A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Pig Rearing Houses at Wheaton Aston Farm Pig Unit, Little Onn, near Church Eaton in Staffordshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Harry Edwards of The Farm Consultancy Group, on behalf of Belmont Farms Ltd., to use computer modelling to assess the impact of ammonia emissions from the pig rearing houses at the Wheaton Aston Farm Pig Unit, Little Onn, Church Eaton, Stafford, Staffordshire, ST20 0AU.

Ammonia emission rates from the piggery have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors and figures obtained from the UK Ammonia Emissions Inventory (UKAIE). 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

The piggery at Wheaton Aston Farm is sited on a former RAF base in a rural area south of the hamlet Little Onn and approximately 2.4 km to the south of the village of Church Eaton in Staffordshire. The surrounding land is used primarily for arable/pastoral farming and there are some semi-natural woodlands lining the Shropshire Union Canal to the east of the site. The site is at an elevation of around 110 m, with the land rising gently towards higher ground to the north-west and falling slightly towards the south-east.

Historically Wheaton Aston Farm has been used to accommodate dry and farrowing sows, rearing piglets, served gilts and production pigs. The pigs have been housed across twenty-four naturally ventilated buildings with either solid straw or fully slatted floors.

It is proposed that some of the existing pig rearing houses at Wheaton Aston Farm be used to accommodate dry and farrowing sows, growers and maiden gilts. The pigs would be housed across nine buildings with varying flooring and ventilation types. One of the houses, which would be used to accommodate dry sows, would be naturally ventilated and have a solid floor with straw. The remaining eight houses would be ventilated by either high velocity roof fans or wall fans and have a fully slatted floor (FSF) with 800 mm slurry depth. Frequent slurry removal (FSR) from the buildings with fully slatted floors would be stored in two slurry tanks with solid covers, a slurry lagoon with floating cover and a slurry lagoon with low-tech cover on site.

Breakdowns of pig weights and numbers, housing types and ventilation details and manure storage details for the baseline and proposed scenarios are provided in Section 3 of this report.

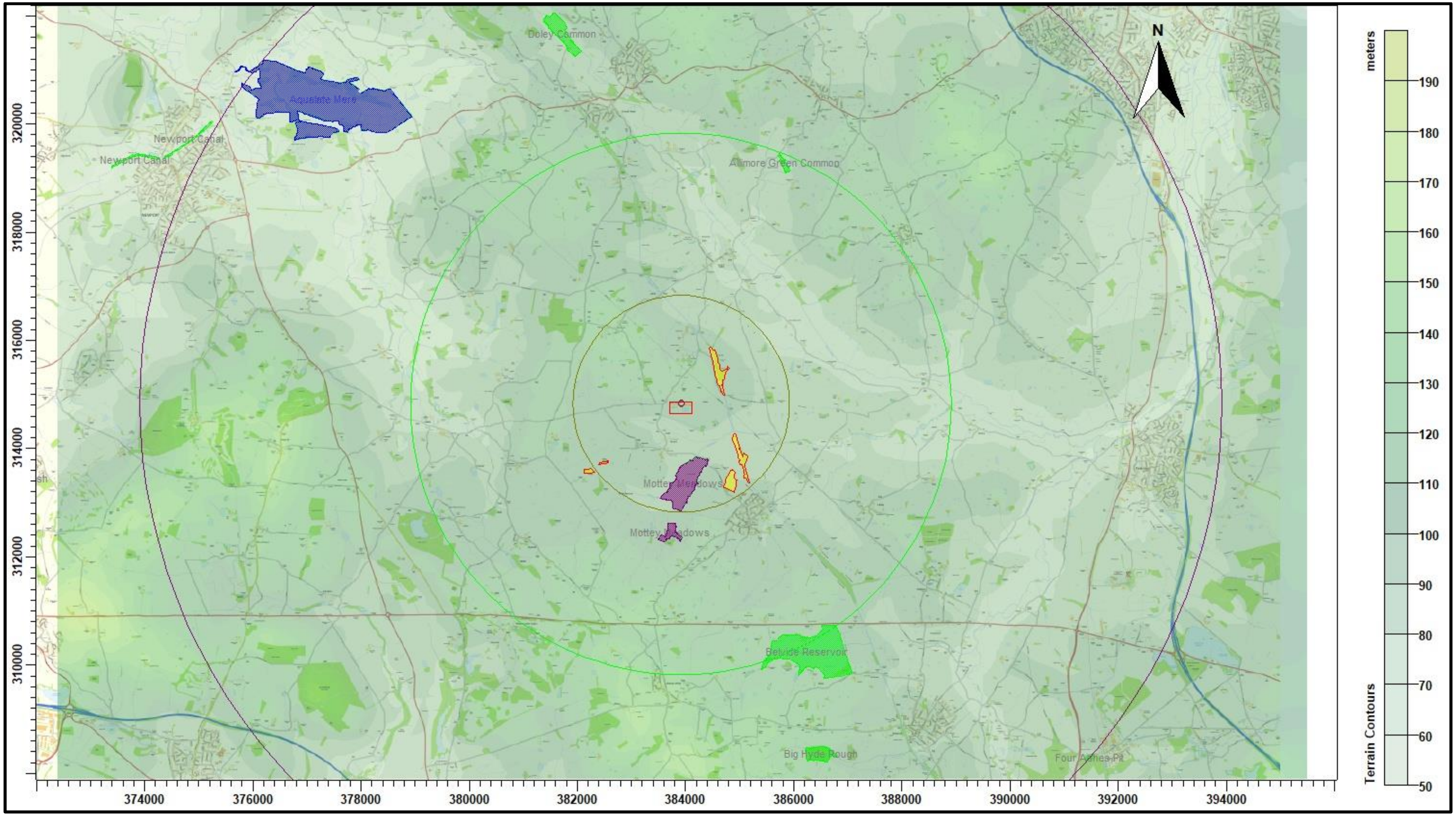
There are several areas designated as Local Wildlife Sites (LWSs) within 2 km of Wheaton Aston Farm (which is the normal screening distance for non-statutory sites). There are also eight Sites of Special Scientific Interest (SSSIs) within 10 km (the normal screening distance for a statutory site), one of which shares an international designation as a Special Area of Conservation (SAC) and another with a Ramsar site. Further details of the statutory sites are provided below:

- **Mottey Meadows SSSI/SAC** - Approximately 900 m to the south. Grassland with hedgerows, hedgerow trees, watercourses and ditches. The site is noted for breeding wading birds and beetles.
- **Belvide Reservoir SSSI** - Approximately 4.5 km to the south-south-east. Ornithological designation.
- **Big Hyde Rough SSSI** - Approximately 6.5 km to the south-south-east. An ancient woodland with stream and an area of ungrazed marshy grassland, succeeding to the woodland.
- **Four Ashes Pit SSSI** - Approximately 9.8 km to the south-east. Geological.
- **Allimore Green Common SSSI** - Approximately 4.7 km to the north-north-east. A small but species rich unimproved lowland grassland. There is an outstanding flora with many uncommon and rare plants and notable microlepidoptera.
- **Doley Common SSSI** - Approximately 6.5 km to the north-north-west. A low lying, agriculturally unimproved pasture, especially noted for a rare acidic marshy grassland community. There are also peripheral watercourses and flooded ditches providing habitats for water plants and breeding amphibia and there are Lepidoptera and wintering and breeding birds.
- **Aqualate Mere SSSI/Ramsar** - Approximately 7.1 km to the north-west. The largest of the Meres & Mosses of the north west Midlands with an extensive reedswamp community. It has open water, fen, grassland and woodland.

- **Newport Canal SSSI** - Approximately 9.8 km to the north-west. Submerged and broad-leaved plant communities, marginal swamp and fen.

A map of the surrounding area showing the positions of the pig houses and the wildlife sites are provided in Figure 1. In the figure, the LWSs are shaded in yellow, the SSSIs are shaded in green, the SAC is shaded in purple, the Ramsar site is shaded in blue and the site of the pig unit at Wheaton Aston Farm is outlined in red.

Figure 1. The area surrounding Wheaton Aston Farm – concentric circles radii 2.0 km (olive), 5.0 km (green) and 10.0 km (purple)



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 source of the background figures is the Air Pollution Information System (APIS, September 2024). It should be noted that the 1 km APIS database background levels are extrapolated from 5 km modelled data. Ammonia levels may vary markedly over relatively short distances and the APIS website itself notes that, the background values should be used only to assist the user in obtaining a broad indication of the likely pollutant impact at a specific location and cannot be considered representative of any particular location within the 5 km grid square; extrapolation to a 1 km grid does not alter this.

The background ammonia concentration (annual mean) in the area around Wheaton Aston Farm and the wildlife sites is 2.51 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 34.78 kg-N/ha/y and to short vegetation is 18.69 kg-N/ha/y. The background acid deposition rate to woodland is 2.51 keq/ha/y and to short vegetation is 1.33 keq/ha/y.

The APIS background figures are subject to correction and revision and appear to change fairly frequently, the latest figures can be obtained at https://www.apis.ac.uk/search-location.

