



A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Piggeries at Fir Tree Farm, near Stokesley in North Yorkshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Ms. Lizzie Bentley of Yorkshire Farmers, on behalf of Bailey Livestock Limited, to use computer modelling to assess the impact of ammonia emissions from the piggery at Fir Tree Farm, Stokesley, North Yorkshire. TS9 5LD.

Ammonia emission rates from the piggery have been derived from ammonia emission factors provided by the Environment Agency for permitting and modelling purposes. 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

Fir Tree Farm is in a rural area, approximately 850 m to the south of Stokesley in North Yorkshire. The surrounding land is used almost exclusively for arable farming. The site is at an elevation of around 70 m above sea level, with the land rising gently towards the North York Moors to the south-east.

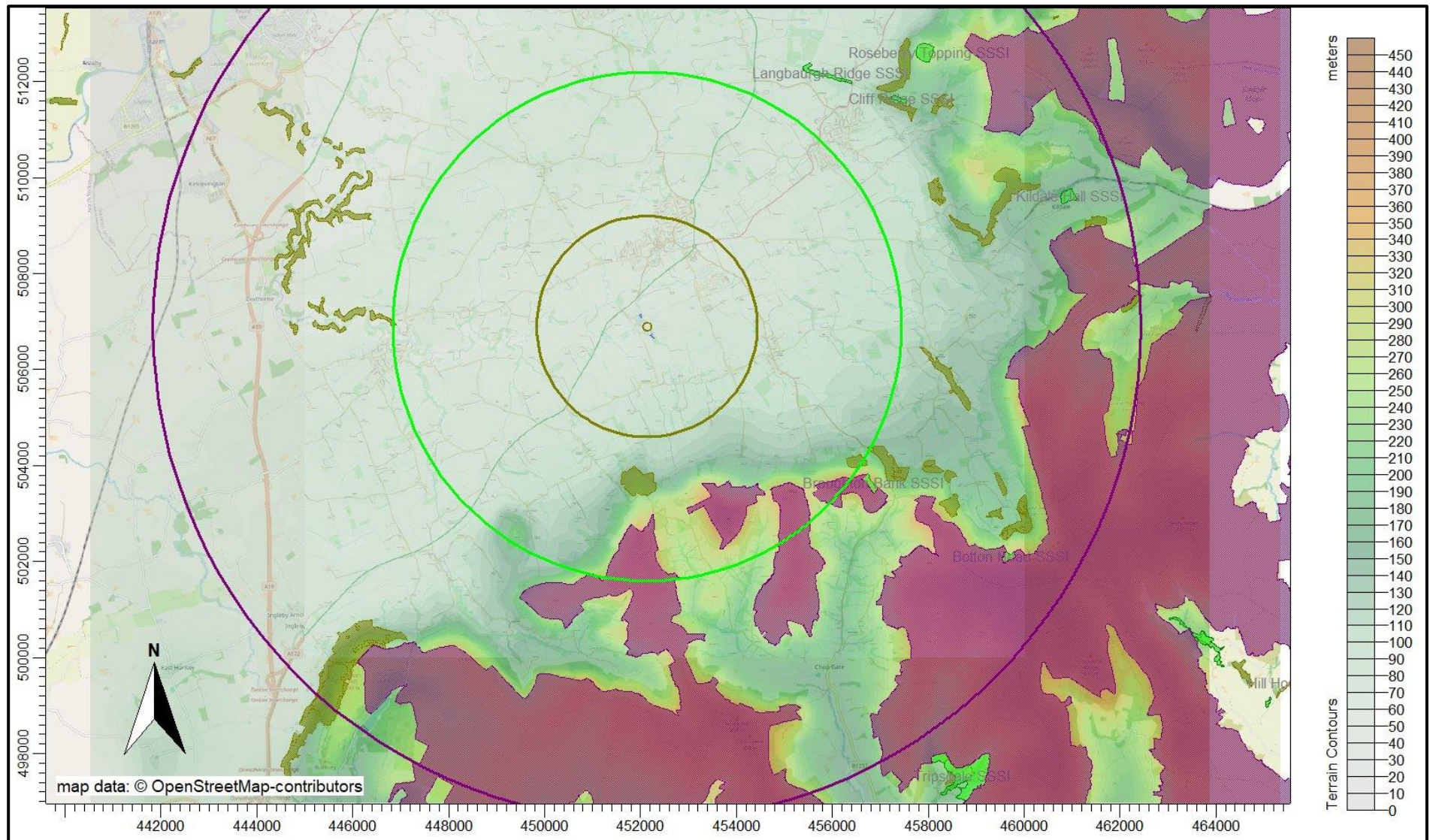
The piggeries at Fir Tree Farm comprise of two sites: the northern site which accommodates up to 1,000 finisher pigs (>30 kg) in naturally ventilated housing with solid flooring and straw litter/bedding; the southern site which accommodates up to 1,600 finisher pigs (>30 kg) in houses with capped ridge fans for ventilation, solid flooring and straw litter/bedding. Manure and spent litter/bedding is stored temporarily in a covered manure store at the southern site.

AS Modelling & Data Ltd. have not identified any Ancient Woodlands, nor any Local Wildlife Sites, that are within 2 km of the farm (the normal screening distance for non-statutory sites). There are seven Sites of Special Scientific Interest (SSSI) within 10 km (the normal screening distance for a SSSI), six of which have a geological designation and one of which, The North York Moors SSSI, is also designated as a Special Area of Conservation (SAC) and a Special Protection Area (SPA). Some further details of the SSSI are provided below.

- **Langbaugh Ridge SSSI** - Approximately 6.1 km to the north-east - Geological.
- **Cliff Ridge SSSI** - Approximately 6.9 km to the north-east - Geological.
- **Roseberry Topping SSSI** - Approximately 7.8 km to the north-east - Geological.
- **Kildale Hall SSSI** - Approximately 9.0 km to the east-north-east - Geological.
- **Broughton Bank SSSI** - Approximately 5.3 km to the south-east - Geological.
- **Botton Head SSSI** - Approximately 8.4 km to the south-east - Geological.
- **North York Moors SSSI/SAC/SPA** - Approximately 3.1 km to the south-south-east (closest point) - The North York Moors contain the largest continuous tract of heather moorland in England. The site is of national importance for its mire and heather moorland vegetation communities and of international importance for its breeding bird populations, particularly merlin and golden plover. The vegetation displays a transition between blanket bog and dry heath land and supports diverse and extensive upland plant communities. The moorland plateaux are dominated by dry heath on the central and western moors and wet heath and mire communities on the northern and eastern moors. The plateaux are defined by a number of valleys, the sides of which support extensive strands of bracken and small areas of native woodland. Acid grasslands occur along some of the moorland edges.

A map of the surrounding area showing the positions of the piggeries, the SSSIs, the SAC and SPA is provided in Figure 1. The positions of the pig rearing houses are outlined in blue, the SSSIs are shaded in green and the North York Moors SSSI/SAC/SPA is shaded in purple.

