Appendix H: Noise Assessment Report (Bassett, 2006)

M5 East Tunnel Filtration Trial
Noise Assessment Report

Construction and Operational Noise and Vibration Assessment

NSW RTA C/O Maunsell Australia Pty Ltd

September 2006

Noise Assessment Report

Prepared for

NSW RTA C/O Maunsell Australia Pty Ltd

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1.0 Introduction

1.1 Background

Bassett Acoustics was commissioned by Maunsell Australia Pty Ltd on behalf of the NSW Roads and Traffic Authority (RTA) to provide a construction and operational noise and vibration assessment as part of the Environmental Assessment (EA) of the proposed M5 East Filtration Plant. This assessment will:

- Identify all sensitive receivers likely to be affected by operational and construction noise and vibration;
- Establish operational environmental noise emission criteria at sensitive locations;
- Calculate the environmental noise levels likely to be associated with the operation of the filtration system;
- Recommend appropriate mitigation measures to control operational environmental noise emission to the appropriate criteria;
- Establish objectives by which construction noise and vibration impacts at sensitive locations may be evaluated;
- Calculate noise and vibration levels likely to be associated with the construction works and evaluate the extent of resulting impacts; and
- Recommend appropriate mitigation measures and performance requirements to be considered further during construction planning and detailed design in order to protect community values and sensitive locations from construction noise and vibration.

Ambient noise levels were continuously monitored for a period of seven days from Thursday 6th July, 2006 until 13th July, 2006 at 5 Johnston Street, Earlwood. It is noted that the noise measurements were completed during the NSW school holiday period during which the traffic volumes may have been marginally reduced at peak times. A 25% reduction in traffic volume is required to reduce noise levels by 1 dB(A). As this level of traffic volume reduction is unlikely to have occurred, the measured noise levels are taken as being representative of the acoustic environment.

The measurements were used to establish the operational environmental noise emission criteria and the construction noise objectives in accordance with procedures recommended by the Department of Environment and Conservation (DEC) (formerly the Environment Protection Authority, EPA) and relevant Australian Standards.

Recommendations have been made to ensure that operational environmental noise emission would meet all relevant criteria. Recommendations have also been presented to ensure a best practice approach is used to minimise construction noise intrusion at sensitive receivers.

Appendix A contains a glossary of acoustic terms used in this assessment.

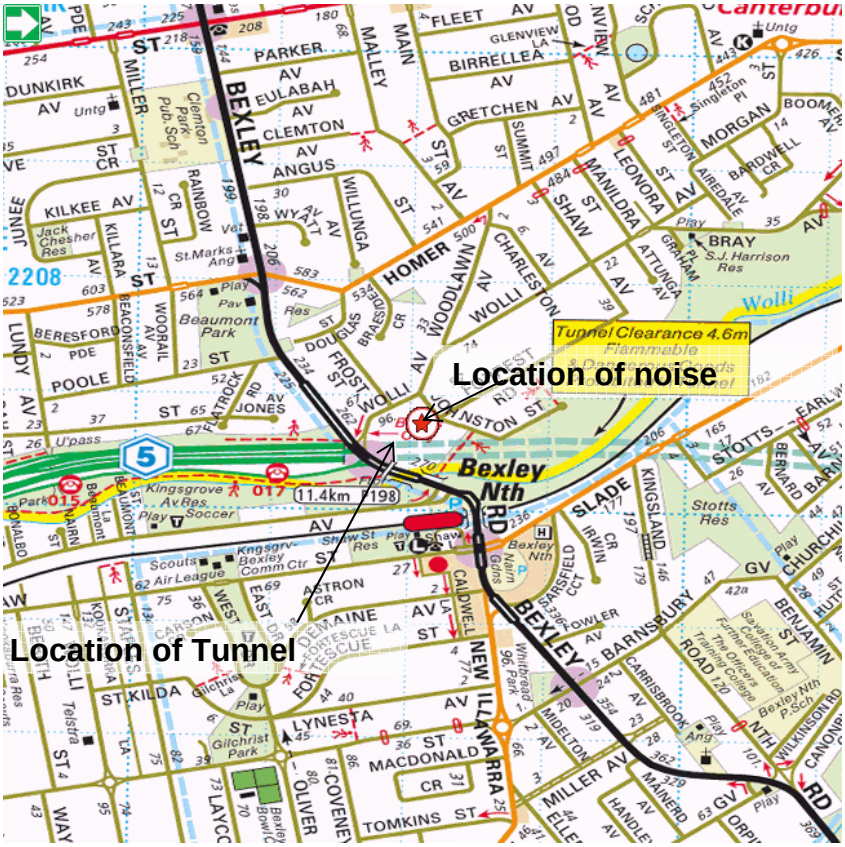
1.2 Works Description

The proposed M5 East Filtration Plant comprises:

- A building approximately 40 m x 20 m x 8 m in bulk at the surface to house the filtration equipment, water treatment plant, jet fans, offices, monitoring laboratory and amenities at the former Bexley Road M5 East construction compound site;
- An approximately 250–500 m long ventilation tunnel for extracting unfiltered tunnel air, concrete block ducting for directing air through the Filtration Plant and returning filtered air for injection back into the westbound tunnel;
- Connections to services including existing power, water, sewer and stormwater systems; and,
- Car parking and landscaping.

A portion of air will be extracted from the western section of the westbound traffic tunnel and delivered into the air filtration plant for treatment before being reinjected into the westbound tunnel.

Figure 1.1 - Site Location Plan



1.3 Affected Properties

The noise and vibration sensitive receivers close to the development site which may be affected by the construction works have been identified as follows:

- Residential Properties on Johnston Street and Wolli Avenue, Earlwood;
- Residential Properties on Slade Road and Kingsland Road, Bexley North;

- Areas specifically reserved for passive recreation such as Wolli Creek Regional Parks and Stott's Reserve; and,
- Aboriginal Heritage Sites including artefacts, shells and earthmounds, Earlwood

1.4 Construction Methodology

The proposed modifications works will require the construction of the following:

- Site establishment including a temporary compound for storage of equipment, staff offices and amenities, site access points and car parking facilities;
- Temporary ramp and portal to provide access for spoil trucks and road header;
- Connection of power for use by road header and filtration plant;
- Installation of a temporary ventilation system, including a dust collector and acoustic silencer, for use during tunnelling;
- Excavation of the new ventilation tunnel;
- Concurrent construction of the surface facility to house filtration plant, fans, and monitoring equipment; and
- Air extraction and injection connections to the M5 East westbound tunnels.

Construction activities would be managed in accordance with the relevant Construction Method Statements (CMS). Where appropriate, Construction Noise Impact Assessments would be prepared for each relevant CMS.

In summary, the following key items of plant and equipment would be required during construction activities.

Table 1.1 - Proposed Modification and Associated Plant and Equipment

Activity	Key Plant and Equipment	Estimated Duration
Site establishment and office/amenities setup	• Concrete agitator trucks • Road transport trucks • Excavators • Concrete pumps • Generators	4 weeks
Surface excavation - portal access and facility foundations	• Bored piling machine • Concrete agitator trucks • Concrete vibrators • Road transport trucks • Excavators • Rock hammers • Concrete pumps	2 – 3months
Ventilation tunnel construction and M5 East connections	• Roadheader • Ventilation fans and dust collector • Road transport trucks • Excavators • Rock hammers • Rock bolters • Shotcreting equipment	8 months

Activity	Key Plant and Equipment	Estimated Duration
Filtration facility construction and plant fit-out	• Mobile crane • Forklifts • Welding equipment • Road transport trucks	8 months
Filtration plant operations	• Road transport trucks for deliveries and waste removal • Light vehicles for staff access	Initial 12 month trial period

Note: An alternative construction methodology for surface excavation may include the use of a dozer fitted with a ripper or the use of a splitter charge such as PCF. This methodology may result in a shorter construction duration however, the use of hydraulic rock hammers is considered a worst case scenario for the purposes of this noise assessment. A detailed Construction Noise Impact Assessment would be included in the relevant CMSs.

