A Dispersion Modelling Study of the Impact of Odour from the Proposed Broiler Chicken Rearing Houses at Brynthomas, Penybont, near to Llandrindod Wells in Powys

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Steve Raasch, on behalf of Ben Owens, the applicant, to use computer modelling to assess the impact of odour emissions from the proposed broiler chicken rearing houses at Brynthomas, Penybont, near to Llandrindod Wells in Powys. LD1 5SP.

Odour emission rates from the 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.

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 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

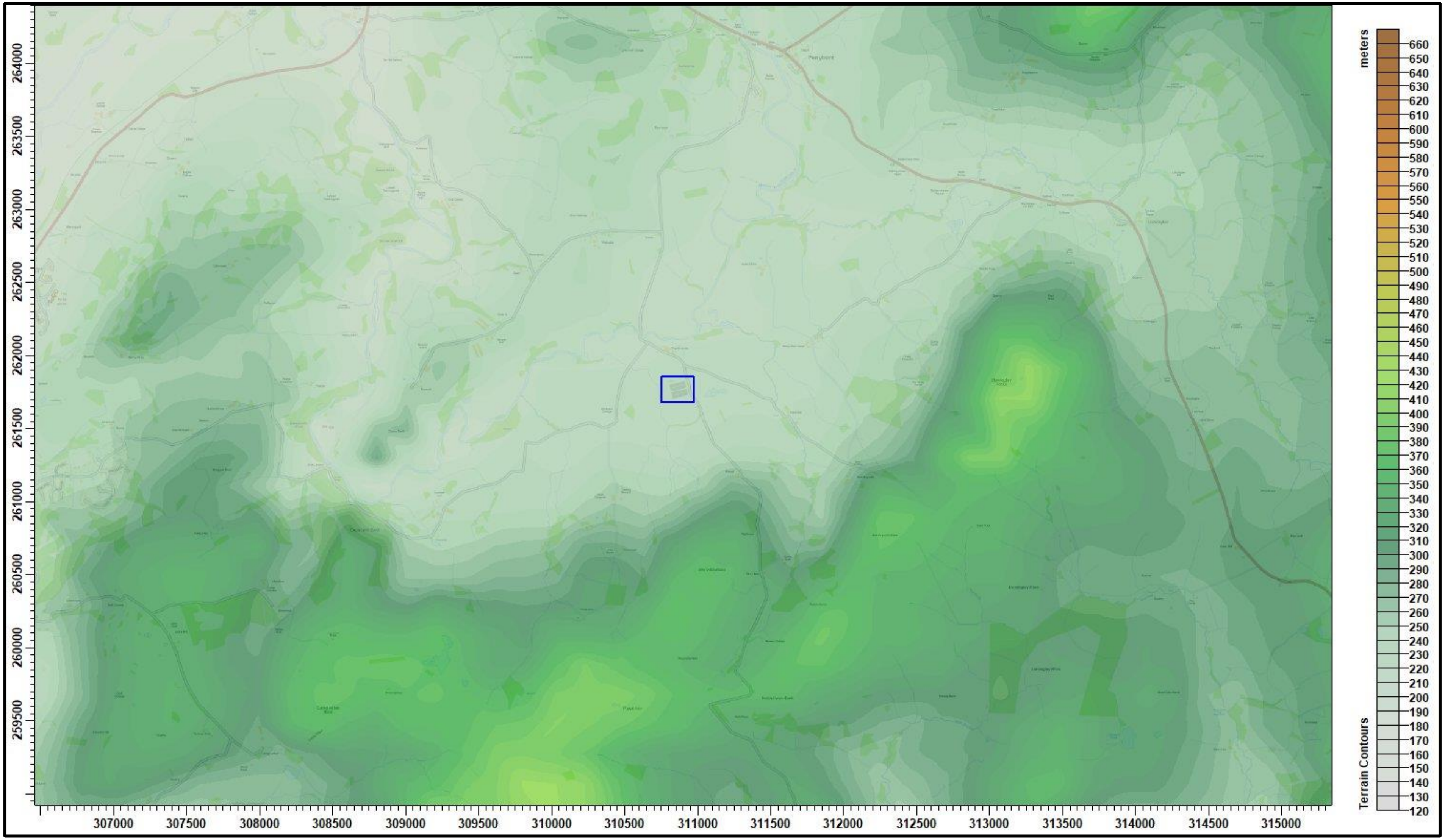
Brynthomas is in a rural area approximately 2.3 km to the south of the village of Penybont, near to Llandrindod Wells in Powys. The surrounding land is used largely for grazing, but there is some arable farming nearby. The farm is located on level ground on the banks of the River Ithon, a tributary of the River Wye, at an elevation of around 230 m, with the land rising to the east and south.

Currently there is a single, naturally ventilated, poultry house at Brynthomas, which provides accommodation for up to 32,000 egg-laying chickens, which have access to outdoor ranging areas via pop holes on the sides of the house. Under the proposal, the current poultry house would be replaced by four new poultry houses on the same site. The new poultry houses would provide accommodation for up to 200,000 broiler chickens and would be ventilated via high speed ridge fans with side inlets.

There are some residences and commercial properties in the countryside around the site of the proposed poultry houses at Brynthomas. The farm buildings at Brynthomas are approximately 190 m to the north; the closest residence is the farmhouse at Brynthomas, which is approximately 240 m to the north-west of the proposed poultry houses. The closest residence not associated with the proposed poultry houses is at Brickyard Cottages, which is approximately 360 m to the west and there are further residences nearby at Nantddu, which is approximately 650 m to the south-east and Abermithel, which is approximately 880 m to the north-east of the proposed poultry houses. There are further residences, farmsteads and farm buildings in the countryside surrounding the site and the denser residential areas associated with the small village of Penybont are from approximately 1.9 km to the north of the proposed poultry houses at Brynthomas.

A map of the surrounding area is provided in Figure 1; in the figure, the site of the proposed poultry houses at Brynthomas are outlined in blue.

Figure 1. The area surrounding the site of the proposed poultry unit at Brynthomas



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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 and Environment Agency guidelines (adopted by Natural Resources Wales) 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 model's 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 (adopted by Natural Resources Wales)

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, indicates 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 on-going odour complaints. The findings of this research and subsequent UKWIR research indicated 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. The UKWIR research is also considered.

3.5 Quantification of odour emissions

Odour emission rates from broiler houses depend on many factors and are highly variable. At the beginning of a crop cycle, when chicks are small, litter is clean and only minimum ventilation is required, the odour emission rate may be small. Towards the end of the crop, odour production within the poultry housing increases rapidly and ventilation requirements are greater, particularly in hot weather, therefore emission rates are considerably greater than at the beginning of the crop.

