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Baseline Noise Survey and <u>Amended</u> Impact Statement

Yellow River Wind Farm
Co. Offaly

Prepared For: Jennings O'Donovan

Report Prepared by: Brendan O'Reilly (March 2014)

TABLE OF CONTENTS

9.0 NOISE

9.1 Introduction

A wind farm development (Yellow River Wind Farm), consisting of thirty two turbines was proposed for an area in Co. Offaly located between Rockfortbridge and Rhode. However to comply with the Proposed Revisions to the Wind Energy Development Guidelines three turbines have been removed from the proposal and in the process other turbines have been moved with additional turbines being set to run in reduced mode setting. Each turbine can have a hub height up to 110m and can deliver a maximum of up to 3MW.

Noise and Vibration Consultants Ltd. were commissioned to undertake a noise assessment to consider the impact of the proposed development on the surrounding area and in particular on the nearest residential properties.

9.1.1 Statement of Authority

This Section has been prepared by Mr Brendan O'Reilly of Noise and Vibration Consultants Ltd. Mr. O'Reilly has a Masters degree on noise and vibration from Liverpool University and has over 35 years experience in noise and vibration control (and many years experience in preparation of noise impact statements) and is a member of a number of professional organisations. Mr. O'Reilly was an author and project partner (as a senior noise consultant) in '*ENVIRONMENTAL QUALITY OBJECTIVES Noise in Quiet Areas*' administered by the Environmental Protection Agency on behalf of the Department of the Environment, Heritage and Local Government (as a first step towards implementation of the EC Directive relating to the Assessment and Management of Environmental Noise (EU, 2002).

Noise & Vibration Consultants have considerable experience in the assessment of noise impact and have compiled studies for in excess of 60 planned wind farm developments throughout Ireland ranging in size from 1 to 40 turbines.

9.1.2 Acoustic Terminology

Sound is simply the pressure oscillations that reach our ears. These are characterised by their amplitude, measured in decibels (dB), and their frequency, measured in Hertz (Hz). Noise is unwanted or undesirable sound, it does not accumulate in the environment and is normally localised. Environmental noise is normally assessed in terms of A-weighted decibels, dB (A), when the 'A weighted' filter in the measuring device elicits a response which provides a good correlation with the human ear. The criteria for environmental noise control are of annoyance or nuisance rather than damage. In general a noise level is liable to provoke a complaint whenever its level exceeds by a certain margin the pre-existing noise level or when it attains a level. A change in noise level of 3 dB (A) is the minimum perceptible under normal circumstances while an increase in noise level of 10 dB (A) is perceived as a twofold increase in loudness. A noise level in excess of 83 dB (A) gives a significant risk of hearing damage.

Construction and industrial noise sources are normally assessed and expressed using equivalent continuous levels, L_{Aeq}[1]. Road traffic noise is normally assessed using L_{10} dB (A) or L_{Aeq}. L90 is the background noise and is the level equalled or exceeded for 90% of the measurement interval. Table 9.1 gives a comparison of noise levels in our environment.

[1] L_{Aeq} is defined as being the A-weighted equivalent continuous steady sound level during the sample period and effectively represents a type of average value.

Table 9.1: Comparison of noise levels in our environment

Source/Activity	**Indicative noise level dBA**
Threshold of hearing	0
Rural night-time background	20-50
Quiet bedroom	35
Wind farm at 350m	**35-45**
Busy road at 5km	35-45
Car at 65km/hr at 100m	55
Busy general office	60
Conversation	60
Truck at 50km/hr at 100m	65
Inside a typical shopping centre	70-75
Inside a modern car at around 90km/hr	75-80
Passenger cabin of jet aircraft	85
City Traffic	90
Pneumatic drill at 7m	95
Jet aircraft at 250m	105
Threshold of pain	140

Source: Fact sheet published by the Australian Greenhouse Office and the Australian Wind Energy Association

9.2 Evaluation Criteria

The noise limits suggested by the *Wind Energy Development Guidelines 2006* have been derived with reference to the following, and other, points:

- Existing standards and guidance relating to noise emissions
- Society's need for renewable energy sources to reduce harmful greenhouse gas emissions in pursuance of government energy policy
- The ability of manufacturers and developers to meet these noise limits
- The research of Noise Working Groups in the UK, Denmark, Holland and Germany.

The following are a number of key extracts from the *Wind Energy Development Guidelines* in relation to noise impact:

General Noise Impact

"*Noise impact should be assessed by reference to the nature and character of noise sensitive locations*."

"*Separate noise limits should apply for day-time and for night-time*"

"Noise limits should be applied to external locations, and should reflect the variation in both turbine source noise and background noise with wind speed."

Measurement Units

"The descriptor [$L_{A90\ 10min}$] which allows reliable measurements to be made without corruption from relatively loud transitory noise events from other sources, should be used for assessing both wind energy development noise and background noise."

Specific Noise Limits

'Noise limits should be applied to external locations, and should reflect the variation in both turbine source noise and background noise with wind speed.'

"In general, a lower fixed limit of 45dB(A) or a maximum increase of 5dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours. However in very quiet areas, the use of the margin of 5dB(A) above the background noise at nearby noise sensitive properties is not necessary to offer a reasonable degree of protection and may unduly restrict wind energy developments. Instead in low noise environments where background noise is less than 30 dB(A), it is recommended that the day time level of $L_{A90,10min}$ of the wind energy development noise should be limited to a level within the range 35-40dB(A)".

"Separate noise limits should apply for day-time and for night-time. During the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. A fixed limit of 43dB (A) $L_{A90,10min}$ is deemed to protect sleep inside properties during the night"

<u>Proposed Revisions to the Wind Energy Development Guidelines 2006</u>

<u>The Wind Energy Development Guidelines have just recently been reviewed and draft guidelines have been published for comment. The noise limits used in this amended report were derived from the Proposed Revisions to Wind Energy Development Guidelines 2006; 'Targeted Review in relation to Noise, Proximity and Shadow Flicker- December 11th 2013.'</u>

One substantial difference in the draft is the proposal for a fixed limit of 40dBA for daytime and night-time without the use of a margin above the background noise level. The limit will apply irrespective of time of day or night. There are exceptions to this 40dBA noise limit and it may be possible for the development to proceed provided the owner(s) of the relevant properties are supportive of the development. Under these circumstances the owner of the property or properties must provide written confirmation to the satisfaction of the planning authority that the understand that their property may experience noise levels higher than the 40dBA noise limit and that they have no objection to the proposed wind energy development. In such circumstances the planning authority may consider departing from the 40dBA.

For this development the limits proposed in the draft guidelines is being adopted:

- **A fixed limit of 40dBA $L_{90,10min}$ will apply for daytime and night-time at all houses.**

9.3 Existing Environment

Noise Sensitive Locations (NSL's)

The locations of NSL's within 1.13km of the proposal were identified through map searches, visits to the site and are shown in the Figures 9.21 to 9.25 inclusive (see Appendix N1 for locations). Tables 9.2 give the co-ordinates and distances from each of these houses to the nearest turbine.

Table 9.2: Noise Sensitive Location / Nearest Turbine Separation.

House No.	Easting ING (m)	Northing ING (m)	Altitude (m)	Nearsest Turbine (m)	Distance (m)
1	248567	235952	87	7	787
2	253125	234854	90	13	769
3	252847	235075	88	13	961
4	252814	235059	88	13	996
5	253151	234776	87	13	789
6	253312	234330	86	13	1024
7	253317	234312	86	13	1037
8	253320	234292	86	13	1054
9	253351	234320	86	13	1015
10	253352	234300	86	13	1032
11	253375	234293	86	13	1029
12	253399	234292	86	13	1020
13	253412	234315	86	13	994
14	253443	234315	86	13	983
15	253446	234304	86	13	992
16	248662	235946	86	7	722
17	247686	235439	88	2	1038
18	253533	234720	91	13	576
19	254679	235250	92	14	549
20	257540	239043	73	19	1108
21	257278	239056	74	19	957
22	251645	237031	87	11	1065
23	254330	242124	81	32	697
25	255208	235063	92	14	1109
26	255206	236003	89	15	854
29	255168	236052	87	15	825
30	255056	235079	98	14	963
32	253325	234255	88	13	1085
33	253325	234232	88	13	1105
36	255179	236937	77	16	778
37	255061	236912	76	16	738
41	247997	236211	89	4	662
42	253233	236099	77	13	1032
43	253451	234289	86	13	1004
44	253462	234280	86	13	1009
45	253470	234276	86	13	1010
46	253484	234274	87	13	1008
47	253493	234279	86	13	1000

House No.	Easting ING (m)	Northing ING (m)	Altitude (m)	Nearsest Turbine (m)	Distance (m)
48	253504	234288	86	13	988
49	253505	234299	86	13	977
50	253508	234312	86	13	964
51	253506	234321	86	13	956
52	253537	234323	87	13	945
53	253540	234316	87	13	951
54	253536	234301	87	13	967
55	253539	234294	87	13	973
56	253535	234280	87	13	987
57	253538	234274	87	13	992
58	253239	234858	89	13	670
59	256033	237147	75	18	809
60	252914	235036	90	13	902
61	252938	235015	91	13	884
62	253240	235150	91	13	561
63	253230	234878	90	13	667
64	253206	234827	88	13	715
65	254072	234708	91	13	593
66	253659	241041	81	30	622
67	247805	235869	87	2	772
68	251228	237472	106	11	1098
69	253243	234926	91	13	631
74	257892	238120	88	19	1127
75	257889	238079	89	19	1130
77	254061	238638	79	24	617
79	255853	237190	76	18	679
80	254136	234300	87	13	993
81	254085	234740	91	13	571
82	253241	235118	91	13	565
83	253107	235469	82	13	727
85	251205	237399	100	11	1023
86	250527	237235	84	11	764
87	251976	235986	79	12	852
88	255053	235825	96	15	696
89	255277	236775	76	16	967
90	255188	236882	76	16	829
91	255992	236980	76	18	930
92	256000	237349	74	18	633

House No.	Easting ING (m)	Northing ING (m)	Altitude (m)	Nearsest Turbine (m)	Distance (m)
93	256150	237164	74	18	871
94	256553	237273	73	19	995
95	256613	237376	73	19	882
98	255304	235274	86	15	1126
99	255275	235286	87	15	1095
100	254979	235261	91	14	828
102	255190	235126	94	14	1069
103	255140	235061	96	14	1047
104	254117	238648	78	24	628
105	254035	238637	78	24	610
106	255252	239287	79	21	920
107	255119	239662	81	22	1264
108	255299	239972	79	21	1474
110	255240	240390	78	31	1172
111	254501	240623	85	31	632
112	254300	240602	84	31	667
113	255670	239696	79	21	1098
114	256175	239631	81	21	1052
115	256157	239657	81	21	1073
119	257812	237829	87	19	1120
120	257738	237877	85	19	1034
121	257427	237822	76	19	780
122	257348	237814	74	19	719
123	257388	237816	75	19	750
124	257308	237806	74	19	692
125	256922	237544	75	19	716
126	253134	235422	84	13	687
127	253014	234962	92	13	826
129	251194	237368	98	11	990
130	252967	234994	91	13	861
131	252992	234975	92	13	843
132	255432	235683	89	15	1092
133	254782	235295	92	14	629
134	254751	235282	91	14	604
135	255271	236950	77	16	825
136	256580	237359	73	19	905
137	256764	237362	74	19	882
138	254349	238723	76	22	510

House No.	Easting ING (m)	Northing ING (m)	Altitude (m)	Nearsest Turbine (m)	Distance (m)
139	254521	238947	76	22	563
140	254550	238960	76	22	562
141	254905	239054	77	22	622
142	254929	239108	79	22	680
143	253136	235891	77	13	931
144	253157	235988	77	13	988
145	255399	236884	76	17	930
146	253043	234909	92	13	818
147	250459	237281	85	11	828
150	247773	235882	87	2	739
151	253250	234967	91	13	606
152	255344	236871	75	17	927
153	255467	237058	75	18	749
154	255198	235218	91	14	1050
155	255096	235307	90	14	931
156	255078	239295	78	22	901
157	255440	239556	80	21	1037
158	257511	237922	77	19	807
162	255219	240255	79	31	1261
163	255322	239896	79	21	1395
164	255524	239623	80	21	1066
165	255485	239615	80	21	1073
166	255217	239886	78	21	1432
167	255254	239573	80	21	1143
168	255200	239475	80	21	1096
169	255210	239184	80	22	856
170	255025	239163	79	22	759
171	254949	239125	79	22	701
172	254551	239015	77	22	613
173	254312	238769	76	22	566
175	255714	239696	79	21	1090
176	255247	240361	78	31	1198
177	255291	239603	80	21	1149
178	255096	239603	80	22	1201
179	254989	239163	78	22	748
181	257086	237641	78	19	680
182	257093	237687	77	19	643
185	256204	239568	80	21	1001

House No.	Easting ING (m)	Northing ING (m)	Altitude (m)	Nearsest Turbine (m)	Distance (m)
186	255785	239548	81	21	934
187	255615	239684	79	21	1098
188	255448	239926	79	21	1378
190	256750	239334	76	19	1090
191	256307	239403	78	21	890
192	256185	239484	79	21	915
193	254620	240381	83	31	888
194	254652	240610	86	31	674
195	254095	238602	80	24	662
196	254092	238643	78	24	623
197	253684	238390	82	25	771
198	253409	238094	82	25	992
199	254170	238194	76	22	656
200	251779	235993	79	12	656
203	251043	237236	89	12	656
204	251006	237187	88	11	746
205	250489	237255	84	11	794
207	253953	239994	83	28	499
208	254079	240060	84	28	638
209	254261	240143	83	28	836
210	253804	241176	82	32	452
211	254181	240585	83	31	719
212	254232	234223	89	13	1100
213	251956	235813	79	10	844
214	247785	235857	87	2	765
216	255108	240498	79	31	1003
217	255281	240592	79	31	1064
218	255460	240830	75	31	1097
219	255285	241036	78	31	865
220	255608	240886	77	31	1217
221	255523	241106	80	31	1085
222	255330	241212	82	31	883
223	255322	241490	82	31	906
224	255299	241806	80	31	1015
226	256380	237956	73	19	485
227	255224	235079	92	14	1118
228	251226	237475	106	11	1100
229	252058	235989	80	12	933

House No.	Easting ING (m)	Northing ING (m)	Altitude (m)	Nearsest Turbine (m)	Distance (m)
230	255275	236764	76	16	975
231	253711	238425	82	25	752
234	253140	237956	80	25	1148
236	255319	241508	82	31	908
237	254470	238988	77	22	623

Baseline Noise Methodology

In order to represent the prevailing background noise in the area continuous noise monitoring was set up at 10 locations for an extended period from 12th to 30th May 2013 (see Environmental Impact Statement Appendix N1 for monitoring locations).

The following conditions and methods were adhered to in undertaking the survey:

Measurement of background and ambient noise levels using 10-minute intervals was undertaken during varied wind speeds / directions using instruments which comply to; Type 1 standard in IEC 651-1: 1979.

All microphones were fitted with double skin windscreens based on that specified in W/31/00386/REP 'Noise Measurements in Windy Conditions'.

Concurrent measurements of average wind speed / direction and noise levels were recorded at 10-minute intervals with the times synchronised.

The noise monitors were set up to record a number of statistical noise indices, including Leq, L90, maximum and minimum levels on *fast response*. The results were automatically logged at 10 minute intervals.

Wind speed data was recorded from a mast on site with anemometer's sited at 80.8m and 44.8m. The hub height wind speed was derived using the calculated wind shear on site and then standardised to 10m height using a roughness length of 0.05m (methodology to derive the 10m height was according to that described in the '*Acoustic Bulletin*' by the

‘*Institute of Acoustics professional journal dated March/April 2009’* (see Appendix N2). The derived 10m wind speed was plotted against the background noise levels

The baseline noise survey was carried out according to *ISO 1996 Part 1 (Description and Measurement of Environmental Noise - Part 1: Basic Quantities and Procedures taking cognisance of Department of Environment, Heritage and Local Government ‘Wind Energy Development Guidelines 2006’.*

Wind speed data was taken from anemometers on the wind mast on site (co-ordinates 252422E, 234669N). An electronic rain gauge was installed on site at location H226.

Instrumentation Used

The following instrumentation was used in the baseline survey measurements:

- Eight Larson Davis 812 Precision Integrating Sound Level Analyser/Data logger with 828 Pre-amplifier set on ‘fast response’ and 1/2" Pre-polarised Microphone.
- Two Larson Davis 831 Precision Integrating Sound Level Analyser/Data logger with 828 Pre-amplifier set on ‘fast response’ and 1/2" Pre-polarised Microphone.
- Wind Shields Type: Double Skinned Windscreen.
- Fixed Wind Mast on site.
- Calibration Type: Larson Davis Precision Acoustic Calibrator Model CA250.
- One electronic rain gauge to log rainfall

All noise monitoring systems were calibrated on site before and after the survey and the drift of calibration were less than 0.2dB for all noise monitoring systems. All noise instruments (812’s and 831’s have a noise floor below 20dB. The details of the calibration certificates for the noise monitors used in the baseline survey are contained in Table 9.7.

