BALD HILLS WIND FARM
SUMMARY NOISE MONITORING REPORT

CONFIDENTIAL TO J. ZAKULA
AND MONITORING PARTICIPANTS

NMS

Final

Document Control Page

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Signed

Dr Bob Thorne (Principal)

CONFIDENTIALITY AND IP

The monitoring results are detailed in various NMS Reports. The reports are confidential to the destination parties listed above. All raw datasets including residential sound levels, response diaries, questionnaires and audio recordings are the property of the respective participants. The intellectual property rights of the Noise Monitoring Protocols, analysis spreadsheets and processed datasets are held by Noise Measurement Services Pty Ltd.

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- ✓ Mr Geoff Clark, BSc, MSc: Meteorological data analysis
- ✓ Mr Matt Dever, B.Audio: Noise Measurement Services; Instrumentation, data collection and analysis, signal analysis
- ✓ Mr Max Thorne, LLB: Noise Measurement Services oversight
- ✓ Dr Bob Thorne; Program and report coordinator.

In order to be independently verifiable the monitoring and analysis programs are designed with standard instruments and data downloads suitable for standard methods of analysis. The monitoring provides large amounts of sound level, perception data, AEMO power values, meteorological data and audio recordings.

- ✓ Due to the complexity of data analysis Mr Dever prepared standardised analysis spreadsheets to simplify the correlation processes. These spreadsheets are recorded in this report and the datasets are available to the monitoring program participants on a confidential basis.

- ✓ The participation of the residents' in preparing and recording noise diaries for the whole term of the monitoring program is acknowledged with appreciation. The information recorded in the diaries is critical in the assessment of compliance / non-compliance, and for assessment of potential nuisance due to 'special audible characteristics' of wind farm noise.

Executive Summary

This Summary Report is part of the Bald Hill Wind Farm monitoring report series prepared for Mr J. Zakula and participants in the residents' group who have requested monitoring and assessment of noise emissions from the Wind Farm.

Two questions were posed by the residents:

- Does the Bald Hills Wind Farm (BHWF) comply with its approval conditions?; and
- Do nuisance conditions exist due to the operation of the Bald Hills Wind Farm?

Monitoring of sound levels at homes took place over May 2018 to March 2019. Sound levels were recorded inside and outside the primary measurement location, and outside at the other homes. The sound level data is correlated with weather data, power generation data and diaries of personal perceptions of sounds from the wind farm. The data recorded to date allows initial conclusions to be made. Specialized psychoacoustic analysis of monitoring data is not applied as part of the reporting program at this time.

Relevant Approval Conditions for the Bald Hills Wind Farm are recorded in this report. Condition 19 relates to noise management and compliance. The approval condition applies New Zealand standard 6808:1998 'Acoustics-The Assessment and Measurement of Sound from Wind Turbine Generators'. Condition 22 applies where Condition 19 is found to have been breached, and applies noise mitigation measures including removal of turbines.

Findings

- Regular and consistent LA95 background sound levels above 40 dB(A) coinciding with BHWF power generation, were recorded over the period May 2018 to March 2019;
- Increases in background sound levels due to Bald Hills Wind Farm activity and compliance/non-compliance are identified (Approval Condition 19(a));
- Perceived 'Special audible characteristics' of the wind farm operation are identified by individual persons and audio recordings. Therefore, the requirements of clause 4.4.3 of NZS6808:1998 and Condition 19(b) must be applied;
- A penalty of 5 dB(A) applies to measured night-time sound levels affected by special audible characteristics under the New Zealand Standard.
- Nuisance conditions are identified and recorded by individual persons as 'sleep disturbance', 'intrusive noise' and 'annoyance';
- Non-compliance with Approval Condition 19(c) is shown in both the monitored sound levels (reported as 'Night-time 10% Loudest') and through identification of sleep disturbance as reported by individual persons.

The monitoring program confirms that sound levels were exceeded, and sleep disturbance, intrusive noise and nuisance conditions existed at the homes of the persons involved during this monitoring program:

- Mr John Zakula (ML1)
- Mr Don Fairbrother, Mrs Dorothy Fairbrother (ML2)
- Mr Noel Uren (ML3)
- Mr Don Jelbart and Mrs Sally Jelbart (ML4)
- Kilsby residence (ML5) (Roberto working-living on-site)

Similar conditions exist for a home in the vicinity of a potential residential location at King's Park (ML6). Assessment to the monitoring at ML3 is acceptable for this location.

Introduction

This Report is the summary report for the Bald Hills Wind Farm residential noise monitoring program, May 2018 to March 2019. Outdoor sound levels were recorded on a continuous basis at residential monitoring locations adjacent to the Bald Hills wind farm. Audio records and indoor sound levels were recorded at various locations and times during the survey. Personal noise diaries were recorded and form a major component of the program.

Outcomes from the monitoring include:

- Assessment of compliance to Condition 19.
- Application and relevance of Condition 22.
- Assessment of noise nuisance events identified by residents at their respective homes.

Testing and assessment of compliance required sound level monitoring over representative months' of time to capture different wind speeds and directions. This makes compliance assessment complex as data capture required:

- Background sound levels containing wind turbine sounds, at affected homes;
- Background sound levels prior to the turbines being built / operational;
- Wind speeds and directions for the background sound levels;
- Audio recordings for identification and analysis of wind farm character; and
- Personal diaries of residents to identify dates, times and character of 'special audible characteristics', annoyance and sleep disturbance.

The collected data was processed to determine whether or not the recorded sound levels met the requirements of the approval condition and the standard:

- *Background noise assessment*: assessment of wind data, sound levels at homes, and wind farm operational data for compliance with background sound level criteria;
- *Sleep disturbance:* assessment of wind data, sound levels at homes, diary entries and wind farm operational data for compliance with night-time 10% background sound level criteria; and
- *Overall noise compliance assessment*: assessment of compliance with application of the 'special audible characteristics' penalty to recorded diary entries, measured daily and night-time background sound levels.

Wind farm noise is evaluated through tabulation of personal diaries and charting of night-time noise levels affected by audible characteristics as required by NZS6808:

- *"… to account for the adverse subjective response likely to be aroused by sounds containing such characteristics…"* and

- *"Sound from a WTG that has special audible characteristics (clearly audible tones, impulses, or modulation of sound levels) is likely to arouse adverse community response at lower levels than sound without such characteristics".*

Combined, these two factors establish the basis for evaluating the *amenity values* enjoyed by individuals prior to, and after, the operation of the wind farm. The diaries indicate that sound levels from the wind farm are generally not the subject of complaint during the day. Complaints of noise tend to be consistent with times of high power generation or sudden decreases or increases in power generation. That is, the potential for complaint is consistent with variations in power generation from the Bald Hills Wind Farm.

BALD HILLS WIND FARM APPROVAL (NOISE CRITERIA)

The relevant Bald Hills Wind Farm noise approval condition relating to monitoring sound levels is:

19. The operation of the wind energy facility must comply with the New Zealand Standard 'Acoustics – The Assessment and Measurement of Sound From Wind Turbine Generators' (NZ 6806:1998) (the 'New Zealand Standard'), in relation to any dwelling existing at the date of approval of this document to the satisfaction of the Minister for Planning. In determining compliance with the New Zealand Standard, the following apply:

(a) The sound level from the wind energy facility, when measured outdoors within 10 metres of a dwelling at any relevant nominated wind speed, should not exceed the background level (L95) by more than 5dBA or a level of 40dBA, whichever is the greater.

(b) When sound has a special audible characteristic, the measured sound level of the source shall have a 5 dB penalty added.

(c) Compliance at night must be separately assessed with regard to night-time data. For these purposes the night is as defined in SEPP-N1. For sleep protection purposes. A breach of the standard set out in 19(a), for 10% of the night, amounts to a breach of the condition.

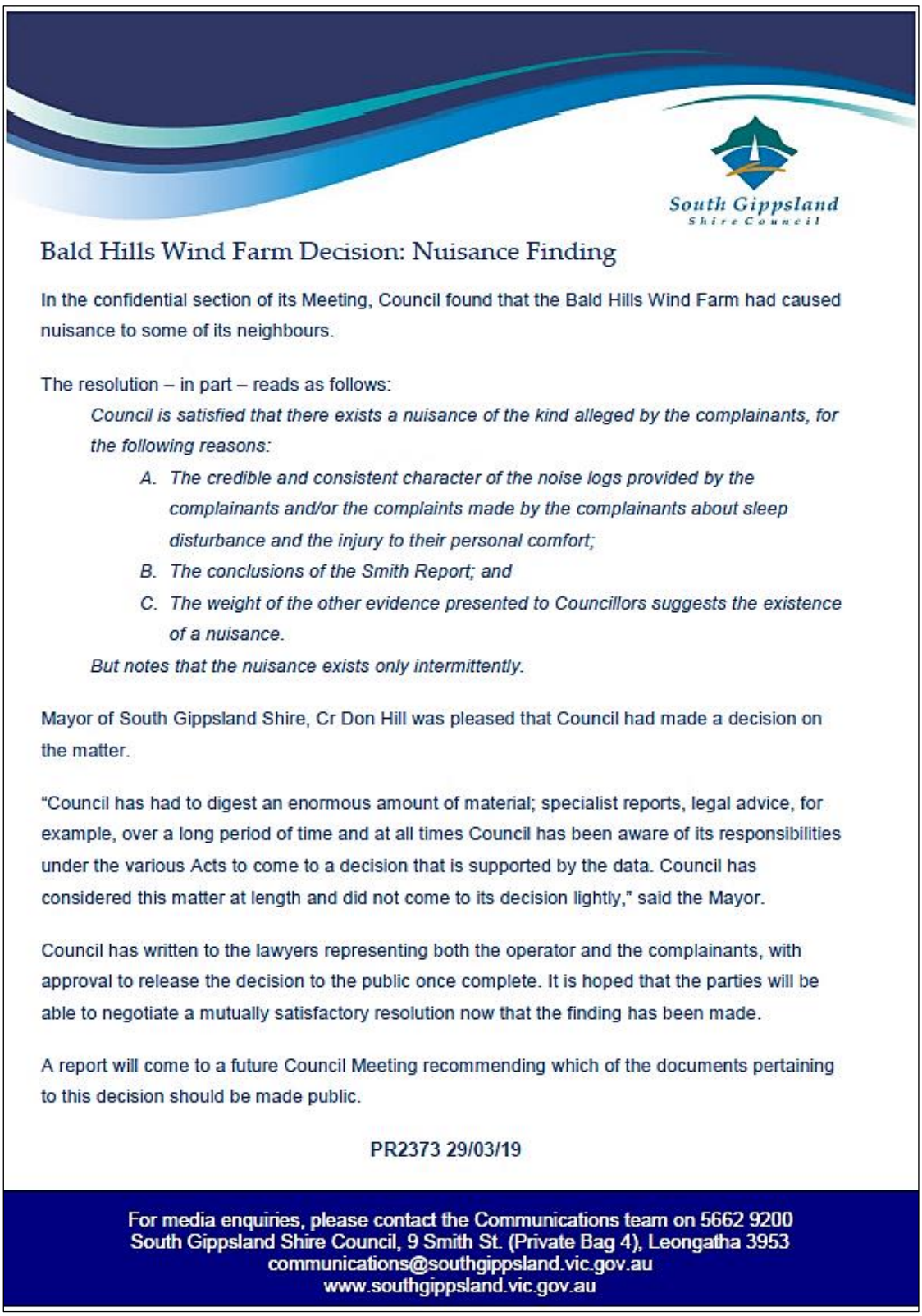
NMS Notes to condition 19:

- The night-time period in SEPP-N1 is the time between 2200 and 0700 hours.
- The expression "6806" should read "6808".
- The standard does not state what is, or isn't, a 'relevant nominated windspeed'. 'Windspeed' is a measurement of the speed of the prevailing wind over a discrete time period. Measurement is in m/s with a tolerance of 0.5 m/s.

The following sections and appendices are provided to help explain the "whys" and "hows" with respect to wind farm noise monitoring and compliance assessment at Bald Hills.

Council Acknowledges Nuisance

In March 2019 the South Gippsland Shire Council found that the Bald Hills Wind Farm had caused nuisance to some of its neighbours.



South Gippsland Shire Council

Bald Hills Wind Farm Decision: Nuisance Finding

In the confidential section of its Meeting, Council found that the Bald Hills Wind Farm had caused nuisance to some of its neighbours.

The resolution – in part – reads as follows:

Council is satisfied that there exists a nuisance of the kind alleged by the complainants, for the following reasons:

A. *The credible and consistent character of the noise logs provided by the complainants and/or the complaints made by the complainants about sleep disturbance and the injury to their personal comfort;*
B. *The conclusions of the Smith Report; and*
C. *The weight of the other evidence presented to Councillors suggests the existence of a nuisance.*

But notes that the nuisance exists only intermittently.

Mayor of South Gippsland Shire, Cr Don Hill was pleased that Council had made a decision on the matter.

"Council has had to digest an enormous amount of material; specialist reports, legal advice, for example, over a long period of time and at all times Council has been aware of its responsibilities under the various Acts to come to a decision that is supported by the data. Council has considered this matter at length and did not come to its decision lightly," said the Mayor.

Council has written to the lawyers representing both the operator and the complainants, with approval to release the decision to the public once complete. It is hoped that the parties will be able to negotiate a mutually satisfactory resolution now that the finding has been made.

A report will come to a future Council Meeting recommending which of the documents pertaining to this decision should be made public.

PR2373 29/03/19

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Nuisance Noise

Many affected people do not know how to best describe the noise that they hear. Noise assessment for individuals is often confused with global noise exposure measures applied to communities. Individuals respond differently to noise depending on the "level" of the noise, its character, and the meaning or effect of the noise on the person.

For a sound to be annoying it must intrude upon an individual. For the purposes of NZS 6808 and 'special audible characteristics' only audible sound is considered and inaudible sound or vibration of the body ('sensation') is not pursued.

The assessment of "intrusive" noise, or "nuisance" noise, is subject to individual sensitivity to the noise in question (that is, why is the sound noise?).

Intrusive noise is a sound that, by its characteristics, is audible and intrudes upon the well-being or amenity of an individual.

In terms of noise, therefore, a person has cause for complaint about noise and is acting in a reasonable manner if he or she is:

- Awoken or suffering from disturbed sleep due to noise;
- Disturbed by noise while relaxing within his or her home; or
- Annoyed by noise inside or outside the home.

The above information is contained in the personal diaries retained by participants and shows regular, on-going disturbance over the term of the monitoring program. The personal observations are an essential part of this report.

Bald Hills Wind Farm Noise Monitoring and Assessment

Monitoring of sound levels at homes took place over May 2018 to March 2019. Sound levels were recorded inside and outside the primary measurement location, inside and outside at two homes, and outside only at two homes. The sound level data is recorded with weather data, power generation data and diaries of personal perceptions of sounds from the wind farm.

Relevant Approval Conditions for the Bald Hills Wind Farm are recorded in this report. Condition 19 relates to noise management and compliance. The approval condition applies New Zealand standard 6808:1998 'Acoustics-The Assessment and Measurement of Sound from Wind Turbine Generators'. Condition 22 applies where Condition 19 is found to have been breached, and applies noise mitigation measures including removal of turbines.

The general format of the monitoring and assessment program is illustrated in Figure 1.

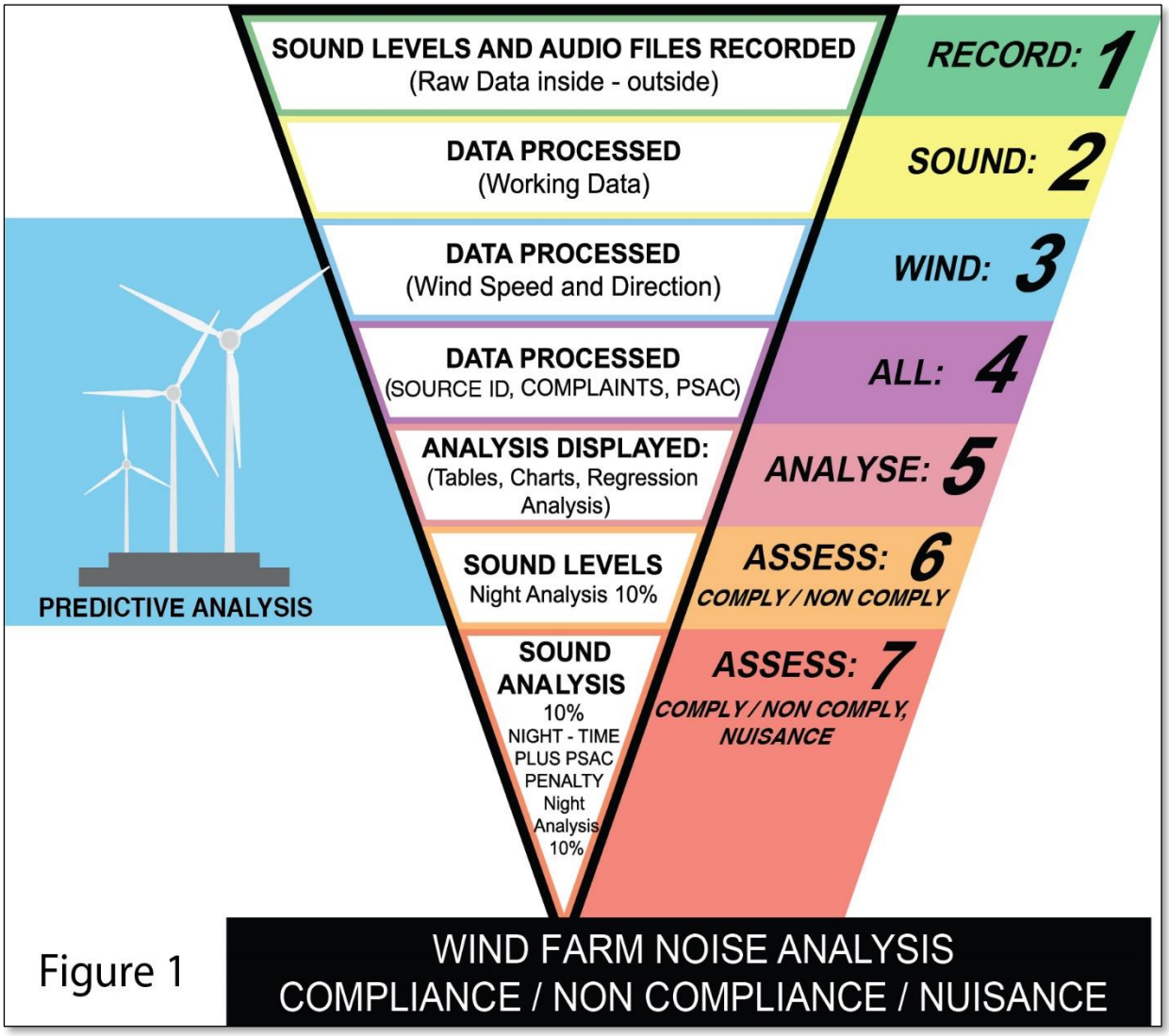


Figure 1

This noise impact assessment report presents summaries of important data and analyses, as well as explanations needed:

- A brief overview of the monitoring program concept;
- A noise map of the affected residences to provide a baseline for comparison with predicted and actual wind farm noise levels;
- A 'key information' summary showing LA95 sound levels exceeding 40 dB(A) vs noise complaints (PSAC) vs daily sound levels vs power generation;
- A summary showing LA95 sound levels exceeding 40 dB(A) PTR vs daily sound levels vs power generation;
- A summary presenting sound character by LAeq and Lden, and third octave bands;
- A summary presenting regression curves, sound levels vs time of day vs wind speed and noise assessment charts for 10% night-time and noise affected by 'special audible characteristics' or nuisance noise.

The daily sound levels are detailed in the respective monthly reports and spreadsheet analysis documents for May 2018 to March 2019.

The Appendices contain the methodologies and explanations applied in this monitoring and assessment program.

VIEW THIS VIDEO BEFORE READING THE REPORT

https://youtu.be/_-iLQBmcu1c

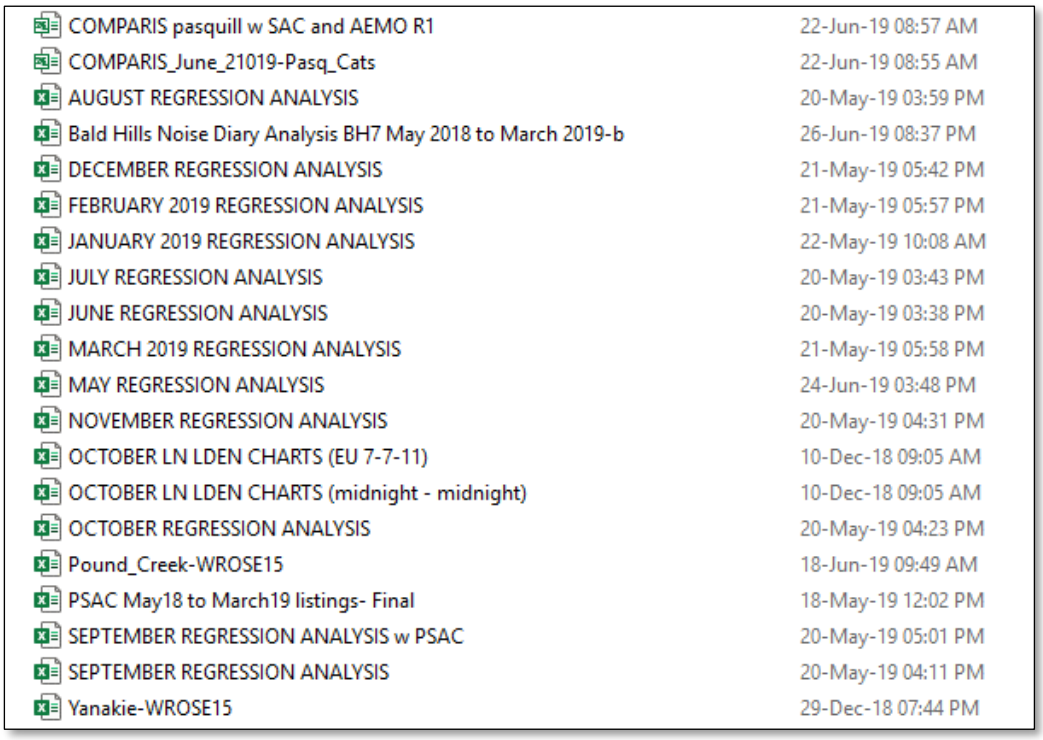
Use good quality headphones or sound system to listen to this video.

Audiofiles:

The audio recordings taken at each home are available to each person for their own home. Audio recordings are not released to any other person. The recordings are not released by NMS to any other party.

Spreadsheets:

The spreadsheets prepared for each home are:



The reports and spreadsheets are available to all persons involved in the monitoring program. The data is not released by NMS to any other party.

NMS ASSESSMENT OF COMPLIANCE (SUMMARY)

The interactions between the approval conditions and NZS6808 are complex. There are the implied averaged levels of condition 19(a) and the regression curves of NZS6808; the implied single sound levels of condition 19(c); and the penalty application to single sound levels in condition 19(b); plus, all the implied variations due to wind speed and direction. 'Single' meaning a single 10-minute set of sound levels.

A noise impact assessment that does not address wind farm noise complaints – special audible characteristics and night-time noise levels is itself non-compliant and of no merit.

The initial test for non-compliance is whether the overall sound levels are above the noise thresholds.

- Sound levels, at any relevant nominated wind speed, should not exceed the background level (LA95) by more than 5dBA or 40dBA, whichever is the greater.

The analysis charts in this Report show a substantial number of occasions where sound levels are "non-compliant".

- The "non-compliant" sound levels are then tested for "Night-time 10% Loudest". This is the 'breach' test under Condition 19(c) of the approval conditions.
- Assessment is not made for daytime exceedance as daytime sound levels were recorded by different residents as being 'audible', rather than as 'annoying'.
- The sound levels are processed for special audible characteristics as recorded by personal diaries. The SAC tests are applied to both the overall levels and the "Night-time 10% Loudest".
- Separate analysis is made for those nights recorded by residents as having intrusive noise that disturbed sleep. Special audible characteristics are present on many nights, as reported in this Report. Consequently, the 5dBA penalty for condition 19(b) applies to these reported sound levels.

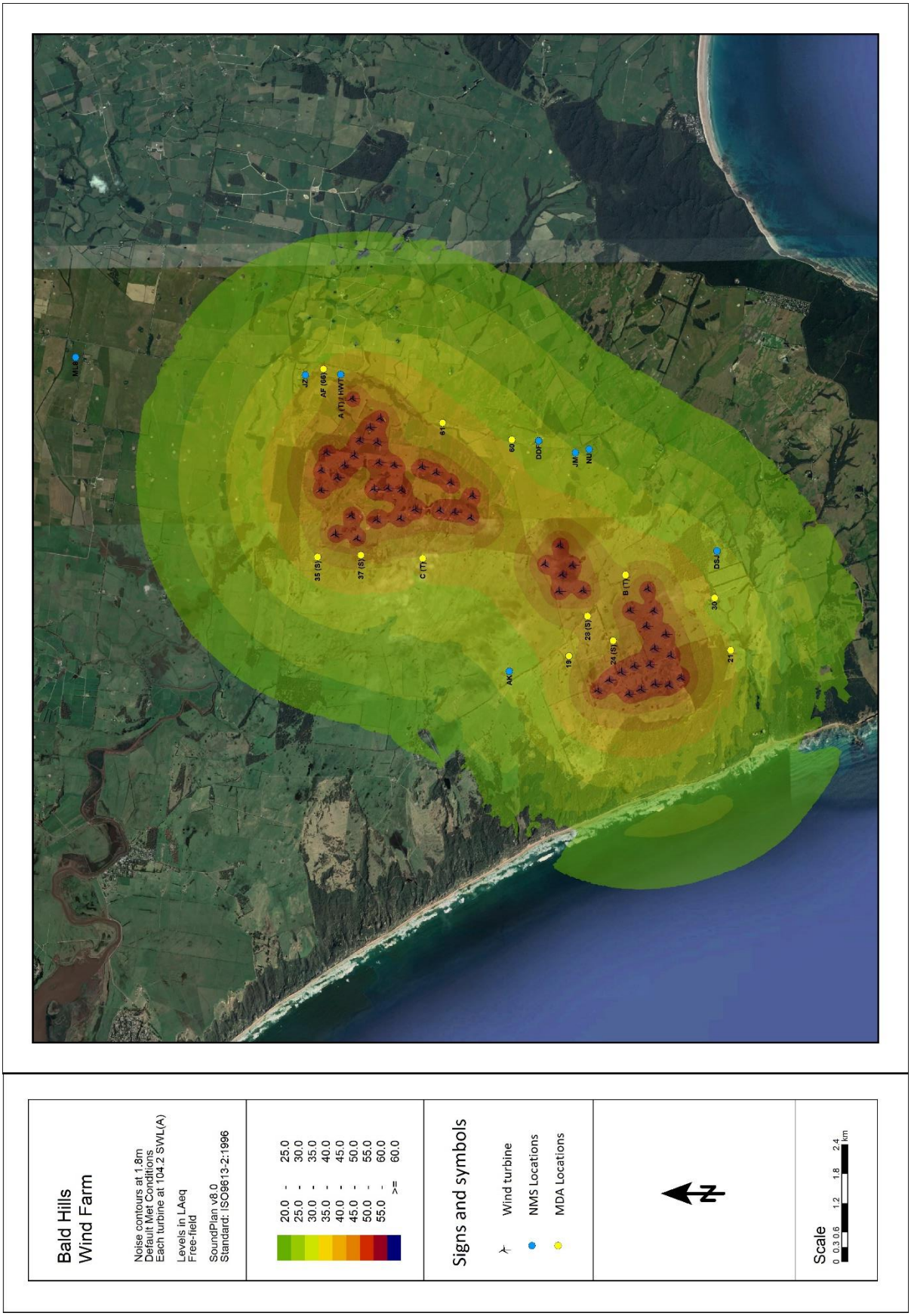
Our noise impact assessment considers all the variations outlined above. The monitoring analyses are contained in the Regression Analysis Spreadsheets for May 2018 to March 2019. The analysis settings are illustrated in Table 1, page 127. The settings are extensive and allow comparison of many different scenarios.

Our analysis confirms that the wind farm is in non-compliance if sound levels are above the derived noise limits (solid black lines on the following charts pages 127 to 150) and above the derived regression curves (red dots on the charts).

BALD HILLS NOISE MONITORING

NOISE MAP OF AFFECTED RESIDENCES

BALD HILLS WIND FARM ISO 9613-2 NOISE MAP



INTRODUCTION – NOISE MAP
HOW TO READ THIS SECTION

A common method of assessing the potential for noise from wind farms is noise impact prediction with a method termed "ISO 9613-2". NMS has prepared a "standard" noise map showing the predicted sound levels from the wind farm (previous page). The map shows isobars or noise contours and these illustrate the potential variability of sound levels predicted in this way. ISO 9613-2 predicted sound levels have a calculation estimation accuracy (uncertainty) of ±3 dB under default (nominal mild downwind or inversion) conditions. The calculations should not necessarily be expected to agree with the variation in measurements made at a given site on a given day; that is, noise levels will vary day by day, hour by hour, depending on weather conditions.

Conversely, noise impact assessment reports may present single-figure predicted noise levels, Table 1. During our discussions (NMS and Residents) it became apparent that noise impact prediction reports may give the impression that the predictions are the maximum levels of noise that will be experienced. This is not true. Predictions are based on assumptions. Assumptions generate variations. The sound levels recorded in this report during the monitoring program show considerable variability. Secondly, noise is a human perception, not something solely related to maximum sound levels. The charts in this report present evidence of large variations in sound levels and characteristics that help explain the perception of "special audible characteristics" in NZS6808:1998.

Table 1: Bald Hills Wind Farm – Predicted sound levels (LAeq) under 'Full' and 'Curtailment' measures

Receptor	Description	Height (metres)	All turbines operating at 104.2 SWL	All turbines but 4, 40, 46, 47 in curtailment mode	All turbines but 4, 40, 46, 47 "removed"	Closest turbine to receptor (number)	Closest turbine to receptor (distance metres)
ML1	JZ	1.8	34.6	34.6	34.5	16	1130
ML2	DDF	1.8	31.6	31.3	31.2	10	1800
ML3	NU	1.8	29.3	28.9	28.7	42	2070
ML4	DSJ	1.8	31.3	30.4	29.9	47	1660
ML5	AK	1.8	31.8	31.5	31.3	33/41	2060
ML6	McD	1.8	30.2	29.9	29.7	42	1820
ML7	HWT	10.0	n/a	n/a	n/a	16	720

Approval condition 22 requires noise mitigation measures should breaches of Condition 19 occur. One measure is to reduce the noise from a particular turbine or turbines.

> *Condition 22*
> *Where condition 19 is found to have been breached, the Minister for Planning shall notify the wind energy facility operator, with a request that steps be taken to ascertain the relevant meteorological circumstances at the time of the breach and to noise optimize the operation of the relevant turbines or turbines in such circumstances. If there is a further breach in similar circumstances, the Minister for Planning shall notify the wind energy facility operator, with a request to noise selectively shut down the operation of the relevant turbine or turbines in those circumstances. In circumstances where optimization or selective shutdown routines have been requested but not reasonably implemented, or have been implemented but have not prevented further instances of recorded breach, the relevant turbine or turbines will be required to be decommissioned and removed.*

Curtailment mode in Table 1 is when selected turbines theoretically operate under 'noise optimization'; that is, with a lower sound emission. This approach is shown to be ineffective.

BALD HILLS NOISE MONITORING SUMMARY OF KEY INFORMATION

OVER 40 dBA (PTR) vs NOISE COMPLAINTS (PSAC) vs SOUND LEVELS vs POWER GENERATION

INTRODUCTION – SUMMARY OF KEY INFORMATION

HOW TO READ THIS SECTION

THE INFORMATION AND CHART IN THIS SECTION ARE THE KEYS TO UNDERSTANDING COMPLIANCE / NON-COMPLIANCE / NUISANCE ISSUES FOR THE WIND FARM

What is presented, in a glance:

- Background sound levels (LA95) on a day-by-day basis for each residence monitored;
- A trace showing the operation of the windfarm generating power (SCADA value);
- The 40 dB(A) noise limit is exceeded on the days coloured 'peach'/'transparent red' (called PTR in the rest of this report);
- The PTR coded times are nearly always when the turbines are running at above 75% or full generation;
- The PTR coded times nearly always occur when the wind at ML1 is less than 3m/s;
- Noise complaints (PSAC) from noise affected persons – shown as coloured dots for the day that annoyance or nuisance conditions from personal diaries;
- Potential nuisance conditions can be identified from full or near full power generation and sudden rises/decreases in power generation (SCADA value).

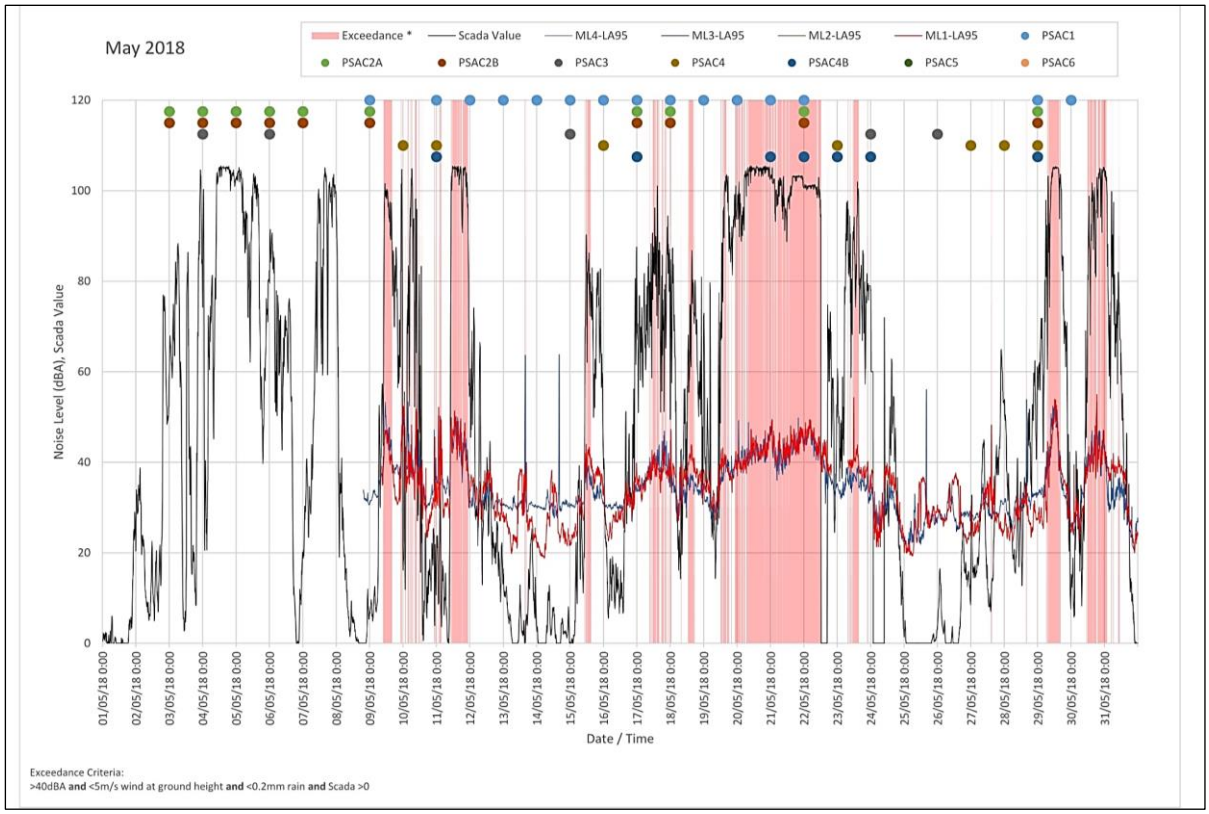
Process:

- Check that the that the turbines are running! This is the black SCADA value line on the chart.
- Check the weather conditions at the residence – wind nominally below 3 m/s (upper range 5 m/s) and no rain.
- Check PTR coded 10-minute blocks.
- The background LA95 levels for the three monitoring locations are recorded on the chart.
- 'No activity' background sound levels can be obtained when the turbines are not running.
- Take a background LA95 sound level of 40 dB(A) in any 10-minute block as being the 'exceedance' assessment starting point.
- These objective tests supplement subjective (complaint) responses to wind farm activity.
- Only those days that have the turbines operational and having a PSAC tag (coloured dot) for night-time are considered as being "possibly non-compliant".
- If special audible characteristics are present (e.g. audible modulation, tones, rumble) a 5 dB penalty is warranted
- The datafiles and audio files can be further assessed to nuisance complaint histories.

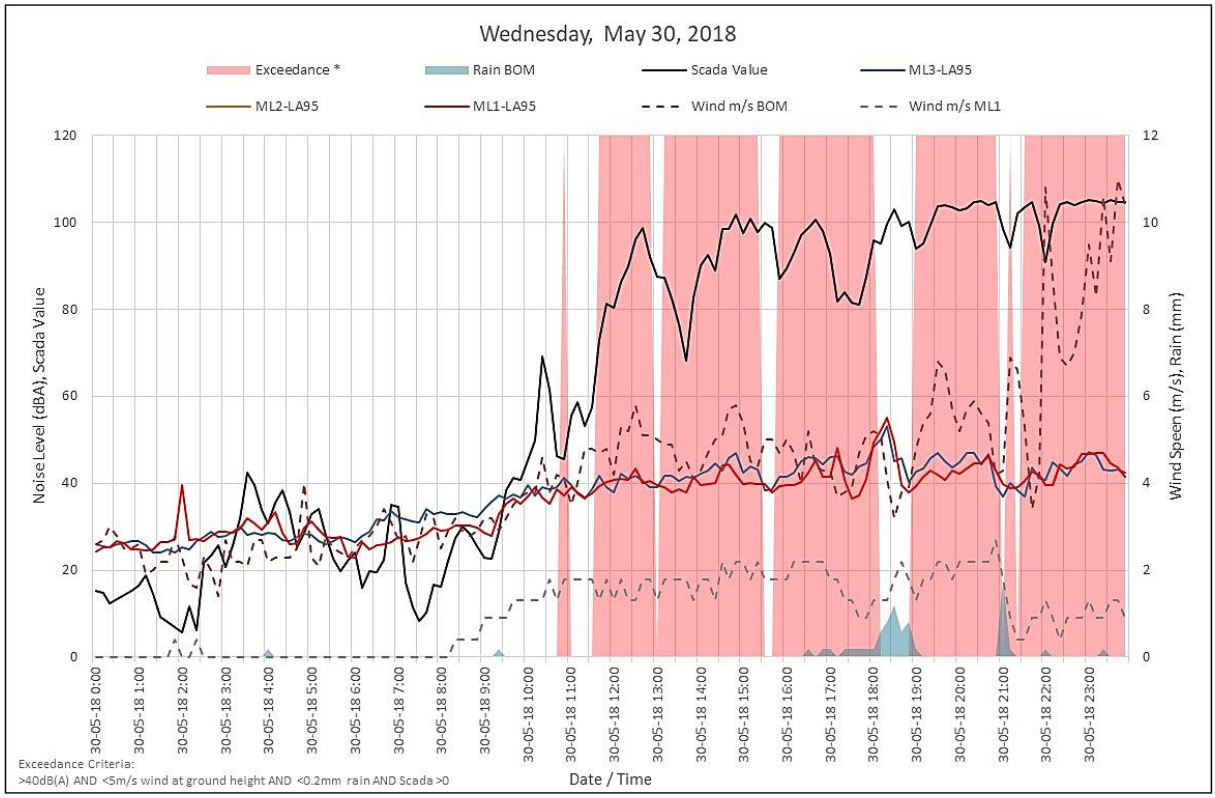
Caution:

- On a few days the PTR coding shows that exceedances have occurred when the background sound levels are high yet the wind farm power generation is not high.
- Compliance / Non-compliance / Potential nuisance assessments are made on the basis of the detailed daily sound levels, wind farm activity, wind /weather conditions and diary entries.

Example 1: Over 40 dB(A) noise limit (PTR colour bands) vs Noise complaints (PSAC) vs Sound Levels (LA95) vs Power Generation (SCADA values)



Example 2: The following chart presents the day-by-day Over 40 dB(A) noise exceedance (PTR) vs Sound Levels (LA95) vs Power Generation (SCADA values) vs wind speed at ground level (ML1) and 10 metres above ground (BOM Pound Creek) vs rain-days (BOM Pound Creek).



Diary entries for personal Perception of Special Audible Characteristics (PSAC) notation

Residents maintained observation diaries over the period May 2018 to March 2019. The "affected days" that form the basis for the following charts are illustrated in the September listing, following. The listings are prepared from the diary notes compiled for each month from May 2018 to March 2019 and diarists are identified as PSAC1 to PSAC6. The observations are recorded on the PTR – PSAC chart presented on the previous page.

How 'YES' is determined:

- the sounds must have caused the adverse effects noted in the diaries
- the sound of the turbines had to be clearly audible inside the home
- the sound had to be intrusive, annoying and/or disturbing sleep
- some people had problems with pressure sensations rather than audible sound

Example 3: Complaint recording by personal diary (PSAC)

MAY	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1								
2								
3		YES	YES					
4		YES	YES	YES				
5		YES	YES					
6		YES	YES	YES				
7		YES	YES					
8								
9	YES	YES	YES					
10	YES				YES			
11	YES				YES	YES		
12								
13								
14								
15	YES			YES				
16	YES				YES			
17	YES	YES	YES		YES	YES		
18	YES	YES	YES		YES			
19	YES							
20	YES							
21	YES					YES		
22	YES	YES	YES			YES		
23					YES	YES		
24				YES		YES		
25								
26				YES				
27					YES			
28					YES			
29	YES	YES	YES		YES	YES		
30	YES							
31								
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

The 'noise complaint' diary entries for the individual persons (PSAC1 to PSAC6) are encoded as coloured dots on the relevant day on the daily charts, Example 1. Noise complaints are usually for night-time, 10pm to 7am. (The detail of the complaints are recorded day-by-day by NMS on an analysis spreadsheet.)

BALD HILLS NOISE MONITORING

SOUND LEVELS vs POWER GENERATION vs 'PTR' EXCCEDANCES

INTRODUCTION – PTR EXCEEDANCES

HOW TO READ THIS SECTION

What is presented:

- Background sound levels vs wind power generation for May (summary for the month and daily detail);
  - L95 background sound levels for each residence (i.e. ML1 to ML5, ML6);
  - Bald Hills power generation shown as the SCADA value (black trace);
  - Wind and rain data from the Pound Creek BOM station and ML1;
- The 40 dB(A) noise limit is exceeded on the days coloured 'peach'/'transparent red' (called PTR in the rest of this report);
- The PTR coded times are nearly always when the turbines are running at above 75% or full generation;
- The PTR coded times nearly always occur when the wind at ML1 is less than 3m/s;
- Potential nuisance conditions can be identified from full or near full power generation and sudden rises/decreases in power generation.

Process:

- Check that the that the turbines are running! This is the black SCADA value line on the chart.
- Check the weather conditions at the residence – wind nominally below 3 m/s (upper range 5 m/s) and no rain.
- Check PTR coded 10-minute blocks.
- The background LA95 levels for the three monitoring locations are recorded on the daily charts.
- 'No activity' background sound levels can be obtained when the turbines are not running.
- Take a background LA95 sound level of 40 dB(A) in any 10-minute block as being the 'exceedance' assessment starting point.
- If the night-time background sounds are dominated by wind turbine noise (e.g. turbine 'signature tones', audible shifts in sound level-'modulation', 'rumble') check data for 10% exceedance.
- As the background sound levels are over 40 dB(A) there is a probability that wind farm noise dominates and consequently potential non-compliance. If special audible characteristics are present (e.g. audible modulation, tones, rumble) a 5 dB penalty is warranted.
- Check night-time sound levels – if PTR coded 10-minute blocks occur more than 6 times over night then the wind farm may be in non-compliance.
- These objective tests supplement subjective (complaint) responses to wind farm activity as recorded in personal diaries.
- The datafiles and audio files can be further assessed to nuisance complaint histories.

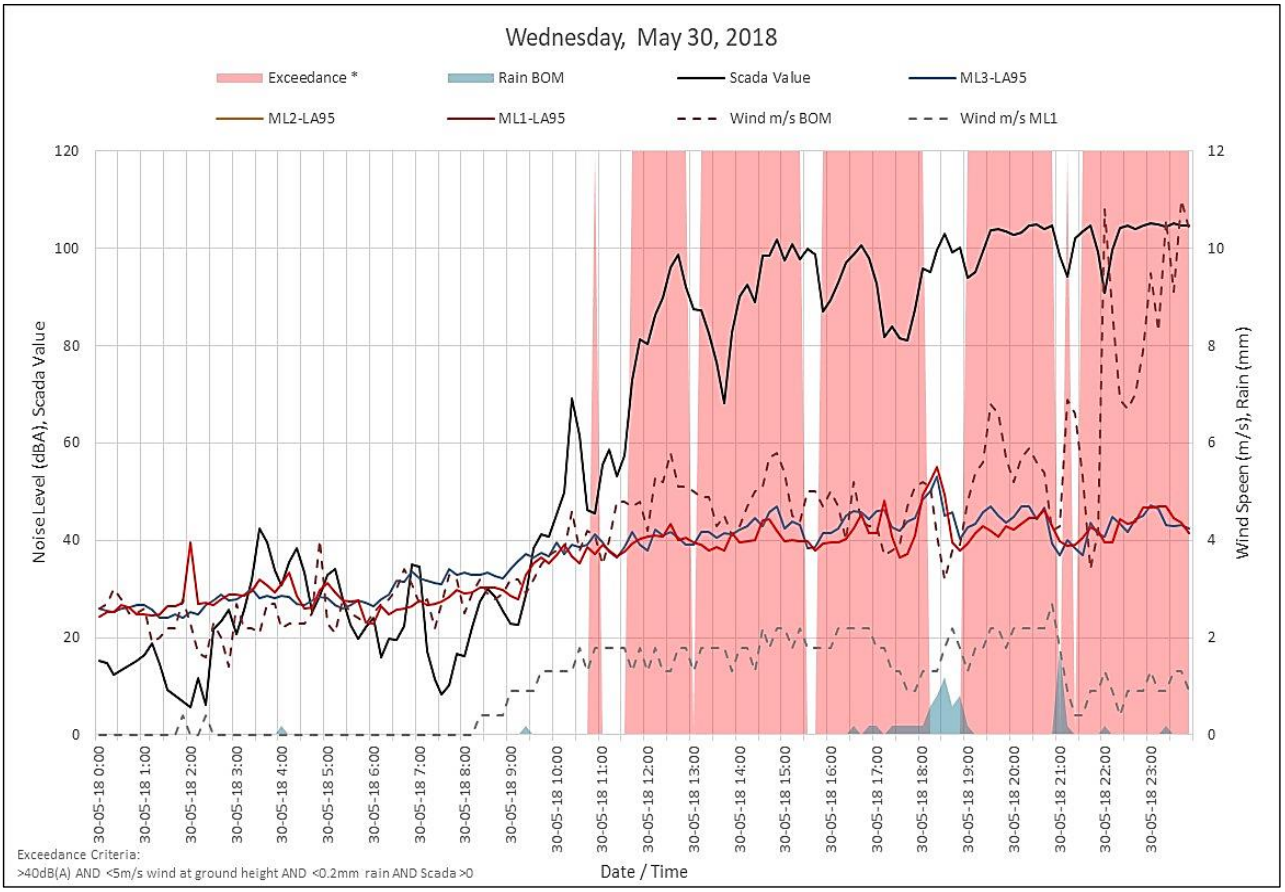
Caution:

- The PTR coding can show that exceedances have occurred when the background sound levels are high yet the wind farm power generation is not high.
- Compliance / Non-compliance / Potential nuisance assessments are made on the basis of the detailed daily sound levels, wind farm activity, wind /weather conditions and diary entries.

Examples:

- 20 May as an example of near-full, consistent power generation over a 24-hour period;
- 25 May as an example of near nil power generation over a 24-hour period;
- 31 May is an example of "choppy" power generation over the night-time midnight to 7am period.
- On the 20th – 21st noise from the windfarm is tagged by residents as containing special audible characteristics and being annoying. These dates can be investigated further for compliance / non-compliance / potential nuisance. The night-time (10pm to 7am) sound levels are investigated rather than daytime as the approval conditions have specific assessment requirements for night-time noise.
- On the 25th noise in the environment is due to local sources. This provides a 'no turbine noise' baseline of 20-30 dB LA95 and 30-40LAeq with excursions to 50 dB(A).
- On the 31st power generation is "choppy"; wind noise between midnight and 7am could be a significant source of noise but there are characteristics (see the relevant 'sound character' in the next section). The midnight to 7am third octave bands have two bands of audible tones around 80Hz and 150 Hz that suggest wind turbine activity. These time periods can be evaluated further by listening to the audio files and analysis for 'special audible characteristics'.
- However, the 31st is not logged by any resident as being a day or night when farm noise is an issue. Consequently, no further analysis is required and this date is **not** tagged as being potentially non-compliant.

Example: The following chart presents the day-by-day Over 40 dB(A) noise exceedance (PTR) vs Sound Levels (LA95) vs Power Generation (SCADA values) vs wind speed at ground level (ML1) and 10 metres above ground (BOM Pound Creek) vs rain-days (BOM Pound Creek).



BALD HILLS NOISE MONITORING

SOUND CHARACTER

INTRODUCTION – SOUND CHARACTER

HOW TO READ THIS SECTION

Decision Process:

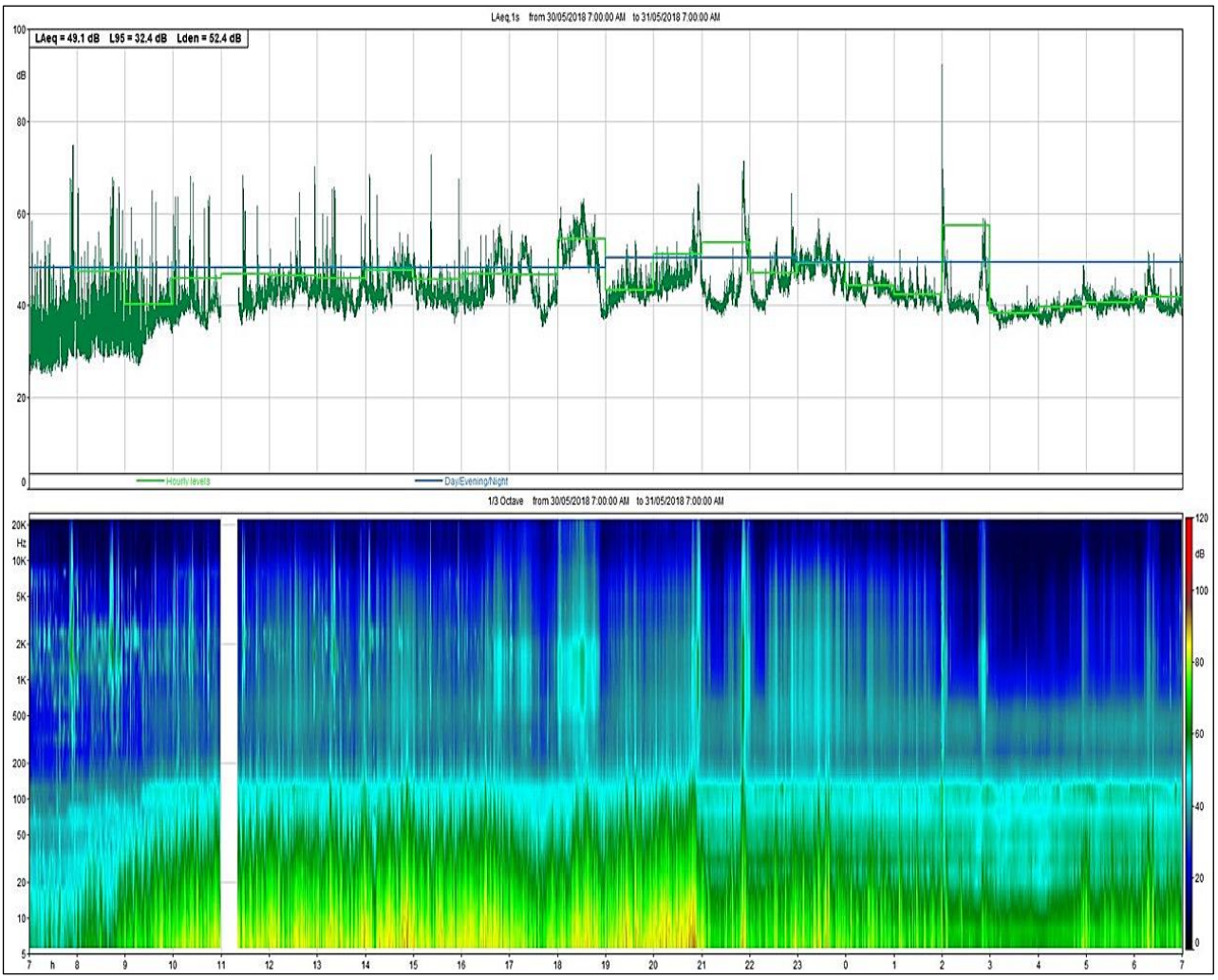
The charts present three sets of information for all sound levels, near and far, not just sound from the wind farm. The sound levels are recorded in 'Noise Tutor' from the outdoor Larson Davis 831 sound level meter at residence ML1.

- The one-second LAeq sound levels for the period 7am one day to 7am the next day (that is, the whole period SEPP-N1 terms as "night") in the upper chart;
- The one-hour LAeq sound levels and the day-evening-night Lden sound levels displayed as straight lines in the upper chart;
- The third octave band LAeq 1-second sound levels for the period 7am one day to 7am the next day in the lower chart.

Process:

- Check that the that the turbines are running! (see the Scada values for each day as presented in previous charts in this report).
- The bright green – yellow bands of colour at the base of the lower chart indicates times of heightened wind noise.
- The chart is for the full 24-hours. Individual 10-minute A-weighted and Z-weighted sound levels are produced by the 831 sound level meter. The charts can be compared to the 831 one-third octave.
- Straight lines within the charts (e.g. in the 50-60Hz and 100Hz-150Hz bands) indicates wind turbine activity, as a rural environment populated by animals and grass does not produce (industrial) constant frequency bands of sound.
- These objective tests supplement subjective (complaint) responses to wind farm activity.
- The datafiles and audio files can be further evaluated to nuisance complaint histories.

Example: Summary of ambient data from Bald Hills ML1 (LD831 2879) from Larson Davis 831 Noise Tutor showing LAeq (1-sec), Lden data (upper chart) and LAeq (1-sec) third octave band data for the time period 7am one day to 7am the next.



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BALD HILLS MONITORING

REGRESSION CURVES

SOUND LEVELS

vs TIME OF DAY

vs 10% NIGHT-TIME

vs WIND SPEED

vs SAC PENALTY

INTRODUCTION – REGRESSION CURVES

HOW TO READ THIS SECTION

This section records the sound levels and the regression curves required for compliance analysis under NZS6808. Sound levels were recorded from 10 May 2018.

Clause 5.4 Compliance assessment of NZS6808:1998 states:

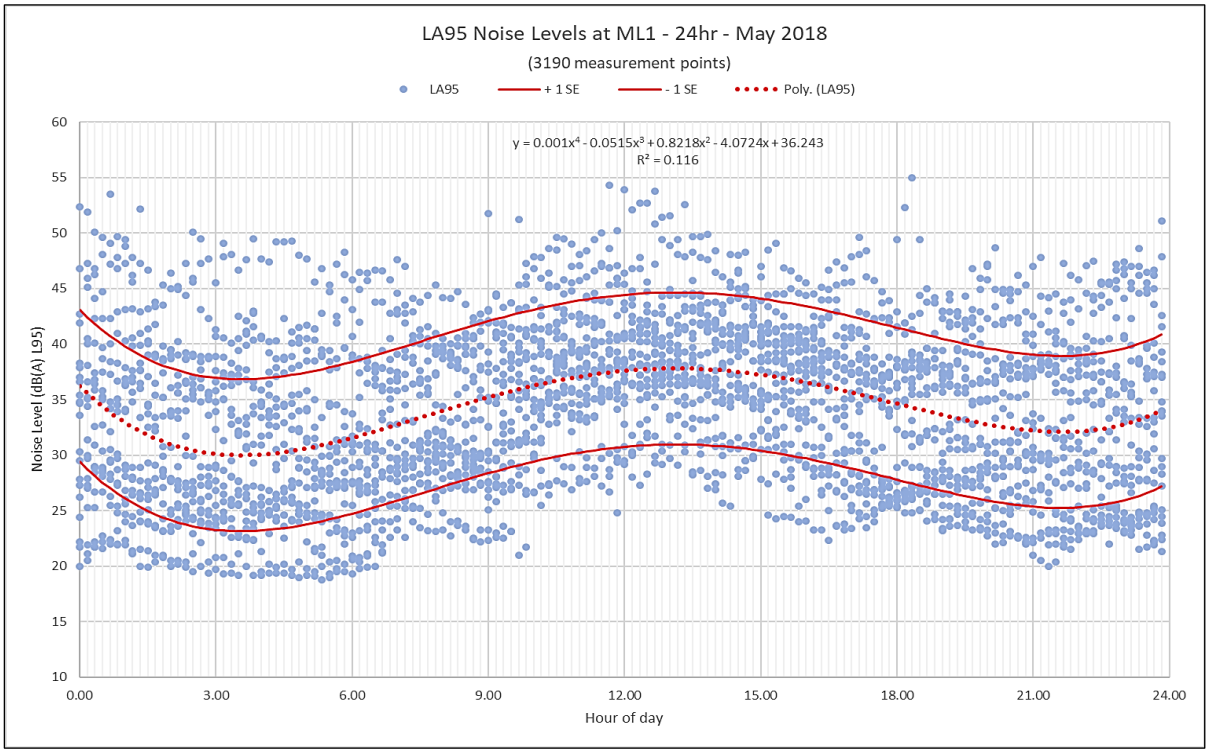
> *To determine conformance with the limits set out in 4.4.2, a comparison shall be made between the best fit regression line of the background sound levels and the regression curve of the operational windfarm corrected for any special audible characteristics. If the background levels were not measured prior to installation (4.5.1), it may be necessary to obtain background sound level measurements for limited periods at critical windspeeds to satisfy 4.4.2 (e.g. if wind turbine or windfarm sound levels exceed 40 dBA L_{95}). This may be for a limited range of windspeeds and directions, with the WTG(s) non- operational.*

Decision Process:

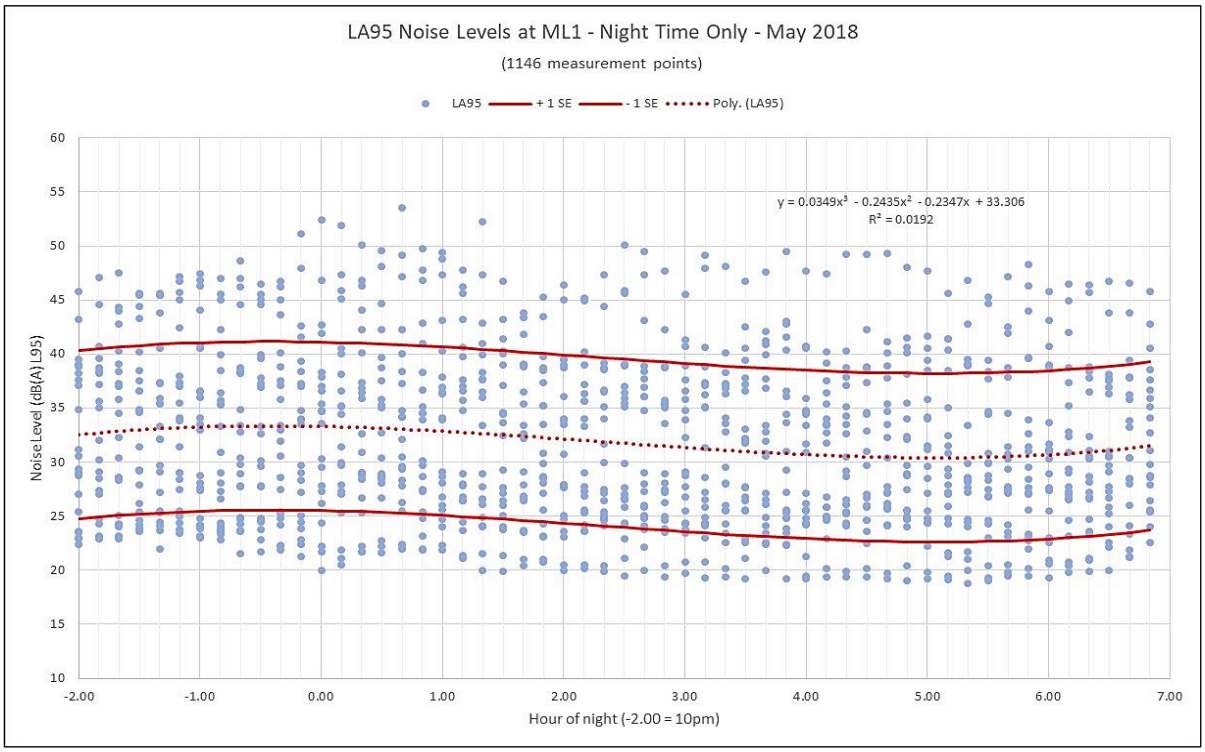
- The outdoor sound level meters record the background (LA95) sound levels every 10 minutes. This is 144 samples every 24 hours.
- The sound levels (shown as blue dots in all the following charts) for each monitoring location are presented for day/night and nighttime only. As can be seen, there is considerable variability over each hour and over the whole day or night period.
- It is common practice to "simplify" this mass of values by calculating an "average" through the process of 'regression analysis. This creates a curve, the red dotted line in the following two charts, with a confidence interval calculated to include 68% of the sound levels – the solid lines above and below the dotted line.
- The regression line is an average. It is not the real level of sound heard by a person and has little relevance to the assessment of nuisance at a specific point in time. It is, however, the concept applied by NZS6808 to assess compliance. To this must be included the 5dB penalty for special audible characteristics.
- The third and fourth charts in this series present the regression curve concept applied by NZS6808 to assess compliance. In these charts we are concerned only with nighttime data as this is the time when noise complaints are recorded.
- The fifth and sixth charts in this series present the regression curve concept applied by NZS6808 to assess compliance. In these charts we are concerned only with the 10% loudest nighttime data as this is the time when noise complaints are recorded and is a specific breach under the approval conditions.
- ➢ The charts are referenced to wind speeds at a height of 10 metres and 80 metres. The solid black line in each chart is the noise limit for the location and 10 metre wind speed as applied by a pre-construction (2012) report by Marshall Day Acoustics.
- ➢ The 80 metre wind data is calculated from the 10 metre BOM data. The purpose is to provide a comparison between noise levels at ground level (10m) and the rated wind speeds the turbines at hub height (80m). The noise limit 'line' may be slightly different for an 80m height wind. The sound levels for the 80m height 'shift-right' compared to the 10m height.

- The MDA background levels and limits are at 10m so our assessment is also at 10m to compare 'like-with-like'.
- Blue dots above the solid black line indicate non-compliance.

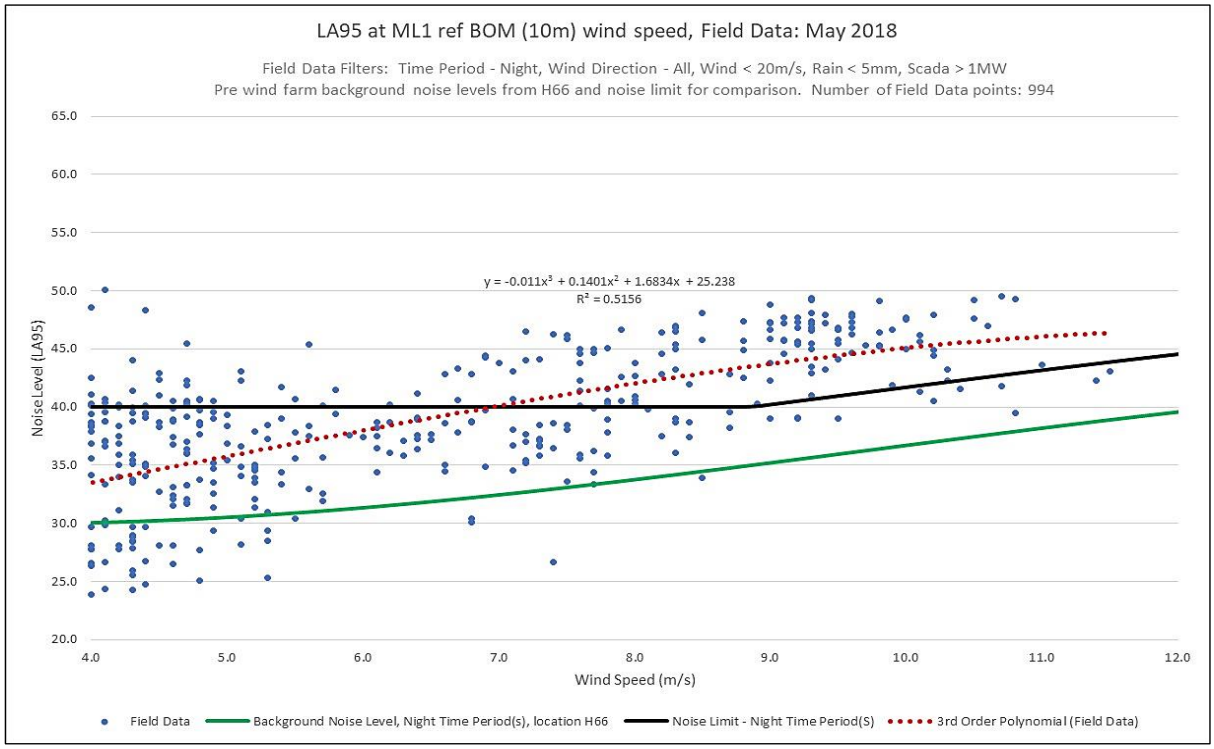
Example: ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



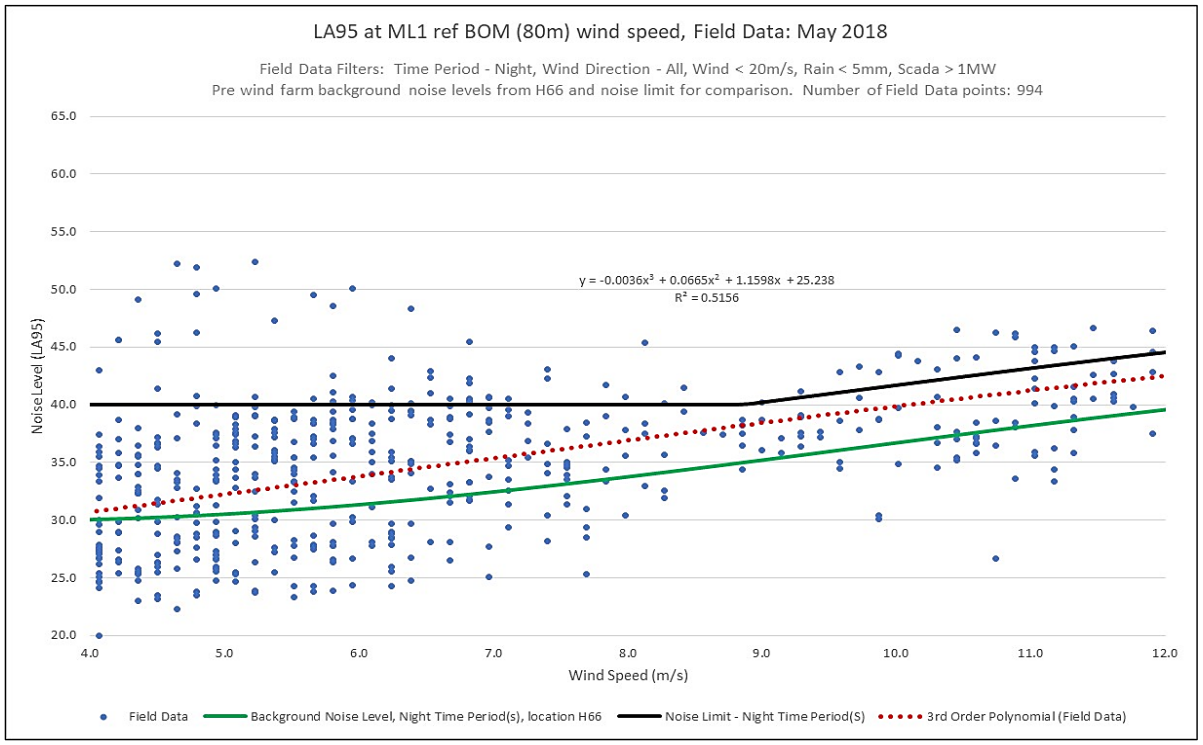
Example: ML1 - The variation in night-time sound levels for the month by time of night



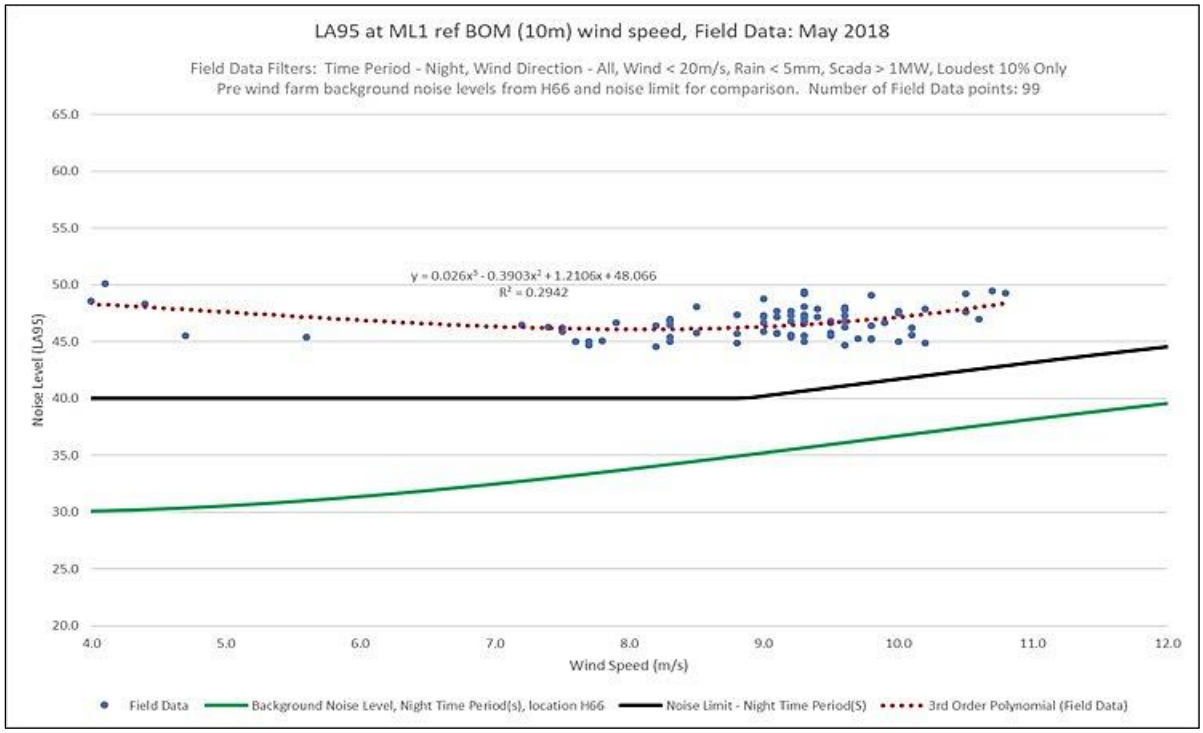
Example: ML1 - Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds



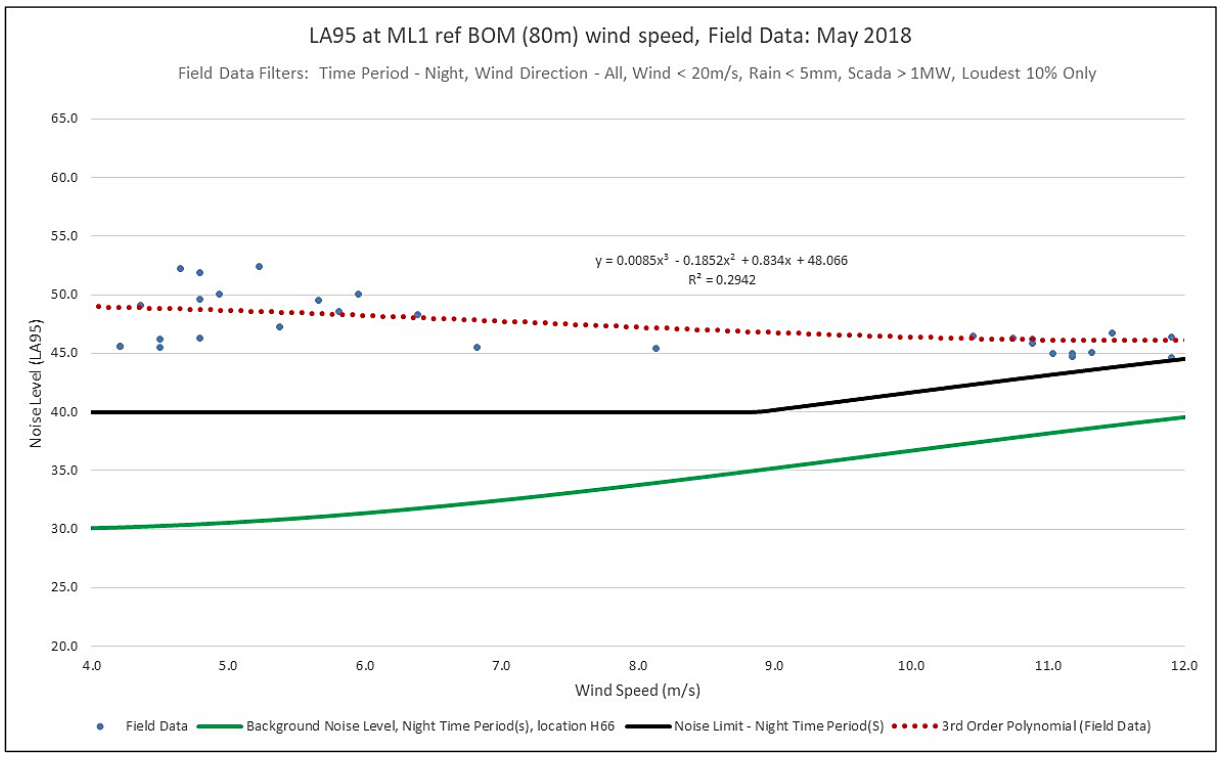
Example: ML1 - Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds



Example: ML1 - Regression curve of night-time 10% loudest sound levels v. noise limits for the month ref. 10m wind speeds



Example: ML1 - Regression curve of night-time 10% loudest sound levels v. noise limits for the month ref. 80m wind speeds



Sound character – Penalty for Perceived Special Audible Characteristics

The following charts for June, July and September are presented as examples of the assessment of recorded sound levels, vs wind speed, vs Perceived Special Audible Characteristics (PSAC) over the critical time periods of 1am to 5am. A penalty of 5dB is added to the recorded sound levels. The examples cover the period investigated by Council and for the month after the August wind farm shut-down. The Pound Creek weather station is applied. The 10 metre data is applied as this is what is necessary for comparison with the MDA background sound level regression curves.

Example of the analysis method, September 2018.

There were 4320 by 10-minute blocks of time in September. The night-time period in September has 1620 separate 10-minute blocks of recorded sound levels at each monitoring location. Of these, 720 10-minute blocks are in the most commonly identified PSAC time period of 1am to 5am. In September, however, not all of these time-blocks were identified as having PSAC values. ML1 has 428, ML2 has 311, ML3 has 287 and ML4 has 525 values.

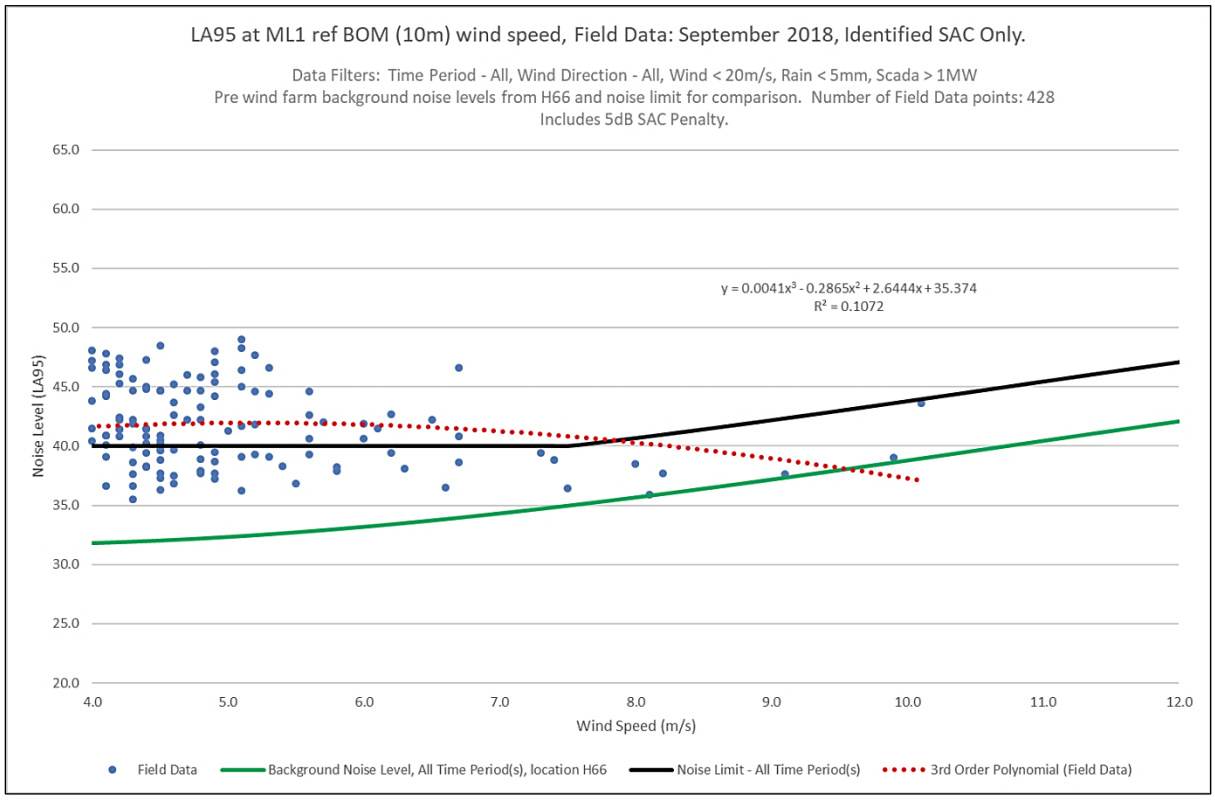
This is what makes the PSAC sound events “special”. The wind farm was generating power for most of the 4320 blocks of time in September, but only a percentage of that time is identified as having ‘perceived special audible characteristics’

The following charts for September are the 1am to 5am night-time sound levels and include the 5dB penalty for special audible characteristics.

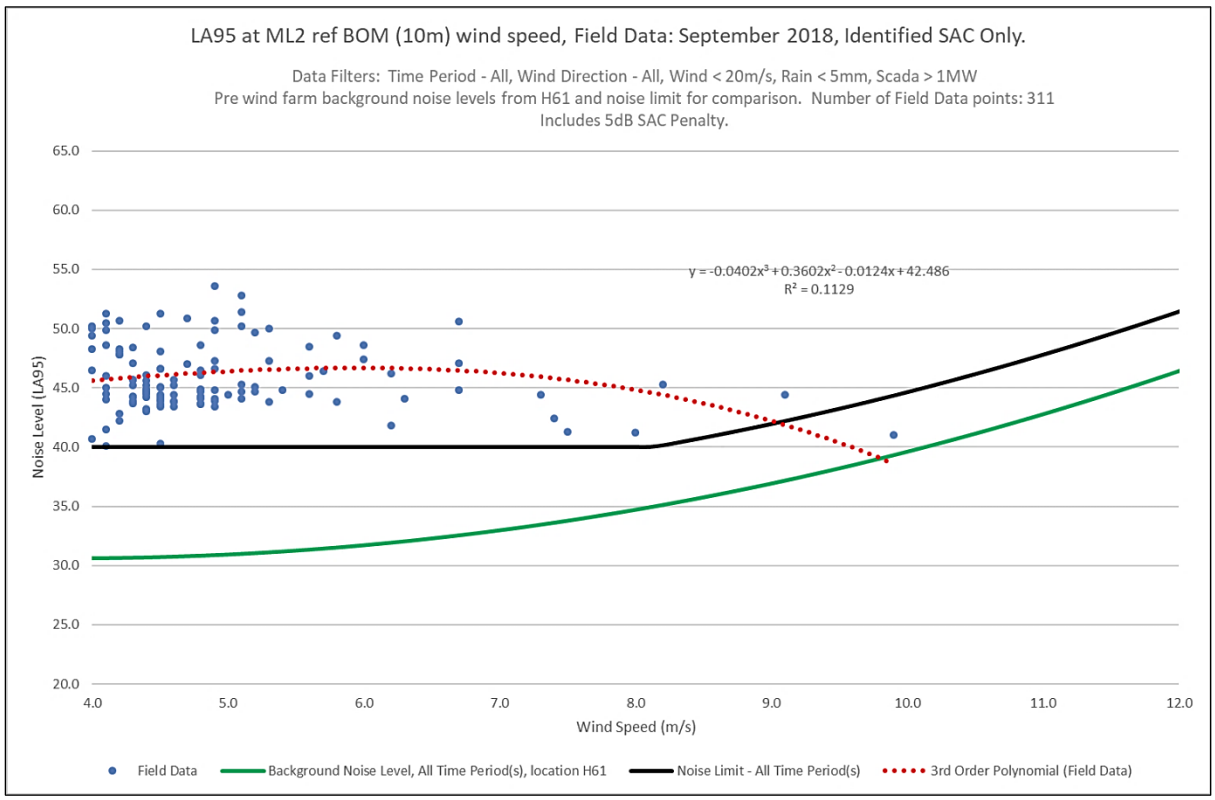
The addition of the 5dB penalty is a mandatory part of the compliance process under the approval conditions and the New Zealand standard. Application of the penalty shows consistent non-compliance for the months of June, July and September. The turbines were operational in late August.

A pattern of non-compliance is shown in all the PSAC datasets of the monitoring program and is recorded in the NMS analysis spreadsheets for May 2018 to March 2019.

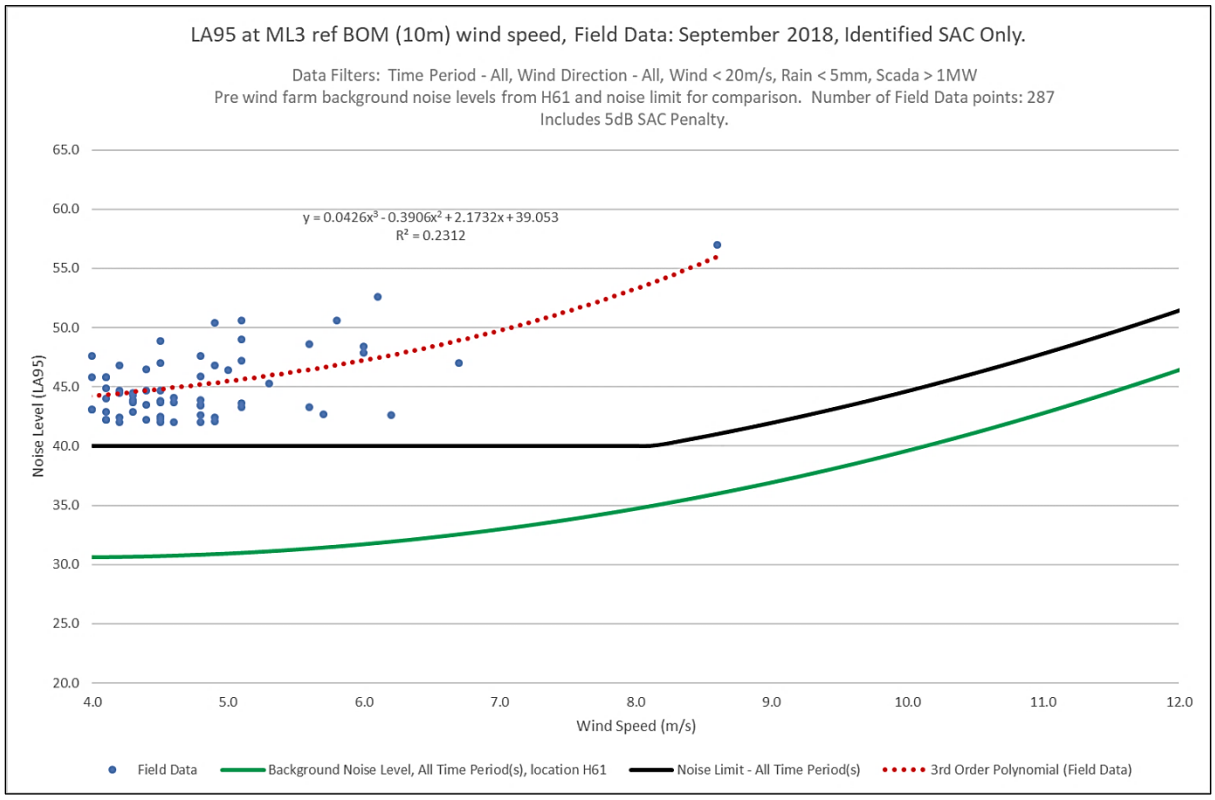
September 2018
ML1 Includes SAC 5dB penalty; 1am to 5am



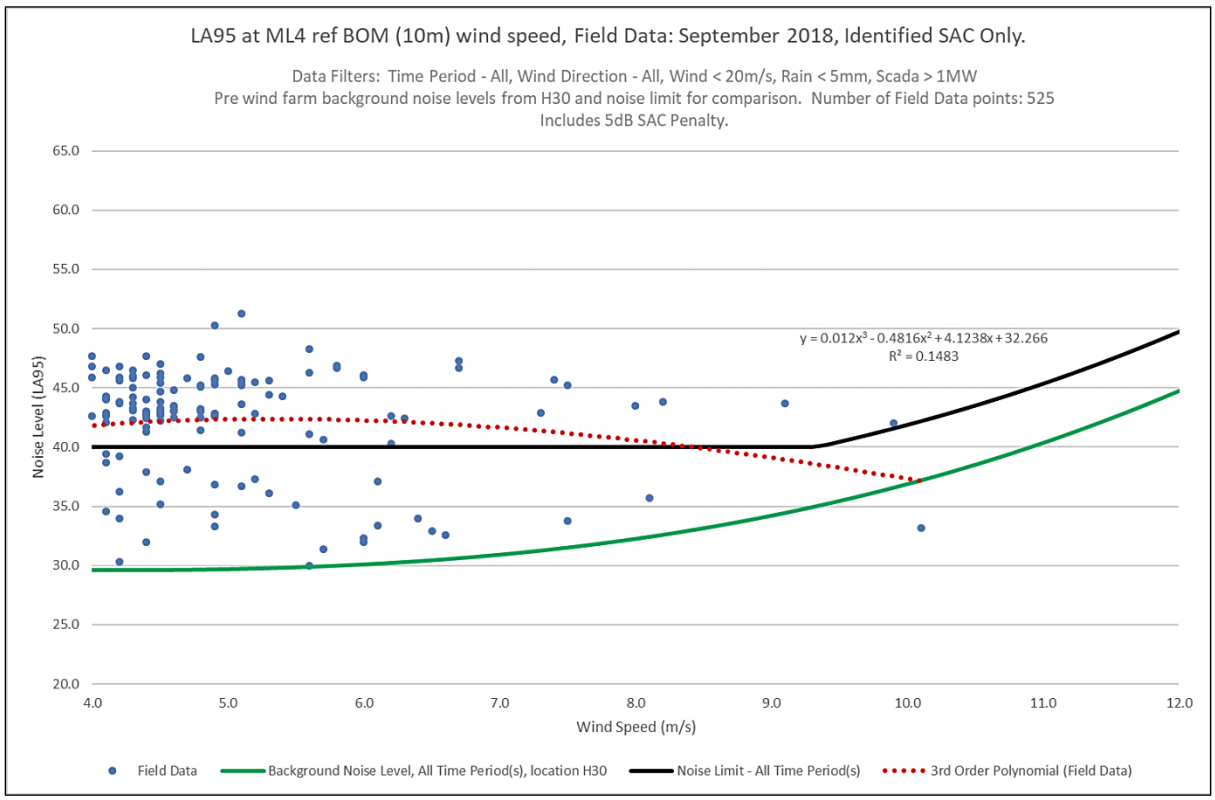
September 2018
ML2 Includes SAC 5dB penalty; 1am to 5am



September 2018
ML3 Includes SAC 5dB penalty; 1am to 5am



September 2018
ML4 Includes SAC 5dB penalty; 1am to 5am



BALD HILLS MONITORING

WIND FARM ACTIVITY

AEMO

POWER GENERATION

WIND FARM ACTIVITY – WIND FARM POWER GENERATION DATA

Analysis of the wind farm activity depends on knowing when the wind farm was producing power. NMS is not able to access the power output from individual turbines within the wind farm and, therefore, not able to use such data to confirm that the wind turbines are operational. There is, however, a very good substitute as power stations provide their generation data to the Australian Energy Market Operator (AEMO).

The advice and assistance of Mr Paul Miskelly in preparing the AEMO-derived datasets for the monitoring is acknowledged with appreciation. The wind farm power generation "5-minute" datasets for this Report are extracted from the AEMO data by Mr Paul Miskelly (*see also Aneroid https://anero.id/energy/wind-energy*). A full explanation is provided in Appendix I.

Figure 1 illustrates the power generation activity of the wind farm in May 2018. The purpose of this Chart is to identify the days and times of day that the wind farm was generating power and potential noise. It is evident that power generation is not constant, nor consistent, hour by hour or day-by-day. There are sudden increases and decreases in generation that cannot be predicted in or for a noise impact assessment. A pattern of higher or "increases" in the background levels vs higher power output is observed as being a regular pattern over May to November.

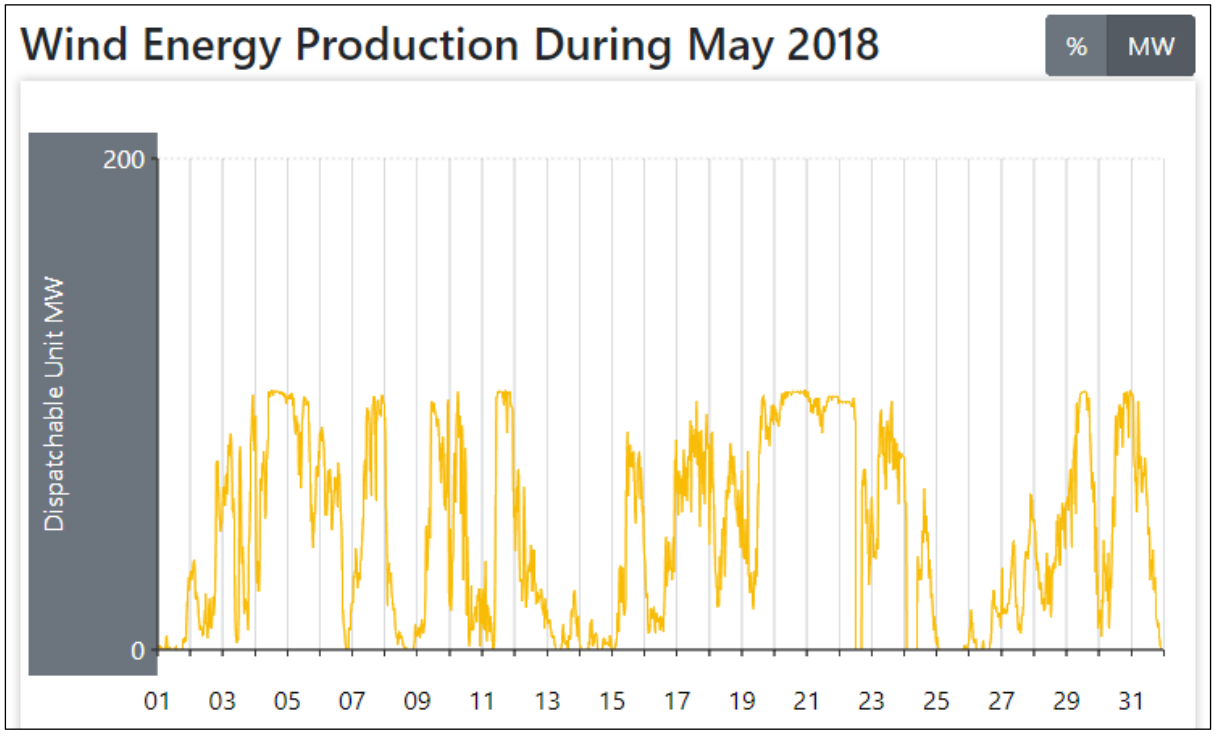


Figure 1: Bald Hills Wind Farm "SCADA" Power Generation (MW) for May 2018
Source: https://anero.id/energy/wind-energy

Figure 2 illustrates the power generation correlated to sound levels and times of day when the "40 dBA noise limit" is exceeded.

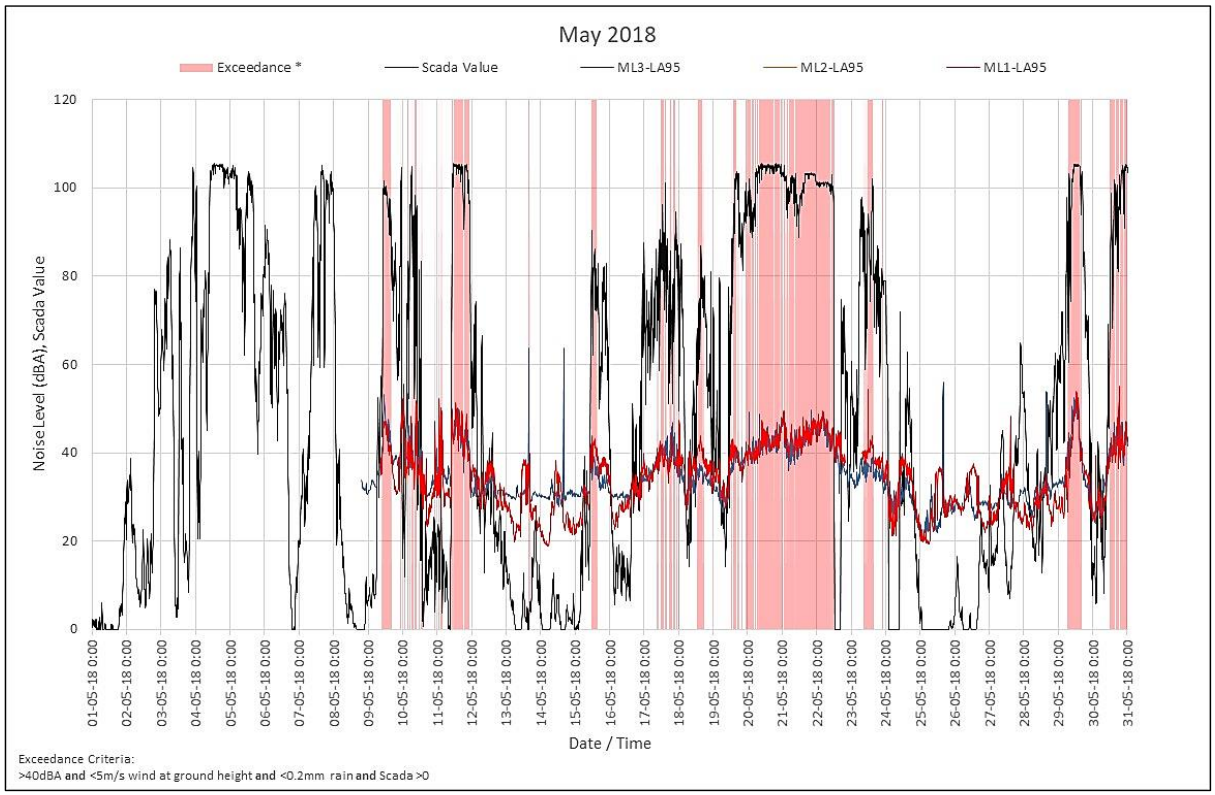


Figure 2: Bald Hills Wind Farm "SCADA" Power Generation (MW) for May 2018 showing background sound levels and the days when the "40 dBA noise limit" is exceeded. The SCADA values are shown as the black line in the figure. Sound level monitoring began on 10 May 2018.

The monitoring program shows that:

- Sound level exceedances over the "40dBA limit", as shown by the PTR coloured bands, tend to follow times of high power generation, or apparent sudden increase or decrease in generation.
- The potential for future noise complaints may be predicted based on the recorded response histories, AEMO power generation data, and weather conditions.

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BALD HILLS MONITORING

WIND FARM
SOUND PROPAGATION
AND
ATMOSPHERIC STABILITY

SOUND PROPAGATION AND ATMOSPHERIC STABILITY

New Zealand Standard NZS 6808:1998 does not discuss the variables involved in sound propagation, apart from air absorption. The significance of wind shear and atmospheric stability are not considered by the Standard even though they are arguably more important in noise propagation than air absorption for wind farm noise assessment. NZS 6808:1998 acknowledges these effects:

- Wind turbines emit higher sound levels as windspeed at the turbines increases;
- It is not possible to exclude wind effects when measuring low level wind turbine sound in a windy environment; sound from the wind turbines is similar to continuous background effects; and
- Concurrent measurement of windspeed and direction shall be taken within the windfarm site at a known height above ground level, preferably at the WTG hub height.

Atmospheric stability has a significant effect on wind shear, a quantity relating to changes in wind power and speed that can vary with height, distance and direction. An increase in wind shear due to atmospheric stability has a significant effect on the sound emission, causing it to be substantially higher than predicted from near-ground wind velocity and a neutral atmosphere, resulting in a higher noise impact on neighbouring residences.

All of these effects are experienced and recorded for the locale in the vicinity of the Bald Hills wind farm.

The advice of an expert in the field of atmospheric stability, Mr Geoff Clark, has provided valuable insight into the stability patterns within the wind farm environment. His analysis is presented in Appendix E *Atmospheric stability within the wind farm environment*. This is a research outcome and is presented as part of the monitoring program nuisance assessment. The advice of Mr Clark is acknowledged with appreciation and is an important component of the sound perception analysis undertaken by Dr Shepherd, Appendix L *Analysis of Special Audible Characteristics (SACs) to sound levels, atmospheric stability classes and SCADA values.*

Appendix E presents atmospheric stability data derived from recordings at the Pound Creek and Yanakie BOM stations, 1 January 2015 – 21 November 2018. The stations are on either side of the wind farm and provide a practical indication of atmospheric stability within the environment.

- Pasquill stability D is the most common for day and night but there are significant times of nighttime category E, F, and G that potentially enhance sound propagation.

- Examples of the winter nighttime stability values are presented to reflect the monitoring program May to August 2018. An example of the 10-minute data for May – August is presented in tabular form.

Discussion

There were significant numbers of occasions where the night-time-occurring Pasquill stability categories E, F and G occur. As is well known, these "temperature inversion" categories can lead to significant noise enhancement. Perhaps surprisingly, a great many of the reported occurrences of SACs (periods when sounds of Special Audible Characteristics were heard/reported) occurred during periods when the near-surface atmosphere at adjacent BOM stations was a Pasquill stability category D.

A detailed assessment of occurrences of Pasquill E, F and G events with respect to instances of noise nuisance is beyond the scope of this Report but such events seem to be unusual at a near-coastal location such as is the Bald Hills Wind Farm location affected by off-shore breeze. This is important as stability 'codes' viewed for this report (e.g. CONCAWE[1], NSW EPA[2], NZS 6801:1999[3]) appear to be based on inland atmospheric conditions, rather than coastal conditions. Inland, for example, has frosts while coastal has fog.

It is considered that, under more continental climate regimes (such is as expected to be at locations that are further inland and/or at higher altitude), the likelihood is that the numbers of these events would be much higher during any given period, thus leading to the likelihood of increased annoyance for residents in the vicinity of wind farms that might be located at such inland sites. The NSW EPA, for example, is concerned with inversion conditions that may occur and affect industrial uses and residents in the locale.

Note 1: CONCAWE Report, The propagation of noise from petroleum and petrochemical complexes to neighbouring communities
https://www.concawe.eu/wp-content/uploads/2017/01/rpt_81-4ocr-2004-01264-01-e.pdf
Note 2: NSW EPA Industrial noise policy (refer to Fact Sheet D)
https://www.epa.nsw.gov.au/your-environment/noise/industrial-noise/noise-policy-for-industry-(2017)

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BALD HILLS MONITORING

METEOROLOGICAL DATA

Meteorological Data

Meteorological data is not available from the wind farm operator so data was sourced from two Bureau of Meteorology (BOM) sites, local stations (ML1, ML7) and the forecasting service meteoblue.

The data from the BOM stations included:

- BOM Pound Creek station 85099 ID
- BOM Yanakie station 85301 ID
- Date and time (local, standard)
- 10 minute data
- Wind speed m/s (average)
- Wind gusts m/s
- Wind direction degrees and cardinal (requires separate requests), average
- Wind standard deviation of direction
- Air temperature degrees C
- Wet bulb temperature
- Dew point temperature
- Relative Humidity %
- Station Pressure hPa
- QNH pressure hPa
- Rain mm

Analysis of the meteorological data was referenced to various heights above ground:

- BOM Pound Creek, 10 metre (standard) and 80 metre (by calculation) heights
- BOM Yanakie, 10 metre (standard) and 80 metre (by calculation) heights
- ML7-HWT 10 metre
- ML1 1.5 metre
- Meteoblue forecast 10 metre and 80 metre heights

Wind speed referenced to turbine cut-in, cut-out

- Zero to upper bound (nominally 15 m/s)

Wind direction

- Wind speed can be assessed for 16 cardinal points for any tower height (above)
- Meteoblue forecast wind roses by month and height (10 metres and 80 metres)
- Meteoblue forecast wind speed frequency and Weibull histograms for 10m, 80m

Noise Monitoring location

- Wind speed can be assessed at any wind direction (above) under any wind tower (above) at any of the current 5 monitoring locations

Weather data has been recorded by wind speed and direction, wind monitoring tower, and sound levels combined into a compendium analysis spreadsheet that allows cross reference for:

- 24 hours
- Day
- Evening
- Night
- Night with 10% loudest sound levels

The meteorological stations are shown in the following figure, relative to the wind farm and residences:

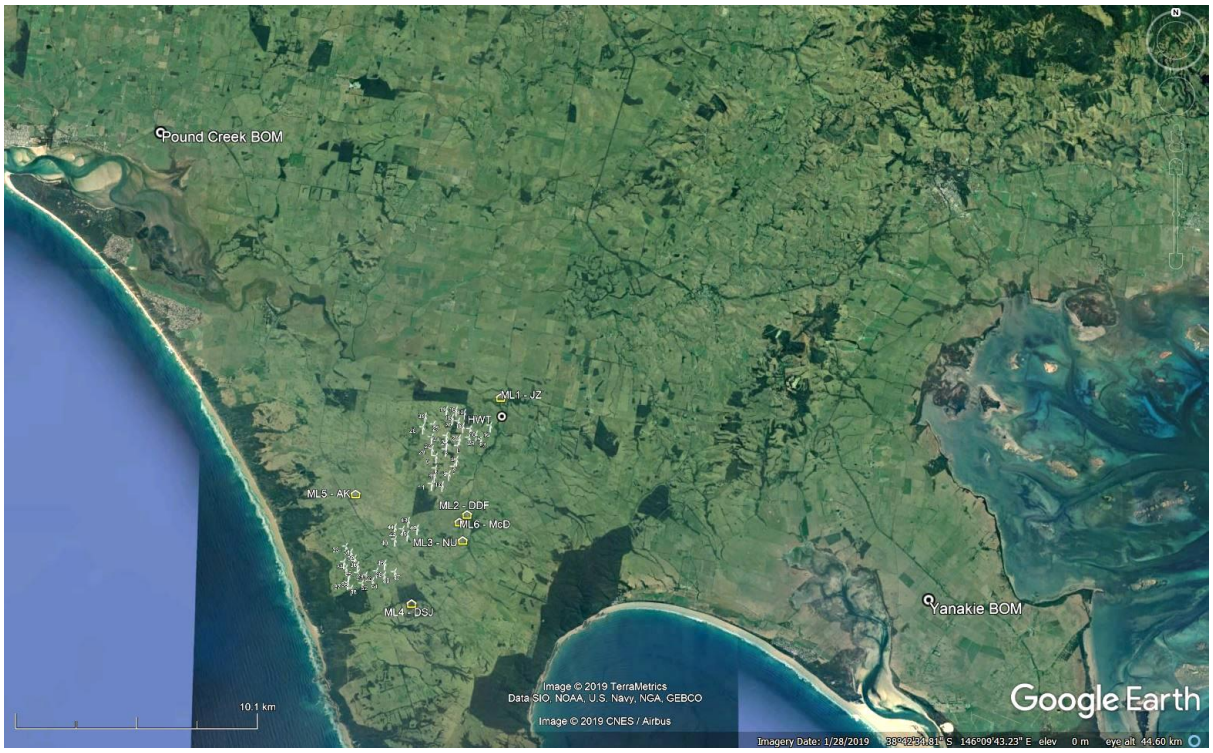


Figure 1: meteorological stations relative to wind farm and residences

Wind Roses

A considerable volume of 10-minute weather data has been collected from BOM stations at Pound Creek and Yanakie, as well as the stations "on-site" and the forecasting site, meteoblue. Individual day and month wind roses can be readily calculated.

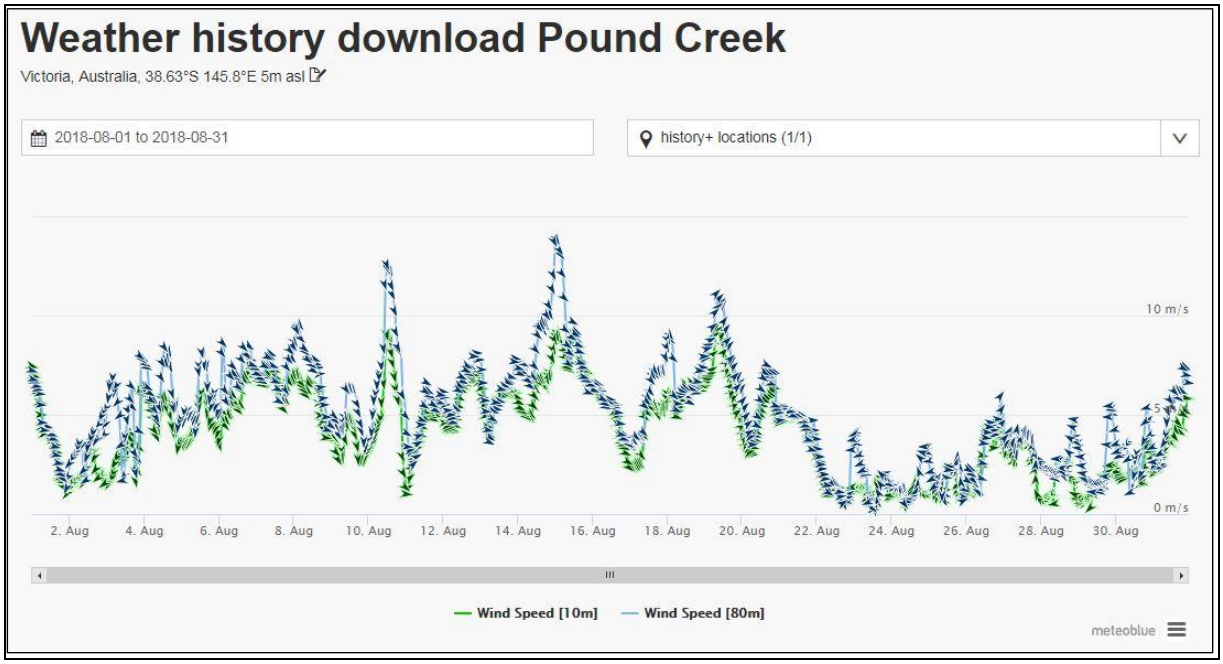
Residents have stated that noise from the wind farm is often more pronounced when the turbines are "side-on" to the homes. The diary notes contain information with respect to wind speed and directions that is very helpful in the consideration of noise propagation in this unique acoustic environment.

The spreadsheets developed by NMS for this monitoring program can display this information. There is a point, however, where all this fine detail obscures the salient points:

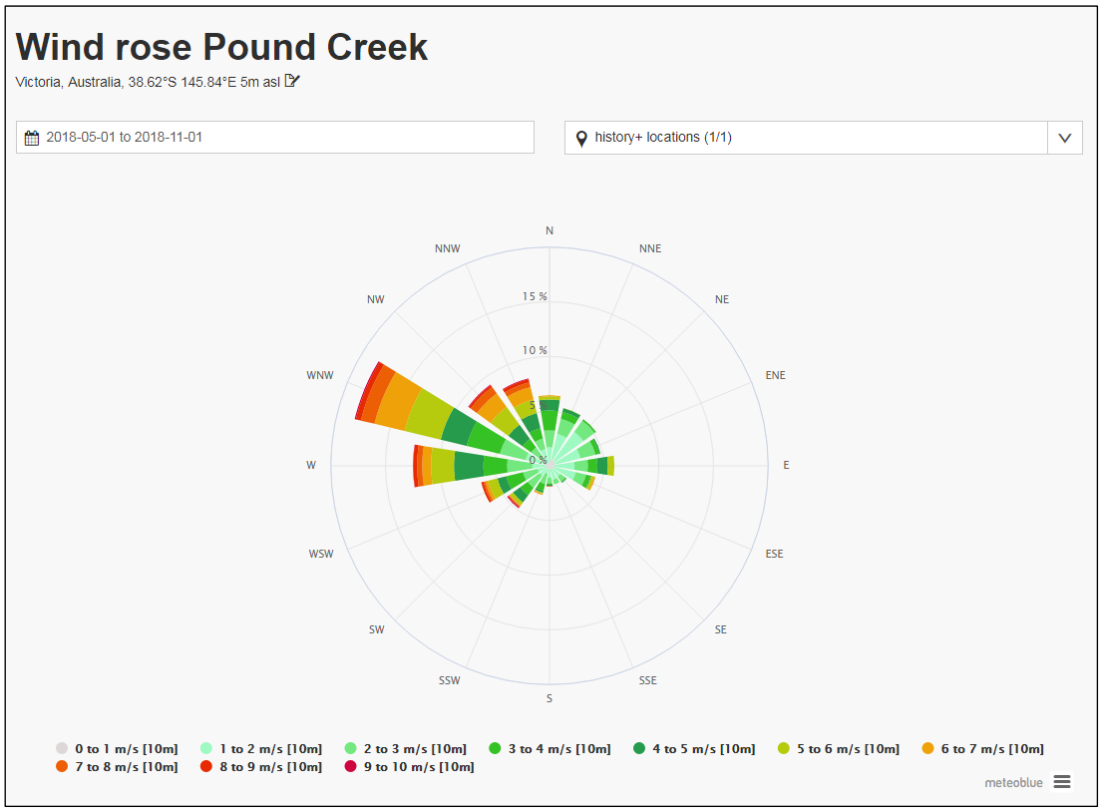
- Wind farm noise can be heard at homes in both calm and strong breeze conditions
- Wind farm noise varies day and night
- Wind speeds and directions affect wind turbine noise propagation

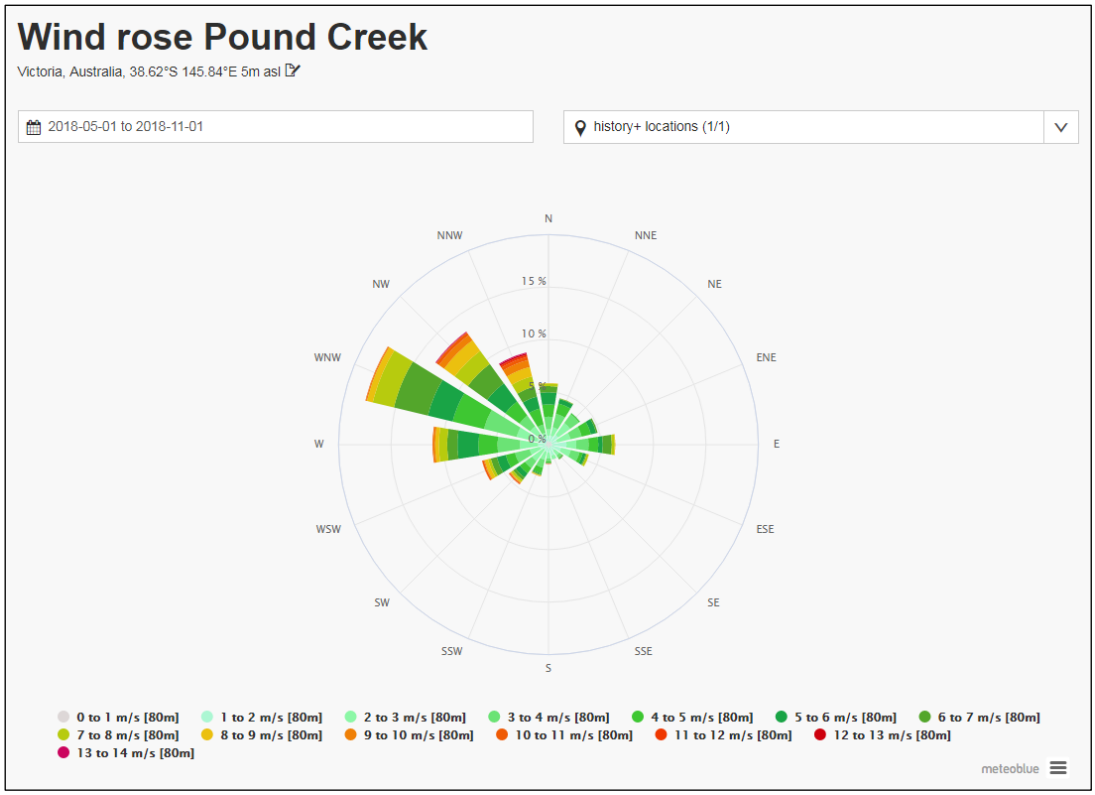
A starting point for assessing meteorological conditions affecting "wind farm noise as-heard" is reviewing the overall wind speeds and directions at the wind farm. Ideally this data is supplemented by actual turbine data.

Meteoblue provides a useful source for comparison of wind speeds and directions. For example, a chart for Pound Creek, August 2018, compares 10m and 80m wind speeds when the turbines were both 'off' and 'on'. The arrows indicate wind direction.



The following 10 metre and 80 metre wind roses for May to November following are sourced from meteoblue. This shows the dominant winds blowing towards the homes.





10 metre to Hub Height Wind Calculation

NZS 6808 also suggests that windspeed should be measured at WTG hub height. The Danish Wind Energy Association provides the following calculation to assist in calculating the 10 metre tower to hub-height wind speeds:

The wind speed at a certain height above ground level is:
$v = v_{ref} \ln(z/z_0)/\ln(z_{ref}/z_0)$
v = wind speed at height z above ground level.
v_{ref} = reference speed, i.e. a wind speed we already know at height z_{ref}. ln(...) is the natural logarithm function.
z = height above ground level for the desired velocity, v.
z_0 = roughness length in the current wind direction.
z_{ref} = reference height, i.e. the height where we know the exact wind speed v_{ref}.

In the above example, assume we know that the wind is blowing at 6 m/s at 10 m height. We wish to know the wind speed at 80 m height. If the roughness length is 0.1 m, then
$v_{ref} = 6.0$
$z = 80$
$z_0 = 0.1$
$z_{ref} = 10$, therefore,
$v = 6.0 \ln(80/0.1) / \ln(10/0.1)$
$= 8.7$ m/s
Therefore, the nominal 10m to 80m windspeed adjustment is times 1.45

Roughness Classes and Roughness Length
Roughness Class is '2' and roughness length is 0.1 m for agricultural land with some houses and 8 metres tall sheltering hedgegrows with a distance of approximately 500 metres. This is the value ascribed to BOM Pound Creek and the wind tower ML7.

Sound levels at 80m vs 10m

The 80m wind data is converted from the 10m data (x1.45 in this case). The purpose is to provide a comparison between noise levels at ground and the rated wind speeds of the turbine. MDA did not do this, so our assessment charts are based on 10m wind data to compare like with like; that is, the default condition.

The sound levels displayed on the 10m chart will be different from that displayed on the 80m chart because our chart starts at 4m/s on the X axis, and some new data appears in the 80m chart that wasn't visible in the 10m chart. The noise data is simply stretched along the X axis; for example, in the images below are circled a selection of corresponding data points. The background level and limit line (green and black lines) are not correct for the 80m charts as they are based on 10m wind speeds – however, the 80 metre background sound level limits are not available.

Chart 1: Sound levels and limits for 10m height – the default condition

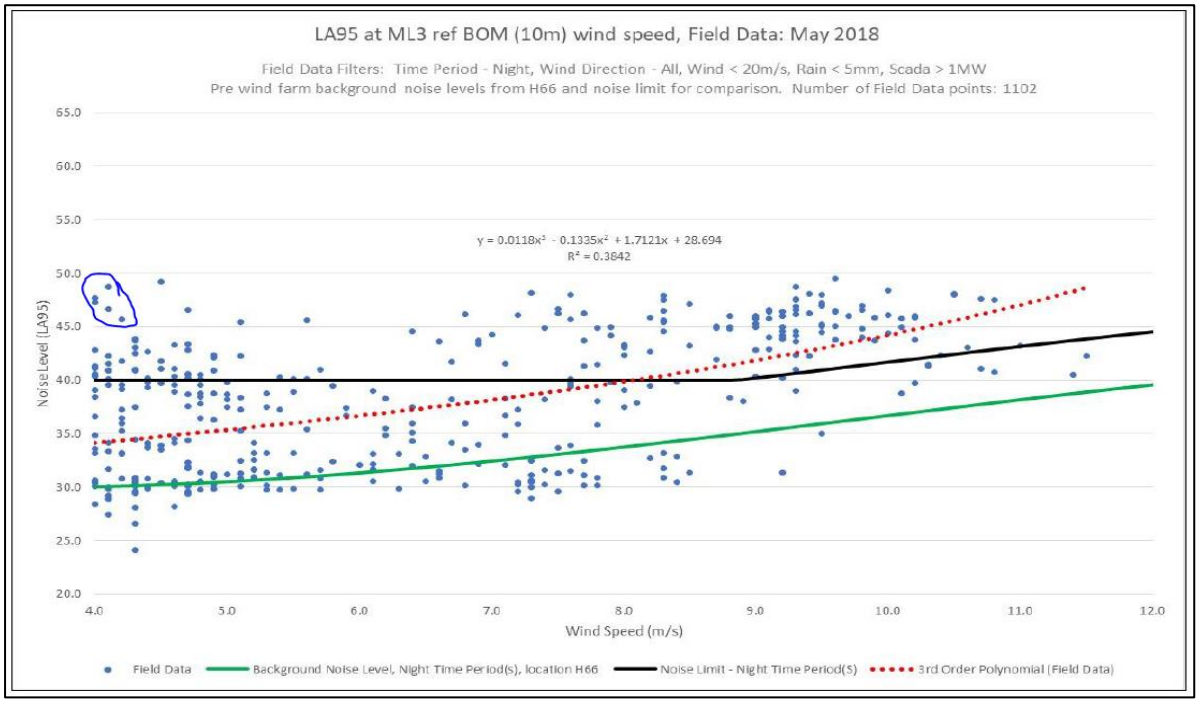


Chart 2: And 80 metre height – the sound levels 'move to the right' relevant to the 10m wind speed

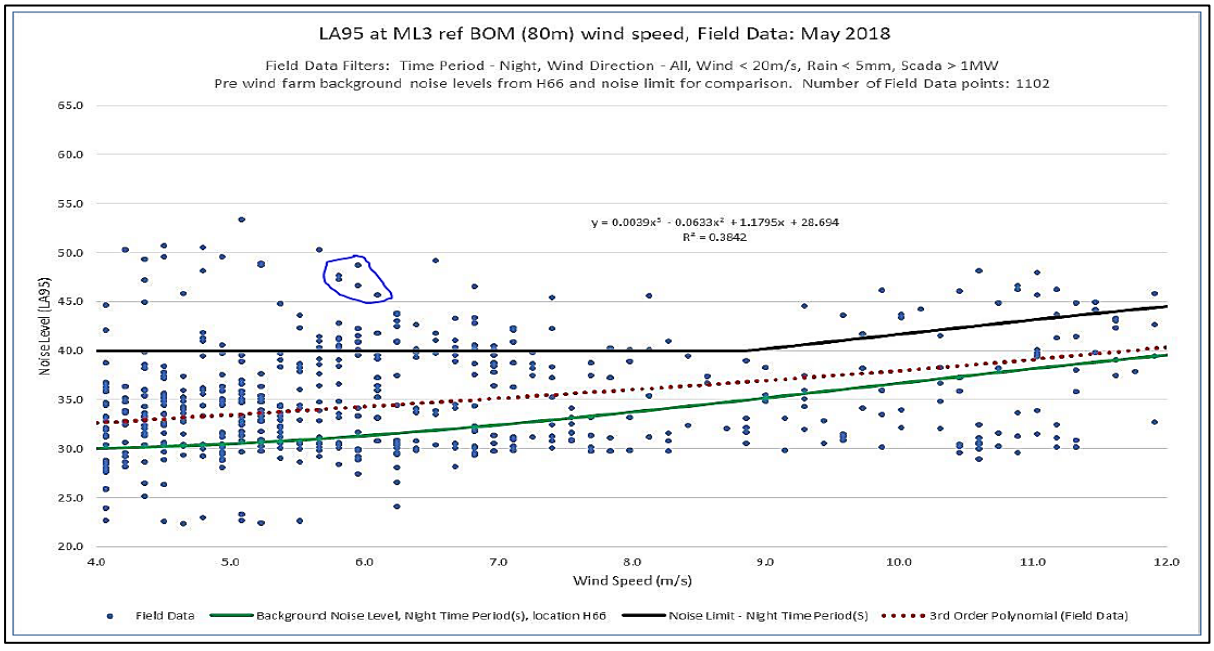


Table 1: Example: Pound Creek, Yanakie and Huson (ML7) 10-minute stability, wind speed and direction data, 10 May 2018, midnight to 7am

		Noise				Pound_Creek				Yanakie				Huson			ML1		
Date	Time	ML1-LA95	ML2-LA95	ML3-LA95	ML4-LA95	Time	Speed	Direction	Stablity	Time	Speed	Direction	Stablity	Time	Speed	Direction	Time	Speed	Direction
10052018	0000	52.4	0	49	0	0000	3.6	242	D	0000	3.8	238	E	0000	1	190	0000	0	calm
10052018	0010	51.9	0	48.2	0	0010	3.3	279	D	0010	3.9	240	E	0010	0.2	191	0010	0	calm
10052018	0020	50.1	0	49.6	0	0020	3.4	290	D	0020	4.1	230	E	0020	1.4	227	0020	0	SW
10052018	0030	49.6	0	50.6	0	0030	3.3	283	D	0030	4.2	255	E	0030	1.5	265	0030	0	SW
10052018	0040	53.5	0	52.1	0	0040	2.3	289	D	0040	3.7	267	E	0040	2.6	245	0040	0.4	NE
10052018	0050	49.7	0	47.5	0	0050	1.5	334	F	0050	4.4	270	D	0050	2.4	266	0050	0.4	NE
10052018	0100	47.3	0	47.4	0	0100	1.9	354	D	0100	4.8	286	E	0100	2.1	279	0100	0	NNW
10052018	0110	47.8	0	44.6	0	0110	1.5	341	D	0110	4	289	E	0110	1.3	297	0110	0	N
10052018	0120	37.7	0	43	0	0120	1.7	308	E	0120	3.1	310	D	0120	1	315	0120	0.4	N
10052018	0130	34.4	0	36	0	0130	2.1	320	D	0130	2.6	323	D	0130	1.7	315	0130	0.4	N
10052018	0140	43.4	0	39.5	0	0140	2.7	325	D	0140	2.6	331	E	0140	2.4	317	0140	0.4	N
10052018	0150	37.4	0	38.8	0	0150	2.8	328	D	0150	2.4	333	E	0150	1.9	305	0150	0.4	N
10052018	0200	34	0	39.9	0	0200	3	332	D	0200	3	324	D	0200	2.2	307	0200	0.9	NNW
10052018	0210	33.3	0	38.3	0	0210	3.8	327	D	0210	3.5	314	E	0210	2.7	313	0210	0.9	N
10052018	0220	34	0	38.6	0	0220	3.8	322	D	0220	4.2	326	D	0220	1.9	313	0220	0.9	NNE
10052018	0230	35.9	0	39.2	0	0230	4.2	320	D	0230	5.2	324	D	0230	2.2	311	0230	0.9	N
10052018	0240	36.9	0	38.5	0	0240	4	325	D	0240	5.7	329	D	0240	2.7	302	0240	1.3	N
10052018	0250	35.4	0	38.6	0	0250	3.9	328	D	0250	6.4	326	D	0250	3.2	304	0250	1.8	N
10052018	0300	36.6	0	39.2	0	0300	3.9	321	D	0300	6.2	326	D	0300	3.1	306	0300	1.3	NNW
10052018	0310	37.1	0	48.7	0	0310	4.1	317	D	0310	6.1	320	D	0310	3.4	299	0310	1.3	N
10052018	0320	36.3	0	53.4	0	0320	3.5	311	D	0320	5.5	315	D	0320	3.6	295	0320	1.3	N
10052018	0330	42.5	0	47.7	0	0330	4	297	D	0330	5.6	312	D	0330	3.3	281	0330	0.9	NNW
10052018	0340	41.2	0	44.6	0	0340	6.4	284	D	0340	5.6	293	D	0340	4	271	0340	0.9	N
10052018	0350	42.8	0	46.2	0	0350	6.8	279	D	0350	7.7	282	D	0350	3.9	270	0350	0.9	NNE
10052018	0400	40.7	0	40.1	0	0400	5.5	287	D	0400	8.9	288	D	0400	3.8	271	0400	0.4	S
10052018	0410	35.4	0	37.5	0	0410	4.3	289	D	0410	6.8	280	D	0410	3.1	275	0410	0.4	SSE
10052018	0420	35.1	0	40.9	0	0420	4.3	290	D	0420	6.2	286	D	0420	2.2	287	0420	0.4	N
10052018	0430	42.3	0	38.4	0	0430	5.1	255	D	0430	4.3	295	E	0430	2.1	300	0430	0.4	NNW
10052018	0440	37.8	0	38.2	0	0440	6.7	282	D	0440	4.4	297	E	0440	2.5	278	0440	0.4	NNE
10052018	0450	38.1	0	36.7	0	0450	7.1	274	D	0450	5.4	296	D	0450	2.2	284	0450	0.4	N
10052018	0500	41.7	0	37.3	0	0500	5.4	292	D	0500	7.3	283	D	0500	2.4	266	0500	0.9	NE
10052018	0510	41.4	0	43.9	0	0510	4.3	307	D	0510	4.7	298	E	0510	4.9	274	0510	1.3	NNW
10052018	0520	39.1	0	39.8	0	0520	4.4	299	D	0520	3.1	299	E	0520	4.5	279	0520	1.3	NNE
10052018	0530	37.7	0	38.5	0	0530	4.8	293	D	0530	3.8	297	D	0530	3.6	279	0530	0.9	N
10052018	0540	37.9	0	36.6	0	0540	4	307	D	0540	6.3	283	D	0540	2.6	261	0540	0.4	E
10052018	0550	48.3	0	40	0	0550	4.4	301	D	0550	5.3	295	D	0550	3.4	256	0550	0.9	NE
10052018	0600	40.7	0	46.7	0	0600	4.1	295	D	0600	4.5	307	E	0600	5.3	258	0600	1.3	E
10052018	0610	37.4	0	41.1	0	0610	4.6	297	D	0610	3.7	312	E	0610	5.1	238	0610	0.9	NE
10052018	0620	37.8	0	38.9	0	0620	5.5	285	D	0620	7.3	310	D	0620	3	272	0620	0.4	ENE
10052018	0630	36.9	0	37.5	0	0630	5	287	D	0630	9.5	291	D	0630	3.5	278	0630	0.4	N
10052018	0640	36.2	0	37.3	0	0640	2.5	305	D	0640	6.4	286	D	0640	2.3	289	0640	0.9	N
10052018	0650	36.7	0	38.5	0	0650	3.1	310	D	0650	5.1	312	D	0650	1.6	295	0650	0.9	N
10052018	0700	37	0	40.6	0	0700	2.7	312	D	0700	5.2	315	D	0700	1.7	285	0700	0.9	NNE

BALD HILLS MONITORING

WIND FARM PRACTICAL MITIGATION MEASURES AND METEOROLOGICAL CONDITIONS

PRACTICAL NOISE MITIGATION MEASURES AND METEOROLOGICAL CONDITIONS

Approval condition 22 envisages that, where condition 19 is found to have been breached, the wind farm operator is required to ascertain the *"… relevant meteorological circumstances at the time of the breach and to noise optimize the relevant turbine or turbines in such circumstances."*

It is understood by NMS that:

- during the May to August 2018 monitoring period at least 4 turbines were in curtailment mode, or "noise optimized" for noise mitigation.
- a formal request was made by DST Legal to the wind farm operator for individual turbine power and wind data for the period May to August 2018. The data are not available to DST Legal for review.
- MDA sound level monitoring data for the affected residences are not available for the period May to August 2018.

