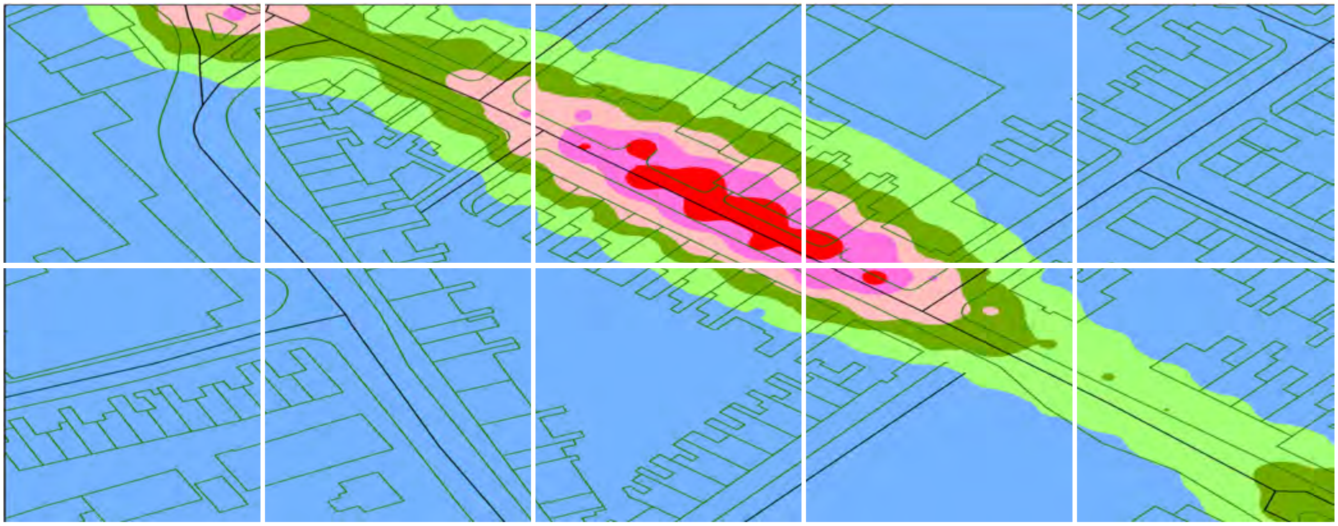

Air Quality Review and Assessment: Further Assessment

Report to Carlisle City Council
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Executive summary

The Government prepared the Air Quality Strategy for England, Scotland, Wales and Northern Ireland for consultation in August 1999. It was originally published in January 2000 (DETR, 2000). The Strategy has been revised since originally published. The latest Air Quality Strategy for England, Scotland, Wales and Northern Ireland was published on 17 July 2007.

At the centre of the Air Quality Strategy is the use of national air quality standards to enable air quality to be measured and assessed. These also provide the means by which objectives and timescales for the achievement of objectives can be set. These standards and associated specific objectives have to be achieved between 2003 and 2010.

Local authorities are required to review and assess the air quality in their areas from time to time to determine whether the air quality objectives are likely to be met. Where the likelihood of exceedences of air quality objectives has been identified in areas of significant public exposure, an Air Quality Management Area (AQMA) should have been declared, followed by a further Stage 4 review and assessment, and the formulation of an action plan to eliminate exceedences.

Carlisle City Council progressed to the Second round of review and assessment. This is undertaken in two steps. The first step is an Updating and Screening Assessment, which updates the Stage 1 and 2 review and assessment previously undertaken for all pollutants identified in the Air Quality Regulations. Where a significant risk of exceedence is identified for a pollutant it is necessary for the local authority to proceed to a Detailed Assessment, equivalent to the previous Stage 3 assessments. Where a local authority does not need to undertake a Detailed Assessment, a progress report is required instead.

Carlisle City Council continued in the Third Round by carrying out an Updating and Screening Assessment in May 2006. This assessment concluded, on the basis of monitoring evidence, that annual average nitrogen dioxide concentrations exceeding the objective were to be found in the Currock Street area of the City. An AQMA was declared for this location in December 2006. The same assessment also concluded that there was a significant risk of exceeding the air quality objective for nitrogen dioxide at relevant locations outside the proposed AQMA. These locations were: the A595 Caldewgate and Castleway; Warwick Road, A6 Botchergate and London Road; and, Charlotte Street, Victoria Viaduct and Junction Street.

A Detailed Assessment was carried out for Dalston Road, A595 Caldewgate, and A6 Botchergate on November 2007. The assessment showed that the air quality objective for nitrogen dioxide was not met in 6 locations:

- Wigton Road;
- A595 Church Street;
- A595 at the junction with Byron Street;
- A595 at the location of the Impact diffusion tube;
- Dalston Road and Junction Street;
- London Road.

The Council is then required to carry out a Further Assessment to confirm the exceedences in these areas. The further assessment is intended to ‘supplement such information as Council has in relation to the designated area in question’. The further assessment should be sufficiently detailed to determine whether an existing AQMA needs amending or revoking.

The concentrations of nitrogen dioxide in AQMAs 3, 4, 5 and 6 have not changed substantially since the Detailed Assessment was carried out in 2007. The dispersion model continues to predict areas within the declared AQMAs where concentrations exceed the air quality objective for nitrogen dioxide.

The following recommendations are suggested:

- The AQMA in Wigton Road should be retained and also should be extended to cover residential properties along Wigton Road to include odds no 1 -11 and even nos 2-24 and also the properties in Caldcotes because:
  - ➢ Diffusion tube measurements continue to show concentrations in excess of the objective;
  - ➢ Measured concentrations have increased since the AQMA was declared;
  - ➢ Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations;
  - ➢ It remains possible, within the uncertainty of the modelling, that exceedence of the objective will occur throughout most or all of the AQMA. Particularly when the effects of localised queuing at junctions with the smaller roads joining the A595 are included.

- The AQMA in Bridge Street should be retained and extended to include the properties in Finkle Street because:
  - ➢ Diffusion tube measurements continue to show concentrations in excess of the objective;
  - ➢ Measured concentrations have increased since the AQMA was declared;
  - ➢ Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations.

- The AQMA in Dalston Road should remain unchanged because:
  - ➢ Modelled and measured concentrations have changed little since the AQMA was declared;
  - ➢ Diffusion tube measurements continue to show concentrations in excess of the objective.

- The AQMA in London Road should remain unchanged because:
  - ➢ Diffusion tube measurements continue to show concentrations in excess of the objective;
  - ➢ Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations.

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Appendices

1 Introduction

This section outlines the purpose of this Further Assessment for Carlisle City Council and the scope of the assessment.

1.1 National Air Quality Strategy

The Government prepared the Air Quality Strategy for England, Scotland, Wales and Northern Ireland for consultation in August 1999. It was originally published in January 2000 (DETR, 2000). The Strategy has been revised since originally published. The latest Air Quality Strategy for England, Scotland, Wales and Northern Ireland was published on 17 July 2007.

At the centre of the Air Quality Strategy is the use of national air quality standards to enable air quality to be measured and assessed. These also provide the means by which objectives and timescales for the achievement of objectives can be set. These standards and associated specific objectives to be achieved between 2003 and 2010 are shown in Table 1-1.

Local authorities are required to review and assess the air quality in their areas from time to time to determine whether the air quality objectives are likely to be met.

1.2 Purpose of the Further Assessment

The primary objective of undertaking a review of air quality is to identify any area that are unlikely to meet national air quality objectives and ensure that air quality is considered in local authority decision-making processes.

The **first round** of air quality review and assessments is now complete and all local authorities should have completed all necessary stages. Where the likelihood of exceedences of air quality objectives has been identified in areas of significant public exposure, an air quality management area (AQMA) should have been declared, followed by a further Stage 4 review and assessment, and the formulation of an action plan to eliminate exceedences. Carlisle City Council completed the first round of review and assessments in March 2000 and it was not considered necessary to declare an AQMA in the Carlisle City Council area.

Local authorities were required to proceed to the **second round** of review and assessment in which sources of emissions to air are reassessed to identify whether the situation has changed since the first round of review and assessment, and if so, what impact this may have on predicted exceedences of the air quality objectives. Such changes might include significant traffic growth on a major road, which had not been foreseen, construction of a new industrial plant with emissions to air, or significant changes in the emissions of an existing plant.

The **second round** of review and assessment is undertaken in two steps. The first step is an Updating and Screening Assessment, which updates the Stage 1 and 2 review and assessments previously undertaken for all pollutants identified in the Air Quality Regulations. Where a significant risk of exceedence is identified outside the AQMA for a pollutant it is necessary for the local authority to proceed to a Detailed Assessment, equivalent to the previous Stage 3 assessments. Where a local authority does not need to undertake a Detailed Assessment, a Progress Report is required instead.

Carlisle City Council carried out an Updating and Screening Assessment (USA) in 2003 and concluded that Detailed Assessment was required for various road sections for nitrogen dioxide and PM_{10}. Carlisle City Council produced a Detailed Assessment for these road sections in 2005. The purpose of the Detailed Assessment was to provide an accurate assessment of the likelihood of an air quality objective being exceeded at locations with relevant exposure; along the A595 running through Caldewgate and alongside the A7 from junction 44 of the M6 and Hardwicke Circus. As a result of the Detailed Assessment, the Council declared an AQMA for the A7. Additionally, on the basis of diffusion tube

monitoring, an AQMA was declared in December 2006 to cover Currock Street at the junction with Rome Street. Further assessment of these AQMAs was completed in 2007.
The **third round** of review and assessment is now in progress. Once again, the assessment is carried out in two steps. An Updating and Screening Assessment was carried out in May 2006 by Carlisle City Council and concluded that Detailed Assessment was required for nitrogen dioxide at the following road sections:

- A595 Caldewgate and Castleway
- Warwick Road/ A6 Botchergate/ London Road
- Victoria Viaduct/ Charlotte Street/ Junction Street

The Detailed Assessment was carried out for these areas in 2007 and concluded that there are four areas in Carlisle where the assessment showed that it was likely that the air quality objective for nitrogen dioxide was not met. These four areas are:

- Wigton Road (the Post Office and Odd Nos. 69 – 95 Wigton Road; Nos. 35, 37 and 39a, and even numbers 26 – 52 Wigton Road);
- Bridge Street (the two properties on which the “Impact” diffusion tube is sited, Brewer House and Old Brewery House);
- Dalston Road (even Nos. 76 – 52 Dalston Road, Nos. 1 and 2 Newcastle Street, Nos. 1 and 2 Kendal Street, Nos. 1 – 6 Dixon Court, the public house on the corner of Dixon Court and Shaddongate, No. 44 Shaddongate, The Guard House and Linton House Shaddongate);
- London Road (No. 33 London Road).

These areas were declared AQMAs on 1st August 2008. Figures 1-1, 1-2, 1-3 and 1-4 show these declared AQMAs.

The Council is then required to carry out a Further Assessment to confirm the exceedences, equivalent to a Stage 4 review and assessment. The Council is also required to formulate an action plan to eliminate the exceedences. The further assessment is intended to ‘supplement such information as Council has in relation to the designated area in question’. The further assessment should be sufficiently detailed to determine whether an existing AQMA needs amending or revoking.

This report is a Further Assessment for Carlisle City Council as outlined in the Government’s published guidance.

Figure 1-1 Air Quality Management Area No. 3 declared for Wigton Road by Carlisle District Council

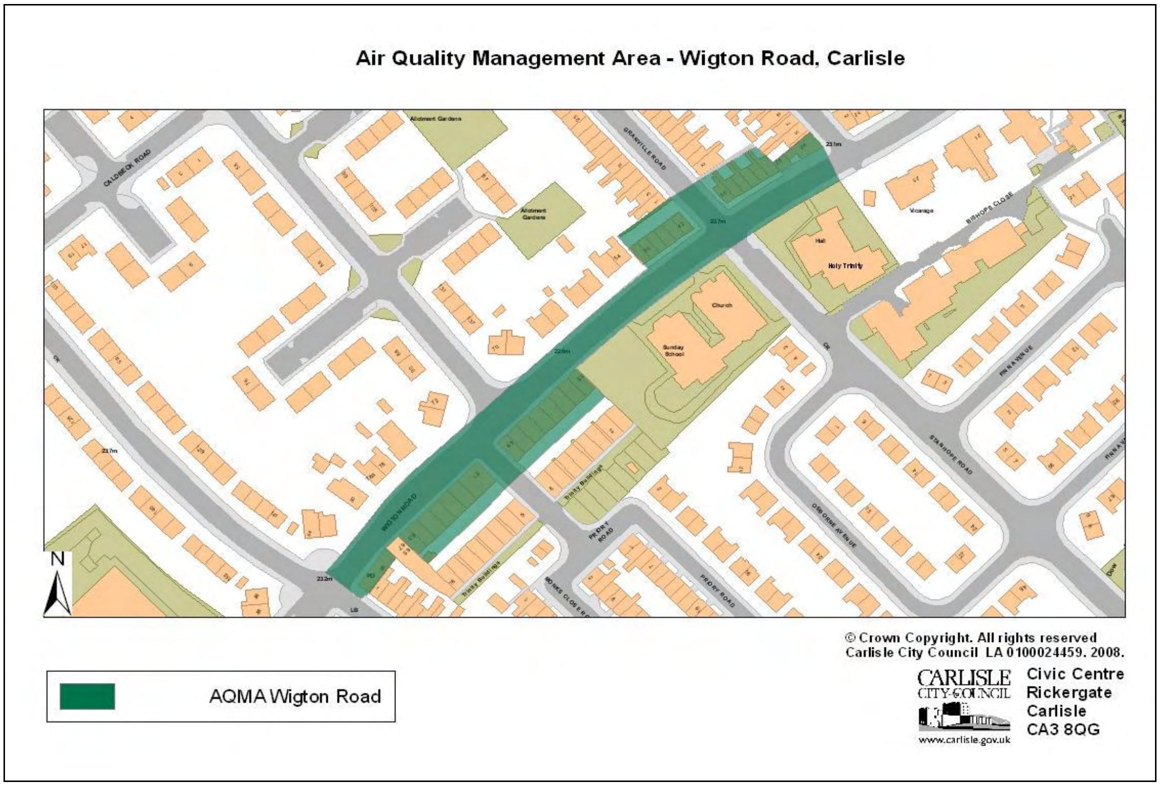


Figure 1-2 Air Quality Management Area No. 4 declared for Bridge Street by Carlisle District Council

