A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing Turkey Rearing Houses and Proposed Broiler Chicken Rearing Houses at Marsh House Farm, near Eaton Bishop in Herefordshire

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Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Steve Raasch, on behalf of Mr. Paul Matthews, to use computer modelling to assess the impact of ammonia emissions from the existing turkey rearing houses and proposed broiler chicken rearing houses at Marsh House Farm, Eaton Bishop, Herefordshire. HR2 9QT.

Ammonia emission rates from the poultry rearing houses have been estimated based upon the Environment Agency's standard ammonia emission factors and figures obtained from the UK Ammonia Emissions Inventory (UKAEI). 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.

Background Details

The site of the poultry rearing houses at Marsh House Farm is in an isolated rural area, approximately 1.5 km to the south-west of the village of Eaton Bishop in Herefordshire. The surrounding land is used largely for arable and livestock farming, but there are also some orchards, isolated meadows and wooded areas. The site is at an altitude of around 75 m in the River Wye valley.

There are four turkey rearing houses at Marsh House Farm, which currently accommodate up to 17,000 turkeys, of which approximately 95% are male and 5% are female. The turkeys are brought on to the site at around 40 days old, weighing approximately 2.0 kg and are reared for around 100 days, to a weight of approximately 17.5 kg (males) or approximately 11.0 kg (females) and there are approximately 3 flocks per annum. The houses are ventilated using cowled side mounted fans.

Under the proposal, two new poultry rearing houses would be constructed to the south of the existing houses. The new houses would be ventilated using uncapped high speed ridge mounted fans, each with a short chimney. The existing and proposed houses would then be used to rear up to 180,000 broiler chickens, which would be reared from day old chicks to around 38 days old, with approximately 7.5 flocks per year.

There are five Local Wildlife Sites (LWSs), within approximately 2 km of the poultry rearing houses at Marsh House Farm. There are eight Sites of Special Scientific Interest (SSSIs) within 10 km of the farm, one of which is also designated as a Special Area of Conservation (SAC). Some further details of the SSSIs and the SAC are provided below:

Littlemarsh Common SSSI - Approximately 850 m to the east - This mixture of wet grassland, semi-aquatic areas and scrub contains a rich variety of plants and provides an important habitat for a good variety of birds, including Nightingale Luscinia megarhynchos.
Cage Brook Valley SSSI - Approximately 2.2 km to the east-north-east - Semi-natural woodland and small areas of unimproved neutral grassland. The wetter alder woodland the ground flora contains a number of plants which are uncommon in Herefordshire, including one of the largest colonies of Monk's-hood *Aconitum napellus* in the West Midlands.
Bishon Meadow SSSI - Approximately 5.5 km to the north - A herb-rich neutral grassland. The diversity of the meadow is enhanced by the presence of small watercourses and areas of marshy grassland. The meadow supports a diverse invertebrate fauna which includes a nationally scarce hoverfly *Neoascia geniculata.*
The Flits SSSI - Approximately 5.3 km to the north-west - Most of the site is marshy grassland, nationally important for its invertebrate fauna. The site is also important as a breeding site for wetland birds.
Moccas Park SSSI - Approximately 9.1 km to the north-west - An ancient deer park lying on the northern flanks of a steep ridge. One of the largest and most diverse examples of wood pasture remaining in Britain, ranking in national importance alongside the New Forest, Windsor Great Park and Sherwood Forest. 116 species of epiphytic lichen have been recorded including a number of uncommon species such as *Enterographa crassa*, *Peltigera horizontalis* and *Arthonia vinosa*. The beetle fauna is particularly outstanding and has been well studied, with over 700 species having been recorded and the Park has considerable importance for other invertebrate groups. The ancient parkland trees provide nesting sites for a wide range of birds.
Chanstone Wood SSSI - Approximately 7.1 km to the west-south-west - An extensive area of ancient semi-natural native broadleaved woodland, with a variety of trees, shrubs and ground vegetation. The woodland provides a valuable habitat for birds.
Wormbridge Common SSSI - Approximately 6.3 km to the south - An area of acidic marshy grassland. It has a rich and varied flora and represents one of the few remaining examples of this habitat now found in Herefordshire
River Wye (Lower) SSSI/SAC - Approximately 2.8 km to the north-east, at its closest point - A rare example of a near natural, large western eutrophic river, which has not been subject to significant modification from human

activities. The SSSI incorporates adjacent areas of riparian habitat including wet woodland, marshy grassland, reed beds and topographical features which directly support the special interest of the river.

Maps of the surrounding area showing the positions of the turkey rearing houses, the LWSs, the SSSIs and the SAC are provided in Figures 1a and 1b. In the figures, the LWSs are shaded in yellow, the SSSIs are shaded in green, the SAC is shaded in purple and the positions of the existing and proposed poultry rearing houses are outlined in blue.

Figure 1a. The area surrounding Marsh House Farm, with circle radii 2.07 km (olive), 5.07 km (green) and 10.07 km (purple)

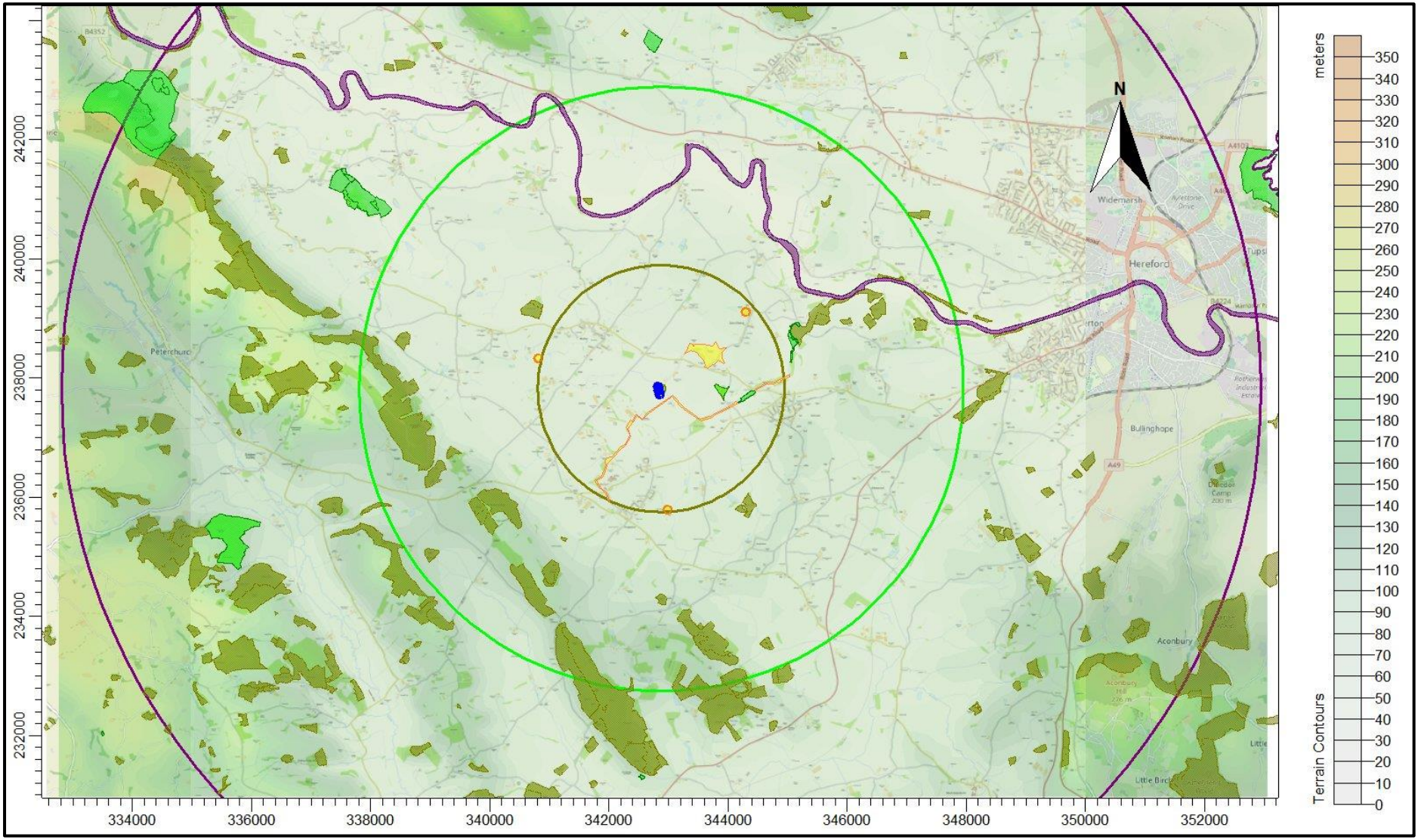
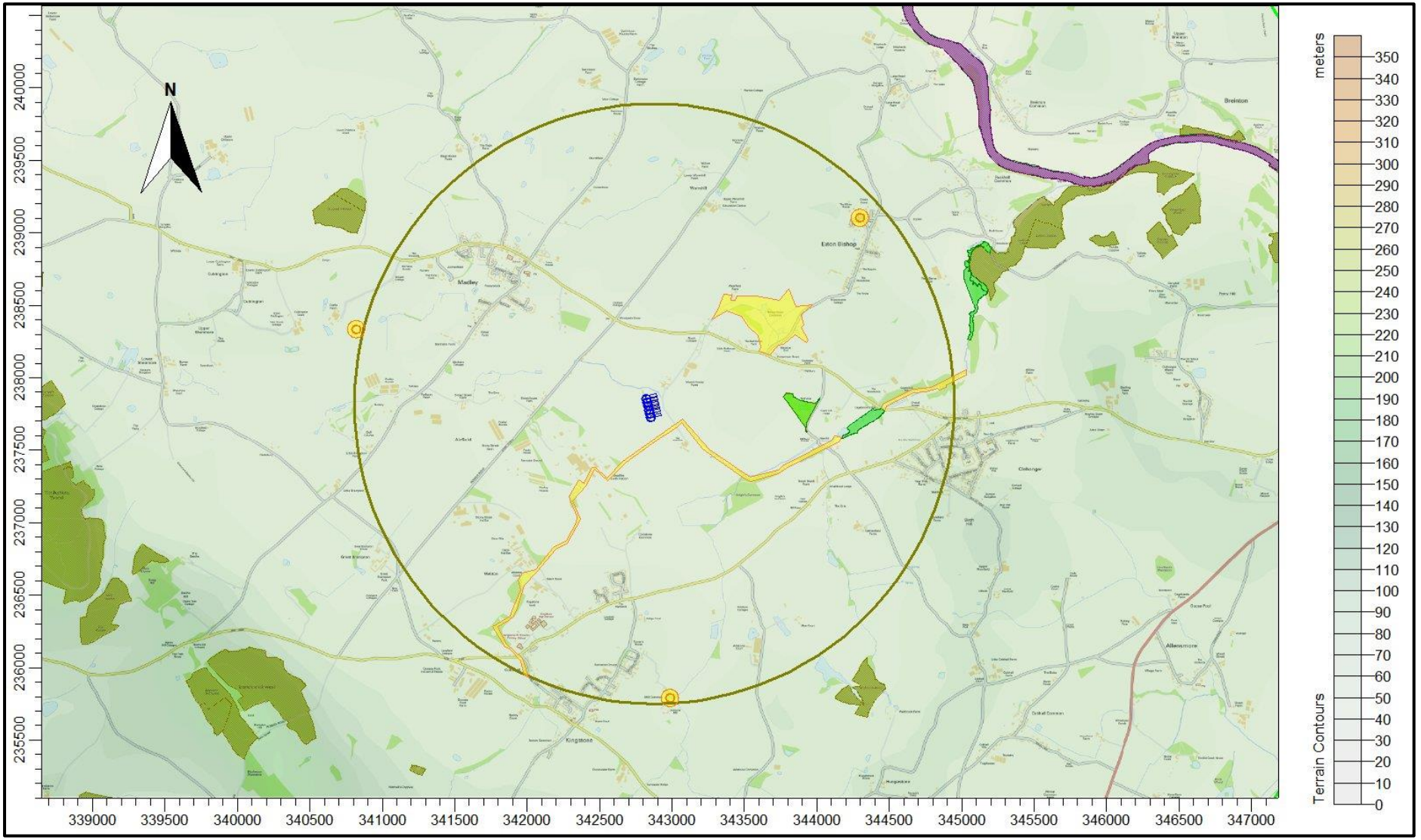


