COLLECTOR WIND FARM
CANDIDATE TURBINE NOISE PREDICTIONS

Rp 003 2015087ML | 30 September 2015

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

Project: **COLLECTOR WIND FARM**

Prepared for: **RATCH-Australia Corporation Limited**
Level 7, 111 Pacific Highway
North Sydney NSW 2059
AUSTRALIA

Attention: **Mr Anthony Yeates**

Report No.: **Rp 003 2015087ML**

Document Control

Status:	Rev:	Comments	Date:	Author:	Reviewer:
Draft	-	Incomplete	1/9/2015	J Adcock	
Draft	-	Complete	3/9/2015	J Adcock	C Delaire
Draft	-	Minor text edit	3/9/2015	J Adcock	-
Final	-	Minor text & figure edit	30/9/2015	J Adcock	-

Certified System ISO 9001

TABLE OF CONTENTS

1.0 INTRODUCTION

This report presents the results of updated noise predictions prepared for the proposed Collector Wind Farm that is being developed by RATCH Australia Corporation (RATCH).

This report was commissioned by RATCH to supplement the modification application to the NSW Department of Planning and Environment to vary the conditions of the Project Approval of Collector Wind Farm. The modification application seeks to vary the Project Approval to include:

- Noise limits based on recent background noise measurements conducted at the two (2) nearest non-involved receiver locations, consistent with the types of noise limits that are normally applied to wind farms in NSW and across Australia
- An increase in the turbine blade length from 56 m to 58.5 m, equating to a total allowable rotor diameter of 117 m, with no change in the allowable maximum tip height of 150 m
- Refinement of the layout of site roads, electrical cabling, and project buildings

The make and model of turbine to be installed at the Collector Wind Farm is yet to be finalised. However, two (2) candidate turbine models manufactured by ACCIONA and Vestas are presently being considered and have been used as the basis for the noise predictions presented herein.

Once the final turbine selection for the site has been made, the noise predictions will be updated for the purpose of the Revised Noise Assessment that must be submitted to the Director-General prior to construction of the wind turbines. The Revised Noise Assessment will also contain additional information as required by the Project Approval, such as C-weighted noise level predictions.

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 in this report is presented in Appendix A.

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 PROJECT DESCRIPTION

2.1 Overview

The NSW Planning Assessment Commission (PAC) issued a Project Approval for the Collector Wind Farm on 2 December 2013 which allows for the construction of fifty five (55) wind turbines and ancillary infrastructure on the Cullerin Range.

The coordinates of the proposed fifty five (55) wind turbines are tabulated in Appendix B.

A total of thirty five (35) receiver locations surrounding the Collector Wind Farm have been considered in this report. The receivers and their locations correspond to the thirty four (34) receivers included in the noise assessment of the wind farm during the planning phase, plus one (1) additional receiver location that is being developed to the southwest of the Collector Wind Farm.

The thirty five (35) receiver locations comprise:

- Thirty (30) receiver locations where the noise requirements of the Project Approval apply
- Five (5) receiver locations where the noise requirements of the Project Approval do not apply

The coordinates of the thirty five (35) receiver locations are tabulated in Appendix C.

A site layout plan illustrating the turbine layout and receiver locations is provided in Appendix D.

The site layout map also illustrates the location of the Collector Village and a number of intermediate monitoring locations which have been documented in the background noise monitoring report submitted with the modification application (Marshall Day Acoustics' document reference *Rp 002 2015087ML* dated 30 September 2015).

The turbine layouts and the nearest receiver locations are also illustrated in the predicted noise contour maps provided in Section 4.0.

2.2 Candidate Turbines

2.2.1 Overview

Details of the two candidate ACCIONA and Vestas turbines presently being considered for the Collector Wind Farm are documented in Table 1.

Table 1: Candidate turbines – description

Detail	Candidate Turbine	
	ACCIONA	Vestas
Make	ACCIONA	Vestas
Model	AW116	V117
Rotor Diameter	116 m	117 m
Hub Height	92 m	91.5 m
Blade Orientation	Upwind	Upwind
Rotor speed	9.2 – 15.6 rpm	16.2 – 17.7 rpm
Cut-in Wind Speed (hub height)	3.5 m/s	3 m/s
Rated Power Wind Speed (hub height)	10.5 m/s	13 m/s
Cut-out Wind Speed (hub height)	25 m/s	25 m/s

2.2.2 ACCIONA AW116 Sound Power Data

The noise emissions of the ACCIONA AW116 wind turbine are represented by sound power level data sourced from the following documents:

- ACCIONA AW116 sound specification titled General Document (ACCIONA document reference DG200266 revision E)
- Supplementary reference information contained in ACCIONA document *Noise Emission for the AW116/3000 at Different Hub Wind Speeds* (ACCIONA document reference DPI.450 revision A)

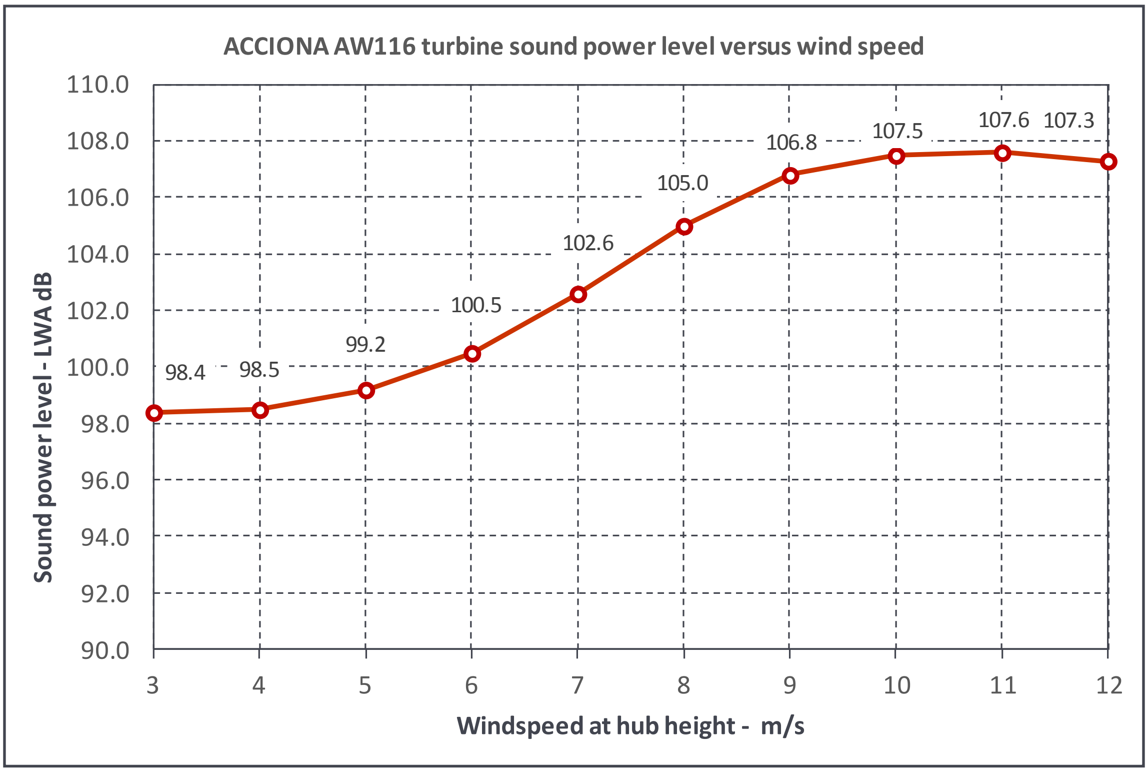
Guaranteed sound power levels for the project would be supplied as part of a formal contract for the supply of turbines. In advance of a formal supply contract, the noise modelling presented herein has been based on the apparent sound power levels in the sound specification adjusted by the addition of 1.0 dB to account for typical sound power level test uncertainties.

The adjusted values are presented in Table 2 and illustrated in Figure 1.

