

A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Operations at Top House Farm and Home Farm, near Arowry in Wrexham

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Will Phillips of P&L AgriConsulting, on behalf of Mr T Hanmer, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed operations at Top House Farm and Home Farm, near Arowry in Wrexham. Jointly the farms are referred to as Merehead, after the area where a new milking parlour would be constructed.

Ammonia emission rates from the existing and proposed operations at the farms have been assessed and quantified based upon: Environment Agency standard emission factors; emission figures obtained from the UK Ammonia emissions (UKAIE) and Ammonia emission factors for UK agriculture (Misselbrook *et al*). 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 farms 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

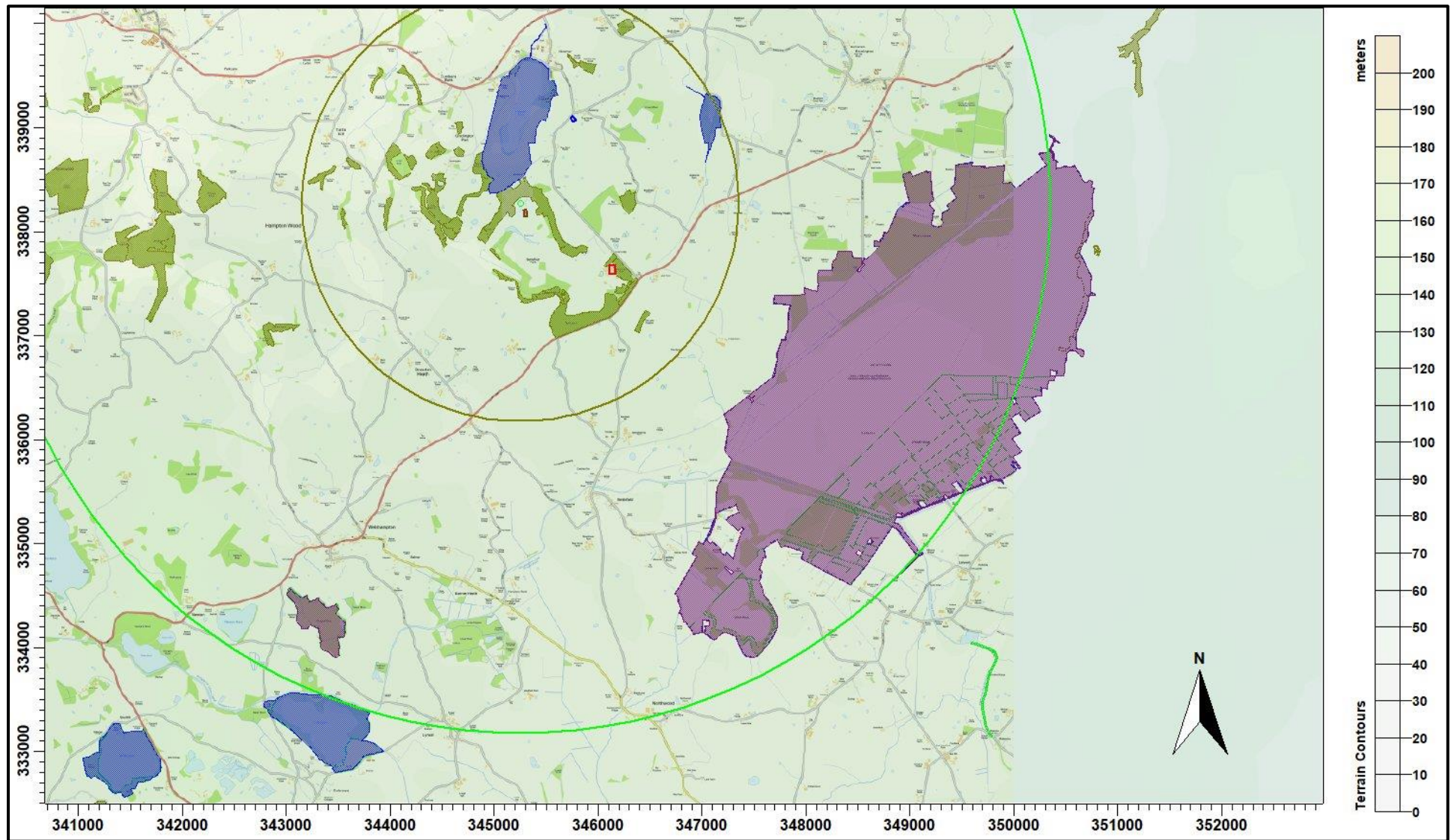
Merehead is a rural area, the existing farm at Top House Farm is located in the small village of Arowry and is approximately 400 m to the south of the larger village of Hanmer in Wrexham; Home Farm is located approximately 1.44 km to the south-south-east of Top House Farm and approximately 930 m to the south-east of the site of the proposed milking parlour at Merehead. The surrounding land of all three sites is used primarily for arable and livestock farming, with several wooded areas nearby. The sites of the existing farms at Home Farm and Top House Farm and the proposed parlour are atop slightly higher ground at an altitude of around 100 m with the surrounding land falling gently away.

Home Farm currently provides accommodation and grazing land for 50 suckler cows, 50 beef youngstock, 450 breeding ewes and 150 ewe hoggs and has a manure store. Top House Farm currently provides accommodation and grazing land for 100 dairy cows, 50 dairy heifers and has a milking parlour. Under the proposal, all previous farming activities at Home Farm and Top House Farm would cease and a new milking parlour and associated buildings would be erected on land approximately 930 m north-west of Home Farm. A herd of up to 150 dairy cows would be housed in accommodation at Home Farm and the cows would be grazed on land at both Home Farm and Top House Farm.

There are several areas designated as Ancient Woodlands (AWs) within 2 km of Merehead. There are five Sites of Special Scientific Interest (SSSI), parts of which are also designated as Special Areas of Conservation (SACs) and as Ramsar Sites within 5 km of the farms.

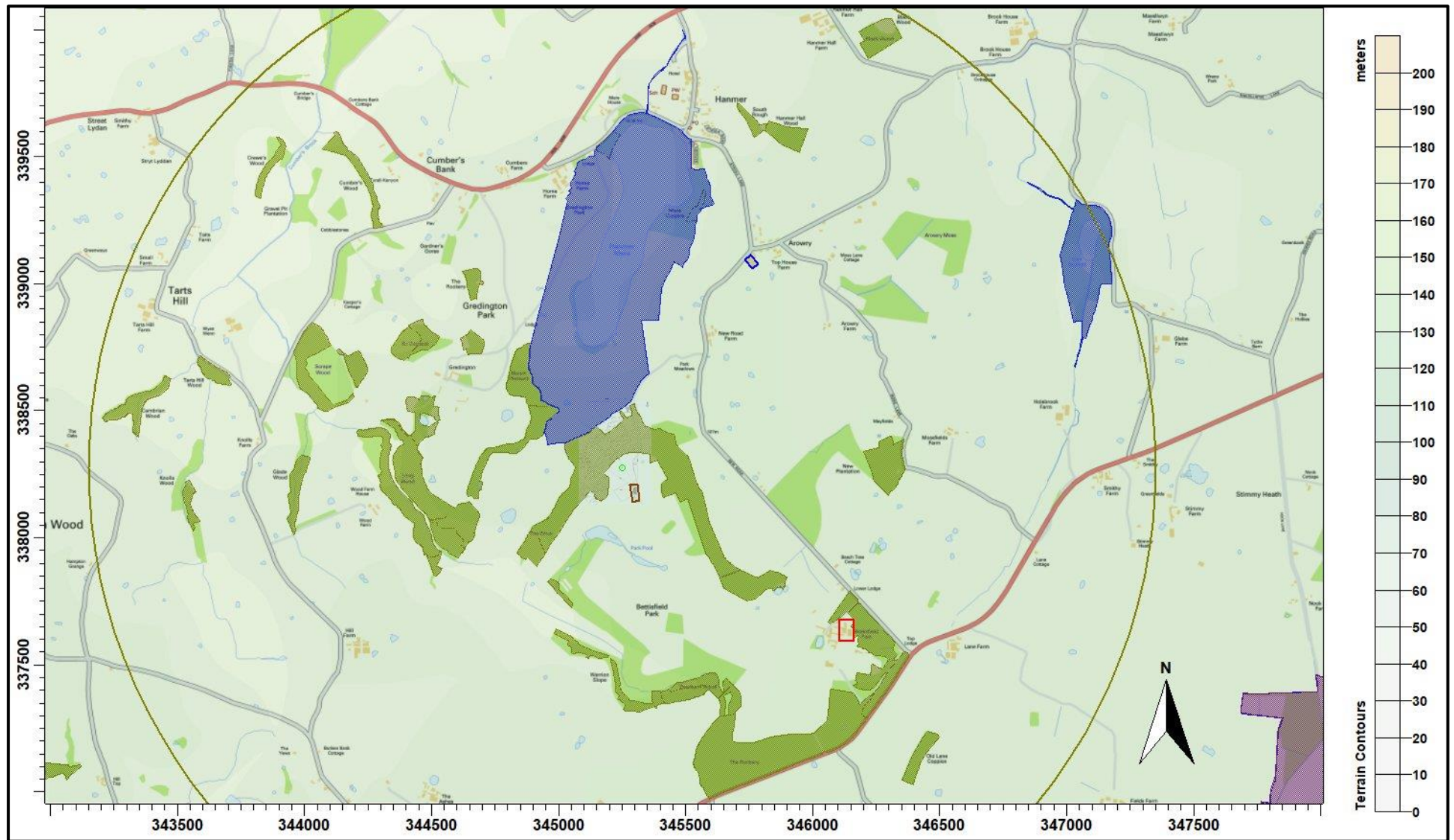
Maps of the surrounding area showing the, the non-statutory sites, SSSIs, SACs and Ramsar Sites are provided in Figures 1a and 1b. In the figures, the AWs are shaded in olive, the SSSIs are shaded in green, the SACs are shaded in purple, the Ramsar Sites are shaded in blue, the site of Top House Farm is outlined in blue, the site of Home Farm is outline in red and the site of the proposed milking parlour is outlined in brown.

Figure 1a. The area surrounding the sites at Merehead – concentric circles radii 2 km (olive) and 5 km (green)



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Figure 1b. The area surrounding the sites – a closer view



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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 ($\mu\text{g-NH}_3/\text{m}^3$) 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 the proposed site at Merehead and the surrounding wildlife sites is $2.54 \mu\text{g-NH}_3/\text{m}^3$. The background nitrogen deposition rate to woodland is 35.7 kg-N/ha/y and to short vegetation is 21.28 kg-N/ha/y . The background acid deposition rate to woodland is 2.49 keq/ha/y and to short vegetation is 1.52 keq/ha/y . The source of these background figures is the Air Pollution Information System (APIS, April 2020).

3.3 Critical Levels & 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 $\mu\text{g-NH}_3/\text{m}^3$ 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 $\mu\text{g-NH}_3/\text{m}^3$ 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 for Rock Farm and Pen-y-Parc are provided in Tables 1a and 1b respectively. N.B. Where the Critical Level of 1.0 $\mu\text{g-NH}_3/\text{m}^3$ 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 surrounding Merehead

Site	Critical Level ($\mu\text{g-NH}_3/\text{m}^3$)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
Non-statutory sites	1.0 ¹	-	-
Hanmer Mere SSSI	3.0 ²	n/a ²	-
Llyn Bedydd SSSI; Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC; Clarepool Moss SSSI	1.0 ³	5.0 ^{3 & 4}	-
Cole Mere SSSI	1.0 ^{1 & 3}	10.0 ^{3 & 4}	-
West Midland Mosses SAC	1.0 ^{1 & 3}	10.0 ⁵	-
Midland Meres & Mosses Phase 1 and Phase 2 Ramsar Sites	n/a ⁶	n/a ⁶	n/a ⁶

1. A precautionary figure used where details of the site are unavailable, or citations indicate that sensitive lichens and bryophytes may be present.
2. A site visit has confirmed land is agricultural/riparian and no sensitive lichens or bryophytes are present (September, 2019).
3. Based upon the citation for the sites and information obtained from APIS (April, 2020).
4. The lower bound of the range of Critical Load obtained from APIS.
5. The upper bound of the range of Critical Load for Natural dystrophic lakes and ponds is used.
6. No Critical Levels or Critical Loads for the designation.

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). OGN 020 contains essentially the same criteria and thresholds as does OGN 041.

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.

For Local Nature Reserves (LNRs), Local Wildlife Sites (LWSs) and Ancient Woodlands (AWs), the current assessment procedure usually applied is based on 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%).

3.5 Quantification of ammonia emissions

Ammonia emission rates from livestock housing and grazing, dairy parlours and manure stores depend on many factors and are likely to be highly 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.

Ammonia emission rates from the existing and the proposed livestock units and manure storage have been assessed and quantified based upon emission figures obtained from the UK Ammonia emissions (UKAIE) and Ammonia emission factors for UK agriculture (Misselbrook *et al*). The emission factors for the existing and proposed farms used are shown in Tables 2a, 2b and 2c.

