A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing and Proposed Poultry Houses at Marlbrook Hall, near Leinthall Starkes in Herefordshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Rosina Bloor of Roger Parry and Partners LLP, on behalf of Mr. Andrew Morgan, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed egg laying chicken houses at Marlbrook Hall, near Leinthall Starkes in Herefordshire. SY8 2HR.

Ammonia emission rates from the existing poultry houses have been assessed and quantified based upon the Environment Agency standard ammonia emission factors/Bref emission factors. Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon an emissions model that estimates emissions from the Inno+ ammonia scrubbing equipment that would be fitted to the poultry houses. 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 site of the existing and proposed poultry houses at Marlbrook Hall is approximately 1.1 km north-north-east of the village of Leinthall Starkes in Herefordshire. The surrounding land is used largely for arable farming, although there is some livestock grazing and isolated areas of woodland nearby. The site is at an altitude of around 120 m and the land rises to hill tops to the south-east and falls gently toward the River Teme valley to the west.

There is currently a single poultry house at Marlbrook Hall, which provides accommodation for up to 8,000 birds; most of the chickens are egg laying hens, but there is also a small proportion of cockerels. The existing poultry house is ventilated by high speed uncapped ridge fans and gable end fans are used as additional ventilation during hot weather.

Under the proposal, three poultry houses would be constructed to the east of the existing house. The new poultry houses would provide accommodation for an additional 27,000 chickens; most of the chickens would be egg laying hens, but there would be a small proportion of cockerels. The fertilized eggs produced would be transferred to hatcheries elsewhere. Manure would collect within the houses and would be removed and transported off site at the end of each flock cycle, which is approximately once every 10 months. Under the proposal, the primary ventilation for both the existing house and the proposed houses would be provided by air scrubber units, which would provide the majority of the ventilation. Backup ventilation in case of scrubber failure and supplementary ventilation, which might be required in very warm weather, would be provided by high speed ridge or roof fans, each with a short chimney.

There are several areas designated as Ancient Woodlands (AWs) and/or Local Wildlife Sites (LWSs) within 2 km (the normal screening distance for non-statutory sites) of Marlbrook Hall. There are seven Sites of Special Scientific Interest (SSSIs) within 5 km (the normal screening distance for SSSIs) of the site. There are also a further five SSSIs is within 10 km. Two of the SSSIs are also designated as Special Areas of Conservation (SACs) Further details of the SSSIs and SACs are provided below.

- Burrington Meadow SSSI - Approximately 760 m to the north-east - An area of damp marshy permanent pasture bounded by scrub and drier neutral grassland.
- Burrington Sections SSSI - Approximately 1.4 km to the north-east - Geological.
- River Teme SSSI - Approximately 850 m to the north-west at its closest point - Of special interest as a representative, near-natural and biologically rich river type associated with sandstone and mudstones.
- Church Hill Quarry SSSI - Approximately 3.7 km to the north-west - Geological.
- Mocktree Quarries SSSI - Approximately 4.8 km to the north-north-west - Geological.
- Mortimer Forest SSSI - Approximately 3.1 km to the north-west at its closest point - Geological.
- 30 Elton Lane Cutting SSSI - Approximately 2.4 km to the east-south-east - Geological.
- Fishpool Valley SSSI - Approximately 4.4 km to the south-south-east - A secluded and well wooded stream valley which contains a series of pools created by damming the stream several centuries ago.
- Brampton Bryan Park SSSI - Approximately 6.9 km to the west - Selected because of its national importance as a wood pasture, ranking alongside sites such as the New Forest, Windsor Great Park, Sherwood Forest and Moccas Park. Associated with this are important communities of lichens and invertebrates.
- River Lugg SSSI - Approximately 5.2 km to the south-south-west at its closest point - The middle and lower reaches have species-rich, calcareous, lowland river communities due to the downstream influence of the drainage from the Silurian mudstones, siltstones and limestones.

- View Edge Quarries SSSI - Approximately 9.5 km to the north-north-west - Geological
- Downton Gorge SSSI/SAC - Approximately 2.0 km to the north-north-west at its closest point - Selected as an example of ancient semi-natural woodland displaying a number of types of woodland, some of which are nationally scarce. Over 100 species of lichen have been recorded from Downton Gorge which is considered to be a site of national importance for this group of plants. A number of these are typically associated with ancient wood pasture, and one of these, tree lungwort *Lobaria pulmonaria* is only found at one other site in central England. Similarly, over 90 species of mosses have been recorded including a number of local and rare species.
- River Clun SAC/River Teme SSSI - Approximately 4.5 km to the north-west at its closest point - Of special interest as a representative, near-natural and biologically rich river type associated with sandstone and mudstones.

Maps of the surrounding area showing the positions of the poultry houses, the AWs, the LWSs, the SSSIs and the SACs are provided in Figures 1a and 1b. In the figures, the AWs are shaded in olive, LWSs are shaded in yellow, the SSSIs are shaded in green, the SACs are shaded in purple and the site of poultry unit is outlined in blue.

Figure 1a. The area surrounding Marlbrook Hall – concentric circles radii 2 km (olive), 5 km (green) and 10 km (purple)

