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TECHNICAL MEMORANDUM

Project	10654 Kessingland Wind Farm	**Date**	18 May 2012
Memo to		**Memo No**	M001
From		**Checked by**	Adrian James

ANALYSIS OF DATA AND AUDIO RECORDINGS – NOISE COMPLAINTS, KESSINGLAND WIND FARM

Introduction

This memo sets out our analysis of noise data relating to the Kessingland wind farm, our own measurements and subjective assessments, and the analysis of complaints correlated with noise levels, wind direction and wind speed.

This is not an ETSU R97 assessment but an investigation of alleged noise nuisance. Compliance with ETSU R97 would not in itself be a defence against action under Section 80 or 82 of the Environmental Protection Act.

The planning consent for the turbines included conditions that require the noise from the turbines to comply with criteria set out in ETSU R97 the Assessment and Rating of Noise from Wind Farms. The developer commissioned Atkins to undertake a pre-construction assessment and Hayes McKenzie Partnership to measure noise from the installed turbines to assess compliance with ETSU R97. Our comments on these assessments are contained in our document 10654/E01.

Data received

We have received and analysed the following data:

- **Complaints log** - Log of complaints received by Waveney District Council (WDC) relating to noise from Kessingland Wind Turbines for the period 13 June 2011 to 26 February 2012. This includes the time, date and location of the noise complaint along with notes on the nature of the complaint.
- **Meteorological data** - Data for wind speed, wind direction and ambient temperature at both wind turbines at hour intervals over the period 9 June 2011 to 26 February 2012 as supplied by Ecogen Ltd.

- **Ambient noise data** - Noise data measured over consecutive 10 minute periods by Hayes McKenzie Partnership Ltd (HMP) in the gardens of 48 Whites Lane and Rustyk House between 10 October 2011 and 31 October 2011. The turbines were turned off for one hour each night between 0200 and 0300 on 18 - 31 October 2011.
- **Audio Recordings** - 1 minute long recording samples recorded at ten minute intervals by HMP at 48 Whites Lane between 10 October and 14 October 2011, and 1 minute long recordings taken using WDC noise logging equipment inside a complainant's house in April and May 2011.

Specific Complaints

We have a log of 70 complaints in total over the period 13 June to 26 February 2012. Only two of these complaints occur within the 10-31 October noise monitoring period and neither of these falls within the HMP audio sampling period. It is therefore not possible to draw any significant conclusions from the direct analysis of the noise levels and audio recordings at times of specific complaints during HMP's noise monitoring.

Trends in complaints

The majority of complaints are clustered around an area to the north-east of the turbines as shown in Figure 1 below. This is to be expected because this is the most populated area in the vicinity of the turbines.

