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Decision-making Thresholds for Air Pollution

Air Quality Consultants Ltd

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Summary

This report describes the setting of decision-making criteria for air quality impacts to designated nature conservation sites. The criteria are intended to be applied to changes caused by individual plans and projects, thus removing the need to consider air quality effects further, including in combination with other plans and projects.

Court judgements have been interpreted to mean that plans and projects may only be exempted from individual assessment if a suitable ‘assessment in advance’ has already been carried out. This report provides a robust evidence base upon which decisions may be made in relation to individual projects and plans by bringing together a large amount of information from pre-existing national-level modelling, local-scale dispersion modelling, and relationships based on first principles.

The basis upon which most of the criteria have been set is that concentrations and deposition fluxes are predicted to fall widely across the UK even when including the development of expected plans and projects. This information has informed detailed discussions with a range of ecology experts. The outcomes of these discussions were used to define the total magnitude of change which will not undermine the achievement of conservation objectives or site condition. Dispersion modelling has then been used to test large numbers of alternative spatial configurations of new projects and plans to identify the increment of this total allowable change which may be allocated to each individual project as part of the ‘assessment in advance’.

An alternative approach is necessary for road traffic. The focus for road traffic has been to identify those plans and projects which might make a meaningful contribution to the overall forecast changes.

The thresholds which are recommended for practitioner use are set out in Table 1. They are separated into projects with on-site emissions, e.g. poultry farms, industrial sources etc. and projects giving rise to road traffic emissions, e.g. residential developments, schools, etc.

It is expected that a bespoke in-combination assessment will be required wherever a project exceeds a Site-Relevant Threshold. Where the Decision-Making Threshold for road traffic is exceeded then it may be appropriate to consider the requirement for further assessment on a case-by-case basis.

In applying these criteria, it should be noted that:

- the Site-Relevant Thresholds should be applied to the maximum predicted impact anywhere within the designated nature conservation site or area of habitat being assessed;
- a list of important exclusions, for cases where Site-Relevant Thresholds are considered to provide insufficient protection, has been provided by Chapman and Kite (2021); and
- the Decision-Making Threshold for road traffic is not intended for use in the context of strategic development plans (where a bespoke in-combination assessment is always expected to be required).

The Guidance on Decision-making Thresholds document (Chapman & Kite 2021) further advises that increases of traffic flows on roads which form part of the strategic network also need to be dealt with at a strategic level. Full details of how the criteria defined in this report should be applied is provided in guidance by Chapman and Kite (2021).

Table 1: Site-Relevant and Decision-Making Thresholds for Application to Individual Plans and Projects.

Development Density	Very Low	Low	Medium	High
Description	Remote area which sees very little development	Area which sees small amounts of development	Typical agriculture / industrial area	Area experiencing intensive growth (e.g. Powys or Immingham docks)
Example Number of additional new projects below the DMT within 5 km of proposed development over 13 yrs [a]	1	5	10	30
Site-Relevant Thresholds for On-site Emissions				
Annual Mean NH_3 (lichens/bryophytes) ($\mu g/m^3$)	0.0075	0.0034	0.0020	0.00079
Annual Mean NH_3 (higher plants) ($\mu g/m^3$)	0.022	0.010	0.0060	0.0024
Annual Mean NOx ($\mu g/m^3$)	0.087	0.046	0.030	0.014
Annual Mean N dep (woodland (kg-N/ha/yr)	0.13	0.057	0.034	0.013
Annual Mean N dep (grassland) (kg-N/ha/yr)	0.088	0.040	0.024	0.0093
Decision-Making Threshold for Road Traffic				
Increase in Traffic Flow	0.15% of AADT in the year that the assessment is carried out			

[a] These might be either industrial or agricultural projects, or both.

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1 Introduction

This report describes the setting of decision-making criteria for air quality impacts to designated nature conservation sites (or area of habitat being assessed) that can be applied to changes in concentrations and deposition fluxes caused by individual plans and projects. It has been prepared by Air Quality Consultants Ltd. (AQC) and describes work funded by the Joint Nature Conservation Committee (JNCC) which was carried out in association with DTA Ecology, Ecological Planning and Research (EPR), and the UK Centre for Ecology and Hydrology.

Assessments carried out under the Habitats Regulations must take account of potential effects caused either alone or in combination with other plans and projects. Assessments of nationally- and locally designated nature conservation sites can also require some consideration of cumulative effects. This report defines criteria for changes to concentrations and fluxes caused by each plan and project in isolation. These criteria may be used to exempt individual plans and projects from needing to consider their air quality effects in combination with those from other plans and projects.

The Guidance on Decision-making Thresholds document (Chapman & Kite 2021) (Section 2.3 and Appendix 3) summarises recent case law. It explains how the courts have signposted an approach which allows those changes which are very small to be ignored so long as an assessment has already been carried out which demonstrates that the plans and projects which might be exempted from further assessment will have no adverse effects on the integrity of the nature conservation site. The current report sets out the basis on which thresholds have been set.

1.1 Conceptual Overview and Definitions

The term De minimis is taken from a longer Latin phrase which translates into "*the law does not concern itself with trifles*". In this report, De minimis is a concept which refers to an overall magnitude of change which can properly be ignored, irrespective of other considerations. De minimis thus defines the concept under which the work presented in this report sits. This report does not, however, seek to assign a precise value to De minimis; which most helpfully remains a concept rather than a numerical value.

The approach that has been taken is to first define a magnitude of change to concentrations and deposition fluxes, across a defined period of time, which will not undermine the achievement of the conservation objectives. This has been termed the ‘Objective Compliant Change’ (‘OCC’), in which ‘Objective’ refers to the site-specific conservation objectives.

The rationale is then that individual plans and projects may be exempted from individual in-combination assessments if the changes to concentrations and fluxes from those plans and projects **when added together** are less than the OCC.

There is an important distinction between those plans and projects which will be exempted from requiring a bespoke in-combination assessment by application of the criteria defined in this report, and those that will not. Air quality modelers aim to ensure all sources are included in all assessments and it thus seems most logical that all future plans and projects should be considered in-combination with one another; since they will all contribute to the OCC. DTA ecology has advised that the requirement for proportionality in Habitats Regulations Assessments makes it necessary for those assessments to focus only on some plans and projects at any one time, and that the correct approach here is to define the in-combination impacts only of those plans and projects which will be exempted within this report. This is on the basis that those projects which will not be exempted will receive detailed individual consideration before they are permitted.

In this instance, the OCC has thus been used as the basis for defining ‘Decision-Making Thresholds’ (‘DMTs’). These relate to the impacts[1] of individual plans and projects. They take account of the potential for impacts from multiple projects to combine and thus exceed the OCC. The DMTs are thus always smaller than the OCCs.

The DMTs have been defined for areas with the highest numbers of new projects, i.e. those areas where in-combination impacts will be greatest. However, most parts of the UK can reasonably expect smaller numbers of new developments. A further set of criteria has thus been defined which can be applied to individual projects in areas where development pressure is lower. These are termed ‘Site-Relevant Thresholds’ (‘SRTs’). In areas of high development pressure, the SRTs are the same as the DMTs, but in all other areas the SRTs are less stringent than the DMTs. The SRTs are always more stringent than the OCCs.

It should be noted that a series of exclusions has also been defined, which describe situations where the DMTs and SRTs will not necessarily provide adequate protection and should not, therefore, be used. Further details are provided in Section 3.2 and Appendix 4 of the Guidance on Decision-making Thresholds document (Chapman & Kite 2021).

OCCs, DMTs, and SRTs have all been defined on the basis that large numbers of new projects will not all occupy exactly the same space. This, in turn, means that the maximum impacts[2] caused by emissions released within the boundaries of the development sites (termed ‘on-site emissions’) of multiple projects will very rarely coincide. The same cannot be said for impacts caused by emissions from road traffic, as multiple projects all have the potential to generate traffic on the same roads, which will cause the maximum impacts[2] from multiple projects to coincide precisely. For this, and other reasons explained in Section 7, an alternative approach has been taken to defining DMTs for road traffic, which are not based on the OCCs.

A final helpful definition relates to different types of plans or projects. For the purpose of this report, the ‘target project’ is the project or plan which decision makers would be considering with respect to individual planning or environmental permit applications. The ‘in-combination projects’ are other projects or plans which are also expected to go ahead, such that the total project-related change is that caused by the target project added to that caused by all in-combination projects.

Table 2 summarises these definitions. It is adapted from Section 1.5 of the Guidance on Decision-making Thresholds document (Chapman & Kite 2021) which provides further explanation of the terms and their rationale. To ensure consistency with Guidance document (Chapman & Kite 2021), the term ‘assessment of cumulative effects’ has been used in this report in accordance with the definition set out in Table 2. This definition has been provided in the context of an ‘assessment in advance’ (see Table 2). It should be noted that the term ‘assessment of cumulative effects’ is used differently in other contexts where air quality assessment is required.

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[1] The terms ‘impact’ and ‘effect’ are often used with subtly different meanings by ecologists and air quality professionals. In this report, the term ‘impact’ is used to refer to a change in concentrations or fluxes irrespective of any consequent effects that this may have on biodiversity. The terms effect is used to describe any consequential response.

[2] i.e. the maximum change to annual mean concentrations or fluxes anywhere within a designated site.

Table 2: Definitions of Key Terms used in this Report.

Term	Definition
De minimis	A concept which refers to an overall quantum of change (however it arises) that is of no consequence, irrespective of other considerations.
Objective Compliant Change (OCC)	A quantified magnitude of change, across a defined period of time, which will not undermine the achievement of the conservation objectives.
Decision-Making Threshold (DMT)	A quantifiable contribution from an *individual source* which can properly be ignored for the purpose of decision-making as the combined effects of proposals excluded by it will not undermine the achievement of the conservation objectives Further assessment would not change the outcome of the decision to be taken.
Site-Relevant Threshold (SRT)	Taking account of *site-specific considerations*, a quantifiable contribution from an individual source which can properly be ignored for the purpose of decision-making. The cumulative effects of proposals excluded by it will not undermine the achievement of the conservation objectives for the site concerned.
On-site Emissions	Emissions released within the boundary of a development site (as distinct from emissions from road traffic generated by a project).
Assessment in advance	An assessment carried out in advance for the purpose of: i) examining the cumulative effects of nitrogen deposition on designated sites, and ii) determining decision making thresholds.
Assessment of cumulative effects	An assessment of the cumulative effects of nitrogen emissions resulting from anticipated future plans and projects over a defined time period for the purpose of carrying out an Assessment in Advance.
In-Combination Assessment	A formal assessment of the effects of ‘other plans and projects’ which are relevant at the point at which a specific plan or project is subject to assessment.
Target Project	The project or plan which decision-makers would be considering with respect to individual planning or environmental permit applications.
In-combination Projects	Other projects or plans which are also expected to go ahead that may generate impacts that combine with those of the target project.

1.2 Pollutants Considered

OCCs, DMTs, and SRTs have been set for annual mean concentrations of nitrogen oxides (NOx) and ammonia (NH_3), as well as for nitrogen deposition fluxes.

1.3 Pollutants Excluded

Values have not been set for 24-hour mean NOx concentrations because of the procedural complexity combined with the relative infrequency with which impacts on 24-hour NOx concentrations provide the principal air quality constraint to development. Impacts from multiple projects are much more likely to combine with respect to annual mean concentrations than to 24-hour mean concentrations.

Values have also not been set for acid deposition, sulphur dioxide concentrations, or other acidic gases. Most air local-scale quality assessments of acid deposition focus on nitrogen-driven acidity. Assessments are then made using the Critical Load Functions on the Air

Pollution Information System (APIS) website[3], which take account of factors including background conditions for both nitrogen and sulphur deposition. The relationship between nitrogen deposition and its acidifying potential is linear, so 1 kg-N/ha/yr reduction will always deliver a 0.07 keq/ha/yr reduction in acidity. This means that increases and reductions in nitrogen-driven acidity are directly proportional to reductions and increases in nitrogen deposition.

As explained in Section 2, the OCC for nitrogen deposition and NOx concentrations relies on national-level modelling of the rate of change in these pollutants. Equivalent modelling is not available for sulphur dioxide concentrations and sulphur deposition. However, the UK Government's March 2020 submission under the National Emissions Ceiling Directive predicts that UK total SO_2 emissions will fall by 42% between 2018 and 2030, with much of this driven by sectors which have previously been targeted effectively (e.g. emissions from large power stations). There is thus some confidence that these concentrations and fluxes will fall across most parts of the UK to 2030. This means that the changes to nitrogen deposition predicted in Section 2 can reasonably be expected to be more than matched by concurrent changes to acid deposition, and that focusing on DMTs and SRTs for nitrogen deposition will, for most projects, provide the most precautionary assessment.

Most new processes which emit significant amounts of sulphur oxides or other acidic gases also emit nitrogenous species. While there are exceptions to this, they are relatively uncommon. If a new development is removed from requiring further assessment because it falls below the DMT or SRT for nitrogen deposition, NOx concentrations, and ammonia concentrations, then no further assessment will be required for that project. This does not preclude consideration of these pollutants in detail should a full in combination assessment be required.

1.4 Report Structure

Section 2 of this report describes the approach which has been used to quantify the Objective Compliant Change. Section 3 explains the additional modelling that is then required and defines the spatial boundaries of that modelling. It also explains further why different approaches have been adopted for different emissions sources. Section 4 uses historic planning records to define the expected density of future development. Section 5 then describes the local-scale dispersion modelling which has been carried out and explains how this has been used to define values of DMT and SRT for on-site emissions. Section 6 explains how these DMT and SRT values might later be adjusted to take account of better information. Section 7 describes the modelling that has been carried out for road traffic and presents DMT values for road vehicles. Section 8 comments on the uncertainty and limitations to this work, and Section 9 summarises the overall conclusions.

3 http://www.apis.ac.uk/

2 Objective Compliant Change

As noted in the third paragraph in Section 1, changes caused by individual plans and projects may only be properly ignored if an assessment has already been carried out to demonstrate that those plans and projects will have no adverse effects on the integrity of a designated nature conservation site. This presents a particular problem for air quality impacts because air blows around. This means, for example, that a small poultry farm in Cornwall may be shown, through modelling, to have a non-zero effect on concentrations and deposition in Aberdeen[4]. As such, for any individual scheme, a complete and comprehensive assessment of impacts in combination with other UK plans and projects is only possible using a national-level model which includes all UK plans and projects. While it would clearly represent "*legislative overkill*"[5] to require such an assessment for each individual project, it is also clear that all assessments which do not have a national (or international) scale study area will miss some of the incremental increases from other live plans and projects[6].

2.1 National-level Modelling

JNCC has recently commissioned a national-level modelling study dubbed 'Nitrogen Futures', which includes an allowance for all forecast growth and activity changes across the UK, as well as an allowance for forecast changes to emissions outside of the UK (Dragosits *et al.* 2020). The modelling, which was carried out by a team of experts from the UK Centre for Ecology and Hydrology, AQC, Aether, Rothamsted Research, and Manchester Metropolitan University, was principally focused on determining the likely effects of spatially targeted mitigation measures, but also included detailed forecasts against which these mitigation scenarios were tested. Predictions were thus made for a 2017 base year and for 2030 assuming development and activity growth in line with national-level predictions.

The Nitrogen Futures modelling is necessarily high-level, in that the precise locations of all new plans and projects cannot be predicted. The approach was to scale emissions from existing sources based on forecast activity changes. The effect is that the anticipated effect of all plans and projects is included, but the spatial distribution of this growth is approximate. This modelling nevertheless provides the best available assessment of the predicted in-combination effects of all expected UK plans and projects over the period 2017 to 2030.

2.2 Autonomous Measures

The term 'Autonomous Measures' has seen widespread use in the context of air quality effects on biodiversity since the Opinion and Judgement on the Dutch Nitrogen Cases[7]. It refers to measures which are unrelated (and thus autonomous) to the plan or project being consented and is usually used in the context of relying on forecast improvements to create 'headroom' for new plans or projects.

Many commentators have interpreted the Opinion and Judgement on the Dutch Nitrogen Cases to mean that future emissions reductions may not be taken into account when granting new permissions unless the measures which will deliver those reductions are already in place and have a very high degree of certainty of delivering the forecast benefits.

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4 This does not mean that it is possible to accurately quantify this effect, but the spatial limit on reliable predictions (for any given model) is not the same as the distance at which the effect reaches zero.

5 Sweetman (AG Opinion) Case C-258/11 (2012).

6 Most assessments will include existing plans and projects within the baseline but not expected future plans and projects which fall outside of a predefined study area.

7 Joined Cases C-293/17 and C-294/17.

This has been particularly problematic with respect to air quality modelling, owing to a protracted recent history over which models predicted that NOx concentrations and consequent nitrogen fluxes would reduce quite rapidly but ambient measurements showed no reductions. It is also complicated by the fact that different models, and different aspects of the same model, will have very different levels of uncertainty but that this uncertainty is seldom quantified. For example, a model which predicts the impact of a new project in the future may combine the impact footprint of that project with a projection of reductions in the baseline over time. There can be absolute certainty that the new project will increase concentrations[8], and the only uncertainty relates to the scale of that increase. On the other hand, there can never be absolute certainty that baseline concentrations will reduce over time, and the myriad of factors upon which such projects are based necessarily increases the uncertainty of those projections.

Within the UK, these issues received in-depth and high-profile discussion during the 2019 Examination in Public of the Wealden Local Plan[9]. The clear direction provided by the Planning Inspectorate, having regard to advice from Natural England and the Dutch Nitrogen Ruling, is that forecast pollutant trends which rely on autonomous measures should be taken into account when assessing the predicted effects of future growth.

The result of this Examination made it clear that there needs to be reasonable certainty that the measures will be in place if they are relied on to drive emissions reductions, but that uncertainty in the efficacy of those measures need not preclude reliance on them, so long as the modelling uses best-practice approaches. Further discussion of model uncertainty in the context of the current project is provided in Section 8, and further interpretation of the certainty requirements of the Habitats Regulations is provided in Section 2 of the Guidance on Decision-making Thresholds document (Chapman and Kite, 2021).

2.3 Forecast Scenarios

As explained in Section 2.1, the air quality modelling for Nitrogen Futures project (Dragosits *et al.* 2020) allowed for all anticipated growth and activity changes across the UK between 2017 and 2030. This included all growth that will be delivered through new plans and projects. The modelling also included the predicted effects of autonomous measures. Because of uncertainty regarding the delivery of some of these measures, two future 2030 baseline scenarios were considered:

- **2030 Business as Usual (BAU) With Measures (WM)** – This included only those policies that had already been adopted or implemented at the time of the projection compilation. It did not include additional measures set out in the National Air Pollution Control Programme (NAPCP) which are designed to meet National Emissions Ceiling Directive/Regulations (NECD/NECR) targets. This baseline therefore represents an incomplete set of measures to meet the 2030 NECR targets.

- **2030 NAPCP + Devolved Administration (DA) (NECR NOx)** - This was considered the most likely scenario for achieving NECR targets. It included additional measures to meet those targets which are currently in development, but not yet adopted or implemented. These additional measures are represented by NAPCP, with some country-specific modifications from consultations with the Devolved Administrations of Scotland, Wales and Northern Ireland.

8 Since if it is occupied it will have to emit something.

9 This is different from High Court Case CO/3943/20169, which is often referred to as “the Wealden Decision” which has informed some approaches to addressing in combination effects.

In the current report, these scenarios are referred to as ‘BAU’ and ‘NAPCP’.

Predictions were made for annual mean nitrogen deposition fluxes, as well as NO_2 and NH_3 concentrations for all parts of the UK on a 1 km x 1 km grid. The changes between 2017 and 2030 are summarised in Figure 1 and Figure 2. It should be noted that Figure 1 is based on the assumption that all UK land cover is first low-growing vegetation and then woodland (i.e. the actual UK land cover does not form part of these outputs).

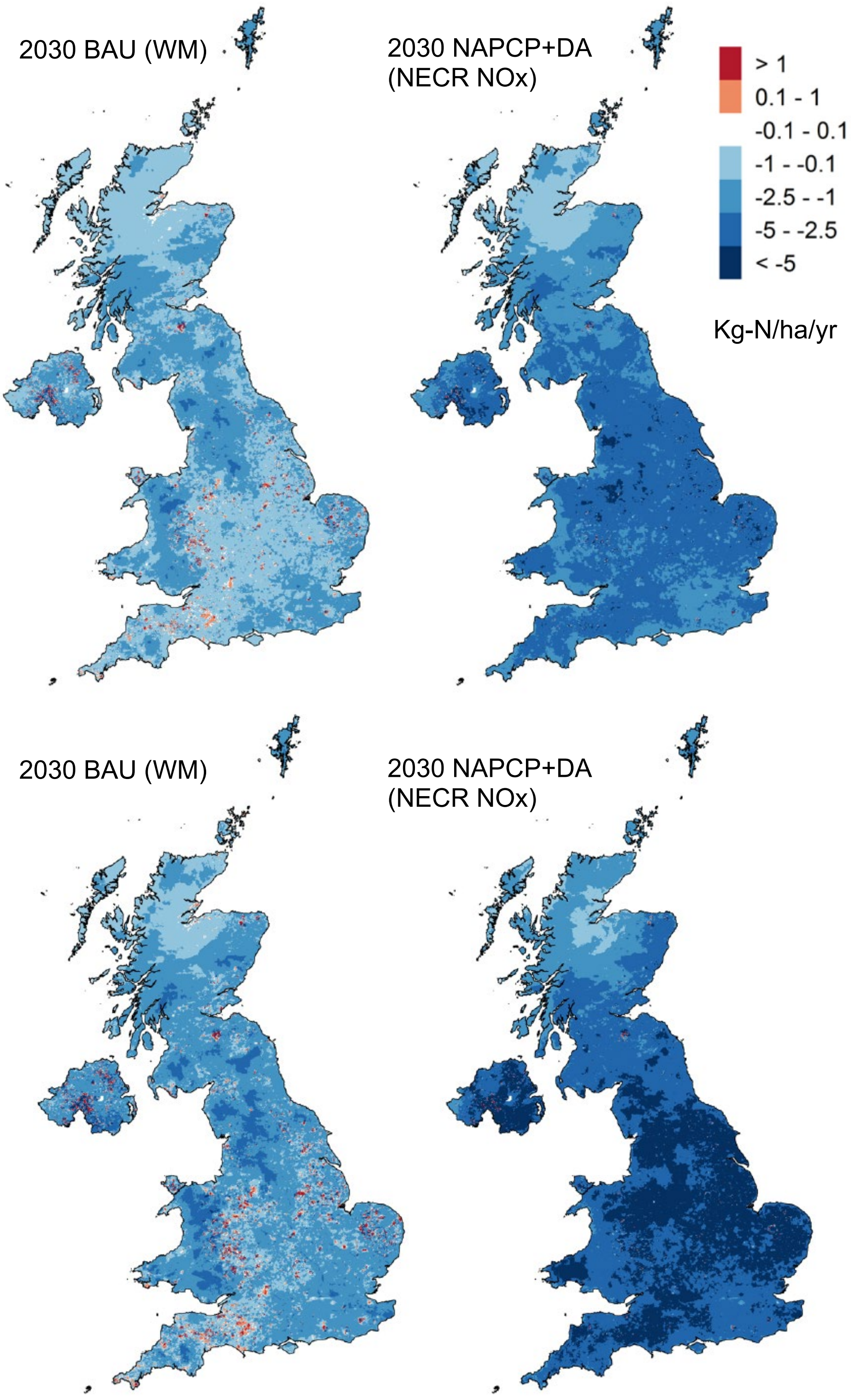

Figure 1: Changes to 1 km^2 Average Nitrogen Deposition Across the UK, Comparing Two 2030 Baseline Scenarios with 2017 – top, to Low-growing Semi-natural Vegetation; and bottom, to woodland (Dragosits *et al.* 2020).

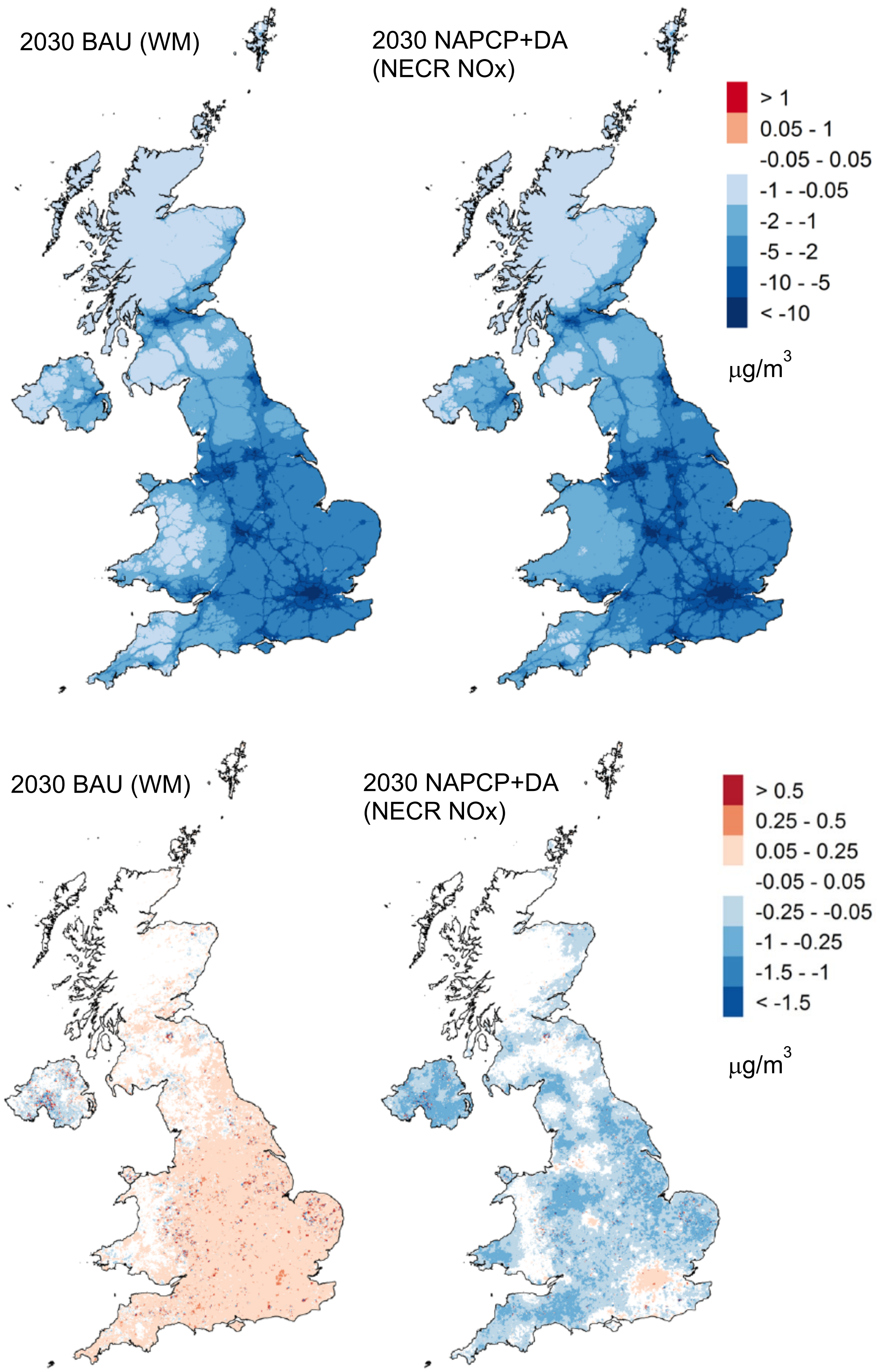

Figure 2: Changes to 1 km^2 Average Annual Mean NO_2 (top) and NH_3 (bottom) Concentrations Predicted Across the UK, Comparing Two 2030 Baseline Scenarios with 2017 (Dragosits *et al.* 2020).

2.4 Forecast Changes to Nitrogen Deposition: 2017 to 2030

Figure 1 shows that, across most of the UK, nitrogen deposition fluxes are predicted to reduce appreciably between 2017 and 2030. The reductions are greatest in the NAPCP scenario but, in most areas, reductions are predicted for both future scenarios. These changes are principally driven by forecast reductions in NOx emissions but predicted changes to ammonia emissions are also important.

Figure 3 presents the same data as Figure 1, but in an alternative way. It shows the % of the UK predicted to experience reductions in 1 km^2 average nitrogen deposition, from a 2017 base year, of at least the increments on the vertical axis. The results are the change that will be achieved by the calendar year at end of the forecast period. The BAU and NAPCP scenarios are shown by the solid blue and red lines. The rows of dots in between the two solid lines then show the effect of interpolating between the two future baseline models on a grid cell by grid cell basis. Thus, the row of blue circles shows the effect that achieving 25% of the additional (NAPCP) reductions would have, while the row of brown crosses shows the effect of achieving 50% of NAPCP reductions, etc. The row of orange dots at the far righthand side of the plots shows the maximum effect that any of the additional targeted measures considered within the Nitrogen Futures study would have, including projections to 2040.

The vertical line highlights the value at which a reduction is predicted across at least 90% of the UK. Thus, for deposition to short vegetation and assuming 25% efficacy of the NAPCP, an improvement of at least 0.59 kg-N/ha/yr is predicted over 90% of the UK. The equivalent figure for deposition to woodland is 0.84 kg-N/ha/yr. Improvements smaller than this are predicted over 10% of the UK. The point at which each curved line reaches the top of the graph show the total area over which deposition fluxes are predicted to increase over this period. As explained in Section 2.1, these predictions include all expected growth, which implicitly allows for all new plans and projects, between 2017 and 2030.

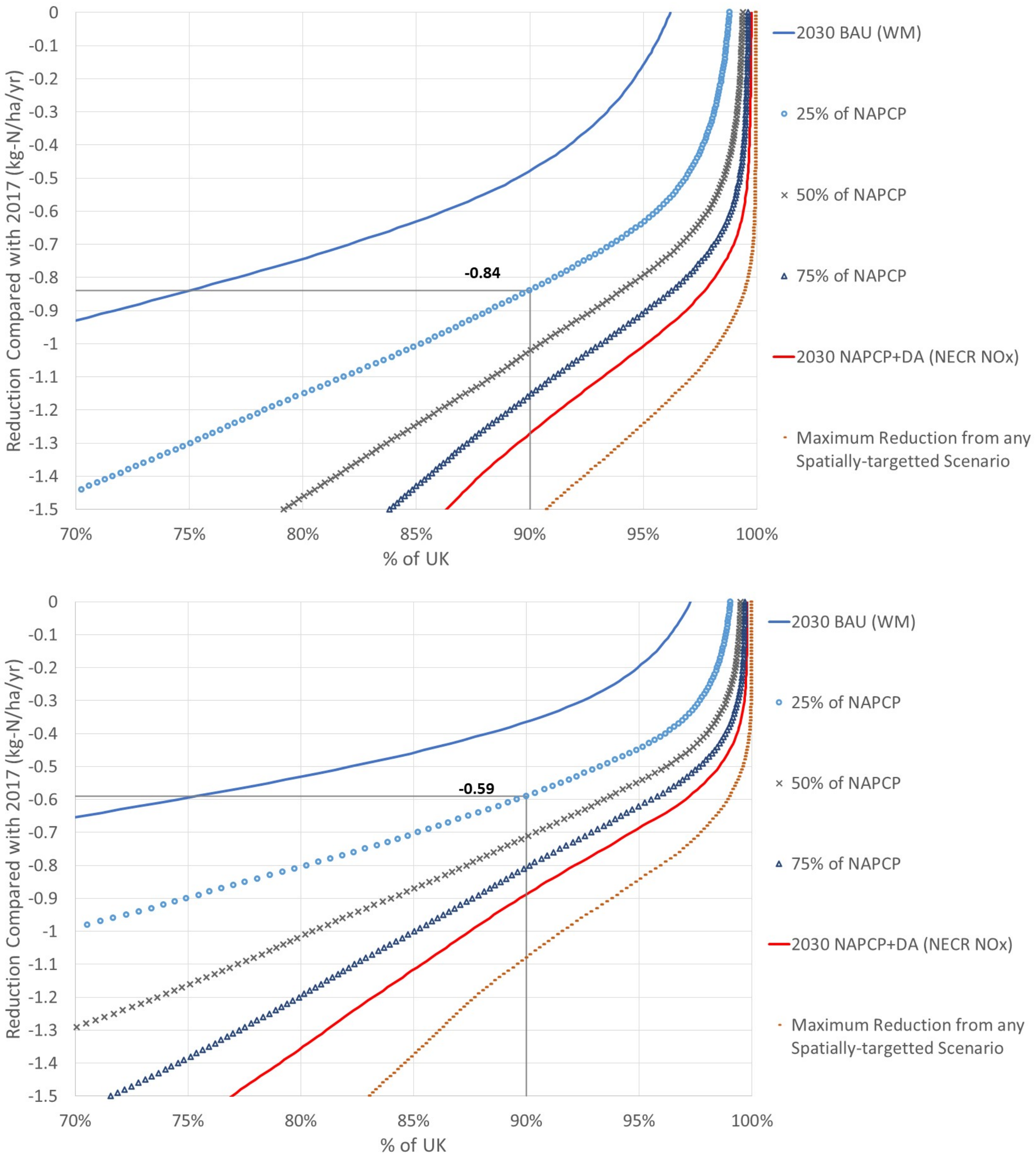

Figure 3: Percentage of UK Predicted to Experience Different Reductions in 1 km^2 Average Nitrogen Deposition in Different Future Forecasts – Top Moorland; Bottom Forest. Showing the 2030 BAU and 2030 NAPCP scenarios. Also showing the effect of interpolating between these two scenarios on an individual grid cell basis (labelled as x% of the additional NAPCP reductions). Finally, showing the maximum effect that any of the additional targeted measures considered within the Nitrogen Futures study would have.