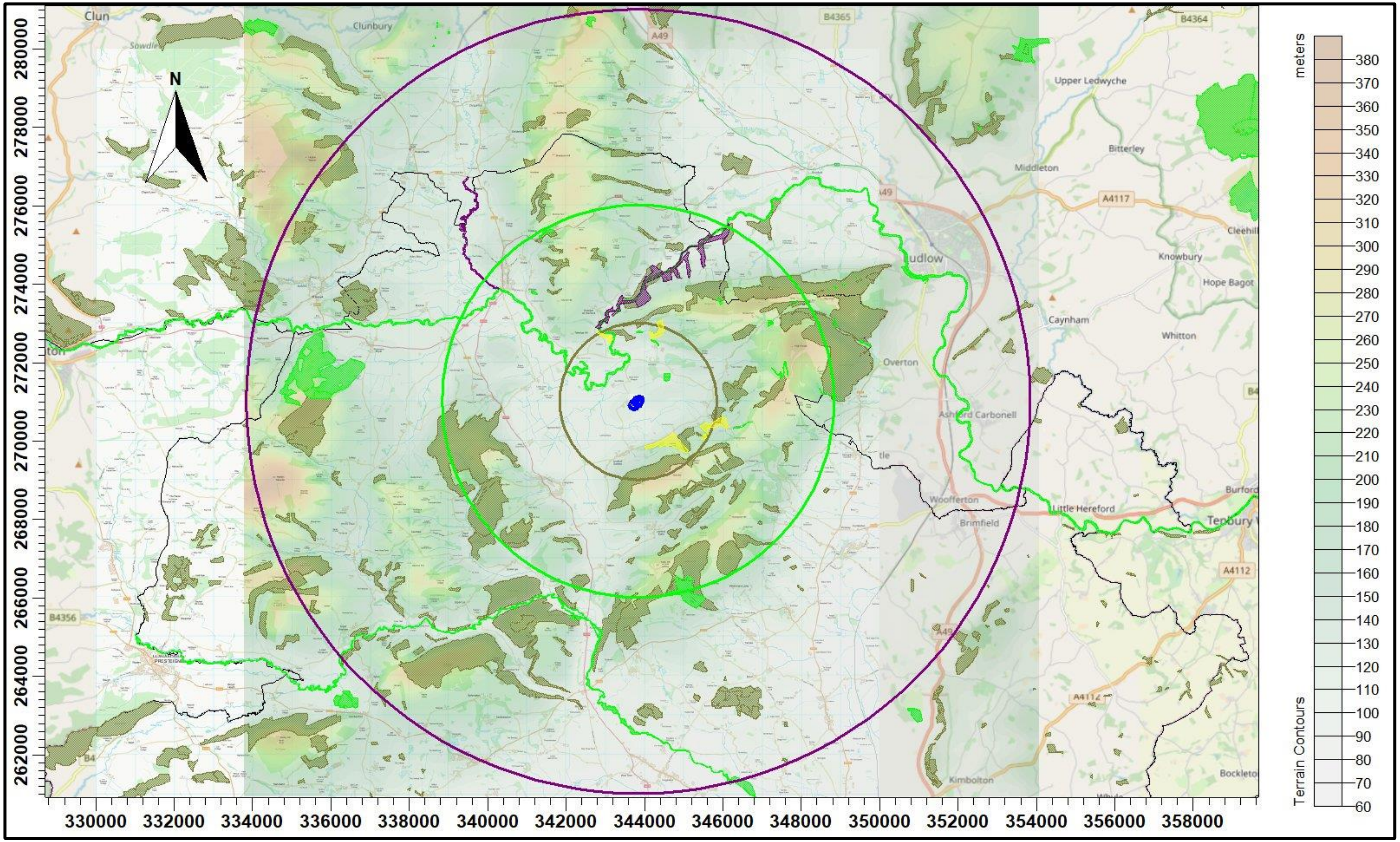
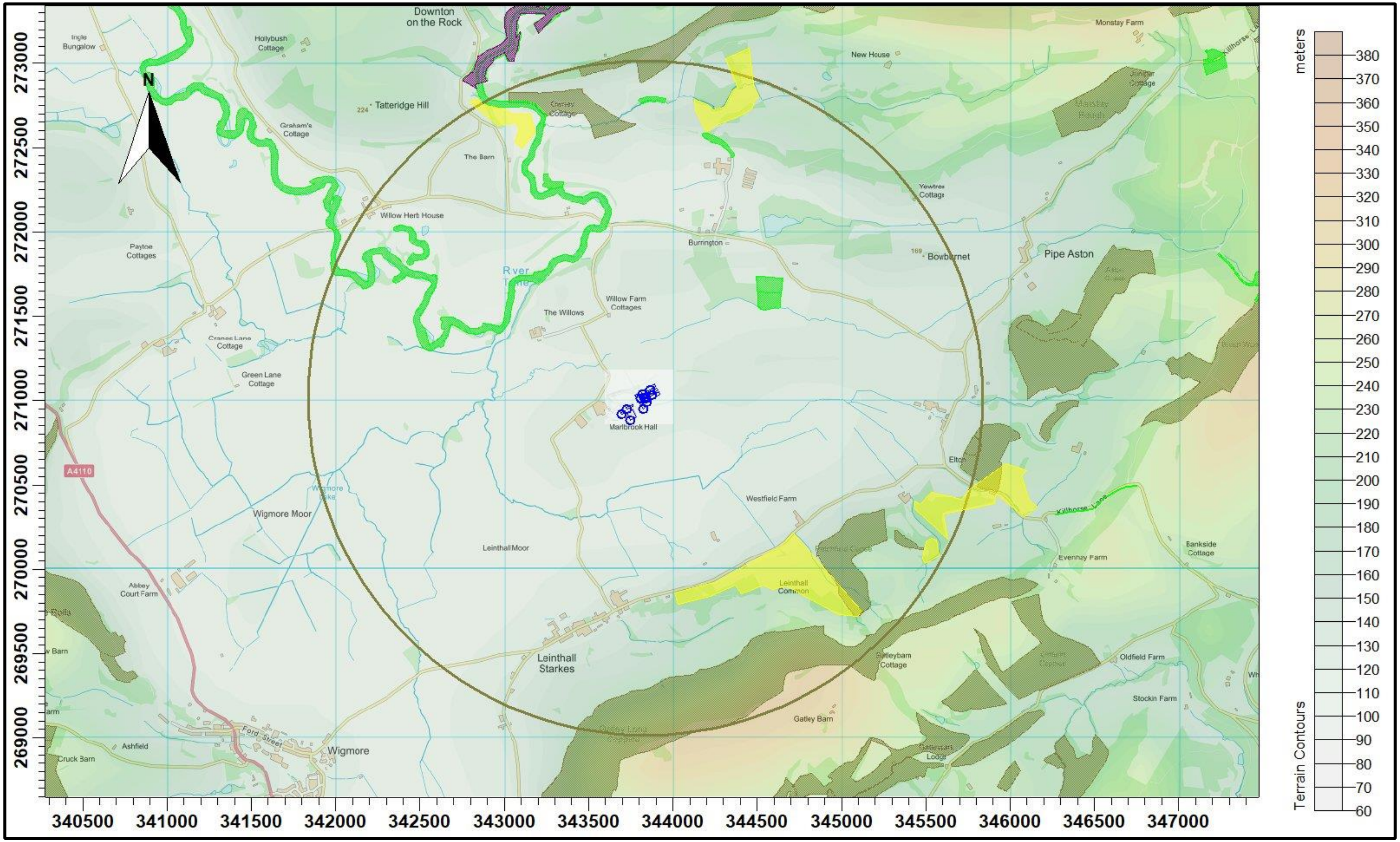


Figure 1b. The area surrounding Marlbrook Hall – a closer view



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

3.1 Ammonia concentration and nitrogen and acid deposition

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

3.2 Background ammonia levels and nitrogen and acid deposition

The background ammonia concentration (annual mean) in the area around Marlbrook Hall and the wildlife sites is 1.93 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 29.96 kg-N/ha/y and to short vegetation is 17.78 kg-N/ha/y. The background acid deposition rate to woodland is 2.06 keq/ha/y and to short vegetation is 1.29 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, October 2020).

3.3 Critical Levels & Critical Loads

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

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

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

For ammonia concentration in air, the Critical Level for higher plants is 3.0 $\mu g\text{-}NH_3/m^3$ 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 $\mu g\text{-}NH_3/m^3$ as an annual mean.

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

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

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

Site	Critical Level (µg-NH_3/m^3)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
AWs and LWSs	1.0 [1]	-	-
Burrington Sections SSSI; Burrington Farm Stream Section SSSI; Church Hill Quarry SSSI; Mocktree Quarries SSSI; Mortimer Forest SSSI; Elton Lane Cutting SSSI, View Edge Quarries SSSI	n/a [3]	n/a [3]	n/a [3]
River Teme SSSI, Downton Gorge SAC/SSSI and Brampton Bryan Park SSSI	1.0 [1 & 2]	10.0 [2]	-
Burrington Meadow SSSI	3.0 [2]	15.0 [2]	-
Fishpool Valley SSSI	1.0 [1 & 2]	15.0 [2]	-
River Clun SAC	3.0 [2]	n/a [4]	n/a [4]

1. A precautionary figure used where details of the site are unavailable, or citations indicate that sensitive lichens and bryophytes may be present.
2. Based upon the citation for the site and information obtained from APIS.
3. Designated for geological features only.
4. No Critical Loads for listed species.

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% 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. This advice is based primarily upon the Habitats Directive, EIA Directive and the Countryside and Rights of Way Act.

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.

Note that a process contribution of 1% of Critical Level or Critical Load would normally be considered insignificant. A process contribution that is above 1% of Critical Level or Critical Load should be regarded as potentially significant; however, 1% of Critical Level or Critical Load should not be used as a threshold above which damage is implied.

3.5 Quantification of ammonia emissions

Ammonia emission rates from poultry houses 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.

3.5.1 Ammonia emissions from the existing housing

The Environment Agency provides an emission factor for egg laying chickens of 0.21 kg-NH_3/bird place/y; this figure is used to calculate the emissions from the existing poultry houses.

3.5.2 Ammonia emissions from the proposed housing/scrubbers

For the calculation of the emission rates from the air scrubbers, the outlet ammonia concentration is assumed to be a constant 2 ppm (1,408.8 µg/m^3). The guaranteed maximum outlet concentration from the manufacturers of the ammonia scrubbing equipment is 1.2 ppm and typically, an agricultural wet chemical scrubber can achieve 1 to 1.5 ppm outlet ammonia concentration, therefore the 2 ppm assumed is precautionary.

The ventilation rates used in the calculations are based on industry standard practices. For the calculations, the minimum ventilation rate is set at 1.0 m^3-air/bird/h and the maximum ventilation rate is 7.5 m^3-air/bird/h. If the external temperature is 13 Celsius, or lower, minimum ventilation only is assumed for the calculation. If the external temperature is 23 Celsius, or more, then the maximum ventilation rate is assumed. A transitional ventilation rate is calculated between these extremes. Based upon these principles, an ammonia emission rate for each hour of the period modelled is calculated by multiplying the outlet concentration by the ventilation rate.

The capacity of each of the air scrubbers would be 100,000 m^3/h (27.778 m^3/s), if the modelled ventilation rate exceeds the scrubber capacity, additional ventilation would be provided by the ridge mounted fans, in this case it is expected that this would occur very rarely. The concentration is dependent upon the crop stage and the ammonia concentration is assumed to be approximately 22 ppm; this figure is used because, assuming standard ventilation rates, it approximates the regulatory ammonia emission factor. Similarly, to the scrubber emissions, an emission rate from the bypass ventilation system is calculated by multiplying the internal concentration by the ventilation rate. Overall, the emissions are equivalent to an emission factor of 0.01925 kg-NH_3/bird place/y, which is approximately 9% of the regulatory figure.

