



Ashdown Forest SAC: Air Quality Monitoring 2014 to 2020 – Main Report

May 2021



Experts in air quality
management & assessment

Document Control

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1 Introduction

- 1.1 Wealden District Council (WDC) commissioned a long-term monitoring study of traffic-related air quality within the Ashdown Forest Special Area of Conservation (SAC). The study, which was carried out by Air Quality Consultants Ltd (AQC), ran from August 2014 until April 2020. This report describes the methodology and presents the results.
- 1.2 Figure 1 shows the location of the SAC and labels various place names which are used throughout the report. The green shading for the SAC in Figure 1 is repeated in most other maps throughout the report, but is not labelled again.

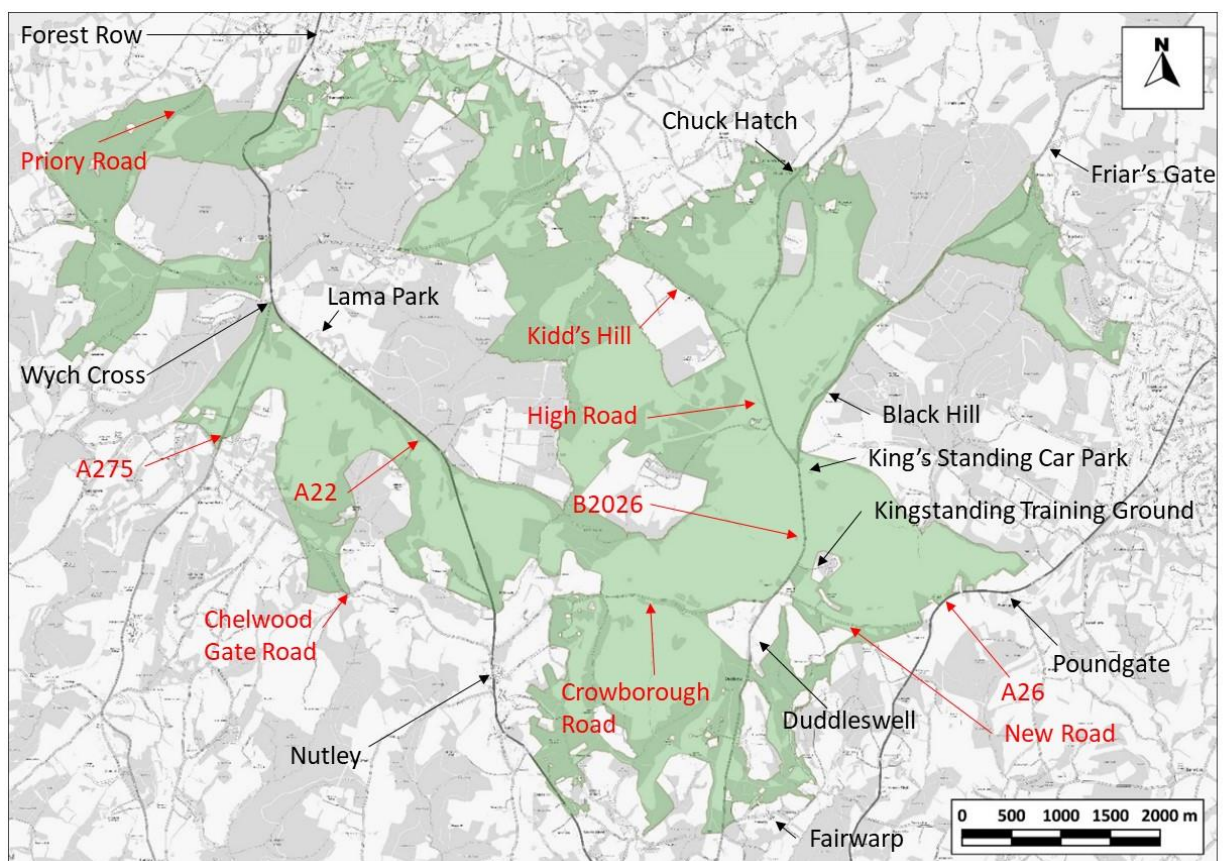


Figure 1: Ashdown Forest SAC (green shading) and Place Names used in this Report (Red for road names, black for place names)

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- 1.3 The pollutants considered in this report are:
- nitrogen dioxide (NO₂);

- nitrogen oxides¹ (NO_x);
- nitric acid (HNO₃);
- nitrous acid (HONO);
- ammonia (NH₃);
- particulate ammonium (pNH₄⁺);
- airborne reduced nitrogen² (NH_x);
- particulate nitrate (pNO₃⁻); and
- particulate nitrite (pNO₂⁻).

- 1.4 As far as the authors are aware, this report describes the most extensive monitoring study of traffic-related nitrogen deposition that has ever taken place; either in the UK or internationally. The large number of monitors, and monitoring sites, used in the study described here means that spatial and temporal trends can be determined with far greater certainty than would be possible had fewer sites been used. The study thus provides important information not only regarding air quality in Ashdown Forest, but also with respect to traffic-related air quality more generally.
- 1.5 A key local benefit of this monitoring network is its ability to inform modelling. Models assume that conditions which occur 'on average' occur everywhere and thus models calibrated against small numbers of monitors are likely to be biased toward the specific conditions in those locations. By providing a large number of calibration points in a variety of different settings, the network described here reduces the potential for bias in any future modelling studies of air quality in Ashdown Forest. The network also includes measurements of pollutants such as HNO₃, as well as background measurements of NH₃, which are often inferred from coarse national models. The measurements of these pollutants, which are presented here, will thus allow more accurate future modelling.
- 1.6 Section 2 of this report describes the monitoring methodology. It describes the instruments used, their locations, and the exposure dates. Section 3 describes the quality assurance of the data, including how the measurements have been adjusted to annual mean equivalence, and where data have had to be discarded. Section 4 then sets out the measurements.
- 1.7 In addition to providing a more robust basis for future modelling, it is possible to discern spatial and temporal patterns directly from the measurements themselves. In order to maximise value from the monitoring study, Section 5 presents a detailed analysis of spatial patterns in the measured concentrations. This includes an examination of what these spatial patterns can reveal of the relative composition of reactive nitrogenous pollution across the SAC. Section 6 then analyses how the

¹ NO_x = NO₂ + NO.

² NH_x = NH₃ + pNH₄⁺.

measured concentrations changed over the course of the study and how different sources may have contributed to these changes. Section 7 provides a summary and conclusions.

2 Monitoring Methodology

2.1 Ambient pollutant concentrations were measured using the following methods:

- 1 x continuous analyser measuring hourly-mean concentrations of NO₂, NO, and NH_x³;
- 102 x passive NO₂ diffusion tube sites, measuring monthly-mean concentrations of NO₂;
- 6 x DENuder for Long-Term Atmospheric ('DELTA') II systems, measuring monthly-mean concentrations of NH₃, HNO₃, HONO, pNH₄⁺, pNO₃⁻, and pNO₂⁻⁴; and
- 87 x Adapted Low-cost Passive High Absorption ('ALPHA') samplers, collocated in triplicate across 29 sites, measuring monthly-mean concentrations of NH₃.

2.2 It is not practical to measure nitrogen deposition directly. Dry deposition of reactive nitrogen is typically modelled based on the ambient concentrations of the pollutant species listed above. Total deposition is the sum of dry deposition and wet deposition. Wet deposition is measured by Defra as part of the United Kingdom Eutrophying and Acidifying Network (UKEAP)⁵.

2.3 In addition to the air quality monitoring, traffic flows have been measured at eight sites across the SAC using Automatic Traffic Counters (ATCs). These counters accompanied five traffic monitoring sites operated by East Sussex County Council (ESCC).

Commissioning Dates

2.4 Table 1 provides the dates of commissioning and decommissioning for each of the monitoring methods discussed within this report.

³ The analyser purportedly measures NH₃, but the potential for cross-contamination with pNH₄⁺ could not be discounted. The instrument is thus described in this report as an NH_x analyser.

⁴ The DELTA samplers also measure other components which are not of direct interest to this study except for the data quality assurance which has been applied, namely sulphur dioxide, hydrogen chloride, and particulate sulphate, chloride, sodium, calcium, and magnesium. These components are not mentioned further in this report.

⁵ The closest current site is at Lullington Heath, ca. 25 km south of the SAC. Wet deposition fluxes do not change much over small distances unless there are significant differences in land elevation.

Table 1: Dates of Commissioning and Decommissioning

Method	Date of Commissioning	Date of Decommissioning
NO_x / NH_x Continuous Analyser	29 th October 2014	23 rd March 2020
Diffusion Tubes	7 th / 8 th August 2014 (Individual Sites)	24 th March 2020
	4 th / 5 th September 2014 (Transects)	
DELTA Denuder Sites	12 th November 2014	23 rd - 24 th March 2020 ^a
ALPHA Sites	12 th – 13 th November 2014 (25 sites)	23 rd - 24 th March 2020
	9 th – 11 th December 2014 (4 sites)	
ATC Sites	30 th August – 13 th September 2015	1 st April 2020

^a As explained in Paragraph 3.22, one of the sites was destroyed by vandalism during 2018 and was not replaced.

Details of the NO_x/NH_x Continuous Analyser

- 2.5 The continuous ('automatic') monitor was located beside the eastern kerb of the B2026 between New Road and High Road (Figure 2). The site was located within the grounds of Kingstanding police training grounds, which provided both a secure site and a fixed electrical power supply. The continuous analyser is shown in Figure 3.
- 2.6 The instrument was a Teledyne API T201 Chemiluminescent NH_x/NO_x combined analyser. This measured NH_x, NO, NO_x and NO₂ over 15-minute averaging periods. The instrument was housed in an air-conditioned enclosure to ensure correct operation. This was a pumped instrument, with air drawn in from an inlet at the roadside edge of the enclosure, 1.7 m from the kerb.
- 2.7 This type of monitoring method for NO_x was used because it is the methodology used by Defra in its Automatic Urban and Rural Network (AURN) and it represents the 'reference' method for NO_x and NO₂ in the UK. A version of this monitor that can also measure NH₃ was chosen to provide more information short-term temporal variation in NH₃ concentrations.



Figure 2: Location of Automatic Monitor

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Figure 3: Automatic Monitor Enclosure at Kingstanding Police Training Grounds

Details of the NO₂ Diffusion Tubes

- 2.8 The NO₂ diffusion tubes are termed ‘passive’ samplers because they do not pump air and thus require no power supply. They were 7.1 cm long plastic tubes with an absorbent grid at one end. Gas diffused up the tube and was collected on the absorbent. After exposure, each tube was returned to the laboratory for analysis. All diffusion tubes were supplied and analysed by Gradko Environmental using the 20% TEA in water method. Gradko Environmental holds United Kingdom Accreditation Service (UKAS) accreditation to ISO 17025:2005 for this service.
- 2.9 Tubes were exposed in singlet (i.e. one tube in each location) following Defra’s advice for Local Air Quality Management, and to maximise value of the dataset in terms of characterising conditions in as many alternative locations as possible. The exception to this was the use of triplicate tubes co-located with the automatic monitor. Each tube was exposed for a period of approximately four weeks.
- 2.10 NO₂ diffusion tubes were used since they provide reasonable information on long-term NO₂ concentrations for a relatively low cost and with minimal infrastructure requirements. This means that it has been possible to sample NO₂ concentrations at a large number of sites and thus improve knowledge of concentrations across the SAC.
- 2.11 The site locations are shown Figure 4 to Figure 13. Tubes were either attached to street furniture (lamp posts etc.) or to wooden posts. Figure 14, below, shows one of the NO₂ diffusion tube sites. The sites comprised roadside and background locations, as well as four transects. Each transect was made up of 7 to 8 sites located at increasing distances from the kerb. The first site was as close as possible to the kerb, the next site was 2.5 m from the kerb, and then the next five sites were 5 m, 10 m, 22 m, 50 m, 100 m, and 200 m from the kerb⁶. The four transects were:
- running west of the A22 between Nutley and Wych Cross (Transect 1 = Sites R1.1 to R1.8);
 - running east of the A22 between Nutley and Wych Cross (Transect 2 = Sites R2.1 to R2.8);
 - running east of the B2026 between New Road and High Road (Transect 3 Sites R3.1 to R3.8); and
 - running north of the A26 at Poundgate (Transect 4 = Sites R4.1 to R4.7⁷).

⁶ Transects 1, 2 and 3 were initially installed (in October 2014) with a monitor 1 m from the kerb. The following month, as a result of concerns raised by the Conservators of Ashdown Forest regarding ease of access for mowing equipment, these monitors were moved back 70 cm, to be 1.7 m from the kerb. In other respects, the positions of the monitors have not altered since they were first installed.

⁷ The gorse 200 m along Transect 4 was impenetrable and thus this transect ended approximately 100 m from the road. The nearest background site (T18) did not appear to provide the best indication of background conditions along this transect since it often recorded higher concentrations than those at 100 m from the road.

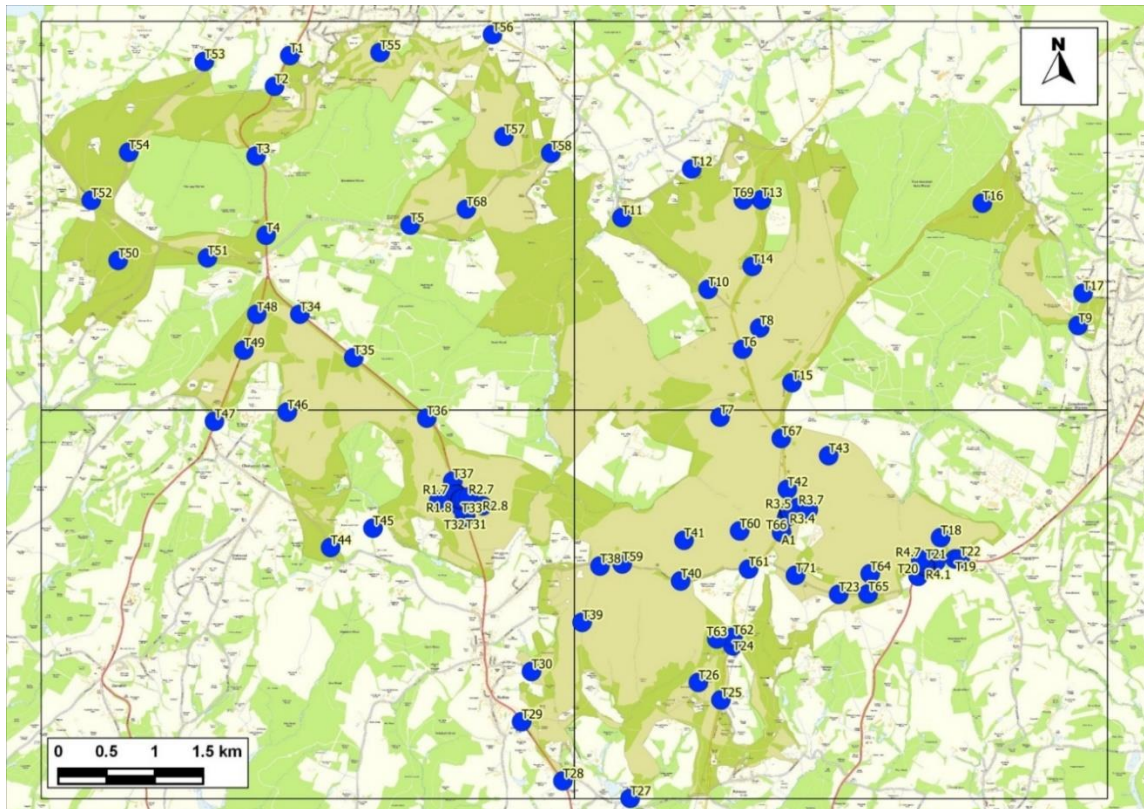


Figure 4: All Diffusion Tube Sites (Also showing four quadrants used for the following more detailed maps)

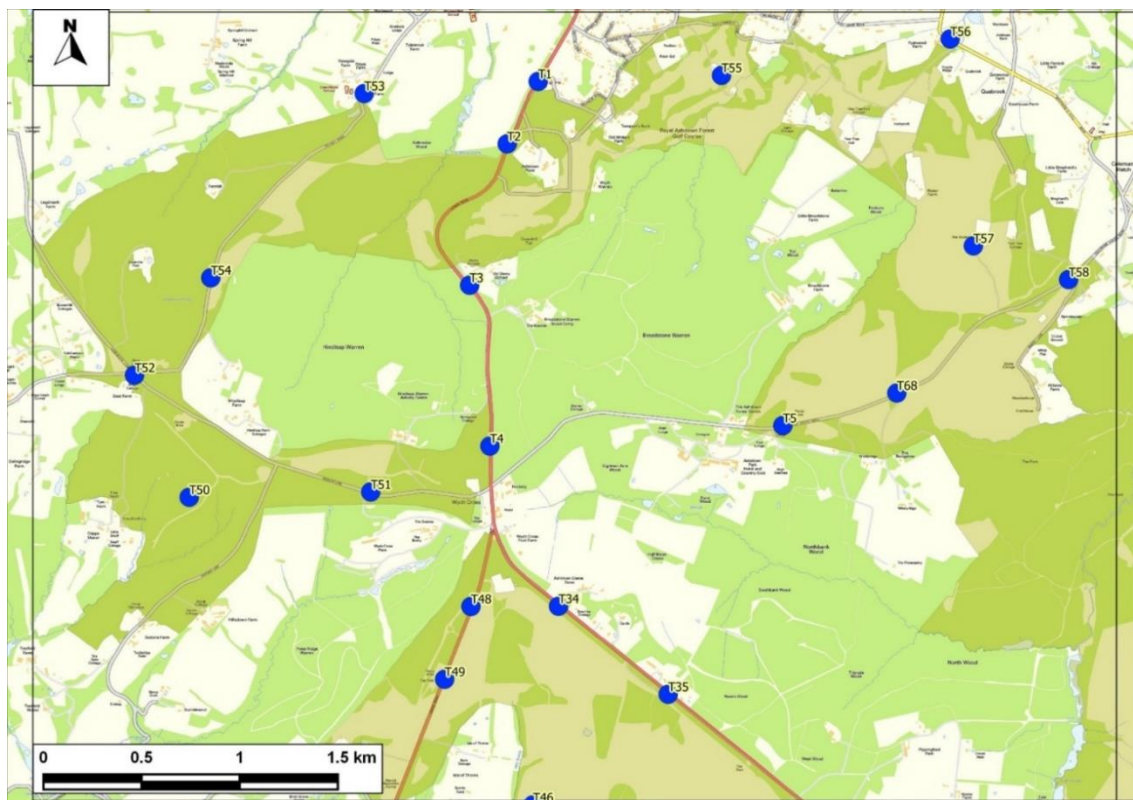


Figure 5: Diffusion Tube Sites in Northwest Section of Study Area

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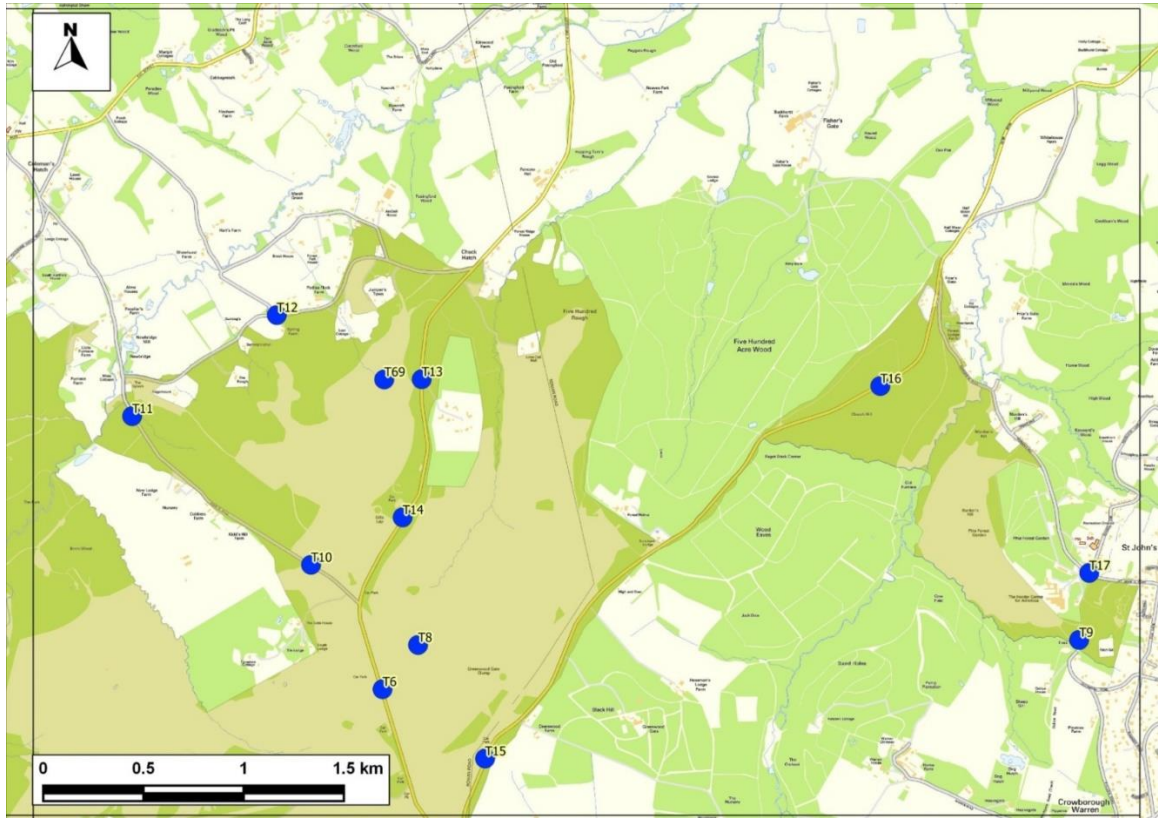


Figure 6: Diffusion Tube Sites in Northeast Section of Study Area

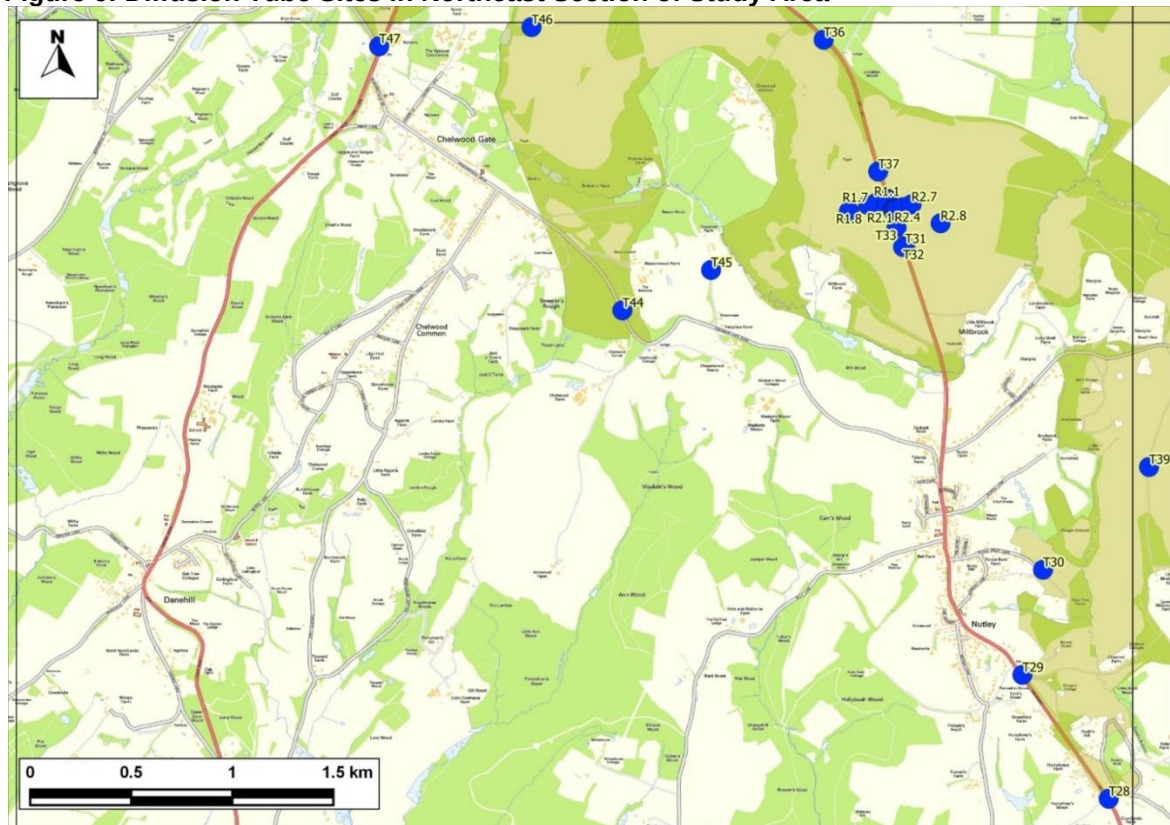


Figure 7: Diffusion Tube Sites in Southwest Section of Study Area

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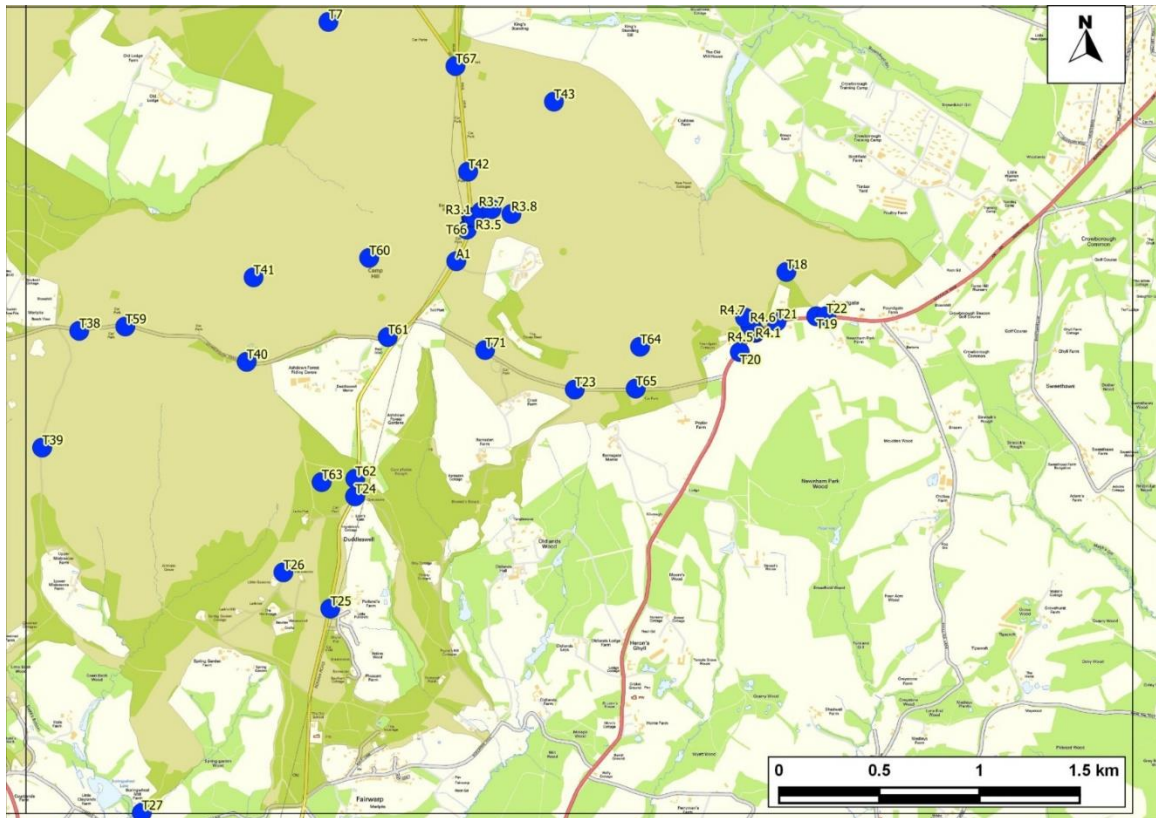


Figure 8: Diffusion Tube Sites in Southeast Section of Study Area



Figure 9: Monitoring Transects

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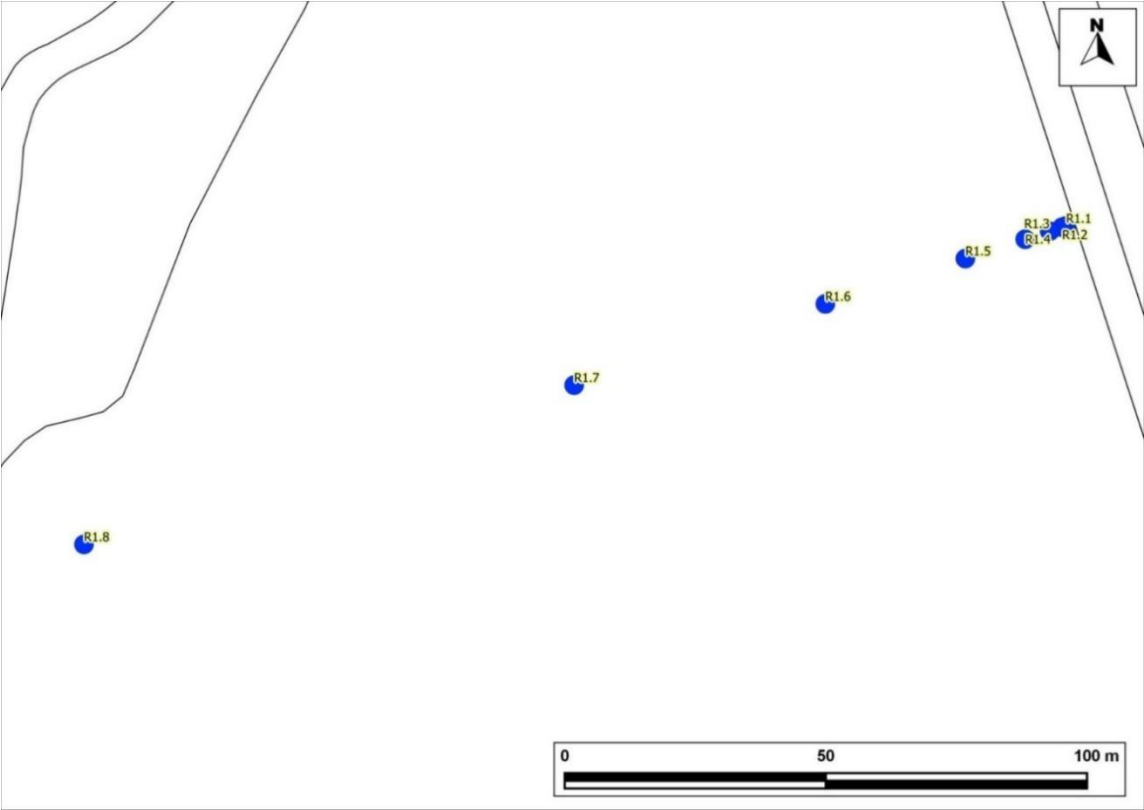


Figure 10: Transect 1 (Sites R1.1 to R1.8)

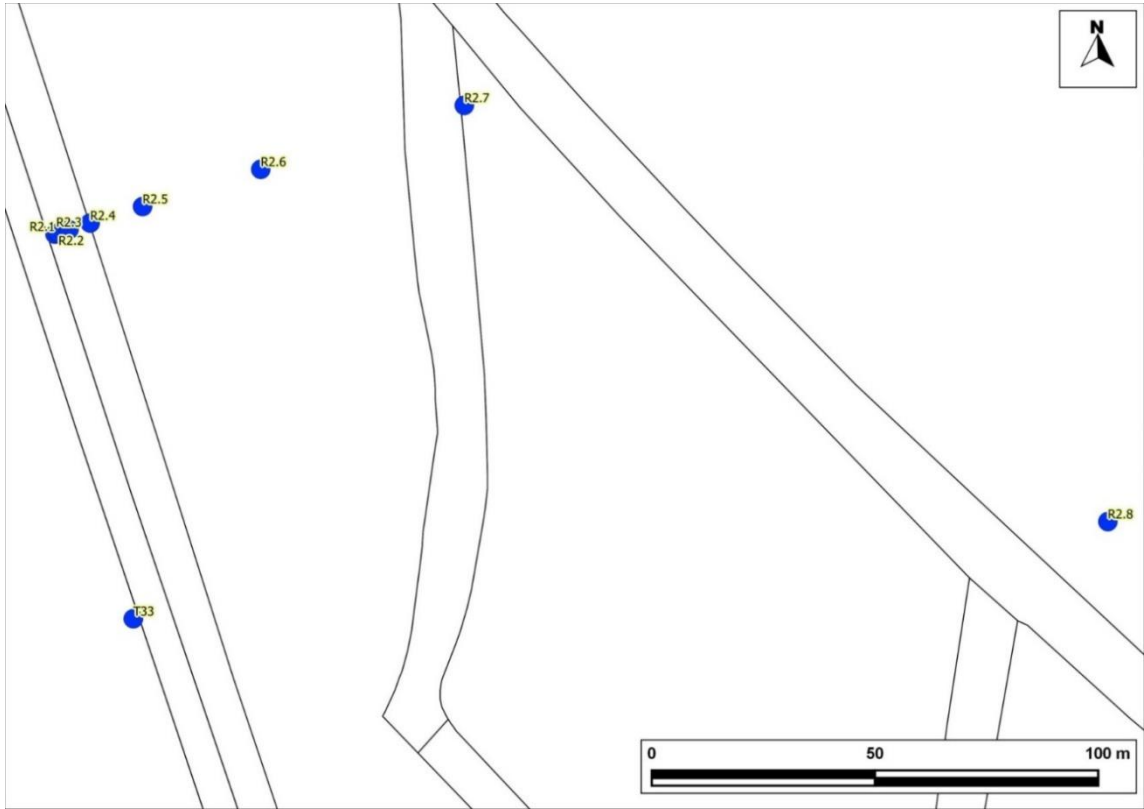


Figure 11: Transect 2 (Sites R2.1 to R2.8)

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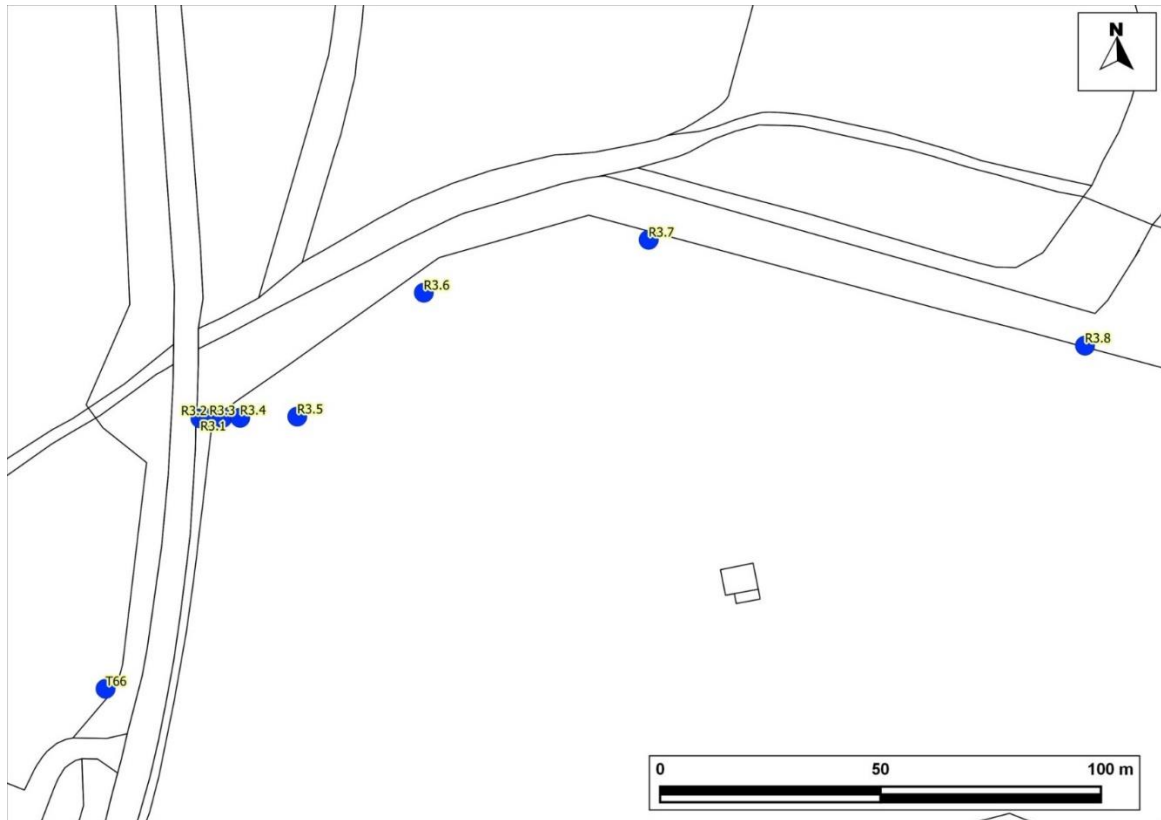


Figure 12: Transect 3 (Sites R3.1 to R3.8)

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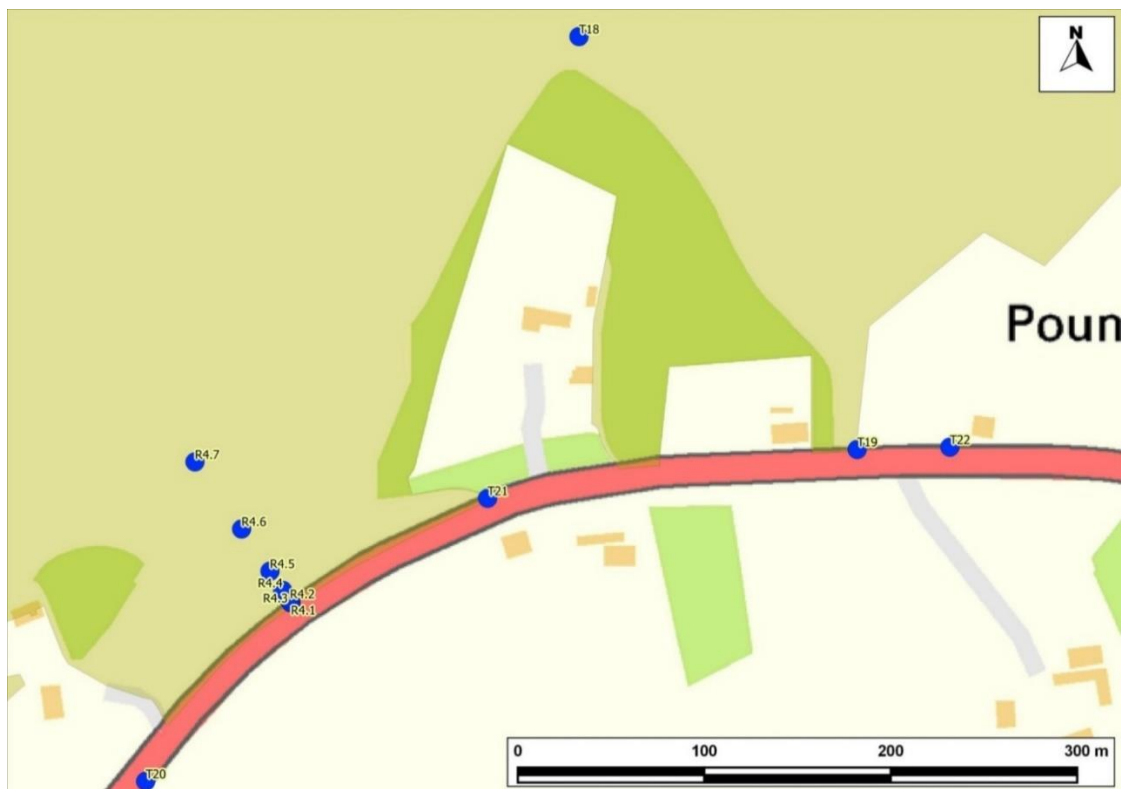


Figure 13: Transect 4 (Sites R4.1 to R4.7)

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Figure 14: Diffusion Tube Monitor (Site T43)

Details of the DELTA Samplers

- 2.12 Each DELTA system consisted of an extended denuder-filter pack sampling train through which ambient air was drawn by a pump, with air volume captured by a high sensitivity dry gas meter (Conolly et al., 2016). The walls of the denuders (borosilicate glass tubes) were coated with acid and alkaline solutions which capture basic (NH_3) and acidic (HNO_3) gases respectively. Particles were then collected on filters. Each set of tubes and filters was exposed for approximately one month before the samples were returned to the laboratory for analysis. By comparing the amount of material deposited on the sampler with the volume of air drawn through the system, as recorded by a gas flow meter, the average ambient concentration during the monitoring period was derived. The DELTA samplers were provided and analysed by the UK Centre for Ecology and Hydrology (UKCEH).
- 2.13 DELTA samplers were used for this project as they form the basis of Defra's National Ammonia Monitoring Network (NAMN) and UK Acid Gases and Aerosols Monitoring Network (AGANet) and thus form the 'reference' method for measuring NH_3 and HNO_3 in the UK.

- 2.14 The locations of the six DELTA monitors are shown in Figure 15. One of the sites (D3) was co-located with the automatic monitor and took electricity from the same fixed power source. The remaining five sites were equipped with their own solar panels and wind-powered generators, along with deep cycle batteries to generate and store electricity.

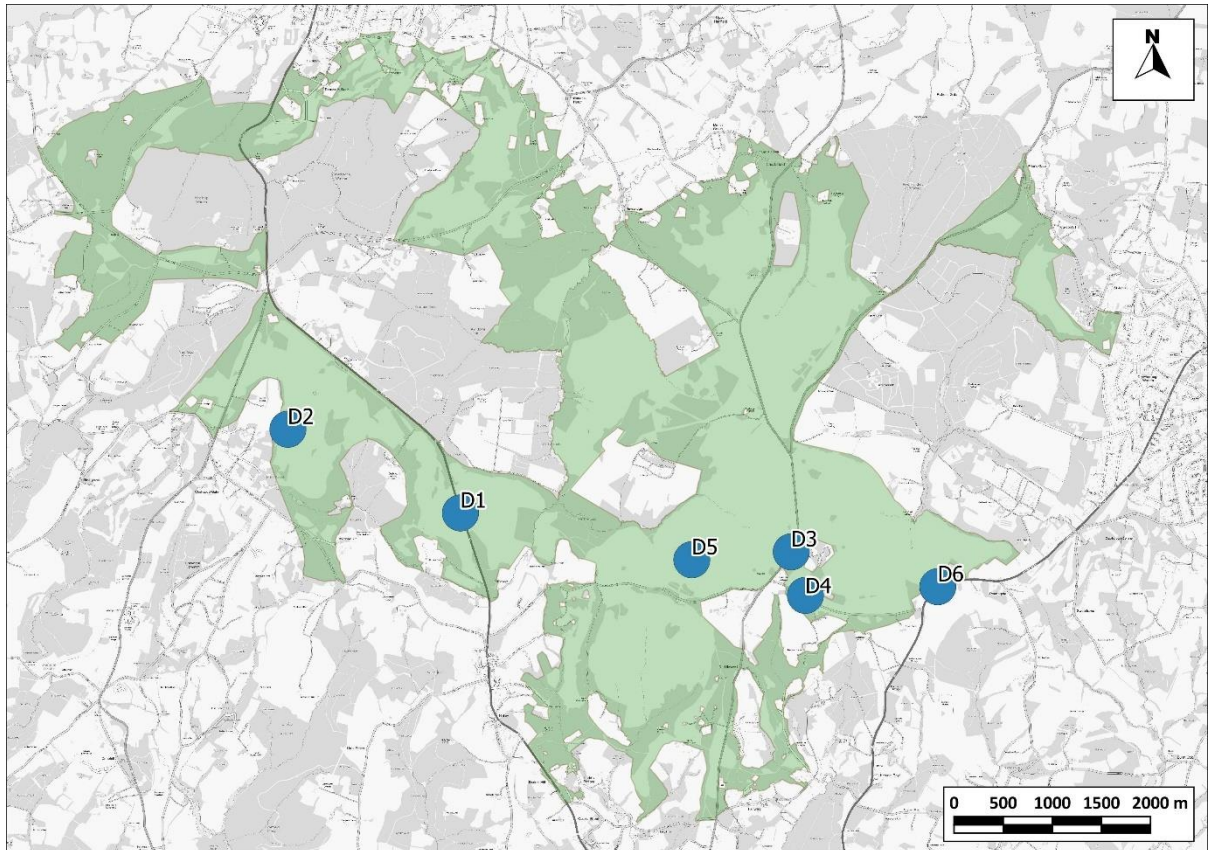


Figure 15: Locations of DELTA Monitors

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- 2.15 Two of the DELTA sites represented background conditions. The remaining three were all roadside sites. The roadside sites were:
- 5 m from the A26 at Poundgate (Site D6);
 - 5 m from the A22 between Nutley and Wych Cross (Site D1); and
 - 5 m from New Road, between the B2026 and the A26 (Site D4).
- 2.16 Figure 16 shows one of the DELTA samplers, together with its wind-powered generator.



Figure 16: DELTA Sampler, Wind Generator, Gas Meter, Solar Panel (and Moat) (Site D4)

Details of the ALPHA Samplers

- 2.17 Like the NO₂ diffusion tubes, the ALPHA samplers were passive samplers. Each ALPHA sampler was a short, flat tube with an absorbent filter paper at the top and a PTFE membrane across the inlet at the bottom (Figure 17). Air passed through the PTFE membrane and NH₃ was collected by the filter paper. After exposure, the samplers were returned to the laboratory for analysis. The ALPHA samplers were supplied and analysed by UKCEH.
- 2.18 ALPHA samplers were used for this project as they are cheaper than DELTA samplers and require less infrastructure. They can thus be used in greater numbers than DELTA samplers and can be deployed in locations where the siting of DELTA samplers would be impractical. ALPHA samplers are used as part of the NAMN and have been shown to be reasonably accurate. Alternative low-cost methods of NH₃ sampling were not used because there is evidence that they are unable to reliably record the ambient background concentrations which were expected to be found (and were found) in this study (e.g. Tang et al., (2001), Martin et al., (2019)).

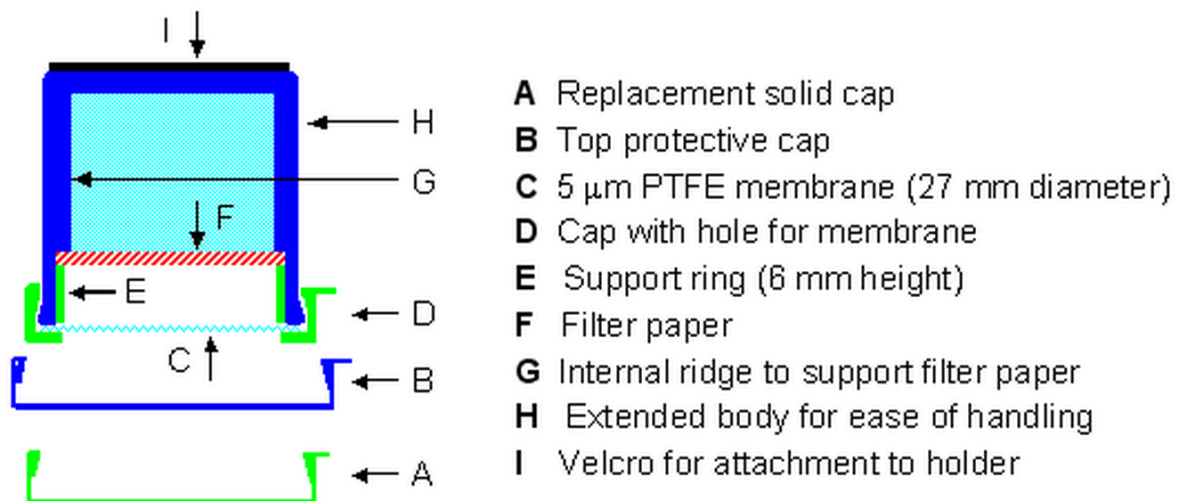


Figure 17: Diagram of an ALPHA sampler (Tang et al., (2001))

2.19 Each month, 87 ALPHA samplers were exposed in triplicate across 29 monitoring sites as shown in Figure 18. Triplicate samplers were used to provide more reliable measurements and to replicate the operation of the NAMN.

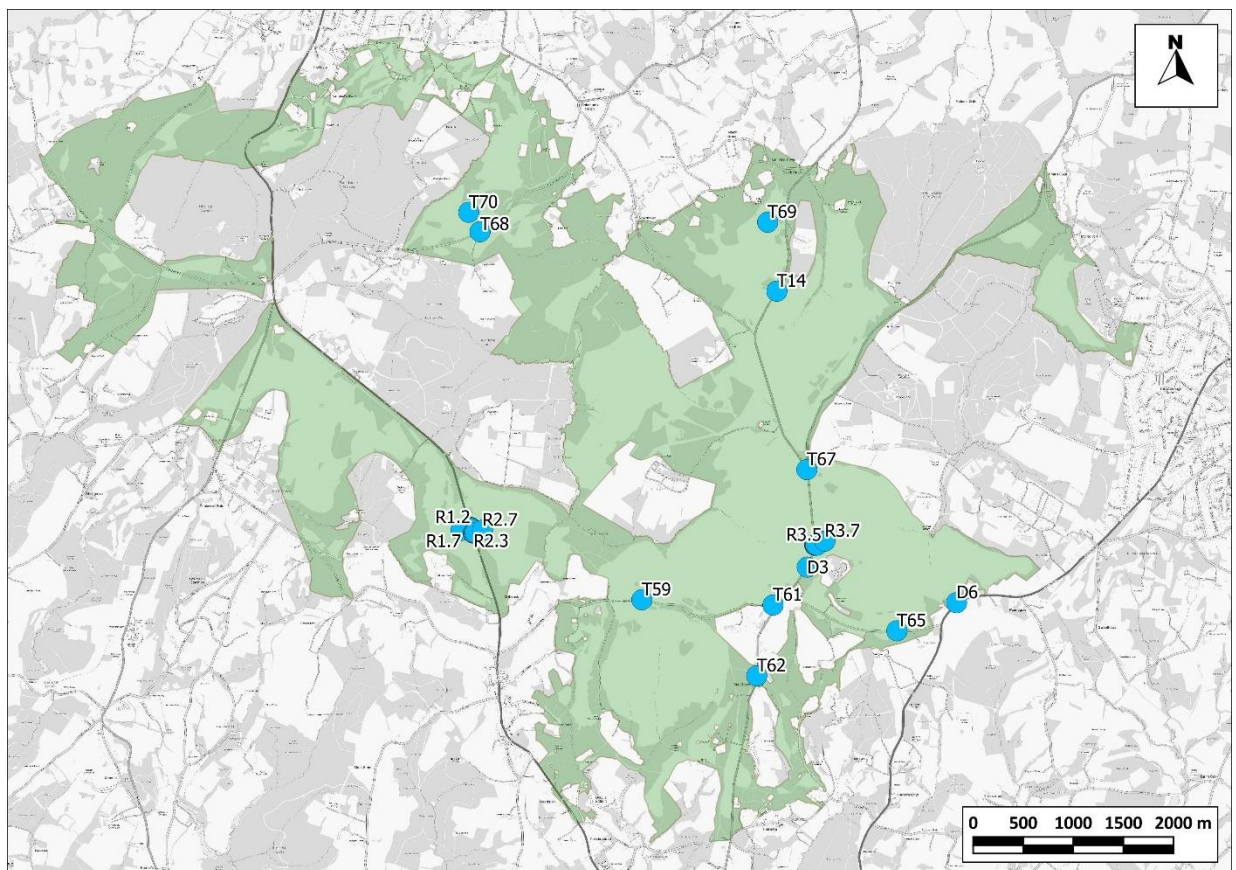


Figure 18: Locations of ALPHA Monitors ^a

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^a Not all sites on the three transects are labelled. See Figure 10 to Figure 12 for transect monitor locations.

- 2.20 One of these 29 sites was co-located with the automatic monitor (A1) and DELTA sampler (D3) at Kingstanding police station, and one was co-located with the DELTA site beside the A26 at Poundgate (Site D6).
- 2.21 Eighteen of the sites were arranged over three transects. Each transect was made up of six sites located at increasing distances from the kerb. The first site was located as close as possible to the kerb, the next site was 2.5 m from the kerb, and then the next four sites were 5 m, 10 m, 22 m, and 100 m from the kerb. The three transects were:
- running west of the A22 between Nutley and Wych Cross (Transect 1 = Sites R1.1, R1.2, R1.3, R1.4, R1.5, and R1.7);
 - running east of the A22 between Nutley and Wych Cross (Transect 2 = Sites R2.1, R2.2, R2.3, R2.4, R2.5, and R2.7); and
 - running east of the B2026 between New Road and High Road (Transect 3 = Sites R3.1, R3.2, R3.3, R3.4, R3.5, and R3.7).
- 2.22 Each set of three samplers was attached to an aerodynamically shaped support. Figure 19 shows one of the ALPHA sites.



Figure 19: Example of an ALPHA Site

Combined Sites

- 2.23 Where appropriate, sites were equipped with more than one type of monitor. For example, transects 1, 2, and 3 were used for both NO₂ diffusion tubes and ALPHA samplers. Table 2 provides details of all the sites and shows which instruments were co-located.
- 2.24 Each of the sites with DELTA instruments have more than one name. This is because it makes most sense, when considering the NO₂ diffusion tube network, to use the name specific to that network (i.e. 'T1' to 'T71' for isolated sites, and 'R1.1' to 'R1.7' for the transects), but when considering the much smaller DELTA network, the nomenclature for that network ('D1' to 'D6') is more convenient. Table 2 provides both names for the DELTA sites. Subsequent discussion of the results uses the diffusion tube network nomenclature for NO₂ measurements and the DELTA network nomenclature for ammonia measurements; where appropriate, making clear the alternative site name in each case. The analysis in Sections 5 and 6 takes account of the co-located sites irrespective of their nomenclature.

Table 2: Monitoring Site Locations ^a

Site	No. NO ₂ Tubes	No. ALPA Samplers	No. DELTA Samplers	Auto Monitor	O.S. X	O.S.Y	Distance - edge of nearest road (m)	Height above ground (m)
A1 (D3)	3	3	1	1	547293.88	129153.34	1.7	1.5
T1	1	0	0	0	542198.77	134088.21	1.54	2.6
T2	1	0	0	0	542040.65	133769.82	2.1	2.7
T3	1	0	0	0	541849.49	133049.07	1.6	2.7
T4	1	0	0	0	541952.70	132229.07	1.7	2.5
T5	1	0	0	0	543445.64	132333.46	1.0	2.3
T6	1	0	0	0	546889.52	131049.36	3.7	1.3
T7	1	0	0	0	546655.64	130346.75	417	1.5
T8	1	0	0	0	547067.00	131270.00	240	1.5
T9	1	0	0	0	550366.00	131295.00	313	1.5
T10	1	0	0	0	546532.76	131669.66	0.8	3.1
T11	1	0	0	0	545639.95	132411.01	0.68	3
T12	1	0	0	0	546361.87	132915.11	1.3	3.1
T13	1	0	0	0	547085.20	132595.00	0.97	2.85
T14	1	3	0	0	546989.94	131906.04	2.5	1.85
T15	1	0	0	0	547401.21	130703.49	1.3	2.4
T16	1	0	0	0	549373.96	132561.04	1.64	1.8
T17	1	0	0	0	550416.54	131629.33	1.42	3
T18	1	0	0	0	548941.00	129100.00	233	1.5
T19	1	0	0	0	549090.26	128878.67	2.6	2.9

Site	No. NO ₂ Tubes	No. ALPA Samplers	No. DELTA Samplers	Auto Monitor	O.S. X	O.S.Y	Distance - edge of nearest road (m)	Height above ground (m)
T20	1	0	0	0	548708.55	128700.71	1.2	2.8
T21	1	0	0	0	548892.00	128852.47	1.3	2.25
T22	1	0	0	0	549139.98	128879.91	2.6	2.6
T23	1	0	0	0	547885.01	128513.63	3.5	1.7
T24	1	0	0	0	546788.44	127980.71	4.75	2.7
T25	1	0	0	0	546665.10	127421.12	1.4	2.8
T26	1	0	0	0	546431.00	127602.00	258	1.5
T27	1	0	0	0	545724.53	126402.87	560	1.5
T28	1	0	0	0	545027.61	126583.51	2.3	2.7
T29	1	0	0	0	544600.43	127196.17	1.45	3.03
T30	1	0	0	0	544702.53	127715.86	460	1.5
T31	1	0	0	0	544020.36	129315.55	2.7	1.75
T32	1	0	0	0	544009.75	129311.63	1.22	2.07
T33	1	0	0	0	543977.68	129407.25	1.3	1.63
T34	1	0	0	0	542302.44	131412.07	1.7	1.65
T35	1	0	0	0	542861.22	130963.30	2.9	2.3
T36	1	0	0	0	543617.15	130336.53	2.0	1.95
T37	1	0	0	0	543887.14	129684.60	1.18	2.4
T38	1	0	0	0	545411.96	128806.19	0.97	2.27
T39	1	0	0	0	545227.00	128224.00	560	1.5
T40	1	0	0	0	546247.69	128651.75	1.76	2
T41 (D5)	1	0	1	0	546282.00	129073.00	390	1.5
T42	1	0	0	0	547352.68	129599.94	1.4	1.8
T43	1	0	0	0	547781.00	129949.00	453	1.5
T44	1	0	0	0	542621.24	128998.36	1.36	2.54
T45	1	0	0	0	543060.13	129197.94	264	1.5
T46 (D2)	1	0	1	0	542172.00	130399.00	660	1.5
T47	1	0	0	0	541418.04	130304.02	0.9	1.82
T48	1	0	0	0	541855.99	131411.04	1.35	2.3
T49	1	0	0	0	541721.88	131039.81	2.34	2.48
T50	1	0	0	0	540420.00	131968.00	328	1.5
T51	1	0	0	0	541345.22	131995.00	1.03	2.26
T52	1	0	0	0	540141.46	132590.48	1.3	2.1
T53	1	0	0	0	541312.17	134026.87	1.45	2.2
T54	1	0	0	0	540530.12	133086.95	0.85	2.15
T55	1	0	0	0	543133.18	134119.21	215	1.5
T56	1	0	0	0	544298.77	134305.08	1.2	2.7

Site	No. NO ₂ Tubes	No. ALPA Samplers	No. DELTA Samplers	Auto Monitor	O.S. X	O.S.Y	Distance - edge of nearest road (m)	Height above ground (m)
T57	1	0	0	0	544416.83	133249.84	356	1.5
T58	1	0	0	0	544902.14	133077.79	1.5	2.22
T59	1	3	0	0	545642.20	128827.77	2.0	2.2
T60	1	0	0	0	546859.00	129170.00	360	1.5
T61	1	3	0	0	546951.93	128775.36	2.8	2.7
T62	1	3	0	0	546789.61	128068.66	2.4	1.8
T63	1	0	0	0	546622.00	128052.00	166	1.5
T64	1	0	0	0	548211.00	128727.00	211	1.5
T65	1	3	0	0	548189.22	128518.40	1.4	1.75
T66	1	0	0	0	547346.78	129311.23	1.6	1.9
T67	1	3	0	0	547289.80	130126.40	1.8	1.75
T68	1	3	0	0	544026.69	132499.39	2.1	1.8
T69	1	3	0	0	546898.00	132594.00	181	1.5
T70	0	3	0	0	543914.00	132693.00	226	1.5
T71 (D4)	1	0	1	0	547437.74	128710.57	5.5	1.5
Transects								
R1.1	1	3	0	0	543930.75	129549.48	1.7	1.2
R1.2	1	3	0	0	543929.99	129549.24	2.5	1.5
R1.3 (D1)	1	3	1	0	543927.61	129548.47	5.0	1.5
R1.4	1	3	0	0	543922.91	129546.94	10	1.5
R1.5	1	3	0	0	543911.46	129543.24	22	1.5
R1.6	1	0	0	0	543884.64	129534.57	50	1.5
R1.7	1	3	0	0	543836.54	129519.01	100	1.5
R1.8	1	0	0	0	543742.67	129488.55	200	1.5
R2.1	1	3	0	0	543960.13	129493.36	1.7	1.75
R2.2	1	3	0	0	543960.93	129493.60	2.5	1.5
R2.3	1	3	0	0	543963.26	129494.34	5.0	1.5
R2.4	1	3	0	0	543968.01	129495.84	10	1.5
R2.5	1	3	0	0	543979.76	129499.53	22	1.5
R2.6	1	0	0	0	544006.23	129507.86	50	1.5
R2.7	1	3	0	0	544051.83	129522.19	100	1.5
R2.8	1	0	0	0	544196.00	129429.00	206	1.5
R3.1	1	3	0	0	547368.31	129372.53	1.0	1.7
R3.2	1	3	0	0	547369.77	129372.55	2.5	1.3
R3.3	1	3	0	0	547373.29	129372.62	6.0	1.7
R3.4	1	3	0	0	547377.33	129372.66	10	1.9
R3.5	1	3	0	0	547390.27	129372.92	23	1.9

Site	No. NO ₂ Tubes	No. ALPA Samplers	No. DELTA Samplers	Auto Monitor	O.S. X	O.S.Y	Distance - edge of nearest road (m)	Height above ground (m)
R3.6	1	0	0	0	547419.00	129401.00	51	1.9
R3.7	1	3	0	0	547470.00	129413.00	100	1.9
R3.8	1	0	0	0	547569.00	129389.00	200	1.8
R4.1	1	0	0	0	548786.49	128796.40	2.0	1.7
R4.2	1	0	0	0	548785.95	128797.20	3.0	1.65
R4.3 (D6)	1	3	1	0	548784.83	128798.90	5.0	1.8
R4.4	1	0	0	0	548782.03	128803.12	10	1.5
R4.5	1	0	0	0	548775.22	128813.38	22	1.5
R4.6	1	0	0	0	548760.00	128836.00	50	1.5
R4.7	1	0	0	0	548735.00	128872.00	96	1.5

- ^a Coordinates are reported to the nearest cm to assist modellers. Close to roads, these coordinates have been set as precisely as possible. For background sites they are less precise (1 m precision). The distances are all given to the precision to which measurements were recorded in the field. This was based on what was considered reasonable and practical for each site. Where whole metres are given for short distances, this most often reflects the choice of post location rather than measurement imprecision. Distances shorter than 50 m were measured in the field. Longer distances were measured using mapping and GPS and are thus less precise. All distances are measured perpendicular to the nearest road and are measured horizontally (i.e. take no account of monitor height). Monitor heights close to roads were measured in the field. Heights are above the ground beneath the monitor and take no account of slopes or surrounding vegetation. Instrument heights at background sites were not measured but were generally set to be approximately 1.5 m and so this value has been used.

Details of the Automatic Traffic Counters

- 2.25 The ATCs consisted of pneumatic loops buried in the surfaces of the roads. Vehicles travelling along the roads depressed the loops, causing pneumatic pulses to be sent to the counter units. The counter units stand at the roadsides and were powered by solar panels and batteries. They were fitted with modems to allow the data to be polled remotely. The ATCs were installed and maintained by Q-Free TDC and used Hi-TRAC UTC-L systems. Figure 20 shows one of the ATC units. ATCs were used for this project following the advice of East Sussex County Council.



