EASTERLY ALTERNATION INFRASTRUCTURE PROJECT

Environmental Impact Assessment
Environmental Statement, Volume III
Appendix 6.1: Air Quality Modelling Methodology

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1. Introduction

1.1.1 This Appendix describes in detail the methodology applied in the air quality emissions calculations and dispersion modelling, as discussed in **Chapter 6: Air Quality**. The assessment has focussed on the prediction of total pollutant concentrations under a variety of scenarios, both with and without the Proposed Development, at receptors throughout the air quality study area, namely the 9 km × 9 km region between 503000–512000 easting and 172000–181000 northing.

1.1.2 The assessment has combined the contributions of several sources in order to determine total pollutant concentrations. The approach taken to determining these contributions is set out in detail for each source in this Appendix. The sources are:

- The emissions from aircraft and all airside sources (including airside vehicles, machinery and energy plant), modelled using the ADMS-Airport model;
- Road traffic emissions, modelled using the ADMS-Roads model;
- Emissions from vehicles using car parks at Heathrow Airport, including additional cold start emissions), modelled using the ADMS-Airport model;
- The contribution of the Lakeside Waste Management Facility, modelled using the ADMS-6 model; and
- The contribution from all other sources (i.e. background concentrations).

2. Dispersion modelling parameters

2.1.1 Meteorological data from the monitoring station at Heathrow for the years 2017, 2018 and 2019 has been purchased from the Met Office for use in the assessment.

2.1.2 The surface roughness for the area has been set in the model at 0.5 m, with the minimum Monin-Obukhov length set at 30 m. The surface roughness for the meteorological site has been set in the model at 0.2 m, with the minimum Monin-Obukhov length set at 30 m.

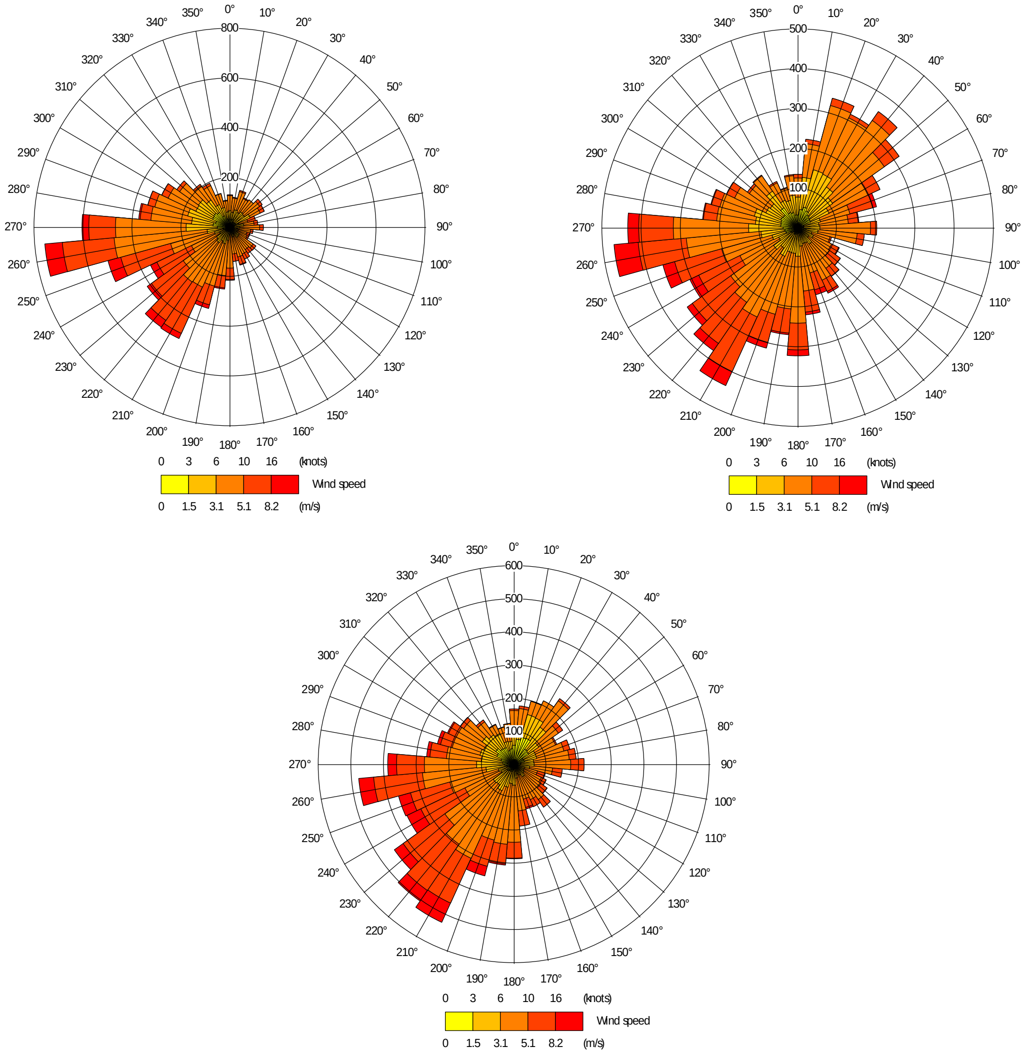
2.1.3 Wherever possible, the urban canopy flow module has been utilised to better represent the effects of buildings on the flow of air throughout the model domain. This module cannot be used when modelling certain sources (e.g. jet sources), but has been used when modelling road sources, car park sources, and the Lakeside Waste Management Facility. Input data used for the urban canopy flow module was the 1 km resolution dataset published by Cambridge Environmental Research Consultants (CERC)[1], who developed the ADMS models.

2.1.4 Buildings and other structures (such as the noise barrier) have not been included via the buildings module of ADMS. The very large number of buildings and structures in the study area cannot be individually modelled by a gaussian plume model such as ADMS. In addition, the distances between airfield sources and receptors are sufficiently large that the effect of individual buildings and structures will be to increase the surface roughness of the domain rather than make appreciable individual perturbations to the airflow. Therefore, buildings and structures have been modelled through a suitable choice of surface roughness length and the use (where possible) of the urban canopy flow module.

2.1.5 Wind roses for Heathrow Airport for the years 2017, 2018 and 2019 are shown in **Graphic 6.1.1**. The wind roses show that the proportion of easterly winds was high in 2018 and particularly low in 2017.

[1] CERC (2016), London Urban Canopy Data [online]. Available: http://www.cerc.co.uk/IJARSG2016.

Graphic 6.1.1: Wind roses for Heathrow Airport (2017 – 2019 inclusive, from left to right)



3. Aircraft emissions

3.1 General procedure

3.1.1 There are two principal sets of recommendations for carrying out an airport air quality study. The first arises from the Project for the Sustainable Development of Heathrow (PSDH). The objective of PSDH was to develop the best practical methodology for assessing the air quality impacts of a third runway at Heathrow. This came up with a number of specific recommendations but contains some areas where the best approach depends on data availability. For example, PSDH does not make any recommendations about how to determine how long aircraft spend operating in various modes as there are various potential data sources, and it is left to the analyst to use their judgement as to the best way of extracting suitable operating durations.

3.1.2 The PSDH methodology was implemented by Heathrow Airport for its 2008/9 emissions inventory[2], modelling study[3] and model evaluation study[4]. The reports give a detailed description of the methodology used and form a useful reference. The model evaluation found that modelled concentrations generally agreed well with the extensive monitoring data around Heathrow and formed a suitable basis for evaluating the impacts of future airport developments. Subsequent inventories produced for Heathrow have used essentially the same methodology, with some updates where new airport-specific data has become available (e.g. for taxiing times).

3.1.3 The second methodology was published by the International Civil Aviation Organization (ICAO) in 2020[5] ('the ICAO Manual'). This document considers production of emission inventories for historic years, with very little attention paid to how inventories for future years might be produced.

3.1.4 The ICAO methodology offers different levels of assessment, described as 'simple', 'advanced' and 'sophisticated', each requiring increasingly detailed data. The sophisticated approach generally requires detailed data on times, engine settings and so forth for each individual aircraft movement, so it is unsuitable for modelling future scenarios where assumptions on future operation must be made. The advanced approach is similar to the PSDH recommendations in terms of data requirements and can generally be adapted to future scenarios given suitable forecast data. Much of the detail of the methodology is the same or similar between PSDH and ICAO.

3.1.5 A third 'standard' is the Aviation Environmental Design Tool (AEDT), published by the US Federal Aviation Administration (FAA) for airport air quality inventories and noise studies.

3.1.6 While various research groups have suggested ways in which parts of the inventory calculation can be improved, few of these have been generally incorporated into received

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[2] Underwood *et al.,* (2010). *Heathrow Airport Emission Inventory 2008/9*. AEAT/ENV/R/2906 Issue 1, July 2010.
[3] Underwood *et al.,* (2010). *Air Quality Modelling for Heathrow Airport 2008/9: Methodology.* AEAT/ENV/R/2915 Issue 1, July 2020.
[4] Underwood *et al.,* (2010). *Heathrow Airport Air Quality Modelling for 2008/9: Results and Model Evaluation.* AEAT/ENV/R/2948 Issue 1, July 2020.
[5] ICAO, (2020). *Airport Air Quality Manual. Doc 9889*, Second Edition, 2020.

methodologies. One notable exception is the First Order Approximation (FOA) 4 method for calculating PM_{10} emissions from smoke number emissions, introduced in the second edition of the ICAO Manual.

3.1.7 The Department for Environment, Food and Rural Affairs (Defra) issues technical guidance on Local Air Quality Management (LAQM) (the latest version being TG.22[6]), which is an important source of guidance on approaching common sources of air pollution. However, other than providing a screening threshold of 10 million passengers per annum or 1 million tonnes of freight, it does not provide recommendations on the technical issues of modelling air quality around large airports.

3.1.8 The methodology used in this assessment follows the general approach of the ICAO advanced and PSDH approaches, and implements many of their specific recommendations, with decisions about the best approach being led by the availability of data.

3.2 The dispersion model

3.2.1 The PSDH carried out a model inter-comparison study to compare the use of various dispersion modelling tools for airport air quality modelling. As a result, the PSDH endorsed the use of ADMS-Airport, a version of the long-established dispersion modelling tool ADMS adapted to account for the momentum and buoyancy fluxes from jet engines. However, the use of the regular version of ADMS with suitable initial dispersion characteristics was also found to be acceptable.

3.2.2 AEDT uses AERMOD for the dispersion modelling. AERMOD was developed in the United States by the American Meteorological Society (AMS)/United States Environmental Protection Agency (USEPA) Regulatory Model Improvement Committee (AERMIC). ADMS was developed in the UK by CERC in collaboration with the Meteorological Office, National Power and the University of Surrey. Both AERMOD and ADMS are termed ‘new generation’ models, parameterising stability and turbulence in the planetary boundary layer by the Monin-Obukhov length and the boundary layer depth. This approach allows the vertical structure of the planetary boundary layer to be more accurately defined than by the stability classification methods of earlier dispersion models such as the R91 Gaussian plume model or Industrial Source Complex (ISC).

3.2.3 Numerous model inter-comparison studies have demonstrated little difference between the output of ADMS and AERMOD, except in certain complex terrain scenarios. The principal difference between ADMS and ADMS-Airport is the jet engine module, which tends to reduce modelled ground-level concentrations from aircraft engines, especially at high thrust settings, as a result of the heat of the plume.

3.2.4 Taking the jet engine module into consideration, ADMS-Airport (Version 5.0) has been selected as the most appropriate model to use for the purposes of this air quality assessment.

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[6] Department for Environment, Food and Rural Affairs (Defra), (2022). *Local Air Quality Management Technical Guidance (TG22)* [online]. Available: https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf (Accessed 01 October 2024)

3.3 Emissions sources: Aircraft emissions

Modes of runway operation

3.3.1 Each of the runways at Heathrow Airport can be used in two directions, with aircraft moving along it either eastwards or westwards. This means there are two distinct and independent aspects to the way that the runways are used for departures, landings or both ('mixed'):

- whether aircraft take off and land facing in a westerly direction or in an easterly direction; and
- which physical runways are used for departures and which for landings.

3.3.2 Whether the Airport operates in westerly or easterly mode at any given time depends on the weather. It is safer and more efficient for aircraft to take off and land facing into the wind, although at Heathrow there is a preference to use westerly operations as long as the tailwind is only slight. Since the wind direction also affects the dispersion of pollutants, it is essential to ensure that runway assignments are aligned with the meteorological data used for the dispersion modelling. The Airport changes between easterly and westerly operations at unpredictable times, since it depends on the weather. At Heathrow, westerly operations are more common than easterlies. The fraction of westerly and easterly operations in each year 2017–2019 is given in **Table 6.1.1**.

Table 6.1.1: Movements per year by direction

Year	Number of movements		Percentage (%) of movements	
	Westerly	Easterly	Westerly	Easterly
2017	383,941	91,978	80.7%	19.3%
2018	308,469	169,289	64.6%	35.4%
2019	351,483	126,576	73.5%	26.5%

3.3.3 The choice of which runway is used for departures and which for landings is called the runway operating mode. In order to provide noise respite to residents near the Airport these modes change regularly, in what is called a runway alternation pattern. There are two alternation patterns relevant to this air quality assessment, as described below.

3.3.4 The alternation pattern currently operated and used for the assessment of baseline years (2017–2019) and future Without Proposed Development scenarios, is as follows. In westerly operations (i.e. when aircraft are landing and departing facing in a westerly direction), there are two modes of operation, identified by a two-letter abbreviation:

- DL: Departures on the northern runway (27R), landings on the southern runway (27L); and

- LD: Landings on the northern runway (27R), departures on the southern runway (27L).

3.3.5 The Airport alternates between these two modes at regularly scheduled times, so that they are used equally often. The result is that over the course of a year, there is an equal number of departures on each runway, and an equal number of landings, for westerly operations.

3.3.6 In easterly operations, there is currently a single mode of operation: Landings on the northern runway (09L) with departures on the southern runway (09R). Some landings also take place on the southern runway early in the morning when there are a large number of arrivals.

3.3.7 The Proposed Development will introduce a new alternation pattern for all future years. In this pattern, westerly operations alternate as at present, but in easterly operations a pattern of alternation similar to that for westerlies will be introduced, alternating equally between two modes of operation:

- DL: Departures on the northern runway (09L), landings on the southern runway (09R); and
- LD: Landings on the northern runway (09L), departures on the southern runway (09R).

3.3.8 The effect of this is that whether operating in easterlies or westerlies, each runway will be used for an equal number of departures and an equal number of landings.

3.3.9 To summarise, the operating modes in the various scenarios are:

- Baseline years 2017–2019 and future year Without Proposed Development:
  - westerlies alternating between DL and LD; and
  - easterlies LD only.
- Future year With Proposed Development:
  - westerlies alternating between DL and LD; and
  - easterlies alternating between DL and LD.

3.3.10 For future scenarios, it is not possible to know which mode will be in operation and when. Therefore, for each scenario, each relevant mode has been modelled for the full assessment year and the average of the two modes taken. This provides the best estimate of the long-term average emissions. The runway direction (easterly or westerly) for each hour of the year is taken from the historical usage corresponding to each hour of meteorological data.

Aircraft activity

3.3.11 For the baseline modelling, aircraft activity has been taken from movement records extracted by Heathrow from their DidFly database. For each movement in the year, this provides:

- Hour of the year;
- Whether arrival or departure;
- Aircraft type;
- Stand; and
- Runway (including direction).

3.3.12 For the future scenarios, the details of the aircraft movements are taken from the forecast schedule. This gives a list of movements for each cargo and passenger aircraft type for a typical busy summer day, for the future assessment year (2028). The forecast schedule is identical for each of the modelled scenarios (With and Without Proposed Development). For each movement in the day, this provides:

- Hour of the day;
- Whether arrival or departure;
- Aircraft type; and
- Stand.