Table 9.7: Summary Details of Calibration Certificate

Instrument/Model	Date of Calibration	Serial Number	Calibration By
Larson Davis 812	12th April 2013	0590	MTS Calibration Ltd
Larson Davis 812	8th Feb'2012	0712	MTS Calibration Ltd
Larson Davis 812	4th Oct 2012	0713	MTS Calibration Ltd
Larson Davis 812	19th Oct 2012	0775	MTS Calibration Ltd
Larson Davis 812	11th Oct 2012	0726	MTS Calibration Ltd
Larson Davis 812	14th Oct 2011	0583	MTS Calibration Ltd
Larson Davis 812	15th Dec'2011	0606	MTS Calibration Ltd
Larson Davis 812	19th Dec'2011	0783	MTS Calibration Ltd
Larson Davis 831	11th July 2012	0002920	PCB Piezotrinics
Larson Davis 831	27th June 2012	0002904	PCB Piezotrinics
Larson Davis Calibrator CA250	19th Sept 2012	3034	MTS Calibration Ltd

NB All instruments have been calibrated with pre-amp and microphone, with certificates available on request

Measurement Procedure

Continuous noise monitoring was carried out at 10 locations representing houses within the environs over a 20-day period using environmental noise analysers with data logging facilities set on real time. All Instruments were synchronised to standard time.

All microphones were positioned more than 10m from any reflecting façade at 1.5m above ground level. The logged data was later downloaded to a personal computer. All acoustic instrumentation was calibrated before and after each survey and the drift of calibration observed was less than 0.2dB so no adjustments were made to the recorded levels.

The baseline survey locations were selected on the basis of their location relative to wind turbines and the nearer residential properties as given in Table 9.8 (see photos of locations in Appendix N3). Where the noise levels in a locality or cluster of houses are similar, then that single monitoring location can represent a group of houses in that locality.

Table 9.8: Noise monitoring details

Monitoring Locations	Description
H210	Microphone at 1.2m height in back garden as in photo
H138	Microphone at 1.2m height, approx. 40 from house in field
H192	Microphone at 1.2m height, approx. 200m from house in field
H226	Microphone at 1.2m height in front garden of farmhouse
H145	Microphone at 1.2m height in back garden
H88	Microphone at 1.2m height in garden in front of house
H18	Microphone at 1.2m height in front garden of 2 storey house
H87	Microphone at 1.2m height in back garden of bungalow
H41	Microphone at 1.2m height in garden at side of farmhouse
H220	Microphone at 1.2m height in back of bungalow

The time subsets are according to UK guidelines as given in ETSU-R-97 and are as follows:

Quiet waking hours or quiet day-time periods defined as;

All evenings from 18.00 to 23.00hrs

Plus Saturday afternoon from 13.00 to 18.00hrs plus all day Sunday 07.00 to 18.00hrs

Night-time is defined as 23.00 to 07.00hrs

Noise Survey Results and Analysis of Data

The lands in the proposal area are a flat rural farming landscape. The local environment is predominately controlled by wind influence on vegetation, agricultural activity and road traffic on the local road network. The higher background levels were recorded from monitoring locations which were closer to the higher traffic flow roads (Regional roads) and Motorway. Background noise levels from a motorway at up to 5km can be increased by anything up to 7dBA depending on wind direction and traffic flow.

The prevailing background noise level has been calculated based on the methodology contained in the UK document ETSU-R-97 and referenced in the Guidelines for Planning Authorities issued by the Department of Environment, Heritage and Local Government.

The general methodology uses a polynomial regression line calculated through the background noise data for each 10 minute period to give the prevailing background noise data. A 2nd or 3rd order polynomial regression line is then plotted through the background noise data. The choice of order of polynomial regression line is based upon whichever order of curve gives the *best-fit* to the measured data.

Prior to analysis, the acoustic data is filtered and noise due to heavy rainfall or activity that gave unusually elevated levels (including dawn chorus) was removed from the data set. Table 9.9 gives the background noise levels at varying wind speed derived from polynomial regression analysis with best-fit curve /line for day time and night time.
The derived background with wind speed takes account of wind shear.

Table 9.9: Background noise levels with varying wind speed derived from regression analysis with best-fit plotted line for day and night

Monitoring Location	**Period**	**Average wind speed (m/s)**						
		4	**5**	**6**	**7**	**8**	**9**	**10**
		Background noise L_{90} dBA at varying wind speed						
H210	**Day**	32.9	33.9	35.1	36.6	38.3	40.3	42.5
	Night	28.3	29.7	31.1	32.3	33.5	34.5	35.5
H138	**Day**	30.7	31.6	33.0	35.1	37.7	41.0	44.8
	Night	29.0	30.3	31.8	33.6	35.6	38.0	40.7
H192	**Day**	33.1	34.3	35.9	37.8	40.1	42.7	45.7
	Night	29.0	30.4	32.3	34.8	37.9	41.5	45.8
H226	**Day**	33.9	34.6	35.8	37.4	39.5	42.1	45.2
	Night	26.5	28.2	30.3	32.8	35.7	38.9	42.4
H145	**Day**	34.5	35.3	36.3	37.4	38.6	40.0	41.5
	Night	32.8	33.9	35.0	36.2	37.5	38.8	40.2
H88	**Day**	30.2	31.8	34.0	36.9	40.1	43.8	48.0
	Night	23.9	26.2	29.1	32.3	35.9	39.6	43.3
H18	**Day**	37.0	37.9	39.3	41.3	43.9	47.1	50.8
	Night	27.5	28.4	29.8	31.6	33.9	36.6	39.8
H87	**Day**	33.6	34.5	36.0	38.1	40.7	43.9	47.7
	Night	23.9	25.6	28.3	32.0	36.6	42.3	48.9
H41	**Day**	34.6	36.3	38.8	41.8	45.5	49.9	49.9
	Night	28.8	30.7	32.9	35.3	37.7	40.4	43.2
H220	**Day**	31.7	32.6	33.9	35.7	38.0	40.8	44.1
	Night	28.3	29.1	30.3	31.8	33.7	36.0	38.6

9.4 NOISE IMPACT

Characteristic of Proposal

There are two quite distinct types of noise sources within a turbine. The mechanical noise produced by the gearbox, generator and other parts of the drive train; and the aerodynamic noise produced by the passage of the rotor blades through the air. Over the last number of years there has been a significant reduction in the mechanical noise generated by wind turbines, and it is now generally less than the aerodynamic noise.

Aerodynamic noise is a low level noise generated as a result of the turbine rotor blades moving through the air. Turbine noise is generally classed as broadband in nature, not unlike wind blowing through vegetation but modulated with a regular swishing sound. With distance from a turbine this blade swish normally decreases as the sound decays into the background. Because of the low level of noise generated from a turbine it is very difficult to measure at distance as the sound generated is masks into the background noise. In very low wind speeds turbines do not operate. As the wind speed increases so too does the sound generated by the turbine along with the sound generated by the action of wind on vegetation and objects.

With continuing improvements in design, lower rotational speeds produce higher rated outputs. Low rotational speeds reduce the probability of any audible tonal or impulsive components.

The audibility of noise from wind turbines will generally be greatest at lower wind speeds, less than 6 m/s. At receptor ground level and at average wind speeds of around 7-8 m/s and above, it generally becomes quite an abstruse issue to discuss sound emissions from modern wind turbines since background noise (wind on vegetation / objects) will generally mask any turbine noise.

<u>To address some of the issues raised by Offaly County Council and others regarding the Proposed revisions to the Wind Energy Guidelines a noise limit of 40dBA for day and night has been adopted and a some changes have been made to the layout of the proposed wind farm. The number of turbines have been reduced from 32 to 29 (T20, T23 & T28 have been dropped from the proposal) and T22, T24 & T31 are moved with very minor movement to T5 & T6.</u>

This amended proposal is for 29 no. wind turbines. The candidate turbine used in the assessment is a Siemens SWT-3.0-113 which can produce a maximum of 3MW and can be noise controlled by applying settings ranging from 'standard' to -1dB to -6 dB. There are other 3MW turbines in the market place which can operate with the same maximum sound power level of emission and which have noise control settings.

Noise levels were calculated using the data supplied by the turbine manufacturer Siemens for the SWT-3.0-113, 3MW turbine. The data was obtained from a Standard Acoustic Emission document id: E W EN OEN DES TLS 7-10-0000-0763-00 GBI / 2012.12.18. The sound power level of a Siemens 3MW turbine at varying wind speeds at 10m height wind speeds for a turbine hub height of 122.5m was used as it gave a marginally higher sound power level output. This data is given in Table 9.10 below. The sound power levels of the SWT turbine does not increase with wind speed above 7m/s. The turbine has a cut-in speed of 3 m/s and a cut-out speed of 25 m/s. The 1/1 octave band analysis from the test measurement is given in Table 9.12 for a wind speed of 8m/s.

Table 9.10: Sound power levels for the Siemens-3.0-113, 3MW turbine, (hub height of candidate turbine not to exceed 110m)

10m Height Wind Speed,	**Sound Power Level L_{WA} [dB(A)]**	
V_{10}/m/s	**No uncertainty**	**+1dBA added**
4	98.9	99.9
5	101.9	102.9
6	104.9	105.9
7	105.5	106.5
8	105.5	106.5
9	105.5	106.5
10	105.5	106.5

Assessment Methodology

The assessment was carried out using guidance given in ETSU-R-97 taking into account The Wind Energy Development Guidelines, *'Guidelines for Planning Authorities',* June, 2006 and recommendations in '*The Prediction and Assessment of Wind Turbine Noise*', published in the Institute of Acoustics *'Acoustics Bulletin.*' and '*A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise,'* May

2013. The noise limits were derived from those given in the 'Proposed Revisions to Wind Energy Development Guidelines 2006.'

Continuous measurements of noise and wind speed were made at 10 minute intervals and the data was analysed to produce a best-fit line. The line was then used to derive a limit upon which the assessment was made. Figures 9.1 to 9.28 shows the fixed and derived line corresponding to the limits set for the ten baseline monitoring locations around the site.

Based on the noise specification for the Siemens turbine the following details have been assumed:

- a maximum hub height of 110m
- a rotor diameter of 113m
- a sound power level, L_{WA} of 105.5dBA, for a 10m height wind speed (v_{10}) of 8m/s (see Table 9.10)
- an 1/1 octave band spectrum, in reference conditions, as given in Table 9.11
- tonal emission characteristics such that no clearly audible tones are present at any wind speed at distances > than 500m
- one dBA is added to SPL values to account for uncertainty (see Table 9.10)
- each turbine is modelled as a point source at hub-height
- the turbines are identical with some operated at a lower noise output setting
- an estimated gradient of 3dBA/m/s between a wind speed of 4 to 6m/s
- the noise control setting for specified turbines are as follows; T31 at -1dB setting, (T2 & T14) at -2dB setting, (T4 & T30) at -3dB setting and (T22 & T24) at -4db setting (see Table 9.12).

Other combinations of setting to the ones listed above could also be used to ensure that the maximum turbines noise levels is kept within the 40dBA noise limit at all houses with no financial interest in the project.

In the software model for prediction, 1 dBA is added (for uncertainty) to the values given in Table 9.11 over the range of octaves between 63 and 8000Hz (Standard setting equals a SPL value of 106.5dBA as input to model).

Table 9.11: 1/1 Octave band analysis for the Siemens-SWT-3.0-113, 3MW turbine

SWT-3.0-113-3.0MW	122.5m hub height								
		1/1 Octave at 8m/s							
Standard Setting									SPL
Frequency (Hz)	63	125	250	500	1000	2000	4000	8000	dba
Sound Power Level (LWA) 8m/s	92.2	94.2	97.2	97.9	99.5	98.6	95.2	86.3	105.5

Table 9.12: Sound power noise levels for Siemens-SWT-3.0-113 for various control settings

Other Values used in model input	**SPL**
1/1 Octave at 8m/s	**dBA**
Standard Setting	105.5
Setting -1db	104.5
Setting -2db	103.5
Setting -3db	102.5
Setting -4db	101.5
Setting -5db	100.5
Setting -6db	99.5

NB: Other combinations of noise control setting with directivity on turbines could also be used to keep within the adopted 40dBA limit

4.1 Predicted Wind Turbine Noise

There are numerous models for predicting noise from a point source and some of these models are specifically used for the prediction of noise from wind farms. In this instance a version of WindFarm by Resoft wind energy development software package was used to determine the noise levels at the prediction locations. Noise predictions have been carried out using International Standard ISO 9613, Acoustics – Attenuation of Sound during Propagation Outdoors. The propagation model described in Part 2 of this standard provides for the prediction of sound pressure levels based on either short term down wind (ie. worst-case) conditions or long term overall averages. Only the worst-case down wind condition has been considered in this assessment; that is for wind blowing from each turbine directly to each house.

The ISO propagation model calculates the predicted sound pressure level by taking the source sound power level for each turbine in their respective octave bands and subtracting a number of attenuation factors according to the following formulae:

Predicted Octave Band Noise level = LW +D – (A_{geo} +A_{atm} +A_{gr} + A_{br} +A_{mis})

These factors are discussed in detail below. The predicted octave band levels from each of the turbines are summed to give the overall 'A' weighted predicted noise level from all the turbines operating together.

No allowance has been made for the character of noise emitted by the turbines, however the emissions from wind turbines are assumed to be broad band in nature.

A_{geo} –Geometric Spreading

Geometric (spherical) spreading from a simple free-field point source results in attenuation over distance according to:

$$Lp = Lw – (20 \log R + 11)$$

Where:
Lp = sound pressure level

Lw = sound power level

R = distance from the turbine to receiver

D – Directivity Factor

The directivity factor allows for adjustment where the sound radiated in the direction of the receptor is higher than that for which the sound power level is specified. In this case the sound power levels are predicted as worst case propagation conditions, i.e. in downwind conditions, so no additional adjustments are necessary.

A_{gr} - Ground Effects

Ground effect is the result of sound reflected by the ground interfering with the sound propagating directly from the turbine to receiver. The prediction of ground effects are complex and depend on the source height, receiver height, propagation height between the source and receiver and the intervening ground conditions.

Ground conditions are described according to a variable defined as G, which varies between 0 for hard ground and 1 for soft ground. Although in reality the ground is predominately porous / soft, it has been modelled as corresponding to a ground absorption coefficient of 0.5. The predictions were carried out corresponding to the proposed height of the turbine nacelle and a receiver height of 4m. The Prediction and Assessment of Wind Turbine Noise agreement, published by the '*Institute of Acoustics*', May 2013, suggests that the use of G =0.5, a receptor height of 4m will generally result in realistic estimates of noise emission levels at receptor locations downwind of wind turbines where predictions are based on manufacturers noise data.

A_{bar}-Barrier Attenuation

The effect of a barrier (including a natural barrier) between a noise source and receptor is that noise will be reduced according to the path difference (difference between the direct distance between source to receptor and distance between source and receptor over the barrier). The reduction is relative to the frequency spectrum of the sound and may be predicted according to the method given in ISO 9613. In practice barriers can become less effective in downwind conditions. A barrier can be very effective when it lies within a few metres of the receptor. In the prediction model zero attenuation is given for barrier effects, which is a worst case scenario setting.

A_{atm} - Atmospheric Absorption

Sound emergency through the atmosphere is attenuated by conversion of sound energy to heat. This energy is dependent on the temperature and relatively humidity of the air through which the sound is travelling and is frequency dependent. The attenuation by atmospheric absorption depends on distance according to:

$A_{atm} = \alpha$

Where, d = distance from the turbine

α = atmospheric absorption coefficient in dBm^{-1}

The values used in the model are according to ISO 9613 and assumes atmospheric conditions of 10^0C and 70% relativity humidity. The octave band attenuation co-efficient at the various frequencies are given in Table 9.13 below.

Table 9.13: 1/1 Octave band coefficient (dB/m)

1/1Octave Band Attenuation Coefficients (dB/m)								
Octave Band (Hz)	63	125	250	500	1k	2k	4k	8k
dB/m	0.0001	0.0004	0.001	0.0019	0.0037	0.0097	0.0328	0.117

A_{misc} – Miscellaneous Other Effects

ISO 9613 includes effects of propagation through foliage, industrial plants and housing as additional attenuation effects. These have not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

The ISO 9613-2 standard calculates under downwind propagation conditions and therefore predicts the average downwind sound pressure level at each dwelling. Downwind propagation conditions are wind direction within +/- 45^0 of the direction connecting the dominant noise source and the receiver dwelling.

