MARSHALL DAY Acoustics

MT EMERALD WIND FARM
BACKGROUND NOISE MONITORING

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6 Gipps Street
Collingwood 3066 Victoria Australia
T: +613 9416 1855 F: +613 9416 1231
A.C.N. 006 675 403
www.marshallday.com

Project: **MT EMERALD WIND FARM**

Prepared for: **RATCH Australia Corporation Pty Ltd**
Level 4
231 George Street
Brisbane QLD 4000

Attention: **Terry Johannesen**

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1.0 INTRODUCTION

This report presents the results of recent background noise monitoring undertaken for the proposed Mt Emerald Wind Farm that is being developed by RATCH Australia Corporation Pty Ltd (RATCH).

The wind farm is proposed to be located between Mareeba and Atherton in Far North Queensland. RATCH has obtained development permission for the construction of up to sixty-three (63) turbines at the wind farm. Background noise surveys were previously carried out in 2011 around the wind farm by Noise Mapping Australia during the planning phase of the project.

The purpose of the more recent background noise surveys is to establish an updated representation of typical background noise conditions around the proposed Mt Emerald Wind Farm which could be used to:

- Determine operational noise limits in accordance with the Development Permit
- Assist the identification of background noise dominated periods during any future compliance surveys for the wind farm.

This report describes the methodology and results of the background noise survey, and presents the proposed background related noise limits which would be used to assess the wind farm's compliance with operational noise conditions contained in the Development Permit.

The basic quantities used within this document to describe noise adopt the conventions outlined in ISO 1996-1:2003 *Acoustics - Description measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures.* Accordingly, all frequency weighted sound pressure levels are expressed as decibels (dB) in this report. For example, sound pressure levels measured using an "A" frequency weighting are expressed as L_A dB. Alternative ways of expressing A-weighted decibels such as dBA or dB(A) are therefore not used within this report.

Acoustic terminology used throughout this report is presented in Appendix A. Site layout and relevant coordinates are detailed in Appendix B.

Throughout this report, the term *receiver* is used to identify locations in the vicinity of existing or planned residential locations around the proposed Mt Emerald Wind Farm.

2.0 BACKGROUND NOISE SURVEY & ANALYSIS METHODOLOGY

The background noise survey and analysis has been conducted in accordance with the following:

- The *Development Permit for Material Change of Use* for the Mt Emerald Wind Farm, as amended by the notice of the Minister for Local Government and Planning dated 18 December 2015 (the Development Permit). Relevant extracts from the Development Permit are reproduced in Appendix C
- Australian Standard AS 4959-2010 *Acoustics - Measurement, prediction and assessment of noise from wind turbine generators* (AS 4959-2010), as referenced in the Development Permit
- Supplementary guidance contained in UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* dated May 2013 (UK IOA good practice guide)

In addition, the proposed noise monitoring has been described in Marshall Day Acoustics correspondence Lt 002 2015545ML dated 3 February 2016, which we understand was provided to the Department of Infrastructure, Local Government and Planning for comment. The background survey adhered to the procedures outlined in this correspondence.

This section of the report presents:

- An overview of the survey methodology
- Details of the selected noise monitoring locations
- A summary of the measurement data analysis procedures

2.1 Monitoring Locations

The monitoring locations were selected on the basis of:

- A turbine layout of up to fifty-three (53) turbines of the consented sixty-three (63) turbines. The turbine coordinates for the site layout at the time of the survey planning is provided in Appendix B
- The operational noise requirements detailed in the Development Permit
- The noise monitoring procedures outlined in AS 4959-2010
- Upper predicted operational wind farm noise levels prepared at the time of the survey planning.

The above information was used to identify the locations where noise compliance monitoring is expected to be carried out once the wind farm is operational.

A total of six (6) locations were proposed in the correspondence provided to the Department of Infrastructure, Local Government and Planning (Marshall Day Acoustics correspondence Lt 002 2015545ML dated 3 February). Noise monitoring was subsequently carried out at the proposed locations, with the exception of proposed receiver location R46 which could not be accessed for the survey. An alternative nearby location R48 was adopted in lieu of R46.

The selected monitoring locations where background noise measurements were carried out are summarised in Table 1 and illustrated in Figure 1 on the following pages.

Table 1: Monitoring locations

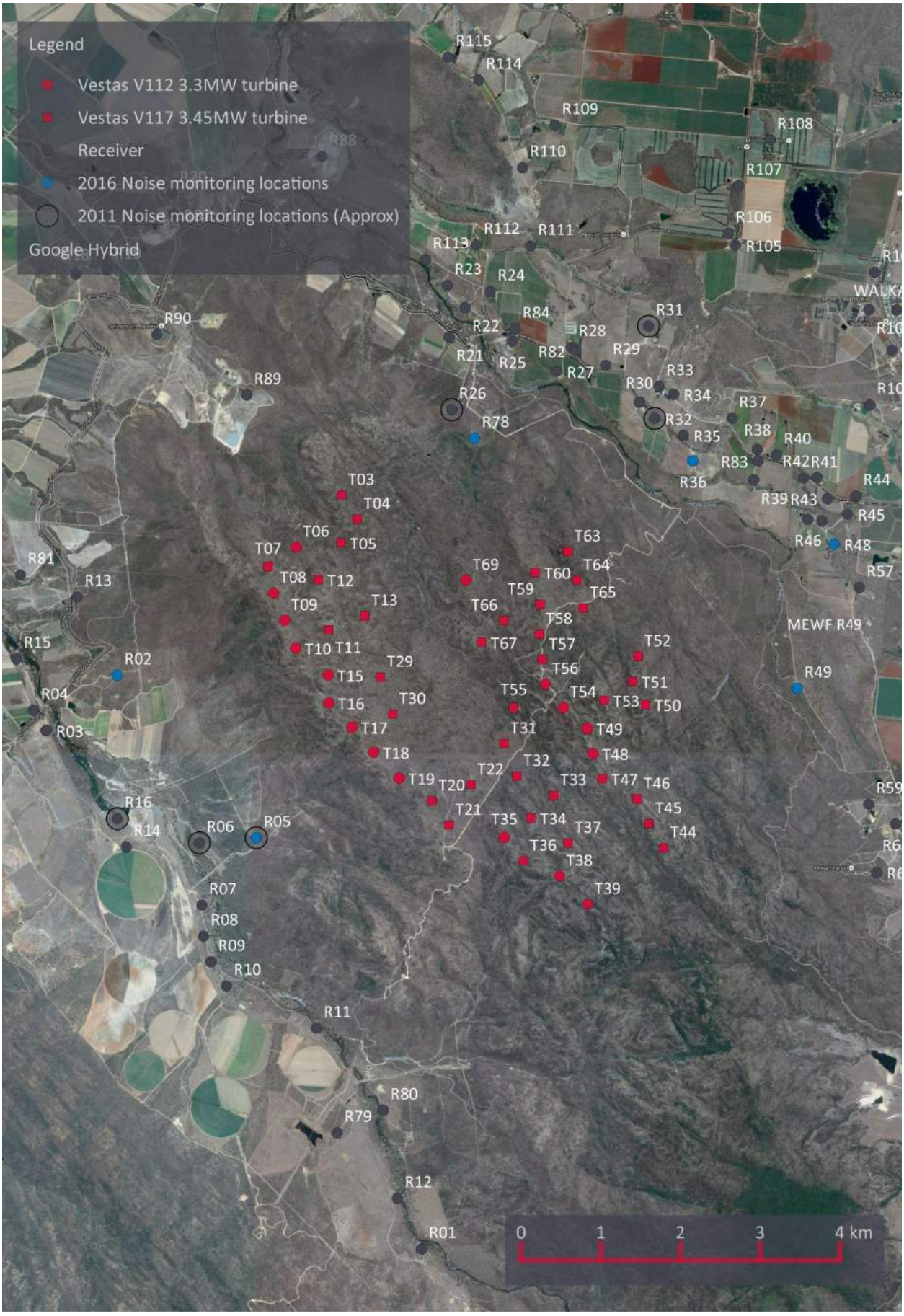
Receiver	Description
R02	Nearest residential property to the west
R05	Nearest residential property to the southwest
R36	Nearest residential property to the northeast
R48	Selected in lieu of access to originally proposed located R46 Chosen as an additional reference for properties located near to the area between monitoring locations R36 and R49
R49	Nearest residential property to the east
R78	Nearest residential property to the north

Full details of the coordinates and periods of monitoring are provided in Section 3.0 of this report.

At each of the receiver locations where noise monitoring was carried out, the choice of location relative to the dwelling was made on account of the range of considerations specified in AS 4959-2010. The following specific considerations were factored:

- The noise monitors were located on the proposed wind farm side of the dwelling
- The noise monitors were located at least 5 m away from the dwelling and any significant vertical reflecting structures
- The noise monitors were located as far as practical from taller vegetation at each dwelling and any obvious sources of extraneous noise.

Figure 1: Monitoring locations relative to the proposed Mt Emerald wind farm



2.2 Survey Methodology Overview

The key elements of the background noise survey are summarised in Table 2 below.

Table 2: Summary of key elements of background noise survey

Item	Description
Monitoring locations	Six (6) residential receiver locations. See further discussion in Section 2.1.
Monitoring Period	10 May 2016 to 29 June 2016 equating to approximately seven (7) weeks at each location. Duration chosen to satisfy the requirements of AS 4959-2010 which states the objective of the measurement program is to obtain a representative range of at least 2,000 valid data points covering the required range of wind speeds and directions (each data point being a 10 minute measurement and 2,000 valid points equating to approximately 14 days of data).
Equipment	01dB DUO integrating sound level meters • Certified to Type1 / Class 1 (precision grade) standards in accordance with AS 1259.2-1990[1] and IEC 61672.1-2004[2] • Global Position System time synchronisation • Noise floor below 20 dB See equipment details in Appendix E.
Wind shielding	All primary reference microphones mounted at approximately 1.5 m above ground level and fitted with enhanced wind shielding system based on the design recommendations detailed in the UK IOA good practice guide. The system comprises an inner solid primary wind shield and an outer secondary large diameter hollow wind shield.
Noise measurement data	• A-weighted and C-weighted average and statistical sound pressure level data • One-third octave band frequency noise levels, and one (1) minute audio samples every ten (10) minutes to aid the identification of extraneous noise influences (particularly bird and insect noise)
Local wind speed and rainfall data	The primary method of addressing wind induced microphone noise is the secondary wind shield arrangement which was fitted to all noise monitoring systems. A local weather station was also installed beside each noise monitoring location to concurrently record rainfall and wind speeds at microphone heights to provide a secondary reference for wind induced noise at the microphone. Weather was measured using a Vaisala WXT520 weather monitors, integrated and time synchronised with the noise measurement systems.

[1] Australian Standard 1259.2-1990: *Acoustics - Sound level meters - Integrating - Averaging*

[2] International Electrotechnical Commission 61672.1-2004: *Electroacoustics - Sound level meters - Specification*

Item	Description
Site wind speed data	Site wind speed data was sourced from two reference met masts at the site: • Mast reference 9350 extending to a height of 80 m • Mast reference 9351 extending to a height of 50 m The reference masts were chosen on the basis of the position of the mast within the site, and the anticipated availability of comparable data in the future when the wind farm is constructed and operating. Hub-height wind speed data (90 m above ground level) was provided by RATCH, based on analysis conducted by consultants WSP / Parsons Brinckerhoff to extrapolate the 50 m and 80 m height anemometer wind speed data to 90 m using site-specific wind shear calculations. A copy of the WSP / Parsons Brinckerhoff correspondence summarising the analysis process is reproduced in Appendix D.
Uncertainty	A discussion of measurement and assessment uncertainty in provided in Appendix E.

2.3 Wind speed reference height

AS 4959-2010 requires that wind speeds used in a wind farm noise assessment be referenced to the hub height of the candidate wind turbine. The currently proposed wind farm configuration comprises two (2) turbine models with hub-heights of 84 m and 90 m.

To assess the combined noise of all turbines types at the site, it is necessary to designate a single wind speed reference height. For this purpose, a reference height of 90 m has been adopted for this assessment for the following reasons:

- The 90 m reference height is applicable to the majority of the turbines on the site
- A difference of 6 m between the hub-heights of the two turbines is negligible for noise assessment purposes, particularly when considered in the broader context of wind speed variations related to atmospheric turbulence and changes across the wind farm site
- Although the difference in wind speed between the two heights is considered negligible, the adoption of a 90 m reference height with hub-height sound emission data for the 84 m hub-height wind turbines will mean that the predictions are theoretically marginally conservative (i.e. the predicted contribution of the 84 m hub-height turbines at each integer wind speed will be theoretically slightly higher than would be the case with an 84 m reference height, albeit by a negligible margin).

2.4 Data Analysis

The analysis of the survey data has been conducted in accordance with the AS 4959-2010 as referenced in the Development Permit requirements.

This analysis broadly involves:

- Collating the measured noise levels, site wind speeds and local weather data into a single time series
- Filtering the data set to remove measurement results affected by extraneous or atypical noise influences
- Filtering the data for the range of site wind speeds in which the turbines are expected to operate
- Filtering the data where necessary to account for site wind directions
- Plotting a chart of noise levels versus wind speeds and determining the line of best fit to the data.

A summary of the key steps in the analysis of the data is presented in Table 3.

Table 3: Background noise data analysis

Process	Description
Data collation	Time stamps for each source of measurement data are reviewed to clarify start or end times and measurement time zone. Measured noise levels, site wind speeds and local weather conditions are then collated for each ten-minute measurement interval.
Local weather data filtering	10-minute intervals are identified and filtered from the analysis if: • rainfall was measured • A-weighted levels analysis: average wind speeds were greater than 5 m/s • C-weighted levels analysis: average wind speeds were greater than 3 m/s [3]
Extraneous noise filtering	The measured sound frequencies (one-third octave bands) in each 10-minute interval are used to identify periods that are potentially affected by extraneous noises, including elevated bird or insect sounds. 10-minute intervals are have been identified, and filtered from the analysis, when the following conditions[4] are satisfied: • the highest A-weighted one-third octave band noise level is within 5 dB of the broadband A-weighted background noise level for that interval; and • the identified one-third octave band A-weighted noise level is greater than a level of 20 dB L_{A90}.
Site wind speed data filtering	10-minute intervals in which the site wind speeds are below cut-in (approximately 3 m/s) and above rated power (approximately 13 m/s) are removed from the analysis.
Site wind direction filtering	10-minute intervals in which site wind speeds are outside the downwind direction range are filtered from the analysis for the following situations: • Analysis for estimating background influences during future compliance monitoring • Analysis for deriving noise limits related to background noise levels at sites where the trend of the noise levels exhibits systematic differences according to wind direction. Further detail and references on this subject are provided in Section 2.5.
Time periods	In accordance with the Development Permit, the data sets are considered for separate periods as follows: • Day: 0600 to 2200 hours • Night: 2200 to 0600 hours
Regression analysis	Two datasets are plotted on a chart of noise levels versus wind speeds: • All data points that have been filtered from the analysis using the above processes • The final filtered dataset which provides the basis for assessment A line of best fit is determined for the final filtered data set using a regression analysis (linear up to a maximum of 3rd order as per AS 4959-2010).

[3] Value selected on the basis of a case study of site measurement data for a proposed wind farm site involving comparison of simultaneous data obtained from ground board based microphones and conventional microphone heights – value chosen as a compromise between obtaining sufficient data and limiting the potential influence of wind induced extraneous noise

[4] Griffin, D., Delaire, C., & Pischedda, P. (2013). Methods of identifying extraneous noise during unattended noise measurements. *20th International Congress of Sound & Vibration*.

2.5 Downwind Directions

Background noise levels are used to:

- Determine operational noise limits in accordance with the Development Permit
- Assist the identification of background noise dominated periods during any future compliance surveys for the wind farm.

The effect of wind direction on background noise levels must be considered for both of the above applications.

2.5.1 Determining noise limits

In relation to defining proposed noise limits, AS 4959-2010 does not specify allowable wind speed or direction ranges for background data sets used to derive noise limits. However, the standard notes the following:

> *Due consideration should be given to excluding data from analysis collected below cut-in and above the rated wind speed of the* [wind turbine generator] *which could influence the slope of the fitted regression line. However, there are instances where the inclusion of such data may lead to a more accurate regression analysis.*

And:

> *Consideration should be given to carrying out separate correlations of background sound levels with wind speed for different wind directions and/or times of day, particularly where atmospheric stability issues are apparent or are suspected.*

Based on the above, the analysis to determine proposed noise limits includes a review of the presence of data trends which could be related to wind direction. The analysis procedures defined in Section 2.2 also address the above considerations by limiting the analysis to wind speeds between cut-in and rated power, and separately conducting the analysis for day and night periods.

2.5.2 Future compliance monitoring

In terms of the influence of wind direction on background noise levels that may influence any future noise compliance monitoring, it is necessary to analyse the background data in a comparable manner to the procedures expected to be used to analyse compliance monitoring data.

AS 4959-2010 guidance for compliance monitoring involving extended measurements at receiver locations (Method 1 of AS 4959) defines measurement and analysis procedures which are broadly similar to those recommended for background noise monitoring. However, in terms of the wind speeds and directions, AS 4959 notes:

> *The specific range of wind speeds and directions that shall be covered during compliance testing should be agreed with the regulatory authority prior to measurements being carried out. Generally, data collected when the wind direction is from the wind farm to the relevant receiver would be the data of primary interest to the Relevant Regulatory Authority.*

The Development Permit does not specify whether the compliance measurements are to be based solely on data collected when the direction is from the wind farm to the relevant receiver (referred to as downwind conditions). However, it is expected this approach would most likely be adopted for compliance monitoring of the Mt Emerald Wind Farm. Accordingly, to represent comparable conditions, the background data sets are also filtered for downwind conditions.