Figure 1. The area surrounding Fir Tree Farm



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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, December 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 Fir Tree Farm is $1.61 \mu\text{g-NH}_3/\text{m}^3$. The background nitrogen deposition rate to woodland is 28.85 kg-N/ha/y and to short vegetation is 16.11 kg-N/ha/y . The background acid deposition rate to woodland is 2.18 keq/ha/y and to short vegetation is 1.24 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/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 $3.0 \mu\text{g-NH}_3/\text{m}^3$ 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. 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 ($\mu\text{g-NH}_3/\text{m}^3$)	Critical Load Nitrogen (kg-N/ha/y)	Critical Load Acid (keq/ha/y)
North York Moors SSSI/SAC/SPA	1.0 ¹	5.0 ²	-
Langbaugh Ridge SSSI; Cliff Ridge SSSI; Roseberry Topping SSSI; Kildale Hall SSSI; Broughton Bank SSSI and Botton Head SSSI	n/a ³	n/a ³	n/a ³

1. A precautionary figure used where details of the site are unavailable, or the citation of the site indicates that sensitive lichens and /or bryophytes are/may be present.
2. The lower bound of the range of Critical Loads, based upon the citation for the site.
3. Designated for geological features.

3.4 Guidance on the significance of ammonia emissions

3.4.1 Environment Agency Criteria

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

If the predicted process contributions to Critical Level or Critical Load are in the range between the lower and upper thresholds; 4% to 20% for SACs, SPAs and Ramsar sites; 20% to 50% for SSSIs and 100% to 100% for other non-statutory wildlife sites, whether or not the impact is deemed acceptable is at the discretion of the Environment Agency. In making their decision, the Environment Agency will consider

whether other farming installations might act in-combination with the farm and the sensitivities of the wildlife sites. In the case of LWSs and AWs, the Environment Agency do not usually consider other farms that may act in-combination and therefore a PC of up to 100% of Critical Level or Critical Load is usually deemed acceptable for permitting purposes and therefore the upper and lower thresholds are the same (100%).

3.4.2 Natural England advisory criterion

Natural England are a statutory consultee at planning and usually advise that, if predicted process contributions exceed 1% (or lower in some circumstances) of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming 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.

3.4.3 Environment Agency and Natural England May 2022 Air Quality Risk Assessment Interim Guidance

Although it seems important to include a reference to this document, it appears to be primarily a discussion document about internal Environment Agency screening models and the SCAIL model and AS Modelling & Data Ltd. have been unable to draw any conclusions from the document as to what thresholds may or may not apply, nor in what circumstances the threshold may or may not apply.

3.4.4 Joint Nature Conservancy Committee - Guidance on Decision-making Thresholds for Air Pollution

In December 2021, the Joint Nature Conservancy Committee (JNCC) published a report titled, “Guidance on Decision-making Thresholds for Air Pollution” This report provides decision-making criteria to inform the assessment of air quality impacts on designated conservation sites. The criteria are intended to be applied to individual sources to identify those for which a decision can be taken without the need for further assessment effort.

The Decision-making thresholds (DMT) for on-site emission sources provided in the JNCC report are reproduced below:

- For lichens and bryophytes - 0.08%, 0.20%, 0.34% and 0.75% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For higher plants - 0.08%, 0.20%, 0.34% and 0.75% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For nitrogen deposition to woodland (Critical Load 10 kg-N/ha/y) - 0.13%, 0.34%, 0.57% and 1.30% of the Critical Level for high, medium, low and very low development density areas, respectively.
- For nitrogen deposition to grassland (Critical Load 10 kg-N/ha/y) 0.09%, 0.24%, 0.40% and 0.88% of the Critical Level for high, medium, low and very low development density areas, respectively.

Note that 'development density' is defined as, the assumed number of additional new sources below the DMT within 5 km of the proposed development over 13 years: very low density being 1 development; low 5 developments; medium 10 developments and high 30 developments.

Subject to some exceptions, where the process contribution from an on-site source is below the DMT, no further assessment is required. Where the process contribution exceeds the DMT there are two possible outcomes:

- Where site-relevant thresholds have been derived these can be applied to see if it is possible to avoid further assessment effort on the basis of site-specific circumstances.
- If site-relevant thresholds have not yet been derived, further assessment in combination with other plans and projects is required.

3.5 Quantification of ammonia emissions

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

3.5.1 Pig Rearing Houses

Ammonia emission rates from the pig rearing houses have been derived based upon emission factors provided by the Environment Agency (<https://www.gov.uk/guidance/ammonia-emission-factors-for-pig-and-poultry-screening-modelling-and-reporting#ammonia-emission-factors-for-pigs>). The emission factor of 1.888 kg-NH₃/place/y, has been used to calculate emissions from the pig housing at Fir Tree Farm.

3.5.2 Manure Store

Ammonia emission rates from the manure store have been derived based upon emission factors provided by the Environment Agency (<https://www.gov.uk/guidance/ammonia-emission-factors-for-pig-and-poultry-screening-modelling-and-reporting#ammonia-emission-factors-for-pigs>). The emission factor is 0.85 kg-NH₃/t/y.

Details of the pig numbers and manure store, emission factors used and calculated ammonia emission rates are provided in Table 2a and 2b.

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

SOURCE	Number of Pigs	Type	Flooring	Ventilation	Emission Factor (kg-NH ₃ /place/y)	Emission rate (g-NH ₃ /s)
N1	690	Finisher Pigs	Straw	Natural	1.888	0.041301771
N2	310	Finisher Pigs	Straw	Natural	1.888	0.018525339
S1	800	Finisher Pigs	Straw	Capped Ridge	1.888	0.047861688
S2	800	Finisher Pigs	Straw	Capped Ridge	1.888	0.047861688

Table 2b. Details of slurry store and ammonia emission rates

SOURCE	Tonnes	Type			Emission Factor (kg-NH ₃ /t/y)	Emission rate (g-NH ₃ /s)
MAN	200.0	Covered store			0.85	0.009443

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 (FLOWSTAR²). The use of NWP data has advantages over traditional meteorological records because:

- Calm periods in traditional records may be overrepresented 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 Fir Tree Farm is shown in Figure 2b; as might be expected, Figures 2a and 2b show some modification in this case, however, elsewhere in the modelling domain the modified wind roses may differ more or less 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 350 m. Please note that FLOWSTAR¹ 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 σ_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 54.455 N, 1.196 W, 2020-2023

