A Dispersion Modelling Study of the Impact of Odour from the Existing and Proposed Free Range Egg Laying Chicken Houses at Argoed, Trefeglwys, near Caersws in Powys

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Gail Lewis of Roger Parry & Partners LLP, on behalf of R J Hughes and Co, to use computer modelling to assess the impact of odour emissions from the existing and proposed free range egg laying chicken houses at Argoed, Trefeglwys, near Caersws in Powys. SY17 5QT.

Odour emission rates from the existing and proposed poultry houses have been assessed and quantified based upon emission rates mandated by Natural Resources Wales. 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 existing and proposed free range egg laying houses at Argoed are in an isolated rural area. The surrounding land is used primarily for livestock farming, with some areas of semi-natural woodlands and grassland. The site is atop a hill at an altitude of around 175 m, with the land sloping gently towards the River Trannon to the south-west and rising towards hills and mountains to the north-west.

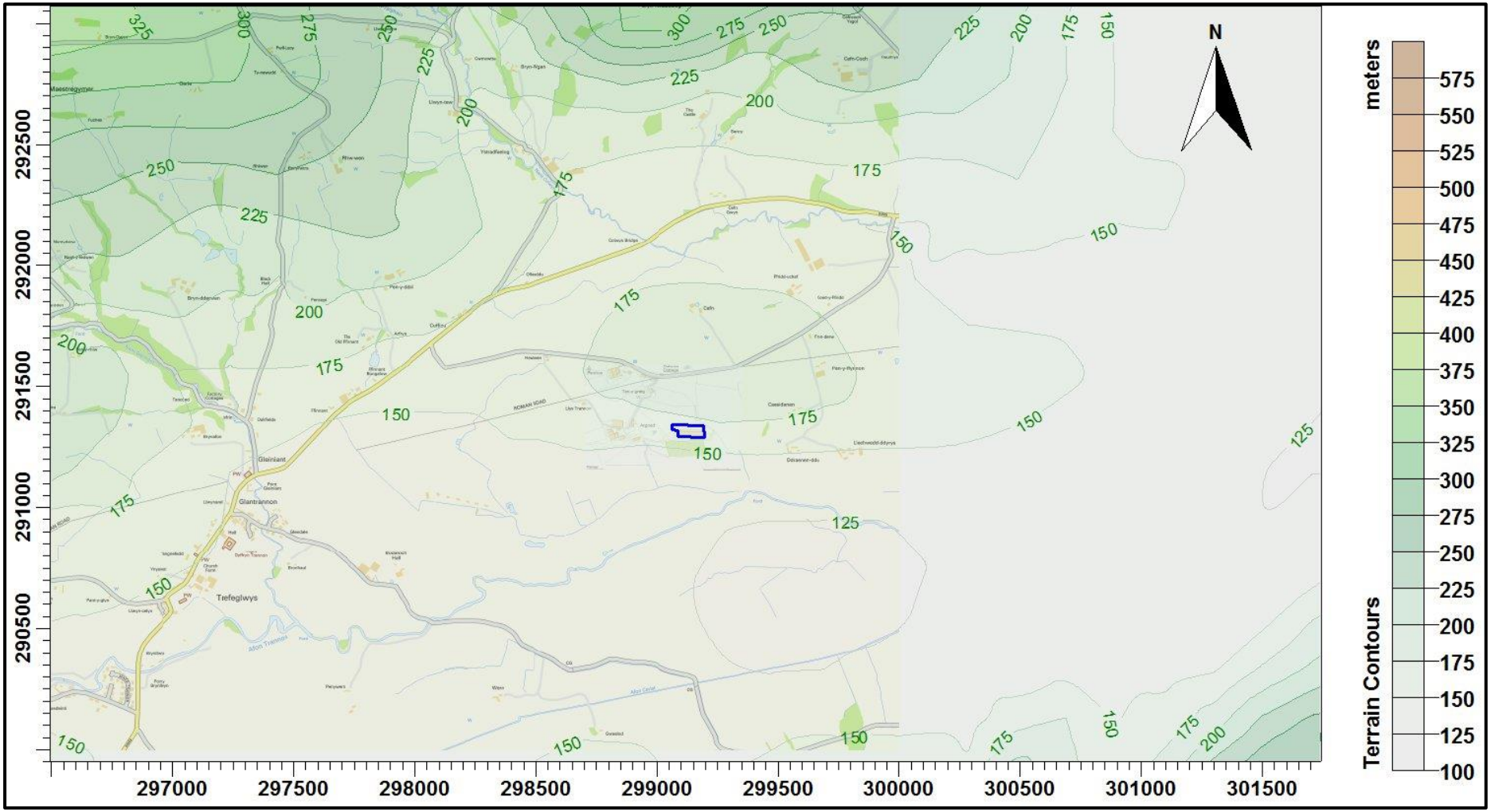
There is currently a poultry house at Argoed which provides accommodation for up to 32,000 egg laying chickens. There are pop holes on the side of the house, which provide daytime access to an outside ranging area. The poultry house is ventilated primarily by uncapped high speed ridge/roof mounted fans, each with a short chimney; however, there are also side extraction fans which are used to provide supplementary ventilation in hot weather. The bird's droppings are removed from the houses by a belt collection system twice weekly and transferred directly to a trailer for removal from site, or transferred directly to a manure spreader to be applied to the land locally, or stored temporarily on the farm.

