A Dispersion Modelling Study of the Impact of Odour from the Existing and Proposed Free Range Egg Laying Houses at Tosside Road near Slaidburn in Lancashire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Richard Robinson to use computer modelling to assess the impact of odour emissions from the existing and proposed free range egg laying chicken houses at Tosside Road, near Slaidburn in Lancashire. BB7 4TP.

Odour emission rates from the existing and proposed poultry houses have been assessed and quantified based upon an emissions model that takes into account the likely internal odour concentrations and ventilation rates of the poultry house. The odour emission rates so obtained have then been used as inputs to an atmospheric dispersion model which calculates odour exposure levels in the surrounding area.

This report is arranged in the following manner:

- Section 2 provides relevant details of the site and potentially sensitive receptors in the area.
- Section 3 provides some general information on odour; details of the method used to estimate odour emissions from the existing and proposed poultry houses; relevant guidelines and legislation on exposure limits and where relevant, details of likely background levels of odour.
- Section 4 provides some information about ADMS, the dispersion model used for this study and details the modelling parameters and procedures.
- Section 5 contains the results of the modelling.
- Section 6 provides a discussion of the results and conclusions.

2. Background Details

The site of the free range egg laying houses is in a rural area approximately 2.3 km to the east-north-east of the village of Slaidburn in Lancashire. The surrounding land is used primarily for livestock farming. The existing poultry houses are on a col at an altitude of around 243 m with the land falling to the south-west and north-east and rising gently towards higher ground to the north-west and south-east. The site of the proposed houses is approximately 450 m to the north-east

There are currently two poultry houses at Tosside Road. The poultry houses provide accommodation for up to 32,000 egg laying chickens. There are pop holes on the sides of the houses to provide daytime access to outside ranging areas. The poultry houses are ventilated by uncapped high speed ridge mounted fans. The bird's droppings are removed by a belt collection system and stored temporarily in a sealed skip prior to removal from the site on a twice weekly basis.

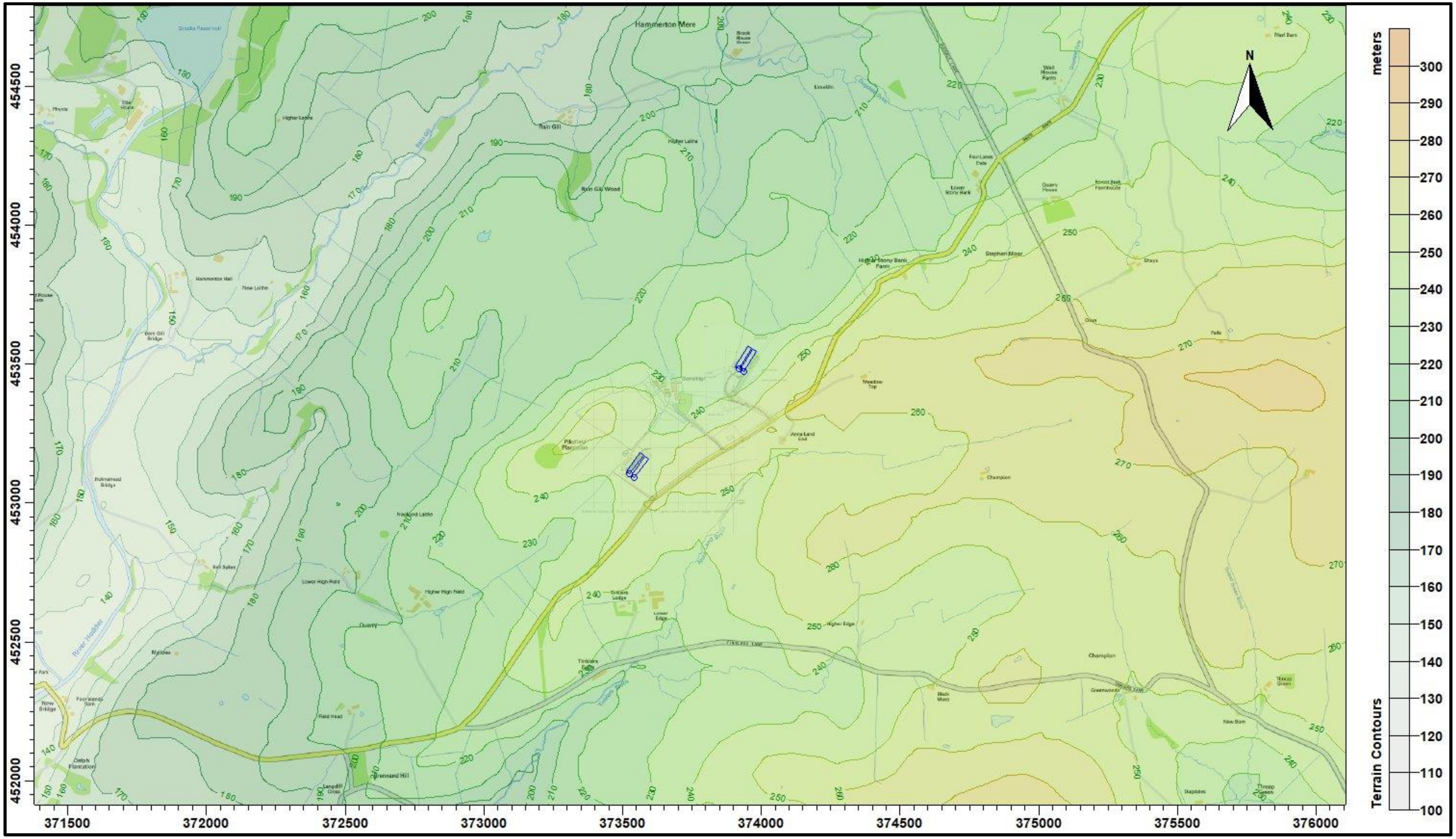
It is proposed that two new poultry houses be constructed approximately 450 m to the north-east of the existing houses. The new poultry houses would provide accommodation for an additional 32,000 egg laying chickens. Similarly to the existing houses, there would be pop holes on the sides of the houses to provide daytime access to outside ranging areas. The new houses would be ventilated by uncapped high speed ridge mounted fans. The bird's droppings would be removed by a belt collection system and stored temporarily in a sealed skip prior to removal from the site on a twice weekly basis.