Table 2: Sound power levels for the ACCIONA AW116 turbines (including uncertainty adjustment)

	L_{WA} dB at hub height wind speed (m/s)									
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
ACCIONA AW116	98.4	98.5	99.2	100.5	102.6	105	106.8	107.5	107.6	107.3

Figure 1: ACCIONA AW116 total sound power levels



The available octave band data for the ACCIONA AW116 corresponding to the highest sound power level at a hub height wind speed of 11 m/s is provided in Table 2. This data has been used as a representation of the spectral characteristics of the turbine across the range of integer wind speeds.

Table 3: ACCIONA AW116 octave band sound power level data

	L_{WA} dB Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	Total
11 m/s at hub height	84.5	93.9	100.4	103.0	102.5	97.4	86.8	80.5	107.6

2.2.3 Vestas V117 Sound Power Data

The noise emissions of the Vestas V117 wind turbine are represented by sound power level data sourced from the following documents:

- Vestas general specification titled *General Specification V117-3.3/3.45 MW 50/60 Hz* (Vestas document reference 0035-1209 V10 dated 2015-07-10) for the serrated trailing edge option
- Delta test report *Measurement of Noise Emission from a Vestas V117-3.3MWMk2-IEC2A-50Hz in Mode 0 wind turbine; serial no 201303* (Delta document reference DANAK 100/1854 dated 22 October 2014). This data relates to a V117 fitted with the serrated trailing edge option.

In advance of a formal supply contract, the noise modelling presented herein for the Vestas V117 turbine has been based on the sound specification adjusted by the addition of 1.0 dB to account for typical sound power level test uncertainties.

The adjusted values are presented in Table 3 and illustrated in Figure 2.

Table 4: Vestas V117 total sound power levels

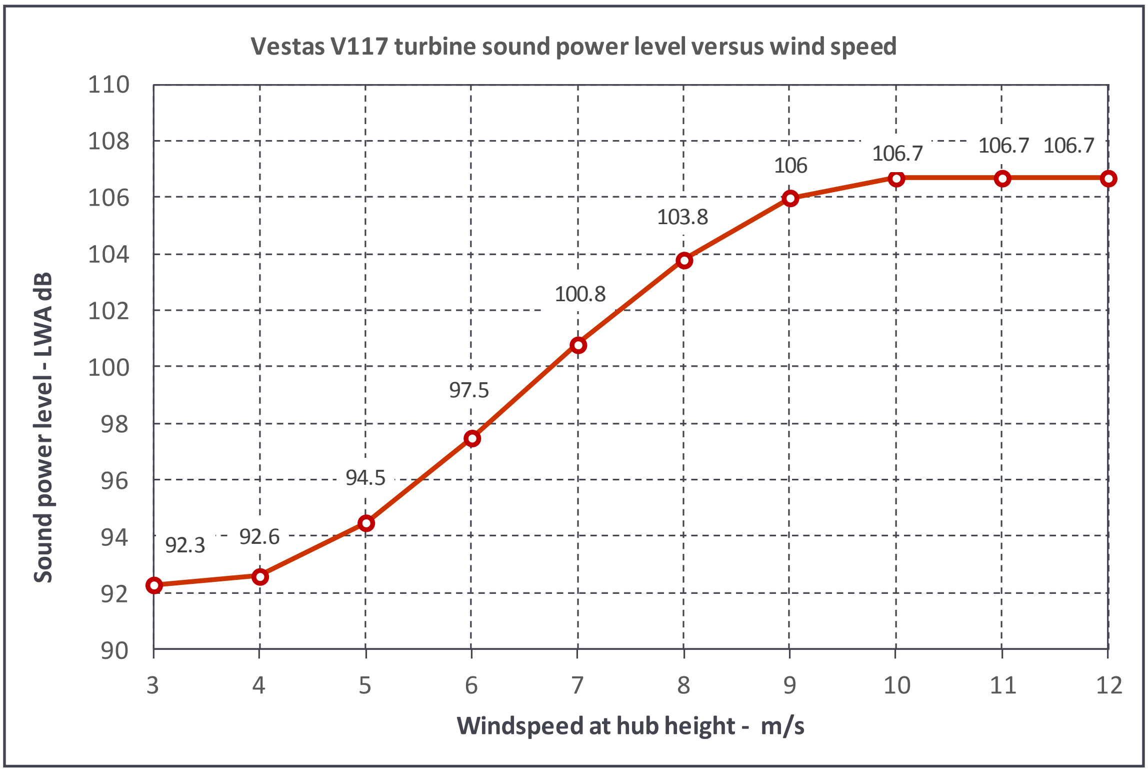
	L_{WA} dB at hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Vestas V117	92.3	92.6	94.5	97.5	100.8	103.8	106	106.7	106.7	106.7

Octave band data for the Vestas V117 for the hub height wind speed range 8 – 12 m/s is provided in Table 5. Predicted noise levels at wind speeds below 8 m/s are based on the 8 m/s spectra.

Table 5: Vestas V117 octave band sound power level data at a hub height wind speed of 11 m/s

	L_{WA} dB Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	Total
8 m/s at hub height	86.5	93.9	96.1	97.8	97.6	95.4	92.1	81.3	103.8
9 m/s at hub height	89.3	96.0	98.1	99.8	99.8	97.8	94.6	83.8	106
10 m/s at hub height	90.6	96.7	98.7	100.3	100.5	98.5	95.3	84.0	106.7
11 m/s at hub height	91.6	97.3	98.9	100.2	100.4	98.4	95.0	82.7	106.7
12 m/s at hub height	92.6	98.2	99.4	100.3	99.8	97.8	94.8	81.3	106.7

Figure 2: Vestas V117 total sound power levels



2.2.4 Tonality

Limited data is presently available to assess the characteristics of the two (2) candidate turbines with respect to tonality.

The available information suggests tonal audibility levels up to 2 dB for sound power level tests conducted in accordance with IEC 61400-11:2012 *Wind turbines - Part 11: Acoustic noise measurement techniques*. Tonal audibility levels measured at sound power test locations near to the turbines cannot be reliably extrapolated to receiver locations, due to the complexities of sound propagation associated with individual sound frequencies. However, a tonal audibility level of 2 dB at a sound power test location is relatively low. Further, it is not expected that these values would be sufficient to warrant the application of adjustments to noise levels at greater separating distances corresponding to receiver locations.

Notwithstanding the above, the procurement contract for the turbines is proposed to include a performance requirement that the turbines shall not produce tonal audibility levels at receiver locations that would warrant the application of adjustments in accordance with the requirements established by condition E9 of the Project Approval.

On the basis of the above, adjustments for tonality have not been applied to the predictions presented in this report.

3.0 PREDICTION METHODOLOGY

Operational noise levels associated with the wind farm have been predicted on the basis of:

- The sound emissions of the candidate turbines as outlined in Section 2.2
- A 3D digital model of the site and the surrounding environment
- International standards used for the calculation of environmental sound propagation, with input settings and adjustments specifically suited to wind farm noise assessment.

Details of the prediction methodology are summarised in Table 6 below. The prediction method is consistent with the procedures used to calculate operational noise levels during the planning stages of the project.

