A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Proposed Piggery at Willow Tree Farm, Rysome Road, near Weeton in East Riding of Yorkshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mrs. Lizzie Bentley, on behalf of Cattle Holderness Ltd., to use computer modelling to assess the impact of ammonia emissions from the existing and proposed pig rearing houses at Willow Tree Farm, Rysome Road, Weeton, Withernsea, Hull. HU12 0TA.

Ammonia emission rates from the existing and proposed pig rearing houses have been assessed and quantified based upon: the Environment Agency's standard ammonia emission factors and factors given in their pre-application report; the Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs and the AHDB Pork ammonia emission monitoring trials (2017). 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 proposed pig houses at Willow Tree Farm is in an isolated rural area approximately 1.1 km to the north-north-east of the village of Weeton in East Riding of Yorkshire. The surrounding land is used almost extensively for arable farming. The site of the piggery is at an altitude of around 17 m and the surrounding land falls gently towards The Humber Estuary to the south and rises towards higher ground to the north.

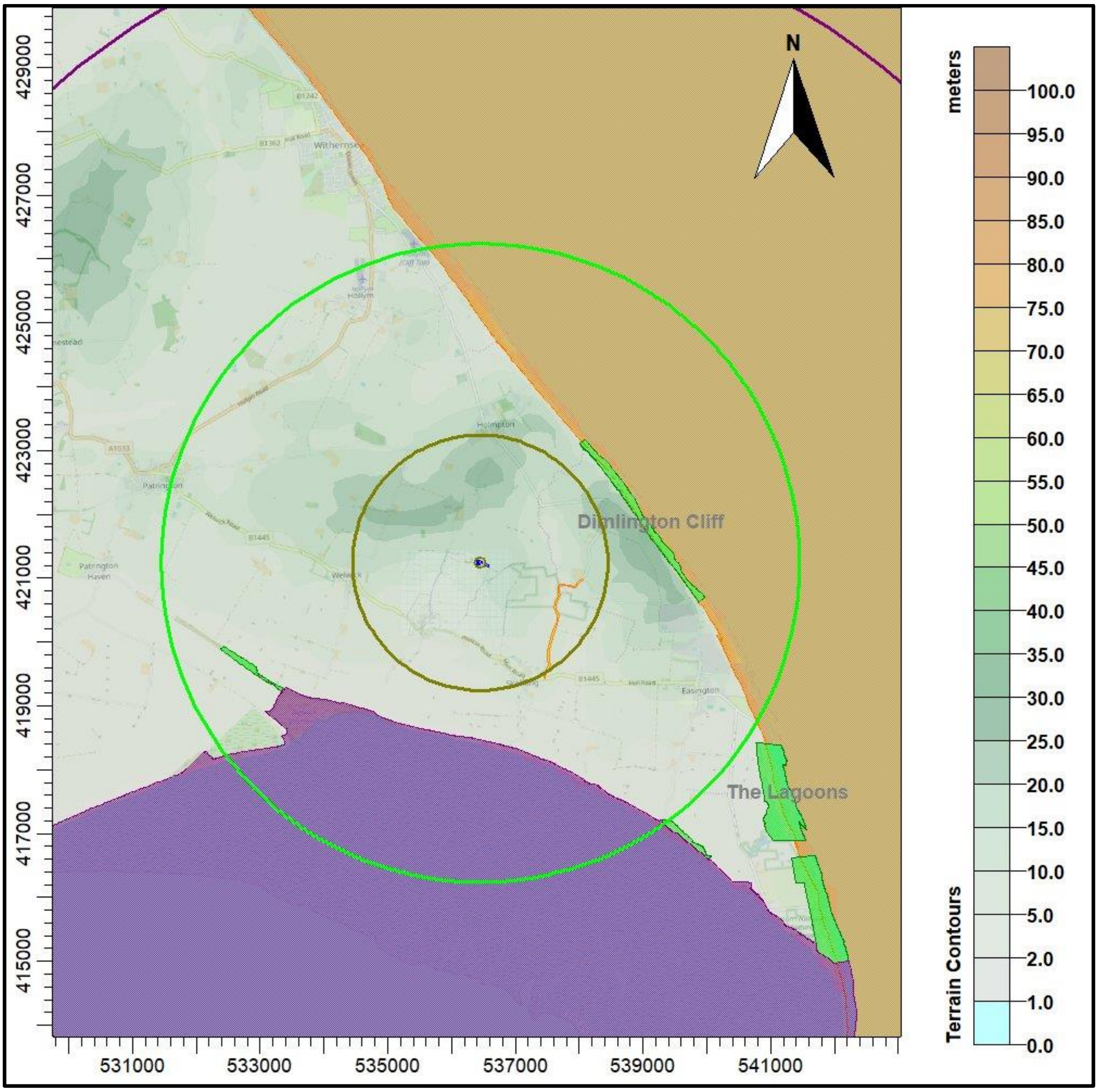
There are currently two pig houses operating at the site and it is proposed that a new pig house be constructed on land adjacent to the existing buildings. The existing houses provide accommodation for up to 4,000 finisher pigs and the new pig rearing house would provide accommodation for up to 2,000 pigs. The pigs are/would be reared from a weight of approximately 40 kg to a finishing weight of around 110 kg. The pig housing has/would have fully slatted floors with a vacuum system for frequent slurry removal, which would then be separated into solid and liquid fractions, with the liquid fraction stored in an enclosed slurry bag located to the east of the housing. The houses are/would be ventilated by uncapped high speed ridge or roof fans, each with a short chimney.

There is one Local Wildlife Site (LWS) within 2 km (the normal screening distance for non-statutory sites), a roadside verge to the south-east of the site. There are three Sites of Special Scientific Interest (SSSIs) within 10 km (the normal screening distance for statutory sites) of the site of the piggery, parts of two of these sites are also designated a Special Area of Conservation (SAC), and/or a Special Protection Area (SPA) and/or a Ramsar site. Some further details of the statutory sites are provided below.

- **Dimlington Cliff SSSI** - approximately 2.4 km to the north-east at closest point – Geological Designation.
- **Humber Estuary SSSI/SAC/SPA/Ramsar Site** - approximately 2.7 km to the south at closest point – Estuarine habitats.
- **The Lagoons SSSI** - approximately 5.2 km to the south-east – Coastal habitats including saltmarsh, shingle, sand dune, swamp and saline lagoons.
- **Greater Wash marine SPA** - approximately 2.5 km to the north-east at closest point – Marine/ornithological designation.

A map of the surrounding area showing the position of the piggery and the nearby wildlife sites is provided in Figure 1. In the figure, the LWS is shaded in olive, the SSSIs are shaded in green, the SAC is shaded in purple, the SPAs are shaded in orange, the Ramsar Site is shaded in blue and the positions of the pig house are outlined in blue.

Figure 1. The area surrounding the site, with concentric circles radii at 2km (olive), 5 km (green) and 10 km (purple)



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

3.1 Ammonia concentration and nitrogen and acid deposition

When assessing potential impact on ecological receptors, ammonia concentration is usually expressed in terms of micrograms of ammonia per metre cubed of air ($\mu g\text{-}NH_3/m^3$) 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 source of the background figures is the Air Pollution Information System (APIS, September 2024). It should be noted that the 1 km APIS database background levels are extrapolated from 5 km modelled data. Ammonia levels may vary markedly over relatively short distances and the APIS website itself notes that, the background values should be used only to assist the user in obtaining a broad indication of the likely pollutant impact at a specific location and cannot be considered representative of any particular location within the 5 km grid square; extrapolation to a 1 km grid does not alter this.

