Noise in urban land seismic surveys

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SUMMARY

Land seismic surveys are most often acquired in remote areas, thus the predominant noise source is often the wind. In urban areas, however, noise sources abound, including electrical cables, mechanical equipment, aircraft, and traffic. We recorded seismic data continuously over three days at a test site located in suburban Perth, Western Australia (32° 0' 40"S, 115° 53' 22"E). and found that the highest amplitude noise was mechanical (centred on 75 Hz), but the most consistent noise was traffic related (10-25 Hz). Electrical noise was identified but given its moderate amplitude and relatively consistent frequency it should be easily removed in processing. Aircraft flying over the test site resulted in moderately high level of noise with a wide bandwidth (30-200 Hz) but the noise generally lasted only a minute.

Based on these results we recommend that: acquisition should be carried out during the late night/early morning; receiver locations should be chosen with care to avoid sources of noise; analogue cabling should be as short as possible to avoid electrical noise; real-time QC should be in place to identify short-duration high-amplitude noise periods during which acquisition should cease.

Key words: urban, land, seismic, acquisition.

INTRODUCTION

In a previous work (Dean, Dupuis, and Hassan 2015) ambient noise on seismic data was defined as anything that is not related to the source or the recording system (i.e. system noise). An obvious source of noise in urban areas is pickup from electrical cables. Such noise generally appears at the fundamental frequency of transmission, but additional harmonics may also be present. Another likely source of noise is mechanical equipment, which often occurs as bursts of noise when the machine is in operation (Miller et al. 2016). Short periods of high amplitude noise from aircraft are frequently noticed during acquisition; Fidell et al. (2002) show that the majority of aircraft related noise is below 85 Hz while Berglund and Job (1996) found it peaked at around 100 Hz. The predominant source of noise in urban environments is generally accepted as being traffic (Miller et al. 2016, Miller et al. 2011, Groos and Ritter 2009). Previous studies give a dominant frequency range of between 5 and 30 Hz (Coward et al. 2003, Groos and Ritter 2009, Halliday, Curtis, and Kragh 2008, Hao and Ang 1998, Nakata et al. 2011). Being related to human activity such noise tends to decrease overnight and during the weekend (Groos and Ritter 2009).

Surface seismic data acquired in urban settings, therefore, will have much higher noise levels than are observed in, more typical, remote locations. In this paper we describe an experiment we conducted to identify and characterise the major sources of noise at a test site in the centre of Perth, Western Australia. We begin by describing the seismic data we recorded along with the traffic, aircraft, and weather data obtained from government agencies. We then show the relationship between seismic noise and these noise sources. Finally we discuss the implications of the results for future acquisition projects.

METHOD

The test site was located in suburban Perth, Western Australia (32° 0' 40"S, 115° 53' 22"E). The immediate area contains several major roads and is ~1500 m to the north of the flight path of Perth airport, which lies 8 km to the north-east (Figure 1). Seismic data was recorded continuously over a three day period from 9 am on 4 April 2017 to 11:30 am on 6 April 2017. 3-component 10-Hz geophones were used with the data being recording using a nodal acquisition system. Data was recorded using sensors positioned on the surface, as well as geophones buried at depths of 0.1, 0.2, 0.4, 0.6, 0.8, and 1 m.

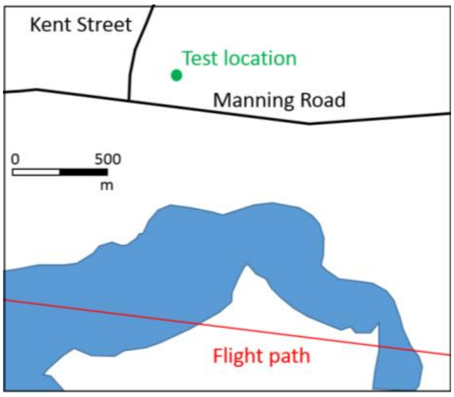

Figure 1: Map of the immediate area surrounding the test location. Major roads are shown in black and the flight path for the local airport in red.