Consequently, neither the wind farm operator nor MDA have provided evidence as required for the application of Condition 22; that is,

- Relevant meteorological data
- Individual turbine output data
- Sound levels attributable to individual turbines
- Noise optimization (*mitigation*) that works.

Critically, the wind farm operator has not provided evidence of the complaint histories necessary to identify dates and times of breaches as heard at residences.

The NMS monitoring program provides evidence that condition 19 has been breached over the period May to August 2018.

Consequently, the removal provisions of Condition 22 can apply:

> *"In circumstances where optimization or selective shutdown routines have been requested but not reasonably implemented, or have been implemented but have not prevented further instances of recorded breach, the relevant turbine or turbines will be required to be decommissioned and removed."*

In order to test the application of Condition 22 NMS arranged for an analysis to be made of monitored complaint data, sound levels, meteorological conditions and wind farm power output. A summary of this analysis follows.

Meteorological Conditions and Special Audible Characteristics

Dr Daniel Shepherd has prepared an assessment of the relationship between special audible characteristics (SAC) responses, sound levels, atmospheric stability classes and SCADA values for daytime and nighttime 10 May to 23 September 2018. The full report by Daniel, with the associated statistical tables and charts, is recorded in Appendix L.

This relationship is an evidential methodology to assess Condition 22 and wind farm operation generally for assessment of compliance or non-compliance with Condition 19 and potential for nuisance conditions.

The atmospheric stability classes referred to are recorded in part in Appendix E by Geoff Clark, meteorologist. SCADA values are the wind farm power output data recorded by Paul Miskelly, Appendix I and analysis charts within this report. Sound levels are the background (LA95) sound levels recorded at various residences near to the wind farm.

In summary, Daniel reports his analysis as follows:

> The preliminary analysis determined that participant reports of special audible characteristics (SACs) are linked to atmospheric stability classes obtained from the Pound Creek and Yanakie measuring sites.
>
> **SACs are linked to atmospheric stability**
>
> - Specifically, the category D stability class was, proportionally, more likely to be associated with reports of SACs, while category E was also prominent.
>
> **Noise levels are associated with atmospheric stability**
>
> - Stability, in turn, was associated with noise level, though interestingly reports of SACs were not especially well predicted by noise level, suggesting a dose-response relationship between noise level and SAC detection is not present.
>
> **SACs are associated with noise levels;**
> **SACs are weakly related to wind direction; and**
> **SACs are strongly related to SCADA values**
>
> - SCADA values predicted SACs, even though SCADA values are strongly correlated with noise levels.
>
> **Wind direction is sometimes strongly correlated to noise levels**
>
> - Correlation coefficients between wind direction and noise levels vary depending upon measuring location.
>
> **Wind speed is strongly related to noise levels.**

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BALD HILLS MONITORING

SOUND LEVELS

MAY 2018 – MARCH 2019

Bald Hills Wind Farm Sound Levels

The Bald Hills Wind Farm has been monitored from May 2018 to date (March 2019) at different locations and varying weather conditions. Monitoring of the wind farm under 'no activity' wind conditions was possible in August. The monitored sound levels and wind data are retained on spreadsheet and raw data files. The charts in this section present summary information to address approval conditions 19(a) and 19(c).

The following charts are presented to identify sound levels recorded at various homes:

- Variation in day and night sound levels for the month by time of day/night
- The variation in night-time sound levels for the month by time of night
- Regression curve of night-time sound levels v. noise limits for the month referenced to 10m wind speeds
- Regression curve of night-time sound levels v. noise limits for the month referenced to 80m wind speeds

In all cases the 10 metre wind speeds from the Bureau of Meteorology Pound Creek station are applied. The 80 metre wind speed is by calculation as explained later in this report.

The two variation charts for each month present the '24-hour' and 'night-time' background sound levels for the month. A regression curve (*shown as red dots*) is shown presenting the 'most likely sound levels' for a specific time period. Two additional lines are shown approximately 5dB – 7dB either side of the line; these are known as the 'standard error' or 'confidence interval' for the spread of the data. The two lines 'capture' 68% of the monitored sound levels. That is to say, the regression line itself is a calculated value, and will change as data is added or removed.

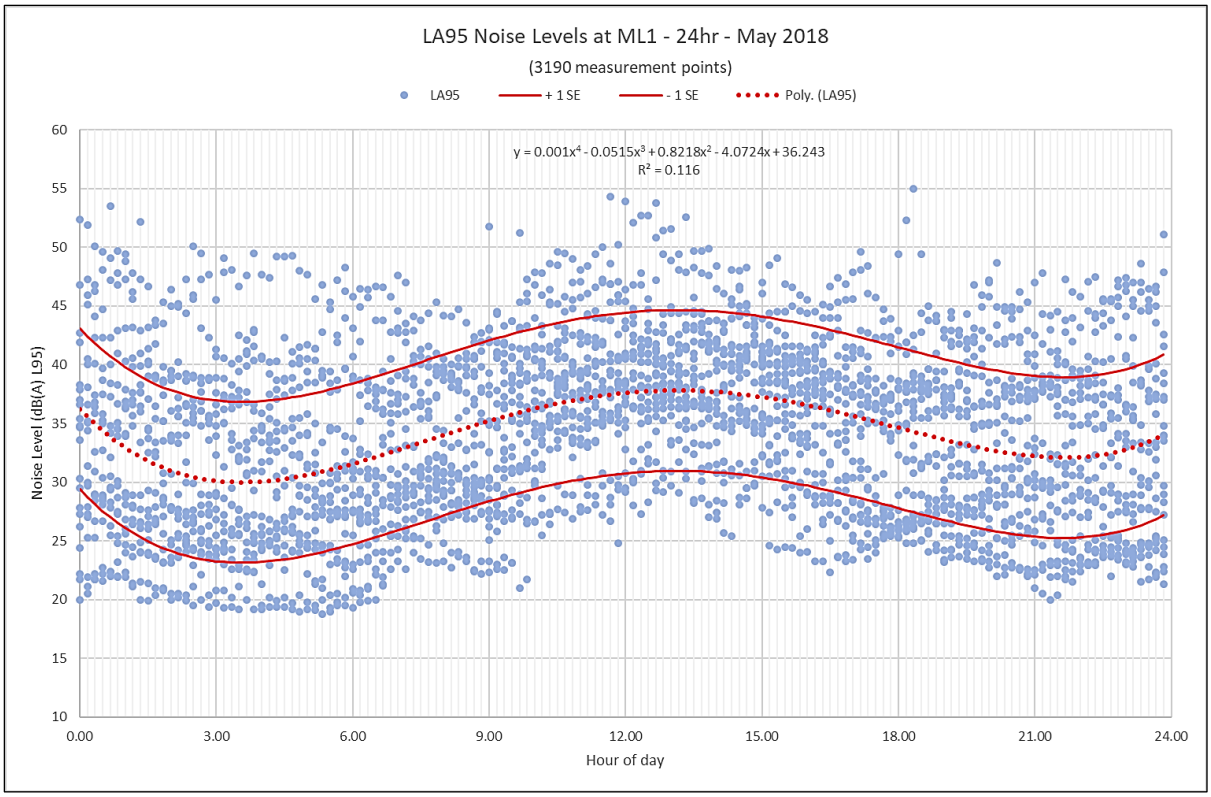
Potential 'non-compliance' sound levels in the charts are those that are above the solid black noise limit line and the regression curve in the analysis charts. Approval conditions 19(a) and 19(c) apply.

All outdoor background sound levels were recorded with the BSWA Class 1 sound levels meters. The BSWA data are applied in the analysis spreadsheets.

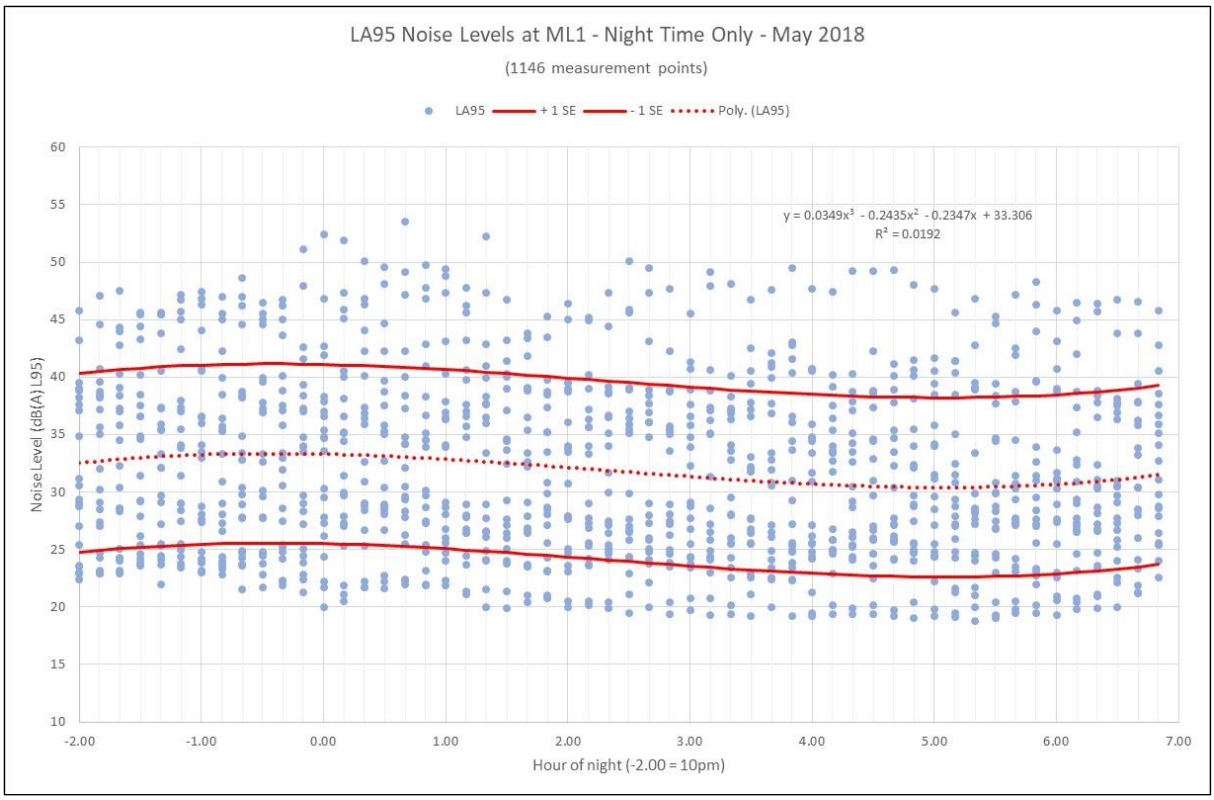
The Larson Davis sound level meters recorded background and ambient sound levels, various acoustical measures, third octave band sound levels and audio. The LD831 meters also allowed access to the internet for observations. The LD831 at residence ML1 provided an immediate online function to recorded sound levels and time-history.

May 2018

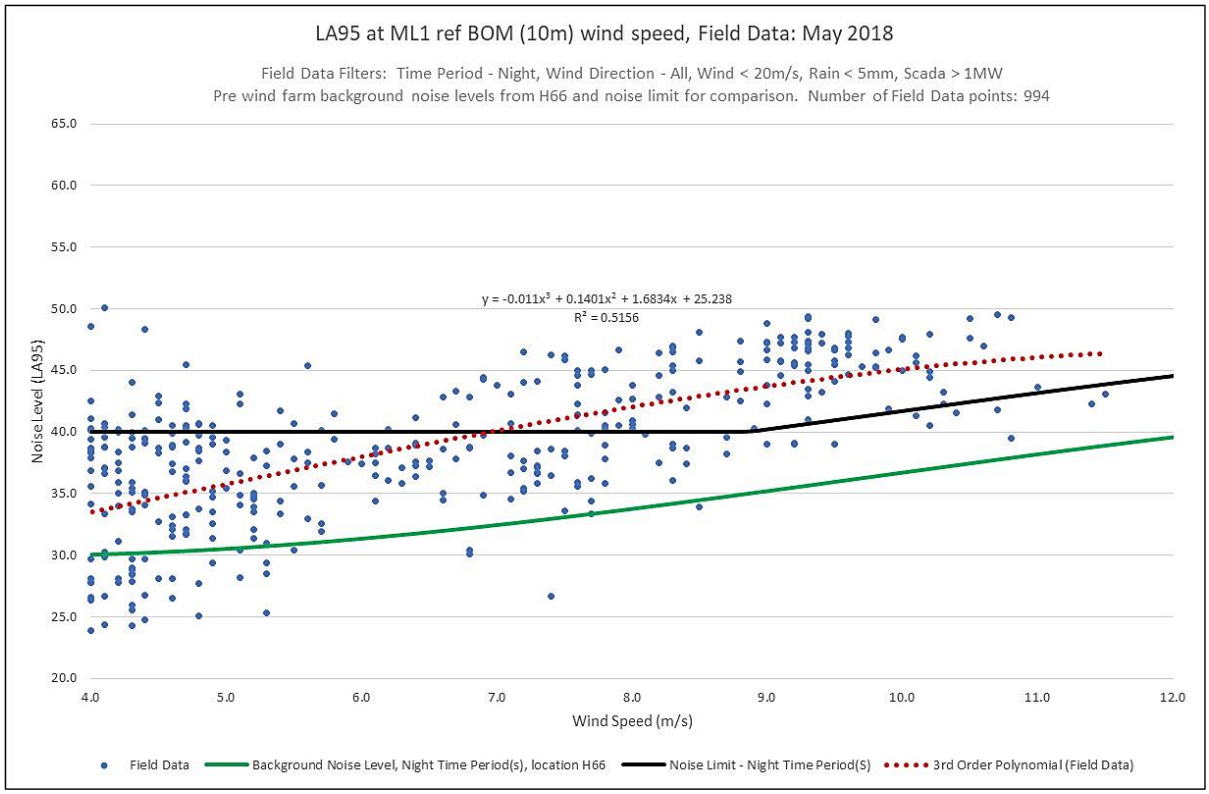
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



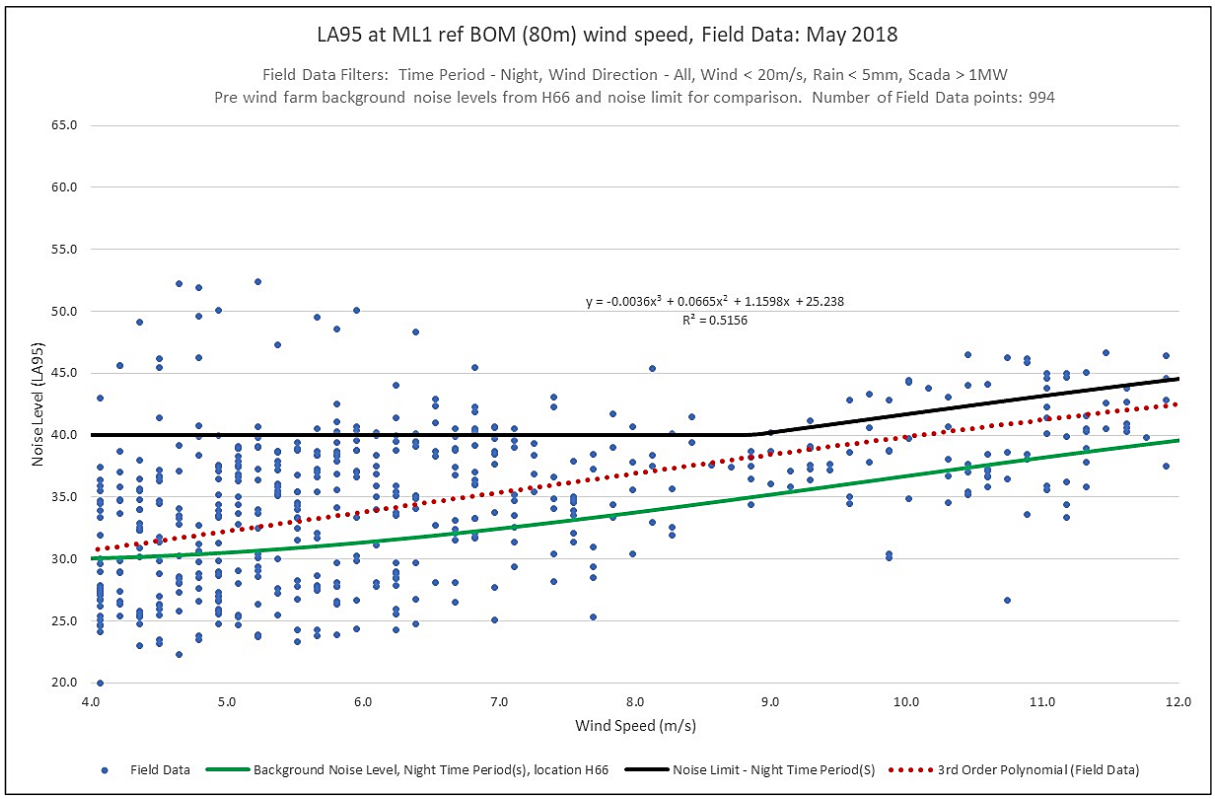
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

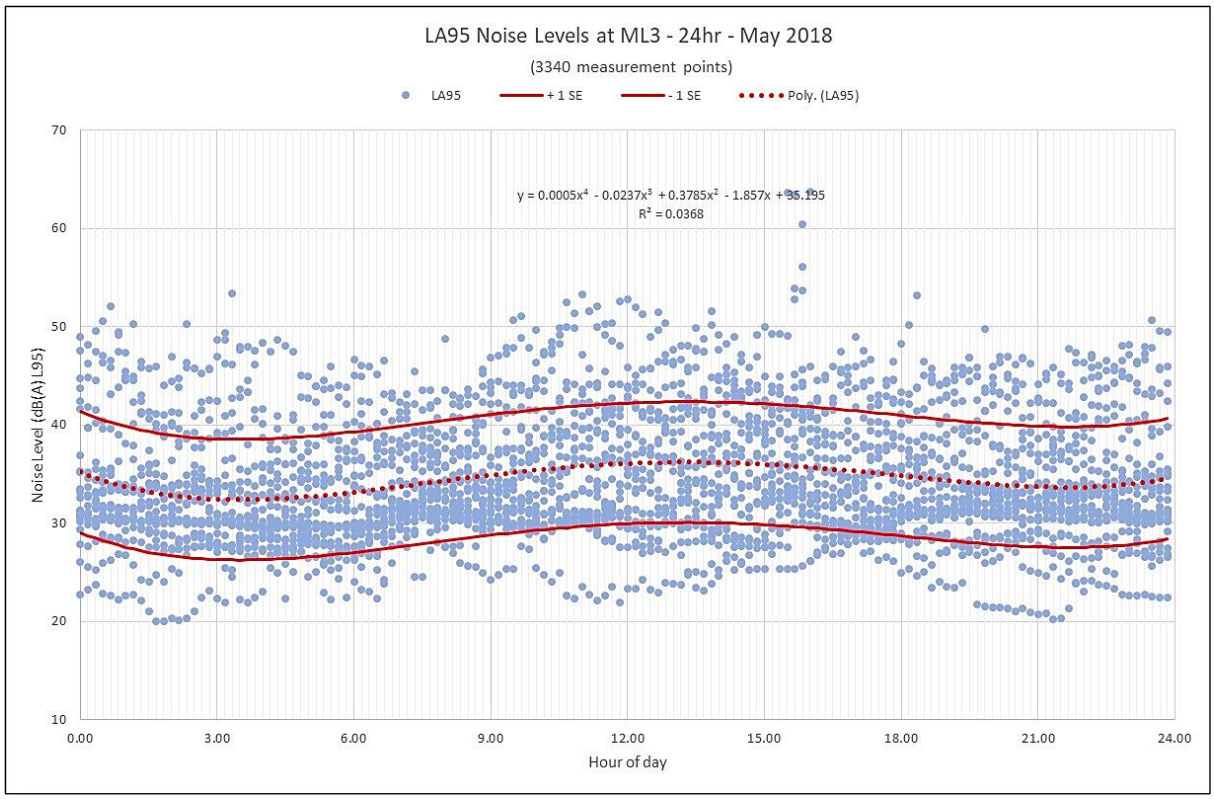


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

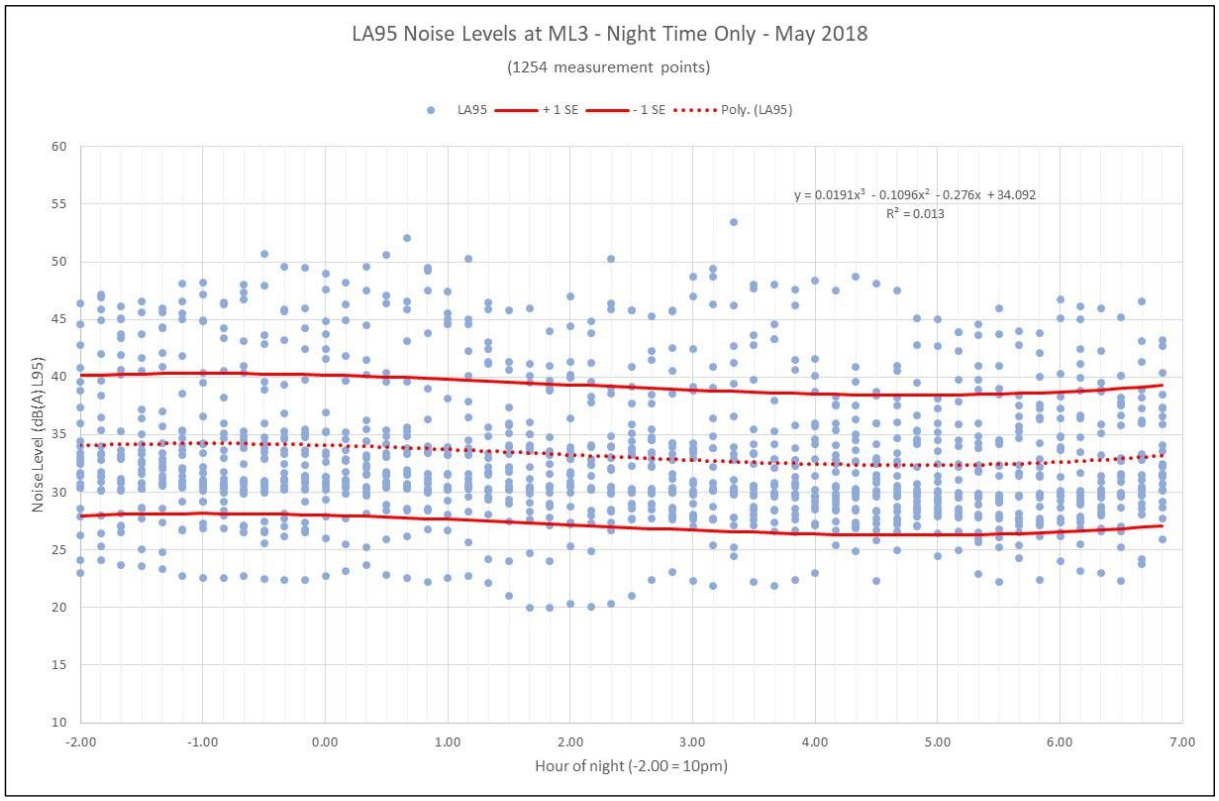


MAY 2018 – ML3 (NU)

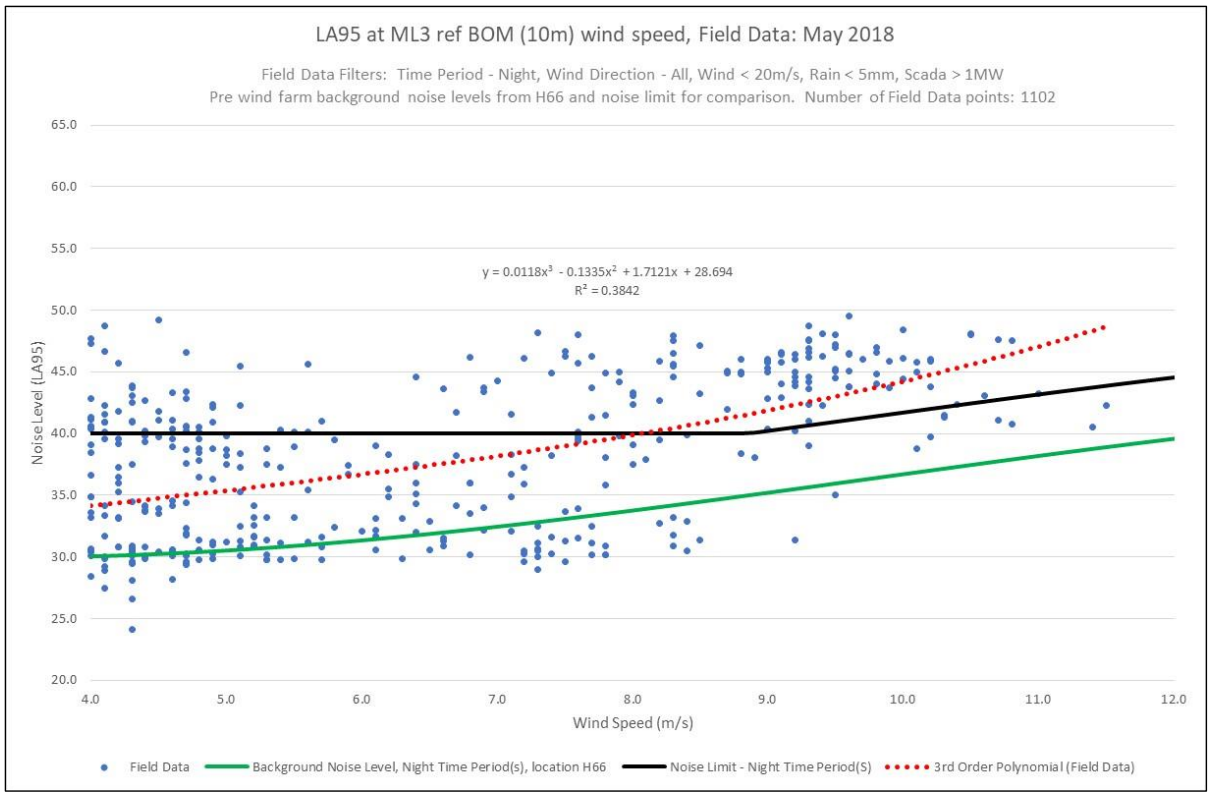
Variation in day and night sound levels for the month by time of day/night



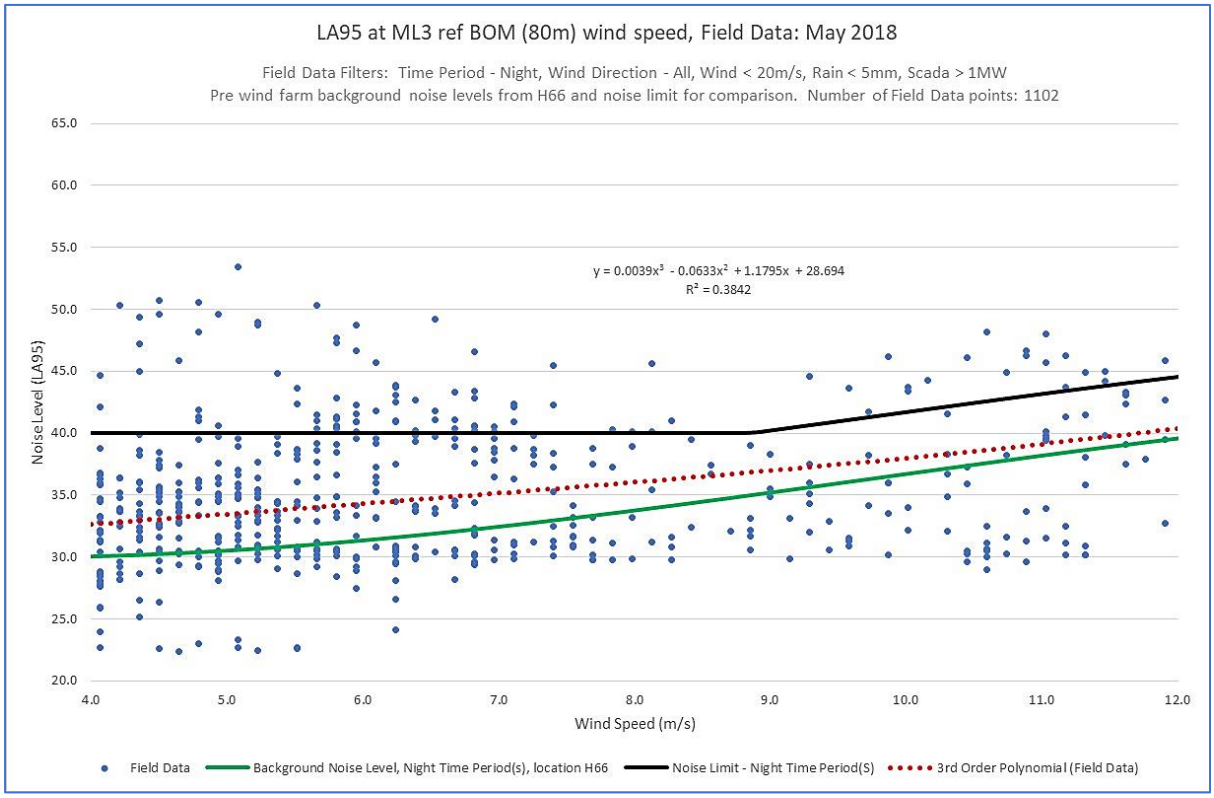
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

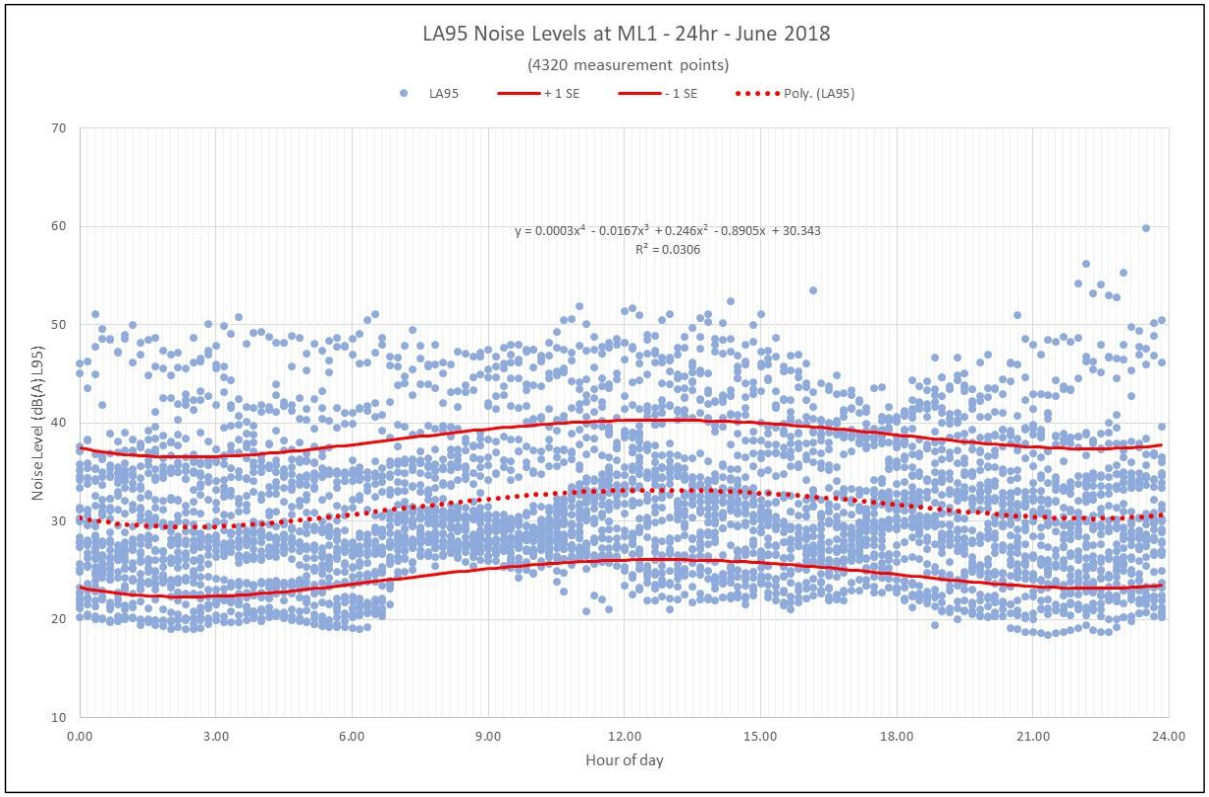


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

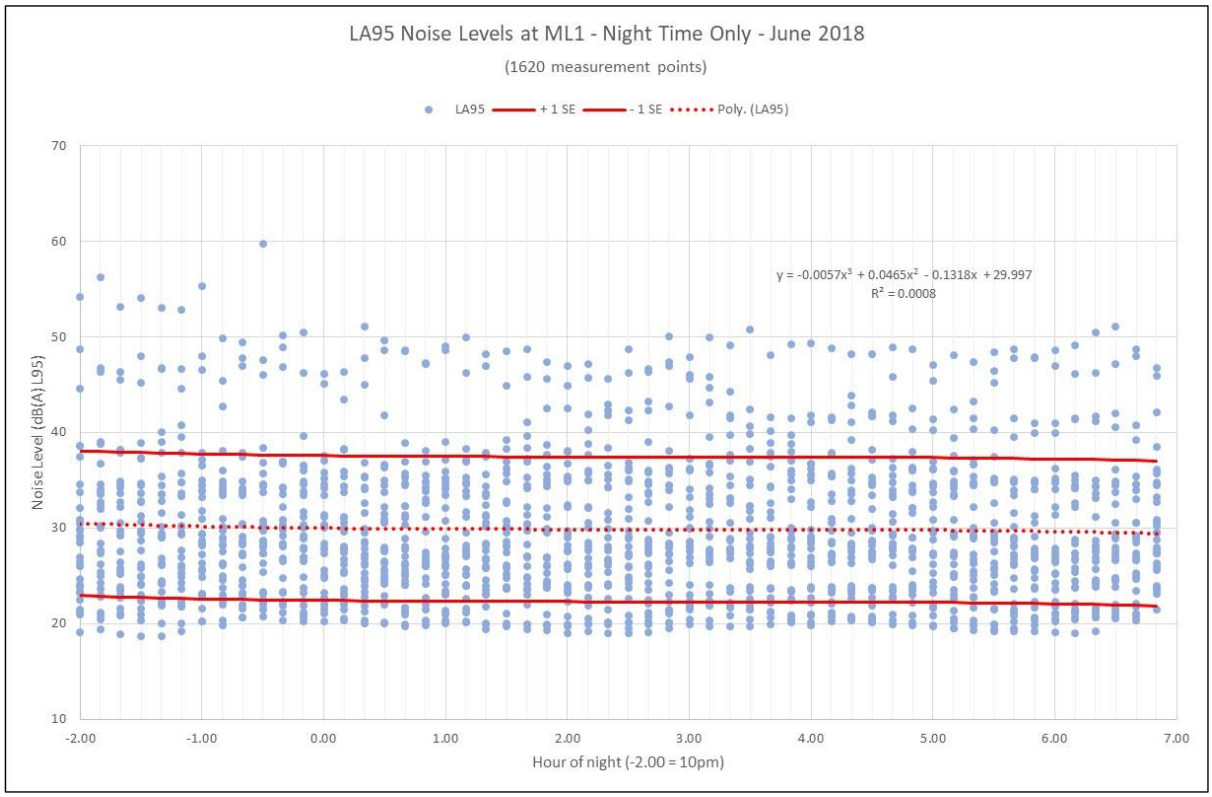


June 2018

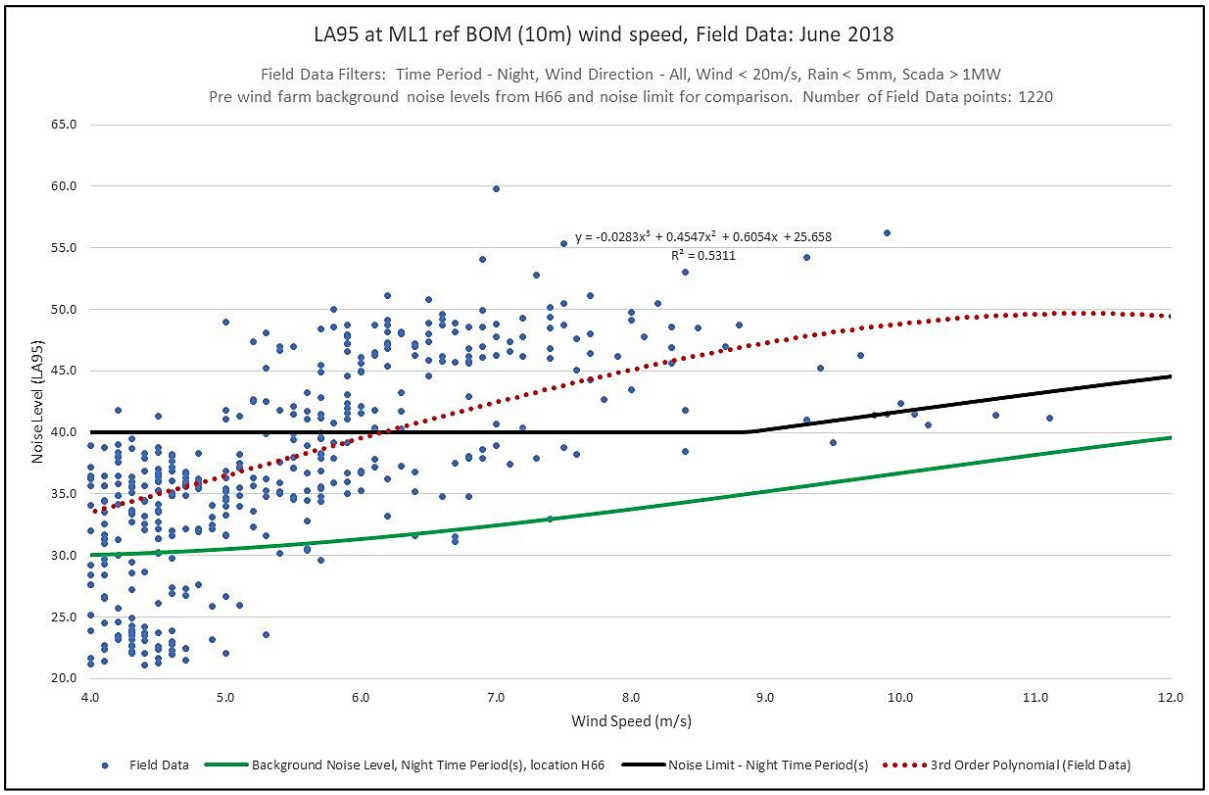
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



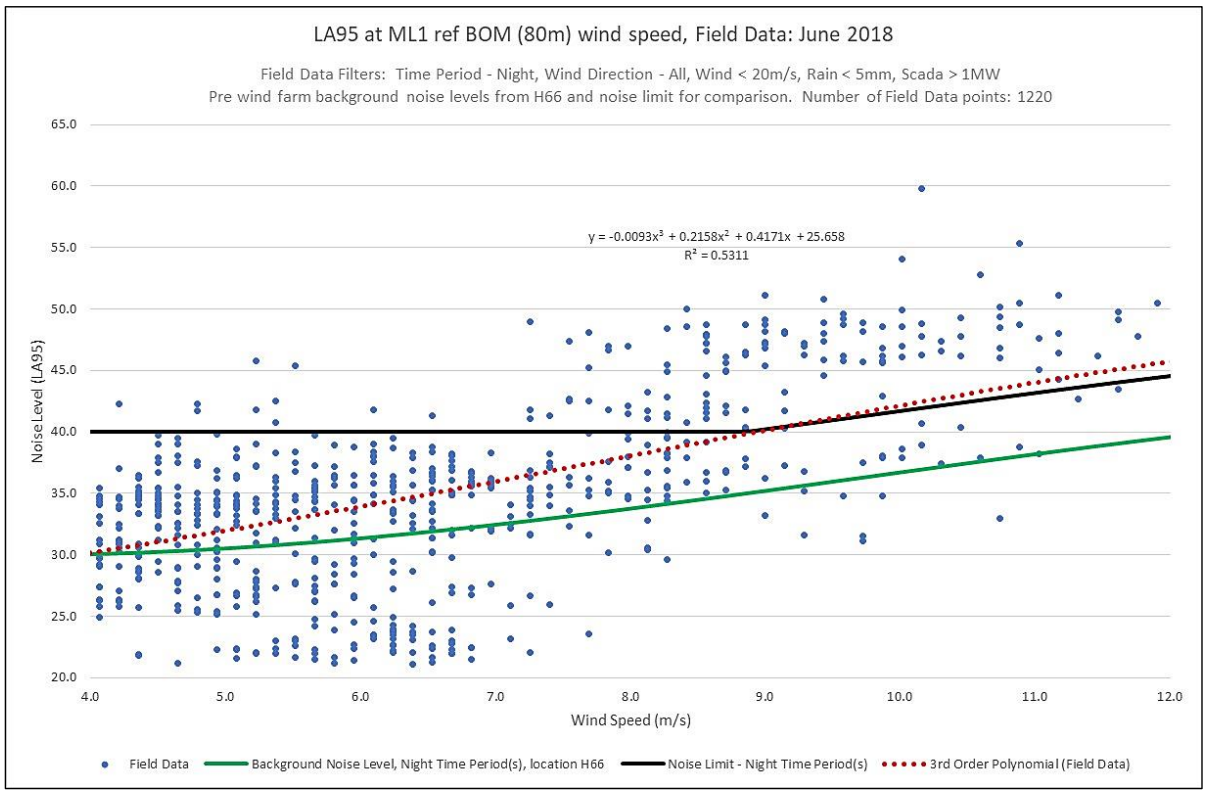
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

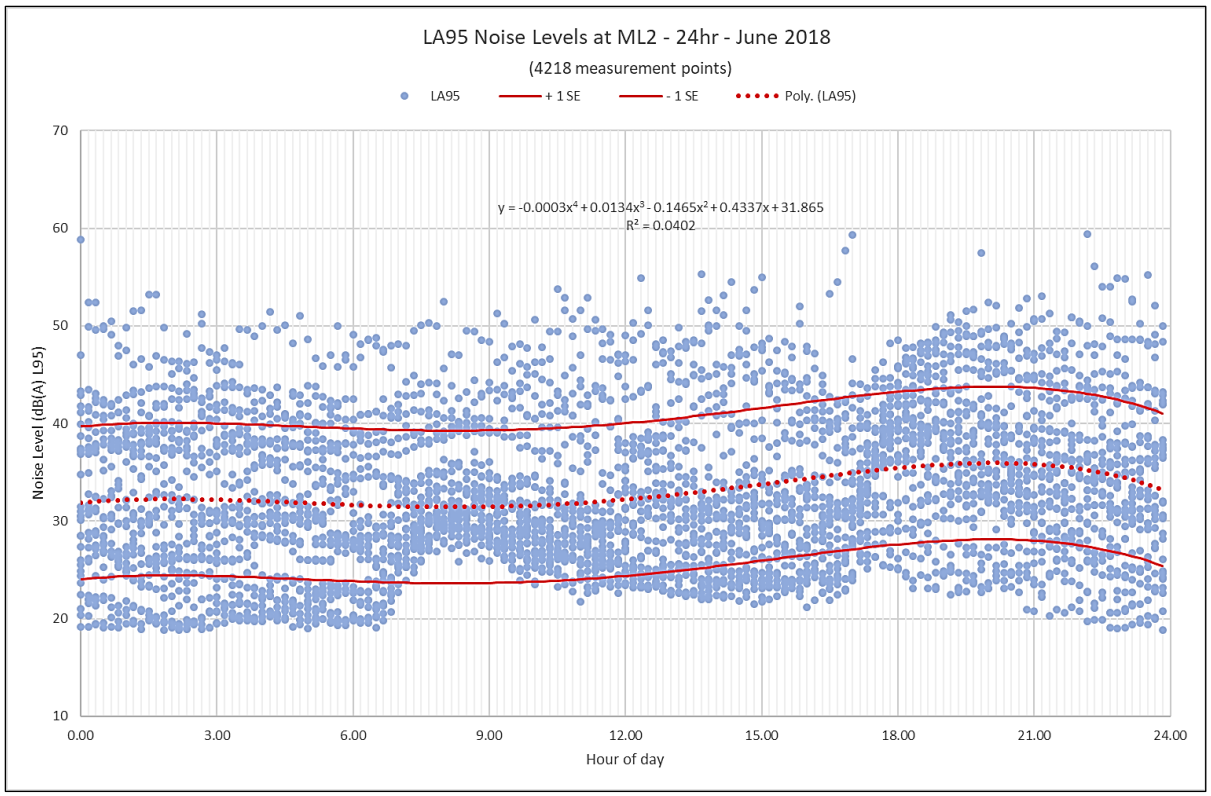


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

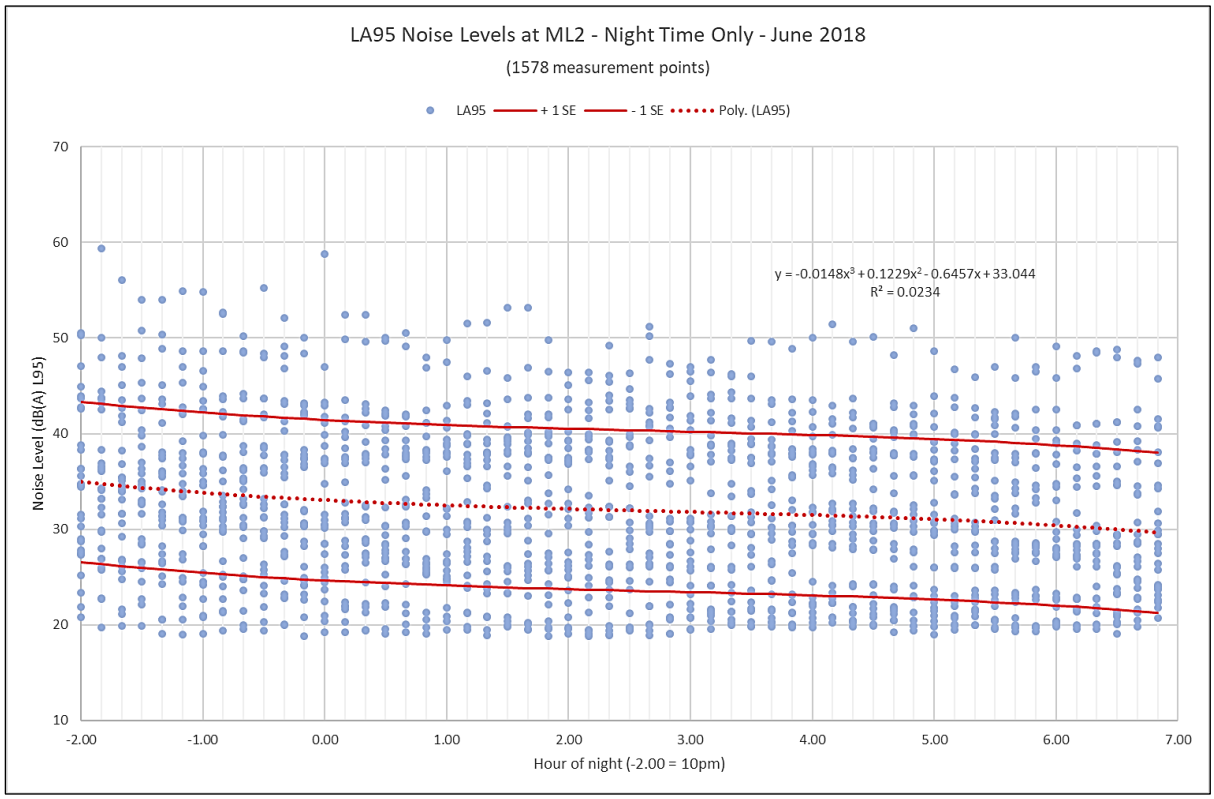


June 2018 – ML2 (DDF)

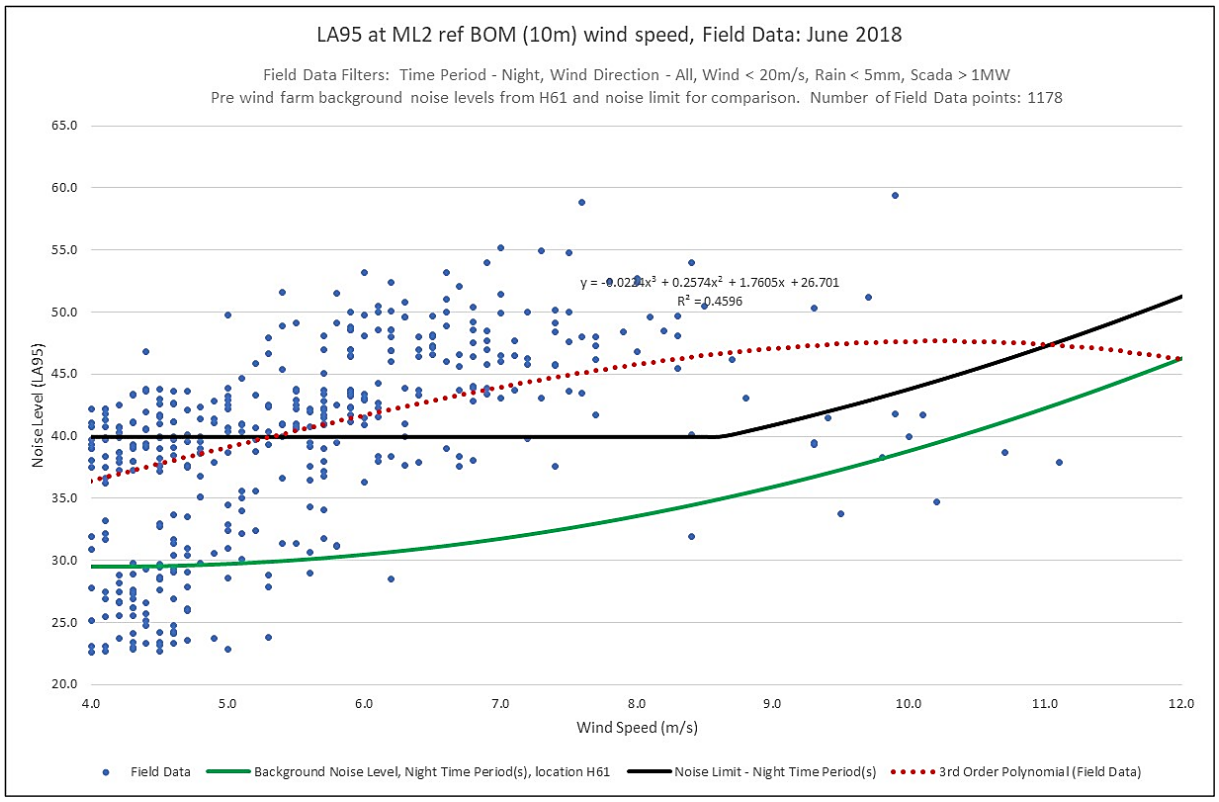
Variation in day and night sound levels for the month by time of day/night



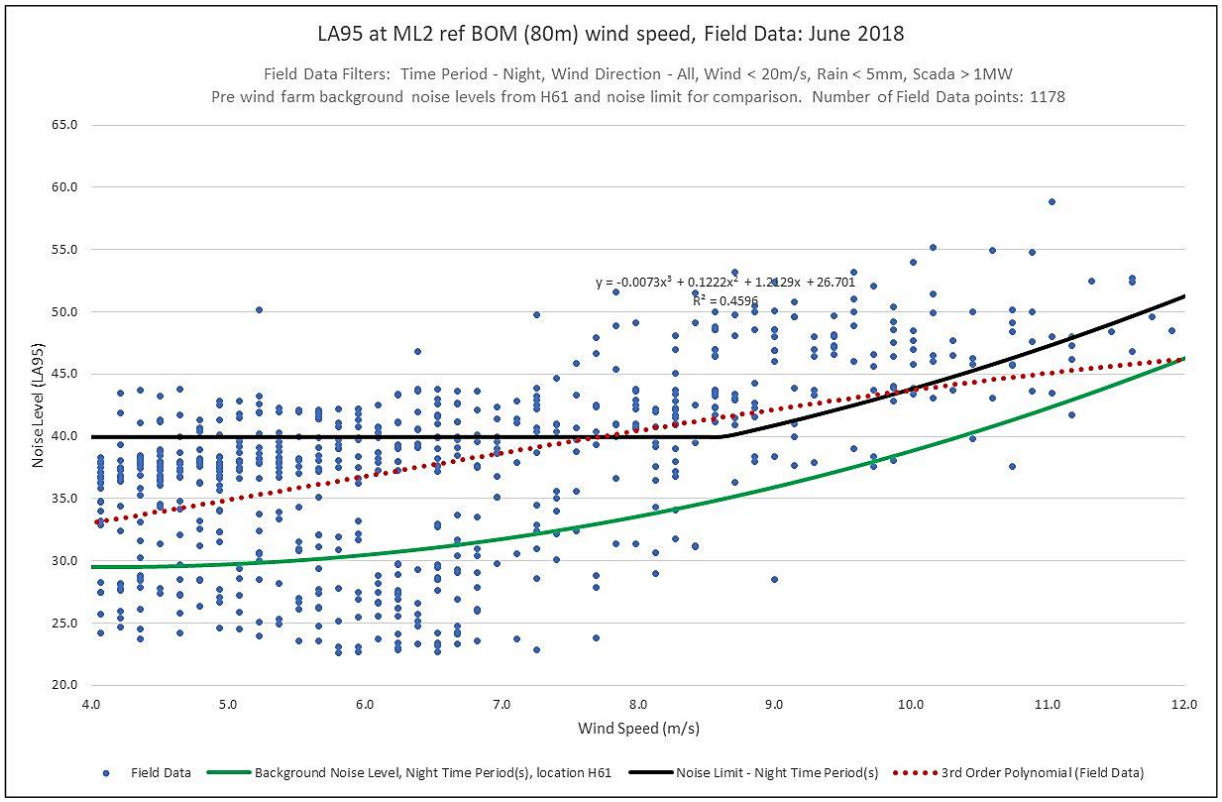
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

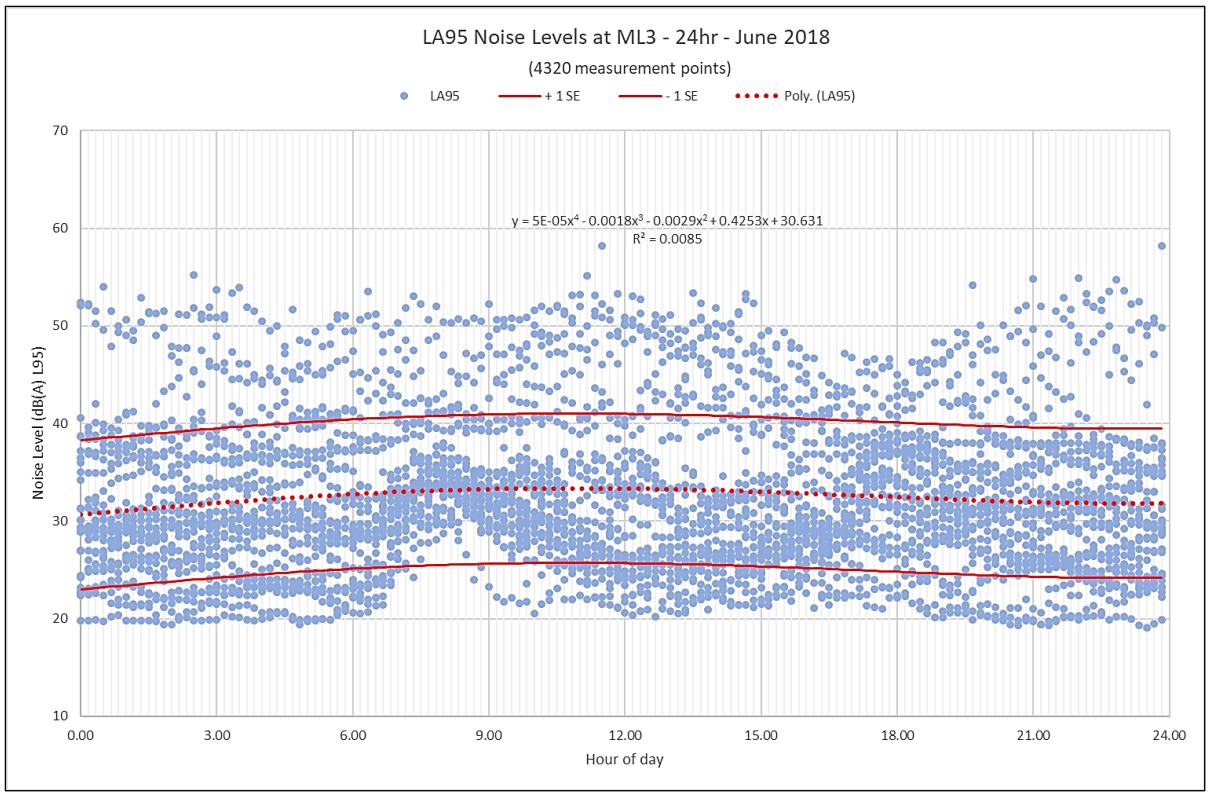


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

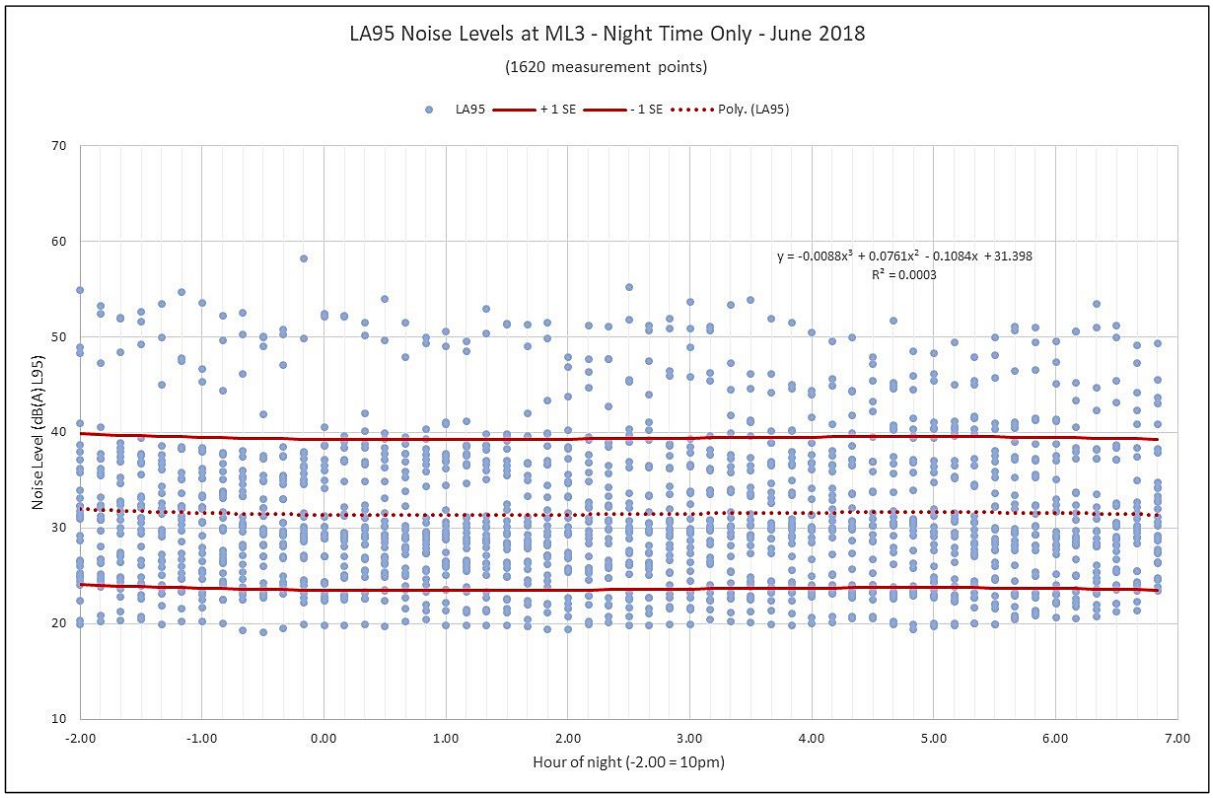


June 2018 – ML3 (NU)

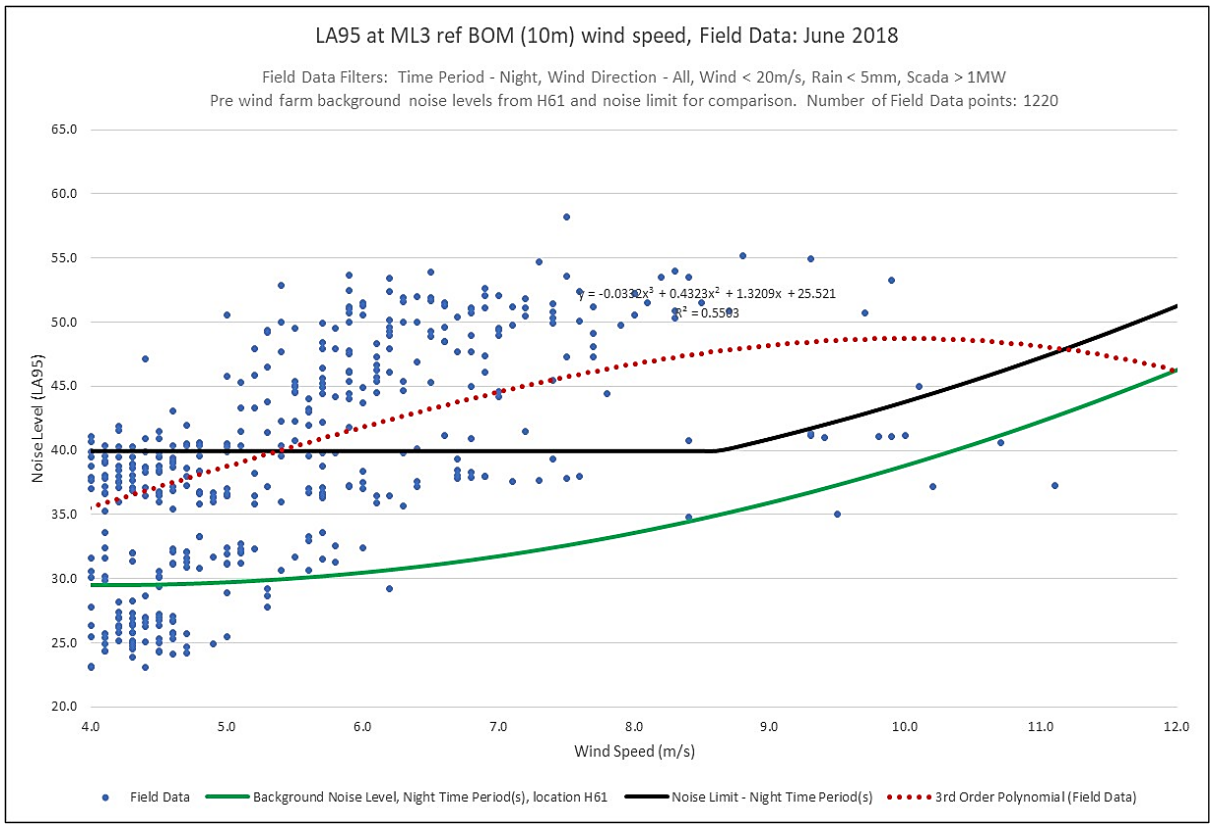
Variation in day and night sound levels for the month by time of day/night



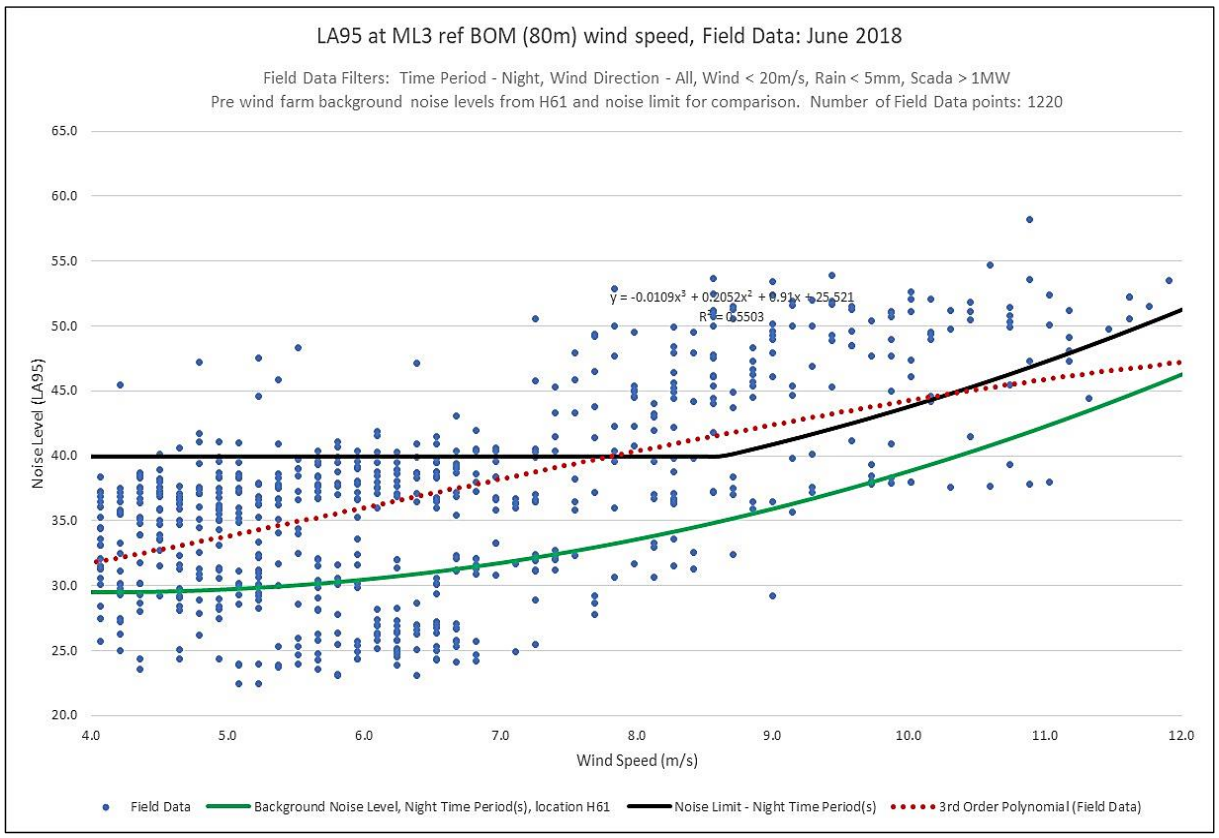
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

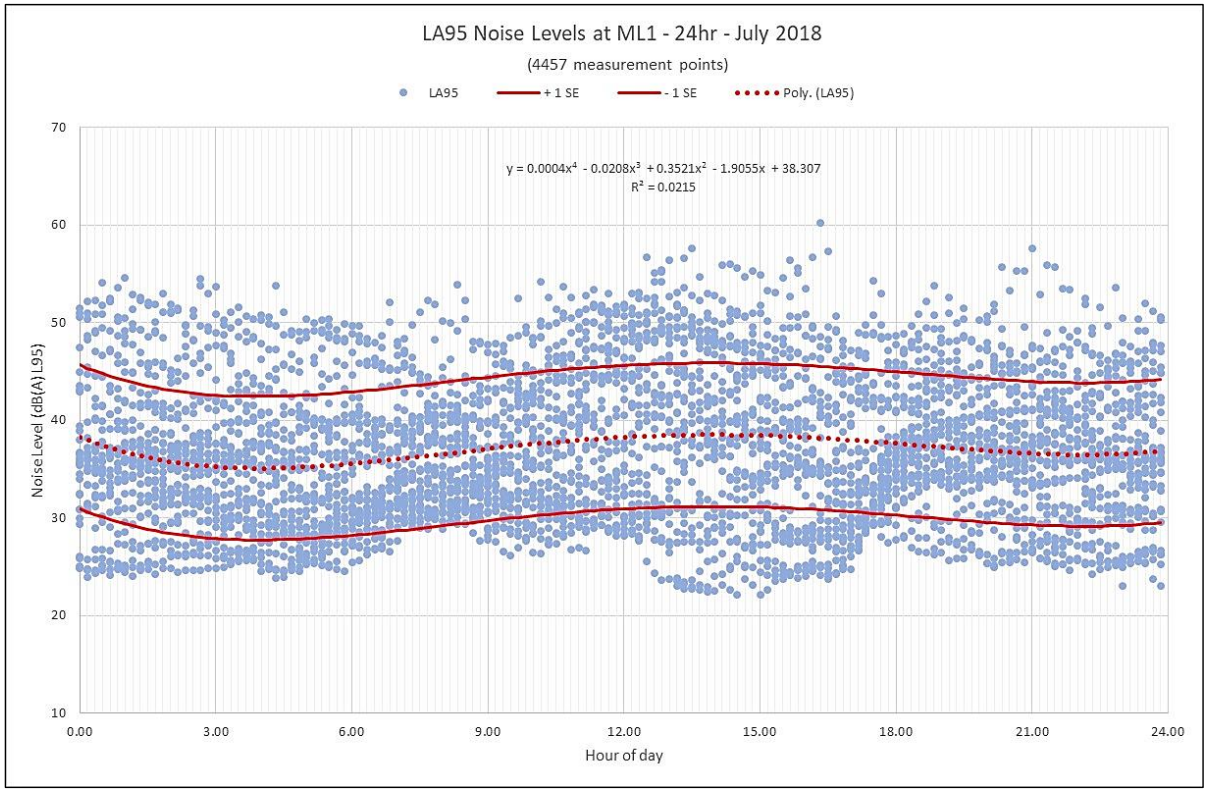


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

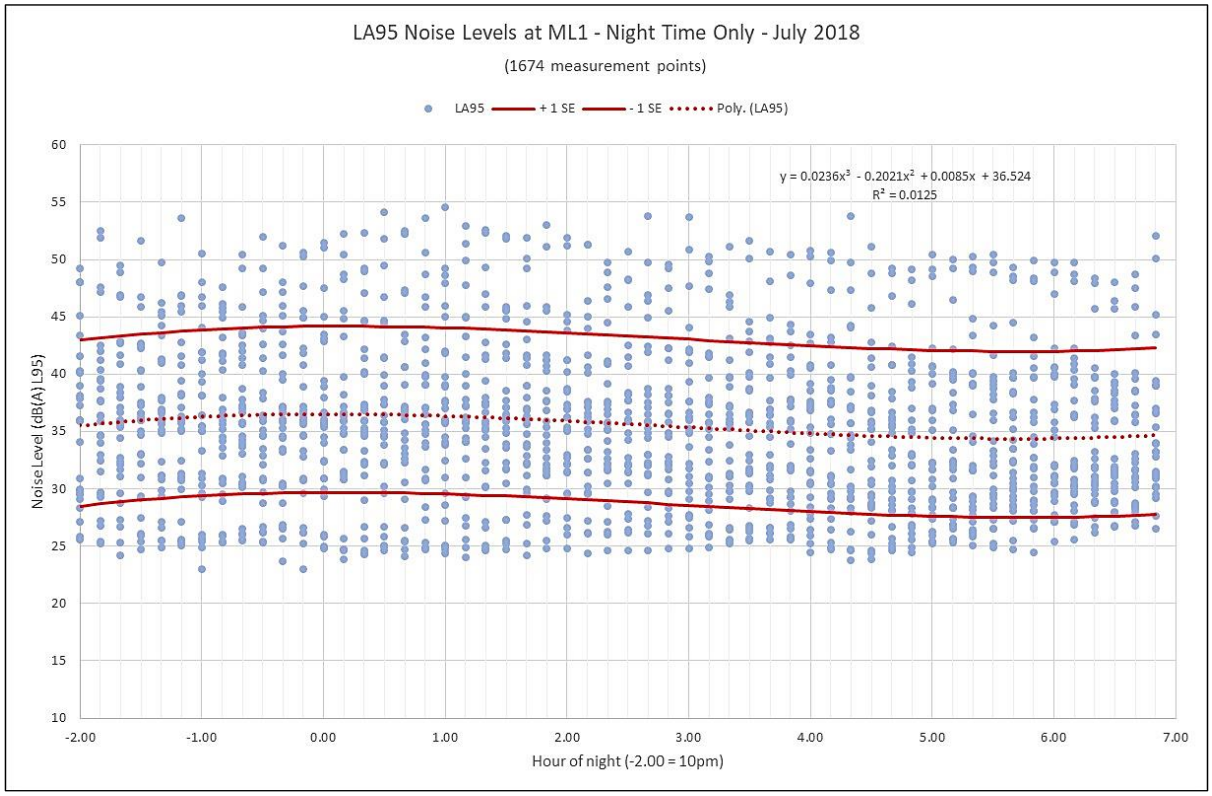


July 2018

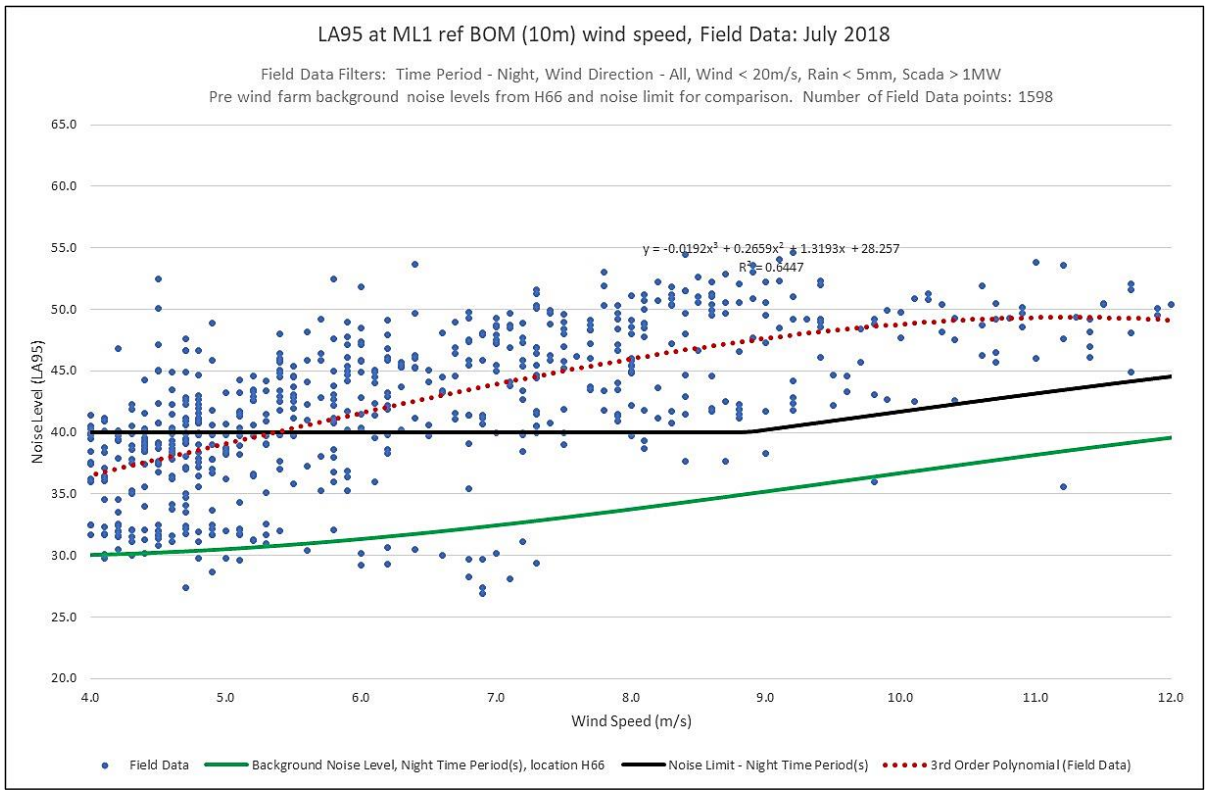
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



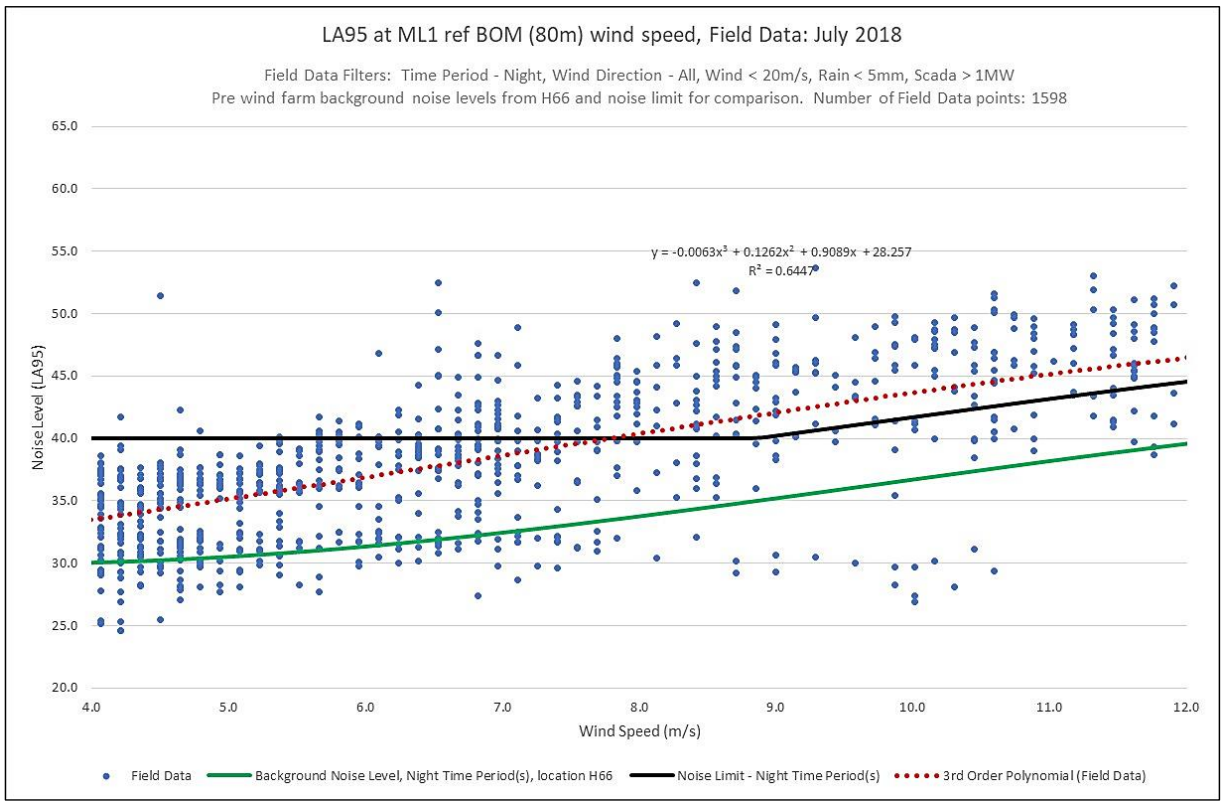
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

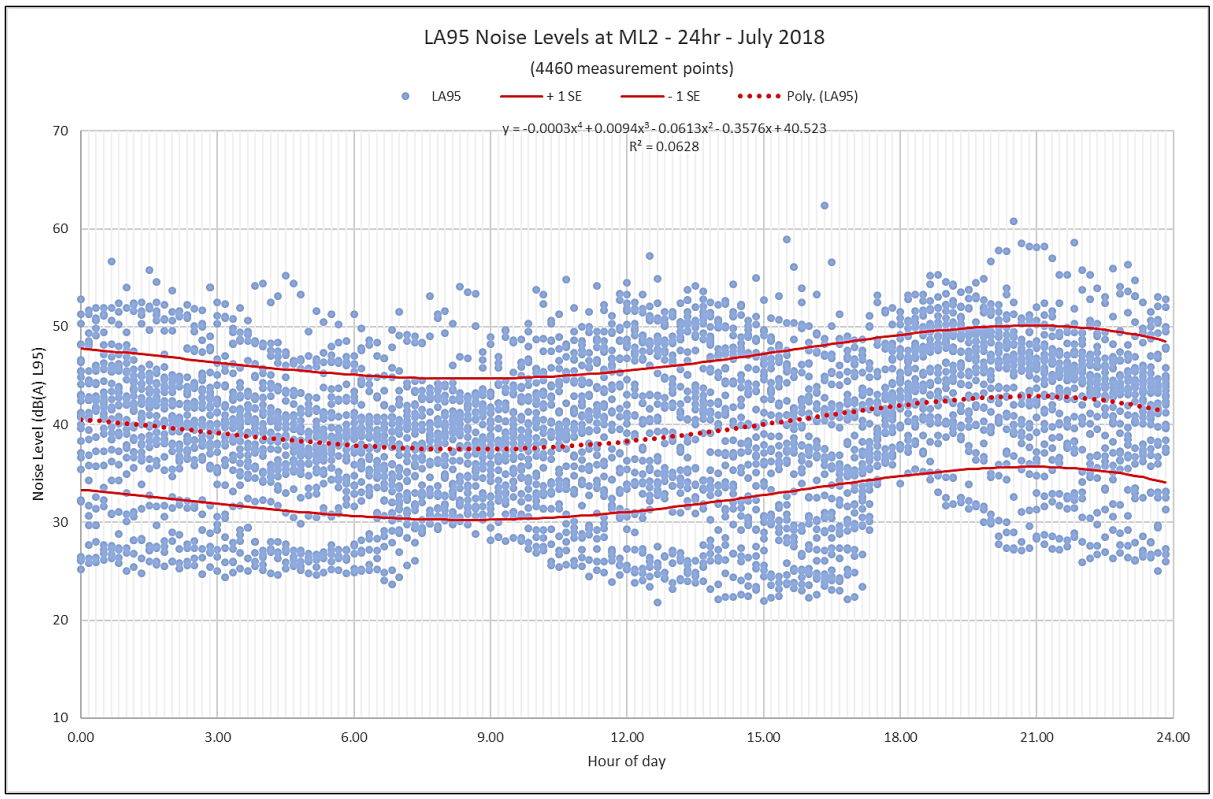


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

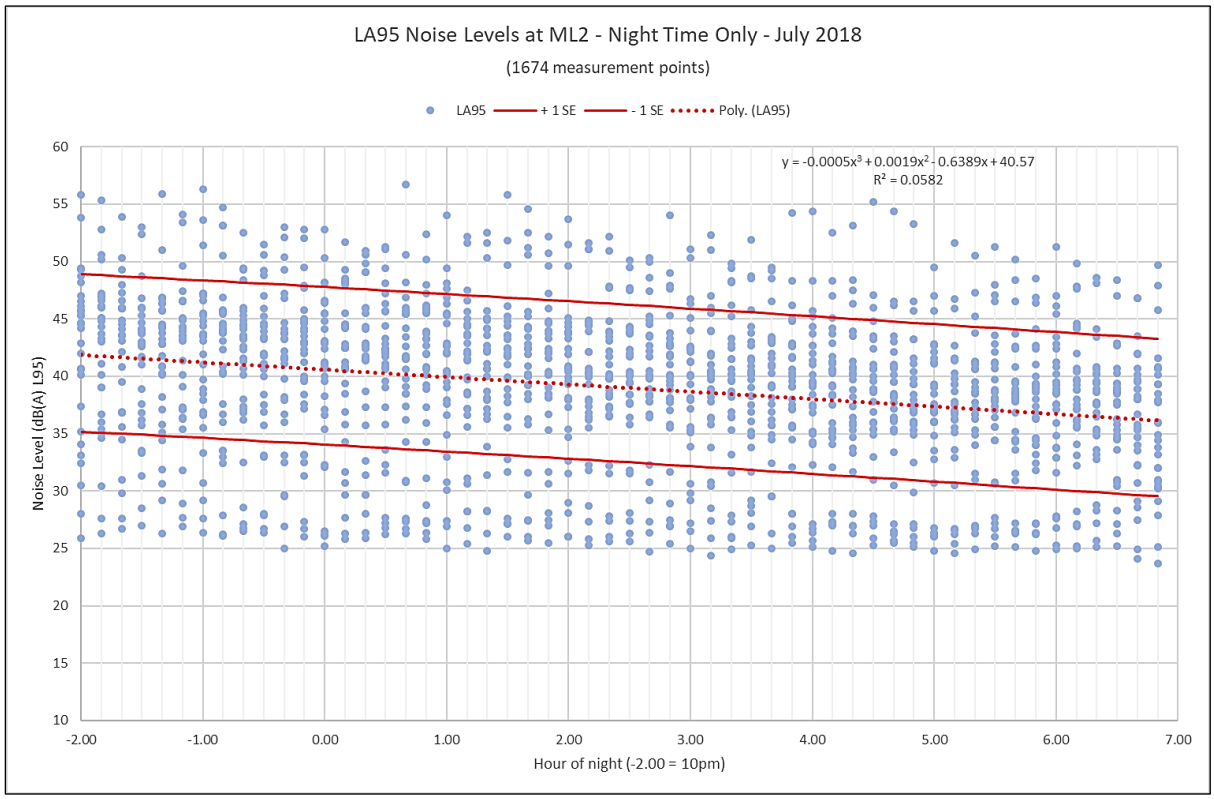


July 2018 – ML2 (DDF)

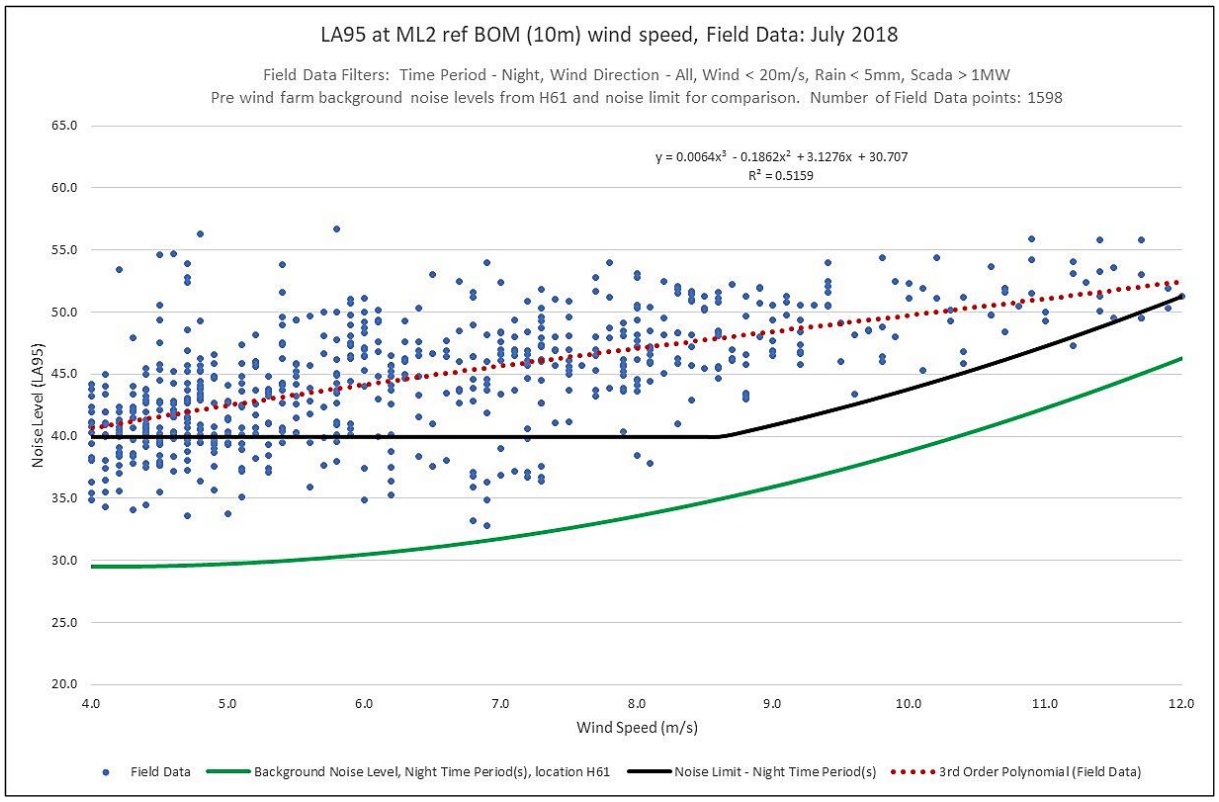
Variation in day and night sound levels for the month by time of day/night



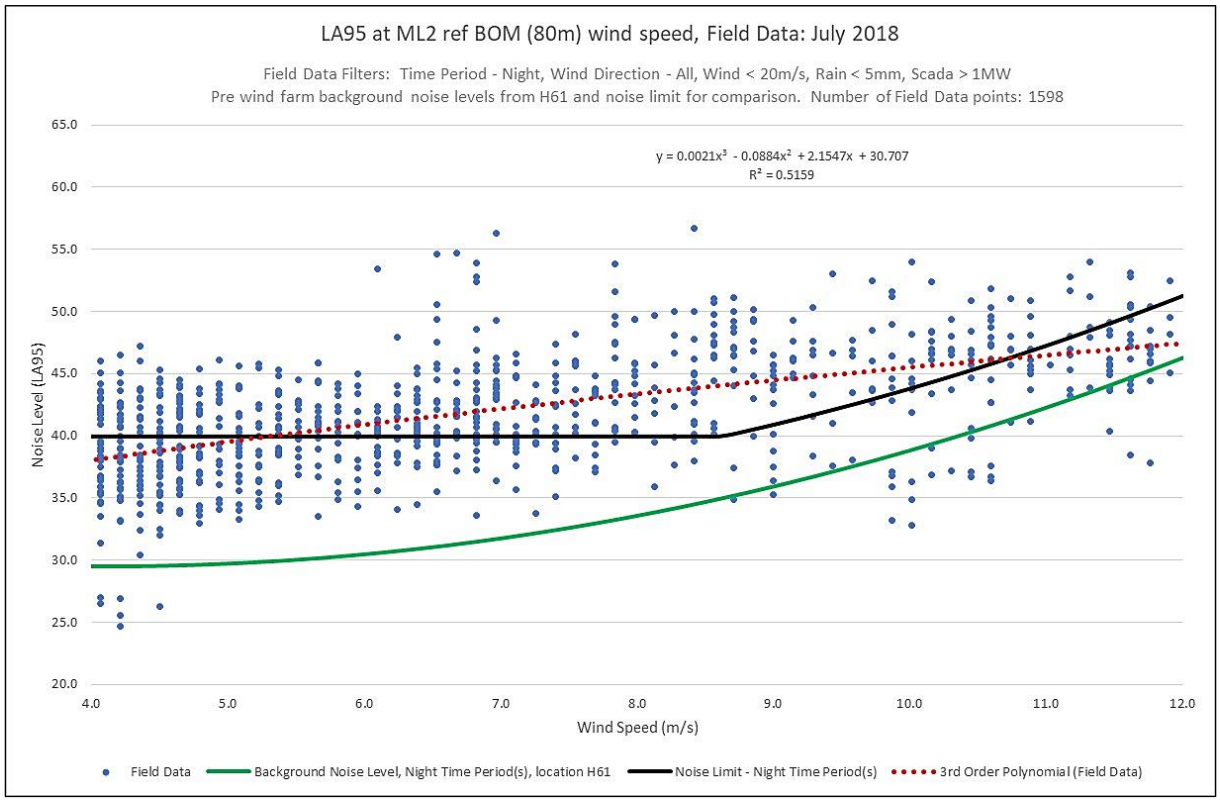
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

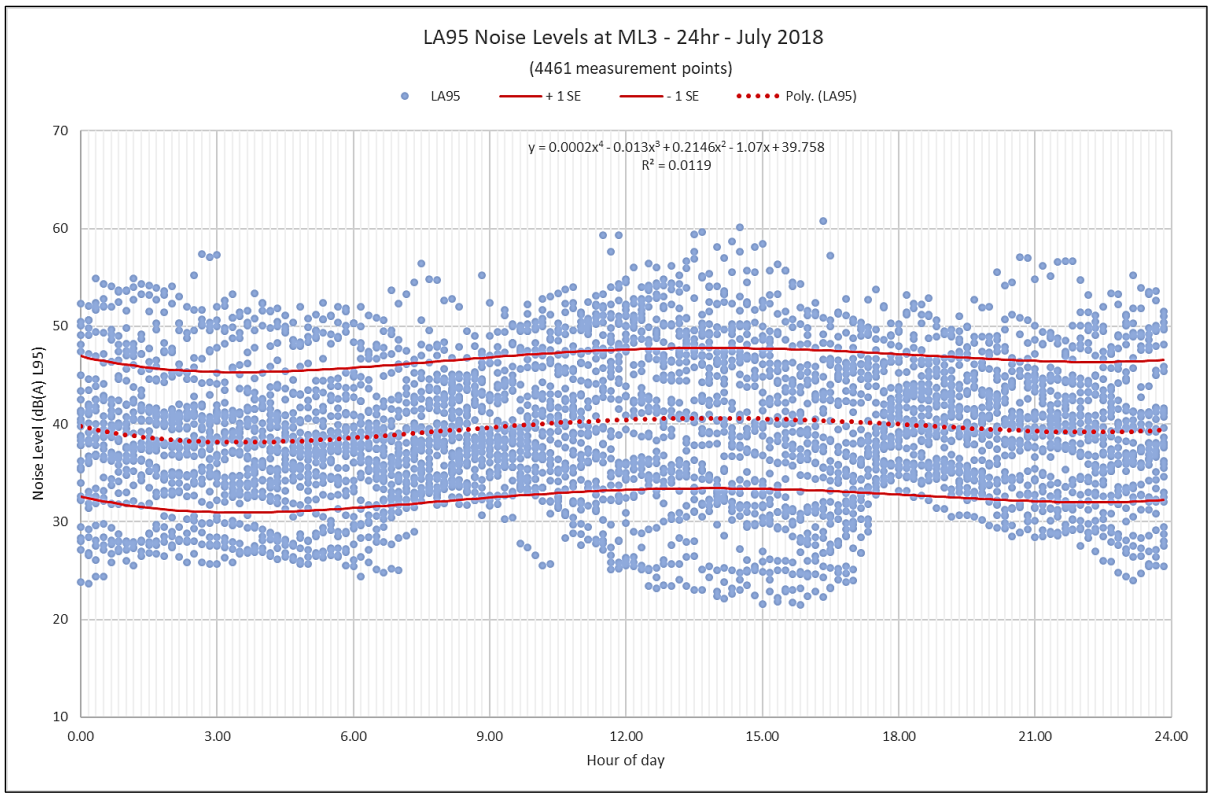


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

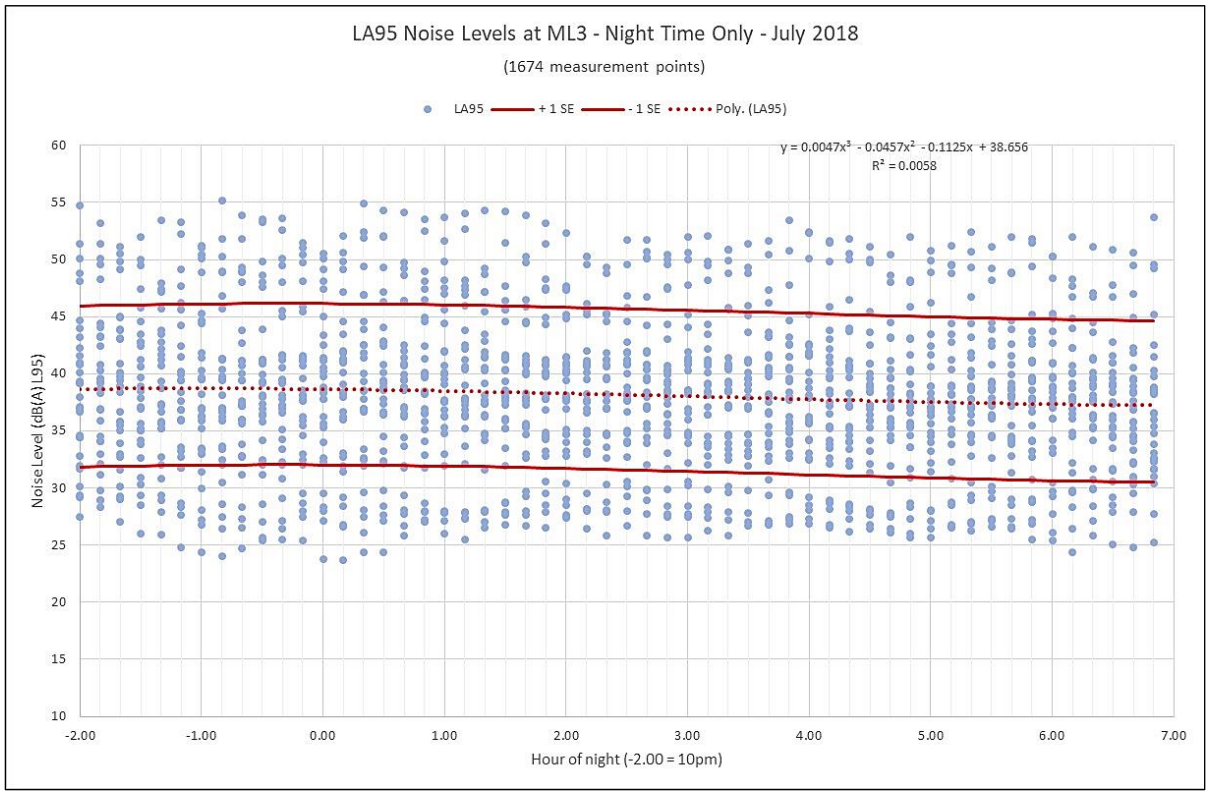


July 2018 – ML3 (NU)

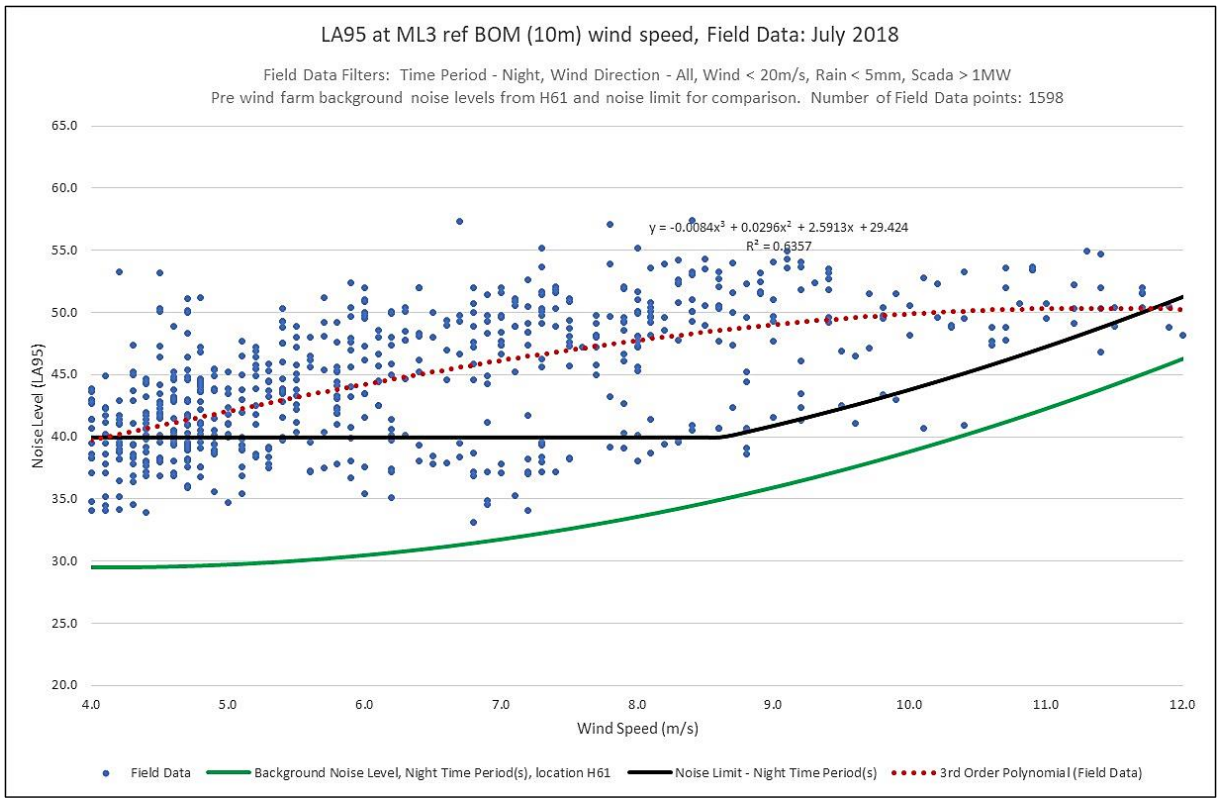
Variation in day and night sound levels for the month by time of day/night



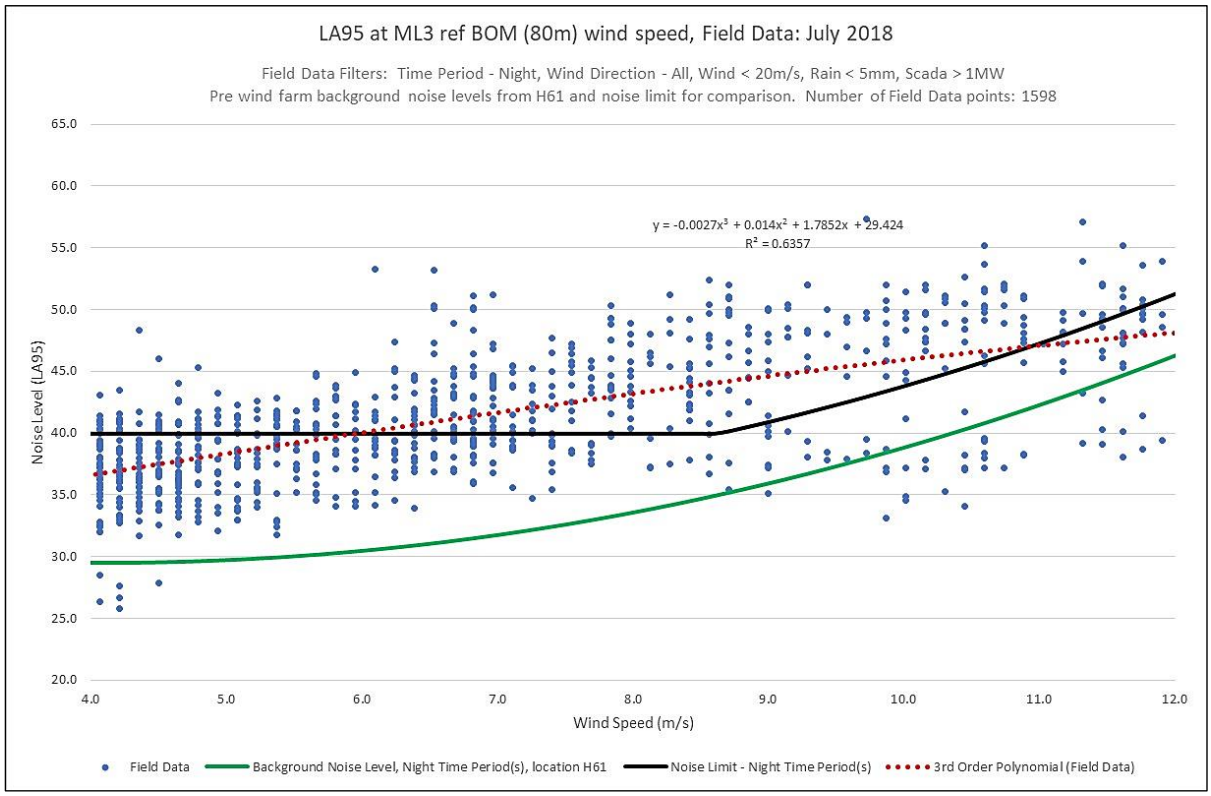
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

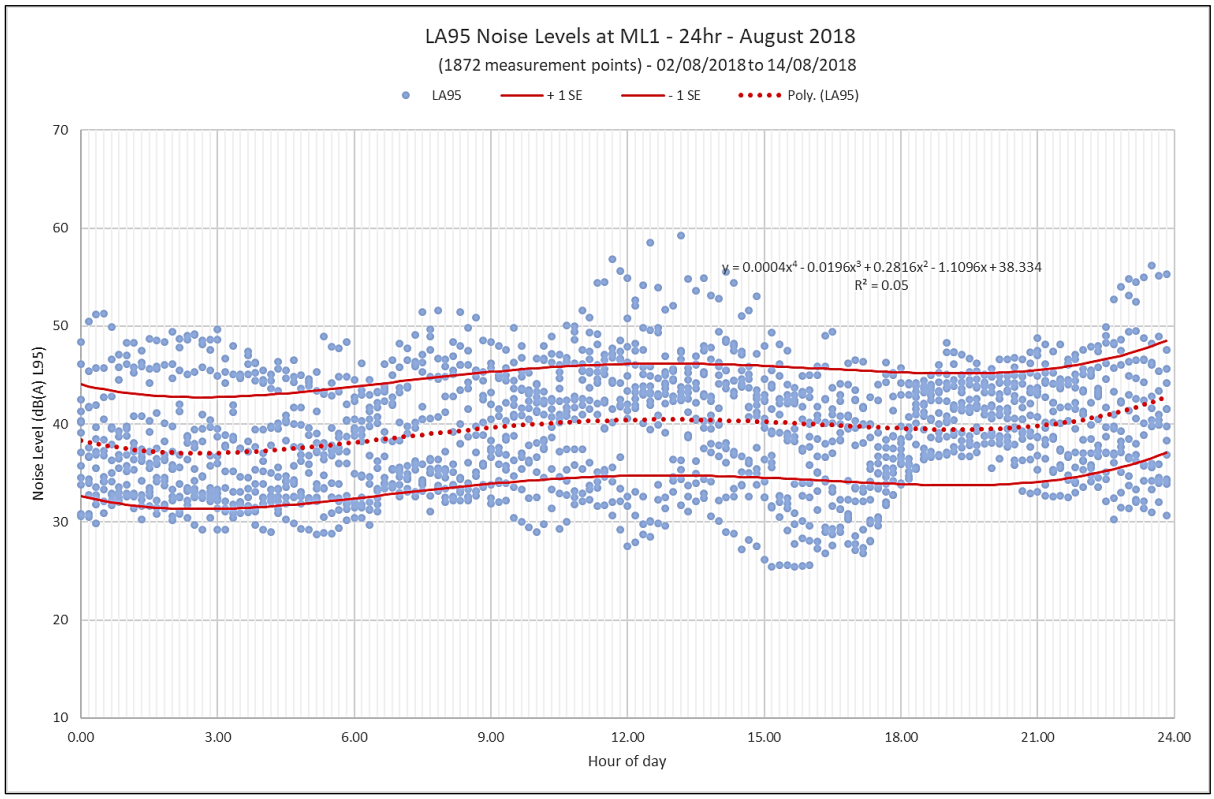


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

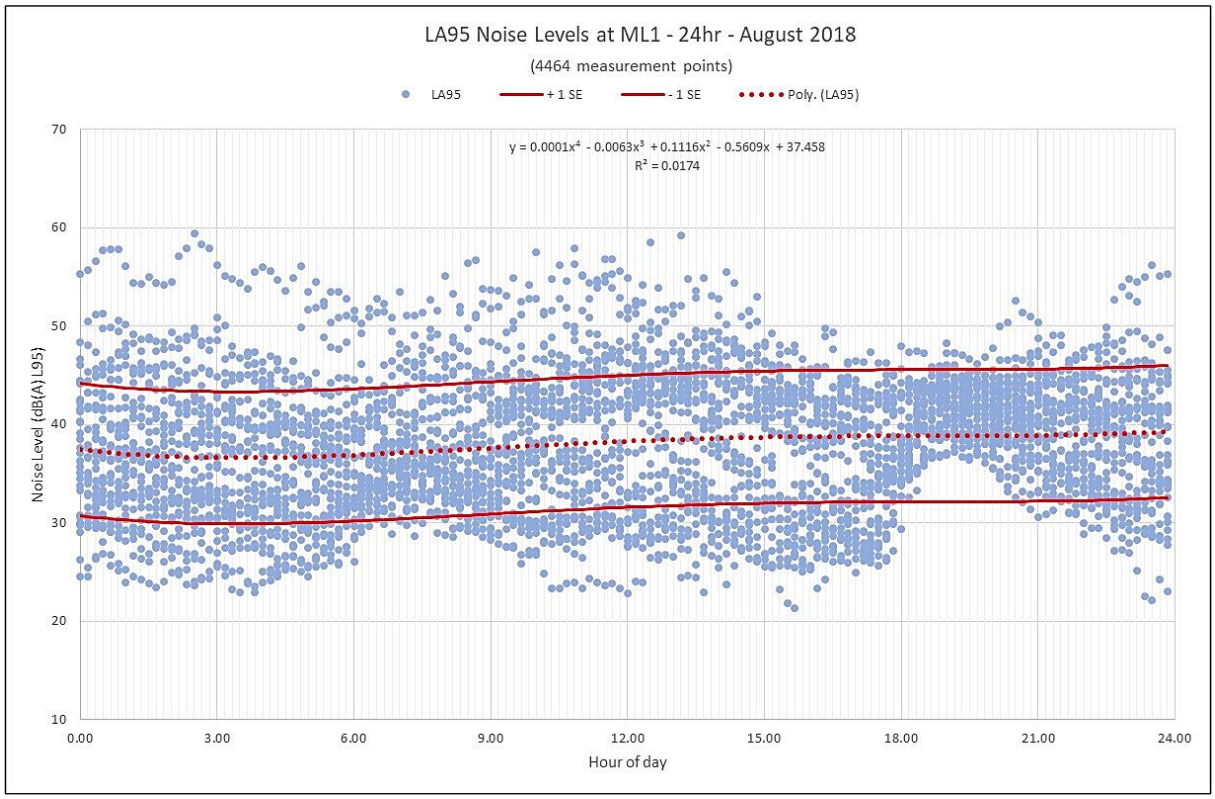


August 2018

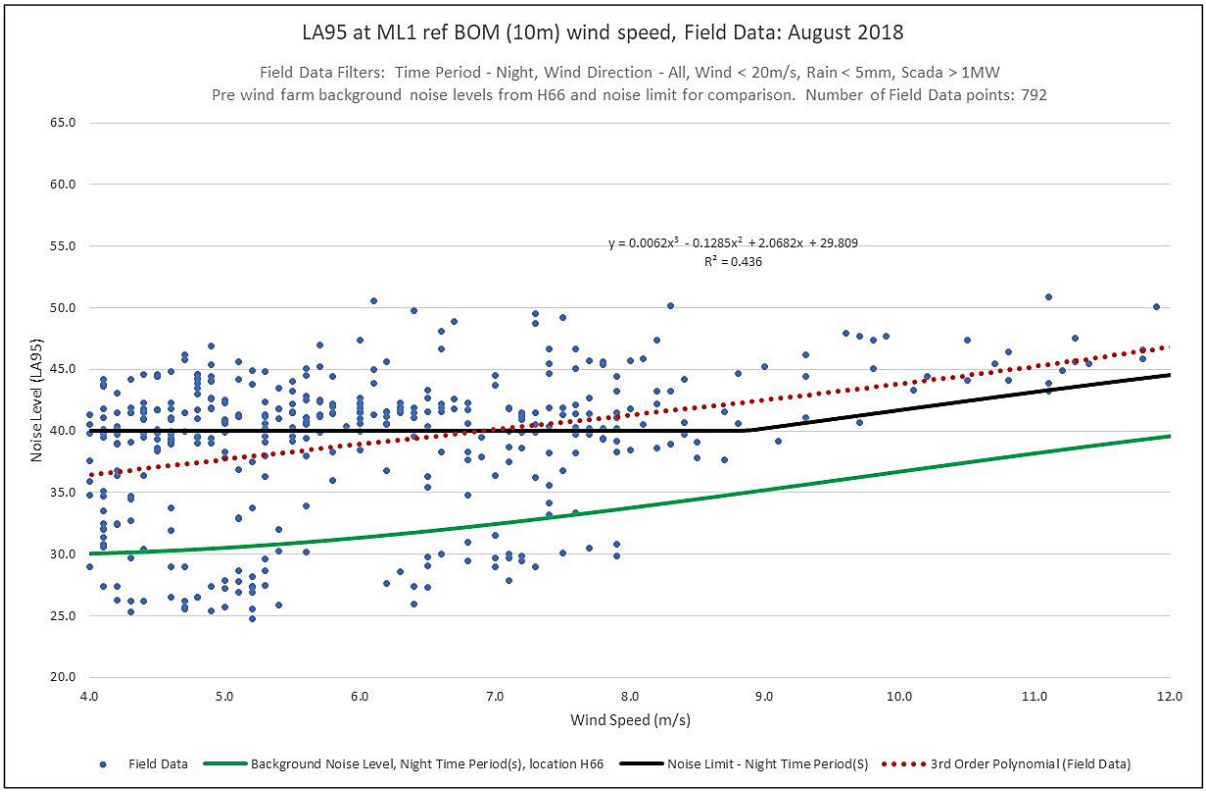
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night – TURBINES OFF



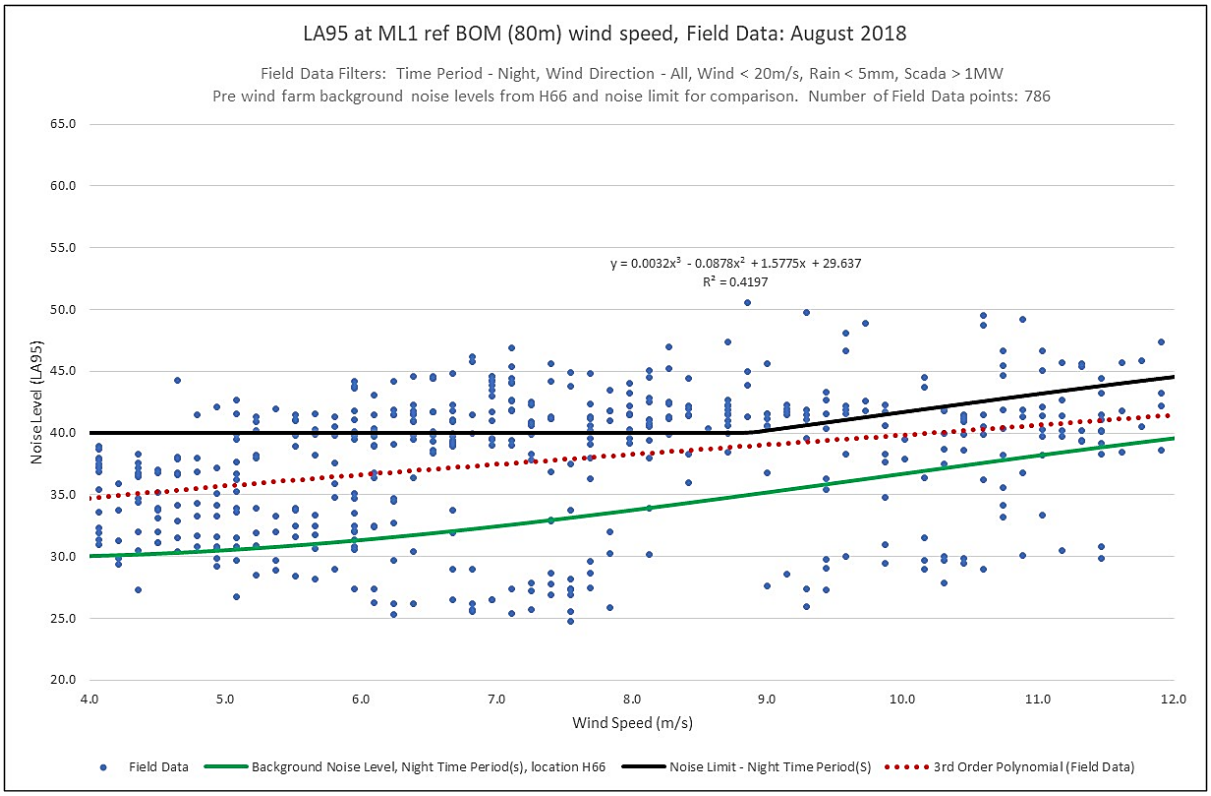
Variation in day and night sound levels for the month by time of day/night – TURBINES ON



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds; turbines ON

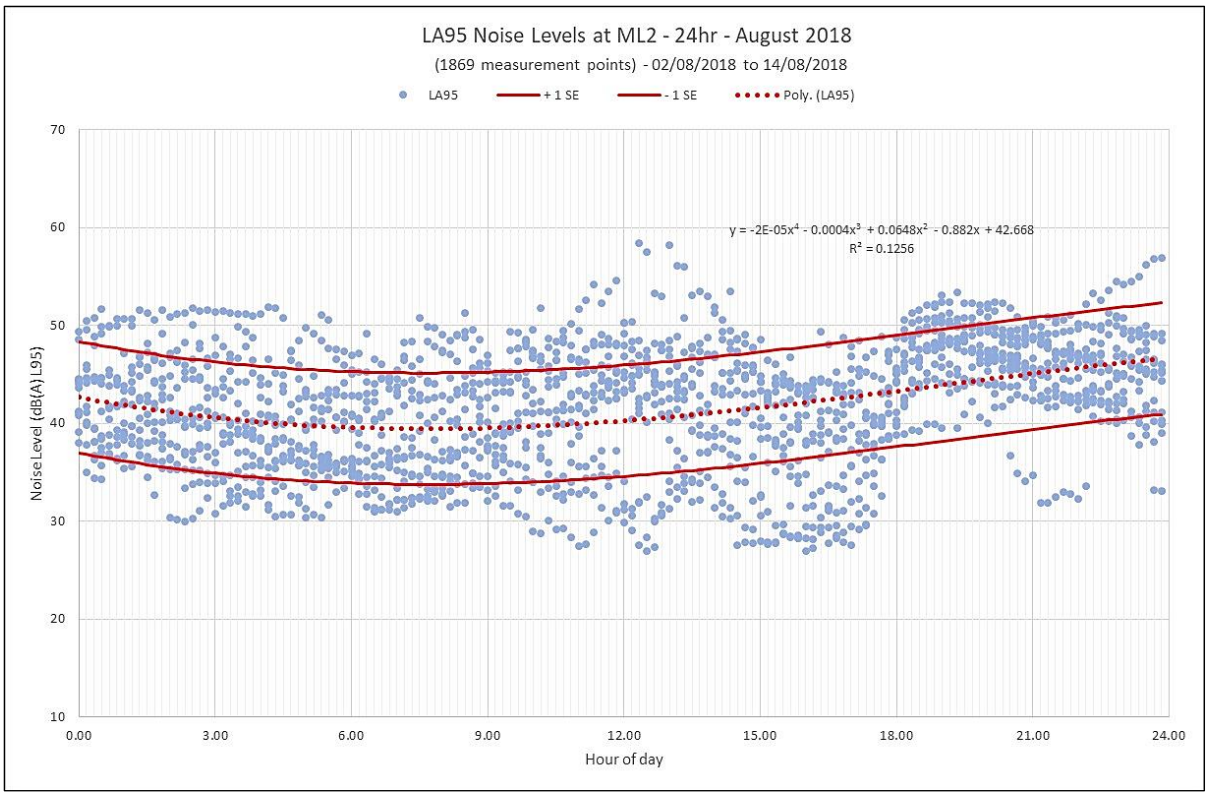


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds; turbines ON

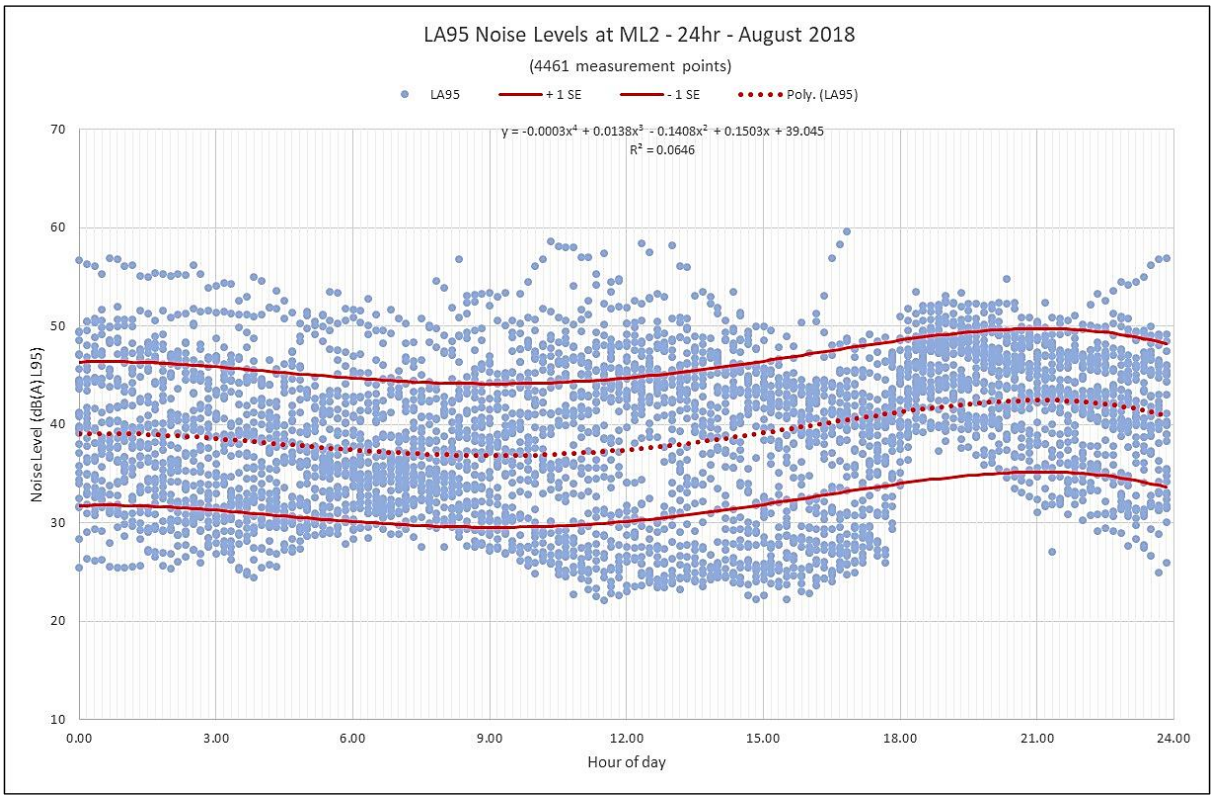


August 2018 – ML2 (DDF)