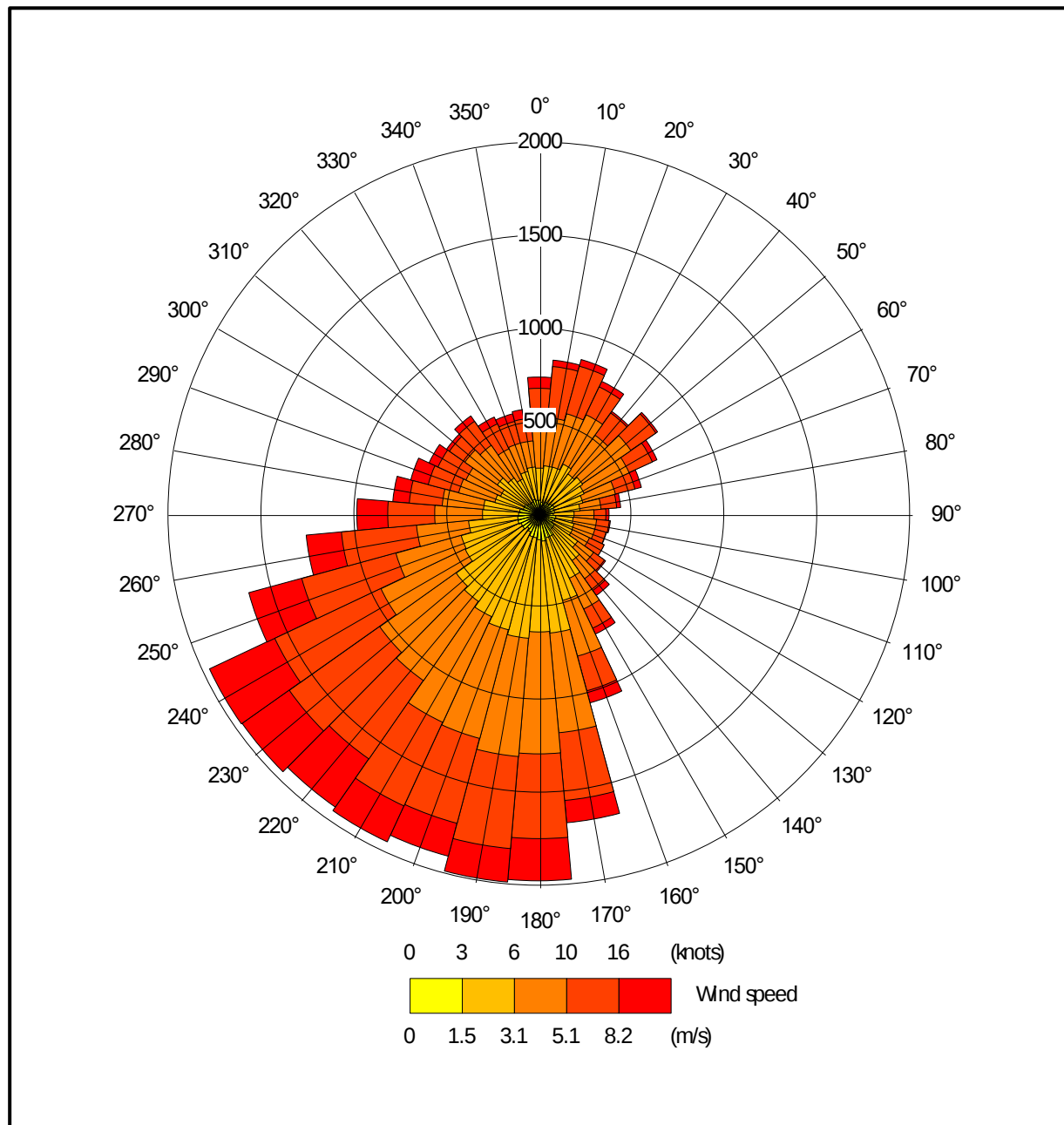
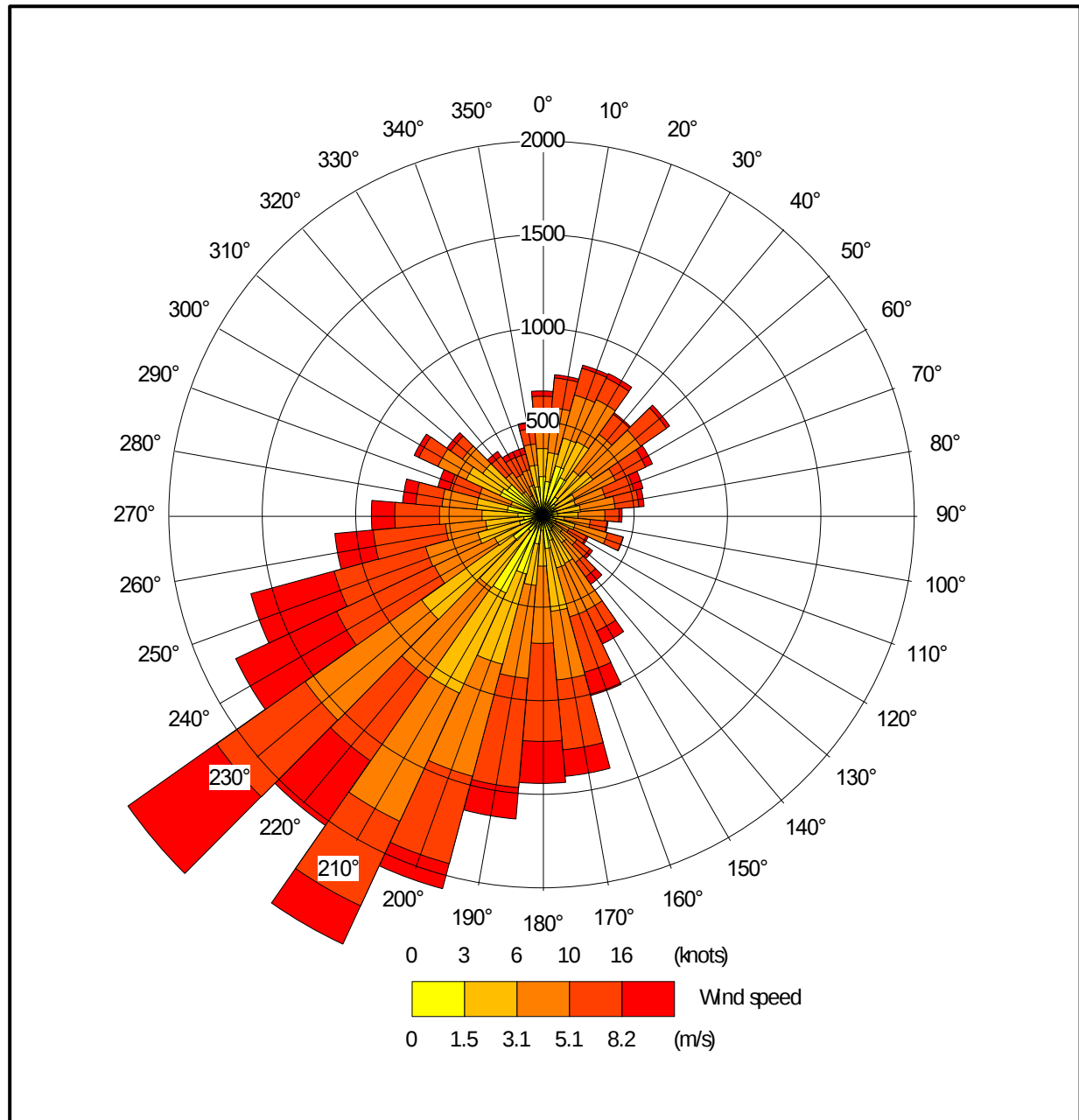


