Sound Reflection from a Motorway Barrier

Christopher W Day
Marshall Day Acoustics Ltd, P O Box 5811, Auckland 1036, New Zealand
chrisday@marshallday.co.nz

Refereed

Abstract

The erection of a noise barrier on one side of the southern motorway in South Auckland caused complaints from a number of residents on the 'reflected' side of the barrier with claims of significantly increased noise levels. A successful application to the Environment Court for orders to have the barrier removed, gave the opportunity to measure the difference in noise level with and without the barrier.

Three measurement positions were used which were representative of the complainants. Noise levels at residences close to the motorway (30m) were consistent day to day and the difference with and without the barrier was less than 0.4 dBA. Noise levels at the more distant residences varied by up to 17 dBA due to traffic flow and meteorological effects. There was no measurable change in noise level (≤ 0.5 dB) at these outer positions following removal of the barrier.

On the basis of these measurements, there does not appear to be any link between the residents' reaction and the change (or lack thereof) in the noise environment.

Introduction

In February 2001, a noise barrier was erected on the eastern side of the Southern Motorway (Auckland) to reduce the level of noise in the adjacent Regional Botanic Gardens. The Manukau City Council had issued a resource consent for the barrier based on advice that any reflected noise to the western side, would not be significant (a predicted increase of less than 1 dB) and would not be noticeable by residents.

The barrier was made of steel and polystyrene panels as used in the construction of cool rooms and was approximately 500 metres long and 3.5 metres high.

Following erection of the noise barrier, a number of residents (living on the western side of the motorway) made complaints to the Council that the motorway noise had increased significantly and the barrier was having an adverse noise effect on the environment. They formed a Residents Action Association to pursue the matter in the Environment Court. The Environment Court accepted the residents' opinion and issued an enforcement order for the barrier to be removed.

The removal of the barrier gave the opportunity to carry out detailed noise measurements in the area with and without the barrier in place. A relatively small window of time was available for measurements before the barrier was removed due to the immediacy of the enforcement order.

Three measurement locations were used by Marshall Day Acoustics as shown in figure 1. The measurement locations were chosen to be representative of the clustering of the main complainants that appeared at the Environment Court hearing (houses shown shaded).

The first measurement position at 94 Lawrence Crescent was located approximately 30 metres from the motorway and midway along the noise barrier.

The second measurement position was located on the grass verge between numbers 9 and 11 Frank Place, approximately 400 metres from the noise barrier.

The third measurement position was located on the grass verge outside number 1 Patricia Place, approximately 650 metres from the barrier.

At position 1 the noise environment is dominated by noise from the motorway at approximately L_{dn} 73 dBA and interference from other noise sources is not a significant issue. Measurement of the acoustic effect of the barrier is relatively simple and accurate.

On this basis, an automated noise logger was used to measure the noise level continuously at this position. Unfortunately due to adverse weather conditions and instrumentation failures, only two full days of data (200 fifteen minute measurements) were obtained at this position before the barrier was removed.

Measurement of the effect of the barrier at 400m to 700m from the motorway is significantly more difficult due the effects of local road traffic, variation in motorway traffic flow and the meteorological effects on sound propagation. For this reason, manual measurements

