A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Broiler Chicken Rearing Houses at Land North of Redhouse Farm, Oakley Road, Wix, near Manningtree in Essex

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[redacted]

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Ian Pick of Ian Pick Associates Ltd., on behalf of A H Brown Farms, to use computer modelling to assess the impact of ammonia emissions from the proposed broiler chicken rearing houses at Land North of Redhouse Farm, Oakley Road, Wix, Manningtree, Essex. CO11 2SF.

Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's 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 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 proposed broiler rearing houses at Land North of Redhouse Farm is in a rural area, approximately 1 km to the east of the village of Wix in Essex. The surrounding land is used largely for arable farming, but there are also some isolated meadows and some wooded areas. The site is at an altitude of around 16 m with the land falling gently to the south-east along the Ramsey Creek and rising gently towards higher ground to the north, west and south-west.

There are currently two poultry houses at Land North of Redhouse Farm. The poultry houses are currently used to provide accommodation for up to 100,000 broiler chickens. The houses are ventilated primarily by uncapped high speed ridge fans, each with a short chimney, with gable end fans which would provide additional ventilation in hot weather conditions. The chickens are reared from day old chicks to around 38 days old and there are approximately 7.5 crops per year.

Under the proposal, three new poultry houses would be constructed to the east of the existing houses. The new poultry houses would provide accommodation for up to 132,402 broiler chickens (additionally, the stocking of the existing houses would be reduced to 88,268 birds). The new houses would be ventilated primarily by uncapped high speed ridge fans, each with a short chimney and there would also be gable end fans which would provide additional ventilation in hot weather conditions. The chickens would be reared from day old chicks to around 38 days old and there would be approximately 7.5 crops per year.

There are two areas of Ancient Woodlands (AWs) and one area designated as a Local Wildlife Site (LWS) within 2 km of the site of the proposed poultry houses at Land North of Redhouse Farm. There are ten Sites of Special Scientific Interest (SSSIs) that are within 10 km of the farm. There is one Special Area of Conservation (SAC), within 10 km of Land North of Redhouse Farm and also three areas designated as Special Areas of Conservation (SPAs) and Ramsar sites. Some further details of the AW, LWS, SSSIs, SAC, SPAs and Ramsar sites are provided below.

- Dengewell Wood AW - approximately 1.3 km to the south-west.
- Broadmeadow Wood AW - approximately 2.0 km to the south-south-west.
- Soils Wood LWS - approximately 2.0 km to the east.
- Stour & Copperas Woods, Ramsey SSSI - Approximately 2.4 km to the north-north-east - The largest area of woodland in north-east Essex. They have a coppice-with-standards structure and contain the only example in the county where coastal and woodland habitats meet.
- Little Oakley Channel Deposit SSSI - Approximately 4.3 km to the east-north-east - Geological.
- Hamford Water SSSI/SACS/PA/Ramsar - approximately 3.2 km to the south-east at its closest point - A tidal inlet whose mouth is about three miles south of Harwich. It is a large and shallow estuarine basin comprising tidal creeks, intertidal mud and sand flats, saltmarshes, islands, beaches and marsh grasslands. The site is of international importance for breeding Little Terns and wintering Dark-bellied Brent Geese, wildfowl and waders, and of national importance for many other bird species.
- Stour Estuary SSSI/SPA/Ramsar - Approximately 3.4 km to the north-north-east at its closest point - The estuary is nationally important for 13 species of wintering waterfowl and three species on autumn passage and is also of national importance for coastal saltmarsh, sheltered muddy shores, two scarce marine invertebrates and a vascular scarce plant assemblage.
- Orwell Estuary SSSI/SPA/Ramsar - Approximately 9.0 km to the north-east at its closest point - The estuary is of national importance for breeding avocet *Recurvirostra avosetta*, its breeding bird assemblage of open waters and

their margins, nine species of wintering waterfowl (including black tailed godwit *Limosa limosa islandica*), an assemblage of vascular plants, and intertidal mud habitats.

- Weeleyhall Wood SSSI Approximately 7.4 km to the south south west One of the largest ancient woods in the Tendring peninsula. It contains one of the best examples in Essex of base poor spring line alder woodland, a type of woodland which is rare in the county, as well as good examples of lowland hazel pedunculate oak and some wet ash maple woodland, and chestnut coppice with standards derived from these last two.
- Holland Haven Marshes SSSI Approximately 8.6 km to the south An area of reclaimed estuarine saltmarsh and freshwater marsh. The ditch network represents an outstanding example of a freshwater to brackish water transition intimated by the aquatic plant communities, which include a number of nationally and locally scarce species. The adjoining grasslands are of botanical importance in their own right, as well as acting as a buffer zone to the ditch system.
- The Naze SSSI Approximately 9.7 km to the south east Geological.
- Harwich Foreshore SSSI Approximately 8.6 km to the east north east Geological.
- Freston and Cutler's Woods with Holbrook Park SSSI Approximately 9.9 km to the north north west One of the largest areas of ancient woodland in Suffolk. They contain a variety of woodland types typical of light, sandy soil and spring fed valleys.

Maps of the surrounding area showing the positions of the proposed poultry houses and the nearby wildlife sites are provided in Figures 1a and 1b. In these figures, AWs are shaded olive, the LWS is shaded yellow, the SSSIs are shaded green, the SAC is shaded purple, the SPAs/Ramsar sites are shaded orange and the positions of the proposed poultry houses are outlined in blue.

Figure 1a. The area surrounding the site, with concentric circles radii 10.0 km (purple), 5.0 km (green) and 2.0 km (olive)

