THE EFFECTS OF WIND SPEED AND DIRECTION ON AMBIENT AND BACKGROUND NOISE LEVELS IN THE SUBURBAN ENVIRONMENT

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1 INTRODUCTION

Noise assessments based on comparisons of existing or future specific noise levels against the context of existing measured noise levels depend on the assumption that all baseline data is fully representative of long term conditions. The typical variation in measured ambient and background noise levels over the 24 hour diurnal cycle is widely understood but, and depending on the relative distances from the main noise sources in the area, additional variation or uncertainty can also arise associated with differences in meteorological conditions. Particularly in rural areas, high wind speeds passing through nearby trees and foliage can generate significant contributions to baseline noise levels, while wind and temperature gradients associated with different meteorological conditions can lead to moderate enhancement or significant attenuation attributable to downward or upward sound ray curvature. This paper reports an investigation of the relationships between long term measurements of ambient and background noise levels and wind speed and direction conditions at two fixed locations, one near Birmingham and the other near Heathrow. A number of other meteorological variables such as rainfall, temperature, and humidity were also investigated but the range of variation or rate of occurence in each of these variables was insufficient to yield any interesting results.

2 METHODOLOGY

2.1 Noise monitoring sites

The Birmingham noise monitor was installed in an open field just north of Shenstone village, approximately 750m south west from the roundabout junction between the A5(T), A5148 and A5127 and approximately 350m west of the A5127 which runs north to south through the area. The A5(T) passes by the noise monitoring site from the east to the north west. There is a secondary railway route passing from north to south approximately 150m west of the noise monitoring site, but this is in a partial cutting and trains are relatively infrequent. A meteorological recording station was positioned in the same open field at approximately the same distance from the A5(T) but approximately 200m closer to the A5127. The principal ambient and background noise sources at this site are distant road traffic on the A5(T), although there is also a contribution from the much closer but also much less heavily trafficked A5127. There is a row of trees alongside a meandering stream or drainage ditch approximately 75m south of the noise monitoring position.

The Heathrow noise monitor was installed on a disused plant nursery site approximately 75m west of the A3044 which runs north to south around the western end of the airport, and nearby to the now disused Perry Oaks Sewage Treatment Works. The site is between the western extended centrelines of the main north and south runways, and very slightly closer to the south runway extended centreline than to the north runway extended centreline. The site is nearly 3 km from the centre of the main Heathrow central terminal area (CTA). The main London orbital motorway, the M25, is approximately 900m to the west and the A3113 airport spur road from the M25 junction 14 is approximately 400m south west of the site. The site is approximately 1500m south of the A4 and approximately 2700m south of the main M25 junction 15, M4 junction 4b. A meteorological recording station was positioned adjacent to the noise monitoring equipment. The principle ambient and background sources at this site are mainly road traffic and aircraft, but there is also some light industrial activity on the disused plant nursery site which is currently used a main depot for a company installing noise insulating windows at houses around the airport. The centre of the site is relatively open, but there is an 8m high industrial building at around 30m from the microphone position and there are a number of mature trees around the periphery of the site.

2.2 Noise monitoring equipment

The Birmingham noise monitor was a Larson Davis model LD-820 type 1 Integrating Sound Level Meter operating with a ½ inch microphone and preamplifier mounted in a double layer windshield on a portable steel pole at 4m above the local ground surface in accordance with current EC recommendations for strategic noise assessment. The noise monitor was installed in a steel box with a rechargeable battery power supply and system was calibrated and the data downloaded at regular intervals by visiting the site. The meteorological recording station was installed separately with the wind speed and direction instruments installed on a portable mast system at 10m above the local ground level.

The Heathrow noise monitor was a Larson Davis model LD-824 type 1 Integrating Sound Level Meter operating with a ½ inch microphone and preamplifier and also mounted at 4m above the local ground surface. In this case an LD2100 outdoor microphone unit was used fitted with an electrostatic actuator which was set up to confirm system calibration every night at 2359 hrs. The noise monitor was installed in a semi-permanent equipment cabin with a mains power supply and telephone landline for data download via a modem connection. The meteorological recording equipment was mounted on the equipment cabin with the wind speed and direction instruments installed at 6m above the local ground surface.

The Birmingham noise monitor was operated over a three month period from February to April 2001. The Heathrow noise monitor was installed on a semi-permanent basis in January 2002 and the analysis reported in this paper is based on over 2 months of data collected up until the end of March 2002.