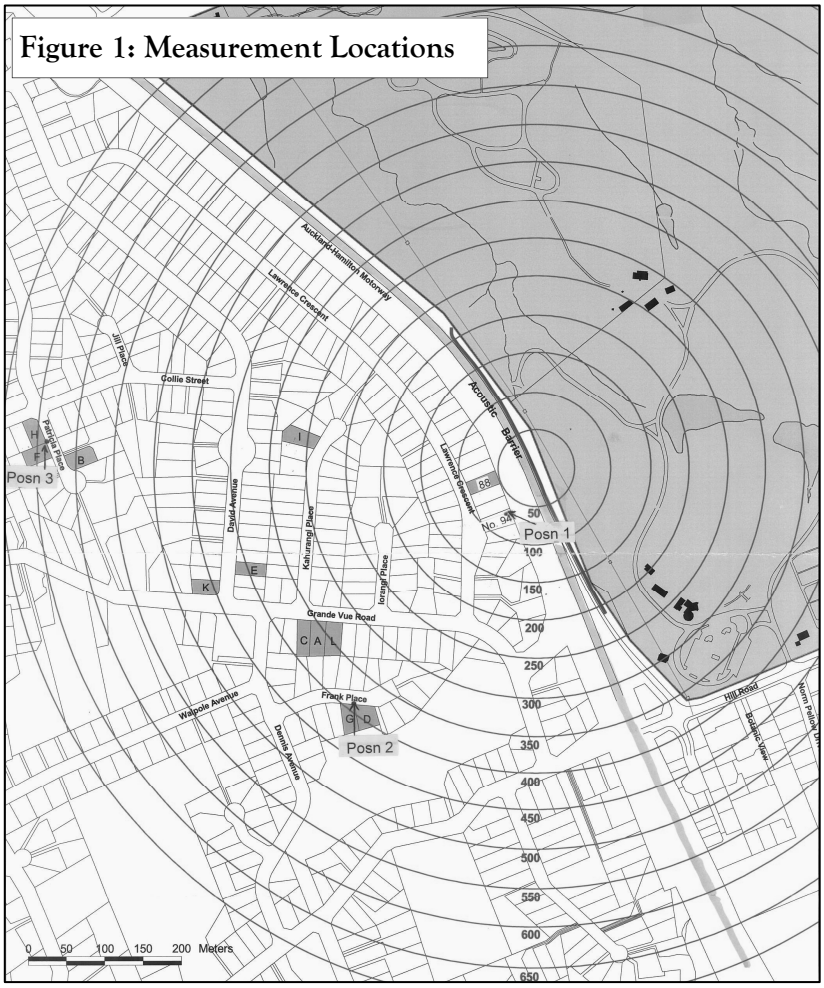


Figure 1: Measurement Locations

were made in these locations and meteorological measurements and traffic flow data were analysed.

The same measurement positions and measurement procedures were used before and after the motorway barrier was removed. As far as possible, measurements were made in similar meteorological conditions after the barrier removal.

Raw Data

Lawrence Crescent

An automatic data logger was set up on the rear balcony of number 94 Lawrence Crescent with a clear view of the motorway approximately 30m away.

The measurement parameters were stored every 15 minutes and transferred into a spreadsheet to enable calculation of the daily L_{dn} from 96 fifteen minute samples.

The two full days of measurement

Table 1: No. 94 Lawrence Crescent, Raw Data
(Day-night Sound Level L_{dn} dBA)

Date	With Barrier	Without Barrier
26 March 2003	72(.4)	
27 March 2003	73(.2)	
23 April 2003		73(.4)
24 April 2003		73(.6)
7 May 2003		73(.1)
8 May 2003		73(.1)
Average	72(.8)	73(.3)
Change in Level		**+0(.5) dB**

made before the barrier was removed were Wednesday 26 March 2003 and Thursday 27 March 2003.

To maintain consistency of traffic patterns, Wednesdays and Thursdays during April and May, after the barrier was removed, were analysed for comparison. Table 1 shows the results of this analysis.

This analysis of 576 fifteen minute measurements, showed that the noise level at number 94 Lawrence Crescent was consistent and did not change significantly (0.5 dB increase) following removal of the noise barrier.

Frank Place and Patricia Place

The noise environment at Frank Place (400m) and Patricia Place (650m) is dominated by noise from cars travelling on local roads with the motorway noise making up the background noise level. For this reason, noise measurements at these positions were made during the evening, when local traffic flows were lower and the measurements were made manually with the opportunity to pause the sound level meter during local traffic to ensure measurement of the motorway noise only. These measurements would sometimes require 30 minutes on site to obtain a 10 minute sample of motorway noise, unaffected by the louder local traffic.

These two measurement positions were selected close to clusters of complainants and in a cul de sac to further reduce the influence of local traffic (see figure 1).

A number of measurements were able to be made before and after the barrier was removed and the 10 minute L_{eq} results are shown in table 2.

