Noise Assessment Report

Wood Centre Development
Southwood Resources
Huon

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Appendices

1. Introduction

The likely noise impacts and issues are investigated in this report. The following matters have been considered:

- the existing noise climate in the proposed Southwood integrated timber processing site (I.T.P.S.)
- the predicted operating noise levels at the residences in other ownership, 6000 metres away from the I.T.P.S. complex
- possible DPWIE permit (Noise) conditions and limits
- 9 assessment of predicted noise levels against possible DPWIE noise limits
- noise mitigation measures
- truck noise levels
- traffic induced vibrations.

There are two major problems with accurately predicting noise levels from distant sources. One is the difficulty in obtaining reliable sound power levels of noise sources such as large machines because of the influence of ground effects and the impracticality of exploring sound fields over an imaginary hemisphere that encompasses the large sound source. Many measurements have to be taken in order to express the mean values with some confidence. For example, a sample with a standard deviation of 6 dB(A) may require 28 measurements to obtain the correct mean within +/- 2 dB(A), nine times out of ten. The other major problem that makes accurate prediction difficult is the variability of weather conditions. The input data requirements regarding meteorological factors (temperature gradients, wind velocity profiles) are comprehensive, resulting in considerable computational effort.

The method used to predict the noise levels likely to be encountered at 6000 m (the nearest neighbour) is as follows:

- Distant noise level data has been obtained for existing operating facilities located in Tasmania because manufacturers of 'one of' large machines or plants do not have noise data of their products, especially if the plant is in the design stage. These Tasmanian facilities include sewage plants, merchandising yards, sawmills, veneer mills and wood chip mills. However, the noise data for the wood fired power station and the portable chip plant came from Siemens in Germany, and Peterson Pacific Corporation in USA, respectively.

- Fricke (1987) quotes work by Kenna et al (1986) at the National Acoustic Laboratories regarding outdoor sound propagation which suggests that a good fit for their data is given by:

  Attenuation, dB(A) = 6 dB(A) / dd + 3 dB(A) / km,
  where dd = doubling of distance.[1]

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[1] Fricke, F. & Treagus. R., "Sound Attenuation Rates Near the Ground' Proc. Aust. Acoustical Soc. Annual Conference 1987, p. 57.

The above formulae is suitable for determining the attenuation of sound over flat and undulating ground and large distances and is claimed to give results comparable in accuracy to that given by complex models. Noise levels obtained from actual plants located at 45 m, 370 m, 450 m, 1000 m and 4100 m are used to calculate the noise levels at 6000 m using the above formulae. The calculations do not include the attenuation provided by topographical features, and so the results are conservative.

The calculated noise levels are then compared to the existing ambient noise levels in the area. Whether a noise is intrusive or not depends on the following factors:

1. the level of the background noise;
2. the level of the intruding noise;
3. whether the noise has tonal components;
4. whether the noise has impulsive components;
5. whether the noise is regretfully inflicted or mindlessly caused;
6. the time of day or night the noise occurs.

2. Existing Noise Climate

This is a first major development of this type within the State Forest in the Huon. Consequently true background noise levels can be obtained that are not inflated by the presence of other industrial noise in the area.

Noise measurements were conducted in the State Forest during the day and in the evening. During the day there was some distant noise associated with logging. The results of 15 minute statistical noise analysis is given below.

date	time		dB(A)		
		L_1	L_{10}	L_{90}	L_{eq}
13/12/00	1435 h	51.3	47.3	36.8	44.0
26/8/00	1830 h	41	39.8	36.5	38.3

In the table L90 is the noise level exceeded for N% of the sampling time. L90 is a descriptor of the background noise levels encountered. L10 is a descriptor of the fluctuating higher noise levels. Leq is the equivalent 'A'weighted noise level. For example, a fluctuating noise having an Leq = 38.3 has the same acoustic energy as a steady noise of 38.3 dB(A).

The author has conducted noise surveys and analysis in Tasmania over the past eighteen years and the results have been used to determine the means and standard deviations of noise levels in rural and semirural areas. The results are given overpage.