Figure 20: ATC Control Box and Loop

2.26 The sites were located to complement the existing ATC sites in the area which are operated by ESCC. The locations of the WDC ATC sites were as follows:

- Site 1201 – New Road (between B2026 and A26)
- Site 1202 – B2188 (towards Friar's Gate)
- Site 1203 – Crowborough Road
- Site 1204 – B2026 (near junction with Kidd's Hill)
- Site 1205 – B2026 (near Chuck Hatch)
- Site 1206 – A22 (near Forest Row)
- Site 1207 – Coleman's Hatch Road
- Site 1208 – B2026 (towards Fairwarp)

2.27 The locations of the ESCC ATC sites were as follows:

- Site 16 – A22 (near Ashurstwood)
- Site 18 – A26 (near Poundgate)

- Site 38 – A275 (near Wych Cross)
- Site 41 – B2026 (between Duddleswell and Black Hill)
- Site 129 – A22 (near Wych Cross)

2.28 The ATC site locations are shown in Figure 21.

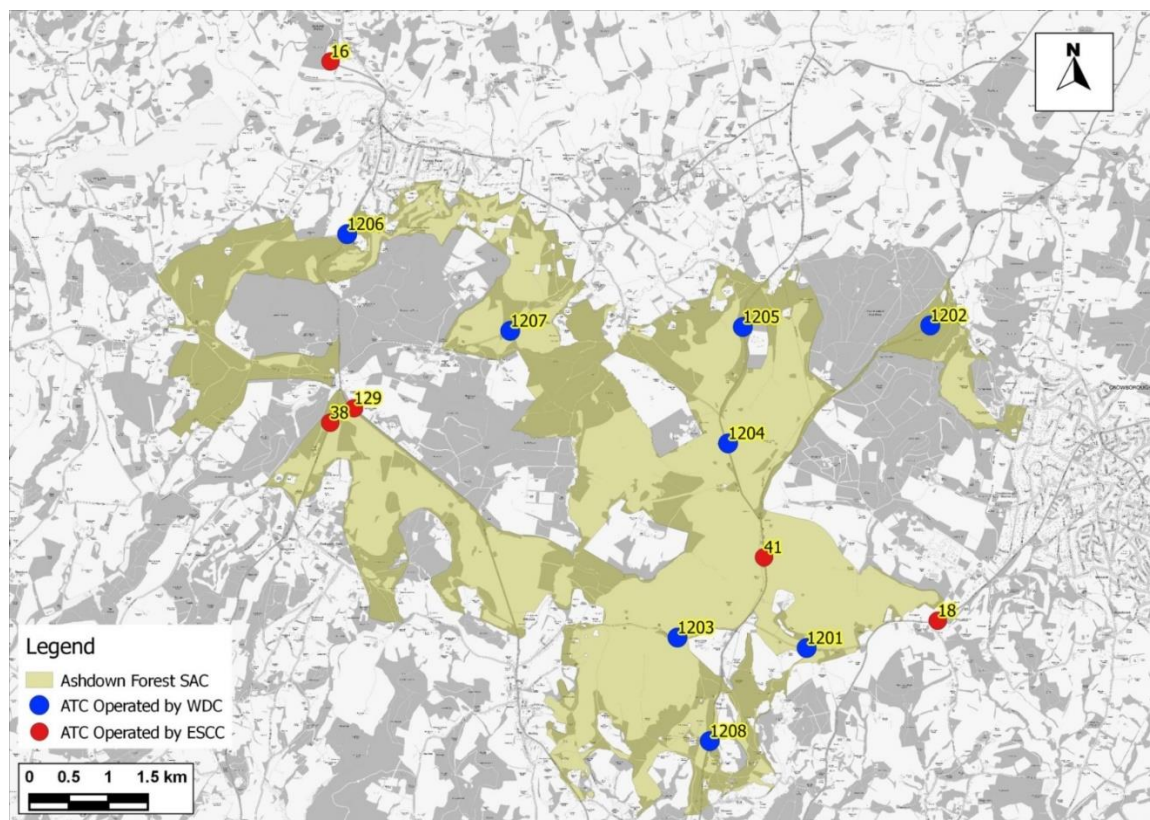


Figure 21: Locations of WDC and ESCC ATC Sites

Map Data ©2021 Google Additional data sourced from third parties, including public sector information licensed under the Open Government Licence v1.0

3 Quality Assurance

NO_x/NH_x Continuous Analyser

Routine Checks

- 3.1 The instrument housed a fixed IP address modem, allowing data to be downloaded automatically to a remote server. The data were checked regularly by AQC staff in order to identify and swiftly rectify any data quality issues.

Calibration

- 3.2 Routine on-site calibrations were carried out each month following standard procedures. These calibrations were carried out by Enviro Technology Services and WeCare4Air.

Servicing

- 3.3 Servicing of the instrument was carried out at approximately 6-month intervals following manufacturer protocols. This was carried out by Enviro Technology Services and WeCare4Air.

External Audits

- 3.4 External quality control site audits were carried out twice each year by Ricardo Energy and Environment.

Ratification

- 3.5 The 15-minute readings were aggregated to 1-hour mean concentrations. Ratification of the data was based on calibration factors determined from the monthly calibrations and external audits, along with visual examination of the data and comparison with monitoring data from the nearby AURN monitors at Lullington Heath, Eastbourne, and Horley⁸. Any erroneous data were flagged and removed from subsequent analysis.

Data Capture

- 3.6 Table 3 summarises the data capture achieved by the automatic analyser.

⁸ Defra (2021), Defra Air Quality Website, Available at: <http://laqm.defra.gov.uk/>

Table 3: Data Capture by the Automatic Analyser

Year	Data Capture ^a	Residual Data after Ratification
2014	99.7%	94.9%
2015	99.8%	92.5%
2016	98.2%	77.4%
2017	99.7%	87.5%
2018	99.6%	99.1%
2019	99.98%	98.9%
2020	99.9%	99.2%

^a For 2014 and 2020, values relate to the period after commissioning and before de-commissioning.

NO₂ Diffusion Tubes

Overall Approach

- 3.7 NO₂ diffusion tubes provide results on a 1-month time-step but it is most common to use the results to describe annual mean concentrations. In particular, results for individual months are known to exhibit bias. While it is possible to correct for this bias on an annual mean basis (see Paragraph 3.18), adjusting individual monthly data for bias is subject to much greater uncertainty. The NO₂ diffusion tube results collected during this study have thus been aggregated by calendar year to provide annual mean concentrations, i.e. for the five years 2015 to 2019 inclusive.

Data Capture and Quality Assurance

- 3.8 Diffusion tubes are fixed, at around head height, using readily-detached clips. A key feature of diffusion tubes is that, because they require minimal infrastructure, they can be sited in exposed or in hard-to-reach locations. A common consequence of this is that individual tubes can become dislodged or removed by passing people or animals, causing data for an individual site/month to be lost. Another common issue with diffusion tubes is contamination, for example by nesting spiders. These issues are usually flagged by the Local Site Operators (LSOs) but can also often be seen in the results returned from the analytical laboratory. The beneficial feature of the method is that the relatively low cost of diffusion tubes allows the concurrent operation of multiple sites. This minimises the overall risk to a study of losing data from any individual site.
- 3.9 As well as the issues cited above, which are common to most urban diffusion tube studies, additional difficulties faced in Ashdown Forest were:
- removal of posts. This was often associated with evidence of nearby off-road vehicle activity (e.g. mowing);

- repeated dislodging of tubes from clips. It is believed that this was caused by animal activity, most likely cows or deer scratching against the posts; and
- difficulty accessing several of the more remote sites when conditions were too waterlogged, vegetation growth was too high, or areas were temporarily fenced off for grazing.

3.10 In addition to these long-term difficulties, there were isolated issues with the LSOs accessing some of the more remote background sites during 2017 and 2018. This caused some of the exposure periods to be longer than planned. In these cases, samples which were exposed for periods of up to two months were retained within the dataset, but values obtained from exposures longer than two months were discarded.

3.11 All of the individual data received back from the laboratory were examined in the context of the spatial patterns seen during other months and temporal patterns seen at other sites. Data which appeared erroneous in this context were examined further in terms of on-site LSO records. In some instances, it was clear that the LSOs had incorrectly recorded the start and/or end time, meaning that the laboratory had misrepresented the concentration. These issues were verified and corrected, and a revised concentration was calculated. In other cases, there was a clear explanation given in the LSO notes for the unusual measurement and so the value was removed from the dataset. In some cases, no explanation for an erroneous measurement could be found. A decision was thus made by the project team regarding whether these values were representative of concentrations or whether they were affected by interferences in the laboratory or some other unknown factor. The experience of the project team in developing Defra guidance on laboratory harmonisation methods was useful in this respect (AEA Energy and Environment, 2008).

3.12 Figure 22 summarises the data capture achieved at the diffusion tube sites, following all data removals. Values are expressed as a percentage of full calendar years, and so the low data capture during 2014 and 2020 should be understood in the context that many of the sites were not commissioned until the end of 2014 and all were decommissioned in early 2020. During other years, most sites achieved >90% data capture despite the issues described above.

3.13 Because it is common for diffusion tube surveys to lose data from individual months, there are recognised procedures for addressing this data loss (e.g. (Defra, 2016a)). Thus, where a substantial proportion of a year becomes lost, it is common practice to adjust the period averages to account for trends over the year. Paragraph 3.14 explains the approach which has been taken to annualisation. Annualisation does, however, require a minimum data capture during each year (Paragraph 3.14). Table 4 describes the final data capture in terms of valid annual means following the annualization described in Paragraph 3.14. Annual mean equivalent data have not been produced for 2014 or 2020. During 2015 to 2017, valid annual mean concentrations were recorded at all sites. During 2018, valid annual mean concentrations were recorded by 89 out of the 102 sites. During 2019, valid annual mean concentrations were recorded by 101 out of the 102 sites.

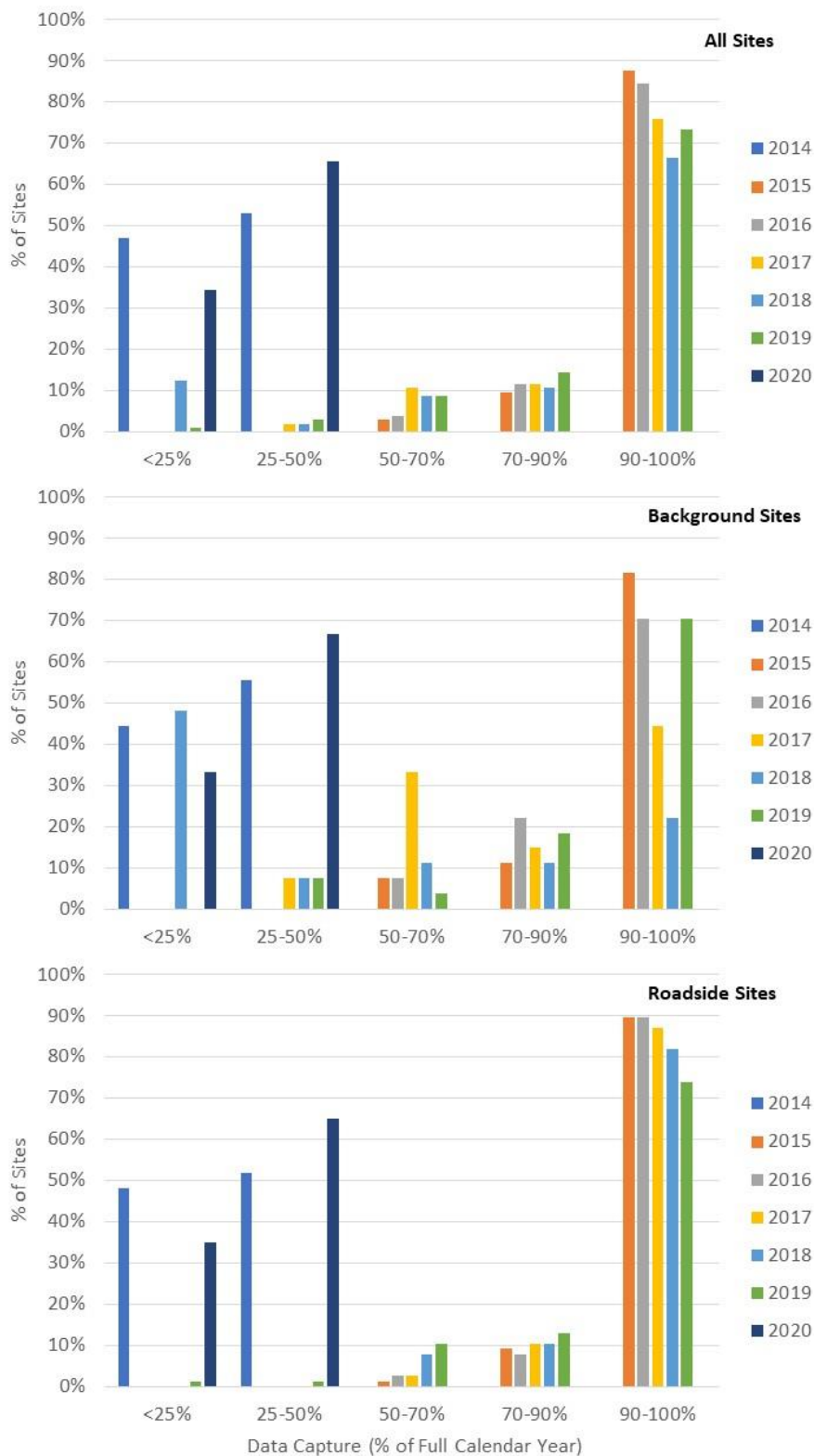


Figure 22: Summary of Diffusion Tube Data Capture (following manual removal of suspect data)

Table 4: Final Annual Mean Data Capture at Diffusion Tube Sites

	2014	2015	2016	2017	2018	2019	2020
All Sites	0 ^a	102	102	102	89 ^b	101 ^c	0 ^a
Background Sites	0 ^a	27	27	27	14 ^b	27	0 ^a
Roadside Sites	0 ^a	75	75	75	75	74 ^c	0 ^a

- ^a The start and end dates of the survey were such that consistent annual mean concentrations have not been produced.
- ^b 13 background sites (Sites T7, T8, T12, T18, T43, T50, T57, T60, T64, R1.7, R1, R2.8 and R3.8) lost too much data during 2018 for valid annual mean concentrations to be calculated.
- ^c Site T32, which is alongside the A22 to the south of transects 1 and 2, was subject to repeated loss during 2019 such that a valid annual mean could not be calculated.

Annualisation

- 3.14 Annual averages have been calculated for each calendar year period. For measurements collected during 2015-2019 inclusive (i.e. those years where the campaign was running from the start to the end of the year) where one or more months of data for an individual site were missing or excluded, the data have been annualised. This is the process of estimating annual means from the extrapolation of short-term monitoring results. Defra (2016a) provides a method for this based on comparison with distant automatic monitoring sites. This approach has been adapted for the current study to make better use of the high-density local network and the fact that bias in diffusion tubes is seasonal (and thus diffusion tube data provide a better comparator dataset than automatic monitors).
- 3.15 For each site, a period average NO₂ concentration has been calculated, taking account of the precise number of hours in each individual monitoring period. The relative average monthly profile at those roadside sites with a full set of annual data has then been determined. This relative profile has then been used to predict the concentration during each missing month at the remaining roadside sites. The same procedure was then repeated for the background sites (i.e. using the relative monthly profile at full data-capture background sites to adjust the measurements at low data-capture background sites). Where a site provided fewer than three valid monthly readings in a calendar year, those results have been excluded and not annualised.
- 3.16 While it would be possible to annualise the 2014 and 2020 data by comparison with measurements made outside of Ashdown Forest, this would represent a change from the approach used for other years and would most likely affect the calculation of long-term trends. The 2014 and 2020 data have not, therefore, been annualised.
- 3.17 The end of this study coincided with the start of UK activity restrictions in response to the COVID-19 pandemic. The measurements which were collected thus do not provide any insight into the effects of the pandemic on air quality conditions. Other sites in the UK which measured NO₂ concentrations throughout the whole of 2020 will, however, have been affected by COVID-19 restrictions. This

provides a further reason why using 2020 annual mean values within the analysis of long-term trends would not have been informative. Analyses of the effects of COVID-19 restrictions on UK air quality have been provided elsewhere (e.g. (AQEG, 2020)).

Bias Adjustment

- 3.18 The annualised (and period-mean for 2014 and 2020) data have been adjusted for bias. This could either have been done using the triplicate-tube co-location with the Kingstanding automatic analyser, or using a national database published by Defra. The principal causes of diffusion tube bias relate to issues within the laboratory (Heal, Laxen and Marner, 2019). Since the national co-location factors were based on multiple studies (between 30 and 40), compared to the single co-location provided within the current study, it is more robust to use the nationally-derived values than those from the single local co-location. Furthermore, Box 7.11 of Defra’s technical guidance on local air quality management (Defra, 2016a) explains that the national co-location factor will be more appropriate than a local factor when “*the survey consists of tubes exposed over a range of settings, which differ from the co-location site*”. This is considered to apply to this study, which includes diffusion tube sites which range from busy kerbside sites to background sites. The applied annual mean bias adjustment factors for years 2014 to 2019 have been taken from the spreadsheet version 09/20 available from Defra⁸. The adjustment factor for 2020 was taken from spreadsheet version 03/21. The bias adjustment factors applied to each year are provided in Table 5.

Table 5: Bias Adjustment Factors ^a

Year	Bias Adjustment Factor
2014	0.92
2015	0.87
2016	0.92
2017	0.87
2018	0.92
2019	0.91
2020	0.81

^a Taken from the National Diffusion Tube Bias Adjustment Factor Spreadsheet, Version 09/20⁸.

DELTA Samplers

Overall Approach

- 3.19 As with the NO₂ diffusion tubes, the DELTA samplers provide month-by-month results, but it is most useful to only consider annual averages. Measured concentrations have thus been aggregated by calendar year. For consistency with the approach used for the NO₂ sampling, annual averages were

weighted by the relative duration of each sample period. This gives slightly different results than would be derived by taking the simple arithmetic mean of 12 samples (which is the method used for reporting in the NAMN and AGANet). The approach used here is more precise and made necessary because of the uneven sample periods (which were set to match the diffusion tube exposures) and because the results from different instrument types are used alongside one another, necessitating a consistent approach.

Data Capture and Quality Assurance

3.20 Over the course of the study, individual monthly samples were lost for a number of reasons, including:

- insufficient charging of batteries via solar panels and wind turbines, resulting in low or inconsistent air flow rates (This was confined to the early period of the study and subsequently resolved);
- contamination of samples;
- unreadable flow rate values;
- wildfire; and
- theft and vandalism.

3.21 Checking and screening of DELTA measurement data followed the protocols in the quality management system applied to the UK air monitoring networks (Tang and Sutton (2003), Conolly et al. (2016)). This included screening the whole dataset for sampling anomalies and outliers, e.g. due to contamination or other issues. This was carried out by UKCEH, who also run the UK national network. There were also several instances where, as part of this process, data were removed since the measurements were below the instrument's limit of detection, which means that overall data capture rates are not the same for different pollutants recorded at the same site.

3.22 Particular issues were encountered with sites D1, D5 and D6, as follows:

- a wildfire destroyed site D5 during 2015;
- in October 2018, the instrumentation at Site D1 was stolen. By then, it had already been observed that the concentrations of those pollutants which are only measured by the DELTA instruments are fairly spatially consistent across the SAC. The decision was thus taken not to replace this equipment; and
- at the end of 2018 an electrical fault at Site D6 required replacement equipment. Very shortly after the repair was carried out, the same site suffered vandalism and theft.

3.23 Figure 23 summarises the overall data capture at each DELTA site.

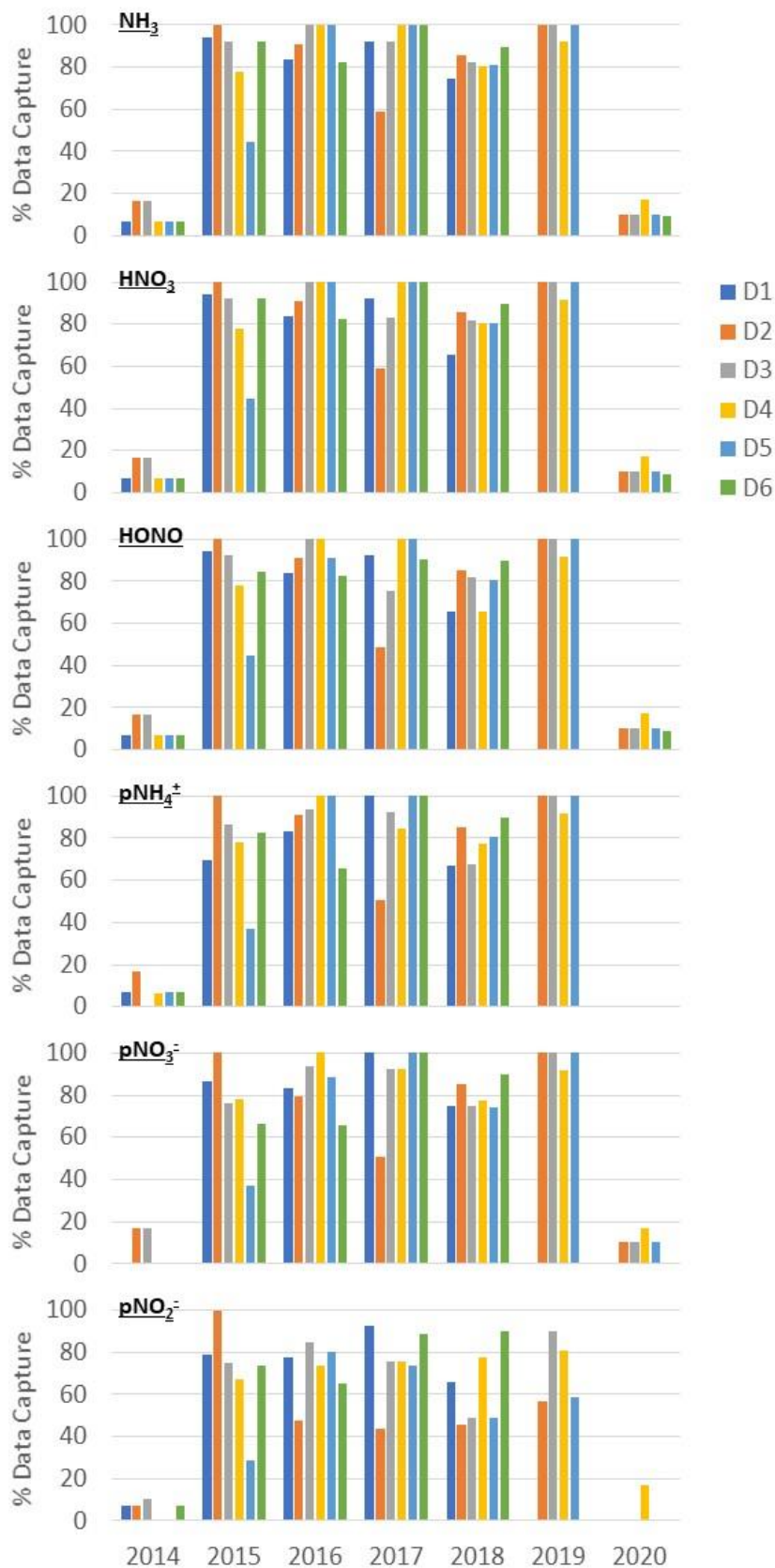


Figure 23: Data Capture at the DELTA Sites (% of Calendar Year) (following manual removal of suspect data)

Annualisation

- 3.24 Where data capture was less than 75%, the data have been annualised following the same method described for nitrogen dioxide in Paragraph 3.14. Following this approach, the only sites which did not provide a valid annual mean concentration were Sites D1 and D6 in 2019. In addition, for reasons explained in Paragraph 3.16, annual mean values were not calculated for 2014 or 2020.

ALPHA Samplers

Overall Approach

- 3.25 As with the NO₂ diffusion tubes and DELTA samplers, ALPHA samplers provided month-by-month results, but it is most useful to only consider annual averages. Measured concentrations have thus been aggregated by calendar year. As noted for the DELTA survey, for consistency with the approach used for the NO₂ sampling, annual averages were weighted by the relative duration of each sample period. This gives slightly different results than would be derived by taking the simple arithmetic mean of 12 samples (which is the method used for reporting in the NAMN). The approach used here is more precise and made necessary because of the uneven sample periods and because the results from different instrument types are used alongside one another, necessitating a consistent approach.

Data Capture, Quality Assurance, and Annualisation

- 3.26 The ALPHA samplers were affected by many of the same issues as described for the diffusion tubes. There were also additional losses of individual ALPHA samplers and it was speculated that the citric acid used in the sample preparation might have made the sites more attractive to disturbance by animals. There was also, for consistency with the NAMN, a desire to keep the ALPHA samplers no higher than 2 m above ground, and preferably 1.5 m. This makes the instruments more susceptible to disturbance than roadside diffusion tubes, which are typically mounted somewhat higher. Finally, the size of the sample shelters (Figure 19) makes them easier to dislodge (e.g. by passing or scratching animals) than a small NO₂ diffusion tube clip (Figure 14).
- 3.27 Analytical quality assurance was provided by UKCEH, using the same procedures as used for Defra in the NAMN network. As with the DELTA samples, this resulted in the removal of individual values from the final dataset. Where a site provided one or more valid samples from the triplicate exposure in a month, these were taken as a valid reading for that month. The residual data capture is summarised in Table 6.

Table 6: Data Capture at the ALPHA Sites (% of Calendar Year) (following manual removal of suspect data)

Site	2014	2015	2016	2017	2018	2019	2020
R1.1	17%	100%	100%	100%	100%	90%	23%
R1.2	9%	100%	100%	100%	100%	90%	23%
R1.3	17%	100%	100%	100%	100%	82%	23%
R1.4	17%	100%	100%	100%	91%	90%	23%
R1.5	17%	100%	100%	100%	100%	72%	8%
R1.7	17%	100%	100%	100%	100%	76%	23%
R2.1	17%	100%	100%	100%	100%	90%	23%
R2.2	9%	100%	100%	100%	100%	90%	23%
R2.3	17%	100%	100%	100%	100%	62%	23%
R2.4	17%	100%	74%	68%	85%	64%	23%
R2.5	17%	100%	54%	68%	66%	47%	15%
R2.7	17%	100%	66%	74%	64%	42%	8%
R3.1	18%	100%	100%	100%	90%	69%	14%
R3.2	18%	100%	100%	100%	94%	75%	14%
R3.3	18%	100%	100%	92%	93%	90%	14%
R3.4	18%	100%	100%	100%	93%	90%	6%
R3.5	11%	100%	100%	100%	100%	81%	14%
R3.7	11%	100%	100%	100%	100%	90%	14%
T59	19%	100%	62%	73%	55%	76%	7%
T61	19%	100%	71%	83%	65%	74%	23%
T62	24%	100%	100%	100%	100%	90%	23%
T65	18%	100%	100%	100%	100%	90%	23%
D3	18%	100%	100%	100%	100%	81%	21%
T67	18%	100%	100%	100%	100%	90%	23%
T14	18%	100%	100%	100%	100%	90%	23%
T69	24%	100%	100%	65%	68%	90%	15%
T68	17%	100%	100%	100%	100%	90%	23%
T70	24%	100%	100%	85%	92%	81%	23%
D6	24%	100%	100%	92%	100%	56%	23%

- 3.28 The triplicate values were averaged for each site for each month. No weighting was applied in cases where one or two samples from a triplicate were invalid. Following the same method as applied to nitrogen dioxide, as described in Paragraph 3.14, data were 'annualised' against the results from those sites which achieved 100% data capture. For reasons explained in Paragraph 3.16, this was not done for the measurements made during 2014 or 2020. Following this correction, valid annual mean concentrations were provided for 100% of sites for each year 2015 to 2019.

ATC data

The ATCs were not operated directly within the air quality monitoring project. The ATC sites owned by WDC were operated and maintained by the traffic management specialists Q-Free. Q-Free provided annual servicing of the sites, as well as daily polling and checking of the data. Issues identified by Q-Free were reported to the client and rectified as soon as possible. Q-Free provided AQC with quality assured monitoring reports for every month of the study. Those instances where the instruments malfunctioned are not included in the data presented in this report. The ESCC-managed sites are operated and maintained by ESCC, who provided data for the preparation of this report.

4 Results

- 4.1 Where relevant, the measurements have been compared against the critical levels given in Table 7. Advice on which critical levels should apply within Ashdown Forest has been given by UKCEH. Critical loads refer to nitrogen deposition which was not measured directly and so assessment against the critical loads is not provided in this report.

Table 7: Critical Levels Considered in this Report

Year	Critical Level
Annual Mean NO _x	30
Maximum 24-hour Mean NO _x	75
Annual Mean NH ₃	1

NO_x/NH_x Continuous Analyser

- 4.2 The ratified hourly measurements of NO_x, NO₂ and NH_x are presented in Figure 24 to Figure 26 for the years 2014 to 2020, inclusive. Table 8 sets out the annual mean concentrations of NO_x, NO₂ and NH_x over the reporting period. It also shows the maximum 24-hour mean NO_x concentration during each year. The annual mean NO_x concentrations were below the critical level of 30 µg/m³ during each year. The 24-hour NO_x critical level was exceeded during 2016. The annual mean NH_x concentrations exceeded the 1 µg/m³ critical level for NH₃ but, as explained in the next paragraph, this finding should be treated with caution.

Table 8: Summary of Annual Concentrations Measured at the Continuous Analyser ^a

Year	Annual Mean NO _x	Max 24-hour Mean NO _x	Annual Mean NO ₂	Annual Mean NH _x
2014 ^b	19.7	63	12.5	2.5
2015	15.8	52	9.7	3.0
2016	20.6	92	12.8	2.9
2017	19.2	72	12.4	2.6
2018	16.3	64	10.9	2.6
2019	16.6	59	10.9	2.6
2020 ^b	16.0	53	10.7	1.6
Critical Level	30	75	n/a	1 ^c

^a Exceedances of the critical levels are highlighted in blue and bold.

^b Data are not for a full year.

^c The critical level is for NH₃ only.

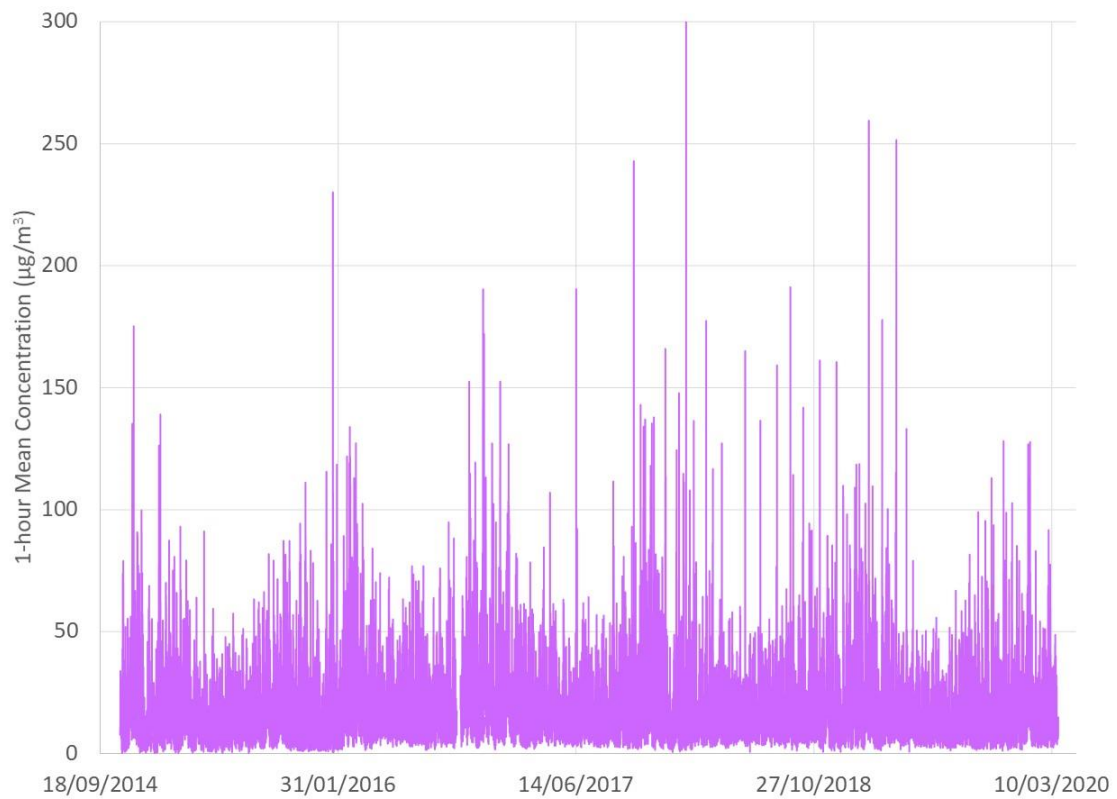


Figure 24: 1-hour Mean Nitrogen Oxides Concentrations at Kingstanding During the Monitoring Period

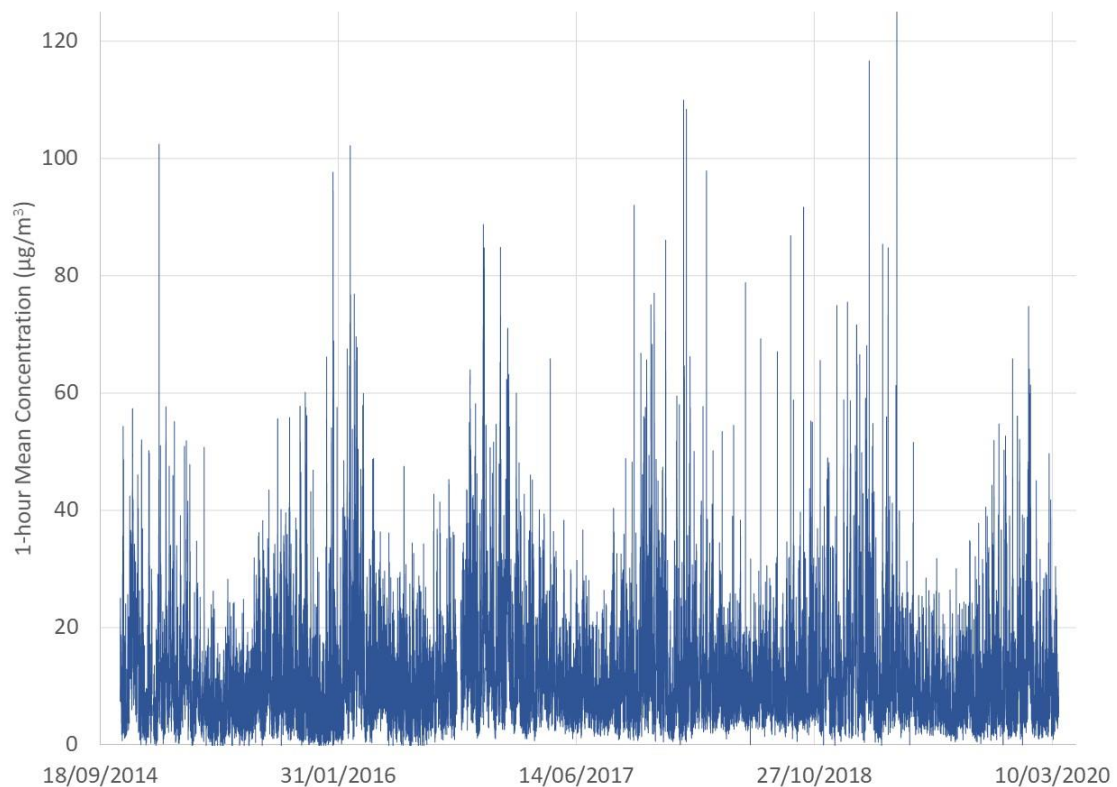


Figure 25: 1-hour Mean Nitrogen Dioxide Concentrations at Kingstanding During the Monitoring Period

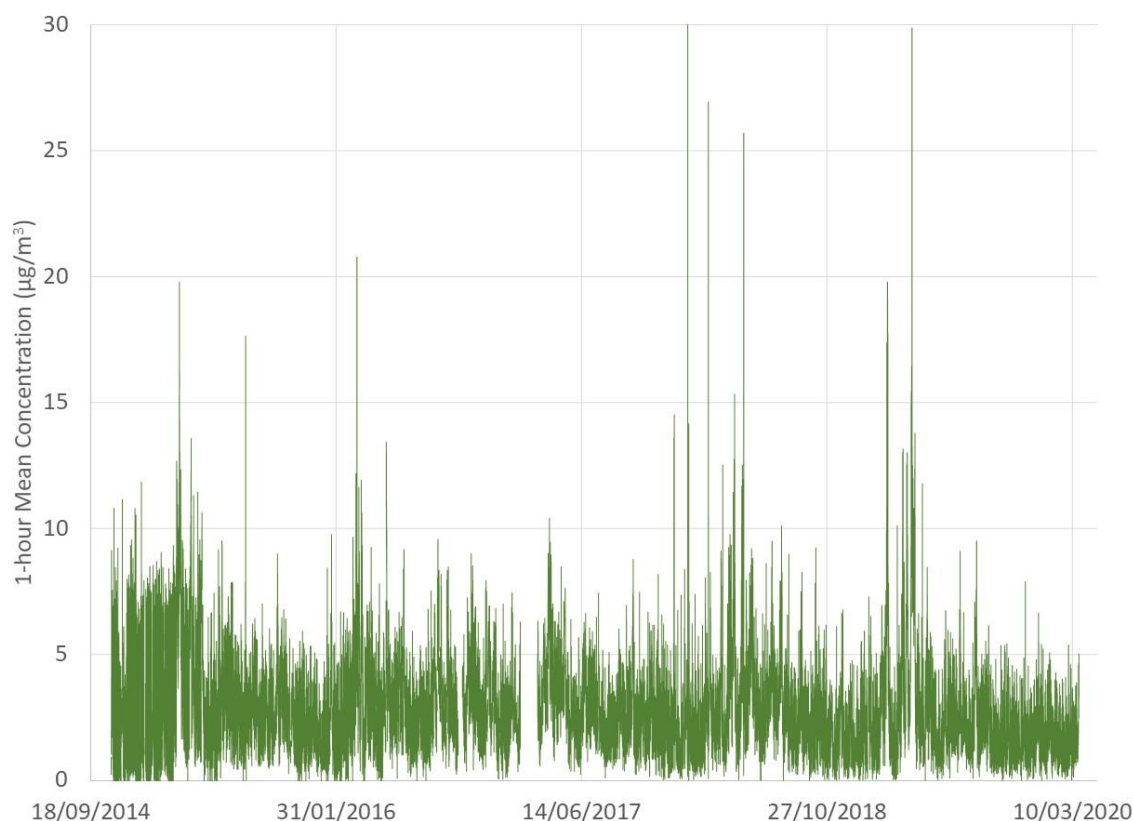


Figure 26: 1-hour Mean NH_x Concentrations at Kingstanding During the Monitoring Period

- 4.3 The NH_x analyser is co-located with DELTA site D3, which represents the ‘reference’ monitor for NH₃ concentrations. It is thus helpful to compare the measurements made by both instruments over matched averaging periods. This comparison is summarised in Figure 27. Figure 27 shows clearly that while the NH_x analyser was able to record the relative changes to NH₃ concentrations over time, it measured consistently higher values than the DELTA sampler. There is an expectation that the NH_x analyser may experience interference from pNH₄⁺ concentrations and Figure 27 thus also shows the sum of NH₃ and pNH₄⁺ (expressed as NH₃) measured at DELTA site D3. While the NH_x analyser clearly compares better with the sum of NH₃ and pNH₄⁺ than it does with NH₃ alone, it continues to over-read during all months.
- 4.4 It is not within the scope of this study to establish the causes of the over-read by the NH_x instrument. The apparent ability of the monitor to measure changes in concentrations over time is of immense value and has been used in the analysis presented in Sections 5 and 6. The questionable ability of the instrument to measure absolute concentrations is, in this case, of less concern because the reference DELTA sampler is able to provide long-term mean concentrations at this site. It is suggested that annual mean NH₃ concentrations at this site should be taken from the DELTA instrument and not from the co-located automatic analyser.
- 4.5 A discussion of temporal trends and patterns in these measurements is provided in subsequent sections of the report.

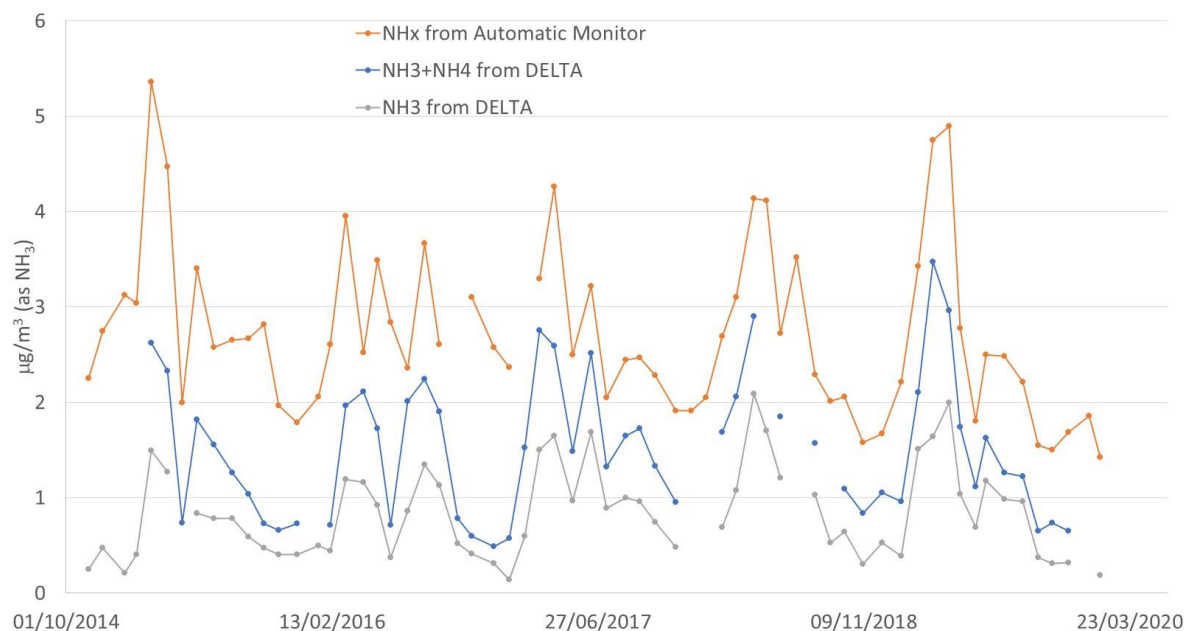


Figure 27: Comparison of Monthly-mean Concentrations Recorded by the Automatic Monitor and Co-located DELTA Sampler

Diffusion Tubes

Nitrogen Dioxide

- 4.6 The annualised and bias-adjusted nitrogen dioxide measurements for the non-transect monitoring sites in the years 2015 to 2019, inclusive, are presented in Table 9. Data for 2014 and 2020 are also provided, although these have not been annualised and so represent a short period mean that cannot be compared directly with the annual mean values. Maps of the measured annual mean nitrogen dioxide concentrations for 2015 to 2019 are shown in Figure 28 to Figure 30. There are no critical levels for nitrogen dioxide, but nitrogen dioxide contributes to nitrogen deposition and so the values in Table 9 may be used to support more accurate modelling of nitrogen deposition to the SAC. Analyses of spatial and temporal patterns in these measurements are provided in subsequent sections of this report.

Table 9: Annual Mean NO₂ Concentrations at Diffusion Tube Sites

Monitoring Site	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
T1	(25.7)	21.4	22.7	21.8	21.2	20.5	(17.1)
T2	(14.7)	15.9	18.4	18.9	18.4	15.5	(12.4)
T3	(34.8)	26.4	30.1	25.1	21.8	20.8	(17.6)
T4	(29.7)	24.8	27.9	25.3	24.7	24.3	(19.9)
T5	(13.0)	10.3	11.9	12.2	11.3	10.2	(8.2)

Monitoring Site	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
T6	(16.8)	11.9	14.3	14.8	13.2	12.6	(9.5)
T7	(12.4)	10.1	9.9	10.5	- ^b	8.4	(7.4)
T8	(7.4)	7.9	9.1	9.1	- ^b	7.3	(5.3)
T9	(7.8)	7.0	7.8	7.5	6.3	7.1	(6.2)
T10	(14.3)	9.6	11.4	12.3	11.7	11.0	(8.8)
T11	(13.7)	10.8	11.3	12.8	12.0	11.1	(6.9)
T12	(9.6)	7.9	8.0	8.3	- ^b	7.2	(6.9)
T13	(14.7)	12.8	14.9	14.5	12.0	14.9	(12.5)
T14	(15.9)	12.2	13.9	13.4	13.0	11.4	(9.2)
T15	(14.8)	11.1	12.3	12.5	11.4	11.8	(9.0)
T16	(14.7)	11.7	14.1	13.0	11.2	11.3	- ^b
T17	(12.8)	10.8	11.9	12.1	10.6	10.8	(9.1)
T18	(11.4)	8.9	10.7	11.3	- ^b	9.0	(6.3)
T19	(33.8)	26.4	28.3	27.7	26.7	25.6	(25.6)
T20	(24.2)	22.9	27.8	23.0	24.5	25.3	- ^b
T21	(41.3)	33.7	34.1	33.2	31.4	33.2	(28.5)
T22	(30.9)	28.5	27.6	25.4	25.0	24.9	(19.3)
T23	(18.9)	14.9	16.7	17.2	16.1	16.2	(14.0)
T24	(16.5)	13.6	14.5	12.5	14.1	12.9	(10.5)
T25	(15.8)	15.2	16.4	17.6	15.6	15.1	(12.6)
T26	(10.2)	7.9	8.8	10.8	7.5	8.1	(5.0)
T27	(7.3)	5.8	6.4	5.3	4.0	4.9	(4.9)
T28	(25.1)	20.6	21.9	22.3	21.2	20.7	(16.7)
T29	(20.9)	16.6	17.9	18.2	16.8	15.4	(13.1)
T30	(8.0)	8.0	8.8	13.8	7.8	7.9	(7.2)
T31	(27.8)	22.6	25.1	23.4	27.5	25.3	(14.9)
T32	(44.5)	21.9	25.9	26.3	22.8	- ^b	(11.9)
T33	(25.7)	27.3	34.2	33.2	27.3	25.9	(17.8)
T34	(18.9)	15.9	16.3	15.7	17.0	13.9	(10.1)
T35	(25.3)	18.9	21.5	19.8	20.2	18.4	(11.1)

Monitoring Site	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
T36	(24.5)	22.3	24.7	22.8	23.5	21.6	(15.1)
T37	(27.0)	21.2	24.5	23.0	22.6	18.2	(11.9)
T38	(14.7)	12.3	13.0	12.9	12.7	10.6	(9.2)
T39	(9.1)	7.0	7.6	8.7	8.4	7.3	(6.3)
T40	(13.3)	11.0	10.4	13.0	11.5	10.9	(9.4)
T41	- ^b	8.8	9.8	10.7	10.0	10.0	(9.0)
T42	(15.0)	12.6	13.7	13.4	12.7	12.3	(10.7)
T43	(13.5)	11.0	11.9	12.0	- ^b	10.3	(8.9)
T44	(11.6)	9.3	10.5	10.7	10.2	9.7	(7.2)
T45	(5.9)	6.8	7.0	7.7	8.3	6.8	(5.5)
T46	(7.0)	8.1	9.1	9.7	8.3	7.5	(7.4)
T47	(19.4)	15.7	17.4	17.4	16.9	15.2	(15.4)
T48	(18.4)	14.0	15.2	15.7	14.3	12.7	- ^b
T49	(17.2)	12.6	13.2	14.1	13.1	10.5	(10.0)
T50	(10.8)	8.5	9.5	9.6	- ^b	7.5	(6.2)
T51	(17.0)	15.1	16.6	16.9	15.4	15.6	(12.3)
T52	(13.1)	12.9	14.8	15.3	14.9	13.9	(8.8)
T53	(15.0)	13.1	14.3	15.1	15.2	13.4	(10.6)
T54	(11.9)	9.7	10.6	11.0	10.7	10.1	(7.8)
T55	(8.5)	6.8	7.5	8.9	9.8	6.9	(5.5)
T56	(25.9)	22.0	24.2	25.8	24.3	21.1	(15.1)
T57	(8.7)	6.9	8.1	9.7	- ^b	6.7	(6.7)
T58	(16.3)	13.2	15.0	15.0	14.4	14.6	(10.6)
T59	- ^b	11.3	12.8	13.6	12.2	12.0	(12.3)
T60	- ^b	11.2	11.6	11.1	- ^b	9.5	(11.1)
T61	- ^b	16.0	16.5	17.0	16.8	16.0	(13.1)
T62	- ^b	22.7	25.0	23.3	24.7	21.3	(8.0)
T63	- ^b	9.3	10.2	10.2	9.0	10.3	(10.5)
T64	- ^b	9.9	9.6	9.9	- ^b	8.8	(12.4)
T65	- ^b	14.2	16.1	16.7	15.2	15.3	(17.6)

Monitoring Site	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
T66	- ^b	12.0	12.9	13.1	10.6	9.8	(8.6)
T67	- ^b	13.0	13.9	13.1	13.2	12.6	(8.0)
T68	- ^b	11.1	11.9	12.4	12.0	11.3	(12.1)
T69	- ^b	9.5	9.6	10.2	9.8	8.4	(8.5)
T71	- ^b	10.7	12.8	12.7	11.6	11.0	(10.0)
A1	- ^b	13.8	15.6	15.6	14.2	13.8	(12.2)

^a Data are not for a complete year (only three months) and have therefore not been annualised. An annual-equivalent bias adjustment factors has been applied which may not be fully representative.

^b Data not available.

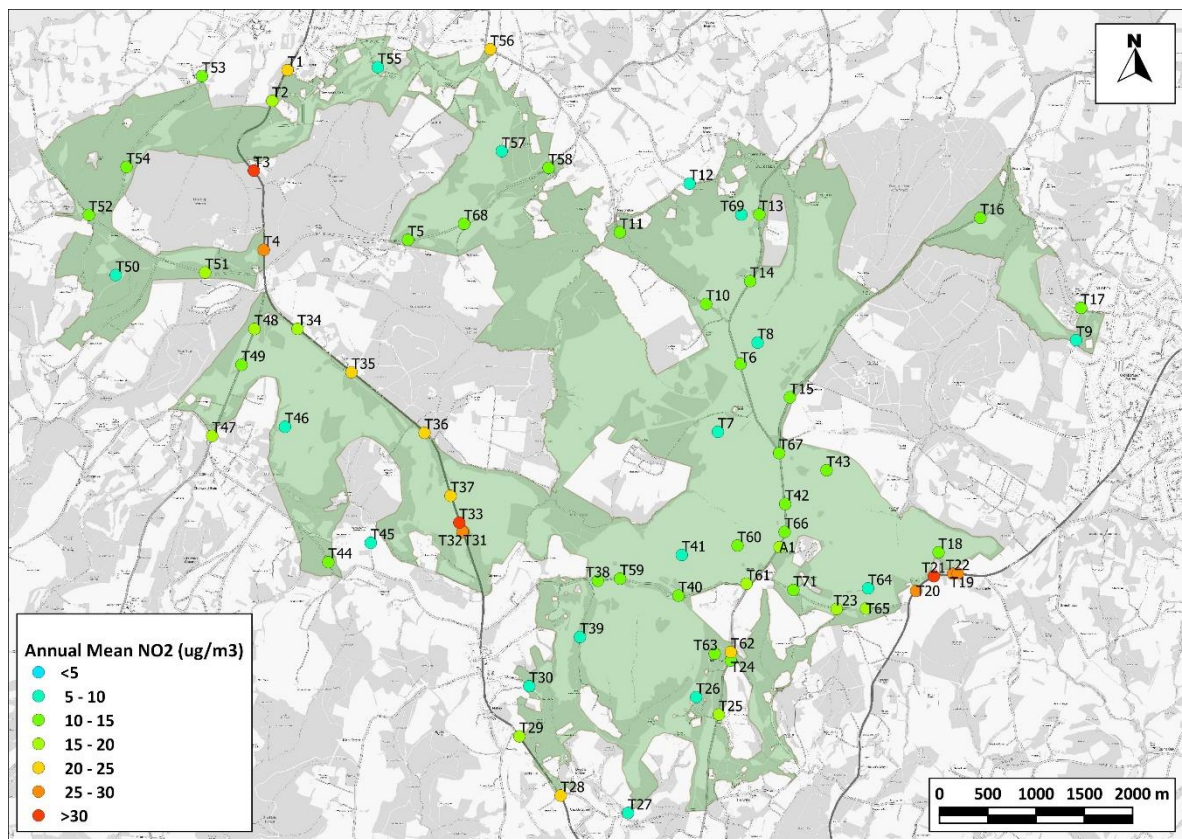
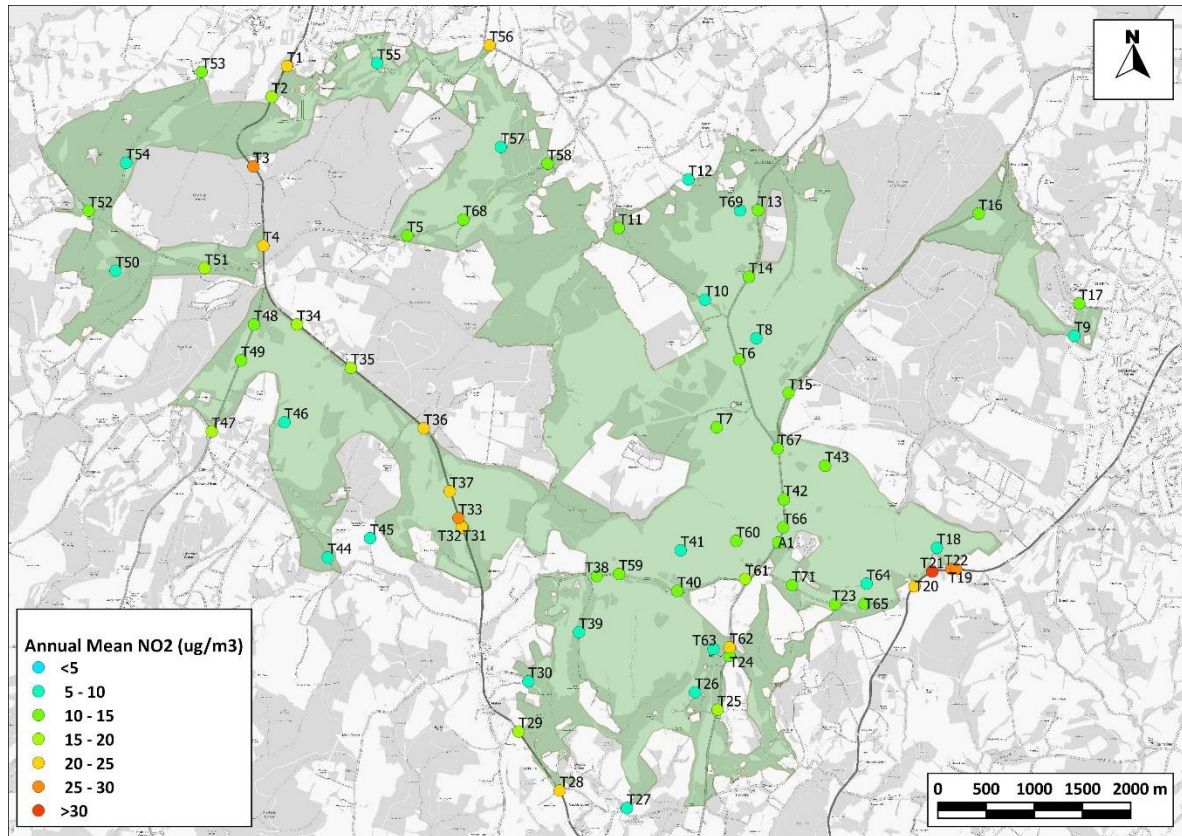
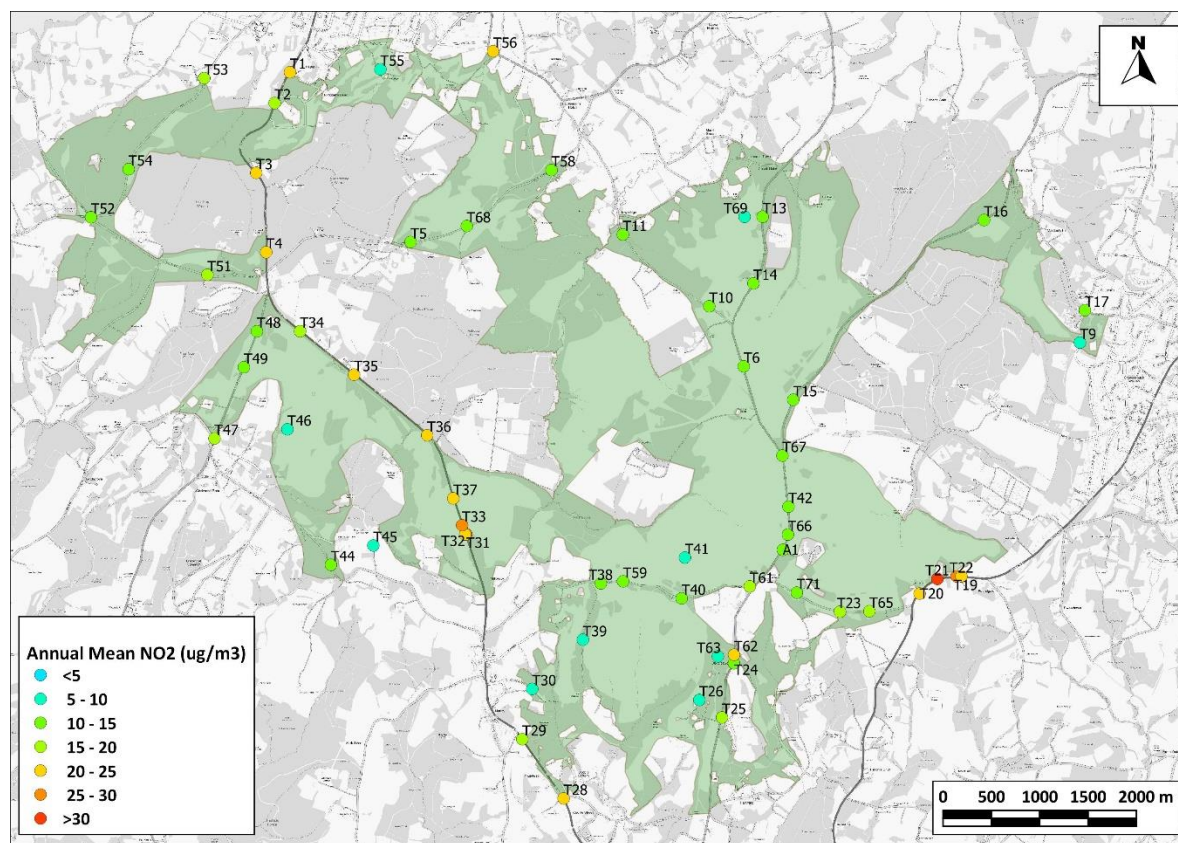


Figure 28: Annual Mean Nitrogen Dioxide Concentrations at Non-transect Diffusion Tube Sites in 2015 (top) and 2016 (bottom)

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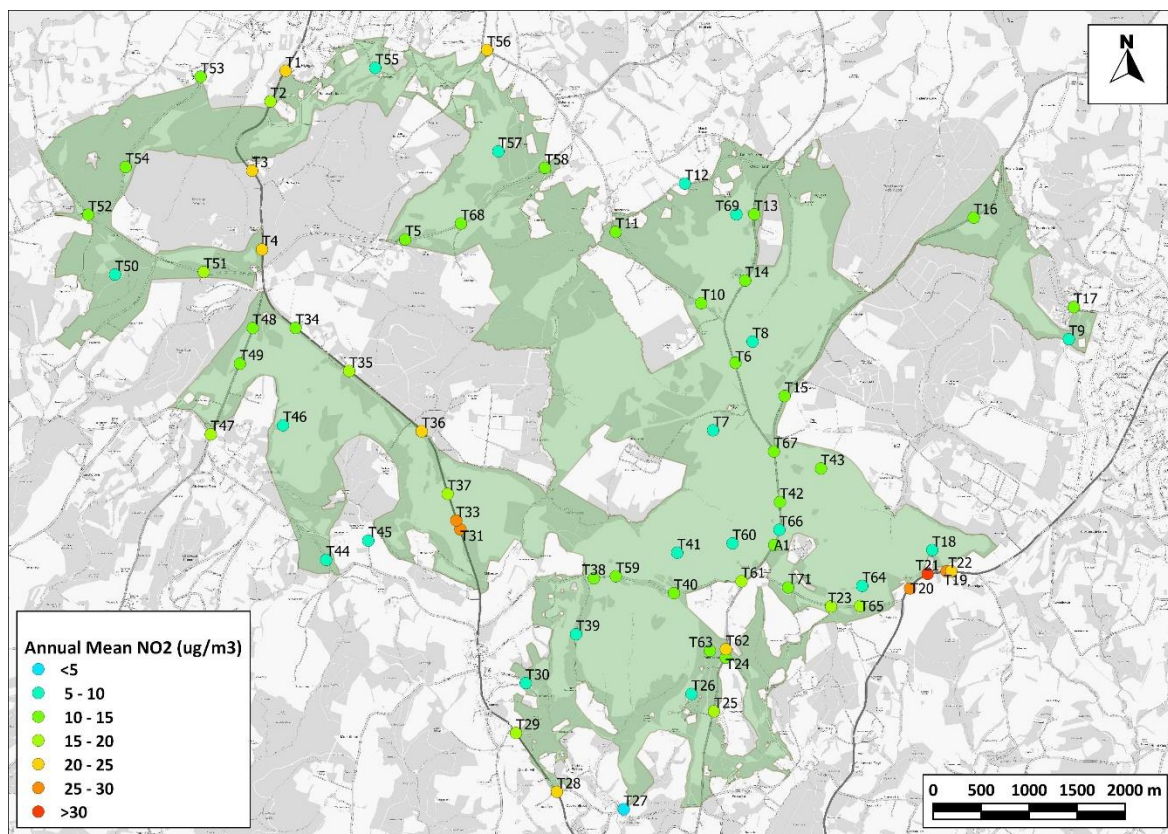


Figure 30: Annual Mean Nitrogen Dioxide Concentrations at Non-transect Diffusion Tube Sites in 2019

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Transect Locations

- 4.7 The annualised and bias-adjusted nitrogen dioxide measurements for the years 2015 to 2019, inclusive, are presented in Table 10 for the four transect locations. Data for 2014 and 2020 are also provided in Table 10, although these have not been annualised and so represent a short period mean that cannot be compared directly with the annual mean values. The 2015 to 2019 (inclusive) values are also shown in Figure 31 to Figure 32. A discussion of the results is provided in subsequent sections of the report.

Table 10: Annual Mean Nitrogen Dioxide at Transect Locations

Transect Point	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
Transect 1							
R1.1	(35.3)	29.1	33.6	31.2	31.7	31.8	(25.2)
R1.2	(27.9)	21.4	25.1	21.5	26.3	21.9	(17.9)
R1.3	(16.5)	15.4	17.5	16.2	16.1	15.5	(13.1)

Transect Point	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
R1.4	(16.4)	13.0	15.3	15.3	14.8	13.6	(11.8)
R1.5	(17.8)	11.4	13.7	13.6	12.4	11.8	(11.4)
R1.6	(16.0)	10.9	12.5	12.5	11.5	10.1	(10.1)
R1.7	(13.1)	10.0	11.5	12.0	- ^b	10.0	(10.4)
R1.8	(15.4)	11.4	10.6	10.3	- ^b	8.3	(5.4)
Transect 2							
R2.1	(18.0)	23.0	23.9	23.7	22.1	21.5	(24.4)
R2.2	(23.8)	21.2	22.9	23.4	21.6	19.6	(21.2)
R2.3	(24.8)	19.2	19.6	20.1	19.5	19.2	(20.0)
R2.4	(22.5)	16.0	17.3	18.3	17.5	15.7	(17.9)
R2.5	(21.8)	14.6	16.9	16.0	14.6	14.9	(15.4)
R2.6	(16.3)	12.9	13.7	13.1	12.3	11.1	(11.8)
R2.7	(15.7)	11.0	11.8	11.5	9.6	7.2	- ^b
R2.8	(14.6)	9.9	10.9	13.4	- ^b	6.7	(9.2)
Transect 3							
R3.1	- ^b	14.1	15.1	16.2	14.1	12.9	(15.6)
R3.2	- ^b	13.4	15.5	15.1	13.4	13.4	(15.3)
R3.3	- ^b	14.7	13.7	13.1	12.7	11.7	(13.5)
R3.4	- ^b	10.8	12.8	13.1	12.1	11.5	(12.4)
R3.5	- ^b	11.3	11.4	12.2	10.4	9.6	(11.5)
R3.6	- ^b	9.5	10.9	11.5	9.4	9.2	(11.0)
R3.7	- ^b	9.6	9.3	9.8	8.2	8.4	(9.3)
R3.8	- ^b	9.0	10.4	11.6	- ^b	10.1	(10.6)
Transect 4							
R4.1	(41.3)	37.5	38.9	40.1	39.5	39.0	(37.5)
R4.2	(35.5)	31.7	36.4	34.9	32.9	33.5	(33.3)
R4.3	(31.9)	23.9	28.6	25.8	25.3	25.5	(28.5)
R4.4	(15.0)	17.4	20.7	20.9	21.0	20.8	(20.8)
R4.5	(22.2)	13.3	15.7	16.2	16.9	17.0	(14.2)
R4.6	(17.4)	11.1	12.1	13.6	12.7	13.0	(11.7)

Transect Point	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
R4.7	(14.0)	8.5	10.0	9.3	10.4	8.5	(8.7)

^a Data are not for a complete year (three months) and have therefore not been annualised. An annual-equivalent bias adjustment factors has been applied which may not be fully representative.

^b Data not available.