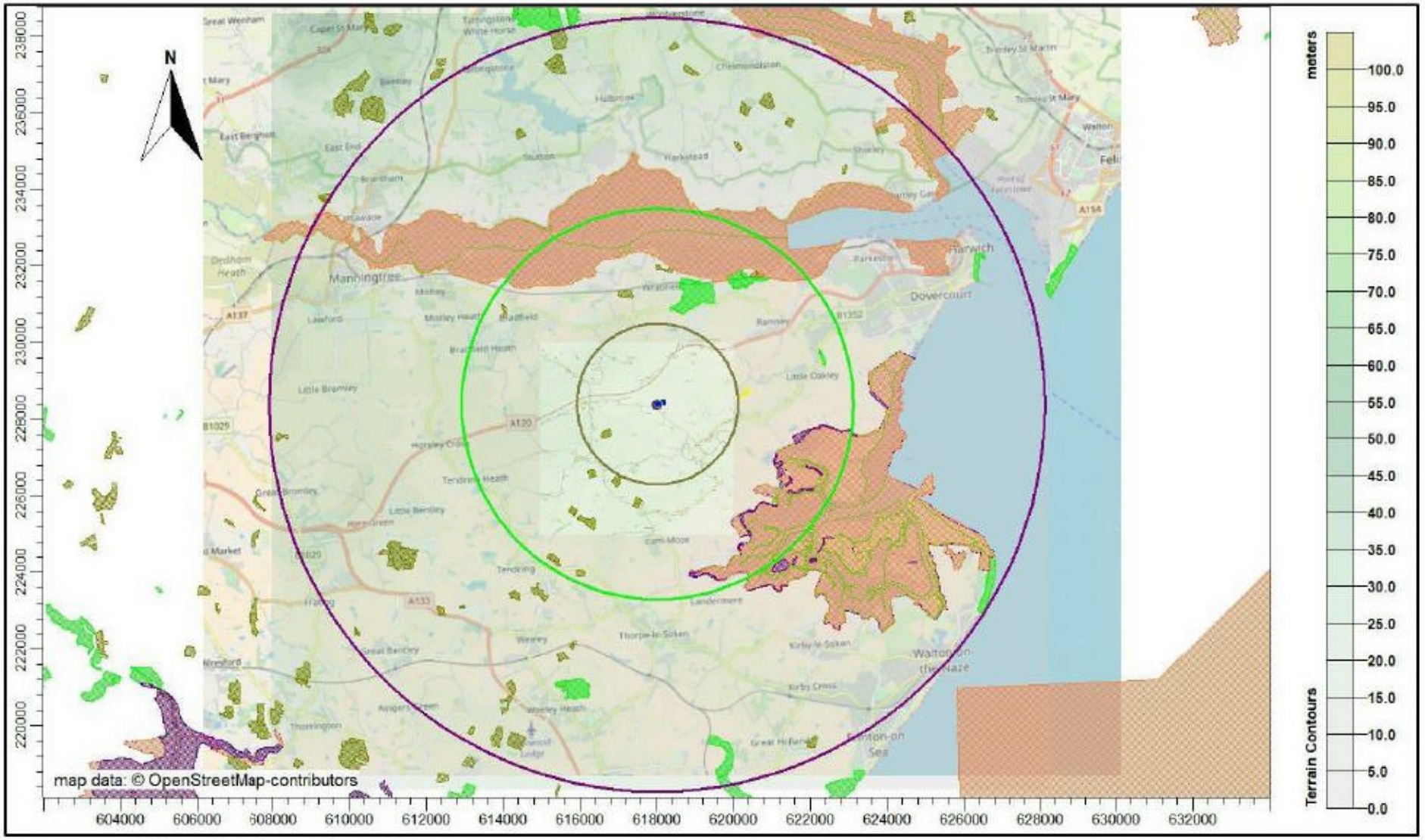
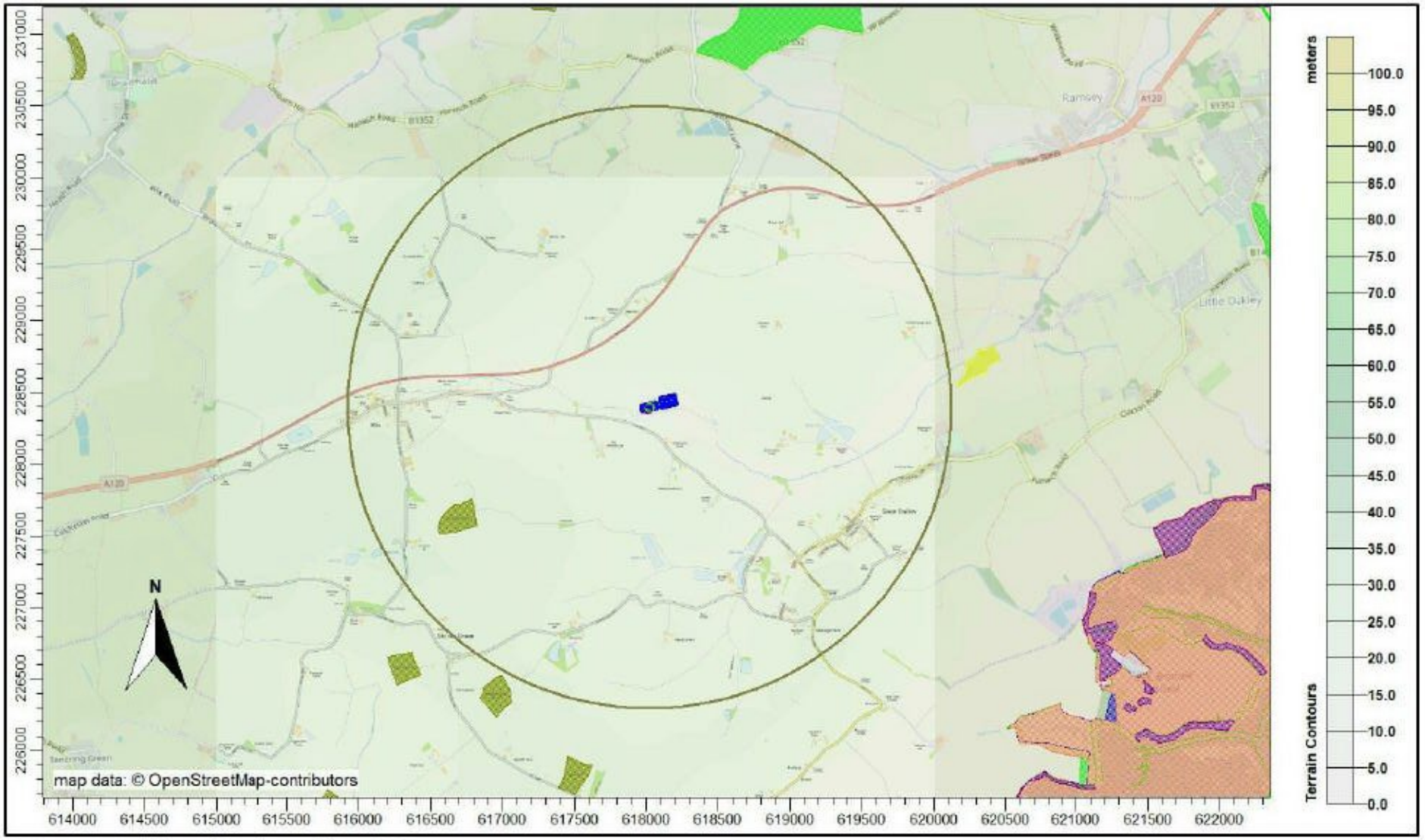


Figure 1b. The area surrounding the site - a closer view



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 Land North of Redhouse Farm and the wildlife sites is 1.74 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 28.70 kg-N/ha/y and to short vegetation is 15.96 kg-N/ha/y. The background acid deposition rate to woodland is 2.10 keq/ha/y and to short vegetation is 1.17 keq/ha/y. The source of these background figures is the Air Pollution Information System (APIS, August 2021).

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. However, it may be necessary to consider nitrogen deposition should a Critical Load of 5.0 kg-N/ha/y be appropriate. Normally, the Critical Load for nitrogen deposition provides a stricter test than the Critical Load for acid deposition.

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

Site	Critical Level (µg-NH_3/m^3)	Critical Load - Nitrogen Deposition (kg-N/ha/y)	Critical Load - Acid Deposition (keq/ha/y)
AWs & LWS	1.0 [1]	-	-
Stour & Copperas Woods, Ramsey SSSI and Weeleyhall Wood SSSI	1.0 [1&2]	15.0 [2&3]	-
Hamford Water SSSI/SACSPA/Ramsar, Stour Estuary SSSI/SPA/Ramsar and Orwell Estuary SSSI/SPA/Ramsar	3.0 [2]	20. 0 [2&3]	-
Holland Haven Marshes SSSI	3.0 [2]	n/a [4]	n/a [4]
Little Oakley Channel Deposit SSSI, The Naze SSSI and Harwich Foreshore SSSI	n/a [4]	n/a [4]	n/a [4]

1. A precautionary figure used where details of the ecology of the site are unavailable or unassessed, or the citation for the site, or information from APIS indicates that sensitive lichens and/or bryophytes are present.
2. Based upon the citation for the site and information from APIS (August 2021).
3. The lower bound of the range of Critical Loads for the site/species, obtained from APIS (August 2021).
4. No Critical Level/Load for the designated features, or no site entry, in APIS (August 2021).

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.

Recent advice from Natural England[2] states that "At the screening assessment stage for agricultural proposals acting alone the threshold is 4% for both SSSI and N2K sites" and "At the detailed assessment stage where there is an in-combination assessment, the threshold for agricultural proposals is 20% for N2K sites and 50% for SSSIs".

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.
2. Hack, Richard M. "NE guideline screening thresholds for air pollution". Message to Nicola Stone, cc Ian Pick. 2nd October 2020. E-mail.

