MARSHALL DAY Acoustics

COLLECTOR WIND FARM
BACKGROUND NOISE MONITORING

Report No.002 2015087ML | 30 September 2015

MARSHALL DAY Acoustics

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: **COLLECTOR WIND FARM - POST CONSENT SERVICES**

Prepared for: **RATCH Australia Pty Ltd**
Level 7
111 Pacific Highway
North Sydney NSW 2059

Attention: **Anthony Yeates**

Report No.: **Rp 002 2015087ML**

Document Control

Status:	Rev:	Comments	Date:	Author:	Reviewer:
Draft	-	For RATCH text review	28/07/2015	J. Adcock	-
Draft	-	Complete for review	31/07/2015	J. Adcock	J. Ellis
Draft	-	Complete for external use	10/08/2015	J. Adcock	C. Delaire
Draft	-	Minor text edit	12/08/2015	J. Adcock	-
Final	-	Additional J int. data & corrected turbine coordinates	30/09/2015	J. Adcock / J. Ellis	J. Adcock / J. Ellis

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1.0 INTRODUCTION

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

Background noise surveys were previously carried out in 2010 around the Collector Wind Farm during the planning phase of the project. The results of the 2010 noise surveys indicated relatively high noise levels during the period when measurements were made at non-involved receiver locations. The effect is believed to have been caused by seasonal influences such as insect noise.

It was therefore determined that the surveys at non-involved locations would need to be repeated before background noise dependent limits could be defined. In advance of these surveys being carried out, the planning phase noise assessment was carried out on a conservative basis by demonstrating that the wind farm could be configured to achieve the lowest potential noise limit.

The NSW Planning Assessment Commission (PAC) subsequently issued a Project Approval for the Collector Wind Farm on 2 December 2013. Part E of the Project Approval details the Operational Environmental Management requirements for a range of considerations including matters related to noise. Specifically, the Project Approval defines the following:

- Limits which apply to the level of noise permitted at surrounding receiver locations as a result of operation of the wind farm.
- A requirement to conduct noise monitoring after the wind farm commences operating in order to verify compliance with the applicable noise limits

As a result of the seasonal anomalies that were evident in the background noise monitoring conducted during the planning phase of the project, the PAC specified a fixed value noise limit rather than a background noise dependent limit. The low value of the fixed limit creates a practical challenge to measuring compliance. In particular, measuring the noise contribution of the wind farm amidst background noise levels that will frequently be comparable to or higher than the limit specified in the Project Approval will not be possible in some instances. In those instances when measured noise levels are above 35 dB solely as a result of background noise, complex analysis of a range of supplementary information sources would be necessary to demonstrate that the results are not attributable to the wind farm. This would involve extended noise measurements and analysis, and has the potential to reduce community confidence in the compliance testing process.

Prior to the conditions of the Project Approval being finalised in December 2013, RATCH consulted with the Department of Planning to request a condition which would allow background noise dependent noise limits according to relevant noise policies used in NSW. Specifically, a condition was requested which would allow the repeat background noise monitoring, and the derived noise limits, to be submitted for review and approval by the Department of Planning prior to commencement of construction of the wind farm. An example of this type of condition has been included in a recent[1] Project Approval modification. However, the Department of Planning advised that a modification application would be necessary to vary the conditions of the Project Approval of Collector Wind Farm to include reference to background noise measurements.

[1] White Rock Wind Farm (application number MP10_0156) Project Approval modification (MOD 2) dated July 2015 - Condition F6 noting that an updated determination of background noise levels and appropriate noise criteria shall be prepared prior to commissioning of the wind farm

Based on the above considerations, the purpose of the recent background noise surveys was to establish a representation of typical background noise conditions around the proposed Collector Wind Farm which could be used to:

- Provide a reference for a modification application to the Department, which includes a proposal to modify the Project Approval noise limits to account for background noise levels in the area
- Assist the identification of periods during the compliance survey when measured noise levels are predominantly related to background noise levels rather than operation of the wind farm.

In relation to the modification application, condition E6 of the Project Approval specifies that the wind farm shall be designed, operated and maintained to achieve a noise level of 35 dB LAeq. The modification application seeks to amend this condition to the following form:

> *The Project shall be designed, operated and maintained to ensure that the equivalent noise level ($L_{Aeq\ (10\text{-}minute)}$) from the Project does not exceed, at any residential receiver (excluding those associated with the wind farm) in existence or the subject of a valid development approval at the date of this Approval:*
>
> *(a) 35 dB, or*
>
> *(b) the existing background noise level ($L_{A90\ (10\text{-}minute)}$) correlated to the integer wind speed at hub height at the wind farm site by more than 5 dB,*
>
> *whichever is the greater, for each integer wind speed (measured at hub height) from cut-in to rated power of the wind turbine generator, as determined with reference to the South Australian Environment Protection Authority Wind Farm Guidelines 2003.*
>
> *For the purpose of this condition, existing background noise levels shall be represented by the analysis presented in the noise report accompanying the modification applications, supplemented, where appropriate, by the results of any background noise monitoring conducted at additional locations prior to commencement of construction of the wind farm.*

The above form of limit is consistent with the types of noise limits that are normally applied to wind farms in NSW and across Australia. For example, this type of background noise related limit has been included in planning conditions for NSW wind farm projects including Bodangora, Crookwell 2, Flyers Creek, Gullen Range, Sapphire and Woodlawn.

This report describes the methodology and results of the background noise survey, and presents proposed background related noise limits for the two (2) nearest receiver locations to the wind farm.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 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 Collector Wind Farm.

2.0 BACKGROUND NOISE SURVEY & ANALYSIS METHODOLOGY

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

- Project Approval dated 2 December 2013 (Application Number MP10_0156). Relevant extracts from the Project Approval are reproduced in Appendix C
- South Australian Environment Protection Authority *Wind Farm Guidelines 2003* (2003 SA Guidelines), as referenced in the Project Approval
- Supplementary guidance contained in:
  - Draft NSW *Planning Guidelines: Wind Farms* (draft NSW Guidelines) for supplementary guidance concerning survey parameters and durations
  - South Australian Environment Protection Authority *Wind farms: Environmental noise guidelines* (2009 SA Guidelines)
  - 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 was described in Marshall Day Acoustics correspondence *Rp 001 2015087ML* dated 10 March 2015, which was provided to the NSW Department of Planning and Environment for comment. The primary purpose of the background monitoring described in this earlier report was to provide a reference for the potential influence of background noise during any future noise compliance monitoring. The additional use of the background noise data for a modification application was subsequently discussed with the Department of Planning prior to conducting the survey. The background survey adhered to the procedures outlined in the correspondence submitted to the Department.

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 Survey Methodology Overview

The key elements of the background noise survey are summarised in Table 1 below.

Table 1: Summary of key elements of background noise survey

Item	Description
Monitoring locations	Two (2) nearest residential receiver locations and six (6) intermediate locations. Refer to Section 2.2 for further details and the purpose of intermediate locations
Monitoring Duration	Approximately six (6) to seven (7) weeks at each location. Duration chosen to satisfy requirements of 2003 SA Guidelines, and guidance of draft NSW Guidelines, which equate to: • 2000 individual 10-minute data points equivalent to approximately two (2) weeks. • a target minimum of 500 individual data points obtained in the downwind direction from the wind farm • extension of surveys for periods of up to six (6) weeks where necessary to obtain data in appropriate conditions
Monitoring Period	Total period 16 April 2015 to 23 July 2015 (approximately 14 weeks) Monitoring separated into two (2) periods, with the locations for each period selected on the basis of general wind direction trends for the area and the likelihood of obtaining downwind conditions during the survey period. The two periods are as follows: • 16 April to 2 June 2015: locations generally to the west and south • 2 June to 23 July 2015: locations generally to the east and north
Equipment	01dB DUO integrating sound level meters • Certified to Type1 / Class 1 (precision grade) standards in accordance with AS 1259.2-1990[2] and IEC 61672.1-2004[3] • Global Position System time synchronisation • Noise floor below 20 dB
Wind shielding	All primary reference microphones mounted at approximately 1.5m above ground level and fitted with enhanced wind shielding system based on the design recommendations detailed in the UK IOA good practice guide. Comprises an inner solid primary wind shield and an outer secondary large diameter hollow wind shield. Additional supplementary measurements were conducted concurrently at the two (2) receiver locations using a near-ground microphone and large diameter secondary windshield system. In the absence of formal guidelines or standards for the measurement of low frequency noise levels in windy conditions, the microphone position and shielding was chosen to conform to the general arrangement specified in IEC 61400-11:2012[4].

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

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

[4] International Electrotechnical Commission 61400-11 edition 3 *Wind turbines - Part 11: Acoustic noise measurement technique*

Item	Description
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 utilised for all monitoring systems. At least one (1) local weather station was installed during each group of monitoring 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 system.
Site wind speed data	Hub-height wind speed data (91.5 m above ground level) sourced from analysis by consultants DNV-GL of concurrent wind speed measurements at multiple heights on a reference mast within the site. The location of the reference mast was 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. Refer to Appendix D for further details.

2.2 Monitoring Locations

The monitoring locations were selected in consultation with the NSW Department of Planning and the Environment on the basis of:

- The fifty-five (55) turbine layout consented by the Project Approval
- The thirty-five (35) receiver locations included in the noise assessment of the wind farm during the planning phase
- Predicted noise data for the wind farm at the time of the survey planning, derived from turbine supplier tenders submitted to RATCH, and MDA's own prior modelling of the development.

The above information was used to identify the locations where noise compliance monitoring is expected to be proposed in a future Noise Compliance Plan prepared in accordance with the Project Approval.

The predicted operational noise levels from the Collector Wind Farm were identified as being comparable to the 35 dB limit at the following non-involved receiver locations:

- Receiver Z[5] to the west-southwest
- Receiver FF to the east.

At other non-involved receiver locations, the predicted noise levels are lower than 35 dB, and generally comparable to or less than 30 dB.

Monitoring locations were therefore selected to:

- Obtain noise data directly relevant to the two key receiver locations Z and FF
- Obtain reference data for future intermediate compliance monitoring locations between the wind farm and surrounding receivers.

The intermediate locations were proposed as a way of representing receiver locations in a range of directions from the proposed Collector Wind Farm. Specifically, directly measuring compliance at receiver locations is not expected to be practical in most instances, due to the relatively large separating distances and low predicted noise levels. The intermediate locations are therefore to be used to infer the operational noise of the wind farm at distant locations where measurements are impractical. The use of intermediate locations for these types of situations is consistent with the draft NSW Guidelines.

The intermediate background noise monitoring locations were generally selected on the basis of being within the site boundary and within the predicted 40-45dB L_{Aeq} noise contour of the wind farm. This choice was based on selecting a location where the noise will be influenced by the operation of multiple distant turbines, while remaining at a point where turbine noise is more likely to be measurable above background noise levels. Siting the intermediate locations within the site boundary also affords the benefit of providing directly accessible and relatively secure reference points for any future compliance monitoring exercise.

The selected monitoring locations where background noise measurements were carried out are summarised in Table 2 and illustrated in Figure 1 on the following pages.

[5] Residence Z is the only residence within 2km of a turbine that will not be hosting any wind farm infrastructure. Residence Z has signed a legal letter of consent (of the type envisaged in the Draft NSW Guidelines), so can be considered a participant in the project. However Residence Z was presented in the planning phase assessment as being a non-involved residence, and will be treated as such for the purposes of this background noise monitoring to remain consistent with the original assessments.