3.3.13 For the future scenarios, the same fleet is assumed to operate every day of the year, but each movement is adjusted by a factor so that the total number of movements in the year equals the regulatory cap of 480,000 air transport movements (ATMs) per year. There are 1,388 movements in the busy day schedule, and the total number of movements over the year is 480,000, so each movement is adjusted by a factor of 480,000 / (1,388 × 365) = 0.947.

3.3.14 It is assumed that there are the same number of movements every day of the year. Historically at Heathrow, there have been slightly more movements per day in summer than in winter, but the data for 2017–2019 shows that there is only a small percentage difference between months.

3.3.15 These movements are summarised in **Table 6.1.2**.

Table 6.1.2: Movements per year by aircraft type

Aircraft code	Aircraft description	2017	2018	2019	2028
221	Airbus A220-100	0	0	12	692
223	Airbus A220-300	0	0	145	6,916
318	Airbus Industrie A318	1,424	1,172	766	0
319	Airbus Industrie A319	79,871	79,007	71,737	13,141
320	Airbus Industrie A320	110,919	99,040	89,358	240,692
321	Airbus Industrie A321	36,387	35,891	36,626	7,954

Aircraft code	Aircraft description	2017	2018	2019	2028
32A	Airbus Ind A320 (Sharklets)	30,421	36,833	22,056	8,300
32B	Airbus Ind A321 (Sharklets)	2,159	3,131	2,462	1,383
32N	Airbus A320neo	0	5,685	31,177	6,916
32Q	Airbus A321neo	0	255	9,083	0
332	Airbus Industrie A330-200	5,000	6,036	6,984	692
333	Airbus Industrie A330-300	10,349	12,358	14,169	4,841
339	Airbus Industrie A330-900	0	0	160	8,646
343	Airbus Industrie A340-300	1,142	660	868	0
346	Airbus Industrie A340-600	4,578	4,121	3,234	0
351	Airbus A350-1000	0	580	1,909	22,478
359	Airbus Industrie A350-900	2,810	4,457	5,662	11,758
388	Airbus Industrie A380-800	18,483	16,695	15,996	12,450
738	Boeing 737-800 Passenger	1,878	986	572	692
73H	Boeing 737-800 (Winglets)	6,147	5,457	6,430	0
73W	Boeing 737-700 (Winglets)	3,842	3,380	2,286	0
744	Boeing 747-400 Passenger	19,651	19,420	18,071	0
74H	Boeing 747-8 Passenger	242	266	274	692
74Y	Boeing 747-400 Freighter	459	434	402	692
75W	Boeing 757-200 Pax (Winglets)	2,944	2,428	1,845	0
763	Boeing 767-300 Passenger	12,917	8,142	1,038	0
764	Boeing 767-400 Passenger	647	2,638	1,159	0
76W	Boeing 767-300 (Winglets)	10,175	5,786	6,978	0
772	Boeing 777-200	28,177	27,778	28,359	8,300
773	Boeing 777-300	4	2	0	2,075
779	Boeing 777-900	0	0	0	8,300
77W	Boeing 777-300ER	32,306	34,796	31,614	30,778
77X	Boeing 777-200 Freighter	326	406	386	692
781	Boeing 787-10	0	0	18	8,991
788	Boeing 787-8	16,049	17,631	17,396	22,824
789	Boeing 787-9	20,435	23,635	28,009	41,499
7M8	Boeing 737 Max 8 (Winglets)	102	2,858	576	4,150
7M9	Boeing 737 Max 9 (Winglets)	0	0	0	1,383
ABY	Airbus Ind A300-600 Freighter	1,850	1,826	1,612	1,383

Aircraft code	Aircraft description	2017	2018	2019	2028
AT7	Aerospatiale/Alenia ATR 72-201/-202	0	0	0	692
CS1	Bombardier CS100	1,258	616	460	0
CS3	Bombardier BD-500-CS300	711	3,137	3,435	0
DH4	De Havilland DHC-8-400	3,442	4,704	8,851	0
E90	Embraer 190	2,284	2,308	2,654	0
Other	Other	6,530	3,203	3,230	0
Total		**475,919**	**477,758**	**478,059**	**480,000**

Reduced engine taxi

3.3.16 Although traditional practice is to have all of an aircraft’s engines running during taxi-out and taxi-in, it is common to use reduced engine taxi (RET) for at least part of the taxi-out or taxi-in stages. In RET, one or more engines is switched off for part of the taxi, the remaining engine or engines being sufficient to propel the aircraft. RET reduces emissions and reduces fuel burn, but there are various safety and operational considerations which constrain its use.

3.3.17 During RET, it is normal to have the Auxiliary Power Unit (APU) operating, to ensure that there is a redundant power source. Use of RET has been modelled by:

- Reducing the number of engines operating during periods of RET, from 2 to 1 for twin-engine aircraft and from 4 to 2 for 4 engine aircraft; and
- Assuming that the APU is operating at ‘normal running’ load during periods of RET.

3.3.18 Heathrow records, for each departure, whether an aircraft uses reduced-engine taxiing. Currently, it is only recorded whether or not RET is used, not the duration of RET, number of engines or associated APU use. The recorded data indicates that around 21% of departures in 2015 used RET, but this number has declined in subsequent years. This may be because RET is less beneficial for modern airliners; it is known that RET cannot be used on Boeing 787 aircraft, and issues with warm-up times have been identified with some A320 neo engines. Therefore, for the present assessment, it is assumed conservatively that there is no RET on departure.

3.3.19 Use of RET for arrivals is not currently recorded, although it is known to be more common than for departures. Heathrow has carried out a survey of airlines to find which airlines use RET, and on which aircraft types. The results of this survey have been used for determining whether a movement uses RET; it is assumed that if an airline uses RET, then all arrivals of that airline use RET, with the exception of Boeing 787 aircraft.

3.3.20 For movements that use RET, it is assumed that the first 2 minutes 30 seconds of taxi-in operate with all engines running (and the APU is not running during these periods).

Main engine emissions: Emission rates

3.3.21 For the baseline modelling, engine assignments were taken from the Heathrow AUWR (All-Up Weight Return) database. These are collected by Heathrow for the purpose of emissions charging. Engine assignments are provided in the form of the engine Unique Identification Number (UID), an identifier used in the ICAO databank of emissions certification data; this allows each aircraft's engines to be indexed directly in the databank. Assignments from AUWR have previously been cross-checked against other published sources (including BuchAir's JP Airline Fleets product) and found to have good reliability.

3.3.22 The ICAO databank does not change the data for a given UID once it has been published; if new data for an engine becomes available, a new UID is assigned and the previous UID marked as superseded. This has affected a great many engines since 2020 as newer particulate emissions data has been added. Where a UID in the AUWR database is marked as superseded, it has been replaced by the latest UID for that engine model.

3.3.23 Emission factors for jet engines are taken from the ICAO databank, version 29B[7] (ICAO, 2023). The databank provides emission indices for nitrogen oxides (NO_X), carbon monoxide (CO) and hydrocarbons (HC), fuel flow rates, non-volatile particulate matter (nvPM) and smoke numbers; each of these is given at four power settings (100%, 85%, 30% and 7% of rated thrust). Emission indices (in g of pollutant per kg of fuel burned) are multiplied by fuel flow rates (in kg/s) to obtain an emission factor in g/s.

3.3.24 The ICAO databank gives smoke numbers which need to be converted to emission indices. This is done using the FOA 4 method[5], except that the nvPM component is taken from the ICAO databank where available. For some engines, smoke number data points at certain thrust settings are missing, so an approach originally developed by Qinetiq for PSDH and documented in the ICAO Manual[5] has been used in which factors are applied to the maximum smoke number.

3.3.25 For turboprop engines, emission factors are taken from the internationally recognised Swedish FOI (Swedish Defence Research Agency) database[8].

3.3.26 For the future scenarios, for those aircraft types whose engines have been certified and are in the ICAO databank, it has been assumed that the same mix of engines as in the current Heathrow fleet continues into the future. These are airline-specific where possible, and a default engine has been assigned where an aircraft type/airline combination is not present in the 2017–2019 fleets. These are: Airbus A320 neo (UID 01P20CM130 since all forecast movements are Air France/KLM); Boeing 777-300 (UID 2RR027); Boeing 777-9 (UID 01P21GE216, as the General Electric GE-9X engine has not yet been certified and this is judged to be the best match among current certified engines); and Boeing 737 Max 9 (UID 01P20CM136).

[7] ICAO, (2023). *ICAO Aircraft Engine Emissions Databank*. June 2023.
[8] Swedish Defence Research Agency (FOI), (no date). *The Environmental Impact of Aircraft*. https://www.foi.se/en/foi/research/aeronautics-and-space-issues/environmental-impact-of-aircraft.html (Accessed 01 October 2024)

3.3.27 This means that, for aircraft types that are currently in service, no improvement in engine emissions is assumed. This is a conservative assumption, since there are likely to be incremental improvements in combustor technology over the lifetimes of some of these aircraft types.

3.3.28 The only turboprop aircraft movements in the forecast schedules relate to a small number (about 0.1% of total movements) of ATR-72 aircraft. For these aircraft, a PW127F has been assigned.

3.3.29 The aircraft engine assignments are summarised in **Table 6.1.3**. The UID is the engine identifier used in the ICAO emissions databank. MTOW is maximum take-off weight, used in the calculation of brake and tyre wear.

Table 6.1.3: Aircraft data (2028 fleet)

Aircraft type	Aircraft description	MTOW (kg)	Number of engines	Most common UIDs
221	Airbus A220-100	58,000	2	16PW111
223	Airbus A220-300	65,000	2	16PW111
319	Airbus Industrie A319	67,465	2	3IA006
320	Airbus Industrie A320	74,519	2	1IA003, 01P10IA021, 3CM026
32N	Airbus A320neo	75,608	2	01P20CM128, 15PW105
321	Airbus Industrie A321	86,288	2	3IA008
32A	Airbus Ind A320 (Sharklets)	74,819	2	01P10IA021, 01P08CM105
32B	Airbus Ind A321 (Sharklets)	89,136	2	3IA008, 01P10IA025
332	Airbus Industrie A330-200	235,047	2	01P14RR102, 9PW094
333	Airbus Industrie A330-300	234,783	2	01P14RR102, 4PW067
339	Airbus Industrie A330-900	242,000	2	02P23RR141
351	Airbus A350-1000	309,000	2	18RR080
359	Airbus Industrie A350-900	273,690	2	01P18RR124
388	Airbus Industrie A380-800	553,977	4	9EA001, 01P18RR103
738	Boeing 737-800 Passenger	78,999	2	8CM065, 01P11CM116, 8CM051
74H	Boeing 747-8 Passenger	447,695	4	01P17GE215
74Y	Boeing 747-400 Freighter	404,831	4	1PW042, 12PW102, 01P03GE187
772	Boeing 777-200	280,406	2	9GE122, 5RR040, 2RR027
773	Boeing 777-300	299,370	2	2RR027
779	Boeing 777-900	351,534	2	01P21GE216

Aircraft type	Aircraft description	MTOW (kg)	Number of engines	Most common UIDs
77W	Boeing 777-300ER	347,863	2	01P21GE217
77X	Boeing 777-200 Freighter	347,633	2	01P21GE216
781	Boeing 787-10	253,104	2	01P17GE213, 01P17GE211
788	Boeing 787-8	227,930	2	12RR061, 01P17GE210, 11GE137
789	Boeing 787-9	251,596	2	12RR067, 12RR068, 01P17GE211
7M8	Boeing 737 Max 8 (Winglets)	81,152	2	01P20CM135, 01P20CM136
7M9	Boeing 737 Max 9 (Winglets)	88,314	2	01P20CM136
ABY	Airbus Ind A300-600 Freighter	157,882	2	1PW048
AT7	Aerospatiale/Alenia ATR 72-201/-202	23,000	2	PW127F

3.3.30 The PSDH recommended a procedure for taking into account changes in ambient temperature, pressure and humidity on aircraft engine emissions, which it found changed overall aircraft NO_X emissions by about 2 or 3%[9]. The PSDH also recommended a methodology for take-off roll, accounting for non-uniform acceleration, effects of the forward speed on the engine thrust, etc. It found that these made a difference of between 2 and 7% on average to NO_X emissions from the take-off roll phase. Unfortunately, the engine-specific data that underlie these methodologies were not published and remain proprietary; moreover, they do not cover engines introduced since about 2007. Therefore, new factors were derived using the same approach as used for the PSDH and have been applied in the same way as recommended by PSDH.

3.3.31 ICAO databank emission factors are based on new production engines, so in-service engines are likely to have suffered deterioration which may affect their emissions. PSDH recommended correction factors to account for this, namely a 4.3% increase in fuel flow and a 4.5% increase in NO_X emission rate (the product of emission index and fuel flow rate). PSDH did not have sufficient data to resolve these factors into individual engine types, ages or thrust setting, so they have been applied uniformly across the engine fleet for all phases of the Landing and Take-Off (LTO) cycle. It should be noted that the ICAO Manual recommends *not* adjusting for engine deterioration, as it considers this unnecessarily conservative.

Main engine emissions: Times in mode

3.3.32 Approach times for the baseline modelling were derived from data from the Heathrow Noise and Track-Keeping (NTK) system for a sample of historic movements. The NTK

[9] Department for Transport, (no date). *Project for the Sustainable Development of Heathrow - Report of the Air Quality Technical Panels*.

system provides radar squawks for arriving and departing aircraft giving position, height and elapsed time, but only while aircraft are more than a few hundred feet above the ground.

3.3.33 Approach times do not depend significantly on runway, so a single approach time was used for all runways, for both historic and future scenarios. Approach is divided into two phases: Phase 1 is from 3000 feet (914 m) to 2000 feet (610 m) at a constant speed of 160 knots (82 m/s), and Phase 2 is from 2000 feet to touchdown, at uniform deceleration to landing speed (which depends on aircraft type). Where aircraft-specific data are not available, an average time by wake vortex category is used. The resulting approach times are given in **Table 6.1.4**.

Table 6.1.4: Approach times

Aircraft type	Approach Phase 1 time (s)	Approach Phase 2 time (s)
221	-	-
223	-	-
319	71	165
320	71	160
320N	-	-
321	72	156
32A	71	160
32B	72	153
332	74	160
333	71	155
339	77	156
351	80	155
359	75	157
388	73	161
738	69	151
74H	77	147
74Y	66	147
772	68	156
773	-	-
779	-	-
77W	72	154
77X	82	154
781	70	154

Aircraft type	Approach Phase 1 time (s)	Approach Phase 2 time (s)
788	72	155
789	70	153
7M8	72	161
7M9	-	-
ABY	84	159
AT7	-	-

3.3.34 Landing roll times were derived from data supplied from the Heathrow Operational Planning and Scheduling (OPAS) database for a sample of historic movements covering five non-contiguous days in June and September. The OPAS system provides similar data to NTK but with a higher time resolution and includes data for aircraft on the ground. These have been extracted as a function of wake vortex category. Landing roll times are assumed not to depend on runway or on runway exit taxiway. Landing roll times are in the range 41–52 s.

3.3.35 Taxi-in and pushback/taxi-out/hold times for the historic scenarios are derived from Heathrow Electronic Flight Processing Strip (EFPS) data. For each movement of the baseline years, this gives the times at which the aircraft passes various gates (exits runway, arrives at stand, starts pushback, starts take-off roll). For the historic scenarios, it is possible to associate most movements with their EFPS data and so obtain movement-specific times. Average times by apron and runway end are used for movements which cannot be matched with an EFPS movement; these times are assumed to be independent of aircraft type. The distribution along the taxi route (including time spent stationary during pushback and hold) was derived from OPAS data for each taxi route.

3.3.36 Taxi-in and pushback/taxi-out/hold times for the future scenarios are derived from CAST simulation data. CAST is a software tool which simulates the movements of every aircraft on the ground and in the air over the course of the day, taking account of interactions between aircraft (e.g. waiting for another aircraft to clear a runway or taxiway). The primary purpose of the simulations is to ensure that the airfield layout and schedule can function properly without excessive delays.