1.4.1 Hours of Operation

Construction Phase

To ensure minimal disruption to residents and businesses, the standard construction hours for the project would generally be limited to between 7.00 am and 6.00 pm Monday to Friday and 7.00 am and 1.00 pm on Saturday (from 8.00 am on Saturdays if work is audible at residences). No work would take place on Sundays or public holidays.

All surface rock breaking rock hammering and other activities which would result in impulsive or tonal noise generation would be limited to the following hours unless otherwise agreed by the Environmental Management Representative (EMR):

- 8 am to 12 pm, Monday to Friday;
- 2 pm to 5 pm, Monday to Friday;
- 8 am to 12 pm on Saturday.

Where these activities are undertaken for a continuous three (3) hour period and are audible to noise sensitive receptors, a minimum respite period of at least 1 hour shall be scheduled before activities recommence.

Work may be permitted outside these standard construction hours. In order that activities undertaken outside the normal working hours do not cause an unreasonable nuisance or disturbance to residents, this work would be restricted to the following:

- 24 hour tunnelling by roadheader only (including ventilation fans and dust collectors);
- Any works which do not cause noise emissions to be audible at any nearby residential property;
- The delivery of materials if requested by police or other authorities for safety reasons;
- Work which would significantly delay traffic or cause traffic management problems if undertaken during the standard construction hours;
- Other works, where a genuine need has been demonstrated and all reasonable measures would be implemented to minimise impacts; or,
- Emergency work to avoid loss of lives, property and/or to prevent environmental harm.

No below ground excavation using rock hammers would be undertaken between 10 pm and 7 am.

Filtration Plant Trial Operations

Operation of the filtration technology may be constant (i.e. twenty four hours per day, seven days per week), dependent upon the efficiency of the systems, maintenance needs and haze levels in the tunnel.

1.4.2 Indicative Construction Programme

The construction program is expected to take a total of 12 months plus time required for testing and commissioning. This would include the key phases shown in Table 1.2.

Table 1.2 - Indicative Construction Program

Activity	Duration (months)	Consecutive/Concurrent
Tunnelling	8	Concurrent
At surface construction (excavation and building erection)	8	Concurrent
Filtration plant manufacture and installation	9	Concurrent
Testing and Commissioning	6	Consecutive to above activities

1.4.3 Construction Traffic Access

Construction traffic including trucks for spoil removal would access the site from Bexley Road. When exiting the site trucks would use Bexley Road when travelling north, south or east and the M5 East when travelling west. The proposed spoil disposal locations are dispersed through the city and wherever possible trucks would remain on State or Regional roads. However, the small volume of trucks per day (estimated up to 25) indicates that the impacts would be minor.

2.0 Ambient Noise Measurements

An Infobyte S2 noise logger was used to continuously measure ambient noise levels close to the proposed development site. The major ambient noise sources in the area are road traffic noise and railway traffic noise. The logger was located in the rear garden of 5 Johnston Street, Earlwood and logged continuously from 11.15 am on Thursday 6th July until 8.45 am on Thursday 13th July 2006.

A noise logger measures the noise level over the sample period and then determines $L_{A,1}$, $L_{A,10}$, $L_{A,90}$, $L_{A,max}$ and $L_{A,eq}$ levels of the noise environment. The $L_{A,1}$, $L_{A,10}$ and $L_{A,90}$ levels are the levels exceeded for 1%, 10% and 90% of the sample period respectively. The $L_{A,max}$ is indicative of maximum noise levels due to individual noise events such as the pass by of a heavy vehicle. The $L_{A,90}$ is taken as the background noise level. The $L_{A,eq}$ level is the equivalent continuous sound level and has the same sound energy over the sample period as the actual noise environment with fluctuating sound levels.

The background noise level is defined by the Department of Environment and Conservation as "the underlying level of noise present in ambient noise when all unusual extraneous noise is removed". It can include sounds that are normal features of a location and may include birds, traffic, insects etc. The background noise level is represented by the $L_{A,90,15\ min}$ descriptor. The noise levels measured at 5 Johnston Street were analysed to determine a single 'Assessment Background Level' (ABL) for each day, evening and night-time period, in accordance with the DEC's NSW Industrial Noise Policy (INP). The ABL is established by determining the lowest ten-percentile level of the $L_{A,90}$ noise data acquired over each period of interest. Table 2.1 below presents individual ABLs for each day's assessment periods. The background noise level or 'Rating Background Level' (RBL) representing the day, evening and night-time assessment periods is based on the median of individual ABLs determined over the entire monitoring period. Table 2.1 also presents the existing $L_{A,eq}$ ambient noise level, selected for each day, evening and night-time period, in accordance with the INP. An overall representative $L_{A,eq}$ noise level is determined by logarithmically averaging each assessment period for the entire monitoring duration.

Table 2.1 - Existing Ambient Noise Levels at 5 Johnston Street, Earlwood

Day	$L_{A,90}$ Background Noise Levels			$L_{A,eq}$ Ambient Noise Levels		
	Day	Evening	Night	Day	Evening	Night
Thursday 6th July, 2006	-	55	45	-	61	58
Friday 7th July, 2006	57	55	47	62	62	58
Saturday 8th July, 2006	56	55	47	62	61	59
Sunday 9th July, 2006	55	55	45	64	61	58
Monday 10th July, 2006	55	54	43	62	62	57
Tuesday 11th July, 2006	57	53	44	62	60	58
Wednesday 12th July, 2006	57	55	45	62	61	57
RBL / Log Average	**56**	**55**	**45**	**62**	**61**	**58**

Notes:

1. Day is defined as 7:00am to 6:00pm, Monday to Saturday and 8:00am to 6:00pm Sundays & Public Holidays.
2. Evening is defined as 6:00pm to 10:00pm, Monday to Sunday & Public Holidays.
3. Night is defined as 10:00pm to 7:00am, Monday to Saturday and 10:00pm to 8:00am Sundays & Public Holidays

3.0 Operational Environmental Noise Emission Criteria

3.1 Noise Emission Criteria – DEC's Industrial Noise Policy

The Department of Environment and Conservation provides guidelines for external noise emissions from developments. These guidelines for industrial noises are provided in the New South Wales Industrial Noise Policy (INP) and apply to all mechanical plant installed at the development.

The assessment procedure for industrial noise sources has two components:

a) Controlling intrusive noise impacts in the short term for residences

b) Maintaining noise level amenity for residences and other land uses

3.1.1 Intrusive Noise Impacts

The INP states that the noise from any single source should not intrude greatly above the prevailing background noise level. Industrial noises are generally considered acceptable if the equivalent continuous (energy-average) A-weighted level of noise from the source ($L_{A,eq}$), measured over a 15 minute period, does not exceed the background noise level measured in the absence of the source by more than 5 dB. This is often termed the Intrusiveness Criterion.

The 'Rating Background Level' (RBL) is the background noise level to be used for assessment purposes and is determined by the methods given in the INP. Using the rating background noise level approach results in the intrusiveness criterion being met for 90% of the time. Adjustments are to be applied to the level of noise produced by the source that is received at the assessment point where the noise source contains annoying characteristics such as tonality or impulsiveness.

During the night-time, which will be the controlling period because it is the quietest, the RBL at the 5 Johnston Street was 45 dB(A). The intrusiveness criterion is therefore 50 dB(A).

3.1.2 Operational Environmental Noise Emission Criteria

To limit continuing increases in noise levels, the maximum ambient noise level within an area from industrial noise sources should not normally exceed the acceptable noise levels specified in the INP. That is, the background noise level should not exceed the level appropriate for the particular locality and land use. This is often termed the "Background Creep" or Amenity criterion.

