A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Free Range Egg-Laying Chicken Houses at Frowen Farm, Login, near Whitland in Carmarthenshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Gail Jenkins, of Roger Parry & Partners LLP, on behalf of Anthony and Fairclough, to use computer modelling to assess the impact of ammonia emissions from the proposed free range egg-laying chicken houses at Frowen Farm, Login, Whitland, Carmarthenshire. SA34 0TP.

Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors. As proposed by Natural resources Wales, ammonia emission from ranging areas have been assessed and quantified based upon the National Atmospheric Emission Inventory (NAEI) emission factor for grazing free range hens. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen and acid deposition rates in the surrounding area.

This report is arranged in the following manner:

- Section 2 provides relevant details of the farm and potentially sensitive receptors in the area.

- Section 3 provides some general information on ammonia; details of the method used to estimate ammonia emissions; relevant guidelines and legislation on exposure limits and where relevant, details of likely background levels of ammonia.

- Section 4 provides some information about ADMS, the dispersion model used for this study and details the modelling procedure.

- Section 5 contains the results of the modelling.

- Section 6 provides a discussion of the results and conclusions.

2. Background Details

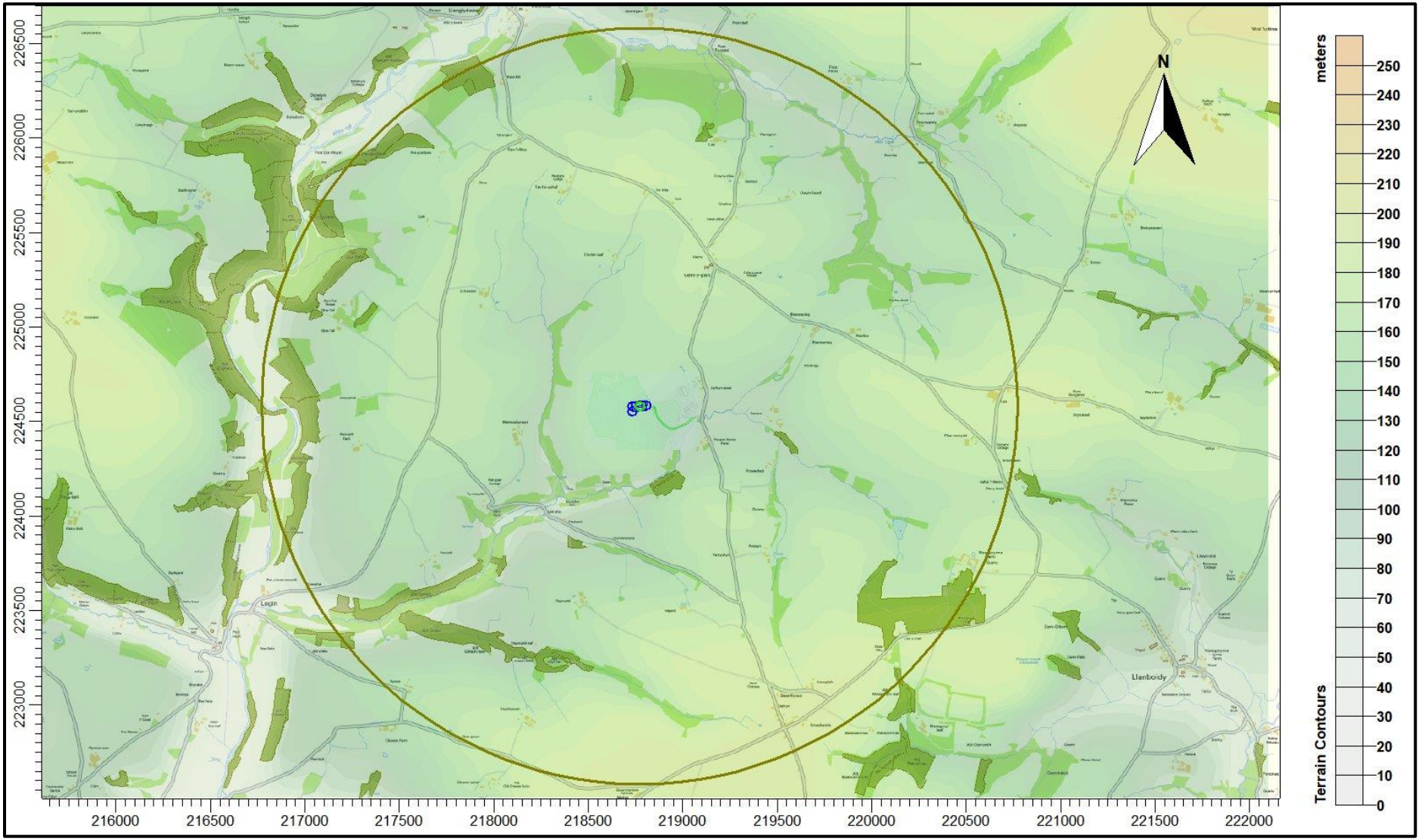
Frowen Farm is in an isolated rural area, approximately 2.1 km to the east-north-east of the village of Login in Carmarthenshire. The surrounding land is used predominantly for livestock farming, but there are some isolated semi-natural wooded areas nearby. The site is at an altitude of around 138 m, with the land rising to higher ground to the north-north-east and falling towards tributaries to the Afon Taf to the west and south-east.