2.3 Data recording and analysis

Both noise monitors were set up to record ambient (L_{Aeq}) and background (L_{A90}) noise levels continuously for consecutive hourly intervals throughout each survey period. In addition, the Birmingham noise monitor was set up to record $L_{Aeq,1min}$ sequences continuously and the Heathrow noise monitor was set up to record 1 minute averaged 1/3rd octave band frequency spectra continuously, but none of this additional data has been used in this analysis.

The meteorological instruments recorded average weather conditions for each hour continuously. For the wind speed and direction measurements, it should be noted that the standard type of rotating vane anemometers used here do not rotate at all below a minimum average wind speed of around 0.3 to 0.5 m/s (under very low average wind speed conditions the anemometers are still likely to rotate slowly for a proportion of the overall time as the instantaneous wind speed rises to perhaps 1 m/s in short bursts). Similarly, under very low average wind speed conditions the wind direction indicator vanes will continue to indicate the wind direction they were pointing during the most recent short period of higher instantaneous wind speed. For these reasons the minimum wind speed shown in the figures is around 0.3 to 0.4 m/s and there are still differences in wind direction shown at these very low average wind speeds.

The data for each noise monitor was divided into overall daytime (0700 to 1900) and night-time (2400 to 0600) periods avoiding the so-called 'shoulder hours' between day and night during which periods ambient and background noise levels are likely to be ramping up or down. The data was then grouped under northerly (316 to 045 degrees), easterly (046 to 135 degrees), southerly (136 to

225 degrees), and westerly (226 to 315 degrees) wind direction conditions and the hourly noise levels plotted against hourly average wind speeds on Figures 1 to 8 below.

3 RESULTS

Figures 1 to 4 show the results for the Birmingham noise monitoring site, designated as Site S, for daytime and night-time L_{A90} and L_{Aeq}. Figures 5 to 8 show the equivalent data for the Heathrow noise monitoring site, designated as Site H. All figures show a relatively wide range of hourly noise levels. The standard deviations are generally around 3 to 4 dB, which implies a range of plus or minus 10 dB or more, as can be seen from the figures. Because of the wide scatter in the hourly noise level data, the figures also show best-fit polynomial trend lines to indicate the central tendencies for each wind direction separately.

For the Birmingham site, figures 1 and 2 show that long term average hourly daytime and night-time background noise levels (L_{A90}) converge at around 48 dBA daytime and 39 dBA night-time at very low wind speeds, irrespective of the residual wind direction. As the wind speed increases to around 3 m/s the wind direction becomes more important with the trend lines separating by 5.5 dB day-time and by 7 dB night-time for the noisiest and quietest wind directions. There is only a very small increase in background noise levels with increasing wind speed above zero wind under the highest trend line wind directions which are downwind from the A5(T), but there is also a much greater decrease in background noise levels with increasing wind speed under the lowest trend line wind directions which are upwind from the A5(T). At even higher hourly average wind speeds up to around 5 m/s, the trend lines begin to converge again, in this case because of the effect of the wind generating turbulence noise as it passes through nearby trees and other large objects and structures nearby.

Figures 3 and 4 show much smaller effects on ambient noise levels (L_{Aeq}) than were observed for background noise levels in figures 1 and 2. During the daytime the effect of wind speed and direction on hourly L_{Aeq}. is relatively small, with the wind direction trend lines separating only by around 2 dB at 3 - 4 m/s. During the night-time the effects are more marked, and in this case there is a more significant difference of around 4 dB at 3 m/s between upwind and downwind conditions.

For the Heathrow site, figures 5 and 6 show that long term average hourly daytime and night-time background noise levels (L_{A90}) converge at around 60 dBA daytime and 50 dBA night-time at very low wind speeds, irrespective of the residual wind direction. Not unexpectedly, given the relative proximity of the Heathrow site to two busy motorways, a number of heavily trafficked main roads, and the worlds busiest international airport, the Heathrow site is more than 10 dBA noisier than the Birmingham site. Because of the relative complexity of the different major noise sources contributing from different directions at this site, the relationships between noise levels, wind speeds and directions are much more complex. First, the trend lines for the different wind directions do not converge at very low speeds. Visual inspection of the individual data points shown on the scatter plots suggest that this could be an artefact of the polynomial regression algorithms resulting from differences at higher wind speeds. Under daytime conditions (figure 5) the highest background noise levels occur for easterly winds whereas under night-time conditions (figure 6) the highest background noise levels occur for westerly winds. This suggest that general airport ground noise is much more significant during the day than during the night, at which times motorway traffic on the M25 becomes relatively more significant.

