DETAILED AIR QUALITY ASSESSMENT

Ipswich Borough Council

Final Report

July 2005

IPSWICH BOROUGH COUNCIL

DETAILED AIR QUALITY ASSESSMENT

FINAL REPORT

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1 INTRODUCTION

1. Introduction

Faber Maunsell was commissioned by Ipswich Borough Council to undertake a Detailed Air Quality Assessment. This Assessment forms part of the second round of the local authority review and assessment process.

The aim of this study was to determine whether there are any locations in Ipswich that are likely to fail to meet the UK National Air Quality Objectives. The previous review and assessment report produced by Ipswich Borough Council [Ref 1] indicated that nitrogen dioxide (NO_2) and particulate matter (PM_{10}) pollution should be further investigated by means of a Detailed Assessment.

2 LITERATURE REVIEW

2. Literature Review

2.1. Overview of Recent Air Quality Legislation and Policy

The provisions of Part IV of the Environment Act 1995 establish a national framework for air quality management, which requires all local authorities in England, Scotland and Wales to conduct local air quality reviews. Section 82(1) of the Act requires these reviews to include an assessment of the current air quality in the area and the predicted air quality in future years. Should the reviews indicate that the standards prescribed in the National Air Quality Strategy (NAQS) [Ref 2] and the Air Quality (England) (Amendment) Regulations 2002 [Ref 3] will not be met, the local authority is required to designate an Air Quality Management Area (AQMA). Action must then be taken at a local level to ensure that air quality in the area improves. This process is known as 'local air quality management'.

2.2. National Air Quality Standards and Objectives

The NAQS identifies eight ambient air pollutants that have the potential to cause harm to human health. These pollutants are associated with local air quality problems, with the exception of ozone, which is instead considered to be a regional problem. The Air Quality Regulations set standards and objectives for the seven pollutants that are associated with local air quality, which aim to reduce the health impacts of the pollutants to negligible levels.

The standards and objectives stated in the Air Quality Regulations are listed in Appendix B. The changes made with regard to benzene, carbon monoxide and particulate matter (PM_{10}), as detailed in the Air Quality (England)(Amendment) Regulations 2002, are included.

2.3. The Phased Approach to Review and Assessment

The second round of the review and assessment process has been split into two phases: an Updating and Screening Assessment and a Detailed Assessment.

The first phase, the Updating and Screening Assessment, has been designed to review the changes in air quality issues that have occurred within each local authority since the first round of review and assessment. Thus, it should cover:

- new monitoring data
- new objectives
- new sources of pollution
- significant changes to existing sources of pollution.

These changes are assessed using appropriate screening methods.

The Updating and Screening Assessment also re-examines locations and sources, e.g. road junctions, bus stations, domestic burning, fugitive sources, etc., that have been highlighted as issues during the previous round of review and assessment.

Where the Updating and Screening Assessment has identified a risk that an air quality objective may be exceeded, the local authority must undertake a Detailed Assessment. The aim of this assessment is to determine, with as much certainty as is possible, whether or not an air quality objective will be exceeded. If an exceedence is predicted, the local authority should designate an AQMA to cover the area of the exceedence.

2.4. Ipswich Borough Council's Updating and Screening Assessment

Ipswich Borough Council completed their Updating and Screening Assessment (USA) in 2003 [Ref 1]. This study stated that the air quality standards and objectives were unlikely to be exceeded in the cases of carbon monoxide, 1,3-butadiene, lead, benzene and sulphur dioxide, and therefore, concluded that no further assessments of these pollutants were required. However, the USA identified that breaches of the standards and objectives relating to nitrogen dioxide (NO_2) were likely at three locations in Ipswich, namely St Margaret's Street, Star Lane and Norwich Road, as a result of road traffic emissions. The report also stated that particulate matter (PM_{10}) emissions from road traffic and an industrial site should be further investigated. Thus, the report concluded that a detailed assessment of NO_2 and PM_{10} was necessary.

3 POLLUTANTS OF CONCERN

3. Pollutants of Concern

3.1. Nitrogen Dioxide

3.1.1. National Air Quality Objectives

In an attempt to reduce ambient nitrogen dioxide (NO_2) levels, the Government and the Devolved Administrations have adopted two air quality objectives to be achieved by the end of 2005:

- an annual mean concentration of 40 µg/m^3 (21 ppb)
- a 1-hour mean concentration of 200 µg/m^3 (105 ppb) not to be exceeded more than 18 times per year (equivalent to a 99.8th percentile).

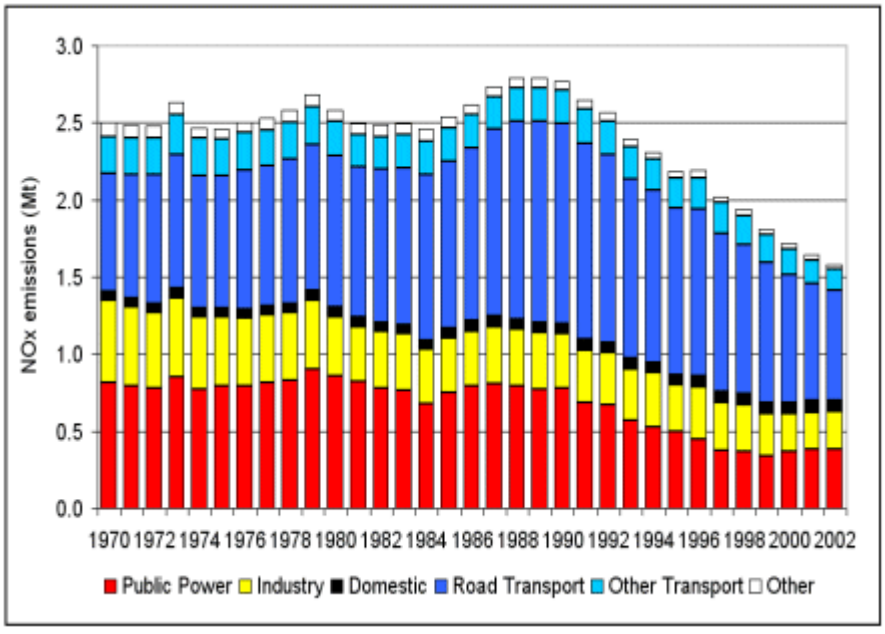
In practice, meeting the annual mean objective in 2005 is expected to be considerably more demanding than achieving the 1-hour objective. Thus, if the annual mean objective is not exceeded, it can be assumed that the 1-hour objective will be met.

3.1.2. UK Emissions

NO_2 is one of the members of a family of pollutants called the oxides of nitrogen (NO_X), the other member being nitric oxide (NO). A major source of NO_X is motor vehicle exhausts as it is formed as a by-product of the high-temperature combustion processes in the engine. The majority of NO_X emitted from vehicles is in the form of NO, a proportion of which is then oxidised in the air to produce NO_2. The conversion of NO to NO_2 takes place in the atmosphere via reactions with chemically active species, such as ozone (O_3).

As illustrated by Figure 1 [Ref 4], estimates for 2002 show that road transport accounted for 43% of the total UK emissions of NO_X, with the energy industry being the other main source. The contribution of road transport to emissions has declined significantly in recent years as a result of various policy measures, and further reductions are expected up until 2010 and beyond. For example, urban traffic NO_X emissions are estimated to fall by about 20% between 2000 and 2005, and by 46% between 2000 and 2010.

Figure 1 National Trend of Oxides of Nitrogen Emissions (MT/yr) (1970 – 2002)



3.1.3. Health Impacts

The health effects of NO_2 exposure can be chronic and/or acute. Studies of artificial exposure have shown that the chronic effects of the upper range of possible exposure concentrations might include changes in lung structure and metabolism, and reduced resistance of the lungs to bacterial infection. No clear link has been established between these effects and exposure to NO_2 from ambient air. Acute effects, including increased airway resistance and associated reduced pulmonary function, are experienced by some asthmatics, but there is no clear dose–response relationship. Exposure to NO_2 may also increase reactivity to natural allergens.

NO_X gases are also recognised as indirect greenhouse gases, and are one of the main contributors to acid deposition. Direct exposure of vegetation to NO_X may result in leaf damage or make plants more susceptible to attack by pests and disease. The effects of NO_X can be greatly influenced by the presence of other pollutants. In particular, NO_X and sulphur dioxide can significantly reduce vegetation growth rates at higher concentrations.

3.1.4. Atmospheric Chemistry of NO_X

Once released into the atmosphere, NO is oxidised to form NO_2 in a reaction with O_3 and other hydrocarbon-based oxidants. The availability of O_3 directly affects the ratio of NO to NO_2. Although motor vehicles are regarded as the primary source of NO, the diurnal variation of the NO_2 formed does not always vary in accordance with local traffic patterns. Nevertheless, measurements of NO_2 taken at kerbside and roadside monitoring sites typically show higher concentrations than those observed at background monitoring sites.

The Advisory Group on the Medical Aspects of Air Pollution Episodes [Ref 5] describe NO_X chemistry in the following way. In the atmosphere, the dominant oxide of nitrogen, NO, is progressively oxidised to NO_2, largely by reaction with ozone.

$$NO + O_3 \rightarrow NO_2 + O_2$$

A consequence of this reaction is that the amount of NO_X present as NO_2 is often limited by the availability of ozone. Close to NO_X sources, the fraction of NO_2 will generally be low. Further from the sources, in conditions of vigorous atmospheric mixing, the NO_X plume will be diluted with more O_3 and therefore the proportion of NO_2 will be higher. The relationship between NO, NO_2 and O_3 is complicated by a reaction that occurs during daylight, whereby NO_2 is photolysed by short wavelength light (greater than 400nm), to reform NO and O_3.

$$NO_2 + h\nu \rightarrow NO + O$$

$$O + O_2 \rightarrow O_3$$

Processes involving volatile organic compounds (VOCs) also influence NO_X chemistry. In the atmosphere, VOCs are oxidised to form peroxy radicals, which can then convert NO to NO_2. These reactions have been shown to significantly contribute to the oxidation of NO to NO_2 in urban locations.[Ref 6]

Understanding the mechanisms that are responsible for the elevated levels of NO_2 that occur during the winter months is an ongoing topic of air quality research. NO_2 levels increased nationally by around 30% between 1986 and 1991, and then decreased up until 2000. Future trends associated with NO_2 remain unclear at present.

3.1.5. Local NO_2 Monitoring

The Council operate one continuous analyser and a network of diffusion tubes to monitor NO_2 in Ipswich.

3.1.5.1 Continuous Analyser Data

The continuous analyser, referred to as the Piper's Court analyser, is located on St Margaret's Street at grid reference (616593, 244748). As the data capture for 2004 was 60%, it was necessary to make a seasonal adjustment in order to obtain an annual mean concentration. The methodology applied is that defined in Technical Guidance Note LAQM.TG(03)[Ref 7]. The four Automatic Urban and Rural Network (AURN) background sites used in the adjustment were Southend-on-Sea, St Osyth, Thurrock and Wicken. The mean concentrations recorded at these

sites during the period in which data was collected at the Piper's Court site were calculated and then compared with the annual mean concentrations to derive seasonal adjustment factors. The average of these factors was then applied to the data collected at the Piper's Court site to determine the annual mean concentration. Further details of these calculations are presented in Tables 1 and 2.