Figure 2b. The wind rose. FLOWSTAR derived data for NGR 452100, 506900, 2020-2023



4.2 Emission sources

Emissions from the capped roof fans that are used to ventilate the pig rearing houses at the southern site are represented by point sources within ADMS. The naturally ventilated pig housing at the northern site and the manure store are represented by volume sources within ADMS. Details of the point and volume source parameters are provided in Tables 3a and 3b. The positions of the sources may be seen in Figure 3 (point sources – green circles and volume source - red shaded rectangle).

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)
S1 1, 2 & 3	5.0	2.0	0.1	Variable ¹	0.015954
S2 1, 2 & 3	5.0	2.0	0.1	Variable ¹	0.015954

1. 21 Celsius or ambient temperature, whichever is the higher.

Table 3b. Volume source parameters

Source ID	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH ₃ /s)
N1_NAT	32.6	47.6	3.0	0.5	Ambient	0.041302
N2_NAT	33.2	21.0	3.0	0.5	Ambient	0.018525
MAN_NAT	25.0	15.0	4.0	0.2	Ambient	0.009443

4.3 Modelled buildings

The structure of the pig rearing houses and other farm buildings may affect the plumes from the point sources. Therefore, these 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

Thirty-five 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 Figure 4 (marked by enumerated pink rectangles).

4.5 Cartesian grid

To produce the contour plots presented in Section 5 of this report and to define the spatially varying deposition field used in the detailed modelling, two regular Cartesian grids have been defined at ground level within ADMS. The positions of the Cartesian grids may be seen in Figure 4 (marked by grey lines).

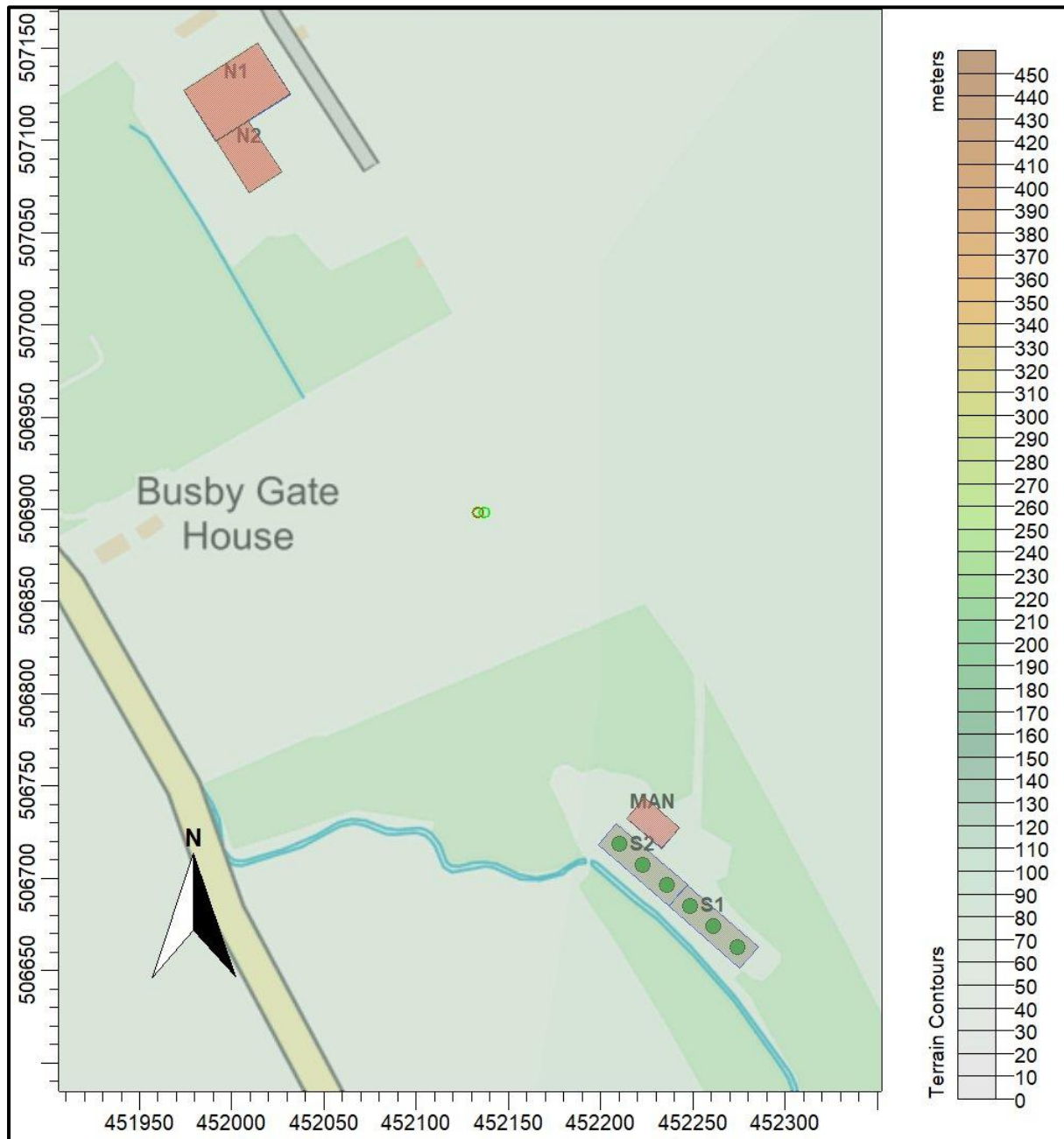
4.6 Terrain data

Terrain has been considered in the modelling. The terrain data are based upon the Ordnance Survey 50 m Digital Elevation Model. A 23.0 km by 23.0 km domain has been resampled at 100 m horizontal resolution for use within ADMS. The resolution of FLOWSTAR is 64 by 64 grid points; therefore, the effective resolution of the wind field for the terrain runs is approximately 350 m.