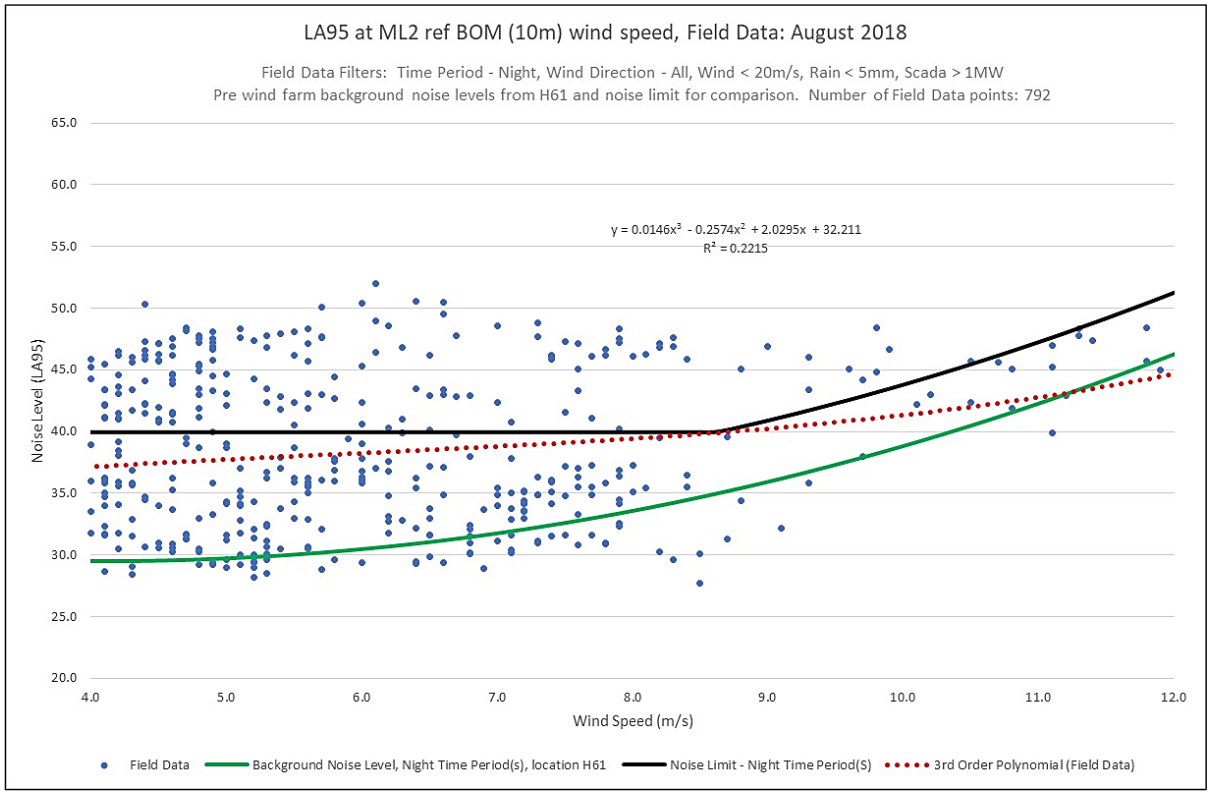
Variation in day and night sound levels for the month by time of day/night – TURBINES OFF



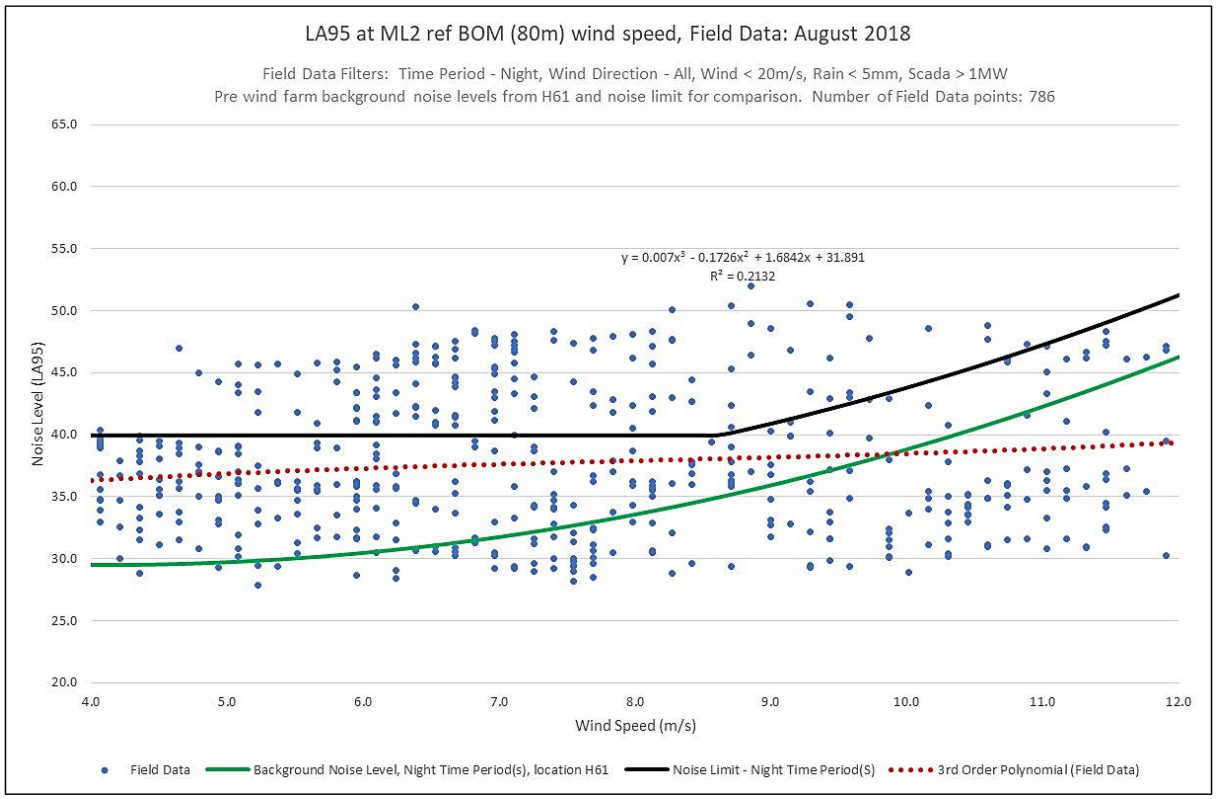
Variation in day and night sound levels for the month by time of day/night – TURBINES ON



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds; turbines ON

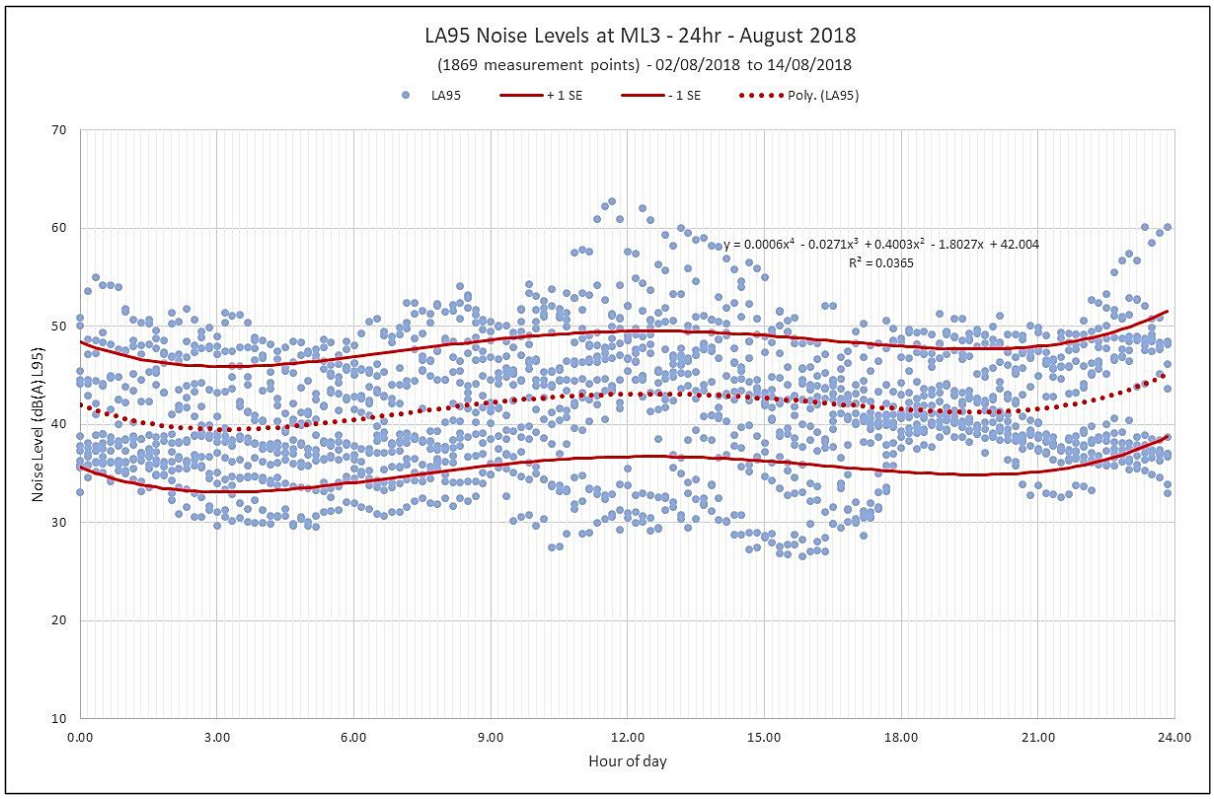


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds; turbines ON

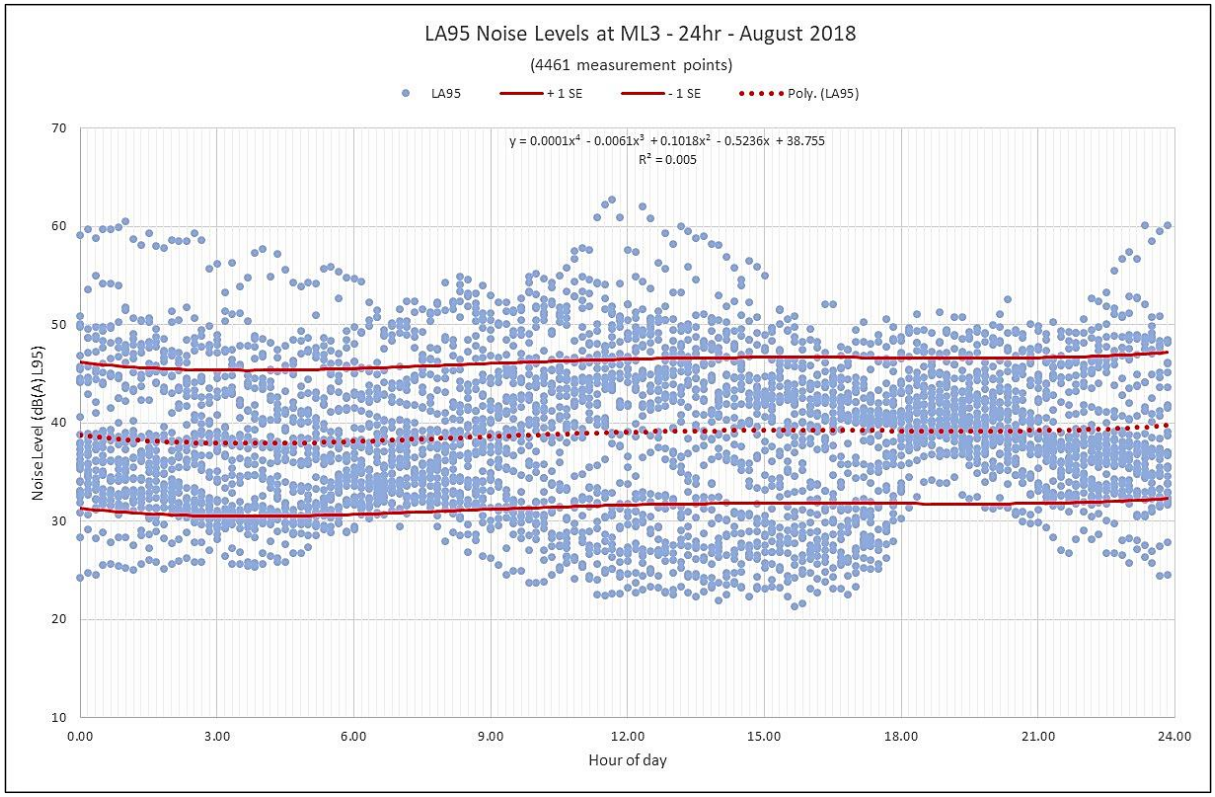


August 2018 – ML3 (NU)

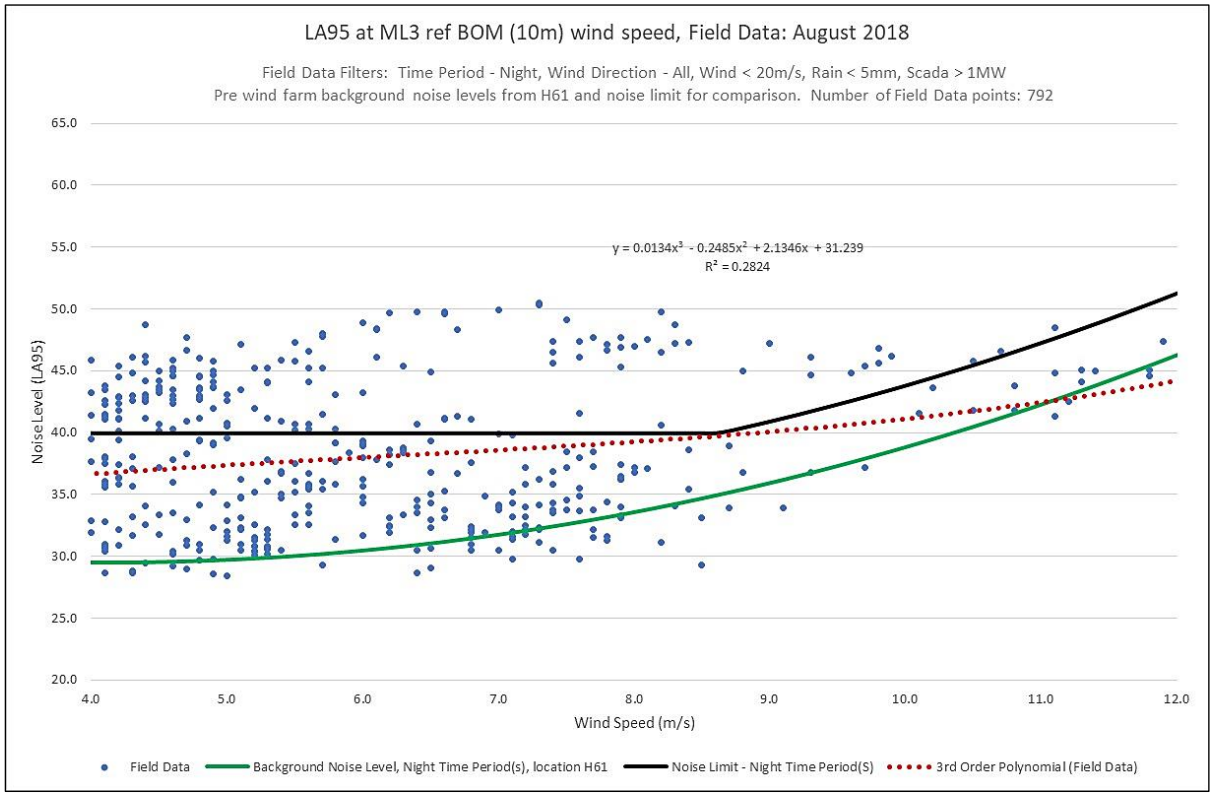
Variation in day and night sound levels for the month by time of day/night – TURBINES OFF



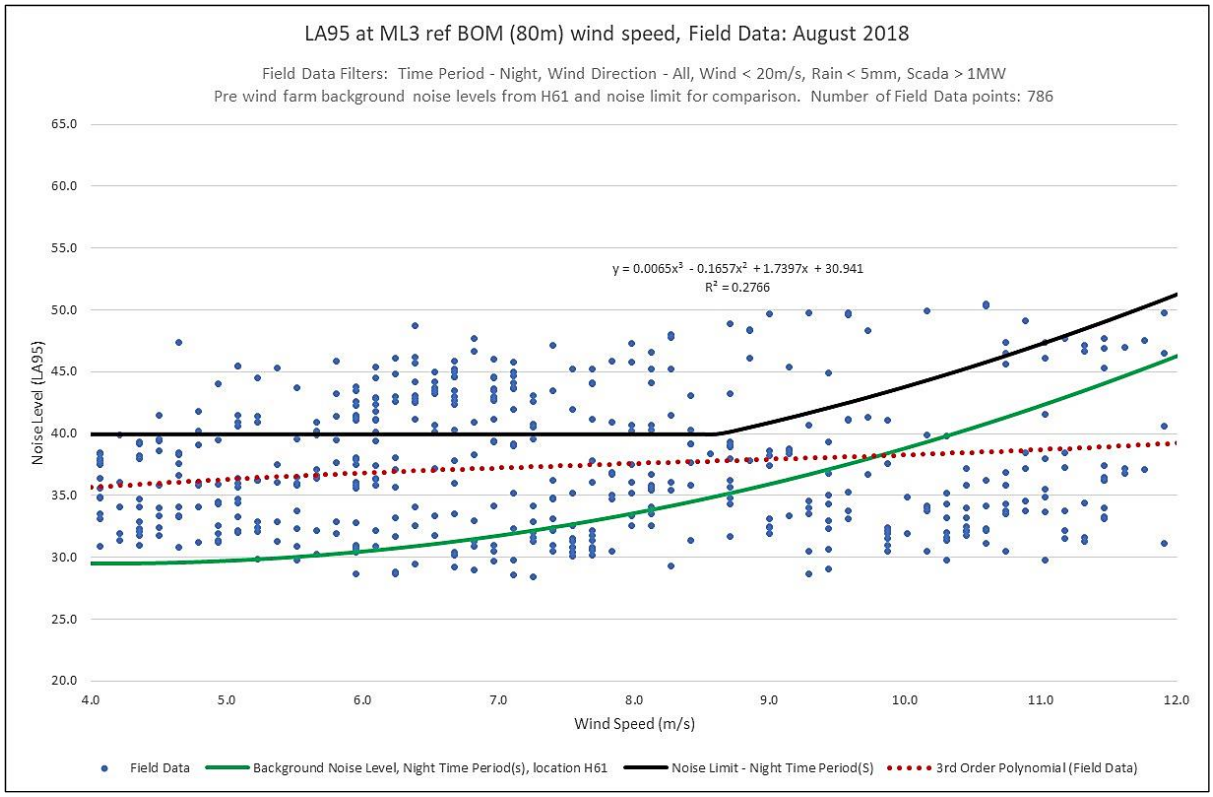
Variation in day and night sound levels for the month by time of day/night – TURBINES ON



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds; turbines ON

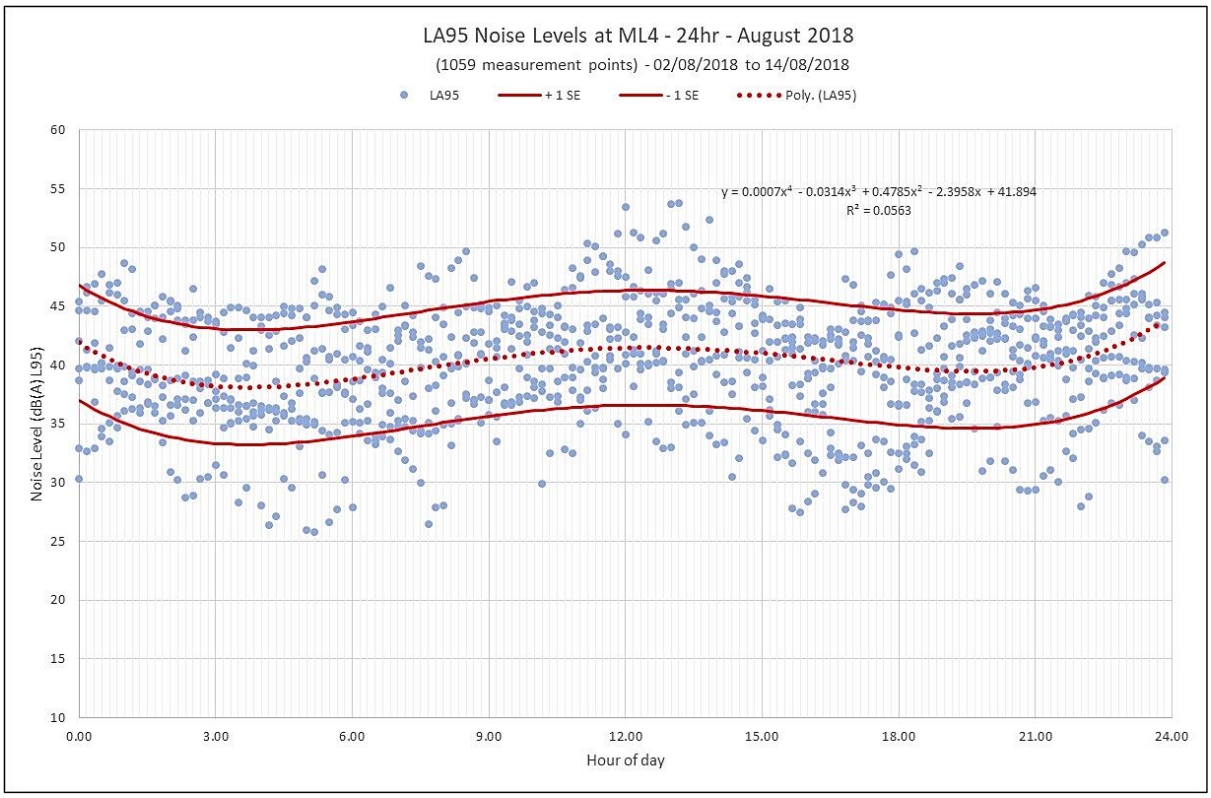


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds; turbines ON

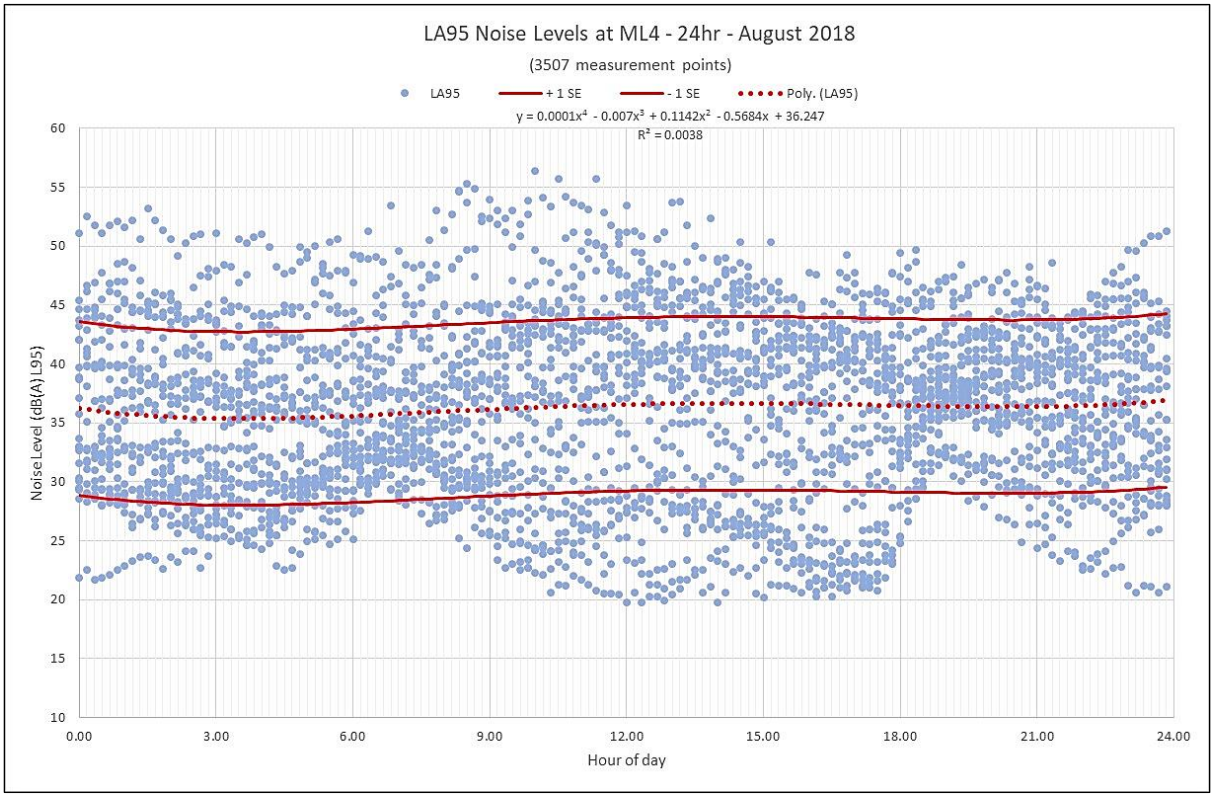


August 2018 – ML4 (DSJ)

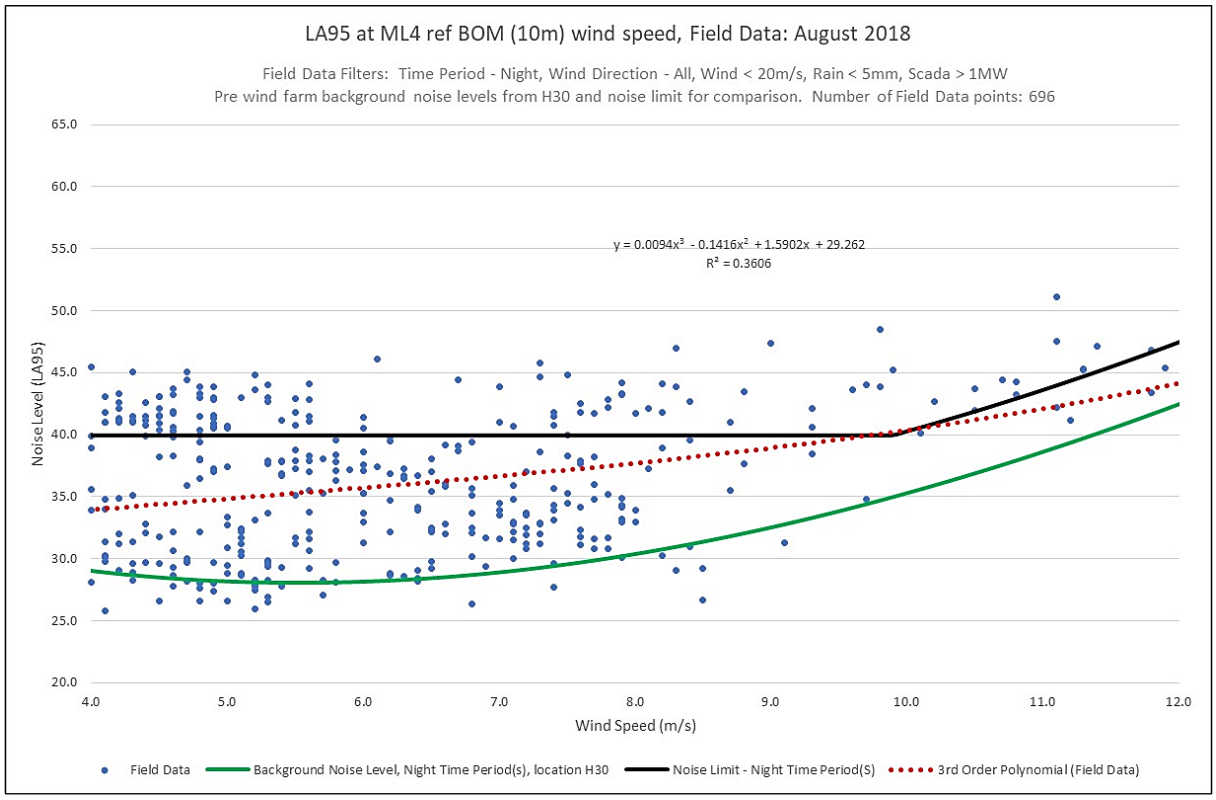
Variation in day and night sound levels for the month by time of day/night – TURBINES OFF



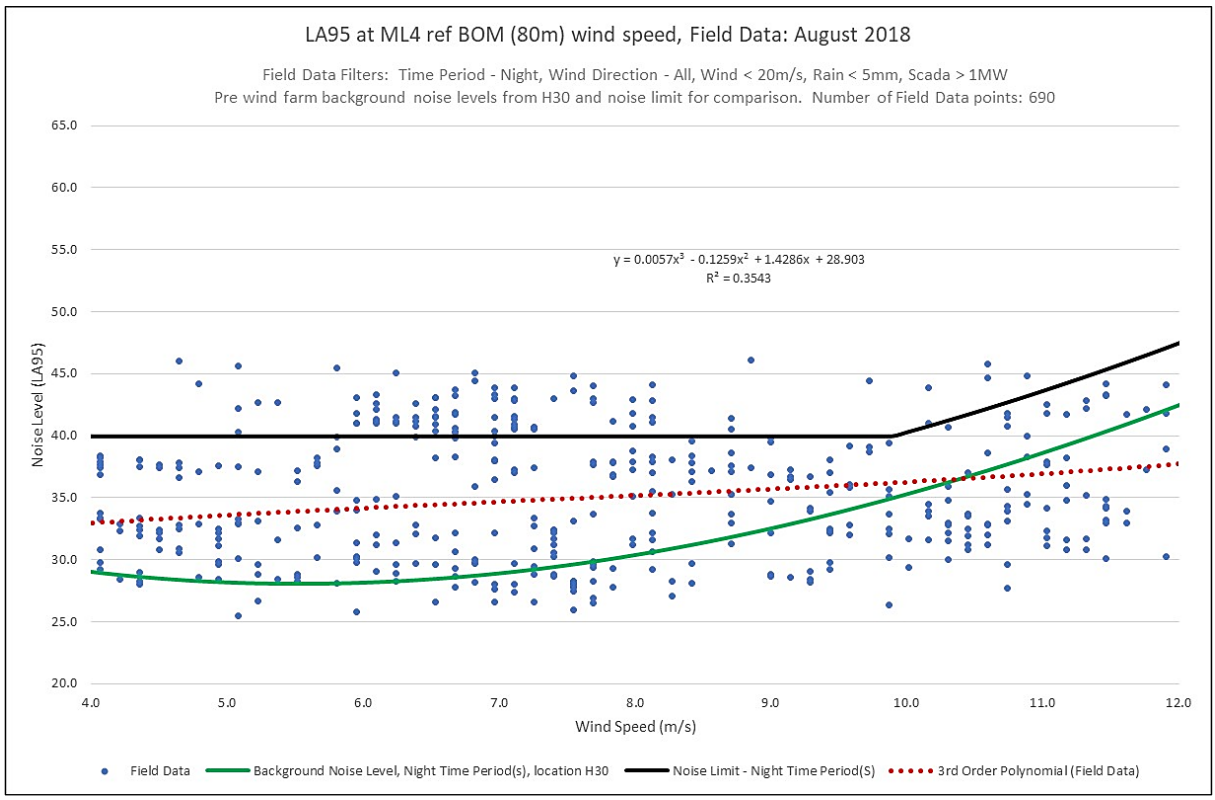
Variation in day and night sound levels for the month by time of day/night – TURBINES ON



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds: turbines ON

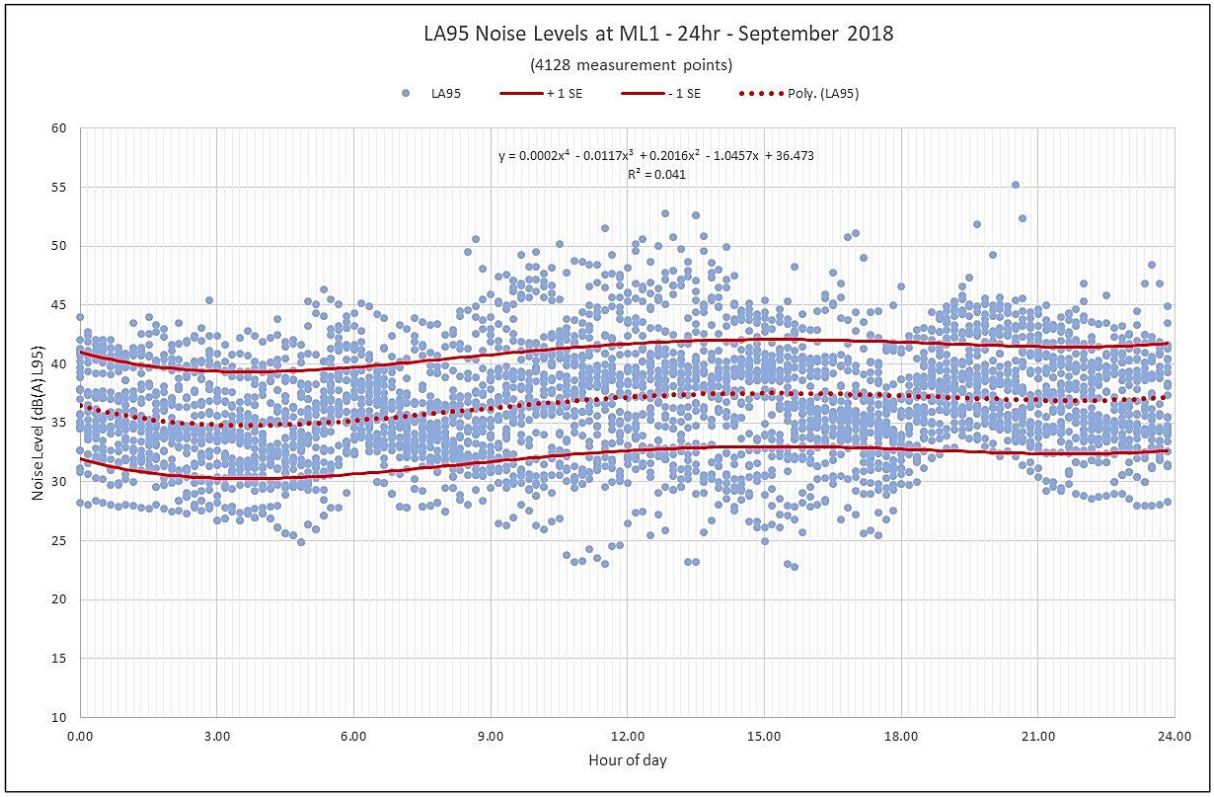


Regression curve of night-time sound levels v. noise limits for the month ref. 810m wind speeds; turbines ON

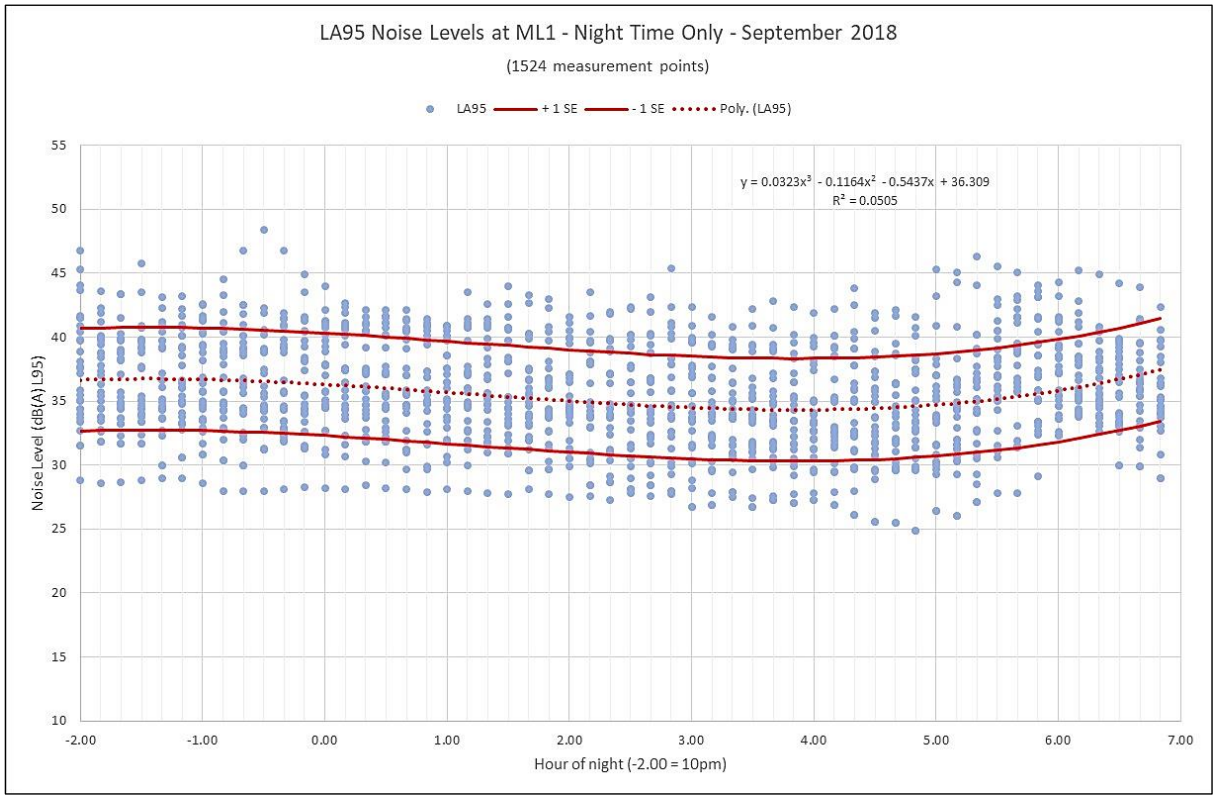


September 2018

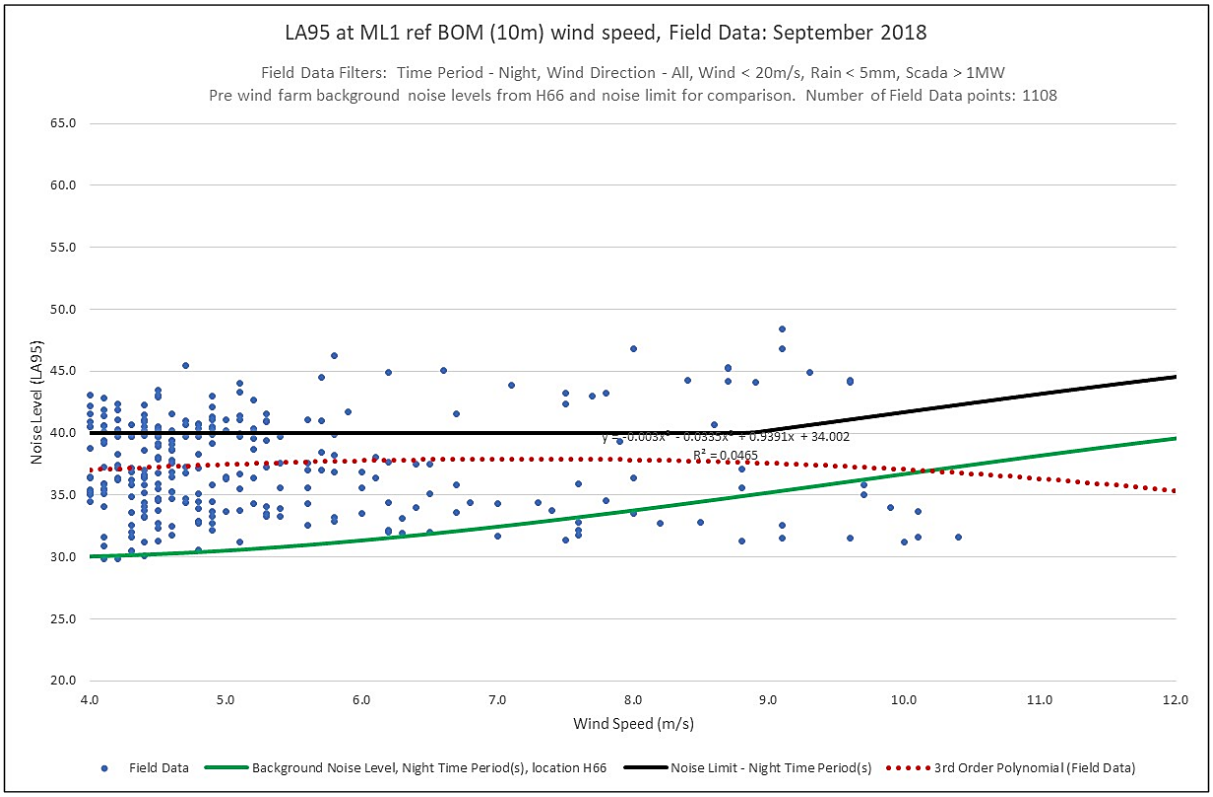
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



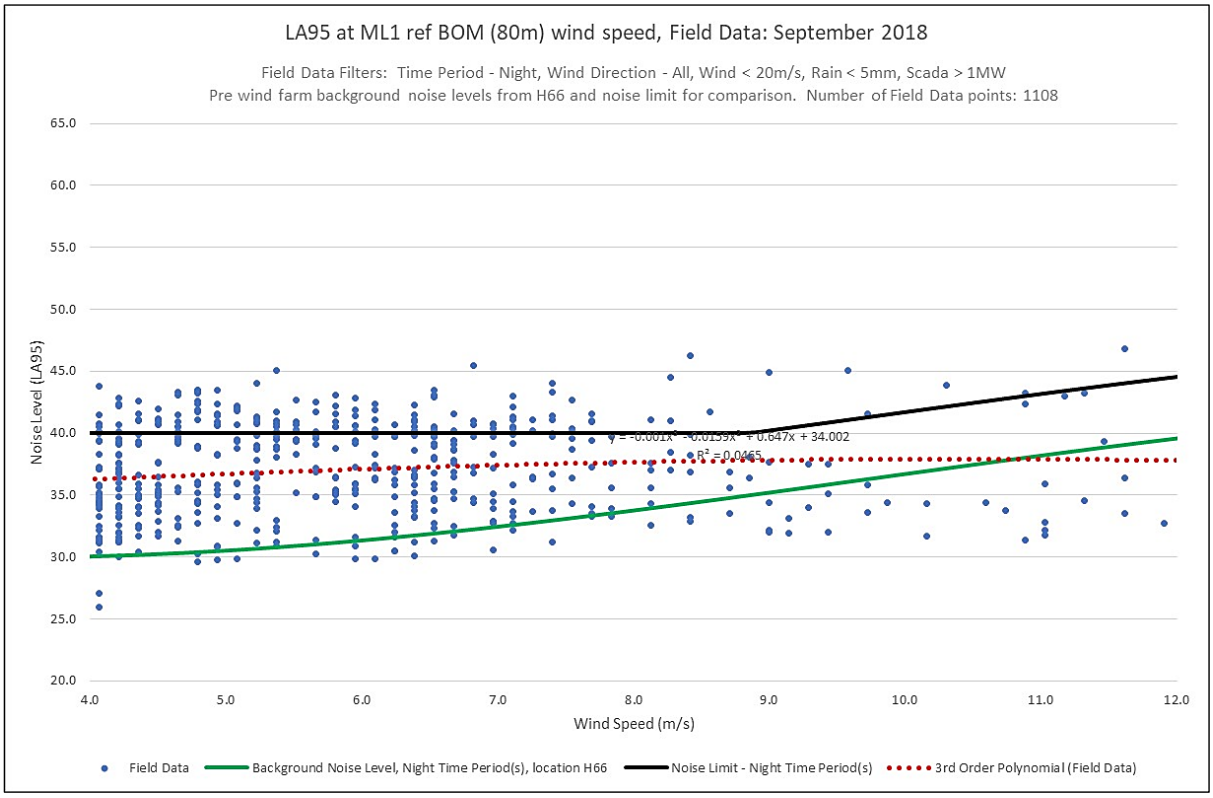
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

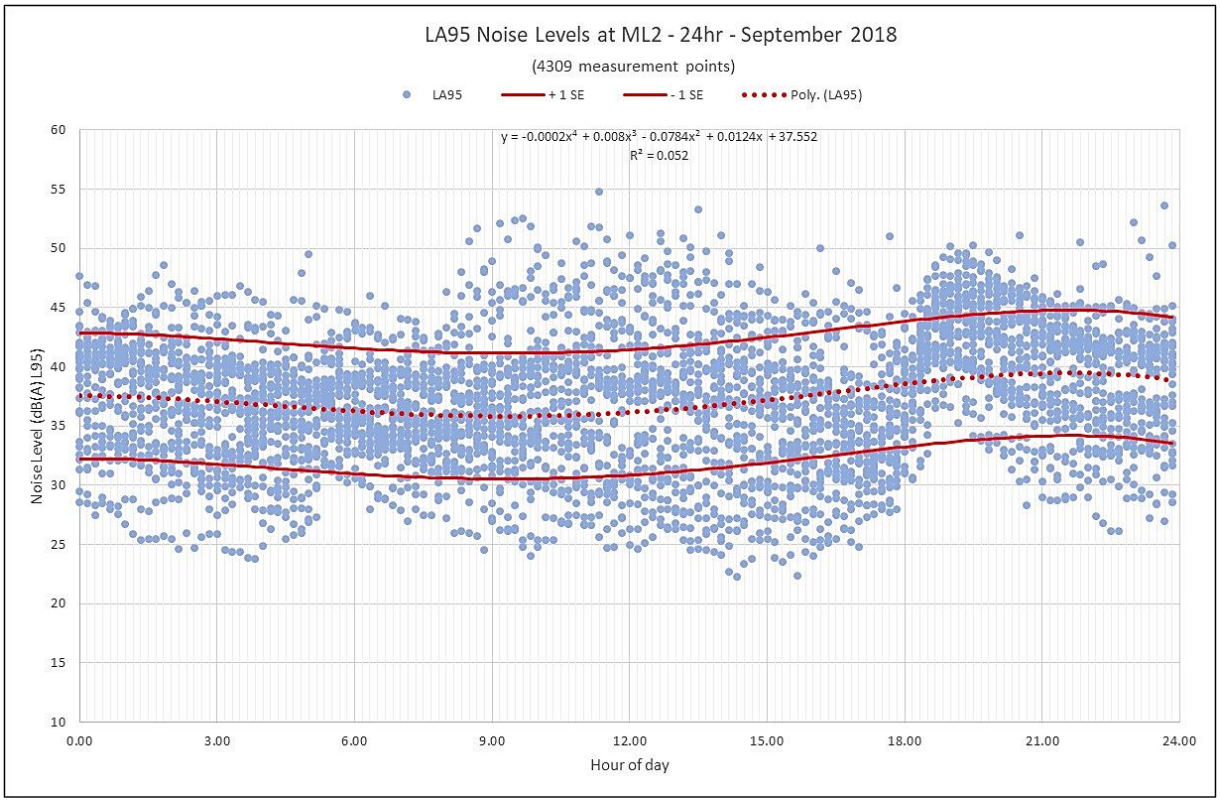


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

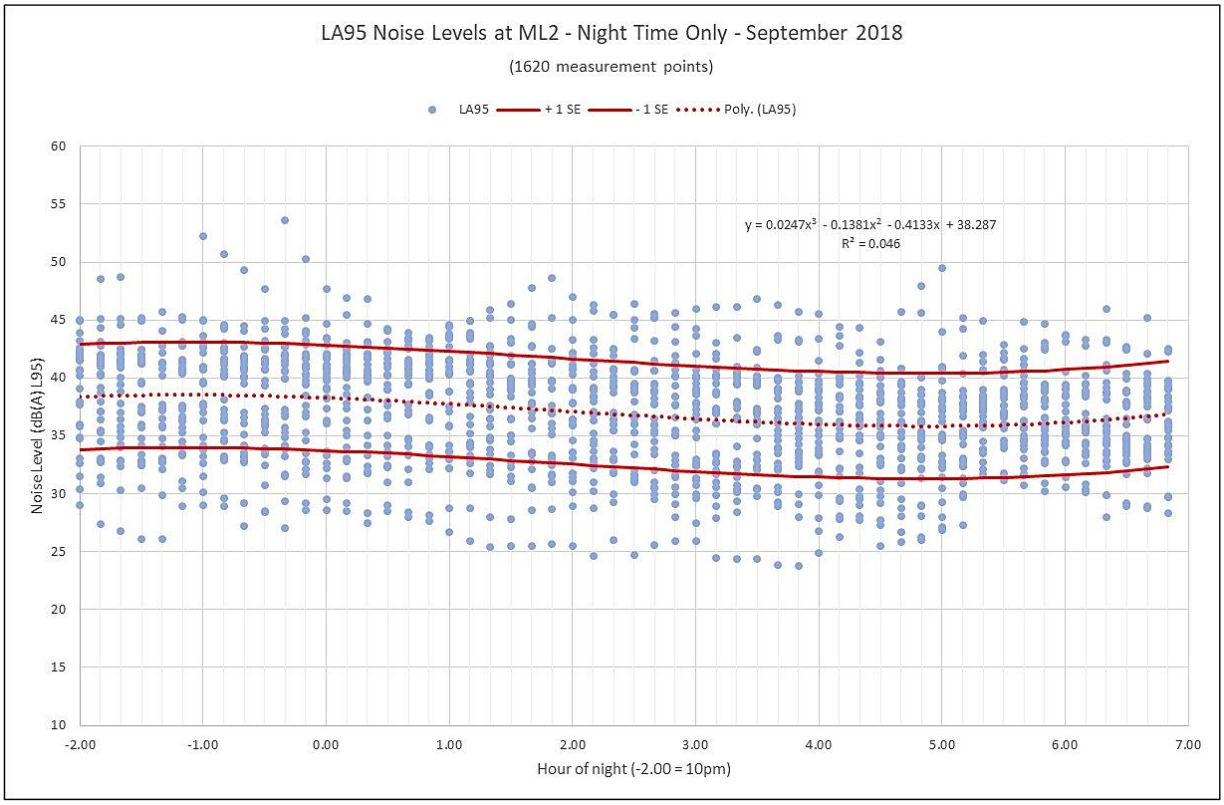


September 2018 – ML2 (DDF)

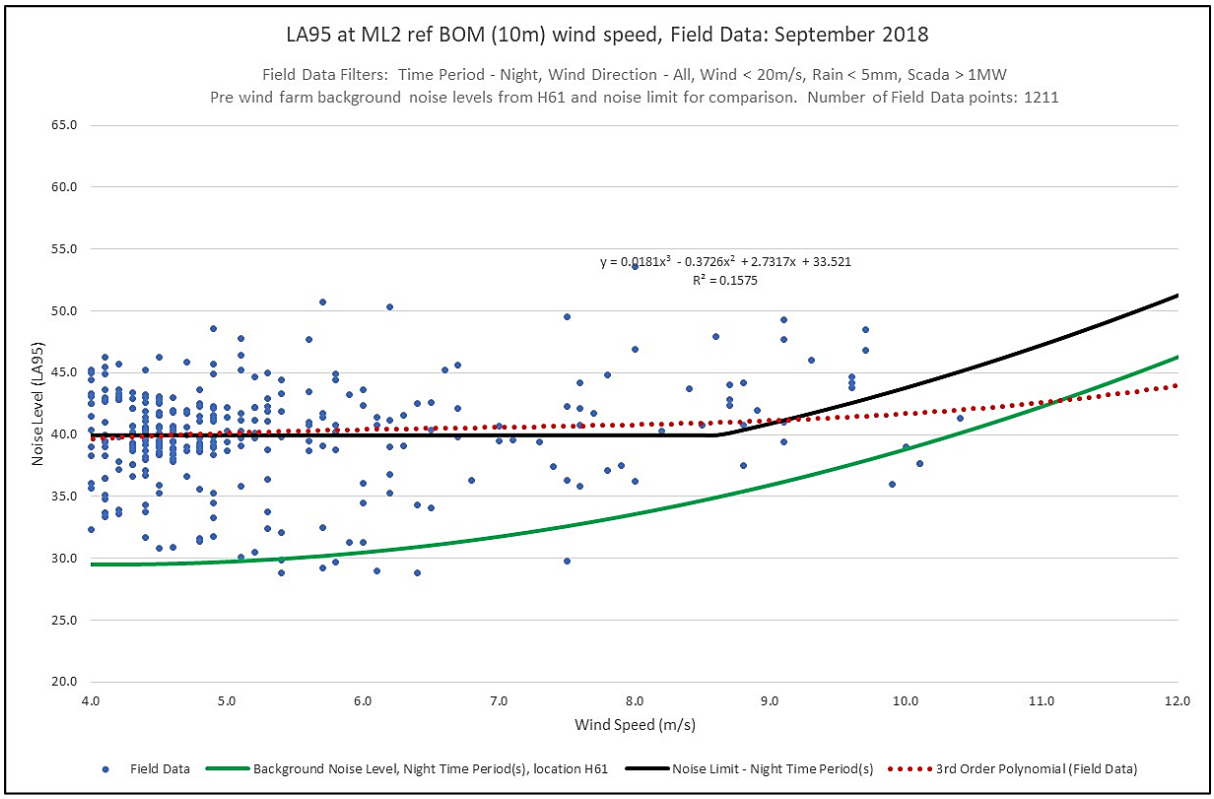
Variation in day and night sound levels for the month by time of day/night



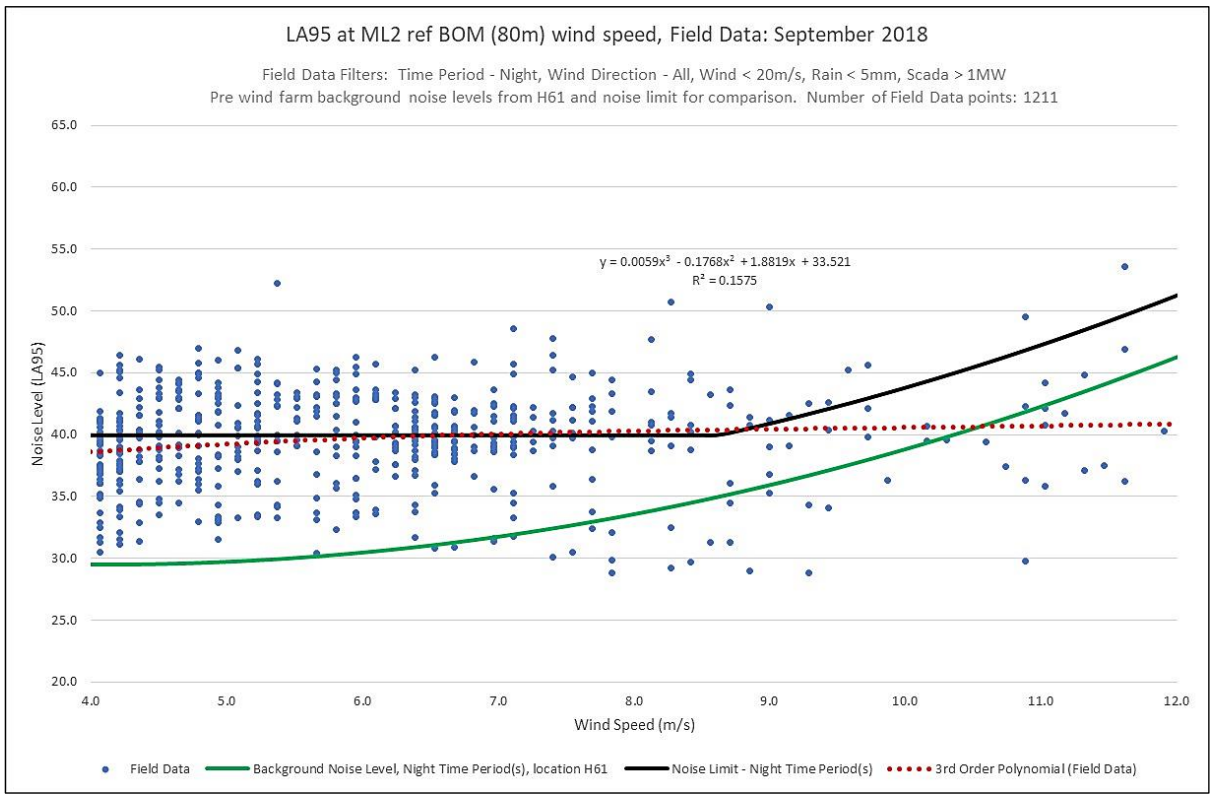
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

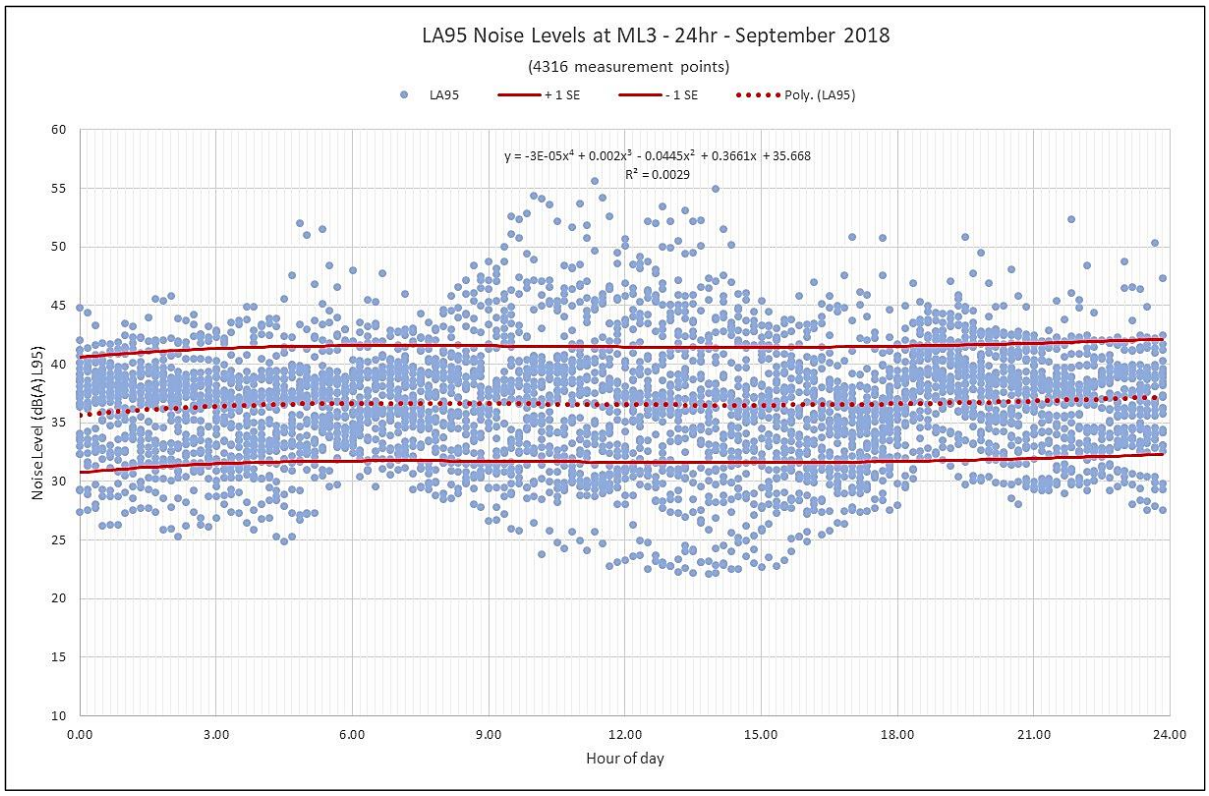


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

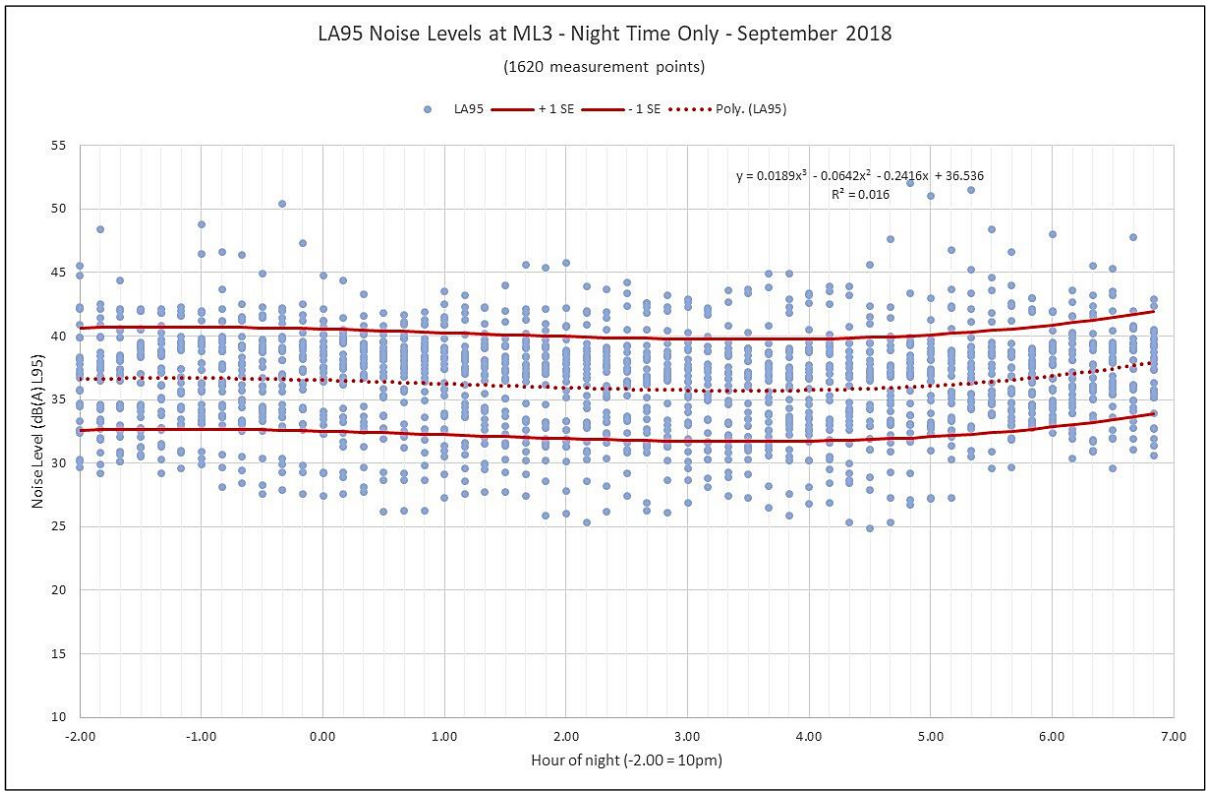


September 2018 – ML3 (NU)

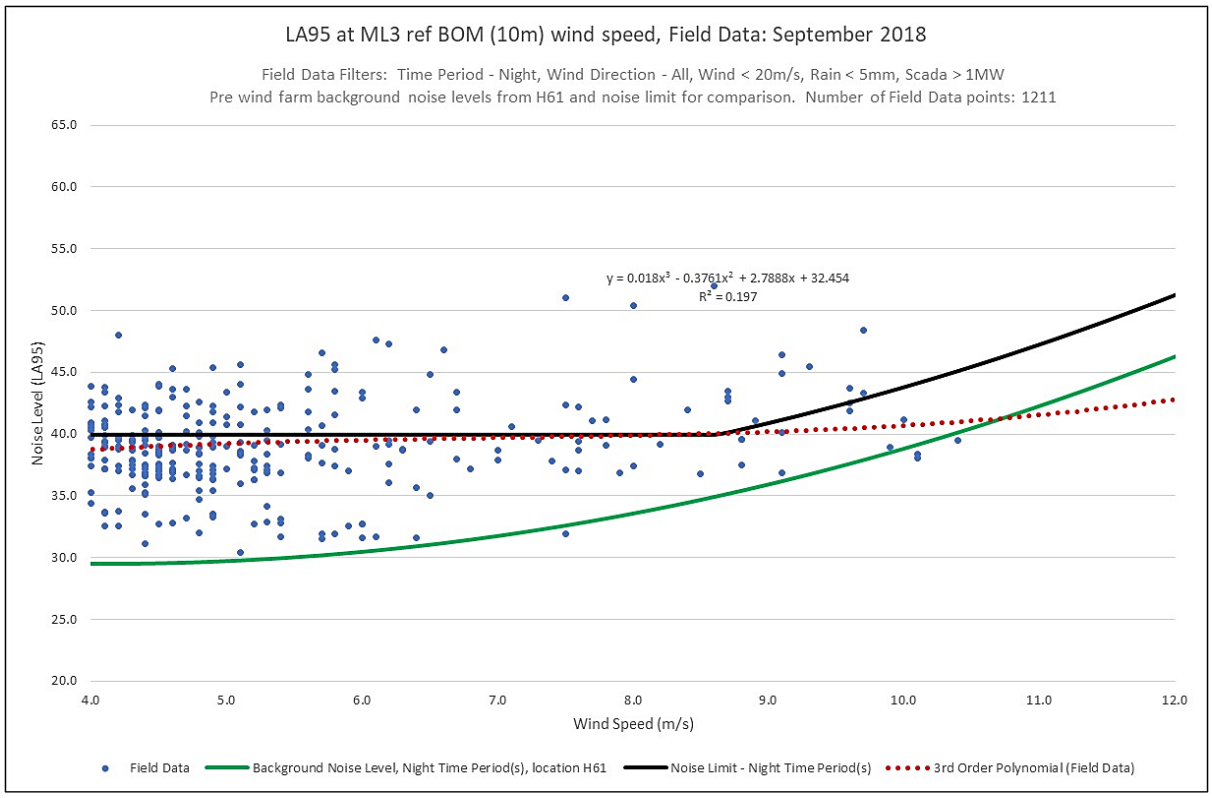
Variation in day and night sound levels for the month by time of day/night



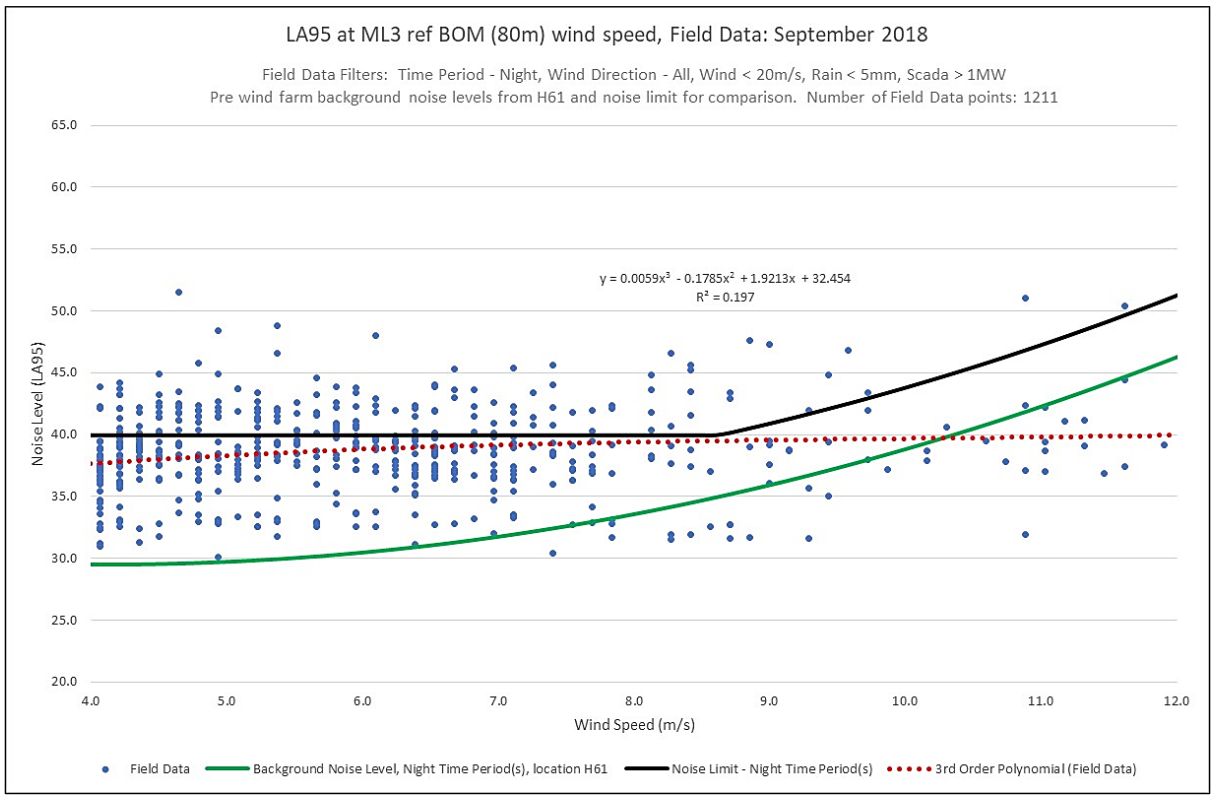
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

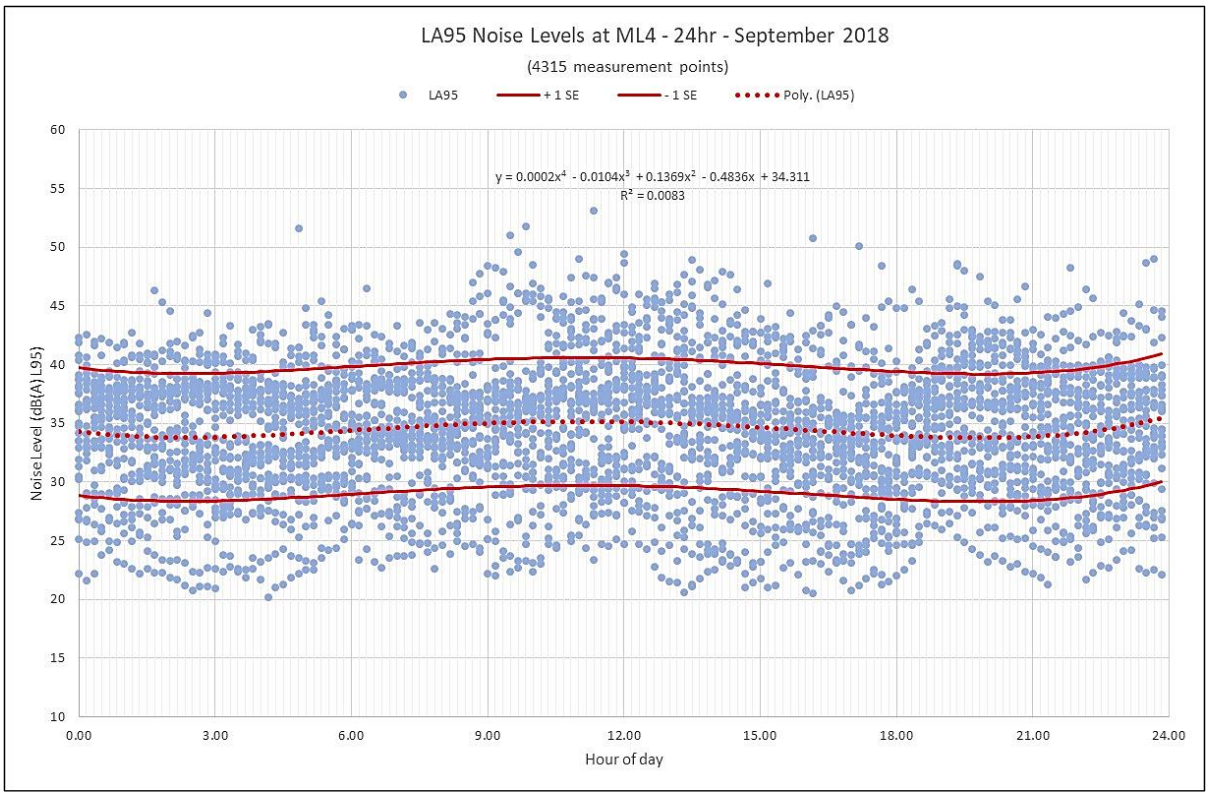


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

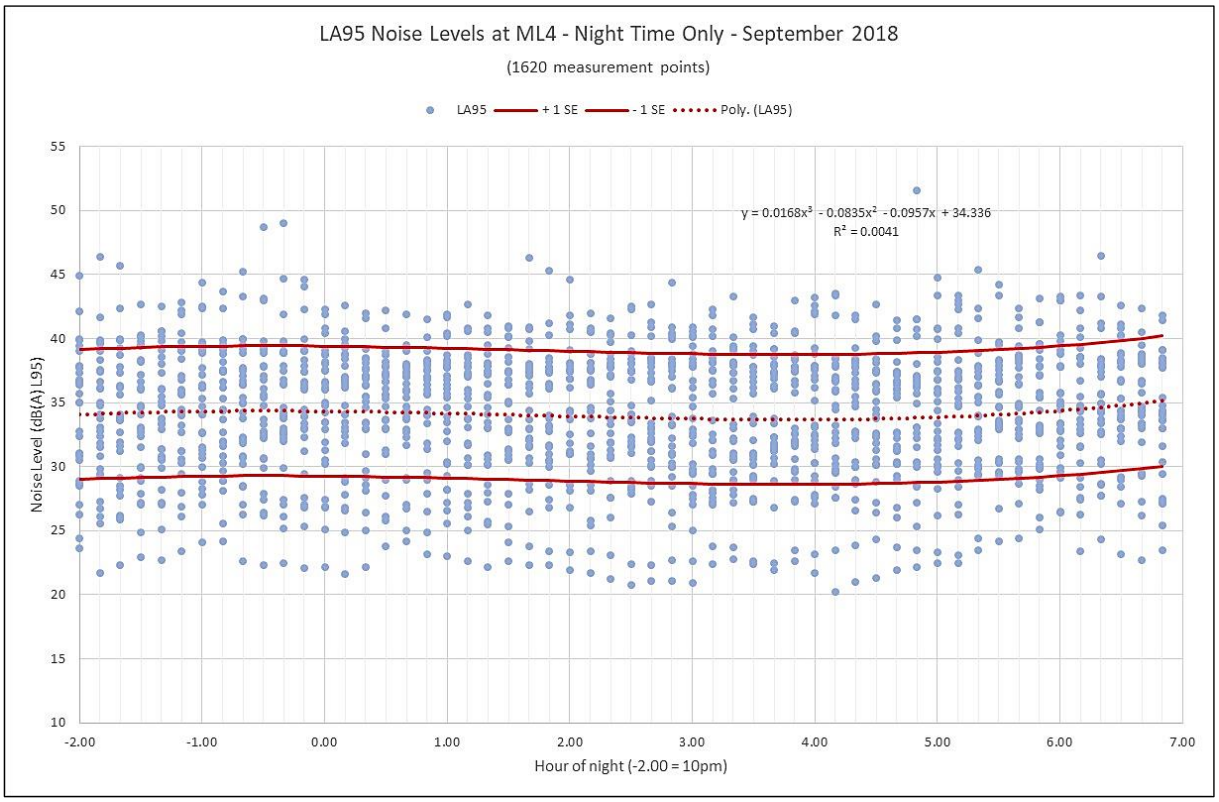


September 2018 – ML4 (DSJ)

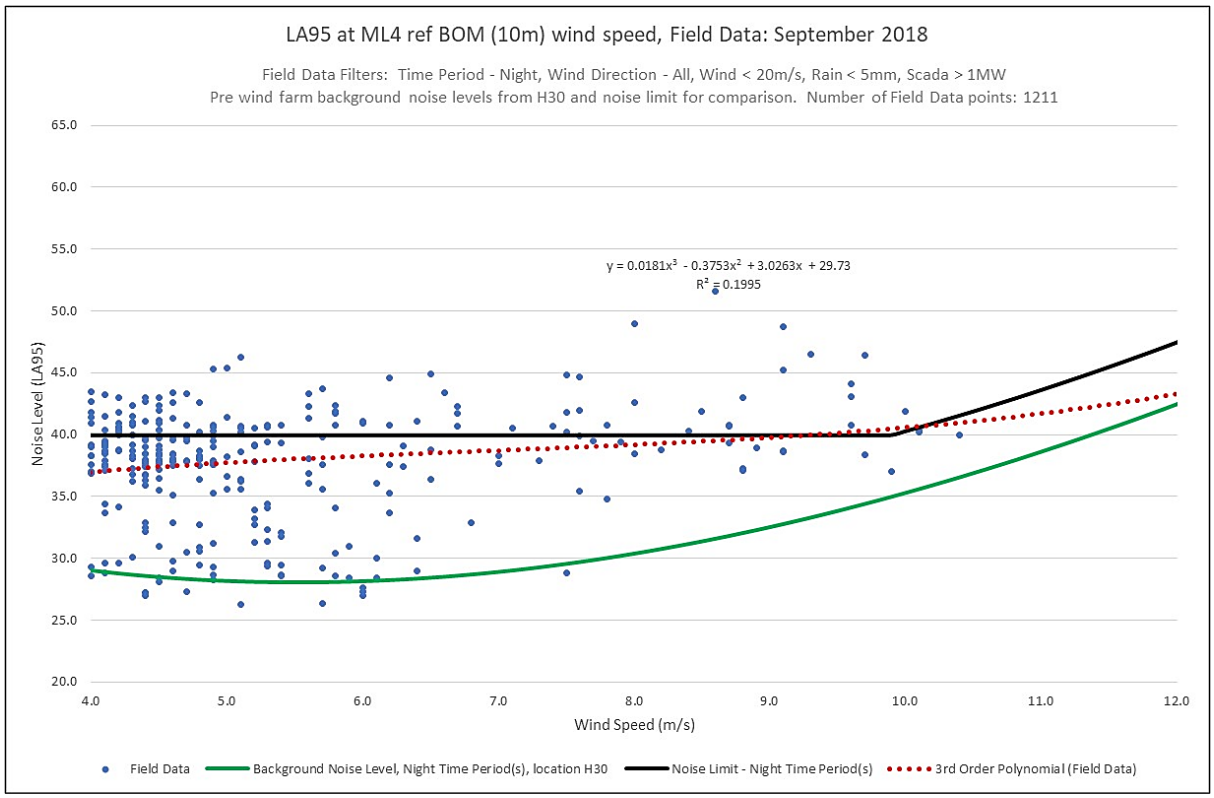
Variation in day and night sound levels for the month by time of day/night



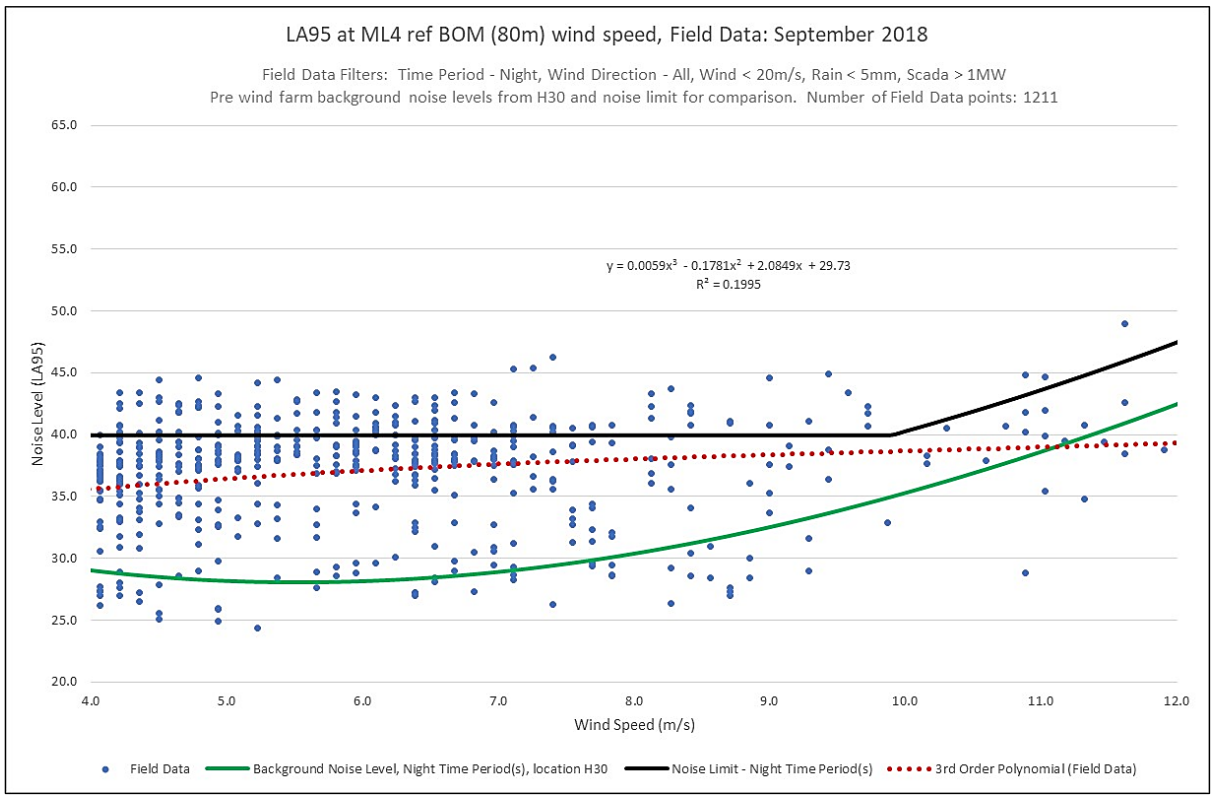
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

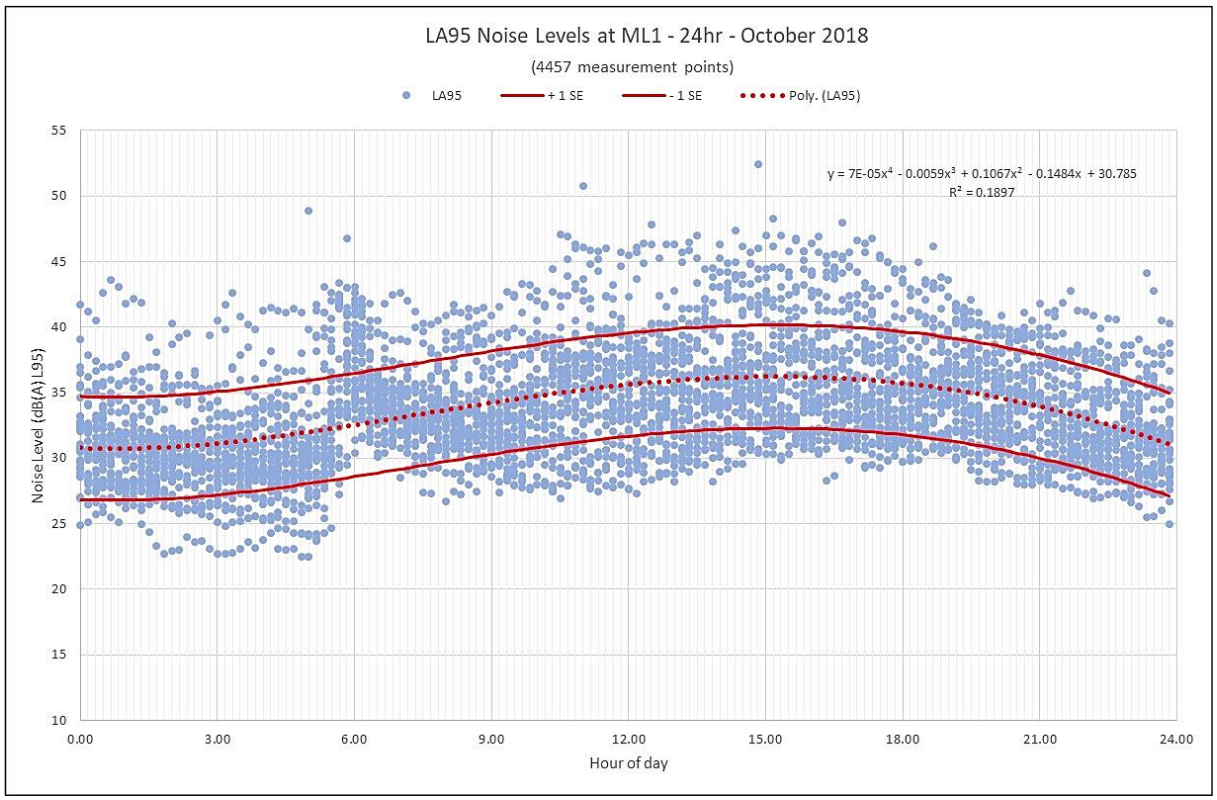


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

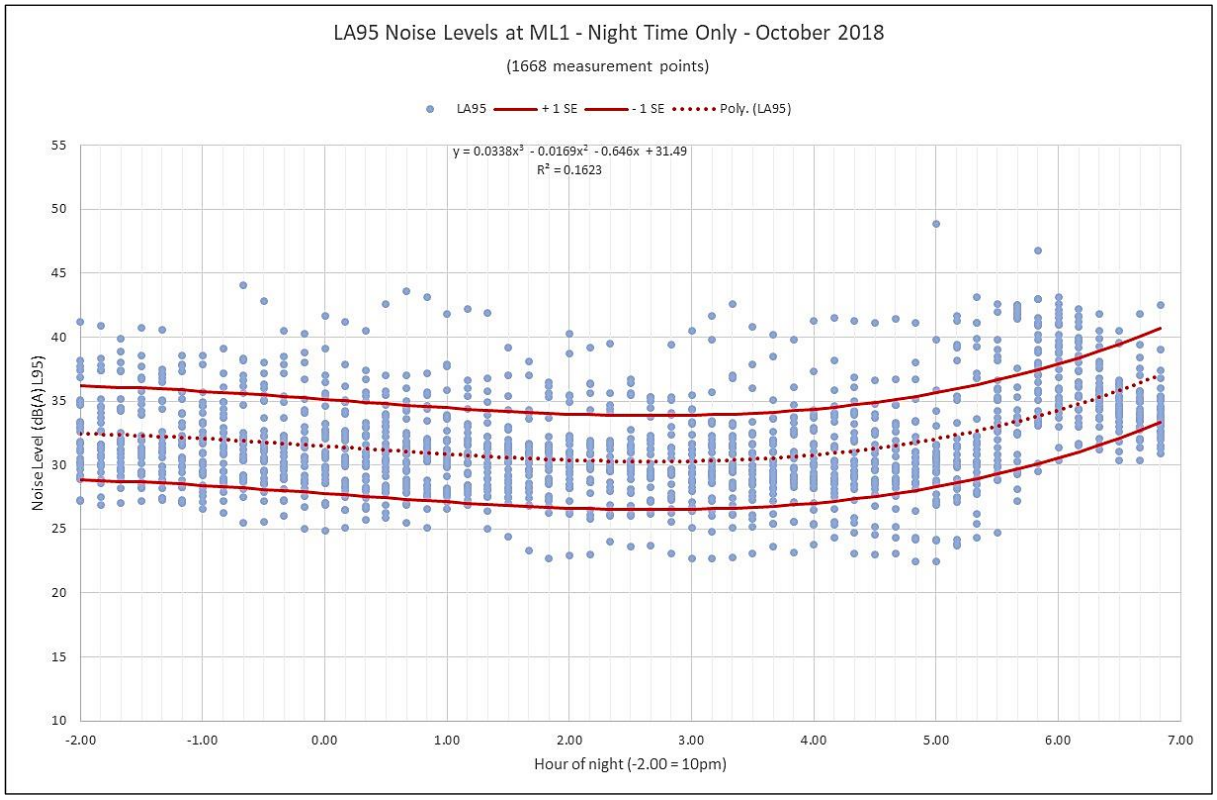


October 2018

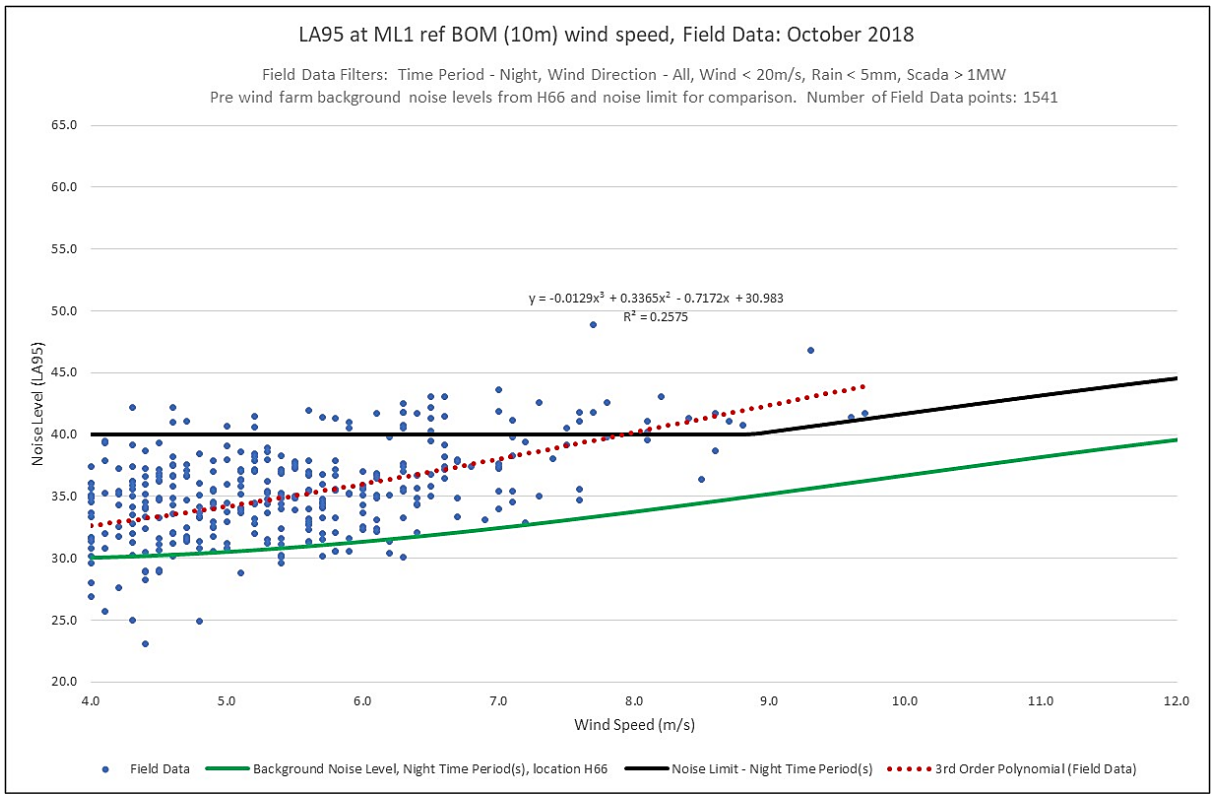
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



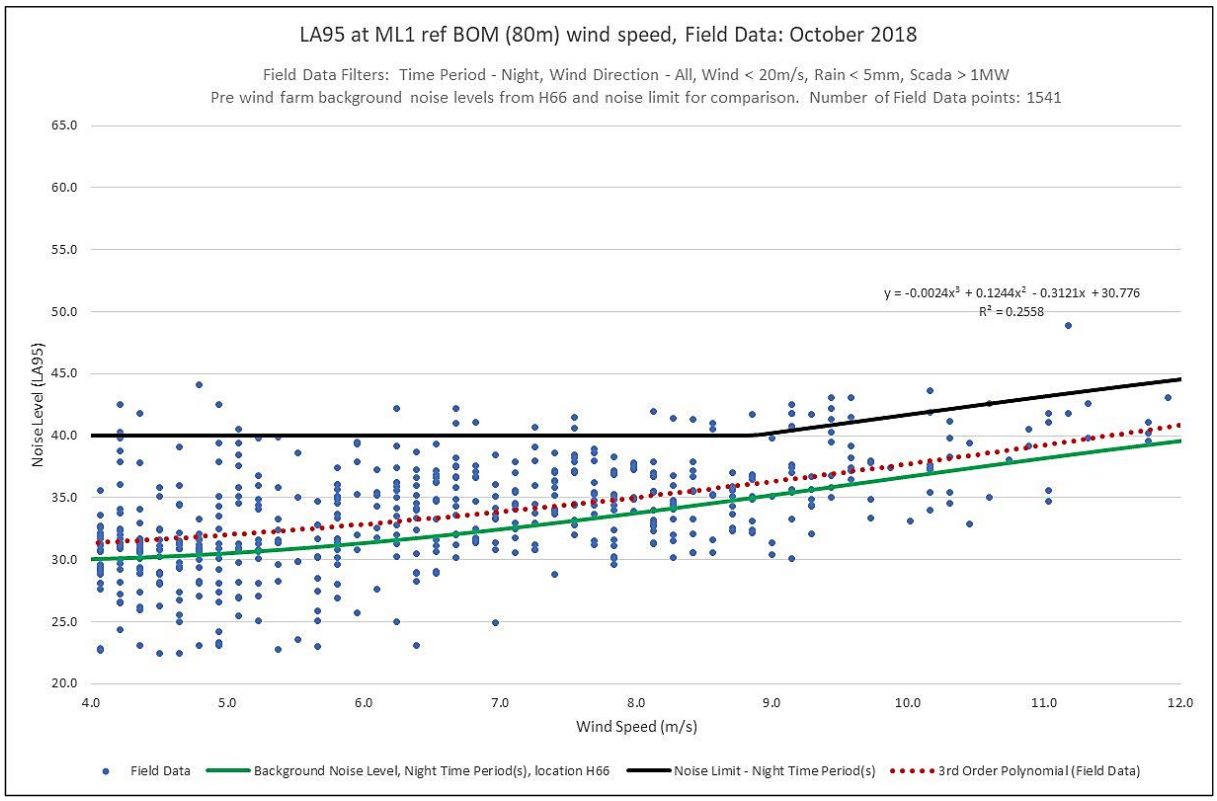
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

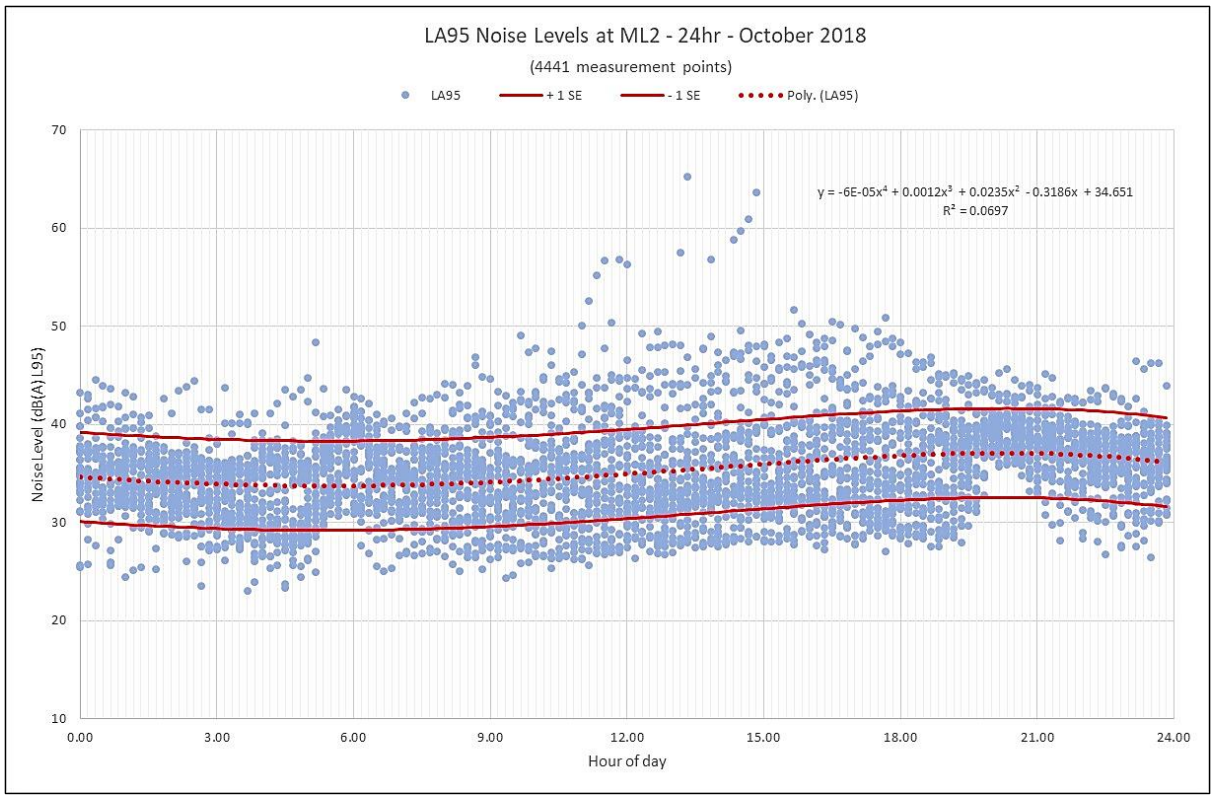


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

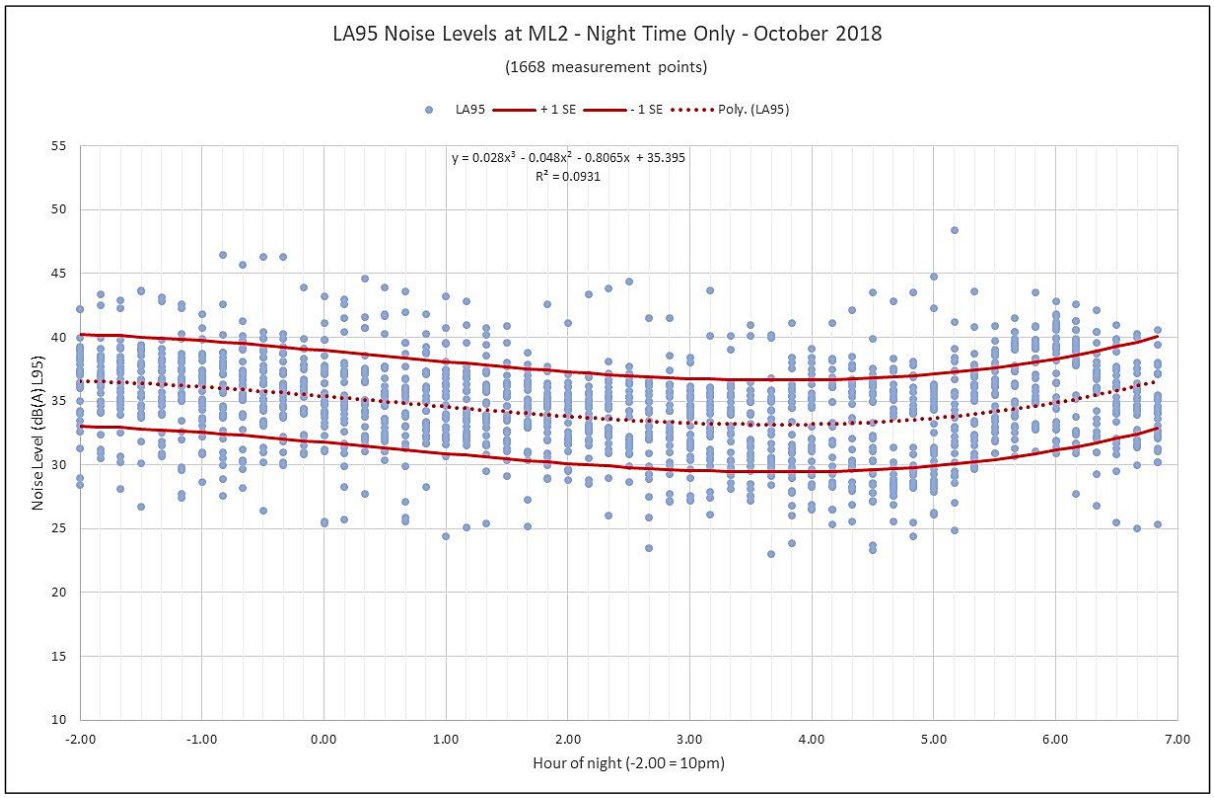


October 2018 – ML2 (DDF)

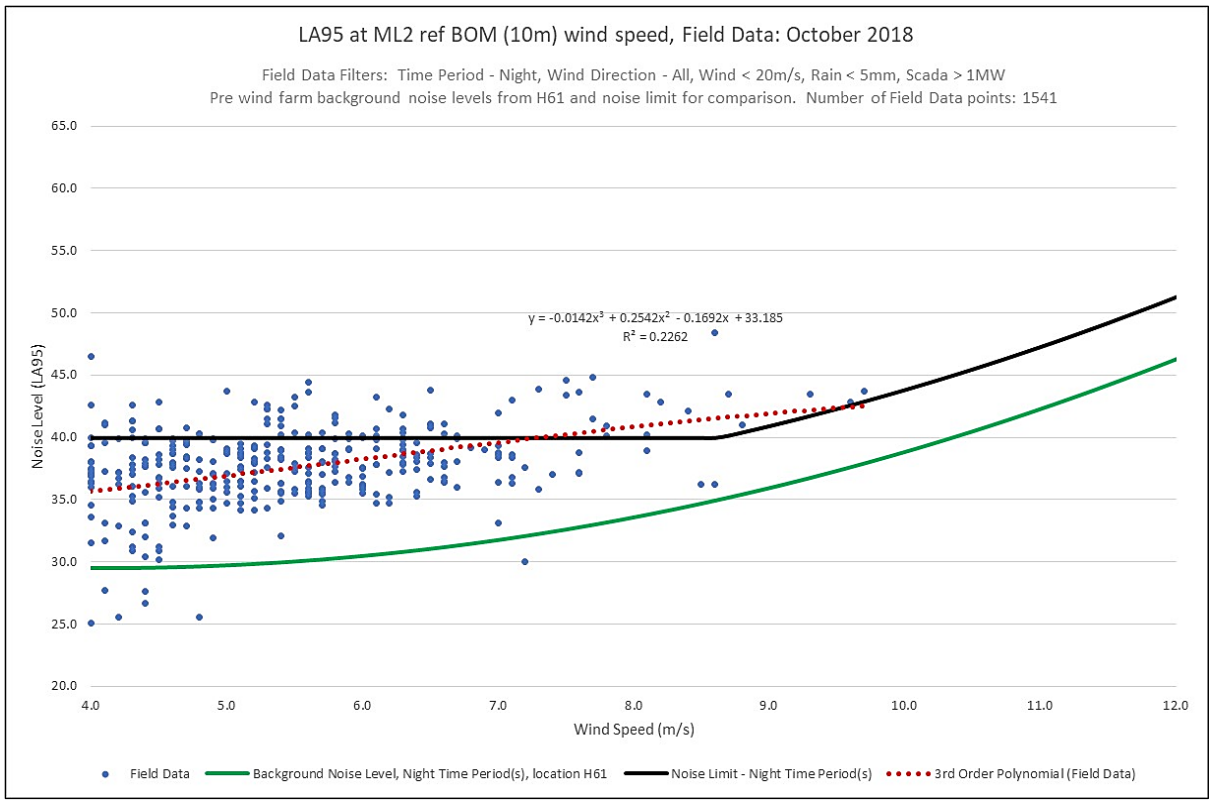
Variation in day and night sound levels for the month by time of day/night



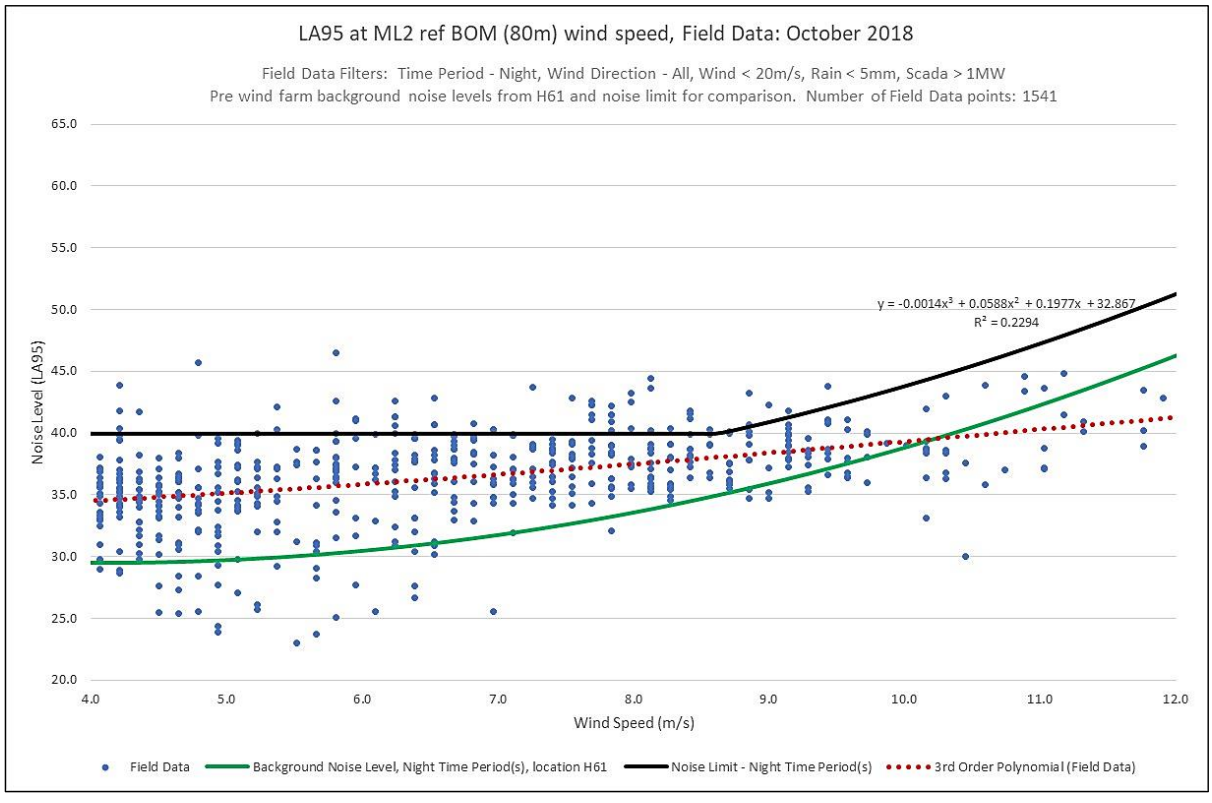
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

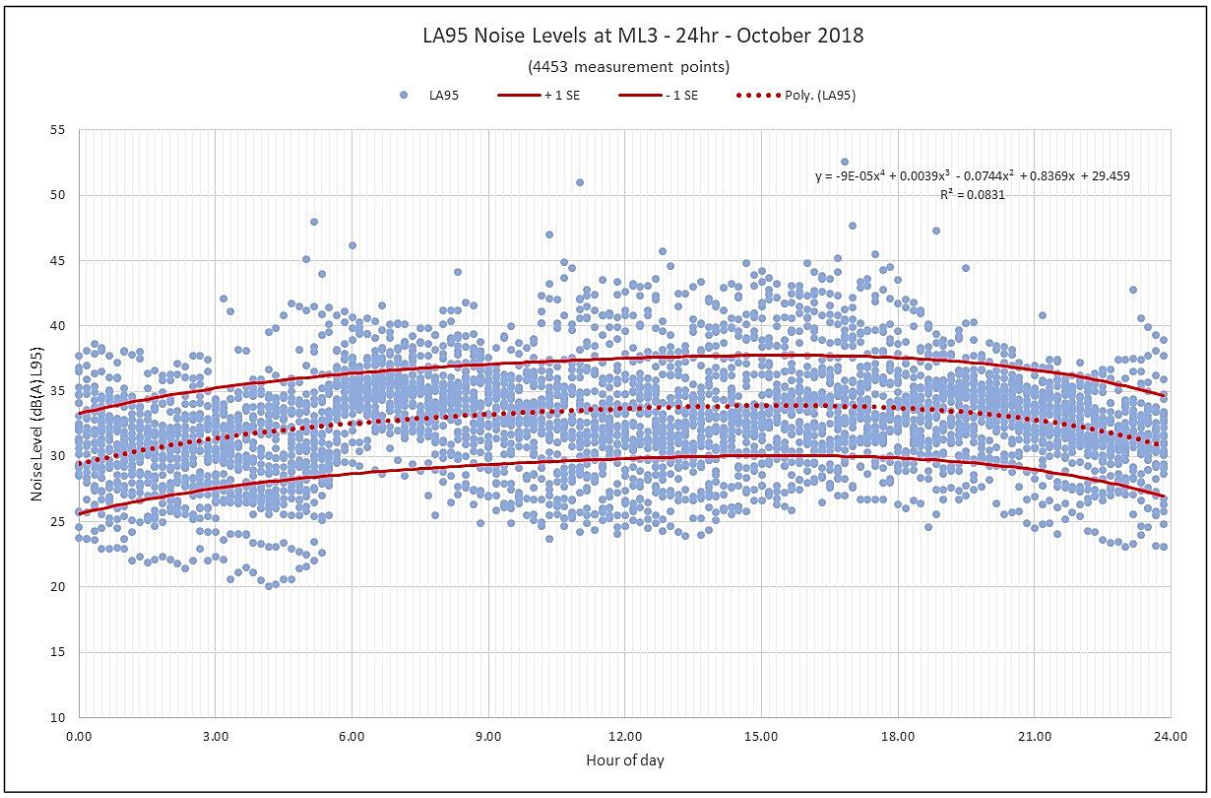


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

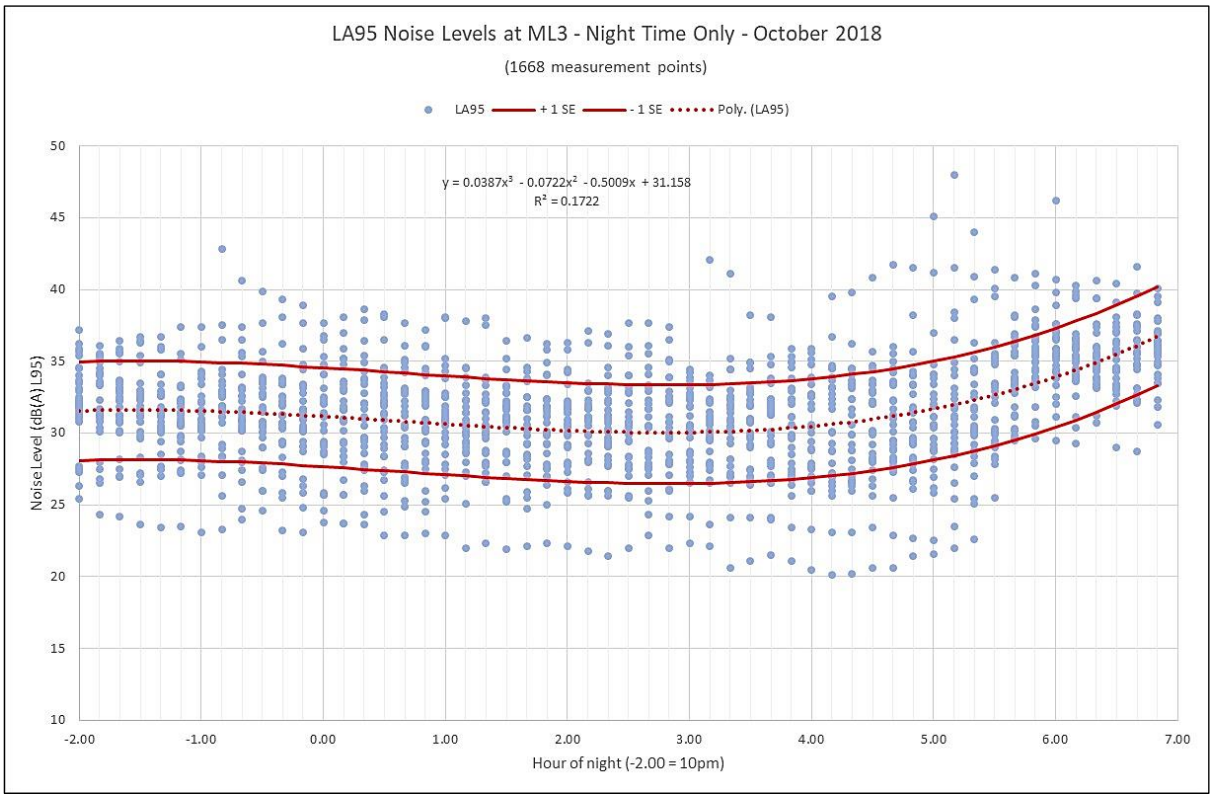


October 2018 – ML3 (NU)

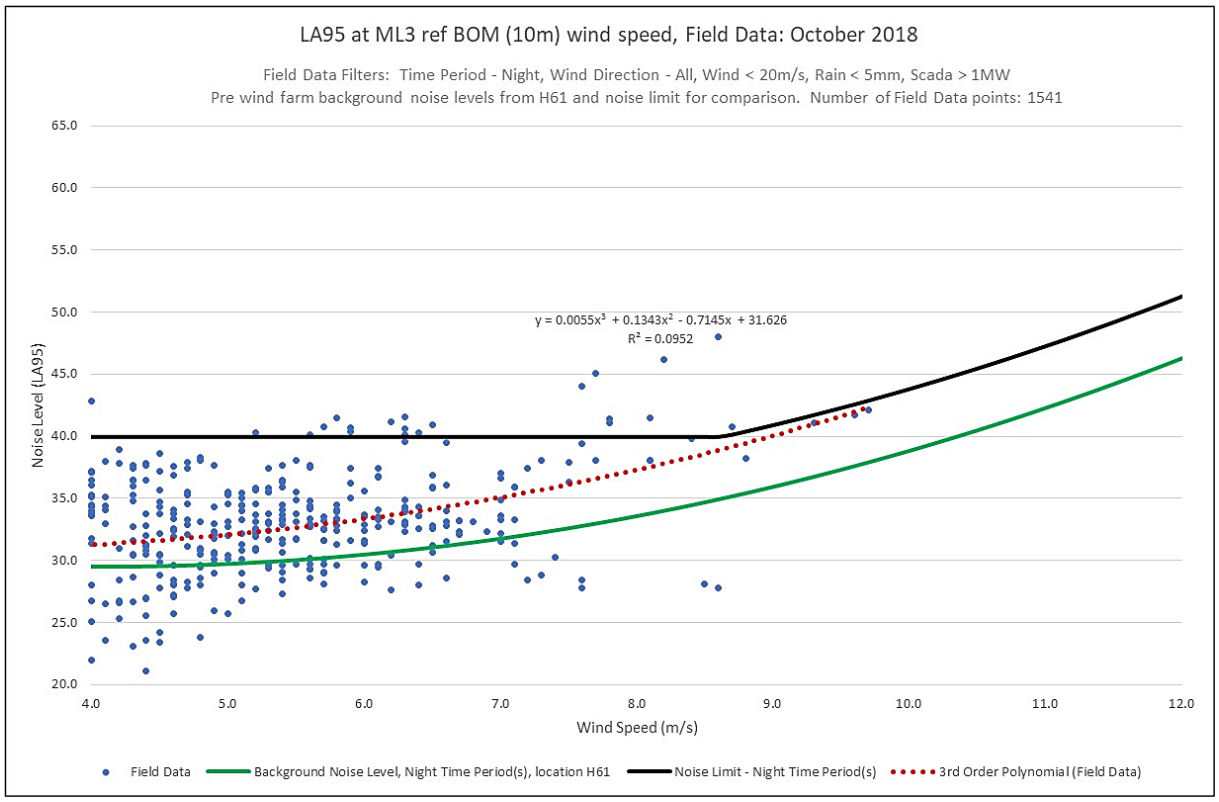
Variation in day and night sound levels for the month by time of day/night



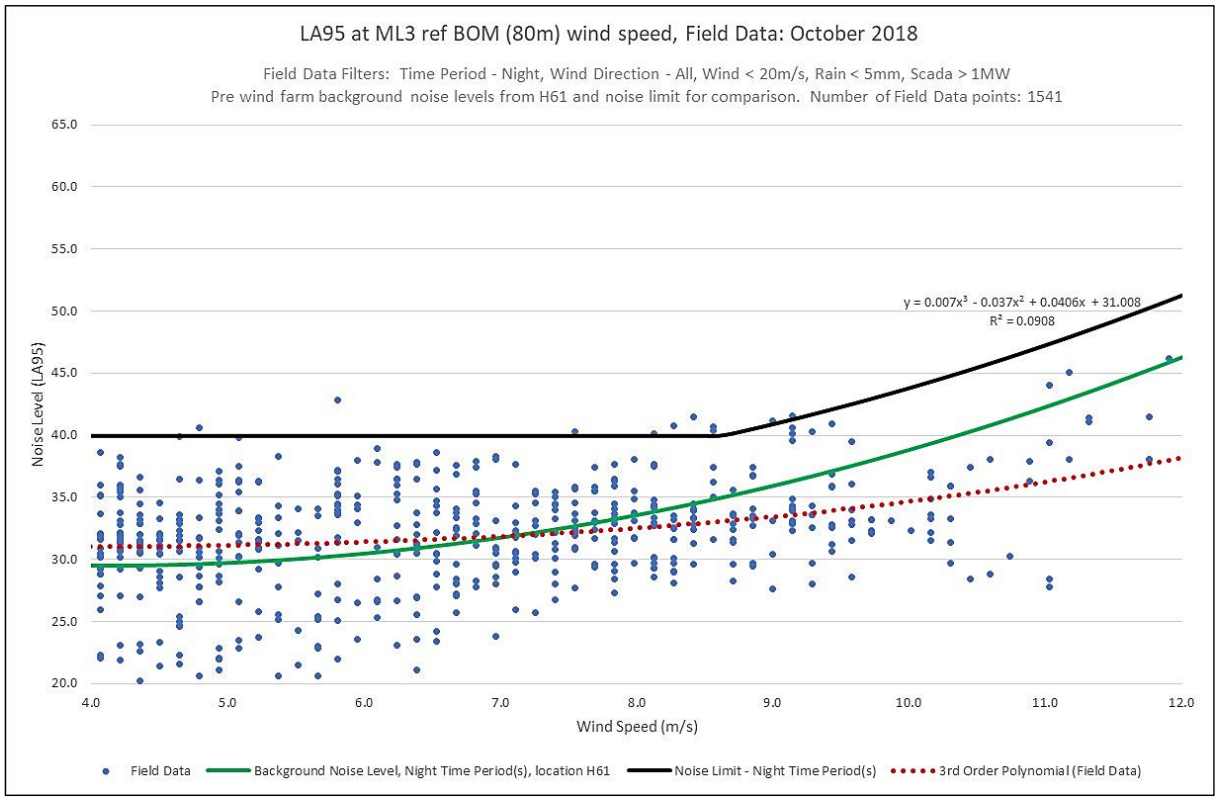
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

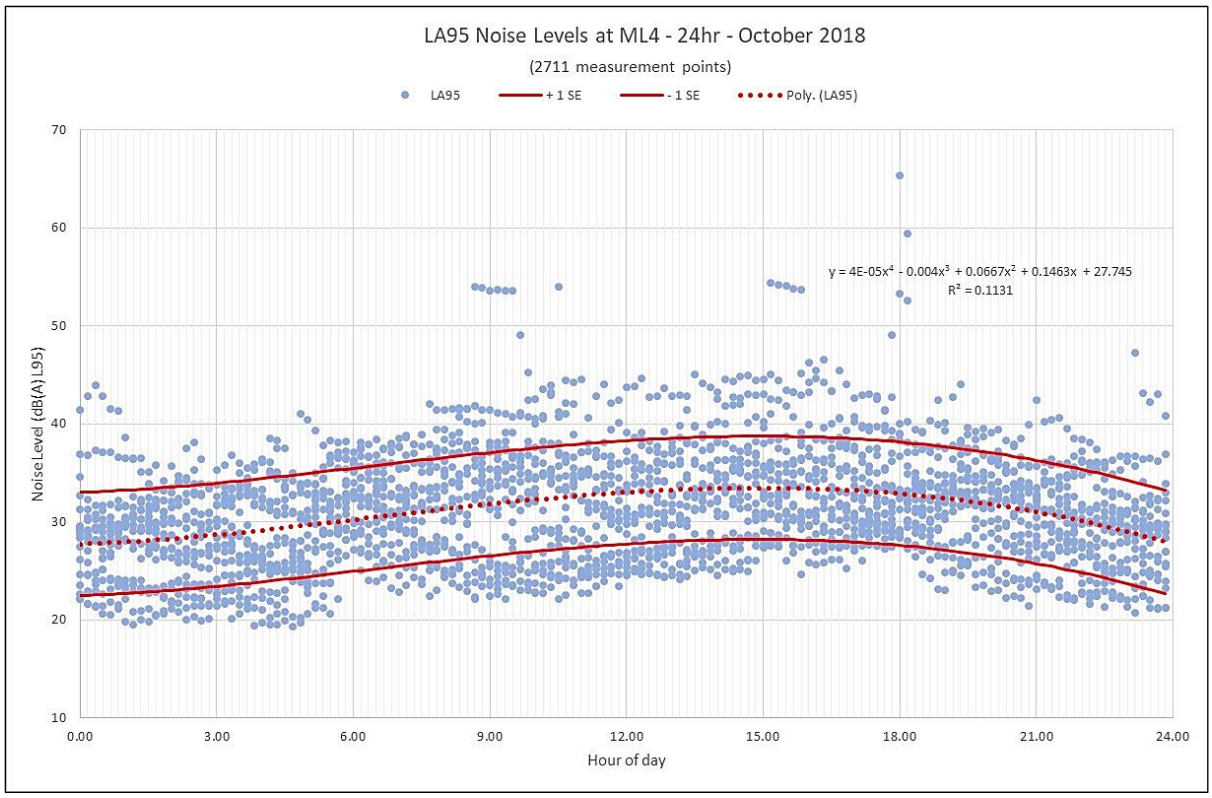


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

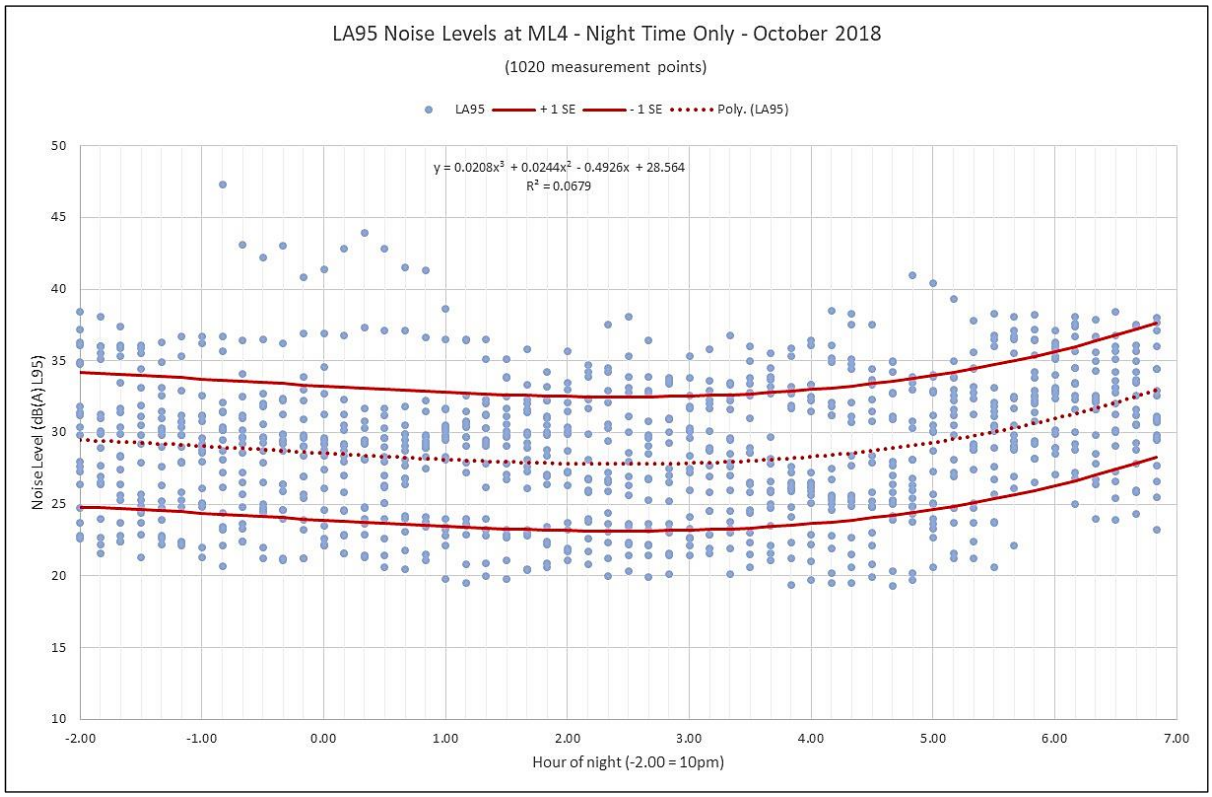


October 2018 – ML4 (DSJ)

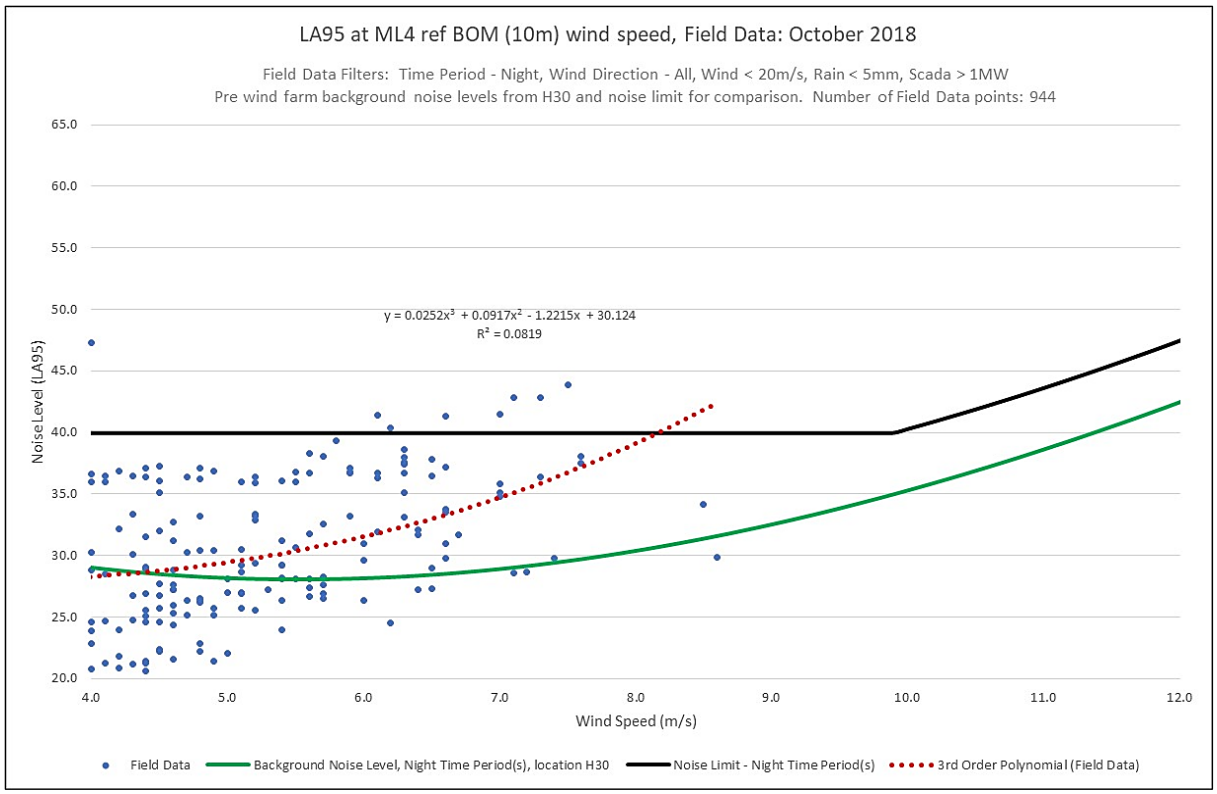
Variation in day and night sound levels for the month by time of day/night



