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Report: **Kaimai Wind Farm**
Acoustics assessment

Client: Kaimai Wind Farm Ltd

Reference: 170201b

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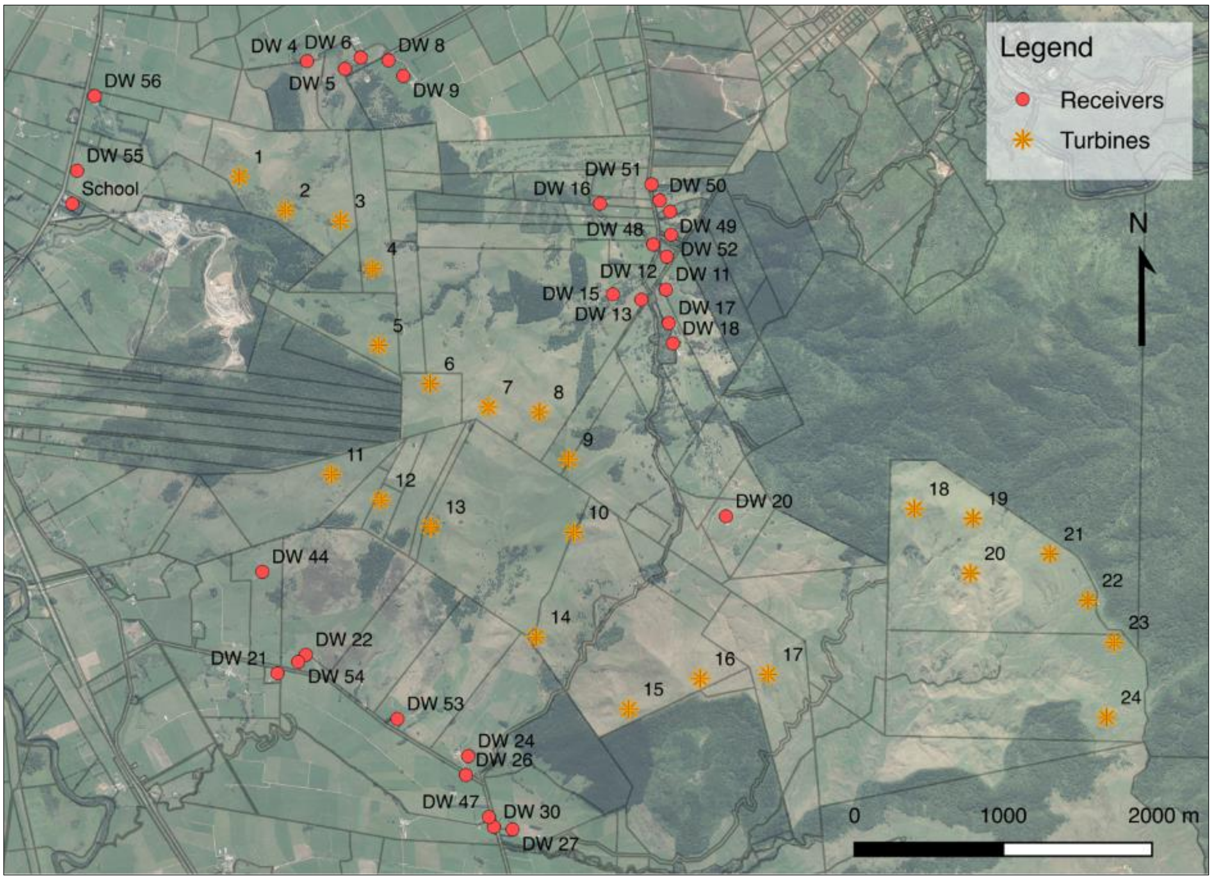
Contents:

1. Introduction

Chiles Ltd has been appointed to make an acoustics assessment of the proposed Kaimai Wind Farm near Tirohia, to the south of Paeroa. The proposal is for twenty-four wind turbines to be installed in the approximate locations shown in Figure 1. This figure also shows the nearest noise sensitive locations / receivers (e.g. residential neighbours).

Figure 1 Indicative turbine and receiver locations



Sound from the proposed wind farm might be heard at nearby residences and is a potential effect that requires assessment. There is a standardised methodology to assess this potential effect that has been used in New Zealand for all recent wind farms. This acoustics assessment applies that method to the proposed Kaimai Wind Farm.

The key parts of this assessment are:

- Determination of appropriate noise limits,
- Measurement of existing background sound levels,
- Prediction of proposed wind farm sound levels,
- Assessment of wind farm sound levels and recommendations for avoidance or mitigation of effects where necessary, and
- Recommendation of appropriate consent conditions.

This report also briefly addresses vibration and construction noise.

2. Criteria

Hauraki and Matamata Piako District Plans

The wind farm site and most nearby houses are in the rural zone of the Hauraki District as shown in maps 29 and 32 of the operative district plan. Houses on Rawhiti Road are within the rural zone of the Matamata Piako District, as shown in map 3 of that operative district plan.

There are no specific wind farm noise limits set in the Hauraki District Plan. Rule 8.3.1.3(1)(a) of the Hauraki District Plan sets general noise limits in the rural zone of 50 dB $L_{Aeq(15\ min)}$ during the day (0700h-2200h) and 40 dB $L_{Aeq(15\ min)}$ at night (2200h-0700h). These limits apply at the notional boundary 20 metres from dwellings. Essentially the same noise limits are set for the rural zone in Rule 5.2.6.i of the Matamata Piako District Plan, although it uses outdated acoustics metrics and standards.

These general noise limits are typical of many district plans and are usually appropriate for rural areas. The objectives and policies in Section 5.1.2 of the Hauraki District Plan and Section 3.5.2 of the Matamata Piako District Plan have been reviewed and nothing has been found that identifies the rural zone around the proposed wind farm as having unusual or special acoustic amenity. This corresponds with the typical values set for the general noise limits.

The Hauraki District Plan specifies in Rule 8.3.1.3(1) that noise limits must be assessed in accordance with NZS 6802:2008 *Acoustics – Environmental noise* (NZS 6802). Clause 1.2.1 of NZS 6802 explicitly prohibits wind farm sound from assessment using that Standard, and requires NZS 6808 *Acoustics – Wind farm noise* (NZS 6808) to be used. A key reason for having a separate standard for wind farms is that the general standard NZS 6802 does not allow for the measurement and assessment of sound in the presence of significant wind, which is inherently present when a wind farm is operating.

Therefore, the general Hauraki District Plan noise limits are not applicable and cannot be applied to the proposed wind farm, but through the reference to NZS 6802 in the district plan it indirectly requires the use of NZS 6808. The Matamata Piako District Plan includes a direct reference in an advice note to Rule 8.3.2 that states *"Noise associated with the operation of a large-scale wind farm must comply with the New Zealand Standard on Acoustics – Wind Farm Noise (NZS 6808: 2010)."*

New Zealand Standard NZS 6808

New Zealand Standard NZS 6808:2010 and its predecessor NZS 6808:1998 have been used for all recent wind farm projects in New Zealand. The latest 2010 version has been accepted by the Environment Court in several cases such as Meridian's Project Hurunui Wind in North Canterbury. The fundamental methodology is well accepted internationally. The Standard includes a noise limit of 40 dB L_{A90}, which can increase at higher wind speeds to 5 dB above background sound.