The prediction model is calculated as a worst-case scenario. As such, it has been shown by measurement–based studies that this model like others, tend to over-estimate the noise levels at nearby dwellings.

The predicted turbine noise has been adjusted by subtracting 2 dBA to give the equivalent L_{90} dBA level as suggested in ETSU-R-97 and the Proposed Revisions to the Wind Energy Development Guidelines 2006.

Tables 9.14 to 9.18 incl. gives the predicted noise levels at varying wind speed at the nearest noise sensitive residences. The following conservatism has been employed in the propagation modelling;

- down-wind propagation is modelled for all turbines so predicted values are over-estimated, upwind and cross wind. In practice dwellings in this development cannot be down-wind of all turbines simultaneously.
- although in reality the ground is predominately porous it has been modelled as mixed corresponding to a ground absorption coefficient of 0.5
- trees and other topography features have not been considered
- all dwellings were modelled at a receptor height of 4m. Using a 4m receptor height results in a more conservative result than using a 1.5m receptor height with the difference being more than 1dBA at 500m.
- the effects of wind shear has been taken into account in deriving the background noise levels with respect to wind speed. However, when using the 'Proposed Revisions to the Wind Energy Guidelines' as this amended report does with an noise limit of 40dBA (irrespective of wind speed) a background noise survey prior to making a planning application becomes unnecessary along with a plot of derived 10m height wind speed using wind shear calculations.

Table 9.14: Predicted noise levels at nearest houses expressed as $L_{90,\ 10min\ dBA}$

House id	Distance to Nearest Turbine (m)	Predicted noise levels L90dBA at varying wind speeds (m/s) 4	5	6	7	8	9	10
1	787	31.8	34.8	37.8	38.4	38.4	38.4	38.4
2	769	30.1	33.1	36.1	36.7	36.7	36.7	36.7
3	961	29.1	32.1	35.1	35.7	35.7	35.7	35.7
4	996	28.9	31.9	34.9	35.5	35.5	35.5	35.5
5	789	29.9	32.9	35.9	36.5	36.5	36.5	36.5
6	1024	27.7	30.7	33.7	34.3	34.3	34.3	34.3
7	1037	27.6	30.6	33.6	34.2	34.2	34.2	34.2
8	1054	27.5	30.5	33.5	34.1	34.1	34.1	34.1
9	1015	27.8	30.8	33.8	34.4	34.4	34.4	34.4
10	1032	27.7	30.7	33.7	34.3	34.3	34.3	34.3
11	1029	27.7	30.7	33.7	34.3	34.3	34.3	34.3
12	1020	27.7	30.7	33.7	34.3	34.3	34.3	34.3
13	994	27.9	30.9	33.9	34.5	34.5	34.5	34.5
14	983	28.0	31.0	34.0	34.6	34.6	34.6	34.6
15	992	27.9	30.9	33.9	34.5	34.5	34.5	34.5
16	722	32.0	35.0	38.0	38.6	38.6	38.6	38.6
17	1038	29.3	32.3	35.3	35.9	35.9	35.9	35.9
18	576	32.3	35.3	38.3	38.9	38.9	38.9	38.9
19	549	33.3	36.3	39.3	39.9	39.9	39.9	39.9
20	1108	26.7	29.7	32.7	33.3	33.3	33.3	33.3
21	957	28.1	31.1	34.1	34.7	34.7	34.7	34.7
22	1065	30.4	33.4	36.4	37.0	37.0	37.0	37.0
23	697	30.7	33.7	36.7	37.3	37.3	37.3	37.3
25	1109	28.1	31.1	34.1	34.7	34.7	34.7	34.7
26	854	30.2	33.2	36.2	36.8	36.8	36.8	36.8
29	825	30.5	33.5	36.5	37.1	37.1	37.1	37.1
30	963	29.1	32.1	35.1	35.7	35.7	35.7	35.7
32	1085	27.3	30.3	33.3	33.9	33.9	33.9	33.9
33	1105	27.2	30.2	33.2	33.8	33.8	33.8	33.8
36	778	32.8	35.8	38.8	39.4	39.4	39.4	39.4
37	738	32.9	35.9	38.9	39.5	39.5	39.5	39.5
41	662	33.4	36.4	39.4	40.0	40.0	40.0	40.0
42	1032	30.1	33.1	36.1	36.7	36.7	36.7	36.7
43	1004	27.8	30.8	33.8	34.4	34.4	34.4	34.4
44	1009	27.8	30.8	33.8	34.4	34.4	34.4	34.4
45	1010	27.8	30.8	33.8	34.4	34.4	34.4	34.4
46	1008	27.8	30.8	33.8	34.4	34.4	34.4	34.4
47	1000	27.9	30.9	33.9	34.5	34.5	34.5	34.5
48	988	28.0	31.0	34.0	34.6	34.6	34.6	34.6
49	977	28.0	31.0	34.0	34.6	34.6	34.6	34.6
50	964	28.1	31.1	34.1	34.7	34.7	34.7	34.7
51	956	28.2	31.2	34.2	34.8	34.8	34.8	34.8
52	945	28.3	31.3	34.3	34.9	34.9	34.9	34.9
53	951	28.2	31.2	34.2	34.8	34.8	34.8	34.8
54	967	28.1	31.1	34.1	34.7	34.7	34.7	34.7
55	973	28.1	31.1	34.1	34.7	34.7	34.7	34.7
56	987	28.0	31.0	34.0	34.6	34.6	34.6	34.6

Table 9.15: Predicted noise levels at nearest houses expressed as $L_{90,\ 10min\ dBA}$

House id	Distance to Nearest Turbine (m)	Predicted noise levels L90dBA at varying wind speeds (m/s) 4	5	6	7	8	9	10
57	992	27.9	30.9	33.9	34.5	34.5	34.5	34.5
58	670	31.1	34.1	37.1	37.7	37.7	37.7	37.7
59	809	31.3	34.3	37.3	37.9	37.9	37.9	37.9
60	902	29.3	32.3	35.3	35.9	35.9	35.9	35.9
61	884	29.4	32.4	35.4	36.0	36.0	36.0	36.0
62	561	32.7	35.7	38.7	39.3	39.3	39.3	39.3
63	667	31.1	34.1	37.1	37.7	37.7	37.7	37.7
64	715	30.6	33.6	36.6	37.2	37.2	37.2	37.2
65	593	32.6	35.6	38.6	39.2	39.2	39.2	39.2
66	622	33.6	36.6	39.6	40.2	40.2	40.2	40.2
67	772	31.9	34.9	37.9	38.5	38.5	38.5	38.5
68	1098	29.4	32.4	35.4	36.0	36.0	36.0	36.0
69	631	31.6	34.6	37.6	38.2	38.2	38.2	38.2
74	1127	26.1	29.1	32.1	32.7	32.7	32.7	32.7
75	1130	26.1	29.1	32.1	32.7	32.7	32.7	32.7
77	580	33.4	36.4	39.4	40.0	40.0	40.0	40.0
79	679	32.6	35.6	38.6	39.2	39.2	39.2	39.2
80	993	28.2	31.2	34.2	34.8	34.8	34.8	34.8
81	571	32.9	35.9	38.9	39.5	39.5	39.5	39.5
82	565	32.5	35.5	38.5	39.1	39.1	39.1	39.1
83	727	31.1	34.1	37.1	37.7	37.7	37.7	37.7
85	1023	29.9	32.9	35.9	36.5	36.5	36.5	36.5
86	764	31.9	34.9	37.9	38.5	38.5	38.5	38.5
87	852	31.6	34.6	37.6	38.2	38.2	38.2	38.2
88	696	31.5	34.5	37.5	38.1	38.1	38.1	38.1
89	967	31.5	34.5	37.5	38.1	38.1	38.1	38.1
90	829	32.3	35.3	38.3	38.9	38.9	38.9	38.9
91	930	30.4	33.4	36.4	37.0	37.0	37.0	37.0
92	633	32.9	35.9	38.9	39.5	39.5	39.5	39.5
93	871	30.8	33.8	36.8	37.4	37.4	37.4	37.4
94	995	29.8	32.8	35.8	36.4	36.4	36.4	36.4
95	882	30.2	33.2	36.2	36.8	36.8	36.8	36.8
98	1126	28.3	31.3	34.3	34.9	34.9	34.9	34.9
99	1095	28.5	31.5	34.5	35.1	35.1	35.1	35.1
100	828	30.5	33.5	36.5	37.1	37.1	37.1	37.1
102	1069	28.5	31.5	34.5	35.1	35.1	35.1	35.1
103	1047	28.5	31.5	34.5	35.1	35.1	35.1	35.1
104	597	33.4	36.4	39.4	40.0	40.0	40.0	40.0
105	570	33.5	36.5	39.5	40.1	40.1	40.1	40.1
106	920	30.9	33.9	36.9	37.5	37.5	37.5	37.5
107	1264	29.5	32.5	35.5	36.1	36.1	36.1	36.1
108	1443	28.5	31.5	34.5	35.1	35.1	35.1	35.1
110	1088	28.6	31.6	34.6	35.2	35.2	35.2	35.2
111	521	33.3	36.3	39.3	39.9	39.9	39.9	39.9
112	561	33.4	36.4	39.4	40.0	40.0	40.0	40.0
113	1098	28.9	31.9	34.9	35.5	35.5	35.5	35.5
114	1052	28.5	31.5	34.5	35.1	35.1	35.1	35.1

Table 9.16: Predicted noise levels at nearest houses expressed as $L_{90,\ 10min\ dBA}$

House id	Distance to Nearest Turbine (m)	Predicted noise levels L90dBA at varying wind speeds (m/s) 4	5	6	7	8	9	10
115	1073	28.4	31.4	34.4	35.0	35.0	35.0	35.0
119	1120	26.3	29.3	32.3	32.9	32.9	32.9	32.9
120	1034	26.9	29.9	32.9	33.5	33.5	33.5	33.5
121	780	29.3	32.3	35.3	35.9	35.9	35.9	35.9
122	719	30.0	33.0	36.0	36.6	36.6	36.6	36.6
123	750	29.6	32.6	35.6	36.2	36.2	36.2	36.2
124	692	30.3	33.3	36.3	36.9	36.9	36.9	36.9
125	716	30.6	33.6	36.6	37.2	37.2	37.2	37.2
126	687	31.4	34.4	37.4	38.0	38.0	38.0	38.0
127	826	29.8	32.8	35.8	36.4	36.4	36.4	36.4
129	990	30.1	33.1	36.1	36.7	36.7	36.7	36.7
130	861	29.5	32.5	35.5	36.1	36.1	36.1	36.1
131	843	29.6	32.6	35.6	36.2	36.2	36.2	36.2
132	1092	28.4	31.4	34.4	35.0	35.0	35.0	35.0
133	629	32.6	35.6	38.6	39.2	39.2	39.2	39.2
134	604	32.8	35.8	38.8	39.4	39.4	39.4	39.4
135	825	32.7	35.7	38.7	39.3	39.3	39.3	39.3
136	905	30.2	33.2	36.2	36.8	36.8	36.8	36.8
137	882	29.7	32.7	35.7	36.3	36.3	36.3	36.3
138	510	33.5	36.5	39.5	40.1	40.1	40.1	40.1
139	563	32.9	35.9	38.9	39.5	39.5	39.5	39.5
140	562	32.9	35.9	38.9	39.5	39.5	39.5	39.5
141	622	32.1	35.1	38.1	38.7	38.7	38.7	38.7
142	680	31.8	34.8	37.8	38.4	38.4	38.4	38.4
143	931	30.2	33.2	36.2	36.8	36.8	36.8	36.8
144	988	30.0	33.0	36.0	36.6	36.6	36.6	36.6
145	930	31.9	34.9	37.9	38.5	38.5	38.5	38.5
146	818	29.8	32.8	35.8	36.4	36.4	36.4	36.4
147	828	31.5	34.5	37.5	38.1	38.1	38.1	38.1
150	739	32.1	35.1	38.1	38.7	38.7	38.7	38.7
151	606	31.9	34.9	37.9	38.5	38.5	38.5	38.5
152	927	31.9	34.9	37.9	38.5	38.5	38.5	38.5
153	749	33.0	36.0	39.0	39.6	39.6	39.6	39.6
154	1050	28.7	31.7	34.7	35.3	35.3	35.3	35.3
155	931	29.8	32.8	35.8	36.4	36.4	36.4	36.4
156	901	30.8	33.8	36.8	37.4	37.4	37.4	37.4
157	1037	29.6	32.6	35.6	36.2	36.2	36.2	36.2
158	807	28.9	31.9	34.9	35.5	35.5	35.5	35.5
162	1171	28.6	31.6	34.6	35.2	35.2	35.2	35.2
163	1395	28.6	31.6	34.6	35.2	35.2	35.2	35.2
164	1066	29.3	32.3	35.3	35.9	35.9	35.9	35.9
165	1073	29.4	32.4	35.4	36.0	36.0	36.0	36.0
166	1432	28.9	31.9	34.9	35.5	35.5	35.5	35.5
167	1143	29.6	32.6	35.6	36.2	36.2	36.2	36.2
168	1096	30.0	33.0	36.0	36.6	36.6	36.6	36.6
169	856	31.4	34.4	37.4	38.0	38.0	38.0	38.0
170	759	31.5	34.5	37.5	38.1	38.1	38.1	38.1

Table 9.17: Predicted noise levels at nearest houses expressed as $L_{90,\ 10min\ dBA}$

House id	Distance to Nearest Turbine (m)	Predicted noise levels L90dBA at varying wind speeds (m/s) 4	5	6	7	8	9	10
171	701	31.7	34.7	37.7	38.3	38.3	38.3	38.3
172	613	32.6	35.6	38.6	39.2	39.2	39.2	39.2
173	566	33.4	36.4	39.4	40.0	40.0	40.0	40.0
175	1090	28.8	31.8	34.8	35.4	35.4	35.4	35.4
176	1113	28.5	31.5	34.5	35.1	35.1	35.1	35.1
177	1149	29.5	32.5	35.5	36.1	36.1	36.1	36.1
178	1201	29.7	32.7	35.7	36.3	36.3	36.3	36.3
179	748	31.5	34.5	37.5	38.1	38.1	38.1	38.1
181	680	30.7	33.7	36.7	37.3	37.3	37.3	37.3
182	643	31.1	34.1	37.1	37.7	37.7	37.7	37.7
185	1001	28.8	31.8	34.8	35.4	35.4	35.4	35.4
186	934	29.6	32.6	35.6	36.2	36.2	36.2	36.2
187	1098	29.0	32.0	35.0	35.6	35.6	35.6	35.6
188	1378	28.4	31.4	34.4	35.0	35.0	35.0	35.0
190	1090	28.6	31.6	34.6	35.2	35.2	35.2	35.2
191	890	29.6	32.6	35.6	36.2	36.2	36.2	36.2
192	915	29.4	32.4	35.4	36.0	36.0	36.0	36.0
193	779	31.1	34.1	37.1	37.7	37.7	37.7	37.7
194	568	32.6	35.6	38.6	39.2	39.2	39.2	39.2
195	627	33.3	36.3	39.3	39.9	39.9	39.9	39.9
196	589	33.4	36.4	39.4	40.0	40.0	40.0	40.0
197	771	32.6	35.6	38.6	39.2	39.2	39.2	39.2
198	992	30.8	33.8	36.8	37.4	37.4	37.4	37.4
199	656	33.0	36.0	39.0	39.6	39.6	39.6	39.6
200	656	33.5	36.5	39.5	40.1	40.1	40.1	40.1
203	805	31.4	34.4	37.4	38.0	38.0	38.0	38.0
204	746	31.9	34.9	37.9	38.5	38.5	38.5	38.5
205	794	31.7	34.7	37.7	38.3	38.3	38.3	38.3
207	718	33.3	36.3	39.3	39.9	39.9	39.9	39.9
208	780	32.5	35.5	38.5	39.1	39.1	39.1	39.1
209	907	31.7	34.7	37.7	38.3	38.3	38.3	38.3
210	452	35.4	38.4	41.4	42.0	42.0	42.0	42.0
211	619	33.2	36.2	39.2	39.8	39.8	39.8	39.8
212	1100	27.5	30.5	33.5	34.1	34.1	34.1	34.1
213	844	31.7	34.7	37.7	38.3	38.3	38.3	38.3
214	765	31.9	34.9	37.9	38.5	38.5	38.5	38.5
216	918	29.4	32.4	35.4	36.0	36.0	36.0	36.0
217	994	28.7	31.7	34.7	35.3	35.3	35.3	35.3
218	1054	27.9	30.9	33.9	34.5	34.5	34.5	34.5
219	838	29.3	32.3	35.3	35.9	35.9	35.9	35.9
220	1183	27.1	30.1	33.1	33.7	33.7	33.7	33.7
221	1070	27.5	30.5	33.5	34.1	34.1	34.1	34.1
222	879	28.9	31.9	34.9	35.5	35.5	35.5	35.5
223	936	28.4	31.4	34.4	35.0	35.0	35.0	35.0
224	1075	27.5	30.5	33.5	34.1	34.1	34.1	34.1
226	485	35.0	38.0	41.0	41.6	41.6	41.6	41.6
227	1118	28.1	31.1	34.1	34.7	34.7	34.7	34.7

Table 9.18: Predicted noise levels at nearest houses expressed as $L_{90,\ 10min\ dBA}$

House id	Distance to Nearest Turbine (m)	Predicted noise levels L90dBA at varying wind speeds (m/s) 4	5	6	7	8	9	10
228	1100	29.5	32.5	35.5	36.1	36.1	36.1	36.1
229	933	31.0	34.0	37.0	37.6	37.6	37.6	37.6
230	975	31.4	34.4	37.4	38.0	38.0	38.0	38.0
233	747	32.8	35.8	38.8	39.4	39.4	39.4	39.4
234	1148	29.8	32.8	35.8	36.4	36.4	36.4	36.4
236	940	28.4	31.4	34.4	35.0	35.0	35.0	35.0
237	623	32.8	35.8	38.8	39.4	39.4	39.4	39.4

Plots have been produced of the derived background (L90dBA) noise level. The plots (Figures 9.1 to 9.28 incl.) give the predicted noise levels versus the background noise level + 5dB and the fixed 40dBA noise limit for all wind speeds. The predicted turbine noise levels are shown in red, the 40dBA noise limit in orange and the derived background +5dBA are shown in green in all figures. Properties with a financial interest in the project are shown with a 45dBA noise limit.