Table 2a. Details of animal numbers and ammonia emission rates at Top House Farm

EXISTING TOP HOUSE FARM								
Type	Number of Animals	Average Weight (kg)	Housed	Grazed	Emission Factor Housing (kg-NH ₃ /animal/y)	Emission Factor Grazing (kg-NH ₃ /animal/y)	Emission Rate Housing (g/s)	Emission Rate Grazing (g/s)
Dairy Cows	100	650	Nov-Apr	May-Oct	13.32	7.50	0.042205	0.023752
Heifers <12 months	25	250	Nov-March	Apr-Oct	4.10	2.31	0.003247	0.001827
Heifers >12 months	25	450	Nov-March	Apr-Oct	9.22	5.19	0.007305	0.004111

Table 2b. Details of animal numbers, manure store and ammonia emission rates at Home Farm

EXISTING HOME FARM								
Type	Number of Animals	Average Weight (kg)	Housed	Grazed	Emission Factor Housing (kg-NH ₃ /animal/y)	Emission Factor Grazing (kg-NH ₃ /animal/y)	Emission Rate Housing (g/s)	Emission Rate Grazing (g/s)
Beef Cattle	50	700	Nov-March	Apr-Oct	10.25	4.70	0.016233	0.007447
Beef Youngstock	50	350	Nov-March	Apr-Oct	7.17	3.29	0.011363	0.005213
Sheep	450	80	Jan-Apr	May - Dec	1.64	1.33	0.023375	0.018973
Sheep	150	50	Jan-Apr	May - Dec	1.02	0.83	0.004870	0.003953
	Tonnes				Emission Factor (kg-NH ₃ /t/y)			Emission Rate (g/s)
Manure Storage	1000				1.11			0.035136

Table 2c. Details of animal numbers and ammonia emission rates of the proposed herd and parlour at Merehead

PROPOSED								
Type	Number of Animals	Average Weight (kg)	Housed	Grazed	Emission Factor Housing (kg-NH ₃ /animal/y)	Emission Factor Grazing (kg-NH ₃ /animal/y)	Emission Rate Housing (g/s)	Emission Rate Grazing (g/s)
Dairy Cows	150	500	Nov-Jan	Feb-Oct	10.25	7.50	0.048698	0.035627
	Area (m ²)	Number Of Animals	Notes		Emission Factor (kg-NH ₃ /m ² /y)		Emission Rate (g/s)	
Yard 1	67	250	2% use		3.68		0.000583	
Yard 2	137	250	2% use		3.68		0.000583	
Collecting Yard	28739	150	5% use		3.68		0.000875	

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 9km); 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 for the Merehead area is shown in Figure 2a.

The GFS wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the site at Merehead is shown in Figure 2b. Note that although as might be expected, there is little modification in these cases, elsewhere in the modelling domains, modified wind roses may differ more markedly. 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 52.938 N, 2.814 W, 2016 – 2019

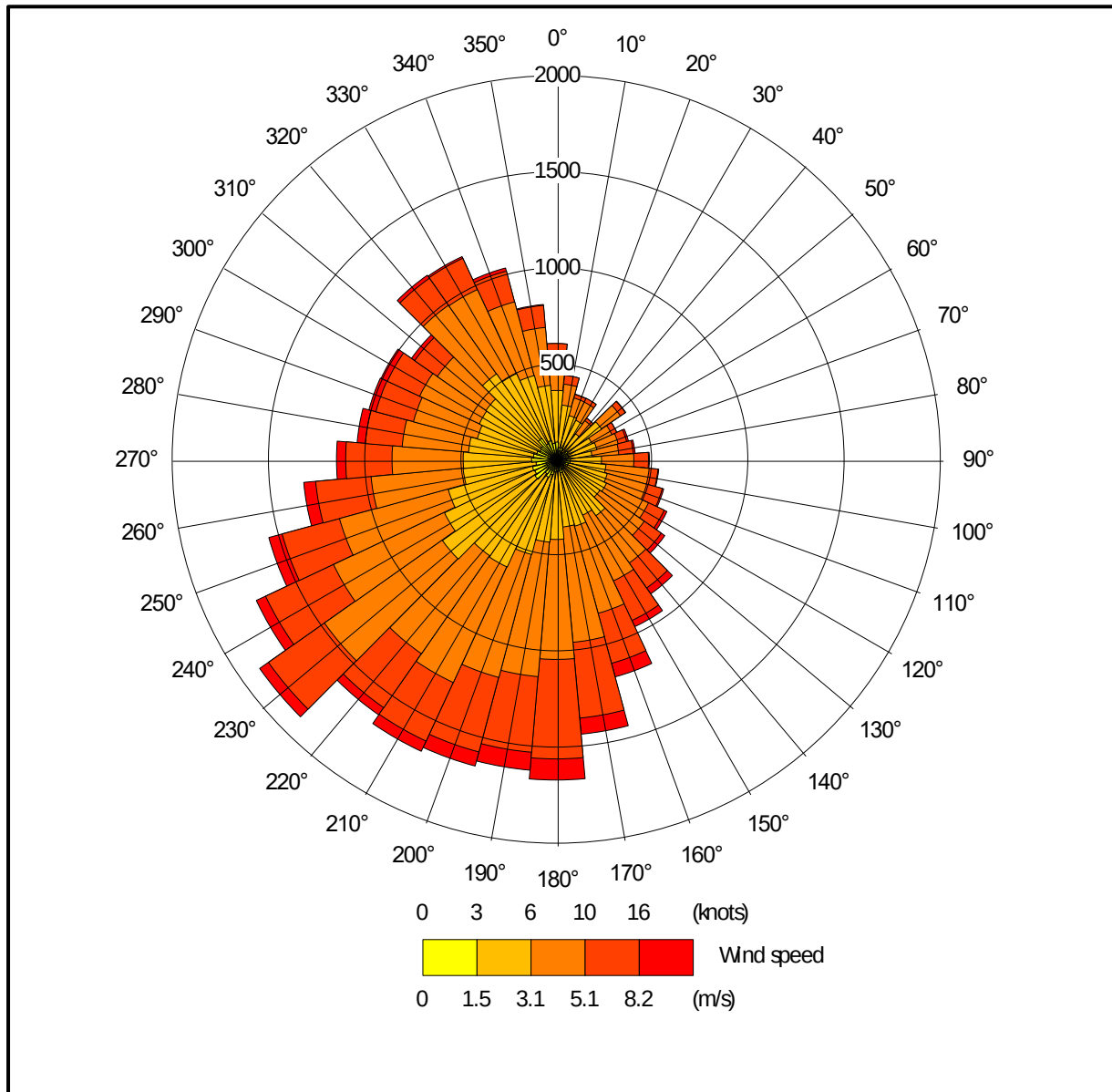
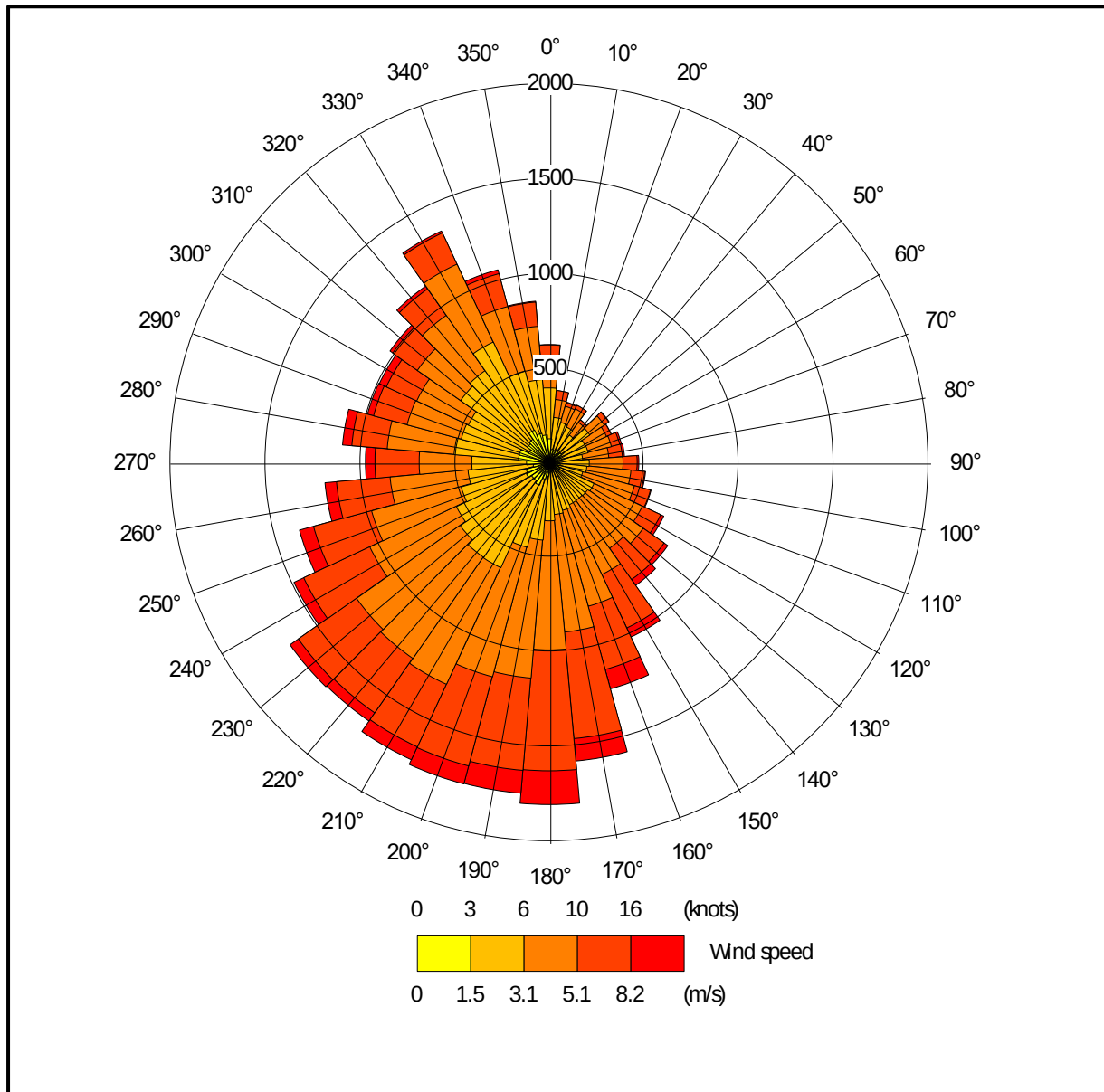


Figure 2b. The wind rose. FLOWSTAR derived data for NGR 345250, 338250, 2016 – 2019



4.2 Emission sources

Emissions from the existing animal housing for the beef cattle (HF_EX_B) and sheep (HF_EX_S) at Home Farm, the dairy cows (TH_EX_C) and heifers (TH_EX_H) at Top House Farm and the manure storage at Home Farm are represented by five volume sources within ADMS. The emissions from the existing fields for grazing are represented by area sources within ADMS. Details of the existing volume and area source parameters at Home Farm and Top House Farm are shown in Tables 3a and 3c.

Emissions from the proposed animal housing, parlour and yards are represented by four volume sources and emissions from the fields for grazing and proposed collecting yard are represented by area sources within ADMS. Details of the proposed volume and area source parameters at Home Farm and the site of the proposed parlour are shown in Tables 3b and 3c.

The positions of the existing area and volume sources at Home Farm and Top House Farm are shown in Figures 3a and 3b. The proposed sources and the site of the proposed parlour are shown in Figures 3c and 3d.

Table 3a. Volume source parameters (existing)

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH ₃ /s)
HF_EX_B	50.0	40.0	4.0	0.0	Ambient	0.027595
HF_EX_S	50.0	40.0	4.0	0.0	Ambient	0.028245
TH_EX_C	38.3	21.4	4.0	0.0	Ambient	0.042205
TH_EX_H	38.3	21.4	4.0	0.0	Ambient	0.010551
EX_MAN	5.0	10.0	1.0	0.0	Ambient	0.035136

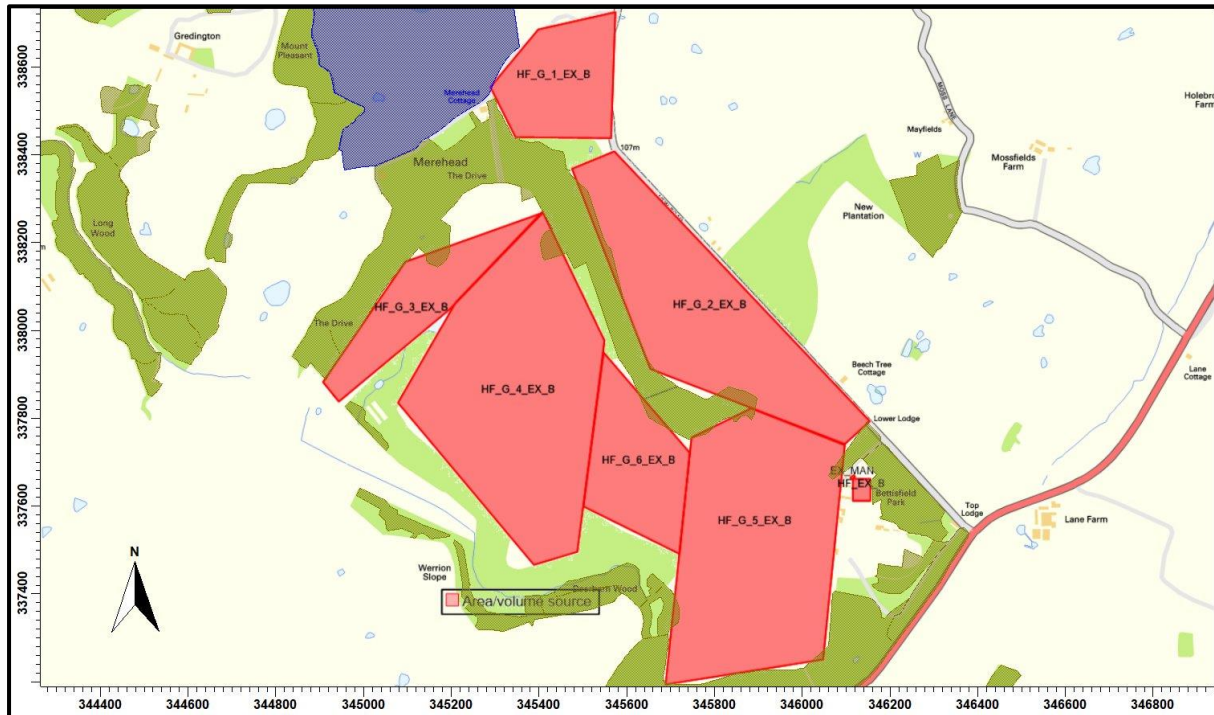
Table 3b. Volume source parameters (proposed)