It is proposed that a new poultry house be constructed at the site, this house would provide accommodation for an additional 32,000 egg laying chickens. There would be pop holes on the side of the house which would provide daytime access to outside ranging areas. The houses would be ventilated primarily by high speed ridge mounted fans; however, there would also be side extraction fans which would be used to provide supplementary ventilation in hot weather. The bird's droppings would be removed by a belt collection system, twice weekly, and transferred directly to a trailer for removal from the site, or transferred directly to a manure spreader to be applied to the land locally, or stored temporarily on the farm.

There are some residences and commercial properties in the area surrounding the site of the poultry unit at Argoed. Excluding the farmhouse at Argoed, the closest residences are at: Tan-y-graig, which is approximately 170 m to the north-west; several residential properties, approximately 200 m to the north-north-west; Ddraenen-ddu, approximately 355 m to the east-south-east; Caesidanen, approximately 370 m to the east-north-east and Llys Trannon, approximately 390 m to the west-north-west of the existing and proposed poultry houses.

A map of the surrounding area is provided in Figure 1 where the site of the proposed poultry houses is outlined in blue.

Figure 1. The area surrounding the site of the poultry houses at Argoed



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 existing and 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 from the existing and proposed houses would be from the chimneys of the ridge/roof mounted fans, used to ventilate the houses. Ventilation rates of laying chicken houses are such that the houses would normally be under negative pressure and therefore, any fugitive emissions would be minimal.

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 poultry houses at Argoed would be cleaned between flocks, because the manure would be collected and removed throughout the flock cycle using belt systems, the magnitude of odours during cleaning would be much lower than from more traditional houses in which manure collects within the house.

Natural Resources Wales housing emission rates

The odour emissions used in this modelling study are calculated based upon a specific emission rate of 0.47 ou_E/bird/s, the use of which is mandated by Natural Resources Wales for permitted sites. It should be noted that for much of the time this figure is probably a rather high one, but conversely, its use probably underestimates peaks in emissions during warm weather when ventilation rates are higher. Therefore, modelling results obtained using this figure as a basis of a continuous emission rate does not account for the variation in emission rates that are likely to occur in reality.

A summary of the Natural Resources Wales emission rates is provided in Table 1. As additional information, the 98th percentile emission rate is 0.47 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.

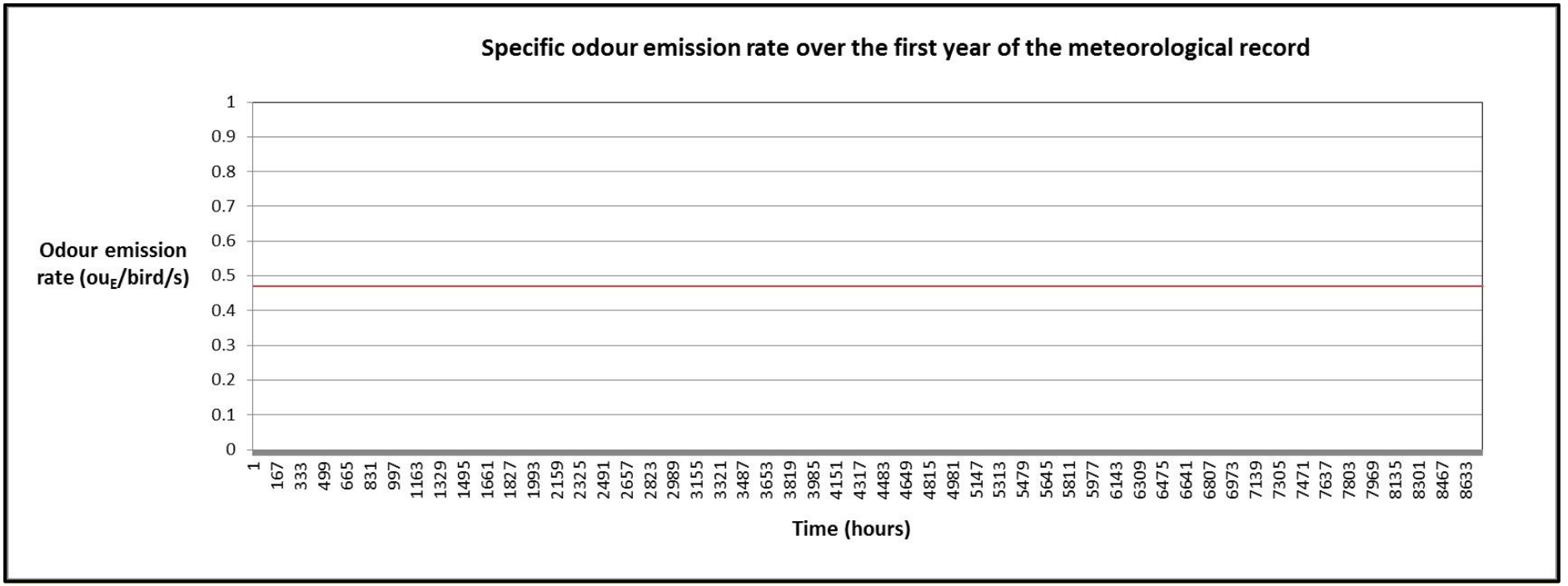
Ranging area emissions

The chickens 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 the housing emissions, is probably quite precautionary and is also intended to account for any fugitive emissions from the pop holes, which might occur when ventilation rates are low.