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 Environment Agency provided an Intensive farming guidance note which lists standard ammonia emission factors for a variety of livestock, including broiler chickens. The emission factor for broiler chickens is 0.034 kg-NH_3/bird place/y; this figure is used to calculate the emissions from the proposed poultry houses.

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 animal numbers and ammonia emission rates

Source	Animal numbers	Type or weight	Emission factor (kg-NH_3/place/y)	Emission rate (g-NH_3/s)
Proposed Housing	132,402	Broiler Chickens	0.034	0.142649

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)[1].

The GFS is a spectral model: over the UK, the physics/dynamics model has an equivalent resolution of approximately 9 km (latterly approximately 6 km); terrain is understood to be resolved at a resolution of approximately 2 km, with sub-9/6 km terrain effects parameterised. Site specific data may be extrapolated from nearby archive grid points or a most representative grid point chosen. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR[2]). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional records may be 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 and wind directions are modified during the modelling by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling. The terrain and roughness length modified wind rose for Westhall Farm is shown in Figure 2b; although there is little modification in this case, elsewhere in the modelling domain the modified wind roses may differ more markedly, reflecting the local flow in that part of the domain. The resolution of FLOWSTAR is 64 by 64 grid points and the effective resolution of the wind field is approximately 340 m. Please note that FLOWSTAR[2] is used to obtain a local flow field, not to explicitly model dispersion in complex terrain as defined in the ADMS User Guide; therefore, the ADMS default value for minimum turbulence length has been amended[3].

1. The GFS data used is derived from the high resolution operational GFS datasets, the data is not obtained from the lower resolution (0.5 degree) long-term archive.
2. Note that FLOWSTAR requirements are for meteorological data representative of the upwind flow over the modelling domain and that single site meteorological data (observational or from high resolution modelled data) that is representative of the application site is not generally suitable (personal correspondence: CERC 2019 and UK Met O 2015). If data are deemed representative of a particular application site, either wholly or partially, then these data cannot also be representative of the upstream flow over the modelling domain. Furthermore, it would be extremely poor practice to use such data as the boundary conditions for a flow-solver, such as FLOWSTAR.
3. When modelling complex terrain with ADMS, by default, the minimum turbulence length has 0.1 m added to the flat terrain value (calculated from the Monin-Obukhov length). Whilst this might be appropriate over hill/mountain tops in terrain with slopes > 1:10 (and quite possibly only in certain wind directions) in lesser terrain it introduces model behaviour that is not desirable where FLOWSTAR is simply being used to modify the upwind flow. Specifically, the parameter sigma z of the Gaussian plume model is overly constrained, which for elevated point sources emissions, may on occasion cause over prediction of ground level concentrations in stable weather conditions and light winds (Steven R. Hanna & Biswanath Chowdhury, 2013), conversely for low level emission sources, this will cause gross under prediction. Note that this becomes particularly important overnight and if calm and light wind conditions are not being ignored, as they often are when using traditional observational meteorological datasets. To reduce this behaviour, where terrain is modelled, AS Modelling & Data Ltd. have set a minimum turbulence length of 0.025 m in ADMS. This approximates the normal behaviour of ADMS with flat terrain.

Figure 2a. The wind rose. Raw GFS derived data for 51.911 N, 1.170 E, 2017-2020

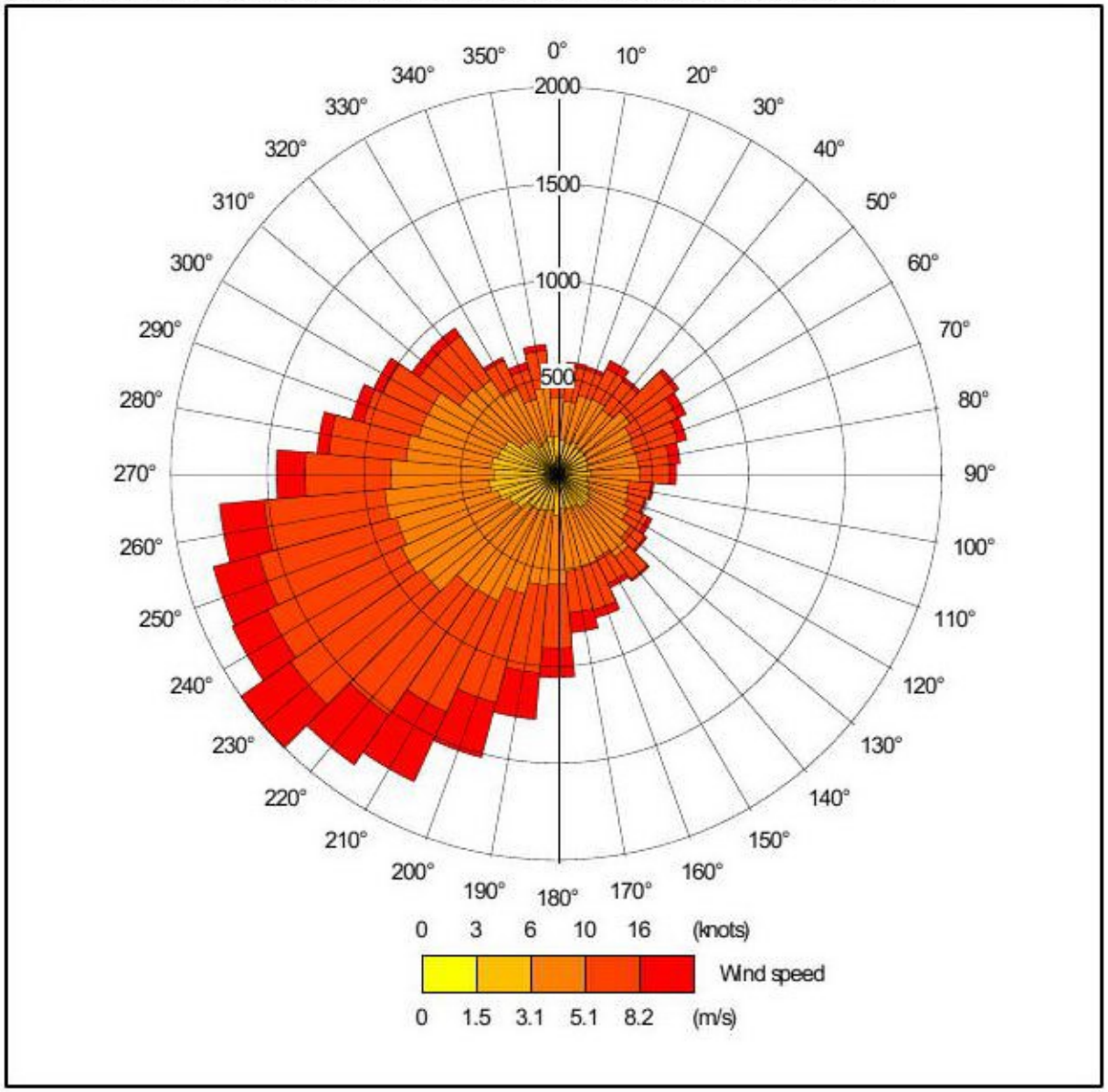
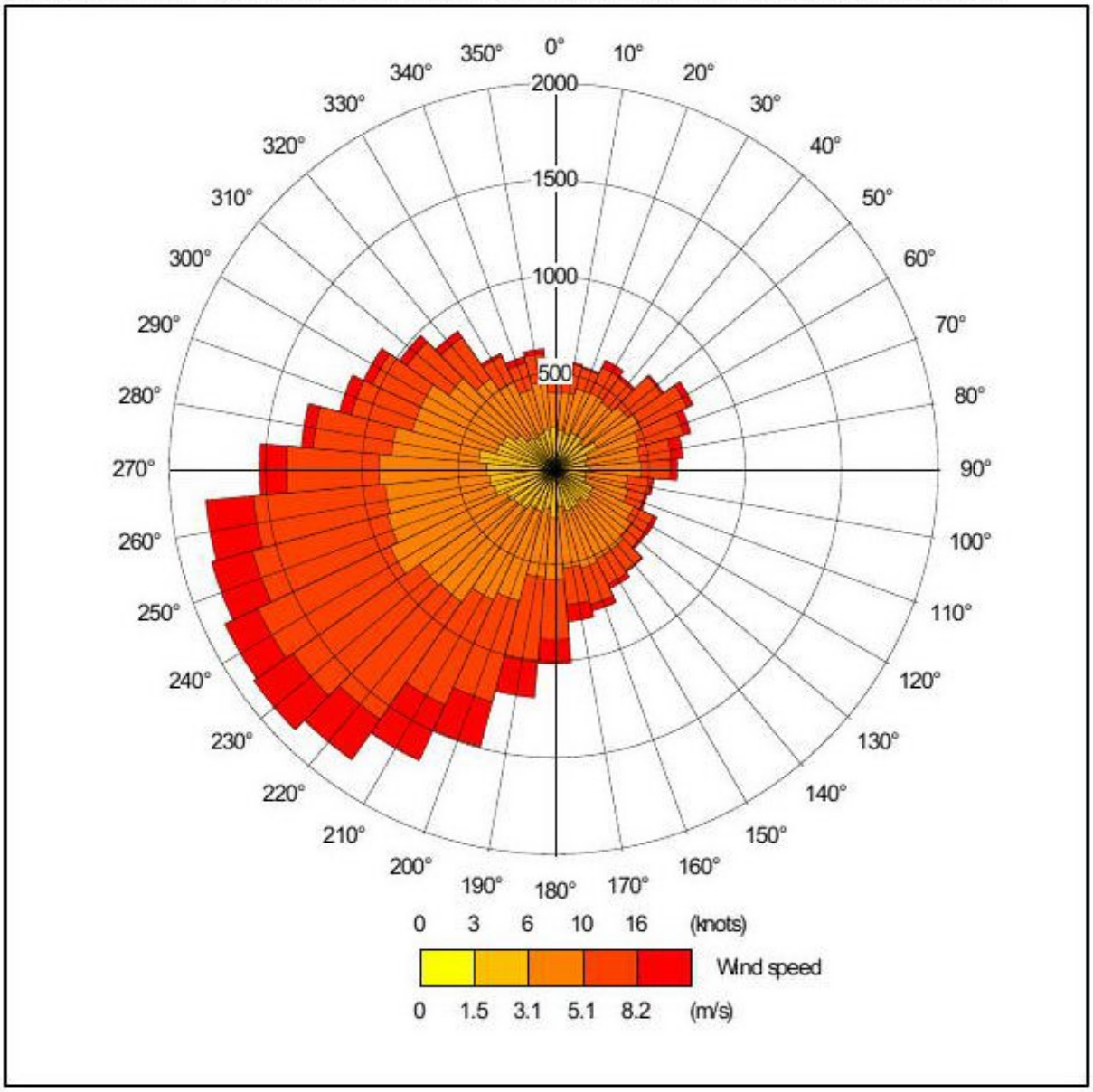