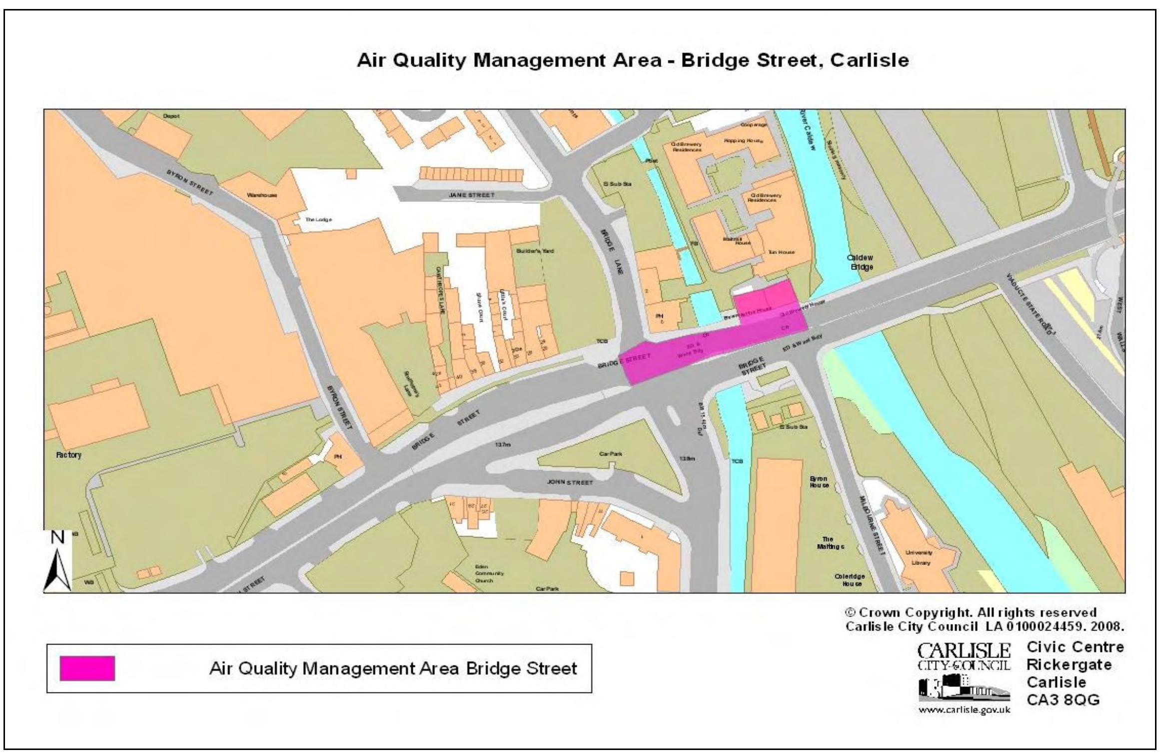


Figure 1-3 Air Quality Management Area No. 5 declared for Dalston Road by Carlisle District Council

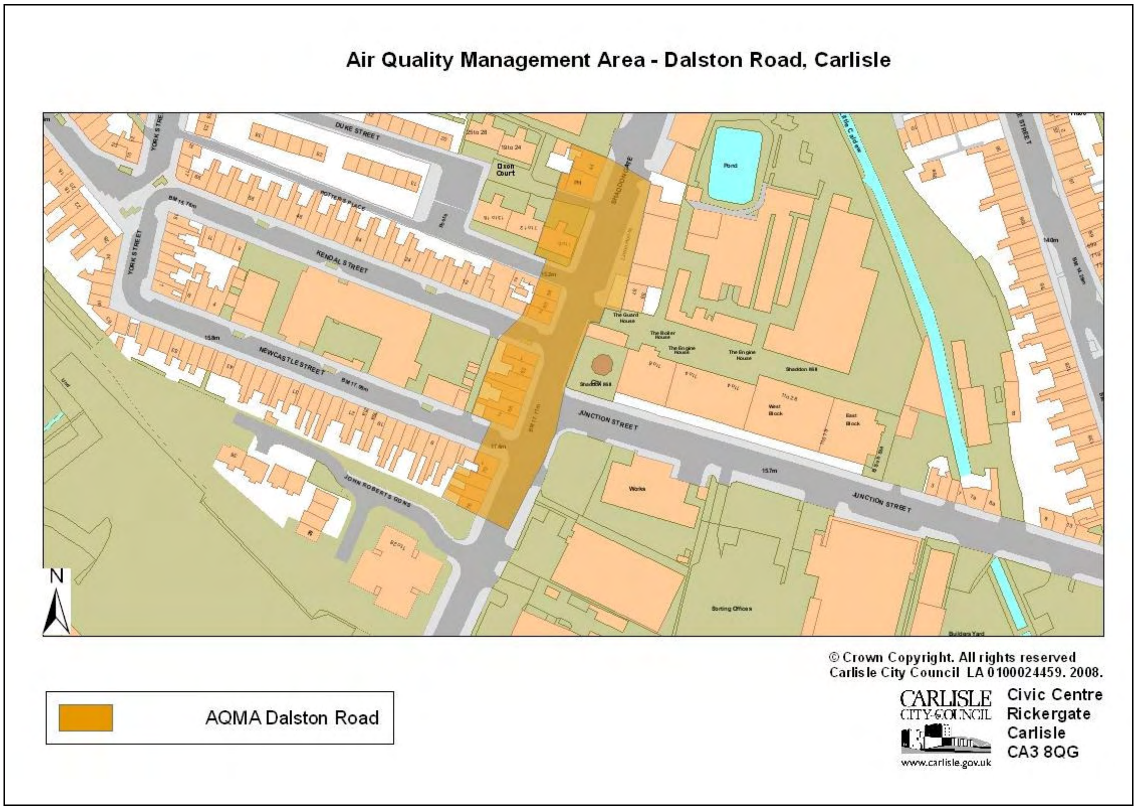
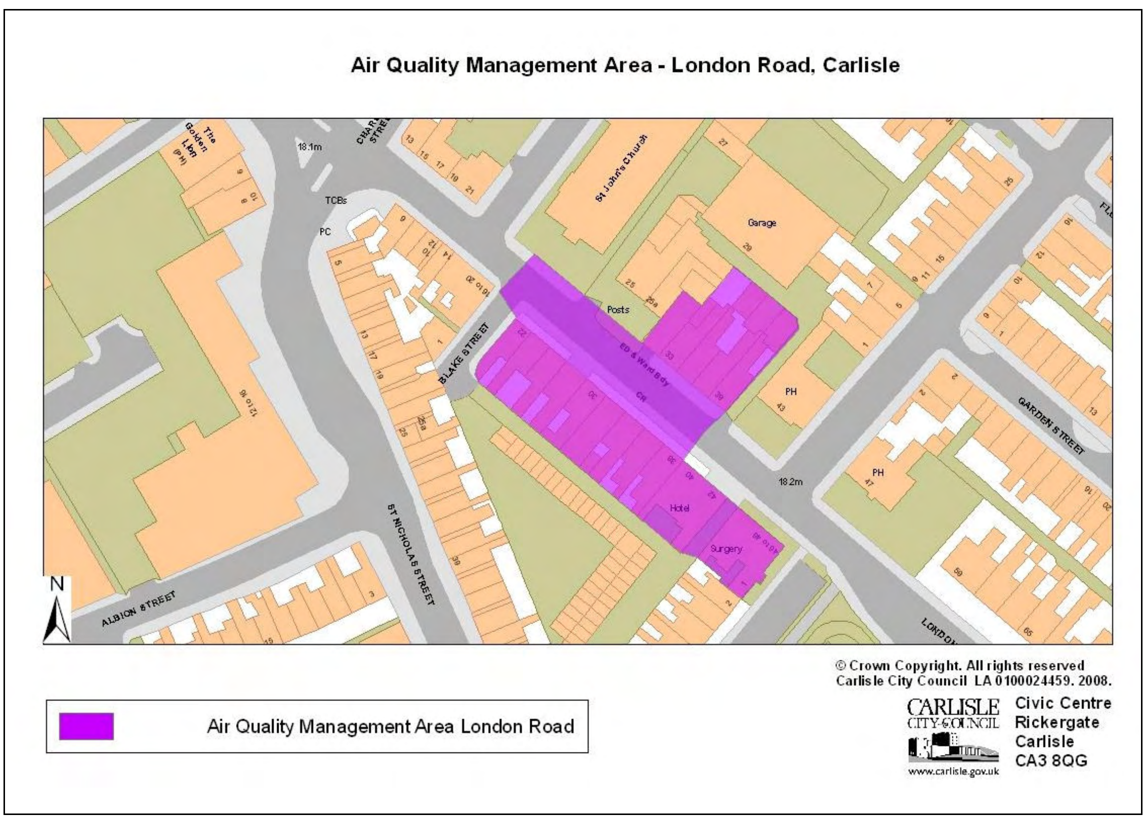


Figure 1-4 Air Quality Management Area No. 6 declared for London Road by Carlisle District Council



1.3 Overview of the approach taken

The general approach taken to this Further Assessment was to:

- Collect and interpret additional data to support the assessment, including detailed traffic flow data around the AQMAs;
- Consider recent continuous monitoring and diffusion tube measurements;
- Use monitoring data from the continuous monitors located beside the A595 at Paddy's Market to assess the ambient concentrations produced by the road traffic and to calibrate the output of modelling studies;
- Model the concentrations of nitrogen dioxide (NO_2) around the AQMAs, concentrating on the locations (receptors) where people might be exposed over the relevant averaging times of the air quality objectives;
- Present the concentrations as contour plots and assess the uncertainty in the predicted concentrations;
- Consider whether the authority should amend or revoke the Air Quality Management Areas and provide recommendations on the scope and extent of any revisions.

1.4 Relevant DEFRA documentation used

This report takes into account the guidance in LAQM.TG(03), published January 2003, the guidance in LAQM TG(09) published in February 2009, and further advice presented as Frequently Asked Questions on the Review and Assessment Helpdesk internet site.

1.5 Pollutants considered in this report

Table 1-1 lists the pollutants included in the Air Quality Regulations for the purposes of Review and Assessment. Nitrogen dioxide is considered in this report.

Table 1-1: Objectives included in the Air Quality Regulations 2000 and (Amendment) Regulations 2002 for the purpose of Local Air Quality Management

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Benzene All authorities	16.25 $\mu g\ m^{-3}$	Running annual mean	31.12.2003
Authorities in England and Wales only	5.00 $\mu g\ m^{-3}$	Annual mean	31.12.2010
Authorities in Scotland and Northern Ireland only	3.25 $\mu g\ m^{-3}$	Running annual mean	31.12.2010
1,3-Butadiene	2.25 $\mu g\ m^{-3}$	Running annual mean	31.12.2003
Carbon monoxide Authorities in England, Wales & N. Ireland only[a]	10.0 mg m^{-3}	Maximum daily running 8-hour mean	31.12.2003
Authorities in Scotland only	10.0 mg m^{-3}	Running 8-hour mean	31.12.2003
Lead	0.5 $\mu g\ m^{-3}$ 0.25 $\mu g\ m^{-3}$	Annual mean Annual mean	31.12.2004 31.12.2008
Nitrogen dioxide[b]	200 $\mu g\ m^{-3}$ not to be exceeded more than 18 times a year 40 $\mu g\ m^{-3}$	1-hour mean Annual mean	31.12.2005 31.12.2005
Particles (PM_{10}) (gravimetric)[c] All authorities	50 $\mu g\ m^{-3}$, not to be exceeded more than 35 times a year 40 $\mu g\ m^{-3}$	24-hour mean Annual mean	31.12.2004 31.12.2004
Authorities in Scotland only[b]	50 $\mu g\ m^{-3}$, not to be exceeded more than 7 times a year 18 $\mu g\ m^{-3}$	24-hour mean Annual mean	31.12.2010 31.12.2010
Sulphur dioxide	350 $\mu g\ m^{-3}$, not to be exceeded more than 24 times a year 125 $\mu g\ m^{-3}$, not to be exceeded more than 3 times a year 266 $\mu g\ m^{-3}$, not to be exceeded more than 35 times a year	1-hour mean 24-hour mean 15-minute mean	31.12.2004 31.12.2004 31.12.2005

a. Measured using the European gravimetric transfer sampler or equivalent
b. These 2010 air quality objective for PM10 apply in Scotland only, as set out in the Air Quality (Scotland) Amendment Regulations 2002

1.6 Locations that the review and assessment must concentrate on

For the purpose of review and assessment, the authority should focus their work on locations where members of the public are likely to be exposed over the averaging period of the objective. Table 1-2 summarises the locations where the objectives should and should not apply.

Table 1-2: Typical locations where the objectives should and should not apply

Averaging Period	Pollutants	Objectives *should* apply at …	Objectives should *not* generally apply at …
Annual mean	1,3 Butadiene Benzene Lead Nitrogen dioxide Particulate Matter (PM_{10})	All background locations where members of the public might be regularly exposed.	Building facades of offices or other places of work where members of the public do not have regular access.
		Building facades of residential properties, schools, hospitals, libraries etc.	Gardens of residential properties.
			Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term
24 hour mean and 8-hour mean	Carbon monoxide Particulate Matter (PM_{10}) Sulphur dioxide	All locations where the annual mean objective would apply.	Kerbside sites (as opposed to locations at the building facade), or any other location where public exposure is expected to be short term.
		Gardens of residential properties.	
1 hour mean	Nitrogen dioxide Sulphur dioxide	All locations where the annual mean and 24 and 8-hour mean objectives apply.	Kerbside sites where the public would not be expected to have regular access.
		Kerbside sites (e.g. pavements of busy shopping streets).	
		Those parts of car parks and railway stations etc. which are not fully enclosed.	
		Any outdoor locations to which the public might reasonably be expected to have access.	
15 minute mean	Sulphur dioxide	All locations where members of the public might reasonably be exposed for a period of 15 minutes or longer.	

It is unnecessary to consider exceedences of the objectives at any location where public exposure over the relevant averaging period would be unrealistic. Locations should also represent non-occupational exposure.

2 Information used to support this assessment

This section lists the key information used in this review and assessment.

2.1 Review and assessment reports

This report draws on information presented in previous Review and Assessment reports:

- Three Stage First round of Review and Assessment, 2000;
- Updating and Screening Assessment, 2003;
- Detailed Assessment, 2005;
- Updating and Screening Assessment, 2006;
- Progress Report, 2007;
- Further Assessment, 2007;
- Detailed Assessment, 2007;
- Progress Report 2008.

2.2 Maps and distances of receptors from roads

Carlisle City Council provided electronic OS LandLine™ data, which were used in the Geographical Information System (GIS) used in this assessment. The maps were used to provide details of the location of road centrelines and road widths. Individual buildings or groups of buildings (receptors) were also identified. The distances of these receptors from the road were accurately determined from the maps.

2.3 Road traffic data

Carlisle City Council provided traffic data for the roads and junctions assessed. The data included:

- Annually Averaged Daily Traffic flows for vehicles
- Queue surveys at junctions;
- Average traffic speed

The data are summarised in Appendix 1.

The base year for the traffic flows was 2007. Traffic flows were projected for 2010 using growth factors calculated from the National Traffic Model regional forecast for the Northwest and correction factors provided by the Tempro 5.4 database. The overall growth factors applied are shown in Table 2-1.

Table 2-1:Traffic growth factors applied

Year	NTM factor	Tempro factor		Overall growth factor
		GB	Carlisle	
2007	105	1	1	1
2010	109	1.042	1.0165	1.01

Vehicle speeds were generally assumed to approach 50 kph in urban areas on straight sections of the roads. Reduced speeds in the range 5-50 kph were applied near to junctions.

2.4 Ambient monitoring

The assessment has considered continuous automatic monitoring data from two continuous monitoring stations in Carlisle. Pollutant concentrations have been monitored at a roadside site at Paddy's Market (OS 339467, 555974) located adjacent to the A595 in Caldewgate since 2005. The Paddy's Market site was affiliated to the Automatic Urban and Rural Network (AURN) in February 2008, previously the site formed a part of a local network. The pollutants measured include oxides of nitrogen, particulate matter, PM_{10} and benzene. The Stanwix Bank site is also a roadside site located adjacent to the A7 (OS 340018, 557044), within AQMA No 1. Stanwix Bank site has been in operation since the beginning of 2007 and measures nitrogen dioxide.

