level exceeds the ECRTN base criteria for redeveloped roads *and* the noise level increase due to the project is greater than 2 dBA.

or

Scenario 2

- The predicted 2021 Future *Design* noise levels are acute (≥65 dBA $L_{Aeq(15hour)}$ or ≥60 dBA $L_{Aeq(9hour)}$) regardless of the incremental impact of the project

Where exceedances of either of the above scenarios are apparent within the M2 Project Area, additional noise mitigation measures are required to be considered. Preference is to be first given to the use of noise walls as a mitigation measure as all sensitive receivers behind a particular noise wall benefit from the resulting reduction in noise.

After the design and optimisation process of any such noise walls is complete, architectural property treatment would then be utilised to mitigate all remaining properties in the M2 Project Area where residual exceedances of the above criteria are apparent.

The relevant sections of this report which relate to these processes are:

- **Noise Walls** affected by the project - **Section 9.7.3**
- **Architectural Treatment** of residual exceedances– **Section 9.7.7**

Evaluation of the incremental impact of the M2 Upgrade Project (2021 – 2011 difference plot are provided in **Appendix F**) concludes a 2 dBA increase in noise is not apparent in any location along the length of the Project Area (excluding two properties immediately adjacent to the realignment of Windsor Road), and as such, additional noise mitigation measures have only been considered where the predicted 2021 Future *Design* noise levels are found to be acute (ie Scenario 2).

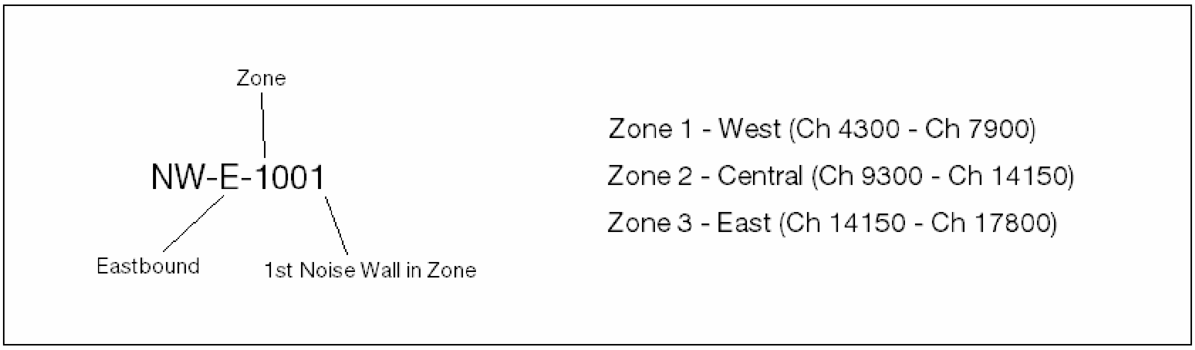
Properties which are outside of the areas directly affected by the upgrade works that currently experience acute noise levels (but are not predicted to experience a noise level increase of greater than 2 dBA due to the proposal) would be subject to the original conditions of approval for construction of the M2 Motorway and will be considered accordingly. This process would be performed separately to the proposed M2 Upgrade Project.

As preference is to be given to noise walls as the primary choice of noise mitigation, a discussion of how the noise walls were designed for the M2 Upgrade Project follows.

Noise Wall Reference Description

The various noise walls which are affected by the M2 Upgrade Project (ie existing noise walls which require horizontal displacement because of the widening works, noise walls which require an increase in height to provide additional mitigation, or entirely new noise walls) are referenced according to which side of the carriageway they are situated and by the zone in which they are located – ie NW-E-1001 is the first noise wall in Zone 1 on the eastbound side of the carriageway – refer to **Figure 21**.

Figure 21 Noise Wall Reference System for the M2 Upgrade



Alteration of Noise Walls

The widening upgrade process of the M2 will require alterations to the existing alignment of the road corridor in many areas along the length of the motorway. These alterations include the modification of various existing cuttings, embankments and batter slopes in areas where widening works are proposed.

The widening process will therefore affect a significant number of the existing noise walls along the route of the motorway. Some of the affected noise walls are situated adjacent to the road carriageway and others are on top of embankments. All such affected noise walls will be required to taken down and relocated as part of the project.

In certain areas, including some where residential receivers are in close proximity to the motorway, the proposed widening of the motorway will bring the new outer running lane (and hence the overall noise emission source) closer to affected receivers.

In all sensitive receiver locations where future exceedances of the operational noise criteria have been predicted, new or increased height noise walls have been considered where three or more exceeding properties are situated within a catchment area. Where the number of exceeding receivers is found to be less than three, the specification of noise walls is not considered to be a reasonable or cost-effective approach, and architectural treatment of these receivers would be considered.

Where noise walls are required to be relocated by the upgrade works, consideration has been given to increasing the existing height of such walls if exceedances of the operational noise criteria are apparent in the 2021 Future *Design* scenario. Where no exceedances of the criteria are apparent, the height of the relocated noise wall has been specified as being the same as the existing wall which it is replacing.

The relocation of noise walls is generally necessary to allow the widening process of the motorway to be completed. Where the horizontal alignment of the noise walls is required to be adjusted, an optimum location has been selected (taking constructability, maintenance, access, the extent of the site boundary and drainage issues into consideration) so as to ensure that the noise wall provides the maximum noise benefit possible to the areas situated behind.

To assist in maintaining the noise environment of affected areas during the construction phase of the project, it is planned that, in locations where noise walls are required to be relocated as part of the project, the new wall will be constructed prior to the existing one being demolished, subject to engineering and feasibility considerations. In areas where this is to happen, an offset distance of approximately 3.5 m will need to be maintained between the new noise wall and existing noise wall to allow for construction access behind the existing wall.

There is also the requirement for a small number of new walls to be included in the design of the proposed widening scheme.

Noise Wall Design and Optimisation

The RTA's ENMM provides guidance on how to optimise the design of noise walls in terms of engineering feasibility and safety. The design of noise walls for the M2 Upgrade Project addresses the following "feasibility" considerations:

- Safety and access requirements
- Structural feasibility and constructability
- Drainage and access requirements
- Accommodation of shared pathways

Consideration of the following "reasonableness" issues have also been addressed:

- Noise level reduction
- Visual impacts
- Overshadowing
- Compatibility with local ground and architectural features
- Cost-effectiveness

Guidelines for determining the cost-effectiveness in the design process of any noise wall are provided within Practice Note iv of the ENMM. The cost-effective height of a particular noise wall is determined by first predicting sensitive receiver noise levels (within a catchment area behind the particular noise wall) for a noise wall that increases in height incrementally from zero to about 8 m.

This data is then used determine the optimum height of a particular noise wall, taking into account the total noise reduction which the wall provides to the sensitive receivers behind the wall together with the cost of the wall.

The cost-effective analysis defined within the ENMM guidelines also states the following requirements:

- Noise walls which are less than 5 m in height should generally achieve a minimum of 5 dBA noise reduction at the ground floor level to be considered cost-effective.
- Noise walls which are 5 m and above should generally achieve a minimum of 10 dBA noise reduction at the ground floor level to be considered cost-effective.
- Noise walls more than 8 m high are generally considered visually unacceptable.

All of the noise wall designs presented within this Report reflect the RTA procedures as contained within the ENMM. Detailed calculation spreadsheets were developed to control this process and are summarised within **Appendix G**.

9.7.3 Noise Wall Affected by the M2 Upgrade Project

Table 40 details each of the affected noise walls which form part of the M2 Upgrade Project and their associated reason for requiring modification. The location of all affected noise walls is also illustrated in **Appendix H**.