4.7 Roughness Length

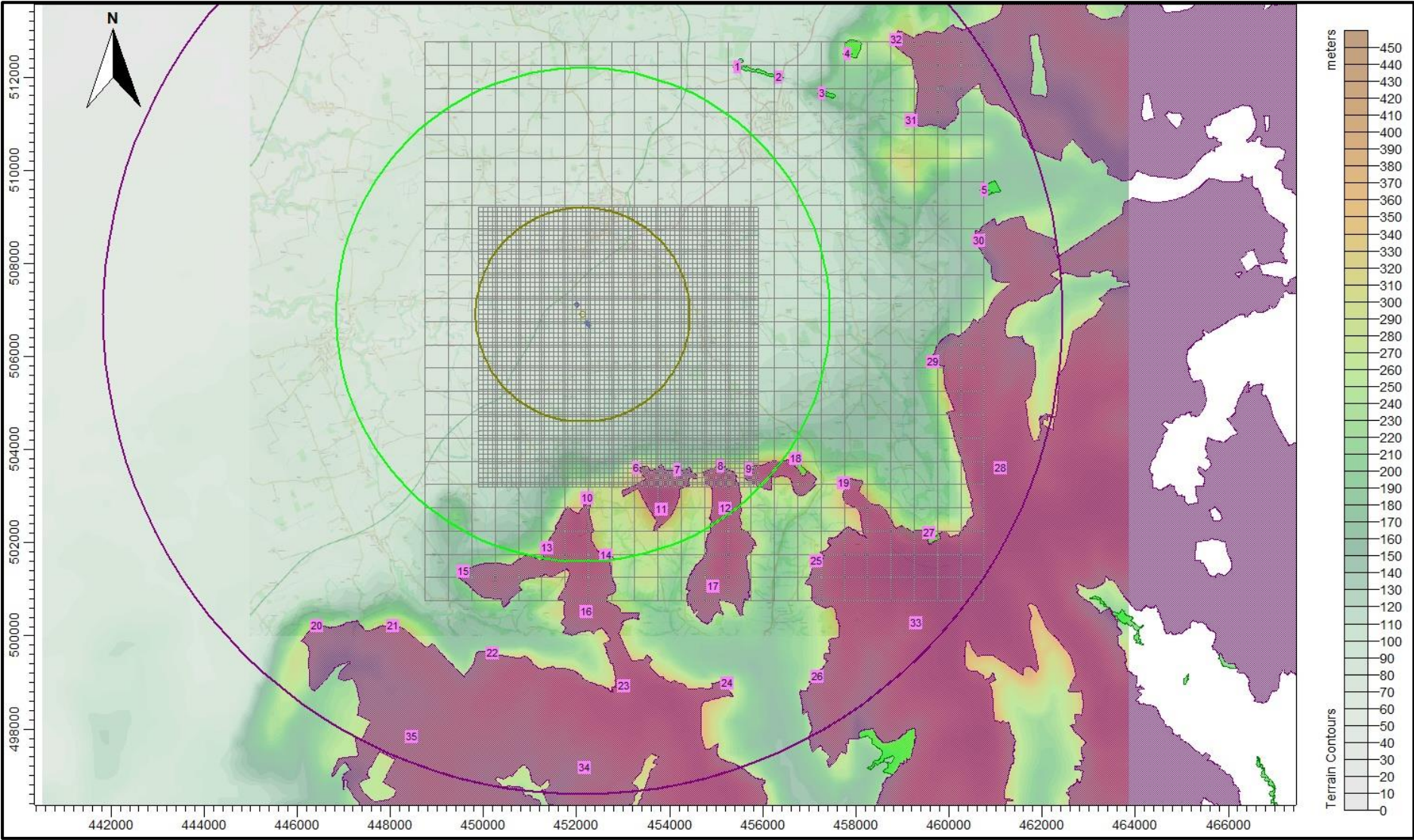
In this case, a spatially varying roughness length file has been defined, this is based upon the Defra Living Landscapes land use database. The GFS meteorological data is assumed to have a roughness length of 0.236 m (arithmetic average of the spatially varying roughness over the modelling domain). The sample of the central area of the spatially varying roughness length field is shown in Figure 5.

Figure 3. The positions of modelled buildings and sources at Fir Tree Farm



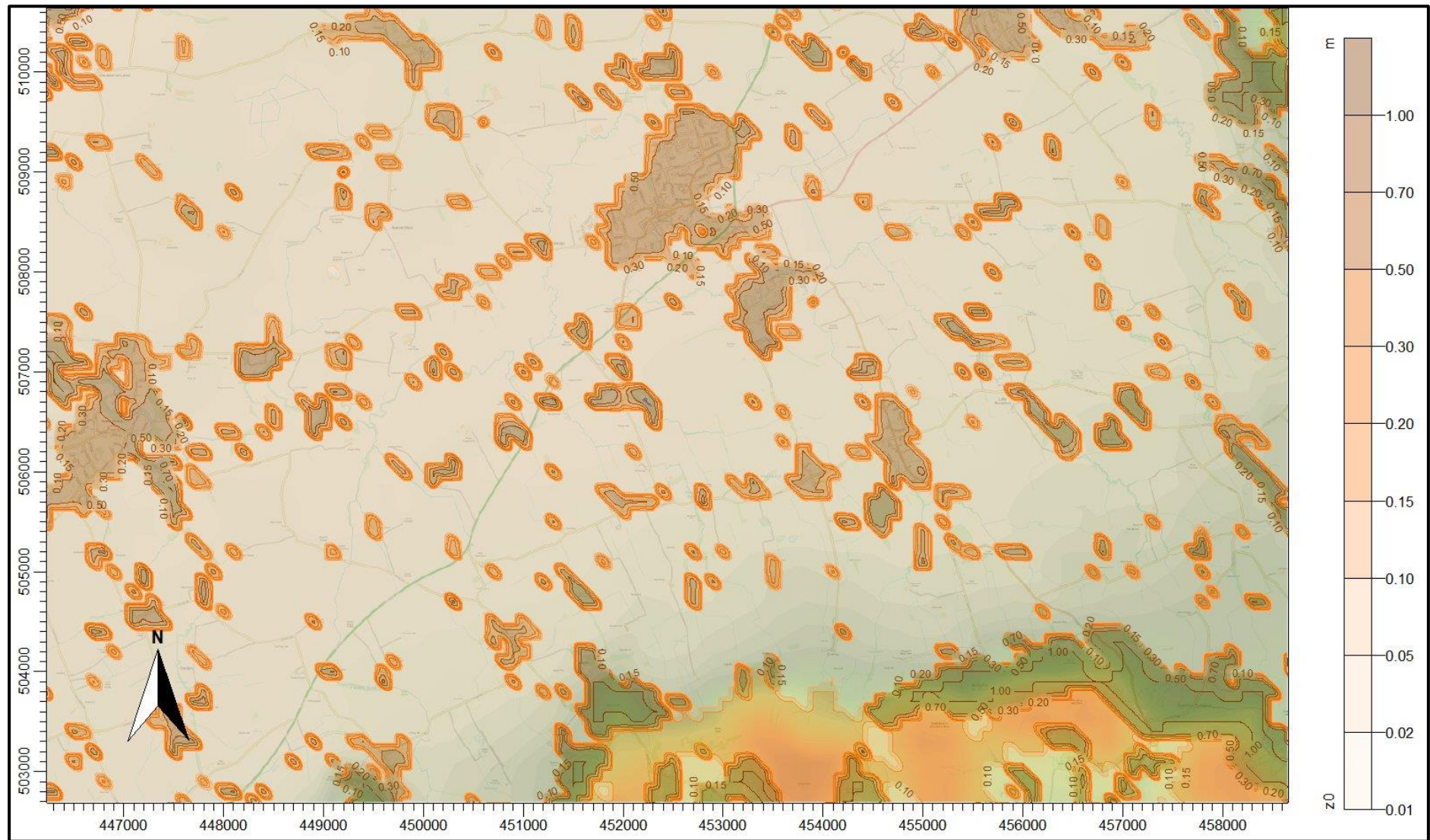
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Figure 4. The discrete receptors and regular Cartesian grids



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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 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, has been used to define a deposition velocity field. The deposition velocities used are provided in Table 4.