Peak odour emission rates are likely to occur when the housing is cleared of spent litter at the end of each crop. There is little available information on the magnitude of this peak emission, but it is likely to be greater than any emission that might occur when there are birds in the house. The time taken to perform the operation is usually around two hours per house and it is normal to maintain ventilation during this time. There are measures that can be taken to minimise odour production whilst the housing is being cleared of spent litter and there is usually some discretion as to when the operation is carried out; therefore, to avoid high odour levels at nearby sensitive receptors, it may be possible to time the operation to coincide with winds blowing in a favourable direction.

To calculate an odour emission rate it is necessary to know the internal odour concentration and ventilation rate of the poultry houses. For the calculation, the internal concentration is assumed to be a function of the age of the crop and the stocking density.

The internal concentrations used in the calculations increase exponentially from 300 ou_E/m^3 at day 1 of the crop, to approximately 700 ou_E/m^3 at day 16 of the crop, to approximately 1,800 ou_E/m^3 at day 30 of the crop and approximately 2,300 ou_E/m^3 at day 34 of the crop. These figures are obtained from a review of available literature and measured concentrations in modern broiler houses available to AS Modelling & Data Ltd. and are based primarily on Robertson *et al.* (2002).

The ventilation rates used in the calculations are based on industry practices and standard bird growth factors. Minimum ventilation rates are as those of an operational poultry house and maximum ventilation rates are based on Defra guidelines. It is assumed that a continuous minimum ventilation rate is maintained, which provides for 2 to 3 air changes per hour of the poultry house, in order to maintain negative pressure and minimise fugitive emissions. Target internal temperature is 33 Celsius at the beginning of the crop and is decreased to 22 Celsius by day 34 of the crop. If the external temperature is 7 Celsius, or more, lower than the target temperature, minimum ventilation only is assumed for the calculation. Above this, ventilation rates are increased in proportion to the difference between ambient temperature and target internal temperature. A maximum transitional ventilation rate (35% of the maximum possible ventilation rate) is reached when the ambient temperature is equal to the target temperature. A high ventilation rate (70% maximum possible ventilation rate) is reached when the temperature is 4 degrees above target and if external temperature is above 33 Celsius the maximum ventilation rate is assumed.

At high ventilation rates, it is likely that internal odour concentrations fall because odour is extracted much faster than it is created. Therefore, if the calculated ventilation rate exceeds that required to replace the volume of air in the house every 5 minutes, internal concentrations are reduced (by a factor of the square root of 7.5 times the shed volume/divided by the ventilation rate as an hourly figure).

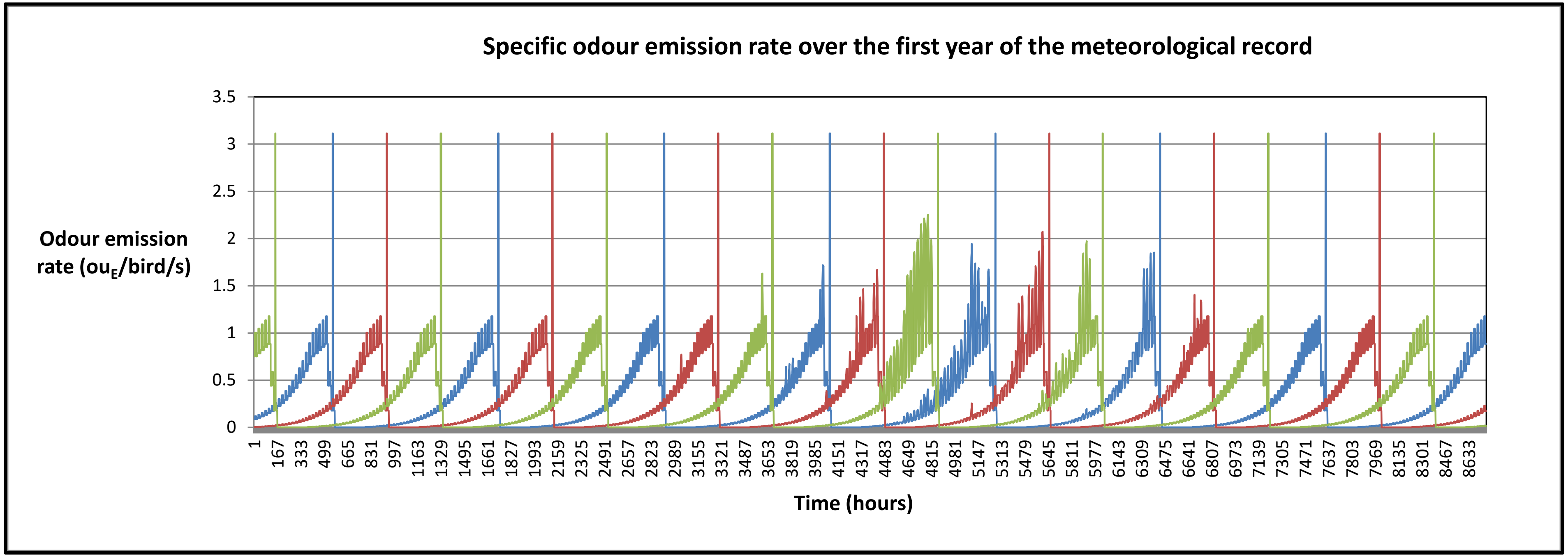
Based upon these principles, an emission rate for each hour of the period modelled is calculated by multiplying the concentration by the ventilation rate. Both the crop length and period the housing is empty can be varied. An estimation of the emission during the cleaning out process can also be included. In this case, it is assumed that the houses are cleared sequentially and each house takes 2 hours to clear.

In this case, it is assumed for the calculations that the crop length is 38 days, with 25% thinning of the birds at day 31 and that there is an empty period of 11 days after each crop. To provide robust statistics, three sets of calculations were performed; the first with the first day of the meteorological record coinciding with day 1 of the crop cycle, the second coinciding with day 16 of the crop and the third coinciding with day 33 of the crop. A summary of the emission rates used in this study is provided in Table 1. It should be noted that the figures in this table refer to the whole of the crop length whilst most figures quoted in literature are figures obtained from the latter stages of the crop cycle and therefore should not be compared directly to these AS Modelling & Data Ltd. figures. The specific odour emission rate used for the clearing process is approximately 3.10 ou_E/bird/s and the 98^{th} percentile emission rate is approximately 1.15 ou_E/bird/s. As an example, a graph of the specific emission rate over the first year of the meteorological record for each of the three crop cycles is shown in Figure 2. A spreadsheet detailing the calculations can be provided upon request.