Table 40 Noise Walls Affected by the M2 Upgrade Project

Noise Wall Ref.	Approximate Chainage	Location	Length (m)	Reason	Height of New Noise Wall[1]
Eastbound Carriageway					
NW-E-1001	3500 – 3900	New Windsor Road off-ramp	415	Re-located	Same as existing noise wall at western end, reduced in height from 3.0 m to 2.4 m at eastern end
NW-E-1002	5100 – 5950	Barclay Road	849	Re-located/ Heightened	Same as existing noise wall for majority of wall. Increased in height from 4.2 m to 4.8 m between chainage 5400 and 5500
NW-E-1003	7600 – 7700	Westmore Drive	132	Re-located	Same as existing noise wall
NW-E-2001	10700 – 10800	Murray Farm Road	92	Re-located	Same as existing noise wall
NW-E-2002	12350 – 12500	West Tunnel Portal	134	Re-located	Same as existing noise wall
NW-E-2003	13300 – 13900	East Tunnel Portal	606	Re-located	Same as existing noise wall
NW-E-3001	14850 – 15050	Busaco Road	208	Re-located	Same as existing noise wall
NW-E-3002	16700 – 17100	Khartoum Road	399	Re-located	Same as existing noise wall
NW-E-3003	17450 – 17600	Lane Cove off-ramp	170	New	2.4 m
Westbound Carriageway					
NW-W-1001	3500 – 4000	New Windsor Road on-ramp	491	Re-located	Same as existing noise wall at western end, reduced in height from 4.0 m to 2.4 m at eastern end
NW-W-1002	5900 – 6200	Hepburn Road	287	Re-located	Same as existing noise wall
NW-W-1003	6450 – 6700	Yale Close	264	Re-located	Same as existing noise wall
NW-W-1004	6750 – 6950	RIDBC	207	Re-located	Same as existing noise wall
NW-W-1005	7000 – 7200	RIDBC	245	Re-located	Same as existing noise wall
NW-W-1006	7500 – 7650	Boundary Road	120	Re-located	Same as existing noise wall
NW-W-2001	9600 – 10150	Lamorana Avenue	560	Re-located	Same as existing noise wall
NW-W-2002	10440 – 10450	Ferndale Road	16	Re-located	Same as existing noise wall
NW-W-2003	10550 – 11150	Murray Farm Road	634	Re-located	Same as existing noise wall
NW-W-2004	11300 – 11350	Kent Street Overpass	76	Re-located	Same as existing noise wall
NW-W-2005	12350 – 12500	West Tunnel Portal	144	Re-located	Same as existing noise wall
NW-W-2006	13250 – 13650	East Tunnel Portal	417	Re-located	Same as existing noise wall
NW-W-3001	14250 – 14400	Vimiera Road	140	New	3.0 m
NW-W-3002	15250 – 15350	Culloden Road	110	Re-located	Same as existing noise wall
NW-W-3003	15700 – 16050	Christie Road	368	Re-located	Same as existing noise wall

Note 1: Noise walls are to be built from modular 0.6 m panels, therefore the noise walls are specified in 0.6 m increments.

A discussion of the noise walls within the M2 Upgrade Project Area follows. **Appendix H**, which illustrates all noise walls affected by the project, should be consulted when considering this discussion.

9.7.4 Eastbound Noise Walls

NW-E-1001 (Relocated Noise Wall on New Off-Access Ramp to Windsor Road)

As part of the M2 Upgrade Project it is proposed to provide two new west-facing access ramps at the intersection of the M2 with Windsor Road (on-access to the M2 in the westbound direction and off-access in the eastbound direction).

As a result of this, the existing noise walls on the both sides of the carriageway, which are currently located at roadside, would be required to be removed and reinstated on the outer most edge of the new access ramps.

Although the new access ramps result in a closer noise source to the first row of houses (future distances of approximately 5 m to the nearest property to the eastbound off ramp and 25 m to the westbound on access ramp) on either side of the motorway, the future noise exposure of the houses on both sides of the carriageway is predicted to reduce. The reason for this has been discussed previously in **Section 5.5.1**.

The height of noise wall NW-E-1001 is approximately inline with existing noise wall at the western end, however, as a result of less future noise exposure to the properties behind the wall being apparent, the eastern end of the noise wall, which runs up the proposed off-access slip road, is able to be slightly reduced in height. The optimised height for this section of the noise wall is 2.4 m.

The proposed new noise wall also terminates slightly earlier than the existing wall, at a point just past the last affected property.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between -4.5 dBA and +1.0 dBA.

The single 2021 Future *Design* acute property which is behind noise wall NW-E-1001, as shown in **Appendix E**, is as a result of noise from Windsor Road.

NW-E-1002 (Relocated Noise Wall - Increased in Height in Middle Section)

This noise wall is required to be displaced as part of the upgrade works as the existing batter slope, on which the wall is currently located, requires modification. The majority of the new noise wall would be at the same height as the existing wall, however as a number of acute properties in the 2021 Future *Design* scenario were predicted immediately behind the section between approximate chainage 5400 and 5500, the height of the wall in this section was optimised. This analysis showed that the noise wall is required to be increased in height from 4.2 m to 4.8 m.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between 0 dBA and +2 dBA.

The five 2021 Future *Design* acute properties which remain after the optimisation process of this noise wall are eligible to be considered for architectural treatment. This is discussed in **Section 9.7.7** of this report.

NW-E-1003 (Relocated Noise Wall)

A relatively small (about 100 m) section of wall is required to be relocated at chainage 7600 – 7700. Although a number of acute properties on Westmore Drive are predicted in the Future *Design* 2021 scenario in the vicinity of this noise wall, increasing the height of this small section of wall would not be sufficient to adequately mitigate these receivers to below the criteria.

To mitigate the noise levels which are subject to these receivers, the entire noise wall (which runs from chainage 7300 to 7700) would be required to be increased in height. As this would require an existing noise wall which is not affected by the widening works to be increased, this is rejected on a cost-effectiveness basis. A discussion on the cost-effectiveness of increasing the height of existing walls which are not affected by the upgrade works is provided in **Section 9.7.6**.

Noise Wall NW-E-1003 has therefore been specified at 4.2 m high, which corresponds to the existing height of the noise wall.

The acute properties in the vicinity of this wall are eligible to be considered for architectural treatment.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +0.5 dBA and +1.0 dBA.

NW-E-2001 (Relocated Noise Wall

There are no acute properties in the vicinity of this noise wall, therefore the height of this relocated wall has been specified as being the same as the existing noise wall which it is replacing. The existing wall is 2.4 m high at the western end, which then rises to 4.2 m at the eastern end.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1 dBA and +1.5 dBA.

NW-E-2002 (Relocated Noise Wall)

As there are only two acute properties which are immediately affected by (ie directly behind) noise wall NW-E-2002 this wall does therefore not meet the minimum requirement of three properties to trigger the need to heighten the wall any further. This relocated wall has therefore been specified at the same height as the existing wall which it is replacing. The existing wall is 4.8 m high when on cutting and 5.4 m at roadside.

The two acute properties in the vicinity of this wall are eligible to be considered for architectural treatment.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.0 dBA and +1.5 dBA.

NW-E-2003 (Relocated Noise Wall)

No acute properties are predicted in the 2021 Future *Design* scenario behind this noise wall, and as such this relocated wall is at the same height as the existing wall. The western end of the wall is 6.0 m high which then incrementally decreases to 3.2 m at the eastern end.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between 0 dBA and +1.5 dBA.

NW-E-3001 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 1.8 m high.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +0.5 dBA and +1.5 dBA.

NW-E-3002 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 3.0 m high for the majority of this wall, with the eastern rising up to 4.2 m high.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.0 dBA and +1.5 dBA.

NW-E-3003 (New Noise Wall)

There is currently no noise wall on the exit ramp to Lane Cove Road. The Fontenoy Road development was recently constructed and therefore no noise walls were provided in the original design of the M2 Motorway.

As exceedances are predicted in the 2021 Future *Design* scenario at these receivers, there is therefore a requirement for a new noise wall in this area to mitigate noise levels. An optimised wall with a height of 2.4 m has been found for this new noise wall.

The new noise wall is located on top of the cutting, at the edge of the M2 exit ramp to Lane Cove Road, and runs for the length of the ramp.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between -3.0 dBA and 0 dBA.

The three 2021 Future *Design* acute multi-unit buildings which are adjacent to noise wall NW-E-3003, shown in **Appendix E**, are as a result of noise from Lane Cove Road.

9.7.5 Westbound Noise Walls

NW-W-1001 (Relocated Noise Wall on New On-Access Ramp to Windsor Road)

As part of the M2 Upgrade Project it is proposed to provide two new access ramps at the intersection of the M2 with Windsor Road (on-access to the M2 in the westbound direction and off-access in the eastbound direction).