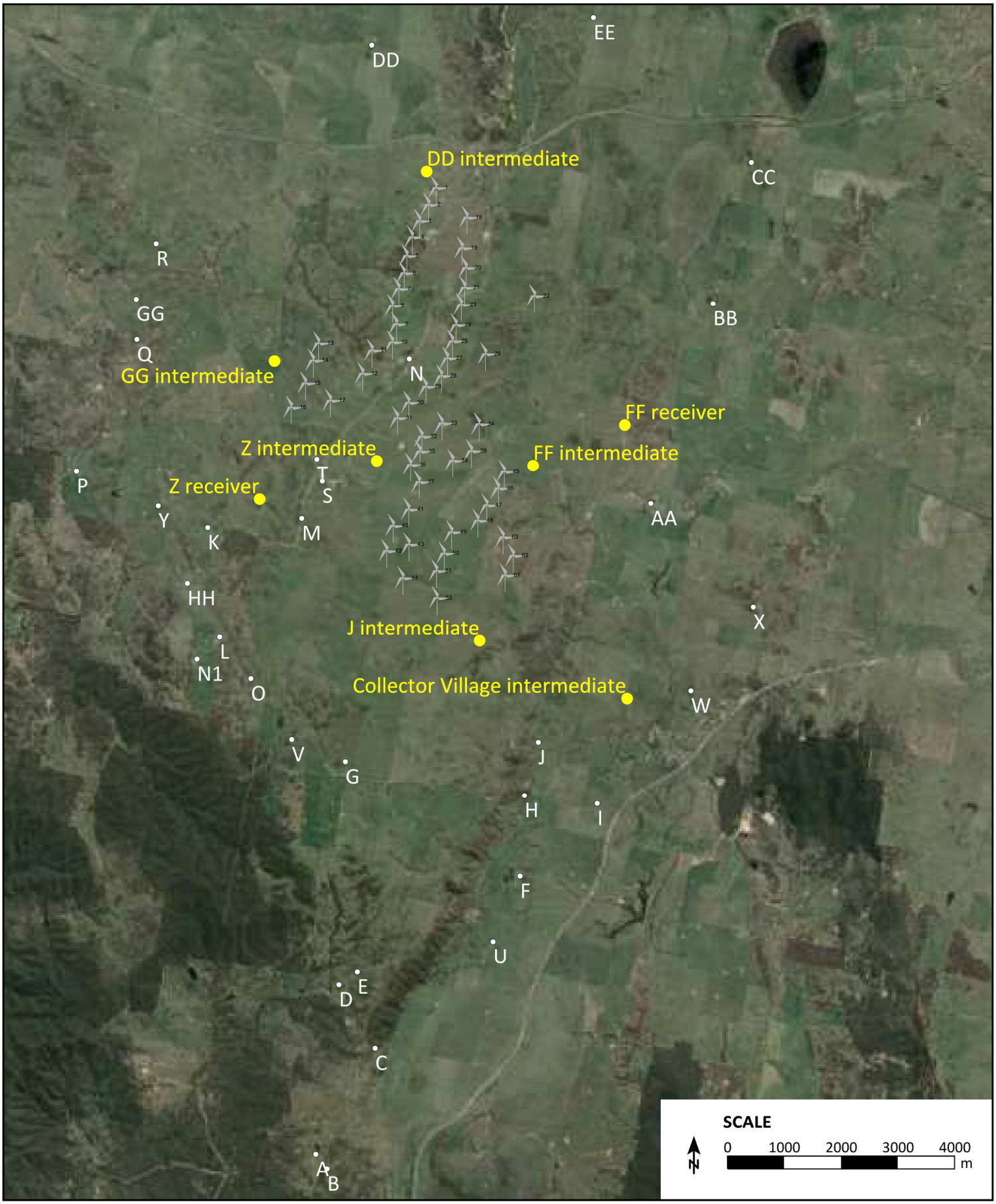
Table 2: Monitoring locations

Name	Direction from wind farm	Location description
Collector intermediate	southeast	Intermediate location between the wind farm and receivers in Collector Village. This location is approximately 2,940m from the nearest wind turbine, and predicted noise levels are well under 35 dB. Monitoring was undertaken at this location to provide a reference dataset for the Collector Village, based on feedback provided to RATCH by the project's Community Consultative Committee.
DD intermediate	north-northeast	Intermediate location between the wind farm and receiver DD. This intermediate location also provides reference information for receiver EE.
FF	east	Near to dwelling located at receiver FF
FF (C-weighted)	east	Near to dwelling located at receiver FF
FF intermediate	east	Intermediate location between the wind farm and receiver FF. This intermediate location also provides reference information for receivers AA and BB.
GG intermediate	west	Intermediate location between the wind farm and receivers in the direction of receivers GG, Q and R.
J intermediate	south-southeast	Intermediate location between the wind farm and receiver J. This intermediate location also provides reference information for receivers H and I, along with more distant receivers to the south-southwest (e.g. V and G).
Z	west-southwest	Near to dwelling located at receiver Z
Z (C-weighted)	west-southwest	Near to dwelling located at receiver Z
Z intermediate	west-southwest	Intermediate location between the wind farm and receiver Z. This intermediate location, along with the data obtained directly at Z receiver, provides reference information for more distant receivers to the west and southwest including HH, K and Y.

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

At each of the receiver locations FF and Z 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 the 2003 SA Guidelines and draft NSW Guidelines. The following specific considerations were factored:

- Noise monitors were located on the proposed wind farm side of the dwelling
- The noise monitors were located at least 5m 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.



LEGEND

- Wind turbine
- Receiver
- Noise Monitoring Location

Project: Collector Wind Farm 2015 - MDL 2

Project number: 2015087ML

Client name: RATCH

COLLECTOR WIND FARM

Noise monitoring and receiver locations

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2.3 Data Analysis

The analysis of the data has been conducted in accordance with the 2003 SA Guidelines as referenced in the Project Approval's requirements for a Noise Compliance Plan.

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, measurement time zone and any applicable corrections for day light saving. 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 in which average wind speeds greater than 5 m/s or rainfall were measured and filtered from the analysis
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 deemed to have been affected, and filtered from the analysis, when the following conditions[6] 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	Lower bound: 10-minute intervals in which site wind speeds are below the operating range of the wind turbines (i.e. below cut-in) are filtered from the analysis

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

Process	Description
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. Downwind directions are those in which the wind (or a vector component of the wind) is directed from the wind farm to the receiver. Further detail and references on this subject are provided in Section 3.0 and Section 4.0.
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 2003 SA Guidelines).

3.0 MEASURED BACKGROUND NOISE LEVELS

This section presents a summary the background noise measurement results for receiver and intermediate monitoring locations, analysed in accordance with methodology described in Section 2.3.

The primary purpose of the data presented in this section is to provide a reference for the potential influence of background noise levels during the noise compliance monitoring for the wind farm.

The results presented in this section include:

- A-weighted measured noise levels for all monitoring locations
- C-weighted measured noise levels for both monitoring systems (conventional microphone arrangement and ground board mounted arrangement) at the two (2) receiver locations.

The 2003 SA Guidelines do not specify wind direction requirements for background noise data referenced during noise compliance monitoring. However, the supplementary guidance contained in the 2009 SA Guidelines indicates that the background noise data referenced during compliance monitoring should be restricted to data obtained under downwind directions. While the 2009 document has not been adopted in NSW, filtering of the background noise data for this application is considered reasonable and appropriate. Accordingly, in lieu of specific guidance in the 2003 SA Guidelines, the background noise data sets presented in this section have been filtered for downwind directions.

The 2003 SA Guidelines notes that a wind direction spread of 45 degrees either side (i.e. 90 degrees total) of the direct line between the nearest wind turbine and the relevant receiver is considered acceptable for defining downwind conditions (specifically for the purpose of compliance checking). A 90 degree wide range has been used throughout this analysis. However, in some instances, alternative wind directions have been selected to provide a better representation of the wind directions in which noise levels from the proposed Collector Wind Farm would be expected to be highest. The principle of this approach was discussed and agreed during consultations with the Department of Planning and Environment prior to conducting the background noise survey. Where applicable, the alternative wind directions were defined by selecting an alternative proposed turbine location, accounting of the arrangement of the turbines relative to each receiver in question. A summary of the downwind directions associated with the nearest turbine and the selected turbine for the analysis is presented in Table 4 below.

Table 4: Downwind directions

Location	Nearest proposed turbine		Selected proposed turbine		Direction Difference (°)
	Reference	Direction (°)	Reference	Direction (°)	
FF receiver	T45	248	T34	271	23
FF intermediate	T45	255	T45	255	-
Z receiver	T16	23	T36	78	55
Z intermediate	T36	94	T35	79	-15
Collector Village intermediate	T61	318	T61	318	-
DD intermediate	T01	131	T02	162	31
GG intermediate	T15	119	T14	88	-31
J intermediate	T52	322	T49	350	28

3.1 FF receiver

A summary of the monitoring and analysis for receiver FF is provided in Table 5.

Table 5: FF receiver monitoring and analysis details

Item	Description
Monitor location (easting : northing)	721629 m E : 6139343 m N
Downwind direction range	226° to 316°
Monitoring period	2/06/2015 to 23/07/2015
Sound Level Logging Device	01dB DUO serial no. 10419
Total number of data points collected	6,877
Total number of data points removed (wind direction related)	4,513 (1,782)
Number of data points used for regression analysis	2,364
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for receiver FF is presented in Figure 2. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

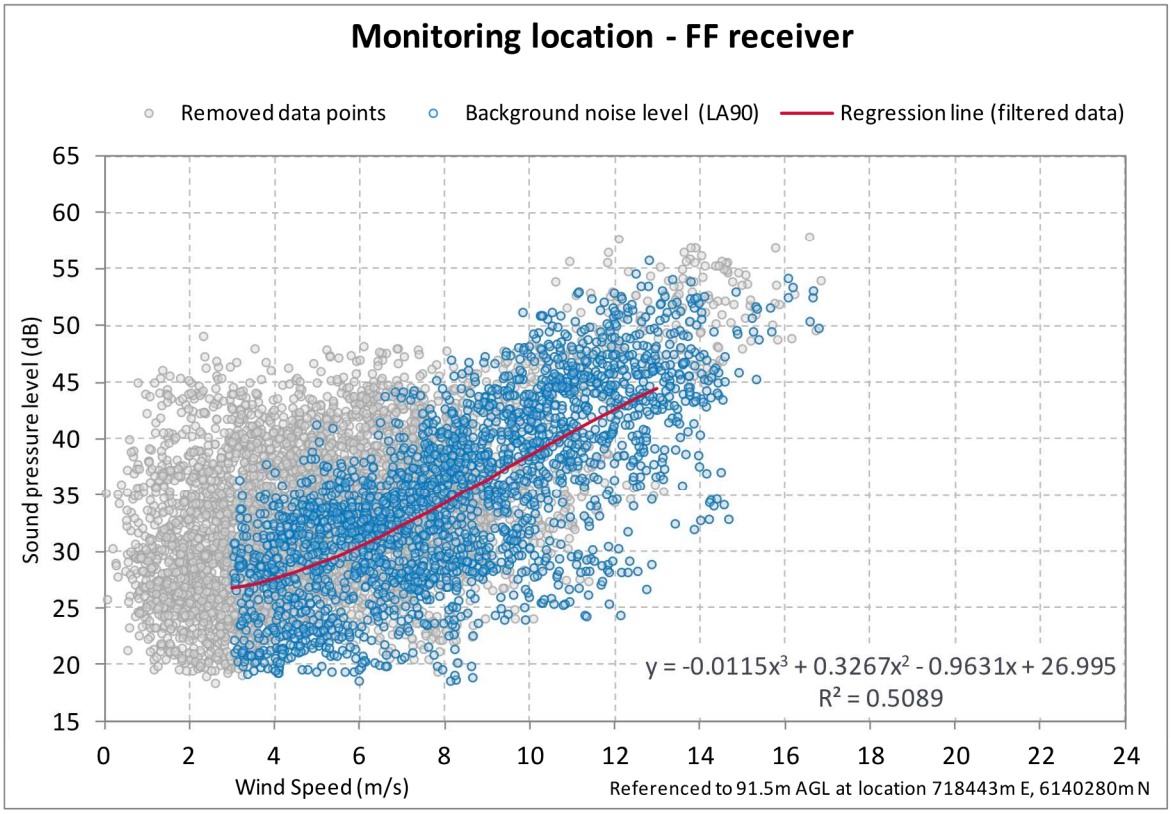


Figure 2: FF receiver – A-weighted background noise levels versus wind speed

In addition to the A-weighted noise levels presented in the previous figure, the results of the C-weighted measurements are presented in Figure 3. These results are from the same measurement system used to measure A-weighted noise levels.

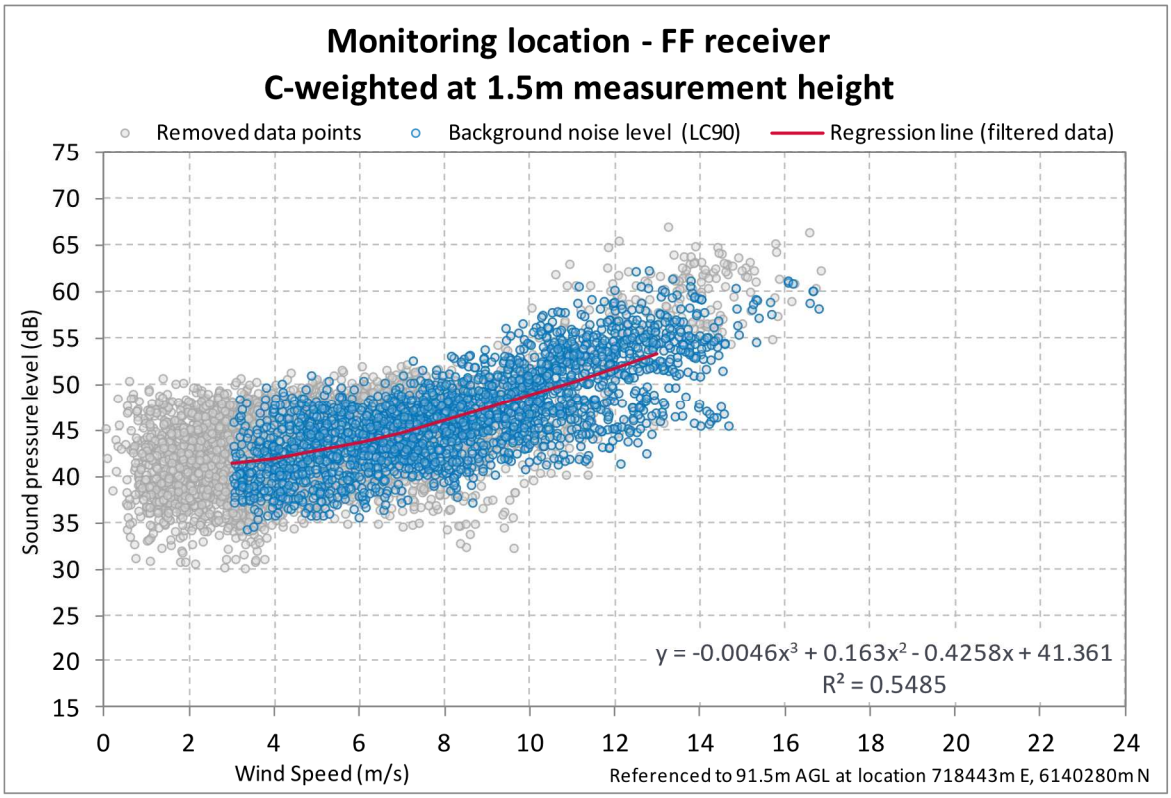


Figure 3: FF receiver – C-weighted background noise levels versus wind speed – 1.5 m microphone height

A comparison of the results from the 1.5 m height microphone and the ground board systems is presented in Appendix G. The combined results indicate:

- C-weighted noise levels below 60-65 dB L_{C90} can be measured at receiver FF using a 1.5 m and enhanced wind shield arrangement up to hub height wind speeds of approximately 10-12 m/s
- Comparison of the results from the two measurements indicates significant and increasing differences with increasing local wind speed. Specifically, at local wind speeds greater than 2-3 m/s, the C-weighted measurement results at 1.5 m above ground level are significantly affected by wind induced noise at the microphone.