		Day dB(A)			**Night dB(A)**		
		L_{10}	**L_{90}**	**L_{eq}**	**L_{10}**	**L_{90}**	**L_{eq}**
Rural	mean	44.9	36	44.8	39.1	32.3	38.4
	std. dev.	6.1	5.5	7.6	5.7	5.7	10.4
	n	24	24	24	21	21	20
Semirural	mean	41.7	33.5	40.8	39.2	31.8	38.9
	std. dev.	6.1	5.6	6.8	6.1	5.4	7
	n	30	30	29	13	13	13

Where n = number of sites. The measurements were generally conducted over 30 minutes to 60 minutes. The results indicated that the day time rural background (L90) noise levels are higher than the noise levels recorded in semirural areas. Rural areas are not always tranquil, there are watering systems, tractors, distant sawmills and quarries. Furthermore the ambient noise in rural areas having forests or trees depends on the wind speed. Wind generates noise in the trees and consequently the background noise levels can vary from 20 dB(A) on a still night without insect noise, to over 50 dB(A) during moderate winds. At night time the rural and semirural noise climates are similar, with a mean background L90 level of about 32 dB(A). For example, wind noise generated by a 16.6 m gum tree at a distance of 16.6 m from the microphone gave the following results:

		dB(A)		
mean wind speed m/ s	std. dev.	L_{10}	L_{90}	L_{eq}
1.1	.26	44.3	42.3	43
1.75	.43	49	45.8	47.1

The wind speed was measured at 1.5 m from the ground. The sound power level of such a tree during a mean wind speed of 1.75 m/s is 79.5 dB(A). If there were 25 such trees in 5 rows and 5 columns (10 m apart) then the 'A'weighted sound pressure level, measured 20m from these trees could be 54.4 dB(A).

Page A1 in the Appendix shows a time recording of noise made by the same tree when the mean wind speed was 3.1 m/s and the standard deviation was 1.2 m/s. These results show considerable noise of wind in the trees. See for example, wind data for the Grove Research Station and Geeveston Station in the Appendix, pages A2 - A5. In addition to the wind interacting with the flora, there are other natural sounds due to fauna, especially birds, frogs and insects. The net result of these noise contributions is a noise climate that only occasionally is tranquil.

3.0 Communal Wastewater Treatment/Reuse Facility, Potential Noise Impact

A large metropolitan sewage plant (44,000 equivalent persons, 9 megalitres/day) capable of tertiary treatment and occupying about 3 hectares generates an Leq = 33.5 dB(A) and L90 = 31 dB(A) measured at a line of sight distance of 370 m. At 6000 m the noise level due to geometric spreading is:

L_{eq} = 33.5 - 20 log (6000/370) = 9.3 dB(A)
L_{90} = 31 - 20 log (6000/370) = 6.8 dB(A).

The plant has a range of irrigators and purpose built pump houses designed for noise mitigation. Additional noise mitigation measures are unnecessary.

4. Merchandising Yard

4.1 Dropping Logs by Log Grabber/ Loader

The main source of noise at a distance is the noise made by dropping of logs during sorting by the log loader/grabber. These noise events have been measured in line of sight conditions as follows: at 450 m the mean L_{max} = 58 dB(A) with a standard deviation of 2.92 dB(A); at 1000 m the mean L_{max} = 50.2 dB(A) with a standard deviation of 2.54. Therefore at 6000 m the mean L_{max} = 58 - 20 log (6000/450) - 3 dB(A)/km = 19 dB(A), or the mean L_{max} = 50.2 - 20 log (6000/1000) - 5(3) = 19.6.

With a standard deviation of 2.5 to 2.9 dB(A), 84% of the log dropping noise events are likely to be less than 19.6 + 2.9 = 22.5 dB(A) and 97.7% of the log dropping noise events are likely to be less than 19.6 + 2(2.9) = 25.4 dB(A).

These noise events may on occasion be heard during very still nights. However, a bedroom with a 20% open window offers about an 11 dB(A) noise reduction and so awakening reactions during sleep are unlikely.

4.2 Log Loader/ Grabber

A CAT 988 log grabber generates 91 dB(A) at 7 m. This machine is typical of the likely equipment to be used at the proposed site. At 6000 m the noise level is likely to be 91 - 20 log (6000/7) - 6 x 3 = 14.3 dB(A). This noise is unlikely to be heard at 6000 m.