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 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. 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. However, it may be necessary to consider nitrogen deposition should a Critical Load of 5.0 kg-N/ha/y be appropriate. 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 Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
Closest LWS	3.0 [1]	10.0 [1]	-
Other LWSs	1.0 [1]	10.0 [1]	-
Belvide Reservoir SSSI and Four Ashes Pit SSSI	n/a [3]	n/a [3]	n/a [3]
Allimore Green Common SSSI and Doley Common SSSI	3.0 [4]	15.0 [5]	-
Big Hyde Rough SSSI and Aqualate Mere SSSI/Ramsar site	1.0 [4]	10.0 [5]	-
Newport Canal SSSI	3.0 [4]	n/a [3]	-
Mottey Meadows SAC	3.0 [4 & 6]	10.0 [5 & 6]	5.071 [6]
Mottey Meadows SSSI	1.0 [4 & 7]	n/a [5 & 6]	n/a [5 & 6]

1. Site visit on 24/09/24.
2. 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. The designation for this site is geological, ornithological or aquatic and there are no assigned Critical Levels/Loads.
4. Based upon the citation for the site and information from APIS (September 2024).
5. The lower bound of the range of Critical Loads for the site/species, obtained from APIS (September 2024).
6. As stated in Environment Agency pre-application report (EPR/BP3709LB/P001 dated 08/02/2024).
7. The Environment Agency pre-application report states that the Critical Level is 1.0 µg-NH_3/m^3 however the information on APIS and in the citation for the site shows lichens and bryophytes are not integral to the habitats and a Critical Level of 3.0 µg-NH_3/m^3 is appropriate. This site has also been inspected previously and no sensitive lichens or bryophytes noted.

3.4 Guidance on the significance of ammonia emissions

3.4.1 Environment Agency Criteria

The Environment Agency web-page titled "Intensive farming risk assessment for your environmental permit", contains a set of criteria, with thresholds defined by percentages of the Critical Level or Critical Load, for: internationally designated wildlife sites (Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Ramsar sites); Sites of Special Scientific Interest (SSSIs) and other non-statutory wildlife sites. The lower and upper thresholds are: 4% and 20% for SACs, SPAs and Ramsar sites; 20% and 50% for SSSIs and 100% and 100% for non-statutory wildlife sites.

If the predicted process contributions to Critical Level or Critical Load are below the lower threshold percentage, the impact is usually deemed acceptable.

If the predicted process contributions to Critical Level or Critical Load are in the range between the lower and upper thresholds; 4% to 20% for SACs, SPAs and Ramsar sites; 20% to 50% for SSSIs and 100% to 100% for other non-statutory wildlife sites, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. In making their decision, the Environment Agency will consider whether other farming installations might act in-combination with the farm and the sensitivities of the wildlife sites. 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%).

3.4.2 Natural England advisory criteria

Natural England are a statutory consultee at planning and usually advise that, if predicted process contributions exceed 1% (or lower in some circumstances) of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming installations[1] might act in-combination or cumulatively with the farm and the sensitivities of the wildlife sites.

1. The process contribution from most farming installations is already included in the background ammonia concentrations and nitrogen and acid deposition rates. Therefore, it is normally only necessary to consider new installations and installations with extant planning permission and proposed developments when understanding the additional impact of a proposal upon nearby ecologies. However, established farms in close proximity may need to be considered given the background concentrations are derived from an average for a 5 km by 5 km grid.

3.4.3 Environment Agency and Natural England May 2022 Air Quality Risk Assessment Interim Guidance

Although it seems important to include a reference to this document, it appears to be primarily a discussion document about internal Environment Agency screening models and the SCAIL model and AS Modelling & Data Ltd. have been unable to draw any conclusions from the document as to what thresholds may or may not apply, nor in what circumstances the threshold may or may not apply.

3.4.4 Joint Nature Conservancy Committee - Guidance on Decision-making Thresholds for Air Pollution

In December 2021, the Joint Nature Conservancy Committee (JNCC) published a report titled, "Guidance on Decision-making Thresholds for Air Pollution". This report provides decision-making criteria to inform the assessment of air quality impacts on designated conservation sites. The criteria are intended to be applied to individual sources to identify those for which a decision can be taken without the need for further assessment effort. The Decision-making thresholds (DMT) for on-site emission sources provided in the JNCC report are reproduced below:

- For lichens and bryophytes - 0.08%, 0.20%, 0.34% and 0.75% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For higher plants - 0.08%, 0.20%, 0.34% and 0.75% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For nitrogen deposition to woodland (Critical Load 10 kg-N/ha/y) - 0.13%, 0.34%, 0.57% and 1.30% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For nitrogen deposition to grassland (Critical Load 10 kg-N/ha/y) 0.09%, 0.24%, 0.40% and 0.88% of the Critical Level for high, medium, low and very low development density areas, respectively.

Note that 'development density' is defined as, the assumed number of additional new sources below the DMT within 5 km of the proposed development over 13 years: very low density being 1 development; low 5 developments; medium 10 developments and high 30 developments.

Subject to some exceptions, where the process contribution from an on-site source is below the DMT, no further assessment is required. Where the process contribution exceeds the DMT there are two possible outcomes:

- Where site-relevant thresholds have been derived these can be applied to see if it is possible to avoid further assessment effort on the basis of site specific circumstances.
- If site-relevant thresholds have not yet been derived, further assessment in combination with other plans and projects is required.

3.6 Quantification of ammonia emissions

Ammonia emission rates from piggeries 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.

The Environment Agency provides an Intensive Farming Guidance note which lists standard ammonia emission factors for a variety of livestock, including for pigs and manure storage. The emission factors for the pigs and manure storage at Wheaton Aston Farm are based on Environment Agency figures and figures obtained from the UK Ammonia Emissions Inventory (UKAIE). Emission factors for gilts and growers in the proposed scenario are reduced by 20% for lower protein diet use.

Details of the pig numbers and types, manure storage, emission factors used and calculated ammonia emission rates in the baseline and proposed scenarios are provided in Tables 2a and 2b.

Table 2a. Details of pig numbers, manure storage and ammonia emission rates – baseline scenario

ADMS ID	Pig type/weight (kg)	Housing type	Ventilation type	Animal numbers	Emission factor (kg-NH_3/animal-place/y)	Ammonia emission rate (g-NH_3/s)
B1-B4	Farrowing sows	FSF	Natural Ventilation	160	5.84	0.029609
B5-B6	Service House	FSF	Natural Ventilation	80	3.01	0.007630
B7-B11	Dry sows	FSF	Natural Ventilation	200	3.01	0.019076
B12	Dry sows	Straw	Natural Ventilation	40	4.57	0.005793
B13-B17	Rearing piglets	FSF	Natural Ventilation	4,200	1.59	0.211613
B21-B25	Served Gilts/Dry Sows	Straw	Natural Ventilation	170	4.57	0.024618
A&B	Production pigs	FSF	Natural Ventilation	3,600	4.14	0.472279
ADMS ID	**Type**	**Cover**		**Area (m^2)**	**Emission factor (kg-NH_3/m^2/y)**	**Ammonia emission rate (g-NH_3/s)**
LAG1	Slurry lagoon	Floating cover		3,250	0.56	0.057672
LAG2	Slurry lagoon	Floating cover		2,600	0.56	0.046138

Table 2b. Details of pig numbers, manure storage and ammonia emission rates – proposed scenario

ADMS ID	Pig type/weight (kg)	Housing type	Ventilation type	Animal numbers	Emission factor (kg-NH_3/animal-place/y)	Ammonia emission rate (g-NH_3/s)
B1	Farrowing sows	FSF with FSR	Wall Fans	420	5.84	0.077725
B2	Dry sows	FSF with FSR	High Speed	656	2.26	0.046979
B3	Dry sows	FSF with FSR	Wall Fans	1020	2.26	0.073047
B4	Dry sows	Straw	Natural	200	4.57	0.028963
B5	Gilts	FSF with FSR	High Speed	300	2.488[1]	0.023652
B6	Gilts	FSF with FSR	High Speed	300	2.488[1]	0.023652
B7	Gilts	FSF with FSR	High Speed	300	2.488[1]	0.023652
B8	Gilts	FSF with FSR	High Speed	300	2.488[1]	0.023652
B9	Growers (15-30)	FSF with FSR	High Speed	500	0.512[2]	0.008112
ADMS ID	Type	Cover		Area (m^2)	Emission factor (kg-NH_3/m^2/y)	Ammonia emission rate (g-NH_3/s)
TANK1	Slurry tank - dome	Solid cover		1017.9	0.28	0.009031
TANK2	Slurry tank - dome	Solid cover		1017.9	0.28	0.009031
LAG1	Slurry lagoon	Floating LECA balls		2794.5	0.84	0.074384
LAG2	Slurry lagoon	Low-tech cover		1386.7	0.68	0.029882

1. Emission factors for gilts are reduced by 20% from 3.11 kg-NH_3/animal-place/y for lower protein diet use post-processing.
2. Emission factors for growers (15-30 kg) are reduced by 20% from 0.64 kg-NH_3/animal-place/y for lower protein diet use post-processing.

4. The Atmospheric Dispersion Modelling System (ADMS) and Model Parameters

The Atmospheric Dispersion Modelling System (ADMS) ADMS 6 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters; the boundary layer depth and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class.

Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetrical Gaussian expression).

ADMS has a number of model options including: dry and wet deposition; NO_x chemistry; impacts of hills; variable roughness; buildings and coastlines; puffs; fluctuations; odours; radioactivity decay (and γ-ray dose); condensed plume visibility; time varying sources and inclusion of background concentrations.

ADMS has an in-built meteorological pre-processor that allows flexible input of meteorological data both standard and more specialist. Hourly sequential and statistical data can be processed and all input and output meteorological variables are written to a file after processing.

