A Dispersion Modelling Study of the Impact of Odour from the Proposed Free Range Egg Laying Chicken Houses at Crugeran, Botwnnog, near Pwllheli in Gwynedd

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Gerallt Davies of Roger Parry & Partners LLP, on behalf of Rhian Parry, to use computer modelling to assess the impact of odour emissions from the proposed free range egg laying chicken houses at Crugeran, Botwnnog, Pwllheli, Gwynedd. LL53 8DS.

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 and also upon a fixed emission rate that is 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 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

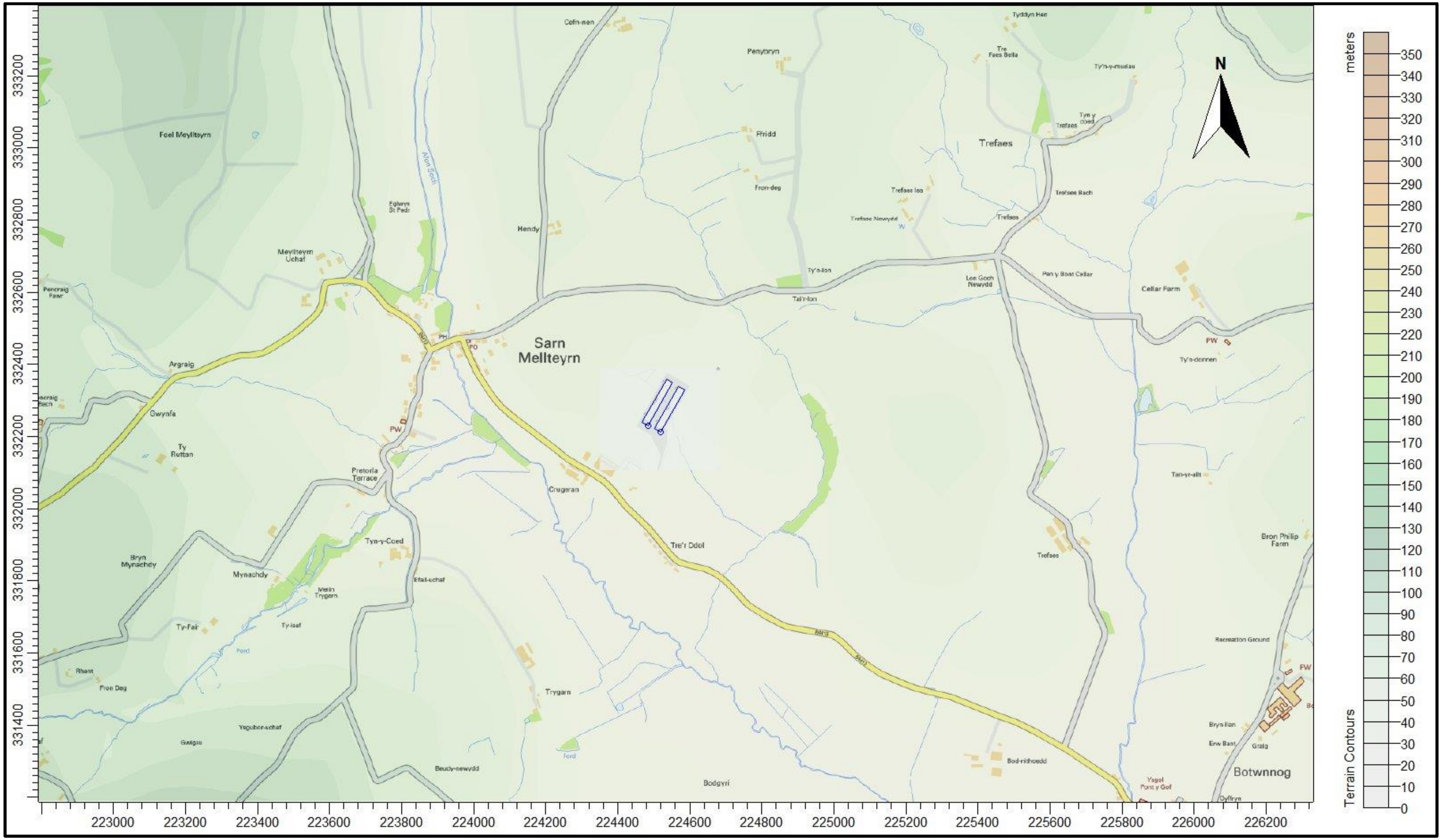
The site of the proposed free range chicken houses at Crugeran is in a rural area, approximately 450 m to the east-south-east of the village of Sarn Mellteyrn in Gwynedd. The surrounding land is used mainly as pasture for livestock farming, although there are some isolated wooded areas. The site is at an altitude of around 40 m within the land rising towards hills to the north and falling towards the Afon Soch to the south.

The proposed poultry houses would provide accommodation for up to 64,000 free range egg laying chickens. The poultry houses would have pop holes which would provide the birds with daytime access to outside ranging areas and would be ventilated by ridge/roof mounted fans, each with a short chimney, located at each end of the houses. Every four days, the birds' droppings would be removed by a belt collection system and stored temporarily on the farm, prior to being removed from site or spreading to land.

There are some residences and commercial properties in the area surrounding the site of the proposed poultry houses at Crugeran. The closest residences are at: Crugeran, approximately 210 m to the south-south-west; residences at Tre'r Ddol the closest of which is approximately 280 m to the south and residences in Sarn Mellteyrn the closest of which is approximately 430 m to the west-north-west.

A map of the surrounding area is provided in Figure 1; the positions of the proposed poultry rearing houses at Crugeran are outlined in blue.

Figure 1. The area surrounding the site of the proposed poultry house at Crugeran



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 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 (Rebranded 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.

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 proposed poultry houses would be from the chimneys of the ridge mounted fans. 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. Note that the modelling assumes that at minimum ventilation there is sufficient ventilation maintained, constantly, to provide the equivalent of 2 to 3 air changes in the house per hour; this level of ventilation is usually accepted to provide sufficient negative pressure to prevent the majority of fugitive emissions. The chickens would have access to ranging areas and some odour would arise from the manure deposited on the ranging areas.

