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North Staffordshire Local Air Quality Plan - Air Quality Results Report (AQ3)

Report for Stoke-on-Trent City Council and Newcastle-under-Lyme Borough Council

ED 12487 | 30th October 2019

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Newcastle-under-Lyme Borough Council

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Newcastle-under-Lyme and Stoke-on-Trent Air Quality Local Development Plan

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1 Introduction and outline scope of modelling

Newcastle-under-Lyme Borough Council (NuLBC) and Stoke-on-Trent City Council (SoTCC) were part of the third wave of UK cities required to carry out a Targeted Feasibility Study by the Government for non-compliance with the nitrogen dioxide (NO_2) limit values. As a result of this study, NULBC and SOTCC were required to carry out a further Clean Air Zone (CAZ) feasibility study to identify measures able to achieve compliance with the NO_2 objective. This report sets out the Air Quality modelling results for the base year in 2018, the future baseline year 2022, and six options that were assessed to determine their ability to achieve compliance with the NO_2 objective by 2022. This report also contains the results of a sensitivity analysis of the model results.

1.1 Background

Newcastle-under-Lyme and Stoke-on-Trent, like many other urban areas in the UK, have locations where NO_2 concentrations are in excess of national and European air quality standards.

Four Air Quality Management Areas (AQMAs) have been declared in Newcastle-under-Lyme, which cover the areas where exceedances of the NO_2 air quality standards are measured or are likely to be measured. The exceedances result mainly from transport emissions of NO_2. A map of the four AQMAs can be found in Appendix D of the most recent Air Quality Annual Status Report.[1] The AQMAs primarily cover the town centre, the ring road and areas affected by principle routes (e.g. the M6). Since the publication of the Air Quality Action Plan (AQAP) 2019 – 2024, only two of the AQMAs (Newcastle-under-Lyme Town Centre and Kidsgrove) have exhibited exceedances of the annual mean objective for NO_2.

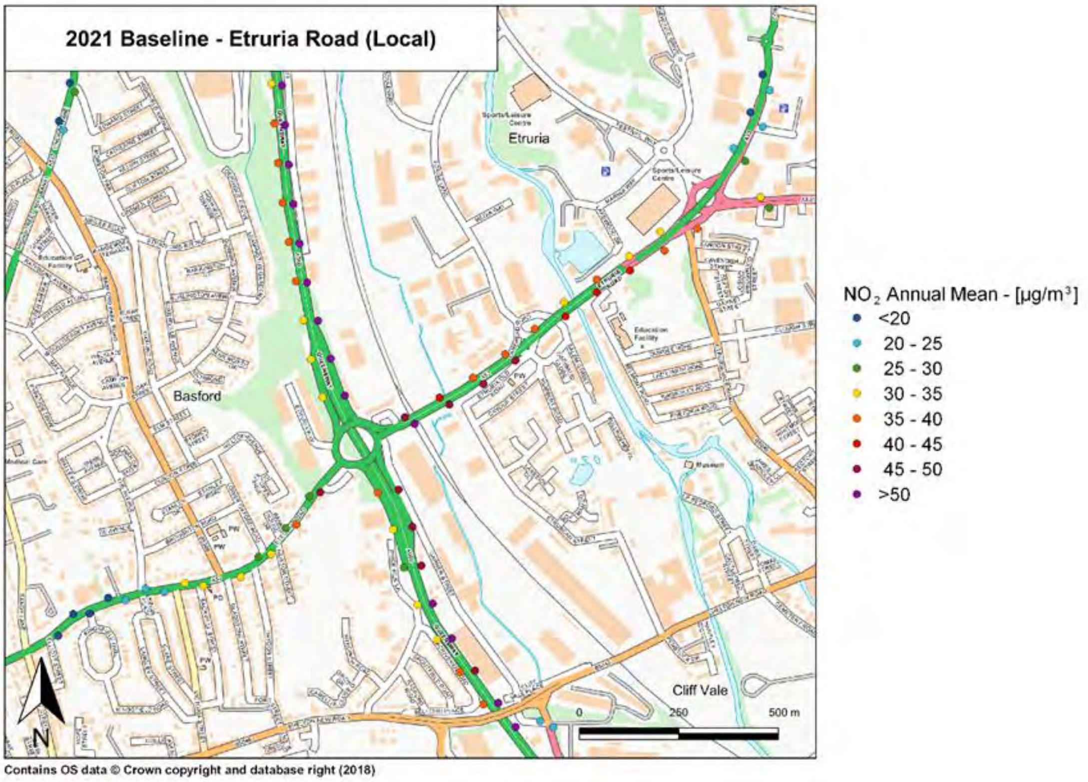
The whole of Stoke-on-Trent was designated as an AQMA for NO_2 in 2006. This was amended to include the NO_2 1-hour mean in May 2011.

NuLBC and SoTCC were identified in the 2015 National Air Quality Plan as two of the 33 councils required to complete a Targeted Feasibility Study. The results of this Feasibility Study highlighted that compliance would not be achieved in Stoke-on-Trent until 2023 and Newcastle-under-Lyme until 2026 without intervention. The Feasibility Study found that the introduction of measures designed to reduce air pollution along the A53 would bring forward compliance in Newcastle-under-Lyme by one year. In 2018, NuLBC and SoTCC were directed to produce an NO_2 compliance plan, which may include a mandatory charging-based CAZ or a range of alternative measures able to deliver compliance as quickly as a charging-based CAZ.

The key areas identified in the Targeted Feasibility study that were modelled to exceed NO_2 limits in 2021 are along the A53 (Census ID: 26555, 28732 and 74058), and are shown in Figure 1-1. The annual NO_2 limit is 40 $\mu g.m^{-3}$.

[1] 2018 Air Quality Annual Status Report In fulfilment of Part IV of the Environment Act 1995 Local Air Quality Management Newcastle-under-Lyme Borough Council June 2018

Figure 1-1: Areas of NO_2 exceedances in 2021 identified in the local Targeted Feasibility Study



1.2 Outline scheme options

1.2.1 Strategic Outline Case

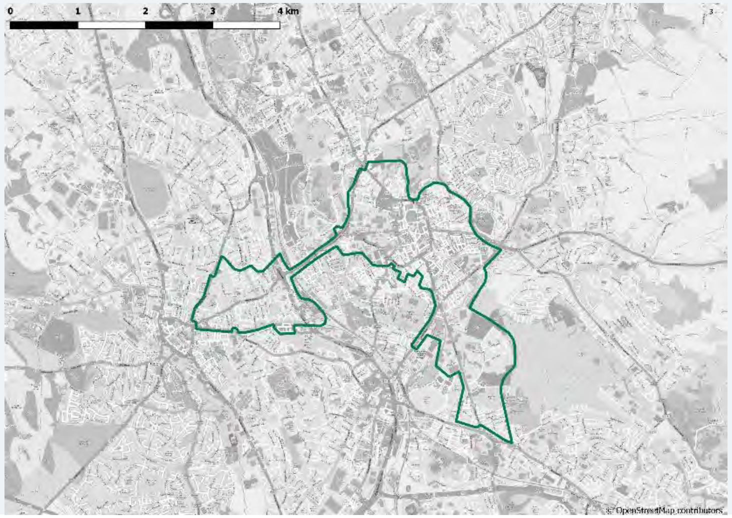
The Strategic Outline Case for measures to reduce the ambient concentrations of NO_2 in Stoke-on-Trent and Newcastle-under-Lyme outlined a shortlist of preferred options to be modelled for the Outline Business Case, including:

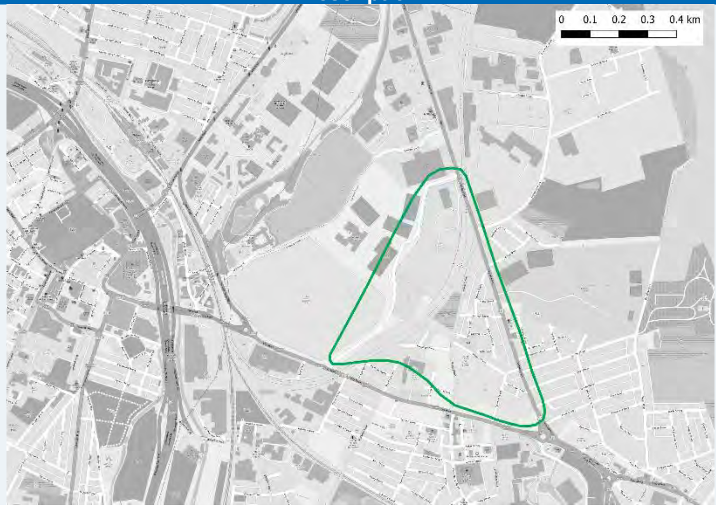
- A city centre / A53 chargeable access restriction (Class A – D).
- A city-wide chargeable access restriction (Class A – D).
- A city centre / A53 traffic management scheme.
- A Low Emission Strategy, comprising a package of measures designed to promote improvements to existing bus and taxi fleets, and encourage mode shift towards low emission transport options.

1.2.2 Outline Business Case

Future year baseline modelling was carried out for 2022. Six options for 2022 were modelled as part of the Outline Business Case and are summarised as below:

Table 1: Description of modelled options

Option	Description	Assumptions
Option 1 Benchmark CAZ D	This is the benchmark CAZ that would likely be required for compliance if just a CAZ scheme were implemented. Class D implies charging scheme for all non-compliant vehicles. The CAZ boundary is as follows: 	The following daily charges through, within, or from the CAZ area are as follows: Cars/Taxis: £5 LGVs: £9 HGVs/Buses: £35/tbc On Bucknall New Road and Victoria Road, 100% bus retrofit In order to account for secondary responses to a charging CAZ, the following assumptions were made, based on the JAQU Third wave Evidence Package report: “75% of non-compliant vehicles owners will replace their non-compliant vehicle with a second-hand compliant vehicle whilst 25% will scrap their vehicle and buy a new one on the same fuel type. Additionally, 75% of those replacing will purchase the cheapest compliant vehicle (so diesel will switch to petrol)”. As a modelling assumption, we assumed that 75% of 75% of additional diesel car vehicles in comparison with the baseline were in fact Euro 4 Petrol car vehicles.
Option 2 “High Impact no CAZ”	• Along the A53: Basford Park right turn ban • On Bucknall New Road: 50% bus retrofit • On Victoria Road: Existing Academy Link Road with limited improvements at both ends (only NB north of Academy) and Victoria Road northbound peak restrictions on the southern end of Victoria Road except buses. 100% bus retrofit on Victoria Road as well as complementary measures: Real-Time Passenger Information (RTPI) and bus shelters.	
Option 3 “High Impact with local CAZ D”	• Local CAZ D around Victoria Road (see map below), with daily charges same as option 1 • Along the A53: A53 westbound peak restrictions (except buses, cyclists and taxis) • On Bucknall New Road: 100% bus retrofit • On Victoria Road: In addition to the CAZ D, buses are permitted northbound of Victoria Road and 100% bus retrofit.	

Option	Description	Assumptions
		
Option 4	• Along the A53: A53 westbound peak restriction plus pedestrian phases at both Albert St and Basford Park traffic lights • On Bucknall New Road: 75% bus retrofit • On Victoria Road: Existing Academy Road Link Road, without junction improvements. Victoria Road northbound peak restrictions on southern end of Victoria Road except buses, cyclists and taxis. 100% bus retrofit	
Option 5 "Class C CAZ"	• Class C CAZ (charging scheme for all non-compliant vehicles except private passenger vehicles). The CAZ boundary and daily charges are the same as Option 1	
Option 6	• Along A53, same as Option 4 with complementary measures: Bus infrastructure Targeted travel planning/marketing Walking & Cycling Electric Vehicle Infrastructure Vegetation Removal and planting • On Bucknall New Road, same as option 4 plus complementary measures as described for the A53 • On Victoria Road, same as option 4 plus complementary measures as described for the A53	

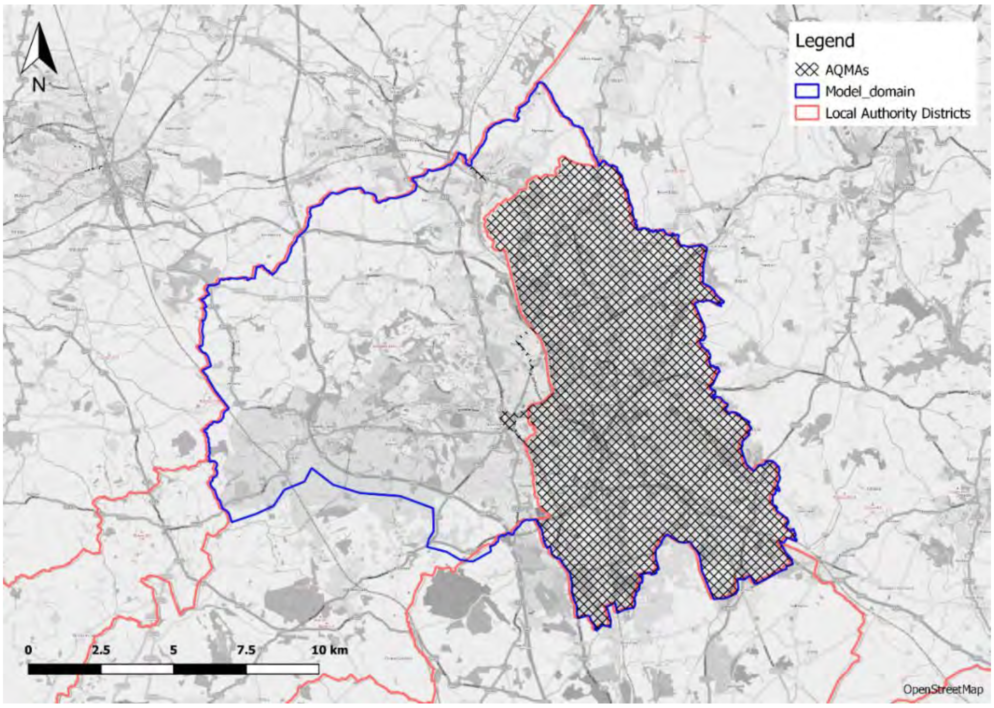
1.3 Model domain

To assess the transport and air quality impacts of the scheme, a model domain is required that covers the potential scheme options, relevant AQMAs and potential diversion routes. The core air quality model domain covers the Stoke-on-Trent and Newcastle-on-Lyme city boundaries, based upon the district boundary from Ordnance Survey mapping products, and is based on the extent of the North Staffordshire Multi-Modal (NSMM) traffic model on which the air quality modelling is based. The model domain used is shown in Figure 1-2 and has been chosen to cover the following:

- All of the AQMAs in Stoke-on-Trent and Newcastle-under-Lyme;
- The main areas of concern identified in the national modelling assessment at the A53 road link and the A500;
- Areas of concern identified from SOTC and NULC air pollutant measurement data.

Concentrations were calculated across a grid covering this area at 3m resolution.

Figure 1-2: Air quality model domain



1.4 Modelling years

There are two key years used in the modelling work, as set out in Table 2 below, plus an additional future reference year. The baseline modelling year of 2018 allows use of the latest air quality and transport data for model verification. The future baseline was modelled for the assumed compliance year in 2022. Data for interim years was generated through interpolation rather than direct model tests.

Table 2: Key model years

Year	Description
2018	**Base year** – using latest available data on air quality and traffic.
2022	**Compliance year** – latest date when the effects of the scheme are assumed to occur.

2 Model verification and adjustment

2.1 Measurement data for model calibration

Annual mean NO_2 measurements from all automatic monitors and diffusion tube sites operated by the Councils in 2018 were used to carry out model verification. Information on monitoring data QA/QC, diffusion tube bias adjustment factors, etc., are as described in the Stoke-on-Trent and Newcastle-under-Lyme 2019 LAQM Annual Status Reports[2].

Table 3 and Table 4 present monitoring sites operated by Newcastle-under-Lyme and Stoke-on-Trent Councils, respectively, together with the monitored NO_2 concentrations. A map showing the monitoring sites is presented in AQ2.

