Salt Creek Wind Farm

Post Construction Noise Monitoring Results

S5168C21

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GLOSSARY

A weighting	Frequency adjustment representing the response of the human ear.
Ambient noise level	Noise level in the absence of the noise from the wind farm.
Background Noise Assessment	*DNV GL Wind Farm Noise Predictions Document PP176581-AUME-T-01 A March 2017 and Reference 6 Background Noise and Compliance Limit Assessment for the Salt Creek Wind Farm Document Number 45539/PR/01*
dB(A)	A weighted noise level measured in decibels.
IEC61400-11	IEC 61400-11: 2012 *Wind turbine generator systems – Part 11: Acoustic noise measurements techniques*
Intermediary Position	A monitoring location between the turbines and a dwelling which assists in determining the contribution of noise from the wind farm.
Intermediary Graph	The graph based on correlation of the Intermediary Position noise level minus the Propagation Loss (refer below) against the hub height wind speed.
L_{A90}	The A weighted sound pressure level that is exceeded for 90 per cent of the time over which a given sound is measured. The L_{A90} measured over a 10 minute time period is commonly and interchangeably termed "background sound level" and "*sound level from the wind energy facility*" with respect to wind farms.
L_{Aeq}	The A weighted equivalent continuous noise level – the energy-average of noise levels occurring over a measurement period.
Permit	*Moyne Shire Council Permit No. PL06/304.01 issued 29 February 2016*
Propagation Loss	The measured reduction in the wind farm noise level from the Intermediary Position to a dwelling.
Re-correlation Graph	The graph based on re-correlation of the noise data at the dwelling with wind speed after filtering (refer to the Data Analysis sections of this report).
NZS6808:2010	*New Zealand Standard NZS 6808:2010 Acoustics – The assessment and measurement of sound from wind turbine generators*
NCTP	*January 2019 Noise Compliance Test Plan S5168C2D* (the NCTP) which provides the noise measurement and analysis methodology to isolate the noise from the wind farm from the noise from other sources at a dwelling.
Near Field Testing	Near Field Testing determines the wind speed at which the maximum noise level is emitted from the wind farm and assists in isolating the noise from the wind farm from the noise from other sources at a dwelling.

1 INTRODUCTION

The Salt Creek Wind Farm (the wind farm) comprises 15 *Vestas V126-3.6 MW* wind turbine generators (WTGs) with hub heights of 87m and serrated blade trailing edges located to the south of Woorndoo in the Moyne Shire Council.

The Permit for the operation of the wind farm includes Conditions 12 and 14:

12. *The operation of the wind energy facility must comply with New Zealand Standard 6808:2010, Acoustics – Wind Farm Noise (the Standard) in relation to any occupied dwellings existing on the land (other than the site) at 8 May 2007, to the satisfaction of the responsible authority. In determining compliance with the standard the following requirements apply:*
    a. *The sound level from the wind energy facility, when measured outdoors within 10 metres of a dwelling at any relevant nominated wind speed, must not exceed the background level (L90) by more than 5dBA or a level of 40dBA L90, whichever is the greater.*
    b. *Compliance at night must be separately assessed with regard to night time data. For these purposes the night is defined as 10.00pm to 7.00am. For sleep protection purposes, a breach of the standard set out at Condition 12a), for 10% of the night, amounts to a breach of the condition.*
    c. *Where special audible characteristics, including tonality, impulsive sound or enhanced amplitude modulation occur, as assessed in accordance with Appendix B of the standard, the noise limit will be modified by applying a penalty of up to + 6dB L90 in accordance with Section 5.4 of the standard.*

    This condition does not apply if the operator of the wind energy facility has entered into an agreement with the landowner under which the landowner acknowledges and accepts that the noise standards in this condition may be exceeded at the landowner's dwelling(s). Evidence of this agreement must be provided to the satisfaction of the responsible authority, and must be in a form which runs with the land for the life of the wind energy facility.

14. *An independent post-construction noise monitoring program must be commissioned but he proponent within 2 months from the commissioning of the first turbine and continue for 12 months after the commissioning of the last turbine, to the satisfaction of the Responsible Authority. The independent expert must have experience in acoustic measurement and analysis of wind turbine noise. The program must be carried out in accordance with New Zealand Standard 6808:2010 Acoustics – Wind Farm Noise. The Permit holder must pay the reasonable cost of the monitoring program.*

Sonus was commissioned by Tilt Renewables to conduct the 12 month *post construction noise monitoring program* for the wind farm. The program occurred between 17 July 2018 and 22 July 2019 with the objective to determine compliance or otherwise with Condition 12 of the Permit.

1.1 Noise Compliance Test Plan

A noise compliance test plan (NCTP) was prepared to assist in the *post construction noise monitoring program*. The NCTP provides the noise measurement and analysis methodology within the framework provided by NZS6808:2010 to isolate the noise from the wind farm. The noise from the wind farm needs to be isolated because noise levels measured at a dwelling in the vicinity of a wind farm will be a combination of noise from the wind farm and also other sources, most typically wind in the trees.

The NCTP incorporates a "primary test method" which at its core comprises measuring noise levels at dwellings over a 12 month period. The noise levels will be an unknown combination of wind farm contribution and noise from other local sources. To assist in isolating the noise from the wind farm at the dwellings over the 12 month program, the primary test method of the NCTP includes additional measurements at intermediary locations (between the wind farm and the dwellings) as well as close to two turbines.

The primary test method has been designed to isolate wind farm noise at a dwelling when measured over an extended period in most circumstances.

In unusual circumstances, such as where the background noise environment has changed, further analysis using a more targeted "alternative test method" is required to determine compliance or otherwise. The need for an alternative test method is envisaged in NZS6808:2010 (in specific circumstances) and is accordingly detailed in the NCTP.

The alternative test method comprises measuring noise at a dwelling with the wind farm both on and off over a short time frame and during comparable conditions in general accordance with Section 7.7 of NZS6808:2010. The measured noise levels during the comparable on and off tests provide the ability to further analyse the 12 month data by targeting the wind farm noise and reducing the influence of local noise sources.

A flow diagram outlining the NCTP pathway to the determination of compliance or otherwise with the Permit is provided below:

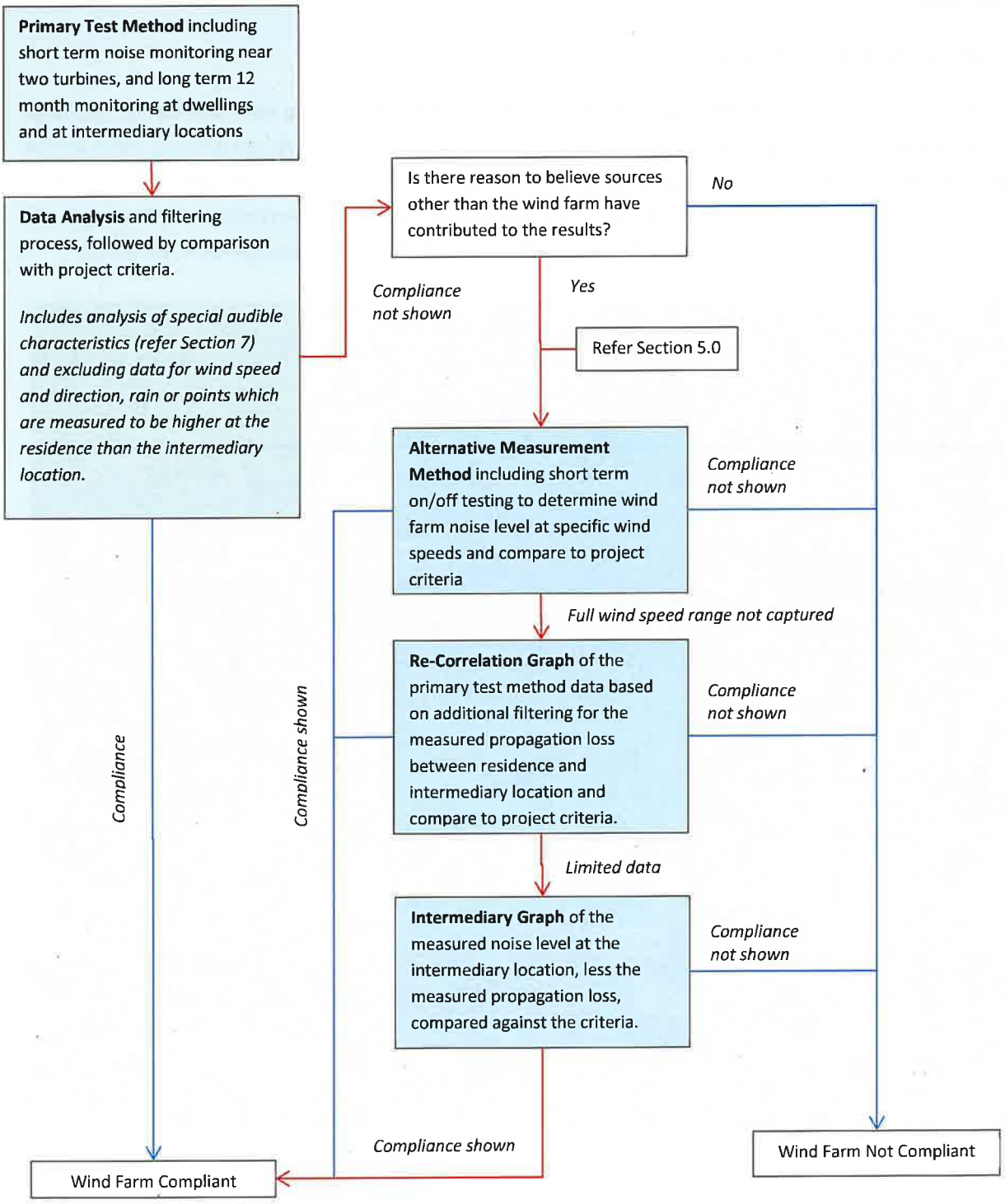


Figure 1: NCTP compliance flow diagram

This report summarises the results of the *post construction noise monitoring program*.