For a residential receiver in an urban area and an area reserved specifically for passive recreation, the recommended amenity criteria are shown in Table 3.1 below.

Table 3.1 - Recommended $L_{A,eq}$ Noise Levels from Industrial Noise Sources

Type of receiver	Indicative Noise Amenity Area	Time of Day	Recommended $L_{A,eq}$ Noise Level dB(A)	
			Acceptable	Recommended Maximum
Residence	Urban	Day	60	65
		Evening	50	55
		Night	45	50
Area reserved for passive recreation	-	When in use	50	55

When the existing noise level from industrial sources is close to the 'Acceptable Noise Level' (ANL) given above, noise from the new source must be controlled to preserve the amenity of the area in line with the INP. Industrial noise is not, however, significant at this site with the dominant noise source being that of road traffic.

Where the existing road traffic noise is high enough to render stationary noise sources effectively inaudible, the ANL can be modified so that the amenity criteria is not unduly stringent in an environment where road traffic noise is the dominant source of environmental noise. If all the conditions below are satisfied, the ANL becomes $L_{A,eq,traffic}$ minus 10 dB(A). The conditions are:

- The road traffic noise is the dominant noise source;
- The existing traffic noise is 10dB(A) or more above the acceptable ANL for the area; and
- It is highly unlikely the road traffic noise levels would reduce in the near future

These conditions occurred during the evening and night-time periods therefore the ANLs will be as shown in Table 3.2.

3.1.3 Summary of Environmental Noise Criteria

A summary of the intrusive and amenity criteria is given in Table 3.2 below.

Table 3.2 – Summary of Environmental Noise Criteria

Receiver	Period	RBL ($L_{A,90}$)	Intrusive Criterion = RBL + 5	Ambient $L_{A,eq}$	Amenity Criteria	Final Environmental Criteria
Residents	Day	56	61	62	60	**60**
	Evening	55	60	61	51	**51**
	Night	45	50	58	48	**48**
Passive recreation area	When in use	-	-	-	50	**50**

4.0 Operational Environmental Noise Emission Assessment & Recommendations

4.1 Fans

The only equipment associated with the Filtration Plant likely to produce significant environmental noise emissions are the ventilation fans. An indicative selection (As provided by Maunsell Australia Pty Ltd) has been assessed, namely four fans (Fantech AP2006F/A9/24) with a sound power level of $L_{A,W}$ of 111 dB(A). It is understood that these fans would be an integral part of the Filtration Plant and would be contained within a concrete structure.

Without the implementation of any noise control measures, it is possible that the $L_{A,eq}$ noise levels from the operation of the four fans would be approximately 63 dB(A) at residential receivers on Johnston Street, Earlwood. Therefore, if exceedances are predicted following completion of detailed design (when the proximity of the grilles to residential receivers is confirmed), acoustic louvres such as Fantech SBL2 may be required to be installed on inlet/outlet grilles. This is likely to reduce the $L_{A,eq}$ noise level to approximately 43 dB(A) at nearest residential receivers on Johnston Street, Earlwood

An Operational Noise Management Plan (ONMP) would be developed for the Filtration Plant in accordance with new Condition of Approval 65A. The ONMP would include:

- Detailed design of acoustic mitigation measures such as:
  - acoustic louvres
  - fan silencers or attenuators; and
  - building materials required in the construction of the filtration plant facility.
- Compliance noise monitoring program.

5.0 Construction Noise & Vibration Criteria

5.1 Department of Environment and Conservation Construction Noise Criteria

The NSW Department of Environment and Conservation's Environmental Noise Control Manual (ENCM) has been largely superseded by the NSW Industrial Noise Policy (INP) and the Noise Guidelines for Local Council (NGLC). Construction noise criteria were previously specified in the ENCM and have not been included in either of the aforementioned publications. The DEC have advised that they are currently developing new draft guidelines for managing construction noise which will adopt a "best practice" type approach that attempts to reduce construction noise to a level that is limited by what is feasible and reasonable.

The guidelines will require a construction noise management plan to be compiled by the developer. Noise level objectives must be set for the day time and evening periods, and must be complied with where reasonably practicable. The objective levels should be identical to those found in the ENCM however the noise descriptor to be used is the $L_{A,eq}$, which will be approximately 3 dB(A) less than the $L_{A,10}$ levels for construction noise. During the night time period, the noise limits detailed in the INP must be met. An objective differs from a limit in that it must be complied with where feasible and reasonable, whereas a limit must be complied with unconditionally.

The noise management plan should detail the "best practice" construction methods to be used, presenting a reasonable and feasible approach. The plan should identify the extent of the residential area affected and assess the impact on residents. The plan should detail any community relation programs which are planned e.g. prior notification for particularly noisy activities, letter box drop regarding out of hours construction work to be undertaken, etc and a 24 hour contact phone number for residents to call should they have any complaints or questions.

The construction site noise section, Chapter 171 of the ENCM, is reproduced below.

> *"**CONSTRUCTION SITE NOISE***
>
> *Where there is a likelihood of annoyance due to noise from construction sites, conditions such as the following may be specified in a development consent or building application. This applies particularly to non-scheduled premises such as commercial buildings where a long construction time is not likely. The criteria may not be applicable to long term constructions such as coal mines which may take several years. Variations should be made according to local conditions.*
>
> ***Level Restrictions***
>
> *(i) Construction period of 4 weeks and under*
> *The L_{10} level measured over a period of not less than 15 minutes when the construction site is in operation must not exceed the background level by more than 20 dB(A).*
>
> *(ii) Construction period greater than 4 weeks and not exceeding 26 weeks*
> *The L_{10} level measured over a period of not less than 15 minutes when the construction site is in operation must not exceed the background level by more than 10 dB(A)."*
>
> ***Silencing***
>
> *All possible steps should be taken to silence construction site equipment. It is particularly important that silenced equipment should be used on road or rail works where 24 hr operation is necessary."*

Note: Although not specifically stated, it is understood that when the construction noise activities exceed 26 weeks, the $L_{A,10}$ level should not exceed the background level by more than 5 dB(A).

5.2 Construction Noise Objectives

5.2.1 Residential Noise Objectives

The construction period is likely to be over 26 weeks, therefore the $L_{A,eq}$ objective will be 61 dB(A) during the day-time at the nearest residential receiver. The $L_{A,eq}$ criterion will be 48 dB(A) during the night-time period at the nearest residential receiver.

5.2.2 Tonal Corrections

For plant or operations with strong impulsive or tonal noise characteristics, such as pneumatic hammers, a noise penalty of 5 dB(A) should be added to the measured or predicted $L_{A,eq}$ (15 minute) noise levels when comparing $L_{A,eq}$ noise levels from construction noise to the objectives presented above.

5.2.3 Resultant Noise Objectives

Table 5.1 below indicates the construction noise objectives applicable to residential properties close to the development site.

Table 5.1 - Construction Noise Criteria Summary

Location	Receiver Type	Time Period	Construction Noise Objective $L_{A,eq}$
Residential Properties Johnston Street Wolli Avenue	Residential	Day	61 dB(A)
		Evening	60 dB(A)
		Night	48 dB(A)*

* During the night-time period, construction noise *limits* apply rather than *objectives*

5.3 Department of Environment and Conservation Construction Vibration Criteria

The DEC has developed a document, 'Assessing vibration: A Technical Guideline' in February 2006 to aid in protecting people from values of vibration above preferred and maximum values felt inside buildings. The guideline does not however address vibration induced damage to structures or building contents or structure-borne noise effects.