The height of noise wall NW-W-1001 is approximately inline with existing noise wall at the western end, however, as a result of less future noise exposure to the properties behind the wall being apparent, the eastern end of the noise wall, which runs along the proposed on-access slip road, is able to be slightly reduced in height. The optimised height for this section of the noise wall is 2.4 m.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between -3.5 dBA and +1.0 dBA.

NW-W-1002 (Relocated Noise Wall)

No acute properties are predicted in the 2021 Future *Design* scenario for this noise wall, and as such this relocated wall is specified at the same height as the existing wall. The existing wall is 4.2 m high.

The acute property in the vicinity of this wall is eligible to be considered for architectural treatment.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between 0 dBA and +1.5 dBA.

NW-W-1003 (Relocated Noise Wall)

As only a single acute property is predicted behind this wall in the 2021 Future *Design* scenario, increasing the height of this wall is rejected for cost-effectiveness reasons. The relocated wall is therefore specified at the same height as the existing wall which is 3.0 m high at the western end, and 5.4 m when at roadside.

The acute property in the vicinity of this wall is eligible to be considered for architectural treatment.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.0 dBA and +1.5 dBA.

NW-W-1004 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 7.2 m high for the majority of its length.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.0 dBA and +1.5 dBA.

NW-W-1005 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 7.2 m high.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +0.5 dBA and +1.5 dBA.

NW-W-1006 (Relocated Noise Wall)

For this noise wall only a single acute property is predicted immediately behind it in the 2021 Future *Design* scenario, and as such this relocated wall is specified as being the same height as the existing wall. The existing wall is 5.4 m high.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +0.5 dBA and +1.0 dBA.

The two acute properties in the vicinity of this wall are eligible to be considered for architectural treatment.

NW-W-2001 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 3.6 m high at the western end of the wall and 4.2 m at the eastern end.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.0 dBA and +1.5 dBA.

NW-W-2002 (Relocated Noise Wall)

NW-W-2002 is a short 16 m length of wall that requires displacement due to the widening process. This wall is the same as the existing wall, which is 6.0m high.

NW-W-2003 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 6.0 m at the western end and 4.2 m at the eastern end.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.0 dBA and +1.5 dBA.

NW-W-2004 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 6.0 m high.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.5 dBA and +2.0 dBA.

NW-W-2005 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 5.4 m high.

The two acute properties in the vicinity of this wall are eligible to be considered for architectural treatment.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +0.5 dBA and +1.0 dBA.

NW-W-2006 (Relocated Noise Wall)

No acute properties are predicted in the vicinity of this noise wall, and as such this relocated wall is the same height as the existing wall. The existing wall is 6.0 m high for the majority of its length.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between 0 dBA and +1.5 dBA.

NW-W-3001 (New Noise Wall)

There is currently a section of the westbound carriageway, in the vicinity of Vimiera Road, where a gap in the existing noise wall is apparent (chainage 14250 to 14450). As three acute multi-unit residences are predicted in the 2021 Future *Design* scenario, it is necessary to mitigate these receivers by filling the gap in the noise wall. The optimisation height of this wall found to be 3.0 m.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between -4.5 dBA and 0 dBA.

NW-W-3002 (Relocated Noise Wall)

As no properties are situated behind this wall, the new wall is specified as being the same as the 2.4 m existing noise wall.

A comparison of the 2021 Future *Design* noise levels with the 2011 Future *Existing* levels at properties in this location shows a predicted sensitive receiver noise level change that varies between +1.0 dBA and +1.5 dBA.

NW-W-3003 (Relocated Noise Wall)

As no acute properties are situated behind this wall, the new wall is specified as being the same as the 2.4 m existing noise wall.

9.7.6 Increasing Height of Existing Walls Which are NOT Affected by the Widening Works

In all situations where three or more 2021 Future *Design* acute properties were located behind an existing noise wall that is not affected by the physical widening works, consideration has been given to increasing the height of these walls. This process included performing the cost-effectiveness analysis which was described in the preceding section.

In all cases, the cost-effectiveness analysis rejected any further increases to the height of these existing noise walls, primarily because of the very small additional noise benefit which is provided by increasing the size of already high noise walls vs the significant costs which the modifications would incur.

The ENMM requirement that for a noise walls to be considered acceptable it should generally provide a noise reduction of at least 5 dBA was also not met.

The locations of the existing noise walls which are not affected by the project but were considered to be increased are detailed below.

Eastbound Carriageway

- Existing Windsor Road on-access slip road (chainage 4000 – 4500)
- South of Westmore Drive (chainage 7300 – 7600)
- South of Austral Avenue (chainage 9800 – 10200)

Westbound Carriageway

- Existing Windsor Road off-access slip road (chainage 4200 – 4500)
- Darling Mills Creek Bridge[1] (chainage 4500 – 4700)
- North of Williams Road (chainage 5000 – 5200)
- North of Carmen Drive (chainage 7800 – 7900)

Note 1: In addition to being rejected on the standard cost-effectiveness reasons alone, the existing noise wall on Darling Mills Creek Bridge (which is currently 1.2 m high) could also not be substantially increased in height without the bridge structure itself being rebuilt. This is due to the extra wind loading forces which would be apparent should the height of this wall be increased.

9.7.7 Residual Architectural Property Treatments

At some locations where the noise criteria are exceeded as a result of the project, the feasibility and reasonableness considerations discussed above have concluded that the construction, or modification, of noise walls is not feasible, reasonable or cost-effective.

At such locations, where residual impacts remain after all feasible and reasonable approaches have been exhausted, noise mitigation in the form of acoustic treatment for existing individual dwellings is required to be assessed.

The details of all the property treatments related to the M2 Upgrade Project are summarised in **Table 41**, noting that a "n/a" means that a property has no first floor, and that grey text represents no exceedance of the criteria at ground floor level.

Table 41 2021 Exceedance Locations[1] and Residual Architectural Property Treatments

No.	Address	Approx. Chainage	Predicted Noise Level $L_{Aeq(9hr)}$ (dBA)			
			GROUND FLOOR		FIRST FLOOR	
			2011	2021	2011	2021
1	52 Junction Road, Baulkham Hills	3350	58	59	**60**	**60**
2	1 Watkins Road, Baulkham Hills	3400	59	**60**	n/a	n/a
3	4 Craig Avenue, Baulkham Hills	3450	**62**	**63**	n/a	n/a
4	10 Craig Avenue, Baulkham Hills	3500	57	58	**62**	**62**
5	5 Linton Street, Baulkham Hills	4100	56	57	**63**	**64**
6	14 Linton Street, Baulkham Hills	4200	57	57	**60**	**61**
7	4 Petrina Crescent, Baulkham Hills	4200	**60**	**60**	**63**	**64**
8	8 Petrina Crescent, Baulkham Hills	4250	**60**	**61**	n/a	n/a
9	10 Petrina Crescent, Baulkham Hills	4300	**61**	**62**	n/a	n/a
10	12 Petrina Crescent, Baulkham Hills	4300	**60**	**61**	n/a	n/a
11	14 Petrina Crescent, Baulkham Hills	4300	**60**	**61**	n/a	n/a
12	7 Petrina Crescent, Baulkham Hills	4350	**61**	**61**	n/a	n/a
13	266 Windsor Road, Winston Hills	4000	**63**	**66**	n/a	n/a
14	262 Windsor Road, Winston Hills	4000	**63**	**67**	n/a	n/a
15	258a Windsor Road, Winston Hills	4000	These three properties are newly built two-storey multi-unit dwellings. See discussion in **Section 9.7.11**			
16	258b Windsor Road, Winston Hills	4000				
17	258c Windsor Road, Winston Hills	4000				
18	254 Windsor Road, Winston Hills	4000	**64**	**66**	**66**	**68**
19	17 Russell Street, Northmead	4300	59	**60**	n/a	n/a
20	19 Russell Street, Northmead	4300	**60**	**60**	n/a	n/a