3.2 FF intermediate

A summary of the monitoring and analysis for the FF intermediate location is provided in Table 5.

Table 6: FF intermediate monitoring and analysis details

Item	Description
Monitor location (easting : northing)	719990 m E : 6138630 m N
Downwind direction range	210° to 300°
Monitoring period	2/06/2015 to 23/07/2015
Sound Level Logging Device	01dB DUO serial no. 10447
Total number of data points collected	6,930
Total number of data points removed (wind direction related)	5,170 (2,571)
Number of data points used for regression analysis	1,760
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for the FF intermediate location is presented in Figure 4. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

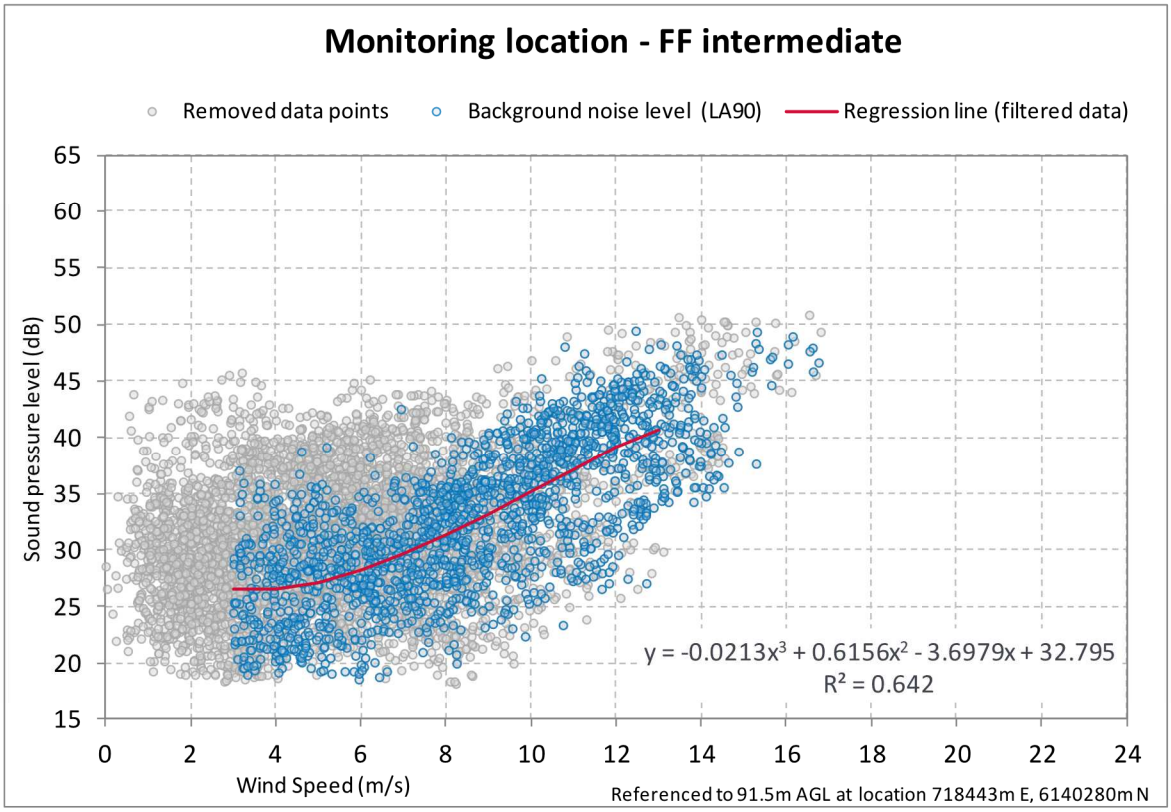


Figure 4: FF intermediate – background noise levels versus wind speed

3.3 Z receiver

A summary of the monitoring and analysis for receiver Z is provided in Table 7.

Table 7: Z receiver monitoring and analysis details

Item	Description
Monitor location (easting : northing)	715215 m E : 6138048 m N
Downwind direction range	33° to 123°
Monitoring period	16/04/2015 to 2/06/2015
Sound Level Logging Device	01dB DUO serial no. 10447
Total number of data points collected	6,763
Total number of data points removed (wind direction related)	5,705 (3,962)
Number of data points used for regression analysis	1058
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for receiver Z is presented in Figure 5. The regression line for this location is plotted up to a maximum wind speed of 12m/s due to the limited number of filtered data points above 12m/s. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

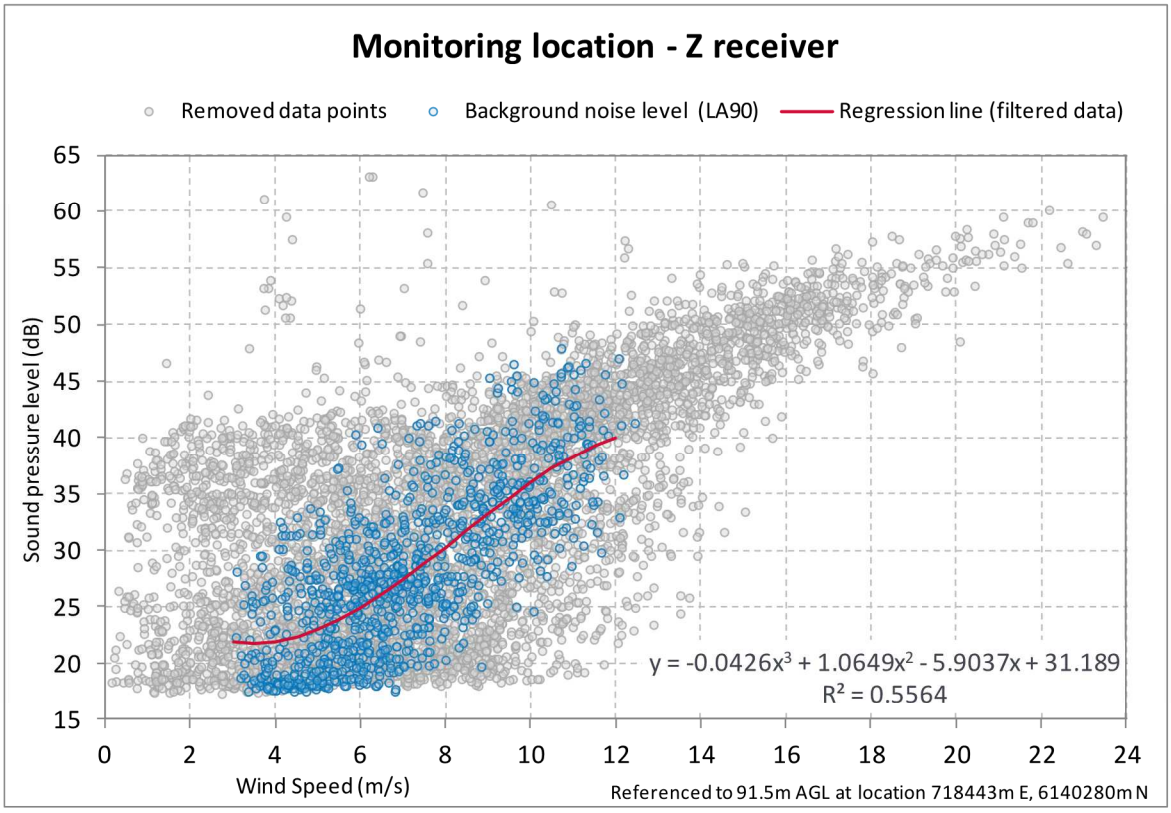


Figure 5: Z receiver – A-weighted background noise levels versus wind speed

In addition to the A-weighted noise levels presented in the previous figure, the results of the C-weighted measurements are presented in Figure 6. These results are from the same measurement system used to measure A-weighted noise levels.

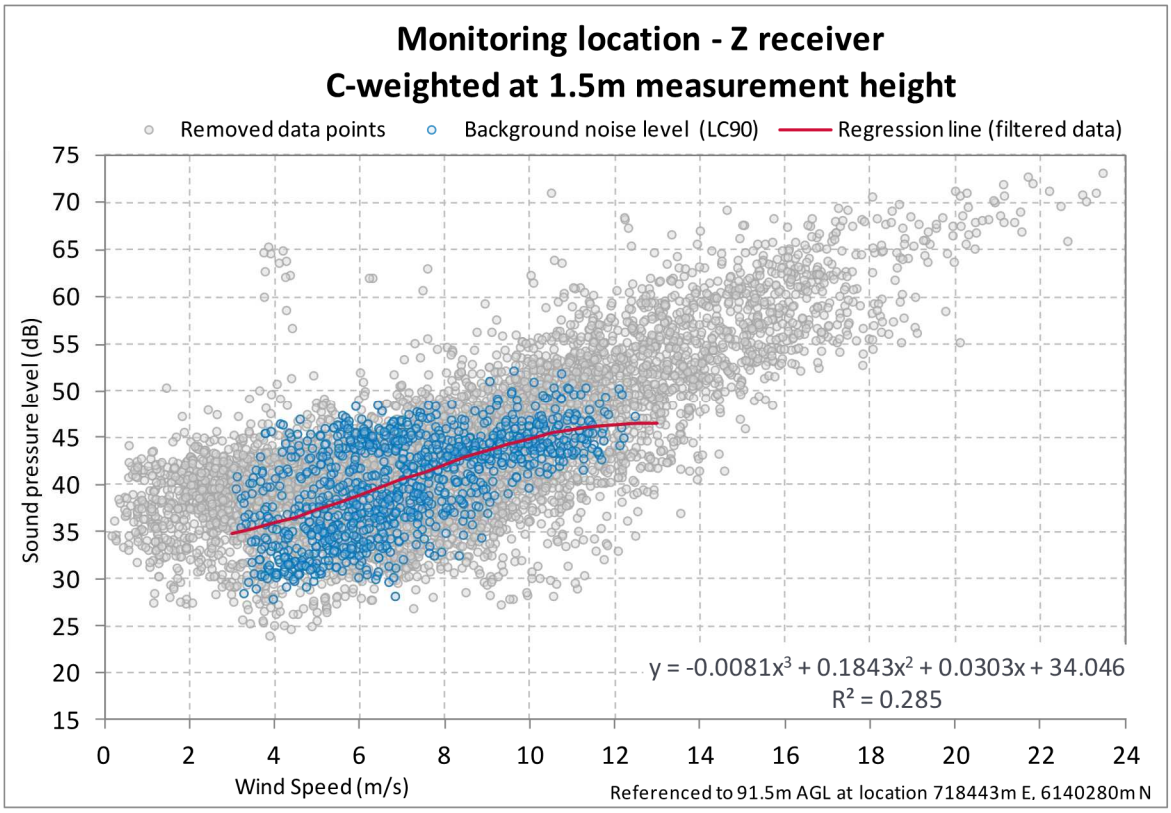


Figure 6: Z receiver – C-weighted background noise levels versus wind speed

A comparison of the results from the 1.5 m height microphone and the ground board systems is presented in Appendix G. The combined results indicate:

- C-weighted noise levels below 60-65 dB L_{C90} can be measured at receiver Z using a 1.5 m and enhanced wind shield arrangement up to hub height wind speeds of approximately 12 m/s
- Comparison of the results from the two measurements indicates significant and increasing differences with increasing local wind speed. Specifically, at local wind speeds greater than 2-3 m/s, the C-weighted measurement results at 1.5 m above ground level are significantly affected by wind induced noise at the microphone.

3.4 Z intermediate

A summary of the monitoring and analysis for the Z intermediate location is provided in Table 8.

