



A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Existing Egg Laying Chicken Houses (Breeders) and the Proposed Broiler Chicken Rearing Houses at Longfield Farm Poultry Unit, Halls Corner Lane, near Hevingham in Norfolk

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Karl Collett, on behalf of Mr. Robert Fowell for ASMD, to use computer modelling to assess the impact of ammonia emissions from the existing egg laying chicken houses (breeders) and the proposed broiler chicken rearing houses at Longfield Farm Poultry Unit, Halls Corner Lane, Hevingham, Norfolk. NR10 5FA.

Ammonia emission rates from the poultry houses have been assessed and quantified based upon the Environment Agency standard ammonia emission factors. 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 poultry houses at Longfield Farm is in a rural area approximately 150 m to the north of the village of Hevingham in Norfolk. Out with the village, the surrounding land is used mainly for arable farming, although there are also some extensive areas of woodland and heath to the south and north-west. The site is at an altitude of around 20 m, with the land falling towards the shallow valley formed by the now heavily modified Hevingham Watercourse to the south.

There are six poultry houses at Longfield Farm Poultry Unit, which are currently used to provide accommodation for up to 24,310 breeder chickens; the majority of the chickens are egg laying hens with a small proportion of cockerels. Fertilised eggs produced by the hens are transferred to hatcheries elsewhere. The poultry houses are currently ventilated using capped ridge mounted fans.

Under the proposal, the existing houses would be converted to broiler chicken rearing houses. The converted poultry houses would provide accommodation for up to 69,000 broiler chickens. The existing capped ridge fans would be replaced with uncapped high speed ridge/roof mounted fans each with a short chimney. The chickens would be reared from day old chicks up to a maximum of around 38 days and houses would be empty for around 10 days at the end of each crop.

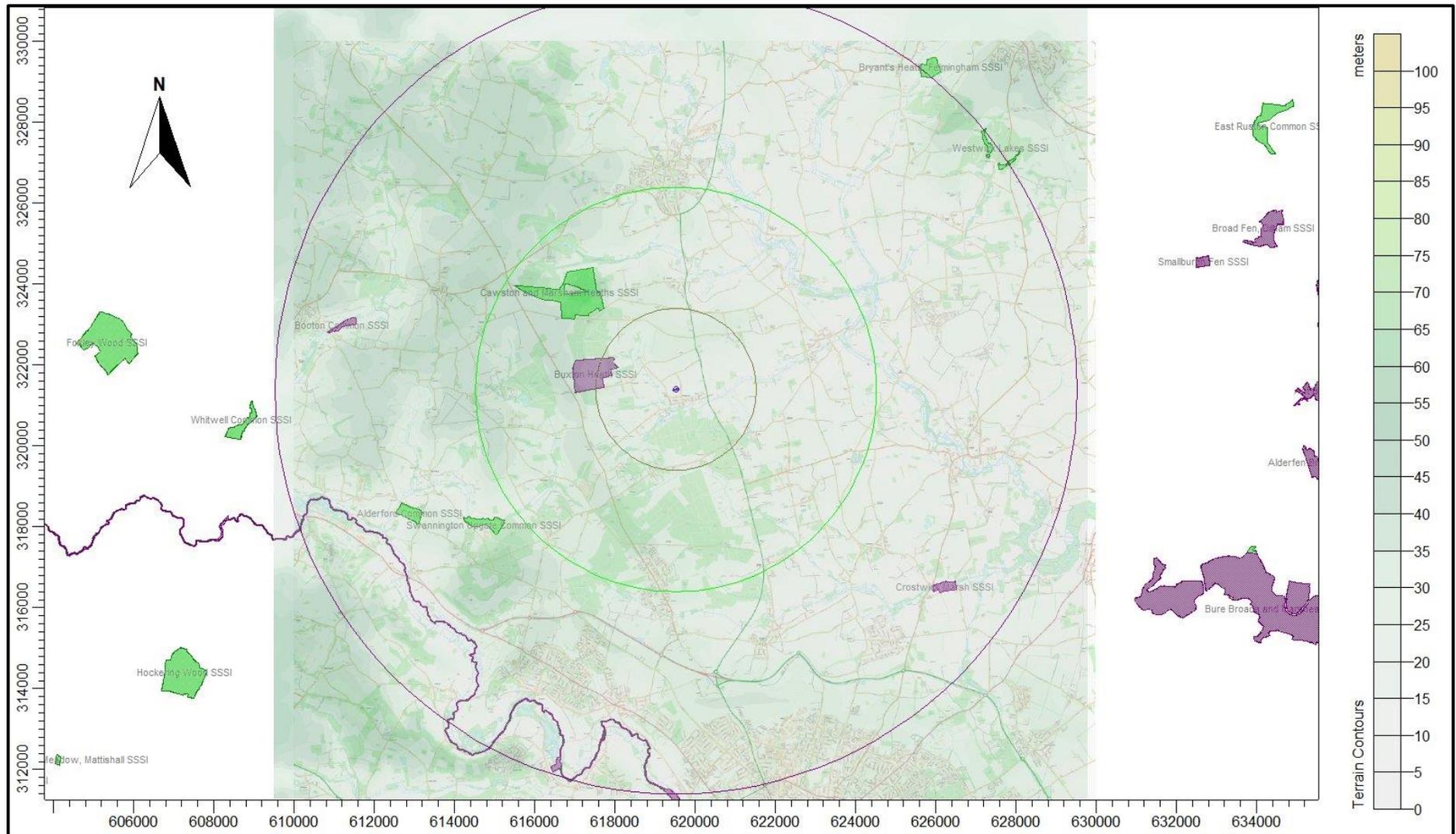
There are three areas designated as Local Wildlife Sites (LWSs) within 2 km (the normal screening distance for non-statutory sites) of Longfield Farm Poultry Unit. Parts of one of the LWSs are also designated as Ancient Woodlands (AWs). There are two areas designated as Sites of Special Scientific Interest (SSSIs) within 5 km of the site and a further eight SSSIs within 10 km. Three of the SSSIs are also designated as Special Areas of Conservation (SACs), and one of these also as a Special Protection Area (SPA) and Ramsar site. Some further details of the statutory sites are provided below:

- **Buxton Heath SSSI/SAC** - Approximately 1.4 km to the west-north-west - A diverse heath-with-fen area situated in a basin of glacial sands. The valley mire is floristically rich and there is a rapid transition from calcareous to acidic plant communities with dry acidic heathland on higher ground. These communities have remained undisturbed for a long period of time and a number of rare relict mosses, liverworts and fungi occur on the site. Several uncommon invertebrates have also been recorded including one species new to Britain.
- **Booton Common SSSI/SAC** - Approximately 8.0 km to the west-north-west - The principal interest of the site is associated with a mosaic of wet calcareous fen grassland and acid heath communities which have developed due to the naturally undulating ground. Areas of tall fen and a strip of valley alder woodland occupy the lower ground adjacent to the stream.
- **River Wensum SSSI/SAC** - Approximately 8.0 km to the south-west - One of a national series of rivers of special interest as an example of an enriched, calcareous lowland river. With a total of over 100 species of plants, a rich invertebrate fauna and a relatively natural corridor, it is probably the best whole river of its type in nature conservation terms.
- **Croswick Marsh SSSI/SAC/SPA/Ramsar** - Approximately 8.0 km to the south-east - An excellent example of unimproved valley meadow which supports a series of intergrading plant communities ranging from damp neutral grassland through species-rich fen grassland to tall fen in the valley bottom. A spring line is present on the valley slopes which provides irrigating water, and calcareous flushes have developed locally at seepage points. A number of uncommon plants are present, several in great abundance and there is additional ornithological interest.
- **Cawston and Marsham Heaths SSSI** - Approximately 2.6 km to the north-west - The largest area of Heather-dominated heathland now remaining in east Norfolk. Dry Heather-heathland has developed on glacial sands and gravels and the site has been subject to generations of grazing and burning. As a result there is a diverse flora which includes a rich assemblage of lichens. The site is also of considerable ornithological interest.

- **Swannington Uigate Common SSSI** - Approximately 5.3 km to the south-west - An unusual site supporting a wide variety of habitat types within a small area. The variations in soils and wetness and a variable topography have provided conditions for the development of an exceptionally wide range of semi-natural vegetation including dry acidic heathland, wet heathland with acidic flushes, fen, birch and alder woodland, scrub, bracken, rough grassland and ponds. These plant communities are distributed in such a manner that interesting transitions between the different associations are clearly seen.
- **Alderford Common SSSI** - Approximately 6.9 km to the west-south-west - A diverse chalk flora has developed in the old marl-pits and the site forms the only remaining example of species-rich chalk grassland in East Norfolk. A bat roost and an outstanding assemblage of breeding birds provide additional interest. The habitats represented include scrub, woodland, bracken heath, marshy grassland and ponds.
- **Westwick Lakes SSSI** - Approximately 9.8 km to the north-east - Westwick Lakes form a compact group of five secluded, man-made lakes. The Perch Lake group is of a type rarely found in East Anglia and closely resembles nutrient-poor lakes found in the upland areas. The acidic waters support an unusual aquatic flora and plankton fauna which includes one locally uncommon species. The other lakes are more typical with abundant water weeds and provide an interesting contrast to the Perch Lake group. There is considerable ornithological interest with large flocks of wildfowl overwintering in the lakes.
- **Bryant's Heath, Felmingham SSSI** - Approximately 9.9 km to the north-east - An area of dry acidic heathland on glacial sands with sloping ground to the south and west. This site is unusual in that it encompasses within a relatively small area a mix of dry heath, wet heath and fen communities. Rich plant communities have developed in association with the flushed areas that occur where nutrient-poor sands meet underlying calcareous clays. These areas include several plants that are now uncommon in East Anglia.