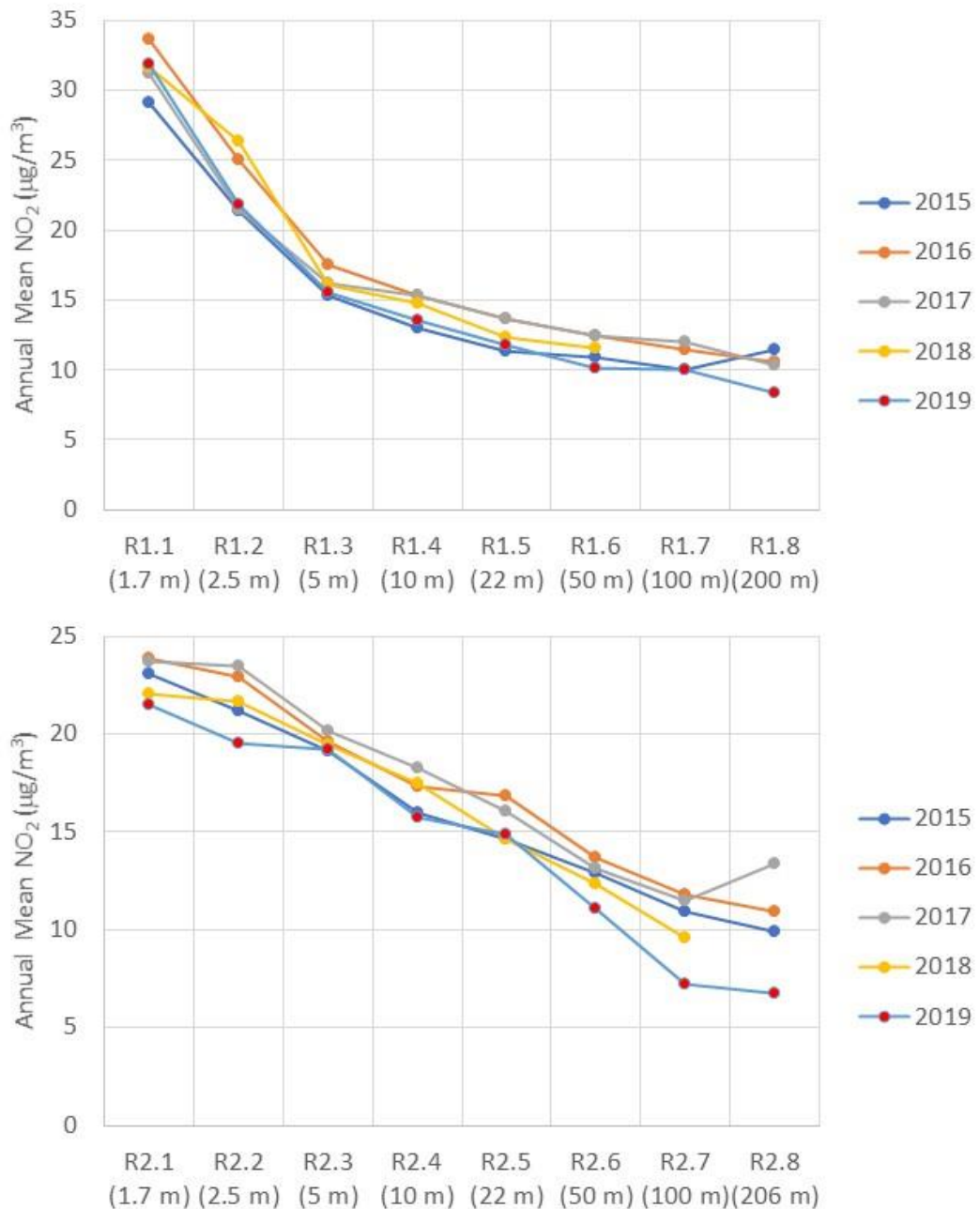


Figure 31: Annual Mean Nitrogen Dioxide Concentrations along Transects 1 and 2 (distance from kerb in parentheses)

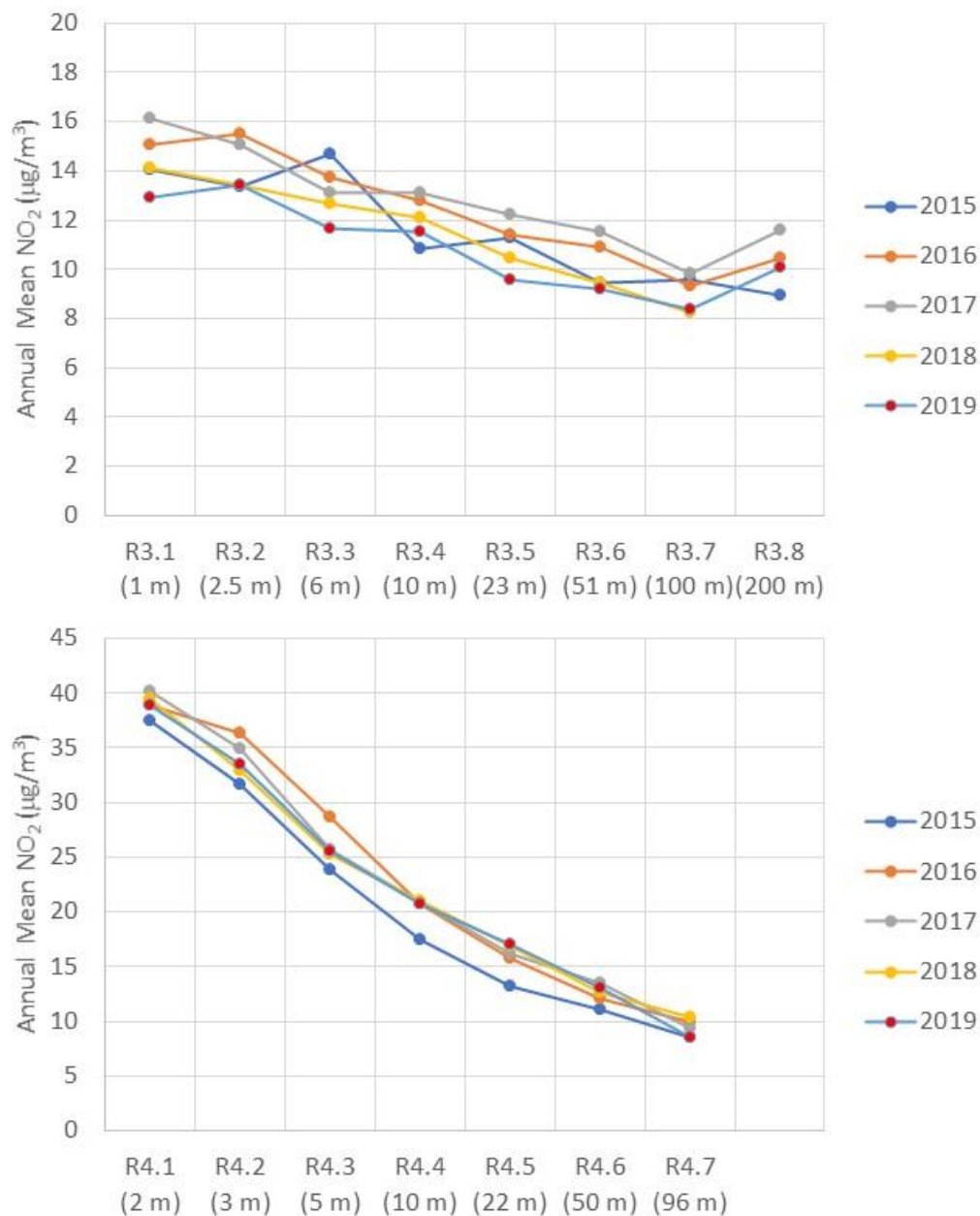


Figure 32: Annual Mean Nitrogen Dioxide Concentrations along Transects 3 and 4 (distance from kerb in parentheses)

NO_x

- 4.8 The diffusion tubes do not measure NO_x directly. NO_x has been calculated from measured NO₂ using two separate approaches depending on whether the monitor was in a roadside or a background location (sites <96 m from roads were classed as roadside and those 96 m or more from

roads were background⁹). For background monitors, the quotient of NO₂ in NO_x has been taken from Defra's background NO₂ and NO_x maps which are provided for Local Air Quality Management (LAQM)¹⁰. For each site, the quotient was taken from the 1 km grid square in which the site sits. 2015 and 2016 values were taken from the 2015-base maps. 2017 values were taken from the 2017-base maps, and 2018 and 2019 values were taken from the 2018-base maps.

- 4.9 For roadside sites, Defra's roadside NO_x from NO₂ calculator has been used¹⁰. The background NO₂ concentration entered into this calculator (for each year separately) was the average of that measured at background sites T9, T26, T27, T30, T39, T41, T45, T46, T55, T63, T69, R2.7, R3.7, and R4.7; these being the background sites which provided a valid annual mean in all five years (2015-2019). V6.1 of Defra's roadside NO_x from NO₂ calculator was used for measurements made in 2015 and 2016, V7.1 was used for the 2017 data, and V8.1 for the 2018 and 2019 data. Defra's calculator estimates the local road component of NO_x above the background. This value was then added to the average background NO_x concentration at the sites listed above.
- 4.10 It is only straightforward to estimate NO_x from NO₂ measured by diffusion tubes over annual periods and so NO_x concentrations have not been calculated for the 2014 and 2020 measurements.
- 4.11 Table 11 sets out the results for the non-transect sites. These are also shown in Figure 33 to Figure 35. The critical level for annual mean NO_x was exceeded during every year at Sites T1, T3, T4, T19 – T22, T28, T31-T33, T35, T36, T56 and T62. It was also exceeded during 2016 and 2017 at Site T2 and in each year except 2019 at Site T37. Most of these sites are close to either the A22 or the A26. The only exceptions are site T62, which is beside the B2026 and T56 alongside the B2110.
- 4.12 An analysis of spatial and temporal trends in the measurements is provided in subsequent sections of this report.

Table 11: Annual Mean NO_x Concentrations at Diffusion Tube Sites ^a

Monitoring Site	Site Type ^b	2015	2016	2017	2018	2019
T1	r	37.8	39.7	37.2	35.3	34.4
T2	r	26.8	31.1	31.5	29.9	24.8
T3	r	48.2	55.2	44.0	36.5	35.0
T4	r	44.8	50.5	44.3	42.3	41.8
T5	r	16.2	18.7	18.6	16.6	14.9
T6	r	19.3	23.2	23.6	20.0	19.4

⁹ 96 m was used since this is the distance of the Site 4.7 from the A26 (dense gorse prevented the transect extending 4 more metres).

¹⁰ <https://laqm.defra.gov.uk/review-and-assessment/tools>

Monitoring Site	Site Type ^b	2015	2016	2017	2018	2019
T7	b	13.2	12.9	13.9	- ^c	10.8
T8	b	10.3	11.8	12.0	- ^c	9.4
T9	b	9.2	10.2	10.0	8.2	9.2
T10	r	14.9	17.9	18.7	17.2	16.3
T11	r	17.2	17.7	19.7	17.8	16.5
T12	b	10.3	10.5	11.0	- ^c	9.2
T13	r	21.0	24.4	23.0	17.9	23.6
T14	r	19.8	22.6	20.9	19.8	17.1
T15	r	17.7	19.5	19.1	16.7	17.8
T16	r	18.9	22.8	20.2	16.3	16.9
T17	r	17.1	18.8	18.5	15.2	15.9
T18	b	11.6	13.9	14.9	- ^c	11.5
T19	r	48.0	51.3	49.5	46.5	44.6
T20	r	40.8	50.2	39.7	41.9	43.9
T21	r	64.3	64.2	61.4	56.4	60.7
T22	r	52.5	49.9	44.6	42.9	43.1
T23	r	24.9	27.8	28.1	25.5	26.1
T24	r	22.3	23.6	19.2	21.8	19.9
T25	r	25.5	27.3	28.8	24.5	24.0
T26	b	10.3	11.5	14.3	9.7	10.4
T27	b	7.6	8.5	7.0	5.2	6.3
T28	r	36.0	38.1	38.2	35.2	34.7
T29	r	28.2	30.2	30.1	26.8	24.6
T30	b	10.5	11.5	18.3	10.1	10.1
T31	r	40.0	44.6	40.5	48.2	43.9
T32	r	38.8	46.4	46.4	38.6	- ^c
T33	r	50.0	64.3	61.6	47.8	45.2
T34	r	26.7	27.1	25.2	27.2	21.7
T35	r	32.7	37.2	33.1	33.4	30.2
T36	r	39.6	43.7	39.1	39.9	36.5

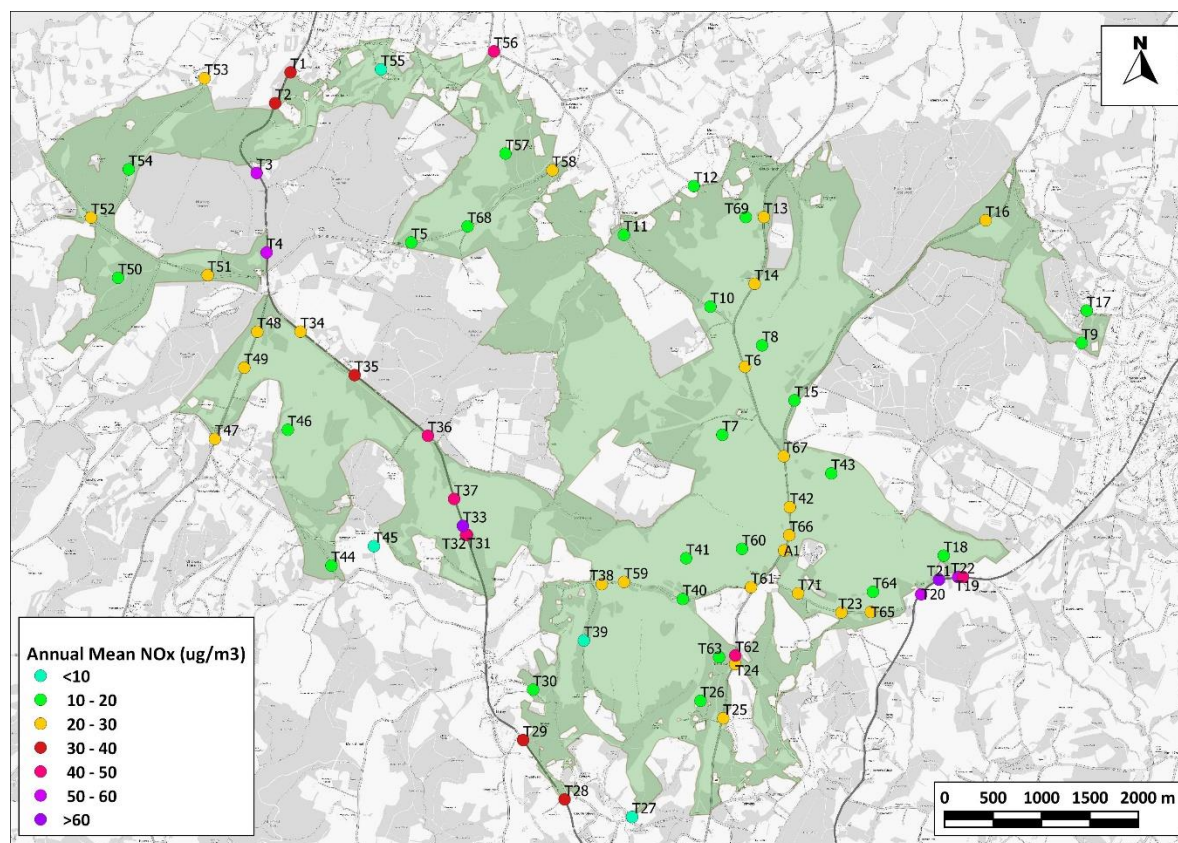
Monitoring Site	Site Type ^b	2015	2016	2017	2018	2019
T37	r	37.3	43.4	39.7	38.1	29.8
T38	r	19.9	20.9	19.9	19.2	15.6
T39	b	9.2	10.0	11.5	10.8	9.4
T40	r	17.5	16.0	20.1	16.9	16.2
T41	b	11.5	12.8	14.2	12.8	12.8
T42	r	20.4	22.1	20.9	19.1	18.8
T43	b	14.4	15.5	15.8	- ^c	13.2
T44	r	14.5	16.3	15.9	14.5	14.0
T45	b	8.9	9.1	10.2	10.7	8.8
T46	b	10.6	11.9	12.9	10.7	9.6
T47	r	26.4	29.2	28.5	26.9	24.2
T48	r	23.1	25.0	25.3	22.2	19.5
T49	r	20.4	21.3	22.2	19.9	15.4
T50	b	11.2	12.4	12.8	- ^c	9.7
T51	r	25.3	27.7	27.5	24.2	24.8
T52	r	21.1	24.3	24.5	23.2	21.8
T53	r	21.5	23.3	24.1	23.8	20.8
T54	r	15.1	16.5	16.3	15.4	14.6
T55	b	9.0	9.9	11.9	12.6	8.9
T56	r	39.0	42.8	45.4	41.5	35.6
T57	b	9.1	10.5	12.9	- ^c	8.5
T58	r	21.6	24.5	23.9	22.3	23.1
T59	r	18.1	20.4	21.2	18.3	18.3
T60	b	14.7	15.2	14.6	- ^c	12.1
T61	r	26.9	27.5	27.7	26.9	25.7
T62	r	40.2	44.4	40.2	42.4	35.8
T63	b	12.2	13.3	13.5	11.5	13.2
T64	b	13.1	12.6	13.1	- ^c	11.2
T65	r	23.5	26.6	27.1	23.8	24.3
T66	r	19.5	20.7	20.4	15.3	14.1

Monitoring Site	Site Type ^b	2015	2016	2017	2018	2019
T67	r	21.2	22.5	20.4	20.1	19.2
T68	r	17.6	18.9	19.1	17.8	16.9
T69	b	12.4	12.5	13.5	12.6	10.8
T71	r	16.9	20.6	19.6	17.2	16.4
A1	r	22.8	25.8	25.0	20.9	21.5
Critical Level	30					

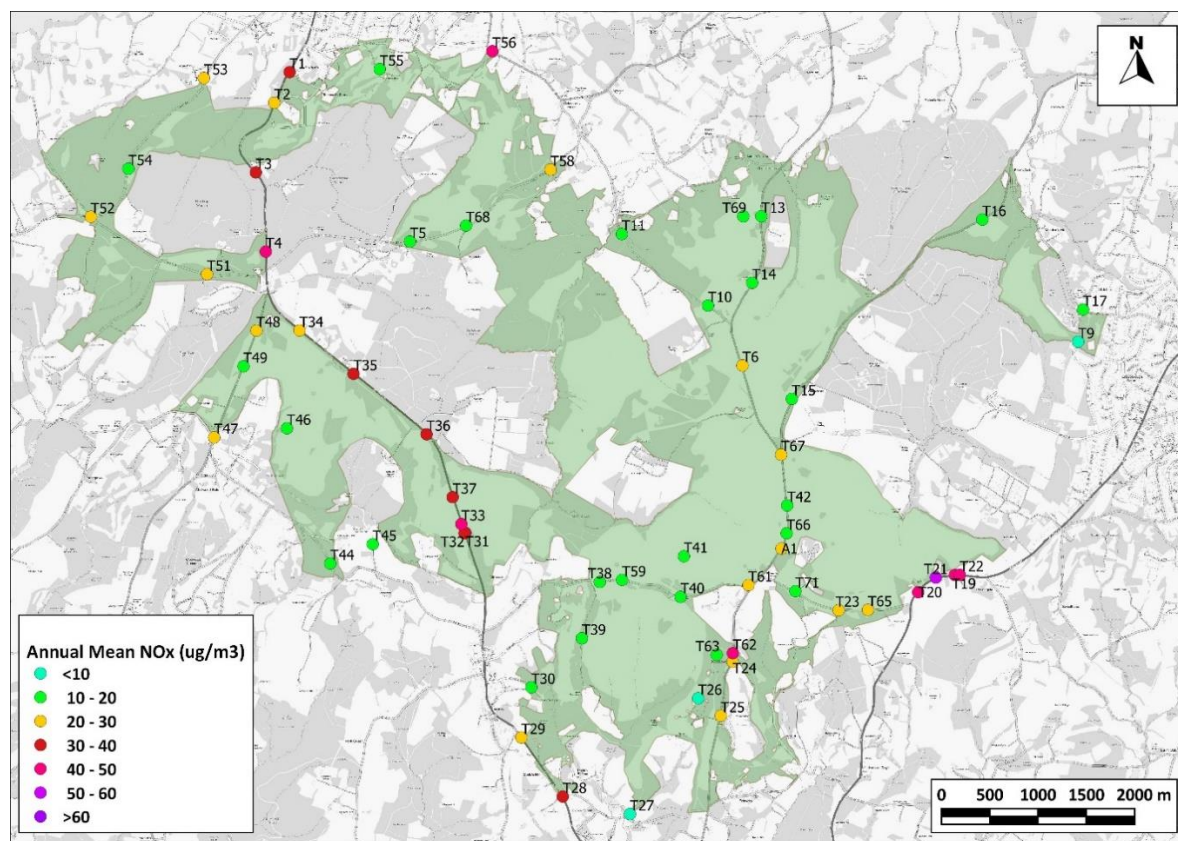
^a Exceedances of the critical levels highlighted in bold and blue shading,

^b r = roadside, b = background.

^c No data.



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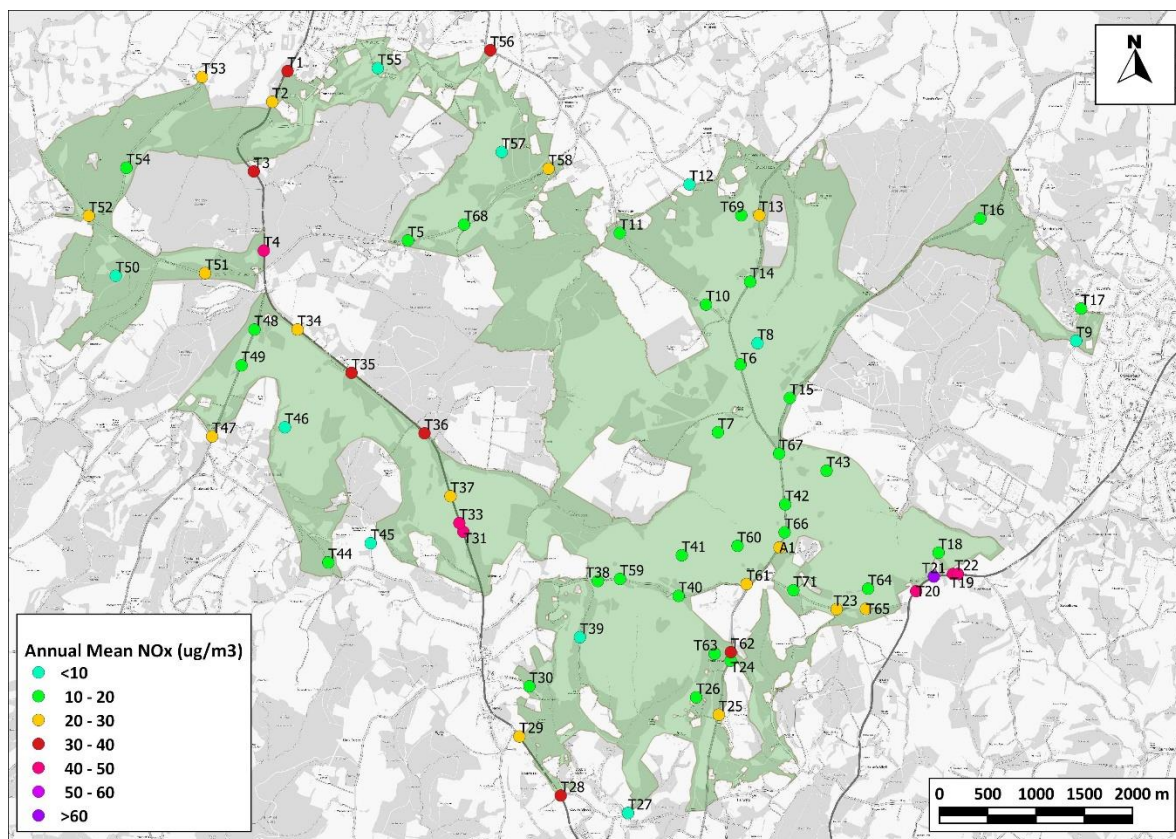


Figure 35: Annual Mean NO_x Concentrations at Non-transect Diffusion Tube Sites in 2019

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Transect Locations

- 4.13 The calculated annual mean NO_x concentrations along the four transects are set out in Table 12, and also shown in Figure 36 Figure 37. The annual mean critical level was consistently exceeded at the first two monitors on Transect 1 (i.e. within 2.5 m to the west of the A22). The critical level was also exceeded during every year at the first three monitors alongside Transect 2 (i.e. within 5 m to the east of the A22). The critical level was not exceeded in any year along Transect 3 (beside the B2026). It was exceeded out to 10 m from the A26 during every year except 2015. An analysis of spatial and temporal trends in the measurements is provided in subsequent sections of this report.

Table 12: Annual Mean NO_x at Transect Locations

Transect Point	Distance from Road (m)	2015	2016	2017	2018	2019
Transect 1						
R1.1	1.7	54.0	63.1	57.1	57.1	57.8
R1.2	2.5	37.7	44.5	36.7	45.7	37.0
R1.3	5.0	25.8	29.4	26.3	25.5	24.7

Transect Point	Distance from Road (m)	2015	2016	2017	2018	2019
R1.4	10	21.3	25.2	24.5	23.0	21.0
R1.5	22	18.2	22.2	21.3	18.5	17.7
R1.6	50	17.2	19.9	19.1	17.0	14.8
R1.7	100	13.1	15.1	15.9	_ ^b	12.8
R1.8	200	15.0	13.8	13.7	_ ^b	10.7
Transect 2						
R2.1	1.7	41.0	42.1	41.1	37.0	36.2
R2.2	2.5	37.2	40.1	40.5	36.2	32.5
R2.3	5.0	33.2	33.4	33.9	31.9	31.8
R2.4	10	27.0	29.0	30.2	28.1	25.2
R2.5	22	24.3	28.2	25.8	22.6	23.6
R2.6	50	21.0	22.2	20.3	18.4	16.5
R2.7	100	14.4	15.4	15.2	12.4	9.3
R2.8	206	13.0	14.3	17.7	_ ^b	8.6
Transect 3						
R3.1	1.0	23.3	24.8	26.1	21.7	19.9
R3.2	2.5	21.9	25.6	24.0	20.5	20.8
R3.3	6.0	24.5	22.2	20.3	19.0	17.6
R3.4	10	17.2	20.5	20.3	18.0	17.3
R3.5	23	18.0	18.0	18.7	15.0	13.7
R3.6	51	14.7	16.9	17.4	13.2	13.1
R3.7	100	12.5	12.2	13.0	10.6	10.8
R3.8	200	11.7	13.7	15.3	_ ^b	13.0
Transect 4						
R4.1	2.0	73.0	75.1	77.5	74.5	73.8
R4.2	3.0	59.6	69.3	65.4	59.6	61.5
R4.3	5.0	42.7	52.1	45.3	43.5	44.4
R4.4	10	29.7	35.7	35.5	34.9	34.9
R4.5	22	21.7	26.0	26.1	26.9	27.5
R4.6	50	17.6	19.1	21.1	19.1	20.1

Transect Point	Distance from Road (m)	2015	2016	2017	2018	2019
R4.7	96	11.2	13.1	12.3	13.3	11.0

a Exceedances of the Critical Levels Highlighted in bold and blue shading,

b No data.

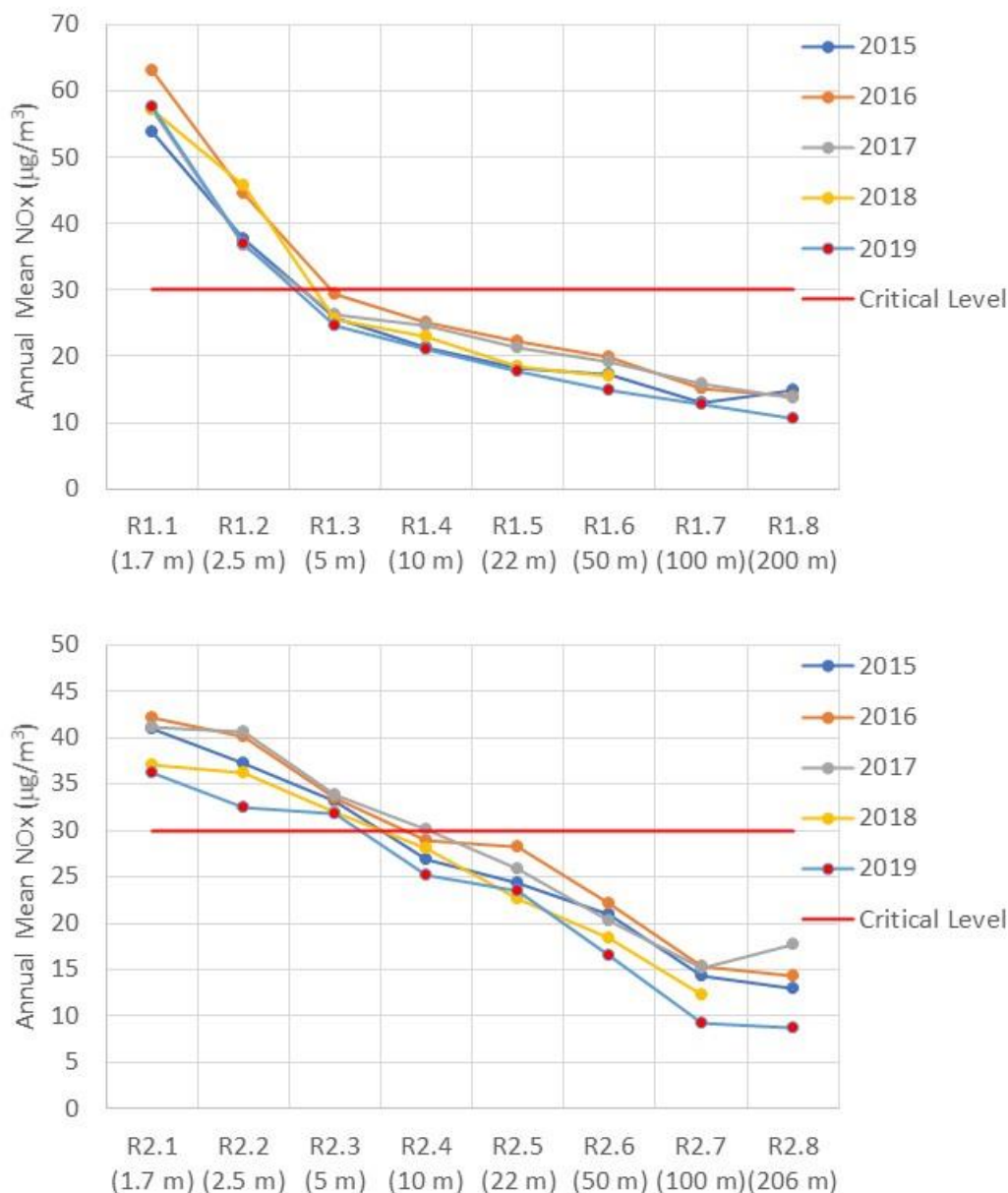


Figure 36: Annual Mean NO_x Concentrations along Transects 1 and 2 (distance from kerb in parentheses)

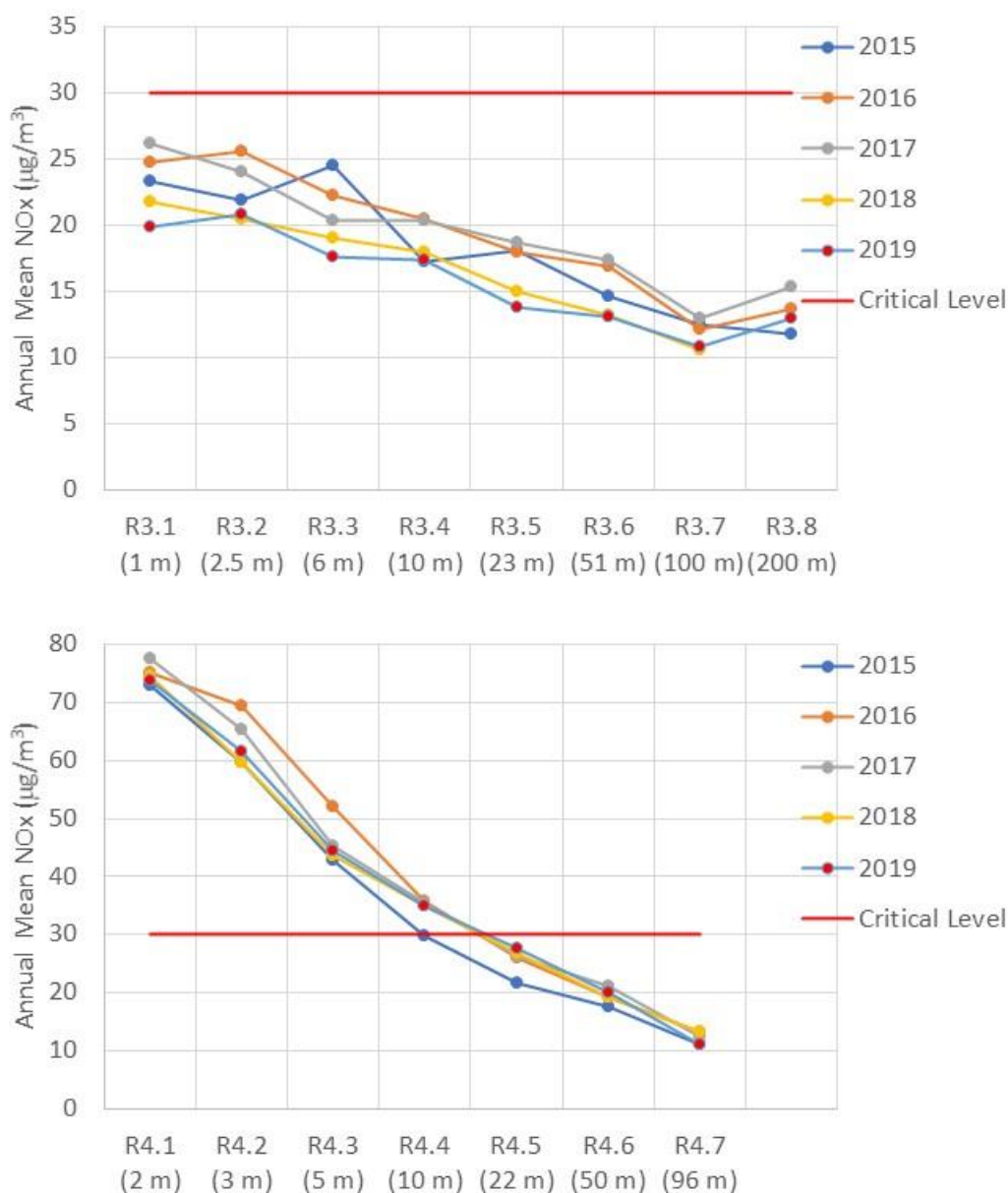


Figure 37: Annual Mean NOx Concentrations along Transects 3 and 4 (distance from kerb in parentheses)

DELTA Samplers

- 4.14 The annualised measurements of NH_3 , HNO_3 , HONO , pNH_4^+ , pNO_3^- , and pNO_2^- for the years 2015 to 2019, inclusive from the six DELTA samplers are set out in Table 13 and Table 14. Data for 2014 and 2020 are also provided in Table 10, although these do not represent annual equivalence so should not be compared directly with annual mean values. The only critical level or critical load which applies directly to these species is the annual mean critical level for NH_3 . This was exceeded at Site D6 in every year with valid measurements, as well as at Sites D1 and D4 in 2018. The critical level was achieved at all other sites and in all other years.

Table 13: Annual Mean Gaseous Concentrations Measured at DELTA Samplers ($\mu\text{g}/\text{m}^3$)*

Monitor	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
NH₃							
D1 (R1.3)	(0.62)	0.80	0.83	0.80	1.18 ^c	- ^b	- ^b
D2 (T46)	(0.19)	0.59	0.74	0.71 ^c	0.74	0.60	(0.22)
D3 (A1)	(0.38)	0.69	0.76	0.97	0.93	0.91	(0.19)
D4 (T71)	(0.32)	0.59	0.89	0.97	1.16	0.92	(0.39)
D5 (T41)	(0.21)	0.41 ^c	0.99	0.80	0.68	0.43	(0.14)
D6 (R4.3)	(1.24)	1.12	1.45	1.45	1.65	- ^b	(1.21)
HNO₃							
D1 (R1.3)	(0.40)	0.88	1.12	0.98	0.92 ^c	- ^b	- ^b
D2 (T46)	(0.78)	0.90	1.19	1.02 ^c	0.88	0.85	(0.40)
D3 (A1)	(0.91)	0.82	0.97	1.16	0.98	0.99	(0.52)
D4 (T71)	(0.83)	0.74	1.16	1.11	1.37	1.05	(0.53)
D5 (T41)	(0.47)	0.94 ^c	1.28	1.21	0.84	0.58	(0.21)
D6 (R4.3)	(0.75)	0.94	1.22	1.09	1.23	- ^b	(0.77)
HONO							
D1 (R1.3)	(0.37)	0.04	0.03	0.04	0.04	- ^b	- ^b
D2 (T46)	(0.14)	0.03	0.04	0.06 ^c	0.04	0.02	(0.01)
D3 (A1)	(0.07)	0.02	0.03	0.05	0.02	0.04	(0.03)
D4 (T71)	(0.37)	0.03	0.03	0.04	0.03 ^c	0.03	(0.08)
D5 (T41)	(0.39)	0.05 ^c	0.05	0.04	0.03	0.01	(0.01)
D6 (R4.3)	(0.43)	0.08	0.11	0.17	0.09	- ^b	(0.20)

* Exceedances of the critical level highlighted in blue and bold.

^a Data are not for a complete year (less than three months) and have therefore not been annualised.

^b No data.

^c Data have been annualised against samplers with 100% data capture as data capture at these sites was <75% of the calendar year. Annualisation of data in 2015 have been made against sampler D2, in 2016 against sampler D4, in 2017 against sampler D5 and in 2018 against sampler D6. No annualisation was necessary for any site in 2019.

4.15 The other pollutants in Table 13 and Table 14 all contribute to nitrogen deposition and so the values presented may be used to support more accurate modelling of nitrogen deposition to the SAC. Analyses of spatial and temporal patterns in these measurements are provided in subsequent sections of this report.

Table 14: Annual Mean Particulate Concentrations Measured at DELTA Samplers ($\mu\text{g}/\text{m}^3$)

Monitor	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
pNH₄⁺							
D1 (R1.3)	(0.86)	0.94 ^c	0.71	0.66	0.78 ^c	- ^b	- ^b
D2 (T46)	(0.46)	0.61	0.85	0.74 ^c	0.67	0.50	- ^b
D3 (A1)	- ^b	0.67	0.62	0.74	0.80 ^c	0.61	- ^b
D4 (T71)	(0.54)	0.44	0.70	0.77	0.66	0.64	- ^b
D5 (T41)	(0.46)	0.55 ^c	0.81	0.73	0.70	0.35	- ^b
D6 (R4.3)	(0.63)	0.70	1.08 ^c	0.81	0.67	- ^b	- ^b
pNO₃⁻							
D1 (R1.3)	- ^b	1.56	1.77	1.72	2.15 ^c	- ^b	- ^b
D2 (T46)	(1.51)	1.33	2.21	1.80 ^c	1.76	1.43	(0.83)
D3 (A1)	(1.73)	1.57	1.76	2.08	2.11 ^c	1.77	(0.89)
D4 (T71)	- ^b	0.98	1.70	2.34	2.10	1.91	(1.05)
D5 (T41)	- ^b	1.36 ^c	2.19	1.97	2.12 ^c	0.99	(0.38)
D6 (R4.3)	- ^b	1.70 ^c	2.30 ^c	2.47	2.26	- ^b	- ^b
pNO₂⁻							
D1 (R1.3)	(0.13)	0.02	0.05	0.05	0.02 ^c	- ^b	- ^b
D2 (T46)	(0.06)	0.02	0.07 ^c	0.002 ^c	0.004 ^c	0.005 ^c	- ^b
D3 (A1)	(0.01)	0.01	0.03	0.02	0.01	0.01	- ^b
D4 (T71)	- ^b	0.01 ^c	0.03 ^c	0.04	0.02	0.01	(0.02)
D5 (T41)	- ^b	0.01 ^c	0.07	0.02 ^c	0.02 ^c	0.004 ^c	- ^b
D6 (R4.3)	(0.21)	0.14	0.18	0.15	0.09	- ^b	- ^b

^a Data are not for a complete year (less than three months) and have therefore not been annualised.

^b No data.

^c Data have been annualised against samplers with 100% data capture as data capture at these sites was <75% of the calendar year. Annualisation of data in 2015 have been made against sampler D2, in 2016 against sampler D4, in 2017 against sampler D5 and in 2018 against sampler D6. No annualisation was necessary for any site in 2019.

ALPHA Samplers

- 4.16 The annualised NH₃ measurements from the ALPHA samplers for the years 2015 to 2019, inclusive, are presented in Table 15. Data for 2014 and 2020 are also provided in Table 15, although these have not been annualised. Values for 2015 to 2019 measured along the three transects (Transect

4 was not equipped with ALPHA samplers) are also shown in Figure 38. The critical level for annual mean NH_3 concentrations was exceeded at 24 out of the 29 sites during 2018. In other years, the critical level was exceeded at between 9 and 15 sites in each year, all of which are roadside sites. The highest annual mean NH_3 concentration recorded at any site was at Site R1.1 (alongside the A22) during 2018. This site is closer to the road than Site D6, which is alongside the busier A26. An analysis of spatial and temporal trends in these measurements is provided in subsequent sections of this report.

Table 15: Annual Mean NH_3 Concentrations Measured by ALPHA Samplers *

Site	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
R1.1	(1.30)	1.59	1.73	1.72	2.09	1.68	(0.97)
R1.2	(1.12)	1.20	1.41	1.52	1.70	1.42	(0.74)
R1.3	(0.42)	0.87	1.19	0.82	0.95	0.98	(0.41)
R1.4	(0.37)	0.89	0.77	0.86	1.11	0.88	(0.48)
R1.5	(0.27)	0.70	0.71	0.82	0.90	0.83	(0.27)
R1.7	(0.28)	0.64	0.77	0.92	1.22	0.78	(0.43)
R2.1	(1.51)	1.41	1.44	1.57	1.77	1.26	(0.89)
R2.2	(1.24)	1.25	1.33	1.37	1.75	1.23	(0.81)
R2.3	(0.62)	1.01	1.21	1.24	1.46	1.37	(0.80)
R2.4	(0.41)	0.88	1.03	1.14	1.31	1.00	(0.68)
R2.5	(0.29)	0.87	0.84	1.04	1.28	0.88	(0.60)
R2.7	(0.22)	0.63	0.66	0.77	0.93	0.57	(0.17)
R3.1	(0.21)	1.06	0.88	1.00	1.21	0.77	(0.32)
R3.2	(0.19)	0.84	0.81	0.94	1.20	0.83	(0.41)
R3.3	(0.19)	0.66	0.72	0.93	1.04	0.89	(0.30)
R3.4	(0.19)	0.68	0.73	0.84	1.06	0.84	(0.76)
R3.5	(0.48)	0.68	0.70	0.85	0.98	0.75	(0.38)
R3.7	(0.50)	0.56	0.65	0.72	0.85	0.64	(0.19)
T59	(0.30)	0.88	1.02	1.02	1.62	1.10	(0.52)
T61	(0.35)	0.86	1.00	1.31	1.36	1.08	(0.87)
T62	(0.67)	1.04	0.98	1.01	1.31	1.16	(0.73)
T65	(0.38)	0.94	0.90	1.03	1.11	0.98	(0.63)
D3 (A1)	(0.33)	0.72	1.07	0.87	1.14	0.94	(0.67)

Site	2014 ^a	2015	2016	2017	2018	2019	2020 ^a
T67	(0.26)	1.32	1.95	1.33	1.83	1.13	(0.54)
T14	(0.35)	0.76	0.76	1.04	1.40	0.93	(0.54)
T69	(0.14)	0.55	0.59	0.97	1.35	0.72	(0.56)
T68	(0.31)	0.79	0.73	0.85	1.38	0.89	(0.42)
T70	(0.20)	0.62	0.61	0.70	1.90	0.72	(0.42)
D6 (R4.3)	(0.65)	1.47	1.31	1.54	2.00	1.42	(1.01)
Critical Level	1						

* Exceedances of the critical level highlighted in blue and bold.

^a Data are not for a complete year (three months) and have therefore not been annualised.



Figure 38: Annual Mean NH_3 Concentrations along Transects 1, 2 and 3 (distance from kerb in parentheses)

Automatic Traffic Counters

- 4.17 The Annual Average Daily Traffic (AADT) total traffic volumes are provided in Table 16. Those sites where data capture issues were considered likely to affect the annual average are excluded from this table except for 2015 and 2020, where a full year's data was not available for any of the sites. The authors of this report are not transport specialists and so no attempt has been made to adjust any of the traffic data to annual equivalence. Table 17 summarises the volume of Heavy Duty Vehicles (HDV = lorries and buses) on each road. Only weekday data were available from the sites operated by ESCC, and no fleet composition data were available for ESCC Site 129. Additional details on the fleet composition data on each road are not tabulated because they are not used in the current report to interpret the air quality measurements and because the authors of the current report are not transport specialists. The hour-by-hour ATC records for each channel can be provided to WDC on request and these hourly data are likely to be useful for modelling traffic-related air quality.

Table 16: Annual Average Daily Total Traffic Volumes

Site	Road	2015	2016	2017	2018	2019	2020
1201	New Road	5,447	5,750	5,776	5,505	5,459	4,786
1202	B2188	2,002	2,140	2,246	2,113	2,104	1,830
1203	Crowborough Road	2,947	3,367	3,463	3,317	3,251	2,775
1204	B2026 Black Hill	3,768	4,002	3,903	- ^a	4,142	3,557
1205	B2026 toward Chuck Hatch	1,616	1,336	992	- ^a	2,583	2,497
1206	A22 south of Forest Row	9,924	9,986	10,099	9,757	- ^a	8,622
1207	Colemans Hatch Road	1,870	1,815	1,886	1,874	1,815	1,509
1208	B2026 south of Duddleswell	5,012	5,069	5,050	5,098	5,050	4,462
18	A26	16,381	16,305	16,260	16,067	16,024	13,095
38	A275	4,502	4,766	4,785	4,561	4,704	3,739
41	B2026 at Kingstanding	5,503	5,714	5,705	5,568	5,810	5,052
129	A22 south of Wych Cross	12,038	12,424	12,110	11,711	11,687	9,044

^a Data discounted from table

- 4.18 The results from Table 16 and Table 17 are also shown graphically in Figure 39 and Figure 40. These highlight that total traffic volumes and HDV flows did not change appreciably year-on-year at

any site, except for a fall in HDV numbers at ESCC Site 18 (A26) in 2019. Some sites showed a small increase in flows over the five-year period, but several sites recorded a small reduction in traffic.

- 4.19 Figure 41 and Figure 42 illustrate the average flows on each road. This shows the higher volumes on the A26 and A22 when compared with the more minor roads. One notable point is that traffic volumes on New Road and much of the B2026 were higher than those on the A275.

Table 17: Annual Average Daily HDV Traffic Volumes

Site	Road	2015	2016	2017	2018	2019	2020
1201	New Road	202	220	239	240	244	241
1202	B2188	48	58	68	66	71	61
1203	Crowborough Road	121	136	147	149	150	158
1204	B2026 Black Hill	85	90	88	- ^a	102	101
1205	B2026 toward Chuck Hatch	52	40	30	- ^a	72	80
1206	A22 south of Forest Row	670	684	685	685	- ^a	664
1207	Colemans Hatch Road	52	51	53	55	54	50
1208	B2026 south of Duddleswell	134	139	159	159	159	149
18	A26	826 ^b	843 ^b	847 ^b	817 ^b	747 ^b	701 ^b
38	A275	- ^a	250 ^b	205 ^b	197 ^b	200 ^b	190 ^b
41	B2026 at Kingstanding	100 ^b	103 ^b	107 ^b	108 ^b	84 ^b	83 ^b
129	A22 south of Wych Cross	- ^a	- ^a	- ^a	- ^a	- ^a	- ^a

^a Data discounted from table

^b AAWT (weekdays only)

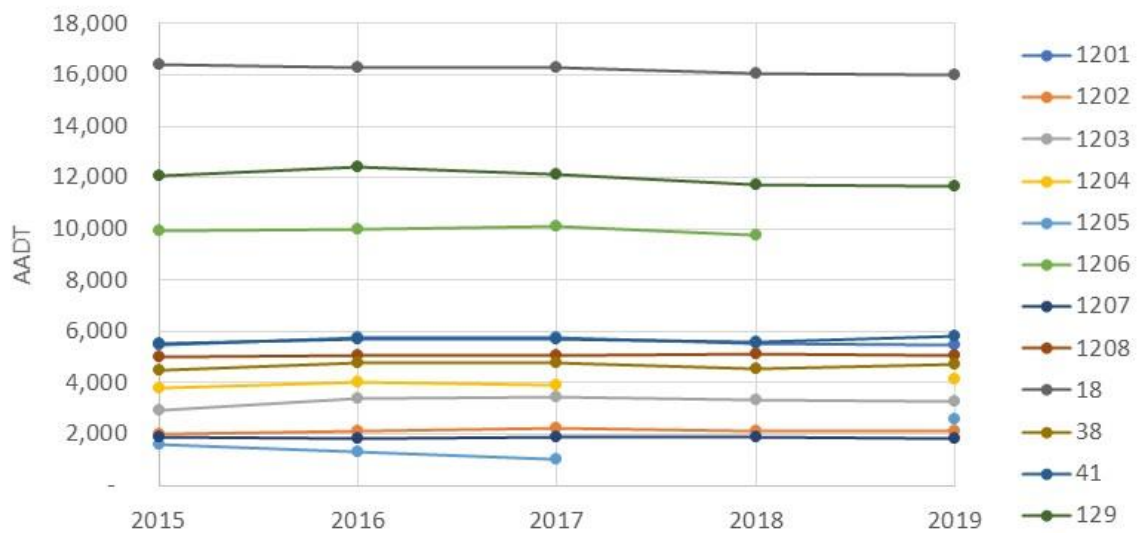


Figure 39: Total Traffic Volumes (vehicles per average day) on 12 Roads over Five Years

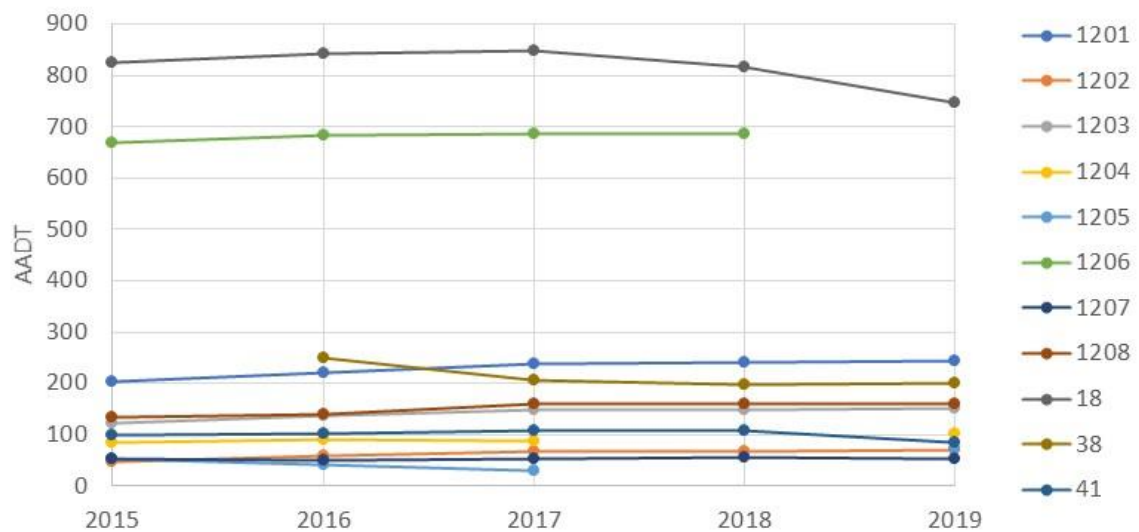


Figure 40: HDV Volumes (vehicles per average day) on 11 Roads over Five Years (Values for Sites 18, 38, and 41 are AAWTs)

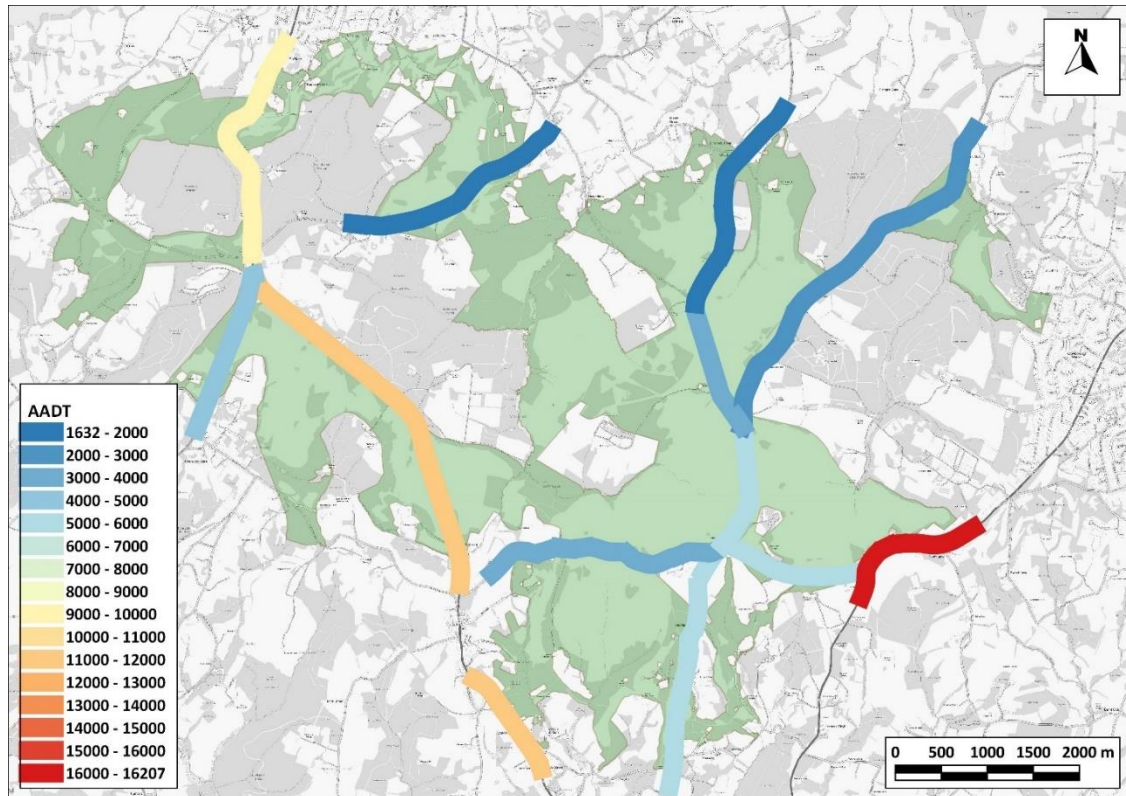


Figure 41: 5-year Mean (2015-2019 Inclusive) Measured AADT on Roads within Ashdown Forest SAC¹¹

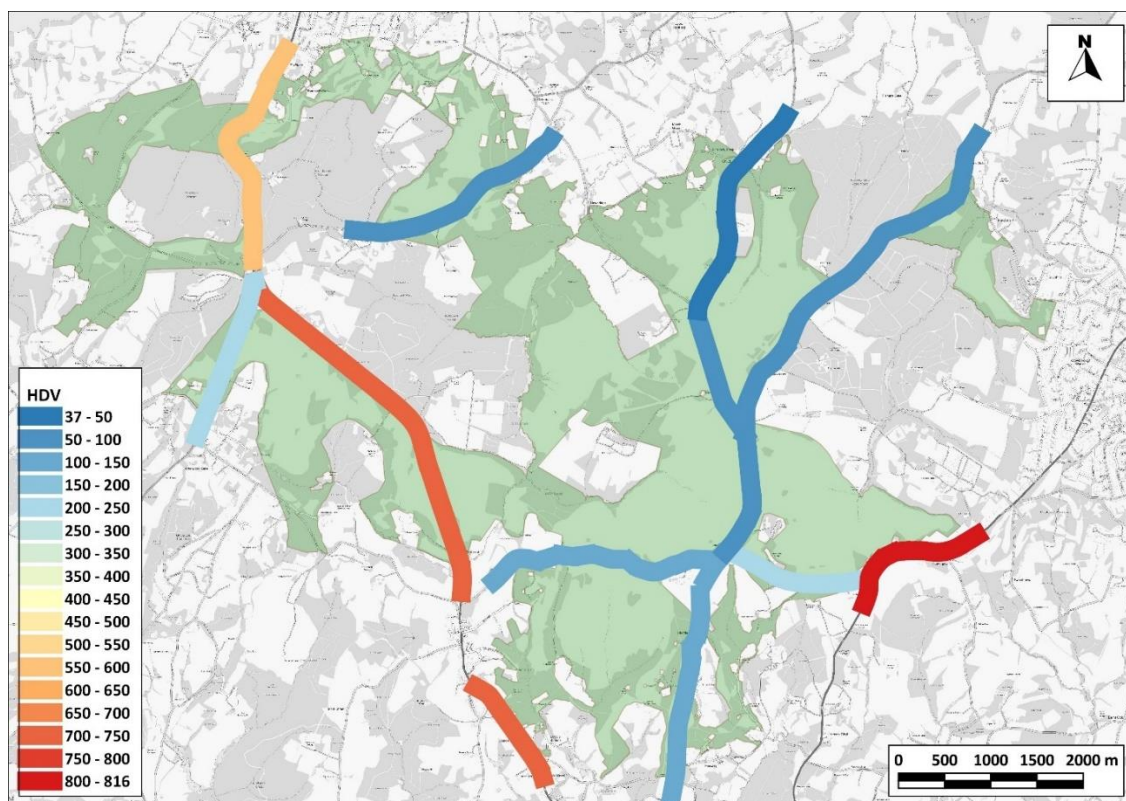


Figure 42: 5-year Mean (2015-2019 Inclusive) Average Daily HDV Volumes (Vehicles per day) on Roads within Ashdown Forest SAC¹¹

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4.20 Figure 43 to Figure 53 show the measured traffic flows in more detail. They show the average hourly volume by hour of the day, for each vehicle class, averaged over each year. It should be noted that for those vehicle classes where total volumes are small (e.g. buses), the data are readily skewed by individual events. Nevertheless, the plots generally show characteristic and well-understood patterns, with volumes of car and Light Goods Vehicle (LGV) traffic peaking during the morning and evening, while Heavy Goods Vehicles (HGVs) often avoid these periods. This is important to understanding the diurnal profiles of emissions because the speed-emissions response of light and heavy vehicles can be very different. The profiles shown for motorcycles may highlight the difference between commuting and leisure riding on different roads (and on weekdays vs weekends), but all of the motorcycle volumes are low.

¹¹ Figure for illustrative purposes only. Values are either 5-year means or 4-year means (for those sites where data were removed from Table 16 and Table 17. HDV volumes at ESCC sites are AAWTs while for the WDC-operated sites they are AADTs. The exception to this is for the A22 south of Wych Cross, where no fleet composition data are reported. The relative fleet composition measured on the A22 south of Forest Row has thus be inferred onto the measured total traffic AADT volume measured south of Wych Cross.

