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REPORT No.: 001 R01 2007398

PROJECT: BERRYBANK WIND FARM
NOISE IMPACT ASSESSMENT

CLIENT: Union Fenosa Wind Australia Pty Ltd
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ATTENTION: Mr Shaq Mohajerani

DATE: 28 May 2009

MARSHALL DAY ACOUSTICS

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DOCUMENT STATUS

Revision	Purpose	Date delivered	Reviewed by
-	Draft issued to client	18 May 2009	-
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1.0 OVERVIEW

This report, commissioned by Union Fenosa Wind Australia Pty Ltd (Union Fenosa), details the results of a noise assessment of the proposed Berrybank Wind Farm located near the township of Berrybank, Victoria.

The assessment has been performed in accordance with the requirements of New Zealand Standard NZS6808:1998 – *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS6808:1998), as required by Victorian state policy. The standard states that the noise level from a wind turbine generator or wind farm at a residential site should not exceed the background noise level (L_{A95}) by more than 5dBA or a level of 40dBA L_{A95}, whichever is greater. Limits are therefore set using these criteria based on noise measurements of existing ambient levels at a range of wind speeds. Noise predictions are then compared against these limits in order to confirm compliance or not, with the standard.

Noise predictions in NZS6808:1998 are based upon a simple equation independent of sound spectrum, but requires the choice of an air absorption coefficient that suits the spectrum of the wind turbine. Implicit in the standard is that residents who experience a worst-case noise level of 35dBA or less will automatically comply with the standard.

The Berrybank Wind Farm is proposed to consist of a total of one hundred (100) wind turbine generators. Six (6) different wind turbine models have been considered by Union Fenosa for this assessment.

Sound power data used to predict noise impact of these wind turbines has been sourced from the manufacturers by Union Fenosa and provided to Marshall Day Acoustics Pty Ltd (MDA).

Background noise monitoring was undertaken throughout March and April 2009 at eleven (11) residential properties in the vicinity of the proposed site.

A preliminary NZS6808:1998 noise assessment, using Vestas V90 wind turbines, identified thirty-five (35) residential properties as potentially sensitive to noise impact. These properties were defined as those with predicted noise levels above 35dBA. Residential sites where predicted noise levels are below 35dBA will comply with the NZS6808:1998 noise limits. Of the thirty-five (35) properties identified, thirteen (13) are owned by stakeholders in the project.

Noise limits determined for nine (9) of the eleven (11) monitored sites can be applied to twenty-one (21) other assessable properties in close proximity. The minimum possible NZS6808:1998 noise limit of 40dBA at all wind speeds will be used for the remaining three (3) assessable properties.

At all monitored positions, both night-time and 24 hour noise limits have been derived by correlating data against wind speed for night-time periods (2200-0700hrs), as well as 24 hour periods.

The method described in NZS6808:1998 has been used to calculate the predicted noise level at each residential site due to the presence of the wind turbines. NZS6808:1998 requires the use of an air absorption coefficient suggested in the standard to be typically 0.005dBA/m. This value varies according to the spectral content of the wind turbines that are being assessed. To predict noise emissions more accurately, we have used the octave band spectrum of the proposed turbine together with the appropriate air absorption coefficient for each octave band in accordance with ISO9613 *Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere (1993)* (ISO9613-1:1993).

Comparison of the predicted noise levels, using Vestas V90 turbines, and the noise limits indicates that all twenty-two (22) assessed non-stakeholders' residential properties will comply with both the 24 hour and night-time NZS6808:1998 noise limits.

Using Vestas V90 wind turbines, the NZS6808:1998 noise limits is exceeded at four (4) of the thirteen (13) assessed stakeholders' properties. However, predicted noise levels, at two (2) of these four (4) stakeholders' properties, will comply with the recommended limit for beneficiaries of such projects as outlined in the final report by *The European Working Group on Noise from Wind Turbines (ETSU-R-97, item 24, p(viii)). ETSU-R-97* is the document on which NZS6808:1998 was based, but goes further in that alternative levels are recommended for financial beneficiaries of wind farm projects.

The remaining two (2) stakeholders' properties are currently derelict and have been considered uninhabitable.

Using the other five (5) selected wind turbine models, compliance with the 24 hour and night-time noise limits will not be achieved without appropriate noise management settings. Compliance is likely to be achieved with an appropriate noise management plan specific to each wind turbine model.

Acoustic terminology used throughout this report is described in Appendix A.

2.0 SITE DESCRIPTION

The proposed Berrybank Wind Farm is located near the township of Berrybank, in Victoria, along the Hamilton Highway between Geelong and Mortlake. The wind farm is proposed to consist of one hundred (100) wind turbines.

The proposed layout is presented in Appendix B.

Six different wind turbine models are presently being considered by Union Fenosa for the project and all six turbine models have been considered in this noise impact assessment.

The wind turbine models selected by Union Fenosa are presented in Table 1.

Table 1
Selected wind turbine models

Model	Power output	Hub height	Rotor diameter
Vestas V90	2.0MW	80m	90m
Vestas V100	1.8MW	80m	100m
Nordex N100	2.5MW	80m	100m
Siemens SWT-101	2.3MW	80m	101m
Repower MM92	2.0MW	80m	92.5m
Mitsubishi MWT-95	2.4MW	80m	95m

3.0 WIND TURBINE NOISE CRITERIA IN VICTORIA

3.1 New Zealand Standard NZS6808:1998

Guidelines from the Victorian Government state that wind farms in Victoria must be assessed in accordance with NZS6808:1998. The standard states that the noise level from a wind turbine or wind farm at a residential site should not exceed the background noise level (L_{A95}) by more than 5dBA or a level of 40dBA L_{A95}, whichever is greater. The lower level of 40dBA is based upon an internationally accepted indoor level of 30-35dBA L_{Aeq} when there is no wind and assumes a reduction from outdoors to indoors, of typically 10dB with windows open.

This requirement should be valid for a range of wind speeds that cover the operation of the wind farm. Moreover, the standard requires a minimum of 10 days continuous background noise monitoring at selected affected sites, together with simultaneous wind speed measurements every ten minutes.

A regression analysis is then performed to describe the relationship between the background noise level and the wind speed.

Special audible characteristics

NZS6808:1998 requires that 5dBA be added to predicted noise levels from wind turbines with *known* special audible characteristics. One of the possible known special audible characteristics is tonality, assessed in accordance with IEC 61400-11 *Wind turbine generator systems – Part 11: Acoustic noise measurement techniques.*

3.2 ETSU-R-97

For stakeholders, there can be some flexibility in the application of the limits from NZS6808:1998, by agreement with the stakeholder. The detailed study on which NZS6808:1998 is based is presented in the document *ETSU-R-97 by the European Working Group on Noise from Wind Turbines.*

In this document, the increased tolerance to noise shown by residents who gain financially from a project is given in Note 24 on Page viii of the summary. It states:

> *The Noise Working Group recommends that both day- and night-time lower fixed limits can be increased to 45dBA and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm.*

For stakeholder residential properties associated with the proposed Berrybank Wind Farm, it is proposed to adopt a 45dBA base criterion. Therefore, noise emissions from the proposed wind farm at a stakeholder's property should not exceed the background noise level (L_{A95}) by more than 5dBA or a level of 45dBA L_{A95}, whichever is greater.

4.0 METHODOLOGY

4.1 Noise prediction method

The following equation from Section 4.3.3 of NZS6808:1998 is used to calculate the sound pressure levels at the residential sites:

$$L_R = L_w - 10\log\left(2\pi R^2\right) - \Delta L_A \qquad \text{Equation (1)}$$

where:

$L_R =$ the sound pressure level from a single wind turbine at 1.2m to 1.5m above local ground level in dBA at distance R

$L_w =$ the sound power of the wind turbine at wind speeds referenced at 80m above ground level (AGL) in dBA. Measured according to IEC 61400-11

$R =$ the distance between source and receiver in metres

$\Delta L_A = \alpha_a R$

$\alpha_a =$ attenuation of sound due to air absorption, in dBA/m for broadband sound.

As stated in Section 4.3.3, it is generally accepted that Equation 1 is slightly conservative (ie, over-prediction of the sound levels) and is the same as that used in IEC 61400-11. Section 4.3.3 states:

> *Equation 1 is based upon hemispherical spreading of the sound from the source and does not take into account attenuation due to screening effects, i.e. where there is no line of sight between the WTG and receiver locations. Acoustic absorption and reflection effects due to vegetation and ground cover are also ignored. The sound level (L_R) predicted at a distance (R) is that at 1.2m – 1.5m above the local ground level, which is assumed non-reflective. Thus, a good estimate can be derived when predicting sound propagation through free space (e.g. across open gullies), and a conservative estimate (i.e. over-prediction), for propagation across flat locations where ground absorption may be significant. For instances where the WTG is not in line of sight from the observation point, there may be an additional attenuation of up to 12dBA. The degree of attenuation will depend upon a number of factors influencing the direct and indirect sound paths between source and receivers.*

4.2 Air absorption

The prediction method outlined in NZS6808:1998, does not consider the spectral content of the wind turbine noise emissions. Spectral content can be important as some larger modern wind turbines emit noise with more low frequency content. Low frequency sound attenuates at a relatively slow rate in air; hence the proposed typical atmospheric absorption coefficient of 0.005dBA/m (5dBA/km) in NZS6808:1998 may, at times, be too great.

For this reason, octave band sound power levels together with the appropriate air absorption coefficient for each octave band in accordance with ISO9613-1:1993 have been used to predict noise emissions from each selected wind turbine model more accurately. The octave band absorption coefficients used are presented in Table 2.

Table 2
ISO9613-1:1993 air absorption coefficients

	Octave band mid frequency								
Description	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**Hz**
Air absorption coefficient	0.11	0.39	1.10	2.18	3.85	9.00	28.80	103.67	dBA/km

4.3 Sound power levels

Sound power levels measured in accordance with IEC 61400-11 are referenced to wind speeds measured at 10m above ground level (AGL), using a reference surface roughness length, z_0, of 0.05. To undertake the noise impact assessment at hub height, the sound power level data provided by Union Fenosa has been referenced to wind speeds measured at 80m AGL using the reference roughness length.

Sound power data used to predict noise impact of the six (6) selected wind turbine models was provided by Union Fenosa and are presented in Figure 1.

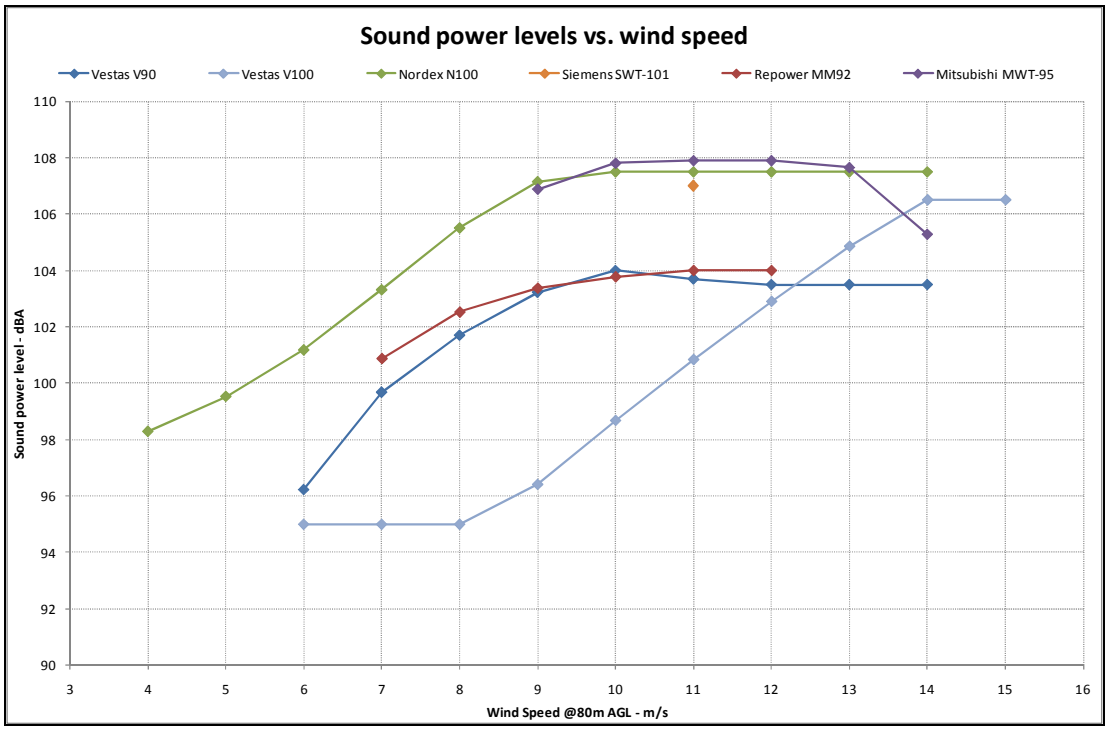

Figure 1: Sound power level profiles

The octave band sound power spectra of the selected wind turbine models are presented in Figure 2.