In traditional flat deck egg laying chicken houses, peak odour emission rates occur when the housing is cleared of spent litter and manure at the end of each crop, which is approximately once per year. Emissions at this time may be several times greater than normal emissions from the housing. However, in a house where there is a belt removal system fitted, because the manure would be collected and removed throughout the flock cycle, the magnitude of odours during cleaning at the end of the flock cycle would be lower than from the more traditional flat deck houses in which manure collects within the house.

3.5.1 AS Modelling & Data Ltd. emissions model

To calculate an odour emission rate, it is necessary to know the internal odour concentration and ventilation rate of the poultry house. For the calculations, the internal concentrations in the proposed houses is assumed to be constant at 750 ou_E/m^3 for a house with belt removal of litter; this figure is based upon a review of available literature and measured internal concentration available to AS Modelling & Data Ltd. Under high ventilation rates 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 rate from the proposed poultry houses used in this study is provided in Table 1a. As additional information, the 98th percentile emission rate is approximately 0.85 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 2a.

The chickens would have access to ranging areas. The AS Modelling & Data Ltd. emissions model assumed that 20%[1] of the droppings are deposited on the ranging areas 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.

1. It should be noted that this figure is probably based primarily upon the widely accepted figure of 80% of dropping occurring at night when birds are housed and a single report; however, because, even under optimal conditions, not all of the birds go outside (50% is considered a high percentage), this does not imply that 20% of droppings occur outside the house.

3.5.2 Natural Resources Wales emission factor

Natural Resources Wales mandate a fixed odour emission rate for egg laying chicken houses of 0.47 ou_E/bird/s. Note that this figure probably overestimates emissions for much of the time, but underestimates peak emissions. A summary of the emission rate from the proposed poultry houses used in this study is provided in Table 1b. As an example, a graph of the specific emission rate over the first year of the meteorological record is shown in Figure 2b.

Table 1a. Summary of odour emission rates (average/maxima of all 3 cycles) – AS Modelling & Data Ltd. emission model

Emission rate (ou_E/s per bird)				
Season	Average	Night-time Average	Day-time Average	Maximum
Winter	0.209	0.209	0.209	0.287
Spring	0.280	0.267	0.294	1.392
Summer	0.532	0.510	0.545	1.527
Autumn	0.271	0.266	0.277	0.945

Table 1b. Summary of odour emission rates (average/maxima of all 3 cycles) – Natural Resources Wales emission factor

Emission rate (ou_E/s per bird)				
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 2a. Specific emission rate over the first year (2015) of each of the three crop cycles– AS Modelling & Data Ltd. emission model

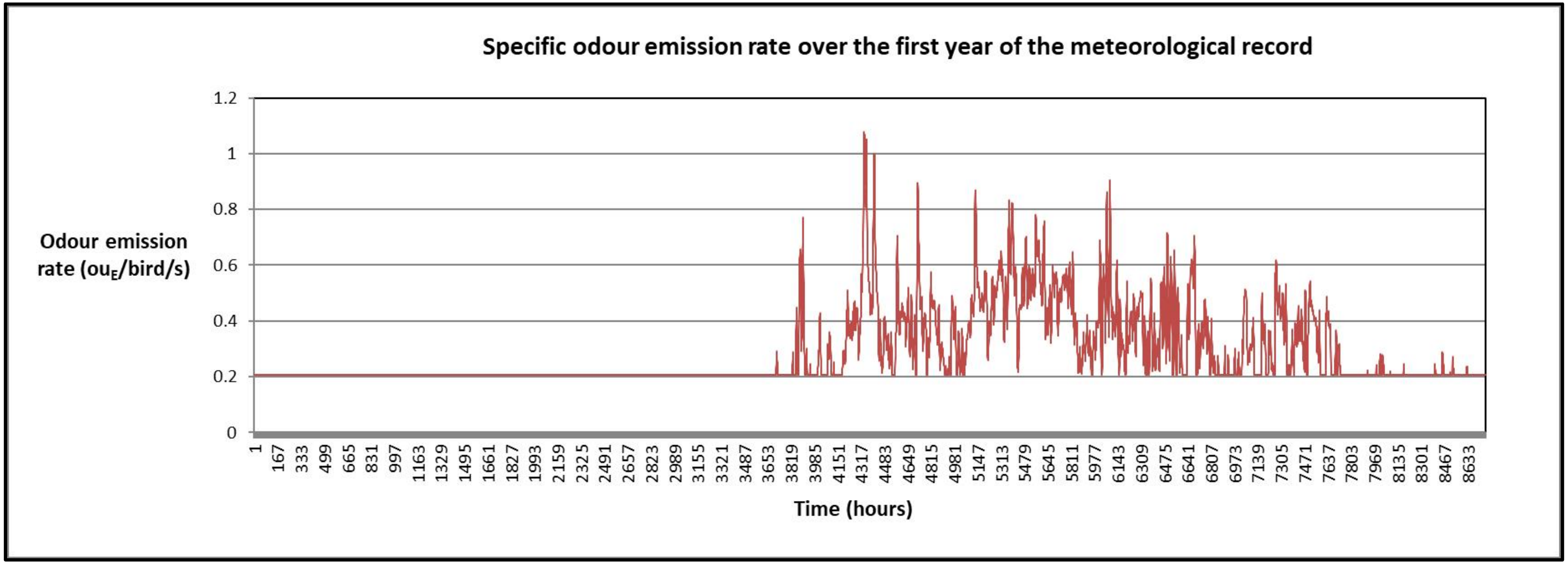
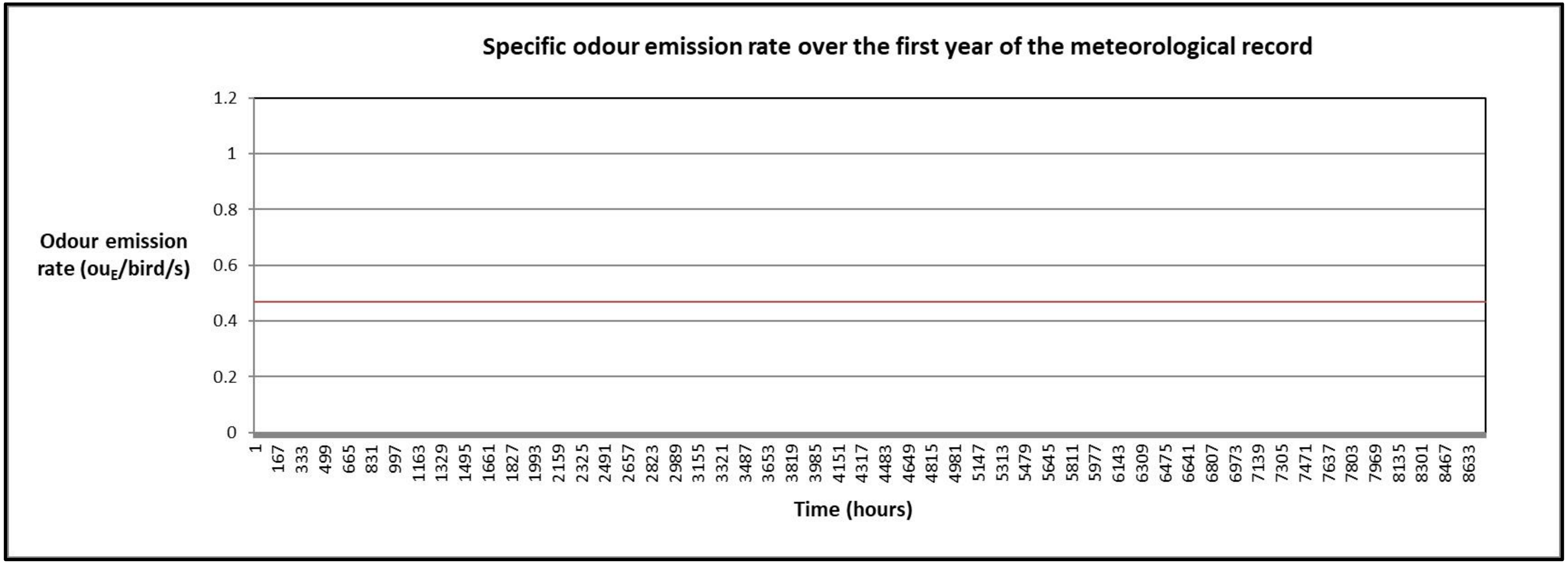