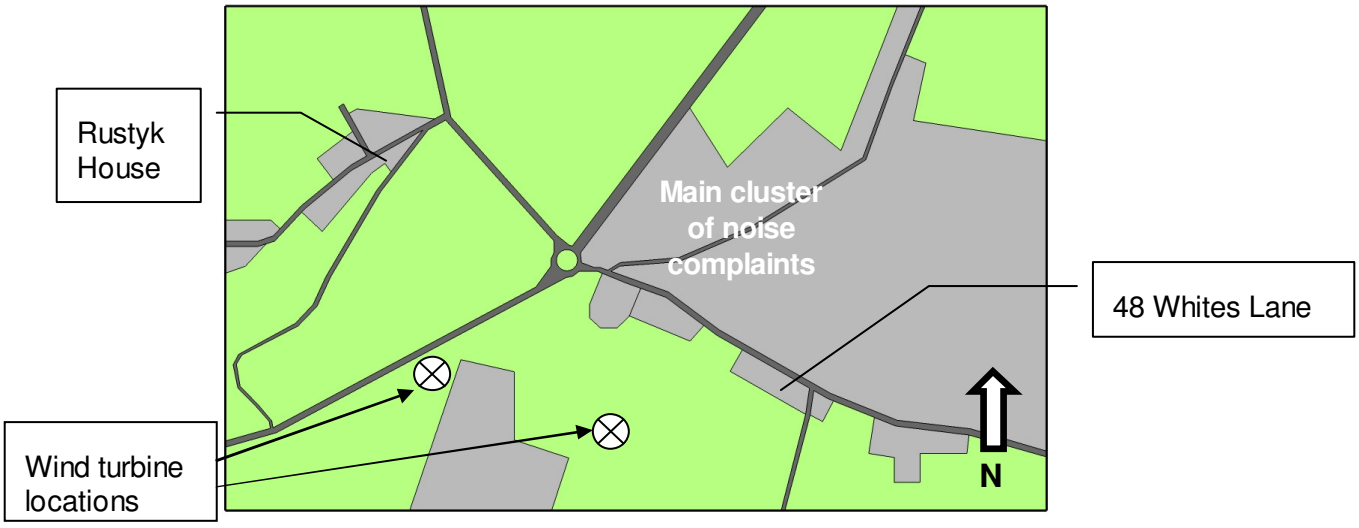
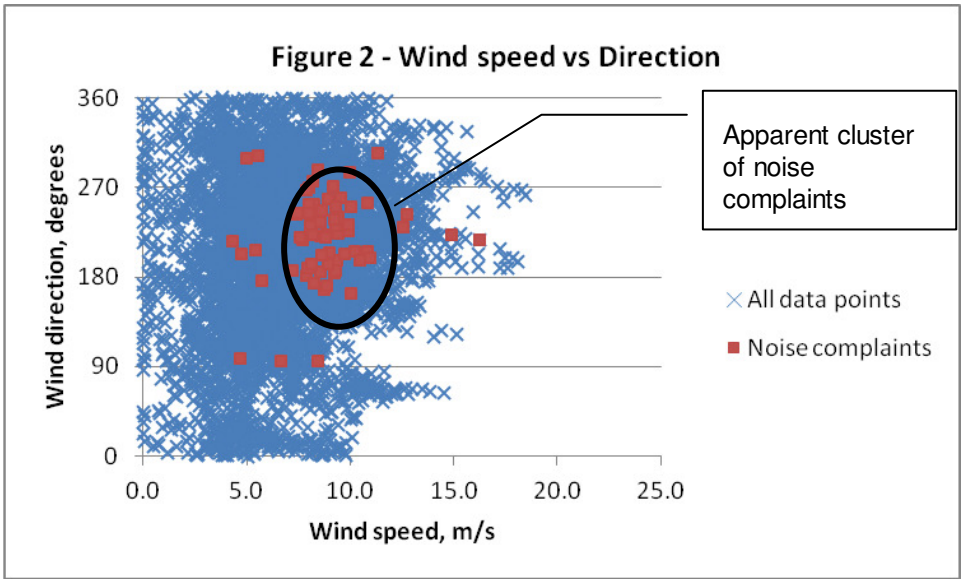


Figure 1 - Location map

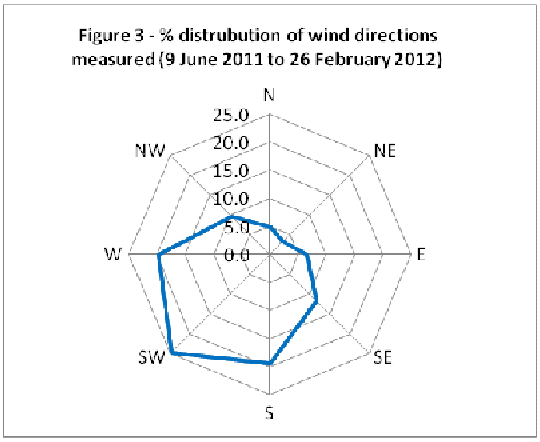
We have compared the complaints log against the meteorological data to investigate whether the occurrence of complaints is related to specific wind conditions. Figure 2 below shows a plot of wind speed vs. wind direction for all of the data points recorded between 9 June 2011 to 26 February 2012. All occurrences are marked in blue and conditions when noise complaints were reported are marked in red.