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

Table 2. Details of poultry numbers and ammonia emission rate

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Existing Housing	8,000	Broiler Breeder Chickens	0.21	0.053236
Existing (as proposed) and Proposed Housing	35,000	Broiler Breeder Chickens	0.01925 (average equivalent)	0.021354 (average equivalent)

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

The Atmospheric Dispersion Modelling System (ADMS) ADMS 5 is a new generation Gaussian plume air dispersion model, which means that the atmospheric boundary layer properties are characterised by two parameters; the boundary layer depth and the Monin-Obukhov length rather than in terms of the single parameter Pasquill-Gifford class.

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

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

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

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

4.1 Meteorological data

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

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

The GFS is a spectral model: the physics/dynamics model has an equivalent resolution of approximately 13 km (latterly 9km); terrain is understood to be resolved at a resolution of approximately 2 km, with sub-13/9 km terrain effects parameterised. Site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional records may be over represented because the instrumentation used may not record wind speed below approximately 0.5 m/s and start up wind speeds may be greater than 1.0 m/s. In NWP data, the wind speed is continuous down to 0.0 m/s, allowing the calms module of ADMS to function correctly.

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

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

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a.

Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location of the poultry unit is shown in Figure 2b; it should be noted that elsewhere in the modelling domain the modified wind roses may differ, reflecting the local flow in that part of the domain. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 340 m. Please also note that FLOWSTAR is used to obtain a local flow field, not to explicitly model dispersion in complex terrain as defined in the ADMS User Guide; therefore, the ADMS default value for minimum turbulence length has been amended.

Figure 2a. The wind rose. Raw GFS derived data for 52.334 N, 2.824 W, 2016 – 2019

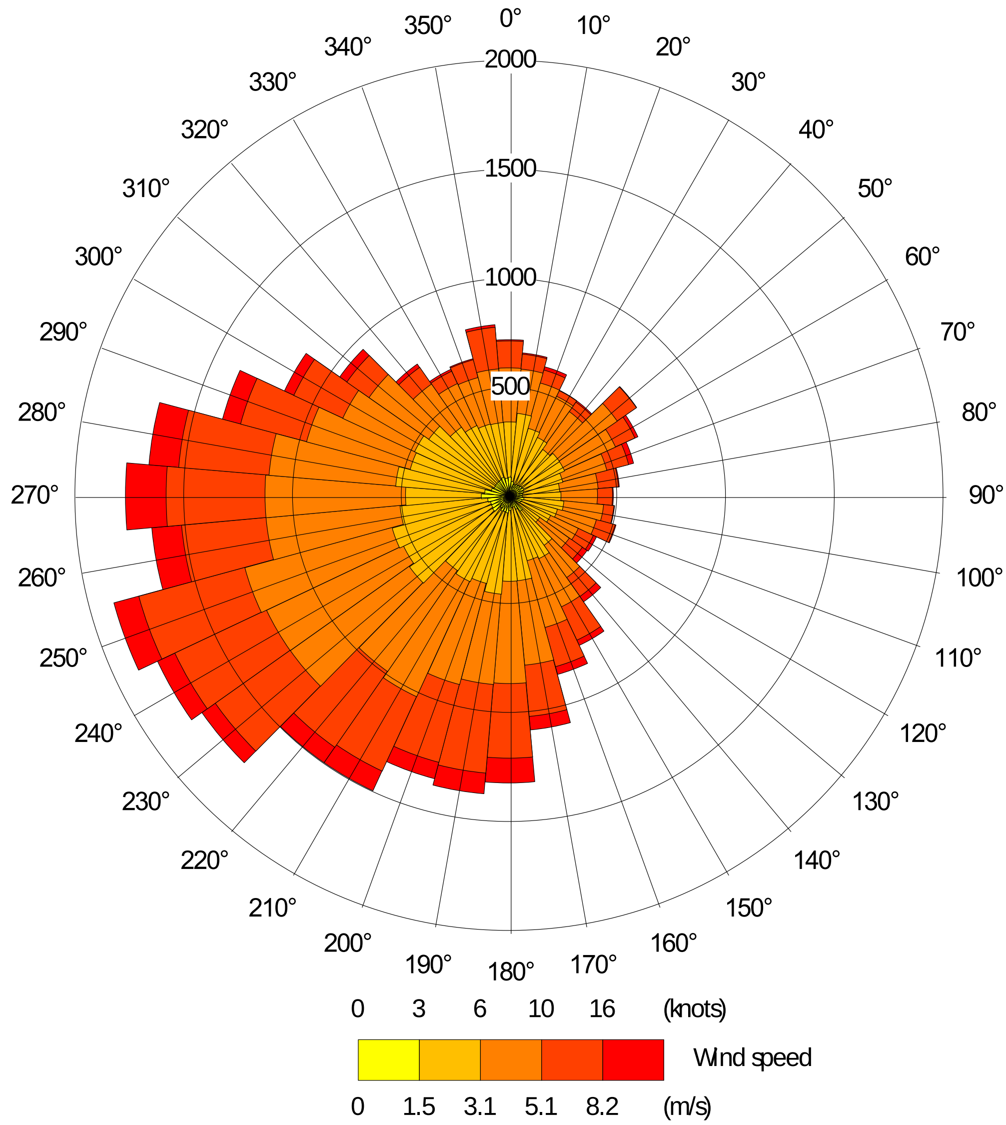
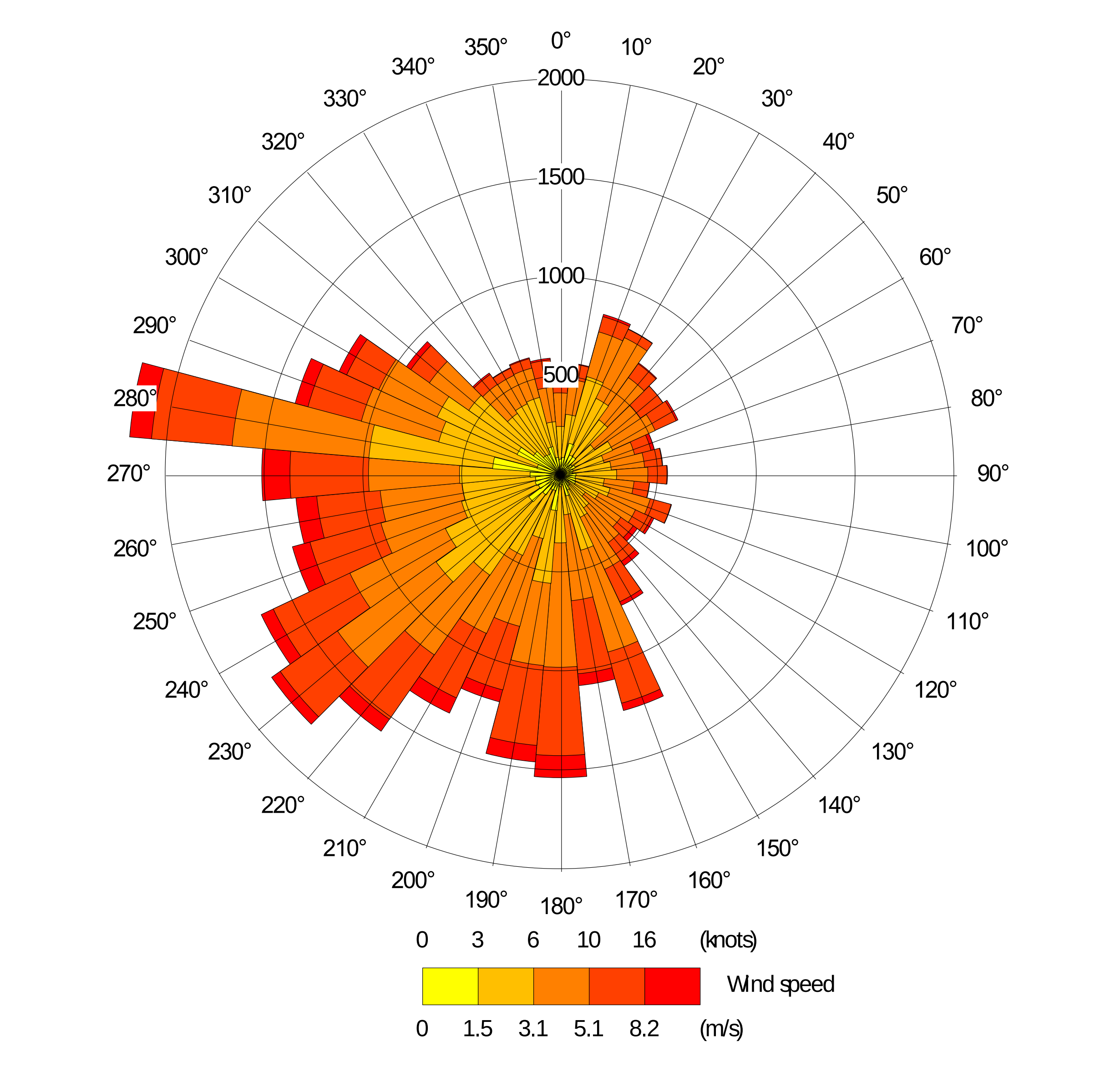


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 343850, 271000, 2016 – 2019



4.2 Emission sources

Emissions from high speed ridge/roof fans that are used to ventilate the existing poultry house are represented by three point sources within ADMS. (EX1 1, 2 & 3). The emissions from the existing gable end fans are represented by two volume sources within ADMS (GAB_SE and GAB_NW).