Table 1 Calculation of Seasonal Adjustment Factors

Site	NO_2 Concentration/µg/m^3		Seasonal Adjustment Factor
	Period Mean	Annual Mean	
Southend-on-Sea	26.3	23.7	0.90
St Osyth	23.0	20.0	0.87
Thurrock	38.6	35.5	0.92
Wicken	52.5	52.5	1.00
		Average Factor	0.92

Table 2 Seasonal Adjustment of the Continuous Analyser Data

Site	Mean Measured NO_2 Concentration /µg/m^3	Average Seasonal Adjustment Factor	Seasonally Adjusted Mean NO_2 Concentration/µg/m^3
Piper's Court	48.9	0.92	45.1

The seasonally adjusted annual mean concentration of NO_2 for 2004 is 45.1 µg/m^3, which exceeds the National Air Quality Strategy objective for 2005.

3.1.5.2 Diffusion Tube Data

Details of the diffusion tube network operated in Ipswich are presented in Table 3.

Table 3 Raw Diffusion Tube Results, 2004

Site Name	Site Number	Grid Reference	Data Capture /%	Mean Measured NO_2 Concentration /µg/m^3
Civic Drive	1	(615999, 244399)	58	31.5
Civic Drive co-locate	2	(615999, 244399)	58	30.2
Stoke Bridge	3	(616315, 243934)	58	34.9
Wherstead Road	4	(616257, 242619)	75	32.3
Star Lane	5	(616858, 244146)	75	44.8
Kings Avenue	6	(617303, 244415)	67	21.5
Nacton Road	7	(618971, 242329)	58	26.5
A14 junction	8	(620095, 241263)	83	34.2
A14 junction co-locate	9	(620095, 241263)	92	34.6
Heath Road	10	(619347, 245136)	42	34.8
St Margaret's Street	11	(616593, 244748)	75	45.7
St Margaret' s Street co-locate	12	(616593, 244748)	75	46.8
St Margaret's Street co-locate	19	(616593, 244748)	67	44.7
Norwich Road	13	(615339, 245423)	75	43.9
Chevalier Street	14	(615275, 245383)	92	49.2
Tavern Street	15	(616280, 244640)	92	28.7
Museum Street	16	(616086, 244571)	75	34.1
Museum Street co-locate	17	(616086, 244571)	75	33.3
Museum Street co-locate	18	(616086, 244571)	75	33.6

It can be seen that the data capture in 2004 ranged from 42% to 92%; therefore it was necessary to apply seasonal adjustments in order to derive annual mean concentrations. See

the previous section for details of the methodology and Table 4 for the derived adjustment factors and resulting annual mean concentrations.

It was also necessary to apply a bias correction factor to the diffusion tube results. Such factors account for the differences that often exist between the concentrations measured by diffusion tubes and those made by a more sophisticated monitoring technique, such as a continuous analyser. The bias correction factor applied to the data (1.10) was derived by AEA Technology by comparing the concentrations measured by the Piper's Court continuous analyser and the three co-located diffusion tubes on St Margaret's Street.

Table 4 Adjusted Diffusion Tube Results, 2004

Site Name	Mean Measured NO_2 Concentration/ µg/m^3	Average Seasonal Adjustment Factor	Seasonally Adjusted Mean NO_2 Concentration /µg/m^3	Bias Corrected Annual Mean NO_2 Concentration /µg/m^3
Civic Drive	31.5	1.03	32.4	35.6
Civic Drive co-locate	30.2	1.03	31.1	34.2
Civic Drive average				*34.9*
Stoke Bridge	34.9	0.86	29.9	32.9
Wherstead Road	32.3	1.03	33.4	36.7
Star Lane	44.8	1.02	45.5	**50.1**
Kings Avenue	21.5	1.04	22.3	24.6
Nacton Road	26.5	0.92	24.4	26.8
A14 junction	34.2	1.04	35.6	39.2
A14 junction co-locate	34.6	1.01	35.0	38.5
A14 average				*38.9*
Heath Road	34.8	1.02	35.3	38.9
St Margaret's Street	45.7	0.92	42.2	**46.4**
St Margaret's Street co-locate	46.8	0.92	43.2	**47.5**
St Margaret's Street co-locate	44.7	0.93	41.5	**45.7**
St Margaret's Street average				***46.5***
Norwich Road	43.9	1.03	45.3	**49.8**
Chevalier Street	49.2	1.01	49.9	**54.9**
Tavern Street	28.7	1.01	29.1	32.0
Museum Street	34.1	1.03	35.3	38.8
Museum Street Co-locate	33.3	1.07	35.6	39.2
Museum Street Co-locate	33.6	1.03	34.7	38.2
Museum Street average				*38.7*

Note: bold type indicates corrected annual mean NO_2 concentrations greater than the 2005 annual mean objective of 40 µg/m^3.

The 2005 annual mean objective for NO_2 was breached at four locations in Ipswich: Star Lane, St Margaret's Street, Norwich Road and Chevalier Street.

3.2. Particulate Matter

3.2.1. National Air Quality Objectives

In an attempt to reduce ambient PM_{10} levels, the Government and the Devolved Administrations have adopted two Air Quality Objectives for PM_{10}, to be achieved by the end of 2004:

- an annual mean concentration of 40 µg/m^3 (gravimetric)

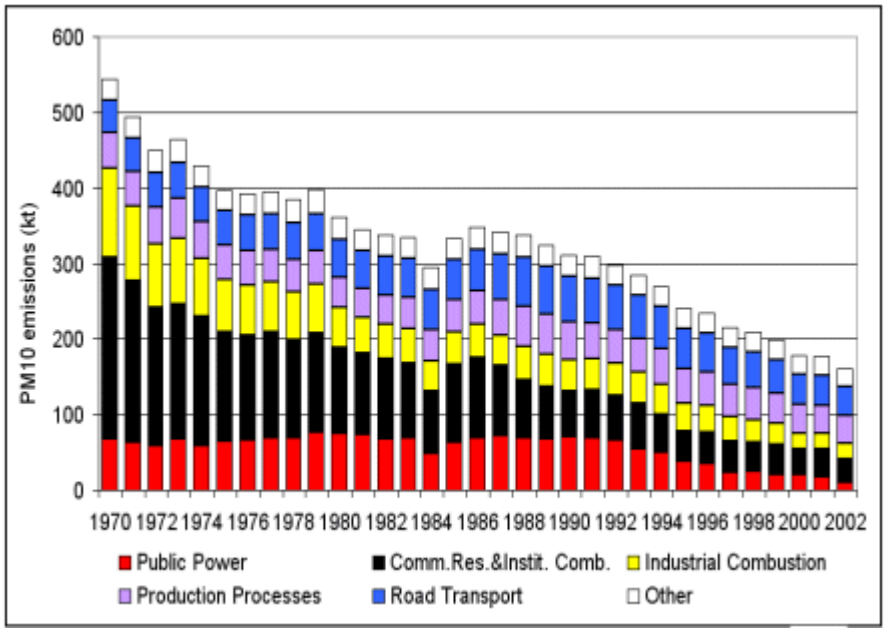
- a 24-hour mean concentration of 50 µg/m^3 (gravimetric) not to be exceeded more than 35 times per year.

Further objectives have been proposed for 2010 for PM_{10}, which are a 24-hour mean of 50 µg/m^3, with a maximum of 7 exceedences per year (equivalent to a 98.1th percentile) and an annual mean of 20 µg/m^3.

3.2.2. UK Emissions

Road transport, production processes, and commercial and residential combustion were the main sources of PM_{10} in 2002, as illustrated by Figure 2 [Ref 4]. It can also be seen that the total national emissions of PM_{10} have decreased considerably in the past few decades. This reduction is the result of legislative and technical control of emissions from both road traffic and industrial sources.

Figure 2 National Trend of PM_{10} Emissions (MT/yr) (1970 – 2002)



3.2.3. Health Impacts

Particulate matter is composed of a wide range of materials, and is typically assessed as total suspended particulates or as a mass size fraction. The European air quality standards have adopted the PM_{10} standard for the assessment of fine particulate matter, which is the total mass size fraction at or below an aerodynamic diameter of 10 µm. Particles of this size have the greatest likelihood of reaching the lung.

Health effects of PM_{10} are largely linked with the worsening of pre-existing conditions. For instance, there is no evidence that exposure can cause asthma but its effects can lead to periods of excess deaths during periods of high particulate concentrations. Increases in mortality rates from heart and lung disease on exposure to different levels of PM_{10} have been measured to be 1.4% and 3.4% per 10 µg/m^3, respectively. However, the impact on heart disease-related fatalities has a greater impact on the population as heart disease accounts for 45% of deaths while lung disorders cause only 5% of deaths. There is some concern that fine particles from diesel exhaust may have a carcinogenic effect as air-stream entrained particles can carry adsorbed carcinogens into the respiratory system. The true effects are difficult to determine as they are masked by other parameters often associated with different exposure levels such as weather and lifestyle.

3.2.4. Regional PM_{10} Monitoring

The Council do not conduct any PM_{10} monitoring in Ipswich; therefore it is necessary to refer to the results of monitoring conducted in other towns and cities in order to obtain an understanding of PM_{10} pollution in the region.

Data from the three closest AURN sites to Ipswich that monitor PM_{10} are presented in Table 5. It can be seen that the annual and daily mean objectives were not exceeded in 2004.

Table 5 Regional PM_{10} Monitoring Data, 2004

Site	Site Type	Annual Mean PM_{10} Concentration/µg/m^3	Number of Exceedences of the Daily Mean
Norwich Centre	UC	22	1
Southend-on-Sea	UB	18	0
Thurrock	UB	25	7

Notes: UC – urban centre; UB – urban background.

4 MODELLING METHODOLOGY

4. Modelling Methodology

4.1. AAQuIRE

The AAQuIRE 6.1.1 regional air quality model was used to predict concentrations of NO_2 and PM_{10} in Ipswich for the base year (2004) and the future air quality objective years (2005 for NO_2 and 2010 for PM_{10}).

The AAQuIRE regional dispersion model was developed by Faber Maunsell and has been used widely for the past 12 years. The model uses the dispersion algorithms, CALINE4 and AERMOD, which have been independently and extensively validated. A more detailed description of the AAQuIRE dispersion model is included in Appendix C.

AAQuIRE is capable of modelling the four main categories of air pollutant sources: road traffic sources; industrial sources (Part A and B processes); diffuse sources (e.g. domestic heating); and mobile sources (e.g. airports, rail and shipping). This study involved an assessment of NO_2 and PM_{10} emissions from traffic on the main roads in Ipswich and also PM_{10} emitted by the industrial site operated by Tarmac. Contributions from other pollutant sources were amalgamated into the background concentration (see Section 4.4).