Figure 2b. The wind rose. FLOWSTAR modified GFS data for NGR 618000, 228400, 2017-2020



4.2 Emission sources

Emissions from the chimneys of the uncapped high speed ridge or roof fans that would be used for the ventilation of the proposed poultry houses are represented by three point sources per house within ADMS (PR3 1, 2 & 3 to PR5 1, 2 & 3). Details of the point source parameters are shown in Table 3a and their positions may be seen in Figure 3 (marked by grey rectangles).

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (°C)	Emission rate per source (g-NH_3/s)
PR3 1, 2 & 3 to PR5 1, 2 & 3	6.7	0.8	11.0	Variable [1]	0.015850 [1 & 2]

1. Dependent on ambient temperature.
2. Reduced by 50% when the ambient temperature equals or exceeds 21 Celsius.

The proposed poultry houses would also be fitted with gable end fans which would be used to provide supplementary ventilation in hot weather conditions. The emissions from these gable end fans are represented by two volume sources within ADMS (PR34_GAB and PR5_GAB). Details of the volume source parameters are shown in Table 3b. The position of the volume sources may be seen in Figure 3 (marked by red shaded rectangles).

Table 3b. Volume source parameters

Source ID (Scenario)	Length Y (m)	Width X (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
PR34_GAB	49.7	10.0	3.0	0.5	Ambient	0.047550 [3]
PR5_GAB	20.4	10.0	3.0	0.5	Ambient	0.023775 [3]

3. 50% of the total emission is emitted when the ambient temperature equals or exceeds 21 Celsius.

4.3 Modelled buildings

The structure of the existing poultry houses (labelled PR1 and PR2) and proposed poultry houses (labelled PR3, PR4 and PR5) 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 grey rectangles).

4.4 Discrete receptors

Fifty-four discrete receptors have been defined at the non-statutory and statutory wildlife sites. These receptors are defined at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 4, 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 velocity field, 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 Figure 4, 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 20.0 km x 20.0 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 300 m.

4.7 Roughness Length

A variable surface roughness file has been used in the terrain runs. Surface roughness is set to 0.02m over the sea and estuaries and 0.2 m over land. Otherwise, a surface roughness length of 0.2 m has been applied over the entire modelling domain. The GFS data are assumed to have a roughness length of 0.2 m.

