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Comparison of Wind Studies for Foster's Mill

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1. Background.

Mead Construction has commissioned WSP Environmental to provide an analysis of the impact of their proposed new development at Mill Hill in Swaffham Prior upon the wind resource of Foster's Mill. The WSP study has been published on Mead's website and Mead have also produced a supplementary document in which they amplify the summary of their wind analysis, and in which they rely heavily upon a report done for another local mill, Wicken, originally written by Sinclair Knight Merz, (SKM). The owner of Foster's mill has likewise asked the author of this document for a wind study, and this has been published as "Wind Study Fosters Mill Planning Application 17_01208_OUM.doc"

In this document the author has compared the critical differences between these two studies, with some reference to the SKM report where it is relied upon by Mead.

2. Comparisons

2.1 Wind Rose

Analysis of the effects of an obstruction such as a house or tree upon the availability of wind at a mill starts with a "wind rose". This plots the incidence, by time, of wind from all points of the compass. Obviously, some points contribute more wind than others, and it is therefore absolutely necessary to know how it is distributed between the different directions. Measurement of a wind rose is, in principle, straightforward, but the measurements need to be taken over a long period – even one year being insufficient to determine appropriate averages. Sites such as local meteorology stations provide wind roses over, typically, a decade, but do not take into account the local features of the actual site. Both studies based themselves on a windrose publically available from RAF Mildenhall. In the case of the WSP report, this rose has been "transposed" to predict what it would have looked like had it been measured at Swaffham Prior. The transposition is carried out by a program called Breve 3.2, a tool designed to enable structural engineers to predict wind loadings at particular sites. The author also had a transposition carried out by Meteoblue, a Swiss company who offer this as a service to wind farm designers and others.

The Breve transposition and the Meteoblue one disagree on fundamentals such as the average wind speed at Swaffham (4.5 m/s at Mildenhall, 4.0 m/s at Swaffham according to Breve, and 5.6 m/s according to Meteoblue) This is a substantial discrepancy. Because of the average speed discrepancy, coupled with other detailed ones, the author rejected the use of transposition as being unreliable. Other example wind analysis results for other mills have likewise rejected the transposition process on the same grounds.

The transposed windrose is plotted in the SWP report (on a very small scale) but not tabulated, so that it is difficult to see in detail what the comparison is. However, one point is clear, and that is that the wind in the relevant quarter (E – NE approx) is much reduced compared to that at Mildenhall. This seems unlikely because, of all the directions, this one is

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the one which is more open for furthest away from the mill, this being the general direction of Newmarket Heath. There is also likely to be a small "speed up" factor due to mill hill itself, again making an overall reduction less plausible, though this effect will be far smaller than the effect quoted in the Meteoblue transposition.

2.2 Effect of a single building

WSP have modelled the effect of a single building (or other obstacle) upon the wind flow to the windmill using Computational Fluid Dynamics (CFD). This is generally the method used by the industry to assess aerodynamic effects. However, the results of using CFD are regarded with some scepticism, for example, in the Wind Energy Industry. Different CFD models produce substantially different predictions, making the authority of an individual program difficult to assess. All such models require "Boundary Conditions" to limit the region over which the flow is calculated and to keep the computational load within the capability of available computers. The wind flow over the ground is an unbounded problem and the results of placing boundaries depends heavily upon the assumed boundary conditions – hence some of the uncertainties in the results.

The acid test of success of CFD is in comparing its results with known ones. Often, CFD fails this test, particularly for complex situations. For example, an extensive study was carried out of wind flows at Askervein hill on Uist isle in the Outer Hebrides in 1983, the purpose of which was to provide a test case against which to compare CFD. Last year, a report was published looking at the use of a CFD modelling program called FLOWSTAR-Energy to simulate the measured Askervein data. This paper says "The FLOWSTAR-Energy results show the same trends as the observed data. The predicted values of ΔS agree well with the measured values on the windward side of Askervein, for both 0.03 m and 0.1 m surface roughness values in the model, but the model does not capture the magnitude of flow deceleration on the lee side of the hill". The lee side of the hill represents a relatively benign version of the downwind side of a building or tree. In particular, the FLOWSTAR program drastically underestimated the wind loss on the lee side – an effect which the author has found in various cases of CFD modelling of wind obstructions.

In Holland, the CFD approach is not used. Instead, they calculate the effects of obstacles using a "lumped parameter" model – the "Molenbiotoop", the basis for which is empirical. Over 70 years they have carried out measurements on real flows at actual windmills and have deduced thereby a set of simplified parameters which predict the end result in terms of the effective wind speed at the wind shaft of the mill. The parameters used are the free wind speed (i.e. over open ground), the height (4.5 m for the proposed bungalows) and distance to the obstacle (100 m), the height of the mill (11.8 m) and the nature of the terrain ("rough" see below) between the obstacle and the mill. These parameters, together with a simple calculator, reliably predict the measured end result. Because of this long history and high success rate of the Molenbiotoop calculation, CFD results which fail to conform with the Molenbitoop prediction should be regarded as suspect.

The Dutch model shows that the least effect occurs when the terrain between the obstacle and the mill is rough (this has the effect of re-mixing the air in the wake of the obstacle as quickly

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as possible so that the free stream is restored within the shortest distance). This is the parameter which was used in the author's analysis. The recovery rate given by this roughness assumption is 2 m of height per 100 m of distance – so that a 4.5 m high building at 100 m produces a 2.5 m height wake at the mill. The Molenbiotoop calculates then that the wind speed loss at the height of the windshaft will be 21%. The WSP model calculates that the reduction in speed would be 4.9%.