Emissions from the air scrubber units that would be used for primary ventilation for existing proposed poultry houses are represented by three point sources per scrubber within ADMS (EX1_SCR 1, 2 & 3 and PR1_SCR to PR3_SCR 1, 2 & 3). Emissions from high speed ridge/roof fans that would be used for bypass/backup ventilation for the existing and proposed poultry houses are represented by three point sources per house within ADMS (EX1_BYP 1, 2 & 3 and PR1_BYP to PR3_BYP 1, 2 & 3).

Details of the point and volume source parameters are shown in Table 3a and Table 3b. The positions of the sources may be seen in Figures 3a and 3b.

Table 3a. Point source parameters

Source ID (Scenario)	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (g-NH_3/s)
EX 1, 2 & 3 (Existing)	5.5	0.8	11.0	Variable [1]	0.017745 [2]
EX1_SCR 1, 2 & 3 (Proposed)	6.2	0.8	9.0	Variable [1]	Variable [1]
PR1_SCR to PR3_SCR 1, 2 & 3 (Proposed)	6.2	0.8	9.0	Variable [1]	Variable [1]
EX1_BYP 1, 2 & 3 (Proposed)	5.5	0.8	11.0	Variable [1]	Variable [1]
PR1_BYP to PR3_BYP 1, 2 & 3 (Proposed)	5.5	0.8	11.0	Variable [1]	Variable [1]

Table 3b. Volume source parameters

Source ID (Scenario)	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate per source (g-NH_3/s)
GAB_SE (Existing)	5.0	15.5	3.0	0.0	Ambient	0.013309 [3]
GAB_NW (Existing)	5.0	15.5	3.0	0.0	Ambient	0.013309 [3]

1. Dependent on ambient temperature.
2. Reduced by 50% when the ambient temperature equals or exceeds 21 Celsius.
3. 50% of the total emission emitted only when the ambient temperature equals or exceeds 21 Celsius.

4.3 Modelled buildings

The structure of the poultry houses, scrubber units and nearby farm buildings may affect the plumes from the point sources. Therefore, the buildings are modelled within ADMS. The positions of the existing and proposed modelled buildings may be seen in Figures 3a and 3b, where they are marked by grey rectangles.

4.4 Discrete receptors

Fifty-three discrete receptors have been defined at the AWs and LWSs, the SSSIs and the SACs. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b, where they are marked by enumerated pink rectangles.

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition field used in the detailed modelling, a regular Cartesian grid has been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The position of the Cartesian grid may be seen in Figures 4a and 4b, where it is marked by grey lines.

4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 22.0 km x 22.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 340 m.

4.7 Roughness Length

A fixed surface roughness length of 0.25 m has been applied over the entire modelling domain. As a precautionary measure, the GFS meteorological data is assumed to have a roughness length of 0.225 m. The effect of the difference in roughness length is precautionary as it increases the frequency of low wind speeds and the stability and therefore increases predicted ground level concentrations.

Figure 3a. The positions of the modelled buildings and sources - Existing Scenario

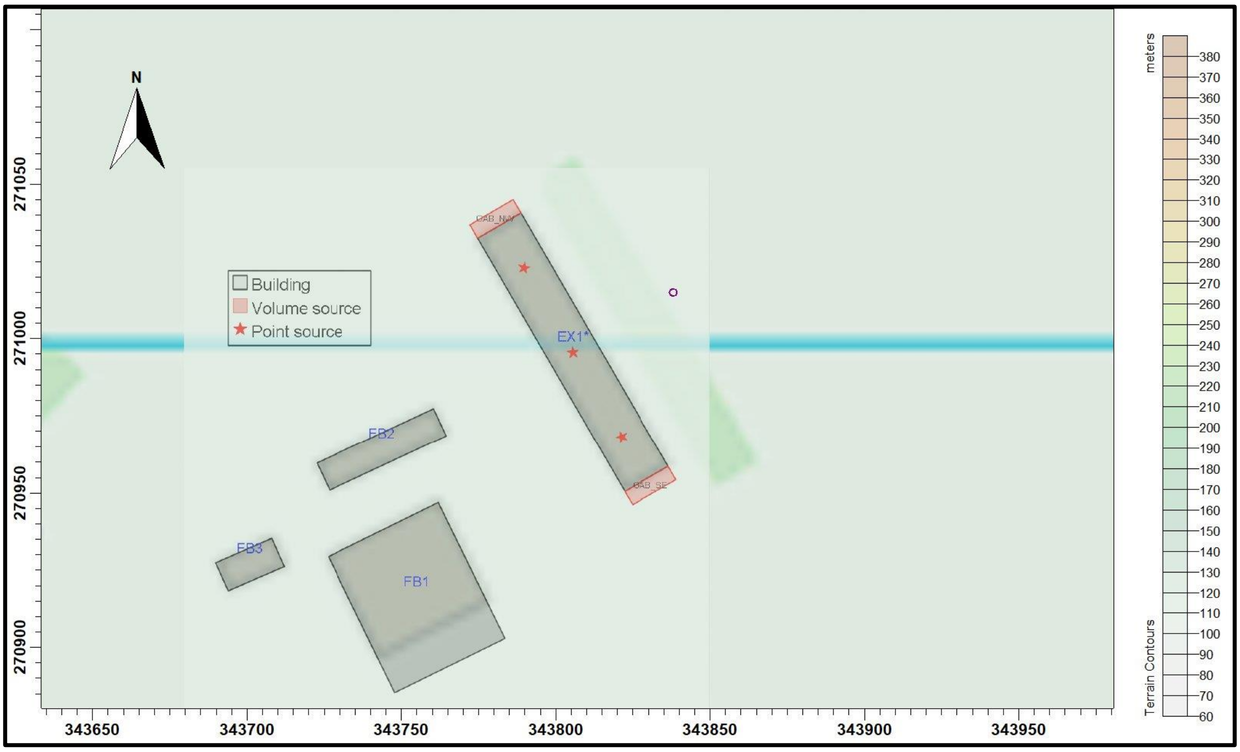


Figure 3b. The positions of the modelled buildings and sources - Proposed Scenario

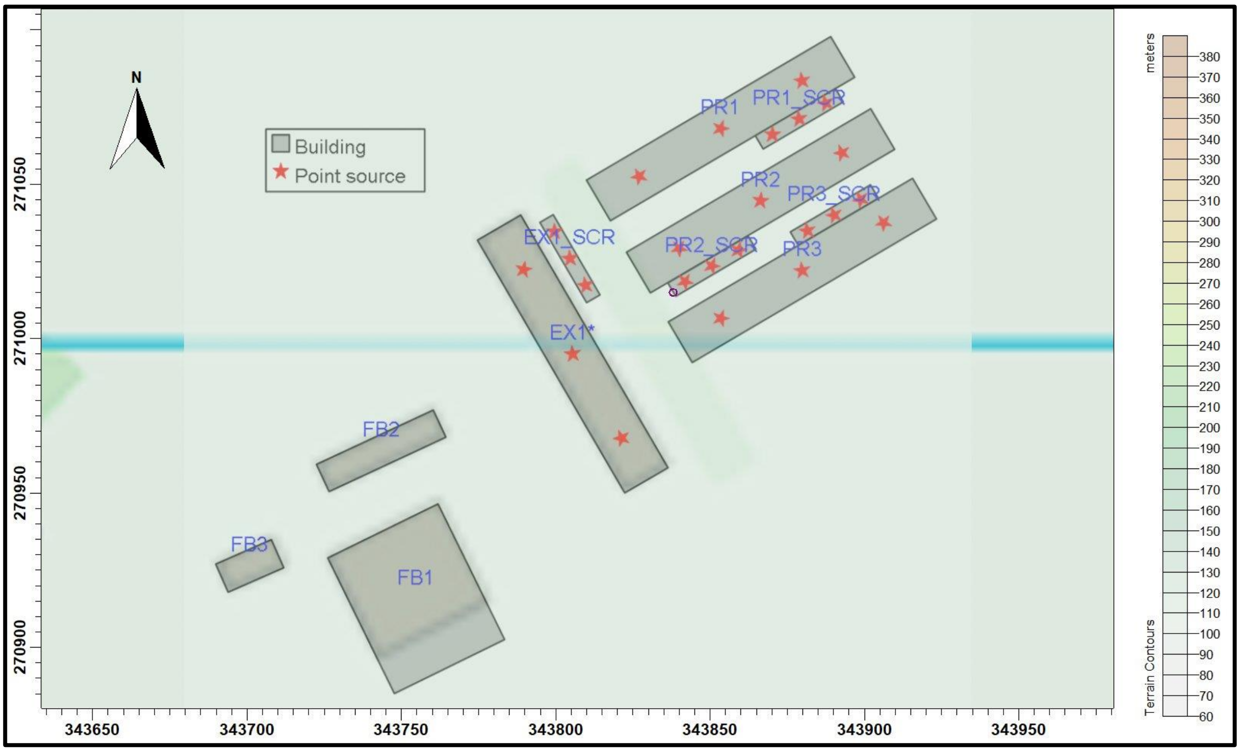


Figure 4a. The regular Cartesian grids and discrete receptors – a broad scale view