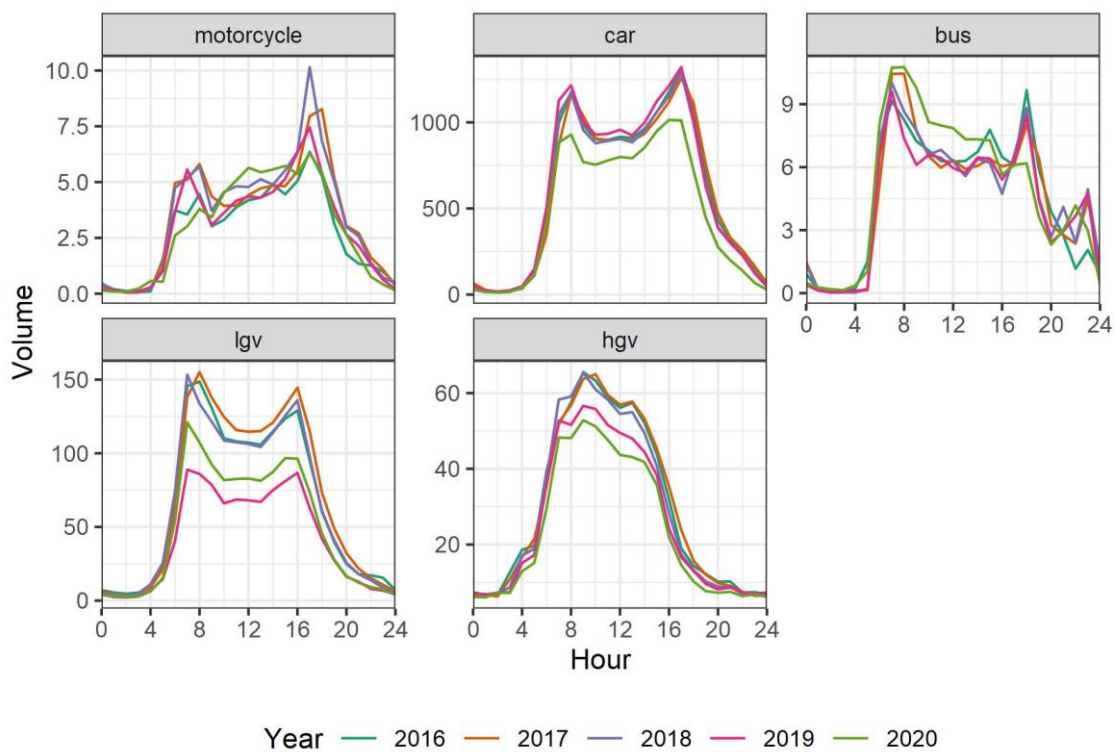


Figure 43: Diurnal Traffic Profiles at ATC 18 (Weekdays)

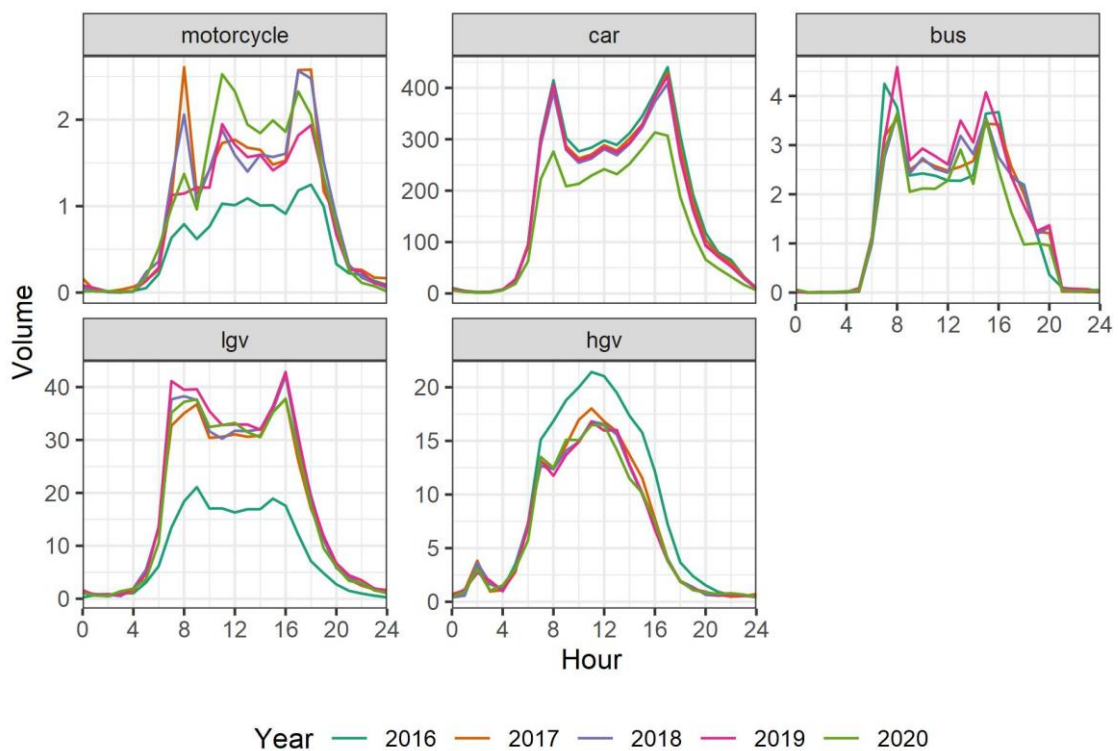


Figure 44: Diurnal Traffic Profiles at ATC 38 (Weekdays)

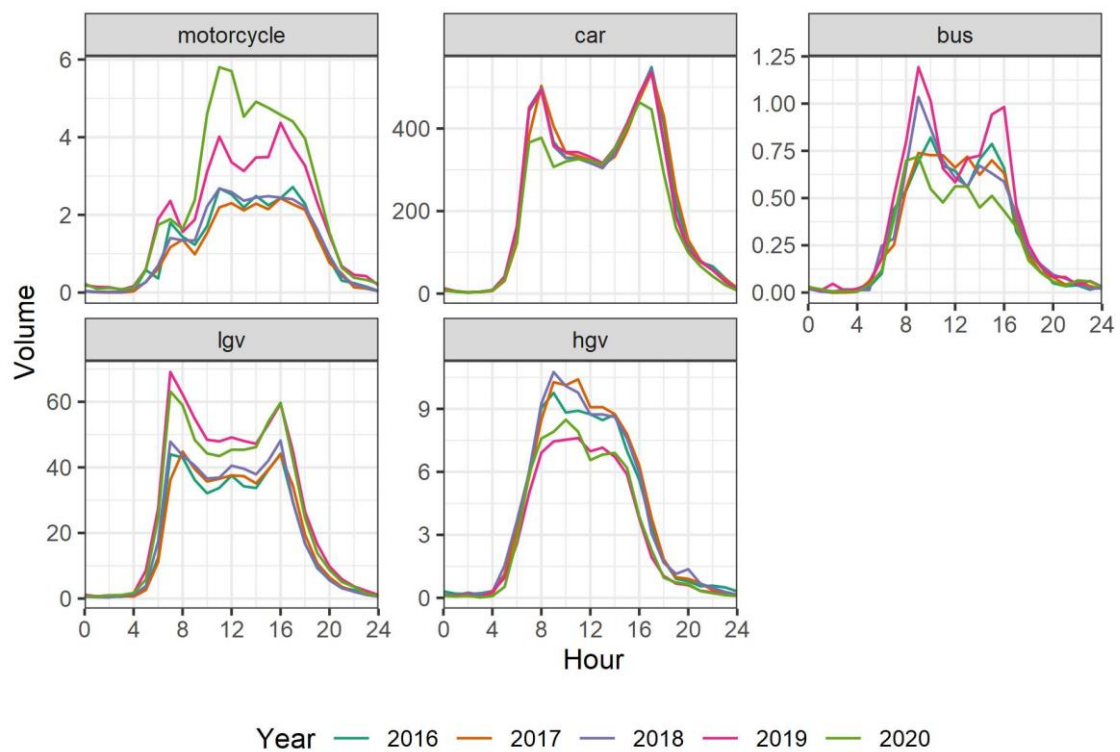


Figure 45: Diurnal Traffic Profiles at ATC 41 (Weekdays)

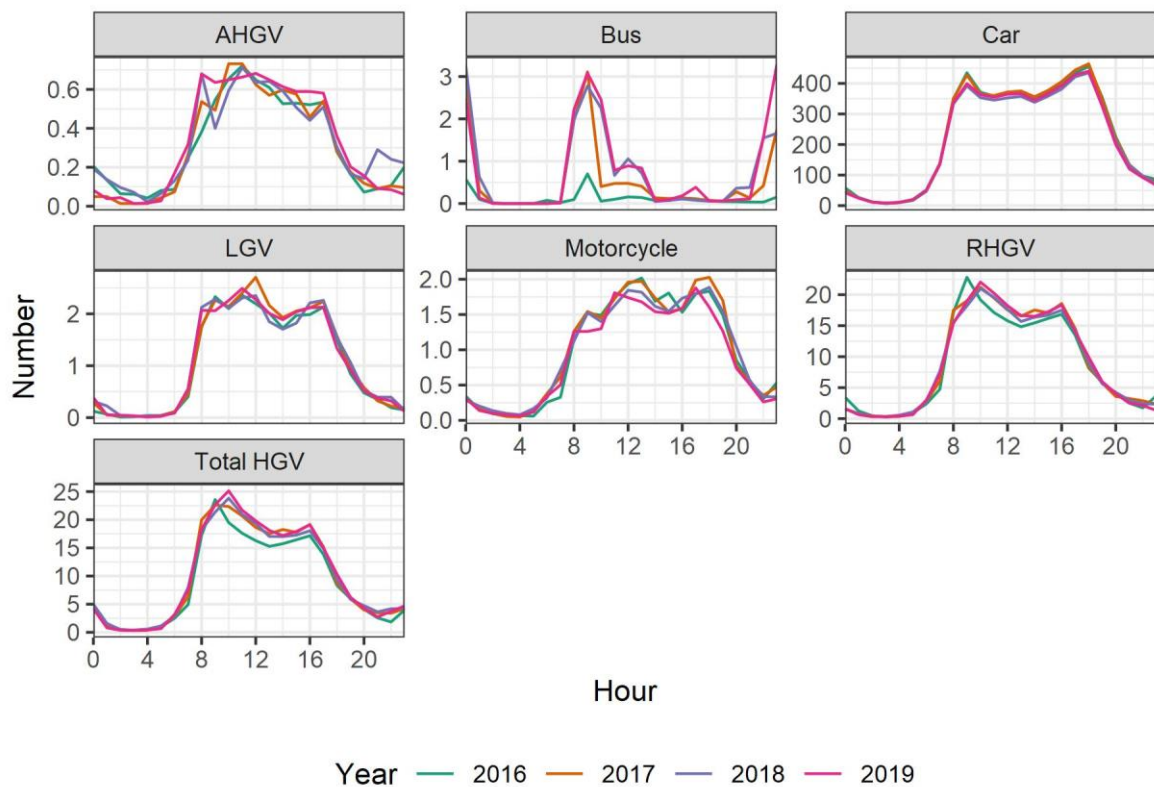


Figure 46: Diurnal Traffic Profiles at ATC 1201 (All Days)

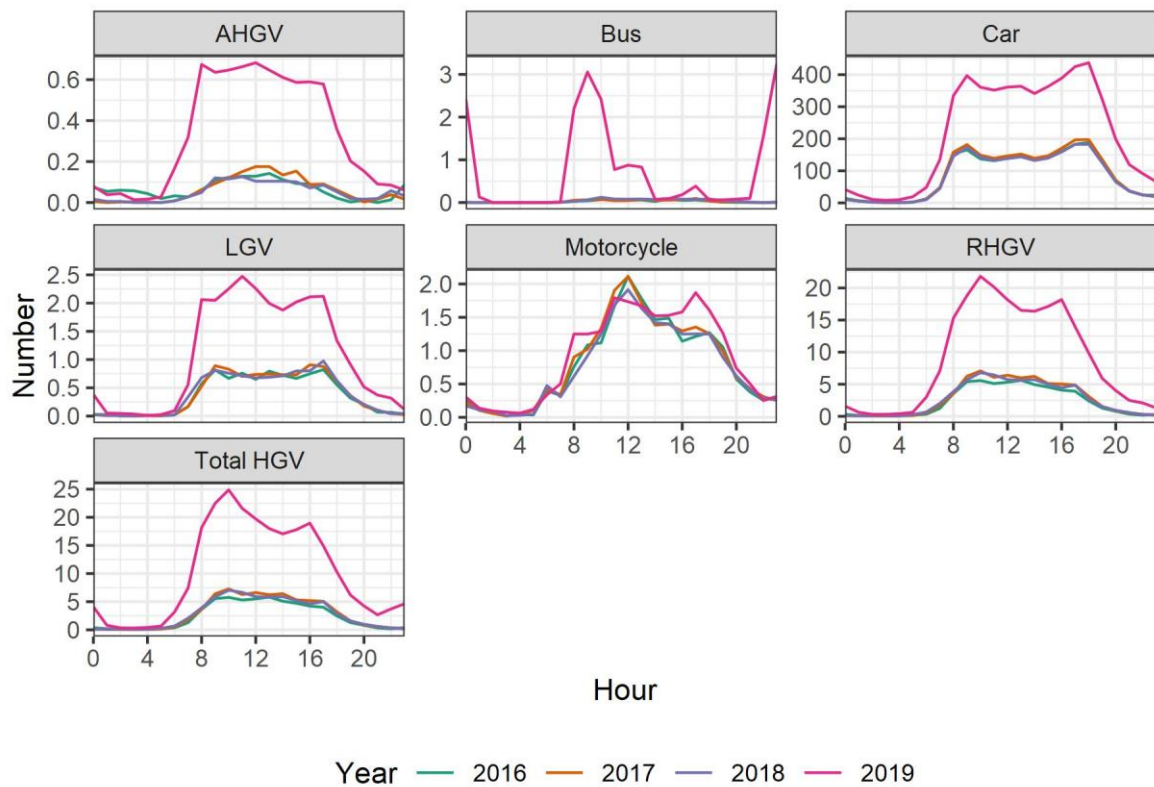


Figure 47: Diurnal Traffic Profiles at ATC 1202 (All Days)

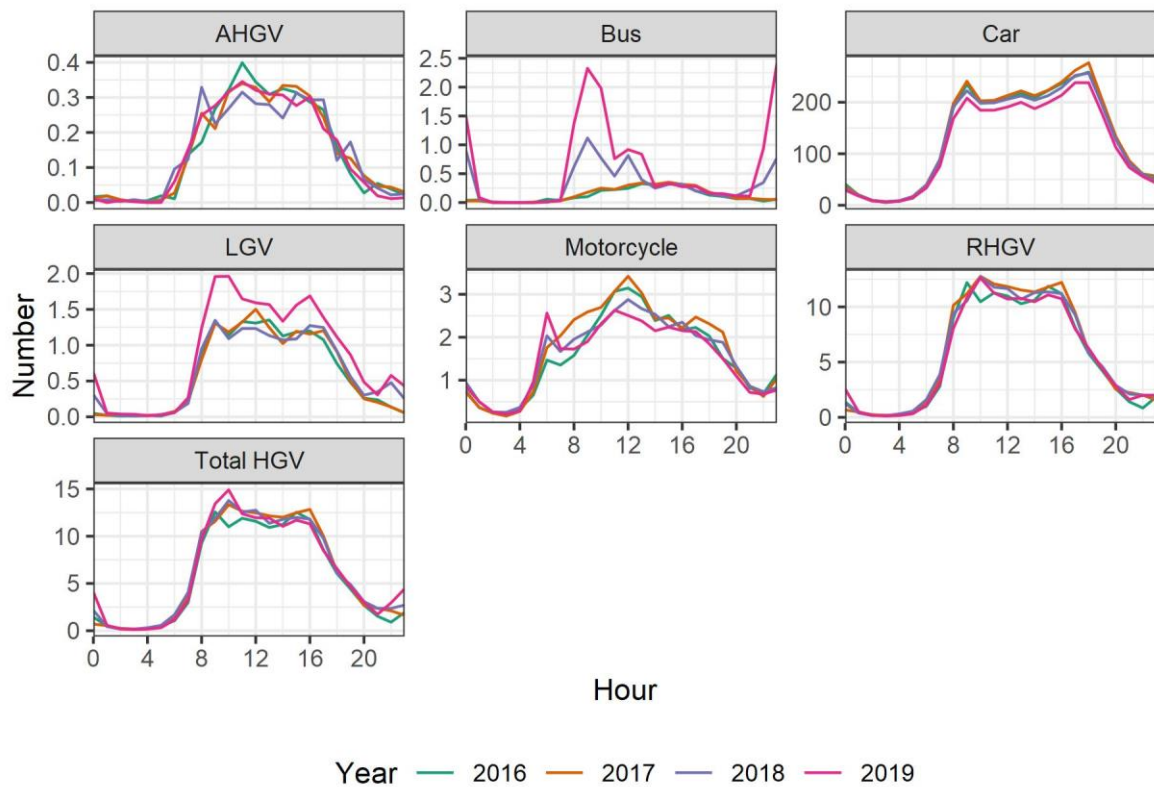


Figure 48: Diurnal Traffic Profiles at ATC 1203 (All Days)

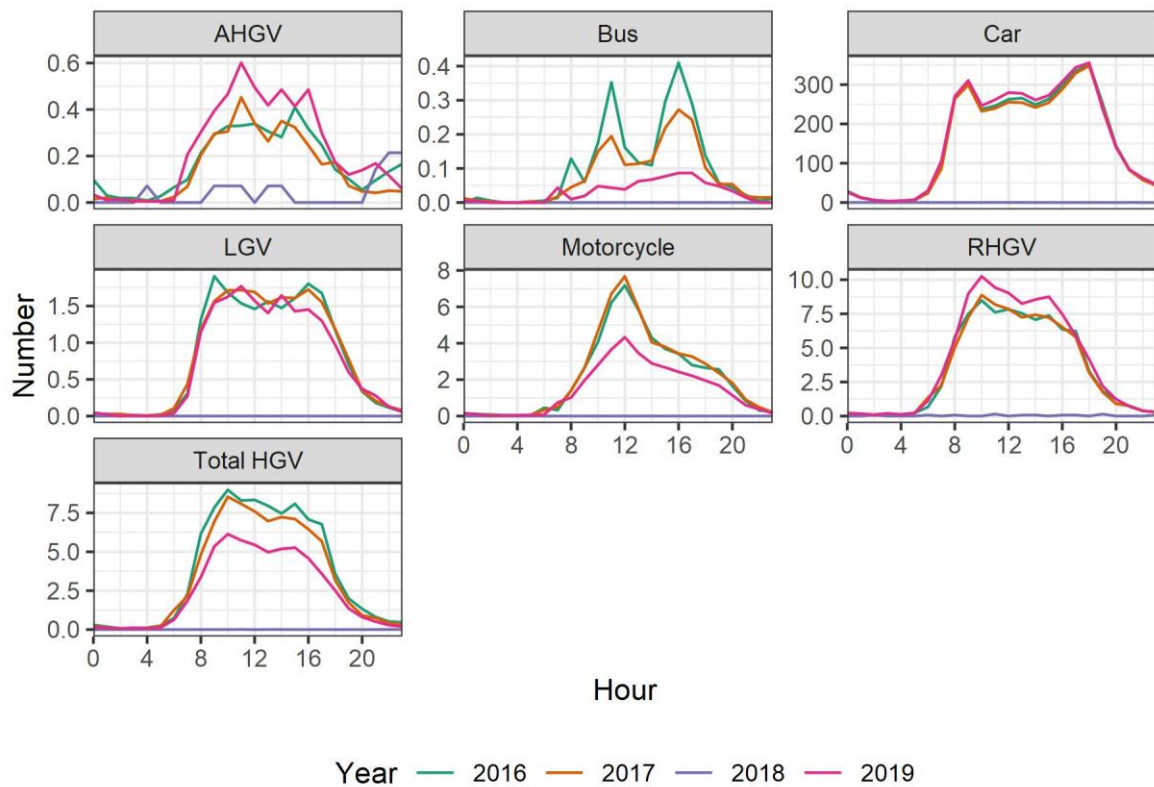


Figure 49: Diurnal Traffic Profiles at ATC 1204 (All Days)

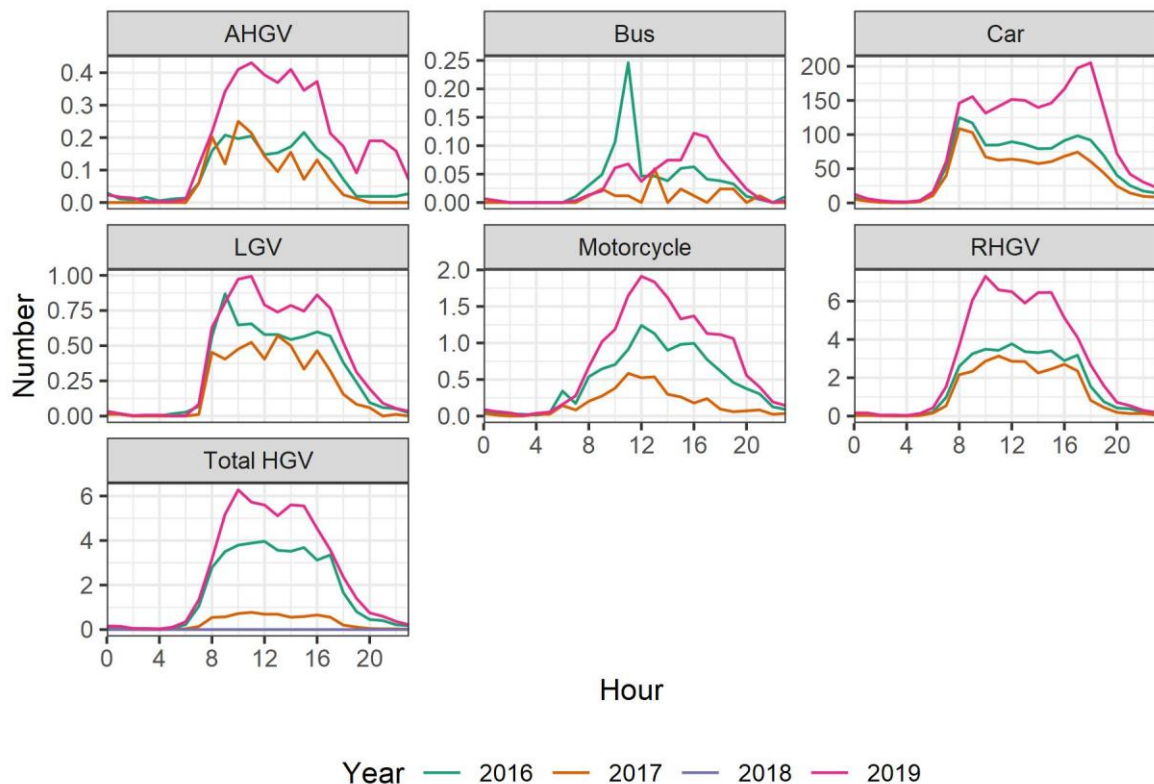


Figure 50: Diurnal Traffic Profiles at ATC 1205 (All Days)

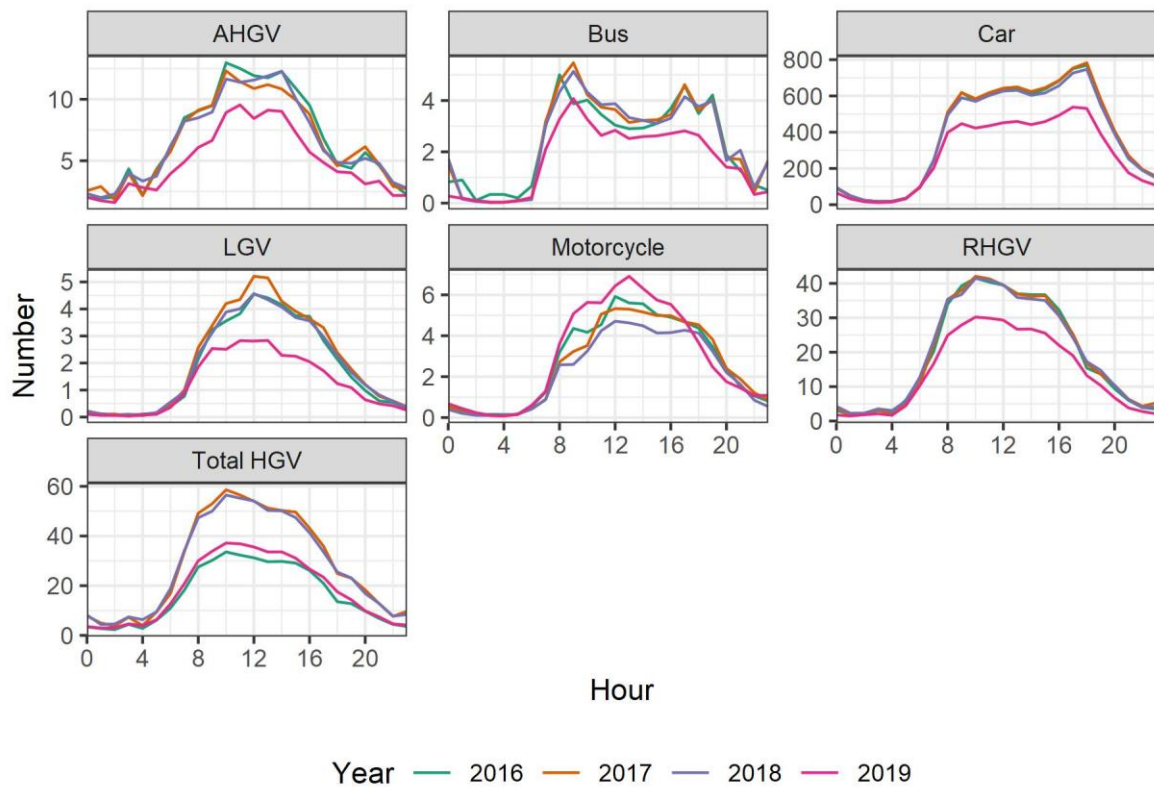


Figure 51: Diurnal Traffic Profiles at ATC 1206 (All Days)

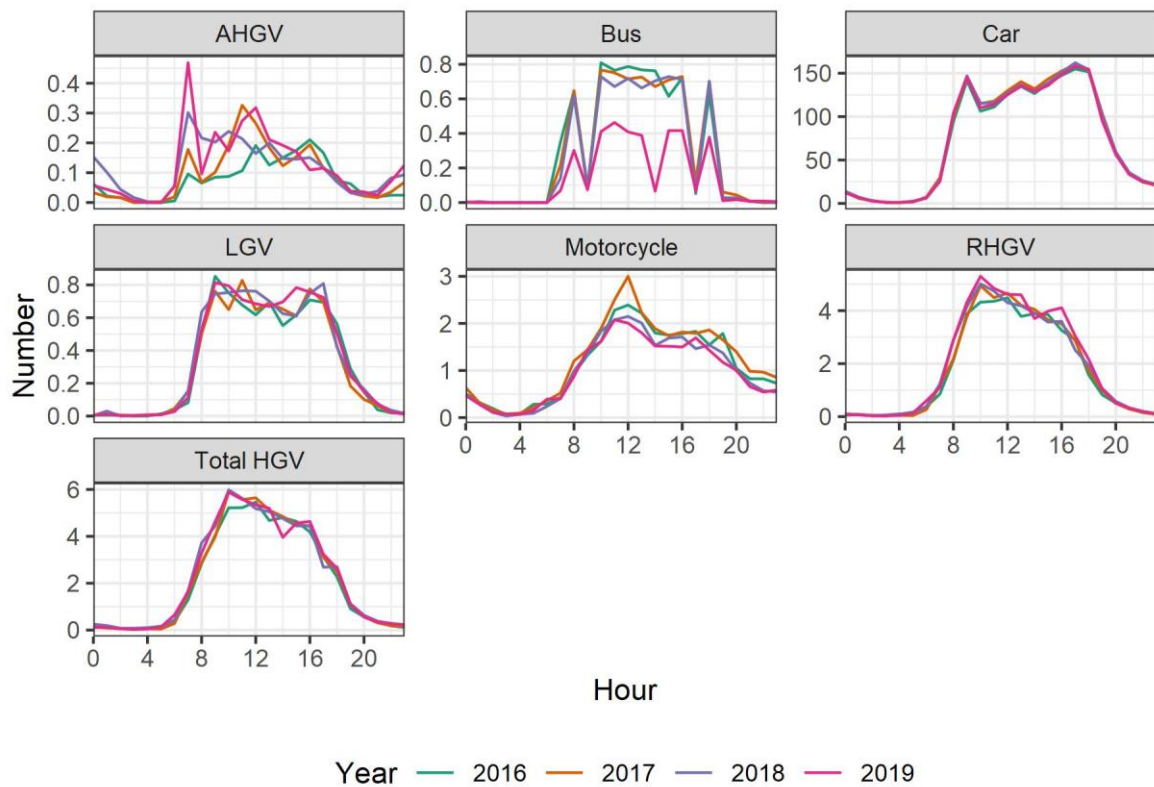


Figure 52: Diurnal Traffic Profiles at ATC 1207 (All Days)

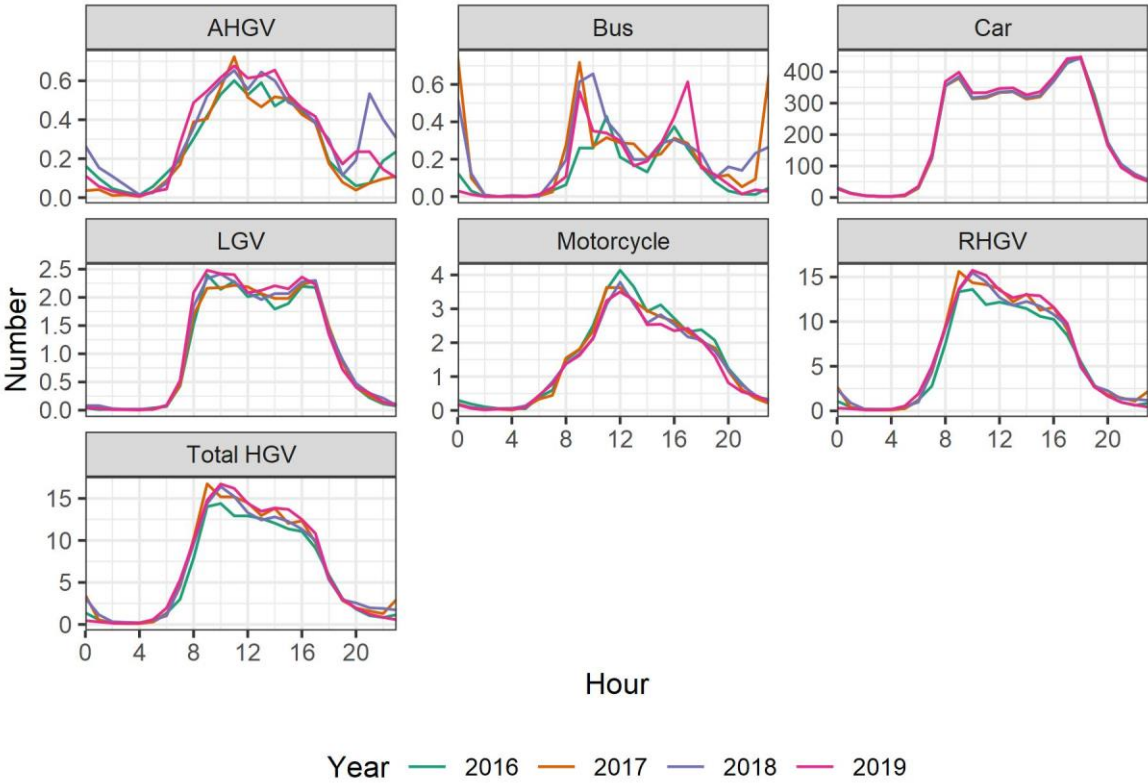


Figure 53: Diurnal Traffic Profiles at ATC 1208 (All Days)

5 Spatial Patterns

- 5.1 This section of the report describes spatial patterns in the measurements. It does not consider changes that have occurred over time, which are described in Section 6. In most cases the spatial patterns can most robustly be understood by considering long-term (multi-year) averages. However, in order to ensure that data capture does not affect the spatial patterns, it is most appropriate to average over a period with full data capture. Because the 2015 to 2019 data have been annualised to represent full calendar years, most of the spatial analysis in this section focuses this 5-year period. The start date for measurements made during 2014 were not spatially consistent (i.e. different sites were commissioned at different times, with many of the instruments not starting until November 2014). Thus, while these data have previously been valuable for model formulation and verification, they are not considered here. Similarly, measurements made during 2020 could not be annualised to represent calendar year equivalence and so including them here would bias the spatial analysis.
- 5.2 Observations on spatial patterns can also be determined by combining high time-resolution measurements with meteorological data. There was only one high time-resolution monitor in the study (Site A1 at Kingstanding) and thus no potential for bias by combining mismatched periods. However, it is still the case that the brief periods of measurements made during 2014 and 2020 will give a less complete picture of patterns over a year. Because this analysis is presented by year, it also focuses only on the 2015 to 2019 (inclusive) period. The analysis presented here uses hour-by-hour meteorological measurements taken from the Meteorological Office site at Gatwick Airport.

NO_x and NO₂

Observations from the Kingstanding Automatic Analyser

- 5.3 Analysis of the hourly data has been performed using the statistical programming language, 'R' and specialist analysis package 'Openair' (Carslaw & Ropkins, 2012). Openair is an open-source set of statistical and graphical analysis tools for the analysis of air pollution data.

Pollution Roses

- 5.4 The overall contributions of different wind sectors to annual mean NO_x and NO₂ concentrations are summarised in Figure 54 and Figure 55. The length of each 'petal' in each pollution rose shows the relative contribution that that wind direction made to the annual mean concentration, while the colour shows the distribution of hourly-mean concentrations from that wind direction.
- 5.5 For both pollutants, the overall mean concentrations were dominated by southwesterly winds, which contributed between 15% and 30% of the total annual mean concentrations. Winds from the northwest and northeast were also important at this site. Southeasterly winds contributed very little to annual mean concentrations.

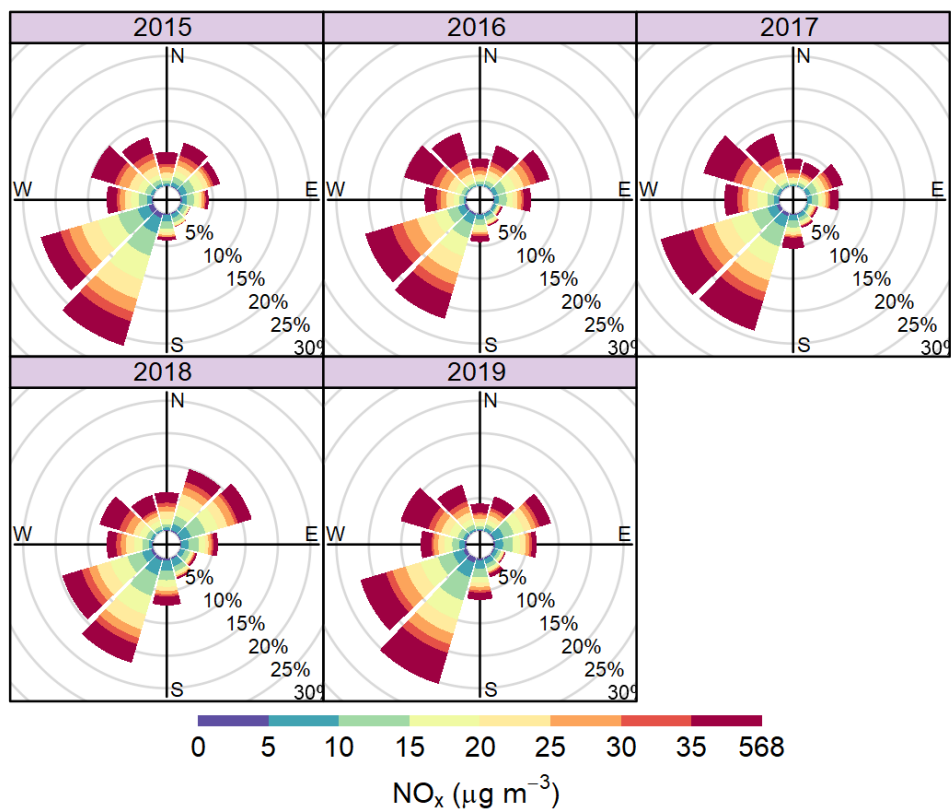


Figure 54: Pollution Rose Plots for NO_x

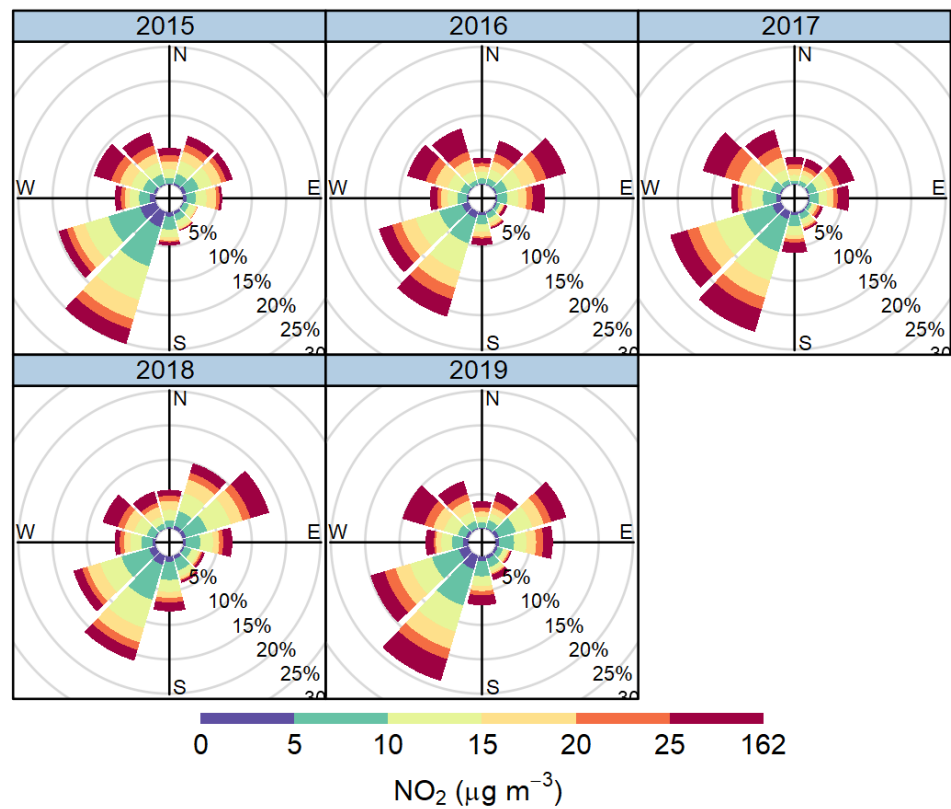


Figure 55: Pollution Rose Plots for NO_2

- 5.6 While Figure 54 and Figure 55 are informative, in that they show how annual mean concentrations experienced at this site are composed, they are more a reflection of wind frequency than of emissions-strength; in other words, concentrations are dominated by southwesterly winds simply because these winds were most frequent.

Polar Annulus

- 5.7 In order to better understand the ambient concentrations associated with each wind direction, polar annulus plots (Figure 56 and Figure 57) have been used. These show the combined dependence of concentrations on both direction and the various temporal factors labelled in the plots. To aid interpretation, Figure 58 shows the precise location of the automatic monitor in relation to its immediate surroundings.
- 5.8 Starting with the 'hour' panel for NO_x in Figure 56, this shows a clear trend for higher concentrations to occur in the early morning and early evening, particularly when winds are from the northwest, but also for other wind directions. The temporal pattern shown here is very common for NO_x and seen at most roadside monitors in the UK. It largely (but not entirely) reflects traffic patterns (see e.g. Figure 43). The greater importance of northwesterly, westerly and southwesterly winds almost certainly reflects the position and orientation of the adjacent B2026 (Figure 58), although superimposed onto this is a clear effect of long-range transport from the north / northwest. This is likely to include emissions from the M25 and London etc.. The lowest concentrations occur in the middle of the night when winds blow from the southeast or southwest.
- 5.9 The pattern in the 'weekday' panel shows the same diurnal profile, with higher concentrations during the day, and lower at night. This plot also shows the importance of weekdays when compared with weekends, with the latter associated with much lower concentrations. This relates to the typically lower traffic volumes at weekends, both locally and regionally. Again, there is a clear tendency for higher concentrations from the north and northwest, which includes the orientation of the adjacent road (Figure 58).
- 5.10 The 'season' panel appears to be affected by a number of isolated events, which can also be seen in the basic timeseries for NO_x (Figure 24). There is also evidence of higher concentrations in the winter months than in the summer, which is a fairly common feature for NO_x and NO₂.
- 5.11 The 'trend' panel describes the entire 5-year period. Again, it shows a clear tendency for higher concentrations from the north and west, as well as for higher concentrations during winter months. This seasonal pattern is observed across most sites in the UK. Higher concentrations were more evident at the start of the period than at the end. However, as explained further in Section 6, there was no strong overall downward trend in concentrations over this period. What Figure 56 does show, however, is a trend of diminishing importance of winter high episodes from the northwest. This might reflect a diminishing importance of emissions from long-range sources, although it is not possible to be certain of the cause.

- 5.12 The equivalent plot for NO₂ (Figure 57) shows a very similar pattern, with a few notable differences. The 'hour' panel shows a greater dependence on concentrations from the northwest, with less defined morning and evening peaks; and a slightly later evening signal. This is likely because NO₂ is largely a secondary pollutant which requires time to form from chemical reaction in the air. The difference between the NO_x and NO₂ plots may thus suggest a greater importance of more distant emissions sources rather than the adjacent B2026, including long-range transport from London etc.. All of the NO₂ plots also show slightly less emphasis on winds from due west to southwest. Again, this may reflect the slower formation time for NO₂, which slightly weakens the importance of the B2026 in comparison with emissions sources which are further away.

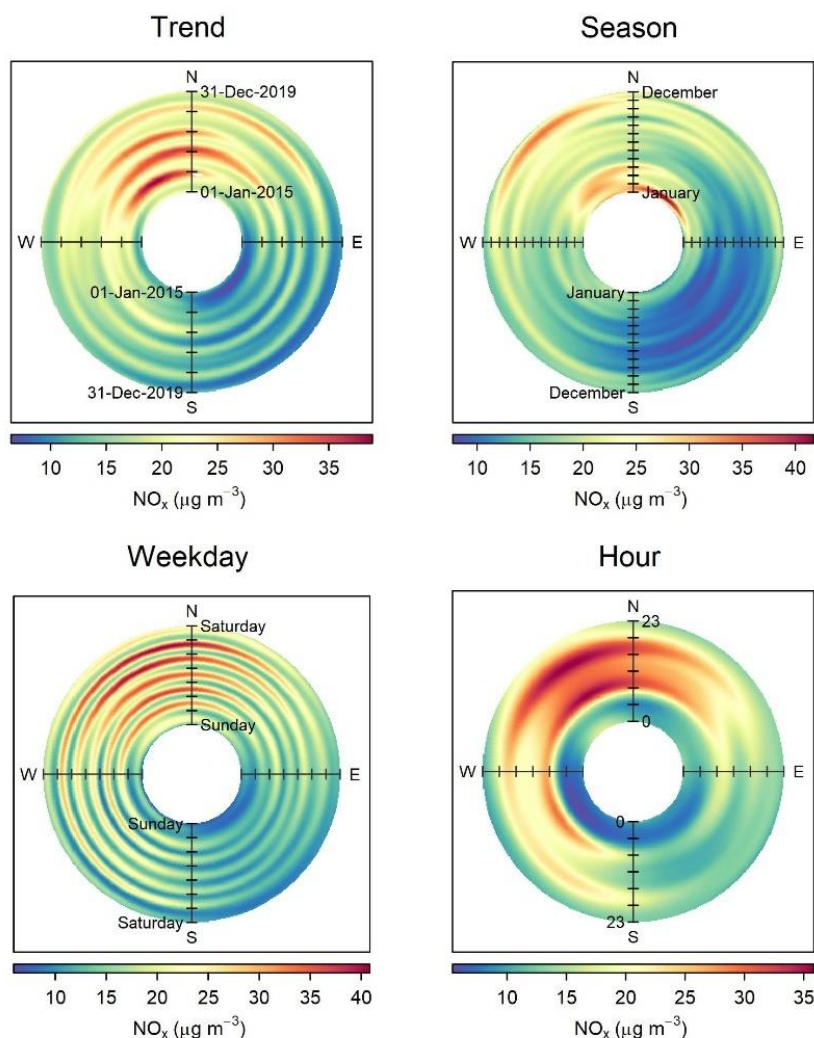


Figure 56: NO_x Polar Annulus Plots Showing Hourly, Weekday, Seasonal and Overall Trends

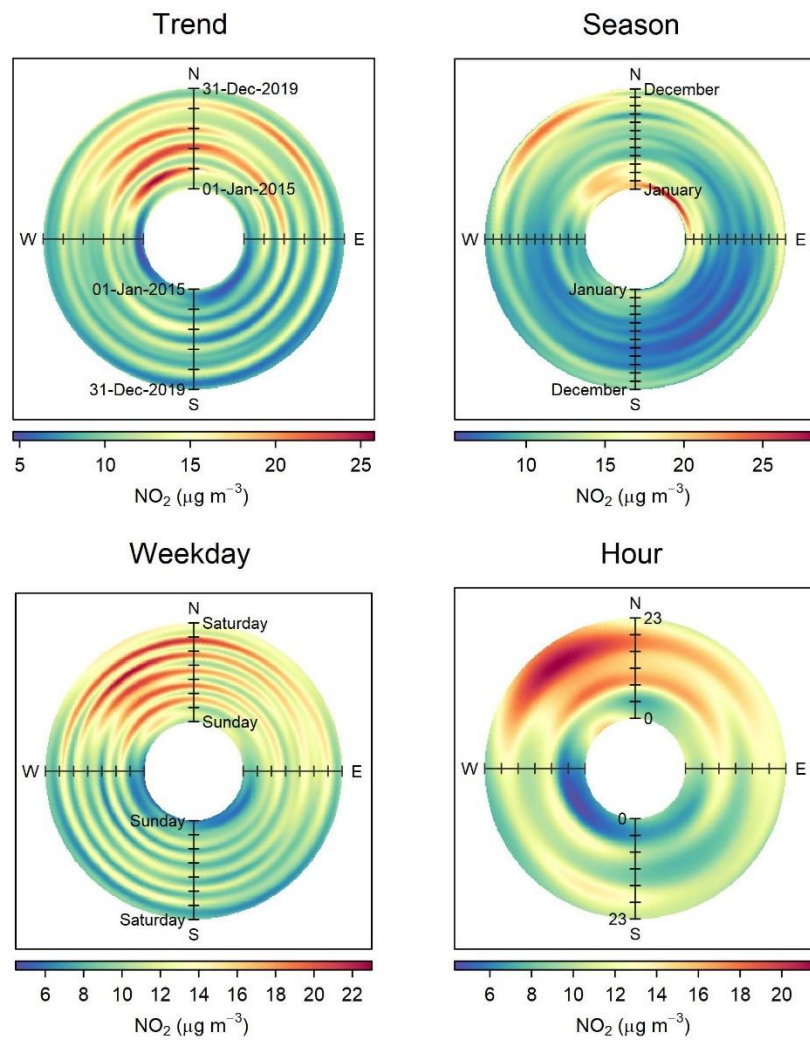


Figure 57: NO₂ Polar Annulus Plots Showing Hourly, Weekday, Seasonal and Overall Trends



Figure 58: Surrounding Environment of Kingstanding Automatic Monitor

Map Data ©2021 Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies

Polar Plots

- 5.13 Polar plots have been used to describe the bivariate dependence of each pollutant on wind direction and speed. The polar plots are shown in Figure 59 and Figure 60. Typically, nearby sources tend

to give rise to elevated concentrations at slow wind speeds, while distant sources are associated with elevated concentrations at higher wind speeds. Thus, the position of the 'hot-spots' in polar plots can indicate the location of important emissions sources.

- 5.14 Figure 59 shows that the highest NO_x concentrations occur when the wind is from the northwest through to north sector, and when wind speeds are less than 5 m/s. This suggests a nearby emissions source. While the B2026 lies to the west and north of the monitor, emissions from the B2026 cannot explain the elevated concentrations at low wind speeds from the northeast. Advice from the operators of Kingstanding Police Training Centre is that there are no significant local activities which would explain this pattern; although there is very occasional off-road vehicular activity in this area. The potential for differences in wind direction between the Meteorological Office site at Gatwick and the Kingstanding monitor can also not be discounted. Stronger winds are associated with elevated concentrations from the east, probably reflecting emissions from Crowborough and beyond. Elevated concentrations with higher wind speeds also come from the north, probably showing the effect of emissions from Greater London, the M25, and Sevenoaks.
- 5.15 The plot for NO₂ (Figure 60) is largely a reflection of that for NO_x, but the high concentrations in the northeast for NO_x extend to higher wind speeds than those for NO₂. This suggests that the emission source driving these high concentrations may be much further away than the police training centre; possibly beyond Crowborough.

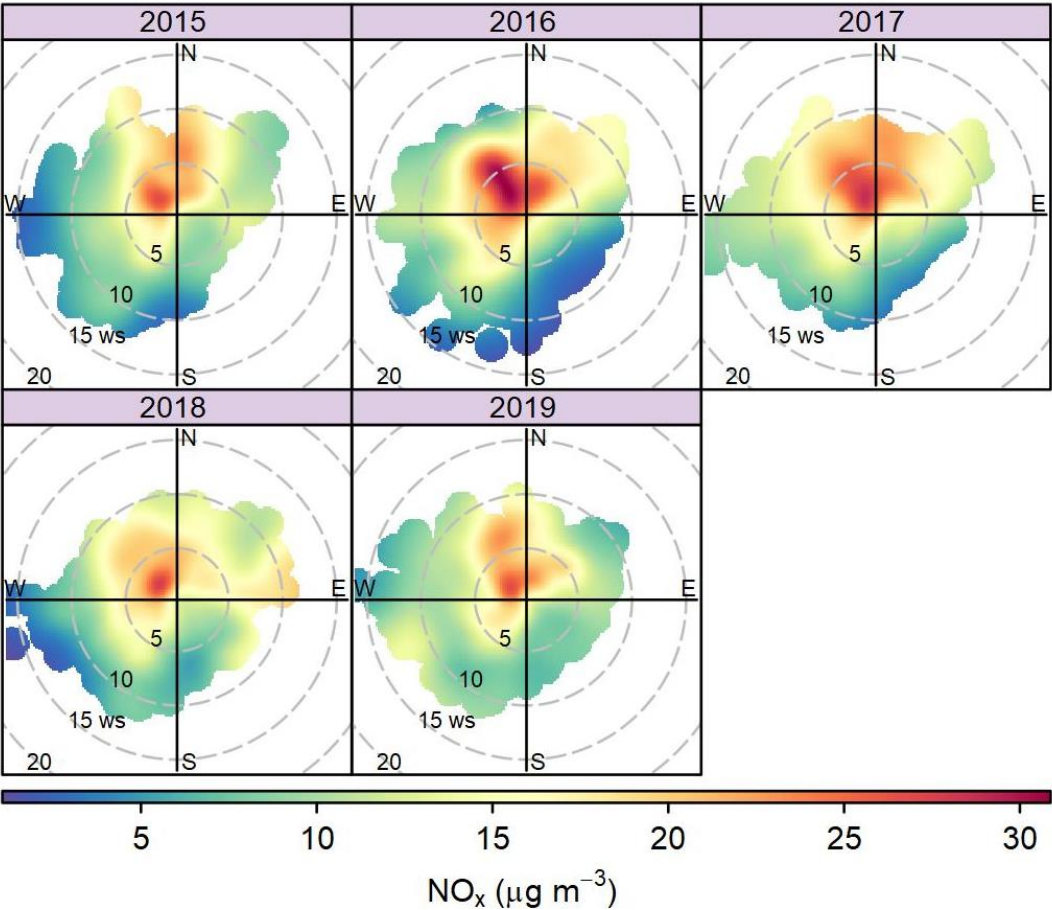


Figure 59: NO_x Polar Plots

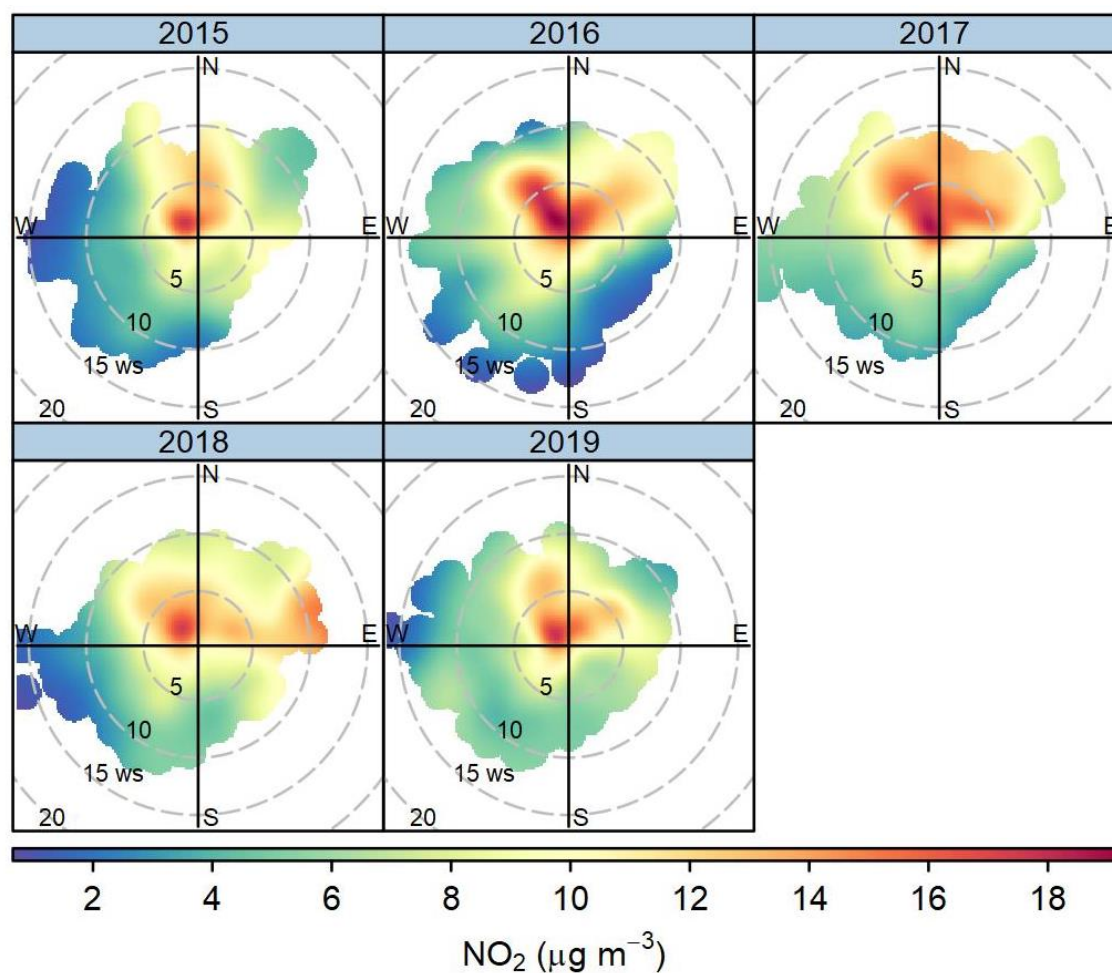


Figure 60: NO₂ Polar Plots

Partial Dependencies

- 5.16 Partial dependency analysis considers how each variable changes when all others are held at their mean values. It shows the relative strength of correlation between concentrations and different measured variables. This analysis uses machine learning based on Boosted Regression Trees (Carslaw and Taylor, 2009). It is termed ‘deweather analysis’ although the variables considered cover more than the effects of weather. The variables considered are provided in Table 18. Partial dependency plots for the automatic analyser, for NO_x and NO₂ are shown in Figure 61 and Figure 62, respectively.

Table 18: Variables Included in Deweather Analysis

Variable	Description
Air_Temp	Hourly ambient air temperature
cl	Hourly cloud cover index
Hour	The hour of the day, representing diurnal variation not accounted for in other variables

Variable	Description
RH	Hourly relative humidity
Trend	The variable representing the time-series trend
Volume	Volume of traffic on the B2026
wd	Hourly wind direction
Week	The week of the year, representing seasonal variation not accounted for in other variables
Weekday	The day of the week, representing weekday variation not accounted for in other variables
ws	Hourly wind speed

- 5.17 The most important predictive factor for NO_x concentrations is traffic volume (21.6% influence). This simply suggests that local road traffic has a strong effect on NO_x concentrations measured at the analyser. There is a broadly linear relationship between traffic volume and NO_x up to a flow of around 625 vehicles **per hour** (above which there are relatively few events to draw a reliable correlation). The derived relationship suggests that each 500 vehicles per hour on the B2026 gives rise to an hourly-mean increment to NO_x concentrations (i.e. over and above NO_x from all other sources) of around 22.5 µg/m³.
- 5.18 The next most important variable for NO_x is wind direction (associated with 17.2% of the variability in concentrations). As noted previously, winds from the north and west were associated with the highest NO_x concentrations, largely reflecting the position of the adjacent road and the contribution from long-range transport into the area. Air temperature and wind speed are also important variables, with concentrations reducing as each of these parameters increases¹². Hour of day and day of week are both important for reasons explained previously. The ‘trend’ panel shows the underlying pattern over time when all other variables are held constant. This is discussed further in Section 6.
- 5.19 Unlike for NO_x, traffic is not the most important factor for determining NO₂ concentrations. As noted above, this likely reflects that NO₂ is a secondary pollutant and so the immediate effects of a source as close as the B2026 are diminished. In other respects, the partial dependencies for NO₂ reflect those for NO_x in terms of the conclusions which can be drawn.

¹² winter conditions are typically associated with high pollutant concentrations owing to a low atmospheric boundary layer height and atmospheric stability which reduce the vertical dispersion of pollutants. Temperature can also be associated with seasonal emissions from combustion sources, such as domestic heating.

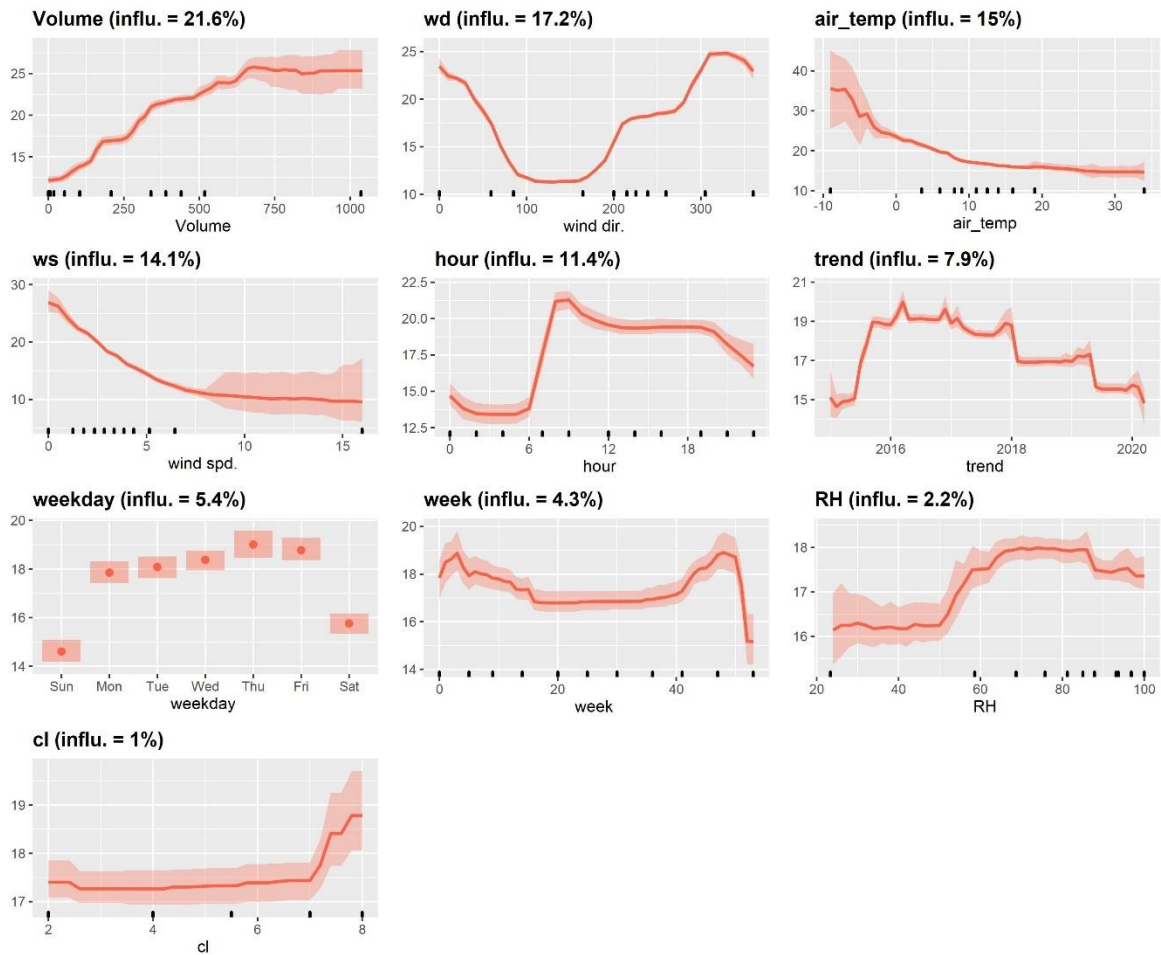


Figure 61: Partial Dependency Plot for NO_x

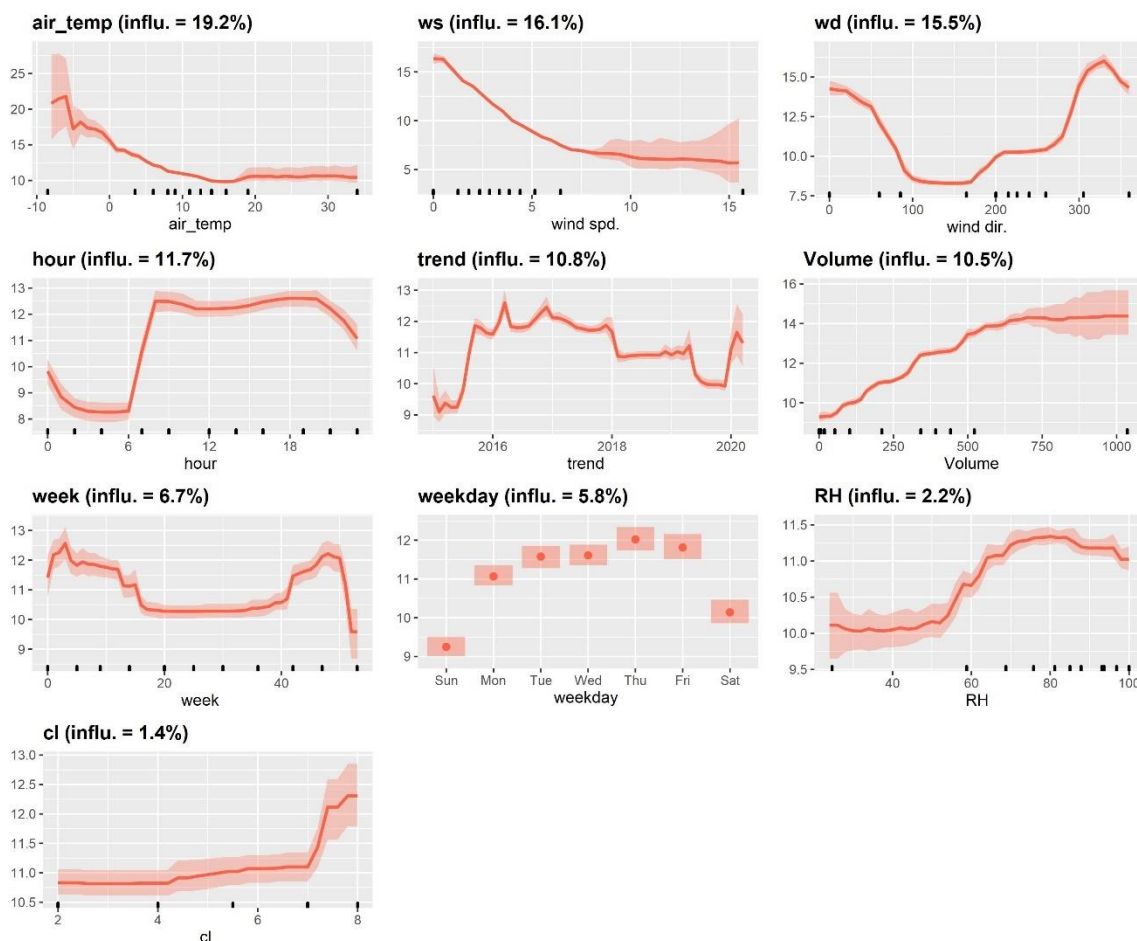


Figure 62: Partial Dependency Plot for NO₂

Patterns at the Diffusion Tube Sites

Observations from the Transects

NO₂

- 5.20 Trends over time are considered in Section 6. For simplicity, and improved signal stability, this section considers long-term average concentrations. Data annualisation and bias adjustment has been applied to calendar years and so the approach here has been to average several full calendar years of measurements. Poor data capture during 2018 at transect sites R1.7, R1.8 and R3.8 mean that the most consistent dataset is achieved by averaging the four calendar years 2015, 2016, 2017, and 2019¹³. Results along monitoring transects for each year separately, including 2018, are reported in Section 4. Figure 36 Figure 37 in Section 4 shows the same overall trend during each year, including 2018, and so omitting 2018 from the multi-year average here will not bias the analysis. The following discussion focuses on the spatial pattern in the 4-year means.

¹³ including 2018 within the multi-year average would cause there to be a different number of years in the average calculated for different sites, which would misrepresent the spatial patterns.

- 5.21 Figure 63 shows the 4-year mean NO₂ concentrations vs distance from the road along all four transects. Distance from road is shown on a logarithmic scale for added clarity. Transect 4 does not have a point at 200 m from the road and so the value used is the average of that measured at all background monitoring sites across the study area with a consistent dataset^{14,15}.
- 5.22 In order to focus on the road component of concentrations, the local background concentration has been subtracted from the total measurements in Figure 63¹⁶. This is a convenient way of isolating the local road contribution to NO₂, but in practice (and as is shown later) even these background values will have experienced a contribution from the road. This means that the calculated 'road-NO₂' will have been underestimated. Within 10 m of roads, the relative importance of this underestimation will be trivial, but at 100 m or more from roads, the relative effect will be much greater; thus underrepresenting the road component of concentrations.
- 5.23 To allow a more direct comparison of the rate of change vs distance at different sites, the calculated road-NO₂ has been expressed as a percentage of the value measured at 10 m along each transect. The results are shown in Figure 64. Figure 64 thus shows the *relative* rate of change in the influence of the road along each transect. The steepest reduction is along Transect 1, which runs to the west of the A22. The effect of the road at 1.7 m from the kerb on Transect 1 is more than 5 times that at 10 m the kerb. The next steepest rate of decline is along Transect 4, which runs to the northwest of the A26, where concentrations at 2 m from the kerb are 2.6 times those at 10 m. The shallowest curve is along Transect 3, where road-NO₂ at 1 m from the kerb was 1.7 times that at 10 m. The patterns shows steeper rates of decline for the two transects on the upwind side of the road in relation to the prevailing wind, but only close to the road. This is likely to be due to mixing of road emissions due to the fast-moving traffic affecting sites close to the road, even against the prevailing wind. Beyond this close-to-road zone, which extends only a few metres, the rates of decline become very similar for all transects.
- 5.24 As well as showing the shallowest rate of reduction, Transect 3 also shows an increase in concentrations between 100m and 200m. Section 4 shows that this pattern was repeated during most years with available measurements. While Figure 64 describes this increment as 'road-NO₂' it is unlikely to relate to emissions from road traffic and may be the effect of activities within the training centre or beyond; possibly the same source as is shown in the Kingstanding Polar Plots (Figure 60).

¹⁴ i.e. those listed in Paragraph 4.9 (T9, T26, T27, T30, T39, T41, T45, T46, T55, T63, T69, R2.7, R3.7, and R4.7).

¹⁵ Previous analyses of these data have used Site T18 to represent background for this transect, but in addition to not providing a consistent dataset, the slightly elevated values at Site 18 are thought to be influenced by proximity to Crowborough and thus less appropriate than the multi-site average.

¹⁶ For Transects 1 and 2 the background is taken to be the 4-year mean value measured at 200 m and 206 m respectively along each transect. For Transects 3 and 4, the 4-year mean value measured at all background sites with a consistent dataset has been used. This alternative approach was necessary for Transects 3 and 4 because Transect 3 appears not to reach background (i.e. concentrations measured 200 m from the road are consistently higher than those measured 100 m from the road) and because Transect 4 does not have a monitoring site 200 m from the road.

This thus provides further evidence of a potentially significant emission source to the east of Kingstanding.