Table 6: Wind farm prediction methodology

Detail	Description
Software	Proprietary noise modelling software SoundPLAN version 7.4 (current release)
Method	International Standard ISO 9613-2:1996 *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation* (ISO 9613-2). Adjustments to the ISO 9613-2 method are applied on the basis of the guidance contained in the 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* (UK good practice guide). The adjustments are applied within the SoundPLAN modelling software and relate to the influence of terrain screening and ground effects on sound propagation. Specific details of adjustments are noted below. Further discussion of the prediction method is provided in Appendix D.
Source characterisation	Each wind turbine is modelled as an incoherent point source of sound. The total sound of the wind farm is then calculated on the basis of simultaneous operation of all wind turbines and summing the contribution of each. Calculations of turbine to receiver distances and average sound propagation heights are made on the basis of the point source being located at the position of the hub of the turbine (91.5 – 92 m AGL according to turbine type). Calculations of terrain related screening are made on the basis of the point source being located at the maximum tip height of each turbine (150 m AGL). Further discussion of terrain screening effects is provided below.
Terrain data	A digital model of the terrain for the site and surrounding areas has been generated on the basis of: • Site and immediate environs: 0.5 m interval contour data acquired from an aerial survey of the site (LIDAR) in July 2013 • Surrounding environs: 10 m interval contour data provided by the NSW Department of Lands and Property Information on 21 July 2015

Detail	Description
Terrain effects	Adjustments for the effect of terrain are determined and applied on the basis of the UK good practice guide and research outlined in Appendix D. • Valley effects: + 3dB is applied to the calculated noise level of a wind turbine when a significant valley exists between the wind turbine and calculation point. A significant valley is deemed to exist when the actual mean sound propagation height between the turbine and calculation point is 50% greater than would occur if the ground was flat. • Terrain screening effects: only calculated if the terrain blocks line of sight between the maximum tip height of the turbine and the calculation point. The value of the screening effect is limited to a maximum value of 2 dB.
Ground conditions	Ground factor of G = 0.5 on the basis of the UK good practice guide and research outlined in Appendix D. The ground around the site corresponds to acoustically soft conditions (G=1) according to ISO 9613-2. The adopted value of G = 0.5 assumes that 50% of the ground cover is acoustically hard (G = 0) to account for variations ground porosity and provide a cautious representation of ground effects.
Atmospheric conditions	Temperature 10 ^{0}C and relative humidity 70 % This represents conditions which result in relatively low levels of atmospheric sound absorption and is chosen on the basis of the UK good practice guide. The calculations are based on sound speed profiles[1] which increase the propagation of sound from each turbine to each receiver location, whether as a result thermal inversions or wind directed toward each calculation point. The primary consideration for wind farm noise assessment is wind speed and direction. The noise level at each calculation point is assessed on the basis of being simultaneously downwind of every wind turbine at the site. Other wind directions in which part or the entire wind farm is upwind of the receiver will result in lower noise levels. In some cases, it is not physically possible for a receiver to be simultaneously downwind of each turbine and the approach is therefore conservative in these instances.
Receiver heights	1.5 m AGL

[1] The sound speed profile defines the rate of change in the speed of sound with increasing height above ground

4.0 PREDICTED NOISE LEVELS

This section presents the highest predicted noise levels at each receiver location for the two (2) candidate turbine options. Predicted noise levels for the range of integer wind speeds assessed are provided in Appendix F for each receiver.

Sound levels in environmental assessment work are typically reported to the nearest integer to reflect the practical use of measurement and prediction data. However, in the case of wind farm layout design, significant layout modifications may only give rise to fractional changes in the predicted noise level. This is a result of the relatively large number of sources influencing the total predicted noise level, as well as the typical separating distances between the turbine locations and surrounding assessment positions. It is therefore necessary to consider the predicted noise levels at a finer resolution than can be perceived or measured in practice. It is for this reason that the levels presented in this section are reported to one decimal place.

4.1 ACCIONA AW116

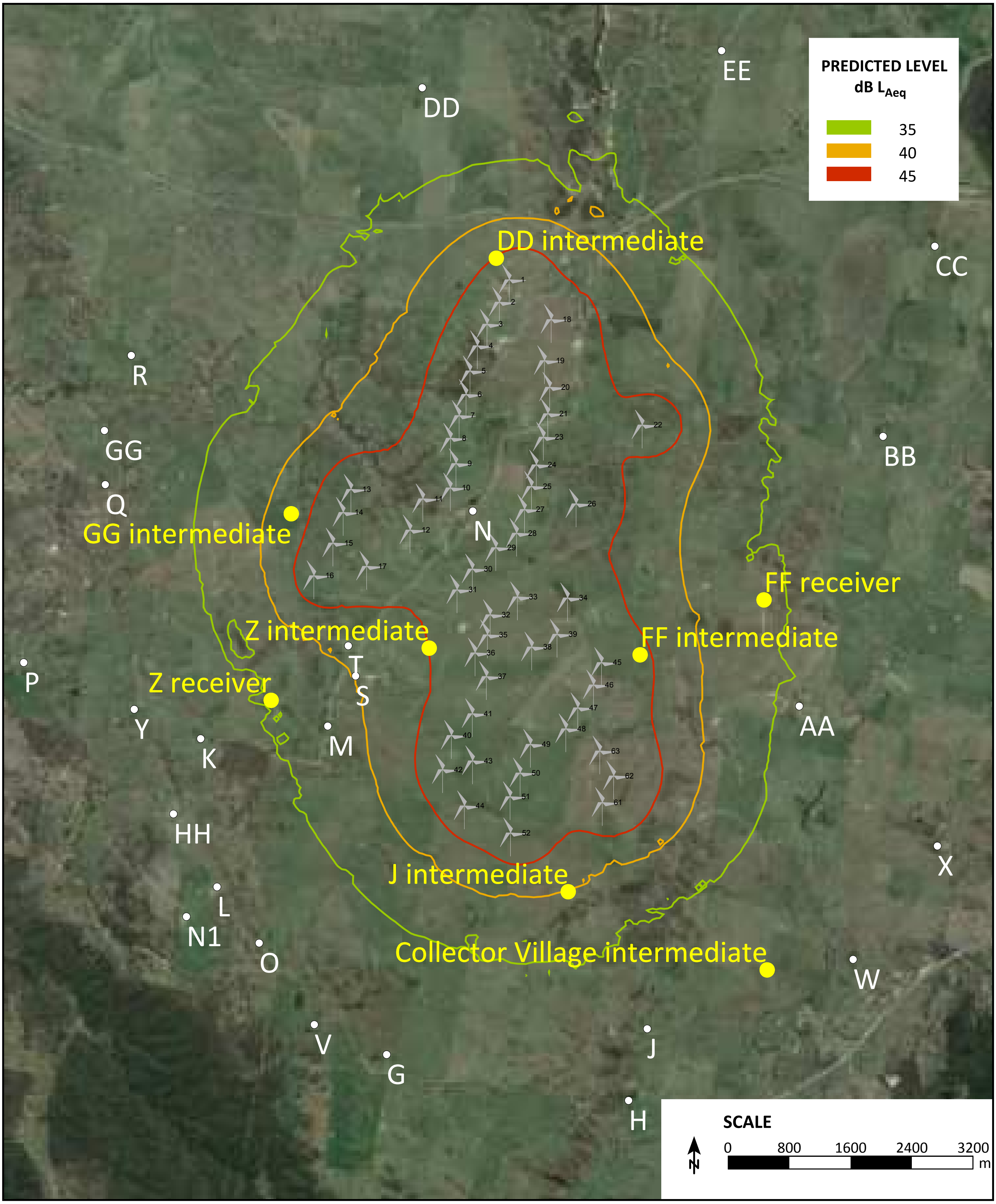
The highest predicted noise levels for the ACCIONA AW116 occur at a hub height wind speed of 11 m/s and are presented in Table 7.

Table 7: AW116 predicted A-weighted noise levels L_{Aeq} dB at a hub height wind speed of 11 m/s

Receiver	L_{Aeq} dB	Receiver	L_{Aeq} dB
A	15.4	K	32.6
AA	33.9	L	30.4
B	15.2	M (s)	37.6
BB	30.5	N (s)	49.7
C	17.9	N1	31.2
CC	28.2	O	30.2
D	19.3	P	25.5
DD	31.4	Q	30.4
E	19.8	R	31.1
EE	26.3	S (s)	40.3
F	23.3	T (s)	41.2
FF	35.9	U	21
G (s)	29.5	V	29.6
GG	29.8	W	28.7
H	26.2	X	29.5
HH	31	Y	29.1
I	26.4	Z	36
J	28.6		

(s) Stakeholder receiver location

A noise contour map illustrating the predicted noise levels for the ACCIONA AW116 turbine are presented on the following page.