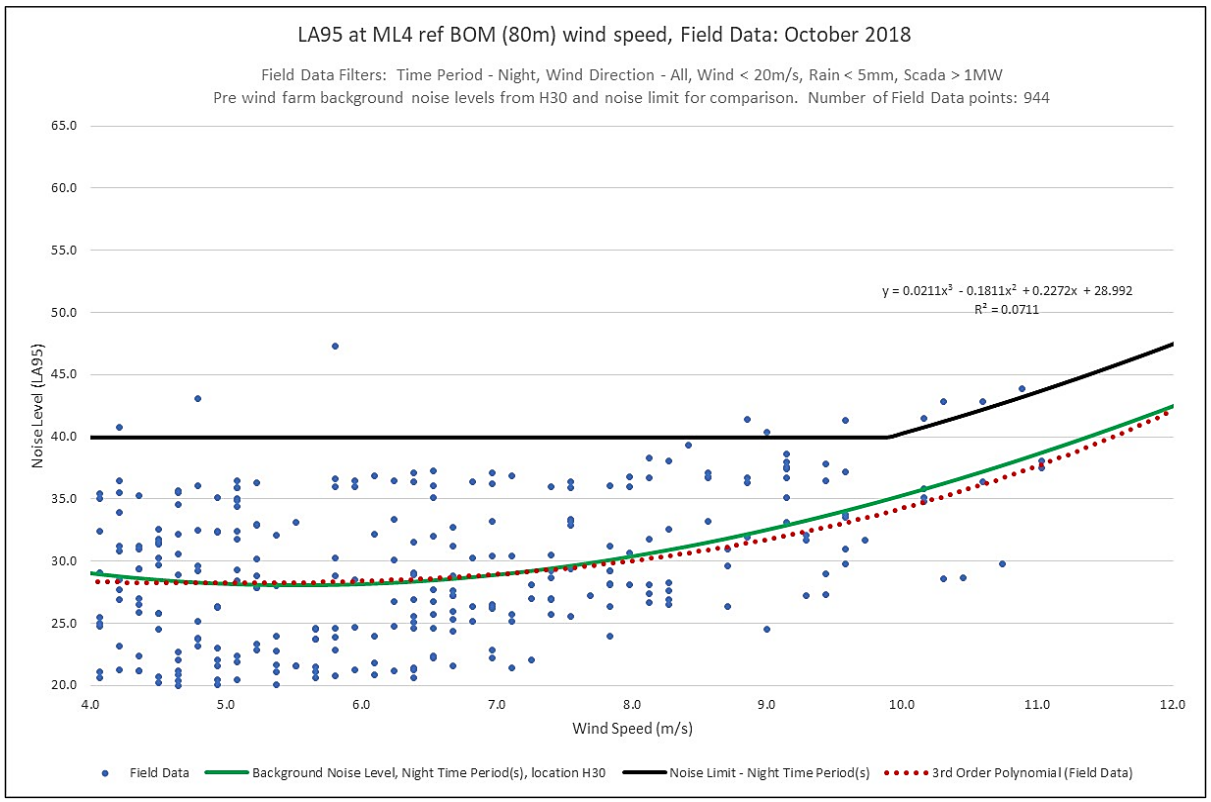
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

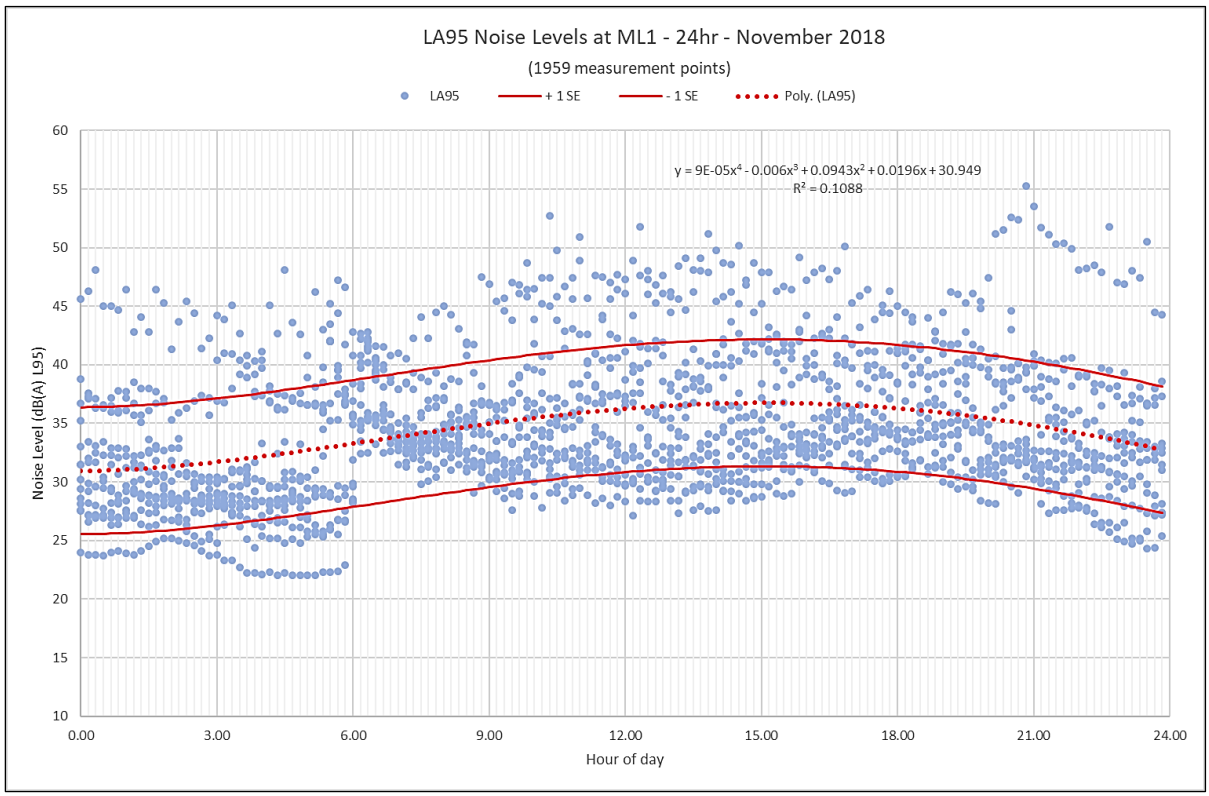


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

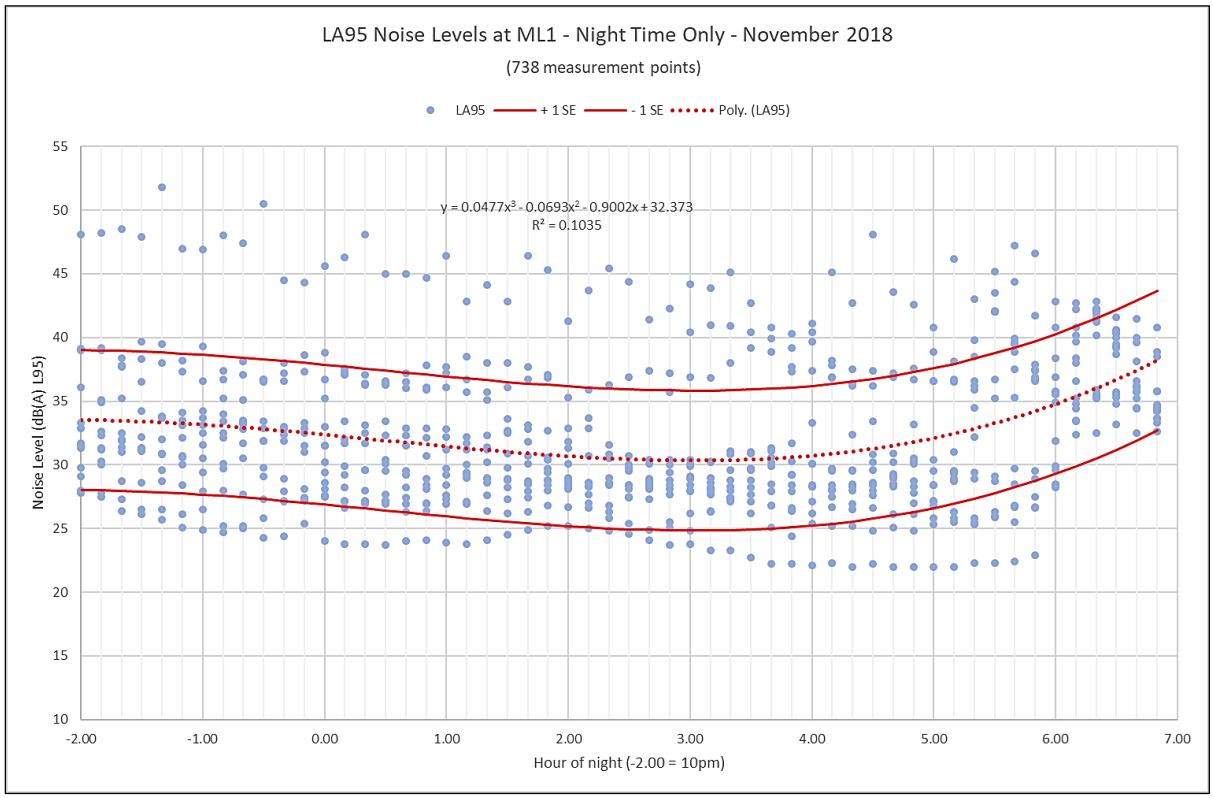


November 2018

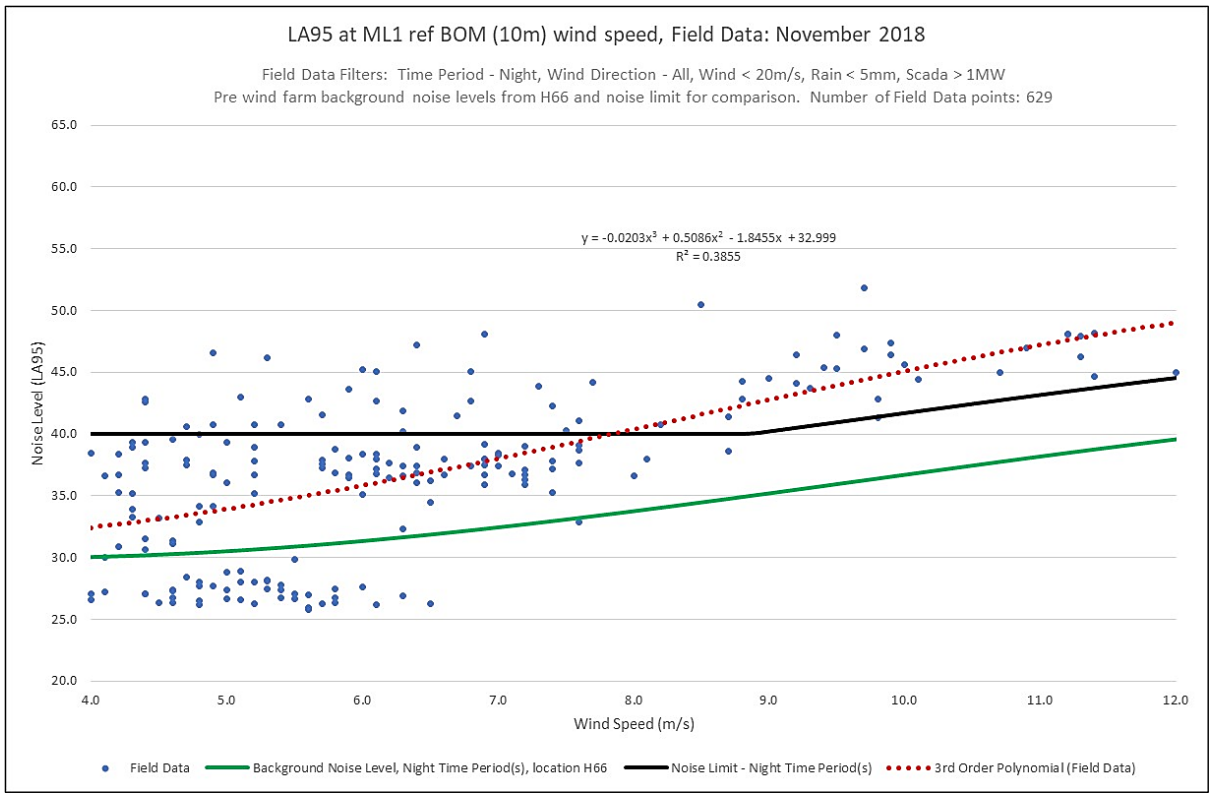
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



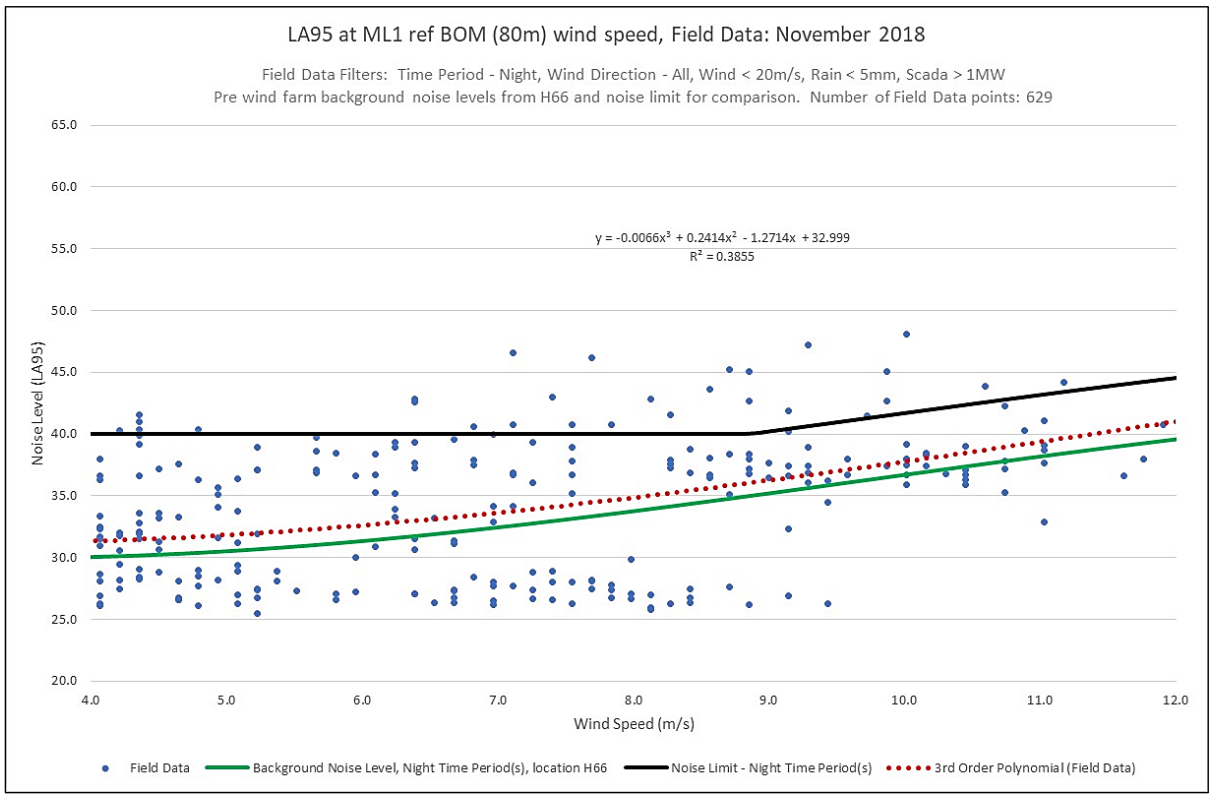
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

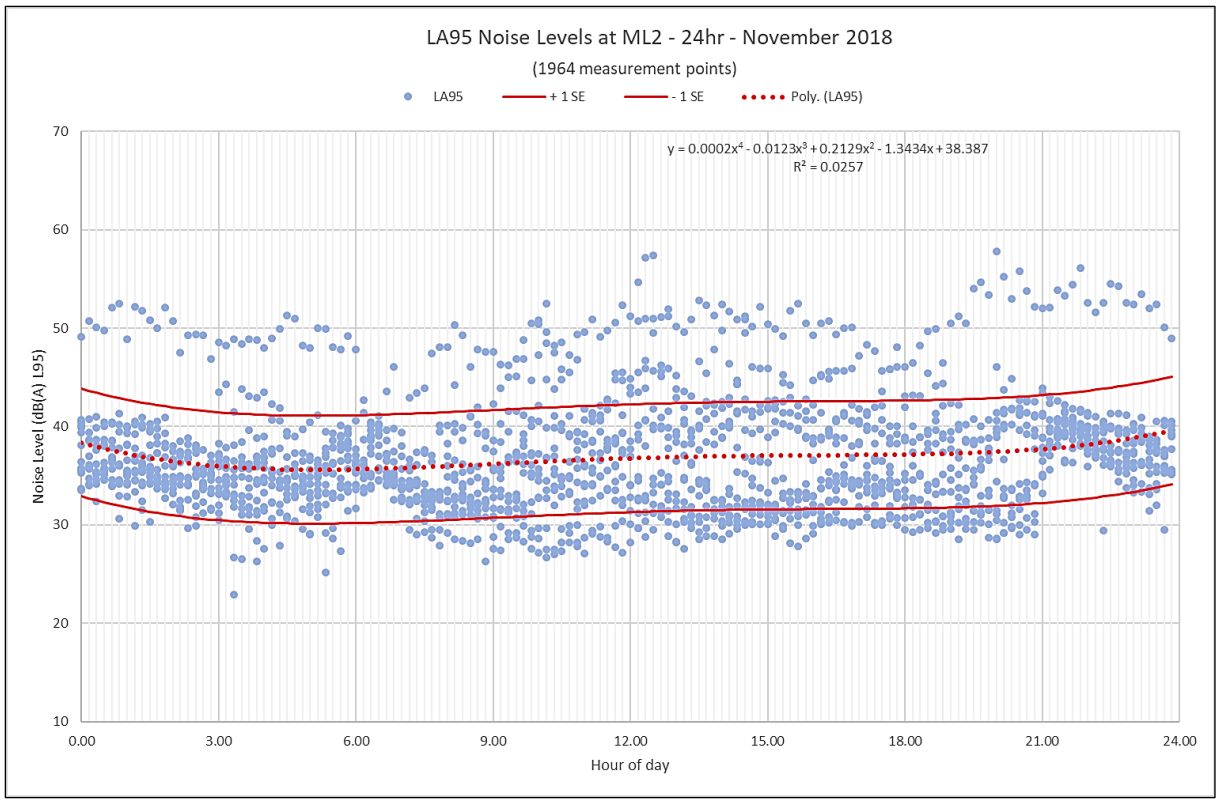


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

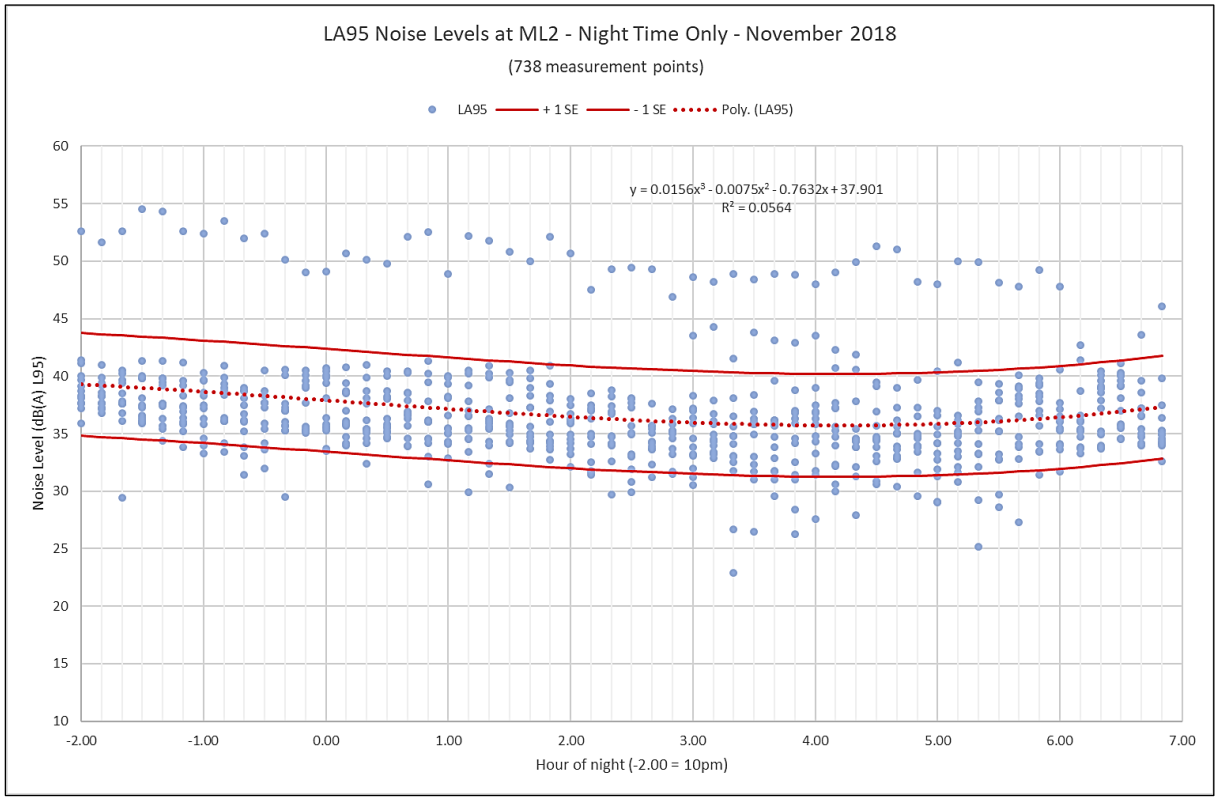


November 2018 – ML2 (DDF)

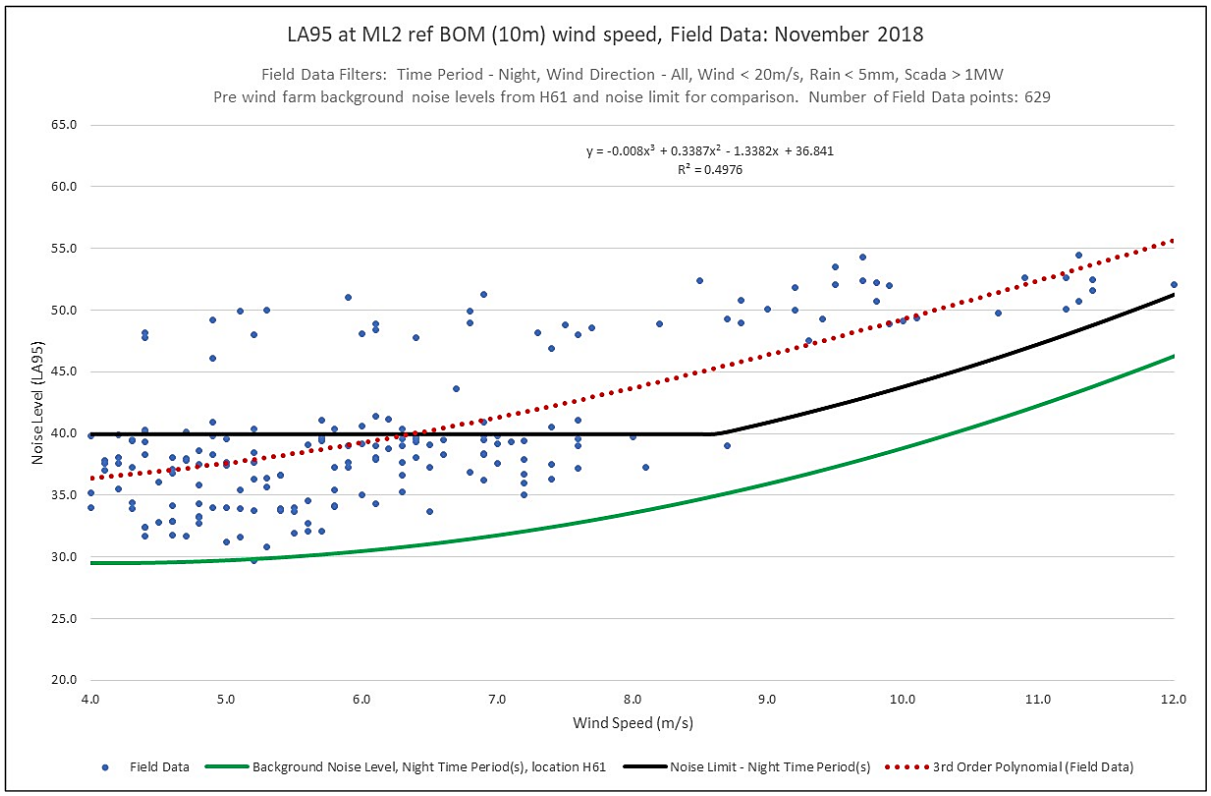
Variation in day and night sound levels for the month by time of day/night



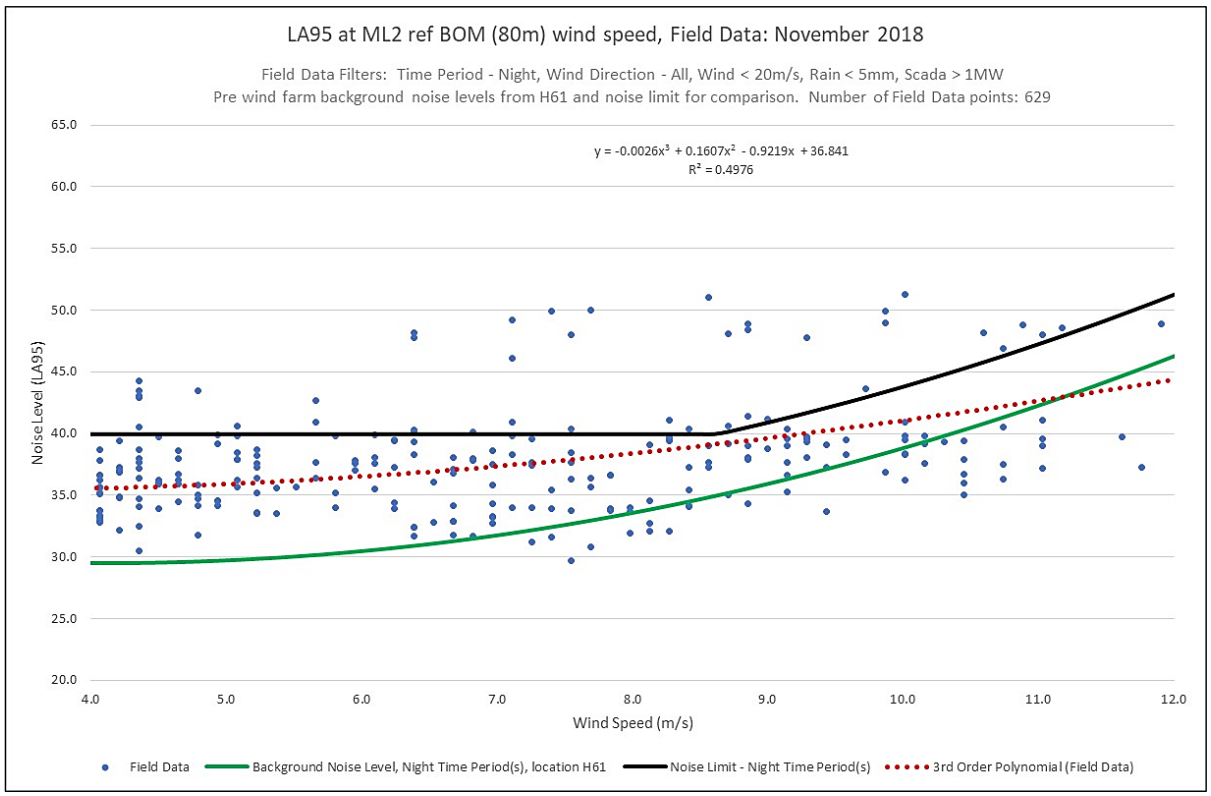
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

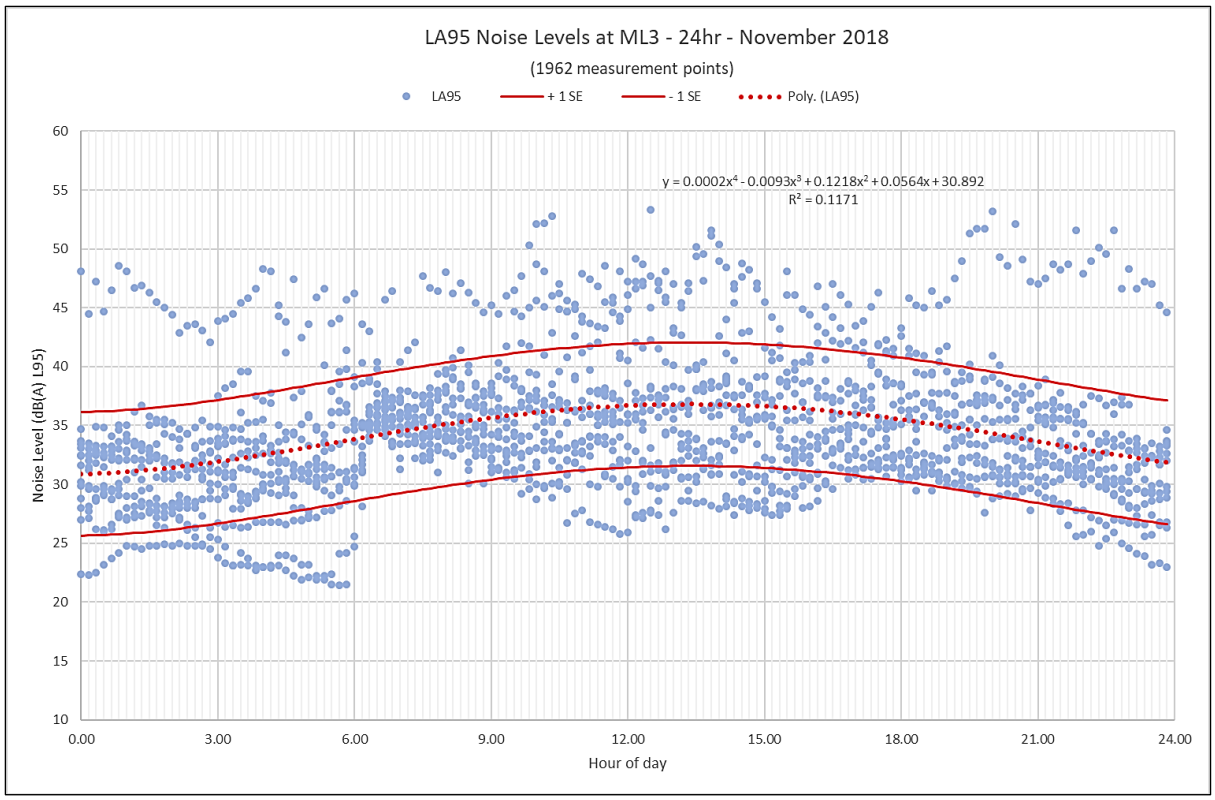


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

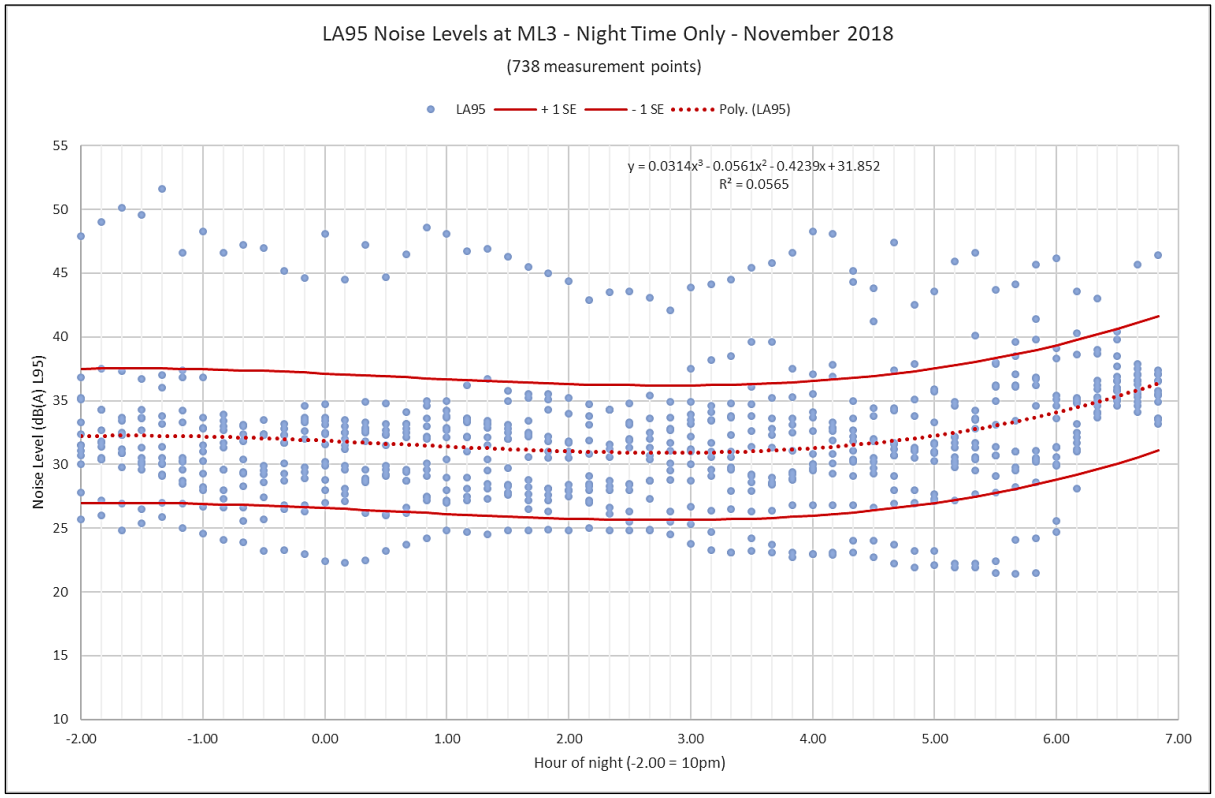


November 2018 – ML3 (NU)

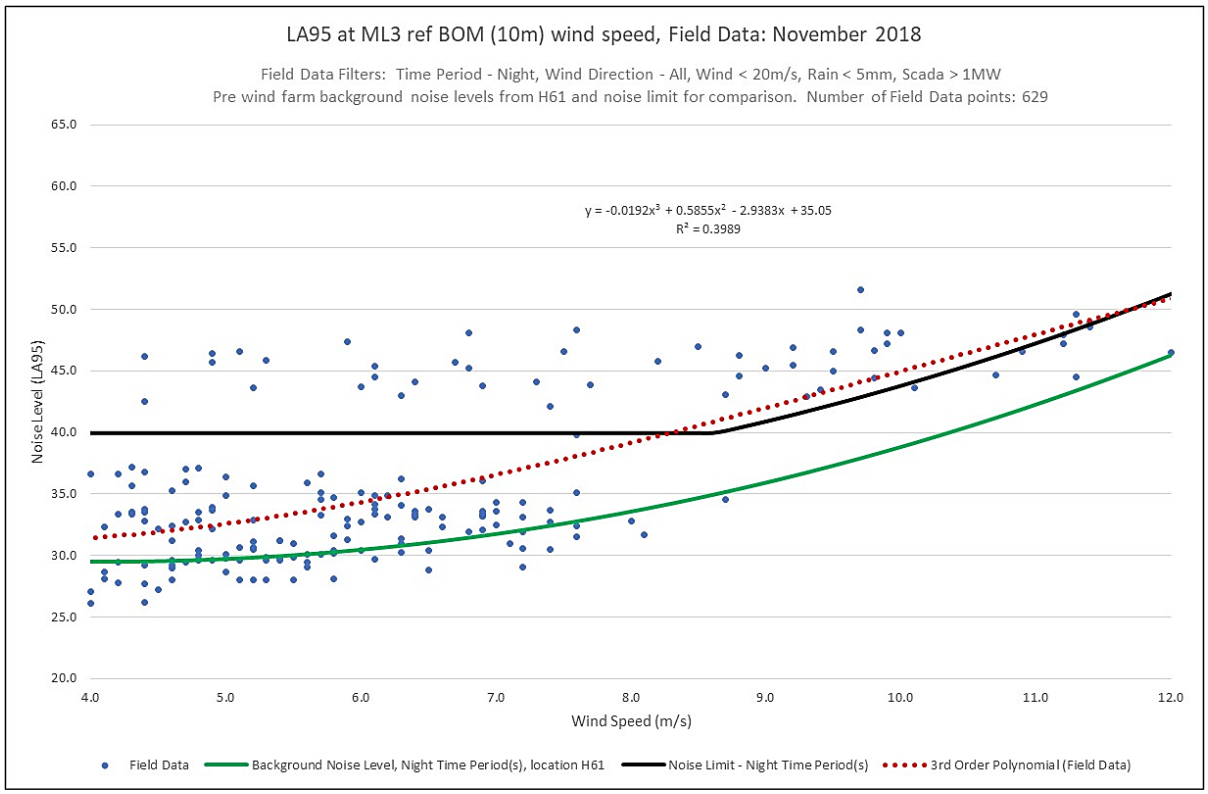
Variation in day and night sound levels for the month by time of day/night



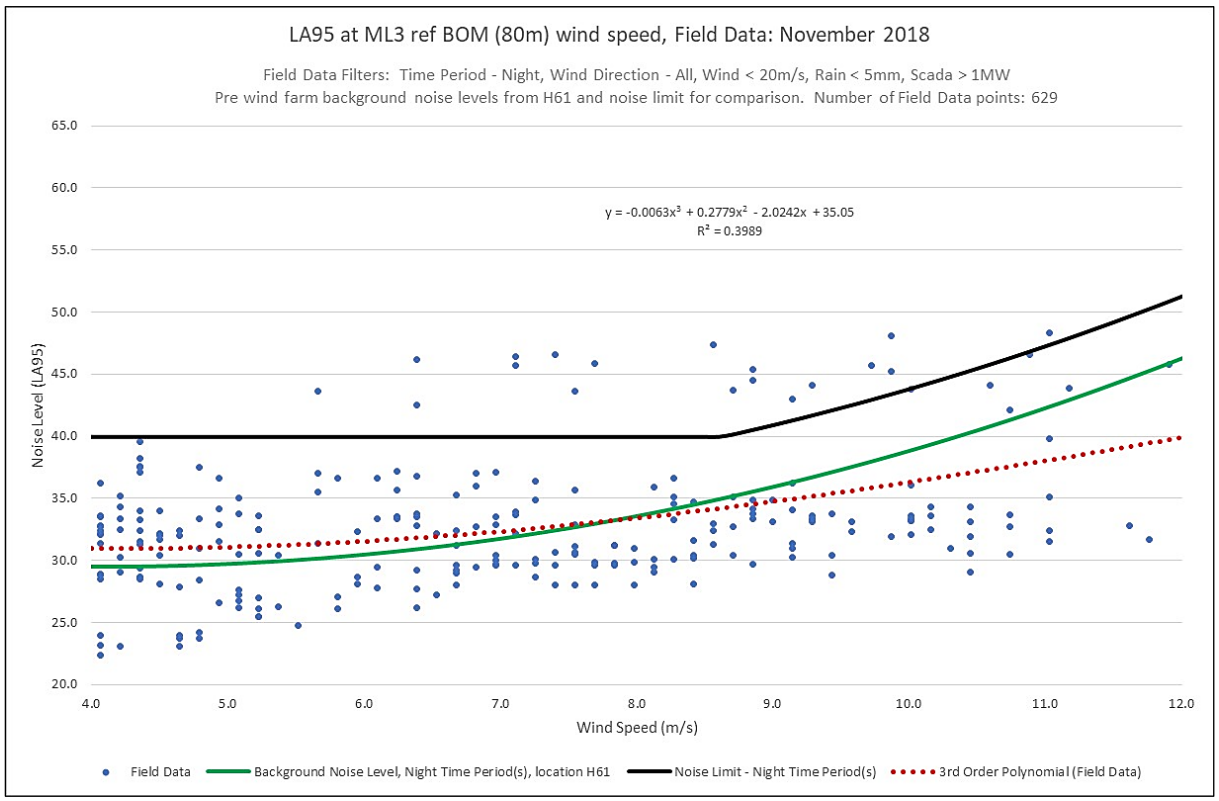
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

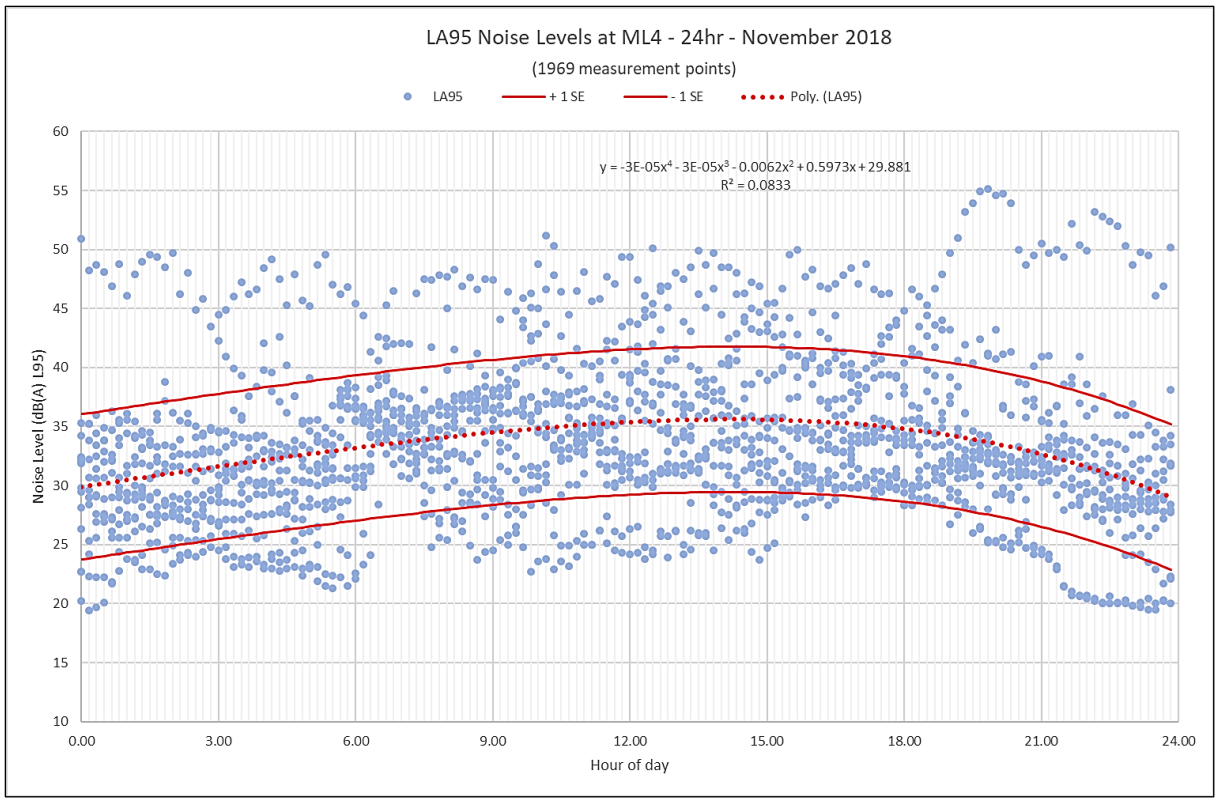


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

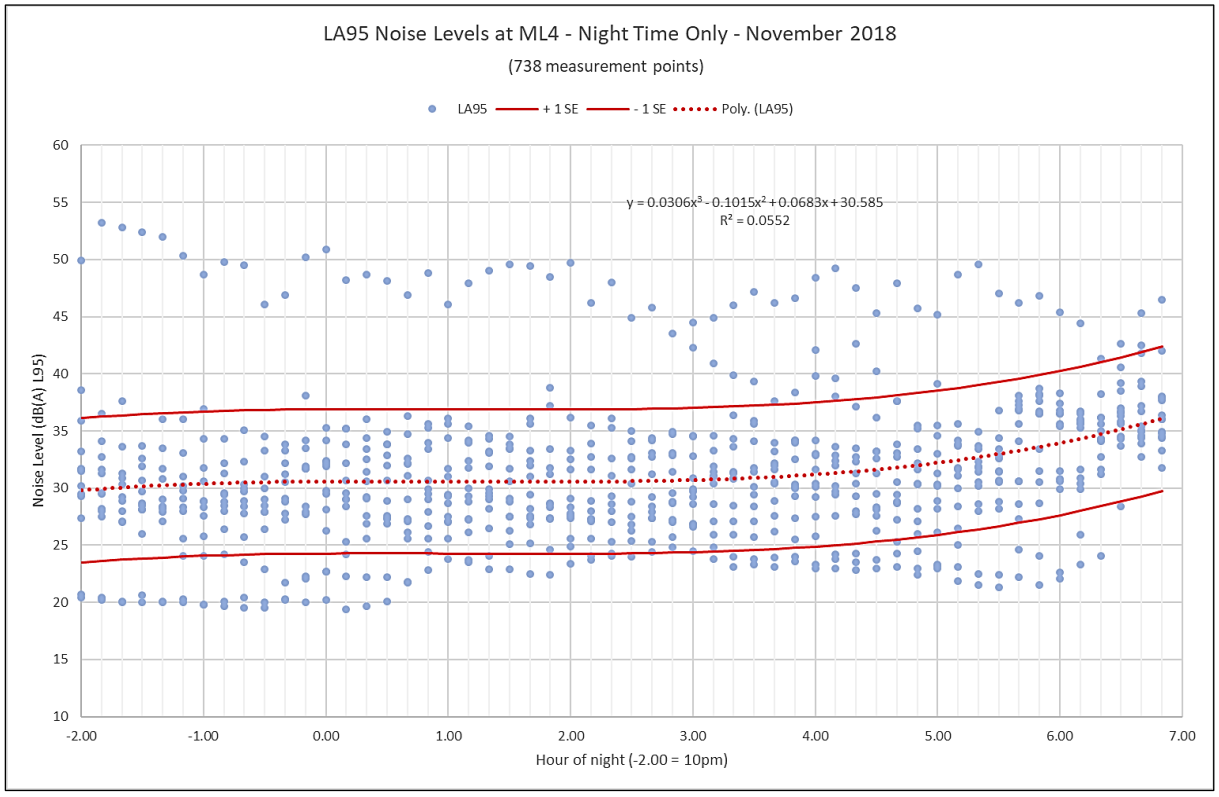


November 2018 – ML4 (DSJ)

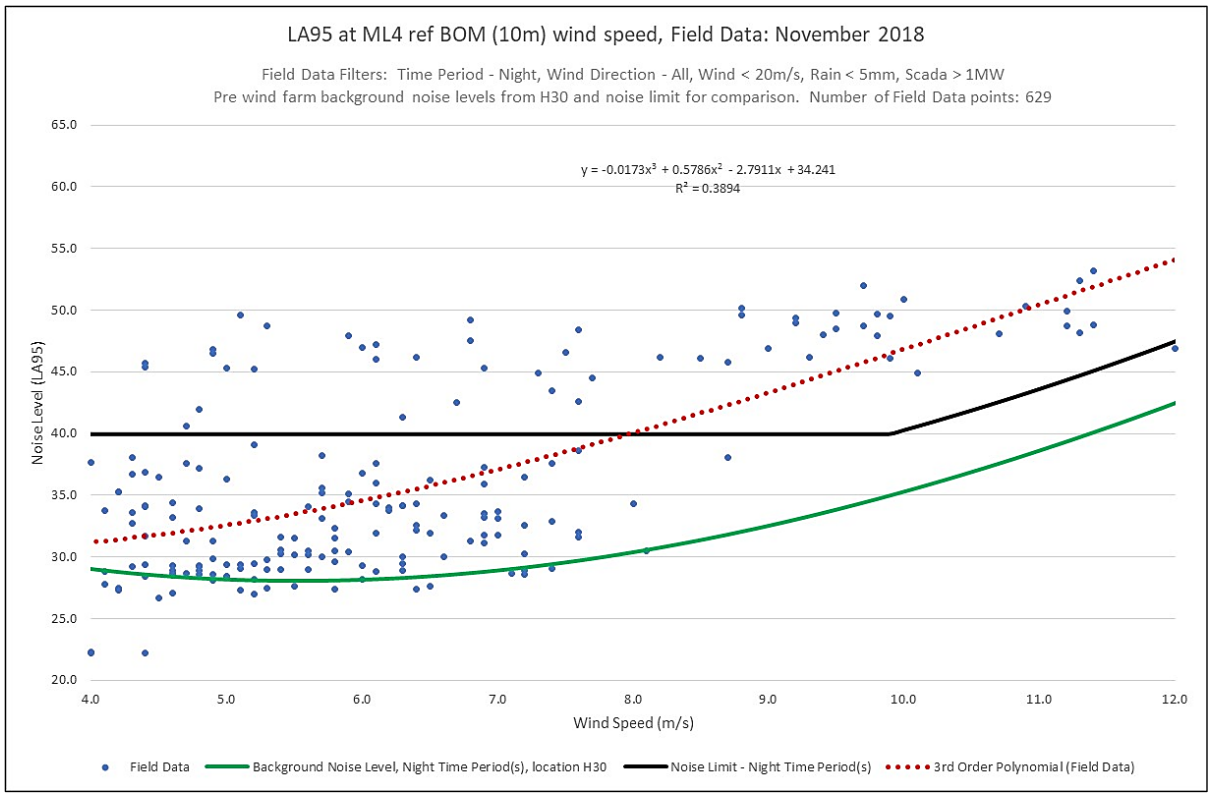
Variation in day and night sound levels for the month by time of day/night



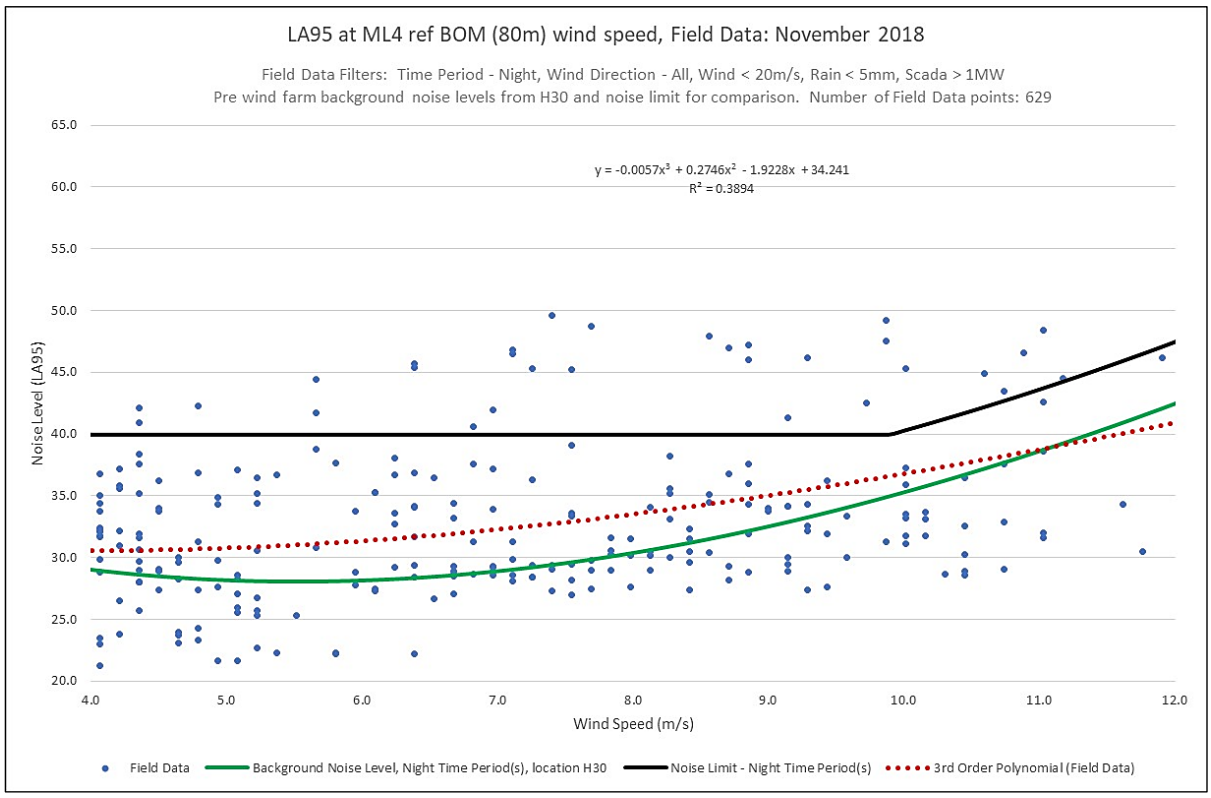
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

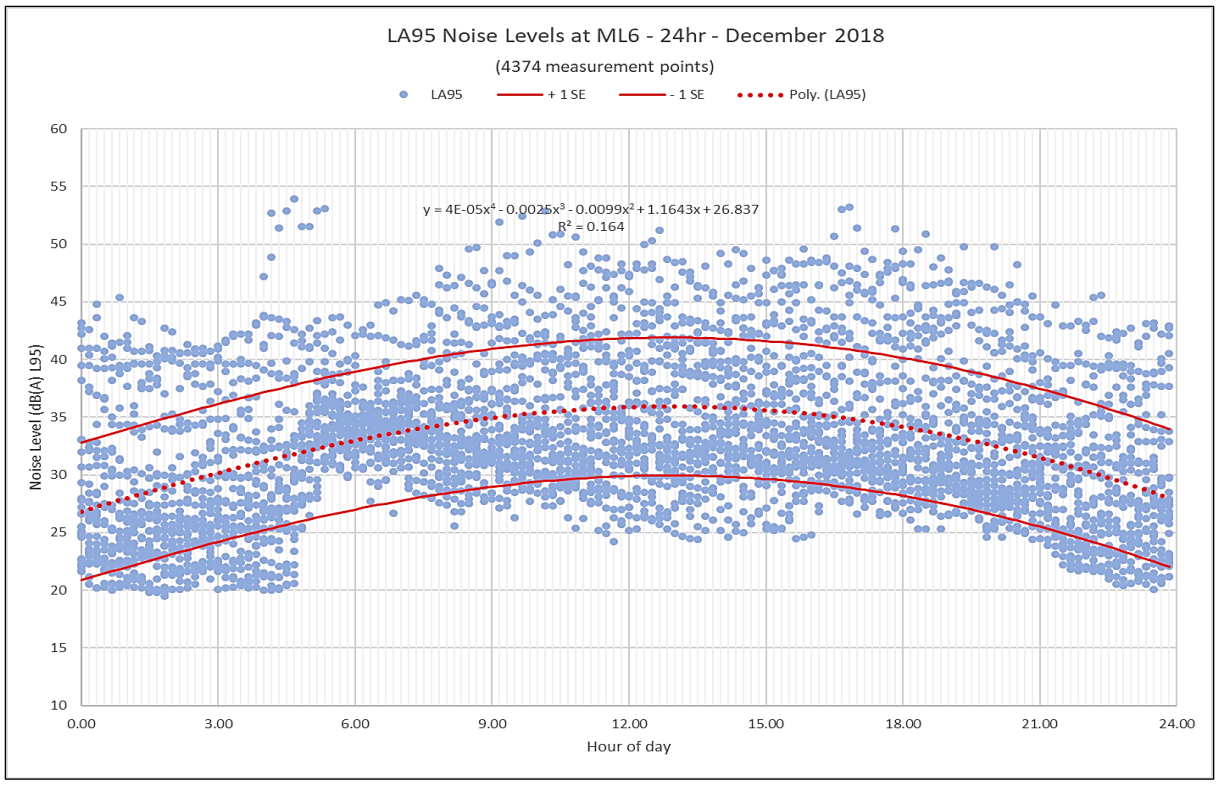


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

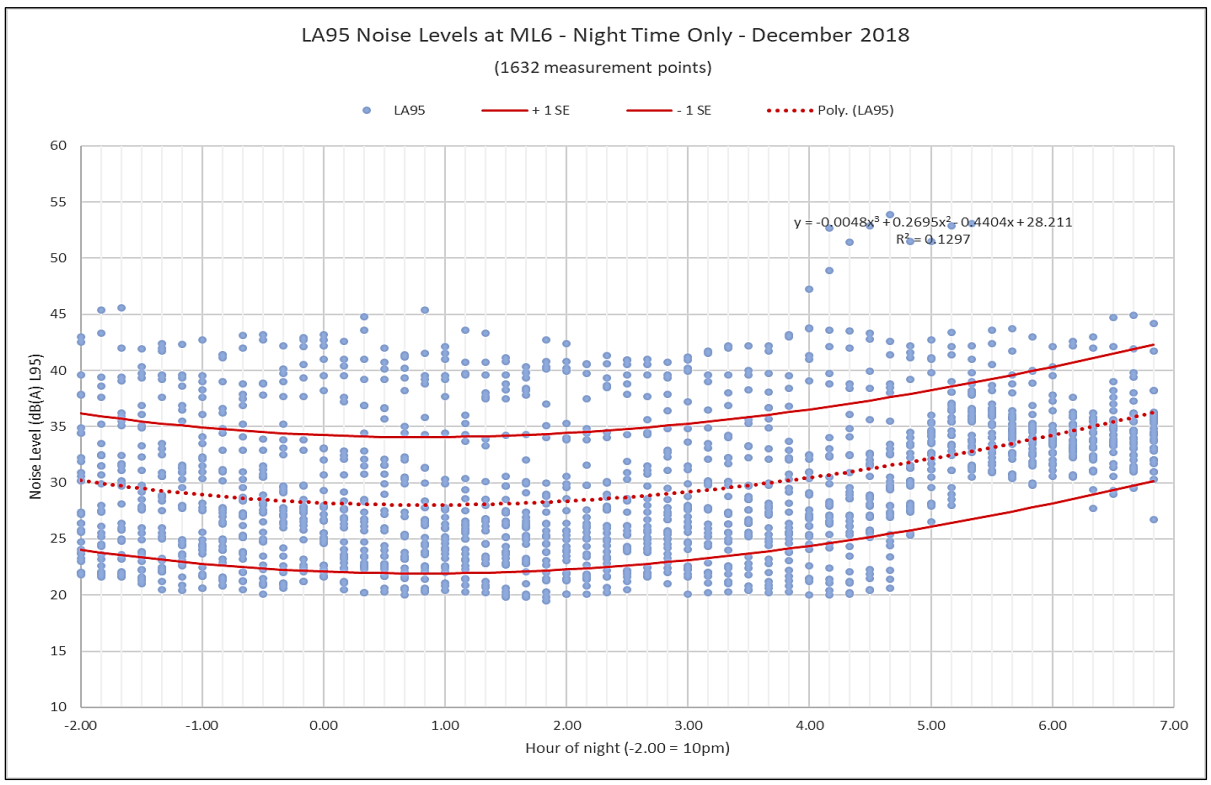


December 2018 – ML6 (JM)

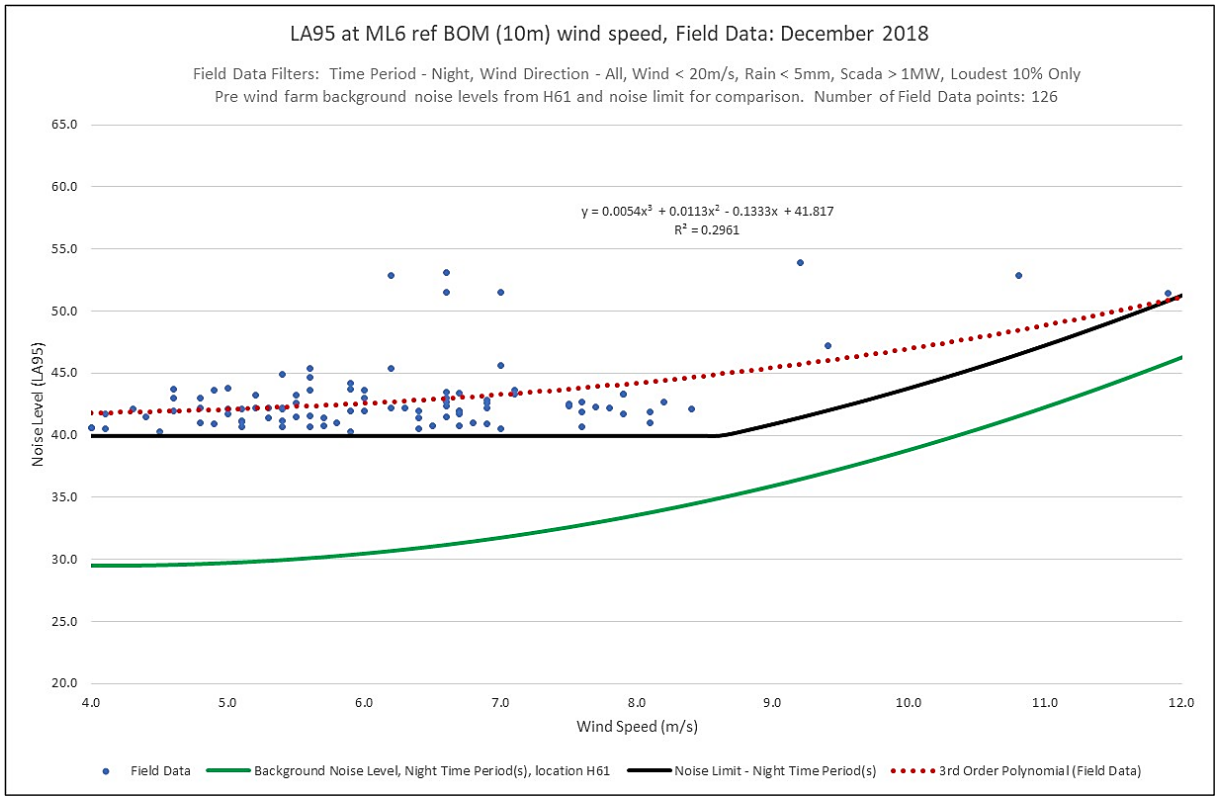
Variation in day and night sound levels for the month by time of day/night



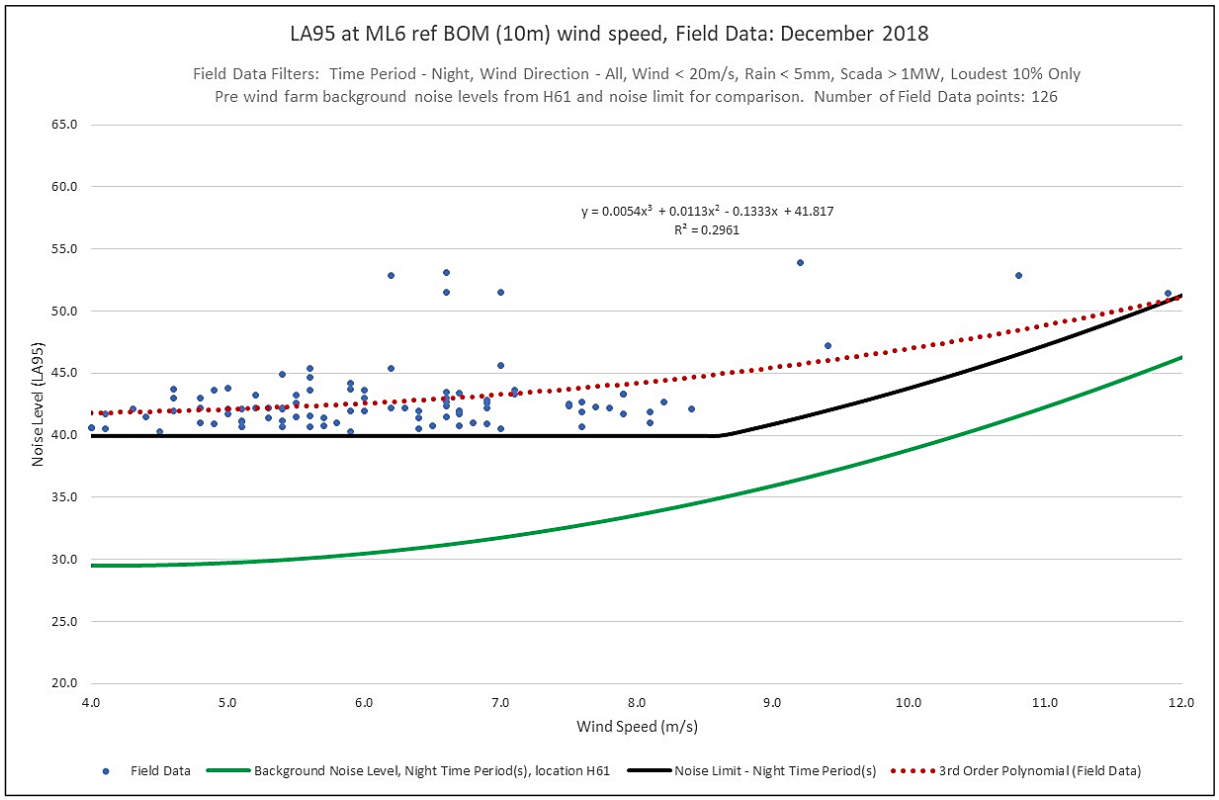
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

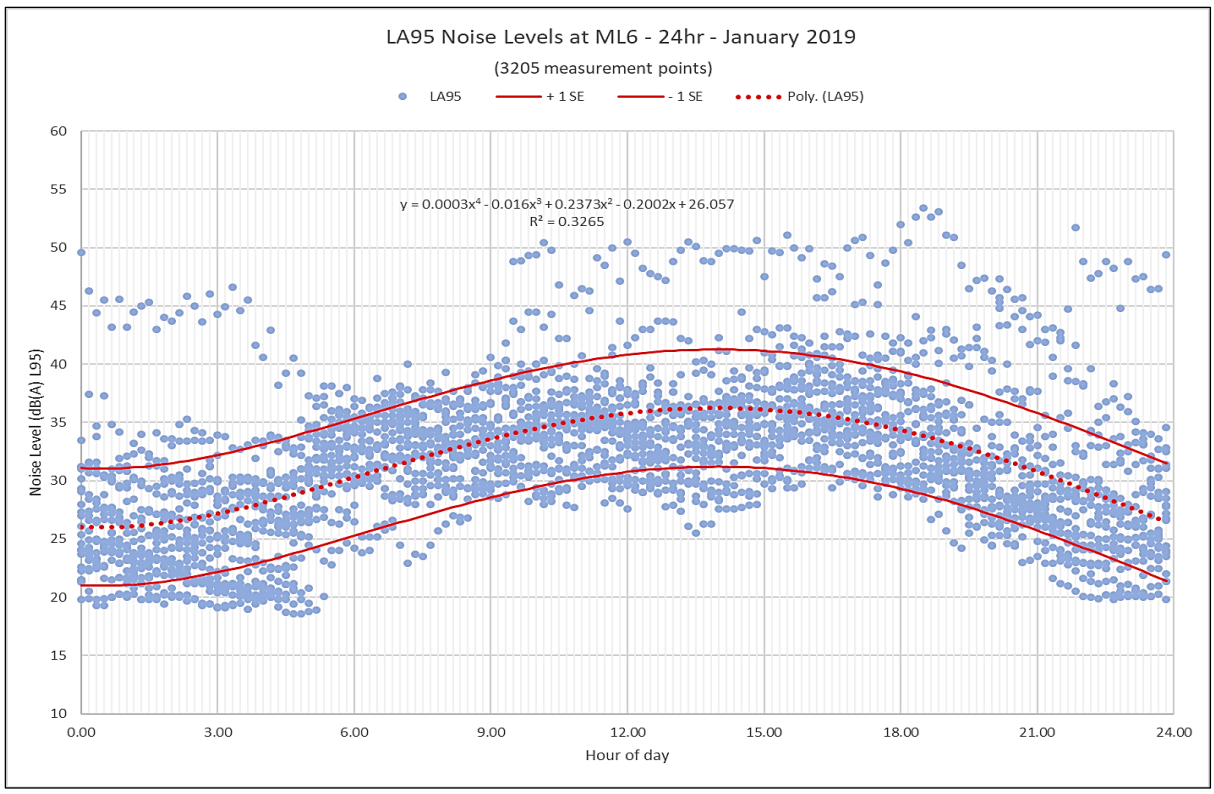


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

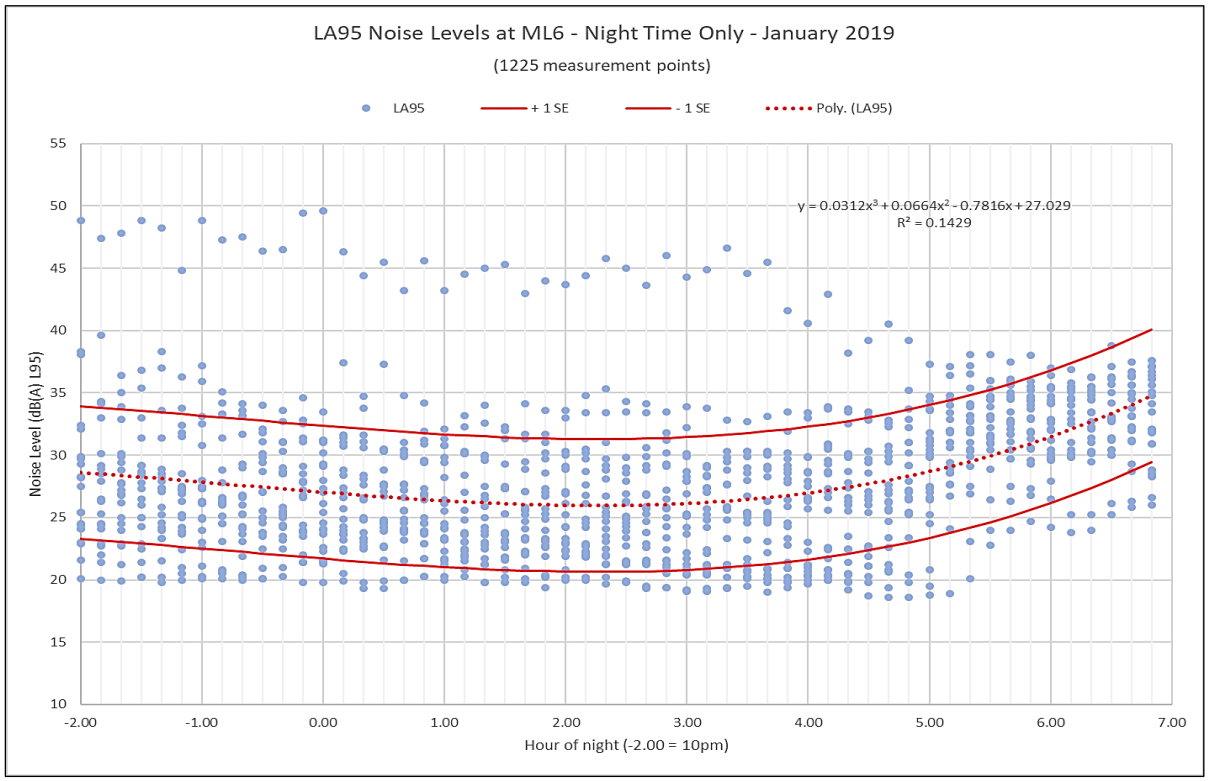


January 2019

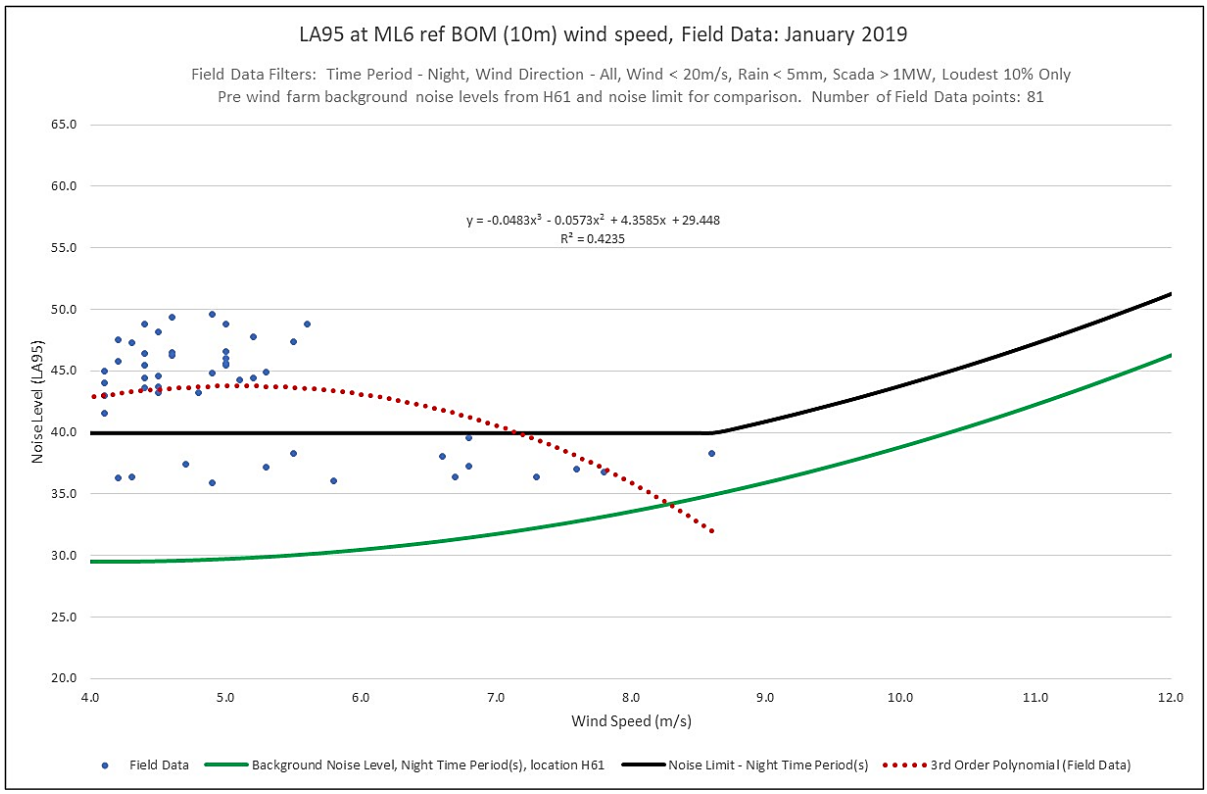
ML6 (JM) - Variation in day and night sound levels for the month by time of day/night



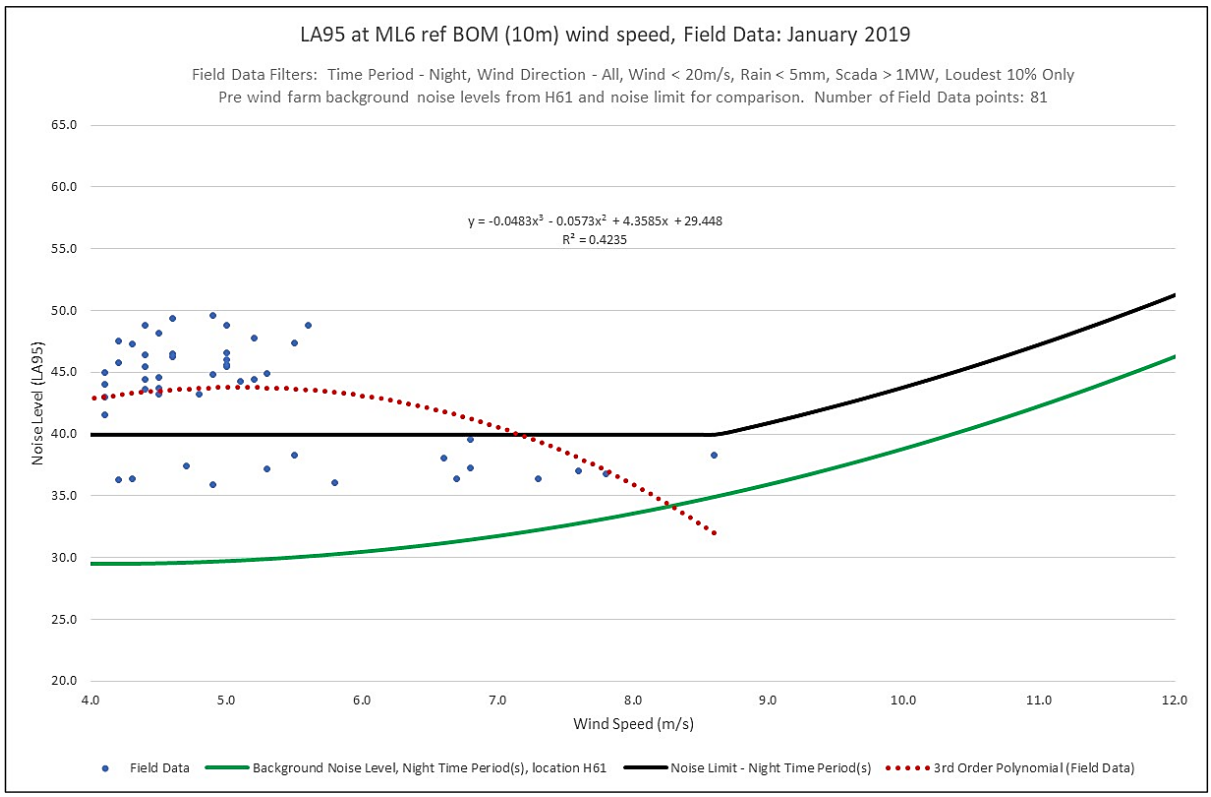
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

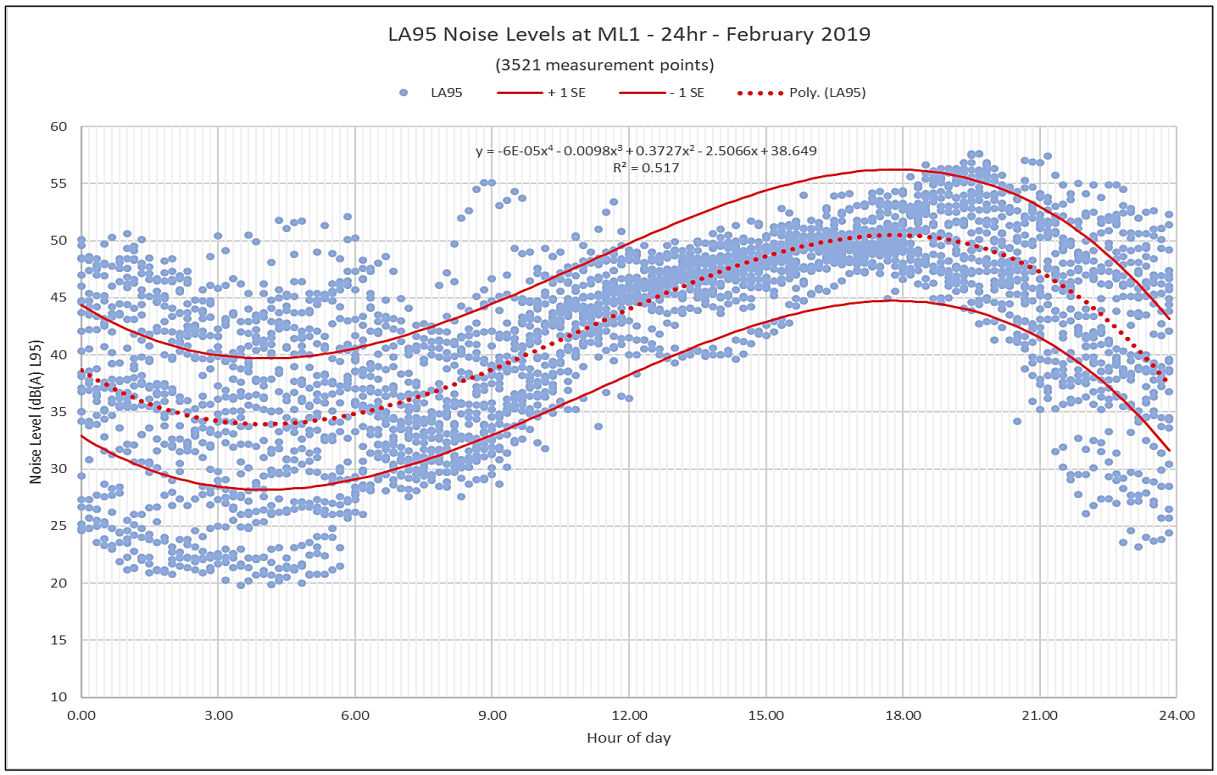


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

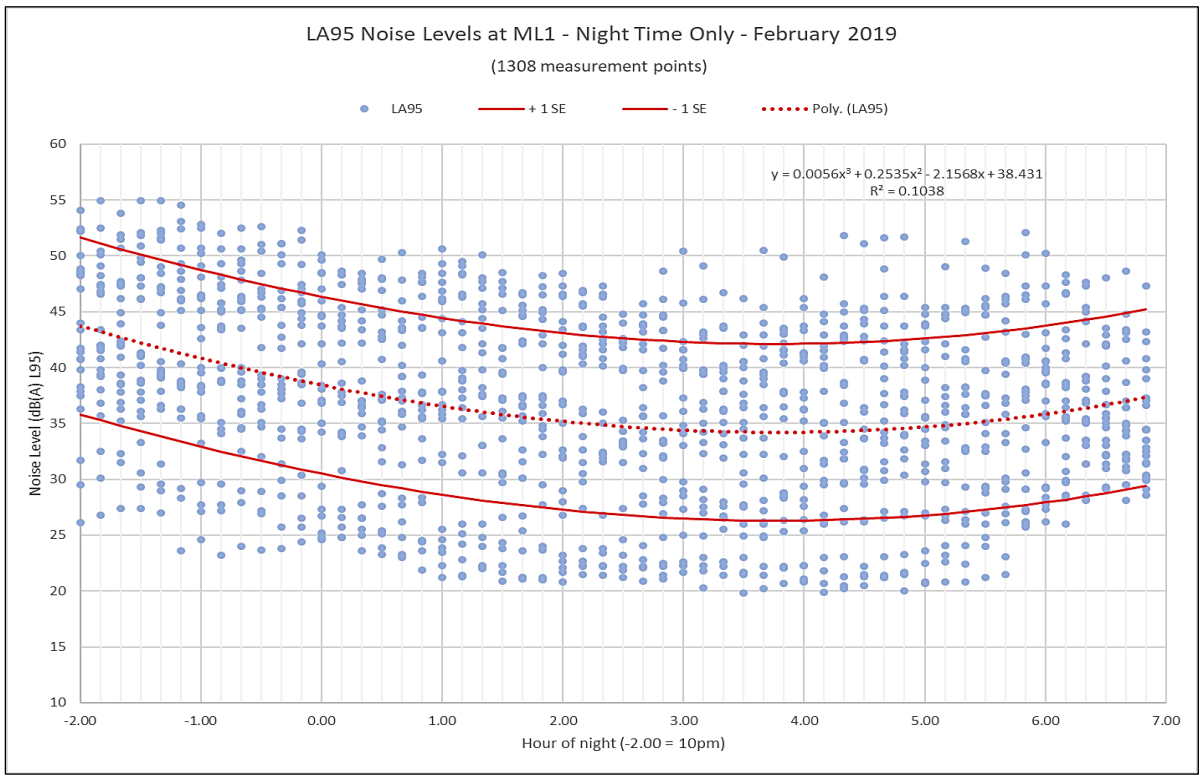


February 2019

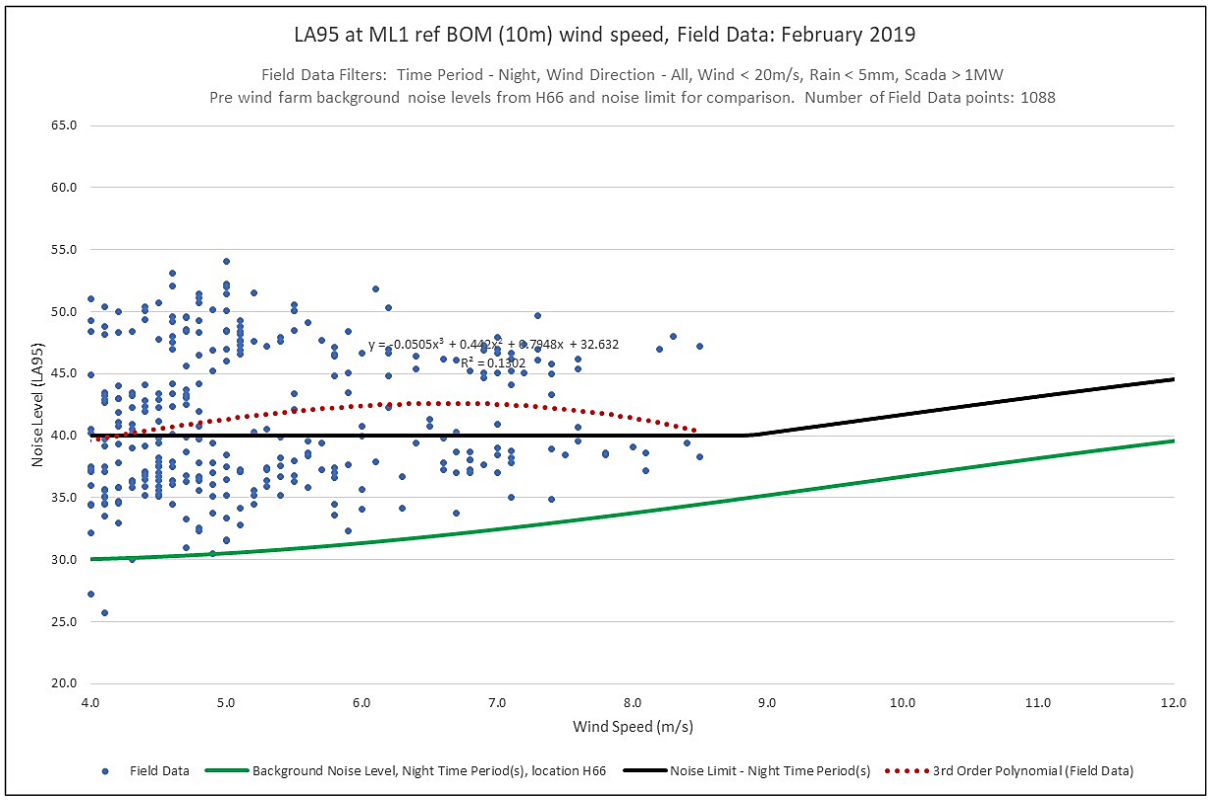
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



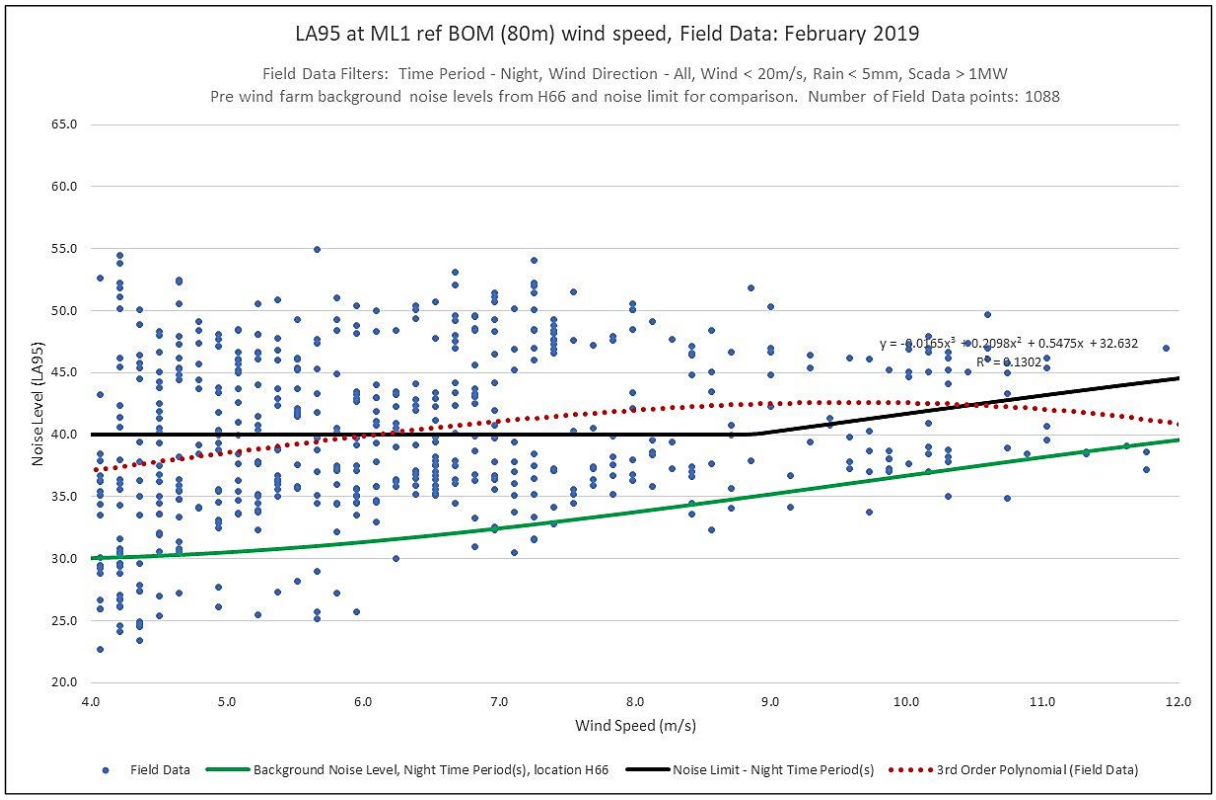
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

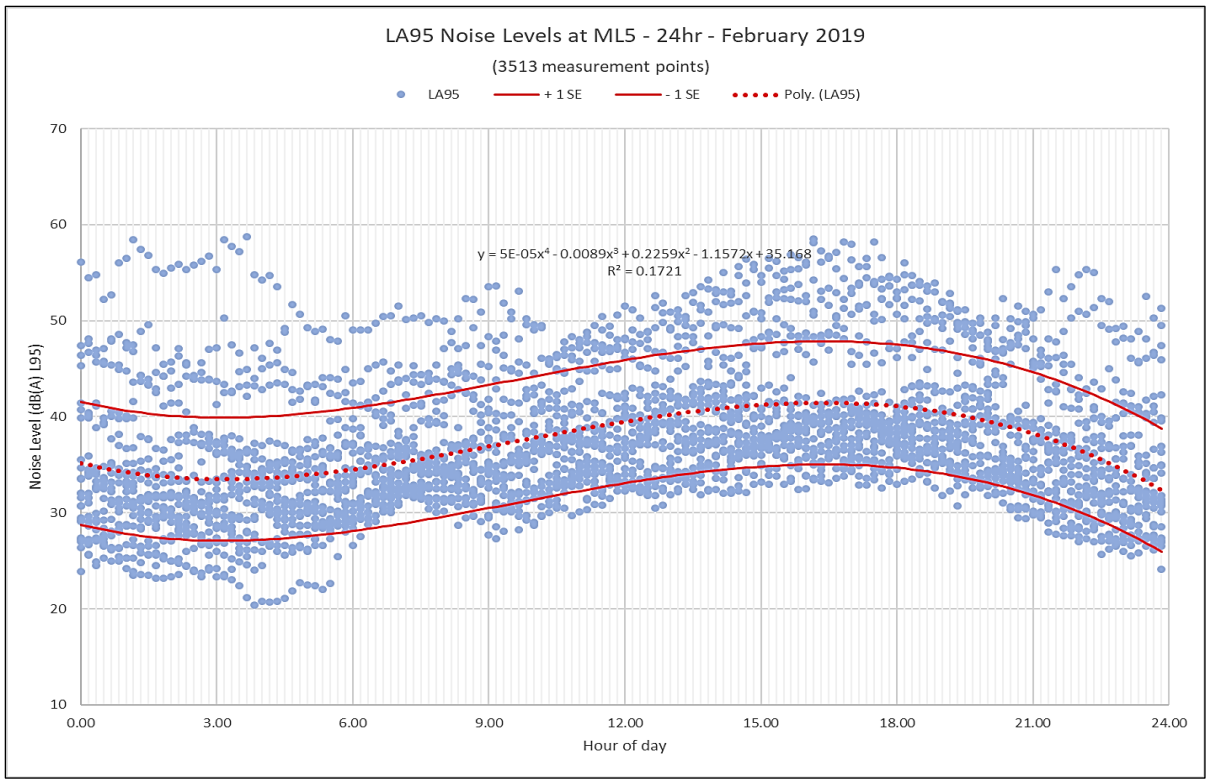


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

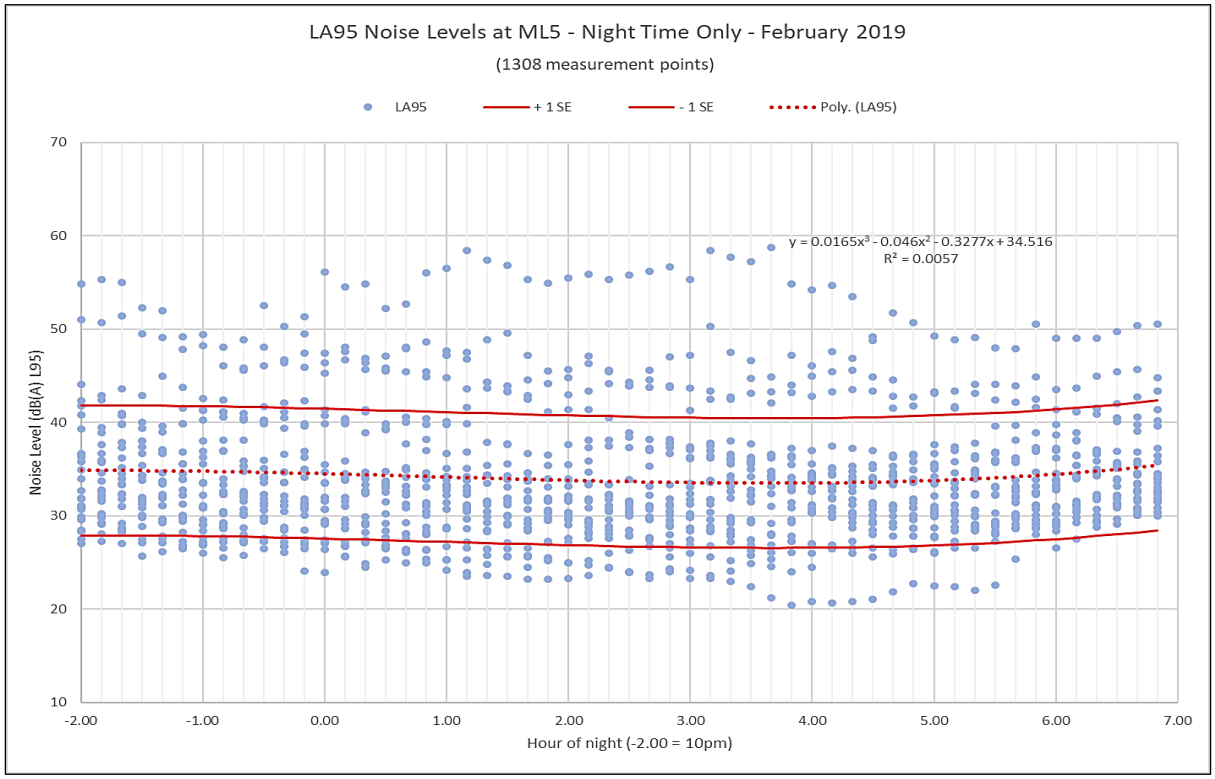


February 2019 – ML5 (AK)

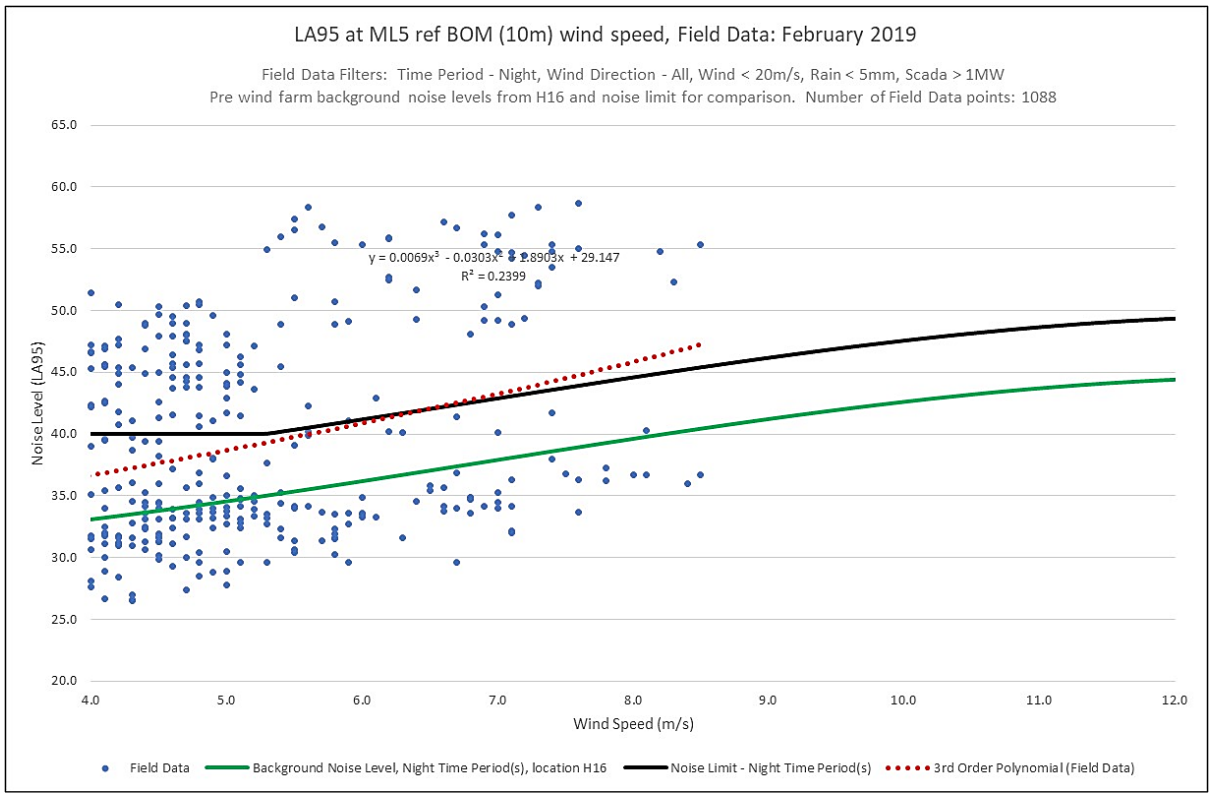
Variation in day and night sound levels for the month by time of day/night



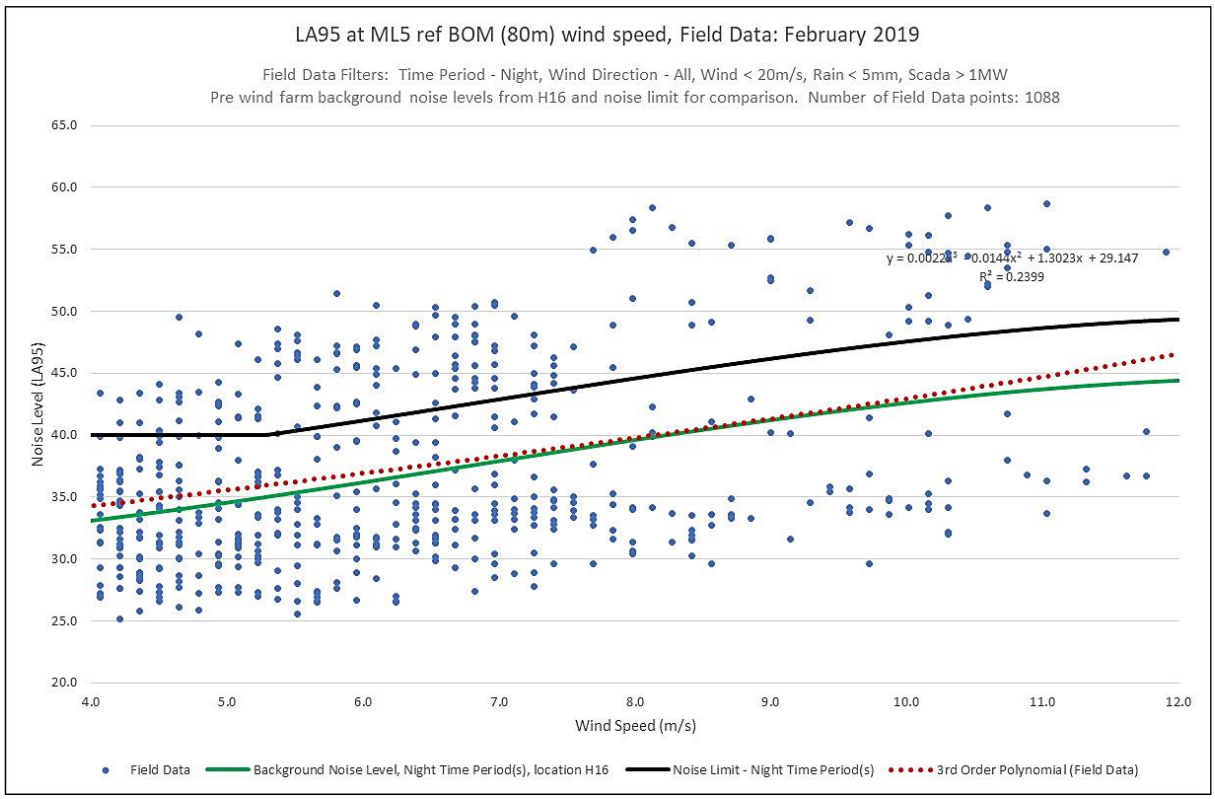
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

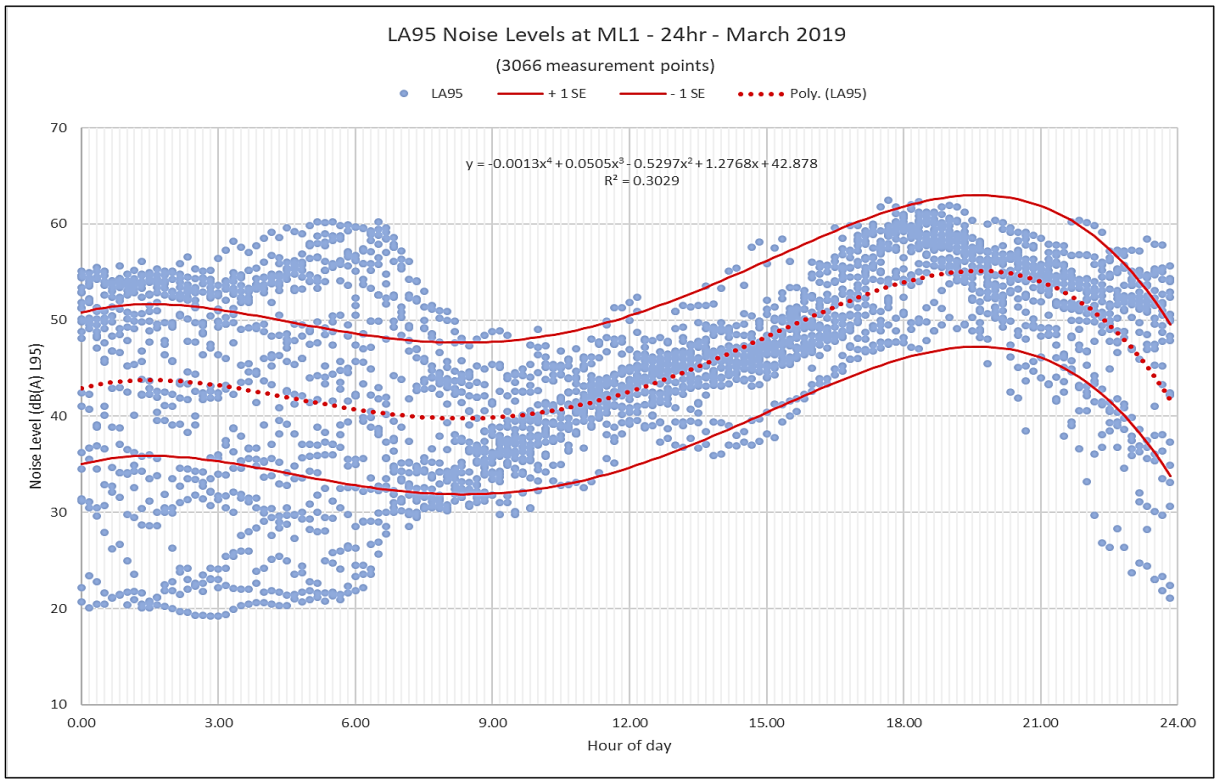


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

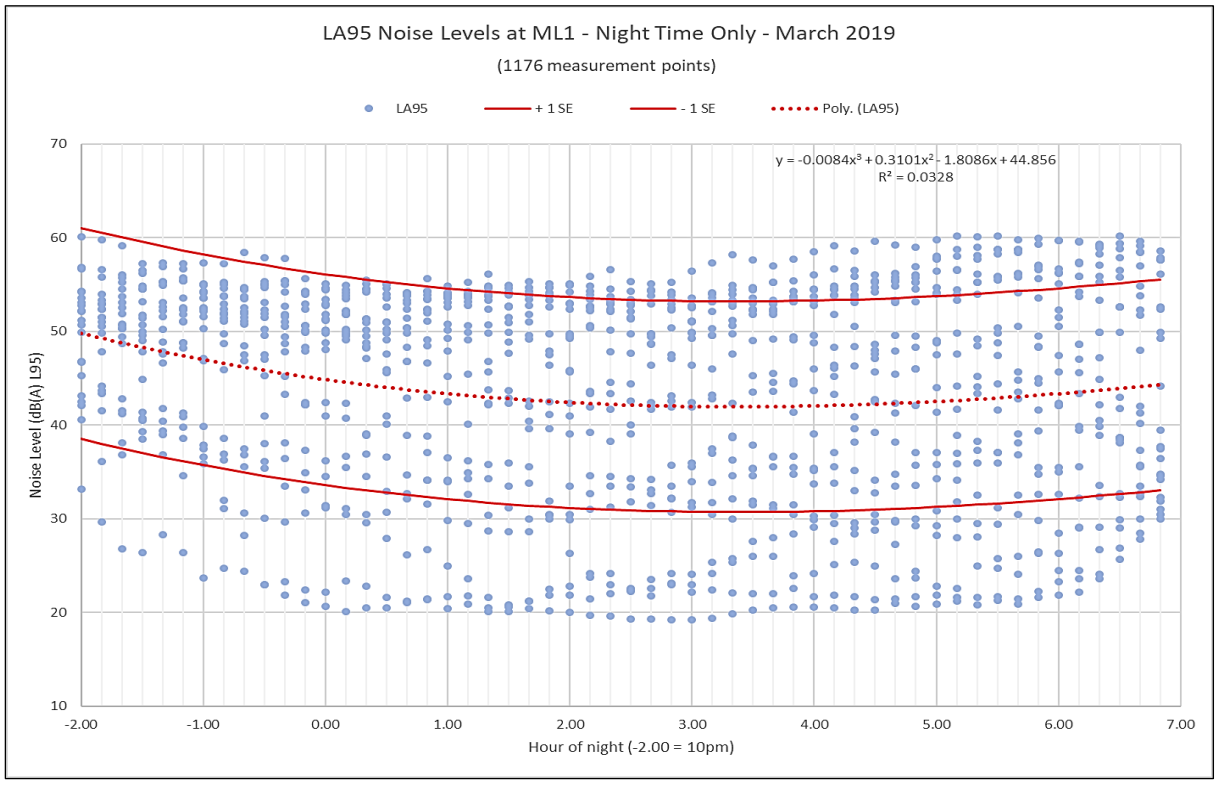


March 2019

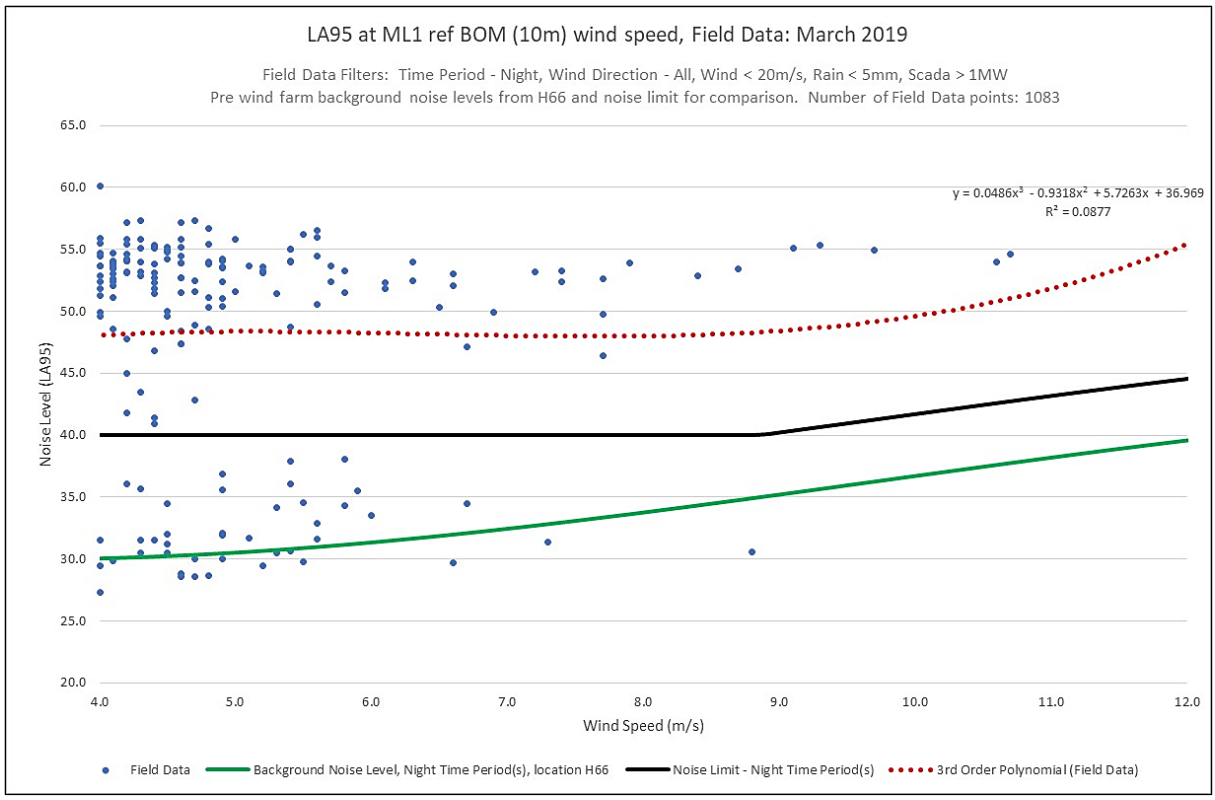
ML1 (JZ) - Variation in day and night sound levels for the month by time of day/night



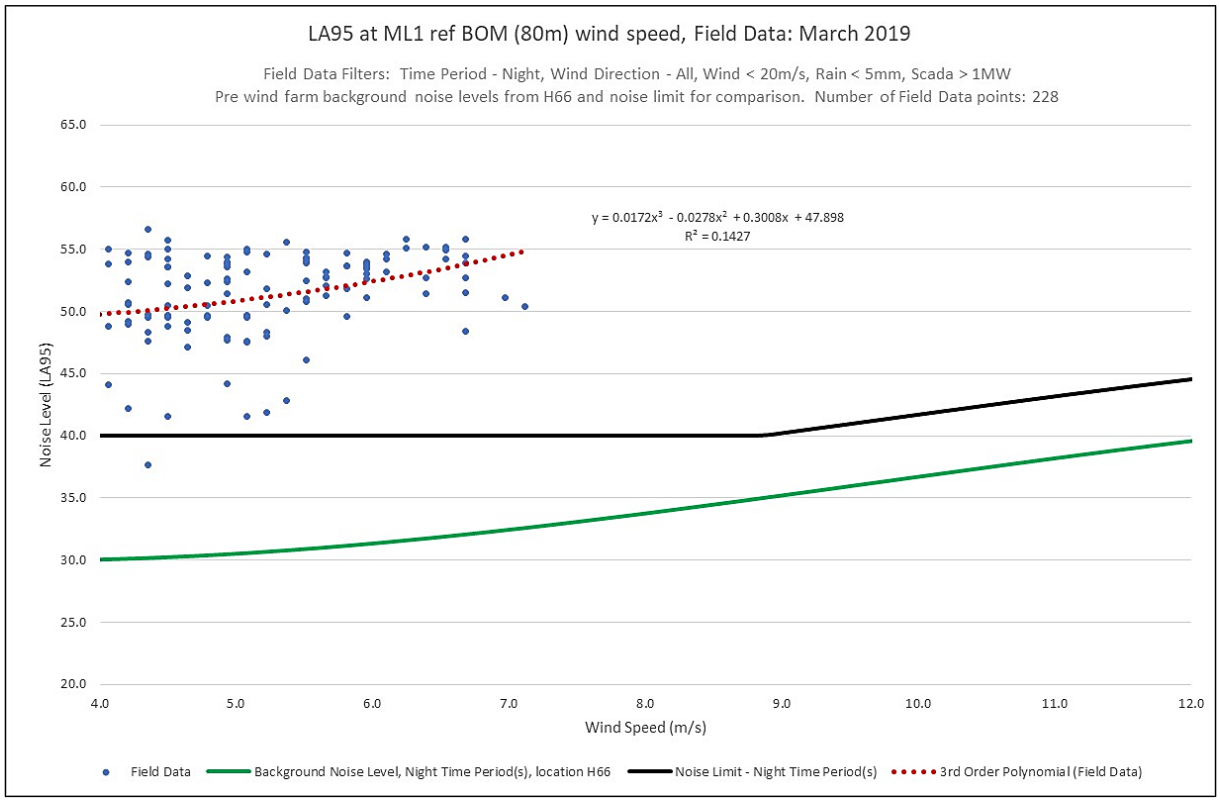
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds

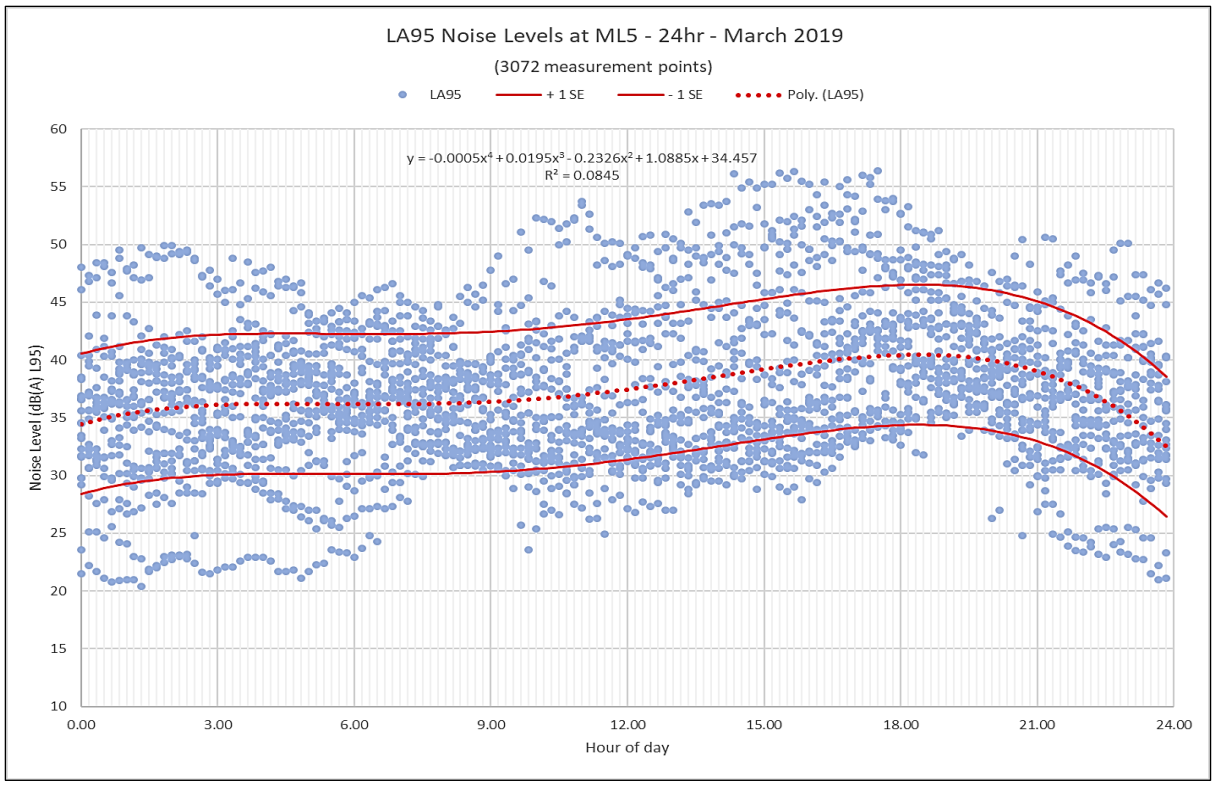


Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds

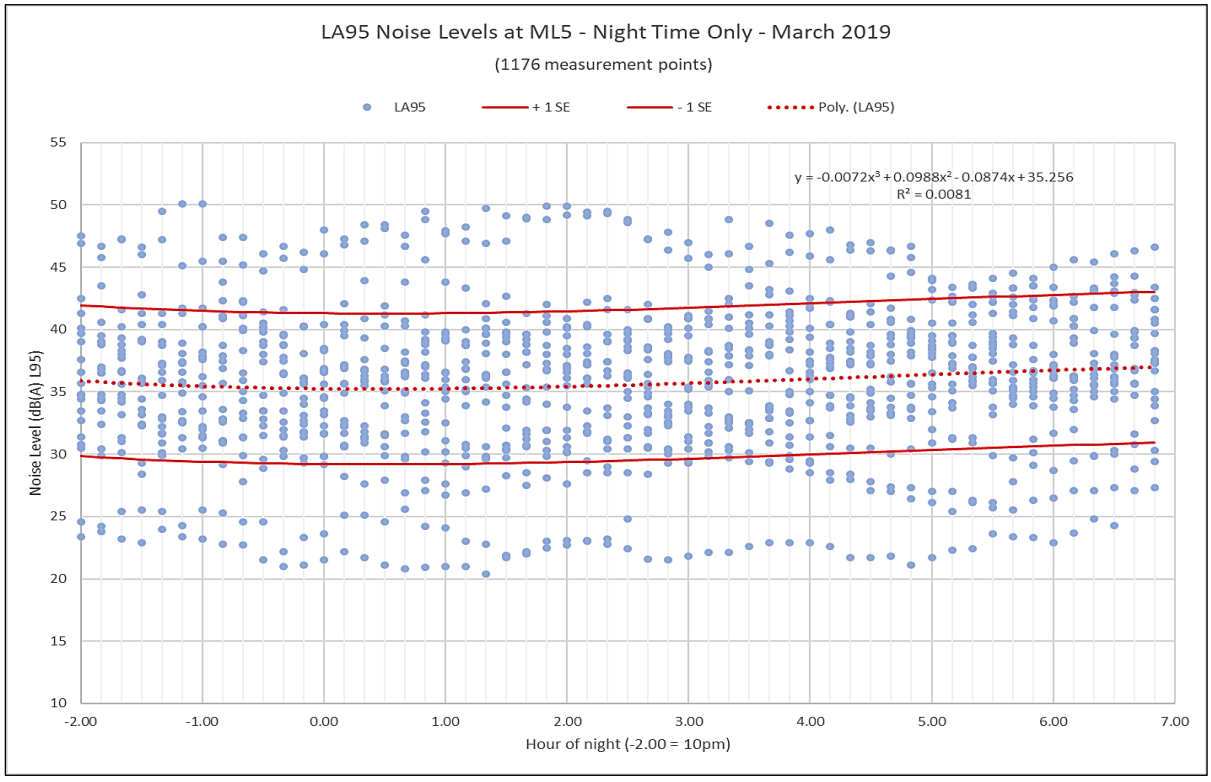


March 2019 – ML5 (AK)

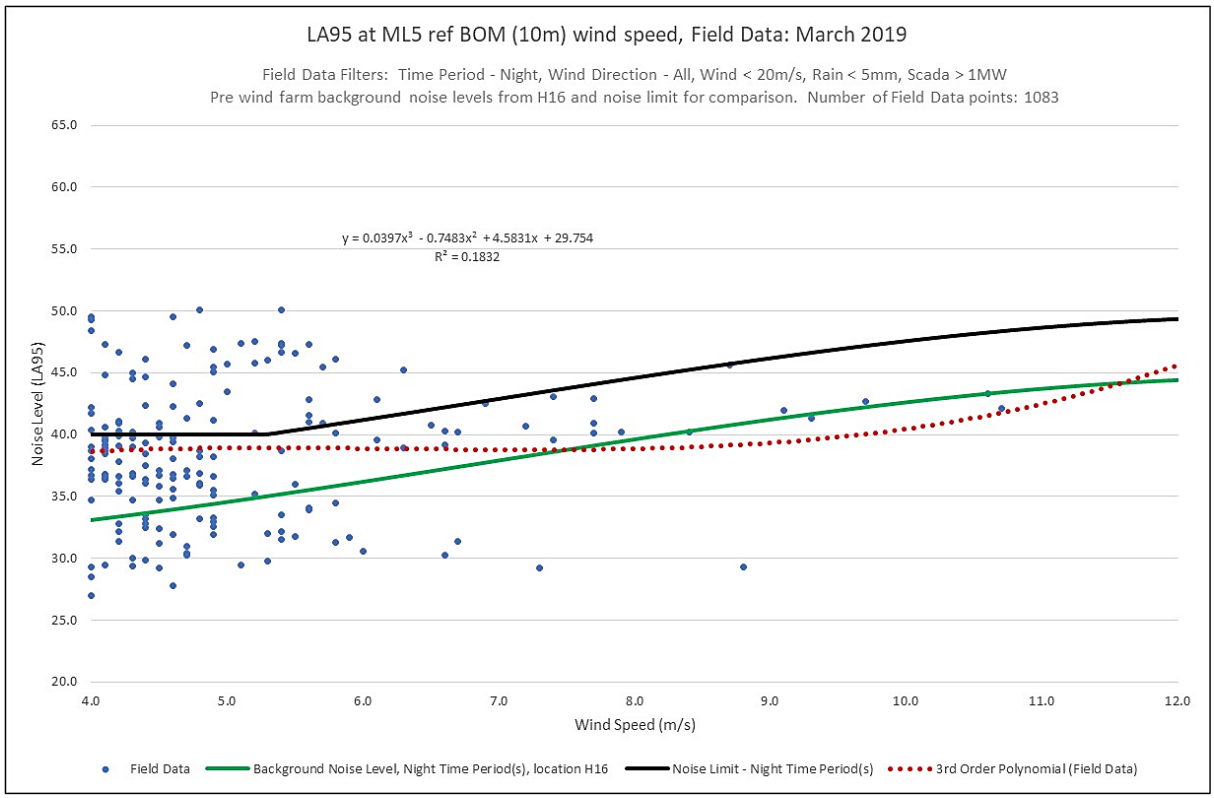
Variation in day and night sound levels for the month by time of day/night



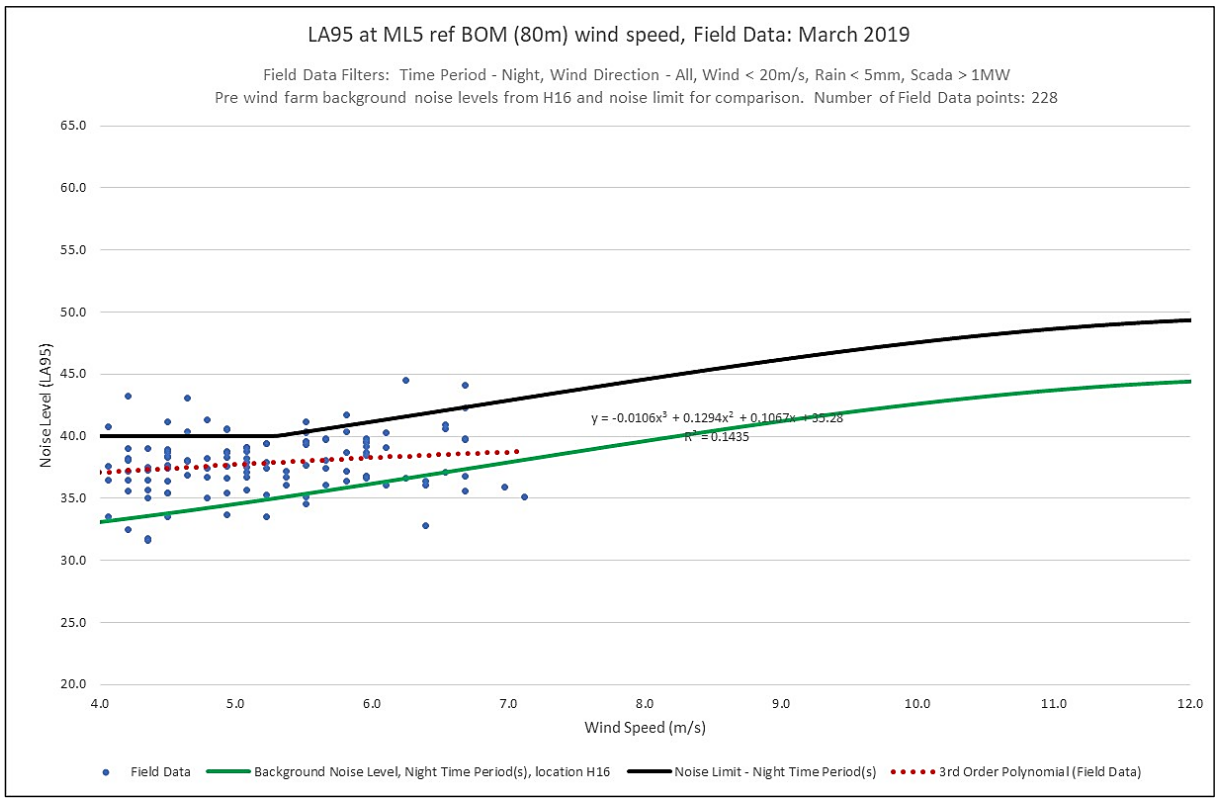
The variation in night-time sound levels for the month by time of night



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds



Regression curve of night-time sound levels v. noise limits for the month ref. 80m wind speeds



Assessment of Compliance with Approval Conditions

The Bald Hills Wind Farm Approval conditions state:

19. The operation of the wind energy facility must comply with the New Zealand Standard 'Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators' (NZ 6806:1998) (the 'New Zealand Standard'), in relation to any dwelling existing at the date of approval of this document to the satisfaction of the Minister for Planning.