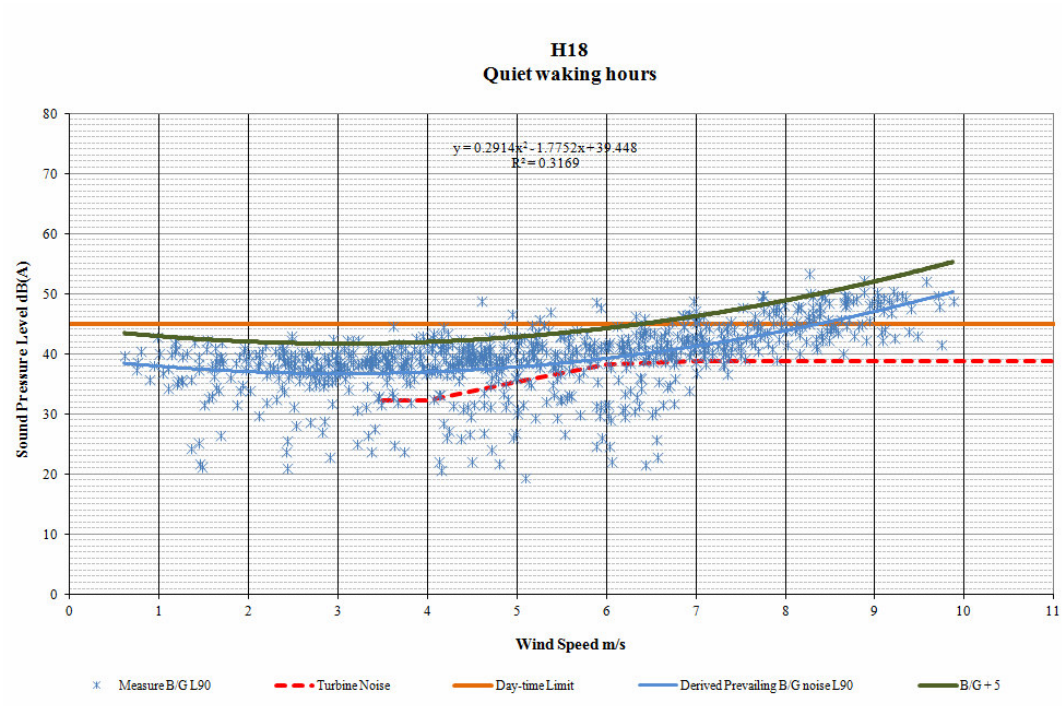

Figure 9. 1 shows that at H18 the total predicted turbine noise level is within the day time noise limit at all wind speeds (Financial interest)

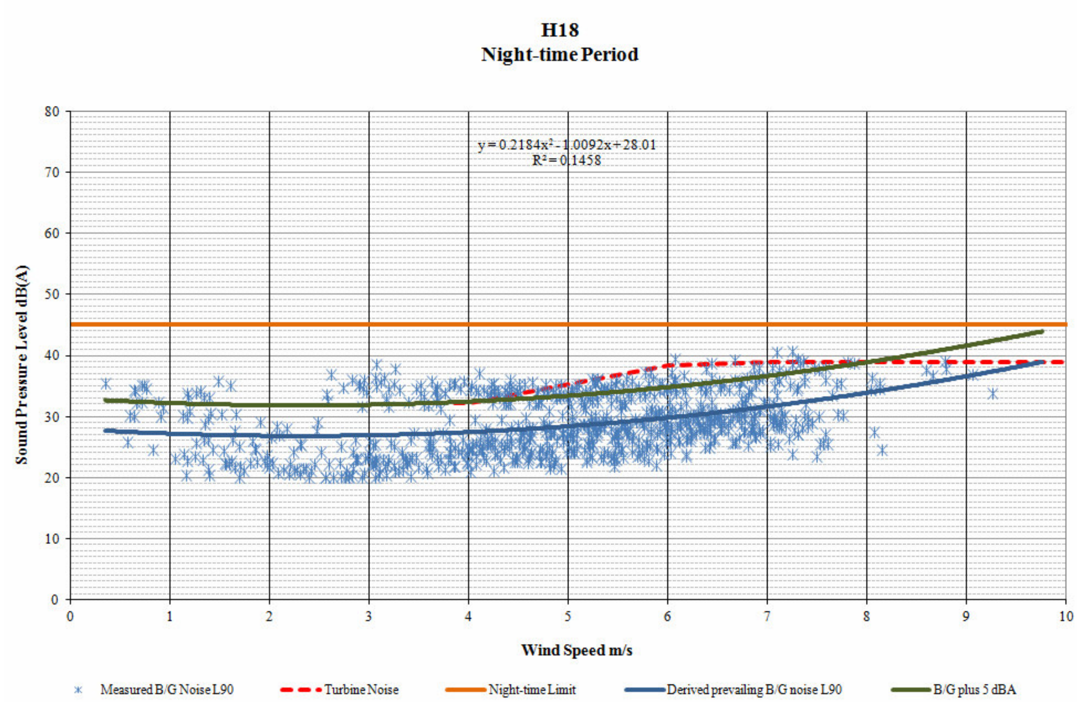

Figure 9.2: shows that at H18 the total predicted turbine noise level within the night time noise limit for all wind speeds (Financial interest)

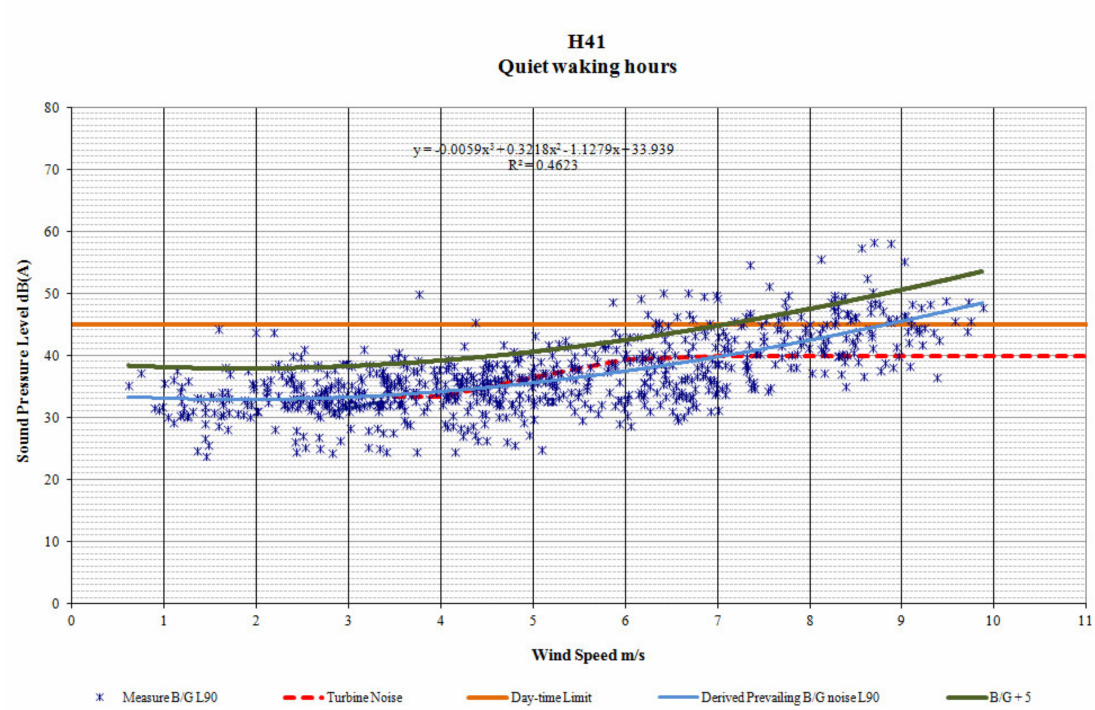

Figure 9.3 shows that at H41 the total predicted turbine noise level is within the day time noise limit at all wind speeds (Financial interest)

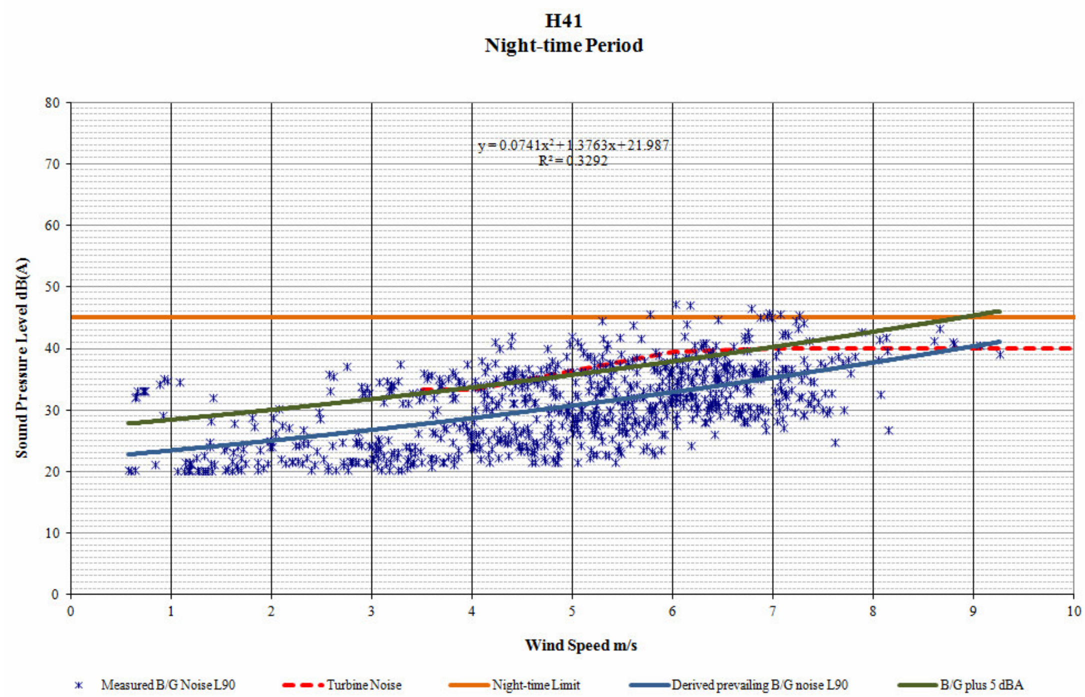

Figure 9.4 shows that at H41 the total predicted turbine noise level is within the night time noise limit at all wind speeds (Financial interest)

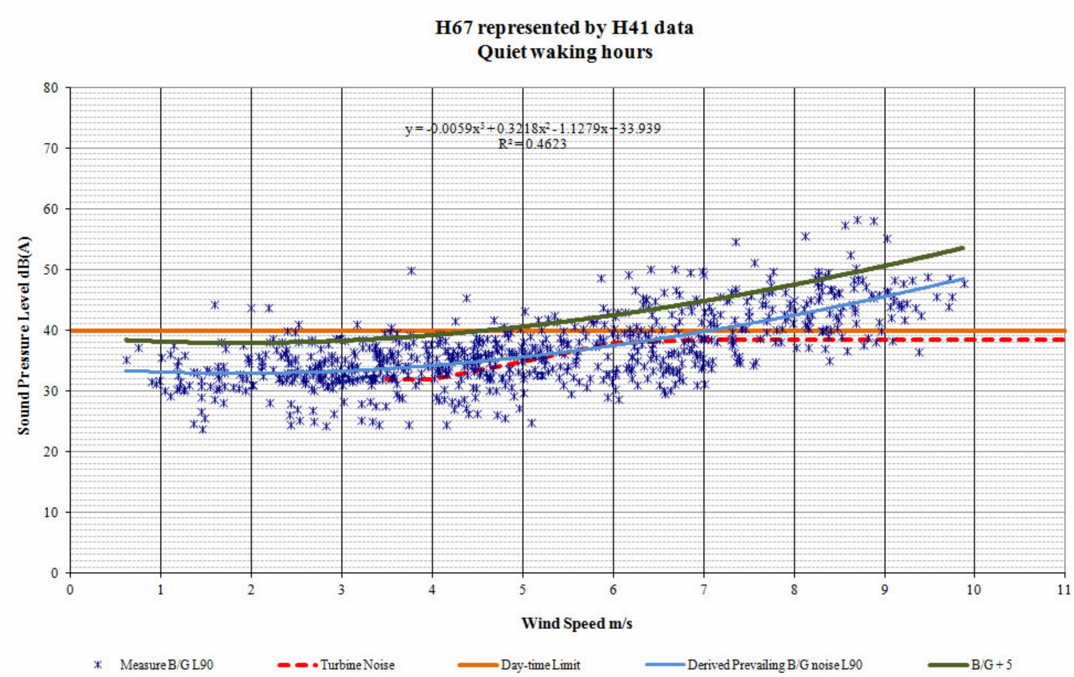

Figure 9.5 shows that at H67 the total predicted turbine noise level is within the day time noise limit at all wind speeds

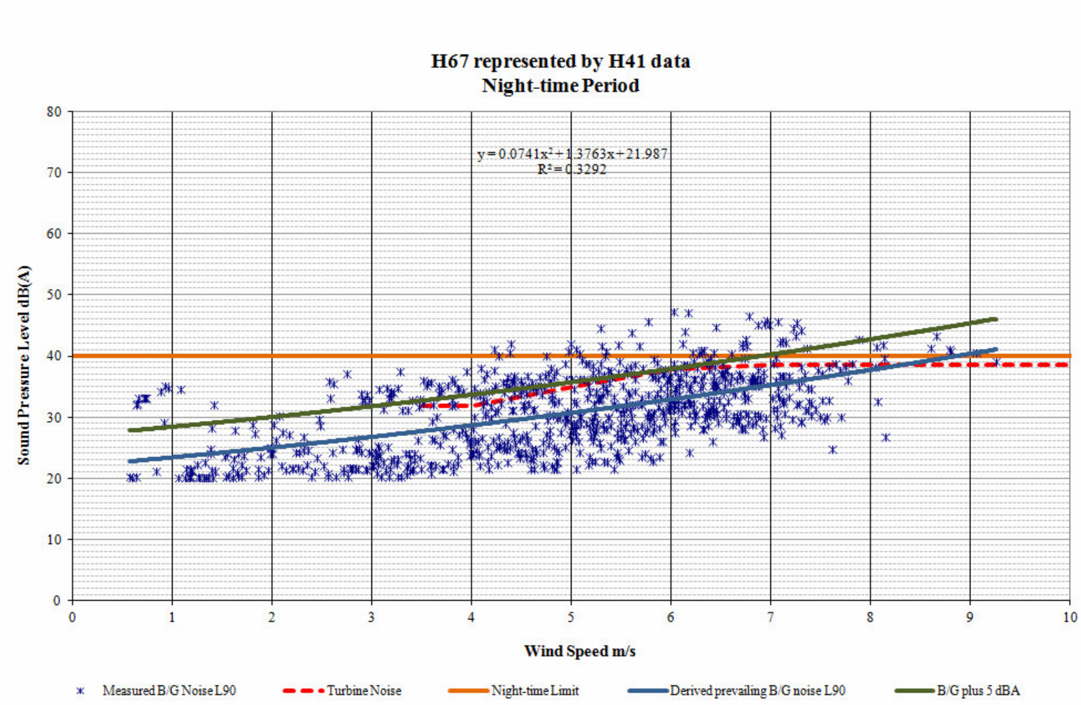

Figure 9.6 shows that at H67 the total predicted turbine noise level is within the night time noise limit at all wind speeds