Nitrogen dioxide concentrations are measured by ozone chemiluminescence. The Paddy's Market site was operated and maintained by Casella Cre Air until February 2008 since then the site has been affiliated to the Automatic Urban and Rural Network (AURN) and the network quality assurance and control procedures are implemented.

The Stanwix Bank site is operated and maintained by Casella CRE Air. Casella CRE Air has a defined quality system, which forms part of the UKAS accreditation that the laboratory holds.

Carlisle City Council operates a network of nitrogen dioxide diffusion tubes across the District. The diffusion tubes are prepared with 10% triethanolamine (TEA) in water by Casella CRE Air. The locations of all the diffusion tubes are listed in Table 2-2. Twenty-five of the diffusion tubes are located within or close the areas to be assessed in this Further Assessment. These are marked in bold in Table 2-2 and shown in Figure 2-1. In addition, diffusion tubes are co-located in triplicate at the Paddy's Market monitoring site. The location of the Paddy's Market monitoring site shown in Figure 2-1 also shows the location of the co-located tubes (E6).

Figure 2-1: Monitoring sites locations in the investigated areas

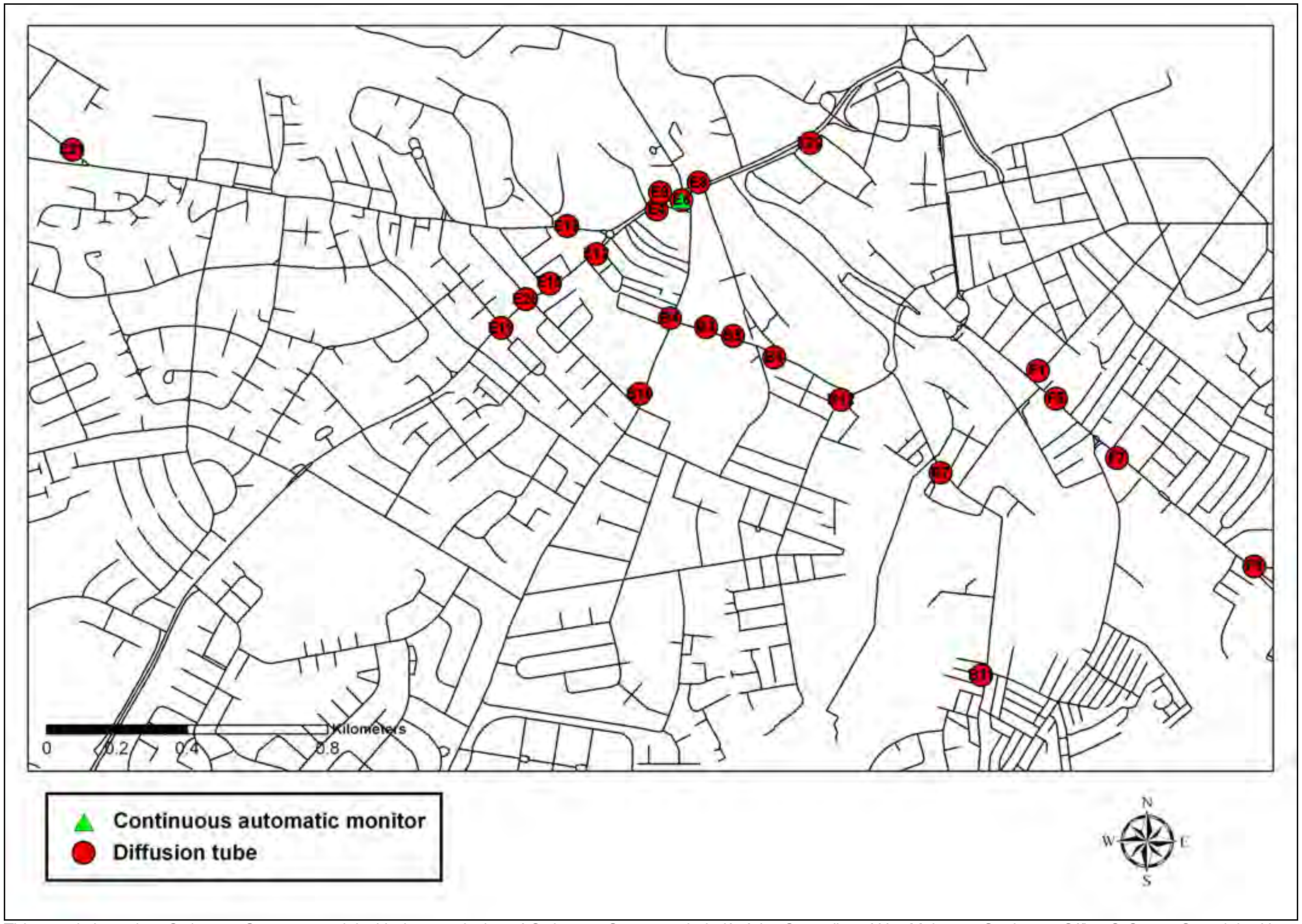


Table 2-2: Diffusion tube locations in Carlisle City Council

Tube No	Location	Northing, m	Easting, m
AREA A -A7			
A1	45 SCOTLAND ROAD	339995	557188
A10	STANWIX BANK	340008	556842
A12	14 ETTERBY ST	339935	557125
A5	37 KINGSTOWN ROAD	339758	558059
A7	282 KINGSTOWN ROAD	339526	559285
A9	BRAMPTON ROAD	340028	556833
AREA B CURROCK ST-DENTON ST			
B10	**24 DALSTON ROAD**	**339347**	**555422**
B11	**6 CURROCK ROAD**	**340321**	**554621**
B12	**DENTON/CHAR**	**339921**	**555406**
B3	**SHADDONMILL**	**339537**	**555613**
B4	**DALSTON ROAD**	**339434**	**555638**
B5	**8 JUNCTION ST**	**339613**	**555587**
B6	**41 CHARLOTTE ST**	**339731**	**555526**
B7	**12 CURROCK STREET**	**340205**	**555198**
AREA C CITY CENTRE			
C1	LOWTHER STREET	340216	556131
C2	TIC	340069	555955
C3	DEVONSHIRE STREET	340218	555768
C4	BAR SOLO	340286	555622
C5	GRIFFEN	340298	555589
AREA D A69 WARWICK ROAD			
D1	VICTORIA PLACE	341106	555954
D10	368 WARWICK ROAD	342044	555907
D11	CARTEF	340426	556040
D12	POST OFFICE	340307	555718
D3	160 WARWICK ROAD	341153	555896
D5	215 WARWICK ROAD	341310	555914
D7	282 WARWICK ROAD	341593	555893
D9	251 WARWICK ROAD	341426	555910
D13	171 WARWICK ROAD		
AREA E CALDEWGATE-WIGTON ROAD-NEWTOWN ROAD			
E22	**FINKLE STREET**	**339834**	**556137**
E12	**3 WIGTON ROAD**	**339225**	**555821**
E15	**WIGTON ROAD 22**	**339091**	**555736**
E16	**JOVIAL SAILOR**	**339141**	**555900**
E17	**NEWTOWN RD**	**338562**	**5559621**
E19	**49 WIGTON ROAD**	**338953**	**555610**
E20	**44 WIGTON ROAD**	**339023**	**555692**
E4	**JOHN STREET**	**339396**	**555947**
E6	**AIR MONITOR 1**	**339467**	**555974**
E6	**AIR MONITOR 2**	**339467**	**555974**
E6	**AIR MONITOR 3**	**339467**	**555974**
E8	**IMPACT**	**339516**	**556024**
E9	**KC**	**339405**	**555996**
E21	**BURGH ROAD**	**337730**	**556118**

Tube No	Location	Northing, m	Easting, m
	AREA F BOTCHERGATE / LONDON ROAD		
F1	**3 TAIT STREET**	**340482**	**555489**
F10	**155 BOTCHERGATE**	**349597**	**555351**
F5	**STANLEY HALL**	**340534**	**555409**
F7	**24 LONDON ROAD**	**340708**	**555240**
F9	**129 LONDON ROAD**	**341099**	**554931**
	AREA H TOWNS		
H1	BRAMPTON	352824	561039
H3	LONGTOWN	338052	568478
H4	WARWICK BRIDGE	347411	556881
H5	AIRPORT		

Sites in **bold** *are situated in the areas of study*

2.5 Emission factors

The vehicle emission factors used for national mapping were revised in 2001 by DEFRA and the devolved administrations. The most recent emission factors have been used in this Further Assessment.

Emissions from stationary traffic in queues and at bus stops were estimated using the emission factor for vehicles moving at 5 km h^{-1} and taking account of the proportion of time stationary vehicles are present and the length of road over which emissions take place. The average length of a queuing vehicle was assumed to be 5 m.

3 Further Assessment for Nitrogen Dioxide

3.1 The national perspective

The principal source of NO_x emissions is road transport, which accounted for about 32% of total UK emissions in 2006. Major roads carrying large volumes of high-speed traffic (such as motorways and other primary routes) are a predominant source, as are conurbations and city centres with congested traffic. Within most urban areas, the contribution of road transport to local emissions will be much greater than for the national picture.

Meeting the annual mean objective is considerably more demanding than achieving the 1-hour objective. National studies have indicated that the annual mean objective is likely to be achieved at all urban background locations outside of London by 2005, but that the objective may be exceeded more widely at roadside sites throughout the UK in close proximity to busy road links. Projections for 2010 indicate that the EU limit value may still be exceeded at urban background sites in London, and at roadside locations in other cities.

3.2 Standards and objectives for nitrogen dioxide

The Government and the Devolved Administrations have adopted two Air Quality Objectives for nitrogen dioxide, as an annual mean concentration of 40µg m^{-3}, and a 1-hour mean concentration of 200µg m^{-3} not to be exceeded more than 18 times per year. The objectives are to be achieved by the end of 2005 and in subsequent years.

3.3 Background concentrations for nitrogen dioxide

The estimated annual average background nitrogen dioxide (NO_2) concentration provided by the UK background maps for 2007 was 7.4µg m^{-3} averaged across Carlisle District with a maximum concentration of 20.7 µg m^{-3}.

The estimated annual average background oxides of nitrogen (NO_x) concentration provided by the UK background maps for 2007 was 8.6 µg m^{-3} averaged across Carlisle District with a maximum concentration of 27.7 µg m^{-3}.

3.4 Assessment of monitoring data

Table 3-1 summarises the measurements of nitrogen dioxide concentrations at continuous monitoring stations in Carlisle for the relevant period.

Table 3-1: Continuous monitoring data

Site	Period	NO_x, Concentration, µg m^{-3}	NO_2 Concentration, µg m^{-3}	Data capture, %
		Period average	Period average	
Paddy's Market	2007	168.4	31.4	96.2
Stanwix Bank	2007	173.0	41.4	94.0

The 2007 annual mean nitrogen dioxide concentration at the Paddy's Market site was markedly less than the annual mean objective of 40 µg m^{-3}. However, the nitrogen dioxide concentrations measured at the Stanwix Bank site in 2007 exceeded the objective.

Table 3-2: Nitrogen dioxide concentrations at diffusion tube sites of relevance to this study factor

Tube No	Site address	Nitrogen dioxide concentration, ug m^{-3}					
		Unadjusted 2007 Annual Mean	Corrected with local bias adjustment factor		Corrected with UK-wide bias		Unadjusted 2008 annual Mean
			2007 Annual Mean	Scaled up to 2010	2007 Annual Mean	Scaled up to 2010	
AREA B CURROCK ST-DENTON ST							
B10	24 DALSTON ROAD	27.0	20.9	18.4	24.1	21.2	-
B11	6 CURROCK ROAD	23.8	18.4	16.2	21.2	18.7	-
B12	DENTON/CHAR	51.8	**40.0**	35.2	**46.1**	40.6	46.8
B3	SHADDONMILL	32.3	25.0	22.0	28.8	25.3	29.6
B4	DALSTON ROAD	58.0	**44.8**	39.4	**51.7**	45.5	58.6
B5	8 JUNCTION ST	38.5	29.8	26.2	34.3	30.2	36.0
B6	41 CHARLOTTE ST	43.0	33.2	29.2	38.3	33.7	38.1
B7	12 CURROCK STREET	47.0	36.3	31.9	**41.9**	36.9	47.7
Average for area B			31.0		35.8		
AREA E CALDEWGATE-WIGTON ROAD-NEWTOWN ROAD							
E22	FINKLE STREET	47.9	37.0	32.6	**42.7**	37.6	43.8
E12	3 WIGTON ROAD	55.3	42.8	37.7	**49.3**	43.4	55.9
E15	WIGTON ROAD 22	50.9	39.4	34.7	**45.4**	40.0	50.2
E16	JOVIAL SAILOR	47.5	36.7	32.3	**42.3**	37.2	52.3
E17	NEWTOWN RD	27.6	21.3	18.7	24.6	21.6	-
E19	49 WIGTON ROAD	58.0	44.8	39.4	**51.7**	45.5	54.0
E20	44 WIGTON ROAD	50.4	39.0	34.3	**44.9**	39.5	48.7
E4	JOHN STREET	47.4	36.7	32.3	**42.2**	37.1	51.4
E6	AIR MONITOR 1,2,3	39.4	30.4	26.8	35.0	30.8	38.6
E8	IMPACT	71.4	55.2	48.6	**63.6**	56.0	65.0
E9	KC	38.6	29.8	26.2	34.4	30.3	40.9
E21	BURGH ROAD	25.1	19.4	17.1	22.3	19.6	17.5
Average for area E			35.2		40.6		
AREA F BOTCHERGATE / LONDON ROAD							
F1	3 TAIT STREET	37.9	29.3	25.8	33.8	29.7	38.5
F10	155 BOTCHERGATE	43.4	33.5	29.5	38.6	34.0	40.3
F5	STANLEY HALL	37.3	28.8	25.3	33.2	29.2	44.6
F7	24 LONDON ROAD	46.5	36.0	31.7	**41.5**	36.5	46.4
F9	129 LONDON ROAD	41.3	32.0	28.2	36.8	32.4	36.8
Average for area F			31.9		36.8		

Nitrogen dioxide diffusion tube measurements were taken at 25 locations in the assessed areas over the period January 2007 to January 2008 including the co-location study with continuous monitoring station at the Paddy's Market. The assessed areas are: area B which includes Dalston Road and Junction Street, area E covering Wigton Road, Bridge Street and Finkle Street, and area F which covers London Road.

The laboratory bias correction factor was calculated using the “diffusion tube” spreadsheet tool and the co-location study at Paddy’s Market site. This “diffusion tube” spreadsheet tool is published by Air Quality Consultants Ltd on behalf of Defra, the Welsh Assembly Government, the Scottish Executive and the Department of the Environment Northern Ireland and it is available on the UWE website (2008).