Vibration and its associated effects are usually classified as continuous, impulsive or intermittent as follows:

- Continuous vibration continues uninterrupted for a defined period (usually throughout daytime and/or night-time). This type of vibration is assessed on the basis of weighted rms acceleration values presented in the guideline;
- Impulsive vibration is a rapid building up to a peak followed by a damped decay that may or may not involve several cycles of vibration. It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds. Impulsive vibration is assessed on the basis of weighted rms acceleration values presented in the guideline; and
- Intermittent vibration can be defined as interrupted periods of continuous or repeated periods of impulsive vibration or continuous vibration that varies significantly in magnitude. It may originate from impulse sources or repetitive sources or sources which operate intermittently, but which would produce continuous vibration. This type of vibration is assessed on the basis of vibration dose value.

When applying the criteria, it is important to note that vibration may enter the body along different orthogonal axes, i.e. x-axis (back to chest), y-axis (right side to left side), or z-axis (foot to head). The three axes are referenced to the human body. Thus, vibration measured in the horizontal plane should be compared with x- and y-axes criteria if the concern is for people in an upright positions, or with the y- and z- axes criteria if the concern is for people in a lateral position (e.g. asleep at night). Where the orientation of the occupant is unknown or could vary, then the most conservative approach should be adopted.

5.3.1 Human Comfort Continuous Vibration Criteria

Structural vibration in buildings can be detected by the occupants and can affect them in many ways including reducing their quality of life and also their working efficiency. Complaint levels from occupants of buildings subject to vibration depend upon the use of the building and the time of day.

Maximum allowable magnitudes of building vibration with respect to human response are shown in Table 5.2 below. It should be noted that the human comfort criteria are more stringent than the building damage criteria.

Table 5.2 - Human Comfort Vibration Limits for Continuous Vibration (8Hz to 80Hz)

Type of Space Occupancy	Time of Day	Vibration Levels over the frequency range 8 Hz to 80Hz likely to cause "Adverse comment"			
		Vertical		Horizontal	
		mm/s (peak)	mm/s^2 (rms)	mm/s (peak)	mm/s^2 (rms)
Residential	Day	0.3-0.6	10-20	0.8-1.6	7-14
	Night	0.2-0.4	7-14	0.6-1.2	5-10

Adapted from BS6472

5.3.2 Human Comfort Intermittent Vibration Criteria

Disturbance caused by vibration will depend on its duration as well as its magnitude. This method involves the calculation of a Vibration Dose Value (VDV) which is used to evaluate the cumulative effects of bursts of intermittent vibration. Various studies have shown that VDV assessment methods far more accurately assess the level of disturbance than methods which assess the vibration magnitude only.

The VDV is the fourth root of the integral of the fourth power of vibration with respect to time. The VDV represents an 'amount' of vibration. In assessing the VDVs, criteria detailed in BS6472:1992 'Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80Hz)' are used, however the base values and multiples are converted into VDVs assuming constant levels over the 16 hour day and 8 hour night. The resulting VDV criteria are shown in Table 5.3.

Table 5.3 - Acceptable Vibration Dose Values for Intermittent Vibration ($m/s^{1.75}$)

Time Period	Low Probability of Adverse Comment
Residential Buildings Day (16 hr)	0.2–0.4
Residential Building Night (8hr)	0.13–0.26

Note: Daytime is 7.00am to 10.00pm; Night-time is 10.00pm to 7.00am

5.3.3 Structural Damage Vibration Criteria

Ground vibration criteria are defined in terms of levels of vibration emission from the works that will avoid the risk of damage to buildings and other structures. It should be noted that human comfort criteria are normally referred to in terms of acceleration whereas structural damage criteria are normally referred to in terms of velocity.

Most commonly specified 'safe' structural vibration levels are design to minimise the risk of threshold or cosmetic surface cracks and are set well below the levels that have the potential to cause damage to the main structure. Examples of threshold or cosmetic cracking include minor non-structural effects such as superficial cracking in cement render or plaster. Structural damage criteria are presented in German Standard DIN 4150-Part 3 'Structural vibration in buildings – Effects on Structures' and British Standard BS7385-Part 2:1993 'Evaluation and Measurement for Vibration in Buildings'. The most stringent of these criteria are applicable to these works.

The German Standard DIN 4150-Part 3 'Structural vibration in buildings – Effects on Structures' provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration. The standard presents recommended maximum limits over a range of frequencies measured in any direction at the foundation or in the plane of the uppermost floor of a building. Damage is defined as minor non-structural effects such as cracking in cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls. Table 5.4 indicates the vibration limits presented in DIN4150 to ensure structural damage does not occur.

Table 5.4 - Structural Damage Vibration Limits (PPV)

Type of Structure	Vibration Velocity Limit in mm/s			
	The measured value of the three orthogonal components measured at the foundation at a frequency of			The maximum value measured in the plane of the floor of the uppermost storey
	Less than 10 Hz	10 Hz to 50 Hz	50Hz to 100 Hz	All Frequencies
1. Buildings used for commercial purposes, industrial buildings and buildings of similar design	20mm/s	20 to 40mm/s	40 to 50mm/s	40mm/s
2. Dwellings and buildings of similar design and/or use	5mm/s	5 to 15mm/s	5 to 20mm/s	15mm/s
3. Structures that because of the particular sensitivity to vibration, do not correspond to those listed in Groups 1 or 2 and have intrinsic value (eg buildings that are under a preservation order)	3mm/s	3 to 8mm/s	8 to 10mm/s	8mm/s

The British Standard BS7385-Part 2:1993 'Evaluation and Measurement for Vibration in Buildings' provides recommended maximum levels of vibration against which the likelihood of cosmetic building damage from ground vibration can be assessed. Guide values for building vibration based on the lowest vibration levels above which cosmetic damage has been credibly demonstrated are presented. These are detailed in Table 5.5 below.

Table 5.5 - Transient Vibration Guide Values for Cosmetic Damage

Type of Building	Peak Component particle velocity in frequency range of predominant pulse (PPV)	
	4 Hz to 15 Hz	15 Hz and above
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

5.4 Construction Vibration Objectives

Table 5.6 below indicates the construction vibration criteria applicable to residential properties and heritage sites close to the development site.

Table 5.6 - Construction Vibration Criteria Summary

Location	Receiver Type	Human Comfort Vibration Objectives		Building Damage Objectives mm/s (peak)
		Continuous Vibration mm/s^2 (rms)	Intermittent $m/s^{1.75}$(VDV)	
Residential Properties Johnston Street & Wolli Avenue, Earlwood, Kingsland Road & Slade Road, Bexley North	Residential Day	10-20	0.2-0.4	5 mm/s
	Residential Night	7-14	0.13-0.26	5 mm/s
Aboriginal Heritage Site Artefact/Shell/Earthmound	Heritage	-	-	3 mm/s

5.5 Regenerated Noise Criteria

Vibration may pass from the ground into the structure of nearby residential buildings. The excitation of building elements may give rise to regenerated noise which may be audible within the internal spaces of nearby residential buildings.

Current NSW best practice for the management of regenerated noise from tunnelling works implemented for similar tunnelling projects in Sydney and most recently the Lane Cove Tunnel, are presented in Table 5.7.

Table 5.7 - Regenerated Noise Criteria for Residences

Time	Criteria $L_{A,eq\ (15\ min)}$
6.00 pm to 10.00 pm	40 dB(A)
10.00 pm to 7.00 am	35 dB(A)

These criteria are considered to be appropriate for this project.

6.0 Construction Noise and Vibration Assessment & Recommendations

6.1 Construction Equipment Noise Levels

Noise levels of various pieces of demolition, excavation and construction equipment were obtained from previous measurements and AS 2436-1981 'Guide to Noise Control on Construction, Maintenance and Demolition Sites'. Some were also taken from BS 5228: Part 1:1984 'Noise control on construction and open sites – Part 1 Code of practice of basic information and procedures for noise control' where equipment had not previously been measured and was not listed in the Australian Standard. The noise levels used in calculations are shown in Table 6.1.