Secondly, under easterly winds and at this relatively complex site during the daytime, there is a significant increase in background noise levels with increasing downwind wind speeds, but no corresponding decrease in background noise levels with increasing upwind wind speeds. This finding may require some additional explanation. In any simple situation with only a single distant noise source, any increase in noise levels above the long term average under increasing downwind wind speed conditions is usually much smaller than any opposite decrease in noise levels below the long term average under equivalently increasing upwind wind speed conditions. This is because increasing downwards ray curvature above the ground under increasing downwind wind speeds (strictly speaking, under increasing positive wind speed gradients above the ground) merely increases the height of the direct propagation path through the air (thereby altering the interference pattern contributed by ground reflected waves but not changing the direct sound ray by very much at all), whereas increasing upwards ray curvature above the ground under increasing upwind wind speed conditions moves the shadow zone on the ground which is not directly reached by any direct ray path from source to receiver closer to the source from the receiver. The Birmingham site, with a relatively simple pattern of main road noise sources predominately to the north and east of the site, shows this simple pattern quite well, whereas the Heathrow site during the daytime is complicated by different noise sources taking over as the main source of background noise at the site under different wind direction conditions.

Figure 6 shows that the situation at the Heathrow site during the night-time is much more consistent with the situation at the Birmingham site, with the highest background noise levels under moderate wind speed conditions (2-3 m/s) occuring under westerly wind conditions. This situation occurs because the central terminal area at Heathrow (to the east of the site) is relatively quiet during the night as compared to during the day and the main residual background noise source is then the M25 to the west.

Figures 7 and 8 show similar relationships between ambient noise levels (L_{Aeq}) and wind speed and direction conditions at the Heathrow site as at the Birmingham site, where the effects of different wind directions are relatively small. Figures 3, 4, 7 and 8 taken together suggest that ambient noise levels (L_{Aeq}) are less sensitive to wind speed and direction conditions than are background noise levels (L_{A90}) at these two noise monitoring sites. At these particular suburban sites, the lower sensitivity of ambient noise levels to wind speed and direction is probably a consequence of the number of different noise sources contributing from different directions to overall ambient noise levels (L_{Aeq}) at both sites. It is not clear whether similar reduced sensitivity would occur at simpler sites where there might be only one major noise source contributing. Long term average ambient noise levels (L_{Aeq}) are likely to be more sensitive to nearby noise sources than long term average background noise levels (L_{A90}) because of the insensitivity of background noise levels (L_{A90}) to the noisier events. The propagation of noise from nearby noise sources is much less sensitive to wind speed and direction conditions than from distant noise sources.

4 CONCLUSIONS

Long term (3 months) noise monitoring data collected at suburban sites near to the A5(T) north of Birmingham and between the M25 and Heathrow Airport in West London show complex relationships between wind speed and direction conditions. At the Birmingham site, which is mainly affected by main roads to the north and east, there are significant differences in background noise levels (L_{A90}) between upwind and downwind conditions. Upwind conditions caused a larger decrease in background noise levels than the corresponding increase in noise levels associated with downwind conditions. At the Heathrow site, the situation was more complicated during the daytime because of the possibility of either distant airport ground noise (from the east) or distant motorway traffic noise (from the west) dominating the background noise environment under different wind direction conditions. At the Heathrow site during the night-time the pattern of results was much more similar to that at the Birmingham site, because airport ground noise tends to be much less significant than the distant motorway noise at night. There was some evidence that local noise sources associated with wind turbulence became relatively more important than distant noise sources at higher wind speeds.

Overall ambient noise levels (L_{Aeq}) were much less affected by wind speed and direction at both sites, presumably because ambient noise levels are much more sensitive to nearby or local noise sources which can be much less affected by wind speed and direction conditions.