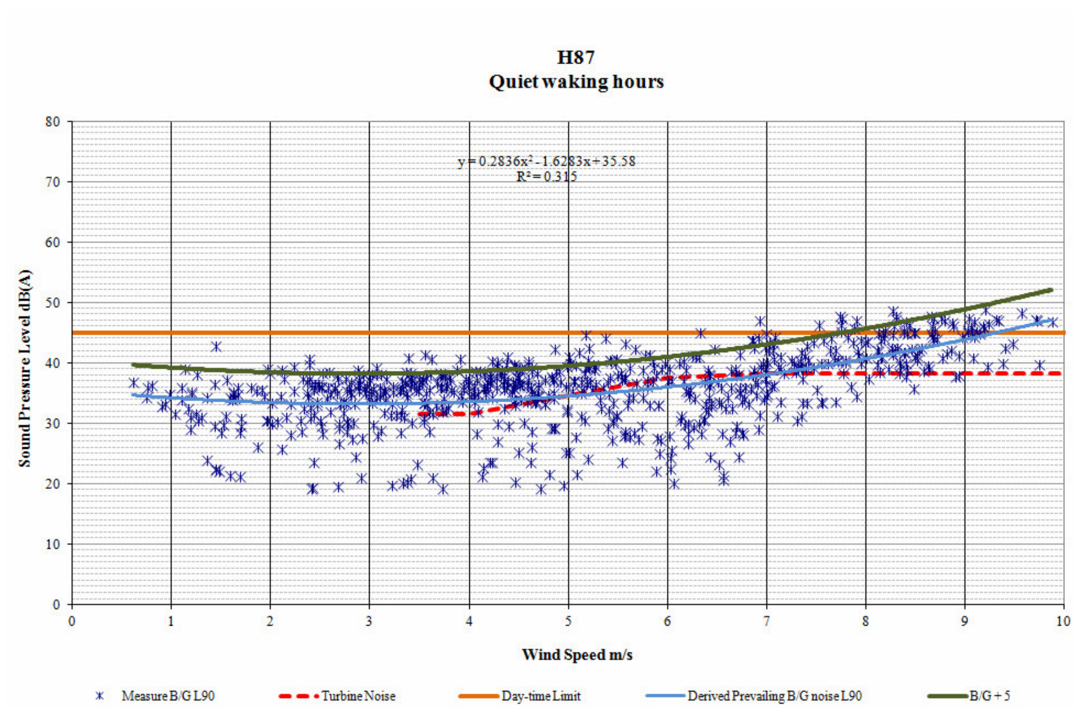

Figure 9.7 shows that at H87 the total predicted turbine noise level is within the day time noise limit at all wind speeds (Financial interest)

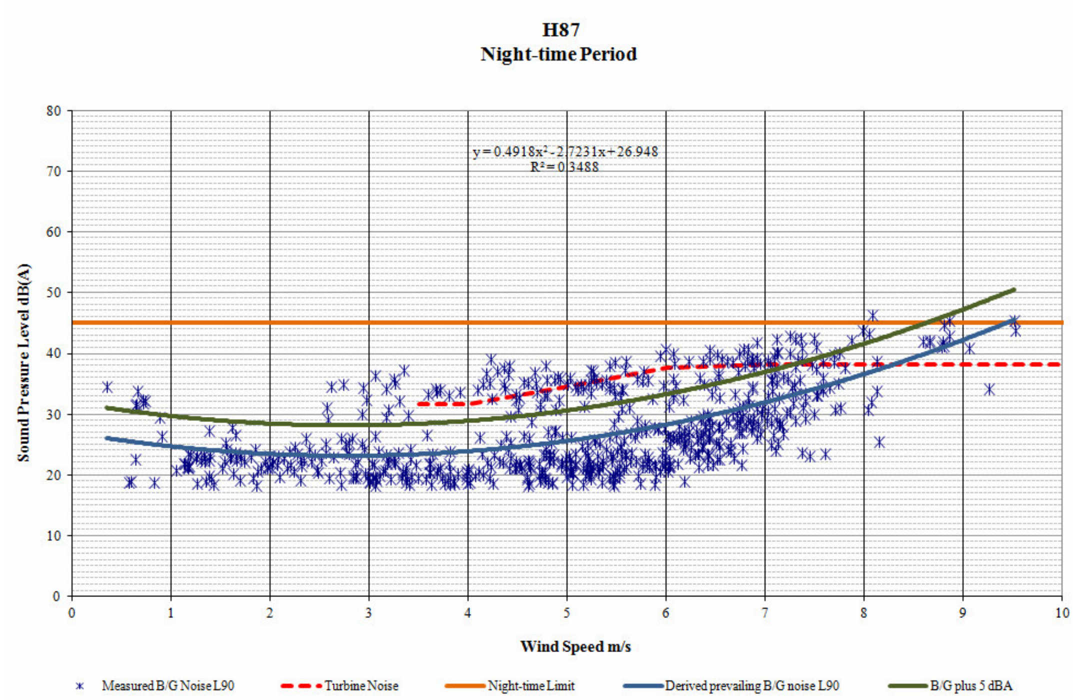

Figure 9.8: shows that at H87 the total predicted turbine noise level is within the night time noise limit al all wind speeds (Financial interest)

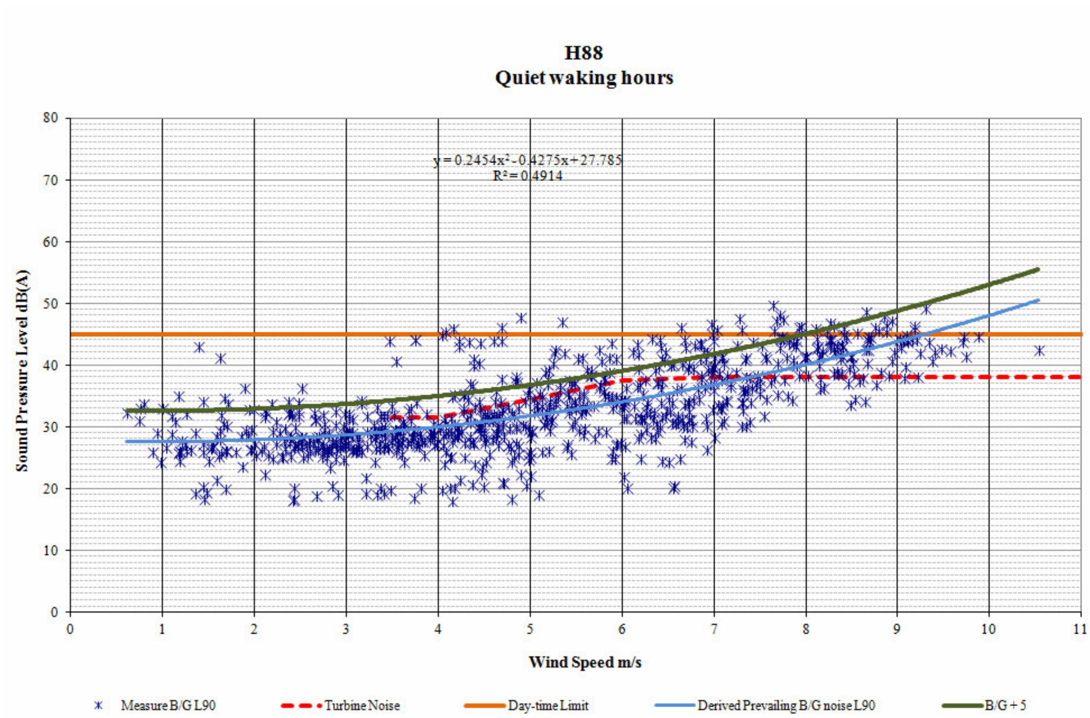

Figure 9.9: shows that at H88 the total predicted turbine noise level is within the day time noise limit at all wind speeds (Financial interest)

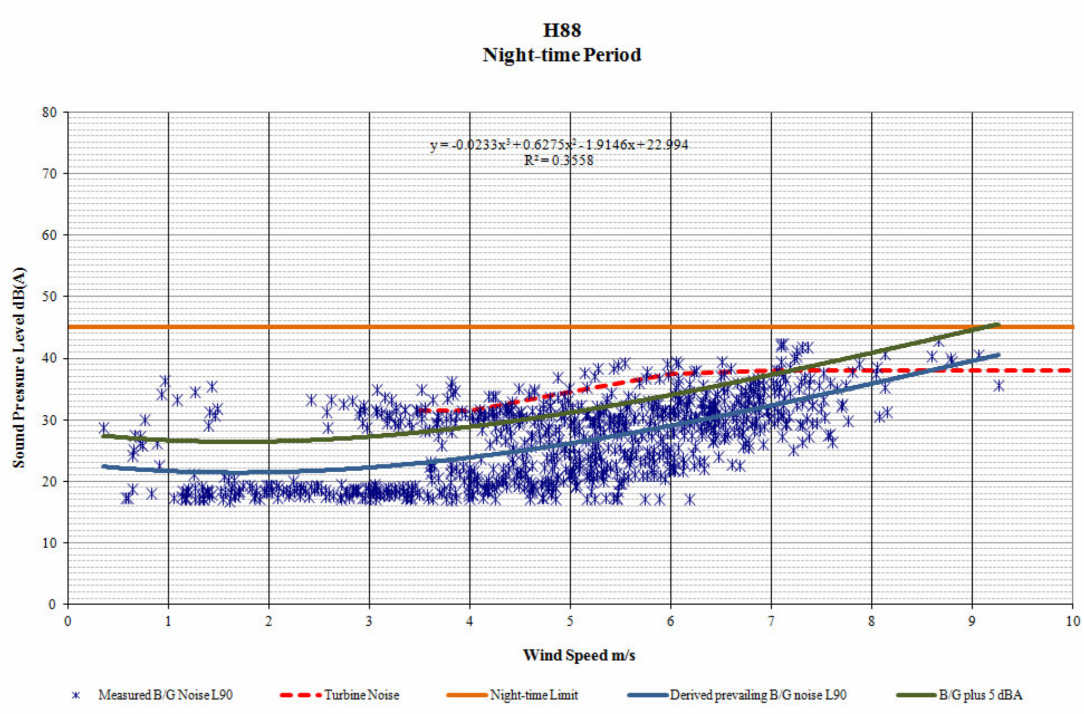

Figure 9.10: shows that at H88 the total predicted turbine noise level is within the night time noise limit at all wind speeds (Financial Interest)

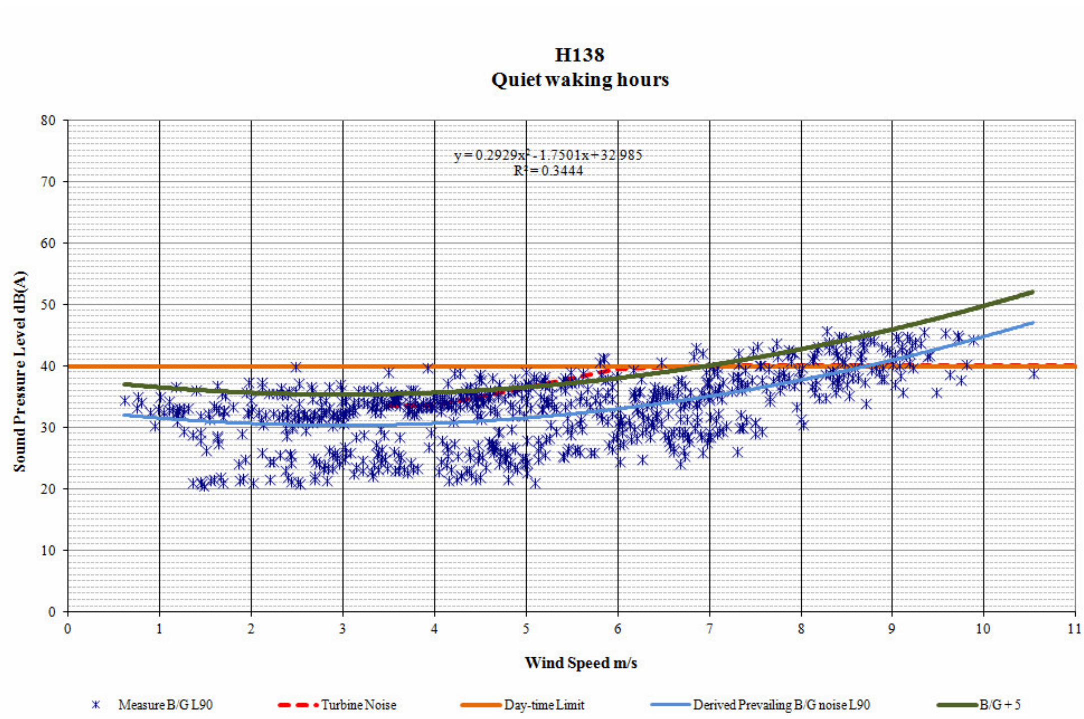

Figure 9.11: shows that at H138 the total predicted turbine noise level is 0.1dB above the day time noise limit at above 6m/s

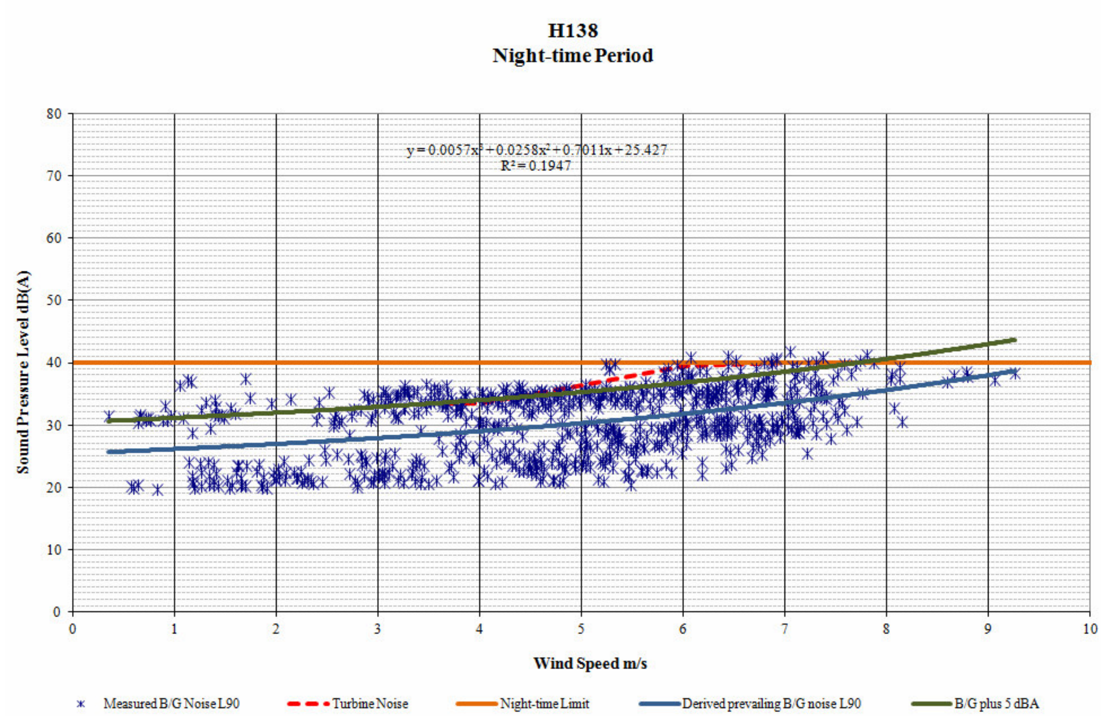

Figure 9.12: shows that at H138 the total predicted turbine noise level is 0.1dB above the day time noise limit at above 6m/s