Figure 1b. The area surrounding Marsh House Farm, a closer view



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 these background figures is the Air Pollution Information System (APIS, October 2022). It should be noted that the APIS background levels are an average over a 5 km grid square (they are also modelled values, they are not measured in any way and no particular farms are included explicitly in the sources attribution data). Ammonia levels vary markedly over relatively short distances and the APIS website itself notes that the background values cannot be considered representative on any particular location within the 5 km grid square. The background ammonia concentration (annual mean) in the area around Marsh House Farm is 2.41 µg-NH_3/m^3. The background nitrogen deposition rate to woodland is 26.96 kg-N/ha/y and to short vegetation is 22.54 kg-N/ha/y. The background acid deposition rate to woodland is 2.78 keq/ha/y and to short vegetation is 1.72 keq/ha/y.

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. 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)
LWSs	1.0 [1]	10.0 [1]	-
Littlemarsh Common SSSI, The Flits SSSI and Wormbridge Common SSSI	3.0 [2]	15.0 [2 & 3]	-
Cage Brook Valley SSSI and Chanstone Wood SSSI	1.0 [2]	10.0 [2 & 3]	-
Moccas Park SSSI	1.0 [2]	15.0 [2 & 3]	-
River Wye SSSI/SAC	3.0 [2]	n/a	n/a
Bishon Meadow SSSI	3.0 [2]	20.0 [2 & 3]	-

1. A precautionary figure used where no details of the ecology of the site are available.
2. Based upon the citation for the site and information listed on APIS (October 2022).
3. The lower bound of the range of Critical Loads for the site/species, obtained from APIS (October 2022).

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 criterion

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 and deposition rates are derived as an average for a 5 km by 5 km grid.

3.4.3 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.

3.5 Quantification of ammonia emissions

Ammonia emission rates from livestock housing depend on many factors and may be rather variable. However, the benchmarks for assessing impacts of ammonia and nitrogen deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen deposition rates. To obtain relatively robust figures for these annual statistics it is not usually 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 provided an Intensive farming guidance note which lists standard ammonia emission factors for a variety of livestock, including turkeys. However, it is understood that the Environment Agency's figures for male and female turkeys assume that they are reared from day old chicks until they are fully grown and at Marsh House Farm this is not the case. Therefore, AS Modelling and Data Ltd. has calculated emission factors specifically for the turkeys reared, or proposed, at Marsh House Farm. The UKAEI has been used, which defines a figure of 64 g-N/livestock-unit/day (a livestock-unit is 500 kg) for turkeys, which equates to a specific emission factor of 0.05677 g-NH_3/kg-live-weight/y.

Currently, male (95%) and female (5%) turkeys arrive at the farm at around 40 days old at a weight of approximately 2.0 kg and are reared to around 140 days old when they may weigh up to 17.5 kg. Assuming industry standard growth rates, the average weight of the turkeys (assuming numbers as initially stocked) is 7.6406 kg. Assuming the housing is empty and clean for approximately fourteen days between crops, the figure obtained for the site specific emission factor for the existing flock of male turkeys is 0.380493 kg-NH_3/bird-place/y.

For comparison, the Environment Agency figures are 0.45 kg-NH_3/place/y for male turkeys and 0.23 kg-NH_3/place/y for female turkeys; it is understood that the Environment Agency figures are also derived using the figure of 64 g-N/livestock-unit/day from the UKAEI. Details of the turkey numbers and weights, emission factors used and calculated ammonia emission rates are provided in Table 2.

For the proposed broiler chicken rearing, the Environment Agency's standard emission factor of 0.034 kg-NH3/place/y is used to estimate ammonia emissions.

Table 2. Details of turkey numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Existing Turkey Rearing	17,000	Male and female turkeys ~2.0 kg to ~17.5 kg	0.380493	0.204970
Proposed Broiler Chicken Rearing	180,000	Standard broiler chickens	0.034	0.193931

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)[1].

Prior to April 2019 the GFS[1] 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[1] 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 observational records may be over represented, this is because the instrumentation used may not record wind speeds below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

- Traditional records may include very local deviations from the broad-scale wind flow that would not necessarily be representative of the site being modelled; these deviations are difficult to identify and remove from a meteorological record. Conversely, local effects at the site being modelled are relatively easy to impose on the broad-scale flow and provided horizontal resolution is not too great, the meteorological records from NWP data may be expected to represent well the broad-scale flow.

- Information on the state of the atmosphere above ground level which would otherwise be estimated by the meteorological pre-processor may be included explicitly.

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and where terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for Marsh House Farm is shown in Figure 2b. The resolution of the wind field in terrain runs is approximately 300 m. Please also note that FLOWSTAR[2] 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[3].

1. The GFS data used is derived from the high resolution operational GFS datasets, the data is not obtained from the lower resolution (0.5 degree) long-term archive.
2. Note that FLOWSTAR requirements are for meteorological data representative of the upwind flow over the modelling domain and that single site meteorological data (observational or from high resolution modelled data) that is representative of the application site is not generally suitable (personal correspondence: CERC 2019 and UK Met O 2015). If data are deemed representative of a particular application site, either wholly or partially, then

these data cannot also be representative of the upstream flow over the modelling domain. Furthermore, it would be extremely poor practice to use such data as the boundary conditions for a flow-solver, such as FLOWSTAR.

3. When modelling complex terrain with ADMS, by default, the minimum turbulence length has 0.1 m added to the flat terrain value (calculated from the Monin-Obukhov length). Whilst this might be appropriate over hill/mountain tops in terrain with slopes > 1:10 (and quite possibly only in certain wind directions) in lesser terrain it introduces model behaviour that is not desirable where FLOWSTAR is simply being used to modify the upwind flow. Specifically, the parameter sigma z of the Gaussian plume model is overly constrained, which for elevated point sources emissions, may on occasion cause over prediction of ground level concentrations in stable weather conditions and light winds (Steven R. Hanna & Biswanath Chowdhury, 2013), conversely for low level emission sources, this will cause gross under prediction. Note that this becomes particularly important overnight and if calm and light wind conditions are not being ignored, as they often are when using traditional observational meteorological datasets. To reduce this behaviour, where terrain is modelled, AS Modelling & Data Ltd. have set a minimum turbulence length of 0.025 m in ADMS. This approximates the normal behaviour of ADMS with flat terrain.