The APIS figures for background ammonia concentration in the area around Willow Tree Farm is 1.32 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 25.04 kg-N/ha/y and to short vegetation is 13.19 kg-N/ha/y. The background acid deposition rate to woodland is 1.78 keq/ha/y and to short vegetation is 0.91 keq/ha/y.

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

3.3 Critical Levels & Critical Loads

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

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

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

For ammonia concentration in air, the Critical Level for higher plants is 3.0 µg-NH_3/m^3 as an annual mean. For sites where there are sensitive lichens and bryophytes present, or where lichens and bryophytes are an integral part of the ecosystem, the Critical Level is 1.0 µg-NH_3/m^3 as an annual mean.

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

The Critical Levels and Critical Loads at the wildlife sites assumed in this study are provided in Table 1. 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 does 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)
Roadside Verge LWS	1.0 [1]	-	-
Dimlington Cliff SSSI	n/a [2]	n/a [2]	n/a [2]
Greater Wash SPA	n/a [3]	n/a [3]	n/a [3]
Humber Estuary SSSI/SAC/SPA/Ramsar Site	3.0 [4]	5.0 - 15.0 [4]	-
The Lagoons SSSI	3.0 [4]	5.0 [4]	-

1. A precautionary figure used where no details of the ecology of the site are available, or the citation for the site contains reference to sensitive lichens and/or bryophytes.
2. Geological, no Critical Level or Load assigned to the site.
3. The Greater Wash SPA extends from mean high water mark to approximately 14 nm offshore and therefore does not contain any of habitats sensitive to ammonia or nitrogen and acid deposition, listed in the APIS database, due to their association with avian species using the SPA as a foraging area. This has been confirmed by Natural England in previous cases.
4. The Critical Loads for habitats present at these wildlife sites listed on the APIS website range from 5.0 kg-N/ha/y to 15.0 kg-N/ha/y. The habitats within 10 km of the proposed pig houses at Weeton include lowland fen, marsh and swamp, littoral sediment, pioneer, low-mid, mid and upper saltmarshes, for which a Critical Load of 10.0 kg-N/ha/y has been assumed and coastal dunes, for which a Critical Load of 5.0 kg/ha/y has been assumed.

3.4 Guidance on the significance of ammonia emissions

3.4.1 Environment Agency Criteria

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

If the predicted process contributions to Critical Level or Critical Load are in the range between the lower and upper thresholds; 4% to 20% for SACs, SPAs and Ramsar sites; 20% to 50% for SSSIs and 100% to 100% for other non-statutory wildlife sites, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. In making their decision, the Environment Agency will consider whether other farming installations might act in-combination with the farm and the sensitivities of the wildlife sites. In the case of LWSs and AWs, the Environment Agency do not usually consider other farms that may act in-combination and therefore a PC of up to 100% of Critical Level or Critical Load is usually deemed acceptable for permitting purposes and therefore the upper and lower thresholds are the same (100%).

3.4.2 Natural England advisory criteria

Natural England are a statutory consultee at planning and usually advise that, if predicted process contributions exceed 1% of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming installations[1] might act in-combination or cumulatively with the farm and the sensitivities of the wildlife sites. This advice is based primarily upon the Habitats Directive, EIA Directive and the Countryside and Rights of Way Act.

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

3.5 Quantification of ammonia emissions

Ammonia emission rates from piggeries depend on many factors and are likely to be highly variable. However, the benchmarks for assessing impacts of ammonia and nitrogen deposition are framed in terms of an annual mean ammonia concentration and annual nitrogen deposition rates. To obtain relatively robust figures for these statistics, it is not necessary to model short term temporal variations and a steady continuous emission rate can be assumed. In fact, modelling short term temporal variations might introduce rather more uncertainty than modelling continuous emissions.

It should be noted that the emission factor for the finisher pigs provided to AS Modelling & Data Ltd. is based upon AHDB trial data, not the UKAEI figures or Environment Agency standard figures. The figures obtained from the AHDB trials are low in comparison to other reported figures for ammonia emissions from finisher pig housing and in the report titled "A data review – ammonia emission factors for permitted pig and poultry operations in the UK" (ADAS and Rothamsted Research January 2024, for the Environment Agency), it is stated in response to the question, "Is it legitimate for applicants to claim equivalence with AHDB pig trial results?", that "The inventory EFs were revised according to the inclusion of these new data. EFs on a 'per animal place' basis (derived using current N excretion estimates) will reflect the inclusion of these new trials data. As the trials provided only one or two data points per housing category, it is more robust to use the full dataset than rely on these values alone.". In this case, the AHDB based emission factor is probably appropriate for modern housing such as the housing at Willow Tree Farm, however AS Modelling & Data Ltd. would note that further reductions applied by the Environment Agency in their pre-application report, 8th March 2024, to take into account "occupancy levels" may not be appropriate, at least for the stated reason, because the AHDB based emission factor already includes consideration of normal occupancy levels.

Details of the modelled pig numbers and types and emission factors used and calculated ammonia emission rates are provided in Table 2. Note that these emissions may be scaled post-modelling.

Table 2. Details of pig numbers and ammonia emission rates used

Source	Number of animals	Type	Weights	Ventilation	Emission Factor (kg -NH_3/place/y)	Modelled Emissions (g/s)
H1	2,000	Finishers	40-110 kg	High speed ridge/roof	2.0 [1]	0.126752
H2	2,000	Finishers	40-110 kg	High speed ridge/roof	2.0 [1]	0.126752
H3	2,000	Finishers	40-110 kg	High speed ridge/roof	2.0 [1]	0.126752
Source	Tonnes/Area			Ventilation	Emission Factor (kg -NH_3/place/y)	Modelled Emissions (g/s)
SB	2,340 m^2	Slurry Bag		Fugitive	0.28	0.020762
SSP	50 t	Slurry separation		Fugitive	1.49	0.002361

1. Modelling results are scaled by a factor of 0.945 to give an effective Emission factor of 1.89 kg-NH3/place/y (after Environment Agency pre-application report, 8th March 2024).

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].

