A Report on the Modelling of the Dispersion and Deposition of Ammonia from the Permitted and Proposed Piggeries at Sheephouse Farm, Southmoor, Abingdon in Oxfordshire

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1. Introduction

AS Modelling & Data Ltd. has been instructed by Mr. Harry Edwards of The Farm Consultancy Group, on behalf of Blanchard Enterprises, to use computer modelling to assess the impact of ammonia emissions from the permitted and proposed piggeries at Sheephouse Farm, Southmoor, Abingdon, Oxfordshire. OX13 5HP.

Ammonia emission rates from the piggeries are based on ammonia emission factors provided by The Farm Consultancy Group, which it is understood are agreed with the Environment Agency. 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

Sheephouse Farm is in a rural area, approximately 1.5 km to the south-south-west of Kingstone Bagpuize and 1.5 km to the north-east of Charney Bassett in Oxfordshire. The surrounding land is used almost exclusively for arable farming. The site is at an elevation of around 60 m above sea level and the surrounding terrain is relatively flat.

Sheephouse Farm currently has a permit for up to 2,500 weaners (7-15 kg), 2,500 growers (15-30kg), 3,600 finishers (>30 kg) and 620 sows, housed on a solid floor straw system in naturally ventilated buildings. The farm has a covered dirty water lagoon located approximately 350 m to the north of the piggery and the permit allows for storage of up to 10,000 tonnes of manure at the farm.

Under the proposal, the piggery would operate a batch system for 6,000 finisher pigs (>30 kg) which would be reared in a batch system. The pigs would be housed on a solid floor straw system in naturally ventilated buildings. The manure storage capacity would be 1,000 tonnes.

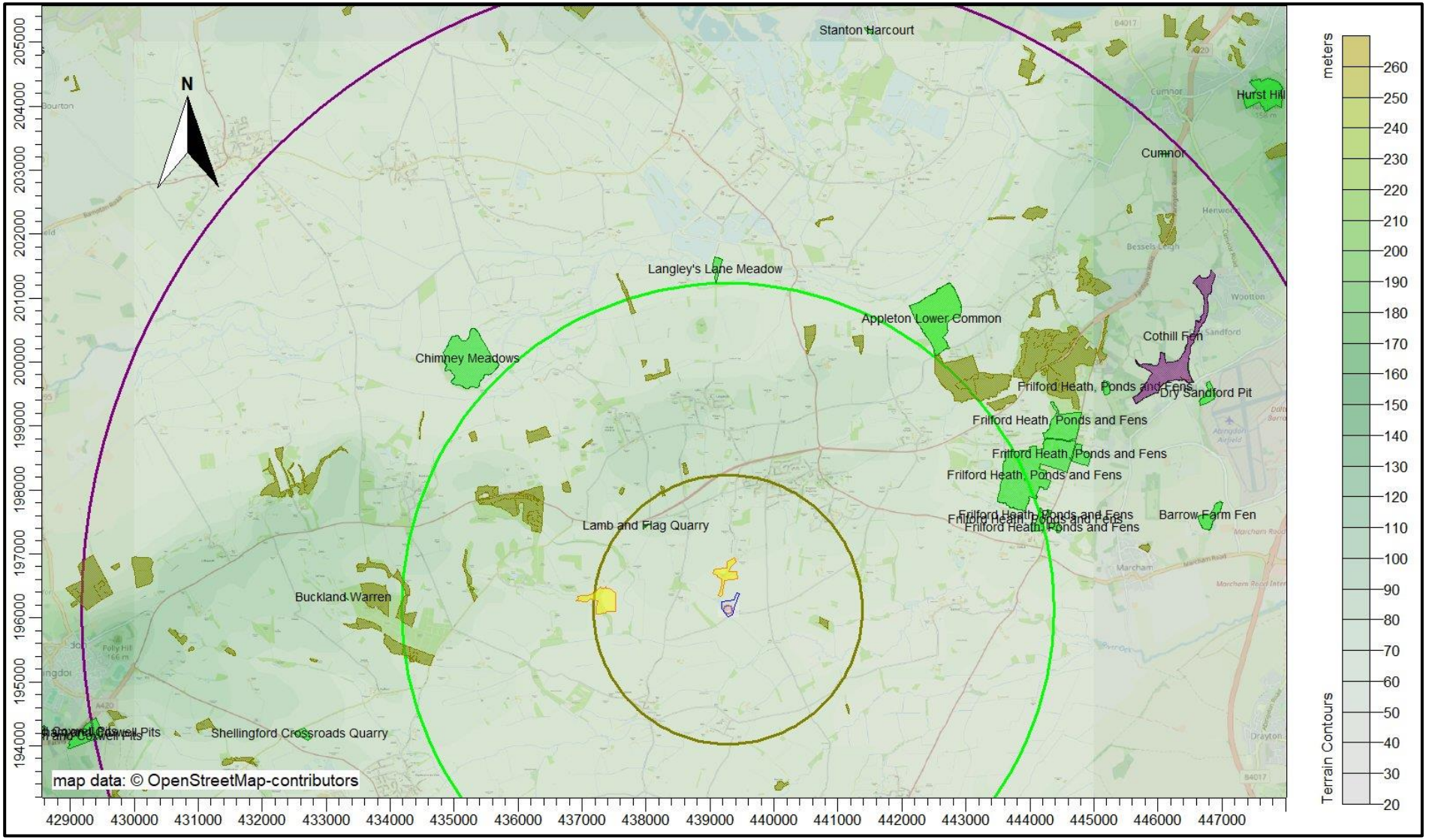
There are two areas of Ancient Woodland (AWs) and two Local Wildlife Sites (LWSs) within 2 km (the normal screening distance for non-statutory sites). There are also thirteen Sites of Special Scientific Interest (SSSI) within 10 km (the normal screening distance for a SSSI), one of which is also designated as a Special Area of Conservation (SAC). No other internationally designated sites have been identified within 10 km. Further details of the SSSIs and SAC are provided below:

- **Lamb and Flag Quarry SSSI -** Approximately 1.7 km to the north-west - Geological.
- **Frilford Heath, Ponds and Fens SSSI -** Approximately 4.5 km to the east-north-east - The acid grassland, heathland and associated valley fens at Frilford Heath are unique in southern England. The site has an exceptionally diverse flora and fauna, with over 400 species of vascular plants recorded, including many national rarities, together with rare beetles, flies, bees and other insects.
- **Appleton Lower Common SSSI -** Approximately 5.0 km to the north-east - A fine example of broad-leaved woodland on the Oxford Clay which has remained unmodified by conifer planting or clear felling. The lower plant flora (mosses, liverworts, lichens and fungi) contains species thought to be confined to ancient woods.
- **Langley's Lane Meadow SSSI -** Approximately 5.1 km to the north - A surviving remnant of unimproved grassland in an area now largely dominated by intensive arable farming and gravel extraction.
- **Chimney Meadows SSSI -** Approximately 5.1 km to the north-west - Six neutral, unimproved and semi-improved alluvial meadows which support a botanically rich sward and are of local importance for breeding birds, particularly waders.
- **Buckland Warren SSSI -** Approximately 5.8 km to the west - A strip of cultivated land between a golf course and an area of woodland. The site supports a community of annual plants including one of the few remaining populations of the nationally rare broad-leaved cudweed *Filago pyramidata*.
- **Shellingford Crossroads Quarry SSSI -** Approximately 6.8 km to the west-south-west - Geological.
- **Wicklesham and Coxwell Pits SSSI -** Approximately 9.9 km to the west-south-west - Geological.
- **Barrow Farm Fen SSSI -** Approximately 7.4 km to the east-north-east - This site is primarily of interest for its remnants of calcareous fen vegetation which are found within a matrix of dense wet and dry carr woodland.
- **Dry Sandford Pit SSSI -** Approximately 8.0 km to the east-north-east - An abandoned sand quarry which has developed a valuable mosaic of calcareous vegetation including fen, grassland, scrub and lichen-rich heath. The entomological value of Dry Sandford Pit is of national importance.
- **Stanton Harcourt SSSI -** Approximately 9.1 km to the north-north-east - Geological.
- **Cumnor SSSI -** Approximately 9.7 km to the north-north-east - Geological.