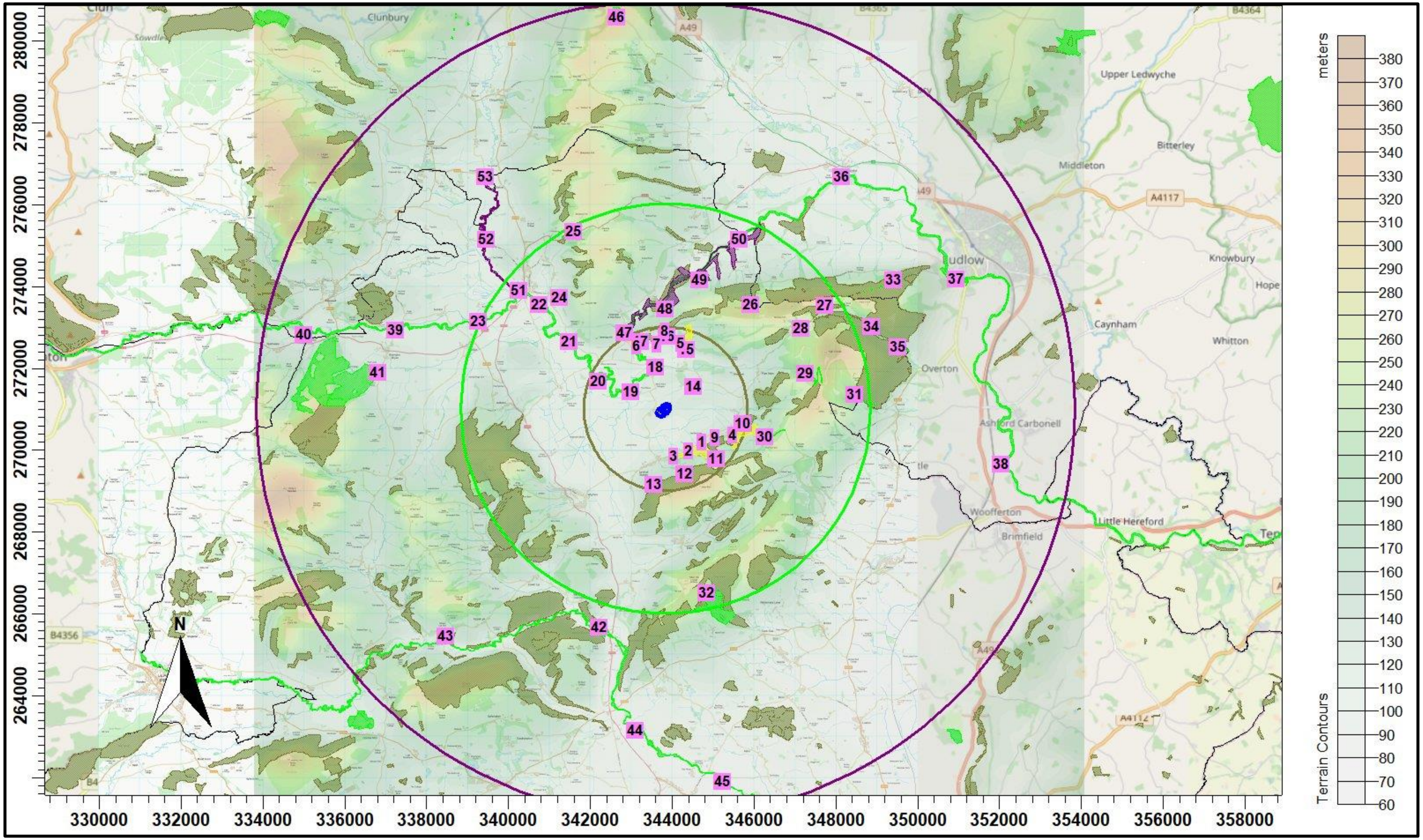
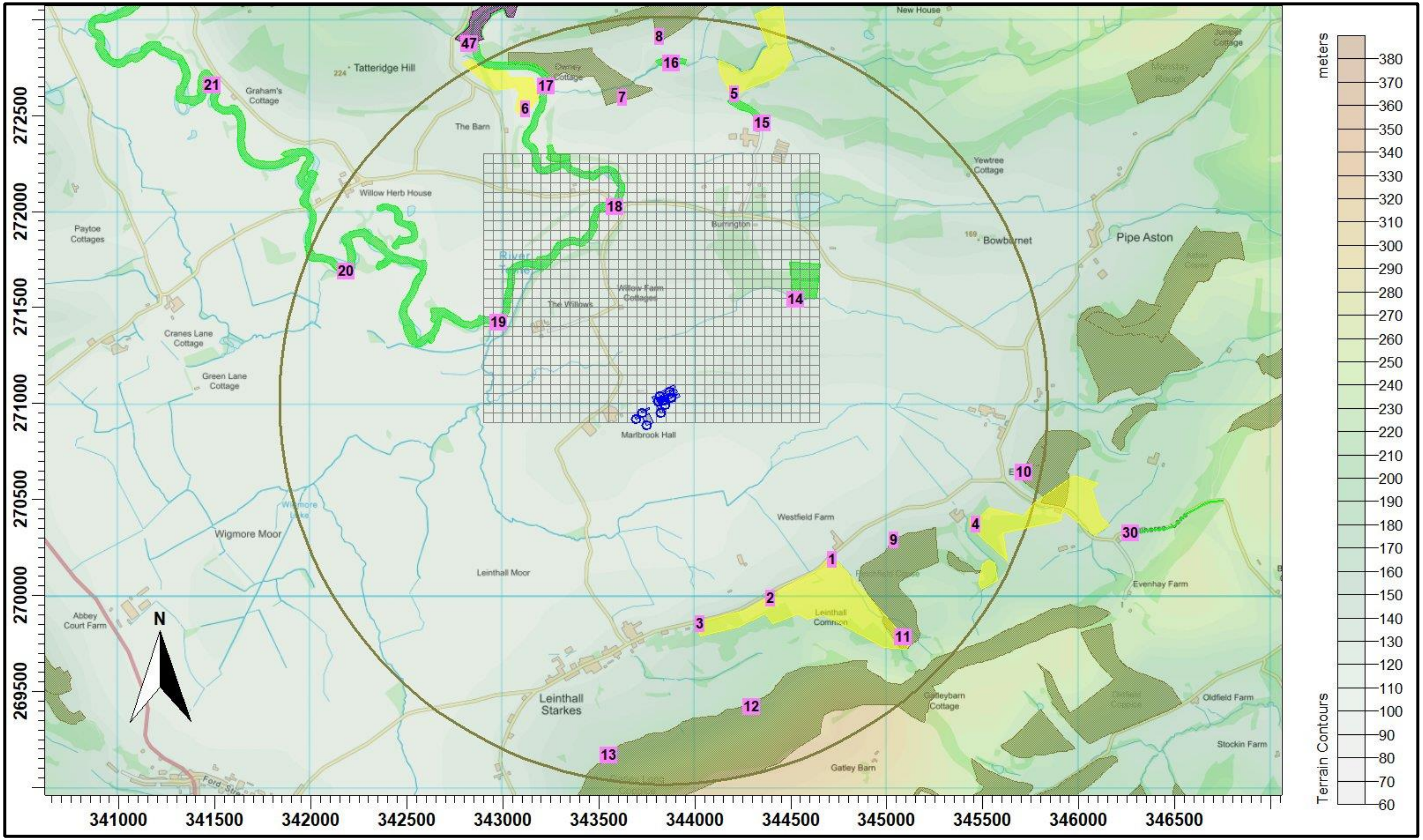