Consistent with related guidance provided in AS 4959-2010, the downwind conditions have generally been defined as a wind direction spread of 45 degrees either side of the direct line between the nearest wind turbine and monitoring location under consideration.

However, in some instances, due to the arrangement of the proposed turbine layout, alternative wind directions have been selected to provide a better representation of the wind directions in which noise levels from the proposed Mt Emerald Wind Farm would be expected to be highest..

A summary of the downwind directions associated with the nearest turbine and variations from the suggested ±45 degrees downwind range are presented in Table 4 below.

Table 4: Downwind directions

Location	Nearest proposed turbine		Downwind range (°)	
	Reference	Direction (°)		
R02	T09	71	26	116
R05	T18	54	9	99
R36	T63	234	189	279
R48	T52	240	195	285
R49	T50	263	218	308
R78	T69	183	138	228
R78 adjusted*	-	-	138	275

* The adjusted wind direction range for R78 is proposed as greater than the suggested ±45 degree range with a view to including downwind directions relative to turbines T03 and T04

3.0 SURVEY & ANALYSIS RESULTS

This section presents a summary of the A-weighted and C-weighted background noise measurement results, analysed in accordance with the methodology described in Section 2.2.

The analysis results include the proposed A-weighted noise limits which, subject to the approval of the chief executive administering the Sustainable Planning Act (as referenced in the Development Permit), would be used during compliance monitoring to assess the operational noise of the Mt Emerald Wind Farm.

3.1 House R02

A summary of the monitoring for House R02 is provided in Table 5.

Table 5: House R02 monitoring and analysis details

Item	Description
Monitor location (easting : northing)	323292: 8101026
Monitoring period	10 May to 29 June 2016
Sound Level Logging Device	01dB DUO 10196

3.1.1 A-weighted Background Noise Levels & Proposed Criteria

A summary of the data for the A-weighted background noise level analysis is provided Table 6.

Table 6: House R02 A-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4770	2364
Total number of data points removed due to local wind speed, rain or insect noise	1632	1126
Number of data points used for regression analysis	3138	1238
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	2523	827

The measured A-weighted background noise levels, regression analysis and proposed noise limits for House R02 are presented in Figure 2 and Figure 3 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 2: House R02 – Daytime A-weighted background noise levels and noise limits versus wind speed

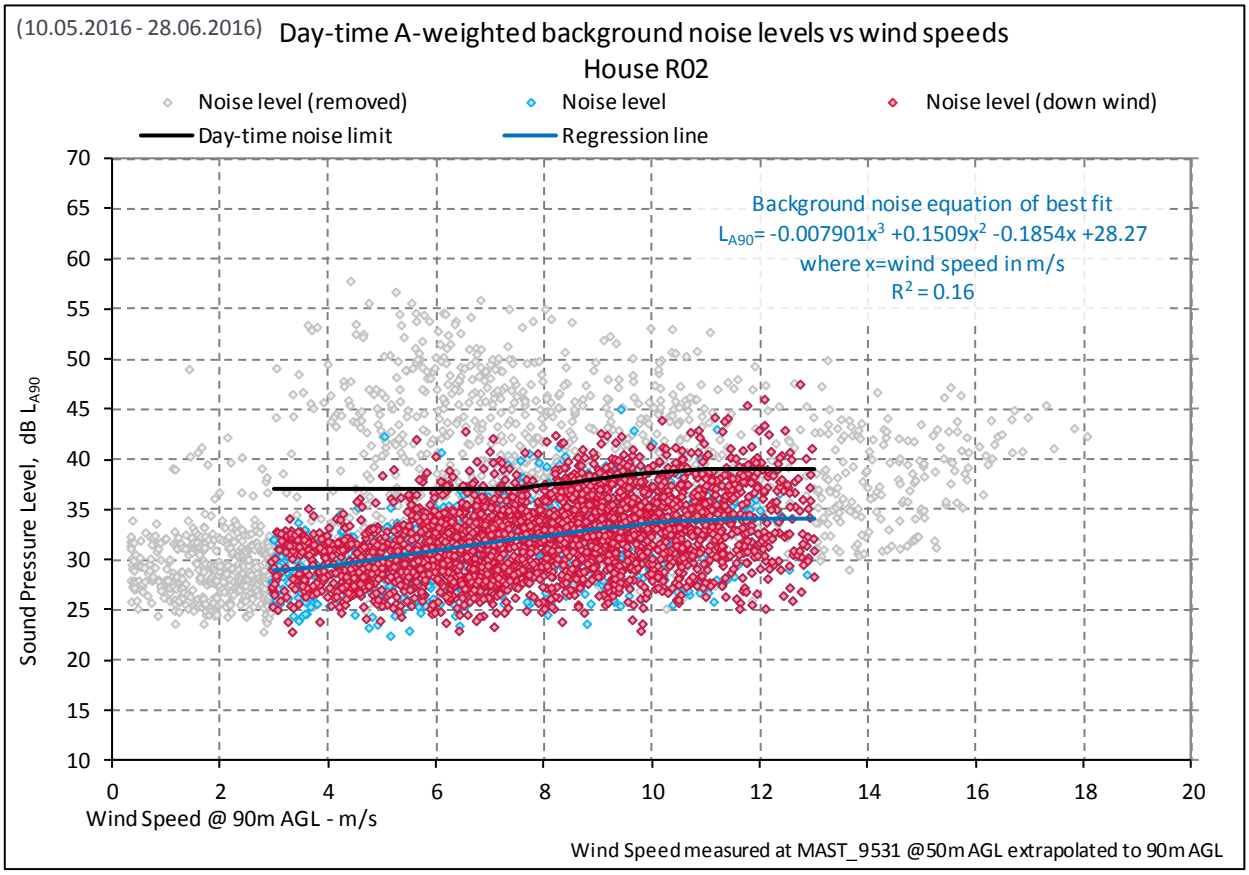
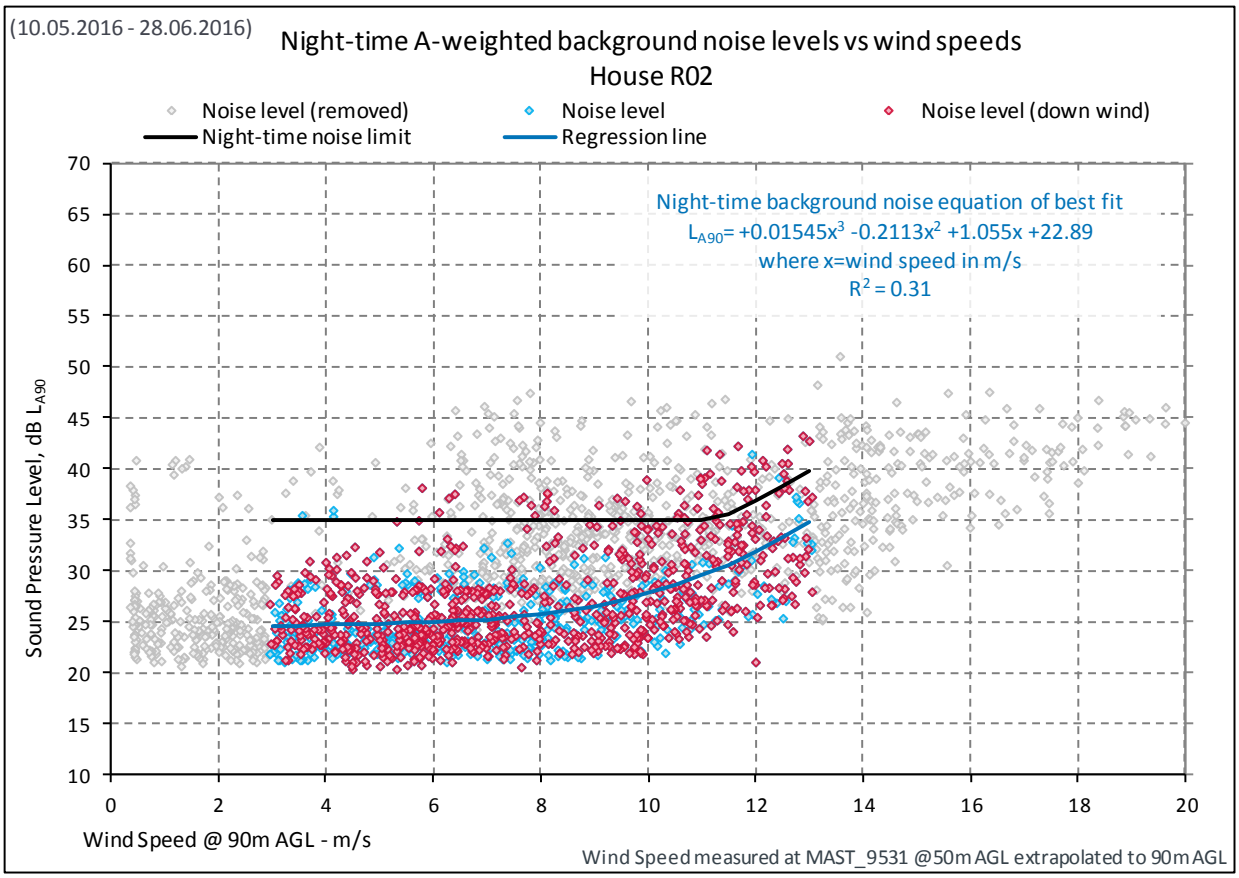


Figure 3: House R02 – Night-time A-weighted background noise levels and noise limits versus wind speed



3.1.2 C-weighted Background Noise Levels

A summary of the data for the C-weighted background noise level analysis is provided Table 6.

Table 7: House R02 C-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4770	2364
Total number of data points removed due to local wind speed, rain or insect noise	1657	1126
Number of data points used for regression analysis	3113	1238
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	2500	827

The measured C-weighted background noise levels and regression analysis for House R02 are presented in Figure 4 and Figure 5 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 4: House R02 – Daytime C-weighted background noise levels versus wind speed

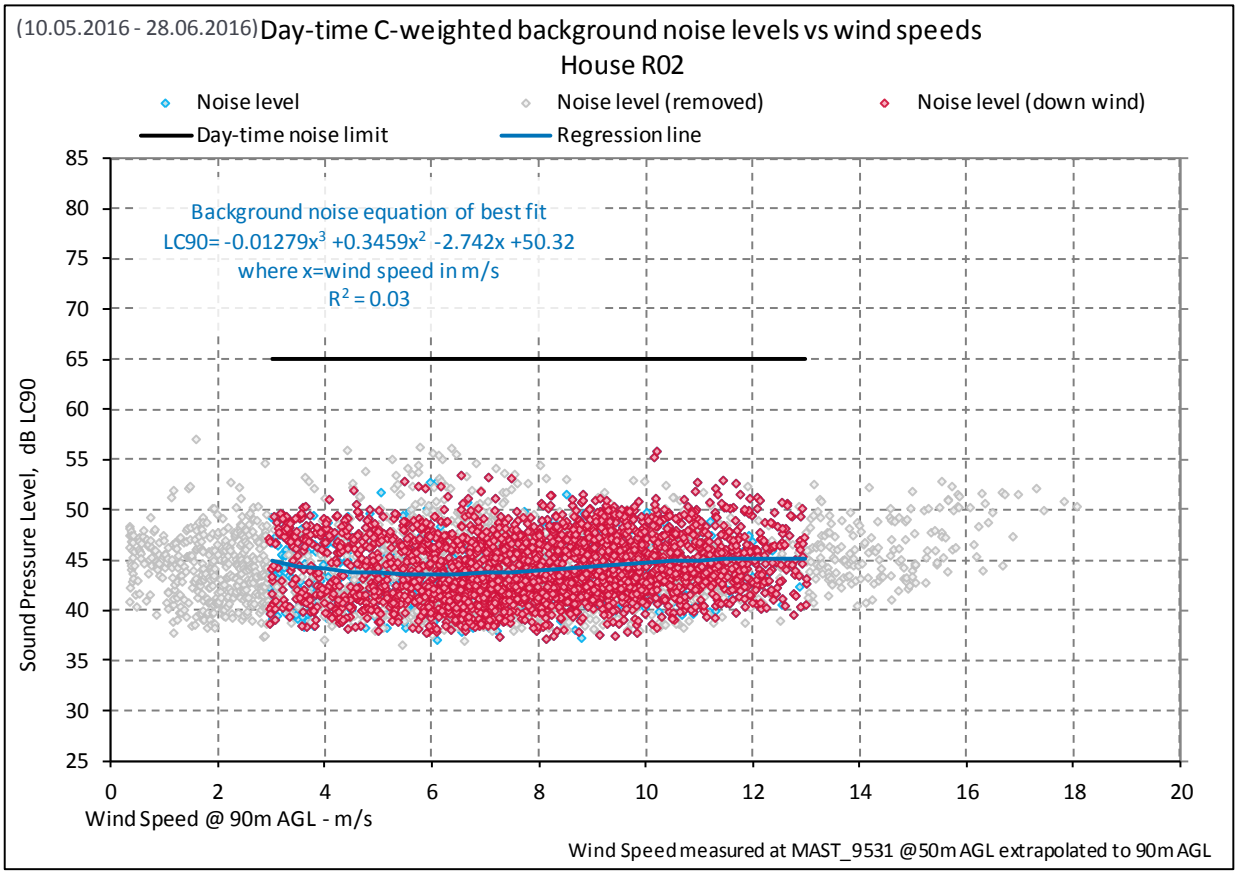
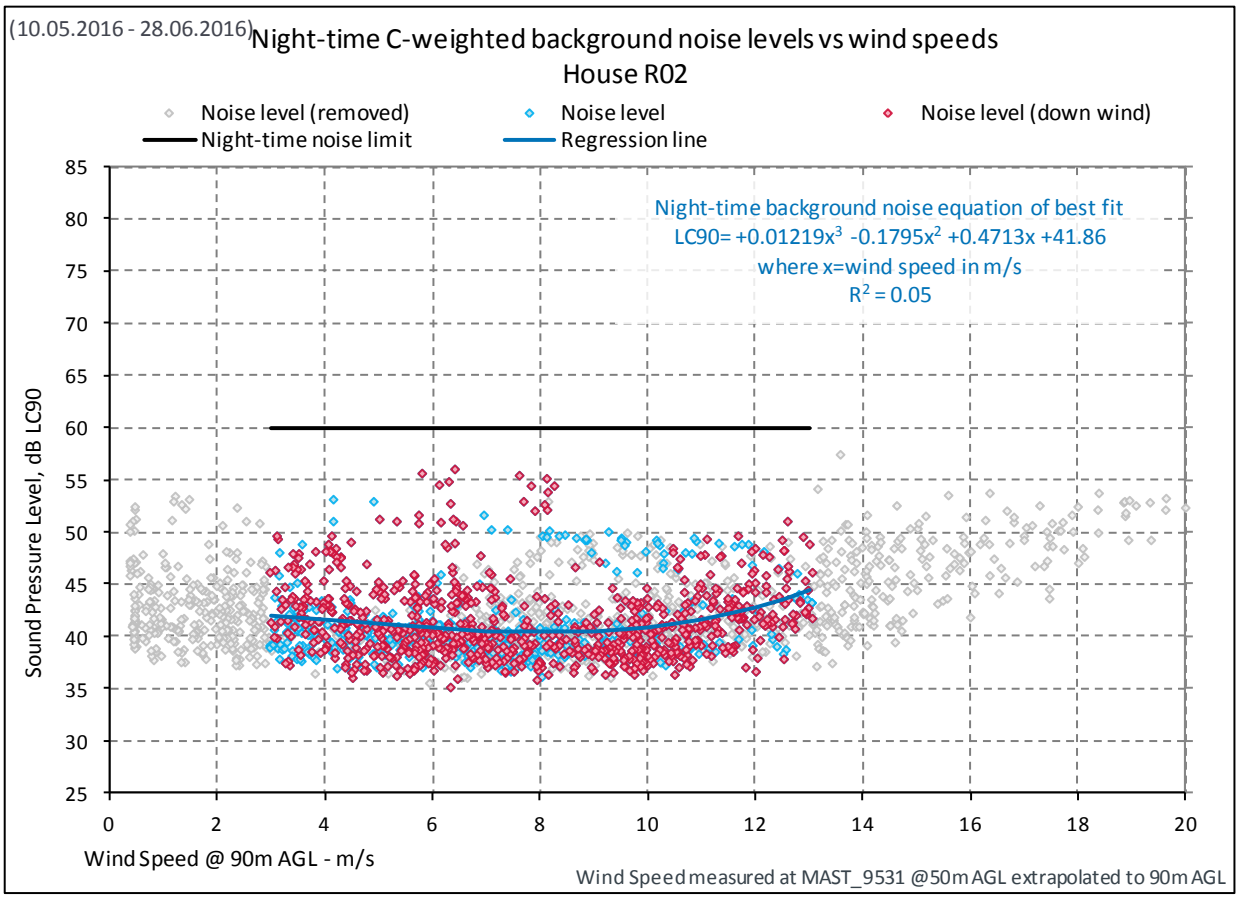


Figure 5: House R02 – Night-time C-weighted background noise levels versus wind speed



3.2 House R05

A summary of the monitoring for House R05 is provided in Table 8.

Table 8: House R05 monitoring and analysis details

Item	Description
Monitor location (easting : northing)	325035: 8099127
Monitoring period	9 May to 29 June 2016
Sound Level Logging Device	01dB DUO 10197

3.2.1 A-weighted Background Noise Levels & Proposed Criteria

A summary of the data for the A-weighted background noise level analysis is provided in Table 9.