Figure 2b. Specific emission rate over the first year (2015) of each of the three crop cycles – Natural Resources Wales emission factor



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 that include: 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). In this case, data from the meteorological observing station at Aberdaron has also been considered.

The GFS is a spectral model (the physics/dynamics model has an equivalent resolution of approximately 13 km (latterly 9 km) and terrain is understood to be resolved at a resolution of approximately 2 km with sub-13 km processes parameterised). The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Larger scale topographical 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.

The wind rose for the raw GFS 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, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location at the proposed poultry houses at Crugeran is shown in Figure 3b. It should be noted elsewhere in the modelling domain, the modified wind roses may differ markedly, reflecting the local flow in that part of the domain. The resolution of the wind field in terrain runs is approximately 150 m. Please also note that FLOWSTAR is used to obtain a local flow field, not to explicitly model dispersion in complex terrain as defined in the ADMS User Guide; therefore, the ADMS default value for minimum turbulence length has been amended.

The meteorological station at Aberdaron is approximately 12 km to the south-west of Crugeran and is in a very exposed cliff-top location; therefore, it cannot be considered entirely representative of the area around the proposed poultry houses at Crugeran. The frequency of winds from a particular direction may be greater, or lesser than they are in the area around Crugeran and wind speeds may be significant different. Therefore, the results obtained using the GFS data as modified by FLOWSTAR should be given more weight when interpreting the results of the modelling. The wind rose for the raw GFS data is shown in Figure 3c.