This graph shows the range of wind conditions at the site over the 8 month period there is a cluster of complaints when the wind speed is between 7 and 12 m/s and the direction is between 180 degrees (south) and 270 degrees (west).

Wind direction

To investigate this further, the percentage distribution of wind direction measured over the eight month measurement period is shown in Figure 3 below alongside Figure 4 which shows the wind direction at times when complaints were received.



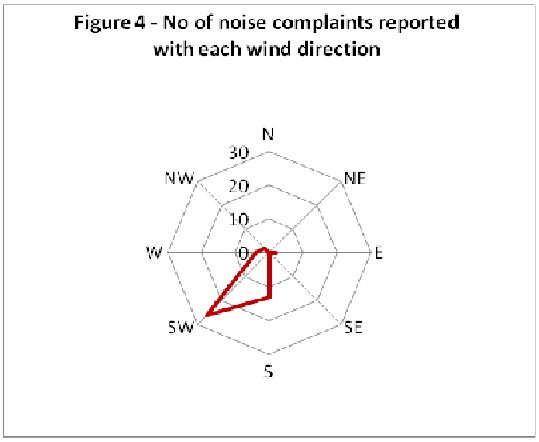
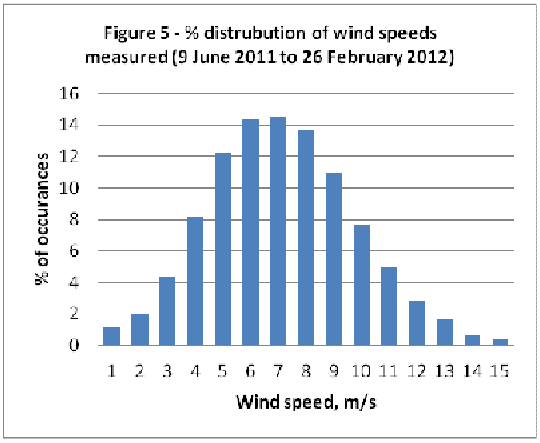


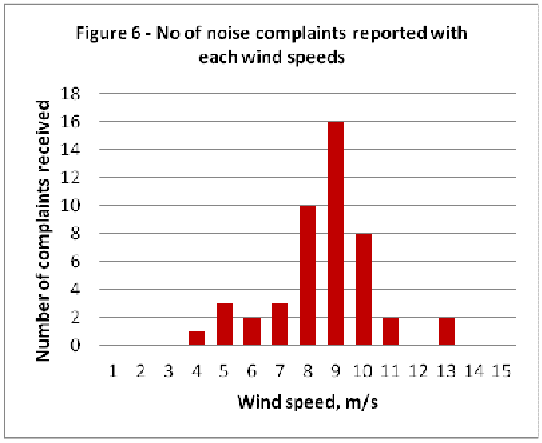
Figure 3 above shows that the wind direction at the site was southerly around 20% of the time, south-westerly 25% of the time and westerly 20% of the time. Figure 4 shows that the majority of the complaints occurred when the wind was coming from the south (30%) or south-west (55%).

It should be noted that these figures are based on a relatively small set of data. However, the data does suggest a clear correlation between wind direction and complaints, and that residents to the north-west of the turbine are more likely to complain when the wind is coming from the south or south-west, i.e. when the residences are approximately downwind of the turbines.

Wind speed

Figure 5 shows the percentage distribution of wind speed measured over the eight month operating period and Figure 6 shows wind speeds at times when complaints were received.





The graphs show that approximately 75% of noise complaints were received at windspeeds 8 - 10 m/s but that these wind speeds occured only around 35% of the time during the 8 month measurement period. This suggests a correlation between noise complaints and windspeed.

Subjective assessment of noise

22 March 2012

We visited the site of the wind turbines with Sarah Long from WDC environmental health on 22 March 2012. At the time of our visit there the wind was North-Easterly at an approximate speed of 9 m/s. (It should be noted that during our investigation there was a prolonged period of northerly and north-easterly winds which did not help out investigation). We assessed the noise around the site of the east turbine and around the residential areas where complaints have occurred.