Table 9: House R05 A-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4830	2436
Total number of data points removed due to local wind speed, rain or insect noise	1570	1460
Number of data points used for regression analysis	3260	976
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	1465	275

The measured A-weighted background noise levels, regression analysis and proposed noise limits for House R05 are presented in Figure 6 and Figure 7 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 6: House R05 – Daytime A-weighted background noise levels & noise limits versus wind speed

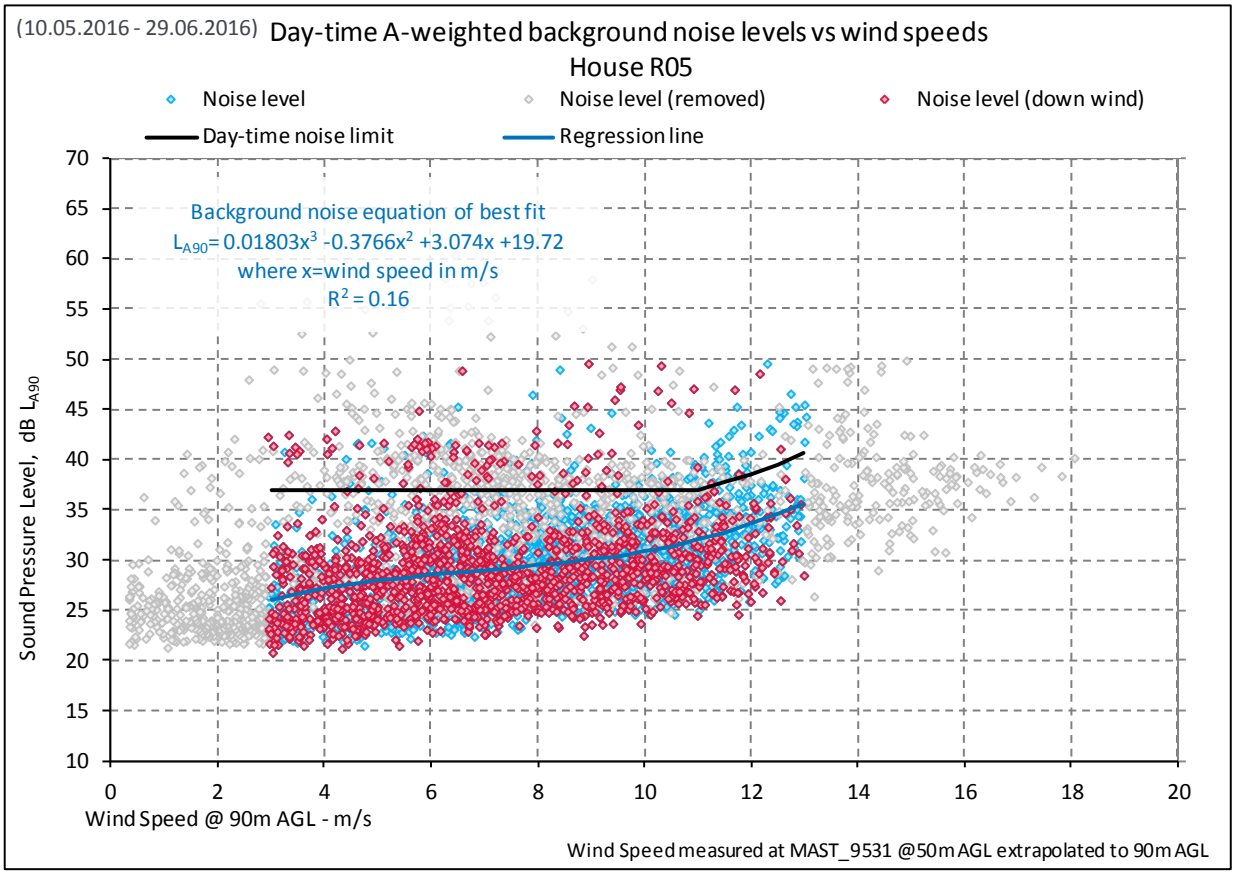
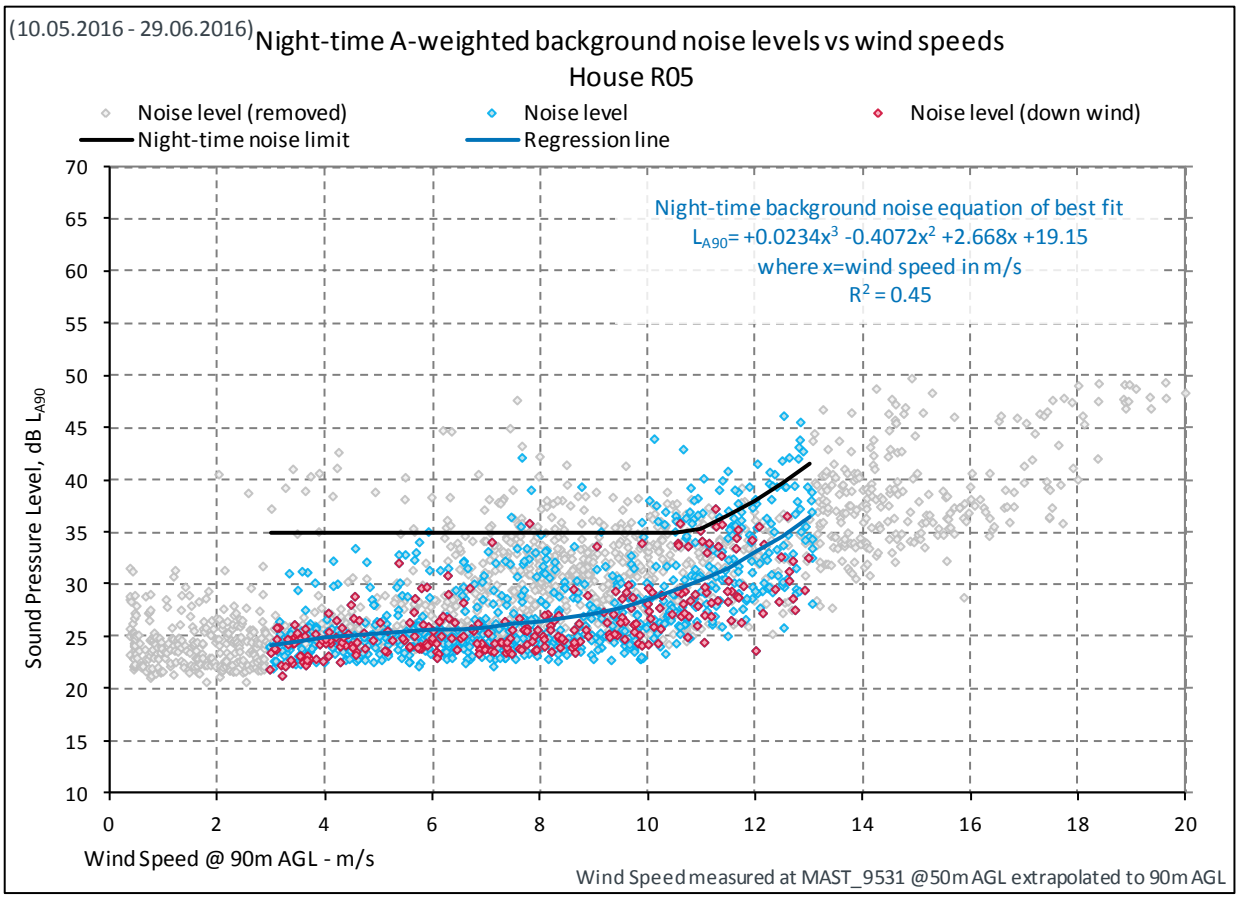


Figure 7: House R05 – Night-time A-weighted background noise levels & noise limits versus wind speed



3.2.2 C-weighted Background Noise Levels

A summary of the data for the C-weighted background noise level analysis is provided in Table 10.

Table 10: House R05 C-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4830	2436
Total number of data points removed due to local wind speed, rain or insect noise	1599	1475
Number of data points used for regression analysis	3231	961
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	1464	275

The measured C-weighted background noise levels and regression analysis for House R05 are presented in Figure 8 and Figure 9 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 8: House R05 – Daytime C-weighted background noise levels versus wind speed

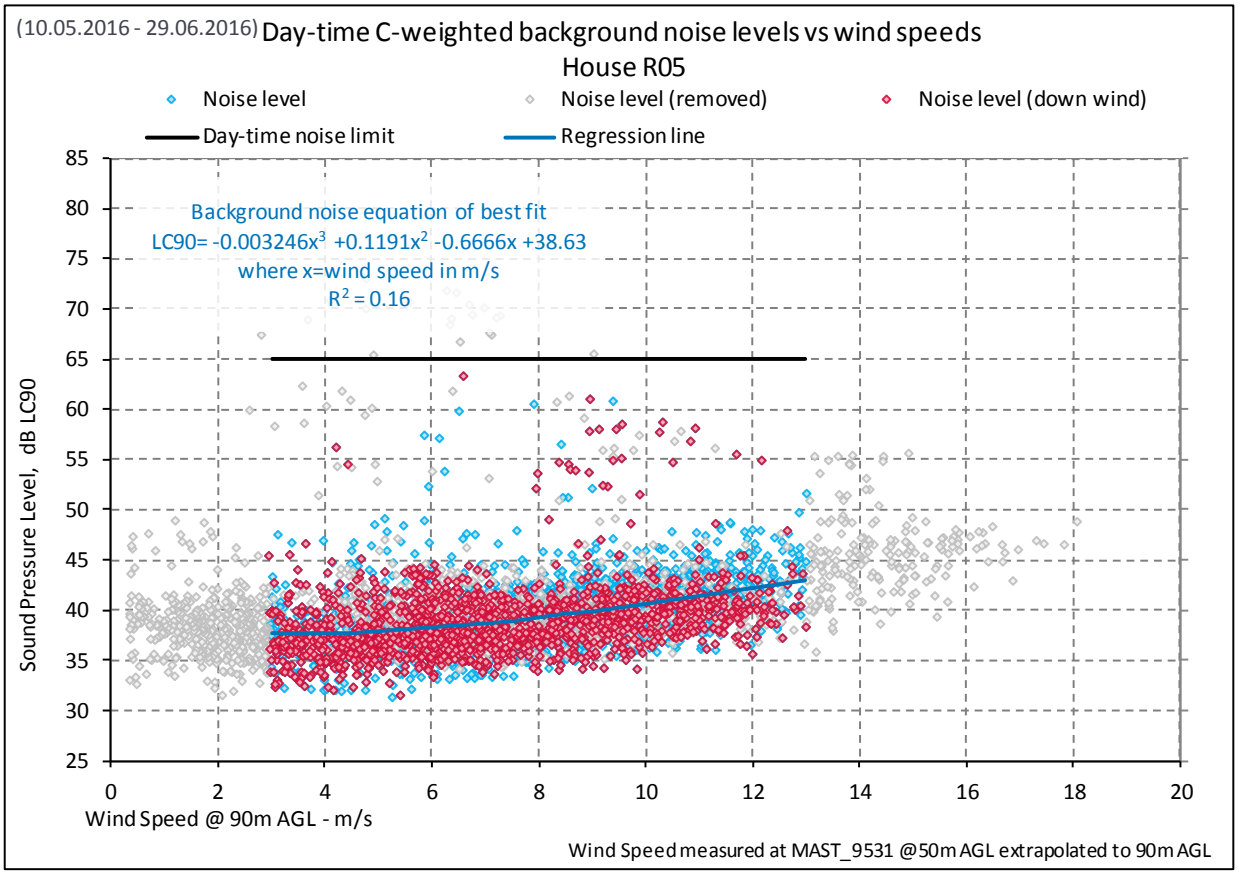
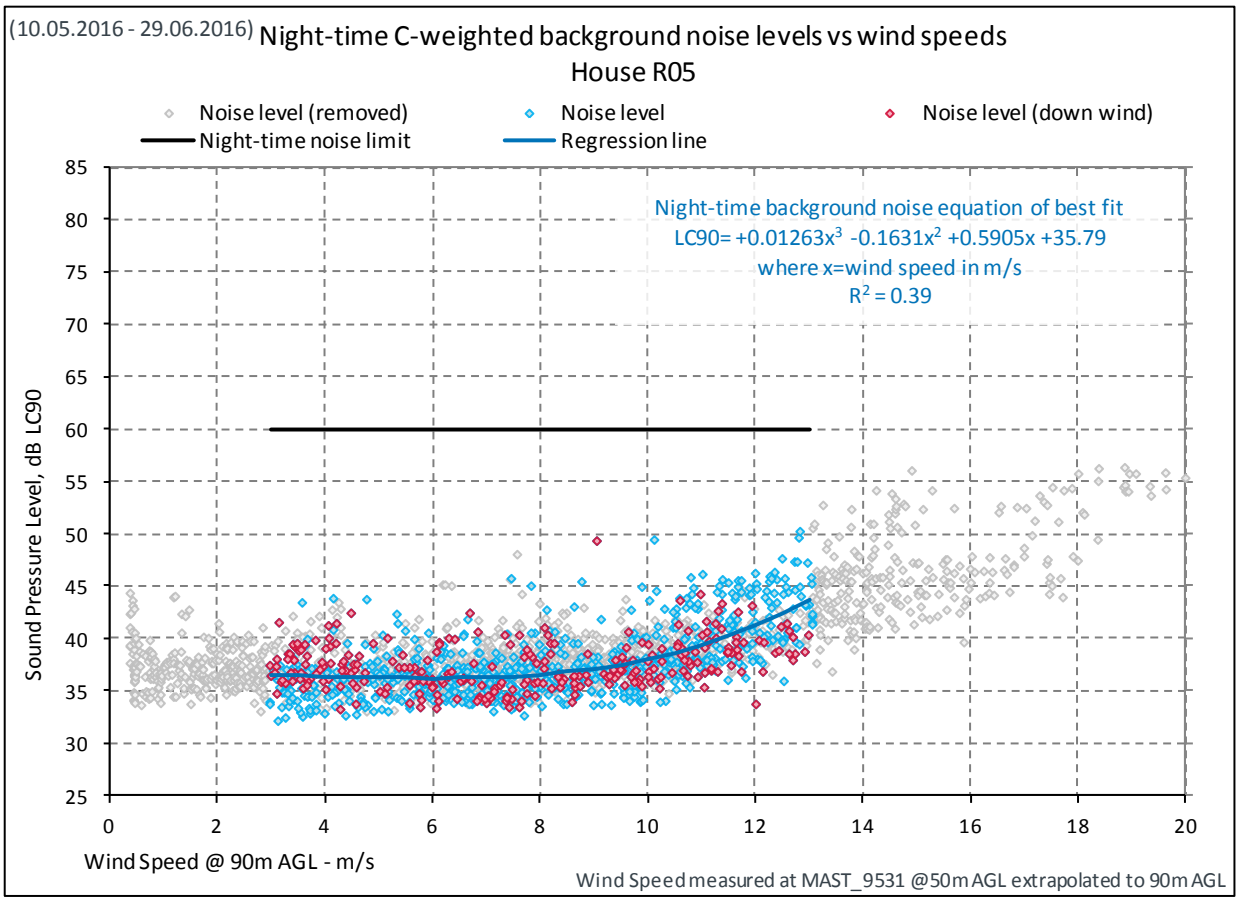


Figure 9: House R05 – Night-time C-weighted background noise levels versus wind speed



3.3 House R36

A summary of the monitoring for House R36 is provided in Table 11.

Table 11: House R36 monitoring and analysis details

Item	Description
Monitor location (easting : northing)	330279: 8103616
Monitoring period	10 May to 29 June 2016
Sound Level Logging Device	01dB DUO 10409

3.3.1 A-weighted Background Noise Levels & Proposed Criteria

A summary of the data for the A-weighted background noise level analysis is provided in Table 12.