LEGEND

- Wind turbine
- Receiver
- Noise Monitoring Location

Project: Collector Wind Farm
Project number: 2015087ML
Client name: RATCH
Version: SoundPLAN 7.4
Prediction method: ISO 9613-2:1996 with terrain corrections
Run Number: 21
Prediction Height: 1.5m

COLLECTOR WIND FARM

ACCIONA AW 116/3000 OPERATION at 11m/s

MARSHALL DAY Acoustics

4.2 Vestas V117

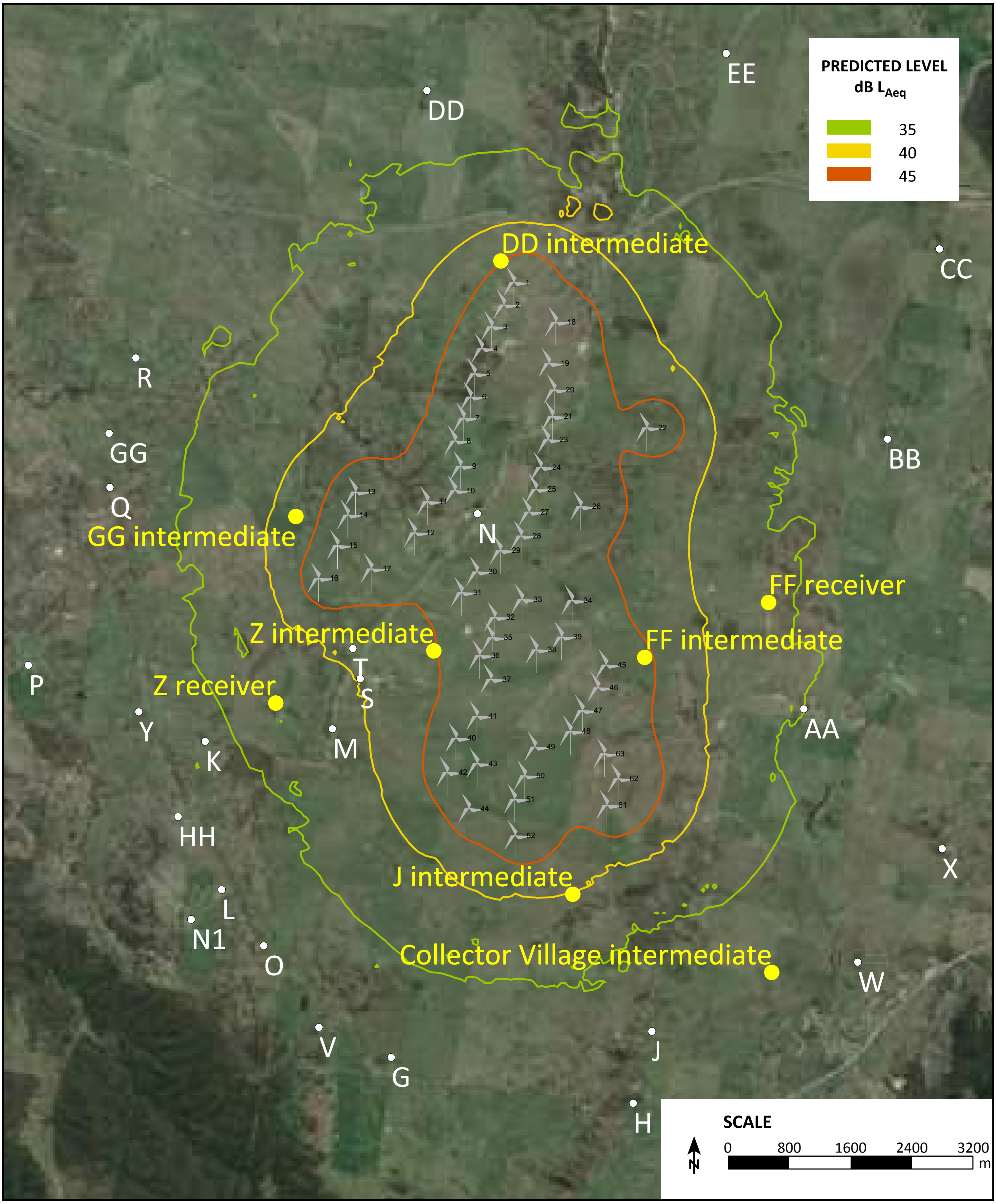
The predicted noise levels for the Vestas V117 occur at a hub height wind speed of 12 m/s and are presented in Table 8.

Table 8: V117 Predicted A-weighted noise levels L_{Aeq} dB at a hub height wind speed of 12 m/s

Receiver	L_{Aeq} dB	Receiver	L_{Aeq} dB
A	20.9	K	34.3
AA	35	L	32.7
B	20.7	M (s)	38.1
BB	32.7	N (s)	49
C	22.8	N1	33.8
CC	31.4	O	32.4
D	23.8	P	28.4
DD	33.1	Q	32.5
E	24.1	R	33.3
EE	29.2	S (s)	40.4
F	26.7	T (s)	41.1
FF	36.9	U	25
G (s)	31.8	V	32.1
GG	31.9	W	31.2
H	28.8	X	32.1
HH	33.3	Y	31.2
I	29.3	Z	36.8
J	30.5		

(s) Stakeholder receiver location

A noise contour map illustrating the predicted noise levels for the Vestas V117 turbine are presented on the following page.



LEGEND

Wind turbine

Receiver

Noise Monitoring Location

Project: Collector Wind Farm 2015 - MDL 2

Project number: 2015087ML

Client name: RATCH

Version: SoundPLAN 7.4

Prediction method: ISO 9613-2:1996
with Terrain corrections

Run Number: 20

Prediction Height: 1.5m

COLLECTOR WIND FARM

VESTAS V117 OPERATION at 12m/s

MARSHALL DAY Acoustics

4.3 Discussion

The results presented in Section 4.1 and Section 4.2 of this report demonstrate that predicted noise levels for both the ACCIONA and Vestas candidate turbines are below 35 dB L_{Aeq} at all non-involved receivers with the exception of receivers Z[2] and FF.

Noise limits at receivers Z and FF are addressed as part of the modification application. Condition E6 of the current Project Approval for the Collector Wind Farm specifies a limit of 35 dB L_{Aeq} at all non-involved receiver locations. However, the modification application seeks to amend Condition E6 to allow noise limits to be defined on the basis of background noise levels in the area; a form of limit is consistent with the types of noise limits that are normally applied to wind farms in NSW and across Australia.

For the purposes of the modification application, recent background noise surveys were conducted at a number of locations around the proposed Collector Wind Farm, including receivers Z and FF. The results of the background noise surveys are documented in the Marshall Day Acoustics report titled *Collector Wind Farm Background Noise Monitoring* dated 12 August 2015 (document reference Rp 002 R02 2015087ML). Section 4.0 of the background noise monitoring report details the 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 predicted noise levels have been compared with the noise limits proposed in the modification application for reference purposes.

4.3.1 Receiver FF – Proposed Noise Limits

The proposed noise limits for receiver FF presented in Figure 12 of Section 4.1 of the background noise monitoring report are reproduced in this section.

The predicted noise levels for the ACCIONA AW116 and Vestas V117 are presented in Figure 5 and Figure 6 respectively, overlaid on the background noise data and proposed limits at receiver FF.

The results presented in Figure 5 and Figure 6 demonstrate that the predicted noise levels are well below the proposed noise limits at receiver FF. Further, the results demonstrate the predicted noise levels are well within the range of background noise levels measured at receiver FF.

[2] 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.