Figure 1

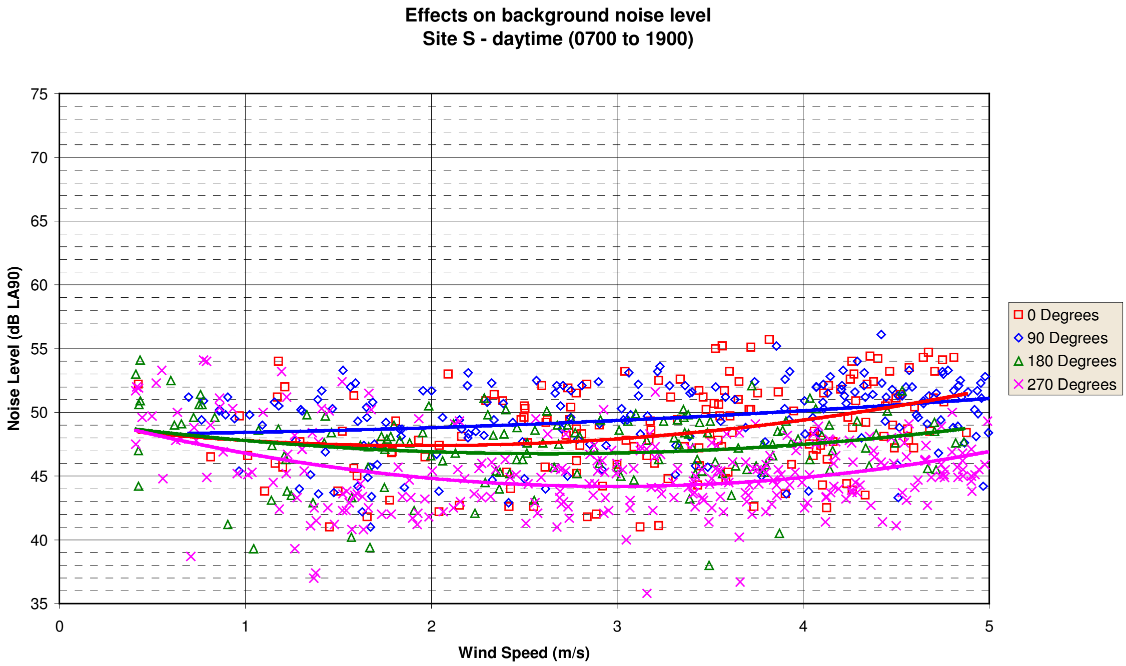


Figure 2

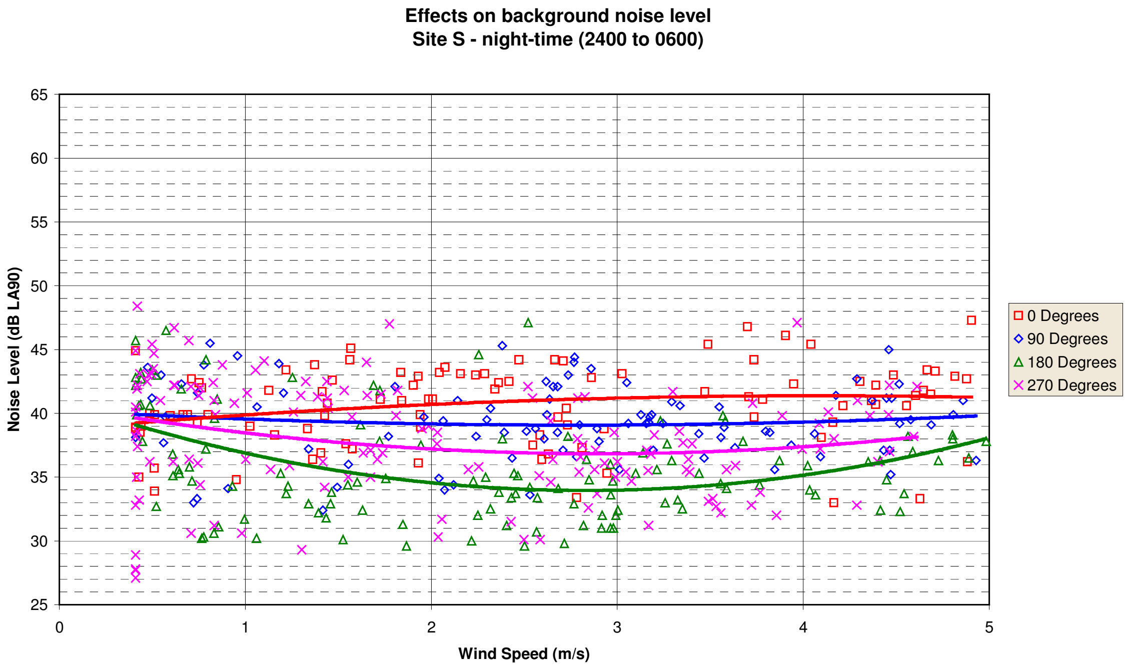
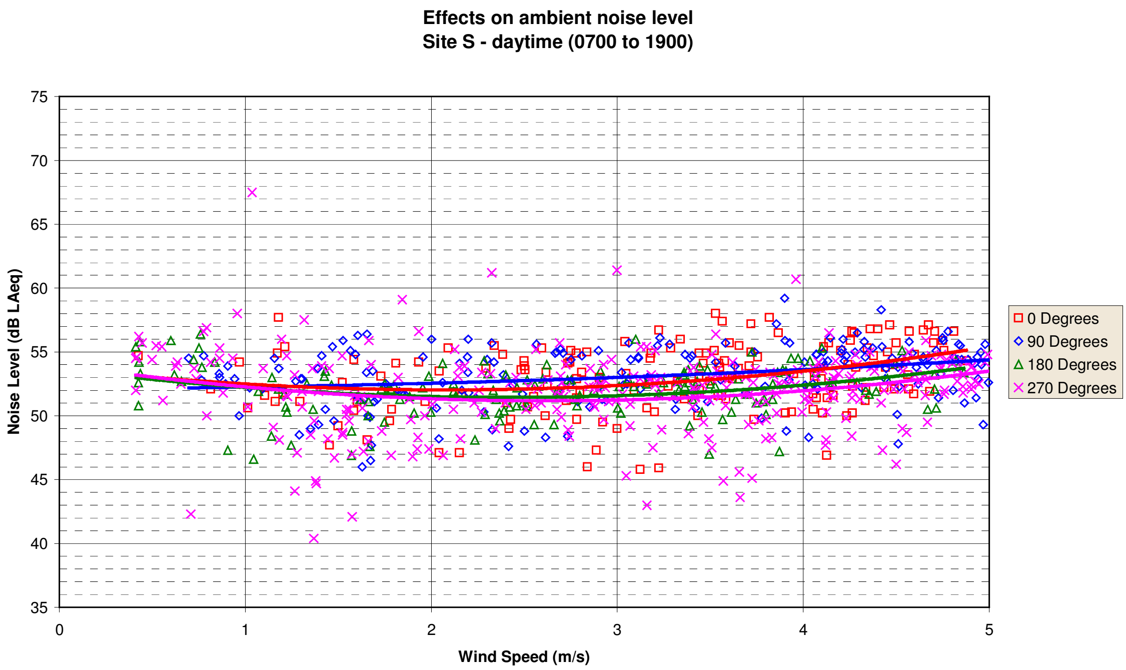