There are some isolated residences and commercial properties in the area surrounding the site of the existing and proposed poultry houses at Tosside Road. The closest residences are:

- The farmhouse at Standridge, which is approximately 250 m to the north-east of the existing poultry houses and approximately 270 m to the west-south-west of the site of the proposed houses.
- Anna Land End, approximately 480 m to the east north-east of the existing poultry houses and approximately 280 m to the south-south-east of the site of the proposed houses.
- Tinkers Lodge and Lower Edge, approximately 280 m to the south of the existing poultry houses and approximately 880 m to the south-east of the site of the proposed houses.
- Meadow Top, approximately 810 m to the east north-east of the existing poultry houses and approximately 380 m to the east of the site of the proposed houses.

A map of the surrounding area is provided in Figure 1, where the positions of the existing and proposed poultry houses are outlined in blue.

Figure 1. The area surrounding the site of the existing and proposed poultry houses at Tosside Road



3. Odour, Emission Rates, Exposure Limits & Background Levels

3.1 Odour concentration, averaging times, percentiles and FIDOR

Odour concentration is expressed in terms of European Odour Units per metre cubed of air (ou_E/m^3). The following definitions and descriptions of how an odour might be perceived by a human with an average sense of smell may be useful. However, it should be noted that within a human population there is considerable variation in acuity of sense of smell.

- 1.0 ou_E/m^3 is defined as the limit of detection, in laboratory conditions.

- At 2.0 – 3.0 ou_E/m^3, a particular odour might be detected against background odours in an open environment.

- When the concentration reaches around 5.0 ou_E/m^3, a particular odour will usually be recognisable, if known, but would usually be described as faint.

- At 10.0 ou_E/m^3, most would describe the intensity of the odour as moderate or strong and if persistent, it is likely that the odour would become intrusive.

The character, or hedonic tone, of an odour is also important; typically, odours are grouped into three categories.

Most offensive:

- Processes involving decaying animal or fish remains.
- Processes involving septic effluent or sludge.
- Biological landfill odours.

Moderately offensive:

- Intensive livestock rearing.
- Fat frying (food processing).
- Sugar beet processing.
- Well aerated green waste composting.

Less offensive:

- Brewery.
- Confectionery.
- Coffee roasting.
- Bakery.

Dispersion models usually calculate hourly mean odour concentrations; Environment Agency guidelines and findings from UK Water industry Research (UKWIR) are also framed in terms of hourly mean odour concentration.

The Environment Agency guidelines and findings from UKWIR use the 98th percentile hourly mean; this is the hourly mean odour concentration that is equalled or exceeded for 2% of the time period considered, which is typically one year. The use of the 98th percentile statistic allows for some consideration of both frequency and intensity of the odours.

At some distance from a source, it would be unusual if odour concentration remained constant for an hour and in reality, due to air turbulence and changes in wind direction, short term fluctuations in concentration are observed. Therefore, although average exposure levels may be below the detection threshold, or a particular guideline, a population may be exposed to short term concentrations which are higher than the hourly average. It should be noted that a fluctuating odour is often more noticeable than a steady background odour at a low concentration. It is implicit that within the models' hourly averaging time and the Environment Agency guidelines and findings from UKWIR that there would be variation in the odour concentration around this mean, i.e. there would be short periods when odour concentration would be higher than the mean and lower than the mean.

The FIDOR acronym is a useful reminder of the factors that will determine the degree of odour pollution:

- **F**requency of detection.
- **I**ntensity as perceived.
- **D**uration of exposure.
- **O**ffensiveness.
- **R**eceptor sensitivity.

3.2 Environment Agency Guidelines

In April 2011, the Environment Agency published H4 Odour Management guidance (H4). In Appendix 3 – Modelling Odour Exposure, benchmark exposure levels are provided. The benchmarks are based on the 98th percentile of hourly mean concentrations of odour modelled over a year at the site/installation boundary. The benchmarks are:

- 1.5 ou_E/m^3 for most offensive odours.
- 3.0 ou_E/m^3 for moderately offensive odours.
- 6.0 ou_E/m^3 for less offensive odours.

Any modelled results that project exposures above these benchmark levels, after taking uncertainty into account, indicate the likelihood of unacceptable odour pollution.

3.3 UK Water Industry Research Findings

The main source of research into odour impacts in the UK has been the wastewater industry. An in-depth study of the correlation between modelled odour impacts and human response was published by UKWIR in 2001. This was based on a review of the correlation between reported odour complaints and modelled odour impacts in relation to nine wastewater treatment works in the UK with ongoing odour complaints. The findings of this research and subsequent UKWIR research indicate the following. Based on the modelled 98th percentile of hourly mean concentrations of odour:

- At below 5.0 ou_E/m^3, complaints are relatively rare, at only 3% of the total registered.
- At between 5.0 ou_E/m^3 and 10.0 ou_E/m^3, a significant proportion of total registered complaints occur, 38% of the total.
- The majority of complaints occur in areas of modelled exposures of greater than 10.0 ou_E/m^3, 59% of the total.

