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EXPERIMENTAL OUTDOOR SOUND PROPAGATION AND ENM

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Abstract

Noise propagation is significantly affected by prevailing meteorological conditions. Several standard modelling methods rely on measured meteorological data and estimation techniques. We decided to obtain realistic and actual noise level data including the effect of atmospheric conditions by conducting a three week experiment on sound propagation. Loud speakers were placed at a central location on a site, to be used as an artificial sound source. A constant sound signal of a set of pure tones with varying sound intensity levels between each frequency is constantly producing sound at a fixed emission level for several hours at a time each night. The primary frequencies in the source signal were chosen to adequately simulate the main frequency range of typical mining plant. The transmitter consists of a CD player with a CD containing the source noise, a power amplifier and loud speakers. The arrangement is powered by a petrol generator, all located in an open area. The sound was recorded by acoustic consultants at distant off-site locations, as well as at near-filed positions 20m from the speakers. There were two personnel conducting measurements simultaneously, each with a Type1 narrow band analysers SVAN912. The operators collected random 1-minute samples at various locations and times through each monitoring period. Meteorological data is continuously collected by a weather station near by. Each narrow band sample was then analysed to filter the discrete pure tones from the ambient noise recorded. In the first instance the fluctuation of absolute source contribution at each monitoring site is quantified. The meteorological and noise data is correlated and analysed to quantify the effects of weather on noise propagation. These measurements are compared to predictive output from a detailed three-dimensional model developed using ENM. The comparison shows interesting divergence of results but with encouraging correlation in noise levels on average.

1. INTRODUCTION

The influences on outdoor sound propagation include geometric spreading, atmospheric absorption, refraction and turbulence, ground effects, reflection and diffraction. Noise propagation is particularly affected by wind and temperature gradients. This leads to day-to-day and hour-to-hour variations in received sound levels from a source. The region of the inversion can act as a boundary to noise. This atmospheric “boundary” can direct sound energy back toward the ground, resulting in an increase in the total noise level at the receiver. Source-to-receiver wind can also enhance noise significantly. The noise impact assessment of proposed industrial facilities in NSW, is required to consider adverse weather conditions.

Hence, accurately quantifying sound propagation can be critical to the success of an industrial facility and can have significant economic consequences for that facility. Noise modelling methods rely on measured meteorological data and estimation techniques. This type of assessment has been conducted through noise modelling software incorporating prevailing wind conditions and atmospheric stability classes. The calculated stability classes are estimations based on historic wind data. Given the uncertainty of these modelling methods, it was decided to obtain realistic and site specific noise level data including the effect of atmospheric conditions by conducting an experiment on sound propagation in areas designated for open cut coal mining activities. These areas are part of existing mining land in the Hunter Valley NSW, owned by Coal and Allied Pty Ltd, who supported this study.

2. ENM NOISE MODEL

ENM (Environmental Noise Model) is the noise modelling software that was used to predict noise levels. The following section relates to validation of the modelling software and in particular its accuracy during positive winds.

ENM utilises weather parameters and intervening topography between the source and the receiver as part of its calculation procedure. While ENM is considered to be accurate for calm weather conditions, it can over predict noise levels during adverse wind conditions. Adverse source-to-receiver winds tend to create a substantial noise impact at receivers. Hence, it was necessary to investigate this phenomenon. Following are procedures that were used to validate the ENM noise model and hence ascertain the accuracy of the modelled results under adverse source-to-receiver wind conditions for this site.

3. OVERVIEW OF VALIDATION PROCEDURE

A known noise source was separately set up at three of the potential mining areas. While the noise source is active, hand-held narrow band sound level analyser measurements were conducted to measure the noise levels generated over various distances under varying weather conditions. The weather conditions were measured simultaneously to the noise measurements by a meteorological station on-site. These meteorological parameters were then input into the ENM noise model together with the known source's sound power level to predict noise levels at the measurement locations. The modelled results were then compared with the measured results under adverse source-to-receiver winds.

4. NOISE SOURCE

The noise source consisted of four 15"Active Speakers mounted on speaker-stands 2 m above the ground. The speakers were arranged back to back facing outwards and were connected to a CD Player.

The CD player played a CD containing pure tones comprising frequencies 100 Hz, 200 Hz, 400 Hz, 630 Hz, 800 Hz and 1000 Hz.