Figure 3a. The wind rose. Raw GFS derived data, for 52.859 N, 4.607 W, 2015-2018

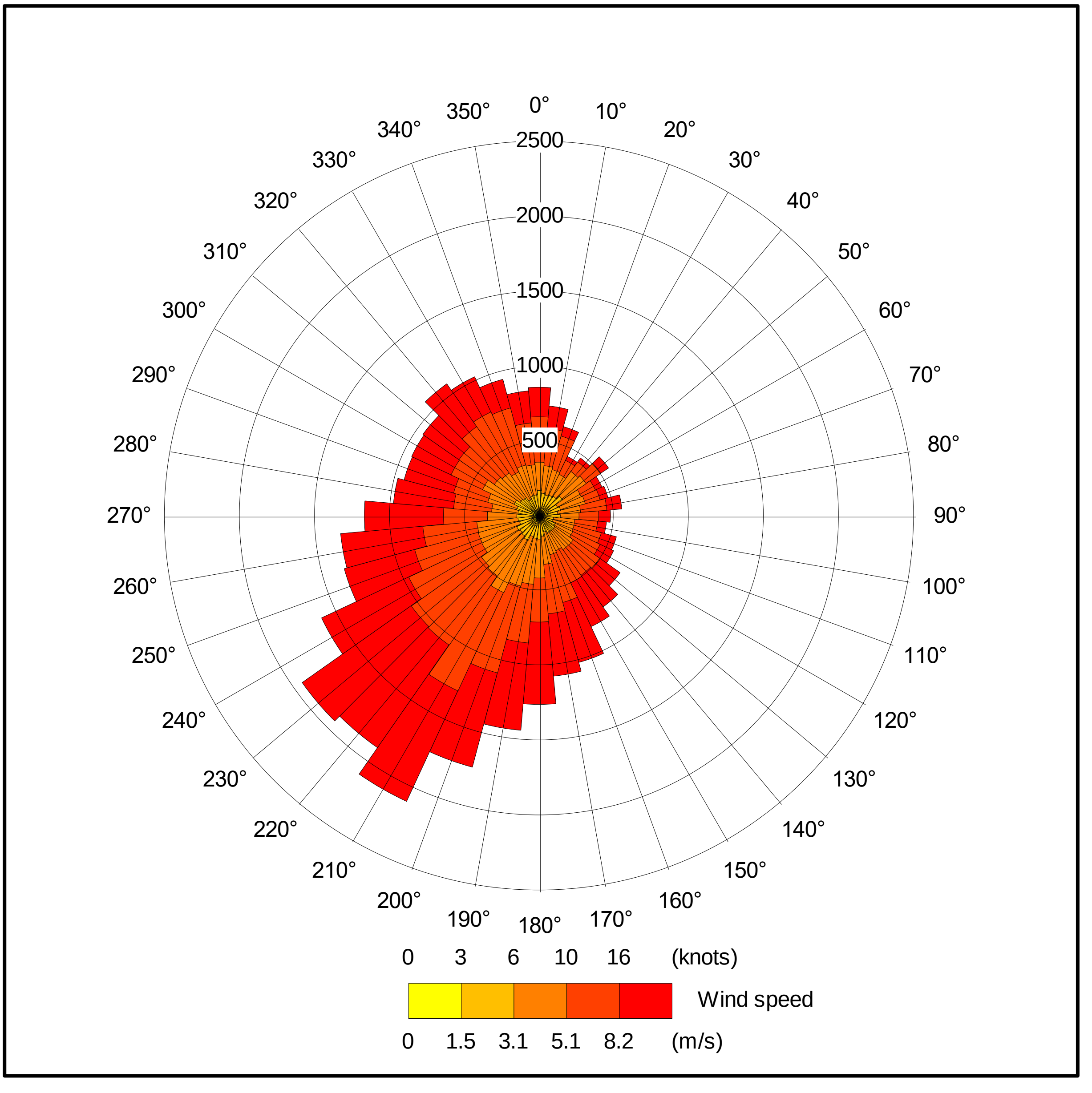


Figure 3b. The wind rose. FLOWSTAR modified GFS derived data for NGR 224550, 332300

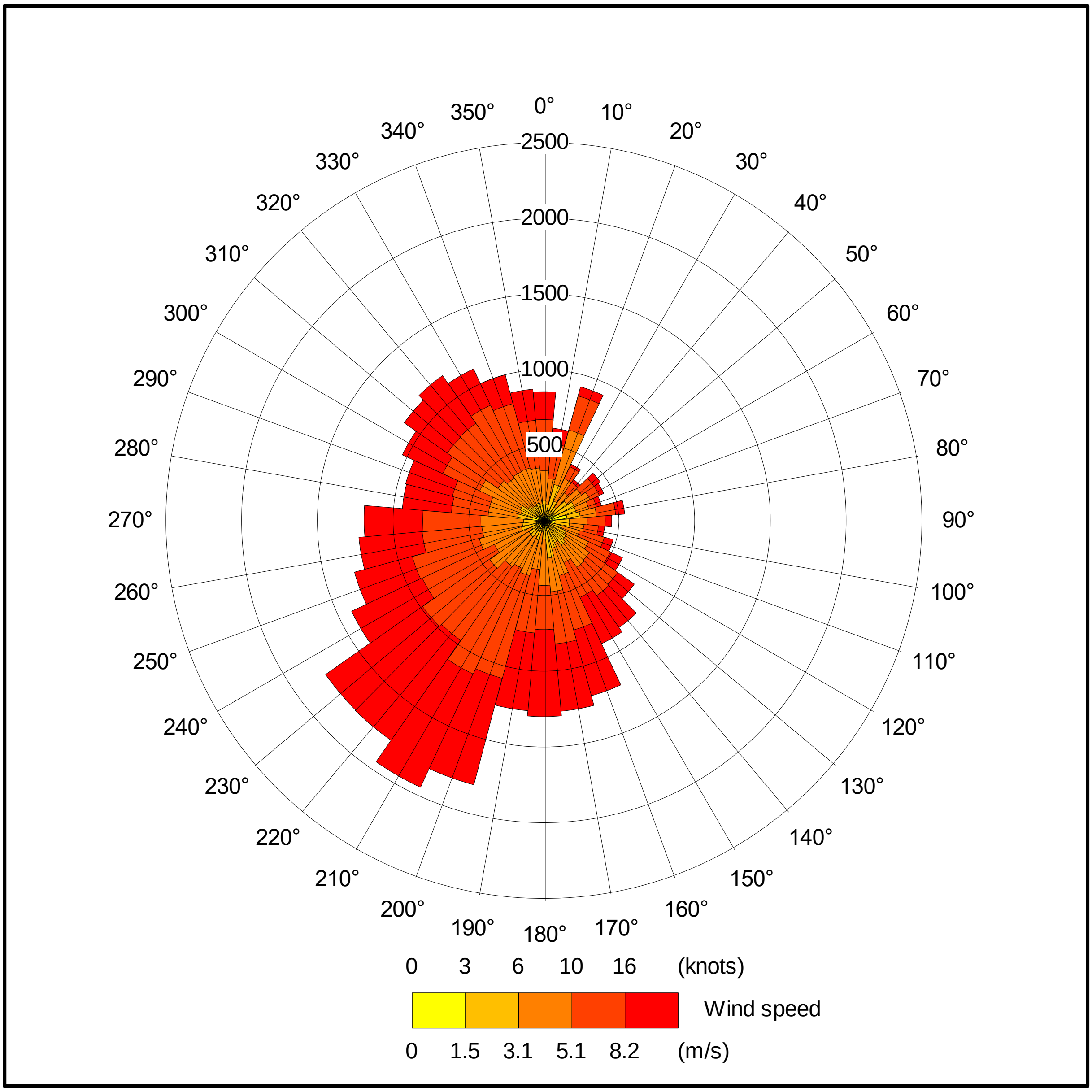
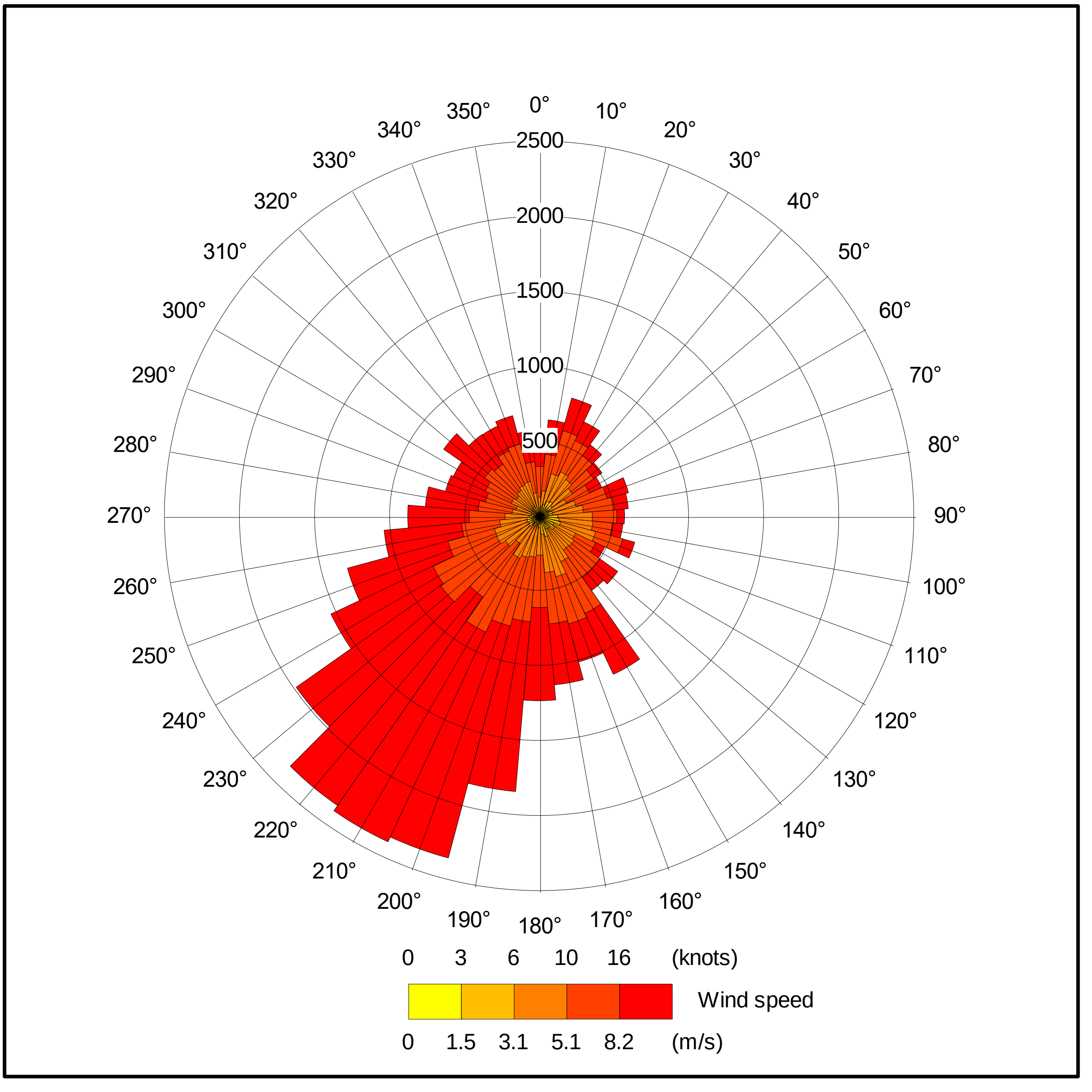