3.4 Choice of Odour Benchmarks for this Study

Odours from poultry rearing are usually placed in the moderately offensive category. Therefore, for this study, the Environment Agency's benchmark for moderately offensive odours, a 98th percentile hourly mean of 3.0 ou_E/m^3 over a one year period, is used to assess the impact of odour emissions from the proposed poultry unit at potentially sensitive receptors in the surrounding area.

3.5 Quantification of Odour Emissions

Odour emission rates from poultry houses depend on many factors and are highly variable. When only minimum ventilation is required the odour emission rate may be relatively small, but in hot weather, ventilation requirements and odour emission rates are greater.

The primary source of odour would be from the chimneys of the ridge mounted fans, which would be used for the majority of the ventilation requirements. Some fugitive emissions from open pop holes would be possible, but because the houses would normally be under negative pressure, these emissions would be minimal. The chickens have/would have access to ranging areas and some odour would arise from the manure deposited on the ranging areas.

In traditional egg laying houses, peak odour emission rates occur when the housing is cleared of spent litter and manure at the end of each crop. Emissions at this time may be several times greater than normal emissions from the housing. However, although the houses at Tosside Road are/would be cleaned between flocks (approximately one per year), because the manure would be collected and removed throughout the flock cycle, the magnitude of odours during cleaning would be much lower than from more traditional houses in which manure collects within the house.

To calculate an odour emission rate it is necessary to know the internal odour concentration and ventilation rate of the poultry house. For the calculation, the internal concentration is assumed to be constant at 750 ou_E/m^3; this figure is derived from a review of available literature. Under high ventilation rates in layer chicken housing there may be a purging effect, that is, internal odour concentrations are reduced because the ventilation system removes odour faster than it is produced; this effect is not considered in the calculations, therefore, if anything, peak emission rates during hot weather may be overestimated. The housing is also assumed to be continuously occupied, but in reality there would be periods between flocks when the housing is empty and clean and emitting little or no odour.

The ventilation rates used in the calculations are based on industry standard practices. For the calculations, the minimum ventilation rate is set at 1.0 m^3-air/bird/h and the maximum ventilation rate is 7.5 m^3-air/bird/h. If the external temperature is 13 Celsius, or lower, minimum ventilation only is assumed for the calculation. If the external temperature is 23 Celsius, or more, then the maximum ventilation rate is assumed. A transitional ventilation rate is calculated between these extremes.

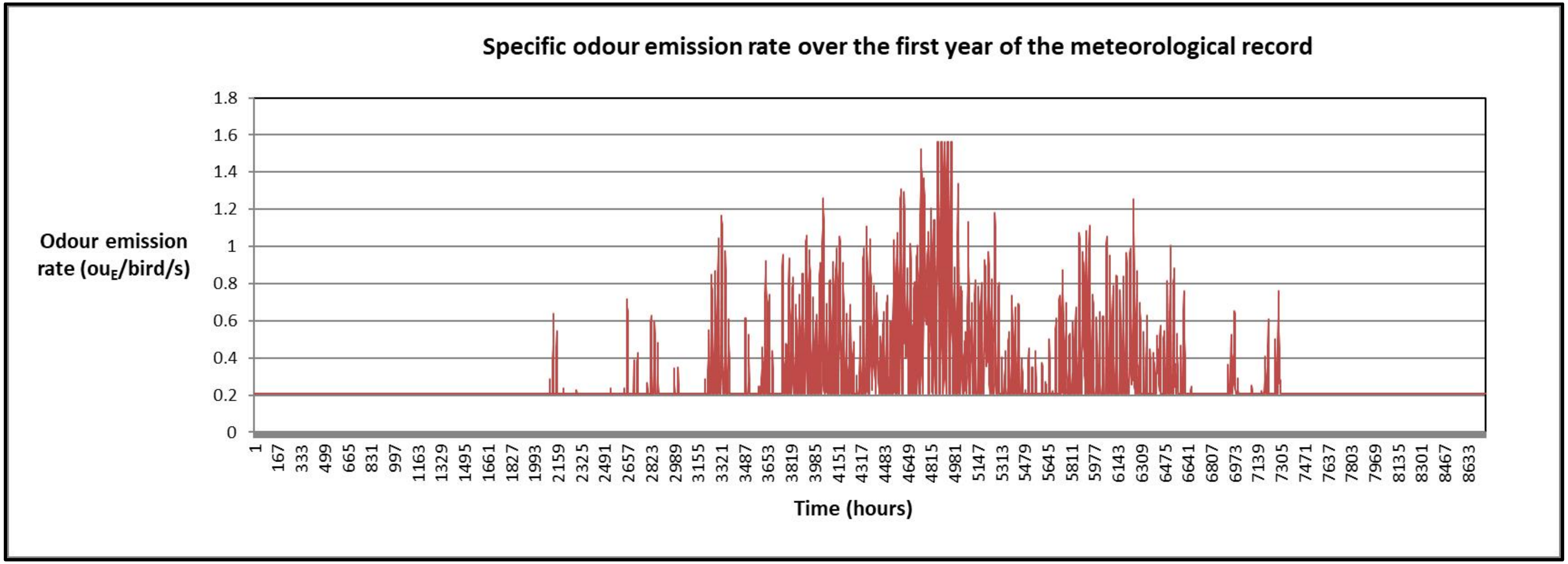
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. A summary of the emission rates used in this study is provided in Table 1. As additional information, the 98^{th} percentile emission rate is approximately 0.9 ou_E/bird/s. As an example, a graph of the specific emission rate over the first year of the meteorological record is shown in Figure 2.