Table 1. Summary of odour emission rates (average of all 3 cycles)

Emission rate (ou_E/s per bird as stocked during crop)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	0.282	0.254	0.338	1.178
Spring	0.304	0.255	0.354	1.870
Summer	0.342	0.255	0.394	2.412
Autumn	0.297	0.254	0.340	1.460

Figure 2. Specific emission rate over the first year of each of the three crop cycles



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). Observational meteorological data from Shobdon Airfield, Trawsgoed and Sennybridge is also considered.

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)[1]. 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.

The wind rose for the raw GFS data for the Brynthomas site is shown in Figure 3a.

Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location of the existing and proposed poultry houses at Brynthomas is shown in Figure 3b. Note that elsewhere in the modelling domain the modified wind roses may differ more, or less, markedly and that the resolution of the wind field is approximately 350 m.

Data from the meteorological recording stations at Shobdon Airfield, Trawsgoed and Sennybridge have also been considered as the closest to the site. Shobdon Airfield is approximately 28.5 km to the east, Trawsgoed is 45 km approximately to the west and Sennybridge is approximately 29 km to the south-west of Brynthomas. However, neither Shobdon Airfield, Trawsgoed nor Sennybridge is considered to have an aspect that in any way could be considered similar to that at Brynthomas; therefore, it should be noted that the frequency of winds from a particular direction in the Shobdon Airfield, Trawsgoed or Sennybridge data may be either high or low in comparison to what might occur at Brynthomas, which means mean concentrations downwind may be either over or under predicted. Additionally, periods of light winds and calms cannot be properly modelled. Therefore, it is the opinion of AS Modelling & Data Ltd. that the results obtained using the GFS data, particularly when modified by using FLOWSTAR [2], are less likely to have gross errors than the results obtained using the observational data and should be given more weight when interpreting the results of the modelling. The wind rose for Shobdon Airfield is shown in Figure 3c, the wind rose for Trawsgoed is shown in Figure 3d and the wind rose for Sennybridge is shown in Figure 3e.

1. Note that FLOWSAR requirements are for meteorological data representative of the upwind flow over the modelling domain and that single site meteorological data that is representative of the application site is not generally suitable.
2. When modelling complex terrain with ADMS, by default, the minimum turbulence length has 0.1 m added to the flat terrain value (calculated from the Monin–Obukhov length). Whist this might be appropriate over hill/mountain tops in terrain with slopes > 1:10 in lesser terrain, it introduces model behaviour that is not desirable where FLOWSTAR is simply being used to modify the upwind flow. Specifically, the parameter sigma z of the Gaussian plume model is overly constrained, which for point sources emissions, may cause over prediction of ground level concentrations in stable weather conditions and light winds (Steven R. Hanna & Biswanath Chowdhury, 2013). Note that this becomes particularly important if calm and light wind conditions are not being ignored as they often are when using traditional observational meteorological datasets. To reduce this behaviour, where terrain is modelled, AS Modelling & Data Ltd. have set a minimum turbulence length of 0.025 m in ADMS. This approximates the normal behaviour of ADMS with flat terrain.

Figure 3a. The wind rose. Raw GFS derived data, for 52.247 N, 3.307 W, 2013-2016

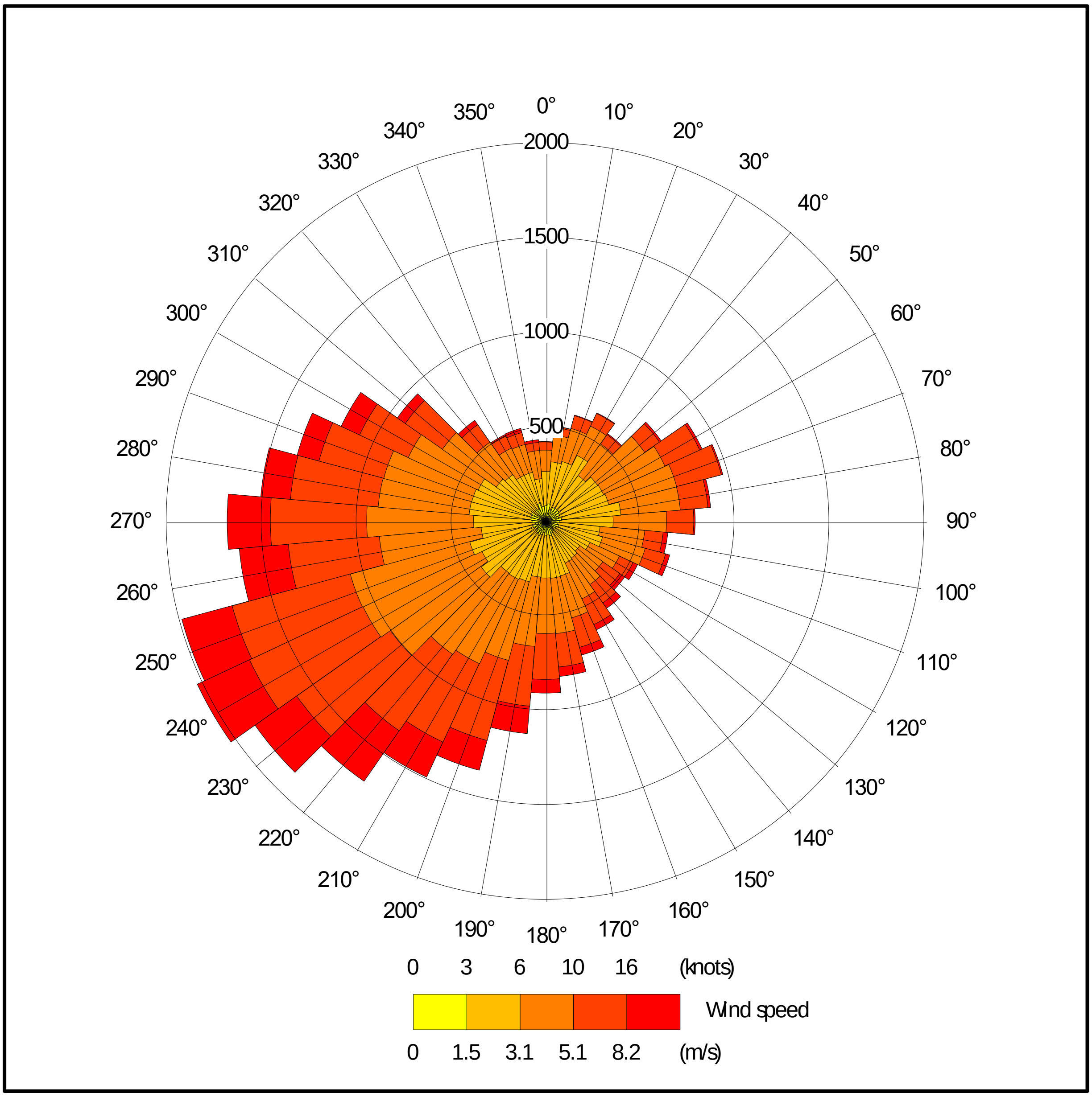


Figure 3b. The wind rose. FLOWSTAR modified GFS derived data for NGR 310875, 261765, 2013-2016