Table 3: Annual mean NO_2 concentrations at Newcastle-under-Lyme monitoring sites, $\mu g.m^{-3}$, 2018

Site ID	Site Name	Monitoring	Site Type	Easting	Northing	Value
CM1	Newcastle under Lyme Queen's Gardens	Automatic	Roadside	385046	346147	22.75
DTK1	A34 Holy Trinity	Diffusion Tube	Kerbside	385051	345726	37.2
DTK2	76 King St, N/C	Diffusion Tube	Urban Centre	385469	346362	26.0
DTUB1	Wolstanton (Harington St)	Diffusion Tube	Kerbside	384739	348326	17.7
DTUB2	Westlands (4 Sneyd Crescent)	Diffusion Tube	Kerbside	383916	345059	15.3
DT3	Collingwood 3 Newcastle Rd	Diffusion Tube	Rural	378116	345488	24.8
DT6	106 Liverpool Rd	Diffusion Tube	Suburban	384014	354429	37.1
DT9	32 Porthill Bank	Diffusion Tube	Suburban	385519	349055	29.3
DT11	34 London Road, N/C	Diffusion Tube	Suburban	385112	345636	35.1
DT24	26 High St, May Bank	Diffusion Tube	Roadside	385574	347530	30.4
DT28	Limbrick Cottage Shraleybrook	Diffusion Tube	Rural	377994	350105	25.2
DT34	15 Barracks Road	Diffusion Tube	Urban Centre	385059	345840	29.2
DT 39	4/6 Liverpool Road, Kidsgrove	Diffusion Tube	Suburban	383560	354739	31.7
DT40	Banktop Court, Porthill	Diffusion Tube	Suburban	385128	348811	25.2
DT46	1 London Road (Trinity Court)	Diffusion Tube	Urban Centre	385073	345685	27.3
DT47	1 London Rd (Brook La)	Diffusion Tube	Urban Centre	385023	345678	24.7
DT49	2 Vale View, Porthill	Diffusion Tube	Urban Centre	385595	349129	27.2
DT64	Kidsgrove Carpets Liverpool Road	Diffusion Tube	Urban Centre	383950	354445	32.7
DT72	134 High Street Newcastle	Diffusion Tube	Roadside	384980	345787	26.9
DT73	21 London Road Newcastle	Diffusion Tube	Roadside	385070	345738	29.3
DT74	39 London Road Newcastle	Diffusion Tube	Roadside	385132	345640	31.9
DT76	11 Brunswick Street Newcastle	Diffusion Tube	Roadside	385226	346156	33.1
DT84	102 King Street Newcastle	Diffusion Tube	Roadside	385548	346400	33.6
DT85	106 King Street Newcastle	Diffusion Tube	Urban Centre	385575	346413	38.8
DT86	Hassell C.P. School Barracks Road N/C	Diffusion Tube	Urban Centre	385075	345910	27.9
DT87	Blue Chilli 1 King Street Newcastle	Diffusion Tube	Urban Centre	385105	346225	34.9
DT88	27 Lower Street Newcastle	Diffusion Tube	Urban Centre	384709	345881	28.2
DT89	Queens Gardens Newcastle	Diffusion Tube	Urban Centre	385054	346134	29.0
DT90	Queens Gardens Newcastle	Diffusion Tube	Urban Centre	385054	346134	29.2
DT91	Queens Gardens, Newcastle	Diffusion Tube	Urban Centre	385054	346134	31.1
DT92	41/43 Liverpool Road Kidsgrove	Diffusion Tube	Urban Centre	383890	354461	31.9
DT93	118 Liverpool Road Kidsgrove	Diffusion Tube	Urban Centre	384056	354393	28.2
DT94	116 Liverpool Road Kidsgrove	Diffusion Tube	Urban Centre	384030	354416	31.8
DT95	76 London Road Newcastle	Diffusion Tube	Urban Centre	385171	345539	28.5
DT96	52/54 London Road Newcastle	Diffusion Tube	Roadside	385131	345601	35.8
DT97	Blackfriars/ Lower Street	Diffusion Tube	Roadside	384795	345796	27.6
DT98	Newcastle Taxis Brunswick Street	Diffusion Tube	Roadside	385327	346148	36.5
DT100	Sainsbury's Carpark Near to Courts	Diffusion Tube	Roadside	384689	346284	27.9
DT101	Blackburn House Lower Street Newcastle	Diffusion Tube	Roadside	384806	345842	32.8
DT102	Maxims Lower Street Newcastle	Diffusion Tube	Roadside	384609	346007	44.1
DT103	Grange Lange/High Street Wolstanton	Diffusion Tube	Roadside	385682	347909	25.1
DT104	7 King Street Newcastle	Diffusion Tube	Roadside	385213	346270	37.9
DT105	The Avenue Kidsgrove	Diffusion Tube	Roadside	383991	354418	26.0

[2] Stoke-on-Trent CC (2018) Stoke-on-Trent Council Air Quality Annual Status Report (ASR); June 2018. Newcastle-under-Lyme Borough Council (2019) Newcastle-under-Lyme Borough Council Air Quality Annual Status Report (ASR); June 2019.

Table 4: Annual mean NO_2 concentrations at Stoke-on-Trent air quality monitoring sites, $\mu g.m^{-3}$, 2018

Site ID	Site Name	Monitoring	Site Type	Easting	Northing	Value
CM1	Stoke-on-Trent Centre AURN	Automatic	Urban Background	388355	347893	23.0
CM2	Joiners Square	Automatic	Roadside	388743	346457	33.0
CM5	Basford	Automatic	Roadside	386288	346802	55.0
CM6	Stoke-on-Trent A50 Roadside AURN	Automatic	Roadside	392584	342569	53.0
DT1	1994/01	Diffusion Tube	Urban Background	386402	343705	18.3
DT2	1999/01	Diffusion Tube	Roadside	389884	347288	39.1
DT3	1999/02	Diffusion Tube	Urban Background	390612	350793	16.2
DT4	2001/04	Diffusion Tube	Roadside	392705	342518	31.9
DT8	2003/02	Diffusion Tube	Roadside	388355	347893	29.0
DT9	2005/01	Diffusion Tube	Roadside	387626	348515	44.8
DT10	2005/02	Diffusion Tube	Roadside	386929	349855	34.9
DT13	2005/07	Diffusion Tube	Roadside	392471	342631	35.2
DT14	2005/08	Diffusion Tube	Roadside	392587	342578	37.4
DT15	2005/11	Diffusion Tube	Roadside	389335.6	344693.4	38.1
DT16	2005/13	Diffusion Tube	Roadside	385975	346574.6	49.4
DT17	2005/14	Diffusion Tube	Roadside	386270	346782.4	72.5
DT20	2005/17	Diffusion Tube	Roadside	388842	346642	35.4
DT23	2005/22	Diffusion Tube	Roadside	388704	347607.7	39.3
DT24	2005/23	Diffusion Tube	Roadside	393201	342409	41.6
DT29	2005/34	Diffusion Tube	Roadside	386904	349828.4	38.4
DT32	2005/41	Diffusion Tube	Roadside	388697.9	346421.5	34.4
DT34	2005/45	Diffusion Tube	Roadside	389231.5	345026.3	46.3
DT37	2005/50	Diffusion Tube	Roadside	393260	342460	41.9
DT40	2005/56	Diffusion Tube	Roadside	392777	342409	38.7
DT41	2005/57	Diffusion Tube	Roadside	392741	342435	36.7
DT42	2005/58	Diffusion Tube	Roadside	392676.1	342481.4	34.3
DT49	2008/13	Diffusion Tube	Roadside	388536	347143	37.7
DT51	2009/04	Diffusion Tube	Roadside	386380.4	346860	38.8
DT52	2009/05	Diffusion Tube	Roadside	385812.3	346545.9	47.9
DT53	2010/01	Diffusion Tube	Roadside	387938	345939	32.2
DT55	2010/05	Diffusion Tube	Roadside	393320	342206	34.6
DT56	2012/01	Diffusion Tube	Roadside	386288	346802	49.5
DT61	2014/01	Diffusion Tube	Roadside	390710	350261	35.0
DT63	2016/01	Diffusion Tube	Roadside	385928.8	346563.2	51.1
DT64	2016/02	Diffusion Tube	Roadside	385937	346531	36.5
DT65	2016/03	Diffusion Tube	Roadside	385943	346504	36.8
DT66	2016/04	Diffusion Tube	Roadside	385978.5	346315.8	29.9
DT67	2016/05	Diffusion Tube	Roadside	386023.5	346152.6	48.6
DT72	2017/01	Diffusion Tube	Roadside	386014	346137	35.0
DT73	2017/02	Diffusion Tube	Roadside	386020.1	345932.7	31.7
DT74	2017/03	Diffusion Tube	Roadside	393294.3	342508.6	43.6
DT75	2017/04	Diffusion Tube	Roadside	393369.6	342177.6	37.6
DT76	2017/05	Diffusion Tube	Roadside	385928.8	349765.3	36.9
DT77	2017/06	Diffusion Tube	Roadside	385957.1	349756.5	47.7
DT78	2017/07	Diffusion Tube	Roadside	386156.7	349596.1	38.4
DT79	2017/08	Diffusion Tube	Roadside	386240	349581	37.8
DT80	2017/09	Diffusion Tube	Roadside	386400	349571.1	31.8
DT81	2017/10	Diffusion Tube	Roadside	386456	349598	34.0
DT82	2017/11	Diffusion Tube	Roadside	386607.1	349656.3	33.2
DT83	2017/12	Diffusion Tube	Roadside	390703.2	350221	36.6
DT84	2017/13	Diffusion Tube	Roadside	386917.9	349850.5	36.4
DT85	2017/14	Diffusion Tube	Roadside	386959	349850	36.6
DT86	2017/15	Diffusion Tube	Roadside	386983	349861	35.6
DT88	2017/17	Diffusion Tube	Roadside	387427.7	348830.1	30.4
DT89	2017/18	Diffusion Tube	Roadside	387499.4	348695.4	36.9
DT90	2017/19	Diffusion Tube	Roadside	387558.2	348623.1	35.2
DT91	2017/20	Diffusion Tube	Roadside	387659.4	348482.3	43.4
DT92	2017/21	Diffusion Tube	Roadside	388725	346464	31.7
DT93	2017/22	Diffusion Tube	Roadside	388673.1	346372	29.6
DT94	2017/23	Diffusion Tube	Roadside	388335	345880	31.3
DT95	2017/24	Diffusion Tube	Roadside	388230	345742	30.7
DT96	2017/25	Diffusion Tube	Roadside	388168.1	345663.4	29.3
DT97	2017/26	Diffusion Tube	Roadside	387972	346002	29.8
DT98	2017/27	Diffusion Tube	Roadside	388006.3	346155.9	27.1
DT99	2017/28	Diffusion Tube	Roadside	388656	347612	48.6
DT100	2017/29	Diffusion Tube	Roadside	388634.3	347613.8	44.8
DT101	2017/30	Diffusion Tube	Roadside	385999	345936	30.1
DT102	2017/31	Diffusion Tube	Roadside	386154.4	345834.5	33.0
DT103	2017/32	Diffusion Tube	Roadside	388114	345483	30.9

Site ID	Site Name	Monitoring	Site Type	Easting	Northing	Value
DT104	2017/33	Diffusion Tube	Roadside	387979	345650.1	42.4
DT105	2018/01	Diffusion Tube	Roadside	386591.3	347017.5	34.2
DT106	2018/02	Diffusion Tube	Roadside	386660	347088	33.0

Some clear outliers were apparent during the model verification process, whereby we were unable to refine the model inputs sufficiently to achieve acceptable model performance at these locations. There are a number of reasons why this could be the case, including:

- A site located next to a large car park, bus stop, or additional emission source that has not been explicitly modelled due to unknown activity data;
- Sites located underneath trees or vegetation i.e. unsuitable locations for diffusion tubes to measure NO_2 concentrations effectively;
- Sites located along roads which are not included in the traffic model, or at junctions with roads that are not included in the traffic model.

Ten out of 111 monitoring sites were considered as outliers and were therefore excluded from the verification process. These sites, and the reason for their exclusion, are detailed in Table 5.

Table 5: Monitoring sites excluded from model verification

Council	Site ID	Monitoring	Site Type	Reason for exclusion
Newcastle-under-Lyme	DTUB2	Diffusion Tube	Kerbside	Located on minor road not present in traffic model.
	DT11	Diffusion Tube	Suburban	Located at the junction with Refinery Street, which is not included in the transport model.
	DT 39	Diffusion Tube	Suburban	Located at the junction with Hardingswood Road, which is not included in the transport model.
	DT72	Diffusion Tube	Roadside	Located at an entrance to a car park which is not included in the air quality model.
	DT96	Diffusion Tube	Roadside	Located at the junction with Vessey Terrace, which is not included in the transport model.
	DT102	Diffusion Tube	Roadside	Located alongside the entryway into a car park, which is not included in the model.
Stoke-on-Trent	DT3	Diffusion Tube	Background	Located on Trentfields Road, which is not included in the transport model.
	DT17	Diffusion Tube	Roadside	The tree canopy at this location produces canyon and tunnel effects, which cannot be adequately represented in the air quality model without significant uncertainty. The Basford continuous monitor (CM5) is located 20m from this location and is included in the model verification.

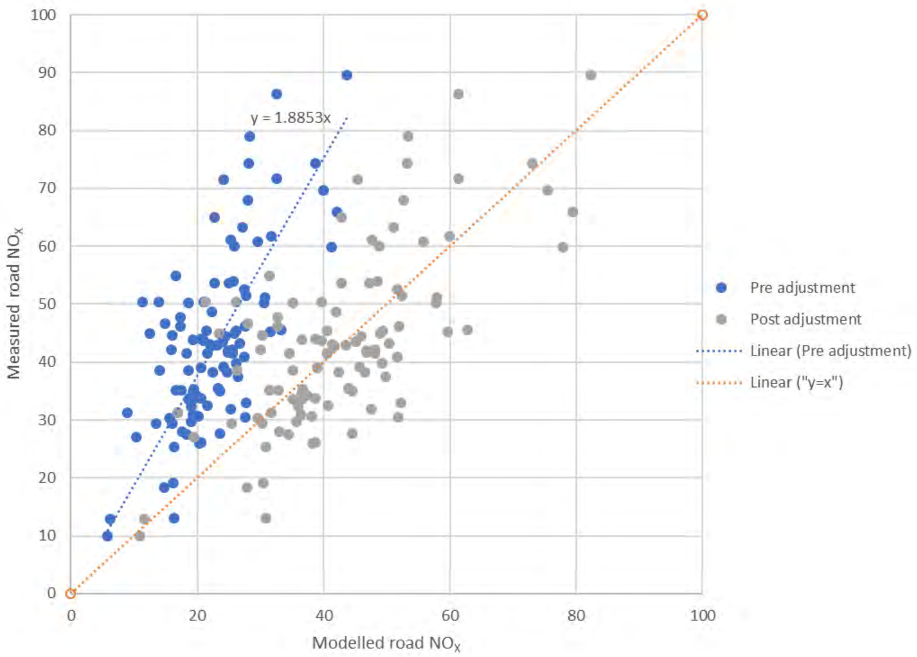
2.2 Model calibration

A total of 101 roadside automatic and diffusion tube NO_2 measurement sites operated by Stoke-on-Trent Council and Newcastle-under-Lyme District Council have been used for model verification.

Adjustment factors for emissions from roads were derived following the methodology described in LAQM.TG (16)[3], whereby the predicted road contribution to NO_X concentrations was compared with measured values.

Diffusion tubes measure NO_2 rather than NOx; the road contribution to NO_X concentrations at these sites was estimated using the latest version of the NOx to NO_2 calculator (version 7.1) published by Defra.[4] Background NO_X concentrations for use in this tool were taken from the Defra background maps. This approach uses background concentrations of NO_X as an input.

Figure 2-1: Measured and modelled annual mean road NOx contributions at monitoring sites, 2018, µg.m^{-3}



The gradient of the best fit line for the modelled road NOx contribution vs. measured road NOx contribution was determined using linear regression and used as a domain-wide road NOx adjustment factor. The total annual mean NO_2 concentrations were then determined using the NOx/NO_2 calculator to combine the background concentration and the adjusted road contribution. A global primary NOx adjustment factor (PAdj) of **1.89** was derived and applied to all modelled road NOx contributions prior to calculating an NO_2 annual mean.

[3] https://laqm.defra.gov.uk/documents/LAQM-TG16-February-18-v1.pdf, accessed 4th September 2018

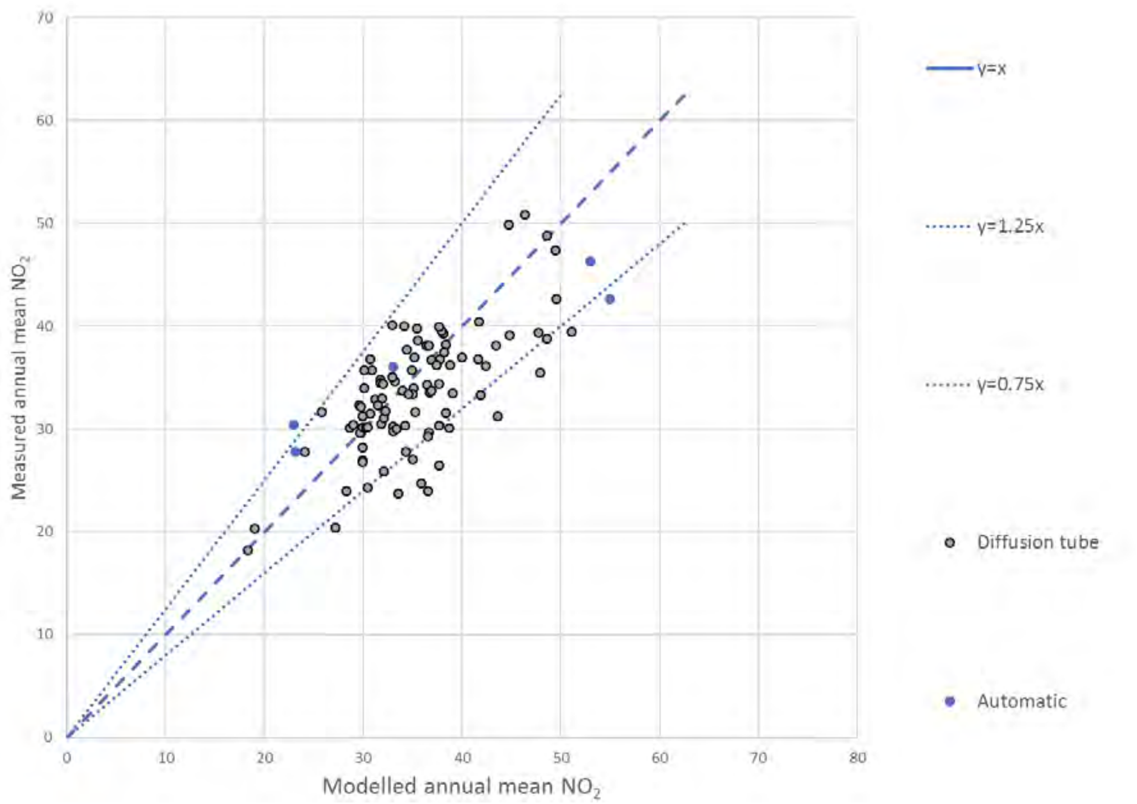
[4] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

2.3 Model verification

The model was verified against annual average NO_2 concentrations using the 2018 baseline emissions inventory described in Section 3. NO_2 concentrations were derived from modelled road NOx contributions, primary NO_2 contributions, and background concentrations using the Defra NOx:NO_2 calculator.

A plot comparing modelled and monitored NO_2 concentrations during 2018 is presented in Figure 2-2.

Figure 2-2: Modelled and measured annual mean NO_2 concentrations, 2018, post adjustment



Following guidance in LAQM.TG(16)[4], the Root Mean Square Error (RMSE) was calculated to define the average error or uncertainty of the model, as described in Box 7.17 of this guidance. The calculation of the RMSE is presented in Table 6. The Root Mean Square Error for the model verification is 5.2 $\mu g.m^{-3}$, corresponding to 13% of the Air Quality Objective (AQO). This is above the 10% ideal threshold specified in LAQM.TG (16)[4], but significantly below the 25% acceptable threshold. The primary cause of the relatively high RMSE is model underprediction towards the edge of the model domain in Baddeley and in the Kidsgrove areas, where the traffic model is less detailed and as a result modelled link speeds may be overpredicted. No exceedances of the AQO were measured in these locations in 2018, and as improvements in the vehicle fleet to 2022 will tend to reduce road emissions in future years, it is considered highly unlikely that these roads will represent a compliance issue in 2022.