Prior to April 2019 the GFS was a spectral model, post April 2019 the physics are discrete. The physics/dynamics model has a resolution or had an equivalent resolution of approximately 7 km over the UK; terrain is understood to be resolved at a resolution of approximately 2 km, with sub-7 km terrain effects parameterised. Site specific data may be extrapolated from nearby archive grid points, or a most representative grid point chosen. The GFS resolution adequately captures major topographical features and the broad-scale characteristics of the weather over the UK. Smaller scale topological features may be included in the dispersion modelling by using the flow field module of ADMS (FLOWSTAR[2]). The use of NWP data has advantages over traditional meteorological records because:

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

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

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

A wind rose showing the distribution of wind speeds and directions in the GFS derived data is shown in Figure 2a. Wind speeds are modified by the treatment of roughness lengths (see Section 4.7) and because terrain data is included in the modelling, the raw GFS wind speeds and directions will be modified. The terrain and roughness length modified wind rose for the location of Willow Tree Farm is shown in Figure 2b. Note that, as might be expected, there is little modification in this case; however, elsewhere in the modelling domain the modified wind roses may differ more markedly. The resolution of FLOWSTAR is 64 by 64 grid points and the effective resolution of the wind field is approximately 300 m. Please note that FLOWSTAR[1] 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 53.670 N, 0.066 E, 2020-2023

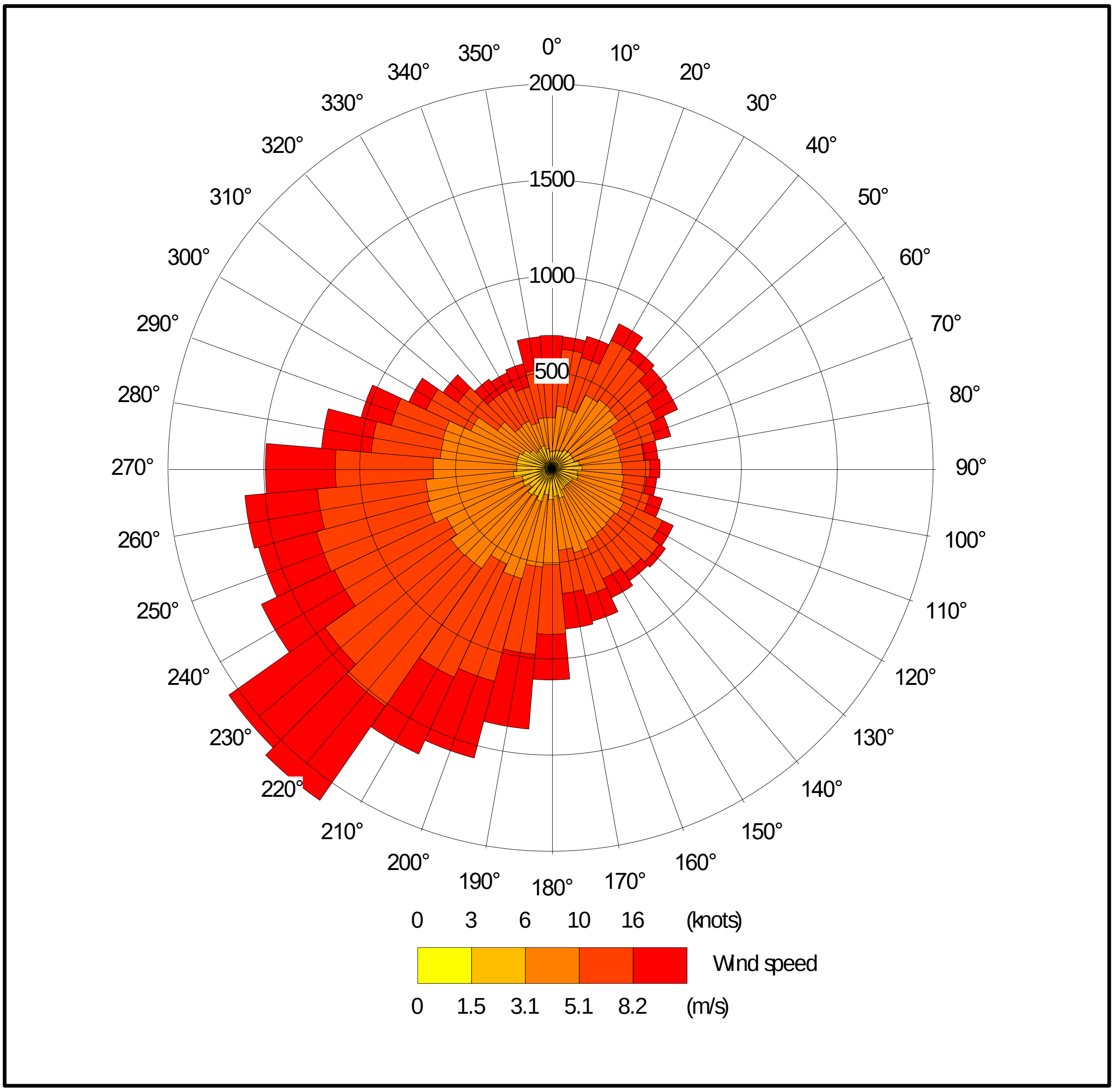
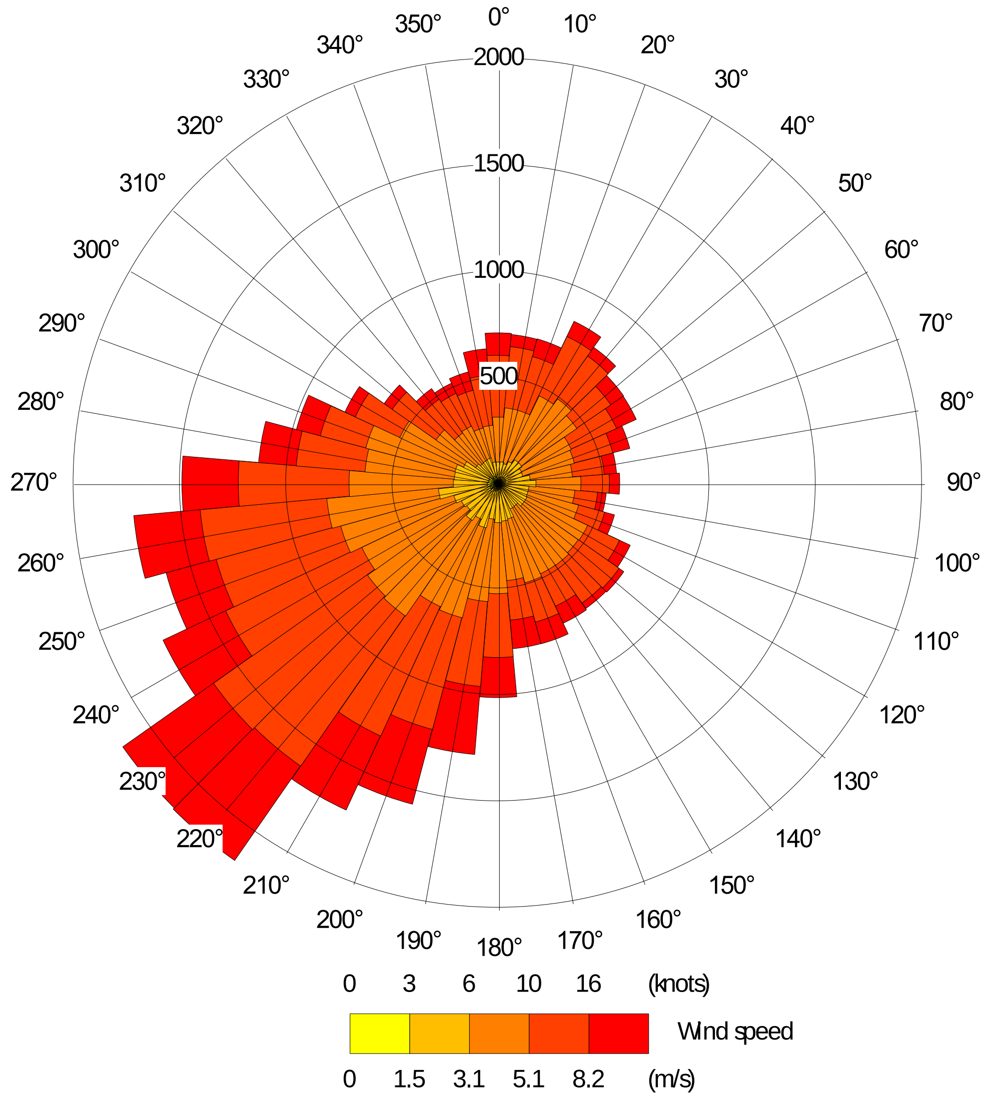