Figure 3c. The wind rose. Aberdaron meteorological data, 2015 -2018



4.2 Emission sources

Emissions from the high speed ridge/roof fans that would be used to ventilate the proposed poultry houses are represented by six point sources per house within ADMS (PR1_N a, b & c, PR1_S a, b & c, PR2_N a, b & c and PR2_S 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, where they are indicated by red star symbols.

Table 2a. Point source parameters

Source ID (emissions model)	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (ou_E/s)
PR1_N, PR1_S, PR2_N & PR2_S – a (AS Modelling & Data Ltd.)	7.2	0.98	11.0	21.0	Variable [1]
PR1_N, PR1_S, PR2_N & PR2_S - b & c (AS Modelling & Data Ltd.)	6.6	0.98	11.0	21.0	Variable [1]
PR1_N, PR1_S, PR2_N & PR2_S – a (Natural Resources Wales)	7.2	0.98	11.0	21.0	2,506.67
PR1_N, PR1_S, PR2_N & PR2_S - b & c (Natural Resources Wales)	6.6	0.98	11.0	21.0	2,506.67

1. Dependent on ambient temperature.

The poultry houses would have ranging areas, which are represented by two area sources within ADMS (PR1_RAN and PR2_RAN). Note that the area sources cover the parts of the range most likely to be used frequently and not the whole ranging areas. Details of the area source parameters are provided in Table 2b. The positions of the area sources are shown in Figure 4.

Table 2b. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (˚C)	Emission rate (ou_E/s)
PR1_RAN	5,586.5	0.0	Ambient	1,600.00
PR2_RAN	6,102.7	0.0	Ambient	1,600.00

4.3 Modelled buildings

The structure of the poultry houses may affect the plumes from the point sources. 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

Twenty-two 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

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 12.0 km x 12.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS for the preliminary modelling and detailed modelling runs. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 180 m.

4.7 Other model parameters

A fixed surface roughness length of 0.225 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 0.2 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and stability and therefore increases predicted ground level concentrations.