Figure 2: Southern Motorway Noise

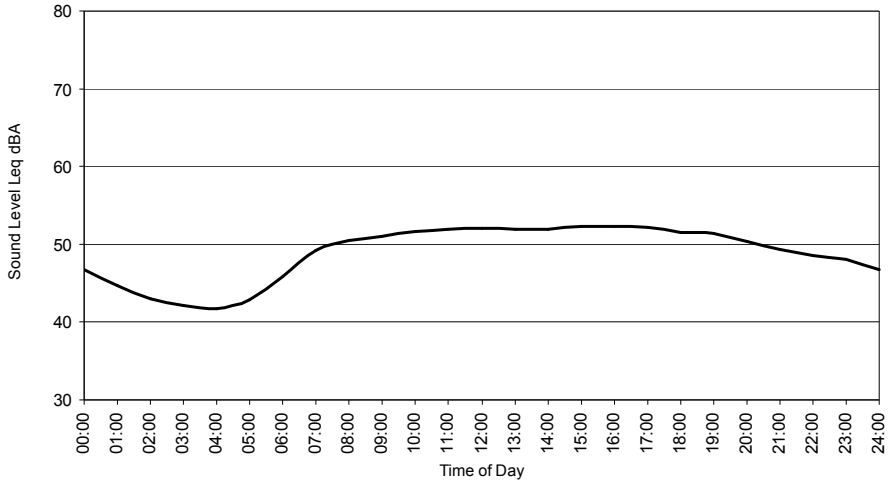


Table 2: Distant Measurements, Raw Data
($L_{eq,10\ mins}$ dBA)

9/11 Frank Place		1 Patricia Place	
With Barrier	Without	With Barrier	Without
36(.4)	39(.5)	36(.5)	42(.8)
36(.7)	41(.8)	41(.0)	44(.8)
38(.3)	41(.9)	42(.0)	45(.3)
42(.3)	43(.0)	42(.3)	45(.3)
44(.6)	45(.0)	45(.1)	48(.2)
45(.7)	45(.6)	49(.0)	49(.8)
45(.9)	46(.6)	49(.3)	49(.9)
45(.9)		53(.1)	
47(.0)			
49(.4)			
Average 43(.2)	**Average 43(.3)**	**Average 44(.8)**	**Average 46(.6)**
S Dev 4(.6)	S Dev 2(.5)	S Dev 5(.4)	S Dev 2(.7)
Change in level	**+ 0(.1) dB**	**Change in level**	**+ 1(.8) dB**

The results show that the average measured noise levels (without adjustment for flow rate) did not change at Frank Place and increased by approximately 2 dB at Patricia Place, following removal of the barrier. The range of levels measured was 17 dB.

Data corrected for Traffic Flow

One of the difficulties with measuring a change in motorway propagation effects, such as barrier reflections, is that the effective 'sound power' of the motorway varies with traffic flow rates and heavy vehicle composition.

Figure 2 shows the typical variation in traffic noise emitted by the

Table 3: No. 94 Lawrence Crescent, Traffic Flow Adjusted

(Day-night Sound Level L_{dn} dBA)

Date	With Barrier	Without Barrier
26 March 2003	72(.4)	
27 March 2003	73(.4)	
24 April 2003		73(.1)
7 May 2003		73(.3)
8 May 2003		73(.1)
Average	72(.9)	73(.2)
Change in Level		**+ 0(.3) dB**

Southern Motorway during the '24 hour day'.

The noise emission typically varies by more than 10 dBA over the 24 hours. In addition the total daily traffic flow rate varies from one day to the next.

For example, the increase in noise level measured at Patricia Place, could be due to a higher traffic flow rate during the measurements made after the barrier removal.

The manual measurements made at Frank and Patricia Place were made generally in the evening period between 21:00hrs to 24:00hrs in an attempt to minimize this variation. However the traffic flow does vary noticeably during this evening period from 1200 veh/hr to 400 veh/hr (approx 5dB).

Traffic flow data for the Southern Motorway were obtained through Transit for the closest traffic counter to the barrier, i.e at Takanini. Data was also obtained for Panama Road which was used when the Takanini station was out of action.

This data allowed the measured levels to be normalized using the Department of the Environment (DoE) UK traffic noise calculation procedures.

A base flow rate of 900 veh/hr was selected as typical for around 21:00 hrs. The actual traffic flow rate during the noise measurement period, was used to correct each of the measured noise levels. Individual corrections required, varied from 0 to 6 dB.

The measured noise levels adjusted for traffic flow are shown in table 3.

Hourly traffic flow data was available so it was possible to adjust the measured noise levels at Frank Place and Patricia Place to allow for the traffic flow being up or down during individual measurements.

Individual corrections varied from 0 to 6 dB. The results following these adjustments are shown in table 4.

The flow adjusted noise levels decreased by 0.6 dB at Frank Place and increased by 0.6 dB at Patricia Place following removal of the barrier. The range of flow adjusted levels was 15 dB.