Table 1. Summary of odour emission rates from the existing and proposed poultry houses

Emission rate (ou_E/bird/s)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	0.209	0.208	0.209	0.638
Spring	0.284	0.222	0.346	1.562
Summer	0.384	0.245	0.468	1.562
Autumn	0.219	0.212	0.225	0.918

The chickens have/would have access to ranging areas. It is assumed that 20% of the droppings are deposited on the ranging area and an emission rate of 0.25 ou_E/bird/s is used to calculate the emission rate. The emission is assumed to be continuous with no diurnal, seasonal, or temperature dependent variations. N.B. This emission is additional to emissions from the housing, it is probably quite precautionary and is also intended to account for any fugitive emissions from the pop holes, which allow the birds access to the ranging areas, that might occur when ventilation rates are low.

Figure 2. Specific emission rate over the first year of the meteorological record (2014)



4. The Atmospheric Dispersion Modelling System (ADMS) and Model Parameters

The Atmospheric Dispersion Modelling System (ADMS) ADMS 5 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters: the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill-Gifford class.

Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetrical Gaussian expression).

ADMS has a number of model options including: dry and wet deposition; NO_x chemistry; impacts of hills, variable roughness, buildings and coastlines; puffs; fluctuations; odours; radioactivity decay (and γ-ray dose); condensed plume visibility; time varying sources and inclusion of background concentrations.

ADMS has an in-built meteorological pre-processor that allows flexible input of meteorological data both standard and more specialist. Hourly sequential and statistical data can be processed and all input and output meteorological variables are written to a file after processing.

The user defines the pollutant, the averaging time (which may be an annual average or a shorter period), which percentiles and exceedance values to calculate, whether a rolling average is required or not and the output units. The output options are designed to be flexible to cater for the variety of air quality limits, which can vary from country to country and are subject to revision.

4.1 Meteorological Data

Computer modelling of dispersion requires hourly sequential meteorological data and to provide robust statistics, the record should be of a suitable length; preferably four years or longer.

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS).

The GFS is a spectral model and data are archived at a horizontal resolution of 0.25 degrees, which is approximately 25 km over the UK (formerly 0.5 degrees, or approximately 50 km). The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional observational records may be over represented, this is because the instrumentation used may not record wind speeds below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

- Traditional records may include very local deviations from the broad-scale wind flow that would not necessarily be representative of the site being modelled; these deviations are difficult to identify and remove from a meteorological record. Conversely, local effects at the site being modelled are relatively easy to impose on the broad-scale flow and provided horizontal resolution is not too great, the meteorological records from NWP data may be expected to represent well the broad-scale flow.

- Information on the state of the atmosphere above ground level which would otherwise be estimated by the meteorological pre-processor may be included explicitly.

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 3a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling, wind speeds and directions will be modified. The terrain and roughness length modified wind rose for a point centrat to the existing and the proposed poultry house is shown in Figure 3b. Note that elsewhere in the modelling domain, modified wind roses may differ markedly and that the resolution of the wind field in the terrain runs is 100 m.