Figure 2a. The wind rose. Raw GFS derived data for 52.036 N, 2.833 W, 2018-2021

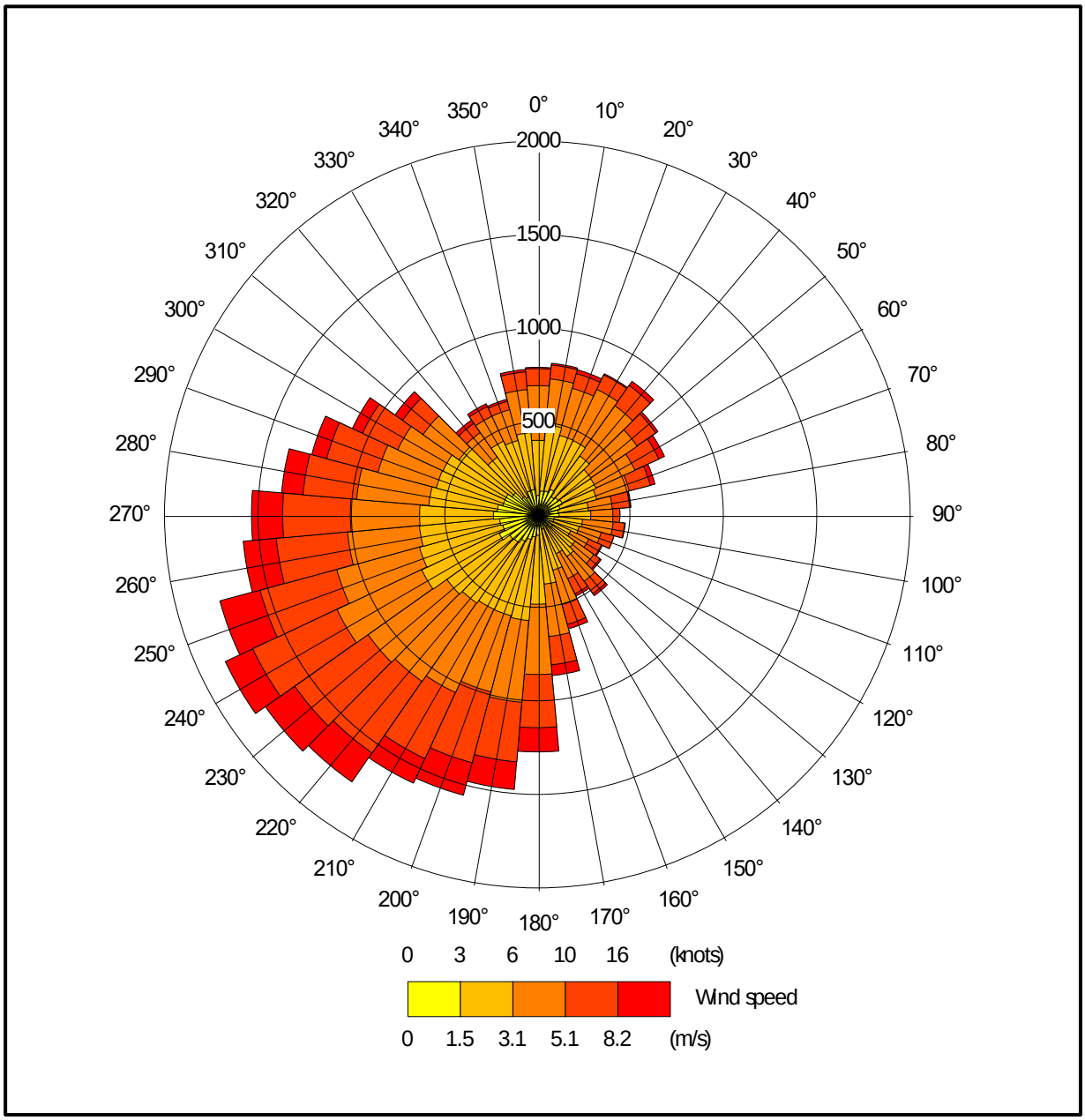
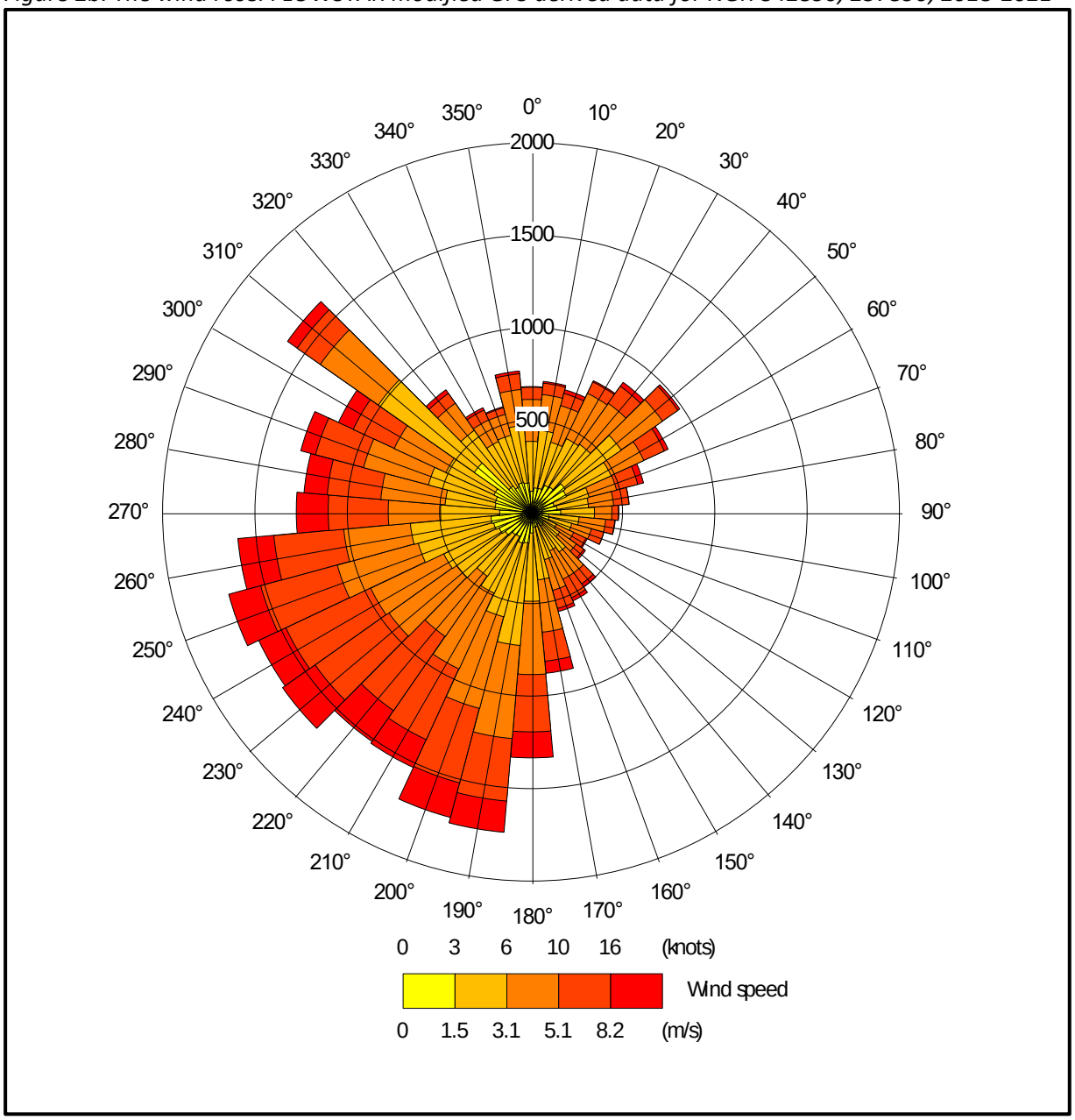


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 342850, 237850, 2018-2021



4.2 Emission sources

Emission from the cowled side fans on the existing poultry houses are represented by a single volume source per house within ADMS (EX1_SIDE to EX4_SIDE). Emissions from the uncapped chimneys of the ridge mounted fans that would be used to ventilate the proposed poultry houses are represented by three point sources per house within ADMS (PR1 1, 2 & 3 and PR2 1, 2 & 3). Details of the volume and point source parameters are shown in Tables 3a and 3b. The positions of the sources may be seen in Figure 3 (point sources are marked by green circles and volume sources by red shaded rectangles).

Table 3a. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX1_SIDE to EX4_SIDE	18.29	73.15	3.0	0.0	Ambient	0.031688 [1]

Table 3b. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (g-NH_3/s)
H1 to H4 1, 2 & 3	5.5	0.8	11.0	22.0	0.010563 [1]

1. Based on a notional 1,000 birds per house, with an emission factor of 1.0 kg-NH_3/bird-place/y. The results of the modelling have then been scaled by factors of: 1.617 for the existing turkey stocking regime and 1.020 for the proposed broiler chicken stocking regime.

4.3 Modelled buildings

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

4.4 Discrete receptors

Thirty-seven discrete receptors have been defined at the 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, a regular Cartesian grid has been defined within ADMS. The grid receptors are defined at ground level within ADMS. The position of the nested Cartesian grid receptors may be seen in Figure 4b (marked by grey gridlines).

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 by 20.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS. The resolution of FLOWSTAR is 64 by 64 grid points; therefore, the effective resolution of the wind field is approximately 300 m.

Figure 3. The positions of the modelled sources and buildings

4.7 Roughness Length

In this case, a spatially varying roughness length file has been defined, this is based upon the UK Centre for Ecology and Hydrology 25 m land use database, with permission[1]. The GFS meteorological data is assumed to have a roughness length of 0.28 m (the average over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 5.

1. Morton, R.D. ; Marston, C.G.; O'Neil, A.W.; Rowland, C.S. (2021). Land Cover Map 2020 (25m rasterised land parcels, GB). NERC EDS Environmental Information Centre. https://doi.org/10.5285/6c22cf6e-b224-414e-aa85-900325baed.