Figure 3. The positions of modelled buildings and sources

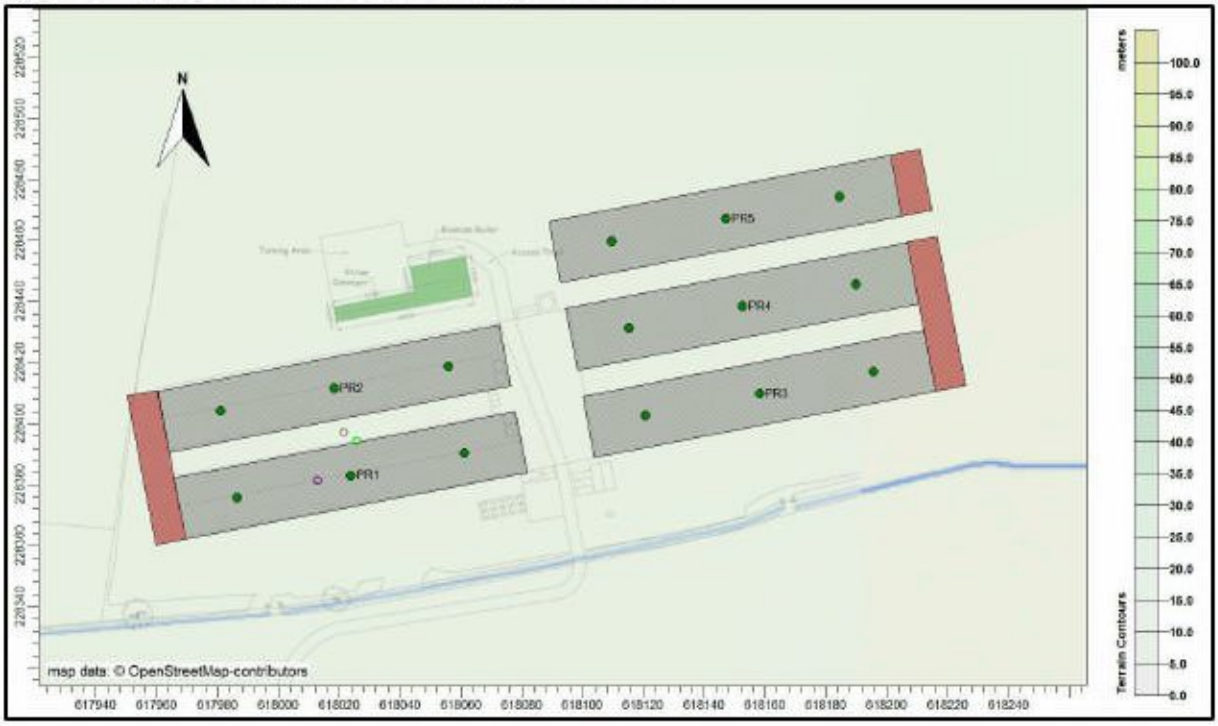
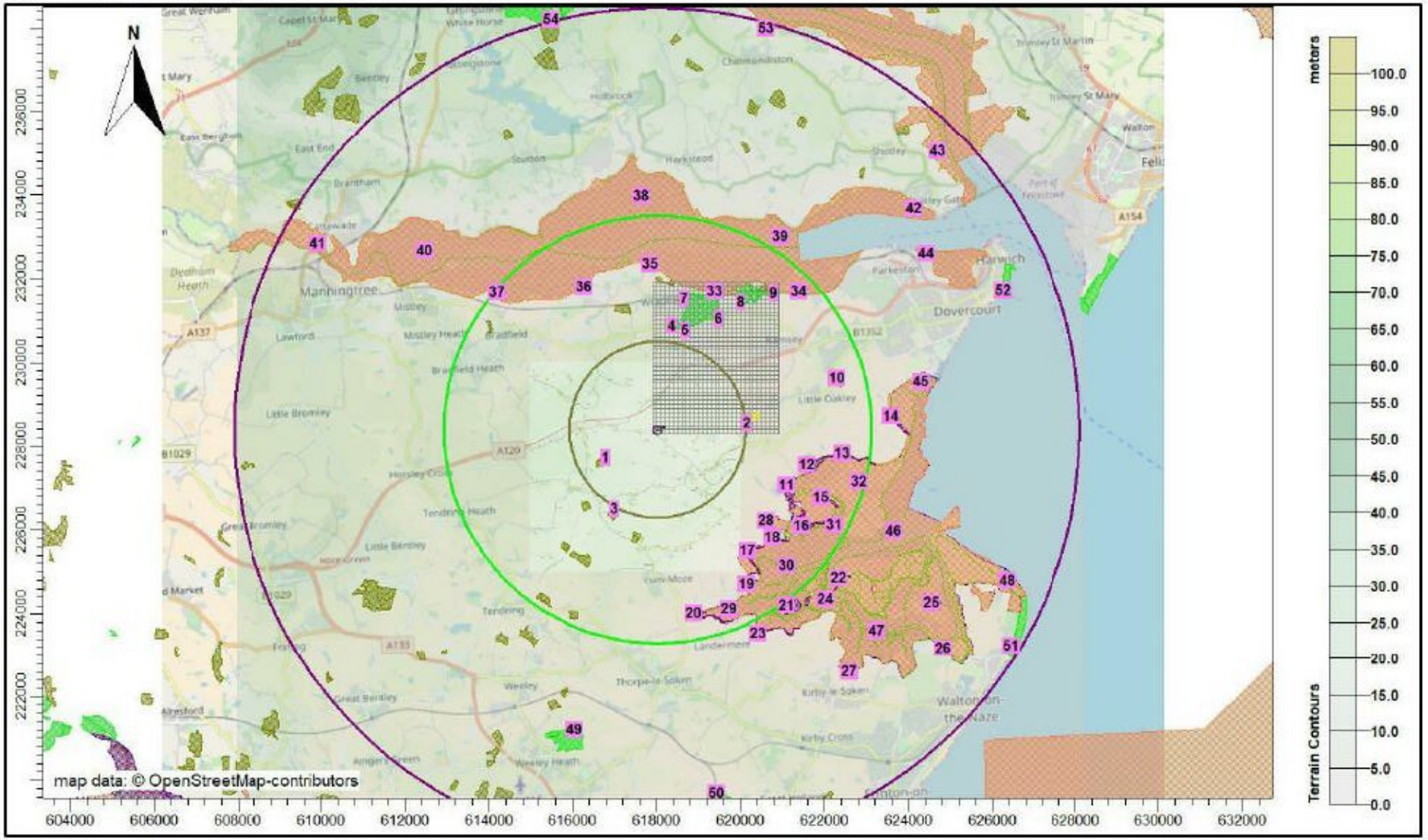


Figure 4. The discrete receptors and regular Cartesian grid



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 piggeries and between 0.010 m/s and 0.015 m/s over heavily grazed grassland. Where deposition over water surfaces is calculated, a deposition velocity of 0.005 m/s is used.

In 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 is used to define a deposition velocity field. The deposition velocities used are provided in Table 4.

Table 4. Deposition velocities

NH_3 concentration (PC + background) ($\mu g/m^3$)	< 10	10 - 20	20 - 30	30 - 80	> 80
Deposition velocity - woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity - short vegetation (m/s)	0.02 (0.015 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

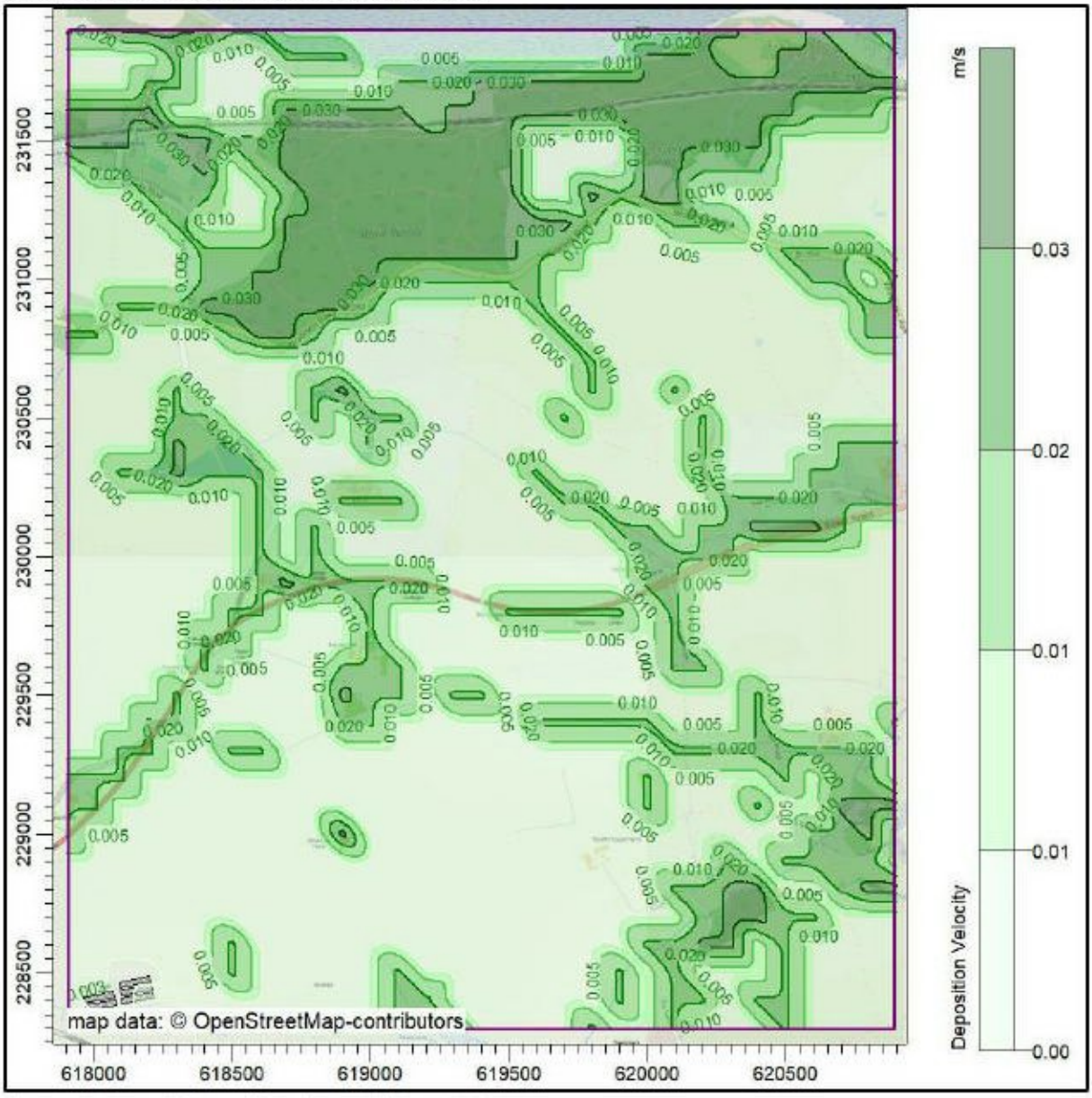
- The model is then rerun with the spatially varying deposition module.