Traffic data was provided by the Main Roads Department of the West Australian Government. It consisted of counts of the total number of vehicles passing through an intersection every five minutes (an indication of traffic volume). The closest major intersection was Kent Street and Manning Road (both roads consisting of four lanes of traffic), 250 m to the south-west (Figure 1). Data was also provided for the nearest major highway (the intersection of Canning Highway and the Kwinana freeway, 3 km to the west). The data from the two intersections shows that the highway intersection had about twice the traffic volume as the closer intersection but as the two datasets were very strongly correlated (r = 0.97) we chose only to include the closest intersection in our analysis.

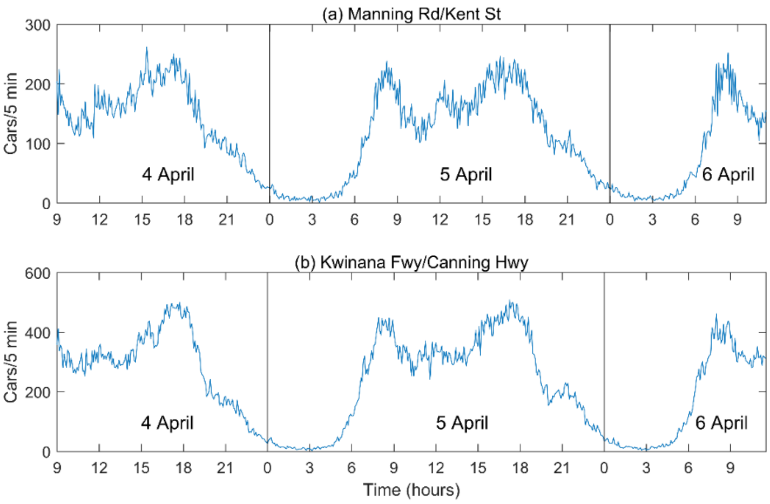

Figure 2. Traffic volume (total cars every 5 minutes) at two major intersections near the test site (a) is 250 m to the south-west whilst (b) is 3 km to the west.

Aircraft data was provided by Airservice Australia in the form of a list of times at which aircraft had passed the test site. Using the webtrak website (http://webtrak5.bksv.com/per3) we located each flight and extracted the aircraft type and altitude at its closest point (e.g. Figure 3). Over the duration of the test a total of 149 flights passed with a mean altitude of 1,200 m (standard deviation of 840 m) and minimum and maximum altitudes of 400 and 9,700 m respectively. The majority of flights occurred between midday and 6 pm (Figure 4) but the airport does not have a curfew so aircraft also passed during the early morning/late night periods when noise from other sources was minimal. The majority of aircraft (85%) were large twin-engine passenger jets, the only other class of aircraft numbering more than 3 were twin propeller aircraft (7%), the remaining aircraft types are given in the caption of Figure 4.

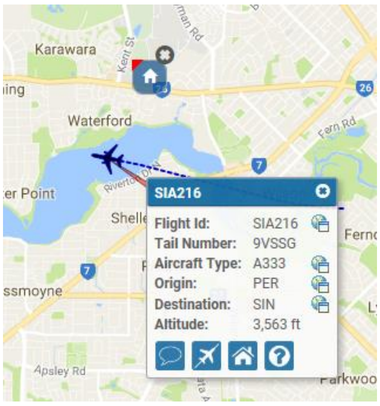

Figure 3. Example plot from webtrak website showing the passage of an aircraft near the test site (shown by the house icon).