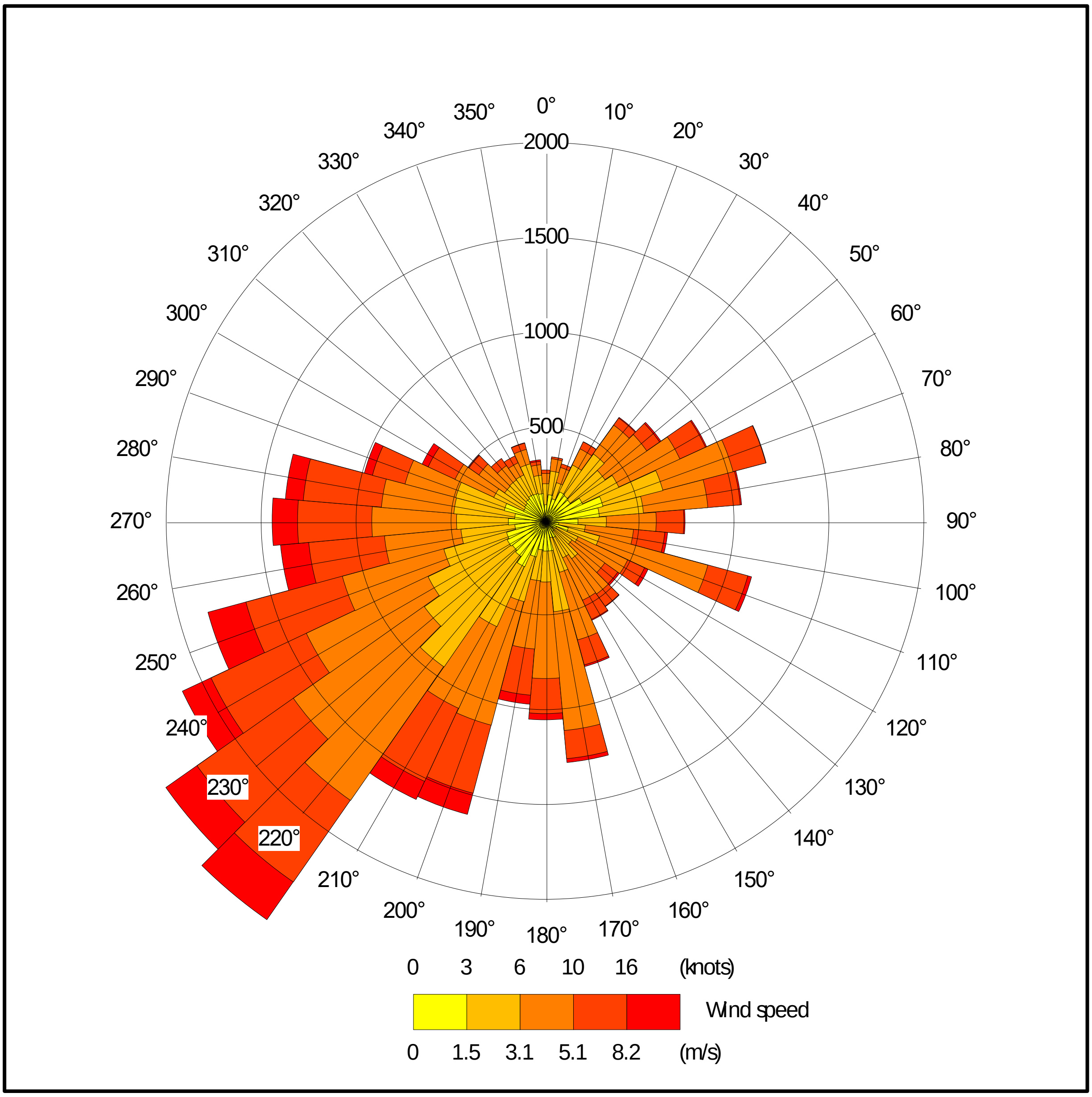


Figure 3c. The wind rose. Recorded meteorological data at Shobdon Airfield, 2013-2016