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

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

Please note that the effects of the existing housing emission are considered in the calculation of local deposition velocities.

Figure 5. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

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 receptor are provided in Table 4a. In the Table, predicted ammonia concentrations (or concentrations equivalent to nitrogen deposition rates) that are in excess of the Environment Agency's upper percentage threshold of the relevant Critical Level or Critical Load (20% for a SAC/SPA/Ramsar site, 50% for a SSSI and 100% for an AW or LWS) are coloured red. Predicted ammonia concentrations (or concentrations equivalent to nitrogen deposition rates) that are in the range between the Environment Agency's upper threshold and lower threshold of the relevant Critical Level or Critical Load (4% and 20% for a SAC/SPA/Ramsar site, 20% and 50% for a SSSI and 100% and 100% for an AW or LWS) are coloured blue. Additionally, predicated ammonia concentrations and nitrogen deposition rates that exceed 1% of Critical Level or Critical Load at a statutory wildlife site are highlighted with bold text.

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

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)			
				Proposed Only			
				GFS No Calms No Terrain	GFS Calms No Terrain	GFS No Calms Terrain	GFS No Calms Terrain Fixed depo 0.003 m/s
1	616774	227729	Dengewell Wood AW	0.030	0.030	0.031	0.025
2	620159	228541	Soils Wood LWS	0.043	0.043	0.046	0.037
3	616983	226501	Broadmeadow Wood AW	0.022	0.022	0.024	0.017
4	618357	230873	Stour & Copperas Woods, Ramsey SSSI	**0.018**	**0.018**	**0.018**	**0.015**
5	618674	230754	Stour & Copperas Woods, Ramsey SSSI	**0.020**	**0.020**	**0.020**	**0.017**
6	619485	231039	Stour & Copperas Woods, Ramsey SSSI	**0.017**	**0.017**	**0.017**	**0.014**
7	618663	231523	Stour & Copperas Woods, Ramsey SSSI	**0.013**	**0.013**	**0.013**	**0.011**
8	620001	231431	Stour & Copperas Woods, Ramsey SSSI	**0.014**	**0.014**	**0.015**	**0.012**
9	620781	231646	Stour & Copperas Woods, Ramsey SSSI	**0.012**	**0.012**	**0.014**	**0.010**
10	622296	229615	Little Oakley Channel Deposit SSSI	0.012	0.012	0.013	0.010
11	621099	227080	Hamford Water SSSI/SAC/SPA/Ramsar	0.016	0.016	0.019	0.014
12	621571	227551	Hamford Water SSSI/SAC/SPA/Ramsar	0.015	0.015	0.018	0.014
13	622414	227823	Hamford Water SSSI/SAC/SPA/Ramsar	0.013	0.013	0.016	0.011
14	623581	228711	Hamford Water SSSI/SAC/SPA/Ramsar	0.011	0.011	0.012	0.008
15	621907	226771	Hamford Water SSSI/SAC/SPA/Ramsar	0.012	0.012	0.014	0.010
16	621444	226109	Hamford Water SSSI/SAC/SPA/Ramsar	0.012	0.012	0.015	0.011
17	620174	225511	Hamford Water SSSI/SAC/SPA/Ramsar	0.008	0.009	0.009	0.008
18	620755	225819	Hamford Water SSSI/SAC/SPA/Ramsar	0.010	0.011	0.013	0.010
19	620138	224703	Hamford Water SSSI/SAC/SPA/Ramsar	0.007	0.007	0.007	0.005
20	618886	224023	Hamford Water SSSI/SAC/SPA/Ramsar	0.008	0.008	0.009	0.006
21	621090	224205	Hamford Water SSSI/SAC/SPA/Ramsar	0.005	0.006	0.006	0.004
22	622342	224858	Hamford Water SSSI/SAC/SPA/Ramsar	0.007	0.007	0.009	0.006
23	620410	223529	Hamford Water SSSI/SAC/SPA/Ramsar	0.005	0.005	0.005	0.003
24	622015	224345	Hamford Water SSSI/SAC/SPA/Ramsar	0.006	0.006	0.007	0.005
25	624546	224264	Hamford Water SSSI/SAC/SPA/Ramsar	0.005	0.005	0.007	0.004
26	624818	223175	Hamford Water SSSI/SAC/SPA/Ramsar	0.004	0.004	0.005	0.003
27	622600	222604	Hamford Water SSSI/SAC/SPA/Ramsar	0.004	0.004	0.004	0.003
28	620614	226223	Hamford Water SSSI/SPA/Ramsar	0.014	0.014	0.017	0.013
29	619716	224128	Hamford Water SSSI/SPA/Ramsar	0.007	0.007	0.006	0.004
30	621090	225148	Hamford Water SSSI/SPA/Ramsar	0.007	0.007	0.009	0.007
31	622233	226114	Hamford Water SSSI/SPA/Ramsar	0.010	0.010	0.012	0.009
32	622832	227161	Hamford Water SSSI/SPA/Ramsar	0.010	0.010	0.012	0.008
33	619390	231691	Stour Estuary SSSI/SPA/Ramsar	0.012	0.012	0.013	0.011
34	621390	231691	Stour Estuary SSSI/SPA/Ramsar	0.010	0.010	0.013	0.009
35	617839	232344	Stour Estuary SSSI/SPA/Ramsar	0.009	0.009	0.010	0.007
36	616268	231793	Stour Estuary SSSI/SPA/Ramsar	0.009	0.009	0.011	0.007
37	614207	231671	Stour Estuary SSSI/SPA/Ramsar	0.007	0.007	0.007	0.004
38	617635	233967	Stour Estuary SSSI/SPA/Ramsar	0.005	0.005	0.006	0.004
39	620941	232987	Stour Estuary SSSI/SPA/Ramsar	0.008	0.008	0.009	0.006
40	612462	232650	Stour Estuary SSSI/SPA/Ramsar	0.004	0.004	0.005	0.003
41	609921	232834	Stour Estuary SSSI/SPA/Ramsar	0.003	0.003	0.003	0.002
42	624124	233661	Stour Estuary SSSI/SPA/Ramsar	0.004	0.004	0.006	0.004
43	624706	235038	Orwell Estuary SSSI/SPA/Ramsar	0.004	0.004	0.005	0.003
44	624430	232589	Stour Estuary SSSI/SPA/Ramsar	0.005	0.005	0.006	0.004
45	624288	229547	Hamford Water SSSI/SPA/Ramsar	0.008	0.008	0.008	0.006
46	623634	225978	Hamford Water SSSI/SPA/Ramsar	0.007	0.007	0.008	0.006
47	623236	223590	Hamford Water SSSI/SPA/Ramsar	0.005	0.005	0.006	0.004
48	626359	224784	Hamford Water SSSI/SPA/Ramsar	0.004	0.004	0.005	0.003
49	616023	221200	Weeleyhall Wood SSSI	0.004	0.004	0.004	0.002
50	619418	219691	Holland Haven Marshes SSSI	0.004	0.004	0.004	0.002
51	626452	223225	The Naze SSSI	0.004	0.004	0.005	0.003
52	626264	231703	Harwich Foreshore SSSI	0.005	0.005	0.005	0.003
53	620608	238001	Orwell Estuary SSSI/SPA/Ramsar	0.003	0.003	0.003	0.002
54	615488	238193	Freston and Cutler's Woods with Holbrook Park SSSI	0.002	0.002	0.003	0.002