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH ₃ /s)
PARLOUR	5.6	22.5	4.0	0.0	Ambient	0.002435
YARD 1	9.5	7.0	1.0	0.0	Ambient	0.000583
YARD 2	4.6	30.0	1.0	0.0	Ambient	0.000583
PR_DAIRY_HF	50.0	40.0	4.0	0.0	Ambient	0.048698

Table 3c. Area source parameters (existing and proposed)

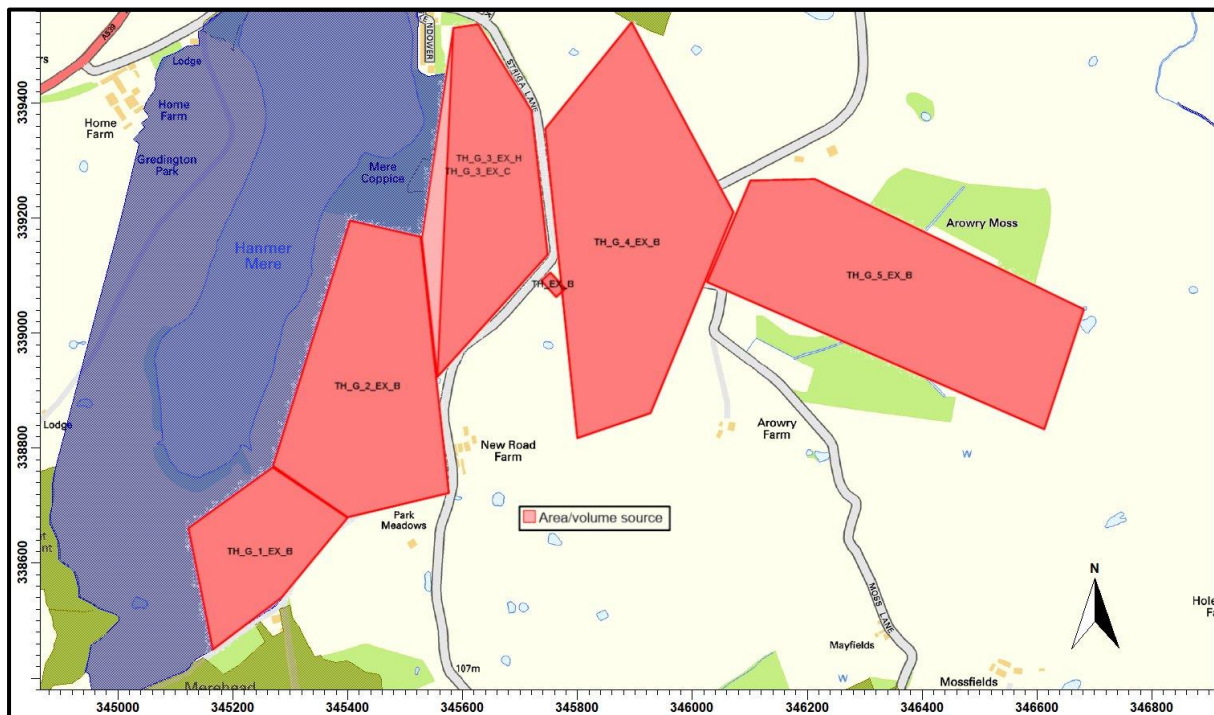
Source ID (Scenario)	Area (m ²)	Base height (m)	Depth (m)	Emission temperature (°C)	Emission rate (g-NH ₃ /s)
HF_G_1_EX_B to HF_G_6_EX_B (existing)	757057.47	0.0	0.0	Ambient	0.012659
HF_G_1_EX_S to HF_G_6_EX_S (existing)	757057.47	0.0	0.0	Ambient	0.022926
TH_G_1_EX_C to TH_G_5_EX_C (existing)	524503.23	0.0	0.0	Ambient	0.023752
TH_G_1_EX_H to TH_G_5_EX_H (existing)	524503.23	0.0	0.0	Ambient	0.005938
HF_G_1_PR_C to HF_G_6_PR_C (proposed)	757057.47	0.0	0.0	Ambient	0.035627
TH_G_1_PR_C to TH_G_5_PR_C (proposed)	524503.23	0.0	0.0	Ambient	0.035627
COLLECT (proposed)	28738.73	0.0	1.0	Ambient	0.000875

Figure 3a. The positions of the existing volume and area sources at Home Farm



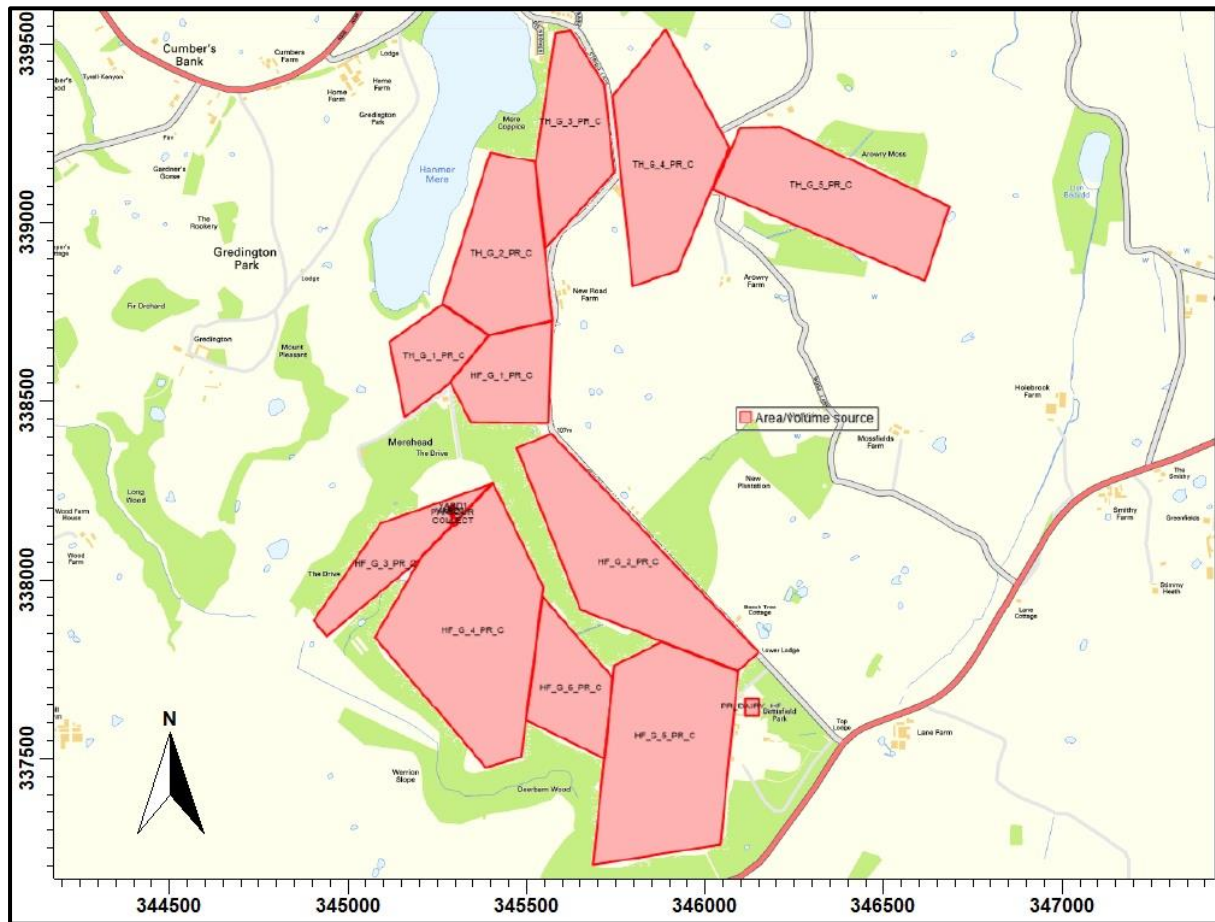
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Figure 3b. The positions of the existing volume and area sources at Top House Farm



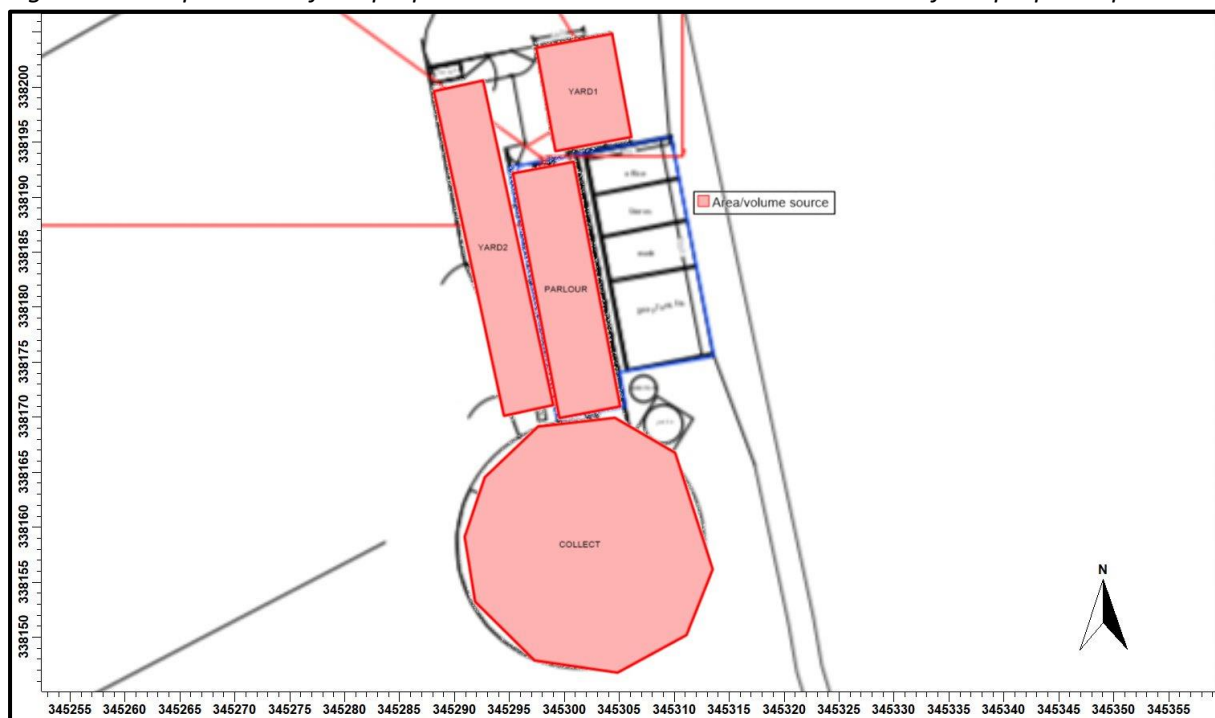
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Figure 3c. The positions of the proposed volume and area sources at Merehead



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Figure 3d. The positions of the proposed volume and area sources at the site of the proposed parlour



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4.3 Modelled buildings

Not Modelled.

4.4 Discrete receptors

Forty-eight discrete receptors have been defined: twenty-nine at the non-statutory sites (1 to 29) and nineteen at the Ramsar Sites/SACs/SSSIs (30 to 48). These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b, where they are marked by enumerated pink rectangles.

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the low and high resolution spatially varying deposition fields used in the detailed modelling, two regular Cartesian grids have been defined within ADMS. The grid receptors are defined at ground level within ADMS. The Cartesian grids may be seen in Figures 4a and 4b, where they are marked by grey lines.