Figure 5: ACCIONA AW116 predicted noise levels overlaid on the background noise levels and proposed limits

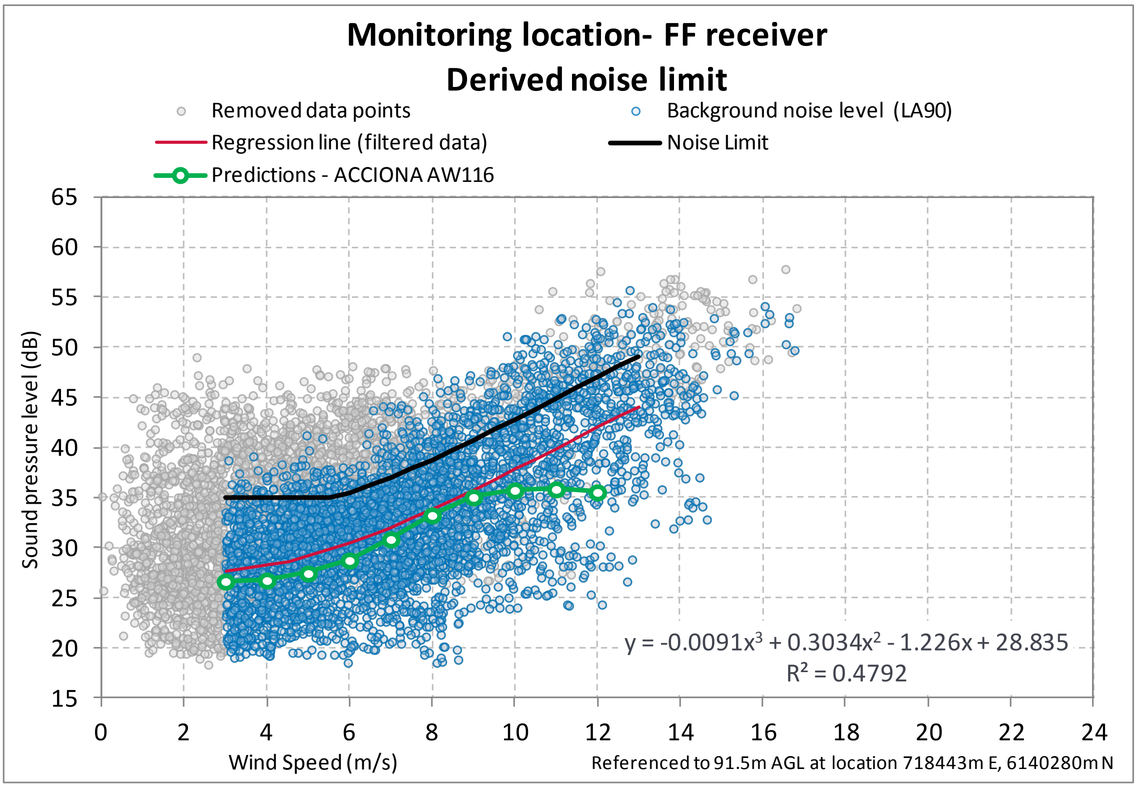
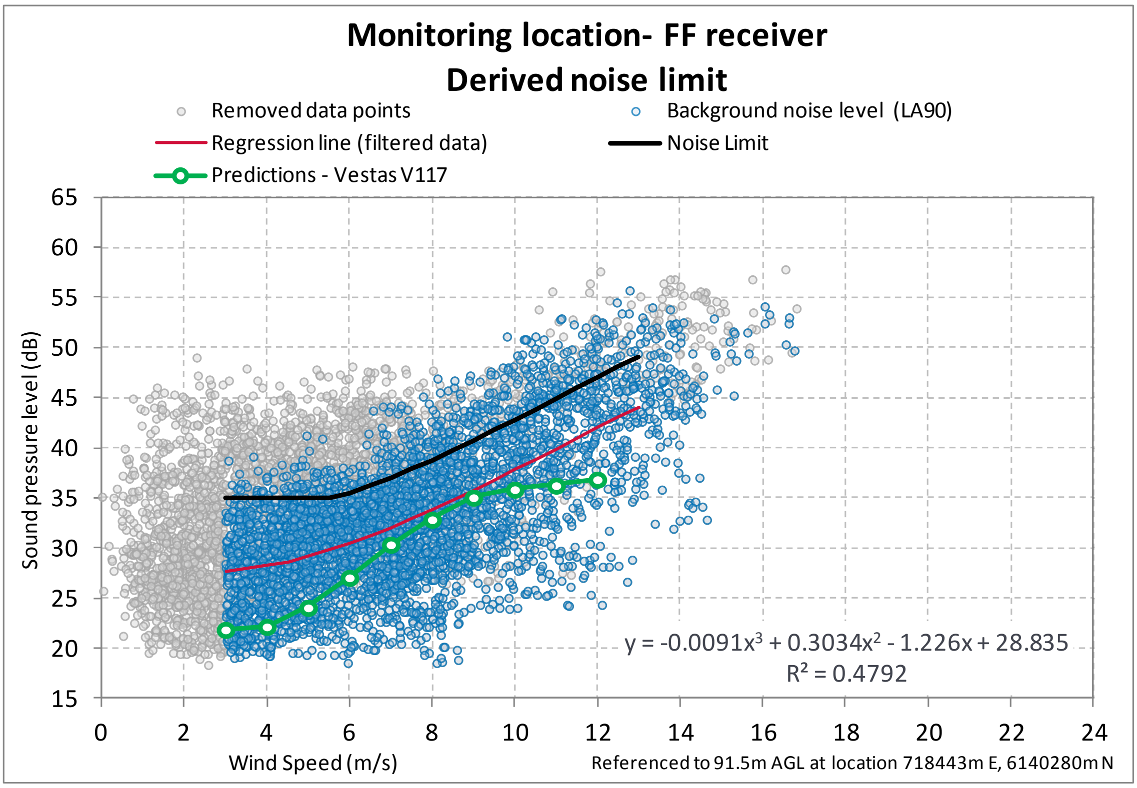


Figure 6: Vestas V117 predicted noise levels overlaid on the background noise levels and proposed limits



4.3.2 Receiver Z – Proposed Noise Limits

The proposed noise limits for receiver Z presented in Figure 13 of Section 4.2 of the background noise monitoring report are reproduced in this section.

The predicted noise levels for the ACCIONA AW116 and Vestas V117 are presented in Figure 7 and Figure 8 respectively, overlaid on the background noise data and proposed limits at receiver FF.

The results presented in Figure 7 and Figure 8 demonstrate that the predicted noise levels are below the proposed noise limits at receiver Z. Further, the results demonstrate the predicted noise levels are within the range of background noise levels measured at receiver Z.

Figure 7: ACCIONA AW116 predicted noise levels overlaid on background noise levels and proposed limits