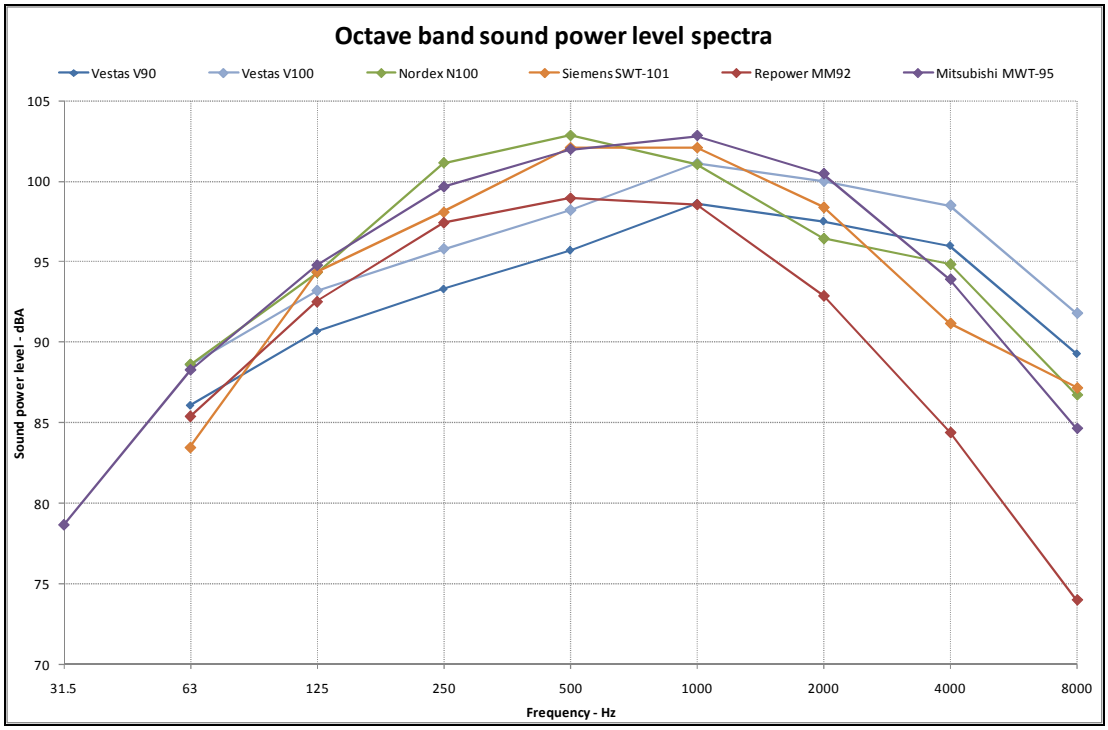

Figure 2: Octave band sound power level spectra

Sound power level data has been sourced from the documents presented in Table 3.

Table 3
Sound power level data documents

Model	Document
Vestas V90	Vestas General Specification 950019.R5 dated 07/09/05 Spectrum data provided by Union Fenosa
Vestas V100	Vestas preliminary specification from Product Presentation dated 11/03/09
Nordex N100	Nordex document F008_228_A03_EN dated 01/01/09
Siemens SWT-101	Siemens document E R WP-EN431-10-0000-0172-00 dated 31/03/09
Repower MM92	Wintest report WT 4993/06 (extract from WT 4992/06) dated 03/03/06
Mitsubishi MWT-95	Wintest draft report WT 6756/08

We understand that sound power level data for the Vestas V100 wind turbine is only preliminary and not based on measurements in accordance with IEC 61400-11. The noise emissions will need to be reassessed for this wind turbine model once an IEC 61400-11 test report is available.

4.4 Selection of background noise monitoring locations

Implicit in NZS6808:1998, is the expectation that residences with a noise impact of 35dBA or more should be included in the noise assessment. The assessable properties were identified as those within the 35dBA noise contour using the proposed layout and Vestas V90 wind turbines, presented in Appendix C.

4.5 Background noise monitoring

The measurement of noise from a source is normally undertaken at wind speeds below 5m/s in order to reduce the influence of windborne noise on the measurement itself. However, by the very nature of wind farms, the noise produced by wind turbines mostly occurs in a windy environment, at wind speeds consistently greater than 5m/s. For this reason, NZS6808:1998 was developed especially for this type of acoustic problem. The parameter L_{A95} is chosen as the compliance parameter, because it is statistically more representative of the type of noise a wind farm produces, and can take into account the background noise levels due to wind.

Background noise monitoring is carried out at selected noise monitoring locations for a minimum period of ten (10) days so as to provide at least 1,400 data points. Simultaneous wind speed monitoring is undertaken at a met mast within the proposed wind farm site.

Where it is considered likely that rainfall has occurred at the monitoring locations, associated noise and wind speed data points must be removed from regression analysis.

4.6 Wind speed measurements

Measurements of wind speed were taken at a tower situated at the Berrybank site with wind anemometers at 20m and 40m and provided to us by Union Fenosa.

Wind speed increases with height above ground, and is dependent on the shape of the velocity profile. Measurements at two or more heights can determine the shape of this profile. In order to convert wind speeds measured at a height of h_1 to that of a height of h_2 AGL, the following Log Law equation which describes a velocity profile in a turbulent boundary layer, may be used:

$$V_1 = V_2 \cdot \frac{\ln\left(\frac{h_1}{z_0}\right)}{\ln\left(\frac{h_2}{z_0}\right)}$$

Where:

$V_1 =$ wind speed at height h_1 in m/s
$V_2 =$ wind speed at height h_2 in m/s
z_0 is the surface roughness length.

A reference roughness factor of 0.05 is used to calculate wind speeds in accordance with IEC 61400-11.

Alternatively, the Power Law equation may be used to describe the velocity profile:

$$V_1 = V_2 \cdot \left(\frac{h_1}{h_2}\right)^{\alpha}$$

where:

V_1 and V_2 are as above
$\alpha =$ measured wind shear.

As wind speed was not available at the hub height of 80m, it was calculated using the real time wind shear calculated between wind speeds at 20m and 40m. The wind shear was then applied to the measured wind speed at 40m.

4.7 Establishment of noise limits

A regression analysis is performed to describe the relationship between the monitored background noise levels and the wind speeds. The noise limits are determined as detailed in Section 3.1 above using this correlation for each monitored property.

Where background noise measurements have not been undertaken, noise limits from a nearby property are used. Alternatively the minimum possible noise limit of 40dBA is used at all wind speeds.

Wind turbine noise is usually most noticeable in the lower wind speed range of 6-9m/s when the sound level produced can be comparable or greater than, the background noise generated by the wind. At greater wind speeds, the background noise due to the wind itself can mask the wind turbine noise.

4.8 Assessment of acceptability of wind farm noise

Finally, a comparison is made between the predicted noise levels and the noise limits determined in accordance with NZS6808:1998 for each assessable property in order to establish compliance.

Where required, a noise management plan may be implemented to achieve compliance by operating selected turbines in noise management mode.

4.9 Stable air effects and impulsiveness

In 2003, Dr van den Berg undertook a study of the Rhede Wind Park located in the north-west of Germany near the Dutch border. His study set out to explain occurrences of wind park noise emission which were higher than had been expected during the planning phase. The study also included a limited investigation into complaints from adjacent residences of a modulation or impulsive character to the noise emissions during night time hours. He presented his findings in a paper entitled *Effects of the wind profile at night on wind turbine sound* published in the *Journal of sound and Vibration 277 (2004)*.

The results of this study are commonly, and somewhat confusingly, referred to as the "van den Berg effect". We consider that van den Berg's paper addressed two, distinct issues, namely: stable air effects, and; impulsiveness.

With regard to stable air effects, Dr van den Berg found that during periods where the air was highly stable noise emissions from the wind farm increased significantly. During stable air conditions the velocity profile may change. For example, for a given wind speed at 10m AGL the wind speed at hub height may be relatively higher and the wind speed nearer to the ground may be relatively lower than expected. This would in turn cause relatively higher turbine SWLs while, concurrently, the background noise levels at adjacent properties may be relatively lower due to a reduction in wind generated noise from surrounding vegetation, etc. In these circumstances, wind farm noise emission could be more noticeable.

We consider that where a noise assessment uses wind speed data collected at the hub height, any potential stable air effects will be better represented in the assessment process. Where an assessment is carried out with 10m AGL wind speed data, there is a greater risk that stable air effects will not be considered during the assessment process.

The noise impact assessment for the Berrybank Wind Farm was undertaken with wind speeds referenced at hub height (80m) in order to reduce the potential effects of air stability on predicted noise levels.

With regard to impulsive character in wind turbine noise emission, van den Berg observed that, on occasion, noise emission from the wind park at selected receivers demonstrated an impulsive character. It was conjectured that this was due to the modulating pattern of noise emission from the nearest cluster of turbines, which operated at approximately the same rotational speed but with the blades being appropriately out-of-phase.

Discussion

It should be noted that the study of the Rhede Wind Park inherently addressed site specific issues including topography and wind turbine type. In particular, around the Rhede Wind Park, stable air most commonly occurred during the night-time hours during summer months. We consider it possible that for an alternative site with different site topography, weather conditions and possibly turbine types, stable air effects and impulsive noise emission may either not significantly affect noise emission or not occur regularly enough to cause significant concern. We are presently not aware of any other published papers which have demonstrated Dr van den Berg's findings at other wind farms.

A recent review of van den Berg's research prepared for the Ontario Ministry of the Environment[1] highlighted the lack of solid scientific data to support the conjecture that stable atmosphere can lead to increased wind turbine noise emission during night-time due to higher than expected hub height wind speeds. Concerning impulsiveness, which is described in this paper as amplitude modulation, it is noted that *"...no strong evidence was provided to show the modulations get worse at night compared to daytime in the summer."* However, the concluding remarks of this report noted that van den Berg's research should be considered *"as the catalyst that started serious discussion on many aspects of wind farm noise"*.

Given the current state of published information regarding both stable air effects and impulsiveness, we do not consider it appropriate to directly assess either effect as part of the pre-construction planning process. It is considered that, should either effect be present once the wind farm is operational then, measures may be taken to control them.

[1] Ramani Ramakrishnan – *Wind turbine facilities noise issues*, Aiolos Report Number: 4071/2180/AR155Rev3 Dec 2007

4.10 Special audible characteristics

If potential special audible characteristics are observed, they will be assessed during the post-construction noise monitoring program.

5.0 SELECTION OF RESIDENCES FOR ASSESSMENT

Implicit in NZS6808:1998 is the expectation that residences with a noise impact of 35dBA or more should be included in the noise assessment. The assessable properties were identified as those within the 35dBA noise contour using the proposed layout and Vestas V90 wind turbines.

Table 4 presents thirty-five (35) properties which have been identified for assessment as well as the highest predicted levels according to NZS6808:1998 using Vestas V90 wind turbines. The "S" and "U" next to the house number indicates that they are stakeholders in the project and uninhabitable properties, respectively.

Table 4
Residential sites to be assessed

House	Easting	Northing	Highest predicted noise level (dBA)
9 (S)	724123	5799807	40
10 (U)	718587	5797888	39
18	719391	5803724	37
27	716501	5793929	37
28	715923	5793021	36
54 (S)	720176	5800321	45
55 (S)	719613	5799970	42
56 (U)	719602	5799532	41
57	719459	5799651	41
58	717818	5801367	38
60	717667	5797118	35
61 (S)	719390	5796269	43
62 (S)	721670	5796577	43
63	722798	5796160	40
64	724012	5796148	37
65 (SU)	723797	5798337	47
66 (S)	722414	5798736	44
67 (S)	718431	5793106	39
68 (SU)	718429	5793061	39
69	718535	5793693	40
70	718346	5793752	40
71 (S)	718590	5793405	39

House	Easting	Northing	Highest predicted noise level (dBA)
72	718520	5793406	39
73	718619	5792068	37
74	718006	5791092	35
76 (SU)	722703	5792293	48
78 (S)	720663	5793064	43
79	719983	5793140	41
80	719684	5793375	41
81 (SU)	719130	5793548	40
83	721502	5791385	39
84	723128	5790975	35
102	725109	5796692	37
103	723431	5793860	41
109 (U)	718502	5793373	39

Note: (S) stakeholder property - (SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property

Seven (7) properties are currently derelict and have been considered uninhabitable in this assessment.

6.0 BACKGROUND NOISE MONITORING

Twelve (12) of the thirty-five (35) assessable residential properties were selected for background noise monitoring. These sites were selected as representative of the properties in the vicinity of the proposed site. Residents at two (2) of the properties, Houses 57 and 60 which are located to the west of the proposed site, did not allow us to monitor background noise levels at their properties. Background noise monitoring was however undertaken at an uninhabitable property, House 10, which is nearby to House 57 and 60.

Monitoring was undertaken between 12 March 2009 and 15 April 2009. Table 5 lists the eleven (11) sites were background noise monitoring was carried out.

Table 5
Background monitoring sites

House	Indicative of House	Monitoring period
10 (U)	60, 61 (S)	12.03.09 to 25.03.09
18	-	12.03.09 to 25.03.09
27	28	12.03.09 to 27.03.09
58	54 (S), 55 (S), 56 (U), 57	12.03.09 to 26.03.09
63	62 (S), 64, 103	02.04.09 to 15.04.09*
70	67 (S), 68 (SU), 69, 71 (S), 72, 109 (U)	12.03.09 to 26.03.09
73	-	12.03.09 to 27.03.09
74	-	12.03.09 to 26.03.09
80	78 (S), 79, 81 (SU)	12.03.09 to 24.03.09
83	84	12.03.09 to 26.03.09
102	-	12.03.09 to 26.03.09

Note: (S) stakeholder property - (SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property
* measurement repeated due to equipment failure during the 1st monitoring period

Due unforseen technical difficulties, background noise levels are not available for House 73 between 13 March 2009 at 2130hrs and 15 March 2009 at 0750hrs and between 15 March 2009 at 1010hrs and 18 March 2009 at 0750hrs.

Good correlation between the measured background noise levels and wind speed indicate that the collected data has not been affected by the equipment failure.

Houses 9, 65, 66 and 76, are stakeholders in the project and were therefore not considered for background noise monitoring. The minimum possible ETSU-R-97 noise limit of 45dBA has been applied at these houses at all wind speeds.