Table 12: House R36 A-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4730	2388
Total number of data points removed due to local wind speed, rain or insect noise	1771	1630
Number of data points used for regression analysis	2959	758
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	188	87

The measured A-weighted background noise levels, regression analysis and proposed noise limits for House R36 are presented in Figure 10 and Figure 11 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 10: House R36 – Daytime A-weighted background noise levels & noise limits versus wind speed

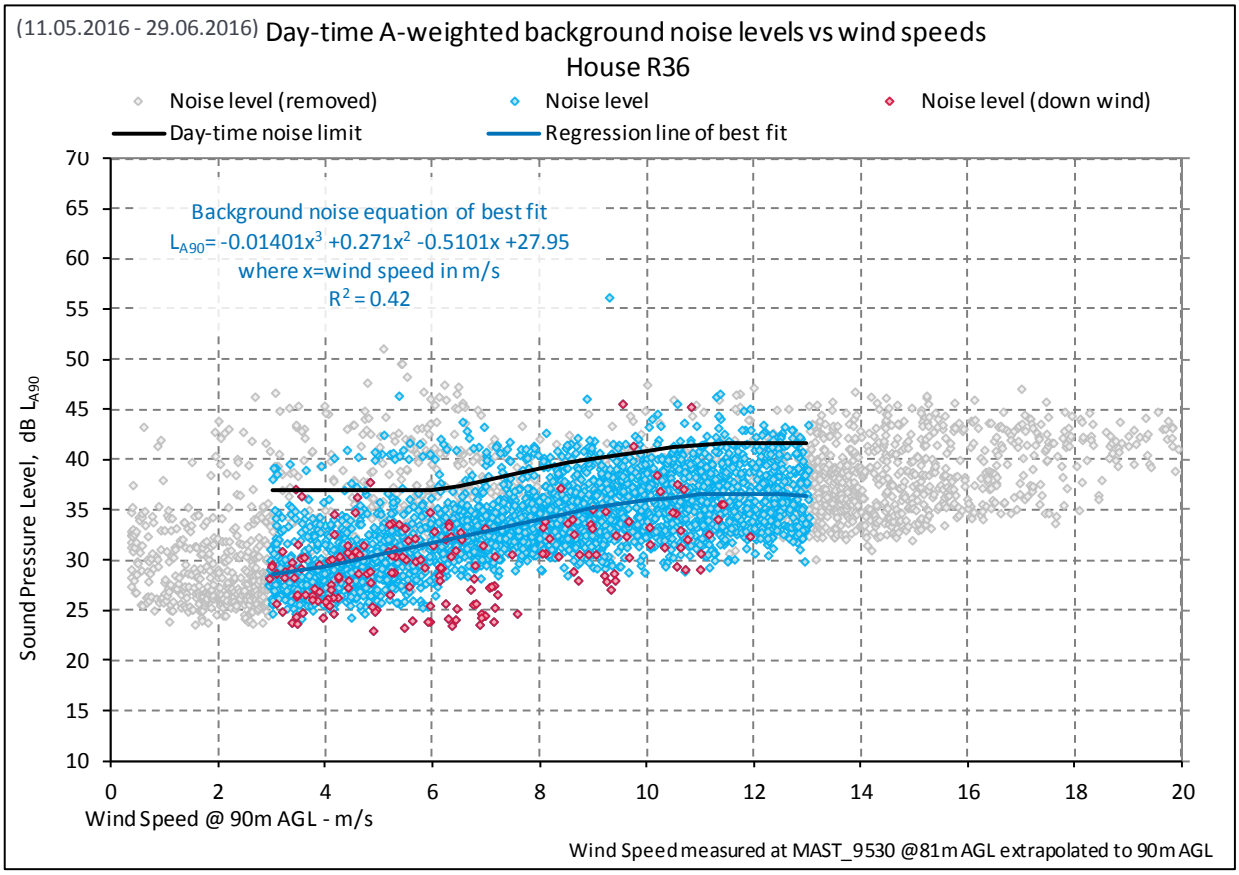
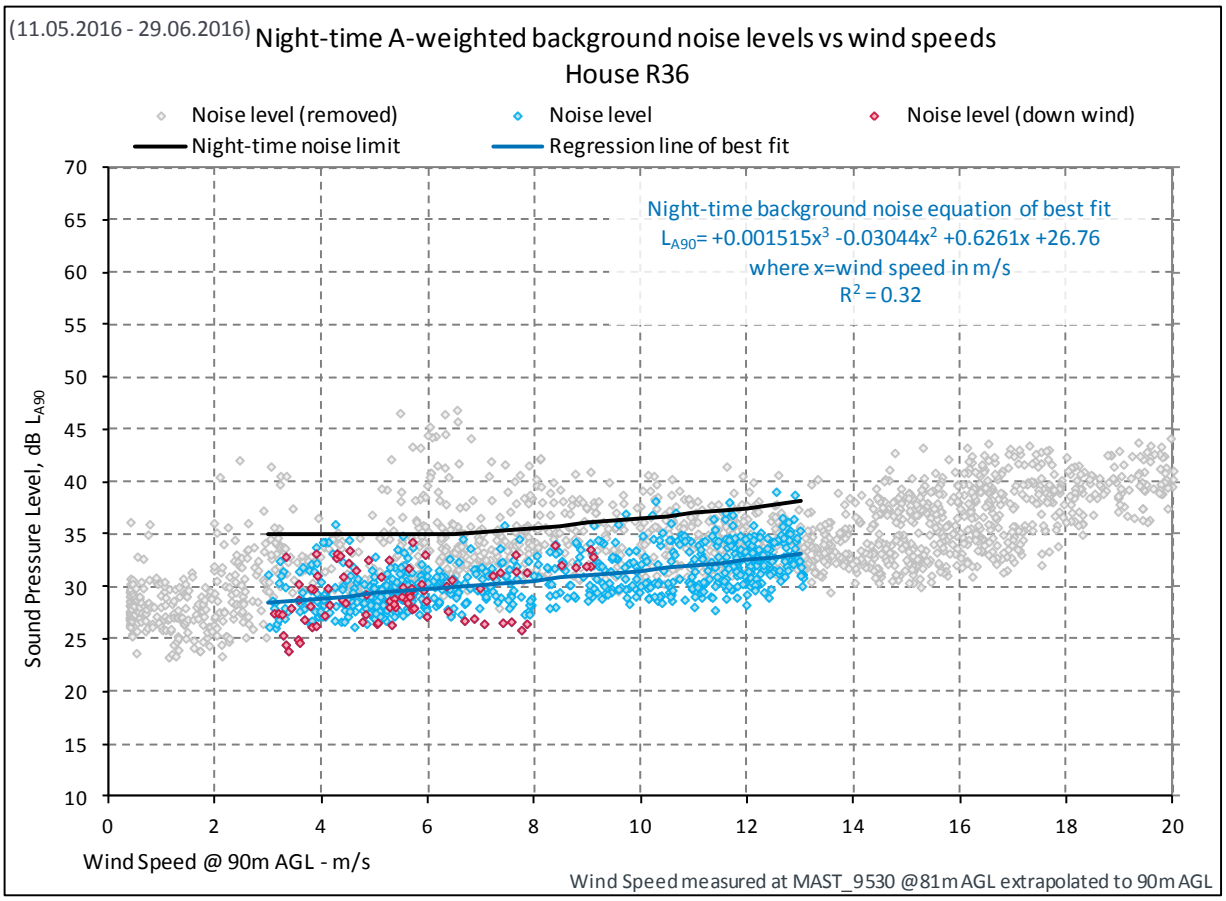


Figure 11: House R36 – Night-time A-weighted background noise levels & noise limits versus wind speed



3.3.2 C-weighted Background Noise Levels

A summary of the data for the C-weighted background noise level analysis is provided Table 13.

Table 13: House R36 C-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4730	2388
Total number of data points removed due to local wind speed, rain or insect noise	2773	1648
Number of data points used for regression analysis	1957	740
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	178	87

The measured C-weighted background noise levels and regression analysis for House R36 are presented in Figure 12 and Figure 13 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 12: House R36 – Daytime C-weighted background noise levels versus wind speed

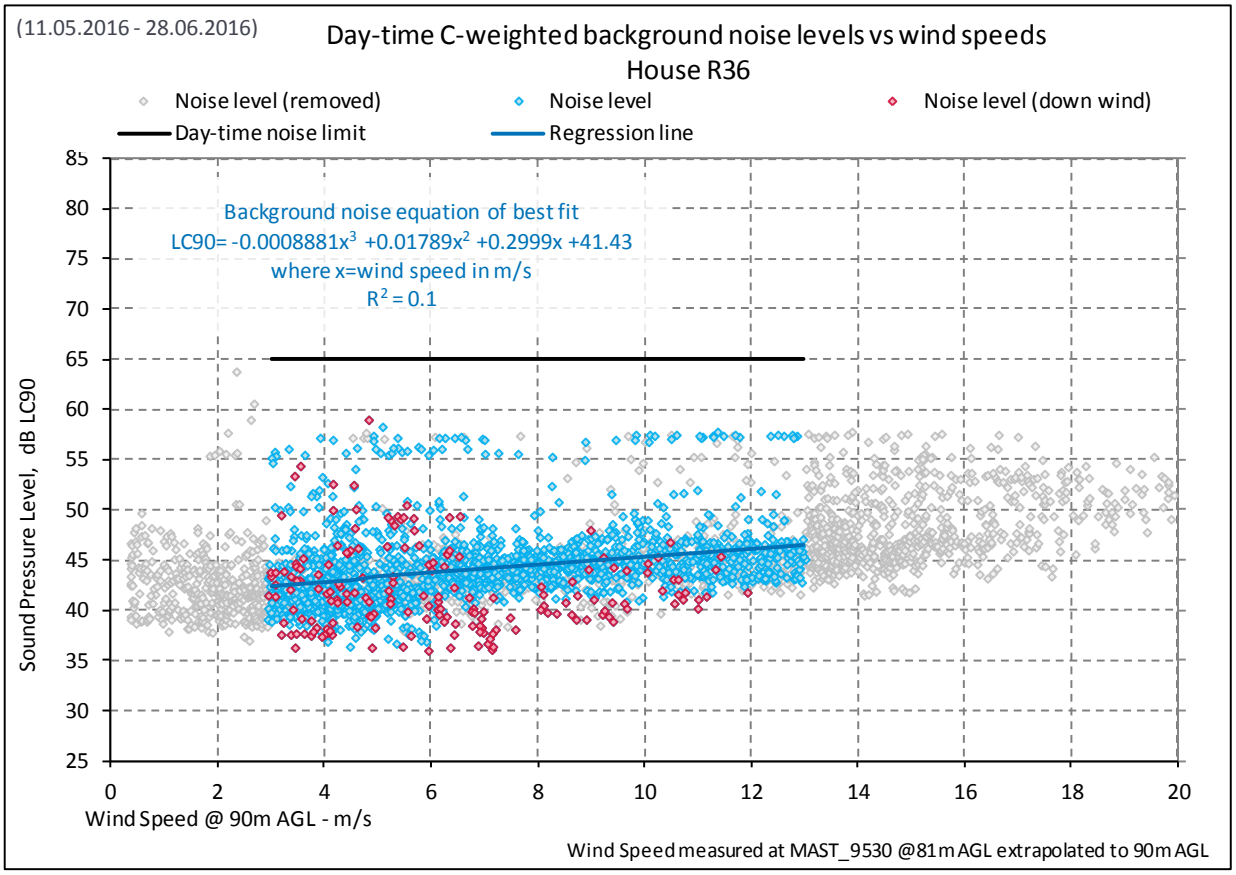
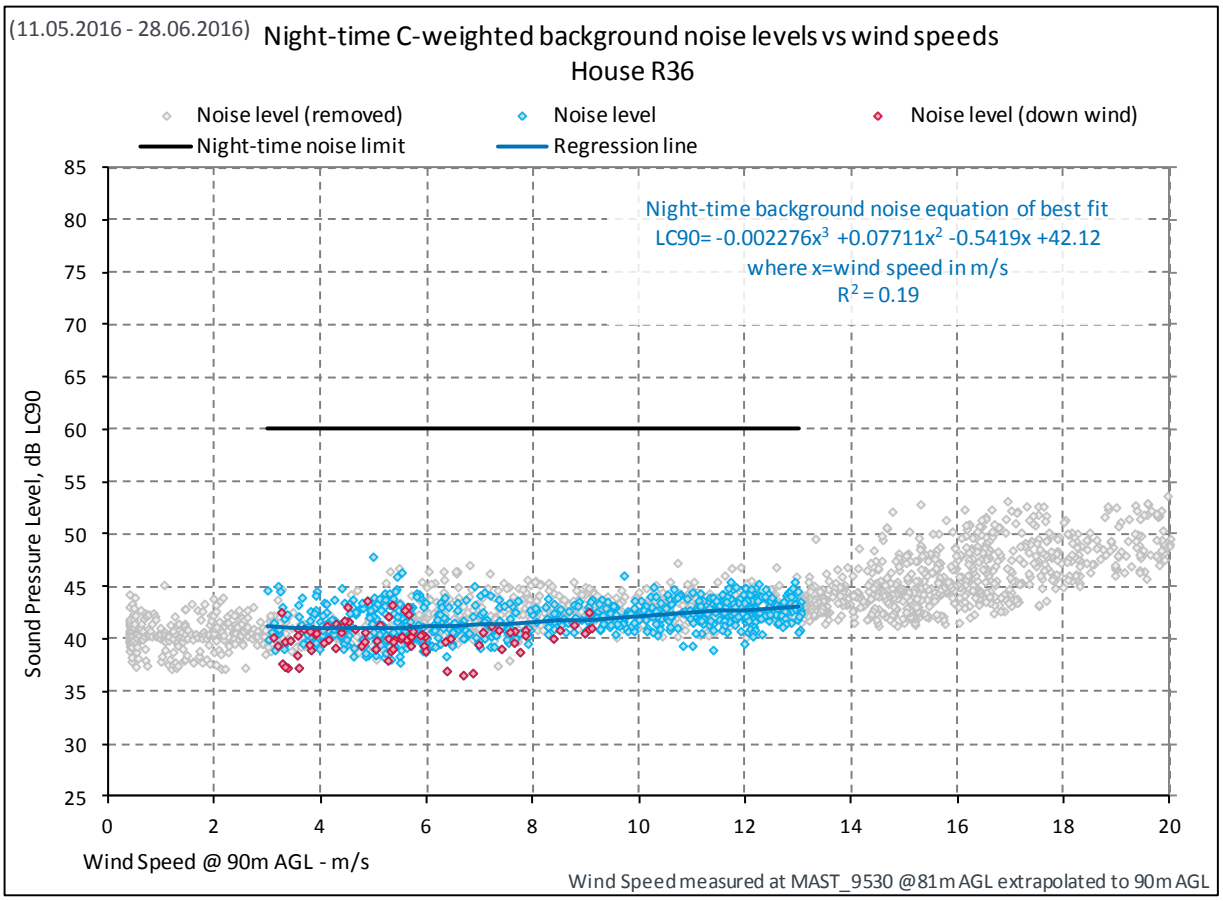


Figure 13: House R36 – Night-time C-weighted background noise levels versus wind speed



3.4 House R48

A summary of the monitoring for House R48 is provided in Table 14.

Table 14: House R48 monitoring and analysis details

Item	Description
Monitor location (easting : northing)	331916: 8102684
Monitoring period	10 May to 29 June 2016
Sound Level Logging Device	01dB DUO 10498

3.4.1 A-weighted Background Noise Levels & Proposed Criteria

A summary of the data for the A-weighted background noise level analysis is provided Table 15.

Table 15: House R48 A-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4727	23878
Total number of data points removed due to local wind speed, rain or insect noise	1694	1543
Number of data points used for regression analysis	3033	844
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	192	91

The measured A-weighted background noise levels, regression analysis and proposed noise limits for House R48 are presented in Figure 14 and Figure 15 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 14: House R48 - Daytime A-weighted background noise levels & noise limits versus wind speed