Figure 4a. The discrete receptors, a broad scale view

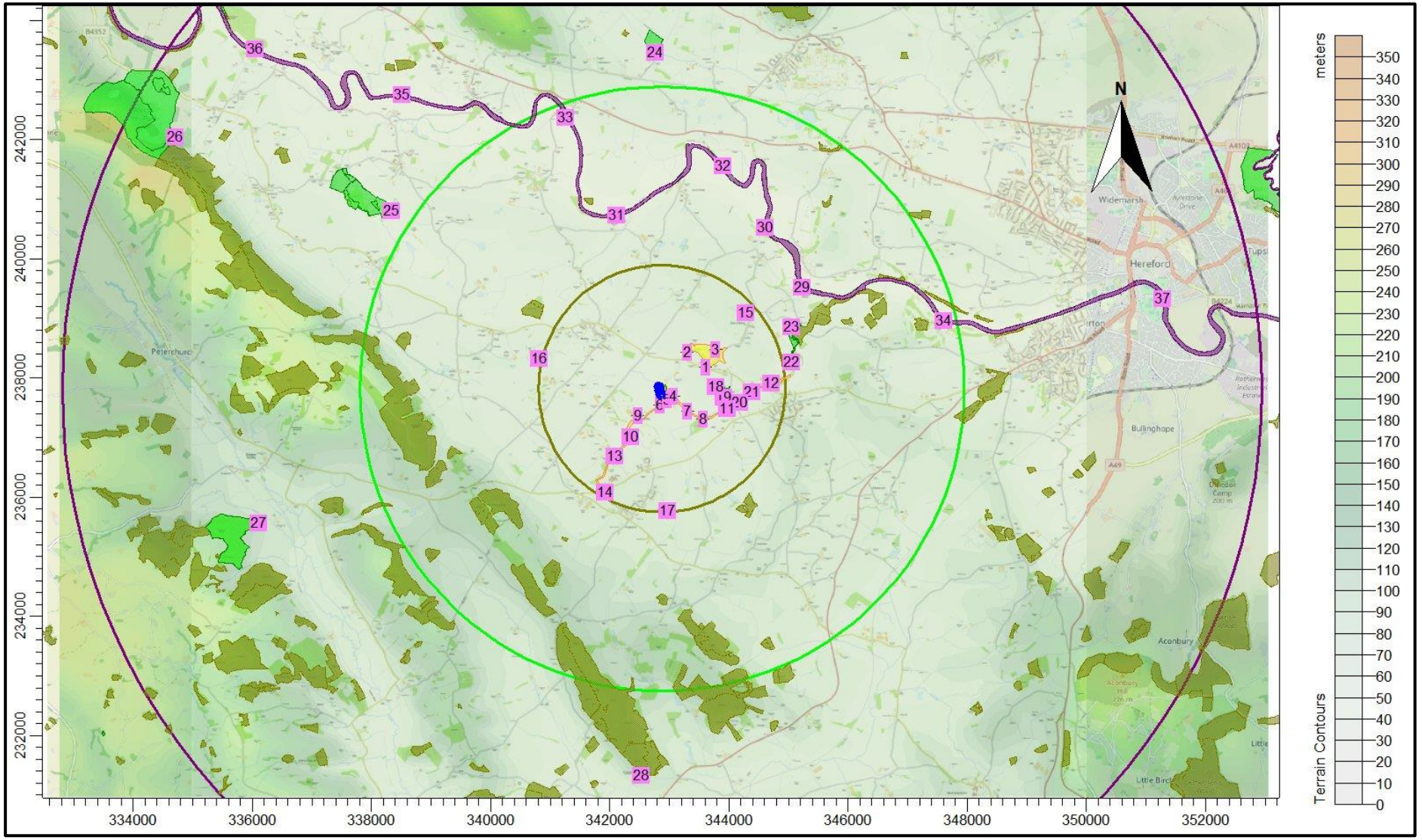


Figure 4b. The discrete receptors and regular Cartesian grid, a closer view

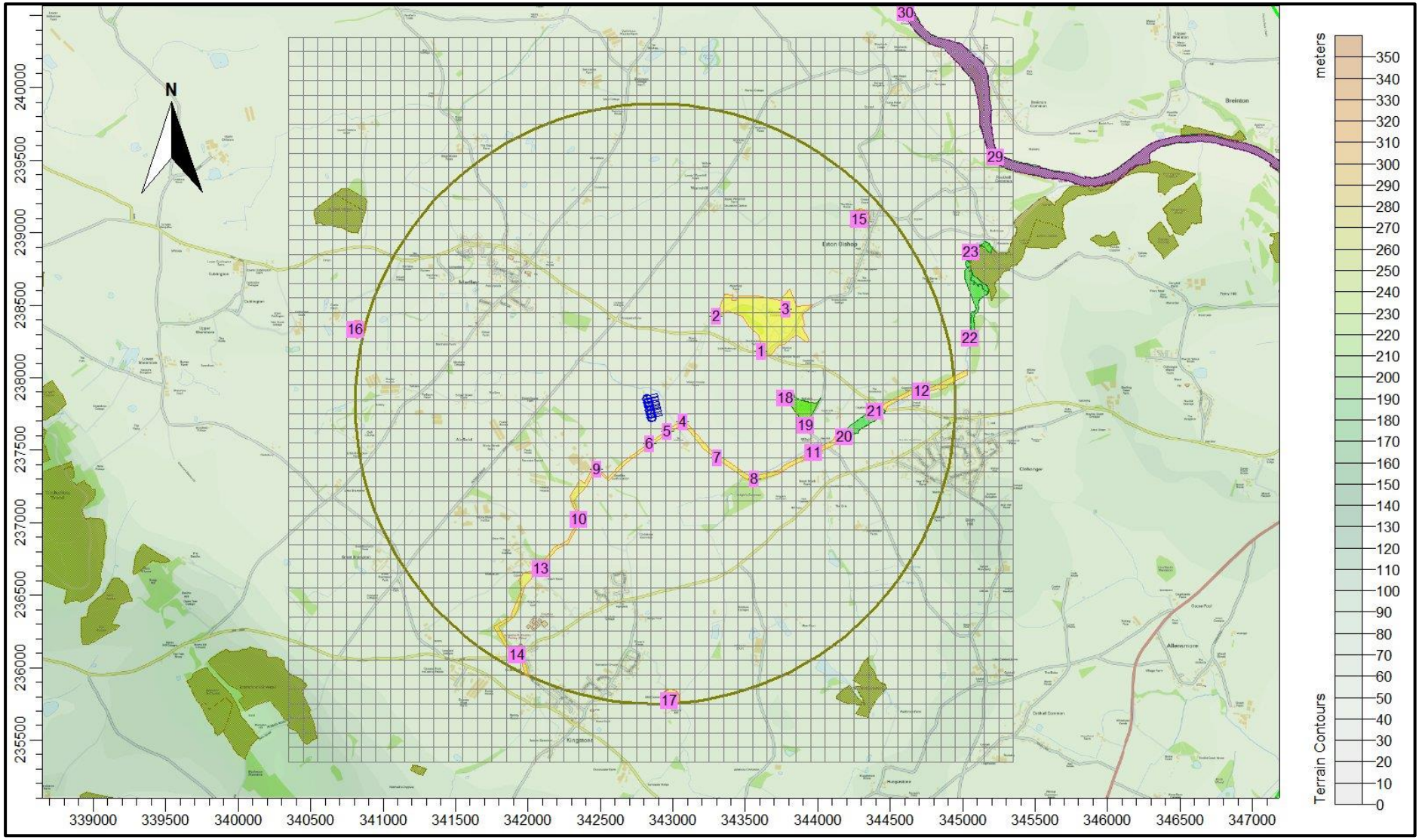
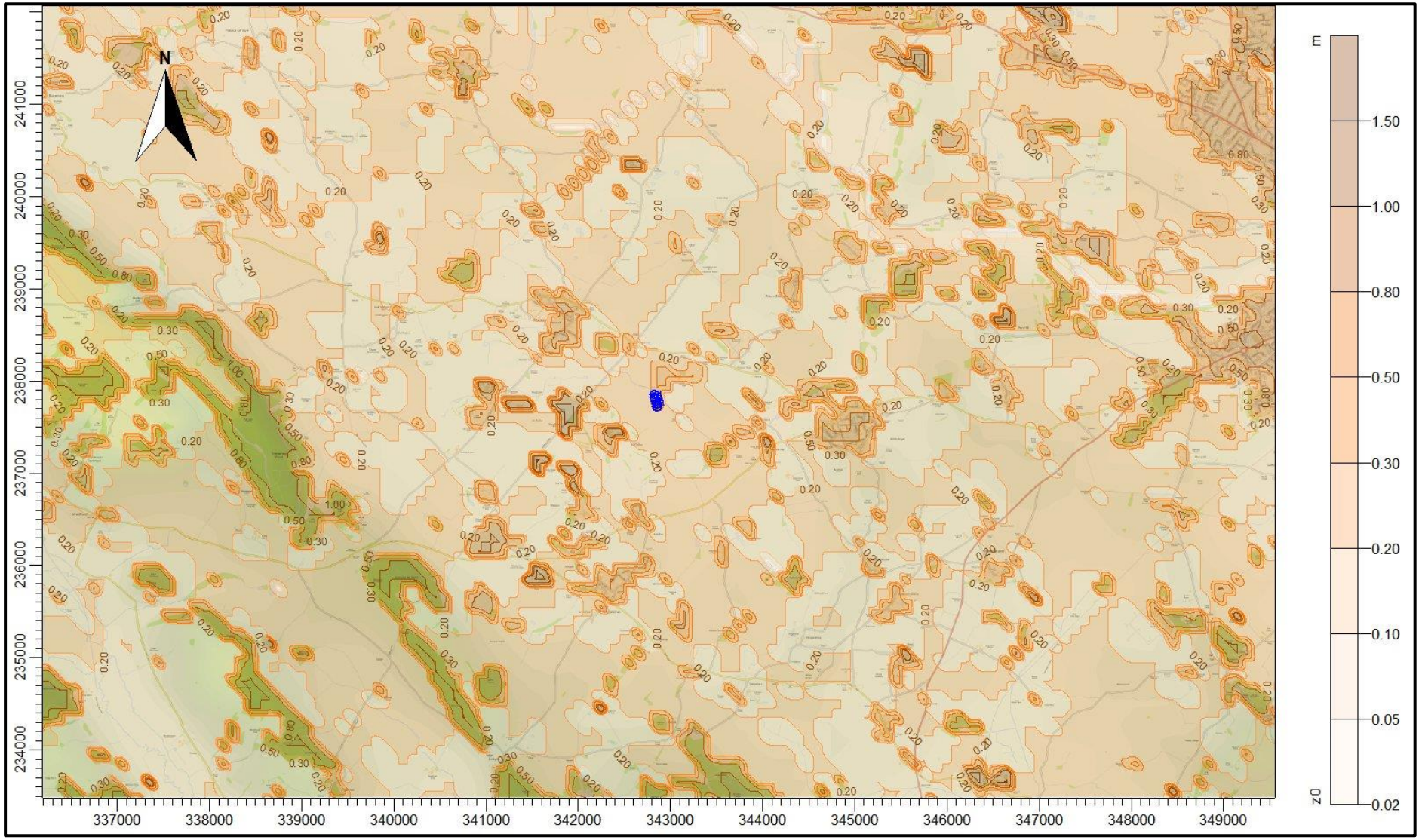