The modelling procedure calculated the pollutant concentrations at a Cartesian grid of receptors that covered the study area. The receptors were evenly spaced at 10-metre intervals to ensure that a high level of spatial resolution was obtained. The results are presented as plots of pollutant concentration contours.

4.2. Traffic Data and Emission factors

In order to determine emission rates of pollutants, the model requires annual average daily traffic (AADT) flows, vehicle speeds and the proportion of heavy goods vehicles (HGVs) for all the road links to be considered. It also takes into account future changes in exhaust emissions resulting from changes in legislation.

Traffic data were supplied by Ipswich Borough Council. These data took the form of AADTs, the percentage of HGVs and average speeds, and were based on 12-hour counts conducted at sixteen locations in Ipswich in 2003 and 2004. The Council calculated data for future years by applying a growth factor of 1% per annum. The traffic dataset is presented in Appendix D.

Road transport represents the major source of pollution in the study areas and it was therefore imperative that the emission data were as accurate as possible. Speed-related emission factors for NO_2 and PM_{10} were derived from the latest factors supplied on the National Atmospheric Emissions Inventory website [Ref 4].

The emission rates of some pollutants are higher when the engine is cold. Cars travel for about 3 minutes or 1.6 km before the engine is 'hot'. This engine warming was accounted for by using a variable vehicle composition profile for each road and for each year. This information was taken from the first report by the Quality of Urban Air Research Group [Ref 6]. The enhancement of pollutant emissions resulting from cold starts is shown in Table 6. This table summarises the results of vehicle emissions testing, which has demonstrated, for example, that a Light Duty Vehicle (LDV) with a cold catalyst will emit 1.3 times the quantity of NO_X as the same LDV once the catalyst has warmed up. It has been assumed that 20% of LDVs are running 'cold' on all the roads in the network.

Table 6 Ratio of Emissions from Cold Engines Relative to Hot Engines

LDV Category	NO_X	PM_{10}
Non catalyst petrol	1.0	1.0
Catalyst petrol	1.3	2.0
Diesel	1.2	1.0

4.3. Industrial Source Data

PM_{10} emissions from an industrial site in Ipswich Port operated by Tarmac were modelled using AAQuIRE. The model requires the emission rate of PM_{10}, the stack height and diameter, and the exit velocity and temperature. These data were provided by Ipswich Borough Council and are listed in Table 7.

Table 7 Industrial Source Data, Ipswich

Site	Tarmac coating plant
Location	(616875, 243377)
Emission rate/g/s	0.001
Stack height/m	26.5
Diameter/m	0.12*
Gas temperature/K	338
Exit velocity/m/s	10.35
Percentage time operational	75

* – see Appendix F for further information regarding the stack diameter.

4.4. Background Concentrations

A large number of small sources of air pollutants exist, which individually may not be significant, but collectively, over a large area, need to be considered in the modelling process. The UK National Air Quality Information Archive[Ref 9] provides estimates of background NO_X and PM_{10} concentrations nationwide, with a spatial resolution of 1 km^2. The background concentrations applied to the model are those listed for the grid square centred on (620500, 243500): see Table 8. The concentrations for future years were determined by following the method outlined in Defra's Technical Guidance note, LAQM.TG(03)[Ref 7].

Table 8 Background Concentrations

Pollutant	Annual Mean Concentration /µg/m^3			
	2001	2004	2005	2010
NO_X	44.3	39.7	36.8	
PM_{10}		20.1		18.4

As the local authority has some control over emissions of NO_X but little or no control over the atmospheric oxidants that oxidise NO to NO_2, it is more appropriate to review NO_2 by first modelling NO_X. It is for this reason that a NO_X background is applied to the modelled NO_X concentration before being converted to NO_2 (see the next section).

4.5. Conversion of NO_X to NO_2

The proportion of NO_2 in NO_X varies greatly with location and time according to a number of factors, including the amount of ozone available and the distance from the emission source. The Derwent-Middleton NO_2/NO_X relationship (see Table 9) was used to convert the annual average NO_X concentrations generated by the model to annual average NO_2 concentrations. This relationship is based on data recorded at several London sites and is a good representation of the roadside ratio of NO_2 to NO_X. The relationship was used for both the base case and future years. However, as NO_X concentrations are expected to decline in future years, NO_2 concentrations will not be limited as much by ozone. Consequently, it is possible that the future year NO_2/NO_X ratio will increase.

Table 9 NO_X/NO_2 Relationship (NO_X expressed as NO_2 equivalent)

$NO_X/\mu g/m^3$	$NO_2/\mu g/m^3$	$NO_X/\mu g/m^3$	$NO_2/\mu g/m^3$	$NO_X/\mu g/m^3$	$NO_2/\mu g/m^3$
0	0.0	170	65.3	340	80.4
10	7.1	180	66.8	350	80.9
20	14.4	190	68.2	360	81.4
30	21.0	200	69.5	370	81.9
40	26.7	210	70.6	380	82.3
50	31.8	220	71.7	390	82.8
60	36.4	230	72.7	400	83.2
70	40.5	240	73.7	410	83.6
80	44.1	250	74.6	420	84.0
90	47.5	260	75.4	430	84.5
100	50.5	270	76.1	440	84.9
110	53.2	280	76.9	450	85.3
120	55.7	290	77.5	460	85.7
130	58.0	300	78.2	470	86.1
140	60.0	310	78.8	480	86.5
150	61.9	320	79.4	490	87.0
160	63.7	330	79.9	500	87.4

It should be noted that although NO_2 and NO_X concentrations were measured at the continuous analyser in Ipswich, a NO_X/NO_2 relationship was not derived from these data for application to the model results as the data capture was only 60%. The Derwent-Middleton relationship was applied instead as it represents the changes in the NO_X/NO_2 relationship that occur throughout the year.

4.6. Meteorological Data

After consultation with Trinity Consultants, a meteorological dataset was compiled using data from the nearest suitable station: Wattisham. Wind roses from the most recent years available were analysed and the most typical year (2001) was selected. The wind rose for Wattisham is presented in Appendix E, along with further details of the methodology used.

4.7. Modelling Errors

Monitoring data are subject to error, as are the results generated by the AAQuIRE 6.1.1 regional air quality model. The systematic errors in model results are caused by many factors, such as uncertainties in vehicle flows, vehicle speeds and the composition of the vehicle fleet. The treatment of error is considered in more detail in the results section of this report.

4.8. Model Verification

Model verification involves a comparison of the model results with local monitoring data. In this study, verification of the model has been undertaken using data collected by the continuous analysers and the diffusion tubes. This procedure is discussed further in the results section of this report.

5 RESULTS

5. Results

5.1. Model Results

This assessment considers the air quality standards and objectives as detailed in the UK NAQS (see Appendix B).

For NO_2, the standards to be achieved by the end of 2005 are an annual mean of 40 µg/m^3 (21 ppb), and an hourly mean of 200 µg/m^3 (105 ppb) to be exceeded no more than 18 times per year (equivalent to 99.8th percentile). It is generally considered that the annual mean objective is more stringent, and so if it is met, it can be assumed that the hourly objective will also be met.

For PM_{10}, the standards to be achieved by the end of 2004 are an annual mean of 40 µg/m^3 and a 24-hour mean of 50 µg/m^3 to be exceeded no more than 35 times per year (equivalent to 90.4th percentile). The 24-hour objective is considered to be more stringent. Using the relationship in Figure 8.1 in LAQM.TG(03), more than 35 exceedences of the 24-hour standard are likely at annual mean concentrations of 32 µg/m^3 and above. UK regulations are provisionally set to change in 2010: then the annual mean objective will be more stringent as it will be reduced to 20 µg/m^3.

Emphasis in the Review and Assessment guidance has been placed on non occupational, near ground-level, outdoor locations where the public might be exposed to air pollutants for a substantial part of the day. These locations include:

- residential properties
- schools, hospitals, libraries, etc.

An exceedence of an air quality objective is only considered to have occurred if the pollutant concentration breaches the objective at such a location.

5.1.1. NO_2 Results

The model results are presented in Appendix A as plots of NO_2 concentration contours. Figures 3 and 4 show the results for 2004, and Figures 5 and 6 show the results for 2005. There are contours 4µg/m^3 above and below the 2005 annual mean objective, the significance of which is explained in the model verification section below.

In the 2004 simulation, concentrations greater than 40 µg/m^3 are predicted along most of the roads included in the study. The areas of concern include the Norwich Road/Valley Road junction, St Margaret's Street, particularly near the junction with Fonnereau Road, the junction of Grimwade Street with St Helen's Street, Star Lane, Fore Street, Key Street, College Street and Bridge Street.

The 2005 simulation produced very similar results, as again, concentrations greater than 40µg/m^3 are predicted along most of the roads included in the study. At the Norwich Road/Valley Road junction, concentrations as high as 60 µg/m^3 are predicted at the roadside and the annual mean objective is breached up to approximately 25 m from the kerb. Similarly high roadside concentrations are predicted at many other locations in the town centre, and breaches occur up to approximately 50 m from the kerb.

5.1.2. PM_{10} Results

Figures 7 and 8 in Appendix A depict the PM_{10} concentration contours resulting from emissions from the industrial site operated by Tarmac. Both the 2004 and 2010 results are below the objective limits and it can be clearly seen that emissions from the main stack at the Tarmac site have very little impact on surrounding PM_{10} concentrations. The 2010 results are approximately 1.7 µg/m^3 lower than the 2004 results because of the predicted reduction in the background concentration. See Appendix F for further information regarding the modelling of emissions from the Tarmac site.

The PM_{10} concentrations resulting from road traffic sources are presented in Figures 9 to 12.

The results of the 2004 simulation (Figures 9 and 10) show that annual mean concentrations throughout the study area are well below 32 µg/m^3. The highest roadside concentrations are found near junctions and are no greater than 22 µg/m^3.

Pollutant levels for 2010 (see Figures 11 and 12) are generally predicted to be lower than the levels in 2004. Again, the changes are a consequence of the decrease in the background concentration of PM_{10}, although greater controls over vehicle emissions also contribute to the reductions. The increased pollution resulting from the predicted increases in traffic flows have been offset by these two factors.

Figures 11 and 12 show that there are very few areas where the 2010 annual mean objective of 20µg/m^3 is exceeded. Roadside concentrations greater than 20 µg/m^3 are only predicted to occur along parts of Grimwade Street, Fore Street, Key Street and College Street.

5.2. Model Verification and Errors

For an assessment such as this it is necessary that systematic and random errors, in both the modelling and the monitoring data, are considered and accounted for. The modelling results discussed above were verified by a consideration of the errors associated with the modelling process and the model input data.