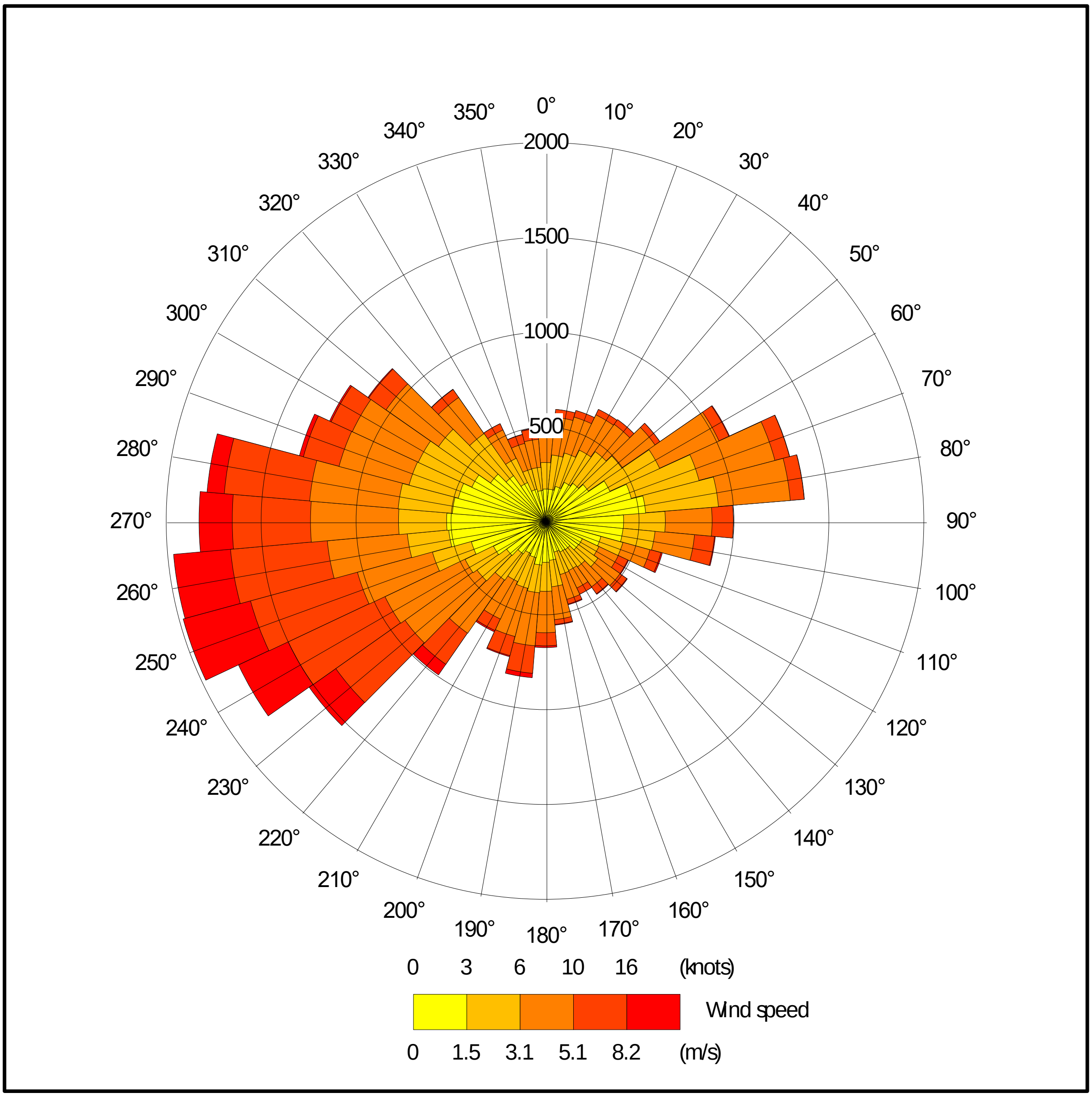


Figure 3d. The wind rose. Recorded meteorological data at Trawgoed, 2013-2016

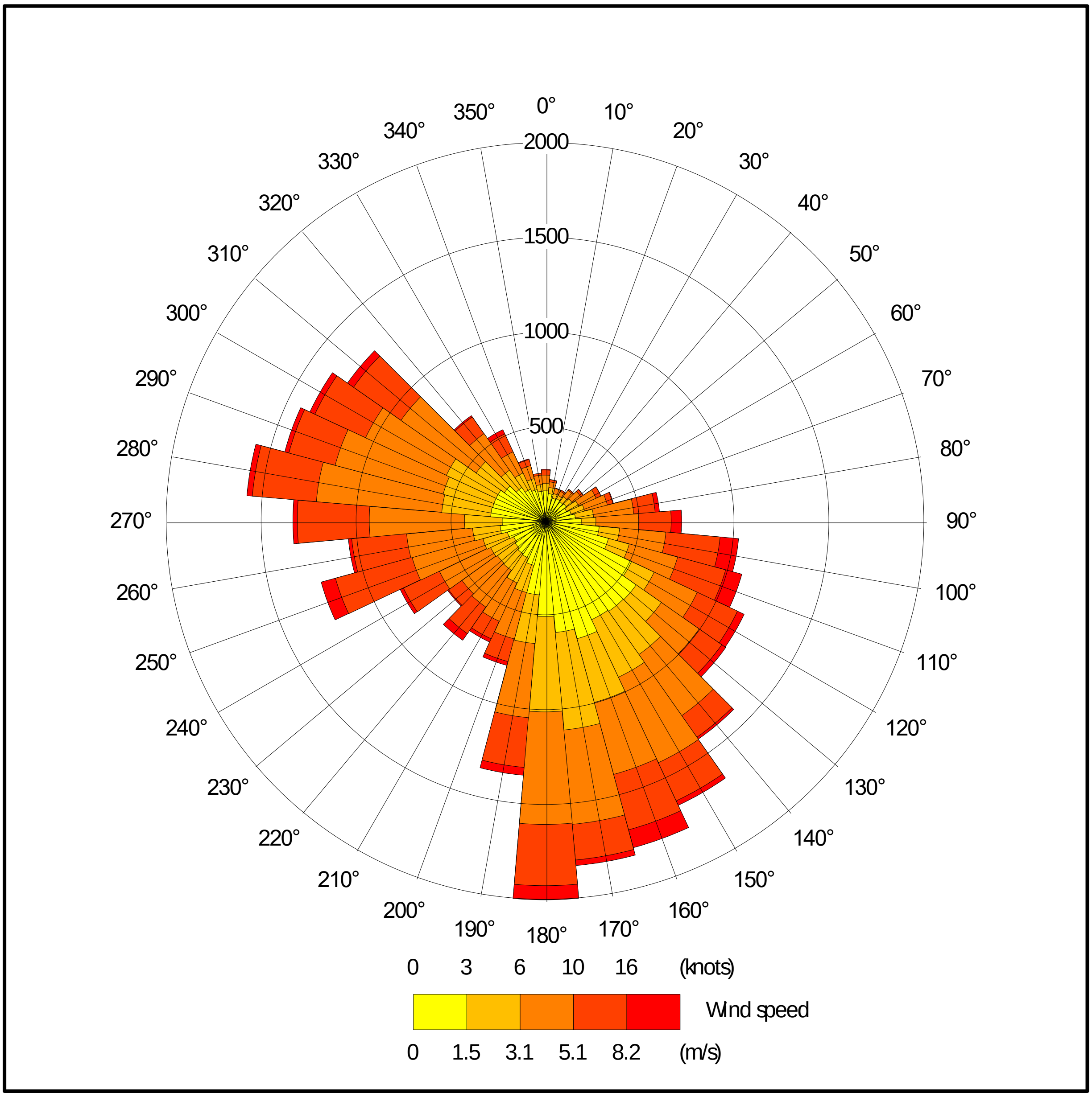
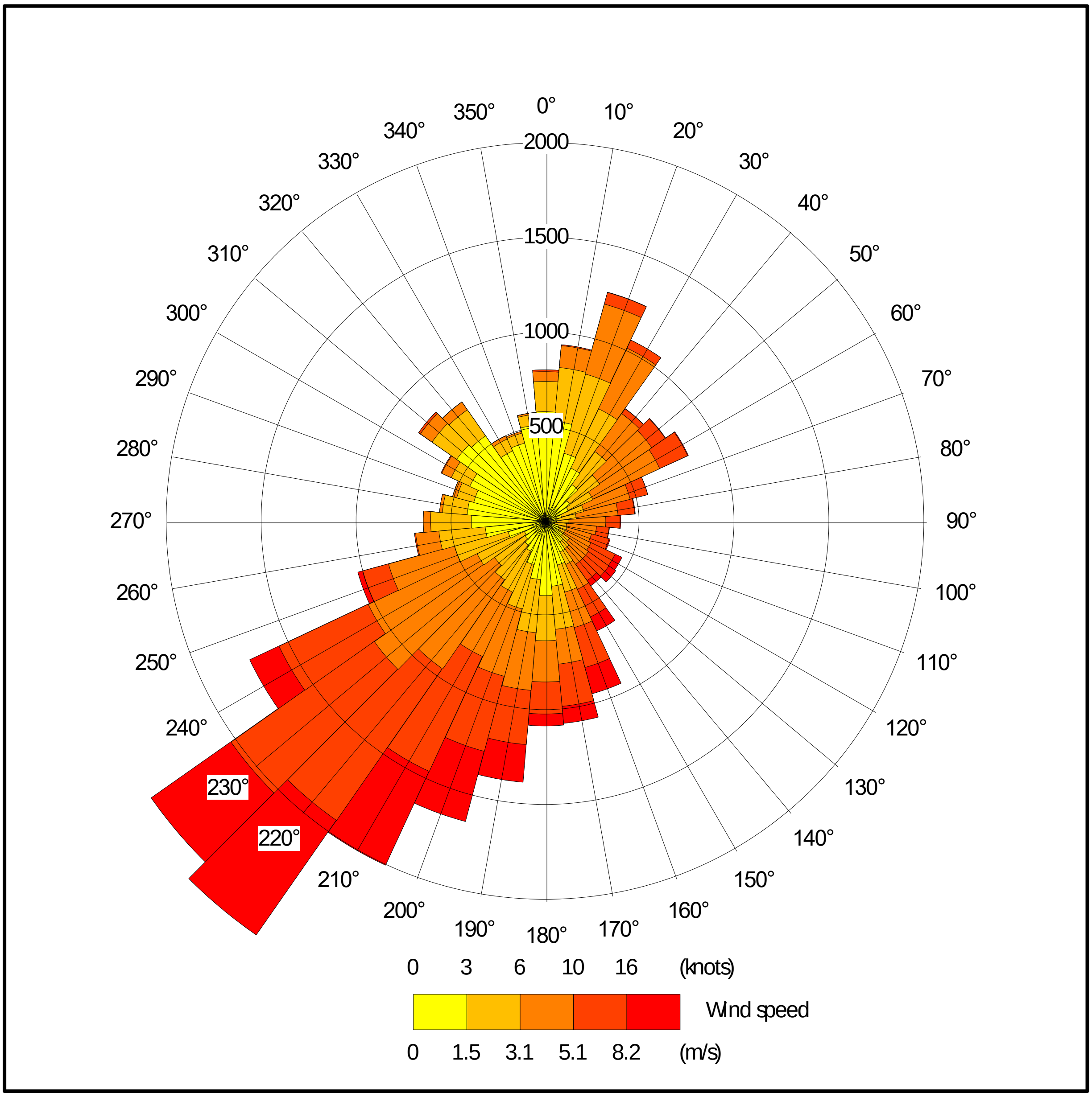