2 CRITERIA

2.1 Background Noise Assessment

The post construction noise monitoring program has been conducted at three non-stakeholder dwellings where background noise level data were measured prior to the wind farm being constructed (refer to the Background Noise Assessment[1] for further detail). Figure 1 shows the dwellings and associated measurement locations (H1, H6 and H8 and M1, M6 and M8 respectively), the Intermediary Positions (H1 Int, H6 Int and H8 Int), the wind speed masts (Mast 1 and Mast 13) and the wind turbine generators (WTGs):

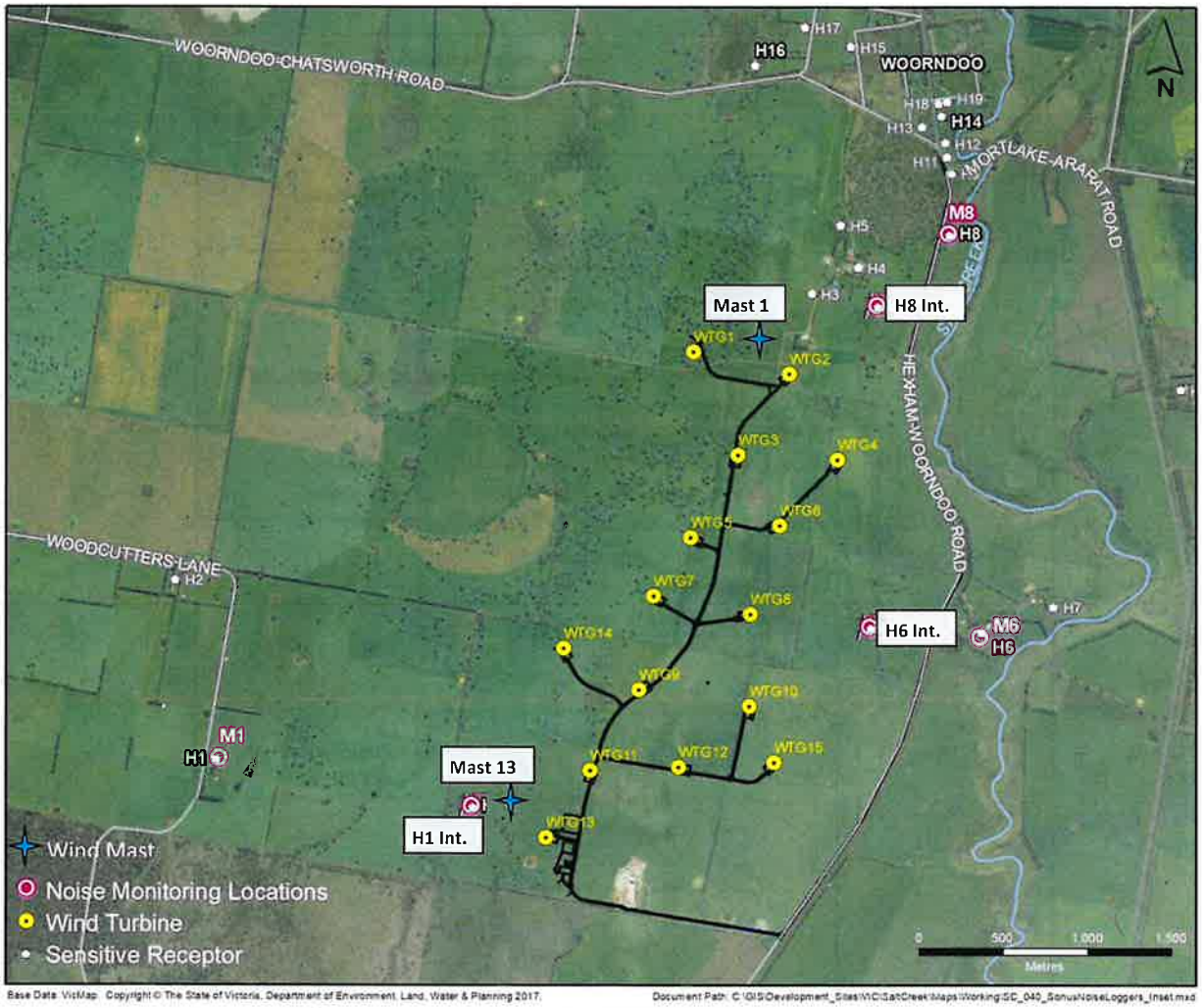


Figure 2: *Post Construction Noise Monitoring Locations*

[1] *DNV GL Wind Farm Noise Predictions Document PP176581-AUME-T-01 A March 2017 and Reference 6 Background Noise and Compliance Limit Assessment for the Salt Creek Wind Farm Document Number 45539/PR/01*

Table 1 provides the details of the monitoring locations at each dwelling:

Table 1: Dwelling noise monitoring locations

Dwelling	Monitoring Location Coordinates M1, M6 and M8 (UTM WGS84 54H)	
	Easting	Northing
H1	653789	5801058
H6	658336	5801780
H8	658150	5804184

The details of the background noise monitoring regime prior to the wind farm being constructed and associated criteria are provided in the Background Noise Assessment. The assessment criteria generated by the background noise monitoring regime are repeated below:

Table 2: Project noise criteria

		Hub Height Wind Speed (m/s)											
		3	4	5	6	7	8	9	10	11	12	13	14
H1	24 Hour L_{A90} (dB(A))	29	29	29	29	30	31	32	34	35	37	38	40
	24 Hour Criteria	40	40	40	40	40	40	40	40	40	42	43	45
	Night Time L_{A90} (dB(A))	28	27	27	27	27	28	29	31	32	34	35	37
	Night Time Criteria	40	40	40	40	40	40	40	40	40	40	40	42
H6	24 Hour L_{A90} (dB(A))	36	36	36	36	36	37	37	38	39	40	41	42
	24 Hour Criteria	41	41	41	41	41	42	42	43	44	45	46	47
	Night Time L_{A90} (dB(A))	32	31	30	30	31	31	32	33	35	36	38	40
	Night Time Criteria	40	40	40	40	40	40	40	40	40	41	43	45
H8	24 Hour L_{A90} (dB(A))	28	27	28	28	29	30	31	32	33	35	36	37
	24 Hour Criteria	40	40	40	40	40	40	40	40	40	40	41	42
	Night Time L_{A90} (dB(A))	26	25	24	24	24	25	26	28	29	31	32	34
	Night Time Criteria	40	40	40	40	40	40	40	40	40	40	40	40

In accordance with condition 12(b) of the Permit, the "Night Time Criteria" provided above have been used for the assessment of the worst case 10% of noise data during the period 10pm to 7am.

3 PRIMARY TEST METHOD

3.1 Dwelling Measurements

Sound level meters and associated equipment (refer details below) were placed at each of the 3 dwellings at the equivalent position to the background noise logging location with the exception of H6. Access to the original measurement location at H6 was not granted. Therefore the sound level meter was placed away from the dwelling and closer to the wind farm at the location requested by the property owner. This alternative location at H6 was deemed to be suitable for the purposes of the 12 month noise monitoring program.

A photograph of the equipment at each dwelling is provided in Appendix A.

In addition to the noise measurements, local wind speed measurements were also conducted at 2 locations (H1 and H6), with rainfall data collected at 1 location (H6). The rainfall data and the measured wind speeds were used to identify periods when data might have been adversely affected by weather. The potentially affected data typically occurs for less than 10% of the measurement period.

3.2 Near Field and Intermediary Measurements

The near field measurements were conducted:

- between 100m and 200m from WTG4 and WTG15 (Figure 1 provides the WTG locations);
- over the range of operational wind speeds from cut-in to greater than rated power;
- with a ground board and windshield dome (in accordance with IEC61400-11);
- in one-third octave bands to assist in the assessment of Special Audible Characteristics; and;
- in 10 second intervals correlated with the hub height wind speed over the same time period (in accordance with IEC61400-11).

The correlations identify the wind speed at which the highest noise level is emitted from the turbines.

Sound level meters were placed at the Intermediary Positions and collected concurrent data with the sound level meters at the dwellings. The coordinates of the Intermediary Positions are as follows:

Table 3: Intermediate noise monitoring locations

Location	Monitoring Location Coordinates (UTM WGS84 54H)	
	Easting	Northing
Intermediary H1	655252	5800593
Intermediary H6	657642	5801797
Intermediary H8	657677	5803735

A photograph of the sound level meter arrangement at each Intermediary Position is provided in Appendix A.

3.2.1 Data Collection

The A-Weighted noise levels (L_{A90}) were measured continuously in 10 minute intervals over the monitoring periods using a NATA calibrated, *Rion NL-21* (Class 2) and *Rion NL-52* (Class 1) sound level meters with a noise floor of less than 20 dB(A). The sound level meter and calibrator serial numbers are provided in Appendix B. Site calibration was also conducted before, after and at regular intervals during the noise monitoring regime with a Type 1 calibrator and the microphones fitted with high wind speed weather proof windshields.

During the noise monitoring regime, hub height (87m) wind speed was monitored by *Vestas* at the following wind farm meteorological masts:

Table 4: Wind farm wind mast locations

Mast	Coordinates (WGS 84 Zone 54)	
	Easting	Northing
Mast 1	656951	5803512
Mast 13	655488	5800700

3.2.2 Data Analysis

The data analysis has been subject to a data filtering process, comprising the removal of 10 minute periods where:

(i) the data might have been adversely affected by rain, hail or wind on the microphone based on the wind speed and rain measurement equipment placed at residence H1 and H6. Data are adversely affected where precipitation occurs in a 10 minute period or where a wind speed greater than 5 m/s is exceeded for 90% of a 10 minute period (and as a result may have an adverse influence on the measured noise level);

(ii) the noise level measured in the same period at the Intermediary Position is at a lower noise level than that measured at the dwelling. Such a result indicates the adverse influence of noise sources other than the wind farm, given that the Intermediary Position is closer to the wind farm and therefore the contribution of noise from the wind farm cannot be lower at the Intermediary Position than at the dwelling.

The remaining data points were correlated with the hub height wind speed at the closest wind mast.

In order to enable a comparison with both the 24 hour and night time requirements of Condition 12 of the Permit, the data have been separated into those collected over the full 24 hour period and those collected between the hours of 10:00pm and 7:00am ("night-time period").

Condition 12b of the Permit requires an assessment of the *worst case 10%* of the night period. The *worst case* (highest wind farm noise level) occurs under downwind (the direction from the closest turbine to the dwelling) conditions and therefore the 10% of data points when the wind direction is most true to downwind have been used in the night time correlation.

The following table provides the number of data points following the above data analysis process. The table also includes the wind mast which has been used for the correlations at each testing location and the wind direction resulting in the 10% of data in the most downwind direction:

Table 5: Data points, wind mast and down wind direction information

Dwelling	Data Points		Mast	Downwind Direction for 10% Data
	24 hour	Night		
H1	24,919	1408	Mast 13	101±32 degrees
H6	19,612	1801	Mast 1	275±14 degrees
H8	25,935	1659	Mast 1	227±20 degrees

The night time data set incorporates significantly fewer data points than the 24 hour data set due to the Permit Condition 12b requirement to consider only the worst case 10% of available night time data.