Figure 3



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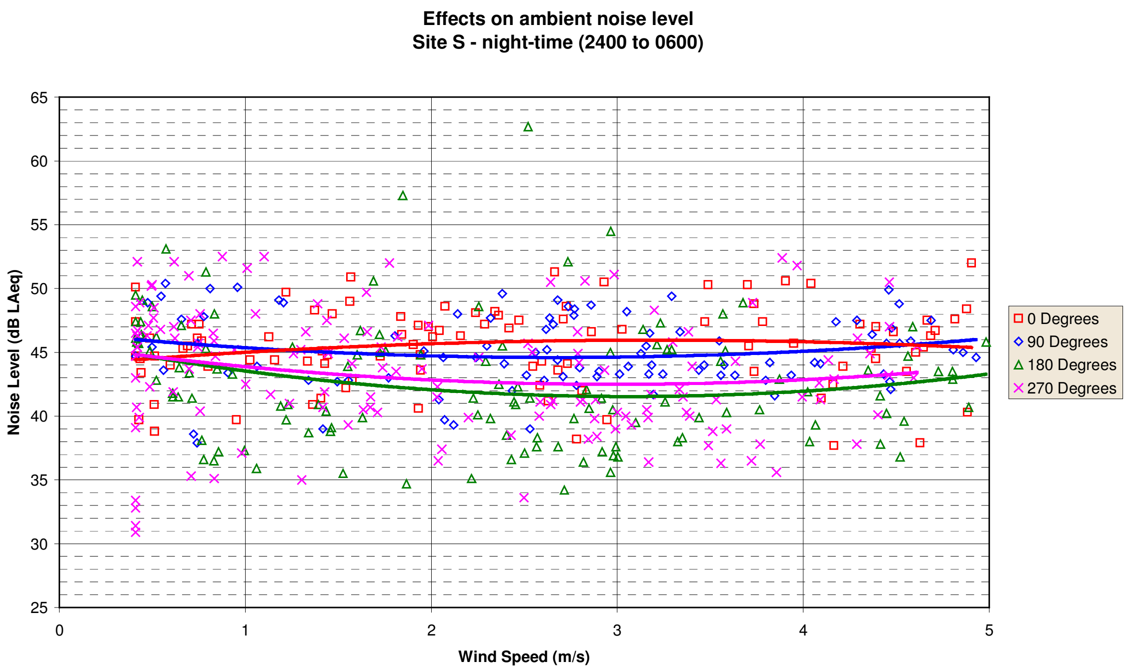