Noise levels close to the east turbine were dominated by noise from the turbine itself, which appeared to be aerodynamic noise emanating from the blade tips. At close proximity the broadband noise varied in amplitude as the blades passed and also varied in frequency due to the Doppler effect of the blades passing at high speed.

In the surrounding residential area, noise from the turbines was audible in and around Market Place, Noah's Drive and Ark Close. It was not audible at Field Lane or Lloyds Avenue, which locations are considerably further from the turbines. It should be remembered that these locations were approximately upwind of the turbines during this survey. Noise from the turbines was also clearly audible at Dam Lane in Gisleham, approximately 500 m to the West of the turbines.

Other noise sources at the time of the survey were traffic noise from the A12 and on local roads, wind in foliage and birdsong. Noise from the turbine was broadband and as far as could be assessed by measurement, listening and audio analysis, was on average at a similar level to the noise from other sources. However, the noise from the turbines had a distinct pulsing at the blade pass frequency and this variation in amplitude gave the sound a distinct character which increased its audibility over other noise sources.

26 April 2012

We returned to the site on 26 April 2012 when the there was a south-westerly wind blowing at approximately 13 m/s. On this occasion, wind-induced background noise from the turbine was not audible outside any of the dwellings or in any of the publically accessible areas that we visited.

HMP Audio recordings

None of the noise complaints logged fall within the HMP audio logging period. However, there are a number of periods within the audio logging period where the wind speed was similar to those when the majority of complaints were received. We have listened to a large sample of audio recordings corresponding to these periods. In a significant number of these recordings noise is clearly audible from a broadband noise source, modulating at frequency of around 0.7 - 0.8 Hz which corresponds to the blade passing frequency of the turbine. This is consistent with the statement from HMP staff that noise from the turbines was clearly audible during their survey.

WDC audio recordings

We have recently received and analysed recordings made using Waveney District Council's noise monitoring and recording equipment installed within a complainant's property. Recordings were manually triggered by the resident when the noise from the turbines was perceived to be a problem. Recordings were triggered around 40 times over a 10 day period. However, noise levels on these recordings were dominated by sources within the resident's property and by background "Hiss" on the recordings, due to the large dynamic range over which recordings were necessary. Turbine noise was not definitively audible on any of these recordings.

Vibration and groundborne noise

We understand that some residents have complained of vibration from the turbines at their properties. We did not perceive any ground-bourne vibration when standing close to the turbine or outside properties several hundred metres away. We consider it most unlikely that ground-borne noise or vibration from the turbines could be an issue at the site. It is possible that the sensation of vibration reported by residents is being confused with the low frequency amplitude modulation of broadband aerodynamic noise from the turbines which has been shown to be audible at the receptors, and which could in theory cause re-generated vibration, in the same way in which low-frequency airborne noise from road vehicles can cause windows to shake.