3.3.37 The CAST model takes the forecast schedule as input, along with a mode of operation (easterly or westerly; DL or LD). The CAST output provides coordinates of each aircraft every five seconds during its arrival or departure, from stand to start of take-off roll or from clearing the runway to arriving at stand. A set of taxi links was defined representing sections of taxiway between taxiway junctions across the airfield. Each CAST data point was used to assign five seconds of taxiing to the taxi link containing the coordinate (or, for pushback, the stand). Thus, each movement was assigned a certain time in mode on each taxi link or stand, for each of the four operating modes. This provides both the total taxi time and the distribution of emissions across the taxiways.

3.3.38 Take-off roll times were derived from the OPAS dataset. A distribution of take-off times was derived for each aircraft, runway and runway access taxiway combination. Fall-back distributions were derived for aircraft types which were not present in sufficient numbers in the sample data, based on wake vortex category. For future scenarios, times were also averaged across runways. Where times are not available for specific aircraft types, averages across wake vortex categories are used. Take-off times are apportioned into five-second intervals, and each distribution consists of the fraction of movements in the source data for which the take-off time falls within each bin. Average take-off roll times are summarised in **Table 6.1.5**.

Table 6.1.5: Take-off roll and climb times

Aircraft type	Take-off roll time (s)	Initial climb to 1000 ft time (s)	Initial climb to 1500 ft time (s)	Climb-out from 1000 ft time	Climb-out from 1500 ft time
221	39	-	-	-	-
223	39	-	-	-	-
319	40	22	22	22	22
320	38	19	19	19	19
320N	37	-	-	-	-
321	38	18	18	18	18
32A	39	19	19	19	19
32B	39	17	17	17	17
332	49	18	18	18	18
333	52	19	19	19	19
339	53	19	19	19	19
351	48	18	18	18	18
359	47	18	18	18	18
388	55	39	39	39	39
738	45	21	21	21	21
74H	54	30	30	30	30
74Y	34	13	13	13	13
772	44	22	22	22	22
773	46	-	-	-	-
779	46	-	-	-	-
77W	46	20	20	20	20
77X	44	19	19	19	19
781	45	24	24	24	24
788	50	24	24	24	24

Aircraft type	Take-off roll time (s)	Initial climb to 1000 ft time (s)	Initial climb to 1500 ft time (s)	Climb-out from 1000 ft time	Climb-out from 1500 ft time
789	50	24	24	24	24
7M8	45	21	21	21	21
7M9	45	-	-	-	-
ABY	41	14	14	14	14
AT7	-	-	-	-	-

3.3.39 Initial climb and climb-out times were derived from NTK data. These do not depend significantly on runway, so a single time was used for all runways, for both baseline and future With and Without Development scenarios. These times have only a weak dependence on aircraft type (aircraft are designed to take off at similar speeds to ensure that separation distances are maintained), but this was retained since data were available. Where aircraft-specific data are not available, an average time by wake vortex category is used.

Main engine emissions: Thrust settings

3.3.40 Approach thrusts are assumed to be 15% of maximum rated thrust between 3000 feet and 2000 feet, and 30% from 2000 feet to touchdown. (Heights are relative to runway level.) This is based on PSDH recommendations.

3.3.41 For taxi, PSDH recommendations are again followed for movements that do not use RET. For these, the fuel flow rate is assumed to be 17.5% or 32.5% lower than the fuel flow rate at 7% thrust, for non-Rolls Royce and Rolls Royce engines respectively. The emission indices are set to those for the 7% thrust setting. For aircraft movements that use RET, the fuel flow rate and emissions indices are those for 7% thrust.

3.3.42 Aircraft sometimes use reverse thrust on landing, usually where the runway is short and/or when weather conditions are poor (e.g. wet or icy). It has not been possible to obtain robust quantitative data on reverse thrust usage at Heathrow. Advice from the Airline Working Group was that use of reverse thrust above idle was uncommon. Therefore, it has been assumed that all aircraft use a thrust setting of 7%, corresponding to idle, during the landing roll.

3.3.43 It is common for aircraft to take-off at less than 100% thrust, sometimes as low as 75%, primarily to reduce wear on the engines. This is possible because engines are overpowered for routine take-offs since aircraft need to be able to complete the manoeuvre safely with the loss of one engine. Pilots may nonetheless use 100% thrust in adverse conditions, such as ice. The only available survey data was compiled for the 2008/9 Heathrow inventory and is increasingly difficult to adapt to current fleets. Therefore, a simpler set of take-off thrust settings have been adopted based on the available data (**Table 6.1.6**), which are intended to ensure the assumptions were conservative.

Table 6.1.6: Take-off roll thrust settings

Aircraft type	Reduced thrust setting (%)	Flights using 100% thrust (%)
Narrow-body, twin engine	80	6
Wide-body, twin engine	80	6
Wide-body, four engine	84	14

Auxiliary power units (APU) emissions

3.3.44 As well as their main engines, many aircraft have APUs, which are small gas turbines used to generate electrical power for purposes such as starting the main engines, powering air conditioning and other services.

3.3.45 Emission factors for NO_X and Particulate Matter (PM) were taken from work carried out for the PSDH, which provided representative emission factors for various groups of aircraft types, including future types. Emission factors for fuel, SO_2 and HC are taken from the FAA Emissions and Dispersion Modeling System (EDMS), the forerunner of AEDT. The PSDH APU classes and model names used for EDMS data are given in **Table 6.1.7**.

Table 6.1.7: APU data

Aircraft type	APU class for NOx	APU class for PM	APU model name
221	a	B	36-100
223	a	B	36-100
319	c	A	36-300
320	c	A	36-300
320N	c	A	36-300
321	c	A	36-300
32A	c	A	36-300
32B	c	A	36-300
332	e	A	331-350
333	e	A	331-350
339	e	A	331-350
351	f	A	HGT1700
359	f	A	HGT1700
388	f	A	PW980A-N
738	b	A	131-9

Aircraft type	APU class for NOx	APU class for PM	APU model name
74H	e	A	PW901A
74Y	e	A	PW901A
772	f	A	331-500
773	f	A	331-500
779	f	A	331-500
77W	f	A	331-500
77X	f	A	331-500
781	c	A	APS5000
788	c	A	APS5000
789	c	A	APS5000
7M8	b	A	131-9
7M9	b	A	131-9
ABY	d	C	331-200ER
AT7	a	B	36-100

3.3.46 Running times for APUs on stand for the baseline modelling are derived from monitoring undertaken between 2013 and 2022 to ensure compliance with Heathrow's Operational Safety Instructions (OSIs). Times are given in **Table 6.1.8**.

Table 6.1.8: APU on-stand running times

Aircraft body class	Time on arrival (minutes)	Time on departure (minutes)
Narrow	10.1	20.6
Wide	12.2	26.9
A380	11.0	36.1

Brake and tyre wear emissions

3.3.47 Emissions of PM from brake and tyre wear are calculated using the PSDH methodology (ICAO omits this source). Brake wear emissions, in g PM_{10} per arrival, are calculated as $2.53 \times 10^{-4} \times$ MTOW, where MTOW is the maximum take-off weight in kg (see **Table 6.1.3**). Tyre wear emissions, in g PM_{10} per arrival, are calculated as $2.23 \times 10^{-4} \times$ MTOW – 8.74 for aircraft with an MTOW > 50,000 kg, and 2.41 × MTOW / 50,000 for smaller aircraft.

3.3.48 $PM_{2.5}$ emissions are calculated by multiplying the PM_{10} emission by 0.4 for brake wear and 0.7 for tyre wear.

Aircraft emissions: Spatial disaggregation

3.3.49 Emissions from approach, landing roll, taxi-in, taxi-out, take-off roll, initial climb, climb-out and APU during taxi-in and taxi-out are modelled in ADMS-Airport as jet sources, spread along a series of straight line segments. Landing roll emissions are assumed to decelerate at a constant rate from 130 knots (67 m/s) at touch-down to 15 knots (8 m/s) when exiting the runway. Take-off roll is assumed to accelerate in accordance with a speed-emission curve, depending on aircraft type, using parameters from PSDH.

3.3.50 Emissions from taxi-in and taxi-out are assigned to a set of straight-line segments making up each of the taxi routes from stand group to runway. Aircraft do not travel at uniform speed along the taxi routes; for example, during taxi-out there are commonly delays for pushback and in the hold zone, as well as waiting for other aircraft to push back and at taxiway crossings. To take this into account, data from OPAS (for baseline modelling) and CAST (for future scenarios) has been analysed to determine average occupancy times for each segment of each taxi route, and emissions are distributed along the taxi routes in proportion to the occupancy times.

3.3.51 Emissions from APU usage on stand are modelled as volume sources, of dimensions 50 m × 50 m horizontally and with vertical extent of 12 m, centred on the respective stands.

3.3.52 Emissions from tyre wear are modelled as volume sources, of length 300 m, width 50 m and vertical extent 15 m, centred on the touchdown point of the respective runways.

3.3.53 Emissions from brake wear are modelled as volume sources, of width 50 m and vertical extent 15 m, extending from the touchdown point to the most common exit taxiway of the respective runways.

3.3.54 For baseline modelling, the stand is known for each movement. For future scenarios, the forecast schedules also provide stand assignments for each movement.

Aircraft emissions: Runway assignments and temporal variation

3.3.55 For modelling, each aircraft movement needs to be assigned to a runway. For baseline modelling, the runway actually used is known for every movement, but for future scenarios, runways are assigned probabilistically. These probabilities need to align with the meteorological data used for the dispersion modelling. Because meteorological data is only available on an hourly basis, it is sufficient to determine runway probabilities for each hour of the year.

3.3.56 The ‘met year’ used for the dispersion modelling corresponds to a historic year for which actual runway usage is available. This historic year is used to obtain the relative frequency of easterly and westerly operations in each hour of the year.

3.3.57 The probability of using each physical runway in any given hour of the year is determined by assuming that each of the two operational modes is equally likely. For the 2028 With Development scenario, and for the 2028 Without Development scenario during westerly operations, each movement is assigned to both northern and southern runways with a weighting factor of 0.5. For the 2028 Without Development scenario during easterly operations, arrivals are assigned to runway 09L and departures to runway 09R.

3.3.58 In addition, the number of aircraft movements varies with hour of the day and the time of year. Since the weather also varies systematically between hours of the day, and between seasons of the year, it is therefore desirable for the model to take this temporal variation in emissions into account. Examination of the historic monthly variation in movements showed this to be very small (only a few percent difference between months), so no monthly profile has been applied to the future scenarios.

3.3.59 The hour of day is known for each movement, in the baseline and future scenarios. Emissions were calculated for each hour of the year, taking into account the movements in that hour and the weather conditions (which affect emissions through temperature, pressure and humidity effects, as described in paragraph 0, as well as the runway direction), for each mode of runway operation. These were used to create an hour-by-hour time-varying emissions weighting (‘hfc’) file for each emission source. The emissions were fed into the dispersion model for each mode of runway operation. This process was carried out for each of the three met years 2017–2019.

Aircraft ground runs

3.3.60 Aircraft engine ground runs are sometimes carried out as part of maintenance testing. Logs of ground runs were provided by the Airside Operations team, recording the location, aircraft type, time and power setting of the run. These were used to calculate emission rates in the same way as other aircraft engine emissions. For dispersion modelling, each run location was treated as a 50 m × 50 m × 15 m volume source. Emission rates were assumed to be the same in each modelled scenario (historic and future).

3.4 Emissions sources: On-airport, non-aircraft emissions

Ground support equipment (GSE)

3.4.1 GSE emissions are calculated using an equipment fleet mix from the Heathrow Airside Vehicle Pass database, which is assumed to represent the mix of equipment types and ages in each future scenario. Vehicle mileages are back-calculated from the actual measured fuel consumption, provided by the Airside Operations team, and emissions of air pollutants are calculated accordingly.

3.4.2 The number of electric equipment items is assumed to remain the same in the 2028 assessment year as at present; this is a conservative assumption, since the number is expected to increase over the next few years. Electric vehicles are assumed to have zero tail-pipe emissions, with only fugitive emissions of PM_{10} and $PM_{2.5}$ from brake and tyre wear.

3.4.3 Emission factors are taken from EMEP/EEA Guidebook[10,11]. In each case, emission factors appropriate to the age of the vehicle, and therefore the assumed emission control standard, are use, based on the age mix from the current airside pass database.

3.4.4 Emissions are assumed to occur on aircraft stands and are modelled as 50 m × 50 m × 3 m volume sources. Total emissions are calculated and then distributed between stands and between hours of the year in proportion to the sum of the MTOWs of the aircraft using that stand during that hour.

Stationary combustion plant

3.4.5 Emissions from stationary combustion plant are included in all scenarios. Data were taken from modelling carried out by Jacobs to support a recent permit application[12], and includes gas boilers in the Terminal 4 boilerhouse, the 448 boilerhouse, the Terminal 5 Energy Centre and the Heathrow Airport Centre, the biomass Combined Heat and Power unit in the Heathrow Airport Centre, and diesel generators in substations 56, 58 and 87.

[10] European Environment Agency, (2023). '*EMEP/EEA air pollutant emission inventory guidebook 2023. Technical guidance to prepare national emission inventories. 1.A.3.b.i-iv Road transport 2023*.'
[11] European Environment Agency, (2023). '*EMEP/EEA air pollutant emission inventory guidebook 2023. Technical guidance to prepare national emission inventories. 1.A.3.b.vi-vii Road tyre and brake wear 2023*.'
[12] Jacobs, (2021). *Application for Environmental Permit Variation Heathrow Airport: Air Quality Impact Assessment.* November 2021.

4. Approach to modelling emissions from road traffic

4.1 Construction traffic

Screening stage

4.1.1 The first step in considering the road traffic impacts of the construction traffic has been to screen the construction traffic generation against the criteria set out in the EPUK/IAQM guidance[13], which considers that a detailed assessment of air quality may be required if a development leads to a change of more than 25 AADT Heavy Duty Vehicle (HDV; > 3.5 T) movements on roads with relevant exposure. Where impacts can be screened out, there is no need to progress to a more detailed assessment.

4.1.2 The number of HDVs that will access and exit the site during enabling and construction works has been provided for each week of the construction programme, and likely delivery and disposal routes have been provided for each element of the programme. Rolling 52-week averages have been calculated to determine the maximum AADT for each route throughout the construction period. Although the air quality objectives relate to calendar years, a rolling 52-week period has been adopted to ensure a worst-case assessment, allowing for the possibility that activity may not occur on the programmed dates. This period has been assumed to occur in 2025, the earliest full year of construction activity, as road vehicle emission factors are reducing over time and this therefore represents a worst case. The sum of these maximum HDV movements along each route has been compared against the EPUK/IAQM criteria. The maximum number of HDV movements generated during the earliest full construction year (2025) is 41 as an AADT flow along Colnbrook Bypass between the Aggregate Industries Heathrow Asphalt facility and Stanwell Moor Road. There are no relevant receptors adjacent to this section of road. The only other road whereby the construction traffic is anticipated to exceed the screening criteria is Stanwell Moor Road, with a maximum of 30 AADT. This section of road has therefore been assessed in further detail.

4.1.3 The following sections describe the approach to dispersion modelling of road traffic emissions.

Modelling methodology

4.1.4 A quantitative assessment of construction vehicle emissions impacts has been carried out based on the number of vehicle trips and the construction vehicle routing. Impacts of the construction traffic increment have been predicted using the ADMS-Roads dispersion model, with vehicle emissions derived using Defra's latest Emission Factor Toolkit (EFT) (v12.0.1)[14].

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[13] Moorcroft and Barrowcliffe *et al*., (2017). *Land-Use Planning & Development Control: Planning For Air Quality v1.2*. IAQM, London [online]. Available at: air-quality-planning-guidance.pdf (iaqm.co.uk) (Accessed 01 October 2024)

[14] Defra, (2024). *Local Air Quality Management (LAQM) Support Website* [online]. Available at: http://laqm.defra.gov.uk/

Assessment scenarios

4.1.5 NO_2, PM_{10} and $PM_{2.5}$ impacts have been predicted for a single scenario for the year 2025, assuming peak levels of construction traffic. This is based on the construction traffic only, without baseline traffic.