Figure 3e. The wind rose. Recorded meteorological data at Sennybridge, 2013-2016



4.2 Emission sources

Emissions from the chimneys of uncapped high speed ridge fans on the proposed poultry houses are represented by three point sources per house within ADMS (PR1 to PR4; a, b & c). Details of the point source parameters are shown in Table 2 and their positions may be seen in Figure 4, where they are marked by red star symbols.

Table 2. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (ou_E/s)
PR1 to PR4; a, b & c	6.0	0.8	11.0	Variable [1]	Variable [1]

1. Dependent on crop stage and ambient temperature.

4.3 Modelled buildings

The structure of the proposed poultry houses may affect the plumes from the point sources. Therefore, these buildings are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 4, where they are marked by grey rectangles.

4.4 Discrete receptors

Thirteen 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, a nested Cartesian grid has been defined within ADMS. The grid receptors are defined at 1.5 m above ground level within ADMS. The positions of the grid receptors may be seen in Figure 5, where they are marked by green crosses.

4.6 Terrain data

There are some slopes that may affect wind flow and dispersion of odour in the area around the site; therefore, terrain has been considered in the modelling. The terrain data used are derived from the Ordnance Survey 50 m Digital Elevation Model. The terrain domain is 6.4 km by 6.4 km and FLOWSTAR is run at a resolution of 64 x 64 points; therefore, the effective model resolution is 100 m.

4.7 Other model parameters

A fixed surface roughness length of 0.25 m has been applied over the entire modelling domain. The GFS meteorological data is assumed to have a roughness length of 0.225 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 4. The positions of modelled buildings & sources