4 PRIMARY TEST METHOD RESULTS

4.1 Dwellings

Graphs of the primary test method results following the data analysis process outlined in Section 3.2.2 at the dwellings are provided in Appendix C and D for the 24 hour and worst case 10% of the night periods respectively.

The data corresponding to the third order regression analysis have also been tabulated below to provide the results and criteria for each integer hub height wind speed from 4m/s to 14m/s.

The Primary Test Method results indicate that compliance can be confirmed at all locations, with the exception of H6 during the night time period for the wind speeds as highlighted in the tables below.

Table 6: Primary Test Method results for 24 hour period dB(A)

Location		Hub Height Wind Speed										
		4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	10m/s	11m/s	12m/s	13m/s	14m/s
H1	Primary Test Results	27	27	27	28	30	32	34	36	38	40	41
	Noise Criteria	40	40	40	40	40	40	40	40	40	42	43
H6	Primary Test Results	29	30	31	33	34	36	38	39	40	42	43
	Noise Criteria	41	41	41	41	41	42	42	43	44	45	46
H8	Primary Test Results	27	28	29	31	32	33	34	35	36	37	39
	Noise Criteria	40	40	40	40	40	40	40	40	40	40	41

Table 7: Primary Test Method results for worst case 10% of night period dB(A)

Location		Hub Height Wind Speed										
		4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	10m/s	11m/s	12m/s	13m/s	14m/s
H1	Primary Test Results	28	28	28	29	30	32	33	35	36	37	38
	Noise Criteria	40	40	40	40	40	40	40	40	40	40	40
H6	Primary Test Results	24	28	31	34	36	38	40	42	43	43	43
	Noise Criteria	40	40	40	40	40	40	40	40	40	41	43
H8	Primary Test Results	25	25	26	28	30	33	35	36	37	37	35
	Noise Criteria	40	40	40	40	40	40	40	40	40	40	40

4.2 Near Field

The correlation of WTG noise level against wind speed is plotted below for turbines WTG4 and WTG15. The vertical line indicates the hub height wind speed at which the noise level generated by the WTG plateaus such that there is no further noise level increase for an increase in wind speed. The following near field results assist in the Alternative Test Method analysis.

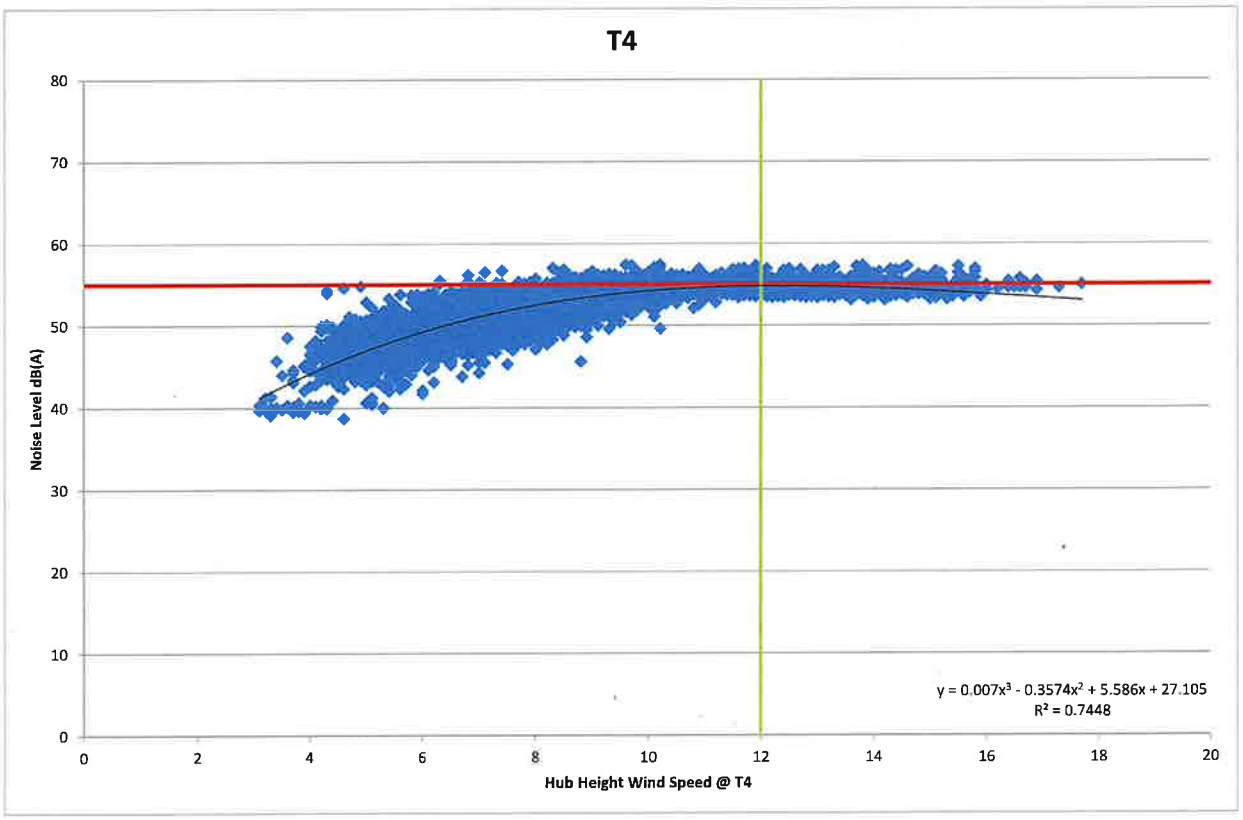


Figure 3: Turbine 4 measured noise curve

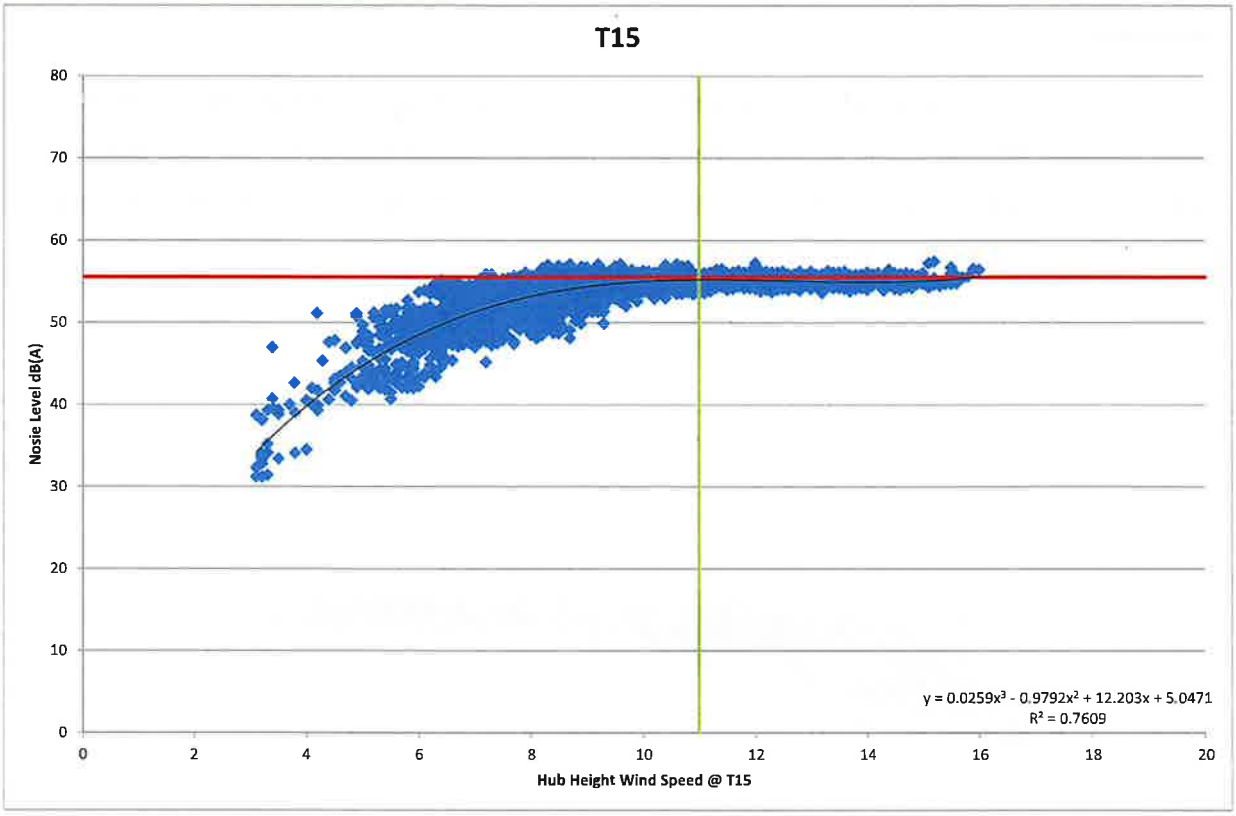


Figure 4: Turbine 15 measured noise curve

The near field testing confirms that the noise level from the wind farm does not increase at wind speeds above 12 m/s and therefore data which indicates otherwise at locations which are further away from the wind farm are associated with noise from other sources.

5 ALTERNATIVE TEST METHOD

The influence of noise from wind in the trees is significant when at H6. Therefore, a key item to resolve in determining compliance at H6 is the influence of the background noise environment. Background noise levels were measured in 2011 and reported on in the Background Noise Assessment.

The following aerial photographs show a change in local conditions and increase in size and density of the tree canopies between the background noise monitoring regime in 2011 and the initiation of the post construction monitoring program in July 2018.