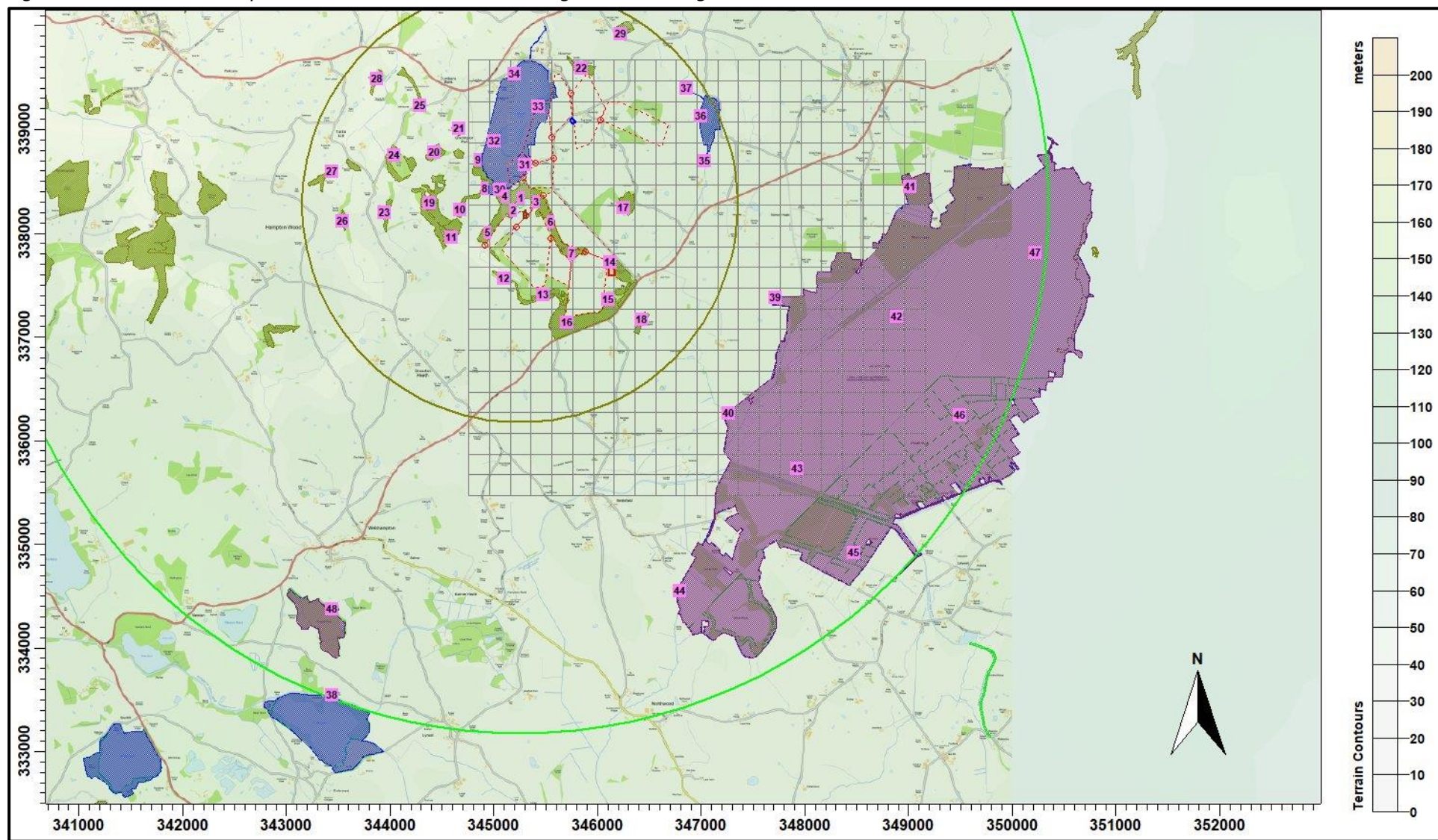
4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 20.0 km x 20.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS in the preliminary modelling and the low resolution detailed modelling and a 6.4 km x 6.4 km domain has been resampled at 50 m horizontal resolution for use within ADMS in the high resolution detailed modelling. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field for the preliminary and low resolution detailed modelling is approximately 300 m and is approximately 100 m in the high resolution detailed modelling.

4.7 Roughness Length

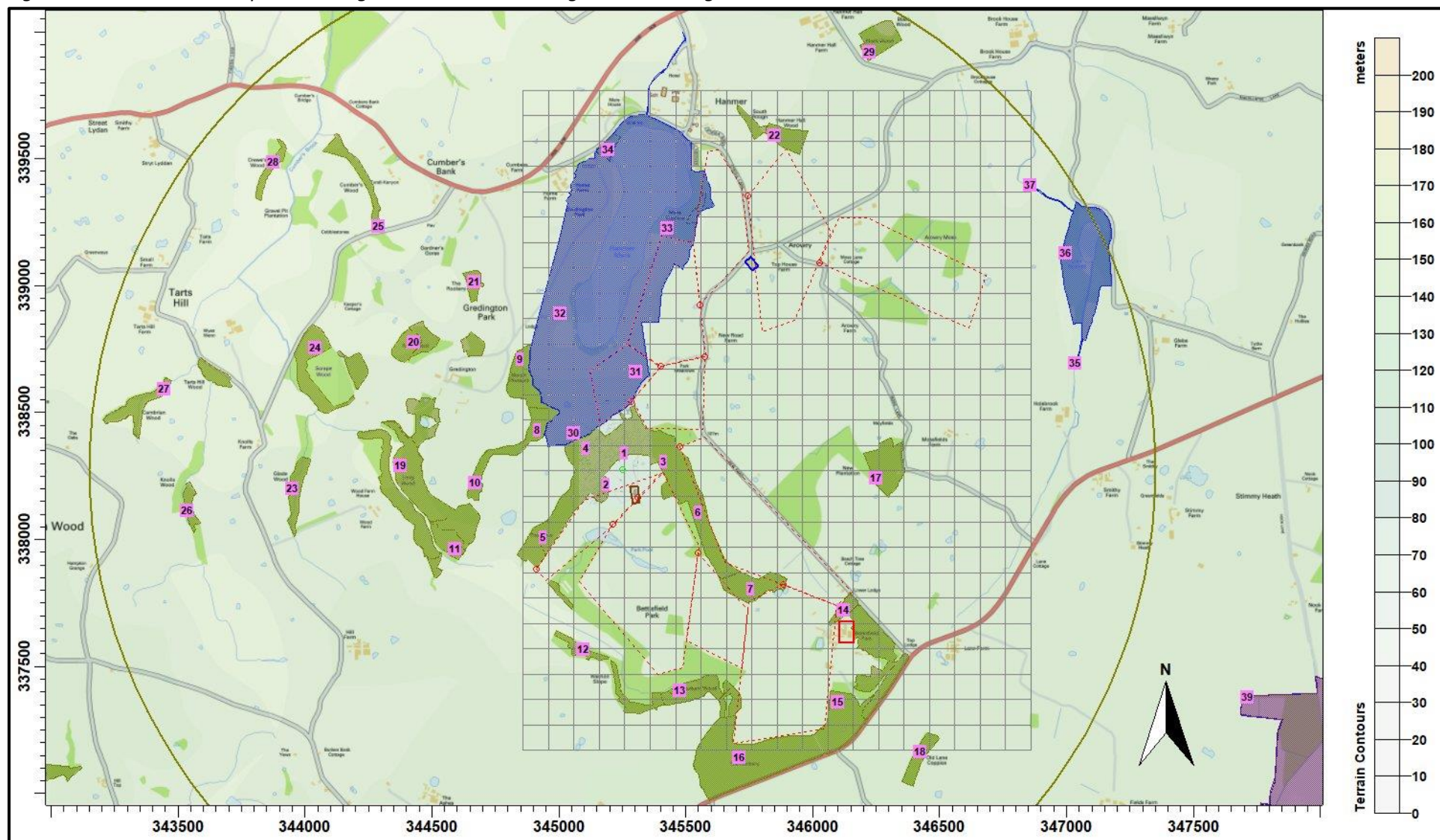
A fixed surface roughness length of 0.275 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.25 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and stability and therefore increases predicted ground level concentrations.

Figure 4a. The discrete receptors and low resolution Cartesian grid surrounding Merehead



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Figure 4b. The discrete receptors and high resolution Cartesian grid surrounding Merehead – a closer view



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4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based on a document titled “Guidance on modelling the concentration and deposition of ammonia emitted from intensive farming” from the Environment Agency’s Air Quality Modelling and Assessment Unit, 22 November 2010. N.B. AS Modelling & Data Ltd. has restricted deposition over arable farmland and heavily grazed and fertilised pasture; this is to compensate for possible saturation effects due to fertilizer application and to allow for periods when fields are clear of crops (Sutton), the deposition is also restricted over areas with little or no vegetation and the deposition velocity is set to 0.002 m/s where grid points are over animal housing and 0.015 m/s over heavily grazed grassland. Where deposition over water surfaces is calculated, a deposition velocity of 0.005 m/s is used.

In this case, a preliminary fixed deposition velocity run has been conducted, it should be noted that this is precautionary compared to full spatially varying deposition modelling.

In summary, the method is as follows:

- A preliminary run of the model without deposition is used to provide an ammonia concentration field.
- The preliminary ammonia concentration field, along with land usage, has been used to define a deposition velocity field. The deposition velocities used are provided in Table 4.

Table 4. Deposition velocities

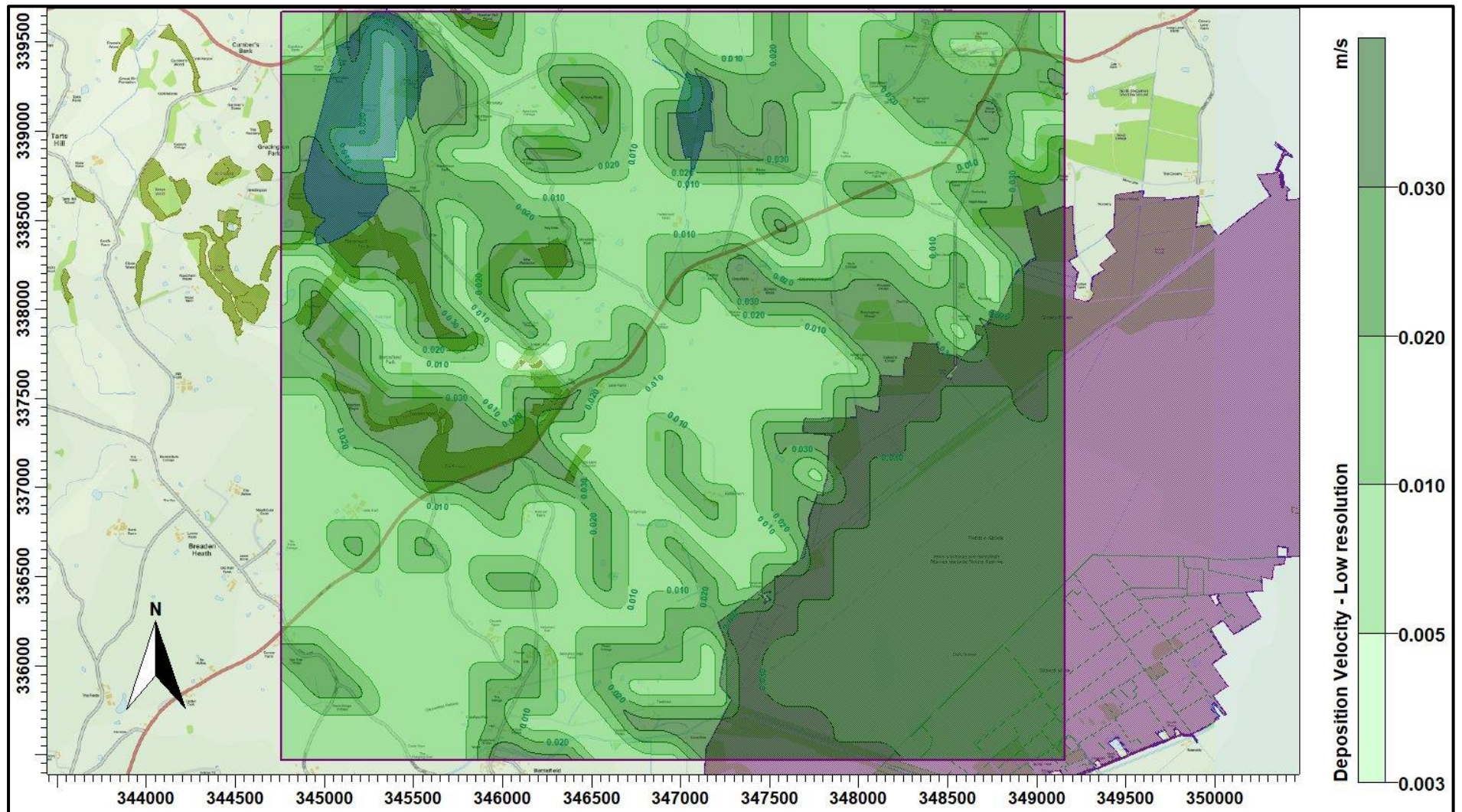
NH ₃ concentration (PC + background) (µg/m ³)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass (m/s)	0.005	0.005	0.005	0.005	0.003

- The model is then rerun with the spatially varying deposition module.

Contour plots of the spatially varying deposition fields at low and high resolution are provided in Figures 5a and 5b.