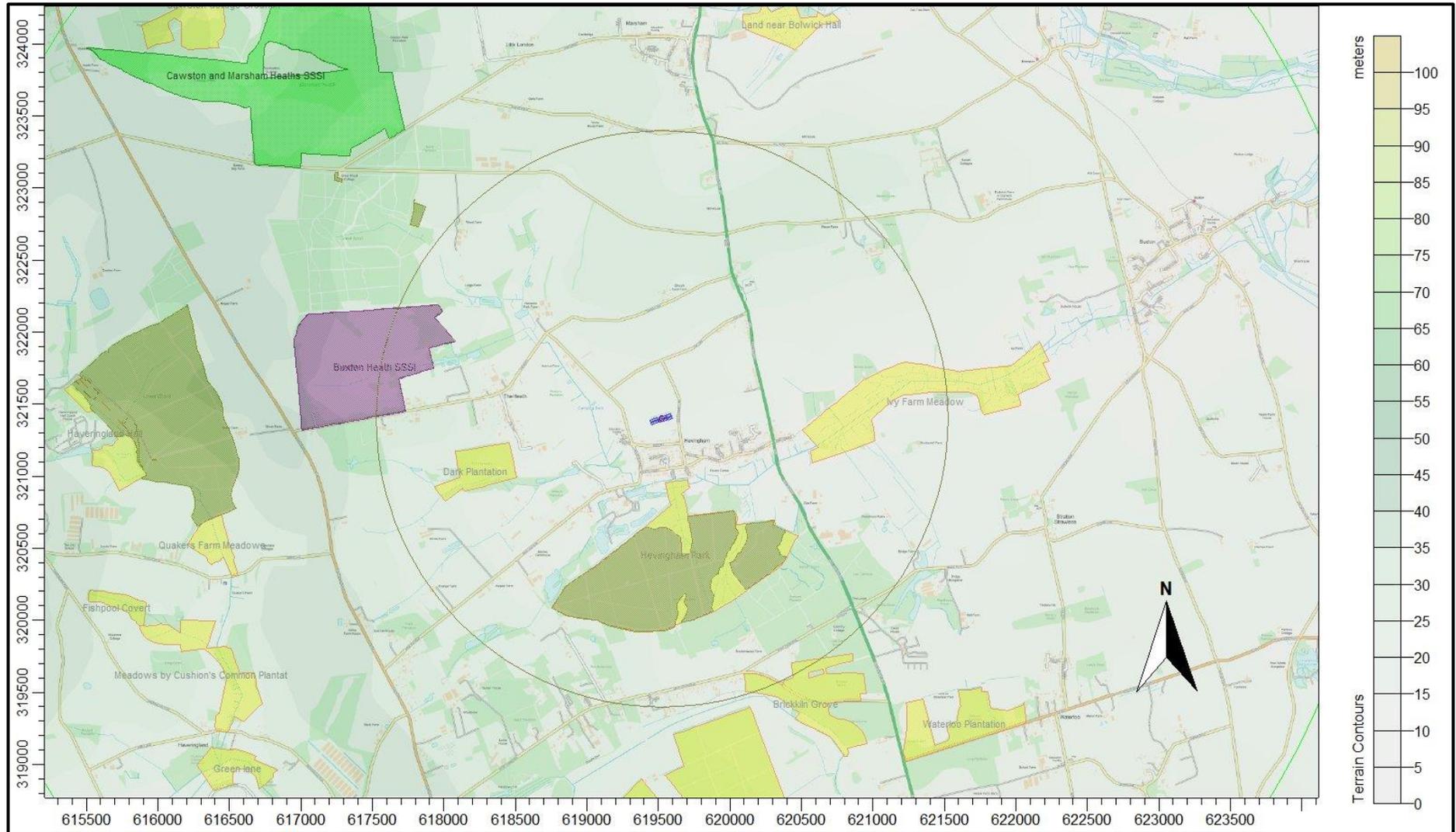
Maps of the surrounding area showing the positions of Longfield Farm Poultry Unit (outlined in blue), the LWSs (shaded in yellow), the AWs (shaded in olive), the SSSIs (shaded in green) and the SACs/SPA/Ramsar site (shaded in purple) are provided in Figures 1a and 1b.

Figure 1a. The area surrounding Longfield Farm Poultry Unit - concentric circles radii 2.0 km (olive), 5.0 km (green) and 10.0 km (purple)



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Figure 1b. The area surrounding Longfield Farm Poultry Unit – a closer view



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

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air ($\mu\text{g-NH}_3/\text{m}^3$) as an annual mean. Ammonia in the air may exert direct effects on the vegetation, or indirectly affect the ecosystem through deposition which causes both hyper-eutrophication (excess nitrogen enrichment) and acidification of soils. Nitrogen deposition, specifically in this case the nitrogen load due to ammonia deposition/absorption, is usually expressed in kilograms of nitrogen per hectare per year (kg-N/ha/y). Acid deposition is expressed in terms of kilograms equivalent (of H^+ ions) per hectare per year (keq/ha/y).

3.2 Background ammonia levels and nitrogen and acid deposition

The source of the background figures is the Air Pollution Information System (APIS, October 2025). It should be noted that the 1 km APIS database background levels are extrapolated from 5 km modelled data. Ammonia levels may vary markedly over relatively short distances and the APIS website itself notes that, the background values should be used only to assist the user in obtaining a broad indication of the likely pollutant impact at a specific location and cannot be considered representative of any particular location within the 5 km grid square; extrapolation to a 1 km grid does not alter this.

The APIS figures for background ammonia concentration in the area around Longfield Farm Poultry Unit is $2.65 \mu\text{g-NH}_3/\text{m}^3$. The background nitrogen deposition rate to woodland is 38.27 kg-N/ha/y and to short vegetation is 20.63 kg-N/ha/y . The background acid deposition rate to woodland is 2.77 keq/ha/y and to short vegetation is 1.48 keq/ha/y .

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

In most cases, the APIS background figures, which are modelled, extrapolated and statistically manipulated figures, nevertheless, are the only figures available and although it is noted that the background values should be used only to assist in obtaining a broad indication of the likely pollutant impact, it is also noted that across the majority of the UK the lower bounds of the Critical Level and Critical Load are already exceeded.

3.3 Critical Levels and Critical Loads

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

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

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

For ammonia concentration in air, the Critical Level for higher plants is $3.0 \mu\text{g-NH}_3/\text{m}^3$ as an annual mean. For sites where there are sensitive lichens and bryophytes present, or where lichens and bryophytes are an integral part of the ecosystem, the Critical Level is $1.0 \mu\text{g-NH}_3/\text{m}^3$ as an annual mean.

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

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. N.B. Where the Critical Level of $1.0 \mu\text{g-NH}_3/\text{m}^3$ is assumed, it is usually unnecessary to consider the Critical Load as the Critical Level provides the stricter test. Normally, the Critical Load for nitrogen deposition provides a stricter test than the Critical Load for acid deposition.

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

Site	Critical Level ($\mu\text{g-NH}_3/\text{m}^3$)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
AWs and LWSs	1.0 ¹	-	-
River Wensum SSSI/SAC and Crostwick Marsh SSSI/SAC/SPA/Ramsar	3.0 ²	15.0 ^{2&3}	-
Alderford Common SSSI	3.0 ²	10.0 ^{2&3}	-
Westwick Lakes SSSI	3.0 ²	n/a ⁴	n/a ⁴
Buxton Heath SSSI/SAC; Booton Common SSSI/SAC; Cawston and Marsham Heaths SSSI; Swannington Upgate Common SSSI and Bryant's Heath, Felmingham SSSI	1.0 ^{1&2}	5.0 ^{2&3}	-

1. A precautionary figure used where details of the site are entirely unknown, or where although citations do not explicitly mention lichens or bryophytes, they are likely to be present.
2. Based upon the citation for the site (note that in some cases, the APIS database contains Critical Levels/Loads for habitats/species that are not present or not present at the site/parts of the site within 10 km).
3. The lower bound of the range of Critical Loads for habitats present at the site. (please note that in some cases, the APIS database contains Critical Loads for habitats/species that are not present at the site/parts of the site within 10 km).
4. No Critical Loads for designated features.

3.4 Guidance on the Significance of Ammonia Emissions

3.4.1 Environment Agency Criteria

The Environment Agency and Department for Environment, Food & Rural Affairs published guidance “Intensive farming risk assessment for your environmental permit” (last updated August 2025) applies to ammonia emitting developments requiring a permit.

The Environment Agency ammonia screening thresholds for designated nature conservation sites are given in Table 2.

Table 2. Environment Agency Screening Thresholds

Nature conservation site designation	Distance from site (km)	Lower threshold %	Upper threshold %
Special Protection Areas (SPAs), Special Areas of Conservation (SACs), Ramsar sites	5	1	No upper threshold
Sites of Special Scientific Interest (SSSIs)	5	20	50
Local nature sites (National Nature Reserves, Local Nature Reserves, Local Wildlife Sites, Ancient Woodlands)	2	100	100

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, 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 Process Contribution of up to 100% of Critical Level and/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% (in some circumstances <1%) of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming installations¹ 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.