Figure 5. The spatially varying surface roughness field (central area)



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 poultry 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 UK Centre for Ecology and Hydrology 25 m land use database, with permission[1].

1. Morton, R.D. ; Marston, C.G.; O'Neil, A.W.; Rowland, C.S. (2021). Land Cover Map 2020 (25m rasterised land parcels, GB). NERC EDS Environmental Information Centre. https://doi.org/10.5285/6c22cf6e-b224-414e-aa85-900325baed.

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

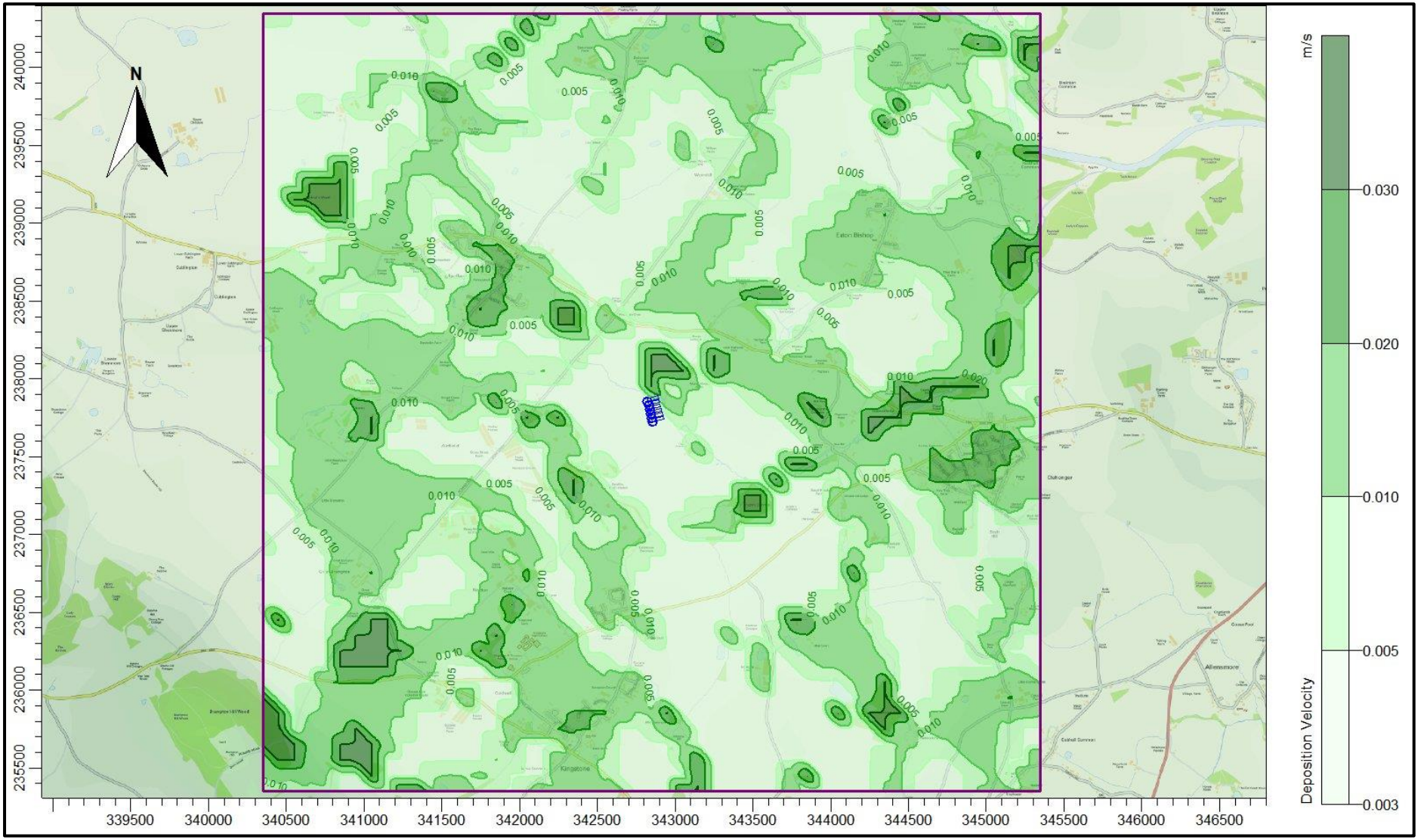
NH_3 concentration (PC + background) (µg/m^3)	< 10	10 - 20	20 - 30	30 - 80	> 80
Deposition velocity - woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity - short vegetation (m/s)	0.02 (0.010 to 0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity - arable farmland/rye 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.

Please note that, outside of the central grid, a fixed deposition at 0.005 m/s or 0.003 m/s is applied and similarly to not modelling deposition at all, the predicted ammonia concentrations (and nitrogen and acid deposition rates) are always equal to, or higher than if spatially varying deposition were modelled explicitly, particularly where there is some distance between the source and a receptor.

Figure 6. The spatially varying deposition field



Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

ADMS was effectively run a total of thirty-two times, once for each year of the meteorological record, for the existing and proposed turkey rearing houses and 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 and surface roughness - GFS data.
- With terrain and surface roughness and a fixed deposition at 0.003 m/s - GFS data.

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled.

Details of the predicted annual mean ammonia concentrations at each receptor for preliminary modelling runs are provided in Table 5. In the Table, predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in excess of the Environment Agency's upper percentage threshold of the relevant Critical Level or Critical Load for the site (20% for a SAC, 50% for a SSSI and 100% for a non-statutory site) are coloured red. Predicted ammonia concentrations (or concentrations equivalent to deposition rates) that are in the range between the Environment Agency's upper threshold and lower threshold percentages (4% and 20% for a SAC, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site) are coloured blue. For convenience, cells referring to the LWSs are shaded yellow, cells referring to the SSSIs are shaded green and cells referring to the SAC are shaded purple.

Table 5. Predicted maximum annual mean ammonia concentration - preliminary modelling