Figure 4. The positions of modelled buildings and sources

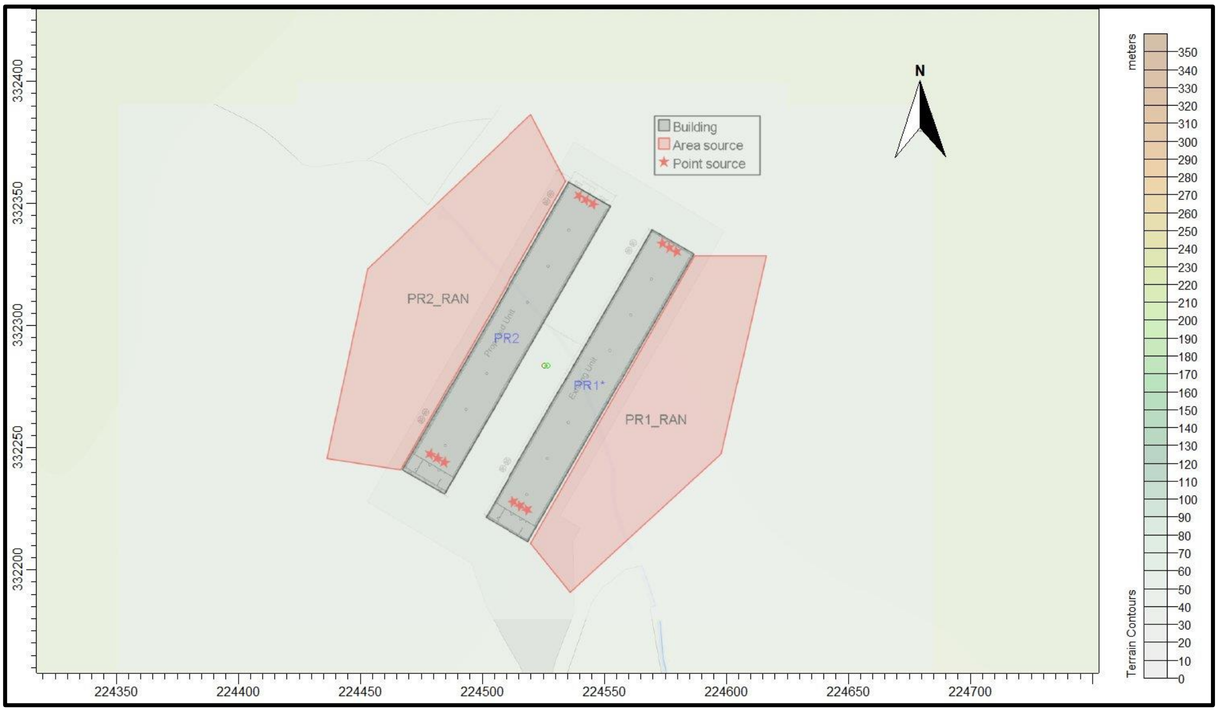
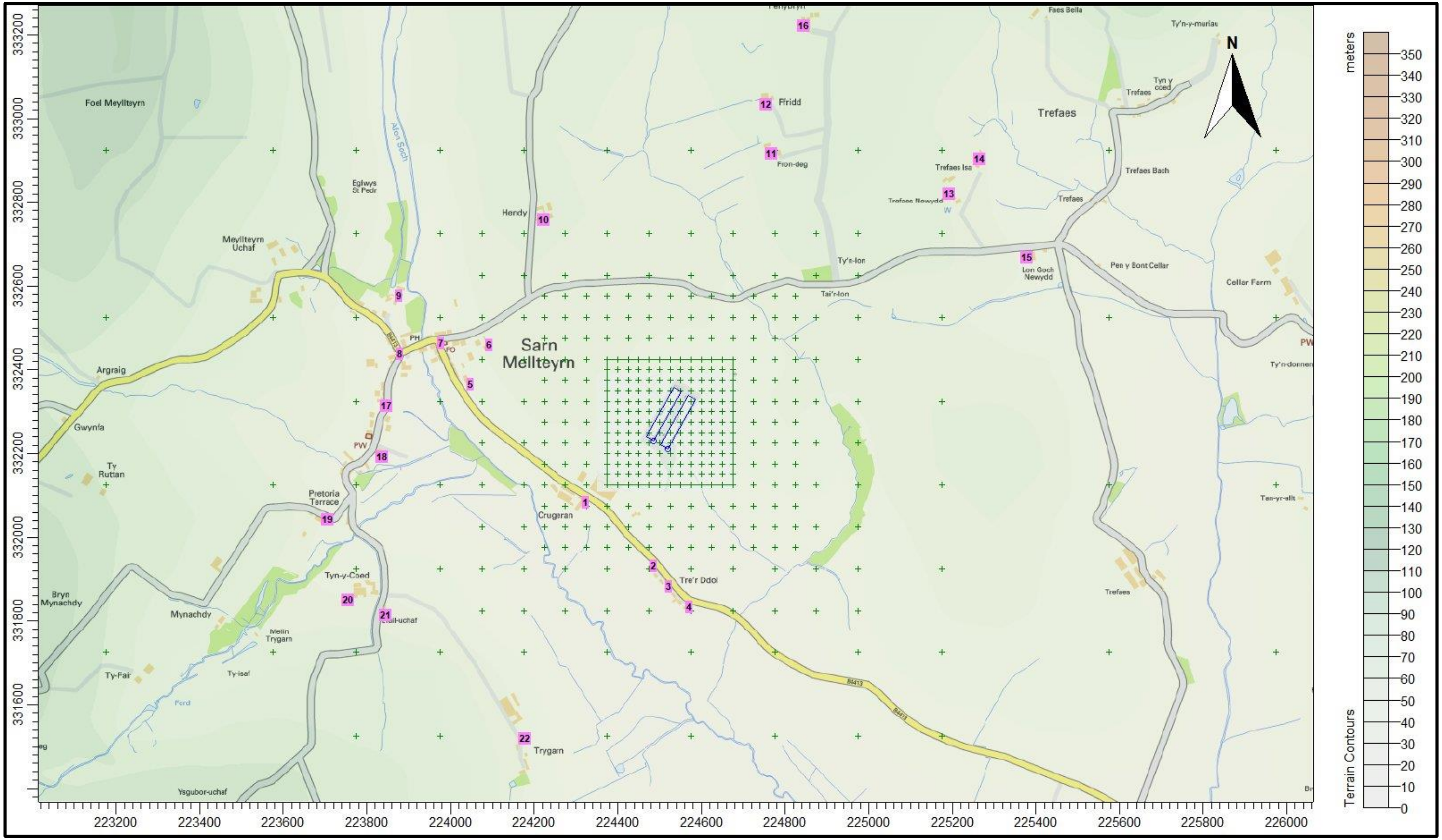


Figure 5. The discrete receptors and nested Cartesian grid receptors



5. Details of the Model Runs and Results

For this study, ADMS was run with the calms and terrain module of ADMS. The model was run eight times, once for each year in the meteorological record and using both the AS Modelling & Data Ltd. emissions model and the Natural Resources Wales fixed emission factor.