It should be noted that the Natural England screening distances (<https://www.gov.uk/guidance/air-pollution-and-development-advice-for-local-authorities#step-1-check-if-emissions-will-reach-a-protected-site>) may differ from the Environment Agency and Department for Environment, Food & Rural Affairs published guidance.

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.

The emission factor used for the existing broiler breeder houses at Longfield Farm Poultry Unit is 0.133 kg-NH₃/bird-place/y; AS Modelling & Data Ltd. understands that this is a bespoke emission factor, previously agreed with the Environment Agency.

The emission factor used for the proposed broiler chicken rearing houses at Longfield Farm Poultry Unit have been obtained from: <https://www.gov.uk/guidance/ammonia-emission-factors-for-pig-and-poultry-screening-modelling-and-reporting#ammonia-emission-factors-for-poultry>

Details of the poultry numbers and types and emission factors used and calculated ammonia emission rates are provided in Table 3.

Table 3. Details of poultry numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH ₃ /place/y)	Emission rate (g-NH ₃ /s)
Existing Housing	24,310	Layers (Single tier/deep litter)	0.133	0.102455
Proposed Housing	69,000	Broiler Chickens	0.024	0.052475

4. The Atmospheric Dispersion Modelling System (ADMS) and model parameters

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

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

ADMS has a number of model options, 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.

The GFS is a discrete model. The physics/dynamics model has a resolution or had a resolution of approximately 7 km over the central UK; terrain is understood to be resolved at a resolution of approximately 2 km, with sub-7 km terrain effects parameterised. Site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR²). 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 the site is shown in Figure 2b. Please note that FLOWSTAR² 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 amended³.

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 52.745 N, 1.253 E, 2021-2024

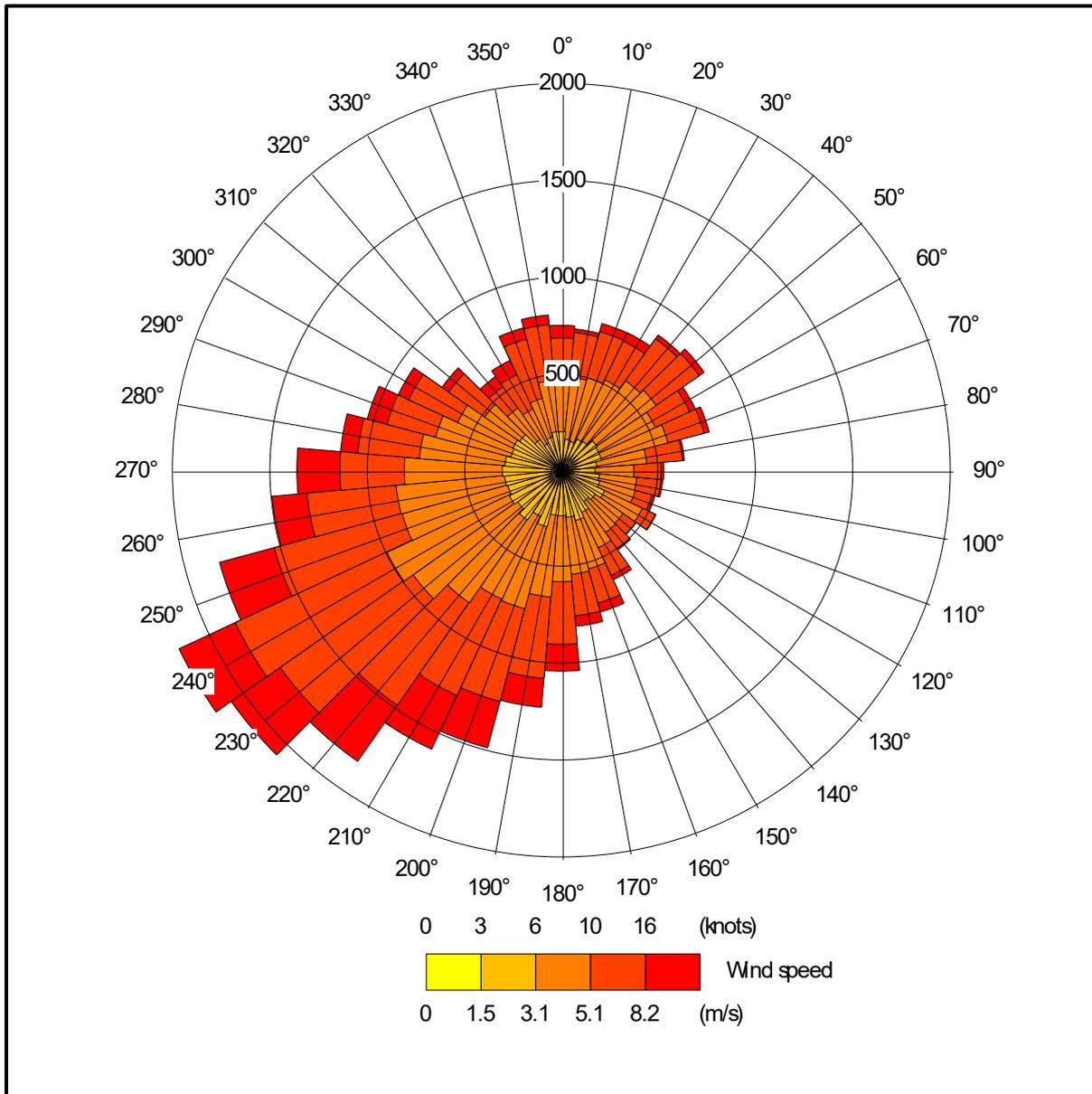
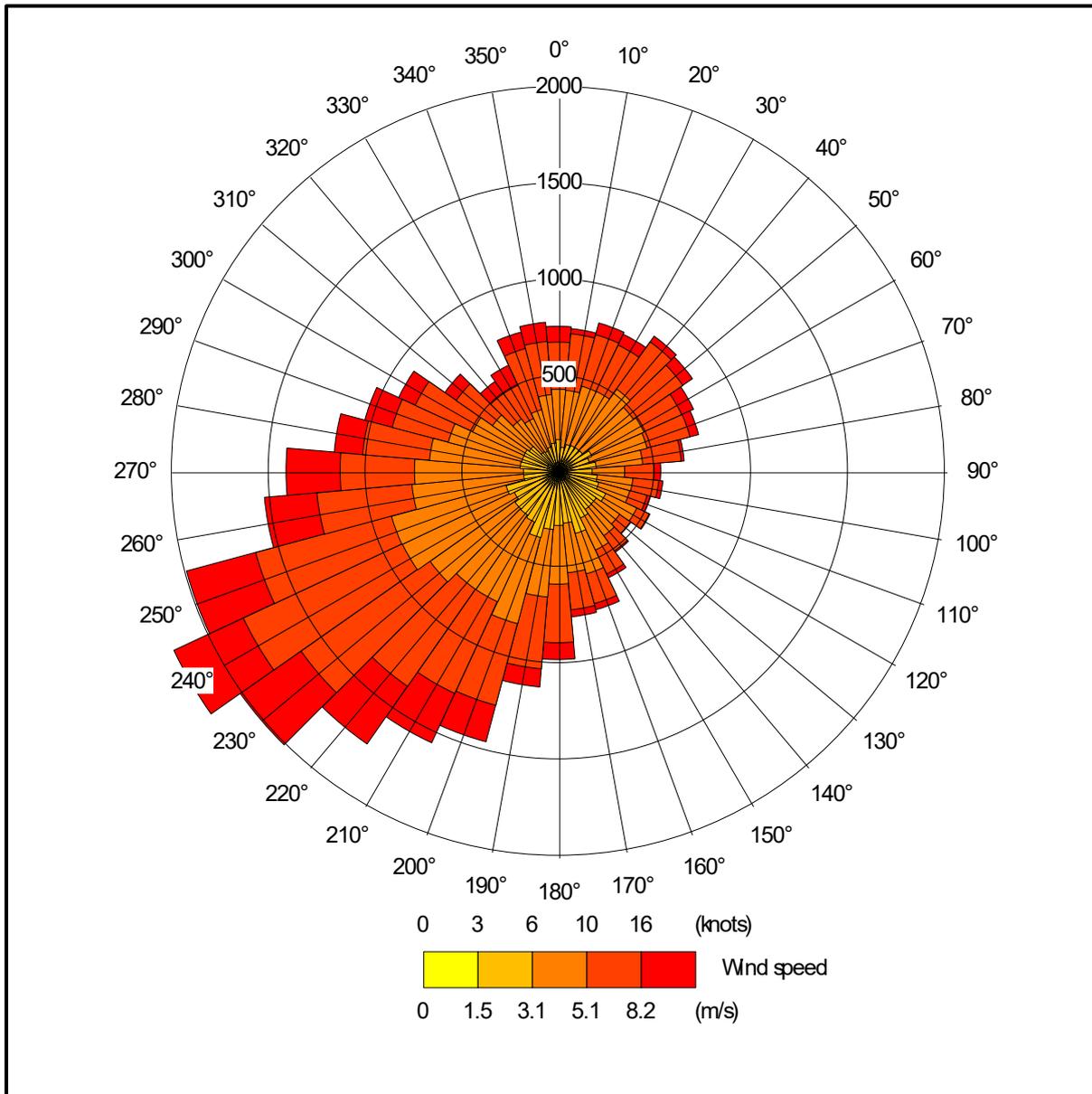


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 619500, 321400, 2021-2024



4.2 Emission sources

Emissions from capped ridge mounted fans that are currently used for the ventilation of the existing poultry houses and the chimneys of the uncapped high speed ridge/roof mounted fans that would be used to ventilate the proposed poultry houses under the proposal are represented by three point sources per house within ADMS (H1_CAP to H6_CAP; 1, 2 & 3).