Environmental Noise Loggers Type EL-215 and EL-316 were used to conduct 24 hour ambient noise level measurements. Measurements were taken at 10 minute intervals. Noise monitoring was undertaken for at least 10 days at all sites in accordance with NZS6808:1998. Noise loggers were placed at least 5m from the nearest dwelling in positions that were representative of the general ambient noise environment.

Photographs of logger positions are presented in Appendix D.

Daily rainfall data collected by the Bureau of Meteorology at Mortlake were reviewed and where rainfall is likely to have occurred, these data points were removed from the analysis. Appendix E shows the background noise and wind vs. time for each study site together with the correlation coefficient.

7.0 NZS6808:1998 NOISE LIMITS

The background sound pressure levels described in Section 6.0 are plotted against wind speed in this section. To determine the noise limits, a regression analysis of the background noise vs. wind speed is performed. An investigation of a suitable regression analysis was carried out using linear, second order or third order polynomial curves. In most cases, it was found that a third order polynomial provided the best representation of the background noise levels.

Presented in the following sections are the graphs used to derive the noise limits for each of the study sites. The solid blue line represents the background noise line of best fit and the solid black line represents the noise limits derived in accordance with NZS6808:1998. The equation of the line of best fit is noted on each graph as is the correlation coefficient.

7.1 House 10

Although House 10 in uninhabitable, background noise levels have been monitored at this property as nearby residents did not allow noise monitoring at their properties (Houses 57 and 60). The noise limits for House 10 also apply to House 60 (approximately 1,200m south-west). Noise limits for House 57 are discussed in Section 7.4 below.

The following two graphs show the 24 hour and night-time noise limits derived for House 10. Photographs of the logger position at House 10 are presented in Figures D1 to D4 of Appendix D.

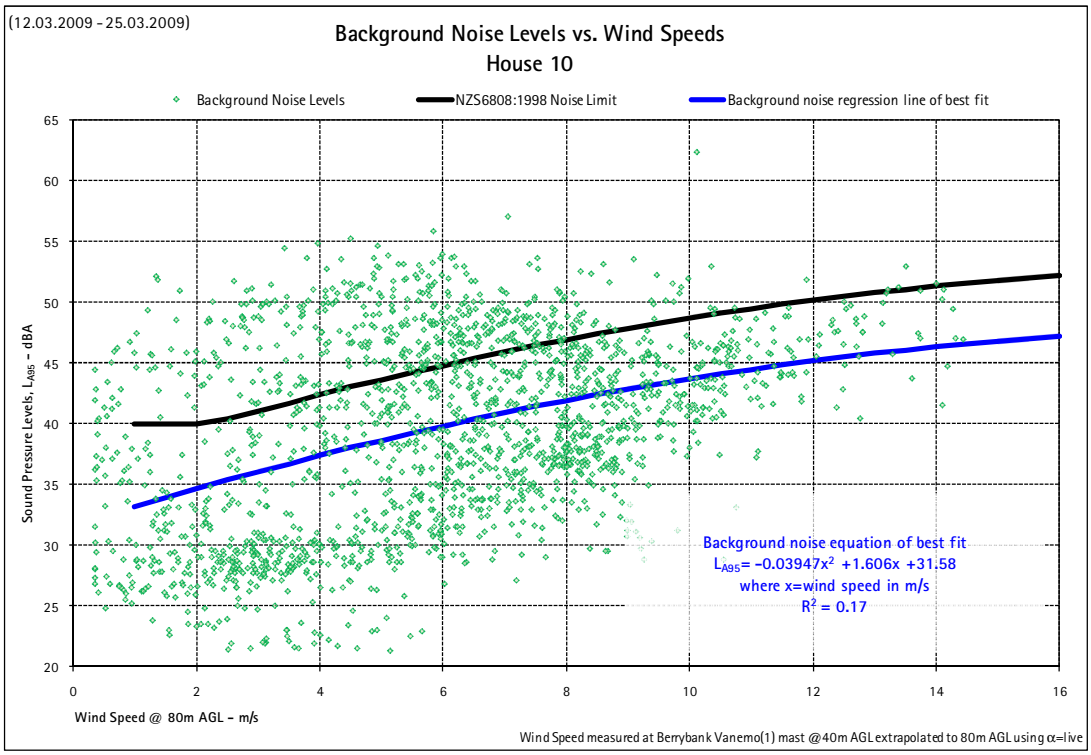

Figure 3: 24 hour noise limits at House 10

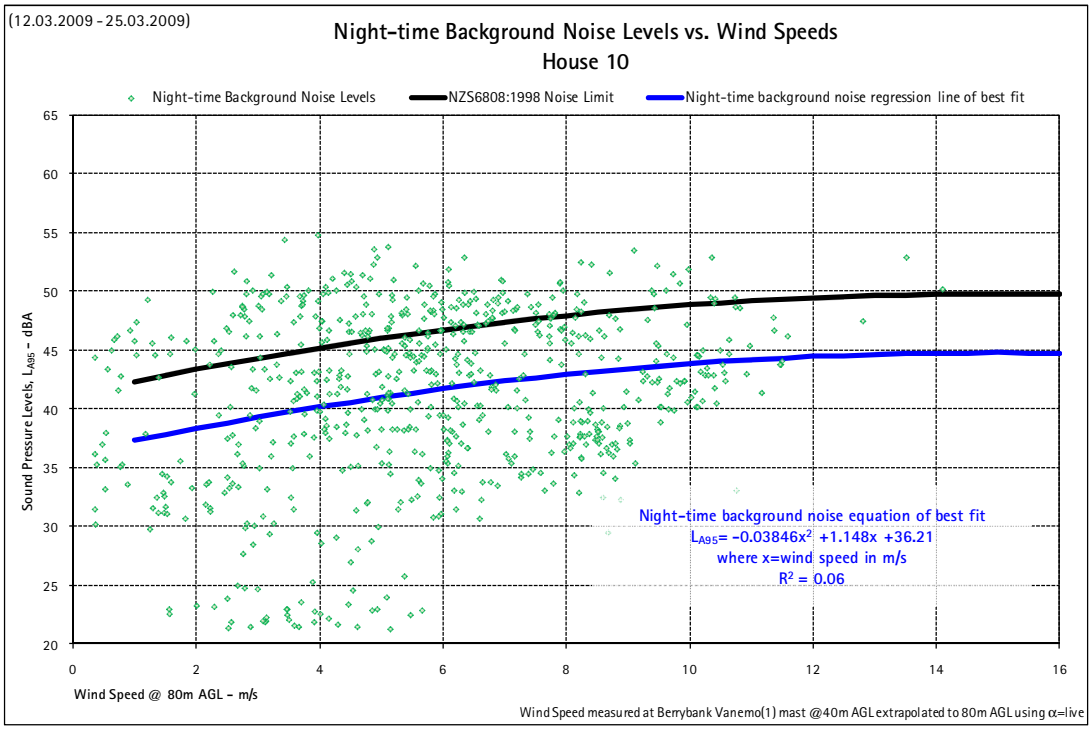

Figure 4: Night-time noise limits at House 10

7.2 House 18

The following two graphs show the 24 hour and night-time noise limits derived for House 18. Photographs of the logger position at House 18 are presented in Figures D5 to D8 of Appendix D.

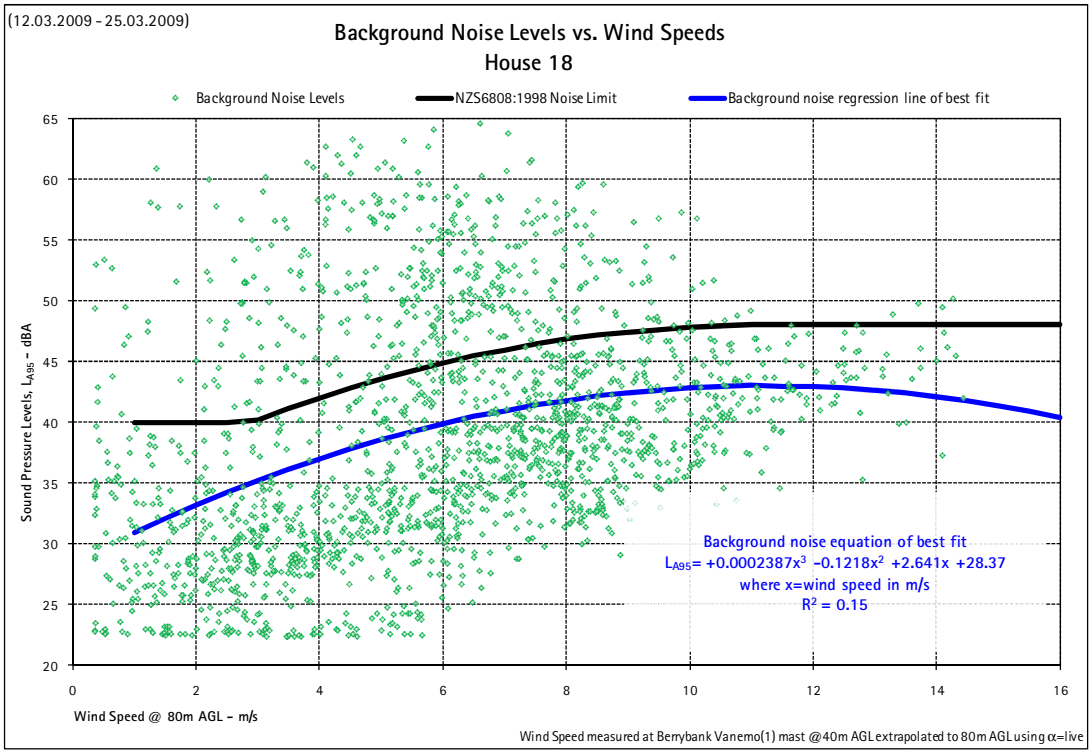

Figure 5: 24 hour noise limits at House 18

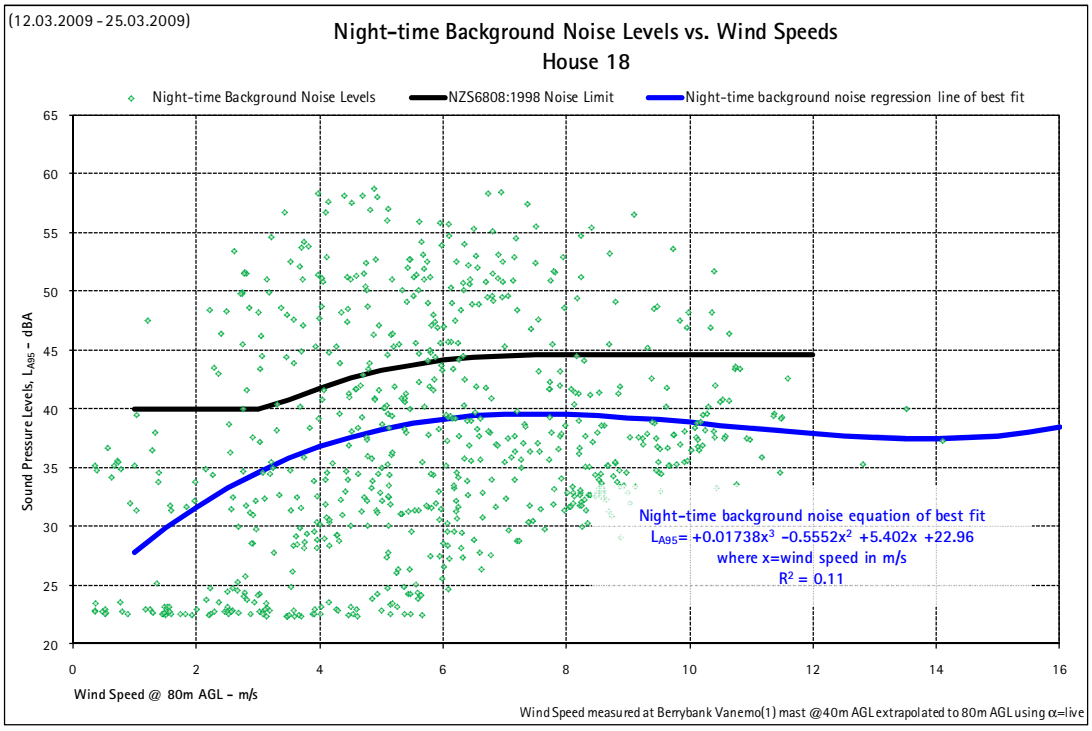

Figure 6: Night-time noise limits at House 18

7.3 House 27

The following two graphs show the 24 hour and night-time noise limits derived for House 27. These limits also apply to House 28 (approximately 1,100m north). Photographs of the logger position at House 27 are presented in Figures D9 to D12 of Appendix D.