The purpose of generating noise levels at these tones is to enable the measurements at the receiver locations to improve identification and quantification from extraneous noise sources. Ambient noise in the area of the measurements was generally minimal at these frequencies and hence, the main contributor of noise at these frequencies was the speakers. However, influence of background or ambient noise was subtracted on some occasions, dependent upon the strength of the received noise.

The speakers were adjusted to almost maximum volume and with the noise source active and stable, sound pressure level measurements were taken 20 m from each speaker using 2 SVAN 912 Sound Level Analysers (Type 1). The measurements consisted of narrow band noise measurements from 1Hz to 1600Hz and 1/3 octave band noise measurements. Both meters were utilised for this purpose and records were kept of the orientation of the speakers with respect to north. The GPS co-ordinates of the speaker positions were also recorded.

5. METEOROLOGICAL DATA

The meteorological parameters collected were one-minute samples of wind speed, wind direction, temperature, relative humidity and hourly samples of sigma-theta (standard deviation of wind direction) information which were used for determining temperature inversions. They were collected at a height of 10 m above the ground.

The meteorological station was located less than 2 km from the location of the speakers and the data collected was representative of the meteorological conditions at the noise source.

6. RECEIVER LOCATIONS

Noise measurements were conducted with 2 SVAN 912 Sound Level Analysers. Both meters had their times synchronised with the meteorological station. The sound level meters were programmed to record narrow band noise levels from 1Hz to 1600Hz. This range covers the pure tones generated by the speakers.

Typically, over a distance of 1 km with a light source-to-receiver wind (~1m/s), the noise from the lower frequencies namely, 100 Hz and 200 Hz were measurable while noise at the higher frequencies was attenuated chiefly by air absorption.

The receiver locations were selected based on several factors, namely:

- source-to-receiver winds as this is the chief phenomenon that is being investigated. Audibility of the noise source over large distances (>1 km) gave an indication of the wind direction (winds blowing in the opposite direction ie receiver-to-source winds will reduce audibility of the noise source over such distances).
- the presence of undulating ground between the source and the receiver location; and
- absence of extraneous noise sources which would mask the source noise contribution (eg passing vehicles).

7. MEASUREMENTS

The measurements were conducted over 2 weeks from 13th June 2006 to 17th June 2006 and from 19th June 2006 to 23rd June 2006. Measurements were conducted between 9pm and 6am when winds are expected to be generally milder. A total of 20 different receiver locations were used for measurements over this period.

Approximately 570 measurements were obtained throughout the two weeks to provide a large enough sample size for analysis.

8. ANALYSIS OF RESULTS

The measurements were processed to filter out the noise levels measured at each tone. Noise at each frequency was analysed to ensure that the level measured was due to the subject noise source. Measurements affected by extraneous noise sources were discarded.

Measurements were also correlated with the one-minute meteorological data from the meteorological station.

Using the meteorological conditions that correspond to each 1-minute measurement, the ENM model was set up based on the GPS co-ordinates of the source and corresponding receivers (or measurement locations).

The ENM model output of noise levels at each frequency band of interest was filtered and was then juxtaposed with the measurement at the same meteorological condition. The result was a large variation between measured and modelled when linear minute by minute data was compared. However, batches of generally 15 minute or longer energy average and overall dB(A) data was analysed. This provided a better correlation between ENM modelling results and measured data on an overall dB(A) basis.

An example of the energy produced by the speakers at 20 m is demonstrated below.

Frequency, Hz	**100**	**200**	**400**	**630**	**800**	**1000**
20m Sound Pressure Level Range, dB	92 to 102	79 to 94	78 to 83	65 to 72	65 to 77	63 to 76

The wind conditions for which data was analysed is demonstrated in the charts below. This shows that the majority of the positive winds where generally below 3m/s.

Whilst the data trends for each frequency indicate increasing noise level with increasing positive wind speed, the gradient and correlation of these trends is low. This demonstrates that conditions (atmospheric or physical) between the source and the receiver are complex and therefore cannot simply be represented by a single set of weather parameters. This was true for minute-by-minute comparisons, however, longer averaging time resulted in better correlations as will be discussed later.

8.1 Results

Figure 1 and 3 display the 1-minute sample results of noise levels as measured and predicted, as well as measured wind speeds used for modelling. The wind speed data is generally below 3m/s. As would be expected, the ENM predictions correlate closely with wind speed, although the highest predicted noise level will not necessarily be associated with the highest recorded wind speed as it depends on the vector wind component as experienced by the receiver in a given position relative to the source.