In determining compliance with the New Zealand Standard, the following apply:

(d) The sound level from the wind energy facility, when measured outdoors within 10 metres of a dwelling at any relevant nominated wind speed, should not exceed the background level (L95) by more than 5dBA or a level of 40dBA, whichever is the greater.

(e) When sound has a special audible characteristic, the measured sound level of the source shall have a 5 dB penalty added.

(f) Compliance at night must be separately assessed with regard to night-time data. For these purposes the night is as defined in SEPP-N1. For sleep protection purposes, a breach of the standard set out in 19(a), for 10% of the night, amounts to a breach of the condition.

NMS Notes to Condition 19.

- The night-time period in SEPP-N1 is the time between 2200 and 0700 hours.
- The expression "6806" should read "6808".

Clause 5.4 of NZS6808:1998 states

5.4 Compliance assessment

To determine conformance with the limits set out in 4.4.2, a comparison shall be made between the best fit regression line of the background sound levels and the regression curve of the operational windfarm corrected for any special audible characteristics. If the background levels were not measured prior to installation (4.5.1), it may be necessary to obtain background sound level measurements for limited periods at critical windspeeds to satisfy 4.4.2 (e.g. if wind turbine or windfarm sound levels exceed 40 dBA L_{95}). This may be for a limited range of windspeeds and directions, with the WTG(s) non- operational.

The limits referred to in (4.4.2) are those stated in Condition 19.

By combining the two requirements compliance is assessed by:

- Applying the procedures of Condition 19;
- Evaluating continuous 24-hour 10-minute sound levels against the sound limits' criteria of condition 19(a); and
- Comparison with approval condition 19(c) (sleep disturbance) and approval condition 19(b) (penalty for special audible characteristics).

Marshall Day Acoustics (MDA) Background Sound Levels for Compliance Assessment

The background levels for this Report are applied from the regression curves and exceedance limits/lines in the 2012 Marshall Day Report 'Rp001 2008393ML – Bald Hills Wind Farm – Revised Noise Predictions – Tenement Plan Layout G Rev 1' dated 24 February 2012 (the '2012 MDA Report').

An "exceedance" line is drawn relating wind speed to the background sound levels so:

> *…[noise levels] at any relevant nominated wind speed, should not exceed the background level (L95) by more than 5dBA or a level of 40dBA, whichever is the greater.*

The exceedance line is shown in the 2012 MDA Report and is reproduced in the charts in this Report. The relevant nominated windspeeds in the 2012 MDA Report are at 10 metres AGL and the same height is applied in this Report.

In preparing this Report reference was made to various MDA reports, including the 'Noise Compliance Testing Plan, 2015. In NCTP section 3, just above Table 2, MDA state that only rain affected data was removed from the background data. The NCTP accepts the use of 10m up to hub height wind speed data "within the site" (NCTP sect 5.1). The background collected by MDA and reported as trend line equations for data obtained prior to construction is an unknown quantity. The collection of background data by MDA in 2012 did not filter for frogs and insects and local wind speed across microphones and these elements must, therefore, be included in our monitoring and analysis program.

NMS reviewed the various reports published by MDA and their approach to 'filtering' data as explained above is adopted in this report. Insect noise was not identified by residents as being an issue nor was it identified in sampled audio recordings.

No other data is excluded as the 2012 MDA Report does not specify and detail the application of other filters.

MDA do not specify a process where only “wind farm affected noise levels” are recorded. This is a significant failure as NZS 6808 and the approval conditions require assessment of wind farm noise.

Conversely, NMS has specific processes to identify wind turbine activity and to assess the background sound levels generated by the wind farm:

The post-installation operational background sound levels are correlated to either

1. Wind farm power generation (AEMO data) to identify “wind farm affected sound levels”; or
2. Identification of ‘turbine signature’ through infrasound analysis.

MDA reports viewed by NMS do not identify dates and times of noise complaints that had ‘special audible characteristics’. Secondly, NMS has not seen verifiable analysis by MDA for special audible characteristics. This is a significant failure as NZS 6808 and the approval conditions require assessment of special audible characteristics.

NMS has not seen a credible defined wind farm monitoring process that includes ‘special audible characteristics” identified as such by affected persons in any report or supporting documentation prepared by MDA, the Minister, the Wind Farm Commissioner or the EPA.

As NZS6808:1998 does not require correction of 'wind across the microphone noise' it is implicit in the method of the standard that ‘wind noise’ is acceptable when measuring background sound levels.

The recorded and monitored sound levels for this monitoring program are calculated in spreadsheet format as outlined later in this report.

NMS Assessment of Compliance (Process)

The interactions between the approval conditions and NZS6808 are complex. There are the implied averaged levels of condition 19(a) and the regression curves of NZS6808; the implied single sound levels of condition 19(c); and the penalty application to single sound levels in condition 19(b); plus, all the implied variations due to wind speed and direction. 'Single' meaning a single 10-minute set of sound levels.

The initial test for non-compliance is whether the overall sound levels are above the noise thresholds.

- Sound levels, at any relevant nominated wind speed, should not exceed the background level (LA95) by more than 5dBA or 40dBA, whichever is the greater.

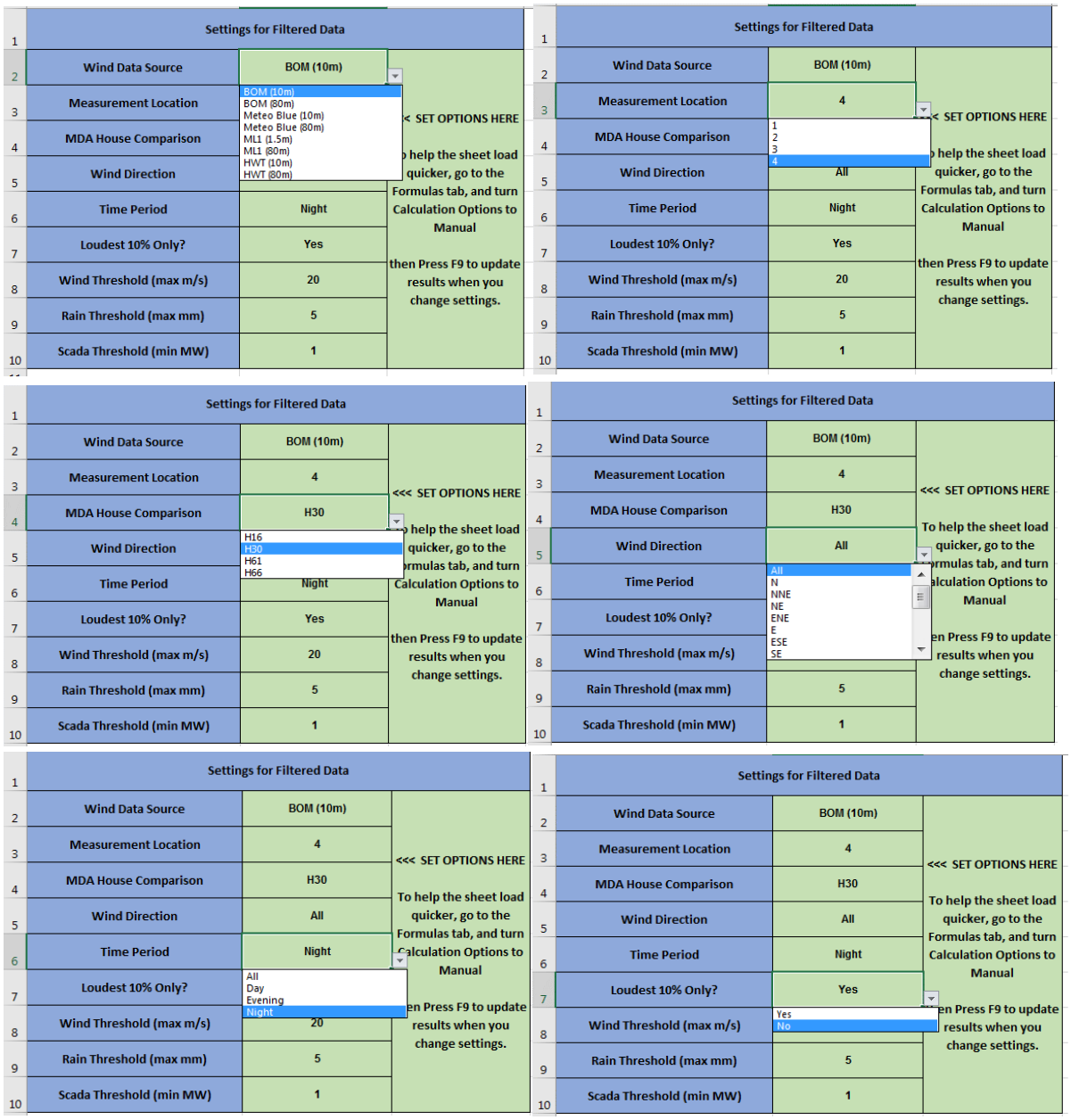
The analysis charts in this Report show a substantial number of occasions where sound levels are "non-compliant". (In our opinion, this pattern can be seen in most, if not all, "compliance" reports published by MDA on behalf of the wind farm).

- The "non-compliant" sound levels are then tested for "Night-time 10% Loudest". This is the 'breach' test under Condition 19(c) of the approval conditions.
- Assessment is not made for daytime exceedance as daytime sound levels were recorded by different residents as being 'audible', rather than as 'annoying'.
- The sound levels are processed for special audible characteristics as recorded by personal diaries. The SAC tests are applied to both the overall levels and the "Night-time 10% Loudest".
- Separate analysis is made for those nights recorded by residents as having intrusive noise that disturbed sleep. Special audible characteristics are present on many nights, as reported in this Report. Consequently, the 5dBA penalty for condition 19(b) applies to these reported sound levels.

Our noise impact assessment considers all the variations outlined above. The monitoring analyses are contained in the Regression Analysis Spreadsheets for May 2018 to March 2019. The analysis settings are illustrated in Table 1. The settings are extensive and allow comparison of many different scenarios.

Our analysis confirms that the wind farm is in non-compliance if sound levels are above the derived noise limits (solid black lines on the following charts pages 127 to 150) and above the derived regression curves (red dots on the charts).

Table 1: Regression analysis by wind speed and residence location

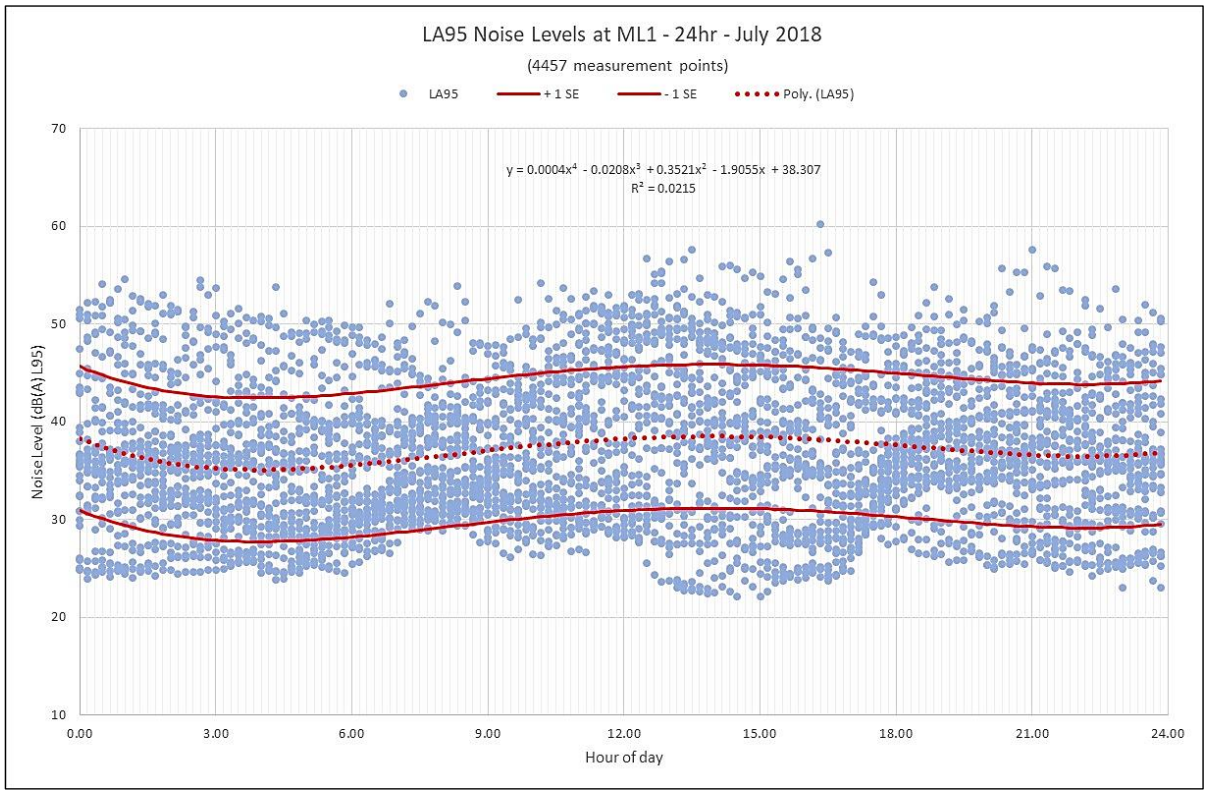


The first set of charts, following, for July 2018 at residence ML1 illustrate the refinements that can be applied through the regression analysis spreadsheets. This allows a ready comparison between the different wind speeds and locations to measured sound levels, day and night.

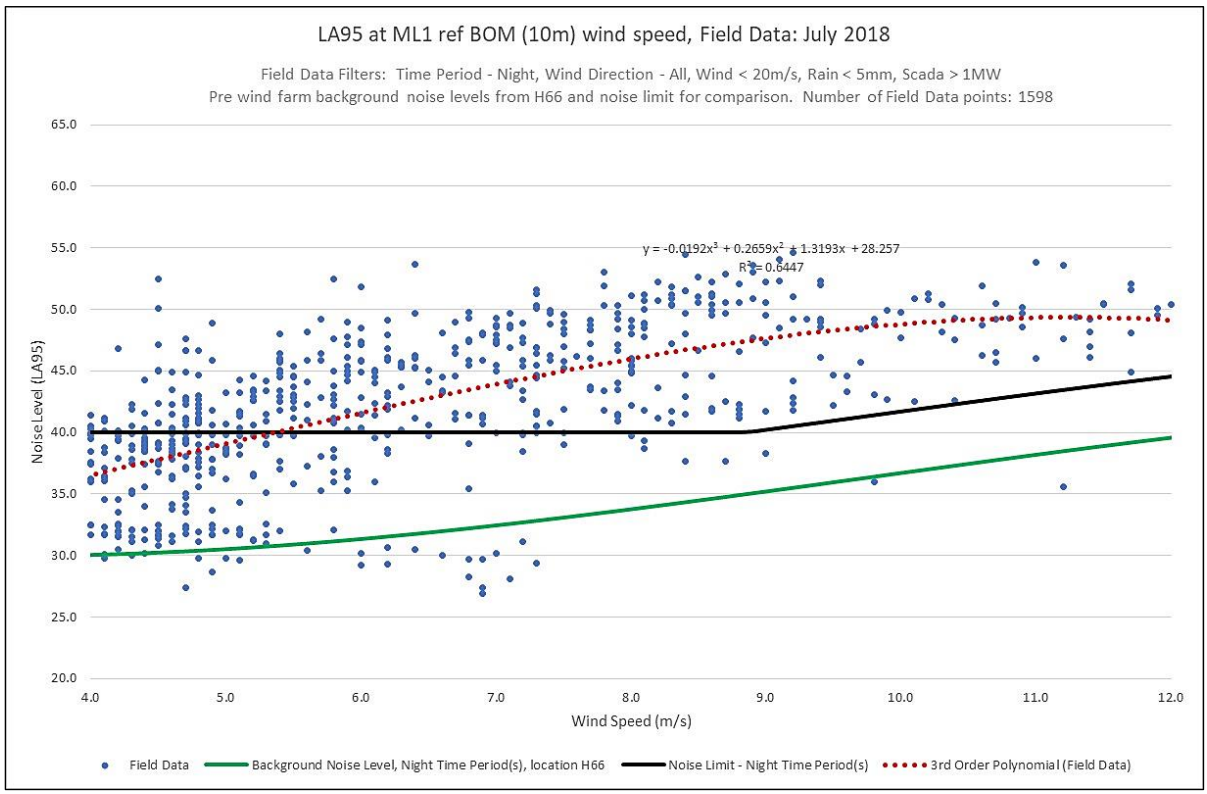
The second set of charts for May 2018 to March 2019 at the various residences apply a 10m BOM wind speed, data from Night-time 10-minutes samples for the whole of the month; applying a '10% loudest' filter.

Examples of data-filtering using the regression charts

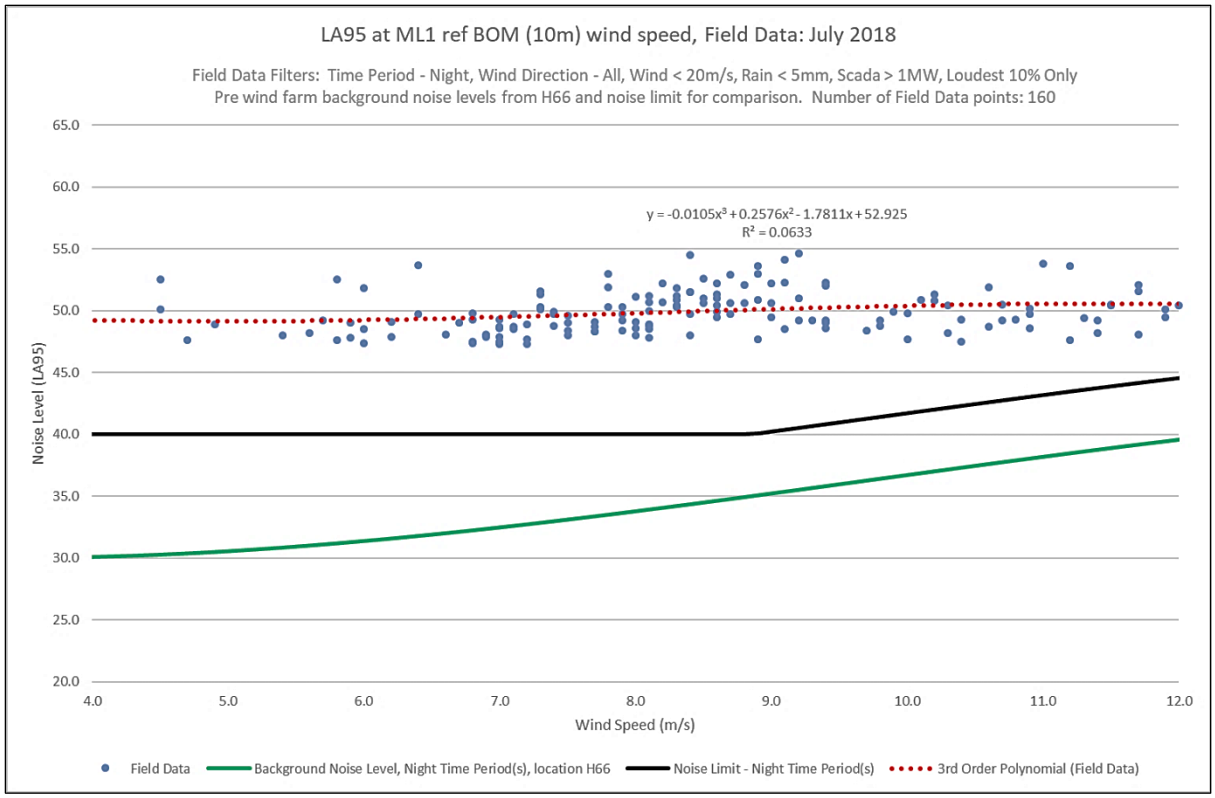
Applying a 10m BOM wind speed, data from all 10-minutes samples for the whole of the month



Regression curve of night-time sound levels v. noise limits for the month ref. 10m wind speeds



Applying a 10m BOM wind speed, data from Night-time 10-minutes samples for the whole of the month; applying a 10% loudest filter.



In summary, the compliance/non-compliance analysis is a three-step process:

- **Record all 10 minute LA95 sound levels, day and night;**

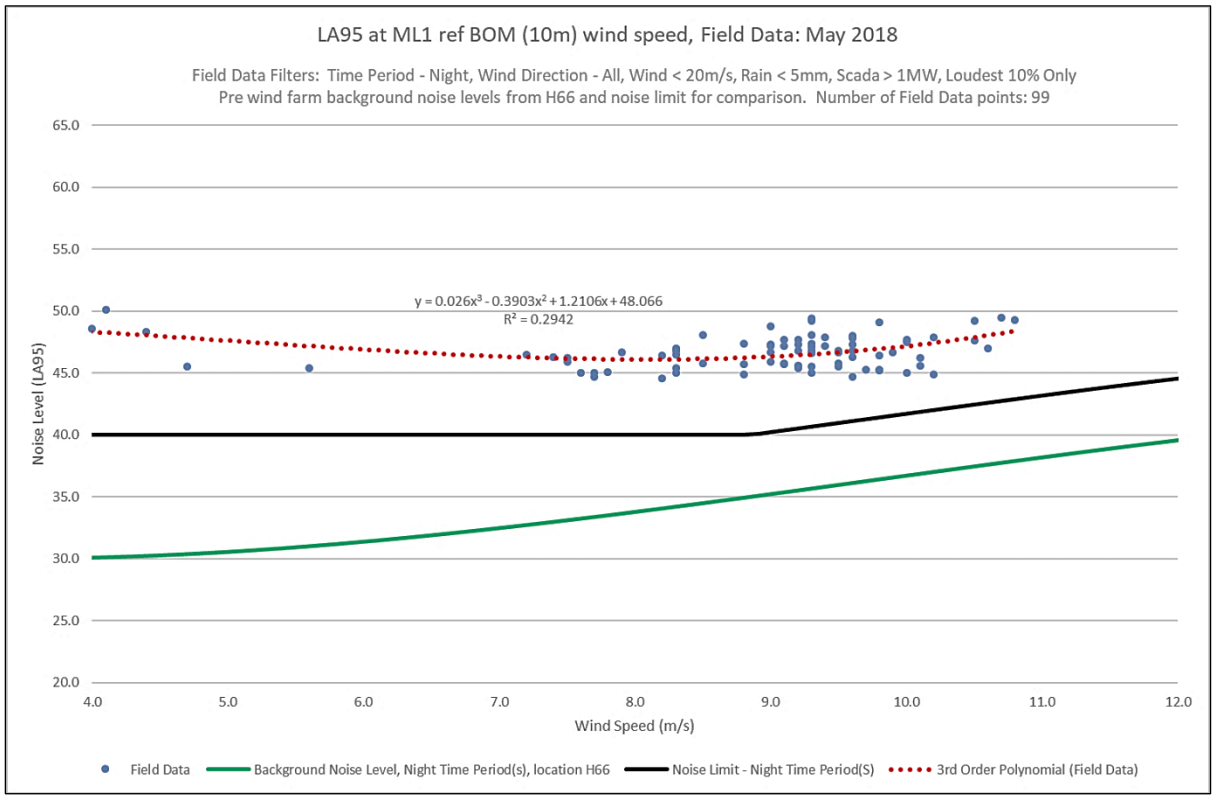
- **Filter to 10% loudest night-time sound levels;**

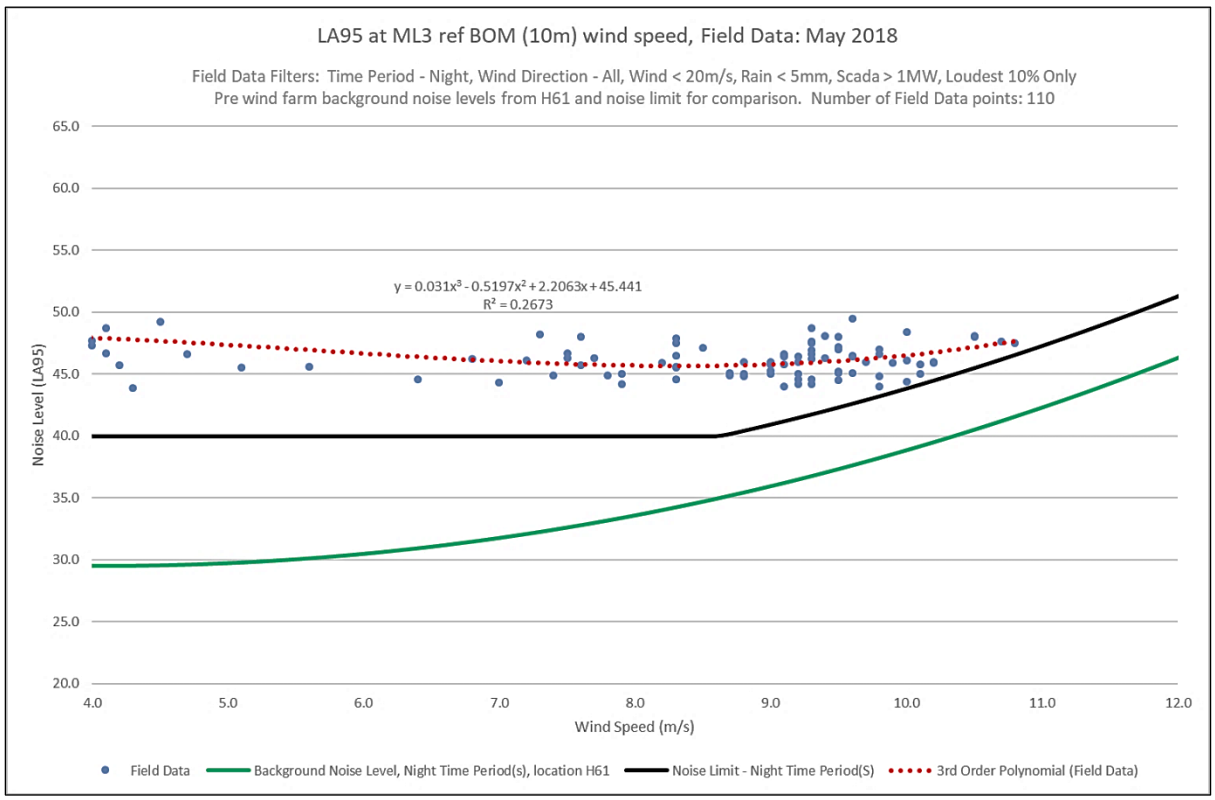
Non-compliance sound levels in the 10% loudest night-time are those that are 5 dB above the regression curve and noise limits. Approval conditions 19(a) and 19(c) apply.

- **Add SAC penalty to 10% loudest.**

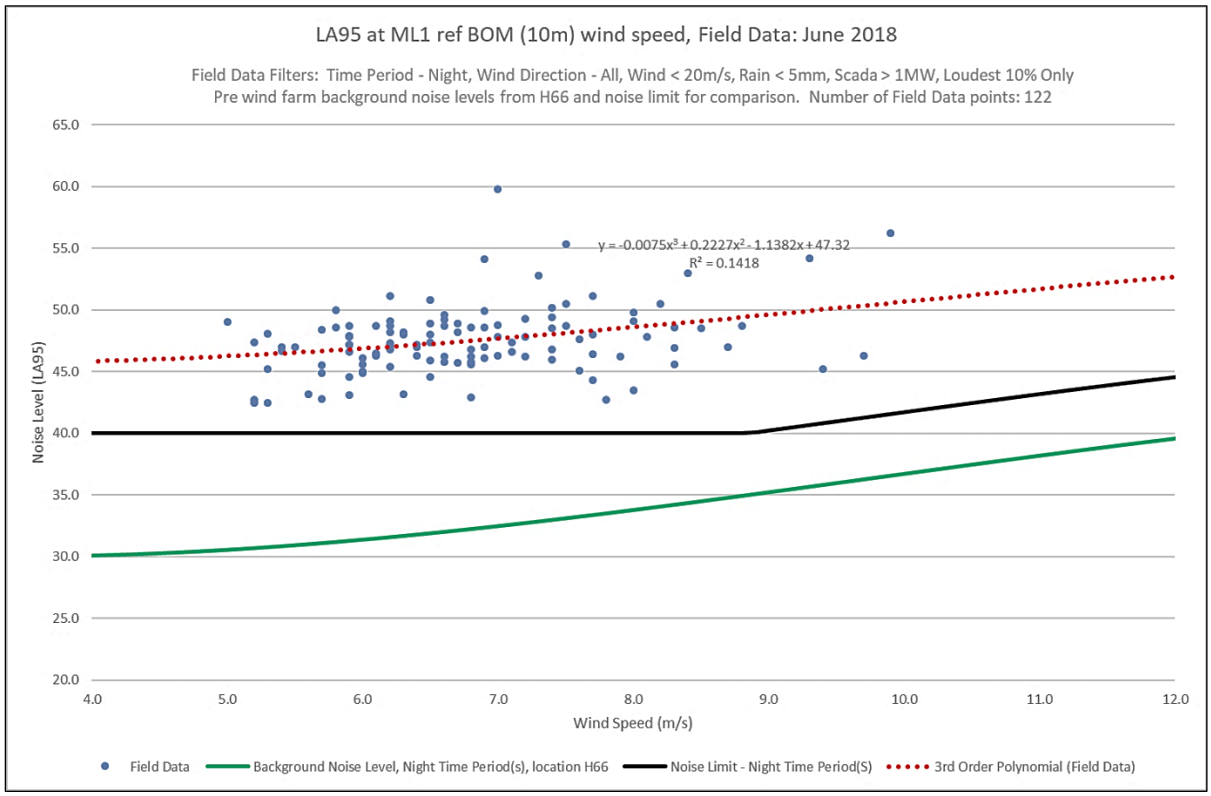
Further analysis for non-compliance is then made by adding the contribution of special audible characteristics affecting the 10% loudest. **This will modify the 10% loudest sound levels by increasing the number of sound levels affected.** Approval condition 19(b) applies.

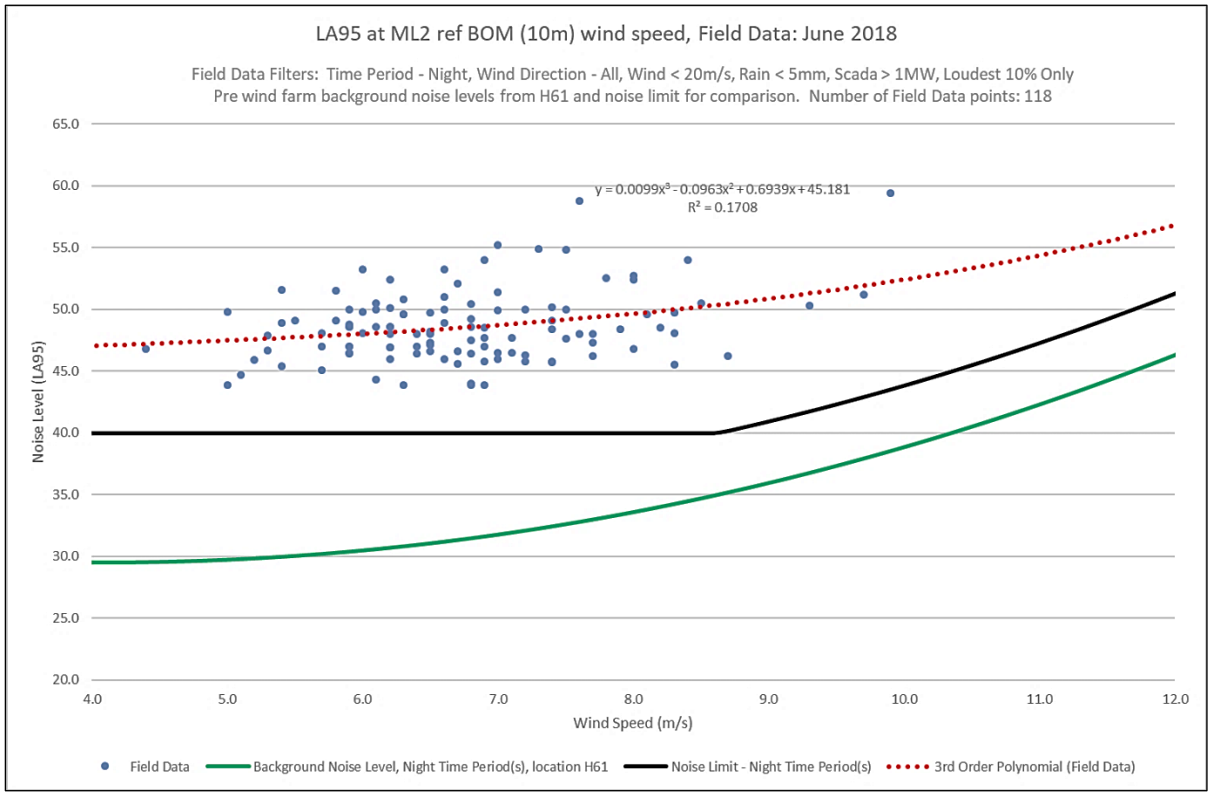
Night-time 10% Loudest Sound Levels for May 2018

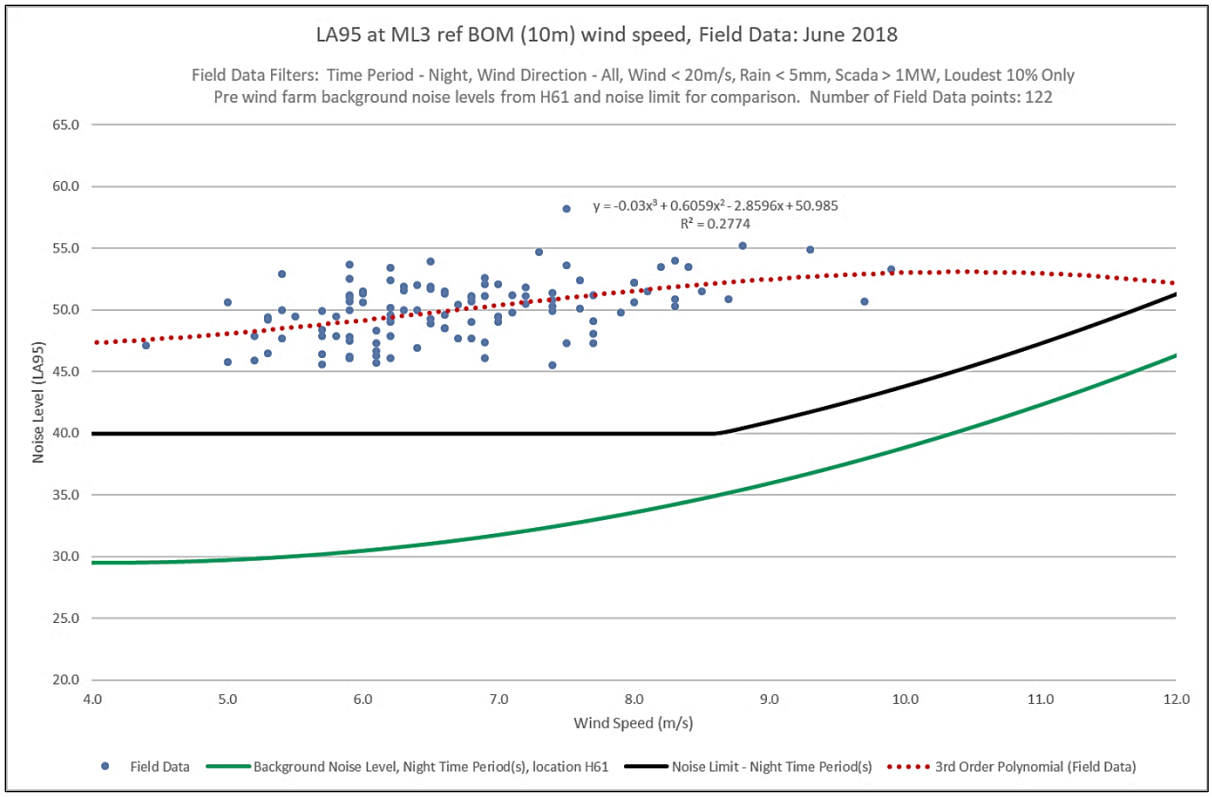




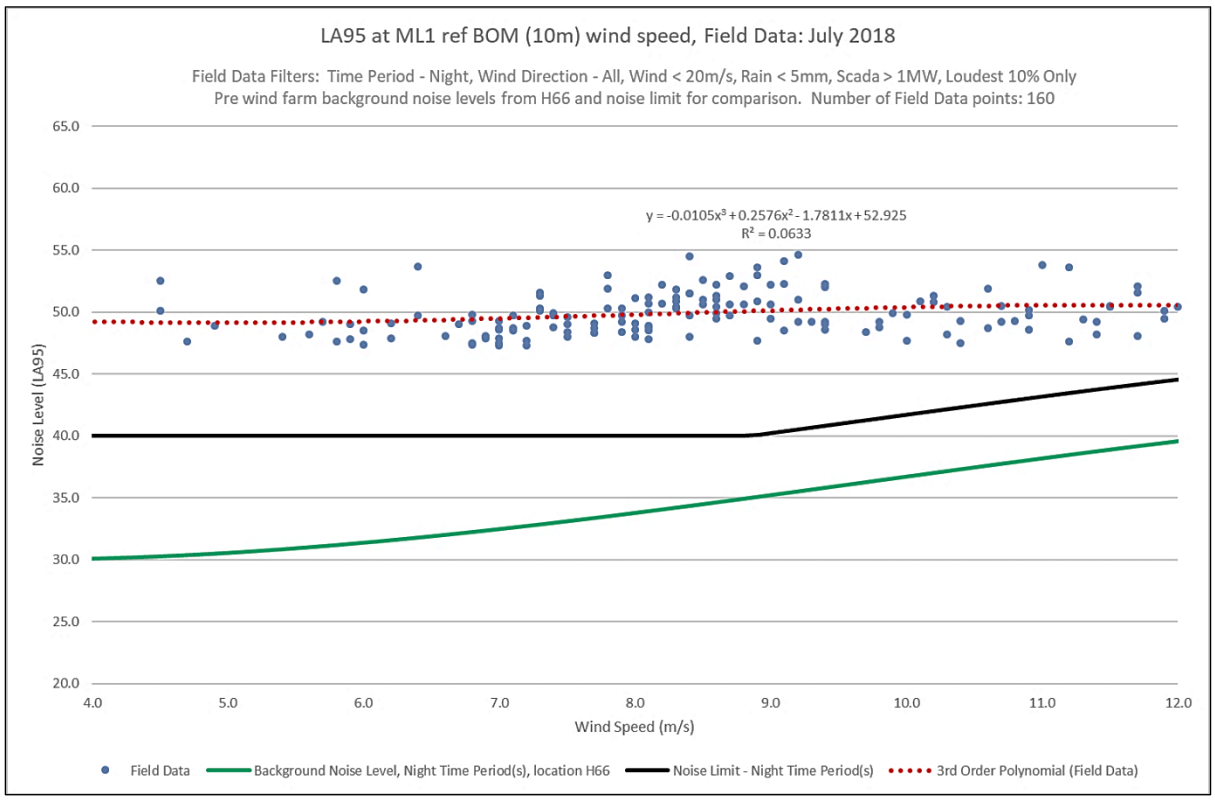
Night-time 10% Loudest Sound Levels for June 2018

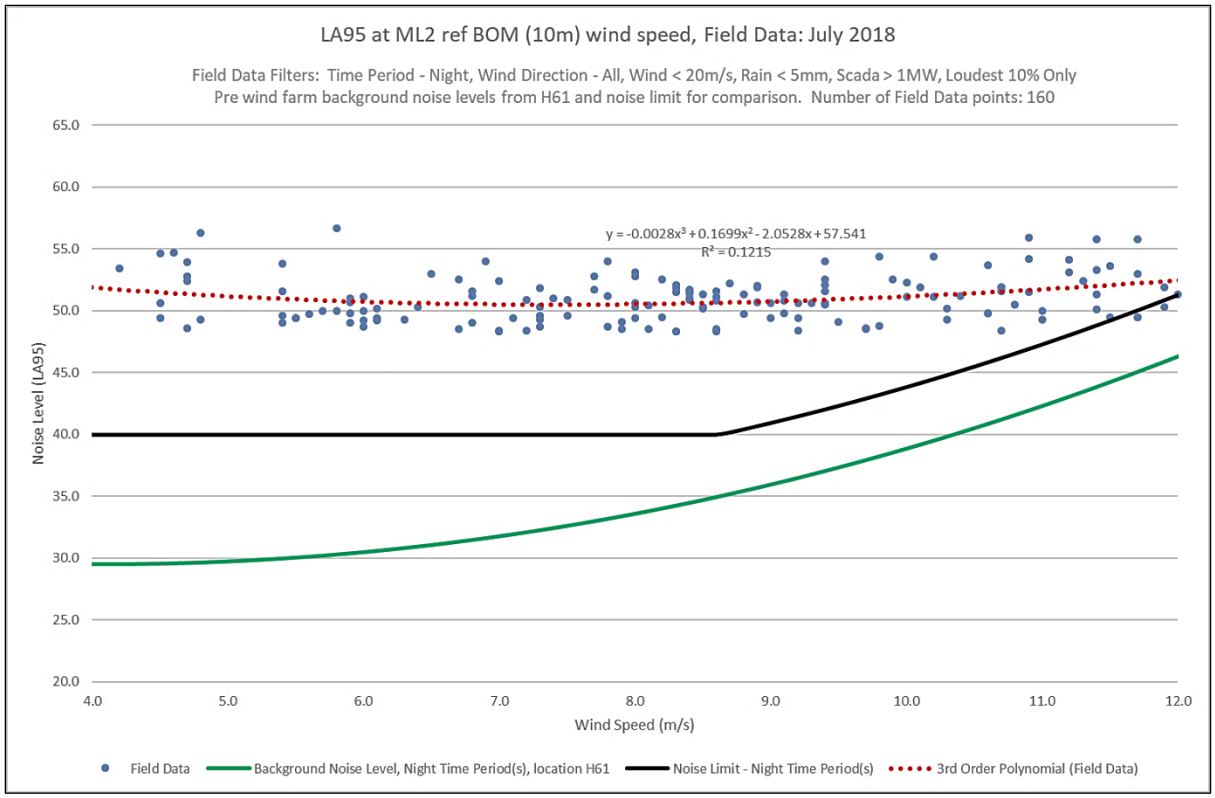


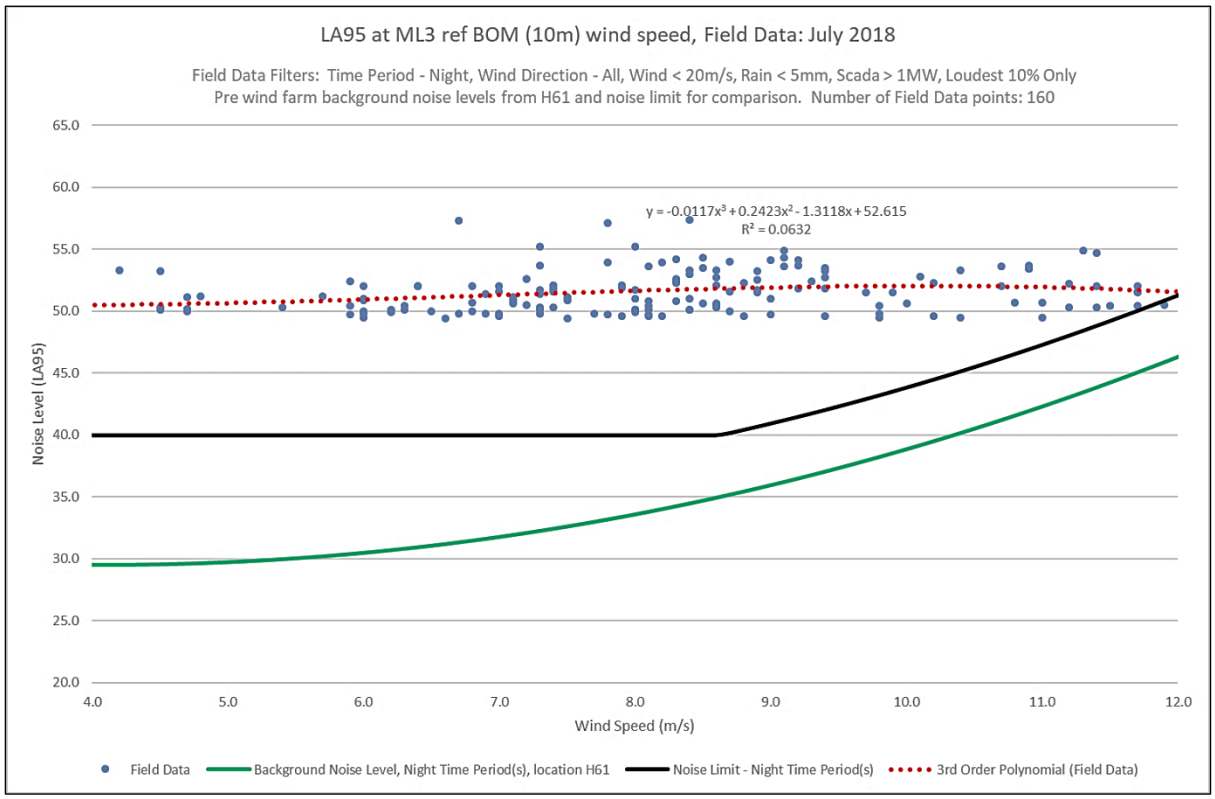




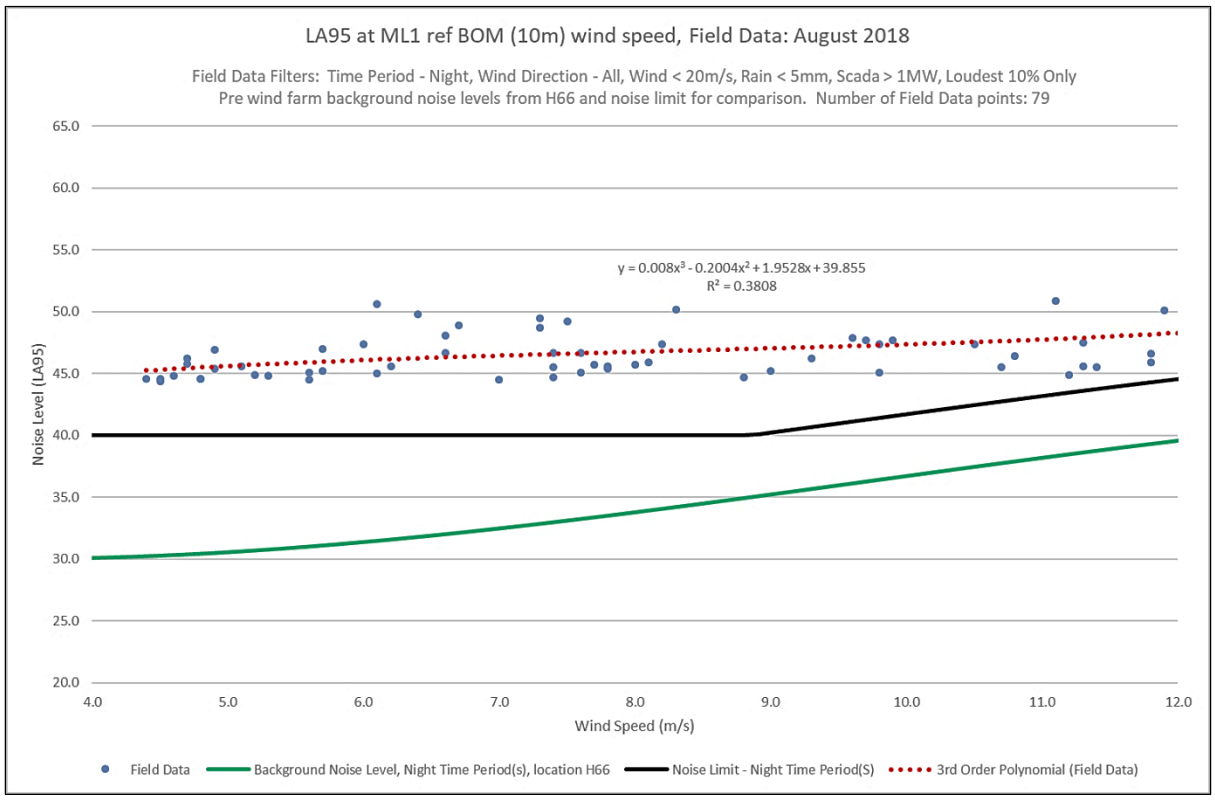
Night-time 10% Loudest Sound Levels for July 2018

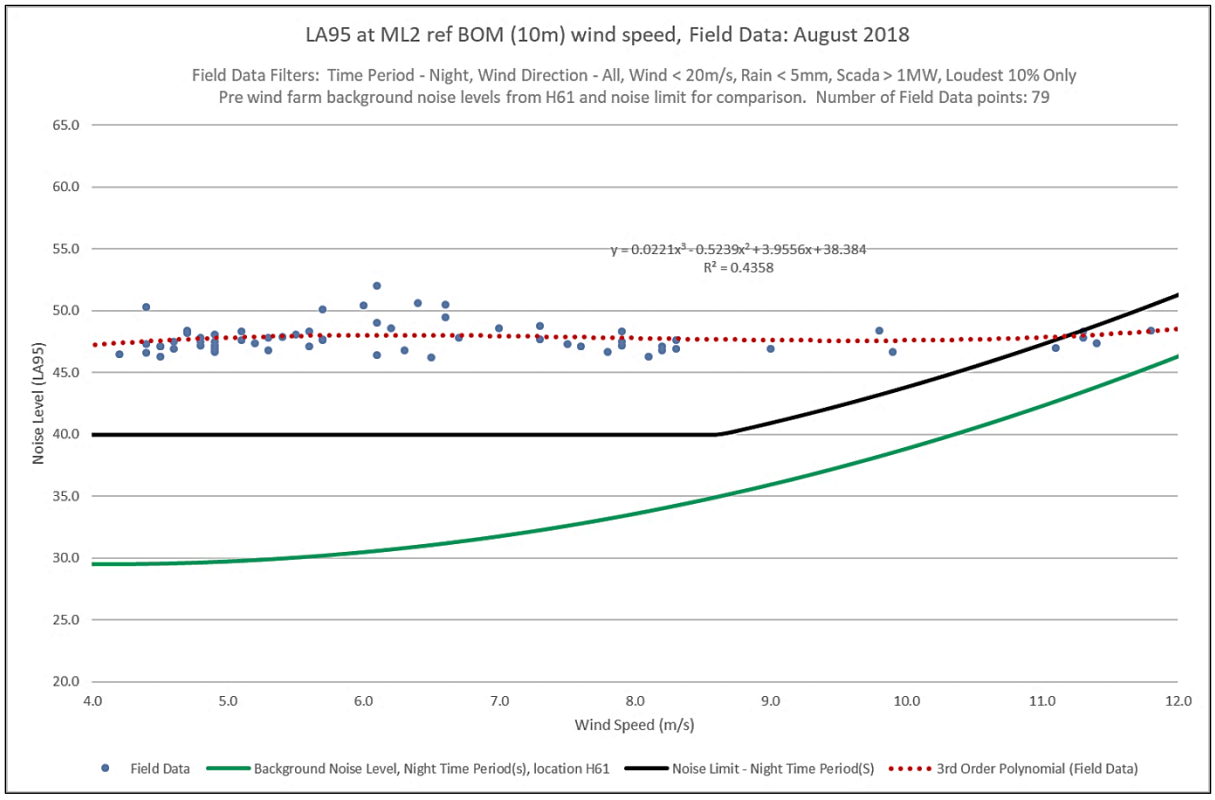


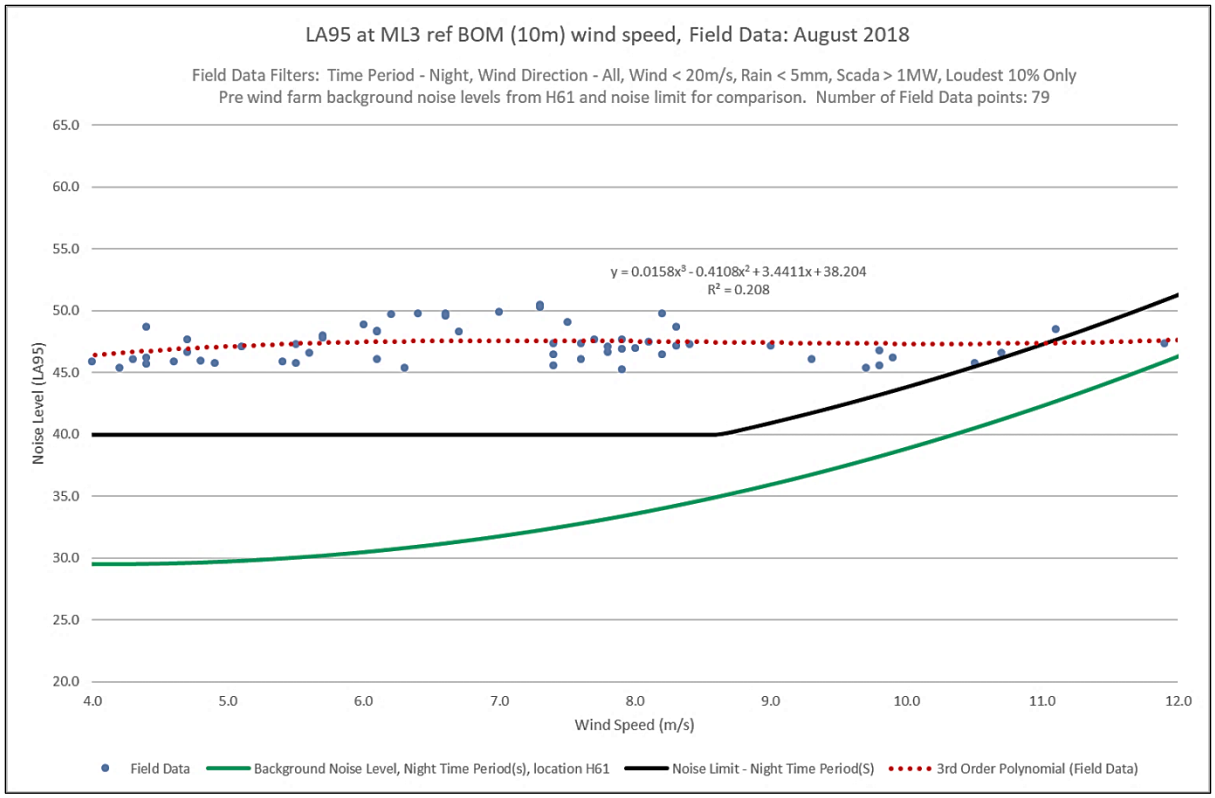

LA95 at ML2 ref BOM (10m) wind speed, Field Data: July 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H61 and noise limit for comparison. Number of Field Data points: 160
y = -0.0028x³ + 0.1699x² - 2.0528x + 57.541
R² = 0.1215
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H61
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)

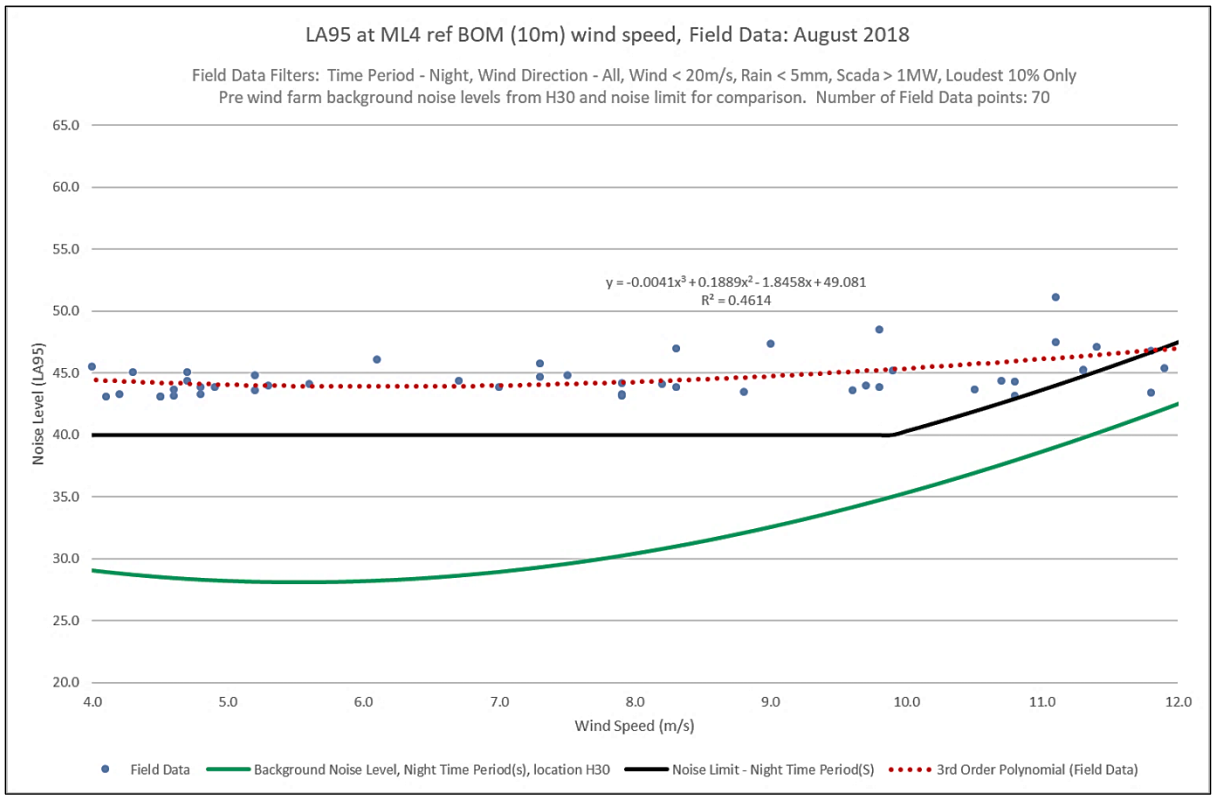

LA95 at ML3 ref BOM (10m) wind speed, Field Data: July 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H61 and noise limit for comparison. Number of Field Data points: 160
y = -0.0117x³ + 0.2423x² - 1.3118x + 52.615
R² = 0.0632
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H61
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)

Night-time 10% Loudest Sound Levels for August 2018

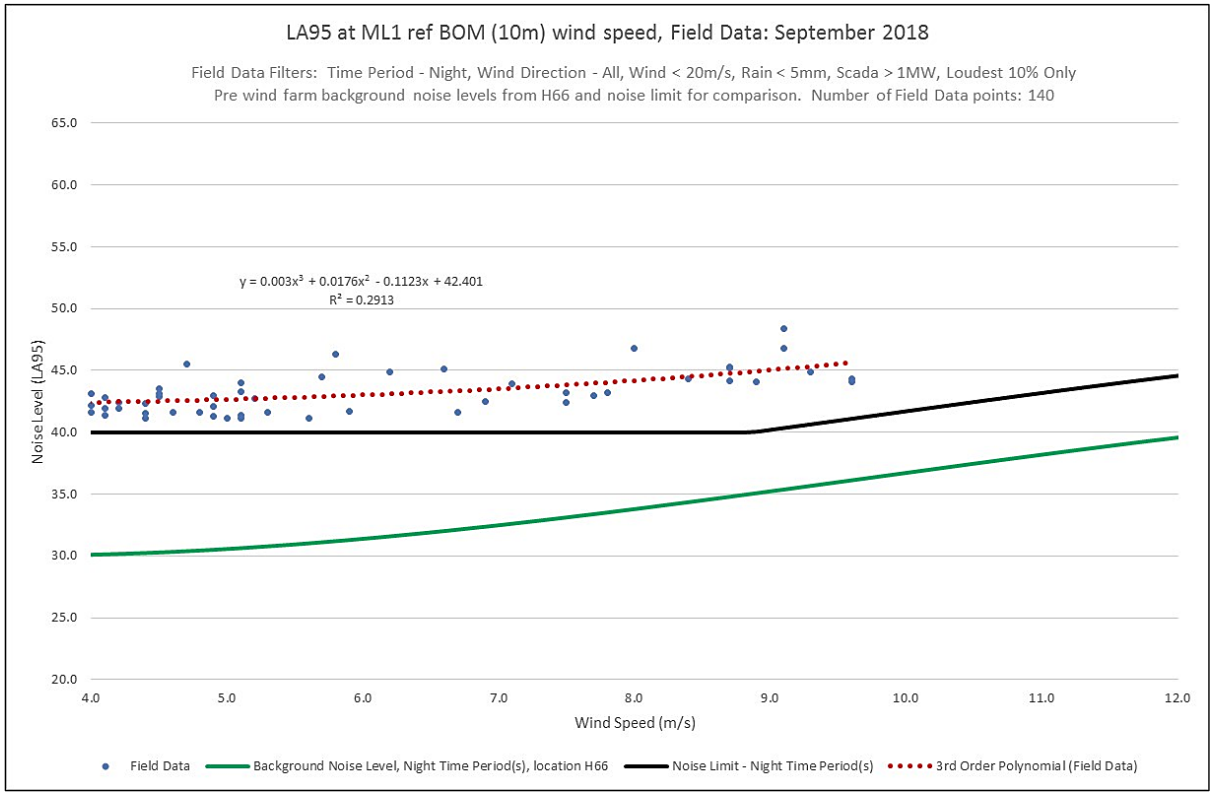


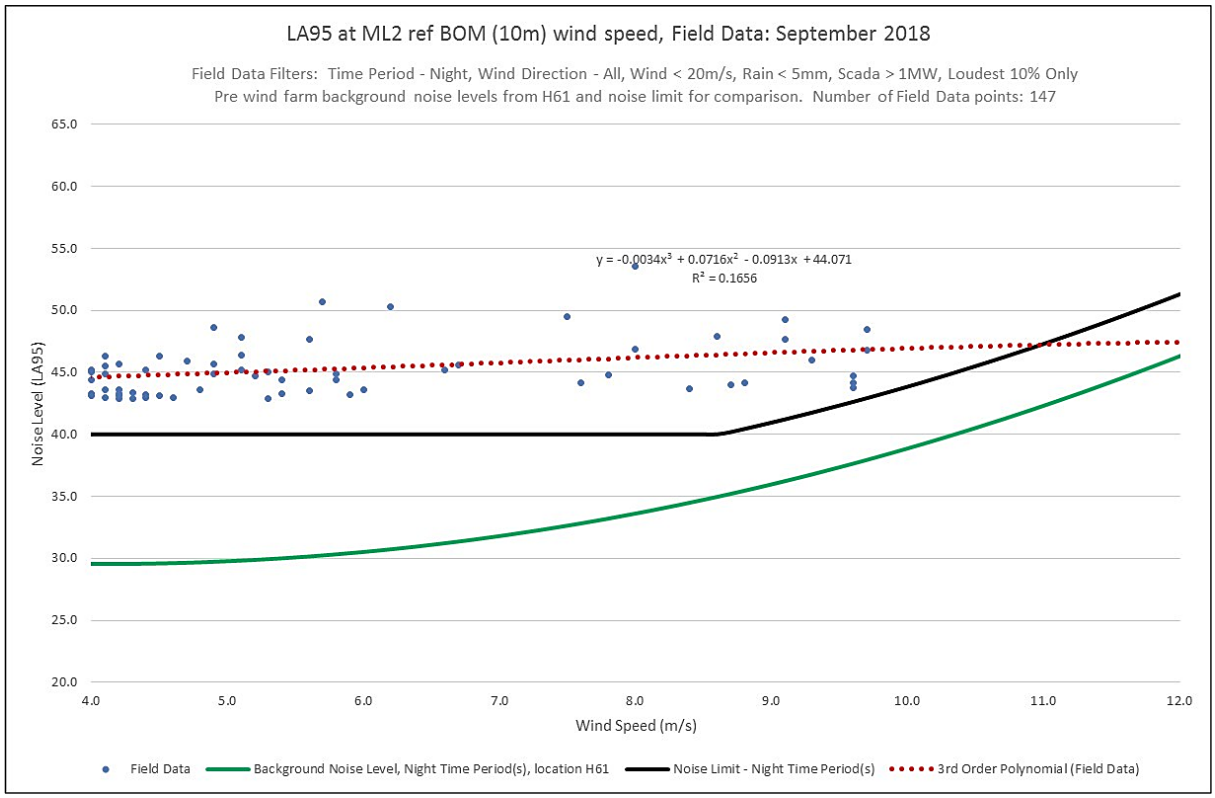


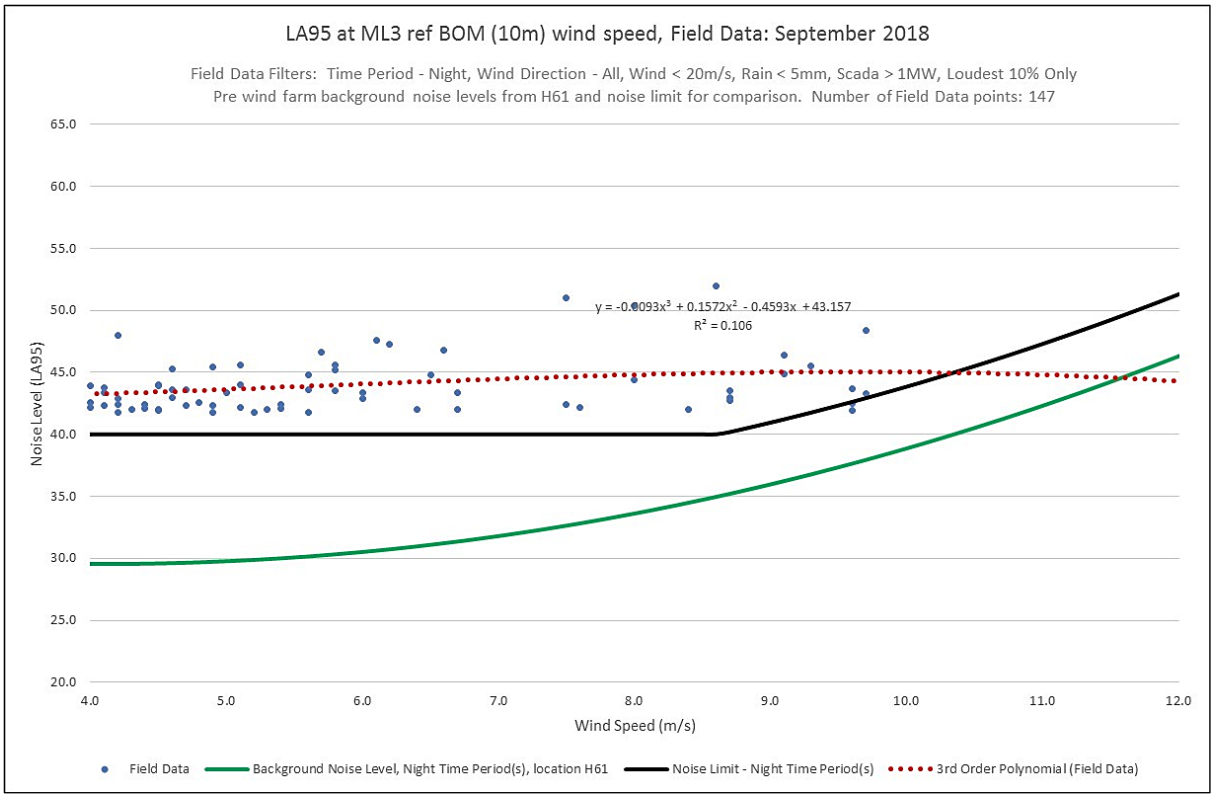

LA95 at ML3 ref BOM (10m) wind speed, Field Data: August 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H61 and noise limit for comparison. Number of Field Data points: 79
y = 0.0158x³ - 0.4108x² + 3.4411x + 38.204
R² = 0.208
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H61
Noise Limit - Night Time Period(S)
3rd Order Polynomial (Field Data)

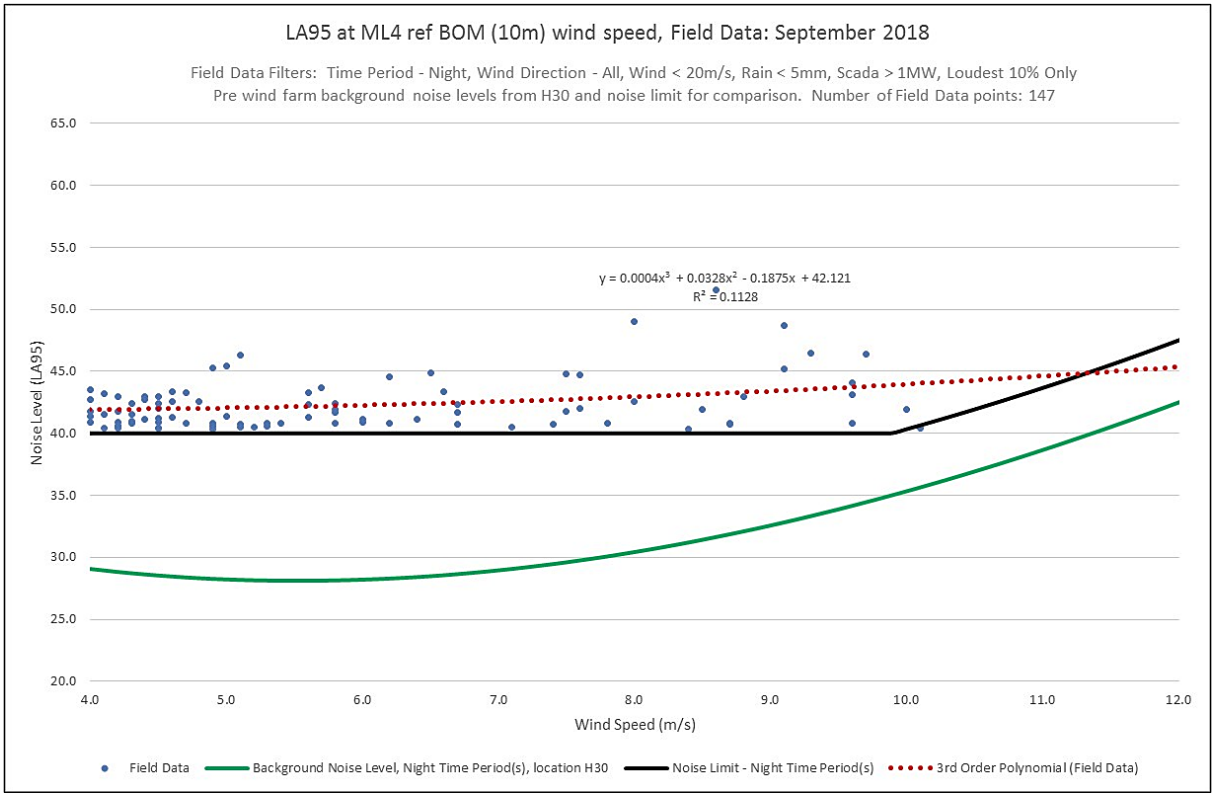

LA95 at ML4 ref BOM (10m) wind speed, Field Data: August 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H30 and noise limit for comparison. Number of Field Data points: 70
y = -0.0041x³ + 0.1889x² - 1.8458x + 49.081
R² = 0.4614
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H30
Noise Limit - Night Time Period(S)
3rd Order Polynomial (Field Data)

Night-time 10% Loudest Sound Levels for September 2018

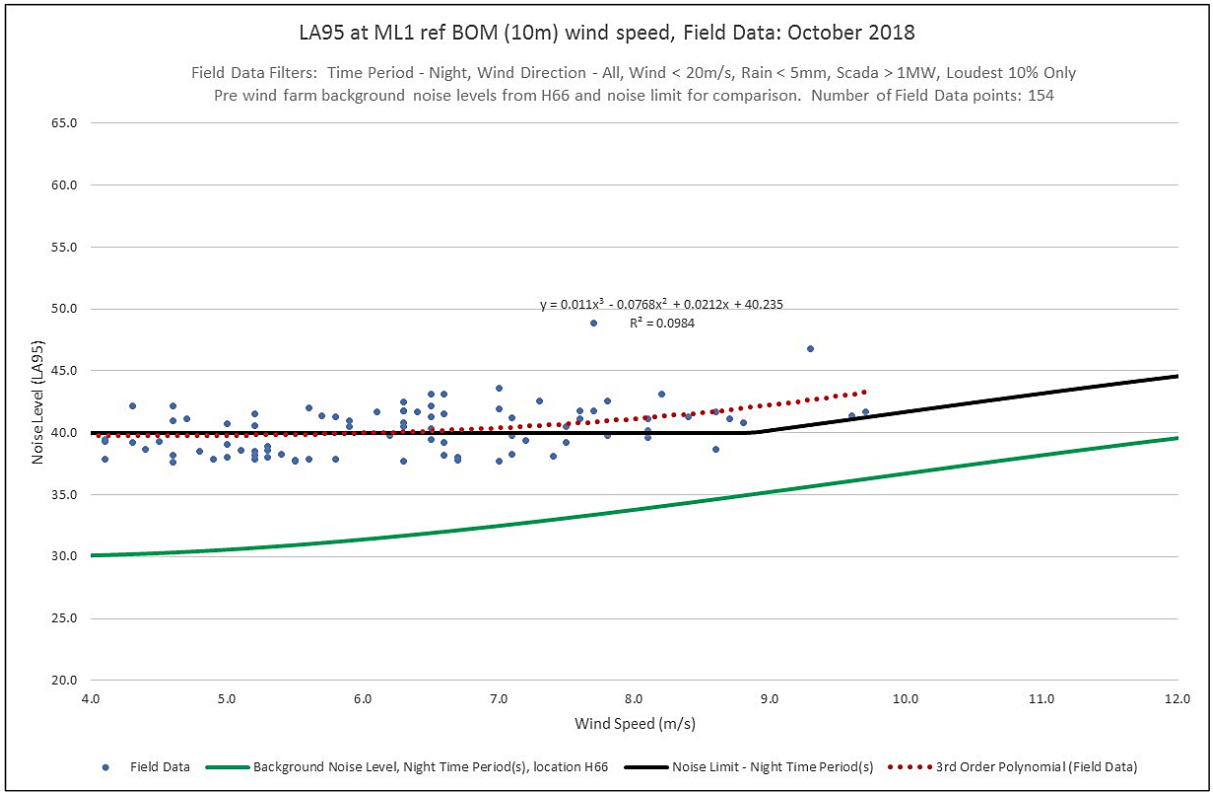


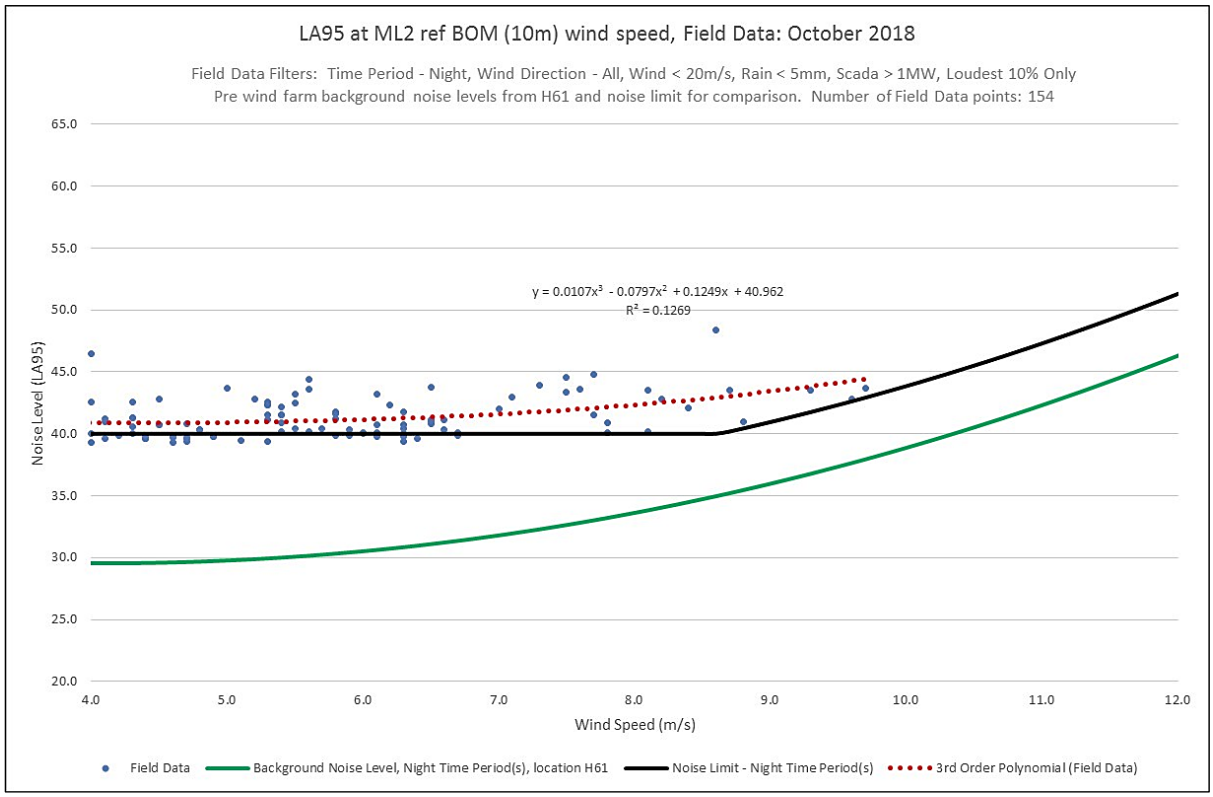


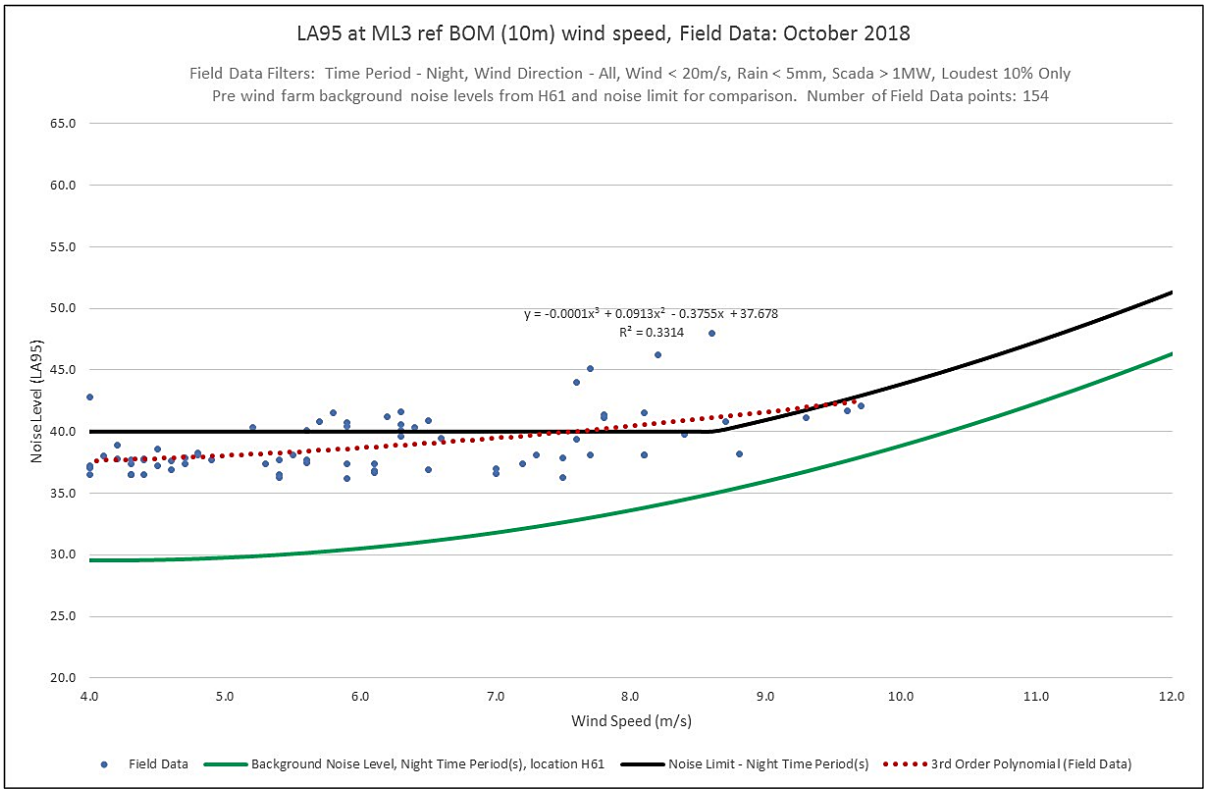

LA95 at ML3 ref BOM (10m) wind speed, Field Data: September 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H61 and noise limit for comparison. Number of Field Data points: 147
y = -0.0093x³ + 0.1572x² - 0.4593x + 43.157
R² = 0.106
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H61
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)

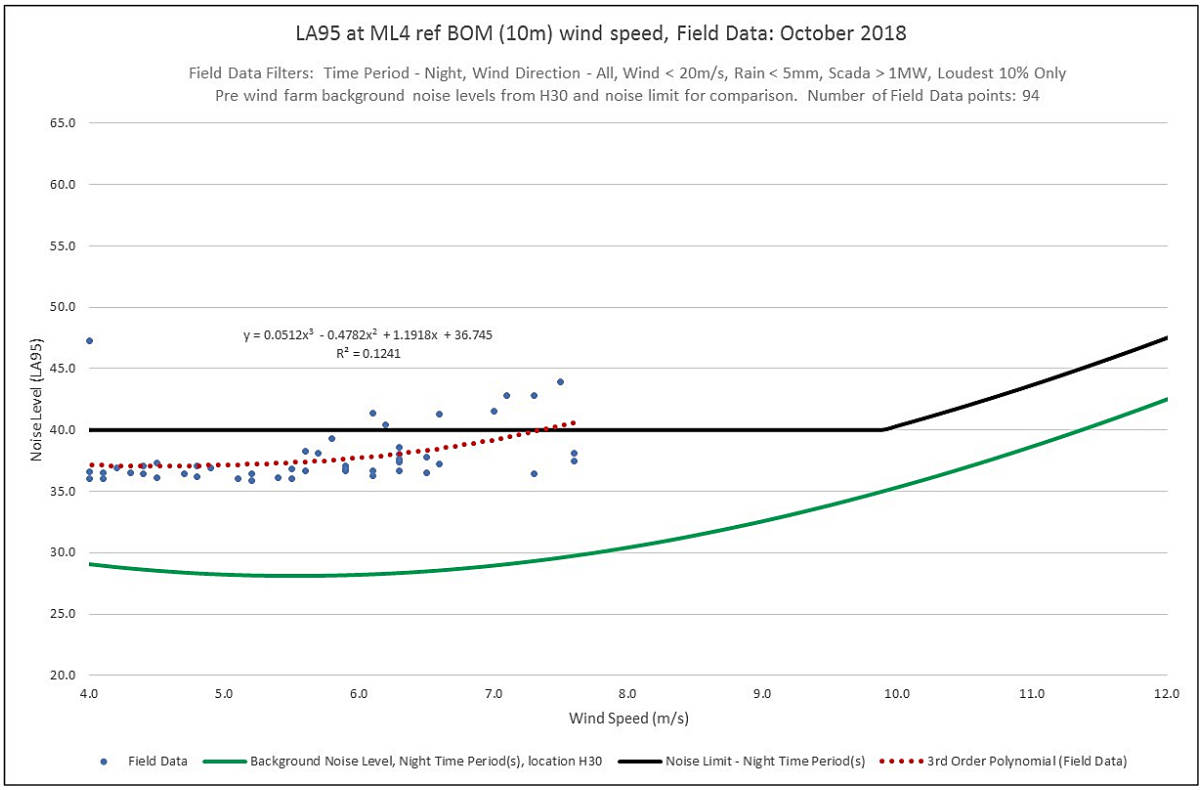

LA95 at ML4 ref BOM (10m) wind speed, Field Data: September 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H30 and noise limit for comparison. Number of Field Data points: 147
y = 0.0004x³ + 0.0328x² - 0.1875x + 42.121
R² = 0.1128
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H30
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)

Night-time 10% Loudest Sound Levels for October 2018

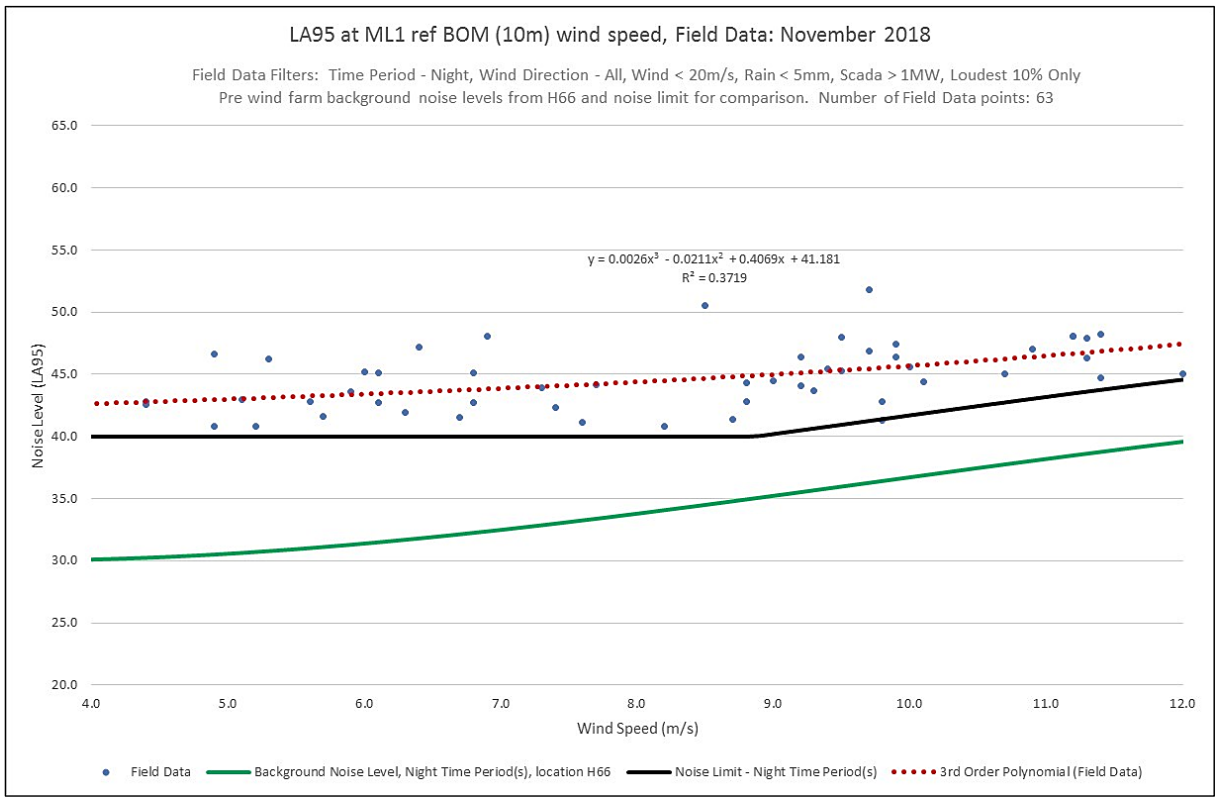


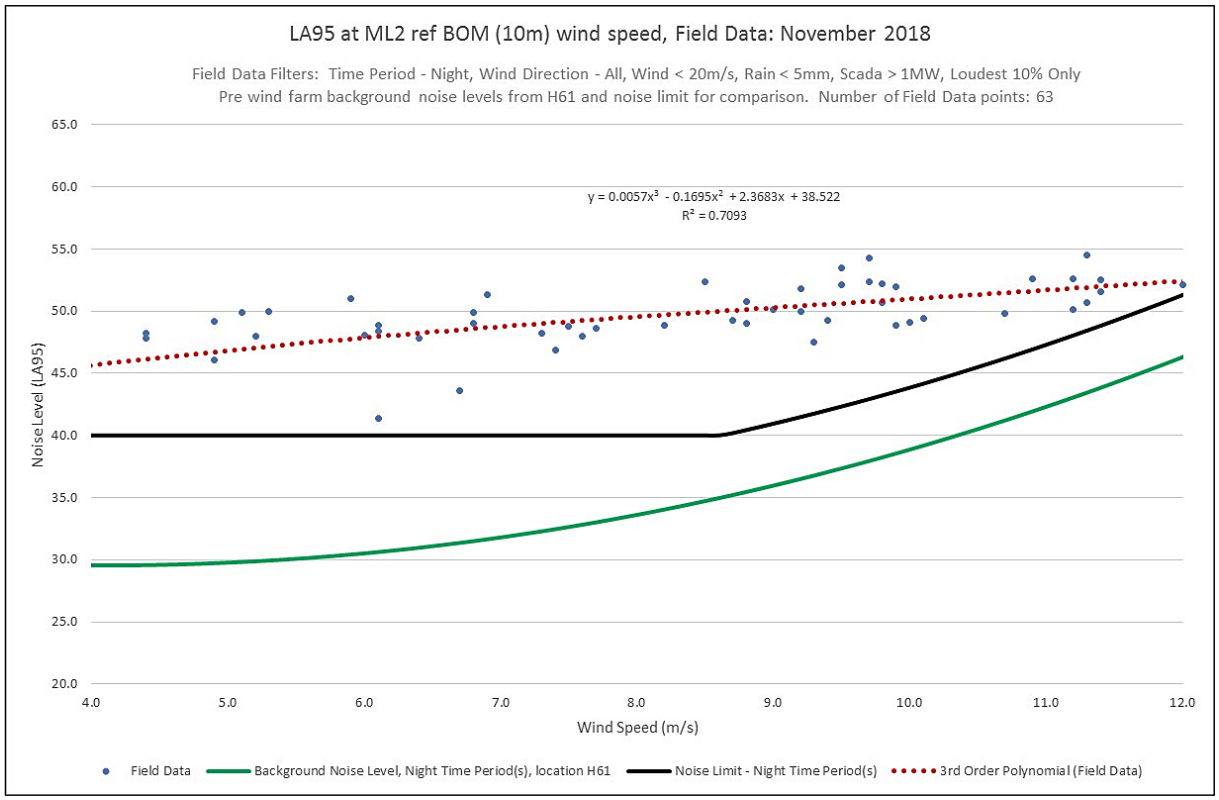


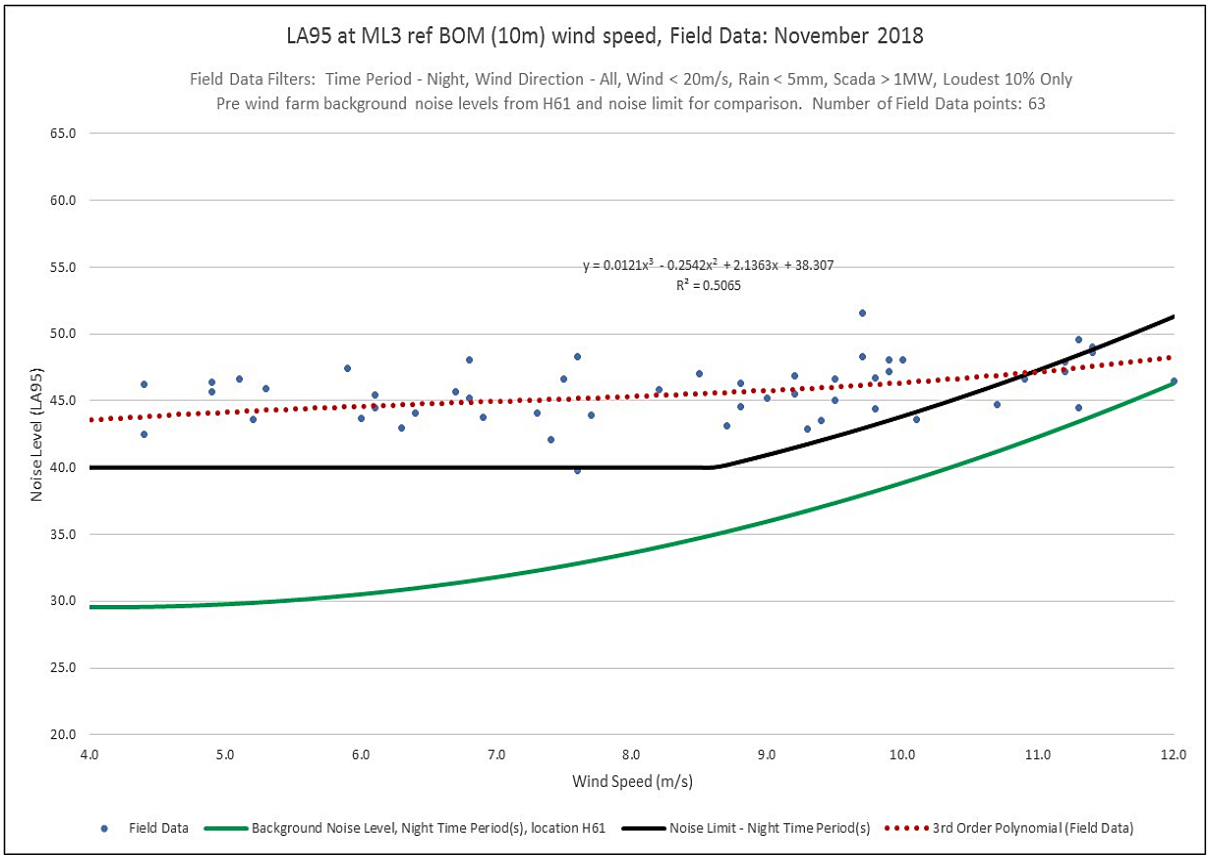

LA95 at ML3 ref BOM (10m) wind speed, Field Data: October 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H61 and noise limit for comparison. Number of Field Data points: 154
y = -0.0001x³ + 0.0913x² - 0.3755x + 37.678
R² = 0.3314
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H61
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)

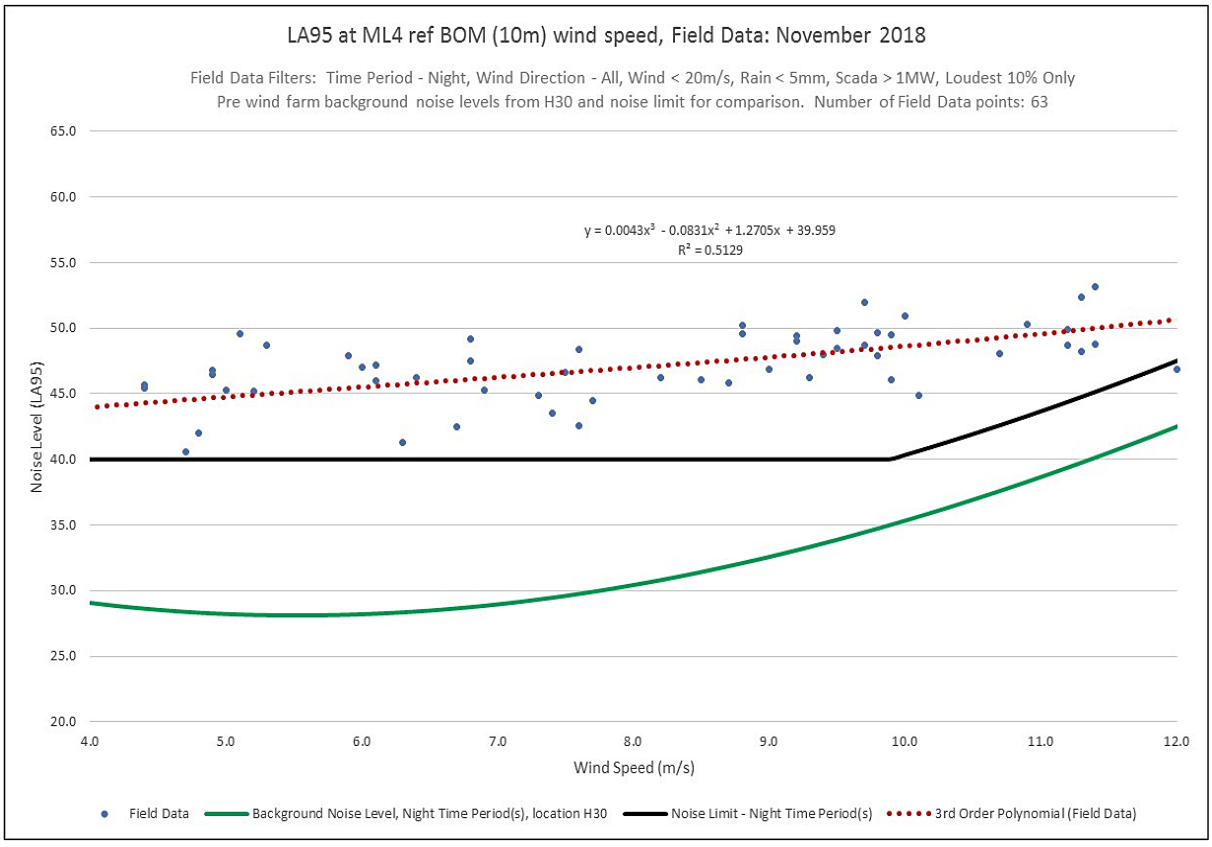

LA95 at ML4 ref BOM (10m) wind speed, Field Data: October 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H30 and noise limit for comparison. Number of Field Data points: 94
y = 0.0512x³ - 0.4782x² + 1.1918x + 36.745
R² = 0.1241
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H30
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)

Night-time 10% Loudest Sound Levels for November 2018

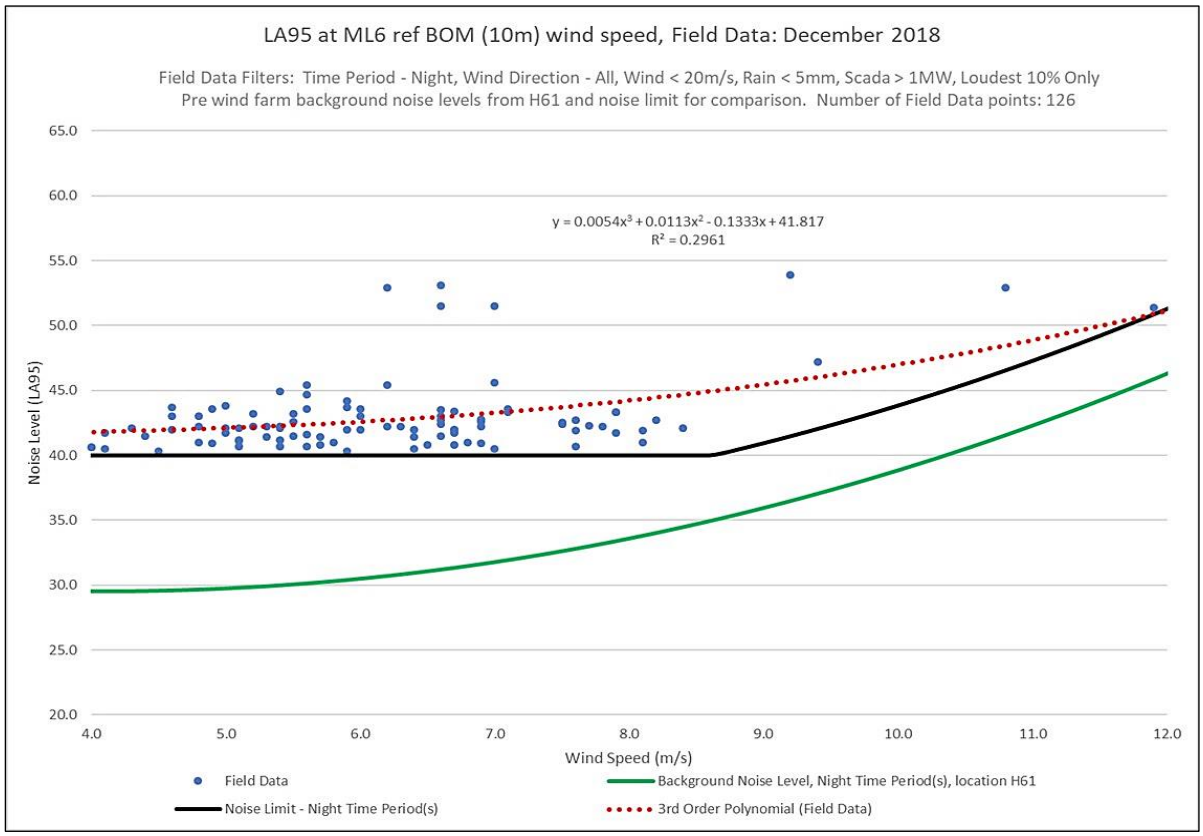




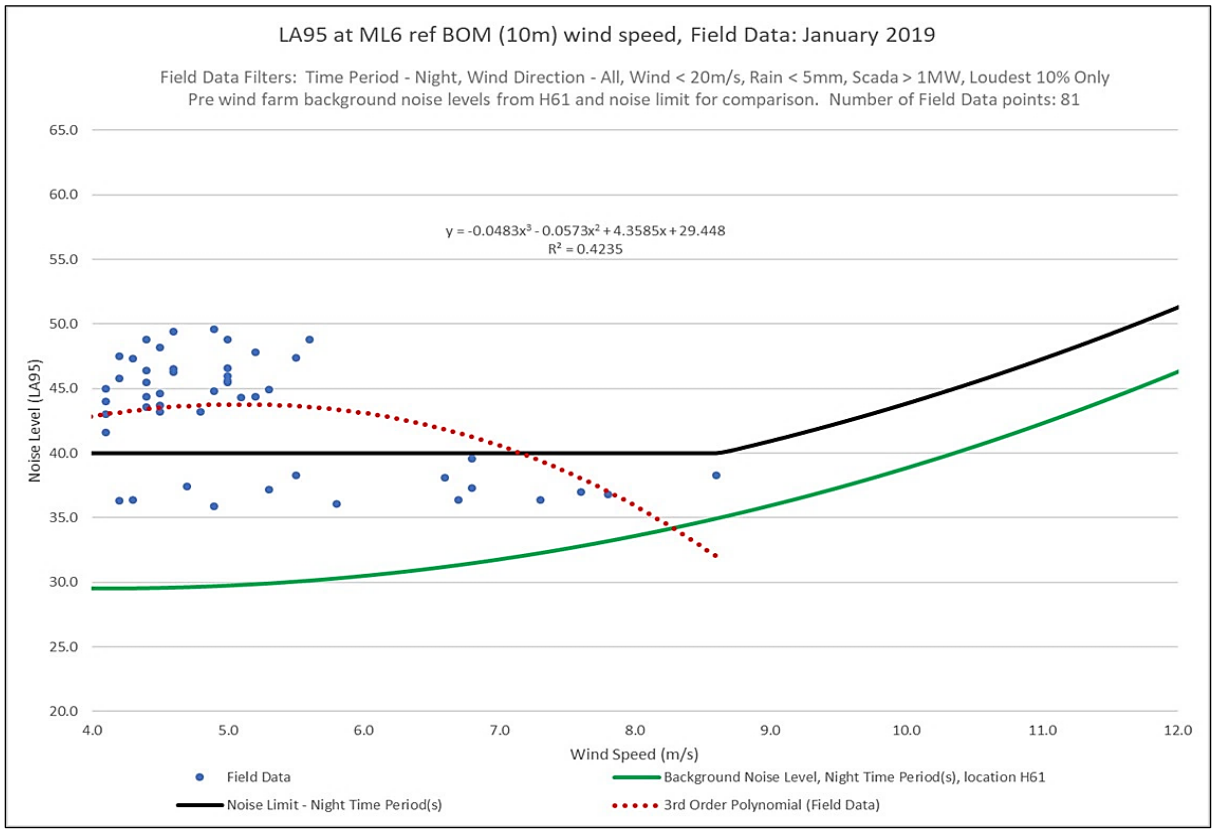

LA95 at ML3 ref BOM (10m) wind speed, Field Data: November 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H61 and noise limit for comparison. Number of Field Data points: 63
y = 0.0121x³ - 0.2542x² + 2.1363x + 38.307
R² = 0.5065
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H61
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)


LA95 at ML4 ref BOM (10m) wind speed, Field Data: November 2018
Field Data Filters: Time Period - Night, Wind Direction - All, Wind < 20m/s, Rain < 5mm, Scada > 1MW, Loudest 10% Only
Pre wind farm background noise levels from H30 and noise limit for comparison. Number of Field Data points: 63
y = 0.0043x³ - 0.0831x² + 1.2705x + 39.959
R² = 0.5129
Noise Level (LA95)
Wind Speed (m/s)
Field Data
Background Noise Level, Night Time Period(s), location H30
Noise Limit - Night Time Period(s)
3rd Order Polynomial (Field Data)

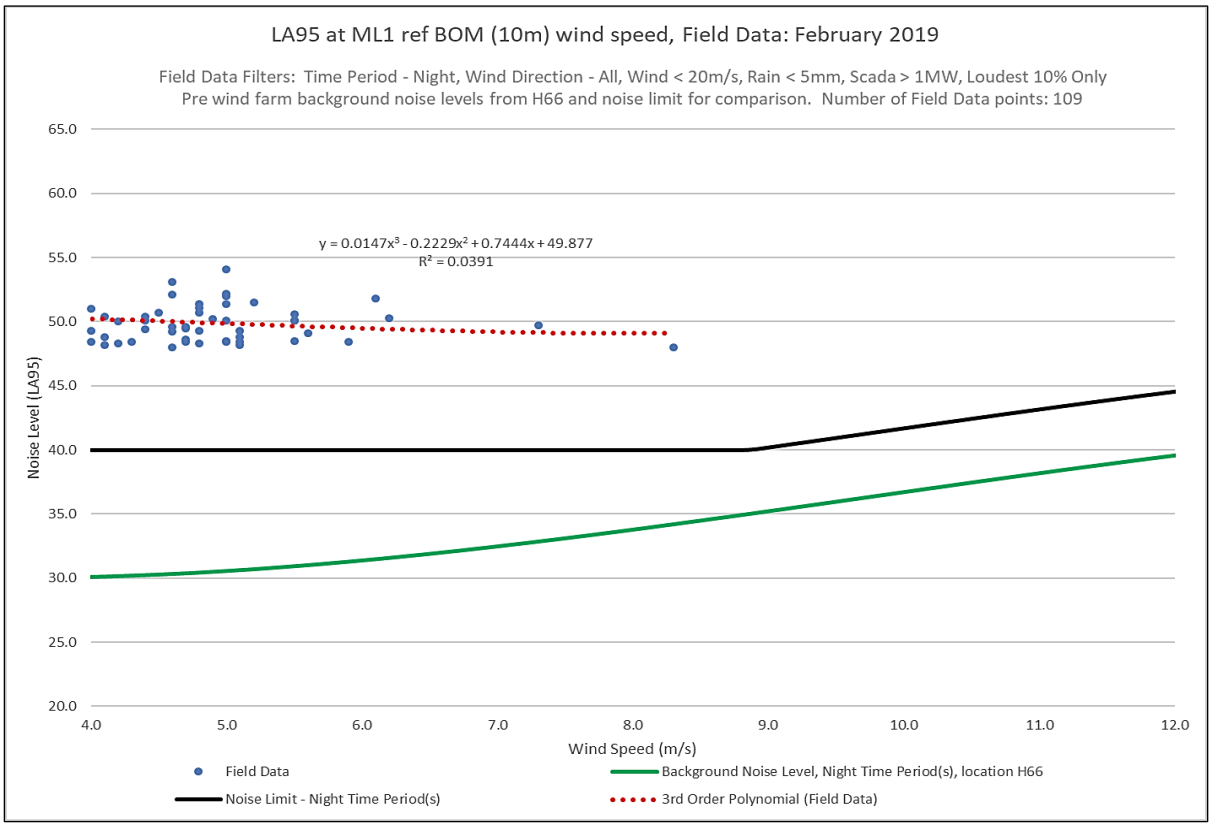
Night-time 10% Loudest Sound Levels for December 2018

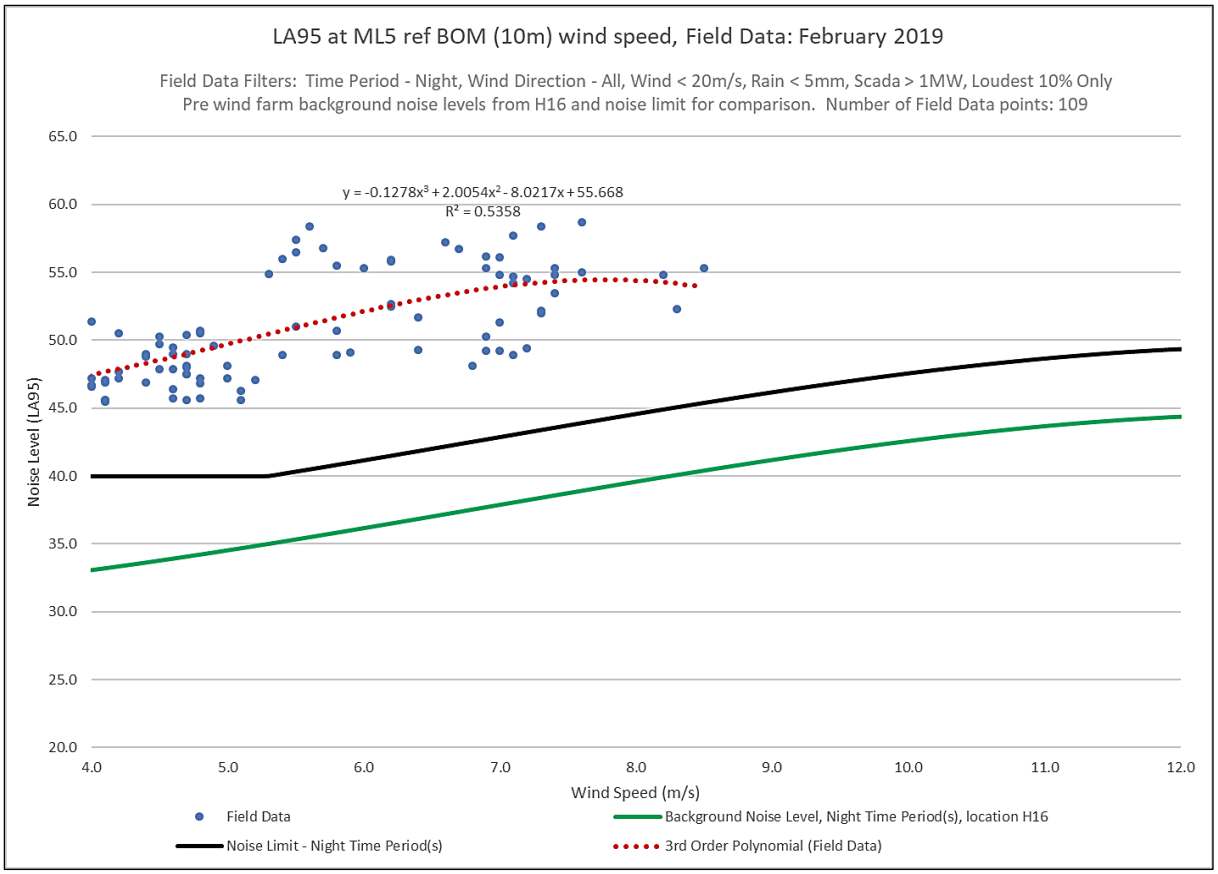


Night-time 10% Loudest Sound Levels for January 2019

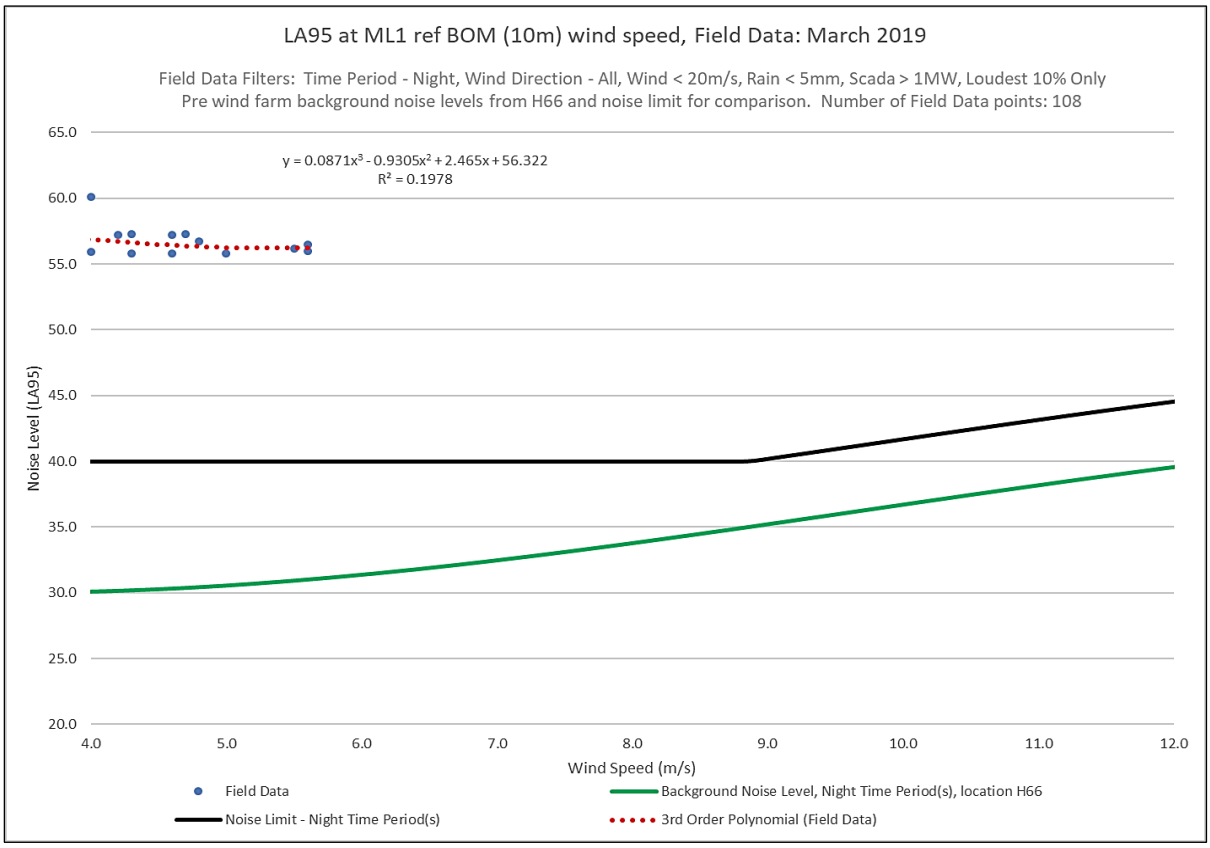


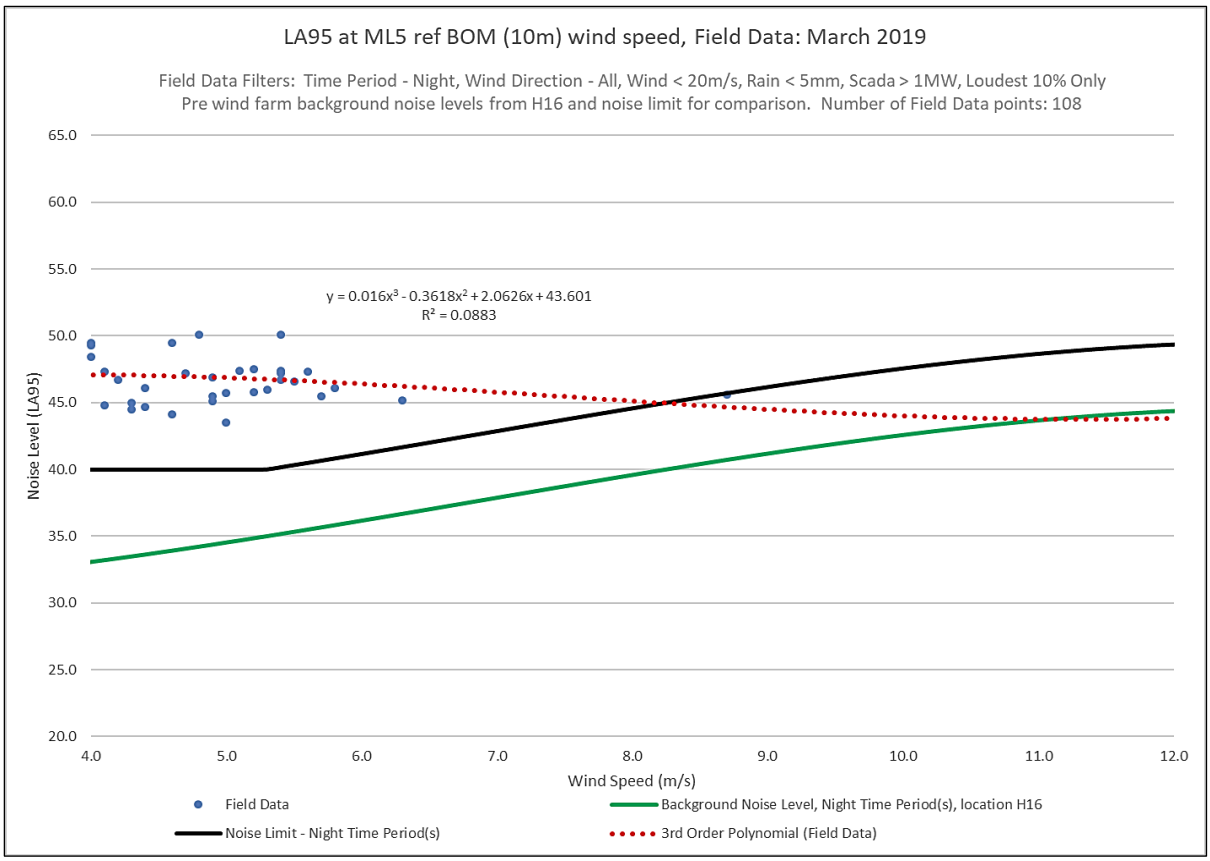
Night-time 10% Loudest Sound Levels for February 2019





Night-time 10% Loudest Sound Levels for March 2019





Sound character – Penalty for Perceived Special Audible Characteristics

The following charts for June, July and September are presented as examples of the assessment of recorded sound levels, vs wind speed, vs Perceived Special Audible Characteristics (PSAC) over the critical time periods of 1am to 5am. A penalty of 5dBA is added to the recorded sound levels. The examples cover the period investigated by Council and for the month after the August wind farm shut-down. The Pound Creek weather station is applied. The 10 metre data is applied as this is what is necessary for comparison with the MDA background sound level regression curves.

Example of the analysis method, September 2018.
There were 4320 by 10-minute blocks of time in September. The night-time period in September has 1620 separate 10-minute blocks of recorded sound levels at each monitoring location. Of these, 720 10-minute blocks are in the most commonly identified PSAC time period of 1am to 5am. In September, however, not all of these time-blocks were identified as having PSAC values. ML1 has 428, ML2 has 311, ML3 has 287 and ML4 has 525 values.

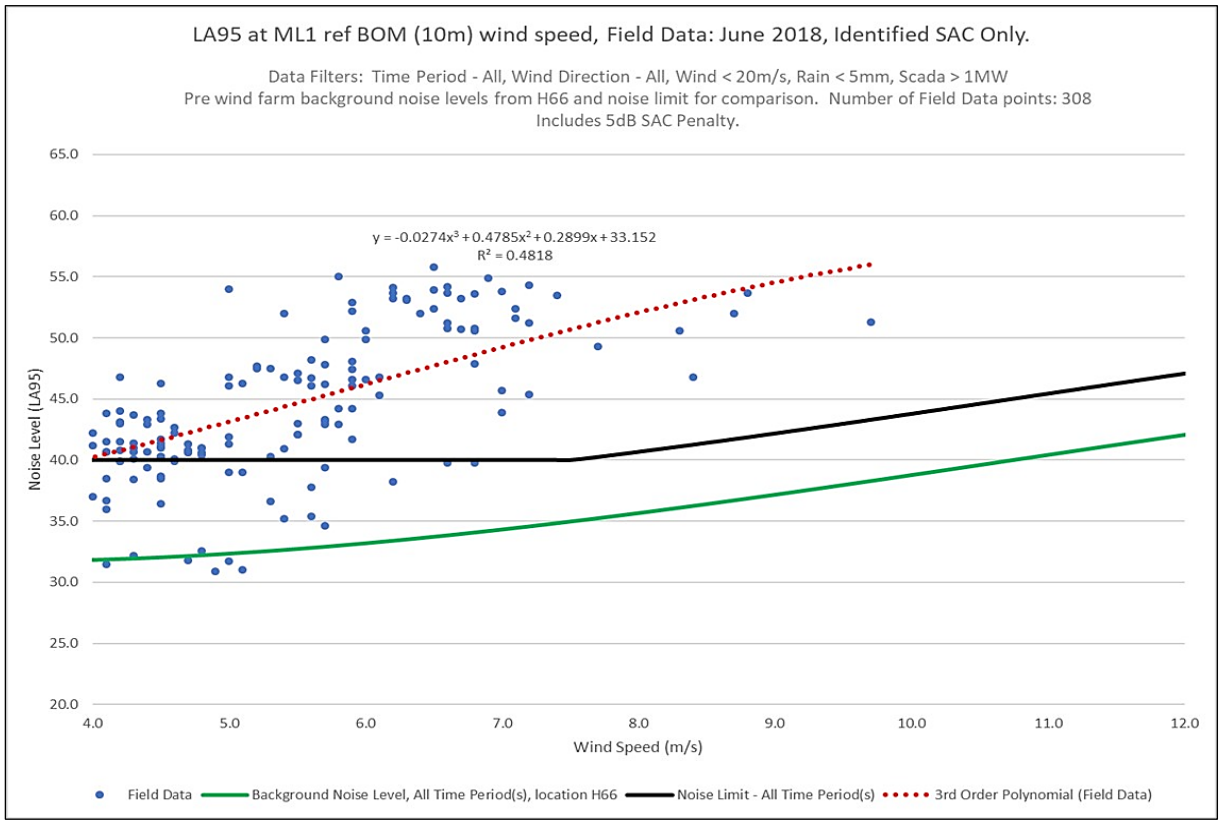
This is what makes the PSAC sound events "special". The wind farm was generating power for most of the 4320 blocks of time in September, but only a percentage of that time is identified as having 'perceived special audible characteristics'

The following charts for June, July and September are the 1am to 5am night-time sound levels and include the 5dB penalty for special audible characteristics.

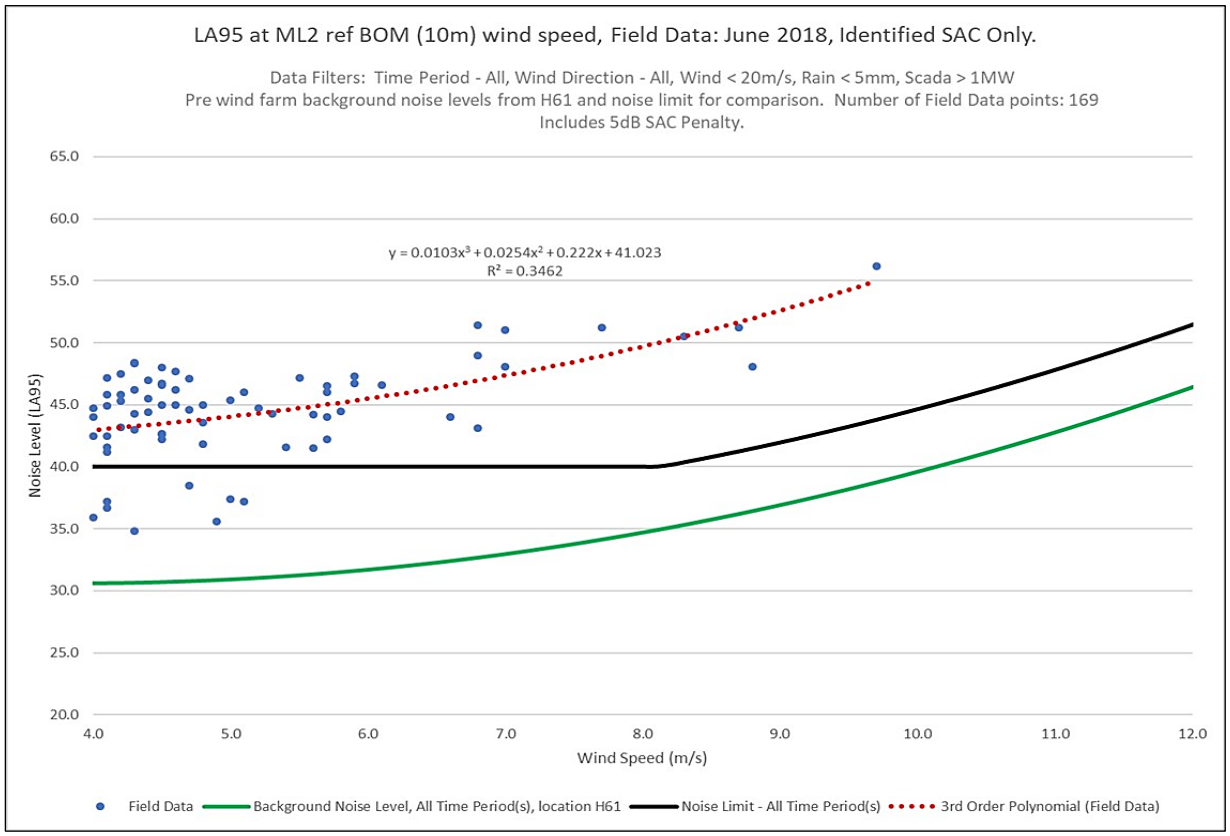
The addition of the 5dBA penalty is a mandatory part of the compliance process under the approval conditions and the New Zealand standard. Application of the penalty shows consistent non-compliance for the months of June, July and September. The turbines were operational in late August.