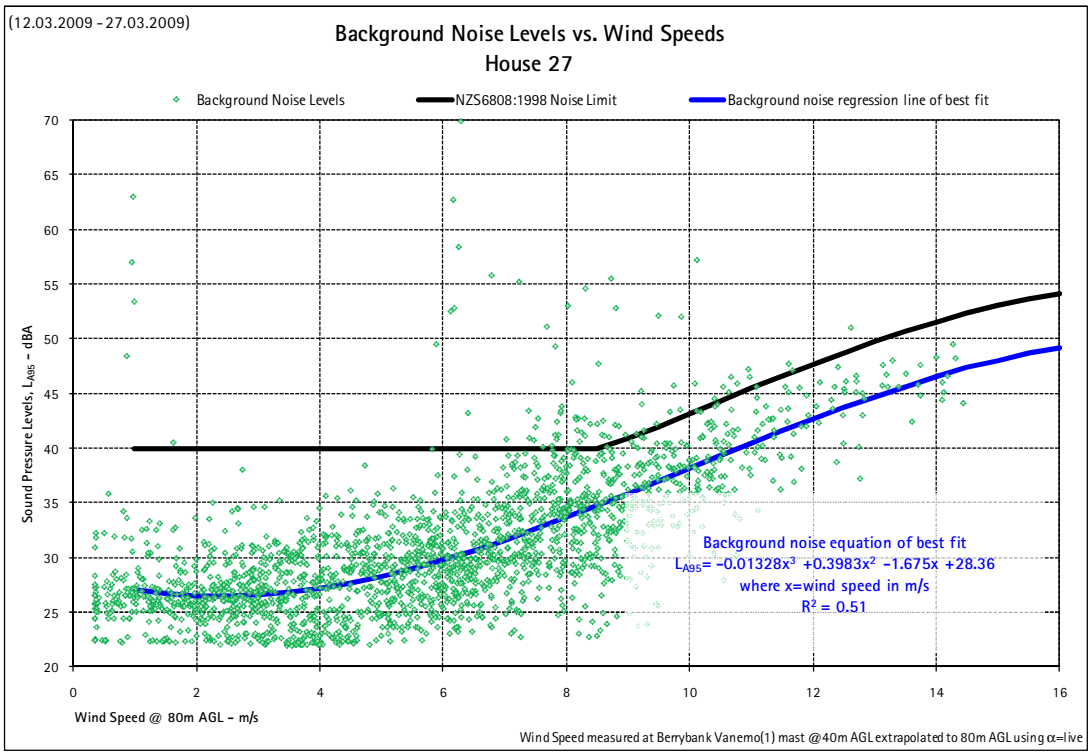

Figure 7: 24 hour noise limits at House 27

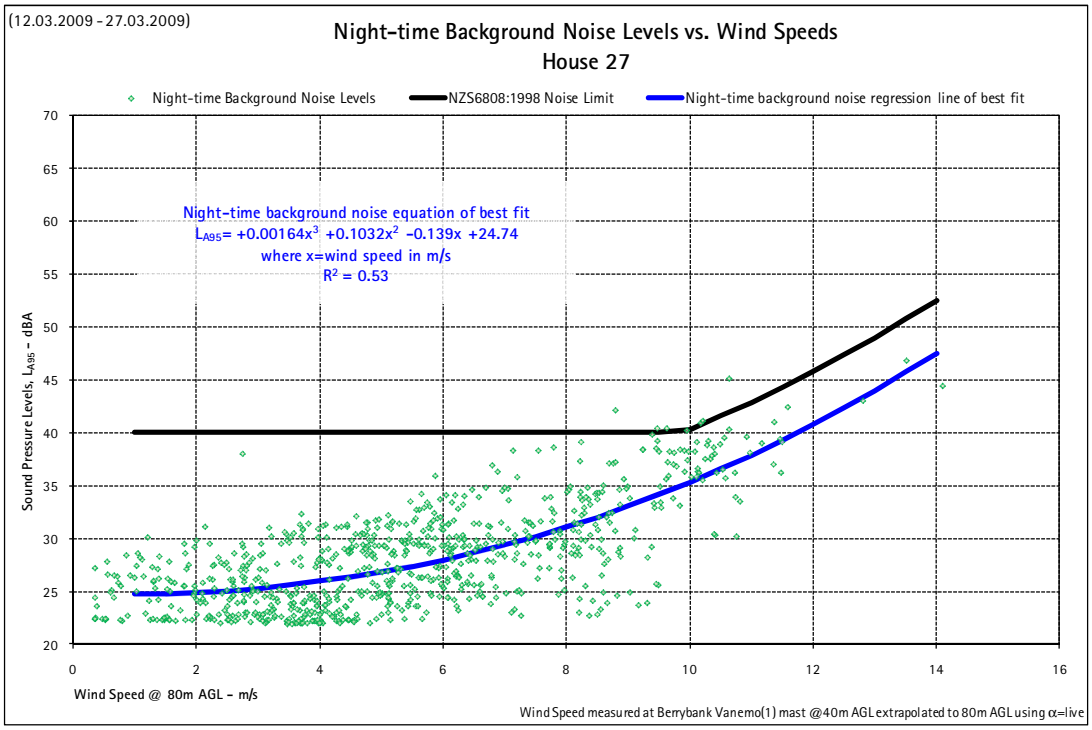

Figure 8: Night-time noise limits at House 27

7.4 House 58

Houses 54, 55, 56 and 57 are located between Houses 10 and 58. Noise limits derived from the background noise monitoring undertaken at House 58 are lower than those at House 10. Therefore, to be conservative, we have applied noise limits from House 58 to House 54 (approximately 2,600m south-east), House 55 (approximately 2,300m south-east), House 56 (approximately 2,600m south-east) and House 57 (approximately 2,400m south-east).

The following two graphs show the 24 hour and night-time noise limits derived for House 58. Photographs of the logger position at House 58 are presented in Figures D13 to D16 of Appendix D.

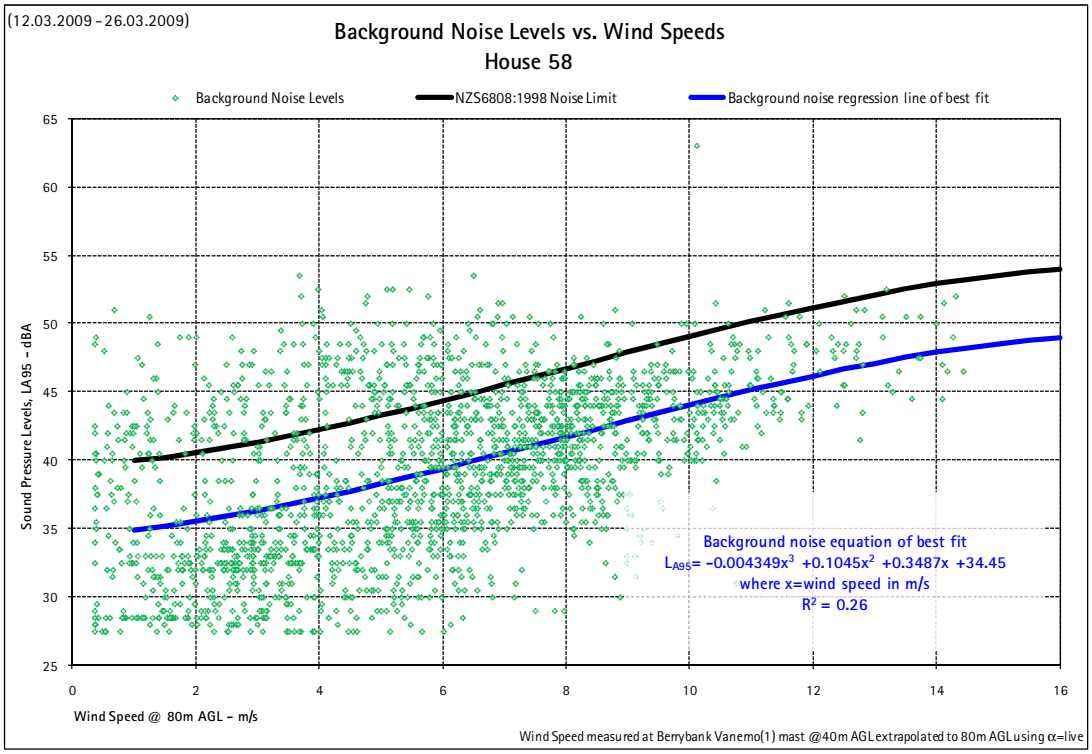

Figure 9: 24 hour noise limits at House 58

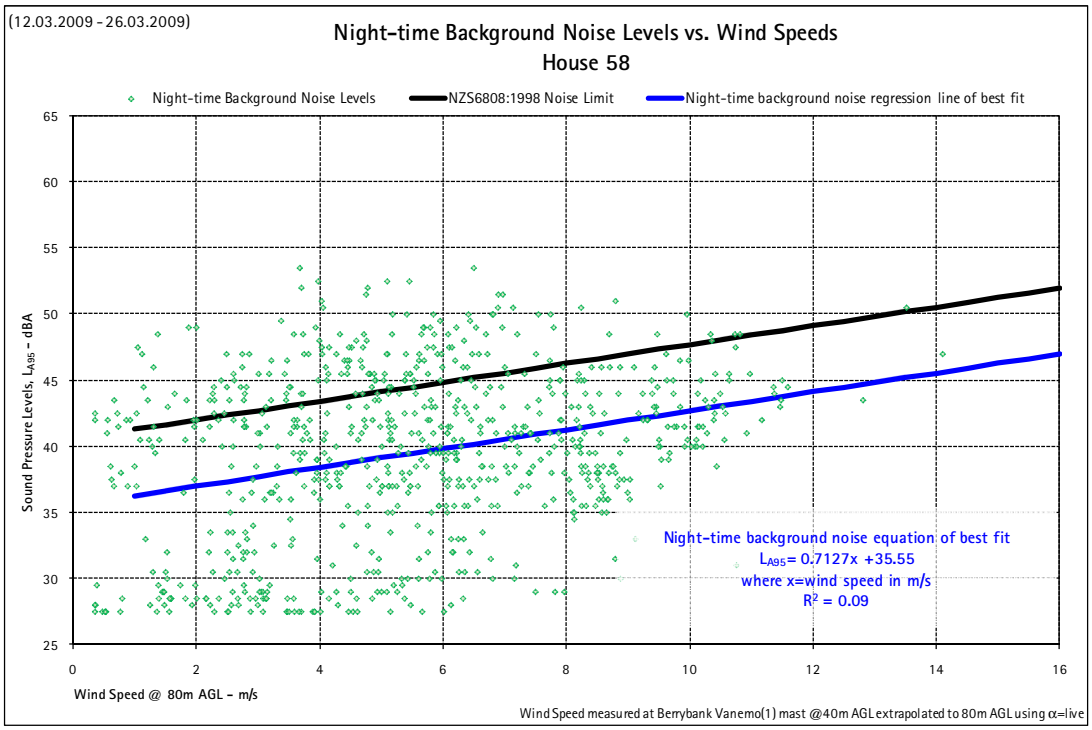

Figure 10: Night-time noise limits at House 58

7.5 House 63

The following two graphs show the 24 hour and night-time noise limits derived for House 63. These limits also apply to House 62 (approximately 1,200m west), House 64 (approximately 1,200m east) and House 103 (approximately 2,400 south).

Although House 103 is not located in close proximity of House 63, noise limits derived from background noise monitored at House 63 are the lowest of the properties to the east of the proposed site. This approach is therefore considered conservative.

Photographs of the logger position at House 63 are presented in Figures D17 to D20 of Appendix D.