- **Cothill Fen SSSI/SAC -** Approximately 7.0 km to the north-east - The fen supports outstanding examples of nationally rare calcareous fen and moss-rich mire communities together with associated wetland habitats. The fen exhibits succession from open water to fen, scrub and carr, together with an adjacent area of ancient woodland. Over 330 vascular plants have been recorded, including species which are uncommon in southern England, together with many uncommon invertebrates. The fen communities, in particular, support a rich assemblage of mosses and liverworts, often growing amongst encrustations of tufa.

A map of the surrounding area showing the positions of the piggery and the wildlife sites is provided in Figure 1. The site of the pig rearing houses at Sheephouse Farm is outlined in blue, the AWs are shaded in olive, the LWSs are shaded in yellow, the SSSIs are shaded in green and the SAC is shaded in purple.

Figure 1. The area surrounding Sheephouse Farm



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, July 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 Sheephouse Farm is 2.07 $\mu g\text{-}NH_3/m^3$. The background nitrogen deposition rate to woodland is 25.02 kg-N/ha/y and to short vegetation is 13.00kg-N/ha/y. The background acid deposition rate to woodland is 1.84 keq/ha/y and to short vegetation is 0.96 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 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 (kg-N/ha/y)	Critical Load Acid (keq/ha/y)
Newhouse Covert LWS	3.0 [1]	10.0 [1]	10.808 [1]
Wick Scrubs AW	1.0 [1]	10.0 [2]	-
Other non-statutory sites	1.0 [2 & 3]	10.0 [2]	-
Frilford Heath, Ponds and Fens SSSI	1.0 [2 & 3]	5.0 [4]	-
Appleton Lower Common SSSI	1.0 [2 & 3]	15.0 [4]	-
Langley's Lane Meadow SSSI and Chimney Meadows SSSI	3.0 [3]	10.0 [4]	-
Buckland Warren SSSI	3.0 [3]	n/a [5]	-
Barrow Farm Fen SSSI	1.0 [2 & 3]	10.0 [4]	-
Dry Sandford Pit SSSI and Cothill Fen SSSI/SAC	1.0 [3]	10.0 [4]	-
Lamb and Flag Quarry SSSI; Shellingford Crossroads Quarry SSSI; Wicklesham and Coxwell Pits SSSI; Stanton Harcourt SSSI and Cumnor SSSI	n/a [6]	n/a [6]	n/a [6]

1. Ammonia Critical Level and Nitrogen/Acid Critical Load provided by the Environment Agency in their pre-application screening report (20/09/2022).
2. 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.
3. Based upon the citation for the site.
4. The lower bound of the range of Critical Loads for the site.
5. No Critical Load.
6. 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% (in some circumstances <1%) of Critical Level or Critical Load at a SSSI, SAC, SPA or Ramsar site, then the local authority should consider whether other farming installations[1] 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 Farm Consultancy Group, which it is understood are agreed with the Environment Agency. It is understood that the Environment Agency's standard emission factors are based upon figures from the UK Ammonia Emissions Inventory (UKAEI); therefore, AS Modelling and Data Ltd. has

calculated emission factors specifically for a lairage and holding pen and hospital using figures derived from the UKAEI and standard pig growth curves for straw based systems.

It should be noted that the emission factors for the finisher pigs provided to AS Modelling & Data Ltd. is based upon AHDB trial data, not the UKAEI 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, whilst the ADDB based emission factor might be appropriate for modern housing, this is unlikely to be true for the older permitted housing.

3.5.2 Manure Storage

The Environment Agency pre-application screening report (20/09/2022, EPR/UP3539UM/V003) also provides ammonia emission factors of 1.49 kg-NH_3/tonne/y for farmyard manure and 1.4 kg-NH_3/ m^2 for an uncovered lagoon.

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

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

Source		Number of Pigs/tonnage	Weight (kg)	Emission Factor (kg-NH_3/pig/y)	Emission Rate (g-NH_3/s)
EX_GROW		2500	15-30	1.14	0.090311
EX_WEAN		2500	7-15	0.21	0.016636
EX_FAR		120	Sows	8.88	0.033767
EX_DRY		320	Sows	4.57	0.046341
SERV		180	Sows	4.57	0.026067
EX_FAT		3600	30+	2.00	0.228154
Source	Area	Tonnage		Emission Factor (kg-NH_3/t or m^2/y)	Emission Rate (g-NH_3/s)
EX_MUCK1	1650	4583		1.49	0.216403
EX_MUCK2	1950	5417		1.49	0.255749
LAGOON	3821.9			0.84	0.101730609

Table 2b. Details of manure storage and modelled ammonia emission rates - proposed

Source		Number of Pigs	Weight (kg)	Emission Factor (kg-NH_3/pig/y)	Emission Rate (g-NH_3/s)
WEAN		1800	7-15	0.21	0.011978
		1800	15-30	1.14	0.065024
FINA		1200	30+	2.00	0.076051
FINB		1200	30+	2.00	0.076051
FINC		1200	30+	2.00	0.076051
FIND		1200	30+	2.00	0.076051
FINE		1200	30+	2.00	0.076051
Source	Area	Tonnage		Emission Factor (kg-NH_3/t or m^2/y)	Emission Rate (g-NH_3/s)
MUCKSHD		500		1.49	0.023608
MUCKPAD		500		1.49	0.023608
LAGOON	3821.9			0.84	0.101731

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 Sheephouse Farm is shown in Figure 2b. Note that elsewhere in the modelling domain the modified wind roses may differ more or less markedly. 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[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 51.662 N, 1.432 W, 2020-2023