Details of the point source parameters are shown in Tables 4a and 4b. Please note that the modelling and the emission rates given in both Tables 4a and 4b are based on a total of 10,000 birds with an emission factor of 1.0 kg-NH₃/bird/y, distributed proportionally depending on size the house; the results obtained are scaled to the appropriate emission factor and numbers post-modelling. The positions of the emission sources used are shown in Figure 3 (marked by green circles).

Table 4a. Point source parameters – Existing Scenario

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (g/s)
H1_CAP; 1, 2 & 3	4.5	2.0	0.1	Variable ¹	0.010760
H2_CAP; 1, 2 & 3	6.5	2.0	0.1	Variable ¹	0.014181
H3_CAP; 1, 2 & 3	5.5	2.0	0.1	Variable ¹	0.020394
H4_CAP; 1, 2 & 3	5.5	2.0	0.1	Variable ¹	0.019811
H5_CAP; 1, 2 & 3	5.5	2.0	0.1	Variable ¹	0.020240
H6_CAP; 1, 2 & 3	5.5	2.0	0.1	Variable ¹	0.020240

Table 4b. Point source parameters – Proposed Scenario

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (g/s)
H1_CAP; 1, 2 & 3	6.0	0.8	11.0	Variable ¹	0.010760
H2_CAP; 1, 2 & 3	8.0	0.8	11.0	Variable ¹	0.014181
H3_CAP; 1, 2 & 3	7.0	0.8	11.0	Variable ¹	0.020394
H4_CAP; 1, 2 & 3	7.0	0.8	11.0	Variable ¹	0.019811
H5_CAP; 1, 2 & 3	7.0	0.8	11.0	Variable ¹	0.020240
H6_CAP; 1, 2 & 3	7.0	0.8	11.0	Variable ¹	0.020240

1. Dependant on ambient temperature.

4.3 Modelled buildings

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

4.4 Discrete receptors

Forty-four discrete receptors have been defined at the nearby wildlife sites. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figures 4a and 4b (marked by enumerated pink rectangles).

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition velocity field, two regular Cartesian grids have been defined within ADMS. The individual grid receptors are defined at ground level within ADMS. The positions of the Cartesian grids may be seen in Figures 4a and 4b (marked by grey lines).

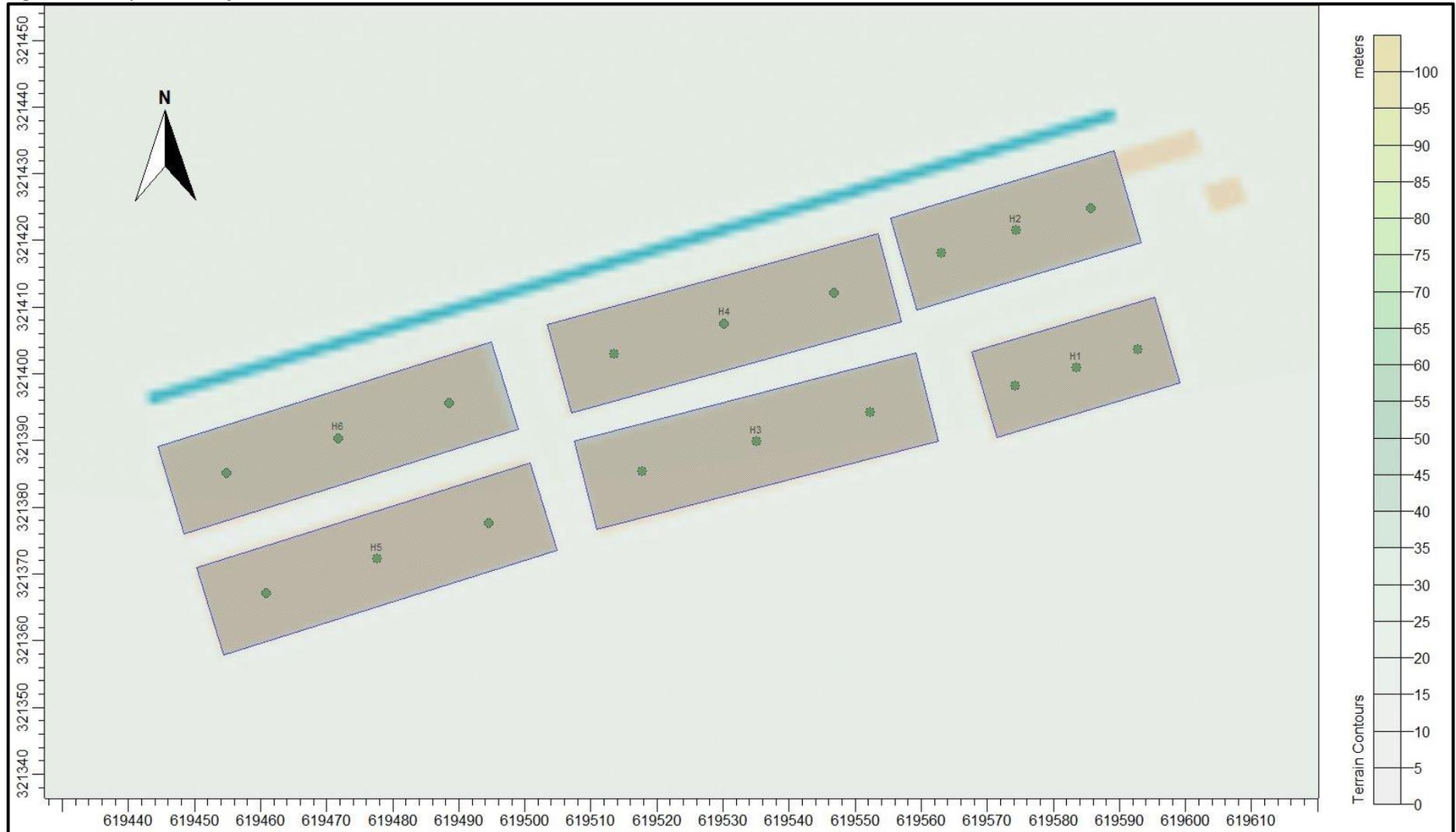
4.6 Terrain data

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

4.7 Roughness Length

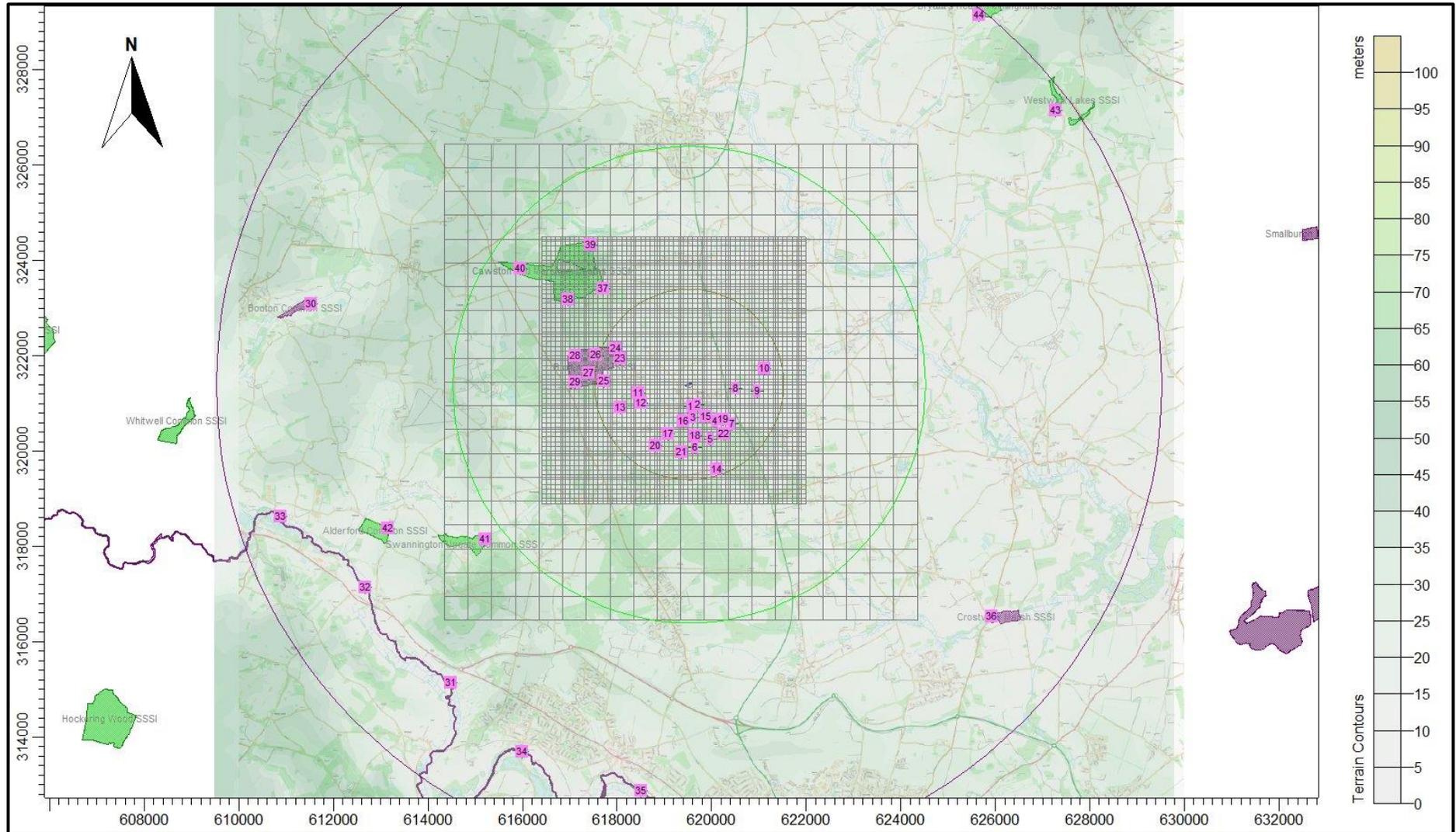
In this case, a spatially varying roughness length file has been defined, this is based upon the UK Centre for Ecology and Hydrology 25 m land use database. The GFS meteorological data is assumed to have a roughness length of 0.270 m (arithmetic average of the spatially varying roughness over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 5.