Figure 5: 2011

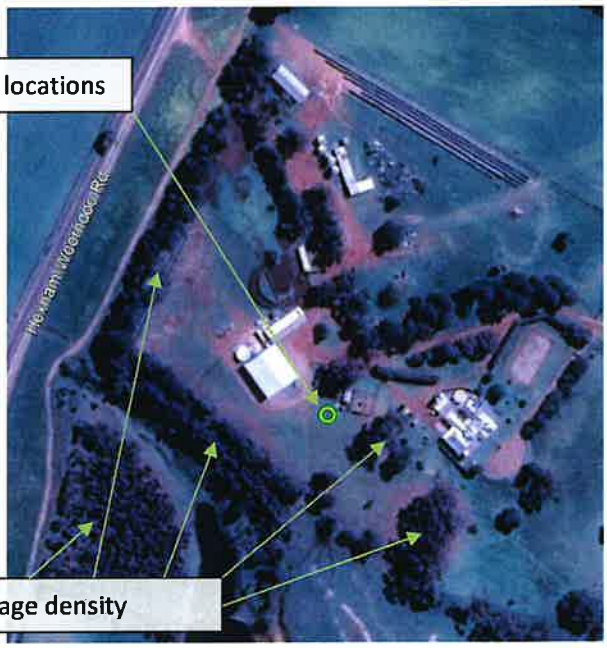


Figure 6: 2018

The background noise levels measured in 2011 will not be consistent with contemporary background noise levels where there is a greater influence from wind in the trees due to an increase in size and density of foliage. In such a circumstance, the 2011 background noise levels would not be applicable for use against the 2018/19 data, which would be a combination of an increased (but unknown) background noise level and the wind farm contribution. The framework of NZS6808:2010 and the NCTP provide for an alternative test method for the determination of compliance where the influence of sources other than the wind farm may have contributed to the results.

5.1 Additional measurements

The following "on/off" testing methodology, in general accordance with NZS6808:2010 Section 7.7, has been conducted at H6 during the night time period for wind speeds up to 10m/s (a wind speed where it was found that the wind farm can be clearly measured above the level of background noise when at dwelling H6):

- At the same measurement location as the primary test method;
- Under a wind direction at the relevant wind mast being within 45 degrees of the direct line from the closest turbine to the dwelling;
- Under a high wind shear condition as defined by review of the 10m AGL and hub height wind speeds;
- Over part (to exclude intermittent noise) or all of a minimum interval of 10-minutes with the wind farm operational and the same interval with the wind farm shut off;
- Monitoring the wind speed and direction over the measurement intervals to identify the comparable *on* and *off* measurements;
- At wind speeds where the wind farm is able to be clearly measured above the level of background noise.

5.2 Data analysis

The following analysis has been conducted for the additional "on/off" measurement data collected at H6:

- Where there is a measurable and consistent difference between the *on* and *off* noise measurements, the contribution of noise from the Wind farm at both H6 and the Intermediary Position has been determined by logarithmically subtracting the *off* measurement result from the *on* measurement result;
- The contribution of the wind farm determined from the above has been compared with the night time assessment criteria detailed in the previous sections of this report;
- Further analysis of the Primary Test Method data has also been made utilising the results of the additional measurements. In the first instance, the difference between the contribution of noise from the wind farm at H6 and at the Intermediary Position has been determined for each integer wind speed of interest. The difference is termed the Propagation Loss for each integer wind speed.
- The Propagation Loss has been used to provide results over a longer term by filtering the H6 noise logger data. The resulting graph is termed the Re-correlation Graph. The Re-correlation Graph only includes data where the noise level at H6 is equal to or lower than the corresponding noise level at the Intermediary Position less the Propagation Loss.
- In the circumstance where wind in the trees is the dominant contributor at H6, the Re-Correlation Graph will be populated with a limited number of data points. To provide results over a longer term with a higher number of data points, a graph of the measured noise levels at the Intermediary Position less the Propagation Loss has been generated. The resulting graph is termed the Intermediary Graph. This approach is a similar concept to a "derived noise point" under the *State Environment Protection Policy (Control of Noise from Industry, Commerce and Trade) NO. N-L No. S31, 16/5/1989, Gazette 15/6/1989.*

6 ALTERNATIVE TEST METHOD RESULTS

6.1 On/off results

The on/off testing was conducted on 8 February 2019, over 10 minute measurement intervals. The noise level was continuously measured at dwelling H6 and at the Intermediate H6 location from 6pm until 2 am the following day.

In this time, the wind farm was turned off three times for 15 minutes each time. Additional attended noise measurements were conducted during and immediately before and after the wind farm was turned off.

The following table summarises the results of the measurements. The results have been rounded for simplicity. The Background Noise Level (*BG*) column is the measured noise level when the wind farm was off at the wind speed of interest. The Background and Wind Farm Noise Level (*BG&WF*) column is the measured noise level when the wind farm was on at the wind speed of interest. The Wind Farm Noise Level Only (*WF*) column is the logarithmic subtraction of the Background Noise Level (*BG*) from the combined Background and Wind Farm Noise Level (*BG&WF*) as follows;

Equation 1: Wind farm noise level based on wind farm on and wind farm off measurements

$$WF = 10 \times Log(10^{BG\&WF} - 10^{BG})$$

Example Calculation:

$$41\ dB(A) = 10 \times Log(10^{41\ dB(A)} - 10^{28\ dB(A)})$$

Table 8: On-Off measurement results

Hub Height Integer Wind Speed	Intermediary Position			H6			Propagation Loss[3]
	Background Noise Level	Background and Wind Farm Noise Level	Wind Farm Noise Level Only	Background Noise Level	Background plus Wind Farm Noise Level	Wind Farm Noise Level Only	
8m/s	28	41	**41 dB(A)**	36	39	**36 dB(A)**	**4 dB(A)**
9m/s	29	41	**41 dB(A)**	32	39	**38 dB(A)**	**4 dB(A)**
10m/s	29	42	**42 dB(A)**	32	39	**38 dB(A)**	**4 dB(A)**

The results indicate that the Wind farm achieves the required criterion of 40 dB(A) at the measured integer wind speeds. It was not possible to isolate the noise from the wind farm at H6 for wind speeds of 11 m/s, 12m/s and 13 m/s due to the environmental conditions on the night of testing and the relative timing of the wind farm being turned off. Further analysis of the nearfield and intermediate noise monitoring data is therefore required to determine compliance.

[3] *Propagation Loss determined before rounding.*

The relative relationship between the wind farm noise level and the increasing hub height wind speed has been established by the near field testing (refer Section 4.1). The wind farm noise level increase is less than 1 dB(A) for integer hub height wind speeds above 10m/s. When this increase is added to the Wind Farm Noise Level Only result at 10m/s, the calculated Wind Farm Noise Level Only result at other integer wind speeds (higher than 10m/s) would also indicate compliance.

To assist in visualising the above, the near field measurement results have been overlaid with the on/off testing results. The following graph plots the measurement results at H6 for Wind Farm Noise Only and then overlays the shape of the wind farm noise generation curve from the near field test results in Section 4.2.

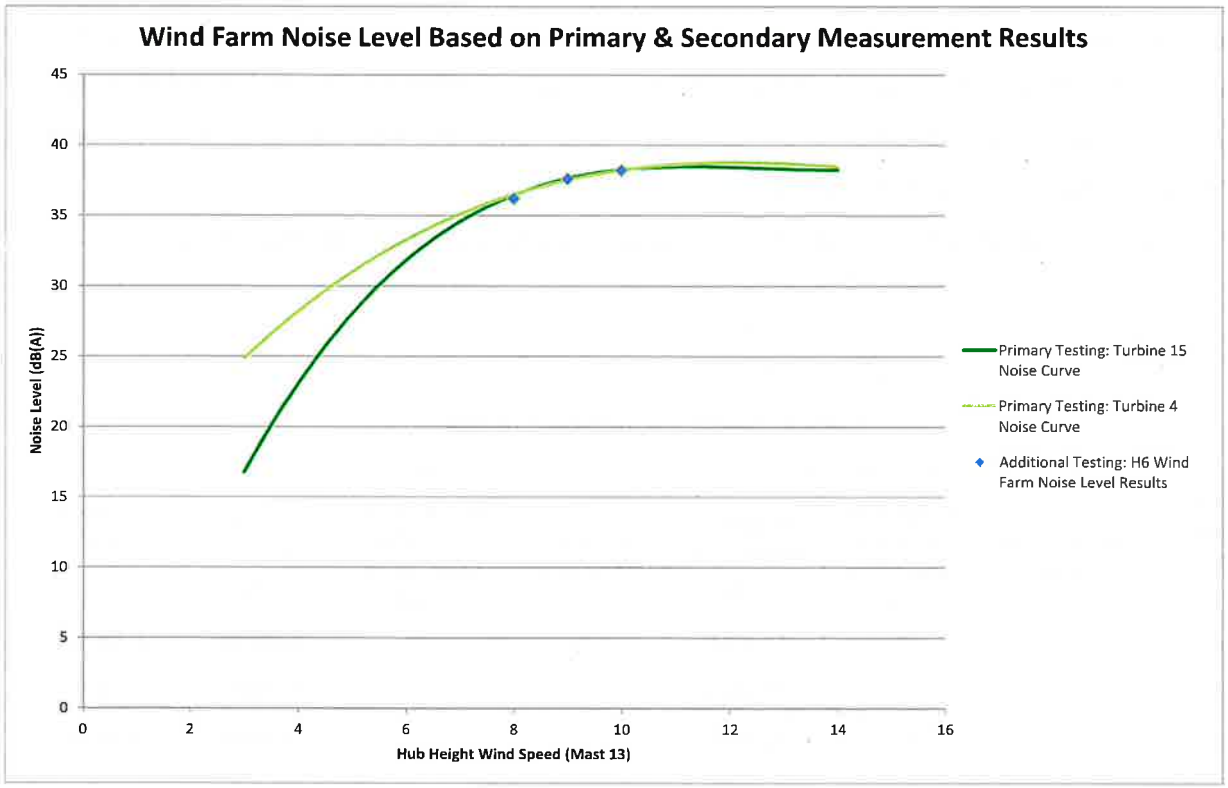


Figure 7: Dwelling H6 wind farm noise level overlaid on measured noise curve

The graph indicates that the on/off testing results are consistent with the expected relationship of the noise from the wind farm versus integer wind speed. This consistency enables an extrapolation to other higher wind speeds which indicates that the noise level from the wind farm achieves compliance (by being less than 40 dB(A)) at all integer wind speeds during the night at H6.

6.2 Re-Correlation Graph

The Propagation Loss for each integer wind speed has been utilised to generate the Re-correlation Graph.

The Re-Correlation Graph is a more targeted version of the Primary Test Method. The Primary Test Method filters data which are higher at H6 than at the Intermediary Position on the basis that the wind farm noise level cannot increase over distance. The Re-Correlation Graph filters data which are higher at H6 than that determined by the Intermediary Position less the Propagation Loss. This is on the basis that any such data must be affected by wind in the trees.

The Re-correlation Graph methodology results in limited data points at H6 during the night time for the 12 month monitoring period. The scarcity of data points is consistent with wind in the trees being the dominant contributor to noise levels at H6. The following graph shows the data points. There are no data points above the noise criteria, which is consistent with compliance with Permit Condition 12.