Table 4: Frank Place & Patricia Place Flow Adjusted Data

($L_{eq,10\ mins}$ dBA)

9/11 Frank Place		1 Patricia Place	
With Barrier	Without	With Barrier	Without
37(.9)	38(.8)	38(.6)	43(.2)
38(.8)	41(.9)	41(.6)	44(.2)
41(.7)	43(.1)	42(.2)	45(.3)
42(.0)	43(.6)	46(.6)	47(.1)
44(.2)	43(.9)	47(.8)	48(.2)
45(.0)	44(.9)	49(.1)	49(.8)
45(.8)	46(.6)	50(.4)	50(.1)
46(.0)		53(.4)	
47(.3)			
50(.5)			
Average 43(.9)	**Average 43(.3)**	**Average 46(.2)**	**Average 46(.8)**
S Dev 4(.2)	S Dev 2(.5)	S Dev 5(.0)	S Dev 2(.7)
Change in level	**– 0(.6) dB**	**Change in level**	**+ 0(.6) dB**

Stable Meteorological Conditions

One of the difficulties with measuring the small changes in noise level due to the barrier, is that the noise level can vary by more than 15 dBA due to environmental effects.

Noise levels measured at 30m from the motorway are not significantly affected by meteorological conditions, however, at greater distances, meteorological conditions have a significant effect on noise propagation.

To monitor the conditions in this case a meteorological station was set up in the adjacent Botanic Gardens.

Still conditions at night or light downwind conditions, provide a more stable environment for noise measurement with a slight positive effect on sound propagation.

These positive conditions were also thought to be the most likely to affect residents on the western side of the motorway ie the highest noise levels.

The data was reduced to contain only measurements made under these positive propagation conditions ie still or light wind from the positive sector.

For example, one of the 'with barrier' measurements, was 9 dBA lower than the other measurements due to the south-westerly

Table 5: Flow Adjusted and Meteorologically Grouped

($L_{eq,10\ mins}$ dBA)

9/11 Frank Place		1 Patricia Place	
With Barrier	Without	With Barrier	Without
37(.9)	41(.9)	41(.6)	43(.2)
42(.0)	43(.1)	42(.2)	44(.2)
44(.2)	43(.6)	46(.6)	45(.3)
45(.0)	44(.9)	47(.8)	47(.1)
46(.0)	46(.6)	49(.1)	48(.2)
47(.3)		50(.4)	49(.8)
		53(.4)	50(.1)
Average 43(.7)	**Average 44(.0)**	**Average 47(.3)**	**Average 46(.8)**
S Dev 3(.4)	S Dev 1(.8)	S Dev 4(.3)	S Dev 2(.7)
Change in level	**+ 0(.3) dB**	**Change in level**	**– 0(.5) dB**

conditions at the time, and was thus omitted in this data reduction.

The results for the 'stable' meteorological conditions are shown in table 5.

These results show a 0.3 dB increase in noise level at Frank Place and a reduction in noise level of 0.5 dB at Patricia Place.

Significance of Results

This flow adjusted, meteorologically grouped data has an overall standard deviation of 2.6 dBA (Frank Place) and 3.4 dBA (Patricia Place). The 95% confidence limits for Patricia Place were 3.1 dBA and 2.0 dBA with and without the barrier.

The measured changes in noise level due to the barrier (+0.3 dB to –0.5 dB) are not significant in the context of the difference limen (smallest subjectively perceptible change) of 2 dB and the variations due to flow rate and meteorological conditions (range 17 dB).

Overall Noise Level

In addition to the study of the change in noise level due to the barrier, a comparison of the noise level at the complainants houses compared with other houses at similar distances from the motorway was made.

This was primarily a 'desktop' study using SoundPlan software to calculate noise levels. This software uses the 3 dimensional digital terrain map and the known traffic flow rates to calculate the noise level using internationally recognised formulae.

The measured noise level at Patricia Place of approximately 47 dBA is typical of many residential areas at 650m from the motorway.

The noise level at Frank Place (44 dBA) is slightly less than expected for a location at 400m from the motorway due to the screening provided by the hill between Frank Place and the motorway.

The noise level at houses along Lawrence Crescent is similar to any other location at approximately 30m from the Southern Motorway.

This was confirmed by measurements made at a residence 500m north of the barrier and at a similar distance from the motorway.

Frequency Characteristics

A-weighted sound levels (dBA) have been used in most of the international studies on community response to transportation noise and 'dBA' is generally accepted as the parameter to be used for the assessment of effects from transportation noise.