Figure 2b. The wind rose. FLOWSTAR modified GFS derived data for NGR 536450, 421250, 2020-2023



4.2 Emission sources

Emissions from the uncapped chimneys on the high speed ridge fans that are/would be used for ventilation of the existing and proposed pig rearing house are represented by three point sources per house within ADMS.

Emissions from the slurry storage bag and slurry separation building are represented by volume sources within ADMS.

Details of the point and volume source parameters used are shown in Tables 3a and 3b. The positions of the sources used are shown in Figure 3 (marked by green circles and red shaded rectangles, respectively).

Table 3a. Point source parameters

Source ID	Height (m)	Diameter (m)	Efflux velocity (m/s)	Emission temperature (˚C)	Emission rate per source ($g\text{-}NH_3/s$)
H1 to 3; 1, 2 & 3	6.5	0.8	12.0	21.0	0.042251 [1]

1. Based upon an emission factor of 2.0 kg-NH3/place/y. Modelling results are scaled by a factor of 0.945 to give an effective Emission factor of 1.89 kg-NH3/place/y (after Environment Agency pre-application report, 8th March 2024).

Table 3b. Volume source parameters

Source	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate ($g\text{-}NH_3/s$)
SB	36.0	65.0	1.0	0.0	Ambient	0.020762
SSP	6.0	24.0	4.0	0.5	Ambient	0.002361

4.3 Modelled buildings

The structure of the pig rearing houses and other nearby farm buildings 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 shaded rectangles).

4.4 Discrete receptors

Thirty-two discrete receptors have been defined at the wildlife sites at ground level within ADMS. The positions of the discrete receptors may be seen in Figure 4 (marked by enumerated pink rectangles).

4.5 Cartesian grids

To define the spatially varying deposition velocity field and to produce the contour plots presented in Section 5 of this report, two regular Cartesian grids have been defined within ADMS. The grid receptors are defined at ground level within ADMS. The positions of the grids may be seen in Figure 4 (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. N.B. The resolution of FLOWSTAR is 64 x 64 grid points; therefore, the effective resolution of the wind field is approximately 300 m.

4.7 Other model parameters

In this case, a spatially varying roughness length file has been defined, this is based upon the Centre for Ecology and Hydrology 25 m land use database. The GFS meteorological data is assumed to have a roughness length of 0.075 m (the average over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 6.