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Existing 17,000 Turkeys				Proposed 180,000 broilers			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS Calms Correction Fixed depo 0.003 m/s
1	343607	238184	LWS	**1.413**	**1.630**	**1.802**	**1.003**	0.964	**1.100**	**1.197**	0.688
2	343297	238427	LWS	**1.263**	**1.514**	**1.528**	0.981	0.871	**1.027**	**1.034**	0.681
3	343779	238473	LWS	0.780	0.915	0.967	0.506	0.538	0.623	0.648	0.353
4	343069	237699	LWS	**9.985**	**11.694**	**13.080**	**9.695**	**6.765**	**7.833**	**8.717**	**6.569**
5	342962	237628	LWS	**9.380**	**11.399**	**10.996**	**8.505**	**6.269**	**7.539**	**7.346**	**5.763**
6	342841	237542	LWS	**5.525**	**6.977**	**6.385**	**4.712**	**3.797**	**4.709**	**4.323**	**3.256**
7	343308	237446	LWS	**1.799**	**2.186**	**2.360**	**1.432**	**1.221**	**1.464**	**1.608**	**1.010**
8	343561	237303	LWS	0.975	**1.172**	**1.291**	0.704	0.666	0.789	0.881	0.501
9	342473	237367	LWS	**1.233**	**1.654**	**1.431**	0.925	0.849	**1.114**	0.987	0.660
10	342348	237021	LWS	0.590	0.787	0.709	0.404	0.408	0.532	0.487	0.290
11	343968	237485	LWS	0.850	0.959	**1.142**	0.565	0.580	0.647	0.756	0.385
12	344717	237909	LWS	0.369	0.419	0.484	0.215	0.259	0.290	0.328	0.152
13	342091	236686	LWS	0.311	0.417	0.382	0.199	0.218	0.285	0.265	0.144
14	341927	236090	LWS	0.181	0.239	0.228	0.105	0.129	0.165	0.159	0.077
15	344287	239094	LWS	0.282	0.340	0.328	0.157	0.202	0.238	0.226	0.113
16	340808	238335	LWS	0.097	0.147	0.122	0.052	0.069	0.100	0.084	0.038
17	342975	235771	LWS	0.184	0.235	0.222	0.105	0.133	0.164	0.153	0.075
18	343777	237860	Littlemarsh Common SSSI	**1.249**	**1.415**	**1.616**	**0.859**	**0.848**	**0.952**	**1.078**	**0.592**
19	343918	237671	Littlemarsh Common SSSI	**1.009**	**1.132**	**1.326**	**0.665**	**0.684**	**0.760**	**0.873**	0.450
20	344185	237596	Littlemarsh Common SSSI	**0.683**	**0.767**	**0.914**	0.430	0.468	0.519	**0.603**	0.293
21	344393	237770	Littlemarsh Common SSSI	0.527	**0.595**	**0.697**	0.320	0.364	0.406	0.464	0.221
22	345051	238274	Cage Brook Valley SSSI	**0.260**	**0.298**	**0.343**	0.152	0.187	0.210	0.240	0.111
23	345058	238865	Cage Brook Valley SSSI	0.222	**0.257**	**0.281**	0.121	0.160	0.182	0.194	0.088
24	342763	243468	Bishon Meadow SSSI	0.027	0.035	0.036	0.015	0.022	0.027	0.028	0.012
25	338336	240812	The Flits SSSI	0.019	0.029	0.022	0.008	0.015	0.021	0.016	0.006
26	334709	242043	Moccas Park SSSI	0.008	0.012	0.009	0.003	0.007	0.009	0.007	0.002
27	336112	235565	Chanstone Wood SSSI	0.017	0.024	0.018	0.006	0.014	0.018	0.014	0.005
28	342528	231338	Wormbridge Common SSSI	0.028	0.035	0.026	0.010	0.022	0.027	0.020	0.008
29	345225	239526	River Wye SSSI/SAC	0.152	0.179	0.185	0.078	0.112	0.128	0.129	0.058
30	344608	240522	River Wye SSSI/SAC	0.100	0.121	0.118	0.056	0.076	0.089	0.088	0.044
31	342118	240736	River Wye SSSI/SAC	0.073	0.096	0.084	0.042	0.055	0.070	0.062	0.032
32	343897	241566	River Wye SSSI/SAC	0.067	0.085	0.091	0.043	0.052	0.063	0.071	0.035
33	341264	242372	River Wye SSSI/SAC	0.030	0.040	0.040	0.017	0.024	0.030	0.030	0.013
34	347608	238957	River Wye SSSI/SAC	0.071	0.081	0.090	0.033	0.055	0.061	0.068	0.026
35	338508	242749	River Wye SSSI/SAC	0.013	0.020	0.017	0.007	0.011	0.015	0.014	0.006
36	336054	243522	River Wye SSSI/SAC	0.008	0.013	0.011	0.004	0.007	0.010	0.008	0.003
37	351286	239337	River Wye SSSI/SAC	0.029	0.033	0.048	0.014	0.024	0.026	0.036	0.011

5.2 Detailed deposition modelling

In this case, detailed modelling has been carried out over a high resolution (100 m) domain that extends 5.0 km by 5.0 km and covers the turkey rearing houses at Marsh House Farm. 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 the 5.0 km x 5.0 km domain a fixed deposition velocity of 0.005 m/s is assumed (with appropriate deposition velocities applied post-modelling at the discrete receptors).

The predicted process contribution to maximum annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors are shown in Tables 6a (existing turkey rearing) and 6b (proposed broiler chicken rearing). In the Tables, predicted ammonia concentrations or nitrogen deposition rates as a percentage of the Critical Level or Critical Load that are in excess of the Environment Agency's upper threshold for the site (20% for a SAC, 50% for a SSSI and 100% for a non-statutory site) are coloured red. Percentages that are in the range between the Environment Agency's upper threshold and lower threshold of the Critical Level or Critical Load for the site (4% and 20% for a SAC, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site) are coloured blue. For convenience, cells referring to the LWS are shaded olive, cells referring to the SSSIs are shaded green and cells referring to the SAC are shaded purple.

Contour plots of the predicted process contributions to ground level maximum annual mean ammonia concentrations and nitrogen deposition rates are shown in Figures 7a and 7b (existing turkey rearing) and Figures 8a and 8b (proposed broiler chicken rearing).

Table 6a. Predicted process contribution to maximum annual mean ammonia and nitrogen deposition at the discrete receptors - existing turkey rearing

Receptor number	X(m)	Y(m)	Designation	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	343607	238184	LWS	0.020	1.0	10.0	0.462	46.2	2.40	24.0
2	343297	238427	LWS	0.020	1.0	10.0	0.479	47.9	2.49	24.9
3	343779	238473	LWS	0.020	1.0	10.0	0.213	21.3	1.11	11.1
4	343069	237699	LWS	0.020	1.0	10.0	7.527	**752.7**	39.10	**391.0**
5	342962	237628	LWS	0.020	1.0	10.0	7.427	**742.7**	38.58	**385.8**
6	342841	237542	LWS	0.020	1.0	10.0	4.265	**426.5**	22.15	**221.5**
7	343308	237446	LWS	0.020	1.0	10.0	1.047	**104.7**	5.44	54.4
8	343561	237303	LWS	0.020	1.0	10.0	0.453	45.3	2.35	23.5
9	342473	237367	LWS	0.020	1.0	10.0	0.786	78.6	4.08	40.8
10	342348	237021	LWS	0.020	1.0	10.0	0.300	30.0	1.56	15.6
11	343968	237485	LWS	0.020	1.0	10.0	0.307	30.7	1.60	16.0
12	344717	237909	LWS	0.020	1.0	10.0	0.090	9.0	0.47	4.7
13	342091	236686	LWS	0.020	1.0	10.0	0.135	13.5	0.70	7.0
14	341927	236090	LWS	0.020	1.0	10.0	0.062	6.2	0.32	3.2
15	344287	239094	LWS	0.020	1.0	10.0	0.068	6.8	0.35	3.5
16	340808	238335	LWS	0.020	1.0	10.0	0.031	3.1	0.16	1.6
17	342975	235771	LWS	0.020	1.0	10.0	0.071	7.1	0.37	3.7
18	343777	237860	Littlemarsh Common SSSI	0.020	3.0	15.0	0.468	15.6	2.43	16.2
19	343918	237671	Littlemarsh Common SSSI	0.020	3.0	15.0	0.349	11.6	1.81	12.1
20	344185	237596	Littlemarsh Common SSSI	0.020	3.0	15.0	0.213	7.1	1.11	7.4
22	345051	238274	Littlemarsh Common SSSI	0.020	3.0	15.0	0.144	4.8	0.75	5.0
23	345058	238865	Cage Brook Valley SSSI	0.030	1.0	10.0	0.062	6.2	0.48	4.8
24	342763	243468	Cage Brook Valley SSSI	0.030	1.0	10.0	0.048	4.8	0.38	3.8
25	338336	240812	Bishon Meadow SSSI	0.020	3.0	20.0	0.007	0.2	0.04	0.2
26	334709	242043	The Flits SSSI	0.020	3.0	15.0	0.004	0.1	0.02	0.2
27	336112	235565	Moccas Park SSSI	0.030	1.0	15.0	0.002	0.2	0.01	0.1
28	342528	231338	Chanstone Wood SSSI	0.030	1.0	10.0	0.004	0.4	0.03	0.3
29	345225	239526	Wormbridge Common SSSI	0.020	3.0	15.0	0.005	0.2	0.03	0.2
30	344608	240522	River Wye SSSI/SAC	0.020	3.0	n/a	0.032	1.1	0.17	-
31	342118	240736	River Wye SSSI/SAC	0.020	3.0	n/a	0.026	0.9	0.13	-
32	343897	241566	River Wye SSSI/SAC	0.020	3.0	n/a	0.022	0.7	0.11	-
33	341264	242372	River Wye SSSI/SAC	0.020	3.0	n/a	0.021	0.7	0.11	-
34	347608	238957	River Wye SSSI/SAC	0.020	3.0	n/a	0.009	0.3	0.05	-
35	338508	242749	River Wye SSSI/SAC	0.020	3.0	n/a	0.015	0.5	0.08	-
36	336054	243522	River Wye SSSI/SAC	0.020	3.0	n/a	0.004	0.1	0.02	-
37	351286	239337	River Wye SSSI/SAC	0.020	3.0	n/a	0.002	0.1	0.01	-

Table 6b. Predicted process contribution to maximum annual mean ammonia and nitrogen deposition at the discrete receptors - proposed broiler rearing