Figure 3a. The wind rose. GFS derived data, for 53.973 N 2.403 W, 2014 - 2017

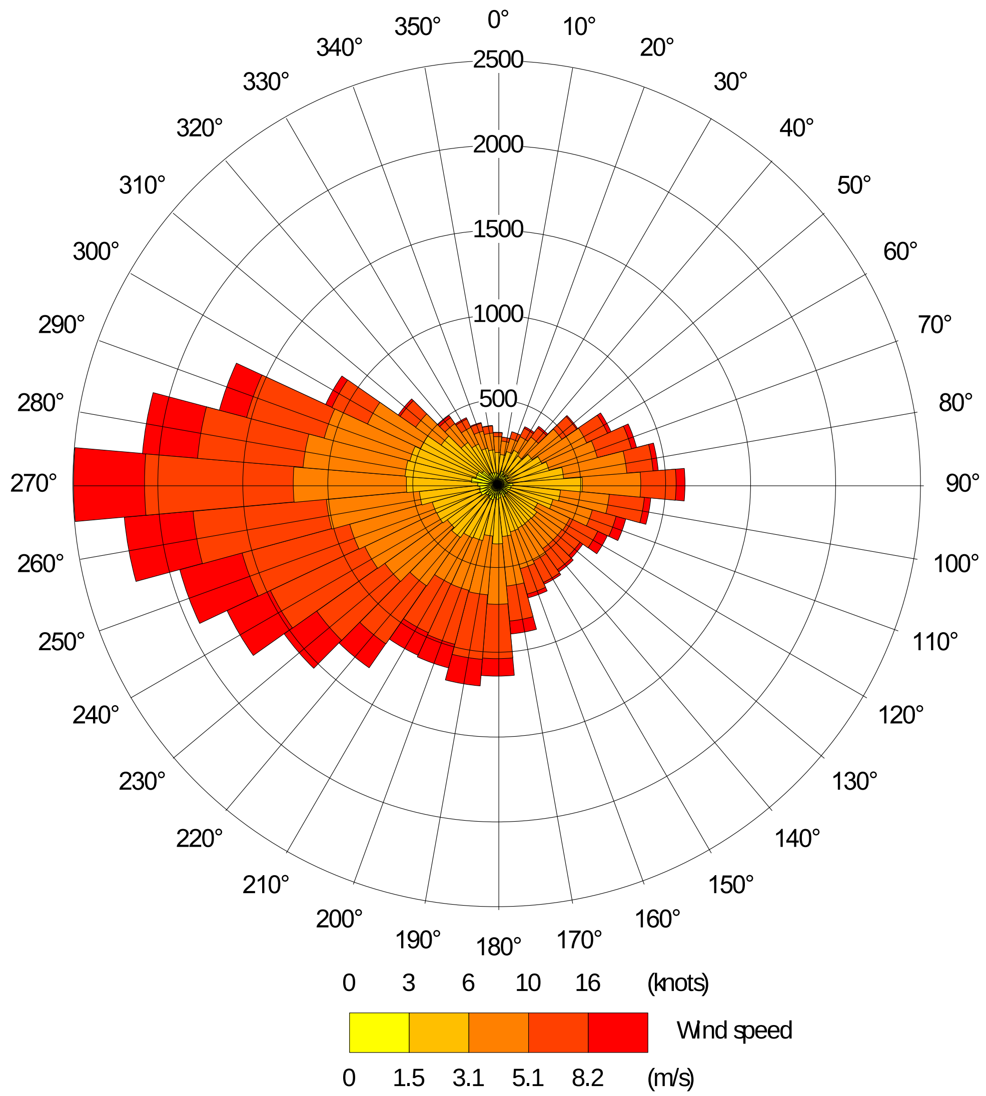
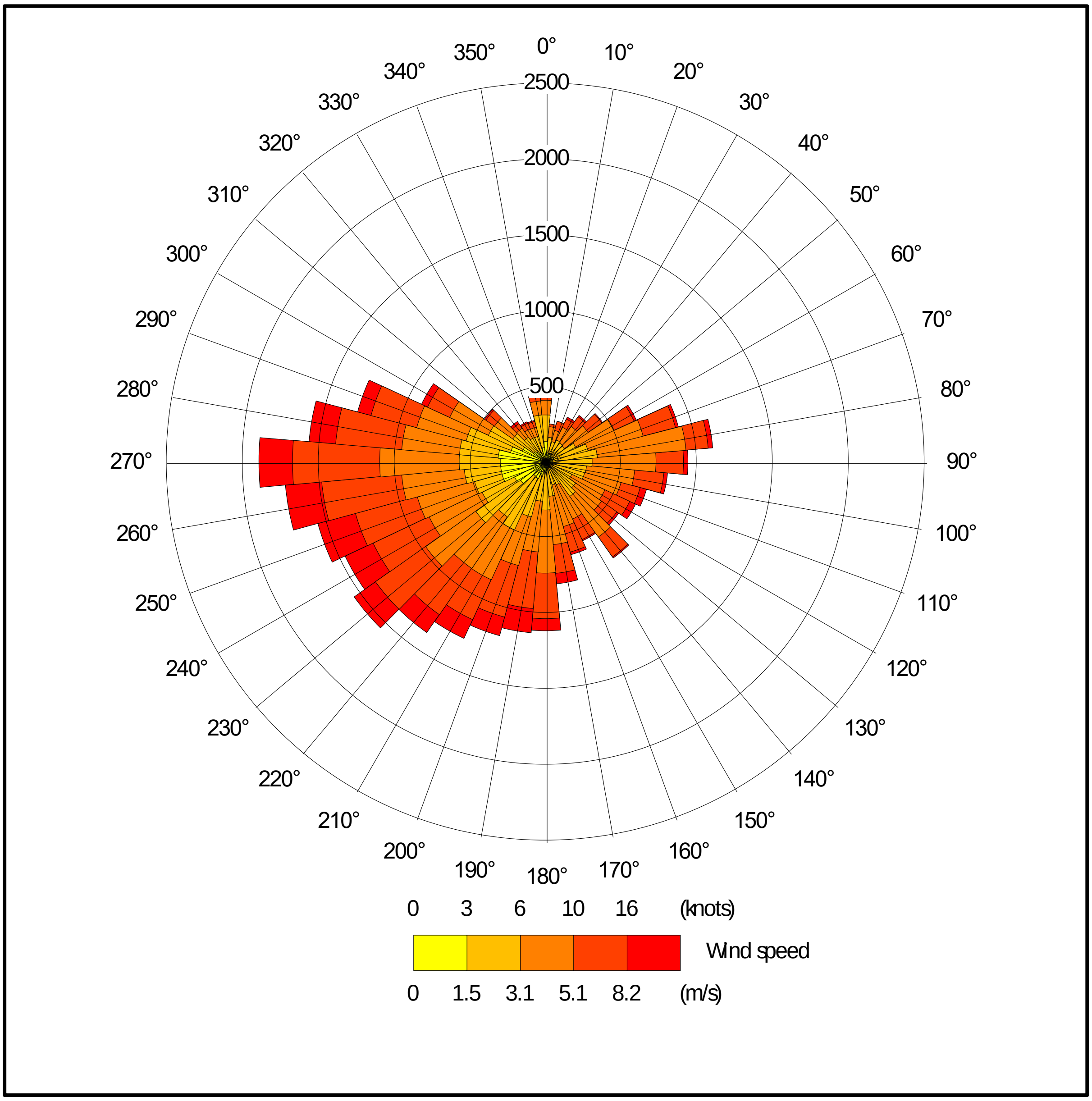


Figure 3b. The wind rose. FLOWSTAR modified GFS derived data for NGR 373750, 453350, 2014-2017



4.2 Emission Sources

Emissions from the uncapped high speed roof fans that are/would be used to ventilate the existing and proposed poultry houses are represented by three point sources per house within ADMS. Details of the point source parameters are shown in Table 2a. The positions of the point sources may be seen in Figure 4, where they are marked by red star symbols.