Table 1. Summary of odour emission rates from the existing and proposed poultry house - Natural Resources Wales emission rates

Emission rate (ou_E/bird/s)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	0.470	0.470	0.470	0.470
Spring	0.470	0.470	0.470	0.470
Summer	0.470	0.470	0.470	0.470
Autumn	0.470	0.470	0.470	0.470

Figure 2. Specific emission rate over the first year of the meteorological record (2013) - Natural Resources Wales emission rates



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). Traditional observational meteorological datasets from Lake Vyrnwy and Shobdon have also been 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). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional records may be over represented, this is because the instrumentation used may not record wind speed 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 Argoed 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 is 200 m.

Data from the meteorological recording stations at Lake Vrynwy and Shobdon have also been considered; these stations are approximately equidistant from Argoed. However, neither Lake Vrynwy nor Shobdon have an aspect that in any way could be considered similar to Argoed; therefore, it should be noted that the frequency of winds from a particular direction in the Lake Vrynwy and Shobdon data may be either high or low in comparison to what might occur at Argoed, 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, 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 roses for Lake Vyrnwy and Shobdon are shown in Figures 3c and 3d respectively.

Figure 3a. The wind rose. GFS derived data for 52.510 N, 3.486 W, 2013 – 2016

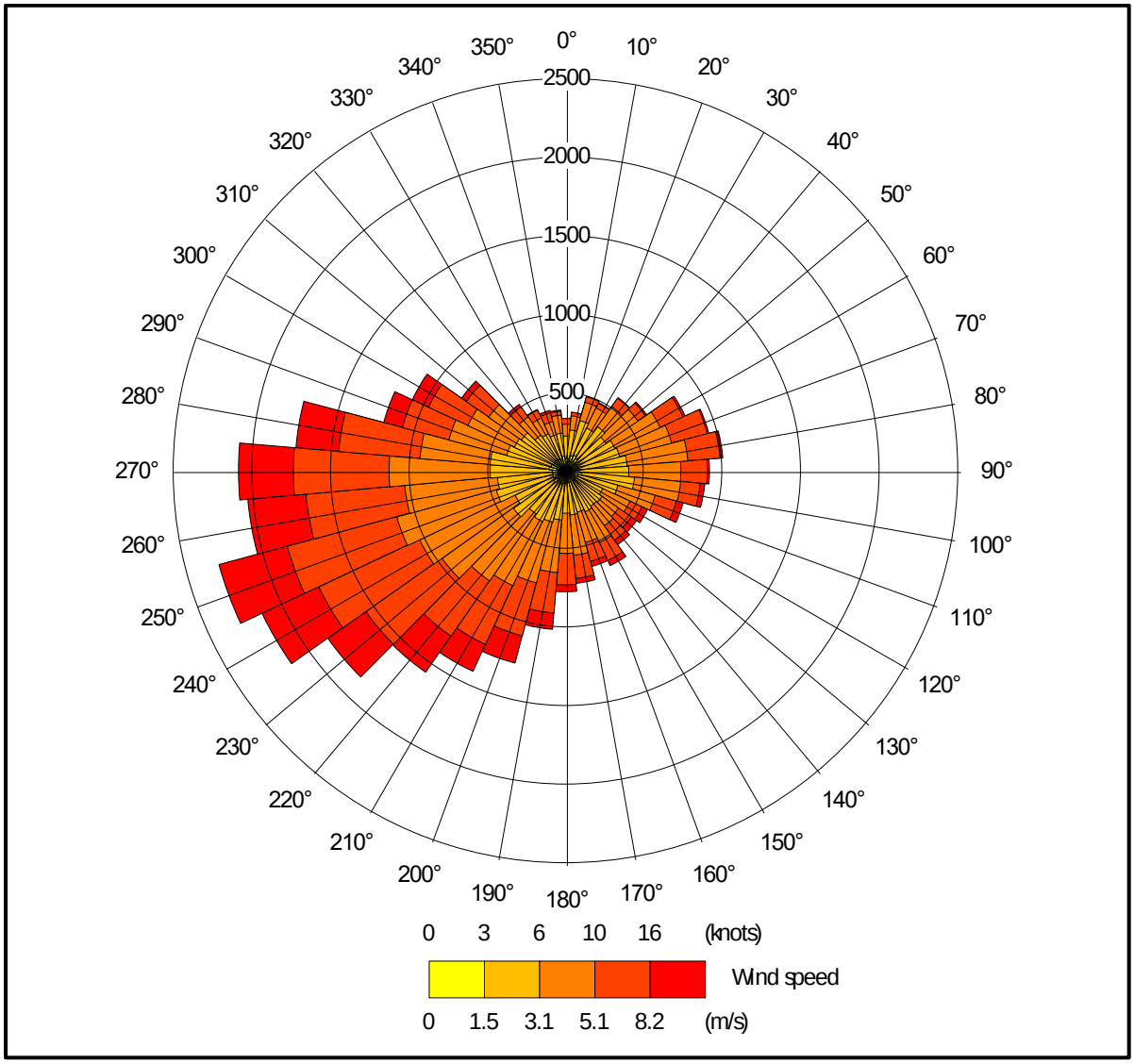


Figure 3b. The wind rose. FLOWSTAR derived data for 52.510 N, 3.486 W, 2013 – 2016