Figure 3. The positions of modelled sources



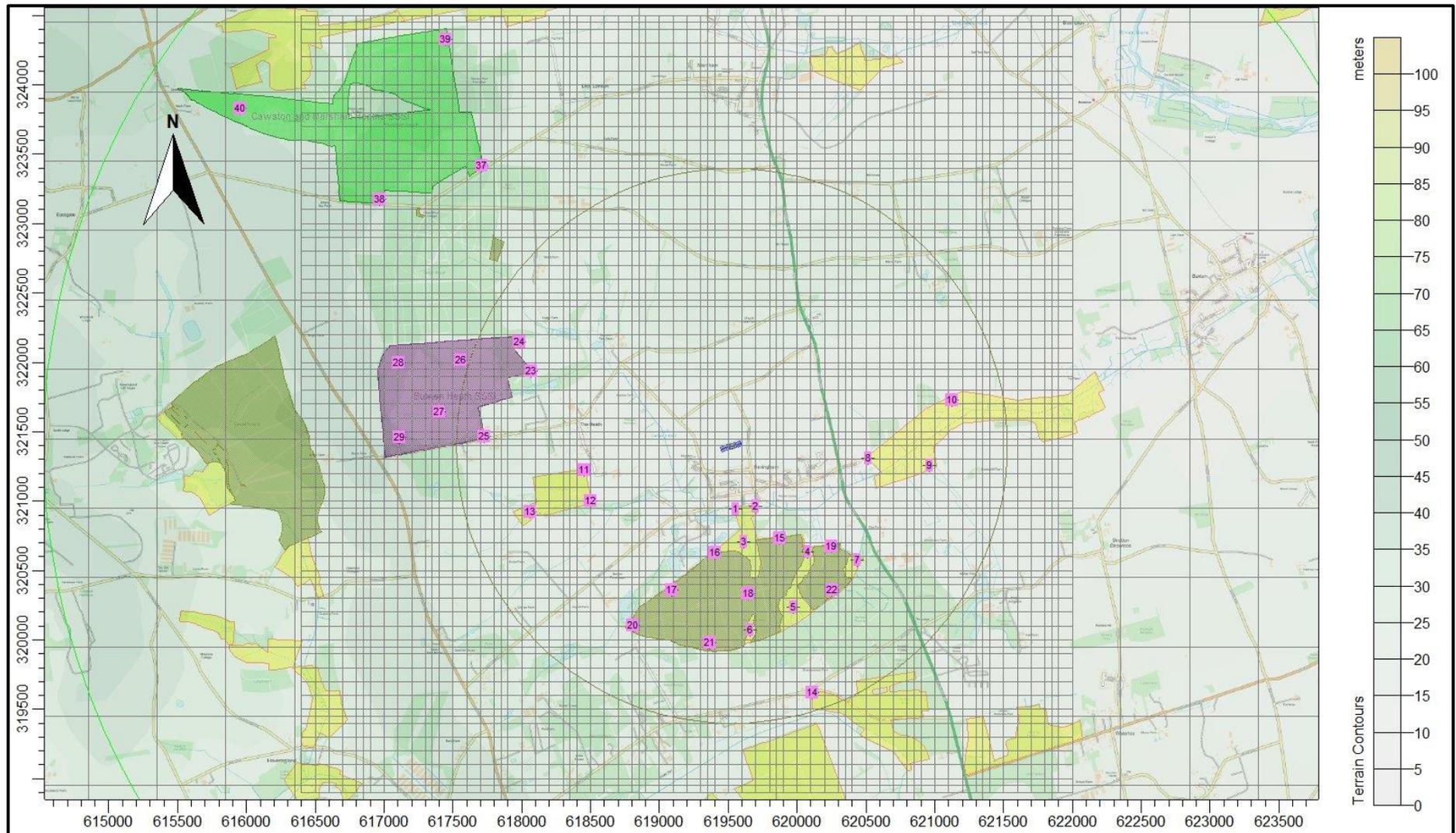
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Figure 4a. The discrete receptors and regular Cartesian grids – broadscale view



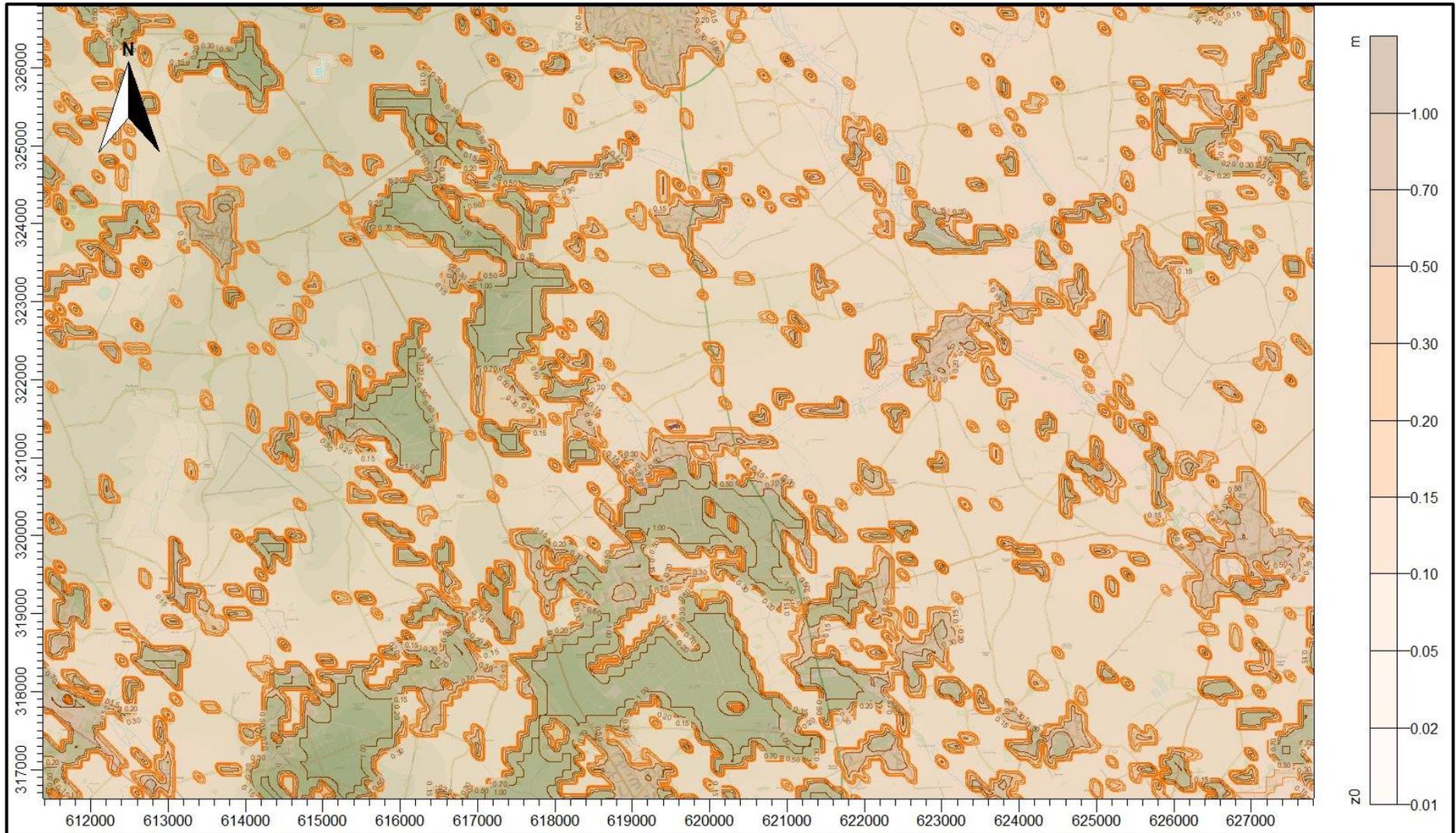
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Figure 4b. The discrete receptors and regular Cartesian grids – a closer view



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



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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.