Emissions from the ranging areas are represented by two area sources within ADMS. N.B. The area source covers the parts of the range most likely to be used frequently, not the whole of the ranging area. Details of the area source parameters are shown in Table 2b. The position of the area sources may be seen in Figure 4.

Table 2a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (ou_E/s)
EX1 and EX2 a, b & c	5.7	0.8	11.0	Variable [1]	Variable [1]
PR1 and PR2 a, b & c	5.7	0.8	11.0	Variable [1]	Variable [1]

1. Dependent on ambient temperature.

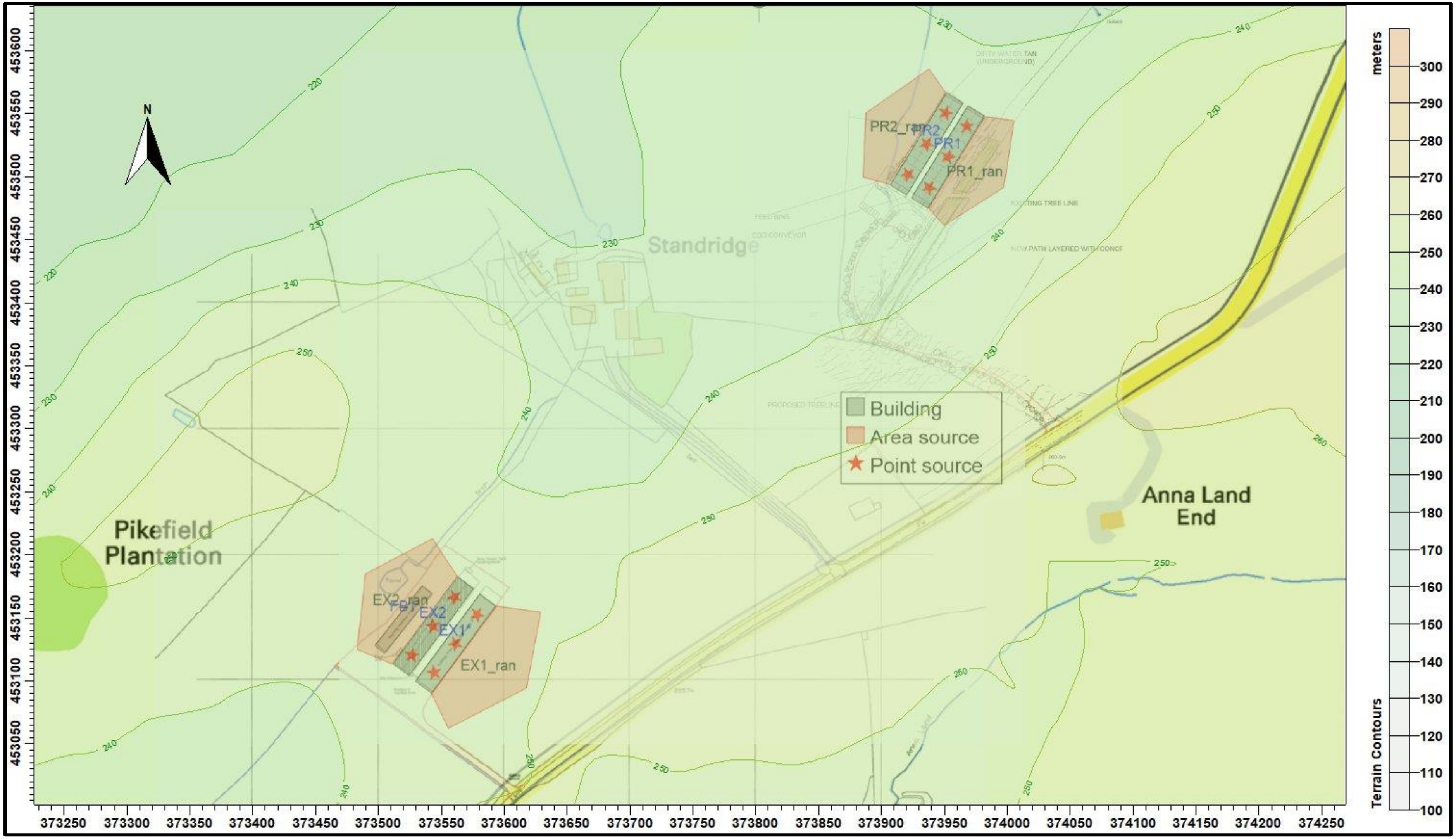
Table 2b. Area source parameters

Source ID	Base Height (m)	Emission temperature (°C)	Area (m^3)	Emission rate (ou_E/s)
EX1_ran	0.0	Ambient	4575.243	800.0
EX2_ran	0.0	Ambient	4461.126	800.0
PR1_ran	0.0	Ambient	2888.267	800.0
PR2_ran	0.0	Ambient	3109.039	800.0

4.3 Modelled Buildings

The structure of the poultry houses and other farm buildings may affect the odour plumes from the point sources and therefore, the buildings are modelled within ADMS. The position of the modelled buildings may be seen in Figure 4, where they are marked by grey rectangles.

Figure 4. The positions of modelled buildings and sources



4.4 Discrete Receptors

Fifteen discrete receptors have been defined at a selection of nearby residences and commercial properties. The receptors are defined at 1.5 m above ground level within ADMS and their positions may be seen in Figure 5, where they are marked by enumerated pink rectangles.