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

A summary of the results at the discrete receptors is shown in Table 3, where the maximum annual 98^{th} percentile hourly mean odour concentration is shown. Contour plots of the predicted maximum annual 98^{th} percentile hourly mean odour concentration is shown in Figure 6a (AS Modelling & Data Ltd. emissions model) and Figure 6b (Natural Resources Wales fixed emission factor).

In Table 3, predicted odour exposures in excess of the Environment Agency's benchmark of 3.0 ou_E/m^3 as an annual 98^{th} 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 98^{th} 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 98^{th} percentile hourly mean, 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/Location	Maximum annual 98th percentile hourly mean odour concentration (ou_E/m^3)			
				AS Modelling & Data Ltd. emission model		Natural Resources Wales emission factor	
				GFS Calms Terrain	Aberdaron Calms Terrain	GFS Calms Terrain	Aberdaron Calms Terrain
1	224324	332083	Crugeran	0.83	0.61	0.79	0.75
2	224486	331931	Tre'r Ddol	0.69	0.66	0.66	0.67
3	224522	331882	Tre'r Ddol	0.52	0.55	0.55	0.44
4	224571	331834	Tre'r Ddol	0.39	0.42	0.42	0.30
5	224047	332365	San Mellteyrn	0.30	0.36	0.36	0.39
6	224093	332458	San Mellteyrn	0.33	0.38	0.38	0.42
7	223977	332463	San Mellteyrn	0.23	0.28	0.28	0.31
8	223879	332437	San Mellteyrn	0.18	0.22	0.22	0.27
9	223876	332576	San Mellteyrn	0.17	0.20	0.20	0.23
10	224223	332759	Hendy	0.31	0.35	0.35	0.37
11	224767	332915	Fron-deg	0.30	0.25	0.25	0.20
12	224755	333033	Ffridd	0.24	0.20	0.20	0.17
13	225192	332819	Trefaes Newydd	0.17	0.19	0.19	0.15
14	225264	332903	Trefaes isa	0.13	0.15	0.15	0.12
15	225377	332669	Lon Goch Newydd	0.16	0.18	0.18	0.17
16	224845	333221	Penbryn	0.16	0.13	0.13	0.11
17	223847	332313	San Mellteyrn	0.16	0.21	0.21	0.23
18	223836	332192	San Mellteyrn	0.15	0.20	0.20	0.18
19	223706	332041	Pretoria Terrace	0.15	0.14	0.14	0.14
20	223755	331850	Tyn-y-coed	0.11	0.11	0.11	0.09
21	223844	331813	Efail-uchaf	0.12	0.11	0.11	0.10
22	224177	331518	Trygarn	0.13	0.14	0.14	0.12

Figure 6a. Predicted maximum annual 98th percentile hourly mean odour concentration – AS modelling & Data emissions model