4.3 Chain Saws

A Stihl 064 chain saw, which is a typical saw used in merchandising yards and sawmills, generated the following noise levels at 15 m during operations:

dB(A)			
L_1	L_{10}	L_{90}	L_{eq}
81.8	78.8	36.3	73.7

At 500 m, a noise level of 47 dB(A) was measured during sawing. At 6000 m the noise level is likely to be 47 - 20 log (6000/500) - 5.5(3) = 8.9 dB(A). This noise is unlikely to be heard at 6000 m.

5. Sawmill

Noise levels were obtained 450 m, line of sight, from a large sawmill processing about 200,000 m3 of raw material annually, compared to the 88,000 M3 intended for processing at the proposed sawmill. The following mean values were obtained over 2 nights and result from eleven 15 minute samples.

	dB(A)		
	L_{10}	L_{90}	L_{eq}
mean	52.6	45.7	49.3
Std. dev.	1.07	2.08	1.88

The sawmill was equipped with chippers for processing waste from the green mill and the dry mill.

At 6000 m the noise level is likely to be L_{eq} = 49.3 - 20 log (6000/450) - 5.5(3) 10.3 dB(A), and L_{10} = 13.6 dB(A) and L_{90} = 7 dB(A). With standard deviation of 1.88 dB(A), 97% of the Leq noise levels from the sawmill could be below 10.3 + 2(1.88) = 14.1 dB(A). The noise is unlikely to be heard at 6000 m.

6. Rotary Peeled Veneer Mill

Veneer Mills are generally quieter than sawmills, with the main noise being external noise generated by the log loader. A microphone traverse of an operating veneer mill gave the following results:

dB(A)			
L_{max}	L_{10}	L_{90}	L_{eq}
98	81	71	79

The large industrial hall is likely to be clad with metal having a weighted sound reduction index (Rw) of about 18.

Measurements conducted 45 m from an operating veneer mill gave the following results.

dB(A)		
L_{10}	L_{90}	L_{eq}
61	58	61

At 6000 m the noise level is likely to be L_{eq} = 61 - 20 log (6000/45) - 6(3) = 0.5 dB(A). The veneer mill is unlikely to be heard at 6000 m.

7. Wood Fibre Generation

The proposed chipper is a 2.84 m diameter disc with 12 knives driven by a 2000 hp motor.

A large wood chip facility (615,000 tpa of woodchips) having a much larger 3.66 m diameter

10 knife disc driven by 4000 hp motor has been subject to extensive monitoring and noise analysis. The mean noise levels obtained during 4 nights at a distance of 4100 m (beyond line of sight) is as follows.

	dB(A) (30 minutes)		
	L_{10}	L_{90}	L_{eq}
mean	36.4	33	35.1
Std. dev.	3.3	1.6	2.6
n	9	9	9

Climatic conditions were as follows:

date	time h	temp. °C	R.H. %	press. hPa	wind m/s	dir.	cloud octals
1.7.97	1930	1.5	92	992	0	-	0/8
2.7.97	2020	5.5	93	982	0	-	0/8
3.7.97	0604	3.5	79	982	2	W	0/8
4.9.97	0615	1.5	90	97	0	-	0/8

There were discrete events associated with chipping and log/metal (debarker) contact that could be heard on occasions. The mean noise events during the 4 nights is as follows:

date	dB(A)
1.7.97	41.3
2.7.97	41.8
3.7.97	40.3
4.7.97	46.8 - possible temperature inversion

At 6000 m the above noise levels obtained at 4100 m are likely to be decreased by 20 log (6000/4100) = 3.3 dB(A) due to geometric spreading and a further 2 x 3 = 6 dB(A) due to the 3 dB(A)/km factor. The above noise levels could be reduced by 3.3 + 6 = 9.3 dB(A). Hence the Leq noise level at 6000 m could be 35.1 dB(A) - 9.3 dB(A) = 25.8 dB(A). Considering the standard deviation of 2.6 dB(A) we can expect that for 97.7yo of the 30 minutes samples the Leq = 25.8 + 2(2.6) = 31 dB(A), or less.

The discrete noise events of 41.3 dB(A) to 46.8 dB(A) are also likely to be reduced by 9.3 dB(A) to 32 dB(A) to 38 dB(A). The 38 dB(A) discrete noise events may be heard on occasions during still evenings and during conditions where temperature inversions occur. However, taking into account the smaller diameter disc and the 50yo smaller hp motor, noise from the wood fibre generation facility is unlikely to be heard. The ambient L_l noise levels at night is 41 dB(A) (see page 2) and hence exceeds the discrete noise events of 38 dB(A). Such noise events do not cause awakening reactions in sleepers.