Table 6.1 - Sound Power Levels of Construction Equipment

Equipment	Typical 'On time' in a 15 minute period (%)	Maximum Noise level $L_{A,eq}$ at 7m under load dB(A)	Estimated Sound Power Level ($L_{A,W}$) dB(A)
30T Excavator Bucket	100%	85	110
Excavator Mounted Hydraulic Rock Hammer	100%	94	119
Truck & Trailer	10%	84	109
25T Concrete Mixer	100%	84	109
Ventilation Fans & Dust Collector	100%	86	111

6.2 Construction Noise Assessment

A worst case scenario during the 'Surface excavation' and 'Ventilation tunnel construction' phases was analysed to determine the extent of mitigation required.

Table 6.2 - Calculated Construction Noise Levels at Residential Properties

Time Period	Worst Case Plant and Equipment in Operation	$L_{A,eq}$ Noise Level		Criterion
		No Noise Controls	With Noise Controls	
Residential Properties, Johnston Street, Earlwood				
Day-time	• Excavators with hydraulic rock hammers • Road Transport Trucks • Roadheader • Ventilation fans and Dust Collector	77 dB(A)	58 dB(A)	61 dB(A)
Night-time	• Ventilation fans and Dust Collector	62 dB(A)	38 dB(A)	48 dB(A)
Residential Properties, Wolli Avenue, Earlwood				
Day-time	• Excavators with hydraulic rock hammers • Road Transport Trucks • Roadheader • Ventilation fans and Dust Collector	77 dB(A)	59 dB(A)	61 dB(A)
Night-time	• Ventilation fans and Dust Collector	62 dB(A)	47 dB(A)	48 dB(A)

6.3 Recommendations

The following Conditions of Approval are identified as relevant to the management of the Modification Works:

- Condition of Approval No. 55 which specifies standard construction hours and outlines specific works which can be undertaken outside these hours;
- Condition of Approval No. 56 which requires the preparation of Construction Noise Impact Assessments for relevant Construction Method Statements (CMS); and
- Condition of Approval No. 57 which requires that construction noise monitoring is undertaken to verify compliance with the predictions made in the Construction Noise Impact Assessments.

As indicated in Table 6.2 it is likely that the construction noise objectives would be exceeded at times at the most affected residential boundaries during the construction period and on this basis reasonable and feasible noise control measures must be implemented for this period. This is most likely to occur as surface construction works are performed. With the implementation of reasonable and feasible noise control measures, however, it is likely that most construction noise objectives can be complied with. Indicative noise control measures include:

- The erection of a 2.4 m high barrier along the northern and western sides of the excavation area to shield residences in Johnston Street from construction noise;
- Installation of a roller shutter type door on the ventilation tunnel portal to minimise the noise breakout from work below the surface;
- Surface excavation works would be undertaken during the daytime period only;
- During the evening and night-time hours spoil must be stockpiled underground and the tunnel portal roller shutter doors must be kept closed; and,
- The construction ventilation system (Indicative selection: Fantech AP2006FA9/24) would be fitted with a 2D circular attenuator.

These control measures would be further considered in the relevant Construction Noise Impact Assessments. Additional best practice innovative noise mitigation measures to be considered include:

- Maximising the offset distance between noisy plant items and nearby noise sensitive receivers;
- Avoiding the co-incidence of noisy plant working simultaneously close together and adjacent to sensitive receivers;
- Orienting equipment away from sensitive areas;
- Carrying out loading and unloading away from noise sensitive areas;
- Selecting site access points and roads as far as possible away from sensitive receivers;
- Ensuring that vehicles required within the tunnels do not ‘queue’ outside the worksite prior to the morning 7 am start time;
- Ensuring all construction vehicles enter and leave the Site in accordance with site entry controls;
- Ensuring no truck associated with the work is left standing with its engine operating;
- Where reasonable and feasible equipment, including bulldozers, cranes, graders, excavators and trucks should have all reasonable and feasible noise controls fitted to reduce noise emission as much as is feasibly possible.. The noise attenuation measures could include:
    - The use of dampened rock hammers;
    - The encapsulation of engine chambers;

- Fitting ‘Department of Environment and Conservation (DEC)’ approved silencers to all powered operated plant; and
- The use of ‘smart’ reversing alarms which automatically adjust output sound levels according to the prevailing ambient noise level. Preferably, broadband noise alarms should be fitted in place of tonal alarms.

The Construction Noise Impact Assessments would include a noise monitoring program, reasonable and feasible noise mitigation measures, a complaint management strategy and contingency plans if noise exceedances or justified complaints were to occur.

6.4 Construction Vibration Assessment and Recommendations

Condition of Approval No. 62, which identifies the criteria discussed above is relevant to the Modification Works. The Contractor should ensure wherever possible that the levels of vibration generated on-site by the works shall at all times be within the limits acceptable to the relevant regulatory authorities. As far as is reasonably practicable, measures shall be taken to minimise the generation of vibrations within the site. The Contractor must use the best available technology and the best practicable means to prevent or mitigate the effects of vibrations from the works.

Vibration radiation is very site specific however some indicative minimum buffer distances between vibration equipment and receivers used to avoid human discomfort during the day time are listed below in Table 6.3.

Table 6.3 - Buffer Distance Requirement

Equipment	Buffer distance typically required
Heavy Road Header	5 m
Dozer	5 m
Truck movements	10 m
Rock Hammer	15 m

It can be seen from Table 6.4 sensitive receivers are further from the development site than the distances typically required to adequately attenuate vibration to meet the human comfort criteria, and therefore also the building damage criteria.

Table 6.4 - Distances between Residential Properties and the Road Header

Location	Approximate worst case distance from Roadheader (m)
Johnston Street	20 m
Kingsland Road	42 m

The Contractor would implement vibration mitigation measures from the commencement of project site operations and would continue to maintain the effectiveness of those measures throughout the duration of the Contract. Good practice vibration mitigation measures include:

- As far as is practicable, all operations causing relatively high levels of vibration should be carried out at a time to cause the least annoyance to neighbours;
- All construction vehicles will enter and leave the Site in accordance with site entry controls; and
- Responding to complaints.

The Construction Noise Impact Assessments would include a vibration monitoring program, reasonable and feasible vibration mitigation measures, a complaint management strategy and contingency plans if noise exceedances or justified complaints were to occur.

6.5 Regenerated Noise Assessment and Recommendations

The following Conditions of Approval are identified as relevant to the management of the Modification Works:

- Condition of Approval No. 56A which specifies the applicable regenerated noise criteria and assessment process; and
- Condition of Approval No. 56B which prohibits excavation using rock hammers below ground during the night time (10 pm to 7 am).

The likely regenerated noise levels occurring in nearby residential properties as a result of the use of the roadheader are shown in Table 6.5 below. The initial noise assessment indicates there is a possibility for an exceedance of the night- time criterion, however, additional detailed noise assessment would be conducted prior to construction in the relevant Construction Noise Impact Assessment when the tunnel alignment is better known. Any potential exceedances would be presented to the EMR and would be fully justified. Proposed tunnelling works should not be commenced prior to approval from the EMR. The length of exposure of individual residences to regenerated noise would be limited by the fact that tunnelling activity would progressively pass underneath the house. It is envisaged that the roadheader would operate at a rate of 5 m/day.

The Construction Noise Impact Assessment for the Tunnelling CMS would include:

- A regenerated noise monitoring program;
- A comprehensive proactive community notification and construction strategy;
- Reasonable and feasible mitigation measures; and
- Contingency plans if noise exceedances or justified complaints were to occur.