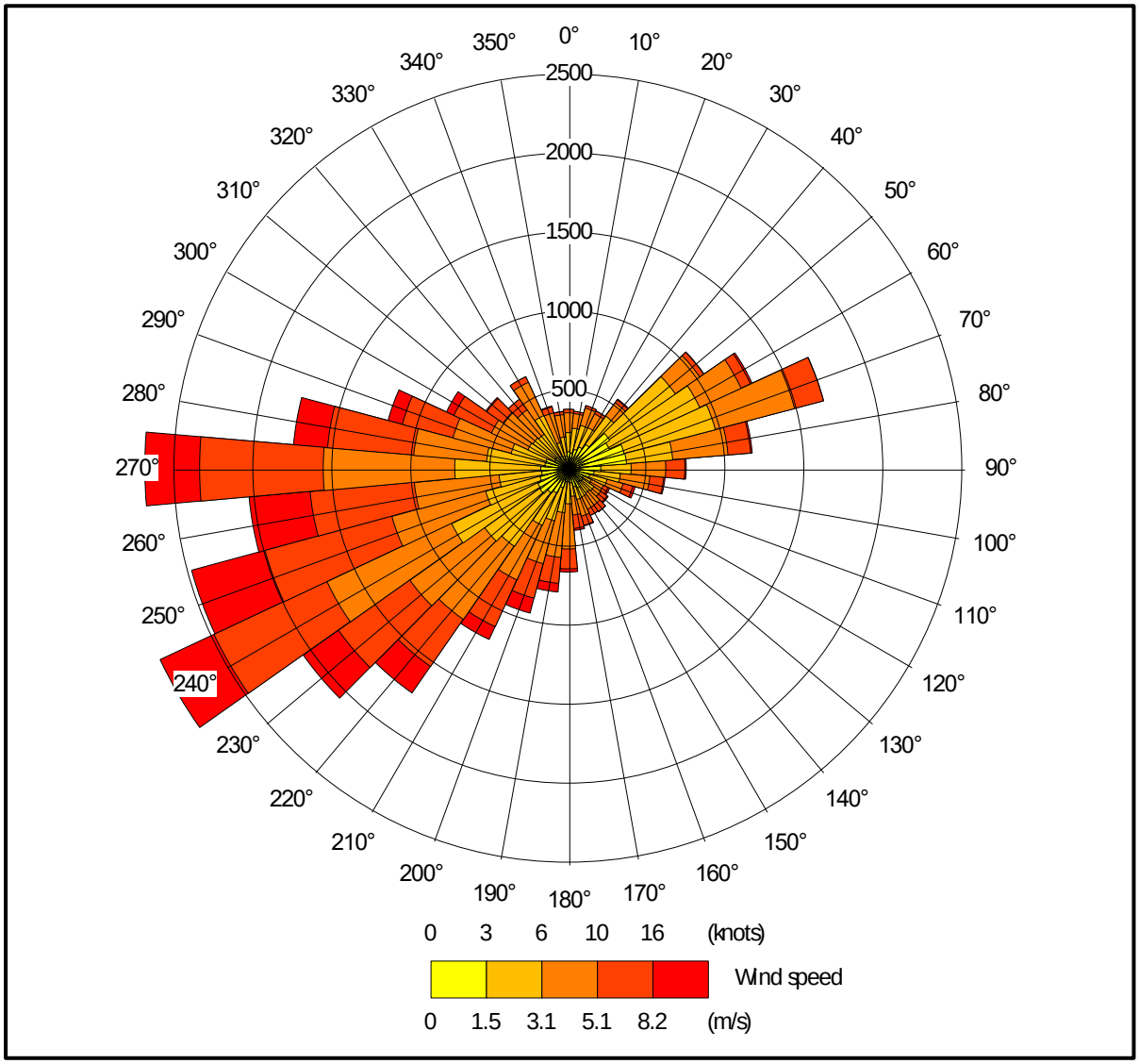


Figure 3c. The wind rose. Lake Vyrnwy data 2013 – 2016