2.5 Forecast Changes to Annual Mean NOx: 2017 to 2030

Modelling carried out for the Nitrogen Futures project predicted concentrations of NO_2 but not of NOx. However, 1 km^2-average NO_2 concentrations are dominated by conditions well away from NOx emissions sources and, at these distances, the relationship between annual mean NO_2 and annual mean NOx is well understood. The approach which has been taken is to use Defra's Pollution Climate Mapping (PCM) 1 km x 1 km background model results which are made available for Local Air Quality Management[10]. The Nitrogen Futures model results and Defra PCM model results have been matched on a 1 km^2 basis. For each individual 1km^2 grid square of the UK, Defra's PCM model results were used to derive the NO_2:NOx quotient in 2017 and in 2030. These were then applied to the 2017 and 2030 Nitrogen Futures NO_2 predictions to derive concurrent NOx[11].

Figure 4 summarises the predictions for NOx using the same approach as described in the second paragraph of Section 2.4 for nitrogen deposition. Unlike for nitrogen deposition, 1km^2-average annual mean NOx concentrations are predicted to fall everywhere between 2017 and 2030 even in the BAU scenario; with 100% of the UK predicted to experience a reduction of at least 0.29 $\mu g/m^3$. Assuming 25% efficacy of the NAPCP, an improvement of at least 0.63 $\mu g/m^3$ in 1km^2-average concentrations is predicted over 90% of the UK.

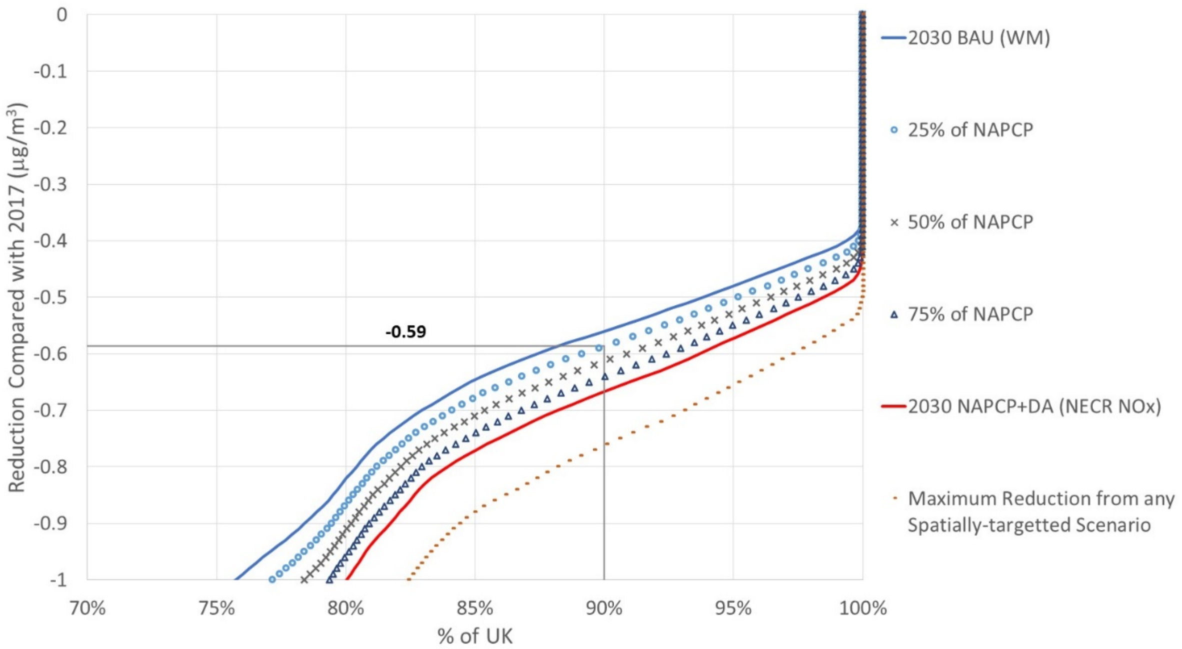

Figure 4: Percentage of UK Predicted to Experience Different Reductions in 1 km^2 Average NOx Concentrations in Different Future Forecasts. Showing the 2030 BAU and 2030 NAPCP scenarios. Also showing the effect of interpolating between these two scenarios on an individual grid cell basis (labelled as x% of the additional NAPCP reductions). Finally, showing the maximum effect that any of the additional targeted measures considered within the Nitrogen Futures study would have.

[10] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html. The 2017-based maps were used so as to match the period of the Nitrogen Futures modelling.

[11] This means that the same NO_2:NOx quotients were applied in both the BAU and NACP scenario which, while not supported mechanistically, provides the best available approach.

2.6 Forecast Changes to Annual Mean NH_3: 2017 to 2030

Figure 5 summarises the BAU and NAPCP predictions for annual NH_3 concentrations from the Nitrogen Futures project. Unlike the equivalent plots for nitrogen deposition and NOx concentrations, the vertical scale extends to show increases as well as reductions, and the horizontal scale has been expanded to show all of the UK. The plot also focuses only on the BAU and NAPCP scenarios. In the BAU scenario, NH_3 concentrations are predicted to increase across 88% of the UK, and under the NAPCP scenario concentrations are predicted to continue to increase over 20% of the UK. Thus, the worst-case change predicted over 90% of the UK is a deterioration rather than an increase, even assuming 100% efficacy of the NAPCP.

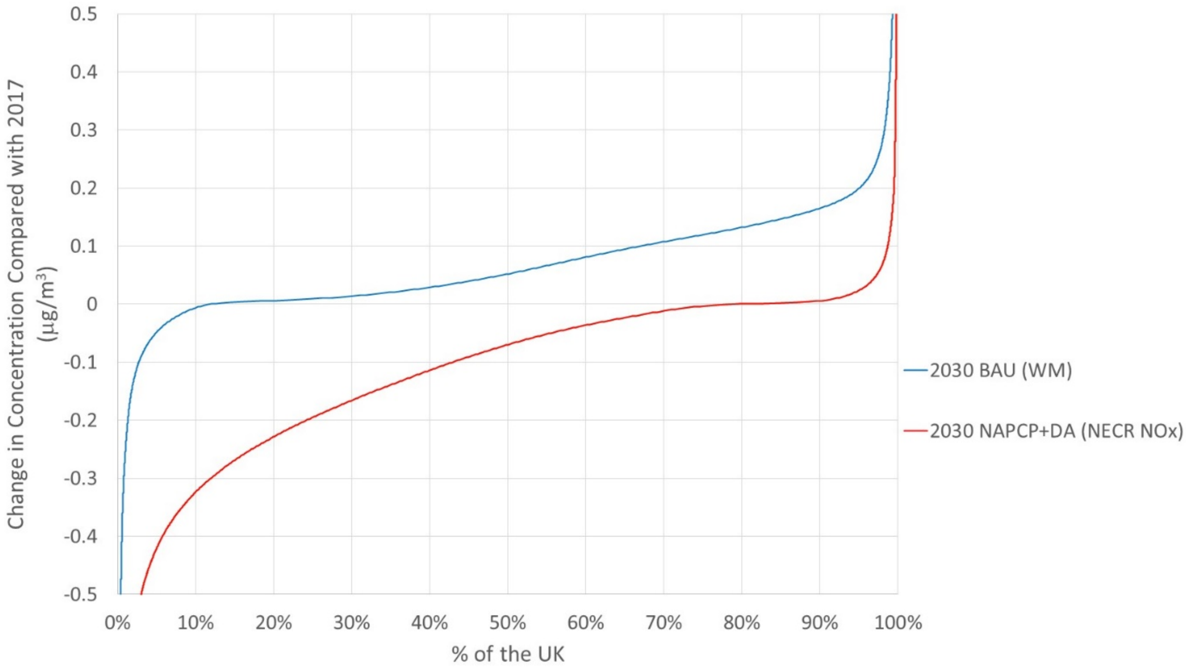

Figure 5: Percentage of UK Predicted to Experience Different Changes to 1 km^2 Average NH_3 Concentrations in Two Different Future Forecasts.

2.7 Defining the OCC Values

2.7.1 Nitrogen Deposition and NOx Concentrations

The forecast improvements to nitrogen deposition fluxes and NOx concentrations provide an opportunity to quantify a magnitude of change which, because it will not create a net deterioration in air quality or deposition, may have the potential to not undermine achievement of the conservation objectives. As noted in Section 2.2, allowing new plans and projects based on expected improvements to air quality in this way is consistent with decisions made in relation to the 2018 Submission Wealden Local Plan. Furthermore, the two future baseline scenarios predicted during the Nitrogen Futures project probably provide the most robust future predictions currently available in the UK; making these data more appropriate than any other for addressing the certainty requirements of the Habitats Regulations.

Following discussions with a range of consultees (see Section 2.8) it was decided that basing the OCC values on the minimum reduction predicted over 90% of the UK (shown by the vertical lines in Figure 3 and Figure 4) was consistent with the certainty requirements of the Habitats Regulations. This means that there will be some locations (10% all other things being equal) where the scale of improvement has been over-predicted, but in the remaining 90% of the UK the scale of improvement will have been under-predicted.

The measures included in the 2030 BAU (WM) scenario are most comfortably compliant with the certainty requirements of the Habitats Regulations, since they are already adopted or implemented. However, there is also a position that the legally binding nature of the NECR targets makes reliance on these reductions also compliant. This is the approach which has been adopted by the Institute of Air Quality Management (Holman *et al.* 2020); although other work has shown that there is considerable uncertainty regarding the ability to meet the NECR targets for many countries, including the UK (AQC 2020a).

Following discussions with a range of consultees (see Section 2.8) it was decided that allowing for 25% efficacy of the UK NAPCP provides a sufficient level of precaution for the certainty requirements of the Habitats Regulations. This means that if the UK implements less than 25% of the measures (or those measures are less than 25% effective) in its NAPCP by 2030, then the rate of improvement will have been over-predicted. Conversely, if the UK achieves more than 25% of these (legally-binding) improvements then the rate of improvement will have been under-predicted. The choice of 25% is a subjective value chosen by the project team to reflect the discussions during the workshops described in see Section 2.8.

Following discussions with a range of consultees (see Section 2.8), it was finally decided to allow 20% of the forecast reductions (after allowing for 25% efficacy of the NAPCP) that will apply across at least 90% of the UK to represent the OCC. This value has been arrived at subjectively, and the circularity of this approach is acknowledged. The Nitrogen Futures modelling already includes all forecast activity growth, which at a high level includes all expected plans and projects. The modelling has thus already demonstrated that, when spatially averaged, the total impacts of all UK plans and projects between 2017 and 2030 will not prejudice the downward trajectory in NOx concentrations and nitrogen deposition fluxes. Exempting from further assessment those plans and projects which, when combined, contribute less than 20% of the reductions that will apply across at least 90% of the UK, is not considered to prejudice the downward trends brought about by autonomous measures. As above, the choice of 20% is a subjective value chosen by the project team to reflect the discussions during the workshops described in see Section 2.8.

The OCC values for nitrogen deposition and NOx concentrations are set out in Table 4.

2.7.1.1 Spatial Scale

The forecast reductions which have been presented are 1 km^2 averages. Within each grid square, the rate of change at any individual location will differ from the average for that grid square. DMTs and SRTs will be applied to the maximum increment caused by a project within a designated habitat. Spatially averaged improvements due to autonomous measures will thus effectively be used as the basis for allowing location-specific maximum impacts.

On average, this feature will tend to make the approach more conservative, since the maximum impact will not, by definition, occur everywhere within a grid square. It does, though, mean that there will be many locations within designated habitats, where the reductions are smaller (or larger) than predicted.

2.7.1.2 Temporal Scale

Because the rate of improvement between 2017 and 2030 will be nonlinear, describing a “reduction per year” is unhelpful. The OCC relates to the entire 13-year period and represent the combined effect of all measures over this period. The OCCs must, therefore, relate to the effect of 13 years' cumulative development growth. It would be inappropriate, for example, to allocate the entire OCC only to projects coming forward over one or two years. There is, however, the potential to review and refine the OCC values prior to 2030 as better information comes available. This is explained further in Section 6. It seems likely that further information will become available prior to 2030 which will allow the OCCs to be refined or extended beyond that date.

2.7.2 Ammonia Concentrations

For the reasons explained in Section 2.6, forecast reductions cannot be used as the basis for setting an OCC for ammonia concentrations. Following discussions with a range of consultees (see Section 2.8) an OCC of 1% of the critical levels for ammonia have been set. This is on the basis that this criterion has a long history of use, first in relation to impacts alone, and later to impacts in-combination[12]. Ultimately, and as described further in Section 2.8, the consensus from ecology specialists consulted was that an increase of 1% of the critical level, when used to describe the combined impacts of all plans and projects over the 13 years from 2017 to 2030, cannot be considered to represent a meaningful change in respect of the conservation objectives or condition at most nature conservation sites. There are some very sensitive habitats where this may not provide sufficient protection and these exceptions are detailed in Appendix 4 of the Guidance on Decision-making Thresholds document (Chapman & Kite 2021).

One observation which can be made is that the OCCs for nitrogen deposition (Table 4), are effectively 1.2% and 1.7% of a common critical load of 10 kg-N/ha/yr, while the OCC for NOx is 0.4% of the critical level. Using an OCC for NH_3 of 1% of the critical level is thus similar to the values used for other pollutants in this respect. For the avoidance of doubt, the OCCs for nitrogen deposition include the forecast increase in NH_3 concentrations (i.e. the nitrogen deposition modelling includes equivalent NH_3 predictions).

The OCC values for nitrogen deposition and NOx concentrations are set out in Table 4.

2.8 Agreeing the OCC Values

Given that OCC is defined in view of the conservation objectives or site condition, a proposed approach to how an OCC value might be derived was tested through an ecological workshop held on 23 and 26 November 2020. The workshop was run by DTA Ecology and EPR. Delegates from the research community, statutory nature conservation advisers and ecological practitioners attended the workshop. The purpose of the workshop was to seek views from recognised experts across the ecological community.

Workshop delegates were asked to complete a questionnaire which was developed by EPR and interpreted by DTA Ecology. Of the twenty delegates that attended, 15 completed questionnaires were submitted. Table 3 summarises the questions and responses with respect to setting the OCCs as described above.

Delegates also identified that there would be limited exceptional circumstances where the OCCs, and by extension the DMTs, could not safely relied upon. This has resulted in a number of Exception Scenarios being developed as described in Appendix 4 to the Guidance on Decision-making Thresholds document (Chapman & Kite 2021). These exceptions, while fundamental to the application of the thresholds, are not instrumental to their derivation and so are not discussed further in this report. Further details of the

[12] The 1% criterion was originally derived based on the likelihood of different industrial sources collocating and the need to target mitigation at major existing sources.

ecological workshop are provided in Appendix 1 of the Guidance on Decision-making Thresholds document (Chapman & Kite 2021).

Table 3: Summary of Ecological Workshop Delegates Responses.

Question	Number of Responses		
	Yes	**No**	**Possibly**
Do you agree that, using the method explained in the workshop, it should be possible to set an [Objective Compliant Change] value for Nitrogen deposition that could be applied in at least the majority of cases (e.g. subject to certain defined exceptions)?	12	0	3
The method used to derive an objective compliant change category could be based only on measures that are already committed (the '2030 BAU' scenario). Is it appropriate to take into consideration at least some of the additional measures that would be needed to deliver the UK's commitments under the National Emissions Ceiling Directive (NECD) as modelled in the '2030 NAPCP+DA' scenario?	8	2[a]	5
For ammonia, no nationally applicable improvement is anticipated up to 2030. However, it might be possible to define an additional amount of Ammonia that is so small as to have no reasonable prospect of affecting a European Designated Site (e.g. a fraction of the most stringent Critical Level of 1µg/m^3) and which would not render post 2030 efforts to reduce Ammonia levels to below Critical Levels materially more difficult. Would this be an acceptable basis for defining an OCC from which a decision-making threshold might be derived?	9	3[b]	3

[a] 'No' responses indicate preference for a BAU scenario on a precautionary basis.
[b] 'No' responses indicated concern given the potentially more damaging effects of ammonia.

2.9 Summary

The final OCC values are set out in Table 4. Except where indicated in the table, these do not relate to specific habitats or specific locations.

Table 4: Universal OCC Values for the 13-year Period 2017-2030.

Pollutant	Value	Rationale
Nitrogen deposition to Short Vegetation (kg-N/ha/yr)	0.12	20% of the reduction which is forecast for at least 90% of the UK, assuming only 25% efficacy of the NAPCP
Nitrogen deposition to Woodland (kg-N/ha/yr)	0.17	
Annual Mean NOx (µg/m^3)	0.12	
Annual Mean NH_3 (lichens/bryophytes) (µg/m^3)	0.010	1% of the Critical Level
Annual Mean NH_3 (higher plants) (µg/m^3)	0.030	

3 Emissions Sources and Spatial Considerations

As noted in Section 2, emissions released in one part of the UK will have a non-zero effect on annual mean concentrations and fluxes everywhere else in the UK. The ideal model for assessing the in-combination effects of UK projects is thus a national-scale one such as used for the Nitrogen Futures project, which has been used to define the OCCs.

While the Nitrogen Futures modelling nominally already includes all UK projects up to 2030, it does so in such a spatially coarse way that it is inappropriate to rely on this for local-scale predictions. For example, the Nitrogen Futures modelling does not account for the precise locations of future development. Instead, it relies on the assumption that the existing spatial distribution of emissions from each individual emissions sector will remain the same between 2017 and 2030, with emissions from each existing mapped source either increasing or reducing over time. Furthermore, the core model outputs from Nitrogen Futures are 1 km^2 averages and these will significantly under-predict concentrations and fluxes close to emissions sources. There is thus a need for additional modelling to test how the precise spatial distributions of future projects might perturb the 1 km^2 – average concentration and deposition fields.

3.1 Catchment Area

While each new project will increase concentrations over an area extending many kilometres, these effects become spatially homogenous with increasing distance from the source[13]. It is a common assumption that concentrations become indistinguishable from the general ‘background’ by certain distance (for example 200 m for road traffic or a few km for industrial sources (e.g. Holman *et al*. 2020). This does not mean that the impact falls to zero; rather the impact becomes so well dispersed that the effect is largely indistinguishable from that at even greater distances. This, in turn, means that the precise location of a project is only significant within its immediate vicinity. The presence of a new project might have a (usually very small) impact on ‘background’ concentrations and fluxes over a very wide area, but this impact will occur regardless of the precise location of that project and is in any case built into the Nitrogen Futures modelling. The location of the project is, however, fundamental to understanding the impact on its immediate surroundings.

When considering the effects of a new project for planning or permitting, it is often necessary to consider its impact footprint over large areas. For example, Environment Agency guidance (Environment Agency 2021) advises that modelling extends 15 km from some major emissions sources such as power stations. This reflects the fact that even a spatially homogenous increase (i.e. to the ‘background’) might have significant adverse effects. However, for the purposes of the current work, the spatially coarse effects of all UK plans, and projects have already been considered by the Nitrogen Futures modelling. What is now needed is a detailed local-scale consideration of how the precise positioning of new projects might perturb the national-scale predictions so that this may be taken into account in the derivation of DMTs and SRTs.

A limitation of the current study is that it is not possible to remove from the national model those projects which are included explicitly at a local scale. Each of these projects is thus, by necessity, double-counted. This creates a risk that if the local-scale modelling extends over too large an area, the effect of double-counting may become significant. There is thus a balance between extending the local-scale modelling sufficiently far to capture any likely perturbation to the national model outputs, without extending it so far that the risk of double-

13 For example, see contour maps in Section 5.

counting becomes too great. It is considered that a distance of 5 km best achieves this balance[14]. The 5 km distance has not been explicitly defined using the results from, or inputs to, modelling, but is a best estimate of the distance beyond which individual in-combination projects should not be considered within the concept of the current study.

The modelling described in Section 5 thus considers the potential for multiple in-combination projects to be within 5 km of each target project requiring assessment.

3.2 Alternative Approaches for Different Emissions Sectors

Some emissions sources tend to cluster together to such an extent that the approach described in Section 5 becomes inappropriate. The most obvious example of this is emissions from road vehicles. Regardless of the precise location of a traffic-generating project, all traffic will be channelled along roads. This means that the location of the maximum impact from one project will very often be the same as that of many other projects. This is very different from the situation for sources such as farms, where the emissions from two separate projects can never co-locate exactly, meaning that the points of maximum impacts are also unlikely to co-locate. Consideration of emissions from road traffic thus requires a fundamentally different approach than that which is appropriate for emissions released within the boundary of a development site, such as a poultry unit or industrial source.

A related situation arises in respect of emissions from heating and power plant within domestic and commercial developments (e.g. domestic gas boilers, etc.). While these emissions sources may be spatially dispersed, domestic and commercial developments typically occur within existing urban areas which are some distance from designated habitats. This is important because the projections for emissions of total reactive nitrogen from this sector, when taken as a whole, are strongly downward even after taking account of future development. There can thus be some certainty that the aggregated total reactive nitrogen emissions from domestic heat and power within each existing urban area will reduce into the future, even where new projects are consented. For this reason, emissions from domestic and commercial heating and power[15] need not be considered within subsequent sections of this report which quantify the proportion of the OCC which must be reserved for in-combination plans and projects. In practice, the contribution from domestic and commercial combustion can be considered to have a neutral effect on the OCC. Importantly, this does not preclude the use of DMT and SRT values in the assessment of impacts from individual projects from this sector; it is simply that these emissions do not need to be subtracted from the OCC.

Other plans and projects which give rise to NOx and/or NH_3 emissions must be removed from the OCC in order to derive a DMT. This includes agriculture and combustion in industry, as well as any other significant non-domestic/commercial sources, e.g. banks of gas-fired generators. This is done in the next sections of this report.

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14 This distance is purely used for the derivation of DMTs and SRTs and does not affect the need to model for greater distances as part of more detailed assessment, e.g. the need to consider impacts 15 km from large industrial sources or protected area search distances for environmental permitting.

15 Including small-scale combined heat and power within domestic and commercial developments which do not require an environmental permit.

4 Density of Future Development

4.1 Approaches Considered

To inform the modelling presented in Section 5, it is necessary to estimate how many projects might conceivably be developed within 5 km of any given target project over the 13-year OCC timeframe. Several different approaches to making these estimates were investigated. A principal problem is that no single centralised record of all relevant historic projects exists. While regulators (e.g. the Environment Agency and Natural Resources Wales) hold data for the permits which they allow, these exclude small projects which don't require such a permit to operate. Furthermore, in many cases the dates recorded alongside the permits relate to the most recent variation rather than the date at which the permit was first granted and these often link to administrative, rather than physical changes to the process.

The growth assumptions which fed into the Nitrogen Futures modelling, as well as those used for other projections such as by the Department for Business Energy and Industrial Strategy (BEIS) (2020) provide a potential means of predicting the aggregate changes in activity (e.g. gas combustion for electricity generation) in the future. However, as explained in Section 1, the DMT value must relate only to those projects which will not be subject to their own, separate, in-combination assessment. Top-down projections such as those from BEIS do not provide a basis for differentiating between nominally large and small projects and thus do not provide an ideal solution.

It is considered reasonable to base future projections on historic permissions (i.e. if there were 10 permissions over the last 10 years then there will be 10 permissions over the next 10 years). Furthermore, all applications which might require consideration by the nature conservation bodies, for either agricultural or industrial facilities, are logged through the planning system. The Northern Ireland Department of Agriculture, Environment and Rural Affairs (DAERA) provided a list of intensive farming applications which it has considered in relation to impacts on specific designated sites between February 2007 and December 2020. These applications can be summarised as shown in Figure 6. In this figure, each individual application is counted multiple times, depending on how many designated sites it was considered to have a potential impact upon. Most designated sites in Northern Ireland were considered to be potentially affected by fewer than 5 new or planned intensive farms over this *ca.* 14-year period. However, there were some designated sites affected by up to 54 separate applications.

A key point that the statistics in Figure 6 miss is that the maximum impacts of each separate application will not co-locate and will often be very distant from one another. For example, the statistic in Figure 6, of 54 separate applications, relates to Lough Neagh and Lough Beg SPA. The perimeter of this SPA is 243 km long, and it is likely that the 54 applications were, at least to some extent, separated along this perimeter. The land area extending 5 km from this SPA covers almost 700 km^2. Thus, while the precise distribution of the 54 applications is not known, the *average* density of these applications is less than 1 for each 10 km^2 of land within 5 km of the SPA. When interpreted in this way, none of the designated sites in Northern Ireland experienced a density of intensive farming applications exceeding 4 applications for each 10 km^2 of adjacent land. For example, a buffer extending 5 km from each designated site but excluding open water and the Republic of Ireland. Extending this further to represent the area of a circle with radius 5 km diameter (i.e. the area extending 5 km from any target project) gives up to 29 applications over this ca. 14 year period. In practice, however, it is known that at least some of these applications were >5 km from designated sites, meaning that the average density will have been over-predicted; potentially by a considerable margin. In practice, because the locations of these applications are unknown, this analysis is fundamentally limited. These data cannot, therefore, be used to define development density within 5 km of a new project.

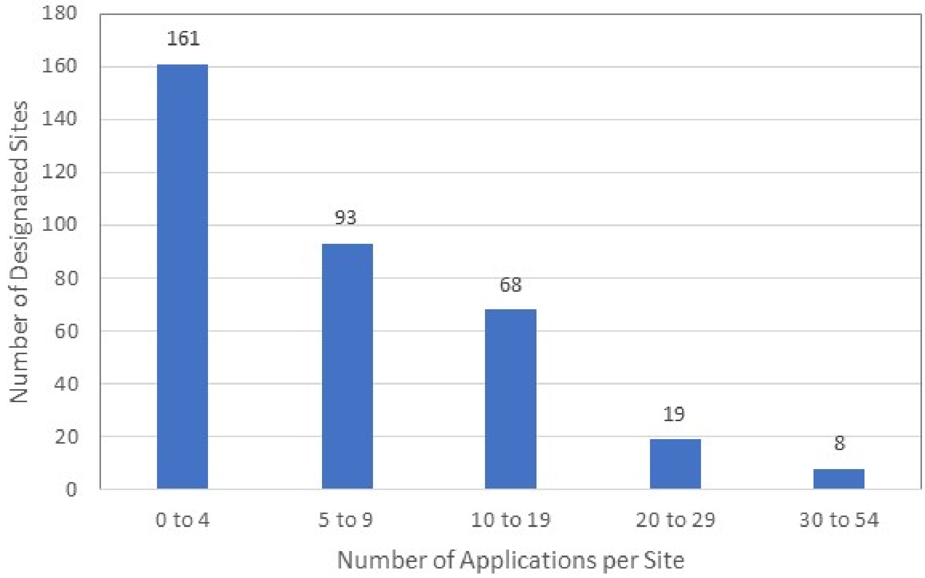

Figure 6: Number of Applications for Intensive Livestock Facilities in Northern Ireland between February 2007 and December 2020 Considered by DAERA to Potentially Affect a Designated Nature Conservation Site (showing both granted and pending applications).

The locations of applications are listed in initial planning application material held by local planning authorities, but due to the resource intensity burden on local authorities, direct requests for this information were not made. Furthermore, collecting the information using open-access portals is time-consuming and was not possible to do extensively within the scope of this project. The approach has thus been to select a small number of locations and use these as the basis for defining the likely range in development density which might occur elsewhere. The principal focus has been those areas where development density is known to be particularly high. In future, a data gathering exercise could be undertaken that provides a more comprehensive list of projects and locations to determine future development density.

4.2 Poultry Farms in Powys

The rate at which new poultry farms have been granted planning permission in Powys has received national media attention (The Guardian 2020). It is considered unlikely that anywhere else in the UK has experienced a significantly higher rate of new intensive agriculture development. The Campaign for the Protection of Rural Wales has retained a log of poultry-related planning permissions in Powys since 2015 and make their results freely available (CPRW 2021). These data have been verified by AQC using the planning portal of Powys County Council, by cross checking a subset of both datasets. Please note the Powys County Council is not the Local Planning Authority for the whole of the County of Powys, as part of the County comes under the Brecon Beacons National Park Planning Authority

Figure 7 shows the locations of all applications for poultry farms in Powys which have been granted permission between June 2015 and November 2020[16]. These data are also

[16] This excludes some of the data collected by CPRW which relate to applications which have not been granted or which predate this period.

summarised in Figure 8, which shows how the rate at which applications have been granted has changed over time[17].

Figure 7 shows that 145 permissions for new poultry developments were granted in Powys between 2015 and 2020. However, what is of principal interest to the current study is how 'densely packed' these projects were. In particular, and for the reasons explained in Section 3, what is needed is to know how many of these applications fall within a single 5 km radius area. A 5 km radius circle has been drawn, centred on each of the 145 farms in Figure 7 (i.e. 145 identical circles drawn in total). The total number of *other* granted permissions (excluding the one around which the circle has been drawn) within each circle has then been counted. This is illustrated in Figure 9, which shows a circle of 5 km radius (shown by the dashed line) drawn around a single small farm (marked by the bold circle). There are 9 other small farms within this 5 km radius, i.e. farms with <40k birds. Figure 10 summarises the results of this analysis for all granted permissions in Powys. It shows that there is only one small farm with 9 other small farms within 5 km of it (this is the farm shown in Figure 9) and no small farms with *more than* 9 others nearby. When considering all sizes of farms, the maximum density is 12 (i.e. there is one farm within 5 km of 12 others).

These results relate to the period June 2015 to November 2020, i.e. marginally over 5 years. The OCC period is 13 years (2017 to 2030). In practice areas may become 'saturated' by new development, either because of a lack of available space or because of increased political resistance. This may help explain the downward trend in granted permissions in Powys since 2018 (Figure 8). In the absence of this 'brake' to new development, the best estimate of future development comes from extrapolating recent trends. This is shown in Table 5, which has been calculated simply by multiplying the maximum values recorded in Figure 10 by 13/5 (i.e. 13 years when compared with 5 years).

[17] It should be noted that 2015 and 2020 in Figure 8 represent incomplete years, and that 2020 might be considered an atypical year because of the COVID-19 pandemic.