Table 8: Z intermediate monitoring and analysis details

Item	Description
Monitor location (easting : northing)	717240 m E : 6138716 m N
Downwind direction range	34° to 124°
Monitoring period	16/04/2015 to 2/06/2015
Sound Level Logging Device	01dB DUO serial no. 10419
Total number of data points collected	6,721
Total number of data points removed (wind direction related)	5,693 (3,566)
Number of data points used for regression analysis	1,028
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for the Z intermediate location is presented in Figure 7. The regression line for this location is plotted up to a maximum wind speed of 12m/s due to the limited number of filtered data points above 12m/s. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

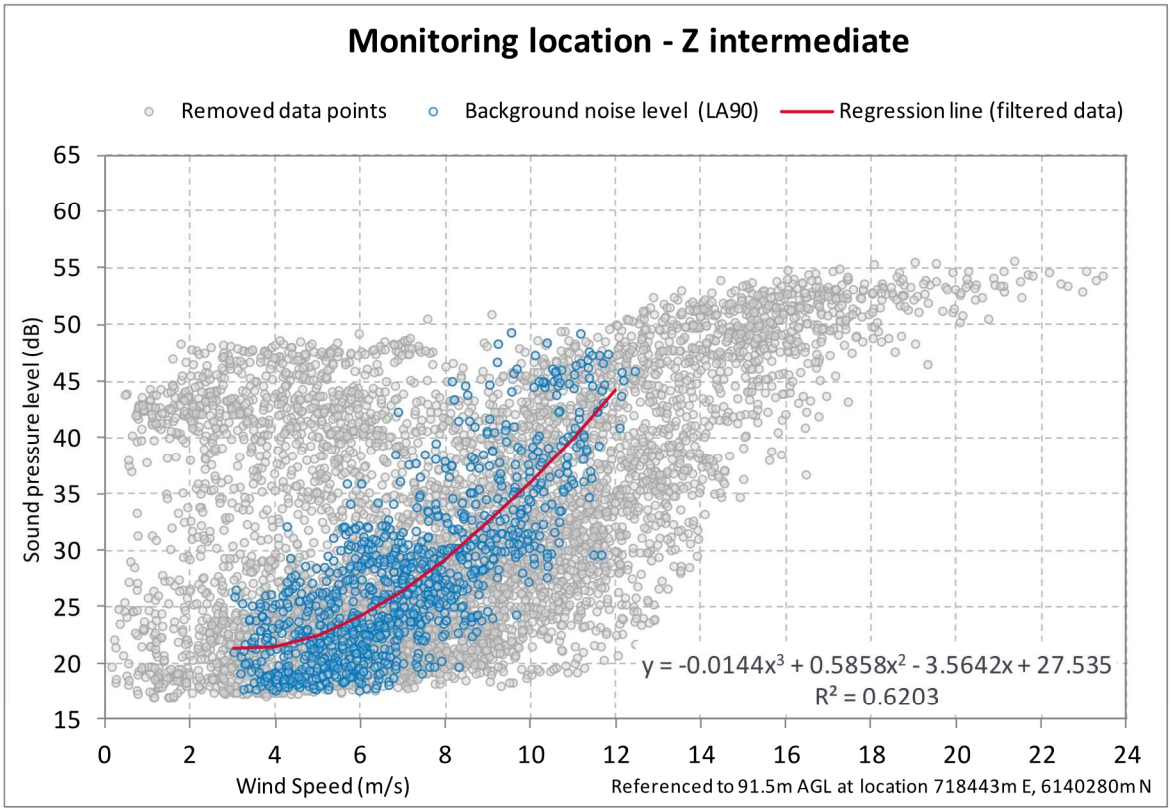


Figure 7: Z intermediate – background noise levels versus wind speed

3.5 Collector Village intermediate

A summary of the monitoring and analysis for the Collector Village intermediate location is provided in Table 5.

Table 9: Collector Village monitoring and analysis details

Item	Description
Monitor location (easting : northing)	721645 m E : 6134523 m N
Downwind direction range	273° to 3°
Monitoring period	16/04/2015 to 2/06/2015
Sound Level Logging Device	01dB DUO serial no. 10417
Total number of data points collected	6,751
Total number of data points removed (wind direction related)	4,500 (2561)
Number of data points used for regression analysis	2,251
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for the Collector Village intermediate location is presented in Figure 4. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

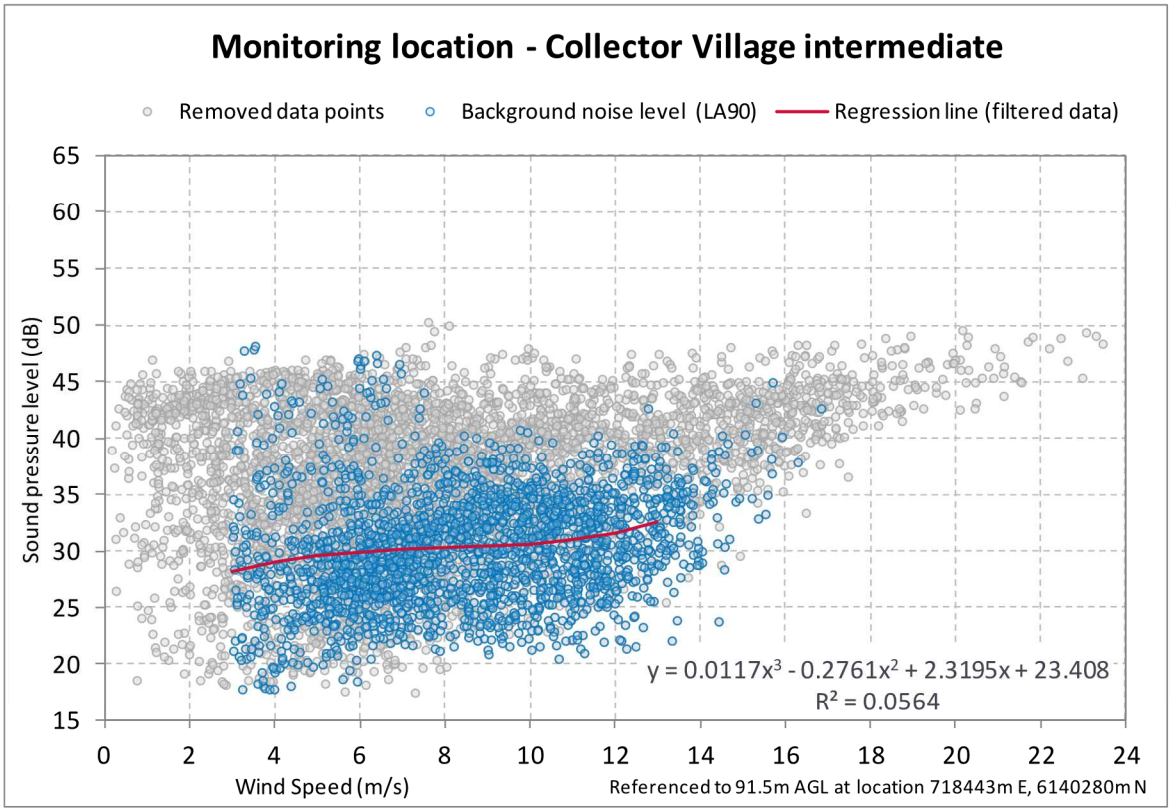


Figure 8: Collector Village intermediate – background noise levels versus wind speed

The trend of noise levels illustrated in Figure 8 is consistent with expectations given the influence of distant vehicle movements on the Federal Highway. Specifically, increased background noise levels were measured during wind directions which favoured the propagation of traffic noise the Federal Highway (southeast winds). These data points were then filtered from the analysis on account of being outside of the downwind range of wind directions from the proposed wind farm.

3.6 DD intermediate

A summary of the monitoring and analysis for the DD intermediate location is provided in Table 10.

Table 10: DD intermediate monitoring and analysis details

Item	Description
Monitor location (easting : northing)	718116 m E : 6143797 m N
Downwind direction range	117° to 207°
Monitoring period	2/06/2015 to 23/07/2015
Sound Level Logging Device	01dB DUO serial no. 10194
Total number of data points collected	6,896
Total number of data points removed (wind direction related)	6,296 (4206)
Number of data points used for regression analysis	600
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for the DD intermediate location is presented in Figure 9. The regression line for this location is plotted up to a maximum wind speed of 12m/s due to the limited number of filtered data points above 12m/s. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

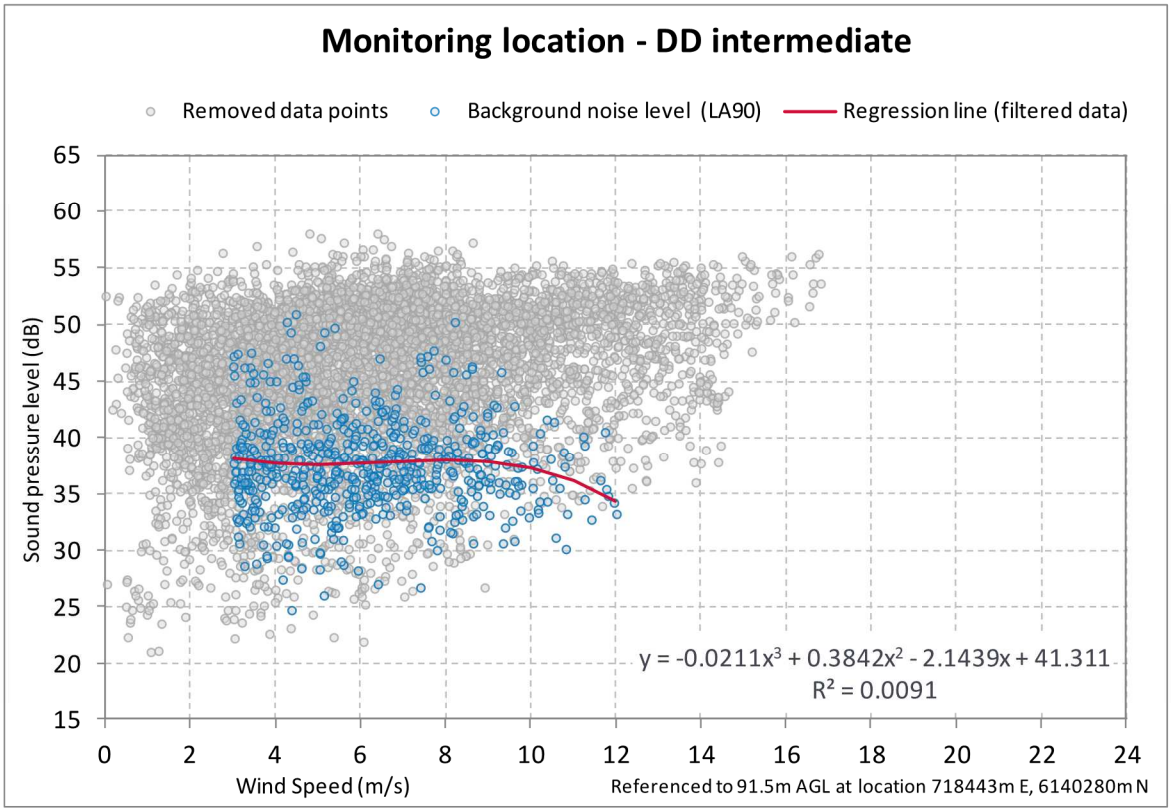


Figure 9: DD intermediate – background noise levels versus wind speed

The trend of noise levels illustrated in Figure 9 is consistent with site observations which indicated a high level of road traffic noise associated with the Hume Highway located to the north. The wind direction filtering applied to the dataset subsequently removes the periods in which the highest noise levels from the Hume Highway occur (i.e. northwest to northeast directions), but road traffic noise still influences the filtered data set (background noise levels are largely independent of wind speed).

3.7 GG intermediate

A summary of the monitoring and analysis for the GG intermediate location is provided in Table 11.

Table 11: GG intermediate monitoring and analysis details

Item	Description
Monitor location (easting : northing)	715442 m E : 6140467 m N
Downwind direction range	43° to 133°
Monitoring period	16/04/2015 to 2/06/2015
Sound Level Logging Device	01dB DUO serial no. 10194
Total number of data points collected	6741
Total number of data points removed (wind direction related)	5,427 (4007)
Number of data points used for regression analysis	1,314
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for the GG intermediate location is presented in Figure 10. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

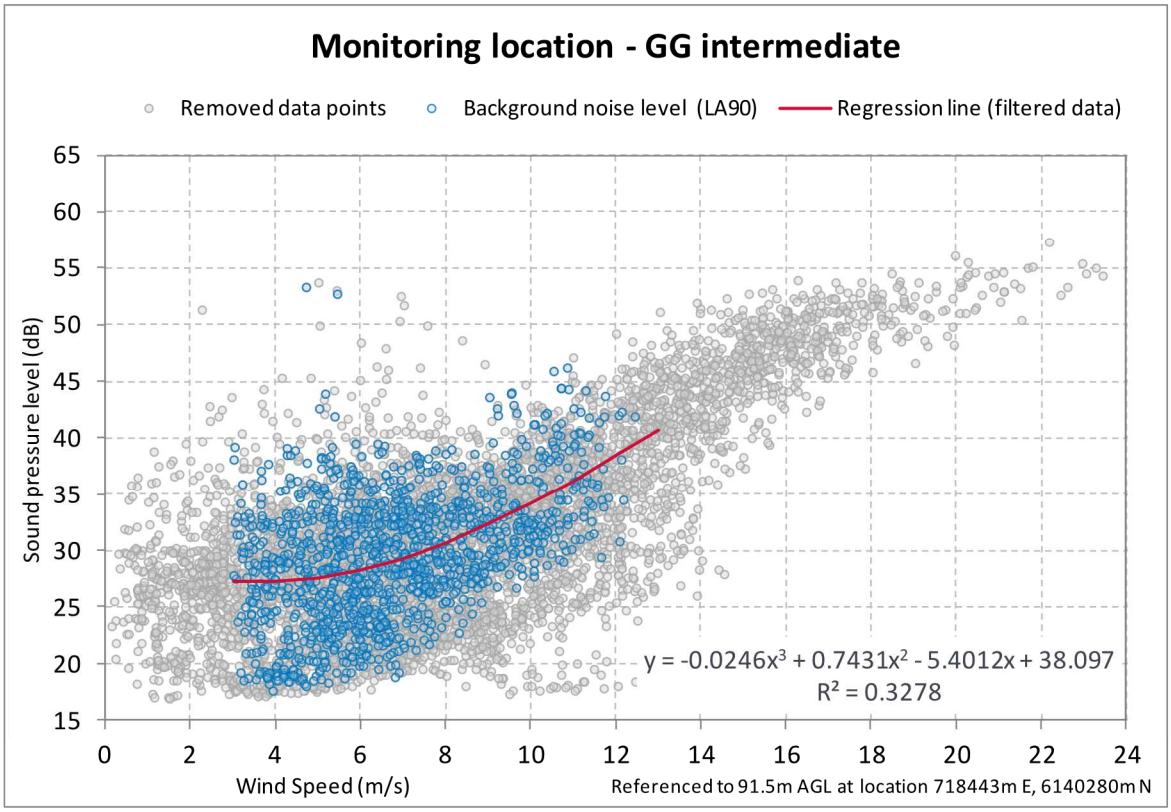


Figure 10: GG intermediate – background noise levels versus wind speed

3.8 J intermediate

A summary of the monitoring and analysis for the J intermediate location is provided in Table 12.