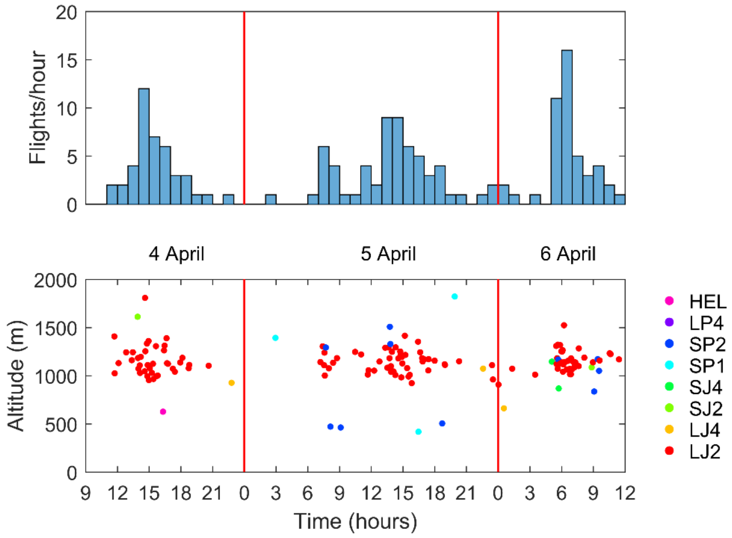

Figure 4. Summary plot showing aircraft movement near the test site. The key to the labels is aircraft size (L: large, S: small), engine type (J: jet, P: propeller), and the number of engines, HEL = helicopter.

Wind speed and gust data as measured by the closest weather station (Perth Airport, 9 km to the north-east) were obtained from the Bureau of Meteorology.

RESULTS

We being the results section by analysing the general characteristics of the seismic data. We then move on to look at its relationship to the sources of noise. Figure 5 shows the power spectral density values calculated for each 30 s record during the study period. Items of particular note are:

- The noise is concentrated between 10 and 25 Hz.
- There is little difference in the noise recorded on the three different components.
- The noise decreases significantly between midnight and 6 am (compare Figure 6a with Figure 6c).
- There are 'bursts' of noise that occur for 5 minute periods every 17 minutes during the day and every 34 minutes at night. The rms of the noise during these periods increases by a factor of between 3 and 4. The noise occurs at a dominant frequency of 75 Hz (compare Figure 6a with Figure 6b).
- A large noise event occurs between midnight and 1 am on 6 April with a predominant frequency of 100 Hz.