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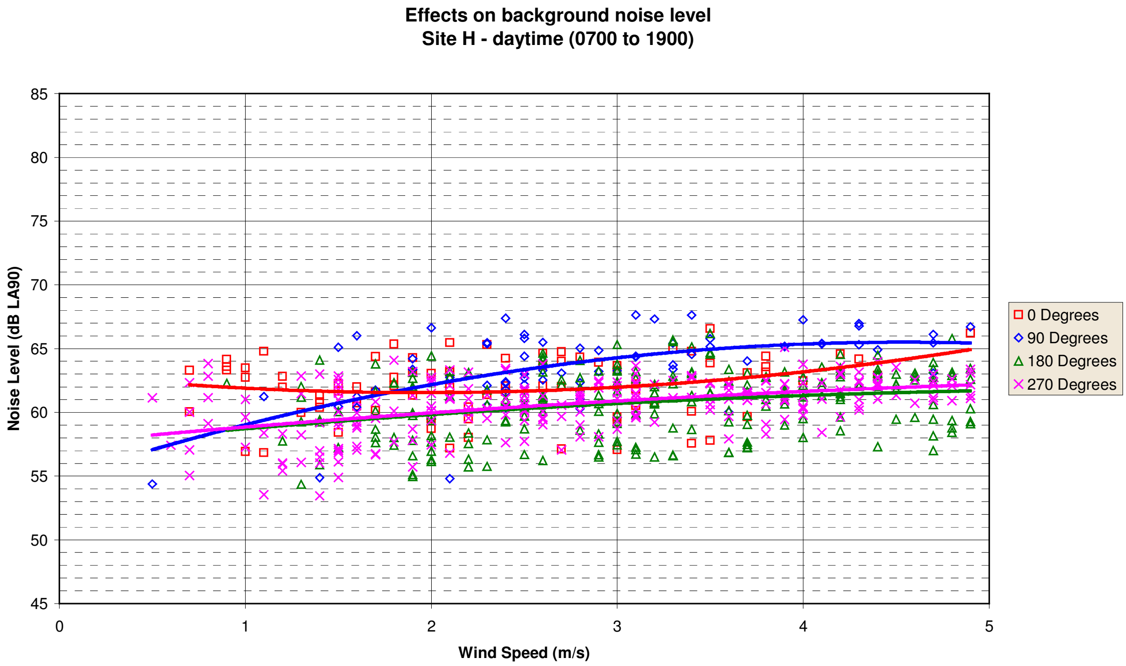