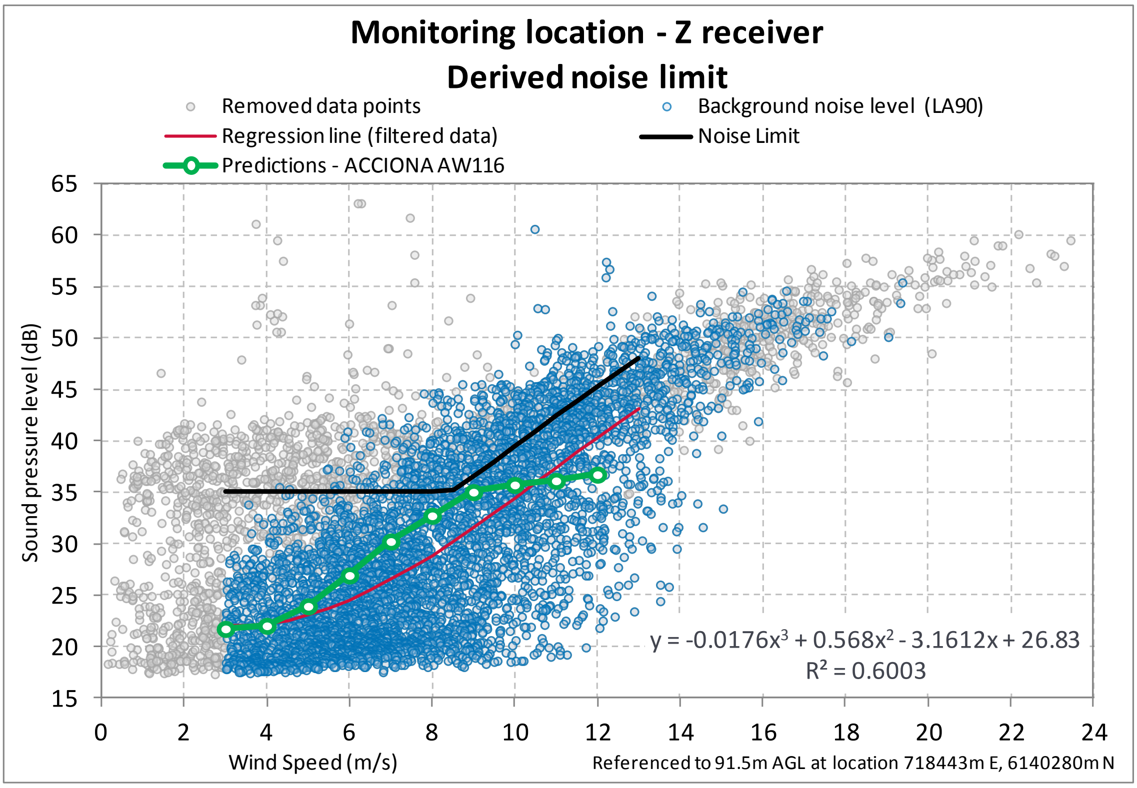
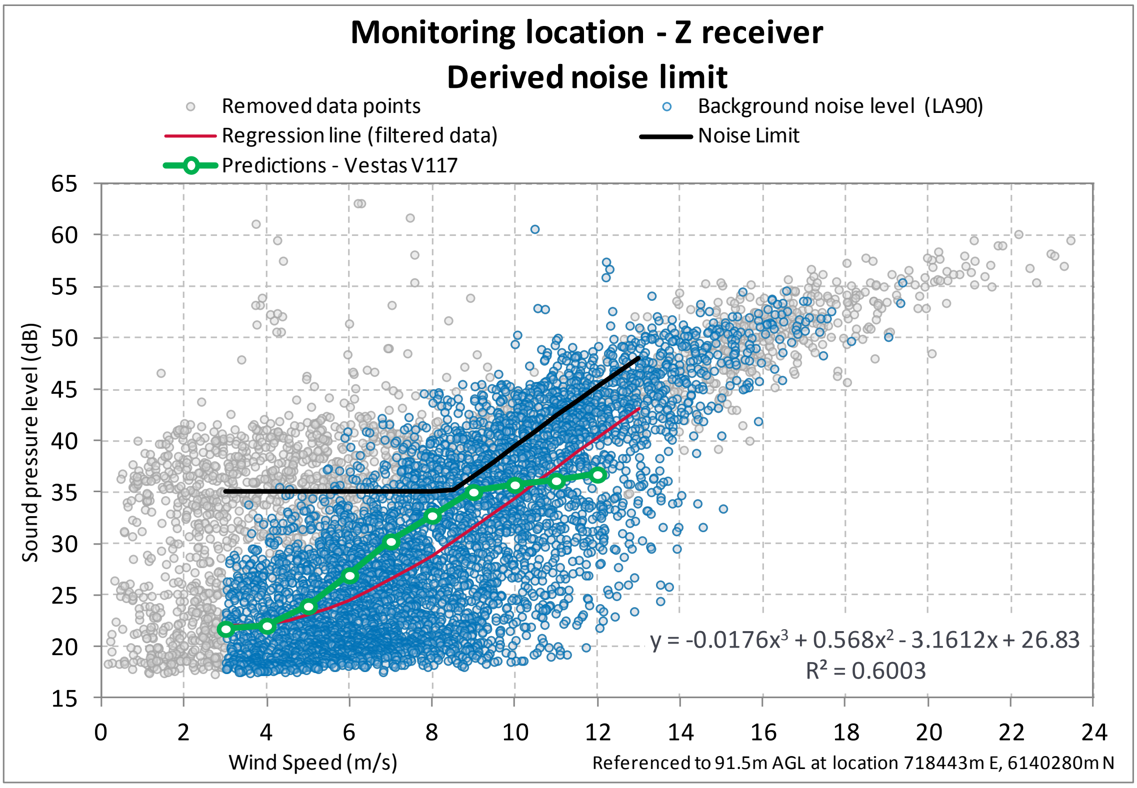


Figure 8: Vestas V117 predicted noise levels overlaid on background noise levels and proposed limits



5.0 SUMMARY

The report presents the results of updated noise predictions prepared for the proposed Collector Wind Farm that is being developed by RATCH Australia Corporation (RATCH)

The make and model of turbine to be installed at the Collector Wind Farm is yet to be finalised. In advance, the predictions have been undertaken for two (2) candidate turbines which are presently being considered for the site. The candidate turbines comprise an ACCIONA AW116 and a VESTAS V117, both of which meet the increased blade length for which the Collector Wind Farm modification application seeks consent.

The results of the noise predictions presented in this report demonstrate that the predicted noise levels are below 35 dB L_{Aeq} at all non-involved receiver locations excluding receivers FF and ZZ.

Noise limits at receivers Z and FF are addressed as part of the modification application. Additional supplementary analysis has been conducted for these two receivers to compare the predicted noise levels with the proposed noise limits which, subject to the approval of the Department of Planning and the Environment, would be used following construction of the wind farm to assess compliance at these locations. The results of this comparison demonstrate that the predicted noise levels for both candidate turbines are below the proposed noise limits at receivers FF and Z. Further, at both locations, the predicted noise levels are within the range of background noise levels measured at the receivers.

The predictions presented in this report are provided to supplement the information contained in the modification application for the Collector Wind Farm. Once the final turbine selection for the site has been made, the noise predictions will be updated for the purpose of the Revised Noise Assessment that must be submitted to the Director-General prior to construction of the wind turbines.

APPENDIX A GLOSSARY OF TERMINOLOGY

dB	Decibel. The unit of sound level.
L_W	The sound power level. The level of total sound power radiated by a sound source.
L_{WA}	The “A” weighted sound power level.
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.

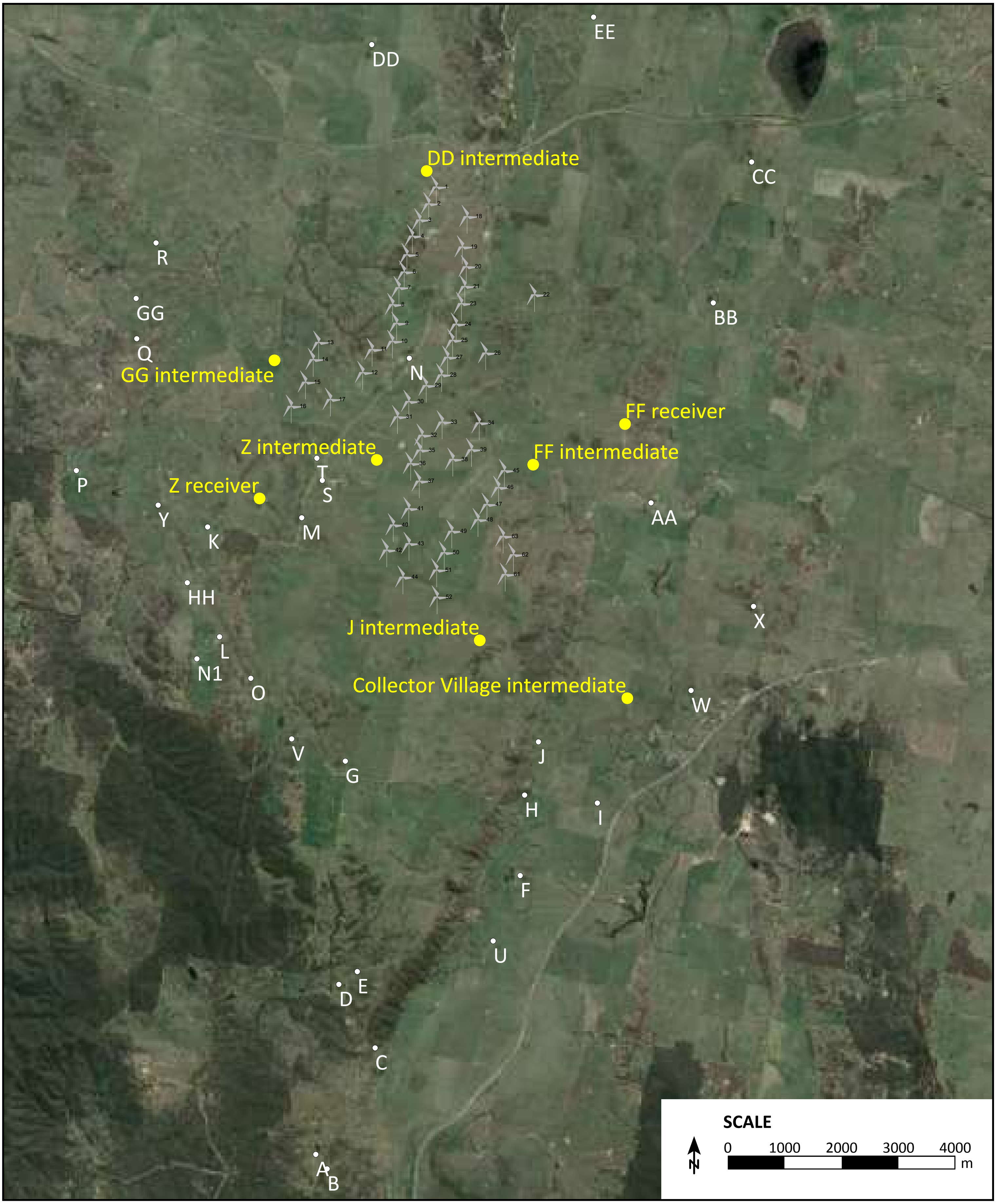
APPENDIX B TURBINE COORDINATES – MGA ZONE 55