Table 6.5 – Likely Regenerated Noise Levels, dB(A)

Location	Approximate Worst Case Distance from Roadheader (m)	Resultant Regenerated Noise Level dB(A)
Johnston Street	20 m	38 dB(A)
Kingsland Road	42 m	31 dB(A)

7.0 Conclusion

This report presents an assessment of the construction and operational noise and vibration likely to be generated as a result of the Filtration Plant.

Construction noise and vibration objectives have been established and are based on the Department of Environment and Conservation (DEC) requirements and measured ambient noise levels at the site. Environmental noise emission criteria have also been established and are again based upon the requirements of the DEC and the measured ambient noise levels at the site.

Construction noise and vibration effects along with operational environmental noise emission to noise and vibration sensitive receivers such as nearby residential, recreational and heritage receivers have been assessed. Indicative noise and vibration control measures deemed to be reasonable and feasible have been detailed.

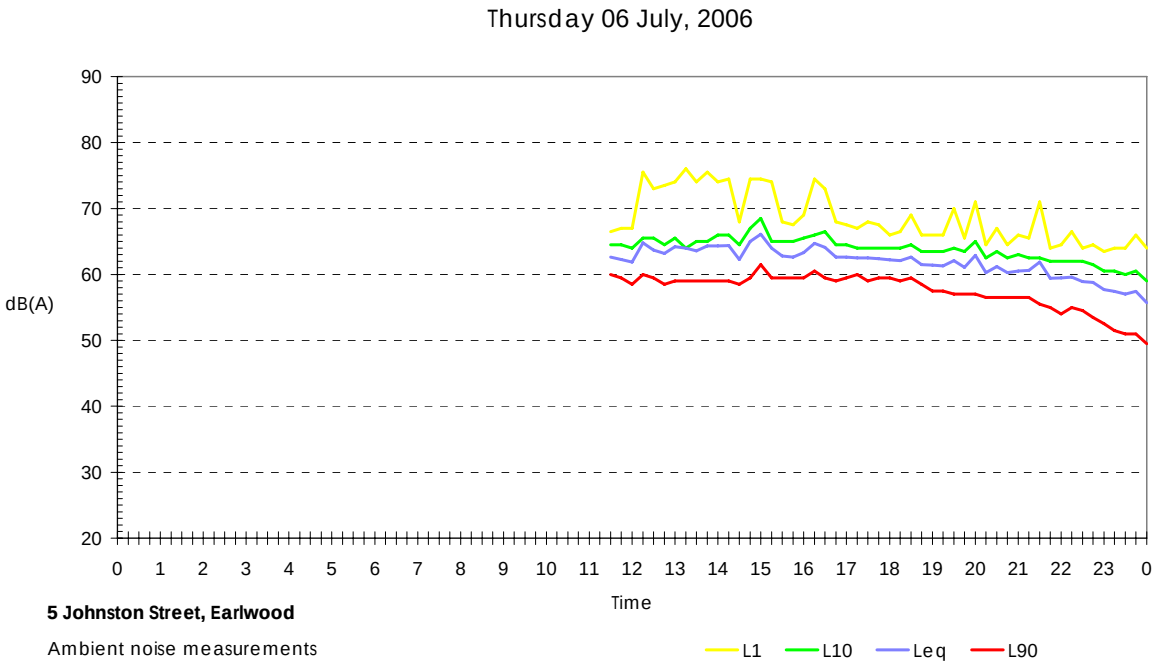
This assessment has concluded that construction and operational noise and vibration impacts associated with the Filtration Plant can generally be controlled by standard noise and vibration control techniques. More detailed construction noise and vibration and operational noise impact assessment would need to be undertaken during detailed design and construction planning to identify specific mitigation measures and monitoring requirements.

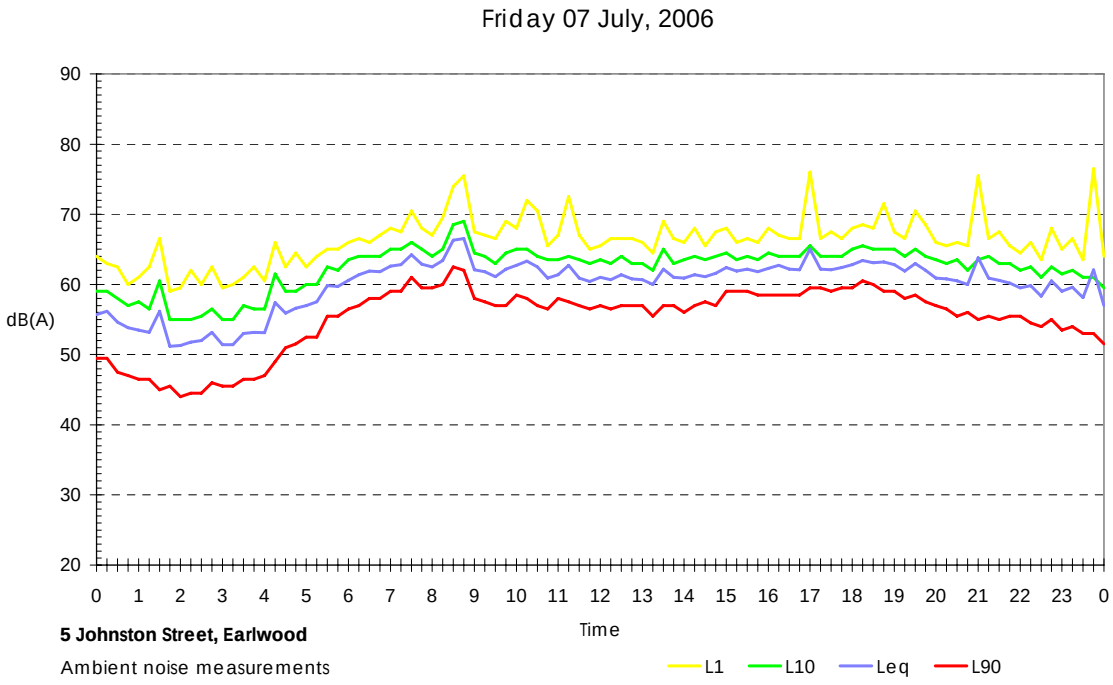
Appendix A - Glossary of Acoustic Terminology

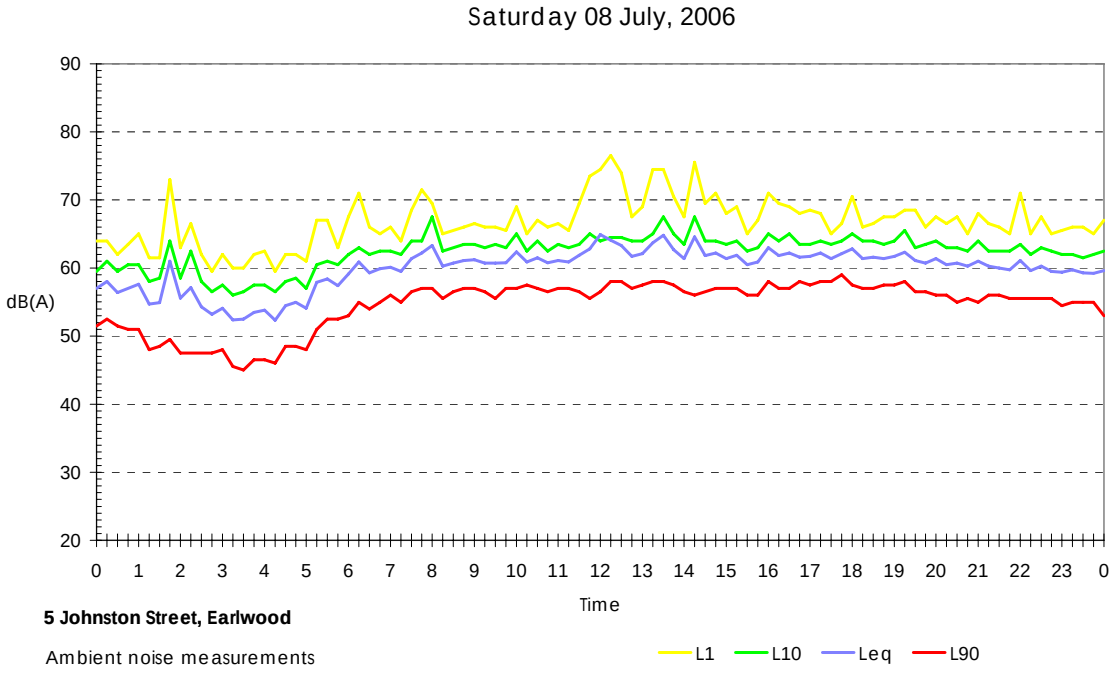
The following is a brief description of the acoustic terminology used in this report.