It is proposed that a pair of poultry houses be constructed at Frowen Farm. The poultry houses would provide accommodation for up to 32,000 egg-laying chickens, which would have day-time access to outside ranging areas. Ventilation would be provided by high speed ridge/roof fans, each with a short chimney. Every four days, the birds' droppings would be removed from the housing by a belt collection system and stored temporarily on the farm, prior to removal from the site, or spreading to land. The birds would have daytime access to outside ranging areas via a series of pop holes on the sides of the houses.

There are several areas of Ancient Woodlands (AWs) within 2 km of the site of Frowen Farm. There are no Sites of Special Scientific Interest (SSSIs) nor any internationally designated wildlife sites within 5 km of the farm.

A map of the surrounding area showing the positions of the proposed poultry houses and the nearby AWs is provided in Figure 1. In this figure, the AWs are outlined in olive and the positions of the proposed poultry houses are outlined in blue.

Figure 1. The area surrounding Frowen Farm –circle radius 2 km (olive)



3. Ammonia, Background Levels, Critical Levels & Loads & Emission Rates

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air (µg-NH_3/m^3) as an annual mean. Ammonia in the air may exert direct effects on the vegetation, or indirectly affect the ecosystem through deposition which causes both hyper-eutrophication (excess nitrogen enrichment) and acidification of soils. Nitrogen deposition, specifically in this case the nitrogen load due to ammonia deposition/absorption, is usually expressed in kilograms of nitrogen per hectare per year (kg-N/ha/y). Acid deposition is expressed in terms of kilograms equivalent (of H^+ ions) per hectare per year (keq/ha/y).

3.2 Background ammonia levels and nitrogen and acid deposition

The background ammonia concentration (annual mean) in the area around Frowen Farm and the wildlife sites is 2.02 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 33.88 kg-N/ha/y and to short vegetation is 21.98 kg-N/ha/y. The background acid deposition rate to woodland is 2.01 keq/ha/y and to short vegetation is 1.42 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, October 2020).

3.3 Critical Levels and Critical Loads

Critical Levels and Critical Loads are a benchmark for assessing the risk of air pollution impacts to ecosystems. It is important to distinguish between a Critical Level and a Critical Load. The Critical Level is the gaseous concentration of a pollutant in the air, whereas the Critical Load relates to the quantity of pollutant deposited from air to the ground.

Critical Levels are defined as, "concentrations of pollutants in the atmosphere above which direct adverse effects on receptors, such as human beings, plants, ecosystems or materials, may occur according to present knowledge" (UNECE).

Critical Loads are defined as, "a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (UNECE).

For ammonia concentration in air, the Critical Level for higher plants is 3.0 µg-NH_3/m^3 as an annual mean. For sites where there are sensitive lichens and bryophytes present, or where lichens and bryophytes are an integral part of the ecosystem, the Critical Level is 1.0 µg-NH_3/m^3 as an annual mean.

Critical Loads for nutrient nitrogen are set under the Convention on Long-Range Transboundary Air Pollution. They are based on empirical evidence, mainly observations from experiments and gradient studies. Critical Loads are given as ranges (e.g. 10-20 kg-N/ha/y); these ranges reflect variation in ecosystem response across Europe.

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. N.B. Where the Critical Level of 1.0 µg-NH_3/m^3 is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. Normally, the Critical Load for nitrogen deposition provides a stricter test than the Critical Load for acid deposition.

Table 1. Critical Levels and Critical Loads at the wildlife sites

Site	Critical Level (µg-NH_3/m^3)	Critical Load Nitrogen (kg-N/ha/y)	Critical Load Acid (keq/ha/y)
AWs	1.0 [1]	-	-

1. A precautionary figure used where no details of the ecology of the site are available, or the citation for the site contains reference to sensitive lichens and/or bryophytes.

3.4 Guidance on the Significance of Ammonia Emissions

In March 2017, Natural Resources Wales (Regulation and Permitting Department, EPP) published Operational Guidance Note 41 (OGN 41), "Assessment of ammonia and nitrogen impacts from livestock units when applying for an Environmental Permit or Planning Permission". This guidance was intended to update the way Natural Resources Wales (NRW) assessed emissions, in particular by changing the thresholds of insignificance and the upper threshold process contributions for designated sites. These designated sites include European sites, such as Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites as well as Sites of Special Scientific Interest (SSSIs).