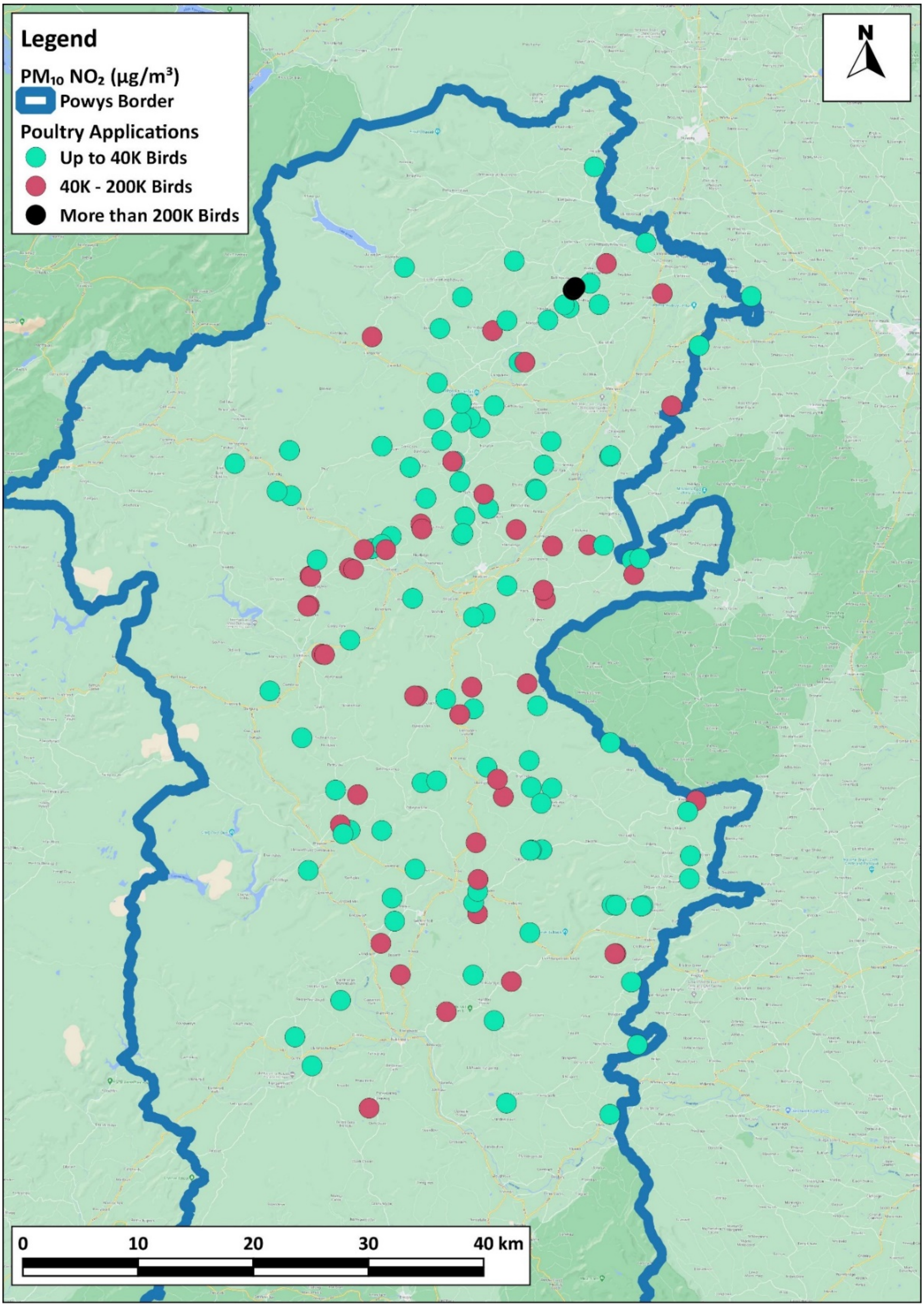

Figure 7: Planning Applications for Poultry Sheds Granted within Powys from June 2015 until November 2020. (Google Map data ©2021)

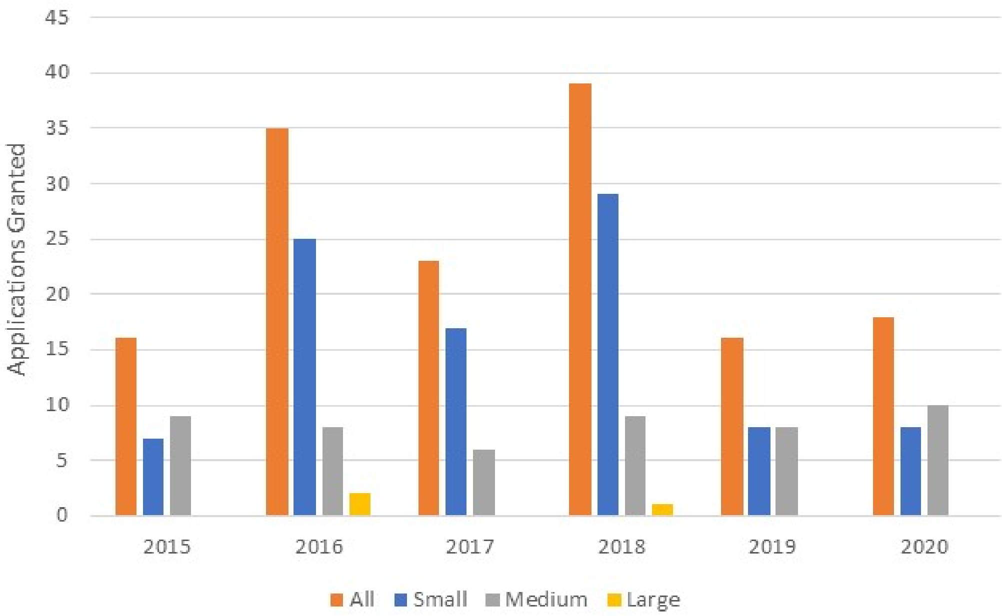

Figure 8: Planning Applications for Poultry Sheds Granted within Powys by Year, 2015 – 2020 (small <40k birds; medium 40-200k birds; large >200k birds).

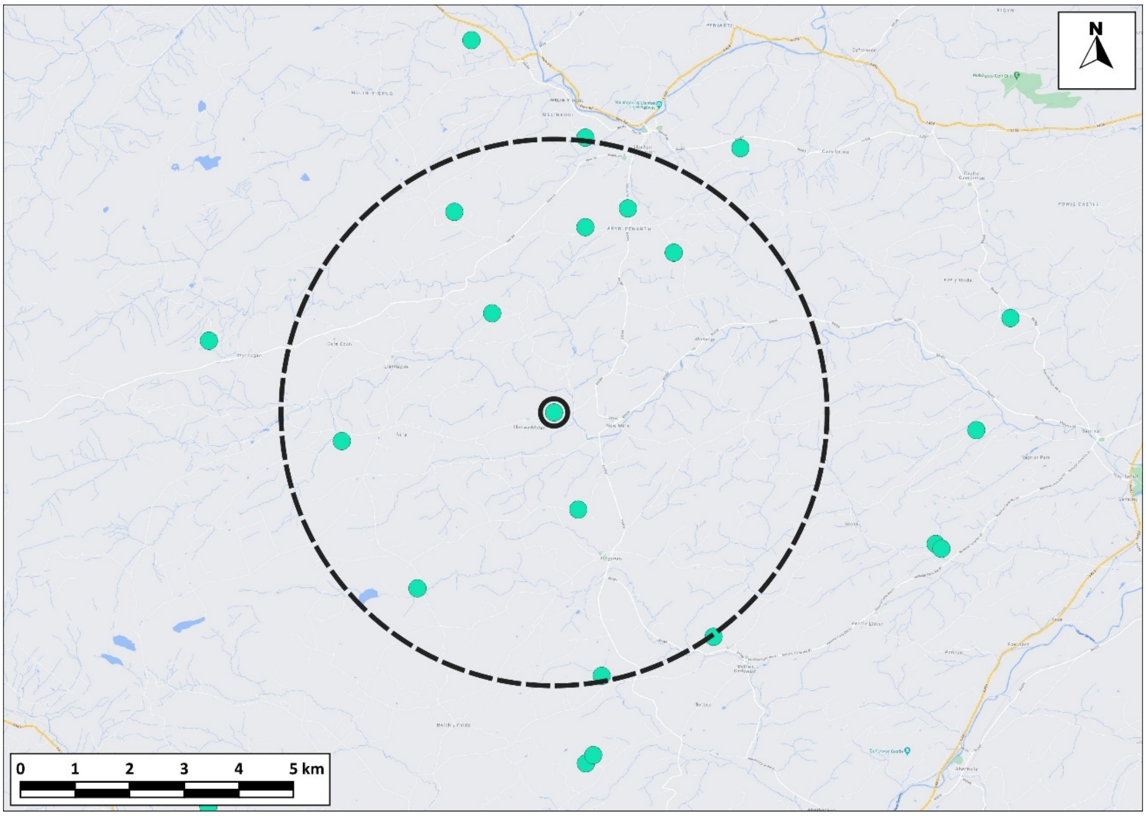

Figure 9: Illustration of 5km Circle Drawn around a Single Farm. Google Map data ©2021

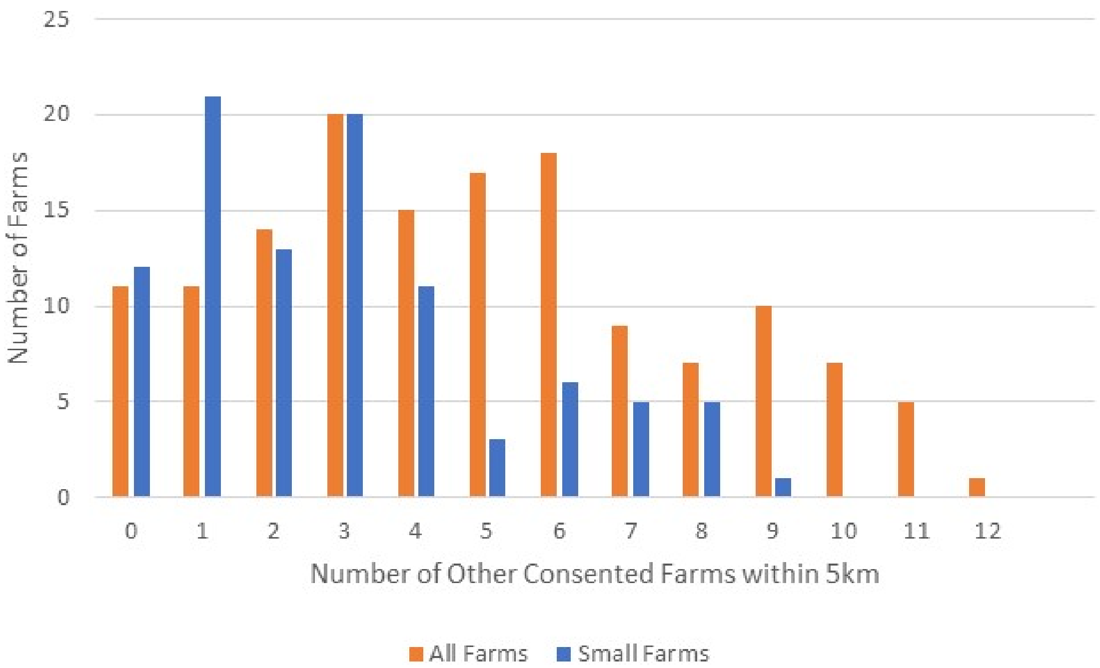

Figure 10: Intersite-proximity of Planning Applications for Poultry Sheds Granted in Powys 2015 – 2020; showing (small <40k birds; and all consented farms).

Table 5: Maximum Number of Poultry Developments Predicted over 13 Years within 5km of a Target Project.

	All Consented Farms	**Small Consented Farms**
Max permissions over 5 years	12	9
Assuming linear trajectory over 13 years	31	23

As explained in Section 1, the DMT value must relate only to those projects which will not be subject to their own, separate, in-combination assessment. A simplistic view might be that small sources might be discounted from additional assessment by virtue of falling below the DMT, while larger sources would not. In practice it is more complex than this; a large farm which is a considerable distance from a designated site might fall below the DMT, while a small farm close to the designated site would not. In any event, it is reasonable to consider that at least some (and possibly many) of the permissions granted in the future would require their own in-combination assessment and thus not require consideration within the DMT. Conversely, Table 5 only relates to poultry developments and does not include other intensive agriculture or industry. On balance, it seems highly unlikely that the DMT criteria would be applied to more than 30 in-combination projects (therefore 31 projects including the target project, none of which are subject to their own in-combination assessment) permitted within 13 years and within any 5 km radius circle in Powys.

For the sake of completeness, analyses were also carried out to determine any correlation between the number of farms and the distance from a designated site (for example Figure 11). Such a pattern might be expected if the protection afforded to the habitats was affecting the pattern of development. There is no clear evidence that this has happened.

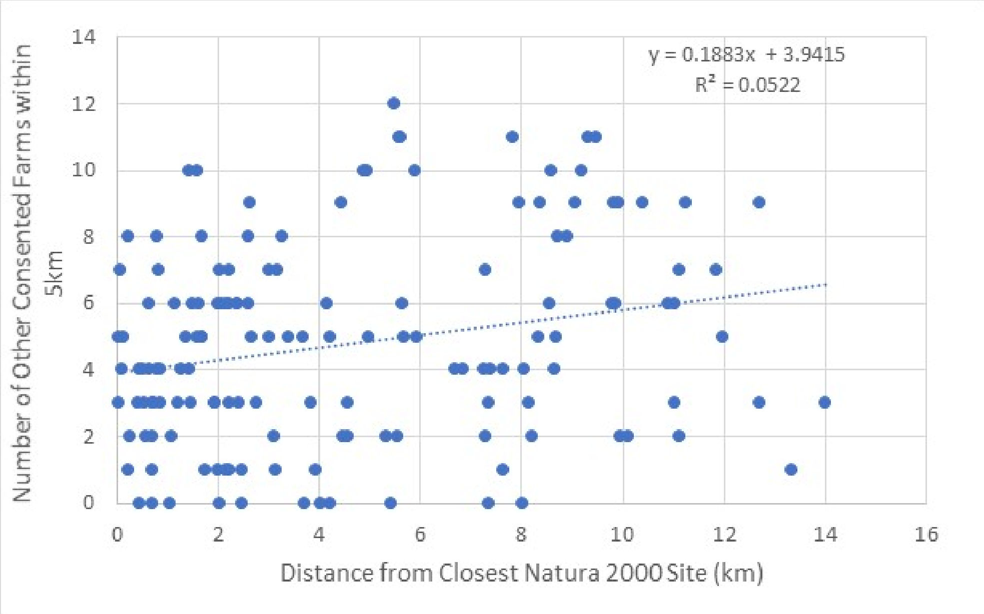

Figure 11: Number of Other Consented Poultry Sheds Granted in Powys 2015 – 2020 within 5 km of Each Shed vs Distance from the Closest Natura 2000 Site (showing all consented farms regardless of size).

4.3 Industrial Centres

AQC's experience of carrying out air quality assessments to accompany planning applications has been used to identify two areas of the UK which have seen an atypically high density of individual planning applications for industrial processes in the last five years. These are Immingham Docks and central Doncaster. The planning portals provided by the local planning authorities were trawled for planning applications related to industrial developments in the last five years in these two areas. It was not considered appropriate to attempt to retrieve records for a 13-year period. A single 5 km-radius circle was then identified which contained the highest density of applications[18]. The identified applications are shown in Figure 12 and Figure 13. The details of these applications were then reviewed. In both areas, the majority of these industrial applications were unlikely to have any significant on-site emissions to air. Distribution centres, for example, can be significant generators of traffic but do not typically have any significant on-site combustion. Table 6 summarises the numbers of applications identified, both including and excluding those considered unlikely to generate significant on-site emissions. Details of each application are listed in Appendix A2.

As has been explained, the DMTs should not allow for all new permissions, only those which will not receive further attention because they fall under the DMT criteria. They should, however, relate to 13 full years of development. On a superficial level, the 11 relevant developments in Immingham over 5 years might be extrapolated to 13 years (11 x 13 / 5 = 29 developments). However, this includes all projects, even those which would fall above the DMT. It also does not reflect the potential for available space to become saturated over time. An upper-bound of 30 in-combination developments has been identified from the case study of Powys and, based on the results in Table 6, it seems highly unlikely that this value will be exceeded in either of these industrial areas.

[18] In the case of Doncaster, two applications which were only marginally outside of the circle were also included.

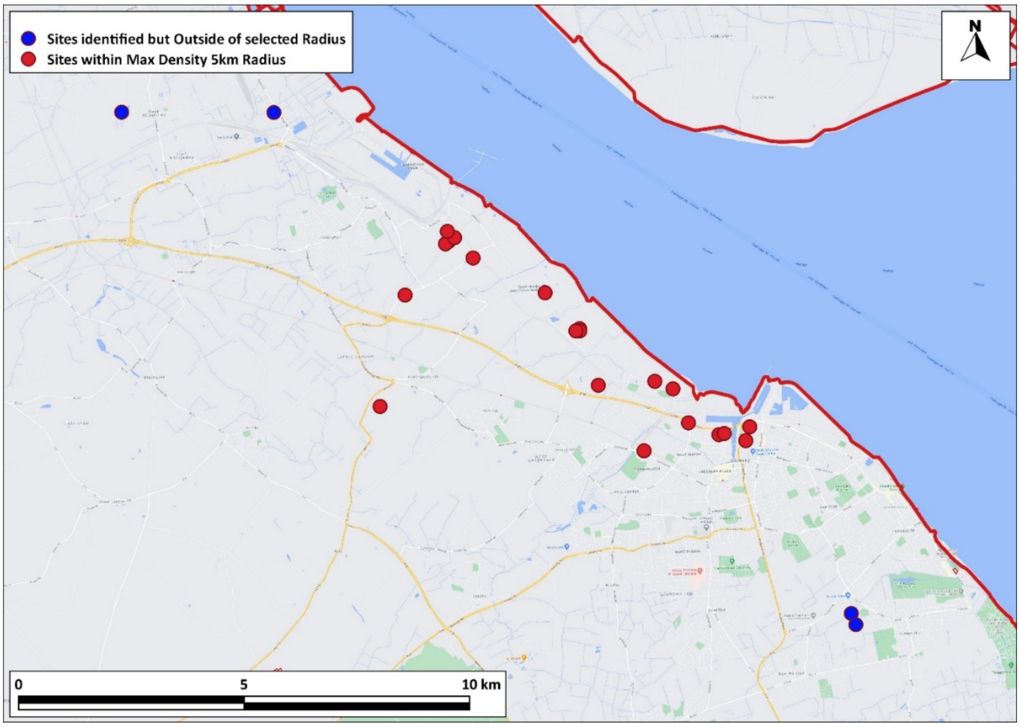

Figure 12: Consented Planning Applications for Industrial Operations near Immingham over 5 Years (2016-2021) (red line shows designated habitat). Google Map data ©2021

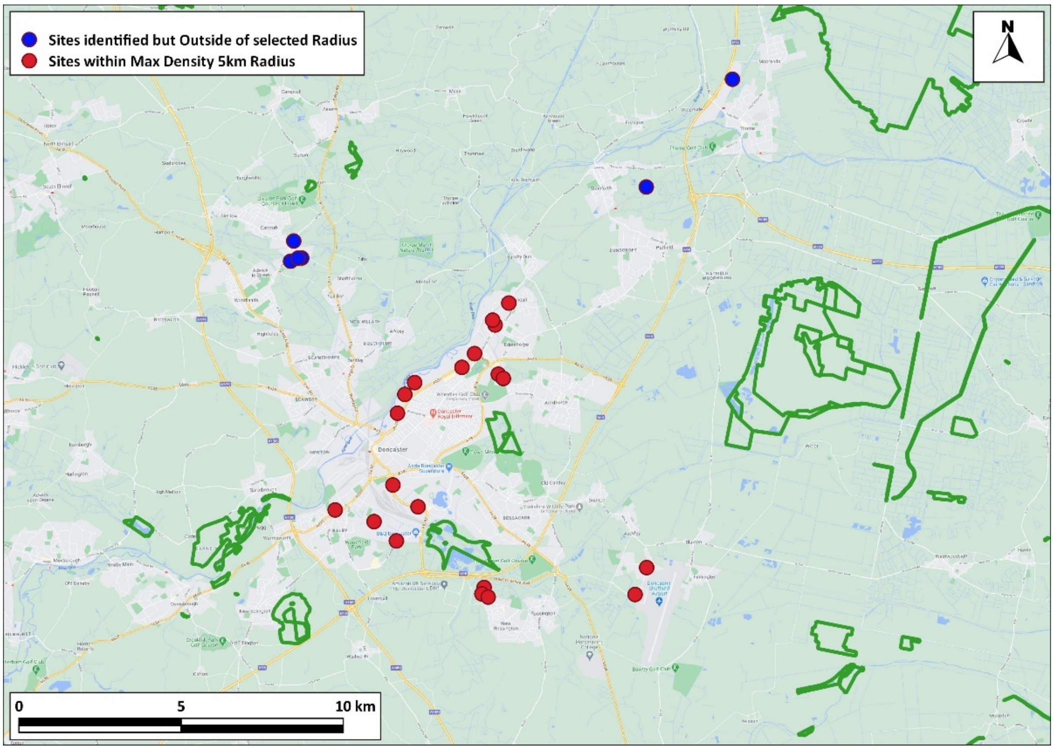

Figure 13: Consented Planning Applications for Industrial Operations around Doncaster over 5 Years (2016-2021) (green lines show designated habitat). Google Map data ©2021

Table 6: Maximum Number of New Industrial Developments within a Circle of 5 km Radius in Two Industrial Areas.

	Search Period	All Industrial Developments	All Industrial Developments which might reasonably be expected to have Appreciable on-site Emissions to Air [a]
Immingham	5 yrs (2016-2020 inclusive)	20	11
Doncaster	5 yrs (2016-2020 inclusive)	18	5

[a] Excluding light industry and distribution, etc.

4.4 Conclusions for Development Density

There is clearly the potential for one area to support both agriculture and industry, but it seems implausible that both a high-density of agriculture projects and a high-density of industrial projects would co-locate within a single 5 km radius. As such, it seems robust to assume no more than 30 of any type of new project within 5 km of a target project.

It is clear that most areas will see significantly fewer than 30 new projects within a single 5 km radius over 13 years. Table 7 provides qualitative descriptors, based on professional judgement, for alternative development density areas, along with how many new projects (below the DMT) might be expected in these areas. They are intended to provide an element of precaution, for example a typical agricultural area (an area of Medium development density) is unlikely to experience 10 applications over 13 years within each and every 5 km radius circle, but this represents a reasonable upper-bound of likely development pressure. Figure 14 shows a hypothetical visualisation of different development densities using imaginary development locations. The numbers of developments for very low, low, and medium density areas shown in Table 7 are based on judgement, but if practitioners refer to these example numbers then the model results will, by definition, align with the local site characteristics regardless of differences in subjective interpretation of the terminology. The concept of development density is used in Section 5 to develop SRTs for areas with lower development pressure, while the results for high development density, with 30 applications over 13 years, is used to derive the DMTs.

Table 7: Development Density Examples.

Development Density	**Very Low**	**Low**	**Medium**	**High**
Description	Remote area which sees very little development	Area which sees small amounts of development	Typical agriculture / industrial area	Area experiencing intensive growth (e.g. Powys or Immingham docks)
Example Number of *additional new* projects below the DMT within 5 km of proposed development over 13 yrs [a]	1	5	10	30

[a] These might be either industrial or agricultural projects.

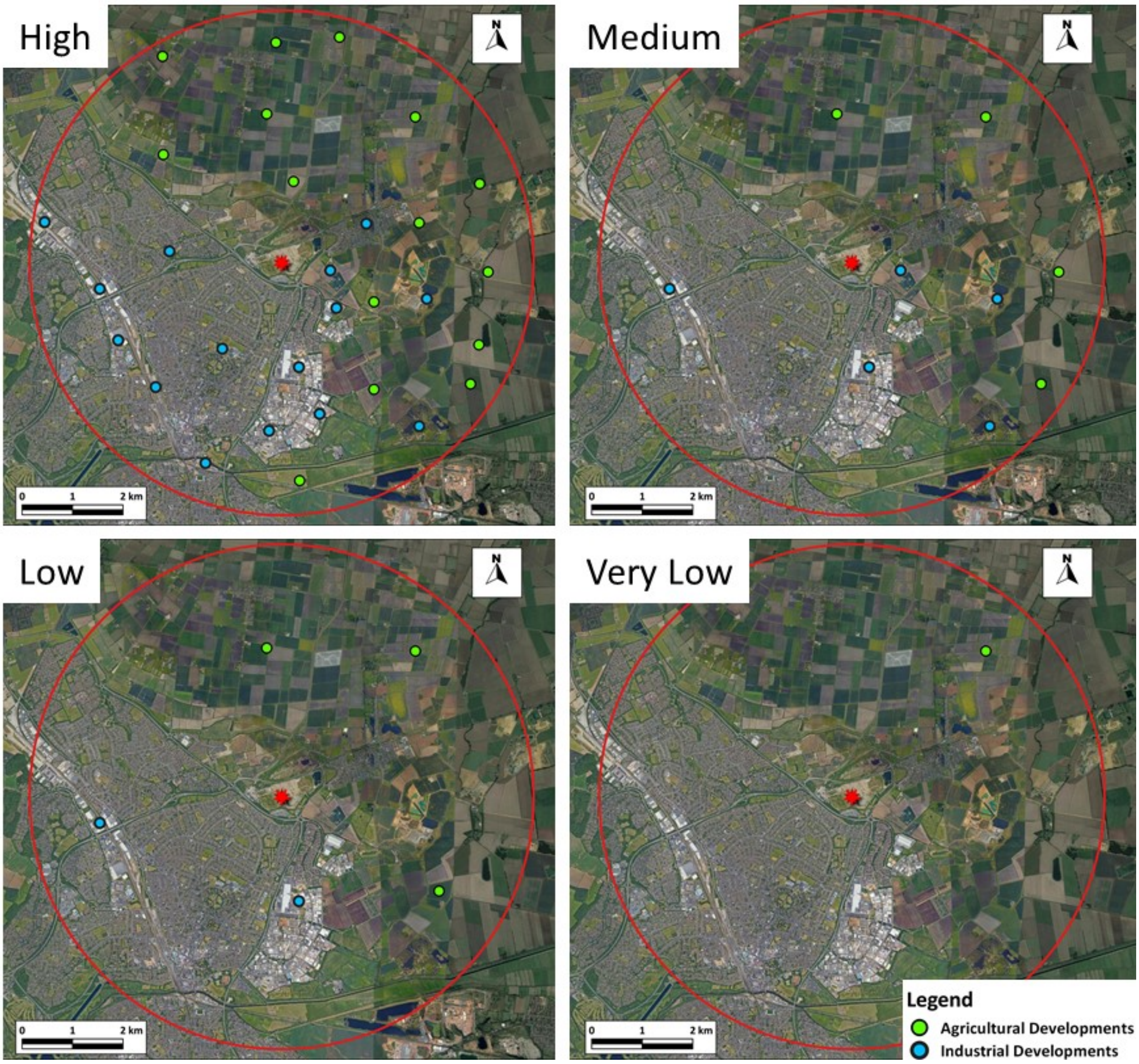

Figure 14: Hypothetical Visualisation of Different Development Densities. The Red Star shows the Target Project and the Red Line shows the Extent of 5 km from this Target Project. None of the locations represent real projects. Imagery ©2021 CHES/Airbus, Getmapping plc, Infotera Ltd & Bluesky Technologies.

5 Dispersion Modelling

The purpose of this section is to determine the portion of the OCC which must be allocated to ‘other’ projects that give rise to the cumulative impact; thus allowing the DMT value to relate to the increment caused by the target project alone. In other words, it has been necessary to predict the changes to concentrations and deposition fluxes which might be caused by all other future plans and projects that individually fall under the DMT which might go ahead within the 13-year timeframe and within 5 km of the target project. The difference between the OCC and the combined contribution from all these other projects will be the DMT. Clearly, in practice, the precise position, or existence, of future local projects is not known and also the DMT criterion which these projects must fall under cannot be defined until their combined contribution is known. Dispersion modelling has been used to test large numbers of alternative spatial configurations of multiple projects. The results from this have been used to determine the DMTs, in relation to the OCCs, as explained further within this section.

5.1 Initial Dispersion Model Runs

The ADMS-5 dispersion model has first been used to predict the effect of an individual project on NOx and NH_3 concentrations. Six example projects have been used; with three representing agricultural sources (two different sized intensive poultry farms and one dairy farm) and three representing industry (a large combined heat and power (CHP), a bank of modular electricity generating plant, and a small power generation facility). Each of these has been run with five years of meteorological data (measured at the Meteorological Office station at Waddington to provide consistency with Defra’s Pollution Climate Mapping (PCM) modelling[19]). Concentrations have been predicted at a Cartesian grid of receptors with 20 m x 20 m spacing and which extends 10 km from the centre of the emission source in all directions. Depletion of ammonia from the plume assumes deposition to short vegetation. NOx is assumed to be conserved within the plume (i.e. with no depletion). Appendix A3 provides further detail on the model configurations.

Figure 15 summarises one of the sets of ADMS results. All 45[20] sets of model outputs are shown in Appendix A4. Each set of model outputs is termed a ‘dispersion kernel’ because these outputs form the kernels of subsequent statistical modelling. A point to note is that no chemical reaction schemes are required to predict the effect of emissions of NH_3 and NOx on concentrations of NH_3 and NOx. This means that, at each individual receptor location, there is a linear relationship between the mass of pollutant emitted at the source, and the predicted concentration at the receptor. Figure 15 presents the annual mean model outputs as a function of the annual total mass emission rate and, notwithstanding changes to the release conditions[21] associated with different mass emissions, it is possible to simply multiply the results shown in Figure 15 by any emission rate to derive the impact at any receptor.

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19 The PCM model is designed to fulfil part of the UK's EU Directive (2008/50/EC) requirements to report on the concentrations of particular pollutants. It is used by Defra to predict concentrations across the UK for international and domestic reporting purposes.

20 i.e. six projects with five alternative meteorological datasets and with results for NOx and NH_3 presented separately for the three industrial sources.

21 For example, larger farms will often be spread over larger areas and larger industrial emissions may have taller stacks or greater initial buoyancy of the plume.

Another point to note is that, except for changes in surface roughness and certain coastal effects[22], the results shown in Figure 15 and Appendix A4 are not locked into any particular geographical location. For example, if the same emission source were modelled in two separate locations, then the model results at a given distance and orientation from both sources would be identical. The results in Figure 15 can thus essentially be 'picked up and moved' to represent any number of alternative locations. This feature of dispersion models is commonly exploited in a range of 'kernel models' including Defra's PCM model[19].

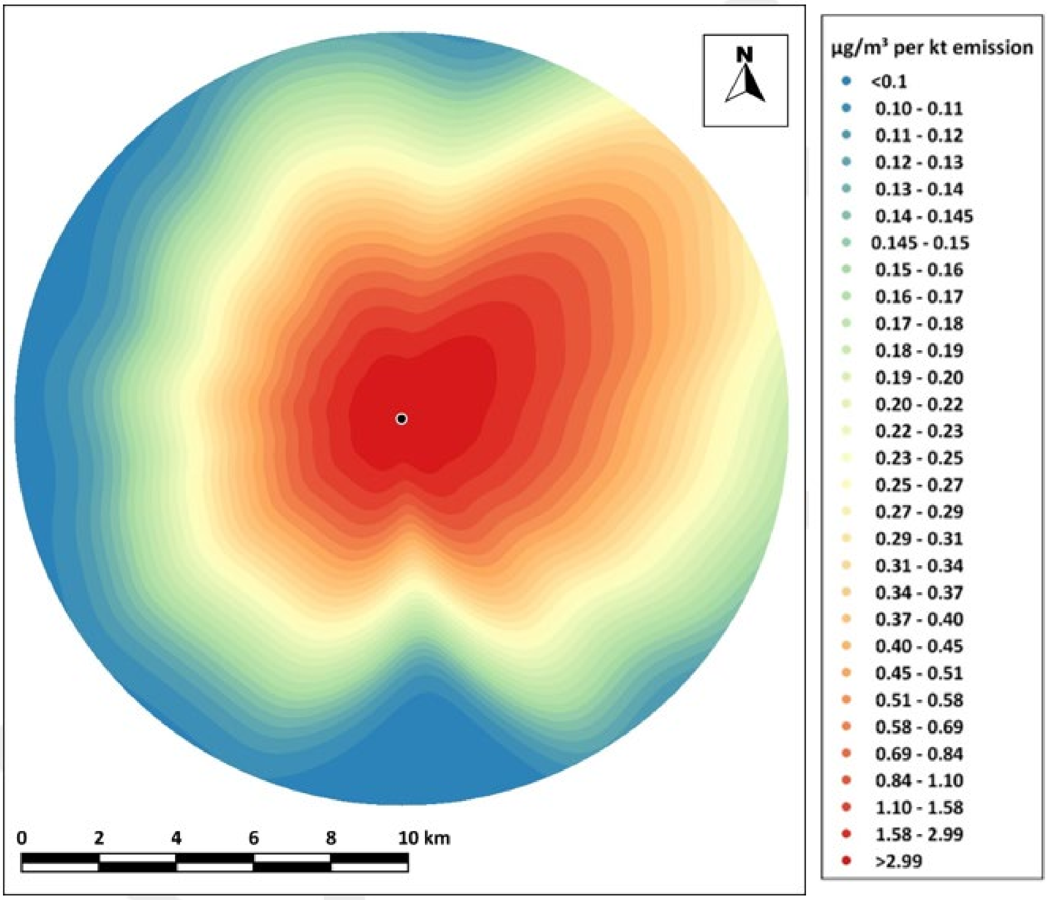

Figure 15: Predicted Annual Mean NH_3 Concentrations as a Function of Annual Total Mass Emission from a Poultry Farm (dispersion kernel 1) with 2015 Meteorology (black dot shows location of the farm).

Nitrogen deposition has been calculated outside of the dispersion model from the predicted concentrations of NH_3 and NOx. Further details are given in Appendix A3.

5.2 Configuring the Kernel Model

The next stage has been to take each of the individual impact footprints shown in Appendix A4 and use it to test how the impacts from multiple projects might overlap and thus interact if those projects are developed in different, alternative, locations within 5 km of one another. Figure 16 presents an illustration of how this has been done. The top panel (panel A) in Figure 16 reproduces Figure 15, but overlays: a circle extending 5 km from this source (i.e.

22 As explained in Appendix A3, the dispersion models have been configured to reflect as 'typical' and thus 'universal' setting as possible. Uncertainty caused by not using local values of surface roughness or coastal effects will be relatively small when compared with other sources of uncertainty as described in Section 8.

the region over which in-combination projects require consideration); an example designated nature conservation site (shown in green); and the location of maximum impacts from this source within the designated site (as a black star). For the purpose of this explanation, Panel A represents the target project and the purpose of the exercise is to establish the combined contribution of other projects which might be developed within 5 km. The features of interest from Panel A are thus those highlighted in Panel B (i.e. the zone extending 5 km from the source and the location of maximum impacts).