A bias adjustment factor of 0.90 was calculated using – the “diffusion tube” - spreadsheet tool, which used 11 studies for the method 10% TEA in water for 2007 (Appendix 2). A bias adjustment factor of 0.77 was calculated from the diffusion tubes co-located at the Paddy’s Market site. This was done by using the AEA “Spreadsheet for calculating Precision, Accuracy and Bias Adjustment factors of Diffusion Tubes’’. The mean coefficient of variance for the collocated diffusion tubes at the Paddy’s Market site was 17% (five months diffusion tube data show poor precision - Appendix 2). The UWE UK-wide adjustment factor will be used for this report and subsequent references to diffusion tube measurements assume that the measurements have been adjusted using that factor.

Table 3-2 shows the adjusted diffusion tube measurements at sites within the areas considered for this study. The average adjusted annual mean concentration for diffusion tubes in area B, was 35.8 µg m^{-3} for 2007. However, only the diffusion tube B4 is located on Dalston Road in the area directly investigated and it measured annual average concentration of 51.7 µg m^{-3} in 2007. The concentration at the location of diffusion tube B12 was 46.1µg m^{-3}, but there is no public exposure during the relevant averaging period of time at this location.

In the area E the average adjusted annual mean concentration was 40.6 µg m^{-3} in 2007. There are two areas in area E to be investigated in this report. The first study area consists of 5 diffusion tubes located in Wigton Road: E12, E15, E19 and E20 and diffusion tube E16 located at Jovial Sailor in Caldcotes. All of the five diffusion tubes measured nitrogen dioxide concentration above the objective with the highest concentration of 51.7 µg m^{-3} at the location of the diffusion tube E19. The second study area investigated is northbound of the A595 from the junction with Shaddongate. This area includes diffusion tube E8 and E22 and the continuous monitoring station. These measured annual average concentration of 63.6 µg m^{-3}, 42.7µg m^{-3} and 31.4µg m^{-3} respectively.

The average annual mean concentration measured in area F was 36.8 µg m^{-3}. However only the F7 diffusion tube is situated in the investigated area and it measured 41.5 µg m^{-3} in 2007.

Table 3-2 also presents the 2008 unadjusted diffusion tube data for the areas assessed, the bias adjustment factor for 2008 measurements was not available at the time of completing this assessment. The 2008 raw nitrogen dioxide data show many exceedances of the air quality objective.

In order to predict 2010 concentrations, the “Year Adjustment Calculator (v2.2a)” was used from the UK National Air Quality Information Archive website (2008). The factor of 0.88 was applied to estimate annual average concentrations in 2010 from 2007 data.

3.5 Overview of the air quality modelling

3.5.1 Summary of the models used

The air quality impact from roads has been assessed using our proprietary urban model (LADS Urban). There are two parts to this model:

- The *Local Area Dispersion System (LADS) model*. This model calculates background concentrations of oxides of nitrogen on a 1 km x 1 km grid. The estimates of emissions of oxides of nitrogen for each 1 km x 1 km area grid square were obtained from the 2006 National Atmospheric Emissions Inventory.
- The *DISP model*. This model is a tool for calculating atmospheric dispersion using a 10 m x 10 m x 3 m volume-source kernel derived from ADMS4 to represent elements of the road. The volume source depth takes account of the initial mixing caused by the turbulence induced by the vehicles. Estimates of emissions from vehicles have been calculated using the latest (and finalised for this round of Review and Assessment) vehicle emission factors.

Concentrations of nitrogen dioxide from road traffic emissions were modelled with a resolution of 10 m close to the road as recommended in the Technical Guidance LAQM.TG(03).

Particular attention was paid to the avoidance of "double counting" of the contribution from major roads in the modelled areas. Thus the emissions from sections of roads modelled using DISP were removed from the LADS inventory.

Hourly sequential meteorological data for 2006 for Carlisle Airport, approximately 10 km east northeast of Carlisle was used. The meteorological data provided information on wind speed and direction and the extent of cloud cover for each hour of the year. A surface roughness of 1 m was used in the modelling to represent the urban conditions corresponding to the most exposed sites. A limit for the Monin-Obukhov length of 30 m was applied to take into account the urban heat effect in the town. An intelligent gridding system was used with receptors at 10 m intervals on a rectangular grid within 150 m of the modelled roads and more widely spaced receptors elsewhere.

The netcen primary oxides of nitrogen model (AQEG 2006) was used to calculate nitrogen dioxide concentrations from the oxides of nitrogen concentrations predicted by LADS Urban. The model takes into account the background ozone, nitrogen dioxide and nitric oxides concentrations, the proportion of the oxides of nitrogen released from vehicles as nitrogen dioxide and the exposure of the site to sunlight. The model was used first to analyse the diffusion tubes monitoring data to estimate the proportion of oxides of nitrogen released as nitrogen dioxide. The analysis took account of background measurements of ozone, oxides of nitrogen and nitrogen dioxide concentrations at the diffusion tubes locations in the area of interest.

A rural background oxides of nitrogen concentration of 8 $\mu g\ m^{-3}$ for 2007, based on measurements from the High Muffles Automatic Urban and Rural Network site, was added to the modelled concentrations.

3.5.2 Validation and verification of the model

In simple terms, model validation is where the model is tested at a range of locations and is judged suitable to use for a given application. The modelling approach used in this assessment has been validated, and used in numerous AEA air quality review and assessments.

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations. Table 3-3 and Figure 3-1 compare modelled predictions using LADS Urban nitrogen dioxide concentrations with measured values from the continuous monitoring site at Paddy's Market.

The predicted modelled concentrations gave a good agreement with the measured nitrogen dioxide concentrations at Paddy's Market automatic station location.

Table 3-3: Comparison of modelled and measured concentrations, 2007

Site	Nitrogen dioxide concentration, μg m^{-3}		% Difference
	Modelled	Measured	
Paddy's Market	30.2	31.4	- 4

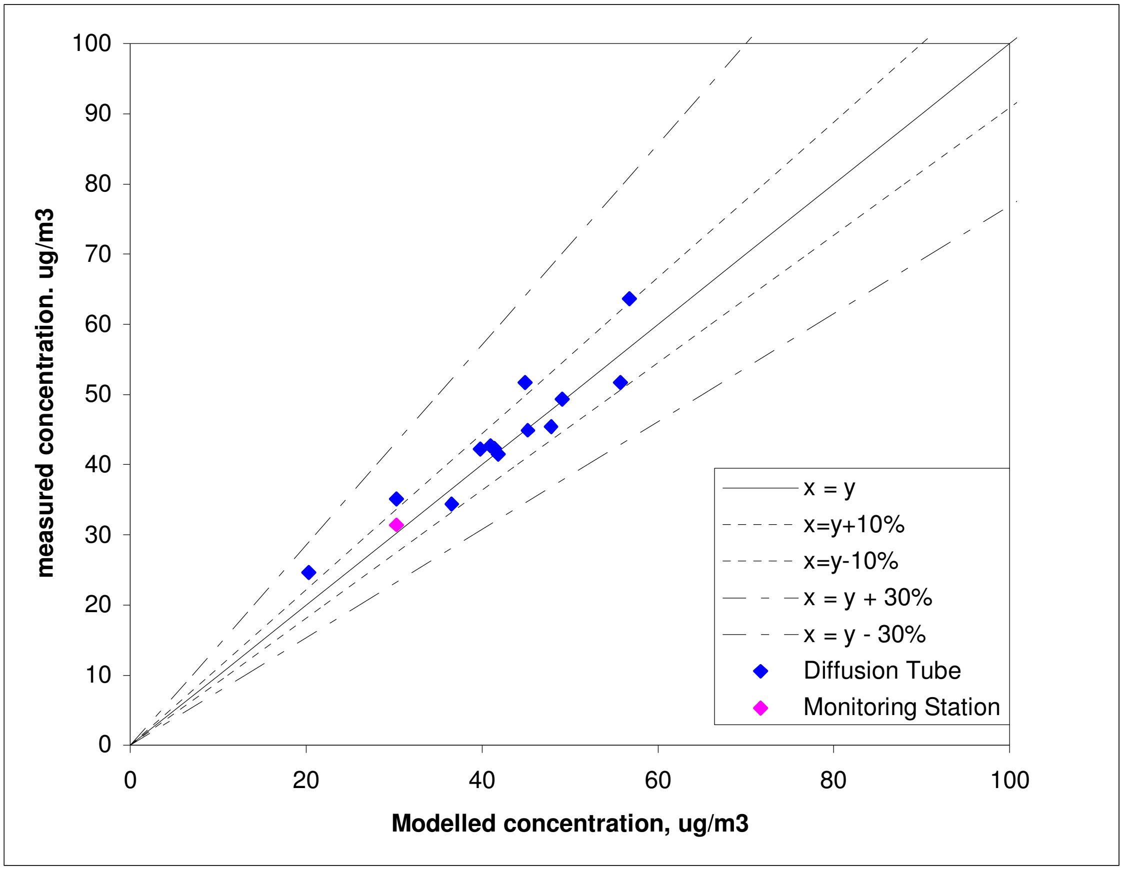
Table 3-4 and Figure 3-1 present the comparison between modelled and measured nitrogen dioxide concentration in Area B, Area E and Area F at the relevant diffusion tubes locations. The agreement between model predictions and measured values is acceptable.
On average, the diffusion tubes concentrations are found to be 3.3% greater than the model predicted values.

Table 3-4: Comparison of modelled and diffusion tube monitored nitrogen dioxide concentrations, 2007

Site Number	Site	Concentration, ug m^{-3}		Difference, %
		Model predicted	Diffusion Tubes (adjusted)	
B4	DALSTON ROAD	**55.7**	**51.7**	8
E22	FINKLE STREET	40.9	42.7	- 4
E12	3 WIGTON ROAD	**49.1**	**42.7**	15
E15	WIGTON ROAD 22	**47.8**	**45.4**	5
E16	JOVIAL SAILOR	**41.4**	**42.3**	- 2
E17	NEWTOWN ROAD	20.3	24.6	-17
E19	49 WIGTON ROAD	**44.9**	**51.7**	- 13
E20	44 WIGTON ROAD	**45.2**	**44.9**	0
E4	JOHN STREET	**39.8**	**42.3**	- 6
E6	AIR MONITOR	30.2	35.1	- 14
E9	KC	36.5	34.4	6
E8	BRIDGE STREET	**56.7**	**63.6**	-11
F7	24 LONDON ROAD	**41.8**	**41.5**	1

The model predicts well the adjusted diffusion tube data in Carlisle in 2007. In the modelled areas the model predicts within 20% the diffusion tube value at all of the sites and within 10% at 8 sites. There are a number of possible explanations accounting for the discrepancies between measured and model concentrations, such as uncertainty regarding traffic speeds, queuing and congestion.

Figure 3-1: Regression analysis of modelled and measured nitrogen dioxide concentration in 2007



Bias adjustment is the process where the concentrations predicted by the model are adjusted to agree with local air quality monitoring data. In this case, the model has provided satisfactory predictions of the measured nitrogen dioxide concentrations without adjustment and so no adjustment has been made.

3.5.3 Model uncertainty

The results of dispersion modelling of pollutant concentrations are necessarily uncertain because of the uncertainties in the estimation of rates of emission, meteorological data and dispersion conditions. Table 3-5 shows confidence levels for modelled nitrogen dioxide concentrations based on a statistical analysis of a comparison of modelled and measured concentrations in London (LAQM. TG(03)). In this report, we present predicted concentrations as contour plots superimposed on a map of the local area. The concentration values selected reflect the uncertainty bands shown in Table 3-5. Predicted concentrations in excess of 40 µg m^{-3} indicate that there is more than a 50 % chance of exceeding the annual average objective for nitrogen dioxide. Public exposure in these areas should be considered in order to assess whether it will be necessary to revise the Air Quality Management Area for nitrogen dioxide.

Table 3-5: Confidence levels for modelled concentrations for future years based on symmetrical concentration intervals and concentration intervals derived purely from the statistics

Description	Chance of exceeding objective	Annual average objective
Very unlikely	Less than 5%	< 28
Unlikely	5 to 20%	28 to 34
Possible	20 to 50%	34 to 40
Probable	50 to 80%	40 to 46
Likely	80 to 95%	46 to 52
Very likely	More than 95%	> 52

3.6 Detailed modelling results

In this section, nitrogen dioxide concentrations predicted for 2007 and 2010 are presented as a series of contour plots for Wigton Road, Bridge Street, Dalston Road and London Road.

3.6.1 Wigton Road, for 2007 and 2010

Figure 3-6 shows the modelled nitrogen dioxide concentrations for 2007 on Wigton Road, Caldcotes and Church Street Junction. The modelling results show that predicted nitrogen dioxide concentrations exceed the annual mean objective along the entire length of Wigton Road: from the junction Wigton Road and Crummock Street up to Church Street junction and the exceedances are also found in Caldcotes up to Church Street junction.

These areas extend from the roadside sufficiently for relevant exposure to occur at residential properties.

There are 5 diffusion tubes located in Wigton Road and Caldcotes. The measured and modelled results are presented in Table 3-6.

Table 3-6: Measured and modelled nitrogen dioxide concentrations in Wigton Road\Caldcotes\Church Street Junction

Diffusion tube number	Corrected with UK-wide bias NO_2 Measured concentrations ($\mu g\ m^{-3}$)	NO_2 Modelled concentrations ($\mu g\ m^{-3}$)
E12	42.7	49.1
E15	45.4	47.8
E16	42.3	41.4
E19	51.7	44.9
E20	44.9	45.2

The model under-predicts at the location of the diffusion tube E19 by 13% calculating a concentration of 44.9 $\mu g\ m^{-3}$. The model over-predicts at the locations of the two diffusion tubes: E15 by 5% and E12 by 15%. There is a very good agreement between measured and predicted concentration at the location of the diffusion tube E20. The model under-predicts the nitrogen dioxide concentration at the Jovial Sailor (E16) in Newtown Road by 2%.

The plot shows that exceedences of the objective for nitrogen dioxide were ***probable*** in 2007 for properties situated along Wigton Road and Caldcotes.

Figure 3-7 presents predicted concentrations for 2010 in Wigton Road. The modelling results show that the ambient concentrations of nitrogen dioxide will decrease sufficiently and that areas exceeding the objective will have smaller extent along Wigton Road.

It is recommended that the AQMA in Wigton Road should be retained and also should be extended to cover residential properties along Wigton Road to include odds no 1 -11 and even nos 2-24 and also the properties in Caldcotes because:

- Diffusion tube measurements continue to show concentrations in excess of the objective;
- Measured concentrations have increased since the AQMA was declared;
- Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations;
- It remains possible, within the uncertainty of the modelling, that exceedence of the objective will occur throughout most or all of the AQMA, particularly when the effects of localised queuing at junctions with the smaller roads joining the A595 are included.

3.6.2 Bridge Street (A595) for 2007 and 2010

Figure 3-8 shows the modelled annual mean nitrogen dioxide concentrations in 2007 in Church Street, Bridge Street, Finkle Street and Castle Way. The model has predicted that it is ***probable*** the annual mean objective of 40 µg m^{-3} for nitrogen dioxide was exceeded in Church Street, Bridge Street, Finkle Street and Castle Way in 2007.