4.5 Nested Cartesian grid

To produce the contour plots presented in Section 5 of this report, nested Cartesian grids have been defined within ADMS. The grid receptors are defined at 1.5 m above ground level within ADMS. The positions of the receptors may be seen in Figure 5, where they are marked by green crosses, or grey lines.

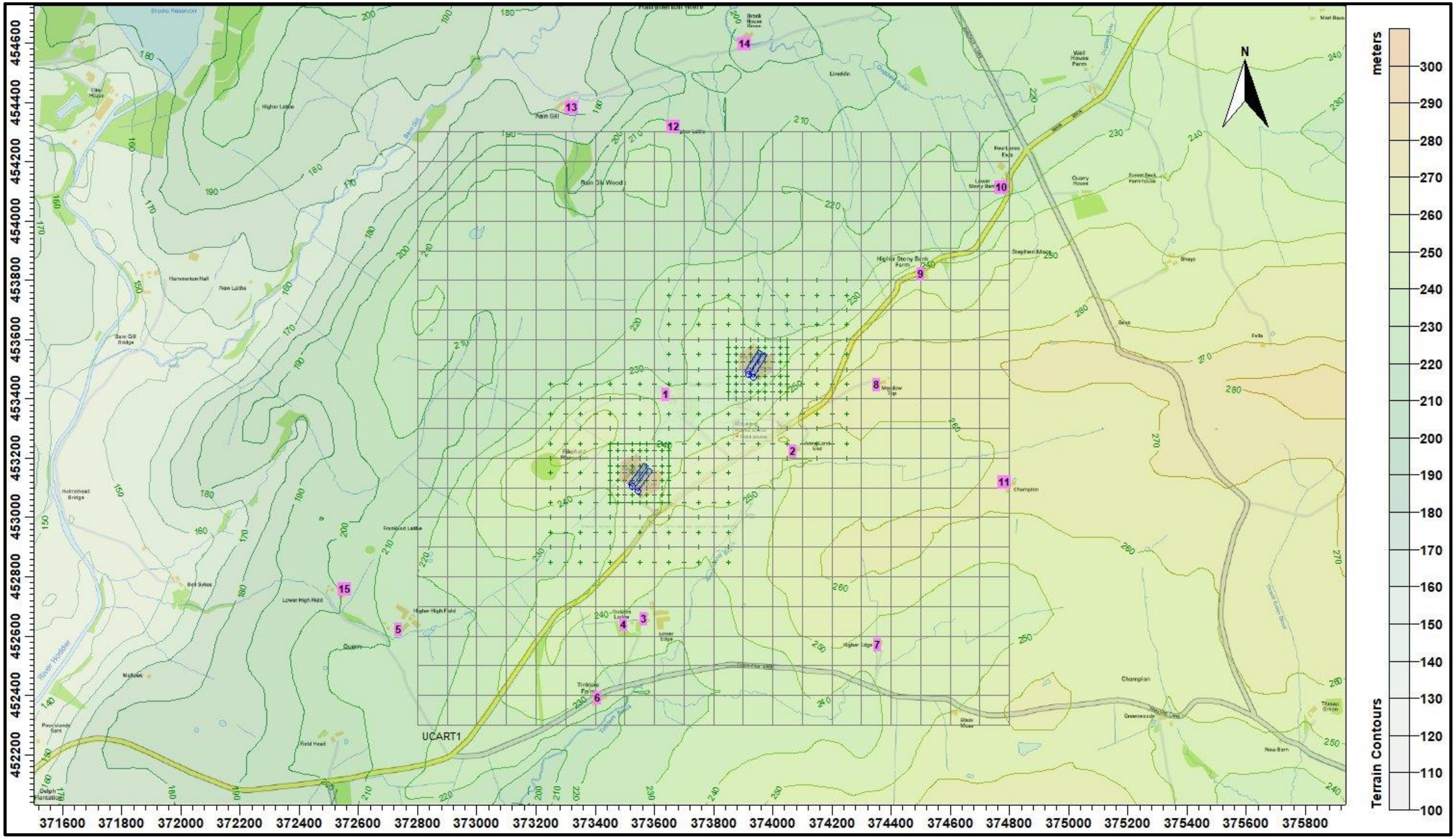
4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 6.4 km x 6.4 km domain has been resampled at 50 m horizontal resolution for use within ADMS. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is 100 m.

4.7 Other model parameters

A fixed surface roughness length of 0.15 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.125 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and the stability and therefore increases predicted ground level concentrations.

Figure 5. The discrete receptors and nested Cartesian grid receptors.



5. Details of the Model Runs and Results

For this study, ADMS was run with calms module of ADMS and with terrain. ADMS was run a total of four times (once for each year of the four year meteorological record). Statistics for the annual 98th percentile hourly mean odour concentration at each receptor were compiled for each of the four runs.