Turbine	Easting (m)	Northing (m)	Turbine	Easting (m)	Northing (m)
1	718433	6143522	29	718256	6140030
2	718303	6143229	30	717952	6139751
3	718143	6142944	31	717751	6139480
4	718016	6142661	32	718184	6139157
5	717920	6142333	33	718539	6139389
6	717869	6142028	34	719192	6139375
7	717778	6141753	35	718149	6138894
8	717667	6141456	36	717986	6138660
9	717737	6141127	37	718135	6138349
10	717665	6140808	38	718725	6138734
11	717307	6140667	39	719054	6138902
12	717140	6140259	40	717678	6137581
13	716368	6140791	41	717952	6137867
14	716269	6140490	42	717564	6137136
15	716134	6140091	43	717954	6137251
16	715885	6139665	44	717848	6136663
17	716574	6139788	45	719633	6138534
18	718978	6143004	46	719531	6138241
19	718891	6142467	47	719325	6137942
20	718960	6142121	48	719170	6137671
21	718935	6141776	49	718708	6137467
22	720164	6141628	50	718574	6137092
23	718878	6141471	51	718443	6136785
24	718785	6141111	52	718448	6136312
25	718721	6140828	61	719646	6136708
26	719303	6140601	62	719793	6137054
27	718632	6140529	63	719612	6137380
28	718527	6140218	-	-	-

APPENDIX C RECEIVER COORDINATES – 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 D SITE LAYOUT PLAN



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

MARSHALL DAY Acoustics

APPENDIX E NOISE PREDICTION MODEL

Operational wind farm noise levels are predicted at all residential dwellings considered within this assessment using a three-dimensional noise model generated in SoundPLAN® version 7.4 software. Specifically, predictions have been carried out using the SoundPLAN implementation of ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO 9613-2:1996) to calculate noise propagation from the wind farm to each receiver location.

The use of this method is supported by international research publications and Marshall Day Acoustics own measurement studies.

The standard specifies an engineering method for calculating noise at a known distance from a variety of sources under meteorological conditions favourable to sound propagation. The standard defines favourable conditions as downwind propagation where the source blows from the source to the receiver within an angle of +/-45 degrees from a line connecting the source to the receiver, at wind speeds between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground. Equivalently, the method accounts for average propagation under a well-developed moderate ground based thermal inversion. In this respect, it is noted that at the wind speeds relevant to noise levels from wind turbines, atmospheric conditions do not favour the development of thermal inversions throughout the propagation path from the source to the receiver.

To calculate far-field noise levels according to the ISO 9613-2:1996, the noise levels of each turbine are firstly characterised in the form of octave band frequency levels. A series of octave band attenuation factors are then calculated for a range of effects including:

- Geometric divergence
- Air absorption
- Reflecting obstacles
- Screening
- Vegetation
- Ground reflections

The octave band attenuation factors are then applied to the sound power level data to determine the corresponding octave band and total calculated noise level at relevant receiver locations.

Calculating the attenuation factors for each effect requires a relevant description of the environment into which the sound propagation such as the physical dimensions of the environment, atmospheric conditions and the characteristics of the ground between the source and the receiver.

Wind farm noise propagation has been the subject of considerable research in recent years. These studies have provided support for the reliability of engineering methods such as ISO 9613-2:1996 when a certain set of input parameters are chosen in combination.

A number of Australian and international studies support the assignment of a ground absorption factor of G=0.5 for the source, middle and receiver ground regions between a wind farm and a calculation point. This ground absorption factor of G=0.5 is adopted in combination with several cautious assumptions; specifically all turbines operating at identical wind speeds, emitting sound levels equal to the test measured levels plus a margin for uncertainty (or guaranteed values), at a temperature of 10 degrees and relative humidity of 70% (conditions which give rise to low atmospheric absorption). The studies demonstrate that applying the ISO 9613-2:1996 prediction methodology in this way provides a reliable representation of the upper noise levels expected in practice.

The following specific adjustments have been made:

- In instances where the ground terrain provides marginal or partial acoustic screening, the barrier effect should be limited to not more than 2 dB
- Screening attenuation calculated based on the screening expected for the source located at the tip height of the turbine (in contrast to hub height in non-adjusted ISO 9613-2:1996 predictions)
- In instances where the ground falls away significantly between the source and receiver, such as valleys, an adjustment of 3 dB should be added to the calculated sound pressure level. A terrain profile in which the ground falls away significantly is defined as one where the mean sound propagation height is at least 50% greater than would occur over flat ground

In support of the use of ISO 9613-2:1996 and the choice of G=0.5 as an appropriate ground characterisation, the following references are noted:

- A factor of G=0.5 is frequently applied in Australia for general environmental noise modelling purposes as a way of accounting for the potential mix of ground porosity which may occur in regions of dry/compacted soils or in regions where persistent damp conditions may be relevant
- NZS 6808:2010 refers to ISO 9613-2:1996 as an appropriate prediction methodology for wind farm noise, and notes that soft ground conditions should be characterised by a ground factor of G=0.5
- In 1998, a comprehensive study, part funded by the European Commission, Development of a Wind Farm Noise Propagation Prediction Model[3] found that the ISO 9613-2:1996 model provided a robust representation of upper noise levels which may occur in practice, and provided a closer agreement between predicted and measured noise levels than alternative standards such as CONCAWE and ENM. Specifically, the report indicated the ISO 9613-2:1996 method generally tends to marginally over predict noise levels expected in practice
- The UK Institute of Acoustics journal dated March/April 2009 published a joint agreement between practitioners in the field of wind farm noise assessment, including consultants routinely employed on behalf of both developers and community opposition groups, and indicated the ISO 9613-2:1996 method as the appropriate standard and specifically designated G=0.5 as the appropriate ground characterisation. It is noted that this publication specifically refers to predictions made to receiver heights of 4m in the interest of representing 2-storey dwellings which are more common in the UK. Predictions in Australia are generally based on a lower prediction height of 1.5m which tends to result in higher ground attenuation factors, however conversely, predictions in Australia do not generally incorporate a -2dB factor (as applied in the UK) to represent the relationship between L_{Aeq} and L_{A90} noise levels. The result is that these differences tend to balance out to a comparable approach and thus supports the use of G=0.5 in the context of Australian prediction methodologies.
- A range of comparative measurement and prediction studies[4, 5, 6] for wind farms in which Marshall Day Acoustics' staff have been involved have provided further support for the use of ISO 9613-2:1996 and G=0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

---

3 Bass, Bullmore and Sloth - *Development of a wind farm noise propagation prediction model*; Contract JOR3-CT95-0051, Final Report, January 1996 to May 1998.

4 Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions: The Risks of Conservatism*; Presented at the Second International Meeting on Wind Turbine Noise in Lyon, France September 2007.

5 Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions and Comparisons with Measurements*; Presented at the Third International Meeting on Wind Turbine Noise in Aalborg, Denmark June 2009.

6 Delaire, Griffin, & Walsh – *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*; Presented at the Fourth International Meeting on Wind Turbine Noise in Rome, April 2011.