A pattern of non-compliance is shown in all the PSAC datasets of the monitoring program and is recorded in the NMS analysis spreadsheets for May 2018 to March 2019.

June 2018
ML1 Includes SAC 5dB penalty; 1am to 5am

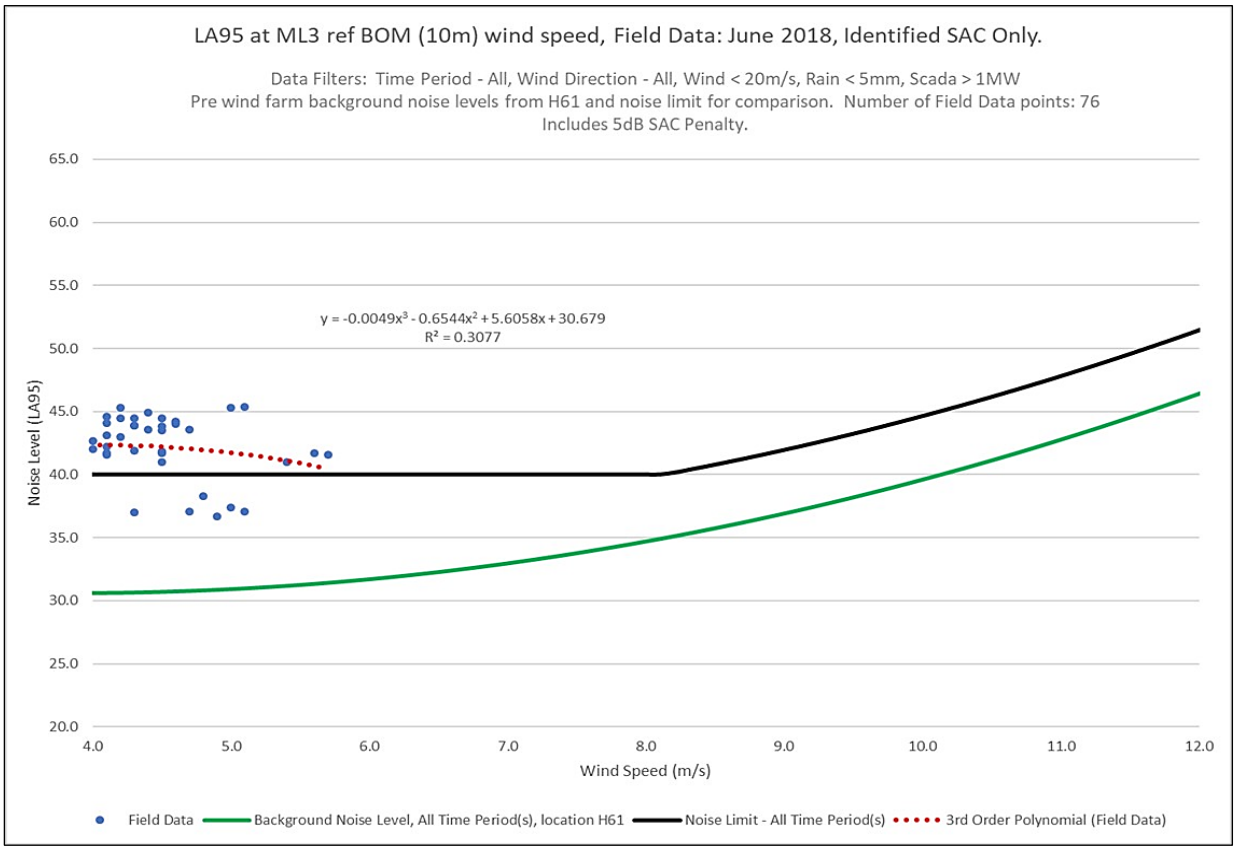


June 2018
ML2 Includes SAC 5dB penalty; 1am to 5am



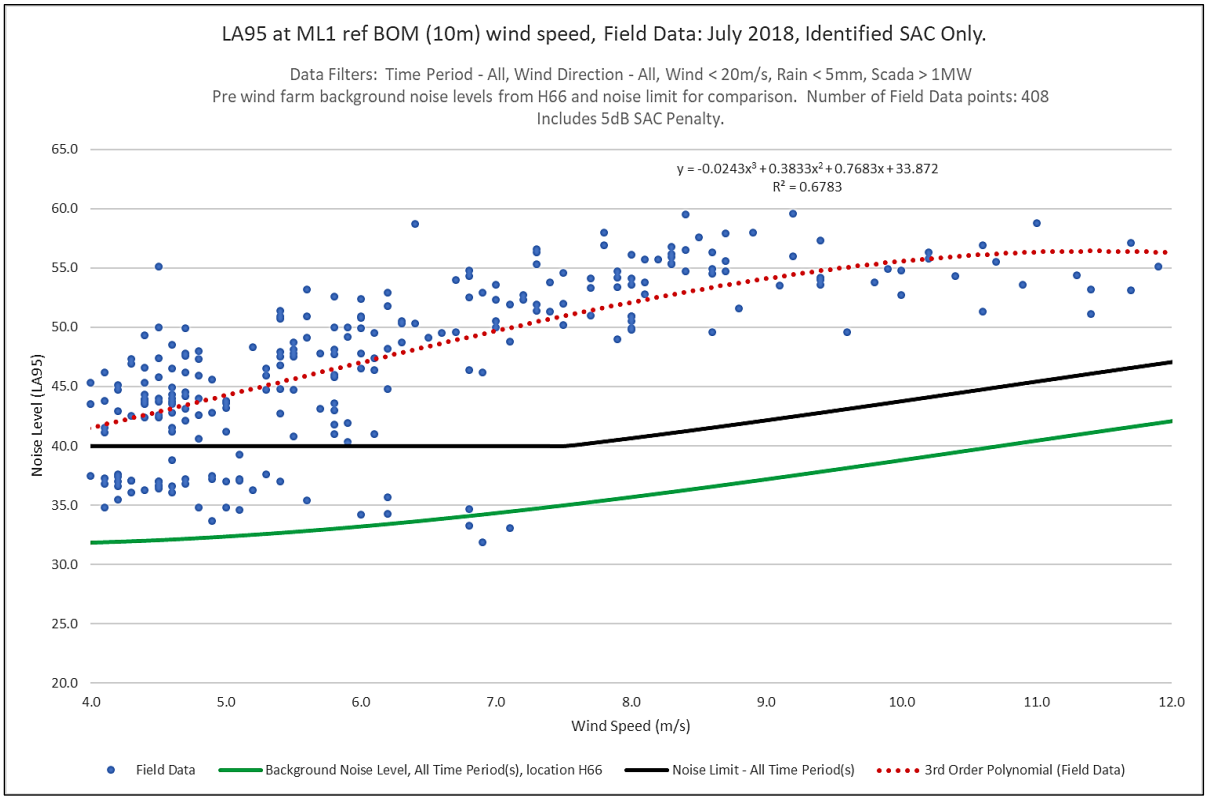
June 2018

ML3 Includes SAC 5dB penalty; 1am to 5am

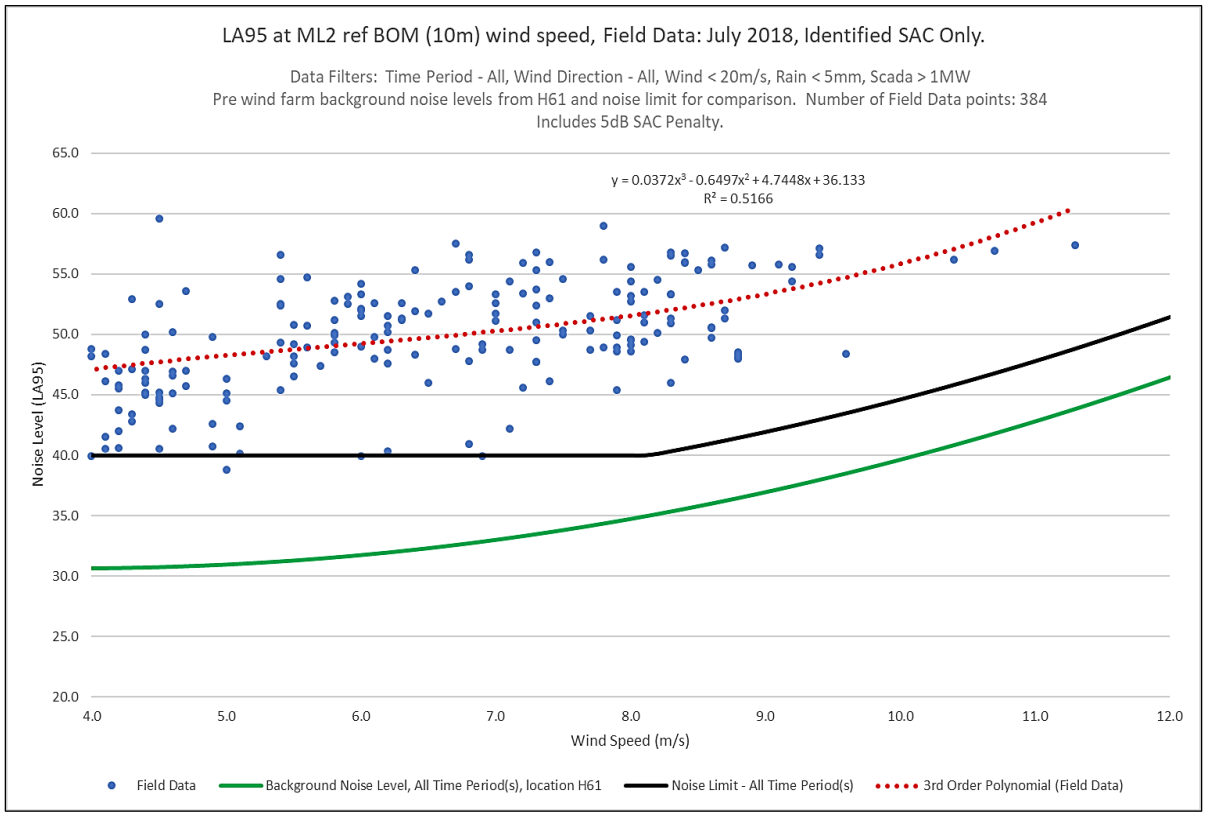


July 2018

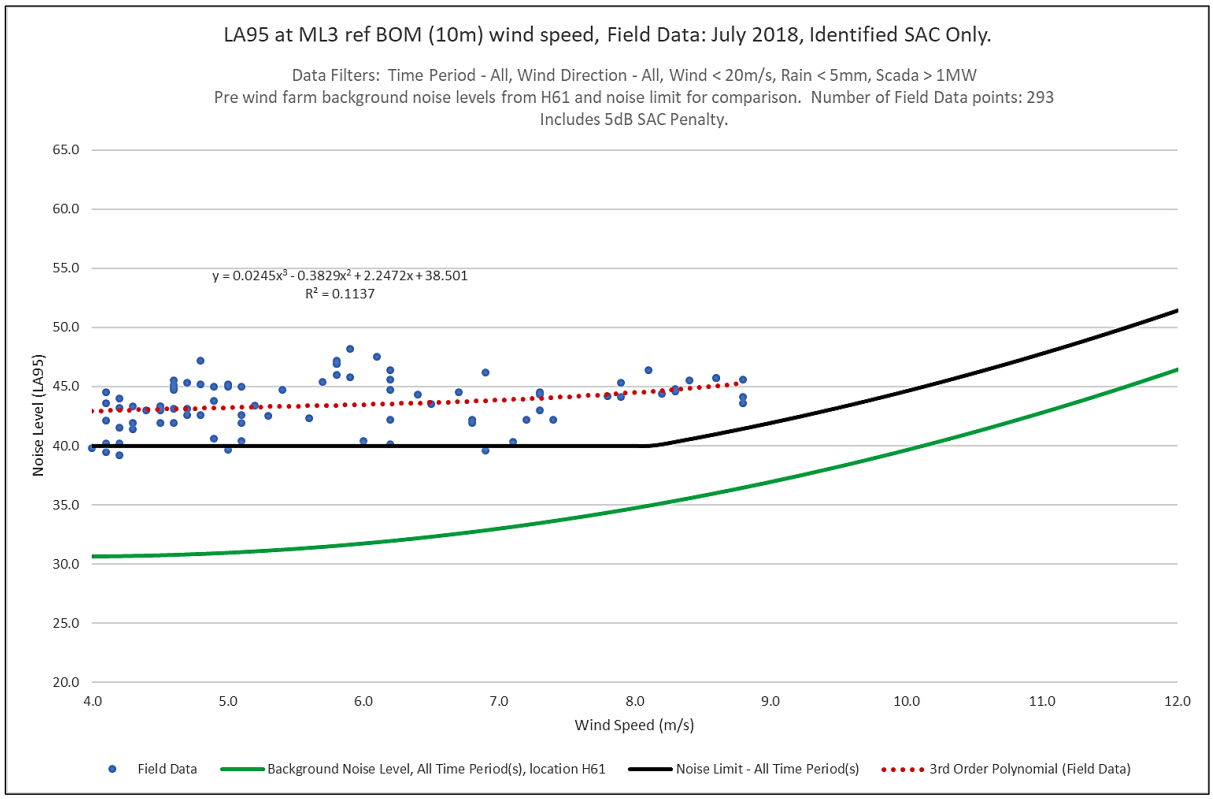
ML1 Includes SAC 5dB penalty; 1am to 5am



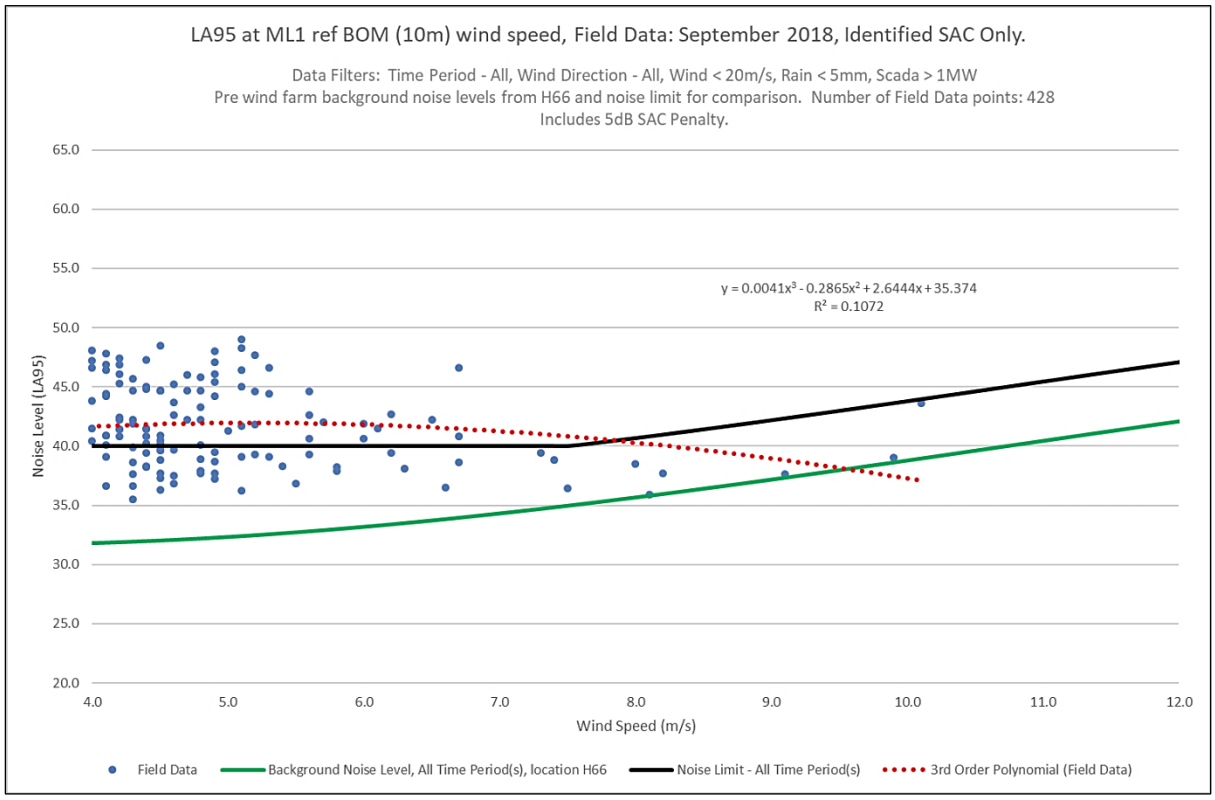
July 2018
ML2 Includes SAC 5dB penalty; 1am to 5am



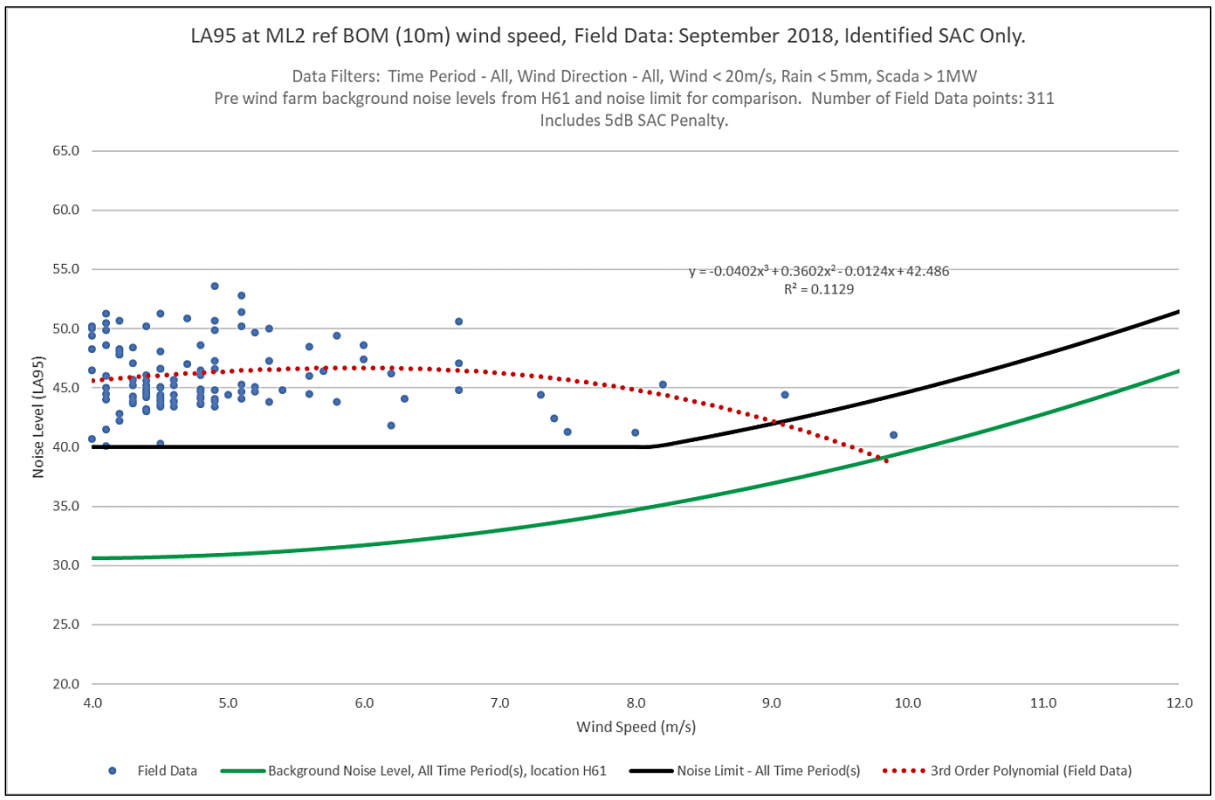
July 2018
ML3 Includes SAC 5dB penalty; 1am to 5am



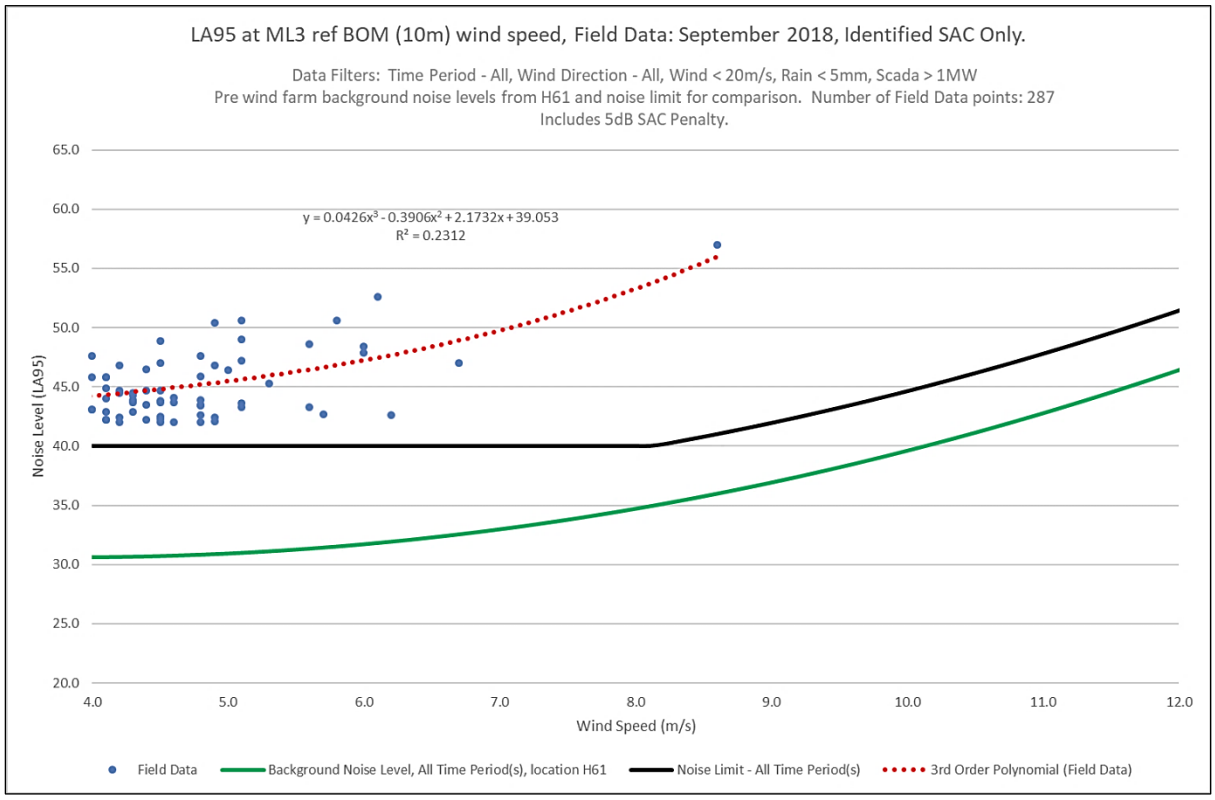
September 2018
ML1 Includes SAC 5dB penalty; 1am to 5am



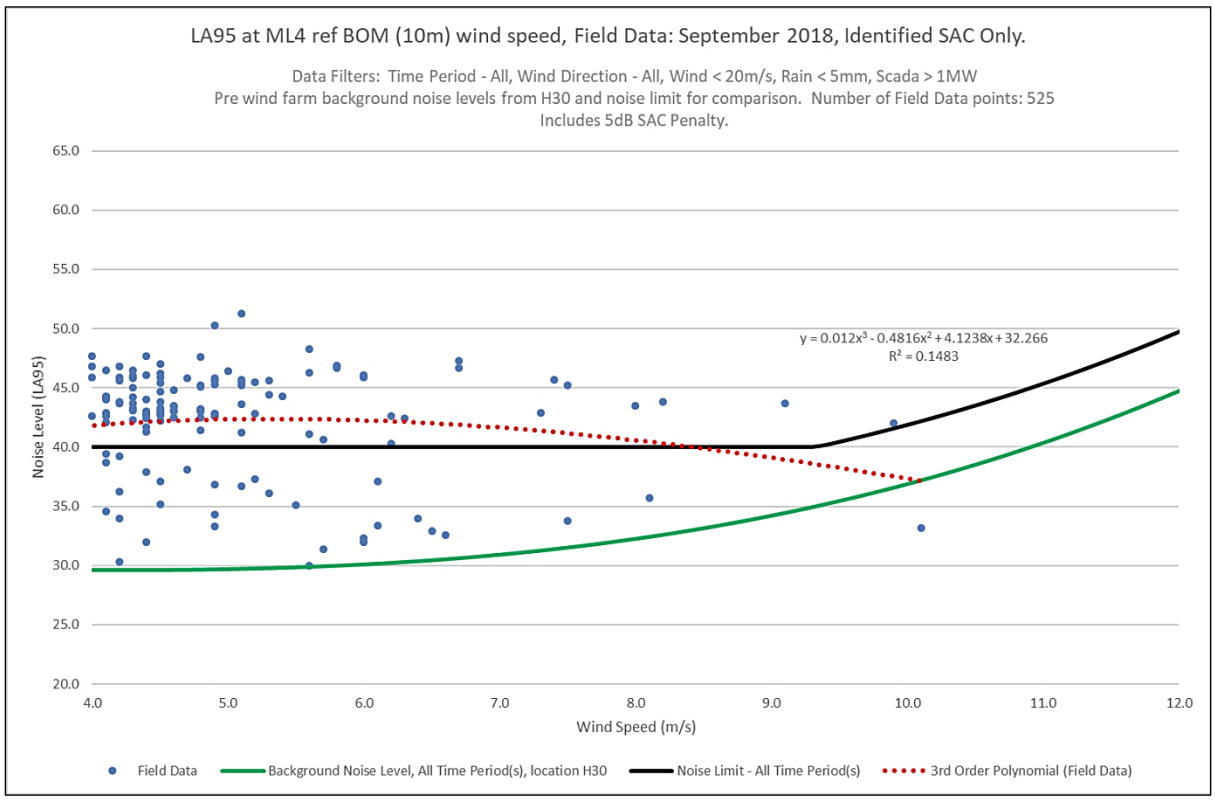
September 2018
ML2 Includes SAC 5dB penalty; 1am to 5am



September 2018
ML3 Includes SAC 5dB penalty; 1am to 5am



September 2018
ML4 Includes SAC 5dB penalty; 1am to 5am



Special Audible Characteristics - Perception of Noise Events

Introduction

Perception surveys are designed to complement the physical noise measurements. The surveys are presented at the start and conclusion of the monitoring program and include self-report assessments on exposure to wind farm and non-wind farm noise and perceived intrusiveness of noise; annoyance and sleep interference due to noise exposure; psychological wellbeing, quality of life, and general health; noise sensitivity and personality traits; attitudes to noise sources; and demographic information. Daily diary notes are maintained by residents.

The diary notes and perception survey responses are recorded in a Perception Survey spreadsheet. The detailed observations made by each person are recorded for each day. There are approximately 600 day-events recorded.

The dates of the events are noted in the following charts, for each of the residents (PSAC1 to PSAC6) who responded. The identifiable noise events do not occur all the time and can, therefore, be described as being 'special' rather than a 24/7 feature of the operation of the Wind Farm. Note: PSAC means 'Perception of Special Audible Characteristics' followed by the person ID.

The coloured dots on the following charts indicate days when residents were awoken, disturbed or annoyed by noise. These are 'adverse subjective responses' and, combined, 'adverse community responses' as defined in NZS6808:1998 as responses to 'special audible characteristics' found within the wind farm noise emissions. The following charts for the May to November sound level monitoring at locations ML1, ML2, ML3, ML4 and Bald Hills Wind Farm power generation are presented in the next section to show:

- the 40 dB(A) noise limit exceeded on the days coloured 'peach'/'transparent red' - called PTR Coded in this Report and the detailed Analysis Report;
- the PTR Coded times are regular and consistent in May 2018 to March 2019. While the times of occurrence may appear random, the descriptors "Regular" and "Consistent" refer to the fact that they nearly always occur when the turbines are running at full, or near full, generation output;
- the PTR Coded times nearly always occur when the wind at ML1 is less than 3m/s.

CAUTION: The PTR Coding does <u>not</u> mean that the wind farm is the <u>only</u> cause of the 40 dB(A) exceedance – this must be checked against the actual background sound levels at the time affected by wind and rain, plus the presence of special audible characteristics as shown in this Report.

Diary entries

Residents maintained observation diaries over the period May to November 2018. The "affected days" that form the basis for the following charts are illustrated in the September listing, following. The listings are prepared from the diary notes compiled for each month from May 2018 to March 2019 and diarists are identified as PSAC1 to PSAC6.

SEPT	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1	YES	YES	YES					YES
2								
3								
4	YES							YES
5					YES			YES
6	YES	YES	YES					YES
7				YES				
8	YES				YES	YES		
9	YES	YES	YES	YES	YES	YES		
10	YES	YES	YES	YES		YES		
11	YES	YES	YES	YES	YES	YES		
12	YES	YES	YES	YES	YES	YES		YES
13	YES	YES	YES	YES		YES		
14	YES	YES	YES			YES		
15	YES	YES	YES	YES		YES		YES
16	YES				YES	YES		YES
17	YES				YES	YES		YES
18	YES	YES	YES	YES	YES	YES		YES
19		YES	YES	YES		YES		
20	YES			YES				
21				YES	YES			
22	YES				YES	YES		
23								YES
24								YES
25								YES
26	YES				YES			YES
27	YES					YES		YES
28	YES			YES		YES		
29	YES					YES		
30				YES		YES		

How 'YES' is determined:

- the sounds must have caused the adverse effects noted in the diaries
- the sound of the turbines had to be clearly audible inside the home
- the sound had to be intrusive, annoying and/or disturbing sleep
- the sound is at night 10pm to 7am
- some people had problems with pressure sensations rather than audible sound

The following charts combine the PSAC data, AEMO data, measured background (LA95) sound levels and the days that have a nominal "40 dB(A)" exceedance.

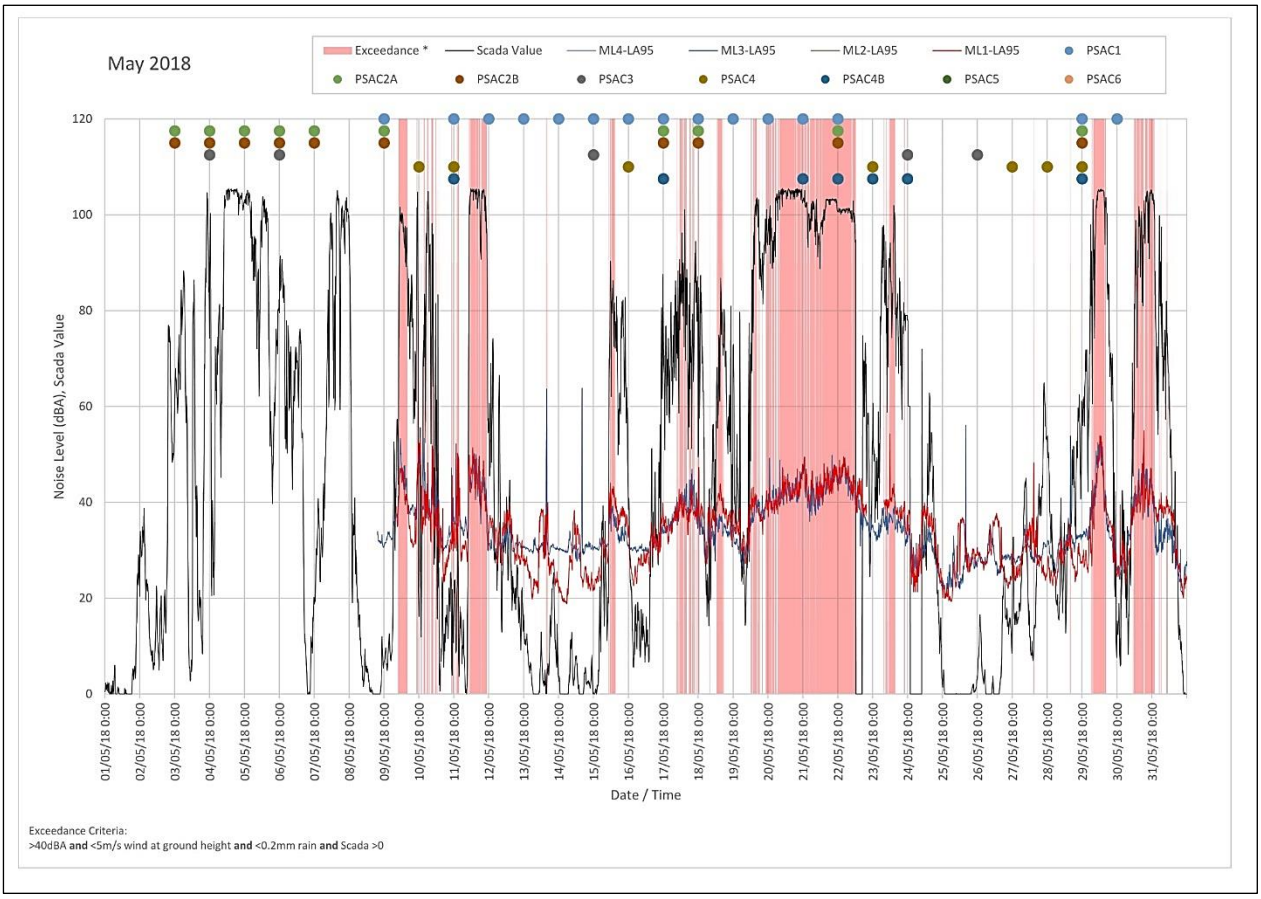
The diary notes provide clear patterns of annoyance and sleep disturbance with 'special audible characteristics' when the turbines are running at full, near full increasing or decreasing power generation output.

MAY 2018

MAY	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1								
2								
3		YES	YES					
4		YES	YES	YES				
5		YES	YES					
6		YES	YES	YES				
7		YES	YES					
8								
9	YES	YES	YES					
10	YES				YES			
11	YES				YES	YES		
12								
13								
14								
15	YES			YES				
16	YES				YES			
17	YES	YES	YES		YES	YES		
18	YES	YES	YES		YES			
19	YES							
20	YES							
21	YES					YES		
22	YES	YES	YES			YES		
23					YES	YES		
24				YES		YES		
25								
26				YES				
27					YES			
28					YES			
29	YES	YES	YES		YES	YES		
30	YES							
31								
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

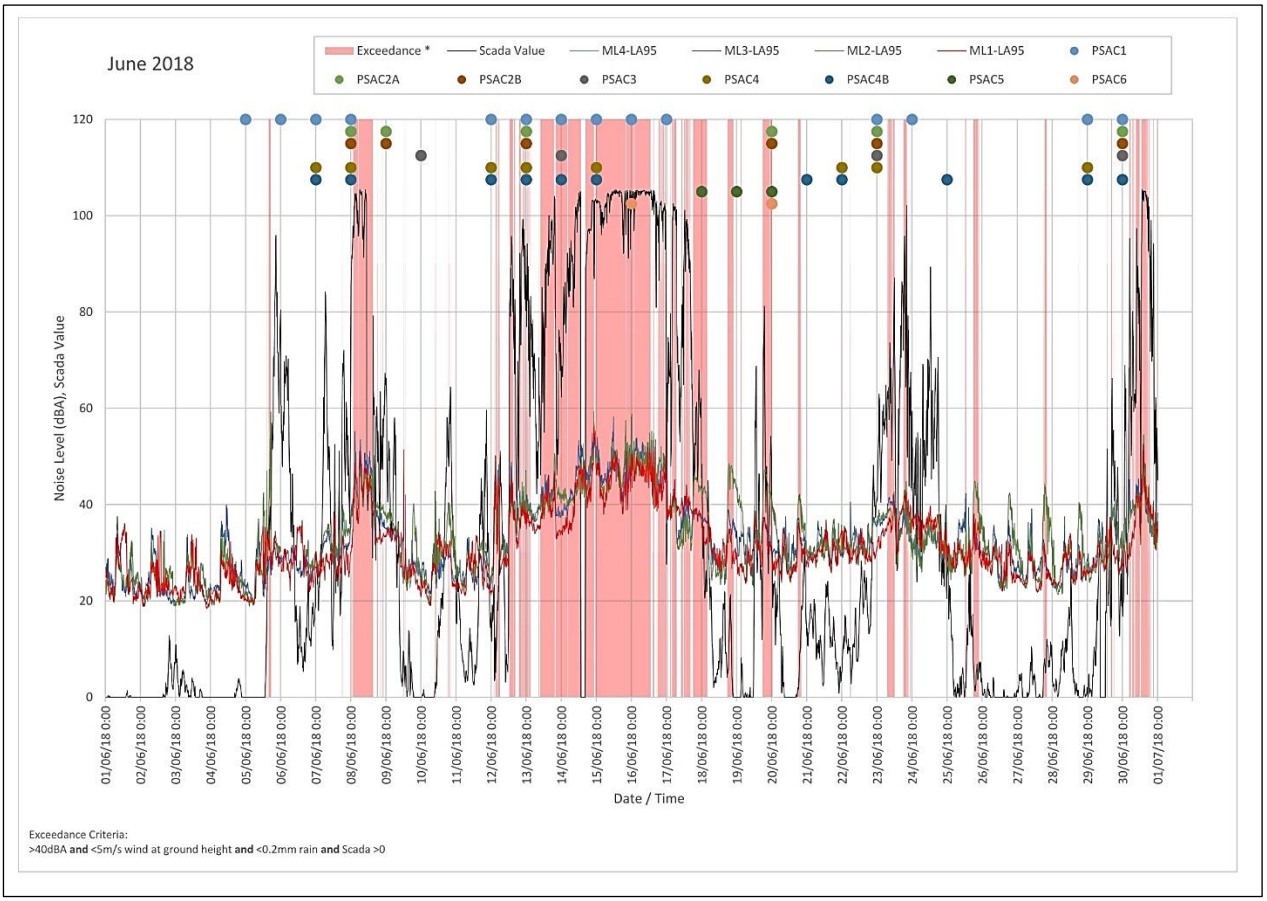


JUNE 2018

JUNE	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1								
2								
3								
4								
5	YES							
6	YES							
7	YES				YES	YES		
8	YES	YES	YES		YES	YES		
9		YES	YES					
10				YES				
11								
12	YES				YES	YES		
13	YES	YES	YES		YES	YES		
14	YES	YES	YES	YES		YES		
15	YES				YES	YES		
16	YES							
17	YES							
18							YES	YES
19							YES	
20		YES	YES				YES	YES
21						YES		
22					YES	YES		
23	YES	YES	YES	YES	YES			
24	YES							
25						YES		
26								
27								
28								
29	YES				YES	YES		
30	YES	YES	YES	YES		YES		
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

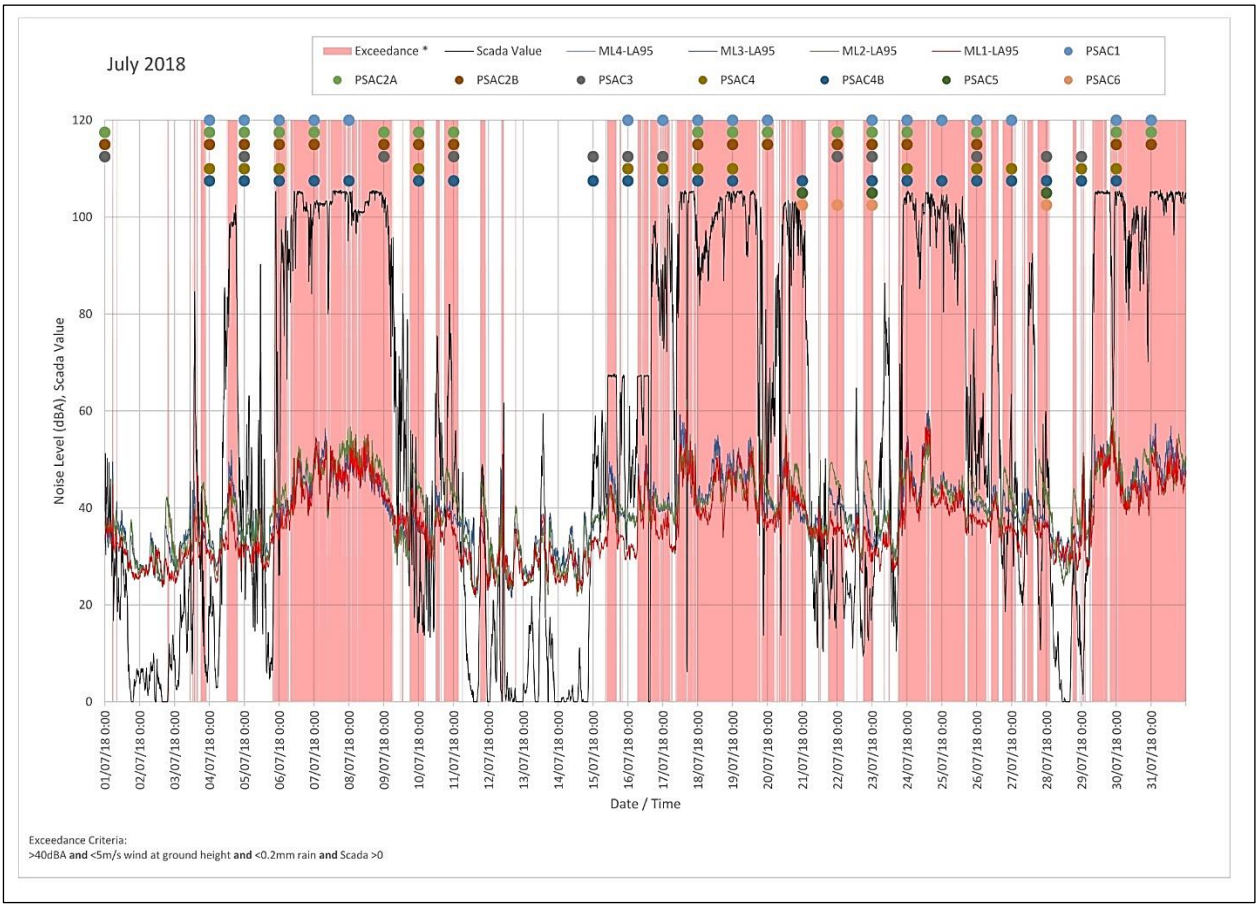


JULY 2018

JULY	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1	YES	YES	YES	YES				
2								
3								
4	YES	YES	YES		YES	YES		
5	YES	YES	YES	YES	YES	YES		
6	YES	YES	YES		YES	YES		
7	YES	YES	YES			YES		
8	YES					YES		
9	YES	YES	YES	YES				
10		YES	YES		YES	YES		
11		YES	YES	YES		YES		
12								
13								
14								
15				YES		YES		
16	YES			YES	YES	YES		
17	YES			YES	YES	YES		
18	YES	YES	YES		YES	YES		
19	YES	YES	YES		YES	YES		
20	YES	YES	YES					
21						YES	YES	YES
22		YES	YES	YES				YES
23	YES	YES	YES	YES		YES	YES	YES
24	YES	YES	YES		YES	YES		
25	YES					YES		
26	YES	YES	YES	YES	YES	YES		
27	YES				YES	YES		
28				YES		YES	YES	YES
29				YES	YES	YES		
30	YES	YES	YES		YES	YES		
31	YES	YES	YES					
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

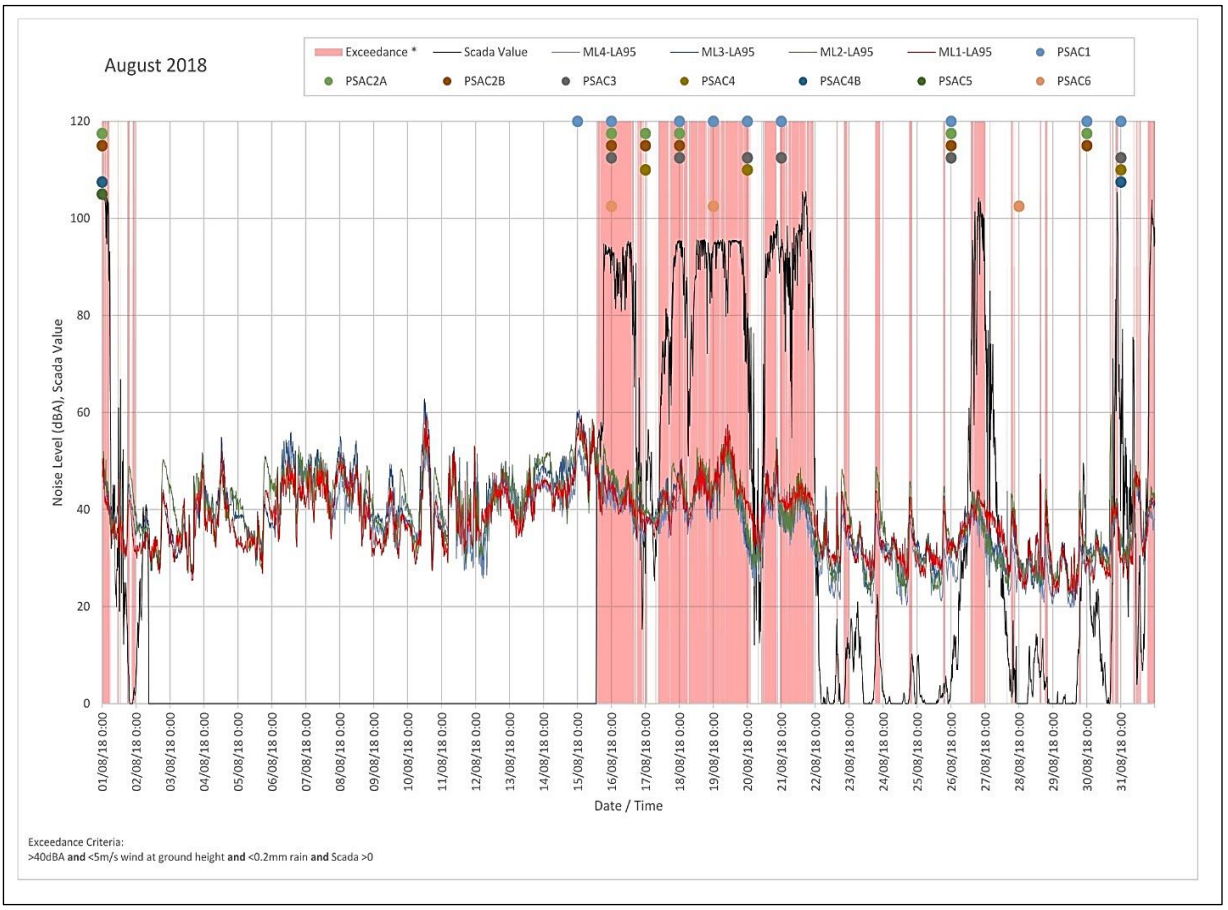


AUGUST 2018

AUG	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1		YES	YES	YES	YES	YES	YES	
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15	YES							
16	YES	YES	YES	YES				YES
17		YES	YES		YES			
18	YES	YES	YES	YES				
19	YES							YES
20	YES			YES	YES			
21	YES			YES				YES
22								
23								
24								
25								
26	YES	YES	YES	YES				
27								
28								YES
29								
30	YES	YES	YES					
31	YES			YES	YES	YES		
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

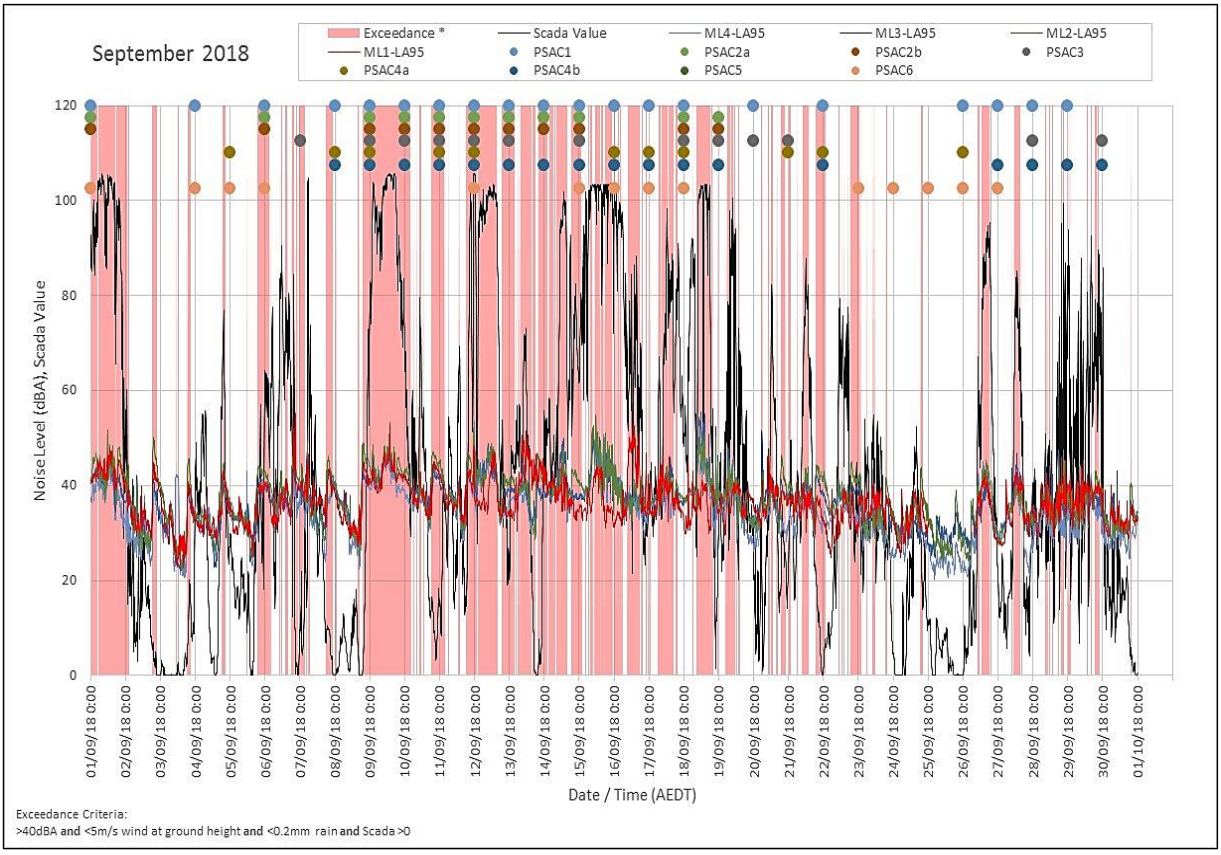


SEPTEMBER 2018

SEPT	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1	YES	YES	YES					YES
2								
3								
4	YES							YES
5					YES			YES
6	YES	YES	YES					YES
7				YES				
8	YES				YES	YES		
9	YES	YES	YES	YES	YES	YES		
10	YES	YES	YES	YES		YES		
11	YES	YES	YES	YES	YES	YES		
12	YES	YES	YES	YES	YES	YES		YES
13	YES	YES	YES	YES		YES		
14	YES	YES	YES			YES		
15	YES	YES	YES	YES		YES		YES
16	YES				YES	YES		YES
17	YES				YES	YES		YES
18	YES	YES	YES	YES	YES	YES		YES
19		YES	YES	YES		YES		
20	YES			YES				
21				YES	YES			
22	YES				YES	YES		
23								YES
24								YES
25								YES
26	YES				YES			YES
27	YES					YES		YES
28	YES			YES		YES		
29	YES					YES		
30				YES		YES		
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

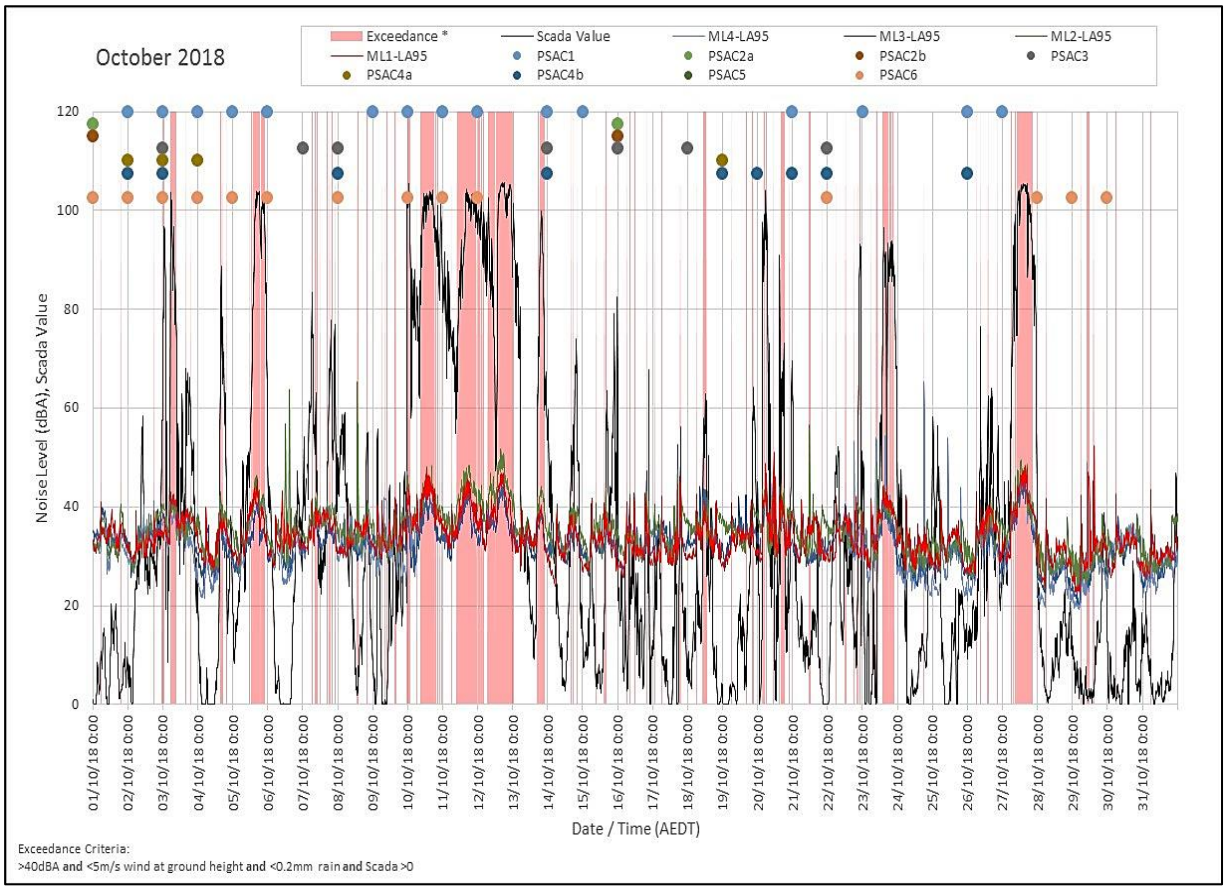


OCTOBER 2018

OCT	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1		YES	YES					YES
2	YES				YES	YES		YES
3	YES			YES	YES	YES		YES
4	YES				YES			YES
5	YES							YES
6	YES							YES
7				YES				
8				YES		YES		YES
9	YES							
10	YES							YES
11	YES							YES
12	YES							YES
13								
14	YES			YES		YES		
15	YES							
16		YES	YES	YES				
17								
18				YES				
19					YES	YES		
20						YES		
21	YES					YES		
22				YES		YES		YES
23	YES							
24								
25								
26	YES					YES		
27	YES							
28								YES
29								YES
30								YES
31	YES							
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

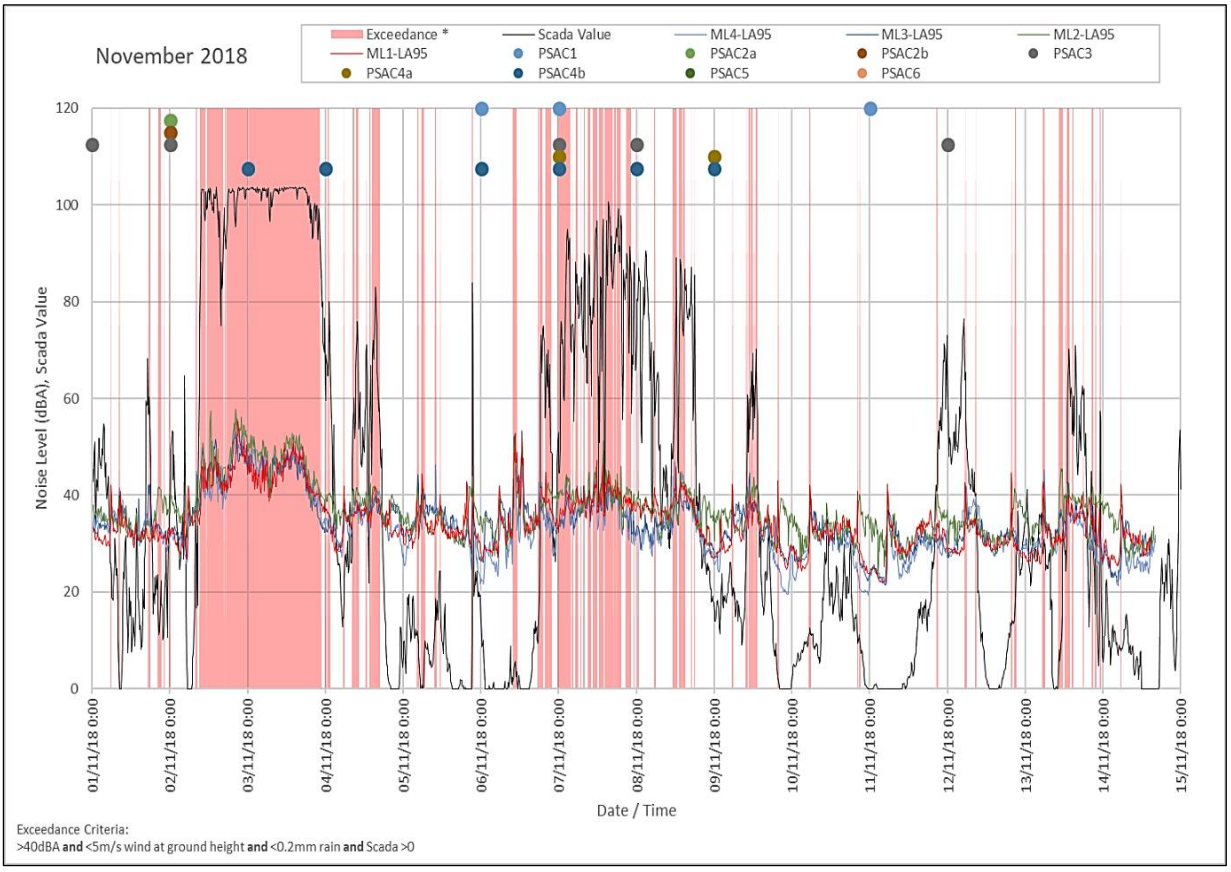


NOVEMBER 2018

NOV	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1				YES				YES
2	YES	YES	YES	YES				YES
3	YES					YES		
4	YES					YES		
5								
6	YES					YES		
7	YES			YES	YES	YES		
8				YES		YES		
9					YES	YES		
10								
11	YES							
12	YES			YES				
13	YES	YES	YES					
14	YES							
15								
16								
17								
18								
19								
20		YES	YES					
21								
22	YES							
23	YES							
24		YES	YES					
25								
26								
27								
28								
29								
30								
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

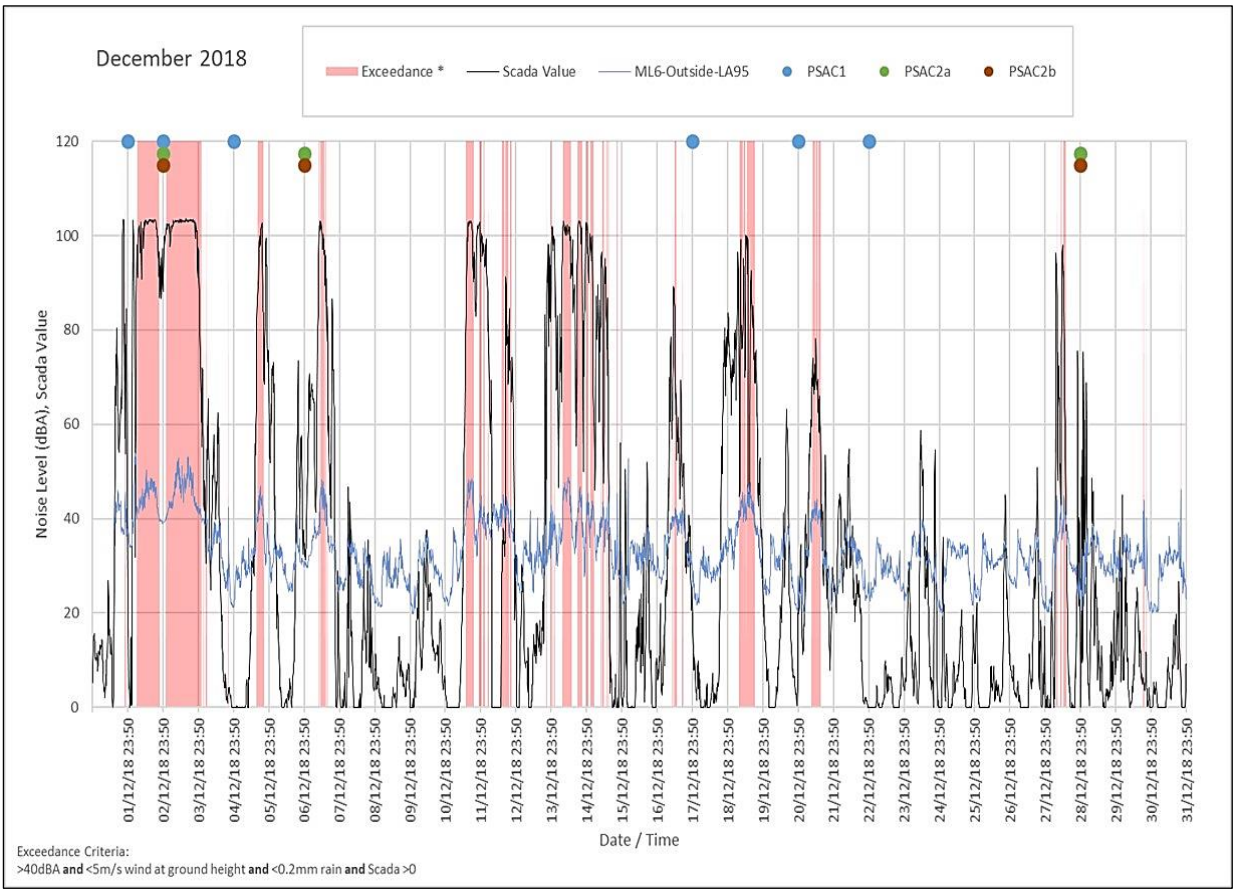


DECEMBER 2018

Day	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1								
2	Yes							
3	Yes	Yes	Yes					
4								
5	Yes							
6								
7		Yes	Yes					
8								
9								
10								
11								
12								
13								
14								YES
15								
16								
17								
18	Yes							
19								
20								
21	Yes							
22								
23	Yes							
24								
25								
26								
27								
28								
29		Yes	Yes					
30								
31								
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)



JANUARY 2019

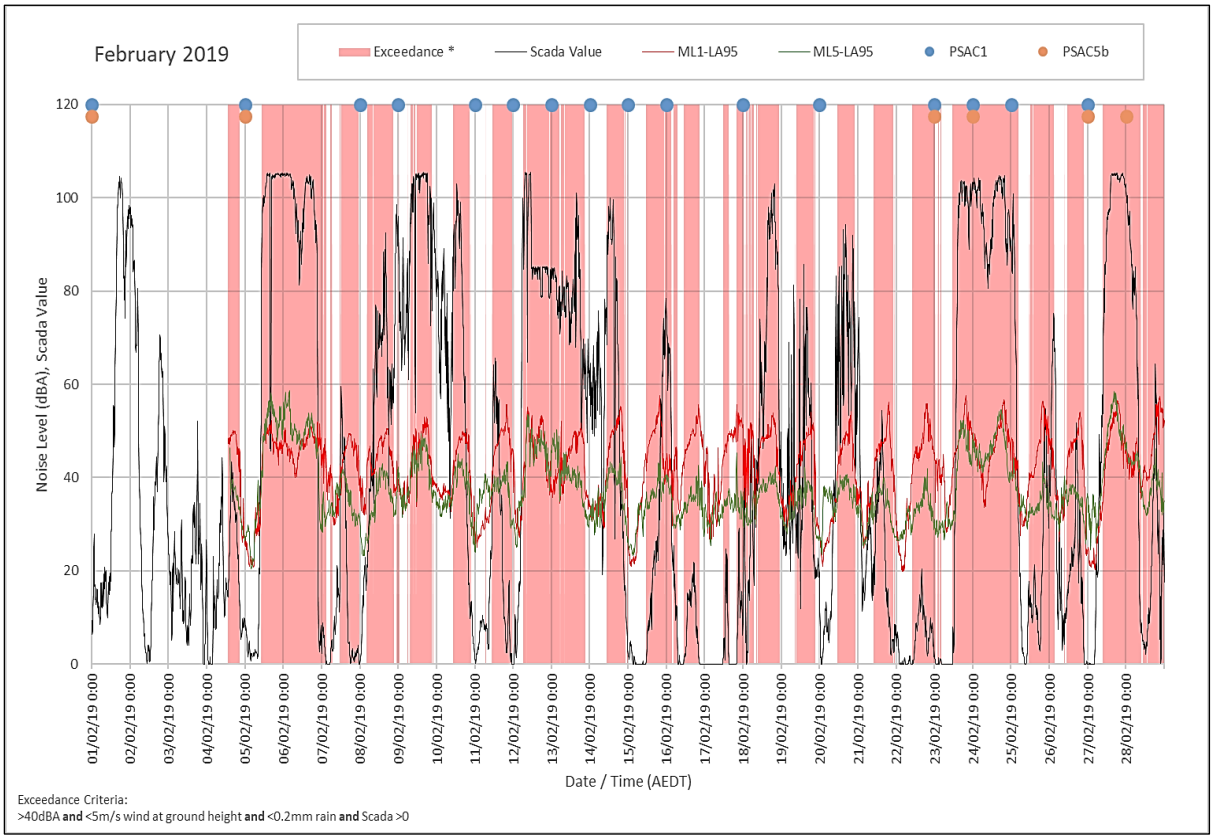
No Observations recorded

FEBRUARY 2019

Day	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1	YES							YES
2								
3								
4								
5	YES							YES
6								
7								
8	YES							
9	YES							
10								
11	YES							
12	YES							
13	YES							
14	YES							
15	YES							
16	YES							
17								
18	YES							
19								
20	YES							
21								
22								
23	YES							YES
24	YES							YES
25	YES							
26								
27	YES							YES
28								YES
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)

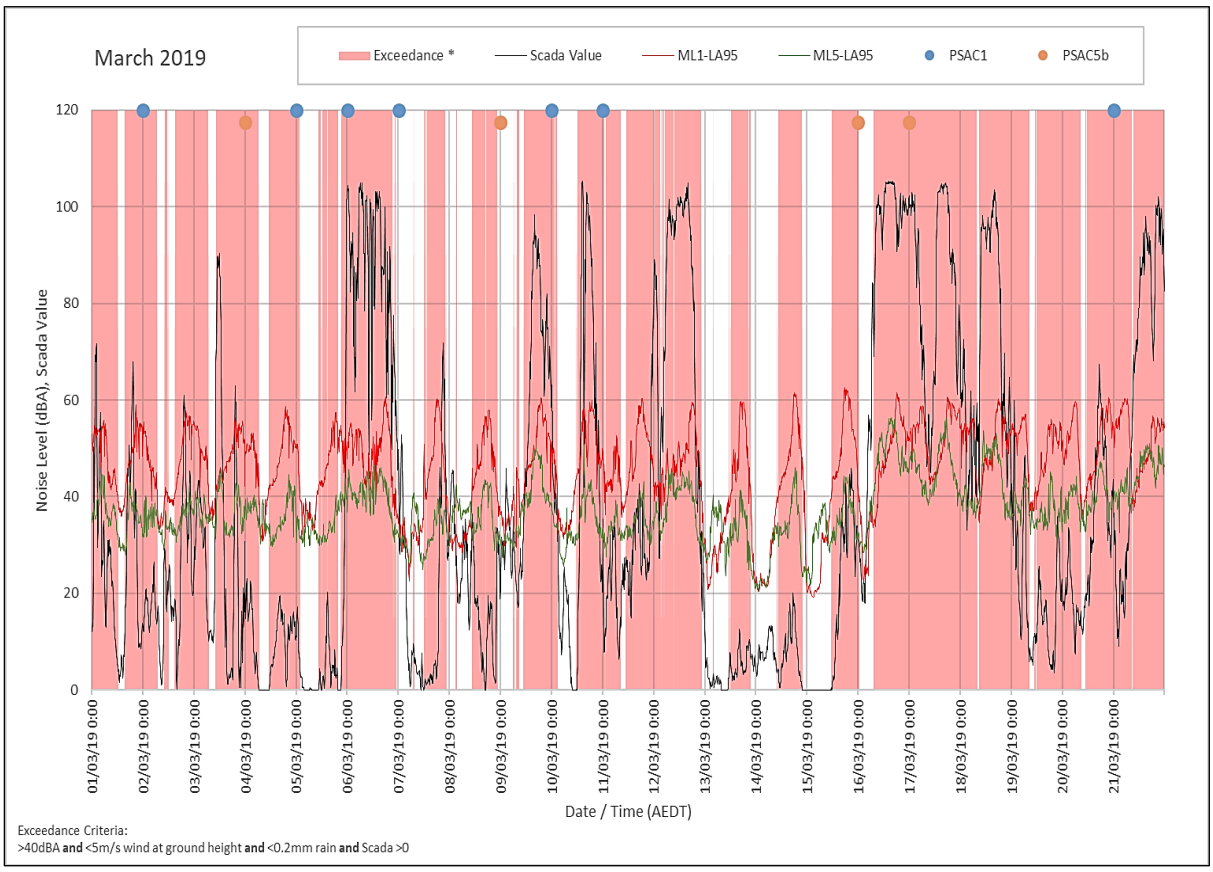


MARCH 2019

Day	Observer							
	JZ	Don F	Dor F	NU	DJ	SJ	SK	RS
	PSAC1	PSAC2A	PSAC2B	PSAC3	PSAC4A	PSAC4B	PSAC5	PSAC6
1								
2	YES							
3								
4								YES
5	YES							
6	YES							
7	YES							
8								
9								YES
10	YES							
11	YES							
12								
13								
14								
15								
16								YES
17								YES
18								
19								
20								
21	YES							
22	YES							
23								
24	YES							
25	YES							
26								
27								
28								
29								
30								
31								
Graph Value	120	117.5	115	112.5	110	107.5	105	102.5

Key to chart

- ✓ Over 40 dB(A) limit PTR colour bands
- ✓ Noise complaints PSAC colour dots
- ✓ Sound Levels (LA95) by location
- ✓ Power generation (SCADA values)



Survey Responses

Residents have been keeping noise diaries for a considerable time and from May for this monitoring program. The perception survey forms are presented in Appendix F. The details of the diaries are summarized into a spreadsheet available to the residents. A summary of the responses for mainly the night-time period, 10pm to 7am, May to August 2018 period follow.

Resident PSAC-1

May

Resident PSAC 1 reported being disturbed during daytime for 8 days while inside the home. He was disturbed for 13 nights during the month. The sounds heard inside the home were felt as an audible physical sensation and described as loud, rumbling, cyclic noise. The sounds are described as being continuous for the night-time. On each occasion he reports his sleep as being disturbed. The sounds are loud, annoying, intrusive and interfering with his lifestyle. His notes include references to turbine operation, wind speed and direction.

June

Resident PSAC 1 reported being disturbed during daytime for 10 days while inside the home. He was disturbed for 14 nights during the month. The sounds heard inside the home were felt as an audible physical sensation and described as loud, rumbling, cyclic noise. The sounds are described as being continuous for the night-time. On each occasion he reports his sleep as being disturbed. The sounds are loud, annoying, intrusive and interfering with his lifestyle. His notes include references to turbine operation, wind speed and direction.

July

Resident PSAC 1 reported being disturbed during daytime for 15 days while inside the home. He was disturbed for 19 nights during the month. The sounds heard inside the home were felt as an audible physical sensation and described as loud, rumbling, cyclic noise. The sounds are described as being continuous for the night-time. On each occasion he reports his sleep as being disturbed. His notes include references to sounds heard as:

- *continuous, loud, roaring, cyclic; pulsating drone action, loud noise; noise can be heard inside the house;*
- *unable to get to sleep, regular awakening mid-morning, cannot get back to sleep, sleep deprivation, leaves property to get relief;*

The effects on him are described as:

- *Stress, anxiety, anxious; heart throbbing-racing experience; head throbbing-ache; uncomfortable inner body, throbbing sensation; dazed on awakening; overall unwell feeling*

August

Resident PSAC1 reported being disturbed during daytime for 9 days while inside the home. He was disturbed for 9 nights during the month. The sounds heard inside the home were felt as an audible physical sensation and described as loud, rumbling, cyclic noise. The sounds are described as being continuous for the night-time. On each occasion he reports his sleep as being disturbed. The sounds are loud, annoying, intrusive and interfering with his lifestyle. His notes include references to turbine operation, wind speed and direction.

Residents PSAC-2 and 2A

May

In May 10 nights are reported as being noisy, with sounds noticed from the morning. Responses identify the turbine sound as being “a grumbling noise and sensation” with the sound being just audible inside.

June

In June 7 nights are reported as being noisy, with sounds noticed from the morning. Responses identify the turbine sound as being “a whirring noise and sensation” with the sound being just audible inside; identifies having bad headaches on awakening on six occasions.

July

In July 17 nights are reported as being noisy, with sounds noticed from the morning. Responses identify the turbine sound as being “a whirring noise and sensation” with the sound being just audible inside; identifies having bad headaches on awakening on ten occasions.

August

In August the turbines were off for the early part of the month yet 5 nights are reported as being noisy, with sounds noticed from the morning. Responses identify the turbine sound as being “a whirring noise and sensation” with the sound being just audible inside; identifies having bad headaches on awakening on two occasions.

Resident PSAC-3

May

In May 10 days are reported as being noisy, with sounds noticed from the morning. Responses identify “swish and thump” with the sound being clearly audible, annoying, intrusive, and preventing sleep.

June

In June 7 nights are reported as being noisy, with sounds noticed from the morning. Responses identify “swish and cyclic noise” with the sound being clearly audible, annoying, intrusive, and preventing sleep.

July

In July 17 nights are reported as being noisy, with sounds noticed from the morning. Responses identify "swish and cyclic noise" with the sound being clearly audible, annoying, intrusive, and preventing sleep.

August

In August the turbines were off for the early part of the month yet 5 nights are reported as being noisy, with sounds noticed from the morning. Responses identify "cyclic swishing" with the sound being clearly audible, annoying, intrusive, and preventing sleep.

Resident PSAC-4A

May

The resident was woken by turbine noise on 9 occasions at times between 2:30am and 4:00am. The sound of the turbines is described as being 'rolling and roaring'.

June

The resident was woken by turbine noise on 8 occasions at times between 1:00am and 4:40am. The sound of the turbines is described as being 'rumbling and thumping' during the day of 14 May. On the 23rd the noise was such that he was awoken at 3:30am *"No sleep; got up at 7am; headache; turned radio on; still could hear noise".*

July

The noise from the turbines was a significant problem this month, with 13 noise events and significant disturbance. The responses say, for example: '*2am woken up, very noisy, never got back to sleep; 4:10am woken up, turned on radio' 5:00am woken up, roaring, put radio on'.*

August

The fact that the wind farm was not operating for 2-15 August is highlighted in the daily diary. When the wind farm started working again he was woken up at times between 12:30am and 6:15am on 3 occasions. Typically the noise is described as: 'woken up, very noisy, roaring, put radio on'.

Resident PSAC-4B

May

In May 7 nights are reported as being noisy, with sounds noticed variously from the morning (5:45am); evening and night. Responses identifies the sound of the turbines variously as 'drone, drone like a plane, groan and a "uhh-uhh sound"' with the sound being variously clearly audible, to annoying, intrusive, and preventing sleep and loud enough to interfere with lifestyle.

June

In June 11 nights are reported as being noisy, with sounds noticed variously from the morning (2am); all day and at night. Responses identifies the sound of the turbines variously as 'drone, groaning, grinding even over wind' with the sound being variously clearly audible, annoying, intrusive, and preventing sleep and loud enough to interfere with lifestyle.

July

In July 21 nights are reported as being noisy, with sounds noticed variously from the morning (1:15am); all day and all night. Responses identifies the sound of the turbines variously as 'grinding and an 'uhh uhh' sound' with the sound being variously clearly audible, annoying, intrusive, and preventing sleep and loud enough to interfere with lifestyle.

August

In August 1 night is reported as being noisy, with sounds noticed in the evening. Responses identifies the sound of the turbines as being "a slow grind" with the sound being variously clearly audible, annoying, intrusive, and preventing sleep.

Resident PSAC-5

June

In June 3 nights are reported as being noisy, with sounds noticed variously from the morning (6am); all day and all night. Responses identifies the sound of the turbines variously as 'groan, roar, thump, loud hum, deep hum, pulsing drone, grind' with the sound being variously clearly audible, annoying, intrusive, and preventing sleep and loud enough to interfere with lifestyle.

July

In July 3 nights are reported as being noisy, with sounds noticed variously from the morning (6am); evening and night. Responses identifies the sound of the turbines variously as 'groan, pulsing groan, dull rumble increasing at night, roar, very loud grind, deep drone' with the sound being variously clearly audible, annoying, intrusive, and preventing sleep and loud enough to interfere with lifestyle.

Resident PSAC-6

June

The turbine sounds are reported as being 'like a big truck running on the road' for one night and 'swish' on 1 night. Notes include weather conditions.

July

The turbine sounds on 4 nights variously as being an audible 'rumble' or 'thump'. Notes include weather conditions.

August

The turbine sounds on 4 nights variously as being an audible 'swish', 'rumble'. Notes include weather conditions.

(Note: some of PSAC6 notes are at level 3, that is, audible sound but not disturbing sleep. However, as the responses are included as the context of the notes suggest sleep disturbance or intrusive noise).

Summary of Responses May 2018 – March 2019

In the following tables, the notation 'NH' means the person was not home or did not fill out a response. The responses are for the night-time period, 10pm to 7am.

Resident PSAC-1

The sounds heard inside the home were felt as an audible physical sensation and described as loud, rumbling, cyclic noise. JZ describes the sounds as being continuous for the night-time. On each occasion he reports his sleep as being disturbed. The sounds are loud, annoying, intrusive and interfering with his lifestyle. His notes include references to turbine operation, wind speed and direction.

PSAC-1 (JZ) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
13	14	19	9	20	16	11
December	Jan 2019	February	March			
6	NH	16	10			

Resident PSAC-2A DonF

The sounds inside the home are heard as a whirring and sensation. DF feels the sound as an inaudible physical sensation and as a faint but detectable audible sound. Notes are kept of wind conditions and taking of Panadol for headaches.

PSAC-2A (DonF) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
10	7	17	5	11	2	4
December	Jan 2019	February	March			
3	NH	NH	NH			

Resident PSAC-2B DorF

The sounds heard inside the home are clearly audible, annoying, intrusive and preventing sleep. The sounds are described as cyclic swishing, and sometimes a grinding, surging sound.

PSAC-2B (DorF) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
10	7	17	5	11	2	4
December	Jan 2019	February	March			
3	NH	NH	NH			

Resident PSAC-3 NU

The sounds heard inside the home are heard as a roaring noise or as "noisy" or as a 'funny rolling noise'. The sounds are sufficient to awaken NU and he is not able to get back to sleep ('turns radio on'). Notes include weather conditions.

PSAC-3 (NU) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
5	4	12	6	13	7	5
December	Jan 2019	February	March			
NH	NH	NH	NH			

Resident PSAC-4A

The sounds of the turbines are clearly audible inside the home and are described as being annoying, intrusive, and disturbing sleep. The character of the noise is described variously as being 'a dull thump', 'groan', 'roar', 'pulsing groan' and 'plane-like'. Notes include weather conditions.

PSAC-4A (DJ) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
9	8	13	3	17	4	2
December	Jan 2019	February	March			
NH	NH	NH	NH			

Resident PSAC-4B

The sounds of the turbines are clearly audible inside the home and are described as being annoying, intrusive, and disturbing sleep. The character of the noise is described variously as being 'grinding', 'grinding with a whoosh whoosh overlay', 'drone', and an 'uhuh uhuh' sound that hurt SJ's ears. Notes include weather conditions.

PSAC-4B (SJ) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
7	11	21	1	17	9	6
December	Jan 2019	February	March			
NH	NH	NH	NH			

Resident PSAC-5

SK reports the turbine noise as a swishing sound that is clearly audible. The sound is such that SK records being unable to concentrate on work, at times. Notes include weather conditions .

PSAC-5 (SK) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
NH	3	3	NH	NH	NH	NH

Resident PSAC-6

RS reports the turbine sounds variously as being an audible 'swish', 'rumble', 'drone' or 'thump'. Notes include weather conditions.

PSAC-6 (RS) Identification of Special Audible Characteristics – Times by Month						
May	June	July	August	September	October	November
NH	2	4	4	14	14	2
December	Jan 2019	February	March			
1	NH	6	40			

Sensation Effects

During the course of the monitoring program a physical 'sensation' effect was recorded by respondents and by visitors to homes. The effects are recorded both in the diary notes and in personal conversation. The effect is variously described as being a 'pressure in the head and body' and as an overall feeling of pressure. Two monitors, one a barometric pressure sensor and the other an infrasound monitor, were established at ML1 to record events. No conclusions have been reached. Further investigation is required in order to refine personal response, sampling and analysis methodologies.

Acoustic Environment Surveys

Acoustic Environment Surveys taken in September for the preceding month of August, provide the following responses from six participants.

Question 3
Wind farm noise is identified as the single noisy activity in the locale (Question 3 of the survey).

Wind farm noise at night was the main concern of the respondents with two people concerned about noise all the time.

To the question

'Generally, how would you rate your area as a place to live before the noisy activities started', all six respondents rated the locale 'high' and 'tranquil'.

To the question

'Generally, how would you rate your area as a place to live now?'
All six respondents rated the locale as 'low' or 'noisy'.

To the question

'Thinking about the last 12 months or so, when you are here at home, how much does noise from the noisy activities in Question 3 bother, disturb or annoy you?'
Four respondents replied 'extremely' and two replied 'very'.

To the question

Thinking about the last 12 months or so, what number from zero to ten best shows how much you are bothered, disturbed or annoyed by noise from the noisy activities in Question 3?
Two respondents replied '10/10' , two replied '8/10' and two replied '7/10'.

Conclusions

- People are very capable of subjectively identifying audible characteristics in wind turbine noise.
- Noticeable intrusive audible characteristics do not occur all the time.
- Noise from the wind farm has adversely affected the community, as indicated by the individual responses.

BALD HILLS NOISE MONITORING

APPENDICES

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Appendix A: Monitoring Locations

Wind farm noise and weather monitoring locations are:

- ML1: JZ, 860 Buffalo Waratah Road Tarwin Lower 3956 (sound and weather)
- ML2: DDF, 1405 Buffalo Waratah Road Tarwin Lower 3956
- ML3: NU, 1550 Buffalo Waratah Road Tarwin Lower 3956
- ML4: DSJ, 102 Mc Burnie and Boag Road Tarwin Lower 3956
- ML5: AK, 965 Walkerville Road, Tarwin Lower 3956 (sound and weather)
- ML6: JM, 'Kings Flat" 1450 Buffalo Waratah Road Tarwin Lower 3956
- ML7: 'HWT' 10 metre wind monitoring station, 940 Buffalo Waratah Road, 3956

Notes:

- Locations ML5 and ML6 on Plate B1 are 'install-locations' for November to March.
- All sound level meters hold current NATA calibration certificates
- All sound level meters were field calibrated at each service check.

Monitoring Timetable:

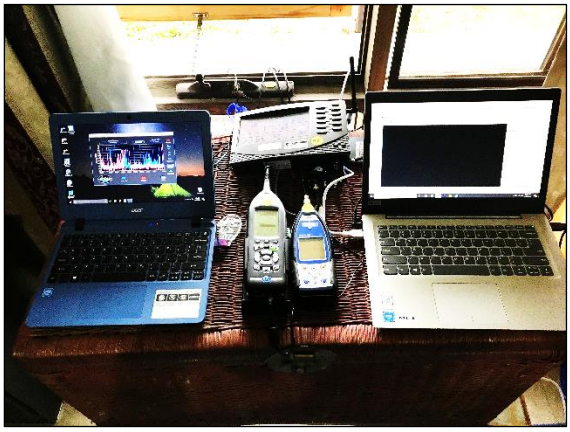
The monitoring timetable required visiting each site on an approximate 4 – 6 week basis. On each visit all instruments were downloaded and audio saved to hard-drive. Each instrument was field calibrated and serviced as required.

- 8-9 May: Systems at ML1 (indoor and outdoor) and ML3 (outdoor) activated and calibrated
- 6-7 June: System at ML2 (outdoor) activated and calibrated; infrasound logging at ML1 activated
- 11 July: service check; ML1, ML2, ML3 all instruments checked and calibrated; system (outdoor) installed at ML4
- 8 August: service check; all instruments checked and calibrated
- 25-26 September: service check; all instruments checked and calibrated; indoor BSWA installed at ML4
- 15 November: service check; units at ML2, ML3 ML4 removed; indoor / outdoor systems installed at ML5 and ML6, indoor system added to ML1.
- 23 January 2019: systems removed from ML1, ML5 and ML6
- 4 February 2019: systems sent to JZ and installed at ML1 and ML5 (outdoor only)
- 22 March 2019: all monitoring concluded and systems ML1, ML5 returned to NMS; serviced, all instruments within specification.

Monitoring Location ML1: 860 Buffalo Waratah Road
38°44'8.92"S, 145°58'54.16"E

ML1 weather station and 2 microphones

Microphones and on-ground microphone location



ML1 instrument layout

ML1 300mm diameter windscreen Nov 2018

Monitoring Location ML2: 1405 Buffalo Waratah Road
38°46'51.09"S, 145°57'58.22"E

ML2 Microphones with clear line of sight to wind farm

Monitoring Location ML3: 1550 Buffalo Waratah Road
38°47'22.96"S, 145°57'49.73"E

ML3 Microphones with clear line of sight to wind farm and monitoring arrangement with audio record and internet access

Monitoring Location ML4: 102 Mc Burnie and Boag Road
38°48'48.14"S, 145°56'21.42"E

ML4 Wind farm screened by trees

Monitoring Location ML5: 965 Walkerville Road, Tarwin Lower
38°46'28.66"S, 145°54'40.14"E

ML5, Western side of wind farm; clear visibility to wind farm; 300mm windscreen installed in November

Monitoring Location ML6: 'Kings Flat' 1450 Buffalo Waratah Road
38°47'00.56"S, 145°57'41.79"E

ML6 No residence as yet; location is very close to residence ML3.

Monitoring Location ML7: HWT wind station, Buffalo Waratah Road
38°44'27.88"S, 145°58'56.23"E

10 metre wind monitoring tower approximately 720 metres from nearest turbine.

Instruments installed

This section outlines the instrumentation arrangements

- All instruments were installed inside the home; the microphones and preamplifiers only were outdoors.
- AEMO data and audio analysis to identify wind farm is operating.
- The audio files allow the identification of turbine 'signature tones' from the wind farm.
- The audio files allow the identification of hum and rumble tones, the subject of nuisance-noise complaints.
- All instruments and analysis applied daylight saving time in Victoria.

ML1 JZ: 860 Buffalo Waratah Road

May to August

Class 1 LD831 Noise Tutor system (s/n 2879), connected to internet with 10 minute and daily download, May to November; standard LD 200mm windscreen

Class 1 BSWA 308 (s/n 560175) and connection to SP soundcard (audio outside);

Class 1 GRAS 40AZ microphone to SP soundcard (audio indoor);

Class 2 BSWA (s/n 560065) indoor; data collection only; power pack

August - November – Jan: BSWA 560175 outside, BSWA 560526 indoor

February – March: BSWA 560526 Outside (no indoor monitor)

Lenovo computer; SpectraPlus SC soundcard and SpectraPlus dual channel audio recording software;

Davis Vantage Pro weather station A00128A045 calibrated 3/11/2017

3G/4G modem; Telstra connection.

Secondary 300 mm wind screen installed over standard 200 mm windscreen from November.

ML2 DDF: 1405 Buffalo Waratah Road (MDA house reference H59)

May to August

Class 1 BSWA 308 (s/n 560097 outside); standard LD 200mm windscreen

LD831 s/n1255 outside with standard LD831windscreen; November replaced 1255 with 3340.

Dual splitter from BSWA connection to Focusrite soundcard (audio inside and outside) with SP recording software; SP dual channel hasp

Lenovo computer; 3G/4G modem; Telstra connection.

LD831 audio recording set to 16KHz, 120 seconds every 10 minutes.

ML3 N: 1550 Buffalo Waratah Road (MDA house reference H57)

May to November

Class 1 BSWA 308 (s/n 560132 outside) standard LD 200mm windscreen

LD831 s/n 3340 with standard LD 200mm windscreen

Dual splitter connection to Focusrite soundcard (audio inside and outside) with Scribe recording software; *Scribe Hasp s/n*

Lenovo computer; 3G/4G modem; Telstra connection.

ML4 DSJ: 102 Mc Burnie and Boag Road

August to November

Class 1 BSWA 308 (s/n 560176 outside) and Class 1 BSWA 308 (s/n 560177 inside);

Dual splitter connection to Focusrite soundcard (audio inside and outside) with Scribe computer and recording software; Scribe hasp (s/n installed)

Lenovo computer; house WiFi.

Standard 200 mm windscreen.

ML5 SK: 965 Walkerville Road

November to January: Class 2 BSWA 308 (s/n 560527 outside) and BSWA 308 (s/n 560177) indoors with standard 200mm windscreens.

Class 2 BSWA 308 (s/n 560527, outside November to March) with secondary 300 mm wind screen installed over standard 200 mm windscreen

Dual splitter connection to Focusrite soundcard (audio inside and outside) with Scribe recording software; scribe hasp

Intel computer & HDMI screen;

Telstra Netgear 4GX modem and sim.

ML6 JM: 'Kings Flat' 1450 Buffalo Waratah Road

Class 2 BSWA 309 (s/n 560176) , 75 watt (JV) Solar power.

Secondary 300 mm wind screen installed over standard 200 mm windscreen.

ML7: WindLog - Wind Data Logger on a 10 metre mast

(https://www.rainwise.com/products/detail.php?ID=6824)

Calibration Certificates to IEC61672-3 Ed2; DIN45657 (2013)

Sound Level Meter	Serial Number	Certificate Number	Date Issued	Noise Floor dB(A)
BSWA 308 Class1	540097	1604	17/2/2017	18.2
BSWA 308 Class1	550132	1826	4/4/2018	18.1
BSWA 308 Class1	560175	1836	17/4/2018	18.8
BSWA 308 Class1	560176	BSWACO21-09-PO274	2/4/2018	<18.0
BSWA 308 Class1	560177	2046	4/9/2018	18.3
BSWA 309 Class2	560065	2037	4/9/2018	19.3
BSWA 309 Class2	560526	2045	4/9/2018	18.5
BSWA 309 Class2	560527	2032	28/8/2018	18.2
LD831 Class1	1255	1816	12/3/2018	17.0
LD831 Class1	2879	LD2017006509	20/6/2017	17.3
LD831 Class1	2879	1924	27/6/2018	17.3
LD831 Class1	3340	1720	10/11/2017	18.5

The NATA certificates are issued by Calibre Technology, Queensland.

The 'Noise Floor' values are the level of self-generated noise. The levels are all below 25 dB(A) and are acceptable for this monitoring program.

The Davis Vantage Pro 2 Weather station at ML1 holds calibration certificate 44031-001 dated 3/11/2017 from HK Calibration Technologies, Queensland.

Appendix B: Monitoring Protocols

The protocols outlined in this Report are subject to continuous revision in order to recognize risks of monitoring and assessment error and to develop best-practice. At the conclusion of the surveys the analysis and assessment methods will be incorporated into an ISO *14001:2015 Environmental Management System* document.

In order to measure and assess Condition 19 the following steps are applied at each residence being monitored:

- Install a BSWA Class 1 sound level meter outside the residence;
- Save sound levels LAF95, LAeq in 10-minute blocks of time;
- Record preamplifier signal direct to soundcard;
- Save *.wav audio files (minimum 44.1kHz, 16 bit) in 10-minute blocks of time;
- Save audio and sound level data to host computer and external hard-drive on-site;
- Access host computer via internet or 4GX/3G;
- At selected residences, install a Class 1 or 2 meter indoors and record audio to sound card and computer.
- At selected residences, install a LD831 Class 1 outdoors and record audio to sound card and computer.

At primary location ML1:

- Save BSWA sound levels LAF95, LAeq, in 10-minute blocks of time;
- Record BSWA preamplifier signal direct to SpectraPlus SC soundcard;
- Install Larson Davis 831 and save LAeq sound levels in 100ms blocks of time;
- Save LD831 third octave band data in 10-minute blocks of time;
- Install weather stations at 1.5 metres above ground at residence and 10 metres at nearby open-ground location with data saved every 10-minutes.
- Install Larson Davis Noise Tutor monitoring system additional to LD831;
- Install GRAS 40AZ microphone and preamplifier (indoor signal) to SpectraPlus SC soundcard;
- Save outdoor and indoor *.wav audio files (SpectraPlus SC 48kHz, 24 bit dual channel) in 10-minute blocks of time;
- Save audio and sound level data to host computer on-site;
- Access host computer via internet or 4GX/3G;
- NT and weather data viewed online in 10-minute blocks.

For all locations:

- Access BOM Pound Creek 10 metre actual weather data (available in 10 minute blocks);

- Incorporate for comparison meteoblue broad area weather simulation (wind rose, cloud base;
- 10 metre and 80 metre wind speeds and directions, temperature and humidity) data;
- AEMO power generation data in daily format (Aneroid) and 5-minute datasets;
- Interrogate sound levels, weather data, AEMO data and audio to confirm presence of wind farm noise ("relevant measured data");
- Correlate sound levels with weather data by wind speed and direction through regression analysis;
- Test relevant measured data against 'turbine-free' background sound levels when turbines are off or from the Pound Creek locale;
- Save all data to server;
- Prepare reports.

In order to fulfil Condition 19(b) the data gathered and assessment prepared:

- Require resident(s) to provide a noise log stating date and time of "special audible characteristics";
- Require residents to self-report sleep disturbance by date, time and event characteristics;
- Identify SAC within Item 9, Condition 19(a), datasets and audio files;
- Add a penalty to the measured sound levels for the time events, where appropriate;
- Prepare an event report.

In order to fulfil Condition 19(c) the data gathered and assessment prepared:

- Analyse daily datasets from Condition 19(a) for night-time wind farm noise;
- Analyse for 10% time-exceedance;
- Prepare a report.

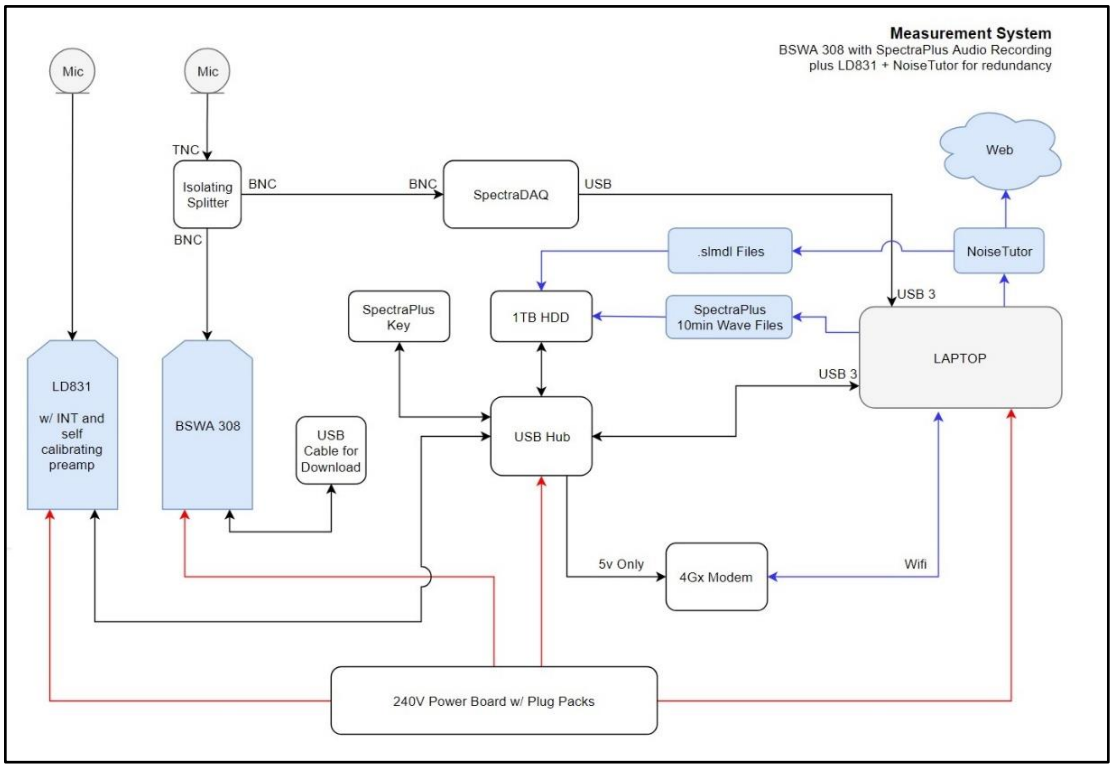
Information required from the resident(s):

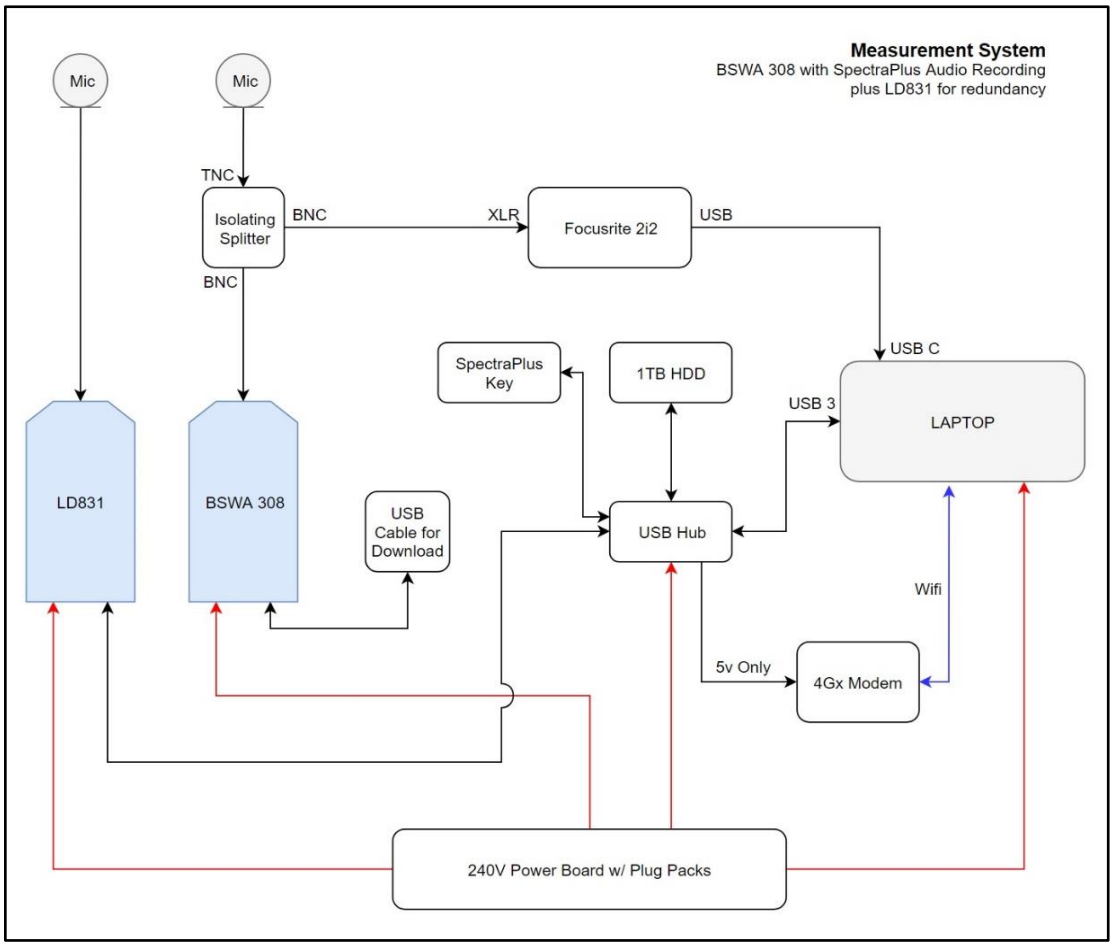
- Complaint histories.
- Action taken by operator to resolve complaints made by the resident(s).
- Perception responses.

Identified Issues:

1. The original background sound level data is not available for this monitoring program to access and apply to meet the 'comparison' requirements of NZS6808.
2. The original weather data is not available for this monitoring program to access and apply to meet the 'comparison' requirements of NZS6808.

Site Monitoring Systems





Hardware – Software Review

The time-consuming problem with all wind farm data assessment is the collection, analysis and reporting of the raw data and audiofiles. The Bald Hills monitoring system contained a combination of systems to help standardize and "smooth-out" the assessment and reporting procedures. The monitoring consisted of 3 primary systems:

Larson Davis

The Larson Davis (1) hardware and software is the best overall data collection system but cannot collect infrasound as the system has a 6.3Hz lower limit. The plus is, however, that it is robust and can save 100ms data as well as 10 minute data and an audiofile (16kHz sampling rate). Optionally the system has a self-calibrating microphone/preamp, can store weather data, and can have a high quality audio output. The audio output, fed through SpectraPlus (2) soundcard and software can record infrasound. Larson Davis Noise Tutor software allows data to be downloaded every 10 minutes in a visual form to a remote server, iPhone, etc and the full suite is stored daily. Optional DNA software can assist analysis but the "standard" analysis method is time-consuming manual spreadsheet and audiofile analysis. Analysis from the Noise Tutor system is presented elsewhere in this report.

BSWA

The BSWA hardware is single-purpose; either statistical data or third-octave band data. Data is stored in the instrument. Standard analysis is by downloading the instrument and manual spreadsheet analysis. The system is enhanced, however, through the Sentinel (3) SRA-EV5 soundcard and sound analysis software. This option is very useful as the software has a standard sampling rate (44.1kHz) and calibration requirement for each audiofile. Data analysis (statistics and third-octave bands) can also be automated through the Sentinel FSRA Report function. Audiofile recording is through the specialised Sentinel hardware designed to capture infrasound, or through the SpectraPlus soundcard. Analysis from both these systems is presented elsewhere in this report.

Infrasound

Three infrasound systems were applied to capture the blade pass frequencies in order to identify turbine operation: GRAS 40AZ microphone and preamplifier; ILFN model LHAInf2 microphone and pressure sensor; Sentinel Primo EM246 microphone and soundcard. Both the Sentinel and SpectraPlus hardware and software were applied in data capture. The Sentinel system was found the easiest to use as there is an automated data analysis program available.

The BSWA and Sentinel systems provide the best value-for-money and would be the best instrument overall for audible sound if combined with a remote logging / access function.

Sources:

1. Larson Davis http://www.larsondavis.com/products/soundlevelmeters
2. SpectraPlus http://www.spectraplus.com/
3. Sentinel http://www.smart-technologies.co.nz/index.html

Windscreen Insertion Loss – Gain Uncertainty

The windscreens used in this monitoring program have been checked for the attenuation values; that is, insertion loss or gain. The various wind screens available for the surveys include NMS, Larson Davis and BSWA products and a 300mm secondary windscreen (NMS). A sound source (Faber Acoustical, Signal Generator), provided random pink noise through a JBL speaker. The speaker was 925 mm from the face of the microphone, with the microphone at the same height as mid-point of the speaker. The microphone position was (a) facing the sound-source (diaphragm vertical) and (b) at right-angles to the sound source (diaphragm horizontal) and 1260mm above the floor. Wind 'over microphone' testing was made using two floor-mounted fans. Five different types of windscreens were tested for insertion loss uncertainty, each for a minimum of three by 2 minutes recordings:

- 90mm diameter: BSWA, Larson Davis
- NMS 100mm diameter (cylinder design)
- Larson Davis 200mm x 100mm cylinder design (standard manufacturers windscreen)
- NMS 200mm x 100mm cylinder design
- NMS 300 mm diameter secondary windscreen design

All wind screens appear to be made from Meracell 25-30 ppi acoustic grade foam, untreated for weather (e.g. rain). The secondary windscreen has a 10mm layer of Meracell 25-30 ppi acoustic grade foam with a primary windscreen (nominally a 200mm cylinder) around the microphone. Insertion test results for the overall LAeq and "wind-affected" LZeq frequencies are provided in Table 1 and Charts:

Table 1: insertion loss data

NO WINDSCREEN VS SMALL WINDSCREENS MICROPHONES POINTED AT SOURCE															
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS AV	69.1	38.9	39.7	38.4	46.4	49.1	44.5	39.6	32.3	35.7	35.7	37.9	42.4	51.0
BSWA 90mm Av	69.1	40.8	39.9	37.5	45.3	47.8	44.4	38.6	32.0	35.5	37.0	38.9	41.9	51.1
IL No Ws - WS	0.0	-1.8	-0.2	0.9	1.1	1.3	0.1	1.0	0.3	0.2	-1.3	-1.0	0.5	-0.1
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS AV	69.1	38.9	39.7	38.4	46.4	49.1	44.5	39.6	32.3	35.7	35.7	37.9	42.4	51.0
NMS 100mm Av	69.0	41.8	43.5	40.2	46.0	50.0	45.2	40.4	32.6	35.7	37.9	37.2	42.1	51.2
IL No Ws - WS	0.1	-2.8	-3.8	-1.7	0.4	-1.0	-0.7	-0.8	-0.3	0.0	-2.2	0.7	0.3	-0.2
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS AV	69.1	38.9	39.7	38.4	46.4	49.1	44.5	39.6	32.3	35.7	35.7	37.9	42.4	51.0
LD 90mm Av	69.1	38.2	37.8	36.6	44.8	46.8	42.3	38.5	33.4	37.5	38.6	39.7	42.1	50.8
IL No Ws - WS	0.0	0.8	1.9	1.8	1.6	2.2	2.1	1.0	-1.1	-1.7	-2.9	-1.8	0.3	0.3
NO WINDSCREEN VS WINDSCREENS MICROPHONES AT RIGHT ANGLE TO SOURCE														
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS Av	68.2	40.0	40.2	37.4	45.5	48.7	43.7	36.7	31.2	37.5	36.3	37.5	42.2	50.8
BSWA 90 Av	68.3	39.8	40.4	38.5	47.7	49.6	44.6	39.1	31.6	37.6	36.2	37.0	42.1	50.8
IL No Ws - WS	-0.1	0.2	-0.2	-1.1	-2.2	-0.8	-1.0	-2.4	-0.4	-0.1	0.0	0.5	0.1	0.0
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS Av	68.2	40.0	40.2	37.4	45.5	48.7	43.7	36.7	31.2	37.5	36.3	37.5	42.2	50.8
NMS 100 Av	68.3	36.4	36.2	34.5	43.6	47.6	42.7	37.4	31.7	36.9	38.0	39.7	43.0	50.9
IL No Ws - WS	-0.1	3.6	4.0	2.9	1.9	1.2	1.0	-0.6	-0.5	0.6	-1.8	-2.3	-0.8	-0.1
NO WINDSCREEN VS WINDSCREENS MICROPHONES AT RIGHT ANGLE TO SOURCE WITH NMS 200 CYLINDER														
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS Av	68.2	40.0	40.2	37.4	45.5	48.7	43.7	36.7	31.2	37.5	36.3	37.5	42.2	50.8
NMS 200x100 CYLINDER Av	68.2	39.1	38.8	38.5	48.3	49.7	43.5	37.7	32.0	36.0	34.9	36.9	41.3	51.2
IL No WS - Cylinder	0.0	0.9	1.4	-1.1	-2.8	-1.0	0.2	-1.0	-0.8	1.4	1.4	0.5	0.9	-0.4
NO WINDSCREEN VS WINDSCREENS MICROPHONES AT RIGHT ANGLE TO SOURCE WITH NMS SECONDARY SHELL ONLY														
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS Av	68.2	40.0	40.2	37.4	45.5	48.7	43.7	36.7	31.2	37.5	36.3	37.5	42.2	50.8
NMS 300 SHELL ONLY Av	68.1	37.2	38.0	36.7	45.0	48.4	43.6	38.1	30.8	34.1	35.7	37.3	41.8	50.5
IL No WS-Shell	0.1	2.8	2.2	0.7	0.5	0.3	0.1	-1.4	0.4	3.4	0.6	0.2	0.5	0.3
NO WINDSCREEN VS WINDSCREENS MICROPHONES AT RIGHT ANGLE TO SOURCE WITH NMS SECONDARY SHELL AND 200 CYLINDER PRIMARY														
Record #	**LAeq**	**6.3**	**8.0**	**10.0**	**12.5**	**16.0**	**20.0**	**25.0**	**31.5**	**40.0**	**50.0**	**63.0**	**80.0**	**100**
NO WS Av	68.2	40.0	40.2	37.4	45.5	48.7	43.7	36.7	31.2	37.5	36.3	37.5	42.2	50.8
NMS SHELL + 200 CYLINDER Av	67.6	36.1	36.9	35.0	44.5	47.4	42.9	35.7	30.8	36.1	36.6	36.1	41.1	49.3
IL No WS - Shell+Cyl	0.6	3.9	3.3	2.4	1.1	1.3	0.8	1.0	0.4	1.3	-0.3	1.4	1.2	1.5

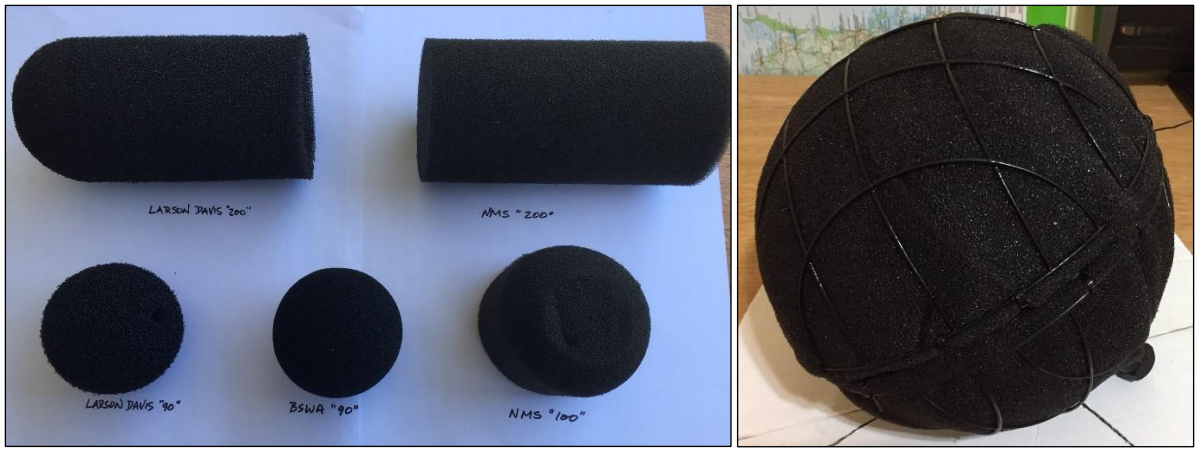
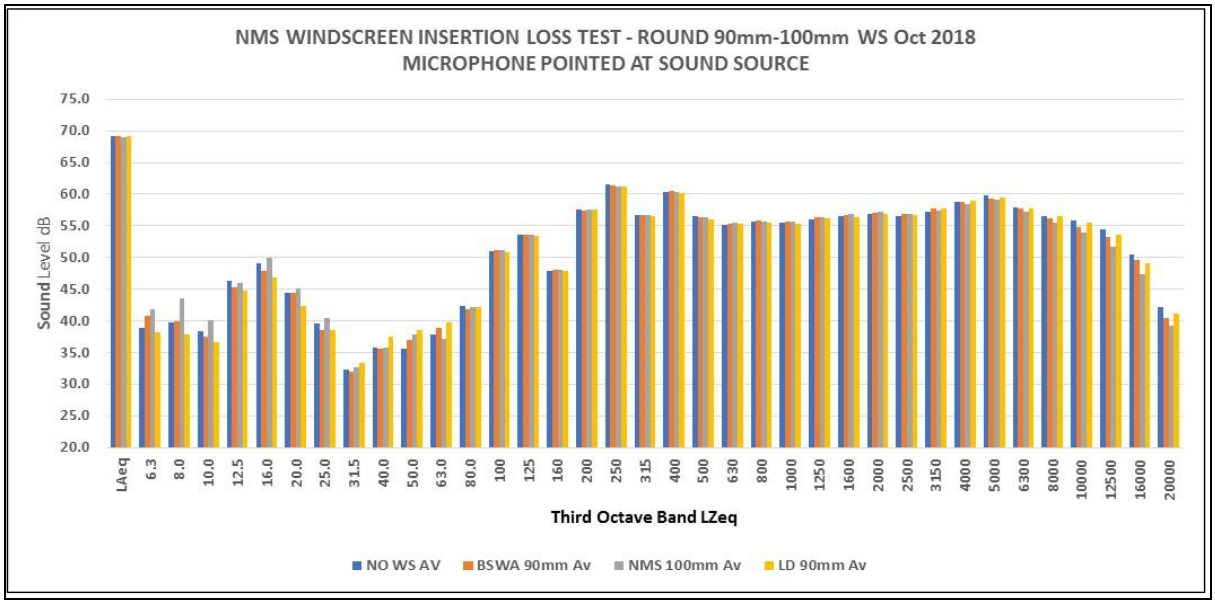
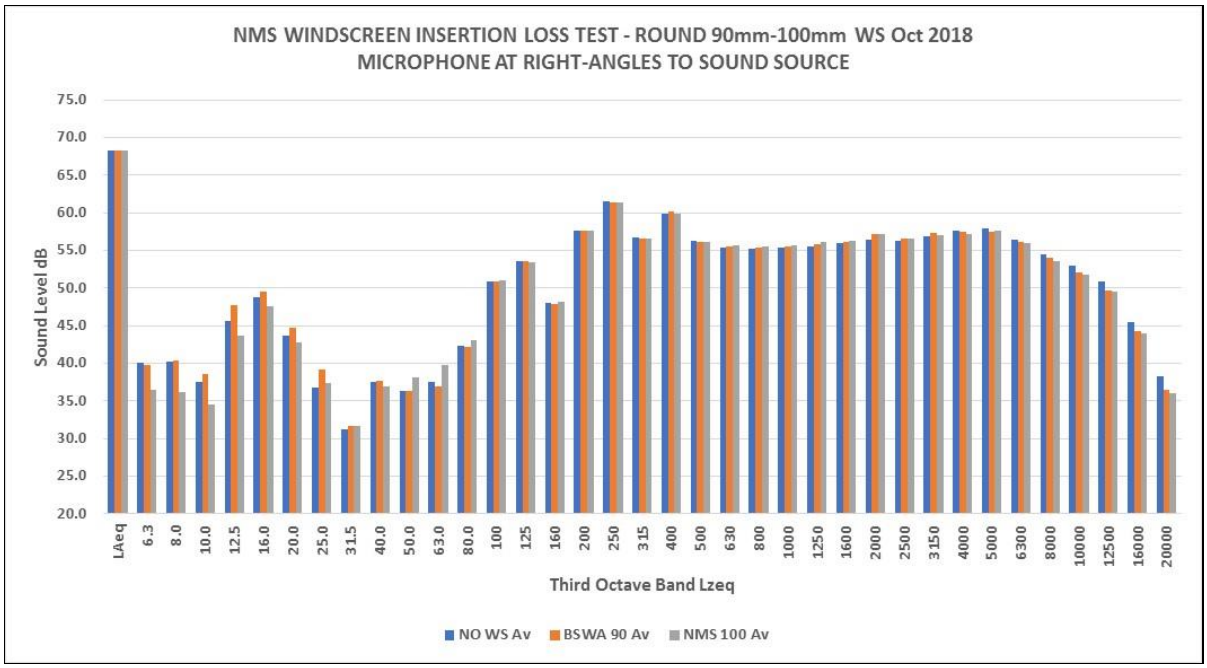
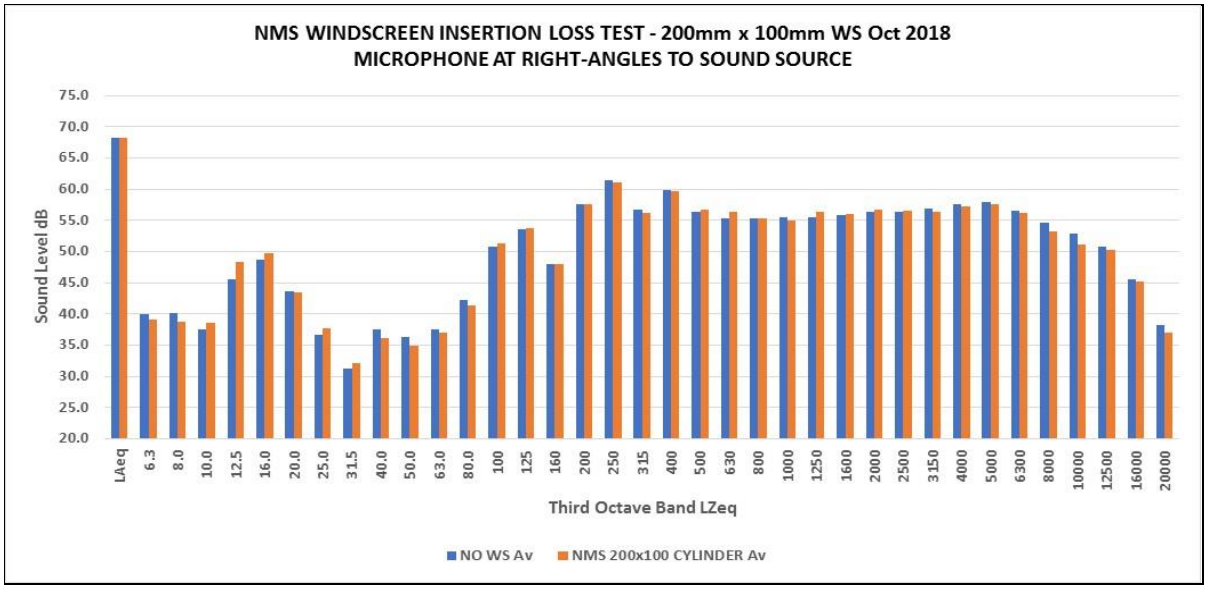
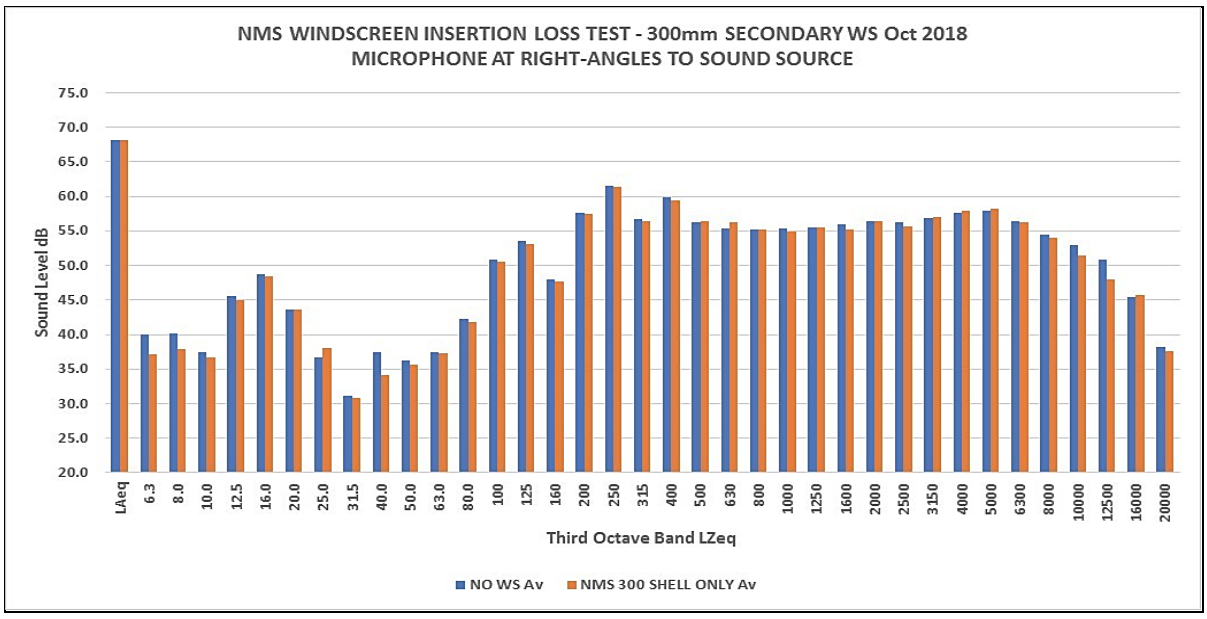


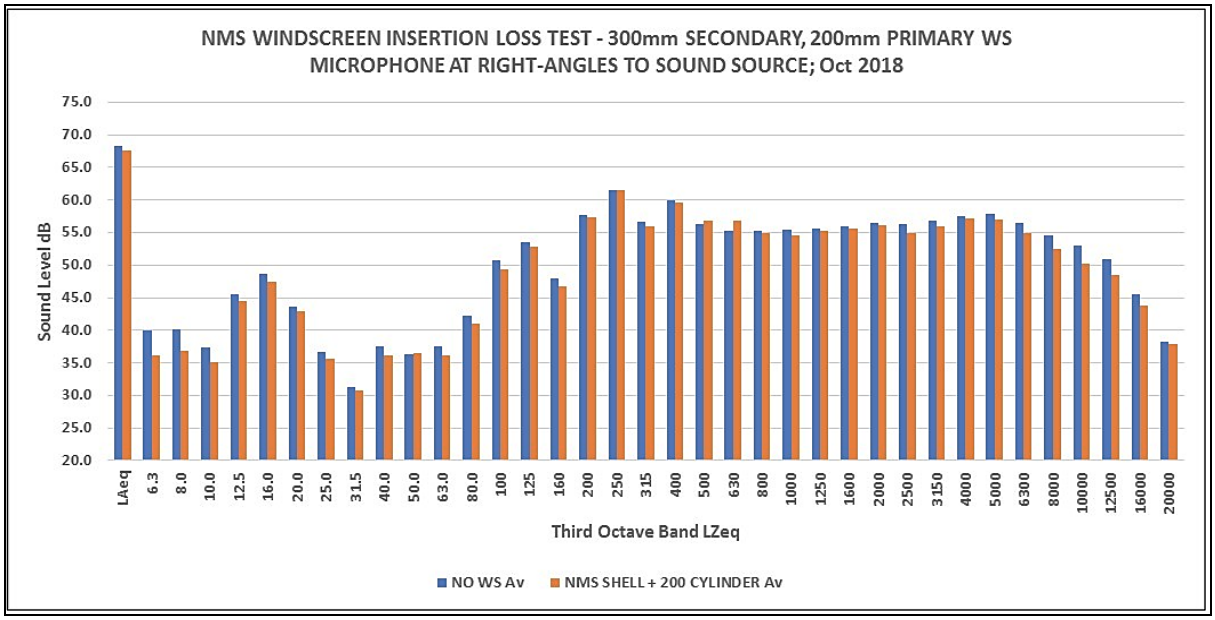
Plate 1: Tested Microphone windscreens



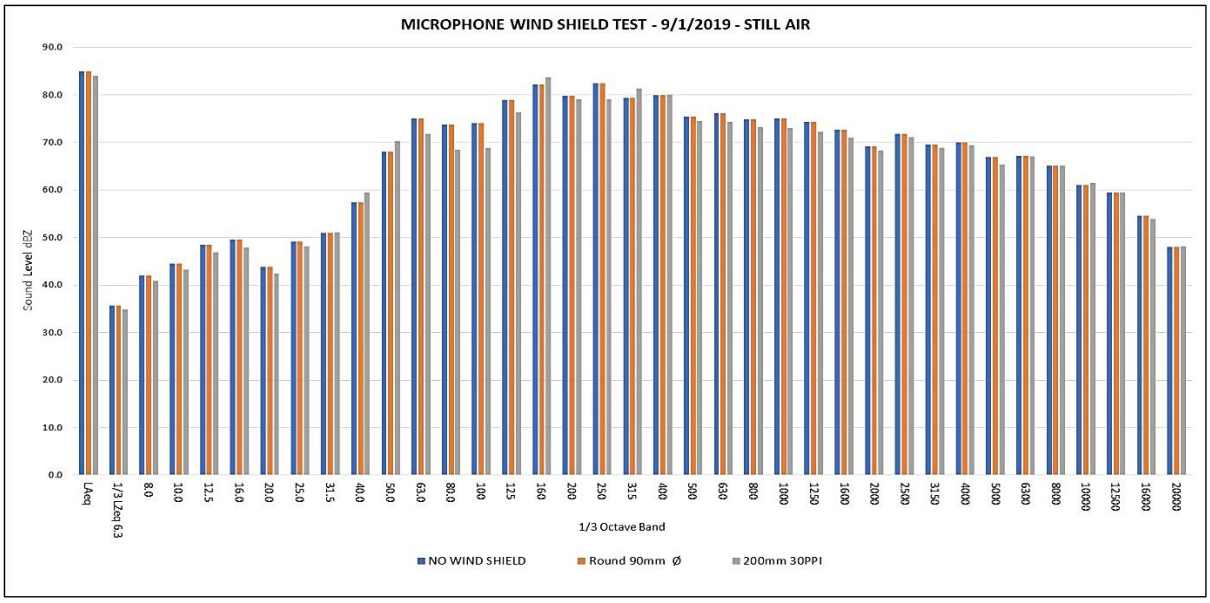


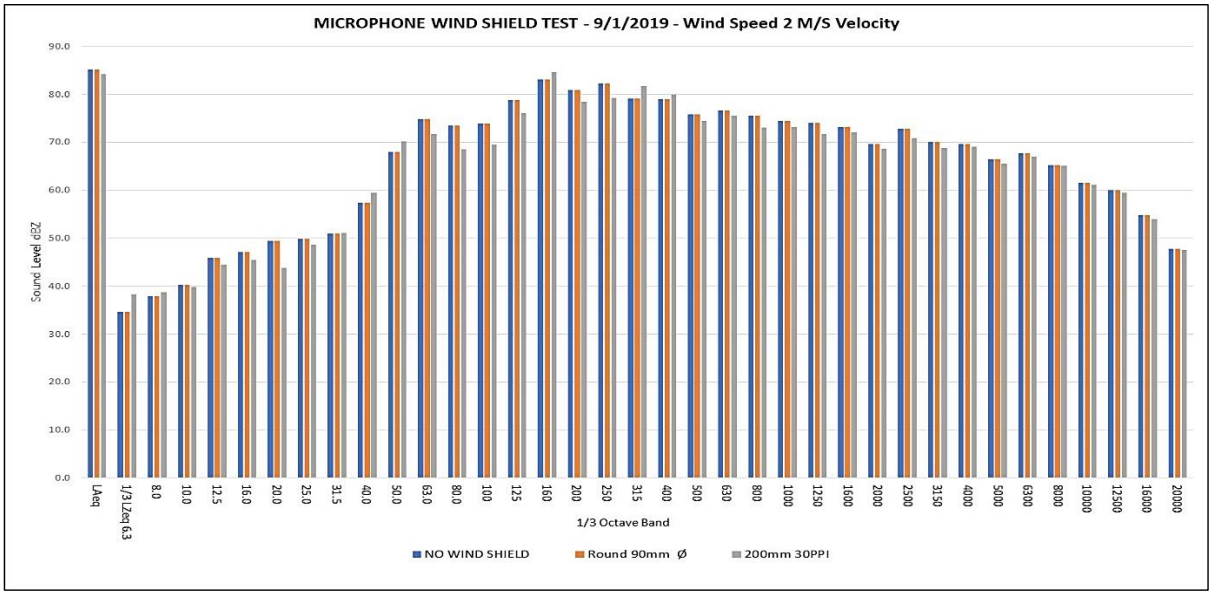

NMS WINDSCREEN INSERTION LOSS TEST - 200mm x 100mm WS Oct 2018
MICROPHONE AT RIGHT-ANGLES TO SOUND SOURCE
Sound Level dB
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
LAeq 6.3 8.0 10.0 12.5 16.0 20.0 25.0 31.5 40.0 50.0 63.0 80.0 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500 16000 20000
Third Octave Band LZeq
NO WS Av
NMS 200x100 CYLINDER Av

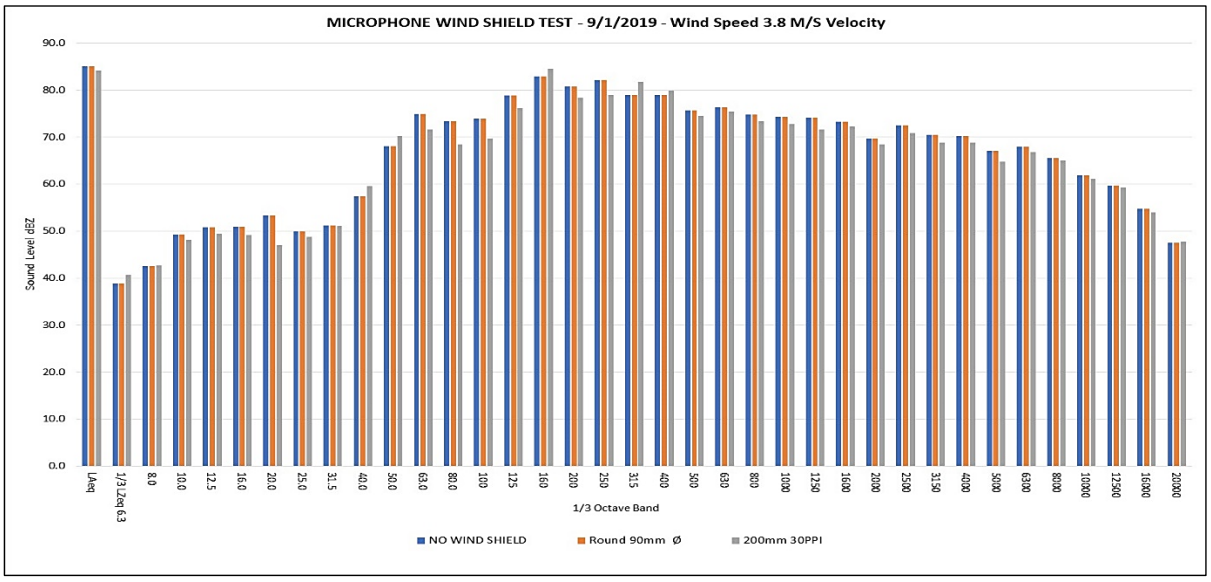

NMS WINDSCREEN INSERTION LOSS TEST - 300mm SECONDARY WS Oct 2018
MICROPHONE AT RIGHT-ANGLES TO SOUND SOURCE
Sound Level dB
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
LAeq 6.3 8.0 10.0 12.5 16.0 20.0 25.0 31.5 40.0 50.0 63.0 80.0 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500 16000 20000
Third Octave Band LZeq
NO WS Av
NMS 300 SHELL ONLY Av


NMS WINDSCREEN INSERTION LOSS TEST - 300mm SECONDARY, 200mm PRIMARY WS
MICROPHONE AT RIGHT-ANGLES TO SOUND SOURCE; Oct 2018
Sound Level dB
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
LAeq 6.3 8.0 10.0 12.5 16.0 20.0 25.0 31.5 40.0 50.0 63.0 80.0 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500 16000 20000
Third Octave Band LZeq
NO WS Av
NMS SHELL + 200 CYLINDER Av

Windscreens were tested with a slight breeze blowing to them; windspeed measured at the face:







Appendix C: Calibration certificates

Calibration Certificates to IEC61672-3 Ed2; DIN45657 (2013)

Sound Level Meter	Serial Number	Certificate Number	Date Issued	Noise Floor dB(A)
BSWA 308 Class1	540097	1604	17/2/2017	18.2
BSWA 308 Class1	550132	1826	4/4/2018	18.1
BSWA 308 Class1	560175	1836	17/4/2018	18.8
BSWA 308 Class1	560176	BSWACO21-09-PO274	2/4/2018	<18.0
BSWA 308 Class1	560177	2046	4/9/2018	18.3
BSWA 309 Class2	560065	2037	4/9/2018	19.3
BSWA 309 Class2	560526	2045	4/9/2018	18.5
BSWA 309 Class2	560527	2032	28/8/2018	18.2
LD831 Class1	1255	1816	12/3/2018	17.0
LD831 Class1	2879	LD2017006509	20/6/2017	17.3
LD831 Class1	2879	1924	27/6/2018	17.3
LD831 Class1	3340	1720	10/11/2017	18.5

The 'Noise Floor' values are the level of self-generated noise. The levels are all below 25 dB(A) and are acceptable for this monitoring program.