Table 12: J intermediate monitoring and analysis details

Item	Description
Monitor location (easting : northing)	719052 m E : 6135542 m N
Downwind direction range	305° to 35°
Monitoring periods	16/04/2015 to 2/06/2015 & 23/07/2015 to 2/09/2015
Sound Level Logging Device	01dB CUBE serial no. 10418 & 01dB DUO serial no. 10419
Total number of data points collected	12,643
Total number of data points removed (wind direction related)	11,673 (6,252)
Number of data points used for regression analysis	970
Wind speed range for regression analysis	Above 3 m/s

The measured background noise levels and corresponding regression analysis for the J intermediate location is presented in Figure 11. This figure also illustrates all data points removed by the filtering process described in Section 2.3.

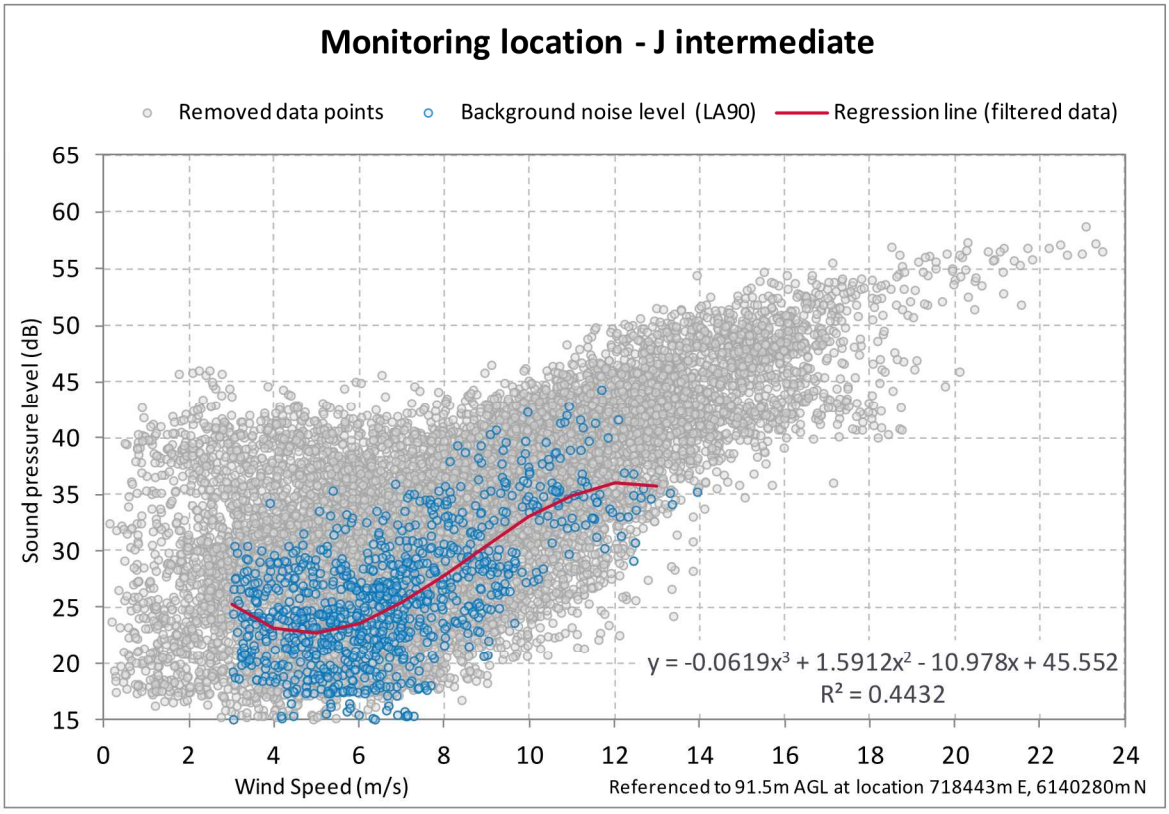


Figure 11: J intermediate – background noise levels versus wind speed

4.0 PROPOSED NOISE LIMITS AT RECEIVERS FF & Z

This section presents proposed noise limits which, subject to the approval of the Department of Planning and the Environment, would be used during compliance monitoring to assess the operational noise of the wind farm at receivers FF and Z.

The limits have been derived in accordance with the methodology of the 2003 SA Guidelines referenced in the Project Approval.

The 2003 SA Guidelines do not specify that background data sets used to derive limits require a minimum number of data points to have been captured under downwind conditions. However, for completeness, the following is noted:

- Consistent with best practice outlined in the UK IOA good practice guide, an analysis of the measured background noise levels at receivers FF and Z was carried out to investigate the potential for background noise to vary with wind direction, and no such trends were systematically evident. Accordingly, the background noise data sets use for the derivation of the proposed noise limits include measurements obtained in all wind directions
- Reference to supplementary guidance contained in the 2009 SA guidelines indicates that the background noise data set should include 2000 data points, of which 500 should be obtained under downwind conditions. While the 2009 document had not been adopted in NSW, it is noted that the datasets obtained at receivers FF and Z contain more than 500 data points obtained in the downwind direction.

4.1 FF receiver

This background noise monitoring data and resulting noise limits for receiver FF are presented in Figure 12 below. The figure also illustrates the points which were filtered from the analysis on account of rainfall, elevated local wind speed (measured at 1.5 m AGL) or potential extraneous noise influences.

The filtered set of background noise levels are considered typical of a rural area, indicating levels regularly below 30 dB L_{A90} during low wind speed conditions. Further, the filtered results do not indicate any significant diurnal trends. Specifically, separate regression analysis of day and night period was found to result in background noise levels generally within 1-2 dB of the regression analysis for the combined dataset.

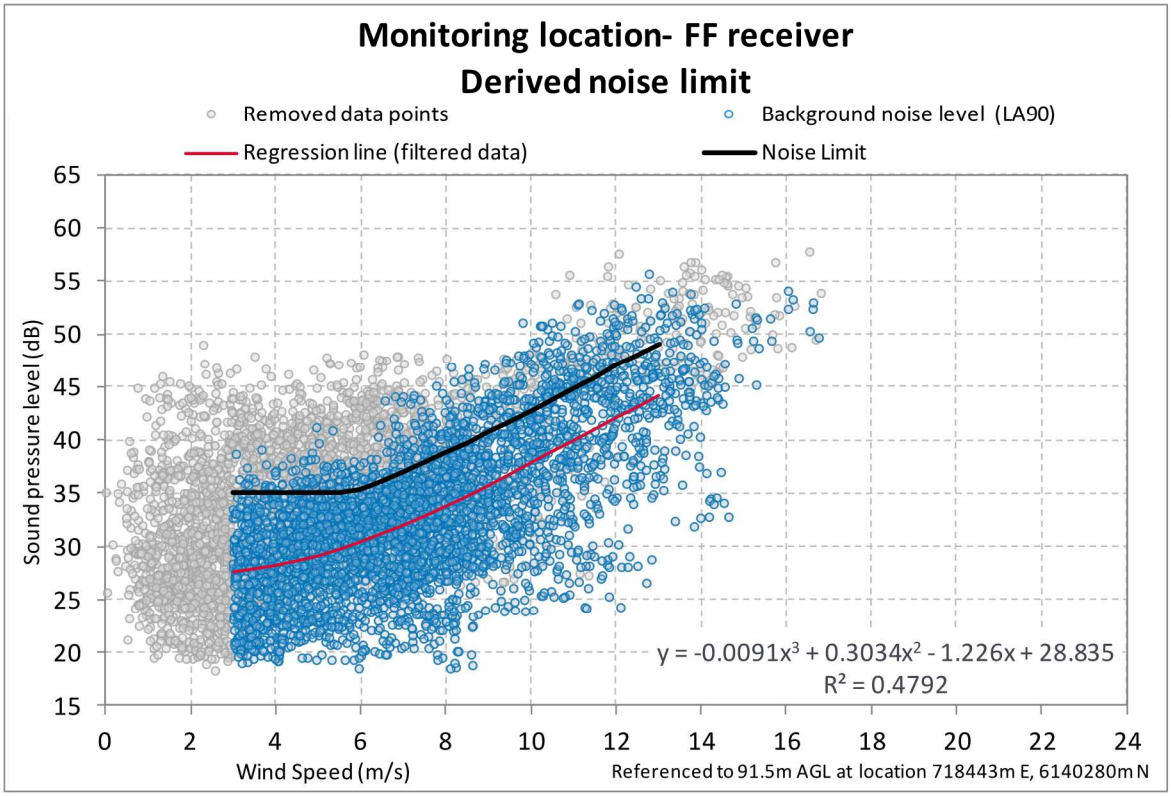


Figure 12: FF receiver – Derived noise limits

The background noise regression analysis and derived noise limits illustrated in Figure 12 are reproduced in tabular form below.

Table 13: FF receiver – Derived noise limits

Description	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Background noise level L_{A90} dB	28	28	29	30	32	34	36	38	40	42	44
Applicable limit L_{Aeq} dB	35	35	35	35	37	39	41	43	45	47	49

4.2 Z receiver

This background noise monitoring data and resulting noise limits for receiver Z are presented in Figure 13 below. The figure also illustrates the points which were filtered from the analysis on account of rainfall, elevated local wind speed (measured at 1.5 m AGL) or potential extraneous noise influences.

The filtered set of background noise levels are considered typical of a rural area, indicating levels regularly below 30 dB L_{A90} during low wind speed conditions. A review of diurnal trends indicated day time noise levels approximately 3-5 dB higher than the regression analysis of the combined data set at wind speeds up to 10 m/s. In relation to the night period, the analysis indicated background noise levels of the order of 1-2 dB lower than the combined dataset.

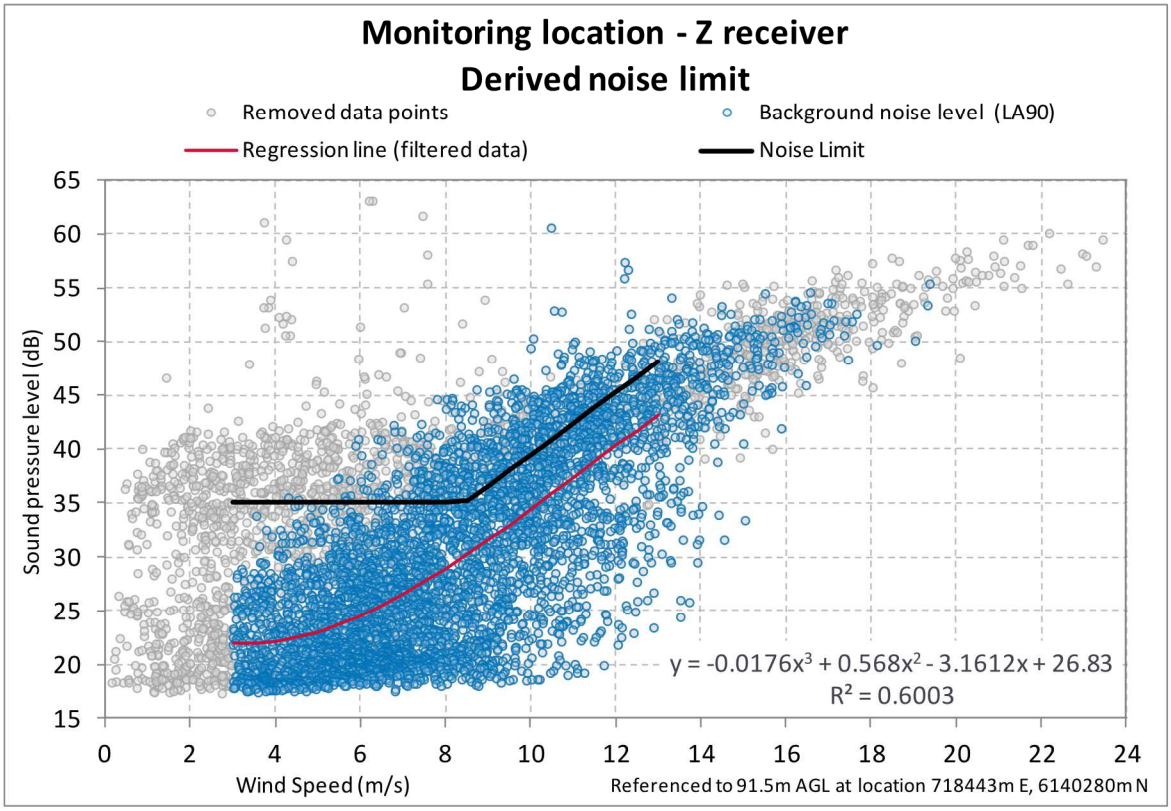


Figure 13: Z receiver – Derived noise limits

The background noise regression analysis and derived noise limits illustrated in Figure 13 are reproduced in tabular form below.