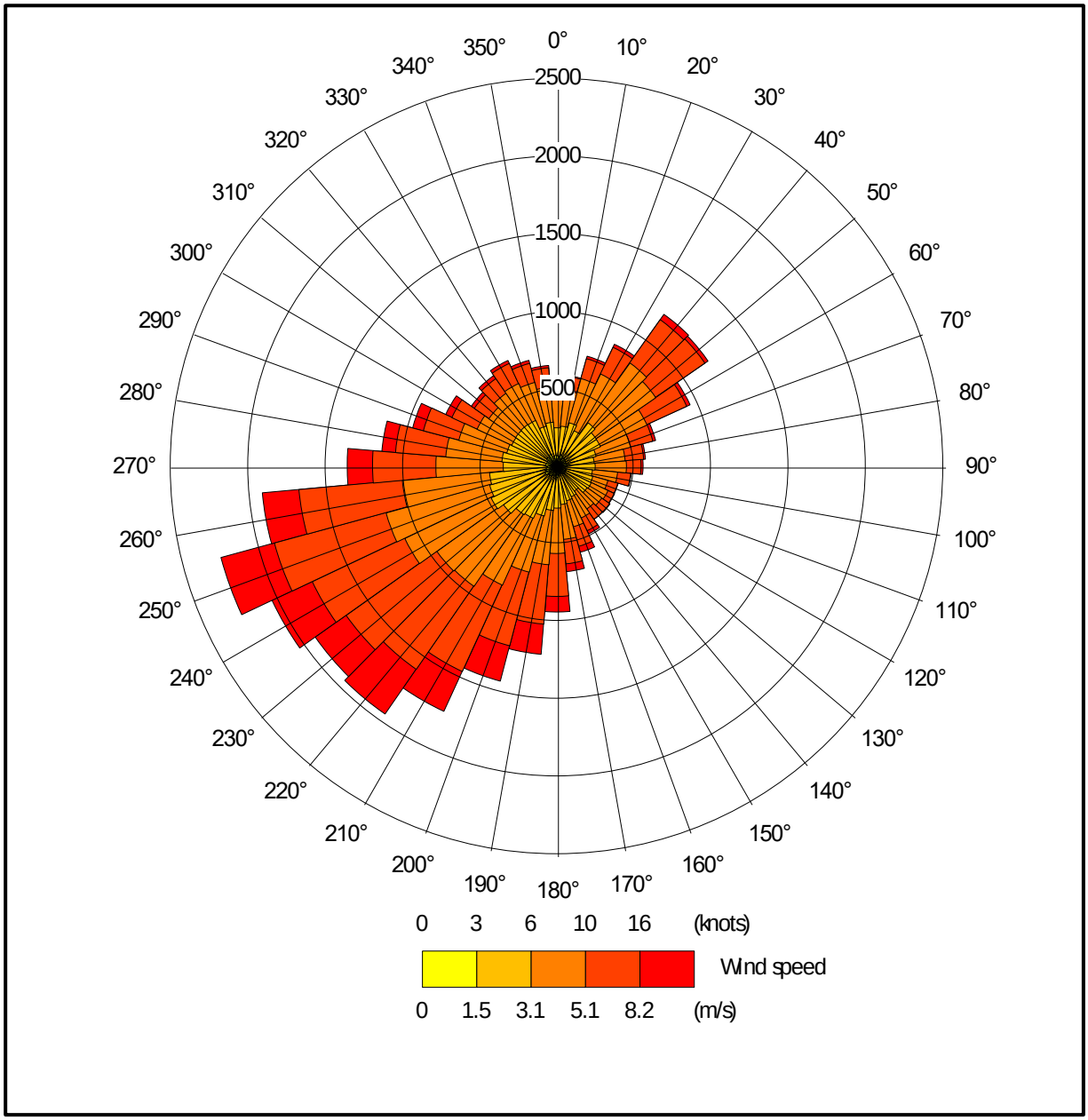
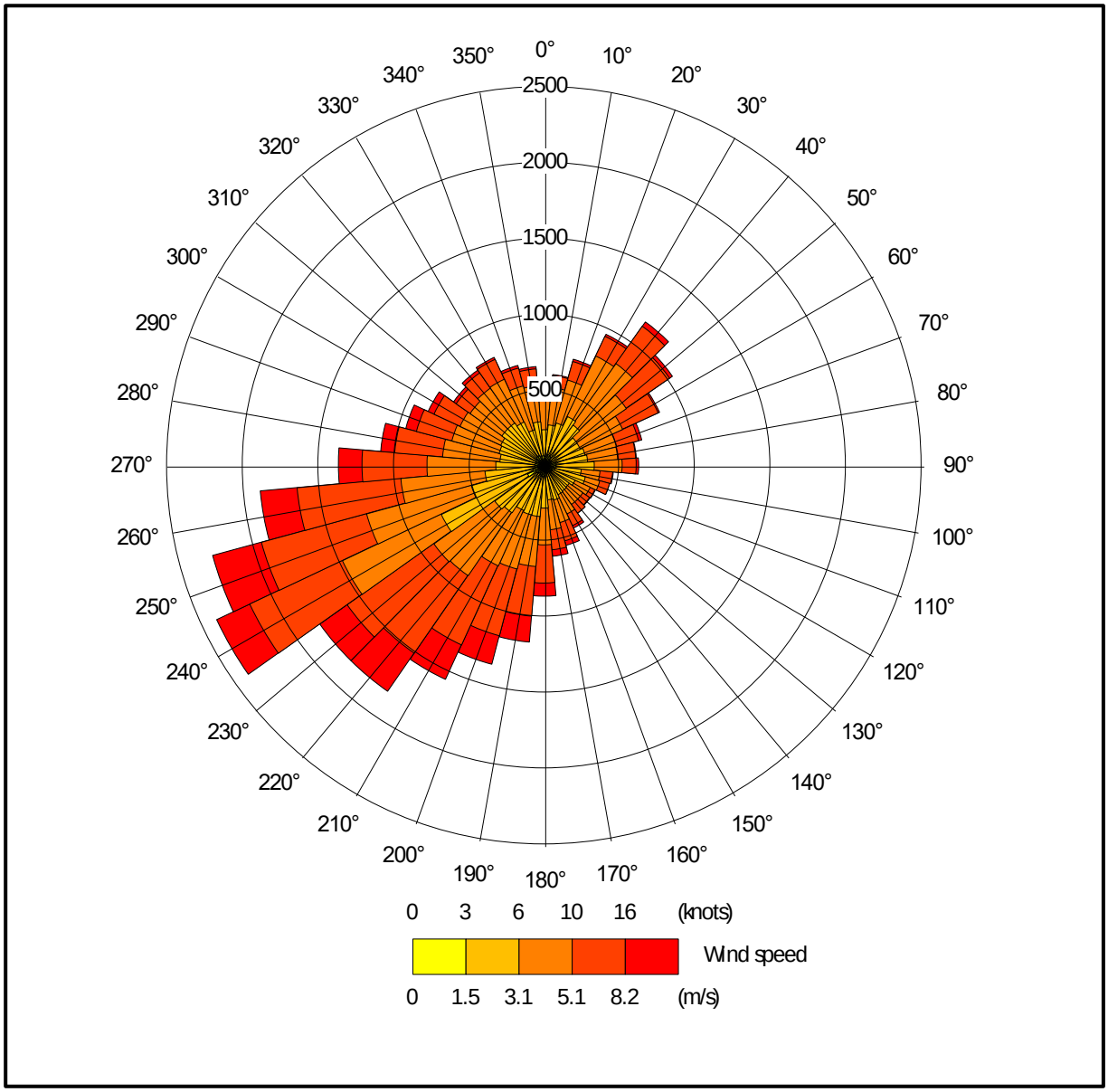


Figure 2b. The wind rose. FLOWSTAR derived data for NGR 439300, 196150, 2020-2023



4.2 Emission sources

Emissions from the naturally ventilated pig housing and manure storage and dirty water storage are represented by volume sources within ADMS. Details of the volume source parameters are provided in Table 3a (permitted scenario) and 3b (proposed scenario).