The key feature of NZS 6808 compared to the district plan noise limits is that the L_{A90} metric is used, which avoids undue effects of wind. Also, allowing the noise limit to rise above the background sound at higher wind speeds enables positive measurements to be obtained.

The noise limits in NZS 6808 have been designed to provide protection from sleep disturbance and to maintain reasonable residential amenity. It is considered this is the appropriate basis for assessing potential noise effects from the proposed Kaimai Wind Farm. While the NZS 6808 noise limits are not directly comparable to the general rural zone noise limits, they should result in more stringent controls for amenity during the day, while maintaining protection from sleep disturbance at night.

3. Existing environment

Noise sensitive locations

All nearby noise sensitive locations (e.g. residences) within approximately 2 kilometres of the proposed wind turbines have been identified by the client and are shown above in Figure 1, and listed in Section 4 below. There are five main groups of noise sensitive locations:

- There is a group of five houses at the end of Thorp Road to the north of the wind farm. These houses are between 900 metres and 1.2 kilometres from the nearest proposed wind turbine.
- To the north west of the wind farm is Tirohia where there are houses and the Tirohia Primary School. All of these noise sensitive locations are over 1 kilometre from the proposed turbines.
- To the east of the north section of the wind farm there are twelve houses along Rotokohu Road. These houses are all over 1 kilometre from the proposed wind turbines, other than a house occupied by one of the wind farm landowners, which is slightly over 900m away.
- In the centre of the wind farm is a single house occupied by another one of the wind farm landowners. This house is approximately 1 kilometre from the nearest turbine.
- To the west of the wind farm are numerous houses on Rawhiti Road. The nearest two houses are approximately 800 metres and 900 metres respectively from the proposed wind turbines. All other houses are over 1 kilometre away from the turbines.

Land around the wind farm is predominantly used for farming and other activities that are not noise sensitive, such as a quarry. However, in addition to the noise sensitive locations discussed above, there is a golf course on Rotokohu Road. During a community meeting, one resident also highlighted potential noise sensitivity of honey bees kept at a property on Rotokohu Road.

Stephen Chiles conducted a site visit on 16 March 2017 to inspect nearby noise sensitive locations, and to observe the local acoustic environment. He drove around and through the wind farm site on State Highway 26, Rawhiti Road, Rotokohu Road and Thorp Road.

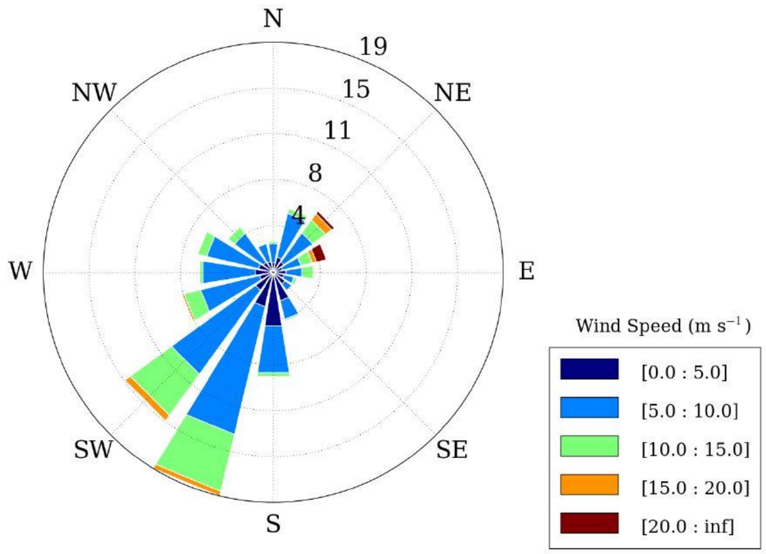
In general, the environment was found to be typical of many rural areas. The sound monitoring discussed below also shows the existing background sound levels to be as expected in a rural area.

Towards the head of the valley on Rotokohu Road the area will be sheltered by the terrain under southerly wind conditions. While this may result in different background sound levels from those measured at Thorp Road, at the time of the site visit the background sound observed at the head of the valley was significantly affected by vegetation and insect sounds to a greater extent than the Thorp Road location.

Wind conditions

Energy 3 has provided the long-term wind rose in Figure 2 below for a position 60 metres above ground level at the site meteorological mast in the northern section of the wind farm. This data is understood to provide an adequate representation of long-term wind conditions. Each segment of the wind rose relates to the direction the wind is coming from in 30° bands (e.g. data at 180° represents a southerly wind coming from between 165° and 195°). The total length of the multi-coloured bar extending out from the centre of the wind rose in each segment shows the percentage of the time the wind comes from that direction. For each wind direction, the percentage can be further split into different wind speeds by the separate colours making up the bars. The wind rose for this site shows a clear prevailing wind from the South West / South South West.

Figure 2 Long-term wind rose



<u>Background sound survey</u>

Background sound levels were measured at two locations around the proposed wind farm in March 2017. As discussed in Section 2, background sound measurements can be required to define periods when the wind farm noise limit increases above 40 dB L_{A90}. However, in this instance the wind farm sound level predictions presented in Section 4 are below 40 dB L_{A90} at all residences. Therefore, background sound level measurements are not required for that purpose. Reasons for conducting the measurements required by NZS 6808 are to quantify the existing environment and to allow for compliance testing, which requires a baseline of background sound levels prior to the wind farm operating. In this instance, the measurements undertaken were primarily to inform an understanding of the existing environment.

Full details and results of background sound level measurements are provided in Appendix A.

Due to the seasonal influence of cicadas, and measurements limited to 9 days at each site, correlations of sound levels with wind speed are not sufficiently robust to be used as a baseline for compliance monitoring. Also, rainfall data was not measured during the survey. Should consent be granted, further background sound level measurements in a different season will be required to enable compliance monitoring as detailed in the proposed consent conditions in Section 8.

While regression curves and correlations have not been determined for the sound level data, general trends can be seen from the graphs in Appendix A. In summer, the monitoring shows background levels to be elevated by cicada sound, generally remaining above 30 dB L_{A90} at all times and commonly over 40 dB L_{A90}. As described in Appendix A, audio recordings have been filtered to provide an indication of likely sound levels in other seasons. Those results show more typical rural levels that fall below 30 dB L_{A90} at times at 181A Thorp Road.