The user defines the pollutant, the averaging time (which may be an annual average or a shorter period), which percentiles and exceedance values to calculate, whether a rolling average is required or not and the output units. The output options are designed to be flexible to cater for the variety of air quality limits which can vary from country to country and are subject to revision.

4.1 Meteorological data

Computer modelling of dispersion requires hourly sequential meteorological data and to provide robust statistics the record should be of a suitable length; preferably four years or longer.

The meteorological data used in this study is obtained from assimilation and short term forecast fields of the Numerical Weather Prediction (NWP) system known as the Global Forecast System (GFS)[1].

Prior to April 2019 the GFS was a spectral model, post April 2019 the physics are discrete. The physics/dynamics model has a resolution or had an equivalent resolution of approximately 7 km over the UK; terrain is understood to be resolved at a resolution of approximately 2 km, with sub-7 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[2]). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional records may be overrepresented 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 and wind directions are modified during the modelling by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling. The terrain and roughness length modified wind rose for the location of the farm is shown in Figure 2b; it should be noted that elsewhere in the modelling domain the modified wind roses may differ more markedly, reflecting the local flow in that part of the domain. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 360 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. GFS derived data, for 53.731 N, 2.239 W, 2020 – 2023

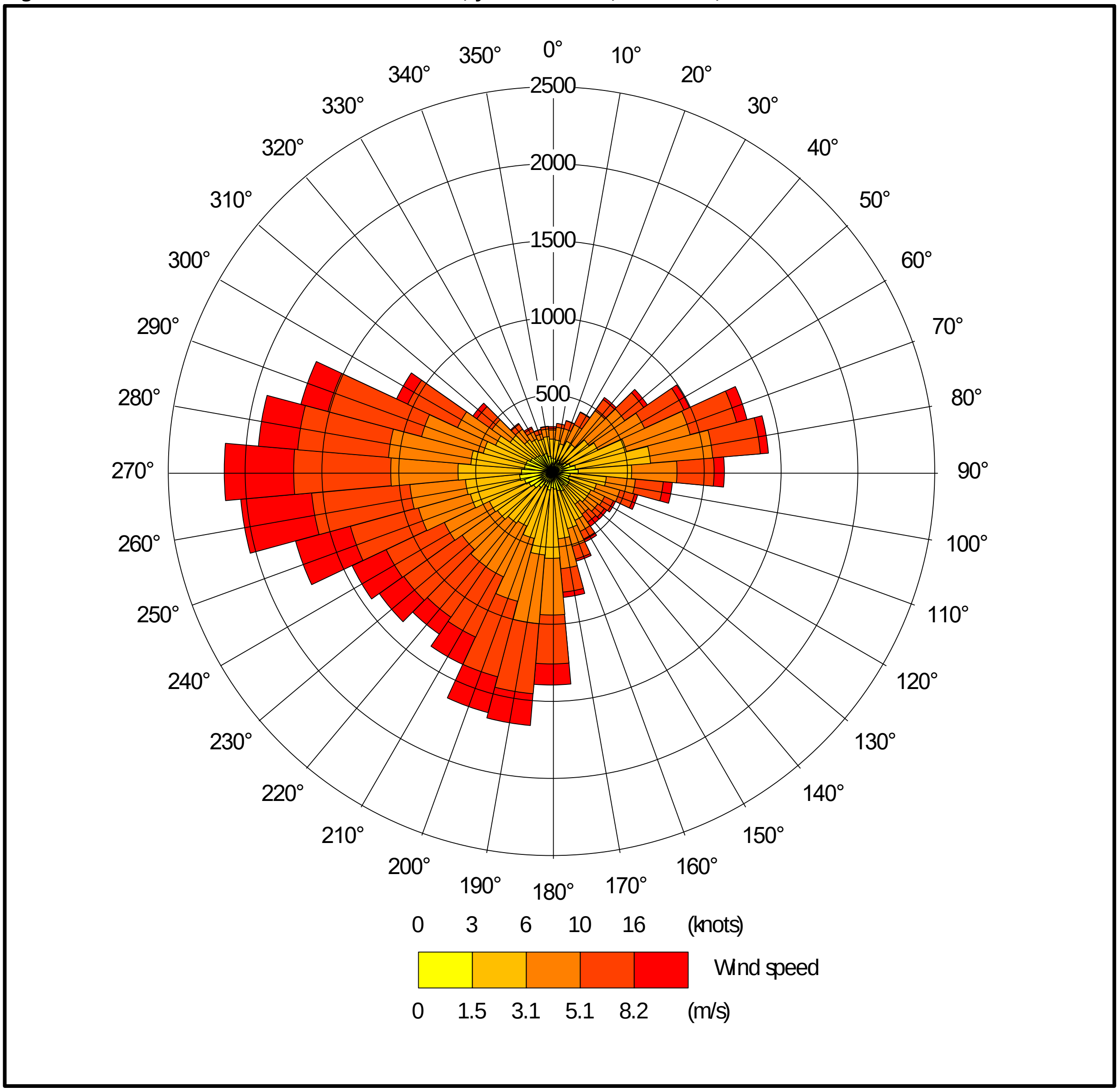
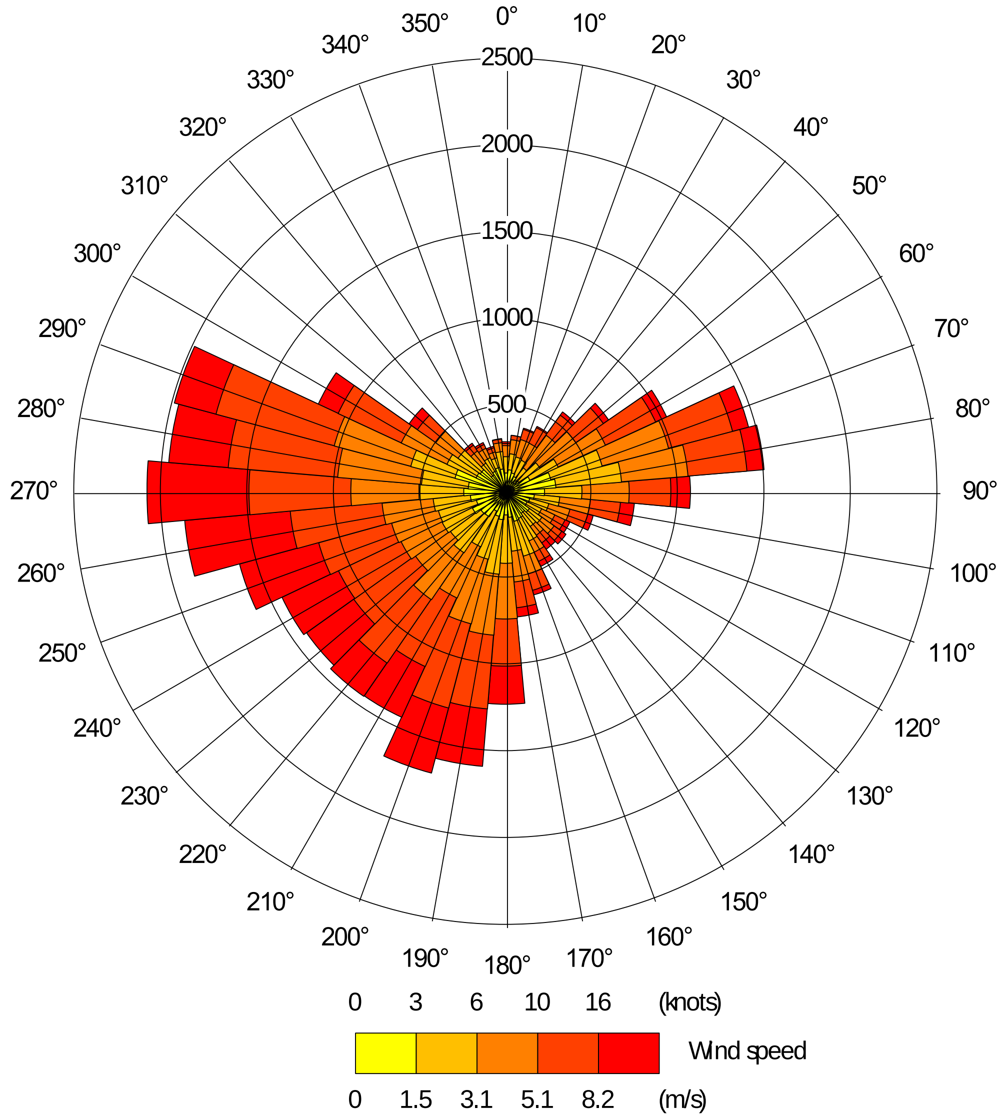


Figure 2b. The wind rose derived from FLOWSTAR output for NGR 383900, 314800



4.2 Emission sources

Fugitive emissions from the naturally ventilated buildings, emissions from the buildings with wall fans and from the slurry storage are represented by volume sources within ADMS. Details of the volume source parameters for the baseline and proposed scenarios are given in Tables 3a and 3b, respectively.