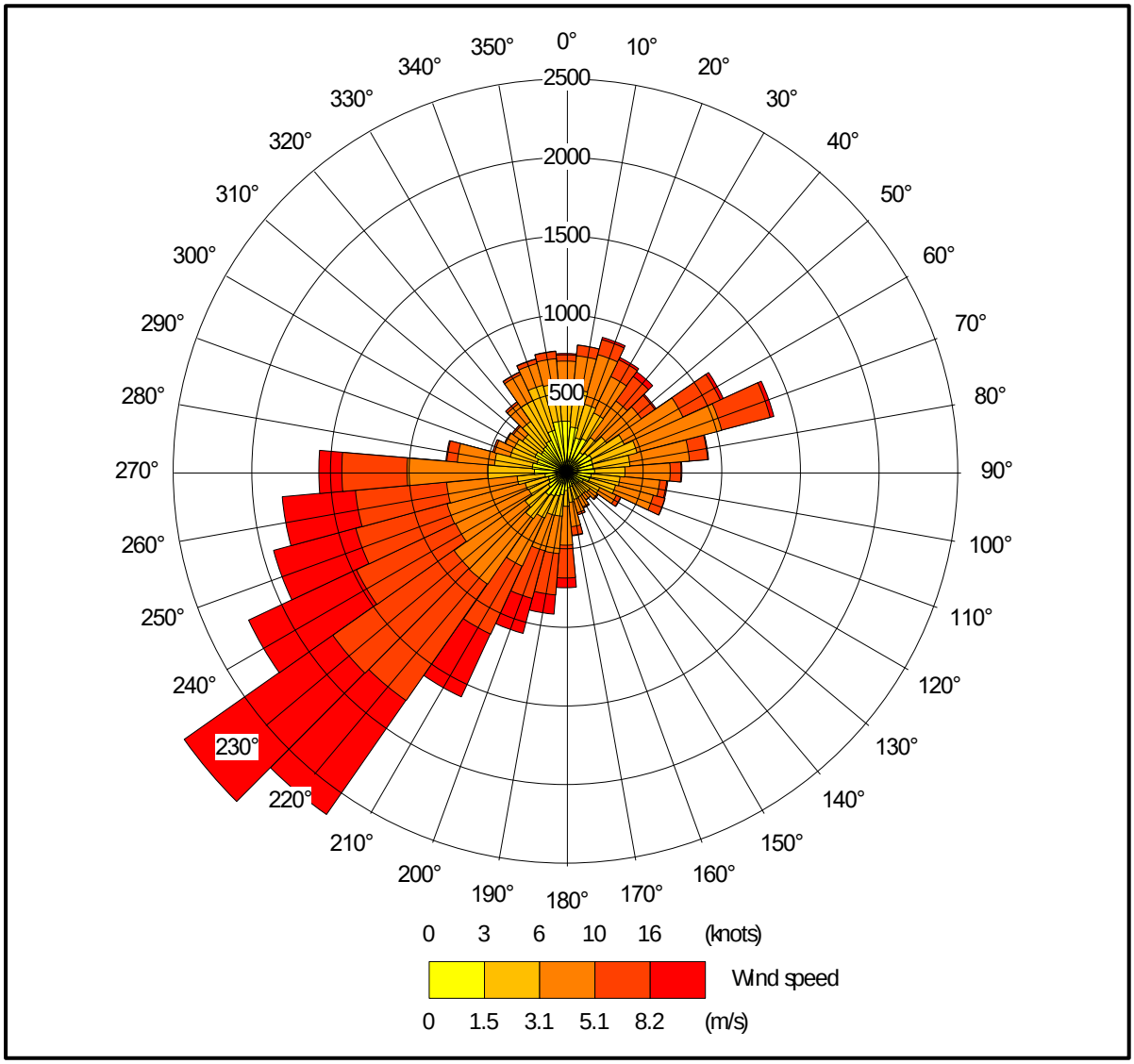
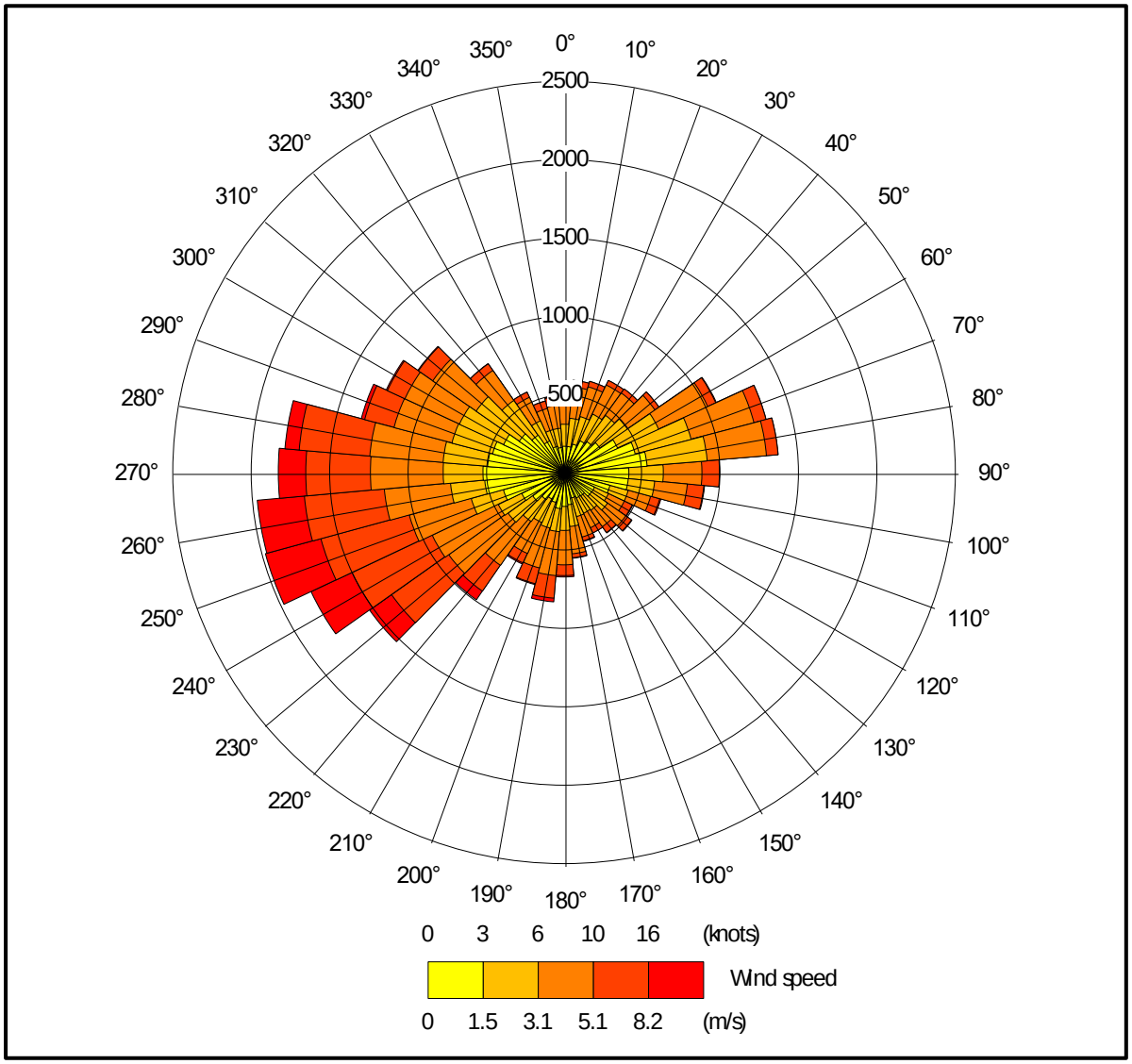