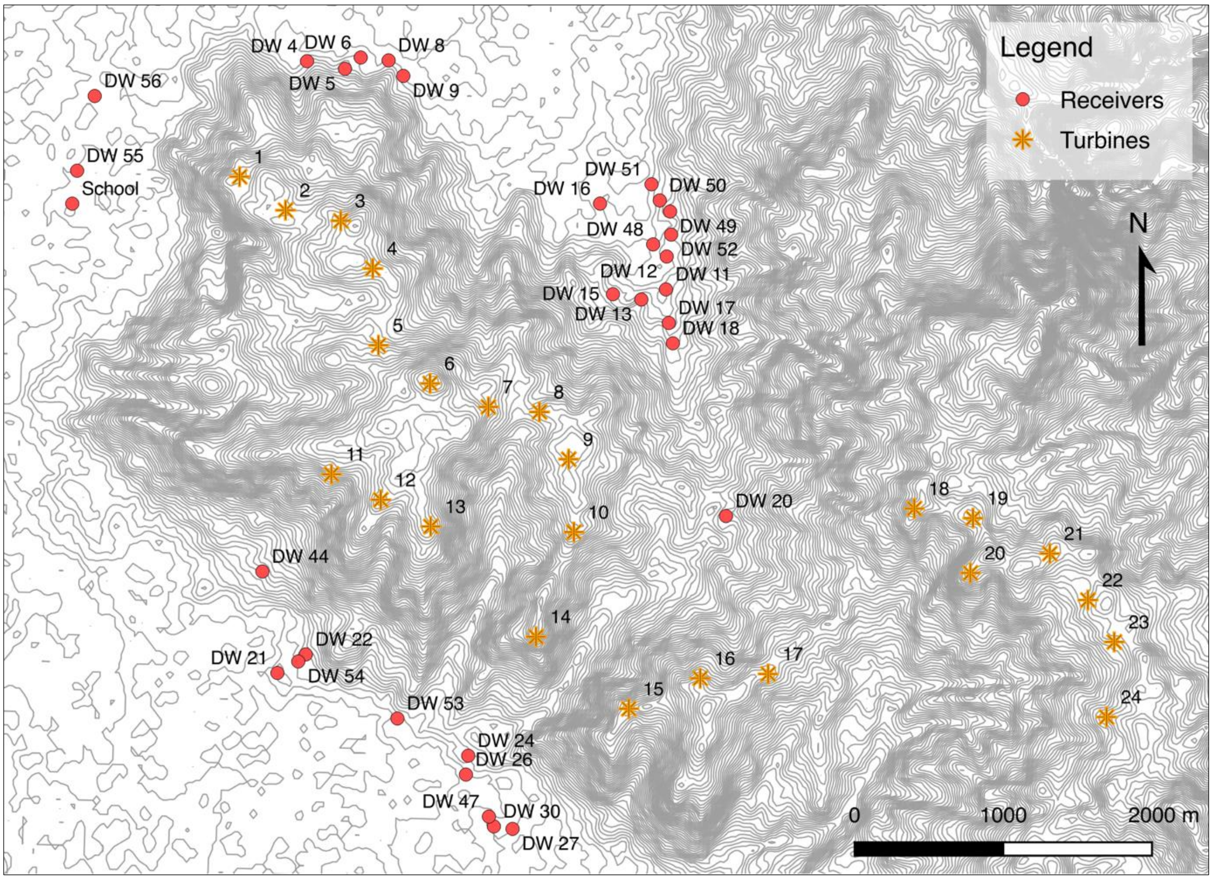
4. Acoustics model

Introduction

NZS 6808 refers to ISO 9613-2:1996 as an appropriate method for calculating wind farm sound levels. Predictions for the Kaimai Wind Farm have been made in accordance with that standard, implemented in iNoise modelling software. Input data used in the model and results are detailed below. All co-ordinates are in terms of the NZTM/NZGD2000. The overall layout of the acoustics model with turbines, receivers and topographic contours is shown in Figure 3.

The ISO 9613-2 prediction method used for this assessment gives results for light downwind conditions in all directions simultaneously. While this is not physically possible, it provides a conservative assessment.

Figure 3 Acoustics model layout



Wind turbines

The wind farm is being proposed to have any of the following turbine dimensions:

Lower Ridge (Turbines 1-17):

(i) 132m hub height, 150m rotor diameter, 207m tip height

(ii) 128m hub height, 160m rotor diameter, 207m tip height

(iii) 110m hub height, 160m rotor diameter, 190m tip height

Upper Ridge (Turbines 18-24):

(i) 112m hub height, 136m rotor diameter, 180m tip height

(ii) 107m hub height, 146m rotor diameter, 180m tip height

(iii) 98m hub height, 146m rotor diameter, 171m tip height

The acoustics modelling adopts conservative assumptions using maximum heights to allow for any turbine dimensions within this proposed envelope. The turbine model could be one of various options. The sound level data used in the model relates to a specific Siemens wind turbine model, which has been selected to allow for indicative sound levels of all likely turbine types. This will require confirmation once the final turbine type has been selected.

Details of the indicative wind turbine details used for the modelling are given in Tables 1 and 2.

Table 1 Wind turbine data

Parameter	Turbines 1-17	Turbines 18-24
Power regulation	Pitch control, variable speed	Pitch control, variable speed
Gears	Direct drive	Direct drive
Number of turbines	17	7
Maximum A-weighted sound power level	106.0 dB	106.0 dB
Special audible characteristics	None	None
Maximum turbine hub height (AGL)	132 m	112 m
Maximum turbine blade tip height (AGL)	207 m	180 m

Table 2 Wind turbine sound power spectrum (8m/s, 10m AGL)

Octave-band, Hz	63	125	250	500	1000	2000	4000	8000
Turbines 18-24	89.6 dB	94.4 dB	94.8 dB	98.3 dB	99.6 dB	100.3 dB	97.7 dB	86.2 dB

In accordance with NZS 6808, the wind turbine sound power levels have been taken as L_{A90} values.

The wind turbines have been modelled at the co-ordinates in Table 3 as shown on Figure 3. The final locations may vary by 20 metres in any direction which would have negligible effect on the sound level predictions. Heights of the wind turbines are hub-height above mean sea level.

Table 3 Turbine locations

Turbine	Hub-height (m)	Easting (m)	Northing (m)
1	313	1835527	5854128
2	333	1835835	5853902
3	360	1836207	5853831
4	364	1836422	5853510
5	360	1836461	5852993
6	451	1836808	5852736
7	396	1837200	5852578
8	364	1837544	5852544
9	385	1837741	5852226
10	370	1837776	5851735
11	377	1836145	5852125
12	419	1836476	5851952
13	437	1836813	5851773
14	359	1837521	5851031
15	387	1838145	5850546
16	440	1838625	5850751
17	439	1839083	5850780
18	584	1840066	5851893
19	577	1840461	5851829
20	597	1840443	5851460
21	589	1840977	5851590
22	563	1841234	5851278
23	568	1841411	5850995
24	571	1841359	5850490

Noise sensitive locations

Noise sensitive locations in the area near the proposed wind farm, are shown on Figures 1 and 3 above and have been modelled at the co-ordinates in Table 4. Addresses marked with an asterisk indicate houses belonging to wind farm landowners or other parties that have provided written approval to the proposed wind farm.