Figure 3. The positions of the modelled buildings and sources

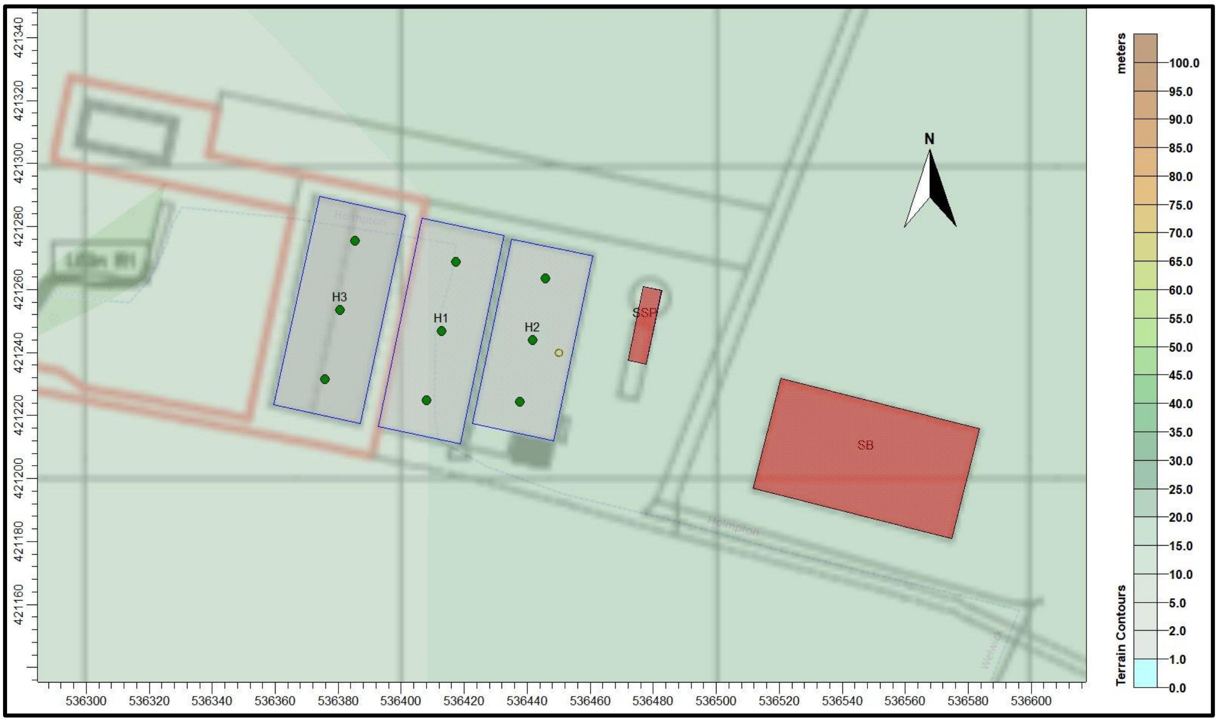


Figure 4. The discrete receptors and regular Cartesian grids

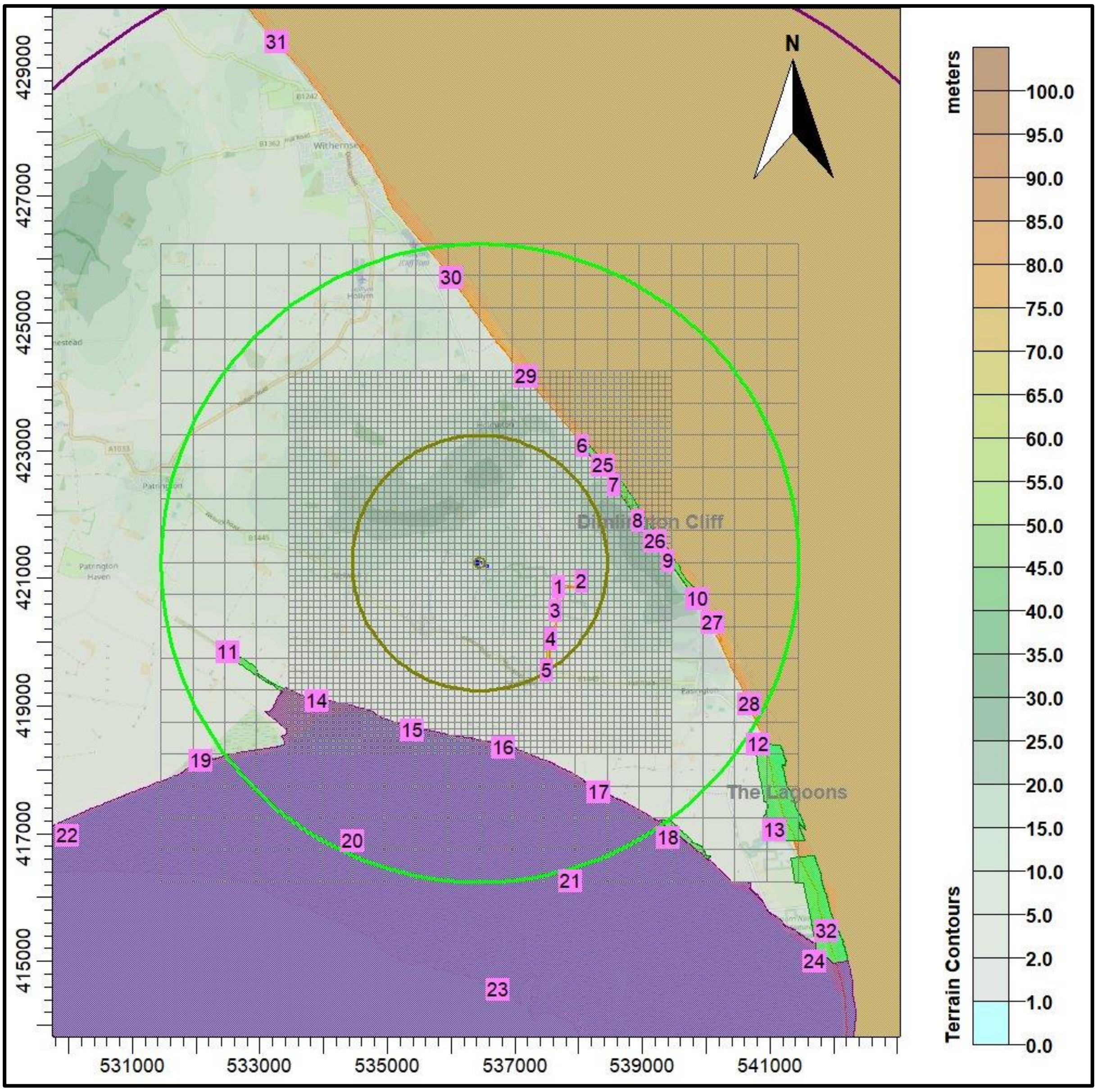
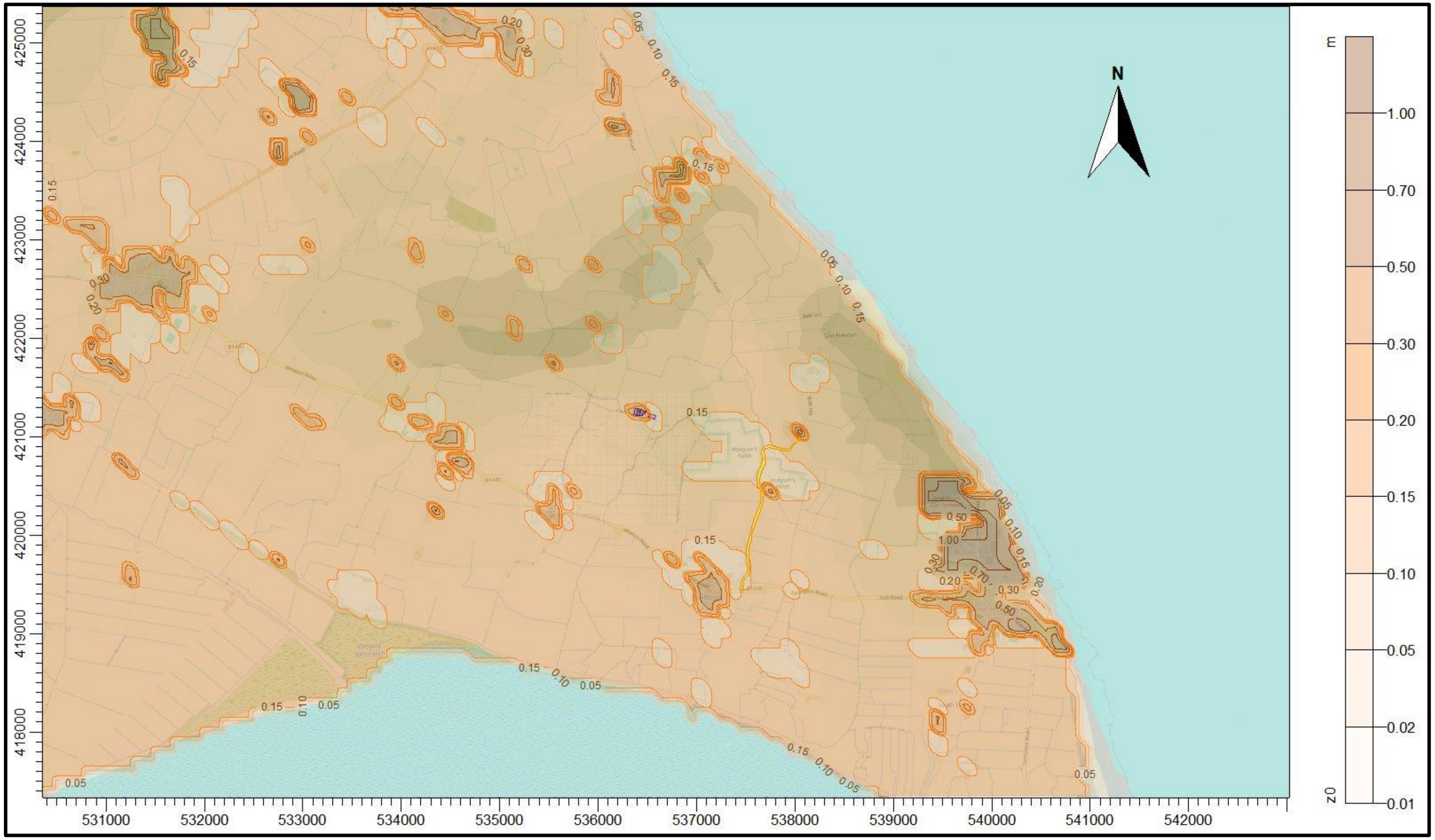


Figure 5. The spatially varying roughness length field (central area)



4.8 Deposition

The method used to model deposition of ammonia and consequent plume depletion is based primarily upon Frederik Schrader and Christian Brümmer. Land Use Specific Ammonia Deposition Velocities: a Review of Recent Studies (2004-2013). AS Modelling & Data Ltd. has restricted deposition over arable farmland and heavily grazed and fertilised pasture; this is to compensate for possible saturation effects due to fertilizer application and to allow for periods when fields are clear of crops (Sutton), the deposition is also restricted over areas with little or no vegetation and the deposition velocity is set to 0.002 m/s where grid points are over livestock housing and 0.010 m/s to 0.015 m/s over heavily grazed grassland. Where deposition over water surfaces is calculated, a deposition velocity of 0.005 m/s is used.