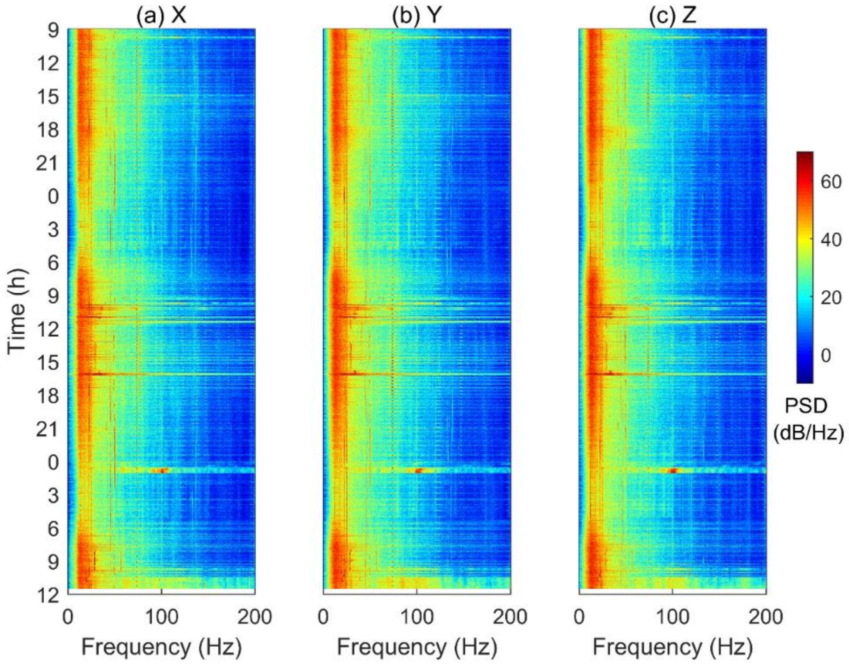

Figure 5. Frequency-time plots of the three component geophone recordings

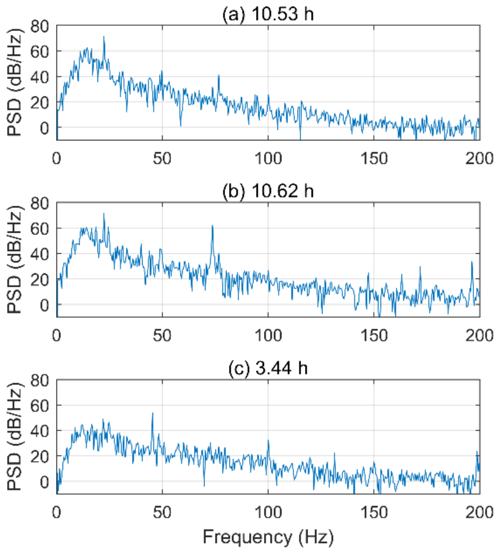

Figure 6. Example PSD functions for 30 second records at three different times.

The frequency of the local power supply is nominally 50 Hz but a peak at 45 Hz (e.g. Figure 7c) was also observed during certain periods. As shown in Figure 7d the level of powerline noise varied considerably during the test period peaking between 9 pm and 1 am each night. During the day (e.g. Figure 7a) the noise level was relatively low. Interestingly, when the 50 Hz noise level dropped the 45 Hz noise level increased (Figure 7d).

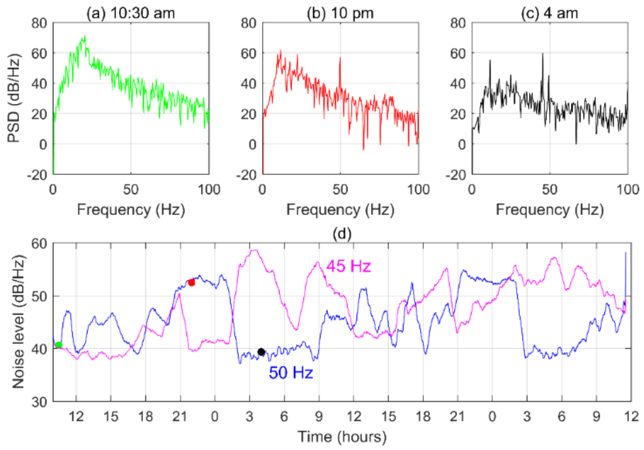

Figure 7. Example PSD results for three 30 s records and the power line noise level during the test period.

Consistent with previous studies, traffic was found to be the most significant source of noise. Comparison of the number of cars at the Manning Road/Kent Street intersection with the RMS of the seismic data (Figure 8a and Figure 8b respectively) show a clear relationship (the red line shown on Figure 8b is the vehicle counts scaled for comparison). The low number of counts during the evening/early morning period makes the correlation coefficient invalid as it breaks the assumption of normality of the variables (Figure 8c). Removal of all values below 50, however, corrects this and gives a significant and strong correlation result (0.57, Figure 8d).