Figure 4b. The high resolution regular Cartesian grid and the discrete receptors – a closer view



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 over heavily grazed grassland. Where deposition over water surfaces is calculated, a deposition velocity of 0.005 m/s is used. In summary, the method is as follows:

In summary, the method is as follows:

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

Table 4. Deposition velocities

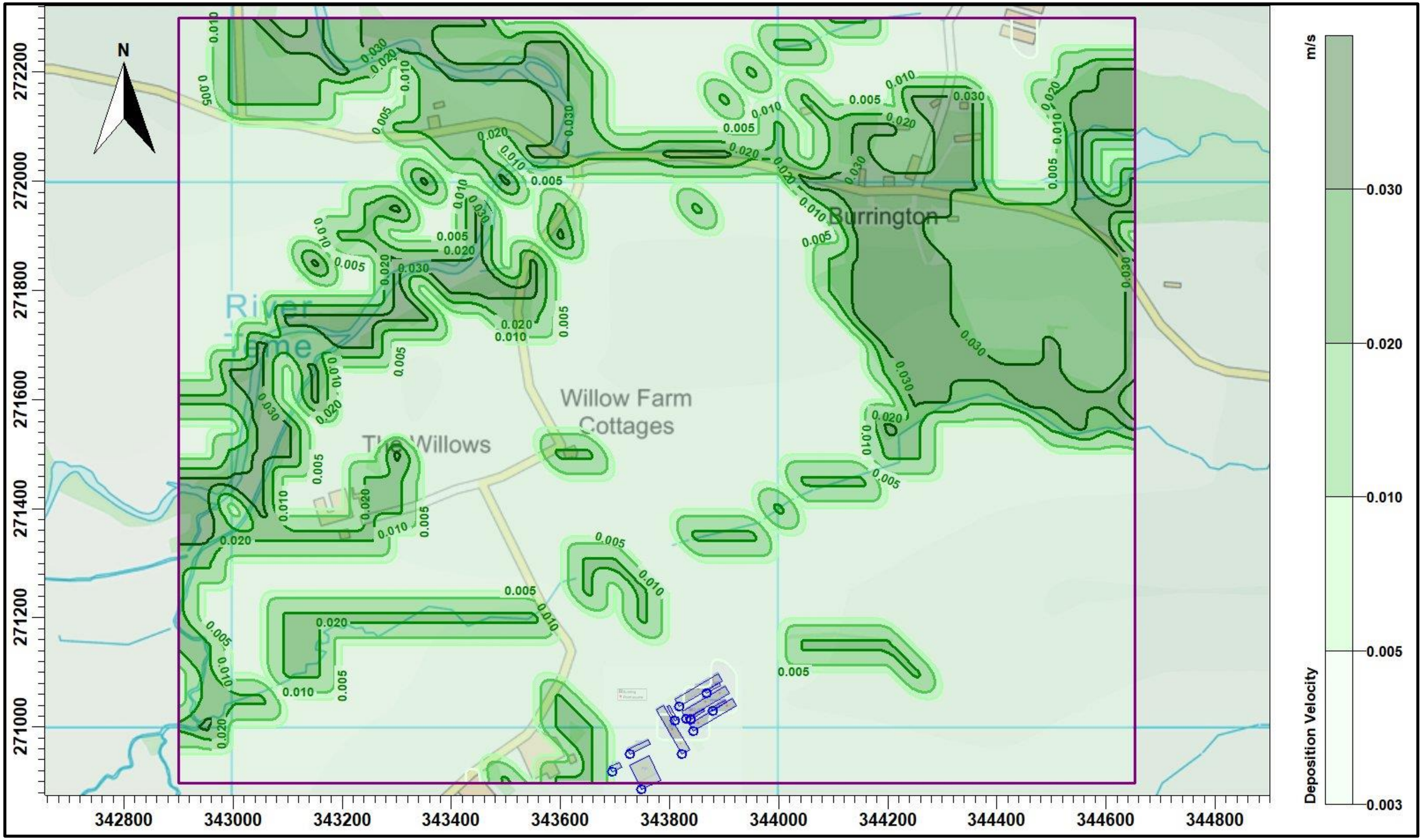
NH_3 concentration (PC + background) (µg/m^3)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity – arable farmland/rye grass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

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

A contour plot of the spatially varying deposition field is provided in Figure 5.

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

Figure 5. The spatially varying deposition field



5. Details of the Model Runs and Results

ADMS was run a total of sixteen times, once for each year of the meteorological record 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 – GFS data.
- Without calms, with terrain and fixed deposition at 0.003 m/s – GFS data.

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

Details of the predicted annual mean ammonia concentrations at each discrete receptor are provided in Table 5. In the Table, predicted ammonia concentrations, or ammonia concentrations that are equivalent to a nitrogen deposition rate, that are in excess of the Environment Agency's upper threshold percentage of the relevant Critical Level or Critical Load (20% for an internationally designated site, 50% for a SSSI and 100% for a non-statutory site) are coloured red. Predicted ammonia concentrations, or ammonia concentrations that are equivalent to a nitrogen deposition rate, that are in the range between the Environment Agency's upper threshold and lower threshold percentage of the relevant Critical Level or Critical load (4% and 20% for an internationally designated site, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site) are coloured blue. Additionally, predicted ammonia concentrations, or ammonia concentrations that are equivalent to a nitrogen deposition rate, that exceed 1% of the relevant Critical Level or Critical Load at a SSSI or an internationally designated site, are highlighted with bold text. For convenience, cells referring to the AWs are shaded olive, cells referring to the LWSs are shaded yellow, cells referring to the SSSIs are shaded green and cells referring to the SACs are shaded purple.

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

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Existing				Existing (as proposed) and Proposed			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s
1	344715	270189	LWS	**0.025**	**0.025**	**0.018**	**0.015**	**0.012**	**0.012**	**0.010**	0.006
2	344396	269987	LWS	**0.018**	**0.018**	**0.011**	0.009	**0.010**	0.010	0.006	0.004
3	344025	269850	LWS	**0.020**	**0.020**	0.009	0.007	**0.012**	**0.012**	0.007	0.005
4	345465	270371	LWS	**0.022**	**0.022**	**0.024**	**0.018**	**0.010**	0.010	**0.012**	0.007
5	344207	272613	LWS	**0.019**	**0.019**	**0.025**	**0.018**	**0.011**	**0.011**	**0.013**	0.009
6	343119	272535	LWS	**0.015**	**0.014**	**0.014**	**0.011**	0.009	0.009	0.010	0.006
7	343621	272593	AW	**0.020**	**0.020**	**0.018**	**0.014**	**0.012**	**0.012**	**0.011**	0.008
8	343816	272909	AW	**0.016**	**0.016**	**0.016**	**0.012**	0.009	0.009	0.008	0.005
9	345038	270290	AW	**0.027**	**0.026**	**0.022**	**0.017**	**0.012**	**0.012**	**0.012**	0.007
10	345712	270642	AW	**0.020**	**0.020**	**0.028**	**0.022**	**0.010**	**0.010**	**0.015**	0.009
11	345087	269782	AW	**0.014**	**0.014**	0.009	0.006	0.008	0.007	0.005	0.003
12	344295	269420	AW	**0.012**	**0.012**	0.004	0.003	0.007	0.007	0.003	0.002
13	343552	269166	AW	**0.012**	**0.012**	0.008	0.005	0.007	0.007	0.005	0.003
14	344526	271540	Burrington Meadow SSSI	**0.057**	**0.056**	**0.061**	**0.054**	**0.032**	**0.032**	**0.035**	**0.029**
15	344349	272460	Burrington Sections SSSI	**0.021**	**0.020**	**0.022**	**0.016**	**0.012**	**0.012**	**0.012**	0.008
16	343877	272770	Burrington Sections SSSI	**0.018**	**0.018**	**0.020**	**0.015**	**0.010**	**0.010**	**0.010**	0.007
17	343227	272652	River Teme SSSI	**0.016**	**0.015**	**0.015**	**0.011**	0.009	0.009	0.010	0.006
18	343581	272022	River Teme SSSI	**0.033**	**0.032**	**0.035**	**0.030**	**0.020**	**0.019**	**0.023**	**0.017**
19	342976	271422	River Teme SSSI	**0.017**	**0.017**	**0.025**	**0.019**	**0.011**	**0.011**	**0.015**	**0.011**
20	342184	271688	River Teme SSSI	0.008	0.008	**0.015**	0.010	0.005	0.005	0.008	0.005
21	341485	272657	River Teme SSSI	0.005	0.005	0.006	0.004	0.003	0.003	0.004	0.002
22	340755	273553	River Teme SSSI	0.004	0.004	0.003	0.002	0.002	0.002	0.002	0.001
23	339261	273138	River Teme SSSI	0.003	0.003	0.004	0.002	0.001	0.001	0.002	0.001
24	341233	273735	Church Hill Quarry SSSI	0.004	0.004	0.003	0.002	0.003	0.003	0.002	0.001
25	341586	275332	Mocktree Quarries SSSI	0.004	0.004	0.002	0.001	0.002	0.002	0.001	0.001
26	345906	273552	Mortimer Forest SSSI	0.009	0.009	0.005	0.004	0.004	0.004	0.003	0.002