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 5.

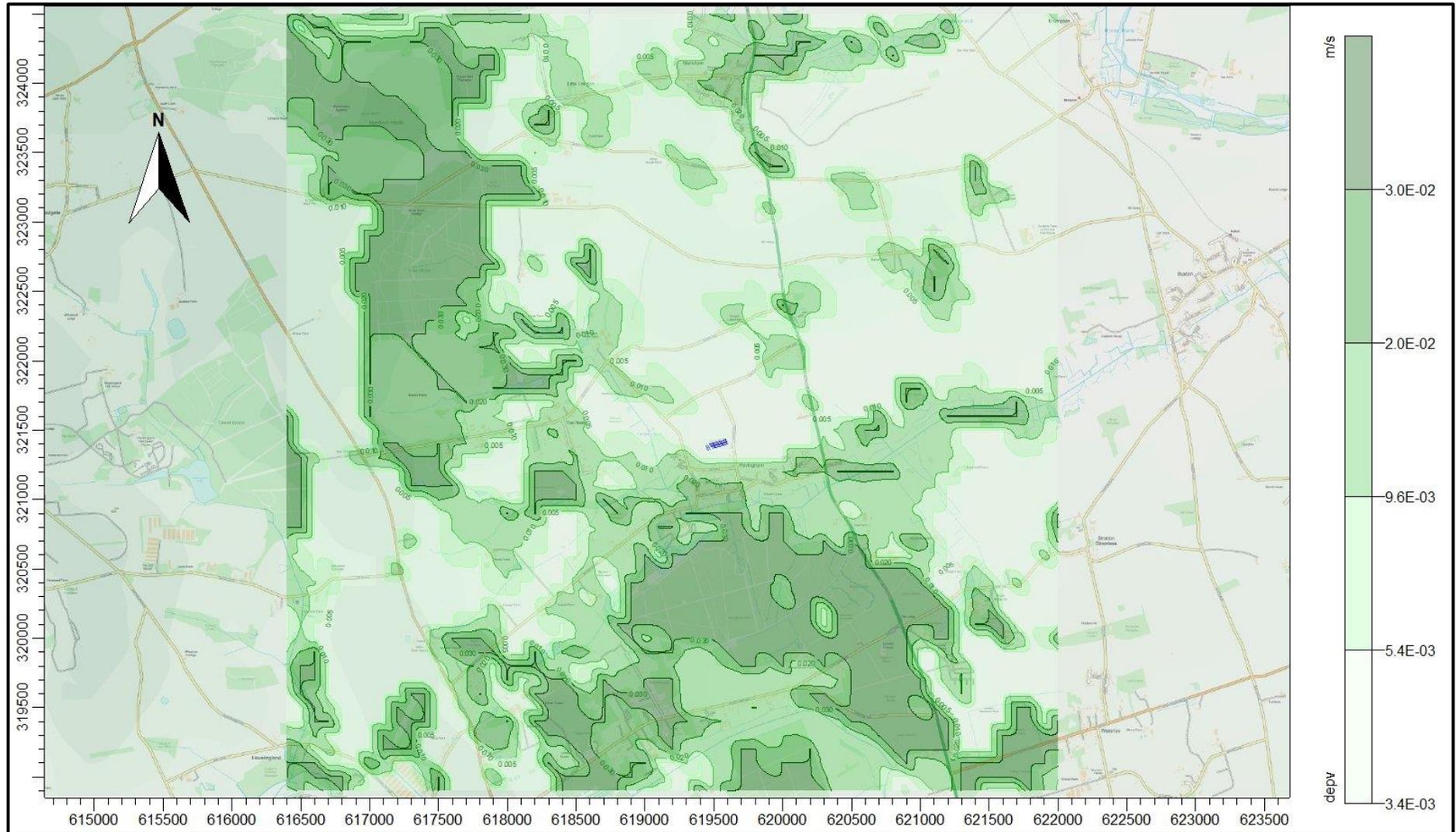
Table 5. Deposition velocities

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 fields is provided in Figure 6.

Figure 6. The spatially varying deposition field



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5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

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

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

For each mode, statistics for the maximum annual mean ammonia concentration at each receptor were compiled. Details of the predicted annual mean ammonia concentrations at each receptor are provided in Table 6. The primary purpose of the preliminary modelling is to assess the effect of calms on the results.

Table 6. Predicted maximum annual mean ammonia concentration at the discrete receptors – preliminary modelling

Receptor number	X(m)	Y(m)	Name/Designation	Maximum annual mean ammonia concentration - ($\mu\text{g}/\text{m}^3$)			
				Existing		Proposed	
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms No Terrain	GFS Calms No Terrain
1	619554	320942	LWS	0.142	0.141	0.073	0.072
2	619699	320964	LWS	0.120	0.119	0.061	0.061
3	619613	320706	LWS	0.072	0.072	0.037	0.037
4	620077	320635	LWS	0.037	0.037	0.019	0.019
5	619972	320239	LWS	0.026	0.026	0.013	0.013
6	619658	320070	LWS	0.026	0.026	0.013	0.013
7	620436	320575	LWS	0.028	0.027	0.014	0.014
8	620515	321312	LWS	0.057	0.056	0.029	0.029
9	620963	321259	LWS	0.031	0.031	0.016	0.016
10	621124	321730	LWS	0.030	0.030	0.015	0.015
11	618451	321226	LWS	0.026	0.026	0.013	0.013
12	618499	321001	LWS	0.033	0.033	0.017	0.017
13	618062	320923	LWS	0.019	0.019	0.010	0.010
14	620111	319618	LWS	0.015	0.015	0.007	0.007
15	619875	320732	AW	0.053	0.053	0.027	0.027
16	619400	320627	AW	0.058	0.058	0.030	0.030
17	619086	320362	AW	0.033	0.033	0.017	0.017
18	619647	320332	AW	0.036	0.036	0.019	0.019
19	620245	320676	AW	0.035	0.035	0.018	0.018
20	618806	320108	AW	0.024	0.024	0.012	0.012
21	619363	319981	AW	0.022	0.022	0.011	0.011
22	620257	320362	AW	0.023	0.023	0.012	0.012
23	618065	321940	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.018	0.018	0.009	0.009
24	617981	322147	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.016	0.016	0.008	0.008
25	617724	321465	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.012	0.012	0.006	0.006
26	617554	322020	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.012	0.012	0.006	0.006
27	617397	321645	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.010	0.010	0.005	0.005
28	617106	321999	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.009	0.009	0.005	0.005
29	617110	321458	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.008	0.008	0.004	0.004
30	611520	323094	Booton Common SSSI/ Norfolk Valley Fens SAC	0.002	0.002	0.001	0.001
31	614476	315146	River Wensum SSSI/SAC	0.003	0.003	0.001	0.001
32	612667	317133	River Wensum SSSI/SAC	0.003	0.003	0.001	0.001
33	610874	318619	River Wensum SSSI/SAC	0.002	0.002	0.001	0.001
34	615995	313692	River Wensum SSSI/SAC	0.002	0.002	0.001	0.001
35	618515	312868	River Wensum SSSI/SAC	0.002	0.002	0.001	0.001
36	625930	316534	Crostick Marsh SSSI/The Broads SAC/ Broadland SPA/Ramsar	0.002	0.002	0.001	0.001
37	617706	323415	Cawston and Marsham Heaths SSSI	0.007	0.007	0.004	0.004
38	616969	323177	Cawston and Marsham Heaths SSSI	0.007	0.007	0.004	0.004
39	617445	324330	Cawston and Marsham Heaths SSSI	0.006	0.006	0.003	0.003
40	615951	323832	Cawston and Marsham Heaths SSSI	0.005	0.005	0.003	0.003
41	615210	318152	Swannington Upgate Common SSSI	0.004	0.004	0.002	0.002
42	613159	318384	Alderford Common SSSI	0.003	0.003	0.002	0.002
43	627277	327159	Westwick Lakes SSSI	0.002	0.002	0.001	0.001
44	625662	329143	Bryant's Heath, Felmingham SSSI	0.002	0.002	0.001	0.001

5.2 Detailed modelling

In this case, detailed modelling has been carried out over a high resolution 5.6 km x 5.6 km domain surrounding Longfield Farm Poultry Unit. 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, but also to provide results should any further LWSs be identified. Outside of the 5.6 km x 5.6 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 detailed deposition run was made with terrain. Calms cannot be used with terrain or spatially varying deposition; therefore, calms have not been included in the detailed modelling. However, the results of the preliminary modelling indicate that the effects of calms are insignificant in the case.

The predicted maximum annual mean ground level ammonia concentrations and annual nitrogen deposition rates at the discrete receptors are shown in Tables 7a (Existing Scenario) and 7b (Proposed Scenario).

In these Tables, there are no predicted ammonia concentrations and nitrogen deposition rates that are in excess of the Environment Agency's upper threshold 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) nor in the range between the lower and upper threshold (4% and 20% for an internationally designated site, 20% and 50% for a SSSI and 100% and 100% for a non-statutory site). Process contributions which exceed 1% of the relevant Critical Level or Critical Load at a statutory site are highlighted with bold text.