Table 4 Receiver locations

Ref	Receiver	Height (m)	Easting (m)	Northing (m)	Nearest turbine (m)
DW 4	181E Thorp Road	25	1835980	5854905	900
DW 5	181C Thorp Road	30	1836235	5854854	1014
DW 6	181D Thorp Road	20	1836341	5854930	1107
DW 8	181B Thorp Road	17	1836529	5854911	1126
DW 9	181A Thorp Road	15	1836628	5854806	1062
DW 11	613 Rotokohu Road *	51	1838395	5853369	1185
DW 12	579 Rotokohu Road	45	1838400	5853590	1351
DW 13	606 Rotokohu Road	65	1838229	5853301	1021
DW 15	604 Rotokohu Road *	62	1838038	5853336	933
DW 16	538 Rotokohu Road	29	1837951	5853947	1460
DW 17	633 Rotokohu Road *	60	1838414	5853143	1056
DW 18	633 Rotokohu Road *	70	1838442	5853006	1009
DW 20	771 Rotokohu Road *	177	1838799	5851843	1028
DW 21	649 Rawhiti Road	25	1835781	5850786	1357
DW 22	636A Rawhiti Road	36	1835972	5850911	1156
DW 24	500 Rawhiti Road	38	1837064	5850229	922
DW 26	501 Rawhiti Road	28	1837049	5850102	1041
DW 27	442 Rawhiti Road	35	1837363	5849737	1125
DW 30	461 Rawhiti Road	35	1837237	5849753	1205
DW 44	680 Rawhiti Road	61	1835680	5851469	804
DW 47	463 Rawhiti Road	33	1837204	5849819	1188
DW 48	564 Rotokohu Road	38	1838309	5853672	1362
School	Tirohia School	25	1834401	5853946	1140
DW 49	561 Rotokohu Road	50	1838423	5853893	1609
DW 50	541 Rotokohu Road	40	1838353	5853968	1637
DW 51	529 Rotokohu Road	31	1838298	5854077	1707
DW 52	569 Rotokohu Road	49	1838430	5853738	1486
DW 53	558 Rawhiti Road	27	1836588	5850480	1083
DW 54	636B Rawhiti Road	31	1835921	5850863	1222
DW 55	6356 SH26 Tirohia	20	1834433	5854168	1094
DW 56	6410 SH26 Tirohia	17	1834552	5854671	1116

Model settings

The settings used in the modelling software are detailed in Table 5.

Table 5 Model settings

Parameter	Value
Operator	John Bull, Altissimo Consulting Ltd
Software	iNoise (release 2018.01)
Algorithm	ISO 9613-2
Ground absorption	0.5
Temperature	10°C
Humidity	70%
Sound contour grid resolution	100 m
Sound contour height	1.5 m
Topography – contour intervals	5 m*

* turbine heights were calculated relative to the supplied base heights

Results

The predicted wind farm sound levels for all wind turbines operating simultaneously at the maximum sound power are shown in Figure 4 and listed in Table 6. The blue contour line is 40 dB L_{A90}, and the green contour line is 35 dB L_{A90}. The contours are interpolated from a 100 metre grid and should only be used as a graphical overview. Predicted levels at houses should be read from Table 6.