Table 3a. Volume source parameters – permitted scenario

Source	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
EX_GROW	80.0	35.0	3.0	0.5	Ambient	0.090311
EX_WEAN	12.8	132.0	3.0	0.5	Ambient	0.016636
EX_FAR	50.0	36.0	3.0	0.5	Ambient	0.033767
EX_DRY	49.2	30.1	3.0	0.5	Ambient	0.046341
SERV	48.5	25.0	3.0	0.5	Ambient	0.026067
EX_FAT	61.4	101.9	3.0	0.5	Ambient	0.228154
EX_MUCK1	10.0	165.0	3.0	0.0	Ambient	0.216403
EX_MUCK2	15.0	130.0	3.0	0.0	Ambient	0.255749
LAGOON			1.0	0.0	Ambient	0.101731

Table 3b. Volume source parameters – proposed scenario

Source	Length (m)	Width (m)	Depth (m)	Base height (m)	Emission temperature (°C)	Emission rate (g-NH_3/s)
Weaners (7-30 kg)	12.8	132.0	3.0	0.5	Ambient	0.077002
Finisher Building A	47.4	26.0	3.0	0.5	Ambient	0.011978
Finisher Building B	47.4	23.4	3.0	0.5	Ambient	0.076051
Finisher Building C	47.4	21.2	3.0	0.5	Ambient	0.076051
Finisher Building D	47.4	21.2	3.0	0.5	Ambient	0.076051
Finisher Building E	47.4	19.5	3.0	0.5	Ambient	0.076051
Muck Shed	12.5	16.8	4.0	0.5	Ambient	0.023608
Muck Pad	9.7	29.6	2.0	0.5	Ambient	0.023608
LAGOON			1.0	0.0	Ambient	0.101731

Emissions from the lagoon and slurry store are represented by area sources within ADMS. Details of the area source parameters are given in Table 3b. The positions of the modelled sources may be seen in Figures 3a (permitted) and 3b (proposed), marked by red polygons.

4.3 Modelled buildings

Not modelled.

Figure 3a. The positions of modelled sources at Sheephouse Farm – permitted scemario

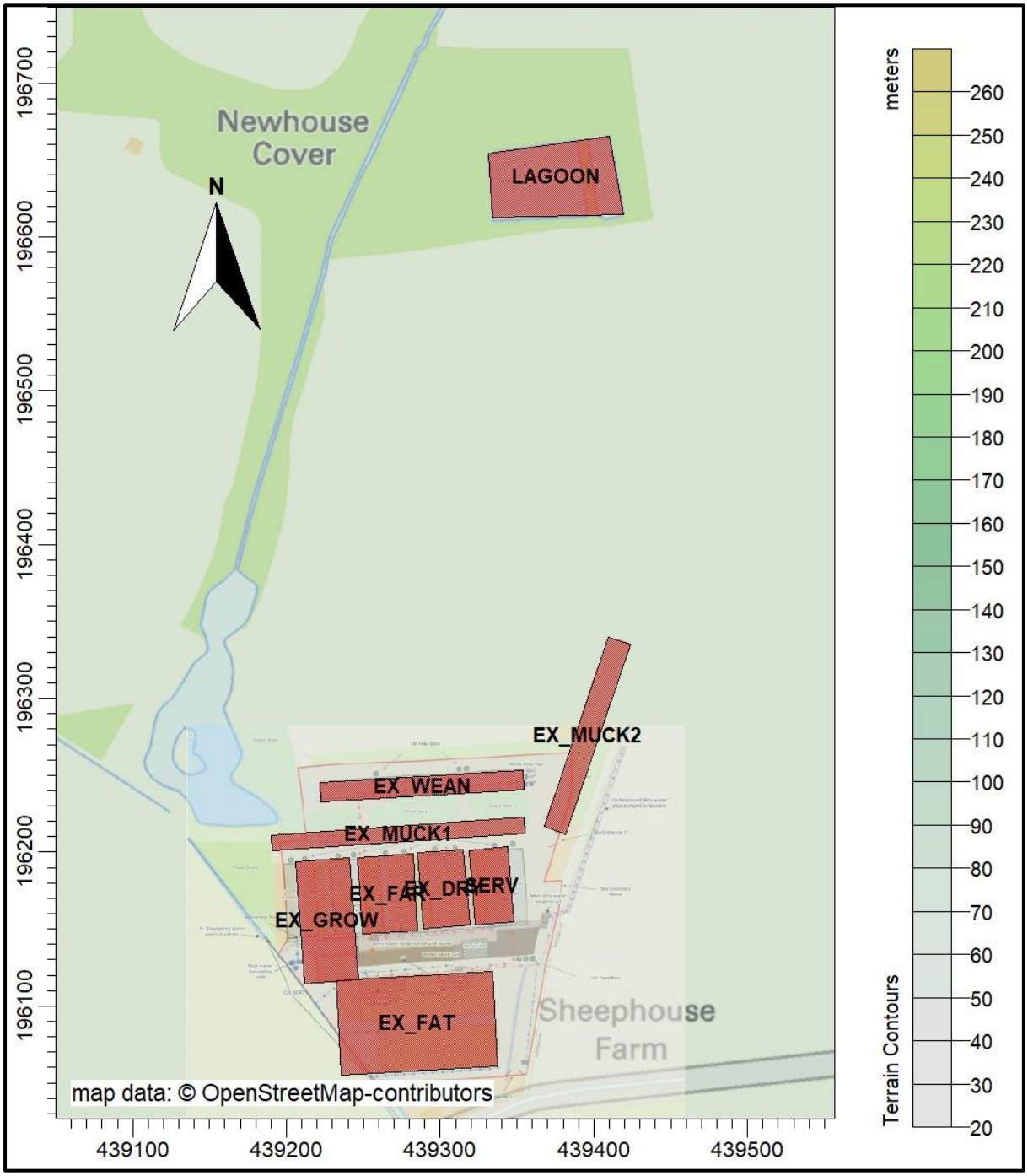
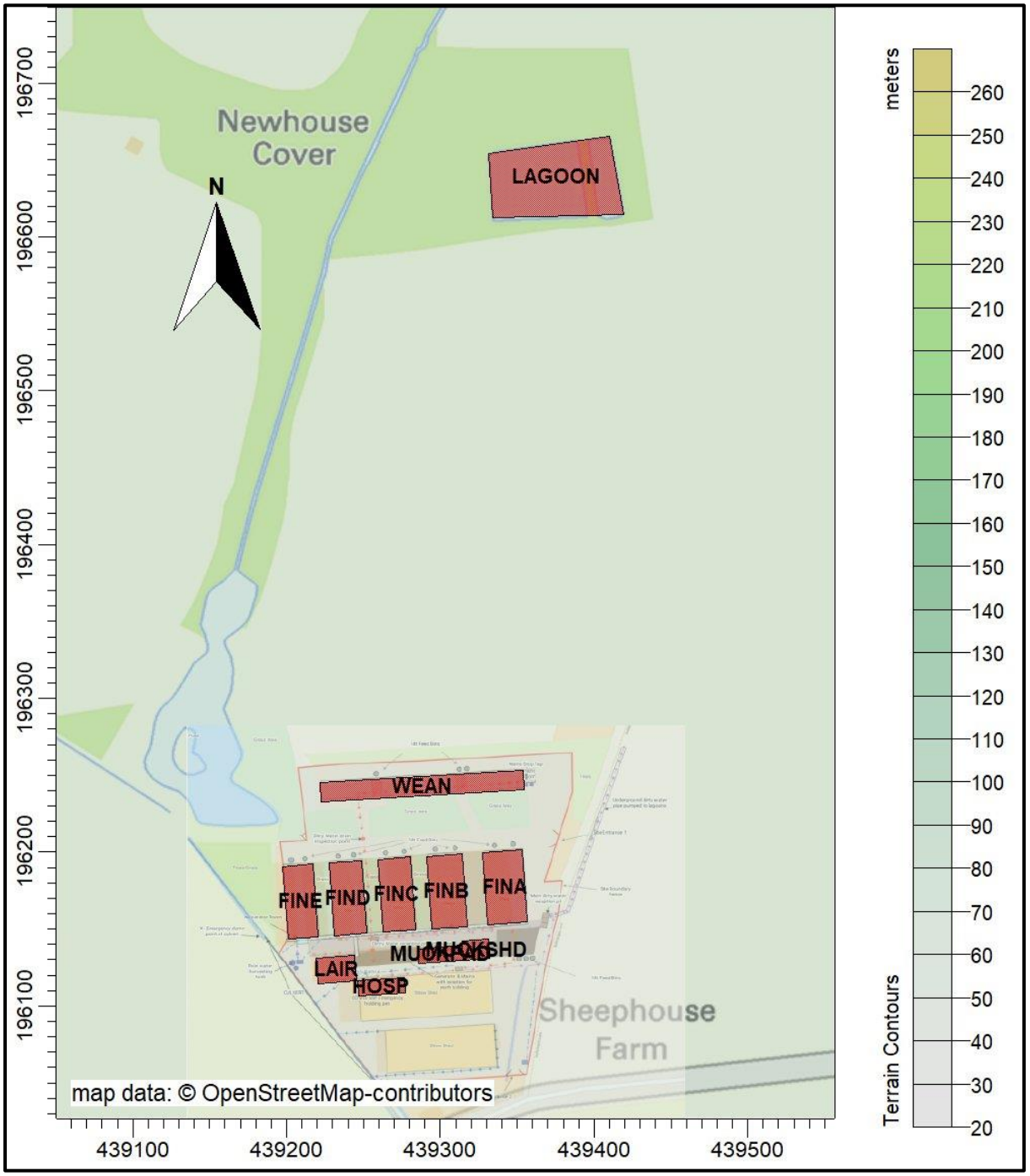