The modelled prediction at the location of the diffusion tube site E8 in Bridge Street was 63.6 µg m^{-3}, a 11% over-prediction than the diffusion tube measurement of 56.7µg m-3. At the location of the diffusion tube E22 in Finkle Street the model predicts nitrogen dioxide concentration of 40.9 µg m^{-3}, a 4% under-prediction of the measured concentration of 42.7µg m^{-3}. Measured concentration at the Paddy's Market continuous monitoring station was 31.4µg m^{-3}, the predicted nitrogen dioxide concentration at this location was 30.2, a 4% under-prediction of the measured value.

Figure 3-9 shows the modelled annual mean nitrogen dioxide concentrations in 2010 in Church Street, Bridge Street, Finkle Street and Castle Way. The predicted concentrations are less than those predicted for 2007. However, the model predicts that the annual average concentration will continue to exceed the objective of 40 µg m^{-3} at the façades of residential properties in Bridge Street at the location of the diffusion tube E8. The model predicts that the concentration on the façades of residential properties in Finkle Street will not exceed the objective in 2010.

It is recommended that the AQMA in Bridge Street is retained and extended to include the properties in Finkle Street because:

- Diffusion tube measurements continue to show concentrations in excess of the objective;
- Measured concentrations have increased since the AQMA was declared;
- Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations.

3.6.3 Dalston Road and Junction Street for 2007 and 2010

Figure 3-10 shows the modelled nitrogen dioxide concentrations along Dalston Road and Junction Street. Close examination of Figure 3-10 indicates that the annual mean objective of 40 µg m^{-3} was exceeded at the façade of many residential properties in Dalston Road. These properties were included in the declared AQMA.

The modelled prediction at the diffusion tube site in Dalston Road of 55.7 µg m^{-3} was slightly higher than the diffusion tube measurement of 51.7 µg m^{-3}.

The model has predicted that it is ***likely*** the annual mean objective of 40 µg m^{-3} for nitrogen dioxide was exceeded in Dalston Road in 2007.

Figure 3-11 shows the predicted nitrogen dioxide concentrations for 2010 along Dalston Road. The predicted concentrations are less than those predicted for 2007. However, the model predicts that the annual average concentration will continue to exceed the objective of 40 μg m^{-3} at the façades of residential properties in Dalston Road.

It is recommended that the AQMA in Dalston Road remains unchanged because:

- Modelled and measured concentrations have changed little since the AQMA was declared;
- Diffusion tube measurements continue to show concentrations in excess of the objective.

3.6.4 London Road for 2007 and 2010

Figure 3-12 shows the modelled annual mean nitrogen dioxide concentrations in 2007 in London Road. The model has predicted that it is ***probable*** the annual mean objective of 40 μg m^{-3} for nitrogen dioxide was exceeded in London Road in 2007.

The modelled prediction at the diffusion tube site in London Road of 41.5 μg m^{-3} shows very good agreement with diffusion tube measurement of 41.8 μg m^{-3}.

Figure 3-13 presents the modelled annual mean nitrogen dioxide concentration in 2010 in London Road. The predicted concentrations are substantially less than those predicted for 2007. However, the model predicts that the annual average concentration will continue to exceed the objective of 40 μg m^{-3} at the facades of the residential properties.

It is recommended that the AQMA in London Road remains unchanged because:

- Diffusion tube measurements continue to show concentrations in excess of the objective;
- Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations.

3.7 Source apportionment

3.7.1 Source apportionment of 'base case' predictions

Source apportionment is the process whereby the contributions from the sources of a pollutant are determined. In local air quality, the relevant sources could include: traffic, local background, industrial and domestic. Contributions from the different types of vehicles (e.g. cars, lorries and buses) can also be considered to highlight which class of vehicle is contributing most to the emissions from traffic. Source apportionment allows the most important source or sources to be identified and options to reduce ambient concentrations of pollutants can then be considered and assessed.

The source apportionment should:

- Confirm that exceedences of nitrogen dioxide are due to road traffic
- Determine the extent to which different vehicle types are responsible for the emission contributions to nitrogen dioxide: this will allow traffic management scenarios to be modelled/tested to reduce the exceedences
- Quantify what proportion of the exceedences of nitrogen dioxide is due to background emissions, or local emissions from busy roads in the local area. This will help determine whether local traffic management measures could have a significant impact on reducing emissions in the area of exceedence, or, whether national measures would be a suitable approach to achieving the air quality objectives.

3.7.2 What is the 'base case'?

The base case in this assessment is defined as the annual mean concentrations of nitrogen dioxide that are predicted in 2007 in the absence of any measures to improve air quality in Carlisle City. They are the concentrations that should be relevant to defining the extent of Air Quality Management Areas.

3.7.3 Receptors considered

The most affected receptors where relevant public exposure is most likely to occur inside the four newly declared AQMAs have been considered: these are shown in Table 3-7 and also in Figures: 3-2, 3-3, 3-4 and 3-5.

Table 3-7: Most affected receptors exceeding annual average objective inside existing AQMAs

General Area	Description	OS Grid reference of receptor
Dalston Road (R1)	Façade of the building	339416, 555591
Dalston Road (R2)	Façade of the building	339433, 555634
Dalston Road (R3)	Façade of the building	339461, 555715
London Road (R4)	Façade of the building	340707, 555239
London Road (R5)	Façade of the building	340741, 555231
London Road (R6)	Façade of the building	340743, 555209
Wigton Road (R7)	Façade of the building	339013, 555684
Wigton Road (R8)	Façade of the building	339052, 555712
Wigton Road (R9)	Façade of the building	339137, 555769
Caldcodes (R10)	Façade of the building	339154, 555901
Wigton Road (11)	Façade of the building	339225, 555818
Bridge Street (12)	Façade of the building	339512, 556023
Bridge Street (R13)	Façade of the building	339834, 556137

Figure 3-2: Receptors' location Dalston Road

Figure 3-3: Receptors' location London Road

Figure 3-4: Receptor Location Wigton Road

Figure 3-5: Receptor location Bridge Street

3.7.4 Sources of pollution considered

We have considered the effects of the following sources in this Further Assessment at the selected receptors:

- Background from sources outside the local area
- Traffic
- Heavy duty vehicles (buses, coaches and heavy goods vehicles)
- Stationary vehicles in queues

Further model runs were carried out for the cases with no stationary vehicles and no heavy-duty vehicles to enable the apportionment of oxides of nitrogen concentrations to those sectors. The concentrations of oxides of nitrogen concentrations apportioned to each source category and the fractions of the total concentrations are shown in Table 3-8. This table shows the contributions from: the rural background (at High Muffles), the modelled background from Carlisle and surrounding district sources and the modelled local roads. It then shows the breakdown of the local road contribution between heavy and light duty vehicles and between moving and stationary vehicles (in queues and at bus stops).

Table 3-8: Apportionment of oxides of nitrogen concentrations at most affected receptors

Contribution to oxides of nitrogen concentration, μg m^{-3}								
Area	Total	Rural background	Modelled background	Local roads	Local HDV	Local LDV	Moving vehicles	Stationary vehicles
Dalston Road (R1)	118.9	8.0	20.7	90.2	56.4	33.8	45.9	44.3
Dalston Road (R2)	217.1	8.0	20.4	188.7	139.2	49.6	98.2	90.6
Dalston Road (R3)	134.7	8.0	19.9	106.8	84.3	22.5	83.2	23.6
London Road (R4)	92.9	8.0	20.5	64.4	47.6	16.8	50.1	14.3
London Road (R5)	176.0	8.0	20.4	147.6	108.2	39.4	118.6	29.0
London Road (R6)	97.8	8.0	20.3	69.5	50.7	18.8	56.8	12.7
Wigton Road (R7)	150.1	8.0	17.0	125.1	103.3	21.8	56.0	69.1
Wigton Road (R8)	125.2	8.0	17.1	100.1	83.0	17.1	42.2	57.9
Wigton Road (R9)	128.1	8.0	17.2	102.8	85.2	17.7	43.2	59.6
Caldcodes (R10)	111.6	8.0	16.4	87.2	65.1	22.1	43.3	43.8
Wigton Road (11)	109.6	8.0	17.5	84.2	69.2	14.9	36.1	48.1
Bridge Street (12)	120.0	8.0	17.5	94.5	65.6	28.9	73.1	21.4
Bridge Street (R13)	100.8	8.0	17.3	75.5	55.1	20.4	42.1	33.5

At each of the receptor sites, the heavy-duty vehicles make a significant contribution to the total oxides of nitrogen concentrations. Stationary vehicles in queues also make a substantial contribution at each of the receptor sites.

3.8 Action plan scenarios

Carlisle City Council's Air Quality Action Plan was published in 2008. The Action Plan focuses on reducing NO_x emissions primarily through measures to reduce traffic flow and vehicle emissions that are consistent with Council wide policies, particularly those in the Local Transport Plan (LTP2). Other actions focus on reducing emissions from buildings and industry as well as measures to raise public awareness of air pollution and greener travel. It should be noted that the plan was formulated following the declaration of AQMAs No 1 and No 2. This Further Assessment considers four additional AQMAs declared in August 2008. The Action Plan will be revised to take account any further actions that will be needed in pursuit of the objective levels for nitrogen dioxide within these areas.

The Carlisle Northern Development Route (CNDR) is the single major scheme in the (LTP2) and the Air Quality Action Plan. It is assumed that the CNDR will remove approximately 25% of through traffic from the A7 and A595 and, in particular, reduced the flow of HDVs through the City. The new road will be just over 5 miles long and will pass west of the city from the A595 to Junction 44 of the M6. The CNDR enables non-Carlisle trips to avoid the City and subsequently will reduce congestion on the radial routes to the North (A7) and West (A595) of the City.

Significant progress continues to be made on the CNDR as the Council's only current major transport scheme. Delivery of the scheme is vital to the economy of the area helping to tackle congestion in the city, supporting the development of the Kingmoor Park regional employment site and improving access to West Cumbria for freight traffic. The CNDR will also have an important impact on the schemes coming forward through Carlisle Renaissance. The reduction in through traffic from the city centre will allow measures to revitalise the public realm and improve access by walking, cycling and passenger transport to be implemented.

Encouraging public transport is one of the key components of both the Local Transport Plan (LTP) covering Carlisle and the Carlisle Renaissance Movement Strategy. The County Council has entered into a Quality Bus Partnership with Stagecoach to improve bus route infrastructure and bus priority measures will take place on the A7 Scotland Road, including traffic signal priority. Carlisle currently has no Park and Ride facilities. One of the priorities of the Local Transport Plan is to develop such facilities on the radial routes into and out of the City.

In order to combat peak congestion occurring during work and school opening and closing times, an important component of the LTP is to promote Travel Plans to schools, businesses and other organisations.

3.8.1 Scenarios

A number of scenarios have been considered in order to investigate the potential improvement as a result of the measures outlined in Carlisle City Council's Air Quality Action Plan. All scenarios for receptors within the AQMAs declared for Wigton Road and Bridge Street considered a 25% reduction in daily traffic flow to represent the reduction in traffic travelling through the city as a result of the proposed road network developments. For the receptors in the AQMAs declared for Dalston Road and London Road, a scenario considered a reduction in stationary vehicles (traffic queues); no change in the average daily traffic flow was considered for these locations.

Given these traffic flows several levels of congestion were considered to represent the impact of reduced traffic flows, Travel Planning, the increased use of public transport and cycling and walking:

- Current congestion (AQMA No. 3 and AQMA No. 4). A worst case scenario, in which the measures have no impact on the congestion around junctions and signals despite a 25% reduction in traffic flow as a result of road network developments;
- No congestion. To represent the optimal reduction of congestion (AQMA No 3 and AQMA No 4);
- Reduced congestion. To represent a partial reduction of congestion, (AQMA No 5 and AQMA No 6);
- Reduced traffic volume and proportion of HDVs. To represent the additional reduction of HDVs travelling through the City, the proportion of HDVs is reduced by 50% (AQMA No 3 and AQMA No 4);

- Reduced proportion of HDVs by 25% in addition to a 25% reduction in queuing traffic (AQMA No. 5 and AQMA No. 6).

3.8.2 Scenario results for Wigton Road and Bridge Street

The results of modelled concentrations at the most sensitive receptors are shown in Table 3-9 for the Action Plan scenarios for 2007 and 2010.
There were three scenarios considered for these locations:

- 25% reduction in daily traffic;
- 25% reduction in daily traffic and 50% reduction in HDV;
- 25% reduction in daily traffic and no stationary traffic.

Table 3-9: Predicted nitrogen dioxide concentrations at selected receptors for the Action Plan scenarios for Wigton Road and Bridge Street

Receptor	Year	Baseline	Scenario 1 25% reduction in daily traffic	Scenario 2 S1 + 50% reduction in HDV	Scenario 3 S1+ no congestion
Wigton Road (R7)	2007	50.4	44.2	35.0	30.6
Wigton Road (R8)		45.5	39.9	31.6	27.2
Wigton Road (R9)		46.2	40.5	32.1	27.5
Wigton Road (R10)		42.5	37.2	30.4	27.2
Caldcodes (R11)		42.2	37.0	29.5	25.7
Bridge Street (12)		44.5	39.0	32.5	34.7
Bridge Street (13)		40.1	35.2	29.0	27.2
Wigton Road (R7)	2010	44.7	38.9	30.7	26.8
Wigton Road (R8)		40.2	35.0	27.7	23.9
Wigton Road (R9)		40.7	35.5	28.1	24.2
Wigton Road (R10)		37.5	32.6	26.7	24.0
Caldcodes (R11)		37.1	32.4	25.9	22.7
Bridge Street (12)		39.4	34.4	28.7	30.5
Bridge Street (13)		35.3	30.8	25.6	24.0

Table 3-9 indicates a substantial reduction in nitrogen dioxide concentrations at the locations of the receptors in AQMA No 3 and AQMA No 4 after the beneficial impacts of the Carlisle Northern Development Route was considered.

Reductions in nitrogen dioxide concentrations of 5 $\mu g\ m^{-3}$ (on average) are possible along Wigton Road and Bridge Street as a result of a 25% reduction to traffic flows. At the receptors locations in Wigton Road, nitrogen dioxide concentrations could be reduced, on average, by around 13 $\mu g\ m^{-3}$ in a scenario where traffic flows are reduced by 25% and HDVs are reduced by 50%. The effect of this scenario along Bridge Street could reduce concentrations by 12 $\mu g\ m^{-3}$.

In an optimal scenario where congestion is removed entirely from the Wigton Road and Brigde Street locations, nitrogen dioxide concentrations are potentially reduced by around 18 $\mu g\ m^{-3}$ and 11 $\mu g\ m^{-3}$ respectively.

3.8.3 Scenario results for Dalston Road and London Road

Three scenarios have been considered to investigate the potential improvements in air quality in AQMA 5 and AQMA 6. The first scenario considered a 25% reduction in queuing traffic in Dalston Road and London Road. The second scenario considered 50% reduction in queuing traffic. The third scenario considered 25% reduction in queuing traffic and 25% reduction in HDV in traffic flows.