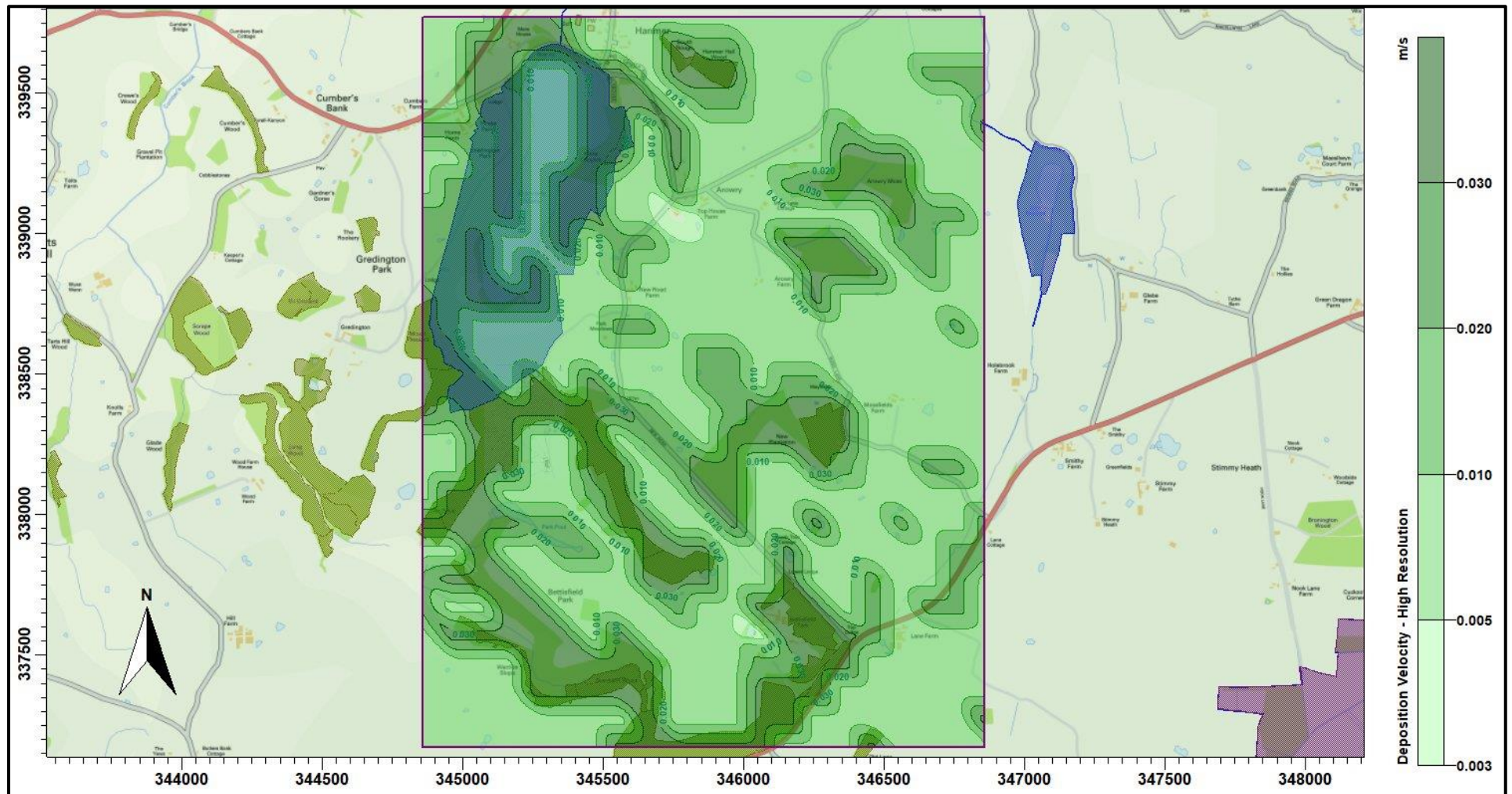
In this case, the model has also been run with a fixed deposition at 0.003 m/s and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always higher than if deposition were modelled explicitly as Environment Agency guidance,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

Figure 5a. The low resolution spatially varying deposition field over Merehead



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Figure 5b. The high resolution spatially varying deposition field over Merehead



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5. Details of the Model Runs and Results

5.1 Preliminary modelling

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.
- With terrain and with fixed deposition at 0.003 m/s and with a correction for calms – GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Note that although calms and spatially varying deposition cannot be run in conjunction, therefore a correction to account for the effect of calms (based upon the difference between the basic and calms modes of the preliminary modelling) has been applied to the results.

Details of the predicted process contribution to annual mean ammonia concentrations at each receptor surrounding Merehead are provided in Table 5. For convenience, cells referring to the non-statutory sites are shaded olive and cells referring to the SSSIs/SACs/Ramsar Sites are shaded blue.

In Table 5, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in excess of the Natural Resources Wales upper threshold percentage (8% of the relevant Critical Level for a statutory site and 100% of the precautionary Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ for a non-statutory site) are coloured red. Predicted ammonia concentrations in the range between the Natural Resources Wales upper threshold and lower threshold (1% to 8% of the relevant Critical Level for a statutory site and 100% and 100% of the precautionary Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ for a non-statutory site) are coloured blue. Additionally, predicted ammonia concentrations (or concentrations equivalent to nitrogen deposition rates) that exceed 1% of the precautionary Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ at non-statutory sites are highlighted in bold text.

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

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Existing				Proposed			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
1	345259	338341	Ancient Woodland	0.270	0.291	0.300	0.173	0.444	0.484	0.523	0.353
2	345186	338215	Ancient Woodland	0.322	0.343	0.370	0.231	0.633	0.704	0.740	0.505
3	345412	338304	Ancient Woodland	0.371	0.397	0.408	0.250	0.679	0.716	0.753	0.513
4	345106	338359	Ancient Woodland	0.194	0.212	0.211	0.112	0.273	0.289	0.313	0.177
5	344939	338009	Ancient Woodland	0.186	0.206	0.213	0.121	0.234	0.242	0.283	0.165
6	345550	338105	Ancient Woodland	0.544	0.583	0.606	0.378	0.673	0.686	0.794	0.510
7	345756	337805	Ancient Woodland	0.823	0.950	0.911	0.593	0.684	0.698	0.803	0.513
8	344914	338430	Ancient Woodland	0.127	0.143	0.129	0.064	0.148	0.155	0.161	0.080
9	344849	338708	Ancient Woodland	0.111	0.124	0.111	0.055	0.117	0.121	0.125	0.061
10	344671	338224	Ancient Woodland	0.090	0.104	0.089	0.044	0.097	0.102	0.101	0.047
11	344592	337963	Ancient Woodland	0.079	0.094	0.082	0.041	0.079	0.083	0.086	0.042
12	345096	337565	Ancient Woodland	0.154	0.181	0.168	0.089	0.163	0.169	0.183	0.095
13	345477	337404	Ancient Woodland	0.265	0.317	0.298	0.174	0.273	0.278	0.320	0.182
14	346122	337723	Ancient Woodland	14.971	16.528	14.833	13.978	2.830	3.060	2.877	2.420
15	346098	337359	Ancient Woodland	1.147	1.348	1.181	0.794	0.555	0.595	0.604	0.403
16	345710	337140	Ancient Woodland	0.296	0.353	0.311	0.182	0.209	0.219	0.231	0.131
17	346249	338241	Ancient Woodland	0.421	0.489	0.442	0.301	0.260	0.271	0.270	0.157
18	346424	337164	Ancient Woodland	0.421	0.469	0.470	0.289	0.210	0.223	0.235	0.133
19	344376	338292	Ancient Woodland	0.060	0.071	0.058	0.029	0.058	0.062	0.059	0.028
20	344428	338776	Ancient Woodland	0.065	0.075	0.061	0.029	0.063	0.065	0.062	0.028
21	344665	339013	Ancient Woodland	0.082	0.092	0.078	0.038	0.079	0.081	0.080	0.037
22	345849	339590	Ancient Woodland	0.241	0.258	0.254	0.179	0.303	0.303	0.349	0.239
23	343949	338200	Ancient Woodland	0.040	0.048	0.039	0.018	0.035	0.037	0.036	0.016
24	344042	338756	Ancient Woodland	0.044	0.052	0.042	0.020	0.041	0.043	0.040	0.018
25	344289	339234	Ancient Woodland	0.054	0.061	0.050	0.023	0.049	0.051	0.048	0.021
26	343536	338112	Ancient Woodland	0.029	0.036	0.030	0.013	0.024	0.026	0.025	0.010
27	343443	338591	Ancient Woodland	0.028	0.033	0.028	0.013	0.024	0.026	0.025	0.011
28	343876	339487	Ancient Woodland	0.037	0.042	0.035	0.015	0.033	0.034	0.032	0.013
29	346223	339919	Ancient Woodland	0.107	0.117	0.104	0.065	0.115	0.116	0.115	0.067
30	345057	338417	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.169	0.187	0.180	0.094	0.217	0.228	0.246	0.133
31	345304	338659	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	1.099	1.095	1.128	0.894	1.627	1.595	1.680	1.364
32	345005	338892	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.135	0.150	0.144	0.076	0.147	0.150	0.168	0.088
33	345428	339224	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.331	0.360	0.393	0.268	0.376	0.375	0.478	0.326
34	345195	339533	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.107	0.119	0.115	0.065	0.111	0.112	0.128	0.072
35	347033	338692	Llyn Bedydd SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.174	0.185	0.179	0.101	0.139	0.142	0.150	0.082
36	346995	339129	Llyn Bedydd SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.149	0.159	0.150	0.083	0.161	0.161	0.163	0.084

Table 5. Continued.

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - ($\mu\text{g}/\text{m}^3$)							
				Existing				Proposed			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Terrain Fixed depo 0.003 m/s
37	346858	339395	Llyn Bedydd SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.132	0.141	0.129	0.075	0.158	0.157	0.156	0.084
38	343436	333540	Cole Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.010	0.012	0.009	0.004	0.007	0.007	0.007	0.002
39	347711	337377	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.092	0.103	0.094	0.050	0.052	0.055	0.053	0.026
40	347262	336265	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.073	0.082	0.077	0.039	0.043	0.045	0.046	0.021
41	349015	338445	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.039	0.043	0.038	0.018	0.028	0.029	0.028	0.012
42	348886	337195	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.039	0.043	0.041	0.019	0.024	0.026	0.026	0.012
43	347924	335731	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.042	0.047	0.044	0.020	0.025	0.026	0.027	0.011
44	346792	334545	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.023	0.027	0.022	0.010	0.016	0.016	0.015	0.006
45	348470	334919	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.026	0.029	0.027	0.012	0.017	0.017	0.018	0.007
46	349496	336244	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.022	0.025	0.023	0.011	0.015	0.015	0.016	0.007
47	350222	337815	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.023	0.026	0.023	0.010	0.016	0.017	0.016	0.006
48	343436	334374	Clarepool Moss SSSI/West Midlands Mosses SAC/Midland Meres & Mosses Phase 1 Ramsar Site	0.013	0.016	0.013	0.005	0.009	0.010	0.009	0.003

5.2 Detailed deposition modelling

The detailed modelling, which includes ammonia deposition and the consequent plume depletion, was carried out over restricted domains at high and low resolution covering the existing and proposed farms, two nearby non-statutory sites, Hanmer Mere SSSI, Llyn Bedydd SSSI and closer parts of Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC and Midland Meres & Mosses Phase 2 Ramsar site. These are areas where the preliminary modelling (GFS fixed deposition run) indicated that annual mean ammonia concentrations or nitrogen deposition rates would potentially exceed 1% of the relevant Critical Level and/or Critical Load of the site. At the other wildlife sites, the preliminary modelling indicated that ammonia levels (or concentrations equivalent to deposition rates) would be below the Natural Resources Wales lower threshold percentage of the relevant Critical Level/Load for the designation of the site.

Terrain effects may be significant at some receptors; therefore, the detailed deposition run was made with terrain. Calms cannot be used with terrain or spatially varying deposition; therefore, calms have not been included in the detailed modelling. However, the results of the preliminary modelling indicate that the effects of calms are likely to be insignificant.

Details of the predicted process contribution to annual mean ammonia concentrations and nitrogen deposition rates at each receptor within the detailed modelling domains in the existing and proposed scenarios are provided in Tables 6a and 6b. In the tables, predicted ammonia and nitrogen deposition rates that are in excess of the Natural Resources Wales upper threshold percentage (8% of the relevant Critical Level or Load for a statutory site and 100% of the precautionary Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ for a non-statutory site) are coloured red. Predicted ammonia concentrations and nitrogen deposition rates in the range between the Natural Resources Wales upper threshold and lower threshold (1% to 8% of the relevant Critical Level or Load for a statutory site and 100% and 100% of the precautionary Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ for a non-statutory site) are coloured blue. Additionally, predicted ammonia concentrations that exceed 1% of the precautionary Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ at non-statutory sites are highlighted in bold text.

Contour plots of the existing and proposed predicted process contribution to ground level maximum annual ammonia concentrations and nitrogen deposition rates at low and high resolution for Merehead are provided in Figures 6a to 6d and Figures 7a to 7d, respectively.

Contour plots showing the change in predicted process contribution to ground level maximum annual ammonia concentrations (expressed as a percentage of the Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$) are provided in Figures 8a (low resolution) and 8b (high resolution).