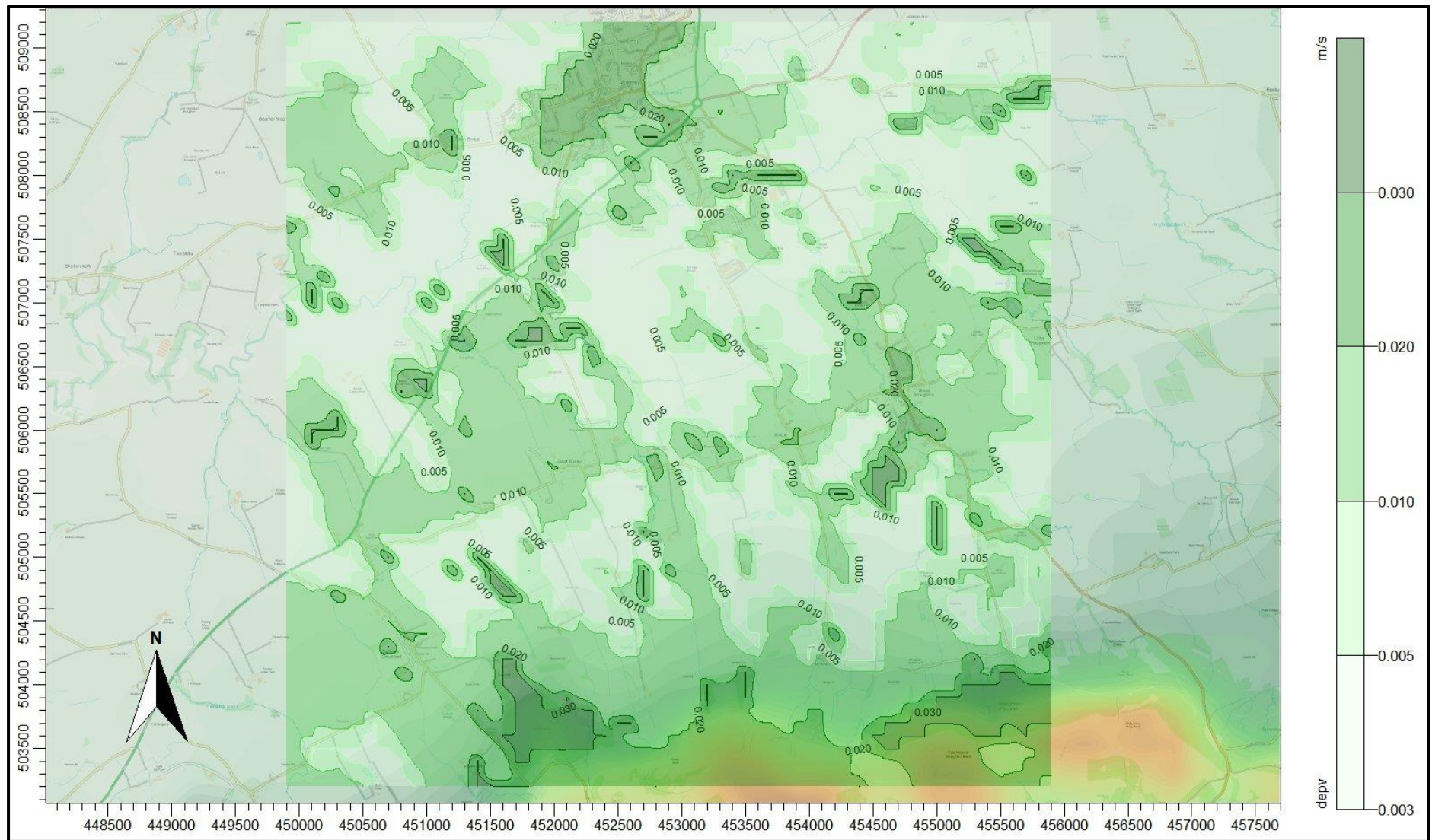
Table 4. Deposition velocities

NH ₃ concentration (PC + background) (µg/m ³)	< 10	10 - 20	20 - 30	30 – 80	> 80
Deposition velocity – woodland (m/s)	0.03	0.015	0.01	0.005	0.003
Deposition velocity – short vegetation (m/s)	0.02 (0.01 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



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5. Details of the Model Runs and Results

5.1 Preliminary modelling and sensitivity tests

ADMS was run a total of eight times, once for each year of the meteorological record and 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 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 concentrations at the discrete receptors - preliminary modelling