Table 6: Root mean square error calculations

Council	Site ID	Measured NO_2 annual mean concentration 2018 (µg.m^{-3})	Modelled NO_2 annual mean concentration 2018 (µg.m^{-3})	Difference (µg.m^{-3})
NC	CM1	23.1	27.7	4.6
NC	DT100	30.0	31.1	1.2
NC	DT101	33.0	34.9	2.0
NC	DT103	24.1	27.7	3.6
NC	DT104	38.2	37.3	-1.0
NC	DT105	27.2	20.3	-6.8
NC	DT24	35.3	31.5	-3.8
NC	DT28	29.9	26.6	-3.3
NC	DT3	30.7	36.6	5.8
NC	DT34	32.1	31.0	-1.1
NC	DT40	28.3	23.9	-4.4
NC	DT46	30.1	33.8	3.8
NC	DT47	25.8	31.5	5.7
NC	DT49	31.5	32.2	0.7
NC	DT6	37.7	26.4	-11.3
NC	DT64	35.9	24.7	-11.2
NC	DT73	32.0	34.3	2.2
NC	DT74	33.0	29.6	-3.4
NC	DT84	36.5	29.2	-7.3
NC	DT85	35.1	33.9	-1.3
NC	DT86	40.0	36.8	-3.2
NC	DT87	29.7	29.5	-0.2
NC	DT88	37.9	39.4	1.5
NC	DT89	29.9	28.1	-1.8
NC	DT9	30.4	30.0	-0.3
NC	DT90	33.4	29.9	-3.5
NC	DT91	30.0	30.0	0.1
NC	DT92	30.3	30.0	-0.3
NC	DT93	33.5	23.7	-9.9
NC	DT94	30.4	24.2	-6.2
NC	DT95	32.1	25.8	-6.3
NC	DT97	34.3	27.6	-6.7
NC	DT98	28.6	30.0	1.3
NC	DTK1	37.7	30.2	-7.4
NC	DTK2	41.7	40.2	-1.5
NC	DTUB1	29.7	29.5	-0.2
SOT	CM1	19.0	20.3	1.3
SOT	CM2	23.0	30.3	7.3
SOT	CM5	33.0	35.9	2.9
SOT	CM6	55.0	42.5	-12.5
SOT	DT1	53.0	46.0	-7.0
SOT	DT10	18.3	18.1	-0.2
SOT	DT100	34.9	35.6	0.7
SOT	DT101	44.8	49.6	4.9
SOT	DT102	30.1	35.6	5.5
SOT	DT103	33.0	30.1	-2.9
SOT	DT104	30.9	35.6	4.7
SOT	DT105	42.4	36.0	-6.4
SOT	DT106	34.2	39.8	5.7
SOT	DT13	33.0	39.9	6.9
SOT	DT14	35.2	36.8	1.6
SOT	DT15	37.4	36.0	-1.4
SOT	DT16	38.1	39.1	1.0
SOT	DT2	49.4	47.1	-2.3
SOT	DT20	39.1	33.3	-5.7
SOT	DT24	35.4	39.6	4.2
SOT	DT29	41.6	36.6	-5.1

Council	Site ID	Measured NO_2 annual mean concentration 2018 ($\mu g.m^{-3}$)	Modelled NO_2 annual mean concentration 2018 ($\mu g.m^{-3}$)	Difference ($\mu g.m^{-3}$)
SOT	DT32	38.4	31.5	-6.9
SOT	DT34	34.4	37.5	3.1
SOT	DT37	46.3	56.1	9.8
SOT	DT4	41.9	33.2	-8.7
SOT	DT40	31.9	32.8	0.9
SOT	DT41	38.7	29.9	-8.7
SOT	DT42	36.7	29.6	-7.1
SOT	DT49	34.3	30.2	-4.1
SOT	DT51	37.7	39.8	2.1
SOT	DT52	38.8	36.0	-2.7
SOT	DT53	47.9	35.3	-12.6
SOT	DT55	32.2	31.7	-0.6
SOT	DT56	34.6	33.3	-1.3
SOT	DT61	49.5	42.5	-7.0
SOT	DT63	35.0	26.9	-8.1
SOT	DT64	51.1	39.3	-11.8
SOT	DT65	36.5	34.2	-2.3
SOT	DT66	36.8	33.4	-3.4
SOT	DT67	29.9	26.9	-3.0
SOT	DT72	48.6	38.6	-10.1
SOT	DT73	35.0	33.3	-1.8
SOT	DT74	31.7	34.4	2.6
SOT	DT75	43.6	31.1	-12.4
SOT	DT76	37.6	34.2	-3.4
SOT	DT78	36.9	36.6	-0.3
SOT	DT79	47.7	39.1	-8.6
SOT	DT8	38.4	38.0	-0.4
SOT	DT80	37.8	36.6	-1.2
SOT	DT81	29.0	30.3	1.3
SOT	DT82	31.8	30.4	-1.4
SOT	DT83	34.0	33.6	-0.4
SOT	DT84	33.2	34.5	1.3
SOT	DT85	36.6	23.9	-12.7
SOT	DT86	36.4	38.0	1.6
SOT	DT88	36.6	38.0	1.3
SOT	DT89	35.6	38.5	2.9
SOT	DT9	30.4	30.0	-0.4
SOT	DT91	36.9	33.6	-3.3
SOT	DT92	44.8	38.9	-5.9
SOT	DT93	43.4	38.0	-5.5
SOT	DT94	31.7	34.7	2.9
SOT	DT95	29.6	32.2	2.6
SOT	DT97	31.3	32.8	1.5
SOT	DT99	30.7	31.4	0.7
RMSE (excluding clear outliers)		**5.16**		

3 Baseline results

3.1 Comparison with PCM

A set of gridded results with a resolution of at least 10m x 10m is required by the JAQU guidance. For this study, RapidAir© was used to model at 3m grid resolution. As RapidAir produces concentration grids (in raster format), modelled NO_2 concentrations can be extracted at receptor locations anywhere on the 3m resolution model output grid. For comparison with the PCM model results, annual mean concentrations at a distance of 4m from the kerb and at 2m height were extracted from the RapidAir model outputs. This provides an assessment of compliance at relevant roadside locations where there may be public access as specified in the Air Quality Directive (AQD) requirements Annex III A, B, and C3.

Concentrations were sampled at 4m intervals along each road, in order to ensure that the maximum predicted concentrations along each link were identified and reported. Receptors within 25m of major road junctions, or inside minor road junctions, were removed, as these were considered not to be representative of relevant exposure.

A comparison of the local model maximum concentration modelled 4m from each PCM road link and the corresponding PCM results from 2018 to 2022 are presented in Table 7. The results for 2018 and 2022 were explicitly modelled; the interim years were interpolated. Maps showing the predicted annual mean NO_2 concentrations in 2018 and 2022 are presented in Figure 3-1 to Figure 3-7. These model results should be considered in context with the model uncertainty quantified during model verification and described in Section2.

The PCM model predicts no links with exceedances in the study area in 2022. The local model, however, identified a number of locations where exceedance of the NO_2 limit value occurs in 2022:

- The A53 (Etruria Road) between Victoria Street and Basford Park Road. The maximum predicted annual mean NO_2 concentration along these links is 43 $\mu g.m^{-3}$.

- The A5008 (Bucknall New Road), at the junction with Potteries Way on Census ID 46553. The maximum predicted annual mean NO_2 concentration along this link is 42 $\mu g.m^{-3}$. There are two NO_2 diffusion tube locations along this Census ID; both locations recorded exceedances in 2018 (44.8 $\mu g.m^{-3}$ and 48.6 $\mu g.m^{-3}$). The exceedance along this link is due to slow traffic speeds entering the junction, relatively high bus flows, and the presence of a street canyon.

- The section of the A50 (Victoria Road) in Fenton, leading towards the junction with King Street, and corresponding to Census ID 16501. The maximum predicted annual mean NO_2 concentration along this link is 46 $\mu g.m^{-3}$. Stoke-on-Trent Council carries out monitoring at two locations along this link, with one measuring an exceedance (46.3 $\mu g.m^{-3}$) in 2018, and the other measuring compliance (38.1 $\mu g.m^{-3}$). The exceedances at these locations are caused by relatively low speeds, and narrow street canyons along particular road segments.

Table 7: NO_2 annual mean concentrations 2018 baseline year, 2022 future baseline year – Comparison of PCM vs local model results by Census ID (µg.m^{-3})

Census ID	Road Name	Length (m)	Managed by	PCM baseline NO_2 concentrations (µg.m^{-3})					Local baseline NO_2 concentrations (µg.m^{-3})				
				2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
26355	A34	1033	HWE	29	28	27	25	24	39	37	35	33	31
48067	A34	226	HWE	27	26	25	23	22	36	34	33	31	29
17975	A34	429	HWE	28	27	26	24	23	39	37	35	33	31
74065	A34	468	HWE	25	24	23	22	20	36	34	32	31	29
6353	A34	1873	HWE	24	23	22	21	20	30	29	27	26	24
56360	A34	2064	HWE	31	30	28	26	25	33	31	30	28	26
16325	A34	1916	HWE	29	27	26	25	23	32	31	29	28	26
77490	A34	1284	HWE	25	24	23	21	20	29	28	27	25	24
73258	A34	695	HWE	25	24	23	21	20	28	26	25	23	22
6352	A34	1070	HWE	18	17	16	16	15	25	24	23	22	21
36360	A34	2366	HWE	28	27	25	24	22	40	38	36	34	32
56326	A34	652	HWE	30	29	27	25	24	30	29	27	26	25
26531	A50	757	HWE	28	27	25	24	23	42	41	39	37	35
48668	A50	1032	HWE	24	23	22	21	20	42	40	38	37	35
75448	A50	581	HWE	29	28	26	25	24	33	31	30	29	27
99215	A50	1531	HWE	26	25	24	23	22	39	37	35	34	32
6522	A50	1407	HWE	27	26	25	23	22	41	39	38	36	35
36543	A50	1115	LA	28	27	26	25	23	44	43	42	41	40
60023	A50	636	HWE	30	29	28	26	24	40	38	37	35	33
60017	A50	1038	HWE	24	23	22	20	19	32	31	30	29	28
46538	A50	1237	HWE	22	21	20	19	18	26	25	24	23	22
16501	A50	1491	LA	31	30	29	27	26	55	53	50	48	46

Census ID	Road Name	Length (m)	Managed by	PCM baseline NO_2 concentrations ($\mu g.m^{-3}$)					Local baseline NO_2 concentrations ($\mu g.m^{-3}$)				
				2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
60024	A50	332	HWE	28	27	26	25	23	39	37	35	33	32
74261	A50	536	LA	35	33	32	30	28	46	44	42	40	39
99335	A50	1838	HWE	47	44	41	39	36	52	49	46	43	40
99331	A50	1048	HWE	42	40	38	36	33	55	53	50	48	46
99333	A50	612	HWE	49	46	43	40	37	48	46	44	42	40
77492	A50	1715	HWE	22	21	20	19	18	26	25	24	23	22
74586	A50	758	HWE	19	19	18	17	16	39	37	35	33	32
75422	A50	339	HWE	46	44	42	39	37	48	45	43	41	39
75424	A50	226	HWE	19	18	17	16	15	38	37	35	33	31
74585	A50	816	HWE	22	21	20	19	18	34	32	31	29	28
99337	A50	1576	HWE	42	40	37	35	33	46	43	41	39	37
99329	A50	1398	HWE	45	43	40	38	35	59	56	53	50	47
60026	A50	1578	HWE	32	30	29	28	26	56	53	51	48	45
47243	A500	2465	HWE	49	46	43	41	38	60	57	55	52	49
8147	A500	1136	HWE	45	43	40	38	35	63	61	58	55	53
8340	A500	2865	HWE	47	45	42	40	37	64	61	58	55	53
38230	A500	1107	HWE	50	47	44	41	39	58	54	51	48	45
57783	A500	1008	HWE	48	46	43	41	38	63	61	58	56	53
75418	A500	130	HWE	48	45	43	40	38	47	45	43	41	39
75420	A500	246	HWE	21	20	19	19	18	36	34	33	31	30
75421	A500	472	HWE	50	47	45	42	40	45	44	42	40	39
18131	A500	751	HWE	40	38	36	33	31	48	46	44	42	40
77480	A5005	1126	LA	16	15	14	14	13	22	21	20	19	18
70279	A5007	1728	LA	20	19	18	17	16	44	42	40	38	37

Census ID	Road Name	Length (m)	Managed by	PCM baseline NO_2 concentrations (µg.m^{-3})						Local baseline NO_2 concentrations (µg.m^{-3})				
				2018	2019	2020	2021	2022		2018	2019	2020	2021	2022
48214	A5006	1313	LA	22	22	21	20	19		38	37	35	33	32
17648	A5006	1859	LA	29	28	27	26	24		44	42	40	39	37
82001	A5006	222	LA	24	23	22	20	19		42	41	40	39	39
80721	A5006	982	LA	22	21	20	19	18		33	32	31	30	29
56539	A5007	1188	LA	27	26	24	23	22		41	39	37	35	34
70277	A5007	1100	LA	29	28	27	25	24		41	39	38	36	34
56306	A5007	769	LA	22	21	20	19	18		37	35	33	31	29
99407	A5007	947	LA	18	17	16	15	14		45	41	38	35	32
70280	A5007	185	LA	22	21	20	19	18		26	24	23	22	21
81450	A5008	572	LA	22	21	20	19	19		34	34	33	33	33
60022	A5008	543	LA	27	26	25	24	22		37	36	35	33	32
46553	A5008	713	LA	30	28	27	25	23		53	50	48	45	42
74903	A5008	364	LA	31	30	28	27	25		44	42	40	37	35
47735	A5009	4465	LA	23	22	21	20	19		44	41	39	37	35
81449	A5010	648	LA	23	22	21	20	19		34	32	31	29	28
81448	A5010	193	LA	30	29	28	26	25		42	40	39	38	37
73257	A5011	400	LA	18	18	17	16	15		23	22	21	20	19
74900	A5035	1065	LA	21	20	19	18	17		35	33	32	30	28
47740	A5035	4073	LA	19	18	18	17	16		27	26	25	24	23
47268	A519	2166	LA	22	21	20	19	18		33	31	30	28	27
38231	A52	1563	LA	35	34	32	30	28		51	48	45	42	40
18584	A52	892	LA	27	26	25	23	22		36	34	32	30	28
38521	A52	363	LA	28	27	26	24	23		43	41	38	36	33
28176	A52	1221	LA	24	23	22	21	20		39	37	35	32	30

Census ID	Road Name	Length (m)	Managed by	PCM baseline NO_2 concentrations (µg.m^{-3})					Local baseline NO_2 concentrations (µg.m^{-3})				
				2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
17860	A52	503	LA	27	26	24	23	22	36	34	32	30	28
6536	A52	1034	LA	26	25	23	22	21	40	37	35	32	30
18132	A52	196	LA	28	27	26	24	23	38	36	35	33	31
57472	A52	266	LA	30	29	27	26	24	40	38	37	35	33
26546	A52	2335	LA	19	18	17	16	15	26	25	24	23	21
99210	A52	263	LA	30	28	27	25	24	41	39	37	35	33
75284	A52	337	LA	28	27	26	24	23	44	42	39	37	34
99026	A52	873	LA	30	29	27	26	25	40	39	37	36	34
56996	A52	292	LA	33	31	30	28	26	46	44	42	40	38
70276	A52	361	LA	26	25	24	23	21	39	38	36	35	33
8148	A52	187	LA	28	27	26	25	23	37	36	34	33	31
27739	A52	662	LA	26	25	24	23	22	46	44	42	40	38
57470	A52	278	LA	26	25	24	23	22	39	37	36	34	32
48504	A52	245	LA	27	26	25	23	22	41	39	37	35	33
57606	A52	455	LA	26	25	24	23	21	48	46	43	41	39
36560	A52	705	LA	32	31	29	28	26	46	44	41	39	37
74894	A520	847	LA	24	23	22	20	19	31	29	27	26	24
99214	A520	1804	LA	23	22	21	19	18	40	38	36	34	33
8605	A520	1001	LA	24	23	21	20	19	31	30	29	27	26
48287	A525	459	LA	23	22	21	20	18	40	39	37	35	33
77488	A525	2113	LA	20	19	18	17	16	30	28	27	25	24
81251	A527	285	LA	17	17	16	15	15	22	21	20	19	18
38303	A527	1298	LA	28	27	26	24	23	37	35	33	30	28
47276	A527	2696	LA	24	23	22	20	19	38	36	35	33	32

Census ID	Road Name	Length (m)	Managed by	PCM baseline NO_2 concentrations (µg.m^{-3})						Local baseline NO_2 concentrations (µg.m^{-3})				
				2018	2019	2020	2021	2022		2018	2019	2020	2021	2022
74060	A527	1086	LA	23	22	21	19	18		27	26	25	24	23
81250	A527	392	LA	29	28	27	25	24		28	27	26	25	24
81253	A527	863	LA	27	26	25	24	22		30	28	27	26	25
74896	A5271	2295	LA	25	24	23	22	21		48	46	44	42	40
81252	A5271	1652	LA	19	18	17	17	16		39	37	35	33	31
74897	A5271	541	LA	20	19	18	17	16		35	34	32	31	29
74895	A5272	5100	LA	24	23	22	20	19		33	31	30	28	27
74898	A5272	2564	LA	26	24	23	22	21		47	45	43	42	40
74899	A5272	3626	LA	28	27	25	24	23		36	35	33	32	30
16526	A53	1989	LA	26	25	23	22	21		28	26	25	24	23
74902	A53	2099	LA	26	25	24	23	21		38	36	34	32	30
99212	A53	1232	LA	25	24	23	21	20		24	23	22	21	20
16527	A53	1773	LA	21	21	20	19	18		22	21	20	19	18
38088	A53	757	LA	20	19	18	17	16		32	31	29	27	26
28732	A53	545	LA	35	34	32	30	28		56	52	49	46	43
6545	A53	643	LA	25	24	23	22	20		53	50	47	44	41
74058	A53	492	LA	44	42	40	38	36		51	48	45	42	39
26555	A53	588	LA	45	43	41	38	36		46	43	41	38	36
46563	A53	1563	LA	36	35	33	31	29		47	45	42	40	38
75283	A53	272	LA	27	26	24	23	22		36	34	32	30	28
75282	A53	218	LA	27	25	24	23	21		41	39	37	34	32