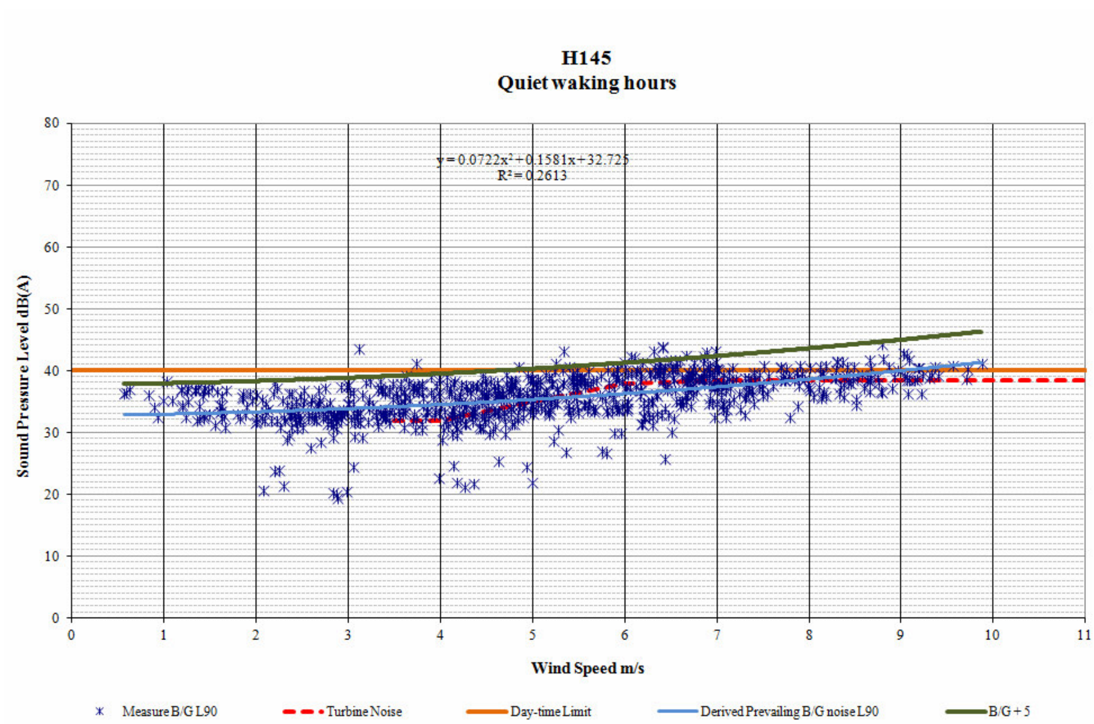

Figure 9.13: shows that at H145 the total predicted turbine noise level is within the day time noise limit at all wind speeds

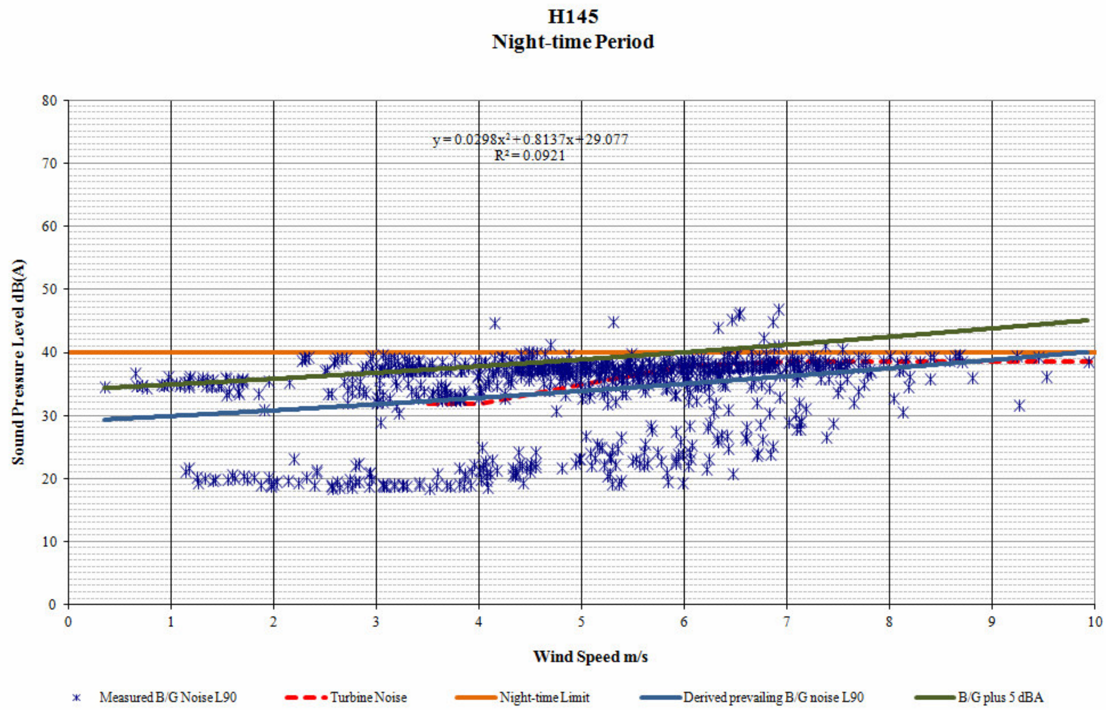

Figure 9.14: shows that at H145 the total predicted turbine noise level is within the night time noise limit at all wind speeds

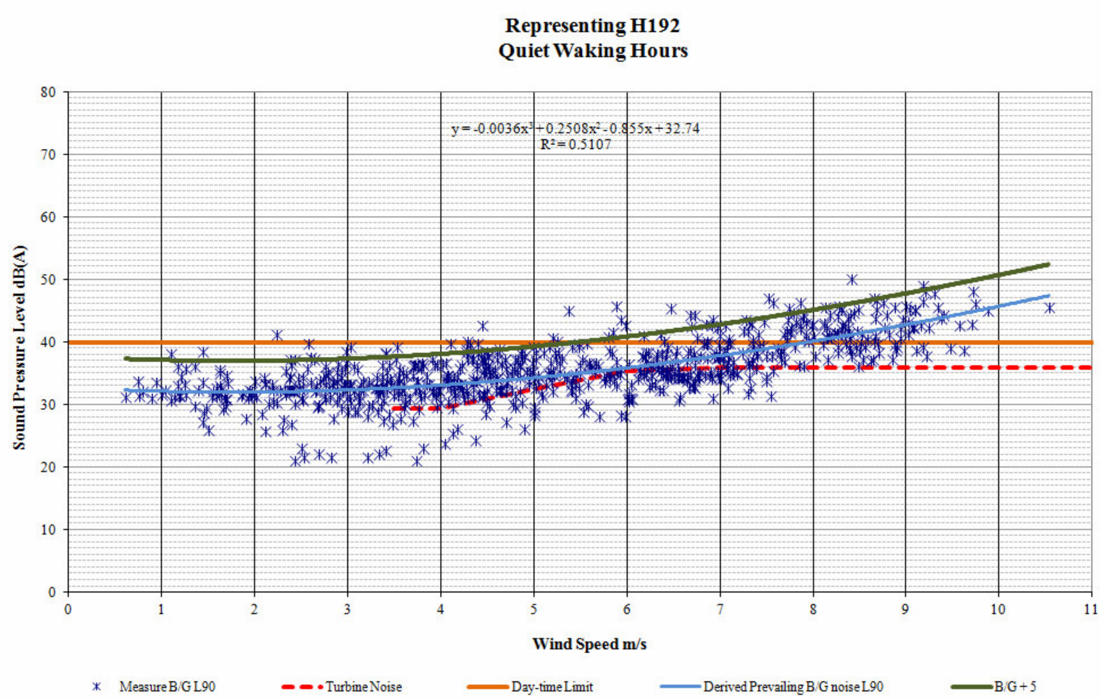

Figure 9.15: shows that at H192 the total predicted turbine noise level is within the day time noise limit at all wind speeds

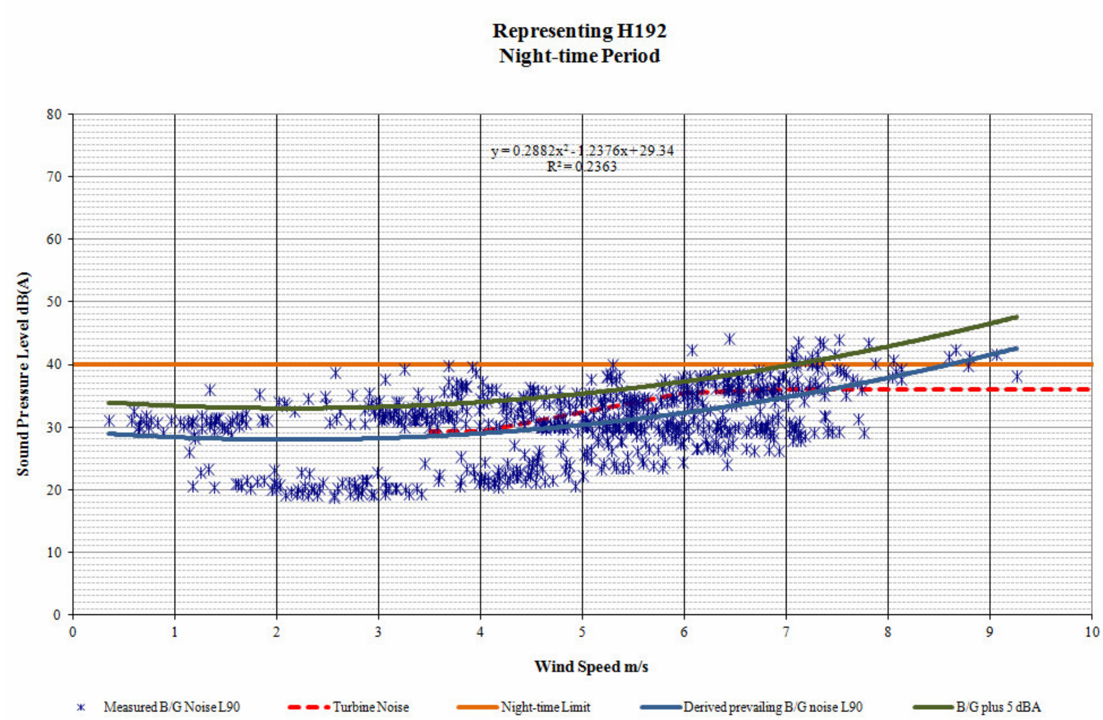

Figure 9.16: shows that at H192 the total predicted turbine noise level is within the night time noise limit at all wind speeds

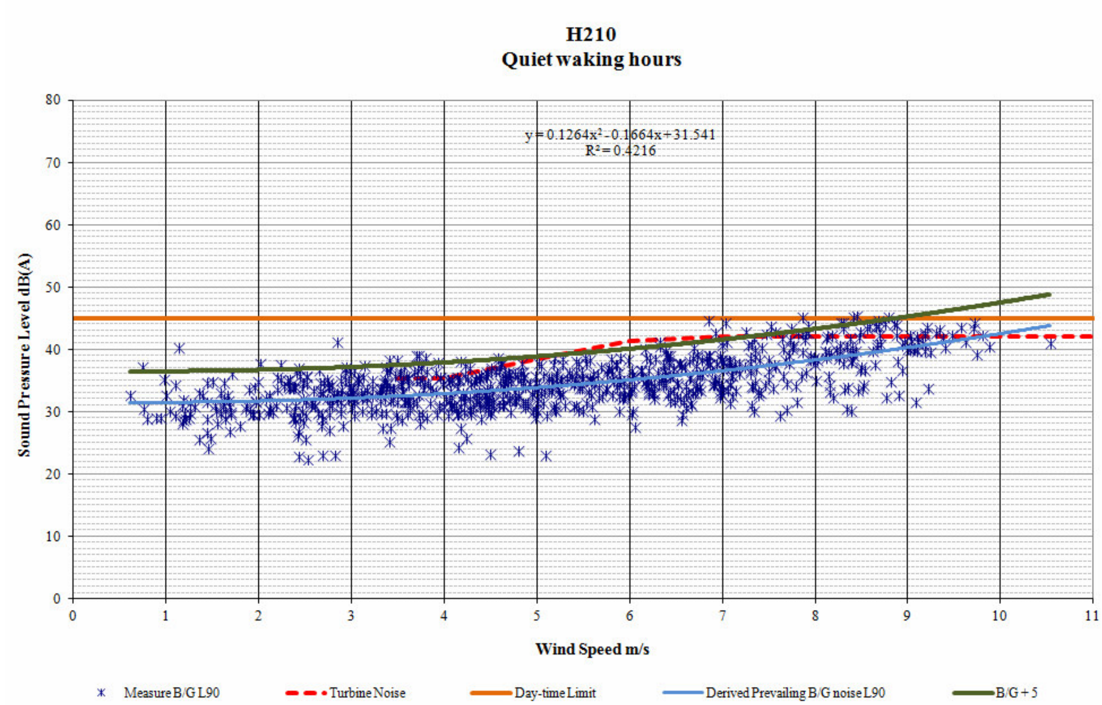

Figure 9.17: shows that at H210 the total predicted turbine noise level is within the day time noise limit at all wind speeds (Financial interest)

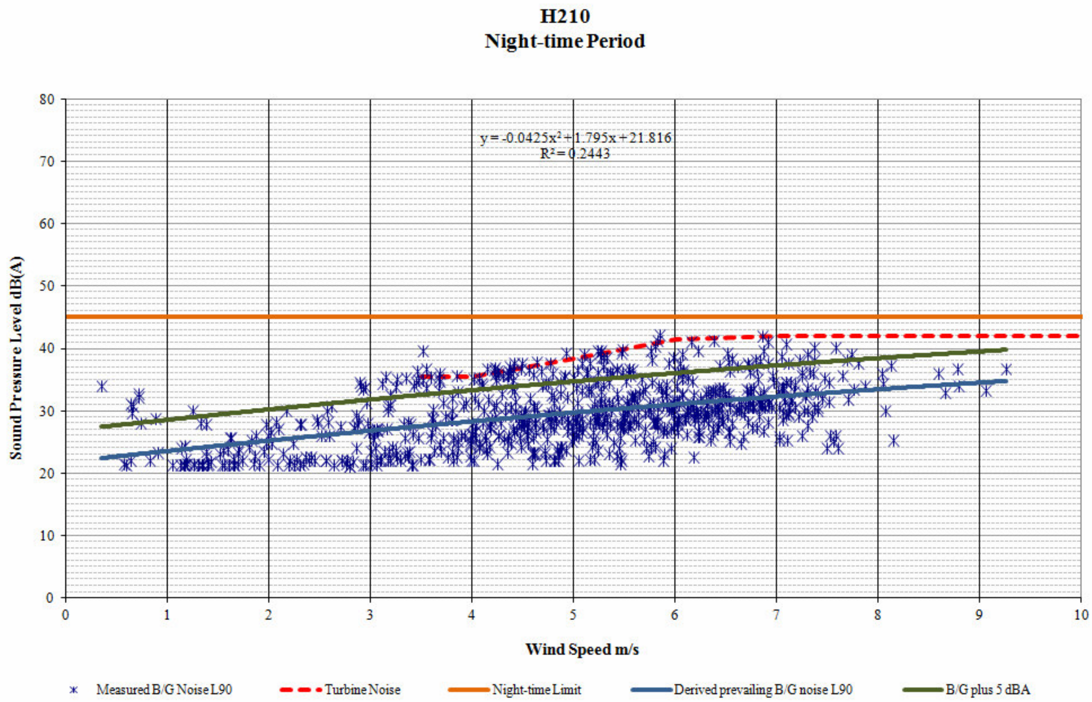

Figure 9.18: shows that at H210 the total predicted turbine noise level is within the night time noise limit at all wind speeds (Financial interest)

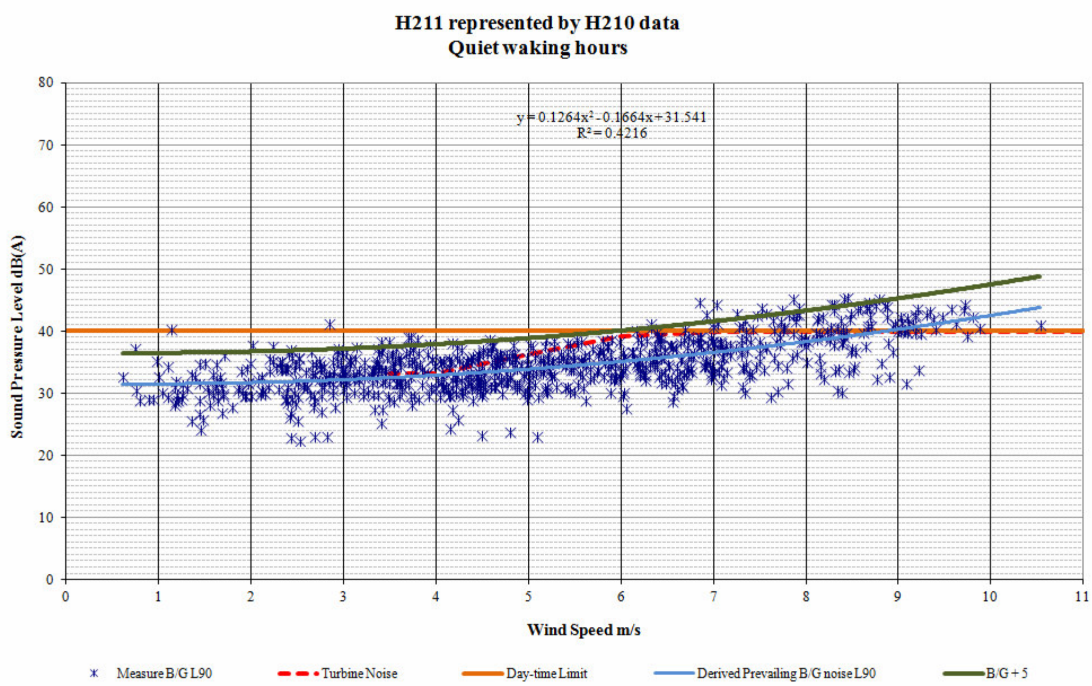

Figure 9.19: shows that at H211 the total predicted turbine noise level is within the day time noise limit at all wind speeds