5.2.1. Verification of Model Results

The systematic errors in modelling results can arise from many factors, such as uncertainties in vehicle flows, speeds and the composition of the vehicle fleet. Such errors can be addressed and corrected for by making comparisons with monitoring data.

The accuracy of the future year modelling results are relative to the accuracy of the base year results, therefore greater confidence can be placed in the future year concentrations if good agreement is found for the base year.

The raw model results for the 2004 NO_2 simulation were compared with the monitoring data collected within the study area in 2004 (see Table 10).

Table 10 Model Verification

Site Name	Analyser Type	2004 Annual Mean NO_2 Concentration /µg/m^3		
		Monitored	Modelled (uncorrected)	Modelled (corrected)
Chevalier Street	DT	54.9	32.4	47.1
Norwich Road	DT	49.8	37.9	60.2
Stoke Bridge	DT	32.9	30.7	42.1
St Margaret's Street	Continuous	45.1	31.8	45.1
Star Lane	DT	50.1	38.4	61.3

Notes: DT – diffusion tube

It can be seen that the model results do not agree very well with the monitoring results, with the exception of the data relating to the Stoke Bridge diffusion tube. The model was under predicting NO_2 concentrations at all five monitoring locations, most likely because of systematic errors in the input data. It was decided to correct the results with respect to the continuous analyser data, in order to more accurately predict NO_2 concentrations for the objective year.

The first step in this process was to subtract the background concentrations of NO_X from the modelled and monitored results to obtain the concentrations produced solely by traffic. Comparison of these figures allowed a linear scaling factor to be calculated, which was then applied to the modelled traffic contributions. Finally, the background concentration was added to the corrected modelled traffic contributions to produce the corrected modelled concentrations.

It can be seen that following correction, agreement between the modelling and monitoring data has improved at Chevalier Street but worsened at Stoke Bridge. Slight improvements have also been made in the Norwich Road and Star Lane data. However, most importantly, the model results relating to the continuous analyser at St Margaret's Street (the most accurate analyser in the study area) have been brought into line with the monitoring data. Despite these

improvements, it can be said that the model appears to be over predicting at the diffusion tube locations.
The model results of PM_{10} concentrations were not corrected because of the lack of monitoring data. It is possible that the model was under predicting PM_{10} concentrations in the study area.

5.2.2. Random Errors

Random errors in modelling and monitoring data also contribute to discrepancies between the two datasets. It is possible to account for the degree of random error in dispersion model results according to guidance provided by the NSCA [Ref 10].

'Stock U Values' allow the standard deviation of the model (SDM) to be calculated. The Stock U Value (U) for the NO_2 annual mean objective is between 0.1 and 0.2. The SDM can be calculated according to:

SDM = U x Co

where Co is the air quality objective. Thus:

SDM = 0.1 x 40 = 4 $\mu g/m^3$.

This calculation quantifies the uncertainty in the identification of areas where an exceedence of the air quality objective can be considered likely. For this reason, the NO_2 plots presented in Appendix A have marked on them concentration contours at 36, 40 and 44 $\mu g/m^3$.

Taking the above SDM value into account, the area of exceedence in Ipswich is extended along all of the roads in the study area to the 36 $\mu g/m^3$ contour.

6 SUMMARY AND CONCLUSIONS

6. Summary and Conclusions

Faber Maunsell was commissioned by Ipswich Council to undertake a detailed modelling study of NO_2 and PM_{10} concentrations arising from road traffic sources and an industrial source operated by Tarmac in Ipswich. Model simulations were run for the base year (2004) and future air quality objective years (2005 for NO_2 and 2010 for PM_{10}).

The assessment was performed using the AAQuIRE 6.1.1 regional dispersion model, which has been independently and extensively validated, and widely used for the past 12 years. Industrial source, traffic and meteorological data, and background concentrations of the two pollutant were input to the model to produce NO_2 and PM_{10} concentration plots for the required years.

The results of the NO_2 assessment indicate that the annual mean objective will be exceeded along most of the roads in the study area in 2005. Concentrations greater than 40 $\mu g/m^3$ are predicted to extend up to 50m from the kerb. The area of exceedence extends further if the standard deviation of the model is taken into account.

The results of the PM_{10} study demonstrate that emissions from the main stack at the Tarmac site have very little impact on surrounding PM_{10} concentrations. The assessment of road traffic emissions show that the resulting concentrations are well below the 2004 objective, and generally less than the 2010 objective (there were only a few areas where the 2010 annual mean objective of 20 $\mu g/m^3$ was exceeded).

A comparison of the 2004 model results of NO_2 concentrations with monitoring data collected in the study area showed that the model was generally under predicting concentrations. Thus the NO_2 model results were corrected. Although agreement between the model and the continuous analyser data was achieved, the corrected model appeared to be over predicting concentrations at diffusion tube locations.

The lack of PM_{10} monitoring data prevented a similar verification of the PM_{10} model results. It is possible that the model was also under predicting concentrations of this pollutant.

Based on the monitoring and modelling data, Ipswich Council are recommended to declare an Air Quality Management Area (AQMA) with regard to NO_2 pollution. The council may consider the following options:

- declare an AQMA according to the 40 $\mu g/m^3$ contour in the concentration plot
- declare an AQMA according to the 36 $\mu g/m^3$ contour in the concentration plot, in recognition of the standard deviation of the model results
- declare an AQMA according to the 44 $\mu g/m^3$ contour in the concentration plot, in recognition of the possible over prediction of the model at the diffusion tube locations in the study area

The council are also recommended to commence PM_{10} continuous monitoring at a roadside location. The resulting monitoring data would greatly improve the management of air quality issues in Ipswich.

7 REFERENCES

7. References

[1] Ipswich Borough Council, Report on the Updating and Screening Assessment for Air Quality in the Borough of Ipswich, December 2003

[2] Defra, The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, http://www.defra.gov.uk/environment/airquality/strategy/index.htm

[3] Defra, The Air Quality (England) (Amendment) Regulations 2002, http://www.hmso.gov.uk/si/si2002/20023043.htm

[4] National Atmospheric Emissions Inventory, http://www.naei.org.uk/

[5] Department of Health, Advisory Group on the Medical aspects of Air Pollution Episodes, Oxides of Nitrogen – Third Report, HMSO, 1993

[6] Department of the Environment, Quality of Urban Air Research Group, Urban Air Quality in the UK, 1993

[7] Defra, Local Air Quality Management, Technical Guidance, LAQM.TG(03), 2003

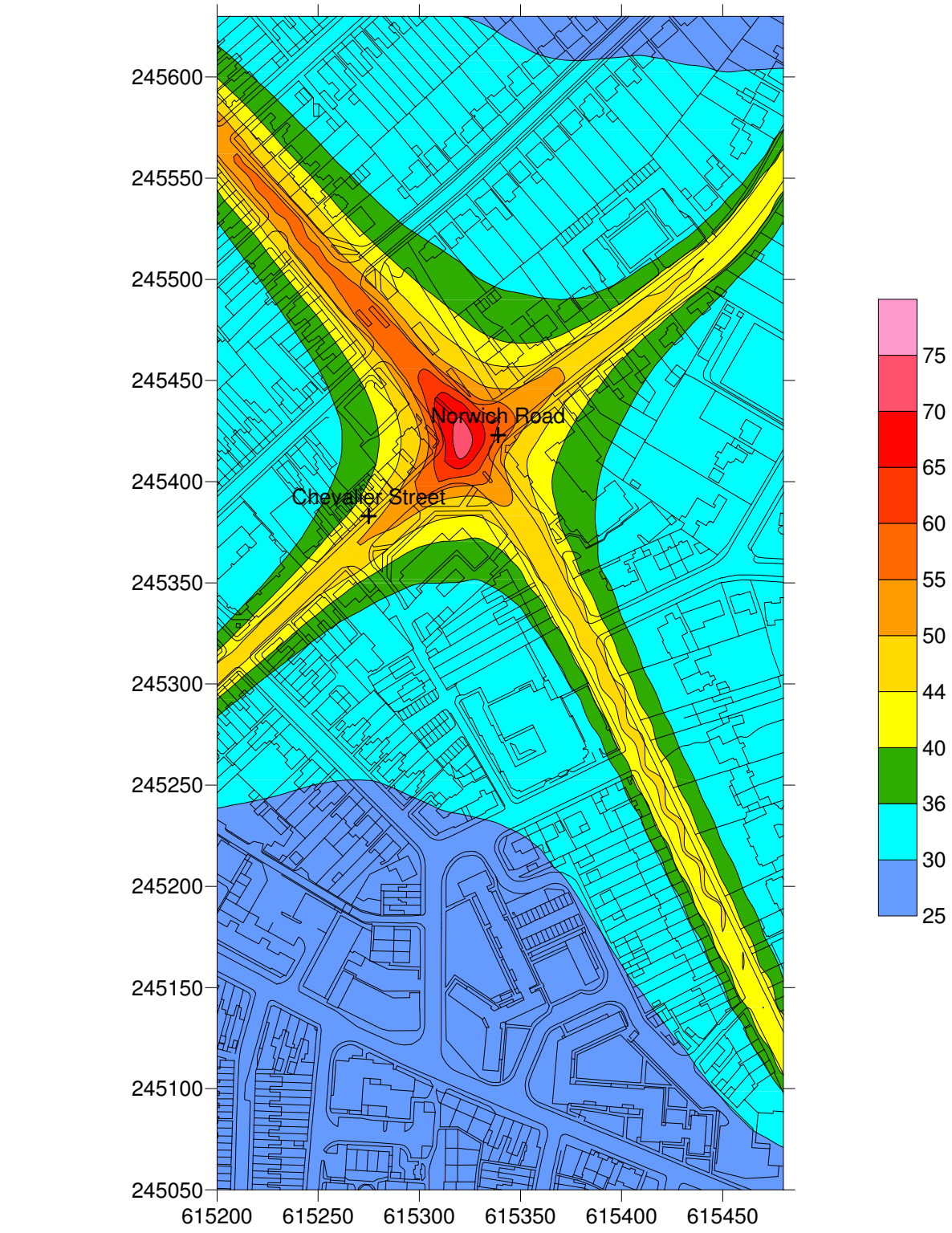
[8] Air Quality Expert Group, Nitrogen Dioxide in the United Kingdom, prepared for Defra, March 2004

[9] The UK National Air Quality Information Archive, http://www.airquality.co.uk/archive/index.php

[10] NSCA, Air Quality Management Areas: Turning Reviews into Action

Appendix A Model Results

Figure 3: Annual Mean NO_2 Concentrations (µg/m^3)
at the Norwich Road/Valley Road Junction, Ipswich (2004)