Table 3b. Volume source parameters – baseline scenario

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (˚C)	Emission rate (g-NH_3/s)
B1-B4	33.0	10.0	3	1	Ambient	0.029609
B5-B6	33.0	10.0	3	1	Ambient	0.007630
B7-B11	33.0	10.0	3	1	Ambient	0.019076
B12	26.0	18.0	3	1	Ambient	0.005793
B13-B17	7.0	29.0	3	1	Ambient	0.211613
B21-B22	10.0	27.0	3	1	Ambient	0.009847
B23-B24	20.0	21.0	3	1	Ambient	0.009847
B25	21.0	22.0	3	1	Ambient	0.004924
A&B	144.0	20.0	3	1	Ambient	0.472279
LAG1	69.0	40.5	1	0	Ambient	0.057672
LAG2	64.5	21.5	1	0	Ambient	0.046138

Table 3b. Volume source parameters – proposed scenario

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (˚C)	Emission rate (g-NH_3/s)
B1	144	20	3	1	Ambient	0.077725
B3	144	20	3	1	Ambient	0.073047
B4	26	18	3	1	Ambient	0.028963
TANK1	36	36	1	4	Ambient	0.009031
TANK2	36	36	1	4	Ambient	0.009031
LAG1	69	41	1	0	Ambient	0.074384
LAG2	64.5	21.5	1	0	Ambient	0.029882

Emissions from the high speed ridge fans that would be used to ventilate some of the proposed pig houses (B2, B5-B9) at Wheaton Aston Farm are represented by three point sources per building within ADMS. Details of the point source parameters are provided in Table 3c.

Table 3c. Point source parameters – proposed scenario

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source (g-NH_3/s)
B2	5.5	0.6	5.0	21.0	0.015660
B5	4.5	0.6	5.0	21.0	0.007884
B6	4.5	0.6	5.0	21.0	0.007884
B7	4.5	0.6	5.0	21.0	0.007884
B8	4.5	0.6	5.0	21.0	0.007884
B9	4.5	0.6	5.0	21.0	0.002704

The positions of the sources may be seen in Figures 3a and 3b (point sources – green circles and volume sources – red shaded polygon).

4.3 Modelled buildings

The structure of the farm buildings may affect the plumes from the point sources in the proposed scenario. Therefore, these buildings are modelled within ADMS. The positions of the modelled buildings in the proposed scenario may be seen in Figure 3b (marked by grey rectangles).

4.4 Discrete receptors

Twenty-six discrete receptors have been defined at the nearby wildlife sites. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b (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 spatially varying deposition velocity field, two regular Cartesian grids have been defined within ADMS. The individual grid receptors are defined at ground level within ADMS.

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 23.0 km x 23.0 domain has been resampled at 100 m horizontal resolution for use within ADMS. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 360 m.

4.7 Surface Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the Defra Living Landscapes land use database. The GFS meteorological data is assumed to have a roughness length of 0.2 m (arithmetic average of the spatially varying roughness over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 5.

Figure 3a. The positions of the modelled sources – baseline scenario

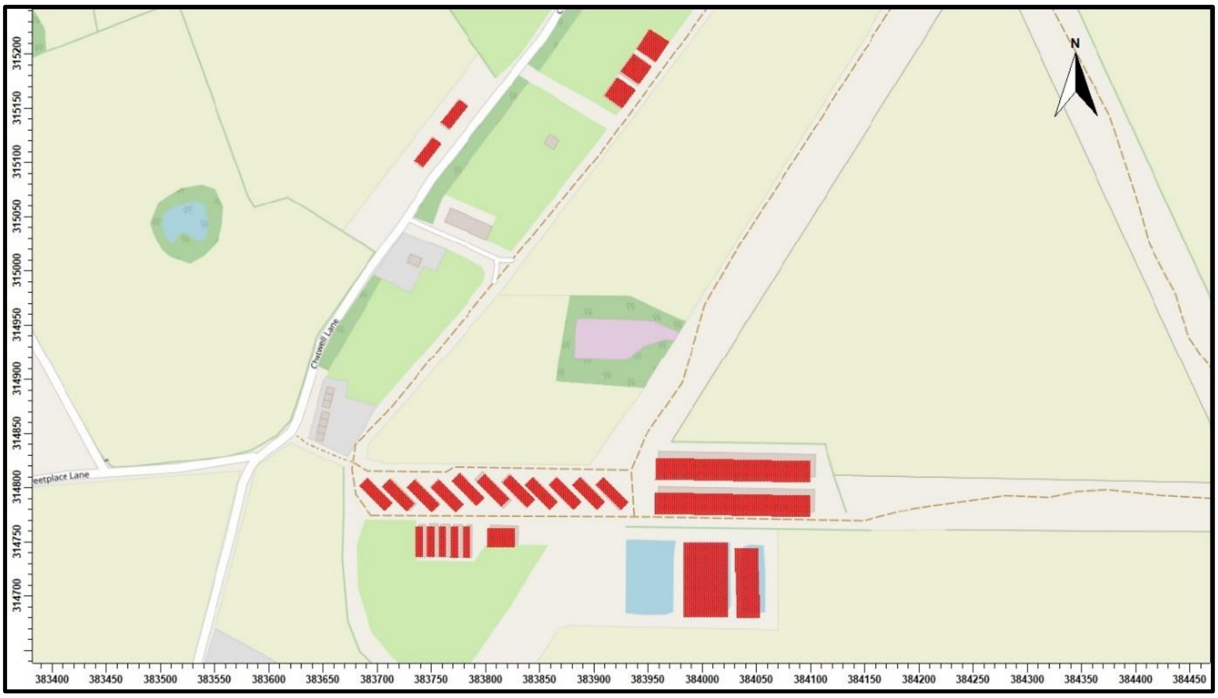


Figure 3b. The positions of the modelled buildings and sources – proposed scenario