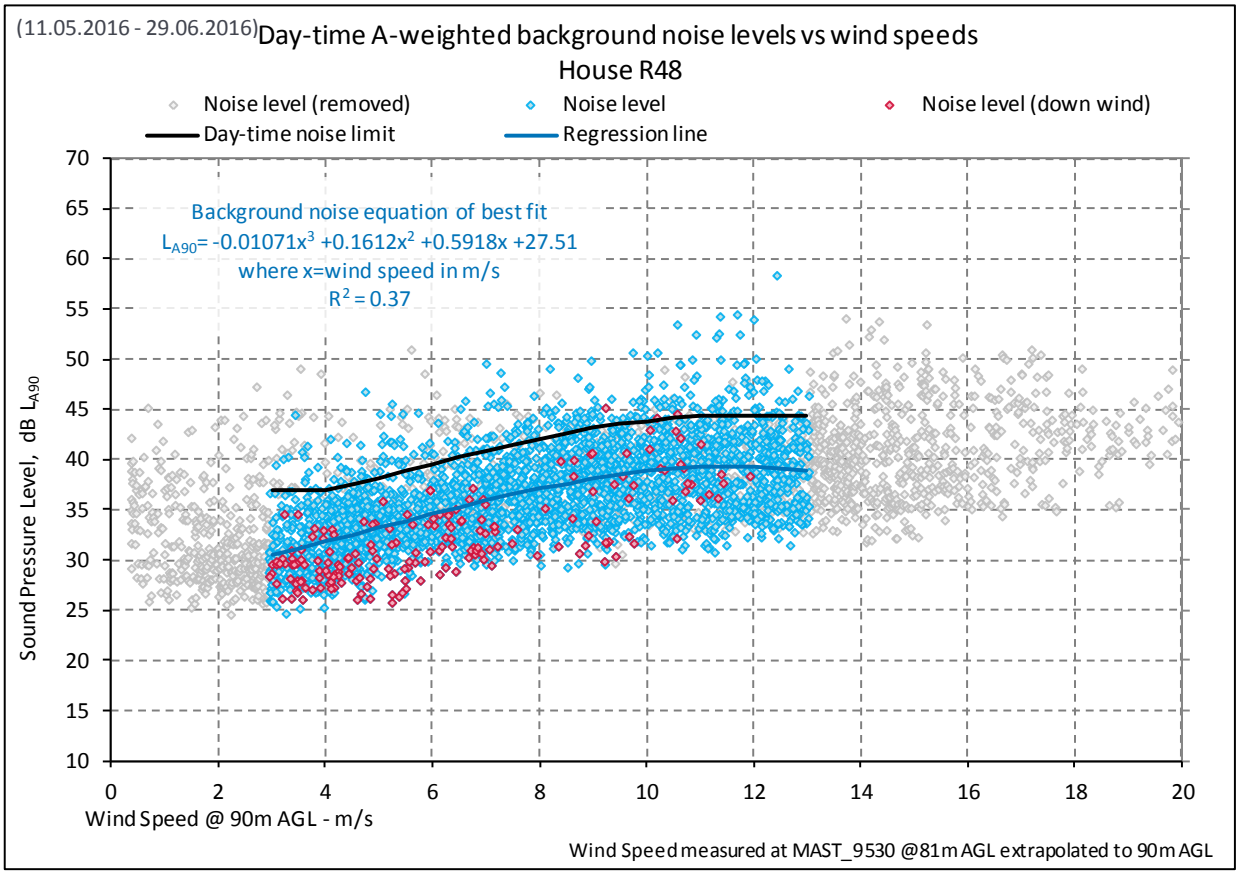
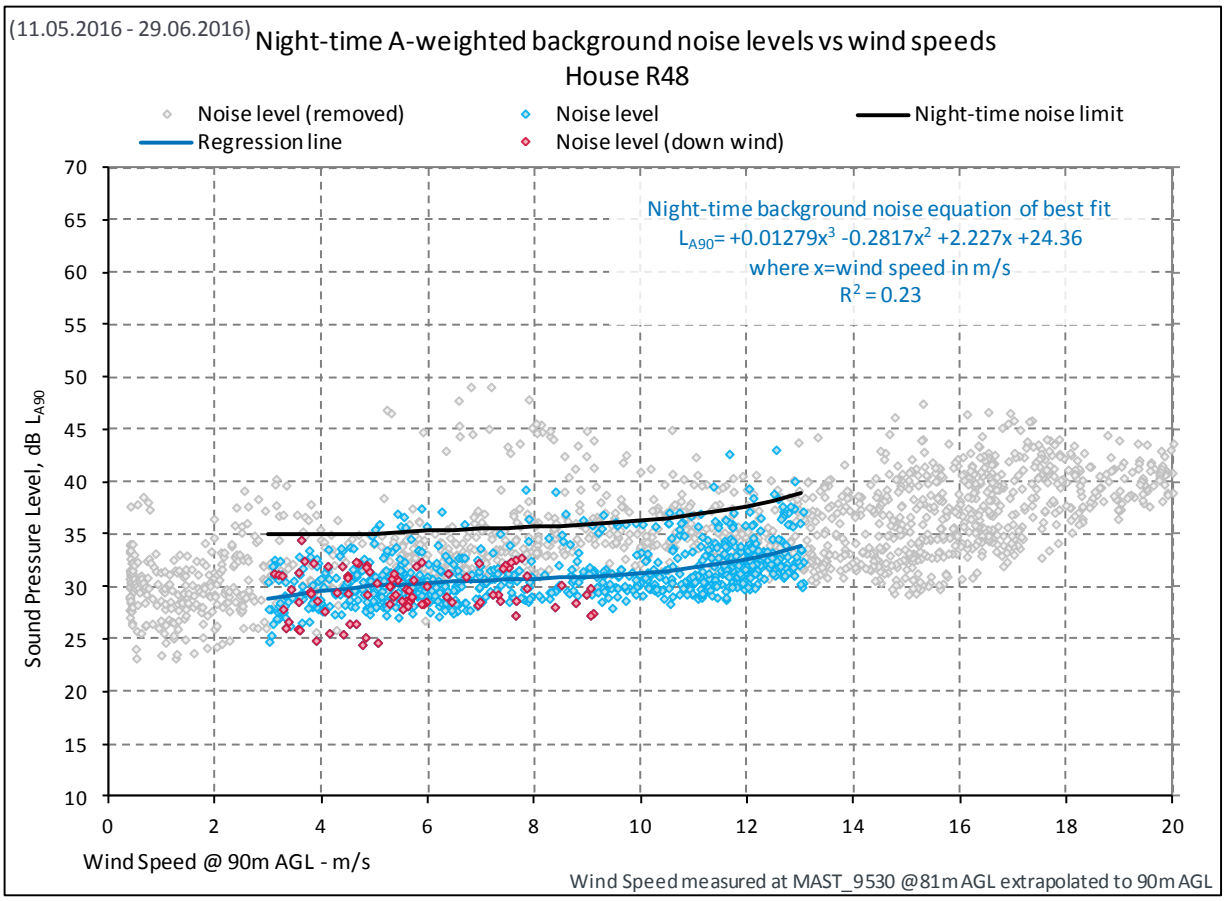


Figure 15: House R48 – Night-time A-weighted background noise levels & noise limits versus wind speed



3.4.2 C-weighted Background Noise Levels

A summary of the data for the C-weighted background noise level analysis is provided in Table 16.

Table 16: House R48 C-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4727	2387
Total number of data points removed due to local wind speed, rain or insect noise	1716	1543
Number of data points used for regression analysis	3011	844
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	170	91

The measured C-weighted background noise levels and regression analysis for House R are presented in Figure 16 and Figure 17 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 16: House R48 – Daytime C-weighted background noise levels versus wind speed

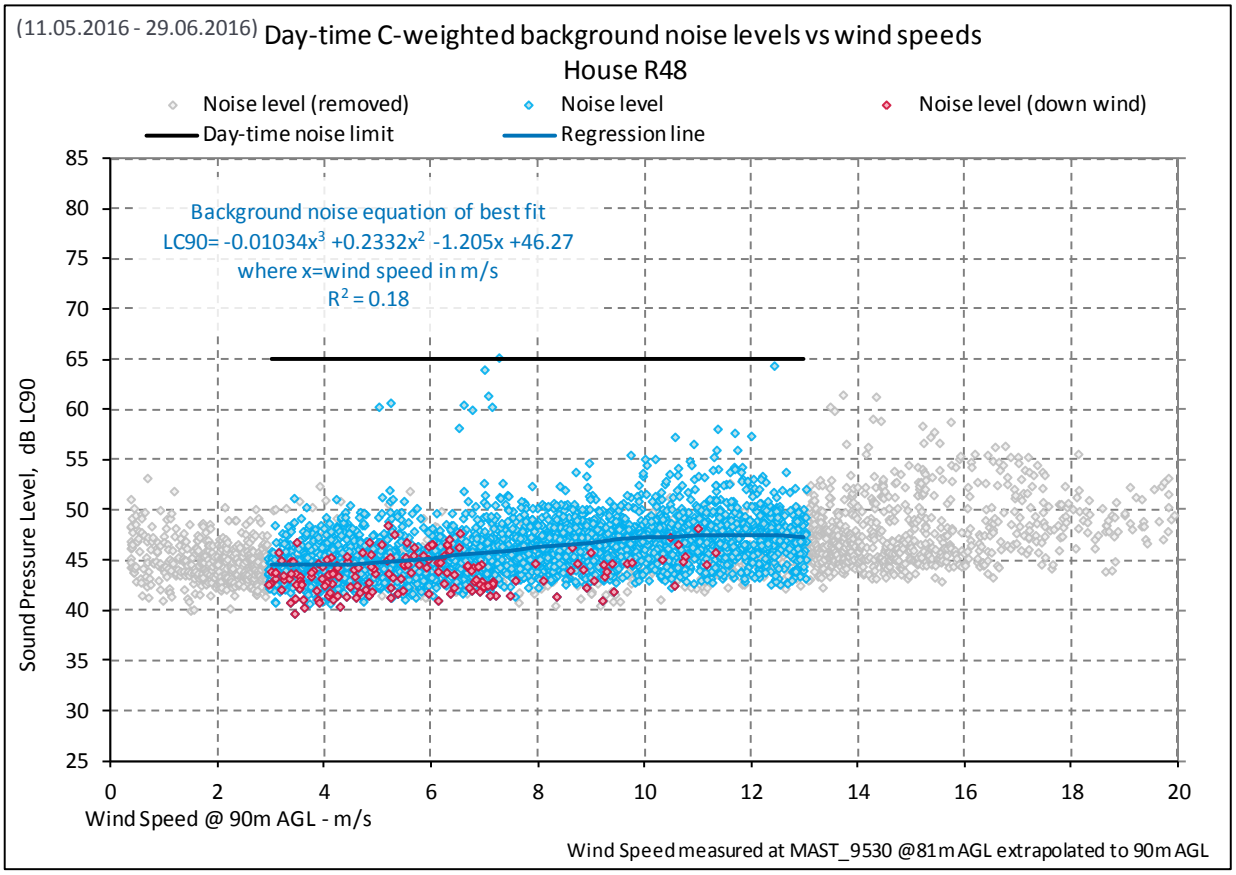
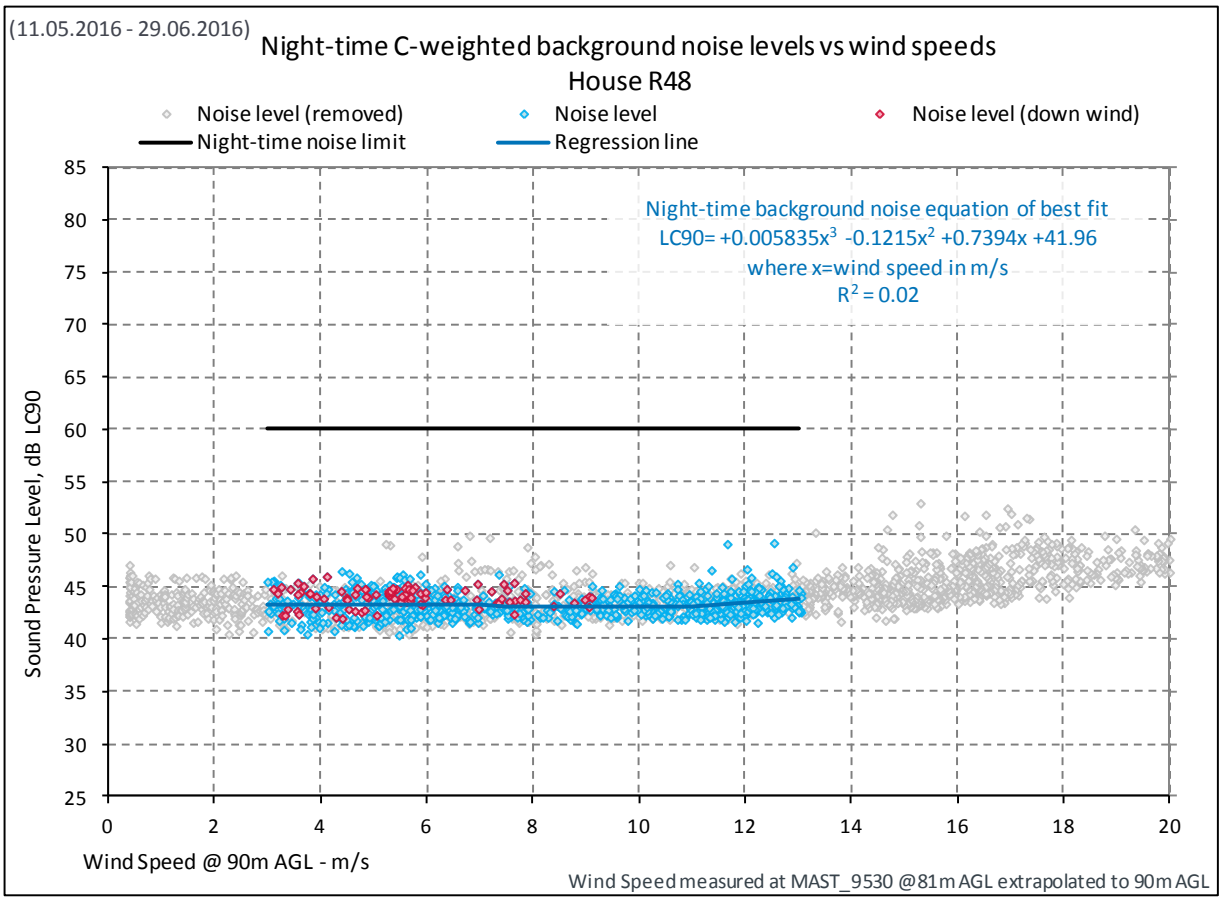


Figure 17: House R48 – Night-time C-weighted background noise levels versus wind speed



3.5 House R49

A summary of the monitoring for House R49 is provided in Table 17.

Table 17: House R49 monitoring and analysis details

Item	Description
Monitor location (easting : northing)	331399: 8101581
Monitoring period	10 May to 29 June 2016
Sound Level Logging Device	01dB DUO 10499

3.5.1 A-weighted Background Noise Levels & Proposed Criteria

A summary of the data for the A-weighted background noise level analysis is provided in Table 18.

Table 18: House R49 A-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4645	2340
Total number of data points removed due to local wind speed, rain or insect noise	1529	1146
Number of data points used for regression analysis	3116	1194
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	202	124

The measured A-weighted background noise levels, regression analysis and proposed noise limits for House R49 are presented in Figure 18 and Figure 19 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 18: House R49- Daytime A-weighted background noise levels & noise limits versus wind speed

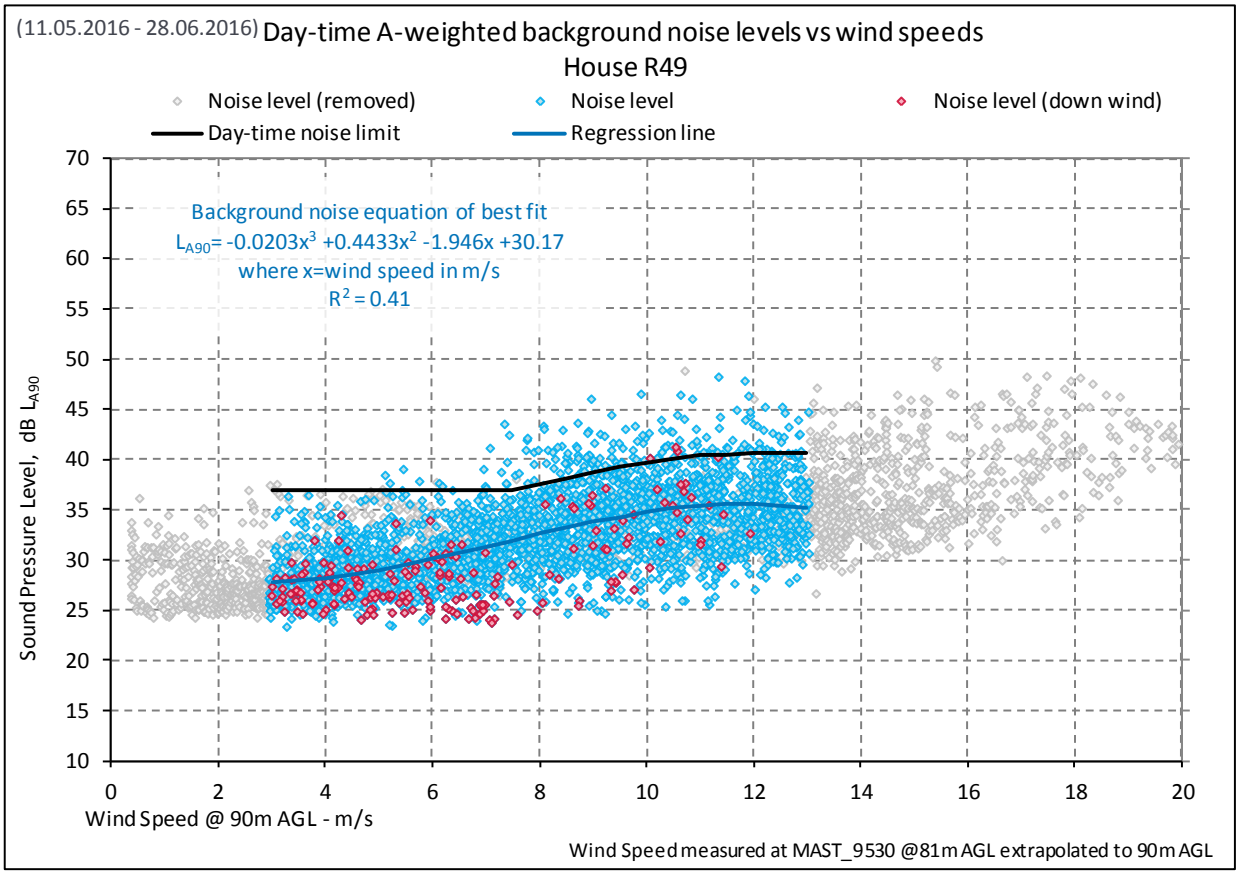
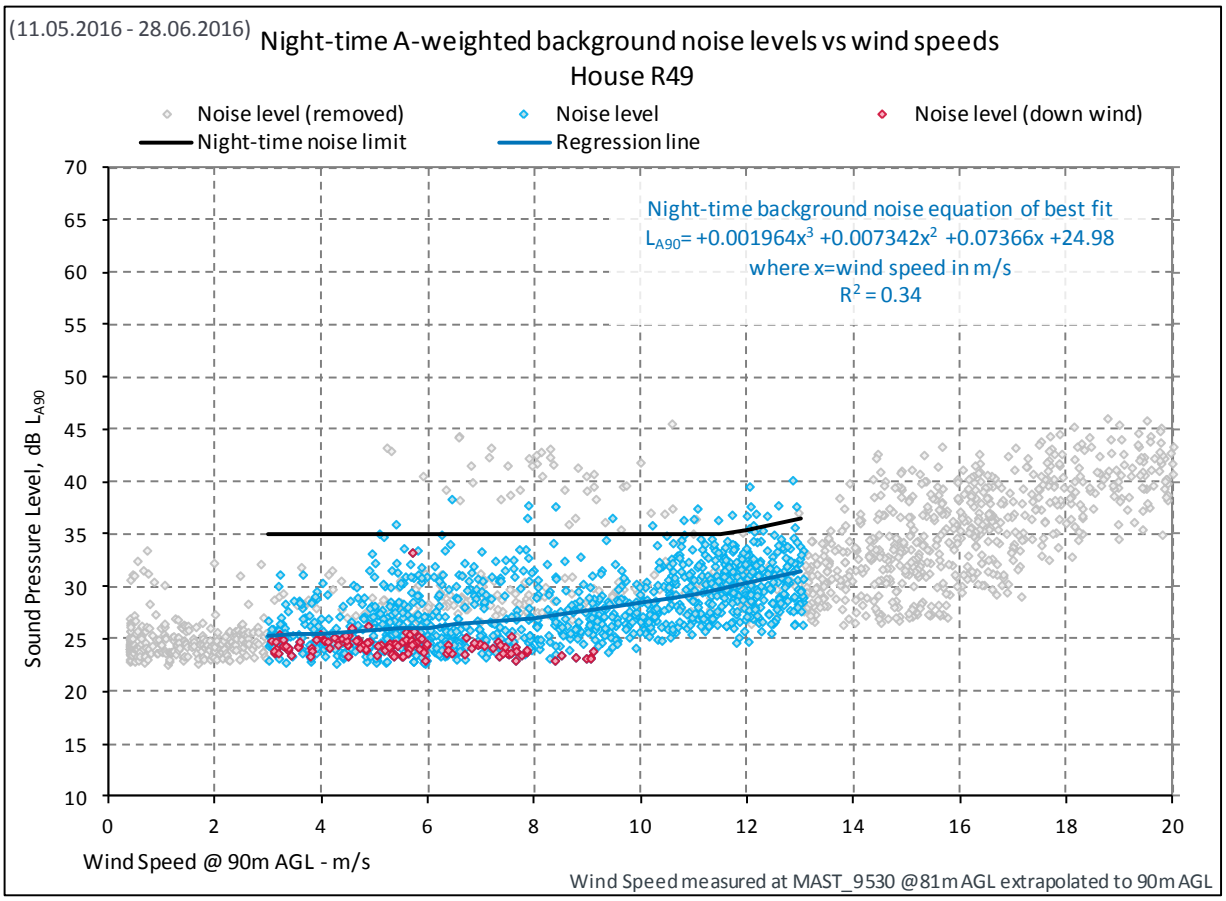


Figure 19: House R49 –Night-time A-weighted background noise levels & noise limits versus wind speed



3.5.2 C-weighted Background Noise Levels

A summary of the data for the C-weighted background noise level analysis is provided in Table 19.