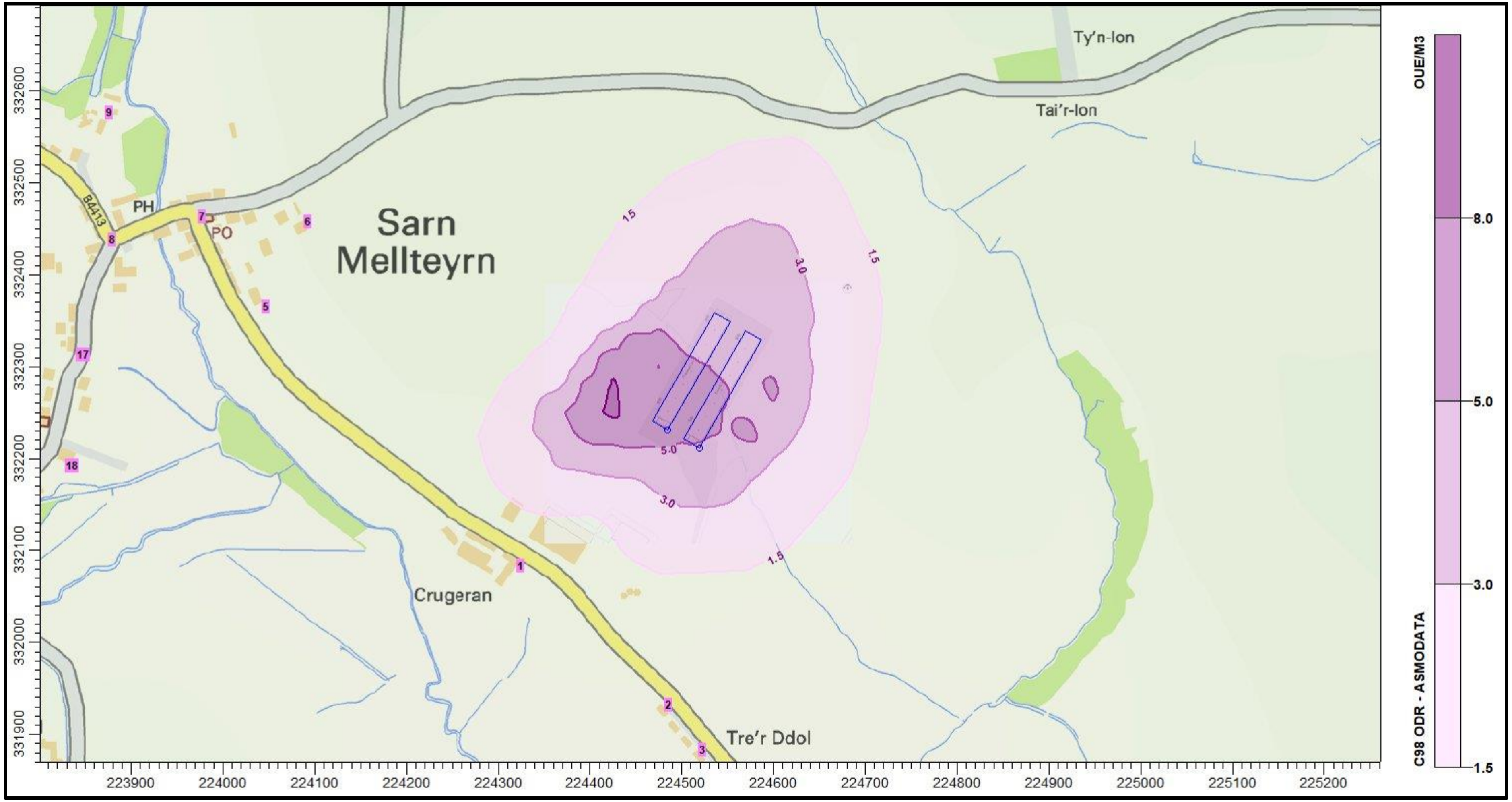
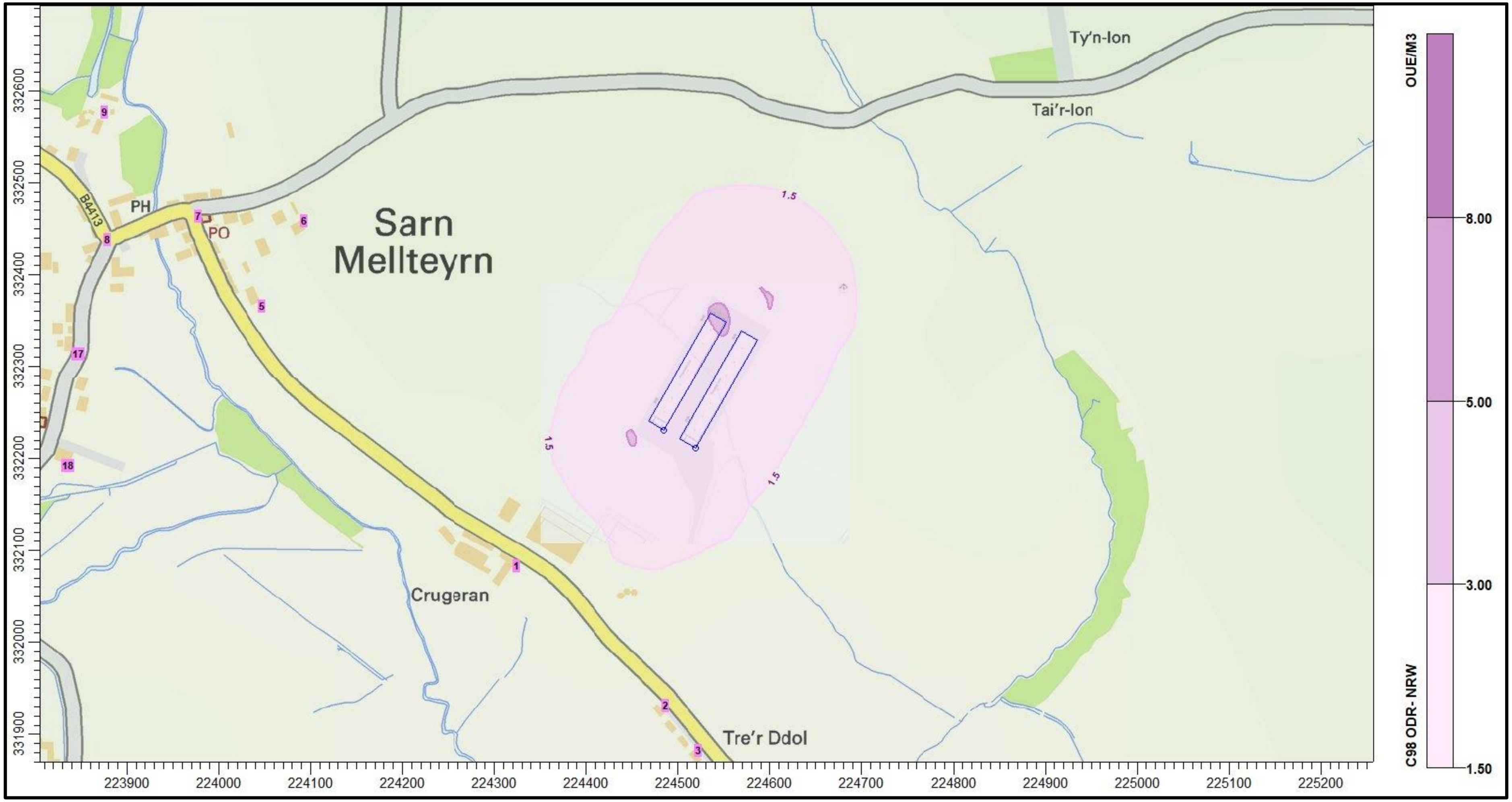


Figure 6b. Predicted maximum annual 98th percentile hourly mean odour concentration – Natural Resources Wales emission factor



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Gerallt Davies of Roger Parry & Partners LLP, on behalf of Rhian Parry, to use computer modelling to assess the impact of odour emissions from the proposed free range egg laying chicken houses at Crugeran, Botwnnog, Pwllheli, Gwynedd. LL53 8DS.

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 and also upon a fixed emission rate that is 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, should the proposed poultry houses be constructed at Crugeran, the odour exposure would be below the benchmark for moderately offensive odours, which is a maximum annual 98^{th} percentile hourly mean concentration of 3.0 ou_E/m^3, at all residential receptors considered.

7. References

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

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

R. E. Lacey, S. Mukhtar, J. B. Carey and J. L. Ullman, 2004. A Review of Literature Concerning Odors, Ammonia, and Dust from Broiler Production Facilities.
http://japr.fass.org/content/13/3/500.full.pdf+html

M. Navaratnasamy. Odour Emissions from Poultry Manure/Litter and Barns.

Fardausur Rahaman et al. ESTIMATION OF ODOUR EMISSIONS FROM BROILER FARMS
– AN ALTERNATIVE APPROACH

A. P. Robertson *et al*, 2002. Commercial-scale Studies of the Effect of Broiler-protein Intake on Aerial Pollutant Emissions.

ROSS. Environmental Management in the Broiler House

Defra. Heat Stress in Poultry - Solving the Problem