Figure 3b. The positions of modelled sources at Sheephouse Farm – proposed scemario



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 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.

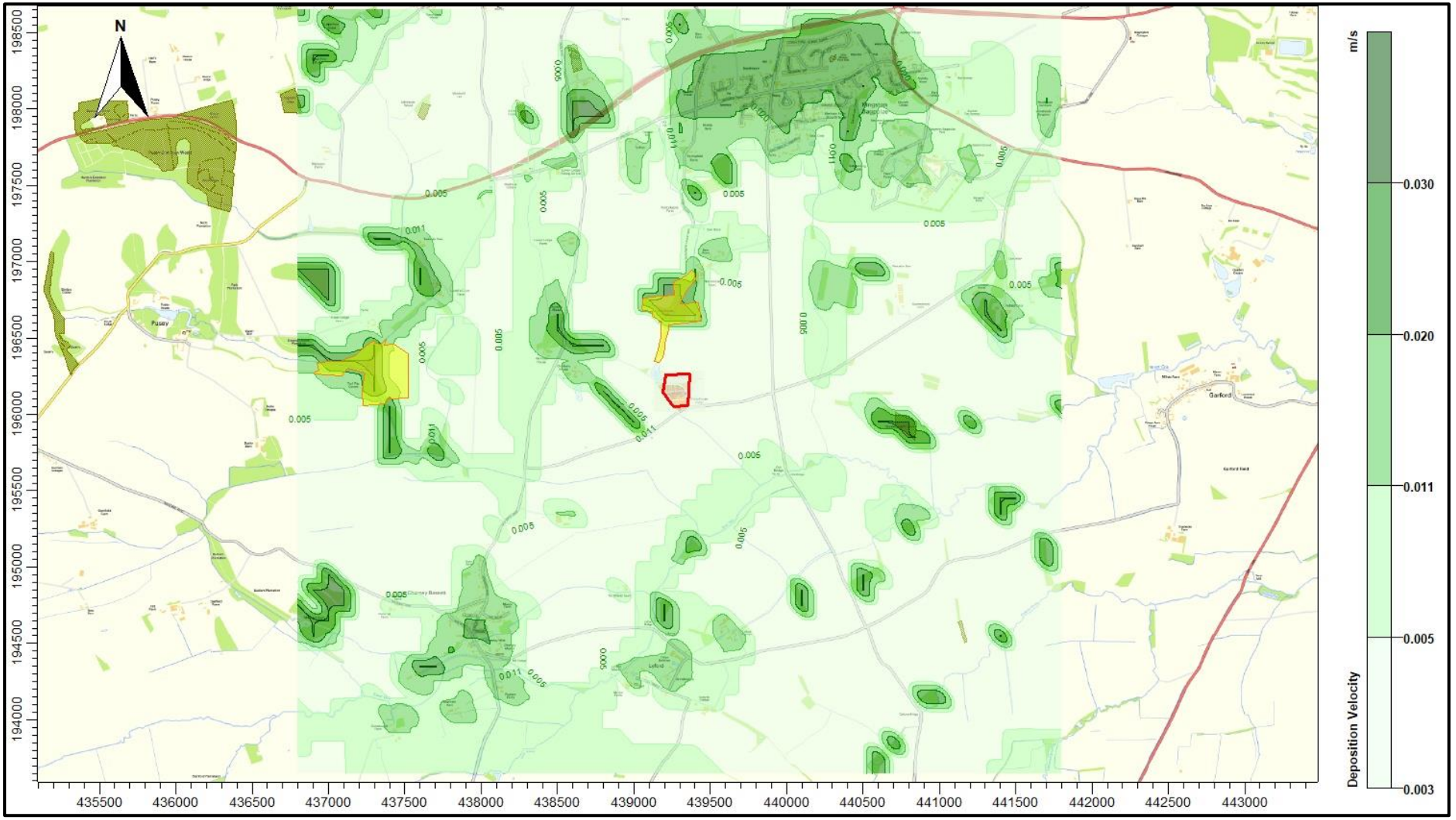
Table 4. Deposition velocities

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



5. Details of the Model Runs and Results

5.1 Preliminary modelling and sensitivity tests

Not conducted. Sensitivities were tested in earlier modelling studies.

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).

Note that although calms and spatially varying deposition cannot be run in conjunction, a correction to account for the effect of calms (a factor of 1.21) which is based upon the difference between the basic and calms modes in previous modelling studies) has been applied to receptors within approximately 2 km of the piggery.