Study Area

4.1.6 The modelled road network is shown in **Figure 6.1.4**. This includes roads along which the EPUK/IAQM screening criteria are expected to be exceeded and that are in proximity to sensitive receptors, and nearby road links along the construction routes within 200 m of the relevant receptors.

Receptors and receptor sensitivity

4.1.7 All human receptors that are locations of relevant exposure (as defined in **Paragraph 6.2.15** in **Chapter 6: Air Quality**) are considered to be 'high sensitivity'. This includes all the specific receptors included in the modelling. All other receptors are considered to be 'not sensitive' as the air quality objectives do not apply at these locations. Receptors included in the construction traffic emissions assessment are shown in **Figure 6.1.5** and described in **Table 6.1.9**.

Table 6.1.9: Description of receptors included in construction traffic impact assessment

Receptor name	X co-ordinate	Y co-ordinate	Height (m)	Description
R01	504685	176688	1.5	Heathrow Special Needs Centre
R02	504680	176727	1.5	Heathrow Special Needs Centre
R03	504794	175576	1.5	Green Corridor Special Educational Needs School
R04	504784	175737	1.5	Possible residential

Traffic data

4.1.8 Traffic data for the assessment, including traffic routing and weekly vehicle movements, have been provided by Volker Fitzpatrick. Traffic speeds have been estimated based on professional judgement, taking account of the road layout, speed limits and the proximity to a junction. The traffic data used in this assessment are summarised in **Table 6.1.10**. Flow profiles for the traffic have been defined, assuming that construction traffic will not use the local road network between 5am and 9am and 6pm to 10pm, to account for vehicles travelling to and from the site outside of those times.

Table 6.1.10: Summary of construction traffic data used in the assessment

Road link	AADT	% HDV
Western Perimeter Road north of Whittle Road, south of Wayfarer Road	21	100

Road link	AADT	% HDV
Western Perimeter Road south of Whittle Road	10	100
Southern Perimeter Road	30	100
Stanwell Moor Road	30	100
Wayfarer Road	10	10
M25 Slip	10	100

Assumptions and limitations

4.1.9 It is necessary to make a number of assumptions when carrying out an air quality assessment; in order to account for some of the uncertainty in the approach, as described above, assumptions made have generally sought to reflect a realistic worst-case scenario. Key assumptions made in carrying out this assessment include:

- That the peak year for construction traffic will occur in 2025 as a worst-case to ensure the assessment takes account of any possible variation in the peak traffic year, whilst providing an element of conservatism;
- That the maximum traffic flow will occur on both possible routes for disposal of material during enabling works; and
- That construction traffic will not be using the local road network between 5am and 9am and 6pm to 10pm, in line with data provided by Volker Fitzpatrick.

Model inputs

4.1.10 Construction traffic impacts have been modelled using the same parameters as described in **Section 2**, using the 2019 met year.

Post-processing

4.1.11 The model predicts road-NOx concentrations at each receptor location. These concentrations have been assumed to equal the NO_2 contribution as a worst-case assessment; in reality less than 100% of road-NOx will have converted to NO_2 by the time is has dispersed to a receptor location. Because the existing traffic flow has not been included, the dispersion model has not been verified against local measurements. Considering the very small impacts predicted and the worst-case approach to NOx to NO_2 conversion, it is considered that any local-applied model adjustment would not affect the overall conclusions of the assessment, as summarised in **Section 9.2**.

4.2 Operational traffic

Model domain

4.2.1 A receptor file has been created that covers the study area on a 50 m grid. It also incorporates specific sensitive receptors as well as a fine nested grid of receptors covering Longford and Stanwell[15]. These are shown in **Figure 6.1.1**. Figures showing labelled receptors in Longford and Stanwell are shown in **Figure 6.1.2** and **6.1.3**, respectively. The modelled road network is shown in **Figure 6.1.4**.

4.2.2 When predicting contributions from modelled roads at receptors, the 'spatial splitting' feature within the ADMS-Roads model has been used to split the model domain into 0.5 km x 0.5 km receptor regions. All roads within each region, and within 250 m in every direction, have been modelled explicitly[16]. **Figure 6.1.6** shows an example of a 0.5 km x 0.5 km selection of receptors and the 1 km x 1 km extent of the road traffic network modelled explicitly for that selection of receptors.

4.2.3 In this way, the explicitly modelled road network has been re-defined for each 0.5 km x 0.5 km grid of receptors, but the number of roads modelled explicitly for each receptor has been minimised, allowing significantly quicker model run times than if all roads were modelled explicitly (which would have been prohibitively slow).

4.2.4 Emissions from road traffic outside of each 1 km x 1 km square have not been ignored; they are effectively included within the background concentrations as described in **Section 7**.

4.2.5 Motorways have been modelled separately from the main road traffic network so as to enable model verification of these sources to be undertaken separately (see **Paragraph 9.2.5** for a discussion).

Operational traffic data

4.2.6 Traffic data for the assessment have been derived from the Heathrow Highway Assignment and Surface Access Model (HHASAM) provided by the surface access modelling team with the outputs processed to give Annual Average Daily Traffic (AADT) flows for each link, along with the fleet composition (proportion of cars, taxis, LGVs, HGVs, buses/coaches and motorcycles) and an average speed.

4.2.7 Where traffic will typically be free-flowing (i.e. away from junctions or other features that will slow traffic on a specific short section of a road), the modelled average speeds have been used to determine average emissions for sections of road. Where there are junctions or other features that will slow traffic on a specific short section of a road, speeds have been reduced using professional judgement to account for increased emissions in these locations as a result of slow-moving and/or queuing traffic. Speeds on the remainder of such links have not been increased to account for this reduction on some sections, as the

[15] Receptors have been modelled over Cartesian grids at 10 m intervals within 100 m of modelled roads, at 20 m intervals between 100 m and 200 m from modelled roads, and at 50 m intervals beyond 200 m from modelled roads.

[16] The model selects roads within this region; it does not split them at the 250m buffer boundary, so long roads that extend past the buffer will be included in the selection.

slow sections are typically short and unlikely to lead to substantial changes in speed along the remainder of the link, and, as a result, unlikely to significantly affect modelled concentrations.

4.2.8 Diurnal traffic flow profiles have been provided by the surface access modelling team. Monthly flow profiles have been derived from the national profiles published by Department for Transport (DfT)[17] for 2017, 2018 and 2019 for the baseline years and 2022 for the future baseline (2028).

Calculating road traffic emissions

4.2.9 The Defra Emissions Factors Toolkit (EFT)[18] v11.0 has been used to calculate vehicle emissions for 2017, and v12.0[19] has been used to calculate vehicle emissions for 2018, 2019 and 2028[20]. This tool requires that the user enter one of seven Road Types:

- Urban (not London);
- Rural (not London);
- Motorway (not London);
- London - Central;
- London - Inner;
- London - Outer; and
- London - Motorway.

4.2.10 It is important to note that these categories describe the vehicle fleet composition rather than the precise physical location of the road. The fleet composition does not, for example, change as a road passes from an urban to a rural area in the absence of any intervening junctions. Note 5 in the EFT v12.0 user guide explains that:

'The urban categorisation relates to the DfT definition of an urban area with a population of 10,000 or more. The London road types are consistent with the area categories defined in the London Atmospheric Emissions Inventory (LAEI).'

4.2.11 The user guide explains that London – Central corresponds to the same area as the Central London Congestion Charge Zone (CCZ); London – Inner includes roads outside of the Central London CCZ up to, but not including, the north and south circular roads; London – Outer includes roads from the north and south circular roads to the Greater London Authority (GLA) boundary; and London – Motorway should be used for the M25 motorway only:

[17] DfT, (2024). Road traffic statistics (TRA03).
[18] Defra, (2024). Emissions Factors Toolkit [online]. Available: https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/
[19] After the modelling was carried out, Defra released version 12.0.1 of the EFT. This version makes a slight change to emission factors for hybrid vehicles travelling above 50 kph. The differences were judged to be sufficiently minor that remodelling was not considered necessary or a proportionate effort.
[20] EFT v11.0 only allows calculation of emissions up to 2030 within London and EFT v12.0 allows calculation of emissions from 2018 to 2050.

'Other motorways and fast dual carriageways in Greater London should be defined as either 'London – Inner' or 'London – Outer' as appropriate.'

4.2.12 Rigidly applying these definitions would artificially introduce step changes in vehicle fleet compositions part-way along links. The following approach has, therefore, been followed when using the EFT to calculate vehicle emissions:

- All sections of the M25 (including all non-M4 slip-roads) have been assigned Road Type 7
- Sections of motorway and slip-roads (other than the M25) outside of the Outer London area have been assigned Road Type 3
- All other roads have been assigned Road Type 6.

4.2.13 Applying this approach ensures minimal step changes in emission factors, and consistency throughout the study area, where emissions are likely to generally be very similar to the Outer London fleet.

4.2.14 Changes were made to the Low Emission Zone (LEZ) in 2021, and the Ultra-Low Emission Zone (ULEZ), originally covering the congestion charge zone, came into force in April 2019, with changes also implemented in 2021. The ULEZ was further expanded in 2023. The changes can be expected to significantly reduce NOx emissions in London. Defra's EFT v12.0 is representative of London-Specific policies, including the expansion of the ULEZ in 2023.

Additional features

4.2.15 There are a number of road tunnels within the model domain. To ensure a robust assessment, these have been modelled as tunnels using the ADMS Tunnels module. Some of the modelled tunnel links are long and would extend beyond the boundary of some of the 1 km x 1 km model grid areas (see **Paragraph 4.2.2**). In order to avoid introducing artificial tunnel ends where this occurs, tunnels have been removed from the primary modelled road network and modelled explicitly with a separate receptor file. The receptor file has incorporated all of the receptors within the multiple 0.5 km x 0.5 km grid cells that would have been modelled using the 'spatial splitting' option in ADMS-Roads if the methodology described in **Paragraph 4.2.2** been applied.

4.2.16 Roadside noise barriers have also been incorporated into the model, where currently present.

4.2.17 Where relevant, flyovers have been modelled as such. Only sections of road longer than 50 m and which have clear air underneath the carriageway have been modelled as flyovers. This is because the option to give road sources an elevation is really intended for true bridges, with the initial mixing of the emissions given an extra downward component to account for the passage of air beneath the source.

5. Approach to modelling car park emissions

5.1.1 Emissions from vehicles using car parks operated by Heathrow have been modelled using the following approach:

- Volume sources of 3 m depth have been defined covering the area of each car park (sensitivity testing has identified a volume source of 3 m depth at ground level as best representing ground level vehicle emissions, when compared to modelling as a line source), with multi-storey car park volume sources given a total depth assuming each storey to be 3 m deep;
- An average trip length through the car park has been defined based on mapping data;
- Emissions have been calculated using the EFT (v11.0 for 2017 and v12.0 for other years) for every vehicle using the car park (using usage figures provided by the surface access team) on the assumption that they travel this average distance at 5 kph, the speed associated with the highest emissions in the EFT. All vehicles have been assumed to be cars;
- The total emission rate for each car park volume source has been calculated and modelled using ADMS-Airport, assuming a constant seasonal profile of emissions. Weekday/weekend diurnal profiles of emissions have been calculated based on local Heathrow traffic data provided by the surface access team; and
- Cold-start emissions have been defined using the National Atmospheric Emissions Inventory (NAEI) cold start emission rates (which are derived from COPERT)[21,22]. 50% of the total cold start emission for each car park has been applied to the modelled volume source, with the other 50% averaged over 200 m long line sources representing the most likely routes of traffic exiting from the car parks.

5.1.2 This is considered to represent a suitably robust approach to modelling emissions from vehicles using car parks, which represent a very small proportion of total concentrations. In reality, there is likely to be some seasonal profile to these emissions, but these will be different to typical road traffic profiles on the highway network, thus it would not be appropriate to apply a default highway network profile. It is considered more appropriate to simply assume a constant profile, in the knowledge that this is unlikely to lead to significant uncertainty in annual mean contributions.

5.1.3 Given that emissions from car parks represent a very small proportion of total concentrations, and to align with the methodology used for the other explicit roads and tunnels, the car park emissions have been modelled for a reduced receptor file incorporating all of the receptors within 250 m of any car park source.

5.1.4 The modelled car park line and volume sources are shown in **Figure 6.1.7**.

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[21] NAEI, (2022). *Emission Factors for Transport. [online]* Available: https://naei.energysecurity.gov.uk/emission-factors/emission-factors-transport

[22] A later version of the dataset is available (2021 v1) however the cold start element of car park emissions represent a very minor contributions to overall emissions and it is considered that the version used will not have any meaningful impact on the results presented here.

6. Approach to modelling Lakeside Waste Management Facility emissions

6.1.1 Emissions from the Lakeside Waste Management Facility have been modelled using the ADMS-6 model, assuming that emissions do not vary from year to year, using meteorological data for 2017, 2018 and 2019. The urban canopy module has been used in order for the modelling to align with the bulk of the other modelling carried out. This has resulted in buildings not being incorporated into the model, but the urban canopy flow module should itself account for some of the effects of the presence of the process building, and the stack at the existing facility is considerably higher than the highest point of the process building (75 m as opposed to 42 m), thus building effects will be relatively limited. As such, the approach is deemed appropriate.

6.1.2 Emissions data for the existing facility have been derived from modelling undertaken by Fitchner as part of the planning application to relocate the facility (planning reference P/17826) to facilitate the Heathrow Airport Third Runway Expansion[23] (see Table 4.1 and 4.2 in that report), and are summarised in **Table 6.1.11**, generally to two significant figures. The facility has three lines of plant; one clinical waste incinerator (CWI) and two energy from waste (EfW).

Table 6.1.11: Emission data for the existing facility

Parameter	CWI	EfW (per line)
Stack Location (x,y)	503900,177341	
Modelled Height (m)	75	
Temperature	140	145
Exhaust Volume Flow Rate (Nm^3/s)	4.1	40.0
Exit velocity	15.0	14.8
NO_X (mg/Nm^3)	200	
NO_X (g/s)	0.82	8.0
PM_{10} (mg/Nm^3)	10	
PM_{10} (g/s)	0.041	0.40

6.1.3 The model has been run using meteorological data for 2017, 2018 and 2019. Concentrations have been predicted at each of the monitoring sites used in the model verification, and all receptors included in the road traffic modelling. These concentrations

23 Fitchner, (2019). *Replacement Lakeside EfW and HTI Facilities Environmental Statement, Technical Appendix D – Air Quality* [online]. Available at: https://www.sbcplanning.co.uk/sbcp/slough01/planapp/P17826(38)/P17826(38).pdf#pagemode=thumbs (Accessed 01 October 2024)

have been added to the total concentrations at receptors in the relevant scenarios using the approach described in **Section 8**.

7. Approach to predicting background concentrations

7.1 Background Maps

7.1.1 Defra's 2017-base year background maps[24] and have been used to provide the concentrations associated with pollutant sources which are not being explicitly modelled for the 2017 baseline year, and the 2018-base year maps have been used for all other years.

7.1.2 In order to avoid double-counting, emissions from sources that have been explicitly modelled have been removed from Defra's maps. This includes contributions from Heathrow Airport associated emissions and Lakeside Waste Management Facility (see **Paragraph 7.1.3** below). To remove the explicitly modelled road traffic component, all 'in-square'[25] emissions from motorways, trunk roads and principal roads have been removed and all 'out-square' emissions have been retained. Each 0.5 km x 0.5 km receptor grid cell has been included within the road traffic emissions model with a 250 m buffer, therefore 50% of the receptor grids are located completely within each of the 1 km x 1 km background grids, and 50% straddle the boundaries. While this approach could it introduce a small level of inconsistency and step-changes in the outputs, the final background concentrations have been interpolated onto the full receptor grid, which will have smoothed the concentrations to a large extent. In addition, since there is no change in traffic caused by the Proposed Development, road traffic emissions will not change between to Without Development and With Development scenarios, and neither will their impact on overall background concentrations across the wider network.