The NATA certificates are issued by Calibre Technology, Queensland. A typical cover page is presented on the next page.

The Davis Vantage Pro 2 Weather station at ML1 holds calibration certificate 44031-001 dated 3/11/2017 from HK Calibration Technologies, Queensland.

THE CALIBRE TECHNOLOGY
ACOUSTIC & VIBRATION CALIBRATION CENTRE

Certificate Number: 2046

CERTIFICATE OF CALIBRATION

Certificate Number: **2046** **NATA Accreditation No: 15841**

Customer: Noise Measurement Services
18 Lade Street, Enoggera, QLD, 4051

Test object:	Manufacturer:	Model:	Serial no:	ID:
Sound level meter	BSWA	308	560177	2046
Microphone:	BSWA	MPA221_231_231T	540102	2046
Preamplifier	BSWA	MA231T	560045	2046
Connecting Cable	None			

Environmental conditions:	Pressure:	Temperature:	Relative humidity:
Reference conditions:	101.325 kPa	23.0 °C	50 %RH
Conditions before measurement:	101.70 kPa	25.1 °C	46.2 %RH
Conditions after measurement:	101.88 kPa	25.5 °C	46.2 %RH

The measurements are performed according to the *IEC 61672 Sound level meters – Part 3: Periodic tests, DIN 45657 Sound Level Meters – Requirements for Special Applications* and *IEC 61260 Electroacoustics – Octave-band and fractional-octave-band filters.*

The expanded uncertainty of measurement is reported at approximately 95% confidence level with a coverage factor k, of 2.

Accredited for compliance with ISO/IEC 17025.

Date of calibration: 04/09/18
Technician: Jaie Wilde
Authorised Signatory:

Beau Weyers

Unit 3, 4 Tombo Street, Capalaba, QLD 4157
07 3245 1730
enquiries@calibretechnology.com.au
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NATA
WORLD RECOGNISED ACCREDITATION
No. 15841

Appendix D: Wind Farm Noise Prediction and Noise Mitigation

Noise Mapping

The Bald Hills Wind Farm consists of fifty-two (52) Senvion MM92 wind turbines, each with an individual sound power level of 104.2 dB(A) at 10 m/s wind speed and 99.5 dB(A) in curtailment mode (source: various Marshall Day Acoustics Reports from 2012 to 2018). NZS 6808:1998 *'Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators'* states that:

> *'Prediction of sound levels from a windfarm or WTG is used to determine their environmental sound impact before the development takes place, e.g. for the purposes of participating in planning procedures under the relevant legislation.'*

The NZ Standard applies an equation for the prediction process. In practice, ISO 9613-2 Acoustics – *Attenuation of sound during propagation outdoors – Part 2, General Method of Calculation* is often applied to noise predictions for wind farms.

However:

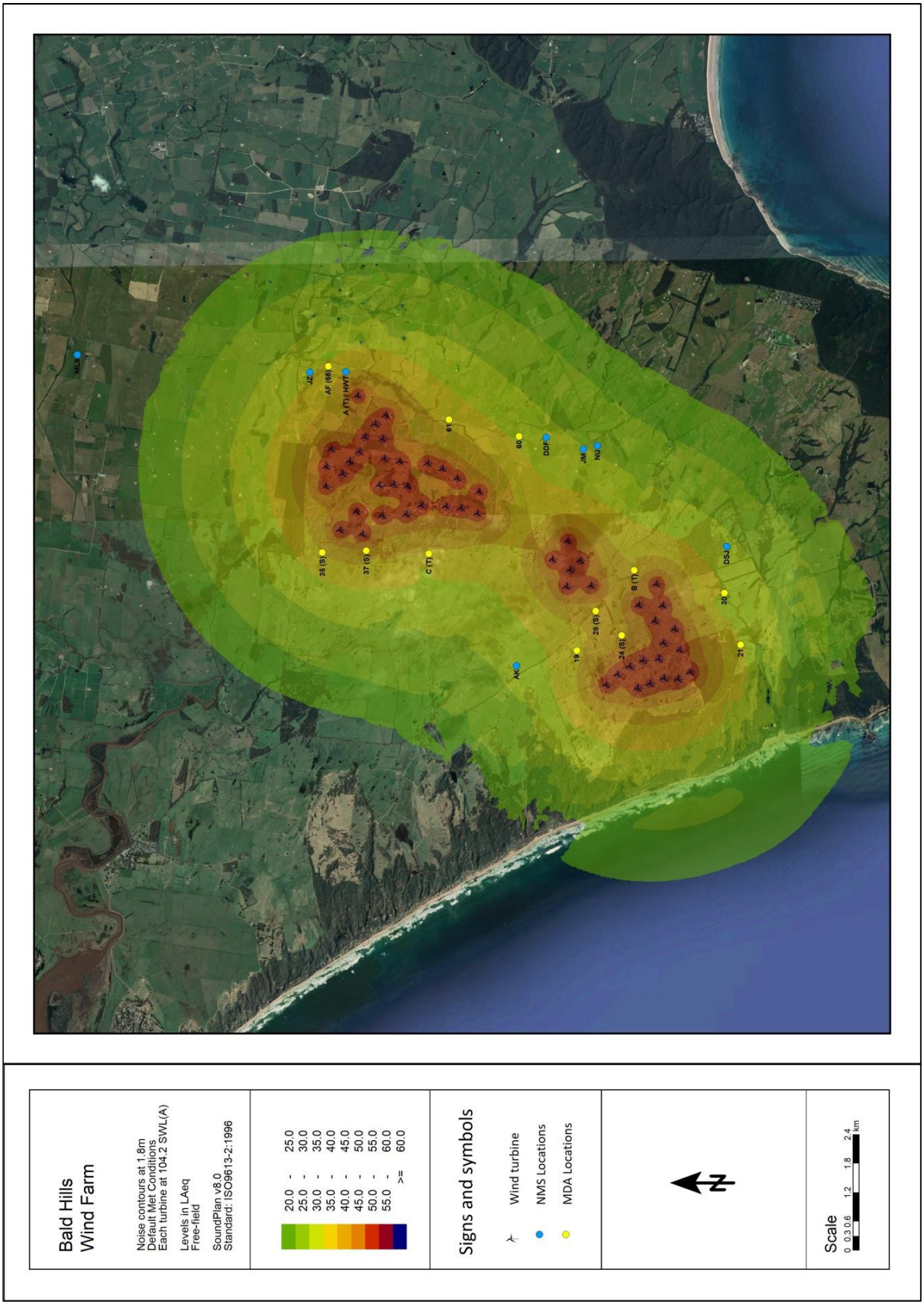
- ISO 9613 is an empirical method and assumes a moderate downwind situation. It is not designed to calculate up-wind.
- Wind farm noise varies due to differing weather conditions.
- Wind turbines are calculated as point sources with no directivity.
- Wind farm turbine layout affects turbulence and turbine interactions that produce identifiable noise events that cannot be predicted with the current noise models.
- Wind farm noise predictions must state the uncertainty inherent in the calculation process.

The following ISO 96132-2 noise prediction map (Plate D1) is prepared with the program SoundPlan 8.0, a verified modelling program.

The predicted sound levels in Plate D1 and Table D1 (following) provide a baseline against which to evaluate the monitored background and ambient (L_{Aeq}) sound levels in order to evaluate the contribution of wind turbine noise in the measurements.

ISO 9613-2 predicted sound levels have a calculation estimation accuracy (uncertainty) of ±3 dB under default (nominal mild downwind or inversion) conditions. The calculations should not necessarily be expected to agree with the variation in measurements made at a given site on a given day.

Plate D.1 Bald Hills Wind Farm predicted noise exposure zones and affected homes



Comparison of Predicted Sound Levels with Turbines in Curtailment Mode

The practical effect of noise prediction modelling is in comparing different operating conditions. It is understood that the wind farm has, during May to August 2018, operated some of the turbines in "noise curtailment mode". The EnviroRisk Audit document, *'Peer Review: Tenement Property B – Attended Measurements Reports Bald Hills Wind Farm August 2018'*, at page 8 refers to

> *"The report, and this peer review, are therefore based on noise mitigation being implemented for turbines 4, 40, 46 & 47 during the night period and when winds are towards the noise sensitive receiver."*

The effectiveness of the curtailment mode (mitigation) strategy was tested by "removing" and "reducing noise emissions" from turbines 4, 40, 46 and 47 and re-calculating the sound levels at various homes, not just the participants in this program, Table D1.

It can be seen that the curtailment - mitigation program has no practical effect.
A reduction of 1.4 dB(A) at location ML4 is not significant as this requires the turbines to be shut down.

Table D1: Bald Hills Wind Farm – Predicted sound levels (LAeq) under 'Full' and 'Curtailment' measures

Receptor	Description	Height	All turbines Operating at 104.2 SWL	'All' turbines (but turbines 4, 40, 46, 47 off)	'All' turbines (but turbines 4, 40, 46, 47 Curtailment Mode)
19		1.8	39.0	38.5	38.7
21		1.8	35.8	35.6	35.7
24 (S)		1.8	44.3	43.6	43.8
28 (S)		1.8	42.7	39.9	41.0
30		1.8	34.3	33.2	33.6
35 (S)		1.8	40.1	40.1	40.1
37 (S)		1.8	44.8	44.8	44.8
60		1.8	33.9	33.5	33.6
61		1.8	38.7	37.9	38.2
A (T) / HWT	(ML7)	1.8	39.7	39.6	39.6
AF (66)		1.8	36.0	36.0	36.0
AK		1.8	31.8	31.3	31.5
B (T)		1.8	42.3	38.1	40.0
C (T)		1.8	39.4	39.3	39.4
JZ	ML1	1.8	34.6	34.5	34.6
DDF	ML2	1.8	31.6	31.2	31.3
NU	ML3	1.8	29.3	28.7	28.9
DSJ	ML4	1.8	31.3	29.9	30.4
AK	ML5	1.8	31.8	31.3	31.5
JM	ML6	1.8	30.2	29.7	29.9
GF	ML8	1.5	<20	<20	<20

(Notes: information concerning curtailment and homes listed above ML1 are found in the 2012 – 2018 Marshall Day Acoustics noise reports; 'height' refers to the receiver height).

Note to Plate D1 and Table D1:

NMS was of the understanding that, for the whole of the monitoring program to date, the wind farm was operating in noise optimization or curtailment mode. The sound levels calculated in Table D1 are for each turbine in noise optimization or curtailment mode (99.5 SWL(A) compared to non-optimization of 104.2 SWL(A). Documentation received by NMS on 9 October 2018 indicates that only turbines 4, 40, 46 and 47 were in curtailment mode during July-August.

The noise exposure contour map (D1) and comparison table (D1) illustrate the critical benefits of preparing noise predictions of the wind farm under various conditions – an assessment of different operating scenarios can be quickly made and tabulated, along with visual representation to show overall noise exposure.

Appendix E: Atmospheric stability within the wind farm environment

The advice of an expert in the field of atmospheric stability, Mr Geoff Clark, has provided valuable insight into the stability patterns within the wind farm environment. This is a research outcome and is presented as part of the monitoring program nuisance assessment. The advice of Mr Clark is acknowledged with appreciation and is an important component of the sound perception analysis undertaken by Dr Shepherd.

Introduction

The generation of wind turbine noise and propagation of the noise to nearby receptors is a complicated mechanism dependent on many factors, both mechanical and atmospheric in origin. In this summary, reference will be made to a number of studies which have detailed the mechanical aspects of wind turbines and its interaction with the local meteorology. However, mostly it will be concentrated on meteorological factors.

Mechanical and aerodynamic aspects of wind turbines and noise generation

In an Acoustics Australia special issue on Wind Turbine Noise Tonin (2012) discusses not only the mechanical aspects of a wind turbine but more importantly the aerodynamic noise generated as air passes of the wind turbine blade. Trailing edge noise in the frequency range 250-1000 Hz is dependent on the angle of attack of the blade to the air through which it is passing. This can result in both frequency and amplitude [AM] (a swish sound) modulation of the sound. This is discussed in more detail by Smith et al (2012):

> "For AM characteristics to change significantly is for the flow into the wind turbine to be non-uniform in some way:
>
> The wind profile is non-uniform, for example due to: a vertical variation in wind speed (wind shear); a lateral variation in wind speed (perhaps due to local wind gusts or very large-scale turbulence); or a spatial variation of the angle of the wind onto the rotor (yaw or veer). AM is caused by the time varying angle of incidence, with increased levels of AM being produced upwind/downwind when local stall occurs. The importance of these effects is likely to be dependent on the control algorithms specific to each design of turbine.
>
> The turbulence distribution is non-uniform, for example due to: a layer of turbulent air affecting the top of the rotor disk; turbulence from upwind obstructions such as buildings or trees affecting the bottom of the rotor disk; turbulence from other wind turbines hitting the side of the rotor disk. This will cause time varying levels of inflow turbulence noise as each blade enters the region of high turbulence."

Tonin (2012) also describes another type of "thumping sound" he defines as impulsive noise. He states that "Although various possible causes for impulsive noise have been suggested such as blade noise directivity, blade-tower interaction, variation of wind speed over the rotor and interaction between the noise from two or more turbines, the mechanism is not well understood". In addition he also discusses other sources of turbine noise such as Inflow Turbulence Sound, Blade Tip Noise and Blade Tower Interaction. **Sedaghatizadeh et al (2017) have investigated these aspects in much more detail**

in terms of the responses of neighbouring receptors. Many of these sources of noise are influenced by the prevailing meteorological conditions which will now be discussed.

Meteorological influences on wind turbine noise impacts

Nowadays many wind turbines have blades that sweep through the lower 200 metres of the atmosphere above the ground. In this region there is much variability of meteorological factors such as wind speed, direction, temperature, atmospheric turbulence and stability. It is the changes in these factors in time and space which will have important influences on the noise impacts of wind turbines on nearby receptors such as people.

Strong diurnal variations occur through the lower atmosphere in many meteorological variables. During the day the lower atmosphere is generally well mixed by convective turbulence with solar heating of the ground generally leading to less vertical variations than at night. Temperatures typically decrease with height above the ground in the daytime but at night they can increase when conditions known as temperature inversions form. Coincident with these temperature variations there are wind speed changes with height which could have significant influences on wind turbine electricity generation as well as noise generation and impacts.

The impacts of winds are certainly the most important for wind turbine operations. At night it has been observed there are significant vertical variations in winds known as wind shear, both in speed and direction. Moore and Bailey (2008) observed the following: "At night, this shear can be substantial (up to 30^{o} or more) even when there is wind greater than 5 or 6 m/s. At one mountaintop site in California, we observed a 180° wind direction shift that propagated down through the depth of a typical wind turbine rotor plane each day for several hours from 1000 to about 1400 for about 10 days. During some periods the wind speed across this direction shift was 7 to 8 m/s even while the directional shear was 180^{o}". Similar observations of significant wind turning with heights were measured by Torabi (2013). Given the discussion above [Smith et al 2012; Tonin 2012] it is apparent that wind speed and direction shears are most important to the potential for noise generation from wind turbines. The influence of noise on nearby receptors is also wind direction dependent not only based on near ground level measurements. Wind direction shears might also be important in drifting sound over receptors under these stable conditions. Toft (2013) has shown that under conditions of wind speed and temperature inversion shears, wind turbine noise is refracted downwards. Under these conditions near ground level winds are very light or near calm and background noise levels are very low. Thus there could be maximum impacts of turbine noise under these stable night time conditions due to the occurrence of wind shear.

Wind shears can also be topographically induced due to upslope winds from the terrain influencing turbine behaviour on ridge lines. Wind turbines are frequently located along ridge lines to gain maximum speeds for their operations. However, atmospheric stability and wind shear are influenced by local topographical factors such as upwind soil type, surface roughness and vegetation. Thus it is important to assess these local features and their impacts on noise propagation.

Evans and Cooper (2013) did noise measurements near a wind farm in South Australia and concluded that wind speed and temperature shears had no influence on their downwind noise measurements. These findings are at odds with all the models and theoretical discussions of Toft (2013) and others. However, they did concede that with the lower background levels "audibility" would likely be greater. It is apparent that more field studies are required with wind shear measurements through the full wind turbine rotor sweep a necessity.

Wind Turbine Noise Generation and Propagation in the Atmosphere

Sedaghatizadeh et al (2017) have stated the following:

> Noise propagation from wind farms depends on source directivity, geometric spreading and atmospheric absorption, ground reflections and absorption, meteorological effects such as refraction and convection, terrain complexity and wind direction.
>
> Noises generated by wind turbines have been described as "swishing and thumping". Normal swish perceived in a short distance from a wind turbine, especially in the cross-wind directions, can be explained by the convective amplification and directivity of the trailing edge noise. As will be discussed in this article, there exists strong evidence that the dominant mechanism of wind farm noise is associated with amplitude modulation of the aerodynamic noise by the eddies generated when the turbine blade partially stalls or due to an interaction with the turbine wake. This hypothesis is primarily based on the low frequency characteristics of the stall and also the distance and direction of the noise propagation. Moreover, it is hypothesised that the wake supplements this effect as it results in refraction and modulation of the emitted noise. Local stall and turbulent-inflow noise have lower frequencies compared with trailing edge noise and can travel greater distances downwind.

Pasquill atmospheric stability estimation

In the analyses for the Bald Hill wind farms studies Mr Clark took the Bureau of Meteorology wind speed and standard deviation of wind direction (σ_θ) data from Pound Creek and Yanakie as well as the time of day using a modified form of the USEPA (2000) scheme described in NSW (2000) and outlined in the tables below.

References:

- Evans, T., Cooper, J. 2013: *Effects of different meteorological conditions on wind turbine noise* Proceedings of Acoustics 2013
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- NSW (2000): NSW Industrial Noise Policy: Appendices. NSW EPA
- Sedaghatizadeh N, Arjomandi M, Cazzolato B and Kelso K (2017): *Wind farm noises: Mechanisms and evidence for their dependency on wind direction*. Renewable Energy, Elsevier, vol. 109(C), pages 311-322.
- Smith, M. A. J. Bullmore, M. M. Cand and R. Davis: *Mechanisms of amplitude modulation in wind turbine noise*. Proceedings of the Acoustics 2012 Nantes Conference 23-27 April 2012, Nantes, France pp 823-828

- Toft, M.W. 2013: *Neglect of wind shear in assessing long range propagation of wind turbine noise.* Unknown presentation but referenced extensively in the literature.
- Tonin, R. 2012: *Sources of wind turbine noise and sound propagation*. Acoustics Australia Vol. 40, No. 1
- Torabi, G. 2013: *Wind Turning in The Atmospheric Boundary Layer*. Master's thesis in Physics and Astronomy, Department of Fundamental Physics, Division of Physics and Astronomy, Chalmers University of Technology, Goteborg, Sweden 2013

EPA Tables

Table E5. Wind flucuation criteria for estimating Pasquill-Gifford stability categories for non-arid areas in NSW[1,2]

Pasquill stability category	Standard deviation of the horizontal wind direction fluctuations[3,4] (σ_A in degrees)
A	$\sigma_A \geq 22.5°$
B	$17.5° \leq \sigma_A < 22.5°$
C	$12.5° \leq \sigma_A < 17.5°$
D	$7.5° \leq \sigma_A < 12.5°$
E	$3.8° \leq \sigma_A < 7.5°$
F	$2.1° \leq \sigma_A \leq 3.8°$
G[5]	$\sigma_A \leq 2.1°$

Adapted from: Irwin (1980) and US EPA (1987)

Notes:

1. These criteria are appropriate for steady-state conditions, a measurement height of 10 m, for level terrain, and an aerodynamic surface roughness length of 15 cm. Ensure that the wind sensor is responsive enough for use in measuring wind direction fluctuations (US EPA 1987).
2. The NSW EPA recommends that the sigma-theta method not be used for arid or semi-arid areas (US EPA 1987).
3. For areas with surface roughness different from 15 cm, the ***table*** values should be modified by multiplying by the surface roughness factor of $(z_o/15\ cm)^{0.2}$, where z_o is the average surface roughness in centimetres within a radius of 1 to 3 km of the source. Note that this factor, while theoretically sound, has not been subjected to rigorous testing and may not improve the estimates in all circumstances. A table of z_o values that may be used as a guide to estimating surface roughness is given in Smedman-Hogstrom and Hogstrom (1978).
4. These criteria are from an NRC proposal (NRC 1972). It would seem reasonable to restrict the possible categories of A through D during daytime hours with a restriction that, for 10-m wind speeds above 6 m/s, conditions are neutral. Likewise, during the night-time hours, some restrictions (as in *Table E6)* are needed to preclude occurrences of categories A through C.
5. Supplemented by data from Mitchell and Timbre (1979) and US EPA (1980).

Table E6. Night-time[1] Pasquill-Gifford stability categories based on σ_A from Table E5

If the σ_A stability category is:	And the wind speed at 10 m is (m/s):	Then the Pasquill stability category is:
A	< 2.9	F
	2.9–3.6	E
	≥ 3.6	D
B	< 2.4	F
	2.4–3.0	E
	≥ 3.0	D
C	< 2.4	E
	≥ 2.4	D
D	Any	D
E	3 to 5[2]	E
F	2 to 3[2]	F
G	< 2[2]	G

Adapted from Irwin (1980) and US EPA (1987).

Notes:

1. Night-time is considered to be from 6 pm to 7 am.
2. The original Mitchell and Timbre (1979) table had no wind speed restrictions. However, the original Pasquill criteria suggest that, for wind speeds greater than or equal to 5 m/s, the D category would be appropriate; and for wind speeds between 3 m/s and 5 m/s, the E category should be used. For wind speeds between 2 m/s and 3 m/s, the F category should be used, and for wind speeds less than 2m/s, the G category should be used.

Note: *Table E5* strictly applies only when the σ_A measurements are made in an area where the surface roughness is 0.15 m. To apply the scheme using σ_A data collected in an area where the surface roughness is different, the limit in the table should be modified by multiplying it by:
$(z_o/15\ cm)^{0.2}$ where z_o = the surface roughness of the area in centimetres

For example, if the surface roughness is 0.20 m, the

The following Tables present atmospheric stability data derived from recordings at the Pound Creek and Yanakie BOM stations, 1 January 2015 – 21 November 2018. The stations are on either side of the wind farm and provide a practical indication of atmospheric stability within the environment.

- Pasquill stability D is the most common for day and night but there are significant times of nighttime category E, F, and G that potentially enhance sound propagation.
- Examples of the winter nighttime stability values are presented to reflect the monitoring program May to August 2018. An example of the 10-minute data for May – August is presented in tabular form.

Table 1: Pound Creek BOM 1 January 2015 to 21 November 2018

Pound	Creek									
Frequency	(%)	of	occurrence	of						
Pasquill	stability	categories								
	Night	Day								
Stability										
A	0	2.34								
B	0	2.24								
C	0.02	15.5								
D	49.68	79.92								
E	27.28	0								
F	14.55	0								
G	8.46	0								
Night	=	starts	in	the	10	minute	period	when	Sunset	occurs
Day	=	starts	in	the	10	minute	period	when	Sunrise	occurs
Dates	:	10115	to	211118						
Pound	Creek	Dates	:010115	to	211118					
Pasquill	stability	categories	vs.	Wind	directions					
DIRECTION	A	B	C	D	E	F	G	TOTAL		
N	0.08	0.05	0.12	4.01	2.28	2.23	1.33	10.1		
NNE	0.12	0.06	0.18	3.82	1.48	0.63	0.47	6.76		
NE	0.1	0.08	0.21	2.08	0.38	0.28	0.21	3.33		
ENE	0.09	0.09	0.25	2.08	0.9	0.62	0.37	4.4		
E	0.09	0.07	0.19	3.93	1.5	0.64	0.48	6.9		
ESE	0.07	0.05	0.22	2.89	0.63	0.35	0.31	4.53		
SE	0.06	0.04	0.14	0.75	0.29	0.23	0.12	1.63		
SSE	0.06	0.03	0.09	0.63	0.14	0.11	0.08	1.14		
S	0.05	0.05	0.19	3.03	0.37	0.13	0.04	3.85		
SSW	0.05	0.06	0.32	5.19	0.76	0.14	0.05	6.57		
SW	0.05	0.05	0.27	8.08	0.98	0.15	0.05	9.62		
WSW	0.05	0.05	0.16	6.58	0.62	0.12	0.05	7.63		
W	0.06	0.05	0.17	4.8	0.71	0.17	0.08	6.04		
WNW	0.09	0.13	1.52	4.7	0.5	0.15	0.06	7.16		
NW	0.1	0.22	2.7	5.23	0.62	0.2	0.08	9.14		
NNW	0.08	0.07	1.1	7.14	1.36	1.05	0.42	11.23		
TOTAL	1.18	1.13	7.83	64.95	13.51	7.2	4.19	197545		
No.	of	calm	periods	=	6869					

Year	:	2018	Pasquill	stability	category	:	D						
Frequencies	(%)												
Months													
Hour	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	45	42.17	36.99	36.88	61.4	49.31	66.99	61.32	48.51	50.32	39.59	40.16	48.64
2	42.26	39.51	37.91	39.79	62.36	51.71	71.09	60.91	51.52	49.93	43.19	38.93	49.57
3	43.58	42.16	35.69	32.54	65.2	53.23	70.73	59.16	52.52	50.73	42.11	35.04	49.09
4	44.62	37.38	35.89	30.71	61.19	51.75	67.41	62	57.54	51.3	40.43	39.22	48.87
5	40.6	38.05	37.55	33.28	61.9	50.23	65.55	62.34	58.88	50.43	42.67	47.76	49.39
6	83.53	56.91	35.4	33.23	59.89	51.32	66.25	61.41	51.09	66.43	83.79	92.01	61.24
7	90.5	89.44	76.45	54.18	57.83	49.93	69.92	62.13	76.97	79.74	82.3	86.93	72.61
8	83.54	83.02	85.38	94.16	74.4	68.57	69.66	72.45	77.67	75.83	75.93	78.32	78.16
9	73.48	75.22	76.55	90.27	74.36	77.86	72.6	69.92	69.58	74.26	73.36	68.35	74.7
10	68.68	70.21	68.83	75.36	74.86	71.34	68.54	60.93	69.03	72.03	70.73	71.97	70.14
11	73.52	70.21	67.92	65.42	71.2	70.09	67.3	63.38	72.92	69.64	71.67	71.68	69.51
12	74.43	73.16	71.1	63.61	70.16	62.31	67.7	67.39	77.3	72.64	80.82	80.79	71.53
13	79.7	76.25	78.9	68.57	76.95	65.08	68.65	69.95	79.17	80.11	83.41	87.99	75.96
14	85.33	82.01	85.22	75.63	75	64.58	70.08	77.96	76.88	82.93	85.48	88.35	78.89
15	87.62	88.2	89.25	82.92	75.54	71.07	74.8	79.17	80	89.11	86.52	92.83	82.84
16	90.57	91.59	91.78	89.31	82.26	74.16	73.49	78.09	83.5	91.26	91.49	91.94	85.58
17	90.82	93.95	95.83	94.97	82.68	74.39	72.91	78.73	88.53	91.92	89.55	93	87.12
18	95.41	95.42	96.91	73.63	62.67	47.47	63.86	68.39	90.22	93.53	93.18	95.88	81.13
19	98.25	95.86	69.85	33.57	59.74	48.76	62.98	56.75	50.07	66.21	88.18	96.59	68.44
20	71.12	57.54	39.12	32.75	61.29	49.41	60.14	54.98	47.58	51.24	47.75	66.55	53.2
21	42.39	43.35	37.36	33.14	62.01	50.94	64.62	57.41	49.64	52.18	43.04	44.32	48.57
22	37.29	46.44	40.56	38.75	60.69	50.07	66.16	58.52	43.58	51.07	41.5	45.15	48.54
23	41.89	43.78	38.94	40.53	66.76	50.07	67.85	59.03	48.18	50.58	43.55	40.75	49.64
24	45.45	45.14	38.04	37.7	63.76	51.04	66.39	56.71	47.52	50.51	42.72	39.69	49.09
Total	68.2	66.19	61.69	56.78	67.8	58.62	68.17	65.12	64.74	67.63	66.35	68.5	64.95

Table 2: Pound Creek wind speeds and direction, winter, nighttime 0000 - 0600

DIURNAL	WIND	SPEED	AND	DIRECTION	ROSES	FOR	Pound	Creek	AT	10	M.
BEGINNING	DATE	:	10115	END	DATE	:	211118				
Season	:	Winter									
TIME	:	0	to	300	EST.						
WIND	SPEED	(M/S)									
DIRECTION	0-1	1-2	2-4	4-8	>8	TOTAL					
N	2.68	6.02	7.38	0.81	0.05	16.94					
NNE	2.32	3.48	3.58	0.71	0	10.09					
NE	1.63	0.95	1.23	0.44	0	4.25					
ENE	1.07	0.92	0.69	0.03	0	2.71					
E	0.75	1.17	0.47	0.03	0	2.42					
ESE	0.6	0.45	0.51	0.09	0	1.66					
SE	0.36	0.36	0.26	0.11	0	1.08					
SSE	0.2	0.09	0.08	0.17	0.12	0.65					
S	0.09	0.02	0.39	0.5	0.02	1.01					
SSW	0.08	0.06	0.32	1.39	0.3	2.14					
SW	0.11	0.03	0.8	2.32	0.98	4.23					
WSW	0.09	0.12	0.54	1.1	0.65	2.5					
W	0.12	0.18	0.84	1.81	0.38	3.33					
WNW	0.2	0.32	1.93	4.07	0.35	6.85					
NW	0.18	1.88	7.23	7.75	0.45	17.5					
NNW	0.62	2.24	11.37	6.64	1.78	22.65					
TOTAL	11.08	18.3	37.61	27.95	5.06	6641					
Frequency	of	calms	=	5.02%	(	No.	of	hours	=	351.)	
Bad	data	observed	for	0	hours						
Total	no.	of	hours	=	6992						
DIURNAL	WIND	SPEED	AND	DIRECTION	ROSES	FOR	Pound	Creek	AT	10	M.
BEGINNING	DATE	:	10115	END	DATE	:	211118				
Season	:	Winter									
TIME	:	300	to	600	EST.						
WIND	SPEED	(M/S)									
DIRECTION	0-1	1-2	2-4	4-8	>8	TOTAL					
N	3.1	6.49	6.54	1.08	0.03	17.24					
NNE	2.52	2.71	3.9	1.17	0	10.31					
NE	1.17	0.87	0.88	0.34	0	3.26					
ENE	0.64	0.61	0.69	0.03	0	1.98					
E	0.72	1.01	0.43	0	0	2.17					
ESE	0.69	0.53	0.39	0.1	0	1.7					
SE	0.21	0.16	0.14	0.06	0	0.58					
SSE	0.13	0.05	0.03	0.34	0.11	0.66					
S	0.11	0.06	0.08	0.48	0.03	0.77					
SSW	0.05	0.05	0.51	1.62	0.47	2.7					
SW	0.13	0.05	0.35	2.43	1.09	4.05					
WSW	0	0.02	0.19	1.04	1.01	2.27					
W	0.24	0.29	0.64	1.53	0.56	3.26					
WNW	0.22	0.48	2.43	3.5	0.22	6.86					
NW	0.24	1.78	7.12	8.34	0.02	17.49					
NNW	0.61	2.67	13.33	7.16	0.93	24.71					
TOTAL	10.8	17.83	37.67	29.22	4.48	6225					
Frequency	of	calms	=	5.98%	(	No.	of	hours	=	396.)	
Bad	data	observed	for	1	hours						
Total	no.	of	hours	=	6622						

Table 3: Yanakie BOM 1 January 2015 to 21 November 2018

Yanakie										
Frequency	(%)	of	occurrence	of						
Pasquill	stability	categories								
Night	Day									
Stability										
A	0	2.15								
B	0	1.41								
C	0.01	14.53								
D	57.89	81.9								
E	23.88	0								
F	11.42	0								
G	6.79	0								
Night	=	starts	in	the	10	minute	period	when	Sunset	occurs
Day	=	starts	in	the	10	minute	period	when	Sunrise	occurs
Dates	:	10115	to	211118						
Yanakie	Dates	:010115	to	211118						
Pasquill	stability	categories	vs.	Wind	directions					
DIRECTION	A	B	C	D	E	F	G	TOTAL		
N	0.23	0.02	0.07	1.77	0.54	0.63	0.79	4.07		
NNE	0.17	0.03	0.11	1.34	0.57	0.52	0.53	3.28		
NE	0.06	0.08	0.42	2.27	0.71	0.38	0.17	4.1		
ENE	0.07	0.1	1.29	9.97	0.61	0.34	0.12	12.5		
E	0.08	0.1	3.12	5.47	0.39	0.15	0.07	9.38		
ESE	0.05	0.04	0.62	1.14	0.19	0.11	0.03	2.19		
SE	0.06	0.03	0.11	0.34	0.19	0.12	0.05	0.89		
SSE	0.05	0.03	0.1	0.43	0.18	0.15	0.06	1.01		
S	0.04	0.04	0.26	1.04	0.15	0.1	0.09	1.73		
SSW	0.05	0.05	0.42	4.08	0.45	0.17	0.08	5.29		
SW	0.04	0.06	0.27	7.29	0.88	0.2	0.13	8.88		
WSW	0.04	0.05	0.15	8.69	0.95	0.25	0.2	10.32		
W	0.04	0.03	0.13	7.76	1.4	0.39	0.27	10.04		
WNW	0.03	0.02	0.11	6.88	1.77	0.76	0.25	9.83		
NW	0.03	0.02	0.08	8.47	2.07	0.91	0.31	11.88		
NNW	0.03	0.01	0.05	3.07	0.77	0.47	0.2	4.61		
TOTAL	1.09	0.71	7.34	70.01	11.83	5.66	3.36	195203		
No.	of	calm	periods	=	6761					

Year	:	2018	Pasquill	stability	category	:	D						
Frequenci	(%)												
Months													
Hour	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	60.63	61.62	55.71	45.05	59.65	53.28	58.94	59.1	52.41	61.06	58.72	57.05	56.97
2	58.52	58.82	55.7	41.08	57.67	51.93	57.08	58.86	54.55	60.99	55.94	55.41	55.58
3	61.01	55.26	54.03	39.57	61.55	53.88	56.54	58.72	54.63	60.61	52.61	58.92	55.65
4	59.72	57.38	55.65	41.96	58.51	54.77	57.81	59.25	51.99	62.19	55.82	57.41	56.11
5	60.89	57.21	54.98	41.73	57.66	55.05	61.01	58.25	56.5	59.39	58.52	70.49	57.45
6	83.97	67.7	55.63	40.91	56.71	54.7	59.5	57.61	56.47	73.85	83.72	83.75	64.18
7	86.63	87.75	78.2	54.04	60.17	53.06	63.33	62.29	85.65	85.07	83.39	83.8	73.41
8	80.06	84.18	84.33	92.81	91.03	73.56	81.47	91.99	93.3	82.83	77.37	74.86	84.16
9	70.09	74.32	78.65	88.26	95.9	92.12	96	91.69	89.83	80.3	71.27	69.01	83.42
10	70.72	71.26	68.73	81.86	90.1	93.98	95.29	91.1	85.71	77.08	70.98	66.12	80.59
11	63.97	68.47	69.42	76.21	87.76	89.5	94.29	88.16	83.12	72.59	72.4	69.01	78.17
12	69.19	66.87	64.68	73.04	86.29	87.46	90.68	87.35	80.61	74.29	75.19	75.99	77.79
13	72.74	73.45	66.67	72.7	85.87	86.79	91.09	86.76	77.68	75.07	78.63	79.46	79
14	76.26	78.2	70.4	74.16	89.66	84.52	89.08	85.56	80.5	75.62	82.47	84.68	80.91
15	77.24	81.5	74.03	77.45	88.06	86.49	91.76	88.77	83.19	80.03	82.16	83.48	82.89
16	76.59	80.93	77.49	78.46	91.1	88.75	95.39	90.23	84.17	80.79	82.33	84.95	84.32
17	72.83	79.85	77.55	80.73	91.93	84.06	94.95	94.34	85.42	81.61	81.26	82.94	84.07
18	77.27	78.58	77.1	73.21	66.2	50.07	63.88	75.54	85.69	78.47	79.03	81.36	73.75
19	75.1	79.03	68.23	55.71	63.78	51.98	63.91	57.66	63.46	74.02	78.06	74.01	66.95
20	72.8	64.42	67.83	52.32	57.84	49.1	62.36	59.97	62.77	70.03	61.62	72.28	62.74
21	67.45	63.47	63.12	49.78	59.15	53.23	59.64	60.06	61.51	68.75	59.87	67.03	61.06
22	68.76	62.11	62.01	44.36	60.67	50.75	57.44	60.23	60.82	66.86	58.95	62.39	59.62
23	63.46	64.46	60.86	45.62	59.44	47.82	57.86	56.8	53.63	68.99	57.87	62.04	58.21
24	59.77	61.57	56.89	47.03	62.65	49.72	57.41	61.32	51.54	68.6	60.96	61.63	58.25
Total	70.27	70.13	66.74	61.4	72.73	67	73.46	72.92	70.87	72.56	70.02	71.65	70.01

Table 4: Yanakie wind speeds and direction, winter, nighttime 0000 - 0600

DIURNAL	WIND	SPEED	AND	DIRECTION	ROSES	FOR	Yanakie	AT	10	M.
BEGINNING	DATE	:	10115	END	DATE	:	211118			
Season	:	Winter								
TIME	:	0	to	300	EST.					
WIND	SPEED	(M/S)								
DIRECTION	0-1	1-2	2-4	4-8	>8	TOTAL				
N	1.48	2.68	2.28	0.3	0.76	7.5				
NNE	0.81	2.12	1.39	0	0	4.32				
NE	0.87	2.32	2.12	0.05	0	5.36				
ENE	0.47	2.28	4.23	0.92	0.02	7.91				
E	0.2	0.7	2.46	0.5	0	3.87				
ESE	0.14	0.34	0.36	0.36	0	1.2				
SE	0.09	0.44	0.31	0.22	0	1.06				
SSE	0.09	0.33	0.55	0.28	0	1.25				
S	0.2	0.06	0.27	0.08	0	0.61				
SSW	0.16	0.23	0.62	0.89	0.19	2.09				
SW	0.3	0.22	0.28	3.29	1.33	5.41				
WSW	0.22	0.37	0.36	2.2	1.61	4.76				
W	0.34	0.67	1.89	2.35	1.36	6.61				
WNW	0.58	1.25	3.96	4.24	2.85	12.88				
NW	0.59	1.29	6.44	11.51	7.06	26.9				
NNW	0.55	0.65	2.18	3.48	1.42	8.28				
TOTAL	7.09	15.97	29.69	30.66	16.59	6413				
Frequency	of	calms	=	7.59%	(	No.	of	hours	=	527.)
Bad	data	observed	for	1	hours					
Total	no.	of	hours	=	6941					
DIURNAL	WIND	SPEED	AND	DIRECTION	ROSES	FOR	Yanakie	AT	10	M.
BEGINNING	DATE	:	10115	END	DATE	:	211118			
Season	:	Winter								
TIME	:	300	to	600	EST.					
WIND	SPEED	(M/S)								
DIRECTION	0-1	1-2	2-4	4-8	>8	TOTAL				
N	1.33	2.25	1.63	0.03	0.74	5.98				
NNE	1.23	2.68	1.4	0.13	0	5.44				
NE	0.58	2.17	1.58	0.08	0	4.41				
ENE	0.61	1.41	5.13	0.67	0	7.83				
E	0.33	0.76	1.97	0.12	0	3.17				
ESE	0.2	0.18	0.26	0.12	0	0.76				
SE	0.15	0.56	0.21	0.16	0	1.09				
SSE	0.13	0.46	0.61	0.3	0	1.5				
S	0.1	0.2	0.08	0	0	0.38				
SSW	0.08	0.08	0.3	1.61	0.35	2.42				
SW	0.2	0.13	0.26	2.88	1.73	5.2				
WSW	0.15	0.3	0.33	1.46	2.1	4.34				
W	0.35	0.66	1.55	2.45	1.27	6.26				
WNW	0.92	1.5	4.49	4.42	2.98	14.3				
NW	0.66	1.22	6.17	13.47	7.17	28.67				
NNW	0.43	0.85	2.09	3.96	0.92	8.25				
TOTAL	7.43	15.41	28.05	31.86	17.25	6082				
Frequency	of	calms	=	7.54%	(	No.	of	hours	=	496.)
Bad	data	observed	for	0	hours					
Total	no.	of	hours	=	6578					

Appendix F: Amenity, Risk and Nuisance

NZS 6808 states:
Sound from a WTG that has special audible characteristics (clearly audible tones, impulses, or modulation of sound levels) is likely to arouse adverse community response at lower levels than sound without such characteristics.

Adverse community response can be described in terms of amenity, risk and nuisance.

Adverse reaction to a sound can lead to noise annoyance, sleep disturbance and a general expression of "noise nuisance". The risk of noise nuisance occurring can, therefore, be assessed by consideration of the audible characteristics of a particular sound and its potential to be intrusive on a person at home trying to get to sleep or relaxing. Broadly, this is called 'auditory sensation' which is the unconscious and conscious processing of the auditory signal to information that is acceptable or unacceptable to an individual. Unacceptable sound is called 'intrusive noise'.

Sensation is influenced by masking, spectral contents, temporal patterns and spatial distribution of sound sources. All of these influences occur with a wind farm in a rural environment.

Noise is also evaluated on its adverse effects on 'amenity'. The concept of amenity is wide and flexible and may embrace not only the effect of a place on the senses but also an individual's subjective perception of a locality and its acoustic environment or 'soundscape' which is the sound from all sound sources modified by the environment. Modification by the environment includes weather conditions and effects on sound propagation. All of these influences occur with a wind farm in a rural environment.

Amenity
The Oxford English dictionary defines 'amenity' as: *A desirable or useful feature or facility of a building or place.* The expression 'Peace and Quiet' is often given as a desirable benchmark for amenity in relation to sound in an environment, but peace, quiet, amenity and noise can vary across contexts, and these expressions can mean different things to different people at different times. The concept of amenity is wide and flexible and may embrace not only the effect of a place on the senses but also an individual's subjective perception of a locality or neighbourhood.

Quietness is part of the "measure" between a tranquil environment and an intrusively noisy sound environment. As such, quiet possesses an intrinsic value in terms of the overall sound within the environment (soundscape) and how individuals and communities will react. People

have expectations for their environment and tend to describe it in terms of 'quiet'; for example: "the environment is quiet"; "we like the sense of peace here"; "the locale is loud, vibrant, noisy"; and so on.

Rural environments such as those in the vicinity of the Bald Hills wind farm tend to be thought of as being 'quiet'. These characteristics can be described in terms of subjective and objective measures, e.g. upon how people feel about an area, its pleasantness or some other value that makes it a desirable place in which to live. In particular, landscape and soundscape characteristics mark an environment as a desirable *('high amenity')* or undesirable *('low amenity')* place to occupy, as uniquely judged by the individual. Localities hosting stressors tend to provoke negative emotions, and motivate an avoidance response, while localities free from stressors may induce positive emotions and motivate an approach response.

Risk

The Oxford Dictionary defines the term "risk" as: *A chance or possibility of danger, loss, injury or other adverse consequences.* Risk is often measured in terms of the likelihood of the risk occurring and the impact, whether positive or adverse, that might result if the risk did occur. The risk for an individual is noise, the impact is adverse noise (by whatever characteristics) and the objectives are to maintain undisturbed sleep and to be free of noise nuisance.

Getting used to a sound in the environment ('habituation') or the reverse, becoming more aware of and focused on a sound ('sensitization') are well known defined risks. The Quality of Life and Noise Sensitivity questionnaires presented at the commencement of the monitoring program and subsequent diary notes indicate that individuals are not habituated to wind farm noise.

Frequency of exposure to a risk is usually expressed in terms relating to the certainty with which the risk will occur. This in practical terms means relating wind turbine operation to wind direction and speeds, received sound levels and complaints. Assessment of risk requires an objective component to the noise monitoring, with identification of special audible characteristics through the subjective responses in the residents' observations as required by NZS6808.

A short video has been prepared to illustrate the variability of turbine sound emissions - characteristics over even a short period of time. Observers can provide their own subjective responses to the questions:

- Are there sounds in the video that are unexpected in a rural locality?
- Might these sounds disturb me if I hear them at night?
- Are the sounds annoying?

A short video of the turbines during the day is available at the following link:
https://youtu.be/_-iLQBmcu1c
Use good quality headphones or sound system to listen to this video.

Nuisance

The Oxford Dictionary defines the term "nuisance" as: *Person or thing causing inconvenience or annoyance.* Annoyance is one of the main effects of noise, whether on an individual or community basis. Annoyance is closely related to nuisance, unpleasantness and disturbance.

The residents' group identify Bald Hills Wind Farm noise as a nuisance. Different individuals are affected differently and at different times of the day. Wind farm noise does not occur all the time; therefore, the potential for 'nuisance events' is a quantifiable risk by:

- Identifying, through noise diaries, times of annoyance or sleep disturbance;
- Comparing 'noisy' with 'no-noise' occasions or times.

The audibility of a sound is its most common feature – a sound must be audible to be heard. This is also known as the 'salience' of a sound; that is, the likelihood of the sound being noticed by a person. The salience must be intrusive for a person to consider it as "noise". This the essential problem with all sound/noise assessment systems: a person is an individual and his or her responses cannot be mimicked by a machine.

No person can tell another person what he or she hears
and how he or she should respond to that sound.

If the sound is similar to the locale then, even if the sound is audible, it is more likely to be accepted. If the character of the sound is foreign to the existing environment then it has less chance of being accepted. To an individual, the time of the day the sound is heard is important with unusual sounds in the early morning being less acceptable than if they are heard during the day. Sounds that disturb sleep are nearly always unacceptable even if they have some potential benefit to the individual.

If a sound affects the personal space of a person while at home, inside or outside, that sound has a high degree of probability as being a **disturbance.**

Additionally, if the sound has information content that the person does not want to hear, that sound is perceived negatively. NZS 6808:1998 describes these attributes as being 'adverse

subjective response' and 'adverse community response' and requires that they be evaluated as 'special audible characteristics' in the assessment of compliance.

Personal perception of nuisance, therefore, combines a variety of attributes that cannot be measured by instrumentation.

The adverse intrusion of a sound into the well-being or amenity of an individual is a significant precursor to annoyance. The amenity of an individual can, therefore, be defined in terms of the effects of exposure to the sound and its character:

- Significant adverse effect. The sound is deemed to be noise irrespective of subjective response causing annoyance or anger and has adverse health reactions including sleep disturbance;
- Nuisance adverse effect causing anger, annoyance, or adverse health reactions including sleep disturbance and critical levels of distress;
- Adverse effects more than minor;
- An adverse effect, but no more than minor (minor irritation);
- No adverse effect, pleasurable sounds or peace and tranquility.

Based on the foregoing, it is practical to define "unreasonable noise" as being the first two dot points, the transition stage between unreasonable and reasonable noise as the third dot point "adverse effects more than minor", and "reasonable noise" as being the fourth dot point. The fifth dot point infers no noise whatsoever.

In terms of noise, therefore, a person has cause for complaint about noise and is acting in a not unreasonable manner if he or she is:

- Awoken or suffering from disturbed sleep due to noise;
- Disturbed by noise while relaxing within his or her home;
- Annoyed by noise inside or outside the home;
- Reacting to the sound because the individual finds that the sound contains perceptually negative information.

It is concluded, from the above discussion, that the people affected by noise from the wind farm meet the test under NZS6808:1998 for 'adverse subjective response' and 'adverse community response'.

Resident Diary and Perception Survey Sheets

Bald Hills Wind Farm Noise Diary - CONFIDENTIAL - For sounds heard inside the home unless otherwise stated

Name/s of person/s filling in the diary: _____

Street address of residence: _____ **vR1 19/8/2018**

Date	Time the noise was first noticed	Time the noise stopped	Continuity of noise for this event (1 – 5)	Description of noise character and effects (e.g. rumble, thump, swish, drone, tone)	Strength of noise event (0 – 6) **In the home**	Strength of noise event (0 – 6) OUTDOORS	Are turbines turning ? (if possible to see them)	Wind Direction (from..)	Weather comments (e.g. Beaufort)	Other comments (No; Yes – attached)

Continuity of Noise Event:

1. Infrequently
2. 25% of the time
3. 50% of the time
4. Most of the time
5. Continuous

Strength of Noise Event:

1. Felt as a physical sensation (inaudible)
2. Faint or just detectable (audible)
3. Clearly audible
4. Annoying; intrusive; noise preventing sleep
5. Loud; interfering with lifestyle (includes #4) (cannot enjoy radio, tv, conversation)
6. Loud rumbling cyclic noise (includes #4)
0. **Cannot hear turbines inside the home**

Wind – measured in metres/sec or Beaufort wind scale *(0 – 6; in m/s)*

0. Calm *(<0.5)* Smoke rises vertically
1. Light air *(0.5 < 1.5)* direction of wind indicated by smoke drift
2. Slight breeze *(1.5 < 3)* wind felt on face; leaves rustle
3. Gentle breeze *(3 < 5)* leaves and small twigs in motion
4. Moderate breeze *(5 < 8)* raises dust & loose paper; branches move
5. Fresh breeze *(8 < 11)* small trees in leaf begin to sway
6. Strong breeze *(11 < 14)* large branches in motion

ACOUSTIC ENVIRONMENT SURVEY

Please answer all questions as best you can. There are no 'right' or 'wrong' answers.

Question 1

Thinking about the last 4 weeks or so, when you are here at home, could you say how quiet or noisy your area is?

Very quiet or tranquil	☐
Moderately Quiet	☐
Quiet	☐
Moderately Noisy	☐
Very noisy	☐

Note: 'Quiet' means undisturbed by noise from traffic, industry or recreational activities.

Question 2

Thinking about the last 4 weeks or so, when you are here at home, does noise in your neighbourhood (not including from those living in your household) affect you-

While reading	YES ☐	NO ☐
While watching TV	YES ☐	NO ☐
While listening/talking indoors	YES ☐	NO ☐
While relaxing indoors	YES ☐	NO ☐
While relaxing outdoors at your home	YES ☐	NO ☐
While working outdoors at your home	YES ☐	NO ☐
While sleeping	YES ☐	NO ☐

Question 3

If 'yes' in Question 2 - what sort of noise or noisy activity affects you and at what time of day?

Please tick the boxes that apply or write comments on a separate page

Source*	Morning 7am -12noon	Afternoon 12 noon -6pm	Evening 6pm -10pm	Night 10pm - 7am	All the time

**Please add noises that affect you.*

Question 4

Thinking about the last 12 months or so, when you are here at home, how much does noise from the noisy activities in Question 3 bother, disturb, or annoy you: *(Please circle your answer)*

NOT AT ALL
SLIGHTLY
MODERATELY
VERY
EXTREMELY

Sound Perception and Amenity Survey SPAS01 Confidential to Participants and NMS Brisbane

ACOUSTIC ENVIRONMENT SURVEY

Question 5

Next is a zero to ten opinion scale for how much noise from the noisy activities in **Question 3** bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between, choose a number between zero and ten.

Thinking about the last 12 months or so, what number from zero to ten best shows how much you are bothered, disturbed or annoyed by noise from the noisy activities in Question 3?

CARD Q.N

NOT AT ALL EXTREMELY

0	1	2	3	4	5	6	7	8	9	10

The chosen answer must be marked clearly within one box.

Note:

'at home' means inside your home or outdoors at home, for example in the garden or on the deck.

Question 6

Generally, how would <u>you</u> rate your area as a place to live BEFORE the noisy activity(s) started?

1	2	3	4	5
☐	☐	☐	☐	☐
Rate it low *(noisy)*		*(quiet)*		Rate it high *(tranquil)*

Note: 'Quiet' means undisturbed by noise from traffic, industry or recreational activities.

Question 7

Generally, how would <u>you</u> rate your area as a place to live NOW?

1	2	3	4	5
☐	☐	☐	☐	☐
Rate it low *(noisy)*		*(quiet)*		Rate it high *(tranquil)*

Note: 'Quiet' means undisturbed by noise from traffic, industry or recreational activities.

Name:
Address/location:
Date:

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Appendix G: Wind Turbine Sound Character

The diary entries clearly identify the sound of the turbines as heard inside the home. The character of the wind farm sounds, in broad terms, can be described as “rumble”, “drone”, “cyclic”, “pulsating”, “whirring”, “swish”.

All these characteristics are well known to the wind turbine industry and are clearly identified, in IEC 61400-11:2012 *Wind turbines Part 11: Acoustic noise measurement techniques* Appendix A: *Other possible characteristics of wind turbine noise emission and their quantification*:

A.1 General

In addition to those characteristics of wind turbine noise described in the main text of this standard, the noise emission may also possess some, or all, of the following:

- *infrasound;*
- *low-frequency noise;*
- *impulsivity;*
- *low-frequency modulation of broad band or tonal noise;*
- *other, such as a whine, hiss, screech or hum, etc., distinct impulses in the noise, such as bangs, clatters, clicks, or thumps, etc.*

These characteristics are described briefly below, and possible quantitative measures discussed. It should be noted that certain aspects of infrasound, low frequency noise, impulsivity and amplitude modulation are not fully understood at present. Thus it may prove that measurement positions farther away from the wind turbine than those specified in the standard may be preferable for the determination of these characteristics.

A.2 Infrasound

Sound at frequencies below 20 Hz is called infrasound. Although such sound is barely audible to the human ear, it can still cause problems such as vibration in buildings and, in extreme cases, can cause annoyance. If infrasound is thought to be emitted, an appropriate measure is the G-weighted sound pressure level according to ISO 7196. Research has shown that modern upwind wind turbines do not produce audible infrasound.

A.3 Low frequency noise

The general procedure extends one-third octave bands to 20 Hz and covers the relevant frequency range to describe the low frequency noise. From the data it is possible to predict the low frequency noise levels in the far field.

A disturbance can be caused by low-frequency noise with frequencies in the range from 20 Hz to 100 Hz. The annoyance caused by noise dominated by low frequencies begins when the noise is clearly audible. At levels close to the hearing threshold the nuisance of such a noise may be overestimated if assessed using only LAeq values.

A.4 Impulsivity

An impulsive, thumping sound may be emitted from a wind turbine due, for example, to the interaction of the blade with the disturbed wind around the tower. Impulsivity is a measure of the degree of this thumping.

A quantification of impulsivity can be obtained from the average of several measurements of the difference between the C-weighted "impulse hold" and maximum C-weighted "slow" sound pressure levels.

A.5 Amplitude modulation of the broad band noise

In some cases, it is possible that the broadband noise emitted by a wind turbine is modulated by the blade passage frequency giving rise to a characteristic "swishing" or "whooshing" sound.

This modulation can be displayed by recording the measured A-weighted sound pressure level with time weighting F for at least ten full rotations of the rotor.

The characteristics of this modulation can be influenced by local atmospheric conditions (see Annex B), and for this reason such conditions should be recorded during measurements.

A.6 Other noise characteristics

If the noise emission contains a whine, hiss, screech, hum, bang, clatter, click, thump, etc., then this characteristic should be reported. A full description as possible of the noise should be given in words, and any measurements that illustrate the nature of the noise should be taken.

Sound character outside the home is different to sound character inside the home.

This is due to the attenuation effects of the building envelope itself and the effect of room resonances, increasing low-frequency sound levels and complex tonalities (frequency- and amplitude- modulated) within a room.

This is why a clear 'rumble', 'thump', 'drone', 'whirr' or 'swish noise' inside the home may not be as clear or distinct <u>outside</u> the home.

It is clear to NMS from discussions with acousticians involved with noise impact assessments that people confuse acoustic measures (things measured by instruments) with psychoacoustic measures (human perception of sound and noise) that often cannot be <u>*measured or assessed*</u> with instrumentation. The acousticians claim that they are one and the same. They are not, and never will be.

Therefore, many of the papers and acoustical measures referenced by acousticians and others fail to assist in evaluating pre-exposure and exposed personal noise perception, annoyance and nuisance.

Listen to this again.

What do you hear?

VIEW THIS VIDEO BEFORE READING THIS SECTION

https://youtu.be/_-iLQBmcu1c

Use good quality headphones or sound system to listen to this video.

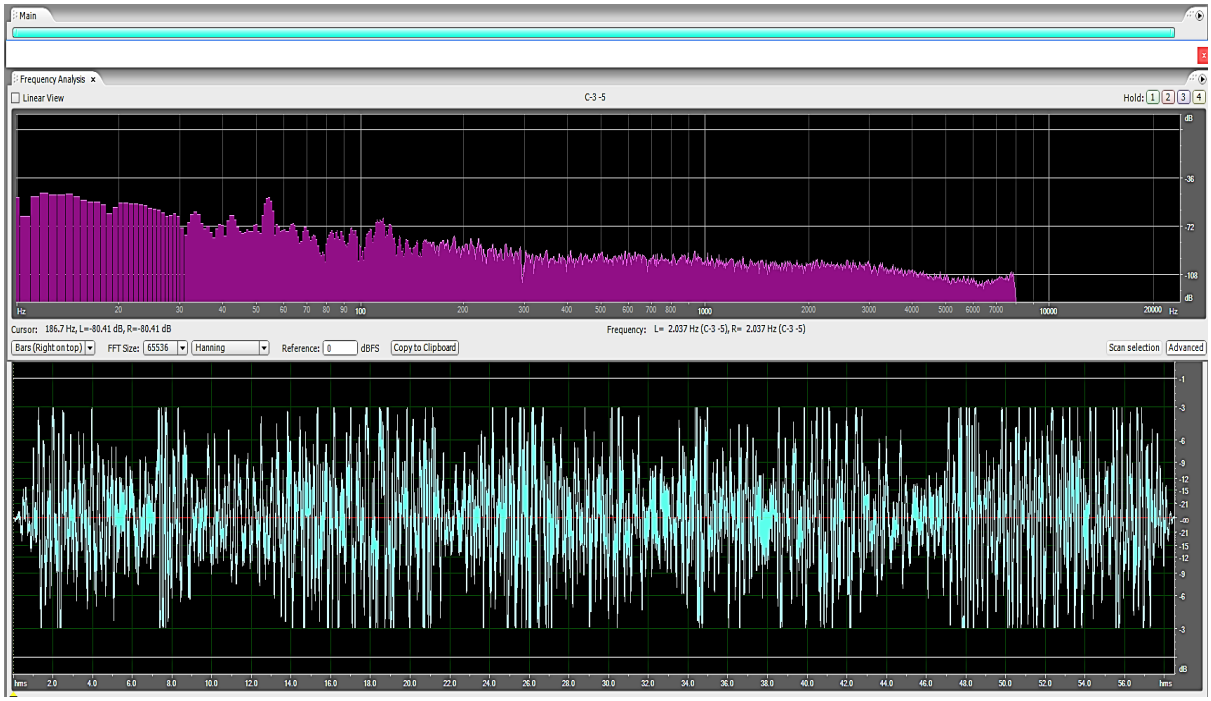
This short video clip is representative of a 10-minute audiofile and video recorded on 26 September 2018 with a Class 1 sound level meter and video recorder.

The sound of the turbines can be clearly heard, as well as animals in the background. The turbine sounds are typical of the wind farm and more noticeable at night and when heard indoors in a home.

Analysis of this audiofile is presented in the 4 charts following. The charts represent the whole of the video and show clear "rumbles" at 53.5Hz and 115.5Hz. Different analysis methods will provide slightly different values. The charts do not represent the 'true' sound levels as the microphone and sound level meter do not have a linear response below 6.3Hz. The frequencies below 6.3Hz are higher than those shown. However, even with this caveat, blade pass frequencies are obvious.

Appendix I has more detail on infrasound signatures. Identification of signatures is important as two or more turbines can create enhanced sound levels within a dwelling. This issue is discussed later as 'Heightened Noise Zones' in Appendix J.

Chart 1a: Frequency analysis and Signal history



Bald Hills Video Clip analysed with Adobe Audition 3.0

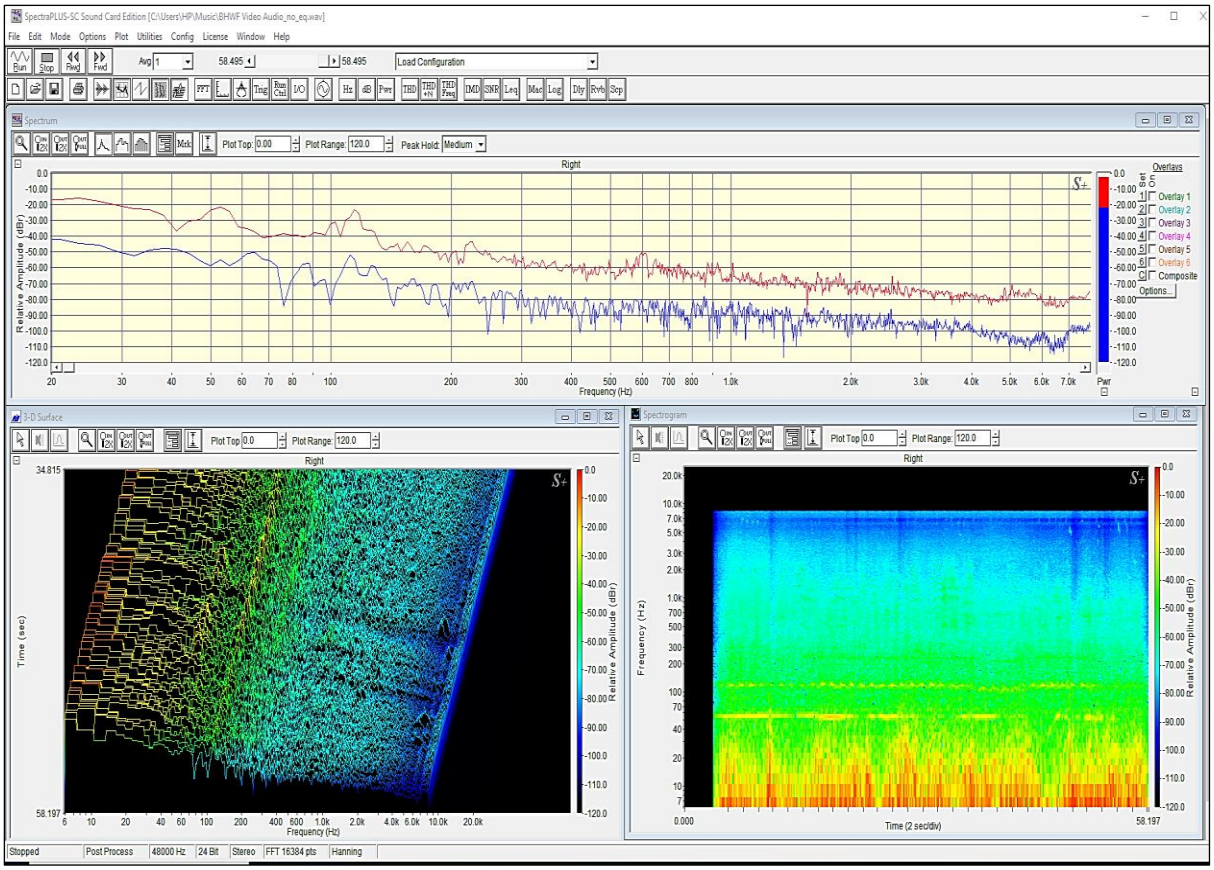


Chart 1b: Spectrum, 3-D surface and Spectrogram of Bald Hills Video Clip analysed with SpectraPLUS-SC

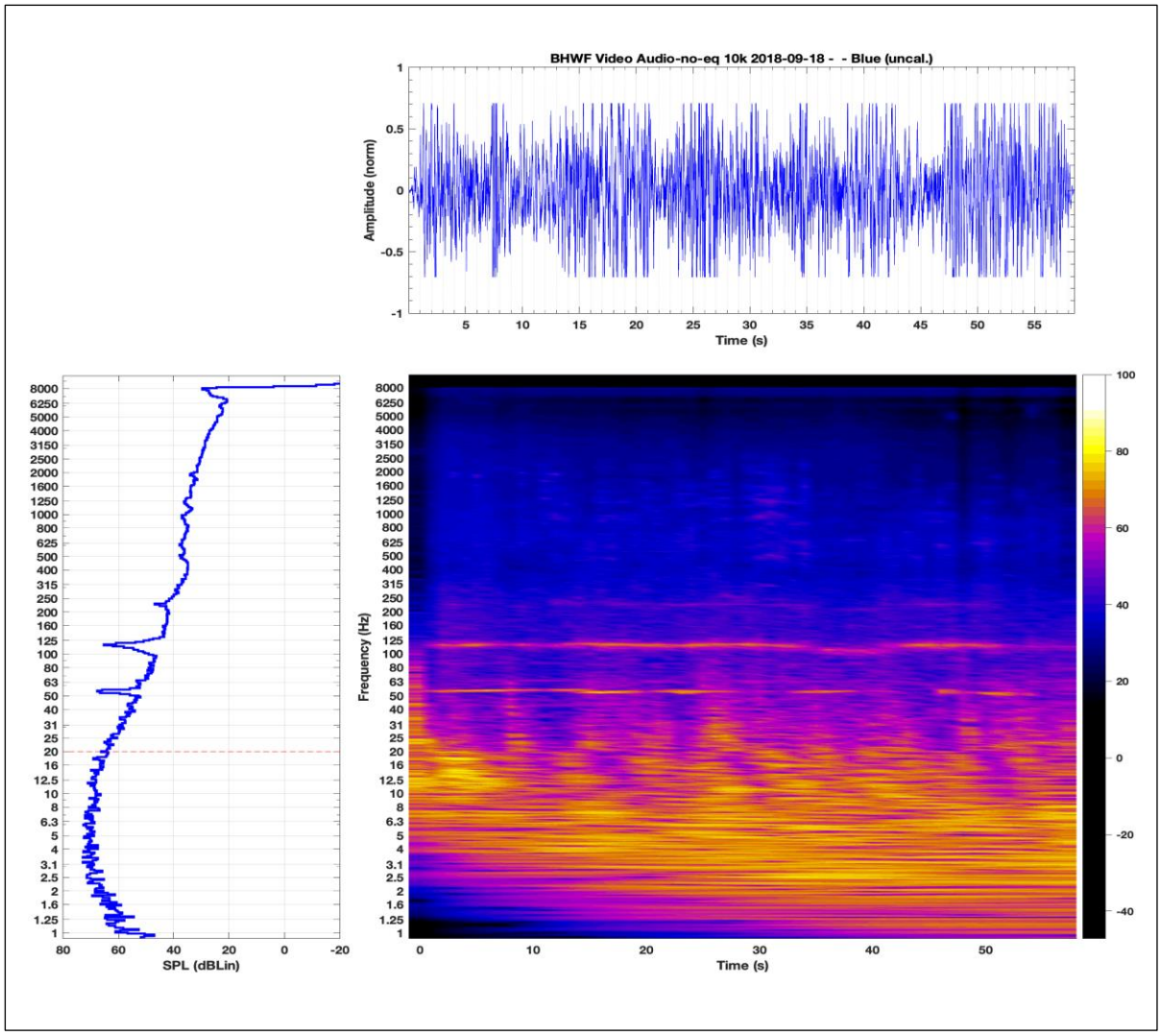


Chart 1c: Spectrum and Sonogram of Bald Hills Video Clip analysed with Sentinel

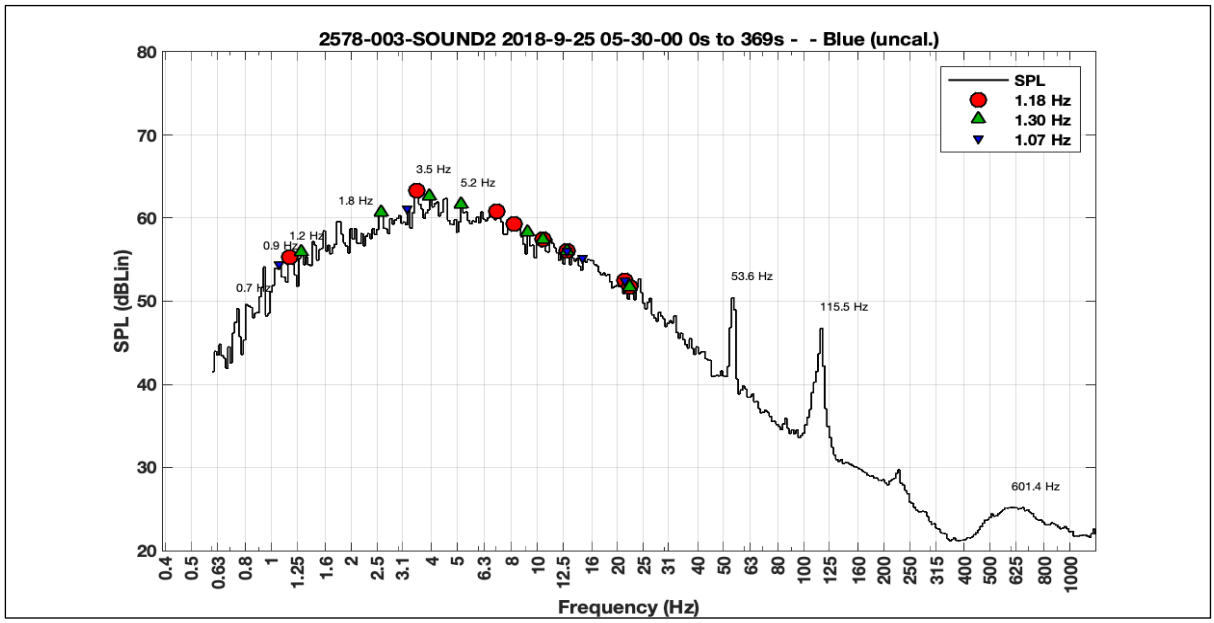
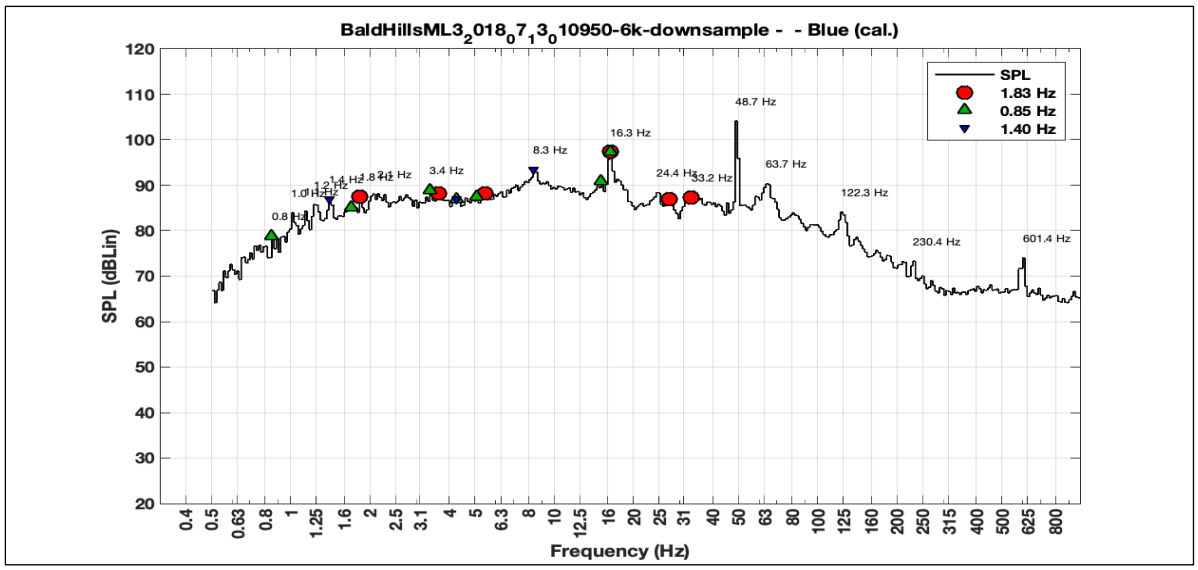
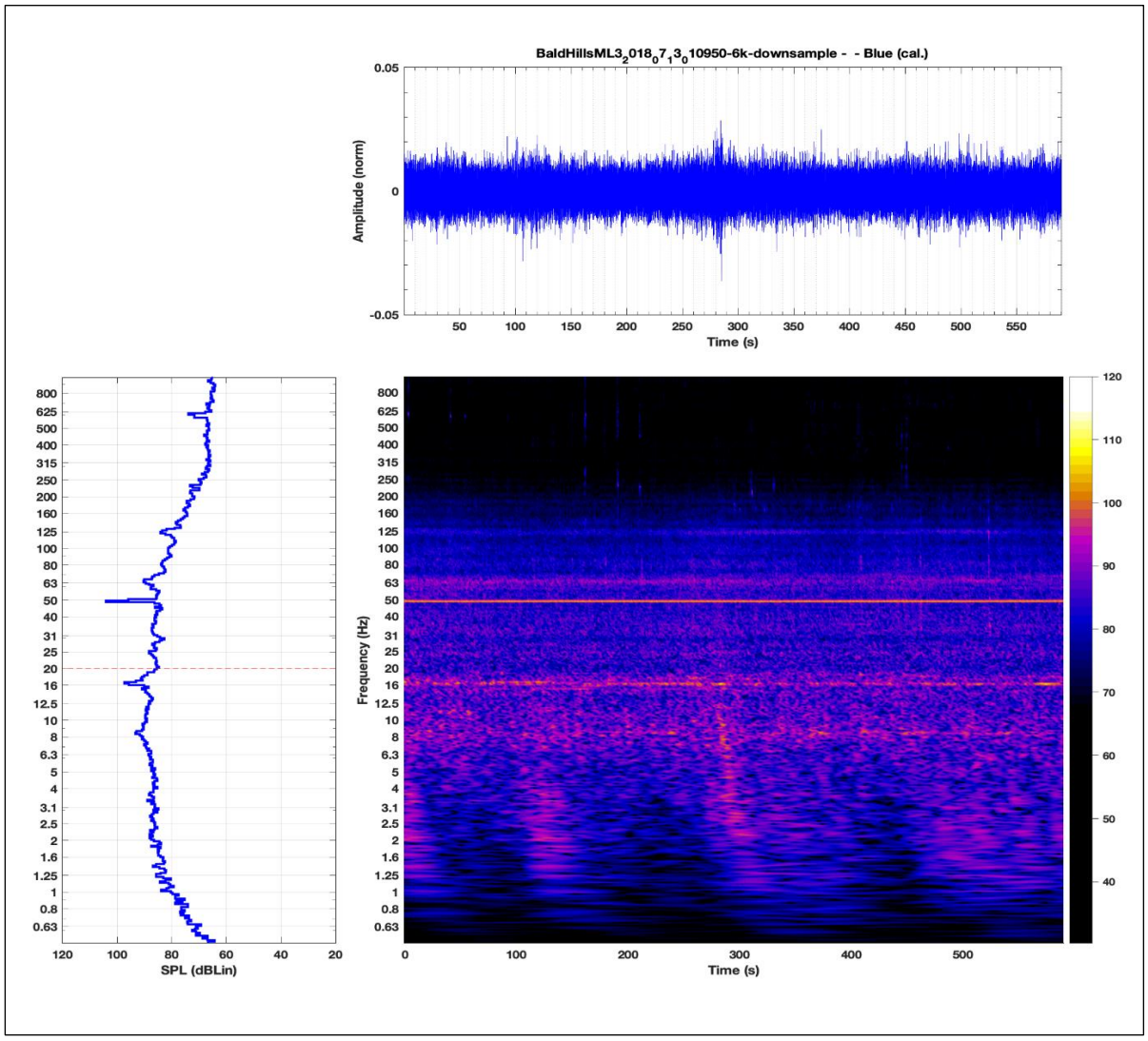


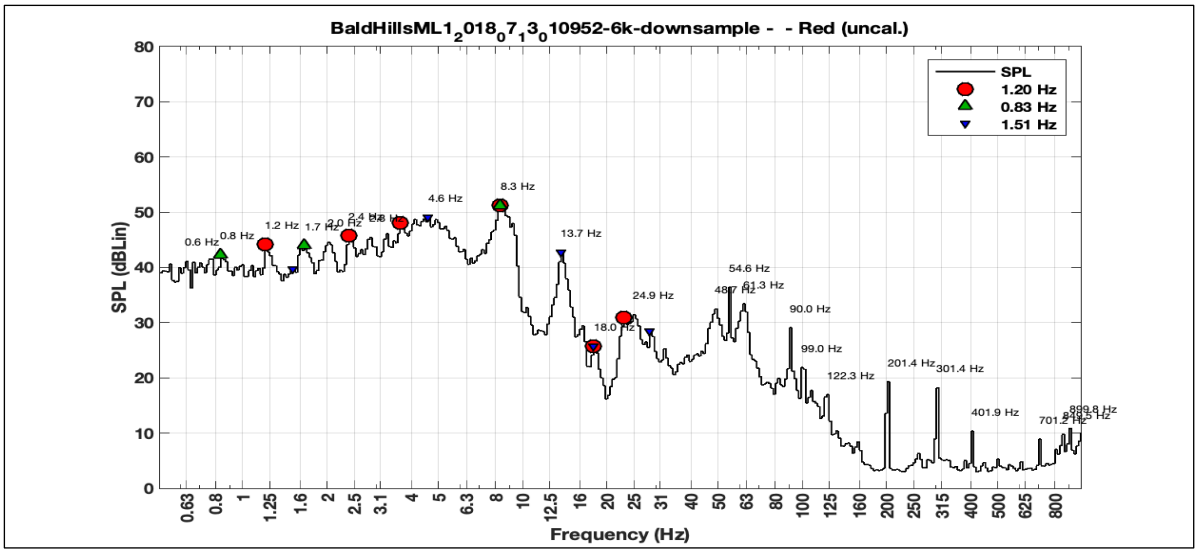
Chart 1d: Spectrum of Bald Hills Video Clip 'as-recorded' audiofile analysed with Sentinel

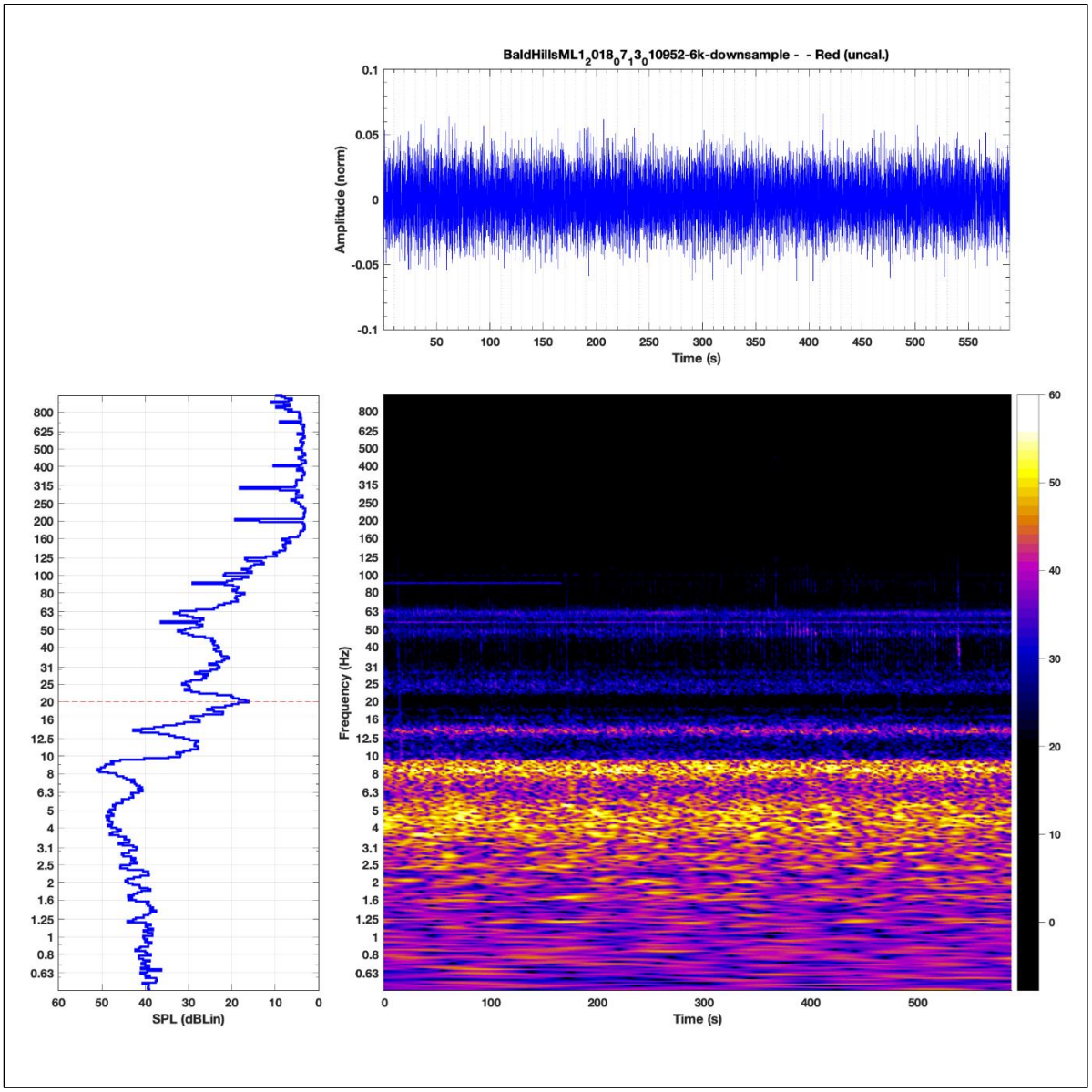
13 July "Quiet day-night", turbines operating

Blue = microphone outside, red = microphone indoors



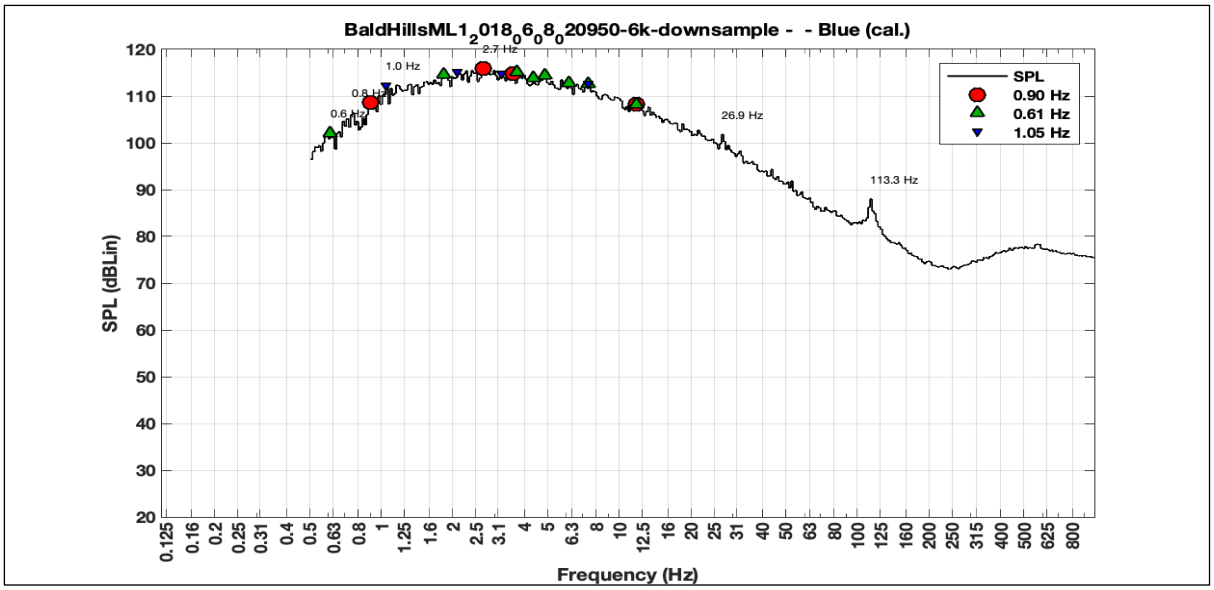


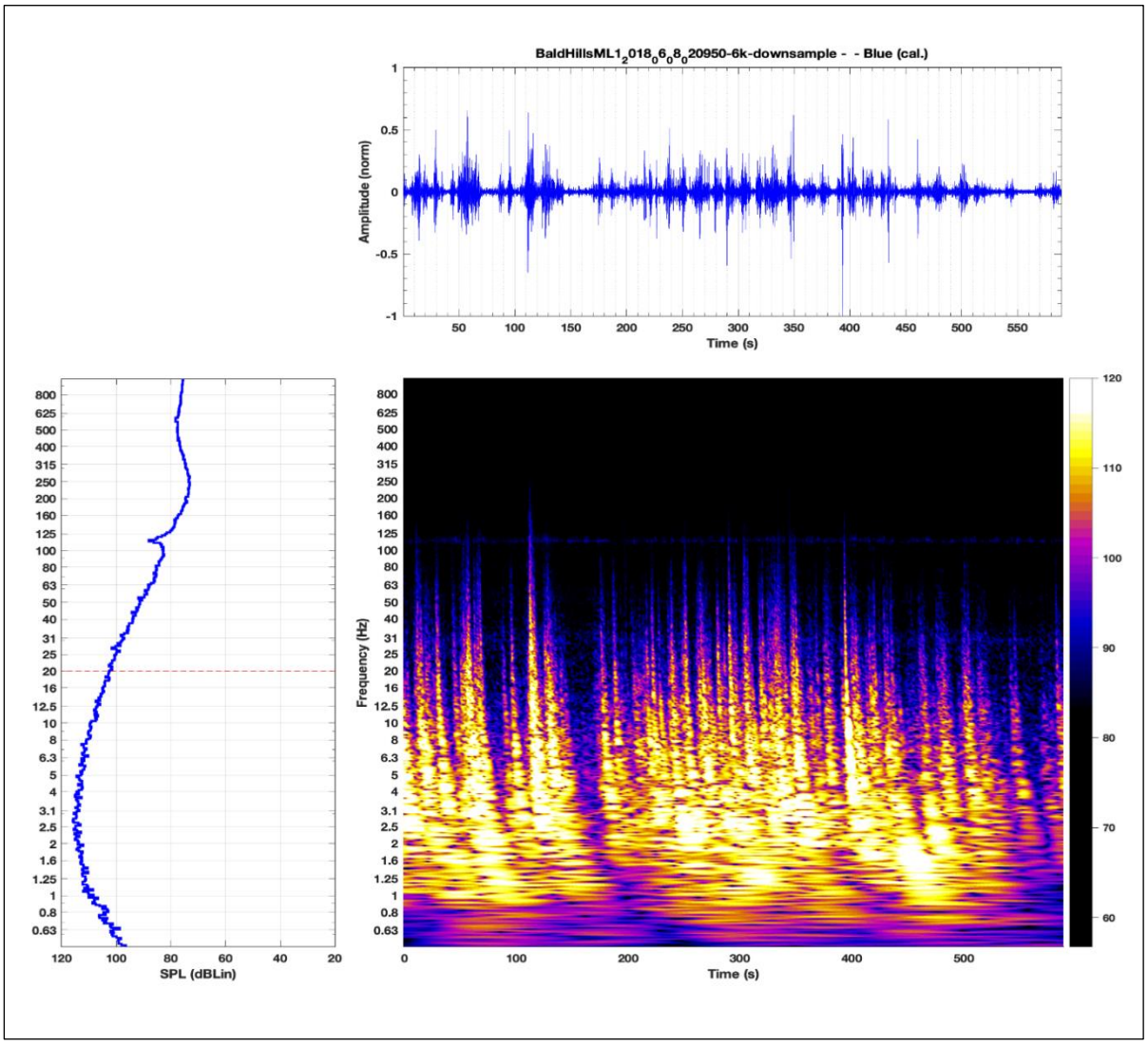

BaldHillsML1_2018_07_30_10952-6k-downsample - - Red (uncal.)
SPL
1.20 Hz
0.83 Hz
1.51 Hz
SPL (dBLin)
Frequency (Hz)
0.6 Hz
0.8 Hz
1.2 Hz
1.7 Hz
4.6 Hz
8.3 Hz
13.7 Hz
18.0 Hz
24.9 Hz
54.6 Hz
61.3 Hz
90.0 Hz
99.0 Hz
122.3 Hz
201.4 Hz
301.4 Hz
401.9 Hz

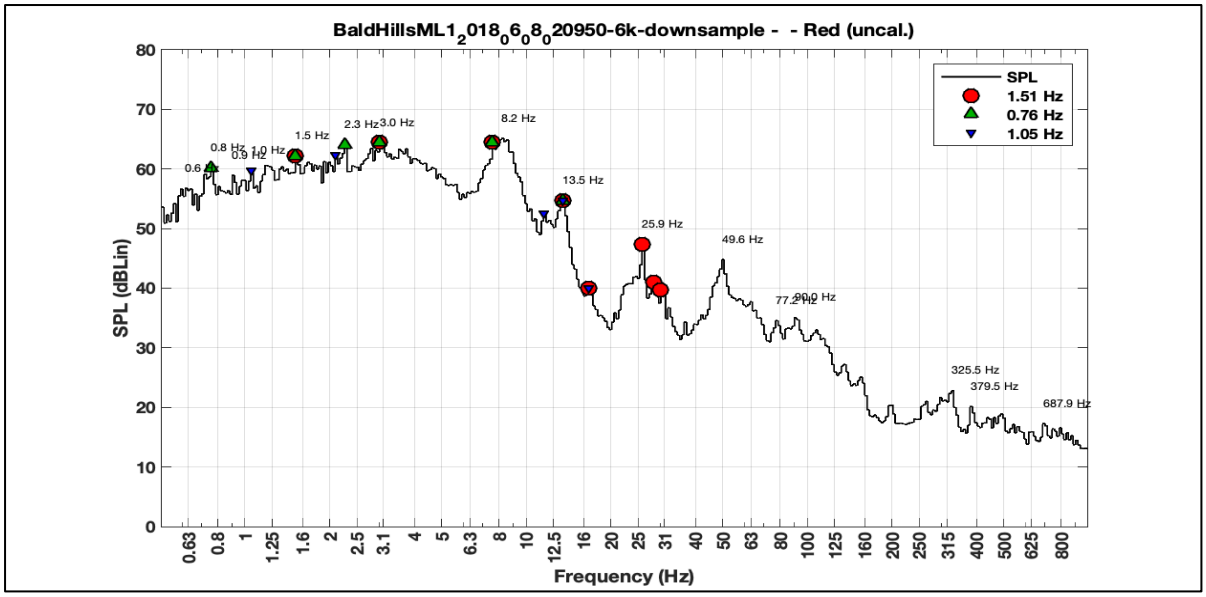

BaldHillsML1_2018_07_30_10952-6k-downsample - - Red (uncal.)
Amplitude (norm)
Time (s)
SPL (dBLin)
Frequency (Hz)
Time (s)

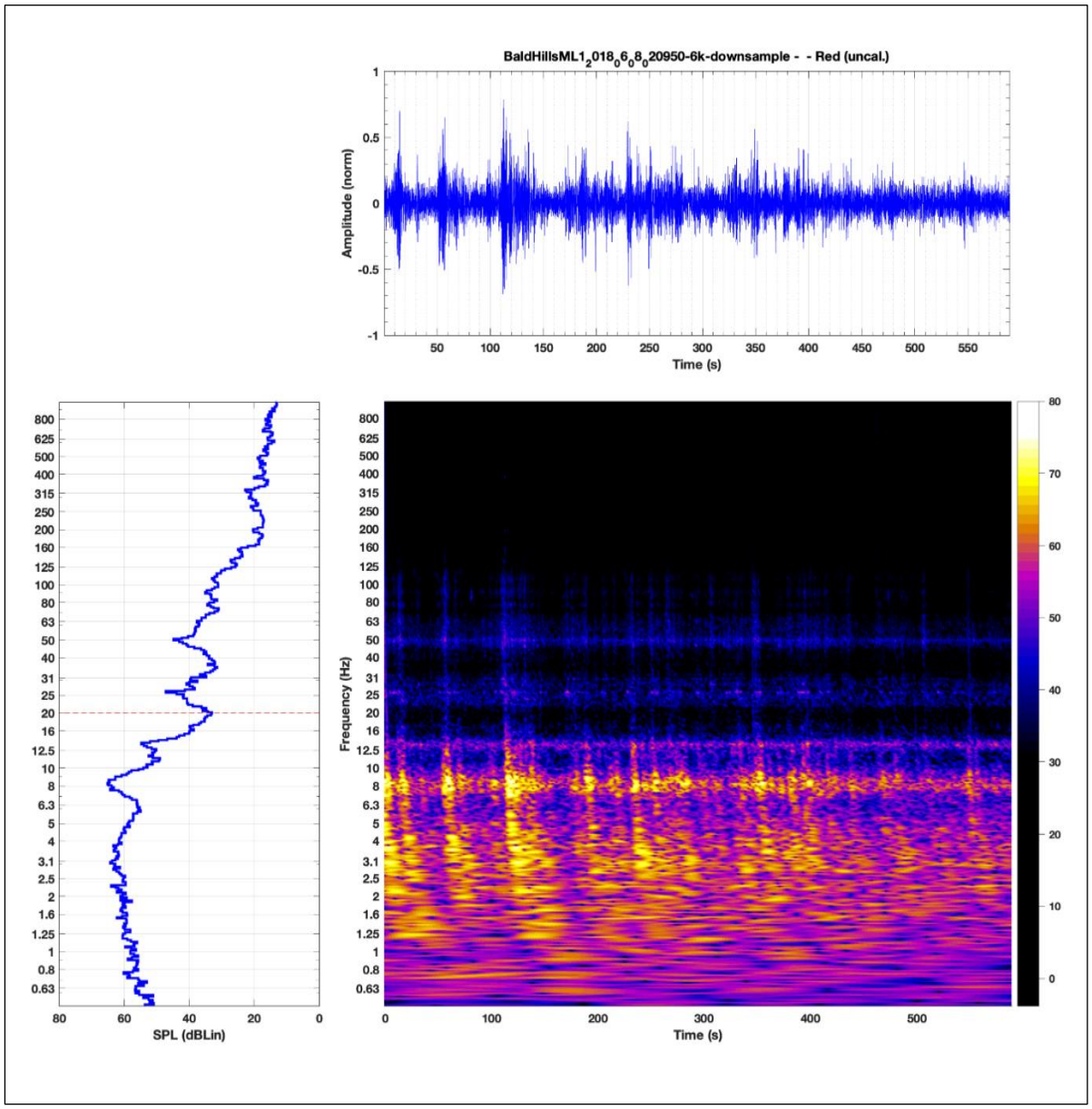
8 June 2am, turbines loud

Blue = microphone outside, red = microphone indoors



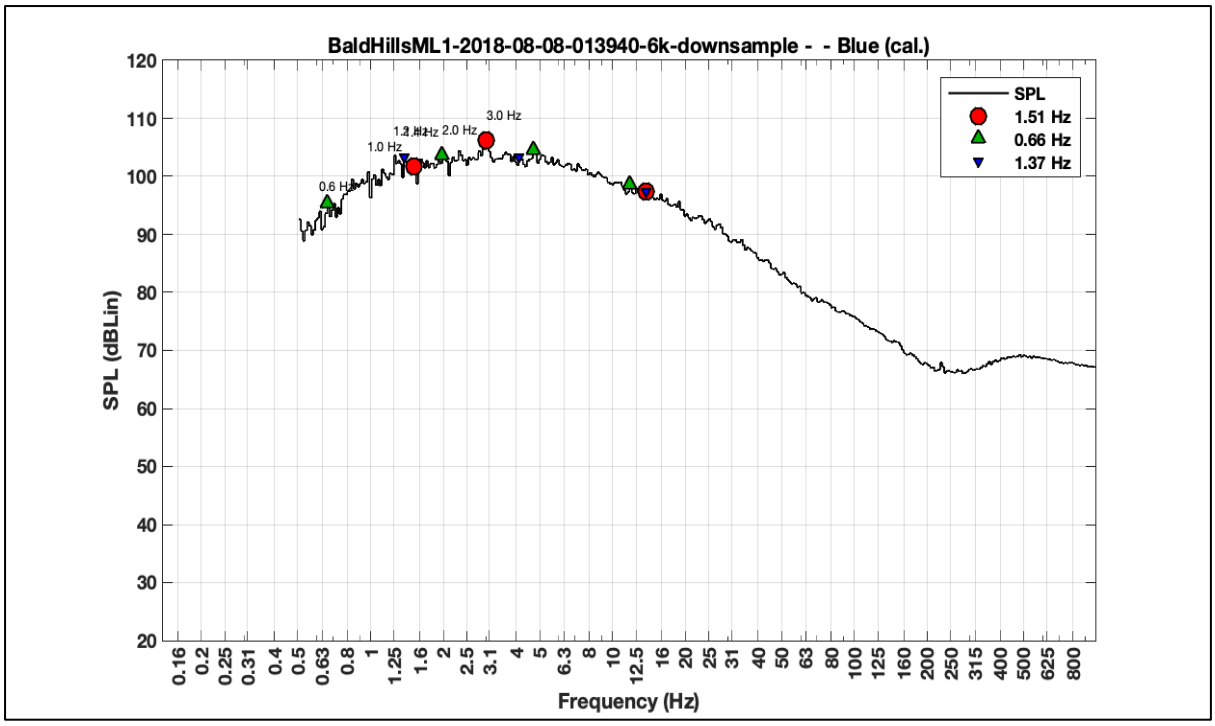


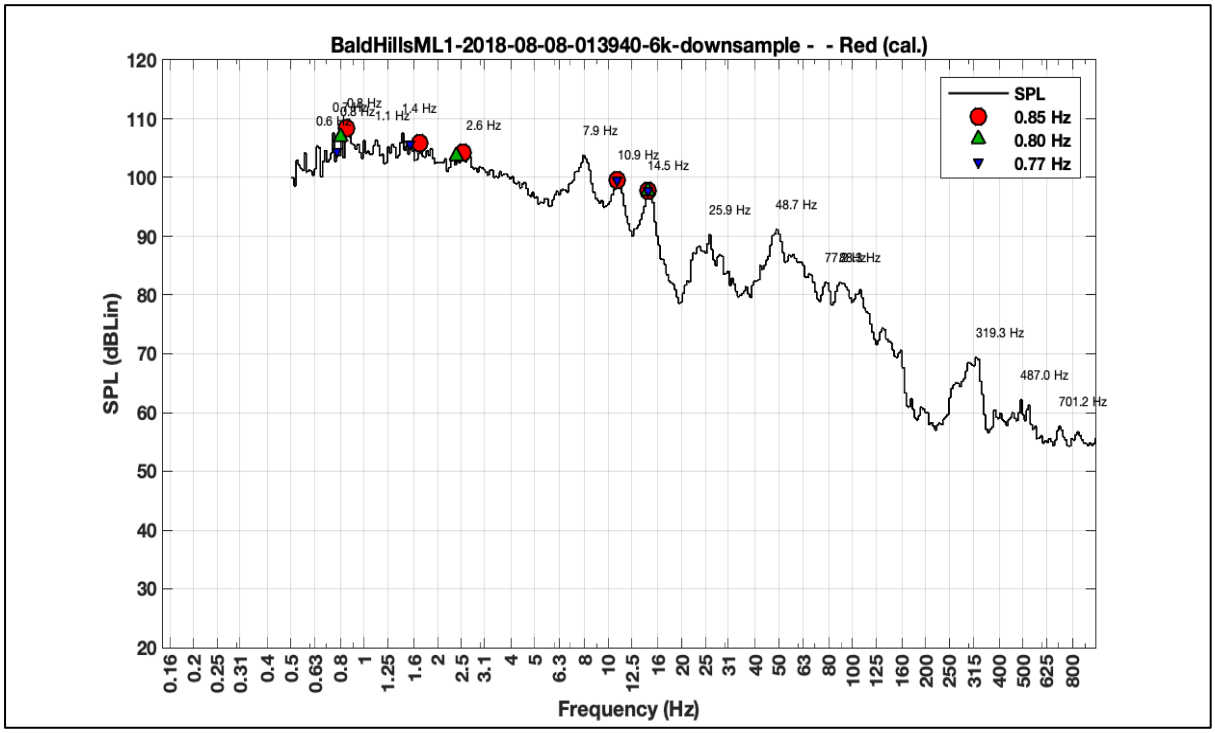

BaldHillsML1_2018_06_08_20950-6k-downsample - - Red (uncal.)
SPL
1.51 Hz
0.76 Hz
1.05 Hz
SPL (dBLin)
Frequency (Hz)
0.6 Hz
0.8 Hz
1.0 Hz
1.5 Hz
2.3 Hz
3.0 Hz
8.2 Hz
13.5 Hz
25.9 Hz
49.6 Hz
325.5 Hz
379.5 Hz
687.9 Hz


BaldHillsML1_2018_06_08_20950-6k-downsample - - Red (uncal.)
Amplitude (norm)
Time (s)
SPL (dBLin)
Frequency (Hz)
Time (s)

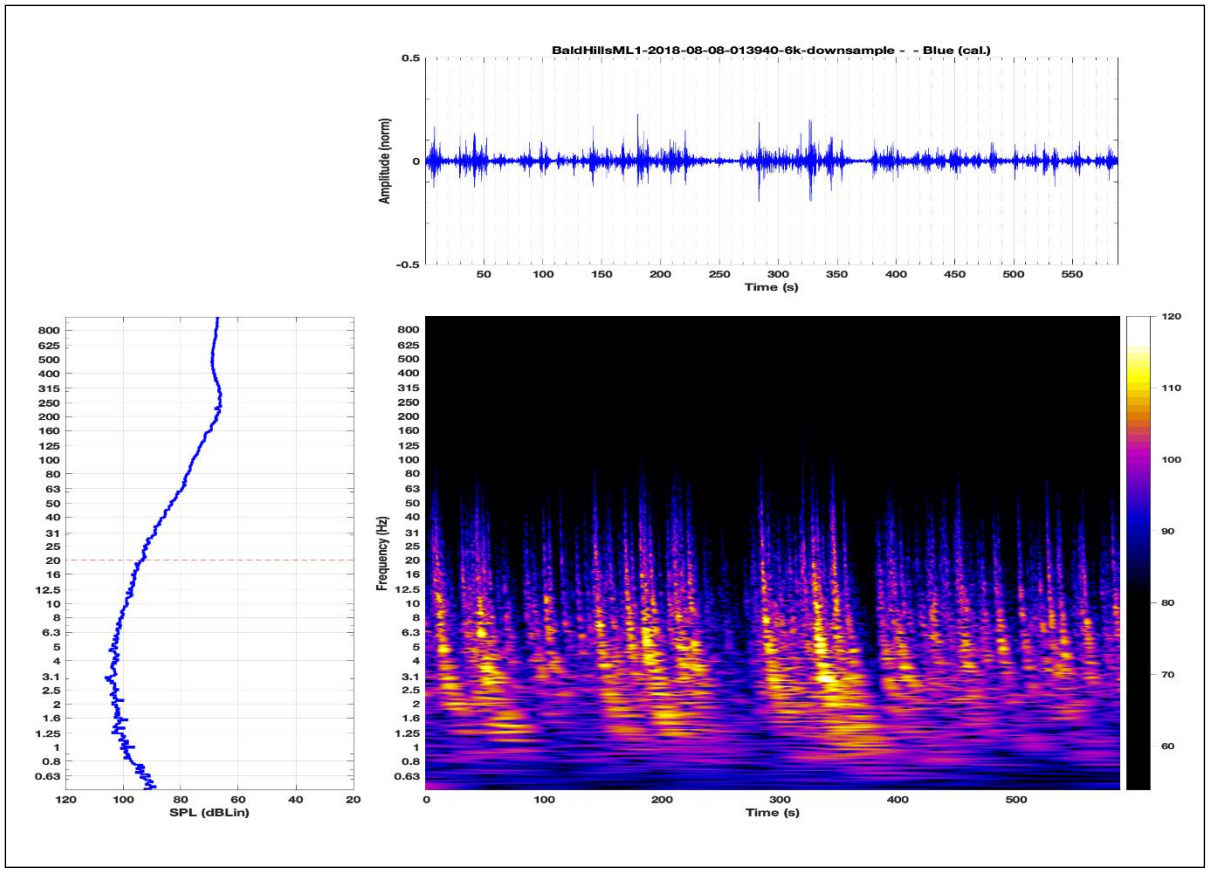
8 August 2018 Windy day, turbines not operating

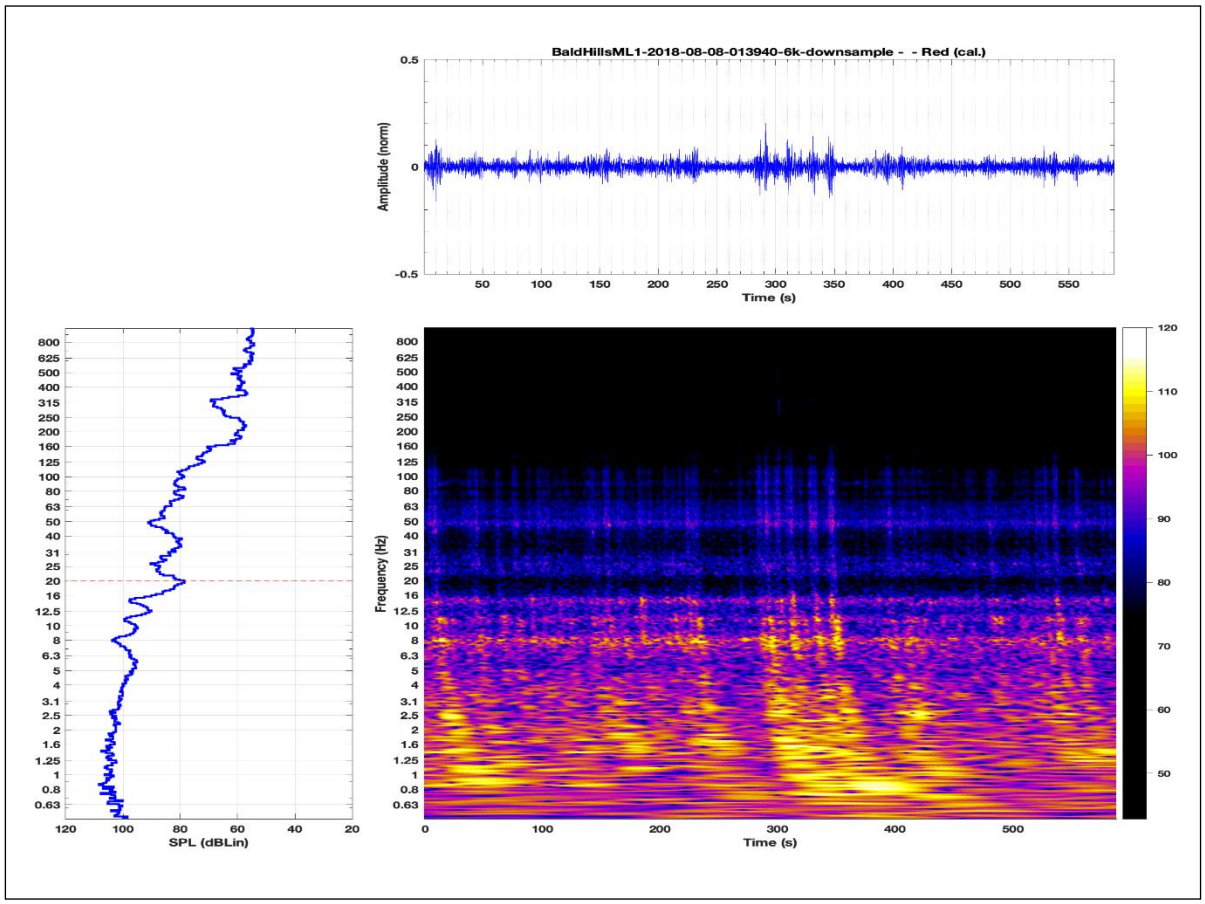
Blue = microphone outside, red = microphone indoors





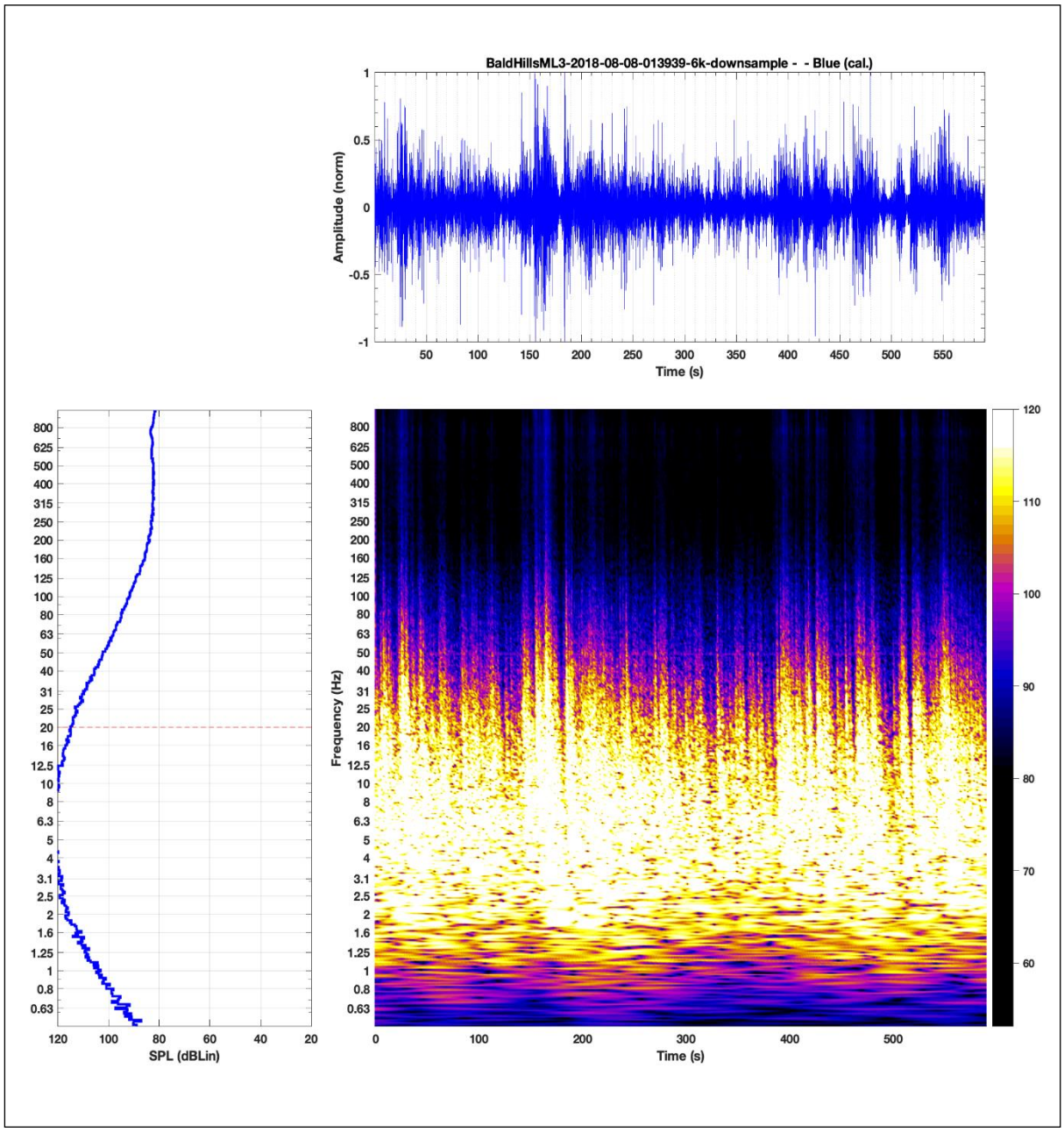
The influence of the indoors sound levels is clear between the upper chart (blue = outdoor microphone) and the lower chart (red = indoor microphone) with high peaks indoors





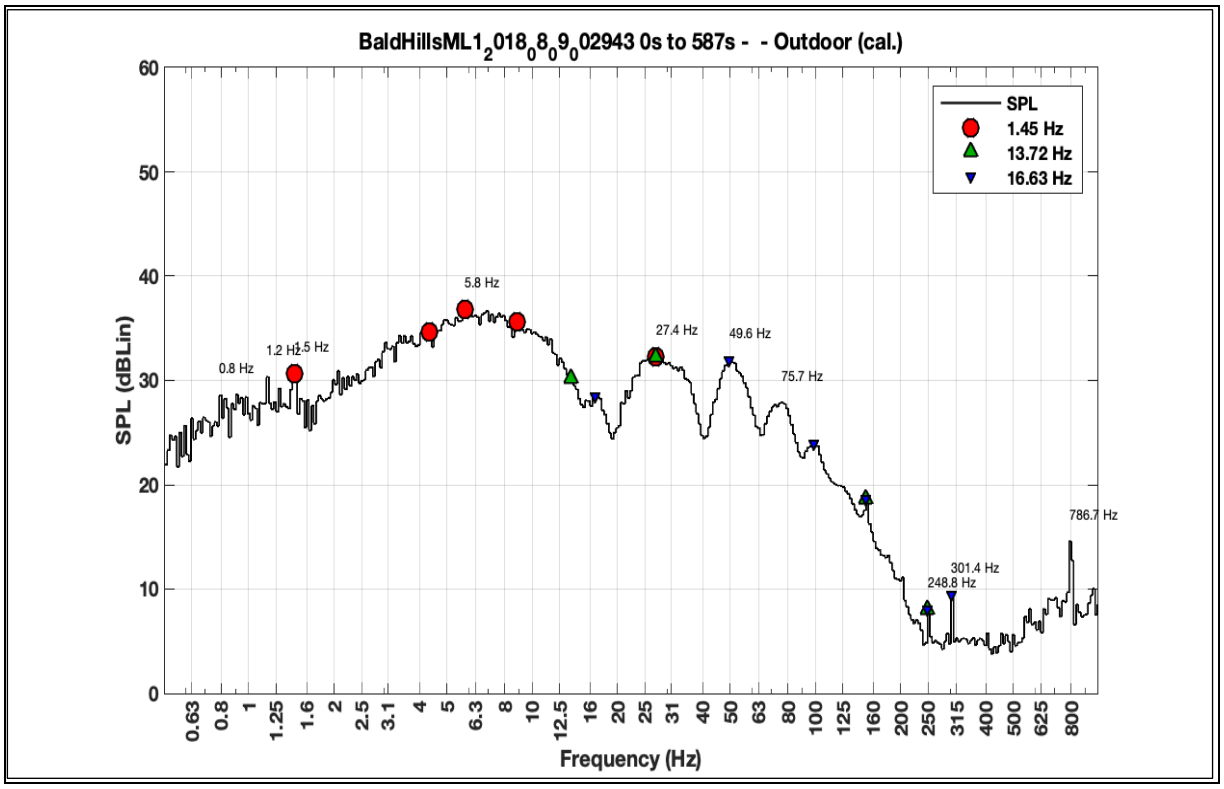
Upper chart is outdoor, lower chart is indoor sound levels

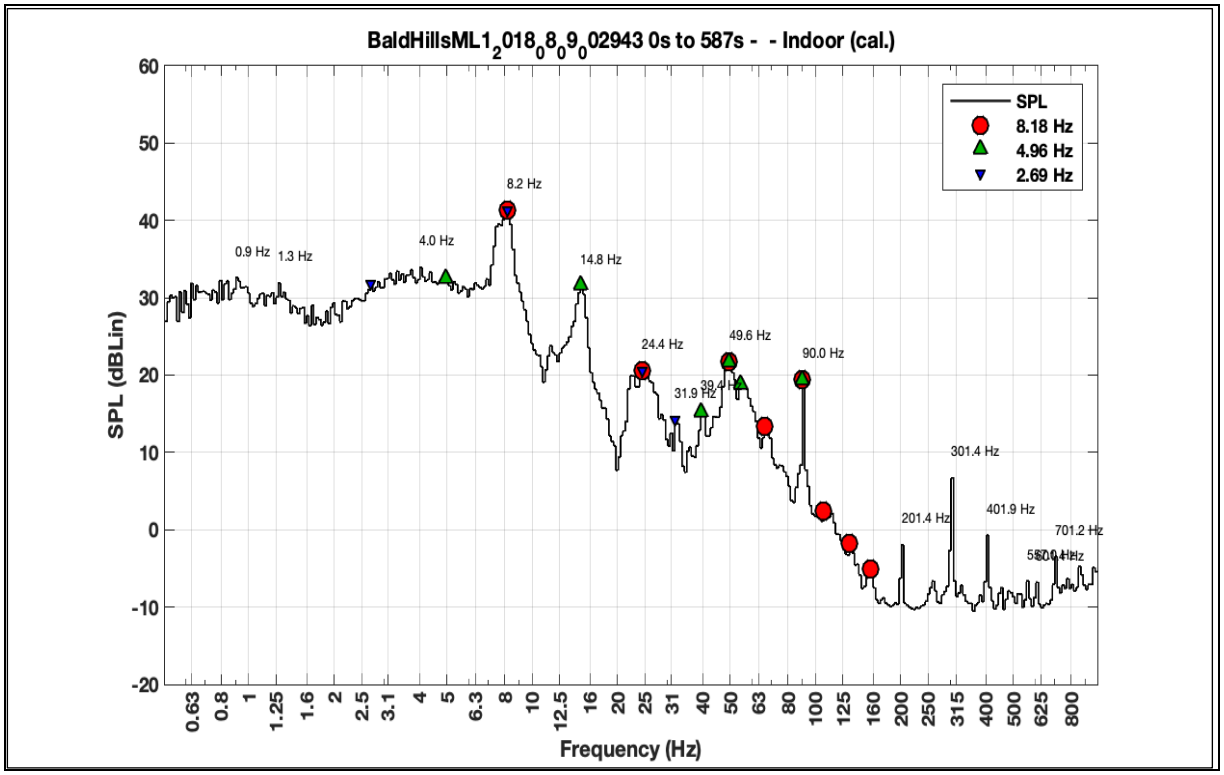
The outdoor sound level spectrum at ML3 is significantly higher