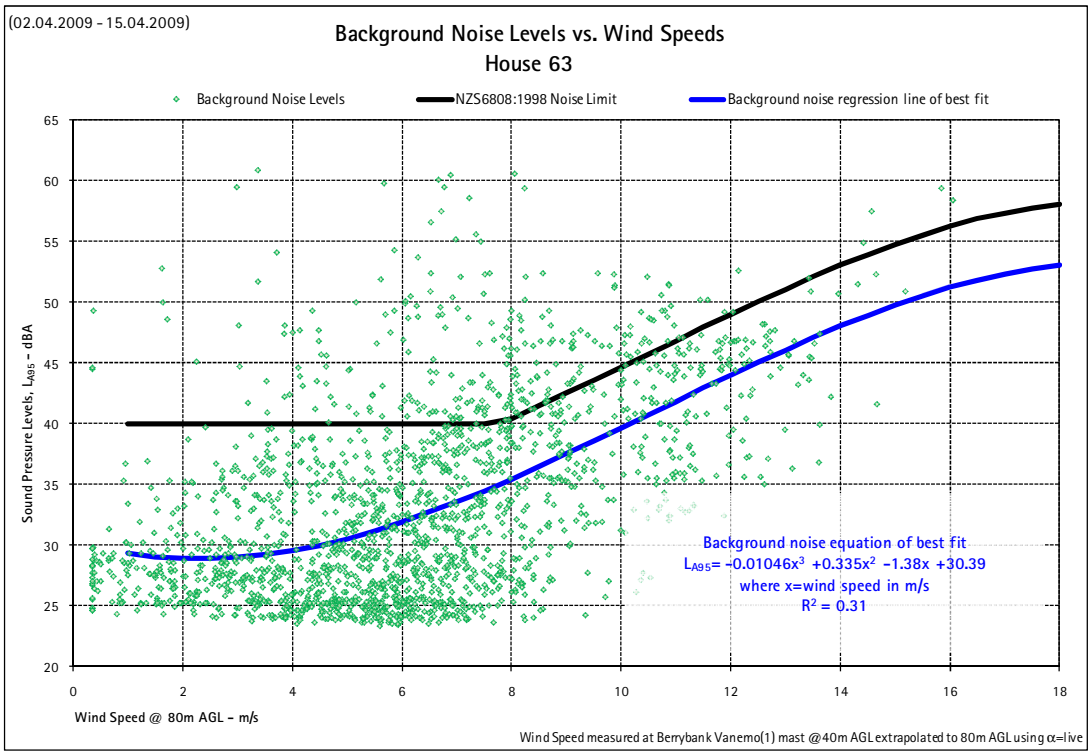

Figure 11: 24 hour noise limits at House 63

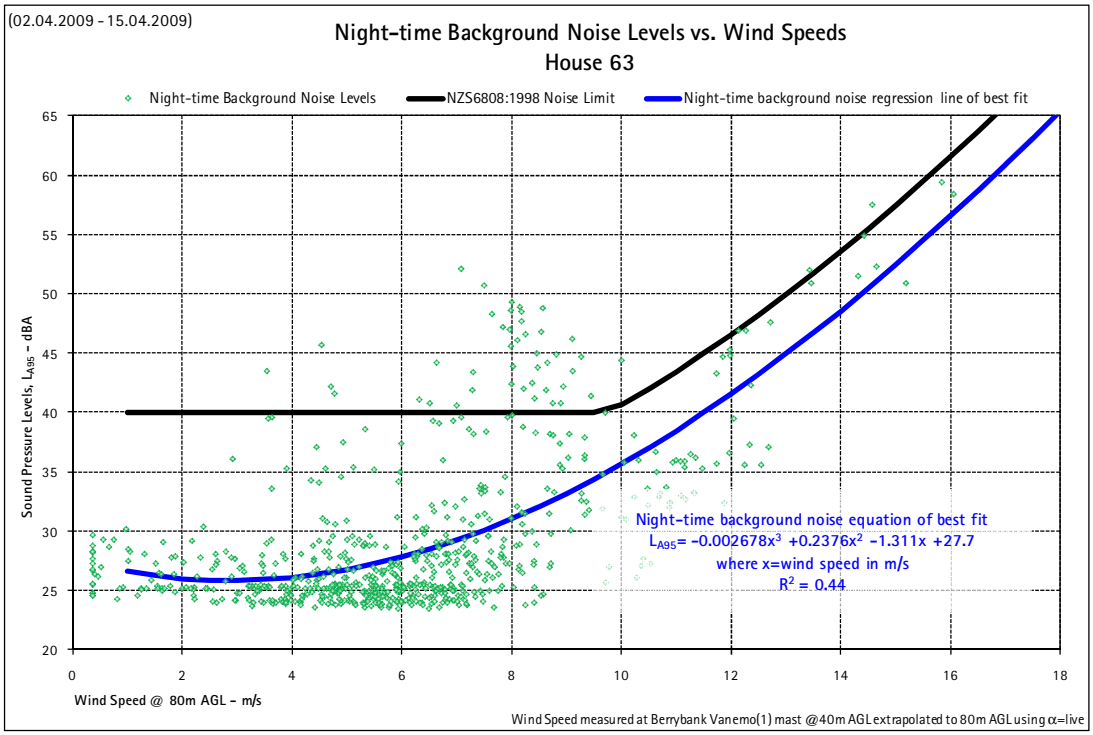

Figure 12: Night-time noise limits at House 63

7.6 House 70

The following two graphs show the 24 hour and night-time noise limits derived for House 70. These limits also apply to House 67 (approximately 650m south), House 68 (approximately 700m south) and Houses 69, 71, 72 and 109 (approximately 400m south-east).

Photographs of the logger position at House 70 are presented in Figures D21 to D24 of Appendix D.

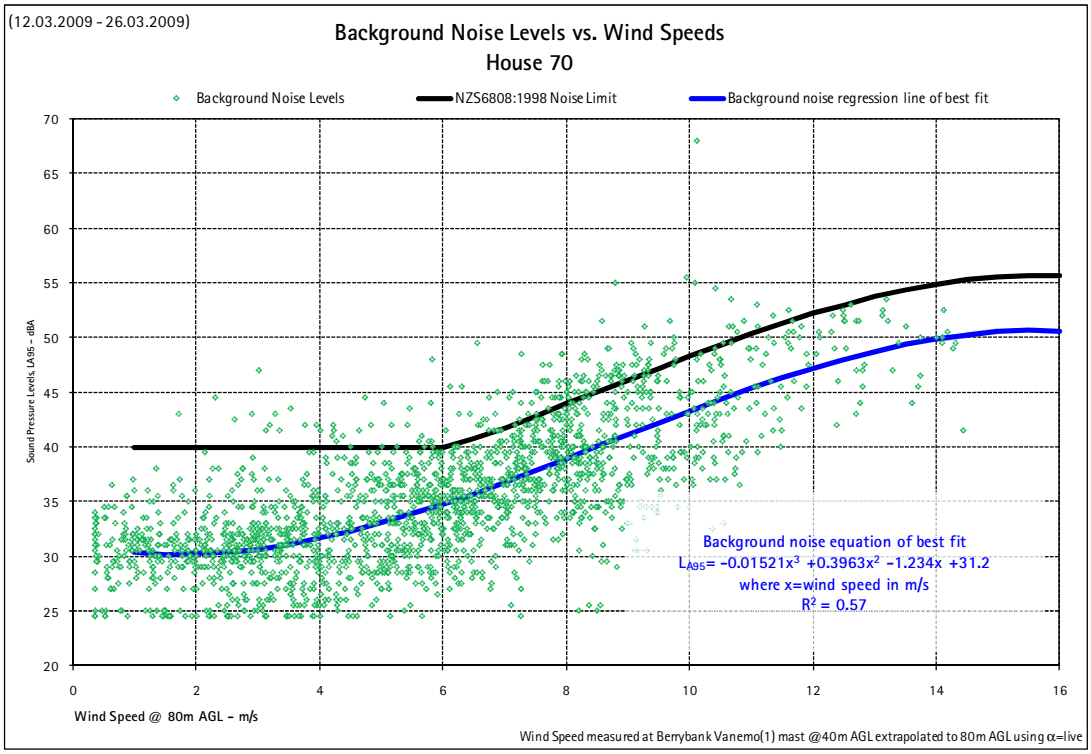

Figure 13: 24 hour noise limits at House 70

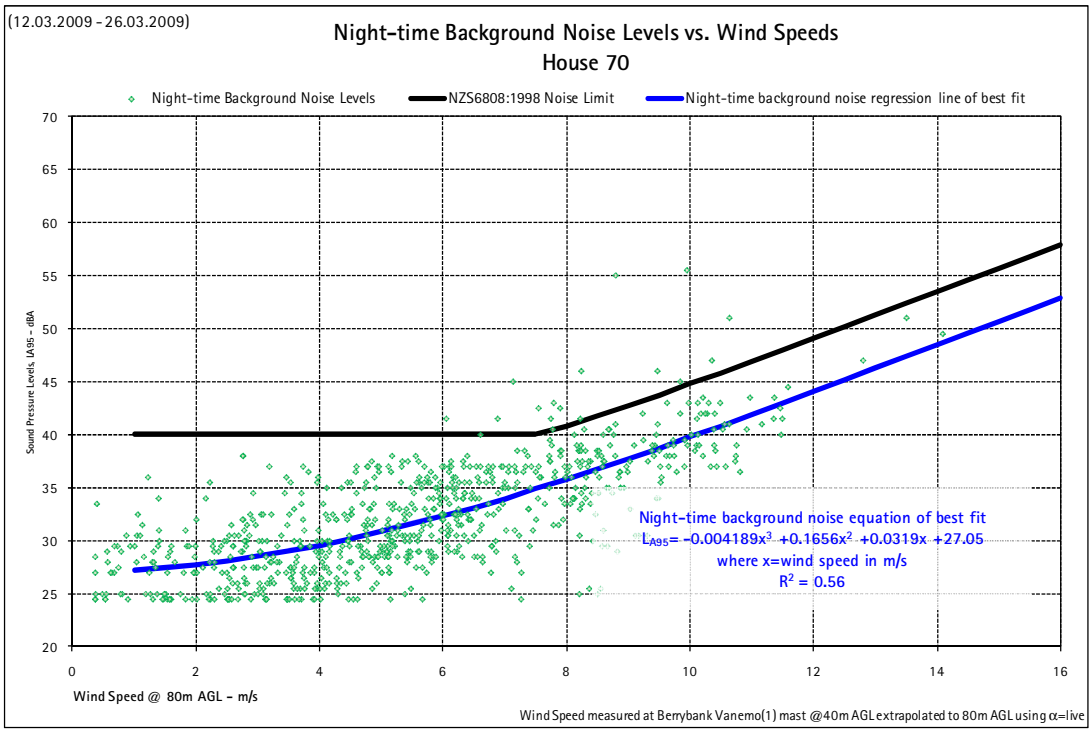

Figure 14: Night-time noise limits at House 70

7.7 House 73

The following two graphs show the 24 hour and night-time noise limits derived for House 73. Photographs of the logger position at House 73 are presented in Figures D25 to D28 of Appendix D.

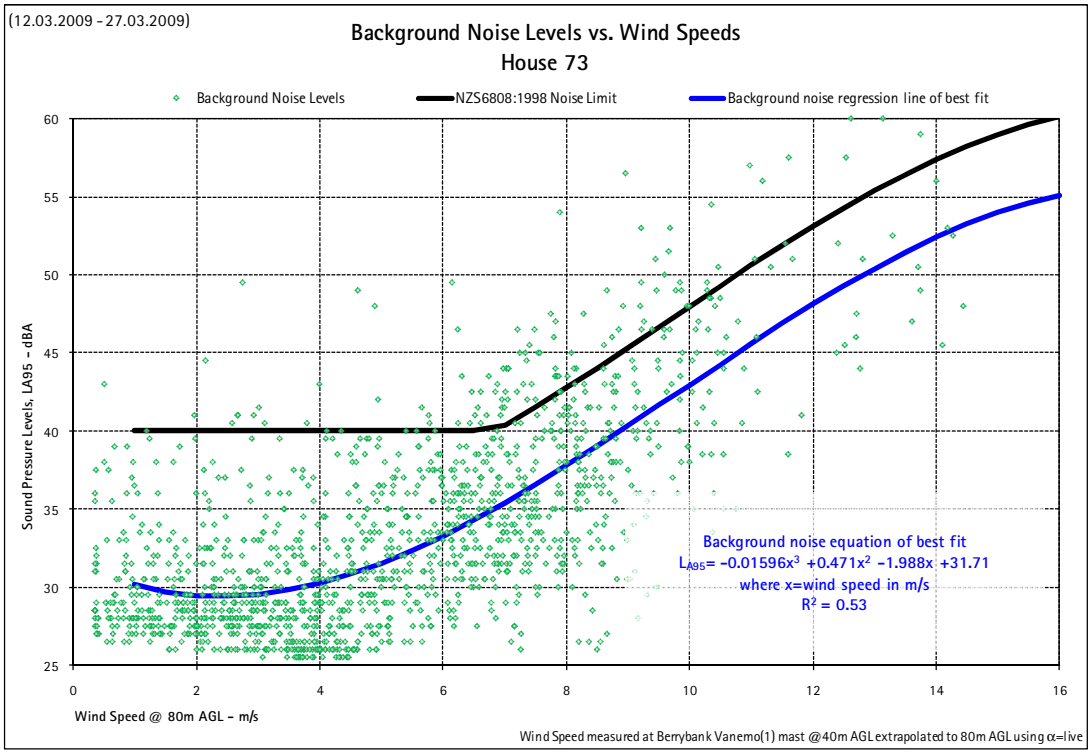

Figure 15: 24 hour noise limits at House 73

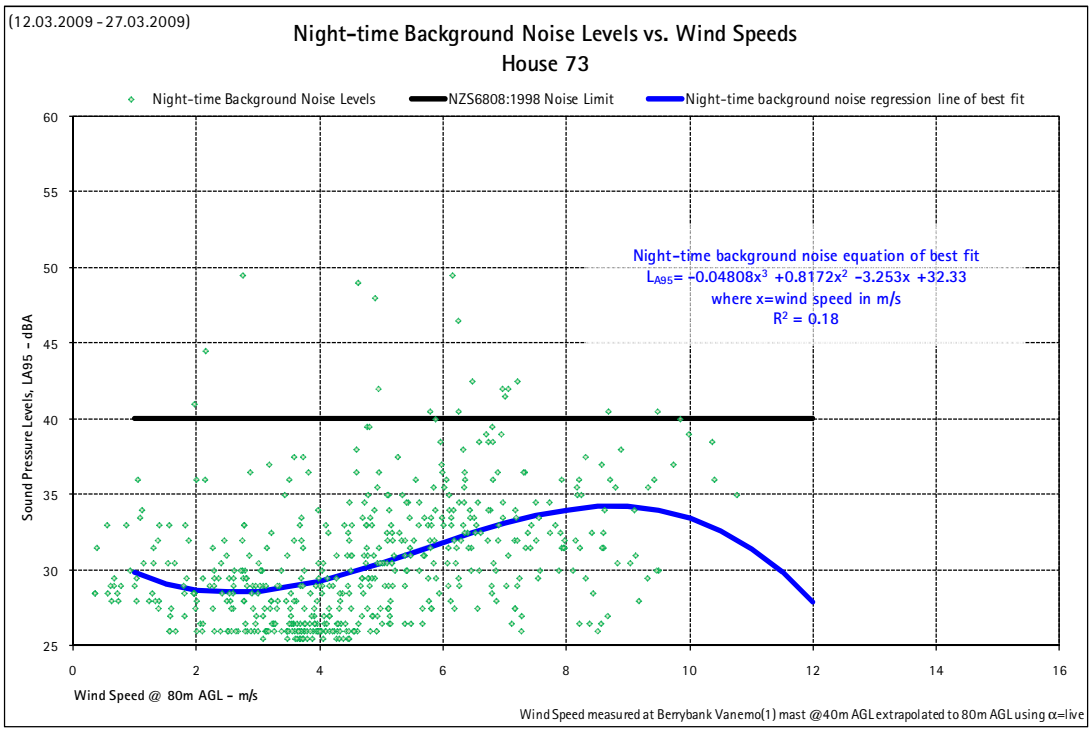

Figure 16: Night-time noise limits at House 73

7.8 House 74

The following two graphs show the 24 hour and night-time noise limits derived for House 74. Photographs of the logger position at House 74 are presented in Figures D29 to D32 of Appendix D.