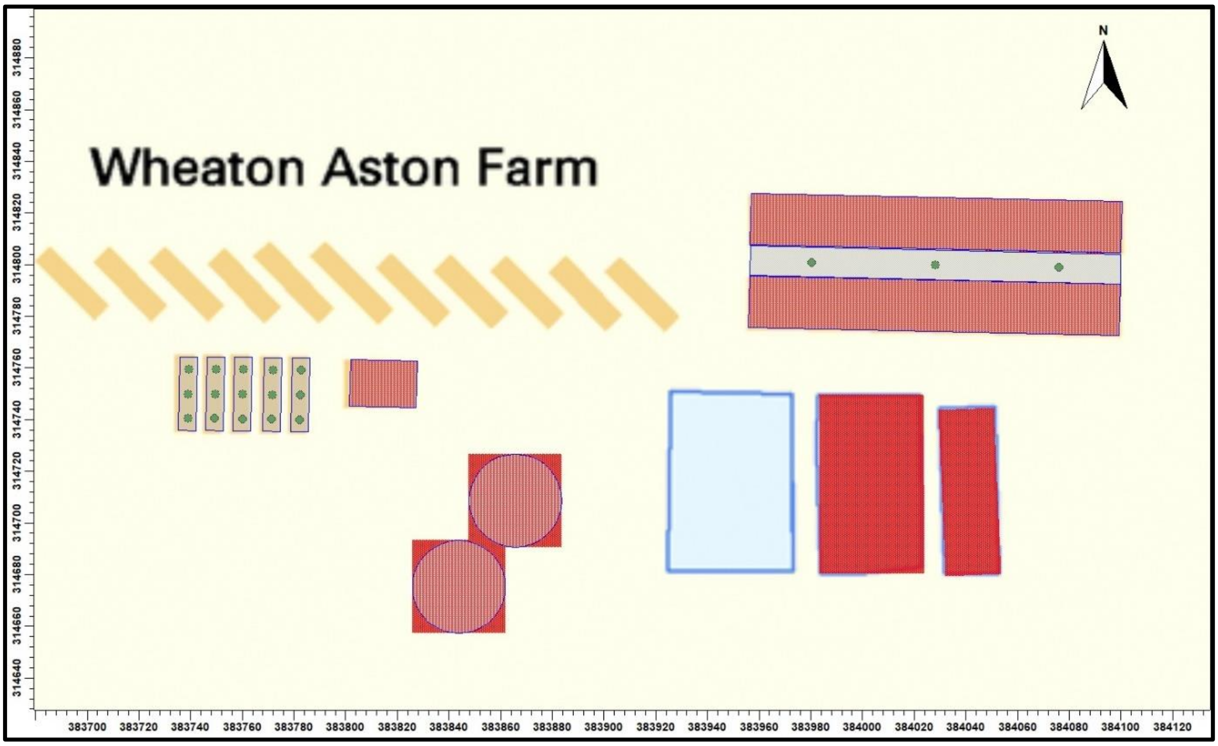


Figure 4a. The discrete receptors and Cartesian grids – a broad scale view

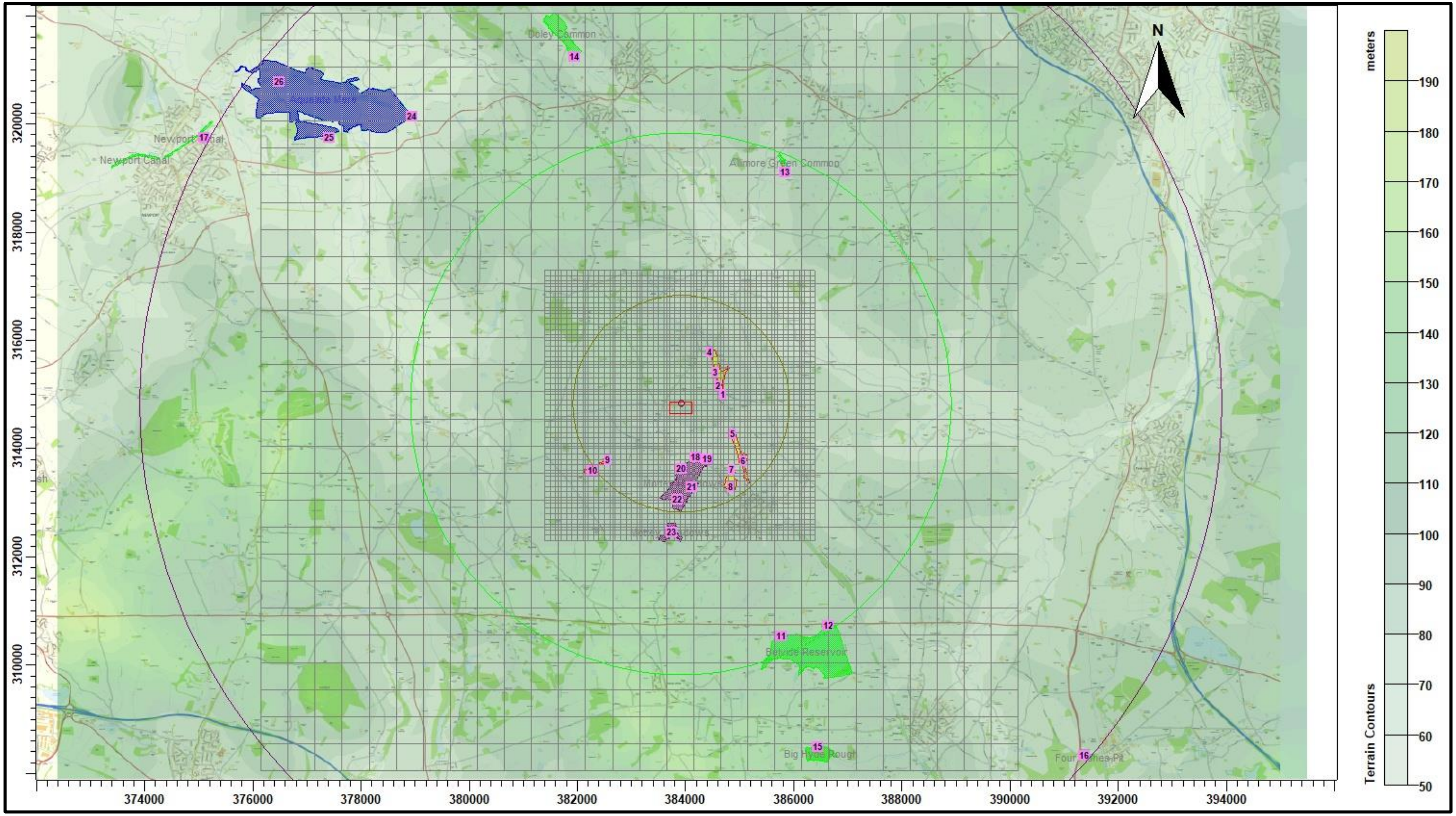


Figure 4b. The discrete receptors – a closer view

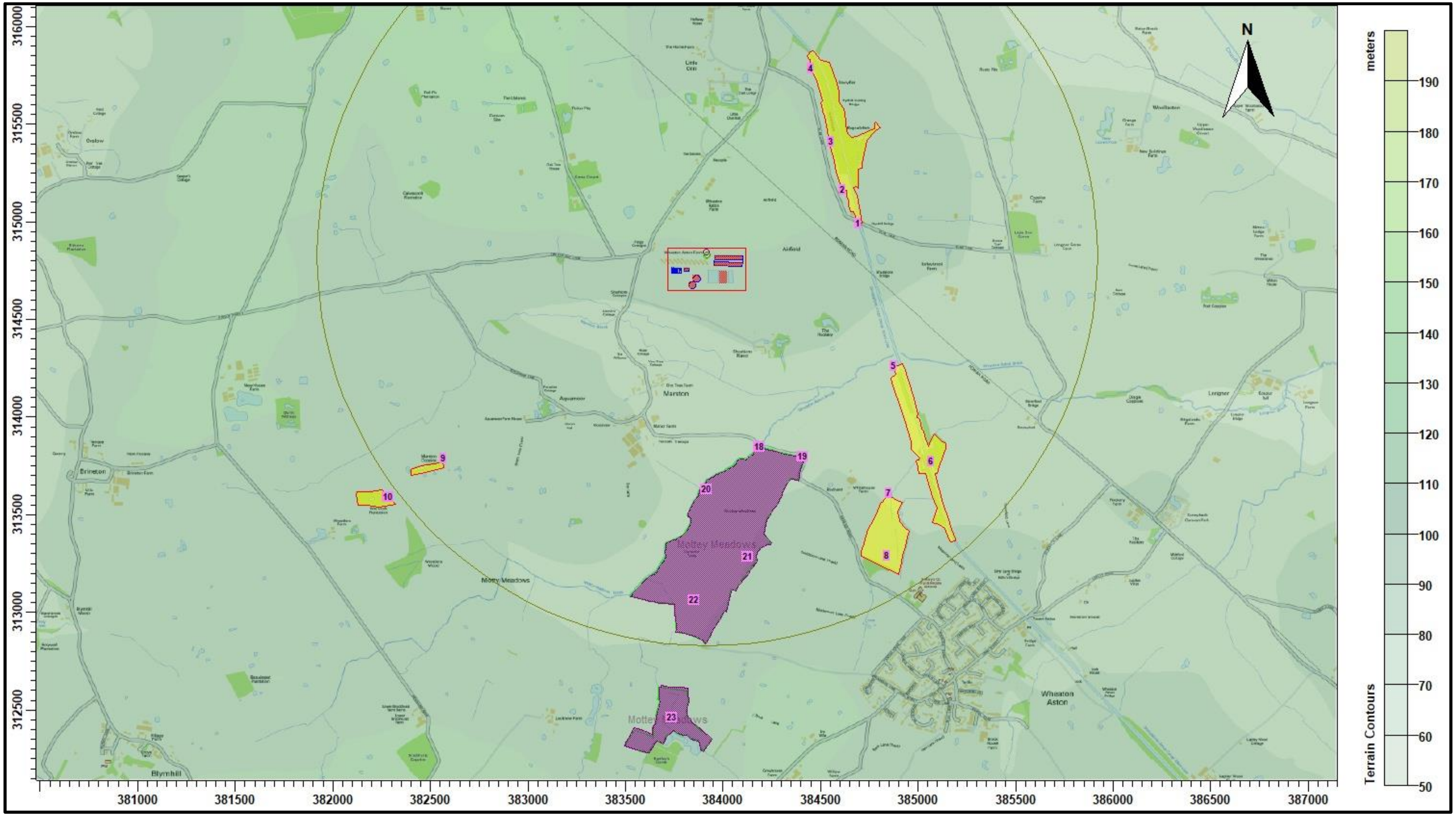


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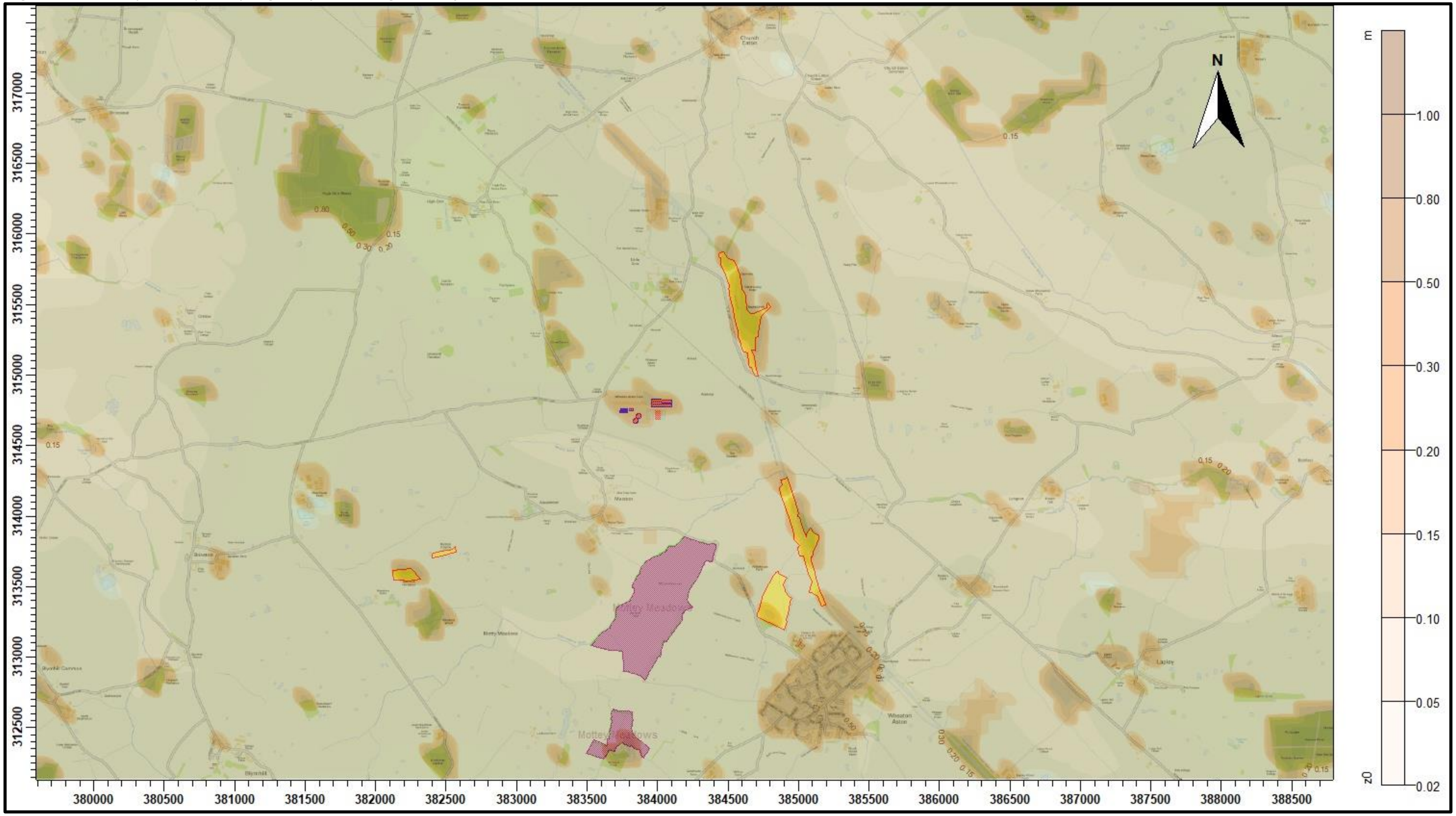
Figure 5. The spatially varying surface roughness field