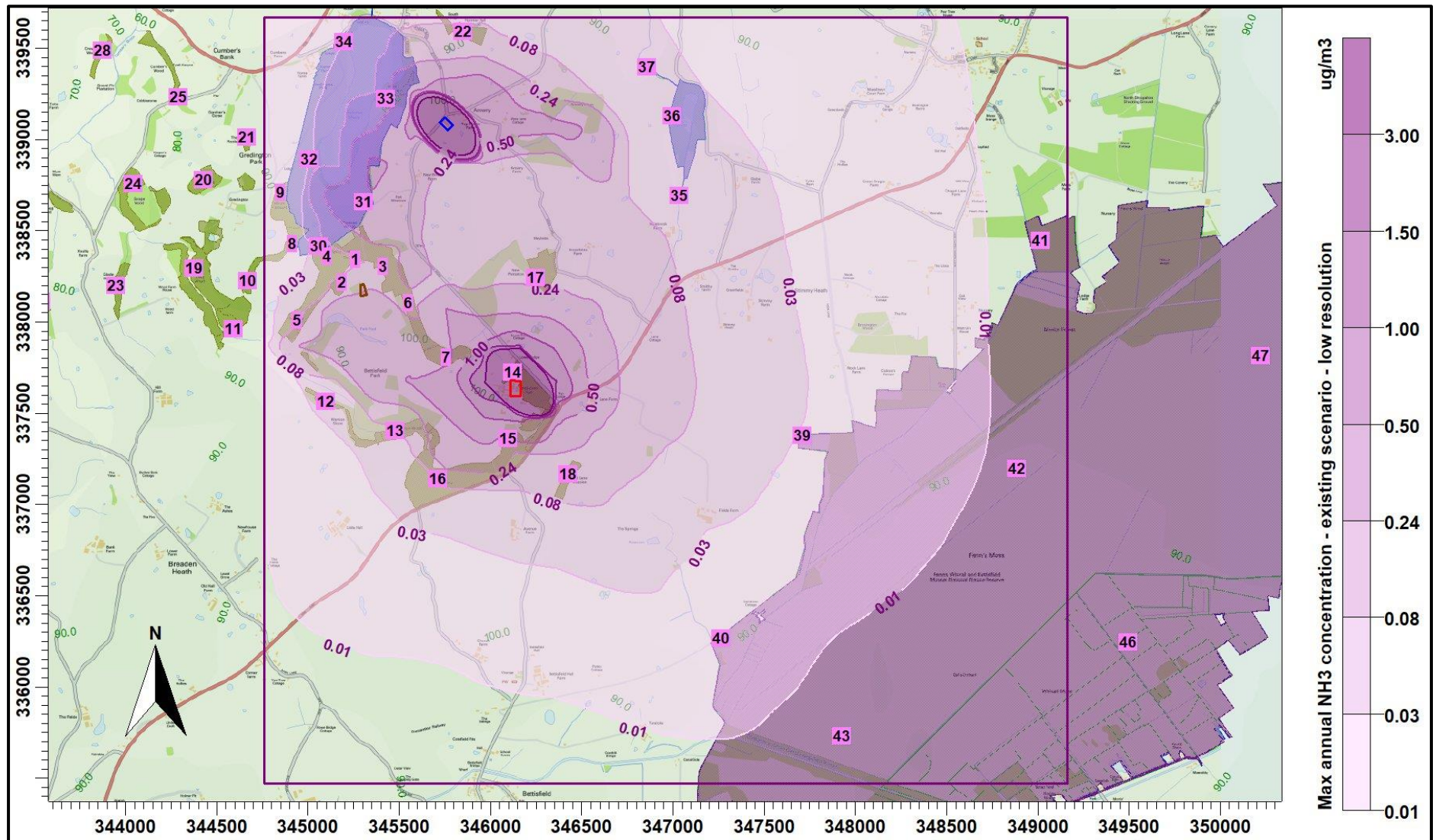
Table 6a. Predicted maximum annual mean ammonia concentrations at the discrete receptors – existing scenario

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	345259	338341	Ancient Woodland	0.030	1.0	10.0	0.061	6.06	0.472	4.72
2	345186	338215	Ancient Woodland	0.030	1.0	10.0	0.090	8.98	0.699	6.99
3	345412	338304	Ancient Woodland	0.030	1.0	10.0	0.094	9.41	0.733	7.33
4	345106	338359	Ancient Woodland	0.030	1.0	10.0	0.041	4.12	0.321	3.21
5	344939	338009	Ancient Woodland	0.030	1.0	10.0	0.046	4.63	0.360	3.60
6	345550	338105	Ancient Woodland	0.030	1.0	10.0	0.155	15.49	1.207	12.07
7	345756	337805	Ancient Woodland	0.030	1.0	10.0	0.266	26.61	2.073	20.73
8	344914	338430	Ancient Woodland	0.030	1.0	10.0	0.022	2.15	0.168	1.68
12	345096	337565	Ancient Woodland	0.030	1.0	10.0	0.043	4.29	0.334	3.34
13	345477	337404	Ancient Woodland	0.030	1.0	10.0	0.090	9.03	0.703	7.03
14	346122	337723	Ancient Woodland	0.030	1.0	10.0	10.434	1043.39	81.290	812.90
15	346098	337359	Ancient Woodland	0.030	1.0	10.0	0.332	33.22	2.588	25.88
17	346249	338241	Ancient Woodland	0.030	1.0	10.0	0.136	13.59	1.059	10.59
22	345849	339590	Ancient Woodland	0.030	1.0	10.0	0.116	11.61	0.905	9.05
30	345057	338417	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.030	3.0	10.0	0.038	1.26	0.295	2.95
31	345304	338659	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.020	3.0	10.0	0.646	21.54	3.356	33.56
32	345005	338892	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.020	3.0	10.0	0.038	1.28	0.199	1.99
33	345428	339224	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.030	3.0	10.0	0.205	6.83	1.597	15.97
34	345195	339533	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.030	3.0	10.0	0.032	1.06	0.249	2.49
37	346858	339395	Llyn Bedydd SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.030	1.0	5.0	0.042	4.16	0.324	6.48
39	347711	337377	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.030	1.0	5.0	0.029	2.65	0.206	4.12
40	347262	336265	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.030	1.0	5.0	0.017	1.52	0.119	2.37
41	349015	338445	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.030	1.0	5.0	0.008	0.71	0.055	1.10
42	348886	337195	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.020	1.0	5.0	0.009	0.79	0.041	0.82
43	347924	335731	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.020	1.0	5.0	0.007	0.67	0.035	0.70

Table 6b. Predicted maximum annual mean ammonia concentrations at the discrete receptors – proposed scenario

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	345259	338341	Ancient Woodland	0.03	1.0	10.0	0.206	20.64	1.608	16.08
2	345186	338215	Ancient Woodland	0.03	1.0	10.0	0.261	26.05	2.030	20.30
3	345412	338304	Ancient Woodland	0.03	1.0	10.0	0.266	26.60	2.072	20.72
4	345106	338359	Ancient Woodland	0.03	1.0	10.0	0.076	7.60	0.592	5.92
5	344939	338009	Ancient Woodland	0.03	1.0	10.0	0.063	6.32	0.493	4.93
6	345550	338105	Ancient Woodland	0.03	1.0	10.0	0.231	23.11	1.801	18.01
7	345756	337805	Ancient Woodland	0.03	1.0	10.0	0.221	22.14	1.725	17.25
8	344914	338430	Ancient Woodland	0.03	1.0	10.0	0.026	2.58	0.201	2.01
12	345096	337565	Ancient Woodland	0.03	1.0	10.0	0.040	3.99	0.311	3.11
13	345477	337404	Ancient Woodland	0.03	1.0	10.0	0.086	8.60	0.670	6.70
14	346122	337723	Ancient Woodland	0.03	1.0	10.0	1.554	155.41	12.108	121.08
15	346098	337359	Ancient Woodland	0.03	1.0	10.0	0.171	17.06	1.329	13.29
17	346249	338241	Ancient Woodland	0.03	1.0	10.0	0.064	6.40	0.498	4.98
22	345849	339590	Ancient Woodland	0.03	1.0	10.0	0.160	16.04	1.250	12.50
30	345057	338417	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.03	3.0	10.0	0.058	1.93	0.451	4.51
31	345304	338659	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.02	3.0	10.0	1.015	33.85	5.274	52.74
32	345005	338892	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.02	3.0	10.0	0.045	1.51	0.235	2.35
33	345428	339224	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.03	3.0	10.0	0.240	7.99	1.867	18.67
34	345195	339533	Hanmer Mere SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.03	3.0	10.0	0.033	1.11	0.260	2.60
37	346858	339395	Llyn Bedydd SSSI/Midland Meres & Mosses Phase 2 Ramsar site	0.03	1.0	5.0	0.044	4.40	0.343	6.85
39	347710.75	337376.75	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.03	1.0	5.0	0.012	1.14	0.089	1.77
40	347261.88	336265.28	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.03	1.0	5.0	0.008	0.72	0.056	1.12
41	349014.56	338445.47	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.03	1.0	5.0	0.004	0.38	0.029	0.59
42	348886.31	337195.06	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.02	1.0	5.0	0.005	0.42	0.022	0.44
43	347924.47	335730.94	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI & SAC/Midland Meres & Mosses Phase 2 Ramsar site	0.02	1.0	5.0	0.004	0.35	0.018	0.36

Figure 6a. Maximum annual mean ammonia concentration – existing scenario at low resolution



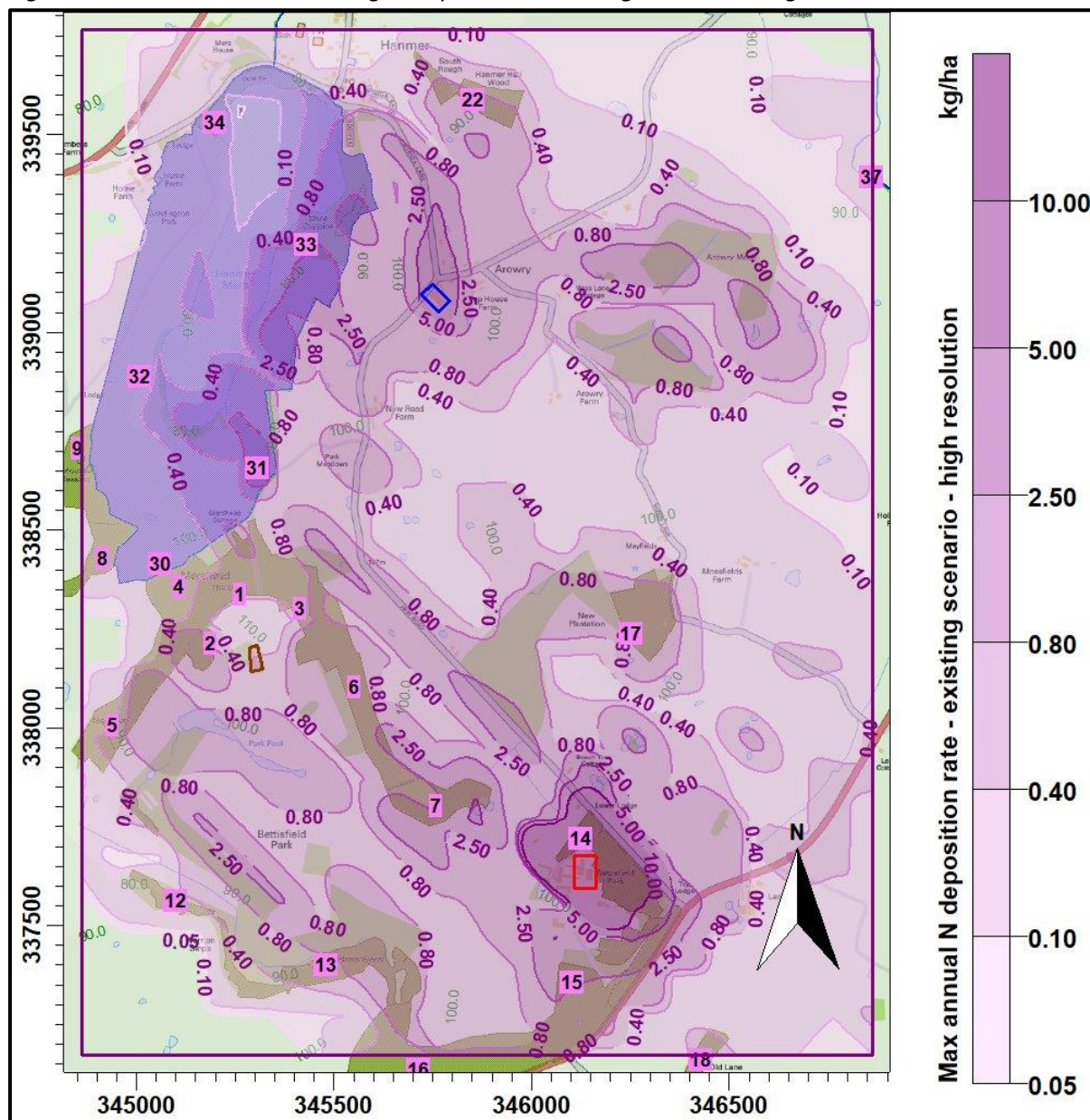
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The map displays the predicted maximum annual nitrogen deposition rates for the year 2010 in the Broadland Heath area. The color scale ranges from 0.05 kg/ha (light pink) to 10.00 kg/ha (dark purple). A red line indicates the 10 kg/ha threshold. A black box highlights a specific area of interest. A north arrow is located in the bottom left corner.

Map of the Arroyo Viejo area showing predicted annual average ammonia concentrations for the existing scenario. The map displays contour lines for concentrations ranging from 0.01 to 3.00 ug/m3. A color scale on the right indicates the concentration levels. A north arrow is present in the bottom right corner. The map includes labels for various locations such as Hanmer, Arroyo, and Bettisfield Park.