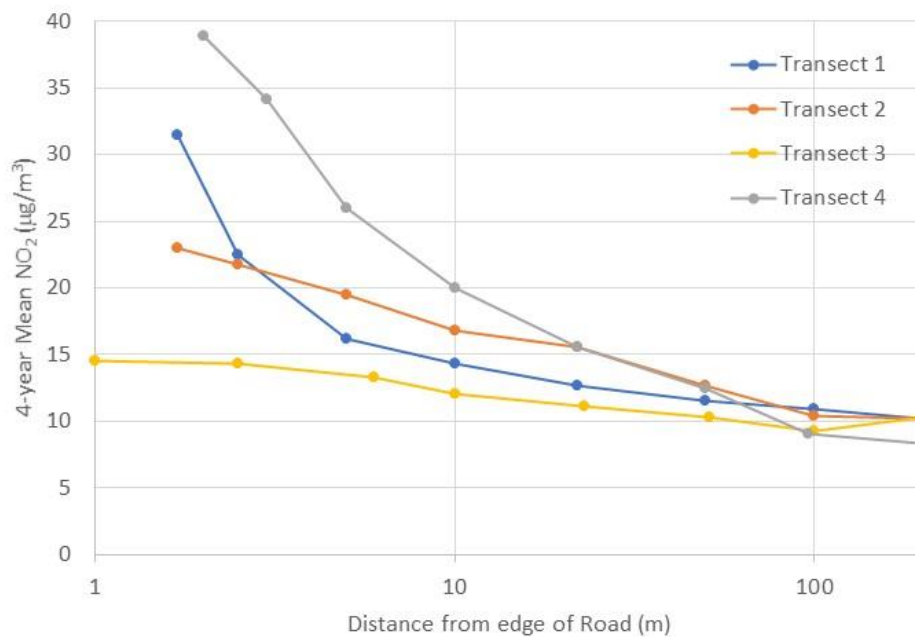


Figure 63: 4-Year Mean NO₂ vs Distance from Road along 4 Transects

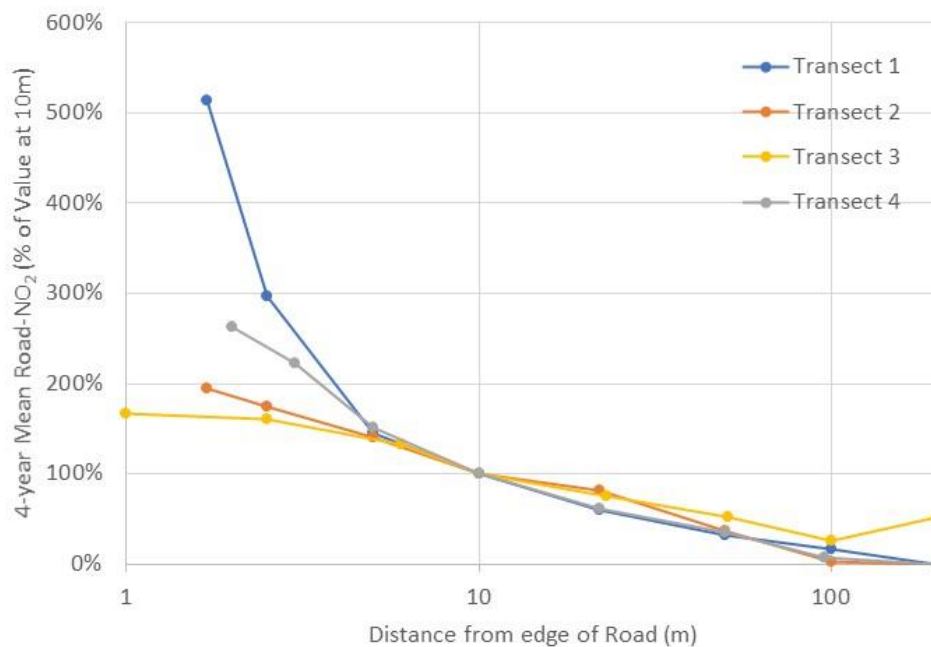


Figure 64: 4-Year Mean Road-NO₂ as a % of the Value 10 m from the Road

5.25 Defra provides a tool LAQM which predicts the rate at which annual mean NO₂ concentrations reduce with distance from a road¹⁷. This is based on an analysis of 6 monitoring transects by AQC

¹⁷ <https://laqm.defra.gov.uk/tools-monitoring-data/no2-falloff.html>

in 2008¹⁸. Figure 65 shows the same results as Figure 64, but superimposes the LAQM ‘fall-off’ with distance curve. The rate of reduction along Transects 2 and 3 is largely in alignment with the LAQM advice, but the rate of reduction along Transects 3 and 4 is much steeper in the first few metres than is typically assumed by local authorities for air quality Review and Assessment purposes. While it is convenient to suggest that this may reflect differences in the relative exposure to wind in urban vs rural settings, this suggestion is not entirely borne out by the data which underpin the LAQM advice, which include several open rural-type settings. More likely, the difference simply reflects more general variability when considering different locations. Differences will be the composite of multiple factors including exposure to wind, but also direction from the road, road orientation, traffic speed, and site-specific local-scale meteorology.

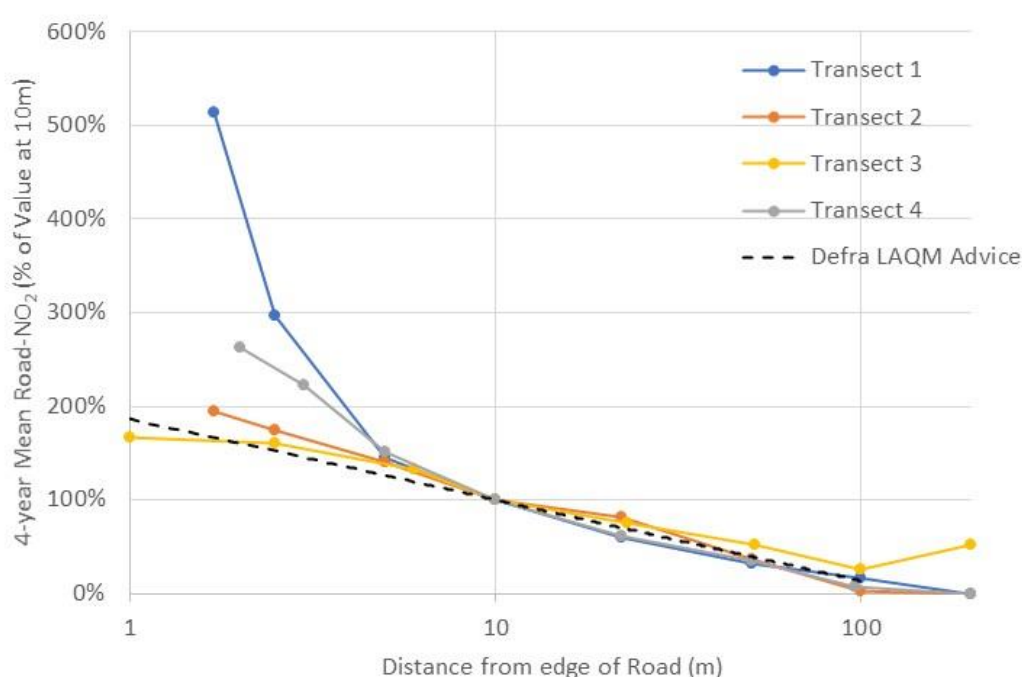


Figure 65: 4-Year Mean Road-NO₂ as a % of the Value 10 m from the Road – Also Showing Defra LAQM Curve

NO_x

- 5.26 In order to show the rate of reduction in NO_x concentrations, Defra’s NO_x from NO₂ calculator has been used¹⁹ to calculate the road-NO_x concentrations from the measured total and concurrent measured background¹⁶ NO₂ values. The results are shown in Figure 66. Defra does not provide a fall-off curve for NO_x concentrations, but AQC (2019) presented an idealised fall-off curve for NO_x based on measurements from 22 monitoring transects. This curve underpins the latest version of

¹⁸ <https://laqm.defra.gov.uk/documents/FallOffWithDistanceReptJuly08.pdf>

¹⁹ The approach is the same as described in Section 4 (the values are the same). V6.1 was used for measurements made in 2015 and 2016, V7.1 for the 2017 data, and V8.1 for the 2018 and 2019 data <https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html#NOxNO2calc>. For each site, the 4 separate values of road-NO_x (for the four separate years) were then averaged.

Highways England's Design Manual for Roads and Bridges (DMRB) model²⁰ and is shown for comparison in Figure 66. The rate of reduction along Transects 1 and 4 is steeper within 5 m of the road than assumed in the DMRB model, while that along Transects 3 and 4 is shallower. In practice, the idealised curve sits roughly through the centre of the Ashdown Forest measurements, showing that while there are clear differences between different settings, the local measurements conform to expectations on average. The precise shapes shown in Figure 66 might be used to more accurately configure local predictive models to account for site-specific dispersion conditions alongside the A22, A26, and B2026.

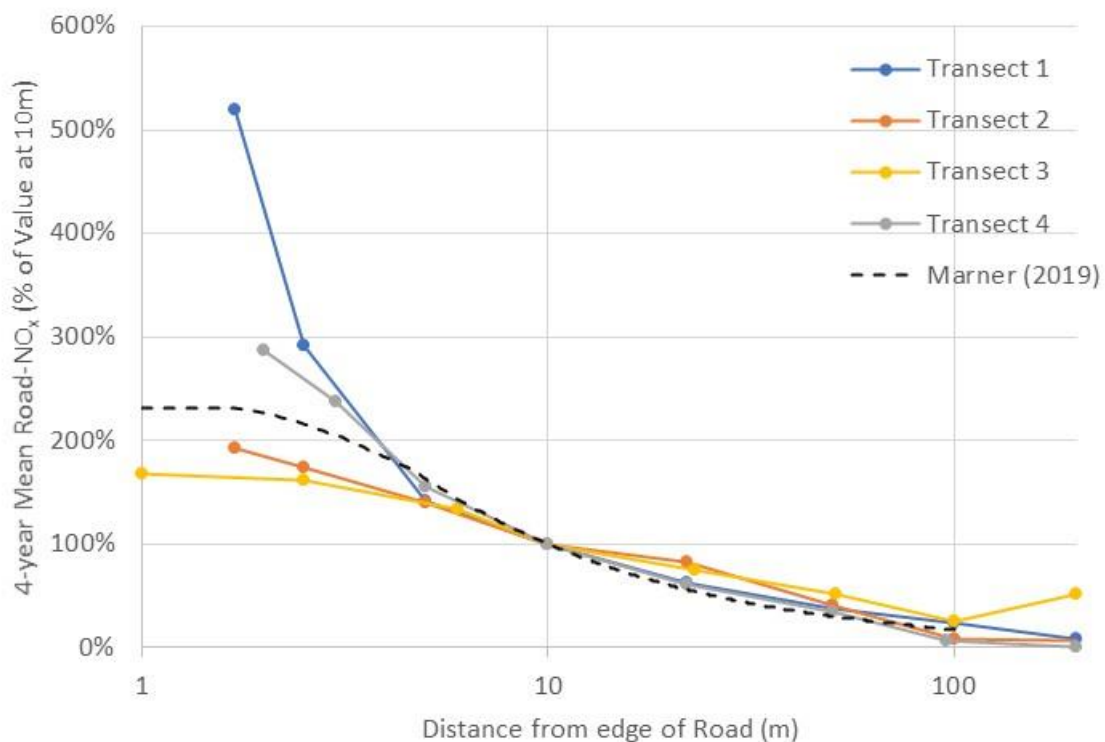


Figure 66: 4-Year Mean Road-NO_x as a % of the Value 10 m from the Road – Also Showing the Idealised Curve from AQC (2019)

Other Spatial Patterns

- 5.27 Maps showing the spatial distribution of measured NO₂ concentrations in each individual year are provided in Section 4. In order to provide greater focus on long-term spatial patterns, this section considers 5-year average (2015 to 2019 inclusive) concentrations²¹.

Background Concentrations

²⁰ This should not be confused with the 2003 or 2007 versions of this model which use a very different relationship with distance from road.

²¹ i.e. now including 2018 because there are sufficient data to make this the most sensible approach.

- 5.28 Figure 67 summarises the average NO₂ measurements at all the sites classified as background. These are all at least 96 m from roads²². These range from 5 µg/m³ to 11 µg/m³. Superficially, there appears to be a spatial pattern in the measured concentrations, with lower concentrations toward the northern and southern ends of the SAC, and higher concentrations running in an east-west band along the middle of the figure. In practice, however, it is quite likely that this is caused by proximity to roads, with a residual contribution from local roads included within the 'background' value (see Paragraph 5.22). There is also increased relative uncertainty of the measurements at very low concentrations²³.
- 5.29 Figure 68 plots the values from Figure 67 vs distance from the nearest road but, to provide a more direct comparison, excludes those background sites which miss a valid annual mean concentration in one or more years. Clearly each road referred to in the figure carries different volumes of traffic, but there nevertheless appears to be a trend of reducing concentrations as the distance increases from 100 m to 700 m from the nearest road. Qualitatively, such a pattern is not unexpected, and is predicted by the DMRB fall-off curve used in Figure 66. The precise slope of the line in Figure 68 is, however, clearly imprecise given the scatter in the data (i.e. the precise rate of reduction vs distance cannot be robustly determined from the plot).
- 5.30 On balance, it is considered that there is no strong spatial gradient NO₂ concentrations across Ashdown Forest that cannot be explained by proximity to roads.
- 5.31 'Background' is a term which air quality specialists frequently use to describe subtly different things. Most commonly, 'background' is taken to be the concentration without any influence of any 'local' sources, but in practice such a value is often impossible to define from measurements. Because the use of more measurements reduces overall uncertainty, it is considered most reliable to take the background NO₂ field across Ashdown Forest to be the average from all of the sites in Figure 67 with a full 5 year's of data and this is the approach which has been used throughout this analysis.

²² The precise distance of one of the '100 m' transect points is 96 m from the kerb, hence this odd number.

²³ For example, the contamination of a sample which added 2 µg/m³ to an individual month's measurement would have a much smaller relative effect at higher annual mean than at lower annual mean concentrations.

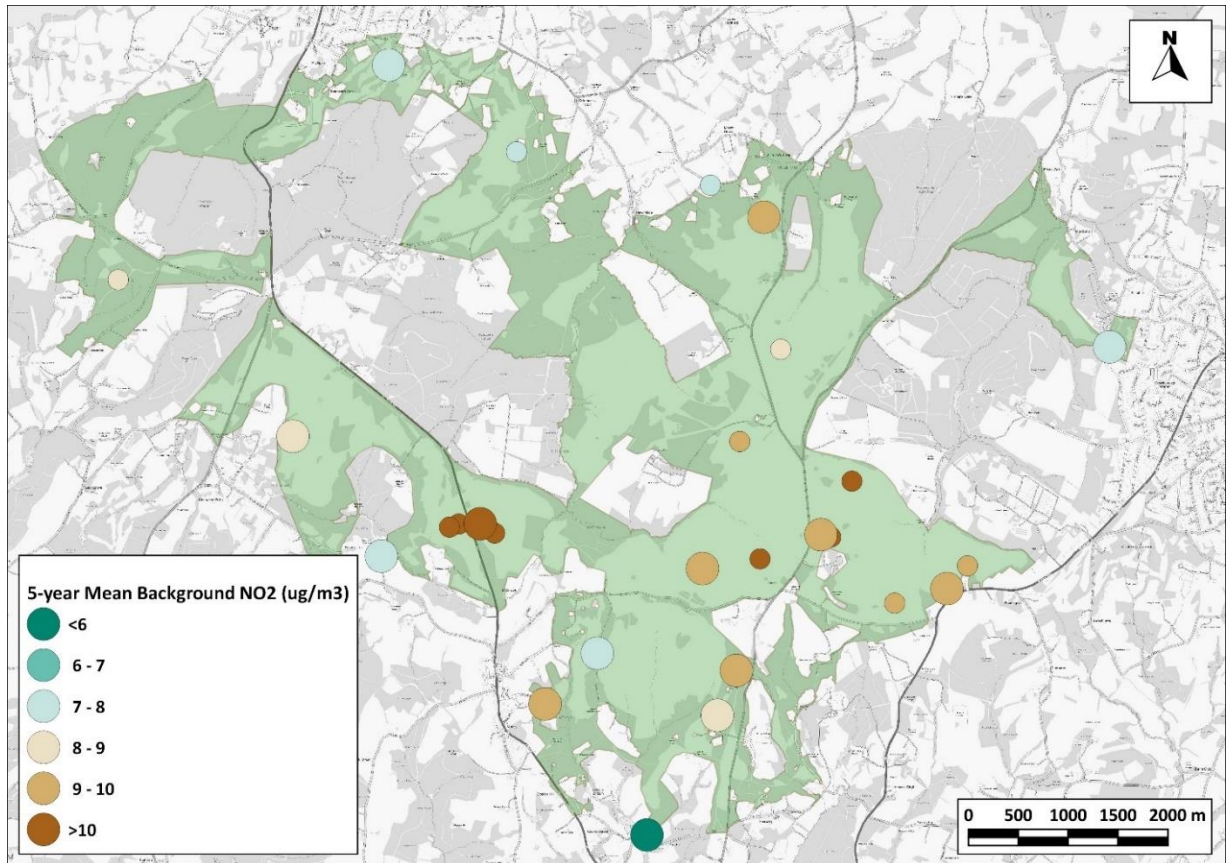


Figure 67: 5-Year Mean Total NO₂ at Sites at Least 96 m from Roads (large circles = 5-year's data, small circles = 4 year's data)

Map Data ©2021 Google Additional data sourced from third parties, including public sector information licensed under the Open Government Licence v1.0

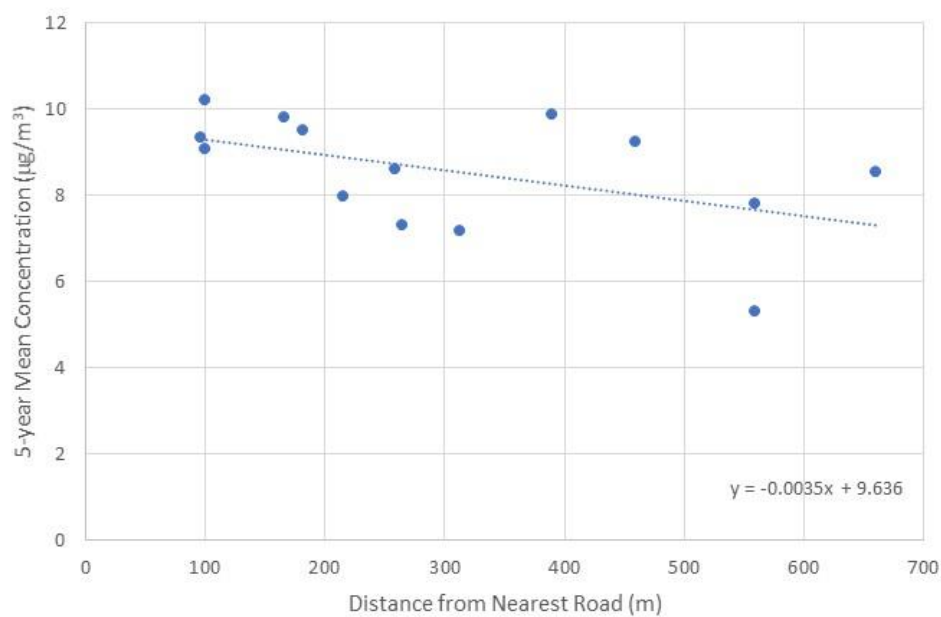


Figure 68: NO₂ Concentrations at Background Sites with 5 Year's Data vs Distance from Nearest Road

Roadside Concentrations

- 5.32 Figure 69 shows the 5-year average NO₂ concentrations measured at sites close to roads (within 96 m). These range from 10 µg/m³ alongside Chelwood Gate Road and Priory Road, to 39 µg/m³, alongside the A26. In practice, as well as being driven by differences in local emissions and dispersion characteristics, much of the variation shown in Figure 69 is simply a response to sampling at different distances from roads. In order to provide a more representative comparison, Figure 70 presents the local road component of NO₂²⁴, normalised to represent concentrations at 10 m from the nearest road. This has been done using the LAQM NO₂ curve shown in Figure 65²⁵ and is simply a method of removing much of the variability caused by sampling at different distances from the road. To further aid visual interpretation, each of the transects is represented in Figure 70 by a single value, which for the monitor closest to the road. The closest site to the road was used because it provides the clearest, and thus most certain, road signal, but in practice, all the points along a transect are very similar once normalised for distance (the spatial patterns in concentrations along each transect have already been described).
- 5.33 As explained in Paragraph 5.26, a fall-off curve has been produced more recently for NO_x. This is based on appreciably more measurements than the LAQM NO₂ curve and is considered to provide a more reliable approach, which also fits better with the local monitoring transects. The calculated road-NO_x values described previously have been averaged across the five years, and the resultant concentrations have then been normalised to a distance of 10 m from the road using the latest DMRB fall-off curve taken from AQC (2019)²⁶. These 5-year mean normalised road-NO_x results are set out in Figure 71.

²⁴ Derived by subtracting the average concentration measured at all background sites with 5 year's data¹⁴.

²⁵ The calculation is: $A = ((B)/(-0.5476 \cdot \ln(C) + 2.7171)) \cdot (-0.5476 \cdot \ln(10) + 2.7171)$. Where A is the road-NO₂ at 10 m from the road, and B is the road-NO₂ concentration measured at distance C from the road.

²⁶ The calculation, using Microsoft Excel nomenclature, is:

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

Where CB = road-NO_x 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-NO_x at distance A from the edge of the road.

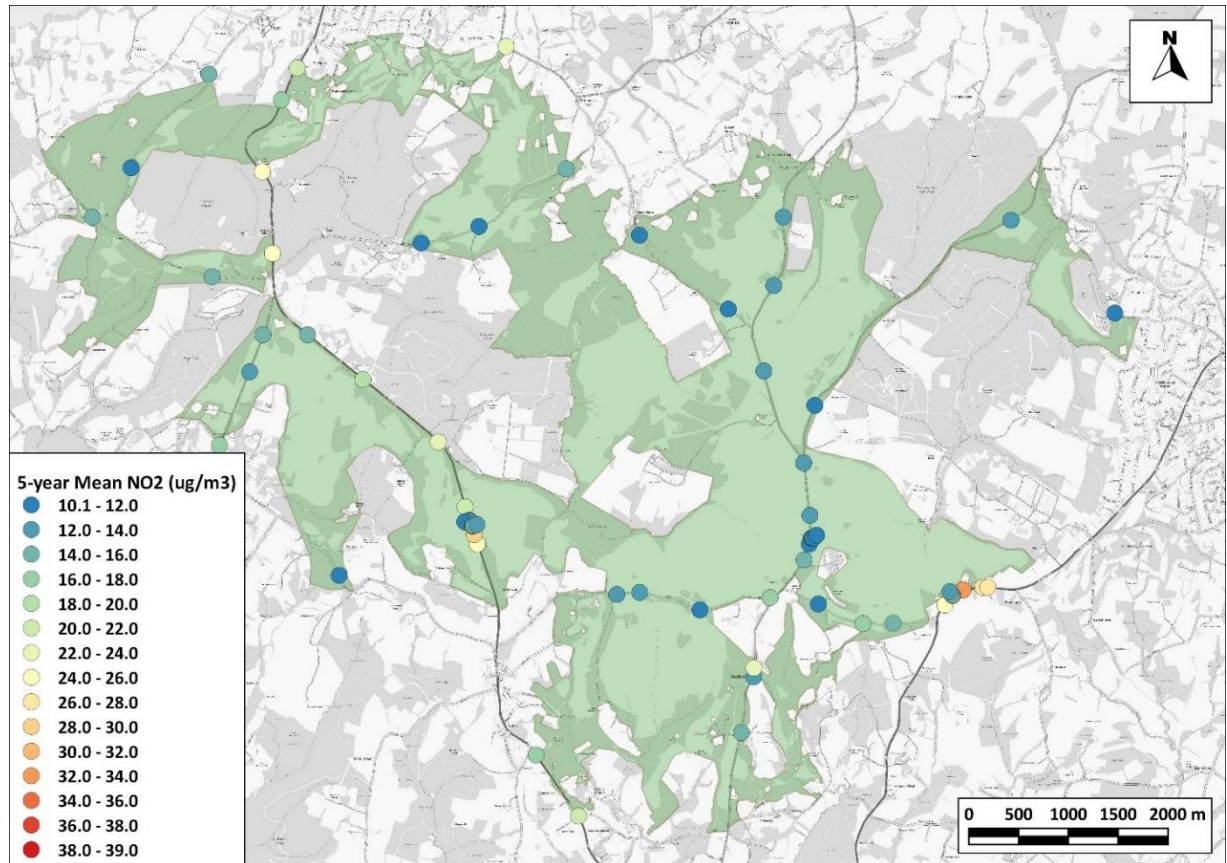


Figure 69: 5-Year Mean Total NO₂ at Sites Less than 96 m from Roads

Map Data ©2021 Google Additional data sourced from third parties, including public sector information licensed under the Open Government Licence v1.0

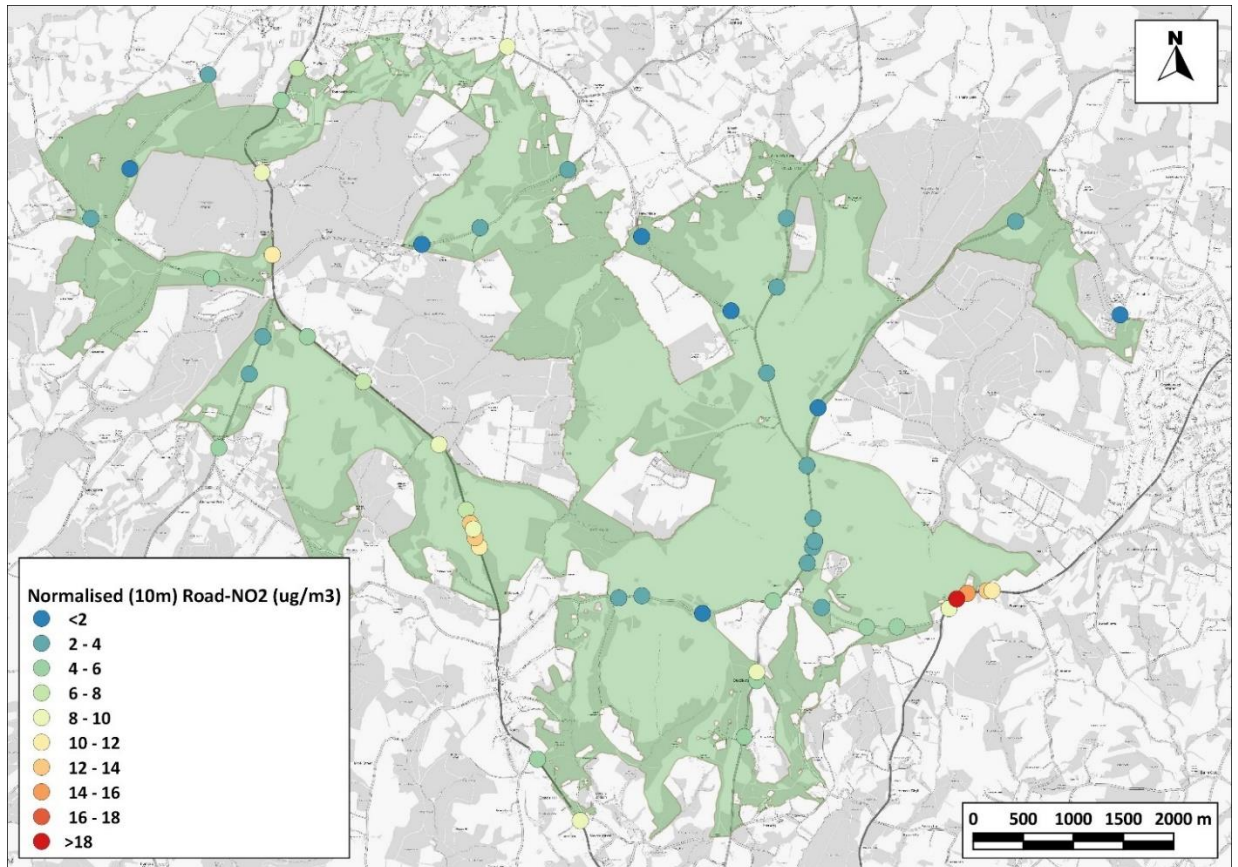


Figure 70: 5-Year Mean Road-NO₂ Normalised to 10 m from the Nearest Road

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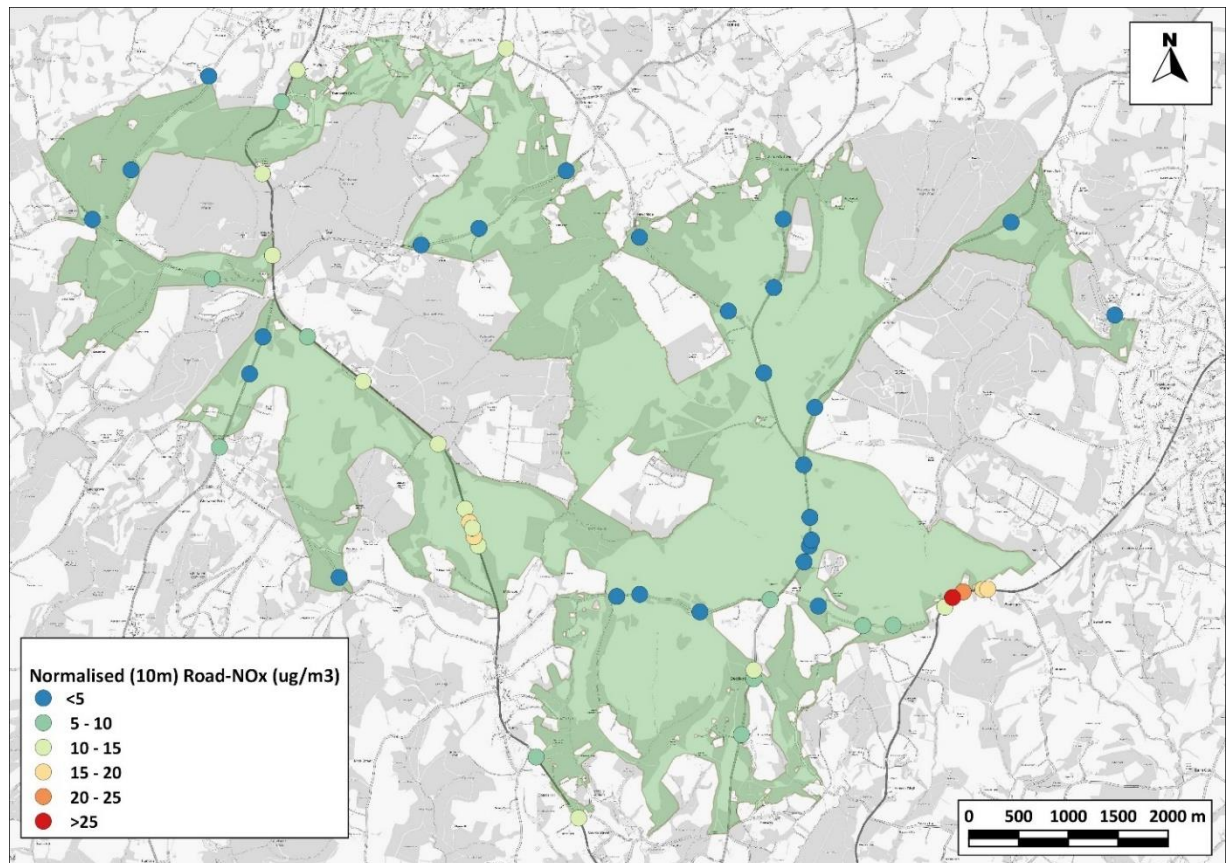


Figure 71: 5-Year Mean Road-NO_x Normalised to 10 m from the Nearest Road

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- 5.34 In practice, the spatial patterns shown in Figure 70 and Figure 71 are almost identical, and what differences there are, are most likely to reflect the greater precision available in the NO_x fall-off curve. The discussion below thus focuses on the spatial patterns in road-NO_x from Figure 71²⁷.
- 5.35 The highest distance-normalised concentrations were measured alongside the A26. Furthermore, of the various monitoring sites along the A26, the highest concentrations coincide with the position of the monitoring transect; with lower concentrations both to the northeast and the southwest. It is not possible to definitively explain this pattern, but it is reasonable to consider that the shape of the road at this point: with a broad curve, changing driver-visibility and changing speed restrictions, might have caused locally-elevated emissions due to slowing and then accelerating. This, in turn, would cause what was observed, with higher concentrations in one place than elsewhere alongside the same road.
- 5.36 The next highest distance-normalised concentrations were along the A22. Interestingly, the A22 is associated with a wide range of different distance-normalised concentrations, ranging from 6 µg/m³

²⁷ In practice, there is added uncertainty in the NO_x values themselves, introduced by Defra's NO_x from NO₂ calculator and the values of primary NO₂ embedded within it. However, for this discussion of spatial patterns, the NO_x data are considered to be most representative.

to 20 $\mu\text{g}/\text{m}^3$. Much of this measured variation is potentially explicable by the siting of each monitor. For example both of the sites which recorded concentrations $>15 \mu\text{g}/\text{m}^3$ (20²⁸ $\mu\text{g}/\text{m}^3$ and 18 $\mu\text{g}/\text{m}^3$) are alongside the uphill lane of the A22, shortly after the speed restriction increases from 40 mph to 60 mph. While most emissions models do not represent variability caused by acceleration and gradients very well, it is unsurprising that these features affected emissions and thus concentrations. The lowest distance-normalised concentration measured along the A22 was outside of the Lama Park, which is a particularly flat and straight section of road, with good visibility and little reason for regular speed changes. Again, this detail would not usually be shown through modelling, but it nevertheless conforms with expectation. The dense trees which surround some parts of the A22 and thus impede dispersion (acting a bit like a canyon) do appear to have had some effect on concentrations, with most of the concentrations at heavily-wooded roadside sites being in the 10 $\mu\text{g}/\text{m}^3$ to 15 $\mu\text{g}/\text{m}^3$ band, but this ‘canyon effect’ seems to be less significant than the gradient and acceleration features which have been highlighted.

- 5.37 It is not possible, within this study, to identify which vehicles emitted more NO_x on roads with gradients. However, given the scale of the increased emissions on the A22, and that HDVs only make up ca. 8% of the total traffic on this road (Table 16 and Table 17), it seems likely that cars and vans have experienced some elevated uphill emissions.
- 5.38 Another point of note in Figure 70 is that distance-normalised concentrations alongside both New Road, and the B2026 south of New Road, tend to be higher than those alongside the A275. This corresponds with the ATC data which showed lower total traffic flows on the A275.
- 5.39 Sites alongside many of the minor roads all fall within the 0 – 5 $\mu\text{g}/\text{m}^3$ band. Within this grouping there is appreciable residual gradation, as well as some consistent spatial patterns. To demonstrate this, Figure 72 shows only those sites with a distance-normalised road-NO_x value $< 5 \mu\text{g}/\text{m}^3$ and uses a more refined colour scale. One of the features highlighted in Figure 72 is the relationship with prevailing wind direction (e.g. Figure 54). For example, the sites alongside the B2026 at Kingstanding which recorded concentrations greater than 4 $\mu\text{g}/\text{m}^3$ are to the east of the road, while the site which recorded a concentration less than 3 $\mu\text{g}/\text{m}^3$ is to the west.
- 5.40 There are also spatial patterns in Figure 72 which are less straightforward to interpret. For example, all three sites alongside Crowborough Road measured concentrations between 2.4 $\mu\text{g}/\text{m}^3$ and 3.3 $\mu\text{g}/\text{m}^3$, which is appreciably lower than the sites beside Chuck Hatch Road (between 3.8 $\mu\text{g}/\text{m}^3$ and 4.4 $\mu\text{g}/\text{m}^3$). The total AADT flows on Chuck Hatch Road were slightly lower than those on Crowborough Road, but Chuck Hatch Road has a number of differentiating features which may have caused the greater road-NO_x per vehicle, including road orientation and fleet composition.
- 5.41 The example of Priory Road, which recorded some of the highest and also lowest concentrations shown in Figure 72, is potentially more straightforward to understand. The high value at the southern end of Priory Road is explicable due to its proximity to the junction with Hindleap Lane, but the

²⁸ The precise value is 19.95 $\mu\text{g}/\text{m}^3$ which is why it shows in the 15-20 $\mu\text{g}/\text{m}^3$ band.

comparison between the other two sites is interesting, since one (measuring a concentration of $1.6 \mu\text{g}/\text{m}^3$) is alongside a straight and fairly flat section of road, while the other (measuring $4.7 \mu\text{g}/\text{m}^3$) is just after a blind bend on a steep hill. This, again, highlights the significant spatial variability in traffic emissions which is not well represented by models.

- 5.42 Similar patterns are evident along, for example, Colemans Hatch Road, where the normalised road-NO_x in the dense wooded area on the eastern end of the road (at a site which is also alongside the uphill lane) is approximately double that at the two sites to the east, where the road is more open and the gradients alongside the monitors are less pronounced.
- 5.43 An important point to note is that all of the concentrations described in this section are values of distance-normalised road-NO_x, which is an artificially constructed metric intended to allow inter-site comparisons. These values should not be compared directly against the critical level, which applies to the total NO_x concentration and to conditions closer than 10 m from roads. It should also be recognised that the discussion presented here is speculative and that many factors, including differences in the rates of NO_x reduction with distance from roads, might contribute to, or explain, some of the patterns observed. It is nevertheless valuable to use the empirical data in this way without recourse to emissions models which are typically underpinned by more extensive chains of assumptions²⁹. It is particularly valuable to carry out an analysis such as this with a monitoring network that has such a fine spatial resolution.

²⁹ As such, while the analysis of distance-normalised concentrations presented in this subsection is described as speculative, it is no less certain than the results from dispersion modelling, and the conclusions are complementary to those from a modelling study. Measurements which are not distance-normalised are more certain than model predictions.

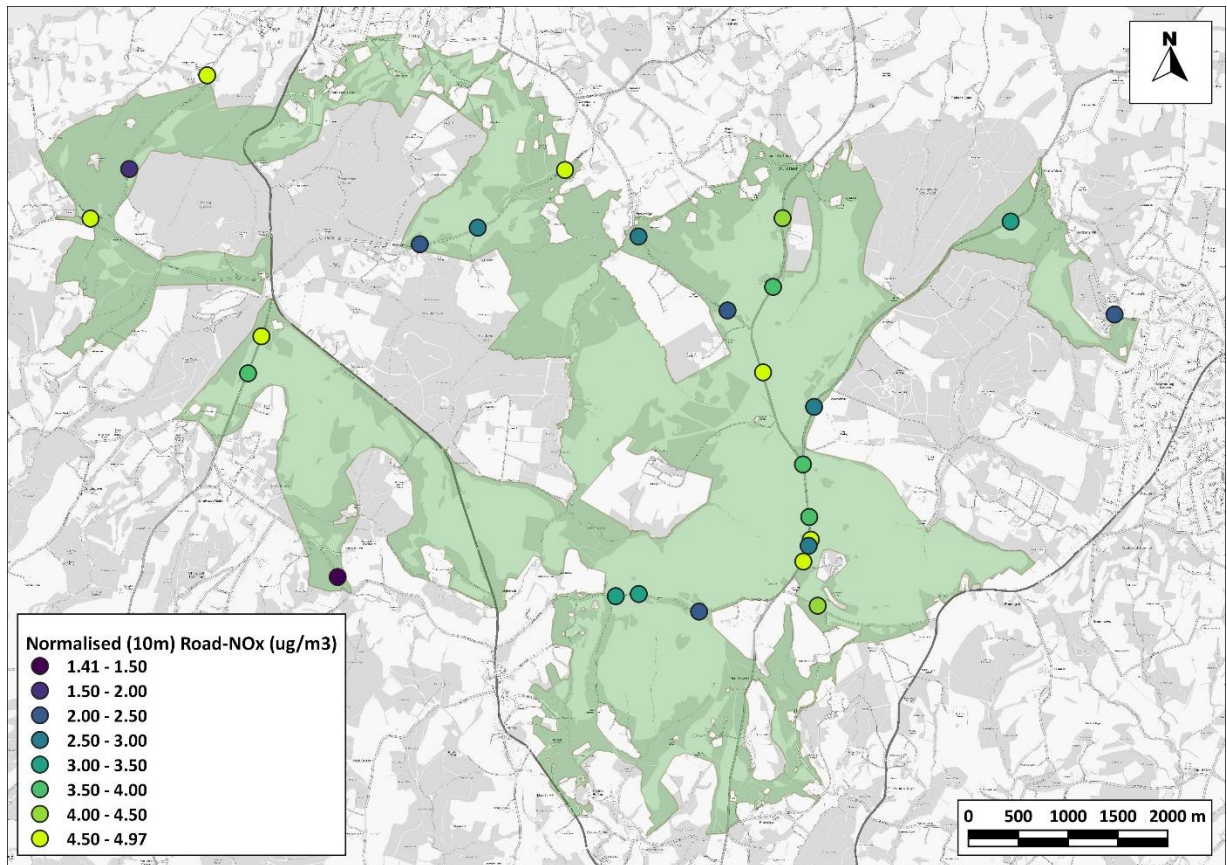


**Figure 72: 5-Year Mean Road-NO_x Normalised to 10 m from the Nearest Road – Only
Showing Sites < 5 µg/m³**

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NH₃ (NH_x)

Observations from the Kingstanding Automatic Analyser

- 5.44 As explained in Section 4, the Kingstanding monitor over-read NH₃ even when compared with the sum of NH₃ and pNH₄⁺ measured by the DELTA system. However, this over-read appears to be systematic and thus, at least on a monthly-basis, consistent over time. There is thus value in analysing the high time-resolution NH_x measurements to better understand patterns and their causes.

Pollution Roses

- 5.45 The overall contribution of different wind sectors to annual mean NH_x concentrations at the Kingstanding site is summarised in Figure 73. As with the equivalent plots for NO_x (Figure 54 and Figure 55), the length of each 'petal' of the rose shows the relative contribution that that wind direction

made to the annual mean concentration, while the colour shows the distribution of hourly-mean concentrations from that wind direction.

- 5.46 Because the overall distribution is driven principally by wind frequency, the plot for NH_x is similar to those for NO_x and NO₂. There are, however, some important differences. In particular, winds from the northeast are more important for NH_x than for NO_x (compare Figure 73 with Figure 54, noting that the ‘%’ scales on the two plots are different). In addition, winds from the southwest are slightly less important for NH_x than for NO_x. This is likely to reflect known differences in the spatial distribution of different emissions sources for NO_x and NH_x (e.g. urban vs rural in UK and continental Europe); as well as typically different resident times in ambient air.

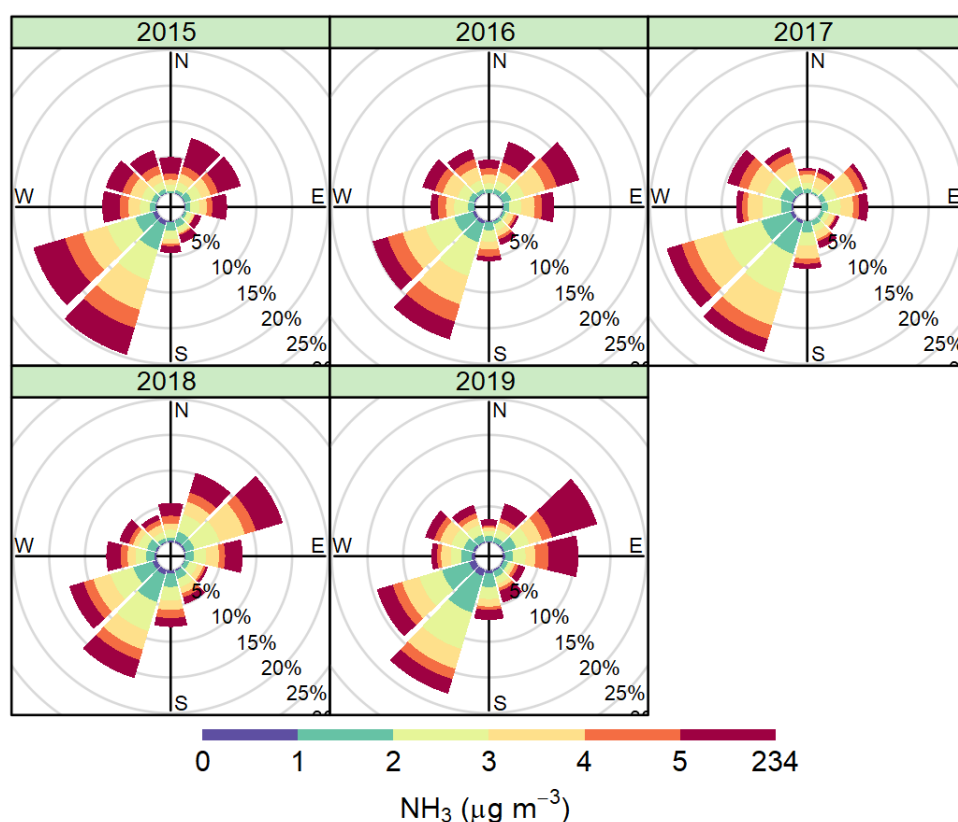


Figure 73: Pollution Rose Plots for NH_x³⁰

Polar Annulus

- 5.47 As with NO_x, in order to better understand the ambient concentrations associated with each wind direction, polar annulus plots (Figure 74) have been used. These show the dependence of concentrations on the overall annual trend and the seasonal, weekly and hourly variation.
- 5.48 The ‘hour’ panel in Figure 74 shows a clear prevalence of higher concentrations from the northeast, with these concentrations occurring throughout the day. As shown in Figure 58, some of this

³⁰ As explained in Section 2 the instrument aims to measure NH₃, but there may be cross-contamination with pNH₄⁺. The different use of NH₃ on individual panels and NH_x in the caption is not important.

corresponds with the alignment of the B2026, but comparing Figure 74 with Figure 56 for NO_x, suggests the importance of another source from the northeast, principally during the daytime. Combustion plant which uses catalytic control to reduce NO_x emissions can give rise to significant NH₃ emissions³¹, but long-range transport of pNH₄⁺ might also explain the observed pattern; which would indicate significant pNH₄⁺ contamination of the NH₃ measurement by this instrument. It is also possible that there is an agricultural source to the northeast, or perhaps more likely that the known spring episodes due to import of NH₃ from Europe (in particular the Netherlands) are having a significant effect on annual concentrations (this is supported by the subsequent polar plots).

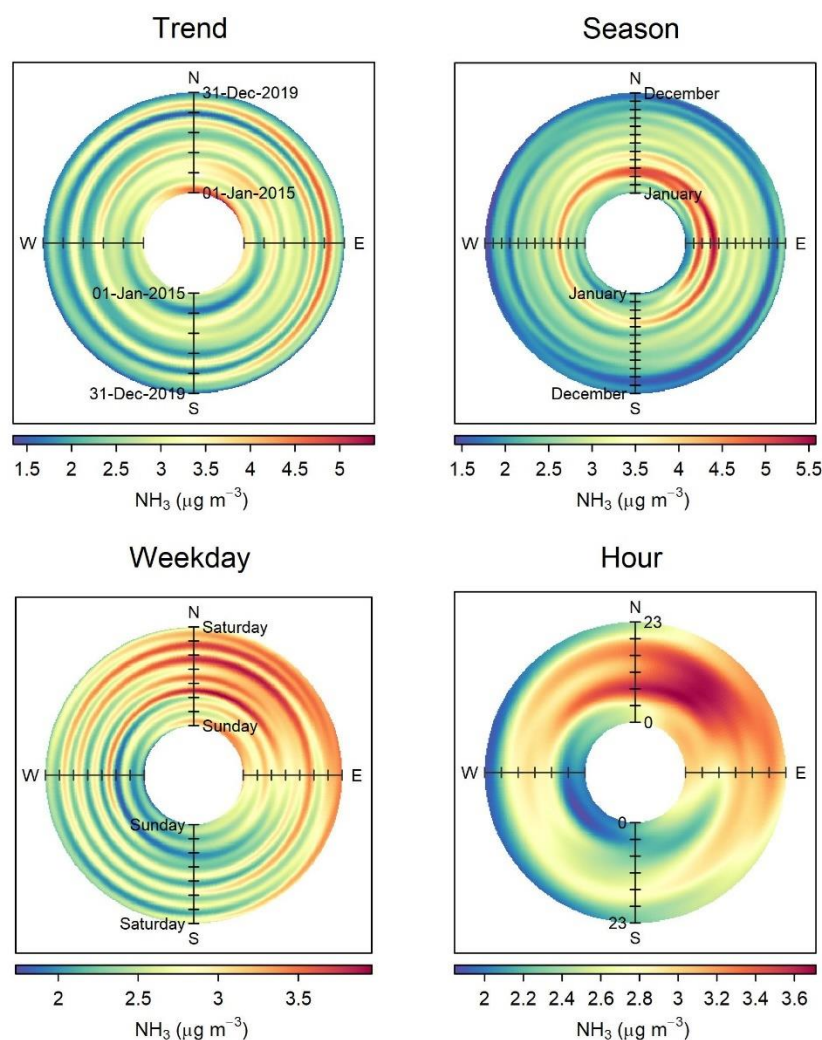


Figure 74: NH_x Polar Annulus Plots Showing Hourly, Weekday, Seasonal and Overall Trends³⁰

5.49 Despite the importance of the northeast direction, there is also a clear signal from the northwest, with a distinct diurnal profile characteristic of that of NO_x and of traffic volumes. This is highly likely

³¹ As explained previously, site managers of Kingstanding training ground have explained that there are no significant on-site emissions, although it remains possible that some plant might occasionally operate on site. There might also be larger plant and/or agricultural sources further afield affecting concentrations.

to reflect the influence of road traffic on the B2026. Behind these peak events is an underlying pattern of higher concentrations during the day, which likely reflects the fact that biogenic NH_3 emissions occur mostly during the daytime.

- 5.50 The 'weekday' panel also show the importance of winds from the northwest through to east. Of note is that weekends are associated with lower concentrations with westerly winds (reflecting the influence of road traffic) but with higher concentrations for easterly winds (likely reflecting non-transport emissions sources).
- 5.51 The 'season' panel for NH_x shows that the highest concentrations from all sectors occurred during early spring. This reflects a well-understood pattern for both NH_3 and pNH_4^+ , related to cycles of temperature, biological activity, and in particular farming practices across Europe. The trend panel shows the influence of each spring, but also highlights individual events at the start of 2015 and in spring 2019.

Polar Plots

- 5.52 The polar plots for NH_x (Figure 75) are possibly the most interesting of those presented in this subsection, particularly when compared with equivalent plots for NO_x (Figure 59). In particular, the high concentrations from the northeast and east are all seen here to be associated with relatively high wind speeds. This suggests that the emission source is some distance away and thus unlikely to be a response to local biogenic emissions or to activities within the Kingstanding compound. This, again, suggests that the instrument may have measured not solely NH_3 , but also a component of pNH_4^+ ; meaning that concentrations may be driven not only by UK but also European NH_3 emissions. By contrast, the highest concentrations from the west, particularly during 2018 and 2019, mostly coincide with slower wind speeds, suggesting very local emissions, such as from the adjacent B2026. Westerly winds did, however bring elevated concentrations at higher wind speeds as well, particularly during 2015 and 2016, suggesting more distant emissions, including the long-range transport of pNH_4^+ .

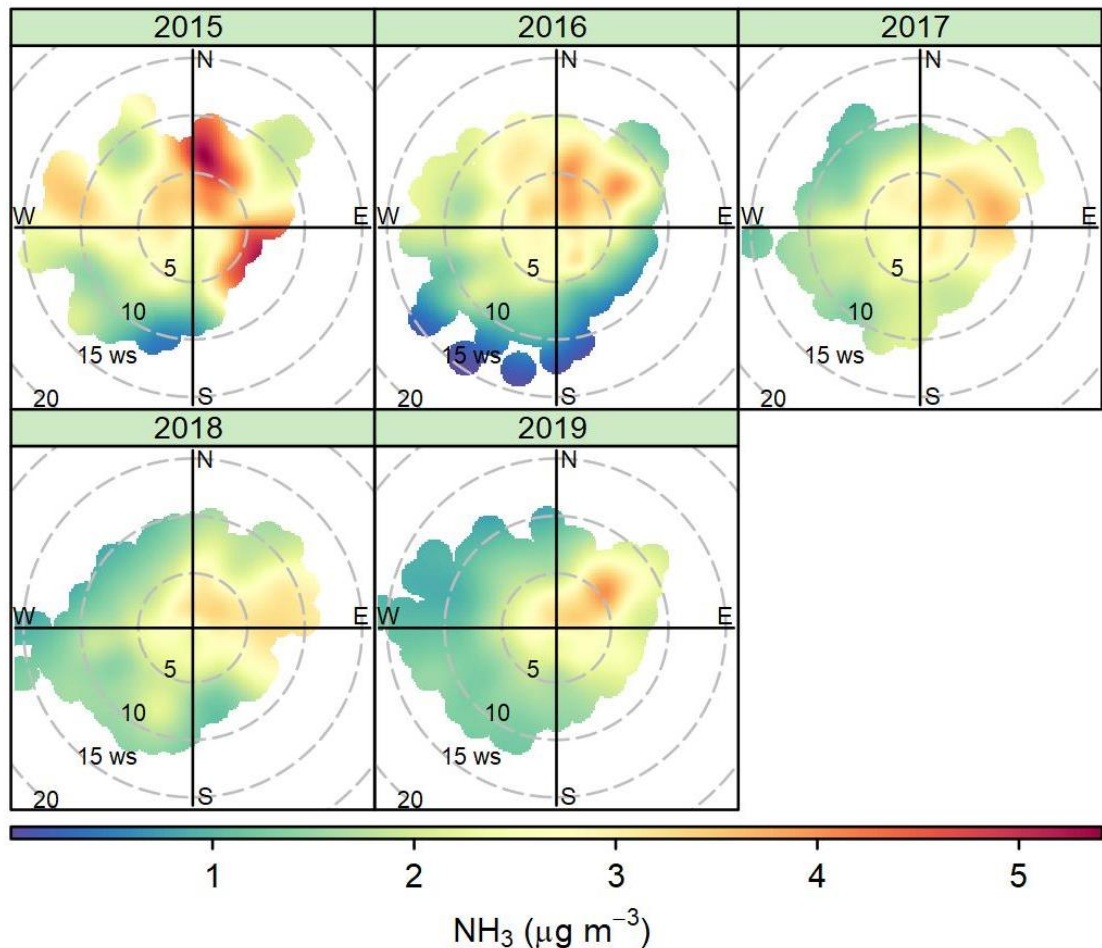


Figure 75: NH_x Polar Plots³⁰

Partial Dependencies

- 5.53 Partial dependency plots for NH_x are shown in Figure 76. Interestingly, the strongest individual influence on NH_x is the underlying trend over time, showing a distinct downward pattern. Trends over time are discussed in Section 6. The influence of wind speed and week of the year reflect well-understood relationships (wind speed increases mixing, and biogenic emissions occur during principally during spring). Traffic volume on the B2026 accounts for 7.5% of the total measured concentration at the monitor, with each 500 vehicles per hour being associated with an increment to hourly NH_x concentrations of approximately 3 µg/m³.
- 5.54 When compared with the same analysis for NO_x (Paragraph 5.17) this suggests a traffic-generated NH₃ to traffic-generated NO_x ratio of approximately 0.13 µg/m³ of NH_x for each 1 µg/m³ of NO_x. It should, however, be recognised that the absolute NH_x concentrations are likely to have been overstated by the instrument and so the actual ratio of NH₃ to NO_x emissions from road traffic at this site are likely to have been lower than 0.13:1.

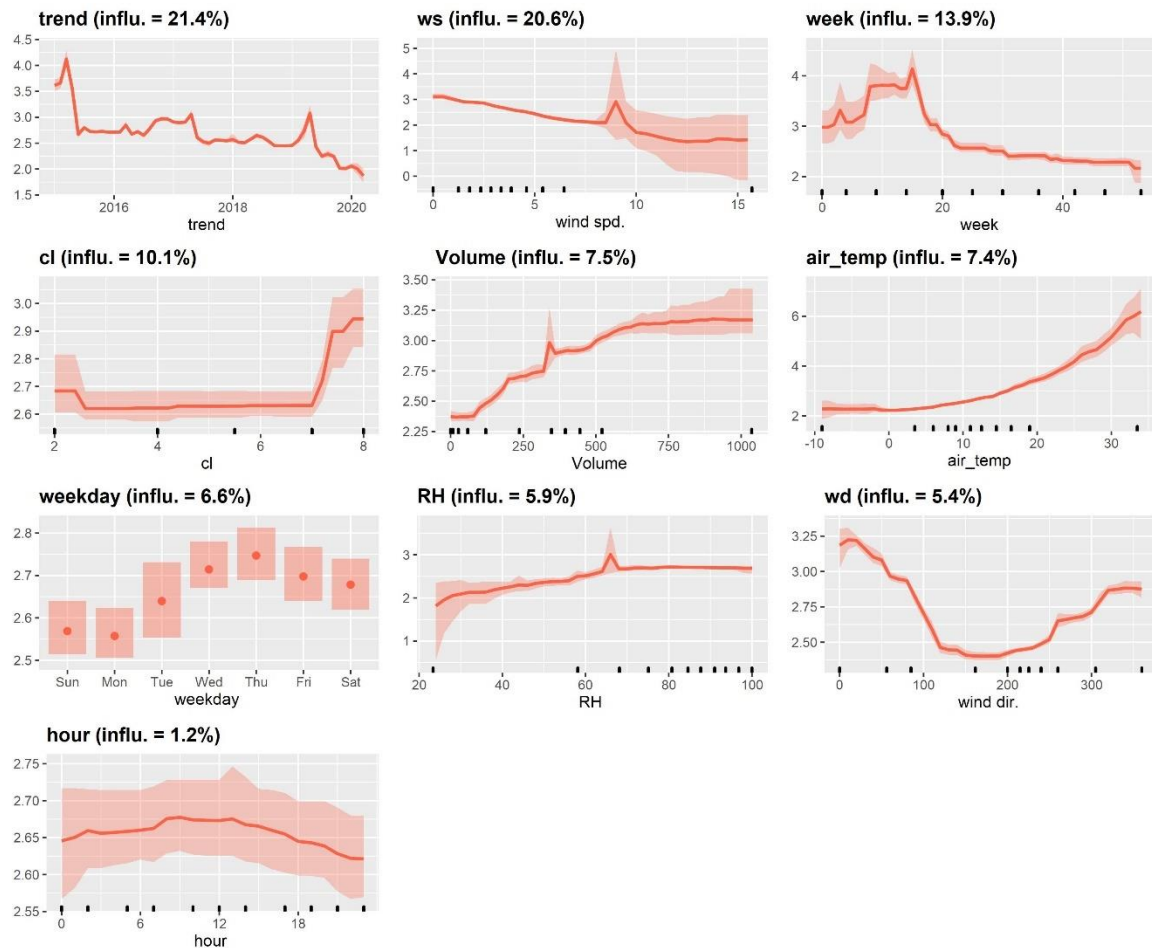


Figure 76: Partial Dependency Plot for NH_x

Patterns at the ALPHA and DELTA Sites

Observations from the Transects

- 5.55 Figure 77 shows the 5-year mean NH_3 concentrations measured using ALPHA samplers vs distance from the road along all three NH_3 transects³². Using the same approach as for NO_2 and NO_x , distance from road is shown on a logarithmic scale for added clarity. As with NO_2 and NO_x , concentrations increase with proximity to the road, reflecting the influence of traffic emissions on ambient concentrations.
- 5.56 The overall shape of the line for Transect 1 in Figure 77 is quite different to the other two lines. Furthermore, the transects for individual years (Section 4) show that these patterns are consistent year-on-year. Transect 1 ran through dense and tall gorse and bracken, meaning that the

³² Only data from the ALPHA samplers are used to ensure consistency along each transect. Multi-year averages are presented for the reasons explained for NO_2 in Paragraph 5.20. Good data capture was achieved in all five full calendar years and so five year-means are used.

instruments between 2.5 m and 25 m from the road were occasionally lower than the vegetation which surrounded them. This may have contributed to the unusual shape shown by this transect.

- 5.57 Figure 78 shows the rate of reduction in the local road increment of NH_3 vs distance from the road following the same approach described in Paragraph 5.22 for NO_2 . Also shown is the ‘fall-off’ curve for NO_x from the latest DMRB model, which is described in Paragraph 5.26. It is clear that the rate of reduction in road- NH_3 along Transect 1 is considerably steeper within a few metres (<5 m) of the road than is typically assumed for NO_x , but the rate of change along Transects 2 and 3 is slightly shallower³³. Beyond the immediate proximity of the road the slopes are broadly similar. The effect on Transect 1, is also seen for NO_x and NO_2 , and may well reflect the role of vehicle induced turbulence increasing concentrations close to the road even against the prevailing wind (see Paragraph 5.23).
- 5.58 A potentially more useful comparison is given in Figure 79 to Figure 81, which compare the rate of reduction in road- NH_3 with that of road- NO_x measured along each individual transect, after subtraction of a background value chosen to be the concentration at 100 m (or 20 m for Transect 1). In order to provide a like-for-like comparison, these results focus on 4-year means (i.e. discounting 2018 as was necessary for the NO_x data). Road- NH_3 reduces much more quickly than road- NO_x close to the road along Transect 1, but the rates of change along Transects 2 and 3 are remarkably similar for the two gases, although with slightly faster reductions for NH_3 than NO_x .
- 5.59 NH_3 deposits much more quickly than NO_x and so it is reasonable to expect (and dispersion models such as ADMS-Roads predict) that NH_3 concentrations should reduce at a steeper rate than NO_x concentrations. In each of the Ashdown Forest transects, NH_3 reduces slightly faster than NO_x , and this is likely a response to this ‘depletion’ effect caused by more rapid deposition. However, it is also the case that NH_3 is a particularly challenging gas to measure precisely and accurately. Some of the observed patterns (such as the minimum at 20 m along Transect 1) may reflect this difficulty, as well as the inhibition of dispersion, and the potential for very local biogenic sources to affect the measured concentrations (see Paragraph 5.56). On balance, however, the high degree of consistency between the curves for NO_x and NH_3 shows clearly that both gases are being emitted from the same source (i.e. the road alongside each transect) and that both gases are responding to the same dispersion patterns.

³³ The suggestion in these figures that road- NH_3 reaches zero within 100 m of the road reflects a necessary artefact of the analysis. In practice, a value of absolute zero is unlikely to be reached.