Receptor number	X(m)	Y(m)	Name/Designation	Maximum annual mean ammonia concentration - ($\mu\text{g}/\text{m}^3$)	
				GFS No Calms No Terrain	GFS Calms No Terrain
1	455458	512215	Langbaurgh Ridge SSSI	0.026	0.029
2	456341	511999	Langbaurgh Ridge SSSI	0.023	0.026
3	457280	511643	Cliff Ridge SSSI	0.021	0.023
4	457824	512497	Roseberry Topping SSSI	0.017	0.019
5	460772	509568	Kildale Hall SSSI	0.013	0.015
6	453288	503609	North York Moors SSSI /SAC/SPA	0.025	0.031
7	454171	503562	North York Moors SSSI /SAC/SPA	0.022	0.026
8	455089	503633	North York Moors SSSI /SAC/SPA	0.020	0.024
9	455701	503585	North York Moors SSSI /SAC/SPA	0.018	0.022
10	452240	502950	North York Moors SSSI /SAC/SPA	0.025	0.030
11	453818	502714	North York Moors SSSI /SAC/SPA	0.016	0.020
12	455207	502738	North York Moors SSSI /SAC/SPA	0.015	0.018
13	451357	501878	North York Moors SSSI /SAC/SPA	0.016	0.020
14	452628	501725	North York Moors SSSI /SAC/SPA	0.016	0.020
15	449566	501373	North York Moors SSSI /SAC/SPA	0.011	0.014
16	452205	500516	North York Moors SSSI /SAC/SPA	0.011	0.014
17	454934	501057	North York Moors SSSI /SAC/SPA	0.009	0.012
18	456706	503798	Broughton Bank SSSI/North York Moors SSSI /SAC/SPA	0.015	0.019
19	457738	503280	North York Moors SSSI /SAC/SPA	0.011	0.014
20	446431	500209	North York Moors SSSI /SAC/SPA	0.006	0.008
21	448055	500209	North York Moors SSSI /SAC/SPA	0.007	0.010
22	450198	499622	North York Moors SSSI /SAC/SPA	0.008	0.011
23	453018	498923	North York Moors SSSI /SAC/SPA	0.008	0.010
24	455229	498991	North York Moors SSSI /SAC/SPA	0.006	0.008
25	457146	501607	North York Moors SSSI /SAC/SPA	0.009	0.011
26	457169	499126	North York Moors SSSI /SAC/SPA	0.006	0.007
27	459583	502216	Botton Head SSSI/North York Moors SSSI /SAC/SPA	0.007	0.009
28	461117	503592	North York Moors SSSI /SAC/SPA	0.008	0.010
29	459650	505871	North York Moors SSSI /SAC/SPA	0.014	0.016
30	460643	508488	North York Moors SSSI /SAC/SPA	0.013	0.016
31	459199	511059	North York Moors SSSI /SAC/SPA	0.016	0.019
32	458861	512796	North York Moors SSSI /SAC/SPA	0.014	0.016
33	459295	500267	North York Moors SSSI /SAC/SPA	0.006	0.008
34	452177	497166	North York Moors SSSI /SAC/SPA	0.006	0.008
35	448465	497827	North York Moors SSSI /SAC/SPA	0.005	0.007

5.2 Detailed modelling

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

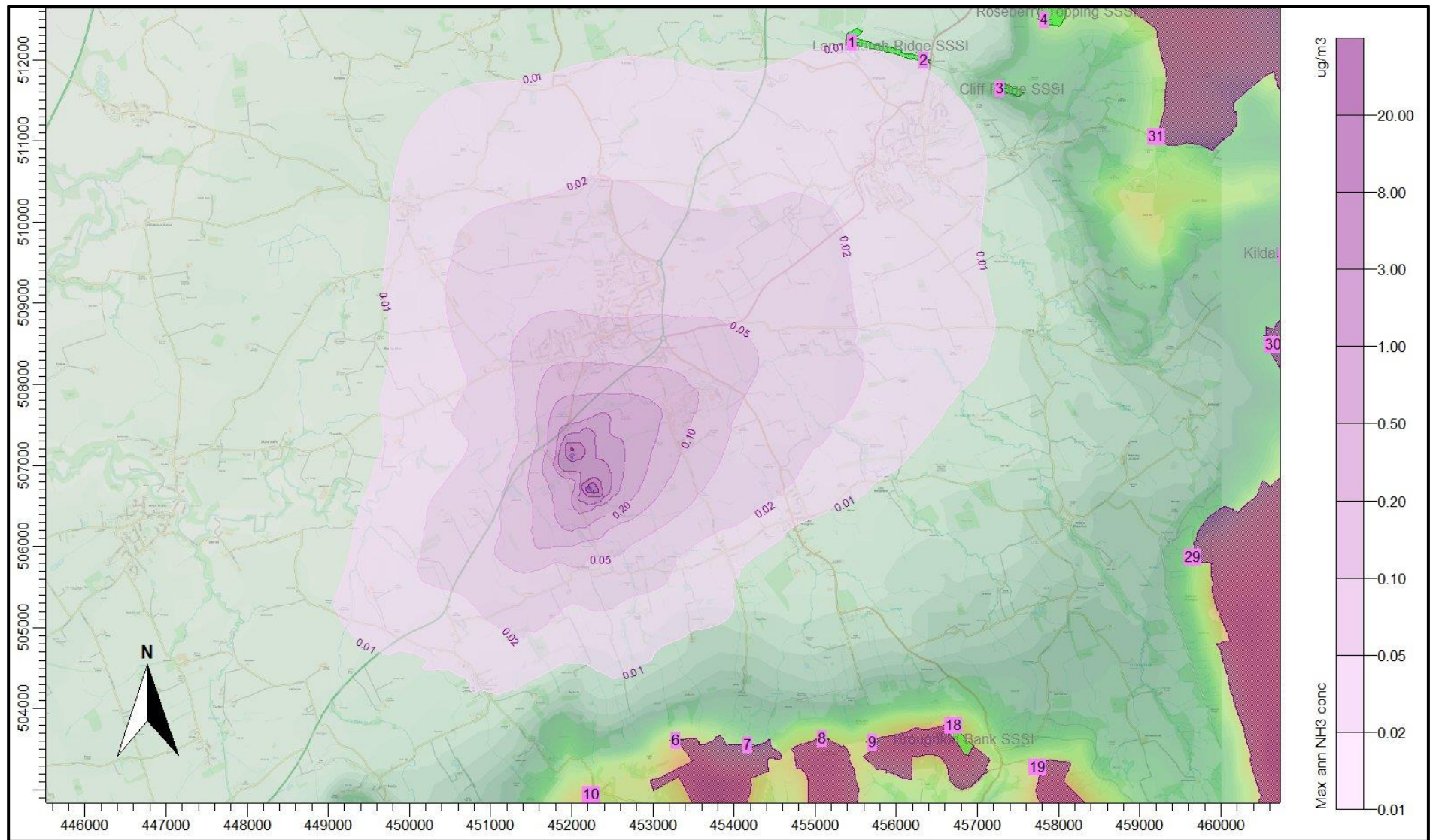
The predicted process contribution to maximum annual mean ground level ammonia concentrations and nitrogen deposition rates at the discrete receptors included within the detailed modelling are shown in Table 6. In the Table, there are no predicted ammonia concentrations and nitrogen deposition rates that are in excess of the Environment Agency's upper threshold of the relevant Critical Level or Critical Load (50% for a SSSI and 20% for a SAC/SPA) nor any in the range between the Environment Agency's lower and upper thresholds (20% and 50% for a SSSI and 4% and 20% for a SAC/SPA). There are also no process contributions which exceed 1% in this case.

Contour plots of the predicted process contributions to ground level maximum annual mean ammonia concentration and maximum annual nitrogen deposition rate are shown in Figure 7a and Figure 7b.