Figure 3d. The wind rose. Shobdon data 2013 – 2016



4.2 Emission Sources

Emissions from the chimneys of the uncapped high speed ridge fans on the existing and proposed poultry houses are represented by three point sources per house within ADMS (EX1 a, b & c and PR1 a, b & c). Details of the point source parameters are shown in Table 2a. The positions of the point 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 a, b & c	6.0	0.8	11.0	21.0	5013.33 [1]
PR1 a, b & c	6.0	0.8	11.0	21.0	5013.33 [1]

The existing and proposed houses are also/would also be fitted with side extraction fans which would be used to provide supplementary ventilation in hot weather conditions. The emissions from the side extraction fans are represented by a single volume source within ADMS (EX1 and PR1_vol). The volume source is assumed to emit 50% of the total emission only when the ambient temperature equals or exceeds 21 Celsius; when the volume source is emitting, emissions from the associated point sources are reduced by 50%. Details of the volume source parameters are shown in Table 2b and their positions may be seen in Figure 4, where they are marked by red rectangles.

Table 2b. Volume source parameters

Source ID	Length Y (m)	Width X (m)	*Depth* (m)	Base height (m)	Emission temperature (°C)	Emission rate (ou_E/s)
PR1_GAB	106.68	47.8	3.0	0.0	Ambient	30080.0 [2]

1. Reduced by 50% when the ambient temperature equals or exceeds 21 Celsius.
2. 50% of the total emission emitted only when the ambient temperature equals or exceeds 21 Celsius.

Emissions from the ranging areas are represented by two area sources within ADMS (EX1_ran and PR1_ran). The area sources cover the parts of the ranges most likely to be used frequently, not the whole ranging area. Details of the area source parameters are shown in Table 2c. The positions of the area sources may be seen in Figure 4.

Table 2c. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (°C)	Emission rate (ou_E/s)
EX1_RAN	7825.47	0.0	Ambient	1600.0
PR1_RAN	14476.45	0.0	Ambient	1600.0

4.3 Modelled Buildings

The structure of the poultry houses may affect the plumes from the point sources and therefore, the 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

Seventeen 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 receptors may be seen in Figure 5 where they are marked by green crosses.

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 32 x 32 grid points; therefore, the effective resolution of the wind field for the terrain runs is 200 m.

4.7 Other model parameters

A fixed surface roughness length of 0.3 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 0.275 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 and sources