Panel C, in Figure 16 shows how the same impact footprint can be used to represent the contribution from another project (project number 2 – with the target project being project number 1). In this case, the in-combination effect at the black star is that from Panel A plus the value shown in Panel C (with both of these contributions being a function of each source's emission rate – i.e. $\mu g/m^3$ per kt emission). Project number 2 might occur anywhere within the 5 km radius circle, and the location of the designated habitat in relation to the target project might also be different; meaning that both project number 2 and the position of the black star may move. For each individual set of ADMS model outputs, 500,000 randomly generated alternative locations for project 2, as well as for the black star, have been tested. For the purpose of this stage of the analysis, both project 2 and the black star have been allowed to be anywhere outside of the source boundary, but no more than 5 km away from its centre[23]. In each case the source has the same geometry and emissions. The results have then been sorted in order, from the maximum in-combination impact down to the minimum in-combination impact. These results can then be visualised as shown in Figure 17.

Figure 17 shows that, in the worst-case locations (which will be when the in-combination project sits very close to the receptor highlighted by the black star, or vice-versa) the potential impact is high, but in most cases (which will be when the in-combination project is further away) the impact is much smaller. Presenting the data in this way provides an estimate of the probability that different events will occur. It is not based on any local geographical considerations which might, for example, prevent development of in-combination projects in certain areas, but all other things being equal, it shows the likelihood of an in-combination project contributing different amounts to ambient concentrations. For example, in 5% of instances the contribution from this in-combination project will be greater than 8.5 $\mu g/m^3$ per kt/yr (as shown by the 95th percentile in Figure 17). In 50% of cases it will be greater than 1 $\mu g/m^3$ per kt/yr (as shown by the 50th percentile) and in 5% of cases it will be less than 0.4 $\mu g/m^3$ per kt/yr (as shown by the 5th percentile).

23 In practice, because both the in-combination emissions source and the receptor of interest (i.e. the black star) are subject to the same spatial boundaries, because the position of each is varied at random, and because all that is required from the model is the contribution from the in-combination source at the highlighted receptor, it is computationally more efficient to simply select a value (subject to the defined spatial constraints) at random from the 10 km radius gridded outputs for the in-combination source.

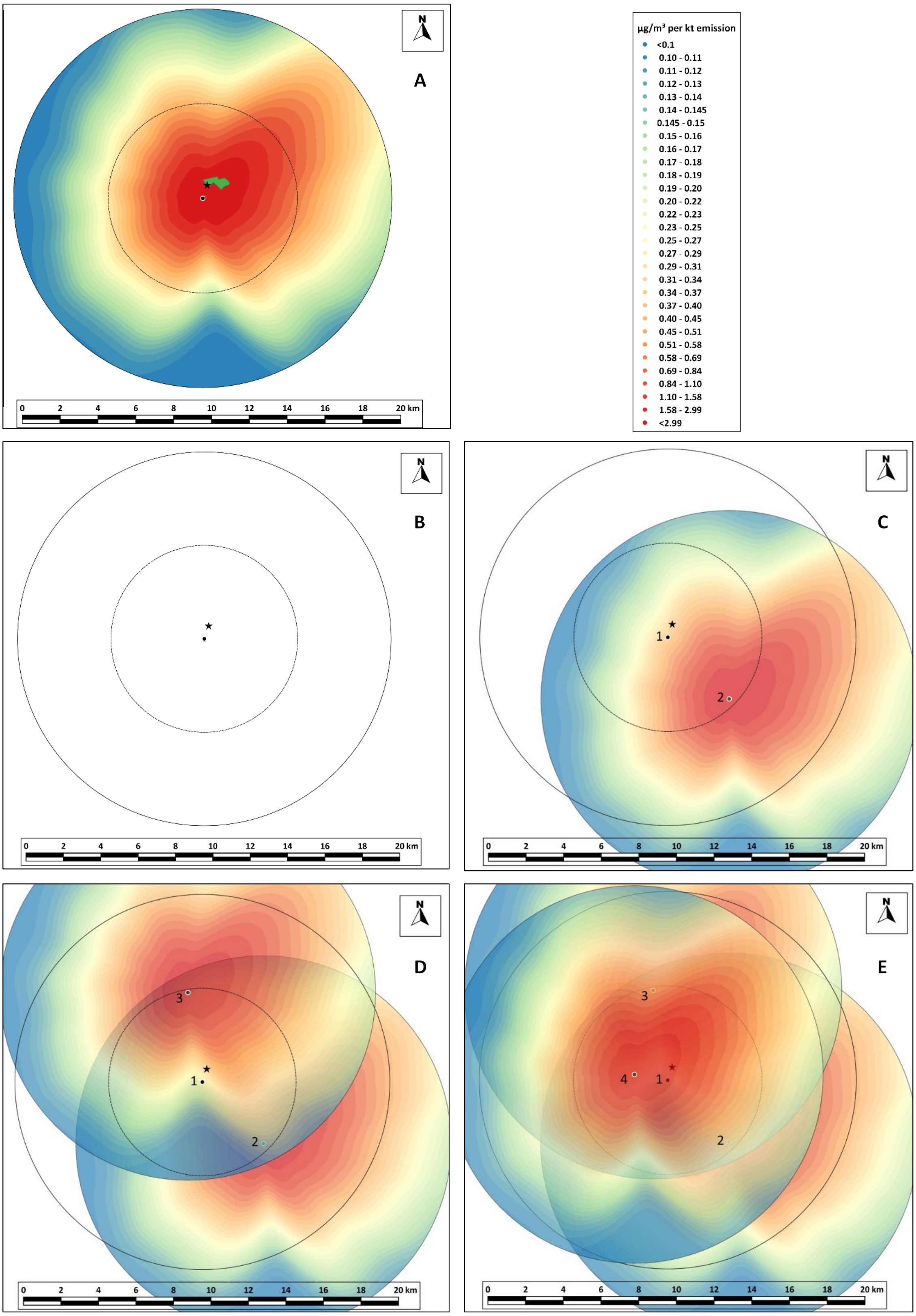

Figure 16: Illustration of Example Kernel Overlays (see first two paragraphs in Section 5.2 for explanation)

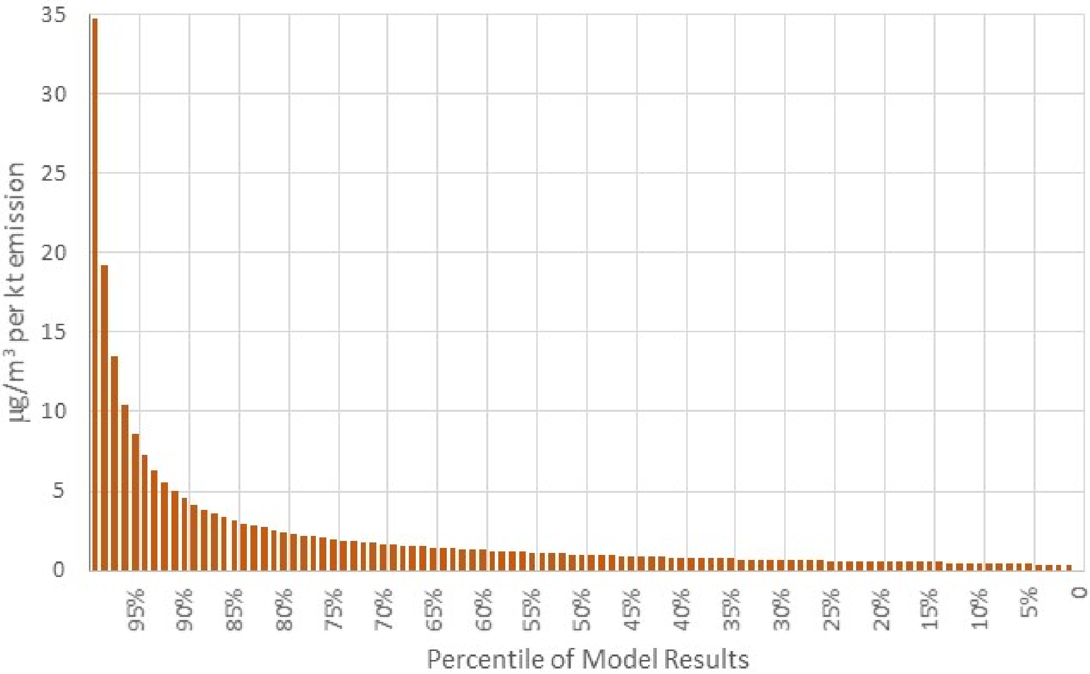

Figure 17: Impact of One In-combination Project at a Specific Location of Interest, summarising 500,000 Randomly generated Project Locations (results for Dispersion Kernel 1 and showing the max over 5 meteorological years).

Section 4 highlighted that there might be significantly more than 1 additional project within 5 km of the target project over the 13-year OCC timeframe. Panels D and E in Figure 16 show how the same concept can be extended to two and then three in-combination projects. In each case, the in-combination impact is that at the location of the black star when summing the contributions from sources 1, 2, 3, and (in Panel E) 4. Again, this just represents an illustration. As described above, for each of the individual ADMS model outputs, 500,000 randomly generated alternative locations for each source, as well as for the location of interest (i.e. the black star) have been tested. This has been repeated for two in-combination sources, for three in-combination sources, and then for: 4, 5, 6, 7, 8, 9, 10, 15, 20, 30, and 50 in-combination sources. In each case, the combined increments from all in-combination sources at the randomly generated location of interest (black star) have been recorded as probability percentiles in the way shown in Figure 17.

5.3 Defining the Source Terms

As explained in Section 1, the approach which has been taken is that the DMT values relate to the in-combination effects only of those projects which will not be subject to their own, separate, in-combination assessment by virtue of their impacts falling under the DMT criteria. This means that those projects which do *not* fall under the DMT do not require consideration here in relation to the OCC. In other words, the maximum impact that any of the in-combination projects to be considered here might have on its own, is equal to the DMT.

As noted in Section 4.2, a project may fall under the DMT either because of its size, or its distance (or even because of its release conditions, such as a tall stack to aid dilution). In the current modelling, it is assumed that all the projects have an equal potential to drive an increase in concentrations or fluxes at a sensitive receptor at a nominal distance. For example, all projects which emit NH_3 would have the same impact at a receptor which lies in the same orientation and distance from the source. Similarly, a project which emits only NOx would have the same potential effect on nitrogen deposition as a project which only emits NH_3, since both will be capped by the same DMT value for nitrogen deposition (i.e. despite the different deposition velocities for the two pollutants, both projects must fall under the same DMT to be considered here – if they exceed the DMT then they would be subject to their own in combination assessment and thus be excluded from this analysis). In other words, notwithstanding differences in the initial rate of dispersion from different types of project, all projects which need to be aggregated within this in-combination modelling are assumed to emit the same mass emission; with this being the maximum that it can be before the DMT is exceeded. On the basis of this rationale, it is most useful to define increases to concentrations and fluxes that alternative numbers and spatial configurations of identical (DMT-limited) in-combination projects will have relative to the maximum impact caused by a single target project (which is also DMT-limited).

5.3.1 Limiting the Spatial Parameters for the Target Project

Because locations have been selected at random, the combined contribution from in-combination projects is not dependent on the location of the receptor of interest (the black star). This is because the spatial relationship between two points selected at random is conceptually no different from the spatial relationship between two points when only one is selected at random. However, when the contribution from in-combination projects is expressed relative to the target project's maximum contribution, this then becomes sensitive to the location at which the target project's maximum contribution occurs. For example, if the target project is immediately adjacent to a designated site then it might contribute 40 $\mu g/m^3$ NH_3 per kt/yr emission. If the same project is 1 km from the designated site it might only contribute 4 $\mu g/m^3$ per kt/yr emission. If the combined contribution from multiple sources is also 4 $\mu g/m^3$ per kt/yr emission, then this either represents a 10% uplift to the target project's own impact at the point of maximum impact, or a 100% uplift 1 km from the target project.

Of the six example projects which formed the model kernels, four were within 1 km of the closest designated nature conservation site. The closest was 200 m away and the furthest was 2.5 km away. AQC's professional experience of carrying out assessments to inform planning and environmental permit applications is that a significant majority of assessments are within 1 km of the closest designated site.

A separate set of model runs has thus been carried out in order to define the maximum predicted concentration in relation to each dispersion kernel from 500,000 samples which can be no closer than 1 km from the centre of each source. All of the in-combination model outputs have then been expressed as a function of this value. This has been done for each kernel separately, having first taken the maximum across any of the meteorological datasets. The results are summarised in Figure 18.

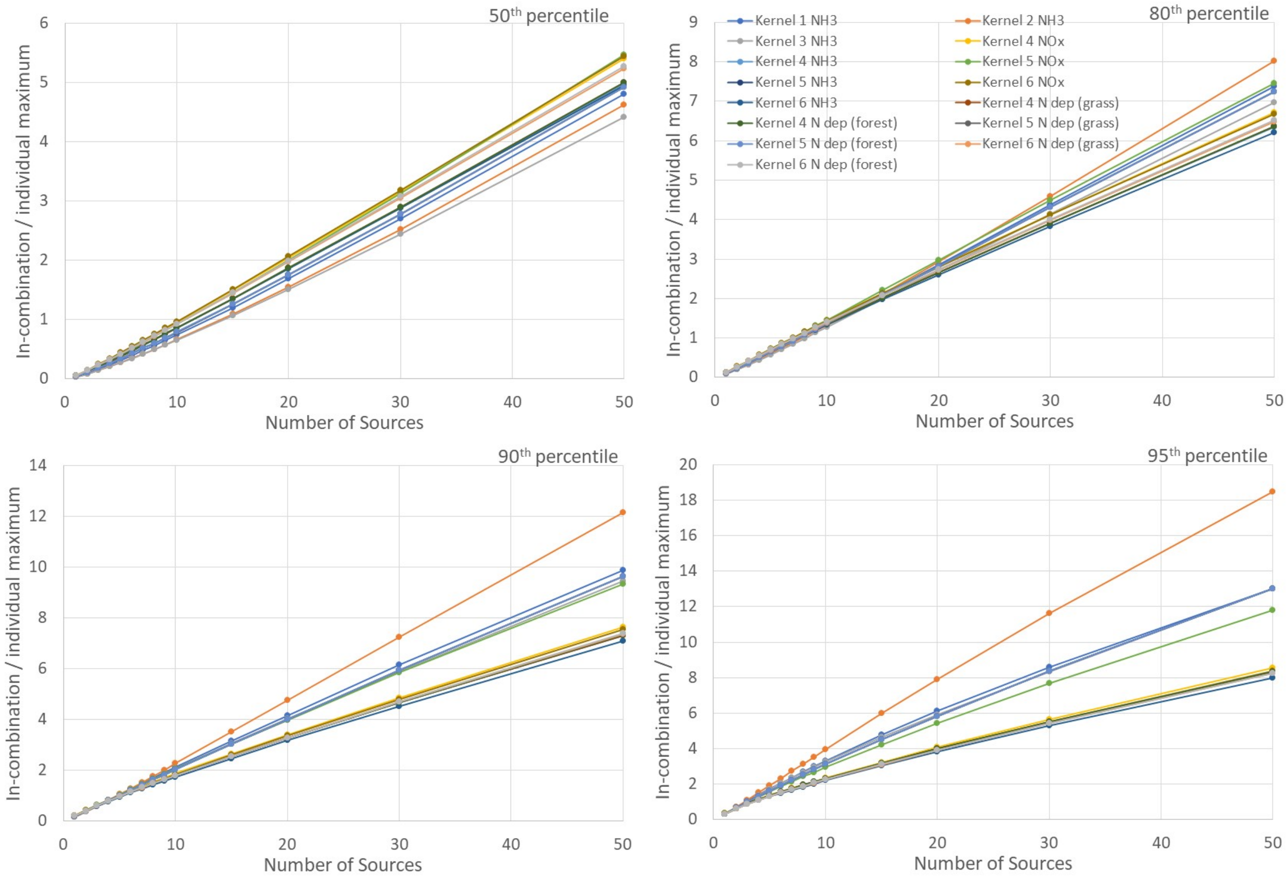

Figure 18: Relative Increase over Impact from Target project Caused by Multiple Identical Projects – Considering Different Probability Levels based on Alternative Spatial Configurations (note varying y scale).

5.4 Probability Model Results

Figure 18 summarises the relative impact that different spatial configurations of multiple identical projects will have when compared with the target project's impact at 1 km. Each line represents a different kernel (i.e. source type) and/or pollutant. Each panel shows a different probability percentile. The results in the top left panel show the most likely situation (the 50th percentile). It highlights the high degree of consistency in the results when comparing different source types and pollutants when viewed in this way. Based on the 50% probability level, 50 in-combination projects would add between 4.4 and 5.5 times the maximum (at 1 km) contribution from a single target project. This range reflects:

- the initial dispersion characteristics of the source type (for example the initial plume rise from a bank of gas-fired power plant is very different to that from a dairy farm);
- the area over which the emission source is spread, which causes a distance 1 km from the centre to be different distances from the edge of the source; and
- the different rates at which NH_3 and NOx deplete from the plume.

Considering the large apparent differences between the different source types considered, this range is notably small.

The range grows at the higher percentile levels. These represent increasingly more pessimistic views on the spatial configurations which might arise in practice. 90% of potential spatial configurations result in increments smaller than those shown by the 90th percentile, with 10% of spatial configurations resulting in higher values. For the 95th percentile plot, just 5% of potential configurations result in higher increments than are shown.

The approach has been to take the 95th percentile results and to focus on the pollutant-specific maxima across all source types. These maxima are shown in Figure 19 and simply represent the upper lines from the bottom right panel in Figure 18. The maxima for NH_3 concentrations and nitrogen deposition relate to kernel 2, which is an agricultural source which is assumed not to emit NOx. Since nitrogen deposition is calculated from ambient concentrations and expressed in relative terms, the lines for nitrogen deposition and NH_3 are all the same (and thus some cannot be seen in the chart).

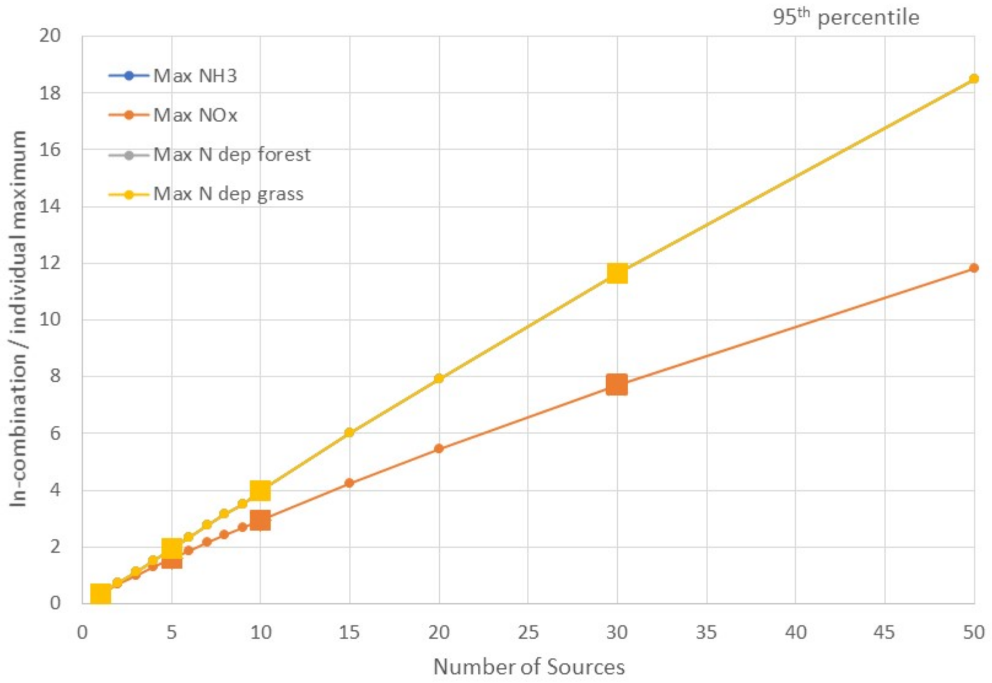

Figure 19: Relative Increase over Impact from Target project Caused by Multiple Identical Projects – Results from Maximum Kernel at the 95th Percentile (values for NH_3 and N dep to forest lie behind the line for N dep to grass – squares highlight values described in the text).

5.5 Deriving the Decision-Making Threshold

As explained in Section 4, the maximum number of additional new sources over a 13-year window, within 5 km of the target project, which fall under the DMT is 30. Furthermore, as explained in the first two paragraphs in Section 5.3, and further justified by the narrow range highlighted in the top left panel of Figure 18, it is not unreasonable to assume that all of the projects which fall under the DMT are identical. On this basis, the DMT can be calculated simply as:

DMT = OCC / (1+A)

Where ‘A’ is the value for 30 sources from Figure 19. This is simply because the combined impact from the target project plus 30 in-combination projects, at the 95th percentile probability level, is 1+‘A’, and the DMT is defined on the basis of 1+‘A’ being equal to the OCC.

By way of example, Figure 19 shows that ‘A’ for nitrogen deposition to forest is 11.62. 30 in-combination projects will thus add 11.6 times the increment of the target project alone. The total increment, including that of the target project, will be 12.62 times the increment of the target project alone. The total increment of these 31 projects is permitted to equal the OCC for nitrogen deposition to forest (0.17 kg-N/ha/yr). 0.17 kg-N/ha/yr divided by 12.62 = 0.013 kg-N/ha/yr. The DMT for nitrogen deposition to forest is thus 0.013 kg-N/ha/yr. All of the DMT values derived in this way are shown in Table 8

Table 8: Decision-Making Thresholds for On-site Emissions Sources.

	OCC	**DMT**
NH_3 (lichens/bryophytes) (µg/m^3)	0.010	0.00079
NH_3 (higher plants) (µg/m^3)	0.030	0.0024
Annual Mean NOx (µg/m^3)	0.12	0.014
N dep (woodland (kg-N/ha/yr)	0.17	0.013
N dep (grassland) (kg-N/ha/yr)	0.12	0.0093

5.6 Deriving Site-Relevant Thresholds

As explained in Section 4.4, few parts of the UK are expected to have as many as 30 in-combination projects falling under the DMT over 13 years within 5 km of a target project. It would therefore be unreasonable to apply the DMT to all new projects. Table 7 in Section 4 defines four alternative development density descriptors and provides the number of in-combination projects associated with each category. These alternative numbers of sources are reflected by the squares in Figure 19. Exactly the same approach as used to derive the DMT values has been repeated using the results in Figure 19 for fewer in-combination sources. The results are set out in Table 9. These represent the SRTs. It should be noted that the SRT for a high development density area is equal to the DMT. The SRTs for lower development density areas are less stringent, reflecting the smaller expected contribution from in-combination projects.

Table 9: Site-Relevant Threshold for On-site Emissions.

Development Density	**Very Low**	**Low**	**Medium**	**High**
Number of relevant in-combination projects assumed in deriving the SRTs	1	5	10	30
NH_3 (lichens/bryophytes) (µg/m^3)	0.0075	0.0034	0.0020	0.00079
NH_3 (higher plants) (µg/m^3)	0.022	0.010	0.0060	0.0024
NOx (µg/m^3)	0.087	0.046	0.030	0.014
N dep (woodland (kg-N/ha/yr)	0.13	0.057	0.034	0.013
N dep (grassland) (kg-N/ha/yr)	0.088	0.040	0.024	0.0093

6 Revising the Site-Relevant Thresholds

The OCC is based on a high-level prediction of change based on national trends and making a precautionary allowance for improvements implemented through the UK NAPCP. There is the potential to take account of local information on forecast or observed changes, so long as this can be demonstrated with sufficient certainty. In particular, where an approach is in place to deliver locally targeted measures to achieve the conservation objectives, the OCC value for the designated nature conservation site might reasonably be reviewed. Section 4.3 of the Guidance on Decision-making Thresholds document (Chapman & Kite 2021) explains how the OCC might, in practice, be reviewed to take account of local measures and considerations which are specific to a designated site.

Once a revised OCC has been confirmed, the DMT and SRT values can simply be scaled from those set out in Table 8 and Table 9, since the relationships between OCC and both the DMT and SRT are linear.

The calculation for this is very simple:

New DMT = New OCC x Old DMT / Old OCC

Or

New SRT = New OCC x Old SRT / Old OCC

For example, if a new OCC for nitrogen deposition to woodland were defined as 0.20 kg-N/ha/yr. The current OCC is 0.17 kg-N/ha/yr and the current DMT is 0.013 kg-N/ha/yr. Thus, the new DMT would be: 0.20 x 0.013 / 0.17 = 0.016 kg-N/ha/yr.

This linear relationship is based on the expected numbers of new projects over a 13-years period and so only holds if the revised OCC relates to improvements over a 13-year timeframe (although this could conceivably relate to a different 13 years (e.g. 2020 to 2033, etc.).

7 Road Traffic

As explained in Section 3, the DMTs for on-site emissions (Section 5) cannot be used for road traffic and an alternative approach is needed. This section sets out the proposed approach.

7.1 Characterising the Issues

7.1.1 Traffic Growth

Traffic volumes are predicted to increase on most UK roads over the period to 2030. There are many different causes of this growth, but most of it would be impossible without new plans or projects. New plans and projects are simultaneously a driver of, and a response to, both economic and population growth. Furthermore, each vehicle trip is made because there is both traffic production and traffic attraction[24]. Assigning the 'cause' of that trip to a single project, when viewed at a macro-level, becomes rather meaningless. In addition, it is debatable to what extent the refusal of permission for an individual project would affect traffic generation outside of a relatively limited area, since development which did not happen in one location might, instead, happen elsewhere. Nevertheless, a very large proportion of all traffic growth predicted on UK roads is associated, at some level, with new plans and projects, all acting in-combination with one another over a variety of different spatial scales.

The National Trip End Model (NTEM) provides forecasts of trip production and attraction in each of 7,700 zones in England, Scotland and Wales (in NTEM V7). These data are ultimately made available through the Trip End Model Presentation Program (TEMPro) system and they commonly underpin air quality assessments of traffic emissions. Figure 20 shows the scale of, and spatial variability in, growth forecasts for the period 2011 to 2031.

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[24] i.e. people are travelling *from* somewhere and *to* somewhere.

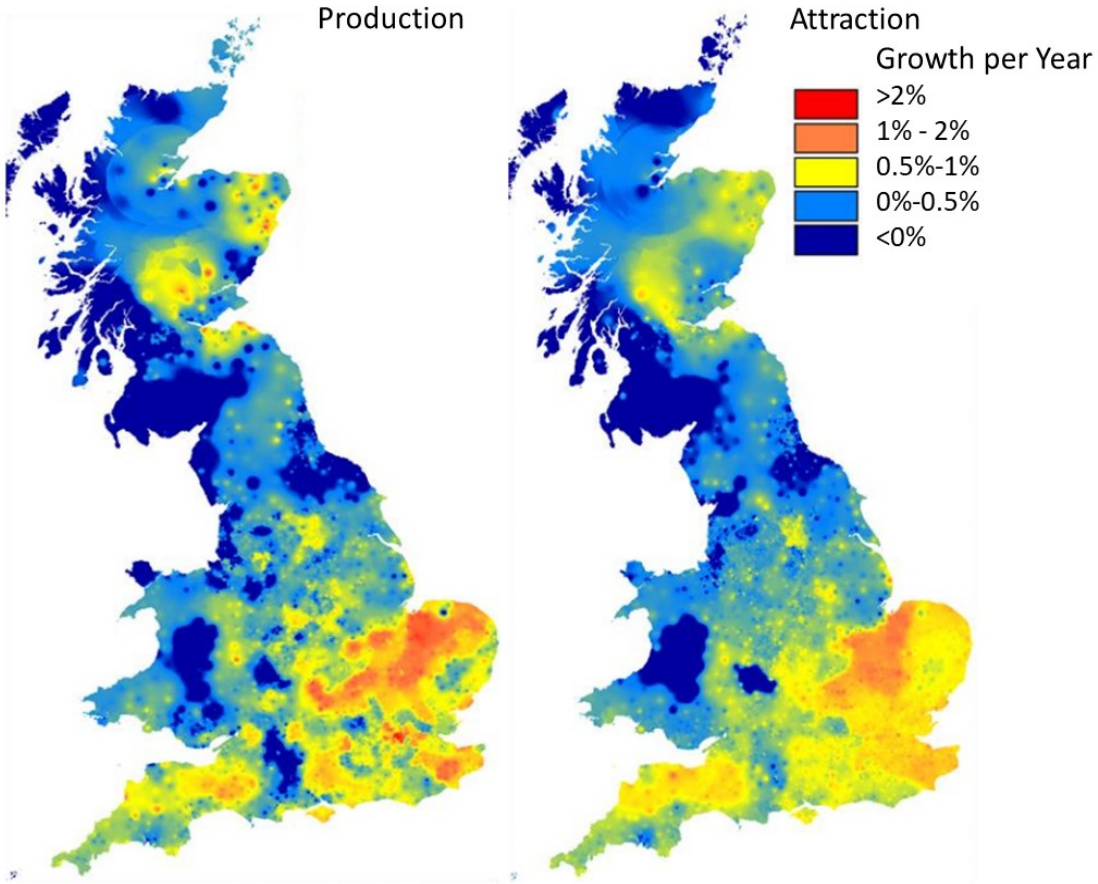

Figure 20: Forecast Annual Rates of Traffic Growth in England, Scotland and Wales 2011-2031 in NTEM V7 (Adapted from DfT 2016).

7.1.2 Emissions Modelling

The spatial patterns shown in Figure 20 have been used to identify 110 representative zones which capture the full expected range in traffic growth rates. The databases which underpin TEMPro have then been used to calculate traffic growth rates in these zones between 2017 and each of: 2020, 2022, 2024, 2025, 2027, 2029, and 2030.

7.1.2.1 Emissions of NOx

Defra's Emissions Factors Toolkit (V10.1) has been used to predict the relative change in emissions of NOx per average vehicle for a rural road using the 'basic split' of vehicle types and assuming:

- all roads in each of England (not London), Wales, Scotland, and Northern Ireland;
- Heavy Duty Vehicles (HDV) proportions of: 0%, 5%, 10%, 15% …. 100%; and
- average speeds of 15, 20, 75, and 80 kph.

This results in 336 alternative configurations within the EFT. Each configuration has been tested to calculate the relative change in NOx emissions per vehicle between 2017 and each of the years listed in the first paragraph in Section 7.1.2. The EFT results and TEMPro results have then been combined, allowing all combinations of traffic growth to combine with all combinations of changes to NOx emissions irrespective of geographical location. This generates several hundred thousand alternative forecasts. These forecasts cover the expected range for the relative rate of change to NOx emissions from roads across the UK, taking account of both the expected increase in traffic and the expected reduction in NOx emissions per vehicle. The results are summarised in Figure 21 as box and whisker plots.

It is reasonable to assume a direct linear relationship between the percentage change in NOx emissions from a road, and the percentage change in the contribution of that road to ambient NOx concentrations[25]. Thus, the relative change in road-specific NOx emissions may also be read as the relative change in the roadside increments of NOx concentrations. Figure 21 thus shows that the impact of road traffic on NOx concentrations will diminish in the future in all locations despite the anticipated growth in traffic caused by plans and projects acting in combination.

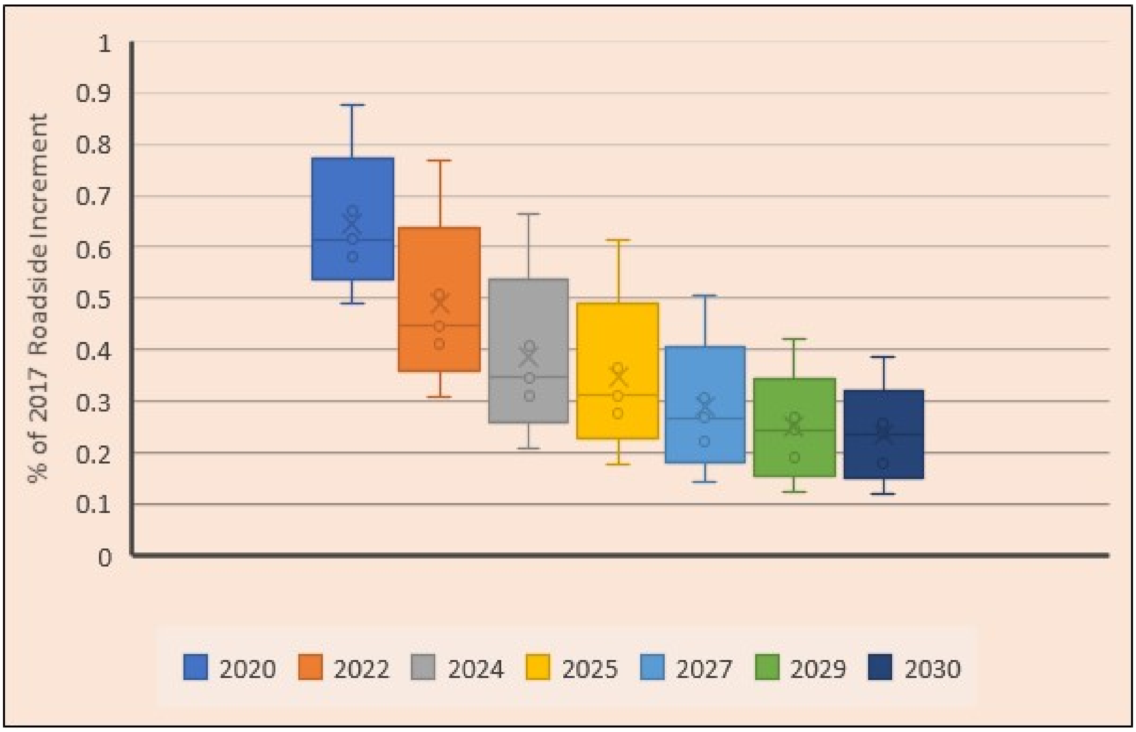

Figure 21: Relative Changes to Local Traffic-related NOx Concentrations taking account of All Growth rates in Figure 20 as well as Concurrent Forecast Emissions Reductions[26].