Table 6. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors

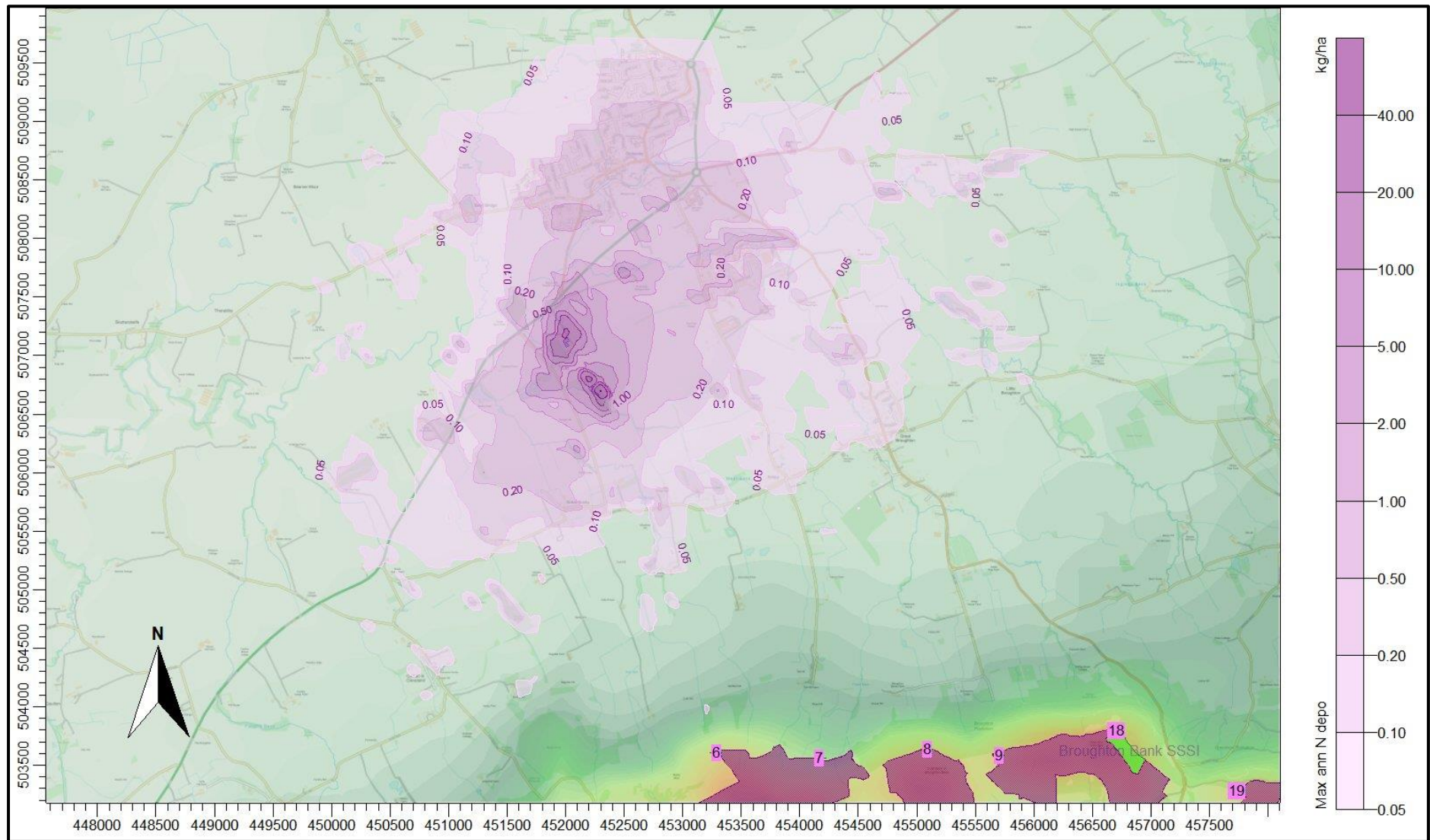
Receptor number	X(m)	Y(m)	Name	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level ($\mu\text{g}/\text{m}^3$)	Critical Load (kg/ha)	Process Contribution ($\mu\text{g}/\text{m}^3$)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	455458	512215	Langbaugh Ridge SSSI	0.03	n/a	n/a	0.010	-	0.08	-
2	456341	511999	Langbaugh Ridge SSSI	0.03	n/a	n/a	0.010	-	0.08	-
3	457280	511643	Cliff Ridge SSSI	0.03	n/a	n/a	0.008	-	0.06	-
4	457824	512497	Roseberry Topping SSSI	0.03	n/a	n/a	0.006	-	0.04	-
5	460772	509568	Kildale Hall SSSI	0.03	n/a	n/a	0.003	-	0.02	-
6	453288	503609	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.005	0.46	0.02	0.48
7	454171	503562	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.003	0.28	0.01	0.29
8	455089	503633	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.002	0.23	0.01	0.24
9	455701	503585	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.002	0.17	0.01	0.17
10	452240	502950	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.002	0.17	0.01	0.18
11	453818	502714	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.11	0.01	0.11
12	455207	502738	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.11	0.01	0.11
13	451357	501878	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.002	0.16	0.01	0.17
14	452628	501725	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.09	0.00	0.09
15	449566	501373	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.002	0.24	0.01	0.25
16	452205	500516	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.07	0.00	0.07
17	454934	501057	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.05	0.00	0.05
18	456706	503798	Broughton Bank SSSI/North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.15	0.01	0.15
19	457738	503280	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.11	0.01	0.11
20	446431	500209	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.14	0.01	0.14
21	448055	500209	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.15	0.01	0.16
22	450198	499622	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.12	0.01	0.12
23	453018	498923	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.000	0.04	0.00	0.04
24	455229	498991	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.000	0.04	0.00	0.04
25	457146	501607	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.08	0.00	0.08
26	457169	499126	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.000	0.04	0.00	0.04
27	459583	502216	Botton Head SSSI/North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.08	0.00	0.08
28	461117	503592	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.07	0.00	0.07
29	459650	505871	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.002	0.25	0.01	0.26
30	460643	508488	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.003	0.33	0.02	0.35
31	459199	511059	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.004	0.37	0.02	0.39
32	458861	512796	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.004	0.35	0.02	0.36
33	459295	500267	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.000	0.04	0.00	0.04
34	452177	497166	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.000	0.03	0.00	0.04
35	448465	497827	North York Moors SSSI /SAC/SPA	0.02	1.0	5.0	0.001	0.08	0.00	0.08

Figure 7a. Maximum annual mean ammonia concentration



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Figure 7b. Maximum annual nitrogen deposition rate



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6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Ms. Lizzie Bentley of Yorkshire Farmers, on behalf of Bailey Livestock Limited, to use computer modelling to assess the impact of ammonia emissions from the piggery at Fir Tree Farm, Stokesley, North Yorkshire. TS9 5LD.

Ammonia emission rates from the piggery have been derived from ammonia emission factors provided by the Environment Agency for permitting and modelling purposes. 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 contributions to annual ammonia concentration and nitrogen deposition rate at all SSSIs, SACs and SPAs are below the Environment Agency's lower threshold percentages of the relevant Critical Level and Critical Load (20% for a SSSI and 4% for a SAC/SPA).
- The process contributions to annual ammonia concentration and nitrogen deposition rate are below 1% of the relevant Critical Level and Critical Load at the North York Moors SSSI/SAC/SPA.

7. References

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