However, because it is a single figure index, it may not necessarily reflect changes that occur at specific frequencies that may be detectable to the human ear.

To investigate whether there were unusual frequency effects caused by the barrier, measurements of the noise spectrum were made while the barrier was in place.

Two measurement positions close to the motorway were used – number 88 Lawrence Crescent which was directly opposite the barrier and concurrently at number 38 Lawrence Crescent, which was approximately 250 metres north of the barrier.

This position at 38 Lawrence Crescent was in a similar physical relationship to the motorway as number 88 but with no effect from the barrier.

Figure 3 shows the noise spectrum of measurements made at these two positions, i.e. with and without the barrier with the identical traffic flowing past.

The figure clearly shows that there are no significant differences in the frequency content of the sound with and without the barrier.

Conclusions

Noise levels were measured at three locations for several days before and after removal of the motorway barrier. The levels of noise measured with the barrier in place were typical of the noise levels experienced at general residential sites along the southern motorway at similar distances and orientation to the motorway.

The Day-Night noise exposure (L_{dn}) measured at the Lawrence Crescent house (30m from motorway) was stable from day to day (range 1 dB). The change in noise level following removal of the barrier was +0.3 dB at this position.

Noise levels at 400m and 650m from the motorway varied significantly day to day, due to changes in flow rate and meteorological conditions (17 dB range).

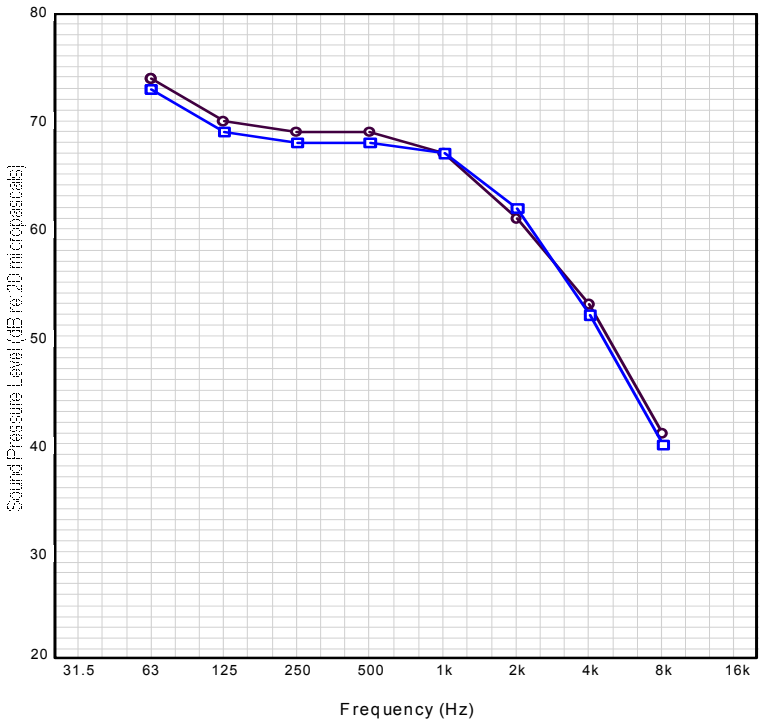
Correcting the data for traffic flow differences and grouping the measurements for meteorological conditions provided more consistent data (12 dB range) but no statistically significant change in noise level due to the barrier (+0.3 dB and -0.5 dB). These changes in noise level (0.5 dB) are not significant subjectively when considered in context with the difference limen of 2 dB.

The study has shown that there was no measurable change in noise level following removal of the motorway barrier. The variation in noise level due to variation in traffic flow and meteorological conditions at the distant positions was significant (17 dB).

Frequency analysis showed no change in noise spectrum due to the barrier.

On the basis of these measurements, there does not appear to be any link between the residents' reaction and the change (or lack thereof) in the noise environment. ❑

Figure 3: Noise Spectrum With/Without Barrier



Noise Kills?

Some years ago, at a conference, a Japanese speaker made reference to the fact that no one had actually been killed by noise.

He said that this was not true as he knew of a case where an electric guitar player in a flat played at such a volume he upset many of his flat neighbours. In spite of appeals to discontinue, he persisted with the high volume nuisance. Finally, during a particularly high volume session, a person from the flat below became so incensed he rushed up and fatally shot the guitar player. So excessive noise can kill!