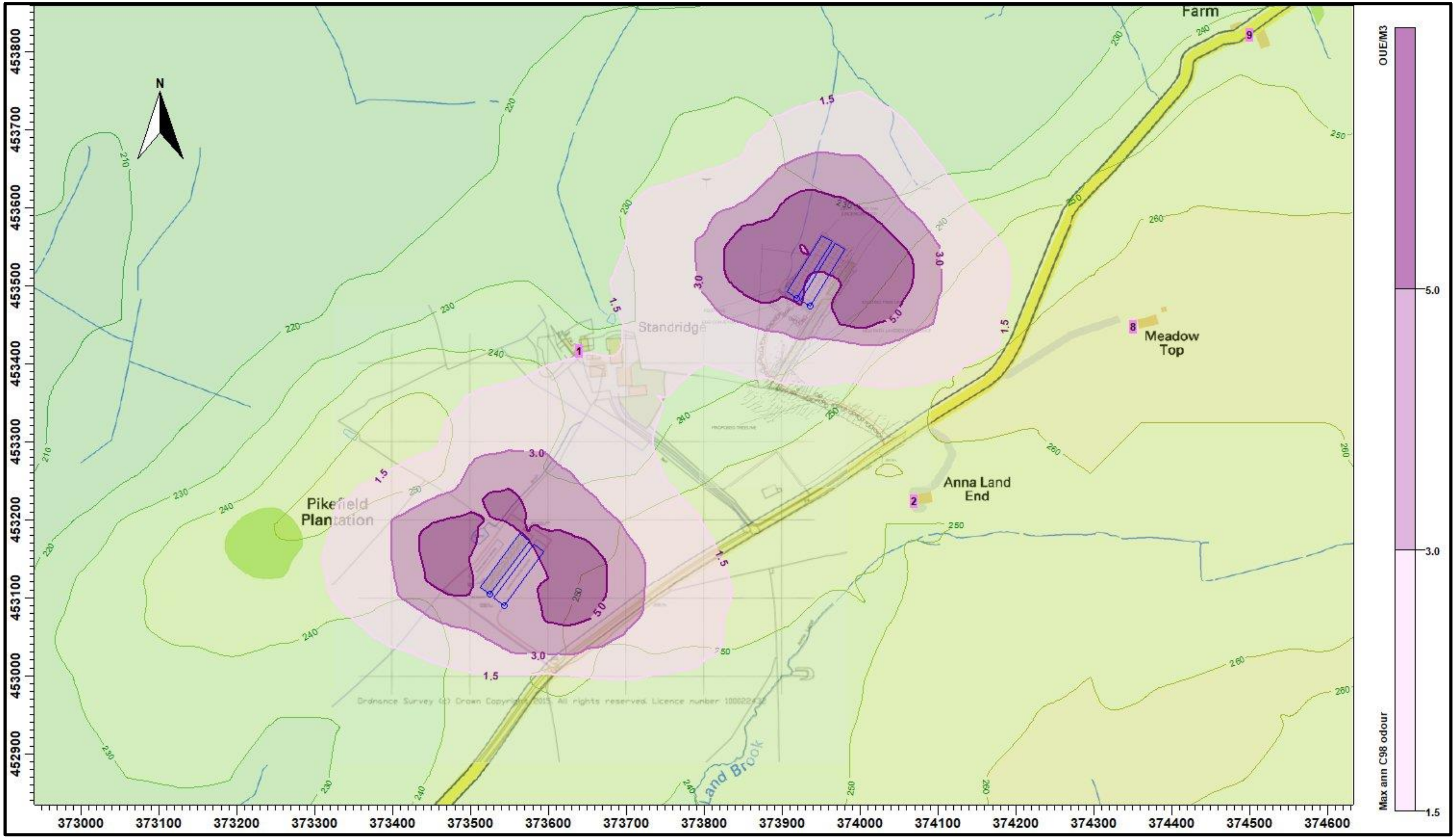
A summary of the results at the discrete receptors is shown in Table 3, where the maximum annual 98th percentile hourly mean odour concentration is shown. A contour plot of the maximum annual 98th percentile hourly mean odour concentration is shown in Figure 6.

In Table 3, predicted odour exposures in excess of the Environment Agency's benchmark of 3.0 ou_E/m^3 as an annual 98th percentile hourly mean are coloured blue; those in the range that UKWIR research suggests gives rise to a significant proportion of complaints, 5.0 ou_E/m^3 to 10.0 ou_E/m^3 as an annual 98th percentile hourly mean, are coloured orange and predicted exposures likely to cause annoyance and complaint are coloured red.

Table 3. Maximum annual 98th percentile hourly mean odour concentrations at the discrete receptors

Receptor number	X(m)	Y(m)	Name/Location	Maximum annual 98th percentile hourly mean odour concentration (ou_E/m^3)
1	373640	453415	Standridge	1.46
2	374069	453224	Anna Land End	0.84
3	373565	452656	Lower Edge	0.25
4	373497	452639	Tinklers Lodge	0.22
5	372735	452620	Higher High Farm	0.18
6	373407	452391	Tinklers Farm	0.12
7	374354	452569	Higher Edge	0.27
8	374350	453447	Meadow Tip	0.71
9	374500	453821	Higher Stoney Bank Farm	0.31
10	374772	454113	Lower Stoney Bank Farm	0.16
11	374784	453118	Champion	0.34
12	373666	454318	Higher Laithe	0.20
13	373322	454382	Rain Gill	0.15
14	373906	454599	Brook House Green	0.14
15	372554	452757	Lower High Farm	0.18

Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration



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6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Richard Robinson to use computer modelling to assess the impact of odour emissions from the existing and proposed free range egg laying chicken houses at Tosside Road, near Slaidburn in Lancashire. BB7 4TP.

Odour emission rates from the existing and proposed poultry houses have been assessed and quantified based upon an emissions model that takes into account the likely internal odour concentrations and ventilation rates of the poultry houses. The odour emission rates so obtained have then been used as inputs to an atmospheric dispersion model which calculates odour exposure levels in the surrounding area.

The modelling predicts that, at all of the residential receptors considered, the odour exposure would be below the Environment Agency's benchmark for moderately offensive odours, which is a 98th percentile hourly mean of 3.0 ou_E/m^3 over a one year period.

7. References

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