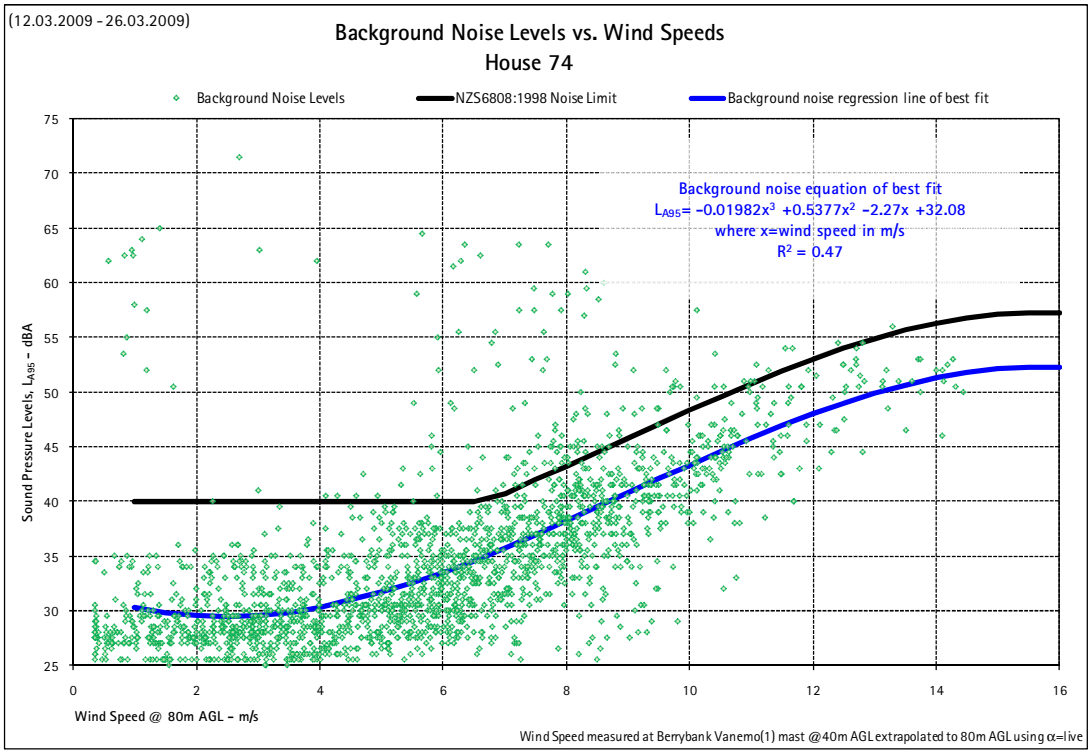

Figure 17: 24 hour noise limits at House 74

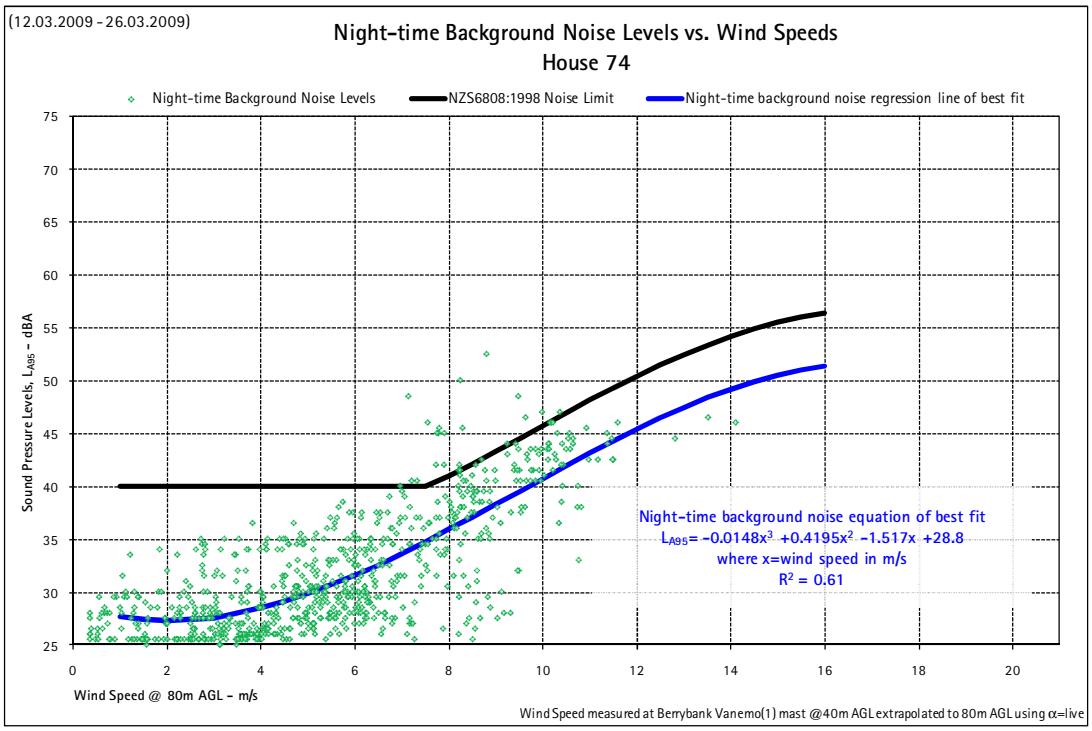

Figure 18: Night-time noise limits at House 74

7.9 House 80

The following two graphs show the 24 hour and night-time noise limits derived for House 80. These limits also apply to House 78 (approximately 1,100m east), Houses 79 (approximately 400m east) and House 81 (approximately 600m south-west).

Photographs of the logger position at House 80 are presented in Figures D33 to D36 of Appendix D.

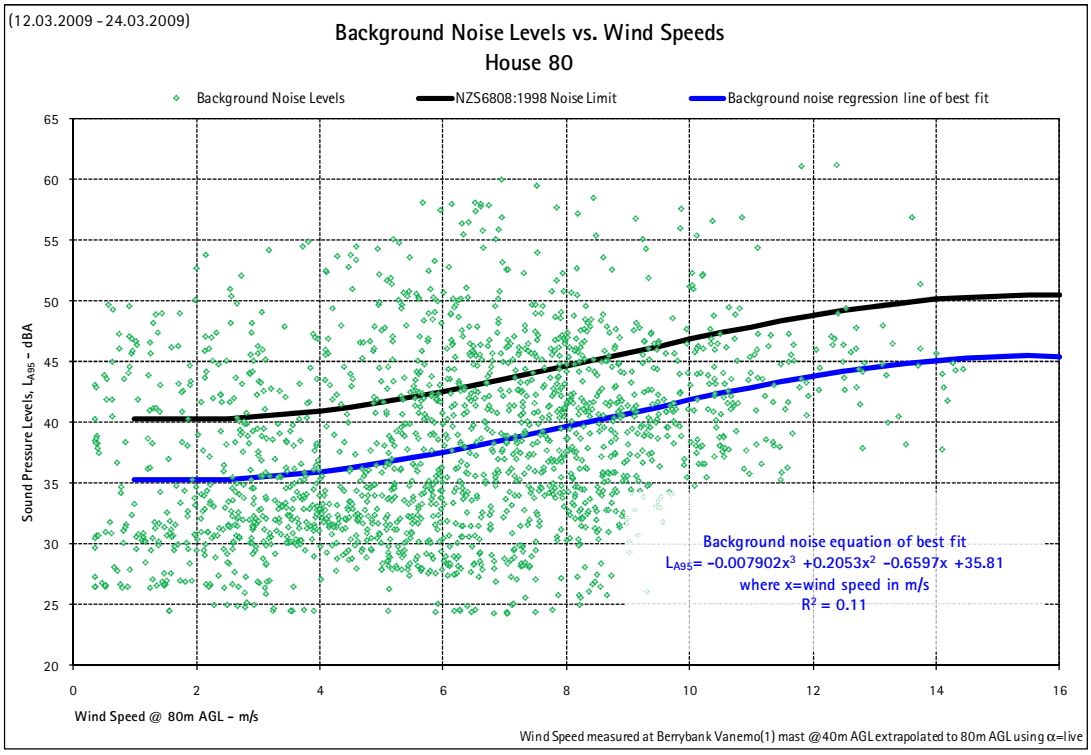

Figure 19: 24 hour noise limits at House 80

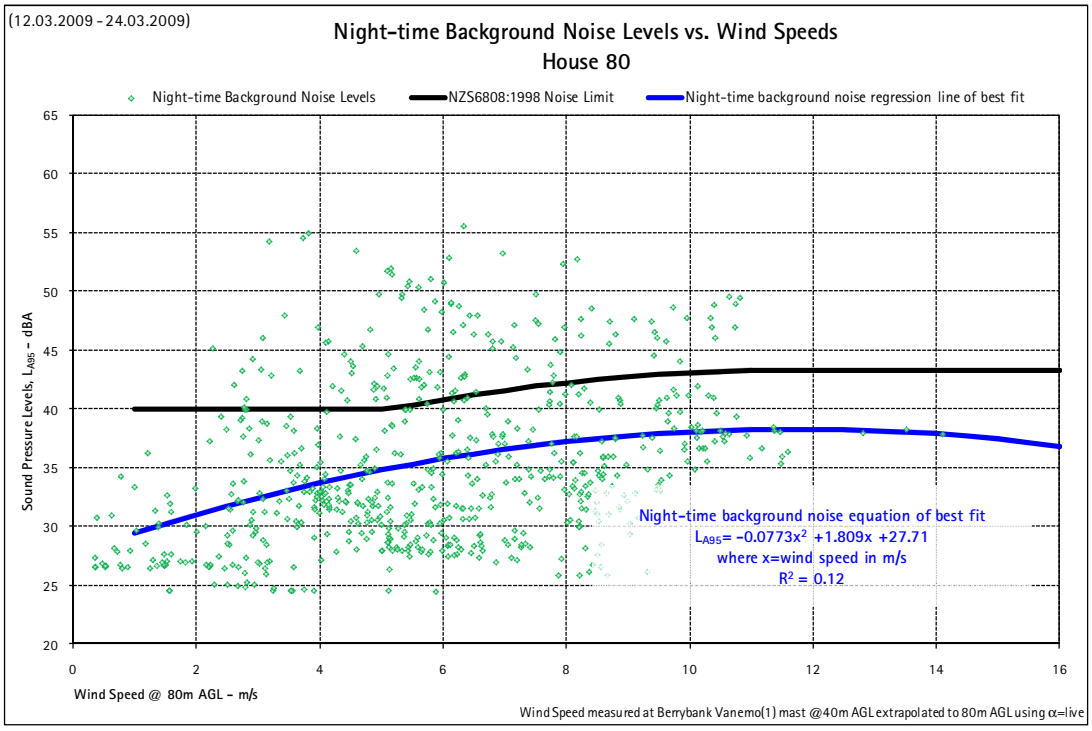

Figure 20: Night-time noise limits at House 80

7.10 House 83

The following two graphs show the 24 hour and night-time noise limits derived for House 83. These limits also apply to House 84 (approximately 1,800m east). Photographs of the logger position at House 83 are presented in Figures D37 to D40 of Appendix D.