8. Wood-fired Power Station

8.1 Steam Turbine Noise

Siemens have estimated the total sound power level of a 50 MW wood fired power station without noise control to be SWL = 118 dB(A), and with maximum noise control SWL = 95 dB(A).

The typical expected sound pressure level at a distance of 250 m from the outermost points of a power plant installation is approximately 60 dB(A) with no noise control and approximately 38 dB(A) with maximum noise control. At 6000 m, without noise control, the noise level is likely to be 60 - 20 log (6000/250) - 5.75(3) = 15.1 dB(A). However this noise may include tonal components due to forced draft and induced draft fans. The adjusted noise level due to tonal components could be 15.1 + 5 = 20.1 dB(A). On occasions, during temperature inversions, the noise level could be higher.

The design should allow for quarter wave tuning tubs or packless silencers should this prove necessary. However, the estimated noise level of 15 - 20 dB(A) is unlikely to be heard at 6000 m in the presence of ambient noise.

8.2 Boiler Blow Down Noise

Boiler blow down/stream purging noise has been recorded from an 8 MW boiler. This boiler had a 30 m stack, was 860 m from the microphone and in direct line of sight. The noise level varied between about 48 dB(A) to 62 dB(A).

A 50 MW boiler may generate a noise level which is: 15 log (50/8) = 11.9 dB(A) higher than that made by the 8 MW boiler. At 6000 m, the noise level is likely to be: (62 + 11.9) - 20 log (6000/860) - 5(3) = 42 dB(A). This noise might be heard at 6000 m both during the day and night. The boiler blow down operation should be conducted during the day time, avoiding especially sunrise and sunset periods. The steam blow down, relief and safety valves should be fitted with silencers such as the R2 series silencers made by Sound Attenuation Australia.

The boiler blow down operations are not daily events. They occur infrequently, have durations of perhaps 15 minutes and are not likely to generate complaints, especially if fitted with silencers.

8.3 Transf ormer

A 50 MVA transformer is likely to have a sound power level SWL of:
SWL = 74 + 14 log MVA = 74 + 14 log 50 = 100.8 dB(A). See AS 2374.6-1994, Power Transformers, page 22.

At 6000 m the sound pressure level is likely to be:

SPL = SWL - 20 log r - 8 - 6(3) = 100.8 - 20 log 6000 - 8 - 6(3) = 17.2 dB(A) 0.8 dB(A).

The ultimate design could consist of two transformers - perhaps 30 MVA each so that one could be taken out of service for maintenance. With two 30 MVA transformers operating together (same frequency and phase) the sound pressure level at 6000 m is likely to be 0.9 dB(A). In any case the transformer or transformers are unlikely to be heard at 6000 m.

8.4 Fuelwood Processor

The HC5400 Portable heavy duty wood recycler is typical of the equipment to be used and has been measured as generating 77 dB(A) at 61 m. Measured noise levels, taken in the field during operations, are shown on page A6. A photograph of the unit is shown on page A 7.

At 6000 m the noise level could be 77 - 20 log (6000/61) - 6(3) = 19.1 dB(A) where 6(3) is the 3 dB(A)/km factor. This level is below the likely day time background noise level L_{90} of 36.5 dB(A) or 20 dB(A) on a still evening. The noise is unlikely to be heard at 6000 m.

9. Construction Noise and Vibration

The contractors are expected to be acquainted with Australian Standard AS 2346-1981 "Guide to Noise Control on Construction, Maintenance and Demolition Sites".

Percussive Piling operations using 5T drop hammer could generate noise levels that may be heard at 6000 m. However, there will be attenuation due to atmosphere, topography, and the noise levels are unlikely to exceed 47 dB(A) at 6000 m.

Blasting may be necessary. Ground vibrations are unlikely to exceed the recommended maximum peak particle velocity of 5 mm/s for the effective charge per delay likely to be used in construction as opposed to quarry blasting, and at a distance of 6000 m. For example, AS 2187.2-1993 ’Use of Explosives" indicates that for heavily confined blasting in far field situations, an effective change of 3150 kg per delay may generate a peak particle velocity of 5 mm/s at 1000 m. This is a large charge. Ground Vibration due to construction is unlikely to exceed 5 mm/s, 6000 m from the blast.