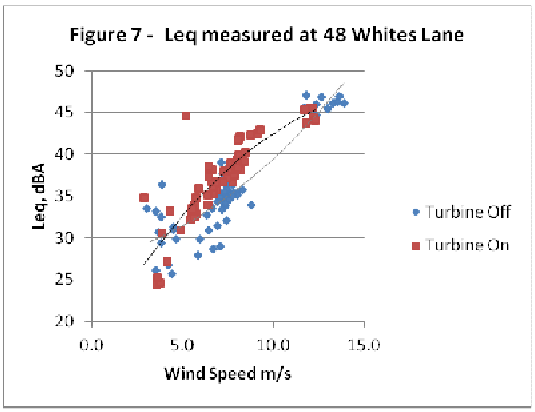
Mechanism of noise generation

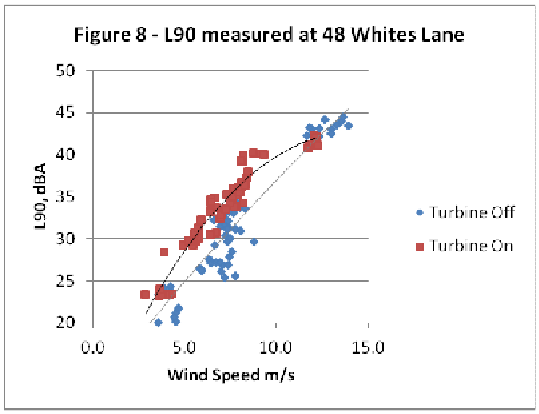
We understand that the turbine rotor speed increases with wind speed up to 15 rpm at around 8 m/s, and that above that speed the turbines are limited to 15 rpm. The level of aerodynamic noise generated by a turbine increases with rotor speed, as does the general background noise caused by the wind. It follows that the wind speed at which turbine noise is highest compared to background noise will be at the wind speed at which the turbine reaches its maximum rotor speed, in this case around 8 m/s. This is consistent with the cluster of noise complaints at wind speeds around 8-10 m/s, and also with our observations that the turbine noise was clearly audible over background noise at a windspeed of 9 m/s but not at 13 m/s.

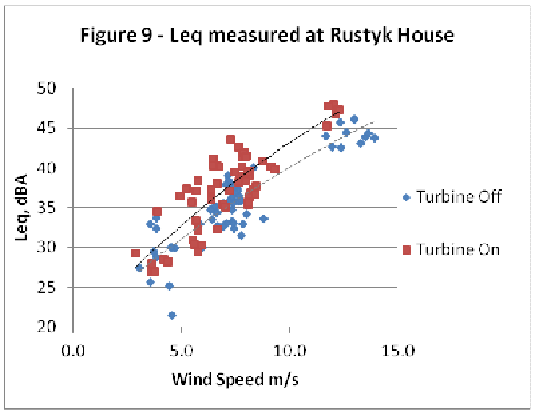
Noise from turbine versus background noise

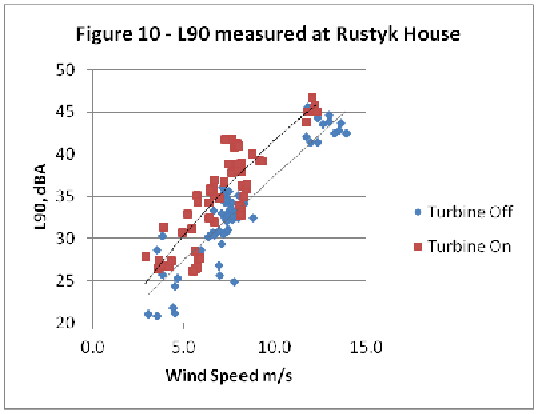
It is clearly not possible to compare simultaneous noise measurements with and without the turbines operating. However, during HMP's noise monitoring the turbines were stopped for one hour between 0200 and 0300 on eleven nights to allow HMP to measure background noise in the absence of noise from the turbine. We have used this data, provided to us by HMP, to compare noise levels during similar weather conditions with and without the turbines in operation.

Figures 5, 6, 7 and 8 compare the noise levels measured between 0200 and 0300 with the turbines stopped against those at the same times when the turbines were operating. It should be noted that these graphs are based on a fairly limited set of data. To assist analysis we have added second-order best fit curves to each data set.









These graphs show that between 0200 and 0300 noise levels with the turbines running were generally higher than noise levels with the turbines stopped. There is a difference of up to 4 dBA between the lines of best fit. This data suggests that the noise from the turbines dominated the measured noises levels at this time of day.

It is also interesting to note that the data at Whites Lane shows that the difference between the noise levels with and without the turbine operating is greatest around 8 m/s. This corresponds with the wind speeds at which the majority of the complaints occurred and the speed at which the turbine reaches its maximum rotor speed.

Amplitude modulation

Subjectively, it is clear that the broadband noise from the turbines is modulated at the blade pass frequency but whether the level of amplitude modulation (AM) is within acceptable limits is a matter of discussion. There is no agreed test methodology or criterion to determine an acceptable level of amplitude modulation of noise from wind turbines. At present, the only published test methodology is set out in a planning condition for the Den Brook wind farm in Devon but this has not been more widely adopted; in fact some practitioners claim that this methodology is fundamentally flawed. Further research is currently being undertaken by Renewable UK (formerly the British Wind Energy Association) but we do not expect a definitive methodology to be agreed in the near future.