Table 8: NO_2 annual mean concentrations 2018 baseline year, 2022 future baseline year – Comparison of PCM vs local model results by road name (µg.m^{-3})

Road Name	Managed by	PCM baseline NO_2 concentrations (µg.m^{-3})						Local baseline NO_2 concentrations (µg.m^{-3})				
		2018	2019	2020	2021	2022		2018	2019	2020	2021	2022
A34	HWE	31	30	28	26	25		40	38	36	34	32
A50	HWE/LA	49	46	43	40	37		59	56	53	50	47
A500	HWE	50	47	45	42	40		64	61	58	56	53
A5005	LA	16	15	14	14	13		22	21	20	19	18
A5007	LA	29	28	27	25	24		45	42	40	38	37
A5006	LA	29	28	27	26	24		44	42	40	39	39
A5008	LA	31	30	28	27	25		53	50	48	45	42
A5009	LA	23	22	21	20	19		44	41	39	37	35
A5010	LA	30	29	28	26	25		42	40	39	38	37
A5011	LA	18	18	17	16	15		23	22	21	20	19
A5035	LA	21	20	19	18	17		35	33	32	30	28
A519	LA	22	21	20	19	18		33	31	30	28	27
A52	LA	35	34	32	30	28		51	48	45	42	40
A520	LA	24	23	22	20	19		40	38	36	34	33
A525	LA	23	22	21	20	18		40	39	37	35	33
A527	LA	29	28	27	25	24		38	36	35	33	32
A5271	LA	25	24	23	22	21		48	46	44	42	41
A5272	LA	28	27	25	24	23		47	45	43	42	40
A53	LA	45	43	41	38	36		56	52	49	46	43

Figure 3-1: Local modelled NO_2 annual mean concentrations, 2018 base year, $ug.m^{-3}$ – PCM links

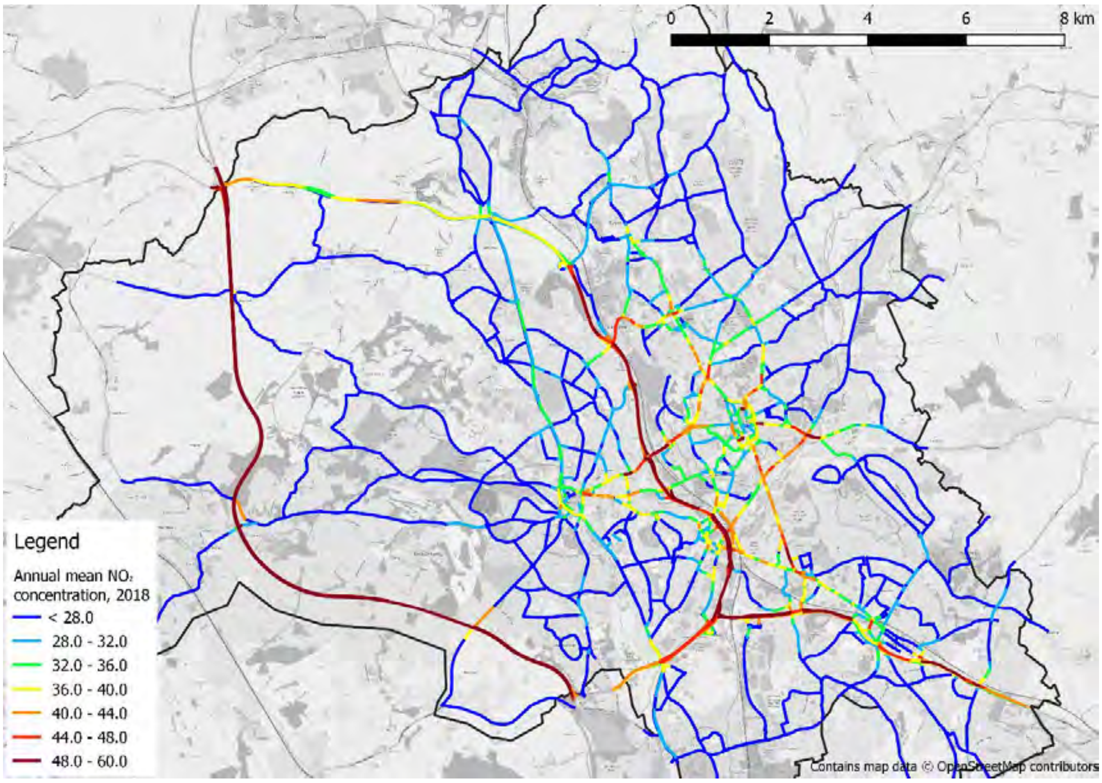


Figure 3-2: Annual mean NO_2 concentrations, 2018, $\mu g.m^{-3}$, model domain

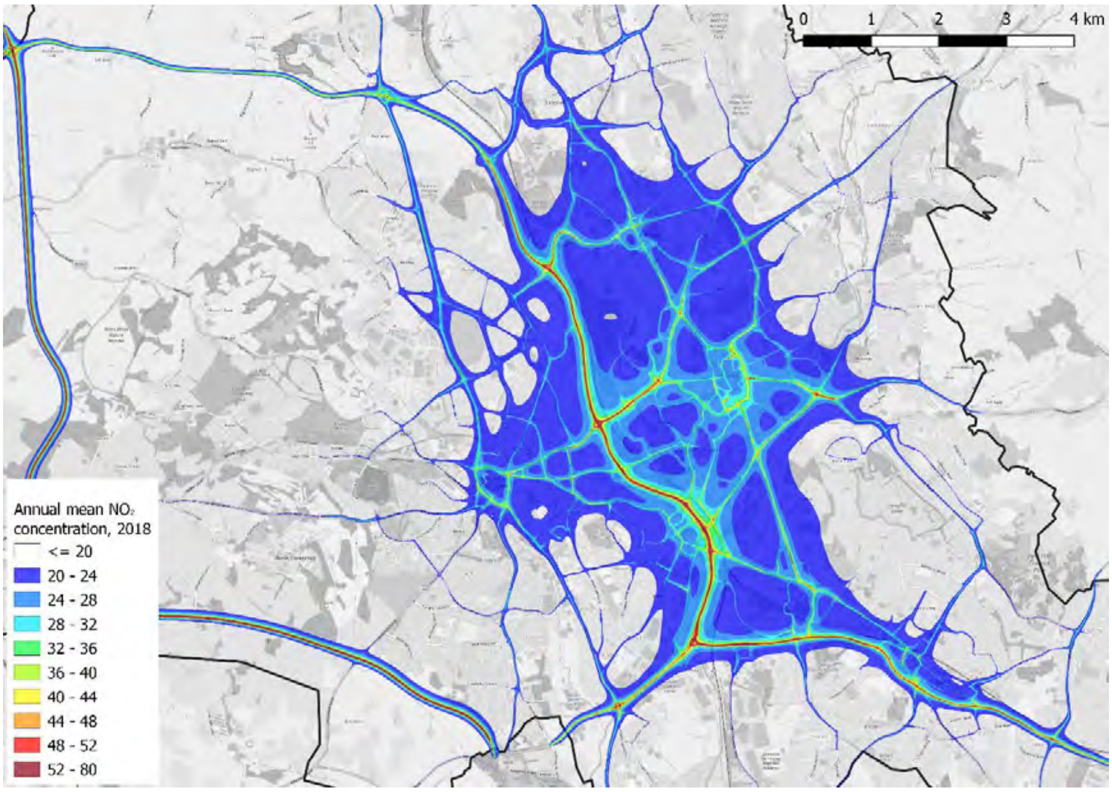


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Figure 3-3: Local modelled NO_2 annual mean concentrations, 2022 baseline year, ug.m^{-3} – PCM links

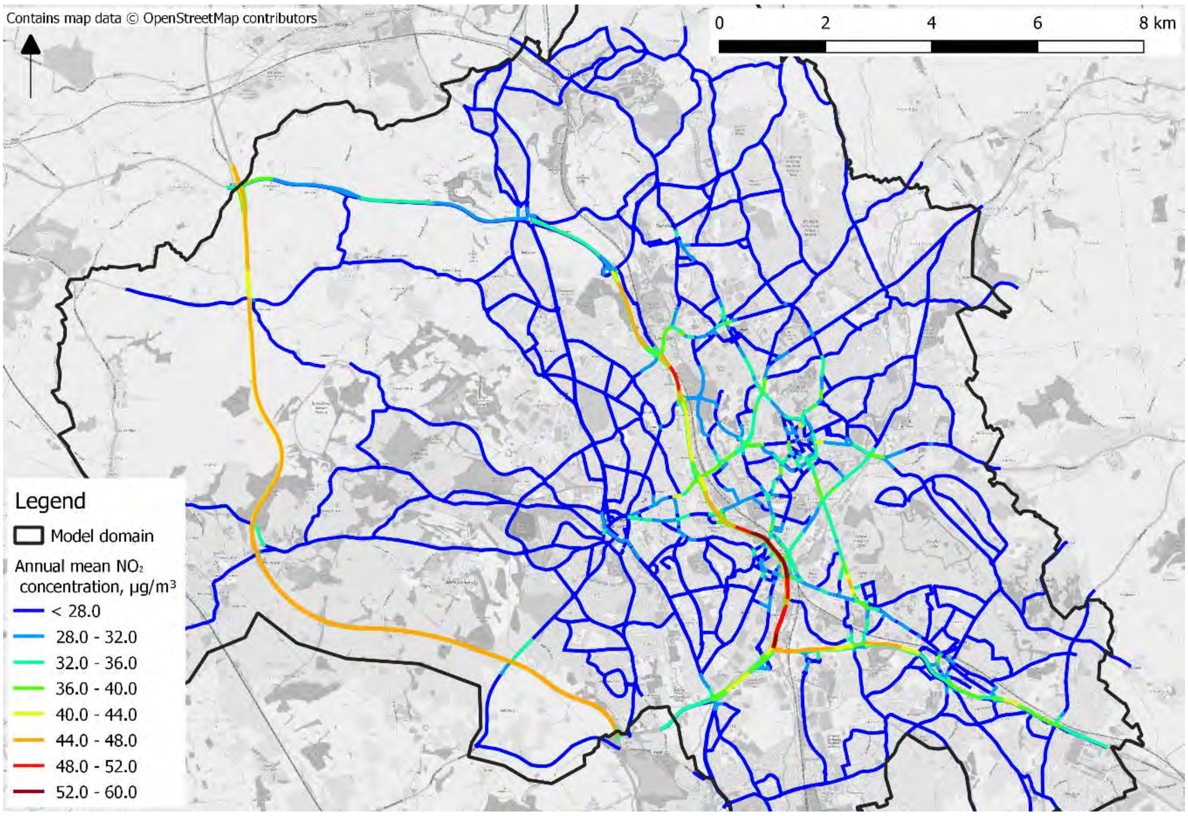

Figure 3-4: Annual mean NO_2 concentrations, 2022, µg.m^{-3}, study domain

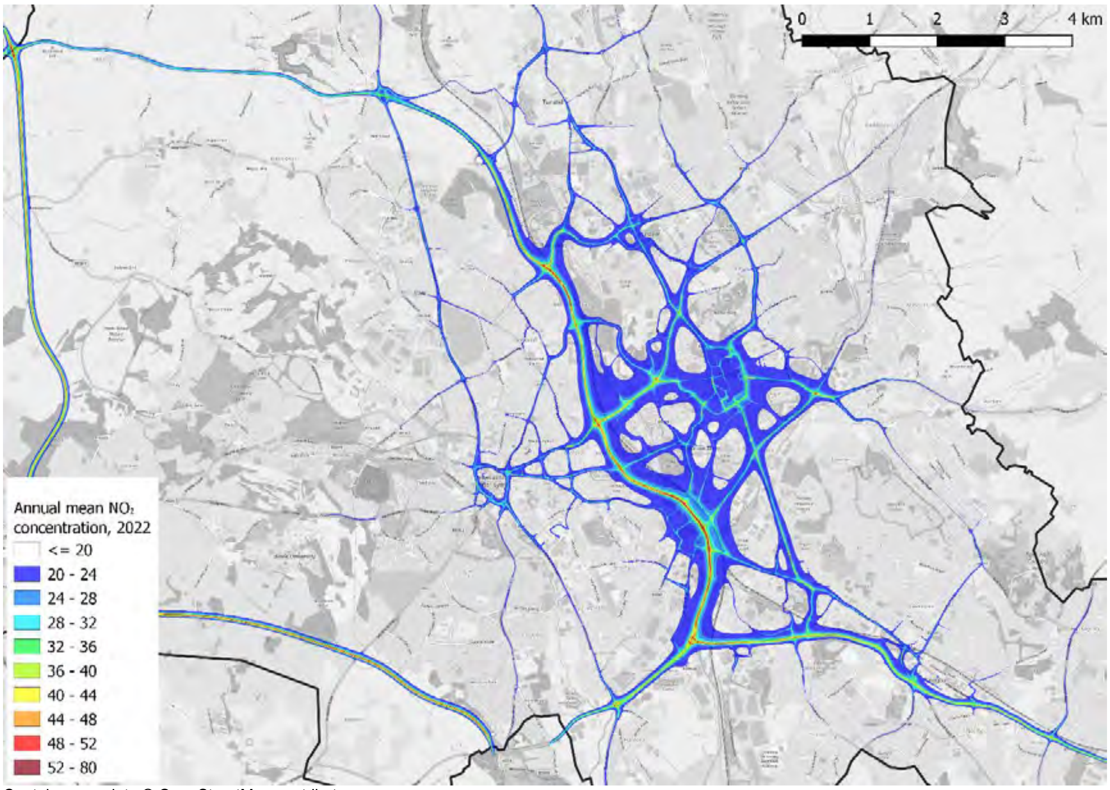

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Figure 3-5: Annual mean NO_2 concentrations, 2022, µg.m^{-3}, centre of model domain

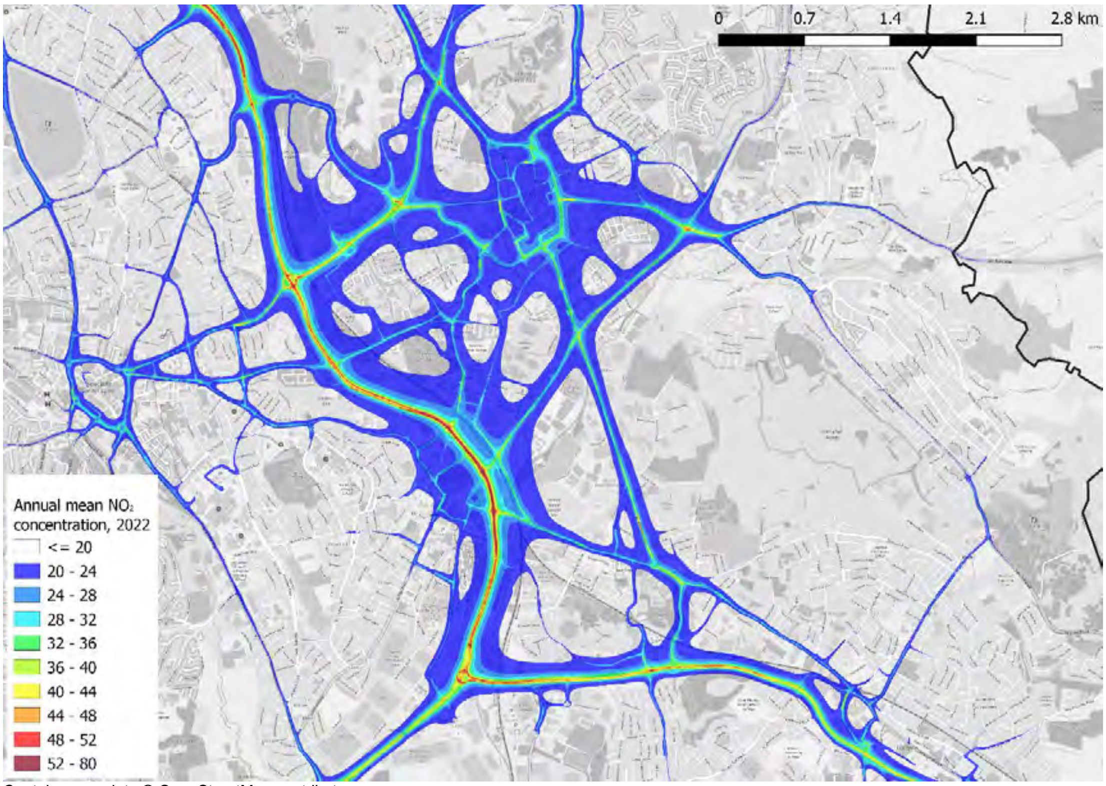

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Figure 3-6 Annual mean NO_2 concentrations, 2022, µg.m^{-3}, Hanley