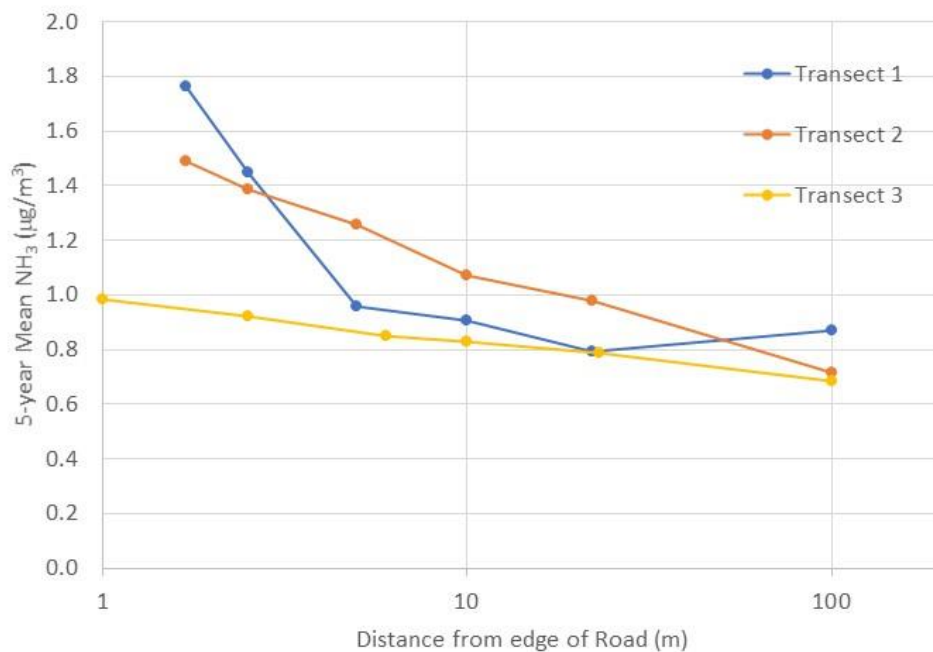


Figure 77: 5-Year Mean NH_3 vs Distance from Road along 3 Transects

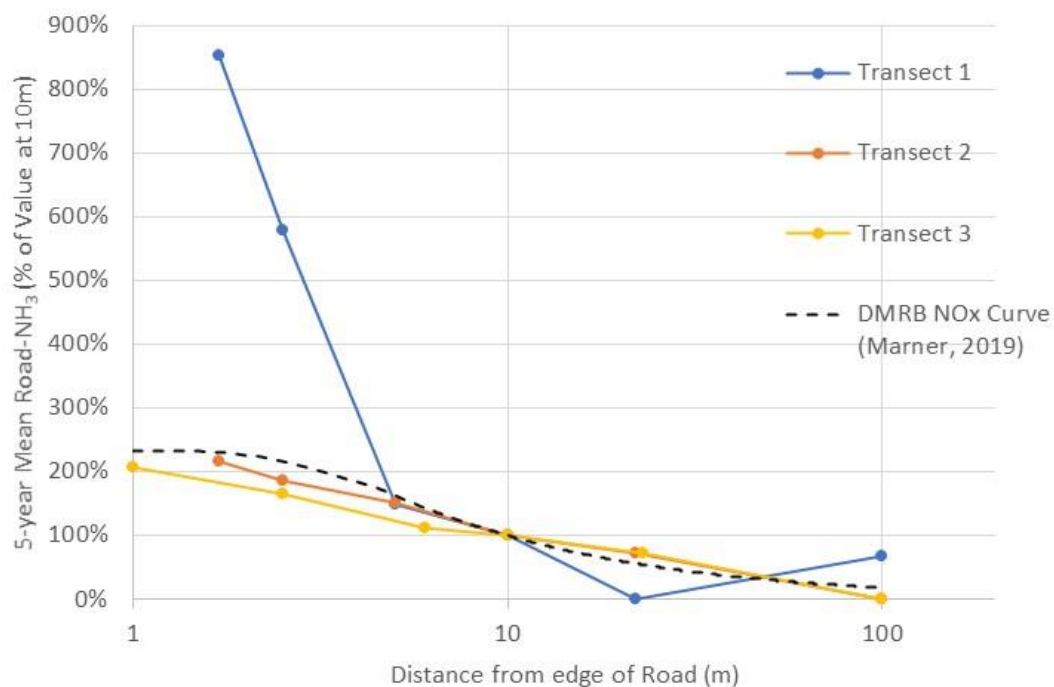


Figure 78: 5-Year Mean Road- NH_3 as a % of the Value 10 m from the Road – Also Showing the DMRB Curve for NO_x (AQC, 2019)



Figure 79: Comparison of the Rate of Reduction vs Distance from Road for Road-NH₃ and Road-NO_x – Transect 1

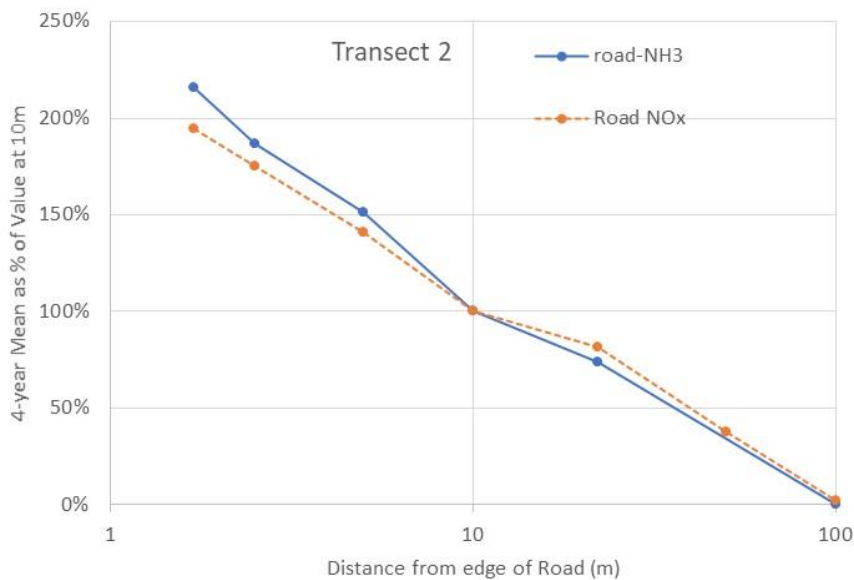


Figure 80: Comparison of the Rate of Reduction vs Distance from Road for Road-NH₃ and Road-NO_x – Transect 2

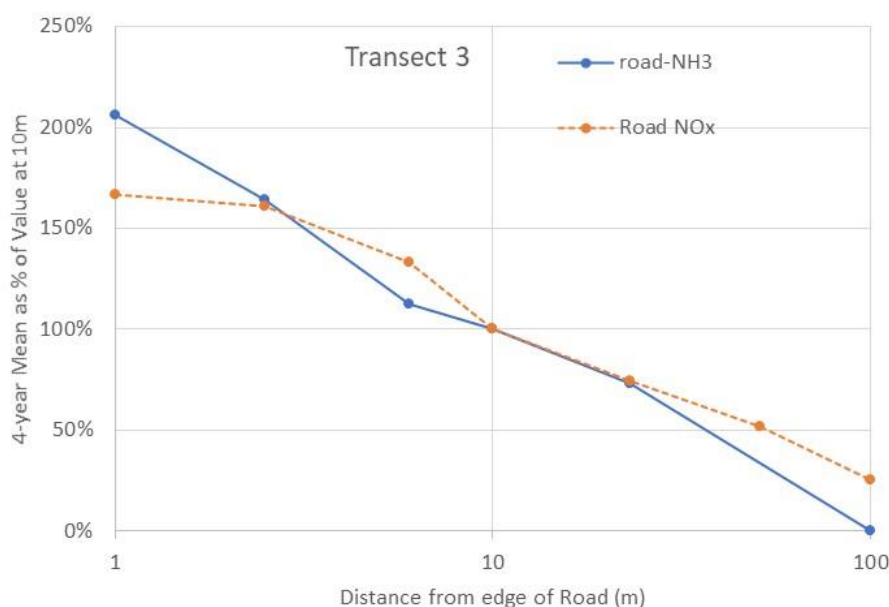


Figure 81: Comparison of the Rate of Reduction vs Distance from Road for Road-NH₃ and Road-NO_x – Transect 3

Other Spatial Patterns

- 5.60 Maps showing the spatial distribution of measured NH₃ concentrations in each individual year are provided in Section 4. In order to provide greater focus on long-term spatial patterns, this section considers 5-year average (2015 to 2019 inclusive) concentrations.

Background Concentrations

- 5.61 Figure 82 summarises the average NH₃ measurements at sites categorised as background (i.e. those at least 100 m from roads). These range from 0.66 µg/m³ to 0.91 µg/m³. NH₃ is emitted from many sources other than road traffic and so there is less reason to expect a correlation between background NH₃ and distance from roads. However, for consistency with the analysis presented for NO₂ (Figure 68), Figure 83 shows the background NH₃ concentrations vs distance from the nearest road. As with NO₂, there does appear to be a relationship, although this does necessarily not mean a pattern of causation. In particular for NH₃, the apparent trend is entirely driven by three of the sites. In practice, the effect of road traffic on NH₃ concentrations will almost certainly not have reached zero at 100 m from the kerb, but the residual traffic-NH₃ is likely to be smaller than the overall measurement uncertainty. The non-traffic concentration field for NH₃ is highly unlikely to be spatially-homogenous over this area owing to differences in local biogenic emissions. The influence of traffic emissions will be overlaid onto this spatially-variable concentration field.

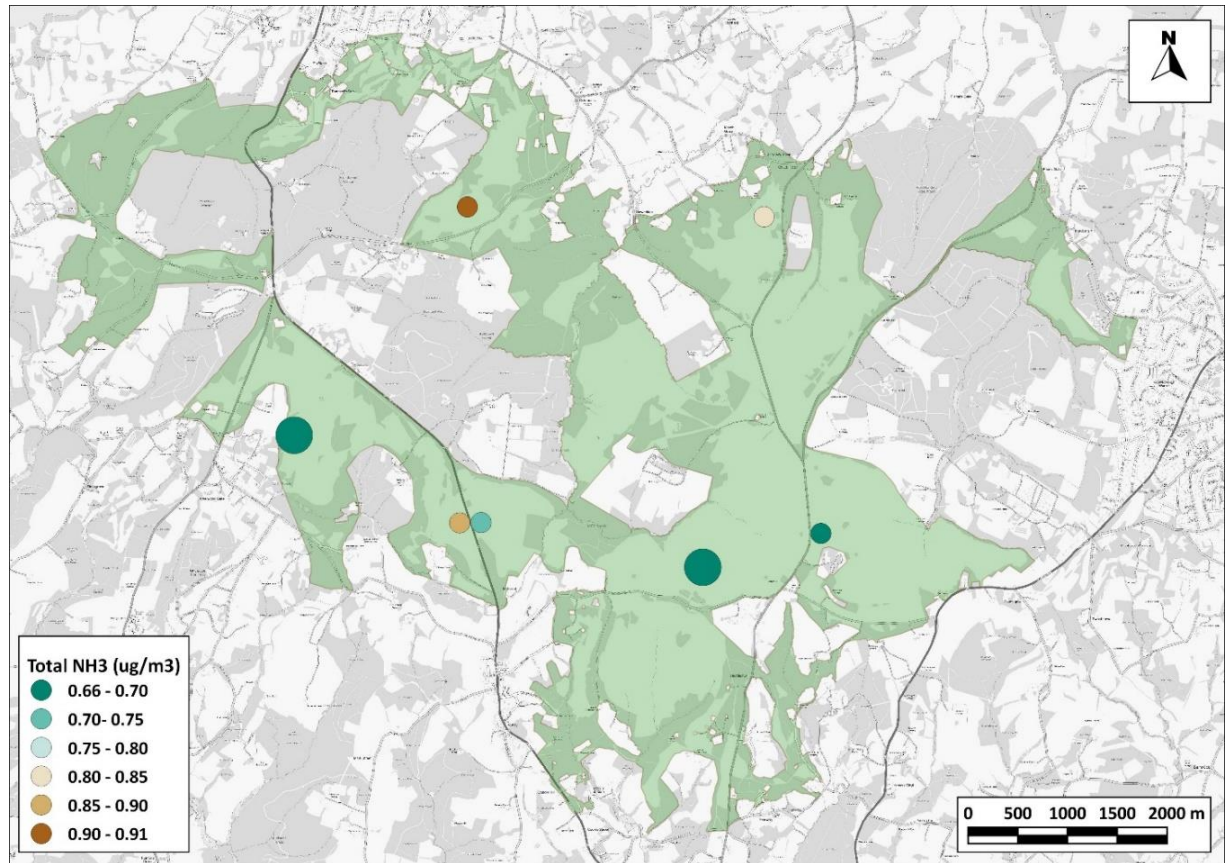


Figure 82: 5-Year Mean Total NH₃ at Background Sites (large circles = DELTAs, small circles = ALPHAs)

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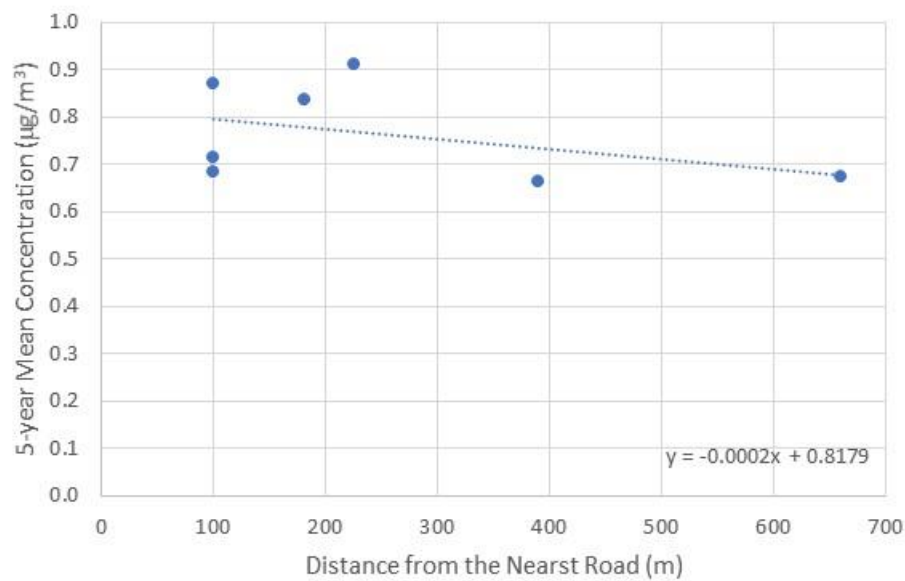


Figure 83: NH₃ Concentrations at Background Sites vs Distance from Nearest Road

Roadside Concentrations

- 5.62 Figure 84 shows the average NH_3 concentrations measured at the roadside sites (i.e. all of those which are less than 100 m from a road). These range from $0.79 \mu\text{g}/\text{m}^3$ at 22 m from the A22 (see Paragraph 5.59 for a discussion of the low values along this transect) to $1.76 \mu\text{g}/\text{m}^3$ at the kerb of the A22. As with NO_2 , as well as being driven by differences in local emissions and dispersion characteristics, much of the variation shown in Figure 68 is simply a response to sampling at different distances from the edges of roads. Following the approach used for NO_x (Paragraph 5.33), the local road contribution to NH_3 (for this part of the analysis, calculated as the total minus the average concentration from all of the sites in Figure 82) has been normalised to a nominal distance of 10 m from the nearest road. This has been done using the latest DMRB NO_x curve (Paragraph 5.33) (An equivalent curve has not been developed for NH_3 , but Figure 79 to Figure 81 show that the rates at which NH_3 and NO_x reduce with distance from the road are very similar and so any additional error caused by using the same curve for NO_x and NH_3 should be inconsequential). Following the approach for NO_x and NO_2 and for improved visual clarity, only the (distance-normalised) value from the first site along each transect is shown. These 5-year mean distance-normalised road- NH_3 results are set out in Figure 85.

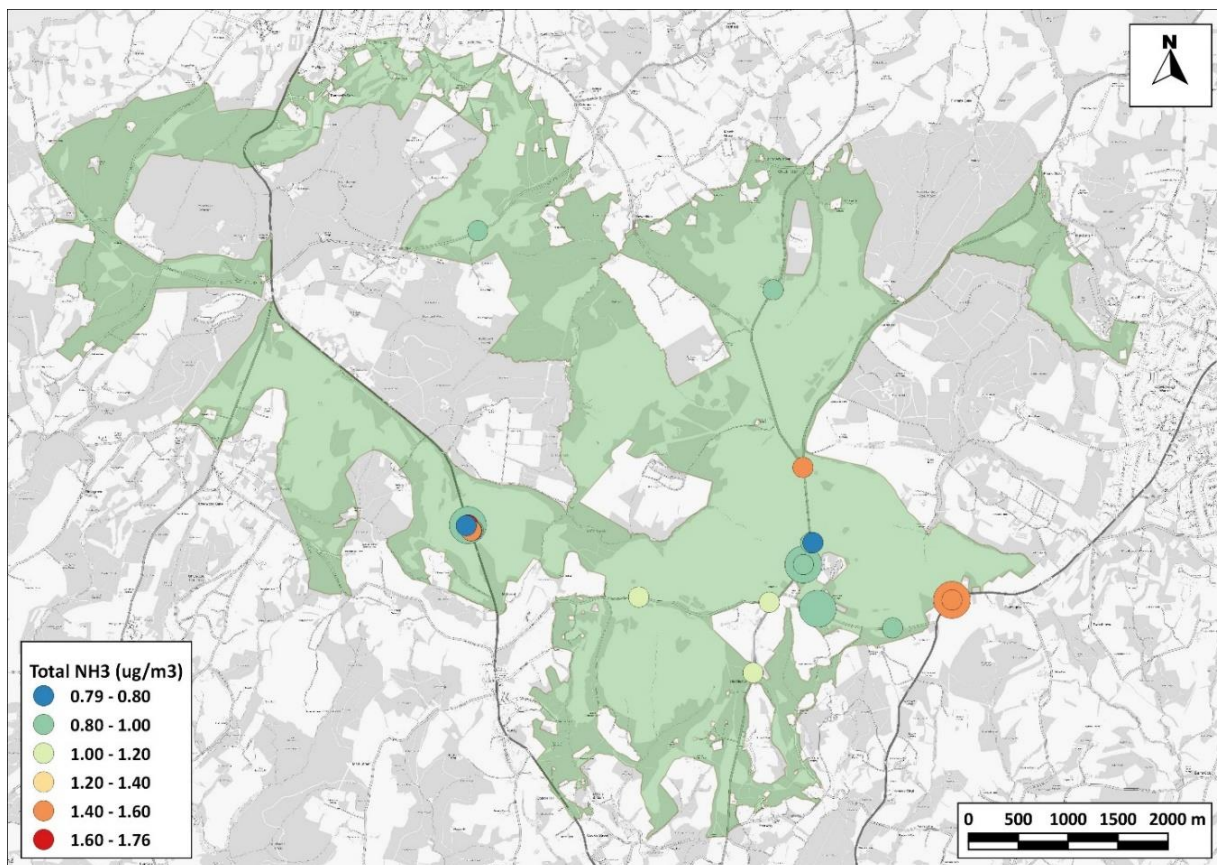


Figure 84: 5-Year Mean Total NH_3 at Roadside Sites (large circles = DELTAs, small circles = ALPHAs)

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- 5.63 Figure 85 shows the general patterns that would be expected for a traffic-generated pollutant, with the highest concentrations alongside the most heavily-trafficked road (A26) followed by the second busiest road (A22) (compare Figure 85 with Figure 41). However, there are some clear differences between the spatial pattern for road-NH₃ shown in Figure 85 and that for road-NO_x (Figure 71 and Figure 72). In particular, Crowborough Road appears to be more important than New Road for road-NH₃, while the reverse is true for road-NO_x. There is open grazing along much of Crowborough Road and it is thus possible that this is an artefact of using a spatially-constant value for non-road NH₃ concentrations; effectively exaggerating the value for road-NH₃ along this road. A high value for normalised road-NH₃ is also shown close to King's Standing car park, despite the same site not being associated with atypically high road-NO_x (see Figure 72). This may also reflect the influence of local grazing. It is also, however, plausible that the most common driving patterns (e.g. acceleration and common engine/catalyst temperatures) in these locations result in a different response in NH₃ emissions than in NO_x emissions.
- 5.64 Because of the different causes of emissions from NH₃ and NO_x from road vehicles³⁴, it would be unreasonable to expect their spatial patterns to correlate precisely. Overall, however, the increased difficulty in isolating the road-NH₃ contribution, and in normalising this for distance, means that only relatively high-level conclusions may be drawn from the spatial distribution shown in Figure 85; i.e. that traffic-NH₃ broadly correlates with traffic volume.

³⁴ NO_x is caused by high temperature combustion and is reduced by emissions-control systems. NH₃ is only emitted by these emissions-control systems and not by the combustion processes themselves.

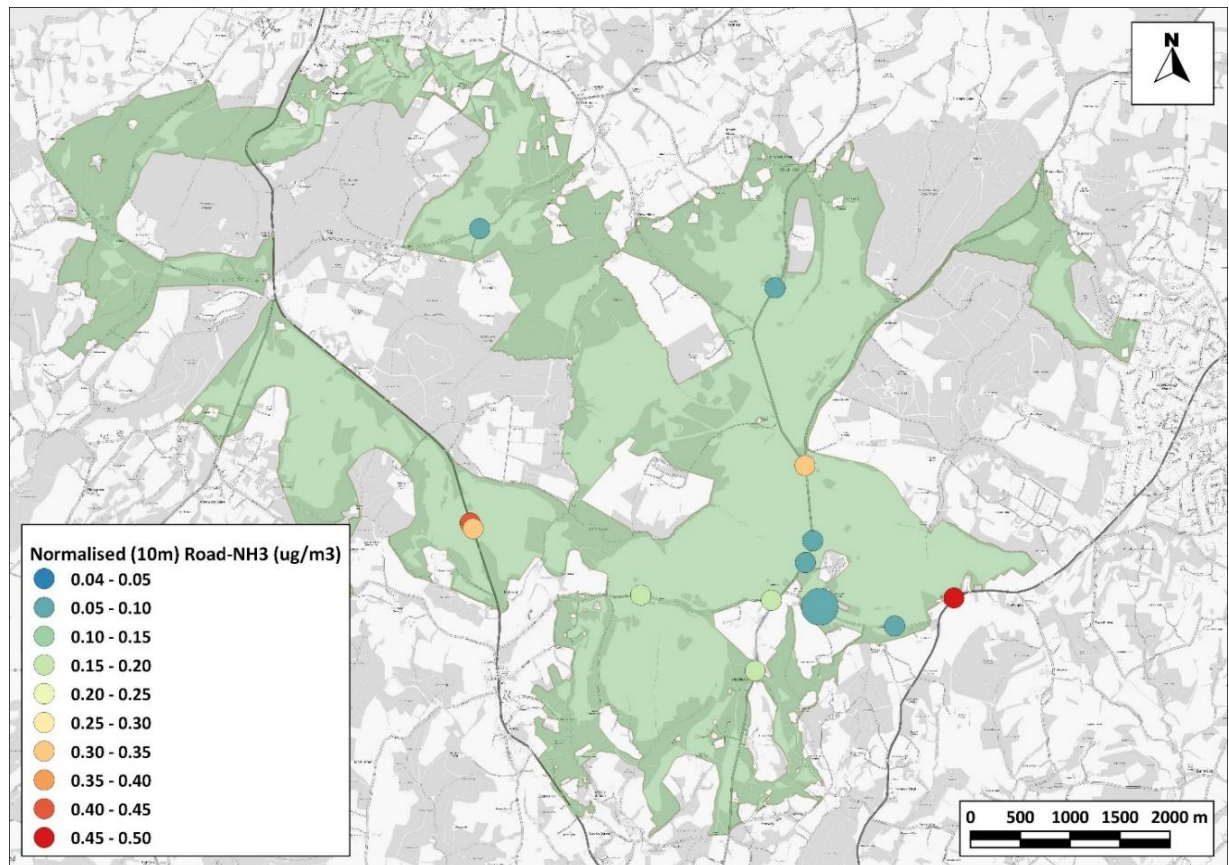


Figure 85: 5-Year Mean Road-NH₃ Normalised to 10 m from the Nearest Road (large circles = DELTAs, small circles = ALPHAs)

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Other Measured Air Pollutants

- 5.65 Other air pollutants were only measured at the six DELTA sites. In order to understand spatial patterns in these measurements, it makes most sense to consider the results from all six monitors. Because Sites D1 and D6 stopped functioning at the end of 2018, and because comparing averages across mismatched sample lengths is likely to misdirect the spatial analysis, the analysis of spatial patterns is of the 4-year mean values (2015-2018 inclusive). Spatial patterns across each individual year (including 2019) are set out in Section 4, and an analysis of temporal patterns (also including 2019) is given in Section 6.
- 5.66 Figure 86 shows the spatial pattern in HNO₃ concentrations. Superficially, there appears to be a spatial gradient, with concentrations increasing from west to east. However, it should be noted that the concentration range (colour scale) shown in this figure is small; with the highest value only 16% greater than the smallest. Furthermore, Section 6 shows that the ranking of sites, from highest to lowest annual mean, is not consistent year-on-year. That said, both of the sites to the west of the A22 (D1 and D2) recorded consistently low values, while the furthest east site (D6) recorded

consistently higher values. On balance, however, there does not appear to be strong evidence of a significant and systematic concentration gradient across the SAC.

- 5.67 When comparing roadside and background sites, the highest long-term average concentration was measured alongside the busiest road, but concentrations at the background site north of Crowborough Road (D5) were consistently higher than those measured alongside the A22. There also does not, therefore, appear to be any clear systematic relationship with proximity to roads.
- 5.68 Comparing multiple sites within such a tight ($0.16 \mu\text{g}/\text{m}^3$) concentration range will inevitably show some sites as higher than others but, as is evident from the inter-year comparisons in Section 6, there does not appear to be a strong systematic variation in HNO_3 concentrations.

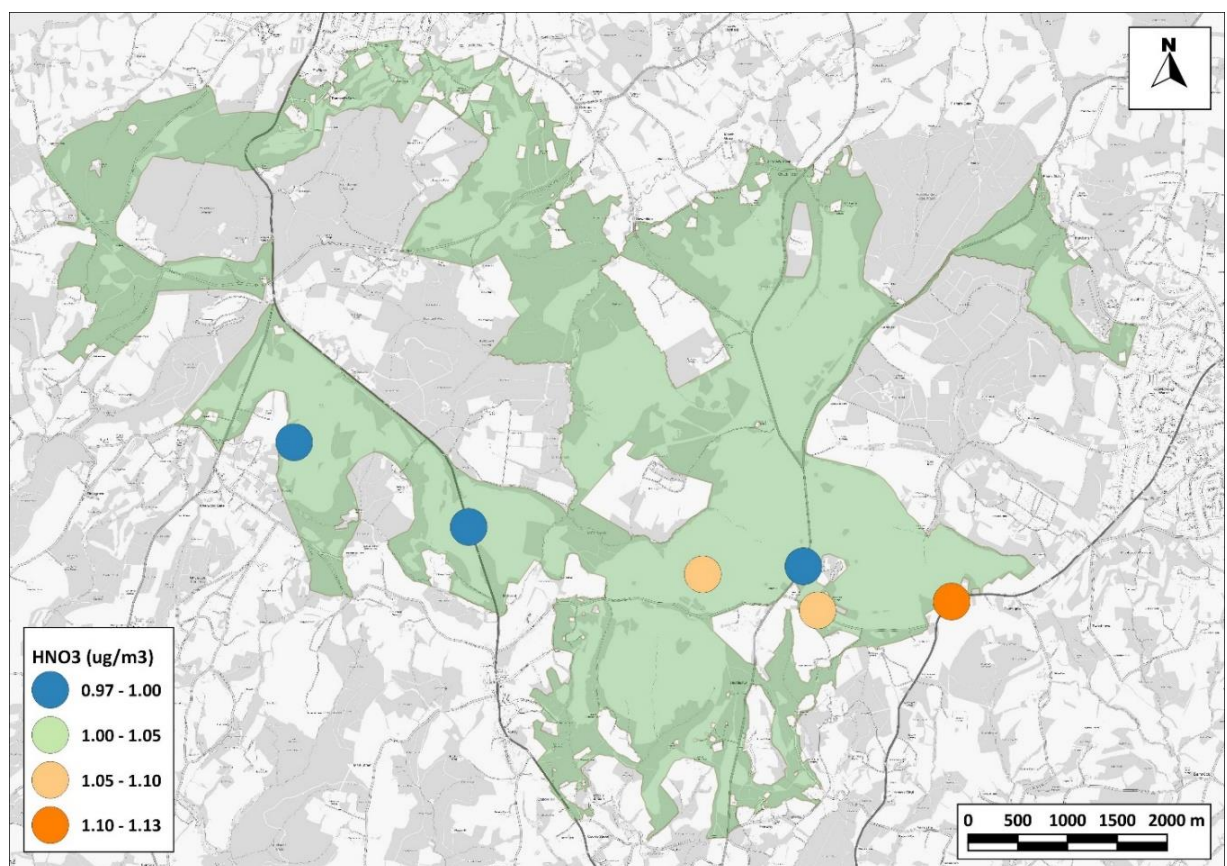


Figure 86: 4-Year (2015-2018 Inclusive) Mean HNO_3

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- 5.69 Figure 87 shows the spatial pattern in 4-year mean HONO concentrations. Figure 87 shows the same very general spatial pattern as Figure 86, but the relative scale is very different. In this case, the mean concentration recorded alongside the A26 (D6) is 2.6 times higher than that recorded at any other site. HONO concentrations at the other heavy traffic site (D1 beside the A22) were lower than those at either of the background monitors. HONO only makes up a very small amount of the total reactive nitrogen in the air and so is unlikely to make a substantial contribution to the total

nitrogen deposition flux to the SAC (see Paragraph 5.72). It is not, therefore, within the scope of this report to understand the very large differences between the measured HONO concentrations.

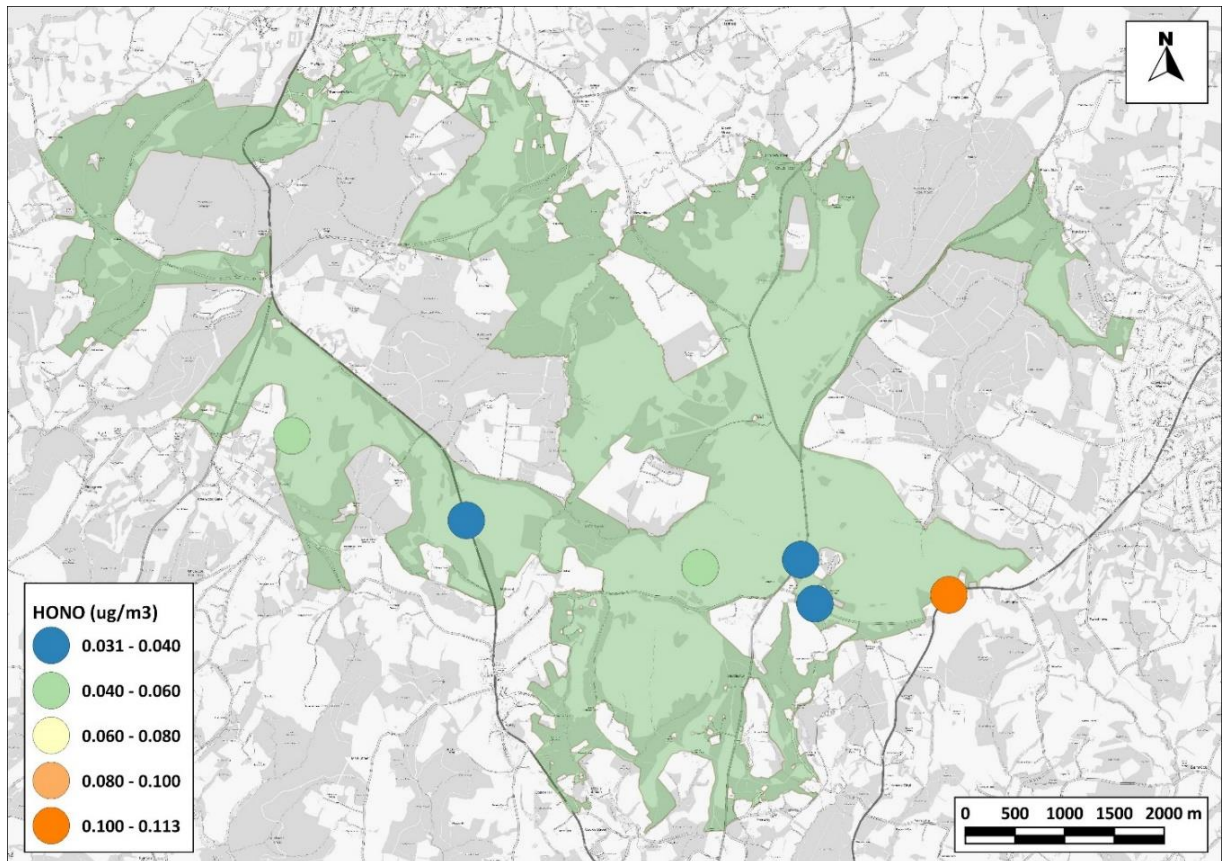


Figure 87: 4-Year (2015-2018 Inclusive) Mean HONO

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- 5.70 Figure 88 shows the 4-year mean pNH_4^+ concentrations. The relative difference between the highest and lowest measured concentrations is much smaller than that observed for HONO, but there does appear to be a spatial pattern, with the highest concentrations measured alongside the busiest road (A26), followed by alongside the next busiest road (A22). However, concentrations at the other two roadside sites (new Road – D4, and the B2026 – D3) were both lower than those measured well away from roads. Furthermore, Section 6 shows that the trend for higher concentrations alongside the main roads was not consistent year-on-year, with both the A26 and A22 sites recording relatively low concentrations during one or more years.
- 5.71 To understand whether different sites are significantly affected by different types of sources, it is helpful to consider seasonal profiles. Figure 89 thus plots the relative monthly profiles averaged across each year. Figure 89 does not compensate for different data capture rates at different sites in different years and thus presents simple averages across each month divided by the overall mean. For NH_3 , all of the profiles are similar, with characteristic peaks in early spring and late summer

which likely relate to well-known biogenic, temperature, and agricultural cycles. However, the profile at Site D6 is somewhat flatter than at the other sites, with a smaller (relative) peak in the spring and a smaller (relative) dip during the winter. This likely reflects the influence of local traffic emissions on NH_3 concentrations. There is no strong seasonality in HNO_3 concentrations, while HONO appears to show higher concentrations during the winter. The monthly profile for pNH_4^+ is consistent across all sites. Unlike for NH_3 , there is no evidence from Figure 89 that the heavy-traffic sites show a systematically different profile from the other sites.

- 5.72 On balance, while the local influence of traffic on particulate ammonium concentrations cannot be fully discounted, this current analysis has not shown any strong evidence that local traffic emissions have significantly affected pNH_4^+ . Figure 88 uses a fine scale and, in practice, the long-term average particulate ammonium concentrations observed across the SAC are quite spatially homogenous; particularly in terms of their contribution to nitrogen deposition (see Paragraph 5.78).

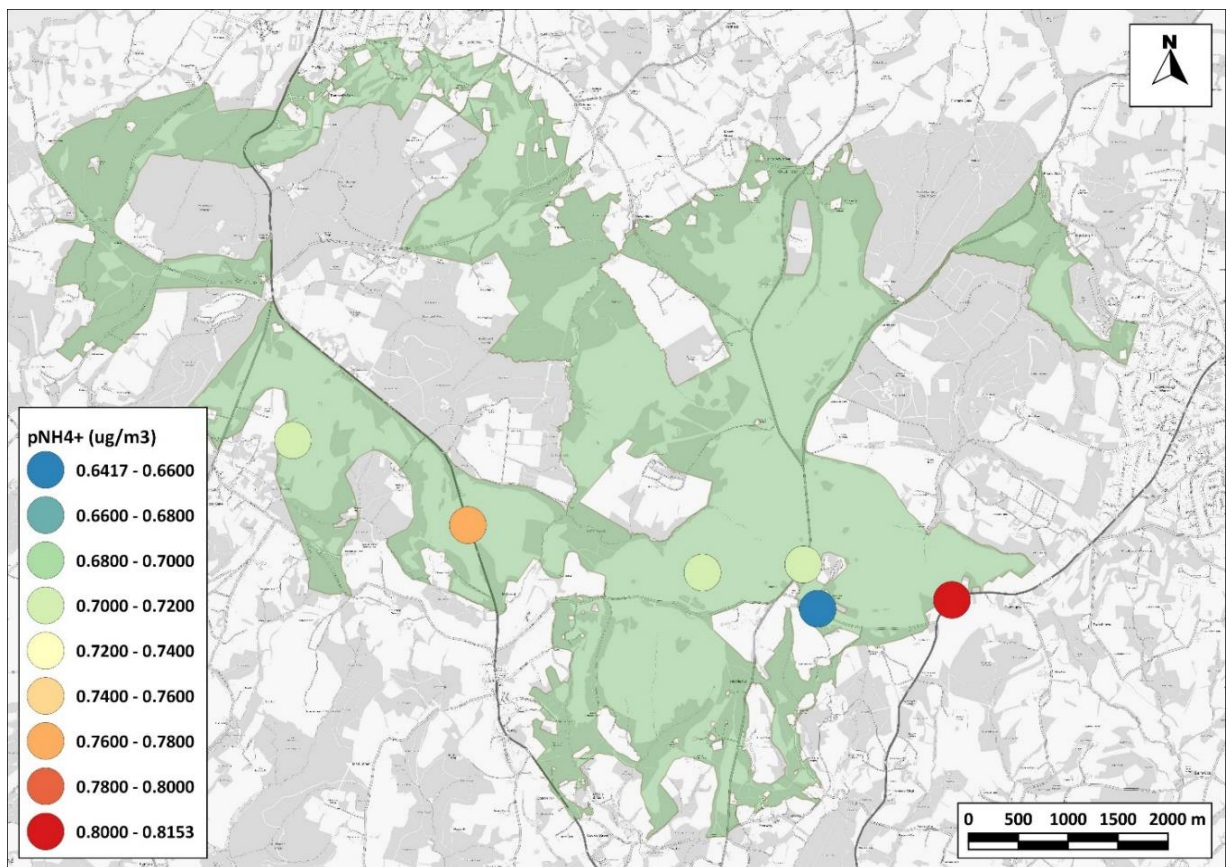


Figure 88: 4-Year (2015-2018 Inclusive) Mean pNH_4^+

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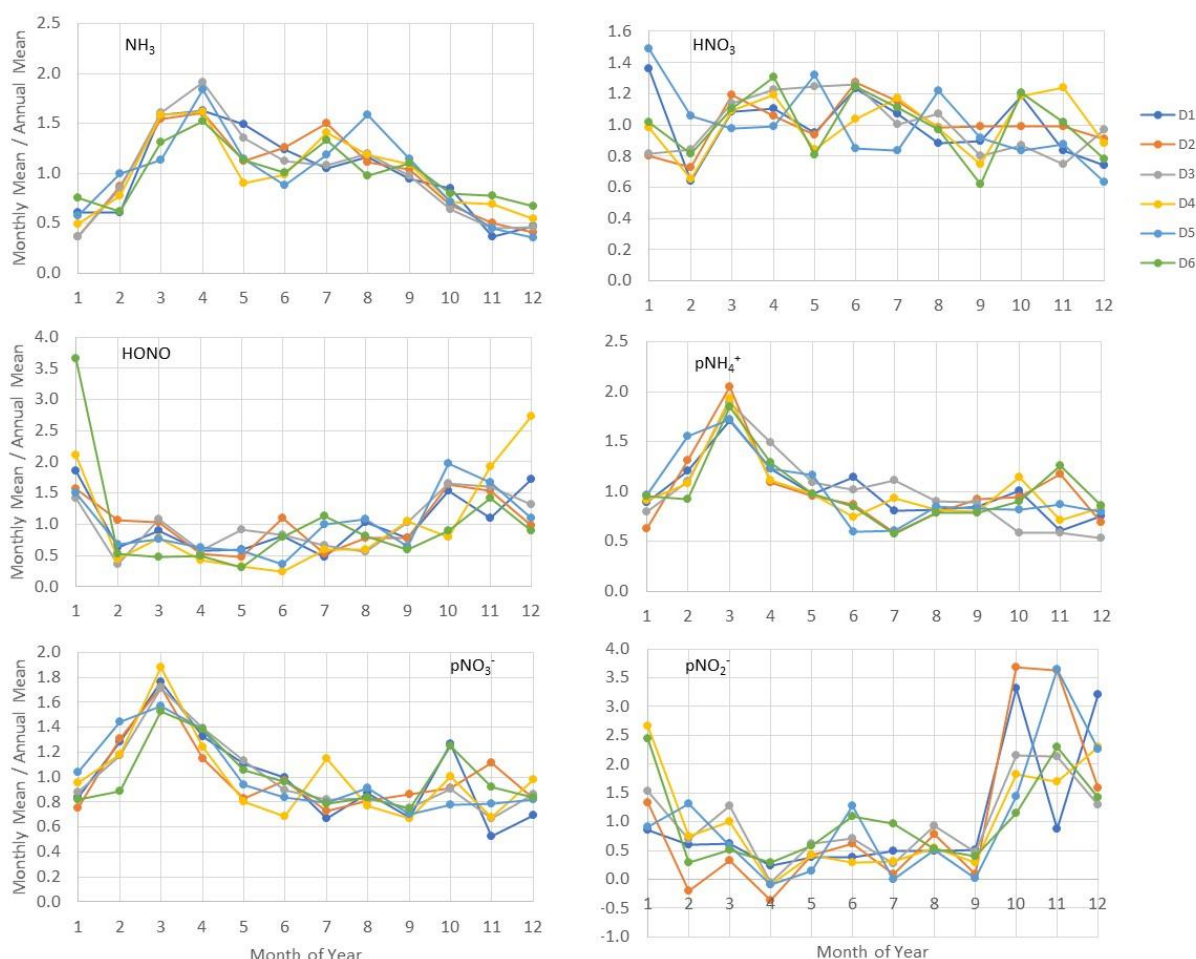


Figure 89: Relative Monthly Profiles at the DELTA Sites

5.73 Figure 90 and Figure 91 show the spatial patterns in long-term average particulate nitrate (pNO_3^-) and nitrite (pNO_2^-) concentrations. As for the other species, the higher measured concentrations alongside the A26 should be understood in the context of the intra- and inter-year variability shown in Figure 89 and Section 6 respectively. Particulate nitrate concentrations were highest beside the A26 during most, but not all, years. Concentrations alongside the A22 were notably high during 2015 and 2018, but were some of the lowest recorded at any site in 2016 and 2017. On balance, as with particulate ammonium, this current analysis has been unable to identify a relationship between local traffic emissions and particulate nitrate concentrations. As with HONO, there are wide variations in measured particulate nitrite concentrations at different sites, in different years, and in different months. However, also like HONO, particulate nitrite concentrations are much smaller than those of the other particulate species measured and are not, therefore, expected to dominate total reactive nitrogen deposition fluxes to the SAC. As such, it is not within the scope of this analysis to understand the reasons for the variability in recorded values.

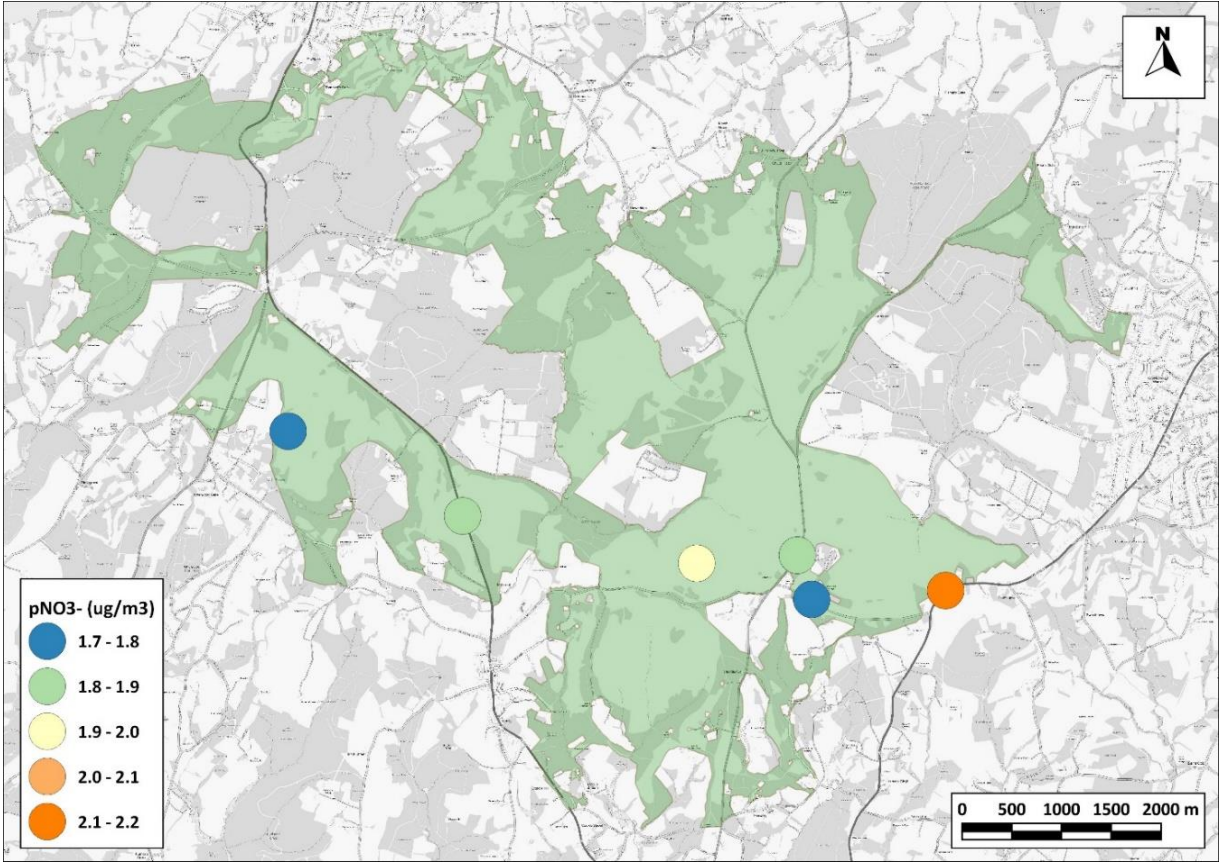


Figure 90: 4-Year (2015-2018 Inclusive) Mean pNO₃⁻

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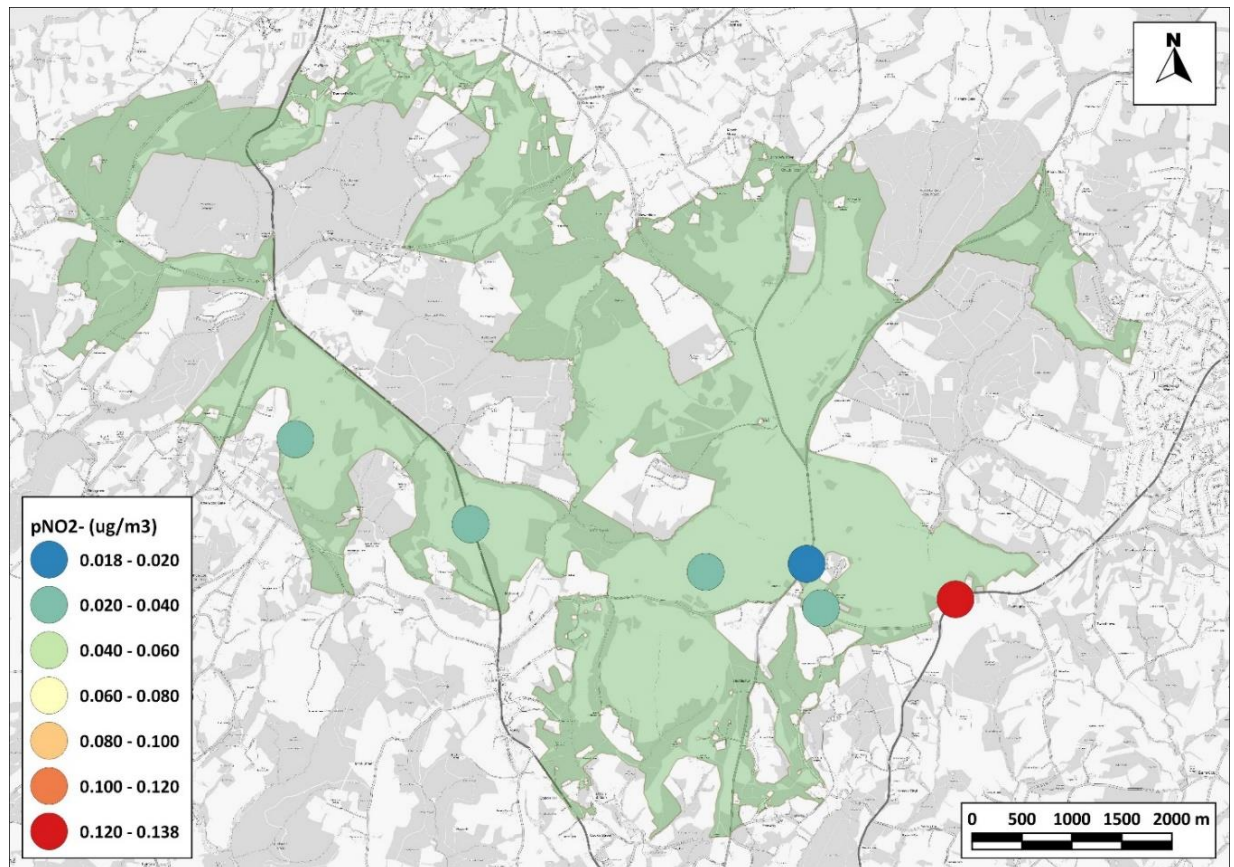


Figure 91: 4-Year (2015-2018 Inclusive) Mean pNO₂

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Nitrogen Deposition

- 5.74 As explained in Section 2, nitrogen deposition is not measured as part of the study. It is, however, possible to calculate the deposition fluxes associated with different measured concentrations. The most precise and accurate way to calculate deposition is on a high time-resolution (e.g. hour-by-hour) basis and taking account of local vegetation structures (e.g. (Smith, Fowler, Sutton, Fletchard, & Coyle, 2000), (Erisman and Draaijers, 1995), (AQC, 2018)). However, it is also possible to provide broad estimates of deposition from longer-term average concentrations, and in the UK, it is common to multiply annual mean concentrations by annual mean deposition velocities to calculate annual mean deposition fluxes. To provide an indication of dry deposition fluxes to the SAC, the measured annual mean concentrations have been combined with the annual mean deposition velocities published by the inter-agency Air Quality Technical Advisory Group (AQTAG) which are given in Table 19. Results are provided first assuming deposition to short vegetation and then assuming vegetation to woodland (i.e. sites have not been matched with their actual land surface).
- 5.75 The only sites where all significant dry depositing species were measured are the DELTA sites (each of which had a co-located diffusion tube monitor (Table 2)). For the reasons explained in Paragraph

5.65, in order to provide representative between-site comparisons covering all six sites, the DELTA results have been averaged over the 4-year period 2015-2018 (inclusive). Figure 92 summarises the long-term average dry deposition fluxes at the six DELTA sites assuming deposition to short vegetation. Figure 93 shows the equivalent values assuming deposition to woodland.

Table 19: Annual Mean Deposition Velocities used in this Study (m/s)

Variable	Short Vegetation	Woodland	Source
NH ₃	0.02	0.03	AQTAG (06)
NO ₂	0.0015	0.003	AQTAG (06)
HNO ₃	0.04		AQTAG (06)
HONO	0.04		Assumed to match HNO ₃
All particulate species	0.01		The value for sulphate aerosol given in AQTAG (06)

- 5.76 It is important to recognise that Figure 92 and Figure 93 only show dry deposition fluxes, since wet deposition has not been measured. Wet deposition and dry deposition are additive, and previous work (AQC, 2018) has shown that wet deposition contributed approximately 9.3 kg-N/ha/yr in 2015. There is no reason to believe that this value changed significantly over the period 2015 to 2019³⁵. Total nitrogen deposition would thus be 9.3 kg-N/ha/yr higher than the values shown in Figure 92 and Figure 93.
- 5.77 Adding 9.3 kg-N/ha/yr to the values shown in Figure 92 suggests that the minimum deposition flux to short vegetation (such as heath) at a background location was > 20 kg-N/ha/yr. This contrasts with modelling presented on APIS³⁶ which predicts an average background (representative of conditions well away from roads) flux to short vegetation of around 14 kg-N/ha/yr in every year since 2011. It also contrasts with the deposition modelling for Ashdown Forest carried out by AQC (2018), which used the same measurements (albeit for a shorter period) to predict both an average and minimum deposition flux to heath of 14 kg-N/ha/yr, thus agreeing with the national model. The principal reason why deposition is predicted to be so much higher than it was in the 2018 modelling is the use, here, of the AQTAG deposition velocities (with the largest relative differences occurring for pNO₃⁻ and pNH₄⁺, as well as for HNO₃). Also, while the AQTAG deposition velocities tend to under-predict deposition fluxes close to roads, they can significantly over-predict NO₂ and NH₃ fluxes to background locations (AQC, 2018b). The use of AQTAG deposition velocities is thus likely to have over-predicted nitrogen deposition fluxes to background locations.

³⁵ For example, the 5 x 5 km resolution modelled deposition data on APIS (which use the same source data as the 9.3 kg-N/ha/yr value was derived from) predict that total nitrogen deposition to short vegetation in Ashdown Forest was the same in 2013-2015 as it was in 2017-2019 (the flux to woodland increased slightly over this period, but this increase is most likely to have been driven by an increase to dry deposition, since wet deposition is the same to woodland and short vegetation).

³⁶ In April 2021.

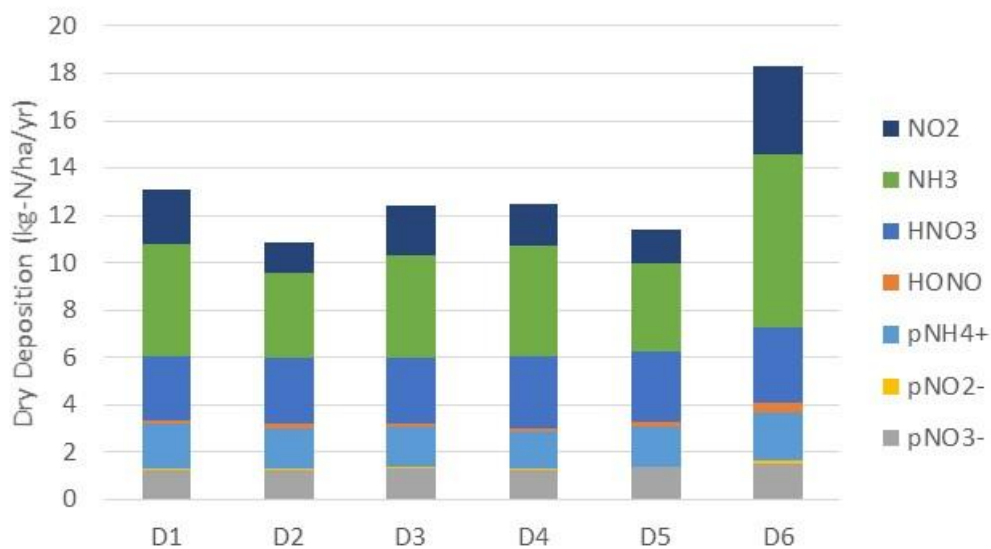


Figure 92: 4-Year (2015-2018 Inclusive) Mean Dry Deposition of Seven Pollutant Species at the DELTA Sites – Using the Spatially- and Temporally-constant Deposition Velocities to Short Vegetation in Table 19

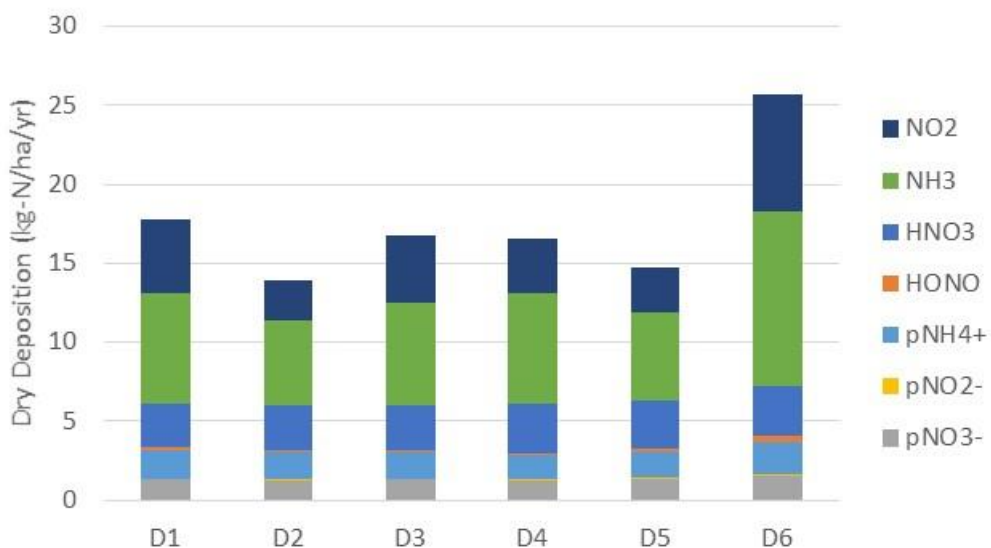


Figure 93: 4-Year (2015-2018 Inclusive) Mean Dry Deposition of Seven Pollutant Species at the DELTA Sites – Using the Spatially- and Temporally-constant Deposition Velocities to Woodland in Table 19

5.78 It is clear from Figure 92 and Figure 93 that, despite the apparent gradation in ambient concentrations suggested by Figure 86 to Figure 91, in the context of their contribution to the overall deposition flux, all of those species which are only measured by DELTA instruments (HNO₃, HONO, pNH₄⁺, pNO₃⁻, and pNO₂⁻) do not vary appreciably across the six sites. In other words, the total calculated deposition fluxes would not be very different at any site if the values for these species had not been measured locally but were, instead, taken from those measured elsewhere. The

biggest differences between the calculated dry deposition flux at the different sites is caused by the NH_3 and NO_2 concentrations (which were also measured by ALPHA samplers and diffusion tubes respectively).

- 5.79 Figure 94 shows the total calculated deposition fluxes to all roadside sites where both NH_3 and NO_2 were measured. NH_3 concentrations have been taken from both ALPHA and DELTA monitors, with the DELTA values labelled “DELTA” in the graph. Because Figure 92 and Figure 93 show that inter-site variation in calculated HNO_3 , HONO , pNH_4^+ , pNO_3^- , and pNO_2^- deposition fluxes is small, the absence of these data for two of the sites in 2019 does not preclude presentation of 5-year average data for the remaining sites. Figure 94 thus assumes spatially constant concentrations of these species, based on the average measured at Sites D2 to D5 (i.e. discounting measurements from sites D1 and D6)³⁷. The value for ‘background NH_3 ’ in the chart is calculated from the average concentration measured at all background sites, while ‘background NO_2 ’ is the average at those background NO_2 monitors which provided valid annual means for every year. As explained for previous analyses in this section, the road increments are then the total values with the background subtracted.
- 5.80 Noting the potential error introduced by using AQTAG deposition velocities (Paragraph 5.77), Figure 94 suggests that the 5-year mean background dry deposition flux, onto which the road increment to deposition is overlaid, was approximately 11 kg-N/ha/yr to short vegetation and 14 kg-N/ha/yr to woodland. The local road increment added between 1 kg-N/ha/yr and 8 kg-N/ha/yr assuming deposition to short vegetation, and between 1 kg-N/ha/yr and 14 kg-N/ha/yr assuming deposition to woodland. Assuming a wet deposition contribution of 9.3 kg-N/ha/yr, the total flux at these monitoring sites thus ranged from 21 kg-N/ha/yr to 29 kg-N/ha/yr to short vegetation, and from 25 kg-N/ha/yr to 38 kg-N/ha/yr to woodland. More accurate deposition calculations are not possible whilst only using the AQTAG deposition velocities.
- 5.81 Figure 95 shows the relative contributions that the road increments of NO_2 and NH_3 each make to the total road increment to deposition. Taking an average across all of these sites, NO_2 made up approximately 42% of the total local traffic effect to short vegetation, increasing to 49% assuming deposition woodland over the years 2015 to 2018, with NH_3 accounting for the remaining slightly higher contribution from local traffic (58% and 51% respectively)³⁸.

³⁷ Thus, even for the DELTA sites in the figure, the values presented for these spatially-homogenous pollutants are the averages of those at both roadside and background sites.

³⁸ Again, these proportions are a function of the relative biases in the AQTAG deposition velocities, which tend to under-predict NO_2 deposition at the roadside (AQC, 2018b) and are thus likely to over-state the relative importance of road- NH_3 .

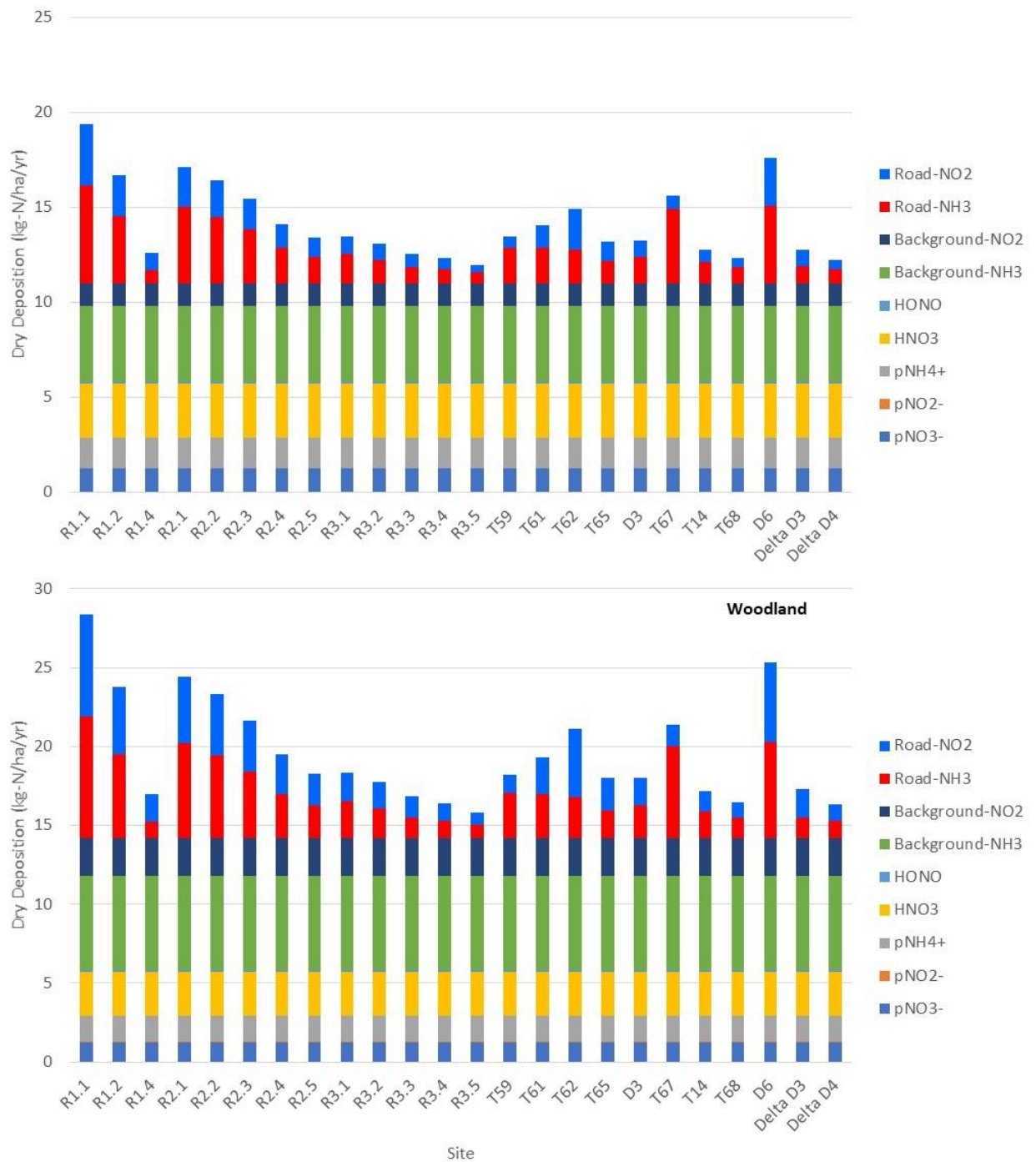


Figure 94: 5-Year (2015-2019 Inclusive) Mean Dry Deposition of Seven Pollutant Species at Roadside NH₃ + NO₂ Monitors with 5 Years' Data – Using the Deposition Velocities in Table 19³⁹

³⁹ The values labelled "D1" and "D6" use the NH₃ concentrations measured using ALPHA samplers in these locations. Sites prefixed "Delta" use NH₃ concentrations measured using the DELTA samplers.

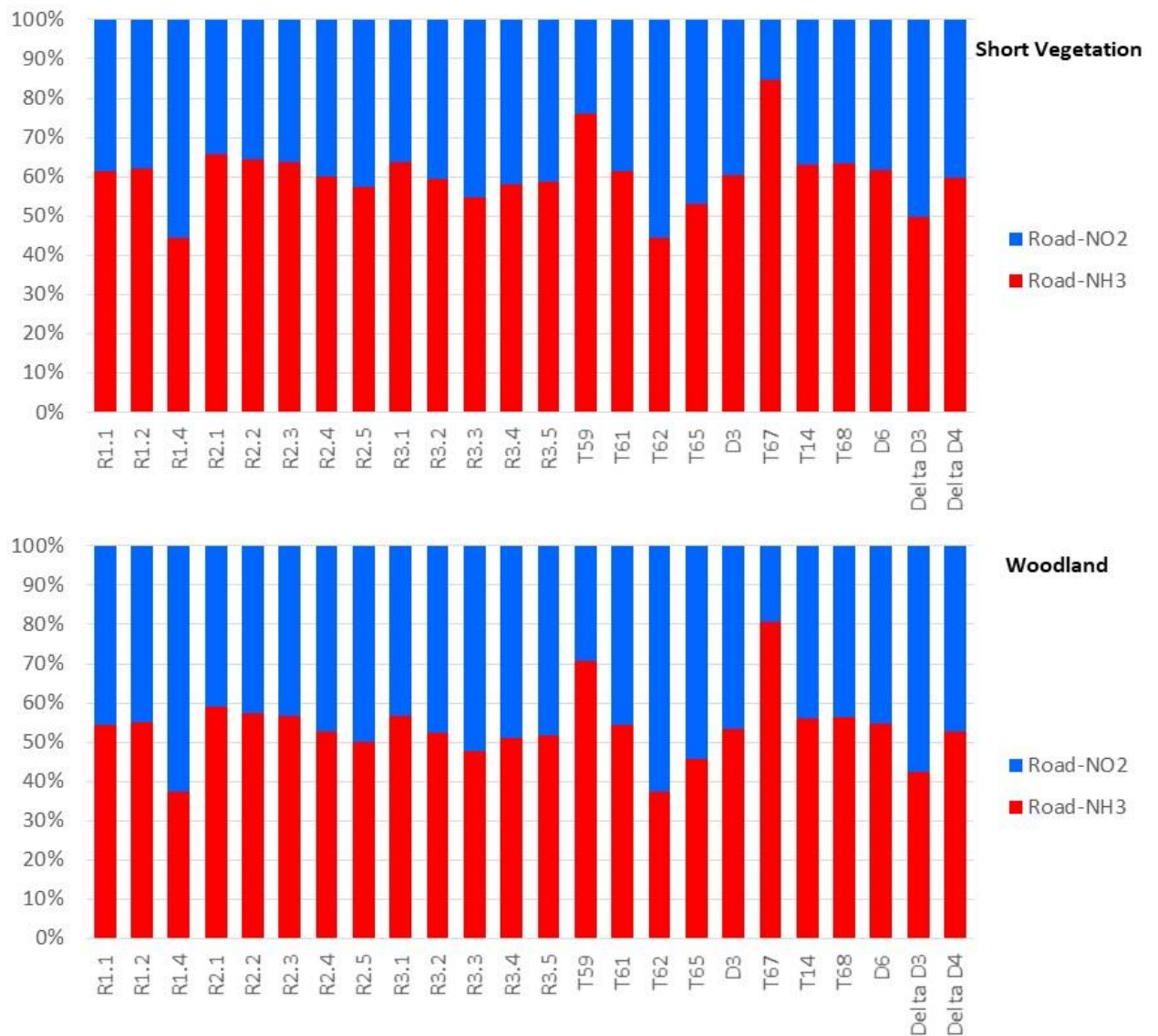


Figure 95: Relative Contribution of Different Traffic Pollutants to the Local Road Increment of Nitrogen Deposition at all Roadside Sites Measuring both NH₃ and NO₂³⁹

6 Trends Over Time

- 6.1 This section focuses on trends over time. Where annual averages are considered, the dataset has been restricted to the period 2015 to 2019 inclusive, since this is the period over which full calendar years of measurements are available.