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.

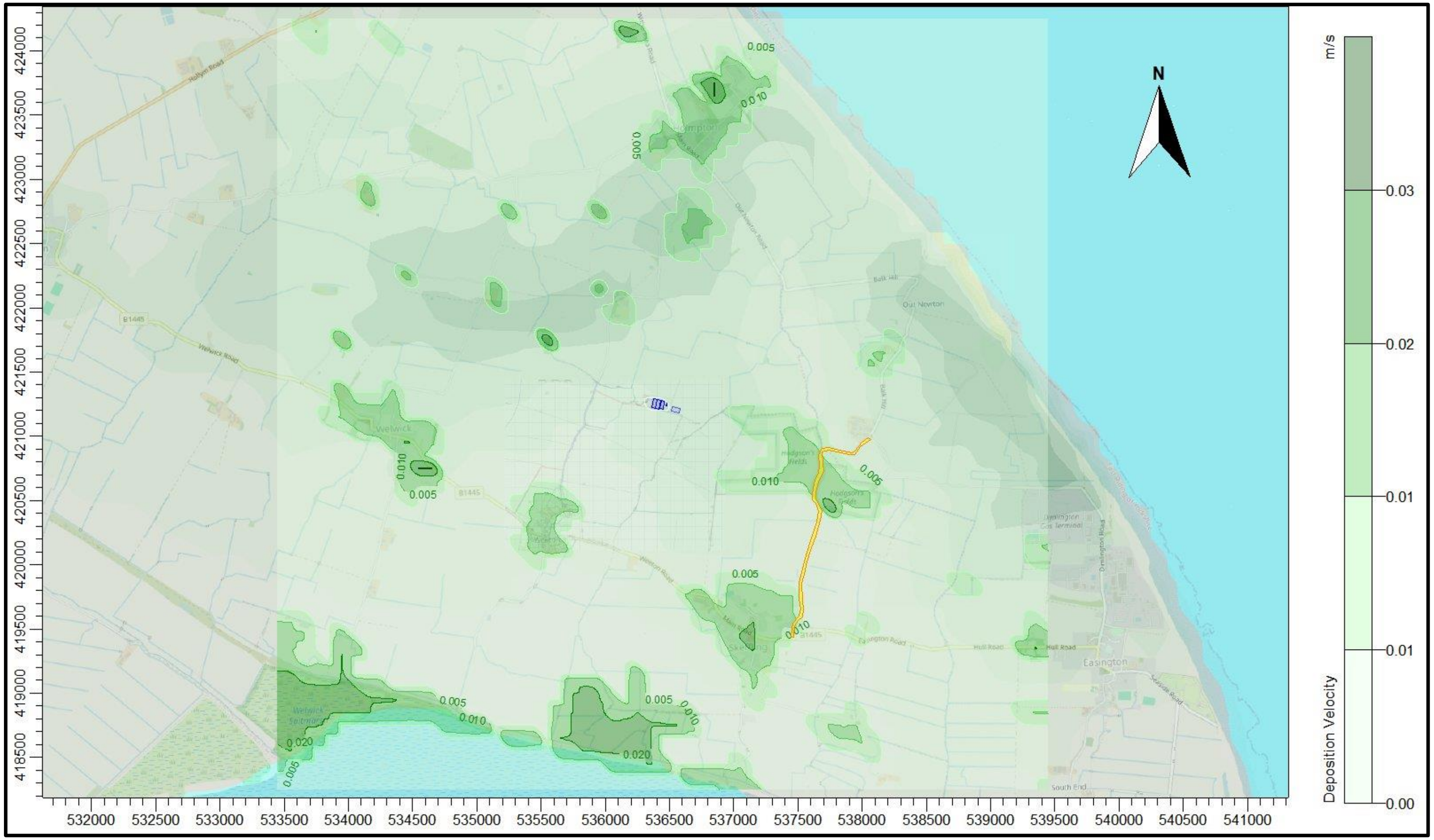
Table 4. Deposition velocities

NH_3 concentration (PC + background) (μg/m³)	< 10	10 - 20	20 - 30	30 - 80	> 80
Deposition velocity - woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity - short vegetation (m/s)	0.02 (0.010 to 0.015 over heavily grazed grassland)	0.015	0.01	0.005	0.003
Deposition velocity - arable farmland/rye grass (m/s)	0.005	0.005	0.005	0.005	0.003

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

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

Figure 6. The spatially varying deposition field



5. Details of the Model Runs and Results

5.1 Preliminary modelling and model sensitivity tests

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

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

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

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

Receptor number	X(m)	Y(m)	Designation	Maximum annual mean ammonia concentration - (µg/m³)	
				GFS No Calms No Terrain	GFS Calms No Terrain
1	537676	420880	Roadside Verge LWS	0.171	0.172
2	538031	420964	Roadside Verge LWS	0.125	0.126
3	537631	420506	Roadside Verge LWS	0.118	0.122
4	537566	420064	Roadside Verge LWS	0.076	0.080
5	537493	419568	Roadside Verge LWS	0.053	0.056
6	538047	423085	Dimlington Cliff SSSI	0.081	0.083
7	538546	422481	Dimlington Cliff SSSI	0.073	0.075
8	538926	421924	Dimlington Cliff SSSI	0.065	0.066
9	539399	421281	Dimlington Cliff SSSI	0.050	0.051
10	539845	420690	Dimlington Cliff SSSI	0.043	0.043
11	532482	419860	Humber Estuary SPA/Ramsar/SSSI	0.018	0.018
12	540792	418407	Humber Estuary SPA/Ramsar/The Lagoons SSSI	0.019	0.019
13	541050	417070	Humber Estuary SPA/Ramsar/The Lagoons SSSI	0.013	0.013
14	533877	419096	Humber Estuary SAC/SPA/Ramsar/SSSI	0.022	0.023
15	535371	418631	Humber Estuary SAC/SPA/Ramsar/SSSI	0.031	0.032
16	536800	418365	Humber Estuary SAC/SPA/Ramsar/SSSI	0.031	0.032
17	538294	417668	Humber Estuary SAC/SPA/Ramsar/SSSI	0.018	0.019
18	539396	416950	Humber Estuary SAC/SPA/Ramsar/SSSI	0.015	0.015
19	532050	418166	Humber Estuary SAC/SPA/Ramsar/SSSI	0.011	0.012
20	534442	416904	Humber Estuary SAC/SPA/Ramsar/SSSI	0.016	0.016
21	537862	416273	Humber Estuary SAC/SPA/Ramsar/SSSI	0.013	0.014
22	529966	416978	Humber Estuary SAC/SPA/Ramsar/SSSI	0.007	0.007
23	536717	414564	Humber Estuary SAC/SPA/Ramsar/SSSI	0.010	0.010
24	541681	415006	Humber Estuary SAC/SPA/Ramsar/SSSI	0.009	0.009
25	538364	422785	Greater Wash SPA	0.078	0.080
26	539184	421599	Greater Wash SPA	0.057	0.058
27	540093	420315	Greater Wash SPA	0.038	0.039
28	540669	419035	Greater Wash SPA	0.025	0.025
29	537156	424178	Greater Wash SPA	0.048	0.049
30	535985	425720	Greater Wash SPA	0.022	0.023
31	533241	429422	Greater Wash SPA	0.009	0.009
32	541879	415481	Greater Wash SPA/The Lagoons SSSI	0.009	0.010

5.2 Detailed deposition modelling

In this case, detailed modelling has been carried out over a high resolution (100 m) domain that extends 6.0 km by 6.0 km and covers the site of the proposed poultry houses and ranging areas. The primary purpose is to determine the magnitude of deposition of ammonia and consequent plume depletion close to the sources where it is of the greatest importance. Outside of this 6.0 km by 6.0 km domain a fixed deposition velocity of 0.005 m/s is assumed (with appropriate deposition velocities applied post-modelling at the discrete receptors).