Table 1 in OGN 41 describes the revised screening distance and thresholds for livestock developments; the threshold of insignificant percentage of the designated site Critical Level or Load is given as 1%; the upper threshold percentage of the designated site Critical Level or Load is given as 8%.

Table 2 in OGN 41 describes the possible outcomes of assessment and for detailed modelling of the application alone, where process contributions, considered in isolation, are up to 1% of the designated site Critical Level or Load, then it should be determined that there is no significant environmental effect/no likely significant effect/damage to scientific interest.

Where process contributions, considered in isolation, are between 1% and 8% of the designated site Critical Level or Load, an in-combination assessment is required. Should the in-combination process contributions be between 1% and 8% of the designated site Critical Level or Load then it should be determined that the application would cause no significant environmental effect/likely significant effect/damage to scientific interest.

When considering process contributions in isolation or in-combination, if they exceed 1% of the designated site Critical Level or Load it is necessary to consider background concentrations and

whether the designated site Critical Level or Load is breached and whether additional controls may be necessary. The application will then be determined based on whether there will be significant environmental effect/adverse effect/damage to scientific interest.

The latter Natural Resources Wales document OGN 020 contains essentially the same thresholds.

For Local Nature Reserves (LNRs), Local Wildlife Sites (LWSs) and Ancient Woodlands (AWs), the current assessment procedure still applies, namely the Environment Agency's horizontal guidance, H1 Environmental Risks Assessment, H1 Annex B - Intensive Farming. The following are taken from this document.

"An emission is insignificant where Process Contribution (PC) is <50% for local and national nature reserves (LNRs & NNRs), ancient woodland and local wildlife sites." And "Where modelling predicts a process contribution >100% at a NNR, LNR, ancient woodland or local wildlife site, your proposal may not be considered acceptable. In such cases, your assessment should include proposals to reduce ammonia emissions."

This document was withdrawn February 1st 2016 and replaced with a web-page titled "Intensive farming risk assessment for your environmental permit", which contains essentially the same criteria. It is assumed that the upper threshold and lower threshold on the web-page refers to the levels that were previously referred to as levels of insignificance and acceptability in Annex B - Intensive Farming.

Within the range between the lower and upper thresholds, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. N.B. In the case of LWSs and AWs, the Environment Agency do not usually consider other farms that may act in-combination and therefore a PC of up to 100% of Critical Level or Critical Load is usually deemed acceptable for permitting purposes and therefore the upper and lower thresholds are the same (100%).

3.6 Quantification of ammonia emissions

Ammonia emission rates from poultry houses depend on many factors and are likely to be rather variable. However, the benchmarks for assessing impacts of ammonia and nitrogen deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen deposition rates. To obtain relatively robust figures for these statistics it is not necessary to model short term temporal variations and a steady continuous emission rate can be assumed. In fact, modelling short term temporal variations might introduce rather more uncertainty than modelling continuous emissions.

3.6.1 Housing emissions

The Environment Agency provides an Intensive Farming guidance note which lists standard ammonia emission factors for a variety of livestock, including poultry. For egg laying chickens with frequent removal of droppings using a belt system, such as the proposed poultry, the Environment Agency figure is 0.08 kg-NH_3/bird place/year.

3.5.2 Ranging area emissions

As the birds would have access to outdoor ranging areas, some of the birds' droppings, which is the source of the ammonia, would be deposited on these ranging areas. The emissions from the ranging areas are based upon the National Atmospheric Emission Inventory (NAEI) emission factor for grazing free range hens, which is 0.015 kg-NH_3/bird/y.

Details of the poultry numbers and types, emission factors used and calculated ammonia emission rates are provided in Table 2.

Table 2. Details of poultry numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Proposed Housing	32,000	Egg laying chickens, belt removal of droppings	0.08 (EA figure)	0.081122
Proposed Ranging	32,000	Egg laying chickens	0.015 (NAEI figure)	0.015210

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).

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 13 km (latterly 9 km); terrain is understood to be resolved at a resolution of approximately 2 km, with sub-13/9 km terrain effects parameterised. Site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen. 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 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 2a.

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 site of the proposed poultry house is shown in Figure 2b; it should be noted that elsewhere in the modelling domain the modified wind roses may differ, reflecting the local flow in that part of the domain. The resolution of the wind field in terrain runs is 100 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.