10. Summary and Combined Noise Level at the nearest neighbour, 6000 m from facility

	dB(A)		
	L_{max}	L_{90}	L_{eq}
Waste water/ reuse facility	-	6.8	9.3
Merchandising yard			
mean, log drops	19.6		
log loader			14.3
chain saw			8.9
Sawmill			
general			10.3
mean, log drops	19.6		
log loader			14.3
chain saw			8.9
Veneer Factory			
general machine hall noise			0.5
mean,log drops	19.6		
log loader			14.3
chain saw			8.9
wood fibre generation			
general			25.8
discrete noise events	32 - 37.5		
wood fired power station			
power station			20.1
transformer			0
fuel wood processor			19.1
Logarithmic total	37.7		28.4

11. Possible DPWIE Permit (Noise) Condition and Limit

11.1 Noise emissions from the activity (or activities) to which the permit relates shall be such that when measurements have been adjusted for noise in accordance with the relevant standards, the noise levels from the activity (or activities) on the land shall not exceed an equivalent continuous A-weighted sound pressure level of 40 dB(A) at any time when measured at any domestic premises in other ownership. Noise level measurements shall be taken in the presence of ambient noise normally existent in the area.

11.2 The time interval over which the noise level is to be determined shall be 15 minutes.

11.3 Where the combined level of noise from the activity (or activities) on the land and the normal ambient noise exceeds the level stated in part 10.1 this condition shall not be considered to be breached unless the noise enussions from the activity (or activities) on the land are audible.

All methods of measurement shall be in accordance with the relevant Australian Standards and the Tasmanian "Code of Practice for Sound Pressure Level Measurement'.

12. Assessment of predicted noise levels against 12ossible DPIWE noise limits

12.1 The criteria of Leq $\leq$ 40 dB(A) is likely to be met.

12.2 Discreet noise events such as those made by the chipper and the banging due to logs dropped into the debarker may reach levels of 38 dB(A) on occasions.

13. Noise Mitigation Measures at I.T.P.S.

13.1 The main noise source is the large chipper. There is merit in orienting the chipper building so that there are no openings in the direction of the nearest occupied residence at 6000 m near the junction of Denison and Weld Roads. The chipper mouth should have sufficient space for a possible set of three, quarter wave tuning stubs.

13.2 Allowance should be made for possible inclusion of silencers in the power station stacks.

13.3 The mobile heavy duty recycler should be located behind a building so that the building provides a noise barrier in the direction of the 6000 m neighbour.

14. Truck Noise

The sound exposure level (SEL) of a number of log trucks travelling about 60 km/h were measured in an open area 15 m from the kerb and found to average 83.6 dB(A). The SEL is a useful concept whereby a truck pass by noise event lasting many seconds is transformed into an equal energy event of duration 1 second. The SEL can then be used to estimate the equivalent 'A' weighted sound level Leq, due to a number of trucks.

The proposal is for a wood chip truck traffic flow of 2 x 24 = 48 movements per day. This means that there will be 48 truck movements in 24 hours, or an average of 2 truck movements per hour. However, truck arrivals and departures may not occur at regular intervals but are likely, on occasions, to be clustered. The arrival of such trucks could follow a Poisson distribution with a mean arrival rate of 2 trucks per hour.

There are also likely to be periods where truck traffic is prohibited, or restricted, to allow for school buses, and so there could be bunching of trucks.

The equivalent 'A' weighted 1 hour sound level due to the wood chip trucks can bedetermined as follows:

$$Leq(l\ h) = 10 \log [n \times 10^{SEL/\ 101} + 10 \log (1\ /T)$$

where n = number of trucks per hour
SEL = sound exposure level at 15 m = 83.6 dB(A)
T = time = 60 x 60 = 3600 seconds

therefore $Leq(l\ h) = 10 \log [2 \times 10^{8.361} + 10 \log (l/\ 3600)$
$= 51.0$ dB(A)