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 5a and 5b. In the Tables, 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 (100% for a non-statutory site, 50% for a SSSI and 20% for an internationally designated site) are coloured red. Concentrations or deposition rates that are in the range between the Environment Agency's lower and upper threshold of the relevant Critical Level or Critical Load (100% and 100% for a non-statutory site, 20% and 50% for a SSSI and 4% and 20% for an internationally designated site) are coloured blue. Additionally, process contributions which exceed 1% of the relevant Critical Level or Critical Load at the statutory sites are highlighted with bold text. For convenience, cells referring to AWs are shaded olive, LWSs are shaded yellow; SSSIs are shaded green and the SAC is shaded purple.

Note that although calms and spatially varying deposition cannot be run in conjunction, a correction to account for the effect of calms (based upon the difference between the basic and calms modes in previous modelling studies) has been applied to receptors within approximately 2 km of the piggery.

The predicted changes in maximum annual mean ground level ammonia concentrations and nitrogen deposition rates are shown in Table 6.

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

Table 5a. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – permitted scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	440716	195988	AW	0.030	1.0	10.0	0.605	60.5	4.72	47.2
2	438270	197908	AW	0.030	1.0	10.0	0.168	16.8	1.31	13.1
3	439158	196343	Newhouse Covert LWS	0.030	3.0	10.0	17.223	**574.1**	134.18	**1341.8**
4	439422	196616	Newhouse Covert LWS	0.030	3.0	10.0	71.993	**2399.8**	560.90	**5609.0**
5	439099	196713	Newhouse Covert LWS	0.030	3.0	10.0	2.463	82.1	19.19	**191.9**
6	439375	196895	Newhouse Covert LWS	0.030	3.0	10.0	2.310	77.0	18.00	**180.0**
7	437519	196387	LWS	0.030	1.0	10.0	0.207	20.7	1.61	16.1
8	437511	196114	LWS	0.030	1.0	10.0	0.211	21.1	1.65	16.5
9	437258	196313	LWS	0.030	1.0	10.0	0.147	14.7	1.15	11.5
10	438058	197461	Lamb and Flag Quarry SSSI	0.030	n/a	n/a	0.210	-	1.64	-
11	443498	197816	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.108	**10.8**	0.56	**11.3**
12	444035	197383	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.087	**8.7**	0.45	**9.1**
13	444549	198840	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.064	**6.4**	0.33	**6.7**
14	442514	200104	Appleton Lower Common SSSI	0.030	1.0	15.0	0.055	**5.5**	0.43	**2.8**
15	442696	201036	Appleton Lower Common SSSI	0.030	1.0	15.0	0.041	**4.1**	0.32	**2.1**
16	439085	201272	Langley's Lane Meadow SSSI	0.020	3.0	10.0	0.034	**1.1**	0.18	**1.8**
17	435560	199804	Chimney Meadows SSSI	0.020	3.0	10.0	0.025	0.8	0.13	**1.3**
18	435054	200249	Chimney Meadows SSSI	0.020	3.0	10.0	0.020	0.7	0.10	**1.0**
19	433338	196289	Buckland Warren SSSI	0.200	3.0	10.0	0.019	0.6	1.01	**10.1**
20	432747	194134	Shellingford Crossroads Quarry SSSI	0.030	n/a	n/a	0.019	-	0.15	-
21	429514	194198	Wicklesham and Coxwell Pits SSSI	0.030	n/a	n/a	0.008	-	0.06	-
22	445156	199507	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.047	**4.7**	0.24	**4.9**
23	446635	197544	Barrow Farm Fen SSSI	0.020	1.0	10.0	0.038	**3.8**	0.20	**2.0**
24	446666	199340	Dry Sandford Pit SSSI	0.020	1.0	10.0	0.037	**3.7**	0.19	**1.9**
25	441475	205143	Stanton Harcourt SSSI	0.030	n/a	n/a	0.015	-	0.12	-
26	446056	203252	Cumnor SSSI	0.030	n/a	n/a	0.016	-	0.12	-
27	445652	199389	Cothill Fen SSSI/SAC	0.020	1.0	10.0	0.044	**4.4**	0.23	**2.3**
28	446498	200287	Cothill Fen SSSI/SAC	0.020	1.0	10.0	0.032	**3.2**	0.16	**1.6**
29	446863	201349	Cothill Fen SSSI/SAC	0.020	1.0	10.0	0.024	**2.4**	0.12	**1.2**

Table 5b. Predicted maximum annual mean ammonia concentrations and nitrogen deposition at the discrete receptors – proposed scenario

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	440716	195988	AW	0.030	1.0	10.0	0.308	30.8	2.40	24.0
2	438270	197908	AW	0.030	1.0	10.0	0.091	9.1	0.71	7.1
3	439158	196343	Newhouse Covert LWS	0.030	3.0	10.0	9.130	**304.3**	71.13	**711.3**
4	439422	196616	Newhouse Covert LWS	0.030	3.0	10.0	68.950	**2298.3**	537.19	**5371.9**
5	439099	196713	Newhouse Covert LWS	0.030	3.0	10.0	1.352	45.1	10.53	**105.3**
6	439375	196895	Newhouse Covert LWS	0.030	3.0	10.0	1.373	45.8	10.70	**107.0**
7	437519	196387	LWS	0.030	1.0	10.0	0.112	11.2	0.87	8.7
8	437511	196114	LWS	0.030	1.0	10.0	0.115	11.5	0.90	9.0
9	437258	196313	LWS	0.030	1.0	10.0	0.079	7.9	0.62	6.2
10	438058	197461	Lamb and Flag Quarry SSSI	0.030	n/a	n/a	0.112	-	0.87	-
11	443498	197816	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.056	**5.6**	0.29	**5.8**
12	444035	197383	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.045	**4.5**	0.23	**4.7**
13	444549	198840	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.034	**3.4**	0.17	**3.5**
14	442514	200104	Appleton Lower Common SSSI	0.030	1.0	15.0	0.029	**2.9**	0.22	**1.5**
15	442696	201036	Appleton Lower Common SSSI	0.030	1.0	15.0	0.021	**2.1**	0.17	**1.1**
16	439085	201272	Langley's Lane Meadow SSSI	0.020	3.0	10.0	0.018	0.6	0.09	0.9
17	435560	199804	Chimney Meadows SSSI	0.020	3.0	10.0	0.013	0.4	0.07	0.7
18	435054	200249	Chimney Meadows SSSI	0.020	3.0	10.0	0.010	0.3	0.05	0.5
19	433338	196289	Buckland Warren SSSI	0.200	3.0	10.0	0.010	0.3	0.53	**5.3**
20	432747	194134	Shellingford Crossroads Quarry SSSI	0.030	n/a	n/a	0.010	-	0.08	-
21	429514	194198	Wicklesham and Coxwell Pits SSSI	0.030	n/a	n/a	0.004	-	0.03	-
22	445156	199507	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	0.025	**2.5**	0.13	**2.6**
23	446635	197544	Barrow Farm Fen SSSI	0.020	1.0	10.0	0.020	**2.0**	0.10	**1.0**
24	446666	199340	Dry Sandford Pit SSSI	0.020	1.0	10.0	0.019	**1.9**	0.10	1.0
25	441475	205143	Stanton Harcourt SSSI	0.030	n/a	n/a	0.008	-	0.06	-
26	446056	203252	Cumnor SSSI	0.030	n/a	n/a	0.008	-	0.07	-
27	445652	199389	Cothill Fen SSSI/SAC	0.020	1.0	10.0	0.023	**2.3**	0.12	**1.2**
28	446498	200287	Cothill Fen SSSI/SAC	0.020	1.0	10.0	0.017	**1.7**	0.09	0.9
29	446863	201349	Cothill Fen SSSI/SAC	0.020	1.0	10.0	0.012	**1.2**	0.06	0.6