4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based primarily upon Frederik Schrader and Christian Brümmer. Land Use Specific Ammonia Deposition Velocities: A Review of Recent Studies (2004-2013). 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 the livestock housing and 0.010 m/s to 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. Land use data used to derive deposition velocity is based upon the Defra Living Landscapes land use database.

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.

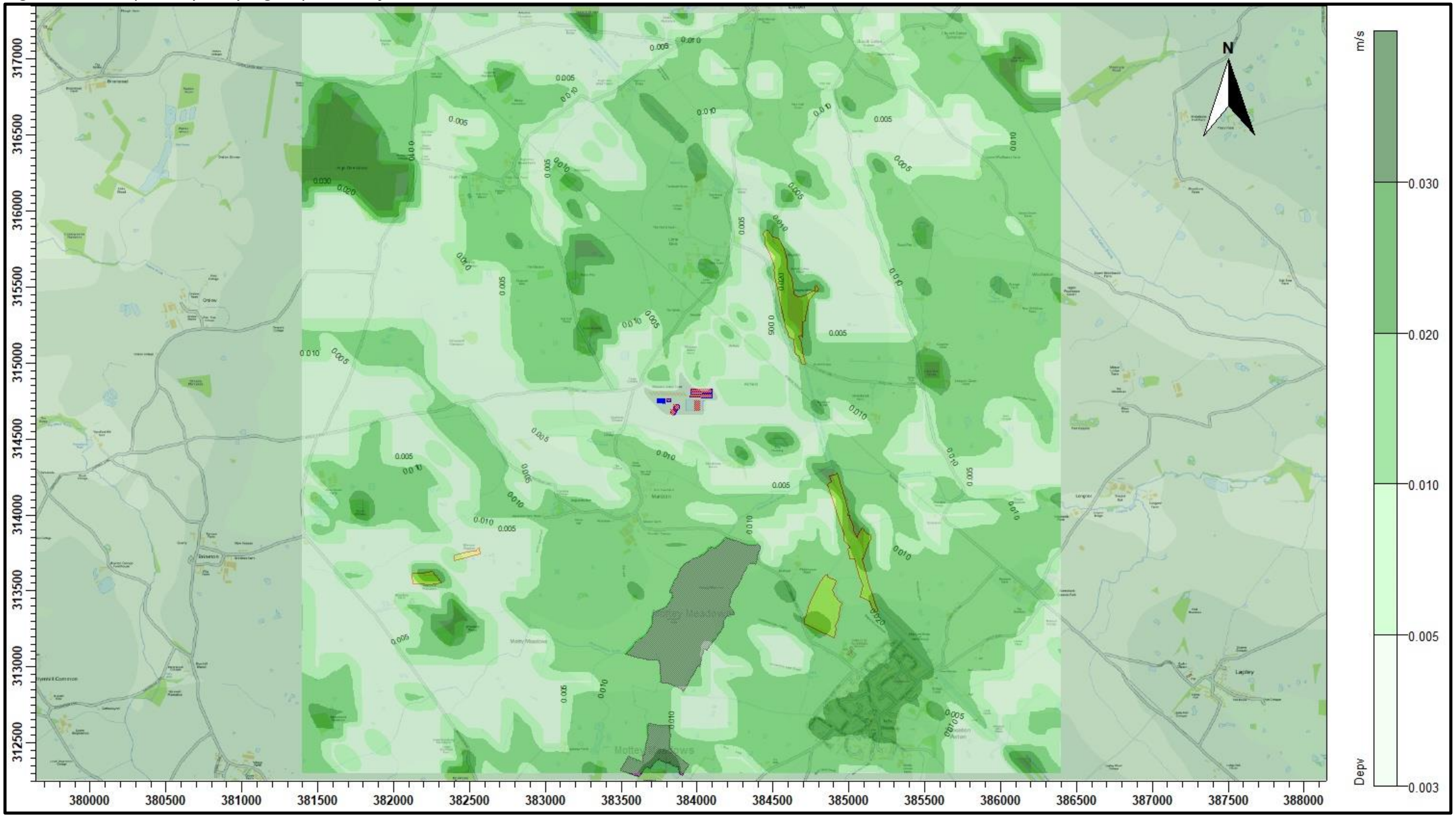
Table 4. Deposition velocities

NH_3 concentration (PC + background) ($\mu g/m^3$)	< 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 (0.010 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.

A contour plot of the spatially varying deposition field is provided in Figure 6.

Figure 6. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

ADMS was effectively run a total of eight times, once for each year of the meteorological record in the following modes:

- In basic mode without calms, or terrain – GFS data.
- With calms and without terrain – GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 5. The primary purpose of the preliminary modelling is to assess the effect of calms on the results.

For convenience, cells referring to the LWSs are shaded yellow, cells referring to the SSSIs are shaded green, cells referring to the SSSI/SAC are shaded purple and cells referring to the SSSI/Ramsar site are shaded blue.

Table 5. Predicted maximum annual mean ammonia concentrations at the discrete receptors - preliminary modelling

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)			
				Baseline Scenario		Proposed Scenario	
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms No Terrain	GFS Calms No Terrain
1	384693	314993	LWS	5.691	7.242	2.877	3.260
2	384610	315162	LWS	3.586	4.667	2.129	2.687
3	384552	315412	LWS	2.042	2.846	1.344	1.696
4	384448	315786	LWS	3.193	3.921	0.805	1.076
5	384872	314262	LWS	1.365	1.710	1.321	1.576
6	385065	313775	LWS	1.209	1.709	0.564	0.673
7	384851	313611	LWS	0.903	1.318	0.484	0.664
8	384837	313290	LWS	1.170	1.472	0.368	0.513
9	382564	313786	LWS	0.859	1.080	0.485	0.580
10	382281	313593	LWS	0.175	0.256	0.363	0.432
11	385768	310534	Belvide Reservoir SSSI	0.160	0.236	0.080	0.108
12	386649	310719	Belvide Reservoir SSSI	0.176	0.249	0.073	0.099
13	385835	319099	Allimore Green Common SSSI	0.112	0.144	0.082	0.106
14	381951	321241	Doley Common SSSI	0.093	0.137	0.052	0.063
15	386451	308480	Big Hyde Rough SSSI	0.063	0.077	0.044	0.059
16	391381	308321	Four Ashes Pit SSSI	0.057	0.078	0.030	0.035
17	375098	319739	Newport Canal SSSI	2.069	3.194	0.027	0.035
18	384188	313848	Mottey Meadows SSSI/SAC	1.926	2.847	0.808	1.203
19	384407	313796	Mottey Meadows SSSI/SAC	1.354	2.101	0.770	1.091
20	383916	313632	Mottey Meadows SSSI/SAC	0.900	1.414	0.531	0.780
21	384125	313285	Mottey Meadows SSSI/SAC	0.686	1.054	0.356	0.533
22	383851	313064	Mottey Meadows SSSI/SAC	0.415	0.632	0.280	0.402
23	383735	312460	Mottey Meadows SSSI/SAC	0.097	0.132	0.176	0.247
24	378940	320133	Aqualate Mere SSSI/Ramsar	0.086	0.115	0.045	0.057
25	377415	319741	Aqualate Mere SSSI/Ramsar	0.067	0.090	0.040	0.050
26	376482	320769	Aqualate Mere SSSI/Ramsar	0.058	0.073	0.032	0.040

5.2 Detailed deposition modelling

Detailed modelling has been carried out over a high resolution (100 m) domain that extends 5.0 km by 5.0 km around the site. The primary purpose is to determine the magnitude of deposition of ammonia and consequent plume depletion close to the sources where it is of the greatest importance. Outside of this domain, a fixed deposition velocity of 0.005 m/s is assumed (with appropriate deposition velocities applied post-modelling at the discrete receptors).

The detailed deposition run was made with terrain. Calms cannot be used with terrain or spatially varying deposition and in this case, the preliminary modelling indicates that the effects of calms are significant. Therefore, in Tables 6a and 6b, a correction based upon the preliminary modelling results is applied to results for receptors within 3 km of the site.