Table 3-10: Predicted nitrogen dioxide concentrations at selected receptors for the Action Plan scenarios for Dalston Road and London Road

Receptor	Year	Baseline	S1 - 25% reduction in queuing	S2 - 50% reduction in queuing	S1 + 25% reduction in HDV
Dalston Road (R1)	2007	44.6	42.1	39.3	39.1
Dalston Road (R2)		48.2	44.6	40.5	42.1
Dalston Road (R3)		47.8	43.4	38.3	41.1
London Road (R4)		38.5	37.5	36.5	34.5
London Road (R5)		40.9	40.0	39.1	36.8
London Road (R6)		39.7	38.9	38.1	35.8
Dalston Road (R1)	2010	39.6	37.3	34.7	34.6
Dalston Road (R2)		42.8	39.4	35.7	37.2
Dalston Road (R3)		42.3	38.2	33.6	36.2
London Road (R4)		33.8	33.0	32.1	30.4
London Road (R5)		36.0	35.2	34.4	32.4
London Road (R6)		34.9	34.2	33.5	31.5

A 25% reduction in queuing traffic is expected to reduce nitrogen dioxide concentrations at relevant receptors by around 4 $\mu g\ m^{-3}$ in Dalston Road and by 1$\mu g\ m^{-3}$ in London Road.

A 50% reduction in stationary traffic at the location of the receptors has the potential to reduce nitrogen dioxide concentrations by around 8 $\mu g\ m^{-3}$ in Dalston Road and by approximately 2 $\mu g\ m^{-3}$ in London Road.

An assumed 25% reduction in queuing traffic in addition to a 25% reduction in HDVs travelling along Dalston Road and London Road is expected to result in a reduction of 6$\mu g\ m^{-3}$ in Dalston Road and 4 $\mu g\ m^{-3}$ in London Road.