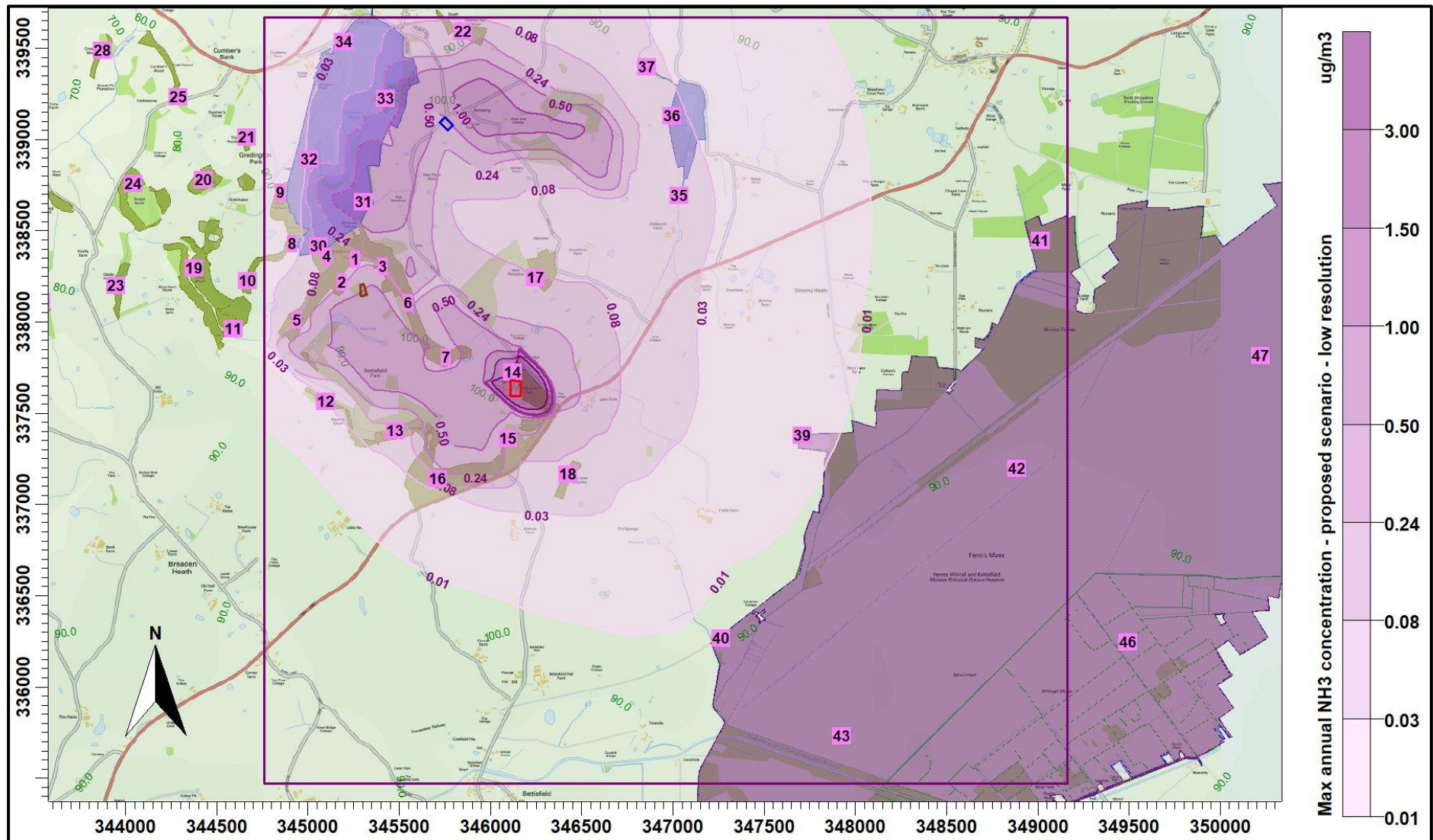
32

Figure 6d. Maximum annual nitrogen deposition – existing scenario at high resolution



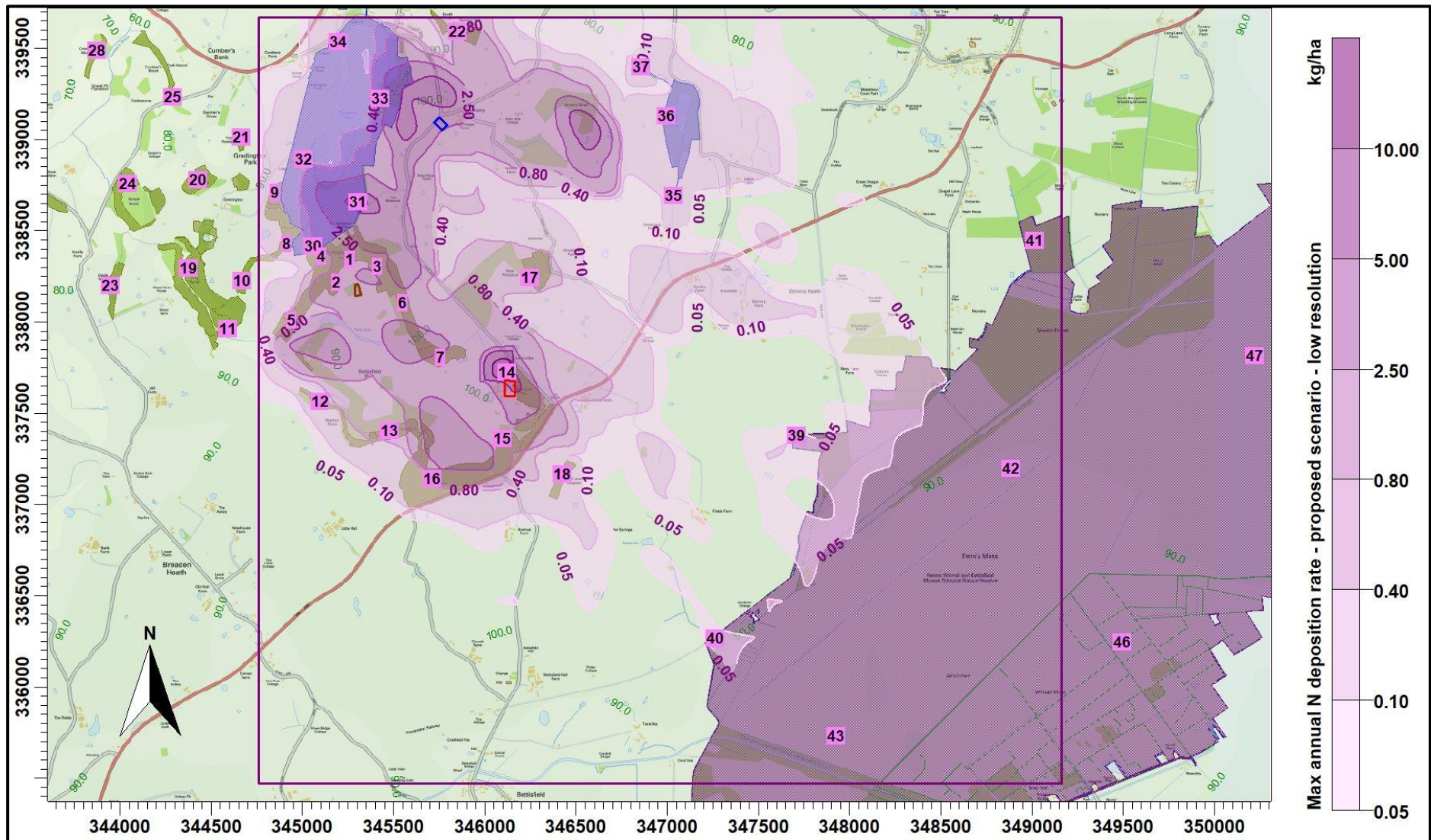
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Figure 7a. Maximum annual mean ammonia concentration – proposed scenario at low resolution



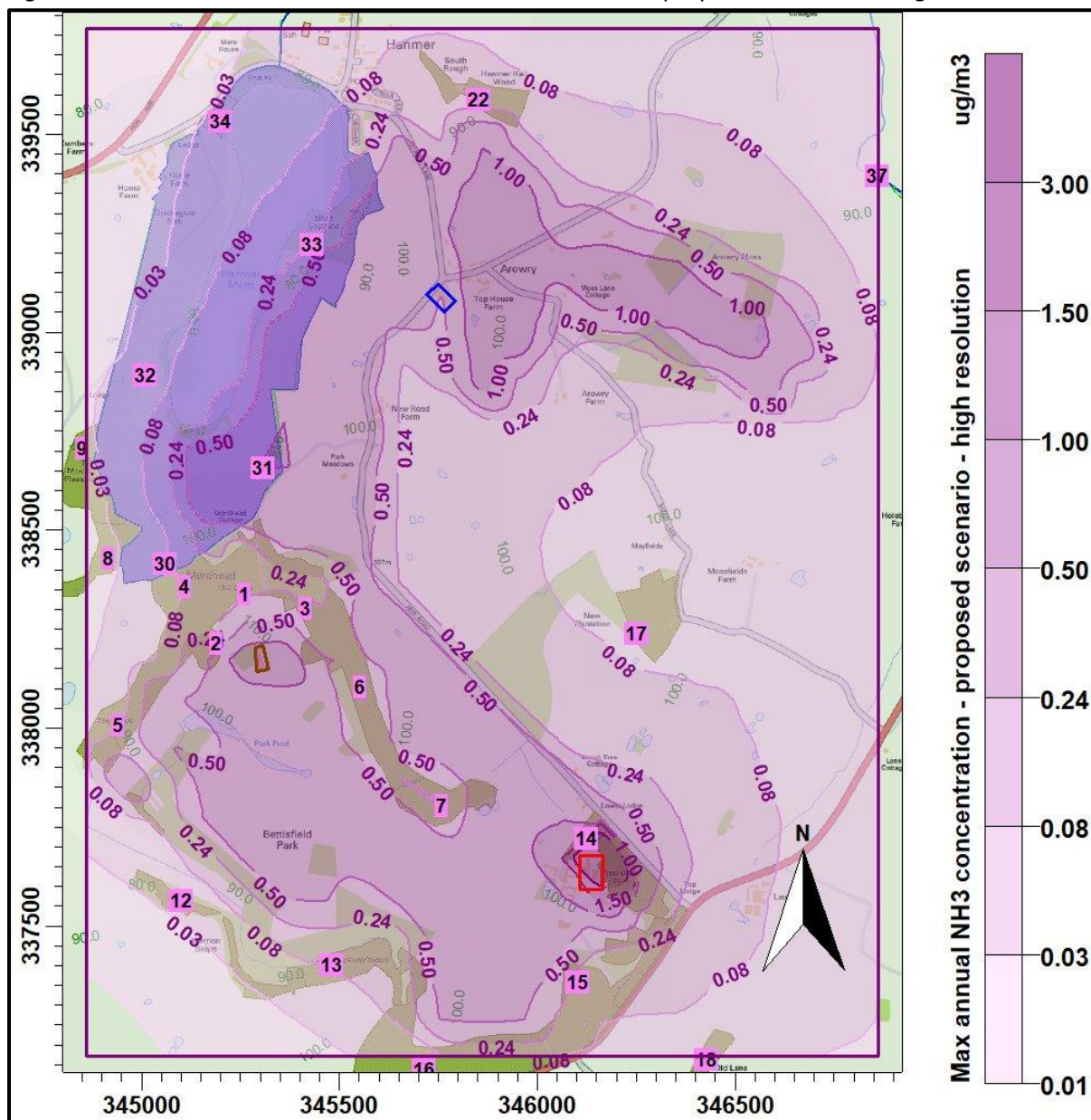
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Figure 7b. Maximum annual nitrogen deposition – proposed scenario at low resolution



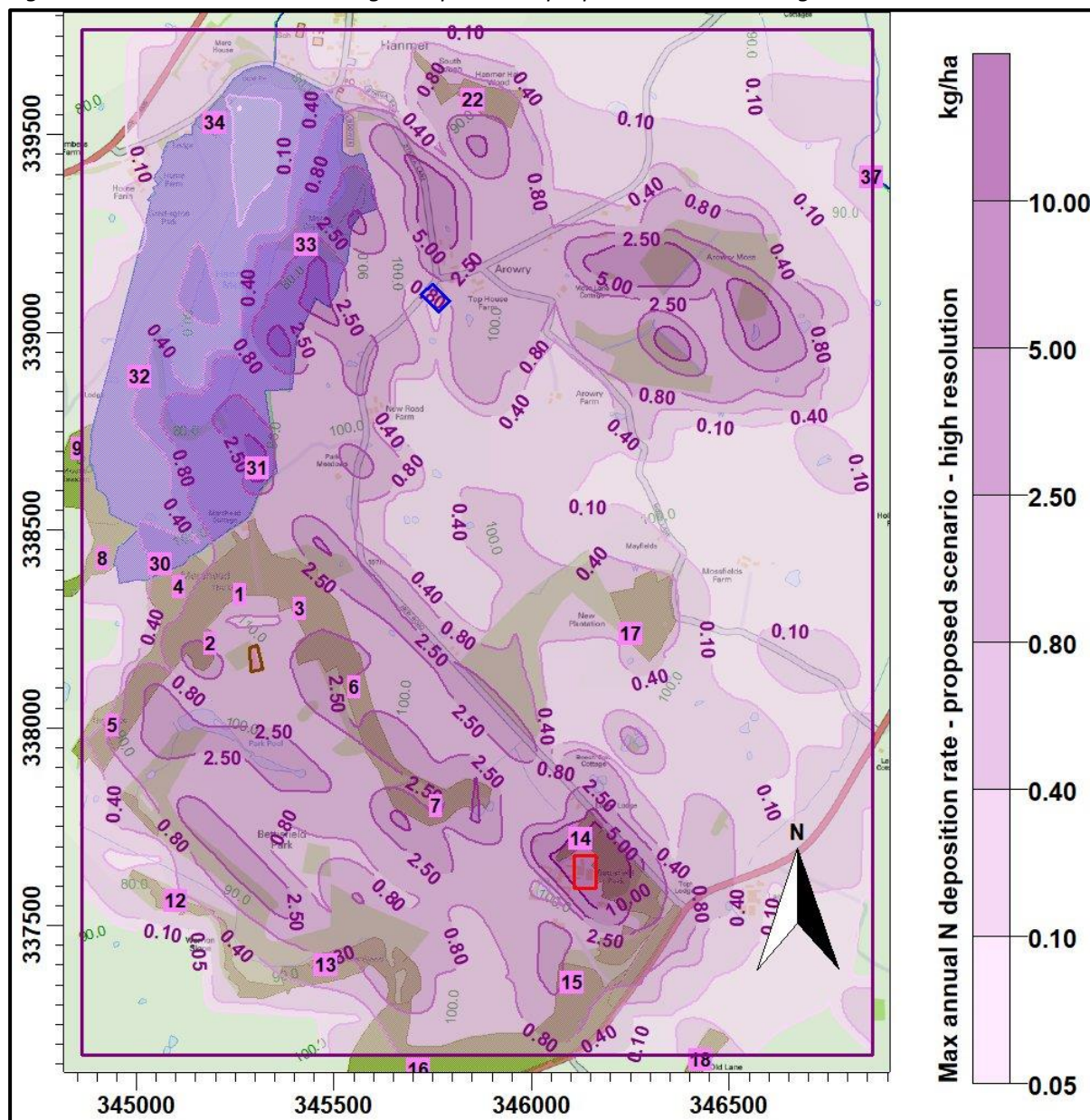
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Figure 7c. Maximum annual mean ammonia concentration – proposed scenario at high resolution