In addition, there will be 28 truck movements carrying product between 0700 h and 1600 h. That is, 28 truck movements in 9 hours or 3.111 truck/ hour. The total trucks/ hour between 0700 h and 1600 h will be 2 + 3.111 = 5.111. The equivalent 'A'weighted 1 hour sound level due to both the chip and product trucks will be:

$$\begin{aligned} Leq\ (1\ h) &= 10 \log [5.111 \times 10^{8..36}] + 10 \log (1\ /\ 3600) \\ &= 90.68 - 35.56 \\ &= 55.1 \text{ dB(A)} \end{aligned}$$

Over a 24 hour period, the equivalent noise level due to the trucks consists of 9 hours where Leq = 555.1dB(A) and 15 hours where Leq = 51.0 dB(A) making Leq(24 h) = 53.0 dB(A).

Day-time noise measurements have been conducted 10 m from North Huon Road at Ranelagh (Playground). The mean of 6 one hour measurements over 2 days was Leq(l h) = 55.4 dB(A) with a sample standard deviation of 2.3 dB(A). See pages Bl and B2.

Night time noise measurements at the same location (two 15 minute samples and one 30 minute sample) gave a mean Leq = 34.9 dB(A), see pages B3 and B4.

Page B5 gives data obtained at Glen Road and North Glen Road.

Pages Cl to C8 give the results of truck noise measurements. The time recording on page C3 shows truck pass by noise events measured at 15 m from the kerb. The mean of the maximum noise levels is 78.3 dB(A) with a sample standard deviation of 2 dB(A) for speeds of 60 km/h.

Page C4 shows spectral content of log truck noise. The features at 63 Hz and 80 Hz are due to engine noise. Page C5 shows narrow band analysis of the truck noise. Page C6 shows comparative spectra of noise of a truck using 'Jacob's'brake.

Truck noise is mainly due to three components:

1) engine, gearbox sound;
2) engine exhaust noise; and
3) road/ tyre interaction noise.

To reduce overall noise by say 5 dB(A), the noise of each of the three above components must be reduced by a similar amount. Present technology does not offer significant reductions in truck noise other than tunnel enclosure of the engine and gearbox. The road surfaces should be well maintained so that they are free from pot holes and in good clean, smooth condition.

15. Peak Truck Noise Levels

Recent research (Kraus, J. 1993[2]) has found that for vehicles greater than 12 tonnes the regression equation that fitted the data was:

$$Y = 0.138\,X + 76.24$$

where X =speed km/ h,
Y = peak noise level rms

For 60 km/h $Y = 0.138(60) + 76.24 = 84.25$ dB(A)

At 15 m the peak noise level is likely to be 84.25 - 6 = 78.25 dB(A). Measurements conducted by the author at Bell Bay of maximum truck noise at 15 m gave a mean value of 78.3 dB(A) and a sample standard deviation (n = 10) of 2 dB(A). The trucks were in a 60 km/h zone.

Trucks using Tehnar retarders are quieter than trucks using Jacob brakes. For example, a descending truck using Jacob brakes generated a noise level of 66 dB(A) at a given location. Another truck, using the same route and descending, generated 50 dB(A) at the same location.

16. Truck Noise Level Criteria

The current Criteria for the noise at the facade of residential dwellings are:

L_{10}(18 h) @68 dB(A)maximum acceptable level
L_{10}(18 h) @63 dB(A)maximum desirable level

The lower level is a design goal, which the Tasmanian Department of Infrastructure, Energy and Resources (DIER) aims to achieve when new works are constructed.

There are no formal criteria for night time noise (2200 h to 0600 h) but the following criteria can be considered as reasonable: Leq(8 h) = 55 dB(A), and

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[2] Kraus, J. (1993) An Investigation of Heavy Vehicle Noise, Criffith University, Queensland.

L_l = 77 dB(A), for low density transportation. Empirical traffic noise studies have shown the following relationship (Road Traffic Authority of NSW):

$$L_{10}(18\ h) = L_{eq}\ (24\ h) + 3.5.$$

Therefore the expected L_{10}(18h) is: $L_{10}(18\ h) = 52.3 + 3.5 = 55.8$ dB(A).

The 63 dB(A) maximum desirable noise level is likely to be met. These two criteria are likely to be met by the proposed schedule of truck movements.