7.1.3 Emissions attributed to Heathrow Airport fall within several sectors, some obvious (e.g. 'Aircraft') and some less so (e.g. 'Other'). In order to ensure that no double-counting of Heathrow emissions occurs, Ricardo Energy & Environment were commissioned, with Defra's approval, to determine the explicit contribution of Heathrow Airport to all non-road sectors of the background maps, so that this can be removed from the mapped background concentrations.

7.1.4 For completeness, the sectors included in Defra's background maps are detailed in **Table 6.1.12**.

[24] Defra, (2024). Background Maps [online]. Available: https://laqm.defra.gov.uk/air-quality/air-quality-assessment/background-maps/

[25] i.e. all said emissions originating inside or outside of a specific cell of the 1km x 1km grid over which the maps are provided.

Table 6.1.12: Sectors included in the background maps

Sector
Motorway
Trunk A Rd
Primary A Rd
Minor Rd+Cold Start
Brake+Tyre Wear (PM Only)
Road Abrasion (PM Only)
Industry
Domestic
Rail
Other
PM secondary (PM Only)
Residual+Salt (PM Only)
Point Sources
Rural (NO_X Only)
Aircraft (NO_X Only)

7.1.5 The following road traffic sources have also been removed from Defra's background maps:

- Motorway (in-square);
- Trunk A Rd (in-square);
- Primary A Rd (in-square);
- Brake+Tyre Wear (PM Only) (in-square); and
- Road Abrasion (PM Only) (in-square).

7.1.6 The contribution of the Minor Rd+Cold Start sector has been retained, given that most minor roads will not be modelled explicitly due to not being incorporated in the HHASAM network, and to allow for the contribution of cold start emissions across the study area. This will result in some double-counting of emissions from minor roads, and cold start emissions from Heathrow's car parks, but this will be very small[26].

[26] Cold start emissions for trips associated with the operational traffic originating at the airport have been modelled explicitly for all Heathrow-controlled car parks. Cold start emissions for trips originating elsewhere will not be counted, other than through the inclusion of the contribution of the Minor Rd+Cold Start sector from the background maps.

7.1.7 In determining appropriate mapped background NO_X and nitrogen dioxide (NO_2) concentrations, Defra's sector removal tool[27] (v7.0 for 2017 and v8.0 for all other years) has been used to remove the relevant road and non-road contributions from the background maps. The end result is a set of background concentrations that do not include the contribution of major roads, sources within Heathrow Airport or the Lakeside Waste Management Facility. These are the background concentrations entered into the Defra NOx to NO_2 calculator when determining total concentrations.

[27] Defra, (2024). *NO_2 Adjustment for NOx Sector Removal Tool* [online]. Available: https://laqm.defra.gov.uk/air-quality/air-quality-assessment/no2-adjustment-for-nox-sector-removal-tool/

8. Calculation of total NO_2 concentrations

8.1.1 NO_X is emitted as a mixture of nitric oxide (NO) and NO_2 (primary NO_2), and reactions in the atmosphere convert NO to NO_2, and vice versa. Concentrations of NO_X are conserved[28], so are straightforward to calculate through dispersion modelling. Concentrations of NO_2 at receptors are, however, a complex function of emissions of NO and primary NO_2, concentrations of oxidants (principally NO_2 and O_3) in the air, the magnitude of incoming solar radiation and travel time. Modellers, therefore, require a procedure for calculating NO_2 concentrations from the NO_X concentrations calculated by dispersion modelling.

8.1.2 The NO_X to NO_2 Calculator available from the Local Air Quality Management (LAQM) website[29] has been used to predict total NO_2 concentrations (v7.1 has been used for 2017 calculations and v8.1 has been used for all other years). It takes a semi-empirical approach which 'uses a one-dimensional finite difference model of the reactions and mixing of NO, NO_2 and O_3 in the surface stress layer of the atmospheric boundary layer.'

8.1.3 The NO_X to NO_2 calculator requires the user to define a specific local planning authority area, which is used to estimate regional concentrations of O_3, NO_X and NO_2 above the surface layer. Hillingdon has been used throughout this assessment, as it is considered to appropriately represent conditions in the vicinity of Heathrow Airport, and using a varied selection would result in unrealistic step changes in concentrations at local planning authority boundaries.

8.1.4 The user is also required to define the traffic mix, which is used to define the appropriate fNO_2 value for road traffic emissions. 'All London traffic' has been used throughout this assessment, as it is considered the most representative option for the area of interest while ensuring no step changes in concentrations.

8.1.5 In order to determine total pollutant concentrations, all of the individual contributions have been combined. The process for this is described below.

8.1.6 The first step has been to determine a receptor-specific background NO_2 concentration. The mapped background concentrations with the contribution of Heathrow Airport and major 'in-square' road sources removed (see **Section 7**) have been interpolated to provide receptor specific Total NO_X, Road NO_X, Non-Road NO_X and Total NO_2 concentrations.

8.1.7 The modelled road NO_X (including the tunnels contribution) has then also been adjusted by applying the primary adjustment factor for road traffic emissions (see **Section 9**), with the modelled motorway, car park, Lakeside Waste Management Facility and interpolated airport contributions then added to give a total modelled NO_X concentration for every receptor. Receptor-specific fNO_2 values have then been calculated by multiplying each

[28] Small losses through deposition are ignored for the purposes of modelling air concentrations, giving rise to a small degree of double counting of the deposited NO_x.
[29] Defra, (2024). *NOx to NO_2 Calculator* [online]. Available: https://laqm.defra.gov.uk/air-quality/air-quality-assessment/nox-to-no2-calculator/

constituent part by its source-specific fNO_2 value, to determine an appropriate overall fNO_2 value.

8.1.8 The total modelled NO_X, total background NO_2 and fNO_2 values for each receptor have then been run through Defra's NOx to NO_2 calculator to define a total modelled NO_2 concentration, to which the secondary adjustment factor has been applied to give a final total NO_2 concentration at every receptor. The application of a secondary adjustment factor in order to bring the modelled NO_2 concentrations into alignment with the local monitoring is considered appropriate, as the bulk of the total concentration has been modelled explicitly. The need for such a factor is thought to relate to the over-estimation of road vehicle fNO_2 in the NOx to NO_2 calculator.

9. Model verification methodology

9.1.1 The model output concentrations have been verified against measured concentrations from suitable automatic monitoring sites within the study area and diffusion tube monitors within, and close to, the detailed road traffic model area shown in **Figure 6.1.1**. While the Slough Brands Hill automatic monitor is outside the study area, it has been included as it is located within the roads model domain. The sites used in the model verification are listed in **Table 6.1.13** and shown in **Figure 6.1.8**. Automatic monitors with data capture ≥75%, and diffusion tube monitors with data capture ≥50% have been included; a lower data capture for diffusion tubes has been allowed as the measurements made at those sites will have been annualised. The site type classification is provided, and further information is provided where sites may be influenced by specific sources where they are not classed as such.

9.1.2 Measured concentrations from the automatic monitoring sites are provided in **Table 6.6**, **Table 6.8** and **Table 6.10** in **Chapter 6: Air Quality**, and concentrations from diffusion tubes are shown in **Table 6.1.14**. Diffusion tube monitoring data have been taken from local authorities' Air Quality Review and Assessment reports (London Borough of Hillingdon, 2018[30], 2019[31], 2020[32]; Spelthorne Borough Council, 2018[33], 2019[34], 2020[35]; Slough Borough Council, 2018[36], 2019[37] and 2020[38]). Automatic monitoring data have been downloaded from the Automatic Urban and Rural Network (AURN) and Air Quality England (AQE) online databases using the R OpenAir package[39].

Table 6.1.13: Sites used in the model verification

Site Name	Site ID	Classification	Years Used	Pollutants Measured
Automatic Monitors				
Heathrow LHR2	LHR2	Suburban Industrial (close to airport / adjacent to Heathrow local road)	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019 $PM_{2.5}$: 2017,2018, 2019	NO_X, NO_2, PM_{10}, $PM_{2.5}$

30 London Borough of Hillingdon (2018), 'Air Quality Annual Status Report, 2017'
31 London Borough of Hillingdon (2019), 'Air Quality Annual Status Report, 2018'
32 London Borough of Hillingdon (2020), 'Air Quality Annual Status Report, 2019'
33 Spelthorne Borough Council (2018), '2018 Air Quality Annual Status Report (ASR)'
34 Spelthorne Borough Council (2019), '2019 Air Quality Annual Status Report (ASR)'
35 Spelthorne Borough Council (2020), '2020 Air Quality Annual Status Report (ASR)'
36 Slough Borough Council (2018), '2018 Air Quality Annual Status Report' (ASR)'
37 Slough Borough Council (2019), '2019 Air Quality Annual Status Report' (ASR)'
38 Slough Borough Council (2020), '2020 Air Quality Annual Status Report' (ASR)'
39 Carslaw D.C. & Ropkins K. (2012), openair — An R package for air quality data analysis, Environmental Modelling & Software, 27–28(0), 52–61. ISSN 1364-8152, doi:10.1016/j.envsoft.2011.09.008.

Site Name	Site ID	Classification	Years Used	Pollutants Measured
Hillingdon Harmondsworth	HIL1	Urban Background (adjacent to minor road)	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2019	NO_X, NO_2, PM_{10}
Hillingdon Sipson	SIPS	Urban Background	NOx/NO_2: 2017, 2018, 2019	NO_X, NO_2
London Harlington	HRL	Urban Industrial (close to airport / adjacent to minor road)	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019 $PM_{2.5}$: 2017,2018, 2019	NO_X, NO_2, PM_{10}, $PM_{2.5}$
Hillingdon Hayes	HIL5	Urban Traffic	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019	NO_X, NO_2, PM_{10}
Hillingdon Oxford Avenue	HI3	Urban Background (close to A4)	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019	NO_X, NO_2, PM_{10}
Hounslow Cranford	HS2	Suburban Background	NOx/NO_2: 2017, 2019 PM_{10}: 2017, 2019	NO_X, NO_2, PM_{10}
Hounslow Hatton Cross	HS7	Urban Background	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019	NO_X, NO_2, PM_{10}
Heathrow Oaks Road	T54 (BAA_OAKS)	Suburban Industrial (adjacent to minor road)	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019 $PM_{2.5}$: 2017,2018, 2019	NO_X, NO_2, PM_{10}, $PM_{2.5}$
Hounslow Feltham	HS9	Urban Background (close to A224)	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019	NO_X, NO_2, PM_{10}
London Hillingdon	HIL	Urban Background (close to M4)	NOx/NO_2: 2017, 2018, 2019	NO_X, NO_2
Heathrow Green Gates	T55	Suburban Industrial (close to airport / adjacent to minor road)	NOx/NO_2: 2017, 2018, 2019 PM_{10}: 2017, 2018, 2019 $PM_{2.5}$: 2017,2018, 2019	NO_X, NO_2, PM_{10}, $PM_{2.5}$
Slough Colnbrook	SLH3	Urban Background	NOx/NO_2: 2017, 2018, 2019	NO_X, NO_2

Site Name	Site ID	Classification	Years Used	Pollutants Measured
Slough Brands Hill London Road	SLH11	Urban Traffic	NOx/NO_2: 2018, 2019 PM_{10}: 2018, 2019	NO_X, NO_2, PM_{10}
		Diffusion Tube Monitors		
Bomber Close, Sipson	HD59	Roadside	2017, 2018	NO_2
28 Pinglestone Close, Sipson	HD65	Roadside	2017, 2018	NO_2
Harmondsworth Green, Harmondsworth	HILL11	Roadside	2017, 2018, 2019	NO_2
Heathrow Close, Longford	HILL12	Roadside	2017, 2018, 2019	NO_2
49 Zealand Avenue	HILL16	Roadside	2017, 2018, 2019	NO_2
Pinglestone Close/Bath Road A4	HILL39	Roadside	2019	NO_2
Sipson Close/Sipson Road	HILL40	Roadside	2019	NO_2
A4 near junction with Sipson Way	HILL41	Roadside	2019	NO_2
Lakeside Road	SLO12	Industrial	2017, 2018, 2019	NO_2
Elbow Meadows	SLO13	Suburban	2017, 2018, 2019	NO_2
Horton Road (Caravan Park)	SLO17	Suburban (adjacent to minor road)	2017, 2018, 2019	NO_2
Colnbrook Bypass	SLO7	Industrial (close to A4)	2017, 2018, 2019	NO_2
Flintlock Close, Stanwell	SP14	Urban Background	2017, 2018, 2019	NO_2
Bedfont Road, Stanwell	SP19	Roadside	2017, 2018, 2019	NO_2

Site Name	Site ID	Classification	Years Used	Pollutants Measured
St Mary's Crescent, Staines	SP26	Urban Background	2017, 2018, 2019	NO_2
Hadrian Way, Stanwell	SP47	Urban Background	2017, 2018, 2019	NO_2
Riverside Road, Stanwell	SP48	Kerbside	2017, 2018, 2019	NO_2
Stanwell Moor Road	SP60	Roadside	2019	NO_2
Horton Road	SP61	Roadside	2019	NO_2
Park Road, Stanwell	SP62	Roadside	2019	NO_2
Northumberland Close	SP63	Roadside	2019	NO_2
Spout Lane	SP65	Roadside	2019	NO_2

Table 6.1.14: Annual mean NO_2 diffusion tube monitoring data used in the model verification

Site Name	Site ID	Classification	2017	2018	2019
Bomber Close, Sipson	HD59	Roadside	32.6	32.9	27.7 [a]
28 Pinglestone Close, Sipson	HD65	Roadside	30.0	30.9	25.1 [a]
Harmondsworth Green, Harmondsworth	HILL11	Roadside	27.8	38.5	25.3 [b]
Heathrow Close, Longford	HILL12	Roadside	34.0	36.0	33.0
49 Zealand Avenue	HILL16	Roadside	42.7	38.6	37.7
Pinglestone Close/Bath Road A4	HILL39	Roadside	-	-	45.7 [c]
Sipson	HILL40	Roadside	-	-	35.5 [c]

Site Name	Site ID	Classification	2017	2018	2019
Close/Sipson Road					
A4 near junction with Sipson Way	HILL41	Roadside	-	-	48.7 [c]
Lakeside Road	SLO12	Industrial	38.6	40.7	39.5
Elbow Meadows	SLO13	Suburban	30.5	31.2	28.9
Horton Road (Caravan Park)	SLO17	Suburban (adjacent to minor road)	25.6 [b]	41.5	33.3
Colnbrook Bypass	SLO7	Industrial (close to A4)	38.7	35.0	32.8
Flintlock Close, Stanwell	SP14	Urban Background	24.9	28.0	28.0
Bedfont Road, Stanwell	SP19	Roadside	32.1	31.8	35.8
St Mary's Crescent, Staines	SP26	Urban Background	27.7	29.4	31.9
Hadrian Way, Stanwell	SP47	Urban Background	24.8	24.6 [d]	25.7
Riverside Road, Stanwell	SP48	Kerbside	30.1	31.6	35.5
Stanwell Moor Road	SP60	Roadside	-	-	57.0
Horton Road	SP61	Roadside	-	-	31.2
Park Road, Stanwell	SP62	Roadside	-	-	29.7
Northumberland Close	SP63	Roadside	-	-	40.2
Spout Lane	SP65	Roadside	-	-	34.6

[a] Low data capture (25%); not used in the verification.
[b] Low data capture (58%).
[c] Low data capture (50%).
[d] Low data capture (67%).

9.2 NO_X and NO_2

9.2.1 Most NO_2 is produced in the atmosphere by reaction of NO with ozone (O_3). It is therefore most appropriate to verify the model in terms of primary pollutant emissions of NO_X (NOx = NO + NO_2).

9.2.2 The model output of road-NOx (i.e. the component of total NOx coming from road traffic) has been compared with the 'measured' road-NOx. Measured road-NOx has been calculated by subtracting the following components from the measured NOx concentration at each monitor:

- Background NOx;
- Airside NOx (including emissions from aircraft, ground support equipment and heating and cooling plant);
- The modelled NOx contribution of Heathrow's car parks; and
- The modelled NOx contribution of the Lakeside Waste Management Facility.