5.2 Detailed deposition modelling

At all wildlife sites considered within 10 km of Redhouse Farm, the predicted process contribution to annual mean ammonia concentrations (or concentrations equivalent to deposition rates) were below the Environment Agency lower and upper thresholds of the relevant Critical Level/Load. Detailed modelling was carried out over restricted domains covering Redhouse Farm and Stour & Copperas Woods, Ramsey SSSI, where annual mean ammonia concentrations were predicted to exceed 1% of the relevant Critical Level.

The results of the predicted process contribution to maximum annual mean ground level ammonia concentrations and nitrogen deposition rates in the detailed deposition modelling are shown in Table 6.

Contour plots of the predicted process contribution to ground level maximum annual ammonia concentrations and nitrogen deposition rates around Redhouse Farm are provided in Figures 6a and 6b.

Table 6. Predicted process contribution to annual mean ammonia concentrations and nitrogen deposition rates at the discrete receptors - proposed only

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu g/m^3$)	Critical Load (kg/ha)	Process Contribution ($\mu g/m^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	616774	227729	Dengewell Wood AW	0.030	1.0	10.0	0.024	2.4	0.19	1.9
2	620159	228541	Soils Wood LWS	0.030	1.0	10.0	0.035	3.5	0.27	2.7
3	616983	226501	Broadmeadow Wood AW	0.030	1.0	10.0	0.016	1.6	0.13	1.3
4	618357	230873	Stour & Copperas Woods, Ramsey SSSI	0.030	1.0	15.0	0.013	**1.3**	0.10	0.7
5	618674	230754	Stour & Copperas Woods, Ramsey SSSI	0.030	1.0	15.0	0.015	**1.5**	0.11	0.8
6	619485	231039	Stour & Copperas Woods, Ramsey SSSI	0.030	1.0	15.0	0.012	**1.2**	0.09	0.6
7	618663	231523	Stour & Copperas Woods, Ramsey SSSI	0.030	1.0	15.0	0.009	0.9	0.07	0.5
8	620001	231431	Stour & Copperas Woods, Ramsey SSSI	0.030	1.0	15.0	0.010	1.0	0.07	0.5
9	620781	231646	Stour & Copperas Woods, Ramsey SSSI	0.030	1.0	15.0	0.008	0.8	0.07	0.4
10	622296	229615	Little Oakley Channel Deposit SSSI	0.020	n/a	n/a	0.009	-	0.05	-
11	621099	227080	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.013	0.4	0.07	0.3
12	621571	227551	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.013	0.4	0.07	0.3
13	622414	227823	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.010	0.3	0.05	0.3
14	623581	228711	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.007	0.2	0.04	0.2
15	621907	226771	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.009	0.3	0.05	0.2
16	621444	226109	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.010	0.3	0.05	0.3
17	620174	225511	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.007	0.2	0.04	0.2
18	620755	225819	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.009	0.3	0.05	0.2
19	620138	224703	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.004	0.1	0.02	0.1
20	618886	224023	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.005	0.2	0.0	0.1
21	621090	224205	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.004	0.1	0.0	0.1
22	622342	224858	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.006	0.2	0.0	0.1
23	620410	223529	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.003	0.1	0.0	0.1
24	622015	224345	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.004	0.1	0.0	0.1
25	624546	224264	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.004	0.1	0.0	0.1
26	624818	223175	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.003	0.1	0.0	0.1
27	622600	222604	Hamford Water SSSI/SAC/SPA/Ramsar	0.020	3.0	20.0	0.002	0.1	0.0	0.1

Table 6. (continued)

Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m³)	Critical Load (kg/ha)	Process Contribution (µg/m³)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
28	620614	226223	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.012	0.4	0.1	0.3
29	619716	224128	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.004	0.1	0.0	0.1
30	621090	225148	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.006	0.2	0.0	0.2
31	622233	226114	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.008	0.3	0.0	0.2
32	622832	227161	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.008	0.3	0.0	0.2
33	619390	231691	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.009	0.3	0.0	0.2
34	621390	231691	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.007	0.2	0.0	0.2
35	617839	232344	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.006	0.2	0.0	0.1
36	616268	231793	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.006	0.2	0.0	0.2
37	614207	231671	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.004	0.1	0.0	0.1
38	617635	233967	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.003	0.1	0.0	0.1
39	620941	232987	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.005	0.2	0.0	0.1
40	612462	232650	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.002	0.1	0.0	0.1
41	609921	232834	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.001	0.0	0.0	0.0
42	624124	233661	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.003	0.1	0.0	0.1
43	624706	235038	Orwell Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.003	0.1	0.0	0.1
44	624430	232589	Stour Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.004	0.1	0.0	0.1
45	624288	229547	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.005	0.2	0.0	0.1
46	623634	225978	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.005	0.2	0.0	0.1
47	623236	223590	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.003	0.1	0.0	0.1
48	626359	224784	Hamford Water SSSI/SPA/Ramsar	0.020	3.0	20.0	0.003	0.1	0.0	0.1
49	616023	221200	Weeleyhall Wood SSSI	0.030	1.0	15.0	0.002	0.2	0.0	0.1
50	619418	219691	Holland Haven Marshes SSSI	0.020	3.0	n/a	0.002	0.1	0.0	-
51	626452	223225	The Naze SSSI	0.020	n/a	n/a	0.002	-	0.0	-
52	626264	231703	Harwich Foreshore SSSI	0.020	n/a	n/a	0.002	-	0.0	-
53	620608	238001	Orwell Estuary SSSI/SPA/Ramsar	0.020	3.0	20.0	0.001	0.0	0.0	0.0
54	615488	238193	Freston and Cutler's Woods with Holbrook Park SSSI	0.030	1.0	10.0	0.001	0.1	0.0	0.1