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Table 6a (baseline scenario) and Table 6b (proposed scenario). In the Tables, predicted ammonia concentrations and deposition rates that are in excess of the Environment Agency's upper threshold (100% of the relevant Critical Level or Load for a non-statutory site, 20% of relevant Critical Level or Load for a SSSI and 4% of relevant Critical Level or Load for an internationally designated site) are coloured red. Concentrations or deposition rates in the range between the Environment Agency's lower and upper thresholds (100% and 100% for a non-statutory site, 20% and 50% for a SSSI and 4% and 20% for an internationally designated site) are coloured blue. Additionally, process contributions which exceed 1% of the relevant Critical Level or Critical Load at a statutory site are highlighted with bold text.

The apparent changes in maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Table 7.

Contour plots of the predicted maximum annual mean ammonia concentration and the maximum annual nitrogen deposition rates for the proposed scenario are shown in Figures 7a and Figure 7b.
Contour plots of the baseline scenario are available on request.

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates – baseline scenario

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	384693	314993	LWS	0.03	3.0	10.0	4.347	**144.91**	33.869	**338.69**
2	384610	315162	LWS	0.03	3.0	10.0	3.514	**117.12**	27.374	**273.74**
3	384552	315412	LWS	0.03	3.0	10.0	2.102	70.08	16.379	**163.79**
4	384448	315786	LWS	0.03	3.0	10.0	1.238	41.25	9.642	96.42
5	384872	314262	LWS	0.03	1.0	10.0	1.601	**160.09**	12.472	**124.72**
6	385065	313775	LWS	0.03	1.0	10.0	0.454	45.42	3.539	35.39
7	384851	313611	LWS	0.03	1.0	10.0	0.387	38.66	3.012	30.12
8	384837	313290	LWS	0.03	1.0	10.0	0.254	25.45	1.982	19.82
9	382564	313786	LWS	0.03	1.0	10.0	0.547	54.71	4.262	42.62
10	382281	313593	LWS	0.03	1.0	10.0	0.352	35.19	2.742	27.42
11	385768	310534	Belvide Reservoir SSSI	0.02	n/a	n/a	0.016	-	0.081	-
12	386649	310719	Belvide Reservoir SSSI	0.02	n/a	n/a	0.013	-	0.070	-
13	385835	319099	Allimore Green Common SSSI	0.02	3.0	15.0	0.055	**1.85**	0.288	**1.92**
14	381951	321241	Doley Common SSSI	0.02	3.0	15.0	0.018	0.61	0.096	0.64
15	386451	308480	Big Hyde Rough SSSI	0.02	1.0	10.0	0.006	0.64	0.033	0.33
16	391381	308321	Four Ashes Pit SSSI	0.02	n/a	n/a	0.007	-	0.038	-
17	375098	319739	Newport Canal SSSI	0.02	3.0	n/a	0.007	0.25	0.039	-
18	384188	313848	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.922	**30.72**	4.787	**47.87**
19	384407	313796	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.797	**26.57**	4.140	**41.40**
20	383916	313632	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.562	**18.72**	2.917	**29.17**
21	384125	313285	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.306	**10.20**	1.590	**15.90**
22	383851	313064	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.234	**7.79**	1.213	**12.13**
23	383735	312460	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.117	**3.89**	0.606	**6.06**
24	378940	320133	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	0.010	0.99	0.051	0.51
25	377415	319741	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	0.009	0.93	0.048	0.48
26	376482	320769	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	0.007	0.74	0.038	0.38

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition rates – 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/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	384693	314993	LWS	0.03	3.0	10.0	1.770	58.98	13.787	**137.87**
2	384610	315162	LWS	0.03	3.0	10.0	1.441	48.04	11.229	**112.29**
3	384552	315412	LWS	0.03	3.0	10.0	0.897	29.91	6.991	69.91
4	384448	315786	LWS	0.03	3.0	10.0	0.585	19.51	4.560	45.60
5	384872	314262	LWS	0.03	1.0	10.0	0.748	74.78	5.826	58.26
6	385065	313775	LWS	0.03	1.0	10.0	0.216	21.64	1.686	16.86
7	384851	313611	LWS	0.03	1.0	10.0	0.169	16.91	1.318	13.18
8	384837	313290	LWS	0.03	1.0	10.0	0.117	11.70	0.912	9.12
9	382564	313786	LWS	0.03	1.0	10.0	0.263	26.25	2.045	20.45
10	382281	313593	LWS	0.03	1.0	10.0	0.170	17.01	1.325	13.25
11	385768	310534	Belvide Reservoir SSSI	0.02	n/a	n/a	0.014	-	0.071	-
12	386649	310719	Belvide Reservoir SSSI	0.02	n/a	n/a	0.012	-	0.064	-
13	385835	319099	Allimore Green Common SSSI	0.02	3.0	15.0	0.043	**1.44**	0.224	**1.50**
14	381951	321241	Doley Common SSSI	0.02	3.0	15.0	0.015	0.51	0.080	0.53
15	386451	308480	Big Hyde Rough SSSI	0.02	1.0	10.0	0.006	0.60	0.031	0.31
16	391381	308321	Four Ashes Pit SSSI	0.02	n/a	n/a	0.007	-	0.034	-
17	375098	319739	Newport Canal SSSI	0.02	3.0	n/a	0.007	0.23	0.035	-
18	384188	313848	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.383	**12.76**	1.989	**19.89**
19	384407	313796	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.335	**11.17**	1.740	**17.40**
20	383916	313632	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.257	**8.58**	1.337	**13.37**
21	384125	313285	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.142	**4.73**	0.737	**7.37**
22	383851	313064	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.117	**3.90**	0.607	**6.07**
23	383735	312460	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	0.062	**2.07**	0.323	**3.23**
24	378940	320133	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	0.009	0.93	0.049	0.49
25	377415	319741	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	0.009	0.87	0.045	0.45
26	376482	320769	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	0.007	0.69	0.036	0.36

Table 7. Apparent changes in process contribution to annual mean ammonia concentration and nitrogen deposition rate – Proposed scenario minus Baseline scenario

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate		% Difference in PC µg/m³
				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	384693	314993	LWS	0.03	3.0	10.0	-2.578	-85.92	-20.083	-200.83	-59.29
2	384610	315162	LWS	0.03	3.0	10.0	-2.072	-69.07	-16.145	-161.45	-58.98
3	384552	315412	LWS	0.03	3.0	10.0	-1.205	-40.17	-9.389	-93.89	-57.32
4	384448	315786	LWS	0.03	3.0	10.0	-0.652	-21.75	-5.083	-50.83	-52.71
5	384872	314262	LWS	0.03	1.0	10.0	-0.853	-85.30	-6.646	-66.46	-53.29
6	385065	313775	LWS	0.03	1.0	10.0	-0.238	-23.78	-1.853	-18.53	-52.36
7	384851	313611	LWS	0.03	1.0	10.0	-0.217	-21.75	-1.694	-16.94	-56.25
8	384837	313290	LWS	0.03	1.0	10.0	-0.137	-13.74	-1.071	-10.71	-54.00
9	382564	313786	LWS	0.03	1.0	10.0	-0.285	-28.45	-2.217	-22.17	-52.01
10	382281	313593	LWS	0.03	1.0	10.0	-0.182	-18.18	-1.417	-14.17	-51.66
11	385768	310534	Belvide Reservoir SSSI	0.02	n/a	n/a	-0.002	-	-	-	-11.50
12	386649	310719	Belvide Reservoir SSSI	0.02	n/a	n/a	-0.001	-	-	-	-7.66
13	385835	319099	Allimore Green Common SSSI	0.02	3.0	15.0	-0.012	-0.41	-0.064	-0.43	-22.13
14	381951	321241	Doley Common SSSI	0.02	3.0	15.0	-0.003	-0.10	-0.016	-0.11	-16.59
15	386451	308480	Big Hyde Rough SSSI	0.02	1.0	10.0	0.000	-0.04	-0.002	-0.02	-5.84
16	391381	308321	Four Ashes Pit SSSI	0.02	n/a	n/a	-0.001	-	-	-	-10.91
17	375098	319739	Newport Canal SSSI	0.02	3.0	n/a	-0.001	-0.02	-	-	-8.60
18	384188	313848	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	-0.539	-17.96	-2.799	-27.99	-58.46
19	384407	313796	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	-0.462	-15.40	-2.400	-24.00	-57.96
20	383916	313632	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	-0.304	-10.14	-1.580	-15.80	-54.16
21	384125	313285	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	-0.164	-5.47	-0.853	-8.53	-53.64
22	383851	313064	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	-0.117	-3.89	-0.606	-6.06	-49.95
23	383735	312460	Mottey Meadows SSSI/SAC	0.02	3.0	10.0	-0.055	-1.82	-0.284	-2.84	-46.78
24	378940	320133	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	-0.001	-0.06	-0.003	-0.03	-5.77
25	377415	319741	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	-0.001	-0.06	-0.003	-0.03	-6.23
26	376482	320769	Aqualate Mere SSSI/Ramsar	0.02	1.0	10.0	0.000	-0.04	-0.002	-0.02	-5.65