Table 5. (continued)

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)							
				Existing				Proposed			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s	GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s
27	347733	273531	Mortimer Forest SSSI	0.006	0.006	0.004	0.003	0.003	0.003	0.002	0.001
28	347150	272976	Mortimer Forest SSSI	0.008	0.008	0.006	0.004	0.004	0.004	0.003	0.002
29	347255	271865	Mortimer Forest SSSI	0.010	0.010	0.006	0.004	0.005	0.005	0.004	0.002
30	346271	270326	Elton Lane Cutting SSSI	**0.014**	**0.013**	**0.017**	**0.013**	0.007	0.007	0.009	0.005
31	348457	271345	Mortimer Forest SSSI	0.006	0.006	0.004	0.002	0.003	0.003	0.002	0.001
32	344830	266513	Fishpool Valley SSSI	0.004	0.004	0.002	0.001	0.002	0.002	0.001	0.000
33	349398	274151	Mortimer Forest SSSI	0.004	0.004	0.003	0.002	0.002	0.002	0.001	0.001
34	348867	273011	Mortimer Forest SSSI	0.006	0.006	0.004	0.002	0.003	0.003	0.002	0.001
35	349523	272527	Mortimer Forest SSSI	0.005	0.005	0.003	0.002	0.003	0.003	0.001	0.001
36	348125	276675	River Teme SSSI	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001
37	350936	274180	River Teme SSSI	0.003	0.003	0.002	0.001	0.002	0.002	0.001	0.001
38	352025	269647	River Teme SSSI	0.003	0.003	0.005	0.002	0.002	0.002	0.002	0.001
39	337237	272932	River Teme SSSI	0.002	0.002	0.003	0.001	0.001	0.001	0.001	0.001
40	335002	272827	River Teme SSSI	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.000
41	336794	271899	Brampton Bryan Park SSSI	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.000
42	342213	265679	River Lugg SSSI	0.003	0.003	0.004	0.002	0.001	0.001	0.002	0.001
43	338460	265447	River Lugg SSSI	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000
44	343099	263149	River Lugg SSSI	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.000
45	345228	261905	River Lugg SSSI	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000
46	342633	280576	View Edge Quarries SSSI	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000
47	342828	272872	Downton Gorge SSSI/SAC	**0.011**	**0.010**	0.008	0.006	0.006	0.006	0.006	0.004
48	343836	273454	Downton Gorge SSSI/SAC	**0.012**	**0.012**	**0.013**	0.009	0.007	0.006	0.006	0.004
49	344678	274148	Downton Gorge SSSI/SAC	0.008	0.008	**0.011**	0.007	0.004	0.004	0.005	0.003
50	345640	275147	Downton Gorge SSSI/SAC	0.005	0.005	0.006	0.004	0.003	0.003	0.003	0.002
51	340256	273898	River Clun SAC/River Teme SSSI	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.001
52	339461	275156	River Clun SAC/River Teme SSSI	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001
53	339433	276673	River Clun SAC/River Teme SSSI	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000

5.2 Detailed deposition modelling

The detailed modelling was carried out over a restricted domain covering Burrington Meadow SSSI and closer parts of the River Teme SSSI, where the fixed deposition runs of the preliminary modelling of the Proposed Scenario indicated that the process contribution to the annual mean ammonia concentrations, or ammonia concentrations that are equivalent to a nitrogen deposition rate, would potentially exceed 1% of the precautionary Critical Level of 1.0 µg-NH_3/m^3.

There are no predicted exceedances of the Environment Agency lower threshold of the relevant Critical Level or Load at any site considered and apart from at Burrington Meadow SSSI and closer parts of the River Teme SSSI, there are no predicted exceedances of 1% of the precautionary Critical Level of 1.0 µg-NH_3/m^3.

The predicted maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors within the detailed modelling domain are shown in Table 6a (Existing Scenario), Table 6b (Existing (as proposed) and Proposed Scenario), Table 6c (Proposed only Scenario), Table 6c (Change in Process contributions - Existing (as proposed) and Proposed minus Existing). In the Tables, predicted ammonia concentrations and nitrogen deposition rates that are in excess of the Environment Agency's upper threshold percentage of the relevant Critical Level or Critical Load (50% for a SSSI) are coloured red. Predicted ammonia concentrations and nitrogen deposition rates that are in the range between the Environment Agency's upper threshold and lower threshold percentages (20% and 50% for a SSSI) are coloured blue. Additionally, predicted ammonia concentrations and nitrogen deposition rates that are greater than 1% of the Critical Level or Load at a SSSI, are highlighted with bold text.

Contour plots of the predicted change (Existing (as proposed) and Proposed minus Existing) in ground level maximum annual mean ammonia concentration and the maximum annual nitrogen deposition rate are shown in Figures 6a and 6b.

Table 6a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors - The Existing poultry house only

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
14	344526	271540	Burrington Meadow SSSI	0.020	3.0	15.0	0.042	**1.4**	0.22	**1.5**
18	343581	272022	River Teme SSSI	0.030	1.0	10.0	0.027	**2.7**	0.21	**2.1**
19	342976	271422	River Teme SSSI	0.030	1.0	10.0	0.018	**1.8**	0.14	**1.4**

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors - The Existing poultry house (as proposed) and the Proposed poultry houses

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
14	344526	271540	Burrington Meadow SSSI	0.020	3.0	15.0	0.024	0.8	0.12	0.8
18	343581	272022	River Teme SSSI	0.030	1.0	10.0	0.015	**1.5**	0.12	**1.2**
19	342976	271422	River Teme SSSI	0.030	1.0	10.0	0.010	**1.0**	0.07	0.7

Table 6c. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors - The Proposed poultry houses only

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
14	344526	271540	Burrington Meadow SSSI	0.020	3.0	15.0	0.019	0.6	0.10	0.6
18	343581	272022	River Teme SSSI	0.030	1.0	10.0	0.012	**1.2**	0.09	0.9
19	342976	271422	River Teme SSSI	0.030	1.0	10.0	0.007	0.7	0.06	0.6

Table 6b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors - The Change in Process Contributions - The Existing poultry house (as proposed) and the Proposed poultry houses minus the Existing poultry houses

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
14	344526	271540	Burrington Meadow SSSI	0.020	3.0	15.0	-0.018	-0.6	-0.10	-0.6
18	343581	272022	River Teme SSSI	0.030	1.0	10.0	-0.012	-1.2	-0.09	-0.9
19	342976	271422	River Teme SSSI	0.030	1.0	10.0	-0.008	-0.8	-0.07	-0.7

Figure 6a. Maximum annual ammonia concentration – The Change in Process Contributions - Existing poultry house (as proposed) and the Proposed poultry houses minus The Existing poultry house