Scale: 1:3000 when A4 size

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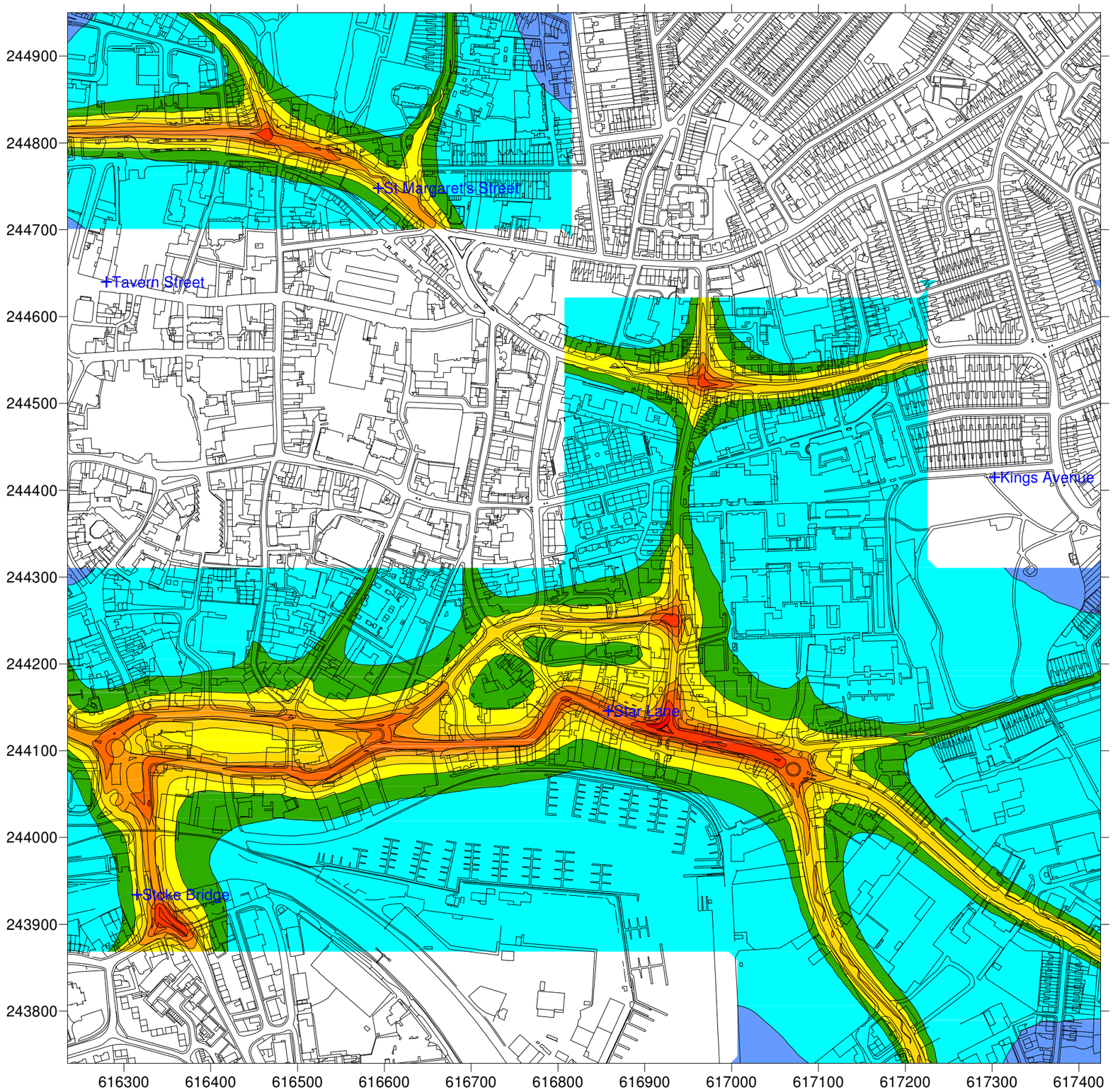

Figure 4: Annual Mean NO_2 Concentrations ($\mu g/m^3$), Ipswich (2004)

0 50 100 150 200 250

Scale: 1:5000 when A3 size

75
70
65
60
55
50
44
40
36
30
25

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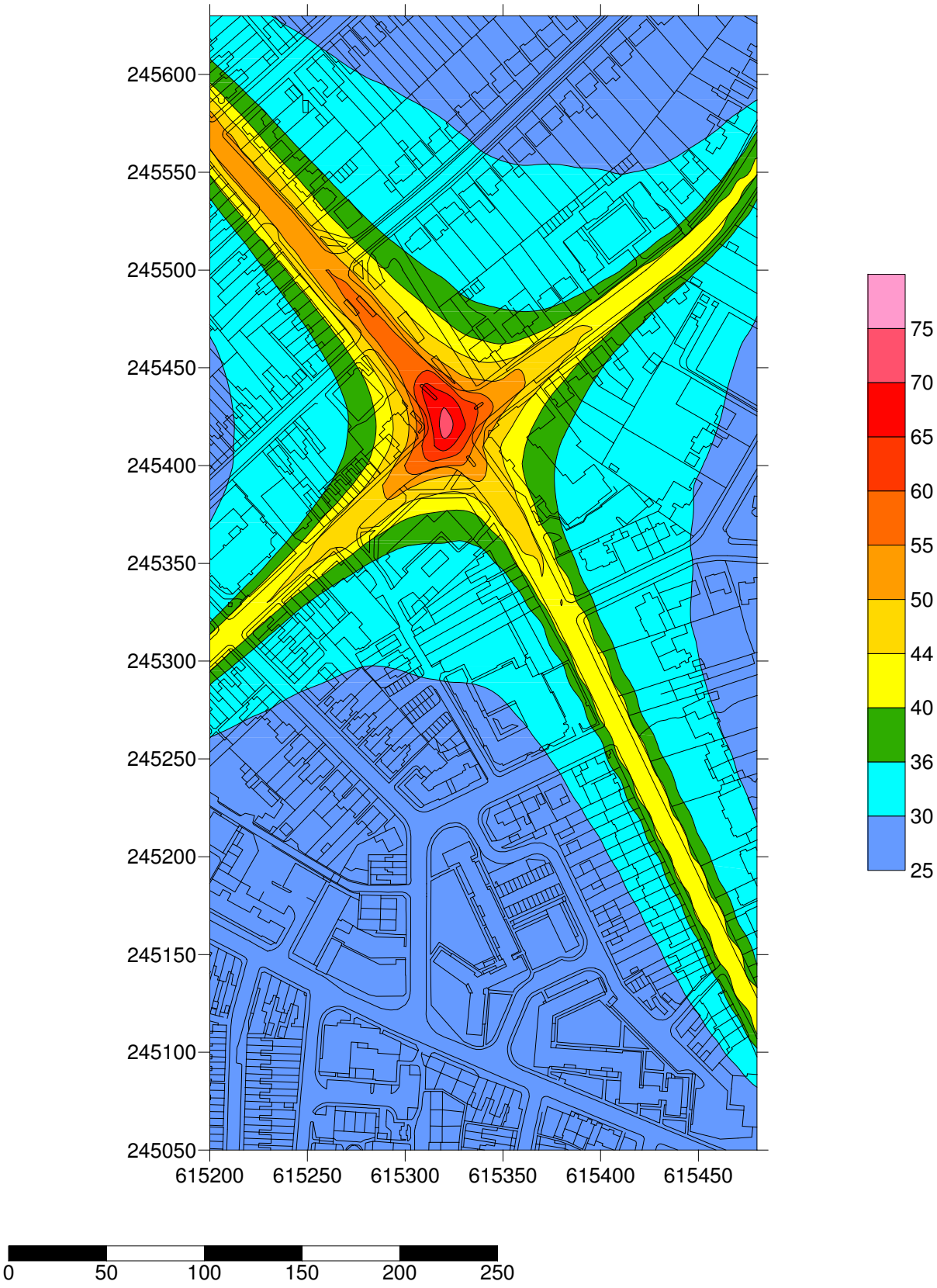
Figure 5: Annual Mean NO_2 Concentrations ($\mu g/m^3$)
at the Norwich Road/Valley Road Junction, Ipswich (2005)



Scale: 1:3000 when A4 size

FABER MAUNSELL | AECOM

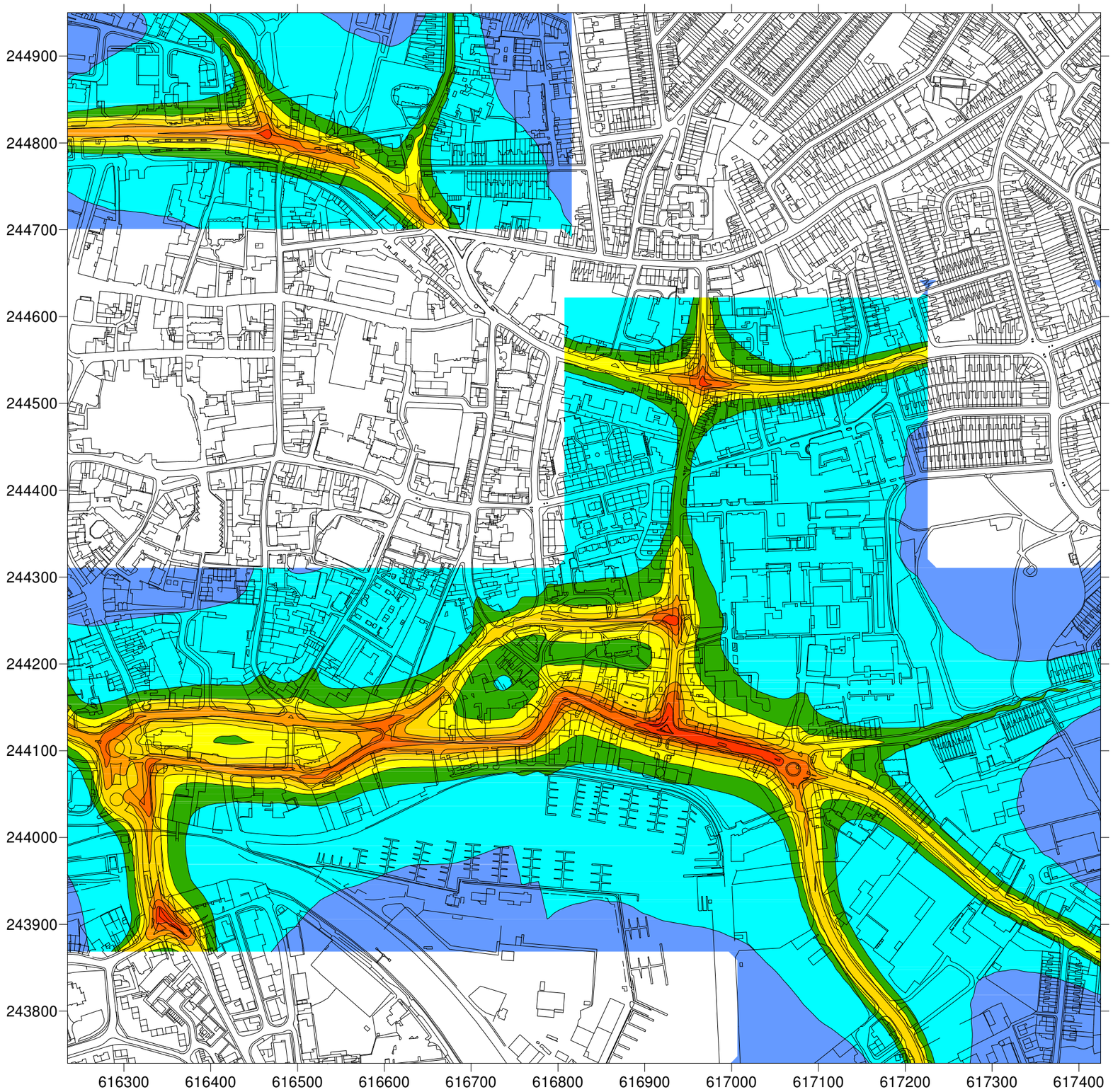


Figure 6: Annual Mean NO_2 Concentrations ($\mu g/m^3$), Ipswich (2005)