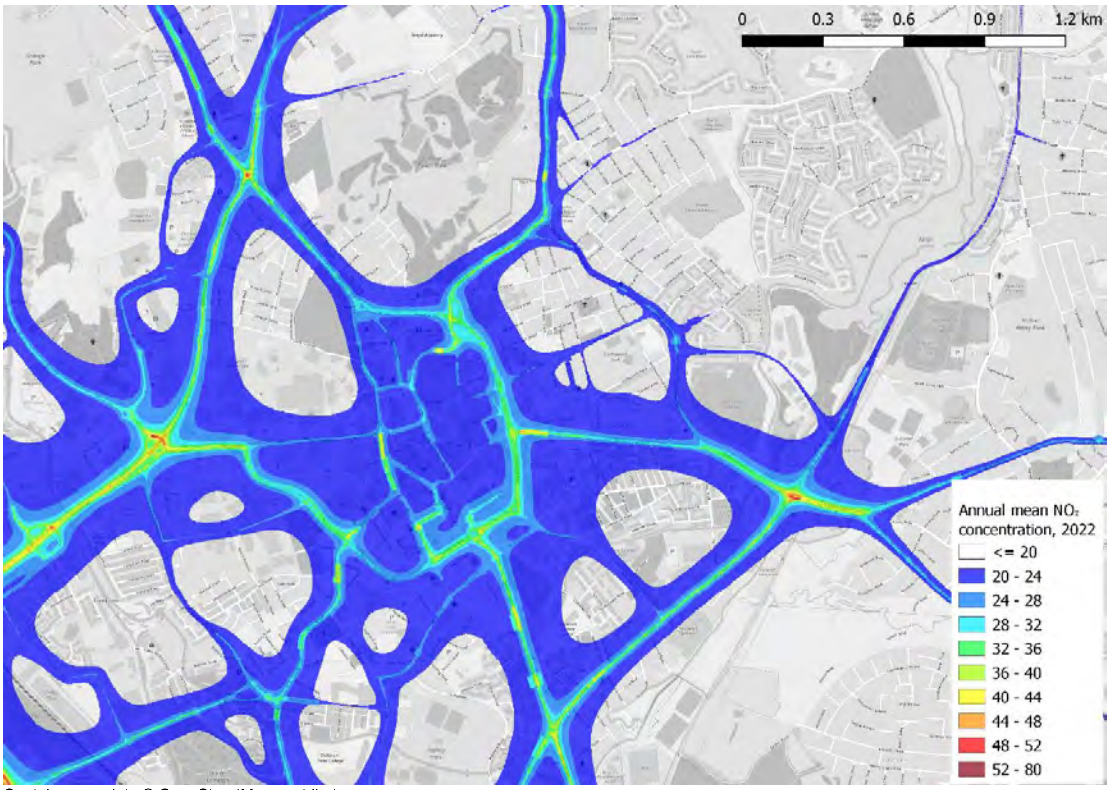

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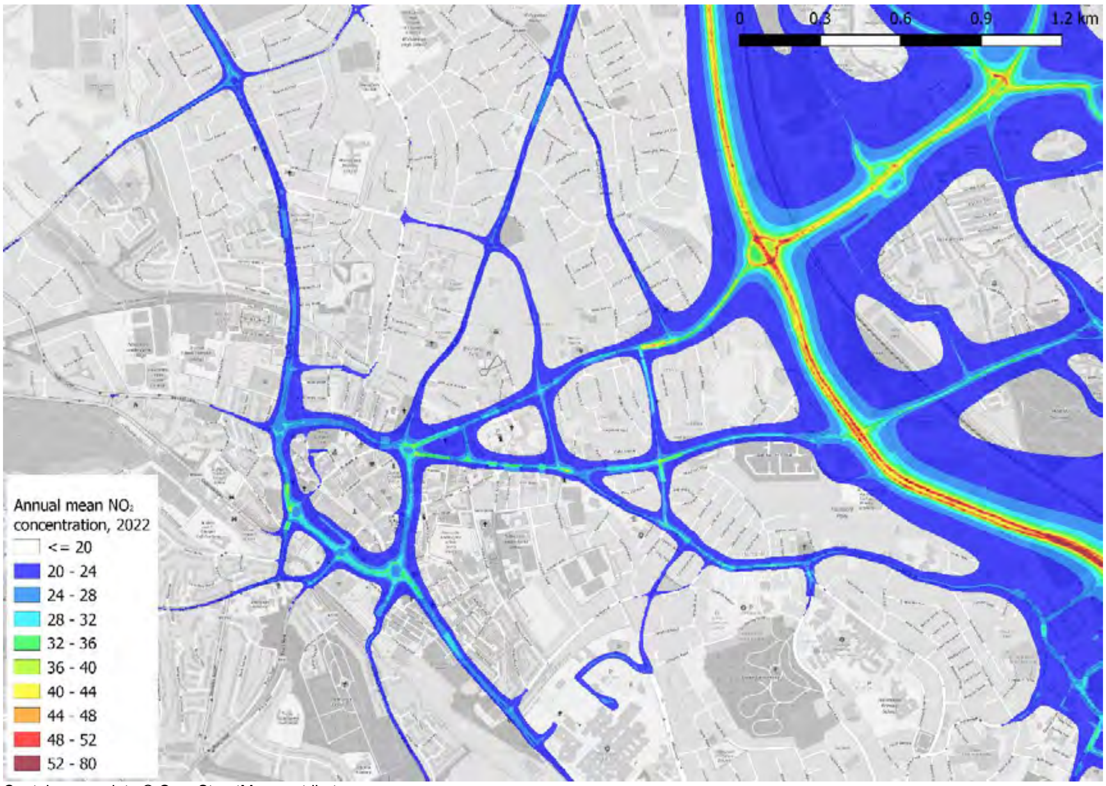
Figure 3-7: Annual mean NO_2 concentrations, 2022, μg.m^{-3}, Newcastle-under-Lyme



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3.2 Results for AQMAs and local exceedances

Diffusion tubes have been sited to capture the 'worst case' exceedance locations on local roads in order to determine Air Quality Management Areas (AQMAs). As such, results at these locations provide a good indication of local air quality and potential exceedances in relation to the local air quality management regime. Annual mean NO_2 concentrations measured in 2018 and predicted annual mean NO_2 concentrations at each of these diffusion tube monitoring sites in 2022 are presented in Table 9.

The results indicate that in 2022, compliance with the 40 μg.m^{-3} NO_2 annual mean objective will be achieved at the majority of current monitoring locations, with the exception of Stoke-on-Trent site DT34, located on Victoria Road.

Table 9: Predicted NO_2 annual mean concentrations at monitoring site locations in 2022

Council	Monitoring site ID	Monitoring type	Site type	NO_2 annual mean (μg.m^{-3})		
				Measured 2018	Modelled 2018	Modelled 2022
Newcastle-under-Lyme	CM1	Automatic	Roadside	23.1	27.8	21.6
	DTK1	Diffusion tube	Kerbside	41.7	40.4	32.6
	DTK2	Diffusion tube	Urban Centre	29.7	29.6	23.0
	DTUB1	Diffusion tube	Kerbside	19.0	20.3	16.5
	DT3	Diffusion tube	Rural	30.7	36.8	28.9
	DT6	Diffusion tube	Suburban	37.7	26.5	22.2
	DT9	Diffusion tube	Suburban	33.4	30.0	24.6
	DT24	Diffusion tube	Roadside	35.3	31.6	26.6
	DT28	Diffusion tube	Rural	29.9	26.7	21.0
	DT34	Diffusion tube	Urban Centre	32.1	31.1	24.4
	DT40	Diffusion tube	Suburban	28.3	24.0	19.5
	DT46	Diffusion tube	Urban Centre	30.1	34.0	27.7
	DT47	Diffusion tube	Urban Centre	25.8	31.6	25.6
	DT49	Diffusion tube	Urban Centre	31.5	32.3	26.8
	DT64	Diffusion tube	Urban Centre	35.9	24.7	20.4
	DT73	Diffusion tube	Roadside	32.0	34.4	27.6
	DT74	Diffusion tube	Roadside	33.0	29.7	24.1
	DT76	Diffusion tube	Roadside	36.5	29.3	23.0
	DT84	Diffusion tube	Roadside	35.1	34.0	26.2
	DT85	Diffusion tube	Urban Centre	40.0	36.9	28.5
	DT86	Diffusion tube	Urban Centre	29.7	29.6	23.2
	DT87	Diffusion tube	Urban Centre	37.9	39.5	30.6
	DT88	Diffusion tube	Urban Centre	29.9	28.2	22.5
	DT89	Diffusion tube	Urban Centre	30.4	30.1	23.3
	DT90	Diffusion tube	Urban Centre	30.0	30.1	23.3
	DT91	Diffusion tube	Urban Centre	30.3	30.1	23.3
	DT92	Diffusion tube	Urban Centre	33.5	23.7	19.5
	DT93	Diffusion tube	Urban Centre	30.4	24.3	20.5
	DT94	Diffusion tube	Urban Centre	32.1	25.9	21.8
	DT95	Diffusion tube	Urban Centre	34.3	27.7	22.7
	DT97	Diffusion tube	Roadside	28.6	30.1	24.0
	DT98	Diffusion tube	Roadside	37.7	30.3	23.9
	DT100	Diffusion tube	Roadside	30.0	31.2	23.7
	DT101	Diffusion tube	Roadside	33.0	35.1	27.4
	DT103	Diffusion tube	Roadside	24.1	27.8	22.7

Council	Monitoring site ID	Monitoring type	Site type	NO_2 annual mean (µg.m^{-3})		
				Measured 2018	Modelled 2018	Modelled 2022
	DT104	Diffusion tube	Roadside	38.2	37.4	29.1
	DT105	Diffusion tube	Roadside	27.2	20.4	16.7
Stoke-on-Trent	CM1	Automatic	Urban Background	23.0	30.4	24.5
	CM2	Automatic	Roadside	33.0	36.1	31.1
	CM5	Automatic	Roadside	55.0	42.6	32.8
	CM6	Automatic	Roadside	53.0	46.3	35.8
	DT1	Diffusion tube	Urban Background	18.3	18.2	14.8
	DT2	Diffusion tube	Roadside	39.1	33.4	26.7
	DT4	Diffusion tube	Roadside	31.9	32.9	25.8
	DT8	Diffusion tube	Roadside	29.0	30.4	24.5
	DT9	Diffusion tube	Roadside	44.8	39.1	33.5
	DT10	Diffusion tube	Roadside	34.9	35.7	29.2
	DT13	Diffusion tube	Roadside	35.2	37.0	28.8
	DT14	Diffusion tube	Roadside	37.4	36.2	28.2
	DT15	Diffusion tube	Roadside	38.1	39.3	32.6
	DT16	Diffusion tube	Roadside	49.4	47.4	36.4
	DT20	Diffusion tube	Roadside	35.4	39.7	32.3
	DT24	Diffusion tube	Roadside	41.6	36.7	31.2
	DT29	Diffusion tube	Roadside	38.4	31.6	26.0
	DT32	Diffusion tube	Roadside	34.4	37.7	32.7
	DT34	Diffusion tube	Roadside	46.3	50.8	**41.9**
	DT37	Diffusion tube	Roadside	41.9	33.3	28.2
	DT40	Diffusion tube	Roadside	38.7	30.1	23.8
	DT41	Diffusion tube	Roadside	36.7	29.7	23.4
	DT42	Diffusion tube	Roadside	34.3	30.3	24.1
	DT49	Diffusion tube	Roadside	37.7	39.9	33.9
	DT51	Diffusion tube	Roadside	38.8	36.2	28.7
	DT52	Diffusion tube	Roadside	47.9	35.4	27.6
	DT53	Diffusion tube	Roadside	32.2	31.8	24.8
	DT55	Diffusion tube	Roadside	34.6	33.4	27.2
	DT56	Diffusion tube	Roadside	49.5	42.6	32.8
	DT61	Diffusion tube	Roadside	35.0	27.0	22.2
	DT63	Diffusion tube	Roadside	51.1	39.5	30.5
	DT64	Diffusion tube	Roadside	36.5	34.3	26.8
	DT65	Diffusion tube	Roadside	36.8	33.5	26.2
	DT66	Diffusion tube	Roadside	29.9	27.0	21.5
	DT67	Diffusion tube	Roadside	48.6	38.7	31.6
	DT72	Diffusion tube	Roadside	35.0	33.4	26.7
	DT73	Diffusion tube	Roadside	31.7	34.5	27.1
	DT74	Diffusion tube	Roadside	43.6	31.3	26.5
	DT75	Diffusion tube	Roadside	37.6	34.4	28.0
	DT76	Diffusion tube	Roadside	36.9	36.7	29.8
	DT77	Diffusion tube	Roadside	47.7	39.3	31.6
	DT78	Diffusion tube	Roadside	38.4	38.1	30.5
	DT79	Diffusion tube	Roadside	37.8	36.8	29.5
	DT80	Diffusion tube	Roadside	31.8	30.5	24.8
	DT81	Diffusion tube	Roadside	34.0	33.7	27.2
	DT82	Diffusion tube	Roadside	33.2	34.6	27.6

Council	Monitoring site ID	Monitoring type	Site type	NO_2 annual mean (μg.m^{-3})		
				Measured 2018	Modelled 2018	Modelled 2022
	DT83	Diffusion tube	Roadside	36.6	24.0	19.7
	DT84	Diffusion tube	Roadside	36.4	38.1	31.1
	DT85	Diffusion tube	Roadside	36.6	38.1	30.9
	DT86	Diffusion tube	Roadside	35.6	38.6	31.2
	DT88	Diffusion tube	Roadside	30.4	30.1	25.2
	DT89	Diffusion tube	Roadside	36.9	33.7	27.8
	DT91	Diffusion tube	Roadside	43.4	38.1	32.9
	DT92	Diffusion tube	Roadside	31.7	34.8	29.9
	DT93	Diffusion tube	Roadside	29.6	32.3	27.8
	DT94	Diffusion tube	Roadside	31.3	32.9	28.1
	DT95	Diffusion tube	Roadside	30.7	31.5	26.7
	DT97	Diffusion tube	Roadside	29.8	32.2	24.6
	DT99	Diffusion tube	Roadside	48.6	48.7	38.5
	DT100	Diffusion tube	Roadside	44.8	49.8	39.4
	DT101	Diffusion tube	Roadside	30.1	35.7	27.2
	DT102	Diffusion tube	Roadside	33.0	30.2	23.3
	DT103	Diffusion tube	Roadside	30.9	35.7	29.5
	DT104	Diffusion tube	Roadside	42.4	36.1	28.4
	DT105	Diffusion tube	Roadside	34.2	40.0	30.8
	DT106	Diffusion tube	Roadside	33.0	40.1	30.8

4 Option testing results

Each of the option model runs has been carried out using the assumptions set out in Section 1. The results have been extracted in the same way as for the baseline and are shown in the sections below.

4.1 Comparison with PCM

A summary of the modelled annual mean NO_2 results for each of the options is shown in Table 10 with details provided in Table 11; the predicted success of each option in delivering the primary objective of producing compliance by 2022 is also given.

Table 10: Summary comparison of modelled NO_2 concentrations for PCM links for the options in 2022

Option	Links > 40 µg.m^{-3}	Links > 35 and <= 40 µg.m^{-3}	Local Authority links > 40 µg.m^{-3}	Local authority links > 35 and <= 40 µg.m^{-3}	Average change in NO_2 (%)	Delivers compliance
2022 Reference Case	12	23	4	16	N/A	N/A
Benchmark CAZ D	8	12	0	5	-7.9%	✓
Option 2	10	23	2	16	-1.1%	X
Option 3	8	22	0	15	-2.7%	✓
Option 4 (Preferred Option)	8	25	0	18	-1.3%	✓
Option 5 (CAZ C)	10	19	2	12	-3.0%	X
Option 6	8	25	0	18	-1.8%	✓

The impact of each option can be summarised as follows:

Benchmark Class D Charging CAZ scheme (Option 1): The scheme was included to provide a benchmark charging access restriction scheme against which the traffic management options could be assessed. The results show that the Class D Charging scheme would match the Preferred Option in removing links which exceed the NO_2 limit, and would reduce average NO_2 concentrations along links by 7.9%. However, it is unlikely that this scheme could be delivered by 2022, as discussed in the Strategic Case.

Option 2 (High impact without charging CAZ scheme): This scheme is not predicted to deliver compliance along Victoria Road (A50) and Bucknall New Road (A5008). This option also produces the smallest average reduction in NO_2 concentrations along links.

Option 3 (High impact including local Class D Charging CAZ scheme around Victoria Road): The combination of bus retrofits along affected routes, and a local class D charging CAZ around the Victoria Road area, delivers compliance and leads to an average reduction in NO_2 concentrations of 2.7%.

Option 4 (Preferred Option): This combination of bus retrofit and traffic management schemes (with wider measures to improve accessibility of public transport) has been specifically designed to limit traffic levels along affected stretches of the A500, A5009, and A53 in order to solve the exceedance problem. This option delivers compliance, and leads to an average reduction in NO_2 concentrations of 1.3% along road links. The number of Strategic Road Network links predicted to exceed the Objective also decreases, showing that the scheme does not move compliance issues elsewhere.

Option 5 (Class C Charging CAZ scheme): Although this option leads to a greater overall reduction in NO_2 concentrations along road links (3%), it does not deliver compliance along Victoria Road (A500).

Furthermore, rerouting of traffic to avoid the CAZ in this scheme leads to concentrations increasing to exceed the objective along Porthill Road (the A5271).

Option 6: This option adds complementary measures to the package of measures identified in Option 4. This option leads to a slightly larger average reduction in NO_2 concentrations of 1.8% along road links.

Table 11 presents the full NO_2 annual mean concentration results for each option in 2022. The mapped results for the PCM links are shown in Figure 12 to Figure 17.