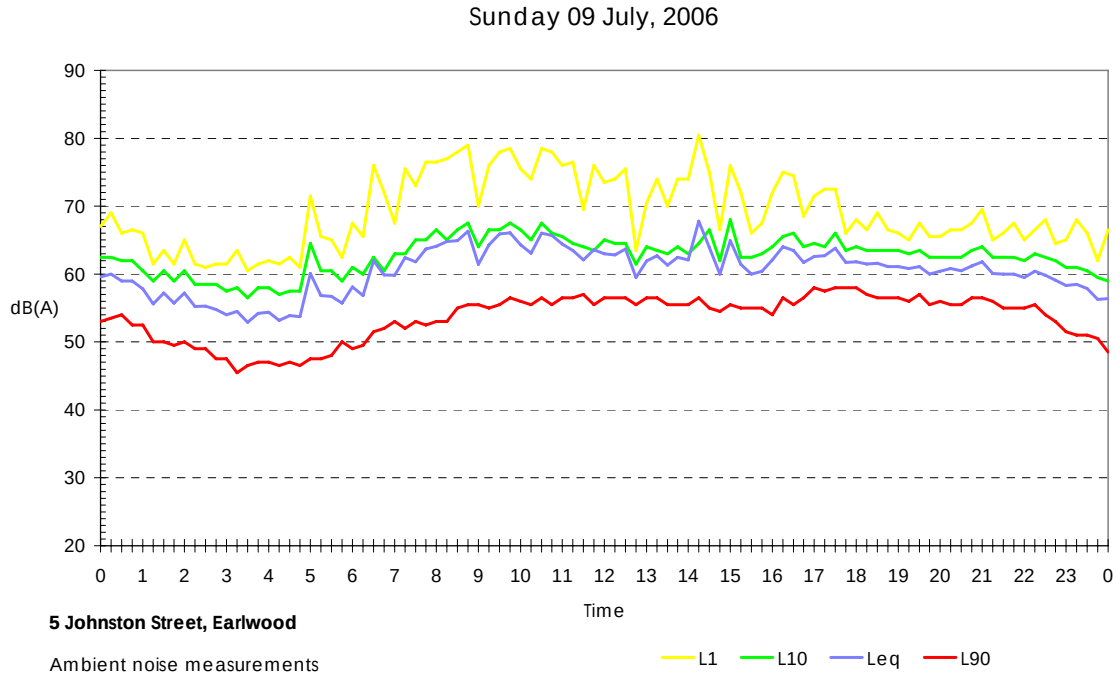
Ambient Sound	The totally encompassing sound in a given situation at a given time, usually composed of sound from all sources near and far.
Audible Range	The limits of frequency which are audible or heard as sound. The normal ear in young adults detects sound having frequencies in the region 20 Hz to 20 kHz, although it is possible for some people to detect frequencies outside these limits.
Character, acoustic	The total of the qualities making up the individuality of the noise. The pitch or shape of a sound's frequency content (spectrum) dictate a sound's character.
Decibel [dB]	The level of noise is measured objectively using a Sound Level Meter. The following are examples of the decibel readings of every day sounds; 0dB The faintest sound we can hear 30dB A quiet library or in a quiet location in the country 45dB Typical office space. Ambience in the city at night 60dB The sound of a vacuum cleaner in a typical lounge room 70dB The sound of a car passing on the street 80dB Loud music played at home 90dB The sound of a truck passing on the street 100dB The sound of a rock band 115dB Limit of sound permitted in industry 120dB Deafening
dB(A)	*A-weighted decibels* The ear is not as effective in hearing low frequency sounds as it is hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter. The sound pressure level in dB(A) gives a close indication of the subjective loudness of the noise.
Frequency	Frequency is synonymous to *pitch*. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
Loudness	A rise of 10 dB in sound level corresponds approximately to a doubling of subjective loudness. That is, a sound of 85 dB is twice as loud as a sound of 75 dB which is twice as loud as a sound of 65 dB and so on
$L_{A,max}$	The maximum sound pressure level measured over a given period.
$L_{A,min}$	The minimum sound pressure level measured over a given period.
$L_{A,1}$	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
$L_{A,10}$	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
$L_{A,90}$	The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L_{90} noise level expressed in units of dB(A).
$L_{A,eq}$	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time.