0 50 100 150 200 250

Scale: 1:5000 when A3 size

75
70
65
60
55
50
44
40
36
30
25

FABER MAUNSELL | AECOM

Figure 7: Annual Mean PM_{10} Concentrations ($\mu g/m^3$) around Tarmac Southern Ltd, Ipswich (2004)

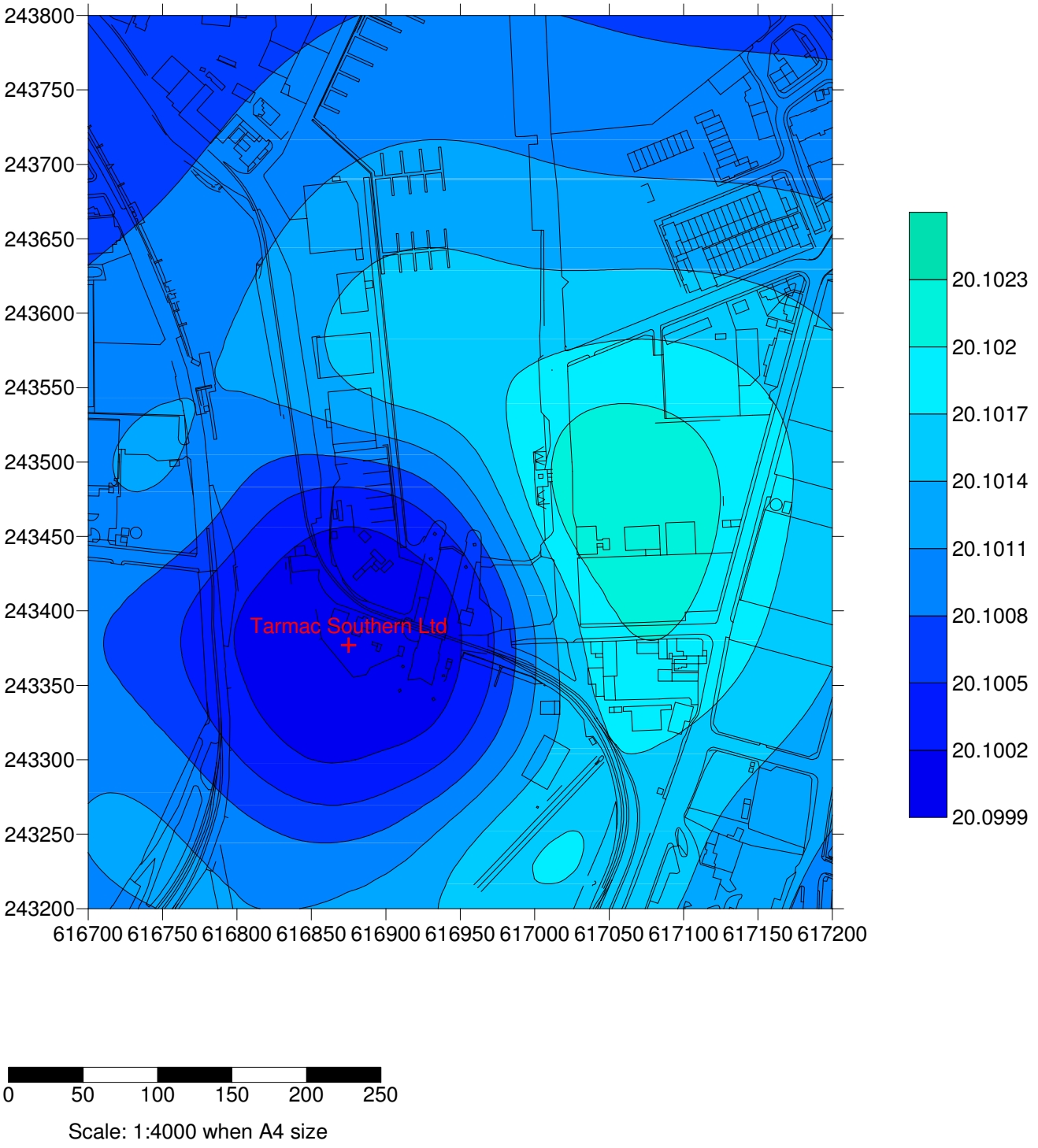


Figure 8: Annual Mean PM_{10} Concentrations (µg/m^3) around Tarmac Southern Ltd, Ipswich (2010)

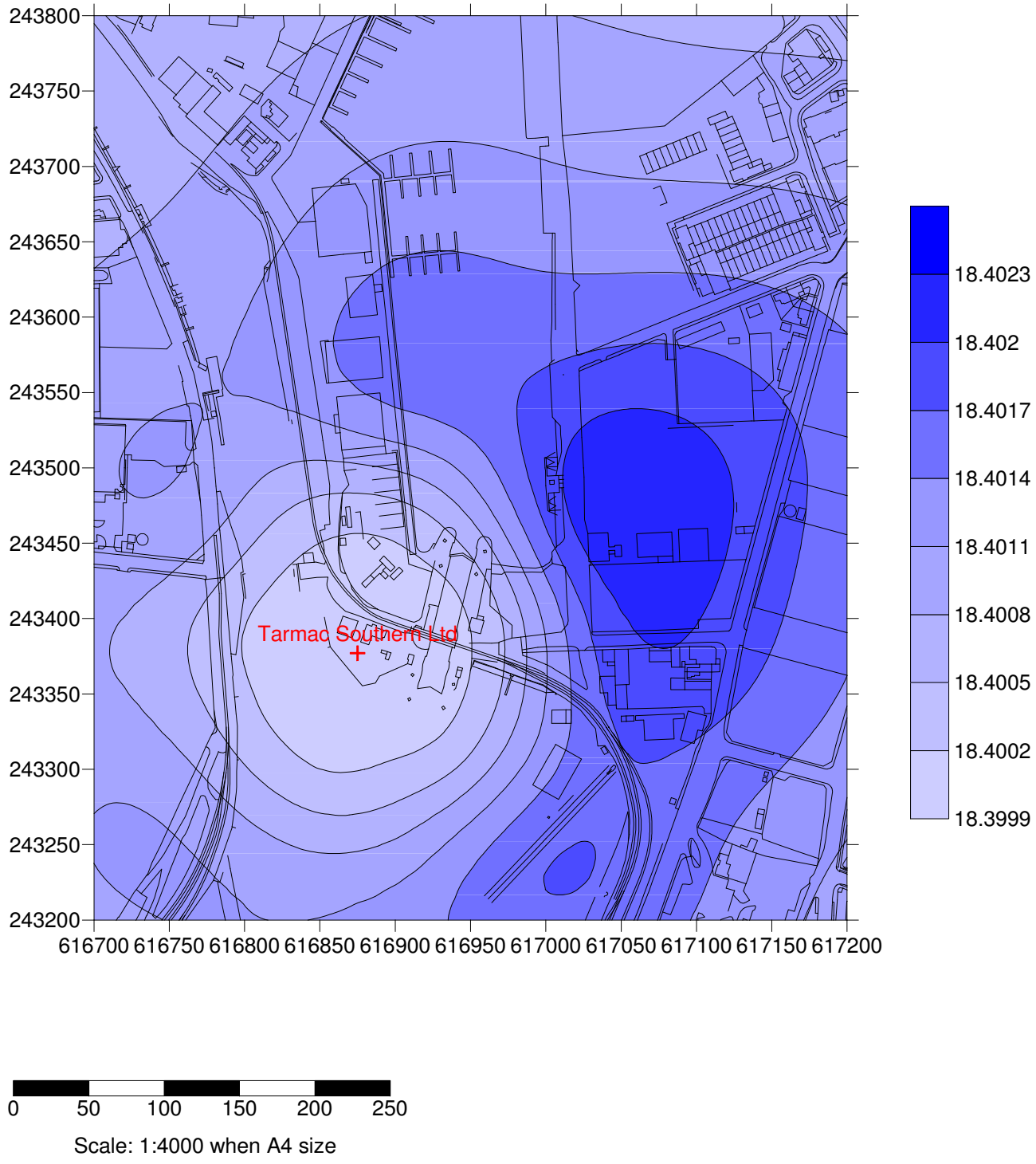
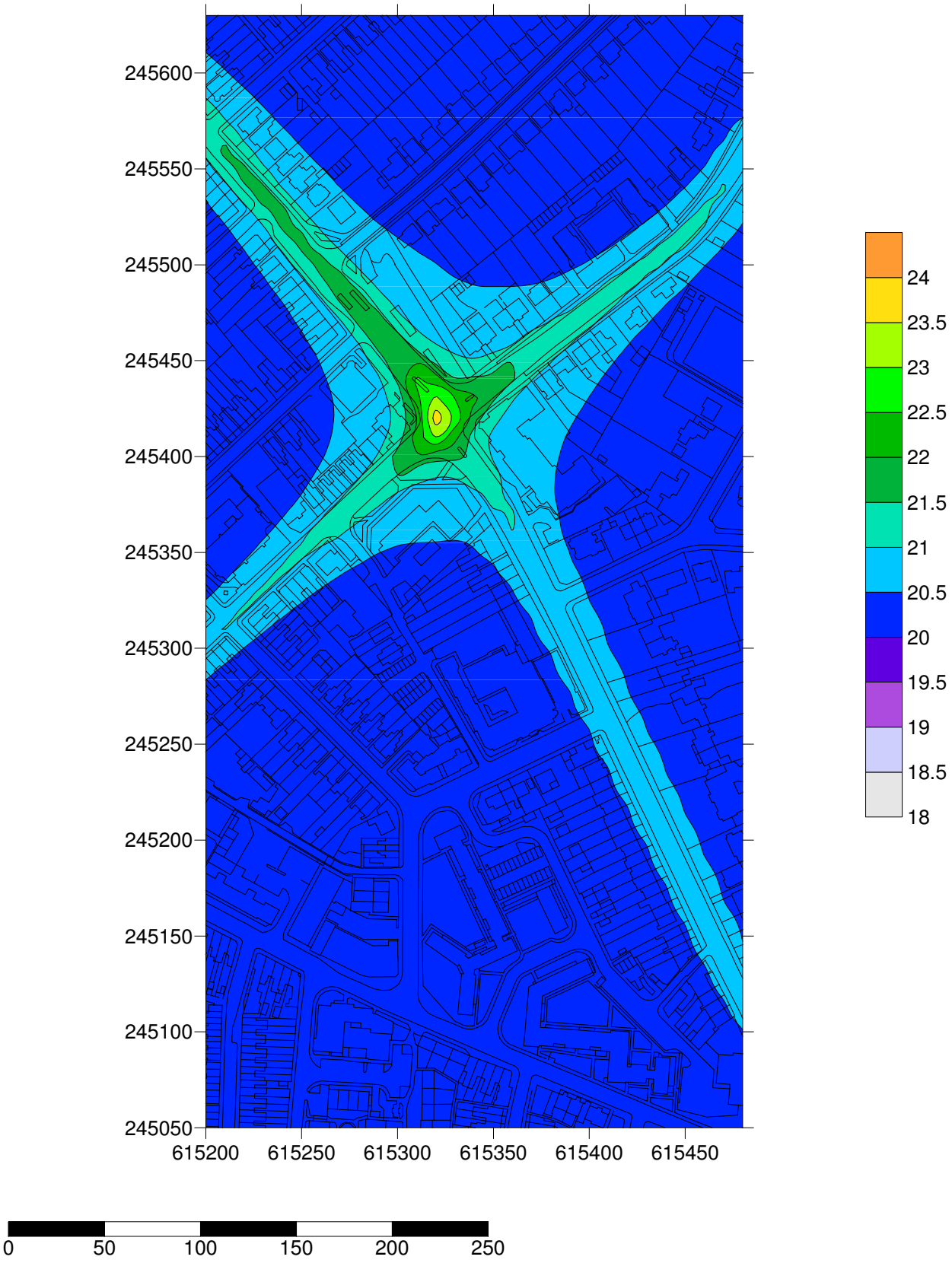