Figure 21 includes the range of eventualities which might reasonably be expected across all UK roads[27]. It does not, however, provide a fully representative indication of the probability of any one eventuality occurring. In particular, the mean HDV proportion on UK roads is significantly smaller than the mean proportion obtained by averaging across all scenarios which have been considered. This should be recognised when interpreting Figure 21.

Figure 21 also does not allow for any changes to vehicle speeds on a road which might be associated with increased traffic volumes. Figure 22 summarises results from the Department for Transport (DfT) (2021) showing the change in flow-weighted average speeds on locally managed A roads in England between 2017 and 2019. When averaged across all roads, there was no overall change in speed, but average speeds reduced on some roads

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[25] While changes to traffic volumes will affect the amount of wake-induced turbulence, and there are other mechanisms which might cause non-linearity, they are relatively trivial in this context.

[26] The horizontal line highlights the median, with the x showing the mean; the three dots show the 25th, 50th and 75th percentile's, with the box showing the extent between the 1st and 3rd quartiles. Finally, the whiskers show the maximum and minimum of the dataset.

[27] While traffic growth rates in Northern Ireland have not been included explicitly, there is no strong reason to expect them to fall significantly outside of the range determined for the other nations.

and increased on others. Only 23% of roads experienced a reduction in speed of more than 1 kph over this two-year period; and only 11% of roads saw a reduction of more than 2 kph. The relationship between flow volumes and speeds is not linear and so it is not possible to extrapolate from these data, but it seems reasonable to consider the possibility that average speeds might reduce by around 5 kph on an appreciable number of roads in the period to 2030.

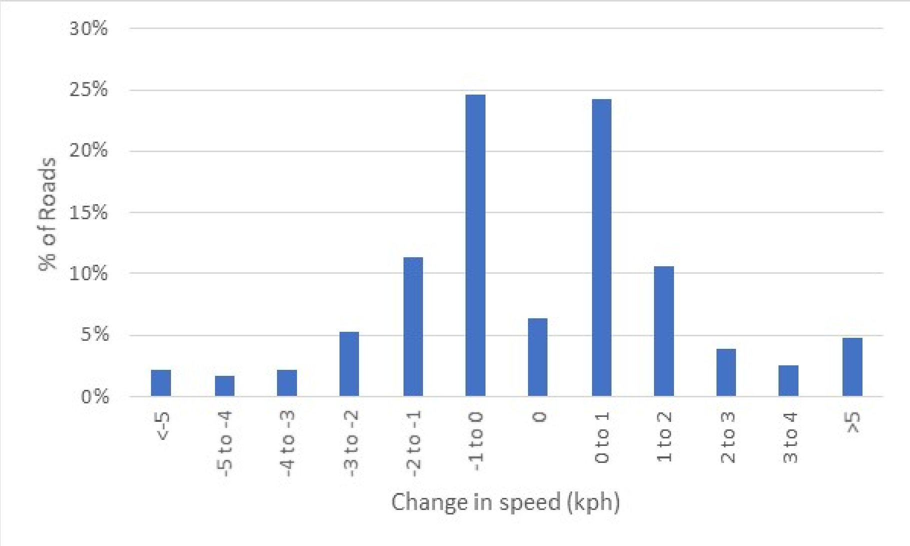

Figure 22: Change in Average Vehicle Speeds on Locally Managed 'A' Roads in England between 2017 and 2019.

The EFT results used in Figure 21 have also been used to examine the effect of reducing the average speed from 20 kph to 15 kph and from 80 kph to 75 kph. The results are summarised in Figure 23. These take account of all fleet configurations (including 0% and 100% HDVs) and all years, with each of these configurations given equal importance regardless of its likelihood of occurring in practice. A reduction in speed of 5 kph (at these two sets of speeds) might increase emissions by up to 35%, but this relates to the extreme and very rare situation of a road carrying 100% HDVs. In most cases, the increase in emissions is predicted to be less than 20%. This is only a very crude and indicative analysis[28], and these results have not been explicitly fed into the analysis presented in Figure 21 (particularly since on average there may be no net change in speeds). However, it is reasonable to consider that the reductions presented previously in Figure 21 might be appreciably smaller if traffic congestion increases notably in the future. There is, however, no reason to suspect that the net improvements to 2030 in Figure 21 would become net disbenefits.

28 Since the results from this analysis are only used qualitatively, the calculations have not been tailored to represent actual vehicle fleets or other speed ranges.

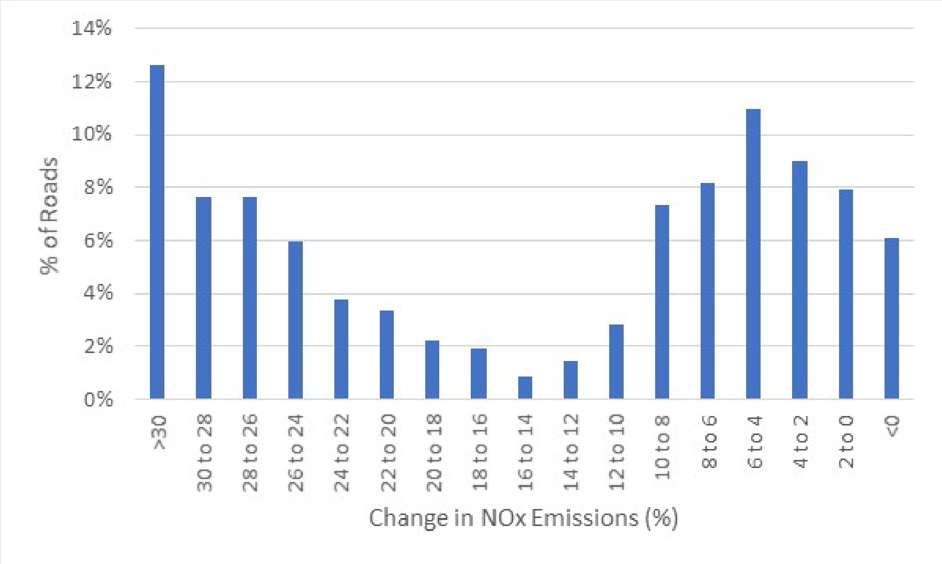

Figure 23: Change in NOx Emissions Caused by a 5 kph Reduction in Speed Across all Different Vehicle Fleets Described in the first Paragraph of Section 7.1.2.1.

The overriding message from the analysis of NOx emissions is that traffic-generated NOx concentrations alongside roads are predicted to fall appreciably in almost all locations irrespective of the in-combination effect of all anticipated plans and projects across the UK. This conclusion is unsurprising since it matches the findings of very many detailed air quality assessments carried out to support planning applications.

The predicted improvements are being brought about by extensive international programmes to reduce NOx emissions from road vehicles. These have been implemented principally because of the effects of NO_2 on human health. Very stringent European type approval standards are in place to limit NOx emissions from new vehicles. This means that, as these vehicles are bought and older vehicles are used less, roadside NOx concentrations will fall. While there were many years during which the type approval process did not result in significant real-world benefits, this has now changed and the clear result of the tightening Euro standards has been recorded in roadside measurements (AQC 2020b). This demonstrates an effective approach is now in place to mitigate and control traffic-related air pollution which acts at a strategic level. These improvements will be further enhanced by the increasing measures to introduce electric vehicles into the fleet.

7.1.2.2 Emissions of NH_3

The forecasts for NOx emissions which are available through the EFT are based on a large amount of information collected over a long period of time; largely reflecting the perceived importance of NO_2 concentrations to human health. Although potentially problematic for biodiversity, typical ambient concentrations of NH_3 are not known to have any direct effects on human health. Because of this, there has been appreciably less interest in NH_3 emissions from vehicles, and this is reflected in the relative paucity of comprehensive and robust information on these emissions. There is a wide range in different published forecasts for NH_3 emissions, and all of these forecasts are subject to considerable uncertainty (AQC 2020c). At the present time it is not possible to predict future NH_3 emissions from traffic with the same confidence that can be applied to NOx predictions.

Defra's EFT does not predict NH_3 emissions. The 1 km x 1 km modelling carried out for the Nitrogen Futures project assumed a 4% reduction in traffic-related ammonia emissions between 2017 and 2030 on all roads, which was based on the UK's historical submissions to the European Commission under the NECD. The current National Atmospheric Emissions

Inventory (NAEI) predicts a slight upward trajectory over the same period. To accompany the 1 km x 1 km data, modelling for the Nitrogen Futures project also provided more detailed local calculations based on the Calculator for Road Emissions of Ammonia (CREAM V1A) (AQC 2020d). For most typical vehicle fleets, this predicts a more substantial upward trajectory in NH_3 emissions from road vehicles (taking account of traffic growth and growth in emissions per vehicle).

CREAM does not differentiate emissions by vehicle speed but otherwise accepts the same input data as the EFT. The same approach described above for NOx (Section 7.1.2.1) has thus been used to predict the combined effect of forecast changes to traffic volumes over time and forecast changes to NH_3 emissions per vehicle. The results are summarised in Figure 24. Unlike the NOx forecasts, which were universally downward, these projections are universally upward. This suggests that the combined effect of traffic growth and emissions changes may cause significant disbenefits in terms of roadside NH_3 concentrations.

As explained earlier in this subsection, the evidence-base which underpins Figure 24 is much smaller than that of the equivalent figure for NOx. This scale of increase cannot, therefore, be considered certain. In practice, emissions of NH_3 may fall over this period rather than increase, but there is not enough information to be able to state this with any confidence.

The example of NOx has shown that strategic-level mitigation can be effective in reducing emissions from road traffic. However, there has been little political pressure to reduce NH_3 emissions from most vehicles and so equivalent strategic mitigation is not currently in place.

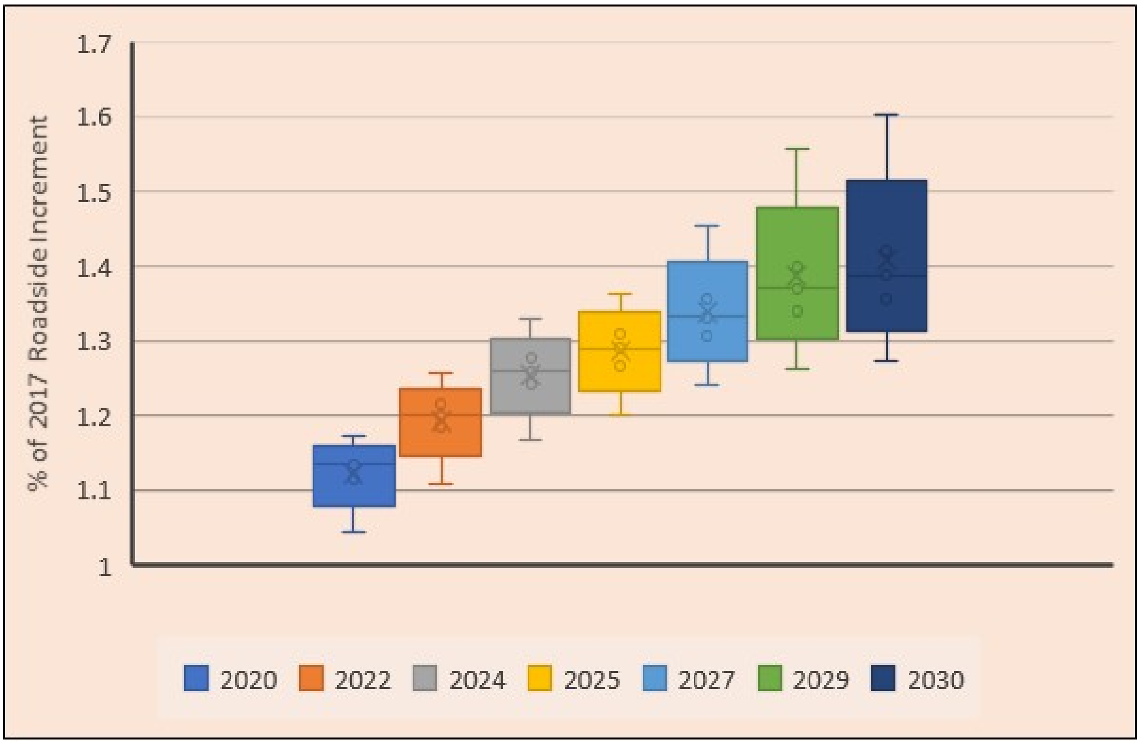

Figure 24: Relative Changes to Local Traffic-related NH_3 Concentrations taking account of All Growth rates in Figure 20 as well as Concurrent Forecast Emissions Changes[26].

7.1.2.3 Roadside Nitrogen Deposition

The increment of NOx from local traffic (Figure 21) and the increment of NH_3 from local traffic (Figure 24) will combine to create the increment of nitrogen deposition from local traffic. NO_2 has been calculated from NOx assuming an annual mean quotient of 60%, which is fairly typical for near-road locations (although in practice, this quotient can vary appreciably). The same deposition velocities shown in Table A3.4 (Appendix A3) have then been applied to all NO_2 (NOx) and NH_3 predictions described above. The fact that the results in Figure 21 and Figure 24 are *relative* changes does not preclude this approach. The relative changes have simply been combined using the NO_2:NOx quotient and deposition velocities as relative weightings so as to determine the relative change in deposition fluxes over time. All of the relative changes in NOx and NH_3 concentrations have first been used to calculate the relative changes in nitrogen deposition to short vegetation and then used again to calculate the relative changes in nitrogen deposition to woodland. The results for both habitats types are combined in the top panel of Figure 25. The bottom panel of Figure 25 shows the equivalent results if total traffic-related NH_3 emissions are held constant over time. This is to reflect the added uncertainty in the NH_3 predictions.

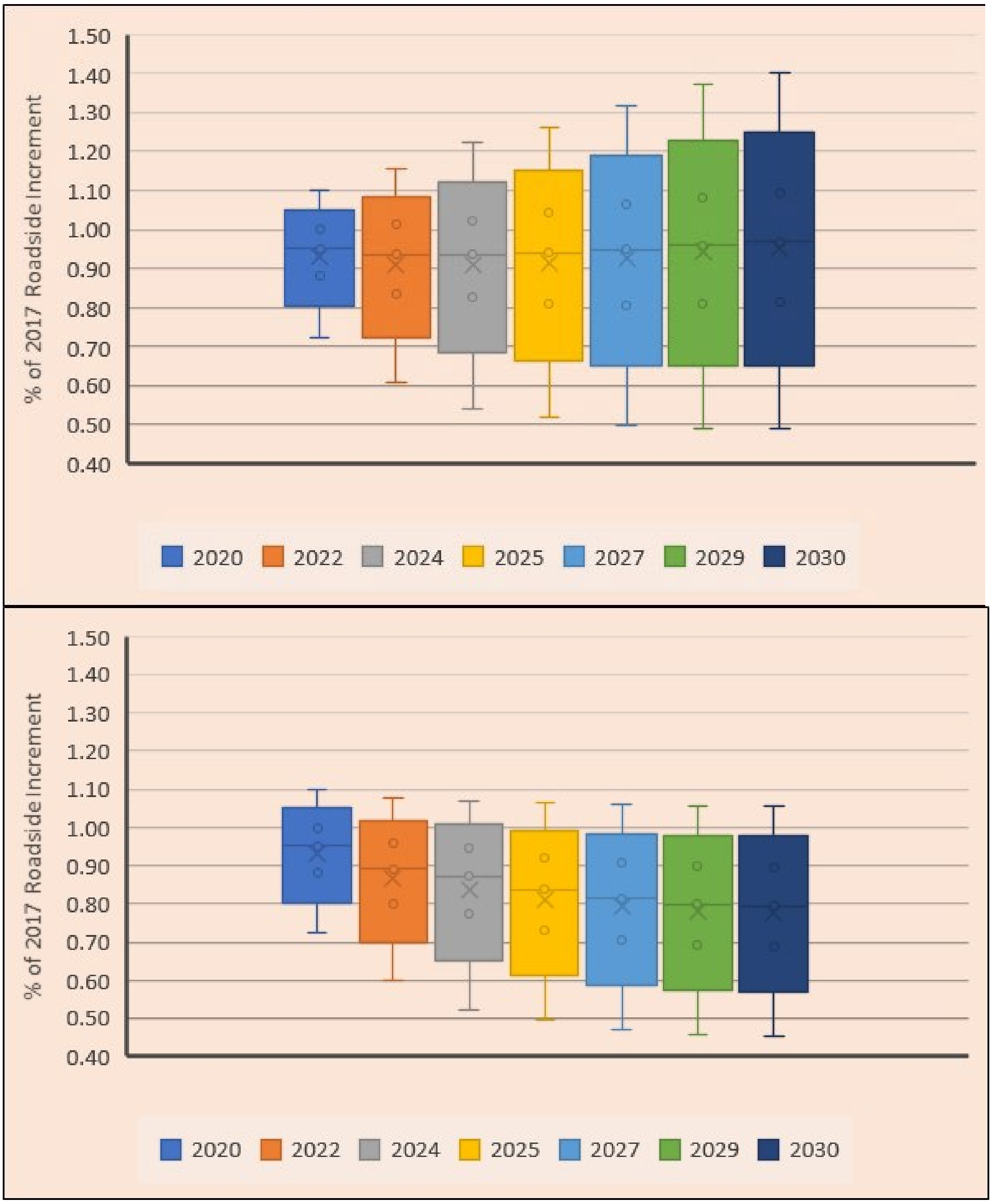

Figure 25: Relative Changes to Local Traffic-related Nitrogen Deposition of All Growth rates in Figure 20 as well as Concurrent Forecast Emissions Changes – Top assuming NH_3 per vehicle changes according to the CREAM model and Bottom assuming total traffic-NH_3 does not change over time.[26].

On average, the contribution of road traffic to nitrogen deposition (and thus, all other things being equal, total nitrogen deposition at the roadside) is predicted to fall between 2017 and 2030 irrespective of which of the two sets of NH_3 forecasts is used (i.e. roadside increments are on average all <1.00). However, if the forecasts predicted by the CREAM model are realised, then there will a net upward trajectory in nitrogen deposition at an appreciable number of roadside locations. On the other hand, if NH_3 emissions per vehicle do *not* increase over time, then the vast majority of roadside locations will see a net improvement regardless of the expected increase in traffic over this period.

7.1.3 Potential for Project-driven Mitigation

As explained in Section 7.1.1, traffic flows are forecast to increase on the majority of UK roads as a result of all UK plans and projects interacting with one another. While it is possible to identify the effect that any one plan or project is having on traffic volumes, it is unusual for this increment to dominate the total predicted growth in traffic. Traffic growth associated with a single plan or project only rarely contributes a major part of the overall forecast change on a road. This limits the overall effect that most available mechanisms for project-specific mitigation might have. For example, reducing the emissions from traffic generated by a single project (such as though parking standards) only has the potential to act on the new vehicles generated by that project; which might only represent a small fraction of the total expected traffic growth. Clearly, any adverse impact is potentially problematic, and any beneficial impact is likely to be welcome, but if resources are limited then focusing on strategic-level mitigation for road traffic emissions is likely to be more effective than focusing on small individual developments.

Effective strategic level mitigation is most appropriately applied at either international/national level[29], or at the regional/local government level[30]. The Guidance on Decision-making Thresholds document (Chapman & Kite 2021) (Section 5) thus explains that the focus, for road traffic, is on strategic-level plans. It explains that, where a full Habitats Regulations Assessment (HRA) of a strategic development plan has been carried out, then so long as the target project has been adequately included in that HRA, then there is no need for additional assessment. Where no such HRA has been carried out (or where it has either not been carried out in sufficient detail or does not adequately include the target project) then a project specific HRA is still likely to be required. The following section details how a DMT might be defined to cover the need for such more detailed assessment.

7.2 Defining a DMT for Road Traffic

In order to facilitate decisions at a non-strategic (planning) level, this section identifies a DMT value to be used for individual projects. Further to the analysis presented above, the DMT for traffic is defined based on the degree to which each individual project contributes to the overall in-combination impact (and thus the degree to which measures for the individual project might meaningfully contribute to mitigating the in-combination impact).

It is considered most appropriate to define a DMT based on vehicle numbers rather than on roadside concentrations or fluxes. The DMT may then be defined as a proportion of the increase in traffic, on any particular road, which is predicted without that project. In those locations experiencing appreciable development pressure, with lots of plans and projects coming forward, it is appropriate for the DMT to reflect only a very small percentage of the total forecast increase in traffic. Conversely, in locations where development pressure is lower, and fewer in-combination projects are expected, then the criterion may be loosened.

In practice, the most useful indicator of development pressure with respect to increases in traffic are the NTEM and TEMPro data which are usually used to define the traffic growth. This introduces an element of circularity which is discussed further below.

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[29] for example, emissions standards for roads vehicles or the realisation of policies to prevent the sale of petrol, diesel, and hybrid vehicle.

[30] For example, the strategic-level mitigation package which was proposed for the 2018 Submission Wealden Local Plan and that proposed for the Epping Forest Local Plan. It is recognised that both of these packages have potential issues regarding either the efficacy of certain measures, or their funding mechanism, but this does not mean that the overall approach is inappropriate.

Following detailed discussions within the project team, it was determined that in those areas where development pressure is high (e.g. where traffic increases by 3% per year), a project-specific increment of 1% of the total traffic generation over a 5 year period[31] provides a sufficiently-precautionary basis for setting a DMT value (i.e. such a project is only contributing 1% to the in-combination impact and thus unlikely to contribute more than 1% to any required mitigation of that impact). Where development pressure is half of this level (1.5% per year), then a value of 2% of the 5-year total growth may be used. Where development pressure is low (e.g. where traffic increases by 0.3% per year) then a project-specific increment of 10% of the 5-year total growth is appropriate. The values of 1%, 2% and 10% were defined subjectively through discussion with the wider project team.

Because of the circularity mentioned earlier in this subsection, all of the values mentioned in the previous paragraph can be expressed as a single percentage of the existing baseline traffic flow. This is shown in Table 10. Where traffic is forecast to increase by 3% per year, then a DMT of 1% of the 5-year total growth represents 0.15% of the existing Annual Average Daily Traffic (AADT). Similarly, where traffic is forecast to increase by 0.3% per year, then a DMT of 10% of the 5-year total growth also represents 0.15% of the existing AADT on a road[32]). **The proposed approach is thus to apply a single DMT of 0.15% of the existing AADT.** This should be the AADT in the year when the assessment is carried out (i.e. not a historic base year or future year).

Clearly, the practical implications of this DMT will be very different for a project which generates an atypical fleet mix (e.g. a distribution depot) but this does not prevent its use or undermine the justification for such an approach described above. Similarly, where forecast traffic growth rates are >3% per year or <0.3% per year then the allowed increment as a proportion of the 5-year total growth will be <1% and >10% respectively. The DMT is nevertheless set at 0.15% of the existing AADT. By way of example, for a road with an existing AADT flow of 10,000 veh/day the DMT flow for a project affecting this road would be 15 veh/day; if the impact of a project on this road is an AADT increase of less than 15 veh/day then this road would be screened out of the need for further assessment.

As explained in the final paragraph of Section 7.1.3 and the first paragraph of Section 7.2, the DMT is not intended for use in strategic-level assessments. It should, not, therefore, be used to set the spatial boundary to strategic-level assessments[33].

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31 A reasonable timeframe to expect a new strategic development plan to be developed.

32 The AADT on a road refers to the total traffic flow, not the increment due to the target project.

33 Section 5.5 of the Guidance on Decision-making Thresholds document (Chapman & Kite 2021) explains that a spatial boundary of 10 km from a local authority boundary provides an appropriate spatial limit on assessments at a strategic level. For the reasons presented in Section 3 of the current report, distant from a development boundary, the precise location of that development becomes unimportant, and a designated site can be expected to be affected by national-level growth regardless of precisely where that growth occurs.

Table 10: Traffic DMT in Alternative Development Pressure Settings.

Description	Traffic Growth per Year	Traffic Growth over 5 Years	Threshold as % of 5-years Growth	Threshold as % of Existing AADT (DMT)
High Development Pressure	3%	15%	1%	0.15%
Medium Development Pressure	1.5%	7.5%	2%	0.15%
Low Development Pressure	0.3%	1.5%	10%	0.15%

7.3 Road-Relevant Approaches for Road Traffic

As explained in the Guidance on Decision-making Thresholds document (Chapman & Kite 2021) (Section 5.7), there are situations where practitioners and regulators may find it helpful, without the need for bespoke modelling, to understand the scale of changes to concentrations and fluxes that might be expected from any given increase in traffic flow and at different distances from roads. There are considerable uncertainties when making such predictions using models, and models which use Defra's official emissions factors typically require adjustment based on verification against measurements to characterise more accurately real-life. Models also require a suite of input information[34] which needs to represent likely real-world conditions. The approach used here has thus been to derive relationships directly from suitable measurements. This means that the relationships are influenced by the conditions at the specific monitoring sites which have been used, but they are nevertheless expected to provide robust and representative, albeit indicative, information which will often be better than a detailed model if that model has not been verified against measurements. Further details of the approach are given in Appendix A5.

In practice, Defra's forecasts, and those upon which other sections of this report rely, predict that the effects of local traffic will change over time as emissions of NOx fall and emissions of NH_3 either fall or rise. Because this analysis is based on measurements, it reflects the situation in the year that those measurements were made. For NOx, this is 2019 and for NH_3 and nitrogen deposition it is 2015; these being the most recent year with good quality published measurements.

Table 11 shows the changes in concentrations and fluxes that (in 2019 and 2015) could reasonably be expected from an increase of 1,000 AADT on a typical road. These may simply be scaled to represent alternative increases in traffic flows; for example, an increase of 100 AADT would result in an impact 1/10th of the values shown in Table 11[35]. Table 12 and Table **13** use these values to show the increase in traffic which would give rise to an increase of 1% or more of a critical level or critical load, which is a familiar statistic to many practitioners, although not recommended through the current work.

[34] For example, average speed, fleet composition, road gradient, etc.
[35] Effects of vehicle-wake-induced turbulence are not included in these figures.

Table 11: Change in Concentrations and Fluxes for an example Change in Flow of 1,000 AADT in a Typical Vehicle Fleet.

Distance from Road Edge (m)	Annual Mean NOx (µg/m³)	Annual Mean NH_3 (µg/m³)	N Dep to Forest (kg-N/ha/yr)	N Dep to Short Vegetation (kg-N/ha/yr)
1	2.5	0.109	1.41	0.85
5	1.8	0.039	0.58	0.34
10	1.1	0.025	0.40	0.23
25	0.55	0.014	0.24	0.14
50	0.33	0.0087	0.16	0.095
100	0.19	0.0056	0.11	0.064
150	0.12	0.0043	0.090	0.051
200	0.093	0.0036	0.077	0.043

The values in Table 12 and Table 13 may appear low to ecology specialists who are familiar with Natural England guidance which equates 1,000 AADT with a change of 1% of the critical loads (Natural England 2018)[36] but they are in line with those that air quality specialists usually derive in their assessments (see Appendix A5.In any event, since they are based on measurements, they can be considered more certain than many modelling-based results. How these values might be used is described in Section 5.7 of the Guidance on Decision-making Thresholds document (Chapman & Kite 2021).

36 The 1,000 AADT criterion used in the Design Manual for Roads and Bridges is justified on the basis of traffic model precision (for models typically used to assess strategic-level highways schemes) and not in relation to an acceptable quantum of environmental change.

Table 12: AADT Change (for a typical fleet composition) Required to Cause a Change of 1% of Critical Levels as a Function of Distance from the Edge of a Road.

Distance from Road Edge (m)	1% of CL for NOx (30 µg/m³)	1% of CL for ammonia (1 µg/m³)	1% of CL for ammonia (3 µg/m³)
1	120	91	274
5	171	259	776
10	278	405	1,214
25	547	731	2,194
50	917	1,145	3,434
100	1,620	1,791	5,372
150	2,410	2,327	6,980
200	3,242	2,802	8,406

Table 13: AADT Change (for a typical fleet composition) Required to Cause a Change of 1% of Critical Loads as a Function of Distance from the Edge of a Road.

Distance from Road Edge (m)	1% of CL (5 kg-N/ha/yr)	1% of CL (10 kg-N/ha/yr)	1% of CL (15 kg-N/ha/yr)	1% of CL (20 kg-N/ha/yr)
Deposition to Woodland				
1	35	71	106	142
5	86	171	257	343
10	125	251	376	502
25	207	415	622	829
50	303	606	909	1,212
100	443	887	1,330	1,773
150	554	1,108	1,661	2,215
200	648	1,297	1,945	2,594
Deposition to Short Vegetation				
1	59	118	177	236
5	145	291	436	582
10	215	429	644	858
25	359	717	1,076	1,434
50	529	1,058	1,587	2,116
100	780	1,561	2,341	3,121
150	980	1,959	2,939	3,918
200	1,151	2,302	3,453	4,604

8 Uncertainty and Limitations

8.1 Source of Uncertainty

The principal sources of uncertainty regarding the OCCs, DMTs and SRTs which have been set are described below. To aid interpretation, each point has been assigned a qualitative description of how likely it is to occur (‘high’, ‘medium’, or ‘low’), as well as the implications that this would have in terms of the degree of change to the DMT and SRT values (‘major’, ‘moderate’, or ‘minor’)[37]. These qualitative descriptors have been assigned based on professional judgement. It is not possible to quantify the overall uncertainty associated with the outcomes of this study. The subsequent section comments on uncertainty with respect to the requirements of this project.

8.1.1 Setting the OCC

- If the measures which are assumed to be introduced by 2030 (i.e. 25% of those needed by the NAPCP) are not delivered, the OCCs will have been over-predicted. The likelihood is judged to be **low** and the implications **moderate**.
- If the measures which are implemented do not deliver the air quality benefits which have been predicted, the OCC’s will have been over-predicted. The likelihood is judged to be **high** and the implications **moderate**.

8.1.2 Setting the DMTs and SRTs for on-site Emissions

- If the spatial distribution of the forecast improvements has been misrepresented, then there will be locations where insufficient protection is potentially being provided. Furthermore, if the 10% of the UK where the forecast changes are smaller than those on which the OCC has been based are co-located with areas where development pressure is highest, then the DMT will be overpredicted (making them insufficiently precautionary). In practice, this is an inevitable outcome of the approach which has been taken of using statistics aggregated at a national level to relate to location-specific conditions. The likelihood of it happening in some locations is thus **high**. The implications, as a national average are expected to be **minor** (but for an individual habitat may be **major**).
- If the projects which are excluded from setting the DMTs (e.g. domestic combustion) make an appreciable net contribution to adverse impacts then the DMTs will have been overpredicted. The likelihood of this occurring is judged to be **low** and the implications are **minor**.
- The OCC is defined as the total magnitude of change which will not undermine the achievement of the conservation objectives. However, all of this change has been allocated to those projects which fall under the DMT. Those projects which fall above the DMT, and thus require a bespoke in-combination assessment, will nevertheless inevitably have emissions to air, which means that the total change (combining the projects below the DMT with those above it) will often be greater than the OCC. The projects which fall under the DMT thus form part of a total in-combination change which may have a significant effect on the designated site. This seems inevitable and so the likelihood is judged to be **high**. It is understood that this fits into the overall

[37] These descriptors relate to the relative effects that different parts of the study will have on the DMT and SRT values themselves. The descriptors do not describe effects on ecosystems or risks to meeting the conservation objectives of any designated site. Furthermore, these descriptors do not contradict the statement in at the end of Section 8.2, that DMTs and SRTs are based on the best information available, thus making them appropriate for use in decision-making.

requirements for an HRA**Error! Bookmark not defined.** and so the implications have not been classified.