No.	Address	Approx. Chainage	Predicted Noise Level $L_{Aeq(9hr)}$ (dBA)			
			GROUND FLOOR		FIRST FLOOR	
			2011	2021	2011	2021
21	1 Russell Street, Northmead	4300	55	57	**67**	**68**
22	2 Russell Street, Northmead	4400	59	59	**65**	**66**
23	37 Dremeday Street, Northmead	4450	59	**60**	n/a	n/a
24	39 Dremeday Street, Northmead	4450	**60**	**61**	n/a	n/a
25	41 Dremeday Street, Northmead	4450	**60**	**61**	**62**	**62**
26	42-44 Dremeday Street, Northmead[2]	4500	**62**	**63**	n/a	n/a
27	46 Dremeday Street, Northmead	4500	**65**	**66**	n/a	n/a
28	46 Roland Avenue, Northmead	4500	**60**	**61**	**61**	**62**
29	48 Roland Avenue, Northmead	4500	**60**	**61**	**61**	**62**
30	41 Williams Road, North Rocks	4950	59	**60**	**60**	**61**
31	39 Williams Road, North Rocks	4950	59	**60**	n/a	n/a
32	33 Williams Road, North Rocks	5000	59	**60**	n/a	n/a
33	31 Williams Road, North Rocks	5000	59	**60**	n/a	n/a
34	29 Williams Road, North Rocks	5100	59	**60**	**61**	**62**
35	25 Williams Road, North Rocks	5100	**61**	**62**	n/a	n/a
36	23 Williams Road, North Rocks	5150	**60**	**61**	n/a	n/a
37	21 Williams Road, North Rocks	5200	**60**	**61**	**63**	**64**
38	11 Williams Road, North Rocks	5250	57	58	59	**60**
39	8 Rajola Place, North Rocks	5300	58	59	**60**	**61**
40	93 Barclay Road, North Rocks	5250	58	59	59	**60**
41	2 Mill Drive, North Rocks	5300	58	59	59	**60**
42	122 Barclay Road, North Rocks	5400	57	57	59	**61**
43	120 Barclay Road, North Rocks	5450	58	59	**61**	**62**
44	118 Barclay Road, North Rocks	5450	58	59	**61**	**62**
45	26 Hepburn Road, North Rocks	6000	55	57	58	**60**
46	24 Yale Close, North Rocks	6500	58	59	**60**	**62**
47	14 Virginia Place, West Pennant Hills	7000	58	59	59	**60**
48	15 Wilshire Avenue, Carlingford	7400	54	55	**62**	**63**
49	13 Wilshire Avenue, Carlingford	7400	57	57	**60**	**60**
50	96 Westmore Drive, West Pennant Hills	7400	58	59	59	**60**
51	86 Westmore Drive, West Pennant Hills	7400	58	59	59	**60**
52	82 Westmore Drive, West Pennant Hills	7500	59	**60**	**60**	**61**
53	80 Westmore Drive, West Pennant Hills	7500	**60**	**61**	n/a	n/a
54	78 Westmore Drive, West Pennant Hills	7550	59	**60**	n/a	n/a
55	76 Westmore Drive, West Pennant Hills	7600	58	59	59	**60**
56	74 Westmore Drive, West Pennant Hills	7600	58	59	59	**60**
57	2 Morton Avenue, Carlingford	7600	**60**	**60**	n/a	n/a
58	53 Carmen Drive, Carlingford	7650	**61**	**62**	n/a	n/a
59	52 Carmen Drive, Carlingford	7800	58	59	59	**60**
60	50 Carmen Drive, Carlingford	7850	58	59	59	**60**
61	33 Carmen Drive, Carlingford	7850	**60**	**61**	**67**	**67**
62	31 Carmen Drive, Carlingford	7850	**61**	**62**	n/a	n/a
63	29 Carmen Drive, Carlingford	7900	**60**	**61**	n/a	n/a
64	27 Carmen Drive, Carlingford	7900	58	59	**61**	**62**

No.	Address	Approx. Chainage	Predicted Noise Level $L_{Aeq(9hr)}$ (dBA)			
			GROUND FLOOR		FIRST FLOOR	
			2011	2021	2011	2021
65	20 Lamorna Avenue, Beecroft	9450	55	56	59	**60**
66	16 Lamorna Avenue, Beecroft	9450	57	58	**60**	**61**
67	16 Austral Avenue, Beecroft	9950	58	59	59	**60**
68	18 Austral Avenue, Beecroft	9950	58	59	59	**60**
69	20 Austral Avenue, Beecroft	10000	58	59	59	**61**
70	22 Austral Avenue, Beecroft	10000	58	59	59	**60**
71	24 Austral Avenue, Beecroft	10050	58	59	59	**60**
72	28 Austral Avenue, Beecroft	10050	58	**60**	59	**60**
73	30 Austral Avenue, Beecroft	10050	**60**	**61**	**61**	**62**
74	34-2/3 Austral Avenue, Beecroft	10100	59	**60**	n/a	n/a
75	36-1/2 Austral Avenue, Beecroft	10100	57	58	59	**60**
76	36-3 Austral Avenue, Beecroft	10100	59	**60**	**60**	**61**
77	6 Ferndale Road, Beecroft	10500	56	57	**61**	**62**
78	24 Barombah Road, Epping	11700	59	**60**	n/a	n/a
79	26 Dunmore Road, Epping	11800	58	58	**61**	**62**
80	13 Stewart Close, Cheltenham	12100	52	53	**61**	**62**
81	28 Old Beecroft Road, Cheltenham	12150	54	55	**62**	**62**
82	28A Old Beecroft Road, Cheltenham	12150	51	52	**62**	**63**
83	3 Constance Close, Epping	12500	57	58	59	**61**
84	5 Callistemon Close, North Epping	12600	57	58	59	**61**
85	3A Callistemon Close, North Epping	12650	**61**	**62**	**62**	**63**
86	27 Somerset Street, Epping	12650	**62**	**63**	**63**	**64**
87	16 Sussex Street, Epping	12650	57	58	59	**60**
88	21 Sussex Street, Epping	12650	56	56	59	**60**
89	83 Devon Street, North Epping	13150	55	56	59	**60**

Note 1: Exceedances are regarded as residential receivers that are subject to "acute" noise levels (ie ≥65 dBA $L_{Aeq,15hr}$ or ≥60 dBA $L_{Aeq,9hr}$) OR the incremental impact of the project is greater than 2 dBA (and the project noise goals are exceeded).

Note 2: This property consists of a number of units and will require further investigation during the detailed design phase to determine exactly how many of the units have exceedances.

9.7.8 Properties Outside of M2 Upgrade Project Area

The widening works associated with the M2 Upgrade Project start from approximately chainage 3500 and finish at around chainage 18000. As has previously been discussed in **Section 5.5.2**, in areas where no physical works are proposed, noise mitigation is only required to be considered where the noise level change as a result of the project is more than 2 dBA.

Reference to **Appendix F** shows that all properties in areas outside of the M2 Upgrade Project Area are predicted to be subject to a noise level increase which is less than 2 dBA and do therefore not trigger the need for further mitigation to be considered as part of the M2 Upgrade Project.

Properties which are outside of the extent of the upgrade works and which currently experience acute noise levels would however be subject to the original conditions of approval for construction of the M2 Motorway and will be considered accordingly. This process would be performed separately to the proposed M2 Upgrade Project.

9.7.9 Areas of New Housing Developments

There are a number of newly built, planned or currently under construction residential developments along the route of the M2 Motorway that were unable to be included in the noise modelling exercise that has been performed to date. These locations have not been able to be included in the model because no building data for any of these developments is currently available.

5 Petrina Crescent, Baulkham Hills

A new property is currently under construction at the eastern end of Petrina Crescent in a location adjacent to the M2 Motorway. The plot is situated behind an existing noise wall and is approximately 35 m away from the carriageway.

Although construction of this property was not complete at the time of writing, it is noted that the rear facade of the development, which faces the M2 Motorway, has two storeys.

Baden Powell Place, Carlingford

An area of land, accessed from Baden Powell Place, has been designated for residential use. It is located to the south of the M2 Motorway between Yale Close and the Royal Institute for Deaf and Blind Children School. The M2 Motorway runs immediately behind this location in cutting.

It is noted that at the time of writing this report all plots in this location were vacant. The ENMM notes that *"the selection and design of noise treatment(s) for vacant land should be based on the assumption that future development will be single storey and adjacent to the building line, regardless of the number of storeys that the zoning may allow".* As such, noise mitigation for single storey dwellings is to be assessed at this location.