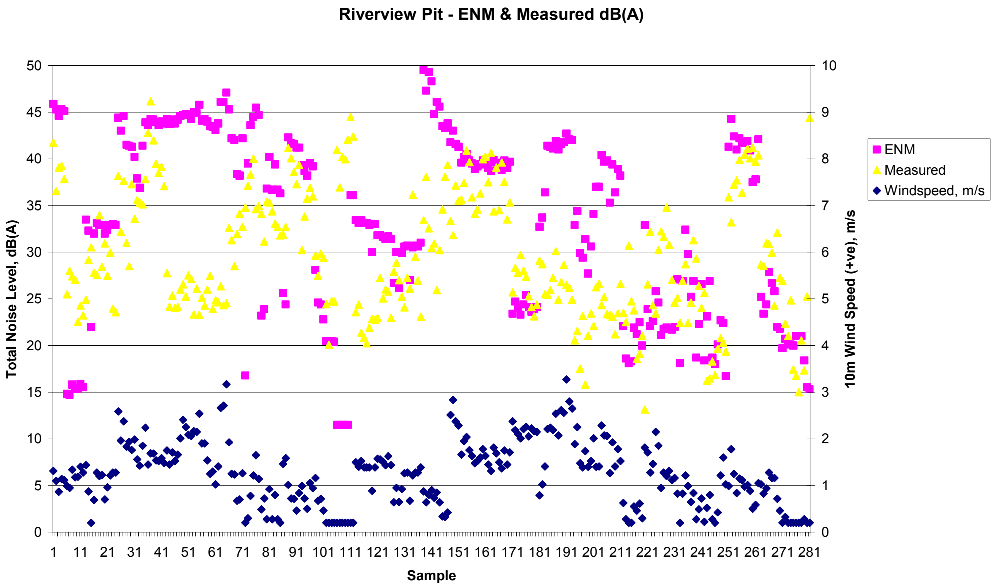

Figure.1 Site A – ENM and Measured Noise Levels for Positive Winds (1-min Data)

Figure 2 and Figure 4 show some correlation between ENM and Measured values with a trend in the expected direction between the two. Of importance is measured levels above 30 dB(A), or a level at or above typical rural background noise and hence audible. For measured levels above 30dB(A) the ENM model mostly over predicts noise. Whilst there is a large spread in the data, a larger portion of this data is demonstrated to be over-predicted by ENM. The overall implication is therefore an overestimation of noise by ENM during positive winds.

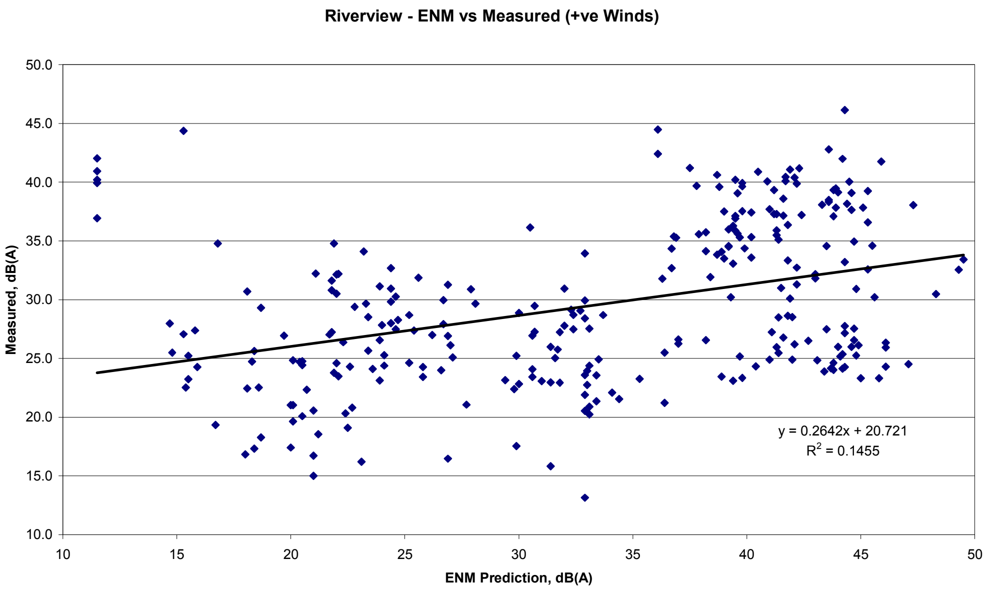

Figure 2 Site A – ENM Vs Measured Noise Levels for Positive Winds (1-min Data)