The wind direction is consistent with that used for the H6 Night Time Primary Test Method graph.

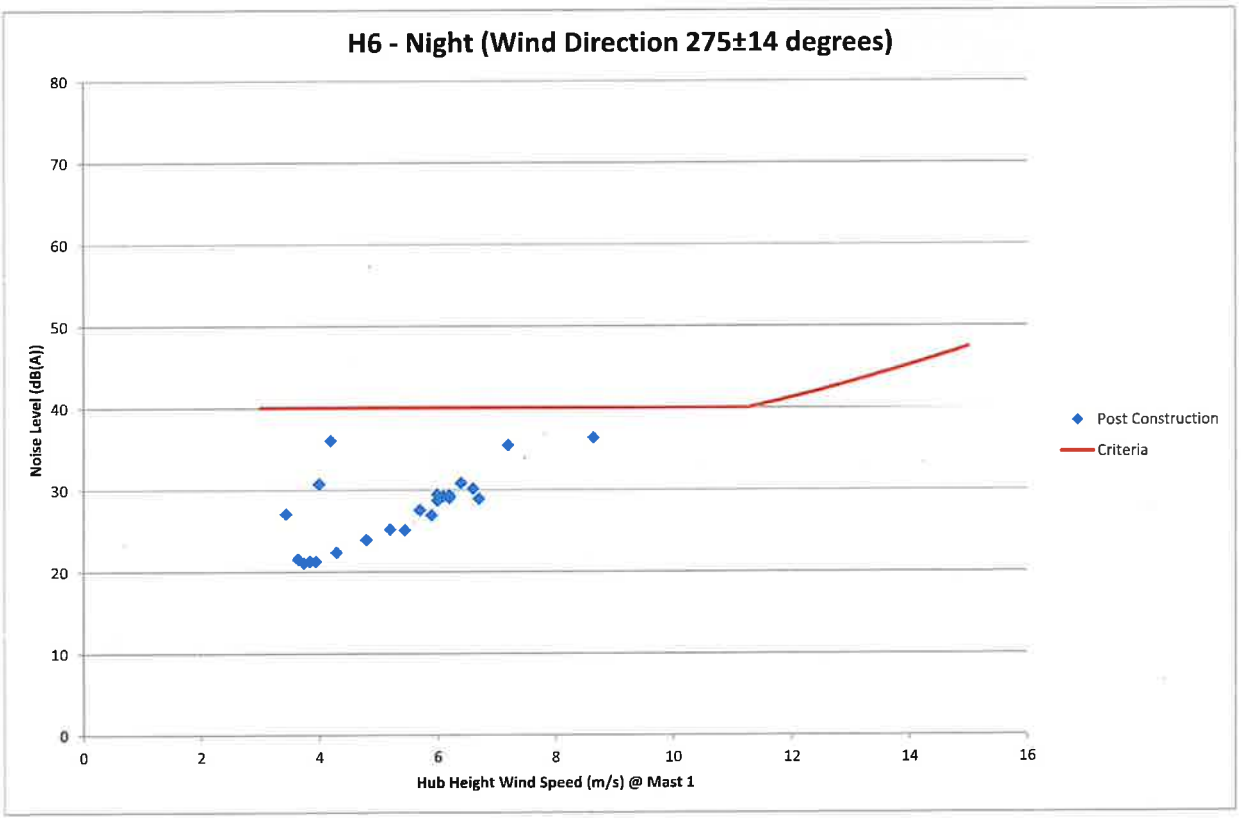


Figure 8: **H6 night time re-correlation graph**

6.3 Intermediary Graph

To provide results over a longer term with a higher number of data points, a graph of the measured noise levels at the Intermediary Position less the Propagation Loss has been generated. The resulting graph is termed the Intermediary Graph.

The wind direction is consistent with that used for the H6 Night Time Primary Test Method graph.

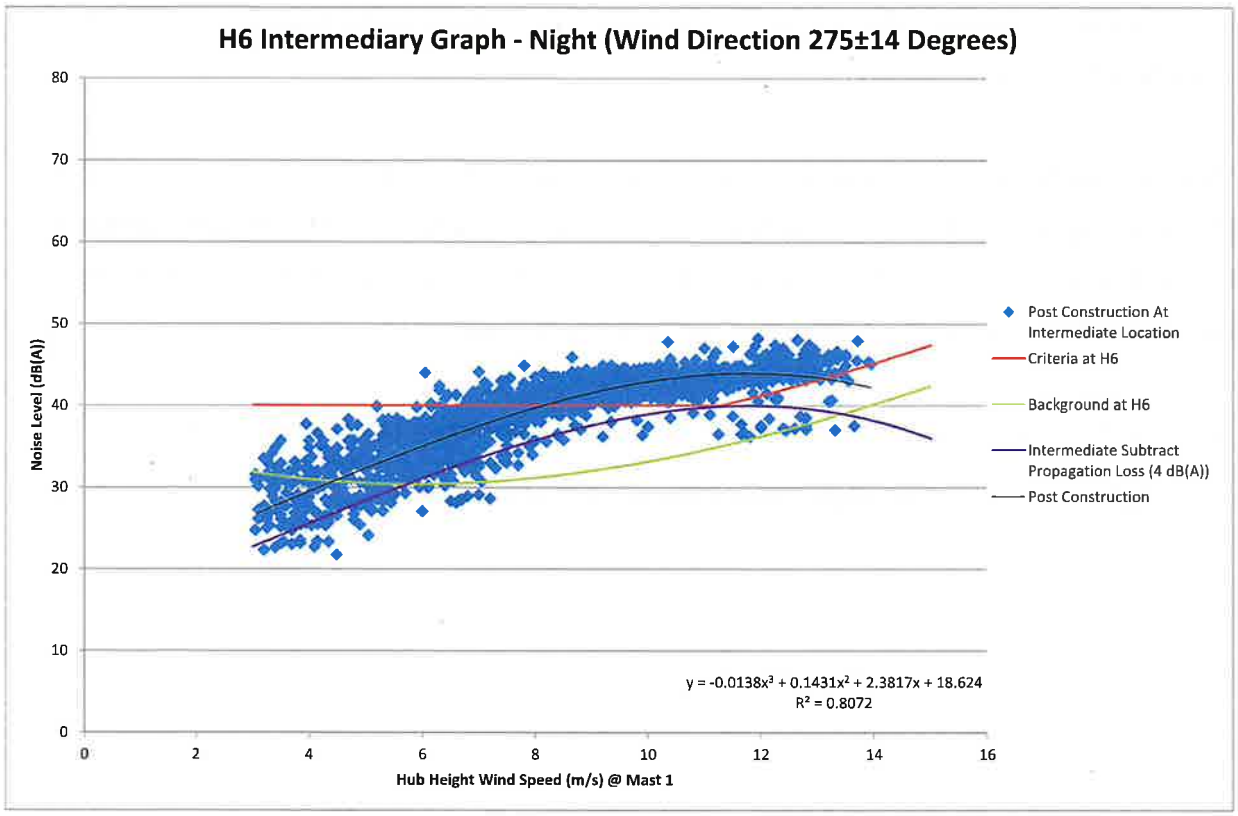


Figure 9: H6 Intermediary graph

The Intermediary Graph has been tabulated to provide the results and criteria at the integer hub height wind speeds from 8 to 14 m/s:

Table 9: H6 Intermediary graph results at integer wind speeds

Location		Hub Height Wind Speed						
		8m/s	9m/s	10m/s	11m/s	12m/s	13m/s	14m/s
H6	Intermediary Graph	36	38	39	40	40	39	38
	Noise Criteria	40	40	40	40	40	41	43

The Intermediary Graph indicates noise from the wind farm is compliant with Condition 12 of the Permit.

When analysing the results, it should be noted that background noise measurements have not been conducted at the Intermediary Position and so it is not possible to entirely isolate the noise from the wind farm at this location. The above graph therefore includes a combination of both wind farm and background noise. Any subsequent adjustment for background noise levels at the Intermediary Position would have the effect of reducing the noise levels in the Intermediary Graph.

7 SPECIAL AUDIBLE CHARACTERISTICS

An assessment of Special Audible Characteristics, including tonality and amplitude modulation, has been conducted in accordance with the NCTP. The method for assessing the measured noise levels at residences and adjusting as necessary is summarised in the flow diagram below.