Figure 2a. The wind rose. Raw GFS derived data, for 51.890 N, 4.634 W, 2016 – 2019

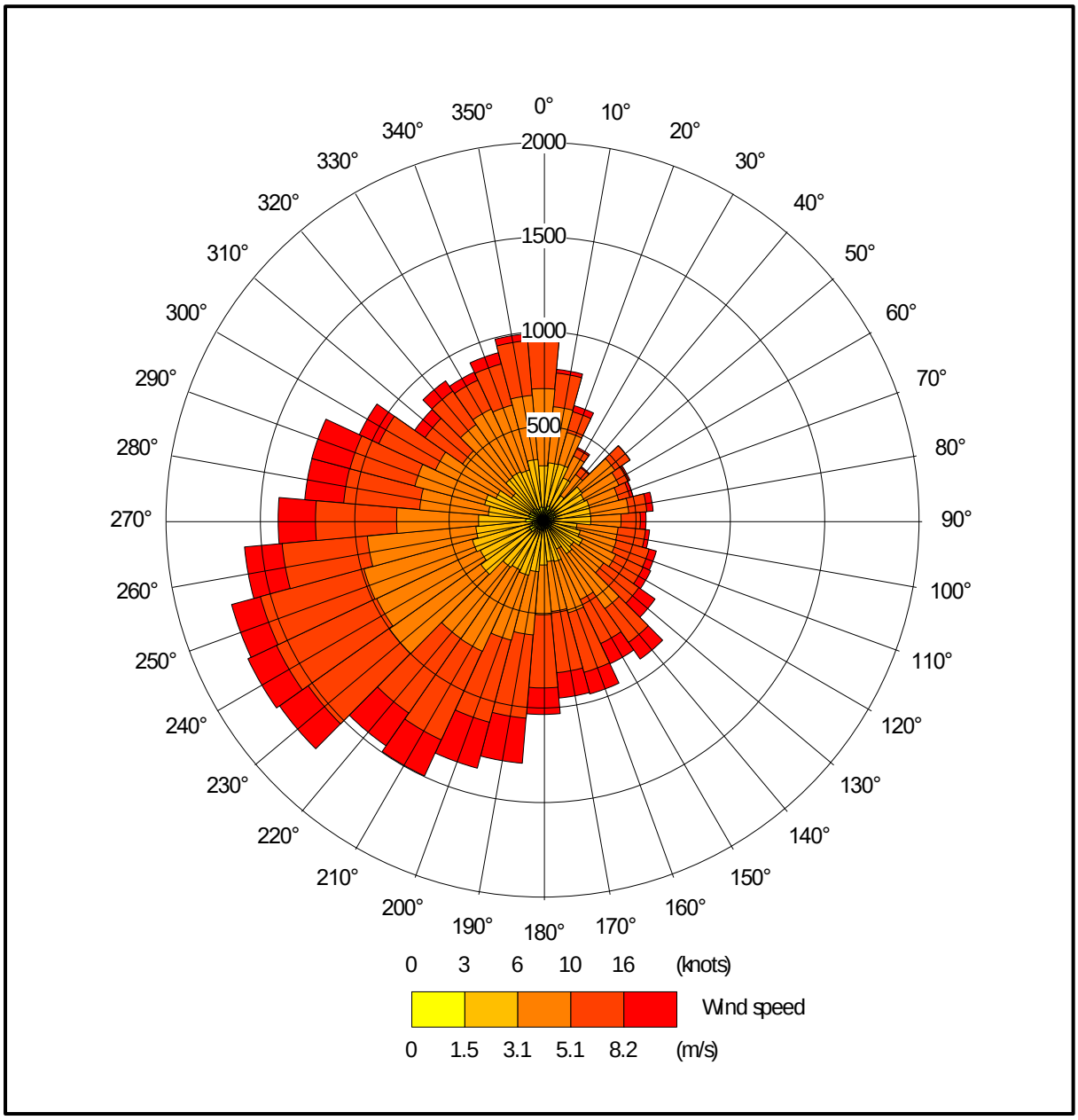
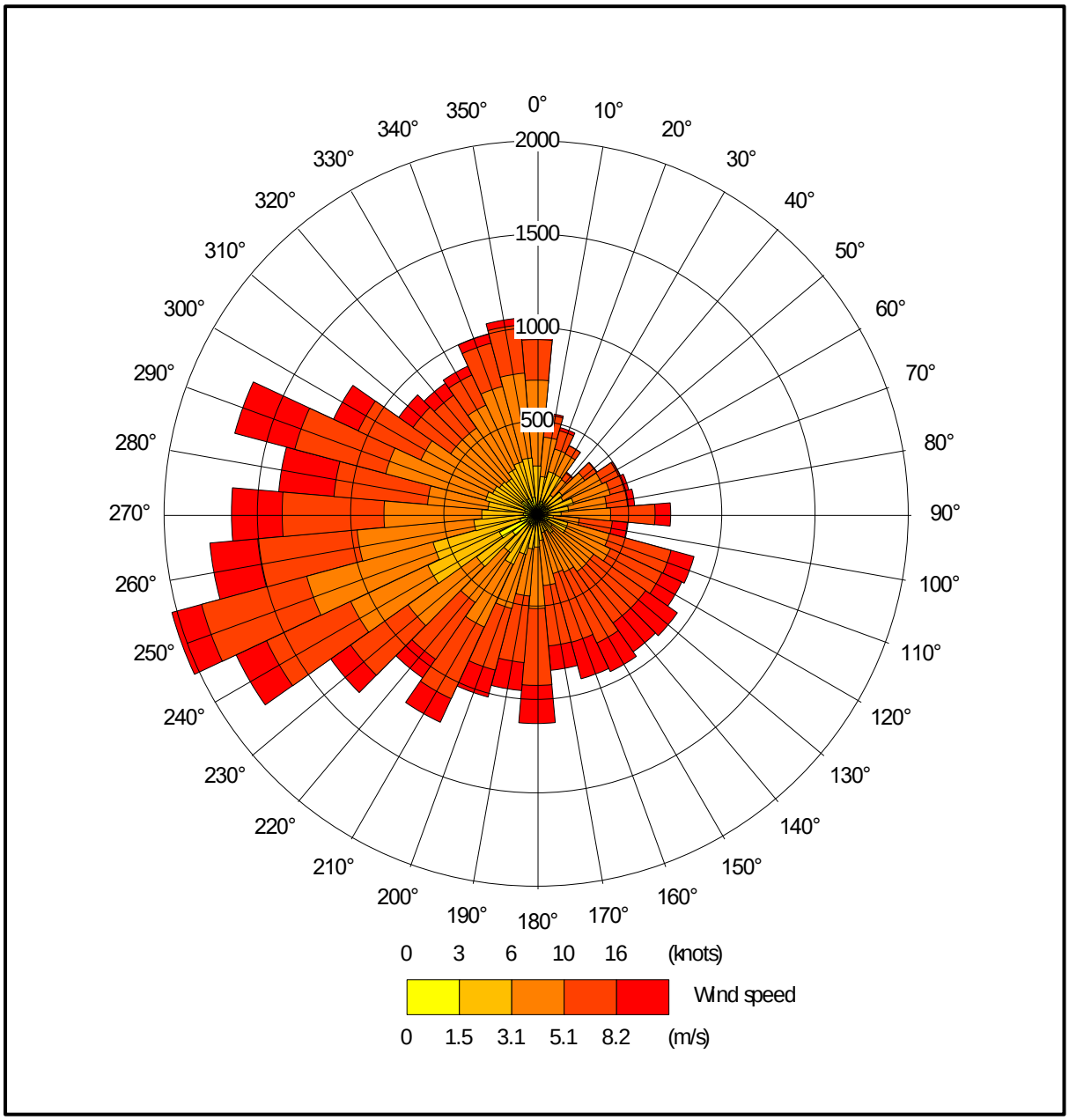