The "Den Brook" planning condition included a test methodology based on the level of modulation and occurrences of AM within noise from the proposed wind turbines. In the absence of any other guidance we have analysed HMP audio recordings of noise from the turbines in accordance with the Den Brook test. This states that noise from a wind farm contains greater than expected amplitude modulation if the following a conditions occur:

i) A-weighted noise levels ($L_{Aeq,\ 125msec}$) from turbines vary more than 3 dB peak-to-trough within a 2 second period **and**

ii) There are five or more 2 second excedance periods within a minute **and**

iii) There are six or more of 1 minute excedance periods within an hour.

We have analysed HMP audio recordings using the Den Brook test methodology. We selected recordings which include audible "swoosh" from the wind turbines, and our analysis has found that conditions i) and ii) are exceeded. We cannot assess the recordings against condition iii) because they consist of 1 minute samples taken every ten minutes rather than a continuous audio recordings , but this analysis suggests that noise from the turbines would exceed the Den Brook AM criterion.

BS4142 Assessment

ETSU R-97 is required to be used for planning assessments but has no status in the assessment of noise complaints. The wind turbines are effectively industrial noise sources. We have therefore considered how this noise would be assessed using the methodology set out in BS4142:1997 "Method for rating industrial noise affecting mixed residential and industrial areas" which is widely applied to other forms of power generation plant. BS4142 sets out a methodology to compare the noise produced by a specific source against the background noise level. In the case of wind turbines, the noise from the turbine and the background noise both vary with wind speed so for the purposes of this indicative assessment we have based our calculations for figures at 8 m/s at which Amplitude Modulation is audible.

Using HMP data measured with and without the turbines operating, between 0200 and 0300, the lines of best fit provide the following figures at 8 m/s. Note that these figures include a correction term for residual noise as set out in Table 1 of BS4142.

<u>Whites Lane</u>

- Noise level with turbines operating – 38 dB $L_{Aeq,\ 10\ min}$ (including -1 dB residual noise correction).

- Background noise level without turbines operating – 32 dB $L_{A90,\ 10\ min}$

Rustyk House

- Noise level with turbines operating – 37 dB $L_{Aeq,\ 10\ min}$ (including -2 dB residual noise correction).
- Background noise level without turbines operating – 34 dB $L_{A90,\ 10\ min}$

BS4142 states that a 5 dB correction should be applied to the specific noise level if the noise level is "irregular enough to attract attention". This would give rating levels of 43 dB (A) at Whites Lane and 42 dB (A) at Rustyk House. These ratings levels are 11 and 8 dB (A) above the respective background noise level.

BS4142 states that a rating level of around +5 dB above background noise level is of marginal significance and around +10 dB or more above the background noise level indicates that complaints are likely.

SUMMARY OF CONCLUSIONS

Analysis of the average noise levels measured by Hayes McKenzie Partnership tend to confirm that the L90 noise levels increase by up to 4 dBA and that turbines comply with the ETSU R-97 condition

There is a correlation between complaints and wind conditions. Complaints tend to occur at windspeeds close to 8 m/s and in south-westerly winds, when the majority of complainants' properties would be downwind.

The turbine rotational speed is limited above 8 m/s and we would therefore expect any amplitude-modulated noise to be most audible over background noise around this wind speed.

Our listening tests on site at this wind speed confirmed that Amplitude Modulated (AM) noise was clearly audible outside residences the turbines. AM noise was also clearly audible in audio recordings supplied by Hayes McKenzie Partnership during their survey.

Analysis of these recordings show that the noise would not comply with the controversial "Den Brook" condition and hence that under that condition the turbines generate greater than expected amplitude modulation.

Our scope of work for this study did not include measurements or recordings inside houses. Analysis of audio recordings taken using equipment installed by the Council inside residents' properties was inconclusive as the recordings are dominated by other noise sources inside the houses. We would suggest that a subjective assessment as to whether statutory noise nuisance occurs inside the houses could include manual measurements and recordings taken professionally in the absence of the residents.