Figure 3-6: Predicted nitrogen dioxide concentrations along Wigton Road, 2007

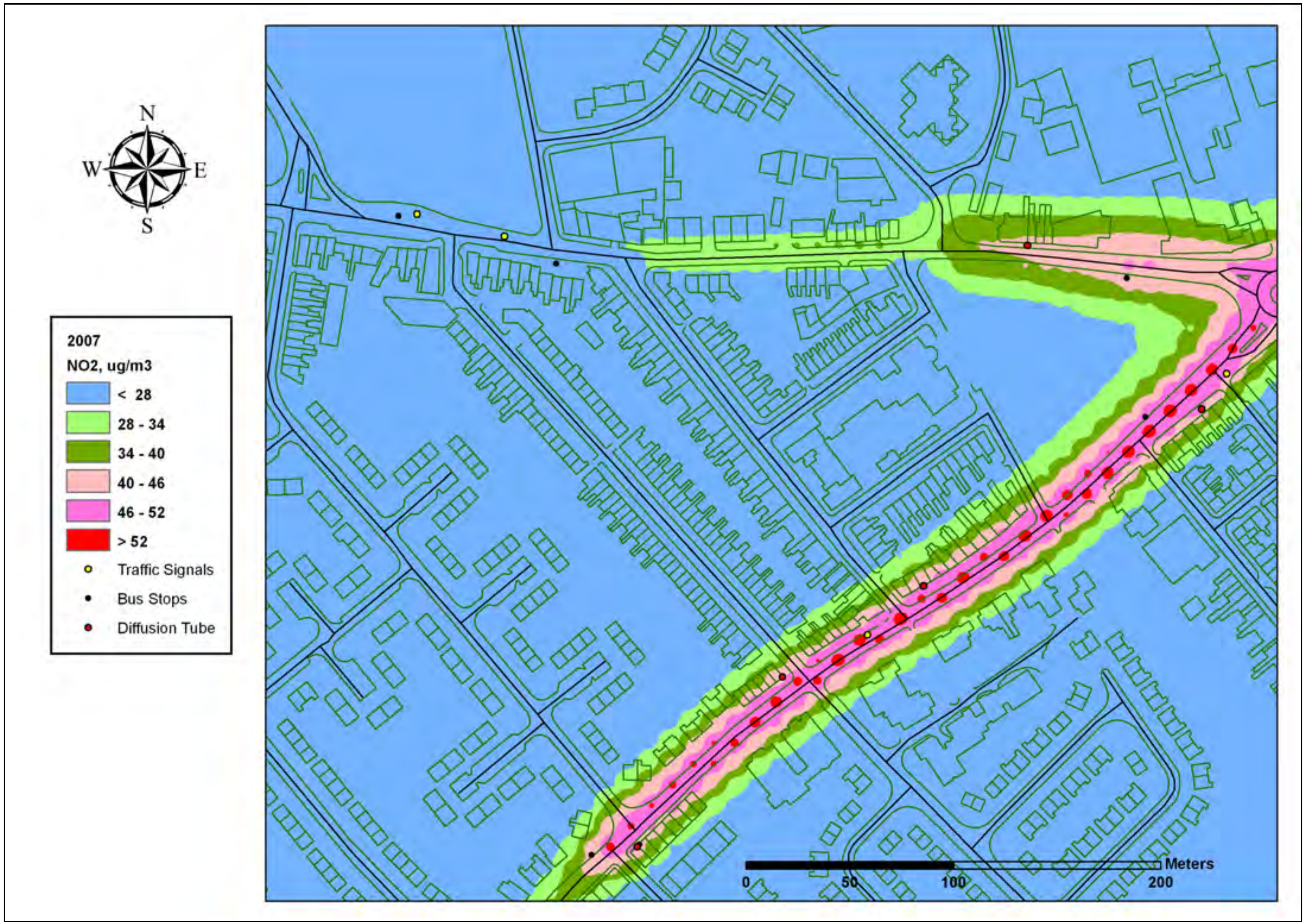


Figure 3-7: Predicted nitrogen dioxide concentrations along Wigton Road, 2010

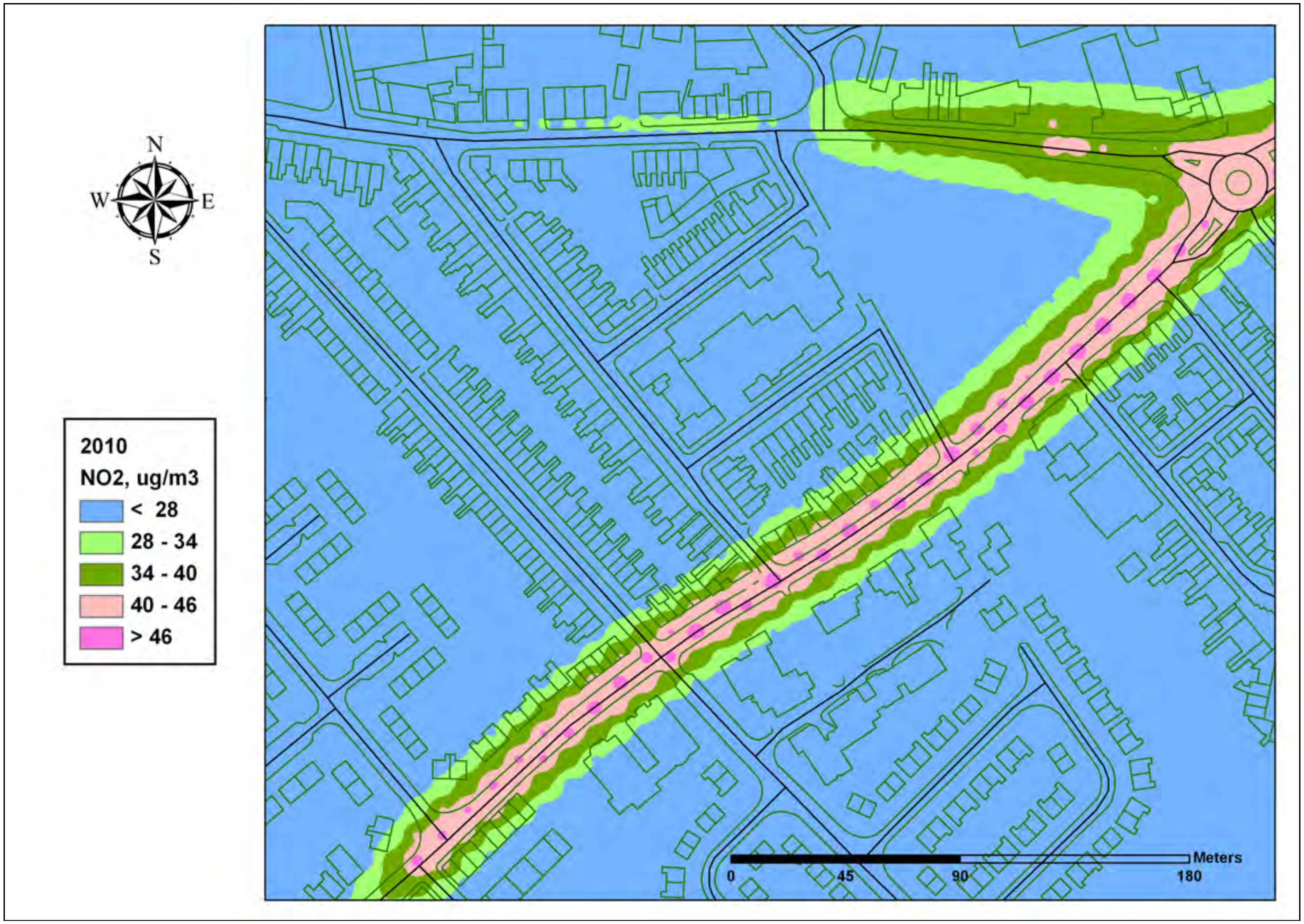


Figure 3-8: Predicted nitrogen dioxide concentrations along Bridge Street, 2007

Figure 3-9: Predicted nitrogen dioxide concentrations along Bridge Street, 2010

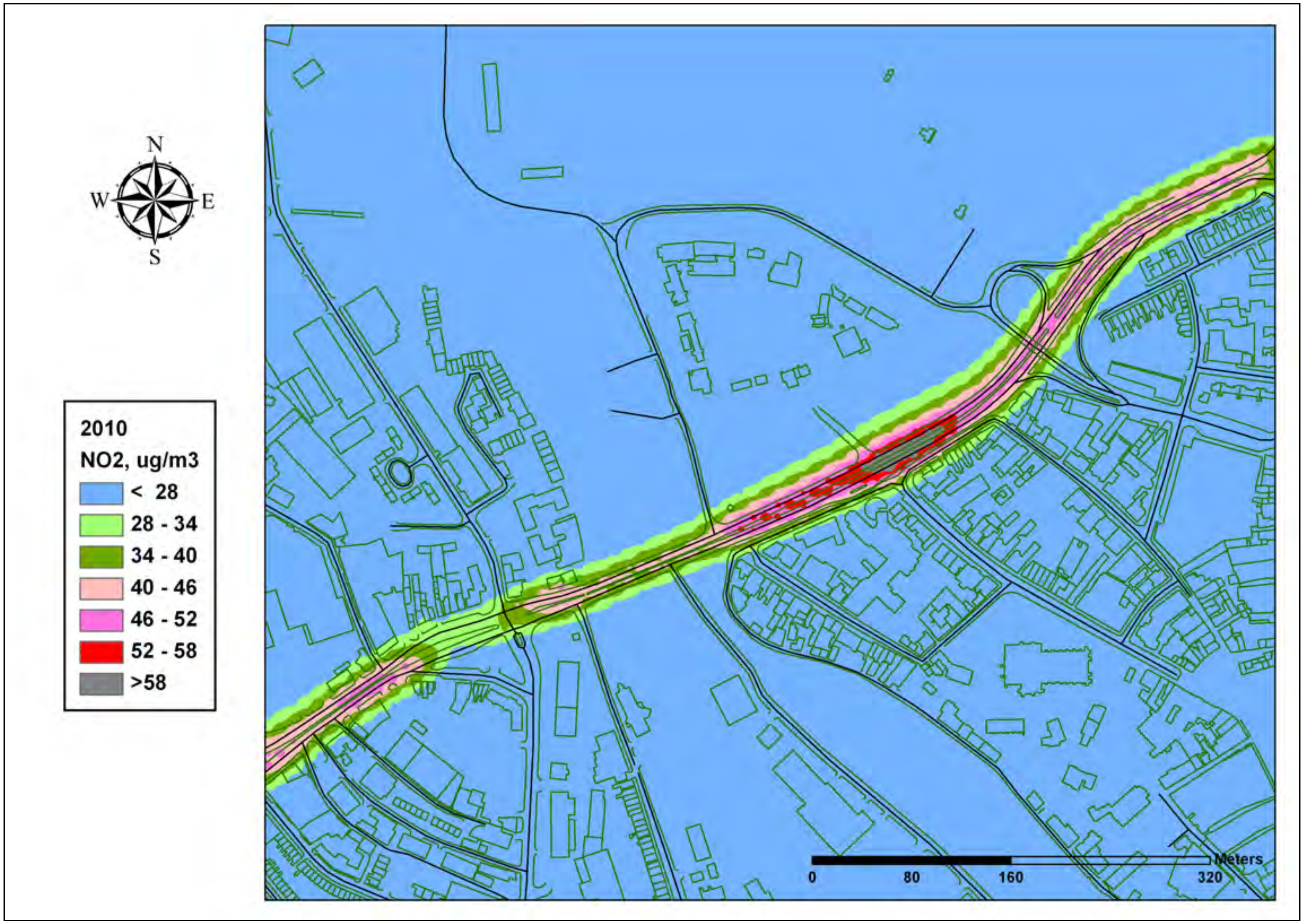


Figure 3-10: Predicted nitrogen dioxide concentrations along Dalston Road, 2007

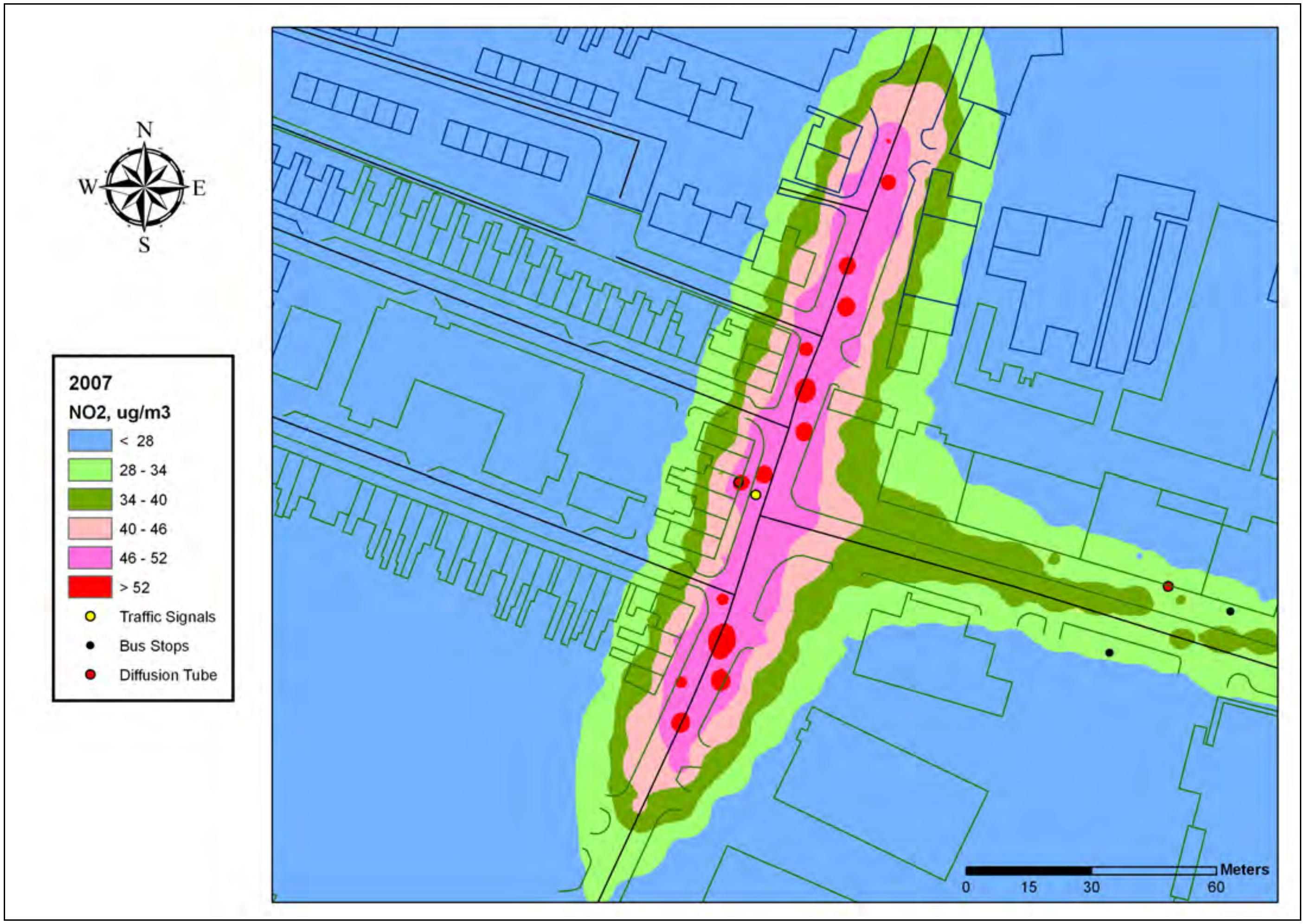


Figure 3-11: Predicted nitrogen dioxide concentrations along Dalston Road, 2010

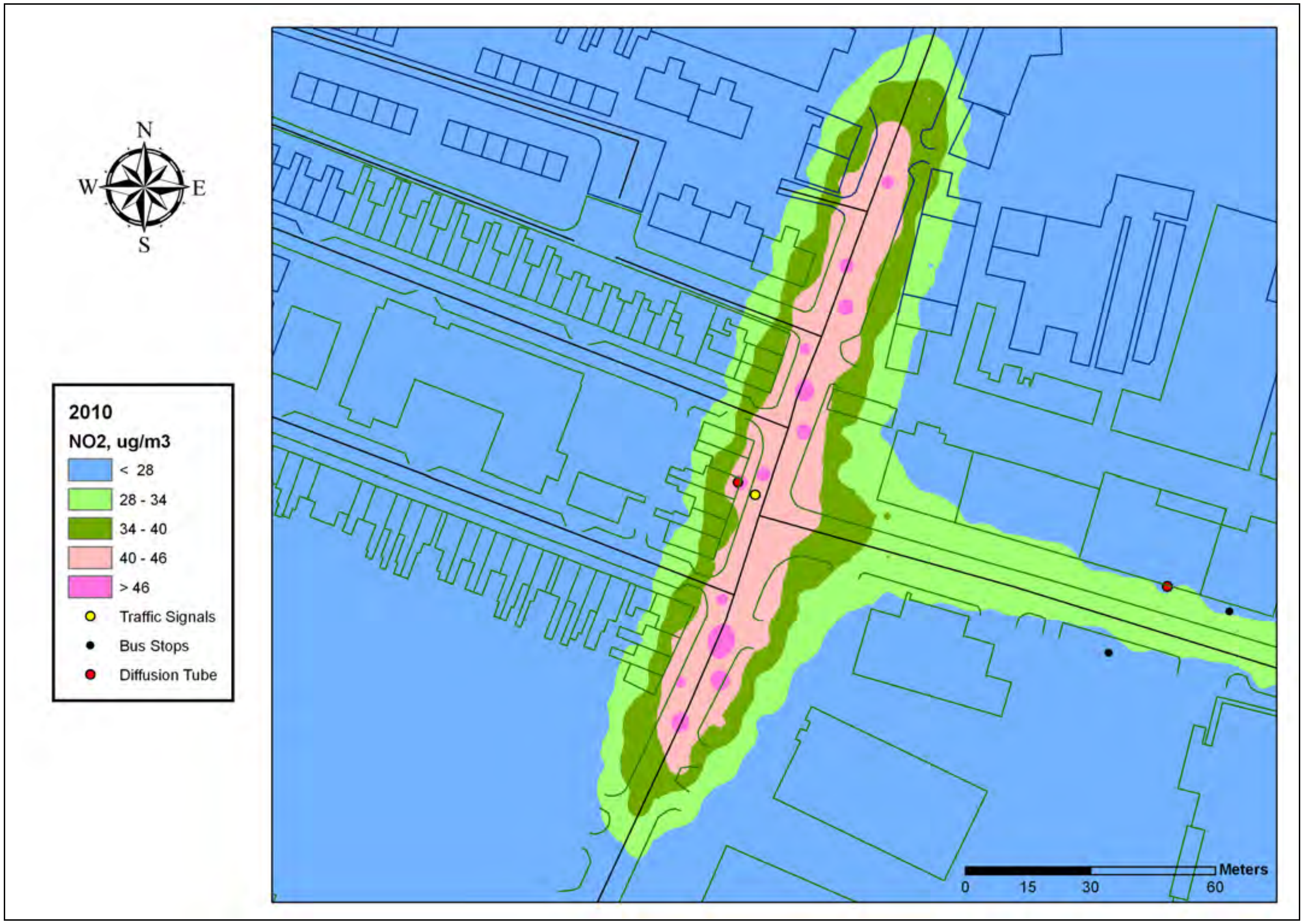


Figure 3-12: Predicted nitrogen dioxide concentrations along London Road, 2007

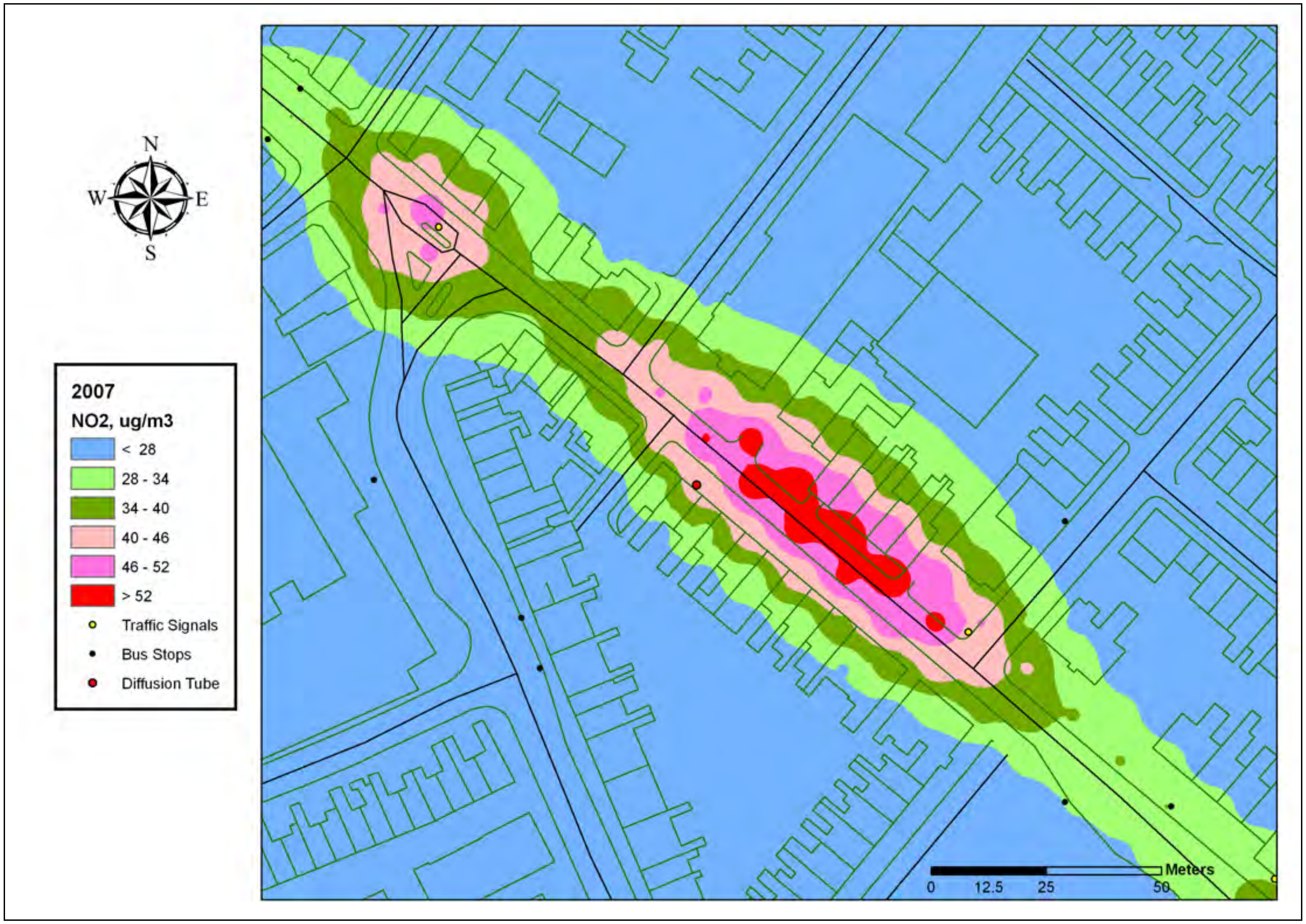
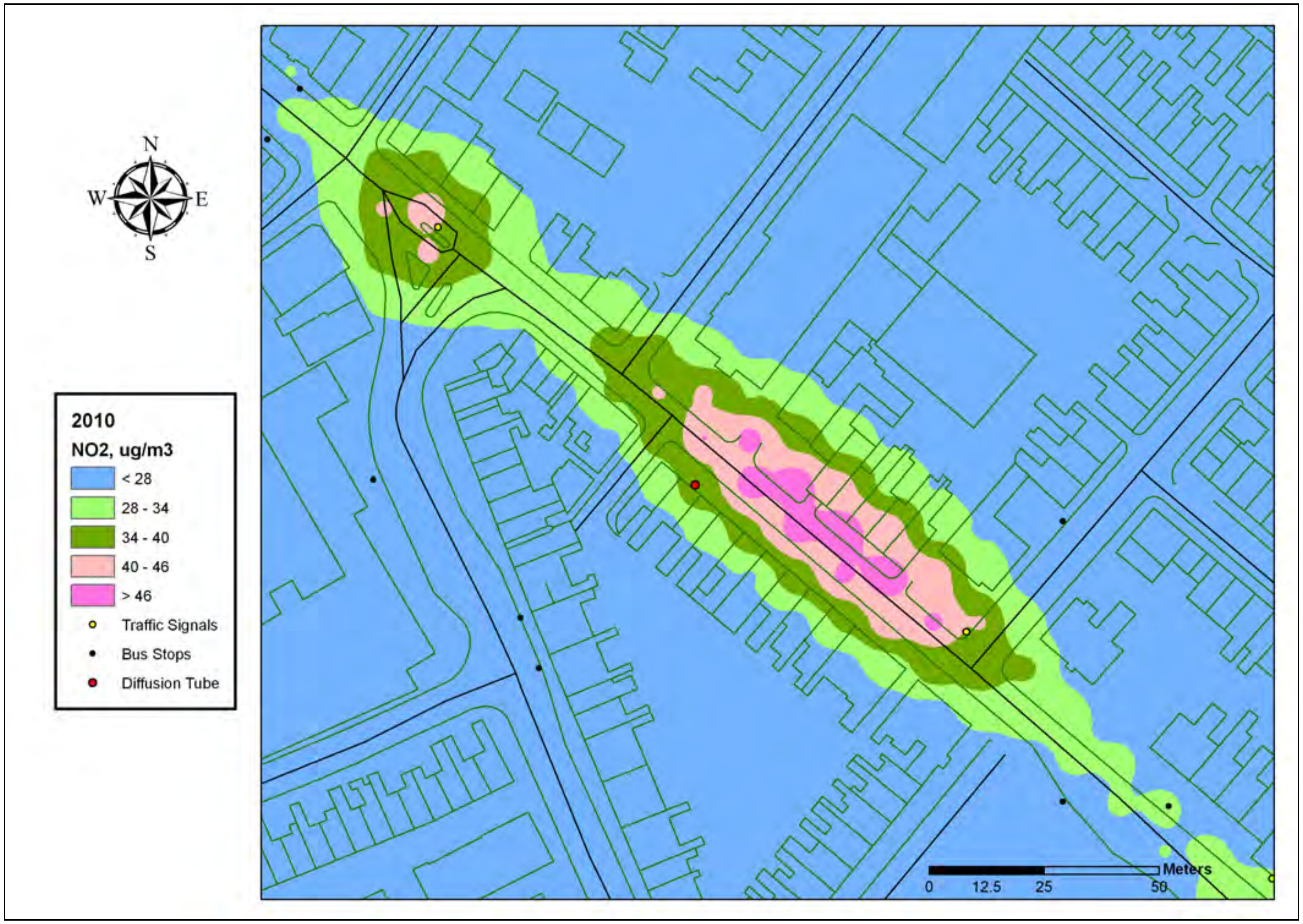


Figure 3-13: Predicted nitrogen dioxide concentrations along London Road, 2010



4 Conclusions

The concentrations of nitrogen dioxide in AQMAs 3, 4, 5 and 6 have not changed substantially since the Detailed Assessment was carried out in 2007. The dispersion model continues to predict areas within the declared AQMAs where concentrations exceed the air quality objective for nitrogen dioxide.

The following recommendations are suggested:

- The AQMA in Wigton Road should be retained and also should be extended to cover residential properties along Wigton Road to include odds no 1 -11 and even nos 2-24 and also the properties in Caldcotes because:
  - Diffusion tube measurements continue to show concentrations in excess of the objective;
  - Measured concentrations have increased since the AQMA was declared;
  - Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations;
  - It remains possible, within the uncertainty of the modelling, that exceedence of the objective will occur throughout most or all of the AQMA. Particularly when the effects of localised queuing at junctions with the smaller roads joining the A595 are included.

- The AQMA in Bridge Street should be retained and extended to include the properties in Finkle Street because:
  - Diffusion tube measurements continue to show concentrations in excess of the objective;
  - Measured concentrations have increased since the AQMA was declared;
  - Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations.

- The AQMA in Dalston Road should remain unchanged because:
  - Modelled and measured concentrations have changed little since the AQMA was declared;
  - Diffusion tube measurements continue to show concentrations in excess of the objective.

- The AQMA in London Road should remain unchanged because:
  - Diffusion tube measurements continue to show concentrations in excess of the objective;
  - Model predictions continue to show areas where members of the public will be exposed to nitrogen dioxide concentrations greater than the annual mean objective at relevant receptor locations.

Furthermore, source apportionment studies indicate that heavy-duty vehicles make a significant contribution to the total oxides of nitrogen concentrations. Stationary vehicles in queues also make a substantial contribution at each of the receptor sites.