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 218800, 224600, 2016-2019



4.2 Emission sources

4.2.1 The proposed poultry housing and ranging areas

Emissions from the chimneys of the high speed ridge/roof fans on the poultry houses are represented by three point sources per house within ADMS (PR1 1, 2 & 3 and PR2 1, 2 & 3).

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 ranges most likely to be used frequently and not the whole ranging area.

Some fugitive emission from the pop holes are possible when ranging areas are in use, these emissions are represented by a single volume source per house within ADMS (FUG).

Details of the source parameters are provided in Tables 3a, 3b and 3c and the positions of the sources are shown in Figure 3.

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
PR1 1, 2 & 3	7.0	0.8	11.0	21.0	0.013521 [1]
PR2 1, 2 & 3	7.0	0.8	11.0	21.0	0.013521 [1]

Table 3b. Area source parameters

Source ID	Area (m^2)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
PR1_RAN	7,986.1	0.0	Ambient	0.007605
PR2_RAN	4,997.2	0.0	Ambient	0.007605

Table 3c. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate per source (g-NH_3/s)
FUG	75	150	1.0	0.0	Ambient	0.008112 [2]

1. Reduced by 10% between 09:00 and 17:00.
2. 10% of the total emission emitted only between 09:00 and 17:00.

4.3 Modelled buildings

The structure of the proposed poultry houses may affect the plumes from the point sources. Therefore, the buildings scrubber are modelled within ADMS. The positions of the modelled buildings may be seen in Figure 3, where they are marked by grey rectangles.

4.4 Discrete receptors

Twenty-one discrete receptors have been defined at the AWs. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 4, where they are marked by enumerated pink rectangles.

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report, a regular Cartesian grid has been defined within ADMS. The grid receptors are defined at ground level within ADMS. The position of the Cartesian grid may be seen in Figure 4, where it is marked by 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. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field for the terrain runs is 100 m.

4.7 Roughness Length

A fixed surface roughness length of 0.35 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 0.325 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.