As night-time traffic is characterised by peak noise events rather than continuous noise, the criteria could include the peak noise made by trucks as they pass. Research on intermittent noise at night (Criefahn, 1992[3]) has suggested that one awakening will probably be evoked in not more than 10% of the exposed people if two noises with peak levels of 59.4 dB(A), or 10 noises of 54.1 dB(A), or 30 noises of 53.6 dB(A) occur during a night.

The mean outdoor/indoor attenuation of houses for maximum noise events is 17.3 dB(A) with the window slightly open (Carter, 1992, page 52[4]). Hence, for 30 noise events through the night the outdoors noise level is 53.6 + 17.3 = 70.9 dB(A). This noise level is likely to be exceeded for houses within about 30 m from the kerb. However, Griefahn's work suggests one awakening reaction in fewer than 10% of the exposed people. There are currently no formal criteria for peak noise levels in relation to truck traffic. The trucks should conform with the Australian Design Rule 28/01 (Table 1, page 4) in relation to truck noise limits, that is, for heavy goods vehicles (NEP $\geq$ 270 KW) 87 dB(A) at 7.5 m. This is about 81 dB(A) at 15 m and 75 dB(A) at 30 m.

17. Truck induced vibrations

Traffic induced ground vibrations depend on the following: vibrational behaviour of trucks; mass of trucks; speed of trucks; tyre characteristics; roughness of road surface; and, subsoil properties. Cracks in houses can be caused by many factors, including: structural overload; shrinkage and swelling of wood framing; uneven foundation settlement; slamming of doors; washing machines (agitator frequency 1.6 Hz); conducting aerobics; temperature variations; bricks in weather board walls; water leakage; trees outside absorbing moisture and causing footings to settle; and, movement of trees in wind causing ground movement by roots. Architects in the USA have identified 40 causes for cracks other than vibration.

The Australian Road Research Board (Mr. A. E. Tynan, 19735[5]) conducted ground vibration tests at Richmond, after the collapse of the Tasman Bridge, when traffic through the town increased by about 700%. The tests showed that the ground vibrations from the traffic were safe when using the

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[3] Griefahn, B., (1992) 'Noise Control During Night' Acoustics Australia Vol. 20, No. 2 pp 43 47, August 1992.

[4] Carter, N. L., (1992) 'Overnight Traffic Noise Measurements in Bedrooms and Outdoors, Pennant Hills Road, Sydney, Comparison with Criteria for Sleep', in Acoustics Australia, Vol 20, No. 2, pp 49 - 55.

[5] Tynan, A. E., 1973, "Daniaging Effects of Ground Vibrations" Australian Road Research Board

criteria of 2 mm/s adjacent to historical buildings. His tests also included trucks travelling over purpose built 100 mm high ramps to simulate pot holes.

The author conducted vibration measurements at Richmond (Bridge Street) with the transducer set on a stone window sill of a stone cottage. The wall was 5 m from the kerb and the following mean vertical peak particle velocities (ppv) were obtained:

36 t truck, near lane 30 - 40 km/ h	1.6 mm/ s
36 t truck, far lane 30 - 40 km/ h	1.4 mm/ s
15 t truck, near lane 30 - 60 km/ h	1.3 mm/ s
15 t truck, far lane 30 - 60 km/ h	1.0 mm/ s
6 t roller pulled by tractor, near lane	9.5 mm/ s
6 t roller pulled by tractor, far lane	4.8 mm/ s

A report by Mr. Chris Nieuwhof, MIE Aust, CP Eng, FIQ, on ground vibrations at the Royal Engineers Building concluded that "no discernible vibration influences due to traffic were identified during the monitoring period’ when trucks moved to and from the Boral concrete plant and container, gravel and log trucks used the Tasman Highway.

Tests conducted by the author found that locomotives weighing 92 t to 96 t are left with their engines idling at about 445 rpm, generate low frequency sound and vibrations at 7.4 Hz, 22.25 Hz and 44.5 lh. The railway track is 10 m from the heritage building. The diesel locomotives are left idling for periods of 30 minutes or more then accelerate and move to other locations to engage in shunting activities. As far as is known, there is no damage to the Royal Engineers Building from sustained air borne or ground borne vibrations from the heavy locomotive accelerations, 10 m from the building. There are sawmills near Judbury and log trucks use the existing roads. It is therefore unlikely that vibrations from heavy log or chip trucks at distances of 10 m will cause damage to domestic buildings.

PEARU TERTS