9.2.3 An adjustment factor has been determined as the slope of the best-fit line between the 'measured' road contribution and the model derived road contribution, forced through zero. The total NO_2 concentrations have then been determined by combining the adjusted total NOx concentrations with the predicted background NO_2 concentration within the NOx to NO_2 calculator. A secondary adjustment factor has then been calculated as the slope of the best-fit line applied to the adjusted total NO_2 concentrations and forced through zero.

9.2.4 Model verification factors for NO_X and NO_2 have been determined for the years 2017, 2018 and 2019. The modelled Road NO_X has been adjusted, followed by total NO_2. There is no strong justification for adjusting any other contributions.

9.2.5 The adjustment has been performed for all modelled road NOx, and for roads other than motorways. For the latter, explicitly modelled motorway NOx has been subtracted from the measured NOx along with the other contributions and has not been adjusted. In all years, removing motorway NOx from the adjustment results in a more conservative primary adjustment factor than including it with other road-NOx. Based on previous experience, the model tends to produce less of an under-prediction, if any at all, when modelling emissions from high-speed motorways, and this appears to be the case here. Thus, it has been assumed here that motorway emissions are correct, and they have not been included in the primary adjustment. The calculated factors for each year are presented in **Table 6.1.15**.

Table 6.1.15: Calculated NOx and NO_2 factors for each year

Year	Primary Road NO_X Adjustment Factor	Secondary Total NO_2 Adjustment Factor
2017	2.9734	0.9995
2018	3.5641	0.9797
2019	3.9880	0.9798

9.2.6 The primary adjustment factors increase year-on-year; this may be due to a discrepancy between the rate of change in monitored concentrations versus the rate of change in emissions calculated using the EFT, but this is not clear. The secondary adjustment factors calculated demonstrate that secondary adjustment is necessary to avoid over-estimation of annual mean nitrogen dioxide concentrations. This is thought to be at least partially due to the over-estimation of primary NO_2 from road traffic in Defra's NO_X to NO_2 calculator.

9.2.7 The statistical performance of each of the models is presented in **Table 6.1.16**. LAQM TG.22[6] advises that '*ideally an RMSE within 10% of the air quality objective would be derived, which equates to 4 µg/m^3 for the annual average NO_2 objective*'. However, it is only recommended that model inputs and verification should be revisited if RMSE values are higher than ±25% of the objective (i.e. 10 µg/m^3). The RMSE value is greater than 4 µg/m^3 for every year, but less than 10 µg/m^3.

Table 6.1.16: Statistical performance of each of the models – NO_2

Year	Correlation Coefficient	Root Mean Square Error	Fractional Bias
2017	0.53	6.94	0.03
2018	0.53	6.35	0.02
2019	0.70	5.80	0.02
'Ideal' value	**1**	**0**	**0**

9.2.8 **Graphic 6.1.2** to **Graphic 6.1.4** plot the final modelled annual mean NO_2 concentrations against the measured concentration for each verification scenario.

9.2.9 The graphs generally show good agreement. There are four locations lying outside 25% of the 1:1 line; HIL London Hillingdon (located very close to the M4 motorway), SLO12 Lakeside Road (located close to the Lakeside Waste Management Facility), SLO17 (located at a caravan park), and SP19 (located close to the junction of Long Lane and Bedfont Road to the south of Heathrow Airport). In 2018 the outliers are SLO12, SP19 and HS9 Hounslow Feltham. In 2019 the outliers are SLO12 and HS9.

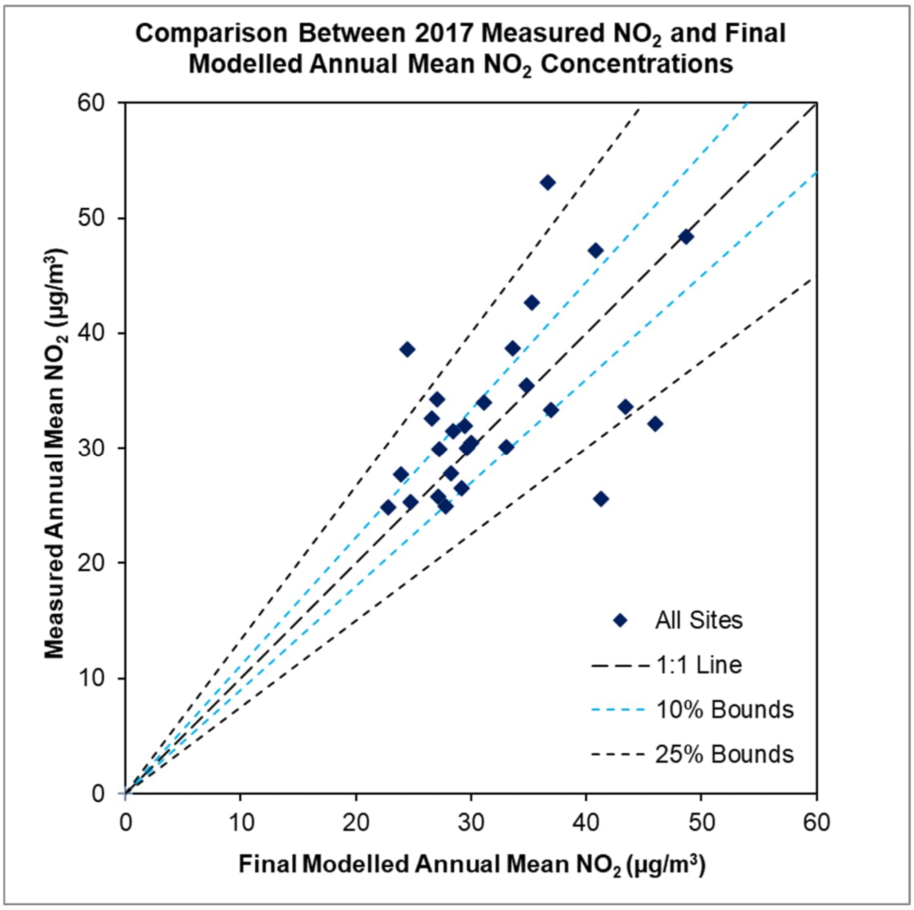
9.2.10 While the modelled concentrations at SLO17 are overpredicted in 2017, they are underpredicted in 2018 and 2019 and the model shows closer agreement. There is no clear reason as to why this change would occur; it may be a very local source causing the variation, and thus the monitor has been included in the verification for all years.

9.2.11 Concentrations at monitor SLO12 are under-predicted in all years. This may be due to the contribution of the Lakeside Waste Management Facility being underrepresented. Including this monitoring site in the verification for all years leads to a higher primary adjustment factor and is therefore conservative.

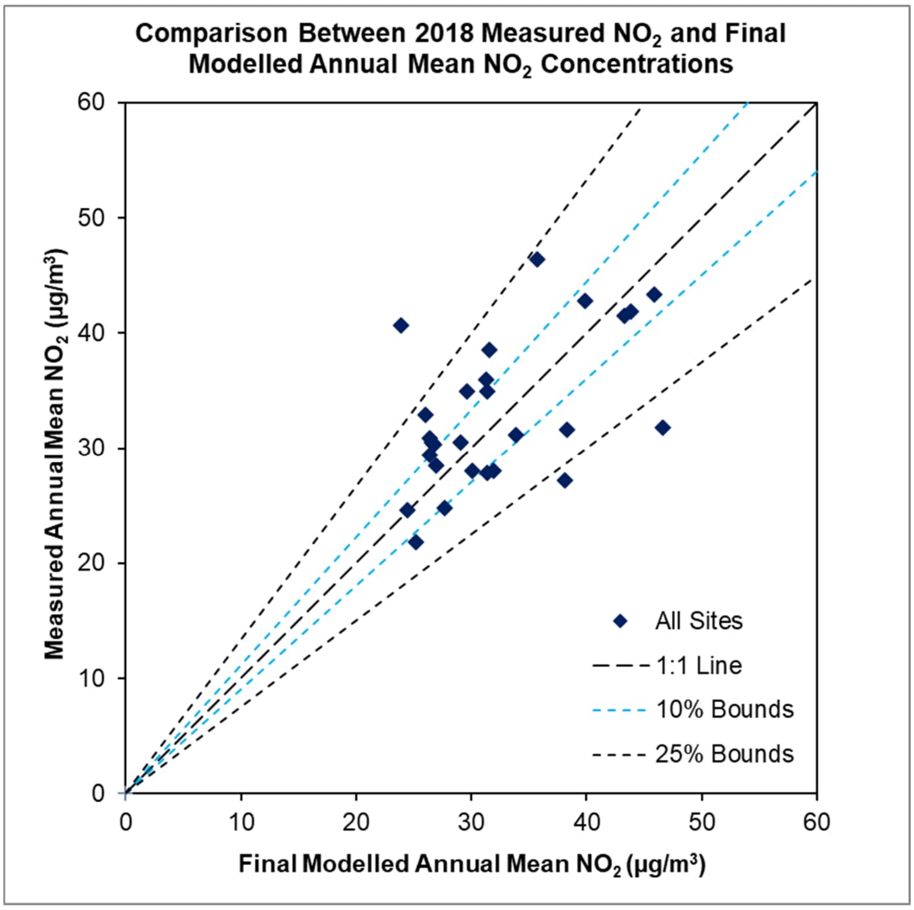
9.2.12 The modelled concentration at monitor SP19 is over-predicted in 2017 and 2018. The modelled road-NOx contribution at this site in those years is very similar to the calculated measured road-NOx, so the application of the primary factor leads to an over-estimation in final NO_2. In 2019, the road-NOx contribution is under-predicted. Similarly, the modelled road-NOx contribution at HS9 is slightly under-predicted in 2018 and 2019, however the application of the primary adjustment factor leads to the final modelled NO_2 concentrations at HS9 in 2018 and 2019 lie just outside the 25% bounds.

9.2.13 While it may be justifiable to remove SLO12 from the verification due to its poor fit in all years, leaving it in provides a more conservative approach. It has been judged that it is best to apply the factors derived using all of the monitoring sites in each year.

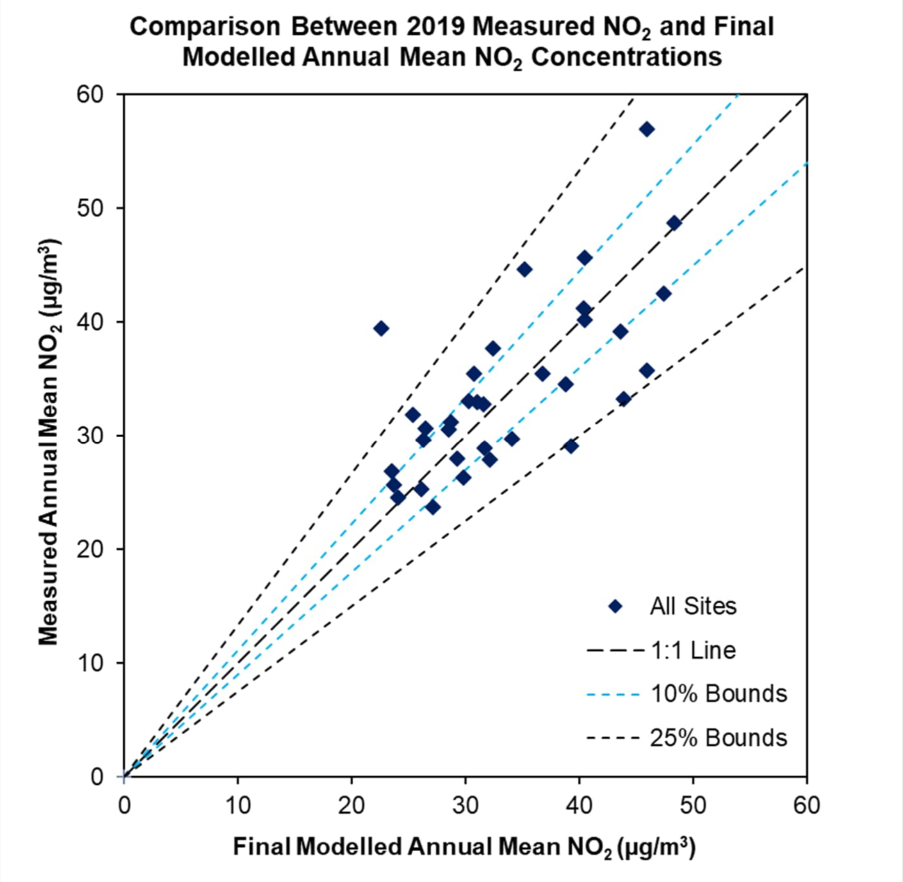
Graphic 6.1.2: 2017 Model performance - NO_2



Graphic 6.1.3: 2018 Model performance - NO_2



Graphic 6.1.4: 2019 Model performance - NO_2



9.3 PM_{10} and $PM_{2.5}$

9.3.1 The model performance has been tested against monitoring data for PM_{10} and $PM_{2.5}$.

PM_{10} Results

9.3.2 **Graphic 6.1.5** to **Graphic 6.1.7** present graphs of the modelled annual mean PM_{10} concentrations plotted against the measured concentrations at all of the appropriate monitoring sites in the study area. Unadjusted total concentrations are shown in the top plot, and total concentrations with adjusted road contribution (not including motorways) are shown in the bottom plot.

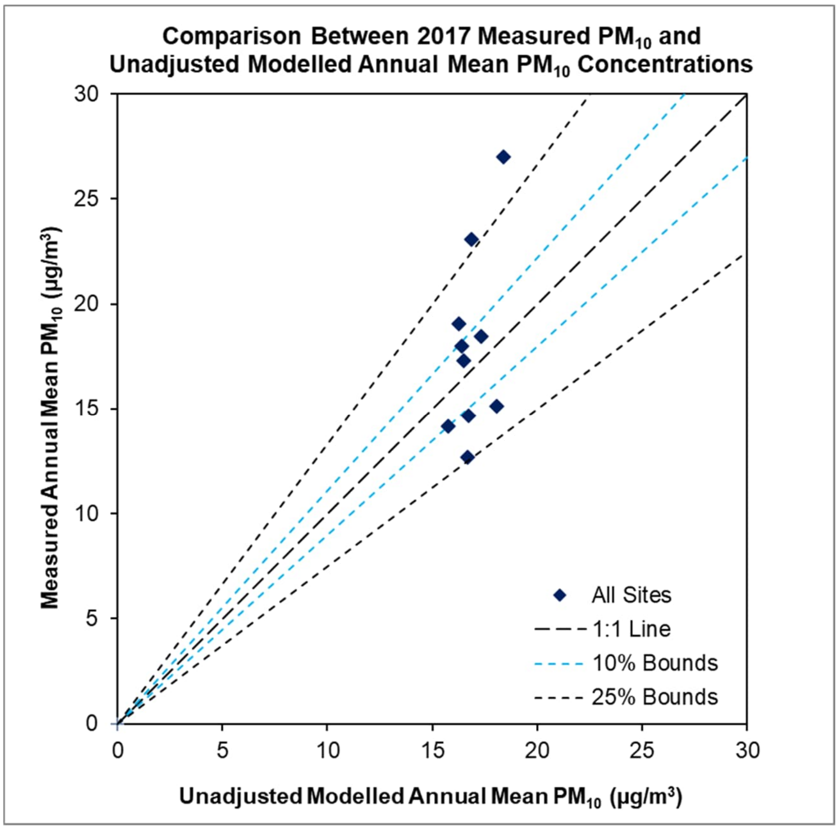
9.3.3 While the adjusted model is performing well at some sites, it is under- or over-predicting concentrations at others (those falling outside, or close to, the 25% bounds shown in the graphics). The calculated road PM_{10} adjustment factors are 3.4195 for 2017, 5.5782 for 2018 and 5.1626 for 2019, indicating one or more of the modelled sources are not being well captured in the model, and/or there is a source that is not being captured at all. Indeed, the mapped background concentrations are higher than the measured concentrations at several of the sites. In these cases, it is clear that adjusting road PM_{10} contributions is not a suitable approach to take. As such, an additional adjustment has been tested, this time calibrating the background concentrations, to determine whether this provides a better overall model fit. These are shown in **Graphic 6.1.8** to **Graphic 6.1.10**. Here, the average ratio of the "measured" background PM_{10} (the measured concentration at each monitor minus all of the explicitly modelled contributions) to the mapped background concentration is used as the adjustment factor. The calculated background PM_{10} adjustment factors are 1.0717 for 2017, 1.1677 for 2018 and 1.1109 for 2019.