Table 11: NO_2 annual mean concentration results for each option in 2022 (µg.m^{-3})

Census ID	Road Name	Road management description	X	Y	Reference Case	Benchmark CAZ D	Option 2	Option 3	Option 4	Option 5	Option 6
16325	A34	West Midlands	383844	349709	26	26	26	27	27	26	27
16501	A50	The Potteries	389274	344897	46	36	40	35	39	41	39
16526	A53	The Potteries	389961	350538	23	22	23	23	23	22	23
16527	A53	The Potteries	384291	345021	18	17	18	18	18	17	18
17648	A5006	The Potteries	387782	345975	37	36	37	37	37	37	37
17860	A52	The Potteries	384968	346229	28	24	28	28	28	27	28
17975	A34	The Potteries	384967	345747	31	30	31	30	31	31	30
18131	A500	Highways England	386684	342780	40	38	40	40	40	39	40
18132	A52	The Potteries	387596	345087	31	29	31	31	32	31	31
18584	A52	The Potteries	390780	347578	28	24	29	27	28	26	28
26355	A34	The Potteries	384606	346067	31	30	31	31	32	31	31
26531	A50	The Potteries	386877	349962	35	34	35	35	35	35	35
26546	A52	The Potteries	391734	347229	21	19	21	21	21	20	21
26555	A53	The Potteries	386899	347280	36	29	36	36	36	33	36
27739	A52	The Potteries	388002	345419	38	34	38	38	38	37	38
28176	A52	The Potteries	387441	345546	30	28	29	30	30	29	29
28732	A53	The Potteries	386020	346599	43	33	42	40	39	40	39
36360	A34	The Potteries	386659	342825	32	31	32	32	33	32	32
36543	A50	The Potteries	388688	346674	38	32	36	33	36	36	36
36560	A52	The Potteries	388887	346690	37	29	36	35	37	34	36
38088	A53	The Potteries	384726	345706	26	25	26	26	26	26	26
38230	A500	Highways England	386534	346672	44	43	44	44	44	44	44
38231	A52	The Potteries	389669	347372	40	32	39	37	38	36	38
38303	A527	The Potteries	385085	346011	28	26	28	27	27	27	27
38521	A52	The Potteries	387441	345531	33	30	32	32	32	32	32
46538	A50	The Potteries	385136	353707	22	22	22	22	22	22	22
46553	A5008	The Potteries	388625	347613	42	31	41	37	39	35	39
46563	A53	The Potteries	387629	348614	38	32	38	38	38	36	38
47243	A500	Highways England	386235	347494	43	44	43	43	43	45	43

Census ID	Road Name	Road management description	X	Y	Reference Case	Benchmark CAZ D	Option 2	Option 3	Option 4	Option 5	Option 6
47268	A519	The Potteries	385007	345655	27	26	27	27	27	27	27
47276	A527	The Potteries	385635	349171	32	31	32	32	32	32	32
47735	A5009	The Potteries	389643	347400	35	29	34	32	34	32	34
47740	A5035	The Potteries	388797	341183	23	23	23	23	23	23	23
48067	A34	The Potteries	384771	345867	29	28	29	29	29	29	29
48214	A5006	The Potteries	387722	344492	32	30	32	31	32	31	32
48287	A525	The Potteries	384624	345910	33	33	34	33	34	33	33
48504	A52	The Potteries	387999	345083	33	30	32	32	32	31	32
48668	A50	The Potteries	387396	348963	35	31	35	35	35	34	35
56306	A5007	The Potteries	390946	343600	29	28	27	27	27	28	27
56326	A34	The Potteries	386659	341254	25	24	25	25	25	25	25
56360	A34	The Potteries	384618	346990	26	25	26	26	26	26	26
56539	A5007	The Potteries	389723	344462	34	30	32	30	32	32	31
56996	A52	The Potteries	388107	345064	38	34	37	36	37	36	37
57470	A52	The Potteries	387933	345300	32	29	32	32	32	31	32
57472	A52	The Potteries	387614	345090	33	31	33	33	34	33	34
57606	A52	The Potteries	387916	345417	39	36	40	39	39	38	39
57783	A500	Highways England	387869	343963	53	49	53	53	54	52	53
60017	A50	The Potteries	385614	352712	28	27	28	27	28	27	28
60022	A5008	The Potteries	388371	347160	32	27	30	29	30	29	30
60023	A50	The Potteries	388587	347648	32	27	32	31	32	30	32
60024	A50	The Potteries	388408	348016	32	27	31	31	31	30	31
60026	A50	Highways England	388656	343695	45	44	46	45	46	45	46
60026	A50	The Potteries	389529	343854	34	31	34	31	33	33	33
6352	A34	The Potteries	382796	354472	21	20	21	21	21	21	21
6353	A34	The Potteries	385548	345115	24	24	24	24	24	25	24
6522	A50	The Potteries	387428	348883	35	31	35	34	35	33	34
6536	A52	The Potteries	386239	345776	30	26	29	29	29	29	29
6545	A53	The Potteries	385966	346586	41	32	40	38	37	38	37
70276	A52	The Potteries	388191	345297	33	31	32	34	32	32	32

Census ID	Road Name	Road management description	X	Y	Reference Case	Benchmark CAZ D	Option 2	Option 3	Option 4	Option 5	Option 6
70277	A5007	The Potteries	388755	344799	34	32	31	34	31	33	31
70279	A5005	The Potteries	390915	343478	37	35	33	33	33	35	33
70280	A5007	The Potteries	391177	343365	22	22	21	21	21	22	21
73257	A5011	The Potteries	382538	353855	19	19	19	19	19	19	19
73258	A34	The Potteries	382682	354204	21	21	21	21	21	21	21
74058	A53	The Potteries	386515	347007	39	31	39	38	38	35	38
74060	A527	The Potteries	387084	352775	23	22	23	23	23	23	23
74065	A34	The Potteries	385219	345513	29	29	29	29	29	30	29
74261	A50	The Potteries	389336	344732	39	31	35	31	34	36	34
74585	A50	Highways England	390684	343400	27	27	27	26	27	27	27
74586	A50	Highways England	390651	343553	32	30	31	30	31	31	31
74894	A520	The Potteries	393513	343914	24	24	24	24	24	24	24
74895	A5272	The Potteries	390067	347134	27	24	26	25	26	25	26
74896	A5271	The Potteries	385711	349345	40	40	40	40	40	41	40
74897	A5271	The Potteries	386262	351089	29	29	29	29	29	29	29
74898	A5272	The Potteries	388718	348571	40	37	39	38	39	39	39
74899	A5272	The Potteries	388544	349652	30	28	30	30	30	30	30
74900	A5035	The Potteries	391079	342954	28	28	28	28	28	28	28
74902	A53	The Potteries	387970	349235	30	29	31	30	30	30	30
74903	A5008	The Potteries	389595	347400	35	29	34	32	34	32	34
75282	A53	The Potteries	385105	346223	32	27	32	31	32	30	31
75283	A53	The Potteries	385395	346346	27	23	28	26	26	26	26
75284	A52	The Potteries	385117	346185	34	28	34	33	33	32	32
75418	A500	Highways England	387748	343655	39	37	40	39	40	38	40
75420	A500	The Potteries	387616	343545	30	29	30	30	30	30	30
75421	A500	Highways England	387616	343503	38	37	39	38	39	38	39
75422	A50	Highways England	391122	343069	39	37	38	37	38	38	38
75424	A50	Highways England	391158	342998	31	30	31	30	31	31	31
75448	A50	The Potteries	386654	350669	27	27	27	27	27	27	27
77480	A5005	The Potteries	391761	342203	18	18	18	18	18	18	18

Census ID	Road Name	Road management description	X	Y	Reference Case	Benchmark CAZ D	Option 2	Option 3	Option 4	Option 5	Option 6
77488	A525	The Potteries	382853	345516	24	23	24	24	24	23	24
77490	A34	The Potteries	382719	353663	24	23	24	24	24	24	24
77492	A50	The Potteries	384221	354266	22	22	22	22	22	22	22
80721	A5006	The Potteries	388077	347805	28	24	28	28	28	27	28
81250	A527	The Potteries	386512	352448	24	24	24	24	24	24	24
81251	A527	West Midlands	386507	352331	18	18	18	18	18	18	18
81252	A5271	The Potteries	386129	351317	31	31	31	31	31	31	31
81253	A527	The Potteries	385708	352470	25	25	25	25	25	25	25
81448	A5010	The Potteries	387351	347552	37	30	37	36	37	34	36
81449	A5010	The Potteries	387640	347562	27	24	27	27	28	26	27
81450	A5008	The Potteries	387964	347233	33	28	32	32	32	30	32
8147	A500	Highways England	387442	345885	53	50	53	52	53	52	53
8148	A52	The Potteries	387864	345072	27	25	26	27	27	26	27
82001	A5006	The Potteries	388113	347549	38	34	38	37	38	36	37
8340	A500	Highways England	388059	345097	53	48	52	52	53	51	52
8605	A520	The Potteries	393354	342622	26	26	26	26	26	26	26
99026	A52	The Potteries	388172	345666	34	29	34	35	34	33	34
99210	A52	The Potteries	385399	346148	33	27	32	32	33	30	32
99212	A53	The Potteries	391609	351969	20	19	20	19	20	19	20
99214	A520	The Potteries	393130	342327	33	32	32	32	32	33	32
99215	A50	The Potteries	386079	351324	31	31	31	31	31	31	31
99329	A50	Highways England	388341	343682	47	46	48	47	48	47	48
99331	A50	Highways England	389741	343803	46	43	45	44	45	45	45
99332	NA	Highways England	391059	343115	35	34	35	34	35	35	35
99333	A50	Highways England	391600	342825	40	38	39	39	39	39	39
99335	A50	Highways England	392363	342684	40	39	40	39	40	40	40
99337	A50	Highways England	393206	342255	37	36	37	36	37	37	37
99407	A5007	The Potteries	391954	342849	32	31	31	30	31	31	31

Figure 4-1: Annual mean NO_2 concentrations, 2022, µg.m^{-3}, Option 1 (Benchmark Class D)

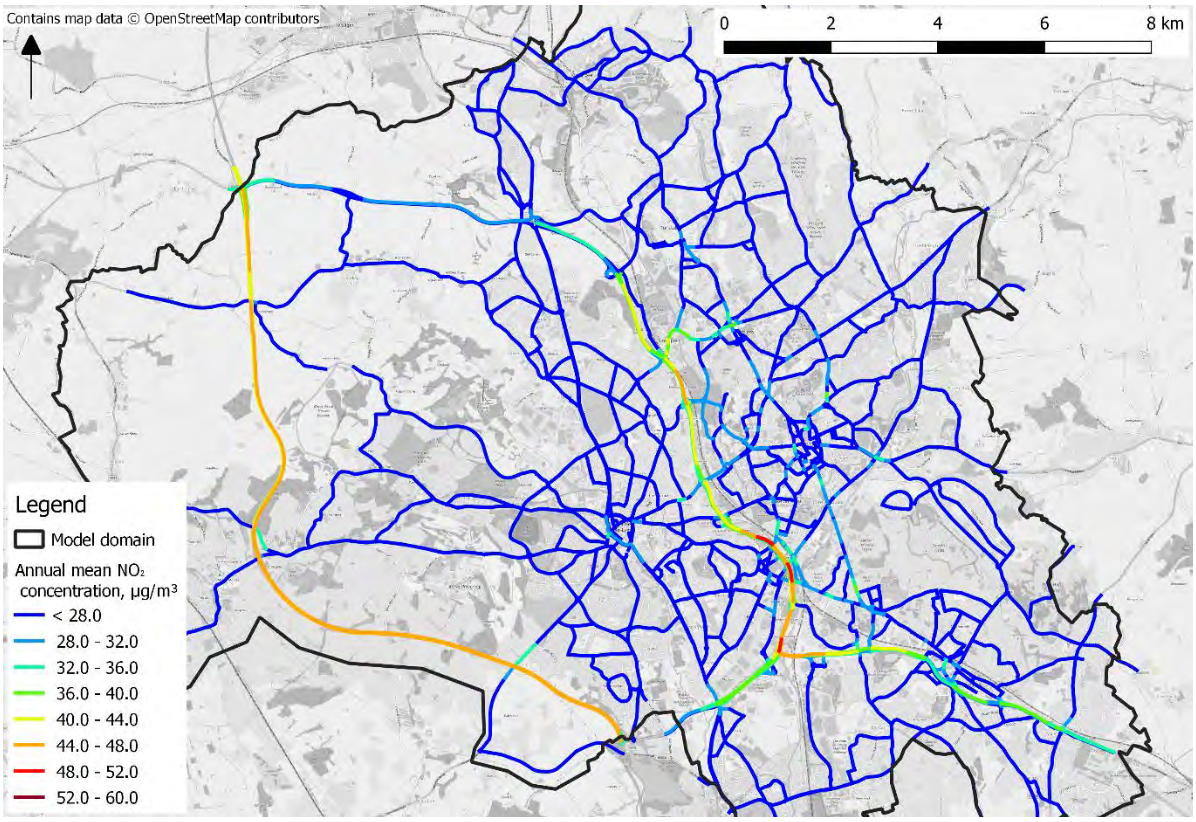


Figure 4-2: Annual mean NO_2 concentrations, 2022, µg.m^{-3}, Option 2 (High impact without charging)

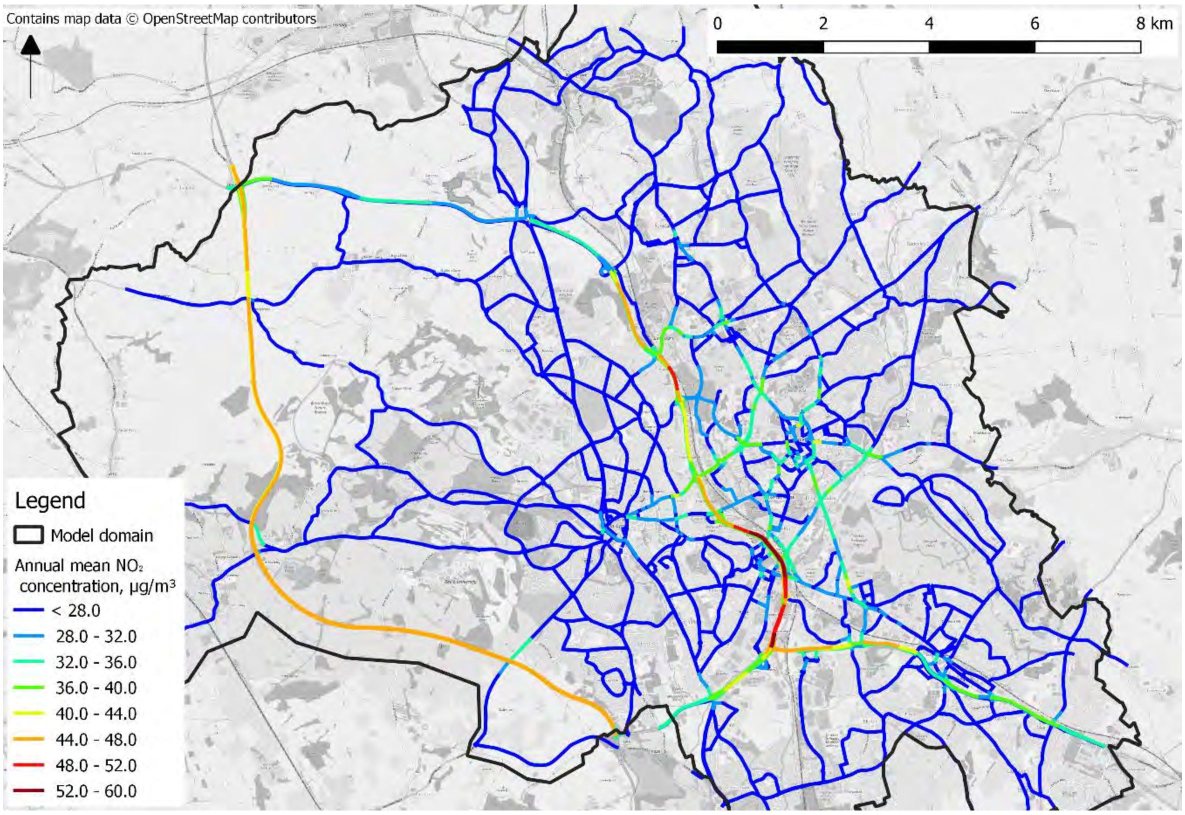


Figure 4-3: Annual mean NO_2 concentrations, 2022, $\mu g.m^{-3}$, Option 3 (High impact)

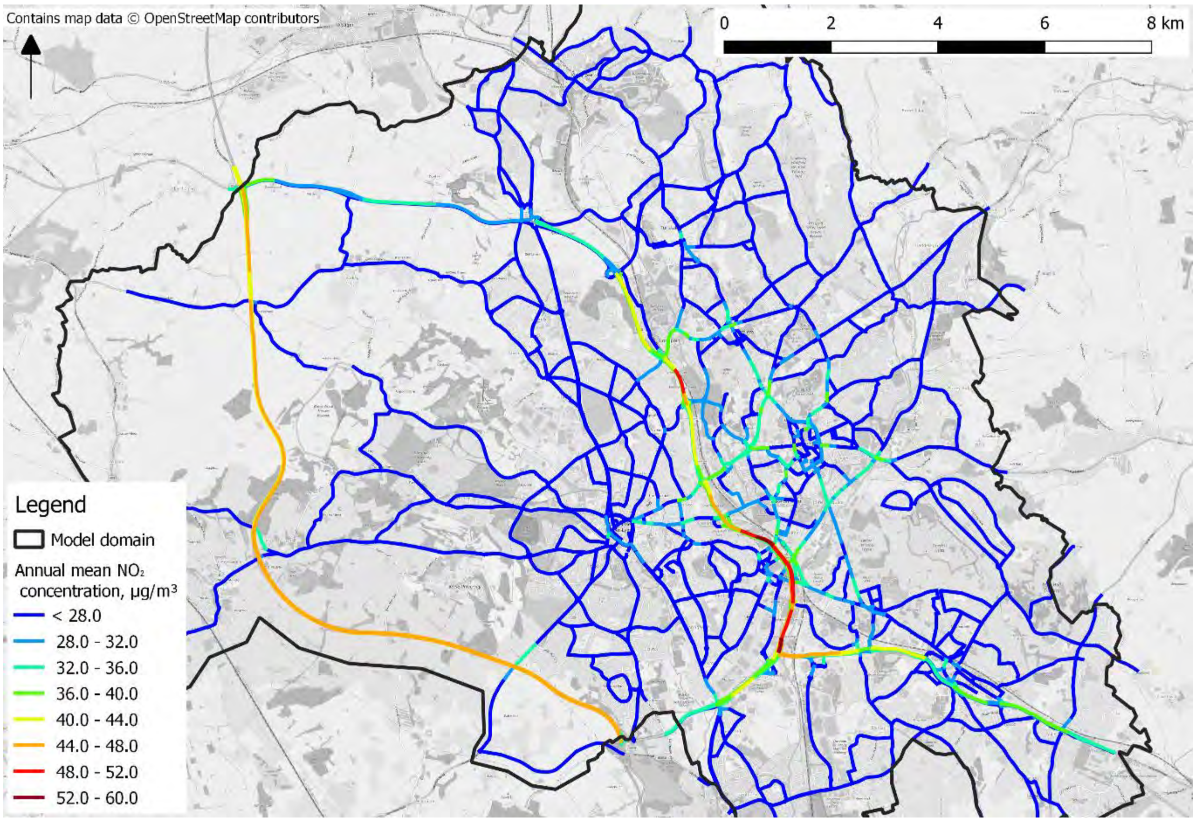


Figure 4-4: Annual mean NO_2 concentrations, 2022, $\mu g.m^{-3}$, Option 4 (Preferred Option)