Table 14: Z receiver – Derived noise limits

Description	Hub Height Wind Speed (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Background noise level L_{A90} dB	22	22	23	25	26	29	32	34	37	40	43
Applicable limit L_{Aeq} dB	35	35	35	35	35	35	37	39	42	45	48

5.0 SUMMARY

Background noise monitoring has been conducted at two (2) receiver locations and six (6) intermediate locations between the wind farm and surrounding receiver locations

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

- the Project Approval
- the 2003 SA Guidelines referred to in the Project Approval
- the documented background noise survey methodology submitted to the Department of Planning and Environment prior the conducting the monitoring
- Supplementary guidance contained in:
  - the 2009 SA Guidelines
  - the draft NSW guidelines
  - the UK IOA Good Practice Guide

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

The results have also been analysed to derive noise limits on the basis of the 2003 SA Guidelines at the two nearest non-involved receivers to the wind farm. Specifically, noise limits have been derived at integer hub-height wind speeds as the greater of 35 dB and the background plus 5 dB.

Subject to the Department of Planning's determination of RATCH's application to modify the Project Approval, the derived noise limits presented in this report would be used during compliance monitoring to assess the operational noise of the wind farm at receivers FF and Z.

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 Zone 55

Turbine	Easting (m)	Northing (m)	Turbine	Easting (m)	Northing (m)
T1	718433	6143522	T29	718256	6140030
T2	718303	6143229	T30	717952	6139751
T3	718143	6142944	T31	717751	6139480
T4	718016	6142661	T32	718184	6139157
T5	717920	6142333	T33	718539	6139389
T6	717869	6142028	T34	719192	6139375
T7	717778	6141753	T35	718149	6138894
T8	717667	6141456	T36	717986	6138660
T9	717737	6141127	T37	718135	6138349
T10	717665	6140808	T38	718725	6138734
T11	717307	6140667	T39	719054	6138902
T12	717140	6140259	T40	717678	6137581
T13	716368	6140791	T41	717952	6137867
T14	716269	6140490	T42	717564	6137136
T15	716134	6140091	T43	717954	6137251
T16	715885	6139665	T44	717848	6136663
T17	716574	6139788	T45	719633	6138534
T18	718978	6143004	T46	719531	6138241
T19	718891	6142467	T47	719325	6137942
T20	718960	6142121	T48	719170	6137671
T21	718935	6141776	T49	718708	6137467
T22	720164	6141628	T50	718574	6137092
T23	718878	6141471	T51	718443	6136785
T24	718785	6141111	T52	718448	6136312
T25	718721	6140828	T61	719646	6136708
T26	719303	6140601	T62	719793	6137054
T27	718632	6140529	T63	719612	6137380
T28	718527	6140218	-	-	-

B2 Receiver locations – MGA Zone 55

Location	Easting (m)	Northing (m)	Nearest Turbine	Distance from nearest turbine (m)
A	716166	6126500	T52	10,077
AA	722062	6137959	T45	2,419
B	716366	6126247	T52	10,280
BB	723156	6141476	T22	2,996
C	717211	6128373	T52	8,036
CC	723831	6143954	T22	4,342
D	716571	6129490	T52	7,079
DD	717150	6146019	T01	2,807
E	716897	6129714	T52	6,781
EE	721052	6146502	T01	3,967
F	719761	6131405	T52	5,075
FF	721605	6139345	T45	2,057
G	716686	6133417	T44	3,377
GG	713009	6141552	T14	3,368
H	719839	6132819	T52	3,753
HH	713908	6136554	T16	3,680
I	721120	6132680	T61	4,229
J	720081	6133755	T61	2,912
K	714263	6137536	T16	2,666
L	714476	6135604	T44	3,447
M	715919	6137699	T42	1,740
N	717810	6140502	T10	376
O	715025	6134872	T44	3,252
P	711956	6138527	T16	4,050
Q	713019	6140846	T16	3,046
R	713357	6142531	T13	3,424
S	716282	6138352	T16	1,408
T	716186	6138745	T16	1,006
U	719285	6130253	T52	6,113
V	715744	6133809	T44	3,462
W	722766	6134658	T61	3,726
X	723865	6136136	T62	4,185
Y	713396	6137919	T16	3,014
Z	715180	6138036	T16	1,777
N1	714078	6135215	T44	3,949

APPENDIX C PROJECT APPROVAL PART 3 – OPERATIONAL NOISE REQUIREMENTS

The following excerpts concerning operational wind turbine noise have been reproduced from pages 30-31 of the Project Approval.

NOISE

Operational Noise Criteria – Wind Turbines

E6 *The Project shall be designed, operated and maintained to ensure that the equivalent noise level ($L_{Aeq\ (10\text{-}minute)}$) from the Project does not exceed, at any residential receiver (excluding those associated with the wind farm) in existence or the subject of a valid development approval at the date of this Approval 35 dB(A).*

E7 *The Proponent shall prepare a **revised Noise Assessment** for the final turbine layout selected, in consultation with the EPA, which shall be submitted to the Director-General prior to construction of the wind turbines. The revised Noise Assessment shall include the noise predictions of the final turbine model and layout selected at each of the receiver locations. The assessment shall demonstrate consistency with the EA and the ability of the final turbine model and layout to meet the requirements of condition E6. The assessment shall include a discussion of the difference of the spectral noise signature between the final turbine model and the original turbine model used within the EA noise assessment.*

E8 *Noise from the Project is to be measured at the most affected point within the residential boundary, or at the most affected point within 30 metres of the dwelling, where the dwelling is more than 30 metres from the boundary, to determine compliance with the noise level limit in condition E6.*

E9 *For the purposes of condition E6 of this Approval, the presence of excessive tonality (a special noise characteristic) is consistent with that described in ISO 1996.2: 2007 Acoustics – Description, measurement and assessment of environmental noise – Determination of environmental noise levels.*

If tonality is found to be a repeated characteristic of the wind turbine noise, 5dB(A) should be added to measured noise level from the wind farm. If tonality is only identified for certain wind directions and speeds, the penalty is only applicable under these conditions.

The tonal characteristic penalty applies only if the tone from the wind turbine is audible at the relevant receiver. Absence of tone in noise emissions measured at an intermediate location is sufficient proof that the tone at the receiver is not associated with the wind farm's operation.

The assessment for tonality should only be made for frequencies of concern from 25Hz to 10KHz and for sound pressure levels above the threshold of hearing (as defined in ISO 389:7; 2005 Acoustics – Reference zero for the calibration of audiometric equipment – Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions).

The maximum penalty to be added to the measured noise level from the wind farm for any special noise characteristic individually or cumulatively is 5dB(A).

Note – for the purposes of this condition, tonality is defined as a repeated characteristic if it occurs for more than 10% of an assessment period. This equates to being identified for more than 54 minutes during the 9 hour night from 10pm – 7am, or for more than 90 minutes during the 15 hour day from 7am – 10pm. This definition refers to valid wind farm noise only.

E10 *For the purposes of condition E6 of this Approval, the presence of excessive low frequency noise i.e. noise from the wind farm that is repeatedly greater than 65dB(C) during the day time of 60dB(C)) during the night-time at any relevant receiver will incur a 5dB(A) penalty, to be added to the measured noise level for the wind farm, unless a detailed internal low frequency noise assessment demonstrates compliance to the Proposed criteria for the assessment of low frequency noise disturbance (UK Department for Environment, Food and Rural Affairs (DEFRA 2005)) for a steady state noise source.*

Note – For the purposes of this condition, low frequency noise is defined as a repeated characteristic if it occurs for more than 10% of an assessment period. This definition refers to verified wind farm noise only.

E11 *Notwithstanding condition E6 of this Approval, the noise limits specified under those conditions do not apply to any residence where a noise agreement is in place between the Proponent and the owner(s) of those residences in relation to noise impacts and/or noise limits.*

APPENDIX D DERIVATION OF SITE WIND SPEED DATA

Wind speed and direction was measured on behalf of RATCH at multiple locations on the site of the proposed wind farm for the duration of the background noise survey.

The mast designated as S4 located at the north end of the site was selected as the appropriate reference mast for the background noise survey for the following reasons:

- The mast is located within the proposed layout of the turbines
- Wind data at the location of the reference mast is expected to be available during future noise compliance monitoring, based on synthesis of data obtained from future meteorological mast locations.

Wind speed and direction was concurrently measured in 10-minute intervals at multiple heights ranging from 37.9 m to 62.8 m. This data has been used by consultants DNV-GL to:

- Evaluate representative wind shear conditions for each 10-minute measurement period
- Based on the derived shear, calculate the wind speed for each 10-minute period at a height of 91.5 m above ground level, corresponding to the maximum hub height of the proposed turbines.

Further details of the analysis conducted by DNV-GL are provided in their correspondence reproduced on the following pages.

DNV·GL

RATCH-Australia Corporation Limited
Level 7, 111 Pacific Highway
North Sydney NSW 2059
Australia

DNV GL – Energy
Renewables Advisory
Suite 25, Level 8
401 Docklands Drive
Docklands
Victoria 3008
Tel: 03 9600-1993
Fax: 03 9602-1714
ABN 19 094 520 760

Date:	Our reference:	Your reference:
03/08/2015	170275-AUME-L-01-A	

Hub height wind speed time series

Dear Anthony Yeates,

DNV GL has been commissioned by RATCH-Australia Corporation Ltd ('RATCH' or 'the Client') to synthesise a time series of hub height wind speed data at the S4 meteorological mast at the Collector Wind Farm site over the period from 15th April 2015 to the 24th of July 2015.

This analysis involved performing correlations between the two on site meteorological masts, S1 and S4 and synthesizing data at S4 where necessary to obtain a complete time series. As the measurements are collected at a lower height than the proposed turbine hub height, an instantaneous shear assessment has been undertaken to predict the 10-minute wind speed values at this level. The assessment has been undertaken given consideration to the recommendations in the UK Institute of Acoustics *A Good Practice Guide to the Application nof ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* May 2013 (UK IOA Good Practice Guide).

DNV GL typically recommends that masts used to define the wind regime at turbine locations have a height of at least 75% of the proposed turbine hub height. There is elevated uncertainty associated with extrapolating to hub height of 91.5 m from the 66 m measurements at Mast S4. However, the mast height is compliant with the recommendations of the UK IOA Good Practice Guide, which states that the mast height should be at least 60 % of the proposed hub height.

The methodology employed to perform this task is outlined below and the resulting time series are provided in the attached '170275PC03 Collector S4 hub height time series 20150724.txt' file.

Sincerely
for Garrad Hassan Pacific Pty Ltd

Mark Purcell
Engineer
m.purcell@dnvgl.com

Trenton Gilbert
Senior Engineer
trenton.gilbert@dnvgl.com

1 METHODOLOGY

In order to synthesise data at the Collector S4 masts representing the period spanning 15th April 2015 to the 24th July 2015 (current date at time of commencement), the following steps were undertaken:

- Correlation relationships by direction sector were established between wind speed data recorded at like heights by both of the two site masts, S1 and S4.
- These correlation relationships were used to synthesize wind speed and direction data at S4 to account for missing data and create a complete time series over the period of interest.
- The power law shear exponent was derived for the each 10-minute period using the measured wind speed data recorded at the three recently installed anemometers at 62.8, 52.7 and 37.9 m on the S4 mast. The power law relates the ratio of measured wind speeds, U_1/U_2, to the ratio of the measurement heights, z_1/z_2, using the wind shear exponent, α, as follows:

$$\frac{\overline{U}(z_1)}{\overline{U}(z_2)} = \left(\frac{z_1 - d}{z_2 - d}\right)^{\alpha}$$

where α is the power law wind shear exponent,
$\overline{U}$ is the mean wind speed,
z is the height above ground level, and
d is the effective flow displacement height, if any.

- This instantaneous shear methodology can result in spurious extreme results in some cases, particularly during low wind speed periods when negative shear may be encountered. These extreme values were removed by limiting the range of valid shear exponents to between 0.0 and 1.0. DNV GL deems this range to be appropriate for the conditions present at the Collector site.
- Power law shear exponents calculated as discussed above were used to extrapolate the measured and synthesised wind speed time series at a height of 66.3 m from measurement height to the specified hub height of 91.5 m for each 10 minute period.
- By evaluating the annual frequency distributions calculated with all the data recorded at mast S4, DNV GL have determined that the mast may have a negative impact on the shear recorded during periods where the anemometers are down-wind of the mast structure. In an attempt to minimise the impact of the mast upon the wind shear profile for wind directions in the direction sector centred on 90° (spanning from 75° to 105°), DNV GL have applied a 1.7% increase to instantaneous10-minute wind speed ratios used to extrapolate wind speeds from measurement height to hub height for this sector.
- By this method, a wind speed dataset representing the S4 mast at Collector over the 15th April 2015 to 24th July 2015 period at a hub height of 91.5 m was created.