Devon Street, North Epping

An area of land situated above the eastern portal of the Norfolk tunnel, accessed from Devon Street, is designated for residential land use. There are currently six premises that are in a completed, or semi completed state, with space for approximately four more dwellings available.

The constructed dwellings are noted as having two storeys.

Waterloo Road, Marsfield

A new complex of three-storey apartment type buildings is nearing completion in Marsfield, situated at the corner of Waterloo Road and Crimea Road. The development is located at the top of a cutting and overlooks the M2 carriageway.

As no building data for any of these developments is currently available they have not been included in the noise model. The assessment of these areas has therefore been performed using free field grid noise contours predicted over the area in which the developments are situated.

A +2.5 dB correction factor has been included in all the contour data calculations to allow for the conversion of free field noise level to facade levels, as required by the ECRTN.

M2 noise contours for each development are illustrated in **Appendix I**. Noise contours have been predicted at both ground floor and first floor heights where appropriate (1.5 m and 4.3 m above the local ground respectively).

Future *Design* noise levels have been predicted for the 2021 night time $L_{Aeq(9hour)}$ scenario only, as the ECRTN criterion for this assessment period is the more stringent of the criteria. The 2021 scenario includes the upgrades to the noise walls as discussed in **Table 40**. The increase in L_{Aeq} noise levels as a result of the proposal are made on the basis of the Future *Existing* (Year 2011) versus Future *Design* (Year 2021) scenarios.

The assessment of the new areas of residential development is summarised in **Table 42**. Reference is to be made to the noise contours in **Appendix I**, where the red contours can be seen to represent the "acute" noise level boundary.

Table 42 New Residential Locations

No.	Location	Storey	Future Noise Levels Above ECRTN Criteria and Incremental Impact > 2dBA?	Future Noise Levels Acute? (≥60 dBA $L_{Aeq(9hour)}$)	Additional Mitigation Identified?
1	5 Petrina Crescent, Baulkham Hills	Ground	No	**Yes**	**Yes**
		First	No	**Yes**	**Yes**
2	Baden Powell Place, Carlingford[1]	Ground	No	No	No
		First	-	-	-
3	Devon Street, North Epping	Ground	No	No	No
		First	No	No	No
4	Waterloo Road, Marsfield[2]	Ground	No	No	No
		First	No	**Yes**	**Yes**

Note 1: These plots are currently vacant, therefore only ground floors require assessment.

Note 2: This is a multi-unit building.

Reference to the above table indicates that a further two properties require architectural treatment.

9.7.10 Sensitive Land Uses

The assessment of areas of sensitive land use (schools, churches, areas of active recreation and hospitals) is discussed in the following paragraphs.

When considering sensitive land uses, the same operational criteria scenarios that have been adopted for residential receivers are applicable. Additional noise mitigation is therefore required to be assessed when either:

Scenario 1

- The predicted 2021 Future *Design* noise level exceeds the ECRTN base criteria for redeveloped roads *and* the noise level increase due to the project is greater than 2 dBA.

or

Scenario 2

- The predicted 2021 Future *Design* noise levels are acute (≥65 dBA $L_{Aeq(15hour)}$ or ≥60 dBA $L_{Aeq(9hour)}$) regardless of the incremental impact of the project

It is noted that the ECRTN base criteria for these land uses is different to that applicable to residential properties. The appropriate assessment criteria for these uses are detailed in **Table 7**.

As has previously been discussed in **Section 5.5.2**, in areas where no physical works are proposed, noise mitigation is only required to be considered where the noise level change as a result of the project is more than 2 dBA.

The following assessment includes the predicted future noise levels at each of these land uses and details.

Reference is to be made to the various grid noise maps regarding sensitive lands uses that are presented in the following appendices:

- Existing Schools – **Appendix J**
- Churches – **Appendix K**
- Active Recreation – **Appendix L**
- Hospitals – **Appendix M**

Existing Schools

The ECRTN noise goal for existing schools is a daytime $L_{Aeq(1hour)}$ noise level of 45 dBA.

It is noted that this noise criterion is based on $L_{Aeq(1hour)}$ internal noise levels. Any "internal noise level" refers to the noise level at the centre of the habitable room that is most exposed to the noise source and applies with windows sufficiently open to provide adequate ventilation (notionally an open area equal to 5% of the floor area of the room).

When considering the correlation of internal noise criteria with externally predicted levels, the following table, as taken from the RTA's ENMM, should be considered.

Table 43 ENMM Table 4.2 - Indicative Noise Reduction (adapted from FHWA 1995)

Building type	Windows	Internal noise reduction
All	Open	10 dB(A)
Light frame	Single glazed (closed)	20 dB(A)
Masonry	Single glazed (closed)	25 dB(A)
	Double glazed (closed)	35 dB(A)

Therefore, as per the ENMM guidance, when assuming the typical (conservative) reduction of 10 dBA for a partially open window, to allow for natural ventilation on the noise exposed facade, the internal ECRTN noise criterion would correspond to an external $L_{Aeq(1hour)}$ noise level at the building facade of approximately 55 dBA.

This criterion may be considered slightly conservative, since the morning and afternoon peaks of traffic will typically occur outside normal teaching hours.

Assessment of all 1-hour noise levels contained within this report has been performed using the appropriate noise corrections as derived from the unattended noise logging noise data described in **Section 6.2**, averaged during the corresponding period of the day (ie day or night).

Table 44 Assessment of Existing Schools

School	ECRTN Criteria (dBA) Daytime	Future Noise Levels Above ECRTN Criteria and Incremental Impact > 2dBA?	Future Noise Levels Acute? (≥65 dBA $L_{Aeq(15hour)}$)	Additional Mitigation Identified?
Model Farms High School[1]	$L_{Aeq(1 hr)}$ 45 dBA (internal)	No	-	No
Winston Hills Public School[1]		No	-	No
Our Lady of Lourdes Primary School		No	No	No
Muirfield High School		No	No	No
Royal Institute for Deaf and Blind Children School		No	No	No
Epping Heights Public School		No	No	No
Macquarie University		No	No	No

Note 1: Located outside of the M2 Project Area, therefore only incremental impact required to be assessed.

Reference to **Table 44**, the noise contours in **Appendix J**, and the 2021 Future Design façade plots in **Appendix E** concludes the following.

Model Farm High School and Winston Hills Public School

At Model Farm High School and Winston Hills Public School, which are both outside of the M2 Upgrade Project Area, the 2021 Future *Design* noise levels are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels and as such, there is no requirement for additional mitigation to be investigated.

Acute 2021 Future *Design* noise levels are not required to be assessed at these schools.

Our Lady of Lourdes Primary School

At this school, where no modification to the existing noise walls are proposed, the 2021 Future *Design* noise levels are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels, neither are the 2021 Future *Design* noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated.

The Royal Institute for Deaf and Blind Children (RIDBC)

At the RIDBC, widening of the M2 is proposed and there is a requirement to relocate a number of the nearby noise walls. The heights of the proposed new noise walls are noted as being in-line with the heights of the existing noise walls (7.2 m for the noise walls immediately north of the school).

The 2021 Future *Design* noise levels at this school are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels, nor are the 2021 Future *Design* noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated.

Notwithstanding the above, an assessment of the change in noise impacts at the RIDBC with the relocated noise walls in this location being increased in height to 7.8 m has been performed. This assessment concluded that raising the height to 7.8 m resulted in only a marginal decrease in noise (less than 0.5 dBA) and that this small noise reduction was found to be insufficient to justify the extra cost.

Epping Heights Public School

At this school, where no modification to the existing noise walls are proposed, the 2021 Future *Design* noise levels are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels, neither are the 2021 Future *Design* noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated

Macquarie University

At this school, the 2021 Future *Design* noise levels are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels, neither are the 2021 Future *Design* noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated

It is noted that situated between the M2 corridor and the relevant Macquarie University campus buildings is a relatively busy section of Talavera Road, to the west of Christie Road. This section is not itself subject to upgrading as part of the new on/off ramps which form part of the M2 Upgrade Project.