4.8 Deposition

In this case, the model has been run with a precautionary fixed deposition rate of 0.003 m/s and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always higher than if deposition were modelled explicitly with realistic deposition velocities, particularly where there is some distance between the source and a receptor.

Figure 3. The positions of modelled buildings and sources

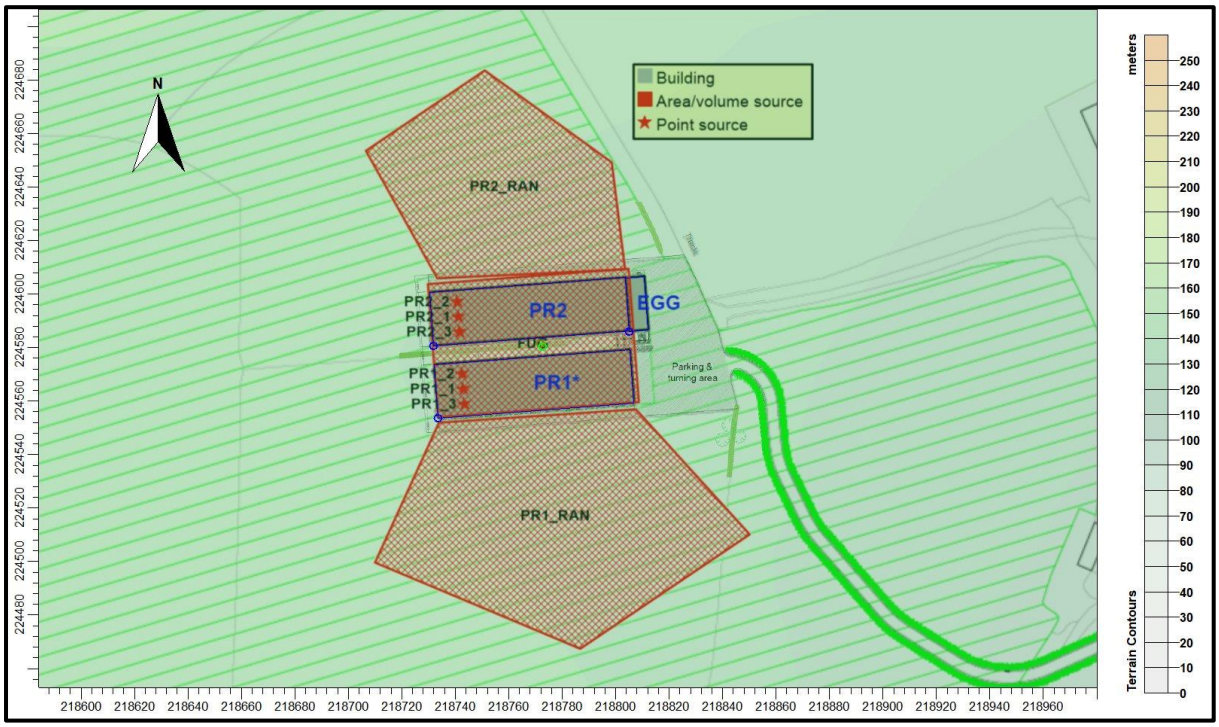
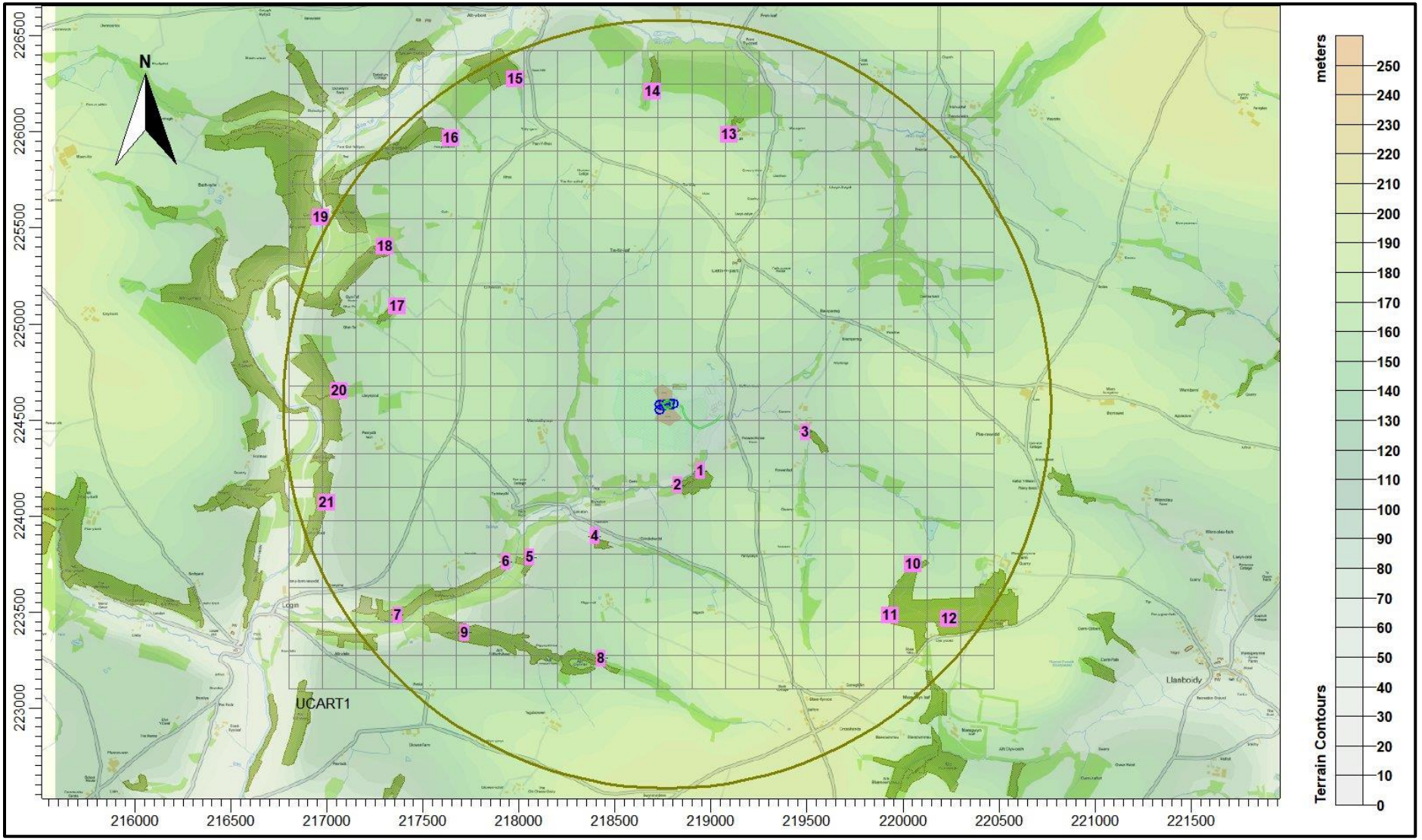