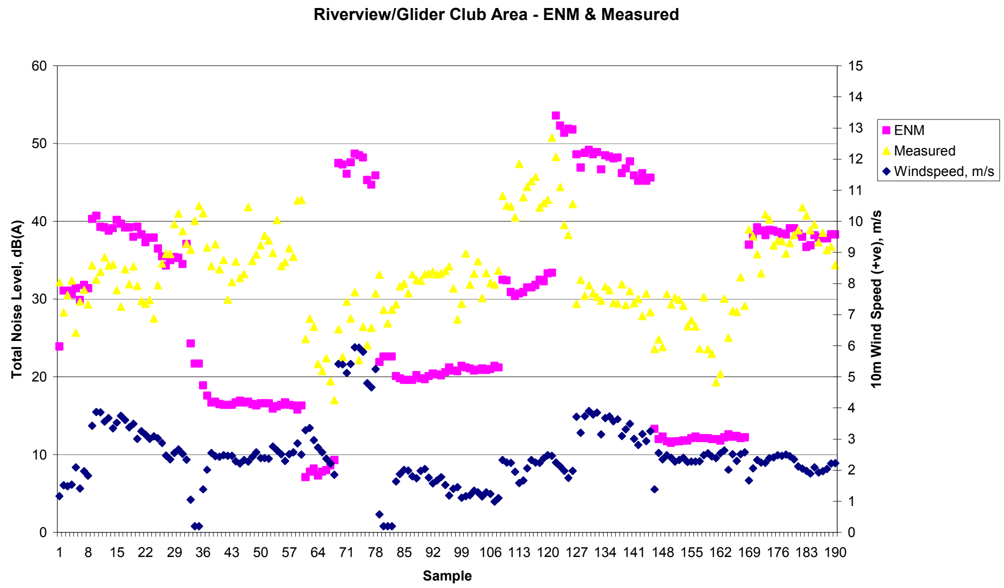

Figure 3 Site B - ENM and Measured Noise Levels for Positive Winds (1-min Data)

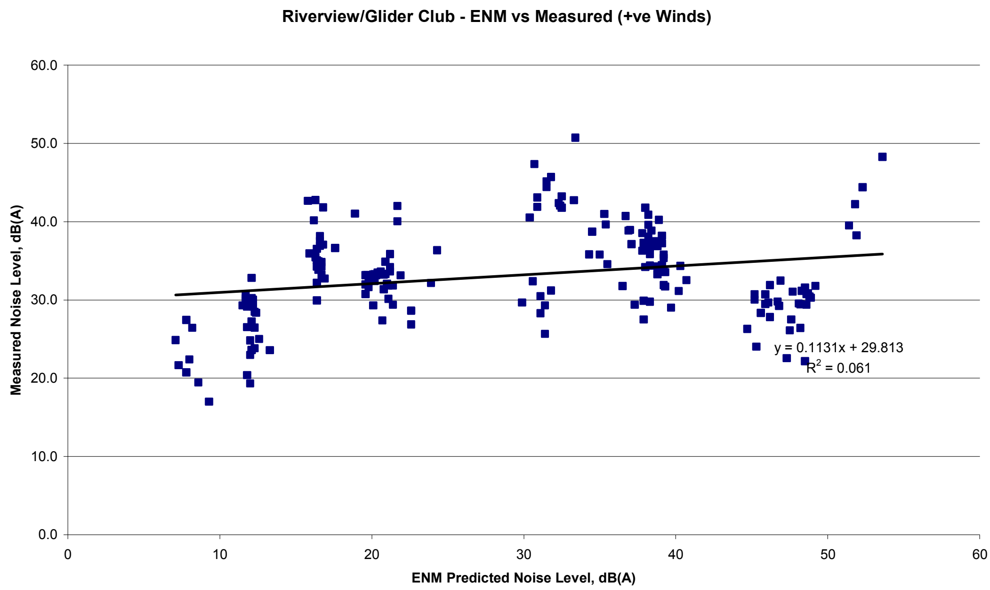

Figure 4 Site B – ENM Vs Measured Noise Levels for Positive Winds (1-min Data)

9. ENM MODEL VALIDATION FACTOR

The measured and modelled data was analysed for periods of generally 15 to 20 minutes for a given location. This provided data points for comparison as shown in Tables 1 and 2 below. The data shows some good correlation between ENM and Measured values or within ±5dB as documented by the software developer.