It has been noted previously that the lower bounds of the Critical Levels and Critical Loads are almost certainly already exceeded and that available background levels are suitable only to provide a broad indication of likely pollutant impact at a specific location; therefore, PECs are not presented in the Tables.

Contour plots of the predicted ground level maximum annual mean ammonia concentration and maximum annual nitrogen deposition rates for the Proposed Scenario are shown in Figures 7a and 7b. Contour plots for other scenarios can be made available upon request.

Table 7a. Predicted maximum annual mean ammonia concentrations and annual nitrogen deposition rates – Existing Scenario

Receptor number	X(m)	Y(m)	Designation/Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu\text{g}/\text{m}^3$)	Critical Load (kg/ha)	Process Contribution ($\mu\text{g}/\text{m}^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	619554	320942	LWS	0.03	1.0	10.0	0.174	17.36	1.35	13.53
2	619699	320964	LWS	0.03	1.0	10.0	0.152	15.20	1.18	11.84
3	619613	320706	LWS	0.03	1.0	10.0	0.079	7.94	0.62	6.19
4	620077	320635	LWS	0.03	1.0	10.0	0.037	3.67	0.29	2.86
5	619972	320239	LWS	0.03	1.0	10.0	0.023	2.32	0.18	1.81
6	619658	320070	LWS	0.03	1.0	10.0	0.023	2.26	0.18	1.76
7	620436	320575	LWS	0.03	1.0	10.0	0.025	2.54	0.20	1.98
8	620515	321312	LWS	0.03	1.0	10.0	0.072	7.17	0.56	5.59
9	620963	321259	LWS	0.03	1.0	10.0	0.037	3.69	0.29	2.87
10	621124	321730	LWS	0.03	1.0	10.0	0.038	3.76	0.29	2.93
11	618451	321226	LWS	0.03	1.0	10.0	0.040	3.95	0.31	3.08
12	618499	321001	LWS	0.03	1.0	10.0	0.043	4.35	0.34	3.39
13	618062	320923	LWS	0.03	1.0	10.0	0.022	2.19	0.17	1.71
14	620111	319618	LWS	0.03	1.0	10.0	0.011	1.11	0.09	0.87
15	619875	320732	AW	0.03	1.0	10.0	0.058	5.82	0.45	4.54
16	619400	320627	AW	0.03	1.0	10.0	0.065	6.48	0.50	5.05
17	619086	320362	AW	0.03	1.0	10.0	0.037	3.69	0.29	2.88
18	619647	320332	AW	0.03	1.0	10.0	0.035	3.46	0.27	2.69
19	620245	320676	AW	0.03	1.0	10.0	0.036	3.57	0.28	2.78
20	618806	320108	AW	0.03	1.0	10.0	0.023	2.30	0.18	1.79
21	619363	319981	AW	0.03	1.0	10.0	0.019	1.92	0.15	1.50
22	620257	320362	AW	0.03	1.0	10.0	0.020	2.00	0.16	1.56
23	618065	321940	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.03	1.0	5.0	0.021	2.12	0.17	3.31
24	617981	322147	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.03	1.0	5.0	0.021	2.09	0.16	3.26
25	617724	321465	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.012	1.25	0.06	1.29
26	617554	322020	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.010	1.03	0.05	1.07
27	617397	321645	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.008	0.81	0.04	0.85
28	617106	321999	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.006	0.60	0.03	0.63
29	617110	321458	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.006	0.64	0.03	0.66
30	611520	323094	Booton Common SSSI/ Norfolk Valley Fens SAC	0.02	1.0	5.0	0.0007	0.07	0.004	0.07

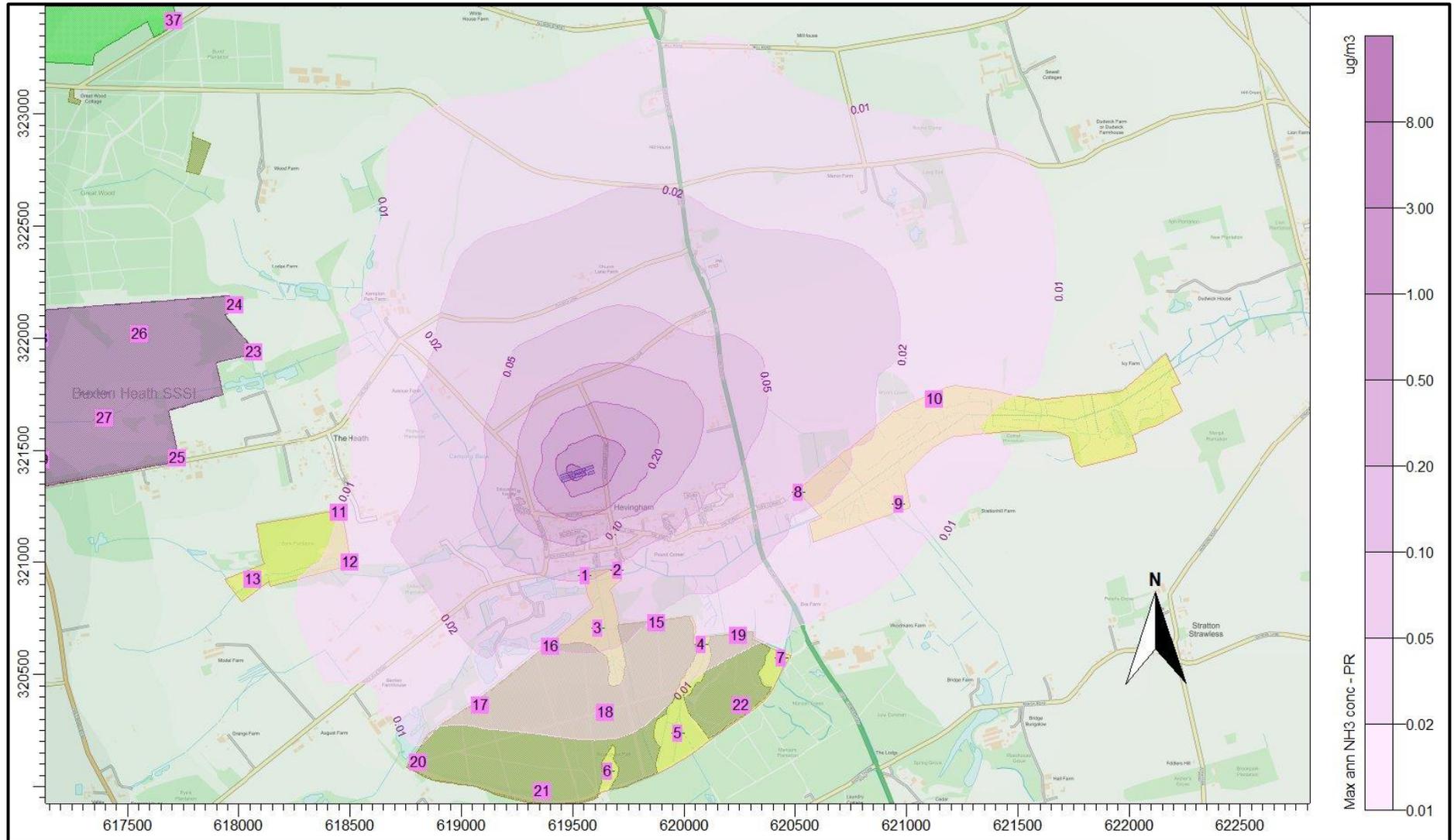
Receptor number	X(m)	Y(m)	Designation/Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu\text{g}/\text{m}^3$)	Critical Load (kg/ha)	Process Contribution ($\mu\text{g}/\text{m}^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
31	614476	315146	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0011	0.04	0.006	0.04
32	612667	317133	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0015	0.05	0.008	0.05
33	610874	318619	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0010	0.03	0.005	0.04
34	615995	313692	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0010	0.03	0.005	0.03
35	618515	312868	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0009	0.03	0.005	0.03
36	625930	316534	Croswick Marsh SSSI/ The Broads SAC/ Broadland SPA/Ramsar	0.02	3.0	15.0	0.0010	0.03	0.005	0.04
37	617706	323415	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0063	0.63	0.033	0.66
38	616969	323177	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0045	0.45	0.023	0.46
39	617445	324330	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0044	0.44	0.023	0.45
40	615951	323832	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0026	0.26	0.014	0.27
41	615210	318152	Swannington Uppgate Common SSSI	0.02	1.0	5.0	0.0028	0.28	0.014	0.29
42	613159	318384	Alderford Common SSSI	0.02	3.0	10.0	0.0019	0.06	0.010	0.10
43	627277	327159	Westwick Lakes SSSI	0.02	3.0	n/a	0.0019	0.06	0.010	-
44	625662	329143	Bryant's Heath, Felmingham SSSI	0.02	1.0	5.0	0.0015	0.15	0.008	0.15

Table 7b. Predicted maximum annual mean ammonia concentrations and annual nitrogen deposition rates – Proposed Scenario