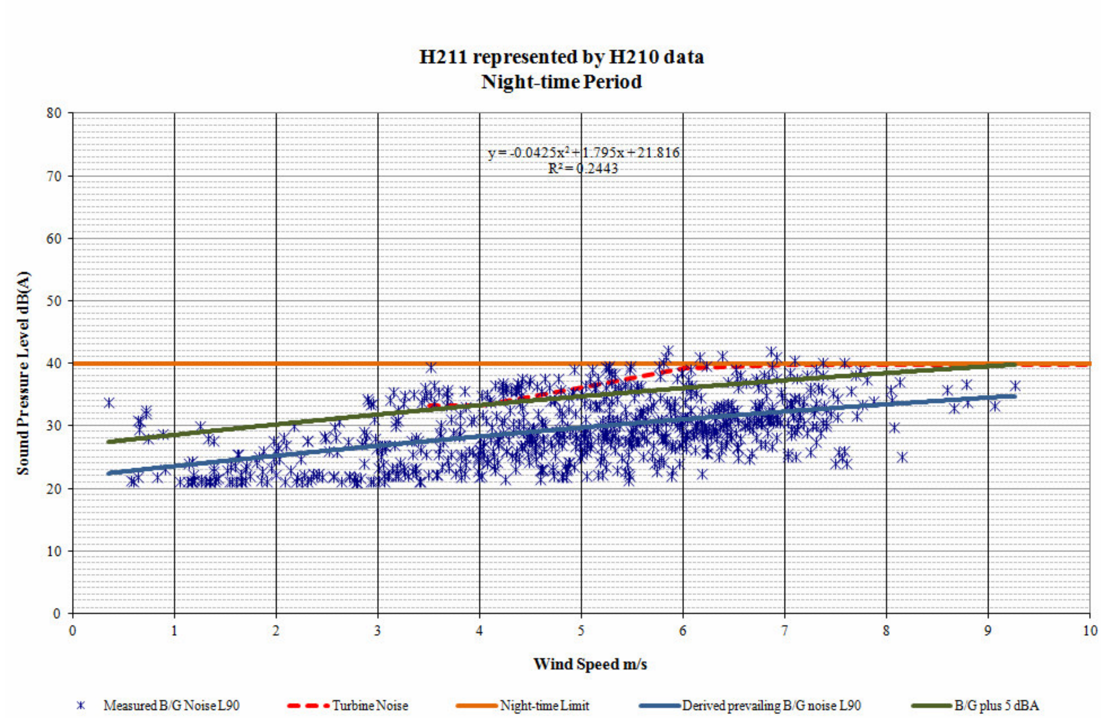

Figure 9.20: shows that at H211 the total predicted turbine noise level is within the night time noise limit at all wind speeds

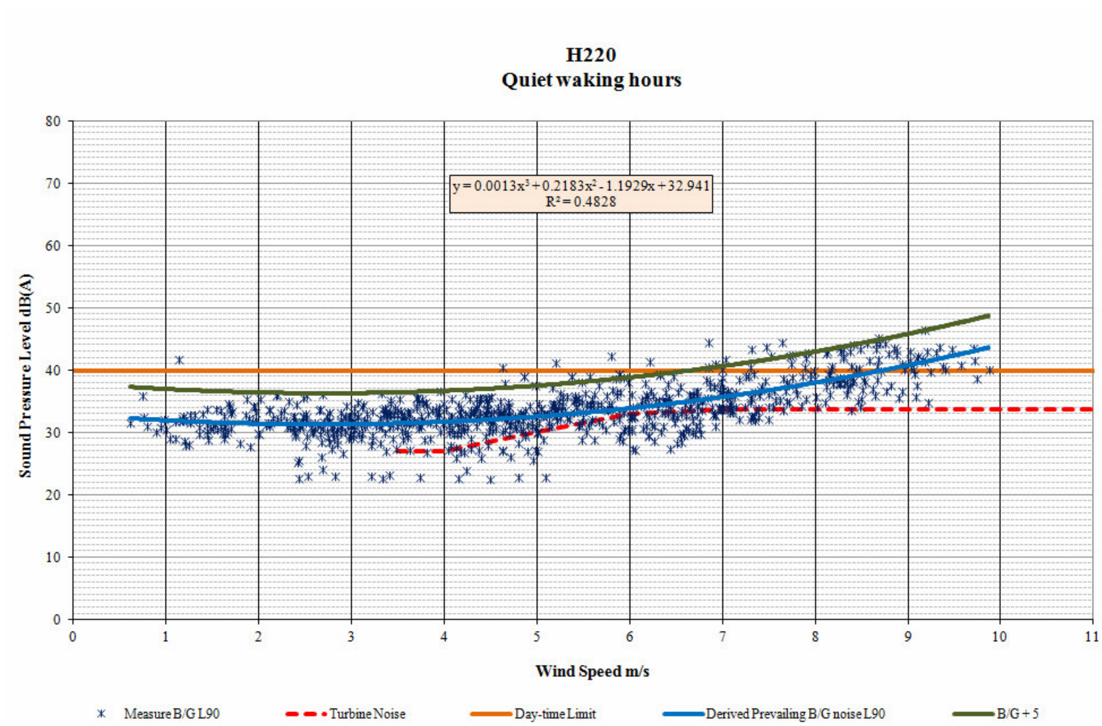

Figure 9.21: shows that at H220 the total predicted turbine noise level is within the day time noise limit at all wind speeds

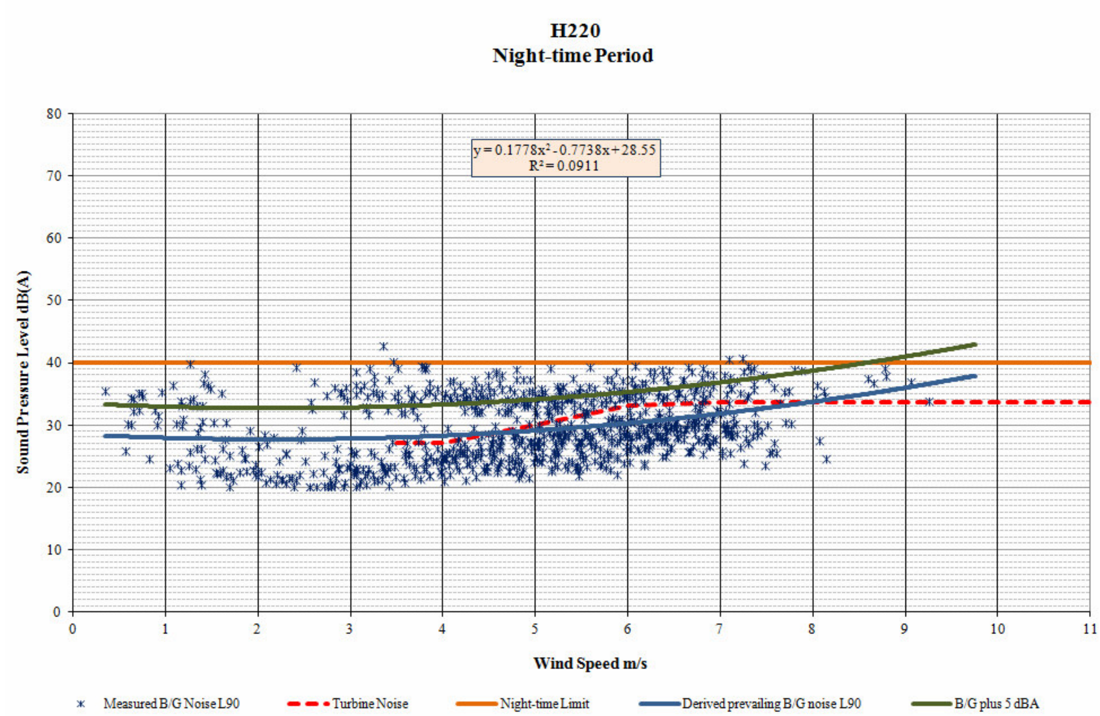

Figure 9.22: shows that at H220 the total predicted turbine noise level is within the night time noise limit at all wind speeds

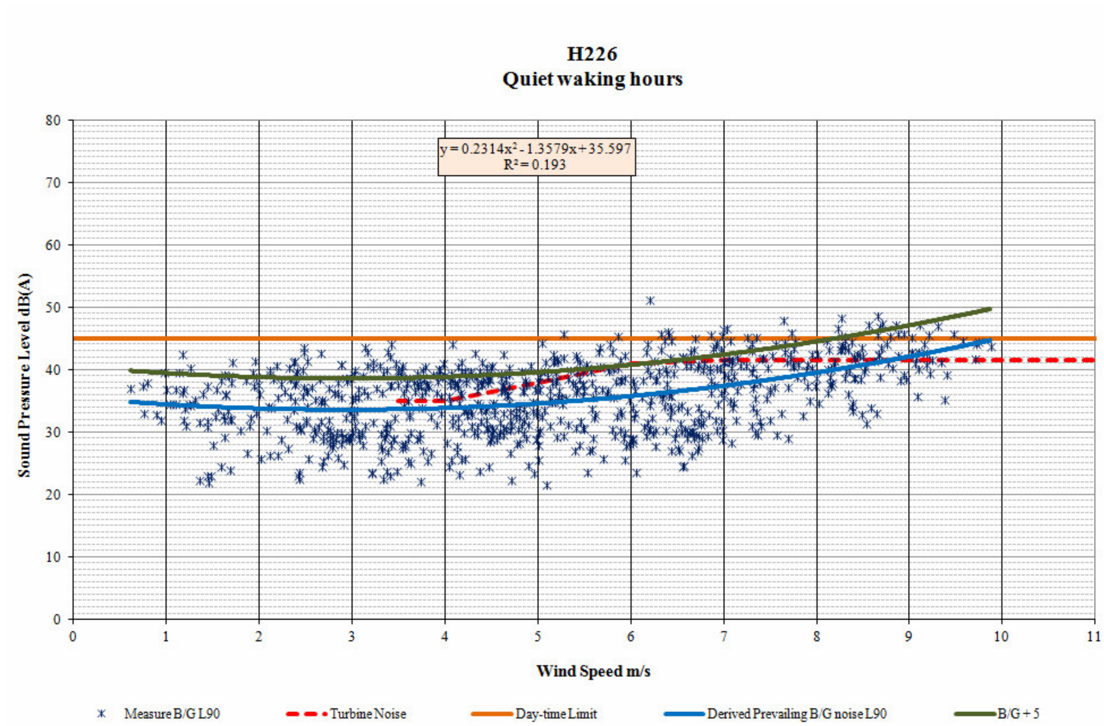

Figure 9.23: shows that at H226 the total predicted turbine noise level is within the day time noise limit at all wind speeds (Financial interest)

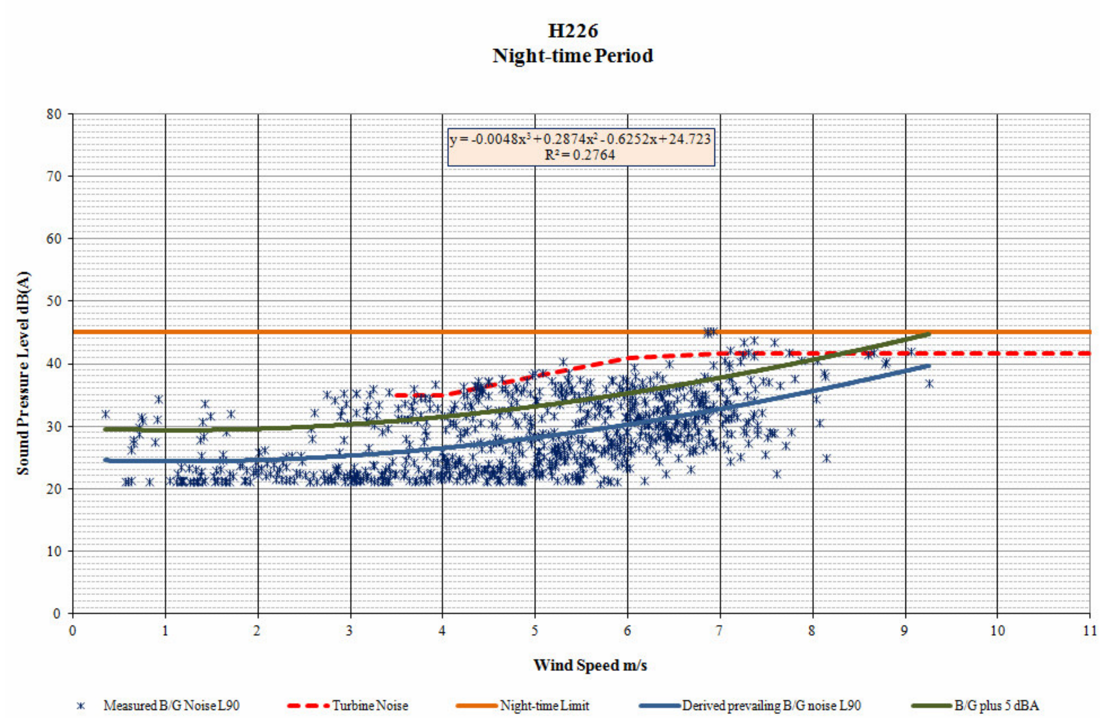

Figure 9.24: shows that at H226 the total predicted turbine noise level is within the night time noise limit at all wind speeds (Financial interest)

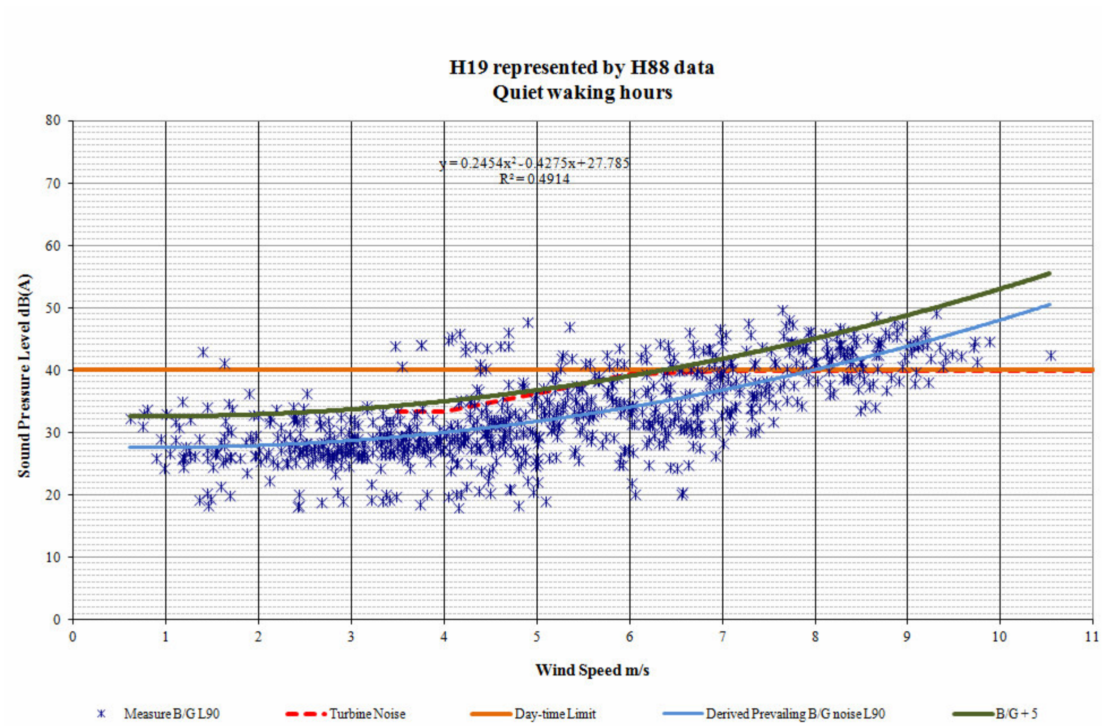

Figure 9.25: shows that at H19 the total predicted turbine noise level is within the day time noise limit at all wind speeds