Figure 7a. Maximum annual ammonia concentration – proposed scenario

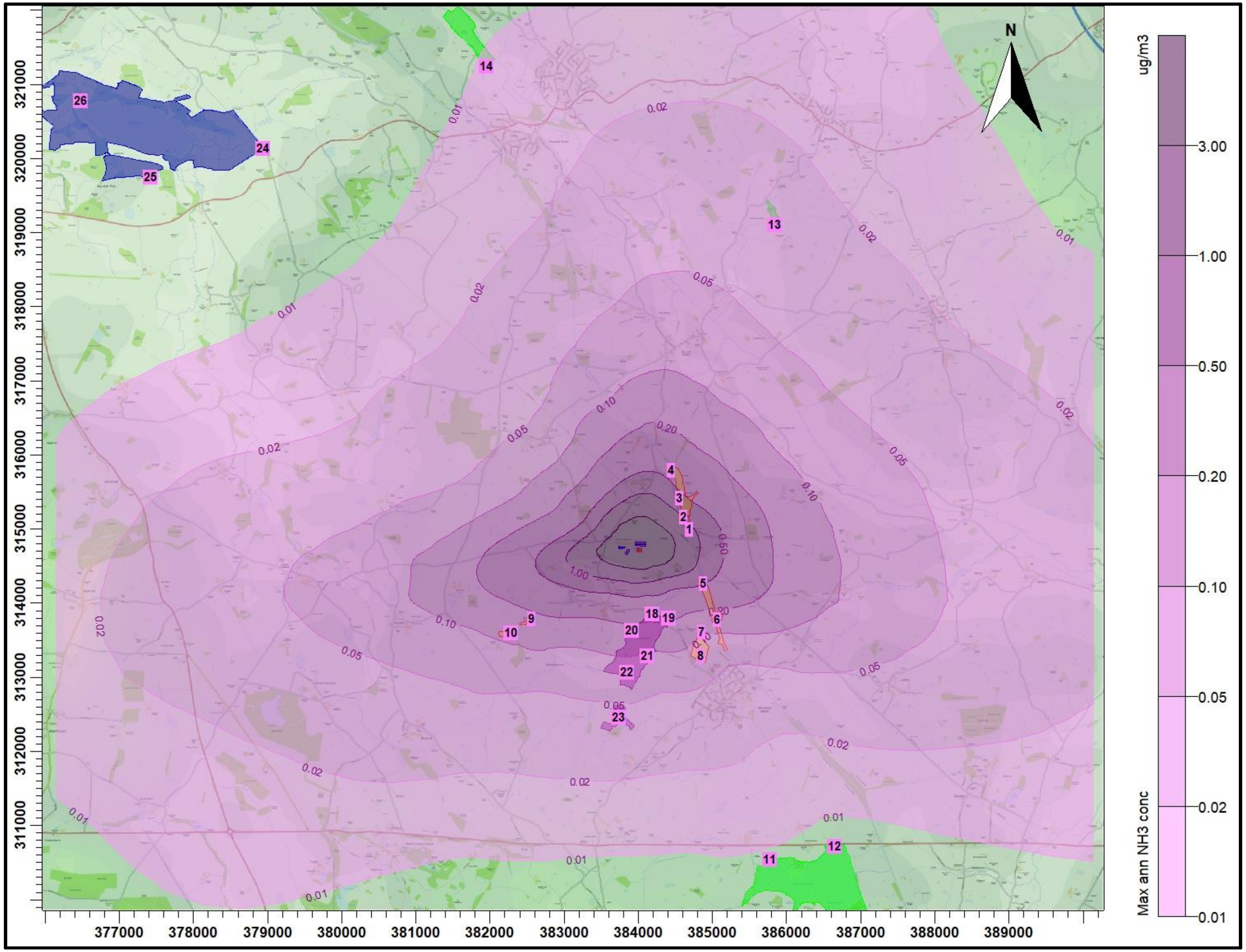
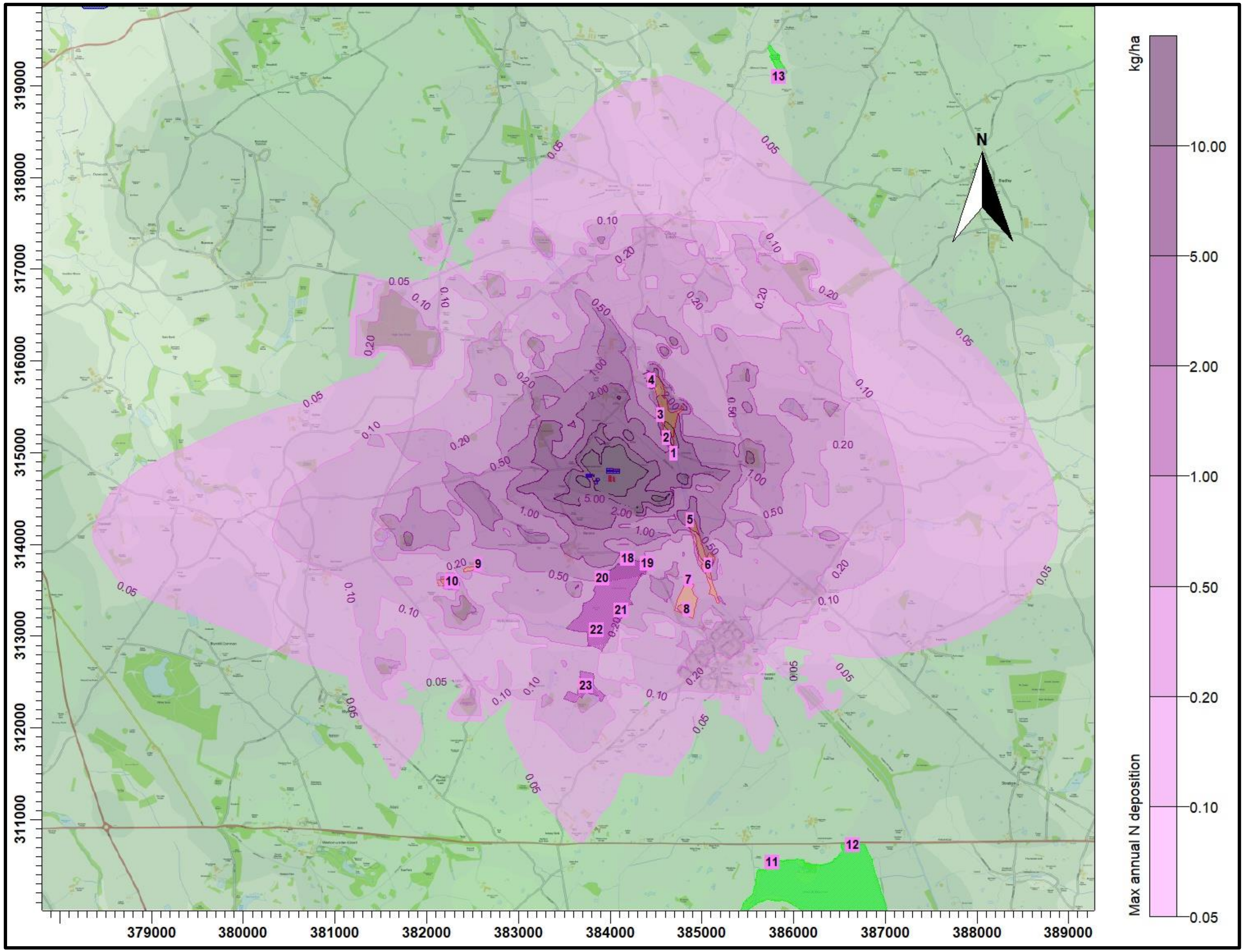


Figure 7b. Maximum annual nitrogen deposition rates – proposed scenario



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6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Harry Edwards of The Farm Consultancy Group, on behalf of Belmont Farms Ltd., to use computer modelling to assess the impact of ammonia emissions from the pig rearing houses at the Wheaton Aston Farm Pig Unit, Little Onn, Church Eaton, Stafford, Staffordshire, ST20 0AU.

Ammonia emission rates from the piggery have been assessed and quantified based upon the Environment Agency's standard ammonia emission factors and figures obtained from the UK Ammonia Emissions Inventory (UKAIE). 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.

Modelling of the proposed scenario predicts that:

- At all wildlife sites considered, the process contribution to maximum annual ammonia concentration and nitrogen deposition rates would be reduced in the proposed scenario when compared to the baseline scenario.

- At the closest LWS, the process contribution to maximum annual ammonia concentration would be below the Environment Agency's lower threshold percentage of 100% (for a non-statutory site) of the Critical Level of 3.0 µg-NH_3/m^3. However, the process contribution to nitrogen deposition rates would exceed the **precautionary** Critical Load of 10.0 kg-N/ha/y over closer parts of the site. The percentage reduction in process contributions from the baseline scenario at receptors covering the LWS would be between **52.71% and 59.29%**.

- At all other LWSs, the process contribution to maximum annual ammonia concentration and nitrogen deposition rates would be below the Environment Agency's lower threshold percentage of 100% of the **precautionary** Critical Level of 1.0 µg-NH_3/m^3 and Critical Load of 10.0 kg-N/ha/y.

- Process contributions would be below the Environment Agency lower threshold percentage of 20% (for a SSSI) of the relevant Critical Level or Load at all of the SSSIs considered. However, there would be exceedances of 1% of the relevant Critical Level or Load at Allimore Green Common SSSI and Mottey Meadows SSSI/SAC.

- The percentage reduction in process contributions from the baseline scenario at receptors covering Allimore Green Common SSSI would be **22.13%.**

- Over parts of Mottey Meadows SAC there would be exceedances of the Environment Agency lower threshold percentage of 4% (for a SAC) of the Critical Level of 3.0 µg-NH_3/m^3 and the precautionary lower bound of the Critical Load (10.0 kg-N/ha/y). The percentage reduction in process contributions from the baseline scenario would be between **46.78% and 58.46%.**

7. References

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