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

Receptor number	X(m)	Y(m)	Designation	Site Parameters			Maximum annual ammonia concentration		Maximum annual nitrogen deposition rate	
				Deposition Velocity	Critical Level (µg/m^3)	Critical Load (kg/ha)	Process Contribution (µg/m^3)	%age of Critical Level	Process Contribution (kg/ha)	%age of Critical Load
1	440716	195988	AW	0.030	1.0	10.0	-0.298	-29.8	-2.32	-23.2
2	438270	197908	AW	0.030	1.0	10.0	-0.077	-7.7	-0.60	-6.0
3	439158	196343	Newhouse Covert LWS	0.030	3.0	10.0	-8.093	-269.8	-63.05	-630.5
4	439422	196616	Newhouse Covert LWS	0.030	3.0	10.0	-3.043	-101.4	-23.71	-237.1
5	439099	196713	Newhouse Covert LWS	0.030	3.0	10.0	-1.111	-37.0	-8.66	-86.6
6	439375	196895	Newhouse Covert LWS	0.030	3.0	10.0	-0.937	-31.2	-7.30	-73.0
7	437519	196387	LWS	0.030	1.0	10.0	-0.095	-9.5	-0.74	-7.4
8	437511	196114	LWS	0.030	1.0	10.0	-0.096	-9.6	-0.75	-7.5
9	437258	196313	LWS	0.030	1.0	10.0	-0.068	-6.8	-0.53	-5.3
10	438058	197461	Lamb and Flag Quarry SSSI	0.030	n/a	n/a	-0.098	-	-0.77	-
11	443498	197816	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	-0.052	-5.2	-0.27	-5.4
12	444035	197383	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	-0.042	-4.2	-0.22	-4.4
13	444549	198840	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	-0.031	-3.1	-0.16	-3.2
14	442514	200104	Appleton Lower Common SSSI	0.030	1.0	15.0	-0.026	-2.6	-0.20	-1.4
15	442696	201036	Appleton Lower Common SSSI	0.030	1.0	15.0	-0.019	-1.9	-0.15	-1.0
16	439085	201272	Langley's Lane Meadow SSSI	0.020	3.0	10.0	-0.016	-0.5	-0.08	-0.8
17	435560	199804	Chimney Meadows SSSI	0.020	3.0	10.0	-0.012	-0.4	-0.06	-0.6
18	435054	200249	Chimney Meadows SSSI	0.020	3.0	10.0	-0.009	-0.3	-0.05	-0.5
19	433338	196289	Buckland Warren SSSI	0.200	3.0	10.0	-0.009	-0.3	-0.47	-4.7
20	432747	194134	Shellingford Crossroads Quarry SSSI	0.030	n/a	n/a	-0.009	-	-0.07	-
21	429514	194198	Wicklesham and Coxwell Pits SSSI	0.030	n/a	n/a	-0.004	-	-0.03	-
22	445156	199507	Frilford Heath, Ponds and Fens SSSI	0.020	1.0	5.0	-0.022	-2.2	-0.12	-2.3
23	446635	197544	Barrow Farm Fen SSSI	0.020	1.0	10.0	-0.018	-1.8	-0.09	-0.9
24	446666	199340	Dry Sandford Pit SSSI	0.020	1.0	10.0	-0.018	-1.8	-0.09	-0.9
25	441475	205143	Stanton Harcourt SSSI	0.030	n/a	n/a	-0.007	-	-0.06	-
26	446056	203252	Cumnor SSSI	0.030	n/a	n/a	-0.008	-	-0.06	-
27	445652	199389	Cothill Fen SSSI/SAC	0.020	1.0	10.0	-0.021	-2.1	-0.11	-1.1
28	446498	200287	Cothill Fen SSSI/SAC	0.020	1.0	10.0	-0.015	-1.5	-0.08	-0.8
29	446863	201349	Cothill Fen SSSI/SAC	0.020	1.0	10.0	-0.011	-1.1	-0.06	-0.6