2.3 Loss of Milling Time due to a Single Obstacle

2.3.1. Comparison of Loss of Milling Time

The WSP report uses a minimum milling speed of 4 m/s. The author's calculated value is 5.9 m/s, and this fits well with the owner's measurements and other values found for similar mills. Moreover, the 4 m/s value is also the one quoted in the SKM report for Wicken, whose owner quotes the actual minimum as about 13 mph i.e. 5.8 m/s. The WSP report says "in the absence of information regarding the operation of the windmill" that it uses the 4 m/s speed which happens to be the same (erroneous) value used at Wicken. Both the owners of Fosters and Wicken mill report the 5.9 m/s figure, and is in no way secret.

Comparison based upon a minimum milling speed of 4 m/s:

	WSP	Molenbiotoop
• Reduction in speed:	4.9%	21%
• Reduction in milling time:	4.4%*	18.5%

Note 1: the large difference in speed reduction is due to the difference in wake effects predicted by the CFD program and the linear reduction measured and used in the Molenbiotoop.

Note 2: the time losses are actually smaller than the average speed losses, due to the very low minimum milling speed.

Comparison based upon a minimum milling speed of 5.9 m/s:

	WSP	Molenbiotoop
• Reduction in milling time:	9.4%	35.9%

Note the much larger time loss compared to the first set of figures, due to the increase in minimum milling speed and the skewed nature of the Rayleigh distribution used by both studies.

2.4 Effect of Multiple Obstacles

An actual wind rose for the mill must be derived from the unobstructed wind rose, taking into account the effect which all the obstacles around the mill have in slowing down the wind. Only on the basis of this derived wind rose can the total milling time available be calculated, and the proportionate losses from new developments be deduced.

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In order to do this, the following steps must be taken.

1. Assess the total time available for milling given the current obstacles at all bearings from the mill.
2. Assess the loss of time due to the new obstacles.
3. Do the above for both Summer and Winter obstacle patterns, calculating two values for the times in both cases.
4. Express the total loss for both cases as a percentage of the sum of the time currently available for summer and winter.

The WSP report did not take into account the difference between summer and winter values, which are drastically different from each other due to the presence of trees, as explained in the author's report.

In the WSP report, the percentage loss due to the new obstacles was calculated by comparing the loss to the whole, transposed, wind rose as derived from Breve3. No attempt was made to show the effects of the local obstacles (within 1-200 m of the mill), which are not accounted for by Breve. The author's report showed that the mill has already suffered major losses of available wind since 1900 due to the presence of houses, the water tower and trees. Consequentially, the loss due to the proposed development appears to be totally insignificant in the WSP report, (0.4%) and much larger in the author's report (22%).

In Mead's comments on the author's report, they state

> The frequency of wind from other directions does not alter the conclusion that the scheme would cause the Mill to be inoperable for 0.4% of total time. This percentage cannot be manipulated by breaking down the wind into workable sectors. This 0.4% is also not a pre- defined period. History tells us that the site would cause the wind to fall below the threshold for being able to operate on an average of 4 out of every 1000 hours. These are not necessarily during the limited hours that the Miller is there working. These hours could be day or night, winter or summer.

The 0.4% figure appears to have been derived by multiplying average speed reduction, 4.9% by the overall proportion of the wind available in the relevant direction, 7.2% from the Breve rose, giving 0.35%, rounded to 0.4%. However, contrary to the above assertions, this direction now provides much more than 7.2% of the total time available **because of the existing loss of time in all other directions from local obstacles**.

Thus, the WSP report understates the proportionate loss because of its failure to take into account local obstacles which increase the current contribution from the open fields in the direction of the proposed development compared to the percentage shown by the Breve derived wind rose.

2.5 Turbulence

The WSP report does not include a turbulence analysis. Mead's response to the publication of the author's wind analysis includes an Appendix that discusses turbulence and uses unreferenced data from the SKM report for Wicken.

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Calculations of turbulence intensity are at least an order of magnitude more difficult than those required for assessment of the wind speed in the wake. Since they require dynamic modelling, they are currently outwith the scope of CFD given the size of models that are required to address this complex situation even in a steady state condition.

This is why, in the author's report, no attempt has been made to quantify the turbulence effects.

It is worth noting that the Wicken SKM report on which Mead rely for their @in depth@ assessment of turbulence has used the same method to average the impact around a full 360° as they did for wind speed, so that the final quoted average is, once again, a severe under-estimate.

Moreover, averaging turbulence only has meaning in relationship to assessing maintenance costs, and since no known relationship exists between these two, the end figure of averaged turbulence is meaningless in itself. The maximum turbulence is of much greater interest - if a gust were to occur at such a magnitude as to damage the mill, then it is no use telling the owner that on average it was much smaller.

All that can be said is that turbulence is known to adversely affect the operation and maintenance of a mill, and that the bearings covered by the proposed development are currently the only turbulence free ones. Therefore, this particular direction is of great value to the miller and currently does no harm to the mill.

3. Conclusion

The WSP report underestimates

- The reduction in average wind speed due to the wake from an obstacle
- The minimum wind speed necessary for milling
- The time lost from the reduced wind speed at the proper milling speed

It does not account for

- The proportionate loss of available milling time when the current local obstacles are taken into account
- The significant difference between the summer and winter wind resource and the effect of tree cover.

Further claims by Mead have been used to indicate that turbulence would be a minimal problem, but there is no scientific basis for this statement.

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