Figure 4 Predicted sound level contours

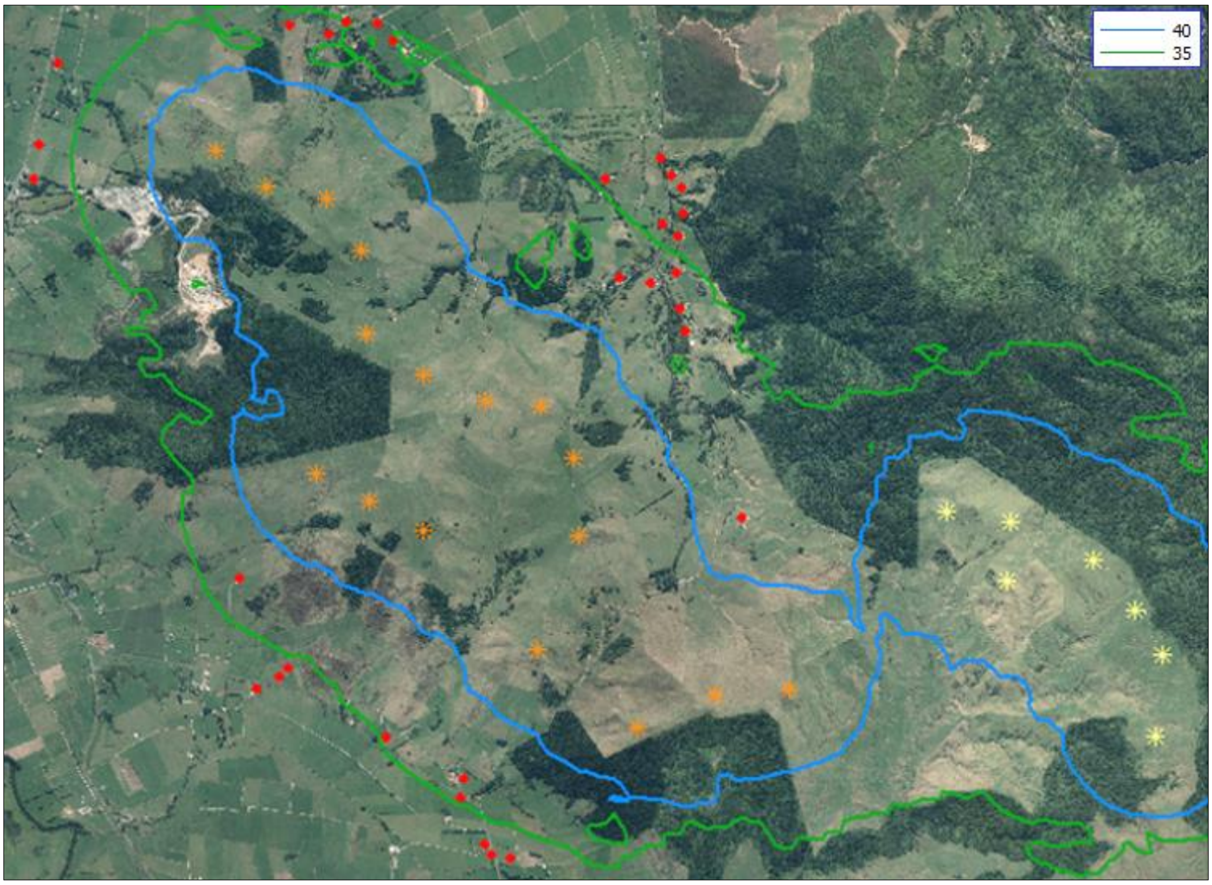


Table 6 Predicted sound levels

Ref	Receiver	Predicted wind farm sound level, L_{A90}
DW 4	181E Thorp Road	36 dB
DW 5	181C Thorp Road	35 dB
DW 6	181D Thorp Road	35 dB
DW 8	181B Thorp Road	35 dB
DW 9	181A Thorp Road	35 dB
DW 11	613 Rotokohu Road *	36 dB
DW 12	579 Rotokohu Road	35 dB
DW 13	606 Rotokohu Road	36 dB
DW 15	604 Rotokohu Road *	37 dB
DW 16	538 Rotokohu Road	35 dB
DW 17	633 Rotokohu Road *	36 dB
DW 18	633 Rotokohu Road *	37 dB
DW 20	771 Rotokohu Road *	39 dB
DW 21	649 Rawhiti Road	34 dB
DW 22	636A Rawhiti Road	34 dB
DW 24	500 Rawhiti Road	36 dB
DW 26	501 Rawhiti Road	35 dB
DW 27	442 Rawhiti Road	34 dB
DW 30	461 Rawhiti Road	34 dB
DW 44	680 Rawhiti Road	37 dB
DW 47	463 Rawhiti Road	34 dB
DW 48	564 Rotokohu Road	34 dB
School	Tirohia School	33 dB
DW 49	561 Rotokohu Road	33 dB
DW 50	541 Rotokohu Road	33 dB
DW 51	529 Rotokohu Road	33 dB
DW 52	569 Rotokohu Road	34 dB
DW 53	558 Rawhiti Road	35 dB
DW 54	636B Rawhiti Road	34 dB
DW 55	6356 SH26 Tirohia	33 dB
DW 56	6410 SH26 Tirohia	33 dB

As recommended by NZS 6808, the model was repeated with all turbines represented at the maximum blade tip height to check any uncertainties associated with terrain screening. This resulted in sound levels within 1 dB of the values set out above, indicating only minor uncertainty relating to terrain that would not alter the conclusions of this assessment.

5. Assessment

At all receivers, the predicted wind farm sound levels comply with the fixed part of the NZS 6808 wind farm noise limit (40 dB L_{A90}). This finding is applicable to the modelled Siemens' turbines, and any other turbine types with the same or lower sound power levels, which includes all those currently under consideration.

As the variable part of the limit ('background + 5dB') can only increase the limit above 40 dB L_{A90}, the predictions also demonstrate compliance with that part of the noise limit. As these limits have been set in NZS 6808 to provide protection from sleep disturbance and maintain reasonable residential amenity, the predicted wind farm sound levels should be acceptable.

While the predicted wind farm sound complies with the noise limits, it will still be audible at times. This is common for all sound sources controlled by district plans which set absolute limits, rather than requiring inaudibility, which would not be a sustainable criterion. In this instance, as the wind farm noise limits are relatively low the wind farm sound would only be quietly audible. Even that scenario is still for a worst case of the maximum wind turbine sound power in downwind conditions. Wind conditions vary, and for receivers that are up-wind and at times of lower wind speeds, the sound levels and audibility would be reduced. Furthermore, the wind farm would generate negligible sound under calm conditions and generally would not be audible at the most sensitive times such as on a still summer's evening. In the context of this area with typical rural characteristics, wind turbine sound that is quietly audible should not cause disturbance or cause undue annoyance.

For activities such as the golf course on Rotokohu Road, occasional wind farm sound quietly audible should not interfere with the activity.

No literature has been found that shows a link between wind turbine sound and adverse effects on honey bees. While online articles include assertions of an effect, no scientific evidence has been found of a causal relationship.

6. Vibration

Researchers internationally have demonstrated that wind turbines do not generate significant infrasound or vibration, including a study to investigate these specific issues through measurements conducted at an operational wind farm in New Zealand (Botha, P. *Ground vibration, infrasound and low frequency noise measurements from a modern wind turbine*. Acustica (99), pp 537-544. 2013). On this basis the proposed wind turbines should not give rise to perceptible ('feelable') vibration at any houses around the wind farm. People are more sensitive to vibration than buildings, and wind farm vibration will be substantially below thresholds for even cosmetic damage to buildings.

7. Construction noise

The following works have the potential to generate significant localised sound levels:

- Earthworks to form site roads and excavation for turbine foundations,
- Aggregate processing,
- Pouring concrete for turbine foundations,
- Haulage of turbine parts and materials up the access road from Rawhiti Road,
- Mobile cranes for installation of turbines, and
- Installation of new substation and internal site transmission.

The construction programme will be greater than 20 weeks and hence the 'long-term' construction noise limits from NZS 6803 *Acoustics – Construction noise* are applicable to the works. Compared to other types of infrastructure projects, most construction activities for wind farms occur at a significant distance from residences, in this case generally over 800 metres away. At this distance, compliance with the NZS 6803 construction noise limits can normally be achieved for daytime construction work with no restrictions. Any night-time work should generally be limited to activities such as continuous concrete pours, and these could also be managed to comply with the construction noise limits with standard practice. The staging areas and any aggregate processing should be kept towards the centre of the project site away from houses (excluding the land-owner house at 771 Rotokohu Road). The works will also involve numerous ancillary and minor construction activities that should not cause any material noise and vibration effects at surrounding houses.

A key area where construction noise management will be required is at the entrance to the site from Rawhiti Road as there are houses in the vicinity (500/501 Rawhiti Road). The entrance area should be designed so that any heavy vehicle waiting/control areas and the start of the access road are sealed and maintained to be free of defects that could induce excess vehicle impact sounds. Night-time activity in this area should be minimised.

The majority of the route to the site for construction traffic will be along the state highway network. Given the function of state highways, any noise effects of both daytime and night-time construction traffic should be minor. Construction traffic between SH26 and the site on Rawhiti Road has potential to cause temporary disturbance for occupants of houses along Rawhiti Road. Such effects should be minimised by training all drivers to adopt considerate driving techniques, such as gentle acceleration/braking and controlled speeds. If it is safe to do so, trucks fitted with audible engine brakes should not to use them on Rawhiti Road. If construction traffic causes deterioration of the surface/pavement of Rawhiti Road, defects should be monitored and repaired so they do not exacerbate any vehicle noise.

While most site activity and associated traffic should be predominantly restricted to the daytime hours, oversized loads may arrive at night, and during turbine foundation concrete pours there will be 24-hour access by concrete trucks. While this night-time construction traffic may cause some disturbance at houses with bedrooms that are close to Rawhiti Road, in the context of this temporary activity and with the management controls discussed above, these effects should remain reasonable.

8. Conditions

Should consent be granted for the wind farm, the following conditions relating to operational wind farm sound are recommended. Noise limits are required to be met at all noise sensitive locations, but for measurements three representative receivers around the wind farm are proposed.