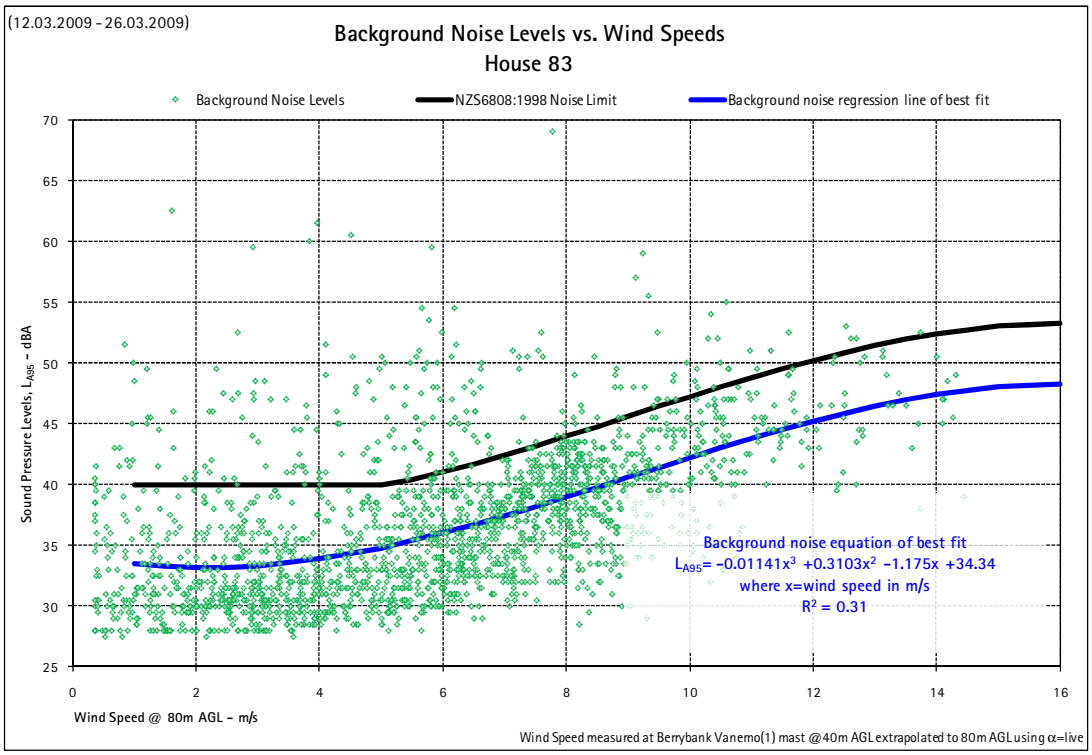

Figure 21: 24 hour noise limits at House 83

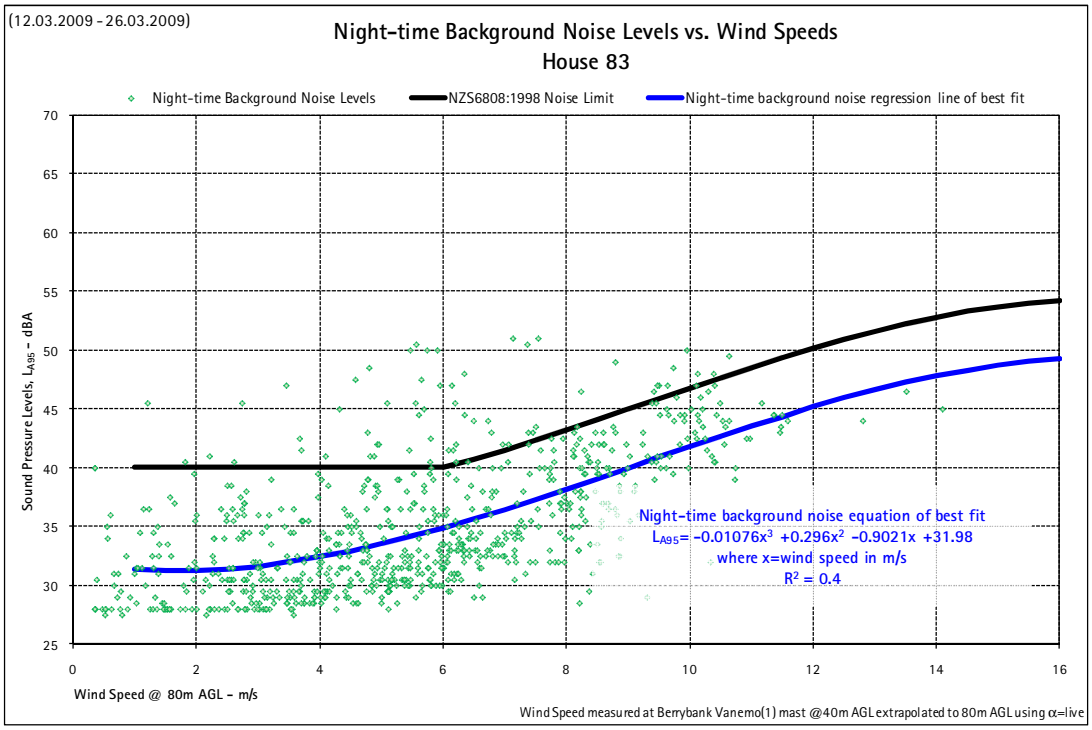

Figure 22: Night-time noise limits at House 83

7.11 House 102

The following two graphs show the 24 hour and night-time noise limits derived for House 102. Photographs of the logger position at House 102 are presented in Figures D41 to D44 of Appendix D.

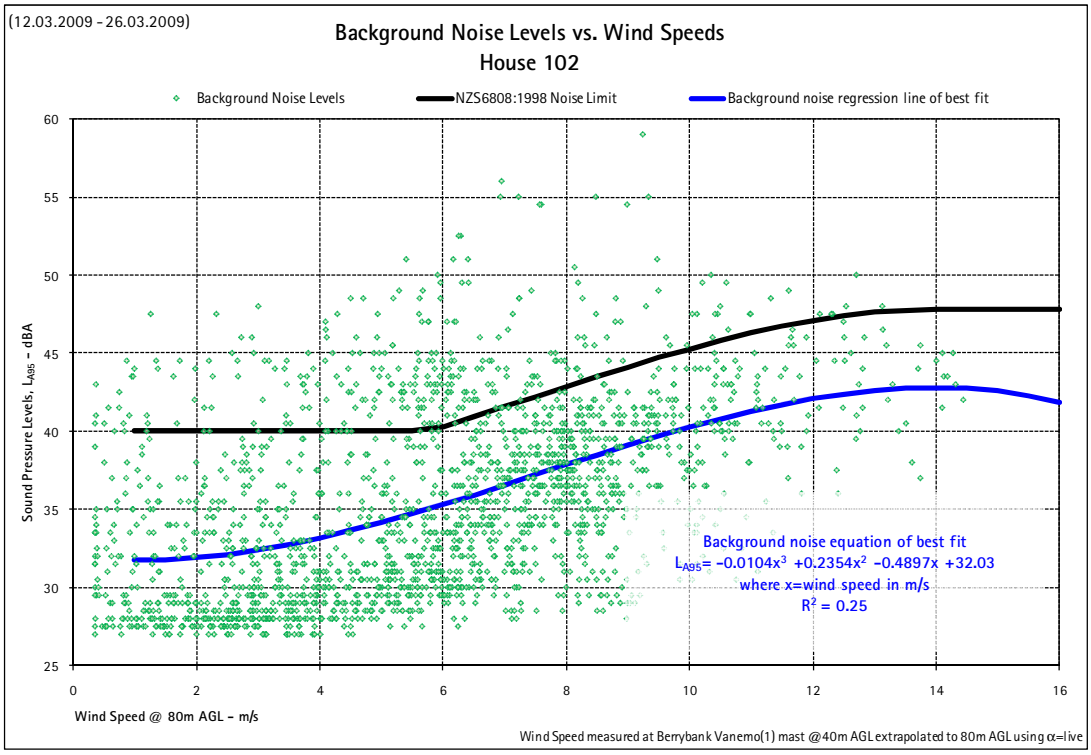

Figure 23: 24 hour noise limits at House 102

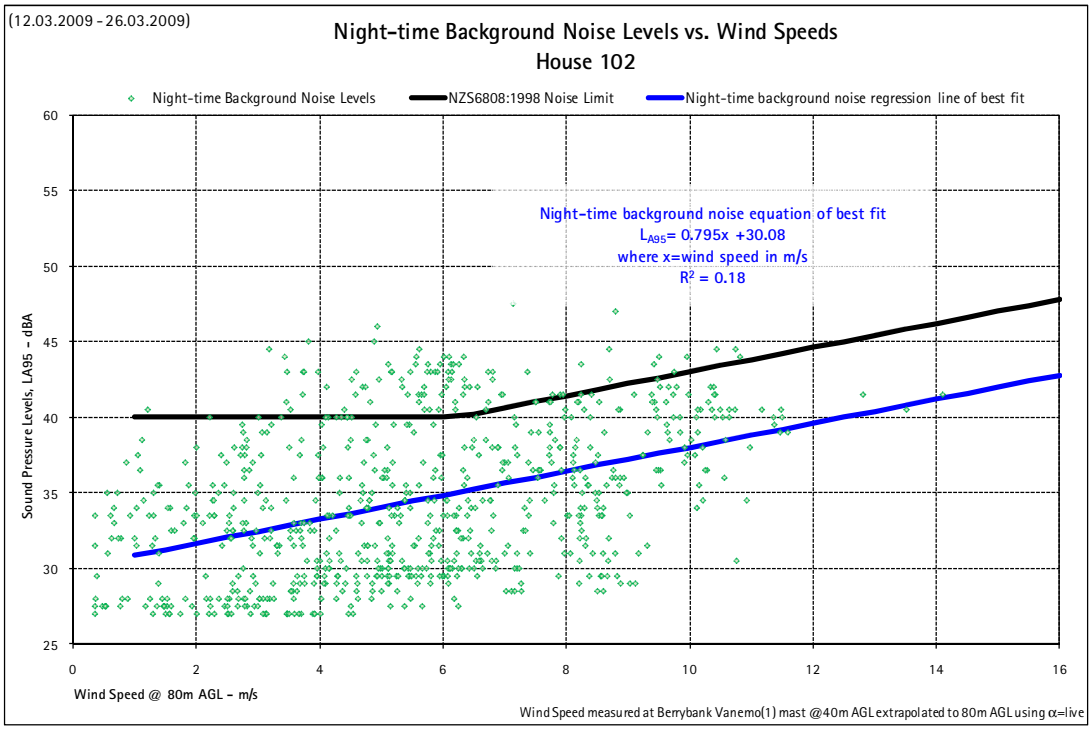

Figure 24: Night-time noise limits at House 102

8.0 NOISE PREDICTIONS

Union Fenosa has selected the six following wind turbine models for this assessment:

- Vestas V90
- Vestas V100
- Nordex N100
- Siemens SWT-101
- Repower MM92
- Mitsubishi MWT-95.

Noise emissions from the proposed Berrybank wind farm at the assessable residential properties have been predicted in accordance with NZS6808:1998 and compliance with the noise limits has been assessed for each of the six selected wind turbines.

Plots comparing predicted wind turbine noise emission and noise limits are provided in Appendices F through K. As detailed in Section 3.2, the base noise criterion of 40dBA has been increased to 45dBA for stakeholder properties in accordance with ETSU-R-97. This alternative noise limit is shown as an orange line on applicable plots.

8.1 Vestas V90

The plots of predicted noise levels against noise limits at each of the assessable residences are presented in Appendix F for the range of wind speeds over which Vestas V90 wind turbines sound power data is available.

Compliance occurs if the line of predicted noise levels remains below the limit line and non-compliance occurs when the predicted noise level line rises above the limit line.

A summary of compliance, using Vestas V90 wind turbines is presented in Table 6 at all assessable properties.

Table 6
Compliance with NZS6808:1998 – Vestas V90

House	24 hour compliance	Night-time compliance	Figure No.
9 (S)	✓	✓	F12
10 (U)	✓	✓	F1
18	✓	✓	F2
27	✓	✓	F3
28	✓	✓	F3
54 (S)	✓	✓	F4
55 (S)	✓	✓	F4
56 (U)	✓	✓	F4
57	✓	✓	F1
58	✓	✓	F4
60	✓	✓	F1
61 (S)	✓	✓	F1
62 (S)	✓	✓	F5
63	✓	✓	F5
64	✓	✓	F5
65 (SU)	×	×	F12
66 (S)	✓	✓	F12
67 (S)	✓	✓	F6
68 (SU)	✓	✓	F6
69	✓	✓	F6
70	✓	✓	F6
71 (S)	✓	✓	F6
72	✓	✓	F6
73	✓	✓	F7
74	✓	✓	F8
76 (SU)	×	×	F12
78 (S)	✓	✓	F9
79	✓	✓	F9
80	✓	✓	F9

House	24 hour compliance	Night-time compliance	Figure No.
81 (SU)	✓	✓	F9
83	✓	✓	F10
84	✓	✓	F10
102	✓	✓	F11
103	✓	✓	F5
109 (U)	✓	✓	F6

Note: (S) stakeholder property
(SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property
✓ compliance
× non-compliance

It can be seen from Table 6 that compliance with both the 24 hour and night-time NZS6808:1998 noise limits is achieved at all non-stakeholder properties, using V90 wind turbines.

Noise predictions using V90 wind turbines exceed the 24 hour and night time noise limits at two (2) stakeholder properties (Houses 65 and 76). However these properties are currently uninhabitable.

Using Vestas V90 wind turbines, all non-assessed sites further from the wind farm will experience worst-case noise levels less than 35dBA, well below the lowest possible limit of 40dBA.

8.2 Vestas V100

The plots of predicted noise levels against noise limits at each of the assessable residences are presented in Appendix G for the range of wind speeds over which Vestas V100 wind turbines sound power data is available.

Compliance occurs if the line of predicted noise levels remains below the limit line and non-compliance occurs when the predicted noise level line rises above the limit line.

A summary of compliance, using Vestas V100 wind turbines is presented in Table 7 at all assessable properties.

Table 7
Compliance with NZS6808:1998 – Vestas V100

House	24 hour compliance	Night-time compliance	Figure No.
9 (S)	✓	✓	G12
10 (U)	✓	✓	G1
18	✓	✓	G2
27	✓	✓	G3
28	✓	✓	G3
54 (S)	✓	✓	G4
55 (S)	✓	✓	G4

House	24 hour compliance	Night-time compliance	Figure No.
56 (U)	✓	✓	G4
57	✓	✓	G1
58	✓	✓	G4
60	✓	✓	G1
61 (S)	✓	✓	G1
62 (S)	✓	✓	G5
63	✓	✓	G5
64	✓	✓	G5
65 (SU)	×	×	G12
66 (S)	×	×	G12
67 (S)	✓	✓	G6
68 (SU)	✓	✓	G6
69	✓	✓	G6
70	✓	✓	G6
71 (S)	✓	✓	G6
72	✓	✓	G6
73	✓	✓	G7
74	✓	✓	G8
76 (SU)	×	×	G12
78 (S)	✓	×	G9
79	✓	✓	G9
80	✓	✓	G9
81 (SU)	✓	✓	G9
83	✓	✓	G10
84	✓	✓	G10
102	✓	✓	G11
103	✓	✓	G5
109 (U)	✓	✓	G6

Note: (S) stakeholder property
(SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property
✓ compliance
× non-compliance

It can be seen from Table 7 that, using Vestas V100 wind turbines, compliance with both the 24 hour and night-time NZS6808:1998 noise limits is achieved at all non-stakeholder properties.

Noise predictions using Vestas V100 wind turbines exceed both the 24 hour and night-time NZS6808:1998 noise limits at three (3) stakeholder properties (Houses 65, 66 and 76). Two (2) of these properties are currently uninhabitable (Houses 65 and 76).

Predicted noise levels at the remaining stakeholder property exceed both the 24 hour and night-time NZS6808:1998 noise limits by up to 2dBA above 14m/s (at 80m AGL).

The lowest possible noise limit of 45dBA has been applied as background noise monitoring has not been undertaken at this property. Predicted noise levels using Vestas V100 wind turbines may comply with noise limits derived from background noise monitoring.

NZS6808:1998 night-time noise limits are also marginally exceeded by less than 1dBA at one (1) stakeholder property (House 78).

Using Vestas V100 wind turbines, all non-assessed sites further from the wind farm will not experience noise levels higher than 37dBA, below the lowest possible limit of 40dBA by 3dBA.