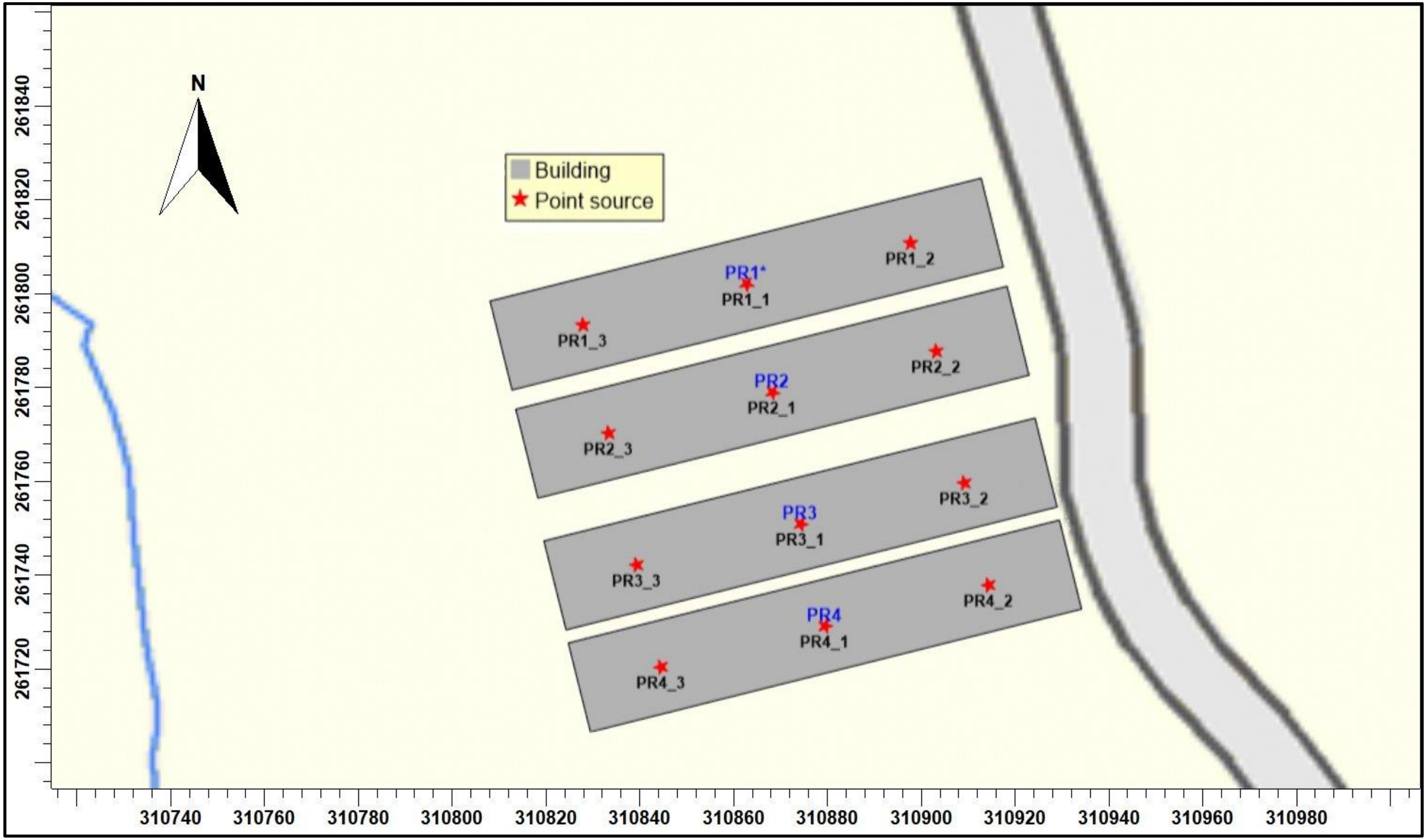


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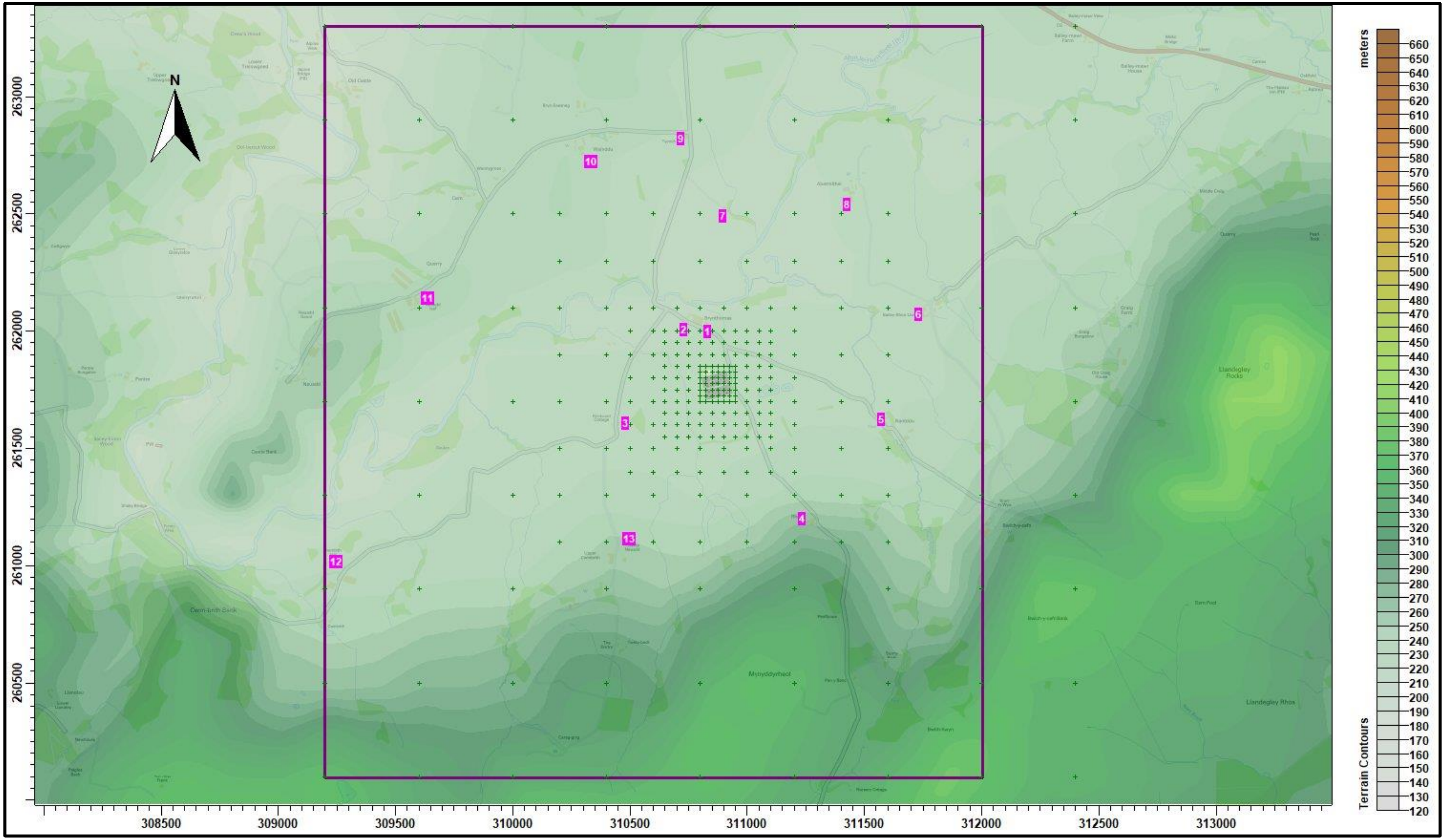
Figure 5. The discrete receptors and nested Cartesian grid receptors



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5. Details of the Model Runs and Results

ADMS was effectively run forty-eight times, once for each year in the meteorological record, for each of the three crop cycles and in the four following modes:

- With the terrain (FLOWSTAR) and calms modules, using GFS meteorological data.
- With the terrain (FLOWSTAR) and calms modules, using Sennybridge meteorological data.
- With the terrain (FLOWSTAR) and calms modules, using Shobdon Airfield meteorological data.
- With the terrain (FLOWSTAR) and calms modules, using Trawsgoed meteorological data.