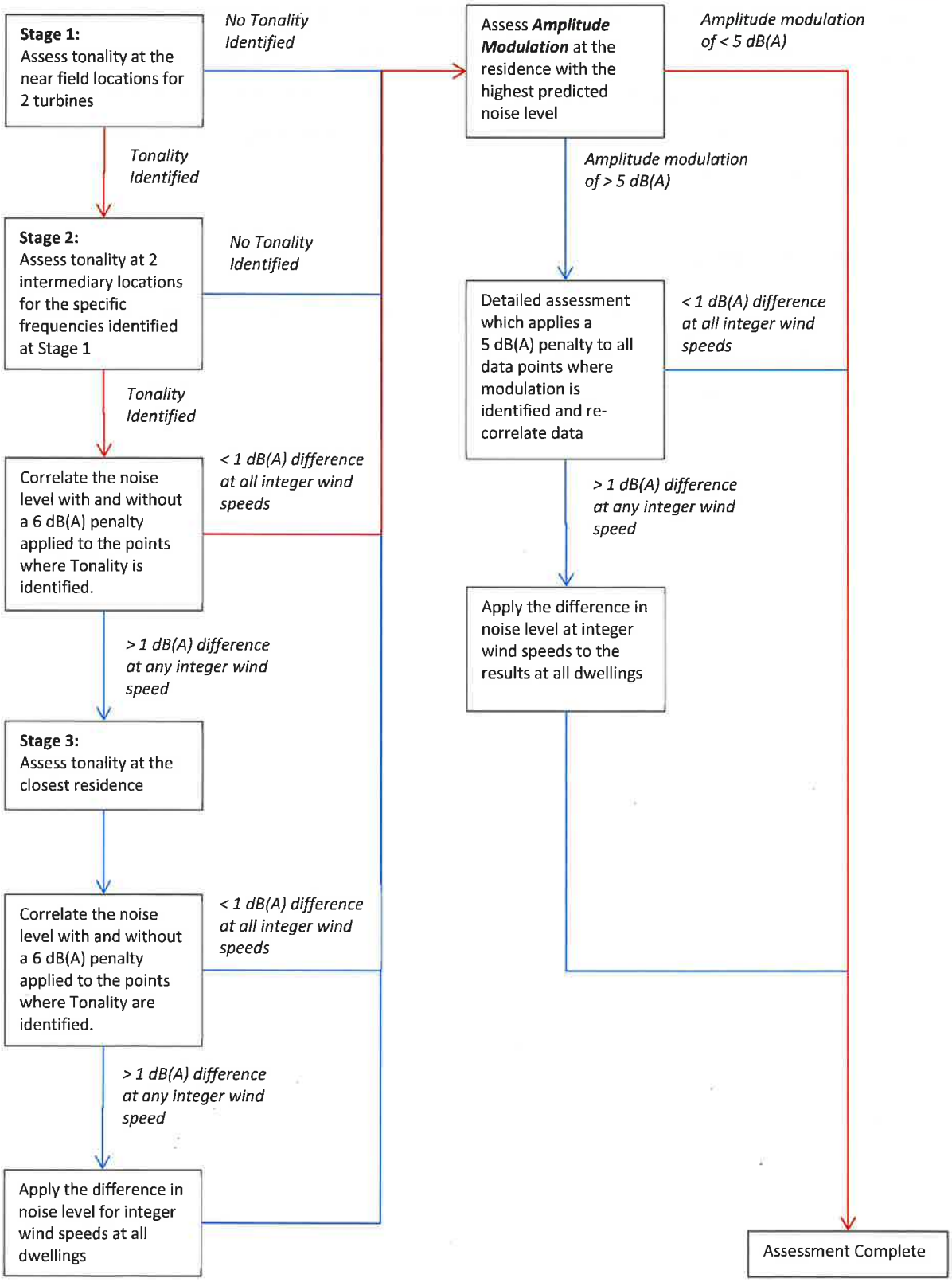


Figure 10: Flow Diagram of Special Audible Characteristics Assessment

7.1 Tonality

Tonality testing has been conducted in accordance with Appendix B2.2 of NZS6808:2010 and the NCTP.

Measurements were conducted in one-third octave bands between 25Hz and 10,000Hz. Tones were identified where the noise level at any hub height integer wind speed, in any one third octave band exceeded the arithmetic average of the adjacent bands by:

- 5 dB or more if the centre frequency of the band containing the tone is in the range 500Hz to 10,000Hz;
- 8 dB or more if the centre frequency of the band containing the tone is in the range 160 to 400Hz; and/or
- 15 dB or more if the centre frequency of the band containing the tone is in the range 25Hz to 125Hz

In accordance with the NCTP, the Stage 1 testing was conducted based on 10 minute noise levels at the near field location and where a tone was identified in the near field, Stage 2 testing was conducted at the Intermediary Position.

As a part of the Intermediary Position analysis, a 6 dB(A) penalty was applied to any 10 minute data pair which is identified to be tonal for the same wind speeds and frequencies identified at the near field location. Correlations of the data at the Intermediary Position have been compared before and after the application of the 6 dB(A) penalty, and in the circumstance where the difference in noise level is greater than 1 dB(A) at any integer wind speed, then Stage 3 tonality testing would extend to the dwellings.

In any other case, no penalty is applied for tonality and no further testing is required.

The near field measurements at turbines WTG4 and WTG15 identified tones from indiscrete sources believed to include but not be limited to the wind farm. The tones were identified at hub height wind speeds between 3m/s and 7m/s, in the 160Hz, 1000 Hz and 1250Hz 1/3 octave bands.

The data at the H1 and H6 Intermediary Positions were then analysed (July 2018 to April 2019). A limited number of tones at the frequencies identified at the near field also occurred at the Intermediary Positions, and the data have been correlated with and without the application of a 6 dB(A) penalty for the data points where tonality is identified. At the Intermediary H1 location, there were 27 occurrences where a penalty has been applied and 2 at the Intermediary H6 location.

The following graphs for the H1 Intermediary Position and the H6 Intermediary Position show the correlations before and after a penalty is applied at each data point where tonality was identified. The two correlations have resulted in less than a 1 dB(A) increase in noise level at all integer wind speeds and therefore assessment of tonality is not required to proceed to the dwellings and no tonality penalties or adjustments need to be applied.

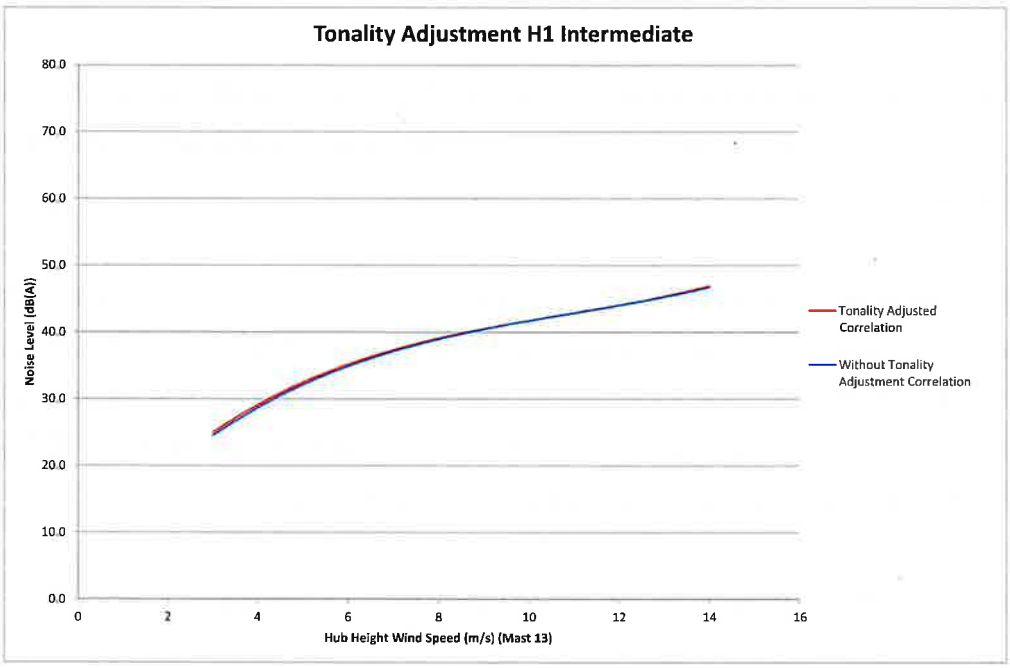


Figure 11: H1 Intermediate correlation with and without tonality adjustment

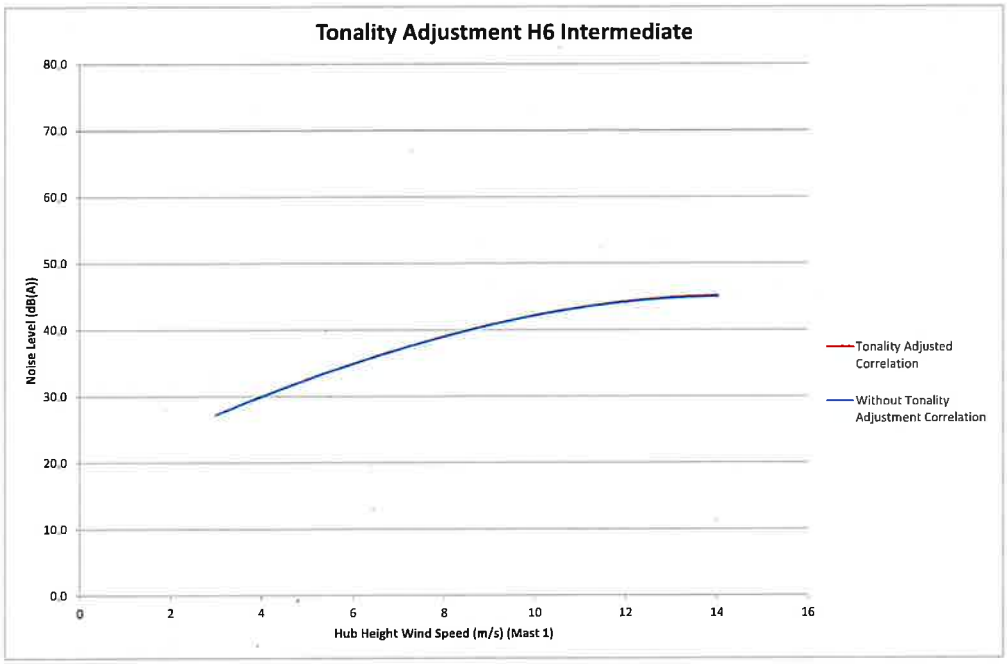


Figure 12: H6 Intermediate correlation with and without tonality adjustment

7.2 Amplitude Modulation

The "interim test method" provided in NZS6808:2010 and the NCTP has been applied to test for amplitude modulation. The test method consisted of the following:

- Measurements of noise levels:
  - at the dwelling with the highest predicted noise levels;
  - at the integer wind speed where the difference between the predicted noise level and the project criteria is the least;
  - under a downwind condition for at least 50% of the measurement period;
  - over a minimum interval of 2-minutes with the wind farm operational;
  - with at least 5 measurement intervals where the modulation of the wind farm was audible;
- Review of the overall noise level time trace for modulation at the blade pass frequency;
- Assessing whether the typical peak to trough values exceed 5 dB(A). The noise from the wind farm exhibits amplitude modulation where the values exceed 5 dB(A);
- Applying a 5 dB(A) penalty to the wind farm noise level for the wind conditions under which the modulation occurs.

Noise level measurements (100 millisecond intervals) have been conducted at H6 to determine amplitude modulation in accordance with the above. Five samples of 2 minute data intervals have been analysed, corresponding to the periods with a 10 m/s wind speed in the down wind direction and no rain on the microphone.

A number of 10 minute audio recordings which correspond to these periods have been reviewed and a 2 minute sample chosen where amplitude modulation is able to be identified.

The samples show modulation at approximately 1 Hz (the approximate blade pass frequency), with peak to trough values in the order of 2 to 3 dB(A). The following graph provides an example of the amplitude modulation, with the typical range 2 to 3 dB(A) and the highest less than 4 dB(A).