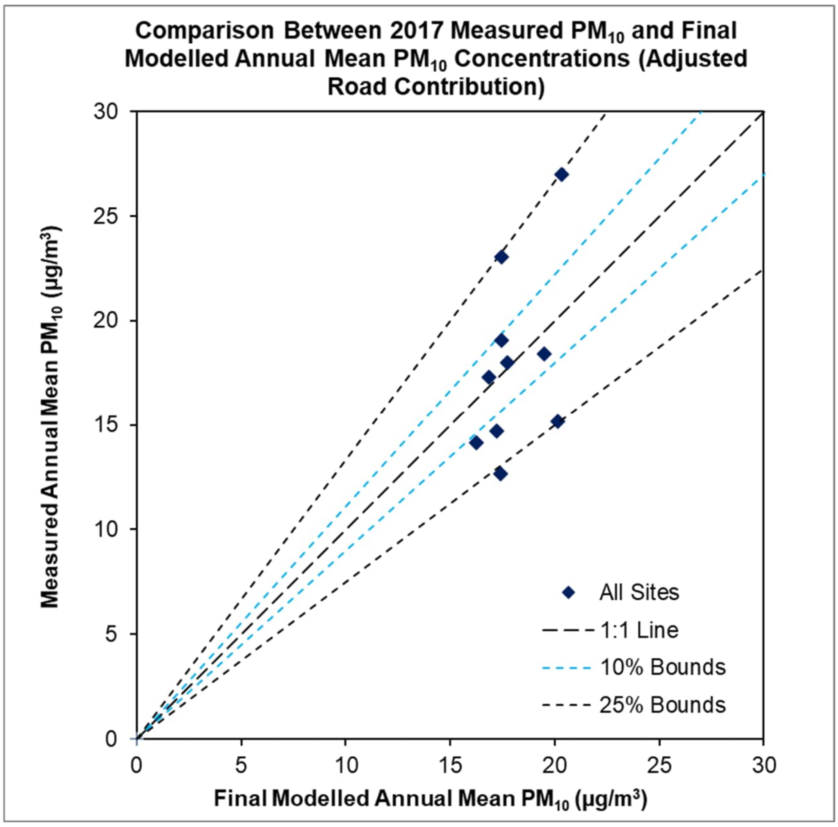
9.3.4 The statistical performance of each of the unadjusted and adjusted models is presented in **Table 6.1.17**. This shows that there is little difference between the performance of unadjusted, road- or background-adjusted total concentrations in all years. While total concentrations would be marginally higher with an adjustment applied, neither of the adjustment approaches is favourable. Applying an adjustment factor for PM_{10} would not affect the overall conclusions of the assessment; no exceedances of the annual mean objective of 40 $\mu g/m^3$ are predicted, and nor are any concentrations above 32 $\mu g/m^3$, the threshold above which exceedances of the daily mean PM_{10} objective are considered possible. Considering this, it has been judged that it would not be appropriate to adjust the PM_{10} model results.

Table 6.1.17: Statistical performance of each of the models – PM_{10}

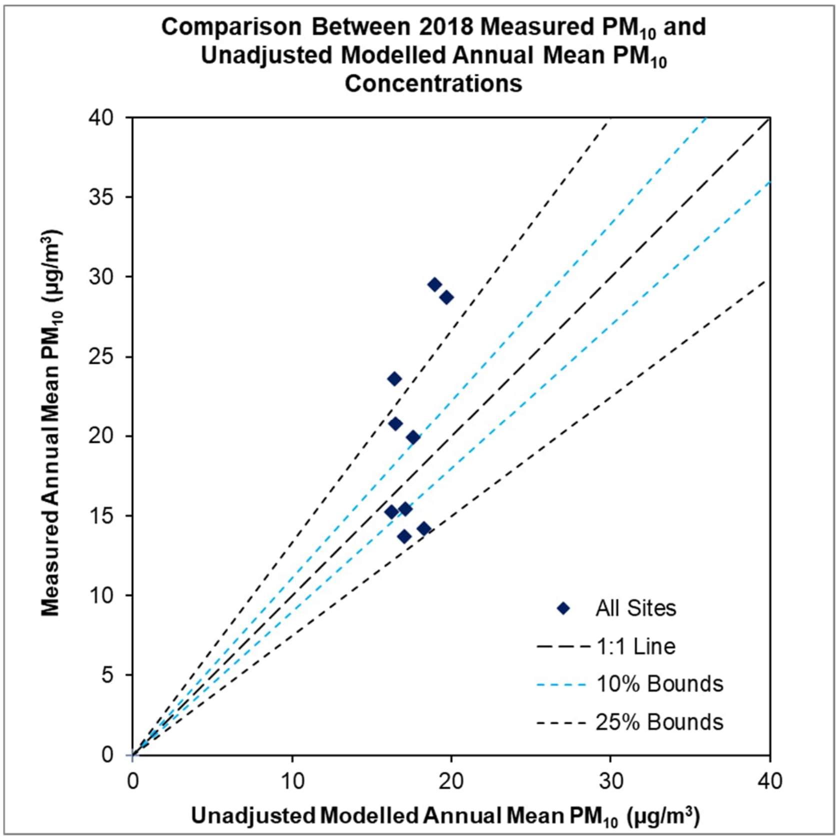
Year	Contributions Adjusted	Correlation Coefficient	Root Mean Square Error	Fractional Bias
2017	None (unadjusted)	0.50	3.95	0.06
	Road	0.45	3.72	0.00
	Backgrounds	0.52	3.78	-0.01
2018	None (unadjusted)	0.58	5.80	0.14
	Road	0.65	4.46	-0.03
	Backgrounds	0.60	5.10	-0.01
2019	None (unadjusted)	0.54	5.03	0.09
	Road	0.65	4.10	-0.04
	Backgrounds	0.55	4.70	-0.01
'Ideal' value		**1**	**0**	**0**

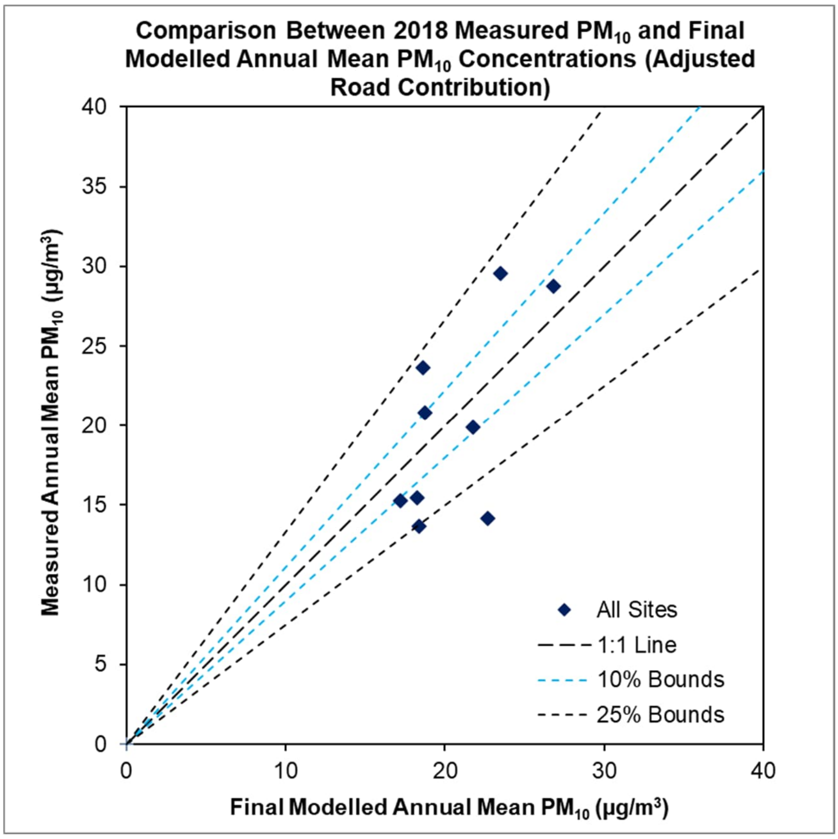
Graphic 6.1.5: 2017 Model performance – PM_{10}. Unadjusted concentrations (top plot) and final concentrations with adjusted road PM_{10} (bottom plot)



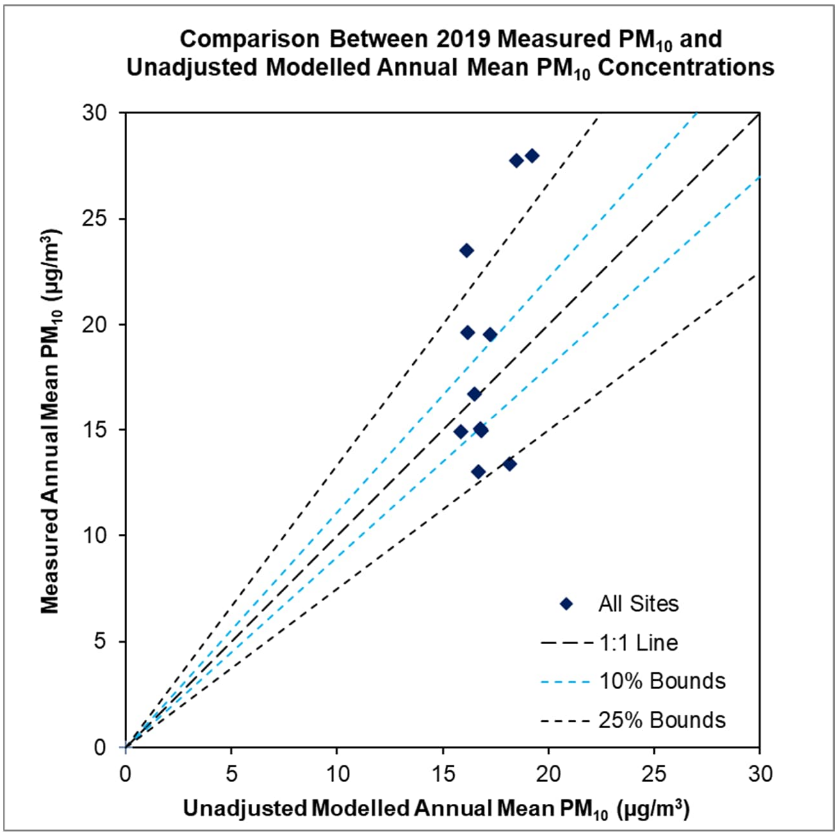


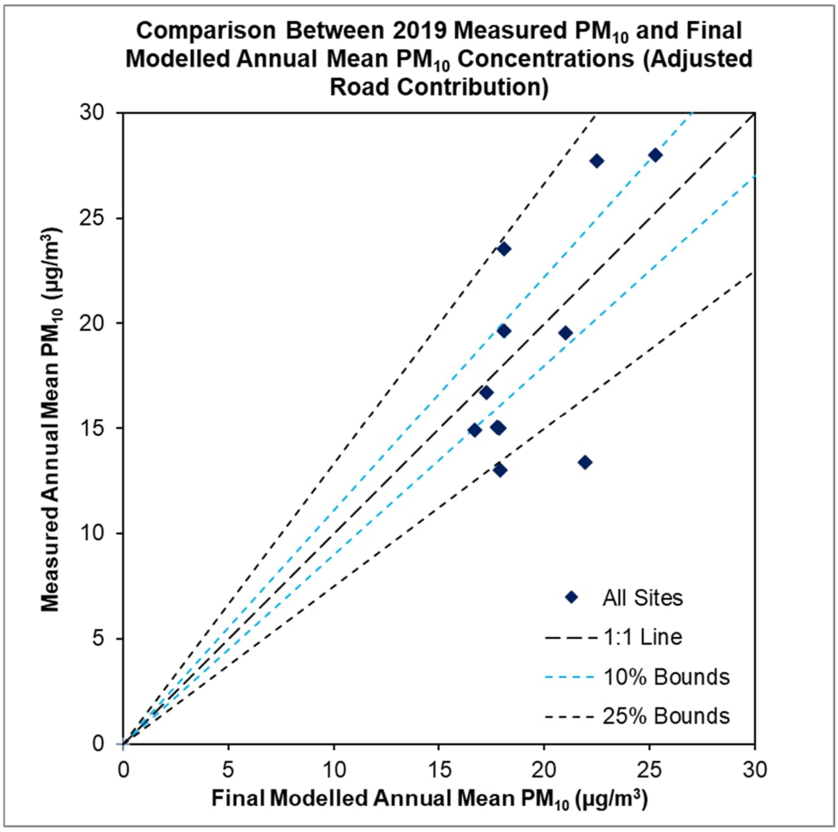
Graphic 6.1.6: 2018 Model performance – PM_{10}. Unadjusted concentrations (top plot) and final concentrations with adjusted road PM_{10} (bottom plot)



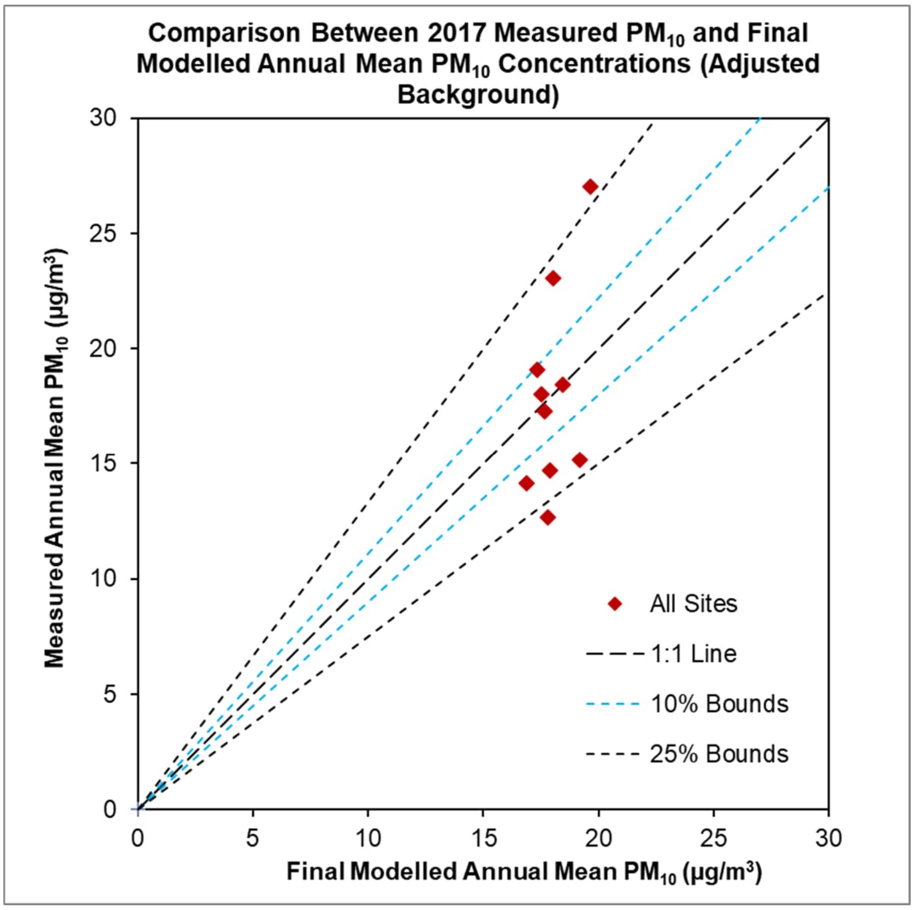


Graphic 6.1.7: 2019 Model performance – PM_{10}. Unadjusted concentrations (top plot) and final concentrations with adjusted road PM_{10} (bottom plot)