Receptor number	X(m)	Y(m)	Designation	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	343607	238184	LWS	0.020	1.0	10.0	0.342	34.2	1.78	17.8
2	343297	238427	LWS	0.020	1.0	10.0	0.356	35.6	1.85	18.5
3	343779	238473	LWS	0.020	1.0	10.0	0.166	16.6	0.86	8.6
4	343069	237699	LWS	0.020	1.0	10.0	5.193	**519.3**	26.97	**269.7**
5	342962	237628	LWS	0.020	1.0	10.0	5.076	**507.6**	26.37	**263.7**
6	342841	237542	LWS	0.020	1.0	10.0	2.968	**296.8**	15.42	**154.2**
7	343308	237446	LWS	0.020	1.0	10.0	0.763	76.3	3.96	39.6
8	343561	237303	LWS	0.020	1.0	10.0	0.339	33.9	1.76	17.6
9	342473	237367	LWS	0.020	1.0	10.0	0.564	56.4	2.93	29.3
10	342348	237021	LWS	0.020	1.0	10.0	0.220	22.0	1.14	11.4
11	343968	237485	LWS	0.020	1.0	10.0	0.217	21.7	1.13	11.3
12	344717	237909	LWS	0.020	1.0	10.0	0.070	7.0	0.36	3.6
13	342091	236686	LWS	0.020	1.0	10.0	0.100	10.0	0.52	5.2
14	341927	236090	LWS	0.020	1.0	10.0	0.048	4.8	0.25	2.5
15	344287	239094	LWS	0.020	1.0	10.0	0.055	5.5	0.28	2.8
16	340808	238335	LWS	0.020	1.0	10.0	0.024	2.4	0.12	1.2
17	342975	235771	LWS	0.020	1.0	10.0	0.052	5.2	0.27	2.7
18	343777	237860	Littlemarsh Common SSSI	0.020	3.0	15.0	0.338	11.3	1.75	11.7
19	343918	237671	Littlemarsh Common SSSI	0.020	3.0	15.0	0.246	8.2	1.28	8.5
20	344185	237596	Littlemarsh Common SSSI	0.020	3.0	15.0	0.153	5.1	0.79	5.3
22	345051	238274	Littlemarsh Common SSSI	0.020	3.0	15.0	0.106	3.5	0.55	3.7
23	345058	238865	Cage Brook Valley SSSI	0.030	1.0	10.0	0.051	5.1	0.40	4.0
24	342763	243468	Cage Brook Valley SSSI	0.030	1.0	10.0	0.040	4.0	0.31	3.1
25	338336	240812	Bishon Meadow SSSI	0.020	3.0	20.0	0.007	0.2	0.04	0.2
26	334709	242043	The Flits SSSI	0.020	3.0	15.0	0.004	0.1	0.02	0.1
27	336112	235565	Moccas Park SSSI	0.030	1.0	15.0	0.002	0.2	0.01	0.1
28	342528	231338	Chanstone Wood SSSI	0.030	1.0	10.0	0.004	0.4	0.03	0.3
29	345225	239526	Wormbridge Common SSSI	0.020	3.0	15.0	0.005	0.2	0.02	0.2
30	344608	240522	River Wye SSSI/SAC	0.020	3.0	n/a	0.028	0.9	0.15	-
31	342118	240736	River Wye SSSI/SAC	0.020	3.0	n/a	0.024	0.8	0.12	-
32	343897	241566	River Wye SSSI/SAC	0.020	3.0	n/a	0.019	0.6	0.10	-
33	341264	242372	River Wye SSSI/SAC	0.020	3.0	n/a	0.020	0.7	0.10	-
34	347608	238957	River Wye SSSI/SAC	0.020	3.0	n/a	0.008	0.3	0.04	-
35	338508	242749	River Wye SSSI/SAC	0.020	3.0	n/a	0.014	0.5	0.07	-
36	336054	243522	River Wye SSSI/SAC	0.020	3.0	n/a	0.004	0.1	0.02	-
37	351286	239337	River Wye SSSI/SAC	0.020	3.0	n/a	0.002	0.1	0.01	-

Figure 7a. Predicted process contribution to maximum annual mean ammonia concentration - existing turkey rearing

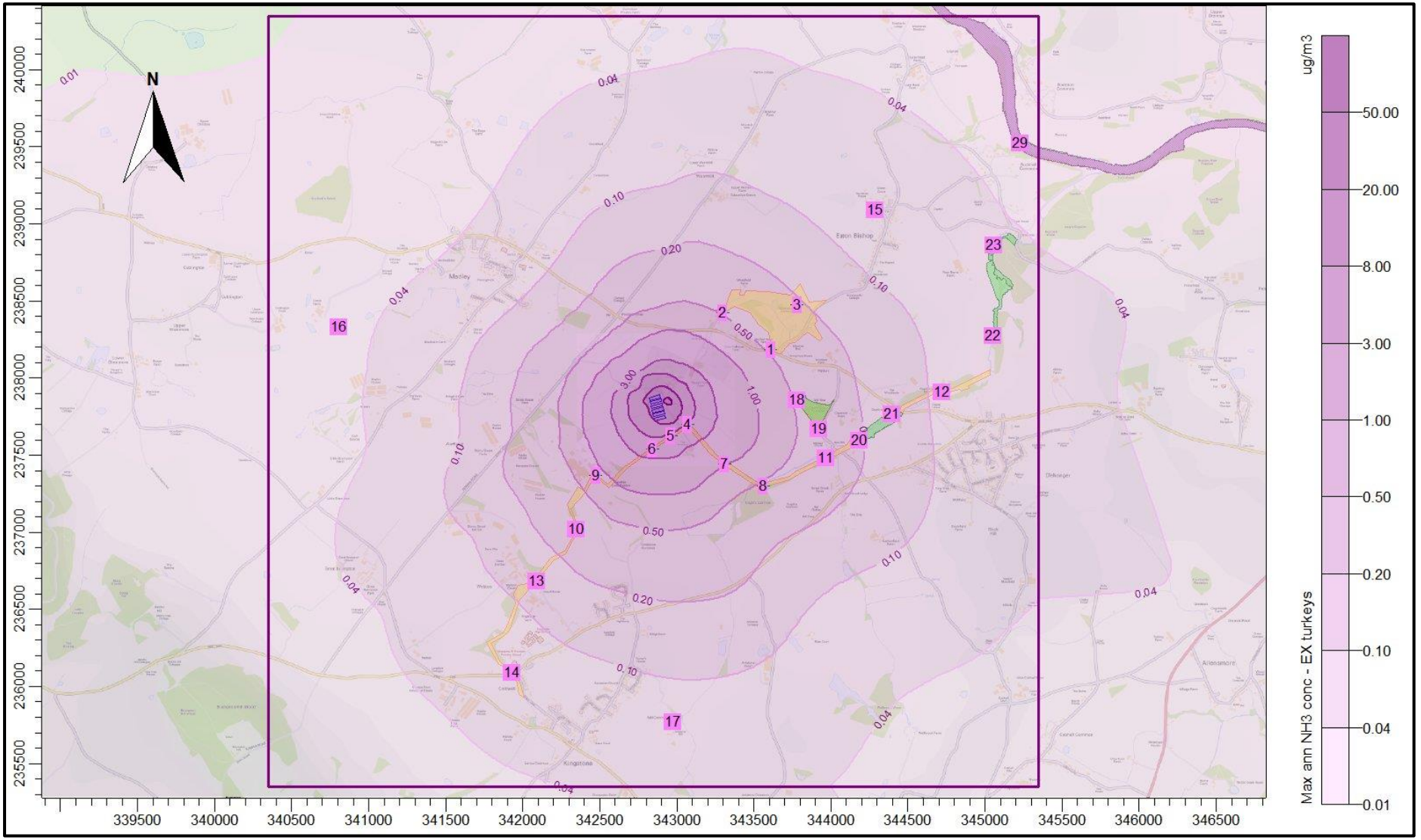


Figure 7b. Predicted process contribution to maximum annual nitrogen deposition rates - existing turkey rearing

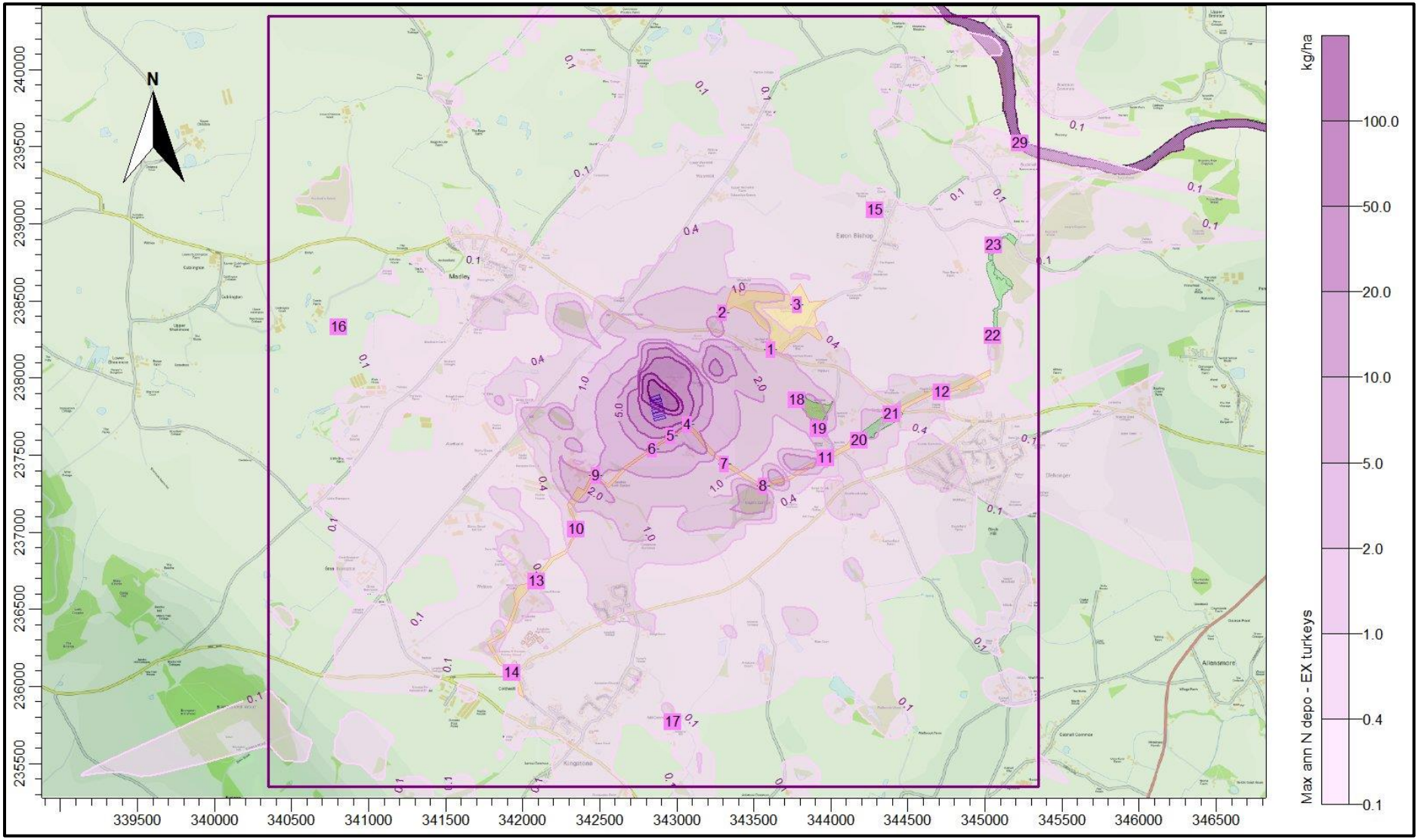


Figure 8a. Predicted process contribution to maximum annual mean ammonia concentration - proposed broiler chicken rearing