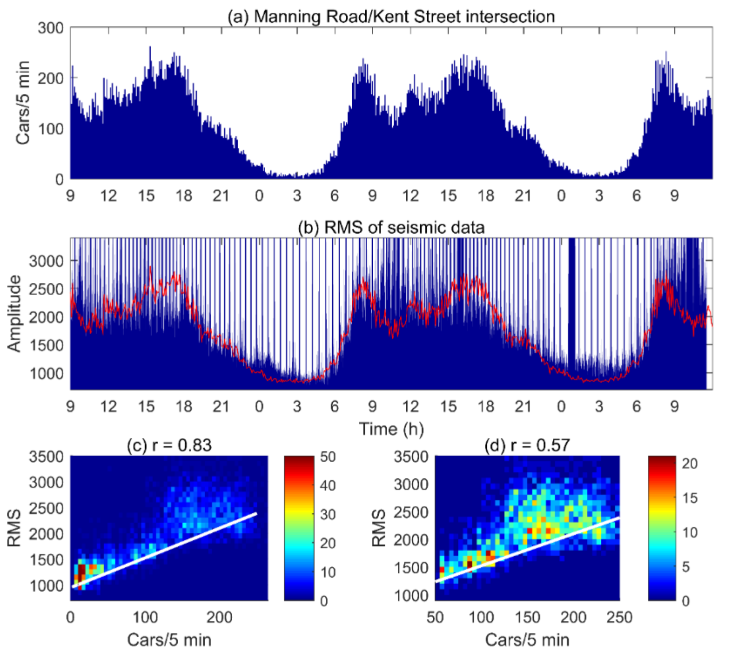

Figure 8. (a) The number of cars crossing the Manning Road/Kent Street intersection every 5 minutes. (b) the RMS of the noise in each 30 second record, the red line is a scaled version of the traffic count added for comparison purposes. The scale of the y-axis has been limited to de-emphasis the effect of the noise bursts. (c) heat-map of the RMS data and the traffic count, the correlation coefficient value is given for interest only as the normality assumption of the traffic data is violated. (d) heat-map of the RMS data and the traffic count showing only the values of the latter greater than 50, resulting in a normal distribution.

As traffic was clearly the dominant source of noise, examination for the effect of wind noise is restricted to the early hours of the morning (1 to 5 am) when traffic was minimal (Figure 8). Neither the time series plots nor the scatter plots show any indication that noise increased with wind speed (Figure 9). On 5 April the wind speed increased over the course of the morning (Figure 9a) but the noise level actually dropped. On 6 April the wind speed remained relatively constant as did the noise level (Figure 9b).

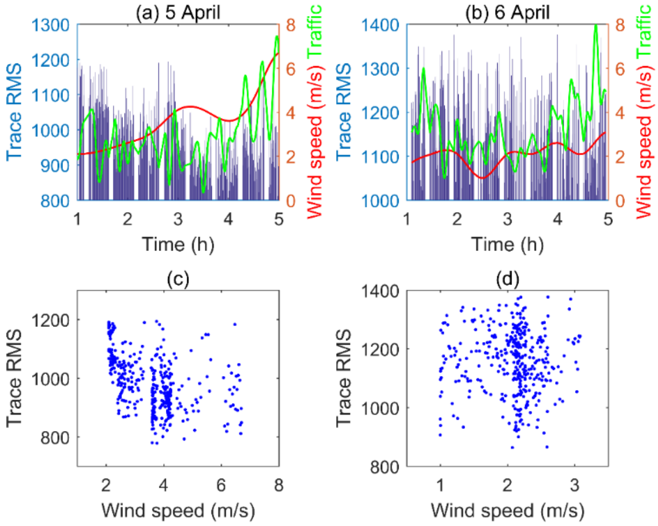

Figure 9. Plots of the trace RMS (excluding periods of high mechanical noise contamination) overlain with the wind speed (red curve) and scaled traffic level (green curve) for the early hours of (a) 5 April and (b) 6 April. The scatter plots shown in (c) and (d) correspond to the data shown in (a) and (b) respectively.

Figure 10 shows two examples of the effects of the data when an aircraft flew past the test site at night (i.e. during a 'low-noise' period). From these plots it can be seen that aircraft noise is predominantly high-frequency (> 30 Hz) and occurs at frequencies typically devoid of noise (at 240 Hz the noise level increased from -5 dB/Hz to nearly 20 dB/Hz).