2 RESULTS

The above analysis resulted in the creation of a synthesised time series at the S4 mast at Collector over the 15th April 2015 to 24th July 2015 period. The time series is presented in the attached '170275PC03 S4 Collector hub height time series 20150724.txt' file and follows the format documented below.

The time stamp represents the start of the 10 minute period.

Date Time [Local]	S4 Predicted wind speed at 91.5 m [m/s]	S4 Wind direction at 65 m
15/04/2015 00:00	5.88	32.1
15/04/2015 00:10	5.94	29.6
15/04/2015 00:20	6.03	27.9
15/04/2015 00:30	6.53	26.7
....	....	....
02/07/2015 23:30	3.89	195.3
02/07/2015 23:40	6.14	191.8
02/07/2015 23:50	8.47	188.4
03/07/2015 00:00	7.81	185.2

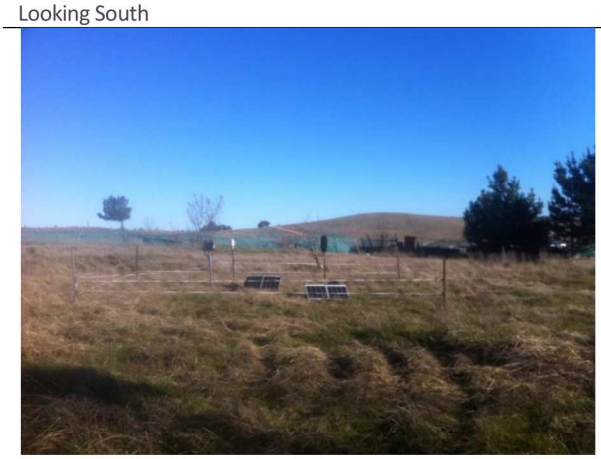
APPENDIX E MONITORING LOCATION PHOTOS

E1 FF receiver

Looking North

Looking East

Looking South



Looking West

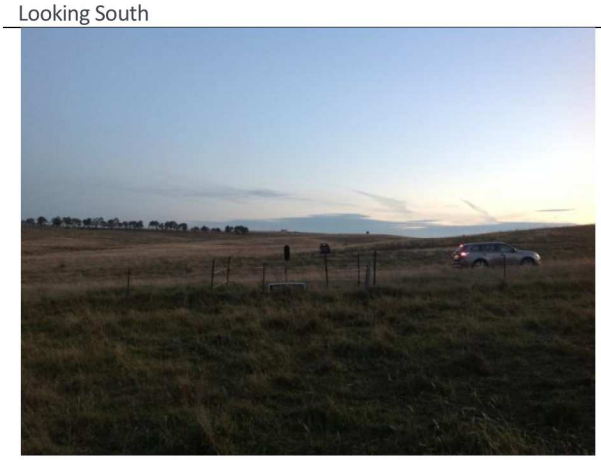
E2 FF intermediate

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

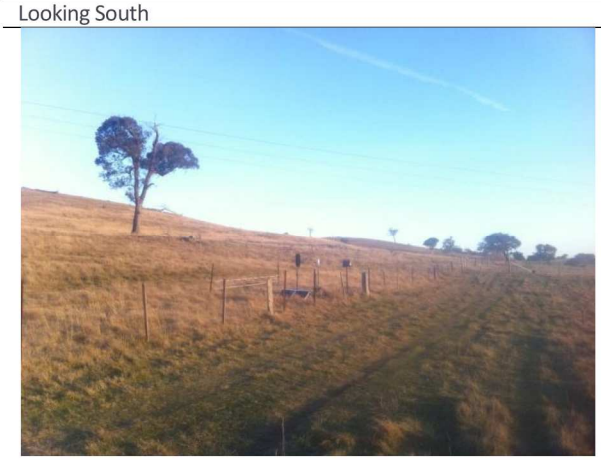
E3 Z Receiver

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

E4 Z intermediate

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

E5 DD intermediate

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

E6 GG intermediate

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

E7 J intermediate

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

E8 Collector Village intermediate

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

APPENDIX F TABULATED A-WEIGHTED BACKGROUND NOISE LEVELS

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

Table 15: Measured background noise levels (L_{A90})

Location	Hub Height Wind Speed (m/s)										
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
FF receiver	27	28	29	30	32	34	36	39	41	43	45
FF intermediate	27	27	27	28	30	31	33	35	37	39	41
Z receiver	22	22	23	25	27	30	33	36	38	40	-*
Z intermediate	21	22	23	24	26	29	32	36	40	44	-*
Collector Village intermediate	28	29	30	30	30	30	30	31	31	32	33
DD intermediate	38	38	38	38	38	38	38	37	36	35	-*
GG intermediate	27	27	28	28	29	31	32	34	36	38	41
J intermediate	25	23	23	24	25	28	31	33	35	36	36

* Lack of measured data at these wind speeds

APPENDIX G C-WEIGHTED MEASUREMENT RESULT COMPARISONS

General measurement practices and wind shielding systems are primarily designed for the prevention of excess extraneous noise influences on A-weighted measurements. In contrast, measurements of C-weighted noise levels in windy environments are prone to increased extraneous noise influences associated with wind passing directly across the microphone diaphragm.

Accordingly, given the inclusion of C-weighted noise level thresholds in the Project Approval, a set of comparative measurements were made at receiver locations Z and FF to investigate the potential effect of wind induced extraneous on C-weighted measurements. Specially, measurements were concurrently made at each receiver location with two separate noise monitoring systems in close proximity:

- A conventional measurement configuration comprising a 1.5m microphone height and secondary wind shield; and
- A dedicated measurement configuration selected to offer further screening of potential wind induced extraneous noise.

In the absence of formal standards for C-weighted measurements, an enhanced wind protection system was implemented for each receiver location on the basis of the general arrangement defined in IEC 61400-11:2012. This arrangement involves placing the microphone at ground level where wind exposure is likely to be reduced, and using a larger diameter secondary wind screen to further reduce the wind exposure of the microphone.

The results of simultaneous measurements from the two systems are then compared to identify the wind speeds at which significant differences being to occur. In turn, this indicates the wind speed where the C-weighted measurements of the conventional measurement configuration become increasingly affected by wind induced extraneous noise.

In relation to this comparison, the following considerations are noted:

- The dedicated measurement configuration offers enhanced screening of wind induced extraneous noise, but would generally be expected to measure higher noise levels on some occasions as a result of:
  - Reduced proximity to insects at ground level
  - Reflected noise from the ground board (the intent of the ground board when used for turbine sound power level testing)
- While the dedicated measurement configuration offers enhanced shielding relative to the standard configuration, wind induced noise across the microphone will still occur at certain wind speeds and the value of this underlying influence on the measurement results cannot be quantified amidst the broader C-weighted noise levels of the ambient noise environment.

The following figures provide:

- The trend of C-weighted noise levels versus hub-height wind speeds for each pair of measurement systems at receivers Z and FF
- A chart for each receiver location which plots the difference between the simultaneously measured noise level of the conventional measurement configuration and the dedicated measurement for each 10 minute period against the corresponding hub-height wind speed.

The data for this analysis is filtered in the same manner as the A-weighted noise level analysis presented in Section 3.0, including the removal of any data points in which the locally measured wind speed exceeded an average of 5m/s.