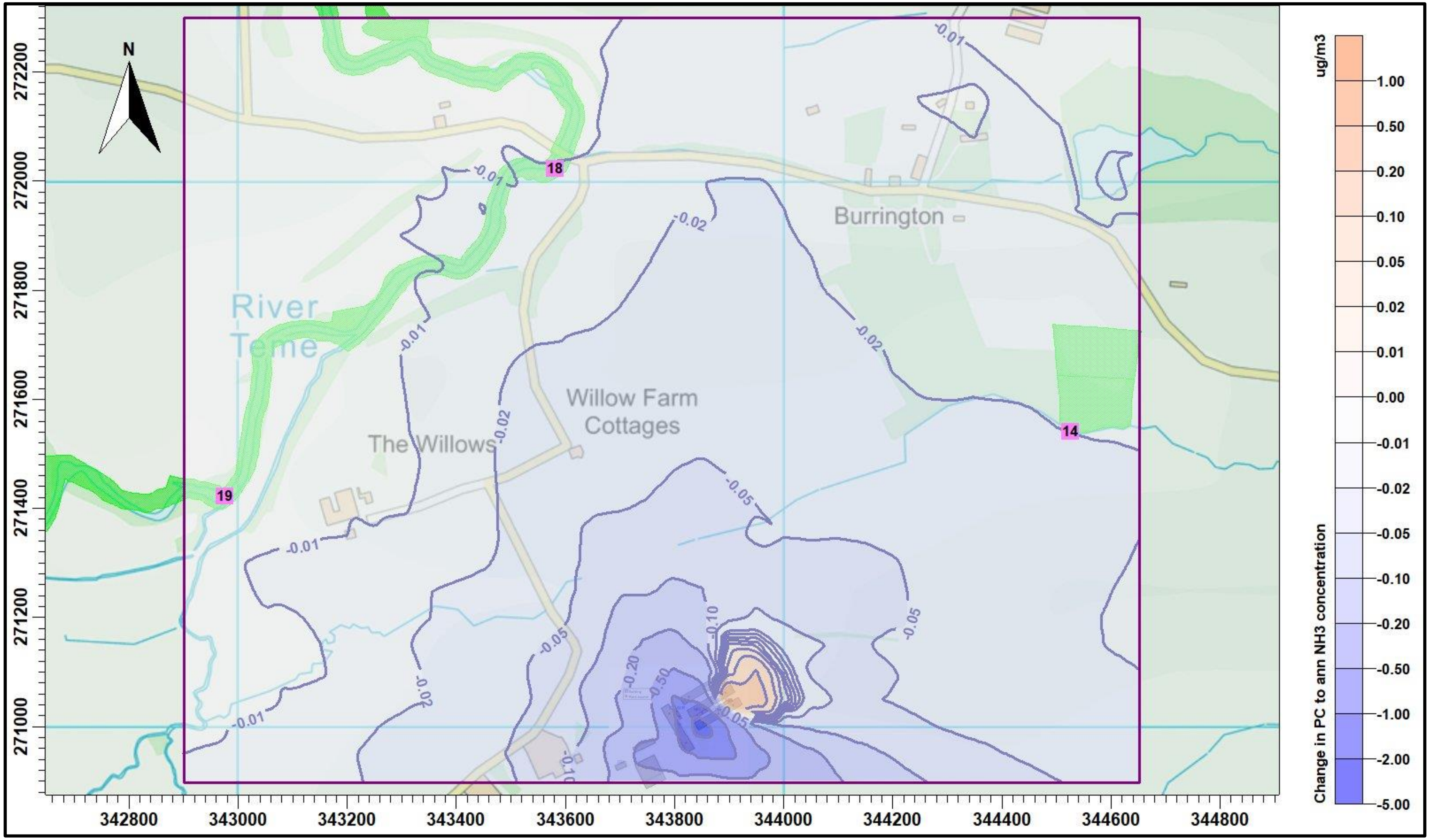
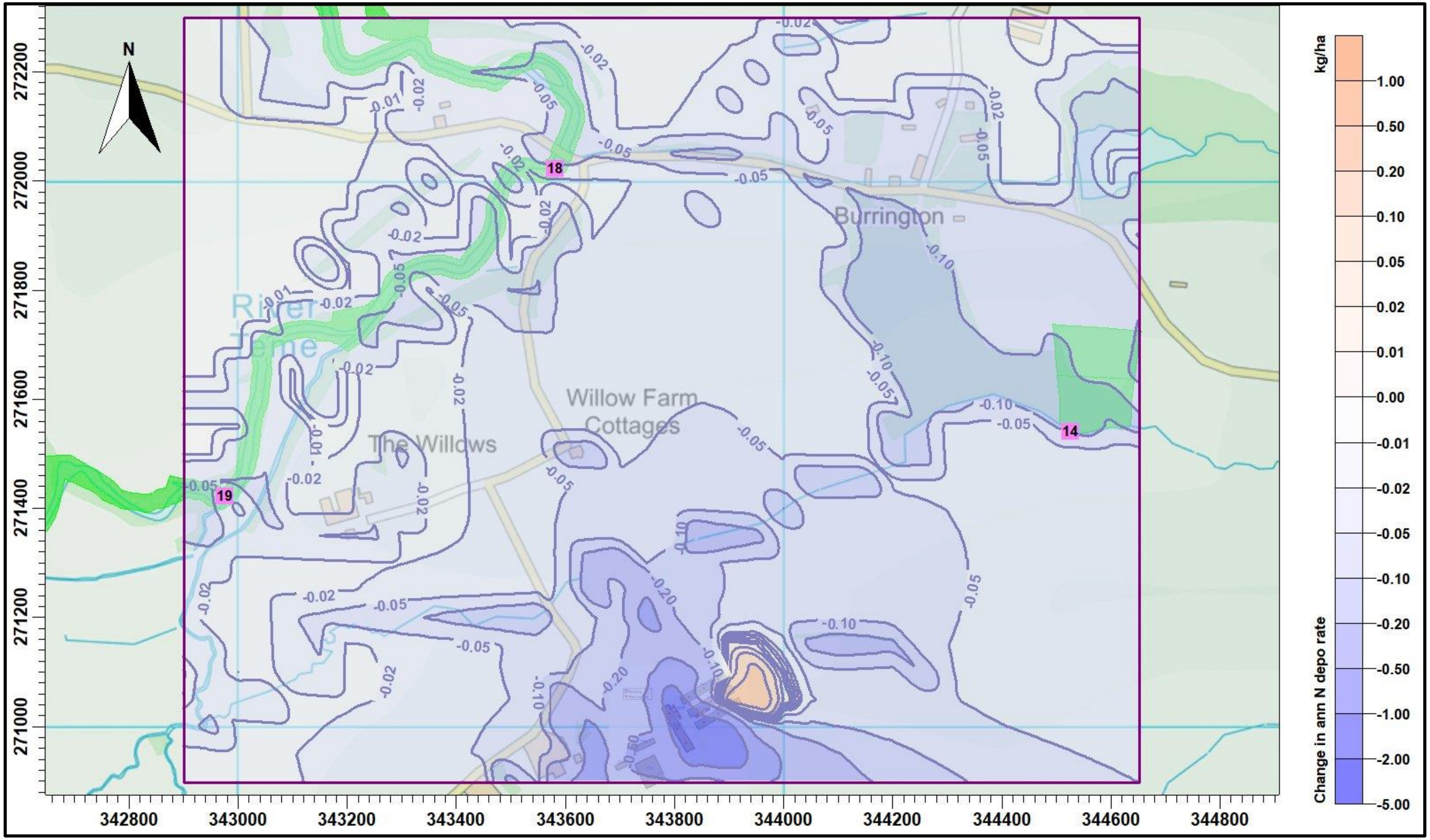


Figure 6b. Maximum annual nitrogen deposition rate – The Change in Process Contributions - Existing poultry house (as proposed) and the Proposed poultry houses minus The Existing poultry house



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Rosina Bloor of Roger Parry and Partners LLP., on behalf of Mr. Andrew Morgan, to use computer modelling to assess the impact of ammonia emissions from the existing and proposed egg laying chicken houses at Marlbrook Hall, near Leinthall Starkes in Herefordshire. SY8 2HR.

Ammonia emission rates from the existing poultry houses have been assessed and quantified based upon the Environment Agency standard ammonia emission factors/Bref emission factors. Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon an emissions model that estimates emissions from the Inno+ ammonia scrubbing equipment that would be fitted to the poultry houses. 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, should the proposed development of the poultry unit at Marlbrook Hall proceed:

- In all cases, the impact of ammonia emissions from the pouty housing at Marlbrook Hall would be reduced when compared to the Existing Scenario.

- The process contribution to ammonia concentrations and nitrogen deposition would be below the Environment Agency's lower threshold (4% and 20% for an internationally designated site, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site) of the relevant Critical Level and Critical Load at all sites considered.

- At Burrington Meadow SSSI, in the Existing Scenario, the process contributions to maximum annual ammonia concentrations and nitrogen deposition rate are above 1% of the Critical level/Load. Under the Proposed Scenario, maximum annual ammonia concentrations and nitrogen deposition rates would be reduced to below 1% of the Critical Level of 3.0 $\mu g/m^3$ and if a deposition velocity of 0.02 m/s is assumed, also below 1% of the Critical Load of 15.0 kg/ha.

- Over closer parts of the River Teme SSSI, although reduced significantly, the predicted process contribution to maximum annual ammonia concentrations and nitrogen deposition rates would remain slightly in excess of 1% of the Critical Level of 1.0 $\mu g/m^3$ and the Critical Load of 10.0 kg/ha.

- The process contribution to ammonia concentrations and nitrogen depositions would be reduced from current levels and would remain below 1% of the Critical Level and the Critical Load at all other SSSIs ands SACs.

7. References

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