Table 19: House R49 C-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4645	2340
Total number of data points removed due to local wind speed, rain or insect noise	1594	1149
Number of data points used for regression analysis	3051	1191
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	193	124

The measured C-weighted background noise levels and regression analysis for House R49 are presented in Figure 20 and Figure 21 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 20: House R49 – Daytime C-weighted background noise levels versus wind speed

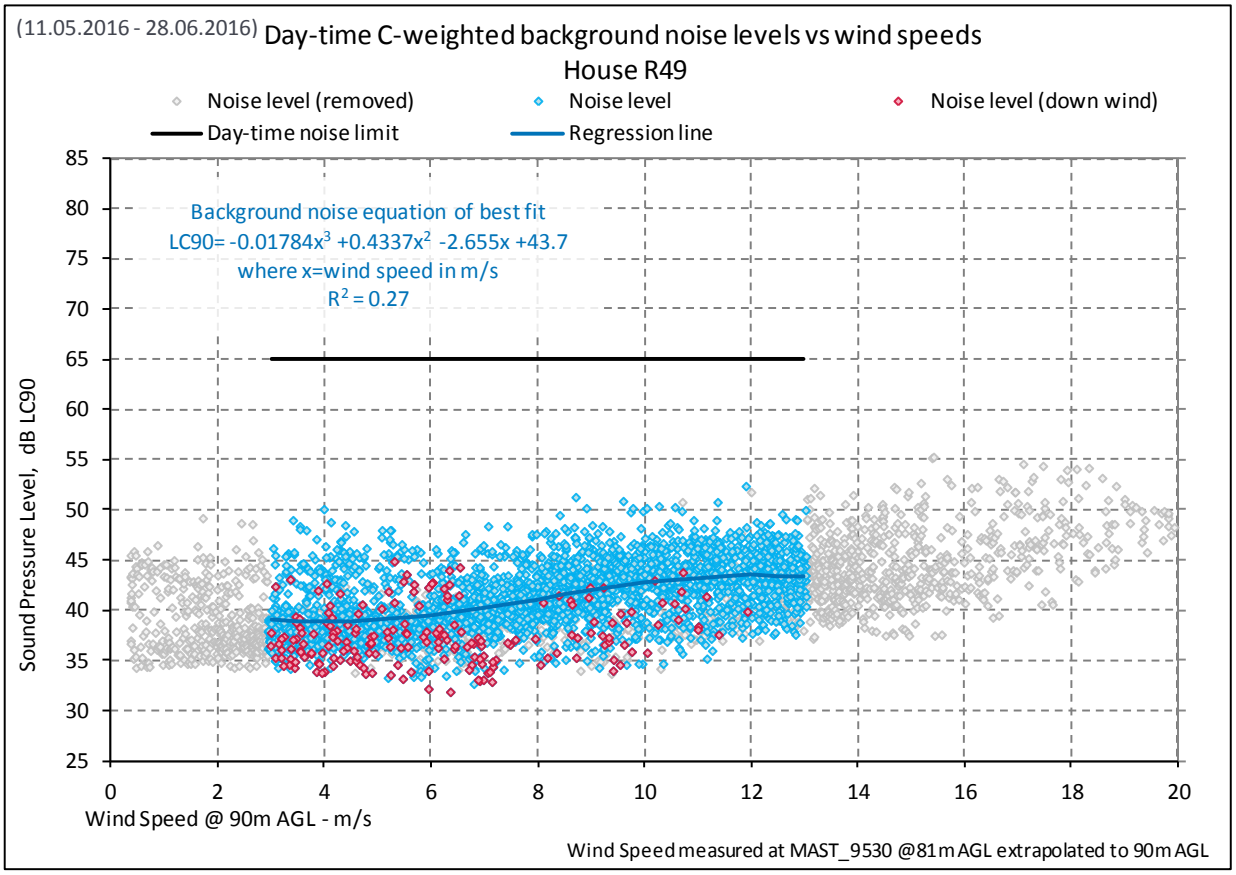
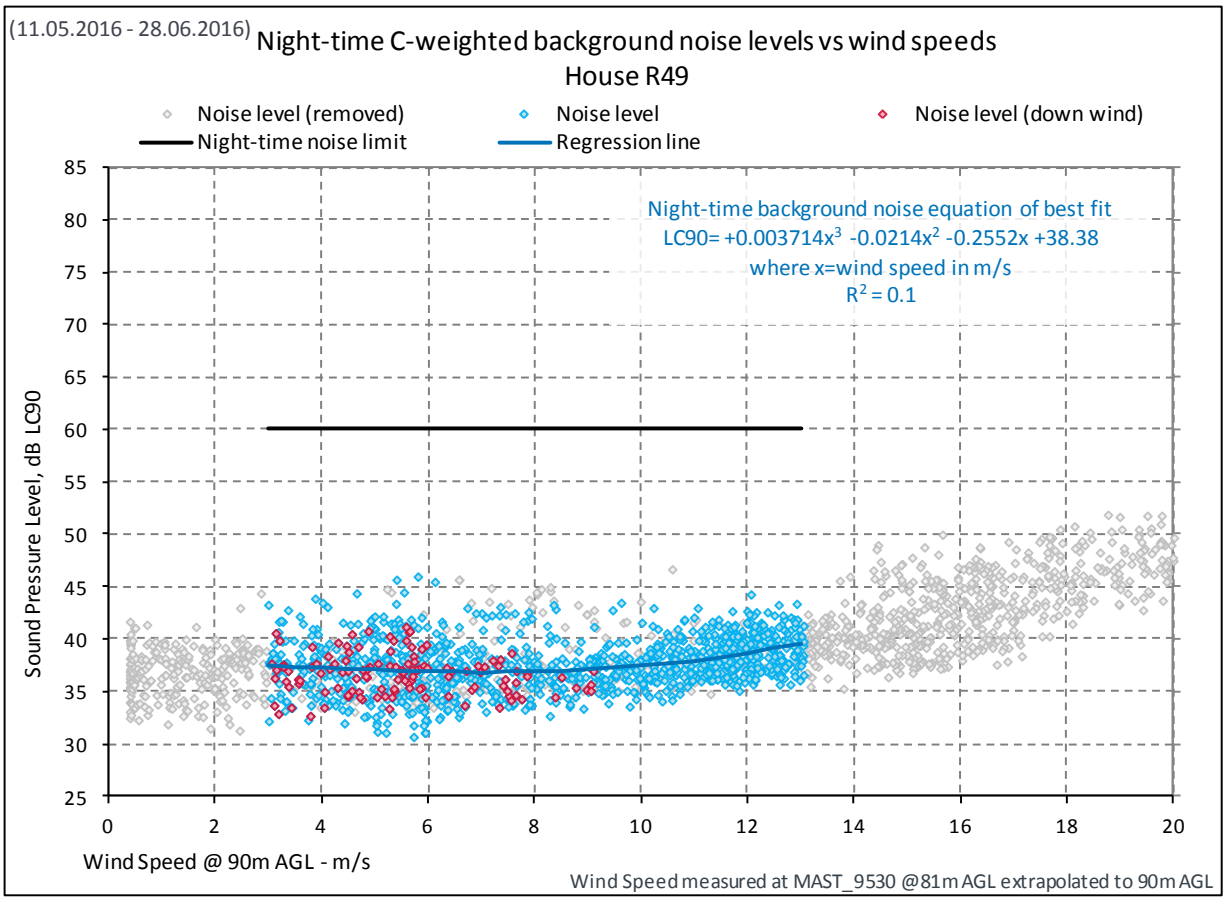


Figure 21: House R49 – Night-time C-weighted background noise levels versus wind speed



3.6 House R78

A summary of the monitoring for House R78 is provided in Table 20.

Table 20: House R78 monitoring and analysis details

Item	Description
Monitor location (easting : northing)	327646: 8103889
Monitoring period	9 May to 29 June 2016
Sound Level Logging Device	01dB DUO 10394

3.6.1 A-weighted Background Noise Levels & Proposed Criteria

A summary of the data for the A-weighted background noise level analysis is provided in Table 21.

Table 21: House R78 A-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4807	2400
Total number of data points removed due to local wind speed, rain or insect noise	1454	1226
Number of data points used for regression analysis	3353	1174
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	214	144

The measured A-weighted background noise levels, regression analysis and proposed noise limits for House R78 are presented in Figure 22 and Figure 23 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 22: House R78 - Daytime A-weighted background noise levels & noise limits versus wind speed

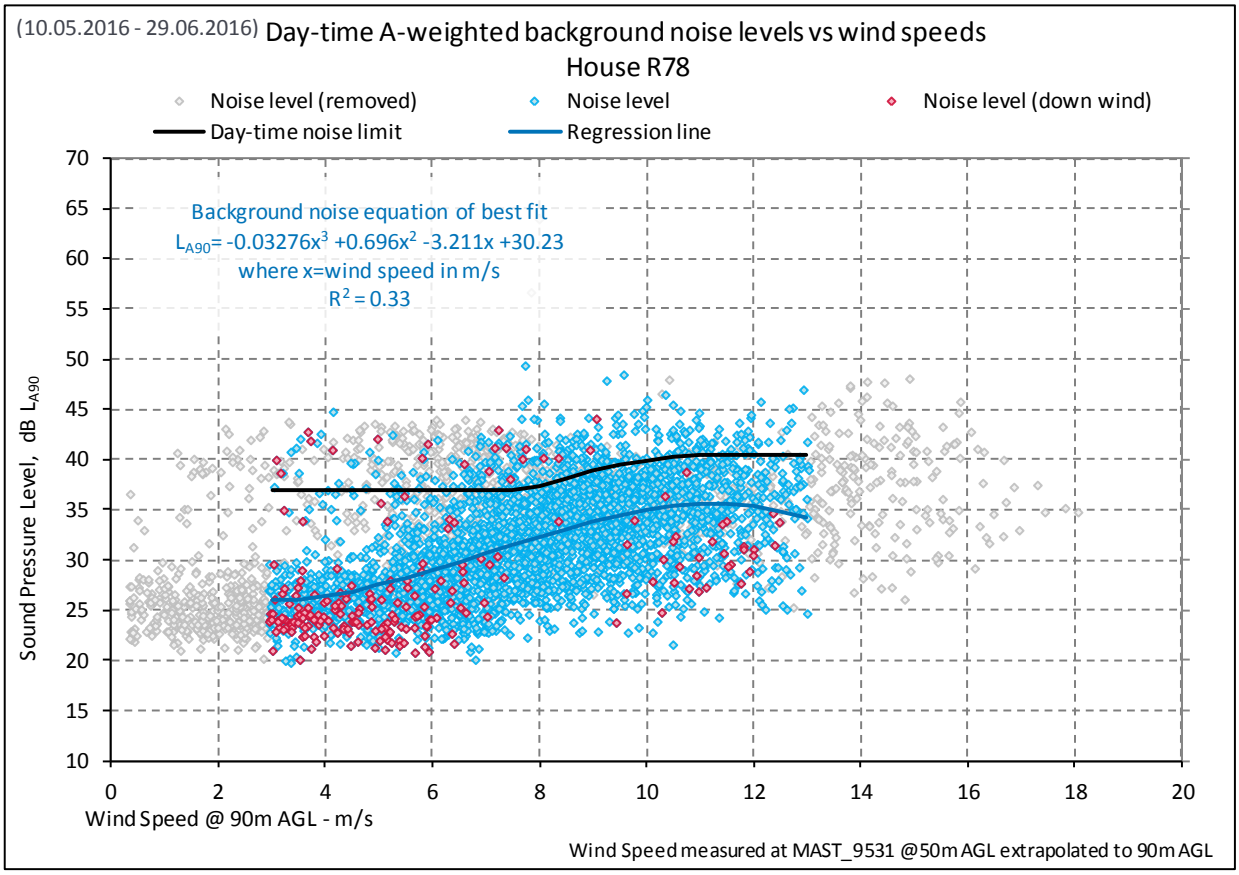
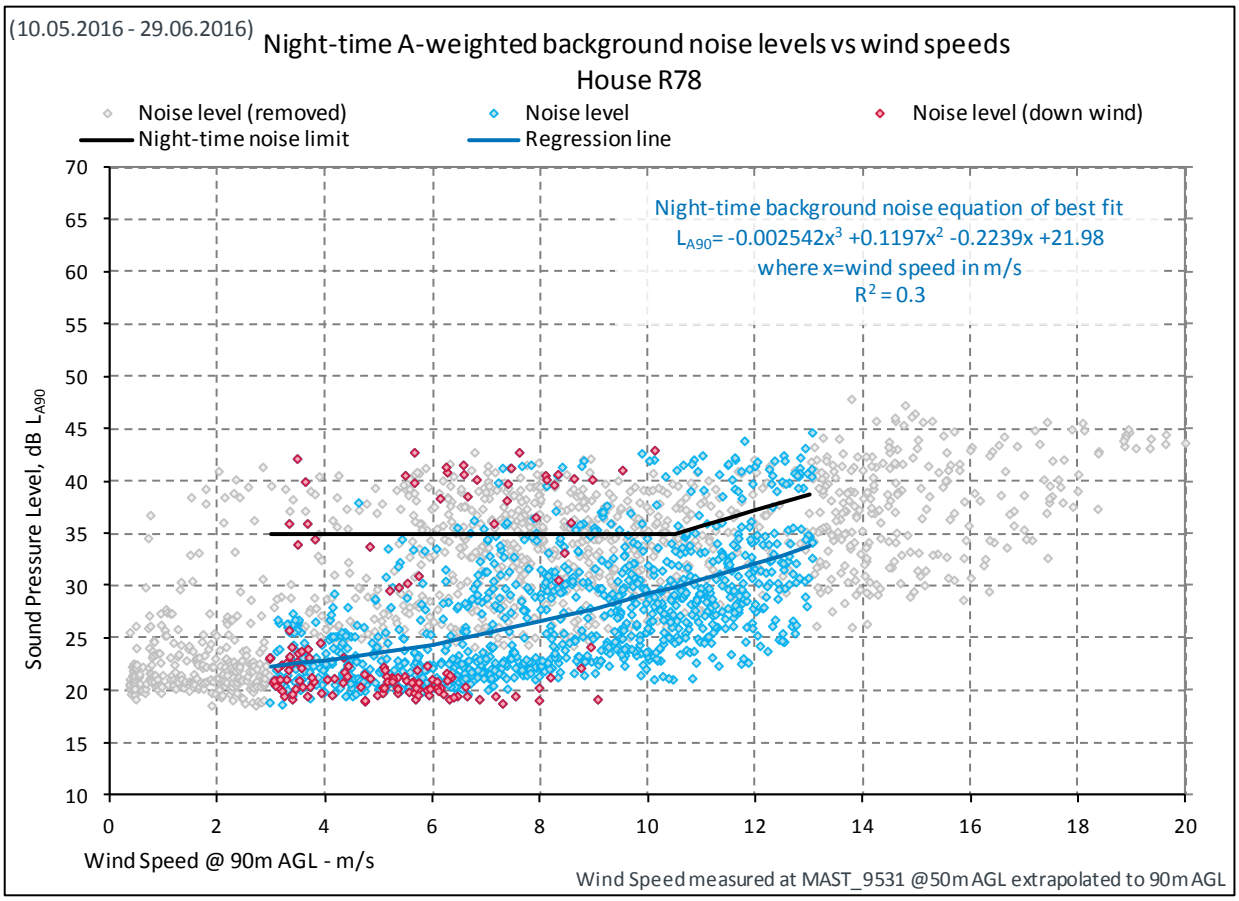


Figure 23: House R78 – Night-time A-weighted background noise levels & noise limits versus wind speed



3.6.2 C-weighted Background Noise Levels

A summary of the data for the C-weighted background noise level analysis is provided in Table 22.