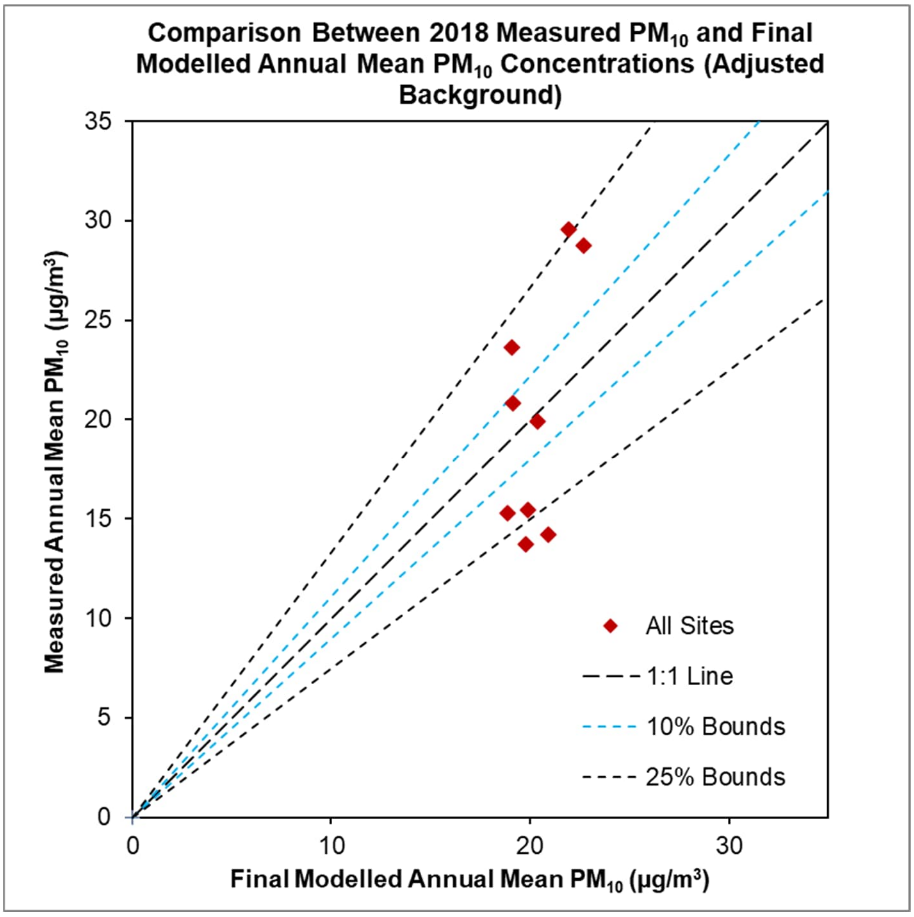




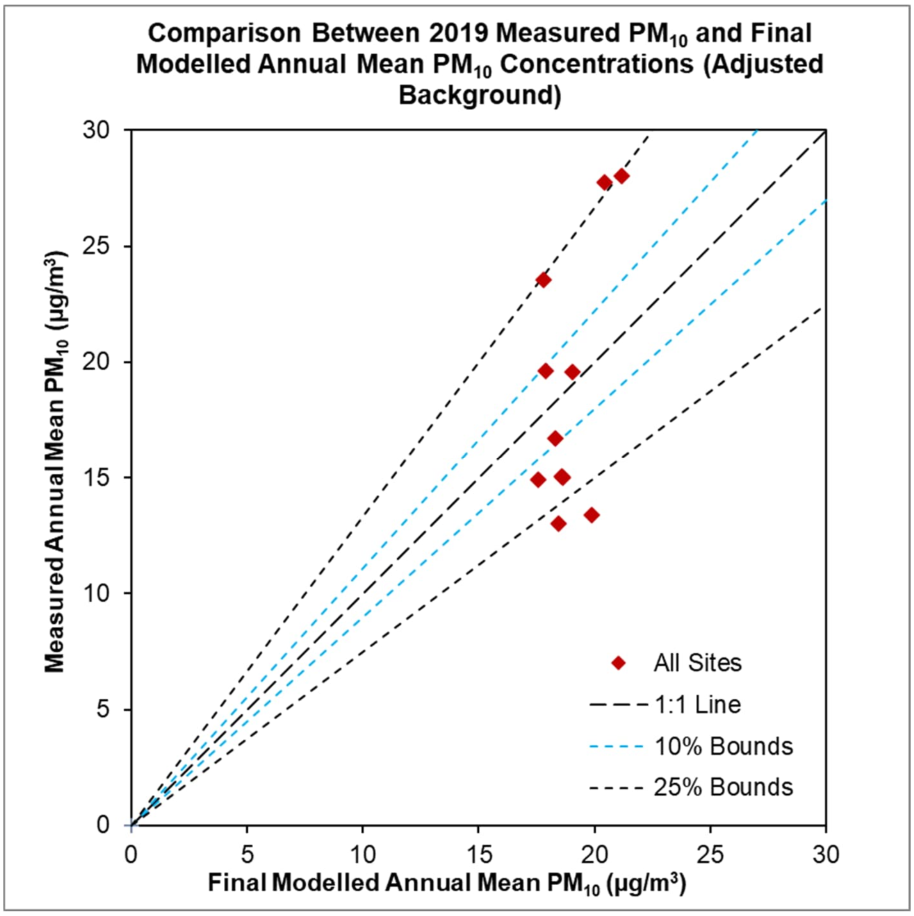
Graphic 6.1.8: 2017 Model performance – PM_{10}. Final concentrations with adjusted background PM_{10}



Graphic 6.1.9: 2018 Model performance – PM_{10}. Final concentrations with adjusted background PM_{10}



Graphic 6.1.10: 2019 Model performance – PM_{10}. Final concentrations with adjusted background PM_{10}



$PM_{2.5}$ Results

9.3.5 For $PM_{2.5}$, the same approach to determine a suitable method of model adjustment as described above for PM_{10} has been used.

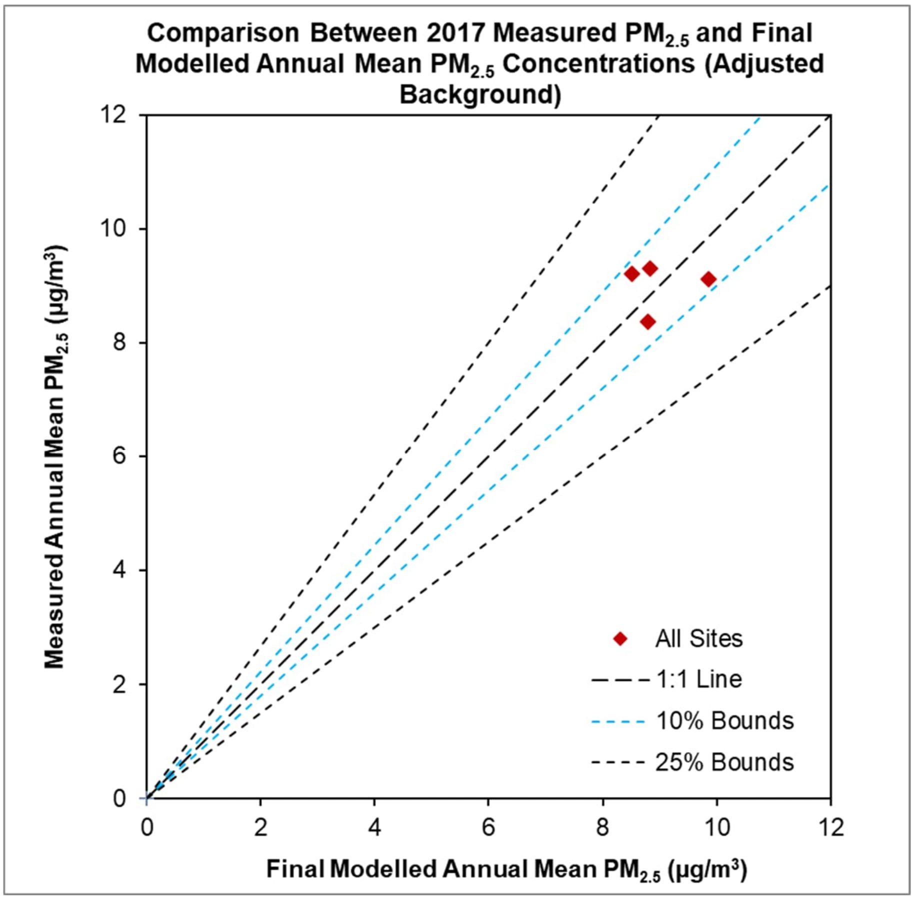
9.3.6 For all of the monitors used in the verification, the mapped background concentrations are higher than the measured concentrations. As such, the calculated road-$PM_{2.5}$ adjustment factors are all large and negative: -7.0742 for 2017, -6.3660 for 2018 and -7.6026 for 2019. It is therefore more reasonable to apply an adjustment to the background concentrations. The calculated background $PM_{2.5}$ adjustment factors are 0.7597 for 2017, 0.7810 for 2018 and 0.7774 for 2019. The statistical performance of each of the models is presented in **Table 6.1.18**, along with the performance of the unadjusted models.

Table 6.1.18: Statistical performance of each of the models – $PM_{2.5}$

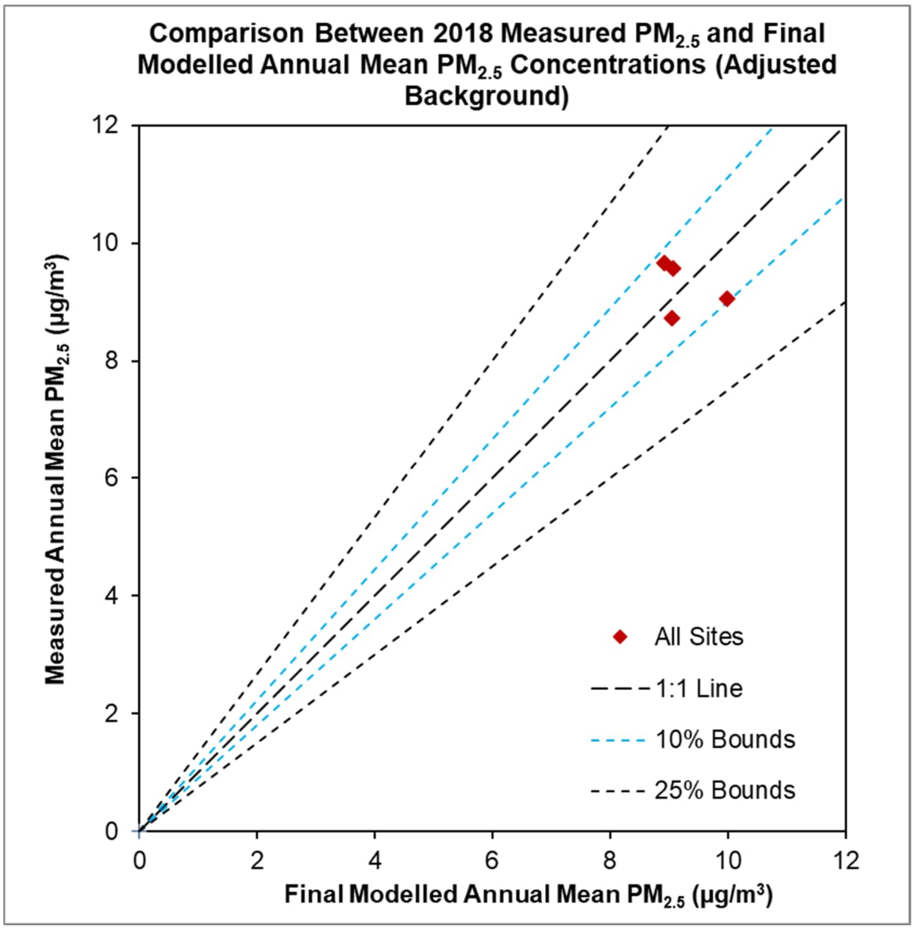
Year	Contributions Adjusted	Correlation Coefficient	Root Mean Square Error	Fractional Bias
2017	None (unadjusted)	0.09	2.71	-0.26
	Road	0.00	1.20	-0.07
	Backgrounds	0.11	0.60	0.00
2018	None (unadjusted)	-0.37	2.50	-0.23
	Road	0.38	1.03	-0.06
	Backgrounds	-0.35	0.66	0.00
2019	None (unadjusted)	-0.42	2.54	-0.23
	Road	0.52	0.91	-0.05
	Backgrounds	-0.41	0.83	0.00
'Ideal' value		**1**	**0**	**0**

9.3.7 **Graphic 6.1.11** to **Graphic 6.1.13** present graphs of the modelled annual mean $PM_{2.5}$ concentrations with adjusted backgrounds plotted against the measured concentrations at all of the appropriate monitoring sites in the study area.

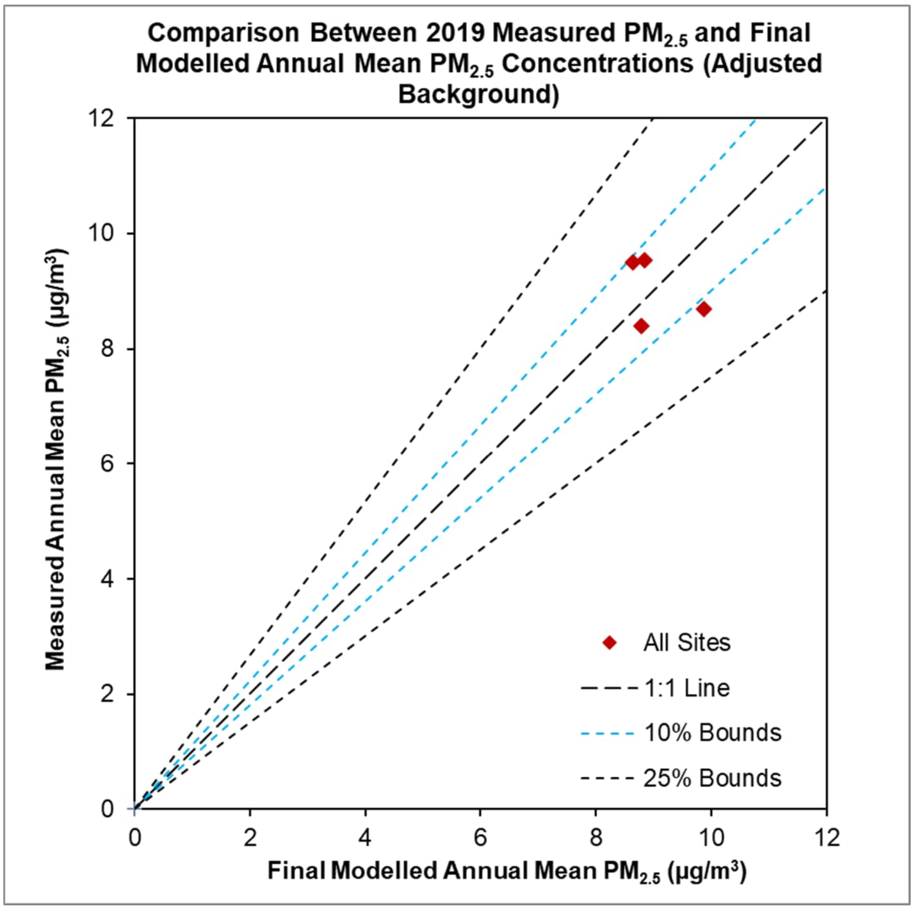
Graphic 6.1.11: 2017 Model performance – $PM_{2.5}$. Final concentrations with adjusted background $PM_{2.5}$



Graphic 6.1.12: 2018 Model performance – $PM_{2.5}$. Final concentrations with adjusted background $PM_{2.5}$



Graphic 6.1.13: 2019 Model performance – $PM_{2.5}$. Final concentrations with adjusted background $PM_{2.5}$



9.3.8