Figure 4. The discrete receptors and regular Cartesian grid



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

It should be noted that the preliminary runs are primarily intended to provide guidance on the model sensitivity and to determine the extent of detailed modelling; in this case the preliminary modelling demonstrates that further detailed modelling is un-necessary.

ADMS was run a total of sixteen times; once for each year of the meteorological record, in the following four modes:

- In basic mode without calms or terrain – GFS data.
- With calms and without terrain – GFS data.
- Without calms and with terrain – GFS data.
- Without calms, with terrain and fixed deposition at 0.003 m/s – GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Note that these are preliminary results for screening and sensitivity testing. Please also note that, because deposition of ammonia and the consequent plume depletion are not accounted for or not fully accounted for, the results are precautionary. Therefore, predicted ammonia concentrations (and nitrogen and acid deposition rates) are always higher than if deposition were modelled explicitly, particularly where there is some distance between the source and a receptor. In this case, a preliminary fixed deposition velocity run has been conducted, it should be noted that this is also precautionary, compared to full spatially varying deposition modelling.

Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. In the Table, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in excess of the Natural Resources Wales upper threshold (100% of a Critical Level or Critical Load for a non-statutory site) are coloured red. Concentrations (or concentrations equivalent to deposition rates) in the range between the Natural Resources Wales lower and upper threshold (100% and 100% of Critical Level or Critical Load for a non-statutory site) are coloured blue.

A contour plot of the predicted maximum annual mean ammonia concentration is provided in Figure 5.