Receptor number	X(m)	Y(m)	Designation/Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu\text{g}/\text{m}^3$)	Critical Load (kg/ha)	Process Contribution ($\mu\text{g}/\text{m}^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	619554	320942	LWS	0.03	1.0	10.0	0.054	5.38	0.42	4.19
2	619699	320964	LWS	0.03	1.0	10.0	0.046	4.62	0.36	3.60
3	619613	320706	LWS	0.03	1.0	10.0	0.026	2.58	0.20	2.01
4	620077	320635	LWS	0.03	1.0	10.0	0.012	1.22	0.10	0.95
5	619972	320239	LWS	0.03	1.0	10.0	0.008	0.82	0.06	0.64
6	619658	320070	LWS	0.03	1.0	10.0	0.008	0.82	0.06	0.64
7	620436	320575	LWS	0.03	1.0	10.0	0.008	0.84	0.07	0.65
8	620515	321312	LWS	0.03	1.0	10.0	0.025	2.45	0.19	1.91
9	620963	321259	LWS	0.03	1.0	10.0	0.013	1.32	0.10	1.03
10	621124	321730	LWS	0.03	1.0	10.0	0.015	1.45	0.11	1.13
11	618451	321226	LWS	0.03	1.0	10.0	0.010	1.01	0.08	0.78
12	618499	321001	LWS	0.03	1.0	10.0	0.012	1.24	0.10	0.97
13	618062	320923	LWS	0.03	1.0	10.0	0.007	0.70	0.05	0.54
14	620111	319618	LWS	0.03	1.0	10.0	0.004	0.43	0.03	0.34
15	619875	320732	AW	0.03	1.0	10.0	0.019	1.87	0.15	1.46
16	619400	320627	AW	0.03	1.0	10.0	0.021	2.10	0.16	1.63
17	619086	320362	AW	0.03	1.0	10.0	0.012	1.16	0.09	0.91
18	619647	320332	AW	0.03	1.0	10.0	0.012	1.21	0.09	0.94
19	620245	320676	AW	0.03	1.0	10.0	0.012	1.16	0.09	0.90
20	618806	320108	AW	0.03	1.0	10.0	0.008	0.79	0.06	0.61
21	619363	319981	AW	0.03	1.0	10.0	0.007	0.71	0.06	0.55
22	620257	320362	AW	0.03	1.0	10.0	0.007	0.72	0.06	0.56
23	618065	321940	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.03	1.0	5.0	0.005	0.50	0.04	0.78
24	617981	322147	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.03	1.0	5.0	0.006	0.60	0.05	0.94
25	617724	321465	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.004	0.37	0.02	0.38
26	617554	322020	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.003	0.31	0.02	0.33
27	617397	321645	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.003	0.27	0.01	0.28
28	617106	321999	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.002	0.22	0.01	0.23
29	617110	321458	Buxton Heath SSSI/Norfolk Valley Fens SAC	0.02	1.0	5.0	0.002	0.22	0.01	0.23
30	611520	323094	Booton Common SSSI/ Norfolk Valley Fens SAC	0.02	1.0	5.0	0.0004	0.04	0.002	0.05

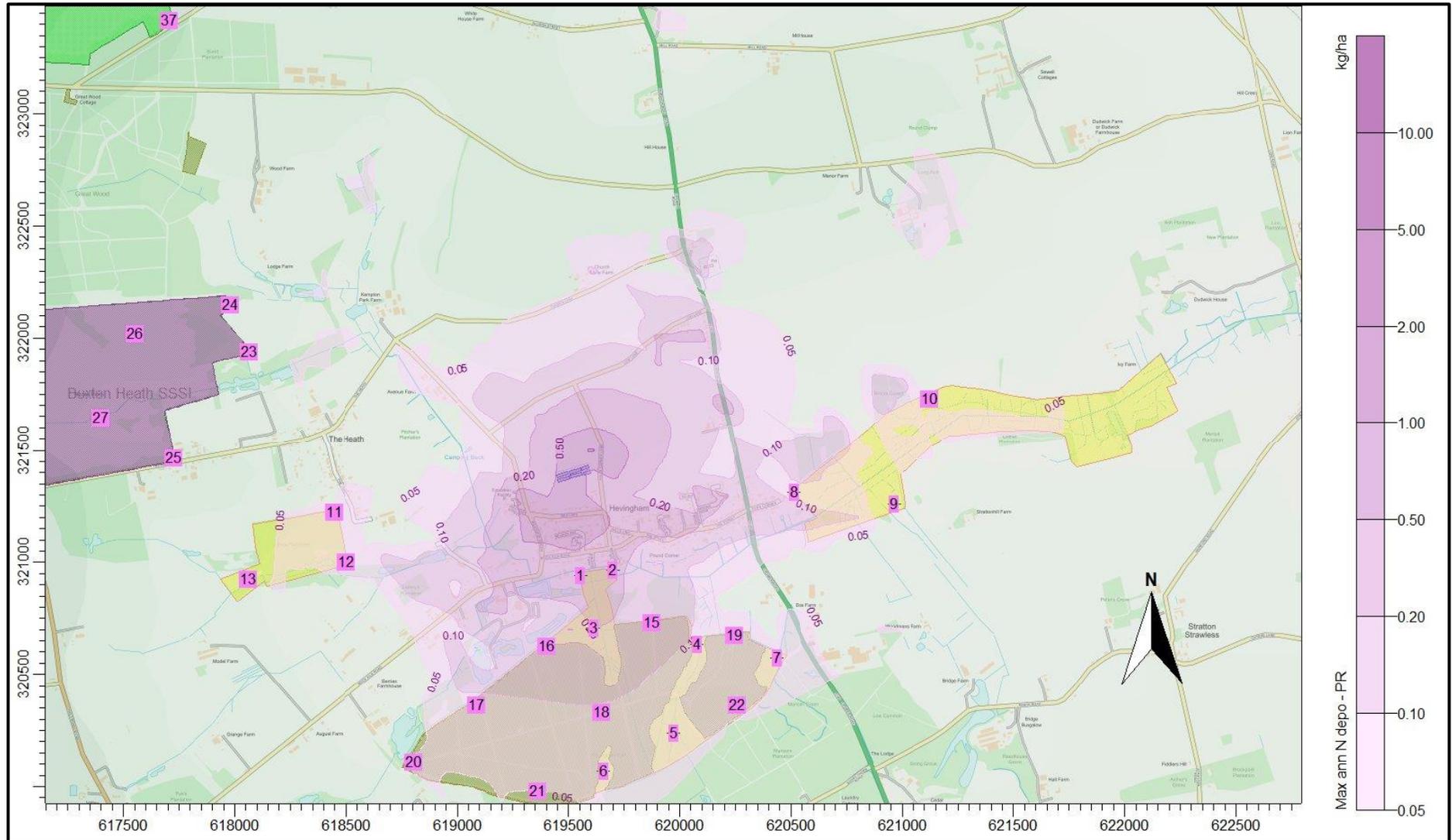
Receptor number	X(m)	Y(m)	Designation/Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu\text{g}/\text{m}^3$)	Critical Load (kg/ha)	Process Contribution ($\mu\text{g}/\text{m}^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
31	614476	315146	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0006	0.02	0.003	0.02
32	612667	317133	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0007	0.02	0.004	0.03
33	610874	318619	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0005	0.02	0.003	0.02
34	615995	313692	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0006	0.02	0.003	0.02
35	618515	312868	River Wensum SSSI/SAC	0.02	3.0	15.0	0.0005	0.02	0.003	0.02
36	625930	316534	Crostick Marsh SSSI/ The Broads SAC/Broadland SPA/Ramsar	0.02	3.0	15.0	0.0006	0.02	0.003	0.02
37	617706	323415	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0024	0.24	0.012	0.25
38	616969	323177	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0019	0.19	0.010	0.19
39	617445	324330	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0019	0.19	0.010	0.20
40	615951	323832	Cawston and Marsham Heaths SSSI	0.02	1.0	5.0	0.0014	0.14	0.007	0.15
41	615210	318152	Swannington Uppgate Common SSSI	0.02	1.0	5.0	0.0012	0.12	0.006	0.13
42	613159	318384	Alderford Common SSSI	0.02	3.0	10.0	0.0009	0.03	0.005	0.05
43	627277	327159	Westwick Lakes SSSI	0.02	3.0	n/a	0.0009	0.03	0.005	-
44	625662	329143	Bryant's Heath, Felmingham SSSI	0.02	1.0	5.0	0.0007	0.07	0.004	0.08

Figure 7a. Maximum annual mean ammonia concentration – Proposed Scenario



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Figure 7b. Maximum annual nitrogen deposition rates – Proposed Scenario



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6. Summary and Conclusions

Ammonia emission rates from the poultry houses at Longfield Farm Poultry Unit have been assessed and quantified based upon the Environment Agency standard ammonia emission factors. The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen and acid deposition rates in the surrounding area.

Existing Scenario

The modelling predicts that the process contributions to the maximum annual mean ammonia concentration and annual nitrogen deposition rates:

- Are currently below the Environment Agency lower thresholds of the relevant Critical Level and Critical Load at all of the wildlife sites considered with the exception of closer parts of the Norfolk Valley Fens SAC.

Proposed Scenario

The modelling predicts that, should the proposed redevelopment proceed, the process contributions to the maximum annual mean ammonia concentration and annual nitrogen deposition rates:

- Would remain below the Environment Agency lower thresholds of the relevant Critical Level and Critical Load at all of the wildlife sites considered.
- Would be below 1% of the Critical Level and/or the Critical Load at Norfolk Valley Fens SAC.
- Would be reduced from current levels at all wildlife sites considered, with significant reductions at most LWSs and AWs and also closer parts of Buxton Heath SSSI/Norfolk Valley Fens SAC.

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