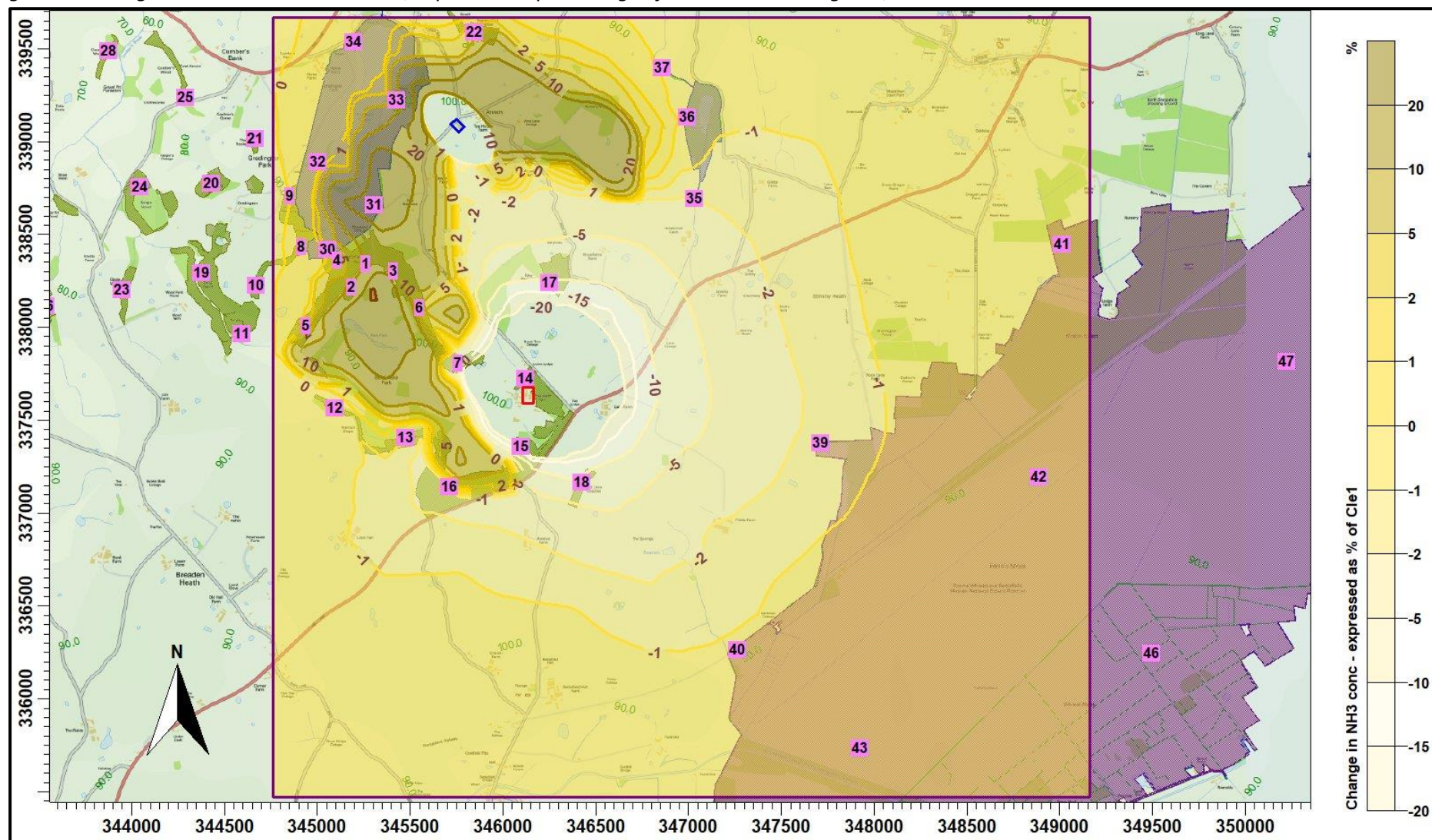
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Figure 7d. Maximum annual nitrogen deposition - proposed scenario at high resolution



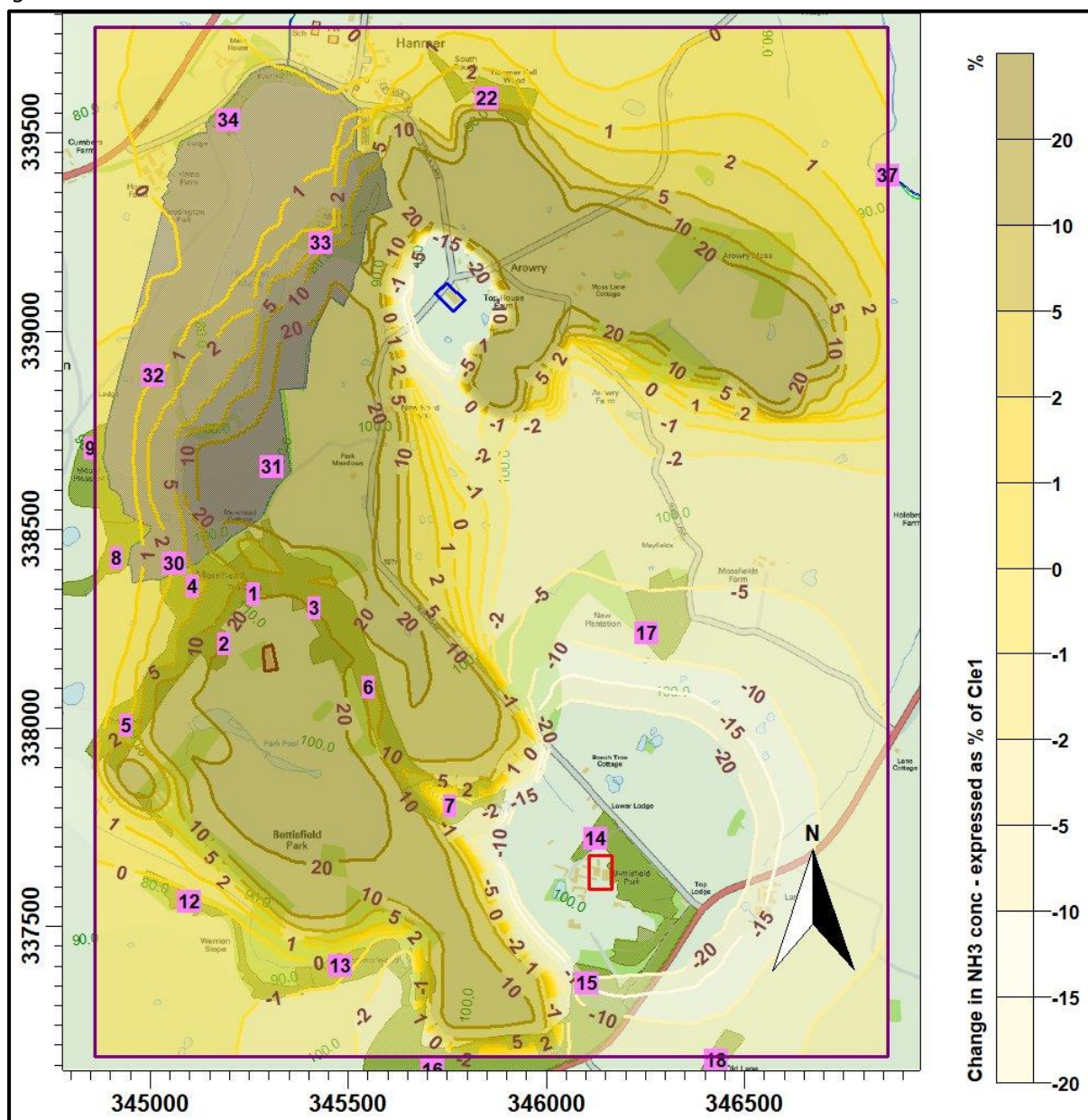
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Figure 8a. Change in ammonia concentration, expressed as percentage of Critical level $1.0 \mu\text{g-NH}_3/\text{m}^3$ - Low Resolution



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Figure 8b. Change in ammonia concentration, expressed as percentage of Critical level $1.0 \mu\text{g-NH}_3/\text{m}^3$ -
High Resolution



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6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Will Phillips of P&L AgriConsulting, on behalf of Mr T Hanmer, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed operations at Top House Farm and Home Farm, near Arowry in Wrexham. Jointly the farms are referred to as Merehead, the area where a new milking parlour would be constructed.

Ammonia emission rates from the existing and proposed operations at the farms have been assessed and quantified based upon: Environment Agency standard emission factors; emission figures obtained from the UK Ammonia emissions (UKAIE) and Ammonia emission factors for UK agriculture (Misselbrook *et al*). 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.

Existing Scenario

Detailed modelling shows that:

- Over the closest parts of an area of Ancient Woodland directly north of the farm buildings at Home Farm (Receptor 14), the predicted process contributions to the annual mean ammonia concentrations and nitrogen deposition rates are currently exceeding the Natural Resources Wales upper threshold percentage (100% of the precautionary Critical Level of $1.0 \text{ ug-NH}_3/\text{m}^3$ for a non-statutory site).
- The modelling predicts that at Hanmer Mere SSSI, which is also designated as Midland Meres & Mosses Phase 2 Ramsar Site, the process contributions to the annual mean ammonia concentrations and nitrogen deposition rates exceed the Natural Resources Wales lower and upper threshold percentages (1% and 8% for a statutory site) of the Critical Level of $3.0 \text{ ug-NH}_3/\text{m}^3$.
- At Lyn Bedydd SSSI, which is also designated as Midland Meres & Mosses Phase 2 Ramsar Site, the annual mean ammonia concentrations and nitrogen deposition rates are predicted to currently be in the range of the Natural Resources Wales lower and upper threshold percentages (1% to 8% for a statutory site) of the Critical Level of $1.0 \text{ ug-NH}_3/\text{m}^3$ and the Critical Load of 5.0 kg/ha/y .
- There are predicted exceedances of the Natural Resources Wales lower threshold percentage (1% for a statutory site) of the Critical Level of $1.0 \text{ ug-NH}_3/\text{m}^3$ and the Critical Load of 5.0 kg/ha/y at closer parts of the Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI, which is also designated as a SAC and Midland Meres & Mosses Phase 2 Ramsar site.

Proposed Scenario

The detailed modelling predicts that:

- Although process contributions to the annual mean ammonia concentrations would exceed the Natural Resources Wales upper threshold percentage (100% of precautionary Critical Level of 1.0 ug-NH₃/m³ for a non-statutory site) at the area of Ancient Woodland directly north of the farm buildings at Home Farm, they are significantly reduced in the proposed scenario.
- At Hanmer Mere SSSI, which is designated as Midland Meres & Mosses Phase 2 Ramsar Site, there continues to be predicted exceedances of the Natural Resources Wales lower and upper threshold percentages (1% and 8% for a statutory site) of the Critical Level of 3.0 ug-NH₃/m³ and Critical Load of 10.0 kg/ha/y. The magnitudes of these exceedances are increased slightly in the proposed scenario.
- The exceedance of the Natural Resources Wales lower threshold percentage (1% for a statutory site) of the Critical Level of 1.0 ug-NH₃/m³ and Critical Load of 5.0 kg/ha/y at Lyn Bedydd SSSI, which is also designated as Midland Meres & Mosses Phase 2 Ramsar Site, is increased by a small margin in the proposed scenario.
- The magnitude and extent of the predicted exceedances of the Natural Resources Wales lower threshold percentage (1% for a statutory site) of the Critical Level of 1.0 ug-NH₃/m³ and Critical Load of 5.0 kg/ha/y at closer parts of Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SSSI, which is also designated as a SAC and Midland Meres & Mosses Phase 2 Ramsar site are reduced in the proposed scenario.
- There are no predicted exceedances of the Natural Resources Wales lower threshold percentage of 1% of the Critical Level of 1.0 ug-NH₃/m³ at Cole Mere SSSI, which is also designated as Midland Meres & Mosses Phase 2 Ramsar Site or Clarepool SSSI, which is also designated as West Midlands Mosses SAC and Midland Meres & Mosses Phase 1 Ramsar Site, in the proposed scenario.

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