Figure 6a. Maximum annual mean ammonia concentration - proposed only

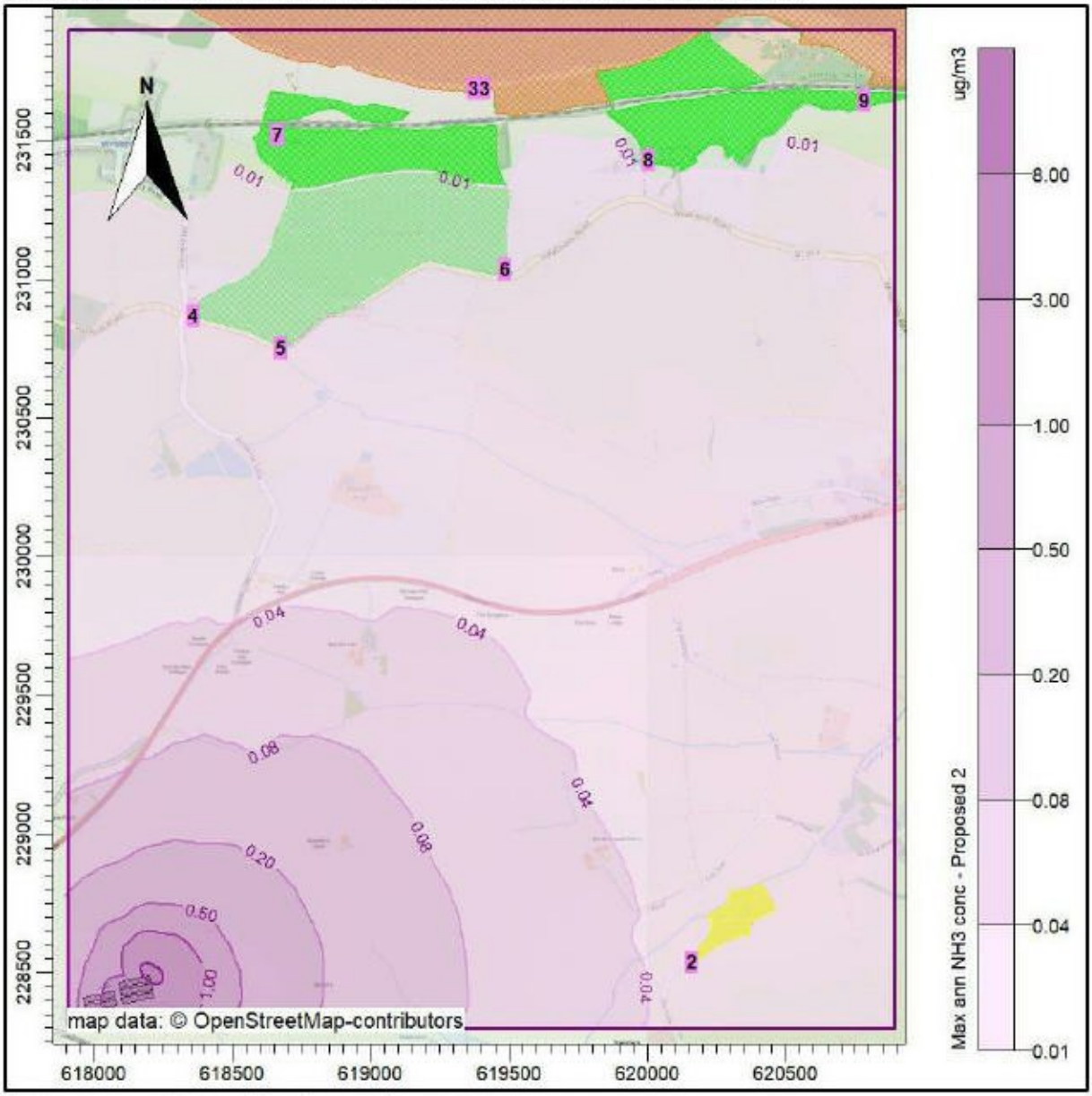
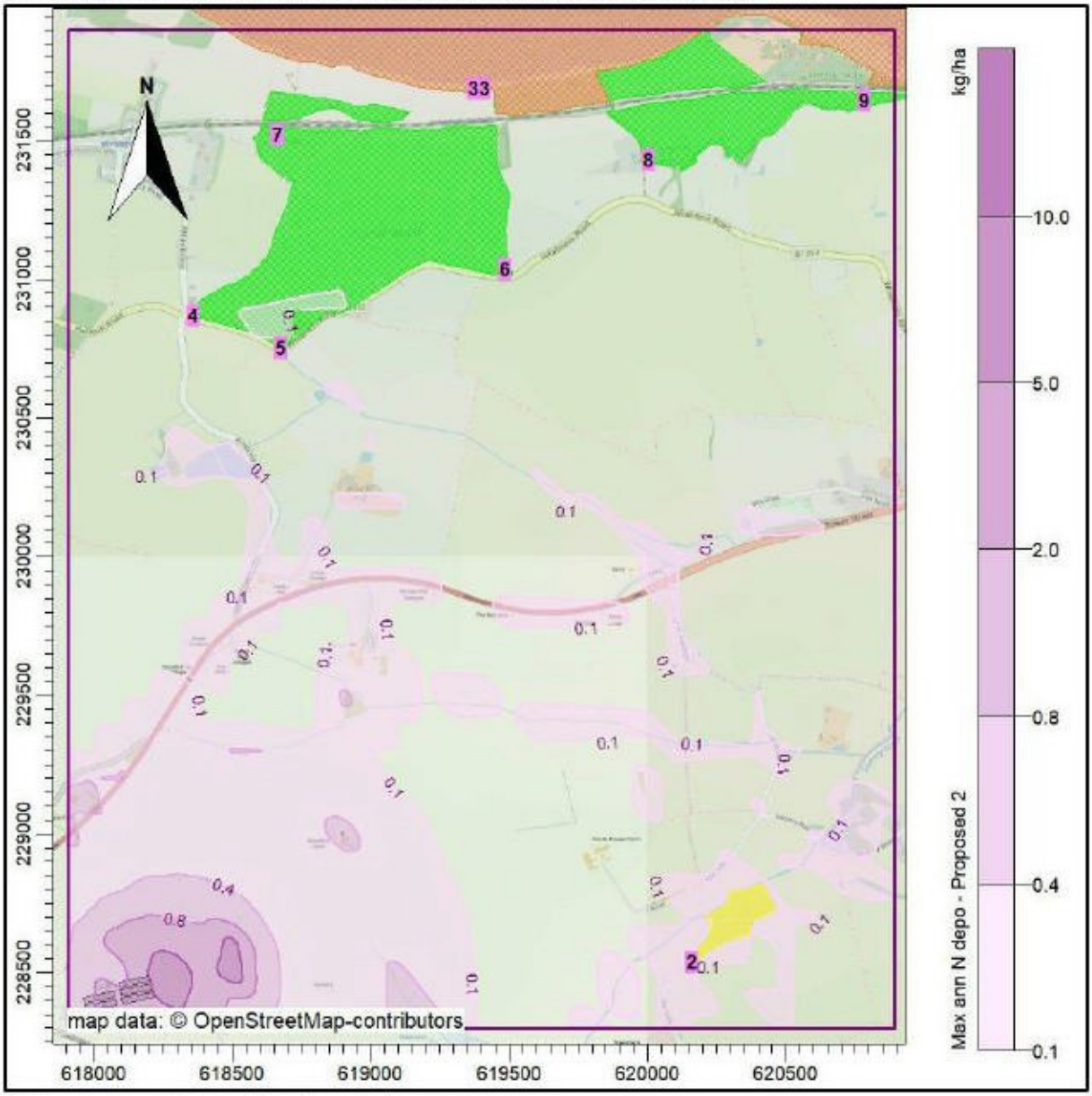


Figure 6b. Maximum annual nitrogen deposition rates - proposed only



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Ian Pick of Ian Pick Associates Ltd., on behalf of A H Brown Farms, to use computer modelling to assess the impact of ammonia emissions from the proposed broiler chicken rearing houses at Land North of Redhouse Farm, Oakley Road, Wix, Manningtree, Essex. CO11 2SF.

Ammonia emission rates from the proposed poultry houses have been assessed and quantified based upon the Environment Agency's 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 deposition rates in the surrounding area.

The modelling predicts that:

- The process contribution (from the proposed development) to annual mean ammonia concentrations and nitrogen deposition rates would be well below the Environment Agency's lower threshold percentage of the relevant Critical Level and/or Load at all wilfdlife sites considered.
- The process contribution (from the proposed development) to annual mean ammonia concentrations would exceed 1% of the Critical Level over southern parts of the Stour & Copperas Woods, Ramsey SSSI, but would be below 4% the Critical Level.
- The process contribution (from the proposed development) to annual mean ammonia concentrations would be below 1% of the Critical Level at all other statutory wildlife sites considered.

7. References

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United Nations Economic Commission for Europe (UNECE) (website).

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