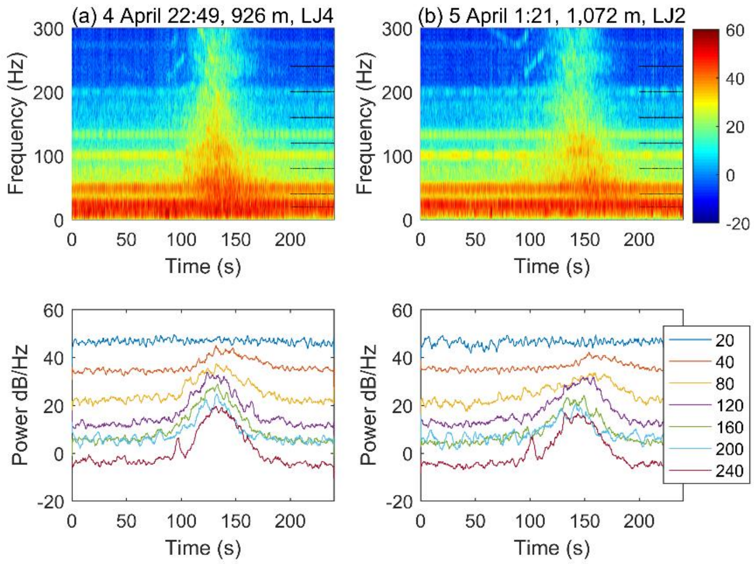

Figure 10. Frequency-time plots of two periods when an aircraft was flying over the test site. The black lines on the right hand-side of the frequency-time plots (a and b) indicate the frequencies shown on the lower pair of plots.

To examine the effect of altitude on the resulting noise level we selected the data where a two engine passenger jet passed during the late evening/early morning periods (a total of 17 records). The plot of the ratio between the maximum and mean PSD levels at 85 Hz and altitude is shown in Figure 11, although there does appear to be a decrease in noise with increased altitude the relationship is heavily influenced by the two extreme altitude values for which frequency-time plots are shown in Figure 11b and c.

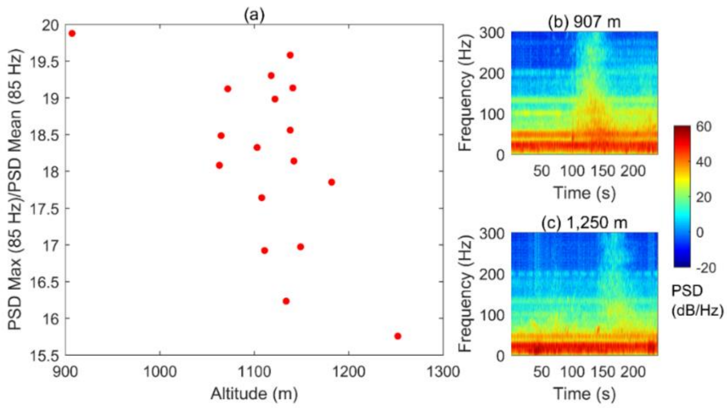

Figure 11. (a) the relationship between the ratio between the maximum and minimum PSD at 85 Hz and altitude. Examples of the frequency-time plots for aircraft at two different altitudes.

DISCUSSION AND CONCLUSIONS

A summary of the strength and bandwidth of the different noise sources is contained in Table 1. The highest amplitude noise we measured was related to mechanical equipment (Figure 8b), specifically the operation of a nearby irrigation pump. Outside of the times when the pump was operating, however, the largest noise source was traffic. The passage of aircraft created bursts of high amplitude noise but these were of a relatively short duration, typically lasting around one minute (e.g. Figure 11b). Take-offs and landings at Perth airport average 15/hour but not all of these are likely to pass over the same area as landings and take-offs tend to take place in opposite directions, similarly flights head off to the east or west depending on their final destination. Thus the maximum number of events observed is likely to be around 7/hour. Given the strength of the other noise sources and the low wind speeds experienced, wind-related noise was negligible and could not be characterised.

Table 1: Summary of the results of the noise levels attributed to different sources.

Noise source	Frequency (Hz)	Level	Duration
Mechanical	75	High (~75 dB/Hz)	5 minutes every 17 minutes
Electrical	50	Moderate (~65 dB/Hz)	Constant
Traffic	10-25 Hz	High	6 am to 12 pm
Wind	N/A	Low	N/A
Aircraft	30-200	Moderate	1 minute, 7 times an hour

Based on these results we make the following recommendations for urban seismic surveys:

- Acquisition should be carried out during the late night/early morning (midnight to 6 am) to avoid high levels of mechanical and traffic noise.
- Receiver locations should be chosen with care to avoid sources of mechanical and electrical noise.
- Cables between the geophone and digitiser should be as short as possible to avoid electrical noise.
- Although nodal systems for urban surveys are logistically advantageous some degree of real-time quality control must be in place to ensure that records are not acquired when high level noise (e.g. from aircraft) is present.

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