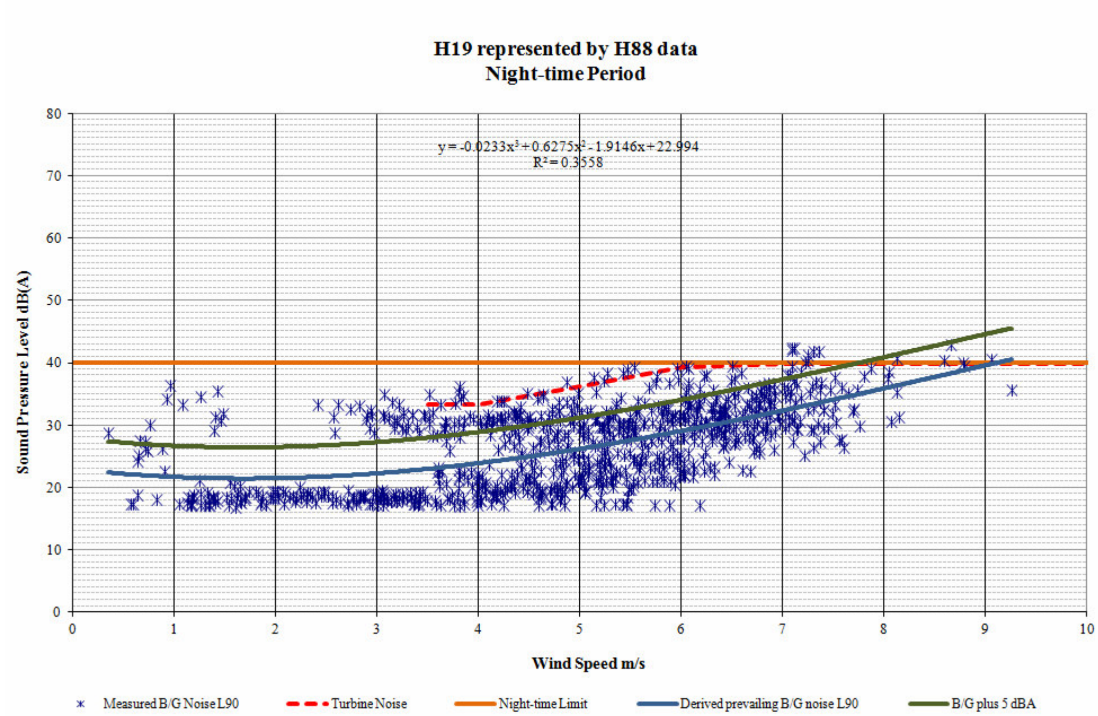

Figure 9.26: shows that at H19 the total predicted turbine noise level is within the night time noise limit at all wind speeds

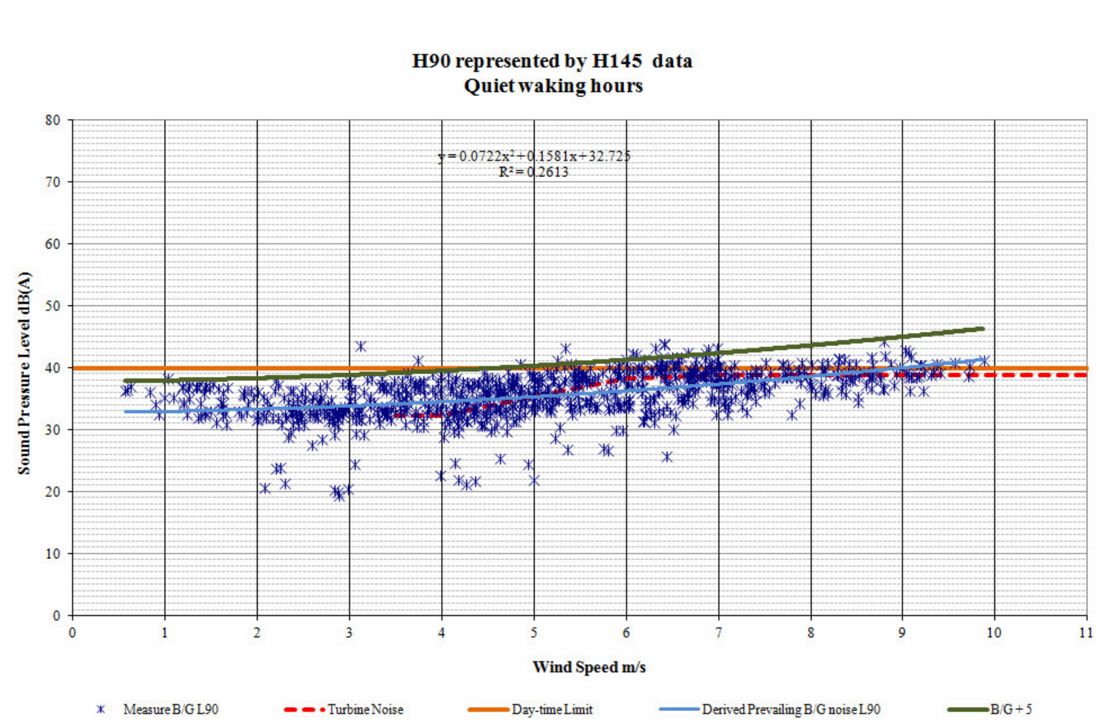

Figure 9.27: shows that at H90 the total predicted turbine noise level is within the day time noise limit at all wind speeds

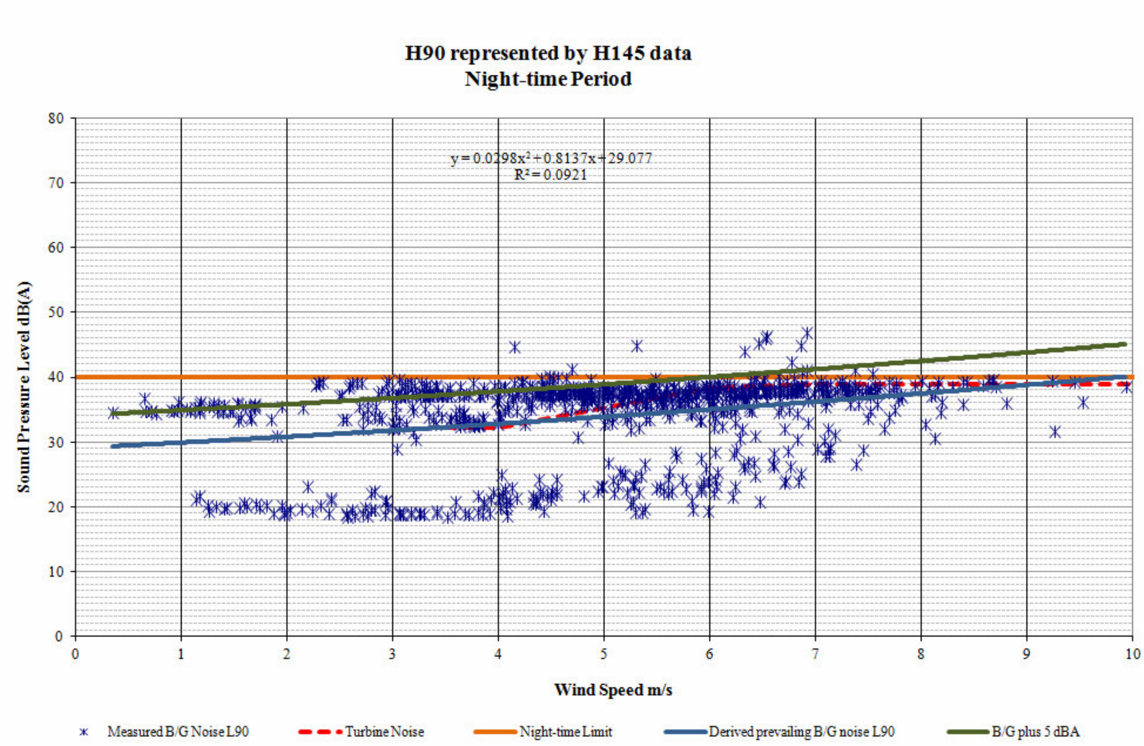

Figure 9.28: shows that at H90 the total predicted turbine noise level is within the night time noise limit at all wind speeds

9.5 Assessment of Noise Levels

The predicted noise levels in Tables 9.14 to 9.18 and examples shown in illustration Figures 9.1 to 9.28 inclusive shows that the predicted noise levels for all residents with no financial interest are below the 40dBA adopted noise limit for day and night at all wind speeds, except for H66, H105, H138 and H200 where the predicted levels marginally exceed the limit by 0.1 to 0.2 dB. In practice the noise levels will be below these predicted values by more than 1.5dBA as the noise predictions assume that the wind direction at these locations will be up-wind and down-wind simultaneously, a situation that can never happen in practice.

There are two residents with financial interest in the project who have predicted noise levels above the 40dBA limit (H210 and H226) , however these residents have provided written evidence in support of the project and are aware of the noise levels predicted at their property.

The houses along the road north-west of T22 and south-east of T24, will have noise levels of more than 1.5dBA below the predicted levels as the wind cannot be blowing down-wind and up-wind simultaneously.

9.6 Aerodynamic Modulation

Aerodynamic modulation (AM) is a highly complex field, and whilst general principles are understood there are still unanswered questions. AM is defined as aerodynamic noise which displays a greater degree of fluctuation than usual, which can occur in some circumstances much more than normal blade swish. A study carried out by the University of Salford in 2007 into operating wind farms found that the incidence of wind farm noise and AM in the UK is low and AM was considered to be a factor 4 sites.

The good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise published in May 2013 by the Institute of Acoustics gave no guidelines with respect to AM.

A report which has been published for Renewable UK; ‘Summary of Research into Amplitude Modulation of Aerodynamic Noise from Wind Turbines and a number of conclusions were made:

- Normal AM (NAM) is a fundamental characteristic of wind turbine noise and its casual mechanisms are well understood.
- Other AM (OAM) is defined in the study as AM whose characteristics cannot be described by the normal source generation mechanism of NAM.
- The influence of modulation on the impact of wind turbine noise decreases as the overall level of noise increases.
- Based on evidence available, the study recognises that even at those wind farms sites where OAM has been reported to be an issue, its occurrence may be relatively infrequent.
- The dominant descriptor of the human subjective response to wind turbine noise is the overall noise level e.g. LAeq, T, not the depth of modulation
- Should OAM arise from a scheme, turbine management systems can be used to control the individual turbines responsible so that the impacts are mitigated under particular conditions that give rise to the phenomenon on a case by case basis.

9.7 Assessment of Construction Noise

It is not possible to specify the precise noise levels emissions from the construction equipment until such time as a contractor is chosen and construction plant has been selected however, Table 9.19 indicates typical construction related noise levels. It is noted that noise generated by construction activities is associated with the short construction phase of the development.

Table 9.19: Typical construction noise from construction activity

Activity	**L_{Aeq} at 10m**
General Construction	70-84 dB(A)
Tracked excavator removing topsoil, subsoil for foundation	up to 87 dB(A)
Vibrating rollers	76-86 dB(A)

The construction activity at 500m from the operating point with attenuation by distance, ground absorption and air attenuation is 34 dB(A) for distance and 4 dB(A) ground absorption and air attenuation) will result in typical noise levels of between 35 and 48 dB L_{Aeq} with maximum levels of 52 dB L_{Aeq} during intensive activity. The maximum levels will pertain for no longer than two weeks-equivalent at any residence.

Maximum Permissible Construction Noise Levels

The following are guidelines recommended by the National Roads Authority:

Monday to Friday

07:00 – 19:00	70 dB $L_{Aeq(1h)}$ and L_{Amax} dB80
19:00 – 22:00	60 dB $L_{Aeq(1h)}$ and L_{Amax} dB65

Saturday

08:00 – 16:30 75 dB $L_{Aeq,12h}$ and L_{Amax} dB75

Sundays and Bank Holidays

08:00 – 16:00 60 dB $L_{Aeq,1h}$ and L_{Amax} dB65

.

The noise from the construction site will be kept well below the aforementioned targets and there will be no constructions works on Sundays.

Mitigation Measures for Construction Noise

All construction will be carried out in accordance with BS 5228-1: 2009 *Code of Practice for Noise and Vibration Control on Construction and Open Sites.* Accordingly all construction traffic to be used on site should have effective well-maintained silencers. Operators of all mobile equipment will be instructed to avoid unnecessary revving of machinery. Where possible the contractor will be instructed to use the least noisy equipment. With efficient use of well-maintained mobile equipment considerably lower noise levels than those predicted can be attained. The Project Engineer will closely supervise all construction activity. Construction activity due to its nature is a temporary activity and thus any impacts will be short term. All construction works will be carried out during the day-time period. Construction plant will be throttled down or turned off when not in productive use.

9.8 Low Frequency Noise and Vibration

The frequency range of audible sound is in the range of 20 to 20,000Hz and low frequency sound / noise is generally from about 2 to 200Hz. Low frequency sound is considerable audible at high amplitudes above 20Hz. Infrasound is sound that is generally inaudible to the human ear, at less than20Hz, however it may still interact with the body or structures and may be felt as vibrations (examples could be blasting or a window vibrating when a large truck passing nearby at low speed).

Researchers such as Leventhall have studied low frequency noise and found that levels were found to be below the hearing threshold of most people, and therefore the research concluded noise from the proposed wind farm installation in the low frequency (10 to 200Hz) range was unlikely to be a problem. However, significant research has also been carried out into low frequency noise in the area of blasting vibrations (air overpressure) which falls into the same frequency range, although with considerably higher magnitude. There appears to be little or no agreement about the biological effects of low frequency noise on human health and there is evidence to suggest that no serious consequences result to human health, from infrasound exposure from wind turbines.

There is always low frequency noise present in an ambient quiet background. It is generated by natural sources such as wind effects on vegetation, surf, water flow in streams and rivers and there are also emissions from many sources found in modern life, such as household appliances (e.g. washing machines, refrigerators, fans etc.). It can also be found in water flowing through pipes within your home and in water flow from municipal water supply. Vibration of structures can also be found in local activity in ones home by way of normal routine activity like climbing stairs, closing doors, walking on floors, etc.

A study of low frequency noise (infrasound) and vibration around a modern wind farm was carried out for ETSU and reported in ETSU W/13/00392/REP – '*Low Frequency Noise and Vibration Measurements at a Modern Wind Farm'*. The results showed levels of infrasound to be below accepted thresholds of perception even on the wind farm site. A recent study by the EPA in South Australia on low frequency noise near wind farms and in other environments found that 'Overall, the study demonstrates that low frequency noise levels near the wind farms in the study are no greater than levels in urban areas at comparable rural residences away from wind farms'. A paper presented at the 159th meeting of the Acoustical Society of America outlined the results of sound measurements from Siemens SWT-2.3 MW -93 turbines and concluded 'that at more than 1000ft (305m) the turbine model does not pose a low frequency noise or infrasound problem as it meets standards published by the American National Standards Institute (ANSI) for indoor levels for low frequency sound for bedrooms, classrooms and hospitals'.

9.9 Mitigation Measures

When the wind farm is commissioned noise monitoring of the operation over a range of wind speeds and direction can be used to demonstrate compliance with the adopted 40 dBA noise limit. The wind turbines have noise control systems in place whereby the noise emission of a turbine can be reduced by a number of means e.g. by wind direction by time of day, by reducing power outputs. .

Noise impacts from the construction and operation of the proposed development will not be significant or adverse.

9.10 Conclusion

An assessment of the likely noise impact of the proposed wind farm development has been carried out. Baseline noise levels measured at ten locations representative of the nearest residential properties to the proposed twenty nine turbines, and noise levels were predicted based on a maximum hub height of 110m.

The predicted noise levels are within the 40dBA noise limit for day time and night time given in the Proposed Revisions to the Wind Energy Development Guidelines, *Guidelines for Planning Authorities*, June 2006, except for H66, H105, H138 and H200 where the predicted levels marginally exceed the limit by 0.1 to 0.2 dB. In practice the noise levels at these four residents will be below these predicted values by more than 1.5dBA as the noise predictions assume that the wind direction at these locations will be up-wind and down-wind simultaneously, a situation that can never happen.

There are two residents with financial interest in the project who have predicted noise levels above the 40dBA limit (H210 and H226) , however these residents have provided written evidence in support of the project and are aware of the noise levels predicted at their property.

The prediction model is calculated as a worst-case scenario. As such, it has been shown by measurement–based studies that this model, like others, tends to over-estimate the noise levels at nearby dwellings. The following conservatism has been employed in the propagation modelling;

- down-wind propagation is modelled for all turbines so predicted values are over-estimated, upwind and cross wind. In practice a significant number of dwellings in this development cannot be down-wind of all turbines simultaneously.
- although in reality the ground is predominately porous it has been modelled as mixed corresponding to a ground absorption coefficient of 0.5
- trees and other topography features have not been considered
- all dwellings were modelled at a receptor height of 4m. Using a 4m receptor height results in a more conservative result than using a 1.5m receptor height with the difference being more than 1dBA at distances >500m.

The low frequency noise and vibration from the turbines of the proposed Yellow River Wind Farm is predicted to have a negligible impact on all residences in the locality.

Any impacts associated with the construction of the Yellow River Wind Farm will be of a temporary nature, associated with the site preparation works and erection of the wind turbines.

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