1. *At the assessment positions shown on Figure [a copy of figure 1 of this report], wind farm sound levels shall not exceed:*

   (a) A noise limit of 40 dB $L_{A90(10\ min)}$, provided that the following noise limit shall apply in the circumstances stated in (b);

   (b) When the background sound level is greater than 35 dB $L_{A90(10\ min)}$, the noise limit shall be the background sound level $L_{A90(10\ min)}$ plus 5 dB.

2. *Wind farm sound shall be measured and assessed in accordance with NZS 6808:2010.*

3. *A prediction report shall be submitted to the Hauraki District Council in accordance with section 8.4.2 of NZS 6808:2010, unless the selected wind turbine layout is the same as the layout for which predictions were provided in the application, and the selected wind turbines have sound power levels no greater than the levels for the three options provided in the application.*

4. *Subject to access being provided, background and post-installation sound level measurements shall be made at:*

   (a) 181E Thorp Road

   (b) 680 Rawhiti Road

   (c) 579 Rotokohu Road

5. *A compliance assessment report shall be submitted to the Hauraki District Council in accordance with Section 8.4.1 of NZS 6808:2010.*

9. Conclusions

Chiles Ltd has assessed sound from the proposed Kaimai Wind Farm near Tirohia. The Hauraki District Plan does not include noise rules that can be applied to a wind farm. Therefore, the assessment has been based on the New Zealand wind farm noise standard NZS 6808. This standard is referenced in the Matamata Piako District Plan.

The existing environment has been found to be typical of a rural area. A survey during March 2017 showed elevated background sound levels due to cicadas, but analysis of audio recordings to remove the influence of cicadas indicates that sound levels are likely to reduce to more common rural levels at other times of year.

A computer model has been used to predict sound levels for the maximum sound power of indicative wind turbines. The wind farm sound levels are predicted to comply with a 40 dB L_{A90} noise limit.

On the basis that predicted sound levels comply with NZS 6808, which recommends limits to protect health and reasonable amenity, the noise effects of the Kaimai Wind Farm are considered to be acceptable in this environment. Vibration from wind farms has been shown to be below thresholds for levels that can be felt by people or cause damage to buildings.

The wind farm construction would cause temporary noise effects, but due to the separation of most activities from neighbouring houses levels should comply with the limits in the New Zealand construction noise standard.

If consent is granted, it is recommended that conditions should be imposed to ensure noise effects remain in accordance with this assessment.

Appendix A

Background sound levels

Background sound level monitoring has been conducted at two residential locations (181A Thorpe Road and 500 Rawhiti Road) broadly representative of the nearest houses on each side of the proposed wind farm. The following sets out the details of the measurements and results, in general accordance with the requirements of NZS 6808:2010 section 8.2.

Acoustical equipment

The acoustical equipment was set-up by Stephen Chiles and collected by Alex Jacob.

The monitoring was conducted using two ARL Ngara kits hired from TechRentals, Auckland. The kits include all required ancillary equipment including pole, cables, microphone, windshield and calibrator. Details of the equipment are as follows:

181A Thorp Road

Logger: ARL Ngara, serial 87805E, calibrated 3 December 2015

Calibrator: Pulsar 105, serial 55043, calibrated 21 February 2017

500 Rawhiti Road

Logger: ARL Ngara, serial 87805F, calibrated 15 August 2016

Calibrator: ARL ND9, serial N452774, calibrated 19 August 2016

At both locations, the loggers were set up in a standard configuration with the microphone mounted on the pole provided, attached to the top of the noise logger case.

The calibration of the loggers was adjusted prior to measurements on site and checked following the measurements once the logger batteries had been recharged. The levels of the reference tones varied by less than 1 dB.

The loggers were set to continuously record audio data at 12 KHz, 16 bits.

Data from the loggers was copied from the attached USB drives and exported to spreadsheets for subsequent analysis. Audio data was also processed as set out below. All sound level data has been analysed using 10 minute periods.

Measurement locations

<u>181A Thorp Road</u>

Aerial photograph showing logger location:

Photographs of the installed logger:

500 Rawhiti Road

Aerial photograph showing logger location:

Photographs of the installed logger:

Anemometry equipment

There are two wind masts on the site. Data from the northern wind mast has been used for this analysis as it is more representative of wind conditions at the turbines that are nearest to houses.

The wind mast is 60 metres tall and has anemometers at heights of 30 m, 45 m and 60 m, and wind vanes at heights of 45 m and 60 m. All wind data is averaged using 10 minute periods.

From the wind speed measurements at the three anemometers the wind shear has been calculated by Energy 3 for each 10 minute period during the survey, and the wind speed has been extrapolated to a nominal hub-height value at 80 metres. These extrapolated values have been used in the following results and analysis. The hub-heights of the indicative wind turbines that were subsequently selected are 109 m / 115 m (Section 4). Future background and compliance measurements will need to be analysed using wind speeds extrapolated to the actual hub-height of the turbines in the final design.

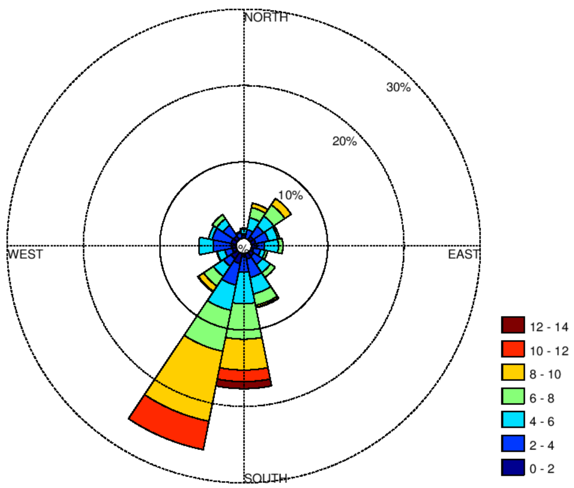
Survey period

The loggers were installed at each location over a two-week period, although due to power used in audio recording the batteries expired on the ninth day. Data was obtained for the following periods:

- 181A Thorp Road 1430h 16 March to 1000h 24 March (1188 10-minute samples)
- 500 Rawhiti Road 1300h 16 March to 1900h 24 March (1125 10-minute samples)