The results of the detailed deposition modelling are shown in Table 6. In the Table, predicted ammonia concentrations and nitrogen deposition rates that are in excess of the Environment Agency's upper percentage threshold (20% for an internationally designated site, 50% for a SSSI and 100% for a LWS) of the relevant Critical Level or Load for the site are coloured red. Concentrations and deposition rates in the range between the Environment Agency's lower and upper threshold percentage of the relevant Critical Level/Load (4% and 20% for an internationally designated site and 20%, 50% for a SSSI and 100% for a LWS) are coloured blue. Additionally, predicted ammonia concentrations and nitrogen deposition rates that are in excess of 1% of the relevant Critical Level/Load at a statutory site are highlighted in bold text.

Contour plots of the predicted ground level maximum annual mean ammonia concentration and the maximum nitrogen deposition rates are shown in Figures 7a and 7b.

Table 6. Predicted process contribution to maximum annual mean ammonia concentration and nitrogen deposition rates at the discrete receptors

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	537676	420880	Roadside Verge LWS	0.02	1.0	10.0	0.103	10.3	0.53	5.3
2	538031	420964	Roadside Verge LWS	0.02	1.0	10.0	0.080	8.0	0.42	4.2
3	537631	420506	Roadside Verge LWS	0.02	1.0	10.0	0.058	5.8	0.30	3.0
4	537566	420064	Roadside Verge LWS	0.02	1.0	10.0	0.033	3.3	0.17	1.7
5	537493	419568	Roadside Verge LWS	0.02	1.0	10.0	0.019	1.9	0.10	1.0
6	538047	423085	Dimlington Cliff SSSI	0.02	n/a	n/a	0.065	-	0.34	-
7	538546	422481	Dimlington Cliff SSSI	0.02	n/a	n/a	0.056	-	0.29	-
8	538926	421924	Dimlington Cliff SSSI	0.02	n/a	n/a	0.049	-	0.25	-
9	539399	421281	Dimlington Cliff SSSI	0.02	n/a	n/a	0.035	-	0.18	-
10	539845	420690	Dimlington Cliff SSSI	0.02	n/a	n/a	0.024	-	0.12	-
11	532482	419860	Humber Estuary SPA/Ramsar/SSSI	0.02	3.0	5.0	0.009	0.3	0.04	0.9
12	540792	418407	The Lagoons SSSI	0.02	1.0	5.0	0.008	0.8	0.04	0.8
13	541050	417070	Humber Estuary SPA/Ramsar/The Lagoons SSSI	0.02	1.0	10.0	0.005	0.5	0.03	0.3
14	533877	419096	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	5.0	0.011	0.4	0.06	**1.1**
15	535371	418631	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.014	0.5	0.07	0.7
16	536800	418365	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.010	0.3	0.05	0.5
17	538294	417668	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.007	0.2	0.04	0.4
18	539396	416950	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.005	0.2	0.03	0.3
19	532050	418166	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.006	0.2	0.03	0.3
20	534442	416904	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.007	0.2	0.04	0.4
21	537862	416273	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.005	0.2	0.03	0.3
22	529966	416978	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.003	0.1	0.02	0.2
23	536717	414564	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.003	0.1	0.02	0.2
24	541681	415006	Humber Estuary SAC/SPA/Ramsar/SSSI	0.02	3.0	10.0	0.003	0.1	0.01	0.1
25	538364	422785	Greater Wash SPA	0.02	n/a	n/a	0.060	-	0.31	-
26	539184	421599	Greater Wash SPA	0.02	n/a	n/a	0.042	-	0.22	-
27	540093	420315	Greater Wash SPA	0.02	n/a	n/a	0.020	-	0.10	-
28	540669	419035	Greater Wash SPA	0.02	n/a	n/a	0.010	-	0.05	-
29	537156	424178	Greater Wash SPA	0.02	n/a	n/a	0.026	-	0.14	-
30	535985	425720	Greater Wash SPA	0.02	n/a	n/a	0.012	-	0.06	-
31	533241	429422	Greater Wash SPA	0.02	n/a	n/a	0.003	-	0.02	-
32	541879	415481	Greater Wash SPA/The Lagoons SSSI	0.02	1.0	5.0	0.003	0.3	0.02	0.3