The key findings of these studies demonstrated the suitability of the ISO 9613-2:1996 method to predict the propagation of wind turbine noise for:

- The types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30 m maximum source heights considered in the original ISO 9613
- The types of environments in which wind farms are typically developed, and the range of atmospheric conditions and wind speeds typically observed around wind farm sites. Importantly, this supports the extended scope of application to wind speeds in excess of 5m/s.

ISO 9613-2:1996 is primarily intended for the prediction of total A-weighted noise levels.

APPENDIX F PREDICTED NOISE LEVELS – TABULATED DATA

Table E1: Predicted noise levels with ACCIONA AW116

House	Hub Height wind speeds – m/s									
	3	4	5	6	7	8	9	10	11	12
A	6.2	6.3	7.0	8.3	10.4	12.8	14.6	15.3	15.4	15.1
AA	24.7	24.8	25.5	26.8	28.9	31.3	33.1	33.8	33.9	33.6
B	6.0	6.1	6.8	8.1	10.2	12.6	14.4	15.1	15.2	14.9
BB	21.3	21.4	22.1	23.4	25.5	27.9	29.7	30.4	30.5	30.2
C	8.7	8.8	9.5	10.8	12.9	15.3	17.1	17.8	17.9	17.6
CC	19.0	19.1	19.8	21.1	23.2	25.6	27.4	28.1	28.2	27.9
D	10.1	10.2	10.9	12.2	14.3	16.7	18.5	19.2	19.3	19.0
DD	22.2	22.3	23.0	24.3	26.4	28.8	30.6	31.3	31.4	31.1
E	10.6	10.7	11.4	12.7	14.8	17.2	19.0	19.7	19.8	19.5
EE	17.1	17.2	17.9	19.2	21.3	23.7	25.5	26.2	26.3	26.0
F	14.1	14.2	14.9	16.2	18.3	20.7	22.5	23.2	23.3	23.0
FF	26.7	26.8	27.5	28.8	30.9	33.3	35.1	35.8	35.9	35.6
G (s)	20.3	20.4	21.1	22.4	24.5	26.9	28.7	29.4	29.5	29.2
GG	20.6	20.7	21.4	22.7	24.8	27.2	29.0	29.7	29.8	29.5
H	17.0	17.1	17.8	19.1	21.2	23.6	25.4	26.1	26.2	25.9
HH	21.8	21.9	22.6	23.9	26.0	28.4	30.2	30.9	31	30.7
I	17.2	17.3	18.0	19.3	21.4	23.8	25.6	26.3	26.4	26.1
J	19.4	19.5	20.2	21.5	23.6	26.0	27.8	28.5	28.6	28.3
K	23.4	23.5	24.2	25.5	27.6	30.0	31.8	32.5	32.6	32.3
L	21.2	21.3	22.0	23.3	25.4	27.8	29.6	30.3	30.4	30.1
M (s)	28.4	28.5	29.2	30.5	32.6	35.0	36.8	37.5	37.6	37.3
N (s)	40.5	40.6	41.3	42.6	44.7	47.1	48.9	49.6	49.7	49.4
N1	22.0	22.1	22.8	24.1	26.2	28.6	30.4	31.1	31.2	30.9
O	21.0	21.1	21.8	23.1	25.2	27.6	29.4	30.1	30.2	29.9
P	16.3	16.4	17.1	18.4	20.5	22.9	24.7	25.4	25.5	25.2
Q	21.2	21.3	22.0	23.3	25.4	27.8	29.6	30.3	30.4	30.1
R	21.9	22.0	22.7	24.0	26.1	28.5	30.3	31.0	31.1	30.8
S (s)	31.1	31.2	31.9	33.2	35.3	37.7	39.5	40.2	40.3	40.0
T (s)	32.0	32.1	32.8	34.1	36.2	38.6	40.4	41.1	41.2	40.9
U	11.8	11.9	12.6	13.9	16.0	18.4	20.2	20.9	21	20.7
V	20.4	20.5	21.2	22.5	24.6	27.0	28.8	29.5	29.6	29.3

House	Hub Height wind speeds – m/s									
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
W	19.5	19.6	20.3	21.6	23.7	26.1	27.9	28.6	28.7	28.4
X	20.3	20.4	21.1	22.4	24.5	26.9	28.7	29.4	29.5	29.2
Y	19.9	20.0	20.7	22.0	24.1	26.5	28.3	29.0	29.1	28.8
Z	26.8	26.9	27.6	28.9	31.0	33.4	35.2	35.9	36	35.7

(s) Stakeholder receiver location

Table E2: Predicted noise levels with Vestas V117

House	Hub Height wind speeds – m/s									
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A	5.6	5.9	7.8	10.8	14.1	15.6	18.1	19.1	20	20.9
AA	20	20.3	22.2	25.2	28.5	30.9	33.2	33.9	34.4	35
B	5.4	5.7	7.6	10.6	13.9	15.4	17.9	18.9	19.8	20.7
BB	17.6	17.9	19.8	22.8	26.1	28.3	30.6	31.4	32	32.7
C	7.5	7.8	9.7	12.7	16	17.6	20	21.1	21.9	22.8
CC	16.2	16.5	18.4	21.4	24.7	26.7	29	29.9	30.6	31.4
D	8.5	8.8	10.7	13.7	17	18.7	21.1	22.1	22.9	23.8
DD	18	18.3	20.2	23.2	26.5	28.8	31.1	31.9	32.4	33.1
E	8.8	9.1	11	14	17.3	19.1	21.5	22.5	23.2	24.1
EE	14	14.3	16.2	19.2	22.5	24.6	26.9	27.8	28.4	29.2
F	11.4	11.7	13.6	16.6	19.9	21.9	24.2	25.1	25.8	26.7
FF	21.9	22.2	24.1	27.1	30.4	32.9	35.1	35.9	36.3	36.9
G (s)	16.7	17	18.9	21.9	25.2	27.3	29.6	30.5	31.1	31.8
GG	16.7	17	18.9	21.9	25.2	27.4	29.7	30.6	31.1	31.9
H	13.6	13.9	15.8	18.8	22.1	24.2	26.5	27.4	28	28.8
HH	18.1	18.4	20.3	23.3	26.6	28.8	31.1	32	32.5	33.3
I	14.1	14.4	16.3	19.3	22.6	24.6	26.9	27.8	28.5	29.3
J	15.4	15.7	17.6	20.6	23.9	26.2	28.4	29.3	29.8	30.5
K	19.2	19.5	21.4	24.4	27.7	30	32.2	33.1	33.6	34.3
L	17.5	17.8	19.7	22.7	26	28.2	30.5	31.3	31.9	32.7
M (s)	23.2	23.5	25.4	28.4	31.7	34.3	36.5	37.2	37.6	38.1
N (s)	34.4	34.7	36.6	39.6	42.9	45.8	48	48.7	48.8	49
N1	18.6	18.9	20.8	23.8	27.1	29.2	31.5	32.4	33	33.8
O	17.2	17.5	19.4	22.4	25.7	27.9	30.2	31	31.6	32.4
P	13.2	13.5	15.4	18.4	21.7	23.8	26.1	27	27.6	28.4
Q	17.3	17.6	19.5	22.5	25.8	28.1	30.3	31.2	31.7	32.5
R	18.1	18.4	20.3	23.3	26.6	28.8	31.1	32	32.5	33.3
S (s)	25.6	25.9	27.8	30.8	34.1	36.7	38.9	39.7	40	40.4
T (s)	26.3	26.6	28.5	31.5	34.8	37.5	39.7	40.4	40.7	41.1
U	9.8	10.1	12	15	18.3	20.1	22.5	23.4	24.2	25
V	17	17.3	19.2	22.2	25.5	27.6	29.9	30.8	31.4	32.1
W	16.1	16.4	18.3	21.3	24.6	26.7	29	29.9	30.5	31.2
X	16.9	17.2	19.1	22.1	25.4	27.5	29.8	30.7	31.3	32.1

House	Hub Height wind speeds – m/s									
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Y	16	16.3	18.2	21.2	24.5	26.8	29	29.9	30.4	31.2
Z	21.8	22.1	24	27	30.3	32.8	35.1	35.8	36.2	36.8

(s) Stakeholder receiver location