Table 22: House R78 C-weighted background noise level analysis summary

Item	Day	Night
Total number of data points collected	4807	2400
Total number of data points removed due to local wind speed, rain or insect noise	2050	1258
Number of data points used for regression analysis	2757	11442
Site wind speed range for regression analysis	3-13	3-13
Number downwind data points within regression analysis dataset	207	138

The measured C-weighted background noise levels and regression analysis for House R78 are presented in Figure 24 and Figure 25 for the day and night respectively. These figures also illustrate all data points removed by the filtering process described in Section 2.2 and separately identify the points measured under downwind conditions as defined in Section 2.5.

Figure 24: House R78 – Daytime C-weighted background noise levels versus wind speed

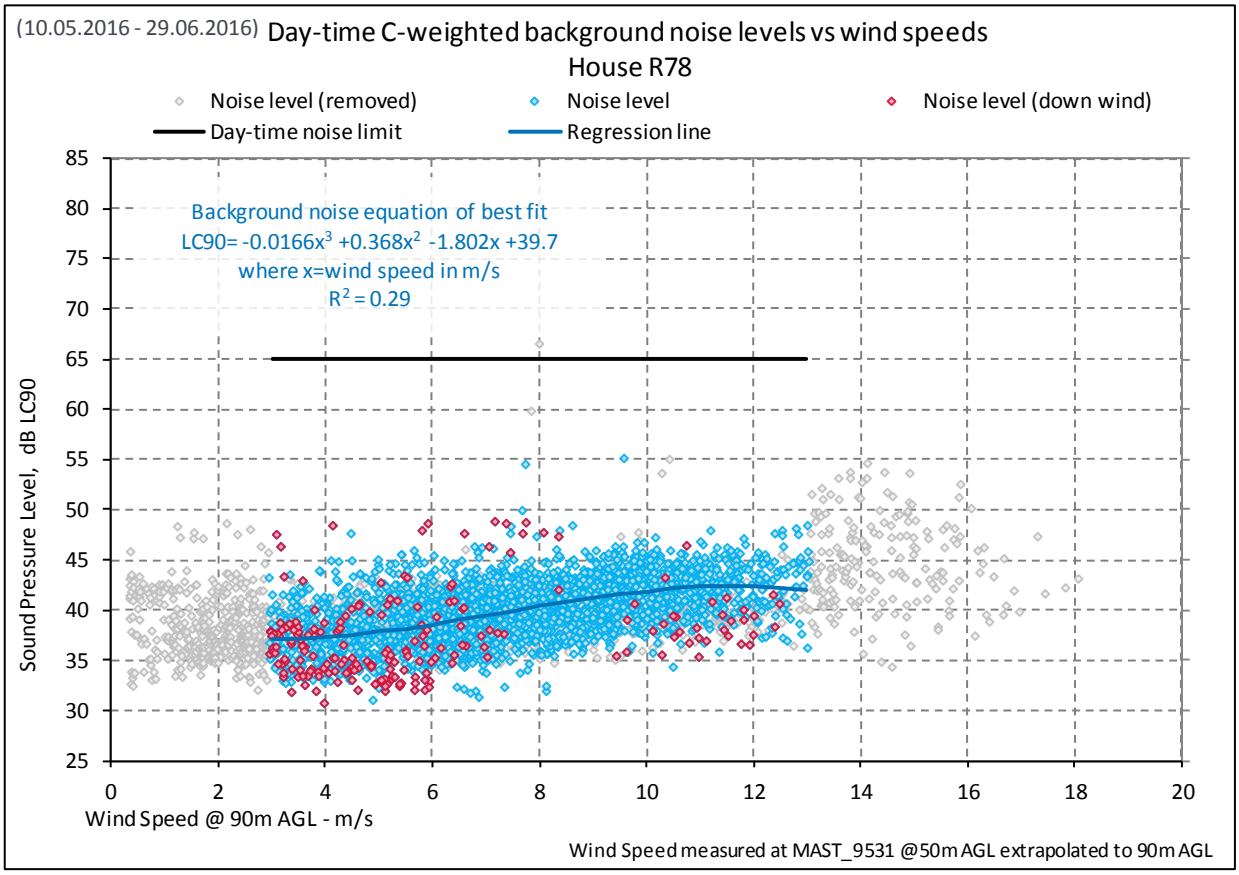
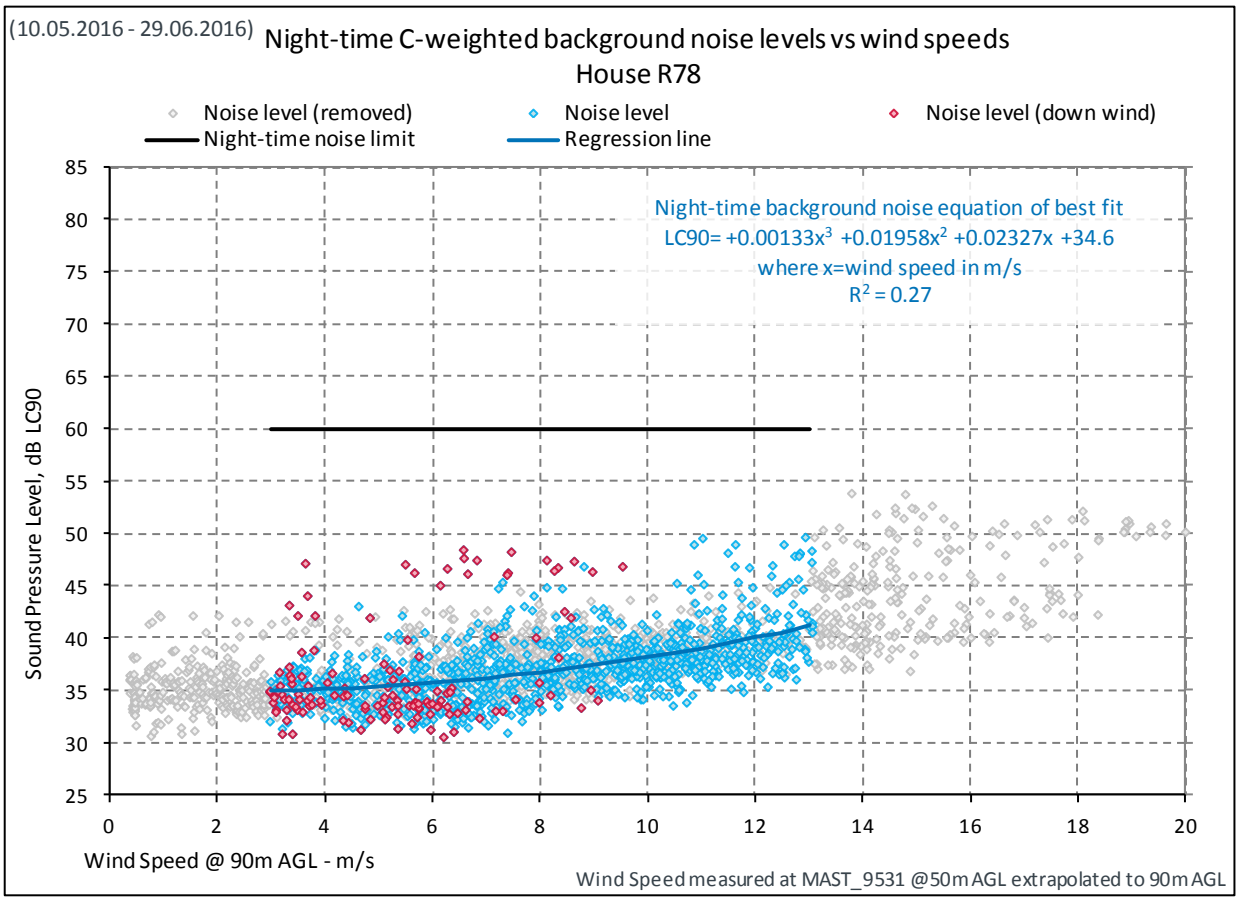


Figure 25: House R78 – Night-time C-weighted background noise levels versus wind speed



4.0 SUMMARY

Background noise monitoring has been conducted at six (6) receiver locations around the proposed Mt Emerald wind farm.

The survey and analysis has been carried out on the basis of:

- The *Development Permit for Material Change of Use* for the Mt Emerald Wind Farm, as amended by the notice of the Minister for Local Government and Planning dated 18 December 2015
- Australian Standard AS 4959-2010 *Acoustics - Measurement, prediction and assessment of noise from wind turbine generators* (AS 4959-2010), as referenced in the Development Permit
- The documented background noise survey methodology submitted to the Department of Infrastructure, Local Government and Planning prior the conducting the monitoring

The results of the measurements are to be referenced during the compliance monitoring phase of the project as an indication of potential A-weighted and C-weighted background noise levels contributing to the compliance measurements.

The results have also been analysed to derive noise limits in accordance with the Development Permit. Specifically, noise limits have been derived at integer hub-height wind speeds as the greater of a minimum limit (35 dB and 37 dB for day and night respectively) and the background level plus 5 dB.

Subject to the approval of chief executive administering the Sustainable Planning Act (as referenced in the Development Permit), the derived noise limits presented in this report would be used during compliance monitoring to assess the operational noise of the wind farm.

APPENDIX A GLOSSARY

Ambient	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.
dB	Decibel. The unit of sound level.
L_w (or SWL)	Sound Power Level. The level of total sound power radiated by a sound source.
L_{eq}	Continuous or semi-continuous noise levels are described in terms of the equivalent continuous sound level (L_{eq}). This is the constant sound level over a stated time period which is equivalent in total sound energy to the time-varying sound level measured over the same time period. This is commonly referred to as the average noise level.
L_{Aeq}	The "A" weighted equivalent continuous sound level.
Octave Band	A range of frequencies where the highest frequency included is twice the lowest frequency. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.
L_{A90}	The noise level exceeded for 90% of the measurement period, measured in A-weighted decibels. This is commonly referred to as the background noise level.
L_{C90}	The noise level exceeded for 90% of the measurement period, measured in C-weighted decibels. This is commonly referred to as the background noise level.

APPENDIX B SITE LAYOUT – TURBINE AND RECEIVER COORDINATES

B1 Turbine locations– MGA 94 Zone 55

The following table sets out the coordinates of the fifty-three (53) turbine layout considered during the survey planning (data received from RATCH 10 November 2015).

Turbine	Easting	Northing	Turbine	Easting	Northing
T03	326071	8103211	T37	328824	8099088
T04	326263	8102926	T38	328726	8098695
T05	326071	8102642	T39	329067	8098362
T06	325535	8102589	T44	329970	8099041
T07	325197	8102351	T45	329790	8099328
T08	325266	8102037	T46	329648	8099620
T09	325402	8101713	T47	329228	8099859
T10	325539	8101383	T48	329113	8100157
T11	325930	8101603	T49	329043	8100457
T12	325803	8102201	T50	329738	8100745
T13	326364	8101775	T51	329581	8101021
T15	325931	8101065	T52	329644	8101320
T16	325941	8100734	T53	329242	8100793
T17	326222	8100448	T54	328753	8100703
T18	326484	8100150	T55	328157	8100695
T19	326793	8099845	T56	328537	8100981
T20	327187	8099577	T57	328498	8101272
T21	327392	8099290	T58	328458	8101575
T22	327652	8099773	T59	328466	8101926
T29	326556	8101046	T60	328402	8102310
T30	326708	8100606	T63	328792	8102560
T31	328045	8100267	T64	328903	8102219
T32	328206	8099881	T65	328983	8101892
T33	328648	8099655	T66	328031	8101732
T34	328376	8099384	T67	327768	8101472
T35	328058	8099149	T69	327574	8102211
T36	328292	8098872	-	-	-

B2 Receiver locations – MGA 94 Zone 55

The following table sets out the one-hundred and twenty three (123) receiver locations considered during the survey planning (received from RATCH 23 November 2015). These correspond to the same receiver locations considering during the planning and development approval stage of the project.

Receiver	Easting	Northing	Receiver	Easting	Northing
R01	327108	8094240	R63	333180	8098115
R02	323399	8101041	R64	333966	8098486
R03	322551	8100377	R65	334769	8098473
R04	322401	8100614	R66	333273	8097584
R05	325084	8099119	R67	333769	8097741
R06	324402	8099053	R68	333818	8097418
R07	324438	8098311	R69	333759	8097284
R08	324461	8097943	R70	333858	8097008
R09	324552	8097638	R71	333837	8096819
R10	324741	8097351	R72	334122	8096447
R11	325824	8096858	R73	334300	8097467
R12	326812	8094840	R74	334315	8097097
R13	322913	8101970	R75	334312	8096814
R14	323526	8098996	R76	334510	8096570
R15	322190	8101228	R77	333420	8095349
R16	323417	8099332	R78	327662	8103902
R17	321385	8101835	R79	326084	8095615
R18	322861	8105817	R80	326633	8095887
R19	323237	8105869	R81	322227	8102228
R20	324011	8106789	R82	328862	8104954
R21	327346	8105105	R83	331064	8103659
R22	327532	8105458	R84	328138	8105207
R23	327320	8105720	R87	324029	8106539
R24	327836	8105651	R88	325804	8107243
R25	328105	8105059	R89	324925	8104393
R26	327385	8104239	R90	323839	8105103
R27	328640	8104706	R91	333946	8102712
R28	328814	8104996	R92	334049	8103397
R29	329227	8104783	R93	333585	8103544
R30	329632	8104345	R94	333738	8103749
R31	329738	8105254	R95	333737	8103972
R32	329821	8104154	R96	333543	8104296
R33	329870	8104536	R97	333476	8104424
R34	330044	8104444	R98	333652	8104597
R35	330166	8103957	R99	332659	8104989
R36	330281	8103655	R100	332380	8105473

Receiver	Easting	Northing	Receiver	Easting	Northing
R37	330744	8104165	R101	332447	8105917
R38	331053	8103796	R102	333013	8104126
R39	331012	8103431	R103	332934	8104276
R40	331286	8103732	R104	332397	8104339
R41	331610	8103457	R105	330771	8106228
R42	331773	8103467	R106	330687	8106366
R43	331900	8103216	R107	330802	8106936
R44	332241	8103249	R108	331175	8107484
R45	332142	8103035	R109	328594	8107639
R46	331667	8102969	R110	328212	8107130
R47	331836	8102949	R111	328314	8106195
R48	331981	8102675	R112	327666	8106205
R49	331555	8100953	R113	327055	8106025
R50	333099	8102820	R114	327675	8108169
R51	333372	8102564	R115	327309	8108440
R52	333849	8102111	R116	324316	8109076
R53	333977	8101981	R117	320884	8102947
R54	334001	8101907	R118	321231	8101117
R55	334143	8101119	R119	321148	8101136
R56	334828	8100860	R120	321240	8101684
R57	332290	8102160	R121	319947	8100527
R58	333082	8100051	R122	333913	8094653
R59	332424	8099580	R123	334862	8095248
R60	332526	8098770	RANGEVIEW	335269	8097070
R61	333441	8099268	WALKAMIN	332711	8105470
R62	332750	8099348	-	-	-

APPENDIX C DEVELOPMENT PERMIT – OPERATIONAL NOISE REQUIREMENTS

The following excerpts concerning operational wind turbine noise have been reproduced from *Schedule 1: Conditions of Approval* of the Development Permit, as amended by the notice of the Minister for Local Government and Planning dated 18 December 2015.

4.	*The wind farm development must be designed and operated to ensure that:* *(a) The outdoor night-time (10pm to 6am) equivalent noise level ($L_{Aeq,10\ minutes}$) at existing and approved sensitive land uses at the date of this approval, does not exceed the higher of:* *(i) 35dB(A); or* *(ii) The background noise level (L_{A90}) plus 5dB(A);* *and* *(b) The outdoor day-time equivalent noise level ($L_{Aeq,10\ minutes}$) at existing and approved sensitive land uses at the date of this approval, does not exceed the higher of:* *(i) 37dB(A); or* *(ii) The background noise level (L_{A90}) plus 5dB(A)* *(c) The equivalent noise levels (L_{Aeq}) are to be assessed at all existing and approved sensitive land uses at the date of this approval for all integer hub height wind speeds from cut-in to rated power of the wind turbine generator.* *(d) Measurements of background noise operational noise from wind turbine generators for the operation shall be in accordance with Australian Standard AS4959-2010 Acoustics – Measurement, prediction and assessment of noise from wind turbine generators (AS4959-2010) at any existing and approved sensitive land uses at the date of this approval. If an alternative standard or guideline to AS4959-2010 is to be followed for the assessment of Special Audible Characteristics, then reasons for the selection of the alternative are to be provided.*	*Prior to commencement of use and then to be maintained.*
5.	*The wind farm development must be designed and operated to ensure that the low frequency noise level does not exceed:* *(a) 60dB(C) for outdoor C-weighted equivalent noise level ($L_{Ceq,\ 10\ minutes}$) during the outdoor night-time (10pm to 6am); and* *(b) 65dB(C) for outdoor C-weighted equivalent noise level ($L_{Ceq,\ 10\ minutes}$) during the outdoor day-time (6am to 10pm).* *The C-Weighted noise levels (L_{Ceq}) are to be assessed at all existing and approved sensitive land uses at the date of this approval for all integer hub height wind speeds from cut-in to rated power of the wind turbine generator.* *Measurements of operational noise from wind turbine generators for the operation shall be in accordance with Australian Standard AS4959-2010 Acoustics – Measurement, prediction and assessment of noise from wind turbine generators at any existing and approved sensitive land uses at the date of this approval.*	*Prior to the commencement of use and then to be maintained*

6.	(a)	*Submit to the chief executive administering the SPA a revised noise assessment report, certified by a suitably qualified acoustic consultant, demonstrating that the proposed wind farm can meet the noise levels specified in conditions 4 and 5 of this approval. The report is to:* *i. Model the acoustic impacts of the wind farm based on the revised Turbine Location and Development Footprint Plan submitted in accordance with condition of this approval.* *The noise modelling should take into account the varied topography between the turbine locations and existing and approved sensitive land use receptors at the date of this approval and any impacts that may have on predicted noise levels, and include an assessment of Special Audible Characteristics including tonality, impulsivity and amplitude modulation.* *ii. Identify any design specifications or operational restrictions that may be necessary to ensure compliance with the noise levels specified in conditions 4 and 5, such as turbine types or limitations on hours of operation of specific turbines.*	(a) *Prior to the commencement of site / operational / building work*
	(b)	*Submit to the chief executive administering the SPA a compliance noise assessment report, by a suitably qualified acoustic consultant, demonstrating that the proposed wind farm meets the noise levels specified in conditions 4 and 5 of this approval. The report is to:* *i. Measure the acoustic impacts of the wind farm based on the final Turbine Location and Development Footprint Plan submitted in accordance with condition 2 of this approval.* *The noise measurements should take into account the turbine locations and any existing and approved sensitive land use receptors at the date of this approval; and include an assessment of Special Audible Characteristics including tonality, impulsivity and amplitude modulation. Assessment of Special Audible Characteristics should be carried out using an appropriate international standard or guideline. Reasons for the selection of the standard or guideline are to be provided with the noise assessment report. The assessment should determine whether Special Audible Characteristics are excessive and require an adverse character adjustment (adj) to specific measurement period.*	(c) *Within twelve (12) months of the completion of construction and then to be maintained*

APPENDIX D SITE WIND SPEED DATA DERIVATION– WSP / PARSONS BRINCKERHOFF CORRESPONDENCE

This appendix reproduces correspondence provided by WSP / Parsons Brinckherhoff documenting the process used to derive the 90 m AGL wind speeds required to analyse the measured background noise data.