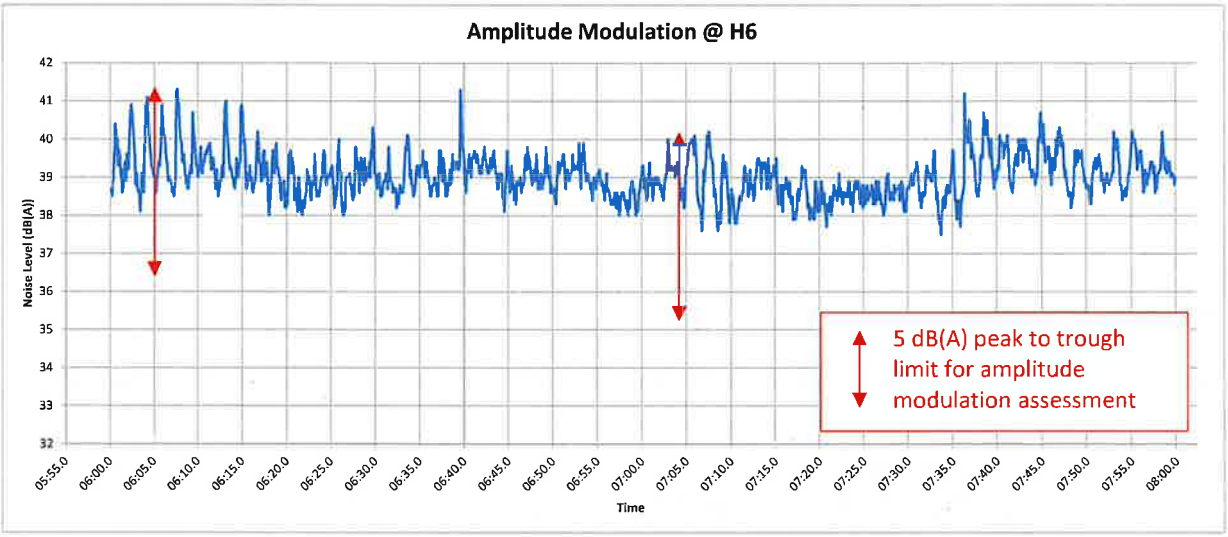


Figure 13: Example 2 minute data sample for amplitude modulation assessment

A review of the 1/3 octave band data has also been conducted to determine if amplitude modulation occurs on a regular basis. Under specific conditions, amplitude modulation at a 1/3 octave band can be identified for short intermittent periods as expected from a wind farm. This instance of short term intermittent amplitude modulation is not on a regular basis.

Based the above, in the absence of the amplitude modulation characteristic in 1/3 octave bands occurring on a regular basis and without typical overall peak to trough values exceeding 5 dB, further assessment is not required.

8 CONCLUSION

The post construction noise monitoring program has been completed for the Salt Creek Wind Farm. The program was conducted in accordance with NZS6808:2010 and the NCTP to determine compliance with Condition 12 of the Permit.

The noise measured in the vicinity of the wind farm has been determined to be a combination of noise from the wind farm and also other sources, most typically wind in the trees. A noise measurement and analysis methodology has been developed within the framework provided by NZS6808:2010 to isolate the noise from the wind farm.

The Primary Test Method comprised measuring noise levels at residences, intermediary locations and in the near field of several turbines. The results enable the determination of compliance with Condition 12 of the Permit for all measurement locations with the exception of H6 at night. In specific circumstances, the Primary Test Method will not isolate the noise from the wind farm and as such compliance cannot be determined without more targeted testing.

Observations at H6 and a review of the density and size of foliage and tree canopies since the original 2011 background noise monitoring regime indicates significant change and a commensurate increase in background noise levels generated by wind in the trees at this location. This is a circumstance whereby further targeted testing is required to isolate the noise from the wind farm.

The Alternative Test Method comprised on/off testing to more clearly differentiate wind farm noise from background noise.

Utilising the on/off results, the wind farm noise contribution at H6 can be more accurately differentiated from the background noise. The additional analysis has been used to determine that the noise from the wind farm achieves the project noise criteria.

The testing has also confirmed that no penalties are applicable to the wind farm noise level for the special audible characteristics of tonality and amplitude modulation.

It can therefore be concluded that the Salt Creek Wind Farm is compliant with the requirements of Condition 12 of the Permit.

APPENDIX A: Logging Locations

H1

H6

H8

Intermediary H1

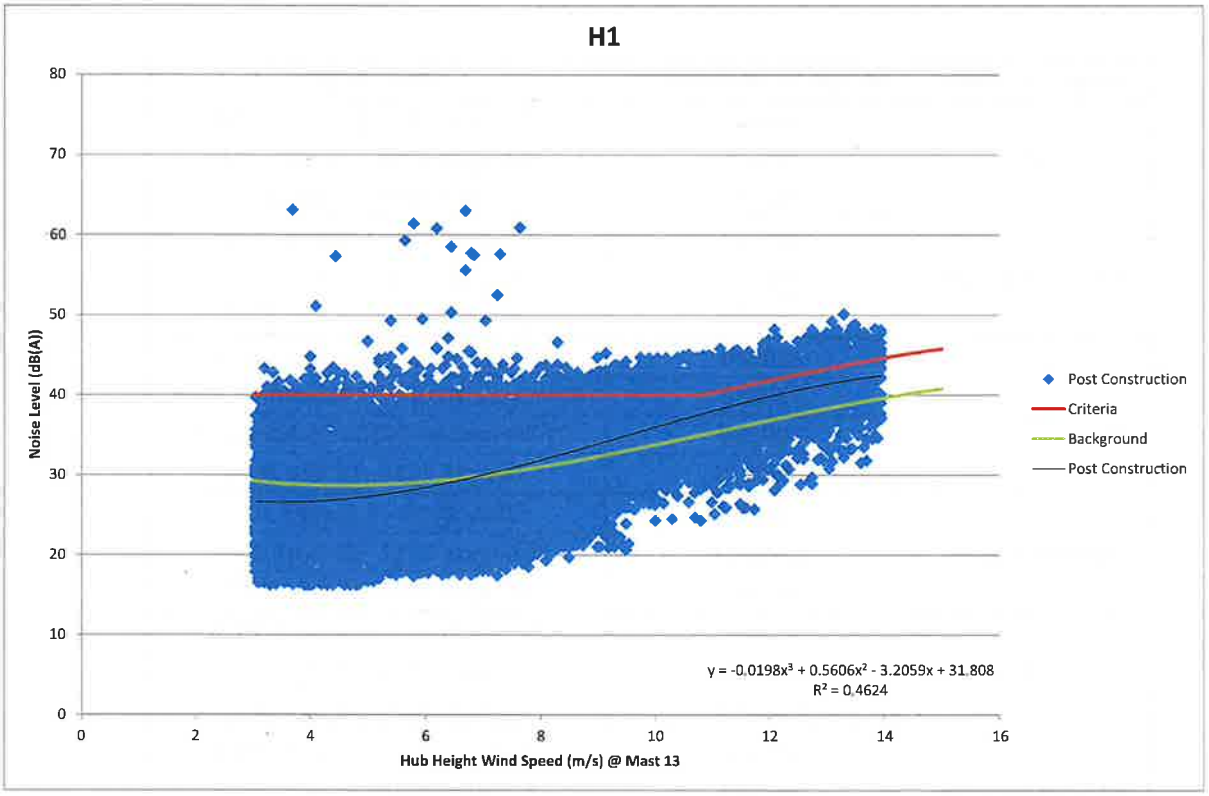
Intermediary H6

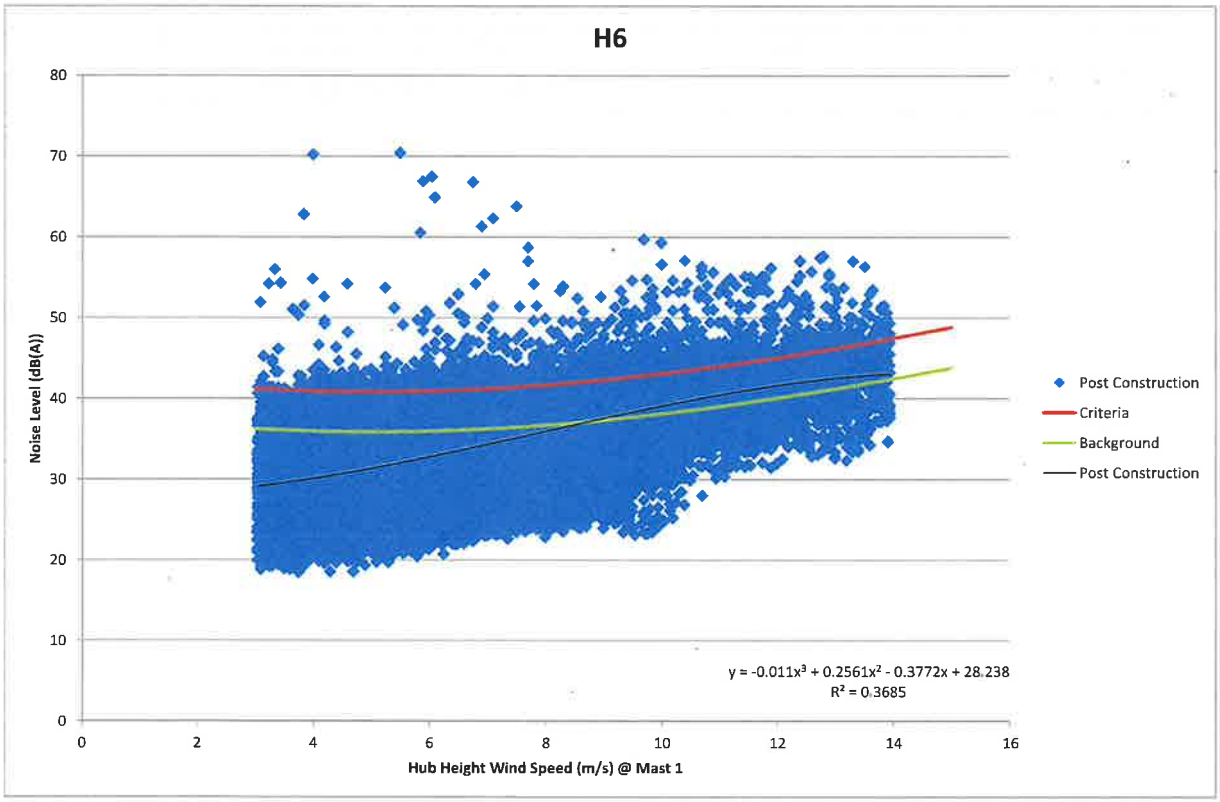
Intermediary H8

APPENDIX B: Sound Level Meter Details

Logger Location	Logger Serial Number	Date Range
H1	320656	17 July 2018 – 30 August 2018
	709525	30 August 2018 - 25 April 2019
	741718	25 April 2019 -18 July 2019
H1 Intermediate	320653	17July 2018 – 3 August 2018
	709524	3 August 2018 - 25 April 2019
	320654	25 April 2019 -18 July 2019
H6	320646	17July 2018 - 30 August 2018
	320656	30 August 2018 – 27 November 2018
	709526	27 November 2018 - 25 April 2019
	1298929	25 April 2019 -18 July 2019
H6 Intermediate	320657	17July 2018 - 3 August 2018
	1298932	3 August 2018 - 25 April 2019
	320657	25 April 2019 -18 July 2019
H8	320648	17 July 2018 - 30 August 2018
	1298930	30 August 2018 - 25 April 2019
	3541109	25 April 2019 -18 July 2019
H8 Intermediate	320654	17 July 2018 - 3 August 2018
	877043	3 August 2018- 25 April 2019
	320646	25 April 2019 -18 July 2019
Site Calibrator	35094478	12/03/2019-onward
	34125503	July 2018 to 10/04/2019