- If there are areas where more than 30 new projects below the DMTs fall within 5 km of a target project then the DMTs will have been overpredicted. The likelihood is judged to be **low** and the implications (for an individual project) **moderate**.
- The dispersion modelling is based on six example projects and five years of meteorology from a single monitoring station. If additional dispersion kernels or meteorological datasets had been used, then a greater range in results would have been predicted. While this is a necessary limitation to the study, because the DMTs and SRTs have been based on the maximum across all scenarios, it is highly likely that using a larger dataset would increase these maxima. However, for the very reason that the DMTs and SRTs are based on maxima, they are expected to be worst-case in the majority of cases. Thus, the likelihood is judged to be **high** and the implications **minor**.
- The 'size' of all in-combination projects is based on them having an equal potential to breach the DMT after setting a spatial constraint that the target project is at least 1 km from a designated habitat. In practice, the different in-combination projects might be positioned such that they may fall under the DMT while still contributing more than has been assumed at the specific location of interest to the target project. In practice, by using the 95th percentile of possible spatial configurations, the risk of this is mitigated. The likelihood of this occurring is judged to be **high** but the implications are judged to be **minor**.
- The distribution of potential projects has been taken as random, meaning that all locations within a 5 km radius of the target project have an equal potential to be developed. In practice, the distribution of new projects is influenced by local constraints, including the presence of a designated nature conservation site. This means that the potential for numerous projects to be developed in the same orientation from the designated site will, in many cases, have been under-predicted. As above, by using the 95th percentile of possible spatial configurations, the risk of this is largely mitigated. The likelihood of this occurring is judged to be **high** but the implications are judged to be **minor**.
- Notwithstanding the two previous points, the DMTs and SRTs are based on the 95th percentile of possible spatial configurations. There is thus a 5% chance that any one real-life configuration has been missed. The likelihood is judged to be **low** and the implications are also judged to be **minor**.

8.1.3 Setting the DMT for Road Traffic

- The DMT for road traffic has been set subjectively, based on an analysis which shows the relative unimportance of individual small increments of traffic generation in the context of wider, much larger, forecast increases in traffic, together with concurrent changes to emissions per vehicle. Because they were determined subjectively, there is no chance that these values are demonstrably 'wrong'. There remains, however, a **high** likelihood that small increments caused by individual projects will be exempted from further assessment despite contributing to the wider in-combination changes. The implications, for any individual project which falls below the DMT, will be **minor**.

8.2 Context for Uncertainty

Article 6(3) of the Habitats Directive explains that "authorities shall agree to [a] plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned". The courts have further explained that: "The competent authority must be certain that the plan or project in question will not adversely affect the integrity of the site concerned"[38] and that there should be "no reasonable scientific doubt" as to the absence of such effects[39]. Furthermore, an appropriate assessment "cannot have lacunae and must contain complete, precise and definitive findings and conclusions capable of removing all reasonable scientific doubt as to the effects of the works proposed on the protected site concerned"[40].

This has previously been interpreted by many parties as requiring a level of certainty that is challenging, if not often impossible, for air quality modelling to meet. In particular, this certainty requirement has been invoked with respect to predicted air quality improvements over time due to autonomous measures and the reliance upon these to excuse negative effects of new development: "*it is only when it is sufficiently certain that a measure will make an effective contribution to avoiding harm to the integrity of the site concerned, by guaranteeing beyond all reasonable doubt that the plan or project at issue will not adversely affect the integrity of that site, that such a measure may be taken into consideration*"[41]. As explained in Section 2.2, the level of uncertainty which accompanies forecasts of future air quality improvements is typically very large, and much greater than that associated with predictions of adverse effects caused by individual projects.

However, in Section 2.3 of the Guidance on Decision-making Thresholds document, DTA Ecology explain in detail the overriding need for pragmatism and how the courts have shown that practical and pragmatic decisions are needed in order to avoid legislative overkill (Chapman and Kite, 2021). Local air quality modelling is never associated with a definitive quantification of uncertainty. Instead, the focus is on making reasonable best estimates, accepting that the true value may be either higher or lower than the prediction but that this should be without bias.

Helpful context regarding the certainty requirements of the Habitats Regulations with respect to air quality modelling of future growth was provided by the Examination in Public of the 2018 Submission Wealden Local Plan. In spite of evidence that local measurements did not reflect nationally forecast improvements, the Planning Inspectorate nevertheless concluded that predicted forecasts based on nationally agreed emissions factors (which account for measures which are already in place or which can reasonably be relied upon to be in place) provide an adequate basis upon which to assess the anticipated effects of future development. The Planning Inspectorate had regard to advice from Natural England in coming to this position.

As explained above, it is not possible to quantify the overall uncertainty associated with the DMTs and SRTs and professional judgement is necessary. The lead author of the current report also led the emissions forecasts which were used by, and which Natural England said should have been used by, Wealden District Council. He was also involved with the Nitrogen Futures modelling. It is his professional judgement that the overall uncertainty associated with the modelling which underpins the OCC, DMTs and SRTs is no greater than the uncertainty in the model scenarios which Natural England recommended for use in relation to the Wealden Local Plan. On that basis, the uncertainty associated with this project is considered not to preclude the use of the DMTs and SRTs for assessments in relation to the Habitats Regulations.

All models have uncertainty, and it is not practical to defer all decision-making because of this. Section 2.2 of the Guidance on Decision-making Thresholds document (Chapman &

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[38] CJEU Case C-127/02 (Waddenzee) Judgement paras 56-57.
[39] CJEU Case C-127/02 (Waddenzee) Judgement para 59.
[40] Case C-258/11 (Sweetman) Judgement para 44.
[41] Cases C-293/17 and C-294/17 (Dutch Nitrogen Ruling) para 126.

Kite 2021) explains that decision-making should be informed by best available information. The DMTs and SRTs are underpinned by the best information which is available at the current time.

9 Conclusions

The OCCs, DMTs, and SRTs are underpinned by extensive modelling and thus provide an evidence base for decision-making in relation to the need to consider air quality impacts on designated nature conservation sites. The final criteria for use are set out in Table 14 and Table 15. Where better information regarding the national or local rate of change is available, then the DMTs and SRTs may be adjusted following the approach given in Section 6.

Table 14: Decision-Making Thresholds.

Category		**OCC**	**DMT**
On-site Emissions	Annual Mean NH_3 (lichens/bryophytes) ($\mu g/m^3$)	0.010	0.00079
	Annual Mean NH_3 (higher plants) ($\mu g/m^3$)	0.030	0.0024
	Annual Mean NOx ($\mu g/m^3$)	0.12	0.014
	Annual Mean N dep (woodland (kg-N/ha/yr)	0.17	0.013
	Annual Mean N dep (grassland) (kg-N/ha/yr)	0.12	0.0093
Road Traffic	Increase in Traffic Flow		0.15% of AADT in the year that the assessment is carried out

Table 15: Site-Relevant Thresholds for On-site Emissions.

Development Density	Very Low	Low	Medium	High
Description	Remote area which sees very little developme nt	Area which sees small amounts of developme nt	Typical agriculture / industrial area	Area experiencin g intensive growth (e.g. Powys or Immingham docks)
Example Number of *additional new* projects below the DMT within 5 km of proposed development over 13 yrs [a]	1	5	10	30
Site-Relevant Thresholds				
Annual Mean NH_3 (lichens/bryophytes) ($\mu g/m^3$)	0.0075	0.0034	0.0020	0.00079
Annual Mean NH_3 (higher plants) ($\mu g/m^3$)	0.022	0.010	0.0060	0.0024
Annual Mean NOx ($\mu g/m^3$)	0.087	0.046	0.030	0.014
Annual Mean N dep (woodland (kg-N/ha/yr)	0.13	0.057	0.034	0.013
Annual Mean N dep (grassland) (kg-N/ha/yr)	0.088	0.040	0.024	0.0093

[a] These might be either industrial or agricultural projects, or both.

Where a project exceeds the SRT (for on-site emissions) then it is expected that a bespoke in-combination assessment will be required. Where the DMT for road traffic is exceeded then it may be appropriate to consider the need for an in-combination assessment on a case-by-case basis, which might be informed by the distance from road relationships set out in Table 11 in Section 7.

In applying these criteria, it should be noted that:

- the SRTs for on-site emissions should be applied to the maximum predicted impact predicted anywhere within the designated nature conservation site;
- a list of important exclusions, for cases where the SRTs are considered to provide insufficient protection, has been provided by Chapman and Kite (2021); and
- the application of the DMT for road traffic is not intended for use in the context of strategic development plans (where a bespoke in-combination assessment is always expected to be required).

The Guidance on Decision-making Thresholds document (Chapman & Kite 2021) further advises that increases of traffic flows on roads which form part of the strategic network also need to be dealt with at a strategic level. Full details of how the criteria defined in this report should be applied is provided in guidance by Chapman and Kite (2021).

10 References

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11 Appendices

A1 Professional Experience

Dr Ben Marner, BSc (Hons) PhD CSci MIEnvSc MIAQM

Dr Marner is the Director of Air Quality Modelling and Assessment at AQC and has over 20 years' relevant experience. He has been responsible for air quality and greenhouse gas assessments of road schemes, rail schemes, airports, power stations, waste incinerators, commercial developments and residential developments in the UK and abroad. He has acted as expert witness at public inquiries, where he has presented evidence on health-related air quality impacts, the impacts of air quality on sensitive ecosystems, and greenhouse gas impacts. He has developed a range of widely used air quality models and contributed to the development of best practice. Dr Marner has provided support and advice to foreign governments, Highways England, Transport Scotland, Transport for London, Greater London Authority, the Joint Nature Conservation Committee, the Environment Agency, and numerous local authorities. He is a Member of the Institute of Air Quality Management and a Chartered Scientist. Since 2016, he has advised the UK Government on air quality as part of its Air Quality Expert Group (AQEG), where his specific area of expertise relates to air quality assessment in the development control process.

Prof. Duncan Laxen, BSc (Hons) MSc PhD MIEnvSc FIAQM

Prof Laxen is an Associate of Air Quality Consultants, a company which he founded in 1993. He has over 40 years' experience in environmental sciences and has been a member of Defra's Air Quality Expert Group and the Department of Health's Committee on the Medical Effects of Air Pollution. He has been involved in major studies of air quality, including nitrogen dioxide, lead, dust, acid rain, PM_{10}, $PM_{2.5}$ and ozone and was responsible for setting up the UK's urban air quality monitoring network. Prof Laxen has been responsible for appraisals of all local authorities' air quality Review and Assessment reports and for providing guidance and support to local authorities carrying out their local air quality management duties. He has carried out air quality assessments for power stations; road schemes; ports; airports; railways; mineral and landfill sites; and residential/commercial developments. He has also been involved in numerous investigations into industrial emissions; ambient air quality; indoor air quality; nuisance dust and transport emissions. Prof Laxen has prepared specialist reviews on air quality topics and contributed to the development of air quality management in the UK. He has been an expert witness at numerous Public Inquiries, published over 70 scientific papers and given numerous presentations at conferences. He is a Fellow of the Institute of Air Quality Management.

Dr Joshua Nunn, MSci (Hons) PhD AMIEnvSc AMIAQM

Dr Nunn is a Senior Consultant with AQC, having joined in 2014. Prior to joining he conducted over three years of scientific research at the University of Bristol, examining the use of sustainable materials in chemical processes using a range of analytical tools and computational modelling. He has since been involved in the preparation of air quality assessments for a range of projects, including residential and commercial developments, road schemes, airports, energy centres, waste management and industrial processes. These have included the use of ADMS dispersion models to examine the impacts of a variety of sources of nitrogen dioxide, PM_{10} and $PM_{2.5}$, and the preparation of air quality assessment reports. He is an Associate Member of the Institute of Air Quality Management and of the Institution of Environmental Sciences.

Paul Outen, BSc (Hons) MIEnvSc MIAQM

Mr Outen is a Senior Consultant with AQC, having joined in 2014. He undertakes air quality and odour assessments for AQC, covering residential and commercial developments, industrial installations, road schemes, energy centres and mineral and waste facilities. These involve qualitative assessments, and quantitative modelling assessments using the ADMS dispersion models, for both planning and permitting purposes. He has also presented evidence at public hearings. Mr Outen has a particular interest in odour assessment and has extensive experience in the assessment of odours across a wide range of industries throughout the UK, Europe and Asia. He also has experience in pollutant monitoring techniques and played a key role in the development and standardisation of isokinetic bioaerosol sampling in the UK. He regularly undertakes site audits for various installations to advise on pollution control and mitigation strategies. He is a Member of both the Institution of Environmental Sciences and Institute of Air Quality Management.

Mr Adam Dawson, BSc (Hons) MSc MIAQM AMIEnvSc

Mr Dawson is a Senior Consultant with AQC with over 7 years' experience in the field of air quality assessment. He undertakes air quality and odour assessments for AQC, covering residential and commercial developments, industrial installations, energy centres and waste facilities. He has experience using a range of dispersion models including ADMS-Roads, ADMS-5 and Breeze AERMOD to complete quantitative modelling assessments, for both planning and permitting purposes. He previously spent over two years as part of the Environment Agency's permitting team, so has extensive experience of the permitting process and industrial emissions. He is a Member of the Institute of Air Quality Management and an Associate Member of the Institution of Environmental Sciences.

Dr Kate Wilkins, BSc (Hons) MSc PhD MIEnvSc MIAQM

Dr Wilkins is a Consultant with AQC, with eight years' postgraduate and work experience in the field of Environmental and Earth Sciences. Since joining AQC in January 2018, she has undertaken numerous air quality assessments for road traffic, combustion plant and construction dust, and has contributed to major projects. Previously, Kate completed a PhD at the University of Bristol, researching atmospheric dispersion modelling and satellite remote sensing of volcanic ash. Prior to her PhD she gained a BSc in Environmental Science and an MSc in Environmental Dynamics and Climatic Change. She also spent a year working at the Environment Agency in Flood Risk Management.

David Bailey, BSc (Hons)

Mr Bailey is an Assistant Consultant with AQC, having joined the Company in 2018. Prior to joining AQC he gained a degree in Environmental Science from the University of Brighton, where his studies included modules focused on Air Quality Management. He is now gaining experience in air quality and greenhouse gas assessments, with the use of the ADMS-Roads and ADMS-5 dispersion modelling software. In addition, he has also gained experience in diffusion tube and automatic monitoring, including data ratification.

Isabel Stanley, MSci (Hons)

Miss Stanley is an Assistant Consultant with AQC, having joined the company in October 2019. Prior to joining AQC she completed an MSci degree in Geology at the University of Bristol, where her studies included modules focusing on GIS, dispersion modelling and environmental geochemistry. She has undertaken numerous air quality assessments, including road traffic and plant emissions modelling, as well as indoor air quality plans and construction dust risk assessments.

Tomáš Liška, BSc (Hons)

Mr Liška is an Assistant Consultant with AQC, having joined in September 2020. He holds a BSc in Meteorology and Climate Science from the University of Leeds and is currently finishing his PhD at the University of Edinburgh, which investigates population exposure to air pollution and its inequality in the UK. Tomáš has a keen interest in modelling and data science. He is now gaining experience in the field of air quality monitoring and assessment.

A2 Industrial Sites Identified on Two Planning Portals

Table A2.1: Consented Planning Applications within Maximum Density 5 km Radius Near Immingham Docks over 5 Years.

Planning App no	Date of consent	Development type	Counted as Likely to Have Significant Onsite Releases to Air that Would be Assessed during Application
DM/0545/20/NMA	11/09/2020	Business Park: general Industrial and Storage and Distribution facility	No
DM/0229/16/FUL	26/02/2020	Light Industrial/ commercial	No
DM/1127/19/CND	11/12/2019	Mixed use: General Industrial, business/financial	No
DM/0891/19/CND	14/10/2019	Europarc: light and general industrial, hotel, shops, leisure	No
DM/0625/19/FUL	24/07/2019	Erection of industrial manufacturing building	Yes
DM/0468/19/SCR	23/05/2019	industrial development for zinc oxide processing	Yes
DM/0329/18/FUL	10/05/2018	power plant (18MW Energy From Waste)	Yes
DM/0135/18/FUL	12/02/2018	powder coating plant	Yes
DM/0951/17/FUL	11/10/2017	change of use storage to industrial	No
DM/0727/17/CND	01/08/2017	Erect single storey extension to side of existing industrial unit	No
DM/0993/20/FUL	16/12/2020	6 light industrial units	No
DM/0333/17/FUL	04/12/2017	waste tyre to energy pyrolysis plant	Yes
DM/1050/16/FUL	08/03/2017	Change of use to general industrial	No

DM/0965/16/FUL	25/11/2016	Change of use to general industrial for steel fabrication	Yes
DM/0923/15/FUL	19/10/2016	erection of two B1/B2 industrial units	No
DM/0626/20/CND	17/09/2020	energy from waste facility	Yes
DM/0274/20/FUL	24/09/2020	waste to energy power generation facility	Yes
DM/0863/19/FUL	09/04/2020	gas fuelled embedded energy generation compound	Yes
DM/0026/18/FUL	12/10/2018	Energy Recovery Facility	Yes
DM/0455/17/CND	06/07/2017	14 containerised generators	Yes

Table A2.2: Consented Planning Applications within Maximum Density 5 km Radius in Doncaster over 5 Years.

Planning App no	Date of consent	Development type	Counted as Likely to Have Significant Onsite Releases to Air that Would be Assessed during Application
20/01675/FUL	03/12/2020	erection of 2 light industrial units	No
19/02683/FULM	18/05/2020	three B1, B2 and B8 use industrial and warehousing units	No
19/02365/OUTM	13/01/2020	retail office/industrial and warehouse units	No
19/02240/FULM	08/01/2021	Erection of proposed industrial/commercial unit	No
18/01150/REMM	23/08/2018	erection of 2 industrial units	Yes
19/00790/FUL	14/05/2019	Erection of a new industrial unit	Yes
18/02409/FUL	16/11/2018	Erection of general industrial units	No
18/00980/FUL	12/06/2018	Rear extension to industrial unit	No

18/00616/FULM	30/07/2018	15 units for industrial/commercial	No
18/00121/FULM	22/05/2018	Erection of industrial units for Use Class B1 (b and c), B2 and B8 use.	No
17/02733/OUTM	10/05/2018	Outline application for business park comprising of Use Class B1 (Office), B2 (General Industry) and B8	No
17/01256/FUL	19/10/2017	erection of 11 industrial units	Yes
17/01221/FUL	28/06/2017	Erection of industrial building	Yes
16/03018/FUL	05/04/2017	Change of use of building from storage (B8) to industrial (B1)	No
16/01792/FUL	10/11/2016	Change of use of land to light industrial (B1) and storage/distribution (B8)	No
16/01635/FUL	17/10/2016	erection of an extension to existing industrial unit	No
16/01111/MAT	31/05/2016	Erection of 5 industrial units	Yes
15/02958/FUL	18/01/2016	Erection of an extension to an existing industrial building	No

A3 Dispersion Model Configuration

The emissions from the six sites (Kernels 1 to 6) have been modelled using the ADMS-5 dispersion model. ADMS-5 is a new generation model that incorporates a state-of-the-art understanding of the dispersion processes within the atmospheric boundary layer. Model input selections are summarised in Table A2.1. The models were run to all represent the same, non-specific location, i.e. no terrain data were included within the models, the effects of downwash from nearby buildings on point sources was not considered and identical surface roughness and Monin-Obukhov lengths were used. The models were run to predict concentrations of NOx and NH_3 across a circular grid of receptors centred on each site (details of which are set out in the table below).

The kernels are all real-life projects which have been modelled for planning permission and/or permitting. The number of sources, their positions, and dimensions (etc.) are all defined by the characteristics of those real-life projects. Each source represents an individually defined emissions release point. In practice, the number of individual releases, their spatial distributions and release characteristics will have a significant effect on the model outputs (i.e. concentration per mass emission) close to the sources, but much less effect further away (which is where the balance of probability dictates that most in-combination projects will be). Section 8 of the report explains that, within the context of this study, uncertainty introduced by using these kernels to provide 'generic' impact footprints is likely to be smaller than that associated with quantifying the effects of autonomous emissions reductions over time at any one location. It also explains that the use of generic dispersion footprints is consistent with the approach of using average patterns to represent individual locations even where local detail is available.

Table A3.3: Summary of Model Inputs (all sites).

	Model Parameter	**Value**
Meteorological Data	**Meteorological Monitoring Site**	Waddington
	Meteorological Data Years	2015 to 2019 (inclusive)
	Dispersion Site Surface Roughness Length (m)	0.2
	Dispersion Site Minimum MO Length (m)	10
	Met Site Surface Roughness Length (m)	0.5
	Met Site Surface Minimum MO Length (m)	30
Receptor Grid	**Resolution (m)**	20
	Radius (km)	10
Dry Deposition Velocity	**NH_3 (m/s)**	0.02

Table A3.4: Summary of Post-processing Carried out Outside of the Dispersion Models.

	Parameter	Value
Chemistry	**Process Contribution NO_2:NOx**	70% [42]
Dry Deposition Velocity NH_3 (m/s)	**Short Vegetation**	0.02
	Woodland	0.03
Dry Deposition Velocity NO_2 (m/s)	**Short Vegetation**	0.0015
	Woodland	0.02

The input parameters for the emissions sources for each kernel are presented in the tables below.

Table A3.5: Kernel 1 – Poultry Farm. Pollutants Modelled NH_3

	Model Parameter	Value
Point Sources	**Number of Sources**	102
	Modelled Height (m)	6.679
	Exit Velocity (m/s)	10.8 and 15.0
Volume Sources	**Number of Sources**	6
	Volume per Source (m^3)	68.707
	Height to Mid-Point of Source (m)	1.425

Table A3.6: Kernel 2 – Dairy Farm. Pollutants Modelled NH_3

	Model Parameter	Value
Area Sources	**Number of Sources**	2
	Area per Source (m^2)	1,238.5 and 8,904
	Height (m)	0
	Exit Velocity (m/s)	0.01

42 NOx as NO_2. Used to be consistent with the majority of assessments of on-site emissions carried out for planning and permitting in the UK.

Table A3.7: Kernel 3 – Poultry Farm. Pollutants Modelled NH_3.

	Model Parameter	**Value**
Point Sources	**Number of Sources**	76
	Modelled Height (m)	0.2 and 5.4
	Exit Velocity (m/s)	0 and 10.714

Table A3.8: Kernel 4 – Combined Heat and Power Plant. Pollutants Modelled NOx and NH_3.

	Model Parameter	**Value**
Point Sources	**Number of Sources**	2
	Modelled Height (m)	14.998
	Exit Velocity (m/s)	26.929

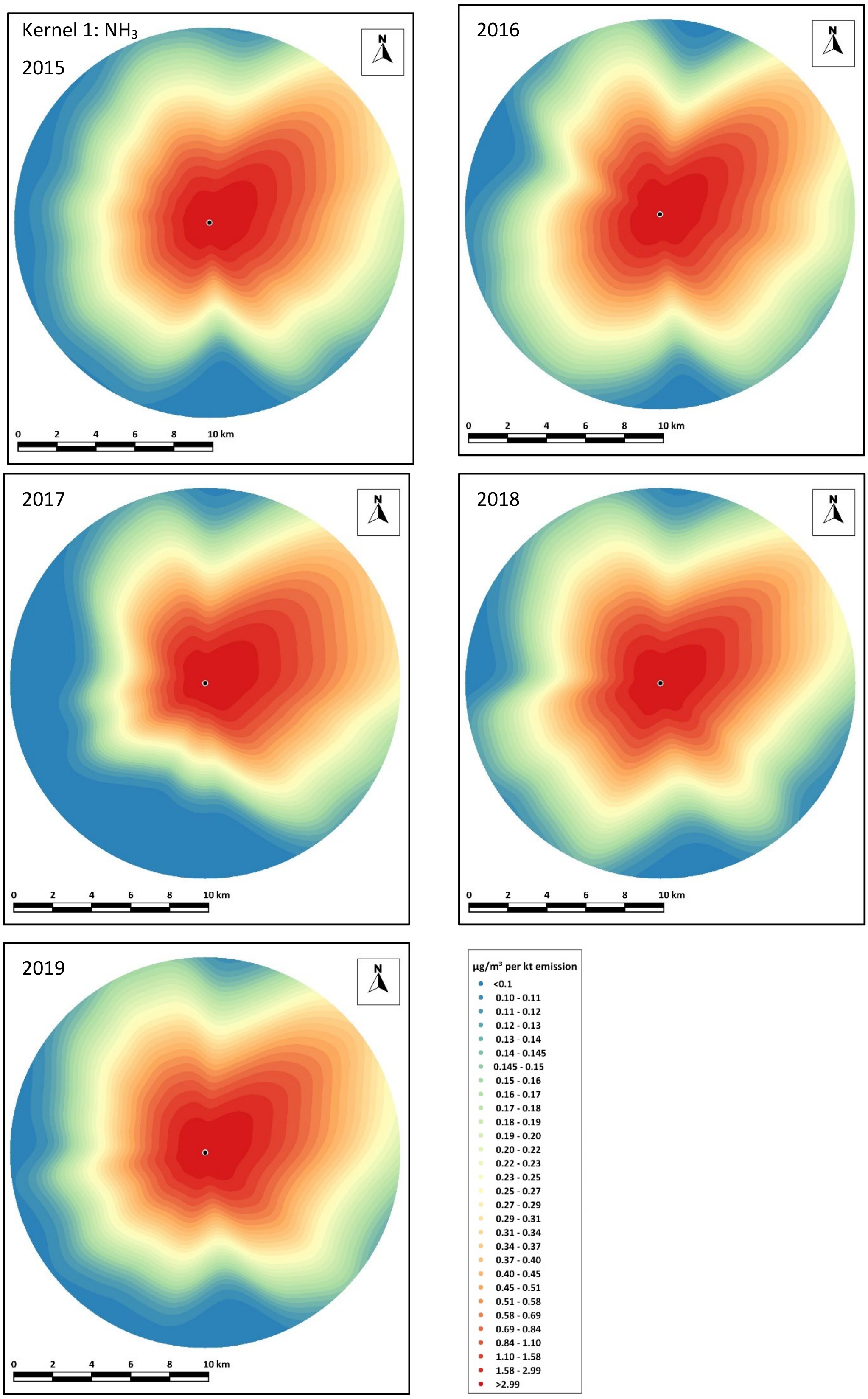
Table A3.9: Kernel 5 – Diesel Generators. Pollutants Modelled NOx and NH_3.

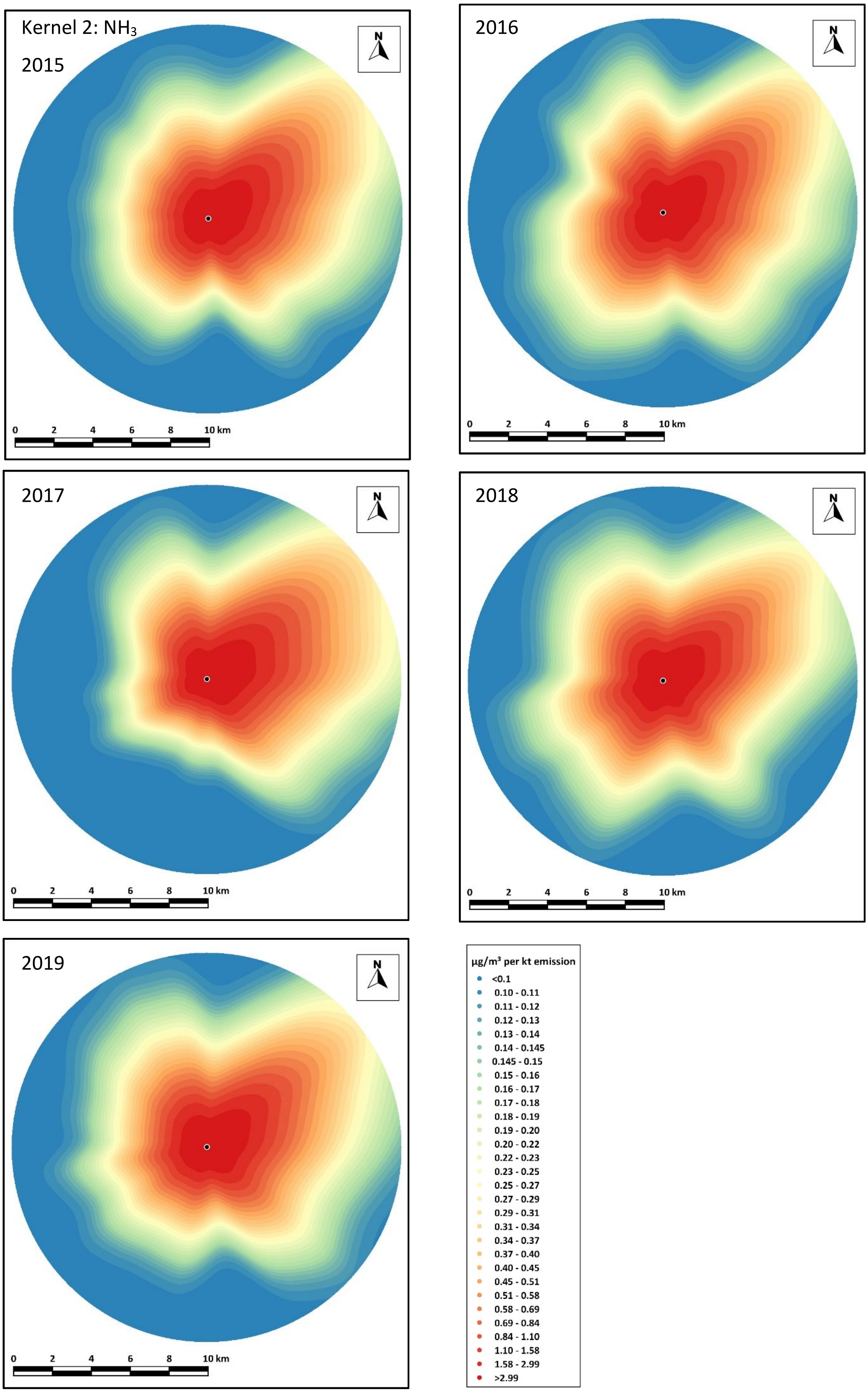
	Model Parameter	**Value**
Point Sources	**Number of Sources**	4
	Modelled Height (m)	3.256
	Exit Velocity (m/s)	32.006 and 38.419

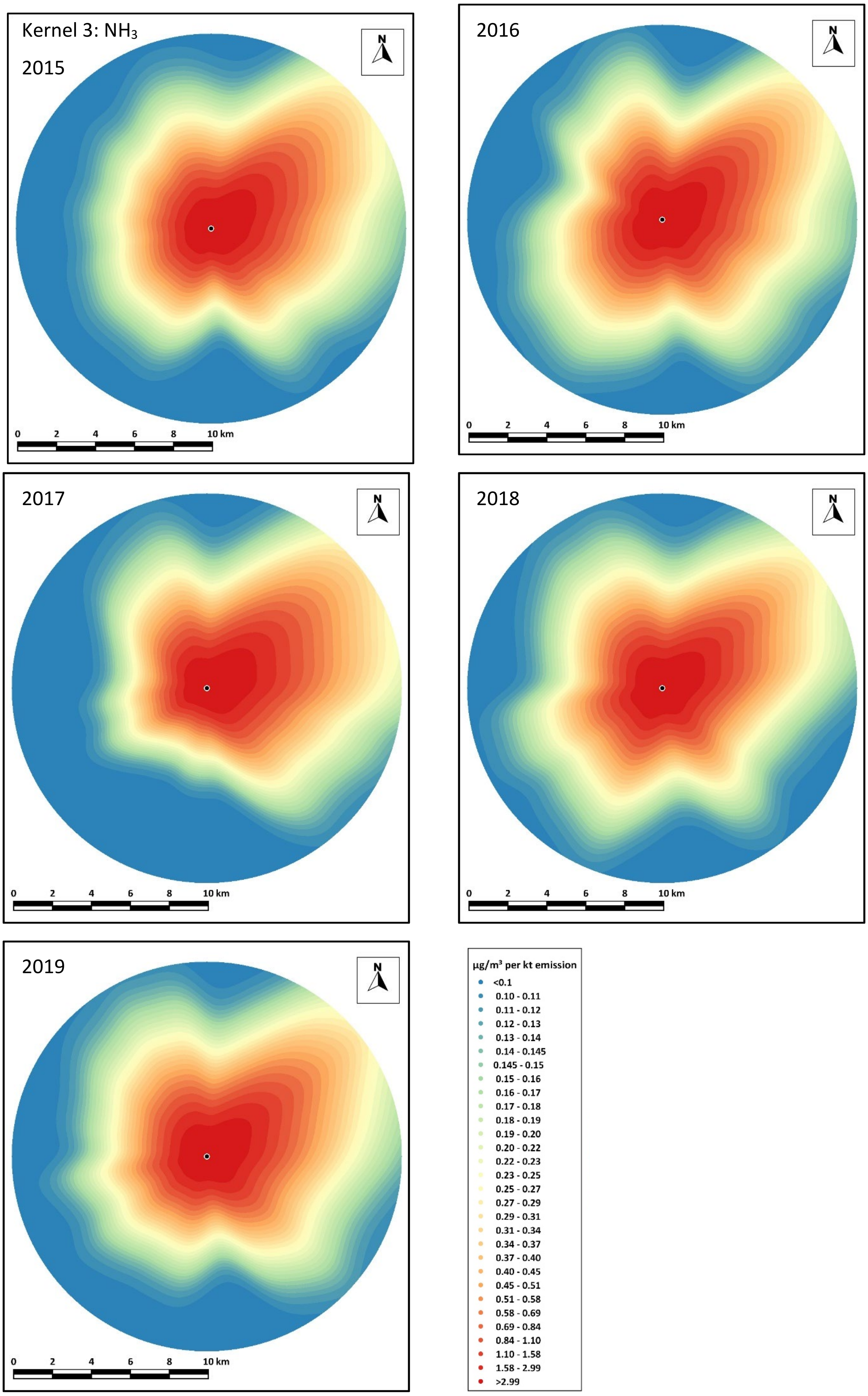
Table A3.10: Kernel 6 – Power Plant. Pollutants Modelled NOx (area and point) and NH_3 (point).