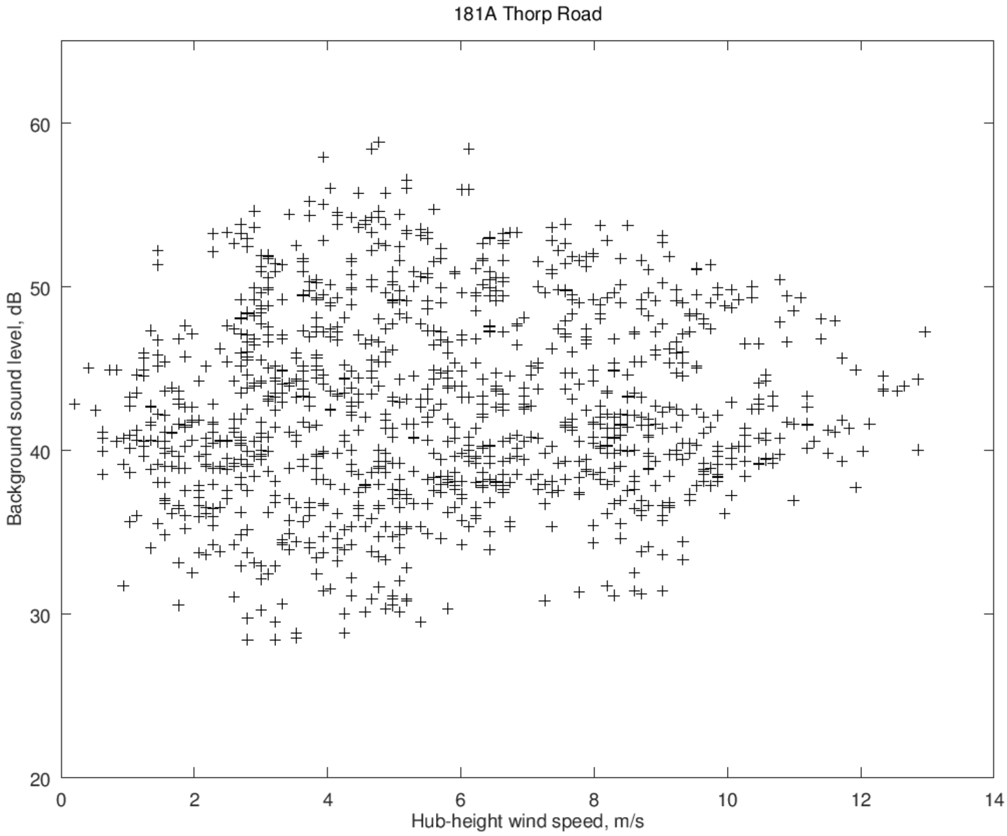
Wind data

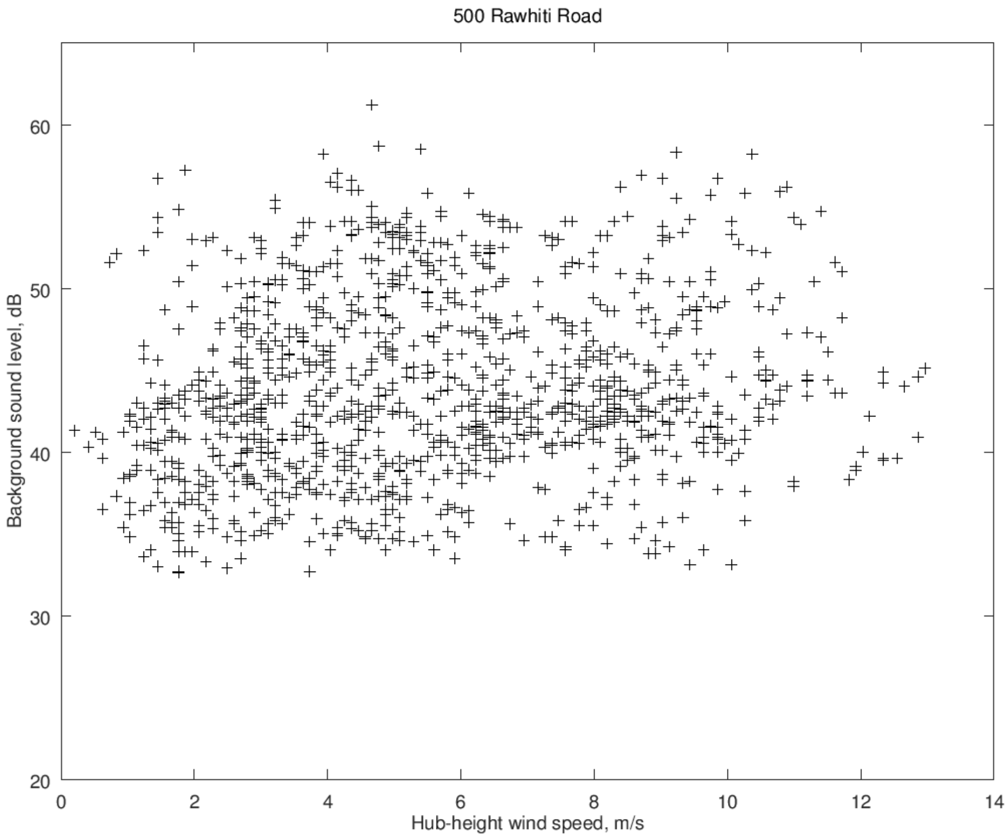
The distribution of wind speeds and directions during the survey period are shown in the following wind rose. The prevailing South South West wind during the survey was representative of long-term conditions at the site.



Analysis

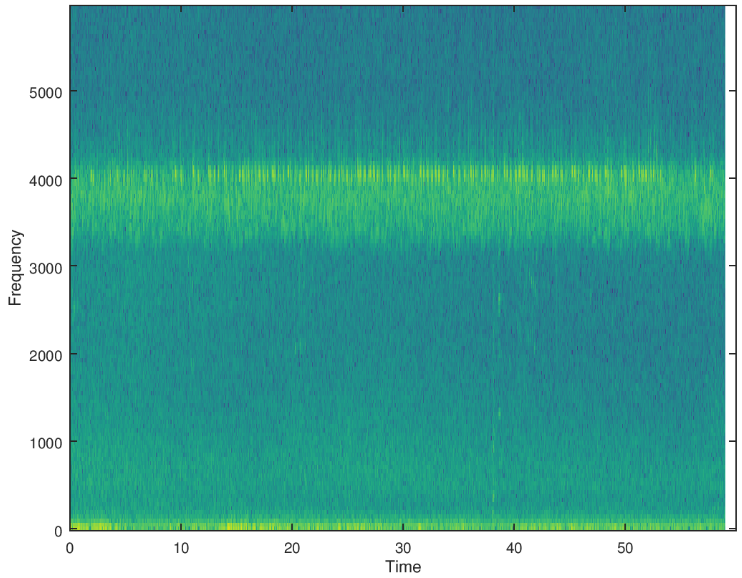
The following two graphs show measured $L_{A90(10\ min)}$ background sound levels for all 10 minute samples at each of the sites. No outliers have been removed and the data shows all wind directions and times of day.