Appendix B – Graphical Logger Results






Saturday 08 July, 2006
dB(A)
Time
5 Johnston Street, Earlwood
Ambient noise measurements
L1
L10
Leq
L90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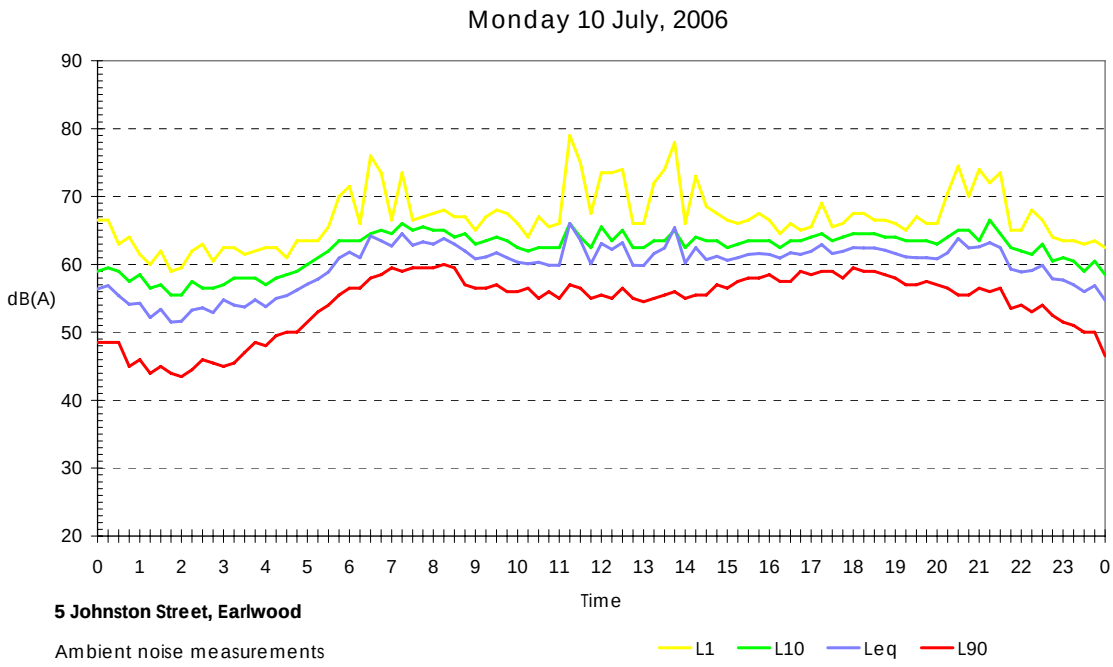
dB(A)
Time
5 Johnston Street, Earlwood
Ambient noise measurements
L1
L10
Leq
L90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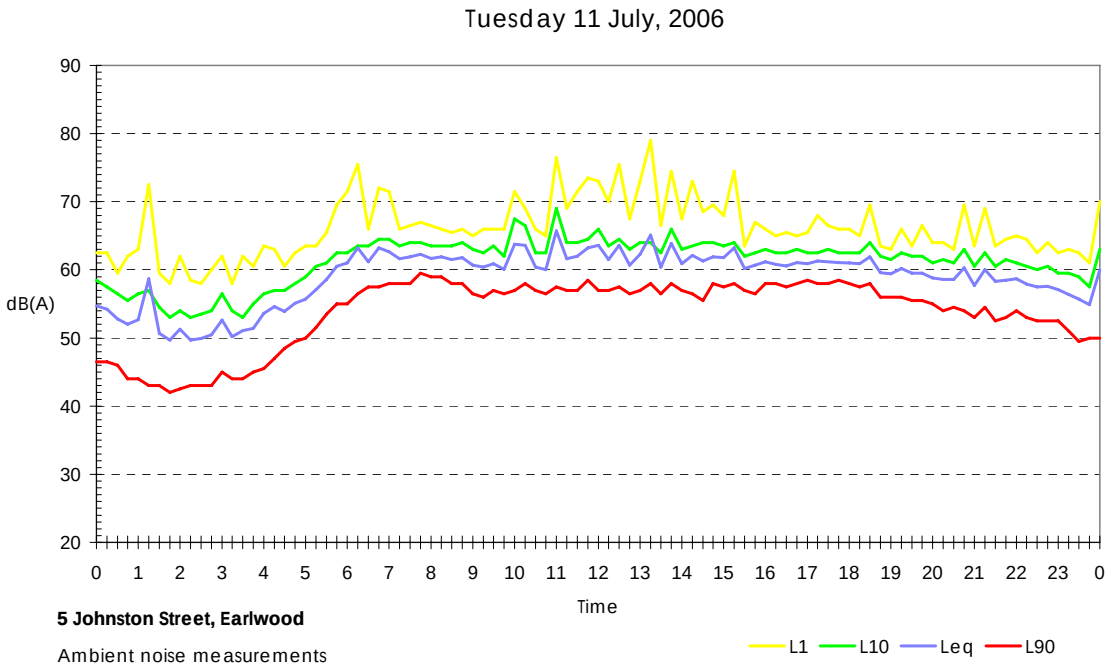
dB(A)
Time
5 Johnston Street, Earlwood
Ambient noise measurements
L1
L10
Leq
L90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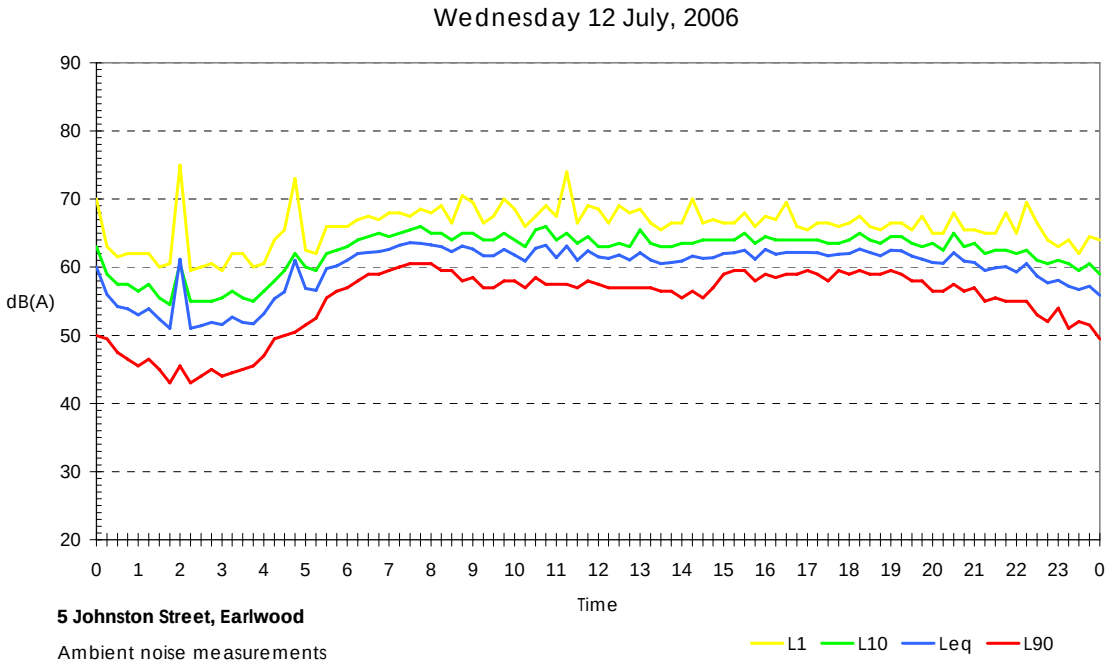
dB(A)
Time
5 Johnston Street, Earlwood
Ambient noise measurements
L1
L10
Leq
L90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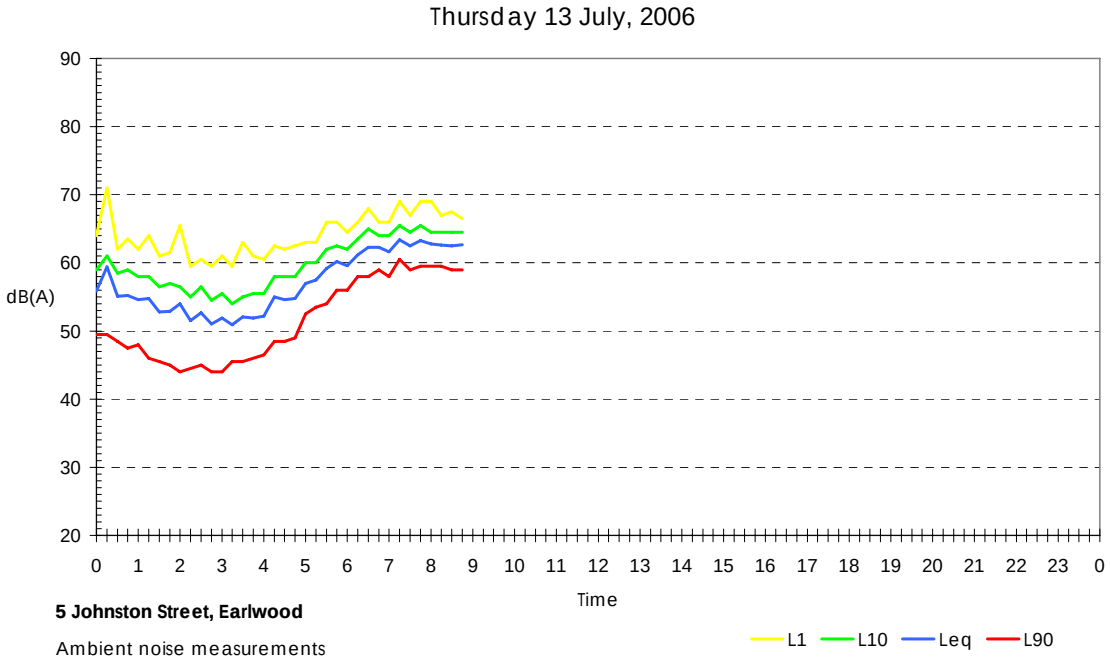
dB(A)
Time
5 Johnston Street, Earlwood
Ambient noise measurements
L1
L10
Leq
L90


Thursday 13 July, 2006
dB(A)
Time
5 Johnston Street, Earlwood
Ambient noise measurements
L1
L10
Leq
L90