Figure 7a. Predicted maximum annual mean ammonia concentrations

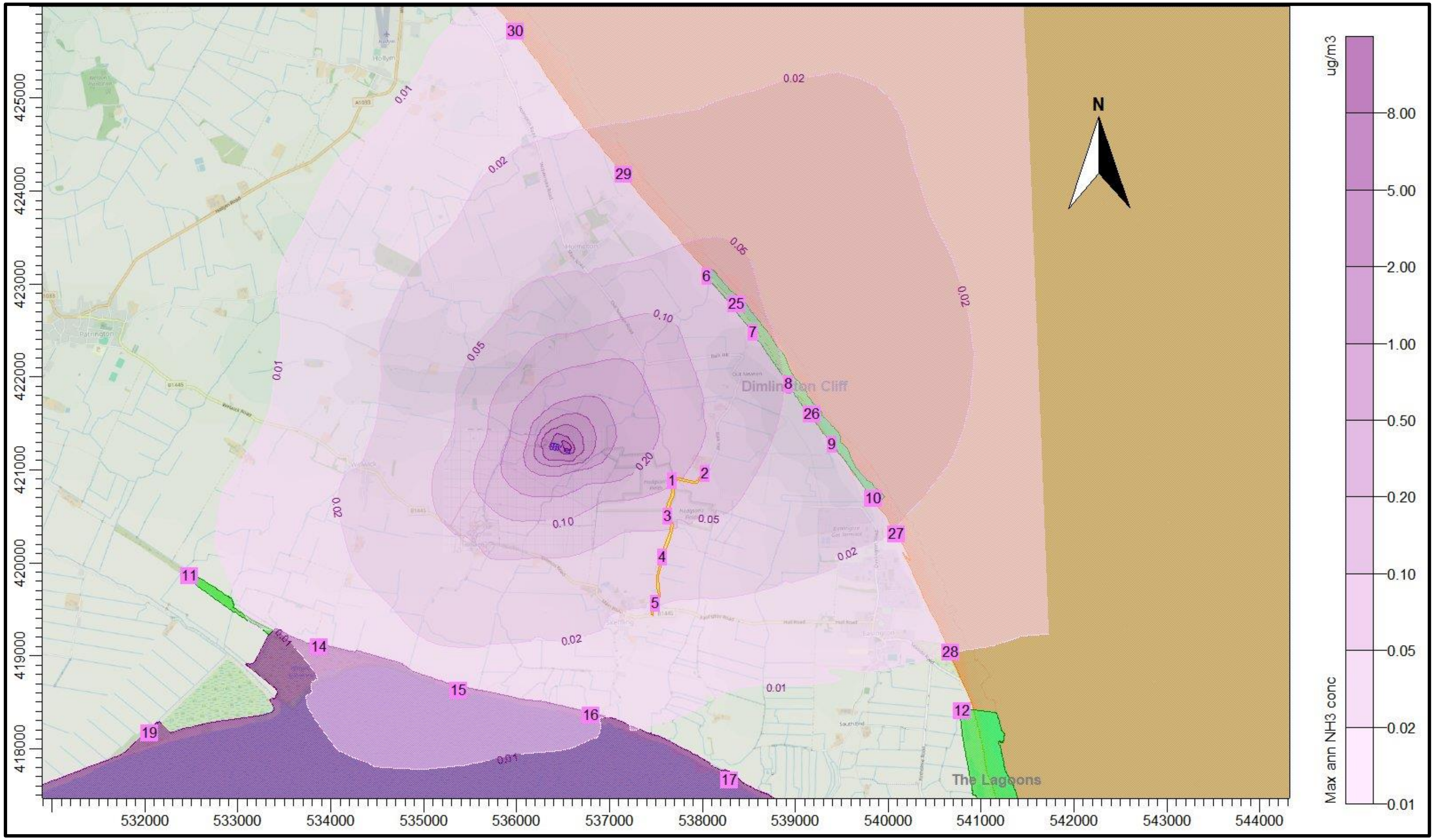
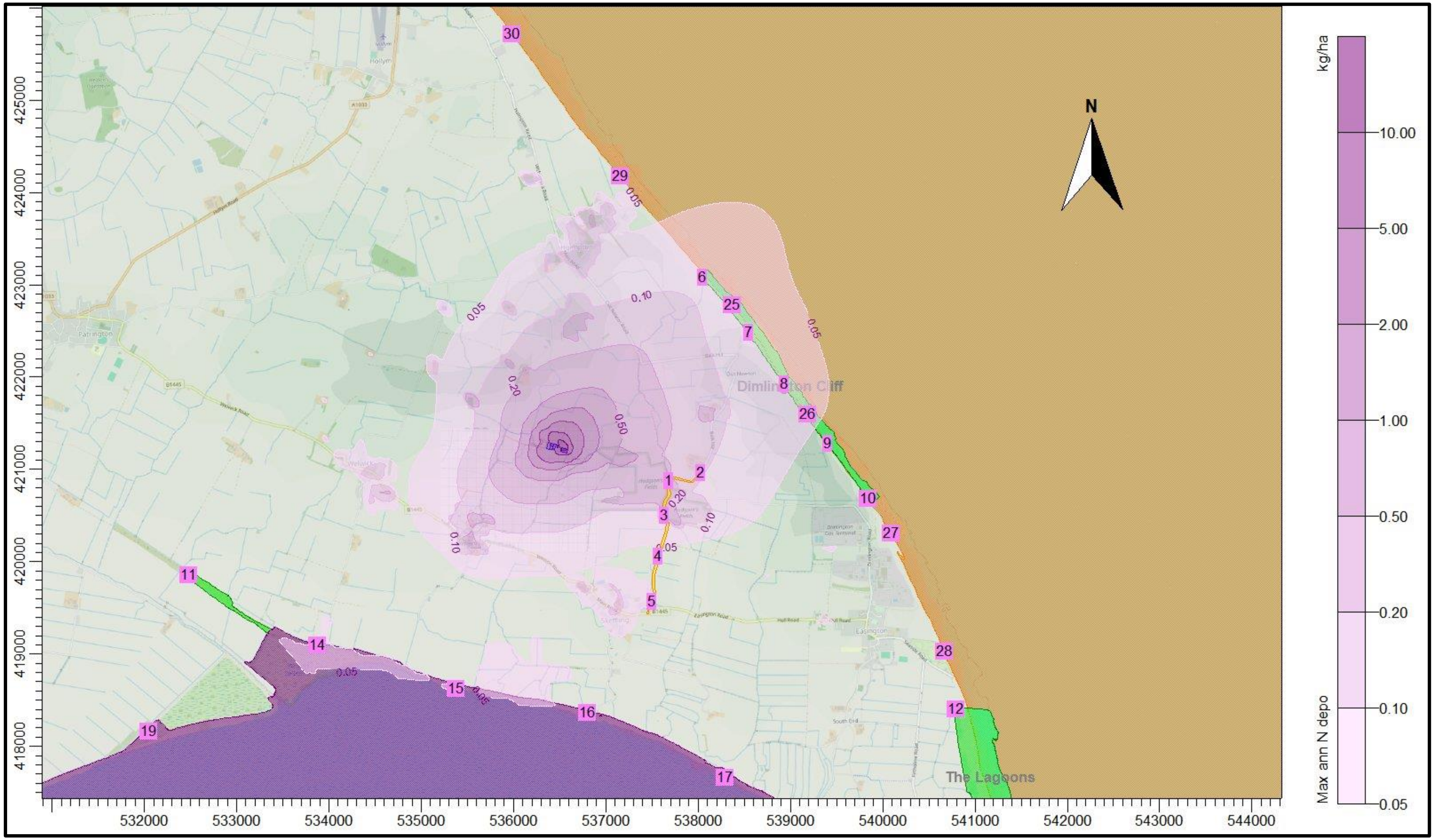


Figure 7b. Maximum annual nitrogen deposition rates



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mrs. Lizzie Bentley, on behalf of Cattle Holderness Ltd., to use computer modelling to assess the impact of ammonia emissions from the existing and proposed pig rearing houses at Willow Tree Farm, Rysome Road, Weeton, Withernsea, Hull. HU12 0TA.

Ammonia emission rates from the existing and proposed pig rearing houses have been assessed and quantified based upon: the Environment Agency's standard ammonia emission factors and factors given in their pre-application report; the Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs and the AHDB Pork ammonia emission monitoring trials (2017). The ammonia emission rates have then been used as inputs to an atmospheric dispersion and deposition model which calculates ammonia exposure levels and nitrogen and acid deposition rates in the surrounding area.

The modelling predicts that:

- The process contribution of the existing and proposed pig rearing houses to the annual mean ammonia concentrations and nitrogen deposition rates would be well below the Environment Agency's lower threshold percentage of the relevant Critical Level/Load (4% for the internationally designated sites, 20% for the SSSIs and 100% for the LWS) at all the wildlife sites considered.

- At all statutory sites considered within 10 km of the pig rearing houses, the process contributions to maximum annual ammonia concentrations and nitrogen deposition rates, where relevant, are predicted to be below 1% of the Critical Level and/or Load for the site.

7. References

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