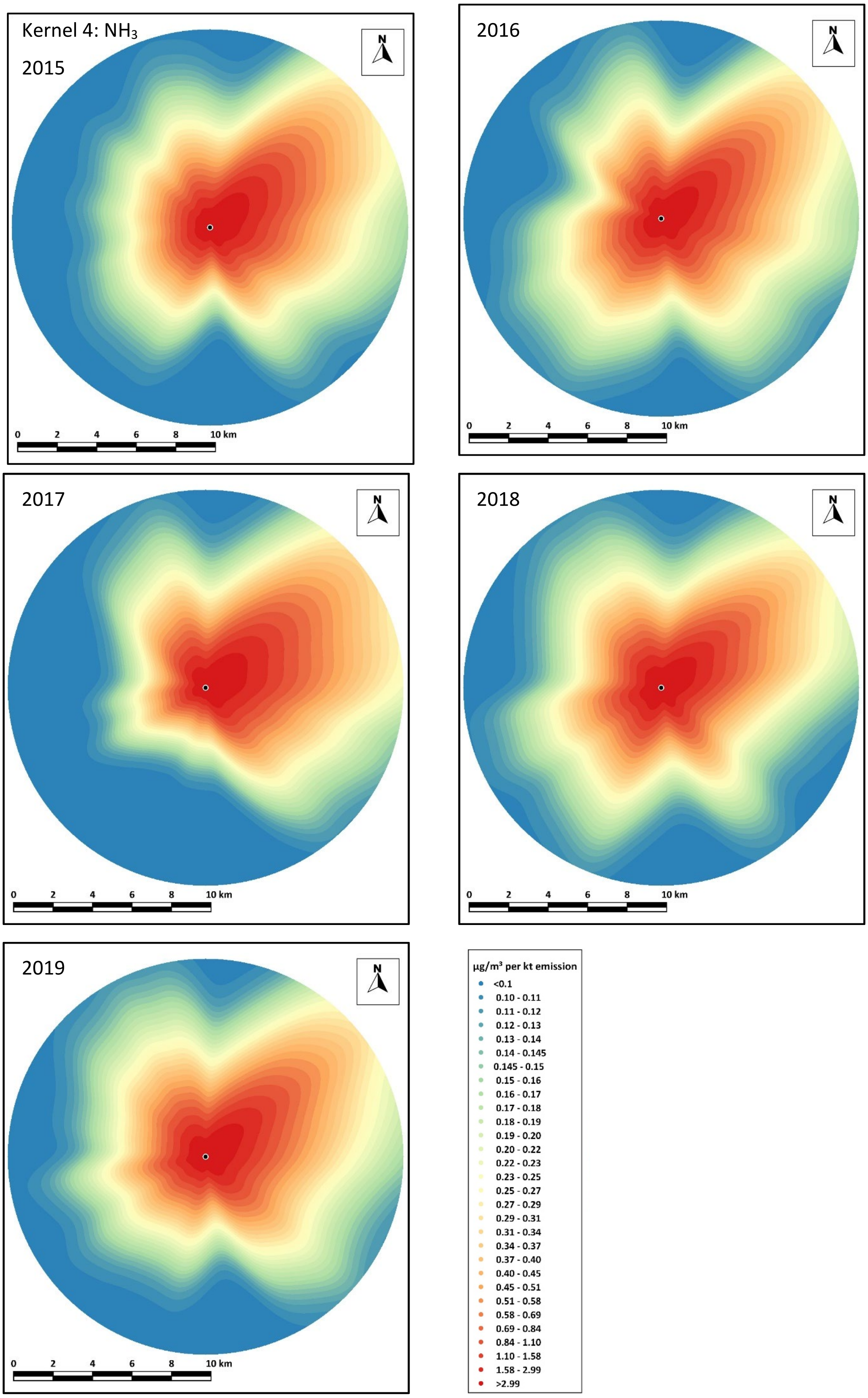
	Model Parameter	**Value**
Point Sources	**Number of Sources**	2
	Modelled Height (m)	15.2
	Exit Velocity (m/s)	19.222 and 21.0
Area Sources	**Number of Sources**	2
	Area per Source (m^2)	10.0
	Height (m)	12.0
	Exit Velocity (m/s)	0.04 and 0.06

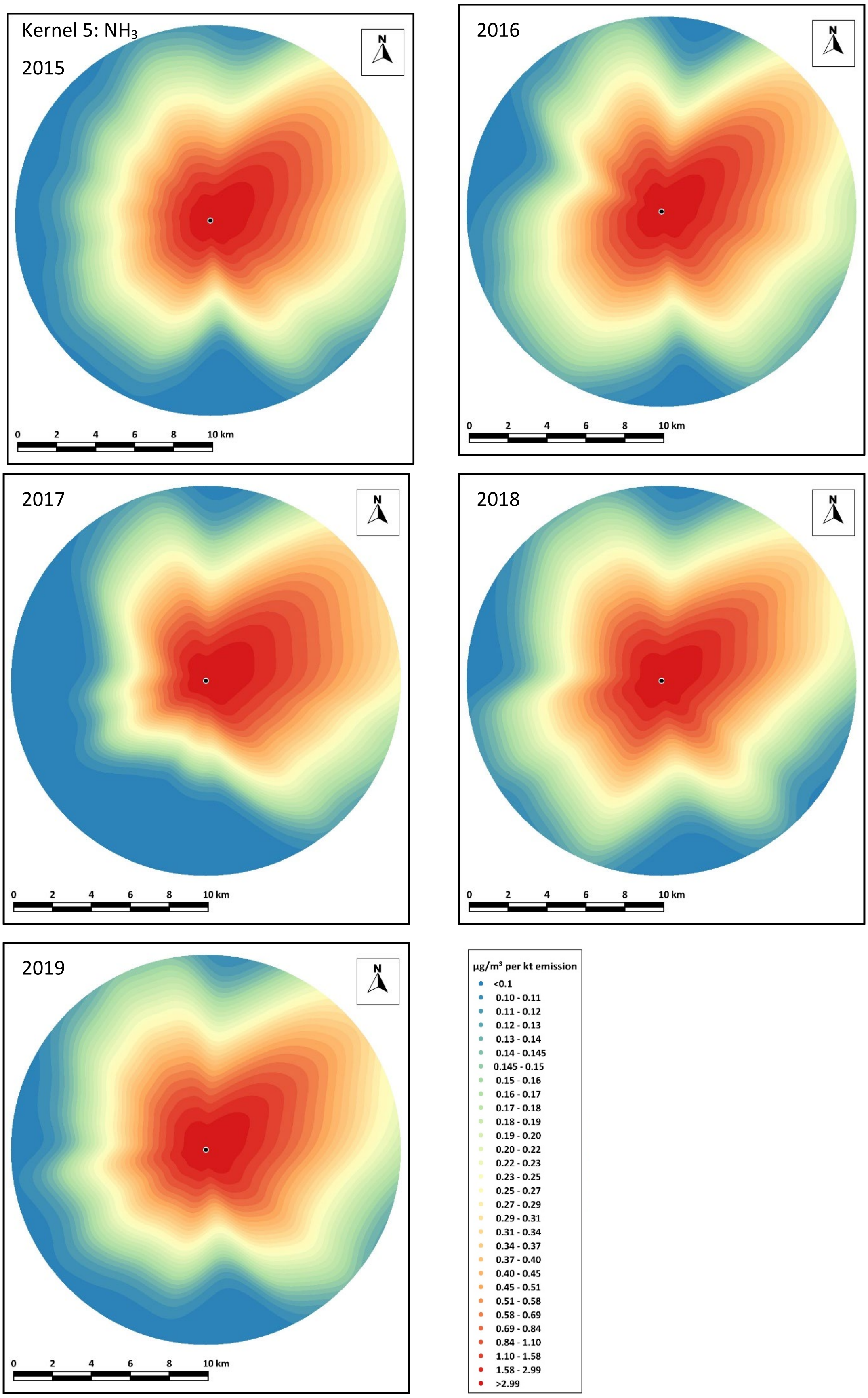
A4 Dispersion Kernel Model Results



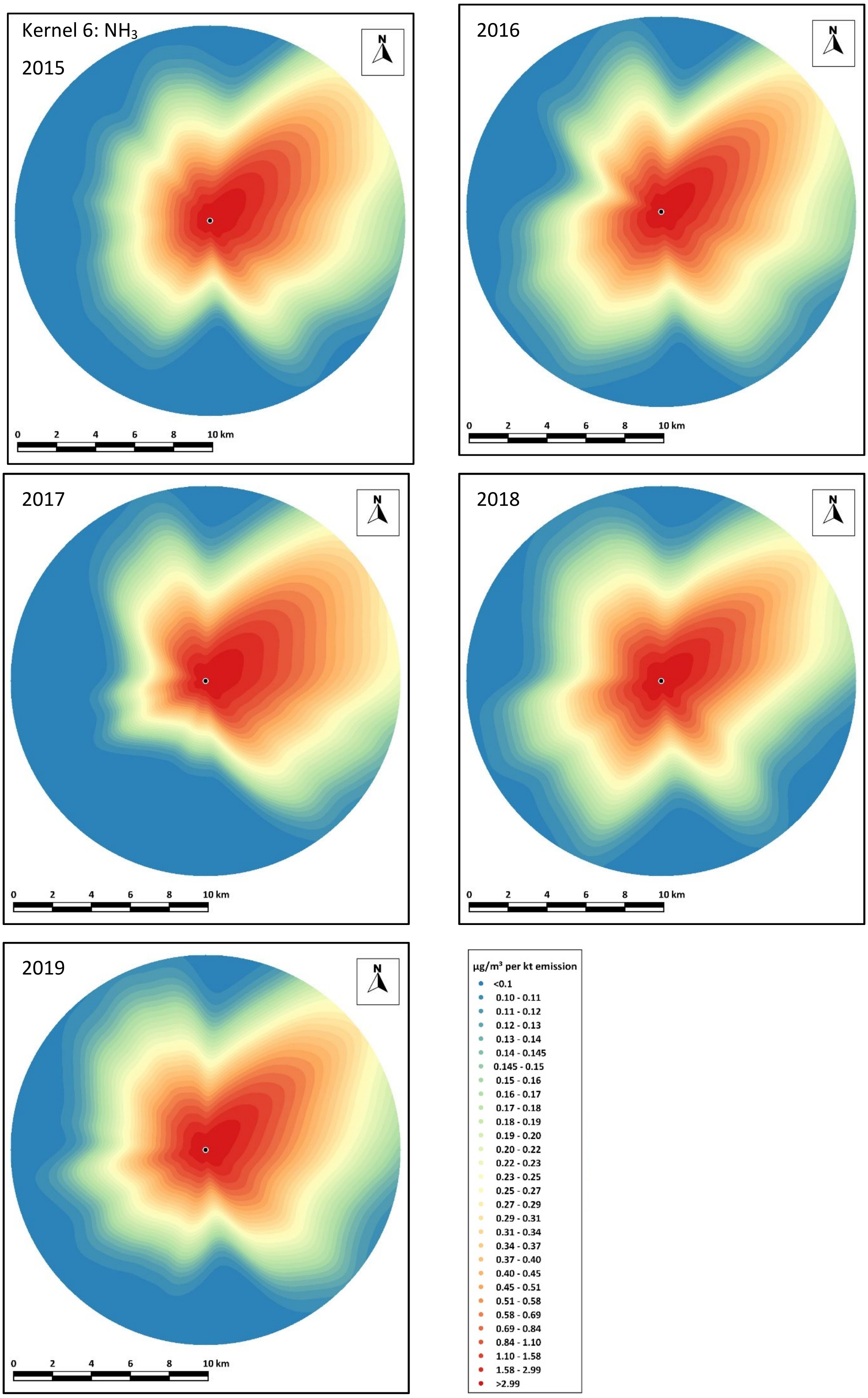

Kernel 2: NH3
2015
2016
2017
2018
2019
N
0 2 4 6 8 10 km
µg/m³ per kt emission
<0.1
0.10 - 0.11
0.11 - 0.12
0.12 - 0.13
0.13 - 0.14
0.14 - 0.145
0.145 - 0.15
0.15 - 0.16
0.16 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.22
0.22 - 0.23
0.23 - 0.25
0.25 - 0.27
0.27 - 0.29
0.29 - 0.31
0.31 - 0.34
0.34 - 0.37
0.37 - 0.40
0.40 - 0.45
0.45 - 0.51
0.51 - 0.58
0.58 - 0.69
0.69 - 0.84
0.84 - 1.10
1.10 - 1.58
1.58 - 2.99
>2.99

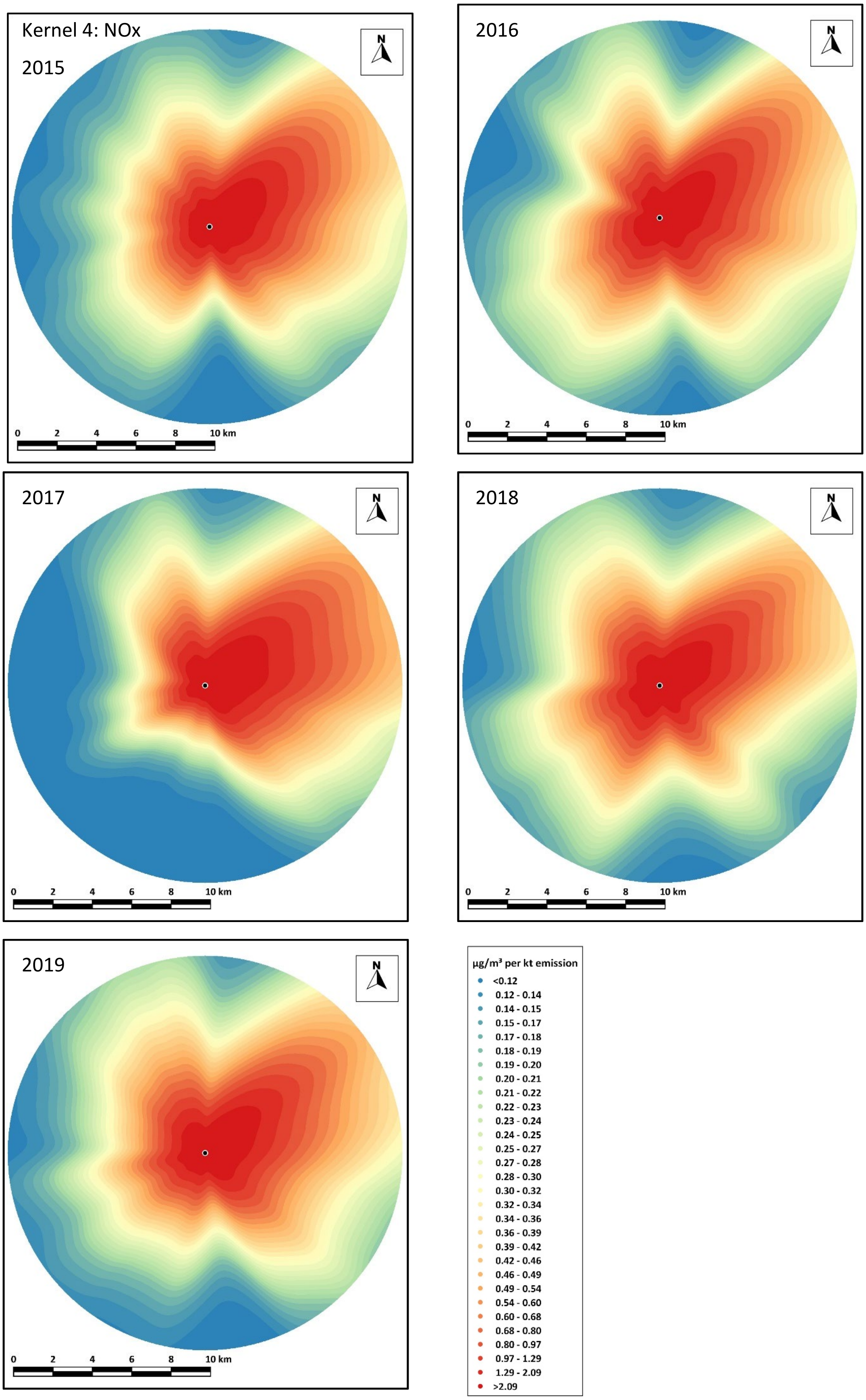

Kernel 3: NH3
2015
N
0 2 4 6 8 10 km
2016
2017
2018
2019
µg/m³ per kt emission
<0.1
0.10 - 0.11
0.11 - 0.12
0.12 - 0.13
0.13 - 0.14
0.14 - 0.145
0.145 - 0.15
0.15 - 0.16
0.16 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.22
0.22 - 0.23
0.23 - 0.25
0.25 - 0.27
0.27 - 0.29
0.29 - 0.31
0.31 - 0.34
0.34 - 0.37
0.37 - 0.40
0.40 - 0.45
0.45 - 0.51
0.51 - 0.58
0.58 - 0.69
0.69 - 0.84
0.84 - 1.10
1.10 - 1.58
1.58 - 2.99
>2.99

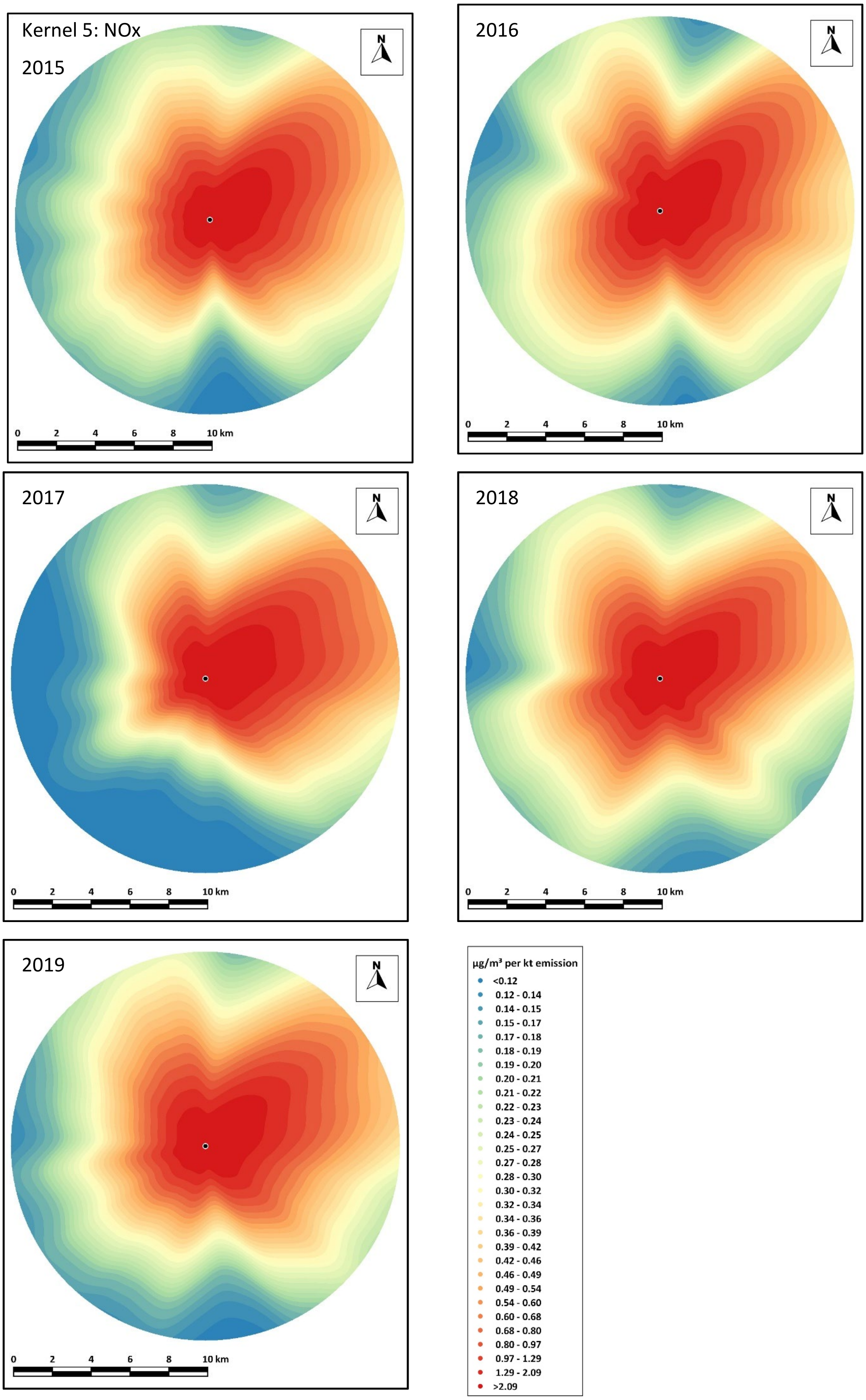

Kernel 4: NH_3
2015
2016
2017
2018
2019
N
0 2 4 6 8 10 km
µg/m³ per kt emission
<0.1
0.10 - 0.11
0.11 - 0.12
0.12 - 0.13
0.13 - 0.14
0.14 - 0.145
0.145 - 0.15
0.15 - 0.16
0.16 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.22
0.22 - 0.23
0.23 - 0.25
0.25 - 0.27
0.27 - 0.29
0.29 - 0.31
0.31 - 0.34
0.34 - 0.37
0.37 - 0.40
0.40 - 0.45
0.45 - 0.51
0.51 - 0.58
0.58 - 0.69
0.69 - 0.84
0.84 - 1.10
1.10 - 1.58
1.58 - 2.99
>2.99

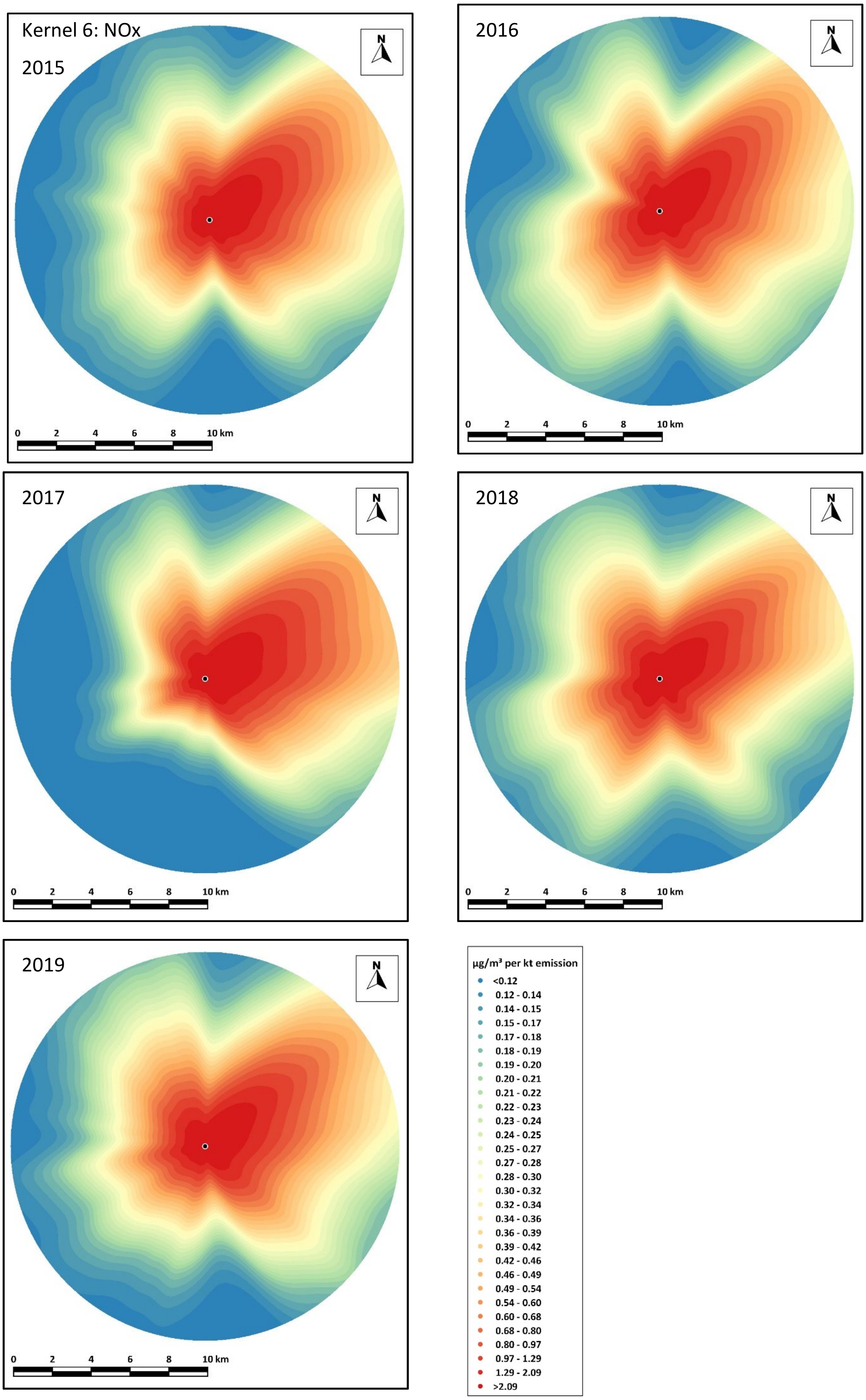


Kernel 5: NH3
2015
2016
2017
2018
2019
N
0 2 4 6 8 10 km
µg/m³ per kt emission
<0.1
0.10 - 0.11
0.11 - 0.12
0.12 - 0.13
0.13 - 0.14
0.14 - 0.145
0.145 - 0.15
0.15 - 0.16
0.16 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.22
0.22 - 0.23
0.23 - 0.25
0.25 - 0.27
0.27 - 0.29
0.29 - 0.31
0.31 - 0.34
0.34 - 0.37
0.37 - 0.40
0.40 - 0.45
0.45 - 0.51
0.51 - 0.58
0.58 - 0.69
0.69 - 0.84
0.84 - 1.10
1.10 - 1.58
1.58 - 2.99
>2.99


Kernel 6: NH3
2015
2016
2017
2018
2019
N
0 2 4 6 8 10 km
µg/m³ per kt emission
<0.1
0.10 - 0.11
0.11 - 0.12
0.12 - 0.13
0.13 - 0.14
0.14 - 0.145
0.145 - 0.15
0.15 - 0.16
0.16 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.22
0.22 - 0.23
0.23 - 0.25
0.25 - 0.27
0.27 - 0.29
0.29 - 0.31
0.31 - 0.34
0.34 - 0.37
0.37 - 0.40
0.40 - 0.45
0.45 - 0.51
0.51 - 0.58
0.58 - 0.69
0.69 - 0.84
0.84 - 1.10
1.10 - 1.58
1.58 - 2.99
>2.99


Kernel 4: NOx
2015
N
0 2 4 6 8 10 km
2016
N
0 2 4 6 8 10 km
2017
N
0 2 4 6 8 10 km
2018
N
0 2 4 6 8 10 km
2019
N
0 2 4 6 8 10 km
µg/m³ per kt emission
<0.12
0.12 - 0.14
0.14 - 0.15
0.15 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.21
0.21 - 0.22
0.22 - 0.23
0.23 - 0.24
0.24 - 0.25
0.25 - 0.27
0.27 - 0.28
0.28 - 0.30
0.30 - 0.32
0.32 - 0.34
0.34 - 0.36
0.36 - 0.39
0.39 - 0.42
0.42 - 0.46
0.46 - 0.49
0.49 - 0.54
0.54 - 0.60
0.60 - 0.68
0.68 - 0.80
0.80 - 0.97
0.97 - 1.29
1.29 - 2.09
>2.09


Kernel 5: NOx
2015
N
0 2 4 6 8 10 km
2016
N
0 2 4 6 8 10 km
2017
N
0 2 4 6 8 10 km
2018
N
0 2 4 6 8 10 km
2019
N
0 2 4 6 8 10 km
µg/m³ per kt emission
<0.12
0.12 - 0.14
0.14 - 0.15
0.15 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.21
0.21 - 0.22
0.22 - 0.23
0.23 - 0.24
0.24 - 0.25
0.25 - 0.27
0.27 - 0.28
0.28 - 0.30
0.30 - 0.32
0.32 - 0.34
0.34 - 0.36
0.36 - 0.39
0.39 - 0.42
0.42 - 0.46
0.46 - 0.49
0.49 - 0.54
0.54 - 0.60
0.60 - 0.68
0.68 - 0.80
0.80 - 0.97
0.97 - 1.29
1.29 - 2.09
>2.09


Kernel 6: NOx
2015
N
0 2 4 6 8 10 km
2016
N
0 2 4 6 8 10 km
2017
N
0 2 4 6 8 10 km
2018
N
0 2 4 6 8 10 km
2019
N
0 2 4 6 8 10 km
µg/m³ per kt emission
<0.12
0.12 - 0.14
0.14 - 0.15
0.15 - 0.17
0.17 - 0.18
0.18 - 0.19
0.19 - 0.20
0.20 - 0.21
0.21 - 0.22
0.22 - 0.23
0.23 - 0.24
0.24 - 0.25
0.25 - 0.27
0.27 - 0.28
0.28 - 0.30
0.30 - 0.32
0.32 - 0.34
0.34 - 0.36
0.36 - 0.39
0.39 - 0.42
0.42 - 0.46
0.46 - 0.49
0.49 - 0.54
0.54 - 0.60
0.60 - 0.68
0.68 - 0.80
0.80 - 0.97
0.97 - 1.29
1.29 - 2.09
>2.09

A5 Concentrations and Fluxes vs Traffic Flow and Distance from Road

A5.1 Annual Mean NOx Concentrations

Figure A5.1 summarises the results from 22 independent transects of ambient long-term monitoring sites which were exposed close to roads. It also includes an average relationship which has been fitted to these measurements, which shows the relative rate of change in local traffic-related NOx concentrations with distance from the edge of the road. This curve was produced as part of the 2013 update to the Design Manual for Roads and Bridges (DMRB) air quality model and is taken here from Marner (2019). The curve of the line, taken from the same published reference, can be described as:

CB=C/(IF(A<1.4765,3.92454283234404,(IF(A<4.704,(EXP((0.0289*(LN(A)^3))-0.2988*(LN(A)^2)+0.2197*(LN(A))+1.3253)),(IF(A<73.47,EXP((0.0064*(LN(A)^3))-0.0656*(LN(A)^2)-0.5226*(LN(A))+1.9991),EXP((-0.0752*(LN(A)^2))-0.2556*(LN(A))+1.5368)))))))*(IF(B<1.4765,3.92454283234404,(IF(B<4.704,(EXP((0.0289*(LN(B)^3))-0.2988*(LN(B)^2)+0.2197*(LN(B))+1.3253)),(IF(B<73.47,EXP((0.0064*(LN(B)^3))-0.0656*(LN(B)^2)-0.5226*(LN(B))+1.9991),EXP((-0.0752*(LN(B)^2))-0.2556*(LN(B))+1.5368)))))))

Where CB = road-NOx at distance B; A = input/monitor location distance to the edge of the road (m); B = output/normalised location distance to the edge of the road (m); and C = road-NOx at distance A from the edge of the road.

This curve provides a means of predicting the relative change in NOx concentrations with distance from the edge of a road. It is based solely on AQC's analysis of ambient measurements but has underpinned a large amount of national modelling.