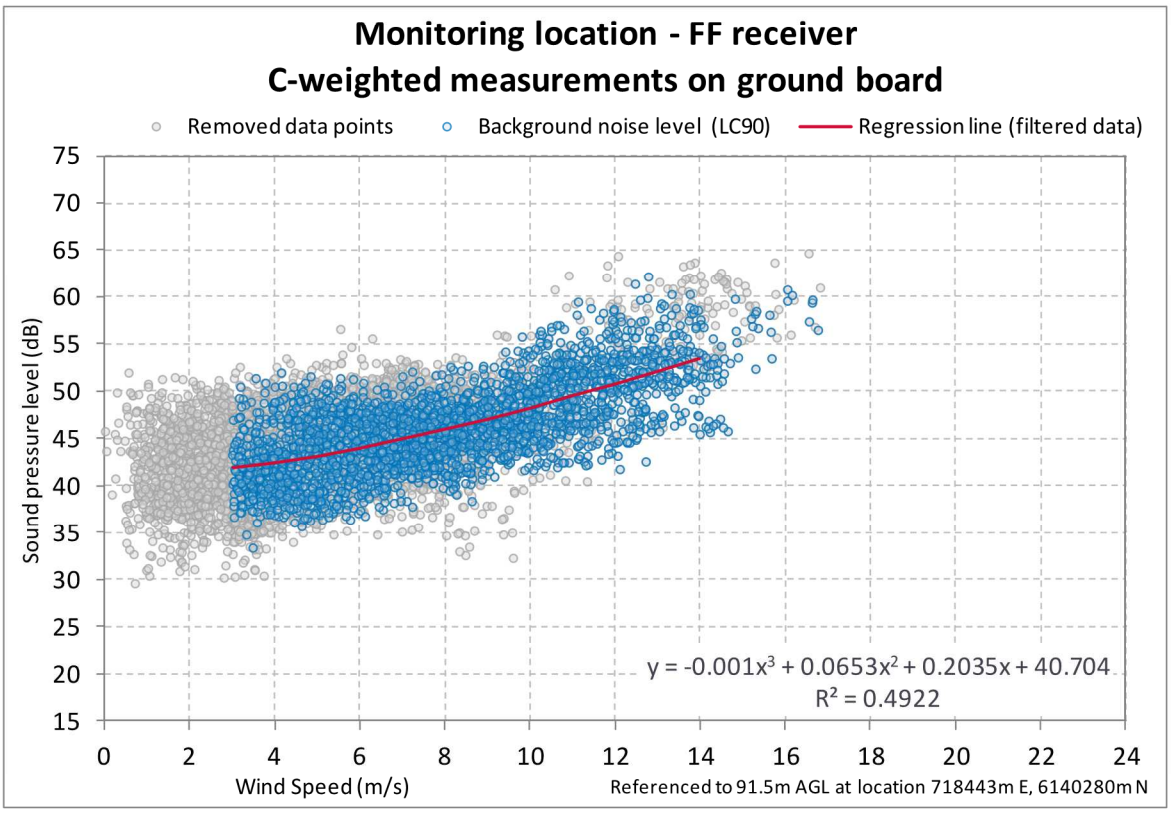


Figure 14: FF receiver C-weighted measurements – ground board system

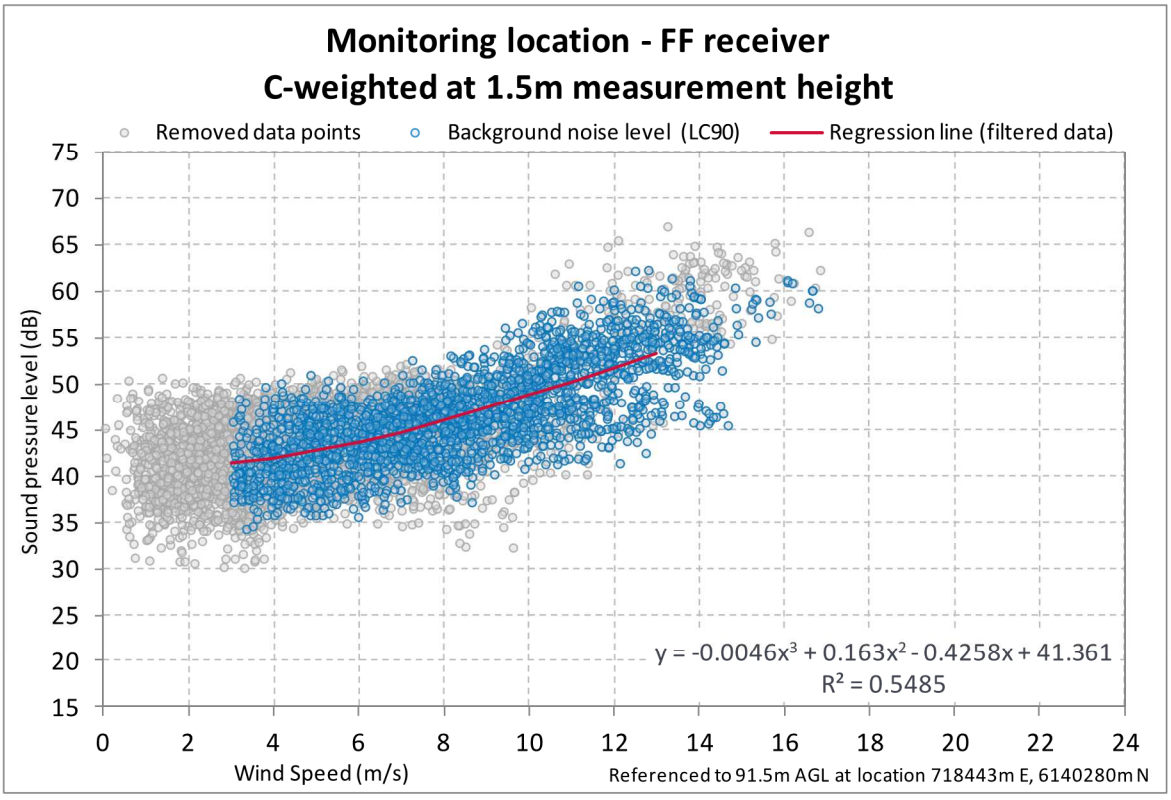


Figure 15: FF receiver C-weighted measurements – microphone at 1.5 m

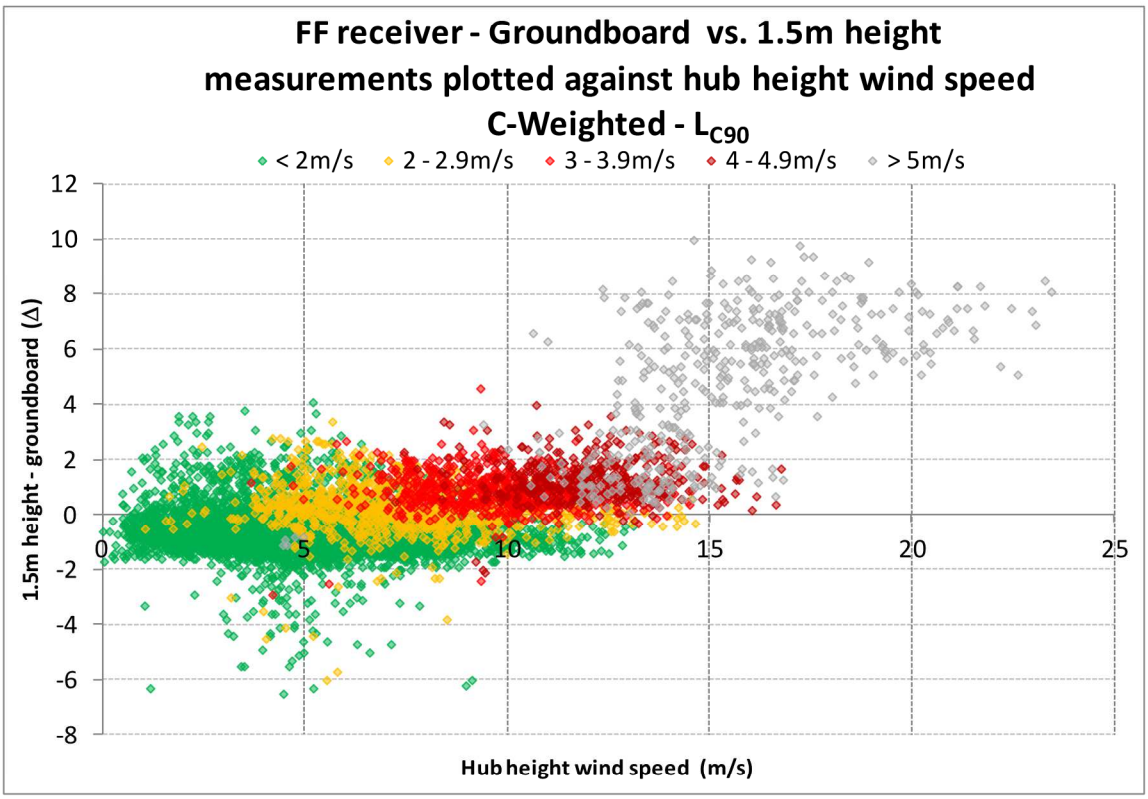


Figure 16: FF receiver C-weighted measurement results – ground board minus 1.5m height results

The results presented in Figure 16 indicate an increased difference between the two measurement systems at local wind speeds greater than 3m/s (red data points). At local wind speeds greater than 5m/s (grey data points), the differences between the two measurements systems becomes relatively large, consistent with the results from the conventional measurement configuration being highly affected by wind induced noise across the microphone.

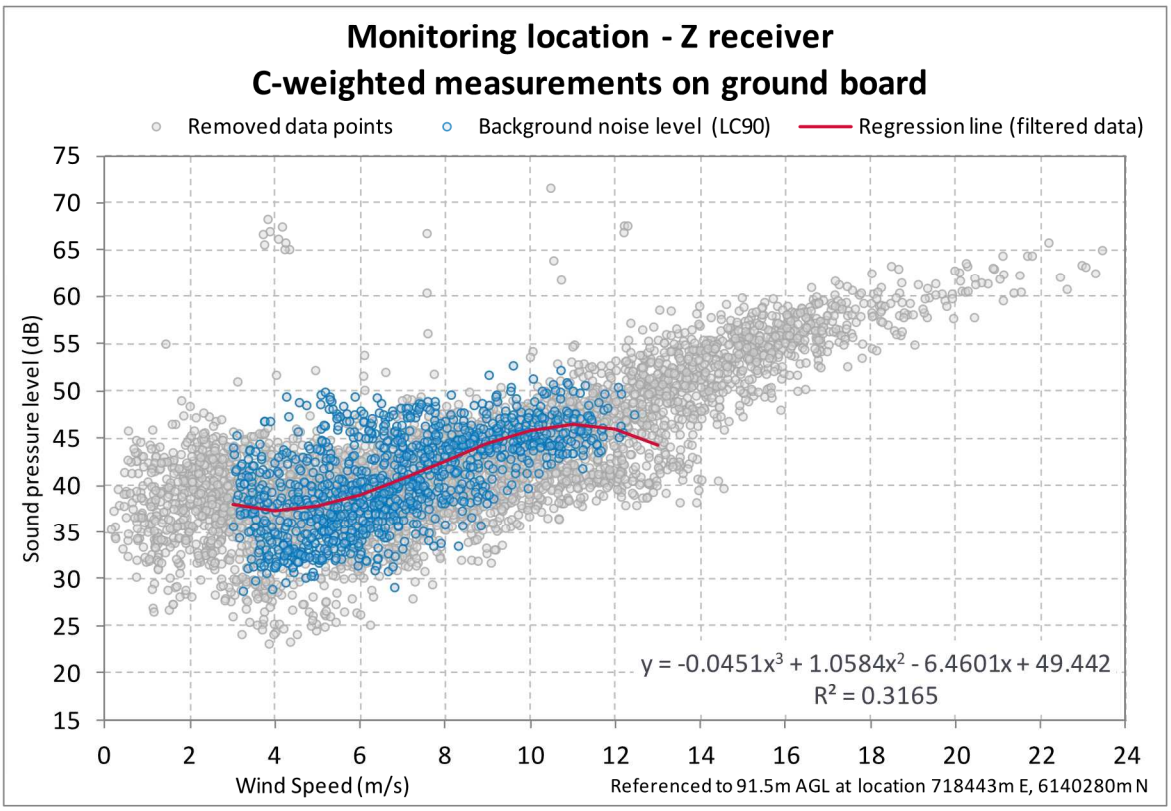


Figure 17: Z receiver C-weighted measurements – ground board system

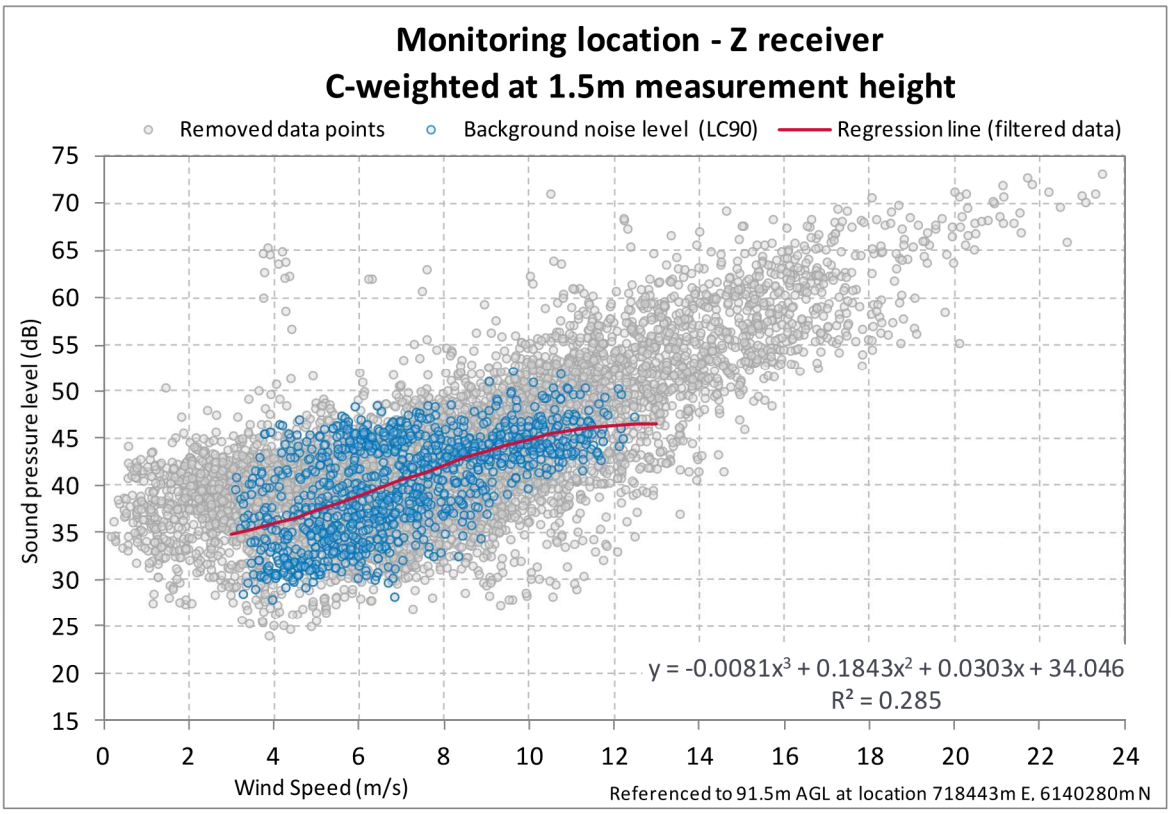


Figure 18: Z receiver C-weighted measurements – microphone at 1.5 m

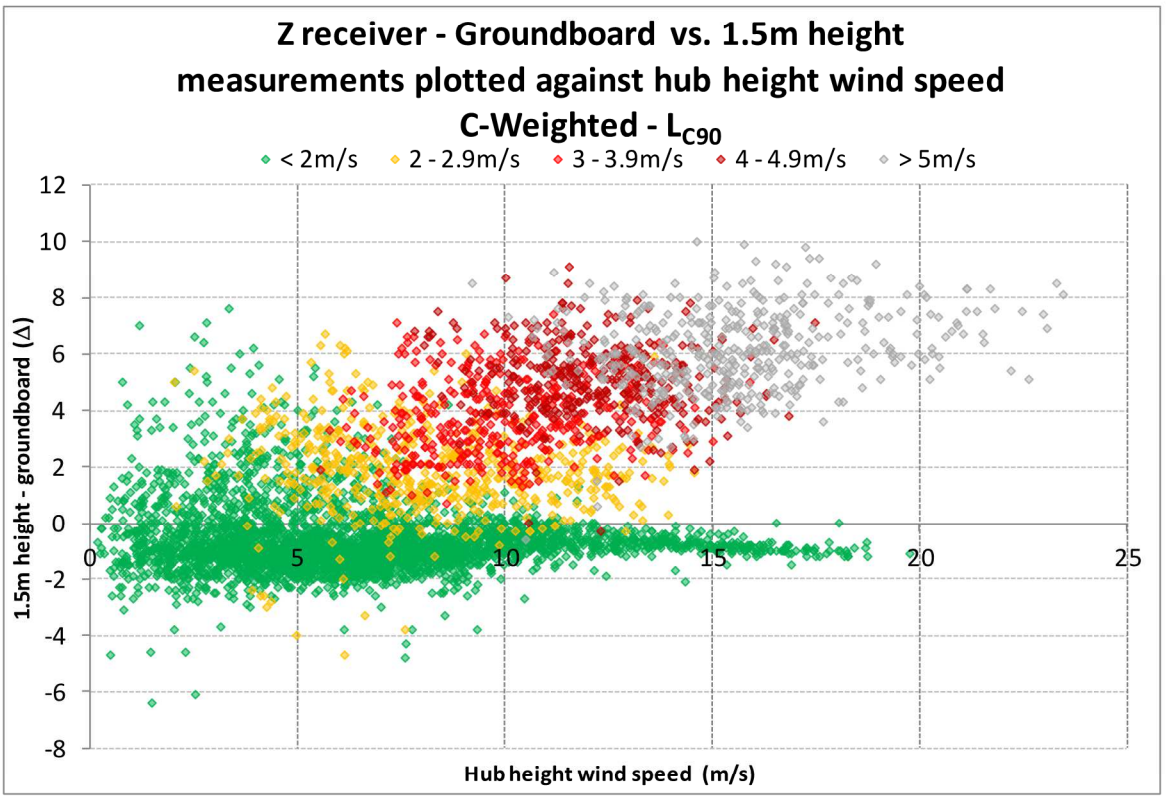


Figure 19: Z receiver C-weighted measurement results – ground board minus 1.5m height results

The results presented in Figure 19 indicate an increased difference between the two measurement systems at local wind speeds greater than 3m/s (red data points). At local wind speeds greater than 5m/s (grey data points), the differences between the two measurements systems becomes relatively large, consistent with the results from the conventional measurement configuration being highly affected by wind induced noise across the microphone.