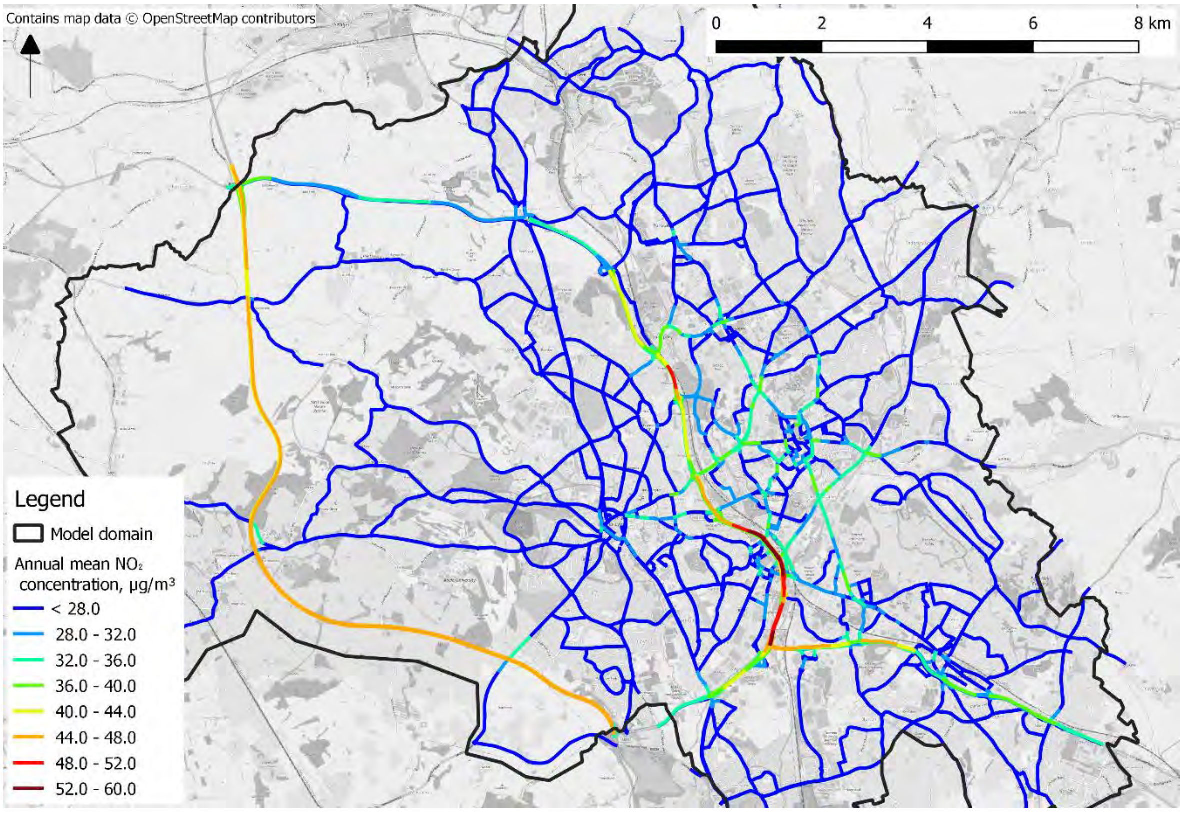


Figure 4-5: Annual mean NO_2 concentrations, 2022, µg.m^{-3}, Option 5 (Class C Charging CAZ scheme)

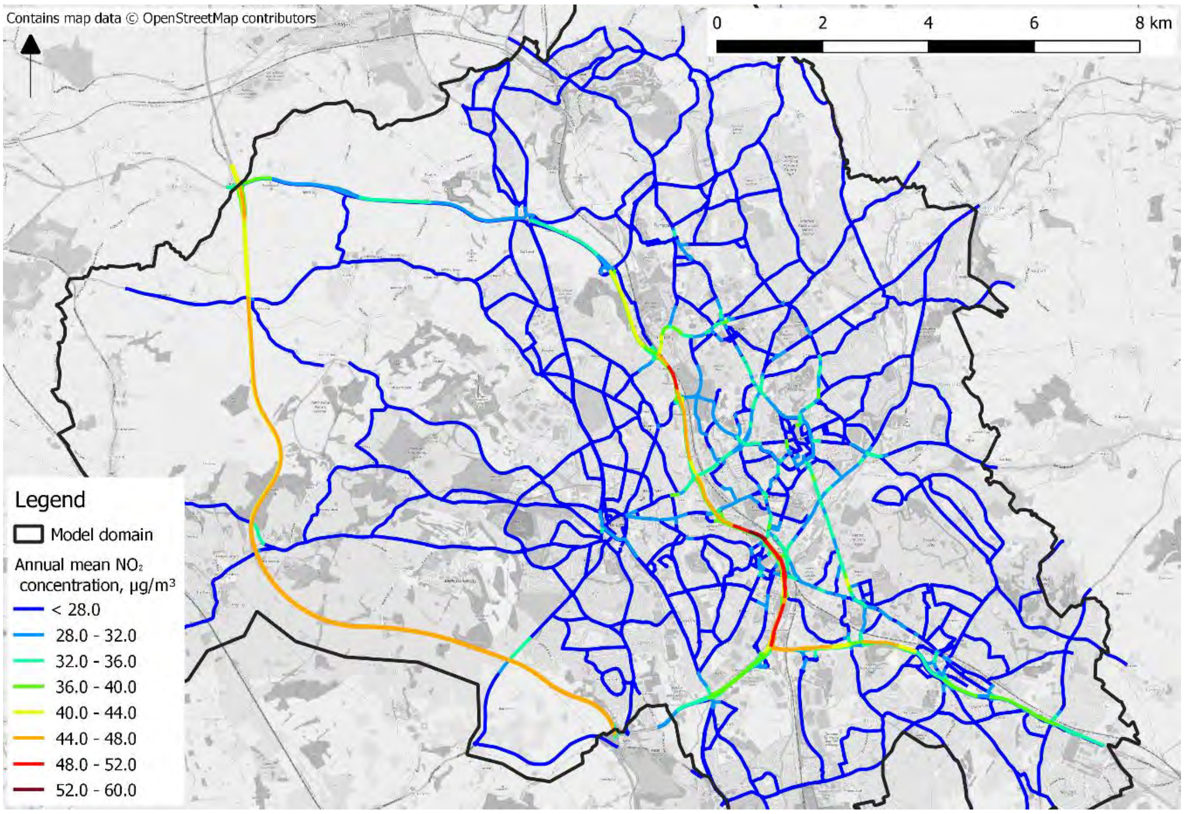
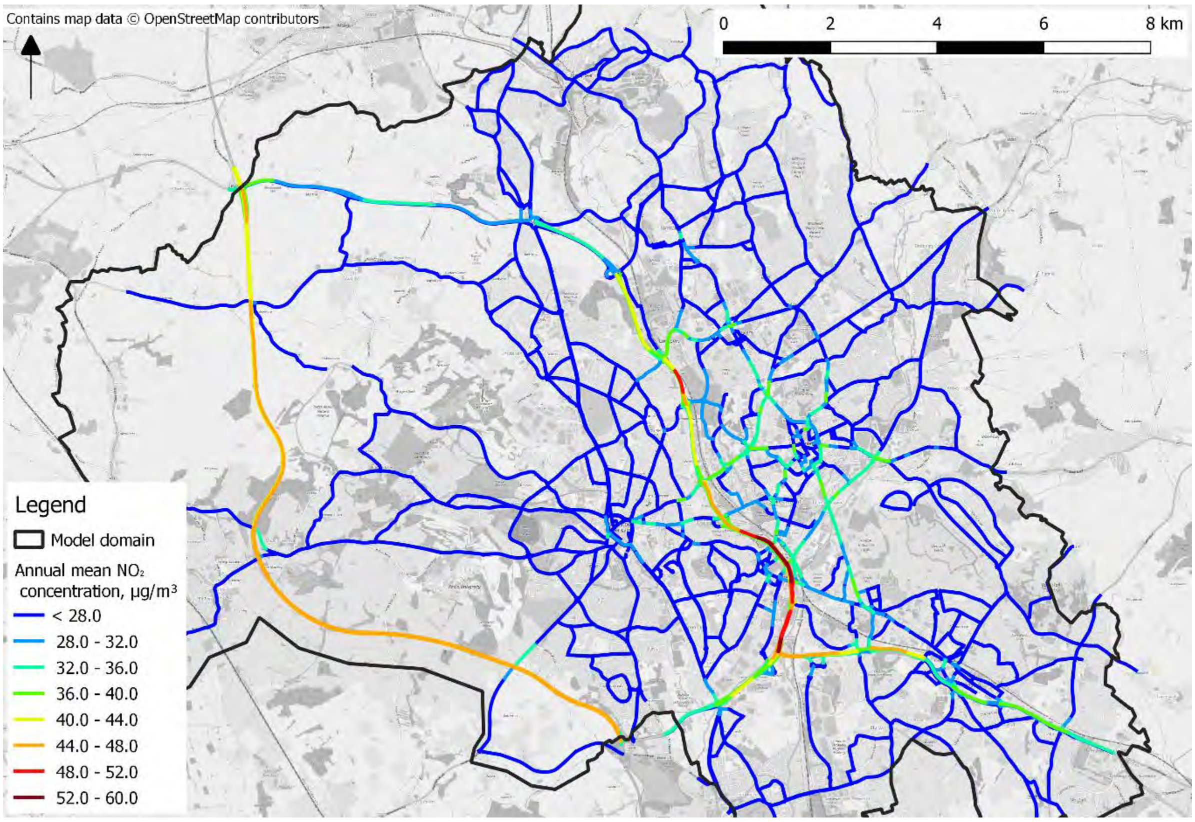


Figure 4-6: Annual mean NO_2 concentrations, 2022, µg.m^{-3}, Option 6



5 Model uncertainty and sensitivity analysis

Some clear outliers were apparent during the model verification process, whereby we were unable to refine the model inputs sufficiently to achieve good model performance at these locations. There are a number of reasons why this could be the case, including:

- A site located next to a large car park, bus stop or other emission source that has not been explicitly modelled due to unknown activity data.
- Sites located underneath trees or vegetation (i.e. unsuitable locations for diffusion tubes to measure NO_2 concentrations effectively).
- Uncertainties in the traffic model outputs (please refer to the traffic model validation report for further information on this).
- Uncertainties introduced by modelling background concentrations at 1 km resolution over such a wide area. In this case we have attempted to address this by interpolating the 1 km background maps to a finer 3 m resolution. This aims to smooth out the sudden changes in background concentrations at the edges of the 1km^2 background maps.

To evaluate model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations was calculated, as detailed in LAQM.TG(16). In this case the RMSE was calculated at 5.16 µg.m^{-3}.

Sensitivity testing has been carried out to assess the robustness of the outcomes from this study. Table 12 summarises the sensitivity testing carried out.

Table 12: Wider sensitivity testing

Priority or recommended?	Test	Notes on Test
Priority	Future Emission standards	Euro-6d_temp not included in EFT v9.1.b, so no testing carried out.
	f-NO_2 projection	Rerun RapidAir for 2022 Reference Case applying adjustment to f-NO_2 emission rates
	Gradient based emission factors	Rerun RapidAir for 2022 Reference Case excluding gradients
	Benchmark CAZ: 0% Upgrade Assumption	Rerun RapidAir for 2022 Benchmark CAZ D scenario using traffic model sensitivity testing results
Recommended	Zonal vs full model domain calibration	Results at monitoring locations using site-specific adjustment factors presented; qualitative assessment of zonal calibration
	Surface roughness length	Qualitative assessment
	Meteorology	Qualitative assessment

5.1 Results at monitoring locations using site-specific adjustment factors

When model verification is carried out this provides a clear indication of how the model is performing at each monitoring location. This can be used to provide an alternative set of results for the monitoring locations using a site-specific adjustment factor. The site-specific adjustment factor is simply derived from the ratio of measured and modelled road NOx at that specific site and used to adjust the predicted 2022 results rather than the global adjustment factor derived from model verification. The site-specific results aim to provide an indication of when compliance may be achieved at each monitoring site without any of the bias introduced by using an average road NOx adjustment factor across the entire domain.

The results at monitoring locations using the site-specific adjustment for the baseline and each of the modelled options are shown in Table 13. The results for the baseline indicate that in 2022, compliance with the 40 $\mu g.m^{-3}$ NO_2 annual mean objective will be achieved at the majority of current monitoring locations, with the exception of:

- The Stoke-on-Trent automatic monitoring station CM5, located on the A53 to the west of the A500; this link is identified as "at risk of exceeding" in the PCM modelling, and is adjacent to other link segments which are predicted to exceed the AQO in the 2022 Reference Case. Any options proposed will seek to further reduce concentrations along this link.

Table 13: NO_2 concentrations at monitoring locations in 2022 using the site-specific adjustment factor

Council	Monitoring site ID	Monitoring type	Site type	Adjustment factor	Output NO_2
Newcastle-under-Lyme	CM1	Automatic	Roadside	1.2	19.9
	DTK1	Diffusion tube	Kerbside	1.7	24.5
	DTK2	Diffusion tube	Urban Centre	1.7	27.4
	DTUB1	Diffusion tube	Kerbside	1.2	21.0
	DT3	Diffusion tube	Rural	1.9	30.7
	DT6	Diffusion tube	Suburban	3.5	23.3
	DT9	Diffusion tube	Suburban	2.3	31.2
	DT24	Diffusion tube	Roadside	2.1	23.6
	DT28	Diffusion tube	Rural	1.4	24.7
	DT34	Diffusion tube	Urban Centre	1.9	26.3
	DT40	Diffusion tube	Suburban	2.6	23.9
	DT46	Diffusion tube	Urban Centre	1.5	26.1
	DT47	Diffusion tube	Urban Centre	1.3	22.9
	DT49	Diffusion tube	Urban Centre	1.5	25.8
	DT64	Diffusion tube	Urban Centre	3.3	32.1
	DT73	Diffusion tube	Roadside	3.6	30.5
	DT74	Diffusion tube	Roadside	1.6	27.2
	DT76	Diffusion tube	Roadside	2.3	28.3
	DT84	Diffusion tube	Roadside	2.7	29.7
	DT85	Diffusion tube	Urban Centre	1.9	28.5
	DT86	Diffusion tube	Urban Centre	2.1	32.1
	DT87	Diffusion tube	Urban Centre	1.8	24.6
	DT88	Diffusion tube	Urban Centre	1.7	30.4
	DT89	Diffusion tube	Urban Centre	2.1	25.5
	DT90	Diffusion tube	Urban Centre	1.8	24.6
	DT91	Diffusion tube	Urban Centre	2.0	27.1
	DT92	Diffusion tube	Urban Centre	1.7	24.4
	DT93	Diffusion tube	Urban Centre	1.8	24.6

Council	Monitoring site ID	Monitoring type	Site type	Adjustment factor	Output NO_2
	DT94	Diffusion tube	Urban Centre	3.6	28.7
	DT95	Diffusion tube	Urban Centre	2.8	26.6
	DT97	Diffusion tube	Roadside	2.6	27.9
	DT98	Diffusion tube	Roadside	2.8	29.5
	DT100	Diffusion tube	Roadside	1.7	24.5
	DT101	Diffusion tube	Roadside	2.7	30.5
	DT103	Diffusion tube	Roadside	1.9	34.6
	DT104	Diffusion tube	Roadside	1.9	24.8
	DT105	Diffusion tube	Roadside	1.7	17.6
Stoke-on-Trent	CM1	Automatic	Urban Background	0.8	20.7
	CM2	Automatic	Roadside	1.5	29.5
	CM5	Automatic	Roadside	2.7	**41.4**
	CM6	Automatic	Roadside	2.1	38.6
	DT1	Diffusion tube	Urban Background	2.1	16.5
	DT2	Diffusion tube	Roadside	1.7	29.5
	DT4	Diffusion tube	Roadside	1.5	35.8
	DT8	Diffusion tube	Roadside	1.3	24.2
	DT9	Diffusion tube	Roadside	2.1	26.1
	DT10	Diffusion tube	Roadside	1.2	25.5
	DT13	Diffusion tube	Roadside	2.1	32.0
	DT14	Diffusion tube	Roadside	1.2	26.3
	DT15	Diffusion tube	Roadside	1.1	25.7
	DT16	Diffusion tube	Roadside	1.4	25.9
	DT20	Diffusion tube	Roadside	1.6	27.5
	DT24	Diffusion tube	Roadside	1.7	32.1
	DT29	Diffusion tube	Roadside	1.9	38.0
	DT32	Diffusion tube	Roadside	2.4	31.9
	DT34	Diffusion tube	Roadside	1.5	30.2
	DT37	Diffusion tube	Roadside	2.1	34.2
	DT40	Diffusion tube	Roadside	2.7	32.2
	DT41	Diffusion tube	Roadside	1.5	31.0
	DT42	Diffusion tube	Roadside	1.6	38.2
	DT49	Diffusion tube	Roadside	2.4	34.5
	DT51	Diffusion tube	Roadside	1.4	23.6
	DT52	Diffusion tube	Roadside	2.4	28.8
	DT53	Diffusion tube	Roadside	2.2	27.2
	DT55	Diffusion tube	Roadside	1.9	25.5
	DT56	Diffusion tube	Roadside	1.6	33.1
	DT61	Diffusion tube	Roadside	1.8	30.0
	DT63	Diffusion tube	Roadside	3.0	37.2
	DT64	Diffusion tube	Roadside	1.6	25.1
	DT65	Diffusion tube	Roadside	1.7	27.4
	DT66	Diffusion tube	Roadside	2.2	37.4
	DT67	Diffusion tube	Roadside	3.1	30.5
	DT72	Diffusion tube	Roadside	2.8	39.8
	DT73	Diffusion tube	Roadside	2.0	29.1
	DT74	Diffusion tube	Roadside	2.1	29.4
	DT75	Diffusion tube	Roadside	2.2	24.6
	DT76	Diffusion tube	Roadside	2.6	40.0
	DT77	Diffusion tube	Roadside	1.9	28.8

Council	Monitoring site ID	Monitoring type	Site type	Adjustment factor	Output NO_2
	DT78	Diffusion tube	Roadside	1.5	26.0
	DT79	Diffusion tube	Roadside	2.9	35.9
	DT80	Diffusion tube	Roadside	1.9	29.8
	DT81	Diffusion tube	Roadside	1.7	29.7
	DT82	Diffusion tube	Roadside	2.4	37.7
	DT83	Diffusion tube	Roadside	1.7	30.7
	DT84	Diffusion tube	Roadside	1.8	30.6
	DT85	Diffusion tube	Roadside	1.5	24.9
	DT86	Diffusion tube	Roadside	1.9	26.7
	DT88	Diffusion tube	Roadside	1.8	28.3
	DT89	Diffusion tube	Roadside	1.6	27.6
	DT91	Diffusion tube	Roadside	4.4	31.9
	DT92	Diffusion tube	Roadside	1.6	30.6
	DT93	Diffusion tube	Roadside	1.7	30.7
	DT94	Diffusion tube	Roadside	1.5	29.8
	DT95	Diffusion tube	Roadside	1.8	26.8
	DT97	Diffusion tube	Roadside	2.1	31.4
	DT99	Diffusion tube	Roadside	2.3	39.3
	DT100	Diffusion tube	Roadside	2.3	38.4
	DT101	Diffusion tube	Roadside	1.5	28.5
	DT102	Diffusion tube	Roadside	1.5	26.7
	DT103	Diffusion tube	Roadside	1.6	27.5
	DT104	Diffusion tube	Roadside	1.6	26.5
	DT105	Diffusion tube	Roadside	1.3	23.0
	DT106	Diffusion tube	Roadside	1.7	38.3

5.2 Priority testing

A summary of the sensitivity testing results for each of priority tests is provided in Table 14, with full results presented in Table 15.