Of note is that two-thirds of the data are over-predictions by ENM. The overall implication is therefore an overestimation of noise by ENM during winds generally below 3m/s. An analysis of the entire data points results in a modest over estimation by ENM of 1.6dB and 2.2 dB, on average, for the two areas respectively. This was therefore applied to modelling results for the proposed operations for equipment in these two areas only.

Table 1 Site A Validation Factor Calculation

	Total Noise Level, dBA		ENM Minus Measured, dB(A)	
Sample	**ENM**	**Measured**	**Over-Prediction**	**Under- Prediction**
1	45.3	39.3	6.0	
2	15.4	25.9		-10.5
3	32.1	29.9	2.1	
4	32.7	28.2	4.5	
5	42.1	35.6	6.5	
6	43.9	40.7	3.2	
7	44.4	25.9	18.5	
8	44.7	24.8	19.9	
9	45.0	25.3	19.7	
10	41.4	32.7	8.7	
11	44.0	37.5	6.5	
12	23.6	32.9		-9.3
13	38.0	34.0	4.0	
14	25.0	32.3		-7.3
15	41.6	39.5	2.1	
16	39.0	35.1	3.9	
17	25.4	29.2		-3.7
18	20.5	23.9		-3.4
19	11.5	40.3		-28.8
20	36.1	43.6		-7.5
21	32.9	22.4	10.4	
22	31.0	26.3	4.8	
23	30.0	29.3	0.6	
24	46.7	35.1	11.7	
25	40.8	36.9	3.8	
26	39.4	38.4	1.0	
27	39.3	46.5		-7.2
28	24.3	28.0		-3.7
29	23.9	24.3		-0.4
30	49.8	27.8	22.0	
31	52.1	37.1	15.0	
32	31.8	21.2	10.6	
33	38.5	34.8	3.7	
34	25.1	24.3	0.8	
35	22.9	30.3		-7.4
36	28.3	25.6	2.7	
37	23.9	27.4		-3.5
38	22.1	19.1	3.0	
39	42.3	37.2	5.2	
40	40.7	40.5	0.2	
41	34.2	29.0	5.2	
42	20.1	22.1		-2.0
43	19.3	36.7		-17.3
		Total Samples	**29**	**14**
		Average Difference		**2.2**

The Average Difference value is that for the combined over and under ENM predictions.

Table 2 Site B Validation Factor Calculation

	Total Noise Level, dBA		ENM Minus Measured, dB(A)	
Sample	**ENM**	**Measured**	**Over-Prediction**	**Under- Prediction**
1	30.0	31.1		-1.1
2	31.2	29.4	1.8	
3	47.2	38.8	8.4	
4	46.9	37.1	9.8	
5	48.4	38.1	10.3	
6	47.8	33.6	14.2	
7	39.8	37.0	2.8	
8	42.7	37.3	5.4	
9	47.3	42.6	4.7	
10	39.7	33.5	6.2	
11	38.5	31.9	6.6	
12	35.9	37.2		-1.3
13	20.2	38.6		-18.4
14	16.6	36.0		-19.4
15	16.3	38.9		-22.6
16	8.1	23.7		-15.6
17	57.1	36.3	20.8	
18	57.9	32.6	25.3	
19	44.6	27.6	17	
20	20.7	32.0		-11.3
21	21.0	32.8		-11.8
22	32.0	44.9		-13
23	52.3	44.1	8.2	
24	45.8	37.0	8.8	
25	40.6	37.2	3.4	
26	48.1	43.2	4.9	
27	48.5	30.8	17.7	
28	46.5	29.9	16.5	
29	12.0	28.1		-16
30	16.2	27.9		-11.7
31	38.5	37.9	0.6	
32	38.0	38.7		-0.7
		Total Samples	**20**	**12**
		Average Difference		**1.6**
The Average Difference value is that for the combined over and under ENM predictions.				

9. CONCLUSION

The experimental outdoor sound propagation monitoring was conducted over a period of 10 nights and for two sites. The results indicate significant fluctuation of received sound level for a demonstrated relatively consistent sound source. This phenomenon is often simulated by weather conditions in modelling software. The results at the two sites suggest ENM marginally over predicts received noise down-wind. In the most, the results show that attempting to predict received noise using a single stable set of weather parameters is difficult due to complex atmospheric conditions between the source and receiver locations.