Figure 9: Annual Mean PM_{10} Concentrations ($\mu g/m^3$)
at the Norwich Road/Valley Road Junction, Ipswich (2004)



Scale: 1:3000 when A4 size

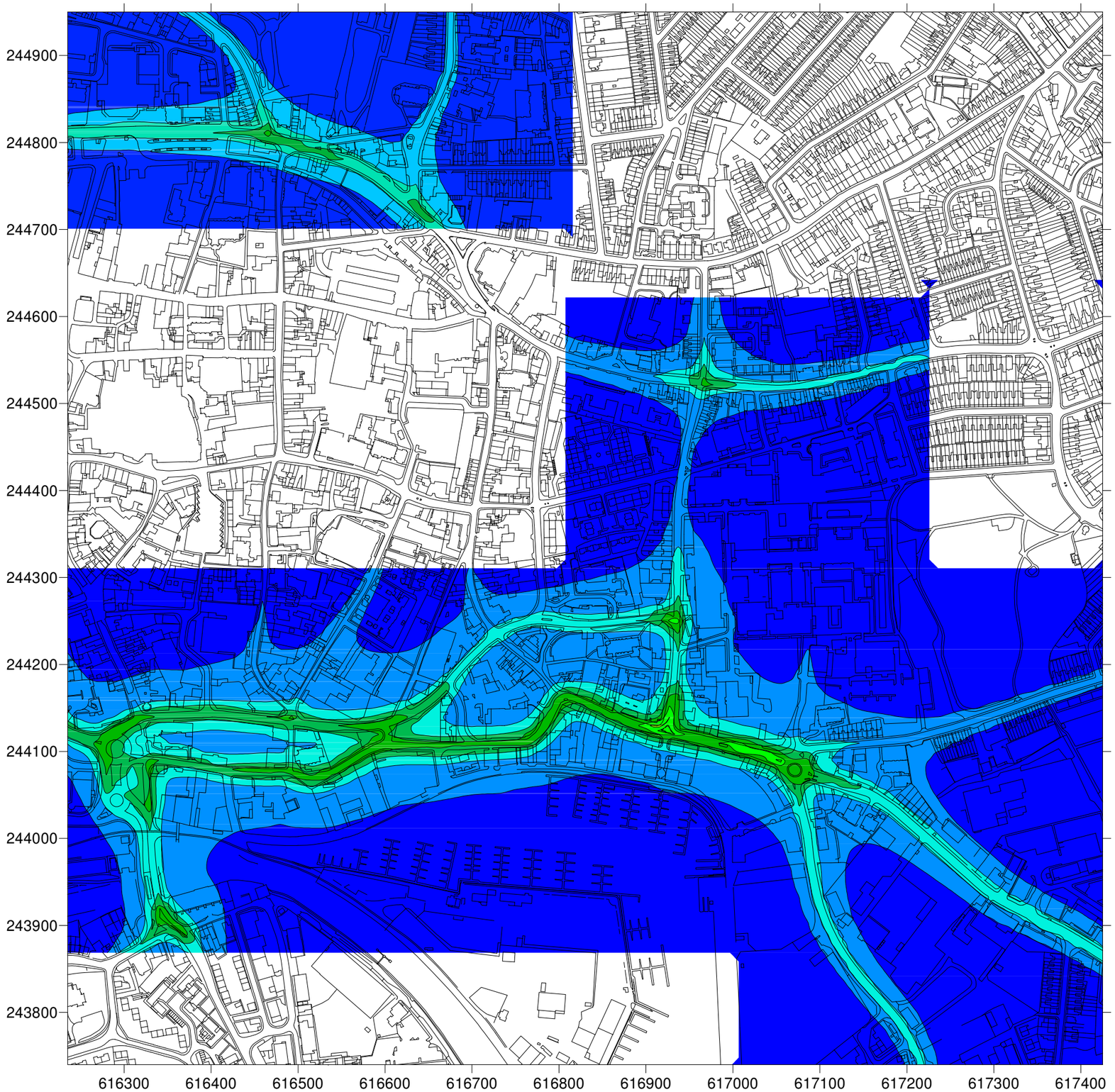


Figure 10: Annual Mean PM_{10} Concentrations ($\mu g/m^3$), Ipswich (2004)

0 50 100 150 200 250

Scale: 1:5000 when A3 size

24
23.5
23
22.5
22
21.5
21
20.5
20
19.5
19
18.5
18

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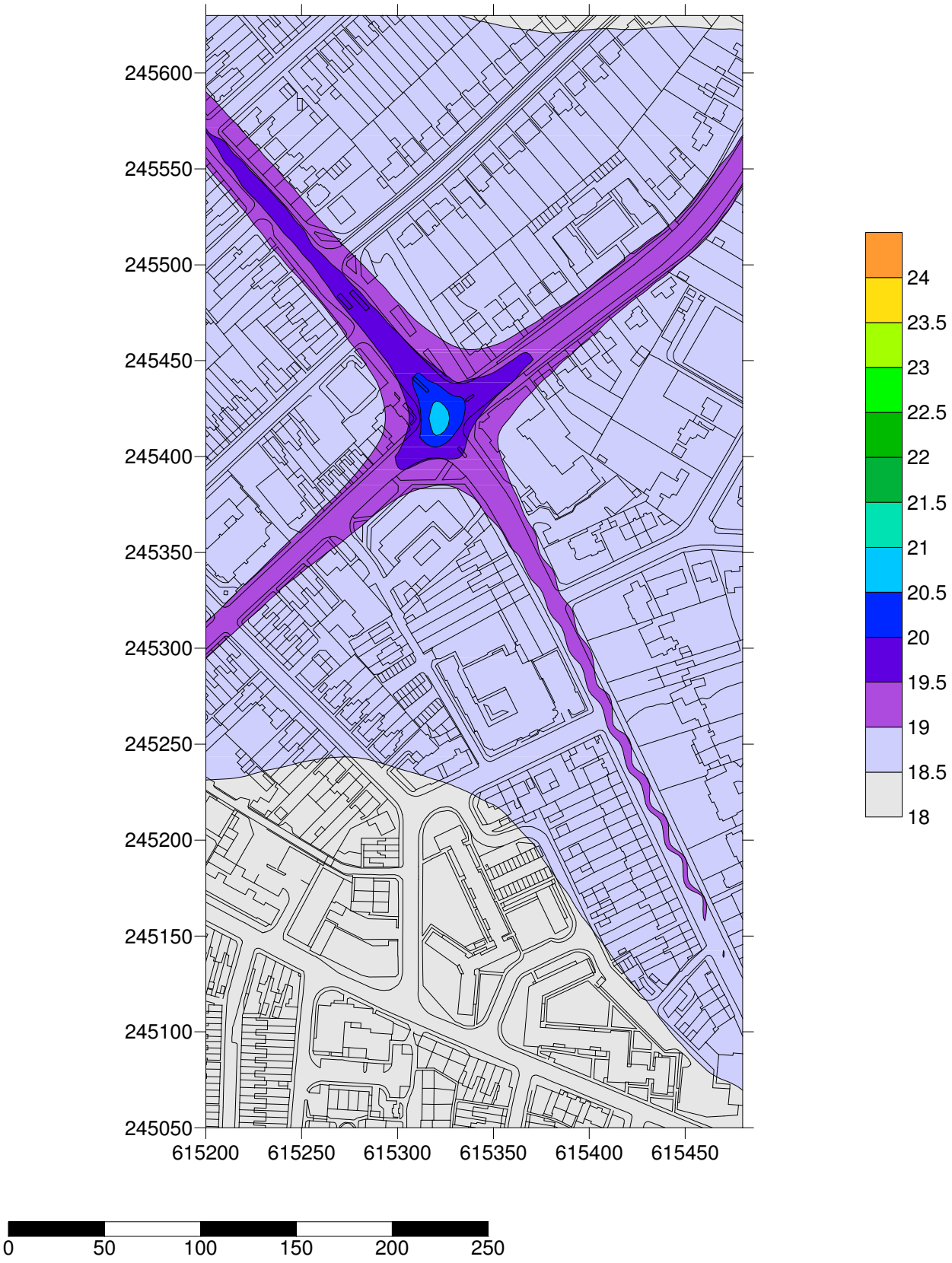
Figure 11: Annual Mean PM_{10} Concentrations ($\mu g/m^3$)
at the Norwich Road/Valley Road Junction, Ipswich (2010)