NO_x and NO₂

Context

National Context

- 6.2 AQC has previously analysed long-term trends measured at a large number of real-time monitoring sites across the UK. This showed that, on average, NO_x and NO₂ concentrations have been falling since about 2010 (Figure 96) but that this average trend belies significant inter-site and regional differences, with some sites showing much more rapid reductions than the average in Figure 96, while other areas have experienced either slower reductions or increases (AQC, 2019b). Subsequent analysis showed that, at many sites in the UK, 2015 was associated with atypically low roadside concentrations. Conversely, 2016 was associated with atypically high roadside concentrations (left panel in Figure 97). It was shown that the unusual conditions in 2015 and 2016 were, in most cases, driven by atypical weather patterns during these years. Following statistical analysis to remove the effects of weather, a more consistent pattern was observed (right panel in Figure 97). Figure 97 shows that, taking an average across most available automatic roadside monitors in the UK, and removing the effects of weather, there was a consistent decline in concentrations over the period 2015 to 2019 (inclusive).
- 6.3 Reductions in roadside NO₂ and NO_x concentrations have also been predicted by models. Defra's projection factors for total roadside NO₂ concentrations predict reductions of 5% to 6% per year⁴⁰ and the national-average data (Figure 97) broadly support this prediction for recent years once the effects of atypical weather are removed. The current version of Defra's Emissions Factors Toolkit (EFT) does not provide predictions for years before 2018, but the most recent version which was available at the start of the monitoring presented in this report (V6.0.1) predicted a reduction in average NO_x emissions per vehicle (for a rural road outside London with 5% HDV and an average speed of 50 kph⁴¹) of between 10% and 11% per year over the 2015 to 2019 period.

⁴⁰ <https://laqm.defra.gov.uk/tools-monitoring-data/roadside-no2-projection-factor.html>.

⁴¹ Which broadly represents Ashdown Forest.

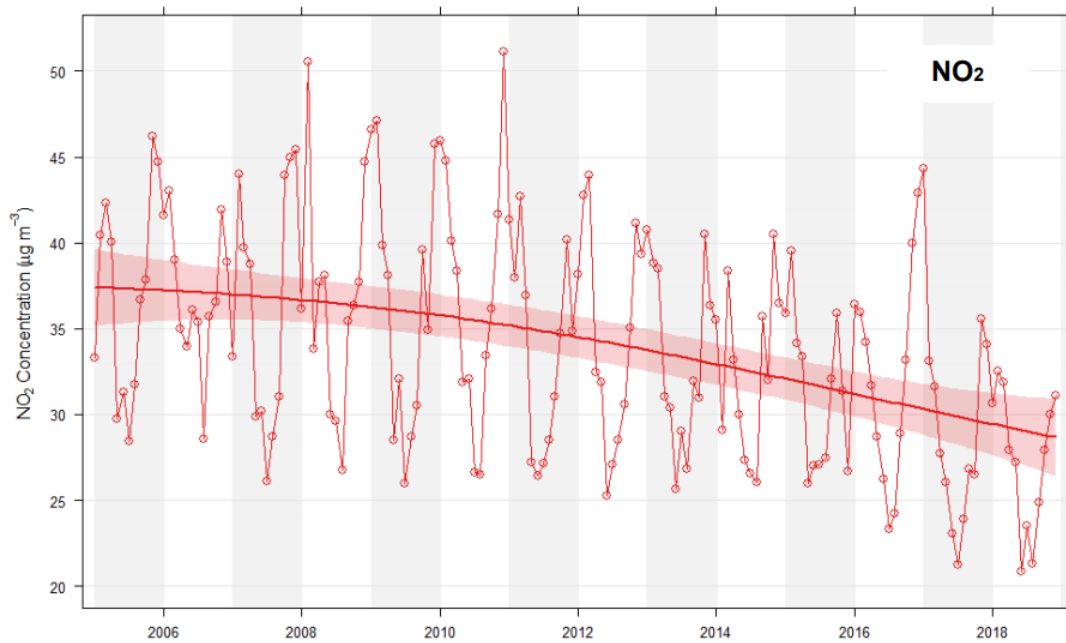


Figure 96: Trend in NO₂ across 112 Real-time Monitoring Sites across the UK and SmoothTrend Fit, 2005-2018 (AQC, 2019b)

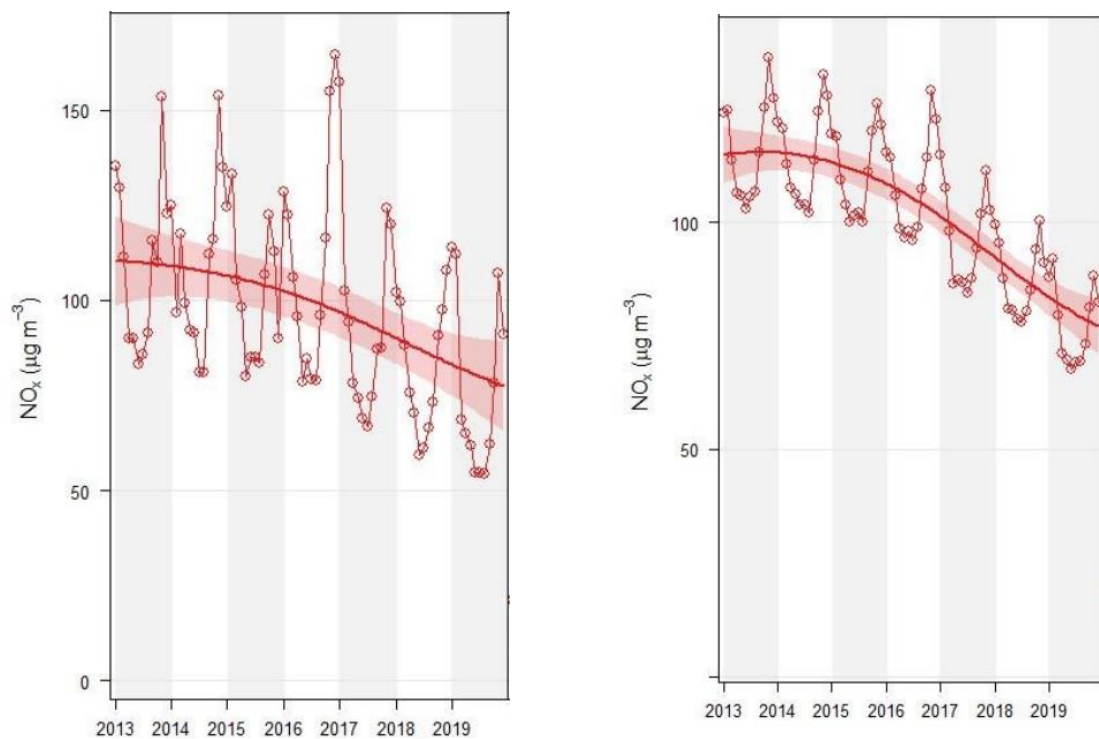


Figure 97: Trend in NO_x across 131 Real-time Roadside Sites across the UK and SmoothTrend Fit, 2013-2020 (left, as measured, and right, adjusted to remove the influence of meteorology) (AQC, 2020)

Local Context

- 6.4 Separate to the measurements presented in this report, WDC also measures nitrogen dioxide concentrations using diffusion tubes for LAQM purposes. While WDC's LAQM network contains fewer sites than the Ashdown Forest network, and none within Ashdown Forest itself, many of the LAQM sites were operational long before the Ashdown Forest study began. The closest long-term sites to Ashdown Forest are in Crowborough and Uckfield (Figure 98). Annual mean results since 2012 are set out in Figure 99. Patterns at the different sites have been mixed. Uckfield Town Centre reported a significant increase in measured concentrations between 2012 and 2016, but it seems unlikely that an increase of this scale would be caused by typical changes to traffic volumes and congestion. It is not known if other local factors or data quality may have affected the reported trend, but there are signs that concentrations have now stopped increasing and may be reducing. Concentrations at the other long-term sites were largely static over the period 2015 to 2019. The LAQM measurements are managed and reported by AECOM who concluded that, except for the increase in concentrations in Uckfield, there was no significant increasing or decreasing trend in nitrogen dioxide concentrations at roadside or background monitoring sites in this area (AECOM, 2020).

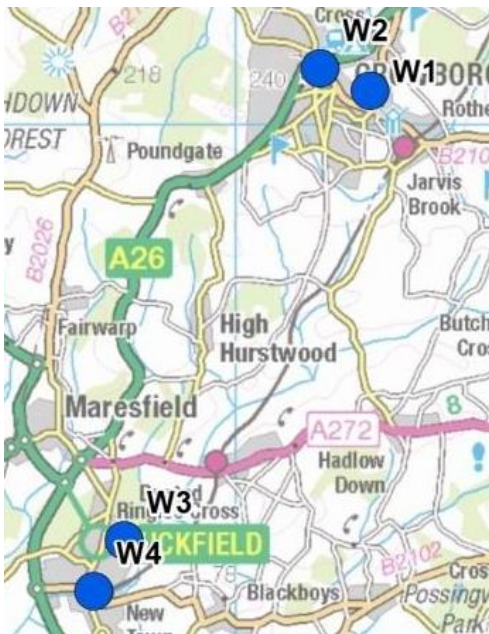


Figure 98: Diffusion Tube Sites Operated for Local Air Quality Management Purposes Close to Ashdown Forest (AECOM, 2020)

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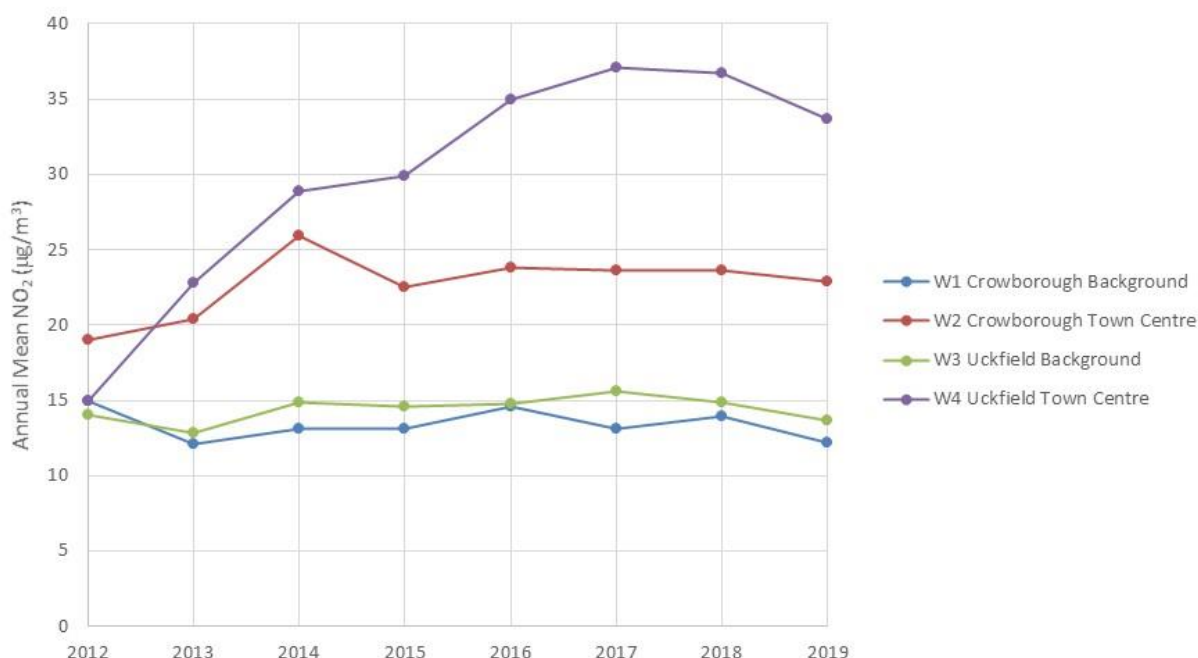


Figure 99: Annual Mean NO₂ Concentrations Measured Close to Ashdown Forest for LAQM (taken from taken from AECOM (2016; 2020))

6.5 For reasons explained below, to help understand trends in NO_x and NO₂ concentrations within Ashdown Forest over the monitoring period, it is helpful to understand whether the measurements made during 2015 and 2016 were either unusually high, or unusually low. Figure 99 is thus helpful in that it provides a long time-series which extends both before and after the 2015-2016 period. There is some indication in Figure 99 that 2015 was atypically low at both town centre sites (i.e. the dot for 2015 sits below an imaginary line joining 2014 and 2016), but such an effect is relatively modest (i.e. the 2015 values at both town centre sites were higher than both the 2012 and 2013 values). There is also no indication in Figure 99 that 2016 was unusually high for nitrogen dioxide in this area.

Trends at the Kingstanding Automatic Analyser

6.6 Figure 100 shows the trend in annual mean NO_x and NO₂ concentrations measured at the Kingstanding automatic analyser. As has been observed nationally (Figure 97) but not locally (Figure 99) 2016 recorded higher concentrations than those in any other recent year, while 2015 recorded the lowest concentrations. The second highest year was 2017. Concentrations in 2019 were not appreciably different (slightly higher) to those in 2018. As noted by AECOM for the longer nitrogen dioxide time-series (Paragraph 6.4), there is no clear pattern of either increasing or reducing annual mean nitrogen and NO_x concentrations over time in Figure 100.

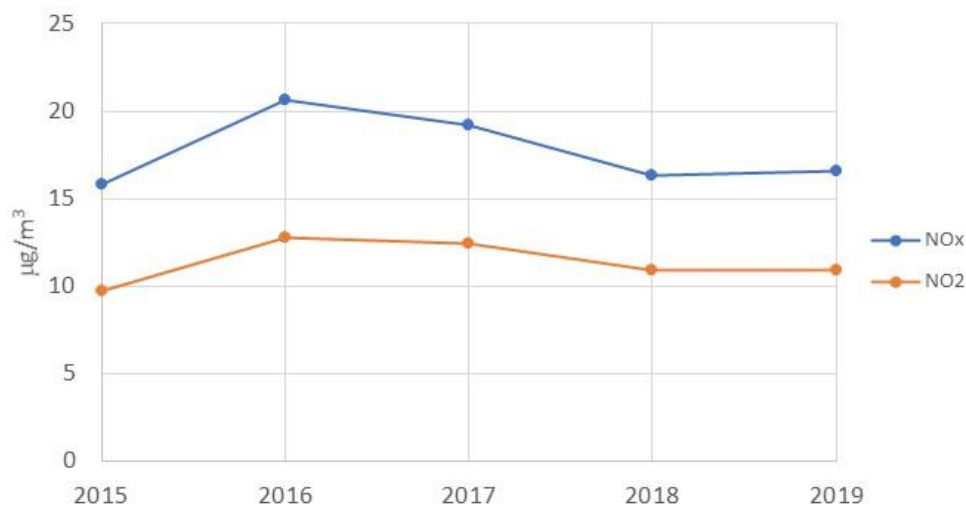


Figure 100: Annual Mean NOx and NO₂ Measured at the Kingstanding Automatic Monitor

- 6.7 In order to remove the influence of meteorology, the same statistical analysis as used in Figure 97 and has been applied. The approach uses machine learning to build Boosted Regression Tree models as described in Paragraph 5.16 and is described further in AQC (2020b). As for the analyses in Section 5, meteorological data from the Meteorological Office site at Gatwick airport have been used, which is considered suitably representative.
- 6.8 Figure 101 and Figure 102 show the raw measurements, for the entire measured time-series, alongside the ‘deweathered’ (‘adjusted’) trend, which simulates the concentration which would have been measured if all meteorological variables were held constant. Statistical analyses such as this are not precise or definitive but nevertheless give a good indication of the underlying patterns and drivers. Small spikes and steps in the ‘deweathered’ line are events which the Boosted Regression Tree models cannot explain in terms of the meteorological measurements alone, but will not all represent significant changes to underlying concentrations or emissions. Overall, the trend in concentrations at this site is relatively static once weather effects are removed, but the deweathered concentrations of both pollutants in 2016 were higher than those in 2015, suggesting an increase which cannot be explained by meteorological variability alone. This was followed by a slow decline so that by 2020, concentrations reverted to be only slightly higher than those during 2015.
- 6.9 The Kingstanding site is beside the B2026. Figure 39 and Figure 40 (also see Table 16 and Table 17) shows that traffic volumes in 2016 were higher than those in 2015 and then fell slightly in 2017 and 2018 (i.e. somewhat showing the same pattern in Figure 100 to Figure 102). However, these changes in traffic were all small (relatively smaller than changes to the NOx and nitrogen dioxide concentrations) and so unlikely, on their own, to explain the observations.
- 6.10 As explained in Paragraph 5.18, and shown in Figure 61 (Section 5), a separate trend analysis has been carried out which, as well as removing the effects of weather, has also sought to remove the effects of traffic volume on the B2026. This shows largely the same pattern as Figure 101, with a

small increase in concentrations to 2016, followed by a gradual reversion toward 2015 levels by 2020. This pattern is not driven by meteorology or by total traffic volumes on the B2026. The most likely explanation, assuming that the pattern is genuine and not an artefact of the analysis, is changes to NO_x emissions per average vehicle over this period.

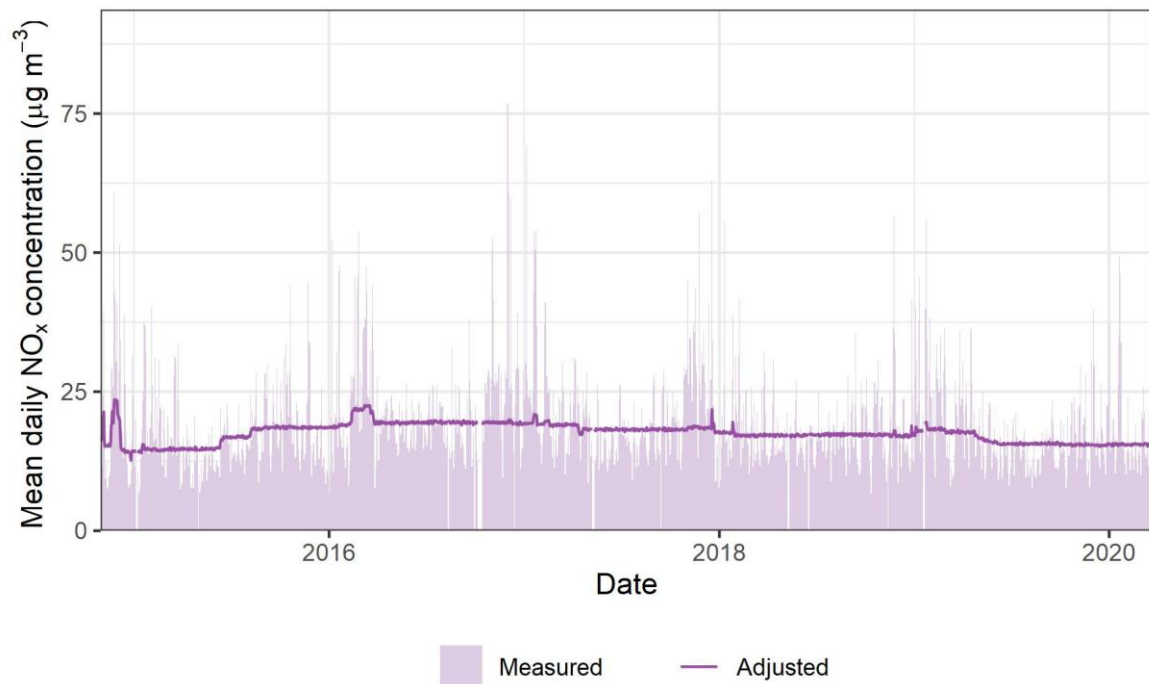


Figure 101: Deweathered Daily Mean Nitrogen Oxides Concentration

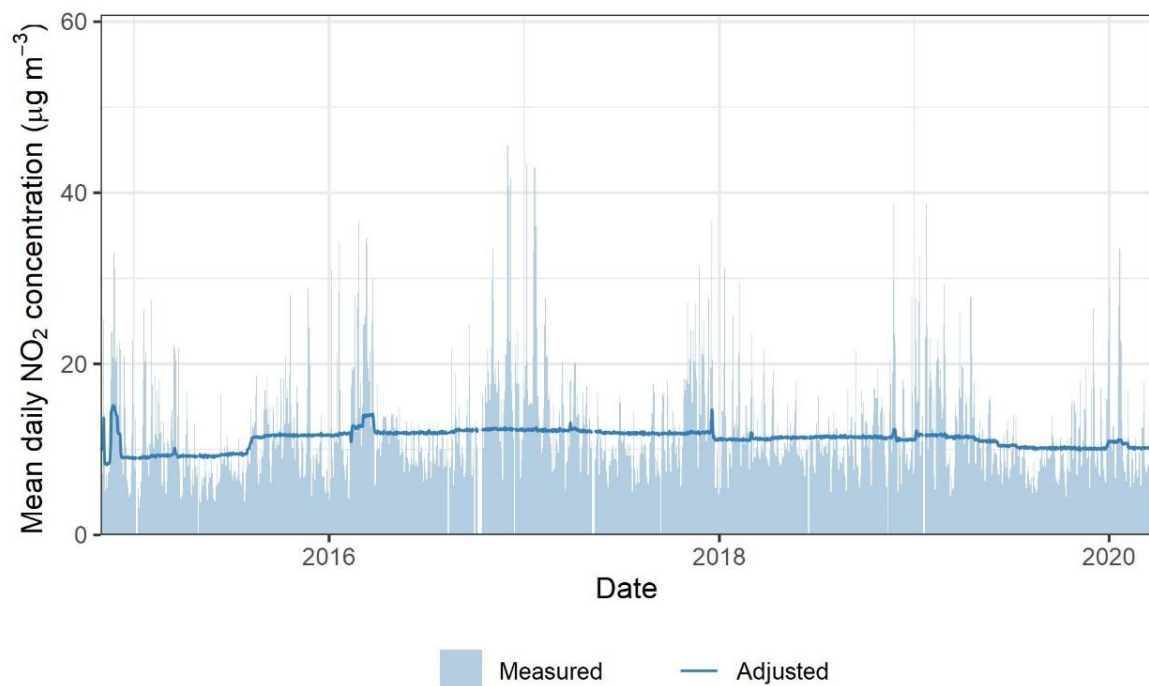


Figure 102: Deweathered Daily Mean Nitrogen Dioxide Concentration

Trends at the Diffusion Tube Sites

- 6.11 Table 9 and Table 10 set out the measured nitrogen dioxide concentrations at each site in each year. These are also shown in Figure 28 to Figure 32. For completeness the trends over time at each site are shown in Figure 103 and Figure 104⁴². In order to make these results more straightforward to interpret, Figure 105 summarises the temporal trends across all of the diffusion tube sites. For each site, each measured annual mean concentration has been expressed as a percentage of the 5-year (2015-2019 inclusive) mean concentration at that site. Figure 105 thus shows the range in the relative temporal changes at all the diffusion tube sites.

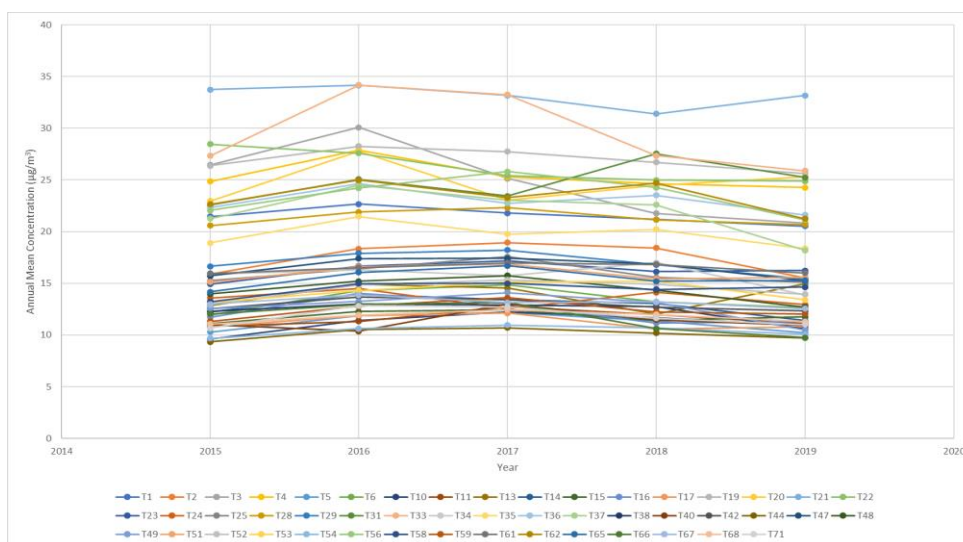


Figure 103: Annual Mean Nitrogen Dioxide Concentrations between 2015 and 2019 at Roadside Sites with 5 Years' Data

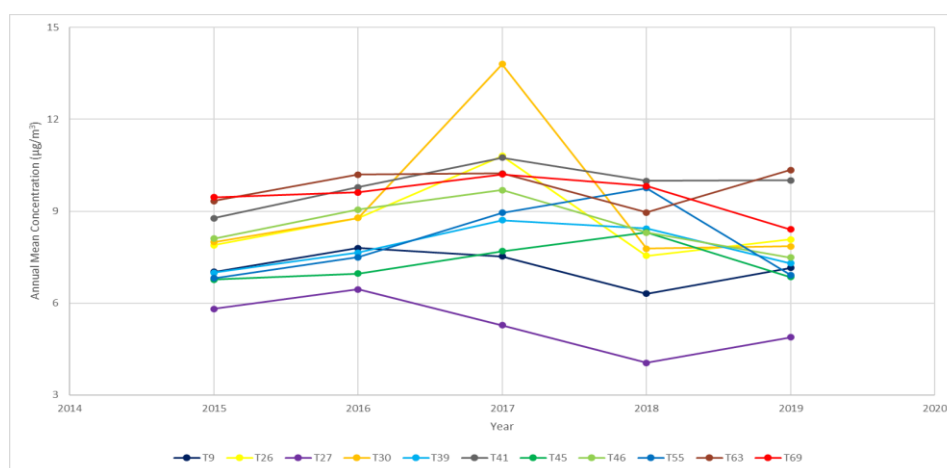


Figure 104: Annual Mean Nitrogen Dioxide Concentrations between 2015 and 2019 at Background Sites with 5 Years' Data

⁴² The intention of these figures is to show the general range in trajectories rather than to specifically allow individual values to be read from the charts. All of the data in these charts are set out in Table 9 and Table 10.

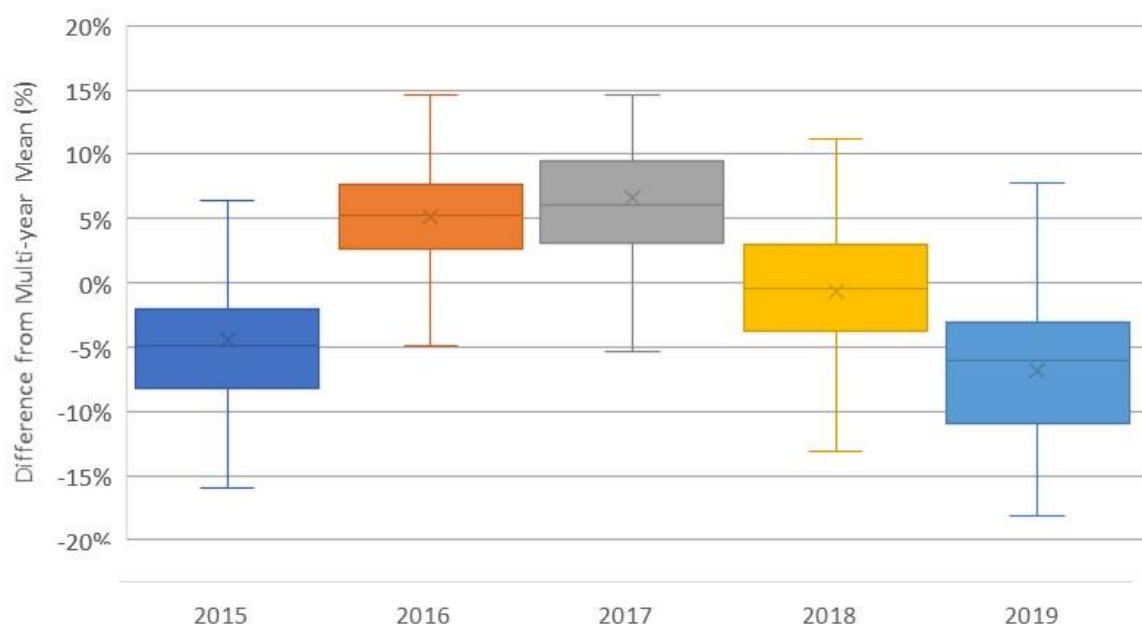


Figure 105: Relative Change in Annual Mean NO₂ at 103 Monitoring Sites in Ashdown Forest, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

- 6.12 All of the values in Figure 105⁴⁴ show a remarkably similar pattern to that shown in Figure 99 for the long-term site at Uckfield Town Centre, with a steep increase between 2015 and 2016, followed by a smaller increase between 2016 and 2017 and by reductions in both 2018 and 2019. While each individual site recorded different patterns, taken on aggregate this pattern shows considerable consistency (i.e. the same pattern is shown across all values in Figure 105⁴⁴).
- 6.13 It is interesting that the Ashdown Forest diffusion tube data show, on average, a maximum in 2017, when 2017 has, at most roadside sites in the UK, been associated with much lower concentrations than those in previous years (e.g. Figure 96 and Figure 97). Figure 106 thus focuses on the trends at background sites. Figure 107 then summarises the same data using the ('% difference') approach for Figure 105. Figure 106 and Figure 107 show that concentrations at the background sites were notably higher in 2017 than in any other year. In particular, the mean value in Figure 107 is significantly (12%) above the long-term average.

⁴³ The horizontal line highlights the median, with the x showing the mean, the box showing the extent between the 1st and 3rd quartiles. Finally, the whiskers show the maximum and minimum of the dataset following removal of outliers which are >1.5 times the interquartile range below the 1st quartile or >1.5 times the interquartile range below the 3rd quartile.

⁴⁴ i.e. the mean, median, quartiles and range excluding outliers.

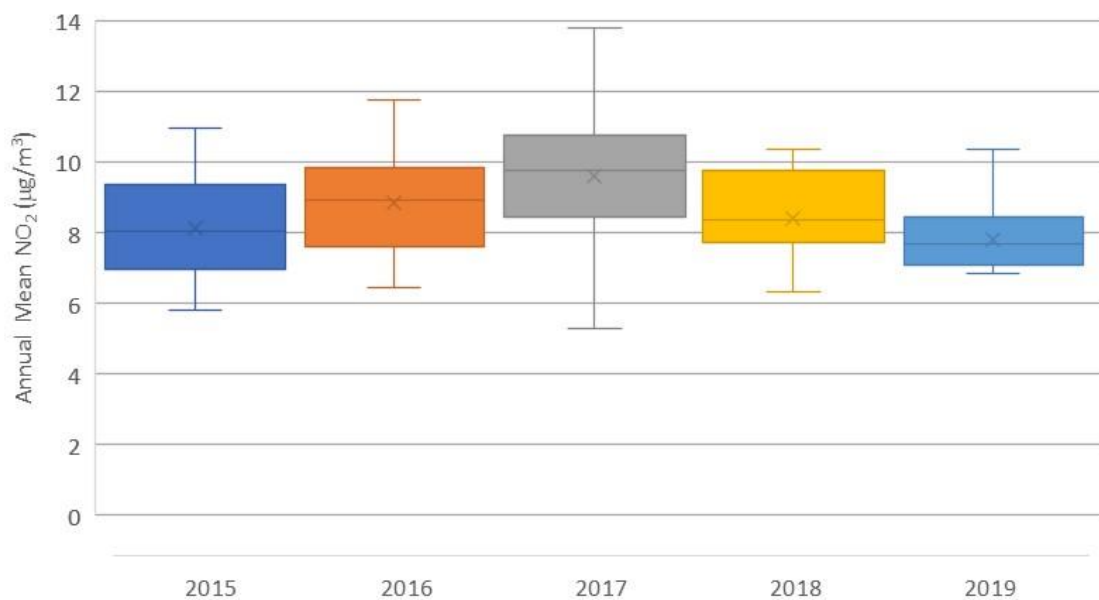


Figure 106: Annual Mean NO₂ at the 14 Background Sites in Ashdown Forest with Valid Readings for 5 Years ⁴³

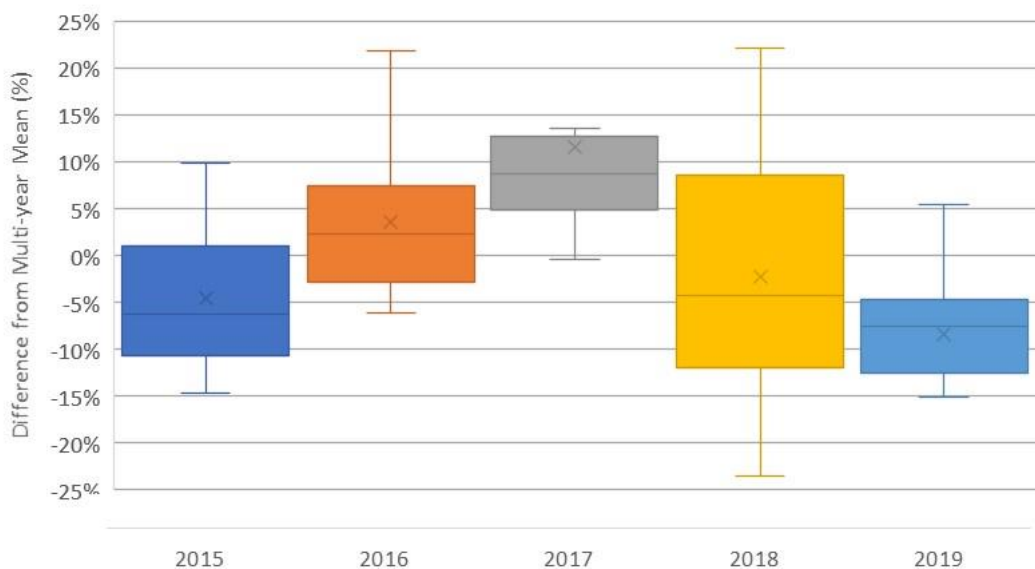


Figure 107: Relative Change in Annual Mean NO₂ at the 14 Background Sites in Ashdown Forest with Valid Readings for 5 Years, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

6.14 Figure 108 shows the results for road-NO₂ (i.e. all of measurements from roadside sites having first subtracted the mean values from Figure 106). Figure 108 thus shows the relative change over time in the local road component of measured NO₂ concentrations. This pattern is particularly interesting since 2016 now stands out as being unusually high, while 2017 is shown to be much lower. This shows that the overall trend over time is a composite of two distinct patterns. The influence of roads within Ashdown Forest was highest in 2016, and remarkably constant in each other year (2015-2019)

inclusive). The background influence (which is made up of emissions from non-traffic sources as well as traffic emissions in the rest of the UK and across Europe) increased, on average, to 2017 and reduced thereafter.

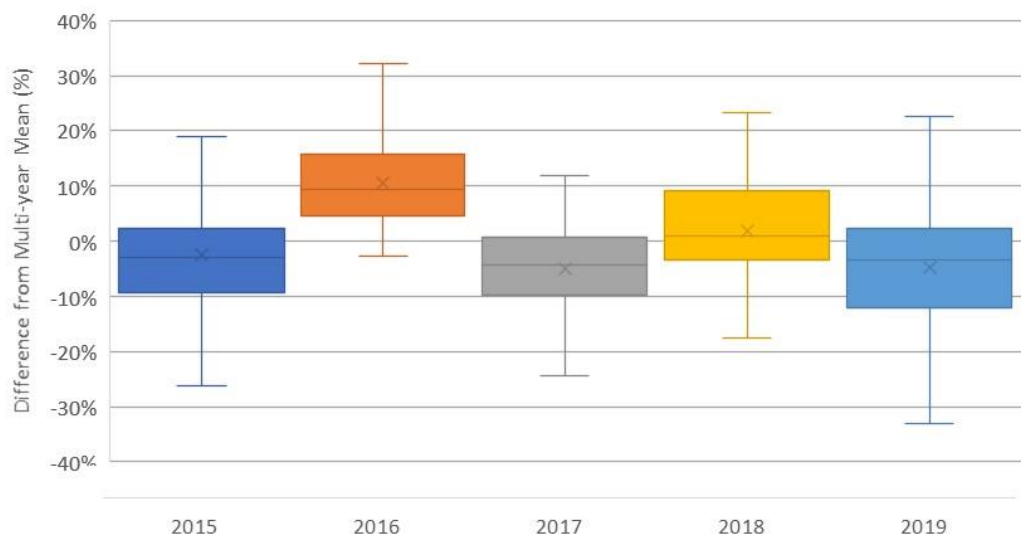


Figure 108: Relative Change in the Local Road Component of Annual Mean NO₂ at 75 Roadside Sites in Ashdown Forest, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

- 6.15 Thus, the reductions in total NO₂ since 2017 (Figure 105) appear not to have been driven by local sources but by changes to the regional background. This is highlighted in Figure 109, which repeats Figure 108 having first removed the year 2016 (so that each site-specific value is expressed relative to a 4-year mean rather than a 5-year mean). All of the mean and median values, in particular, show remarkable year-on-year consistency over these 4 years.
- 6.16 Although the measurements do not show any signs that traffic emissions have fallen, they do show (in Figure 107) that the influence of non-local sources on annual mean NO₂ may have peaked in 2017. It is, however, difficult to conclude a robust trend based on three years of measurements (i.e. two years with a downward trend following two with an upward trend).
- 6.17 The finding that traffic-NO₂ has been constant while background NO₂ has (at least most recently) been falling is not entirely unexpected. The national-level analysis summarised in Figure 96 showed that concentrations in most areas have been falling recently, but that they were not falling everywhere. Various explanations for this disparity have been suggested, but most relate to the specific characteristics of local vehicle fleets. For example, it has been suggested that the largest reductions have occurred near to urban (slow moving) roads with significant bus fleets, while those roads without large bus fleets (or where the fleet has not been upgraded⁴⁵) have not seen these benefits. A situation where the aggregate total NO_x emissions from all UK roads is falling while

⁴⁵ There is anecdotal evidence that, nationally, a drive to improve urban bus fleet has displaced older buses to more rural areas and it is the upgrading of the bus fleet rather than its mere presence which is important.

emissions from local roads are not, would cause the pattern that is observed in the Ashdown Forest diffusion tube measurements.

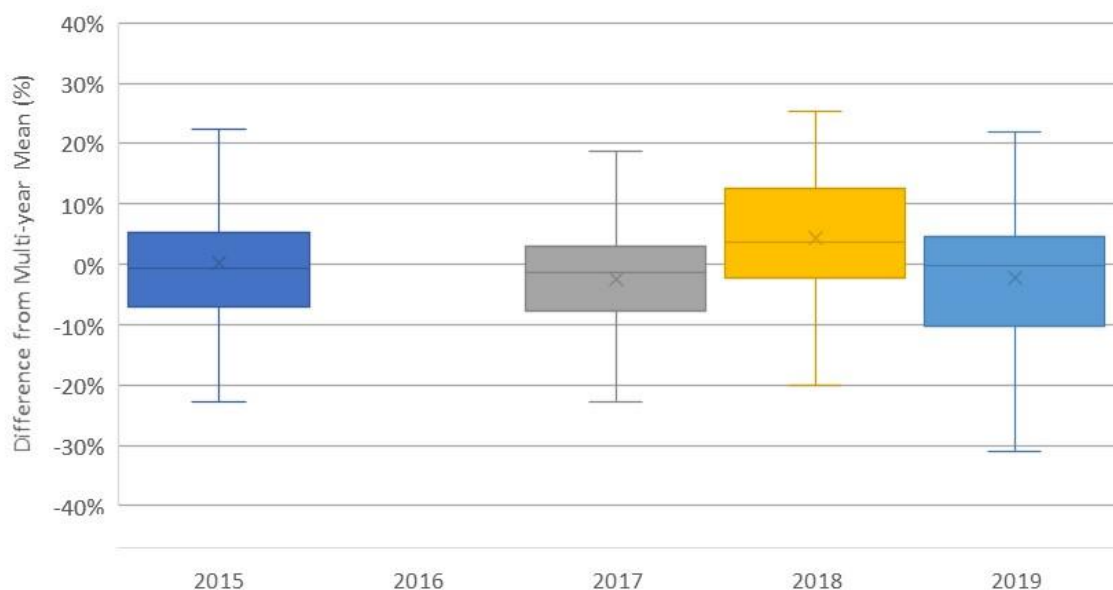


Figure 109: Relative Change in the Local Road Component of Annual Mean NO₂ at 75 Roadside Sites in Ashdown Forest Excluding 2016, Showing the Difference between Each Individual Annual Mean and the 4-Year Mean at that Site ⁴³

- 6.18 Each individual diffusion tube measurement is subject to considerable uncertainty but the large number of sites in the Ashdown Forest network allows the characterisation of these ‘average’ trends with considerable precision and reliability. It is still, however, helpful to consider trends at individual sites albeit that these are subject to greater uncertainty than the network averages. These are presented in the next subsection.

Patterns at Individual Sites

- 6.19 For each site with a consistent set of measurements (i.e. data for all five years), the relative difference of each individual annual mean road-NO₂ value from the five-year mean has been used to calculate a linear trend at each site. This gives the percentage change in road-NO₂ at each site over the period 2015 to 2019 inclusive. These results are set out in Figure 110.
- 6.20 Figure 110 shows some striking spatial patterns. For example, almost all of the monitors alongside the A22 and A275 showed a net downward trend in road-NO₂ over this period, while most of the monitors alongside several minor roads such as Crowborough Road, New Road, and Priory Road, experienced increasing road-NO₂. The transect of monitors on the A26 all experienced an increase while the monitors further north along the A26 experienced a reduction.
- 6.21 Given the sensitivity of these trends to conditions in 2016, which may have experienced atypically high concentrations owing to the weather in that year, Figure 111 repeats this exercise having first

excluded 2016. While all of the individual values change between Figure 110 and Figure 111, the overall patterns remain the same. The A22, A275 and southern sections of B2026 are largely characterised by reductions, while parts of the A26 and many minor roads are characterised by increases.

- 6.22 It is informative to compare Figure 110 and Figure 111 with Figure 39 and Figure 40 in Section 4, which show changes to traffic volumes over this period. The reductions in road-NO₂ along the A22 may be partly explained by the reductions in traffic volumes over this period, but the reductions in road-NO₂ along the A275 and B2026 cannot; since traffic increased on these roads, albeit marginally. The increases in road-NO₂ on New Road and Colemans Hatch Road coincided with a small net reduction in traffic flows. A key point to make, however, is that the scale for road-NO₂ in Figure 110 is in 10's of percent, while all of the changes in traffic volume in Figure 39 are much more modest. On balance, therefore none of the changes shown in Figure 110 can readily be explained by changes to traffic volumes.
- 6.23 While care should be taken not to infer too much from results for individual sites, the spatial patterns in Figure 110 and Figure 111 do appear to provide strong evidence of different effects on different roads. Since this is not caused by changes to total traffic volumes, it seems most likely that the differences relate to different fleet compositions, or different responses to road-specific driving conditions (e.g. speed and acceleration profiles).

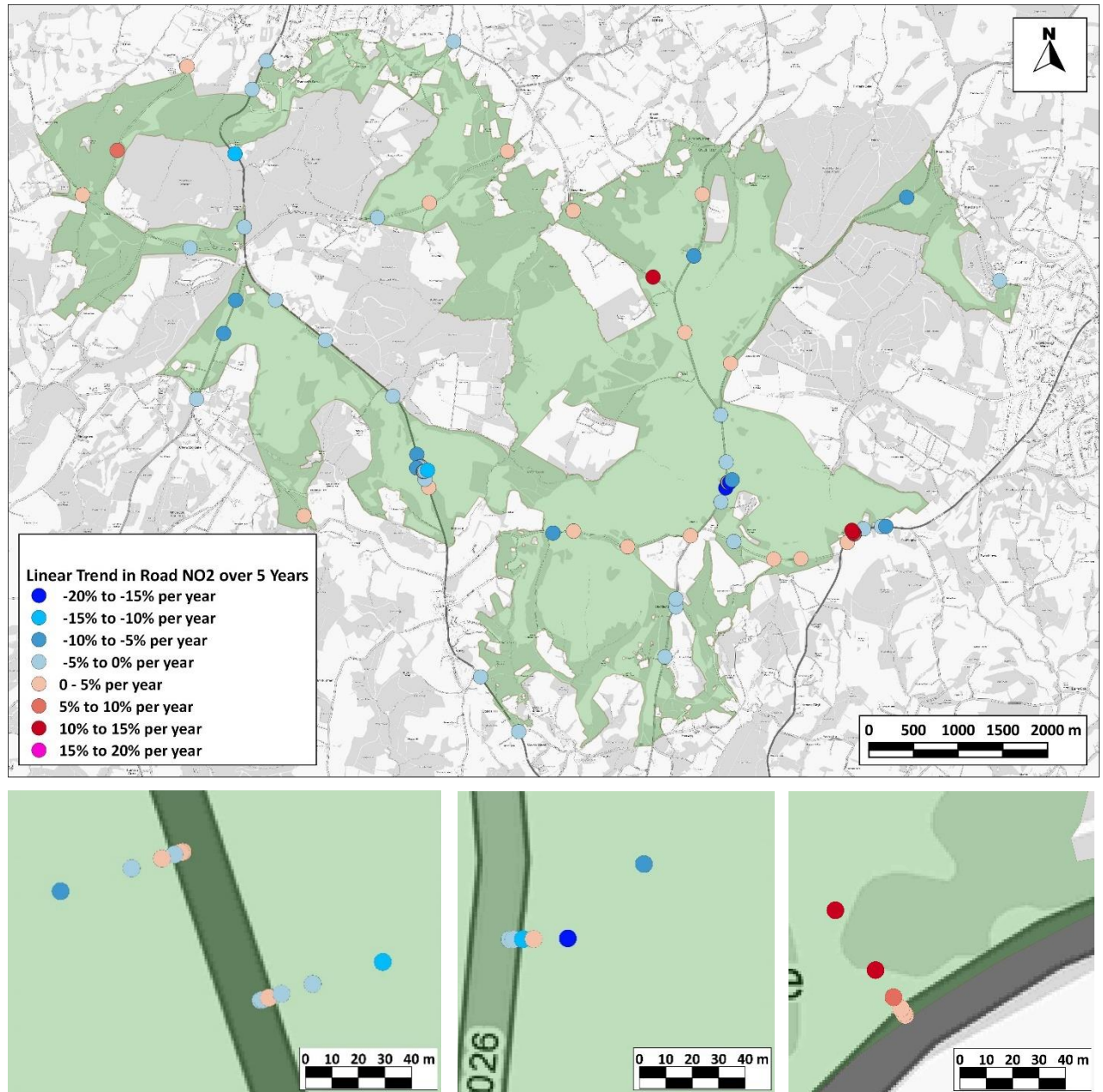


Figure 110: Linear Trend in Road-NO₂ over 5 Years (bottom showing zoomed sections, left to right, for A22, B2026 and A26)

Map Data ©2021 Google Additional data sourced from third parties, including public sector information licensed under the Open Government Licence v1.0

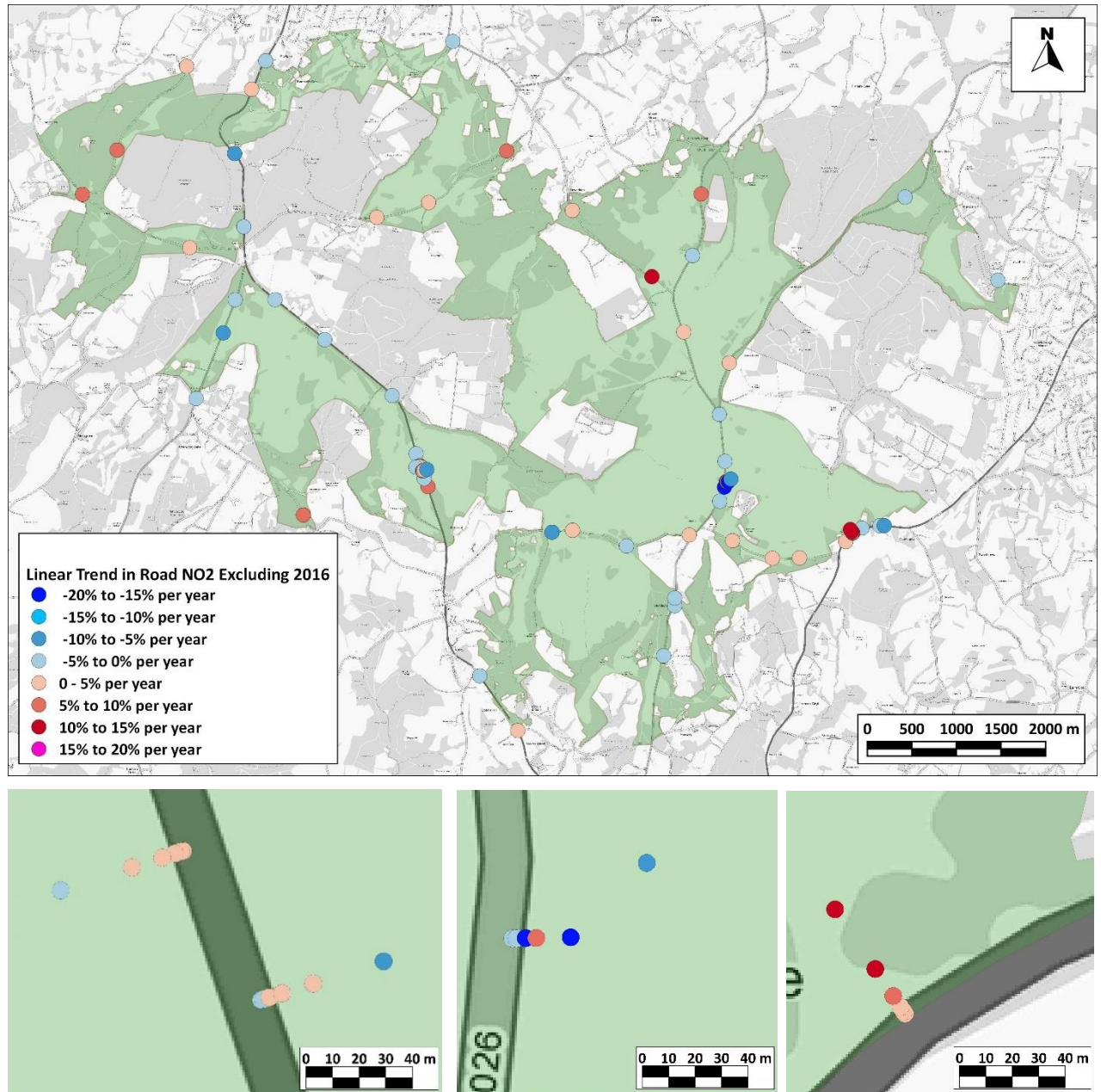


Figure 111: Linear Trend in Road-NO₂ 2015 – 2019 Excluding 2016 (bottom showing zoomed sections, left to right, for A22, B2026 and A26)

Map Data ©2021 Google Additional data sourced from third parties, including public sector information licensed under the Open Government Licence v1.0

NH₃

Context

- 6.24 There are no other long-term monitoring studies of traffic-related NH₃ in the UK which have used comparably robust instruments. AQC's Calculator for Road Emissions of Ammonia (CREAM V1A) model predicts that emissions of NH₃ per vehicle (on a rural road outside London with 5% HDV) would reduce by an average of 0.5% per year between 2015 and 2019 (this is the average of a small reduction to 2018 followed by a small (0.2% per year) increase to 2019). JNCC's Nitrogen Futures project⁴⁶ has predicted that background NH₃ concentrations across Ashdown Forest will increase between 2017 and 2030 by approximately 10% (assuming no new mitigation), while NH₃ concentrations at the roadside might increase by up to approximately 15% over the same period.

Trends at the Kingstanding Automatic Monitor

- 6.25 Figure 112 shows the trend in annual mean NH_x concentrations measured at the Kingstanding automatic analyser. The results show a reduction between 2015 and 2017, with relatively static concentrations thereafter.



Figure 112: Annual Mean NH_x Measured at the Kingstanding Automatic Monitor

- 6.26 As explained for NO_x and NO₂ in Paragraph 6.6, a statistical analysis using Boosted Regression Trees has been used to remove the influences of weather from the timeseries of measured concentrations. Figure 113 shows the raw measured NH_x concentrations alongside the 'deweathered' trend, which simulates the concentration which would have been measured if all meteorological variables were held constant. This includes seasonal factors and so cyclical patterns in biogenic emissions and farming are also, to an extent, compensated for in the 'adjusted' line

⁴⁶ Annex 5 contains detailed modelling for Ashdown Forest. <https://data.jncc.gov.uk/data/04f4896c-7391-47c3-ba02-8278925a99c5/JNCC-Report-665-Annex5-FINAL-WEB.pdf>

shown in Figure 113. As explained in Paragraph 6.6, this analysis is not wholly precise, but nevertheless provides a helpful indication of the effects of weather and of the underlying trend caused by other factors.

- 6.27 The long period of elevated NH_x concentrations during the summer is largely removed in the adjusted trend, suggesting that the elevated concentrations in 2018 when compared with other years were caused by the weather. There appears to be a pattern of reducing concentrations between 2015 and 2020, but the reduction is small and may be a function of uncertainty in the method. Nevertheless, from the data available, there does appear to be a downward trend in weather-adjusted NH_x concentrations over the time series; with average concentrations consistently higher than $2.5 \mu\text{g}/\text{m}^3$ during 2015 and 2016, and being less than $2.5 \mu\text{g}/\text{m}^3$ throughout much of 2018 and 2019.
- 6.28 Figure 76 in Section 5 shows the trend line after normalising not only for weather but also for changes to traffic volumes. This shows essentially the same pattern as Figure 113, which is to be expected given the relatively constant daily traffic volumes measured on the B2026 over this period.

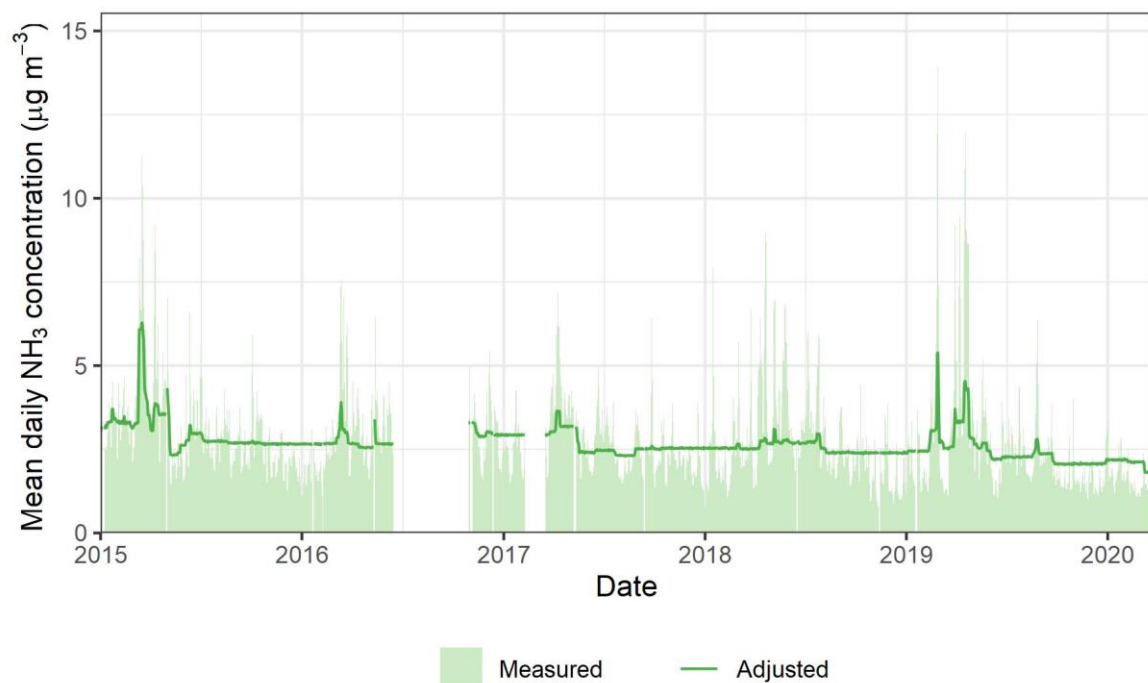


Figure 113: Deweathered Daily Mean NH_x Concentration

Trends at the ALPHA and DELTA Sites

- 6.29 Figure 114 to Figure 116 summarise the measured annual mean NH_3 concentrations over the five full calendar years with available data at all the ALPHA and DELTA sites. There is a general pattern for concentrations at the ALPHA sites to increase over the period 2015 to 2018, and then to reduce to 2019. The patterns are, however, slightly different at each site, with several ALPHA sites

recording reductions between 2015 and 2016, and the increases to 2018 being steeper at some sites than others. The temporal patterns at the DELTA sites are broadly similar, but it is noteworthy that the clear peak to 2018 which is evident at the majority of ALPHA sites is not present at most of the DELTA sites. This does, though, appear to be a function of site location rather than a systematic difference between the two types of analyser. For example, ALPHA Site R1.3 is co-located with DELTA site D1 and the increase to 2018 is steepest at the DELTA site rather than the ALPHA site. Similarly, temporal patterns at the collocated sites “D3” sites do not appear very different when comparing the ALPHA and DELTA plots.

- 6.30 Site D3 is also collocated with the automatic analyser. Thus, while the automatic analyser shows a general downward trajectory for NH_x, both the DELTA and ALPHA at this location show a general upward trajectory. Because the DELTA is considered to be the reference instrument for NH₃ in the UK, it is considered to provide a more accurate summary of long-term trends at this site.

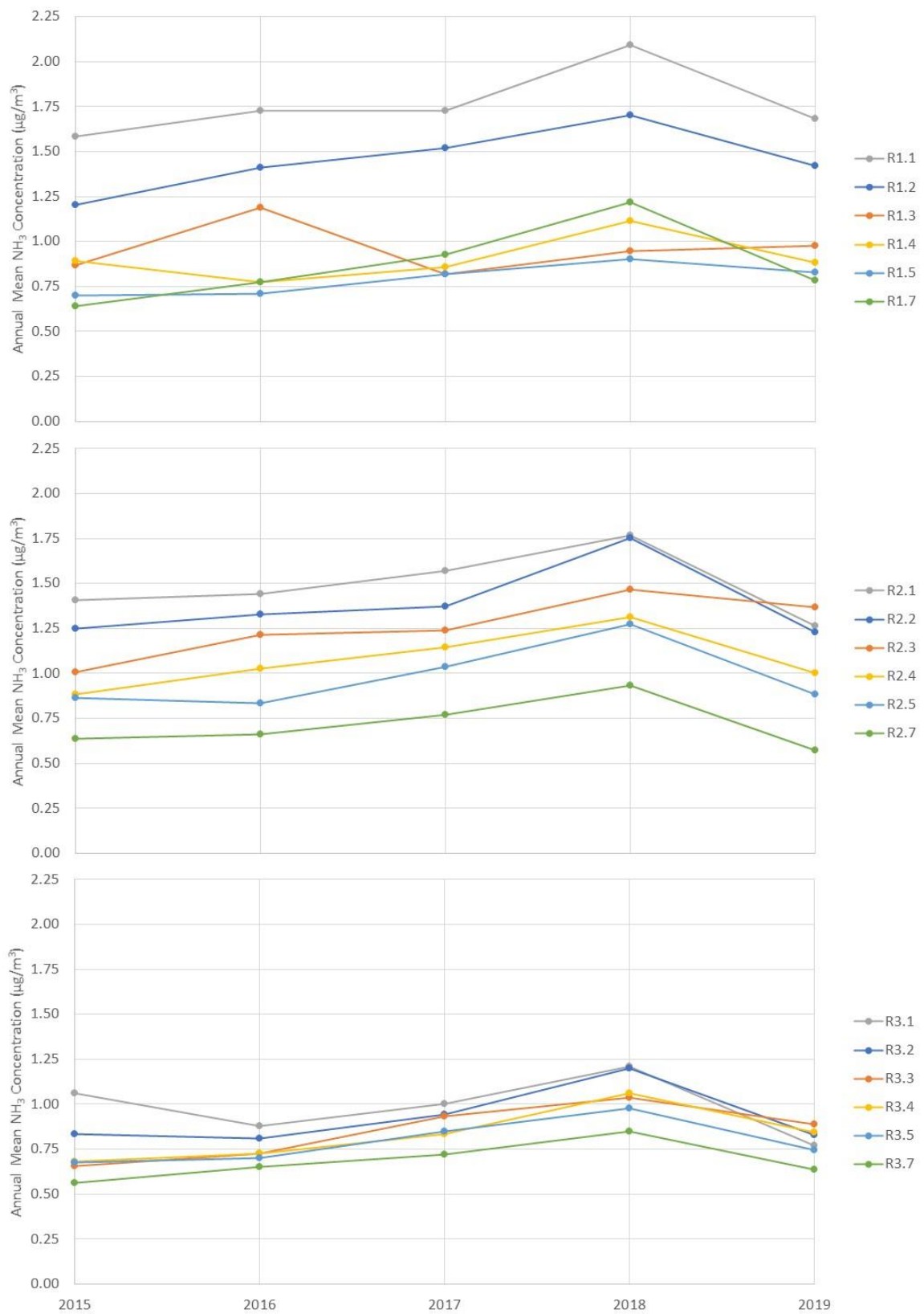


Figure 114: Annual Mean NH_3 over 5 Calendar Years at 18 ALPHA Sites (Transects 1 to 3)

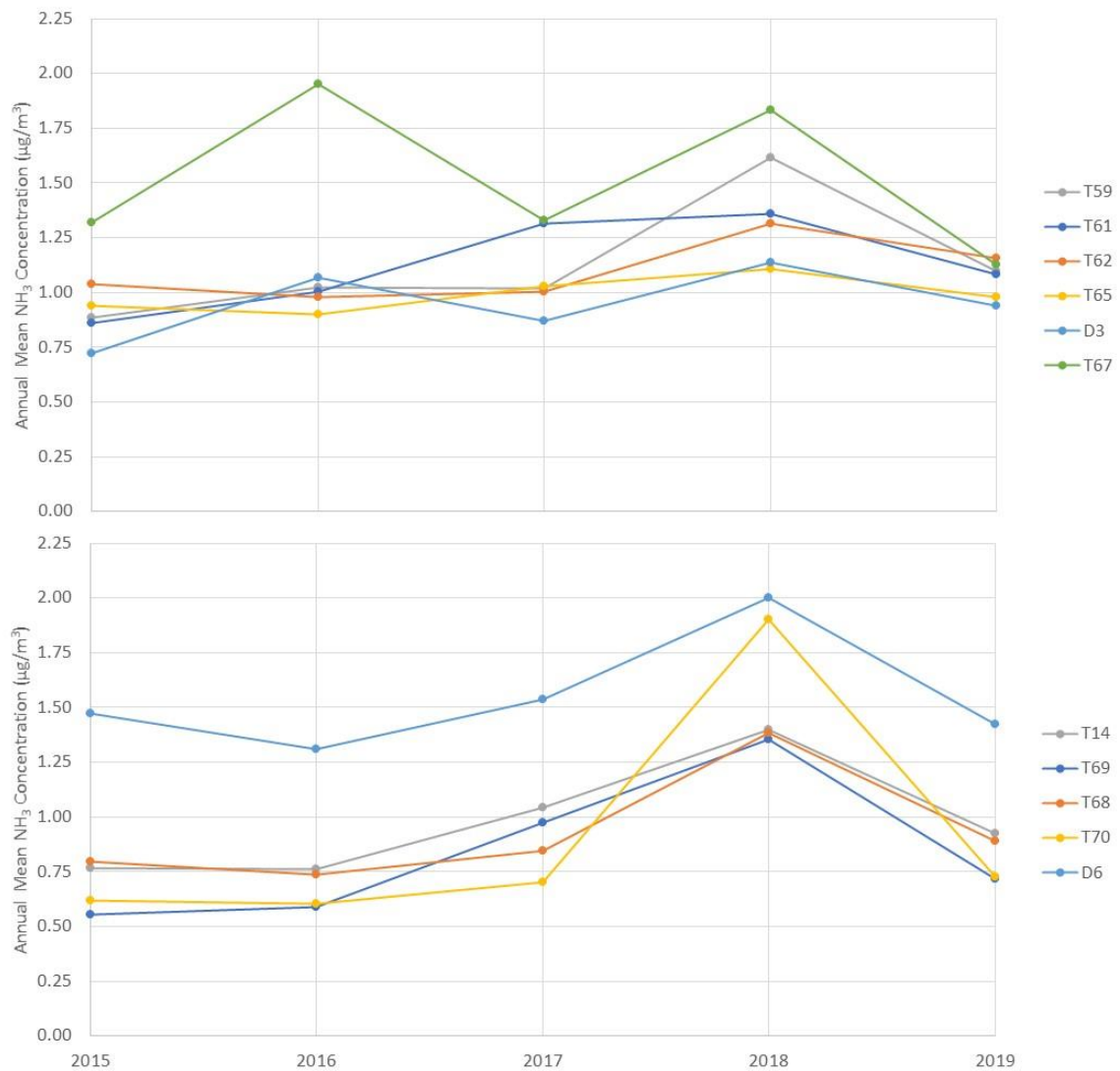


Figure 115: Annual Mean NH_3 over 5 Calendar Years at 11 Non-transect ALPHA Sites⁴⁷

⁴⁷ The choice of which site appears in the top or bottom plot is random. They are separated simply to aid visual interpretation.