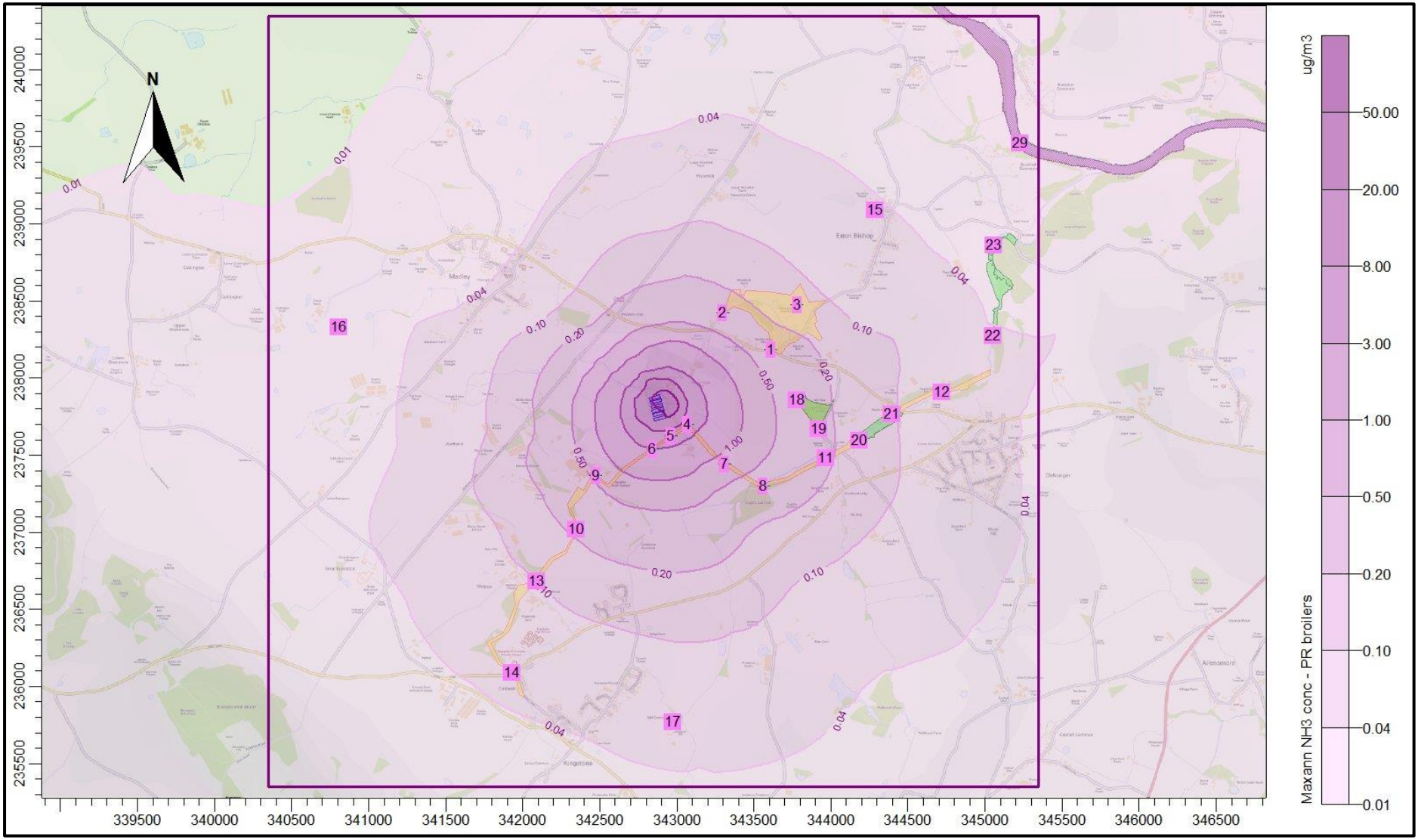
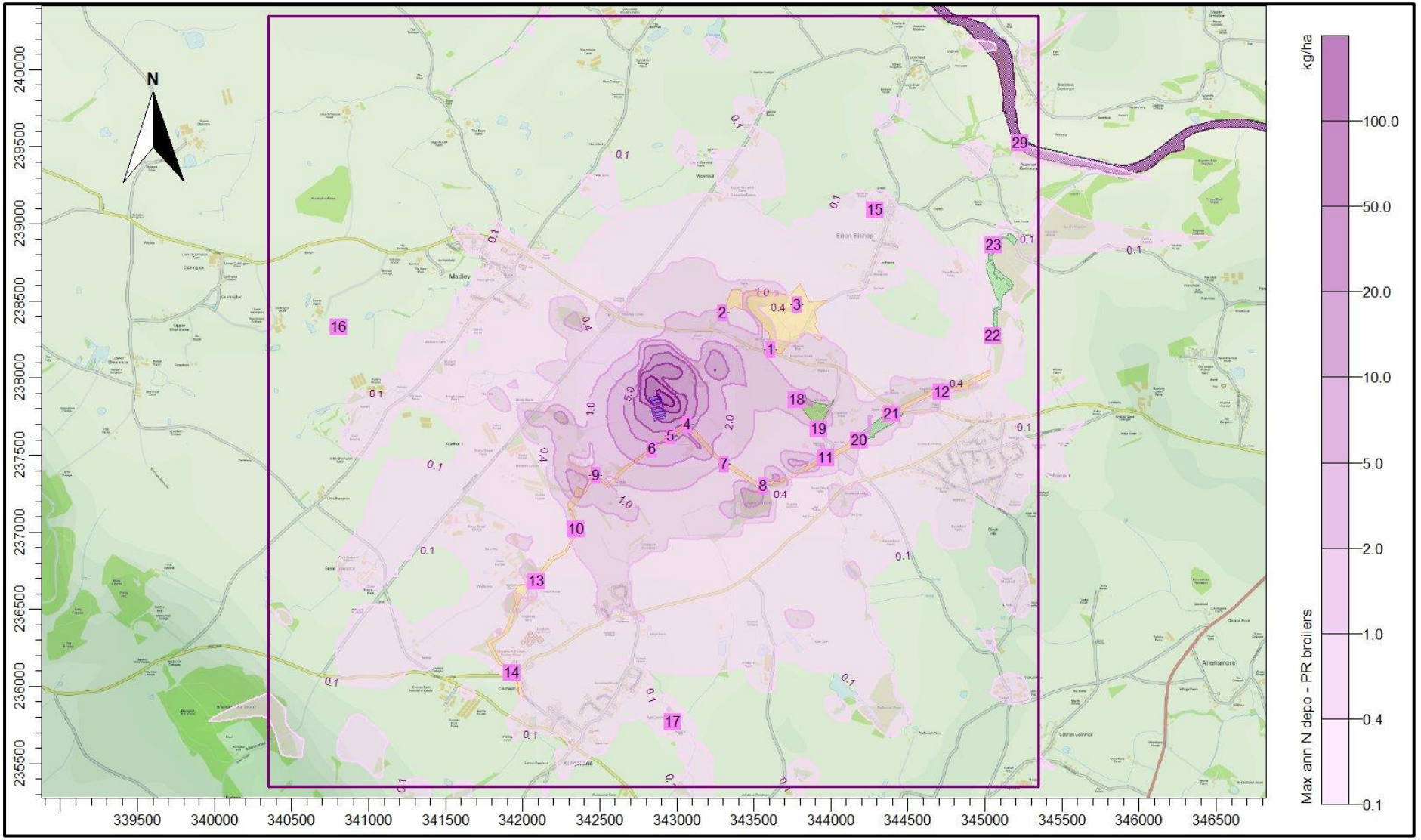


Figure 8b. Predicted process contribution to maximum annual nitrogen deposition rates - proposed broiler chicken rearing



Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Steve Raasch, on behalf of Mr. Paul Matthews, to use computer modelling to assess the impact of ammonia emissions from the existing turkey rearing houses and proposed broiler chicken rearing houses at Marsh House Farm, Eaton Bishop, Herefordshire. HR2 9QT.

Ammonia emission rates from the poultry rearing houses have been estimated based upon the Environment Agency's standard ammonia emission factors and figures obtained from the UK Ammonia Emissions Inventory (UKAEI). 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.

The Modelling predicts that:

- At all statutory wildlife sites considered, the process contributions to annual ammonia concentration and nitrogen deposition rate are and would be below the Environment Agency lower threshold percentage of Critical Level and Critical Load (4% for a SAC, 20% for a SSSI).

- At closer parts of Cage Brook LWS, the process contributions to annual ammonia concentration and nitrogen deposition rate are and would be above the Environment Agency lower and upper threshold percentage of precautionary Critical Level and Critical Load (100% and 100% for a LWS). At all other LWSs, the process contributions to annual ammonia concentration and nitrogen deposition rate are and would be below the Environment Agency lower and upper threshold percentage of precautionary Critical Level and Critical Load (100% and 100% for a LWS).

- Should the proposed change to the rearing of broiler chickens at Marsh House Farm proceed, there would be a reduction in process contributions to ammonia concentration and nitrogen deposition rate at all of the wildlife sites considered.

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