Table 14: Summary comparison of the NO_2 for PCM links for the priority sensitivity testing in 2022

Option	Links > 40 µg/m³	Links > 35 and <= 40 µg/m³	Local Authority links > 40 µg/m³	Local authority links > 35 and <= 40 µg/m³	Average change in NO_2 (%)
Baseline	12	23	4	16	N/A
Benchmark CAZ D	8	12	0	5	N/A
No gradients	12	23	4	16	-1.2%
fNO2 40% reduction	3	4	0	1	-16.7%
CAZ D 0% upgrade	9	13	1	6	3.6%

Lowering the proportion of primary NO_2 in the NOx to NO_2 conversion by 40% significantly reduces concentrations by an average of 17%, varying from 6% to 23% depending on the traffic composition. For the 2022 Reference Case, this reduction would reduce concentrations along all Local Authority road links below the objective of 40 $\mu g.m^{-3}$; only Victoria Road would remain above 35 $\mu g.m^{-3}$. As such, under this test most risk of exceedance is removed.

Remvoing gradient effects from the emission calculations has a small impact on modelled concentrations, leading to a 1.2% reduction in average NO_2 concentrations across the model domain. This does not lead to any change in compliance.

Under the 0% upgrade assumption, the Benchmark CAZ D no longer delivers compliance, as NO_2 concentrations are predicted to exceed the objective along the A5271 as a result of rerouting traffic. This would cause an exceedance along a link which is predicted to comply with the objective in the Reference Case.

Table 15: Modelled NO2 annual mean concentrations for priority sensitivity tests by Census ID (µg.m-3)

Census ID	Road Name	2022 NO_2 annual mean concentration (µg.m^{-3})				
		Baseline	Benchmark CAZ D	% change from no gradients test	% change from fNO_2 40% reduction test	% change from Benchmark CAZ D 0% upgrade test
16325	A34	26	26	0.0%	-11.5%	0.0%
16501	A50	46	36	0.0%	-19.6%	2.8%
16526	A53	23	22	-4.3%	-13.0%	4.5%
16527	A53	18	17	0.0%	-11.1%	0.0%
17648	A5006	37	36	0.0%	-16.2%	11.1%
17860	A52	28	24	0.0%	-14.3%	4.2%
17975	A34	31	30	-3.2%	-16.1%	3.3%
18131	A500	40	38	-2.5%	-22.5%	2.6%
18132	A52	31	29	0.0%	-16.1%	3.4%
18584	A52	28	24	0.0%	-14.3%	4.2%
26355	A34	31	30	0.0%	-16.1%	6.7%
26531	A50	35	34	0.0%	-17.1%	2.9%
26546	A52	21	19	0.0%	-9.5%	5.3%
26555	A53	36	29	0.0%	-16.7%	0.0%
27739	A52	38	34	-2.6%	-18.4%	5.9%
28176	A52	30	28	0.0%	-13.3%	3.6%
28732	A53	43	33	-2.3%	-20.9%	3.0%
36360	A34	32	31	0.0%	-18.8%	3.2%
36543	A50	38	32	-2.6%	-18.4%	3.1%
36560	A52	37	29	0.0%	-16.2%	0.0%
38088	A53	26	25	0.0%	-15.4%	0.0%
38230	A500	44	43	-2.3%	-20.5%	7.0%
38231	A52	40	32	-2.5%	-17.5%	6.3%
38303	A527	28	26	0.0%	-14.3%	3.8%
38521	A52	33	30	0.0%	-15.2%	3.3%
46538	A50	22	22	0.0%	-13.6%	0.0%
46553	A5008	42	31	0.0%	-16.7%	0.0%
46563	A53	38	32	0.0%	-18.4%	3.1%
47243	A500	43	44	0.0%	-18.6%	9.1%
47268	A519	27	26	0.0%	-14.8%	3.8%
47276	A527	32	31	0.0%	-15.6%	6.5%
47735	A5009	35	29	-2.9%	-17.1%	3.4%
47740	A5035	23	23	0.0%	-13.0%	0.0%
48067	A34	29	28	-3.4%	-17.2%	7.1%
48214	A5006	32	30	-3.1%	-18.8%	3.3%
48287	A525	33	33	0.0%	-18.2%	3.0%
48504	A52	33	30	-3.0%	-18.2%	6.7%
48668	A50	35	31	0.0%	-14.3%	6.5%
56306	A5007	29	28	-3.4%	-17.2%	3.6%
56326	A34	25	24	0.0%	-16.0%	4.2%
56360	A34	26	25	0.0%	-15.4%	4.0%
56539	A5007	34	30	-2.9%	-17.6%	3.3%
56996	A52	38	34	-2.6%	-18.4%	5.9%
57470	A52	32	29	0.0%	-15.6%	3.4%
57472	A52	33	31	0.0%	-15.2%	3.2%
57606	A52	39	36	0.0%	-17.9%	5.6%
57783	A500	53	49	-1.9%	-20.8%	4.1%
60017	A50	28	27	-3.6%	-14.3%	0.0%

Census ID	Road Name	2022 NO_2 annual mean concentration (µg.m^{-3})				
		Baseline	Benchmark CAZ D	% change from no gradients test	% change from fNO_2 40% reduction test	% change from Benchmark CAZ D 0% upgrade test
60022	A5008	32	27	-3.1%	-15.6%	3.7%
60023	A50	32	27	0.0%	-12.5%	3.7%
60024	A50	32	27	-3.1%	-15.6%	0.0%
60026	A50	45	44	-2.2%	-20.0%	2.3%
60026	A50	34	31	-2.9%	-17.6%	3.2%
6352	A34	21	20	-4.8%	-14.3%	0.0%
6353	A34	24	24	0.0%	-12.5%	4.2%
6522	A50	35	31	-2.9%	-17.1%	3.2%
6536	A52	30	26	0.0%	-16.7%	7.7%
6545	A53	41	32	0.0%	-19.5%	3.1%
70276	A52	33	31	0.0%	-15.2%	3.2%
70277	A5007	34	32	-2.9%	-14.7%	6.3%
70279	A5005	37	35	-2.7%	-18.9%	0.0%
70280	A5007	22	22	0.0%	-13.6%	0.0%
73257	A5011	19	19	0.0%	-10.5%	0.0%
73258	A34	21	21	0.0%	-14.3%	0.0%
74058	A53	39	31	-2.6%	-17.9%	3.2%
74060	A527	23	22	0.0%	-13.0%	4.5%
74065	A34	29	29	0.0%	-17.2%	6.9%
74261	A50	39	31	-2.6%	-17.9%	6.5%
74585	A50	27	27	0.0%	-14.8%	3.7%
74586	A50	32	30	-3.1%	-18.8%	3.3%
74894	A520	24	24	0.0%	-16.7%	4.2%
74895	A5272	27	24	-3.7%	-14.8%	4.2%
74896	A5271	40	40	-2.5%	-17.5%	5.0%
74897	A5271	29	29	0.0%	-13.8%	0.0%
74898	A5272	40	37	0.0%	-17.5%	5.4%
74899	A5272	30	28	0.0%	-13.3%	7.1%
74900	A5035	28	28	0.0%	-17.9%	3.6%
74902	A53	30	29	0.0%	-13.3%	3.4%
74903	A5008	35	29	0.0%	-14.3%	3.4%
75282	A53	32	27	0.0%	-15.6%	3.7%
75283	A53	27	23	0.0%	-11.1%	4.3%
75284	A52	34	28	0.0%	-17.6%	3.6%
75418	A500	39	37	0.0%	-17.9%	5.4%
75420	A500	30	29	0.0%	-16.7%	3.4%
75421	A500	38	37	0.0%	-18.4%	2.7%
75422	A50	39	37	-2.6%	-20.5%	5.4%
75424	A50	31	30	0.0%	-16.1%	3.3%
75448	A50	27	27	0.0%	-11.1%	0.0%
77480	A5005	18	18	0.0%	-11.1%	0.0%
77488	A525	24	23	-4.2%	-16.7%	0.0%
77490	A34	24	23	0.0%	-16.7%	4.3%
77492	A50	22	22	0.0%	-13.6%	0.0%
80721	A5006	28	24	0.0%	-10.7%	4.2%
81250	A527	24	24	0.0%	-12.5%	0.0%
81251	A527	18	18	0.0%	-5.6%	0.0%
81252	A5271	31	31	0.0%	-16.1%	3.2%
81253	A527	25	25	0.0%	-12.0%	0.0%
81448	A5010	37	30	-2.7%	-18.9%	3.3%
81449	A5010	27	24	0.0%	-11.1%	0.0%
81450	A5008	33	28	-3.0%	-15.2%	3.6%
8147	A500	53	50	-1.9%	-20.8%	10.0%
8148	A52	27	25	0.0%	-14.8%	4.0%
82001	A5006	38	34	0.0%	-13.2%	2.9%
8340	A500	53	48	-1.9%	-20.8%	6.3%
8605	A520	26	26	0.0%	-15.4%	3.8%
99026	A52	34	29	0.0%	-14.7%	3.4%
99210	A52	33	27	-3.0%	-18.2%	0.0%
99212	A53	20	19	-5.0%	-15.0%	0.0%

Census ID	Road Name	2022 NO_2 annual mean concentration (µg.m^{-3})					
		Baseline	Benchmark CAZ D	% change from no gradients test	% change from fNO_2 40% reduction test	% change from Benchmark CAZ D 0% upgrade test
99214	A520	33	32	-3.0%	-21.2%	3.1%
99215	A50	31	31	0.0%	-16.1%	3.2%
99329	A50	47	46	-4.3%	-21.3%	2.2%
99331	A50	46	43	-2.2%	-21.7%	4.7%
99332	NA	35	34	-2.9%	-17.1%	2.9%
99333	A50	40	38	-2.5%	-20.0%	2.6%
99335	A50	40	39	-2.5%	-20.0%	2.6%
99337	A50	37	36	-2.7%	-21.6%	2.8%
99407	A5007	32	31	-3.1%	-18.8%	3.2%

5.3 Recommended testing

5.3.1 Zonal vs full model domain calibration

A single road NOx adjustment factor was derived from model verification and used to calculate:

- Citywide modelling results at receptor points adjacent to relevant PCM road links
- Citywide 3m resolution NO_2 annual mean concentration rasters, providing a continuous representation of the spatial variation in modelled concentrations.

The use of a zonal model adjustment factor was considered. However, this approach was not used due to the following considerations:

- Although two areas of the cities (Kidsgrove to the north, and the area around Baddeley to the northeast) agree less well with monitored data than the rest of the city, monitoring in these areas occurs in clusters, and is isolated from other monitoring sites in the cities; allocating zones between clusters of diffusion tubes would therefore have been a highly subjective process.
- There could be various factors contributing to variable model agreement at individual measurement sites across the domain. These include uncertainties or omissions in the modelled traffic activity data, uncertainties in estimates of background concentrations, and omission of other nearby sources that have not been explicitly modelled e.g. bus stops, car parks, etc. When modelling at the local scale, we typically model with a consistent background concentration across the model domain; and the impact of other sources such as car parks and bus stops can be modelled. However, including this amount of detail is not practical when modelling at city scale.
- Using a zonal approach could be considered relevant when the intention of the modelling is to focus on evidence relevant to specific areas or hotspots within the wider model domain e.g. small AQMAs. For these, applying a zone-specific road NOx adjustment factor may reduce the overall average error between measured and modelled concentrations at that location and hence increase confidence in the model results and associated conclusions. However, when generating evidence relevant to citywide impacts, applying different road NOx adjustment factors across the domain may create sudden step changes in modelled concentrations at the edge of each zone. It may also have led to inconsistencies in the modelled concentrations at receptor points adjacent to relevant PCM road links where these were at the edge of a (subjectively allocated) verification zone.

- We have however presented results using road NOx adjustment factors specific to each monitoring site, as described in Section 5.1, which could be considered as a site-specific zonal verification approach. This aims to provide an indication of when it is likely that compliance will be achieved at each measurement site even if the required road NOx adjustment factor is higher than the slope of the best fit line across all sites.

5.3.2 Surface roughness length

The supplementary guidance states that '*JAQU suggest that LAs model both high and low surface roughness sensitivity tests, scaling surface roughness by appropriate amounts (which will vary on a case by case basis)*.'

And: '*As with other sensitivity tests the focus should be on the baseline and with measures projected year modelling, although in this case LAs should strongly consider also running the sensitivity in the base year. This is because the surface roughness length will impact on concentrations in the base year, therefore could impact on the calibration factors derived in the base year (and applied in the projected year)*.

As described in the AQ2 modelling method report, we have modelled a uniform surface roughness across the entire domain representing a typical roughness for a large urban area.

We would argue that changing the surface roughness modelled would require re-running and re-verification of the 2018 baseline model to derive a Road NOx adjustment (model calibration) factor that is specific to modelling with that roughness input parameter. To model like for like with the updated baseline, all future year scenarios would also need to be re-modelled and the results processed and re-presented. We anticipate that this would not significantly change the future year modelled concentrations and hence conclusions of the assessment. The level of effort required to do this repeat modelling, combined with the current timescale pressures for delivery of the modelling evidence base, mean that exploring this sensitivity by re-modelling is not currently considered proportionate.

5.3.3 Meteorology

The sensitivity guidance contains some useful information regarding the potential for inter-annual variability in meteorological conditions to impact on modelled concentrations.

'*JAQU has attempted to quantify the potential for meteorologically driven inter-annual variability in NO_2 concentrations by investigating the impact of applying 3 different years of meteorological data from the same site (with all other inputs remaining constant) on NO_2 concentrations for a 'mock' LA.*

The study suggests (though results are not statistically meaningful given that only one 'mock' area has been considered with 3 years of meteorological data) that inter-annual changes in meteorology may not have a large impact on the overall distribution of roadside NO_2 concentrations in a local area but can have a significant impact for particular road links (as reflected in the considerably higher maximum concentration in 2015).'

This statement suggests that the use of meteorological data from alternative years would not significantly affect the overall outcome of the analysis. We also note that to conduct a statistically robust sensitivity test of inter-annual variation in meteorological conditions would require modelling using multiple annual datasets. As it is critical to achieve compliance as quickly as possible in Derby, and timescales for submission of evidence have been agreed, we do not currently have enough time or resources to conduct this repeat modelling; therefore exploring this sensitivity in detail by re-modelling multiple times is not currently considered proportionate.

6 Conclusions

This report has provided an overview of the air quality results, in terms of NO_2 concentrations, for the Stoke-on-Trent and Newcastle-under-Lyme CAZ study areas including the 2018 base year, the 2022 future baseline year and six options for 2022.. The results have been provided for the national air quality model (PCM) links and local monitoring locations.

The baseline results for 2022 indicate the following:

- There are 3 exceedances of the 40μ/m^3 limit within the model domain which are managed by the Local Authorities; these occur on sections of the A5008 (Bucknall New Road), A53 (Etruria Road), and A50 (Victoria Road). Further exceedances occur along Highways England roads on the Strategic Road Network;

- One monitoring location was predicted to exceed the 40μg/m^{-3} limit by 2022; this monitoring site is located on the A53.

The air quality assessment has modelled 6 option scenarios. The impact of each option can be summarised as follows:

Benchmark Class D Charging CAZ scheme (Option 1): The Class D Charging scheme would match the Preferred Option in removing links which exceed the NO_2 limit, and would reduce average NO_2 concentrations along links by 7.9%. However, it is unlikely that this scheme could be delivered by 2022, as discussed in the Strategic Case.

Option 2 (High impact without charging CAZ scheme): This scheme is not predicted to deliver compliance along Victoria Road (A50) and Bucknall New Road (A5008).

Option 3 (High impact including local Class D Charging CAZ scheme around Victoria Road): The combination of bus retrofits along affected routes, and a local class D charging CAZ around the Victoria Road area, delivers compliance and leads to an average reduction in NO_2 concentrations of 2.7%.

Option 4 (Preferred Option): This combination of bus retrofit and traffic management schemes (with wider measures to improve accessibility of public transport) has been specifically designed to limit traffic levels along affected stretches of the A500, A5009, and A53 in order to solve the NO_2 exceedance problem. This option delivers compliance, and leads to an average reduction in NO_2 concentrations of 1.3% along road links. The number of Strategic Road Network links predicted to exceed the Objective also decreases, showing that the scheme does not move compliance issues elsewhere.

Option 5 (Class C Charging CAZ scheme): Although this option leads to a greater overall reduction in NO_2 concentrations along road links (3%), it does not deliver compliance along Victoria Road (A500). Furthermore, rerouting of traffic to avoid the CAZ in this scheme leads to concentrations increasing to exceed the objective along Porthill Road (the A5271).

Option 6: This option adds complementary measures to the package of measures identified in Option 4. This option leads to a slightly larger average reduction in NO_2 concentrations of 1.8% along road links.

Overall, the assessment indicates that Option 4, the preferred targeted traffic management scheme, will deliver compliance and not cause knock on problems elsewhere within the city.

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