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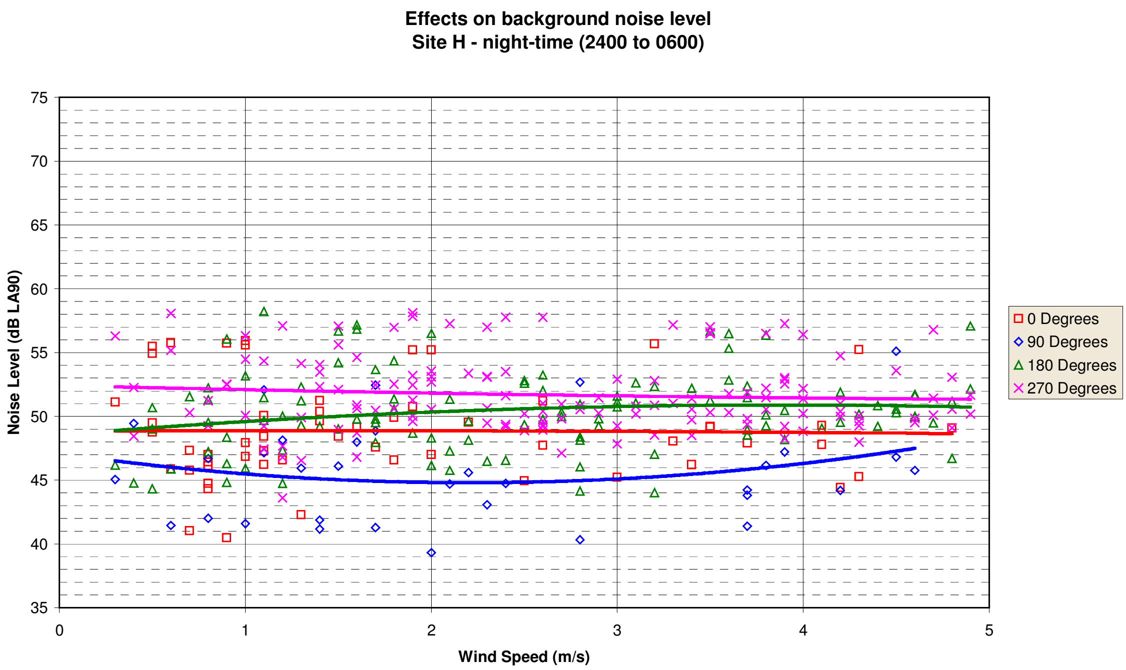

Figure 7

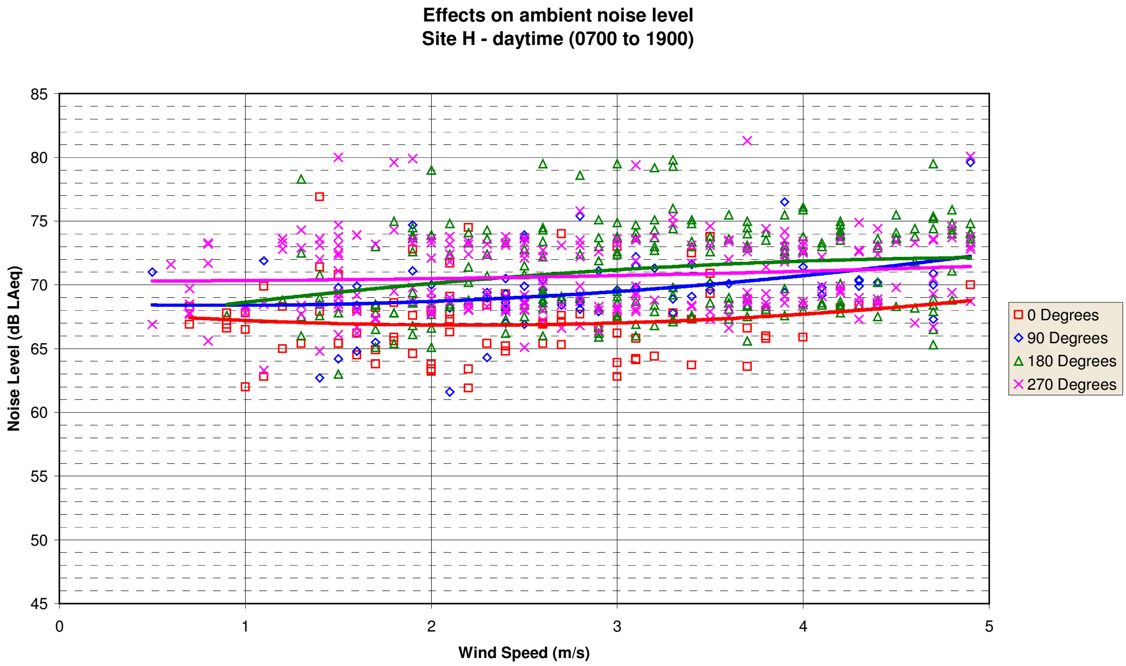

Figure 8