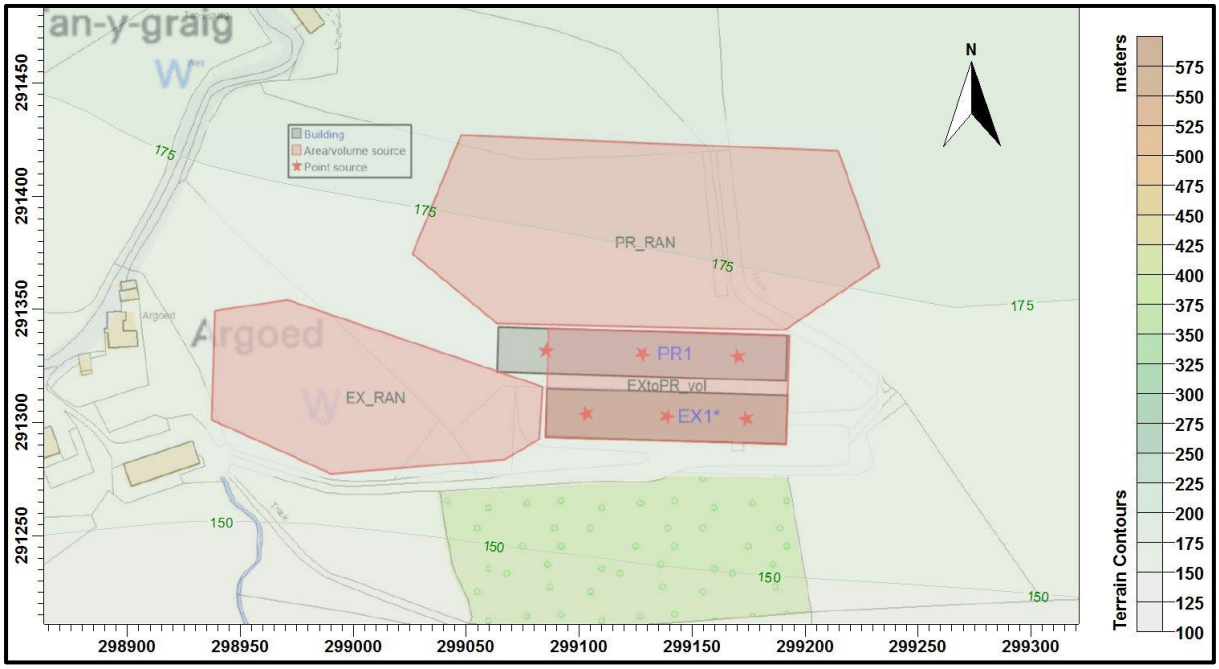
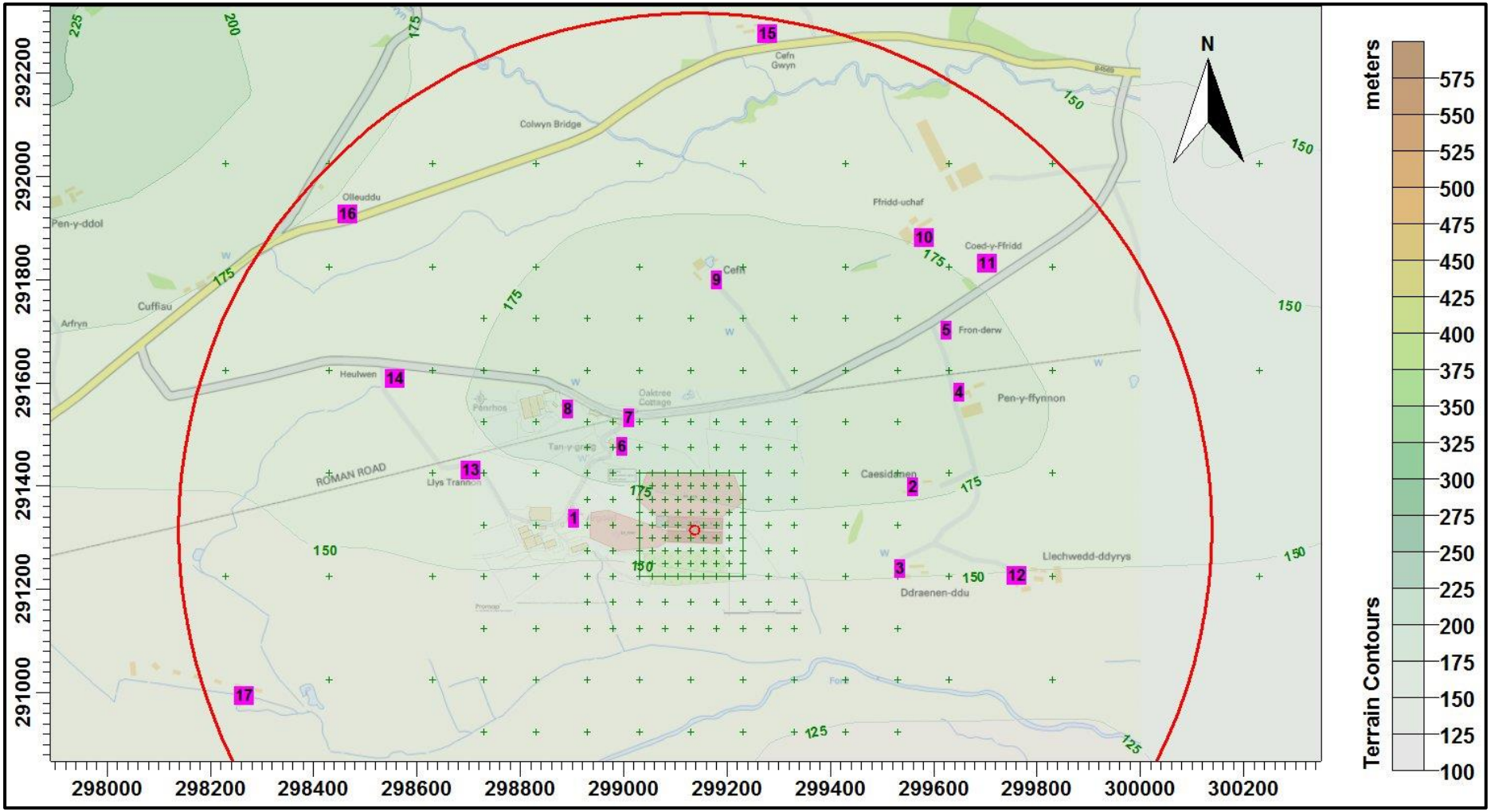


Figure 5. The discrete receptors and nested Cartesian grid receptors



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 twelve times, once for each year of the four year meteorological record in the following three modes:

- With calms and with terrain – GFS data – Natural Resources Wales emissions.
- With calms and with terrain – Lake Vyrnwy data – Natural Resources Wales emissions.
- With calms and with terrain – Shobdon – Natural Resources Wales emissions.