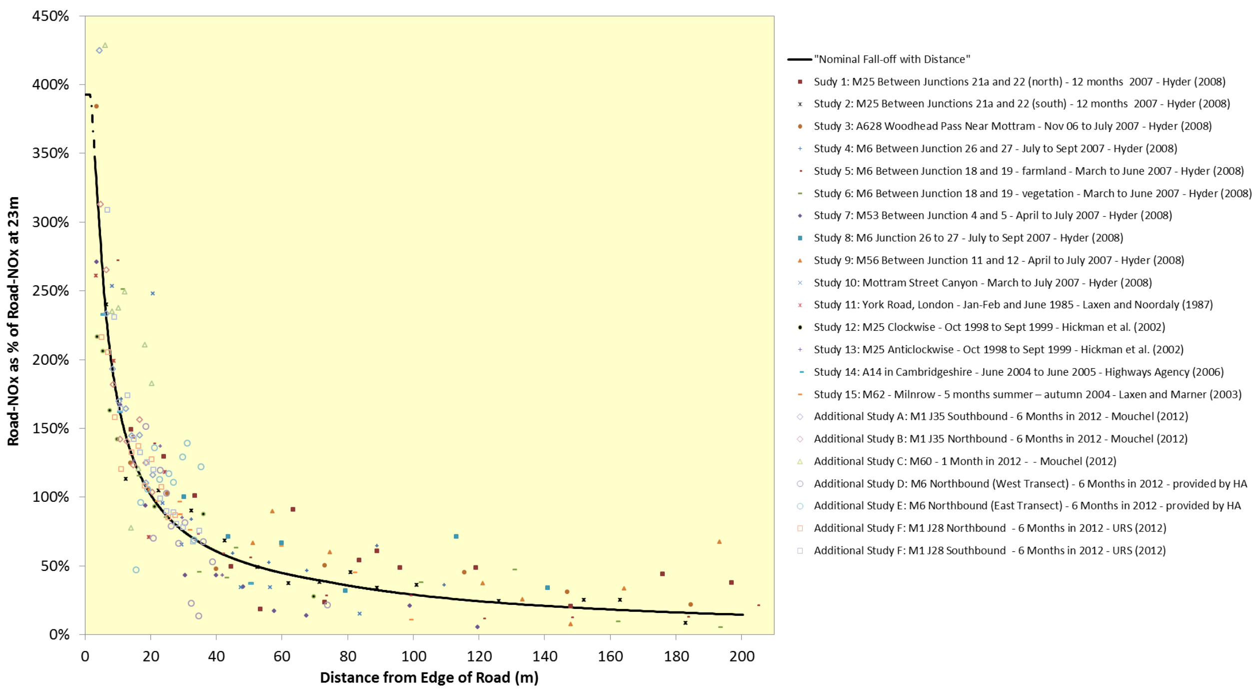


Figure A5.1: Rate of Change in Road Contribution to Annual Mean NOx Concentrations vs Distance from Road across 22 Monitoring Transects (Marner 2019).

More recent transects of measurements have been published by Wealden District Council (WDC) based on a comprehensive campaign of monitoring in and around Ashdown Forest (WDC 2018). Measured NO_2 concentrations at near-road and nearby background locations were used to calculate 'road-NOx' using tools available from Defra (WDC, 2018). These results are shown as function of the concurrent measured traffic flows in Figure A5.2, which also shows the fitted curve[43] from Figure A5.1. These results, which relate to a two-year period centred on 2015, are not used directly in this analysis but are included for completeness because other results from the same survey have been used.

In order to test whether the results in Figure A5.2 are a-typical, or significantly out of date, data have been collated from a selection of recent air quality assessments carried out by AQC, all of which have analysed both roadside measurements and local traffic flows. These have covered measurements made by 38 separate local authorities spread across the UK during the years 2015 to 2019[44]. The measurements have been transformed in the same manner described in the previous paragraph and are shown in Figure A5.3[45]. While there is considerable scatter in these data, there is some consistency in the positions of the fitted lines for each separate year. It is nevertheless clear that, close to roads, there is a very wide range in measured concentrations per vehicle on the adjacent road.

For completeness, Figure A5.4 shows the Ashdown Forest data alongside those from the other 38 local authorities. For added detail, the distance axis is shown on a logarithmic scale. It is clear that the data for Ashdown Forest fit within the range of those typical elsewhere in the UK.

Figure A5.5 shows the calculated road-NOx per vehicle normalised to a distance of 5 m from the road edge (i.e. the height of the fitted curve in Figure A5.2 and Figure A5.3 at a distance of 5 m). This shows very little difference between these two datasets and between the four years of monitoring.

The relationships presented in Table 11 in Section 7 are based solely on the 2019 measurements. They take the value from Figure A5.5 (which is effectively averaged across all of the 2019 measurements shown in Figure A5.3 and extrapolates these data using the curve from the first paragraph of this section (Section A5.1). While this means that the relationships are based on a relatively small dataset (26 anonymised measurements in total), Figure A5.5 demonstrates that using a larger dataset, while less 'up to date', would have given very similar results.

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[43] The curve described in the first paragraph of this section (Section A5.1) has been used to normalise all of the measurements to a single nominal distance. The average of all of the measurements at this distance is then used as the starting point for the curve shown in the figure.

[44] These results contain confidential material and so precise details are not provided. The observed relationships are, however, fairly typical of those observed by very many practitioners working across the UK.

[45] A fitted curve is not shown for the measurements made in 2016, since 2016 is represented by just two data points.

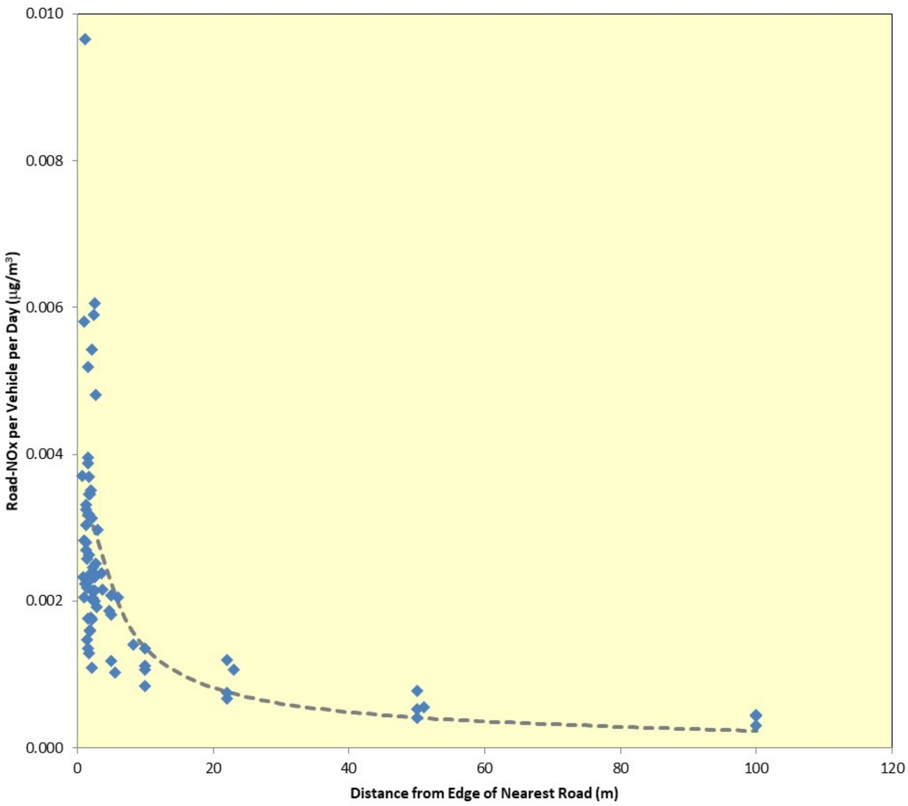

Figure A5.2: Road Contribution to NOx Concentrations (2015) across 105 Monitoring Sites in Ashdown Forest (WDC 2018) – also Showing Fitted Relationship from Figure A5.1.

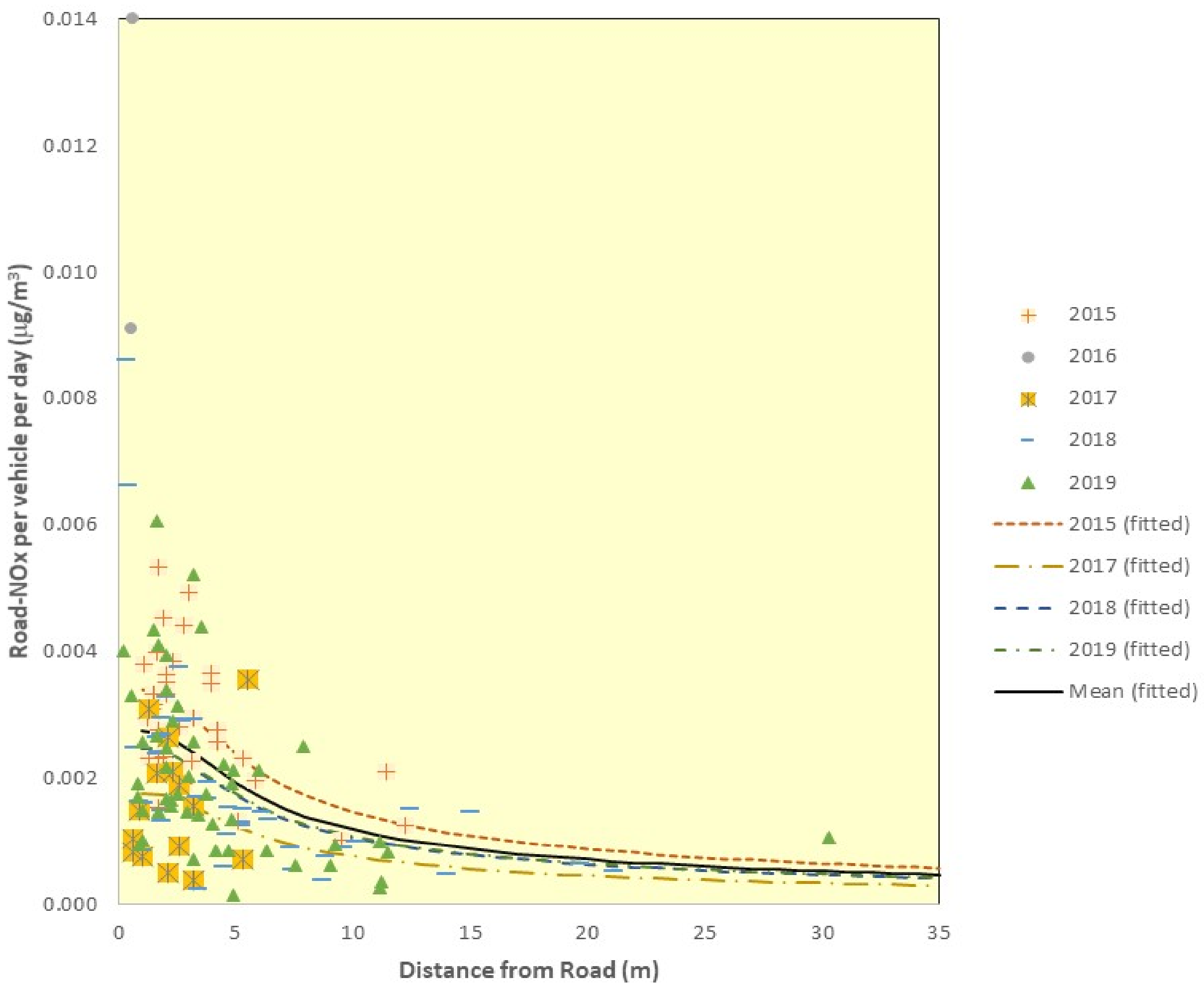

Figure A5.3: Road Contribution to NOx Concentrations in 38 Local Authorities from Across the UK (2015-2019) – also Showing Fitted Relationship from Figure A5.1.

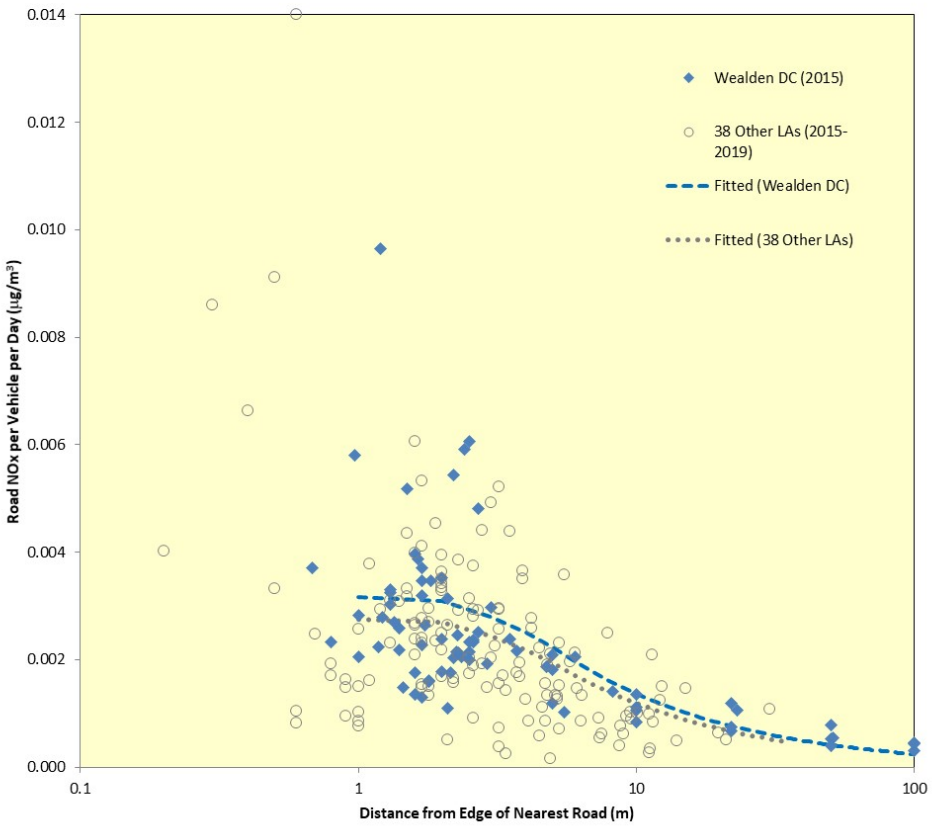

Figure A5.4: Road Contribution to NOx Concentrations Comparing 2015 Ashdown Forest Data (blue diamonds) and 2015-2019 data from 38 Local Authorities.

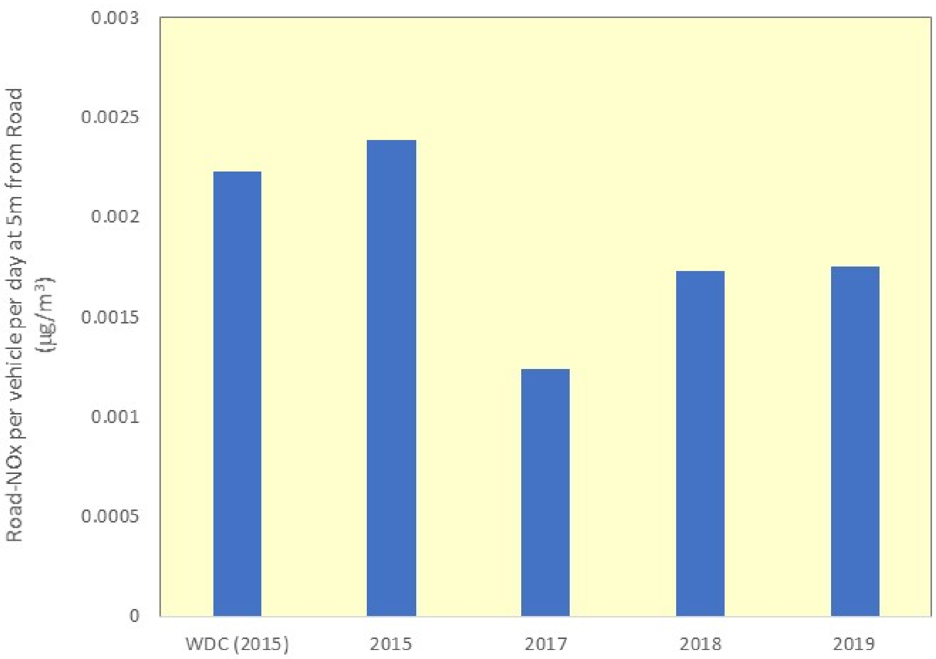

Figure A5.5: Road Contribution to NOx Concentrations at 5 m from Road Edge - Comparing 2015 Wealden District Council (WDC) Data with those from 38 Other UK Local Authorities in Different Years.

A5.2 Annual Mean NH_3 Concentrations

There are very few recent studies which have measured paired roadside and background annual mean NH_3 concentrations using methods capable of accurately characterising background concentrations. Furthermore, the more rapid deposition of NH_3 makes it inappropriate to use the concentration fall-off curve derived for NOx to describe NH_3. The only suitable study which has been published is that carried out in Ashdown Forest by WDC. The measured near-road NH_3 concentrations (WDC 2018) have had the concurrent measured background concentration subtracted. The results have then been divided by the measured traffic flow (WDC 2018) on the adjacent road.

Figure A5.6 summarises the results. Figure A5.7 shows the same measurements using a natural logarithmic distance scale. It also shows a fitted exponential relationship which provides a good fit to these measurements. The fitted relationship shown in Figure A5.7 forms the basis of the NH_3 concentration vs traffic volume statistics given in Table 11 in Section 7[46].

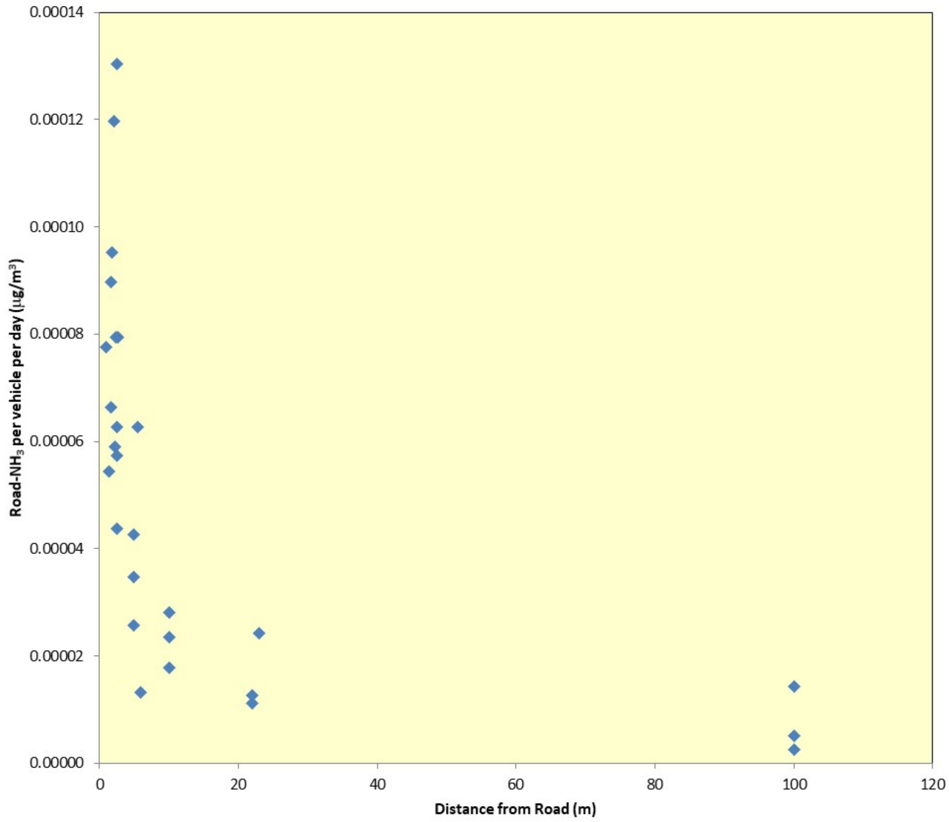

Figure A5.6: Road Contribution to NH_3 Concentrations (2015) across 28 Monitoring Sites in Ashdown Forest (WDC 2018).

[46] Note that the relationship shown in the figure is applied to the natural logarithm of distance from the edge of the road.

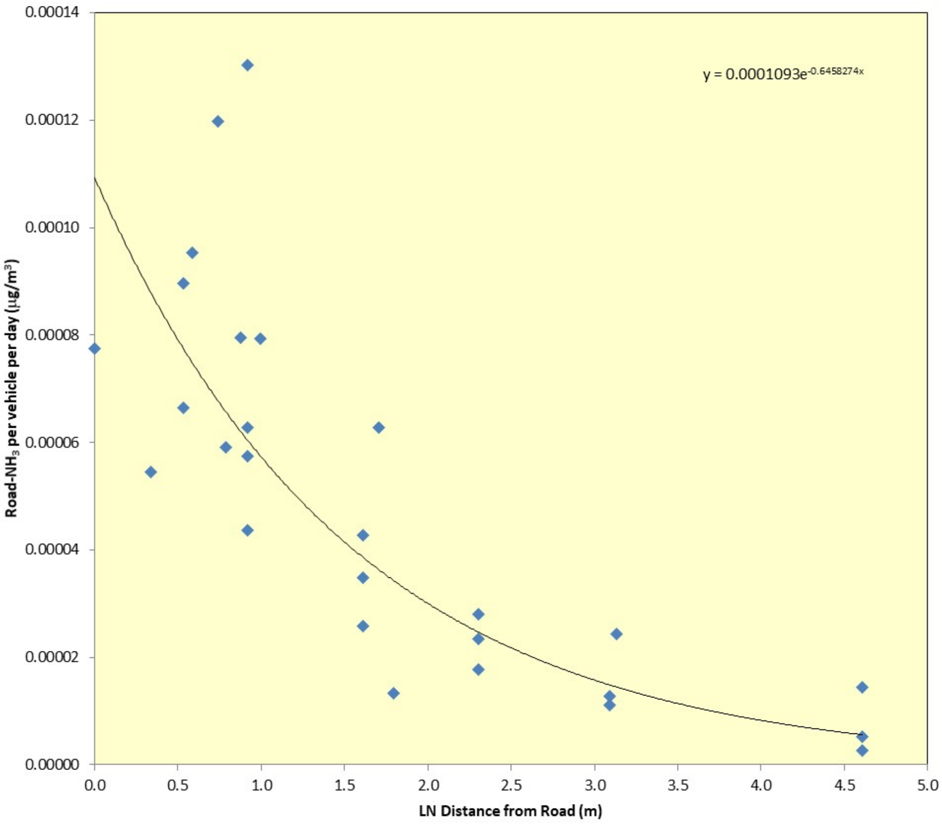

Figure A5.7: Road Contribution to NH_3 Concentrations (2015) across 28 Monitoring Sites in Ashdown Forest vs Natural Log of Distance and Showing Exponential Fitted Relationship.

A5.3 Nitrogen Deposition

Because traffic-related nitrogen deposition is a function of both traffic-related NO_2 and traffic-related NH_3, and because these two values are interrelated[47], the best measurements upon which to derive suitable relationships are those from Ashdown Forest as described above (i.e. since no other suitable roadside NH_3 measurements have been published). The deposition velocities set out in Table A3.4 have been used to calculate nitrogen deposition from the annual mean measurements of NO_2 and NH_3 published by WDC (2018). The results have then been transformed as described above for NH_3. The results are shown in Figure A5.8 and Figure A5.9 for short vegetation, and in Figure A5.10 and Figure A5.9 Figure A5.11 for woodland. The fitted relationships shown in Figure A5.9 and Figure A5.11 have been used to define the relationships given in Table 11 in Section 7[46].

[47] NH_3 is only released because NOx is being controlled.

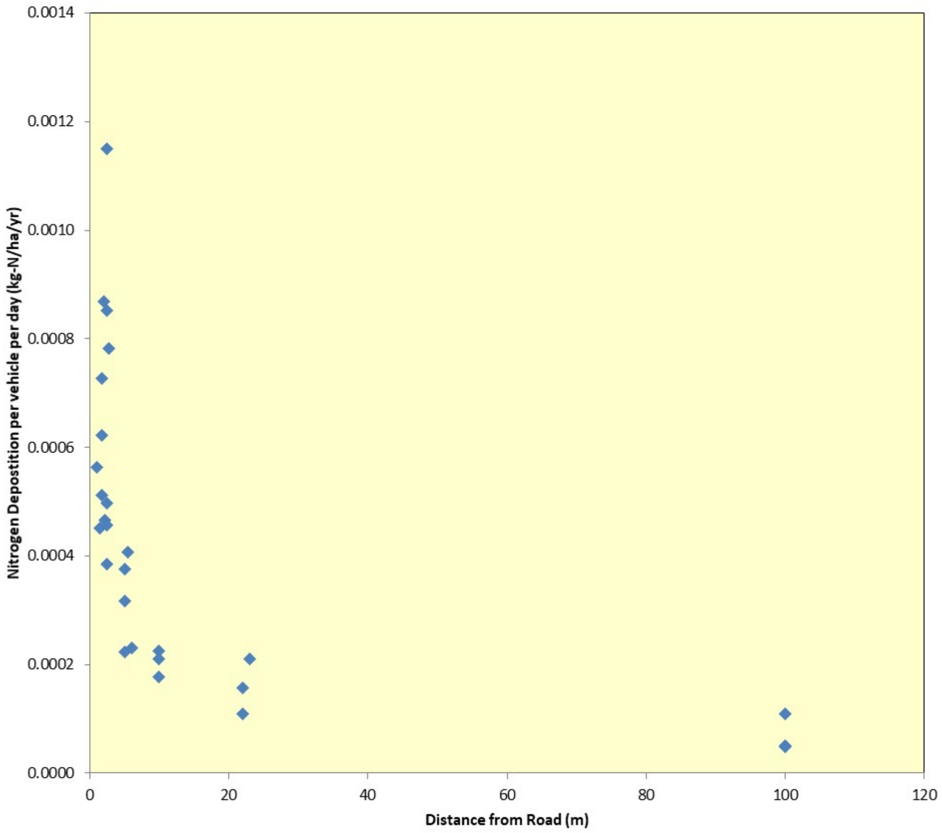

Figure A5.8: Road Contribution to Nitrogen Deposition to Short Vegetation across 28 Monitoring Sites in Ashdown Forest (2015 using AQTAG(06) velocities).

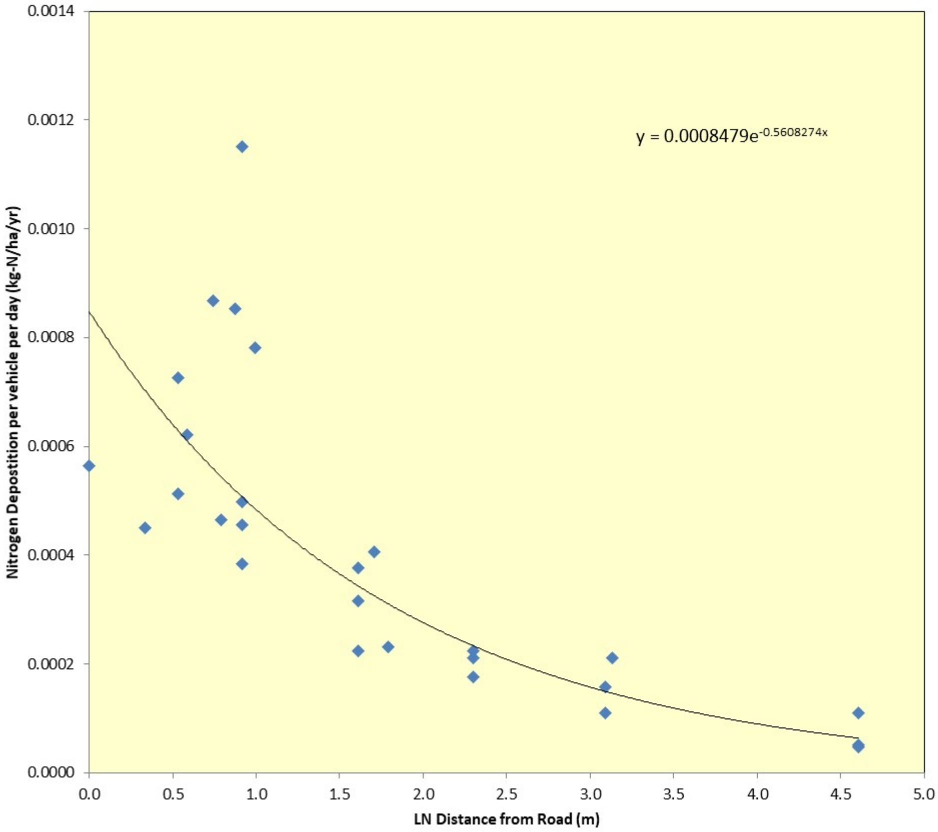

Figure A5.9: Road Contribution to Nitrogen Deposition to Short Vegetation across 28 Monitoring Sites in Ashdown Forest (2015 using AQTAG(06) velocities) vs Natural Log of Distance and Showing Exponential Fitted Relationship.

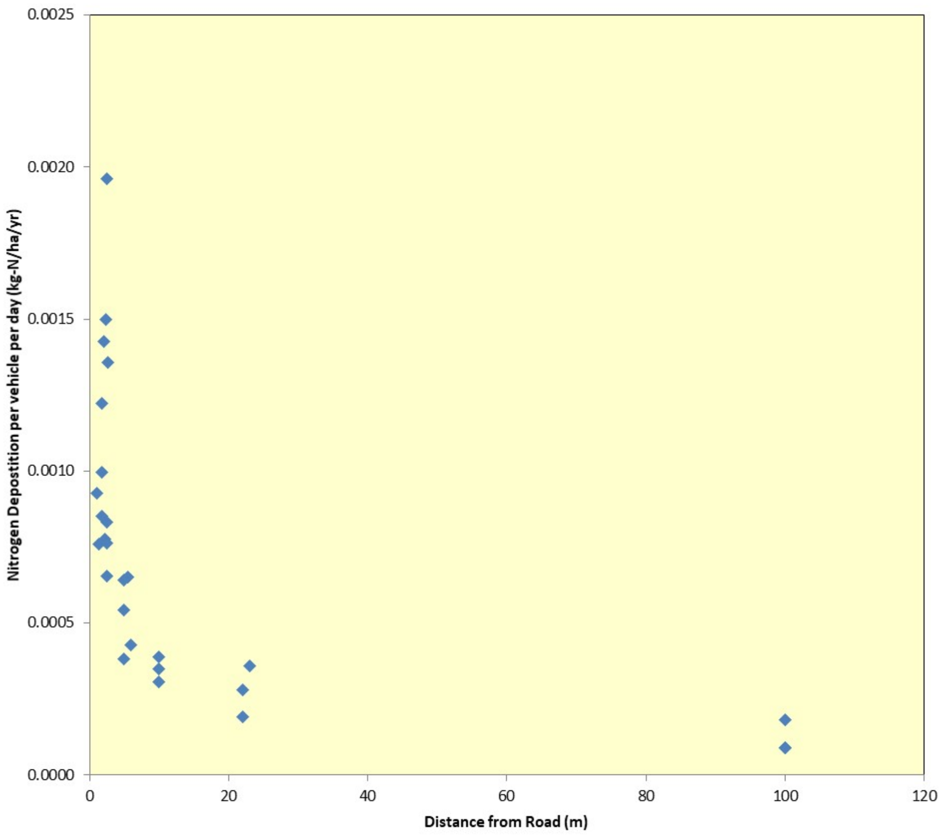

Figure A5.10: Road Contribution to Nitrogen Deposition to Woodland across 28 Monitoring Sites in Ashdown Forest (2015 using AQTAG(06) velocities).

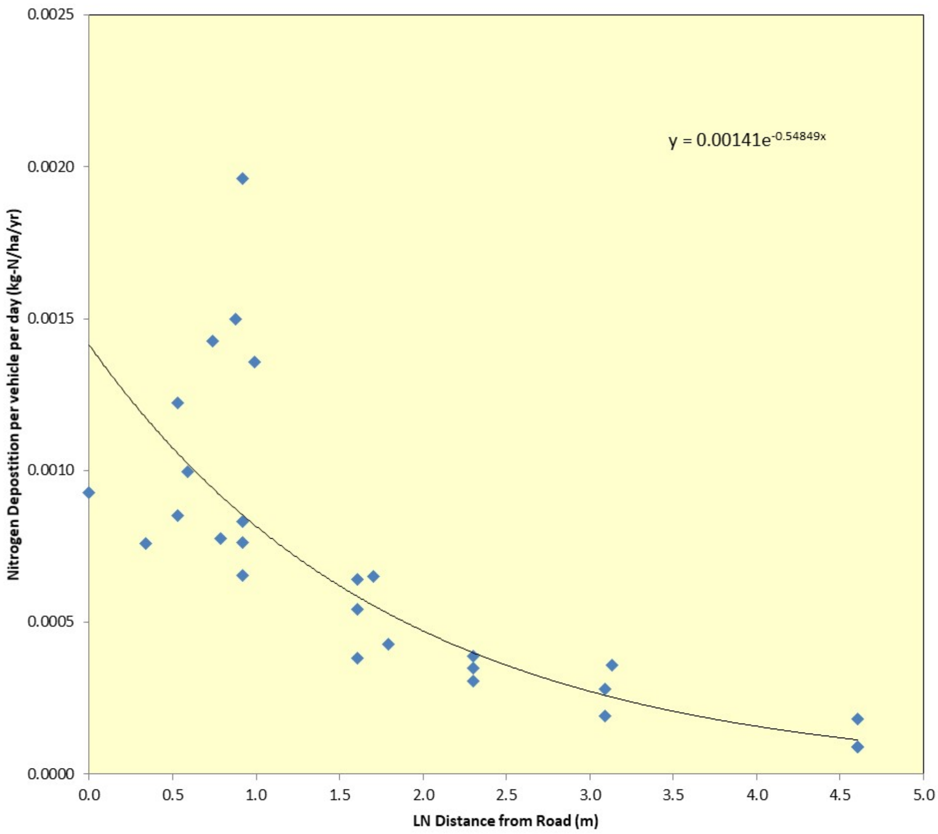

Figure A5.11: Road Contribution to Nitrogen Deposition to Woodland across 28 Monitoring Sites in Ashdown Forest (2015 using AQTAG(06) velocities) vs Natural Log of Distance and Showing Exponential Fitted Relationship.