Figure 7a. Maximum annual mean ammonia concentration - proposed scenario

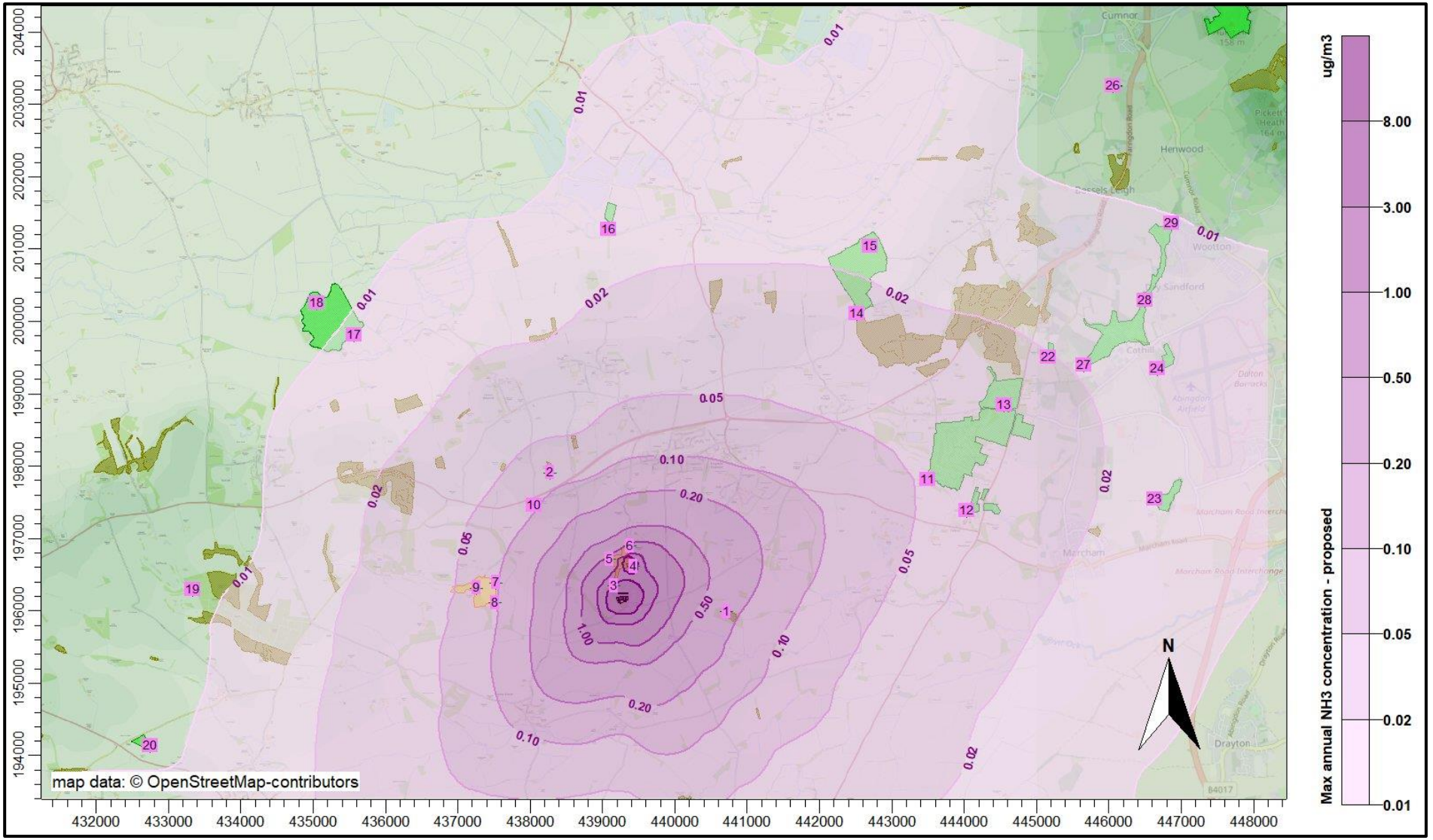
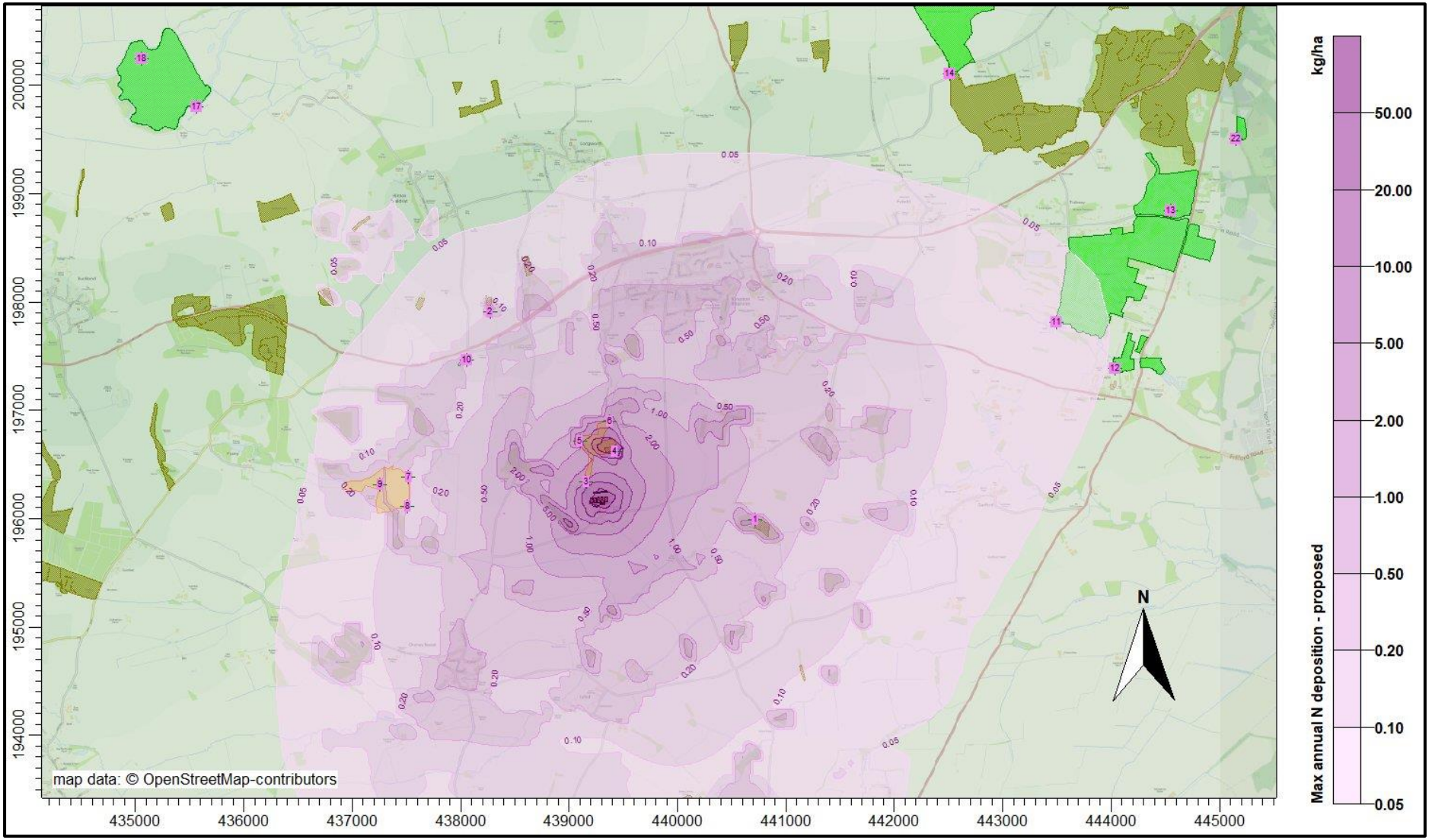


Figure 7b. Maximum annual nitrogen deposition rate - proposed scenario



6. Summary and Conclusions

AS Modelling & Data Ltd. has been instructed by Mr. Harry Edwards of The Farm Consultancy Group, on behalf of Blanchard Enterprises, to use computer modelling to assess the impact of ammonia emissions from the permitted and proposed piggeries at Sheephouse Farm, Southmoor, Abingdon, Oxfordshire. OX13 5HP.

Ammonia emission rates from the piggeries are based on ammonia emission factors provided by The Farm Consultancy Group, which it is understood are agreed with the Environment Agency. 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 closer parts of Newhouse Covert LWS would exceed the Environment Agency's lower threshold percentage (100% for a non-statutory site) of the Critical Level of 3.0 µg-NH_3/m^3 and Critical Load of 10.0 kg-N/ha/y. Predicted exposures are slightly lower under the proposed scenario.

- At all other non-statutory wildlife sites, the process contribution to maximum annual ammonia concentration and the nitrogen deposition rates would be below the Environment Agency's lower threshold percentage of 100% of the precautionary Critical Level of 1.0 µg-NH_3/m^3 in both the permitted baseline and proposed scenarios.

- At all statutory wildlife sites considered, the process contribution to maximum annual ammonia concentrations and the nitrogen deposition would be below the Environment Agency's upper threshold percentage (50% for a SSSI and 20% for an internationally designated site) of the relevant Critical Level/Load for the site in both the existing baseline and proposed scenarios.

- The process contributions to annual ammonia concentrations and/or nitrogen deposition rates in the proposed scenario would exceed 1% of the relevant Critical Level and Critical Load at: Frilford Heath, Ponds and Fens SSSI; Appleton Lower Common SSSI; Farm Fen SSSI Dry Sandford Pit SSSI; Barrow Farm Fen SSSI and Cothill Fen SSSI/SAC.

7. References

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Environment Agency H1 Risk Assessment (website).

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

UK Air Pollution Information System (APIS) (website).