The correspondence refers to a total of three (3) wind speed measurement systems at the site.

The analysis of the background noise measurement data is based on site wind speed data sourced from systems 9530 and 9531 (meteorological masts).

Data from the third system 0534 (085) is not referred to in the background noise measurement data analysis.

WSP | PARSONS BRINCKERHOFF

Level 15, 28 Freshwater Place
Southbank VIC 3006

Tel: +61 3 9861 1111
Fax: +61 3 9861 1144

www.wsp-pb.com

MEMO

TO: Hugh Sangster (RATCH-Australia Corporation)

FROM: Ben Inkster

SUBJECT: **Mount Emerald Wind Farm: Wind data at hub height**

OUR REF: MTEMERALD-WIN-MEM-001 Rev01.docx

DATE: **7 July 2016**

1. INTRODUCTION

At the request of RATCH-Australia Corporation Ltd (RATCH), WSP | Parsons Brinckerhoff (WSP|PB) has performed wind shear extrapolation of three wind datasets, measured at two wind monitoring masts and one Sonic Detection and Ranging (Sodar) device at the Mount Emerald Wind Farm (MEWF). Each data set has been extrapolated to hub heights of 84, 87 and 90 m Above Ground Level (mAGL). The masts and Sodar extrapolated are detailed in Table 1.1.

Table 1.1

SITE ID	EASTING	NORTHING	UTM ZONE	GPS DATUM	MEASURMENT HEIGHT
9530	329088 E	8100271 S	55K	AGD94	81 mAGL
9531	325608 E	8101256 S	55K	AGD94	50 mAGL
0534 (085)	328431 E	8101550 S	55K	AGD94	40-200 mAGL

2. DATA CLEANING AND SUPPLEMENTATION

Each mast dataset has undergone cleaning of erroneous samples based on comparison with wind speed measurements from alternative instruments, and by comparison with alternative measurement sources such as other masts and Sodars. Mast data has undergone modification to account for tower sheltering and mast 9531 has been corrected for a systematic wind direction offset, to be aligned with other data sources.

Sodar data has undergone filtering to remove data with a Triton Sodar quality index of less than 95%. After filtering, the Sodar data achieved a data availability rate of 75%. WSP|PB has conducted a process of data supplementation using synthesised data from a multi-dimensional correlation process with mast 9530. The result of the data supplementation is a dataset with 100% availability. This final dataset consists of 25% synthetic data and 75% measured data.

3. WIND SHEAR EXTRAPOLATION

Wind shear is the term used to describe the change in wind speed with height above ground level. Wind shear is accurately modelled at most sites using the power law wind shear model. The magnitude of wind shear (rate of change of wind speed against height) is known to vary with three main variables:

- Wind direction – the unique topography in each direction has its own influence on wind shear,
- Time of day – thermal effects during the day often result in a lower wind shear than that experienced at night, and

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→ Wind speed – turbulence levels and the impact of topographical features depend on wind speed.

WSP|PB has considered these variables by using multi-dimensional time, speed, direction and season bins to resolve the shear extrapolation for the three monitoring sites. In this process, data recorded at each mast and Sodar has been used to determine the multi-dimensional shear exponents before applying these shear parameters to the annual long term adjusted wind data.

WSP|PB has extrapolated the long term adjusted data from each monitoring site to the three nominal hub heights of 84, 87 and 90 mAGL using the multi-dimensional wind shear analysis. A summary of the extrapolation is shown in Table 3.1.

Table 3.1 Shear extrapolation of longer-term adjusted wind speeds

MAST ID	INSTRUMENTS USED FOR SHEAR MATRIX	MULTI-DIMENSIONAL WIND SHEAR EXPONENT (α)
9530	S1 & S3	0.04
9531	S2 & S3	0.20
0534	S6,S7,S8,S9	0.21

WSP|PB has provided RATCH with time series datasets reduced to measurement periods after 01 May 2016. The datasets provided contain inherent uncertainty due to the processes of wind shear extrapolation and data synthesis and uncertainties should be considered in its use.

Kind regards,

Ben Inkster
Technical Manager - Wind Engineering

APPENDIX E SOUND MEASUREMENT SYSTEMS

E1 Instrumentation

A summary of the equipment deployed for the noise survey, including serial numbers and calibration details (independent/laboratory calibration and site reference checks), is provided in Table 23.

Table 23: Equipment records

Location	System	Unit Serial Number	Microphone Serial Number	Independent Calibration Date [1]	Calibration Drift[3]
R02	01dB Duo	10196	136987	10-Apr-2015	OK
R05	01dB Duo	10197	141100	30-Sep-2014	OK
R36	01dB Duo	10409	136870	13-Aug-2014	OK
R48	01dB Duo	10498	207226	25-Sep-2014	OK
R49	01dB Duo	10499	141223	29-Oct-2015	OK
R78	01dB Duo	10394	144928	13-Jan-2016	OK
All	Rion NC-74 Sound Calibrator	51230896	-	29-Sep-2015	-
	Rion NC-74 Sound Calibrator	34483808	-	12-Apr-2016	-

Note 1: Independent (laboratory) calibration date must be within 2 years of measurement period

Note 2: Difference between reference level checks conducted during deployment and collection of instruments

Note3: Calibration drift OK if within manufacturer recommended tolerance

E2 Measurement Uncertainty

Sound measurement uncertainties relate to:

- Sound measurement instrumentation

  The uncertainty surrounding the difference between the measured sound level for each 10-minute period and the actual sound level that occurred at the monitoring system.

- Sound field variations

  The uncertainty in the use of sound measurement data to represent locations or time periods other than those which were surveyed.

E2.1 Sound Measurement Instrumentation

AS 4959-2010 states that the equipment should be in accordance in accordance with IEC 61672-3 or AS 1259.1 and AS 1259.2, and AS IEC 60942 for sound calibrators. The standard also outlines requirements concerning periodic independent calibration.

All sound measurement instrumentation for the survey conformed to IEC 6172 Class 1 requirements. While AS 4959-2010 does not specify minimum class or type ratings, Class 1 is higher than the example instrumentation referenced in the worked example of Appendix B of AS 4959-2010, and represents the highest class of instrumentation for environmental sound measurements. The calibration of all equipment was checked at the start and end of the survey, and confirmed that no significant drift in calibration occurred over the course of the survey. Automated internal calibration checks were also performed daily. All instrumentation, including reference signal calibrators, was within the specified independent calibration periods (see Table 23 above for details).

Based on the above equipment standards and calibration checks, uncertainties related to sound measurement instrumentation are expected to be significantly less than 1 dB. In the context of measurement uncertainties related to broader sound field variations (discussed in the next section), the measurement uncertainty related to instrumentation accuracy is negligible. The measurement results are therefore considered a true representation of the sound levels that occurred at the monitoring locations during the survey period.

E2.2 Sound Field Variations

Background sound levels vary widely from moment to moment, at different times of day, during different weather conditions and at different times of year.

These variations are evident in the survey results which show a wide range of measured noise levels (typically greater than 10 dB). The variation in the measurement results does not represent uncertainty – the measured variation is a true representation of the range of noise levels occurring in practice. The uncertainty lies in the use of the measurement data to represent locations or time periods other than those which were surveyed i.e. the uncertainty relating to the extent to which a different result could occur if the surveys were conducted at a different location at a different time of year.

AS 4959-2010 does not prescribe a requirement to measure background noise levels at all times of year, nor does it indicate how a single set of results would be derived from the results of varied survey outcomes at different times of year. This is consistent with other wind farm guidance documents which are generally based upon capturing a typical representation of background noise levels, accounting for the sources of variation which should either be excluded (such as rain noise) or considered (e.g. variations in foliage or wind directions).

Based on the above, the uncertainty related to sound field variations is accounted for by addressing the potential sources of variation in the measured background noise levels

To address sound field variations in the Mt Emerald Wind Farm survey, the following procedures were applied:

- The selection of each receiver location where noise monitoring was carried out was generally based on identifying the receiver, among a group of receivers, expected to experience the lowest background noise levels (accounting for elevation and local foliage)
- At each receiver location, the noise monitor was placed at a point where the background noise levels were expected to be lowest around the dwelling. For example, the monitors were placed as far as practically possible from tall local vegetation at each property
- Rainfall was measured at each monitoring location throughout the survey in order to identify and remove any periods in which rain occurred
- The survey duration was extended to a period of at least 6 weeks to enable a broad range of conditions to be measured; this significantly exceeded the AS 4959-2010 minimum data requirements which correspond to a period of approximately 2 weeks of valid data
- Sound frequency measurements were carried out throughout the survey to enable suspected periods of high insect noise to be identified and removed
- Analysis of the data involved a review of the potential for background noise levels to vary under different wind conditions. The analysis included separate plotting of the downwind measurement data (data measured during period when the wind, or a vector component of the wind, is directed from the wind farm to the receiver. The results demonstrated no clear systematic variation with wind direction.

In addition to the above, the foliage around each dwelling was predominantly evergreen and therefore potential seasonal variations related to changes in leaf coverage through the year are not a relevant consideration at this site.

Based on the above procedures and considerations, sound field variations have been appropriately considered in the survey design, implementation and analysis. The inherent variability of background sound levels means that a survey conducted during alternative times of year, or at different locations, could yield different results. However, the measurements have been carried out and analysed in a manner that is suitable for obtaining a representation of typical lower background noise levels expected to occur in practice. This is consistent with the procedures and principles established in AS 4959-2010.

APPENDIX F MONITORING LOCATION PHOTOS

F1 House R02

Looking North	Looking East
	
Looking South	**Looking West**
	

F2 House R05

Looking North	Looking East
	
Looking South	**Looking West**
	

F3 House R36

Looking North	Looking East
	
Looking South	**Looking West**
	

F4 House R48

Looking North	Looking East
	
Looking South	**Looking West**
	

F5 House R49

Looking North	Looking East
	
Looking South	**Looking West**
	

F6 House R78

Looking North	Looking East
	
Looking South	**Looking West**
	

APPENDIX G TABULATED BACKGROUND NOISE LEVELS

G1 All wind directions

A summary of the A-weighted and C-weighted background noise levels derived from the regression analysis graphically presented in Section 3.0 is presented in tabular form below.

Table 24: Measured A-weighted daytime background noise levels (L_{A90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	28.9	29.4	30.1	30.9	31.7	32.4	33.1	33.6	34.0	34.1	34.0
R05	26.0	27.1	27.9	28.5	29.0	29.4	30.0	30.8	32.0	33.5	35.7
R36	28.5	29.4	30.4	31.6	32.9	34.0	35.1	35.9	36.5	36.6	36.3
R48	30.5	31.8	33.2	34.6	35.9	37.1	38.1	38.8	39.3	39.3	38.9
R49	27.8	28.2	29.0	30.1	31.3	32.6	33.8	34.7	35.4	35.6	35.2
R78	26.0	26.4	27.5	28.9	30.6	32.3	33.8	35.0	35.5	35.3	34.2

Table 25: Measured A-weighted night-time background noise levels (L_{A90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	24.6	24.7	24.8	25.0	25.2	25.7	26.5	27.8	29.5	31.8	34.9
R05	24.1	24.8	25.2	25.6	25.9	26.4	27.2	28.5	30.4	33.0	36.4
R36	28.4	28.9	29.3	29.7	30.2	30.6	31.0	31.5	32.0	32.5	33.1
R48	28.9	29.6	30.1	30.3	30.5	30.7	30.9	31.3	31.8	32.6	33.8
R49	25.3	25.5	25.8	26.1	26.5	27.0	27.7	28.4	29.3	30.3	31.5
R78	22.3	22.8	23.5	24.4	25.4	26.5	27.8	29.2	30.6	32.1	33.7

Table 26: Measured C-weighted daytime background noise levels (L_{C90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	44.9	44.1	43.7	43.6	43.7	44.0	44.3	44.7	45.0	45.1	45.0
R05	37.6	37.7	37.9	38.2	38.7	39.3	39.9	40.6	41.4	42.2	43.0
R36	42.5	42.9	43.3	43.7	44.1	44.5	44.9	45.3	45.7	46.1	46.4
R48	44.5	44.5	44.8	45.2	45.7	46.3	46.8	47.2	47.5	47.5	47.3
R49	39.2	38.9	39.0	39.5	40.2	41.1	41.9	42.7	43.2	43.5	43.3
R78	37.2	37.3	37.8	38.5	39.4	40.3	41.2	41.9	42.3	42.4	42.0

Table 27: Measured C-weighted night-time background noise levels (L_{C90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	42.0	41.7	41.3	40.9	40.5	40.4	40.5	40.8	41.6	42.7	44.4
R05	36.4	36.4	36.2	36.2	36.3	36.5	37.1	38.0	39.4	41.2	43.7
R36	41.1	41.0	41.1	41.2	41.3	41.6	41.8	42.1	42.5	42.8	43.1
R48	43.2	43.3	43.3	43.3	43.2	43.1	43.0	43.0	43.1	43.4	43.8
R49	37.5	37.3	37.0	36.9	36.8	36.9	37.1	37.4	37.9	38.7	39.6
R78	34.9	35.1	35.4	35.7	36.2	36.7	37.4	38.1	39.0	40.0	41.1

G2 Downwind directions

A summary of the A-weighted and C-weighted background noise levels derived from the regression analysis graphically presented in Section 3.0 is presented in tabular form below. Specifically, these tables represent filtered background noise levels under downwind conditions only.

Table 28: Measured A-weighted daytime background noise levels (L_{A90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	29.2	29.6	30.2	31.0	31.7	32.5	33.2	33.7	34.1	34.3	34.1
R05	25.9	27.3	28.3	28.9	29.3	29.6	29.8	30.2	30.7	31.6	32.8
R36	*	*	*	*	*	*	*	*	*	*	*
R48	*	*	*	*	*	*	*	*	*	*	*
R49	*	*	*	*	*	*	*	*	*	*	*
R78	*	*	*	*	*	*	*	*	*	*	*

* Lack of measured data at these wind speeds

Table 29: Measured A-weighted night-time background noise levels (L_{A90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	25.2	25.0	25.0	25.1	25.5	26.1	27.1	28.4	30.1	32.3	35.0
R05	*	*	*	*	*	*	*	*	*	*	*
R36	*	*	*	*	*	*	*	*	*	*	*
R48	*	*	*	*	*	*	*	*	*	*	*
R49	*	*	*	*	*	*	*	*	*	*	*
R78	*	*	*	*	*	*	*	*	*	*	*

* Lack of measured data at these wind speeds

Table 30: Measured C-weighted daytime background noise levels (L_{C90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	45.5	44.4	43.8	43.6	43.7	44.0	44.5	44.9	45.2	45.2	45.0
R05	37.3	37.4	37.7	38.2	38.7	39.3	39.9	40.4	40.9	41.1	41.1
R36	*	*	*	*	*	*	*	*	*	*	*
R48	*	*	*	*	*	*	*	*	*	*	*
R49	*	*	*	*	*	*	*	*	*	*	*
R78	*	*	*	*	*	*	*	*	*	*	*

* Lack of measured data at these wind speeds

Table 31: Measured C-weighted night-time background noise levels (L_{C90})

Location	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	42.8	42.4	41.9	41.3	40.7	40.3	40.2	40.4	41.2	42.7	44.9
R05	*	*	*	*	*	*	*	*	*	*	*
R36	*	*	*	*	*	*	*	*	*	*	*
R48	*	*	*	*	*	*	*	*	*	*	*
R49	*	*	*	*	*	*	*	*	*	*	*
R78	*	*	*	*	*	*	*	*	*	*	*

* Lack of measured data at these wind speeds