Statistics for the annual 98th percentile hourly mean odour concentration at each receptor were compiled for each of the forty-eight runs.

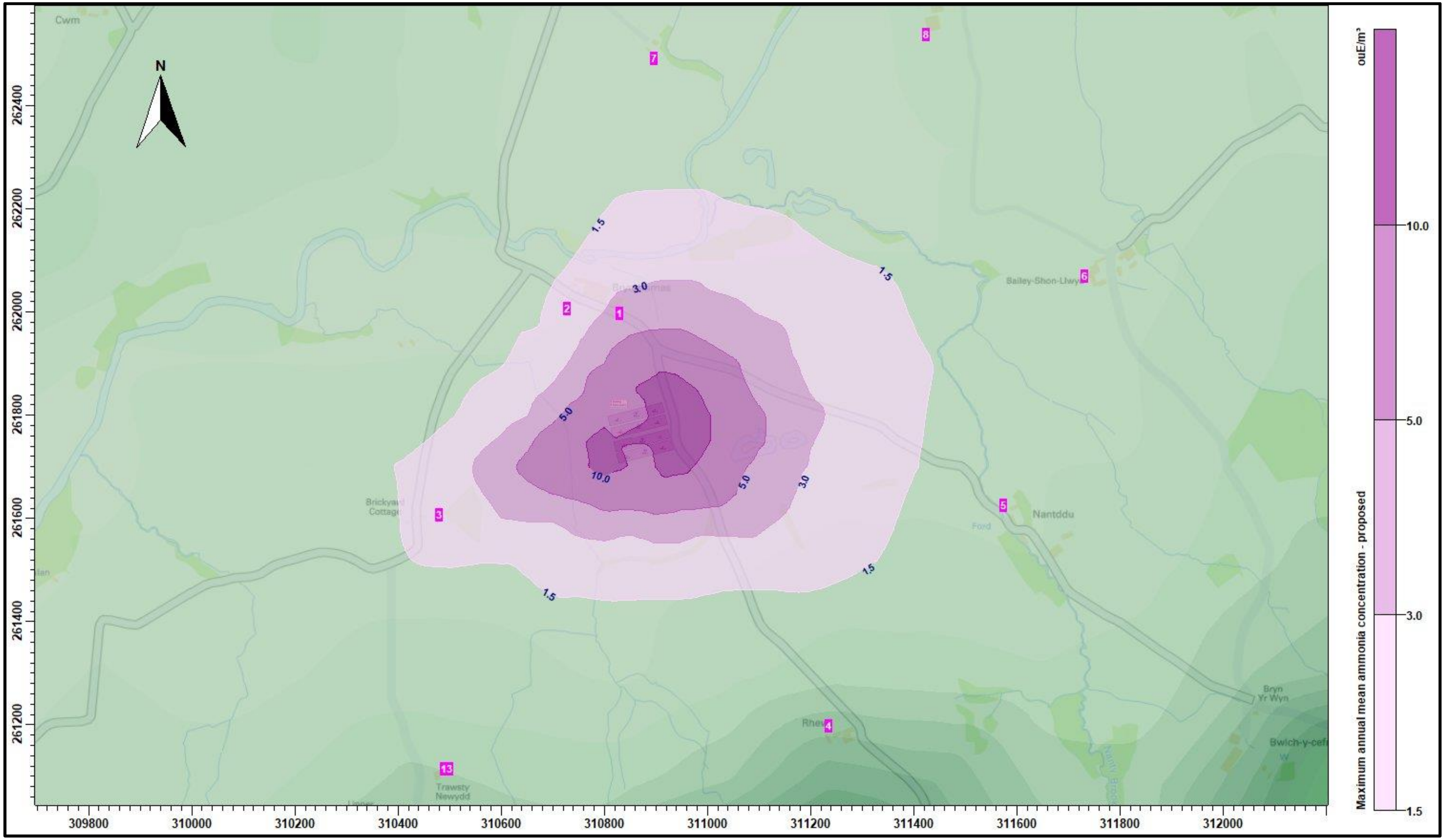
A summary of the results of the forty-eight runs at the discrete receptors is provided in Table 3 where the maximum annual 98th percentile hourly mean odour concentration is shown. A contour plot of the maximum annual 98th percentile hourly mean odour concentrations for the proposed poultry houses for the GFS model runs 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. Predicted maximum annual 98th percentile hourly mean odour concentrations at the discrete receptors

Receptor number	X(m)	Y(m)	Name	Maximum annual mean 98th Percentile Odour Concentration (ou_E/m^3)			
				GFS Calms Terrain	Sennybridge Calms Terrain	Shobdon Airfield Calms Terrain	Trawscoed Calms Terrain
1	310830	261998	Brynthomas	**3.58**	2.73	2.49	**7.04**
2	310728	262006	Brynthomas Farmhouse	1.97	1.28	1.29	**5.95**
3	310479	261607	Brickyard Cottage	2.46	1.82	2.85	2.65
4	311235	261198	Rhewl	0.41	0.32	0.36	0.87
5	311574	261624	Nantddu	0.89	0.41	0.92	1.84
6	311732	262068	Bailey-Shon-Llwyd	0.72	0.47	0.57	1.14
7	310896	262491	Farm buildings	0.71	0.55	0.42	1.91
8	311424	262538	Abermithel	0.51	0.49	0.30	0.93
9	310716	262818	Tycoch	0.29	0.22	0.18	1.27
10	310334	262722	Wainddu	0.23	0.15	0.12	1.17
11	309640	262137	Neuadd Isaf	0.17	0.07	0.15	0.49
12	309249	261014	Cwmbirth Isaf	0.48	0.27	0.47	0.55
13	310496	261114	Trawsty Newydd	0.39	0.65	0.44	0.50

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



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6. Summary and Conclusions

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Odour emission rates from the 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 one nearby property, the farm at Brynthomas, which AS Modelling & Data Ltd. understands is a farm owned by the operator of the poultry unit and is not residential; the predicted 98th percentile odour concentrations would exceed the Environment Agency's benchmark for moderately offensive odours, a maximum annual 98th percentile hourly mean concentration of 3.0 ou_E/m^3.

At all other receptors considered, the modelling predicts that 98th percentile odour concentrations would be below the Environment Agency's benchmark value for moderately offensive odours.

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