Places of Worship

The ECRTN noise goal for places of worship is an internal $L_{Aeq(1hour)}$ noise level of 40 dBA. This applies to both the day and night-time periods.

Again, to adequately assess internal noise levels from those predicted externally, a conservative noise reduction of 10 dBA has been applied to allow for windows along the noise exposed facade being partially open (as defined within the ENMM). This corresponds to an external $L_{Aeq(1hour)}$ noise level at the building facade of approximately 50 dBA.

It is noted that, on average, the assessed 1-hour peak daytime noise levels are approximately 3 dBA higher than the night-time peak level and as such, the daytime is considered to be the governing criteria. This is as would be expected for road traffic generated noise, where the highest daytime peak hours (corresponding to either the morning or evening rush hours) experience far greater traffic volumes, and subsequently higher noise levels, than the night-time peak hours.

One place of worship has been identified as being affected by the M2 Upgrade Project. This is detailed in **Table 45** below. The relevant noise contours are presented in **Appendix K**.

Table 45 Assessment of Places of Worship

Place of Worship	ECRTN Criteria (dBA)		Future Noise Levels Above ECRTN Criteria and Incremental Impact > 2dBA?	Future Noise Levels Acute? (≥60 dBA $L_{Aeq(9hour)}$)	Additional Mitigation Identified?
	Daytime	Night-time			
Our Lady of Lourdes Church	$L_{Aeq(1\ hr)}$ 40 dBA (internal)	$L_{Aeq(1\ hr)}$ 40 dBA (internal)	No	No	No

Note 1: The ECRTN defines the Daytime as 07.00 am to 10.00 pm and the Night-time as 10.00 pm to 07.00 am

At Our Lady of Lourdes Church, where no modification to the existing noise walls are proposed, the 2021 Future *Design* noise levels are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels, neither are the 2021 Future *Design* noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated

Inspection of the surrounding area to the church grounds also concludes that a 4.2 m noise wall is already in place along the site boundary on the sides that face towards the M2 motorway.

Areas of Active Recreation

A number of areas where active recreation occurs have been identified. These are listed in **Table 46**, and illustrated on the noise contours contained **Appendix L**.

Table 46 Assessment of Areas of Active Recreation

Area of Active Recreation	ECRTN Criteria (dBA) Daytime	Future Noise Levels Above ECRTN Criteria and Incremental Impact > 2dBA?	Future Noise Levels Acute? (≥65 dBA $L_{Aeq(15hour)}$)	Additional Mitigation Identified?
Gooden Reserve[2]	Freeway / Arterial Roads: $L_{Aeq(15 hr)}$ 60 dBA	No	-	No
Max Ruddock Reserve[2]		No	-	No
Muirfield Golf Course		No	No	No
Pennant Hills Golf Course		No	No	No
Cheltenham Oval		No	No	No
Epping Oval Athletics Track		No	No	No
Jim Campbell Field		No	No	No
Roger Sheeran Oval		No	No	No
Christie Park		No	No	No

Note 1: The ECRTN defines the Daytime as 07.00 am to 10.00 pm and the Night-time as 10.00 pm to 07.00 am
Note 2: Located outside of the M2 Project Area, therefore only incremental impact required to be assessed.

The assessment of areas of active recreation shows that at all locations, the 2021 Future *Design* noise levels are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels. The 2021 Future *Design* noise levels at the locations which are within the M2 Project Area are also not predicted to be acute. As such, there is no requirement for additional mitigation to be investigated.

It is also noted that in these areas no alteration of the existing noise walls is proposed as part of the M2 Upgrade Project.

Hospital Wards

The ECRTN noise goal for hospital wards is an internal $L_{Aeq(1hour)}$ noise level of 35 dBA. This applies to both the day and night-time periods.

One hospital has been identified as being affected by the M2 Upgrade Project - the Macquarie University Hospital. At the time of writing, it is anticipated that Macquarie University Hospital will open in the first half of 2010.

As the hospital buildings at the Macquarie University Hospital will be newly constructed it has been assumed that mechanical ventilation will be provided to all ward rooms and hence there would be no requirement to open windows. A conservative external to internal noise reduction of 20 dBA has therefore been applied which results in an external $L_{Aeq(1hour)}$ noise level at the building facade of approximately 55 dBA.

The location of the hospital is highlighted in red in **Figure 22**

Figure 22 Location of Macquarie University Hospital

Image Courtesy of Google Earth

It is noted that the Macquarie University Hospital is located near to proposed upgrade of the Christie Road interchange. The upgrade works include:

- A new eastbound on-ramp to the M2 Motorway at Christie Road
- Widening of the Christie Road Bridge and Talavera Road (between Christie Road and Herring Road)

The assessment of Macquarie University Hospital is detailed in **Table 47**, and illustrated on the noise contours contained **Appendix M**.

It is noted that re-surfacing of the Christie Road and Talavera Road intersection would be completed as part of the upgrade works. To be consistent with the main operational assessment, no correction factor has been applied to the re-surfaced Future *Design* model.

Table 47 Assessment of Hospitals

Hospital Ward	ECRTN Criteria (dBA)		Future Noise Levels Above ECRTN Criteria and Incremental Impact > 2dBA?	Future Noise Levels Acute? (≥60 dBA LAeq(9hour)	Additional Mitigation Identified?
	Daytime	Night-time			
Macquarie University Hospital	LAeq(1 hr) 35 dBA (internal)	LAeq(1 hr) 35 dBA (internal)	No	No	No

Note 1: The ECRTN defines the Daytime as 07.00 am to 10.00 pm and the Night-time as 10.00 pm to 07.00 am

The above assessment of the potential noise impacts at the Macquarie University Hospital indicates that the 2021 Future *Design* noise levels are not predicted to rise by more than 2 dBA over the 2011 Future *Existing* levels. As the 2021 Future *Design* noise levels are also not predicted to be acute, there is no requirement for additional mitigation to be investigated

9.7.11 Upgrade to Alignment at Windsor Road Intersection

As part of the M2 Upgrade Project it is proposed to add two additional on/off access ramp at the Windsor Road Intersection with the M2 Motorway. The current junction layout will therefore be required to be significantly altered to allow efficient access to and from the M2.

The properties that are located on Windsor Road in the vicinity of the proposed eastbound off-access ramp are of sufficient distance to not be affected to the realignment of this side of the intersection, however, the proposed layout for the westbound on-access ramp (to the immediate south of the junction) has the potential to impact on the residential receivers in this vicinity as they are situated much closer.

There are a number of properties of Windsor Road which are likely to be affected by the alignment change. Currently the buildings are set back by approximately 10 m to 15 m from Windsor Road. The proposed re-alignment would bring the road to within approximately 5 m to 10 m of some of the properties.

It is noted that three of the affected properties are multi-unit buildings (258 Windsor Road). These three multi-unit residencies are noted as being recently constructed and were not able to be included within the noise model. Assessment of noise impact due to the re-alignment of the Windsor Road junction has therefore been performed using noise contours at their footprint location.

The various contours are illustrated in **Appendix N**. Noise contours have been predicted at both ground floor and first floor heights (1.5 m and 4.3 m above the local ground respectively).

Future *Design* noise levels have been predicted for the 2021 night time $L_{Aeq(9hour)}$ scenario only, as the criterion for this assessment period is the more stringent of the criteria. The 2021 scenario includes the upgrades to the noise walls as discussed in **Table 40**.

A +2.5 dB correction factor has been included in all the contour data calculations to allow for the conversion of free field noise level into facade levels, as required by the ECRTN.

Reference to the grid noise within **Appendix N** shows that Future *Design* noise levels for six properties in the immediate vicinity of the re-alignment at Windsor Road are predicted to be acute (ie >60 dBA $L_{Aeq(9hour)}$). As these properties are directly accessed from Windsor Road and the construction of a noise wall is subsequently not feasible, these properties are therefore to be considered for property treatment mitigation (and have been include in **Table 41 – "2021 Exceedance Locations and Residual Architectural Property Treatments")**.

It is noted that 266 Windsor Road, which is affected by the re-alignment of the intersection, is a heritage listed building.