APPENDIX C: 24 Hour Correlations





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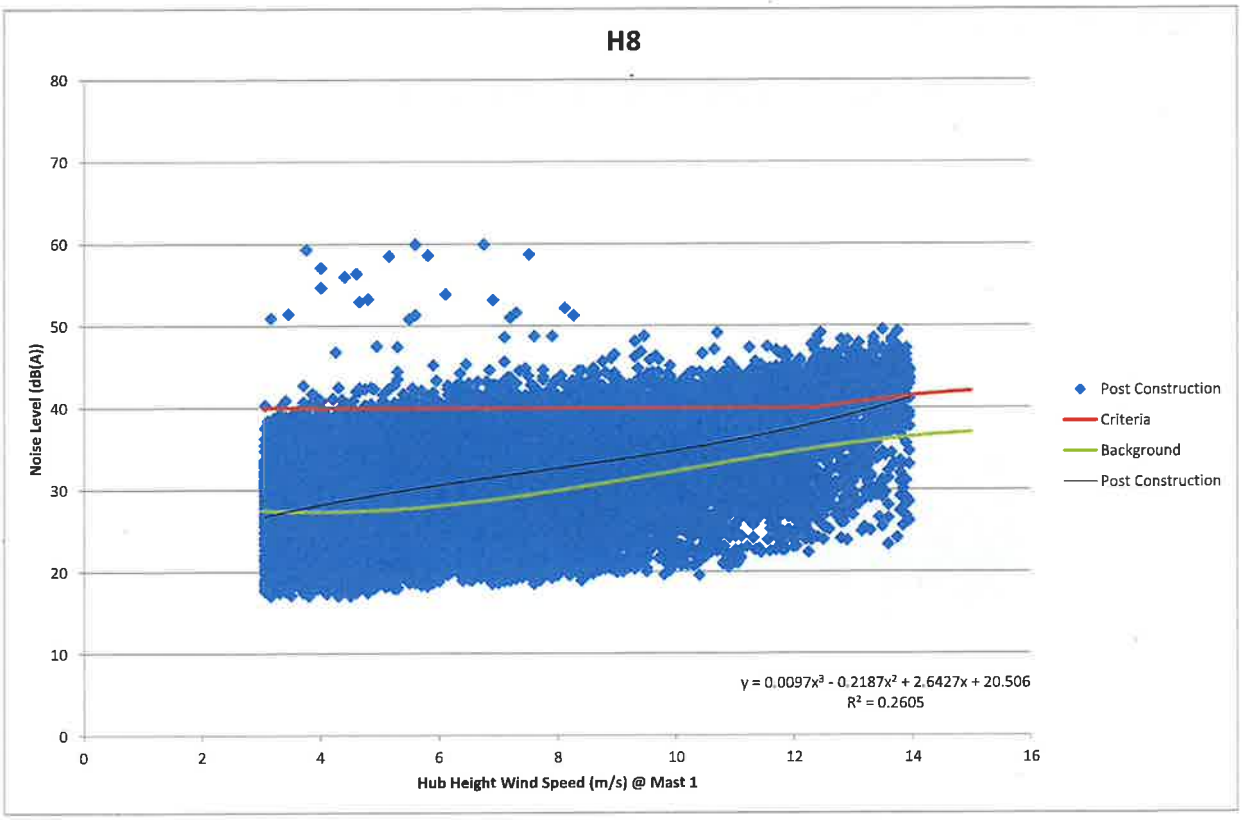
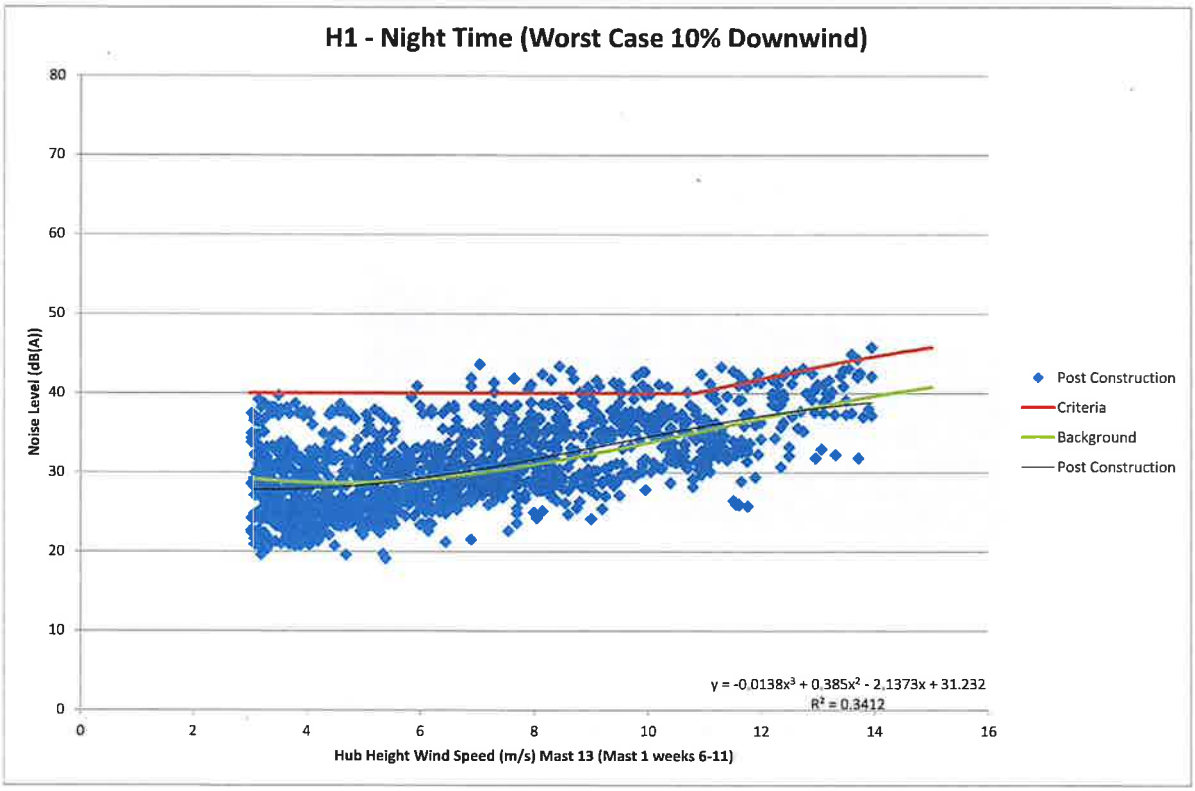
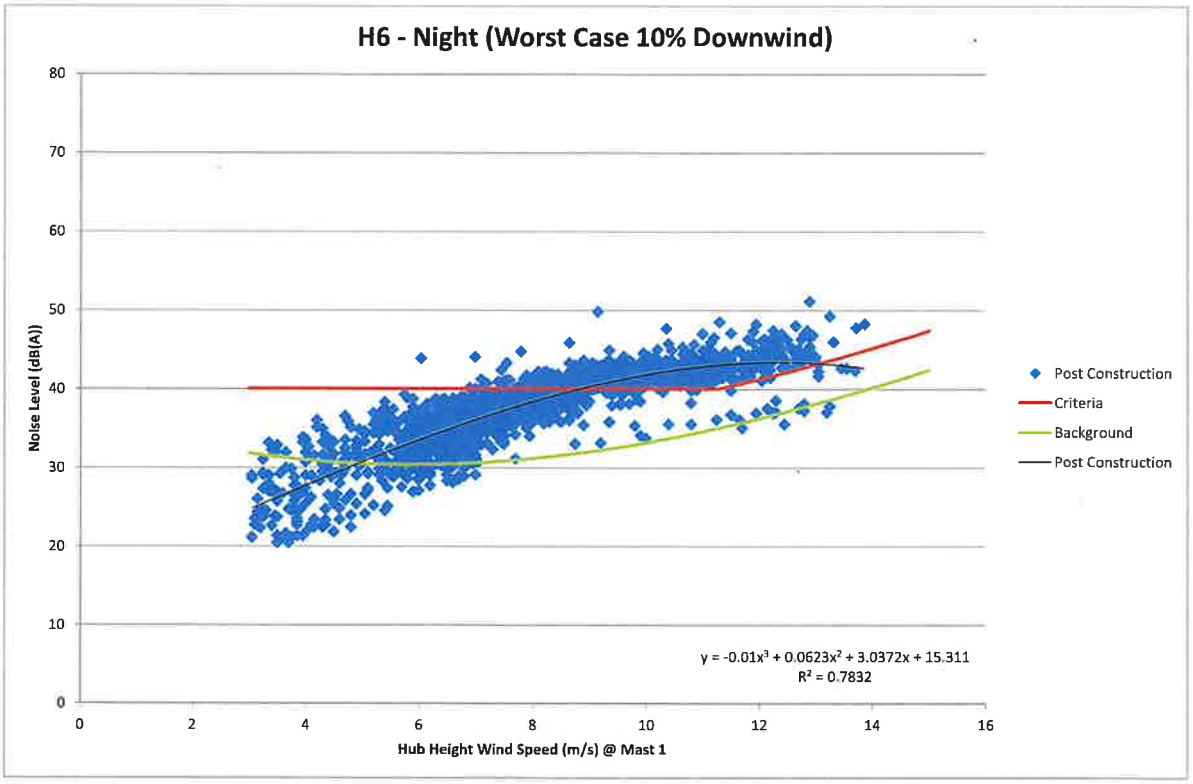


APPENDIX D: Night Time Correlations





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