8.3 Nordex N100

The plots of predicted noise levels against noise limits at each of the assessable residences are presented in Appendix H for the range of wind speeds over which Nordex N100 wind turbines sound power data is available.

Compliance occurs if the line of predicted noise levels remains below the limit line and non-compliance occurs when the predicted noise level line rises above the limit line.

A summary of compliance, using Nordex N100 wind turbines is presented in Table 8 at all assessable properties.

Table 8
Compliance with NZS6808:1998 – Nordex N100

House	24 hour compliance	Night-time compliance	Figure No.
9 (S)	×	×	H12
10 (U)	✓	✓	H1
18	✓	✓	H2
27	×	×	H3
28	✓	×	H3
54 (S)	×	×	H4
55 (S)	✓	×	H4
56 (U)	✓	✓	H4
57	✓	✓	H1
58	✓	✓	H4
60	✓	✓	H1
61 (S)	×	✓	H1
62 (S)	×	×	H5
63	×	×	H5
64	×	×	H5
65 (SU)	×	×	H12
66 (S)	×	×	H12
67 (S)	✓	✓	H6
68 (SU)	✓	✓	H6

House	24 hour compliance	Night-time compliance	Figure No.
69	✓	×	H6
70	✓	×	H6
71 (S)	✓	✓	H6
72	✓	×	H6
73	✓	×	H7
74	✓	✓	H8
76 (SU)	×	×	H12
78 (S)	×	×	H9
79	×	×	H9
80	×	×	H9
81 (SU)	✓	×	H9
83	✓	✓	H10
84	✓	✓	H10
102	✓	×	H11
103	×	×	H5
109 (U)	✓	×	H6

Note: (S) stakeholder property
(SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property
✓ compliance
× non-compliance

It can be seen from Table 8 that, using Nordex N100 wind turbines, compliance with the 24 hour NZS6808:1998 noise limits are exceeded at:

- Six (6) of the twenty-two (22) non-stakeholder properties
- Eight (8) of the thirteen (13) stakeholder properties, including two (2) which are currently uninhabitable.

Using Nordex N100 wind turbines, the NZS6808:1998 night-time noise limits are exceeded at:

- Thirteen (13) of the twenty-two (22) non-stakeholder properties, including one (1) which is currently uninhabitable
- Nine (9) of the thirteen (13) stakeholder properties, including three (3) which are currently uninhabitable.

Using Nordex N100 wind turbines, predicted noise levels at four (4) of the non-assessed sites further from the wind farm will marginally exceed the lowest possible noise limit of 40dBA by less than 1dBA.

8.4 Siemens SWT-101

The plots of predicted noise levels against noise limits at each of the assessable residences are presented in Appendix I for the range of wind speeds over which Siemens SWT-101 wind turbines sound power data is available.

Compliance occurs if the line of predicted noise levels remains below the limit line and non-compliance occurs when the predicted noise level line rises above the limit line.

A summary of compliance, using Siemens SWT-101 wind turbines, is presented in Table 9 at all assessable properties.

Table 9
Compliance with NZS6808:1998 – Siemens SWT-101

House	24 hour compliance	Night-time compliance	Figure No.
9 (S)	×	×	I12
10 (U)	✓	✓	I1
18	✓	✓	I2
27	×	×	I3
28	×	×	I3
54 (S)	×	×	I4
55 (S)	✓	×	I4
56 (U)	✓	✓	I4
57	✓	✓	I1
58	✓	✓	I4
60	✓	✓	I1
61 (S)	×	✓	I1
62 (S)	×	×	I5
63	×	×	I5
64	×	×	I5
65 (SU)	×	×	I12
66 (S)	×	×	I12
67 (S)	✓	✓	I6
68 (SU)	✓	✓	I6
69	✓	×	I6
70	✓	×	I6
71 (S)	✓	✓	I6
72	✓	×	I6
73	✓	×	I7
74	✓	✓	I8
76 (SU)	×	×	I12
78 (S)	×	×	I9
79	×	×	I9
80	×	×	I9

House	24 hour compliance	Night-time compliance	Figure No.
81 (SU)	×	×	I9
83	✓	✓	I10
84	✓	✓	I10
102	✓	×	I11
103	×	×	I5
109 (U)	✓	×	I6

Note: (S) stakeholder property
(SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property
✓ compliance
× non-compliance

It can be seen from Table 9 that, using Siemens SWT-101 wind turbines, compliance with the 24 hour NZS6808:1998 noise limits is achieved at all non-stakeholder properties and nine (9) of the thirteen (13) stakeholder properties.

Two (2) of four (4) stakeholder properties exceeding the 24 hour noise limits are currently uninhabitable.

Using Siemens SWT-101 wind turbines, the NZS6808:1998 night-time noise limits are exceeded at:

- Five (5) of the twenty-two (22) non-stakeholder properties
- Six (6) of the thirteen (13) stakeholder properties, including two (2) which are currently uninhabitable.

Using Siemens SWT-101 wind turbines, all non-assessed sites further from the wind farm will comply with the lowest possible limit of 40dBA.

8.5 REpower MM92

The plots of predicted noise levels against noise limits at each of the assessable residences are presented in Appendix J for the range of wind speeds over which REpower MM92 wind turbines sound power data is available.

Compliance occurs if the line of predicted noise levels remains below the limit line and non-compliance occurs when the predicted noise level line rises above the limit line.

A summary of compliance, using REpower MM92 wind turbines is presented in Table 10 at all assessable properties.

Table 10
Compliance with NZS6808:1998 – REpower MM92

House	24 hour compliance	Night-time compliance	Figure No.
9 (S)	✓	✓	J12
10 (U)	✓	✓	J1
18	✓	✓	J2
27	✓	✓	J3
28	✓	✓	J3
54 (S)	✓	✓	J4
55 (S)	✓	✓	J4
56 (U)	✓	✓	J4
57	✓	✓	J1
58	✓	✓	J4
60	✓	✓	J1
61 (S)	✓	✓	J1
62 (S)	×	×	J5
63	×	×	J5
64	✓	✓	J5
65 (SU)	×	×	J12
66 (S)	×	×	J12
67 (S)	✓	✓	J6
68 (SU)	✓	✓	J6
69	✓	✓	J6
70	✓	✓	J6
71 (S)	✓	✓	J6
72	✓	✓	J6
73	✓	✓	J7
74	✓	✓	J8
76 (SU)	×	×	J12
78 (S)	✓	✓	J9
79	✓	✓	J9
80	✓	✓	J9
81 (SU)	✓	✓	J9
83	✓	✓	J10
84	✓	✓	J10
102	✓	✓	J11
103	×	×	J5
109 (U)	✓	✓	J6

Note: (S) stakeholder property
(SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property
✓ compliance
× non-compliance

It can be seen from Table 10 that, using REpower MM92 wind turbines, compliance with both the 24 hour and night-time NZS6808:1998 noise limits is exceeded at two (2) of the twenty-two (22) non-stakeholder properties (Houses 63 and 103).

Noise predictions using REpower MM92 wind turbines exceed both the 24 hour and night-time NZS6808:1998 noise limits at four (4) stakeholder properties (Houses 62, 65, 66 and 76). Two (2) of these properties are currently uninhabitable (Houses 65 and 76).

Using REpower MM92 wind turbines, all non-assessed sites further from the wind farm will not experience noise levels higher than 37dBA, below the lowest possible limit of 40dBA by 3dBA.

8.6 Mitsubishi MWT-95

The plots of predicted noise levels against noise limits at each of the assessable residences are presented in Appendix K for the range of wind speeds over which Mitsubishi MWT-95 wind turbines sound power data is available.

Compliance occurs if the line of predicted noise levels remains below the limit line and non-compliance occurs when the predicted noise level line rises above the limit line.

A summary of compliance, using Mitsubishi MWT-95 wind turbines is presented in Table 11 at all assessable properties.

Table 11
Compliance with NZS6808:1998 – Mitsubishi MWT-95

House	24 hour compliance	Night-time compliance	Figure No.
9 (S)	✓	✓	K12
10 (U)	✓	✓	K1
18	✓	✓	K2
27	✓	×	K3
28	✓	×	K3
54 (S)	×	×	K4
55 (S)	✓	✓	K4
56 (U)	✓	✓	K4
57	✓	✓	K1
58	✓	✓	K4
60	✓	✓	K1
61 (S)	✓	✓	K1
62 (S)	×	×	K5
63	×	×	K5
64	✓	×	K5
65 (SU)	×	×	K12
66 (S)	×	×	K12
67 (S)	✓	✓	K6

House	24 hour compliance	Night-time compliance	Figure No.
68 (SU)	✓	✓	K6
69	✓	×	K6
70	✓	×	K6
71 (S)	✓	✓	K6
72	✓	×	K6
73	✓	×	K7
74	✓	✓	K8
76 (SU)	×	×	K12
78 (S)	×	×	K9
79	✓	×	K9
80	✓	×	K9
81 (SU)	✓	×	K9
83	✓	✓	K10
84	✓	✓	K10
102	✓	✓	K11
103	×	×	K5
109 (U)	✓	×	K6

Note: (S) stakeholder property
(SU) uninhabitable stakeholder property
(U) uninhabitable non-stakeholder property
✓ compliance
× non-compliance

It can be seen from Table 11 that, using Mitsubishi MWT-95 wind turbines, compliance with the 24 hour NZS6808:1998 noise limits are exceeded at:

- Two (2) of the twenty-two (22) non-stakeholder properties
- Six (6) of the thirteen (13) stakeholder properties, including two (2) which are currently uninhabitable.

Using Mitsubishi MWT-95 wind turbines, the NZS6808:1998 night-time noise limits are exceeded at:

- Twelve (12) of the twenty-two (22) non-stakeholder properties, including one (1) which is currently uninhabitable
- Seven (7) of the thirteen (13) stakeholder properties, including three (3) which are currently uninhabitable.

Using Mitsubishi MWT-95 wind turbines, all non-assessed sites further from the wind farm will comply with the lowest possible limit of 40dBA.

8.7 Compliance summary

A summary of compliance at all assessed properties for the six (6) selected wind turbine models is provided in Tables 12 and 13.

Table 12
Summary of compliance with 24 hour noise limits

	Number of properties where the 24 hour noise limits are exceeded			
Model	Non stakeholder (out of 19)	Uninhabitable non stakeholder (out of 3)	Stakeholder (out of 9)	Uninhabitable stakeholder (out of 4)
Vestas V90	-	-	-	2
Vestas V100	-	-	1	2
Nordex N100	6	-	6	2
Siemens SWT-101	-	-	2	2
Repower MM92	2	-	2	2
Mitsubishi MWT-95	2	-	4	2

Table 13
Summary of compliance with night-time noise limits

	Number of properties where the night-time noise limits are exceeded			
Model	Non stakeholder (out of 19)	Uninhabitable non stakeholder (out of 3)	Stakeholder (out of 9)	Uninhabitable stakeholder (out of 4)
Vestas V90	-	-	-	2
Vestas V100	-	-	2*	2
Nordex N100	12	1	6	3
Siemens SWT-101	5	-	4	2
Repower MM92	2	-	2	2
Mitsubishi MWT-95	11	1	4	3

* Marginal exceedance at one (1) of the two (2) stakeholder properties

It can be seen form Tables 12 and 13 that the Vestas V90 is the best suited wind turbine model for the proposed layout.

Compliance with NZS6808:1998 is likely to be achieved at all properties in the vicinity of the proposed Berrybank Wind Farm with the other five (5) selected wind turbine models if an appropriate noise management plan is implemented. At this stage we do not have sufficient manufacturer's data to assess noise emissions from the proposed wind farm using wind turbines in noise managed settings.

If one of these five (5) wind turbine models is selected, further assessment should be carried out to determine the appropriate noise management plan.

9.0 CONCLUSION

The Berrybank Wind Farm is proposed to consist of one hundred (100) wind turbines with a hub height of 80m. Six (6) wind turbine models have been selected by Union Fenosa for this noise impact assessment.

In this report, suitable noise limits have been calculated for the external noise level of eleven (11) of the thirty-five (35) assessable residential sites near the proposed Berrybank Wind Farm. Using the New Zealand Standard for wind farms, NZS6808:1998, noise limits have been set depending on the relationship between measured existing (pre-wind farm) background noise levels and wind speeds.

Noise limits determined for seven (7) of the eleven (11) monitored sites were applied to twenty (20) of the remaining assessable properties. The minimum possible NZS6808:1998 noise limit of 40dBA at all wind speeds was used for the remaining four (4) assessable properties.

The recommended ETSU-R-97 base noise limit of 45dBA has substituted the NZS6808:1998 base noise limit of 40dBA for properties owned by stakeholders in the project.

The predicted noise levels at each residential property in the vicinity of the proposed wind farm were calculated in accordance with NZS6808:1998 for the range of wind speeds over which the selected wind turbines sound power data is available. These predicted levels were compared with the appropriate noise limits. This comparison was made over a range of wind speeds for each of the six (6) selected wind turbine models.

It was found that, using Vestas V90 wind turbines, both the 24 hour and night-time NZS6808:1998 noise limits are achieved at all assessed non-stakeholder's residential properties and only exceeded at two (2) uninhabitable stakeholder properties.

Using Vestas V90 wind turbines, all non-assessed sites further from the wind farm are predicted experience worst-case noise levels lower than 35dBA, and therefore comply with the NZS6808:1998 lowest possible limit of 40dBA by at least 5dBA.

NZS6808:1998 24 hour and night-time noise limits are likely to be achieved using the remaining five (5) selected wind turbine models at all properties in the vicinity of the Berrybank Wind Farm if an appropriate noise management plan is implemented.

10.0 SUMMARY OF PARAMETERS

Documentation of relevant parameters as required by NZS6808:1998 is contained in Appendix L.