9.7.12 Secondary Roads – Potential Noise Impacts

As the M2 Upgrade Project has the potential to create additional traffic flows on the secondary roads which intersect with the M2, an assessment of the likely impacts resulting from this has been completed. The roads which form part of this assessment include:

- Windsor Road
- Pennant Hills Road
- Beecroft Road
- Lane Cove Road

It is noted that impacts from the alterations to Christie Road, Herring Road and Talavera Road form part of the main assessment.

A comparison of the 2011 Future *Existing* and the 2021 Future *Design* traffic volumes has been undertaken to determine the potential noise increase. This assessment found that the highest increase was apparent on Windsor Road (as a result of the new west facing access ramps) where a 14 % increase for the 2021 traffic flows is anticipated. This equates to a marginal noise level increase of around 0.6 dBA.

9.7.13 Sleep Disturbance Assessment

When assessing short term maximum noise levels from the M2 Upgrade Project, the current sleep disturbance guidelines used in NSW have been considered (refer to **Section 5.5.3**).

A review of research on sleep disturbance in the ECRTN indicates that in some circumstances, higher noise levels may occur without significant sleep disturbance. Based on studies into sleep disturbance, the ECRTN concludes that:

- Maximum internal noise levels below 50 dBA to 55 dBA are unlikely to cause awakening reactions.
- One or two noise events per night, with maximum internal noise levels of 65 dBA to 70 dBA, are not likely to affect health and wellbeing significantly.

It is generally accepted, that internal noise levels in a dwelling, with the windows partially open, are 10 dBA lower than external noise levels (refer to **Table 43**). Based on a worst case minimum attenuation with windows partially open, the first conclusion above suggests that short term external noises of 60 dBA to 65 dBA are unlikely to cause awakening reactions.

The ENMM therefore defines a maximum noise event as any passby for which:

- The L_{Amax} noise level exceeds the $L_{Aeq(1hour)}$ noise level by at least 15 dBA *and* is in excess of 65 dBA.

As there is potential for heavy vehicles to use compression braking to slow upon exiting the M2 Motorway at the location of the proposed new eastbound Windsor Road off-access slip road, a maximum noise level assessment has been performed in this location.

Background noise monitoring to determine the existing amount of maximum noise events was completed at 3 Horwood Avenue, Baulkham Hills, on the evening of 9 February 2010. **Table 48** summaries the results of this noise monitoring.

Table 48 Maximum Noise Level Assessment

Date	Time Period	Measured Noise Level $L_{Aeq(1hour)}$ (dBA)	Number of Maximum Noise Events per Hour
09/02/2010	22:00 – 22:59	56.7	6
	23:00 – 23:59	56.1	12
10/02/2010	00:00 – 00:59	53.2	10
	01:00 – 01:59	53.9	9
	02:00 – 02:59	53.9	16
	03:00 – 03:59	55.6	3
	04:00 – 04:59	58.4	8
	05:00 – 05:59	60.1	4
	06:00 – 06:59	58.9	4
		TOTAL NUMBER OF MAXIMUM NOISE EVENTS	**72**

Results of the analysis of the maximum noise levels show that a maximum noise event (as defined within the ENMM) occurred a total of seventy two times at 3 Horwood Avenue, over the night of monitoring. The measured L_{Amax} maximum noise level events varied between 68 dBA and 81 dBA.

Maximum Noise Level Assessment - Discussion

The assessment of maximum noise levels which are subject to the receivers in the vicinity of the proposed eastbound Windsor Road off-access ramp concludes the following:

- The traffic data for the M2 Upgrade Project as supplied to Heggies shows an increase in traffic (2011 Future *Existing* and 2021 Future *Design*) on the M2 Motorway carriageway in this location which equates to a noise level increase of around 1 dBA. The mix of light and heavy vehicles is noted as remaining the same.
- However, the construction of the proposed new Windsor Road off-access ramp is expected to result in a reduction in L_{Aeq} noise levels at the sensitive receivers situated in the vicinity as a result of the proposed access ramp being required to be built up and hence effectively acting as a noise barrier to the road traffic on the main M2 carriageway (which is the dominant source of noise). This has previously been discussed in **Section 5.5.1** and **9.7.4**.
- Sensitive receiver L_{Aeq} noise level reductions of around 2 dBA to 4 dBA have therefore been predicted between the 2011 Future *Existing* and 2021 Future *Design* scenarios in this location.
- The noise barrier effect of the new Windsor Road (west-facing) ramps will induce a comparable reduction for 2021 Future *Design* L_{Amax} noise levels associated with road traffic on the main M2 Carriageway. As such, the number of maximum noise events associated with heavy vehicles travelling on the main carriageway in this location is anticipated to either remain the same or potentially reduce slightly as a result of the additional attenuation provided by the construction of the proposed off-access ramp.
- The proposed off-access ramp would however bring vehicles (using the off-access ramp) closer to the sensitive receivers in this location: 3 Horwood Avenue is currently ~25 m from the carriageway, the distance from the proposed access ramp to this property would be ~15 m. Although the heavy vehicles on the proposed off-ramp are predicted to be an order of magnitude less than the number of heavy vehicles on the main M2 carriageway, their proximity to the nearest receivers to the north suggests there is potential for the number of maximum noise level events associated with heavy vehicles exiting the M2 via the proposed eastbound off-access ramp to increase slightly compared to current conditions.

9.7.14 Staged Re-Opening of M2 – Operational Impacts

A staged re-opening process is anticipated for the M2 Upgrade Project, occurring in the following manner:

- New west-facing Windsor Road access ramps and tolls – to be operational 14 to 15 months after start of construction.
- New Christie Road and Herring Road access ramp and tolls, including Talavera Road widening – to be operational 21 months after start of construction.
- Widening of Western Zone (Zone 1) from Windsor Road to Pennant Hills Road (including the re-sheeting of the main carriageway) – to be operational 15 to 18 months after start of construction.

The remaining sections of the upgrade works are expected to be completed and then re-opened around 24 months after the construction works commence.

As indicated above, when the construction or upgrade of a particular section of the M2 Motorway is completed, it is expected that it will be fully re-opened to normal operational traffic flow.

Operational Impacts

As the re-opening of a particular section of the M2 would only occur after all the works associated with that section have been completed, it is therefore anticipated that no adverse sensitive receivers noise impacts will be apparent at locations where staged re-opening occurs. For example, in the case of the new Windsor Road west-facing access ramps, the proposed noise walls for these ramps will be in place at the time of the opening of this component of the upgrade works.

9.7.15 Signage to Limit Use Compression Braking by Heavy Vehicles

As the M2 Motorway is subject to significant volumes of heavy vehicles which have the potential to cause noticeable sensitive receiver noise impacts, a suitable strategy to help mitigate heavy vehicle noise may include the erection of signage which attempts to target the inappropriate use of engine/compression brakes.

Some success has previously been achieved on certain major arterial routes in NSW with the use of such signage to promote awareness of their use in residential areas. The newly proposed Windsor Road west-facing access ramps are locations where this could considered.

9.7.16 Bridge Expansion Joints

The M2 Upgrade Project would require modifications to several of the existing bridges which form part of the current alignment. As the impulsive noise from expansion joints in bridges can create significant localised impacts, it is therefore recommended that where expansion joints require replacement or modification as part of the M2 Upgrade Project, the selecting of suitable components should consider the potential noise generating characteristics in an attempt to minimise the impact on the sensitive receivers which are, in some location, situated in very close proximity to some of the bridge joints.

9.7.17 Norfolk Tunnel Widening - Operational Impacts

As part of the M2 Upgrade Project, it is proposed to widen both directions of the existing Norfolk Tunnel to provide an additional lane in the eastbound direction and upgraded lanes in the westbound direction.

Reference to the 2021 Future *Design* facade maps in **Appendix E** concludes that two ground floor and seven first floor properties are predicted to be acute and are therefore eligible for consideration for property treatment. All such properties have previously been identified in **Table 41 – "2021 Exceedance Locations and Residual Architectural Property Treatments"**.

In is however noteworthy that the difference plots in **Appendix F** show that these properties are not subject to an increase of more than 2 dBA as a result of the project.

It is further noted that no additional noise generating equipment (ie additional exhaust fans) is proposed as part of the tunnel upgrade works.