5 References

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Acknowledgments

We are grateful for the help of Fiona Donald from the Carlisle City Council.

Appendices

Appendix 1

Traffic data

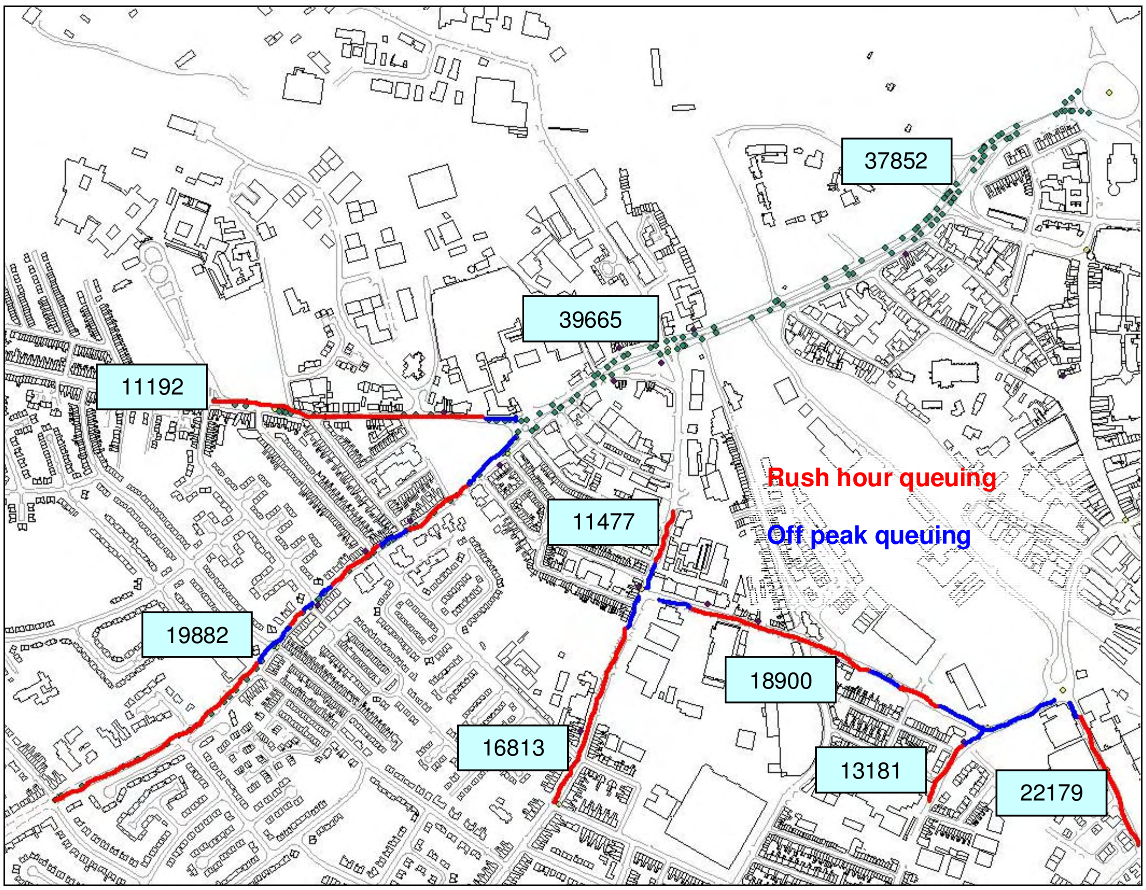
Contents

Off-peak and rush hour queuing was based on estimates provided by Carlisle City Council[1]

It is assumed that during rush hours the A595 between the Hardwicke Circus roundabout and the roundabout with Wigton Road and Newtown Road is a slow moving queue of traffic.

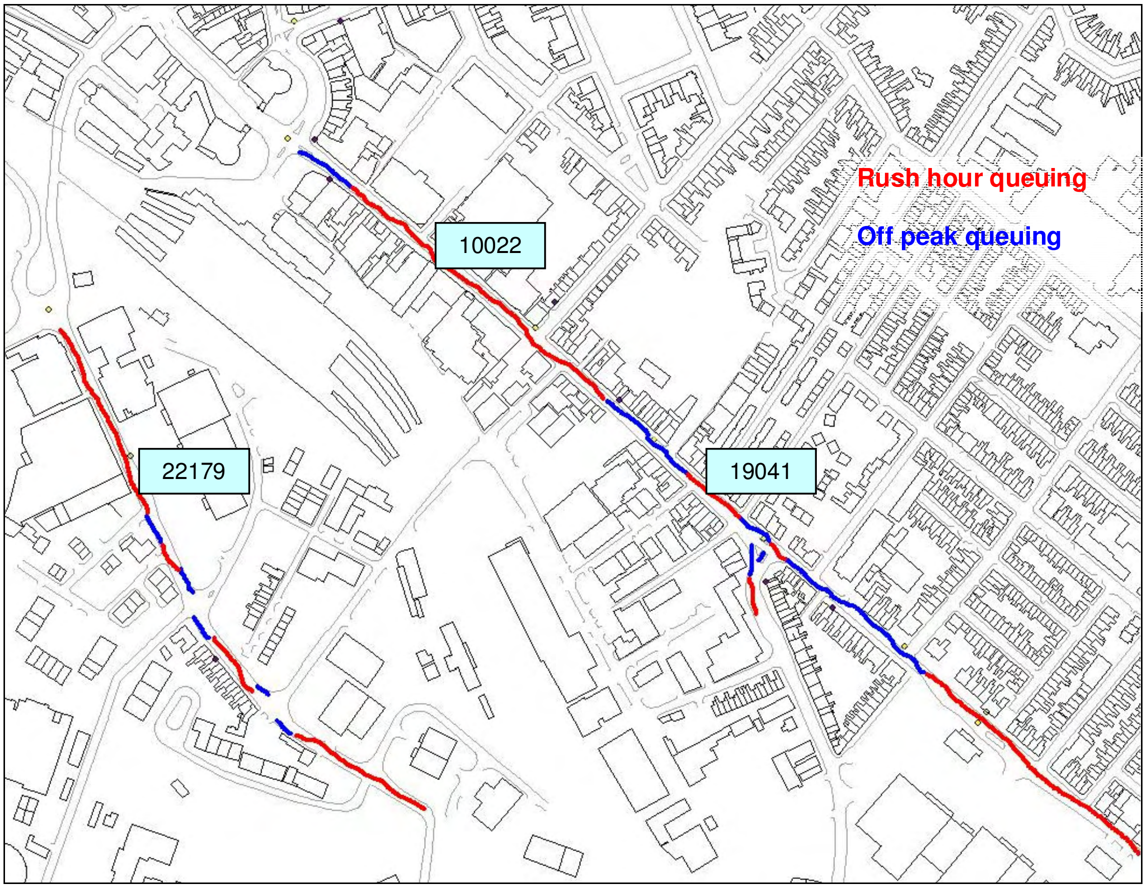
19654	= Traffic counts

Fig. A1.1: Summary of Annually Averaged Daily Traffic Flows and queue lengths; Wigton Road, Newtown Road, Caldewgate, Bridge Street, Castleway, Shaddongate, Dalston Road and Junction Street.



[1] Results are relatively robust to rush hour queuing times in the range 1.5 hours – 2.0 hours (morning and evening), based on modelling of the AQMA 1.

Fig. A1.2: Summary of Annually Averaged Daily Traffic Flows and queue lengths; James Street, Currock Street, A6 Botchergate and London Road.



Appendix 2

Bias adjustment calculation

Table A2-1 Bias adjustment UWE spreadsheet

								Spreadsheet Version Number: 03/08		
Follow the steps below **in the correct order** to show the results of **relevant** collocation studies								This spreadsheet will be updated in late September 2008 on the R&A website		
Data only apply to tubes exposed monthly and are not suitable for correcting individual short-term monitoring periods **Whenever presenting adjusted data, you should state the adjustment factor used**										
This spreadhseet will be updated every few months: the factors may therefore be subject to change. This should not discourage their immediate use.										
Published by Air Quality Consultants Ltd on behalf of Defra, the Welsh Assembly Government, the Scottish Executive and the Department of the Environment Northern Ireland										
Step 1:	**Step 2:**	**Step 3:**	**Step 4:**							
Select the Laboratory that Analyses Your Tubes from the Drop-Down List	Select a Preparation Method from the Drop-Down List	Select a Year from the Drop-Down List	**Where there is only one study for a chosen combination, you should use the adjustment factor shown with caution. Where there is more than one study, use the overall factor[3] shown in blue at the foot of the final column.**							
If a laboratory is not shown, we have no data for this laboratory.	If a preparation method is not shown, we have no data for this method at this laboratory.	If a year is not shown, we have no data[2]	If you have your own collocation study then see footnote[4]. If uncertain what to do then contact the Review and Assessment Helpdesk 0117 328 3668 aqm-review@uwe.ac.uk.							
Analysed By[1]	**Method** To undo your selection, choose (All) from the pop-up list	**Year[5]** To undo your selection, choose (All)	**Site Type**	**Local Authority**	**Length of Study (months)**	**Diffusion Tube Mean Conc. (Dm) (μg/m3)**	**Automatic Monitor Mean Conc. (Cm) (μg/m3)**	**Bias (B)**	**Tube Precision[6]**	**Bias Adjustment Factor (A) (Cm/Dm)**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	R	Castlereagh BC	12	31	33	-6.9%	P	**1.07**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	R	Dumfries and Galloway Counci	12	37	38	-1.9%	P	**1.02**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	R	Lisburn CC	11	29	29	-1.0%	P	**1.01**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	UC	Manchester CC	12	44	45	-2.0%	P	**1.02**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	B	North Down BC	11	47	25	90.3%	P	**0.53**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	B	Warrington BC	12	25	25	3.2%	G	**0.97**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	R	Wrexham CBC	10	21	20	6.0%	P	**0.94**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	S	Chichester DC	10	35	31	13.1%	P	**0.88**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	B	Wigan MBC	11	28	27	1.9%	G	**0.98**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	B	Wigan MBC	11	31	21	45.3%	G	**0.69**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007	K	AEA Tech Intercomparison	11	108	105	3.4%	G	**0.97**
Casella Seal / GMSS / Caselle	10% TEA in Water	2007		**Overall Factor[3] (11 studies)**				**Use**		**0.90**

[1] For Casella Stanger/Bureau Veritas (NOT Bureau Veritas Labs) use Gradko 50% TEA in Acetone; for Bureau Veritas Labs and Eurofins use Casella Seal/GMSS/Casella CRE/Bureau Veritas Labs/Eurofins; for Staffordshire County Analyst use Staffordshire CC SS

[2] In this situation it would be reasonable to use data from the nearest year.

[3] Overall factors have been calculated using orthogonal regression to allow for uncertainty in both the automatic monitor and diffusion tube. The uncertainty of the diffusion tube has been assumed to be double that of the automatic monitor.

[4] If you have your own collocation study, please send your data to us, so that it can be included here. If this is not possible, but you wish to combine these factors with your own, select and copy the relevant data from this spreadsheet and paste them into a new one (otherwise your calculations will include hidden data). Then add your own data and calculate the bias. To obtain a new correction factor that includes your data, average the bias (B) values, expressed as a factor, i.e. -16% is -0.16. Next add 1 to this value, e.g. -0.16 + 1.00 = 0.84 in this example, then take the inverse to give the bias adjustment factor 1/0.84 = 1.19. (This will not be exactly the same as the correction factor calculated using orthogonal regression as used in this spreadsheet, but will be reasonably close).

[5] Where an annual data set falls into two years it has been ascribed to the year in which most of the data fall.

[6] Tube precision is determined as follows: G = Good precision - coefficient of variation (CV) of diffusion tube replicates is considered good when the CV of eight or more periods is less than 20%, and the average CV of all monitoring periods is less than 10%; P = Poor precision - CV of four or more periods >20% and/or average CV >10%; S = Single tube, therefore not applicable; na = not available.

Table A2-2 Bias adjustment calculation, AEA spreadsheet

Checking Precision and Accuracy of Triplicate Tubes

AEA Energy & Environment
From the AEA group

	Diffusion Tubes Measurements									Automatic Method		Data Quality Check	
Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 μgm^{-3}	Tube 2 μgm^{-3}	Tube 3 μgm^{-3}	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean	Period Mean	Data Capture (% DC)	Tubes Precision Check	Automatic Monitor Data
1	04/01/2007	30/01/2007	33.0		30.0	32	2.1	7	19.1	24.9	99.8	Good	Good
2	30/01/2007	01/03/2007	47.0	48.0	45.0	47	1.5	3	3.8	36.5	100	Good	Good
3	01/03/2007	03/04/2007	32.0	42.0	25.0	33	8.5	26	21.2	32.7	100	Poor Precision	Good
4	03/04/2007	02/05/2007	39.0	40.0	27.0	35	7.2	20	18.0	39	99.6	Poor Precision	Good
5	02/05/2007	04/06/2007	27.0	31.0	28.0	29	2.1	7	5.2	30	99.9	Good	Good
6	04/06/2007	03/07/2007	62.0	64.0	60.0	62	2.0	3	5.0	28	93.3	Good	Good
7	03/07/2007	01/08/2007	24.0	20.0	37.0	27	8.9	33	22.1	19	77.8	Poor Precision	Good
8	01/08/2007	05/09/2007	48.0	37.0	29.0	38	9.5	25	23.7	22	91.8	Poor Precision	Good
9	05/09/2007	02/10/2007	41.0	13.0	43.0	32	16.8	52	41.7	26	91.4	Poor Precision	Good
10	02/10/2007	31/10/2007	43.0	32.0	35.0	37	5.7	16	14.1	32	100	Good	Good
11	31/10/2007	03/12/2007		49.0	57.0	53	5.7	11	50.8	32.1	99.7	Good	Good
12	03/12/2007	03/01/200	50.0	49.0	52.0	50	1.5	3	3.8	36.5	99.9	Good	Good
13													

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

Overall survey --> Poor precision | Good Overall DC

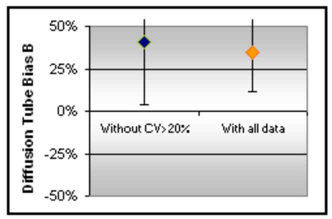
Site Name/ ID:

Precision 7 out of 12 periods have a CV smaller than 20%

(Check average CV & DC from Accuracy calculations)

Accuracy (with 95% confidence interval)
without periods with CV larger than 20%
Bias calculated using 7 periods of data
Bias factor A 0.71 (0.56 - 0.97)
Bias B 40% (3% - 77%)
Diffusion Tubes Mean: 44 μgm^{-3}
Mean CV (Precision): 7
Automatic Mean: 31 μgm^{-3}
Data Capture for periods used: 99%
Adjusted Tubes Mean: 31 (25 - 43) μgm^{-3}

Accuracy (with 95% confidence interval)
WITH ALL DATA
Bias calculated using 12 periods of data
Bias factor A 0.76 (0.64 - 0.92)
Bias B 32% (9% - 56%)
Diffusion Tubes Mean: 40 μgm^{-3}
Mean CV (Precision): 17 caution
Automatic Mean: 30 μgm^{-3}
Data Capture for periods used: 96%
Adjusted Tubes Mean: 30 (25 - 36) μgm^{-3}



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