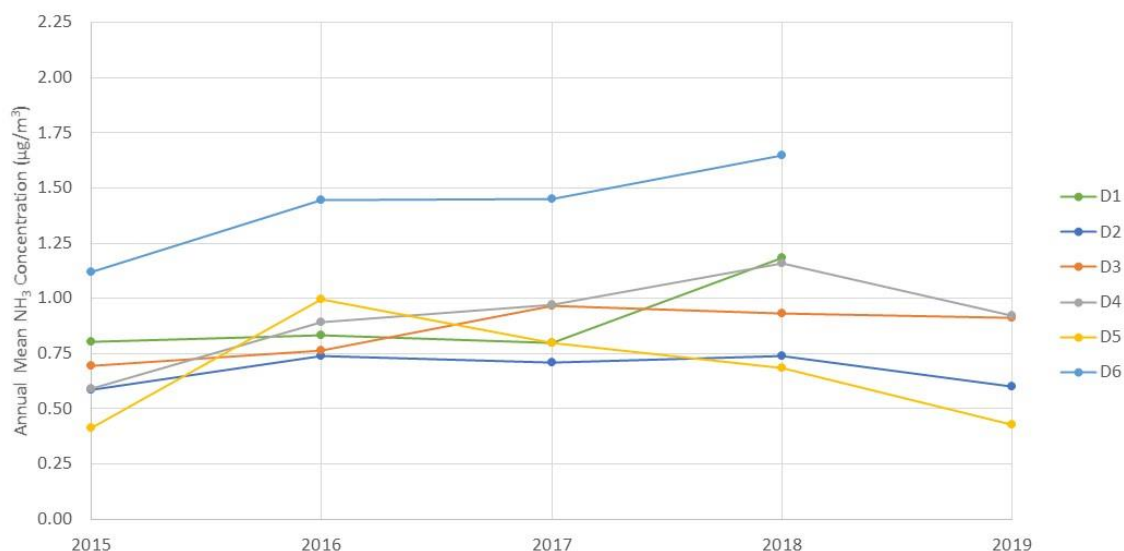


Figure 116: Annual Mean NH₃ over 5 Calendar Years Measured using DELTA Samplers

- 6.31 Figure 117 summarises the temporal trends in measured annual mean NH₃ concentrations across all the ALPHA and DELTA sites, expressed in the same way as used for NO₂ in Figure 105. This highlights the pattern observed in the previous paragraph, with steadily increasing concentrations between 2015 and 2017, a steep increase to 2018, followed by a reduction to 2019.
- 6.32 As with NO₂, it is most informative to separate out the trends at those sites which are well away from roads from those which are not. Figure 118 and Figure 119 summarise the changes over time at the seven background NH₃ sites, first in absolute and then in relative terms. These follow almost the same pattern as the 'all sites' plot in Figure 117. Figure 120 then shows change in the residual component of concentrations at the roadside (i.e. total concentrations minus the relevant background⁴⁸ to give the road increment to concentrations). The temporal pattern in the road increment to NH₃ (Figure 120) is very different from that for total NH₃ shown in Figure 117. Road-NH₃ appears to have reached its minimum in 2016 and has increased, on average, each year since.
- 6.33 As explained in Section 5, NH₃ is more difficult to measure precisely than NO₂ and is also subject to local biogenic emission. The range in the results in Figure 120 is thus greater than in the equivalent plots for NO₂. In order to more precisely define the road increment to concentrations, Figure 121 focuses on only those sites which are within 3 m of the kerb (since the road signal is strongest, and thus clearest, at these sites). The overall pattern in Figure 121 is much the same as that shown for all roadside sites in Figure 120. For completeness, Figure 122 shows the equivalent plot for all roadside sites but excluding 2016 (which was deemed to be a potentially atypical year for NO₂).

⁴⁸ Because background NH₃ is more spatially variable than background NO₂, a single value has not been used for this current analysis. The background for each transect is taken as the minimum point measured on that transect. The background for Site D3 is taken as the minimum measured on Transect 3. The background for all remaining sites was defined as the average across all background monitors.

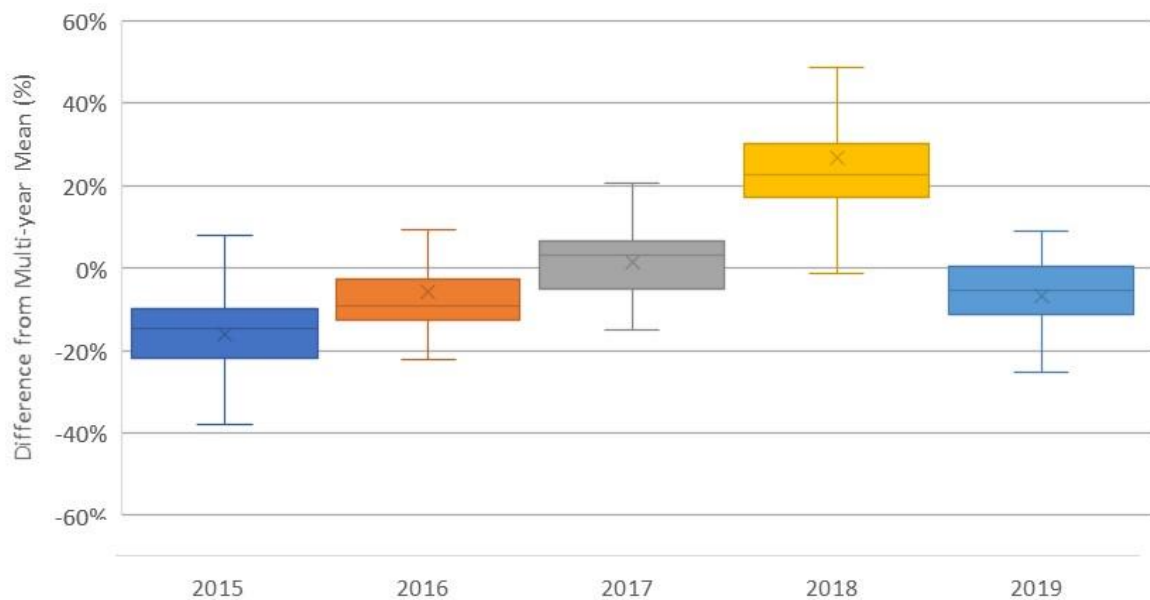


Figure 117: Relative Change in Annual Mean NH_3 at 35 ALPHA and DELTA Monitoring Sites in Ashdown Forest, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

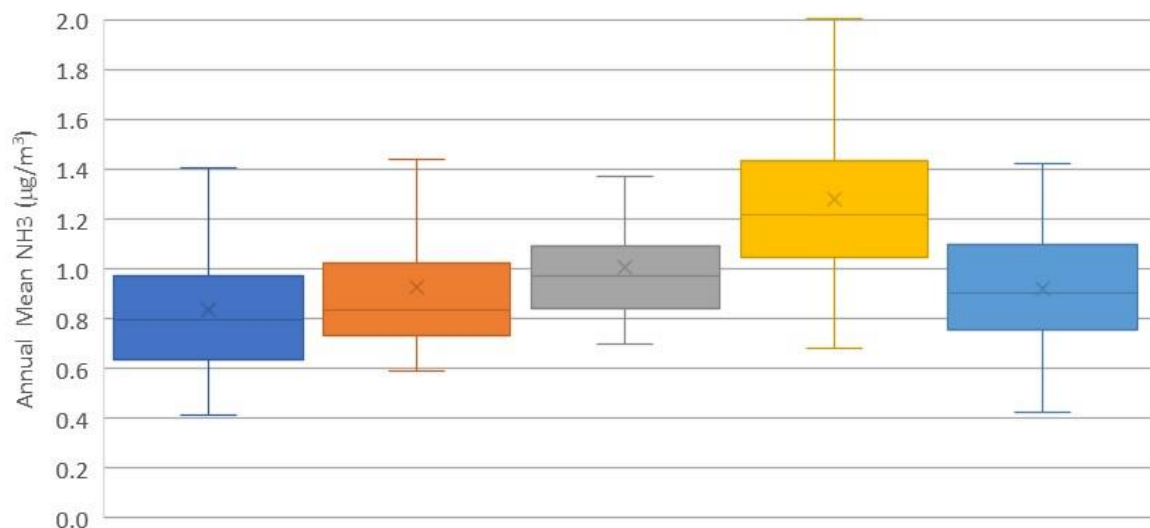


Figure 118: Annual Mean NH_3 at the 7 Background Sites in Ashdown Forest over 5 Years ⁴³

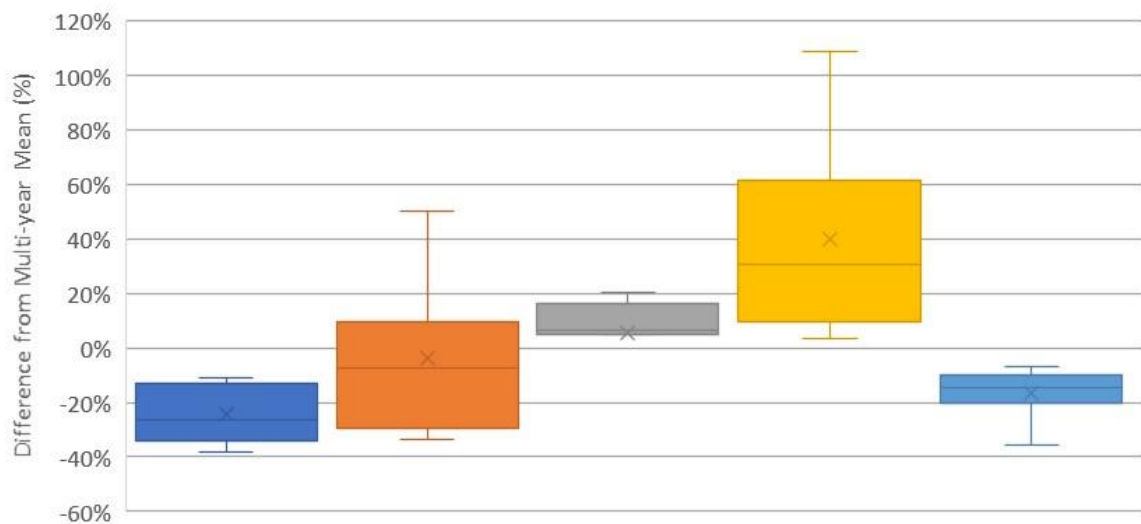


Figure 119: Relative Change in Annual Mean NH_3 at the 7 Background Sites in Ashdown Forest, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

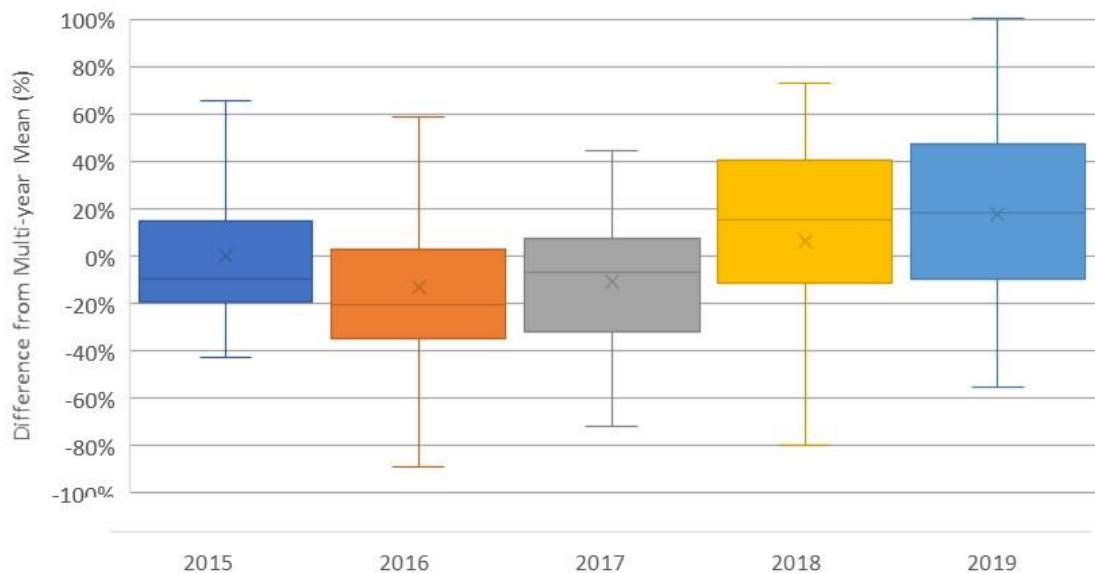


Figure 120: Relative Change in the Local Road Component of Annual Mean NH_3 at 28 Roadside Sites in Ashdown Forest, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

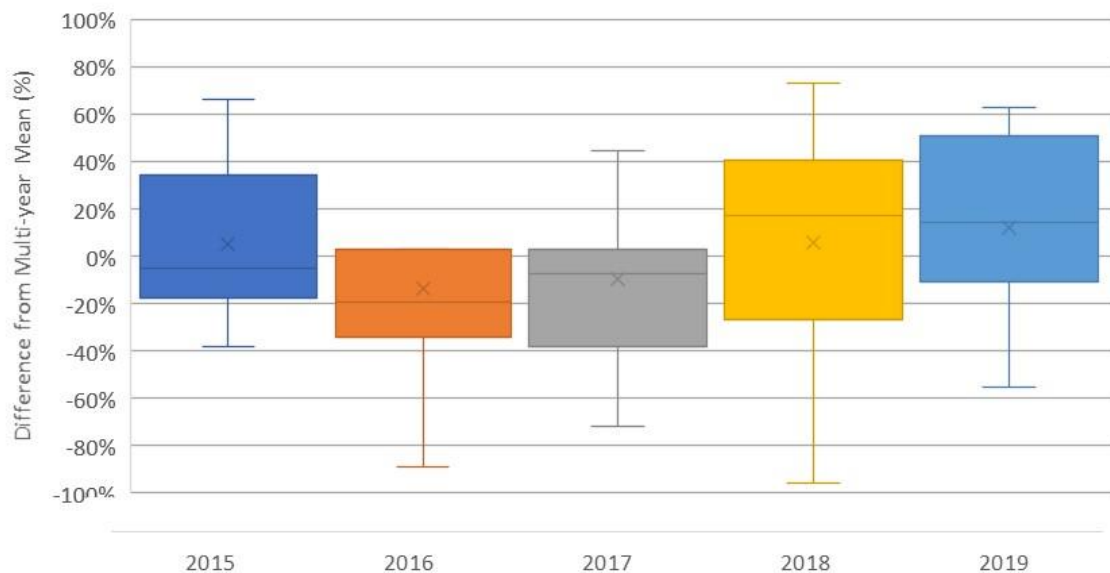


Figure 121: Relative Change in the Local Road Component of Annual Mean NH₃ at the 15 Sites in Ashdown Forest which are Less than 3 m from the Kerb, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

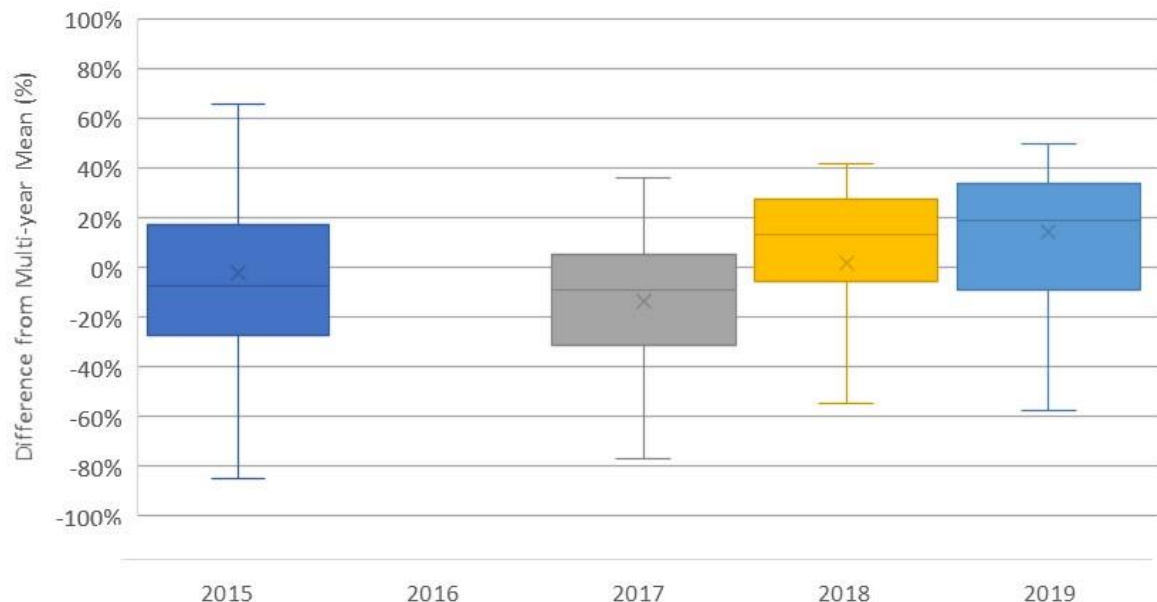


Figure 122: Relative Change in the Local Road Component of Annual Mean NO₂ at 28 Roadside Sites in Ashdown Forest Excluding 2016, Showing the Difference between Each Individual Annual Mean and the 4-Year Mean at that Site ⁴³

6.34 It is interesting that 2016 resulted in unusually high road-NO₂ but some of the lowest values for road-NH₃. Concentrations of both pollutants will have been affected by the same meteorological factors and this suggests that the trends may have been driven more by emissions than by meteorology. It is not possible to discern the reason from the available data.

6.35 Following the same approach used for road-NO₂, Figure 123 shows the average temporal trend in road-NH₃ at each individual site with data for all five years. A downward trend was recorded at 5 sites, while an upward trend was recorded at 19 sites. The increased scale in Figure 123, when compared with the equivalent plots for road-NO₂, should be noted. Increases of up to 29% per year (at DELTA D4) and reductions of up to 20% per year (at ALPHA R3.1) were observed; although it should again be noted that the values for road-NH₃ are considered less precise than those for road-NO₂ and that these analyses of trends at individual sites will be less robust than the multi-site averages shown previously.

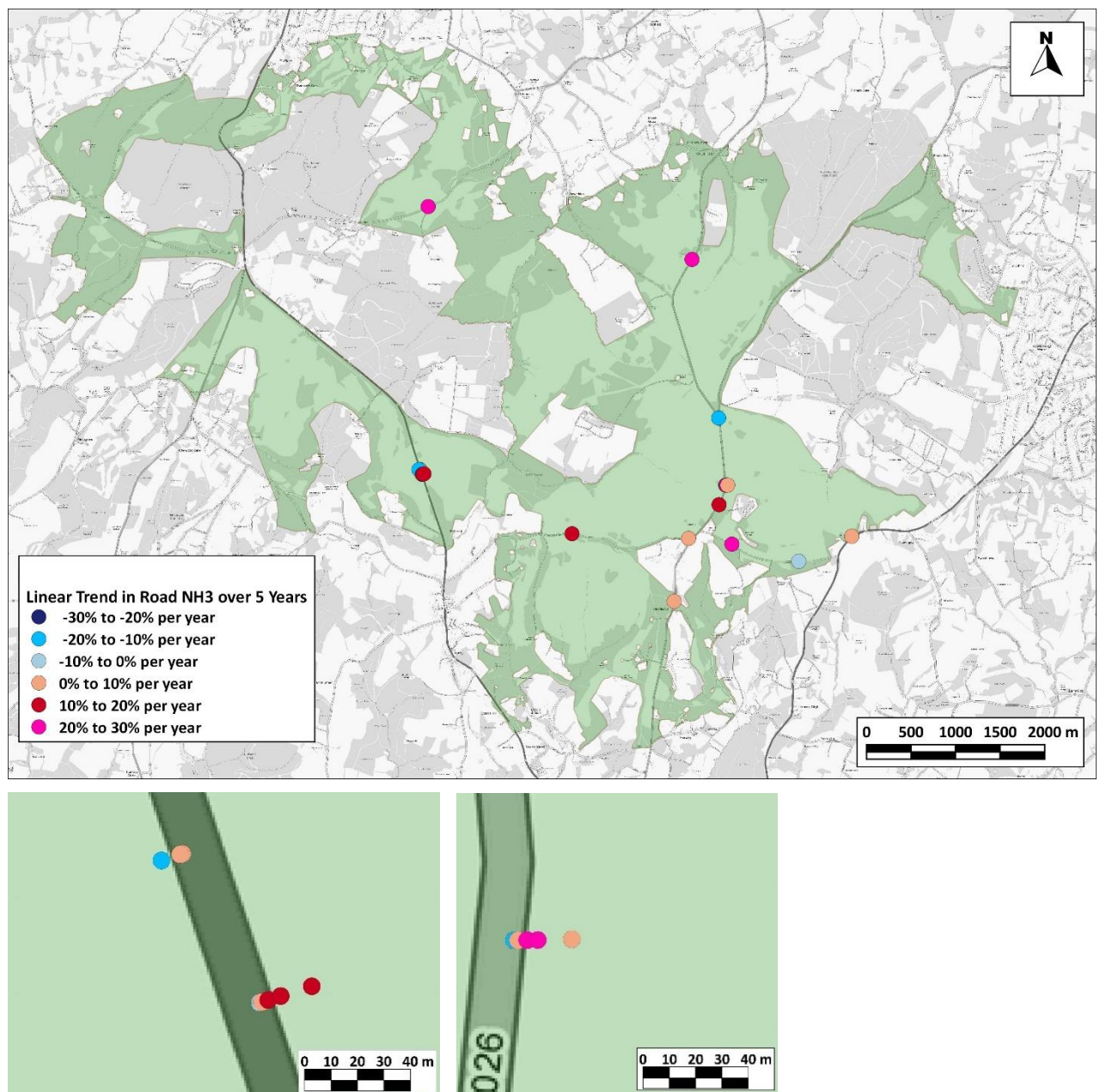


Figure 123: Linear Trend in Road-NH₃ over 5 Years (bottom showing zoomed sections, left to right, for A22 and B2026)

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- 6.36 Figure 123 does not show any clear spatial pattern. The apparent change in trend along each of the transects shown at the bottom of Figure 123 most likely reflects uncertainty in this analysis rather than a real spatial pattern. Given the high level of uncertainty in these results on a site-by-site basis, it is considered most appropriate to focus on the average when taken across all sites. Applying a linear trend to the all-site mean data from Figure 120 suggests that road-NH₃ increased by 5% per year on average between 2015 and 2019 inclusive (Figure 120).

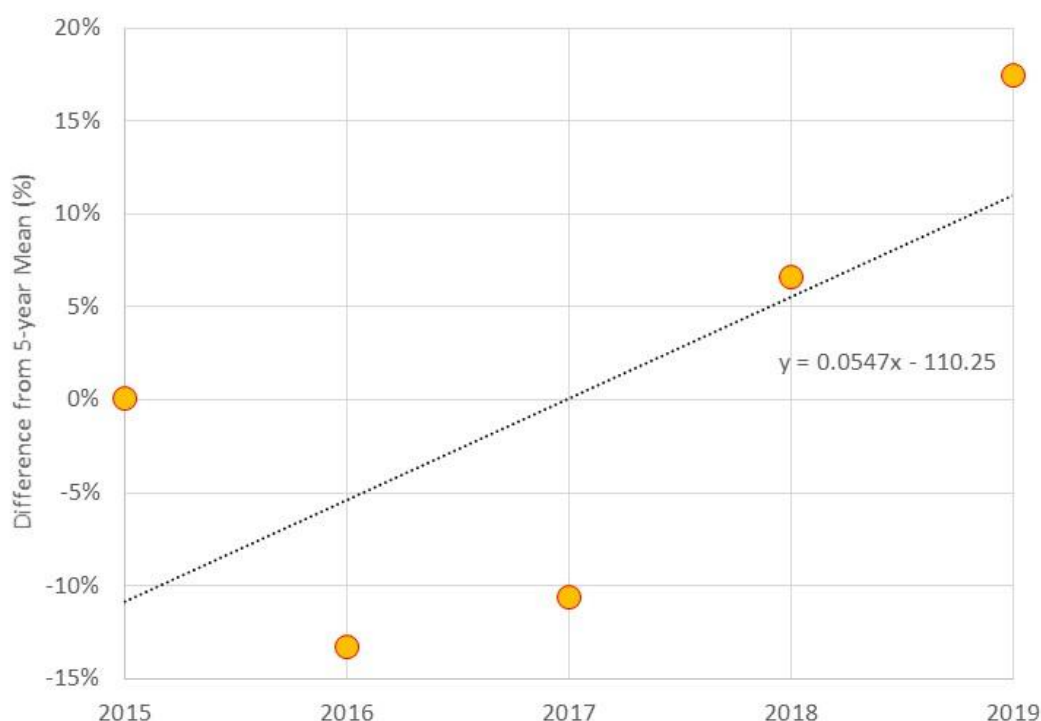


Figure 124: Change over Time in the Average Local Road Component of Annual Mean NH₃ at 28 Roadside Sites in Ashdown Forest

Road-NO_x to Road-NH₃ Ratios

- 6.37 Figure 125 compares all the measured annual mean road-NH₃ values against the concurrent and co-located road-NO_x values⁴⁹. Each plot differentiates between two datasets, with the orange dots showing only those sites which provided a valid annual mean measurement in all five years, while the blue dots show the additional measurements available for each individual year. As would be expected given both gases are emitted from traffic using the same roads, there is a correlation between the two pollutants. The Total Least Squares (TLS)⁵⁰ regression line is thus plotted across both the orange (year-on-year consistent, shown by the orange dashed line) and orange+blue (all

⁴⁹ Road-NO_x calculated from measured roadside and background NO₂ following the approach described in Section 4.

⁵⁰ Measurement error will exist in both the NO_x and NH₃ data and so Total Least Squares (TLS) (also called Bivariate Least Squares) regression has been used, with all variances set to be equal and forced through zero. In practice, to the precision of the slope values shown, Ordinary Least Squares (OLS) regression (which is the more common approach to trend fitting) gives the same values and so, in this case, the difference between TLS and OLS is largely moot.

sites in each year, shown by the blue dashed line) datasets. Each plot also shows the numerical slope of both lines, with orange and blue font used to describe the slope of the orange and blue dashed lines respectively.

- 6.38 Figure 125 shows that, in 2015 and across all sites, road-NH₃ was 0.022 times road-NO_x. However, if only those sites which recorded a valid annual mean measurement in each year are counted, then road-NH₃ was an average of 0.023 times road-NO_x. The purpose for providing two separate trend lines and slope values in each year is to maximise the data availability while also providing a consistent basis for describing any changes over time. It is most appropriate to consider the consistent (orange) data when considering trends over time, although Figure 125 shows that, in practice, there is little difference between the slopes of the blue and orange lines.
- 6.39 Figure 126 compares all of the orange slope values (i.e. for consistent datasets) from Figure 125. It shows that the ratio of road-NH₃ to road-NO_x fell (from 0.22 to 0.19) between 2015 and 2016 but then rose in each subsequent year.
- 6.40 NH₃ and NO_x are both primary pollutants and so Figure 126 provides a like-for-like comparison. However, unlike NH₃, NO_x is not measured directly⁵¹. NO_x has, instead, been calculated from measured NO₂. This introduces potential error into the analysis of changes over time, because the calculation uses year-specific estimates of primary NO₂ proportions, as well as regional background NO₂ and O₃ concentrations. These estimated values might 'drift' over time (because the prediction and reality change at different rates). In order to test whether 'drift' in these modelled values has caused the apparent trend in Figure 126, Figure 127 presents the same analysis using road-NO₂ instead of road-NO_x. Road-NO₂ comes directly from the measurements and is thus not subject to this potential bias. While the numerical values in Figure 127 are different from those in Figure 126, the trend over time is largely the same. This shows that changes to the calculated NO_x:NO₂ ratios have not affected the analysis.
- 6.41 As would be expected from the analyses presented above for changes to road-NO₂ and road-NH₃ over time independently, there appears to be pattern of increasing NH₃ to NO_x ratios in traffic exhausts. It does, though, remain unclear whether either 2015 or 2016 (or both) represent aberrations from a wider trend. Thus, while the measurements suggest a 7% increase in NH₃:NO_x over the 2015 to 2019 period (or, indeed, a 27% increase over the 2016 to 2019 period), this may not reflect a long-term pattern. It does, though, provide the best current evidence that NH₃:NO_x ratios may be increasing in UK vehicle exhausts.

⁵¹ NO_x was measured directly at one of the sites but for consistency, the value used here is taken from the triplicate diffusion tubes at that site.

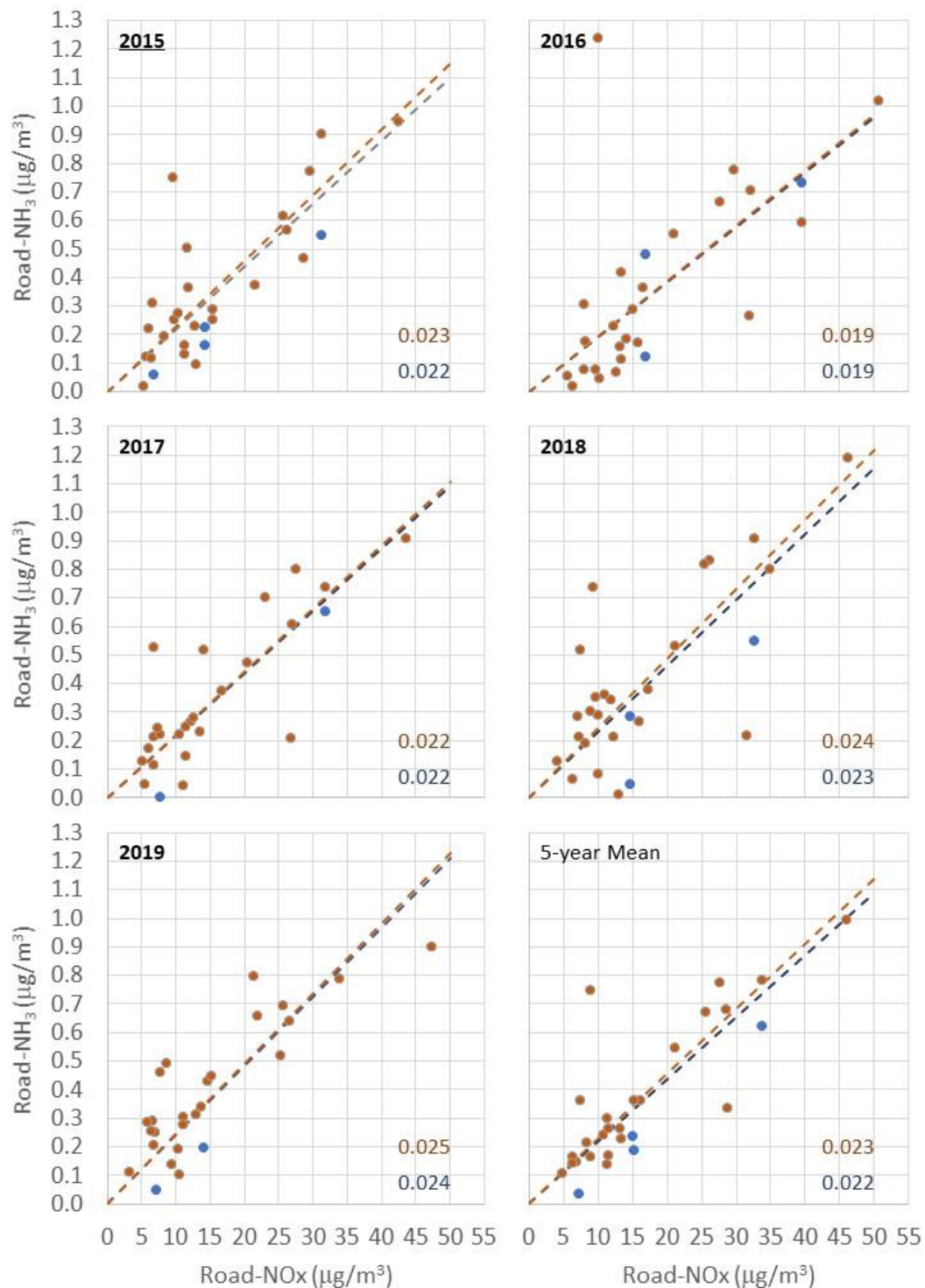


Figure 125: Annual Mean Road-NOx vs Road-NH₃ over 5 Years – orange = only sites available in every year; blue = additional sites available in that year. TLS Regression Lines (orange and blue, with orange representing the consistent dataset and blue representing all sites) fitted to each dataset. Slopes of regression lines (orange and blue) at bottom right of each plot

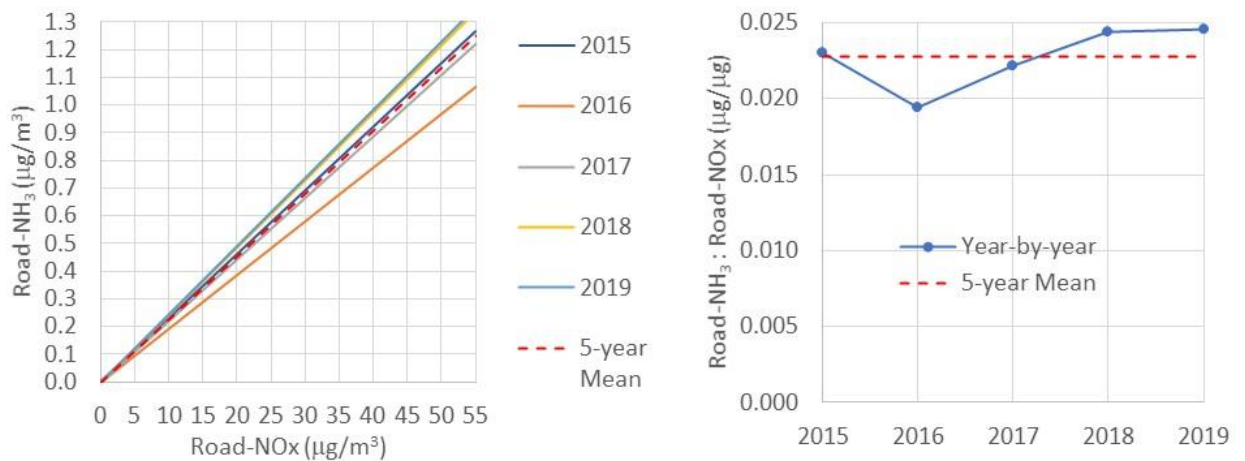


Figure 126: Comparison of the TLS Regression Slopes from the Orange (consistent dataset) Regression Lines in Figure 125 - Left, reproducing the lines from the plots and right, showing the change slope values over time

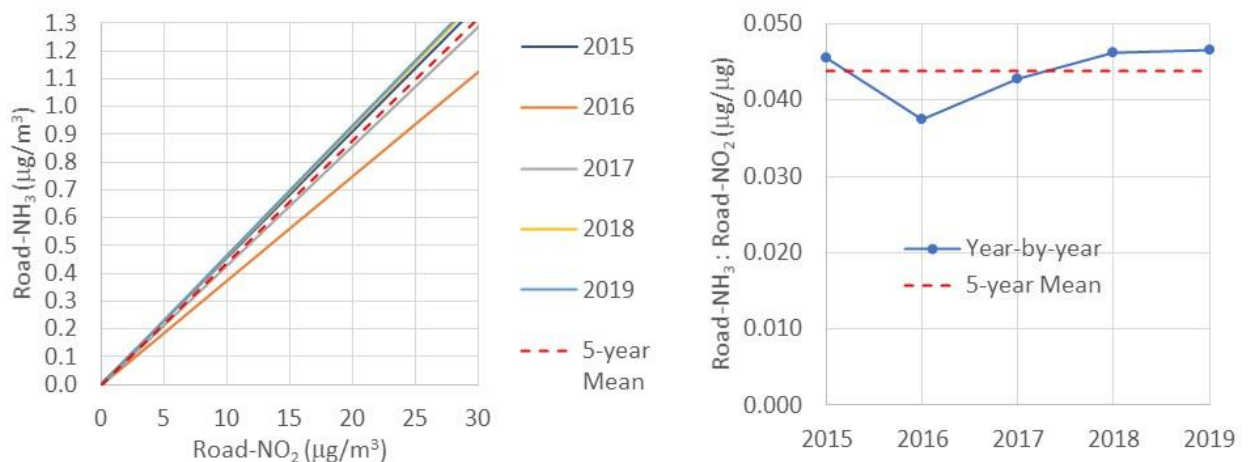


Figure 127: Slope Lines over Time for TLS Regression of Road-NH₃ vs Road-NO₂

6.42 It should also be stressed that the increase in road-NH₃ to road-NOx is based on measured and not modelled values. In particular, it relates to the situation described in Paragraph 6.17, where local road-NO₂ and road-NOx has not been falling, rather than that described in Paragraph 6.3, where appreciable year-on-year falls in road-NO₂ and road-NOx were predicted using Defra's models. It would not, therefore, be appropriate to apply the slope defined in Figure 126 to a modelled trend of reducing NOx emissions.

Deposition

Deposition to Background Locations

- 6.43 Figure 128 shows how the calculated dry deposition flux to background locations changed over the five complete years of the study. As described in Paragraph 5.79, relatively small spatial differences were observed in the calculated HNO_3 , HONO , pNH_4^+ , pNO_3^- , and pNO_2^- fluxes and so the values used in Figure 128 are the averages across all sites which recorded valid annual mean concentrations in all five years (i.e. all DELTA sites excluding D1 and D6). The background NO_2 and background NH_3 fluxes have been calculated from the average concentration measured at all background sites which recorded valid annual mean concentrations in all five years. As explained in Paragraph 5.77, wet deposition (which was not measured as part of the study) is expected to have added in the region of 9.3 kg-N/ha/yr, but Figure 128 describes dry deposition only. As is also explained in Paragraph 5.77, the use of deposition velocities from AQTAG is likely to have caused deposition at background locations to have been over-predicted while under-predicting deposition of NO_2 at the roadside. These biases will, however, be the same during each year and so the pattern of change year-on-year will be more precise than the actual calculated fluxes.
- 6.44 Dry deposition to background locations (i.e. well away from roads) is likely to have increased each year between 2015 and 2018. Dry deposition in 2019 then reduced sharply, to end up only marginally higher than it was in 2015. Most of this change was driven by the deposition of ammonia and HNO_3 . Changes to the deposition of the particulate species also contributed to the pattern. Year-to-year differences in NO_2 , had relatively little effect on the changes over time in background settings.

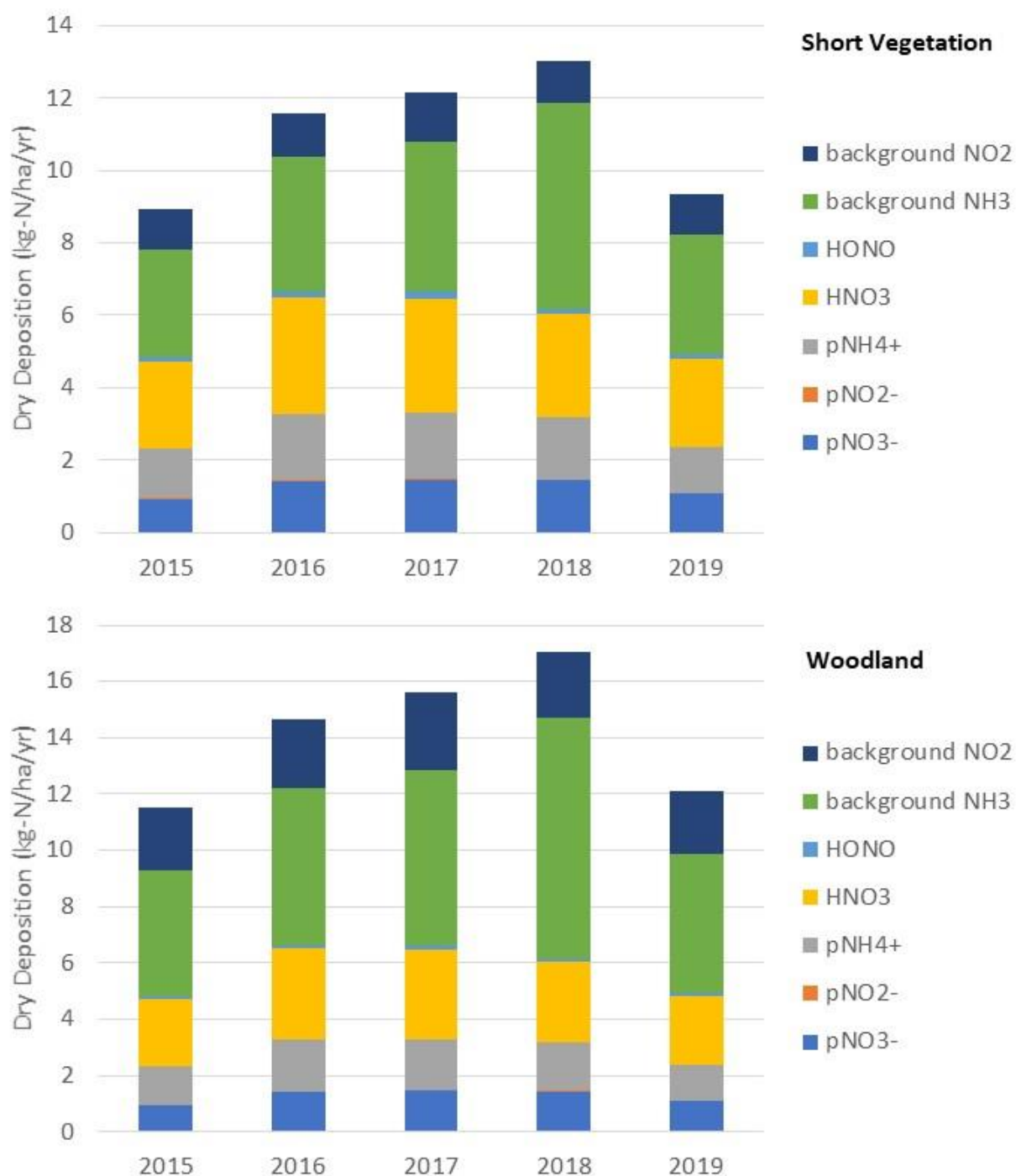


Figure 128: Calculated Dry Deposition to Background Locations (i.e. away from roads) over 5 Years – Using the Deposition Velocities from Table 19

Deposition to Roadside Locations

- 6.45 The monitoring site associated with the highest calculated dry deposition flux is roadside site R1.1. Figure 129 shows the calculated dry deposition flux at this site during each of the five full years of the study. The values for HNO₃, HONO, pNH₄⁺, pNO₃⁻, pNO₂⁻, background NH₃ and background

NO₂ in Figure 129 are those from Figure 128. The values for road-NH₃ and road-NO₂ were calculated from the total NH₃ and total NO₂ concentrations measured at this site, with the same background NH₃ and NO₂ concentrations used in the figure subtracted (e.g. the sum of road-NH₃ and background-NH₃ in the figure equates to the total measured NH₃).

- 6.46 Dry deposition fluxes increased between 2015 and 2016, fell slightly between 2016 and 2017, increased again to 2018, and then fell appreciably to 2019. Dry deposition fluxes at this site in 2019 were thus only 7% higher (short vegetation) and 9% higher (woodland) than those in 2015.

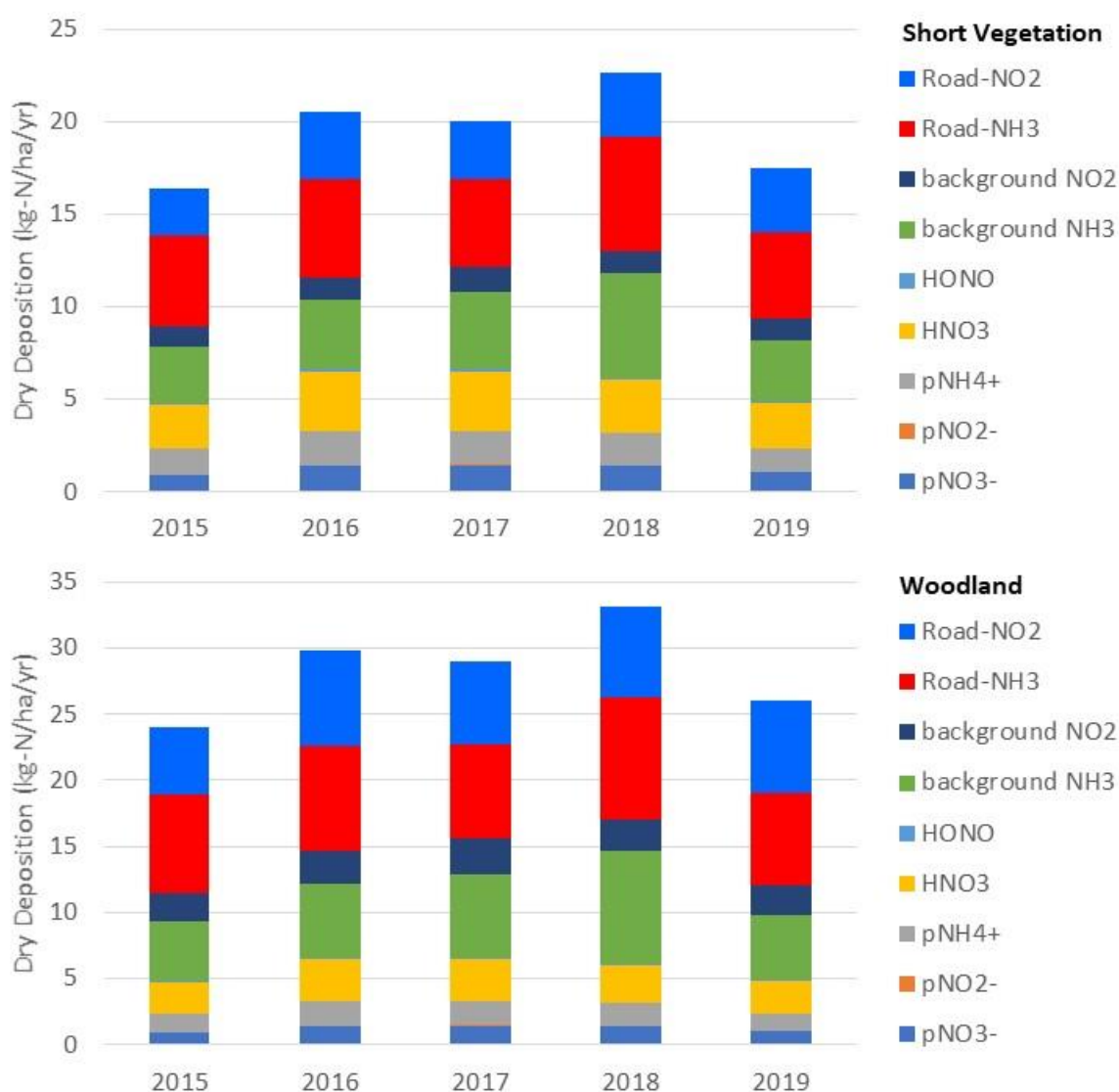


Figure 129: Calculated Dry Deposition Flux at Roadside Site R1.1 over 5 Years – Using the Deposition Velocities from Table 19

- 6.47 Figure 130 uses the same approach as was taken for the concentration data to summarise the relative change to total dry deposition fluxes across all roadside sites which measured both NH_3 and NO_2 . It shows the relative difference from the 5-year mean value during each year. The shape of Figure 130 is driven by that of Figure 128 for the background sites, showing the importance of changes to the background in these temporal trends. As described for Figure 128, dry deposition fluxes increased at most of the roadside sites during each year from 2015 until 2018 and then fell to 2019 so that dry deposition in 2019 was only slightly higher than that in 2015. Dry deposition was 4% (short vegetation) and 5% (woodland) of the long-term mean higher in 2019 than in 2015, but was still at least 10% lower than the 5-year mean.
- 6.48 Figure 131 shows the relative change in the local road increment to deposition across all roadside sites over five years. This is the sum of deposition from road- NO_2 and road- NH_3 . The temporal pattern in the local road contribution to deposition is quite different to that of the total dry deposition, and there is appreciable variability between the trends at different sites. On average, deposition fell marginally between 2015 and 2017, followed by a step upward in 2018. The mean local road contribution to nitrogen deposition increased by 10% (of the long-term mean) between 2015 and 2019. The road contribution in 2019 was thus higher than in any other year of the study⁵².

⁵² As explained in Section 5, the AQTAG deposition velocities used here are likely to underestimate NO_2 deposition at the roadside and thus possibly overestimate the relative importance of NH_3 . This, in turn, will exaggerate the increases in traffic-related nitrogen deposition over time which may be slower than shown in Figure 131.

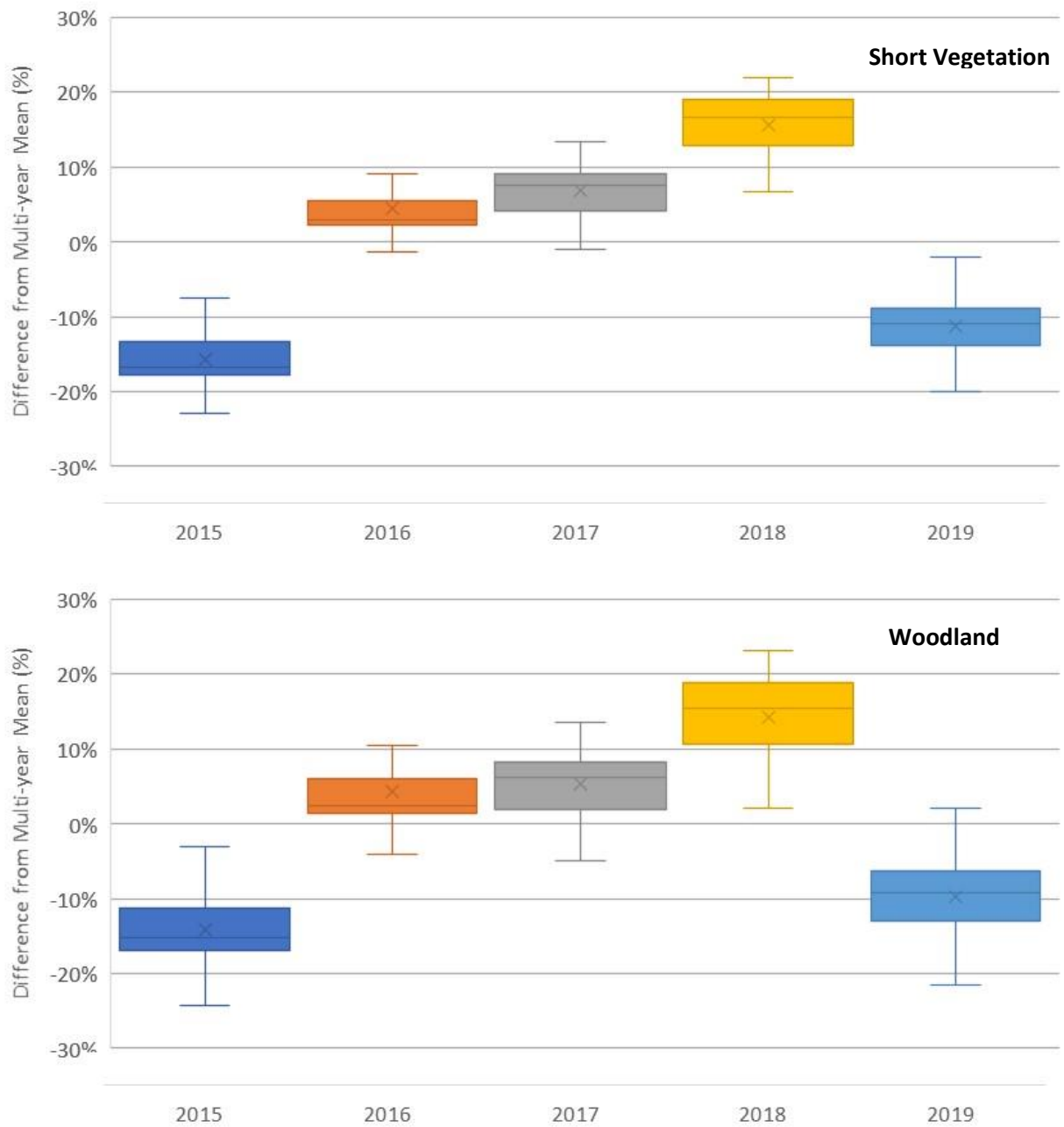


Figure 130: Relative Change in Total Nitrogen Dry Deposition Flux at all Roadside NH₃ Monitoring Sites, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site ⁴³

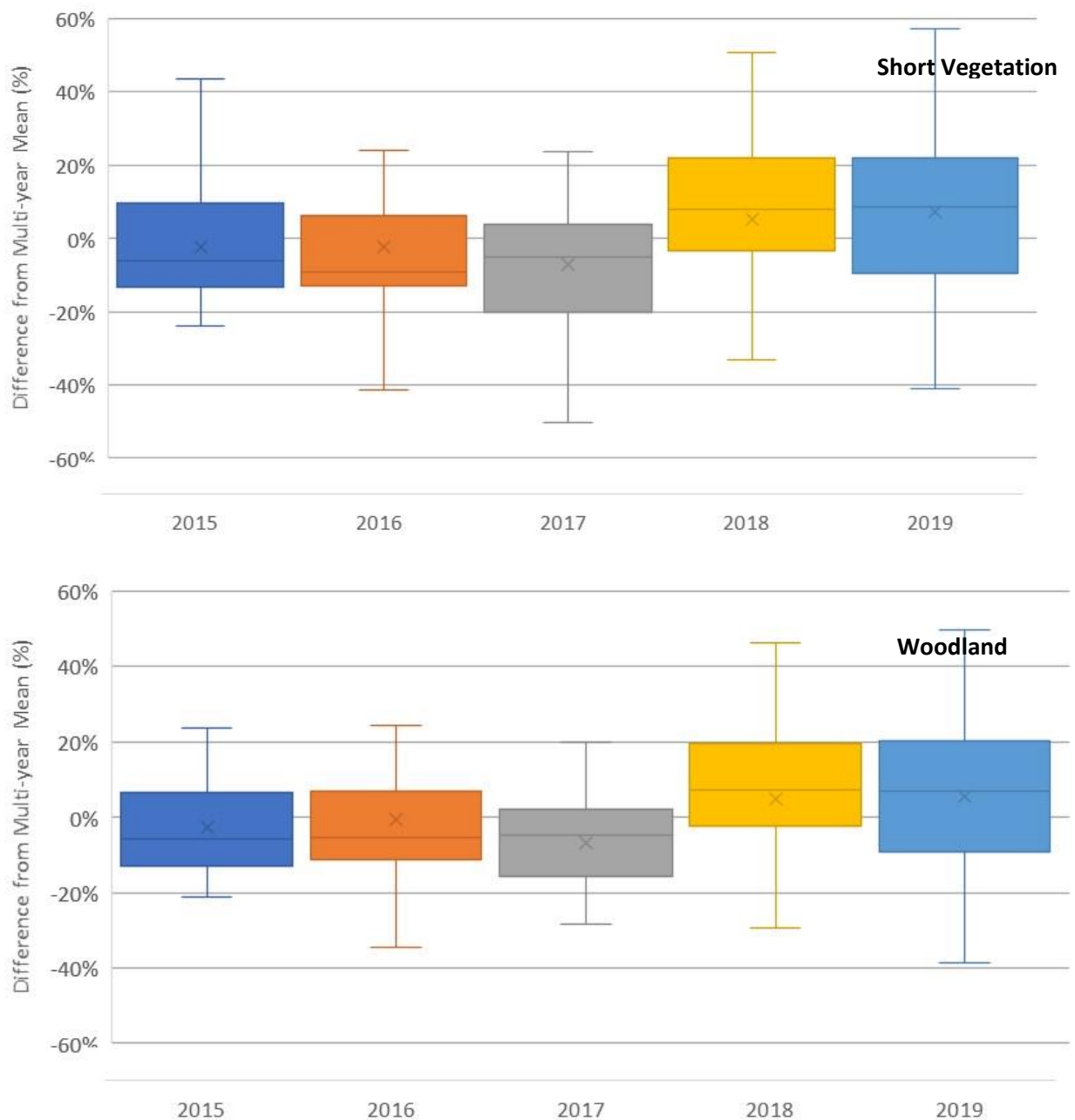


Figure 131: Relative Change in the Local Road Contribution to Nitrogen Deposition at all Roadside NH₃ Monitoring Sites, Showing the Difference between Each Individual Annual Mean and the 5-Year Mean at that Site

7 Summary and Conclusions

- 7.1 This report presents the results of what it believed to be the most extensive monitoring study of traffic-related nitrogen deposition that has ever taken place, either in the UK or internationally. Measurements made at any one site will always be subject to uncertainty, but the large number of monitors used in this study means that spatial and temporal trends can be determined with far greater certainty than would be possible had fewer sites been used. The study thus provides important information with respect not only to air quality conditions within Ashdown Forest, but also regarding spatial and temporal patterns of reactive nitrogenous pollutants more generally.
- 7.2 A key benefit of this monitoring network is its ability to inform modelling. Models assume that conditions which occur ‘on average’ occur everywhere and thus models which are calibrated against small numbers of monitors are likely to be biased toward the specific conditions in those locations. By providing large numbers of calibration points in a variety of settings, the monitoring network described here reduces the potential for model bias. The network also includes measurements of pollutants such as HNO_3 , as well as background measurements of NH_3 , which are often inferred from coarse national models but which can now, for Ashdown Forest, be taken from direct local measurements.
- 7.3 In addition to providing a robust basis for future modelling, it is possible to discern spatial and temporal patterns directly from the measurements. By relying directly on measurements, without the convoluted assumption-chains which characterise most models, it is possible to gain insights which are not possible using models alone.
- 7.4 The results of the monitoring are presented in Section 4 of this report in a format that it likely to be helpful for future modelling. Sections 5 and 6 of the report provide more in-depth analyses of spatial and temporal trends which have been observed. Key findings from these analyses are summarised below.

Spatial Patterns

- 7.5 Analysis of the high time resolution data from the Kingstanding monitor showed that the adjacent B2026 was an important source of NO_x and NH_x (i.e. NH_3 + some pNH_4^+) but that emissions released considerable distances away also made appreciable contributions to annual mean concentrations of both pollutants (e.g. Figure 59 and Figure 75).
- 7.6 Considering all monitoring sites together, the most important feature which determines concentrations of NO_2 and NH_3 across Ashdown Forest is distance from a main road. The highest concentrations of both pollutants were recorded close to the busiest roads and the lowest concentrations were recorded well away from roads. The rate at which concentrations reduced on moving away from roads largely follows well-understood patterns which have been observed elsewhere for NO_x ; albeit with some site-by-site variability, which is likely to be the effect of enhanced

mixing caused by fast moving vehicles in the immediate vicinity of roads (e.g. Figure 66 and Figure 68). The local road component of NO_x reduced at very similar rate to the local road component of NH₃ on moving away from each road (Figure 79, Figure 80, and Figure 81).

- 7.7 There does not appear to be any other strong spatial pattern in NO₂ and NH₃ concentrations which cannot be explained by distance from the road. Similarly, there were no strong spatial patterns in concentrations of HNO₃, HONO, pNH₄⁺, pNO₃⁻, or pNO₂⁻ in terms of their contribution to nitrogen deposition.
- 7.8 After normalising for distance from the road, the highest concentrations of NO_x and NH₃ tended to occur alongside roads where the recorded traffic volumes were highest. Other patterns were, though, observed and it was shown that concentrations vary appreciably along each individual road link, even where traffic volumes will remain constant. Most of these differences are likely to be caused by different responses (likely from most vehicle types) to road gradients and to acceleration profiles (e.g., with more acceleration required when the speed limit changes and when visibility is poorer owing to the road layout). Differences in measured concentrations at different points along a link were, in many cases, more significant than those caused by factors such as shielding due to surrounding trees, or even different total traffic volumes. This has implications for average-speed emissions models which are unable to capture these nuances, as well as either monitoring or modelling studies which only consider a few locations along a link.
- 7.9 Dry deposition of nitrogen has been calculated from the ambient measurements using simple deposition velocities published by AQTAG. Combining the measurements with these AQTAG deposition velocities predicts that deposition fluxes at the NH₃ monitoring sites were up to 29 kg-N/ha/yr to short vegetation and 38 kg-N/ha/yr to woodland; with the minimum deposition fluxes, even well away from roads, reaching no lower than 21 kg-N/ha/yr⁵³.
- 7.10 The local road increment to deposition was made up of road-NO₂ and road-NH₃. The relative contribution made by each of these pollutants varied at different sites (Figure 95) but at almost all of the monitoring sites (and on average), road-NO₂ was slightly less important than road-NH₃ in determining the local road increment to nitrogen deposition⁵³.

Trends over Time

NO_x and NO₂

- 7.11 On average, NO₂ concentrations measured well away from roads increased each year between 2015 and 2017 and have reduced each year between 2017 and 2019 (Figure 106). This is likely to be the

⁵³ In practice, the AQTAG deposition velocities are expected to over-predict deposition well away from roads and to under-predict close to roads, meaning that the minimum will be small than this, and the maximum may be higher. For the same reason, using the AQTAG deposition velocities may over-state the importance of traffic-related NH₃ and thus exaggerate the speed at which traffic-related nitrogen deposition increased over the 5 years of measurements.

combined effect of changes to emissions released outside of Ashdown Forest and differences in meteorological patterns which more frequently bring air masses from different places in different years. On average, background NO₂ concentrations measured in 2019 were slightly lower than in 2015.

- 7.12 The local increment of NO₂ at the roadside was, on average, higher in 2016 than in any other year of the study. Concentrations in every other year (2015, 2017, 2018, and 2019) are not appreciably different, showing no clear trend to either increase or reduce over time (Figure 108).
- 7.13 There are clear spatial patterns with regard to which roadside sites experienced reductions in local NO_x emissions and those where NO_x emissions appear to have increased. In particular, road-NO₂ concentrations reduced between 2015 and 2019 at most sites beside the A22 and A275, but increased at most sites beside Crowborough Road, New Road, and the A26 (Figure 110).

NH₃

- 7.14 On average, NH₃ concentrations measured well away from roads increased each year from 2015 until 2018. They then reduced appreciably in 2019, so that concentrations in 2019 were only marginally higher than those in 2015 (Figure 118). As noted for NO₂, this is likely to be the combined effect of changes to emissions and year-to-year differences to meteorology.
- 7.15 On average, the local increment of NH₃ at the roadside reduced between 2015 and 2016, and increased during each subsequent year (Figure 120). Emissions of NH₃ from local traffic are thus likely to have been higher during 2019 than those in any other year of the study. There do not appear to be any clear spatial patterns in the observed changes in road-NH₃.
- 7.16 On average, over the 5 full calendar years of the study, traffic-related NH₃ concentrations were 0.022 times those of traffic-related NO_x. This average does, though, mask a slight trend of increasing NH₃ to NO_x ratios over the course of the study; which was driven by the increases to road-NH₃ rather than by predicted reductions to road-NO_x.

Deposition

- 7.17 Total dry deposition fluxes to background locations increased each year from 2015 to 2018 and then fell appreciably, so that fluxes in 2019 were only slightly higher than those in 2015 (Figure 128). The importance of background sources to total deposition at the roadside means that this same overall trend was also seen at roadside sites (Figure 130). The contribution of local road traffic to deposition fell marginally between 2015 and 2017 and then increased between 2017 and 2019. On average, the local road contribution to nitrogen deposition increased by 10% of the long-term mean between 2015 and 2019, and the road contribution to deposition in 2019 was higher than in any other year of the study (Figure 131)⁵³.

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