9.8 Stationary Noise Impacts from Mechanical Plant

The only mechanical plant items associated with the M2 Upgrade Project are the exhaust fans located in the Norfolk Tunnel. The exhaust fans are attached in pairs to the centre of the crown of the roof of each of the tunnels.

9.8.1 Noise Goals

Based on Industrial Noise Policy criteria as detailed in **Section 5.6**, **Table 49** presents the calculated RBL and ambient L_{Aeq} noise levels, along with the resulting intrusive and amenity noise goals for a representative residential receiver based on the "suburban area" classification.

The $L_{Aeq(15minute)}$ design noise goal is the *lower* of the intrusive and amenity goals and has been included in the table in bold face type.

Ambient noise level data was measured at both 4 Somerset Street and 56 Somerset Street, which are in the vicinity of the western and eastern tunnel portals respectively. The monitoring at 56 Somerset Street has been used in the following assessment as it was found to have lower ambient levels of noise.

Table 49 Calculated RBL and Ambient L_{Aeq} Noise Levels for Norfolk Tunnel Locations

Location	Period[1]	Recommended LAeq Noise Level[2]	Measured RBL[3]	Measured LAeq	Intrusive Criterion	Amenity Criterion
56 Somerset Street, Epping	Day	55	49	54	54	**49**
	Evening	45	45	51	50	**41**
	Night	40	33	49	**38**	39

Note 1: DECCW Governing Periods are - Day: 7.00 am to 6.00pm, Evening: 6.00pm to 10.00pm, Night: 10.00pm to 7.00 am

Note 2: Criteria are for Residences in a Suburban Area

Note 3: Rounded to nearest dB

The operation of the existing Norfolk Tunnel exhaust fans were noted by the Heggies Technician as not being audible at the logger location detailed above.

9.8.2 Noise Impact Assessment

Detailed noise emission calculations for the proposed exhaust fans have been performed and assessed against the EPA's *"NSW Industrial Noise Policy"* (2000). The noise modelling of the mechanical plant has been carried out using the SoundPLAN V6.5 suite of acoustics software using the CONCAWE prediction model.

The assumptions used within this analysis include the following:

- A representative sound power level of approximately 85 dBA per (silenced) fan-pair has been assumed based on several previous studies carried out recently by Heggies.
- As each tunnel portal will have one fan-pair per carriageway, noise levels are assessed on the basis of two exhaust fan-pairs per carriageway.
- The exhaust fans will operate on a continuous basis for the 15 minute assessment period.
- The nearest affected residential receiver to either of the tunnel portals is 3A Constance Close and is approximately 60 m away from the end of the western portal.
- The noise model incorporates all the proposed changes which would form part of the M2 Upgrade Project (ie updated motorway alignment, altered cuttings and batter slopes, altered noise walls, etc), as described in the preceding sections of this report

Table 50 summaries the calculations related to exhaust fan noise emissions assessed at the nearest critical receiver to the tunnel portals.

Table 50 Norfolk Tunnel Noise Emission Calculations

Computation Item	L_{Aeq} Noise Level
Sound Power Level L_{Aeq} noise emission for a single fan (x2)	85 dBA
Noise level target (day, evening, night)	49 dBA, 41 dBA, 38 dBA
Predicted L_{Aeq} noise level at nearest receptor	31 dBA

Noise levels have been predicted to be below the target noise levels.

9.9 Vibration

Heggies has previously monitored vibration levels due to heavy vehicle traffic. Vibration levels of up to 0.4 mm/s were measured in a range of different geotechnical conditions (ie varying soil types) at a distance of approximately 10 m from the road.

Vibration generated from vehicles (in particular heavy vehicles) travelling along the M2 Motorway – main carriageway, on/off ramps and the Norfolk Tunnel – is therefore not expected to give rise to levels of vibration exceeding the daytime or night-time human comfort criteria recommended in AS 2670.

This is subject to regular maintenance of the roadway to repair any significant potholes, etc, as they occur.

10 CONCLUSION

The purpose of this report is to assess the potential noise and vibration emissions associated with the construction and operation of the proposal. Based on the proposed road alignment, this report identifies the principle areas where noise or vibration mitigation is considered likely to be required.

Construction Noise and Vibration

The M2 Upgrade Project represents a major infrastructure development project, constructed over two years, and as such there would be periods when impacts on the surrounding areas are expected. As it will be necessary for the motorway to, at least partly, remain open during the daytime, works would often be required to be conducted during the less busy night-time period.

At any particular location, the potential noise and vibration impacts can vary greatly depending on factors such as the relative proximity of noise-sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration emissions, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

Notwithstanding the above, it is anticipated that compliance with the daytime Noise Management Levels (NMLs) is typically predicted as a result of the already high ambient noise environment along the route of the M2 Motorway. However, during the evening and night-time periods, higher exceedances are predicted, where sensitive receivers are situated in close proximity to the proposed construction works, as a result of the lower NMLs. Careful management will therefore be required at the nearest receivers.

In general, vibration produced by earthworks and road forming operations is expected to lie below structural damage criteria. Where vibration-intensive operations are being conducted in close proximity to the buildings nearest to the roadworks (eg construction of the Windsor Road Ramps), judicious selection of plant and equipment will be necessary.

At the locations of the Site Compounds, the predicted levels are expected to exceed the NMLs where receivers are situated close by and no natural shielding is apparent. To adequately mitigate the impacts, feasible mitigation measures could include the use of 3 m to 6 m high temporary perimeter noise walls. The exact requirement for these would be investigated in more detail as the project progresses.

During the widening of the Norfolk Tunnel both airborne and ground-borne noise has the potential to exceed the appropriate criteria at times. The potential noise impacts from the widening works which will be performed entirely within the tunnel will be mitigated with the use of acoustic sheds during the excavation of the tunnel, together with an acoustic curtain at either end of tunnel at other times. The acoustic shed will only be in place for the excavation phase of the widening. All other night-time works within the tunnels will have a noise curtain in place at the portal entrances.

For the early widening works (ie adjustment to the portal transition areas and breaking out of existing concrete barriers) there would be limited mitigation measures, as the options for physical noise attenuation devices and procedural management measures (such as scheduling of activities) would either not be effective or are not feasible.

It is recommended that where exceedances are indicated, suitable consultation with the affected land owners should take place to determine the appropriate feasible and reasonable management strategies, together with monitoring to confirm the predicted levels.

A detailed Construction Noise and Vibration Management Plan (CNVMP) would be appropriate to address the potential noise and vibrations impacts associated with construction of the proposed M2 Motorway Upgrade Project. The mitigations measures and strategies outlined in this assessment should be considered for inclusion in that management plan.

Operational Noise

The operational noise assessment was undertaken in accordance with the Environmental Criteria for Road Traffic Noise and the RTA's Environmental Noise Management Manual. These documents provide non-mandatory noise criteria for redevelopment of existing roads, and highlight processes for determining where the potential noise impacts would require the need for additional mitigation measures to be investigated.

With the incorporation of the mitigation measures as discussed in this report, the future noise levels resulting from the M2 Upgrade Project at the majority of sensitive locations do not exceed the criteria relevant to the project and consequently no further assessment of mitigation measures is required at these locations. Where residual exceedances are apparent, architectural building treatments would also be required.

When determining appropriate strategies to address potential operational noise issues, preference has been given to the use of noise walls, where feasible and reasonable, over architectural treatment of properties to mitigate sensitive receiver noise levels.

An optimisation process (including a cost-benefit analysis) has been undertaken when designing the noise walls for the M2 Upgrade Project using the approach outlined in the RTA's ENMM. All of the noise wall designs presented within this Report therefore reflect these RTA procedures. The need for architectural treatment to address residual exceedances of the adopted noise objectives has been considered as part of the optimisation process. A total of 91 properties have been identified as requiring consideration for architectural treatment. Architectural treatment would however be subject to feedback from the community consultation process which would be performed as part of the detailed design phase of the project.

Furthermore, the final mix of the selected noise mitigation strategies will be determined after the opinions of the local affected community have been consulted. The local affected community might prefer (on aesthetic grounds) a different option mix of noise barriers and property treatment than has been proposed in this assessment. The benefits of community preferred options would then need to be considered in light of additional factors such as future noise levels in the affected area and changes in land use in the local area.