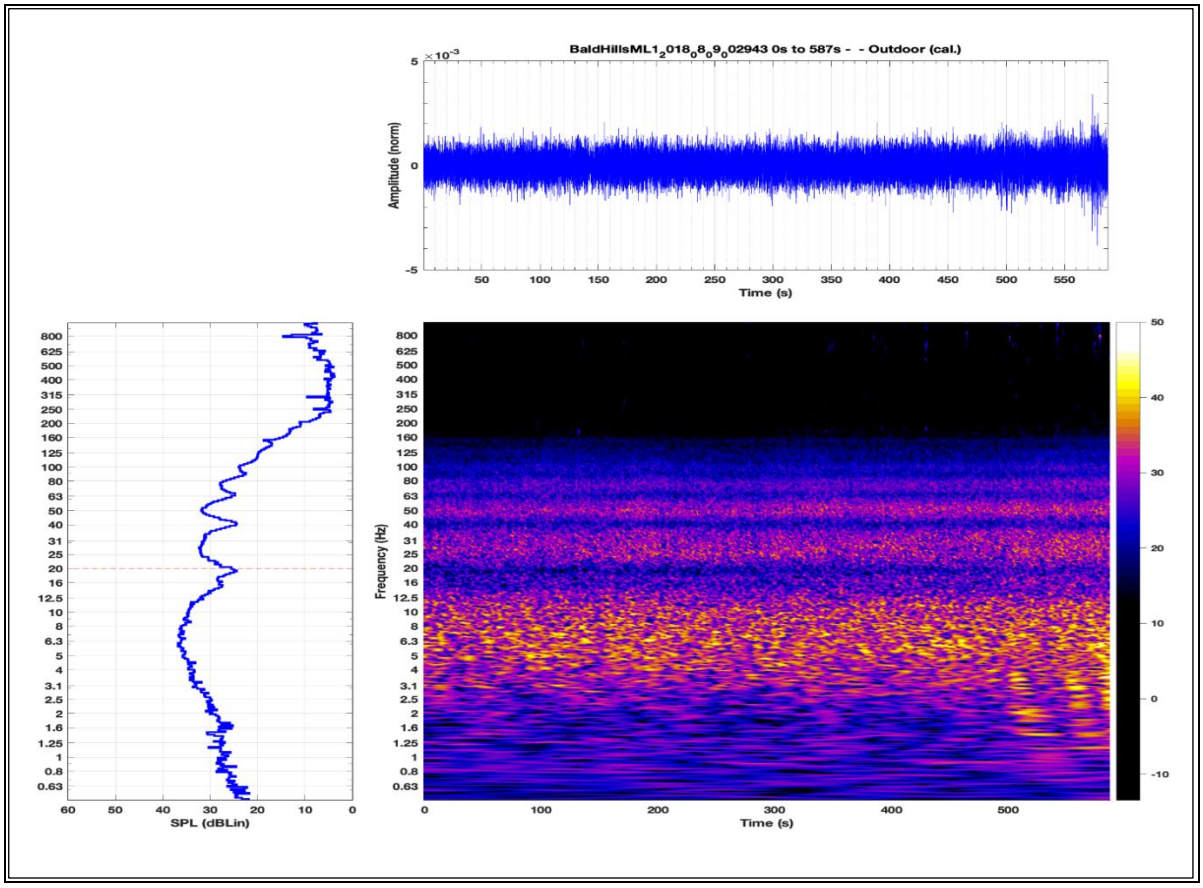


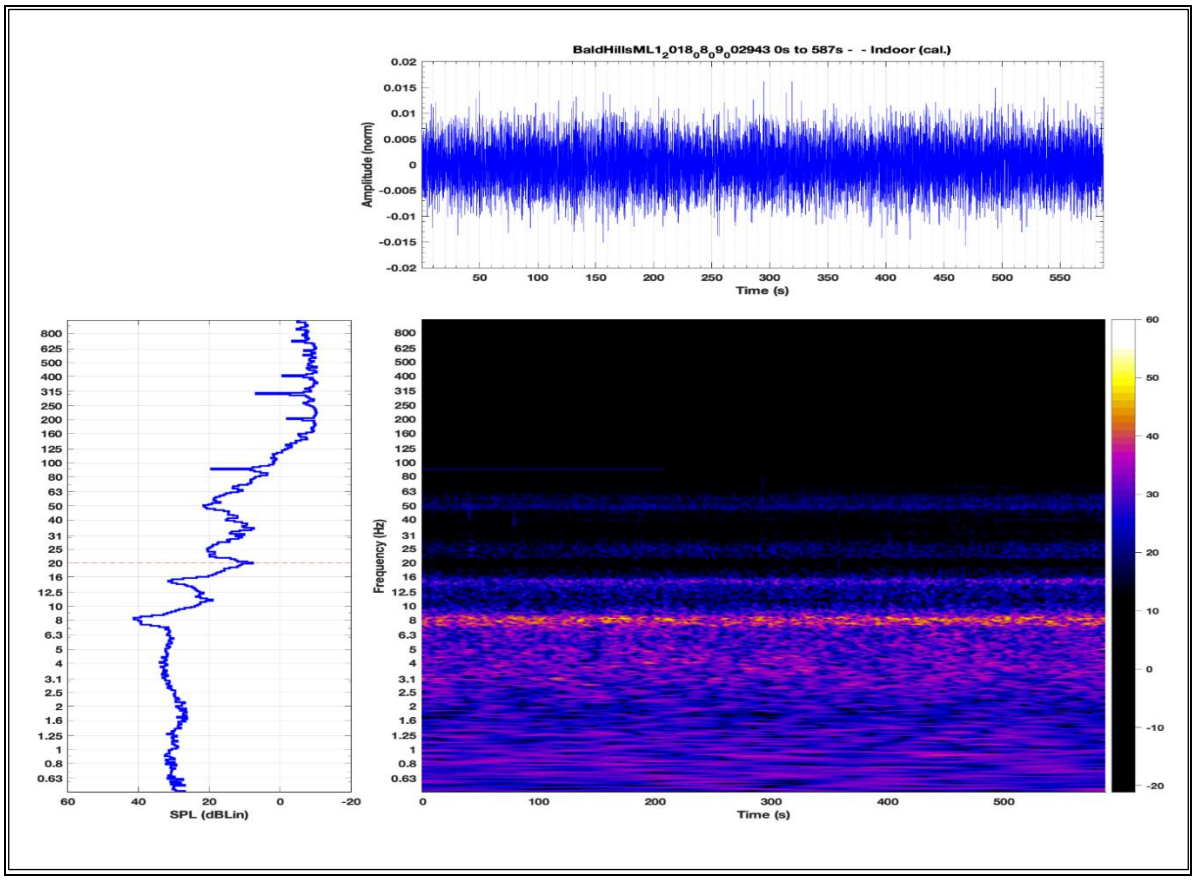
9 August 2018 'not so windy day', turbines not operating

Blue = microphone outside, red = microphone indoors



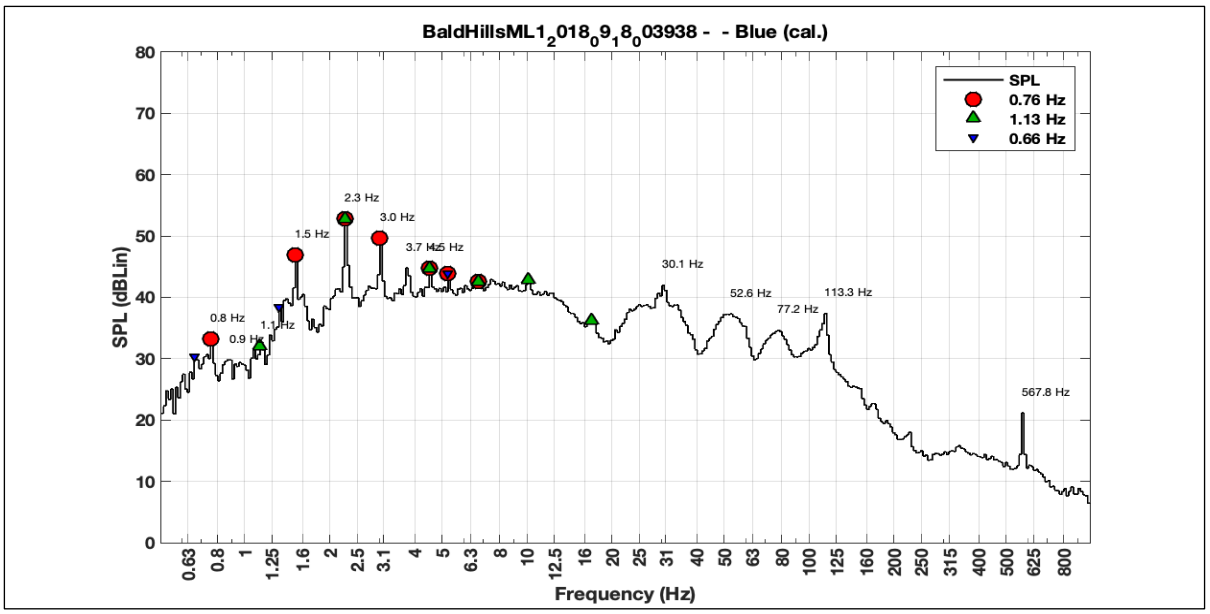


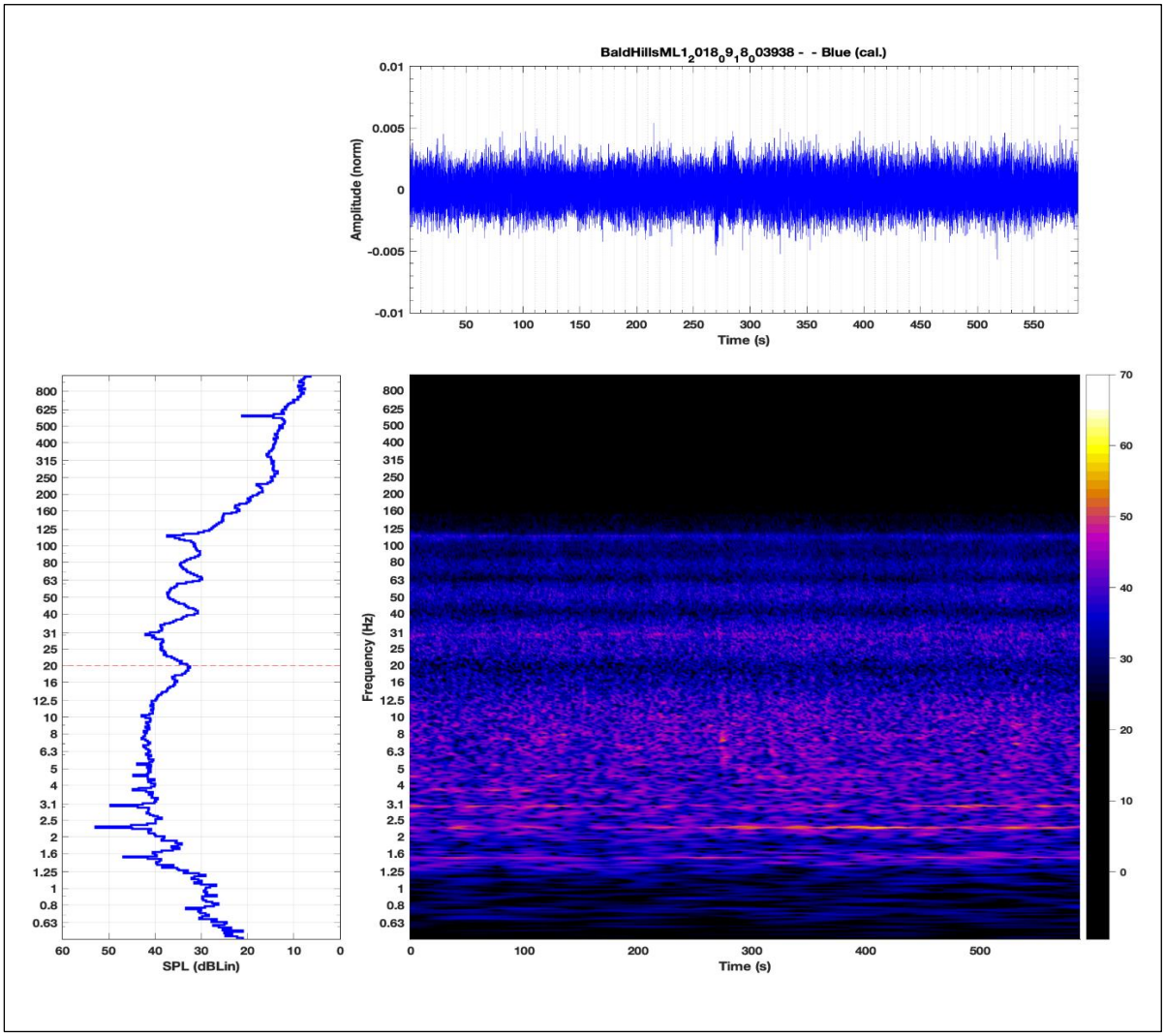

BaldHillsML1_2018_8_9_02943 0s to 587s - - Outdoor (cal.)
Amplitude (norm)
Time (s)
SPL (dBLin)
Frequency (Hz)
Time (s)

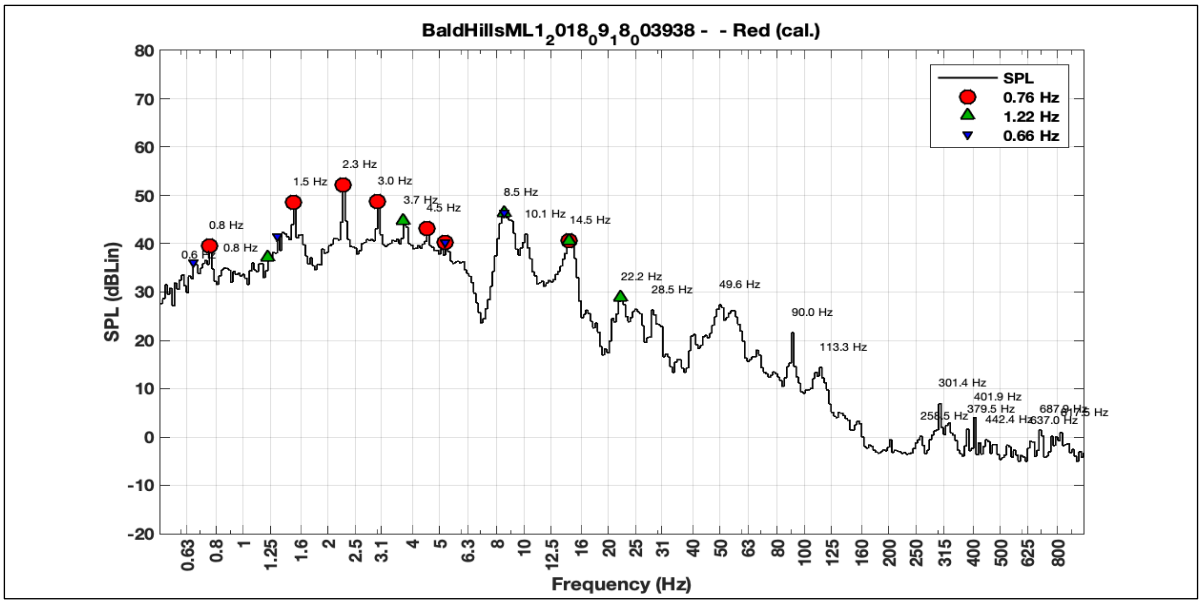

BaldHillsML1_2018_8_9_02943 0s to 587s - - Indoor (cal.)
Amplitude (norm)
Time (s)
SPL (dBLin)
Frequency (Hz)
Time (s)

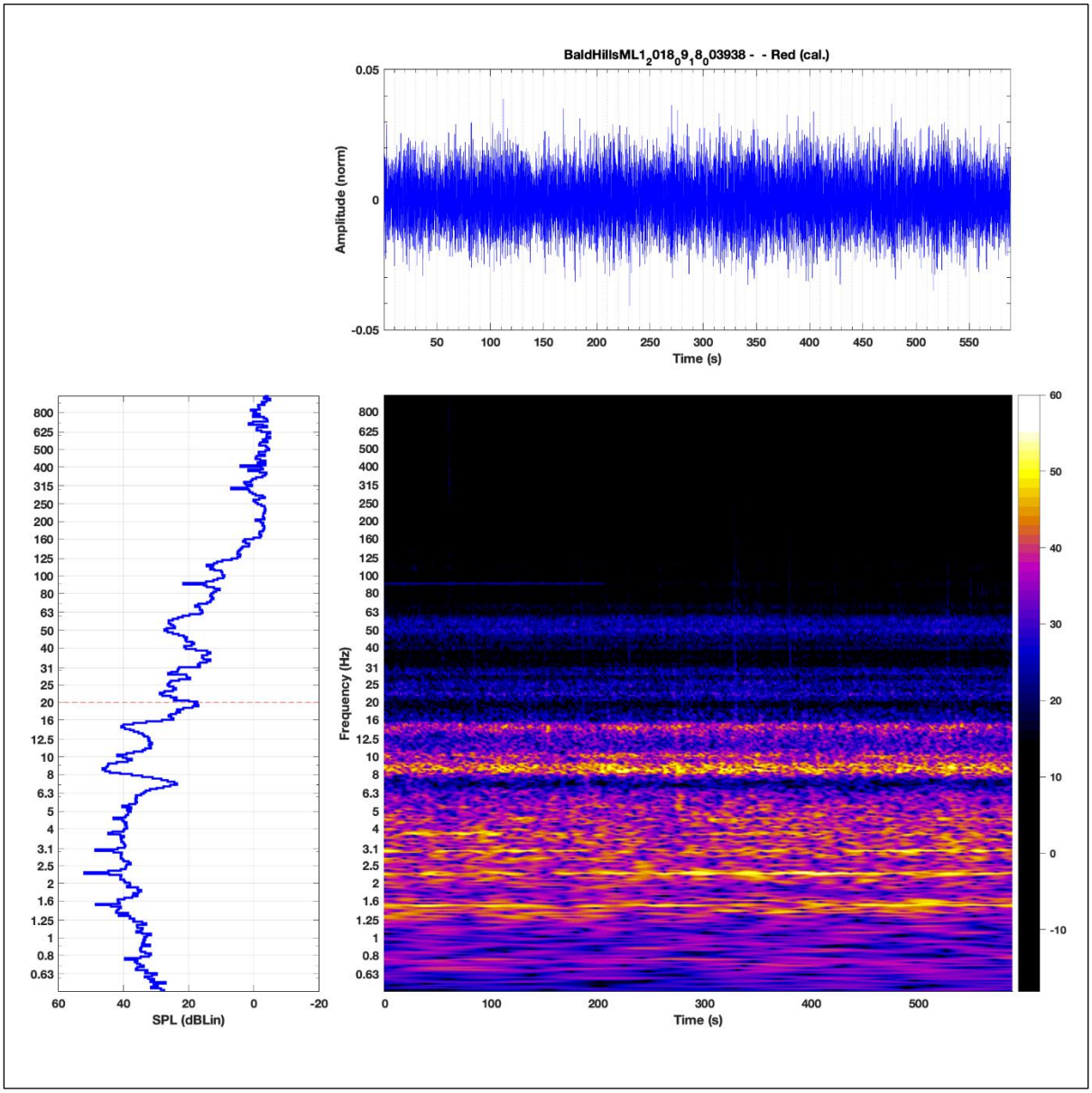
18 Sept 2018 4am complaints of noise

Blue = microphone outside, red = microphone indoors






BaldHillsML1_2018_9_18_03938 - - Red (cal.)
SPL
0.76 Hz
1.22 Hz
0.66 Hz
SPL (dBLin)
Frequency (Hz)
0.6 Hz
0.8 Hz
0.8 Hz
1.5 Hz
2.3 Hz
3.0 Hz
3.7 Hz
4.5 Hz
8.5 Hz
10.1 Hz
14.5 Hz
22.2 Hz
28.5 Hz
49.6 Hz
90.0 Hz
113.3 Hz
301.4 Hz
401.9 Hz
379.5 Hz
258.5 Hz
442.4 Hz
637.0 Hz


BaldHillsML1_2018_9_18_03938 - - Red (cal.)
Amplitude (norm)
Time (s)
SPL (dBLin)
Frequency (Hz)
Time (s)

Examples: Sound Images Indoors vs Outdoors at ML1

Sound images at ML1 are presented in the two charts following. The 'smoother' green line is the outdoor character while the 'peaky' blue line is indoor on two separate days (top 19 July, bottom 14 July, both at 2:00am – 2:10am). The outdoor microphone is a Class 1 BSWA sound level and the indoor microphone is a GRAS 40AZ microphone and preamplifier connected to a SpectraPlus DAQ-200 soundcard. Analysed with a Hanning window, 65536 FFT. The charts show how sound is modified outside to inside and peaks in sounds become more prominent.

Chart 1: ML1 Outside-Inside sound levels, complaints of noise, 020590am, 19 July 2018

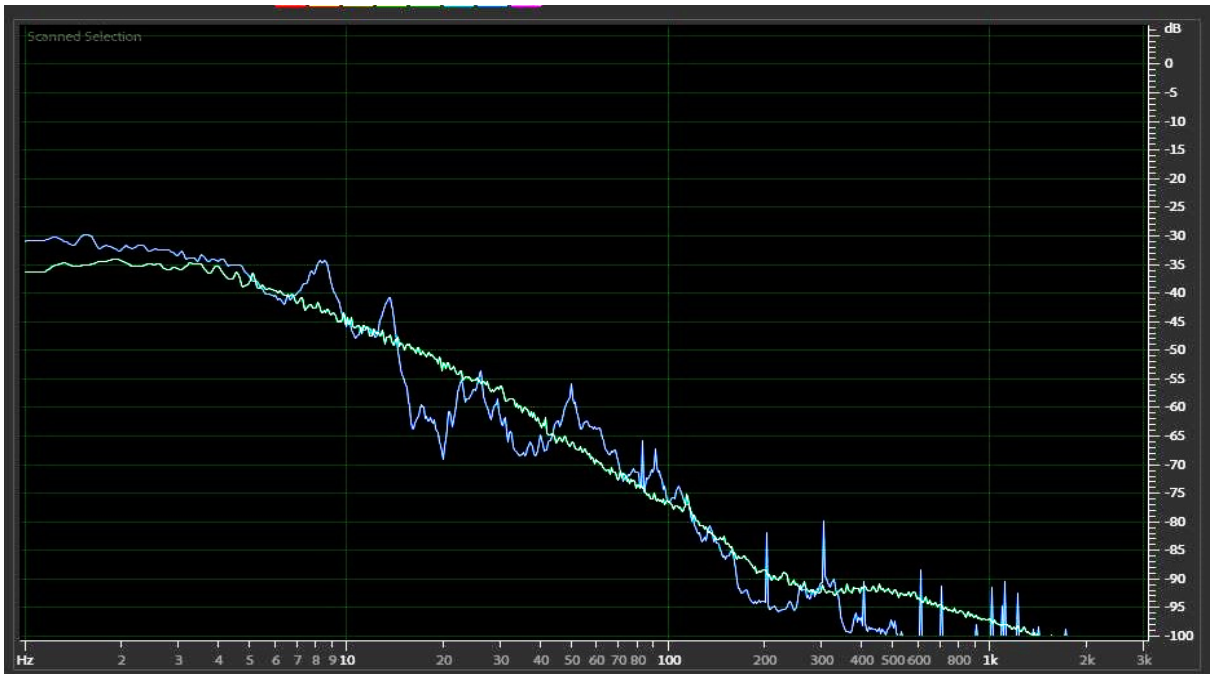


Chart 2: ML1 Outside-Inside sound levels, quiet, 020950am, 14 July 2018

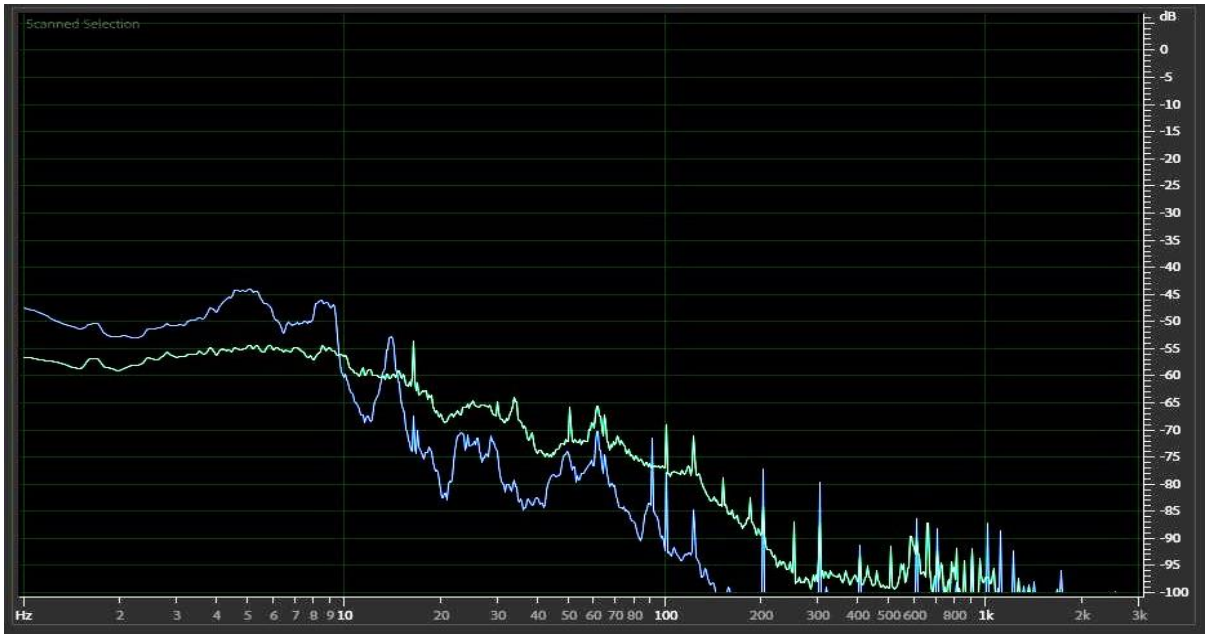


Chart 3: ML2 Outdoor sound levels, complaints of noise, 020590am, 19 July 2018

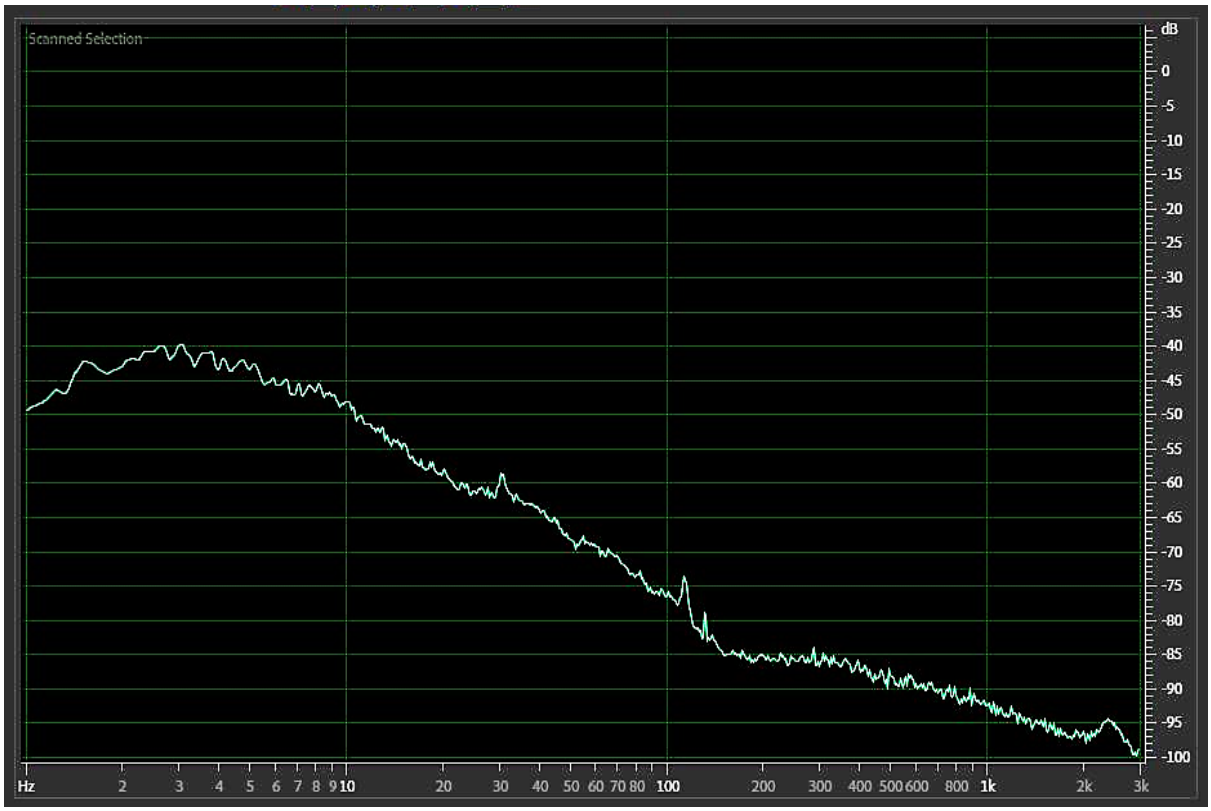
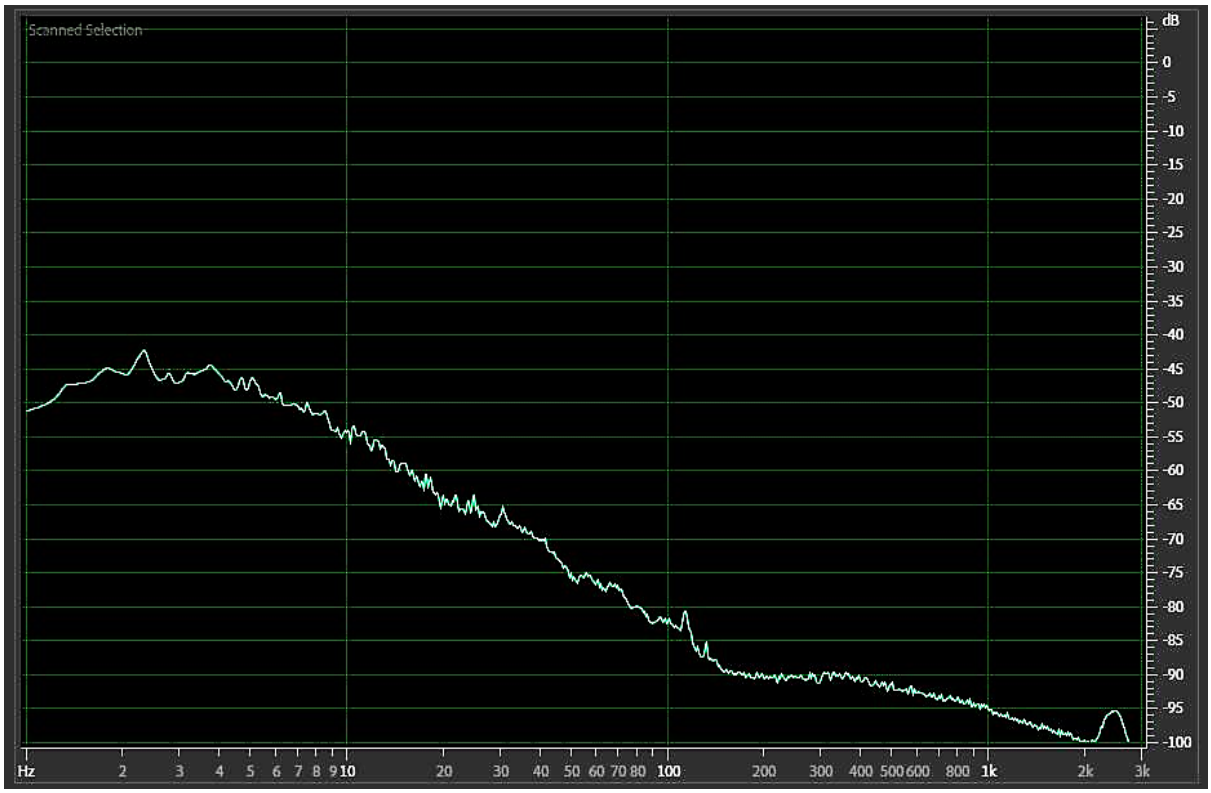


Chart 4: ML3 Outdoor sound levels, complaints of noise, 020590am, 19 July 2018



Examples: Amplitude Modulation

A test for amplitude modulation follows applying what is known as the 'Conditions 20-21' approach, referenced later in this section. Analysis of the 100ms LAeq sound levels for the outdoor microphone at ML1 provides the amplitude modulation data to 'Conditions 20-21', Table 1. The time period is for one (1) hour from midnight to 1am. The results indicate amplitude modulation is present for some of the time periods, Table 1 and Chart 1.

Table 1: Examples of 'Condition 20' analysis for ML1 on different dates

Date	Notes	LAeq Analysis	
		Condition 20 Exceeded?	Duration in hour (min)
May-17		Yes	28
May-21		No	1
May-25		No	0
Jun-04		No	0
Jun-08	No 100ms Data	No 100ms Data	
Jun-15	No 100ms Data	No 100ms Data	
Jul-07	No 100ms Data	No 100ms Data	
Jul-13	Quiet day/night	No	3
Jul-14	Quiet day/night	Yes	7
Jul-19	Complaints of noise	Yes	15
Jul-23	No 100ms Data	No 100ms Data	
Aug-07	Turbines not operating	No	2

This data is available in spreadsheet for a one-hour block of time (nominally midnight to 1am). The next chart presents a 10-minute block and shows considerable variation in the LAeq, 100ms sound levels. The criterion is a change in the measured LAeq, 125 milliseconds turbine noise level of more than 3 dB (represented as a rise and fall in sound energy levels each of more than 3 dB) occurring within a 2 second period. This is exceeded 3 times out of 12, or 25% of the observed time.

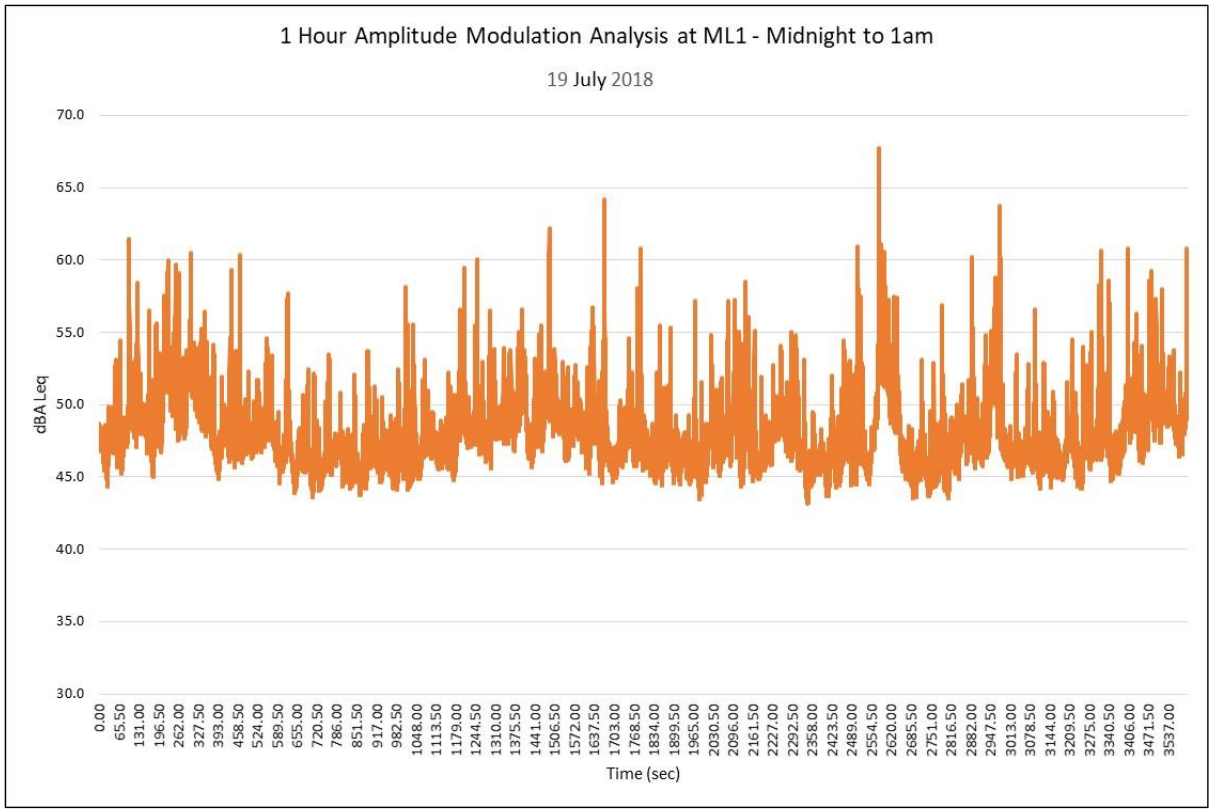


Chart 1: Amplitude modulation ML1, 19 July 2018, midnight to 1am

References

Analysis methods reviewed for this Report include:

Application of IEEE 2400-2016: EEE Standard for Wind Turbine Aero Acoustic Noise Measurement Techniques.

ANSI/ASA S12.9-2016/Part 7 Quantities and Procedures for Description and Measurement of Environmental Sound, Part 7: Measurement of Low-frequency Noise and Infrasound Outdoors and in the Presence of Wind and Indoors in Occupied Spaces

ISO 1996-2:2017 Acoustics — Description, measurement and assessment of environmental noise —Part 2: Determination of sound pressure levels.

This standard applies ISO/PAS 20065 Acoustics – Objective method for assessing the audibility of tones in noise. There appears to be considerable similarity with the method applied in the second edition (2007) of the standard. The 2007 standard has a validated process (Appendix C) and tested application software (Delta NoiseLab Pro). For this reason ISO 1996-2 (2007 Appendix C) is applied rather than ISO/PAS 20065.

Institute of Acoustics (UK) Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise.

Amplitude modulation

The UK Institute of Acoustics (IOA) amplitude modulation working group (AMWG) has developed a method for analysing and rating amplitude modulation (AM). This has been produced as an example of an implementation of the routine described in the IOA AMWG report. It is written in the Python language which is freely available. The program is known as 'the hybrid method'. However, the IOA states:

The responsibility for the correct implementation and application of the software or any modification thereof rests with the end user. It should not be taken as agreement from the IOA or the AMWG that any results produced by this code are recommended or agreed. The example software does not represent an analysis method and requires correct inputs parameters and data, and interpretation of the results. All users should have a suitable understanding of the IOA AMWG document on which this code is based.

The caveat means that this analysis and assessment method must be treated with caution.

ISO 12913-1 Acoustics-Soundscape-Part1: Definition and conceptual framework; and, ISO/DIS 12913-2 Acoustics-Soundscape-Part2: Data collection and reporting requirements

These two standards are essential standards for analysis of acoustic environments and the perception of sound.

Independent Noise Working Group (UK).

(UK) Wind Turbine Amplitude Modulation & Planning Control Study Work Package 8.1 Review of WSP/Parsons Brinckerhoff and Institute of Acoustics Amplitude Modulation Studies. 2017 Referenced to Mr L. Huson

Den Brook Amplitude Modulation "Conditions 20-21"

The Den Brook Amplitude Modulation Assessment is the outcome of in the Court of Appeal (Civil Division) on Appeal from the High Court of Justice, Queen's Bench Division Administrative Court [2010] EWHC 2386 (Admin) Neutral Citation Number: [2011] EWCA Civ 638 dated 26 May 2011 Case No: C1/2010/2166/QBACF

Environmental Protection Agency Victoria & Department of Planning and Community Development Draft Guidance – Wind Farm Noise Supplementary Guidance for NZ Standard 6808. This document, Draft 1 dated 16 May 2012, was prepared by K. Burgemeister and S. Chiles, Arup and URS. The document has not been made public. NMS has a copy.

Sound Quality Measures

Stationary loudness

Stationary loudness is an algorithm for steady-state noises, or signals that do not vary with time. This algorithm measures the 1/3 octave spectrum, combines the fractional-octave bands into critical bands, and then applies spectral masking. Stationary loudness is also known as ISO 532B loudness or Zwicker loudness and is in compliance with ISO 532B and DIN 45631.

Time-varying loudness

Time-varying loudness is an algorithm for calculating the loudness of non-steady-state noises, or signals that vary with time in compliance with DIN 45631/A or Glasberg & Moore.

Roughness

Roughness correlates to how noticeable or annoying a sound is as heard by the human ear. More specifically, roughness is a hearing sensation related to loudness modulations at frequencies too high to discern separately, such as modulation frequencies greater than 30 Hz.

Sharpness

Sharpness is a hearing sensation related to frequency and independent of loudness. Sharpness corresponds to the sensation of high-frequency sound and higher frequency components in the signal generally result in higher sharpness measurements.

Tonality

Tonality is used to determine whether a sound consists mainly of tonal components or broadband noise. There are a variety of algorithms to measures the relative strength or prominence of the tones in a signal compared to the overall signal

Fluctuation

Fluctuation strength is a hearing sensation related to loudness modulations at low frequencies that are discernable individually. Fluctuation strength uses a similar method to "roughness versus time" analysis except that it focuses specifically on signal variations with very low modulation frequencies. The algorithm examines modulations between 0 to 30 Hz, with special emphasis on those near 4 Hz.

Unbiased Annoyance

Zwicker's unbiased annoyance (UBA) is modified by Thorne [2007] as a primary measure for noise assessment. The modified unbiased annoyance UBA*m* measure applies loudness (N10 in sones), Aures sharpness (in acums) and a new approach to fluctuation by implementing Sethare's Tonal Dissonance, *TD(S)* in *sets*, to account for frequency as well as amplitude fluctuation. The UBA*m* measure has an effect on soundfile measured values by emphasising the contribution of dissonance and tonalness.

The calculation is given in 'intrusion units, *iu*':

$$UBAm = d(N10)^{1.3} \cdot \left\{1 + 0.25(S-1)\cdot \lg(N10+10) + 0.3TD(S)\cdot \frac{1+N10}{0.3+N10}\right\} \quad \text{iu}$$

Loudness (N10) is the loudness in sones which is exceeded for 10% of the time. (The exponent in the first expression is 1.3). UBA*m* is modified for night-time. The value of '*d*' in equation 1 for the day is 1, for night-time the value of $d = 1 + (N10/5)^{0.5}$.

Audibility

A method for the prediction of the audibility of noise sources is detailed in the report "Graphic Method for Predicting Audibility of Noise Sources" (1982) by Bolt, Beranek and Newman for the US Flight Dynamics Laboratory Air Force Systems Command, publication AFWAL – TR – 82 – 3086. The report provides technical rationale and relationships between signal-to-noise ratio and frequency that govern detectability of acoustic signals by human observers and provides methods to:

- Predict the frequency region of a spectrum that is most detectable in any given sound environment;
- Quantify the degree of detectability of the signal in question;
- Estimate reduction in signal-to-noise ratio necessary to render the signal undetectable.

Emerging Technology to Record Sleep Disturbance

A significant part of noise nuisance occurs with sleep disturbance. An emerging technology that records sleep disturbance is available in Apple Watch.

It may be beneficial for residents who experience episodic new and unusual changes in their heart rate, and sleep disturbance episodes, to consider using an Apple Watch to help them understand the pattern of sleep and heart rate associated symptoms they are experiencing. This physiological heart rate and sleep data is usefully collected when they are exposed to the noise, and in addition when they are not exposed (i.e. away from home or noise source turned off), for comparison. This data can be useful to educate health professionals as part of their clinical care.

Concurrent full spectrum acoustic monitoring, along with weather data, detailed individual environmental noise diaries kept by the residents can potentially be usefully augmented with this additional physiological data (heart rate and sleep patterns), although this data is not necessary for the establishment of noise nuisance.

A useful reference indicating that when tested, the Apple Watch showed acceptable accuracy (the patient group had cardiac disease, and they were tested during exercise).

https://www.ncbi.nlm.nih.gov/pubmed/30888332

Studies, Reports and Papers

Cooper Steven E. Cape Bridgewater Study and selected conference papers (sensation, amplitude modulation).

Huson L. Papers and Review. Infrasound analysis and associated issues.

Stigwood & Large. UK. Papers referring to amplitude modulation, SWF graphics

Hubbard, Shepherd, Stephens. NASA. Various papers

Moller et al. 2012. Assessment of low-frequency noise from wind turbines in Maastricht.

Evans T & Cooper J. 2015 Tonal noise from wind turbines.

Lenchine V. Various papers and SA guidelines

Van den Berg. Thesis and associated papers

Marshall Day Reports

- Bald Hills Wind Farm Noise Compliance Testing Plan dated 15 April 2015
- Bald Hills Wind Farm Assessment of Wind Farm Operational Noise 12 December 2016
  NOTE: MDA data filtering stated in section 4.6.2 and Table 9
- Bald Hills Wind Farm Assessment of Wind Farm Operational Noise Zakula 7 March 2017
- Bald Hills Wind Farm Assessment of Wind Farm Operational Noise 19 May 2017
- Bald Hills Wind Farm Attended Measurements: Test Plan 28 September 2017
- Bald Hills Wind Farm – Tenement Property B – Attended Measurements 15 August 2018
- EnviroRisk Noise Compliance Peer Review & Verification Bald Hill Wind Energy Facility June 2017
- EnviroRisk Peer Review: Tenement Property B-Attended Measurement Reports Bald Hill Wind Energy Facility August 2018
- L. Huson review dated 20 February 2017 of Bald Hills Wind Farm Assessment of Wind Farm Operational Noise 12 December 2016

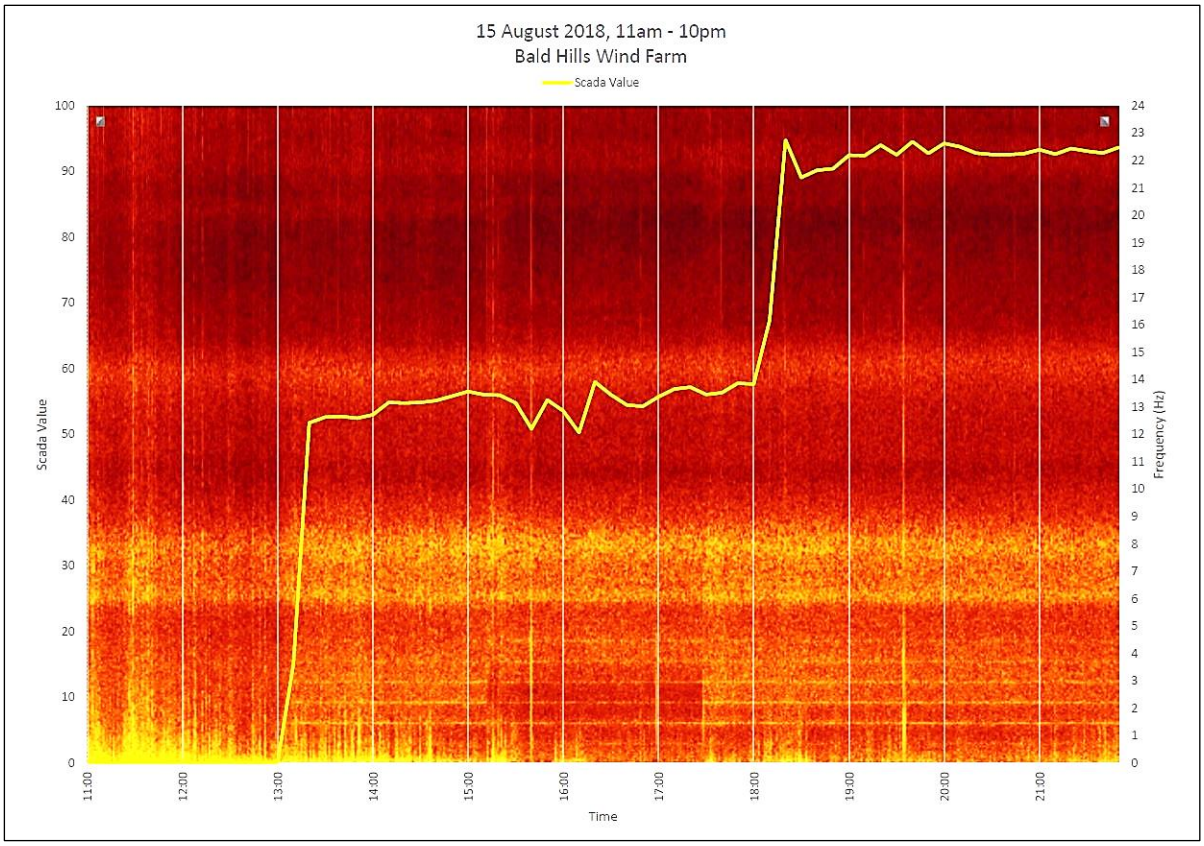
Appendix H. Infrasound

Measurement of infrasound was considered as part of the monitoring program. Infrasound sound levels inside and outside the home at ML1 have been recorded (Appendix G for indoor/ outdoor measurements, and this section for detailed indoor measurements). The charts show the distinctive infrasound signatures within a home:

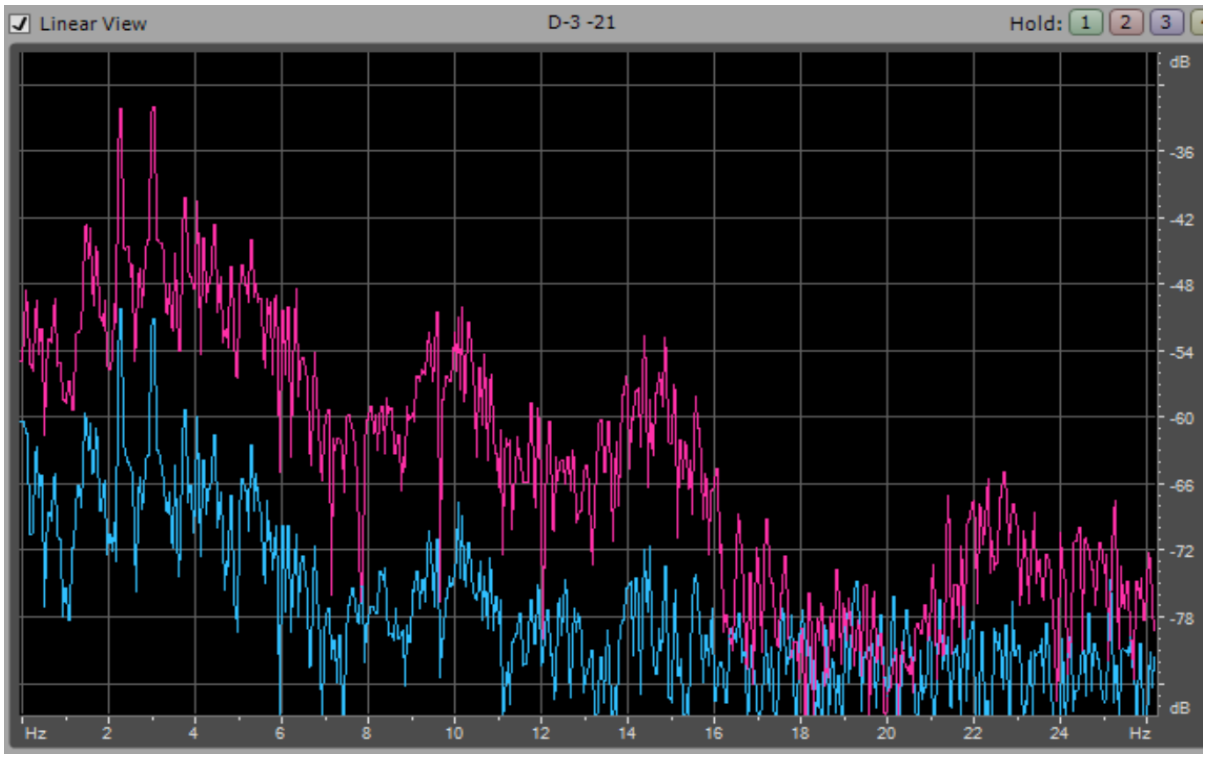
- to provide a comparison to the AEMO power generation data;
- to identify the infrasound signature of individual turbines in order to put in place the mitigation measures envisaged in Approval condition 22.

This section presents data from a specialised instrument, the Infrasound and Low Frequency Noise (ILFN) recorder, Model LHAInf2, serial number 17006. This model records two separate channels from a pressure transducer on the Left channel (of a stereo WAV file) and a microphone on the Right channel. Time is synchronised and location recorded via an inbuilt GPS. The data was calculated using SpectraPlus.

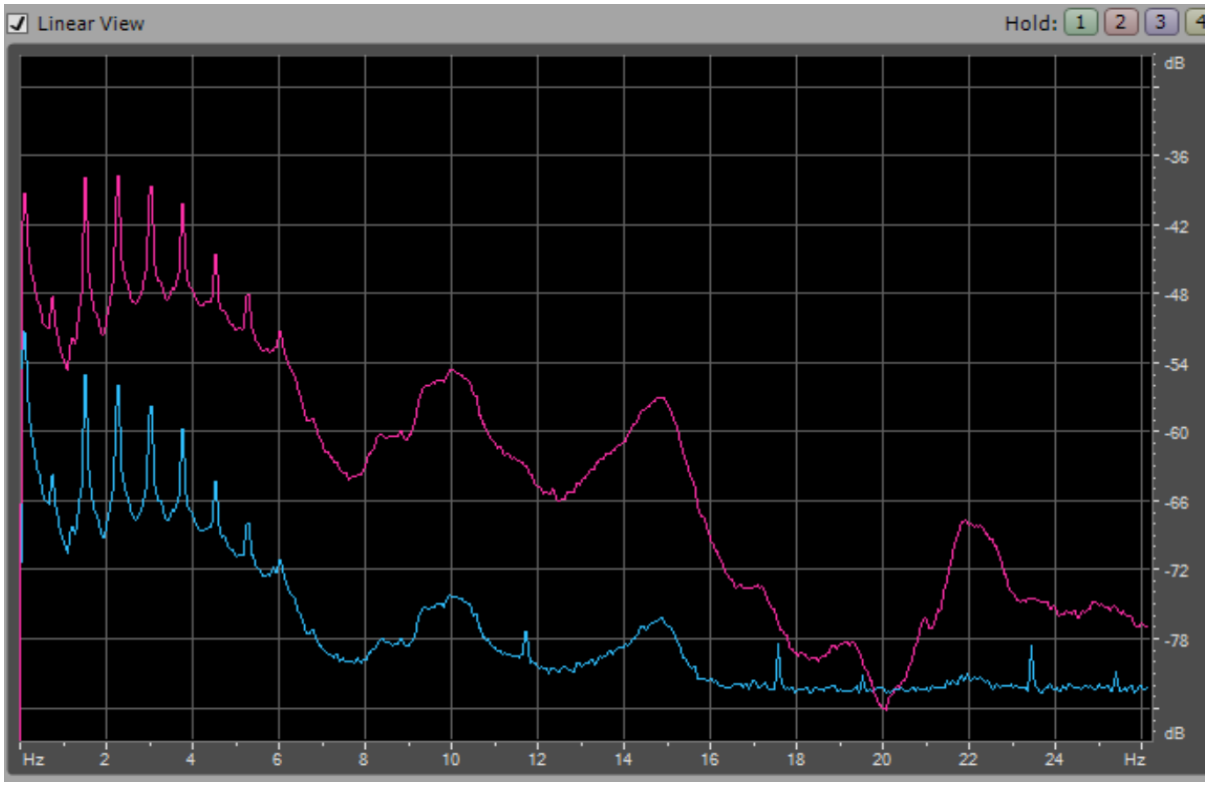
Example Set 1: The indoor file time starts at 11am 15Aug and ends 9pm. The logger ran from 7:20am on 7 August to 5:40am on 26 August. To calibrate add 94dB to Y-axis values. Blade pass harmonics are clearly visible after start-up (1.05pm) and the change in gear to higher power generation at 6.15pm. The SCADA power generation is overlaid to identify turbine activity.



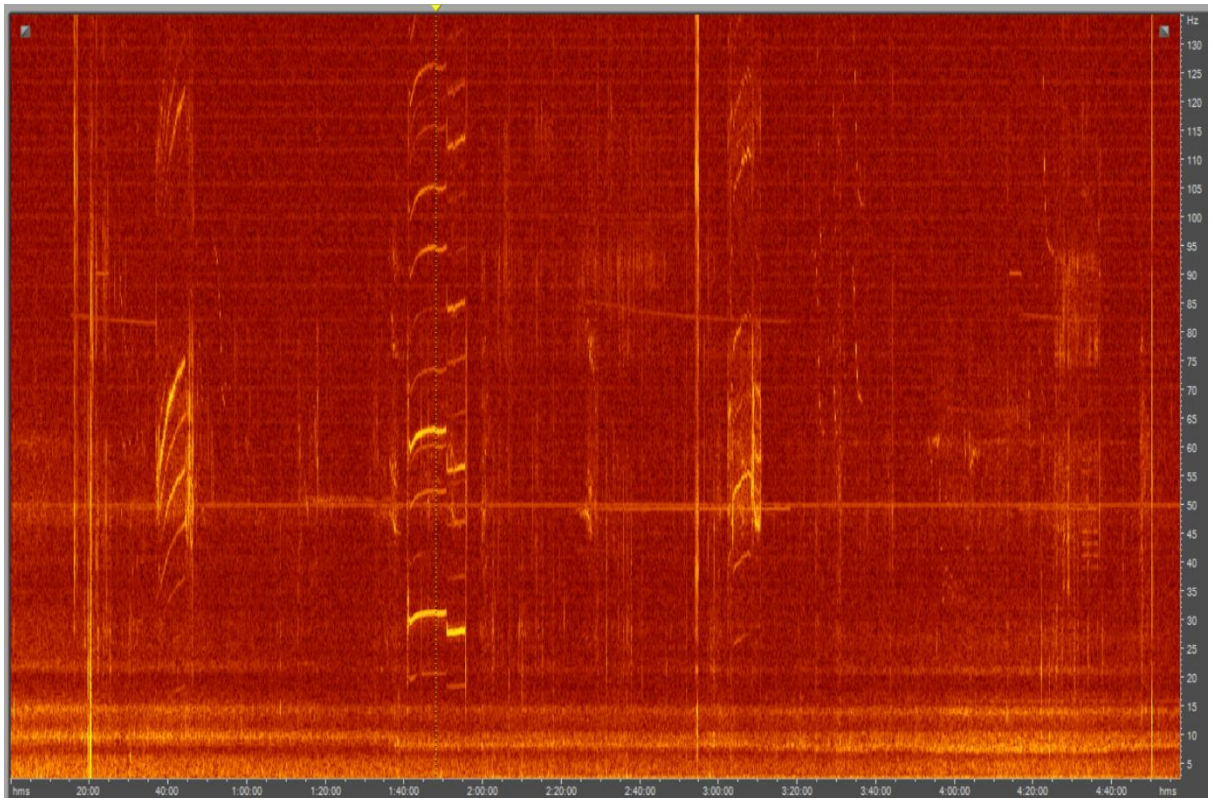
Example Set 2a: Max spectrum indoors around 4:30am 21/8/18 (AEST)
Red is for mic and blue for pressure sensor. Note that noise artefacts occur on both channels below -76dB in the charts.



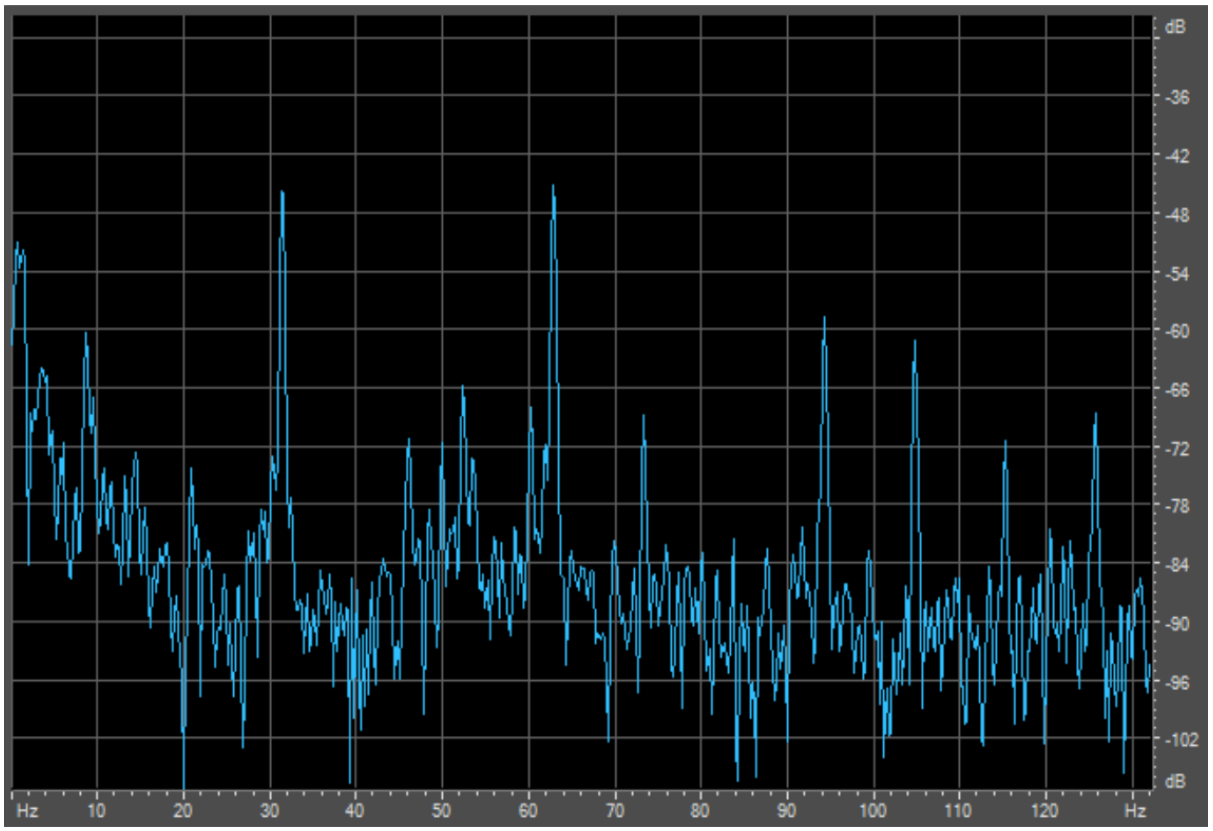
Example Set 2b: A 2 hour average spectrum indoors from 3am to 5am on 21/8/18 (AEST):
Red is for mic and blue for pressure sensor. Note that noise artefacts occur on both channels below -76dB in the charts.



Example 3a: A spectrogram from audiofile 1808230000.lh2 indoors covering 5 hours from 10am to 3pm 23/08/2018. (Note: the time scale is set to the 5 hours). To calibrate add 94dB to Y-axis values.



Example 3b: The indoors spectrum at about 1:47pm shows the character of the signal in more detail.



The two examples following for 21 August 2018 were calculated using SpectraPlus. Analysis is by the mic channel (right) for spectrum levels starting at 0.1Hz. Spectrum resolution chosen was 0.061Hz.

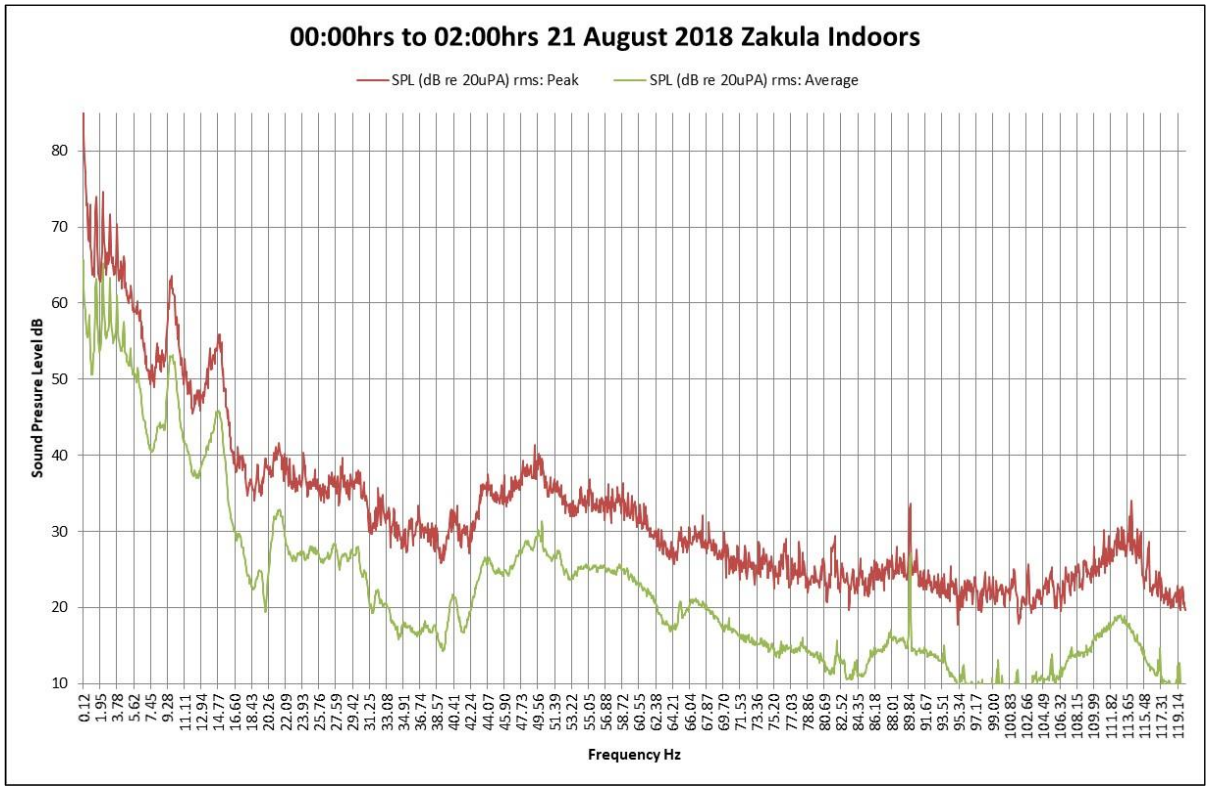


Figure 4a: ChMicCal 0.12Hz to 119.14Hz, midnight to 2am, indoors

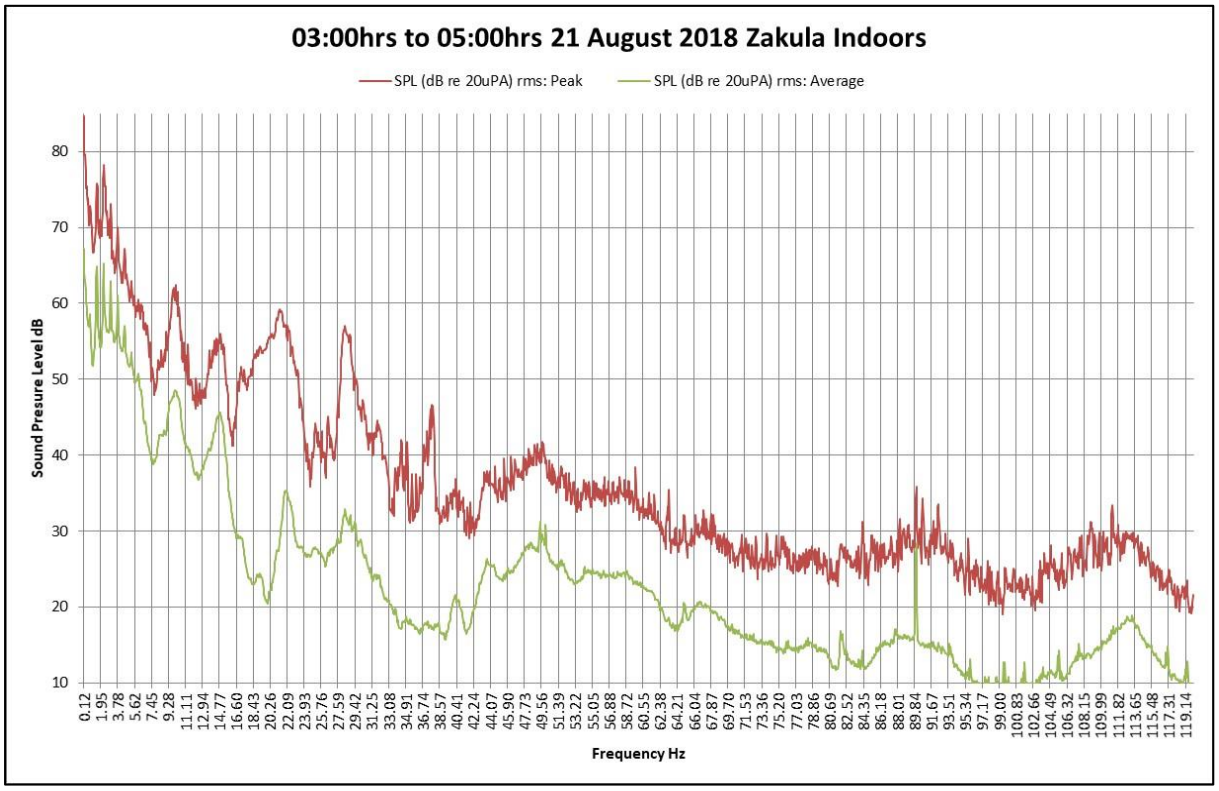


Figure 4b: ChMicCal 0.12Hz to 119.14Hz, 3am to 5am, indoors

Appendix I: AEMO – Wind Farm Power Generation Data

Analysis of the wind farm activity depends on knowing when the wind farm was producing power. Power stations provide their generation data to the Australian Energy Market Operator (AEMO). The advice and assistance of Mr Paul Miskelly in preparing the AEMO-derived datasets for the monitoring is acknowledged with appreciation.

The wind farm power generation datasets for this Report are extracted from the AEMO data by Mr Paul Miskelly (*see also Aneroid https://anero.id/energy/wind-energy*).

- The PSAC responses are observed to occur when the power generation is reaching or at near maximum output.
- A pattern of higher or "increases" in the background levels vs higher power output is observed as being a regular pattern over May to November.

Miskelly (2012) published a paper detailing an analysis of the performance of the then combined total number of wind farms on the Eastern Australian grid.

The analysis showed that the total output for all the wind farms connected to that grid was:

- extremely variable, demonstrating frequent drops to extremely low values;
- even though there is now over 6000 MW of installed wind generation capacity, this unpredictable, highly variable, and frequent virtual total dropout pattern continues.

To view the current behaviour of the total wind generation, perhaps the simplest way to go about it is to view the links below the heading "Monthly Wind Power Graphs" at: https://anero.id/energy/wind-energy.

The output of the wind generators, both individually and collectively, may be viewed in this month-length form at this site for each and every month from the current month all the way back to early 2014. As a first example, one might view: https://anero.id/energy/wind-energy/2019/may

The resulting chart is presented here as Figure AI-1, titled "Wind Eenrgy Production During May 2019".

Selecting the "MW" button at the top-right-hand corner of the chart entitled, "Wind Energy Production during May 2019", the many dips in the total wind generation output (solid black line) during the month may be viewed directly.

To view the output for any other month during the period spanning back to early 2014, the viewer need merely substitute for the year and month in the above link. For example, one might view the output for, say, September 2016, by choosing the link address:

https://anero.id/energy/wind-energy/2016/september will show this data for that particular month.

For residents dealing with the vagaries of neighbouring wind farms its displays of up to near-current times, and of historical data going back to early 2014, or since commencement of wind farm operation, whichever is the shorter, this is an extremely valuable site. It provides a check on the claims made by both wind farm owners and the relevant State authorities as to the behaviour of any particular wind farm at any given time.

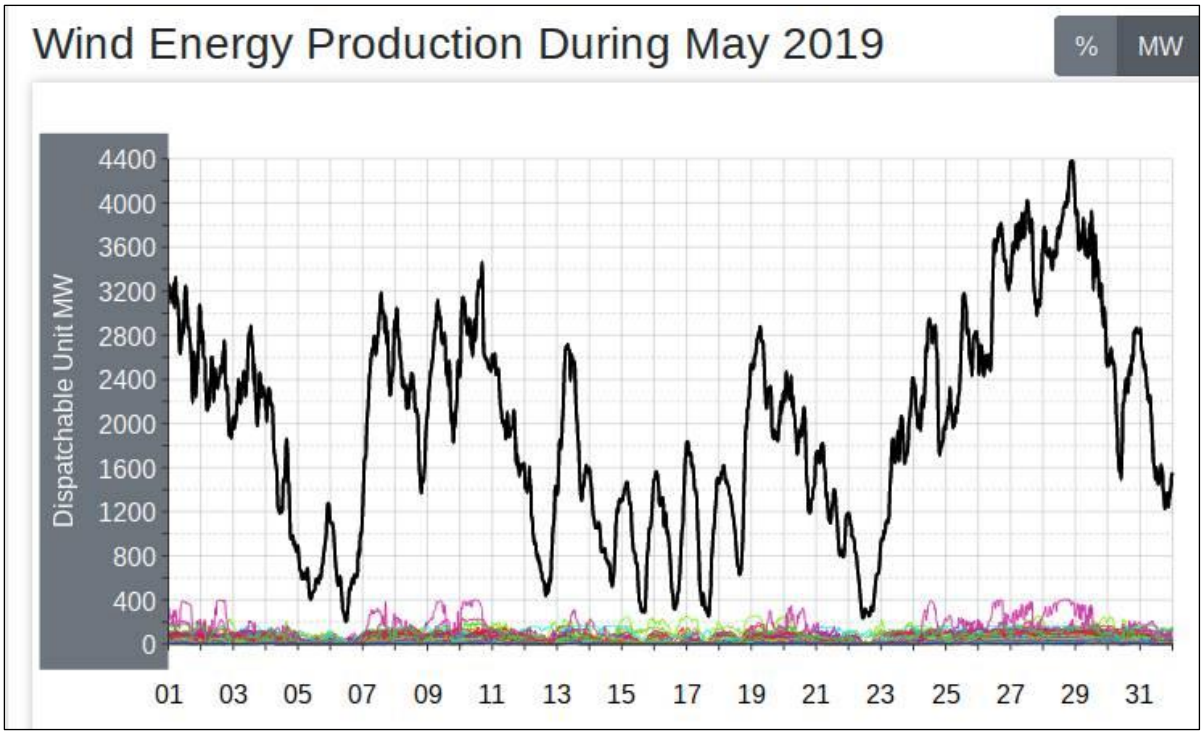


Figure AI-1 Showing Total Wind Farm Output (Megawatts) on the Eastern Australian Grid for May 2019. The extent of the variability (extreme), and the number of dropouts to near-zero is clearly indicated by the black line

Examination of the wind data for other months, whether for 2019 or any other of the years for which the data is available, will show that there are many other months that show a similar pattern to the total wind farm output, that is, being highly variable and showing, similarly, frequent dips towards zero output.

The links below the https://anero.id/energy/ link at the https://anero.id/ site may also be interrogated for the outputs of any of the other types of generators connected to the Eastern

Australian grid, (classified as fossil, hydro, renewable, solar or rooftop solar energy), for presentation in a similar monthly form, in a similar fashion, or for presentation by day as well.

Summary

The intention of this presentation is both to display the intrinsic performance of the wind farm fleet, and to demonstrate a few of the many useful attributes of the https://anero.id/energy site in displaying AEMO generator data.

This by-the-month display of total wind generation output demonstrates the inherent extremely large variability in total wind output, and the frequency with which it dives towards zero. This variability of wind generation ought to be given consideration when assessing any noise impact on residents whose properties are adjacent to a given wind farm.

Reference

Miskelly P 2012 *Wind Farms in Eastern Australia – Recent Lessons* Energy & Environment Vol 23 #12 pp 1233-1260. Available from the publisher on-line (free to download) at: https://journals.sagepub.com/doi/abs/10.1260/0958-305X.23.8.1233 . (Most recent access: 12 June 2019.)

AEMO References

The Australian Energy Market Operator (AEMO) provides regular power generation data for power generators. The generation data is summarized on the Aneroid website:
https://anero.id/energy/wind-energy

The following information for the Bald Hills reports has been made available by Mr Paul Miskelly. Data is saved as eastern standard time, not daylight saving time. The analysis datafiles are adjusted for daylight saving.

> *From the AEMO document titled:* ***Dispatch***
> *Available as:*
> *https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Procedures/SO_OP_3705---Dispatch.pdf*
> *Last accessed: 14 August 2018.*
>
> *From the Glossary of Terms table on pdf page 7:*
> *SCADA Supervisory Control and Data Acquisition*

So, there is the meaning of the term "SCADA" in Dispatch_SCADA: it refers to the data collection instrumentation used to measure the relevant electrical data of the electricity grid systems.

From the AEMO document entitled: MMS DATA MODEL
Available at:
https://www.aemo.com.au/-/media/Files/Electricity/NEM/IT-Systems-and-Change/MMS-Data-Model-Report.pdf .
Last accessed: 14 August 2018.

On Page 170 there is a description of the Dispatch_SCADA information. This page is reproduced as the next page here.

- *Note that under the "Comment" heading of the table of "Section 11.12.6" below, the Dispatch_SCADA value is defined as: "Instantaneous MW reading from SCADA at the start of the Dispatch interval"*
- *This would seem to comprise a complete definition of the meaning of the figure in this column of each line of data.*
- *The unit "MW" is the standard SI unit for power: megawatts.*
- *So, the definition above may be interpreted to mean, in the context of the Bald Hills Wind Farm:*
- *The numerical value given in the column headed "SCADAVALUE", that is, the rightmost column of any set of the performance data is the power output in megawatts (MW) at the time instant indicated by the date-time stamp in the entry on the line in the column headed "SETTLEMENTDATE".*

So, we can say that this value is the power output in megawatts at the beginning of each 5-minute interval, at the time indicated by its date-time stamp.

11.12 Table: DISPATCH_UNIT_SCADA

11.12.1 DISPATCH_UNIT_SCADA

Name DISPATCH_UNIT_SCADA

Comment. Dispatchable unit MW from SCADA at the start of the dispatch interval. The table includes all scheduled and semi-scheduled (and non-scheduled units where SCADA is available)

11.12.2 Description

DISPATCH_UNIT_SCADA data is public data, and is available to all participants.

Source

DISPATCH_UNIT_SCADA shows data for every 5 minutes for all scheduled units

Volume

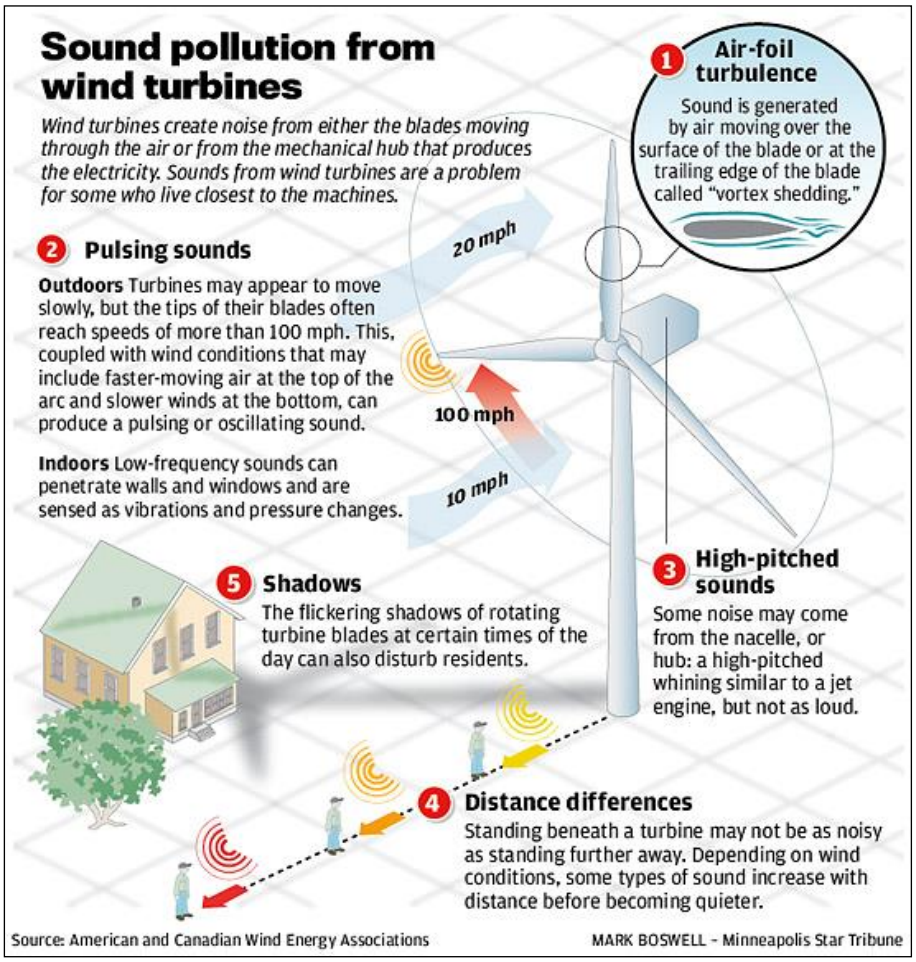
Rows per day: 288 per each scheduled, semi-scheduled (and non-scheduled unit where SCADA is available)

Appendix J: Noise from a Wind farm

Wind turbines are unique sources of noise.

The effects of the wind farm on the environment are illustrated as follows. Plate 1 illustrates the characteristics of a wind turbine. Plate 2 illustrates wind movement and turbulence through an offshore wind park. The effects illustrated apply to Bald Hills wind farm, the consideration of measured sound levels, and 'special audible characteristics'.

Plate 1: Noise generation from a wind turbine (with permission from M. Boswell)



As the turbine turns there are distinct changes in sound character that can be readily observed. These changes are due to the fact that the turbine has rotating blades and is, itself, required to rotate on its axis so it is always in a position to 'catch the wind'.

All of these sounds can be recorded as 'special audible characteristics'. Sound level changes occur as the blade comes down from top of its arc ('swish'); as it passes the tower ('thump'), and as it sheds air ('rumble, whoosh') on its upward/downward arcs and just past the tower. These characteristics change as the towers move into the wind or as they brake. The sound character as-heard depends on where the person is exposed to the sound. Sound from the

mechanical systems can be readily recorded as drones, hums, or tonal sounds, plus various clanks and clunks.

In a wind farm, the air flow from more than one turbine may interact with other turbines and sound can be enhanced due to the turbulence effects of one turbine affecting another turbine. This is illustrated in Plate 2, the off-shore turbines known as *Horns Rev1.*

Plate 2: Turbulence behind the Horns Rev1 wind farm under very humid conditions, 12 February 2008 at 1300 hours. (Photographer: Christian Steiness)

An effect that enhances potential noise, as observed by van den Berg,[1] is when two or more turbines are or nearly synchronous. The blade passing pulses coincide then go out of phase again. With exact synchronicity there is a fixed interference pattern, with near synchronicity synchronous arrival of pulses will change over time and place. Dr van den Berg notes that the relatively high annoyance level and characterisation of wind turbine sound such as swishing or beating may be explained by the increased fluctuation of the sound.

In a stable atmosphere van den Berg measured fluctuation levels of 4 to 6 dB for a single turbine. He observed that:

- *a turbine operating at high speed into a stable atmosphere can give rise to fluctuation increases in turbine sound power level of approximately 5 dB;*
- *fluctuations from 2 or more turbines may arrive simultaneously for a period of time and increase the sound power level by approximately 9 dB.*
- *In-phase beats caused by the interaction of several turbines increases the pulse height by 3 to 5 dB.*

[1] van den Berg, G. P., (2006). The Sounds of High Winds: the effect of atmospheric stability on wind turbine sound and microphone noise. Science Shop, Netherlands

The concept of Heightened Noise Zones[2] created when multiple wind turbines are in operation illustrates the complexity of sound from an operational wind farm. Multiple turbines present a cumulative and complex propagation effect that is observed in practice as a typical beating or modulating sound. This effect is not accounted for in noise prediction but is a reality that is directly affected by the design and operation of the wind farm (location and type of turbines, phase angles between blades) and wind conditions.

Heightened Noise Zones can be small in extent – even for low frequencies – leading to turbine sounds 'disappearing' and 'appearing' in areas spaced only a few metres apart. The background drops when in the trough between the crest of the Heightened Noise Zone levels. However, this effect can change quite quickly depending on wind direction, temperature conditions and turbine activity.

The attributes of Heightened Noise Zones – small size and dependence on time-related factors like wind direction – help to explain the variability of wind farm noise as heard by residents and the potential where some people may be adversely affected while others are not affected.

Observations from residents' record that 'pressure effects' and 'sensation effects' occur when the turbines are seen 'side-on' to the observer. The observation is also made that the air feels 'free' and 'clear' or 'clean' when the turbines are not operating. These are direct amenity effects.

Monitoring and Assessment of Noise from a Wind Farm

Monitoring and assessment of noise from a wind farm is unique because it is the sound of the turbines that must be determined. The metric applied for the Bald Hills Wind Farm, the background sound level, includes all sounds from all sources near and far.

Analysis of 'single-value' A-weighted background levels attributable in the presence of ambient background levels (the real world) is extremely difficult to impossible. The following figure, figure 6, illustrates the issue: there are 3 separate sets of background influencing sound sources – local ambient, the turbines, and distant sources. It is not possible to separate out the contribution of each source once it is recorded as a single-value background measure (LA95) at a specific location, such as a residence.

[2] From research by Astute Engineering, Palmerston North, New Zealand, by permission

By way of example, Figure 1, pour a glass of milk (noise specifically from wind farm activity) into a glass of water (the ambient sound around a residence). Add some orange juice for distant sound (wind in trees, distant water pumps, bird and animal noise, and so on) that affects the background. Now remove the milk. Difficult? Impossible.

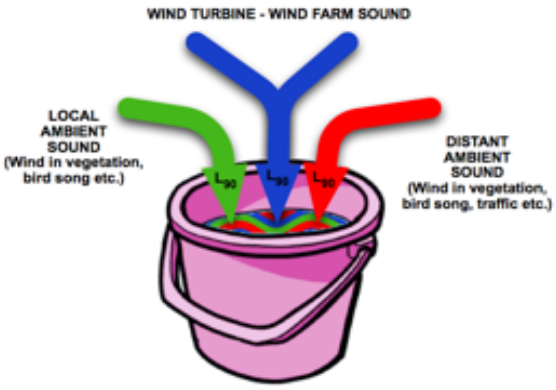


Figure 1: "Bucket of mixed sound" as L_{A95} level.

The three components are completely intermingled. Unfortunately the example holds true for whatever combination of 'single-value' acoustical descriptors are used to describe wind farm mixed with ambient sound levels.

The effect of this is to render compliance monitoring in real-time – using A-weighted sound levels alone – nearly irrelevant. There can be no certainty that the level measured is/was due to the wind farm. Obviously loud levels of sound from a wind farm may be measurable but still very difficult to prove as being the sole source of sound when mixed into sound from vegetation (wind in trees, for example).

The situation is even more difficult if the noise compliance conditions require the identification of 'special audible characteristics'. Application of this condition requires real-time observations or high-quality audio recording and analysis techniques plus correlation with real-time subjective responses by persons affected by the sound of the turbines.

Conversely, it is easy for people to hear wind farm noise within "ordinary" ambient sound.

Any 'compliance' report addressing Condition 19 of the BHWF Approval that fails to specifically address special audible characteristics and/or sleep disturbance as experienced by affected persons, and analysis of the '10% loudest' night-time sound levels, must itself be non-compliant.

Appendix K: WHO Guidelines for Wind Turbine Noise Assessment

WHO and wind turbine noise

The new guidelines conditionally set **45 Lden outside** as '… wind turbine noise above this level is associated with adverse health effects'.
For general night-time noise from all sources the table applies a level of 42 Ln outside as the 'observed effect threshold'.

Night-time Noise

The guideline does not address night-time noise. For guidance the 'older' *WHO 2009 Night Noise Guidelines for Europe* are applied. These state:

Effect		Indicator	Threshold, dB
Biological effects	Change in cardiovascular activity	*	*
	EEG awakening	$L_{Amax,outside}$	35
	Motility, onset of motility	$L_{Amax,outside}$	32
	Changes in duration of various stages of sleep, in sleep structure and fragmentation of sleep	$L_{Amax,outside}$	35
Sleep quality	Waking up in the night and/or too early in the morning	$L_{Amax,outside}$	42
	Prolongation of the sleep inception period, difficulty getting to sleep	*	*
	Sleep fragmentation, reduced sleeping time	*	*
	Increased average motility when sleeping	$L_{night, outside}$	42
Well-being	Self-reported sleep disturbance	$L_{night, outside}$	42
	Use of somnifacient drugs and sedatives	$L_{night, outside}$	40
Medical conditions	Environmental insomnia**	$L_{night, outside}$	42

Table 1 Summary of effects and threshold levels for effects where *sufficient* evidence is available

The level '42 Ln' is above which an effect starts to occur or shows itself to be dependent on the exposure level and is the threshold for the process of evaluating the health consequences of environmental exposure. The insulation applied means that the interior noise design level is 21 dB(A) at night.

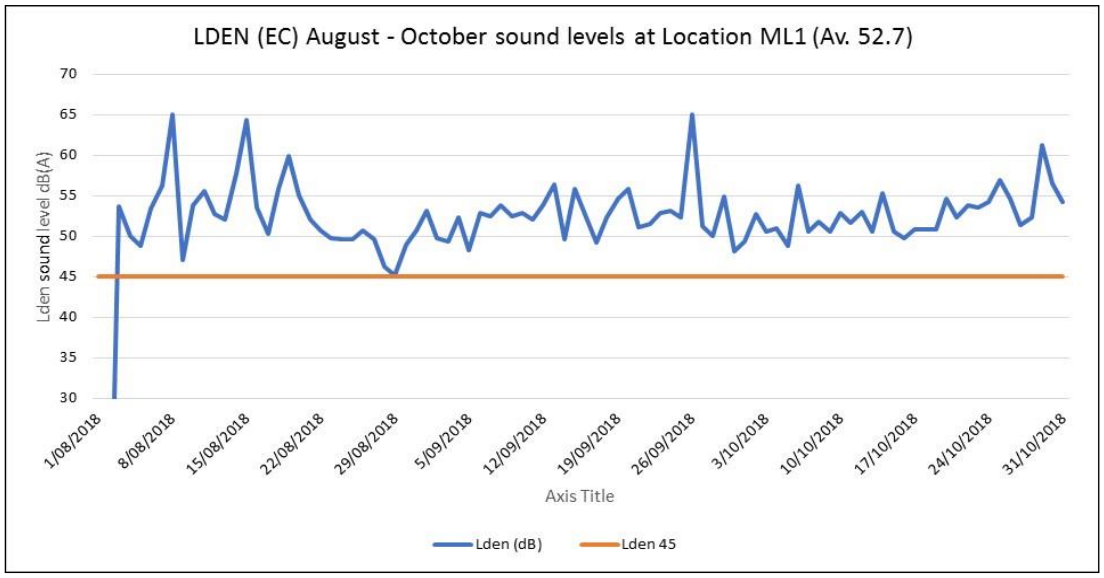
What is the Lden measure?

The selected common noise indicators are Lden, to assess annoyance, and Lnight, to assess sleep disturbance. The measures are 'long-term' or 'yearly' values and are applied broadly through a process of noise mapping and action plans that apply to all major urban areas in the EC. Noise is measured from all sources. At Bald Hills the wind farm is the only constant, dominant source of noise in the locale.

Both the Lden and Lnight measures are applied to give an indication of noise effects and guidance to whether the threshold values of 45 Lden and 42 Lnight are exceeded. The

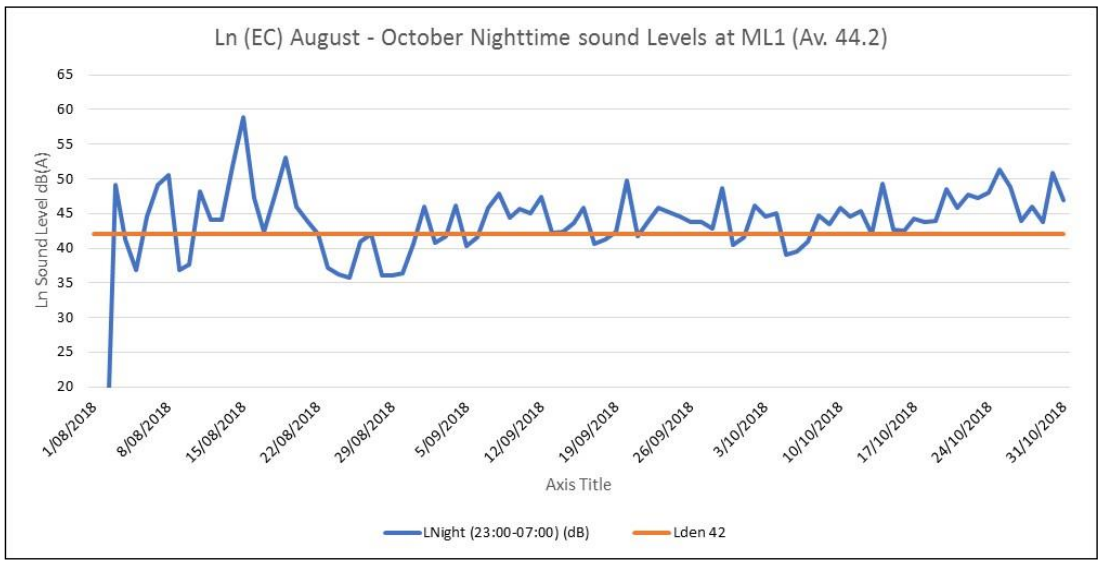
monitoring program at Bald Hills includes the sound levels needed to calculated the Lden and Lnight values. Charts 1 and 2 for the months of August to October, following, apply the measures calculated through the Larson Davis 'Noise Tutor' program installed at dwelling location ML1.

Chart 1: Lden for August to October at ML1



The wind farm was not operating over 2 August to 15 August. The average Lden sound level for the 3 months with this time excluded is is 52.4 dB(A) and 52.7 dB(A) with the "no activity" time included. This is 7 to 8 dB(A) over the guideline level.

Chart 2: Lnight for August to October at ML1



The wind farm was not operating over 2 August to 15 August. The average Lnight sound level for the 3 months with this time excluded is is 43.9 dB(A) and 44.2 dB(A) with the "no activity" time included. Either way this is 2 dB(A) over the guideline level.

Relationship of Lden to noise annoyance

The turbines are clearly audible during the day and at night. Complaints of annoyance and sleep disturbance are recorded mainly for the night-time. Application of the WHO – Lden – Lnight guidelines provide a method to assess amenity, adverse effects, and mitigation measures. The essential requirement is that the sound level and adverse sound character of the turbines operating at night must be reduced; that is, application of the concept of 'avoid-remedy-mitigate' based on best practice.

Apart from the WHO documents, noise annoyance due to wind turbines, in comparison with transportation noise, was reported in 2007 by Delta for the Danish Ministry of Science, Technology and Innovation in the report *The "Genlyd" Noise Annoyance Model.* Figure 22 from the report follows. Delta considers wind turbine noise to be significantly more annoying than transportation noise, for the same Lden values.

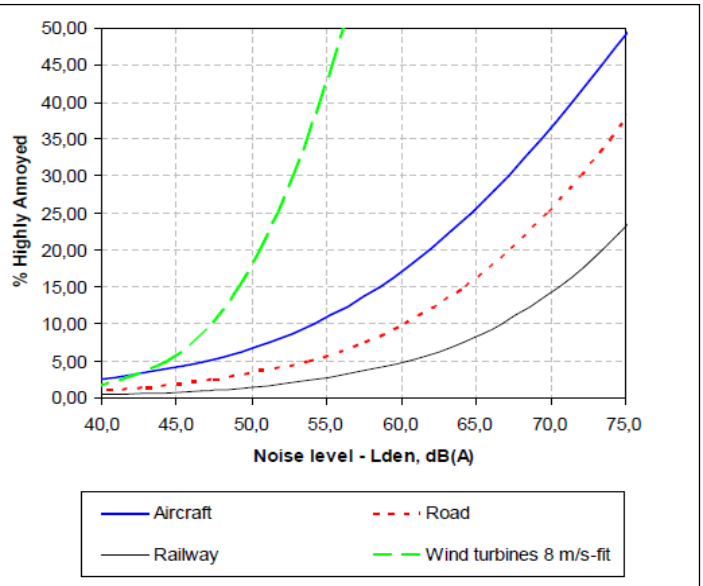


Figure 22
Norm curves (logistic approximation) for the relation between noise level(L_{den}) and % Highly Annoyed from [4]and [24] . The wind turbine data are found by combining data from [37] and [38] and correcting from L_{Aeq}-values to L_{den} by adding 6.4 dB to the L_{Aeq}.

In relation to sound character – a critical component in sound perception, intrusion and annoyance - the WHO Guidelines state:

> *The noise emitted from wind turbines has other characteristics, including the repetitive nature of the sound of the rotating blades and atmospheric influence leading to a variability of amplitude modulation, which can be a source of above average annoyance (Schäffer et al., 2016). This differentiates it from noise from other sources and has not always been properly characterized. Standard methods of measuring sound, most commonly including A-weighting, may not capture the low-frequency sound and*

amplitude modulation characteristic of wind turbine noise (Council of Canadian Academies, 2015).

Discussion: Applying Lden as a design tool for noise mitigation

Application of the Lden outside and Lnight outside criteria indicate:

- Assuming an average Lden value of 52.7 dB(A) and a "target" level of 45 dB(A), the wind farm needs to reduce its Lden sound emissions by 7 to 8 dB(A) at ML1.
- Genlyd 'Figure 22' indicates that the person at ML1 is at high risk of being 'highly annoyed'.
- Night-time sound emissions from the wind farm need to be reduced by at least 6 dB(A) to achieve the WHO guideline value of 21 d(A) Lnight within a home.

The Lden calculations indicate that the wind farm needs to reduce overall sound emissions by 8 dB(A) during the day. Daytime sound levels are not normally identified by the residents as being of concern – whereas night-time sound levels are a consistent source of annoyance and sleep disturbance. A different control measure for daytime may be acceptable.

Addition of the 6 dB(A) night-time sound level reduction, plus the 5 dB(A) penalty, indicates an overall reduction of 11 dB(A) at night.

The only way the wind farm can reduce sound emissions by 11 dB(A) during the night is to ensure all turbines are switched off.

Appendix L. Analysis of Special Audible Characteristics (SACs) to sound levels, atmospheric stability classes and SCADA values

Dr Daniel Shepherd has prepared an assessment of the relationship between SAC responses, sound levels, atmospheric stability classes and SCADA values for daytime and nighttime 10 May to 23 September 2018. This relationship is an evidential methodology to assess Condition 22 and wind farm operation generally for assessment of compliance or non-compliance with Condition 19 and potential for nuisance conditions.

Daniel reports his findings:

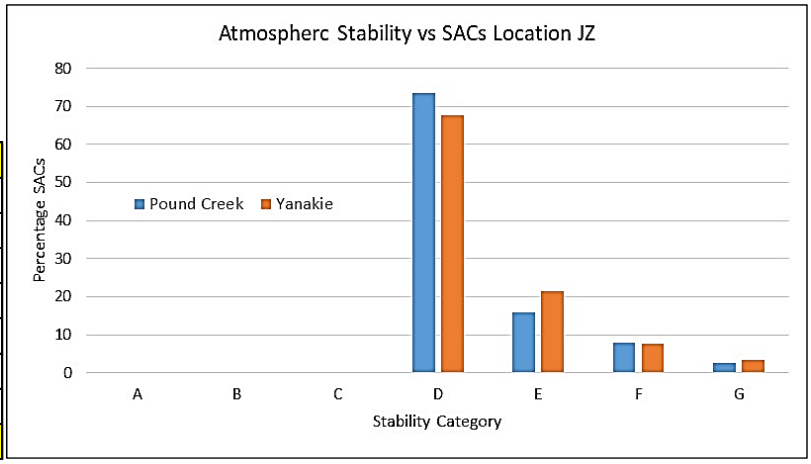
> *The preliminary analysis determined that participant report of special audible characteristics (SACs) was linked to atmospheric stability classes obtained from the Pound Creek and Yanakie measuring sites.*
>
> - *Specifically, the category D stability class was, proportionally, more likely to be associated with reports of SACs, while category E was also prominent.*
> - *These associations were found to be statistically significant when the data were subjected to statistical testing.*
> - *Stability, in turn, was associated with noise level, though interestingly reports of SACs were not especially well predicted by noise level, suggesting a dose-response relationship between noise level and SAC detection is not present.*
> - *SCADA values predicted SACs, even though SCADA values are strongly linked to noise levels.*
> - *Associations between wind direction and noise levels vary depending upon measuring location, and a violation* of statistical assumptions likely explain the pattern of correlations here.*
> - *Finally, wind speed is strongly related to noise levels.*
>
> *(Note*: The correlation coefficient assumes a linear relationship between two variables. The 360 degree of direction might confound that slightly, or not).*

The atmospheric stability classes referred to are recorded in part in Appendix E by Geoff Clark, meteorologist. SCADA values are the wind farm power output data recorded by Paul Miskelly, Appendix I and analysis charts within this report. Sound levels are the background (LA95) sound levels recorded at various residences near to the wind farm.

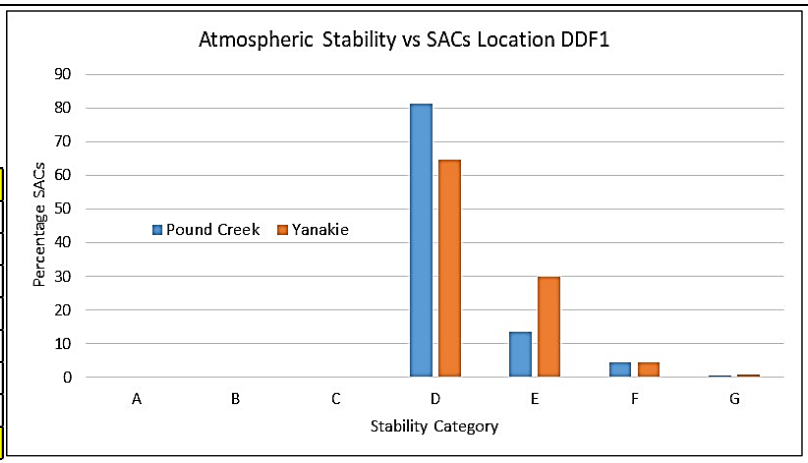
The following charts are linked to the Pound Creek (PC) and Yanakie BOM weather data, with the residents identified by their initials (e.g. ‘JZ’).

1) SACs are linked to atmospheric stability:

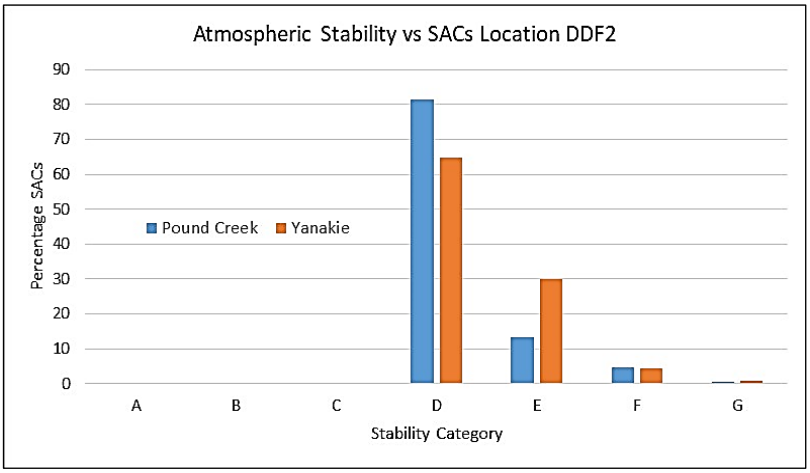
JZ	Pound Creek	Yanakie
A	0	0
B	0	0
C	0	0
D	73.4	67.8
E	15.8	21.4
F	8	7.5
G	2.7	3.3
Total (%):	**99.9**	**100**



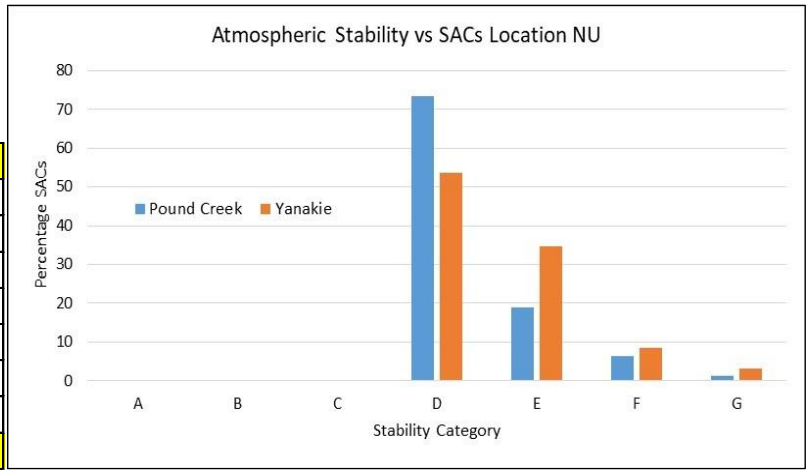
DDF_1	Pound Creek	Yanakie
A	0	0
B	0	0
C	0	0
D	81.4	64.8
E	13.4	30
F	4.6	4.5
G	0.6	0.8
Total (%):	**100**	**100.1**



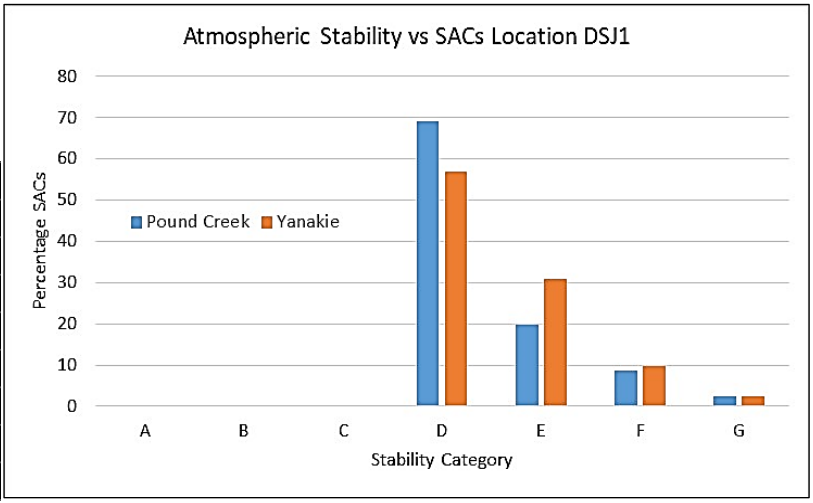
DDF_2	Pound Creek	Yanakie
A	0	0
B	0	0
C	0	0
D	81.4	64.8
E	13.4	30
F	4.6	4.5
G	0.6	0.8
Total (%):	**100**	**100.1**



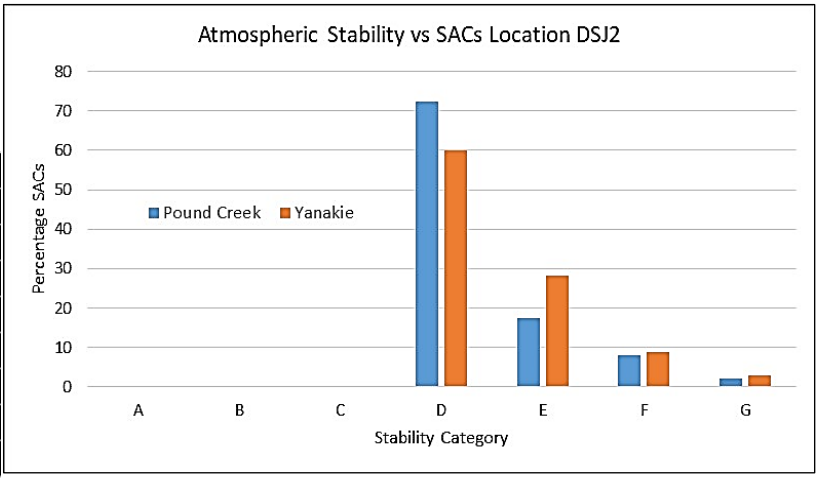
NU	Pound Creek	Yanakie
A	0	0
B	0	0
C	0	0
D	73.4	53.5
E	18.9	34.7
F	6.5	8.6
G	1.3	3.3
Total (%):	**100.1**	**100.1**



DSJ_1	Pound Creek	Yanakie
A	0	0
B	0	0
C	0	0
D	69.2	57
E	19.8	31
F	8.6	9.7
G	2.4	2.3
Total (%):	**100**	**100**



DSJ_2	Pound Creek	Yanakie
A	0	0
B	0	0
C	0	0
D	72.4	59.9
E	17.5	28.3
F	8	8.9
G	2.1	2.9
Total (%):	**100**	**100**



2) SACs are associated with noise levels, but while the effects are statistically significant, the differences in average values are minimal, for example (JZ):

Group Statistics

	PSAC1_JZ	N	Mean	Std. Deviation	Std. Error Mean
ML1LA95	No	16986	35.4	7.2	.0555
	Yes	2520	36.1	7.6	.1523
ML2LA95	No	14471	37.4	7.8	.0648
	Yes	1980	39.4	6.8	.1519
ML3LA95	No	17202	36.4	7.4	.0567
	Yes	2520	38.1	7.1	.1412
ML4LA95	No	5919	35.8	6.4	.0835
	Yes	900	37.1	5.6	.1856

Note:
"Yes" means that SACs can be heard; "No" means that SCAs were not heard;
N= number of sound levels reported; Mean = mean sound level;
Std deviation = 68% standard error of mean

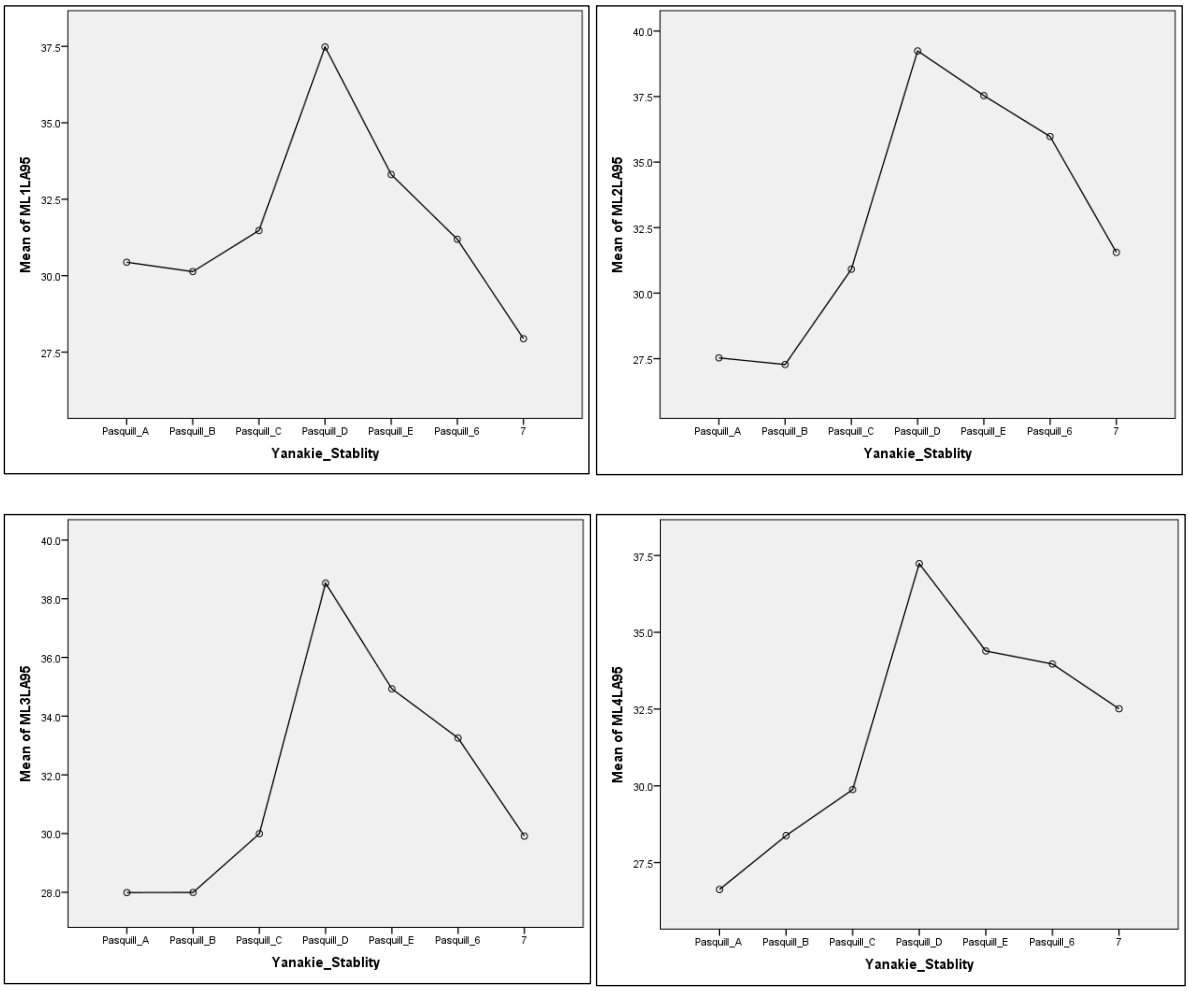
3) Statistically, noise levels are associated with stability.

Four statistical tests were undertaken, one each for measuring station (left column). In the final column, the significance (Sig.) value indicates if statistically significant differences exist across the stability categories for that noise location. For example, stability values estimated at Yanakie:

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
ML1LA95	Between Groups	133434.122	6	22239.020	510.424	≤.001
	Within Groups	806300.602	18506	43.570		
	Total	939734.724	18512			
ML2LA95	Between Groups	90205.477	6	15034.246	298.021	≤.001
	Within Groups	787577.415	15612	50.447		
	Total	877782.892	15618			
ML3LA95	Between Groups	138086.038	6	23014.340	500.016	≤.001
	Within Groups	861722.197	18722	46.027		
	Total	999808.234	18728			
ML4LA95	Between Groups	28393.556	6	4732.259	134.707	≤.001
	Within Groups	231612.663	6593	35.130		
	Total	260006.218	6599			

Charts ML1 to ML4: Sound levels vs Atmospheric stability



4) SACs are strongly related to SCADA values.

For example, comparing mean SCADA values for JZ when (Yes) and when not (No) SACs were audible.

Group Statistics

	PSAC1_JZ	N	Mean	Std. Deviation	Std. Error Mean
ML1_Scada	No	17208	38.5	37.7	.287
	Yes	2520	58.0	35.2	.702

5) SACs are weakly related to wind direction.

For example, comparing mean direction values for JZ when (Yes) and when not (No) SACs were audible.

Group Statistics

	PSAC1_JZ	N	Mean	Std. Deviation	Std. Error Mean
PC_Direction	No	17208	221.5	125.5	.957
	Yes	2520	237.4	124.8	2.487
Yanakie_Direction	No	17208	214.7	114.8	.875
	Yes	2520	232.4	112.4	2.240
Huson_Direction	No	17208	578.0	393.3	2.998
	Yes	2520	545.9	376.5	7.501
ML1_Wind_Dir_Recode	No	10342	107.2	118.7	1.16718
	Yes	1393	109.5	125.1	3.35100

6) SCADA values are correlated to noise levels.

Pearson Correlation values range from -1.0 to 1.0, with a value of, or close to, zero indicating no relationship between SCADA values and noise levels. Considering statistical significance (Sig.), the superscript asterisks (**) indicate that a given Pearson Correlation value is significant.

Correlations

		ML1LA95	ML2LA95	ML3LA95	ML4LA95	ML1_Scada
ML1LA95	Pearson Correlation		.843**	.865**	.765**	.602**
	N	19506	16300	19500	6675	19506
ML2LA95	Pearson Correlation	.843**		.900**	.864**	.549**
	N	16300	16451	16446	6819	16451
ML3LA95	Pearson Correlation	.865**	.900**		.892**	.580**
	N	19500	16446	19722	6819	19722
ML4LA95	Pearson Correlation	.765**	.864**	.892**		.398**
	N	6675	6819	6819	6819	6819
ML1_Scada	Pearson Correlation	.602**	.549**	.580**	.398**	
	N	19506	16451	19722	6819	19728

**. Correlation is significant at the 0.01 level.

7) Wind direction is sometimes strongly correlated to noise levels.

Pearson Correlation values range from -1.0 to 1.0, with a value of, or close to, zero indicating no relationship between SCADA values and noise levels. Considering statistical significance (Sig.), the superscript asterisks (* and **) indicate that a given Pearson Correlation value is significant.

		ML1 LA95	ML2 LA95	ML3 LA95	ML4 LA95	PC Direction	Yanakie Direction	Huson Direction	ML1 WindDir
ML1LA95	Pearson		.843**	.865**	.765**	.407**	.457**	.056**	.067**
	N	19506	16300	19500	6675	19506	19506	19506	11660
ML2LA95	Pearson	.843**		.900**	.864**	.363**	.408**	.102**	.054**
	N	16300	16451	16446	6819	16451	16451	16451	9026
ML3LA95	Pearson	.865**	.900**		.892**	.451**	.498**	.171**	.067**
	N	19500	16446	19722	6819	19722	19722	19722	11729
ML4LA95	Pearson	.765**	.864**	.892**		.240**	.311**	.248**	-.024
	N	6675	6819	6819	6819	6819	6819	6819	2750
PC_Direction	Pearson	.407**	.363**	.451**	.240**		.668**	.161**	.082**
	N	19506	16451	19722	6819	19728	19728	19728	11735
Yanakie_ Direction	Pearson	.457**	.408**	.498**	.311**	.668**		.155**	.081**
	N	19506	16451	19722	6819	19728	19728	19728	11735
Huson_ Direction	Pearson	.056**	.102**	.171**	.248**	.161**	.155**		.016*
	N	19506	16451	19722	6819	19728	19728	19728	11735
ML1_Wind_ Dir_Recode	Pearson	.067**	.054**	.067**	-.024	.082**	.081**	.016*	
	N	11660	9026	11729	2750	11735	11735	11735	11735

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level.

8) As expected, wind speed is strongly correlated to noise levels:

Pearson Correlation values range from -1.0 to 1.0, with a value of, or close to, zero indicating no relationship between SCADA values and noise levels. Considering statistical significance (Sig.), the superscript asterisks (**) indicate that a given Pearson Correlation value is significant.

		ML1 LA95	ML2 LA95	ML3 LA95	ML4 LA95	PC_ Speed	Yanakie Speed	Huson_ Speed	ML1_ Speed
ML1LA95	Pearson		.843**	.865**	.765**	.708**	.772**	.672**	.731**
	N	19506	16300	19500	6675	19506	19506	10602	14817
ML2LA95	Pearson	.843**		.900**	.864**	.585**	.662**	.537**	.598**
	N	16300	16451	16446	6819	16451	16451	7547	11618
ML3LA95	Pearson	.865**	.900**		.892**	.657**	.733**	.638**	.732**
	N	19500	16446	19722	6819	19722	19722	10817	14889
ML4LA95	Pearson	.765**	.864**	.892**		.579**	.668**	.599**	.659**
	N	6675	6819	6819	6819	6819	6819	6704	3363
PC_Spee	Pearson	.708**	.585**	.657**	.579**		.813**	.810**	.687**
	N	19506	16451	19722	6819	19728	19728	10817	14895
Yanakie_	Pearson	.772**	.662**	.733**	.668**	.813**		.834**	.701**
peed	N	19506	16451	19722	6819	19728	19728	10817	14895
Huson_	Pearson	.672**	.537**	.638**	.599**	.810**	.834**		.862**
peed	N	10602	7547	10817	6704	10817	10817	10817	7365
ML1_	Pearson	.731**	.598**	.732**	.659**	.687**	.701**	.862**	
peed	N	14817	11618	14889	3363	14895	14895	7365	14895

*. Correlation is significant at the 0.01 level.

Appendix M: Wind Farm Noise - Potential for Adverse Health Effects

NZS6808 clearly states that sleep disturbance is an issue. Turbine noise can lead directly to annoyance and sleep disturbance (primary health effects), or can induce annoyance by degrading amenity. The secondary health effects include immediate reductions in general well-being, with stress-related disease emerging from chronic annoyance and sleep disturbance.

The effect of noise on health, and on wind turbine noise on health, was fully canvassed in the case *Waubra Foundation v Australian Charities and Not-for-profits Commission* before the Administrative Appeals Tribunal (AAT) in Adelaide, with the decision handed down on 4 December 2017. The full decision can be found at:
https://www.acnc.gov.au/ACNC/Comms/LN/LN_20171204.aspx

Significant findings from the Decision are:

> *473. The applicant submitted that the evidence in the hearing provided plausible and credible evidence of the kind required. Counsel referred in particular to the effect of noise on sleep and, in particular, in disturbing sleep. It was not contentious that impaired sleep, if sufficiently serious, may result in a number of ailments and diseases. Professor Wittert said that "depression and sleep disturbance are, respectively, the first and third most common psychological reasons for patient encounters in general practice". The professor went on to say that insomnia doubles the risk of future development of depression and that insomnia symptoms together with shortened sleep are associated with hypertension. Professor Wittert also said that a person suffering from restricted sleep is exposed to an increased risk of elevated blood sugar levels and endocrine disorders such as diabetes, symptomatic ischaemic heart disease, hypertension, obesity, insomnia and anxiety related illnesses.*
>
> *476. As our earlier findings have indicated, some wind farms generate sound which is capable of causing, and does cause, annoyance. We are further satisfied that annoyance of the kind which is generated (often associated with psychological distress and sleep disturbance), is a recognised pathway to a range of adverse health outcomes, including hypertension and cardiovascular disease.*
>
> *481. It follows in our view that the applicant has established that there is a plausible basis for thinking that wind turbine sound (mediated by annoyance) may lead to adverse health outcomes, such as to warrant further investigation. It is unnecessary for us to draw conclusions as to the precise nature of the annoyance which is caused, and whether annoyance may be caused by sound which is not audible (infrasound). That is*

something which we expect will be the subject of further study and investigation. For our purposes, it is sufficient that annoyance is produced, and it appears that it may be associated with adverse health outcomes. An identification of the causes of that annoyance may allow it to be reduced or mitigated and adverse health outcomes to be reduced or avoided.

483. We have not overlooked the evidence to the effect that, while annoyance is produced by wind farms, it may have no association with wind turbine sound emissions and instead be related to other things, such as loss of amenity, the appearance of the turbines and consequent change to the landscape, blinking lights, or other factors. Whether that is so is yet to be established, one way or the other. We accept that the results of the Health Canada study could be consistent with a conclusion that the annoyance experienced is unrelated to the sound emissions. However, by reason of the limitations to which we have referred, that study cannot be regarded as conclusive. The evidence indicates that more work is needed to either prove or disprove this proposition.

Our monitoring program confirms the statements in paras 473, 476, 481 and 483 of the AAT decision.

Special audible characteristics (SACs) were not especially well predicted by noise level, suggesting a dose-response relationship between noise level and SAC detection is not present.

SCADA values predicted SACs, even though SCADA values are strongly correlated with noise levels.

Nuisance conditions are associated with atmospheric stability which is associated with noise level.

Appendix N. Assessment of Unreasonable Noise

The residents' group identify Bald Hills Wind Farm noise as a nuisance. Wind farm noise does not occur all the time and the potential for 'unreasonable noise' is a quantifiable risk. Updates to Victoria's environmental legislation are included here as the Act is new and restates the precautionary principle of the earlier Act, as well as bringing in the principle that "All people are entitled to live in a safe and healthy environment irrespective of their personal attributes or location". The *Environment Protection Amendment Act 2018 Part 2—Amendments to the Environment Protection Act 2017,* (accessed 31 August 2018) states:

"20 Precautionary principle
If there exist threats of serious or irreversible harm to human health or the environment, lack of full scientific certainty should not be used as a reason for postponing measures to prevent or minimise those threats".

"21 Principle of equity

(1) All people are entitled to live in a safe and healthy environment irrespective of their personal attributes or location.

(2) People should not be disproportionately affected by harm or risks of harm to human health and the environment.

(3) The present generation should ensure the state of the environment is maintained or enhanced for the benefit of future generations."

***"environment** means—*

(a) the physical factors of the surroundings of human beings including the land, waters, atmosphere, climate, sound, odours and tastes; and

(b) the biological factors of animals and plants; and

(c) the social factor of aesthetics;"

***"unreasonable noise** means noise that—*

(a) is unreasonable having regard to the following—

(i) its volume, intensity or duration;

(ii) its character;

(iii) the time, place and other circumstances in which it is emitted;

(iv) how often it is emitted;

(v) any prescribed factors; or

(b) is prescribed to be unreasonable noise;"

Although the Act does not commence until mid- late- 2020 the above definitions assist in considering "adverse community response" under NZS6808:1998 and the potential for nuisance conditions outside the approval conditions.

Appendix O: Glossary

Background sound pressure level (LA95,T), L95

Commonly called the "L95" or "background" level and is an indicator of the quietest times of day, evening or night. The L95 level is calculated as the sound level equalled and exceeded for 95% the measurement time. The measured L95 time-intervals present the “average background” levels in 10-minute blocks of time. The level is normally recorded in the absence of any sound under investigation.

Under the Wind Farm sound/noise standards, however, the background level with turbine activity noise is monitored again for comparison to the pre-activity background sound levels. The level is not adjusted for tonality or impulsiveness.

Equivalent Continuous or time average sound pressure level (LAeq,T), Leq

Commonly called the "Leq" level it is the energy average (antilogarithmic average) sound level from all sources far and near. The levels within the day/evening/night time intervals are referenced for impact and risk assessment. The level can be adjusted for tonality.

Façade-adjusted level

A sound level that is measured at a distance of 1.0 metre from a wall or facade. The level is nominally 2.5 dB higher than the free-field level.

Free-field level

A sound level that is measured at a distance of more than 3.5 metres from a wall or facade.

MDA

Marshall Day Acoustics.

NMS

Noise Measurement Services

PSAC

Perceived special audible characteristic. A sound that a person hears as a distinctive, often adverse sound in the acoustic environment.

SAC

Special audible characteristic. This term is contained in the approval conditions

SEPP-N1

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