181A Thorp Road
Background sound level, dB
Hub-height wind speed, m/s
20
30
40
50
60
0
2
4
6
8
10
12
14


500 Rawhiti Road
Background sound level, dB
Hub-height wind speed, m/s
20
30
40
50
60
0
2
4
6
8
10
12
14

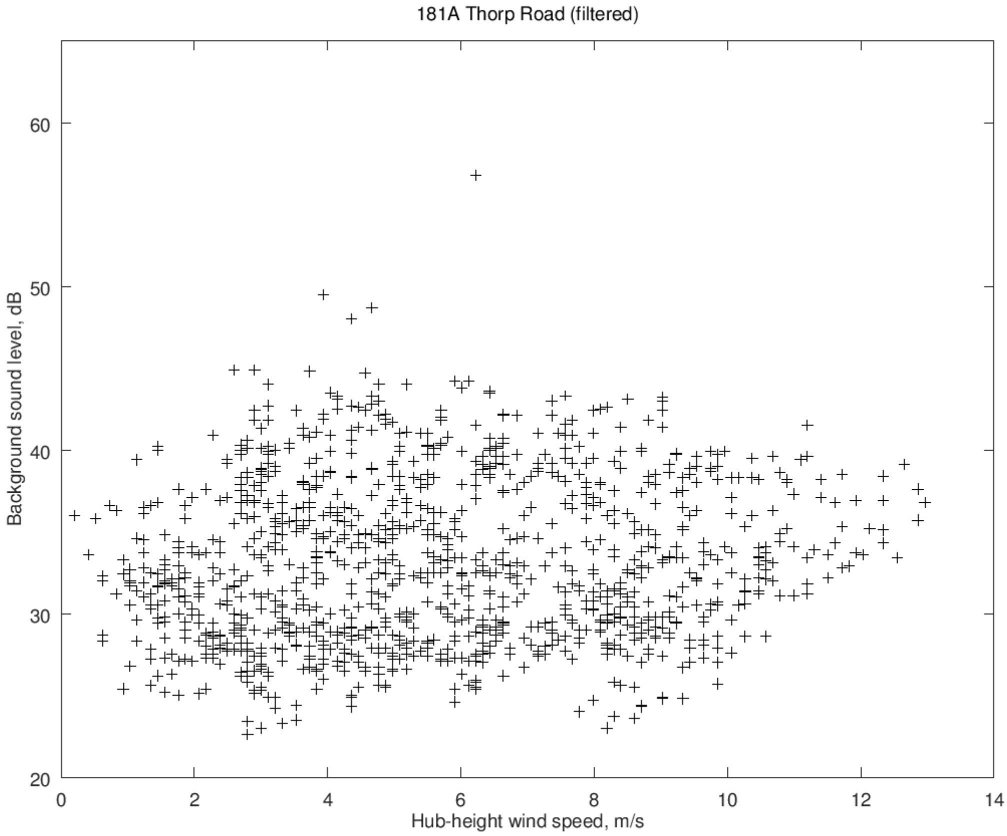
The measured sound levels shown in the previous two graphs are higher than many rural areas, which often have low background sound levels at night during low wind speeds, commonly in the range of 20 to 25 dB. The main reason for the slightly elevated levels is due to the influence of cicadas at the time of year the measurements were conducted (March).

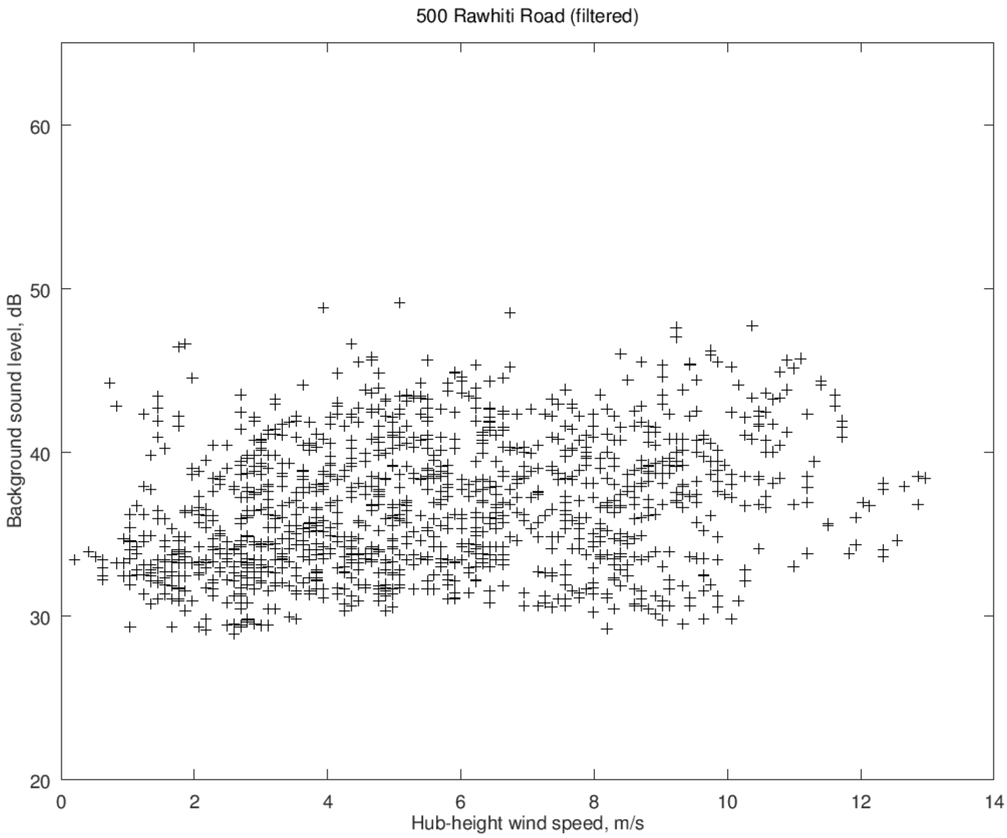
The contribution of cicadas is evident as a horizontal yellow band of colour around 4000 Hz in the following frequency spectrogram for a typical 60 second measurement period. The linear frequency scale on this spectrogram gives the appearance that cicada sound dominates measurements. While the cicada sound is significant, due to the logarithmic response to frequency, other sound shown at the bottom of the graph has more influence than it appears on this representation.



To provide an indication of the background sound environment at other times of year, the audio recordings have been filtered to remove the influence of cicadas. Before filtering, tests were made to check whether the measured sound levels shown on the previous two graphs could be reproduced from audio data. It was found that while the general magnitudes of sound levels were reproduced, there were significant errors using the audio data. A key source of error is the sampling rate of the audio files at 12 KHz, which means sound frequencies over 6 KHz were not recorded. This sampling rate was selected for practicality of file sizes, as for background environmental sound high frequency components generally do not control levels. However, this limits accuracy in reproducing levels.

The audio files were digitally filtered to remove all frequency components above 3 KHz, including cicada sound. The remaining data was then processed to obtain indicative background sound levels without cicadas. These levels are shown in the following two graphs. As expected, the sound levels are significantly reduced and show levels more typical of rural environments. The data is not strongly correlated with wind speed. Further analysis has not been conducted due to the limitations of the audio data sampling rate. However, these graphs provide an indication of sound levels that may occur at other times of the year.


181A Thorp Road (filtered)
Background sound level, dB
Hub-height wind speed, m/s
20
30
40
50
60
0
2
4
6
8
10
12
14


500 Rawhiti Road (filtered)
Background sound level, dB
Hub-height wind speed, m/s
20
30
40
50
60
0
2
4
6
8
10
12
14