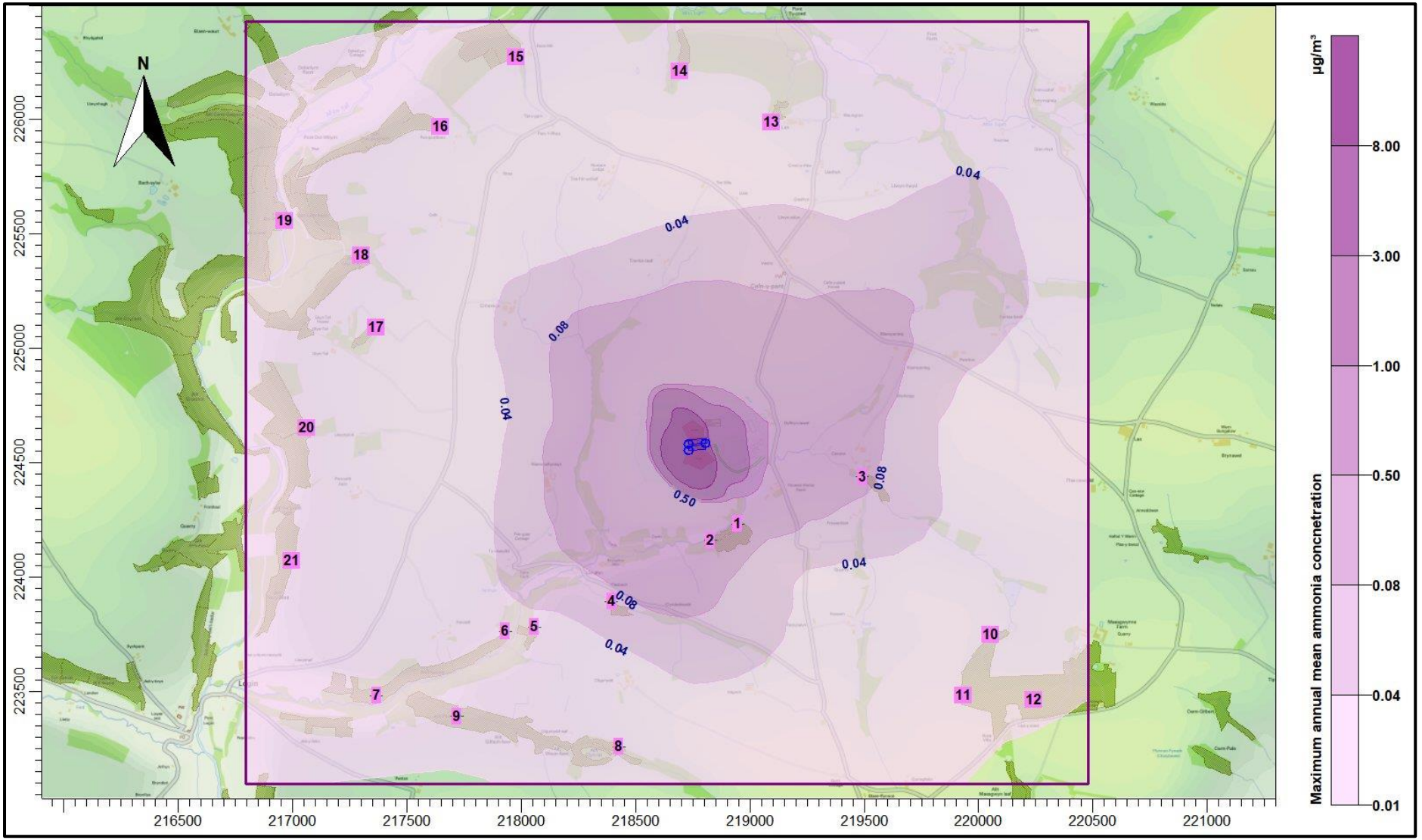
5.2 Detailed modelling

The preliminary modelling indicated that ammonia levels (and nitrogen deposition rates) would be below the Natural Resources Wales lower threshold at all wildlife sites considered, therefore, detailed modelling is un-necessary.

Table 5. Predicted annual mean ammonia concentration at the discrete receptors

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m^3)			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Terrain Fixed depo 0.003 m/s
1	218947	224233	AW	0.399	0.409	0.377	0.257
2	218828	224160	AW	0.340	0.349	0.435	0.320
3	219491	224438	AW	0.163	0.164	0.170	0.118
4	218394	223893	AW	0.091	0.095	0.119	0.085
5	218057	223783	AW	0.062	0.064	0.069	0.045
6	217931	223762	AW	0.059	0.060	0.065	0.042
7	217367	223483	AW	0.034	0.035	0.042	0.026
8	218428	223258	AW	0.042	0.043	0.050	0.031
9	217718	223392	AW	0.034	0.035	0.038	0.022
10	220054	223750	AW	0.041	0.040	0.036	0.022
11	219932	223483	AW	0.034	0.034	0.027	0.016
12	220242	223465	AW	0.028	0.029	0.023	0.014
13	219095	225988	AW	0.045	0.046	0.038	0.028
14	218695	226212	AW	0.032	0.033	0.031	0.021
15	217979	226273	AW	0.023	0.023	0.021	0.014
16	217646	225969	AW	0.028	0.028	0.024	0.016
17	217367	225090	AW	0.031	0.032	0.034	0.023
18	217300	225405	AW	0.031	0.031	0.038	0.026
19	216966	225557	AW	0.023	0.023	0.033	0.021
20	217063	224653	AW	0.032	0.033	0.029	0.018
21	216997	224071	AW	0.034	0.034	0.042	0.025

Figure 5. Maximum annual mean ammonia concentration



6. Summary and Conclusions

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The modelling predicts that:

- The annual ammonia concentration would be below of 100% of the Critical Level at all nearby AWs.

7. References

Cambridge Environmental Research Consultants (CERC) (website).

Environment Agency H1 Risk Assessment (website).

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