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

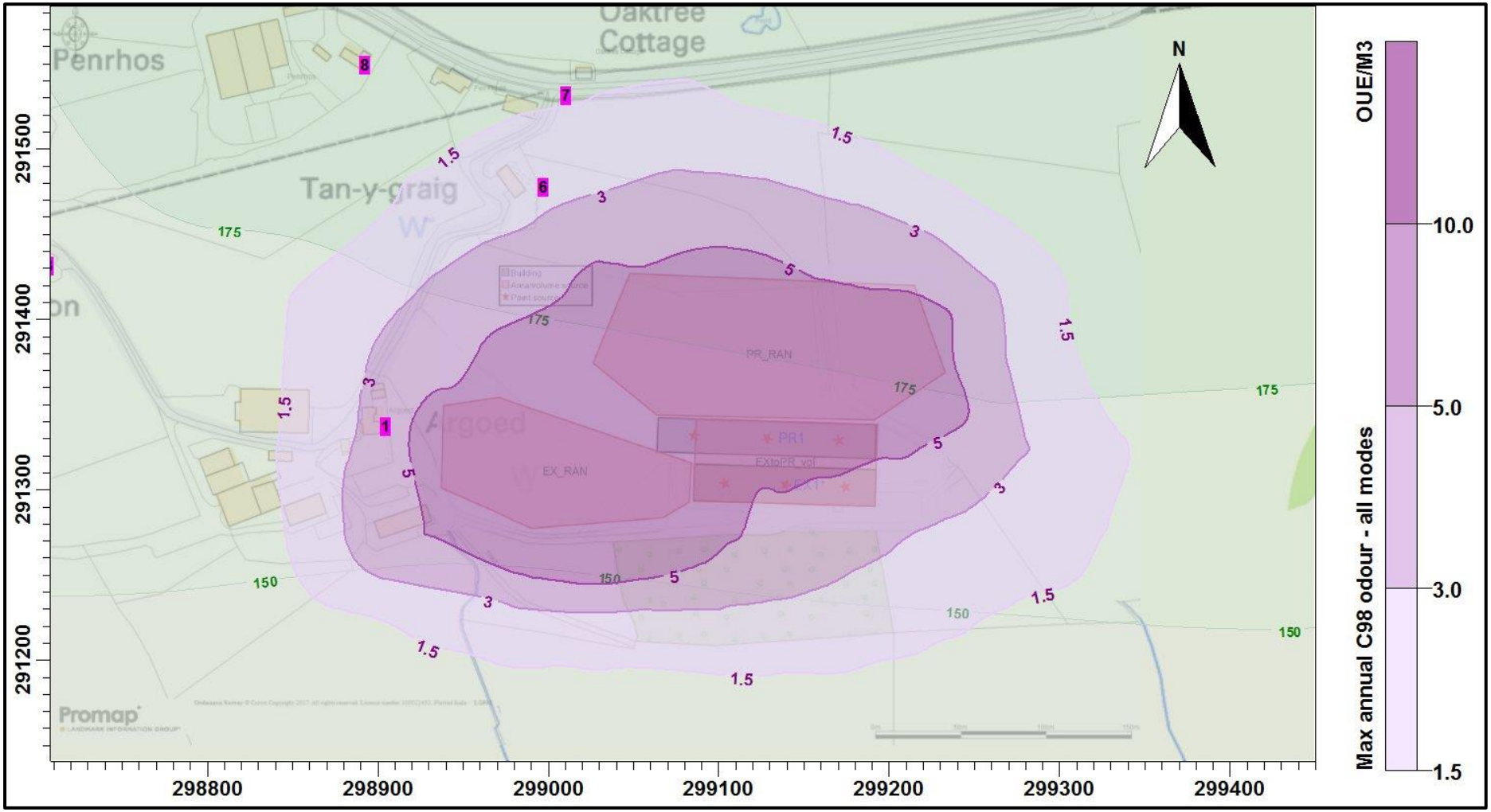
A summary of the results at the discrete receptors is shown in Table 3 where the maximum annual 98th percentile hourly mean odour for each mode is shown. A contour plot of the maximum annual 98th percentile hourly mean odour concentration obtained, using GFS data with calms and terrain modelled, is shown 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, those in excess of 10.0 ou_E/m^e as an annual 98th percentile hourly mean, are coloured red.

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

Receptor number	X(m)	Y(m)	Maximum annual 98th percentile hourly mean odour concentration (ou_E/m^3)		
			GFS Calms Terrain	Lake Vyrnwy Calms Terrain	Shobdon Calms Terrain
1	298904	291337	**3.53**	**4.44**	**10.58**
2	299559	291399	0.24	0.57	1.26
3	299535	291240	0.36	0.70	1.32
4	299650	291581	0.16	0.17	0.52
5	299625	291702	0.13	0.14	0.22
6	298997	291477	2.39	1.65	2.64
7	299011	291531	1.40	0.53	1.32
8	298893	291549	0.66	0.30	0.70
9	299180	291798	0.21	0.20	0.31
10	299582	291880	0.12	0.14	0.14
11	299704	291831	0.10	0.11	0.13
12	299761	291227	0.14	0.32	0.69
13	298704	291431	0.40	0.29	1.02
14	298557	291608	0.17	0.10	0.17
15	299278	292275	0.04	0.04	0.06
16	298465	291926	0.05	0.03	0.04
17	298265	290993	0.06	0.06	0.11

Figure 6. Predicted maximum annual 98th percentile hourly mean odour concentration GFS data – Calms & Terrain modelled



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gail Lewis of Roger Parry & Partners LLP, on behalf of R J Hughes and Co, to use computer modelling to assess the impact of odour emissions from the existing and proposed free range egg laying houses at Argoed, Trefeglwys, near Caersws in Powys. SY17 5QT.

Odour emission rates from the existing and proposed poultry houses have been assessed and quantified based upon emission rates mandated by Natural Resources Wales. 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 residence, namely the farmhouse at Argoed, which AS Modelling & Data Ltd. understands is owned by the operator; 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 the 98th percentile odour concentrations would be below the Environment Agency's benchmark value for moderately offensive odours.

7. References

Chartered Institution of Water and Environmental Management website. Control of Odour.
http://www.ciwem.org/policy-and-international/policy-position-statements/control-of-odour.aspx

Environment Agency, April 2007. H4 Odour Management, How to comply with your environmental permit.
http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho0411btqm-e-e.pdf

S. Fournela, F. Pelletierb, S. Godboutb. Odour emissions, hedonic tones and ammonia emissions from three cage layer housing systems.

Nimmermark S. & Gustafsson G. Influence of Temperature, Humidity and Ventilation Rate on the Release of Odour and Ammonia in a Floor Housing System for Laying Hens.