Scale: 1:3000 when A4 size

FABER MAUNSELL | AECOM

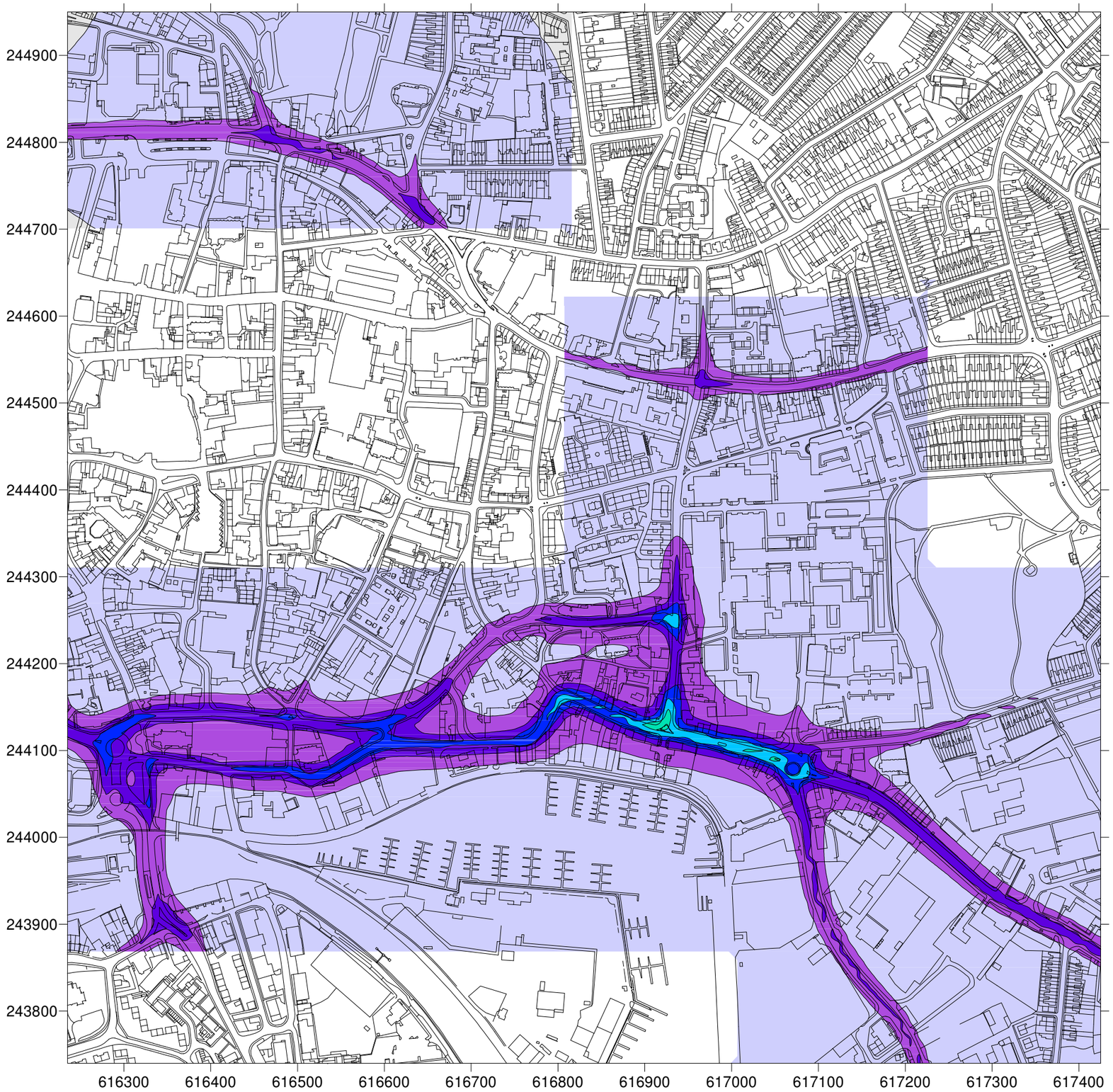


Figure 12: Annual Mean PM_{10} Concentrations ($\mu g/m^3$), Central Ipswich (2010)

0 50 100 150 200 250

Scale: 1:5000 when A3 size

24
23.5
23
22.5
22
21.5
21
20.5
20
19.5
19
18.5
18

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Appendix B UK National Air Quality Standards and Objectives

Table 11 UK Air Quality Standards and Objectives set in Regulations

Pollutant	Applies	Objective		Compliance	EU Objectives	
		Concentration	Measured as		Concentration	Date
Benzene	All UK	16.25µg/m^3 (5ppb)	Running annual mean	Dec 31, 2003	5µg/m^3	2010
	England & Wales	5µg/m^3 (1.5ppb)	Annual mean	Dec 31, 2003		
	Scotland	3.25µg/m^3 (1ppb)		Dec 31, 2010		
1,3-Butadiene	All UK	2.25µg/m^3 (1ppb)	Running annual mean	Dec 31, 2010	N/a	n/a
Carbon monoxide	All UK	10mg/m^3 (8.6ppm)	Maximum daily running 8 hour mean	Dec 31, 2003	10mg/m^3	2005
Lead	All UK	0.5µg/m^3	Annual mean	Dec 31, 2004	0.5µg/m^3	2005
		0.25µg/m^3	Annual mean	Dec 31, 2008		
Nitrogen dioxide	All UK	200µg/m^3 (10 ppb)	1 hour, 18 exceedences	Dec 31, 2005	200µg/m^3 (18 exceedences)	2010
		40µg/m^3 (21ppb)	Annual mean	Dec 31, 2005	40µg/m^3	2010
Particles (PM_{10}) (gravimetric)	All UK	50µg/m^3	24hr mean, 35 exceedences	Dec 31, 2004	50µg/m^3	2005
		40µg/m^3	Annual mean	Dec 31, 2004	40µg/m^3	2005
	Scotland	50µg/m^3	24hr mean, 7 exceedences	Dec 31, 2010	40µg/m^3	2010
		18µg/m^3	Annual mean	Dec 31, 2010	20µg/m^3	2010
Sulphur dioxide	All UK	350µg/m^3 (132ppb)	1 hour, 24 exceedences	Dec 31, 2004	350µg/m^3 (24 exceedences)	2005
		125µg/m^3 (47ppb)	24 hour mean, 3 exceedences	Dec 31, 2004	125µg/m^3 (18 exceedences)	2005
		266µg/m^3 (100ppb)	15 min mean, 35 exceedences	Dec 31, 2005	n/a	n/a

Table 12 UK Air Quality Standards and Objectives not set in Regulations

Pollutant	Applies	Objective		Compliance	Notes
		Concentration	Measured as		
Polycyclic aromatic hydrocarbons (PAHs)	All UK	0.25ng/m^3	Annual mean	Dec 31, 2010	To be set in future regulations, 2005.
Ozone	All UK	100µg/m^3	8 hour mean, 10 exceedences	Dec 31, 2005	Ozone is a national rather then local authority problem.
Particles (PM_{10}) (gravimetric)	London	50µg/m^3 (provisional)	24 hour mean, 10 exceedences	Dec 31, 2010	These particle objectives may be set in regulations once the EU has decided its new limit value.
		23µg/m^3 (provisional)	Annual mean	Dec 31, 2010	
		20µg/m^3 (provisional)	Annual mean	Dec 31, 2015	
	Rest of England & Wales	50µg/m^3 (provisional)	24 hour mean, 7 exceedences	Dec 31, 2010	
		20µg/m^3 (provisional)	Annual mean	Dec 31, 2010	
Nitrogen oxides	All UK	30µg/m^3 (16 ppb)	Annual mean	Dec 31, 2000	Vegetative based directives kept out of regulations as national problem. Targets have been met.
Sulphur dioxide	All UK	20µg/m^3 (8 ppb)	Annual mean	Dec 31, 2000	
		20µg/m^3 (8 ppb)	Winter mean (October – March)	Dec 31, 2000	

Appendix C AAQuIRE Description

The AAQuIRE 6.1.1 software is a system that predicts Ambient Air Quality in Regional Environments and comprises a regional air quality model and statistical package.

AAQuIRE was developed by Faber Maunsell Ltd to meet three requirements in predictive air quality studies. The first requirement was an immediate need for a system that produced results that could be interpreted easily by non-air quality specialists to allow for proper informed inclusion of air quality issues in wider fora, the main example being to allow consideration of air quality issues in planning processes. This was achieved by allowing results to be generated over a sufficiently large study area, and at an appropriate resolution, for the issue being considered. The results are also presented in a relevant format, which is normally a statistic directly comparable with an air quality criterion or set of measured data being considered. For example, the UKNAQS PM_{10} 24-hour objective level of 50µg/m^3 is expressed as a 90th percentile of hourly means. AAQuIRE can also produce results directly comparable with all ambient air quality standards, including:

- the annual average objective for nitrogen dioxide of 40 µg/m^3
- the 90th percentile of 24-hour means for PM_{10} of 50 µg/m^3
- the 99.9th percentile of 15-minute means for sulphur dioxide of 266 µg/m^3
- the nitrogen dioxide 1-hour mean objective of 200 µg/m^3, not to be exceeded more than 18 times a year.

The second requirement was for a system to be based, initially, on existing and well-accepted and validated dispersion models. This has two advantages. The primary one is that it avoids the need to prove a new model against the accepted models and therefore enhances acceptability. The second advantage is that when appropriate new models are developed they can be included in AAQuIRE and be compared directly with the existing models, and sets of measured data, using the most appropriate statistics.

The final primary requirement for AAQuIRE was a consideration of quality assurance and control. An important aspect of modelling is proper record keeping ensuring repeatability of results. This is achieved within AAQuIRE by a set of log files, which record all aspects of a study and allow model runs to be easily repeated.

The ways in which AAQuIRE and the models currently available within it operate are discussed below.

The operation of AAQuIRE can be divided into five main stages. These are:

- the preparation of the input data
- the generation of model input files
- dispersion modelling
- the statistical treatment of dispersion modelling results
- the presentation of results.

The first step in operating AAQuIRE is to prepare the input data. Data are needed on:

- meteorological data expressed as occurrence frequencies for specified combinations of wind speed, direction, stability and boundary layer height
- road system layout and associated traffic data within and immediately surrounding the study area
- industrial stack locations and parameters
- grid of model prediction locations (receptors)

for the year and pollutant to be modelled. The modelling is always carried out to give annual average results from which appropriate shorter period concentrations can be derived.

The second stage is the generation of the model input files required for the study. All the data collated in the first stage can be easily input into AAQuIRE, using the worksheets, drop down boxes and click boxes in the Data Manager section of the software. Data from spreadsheets can be easily pasted into worksheets, so that any complicated procedures required for data manipulation can be achieved before entry into AAQuIRE. Several diurnal and seasonal profiles can be defined for each separate source. The relevant meteorological data can also be specified at this stage.

The third stage is executing the models. The study area will usually be divided up into manageable grids and run separately using the Run Manager in AAQuIRE. The results from the separate files can be combined at a later stage. Pollutant concentrations are determined for each receptor point and each meteorological category and are subsequently combined.

The fourth stage is the statistical processing of the raw dispersion results to produce results in the relevant averaging period. Traffic sources and industrial sources can be combined at this stage provided the same receptor grid has been used for both. Background concentrations should also be incorporated at this stage.

The final stage is presentation of results. Currently the result files from the statistical interpretation are formatted to be used directly by the SURFER package produced by Golden Software Inc. Alternative formats are available to permit interfacing with other software packages. On previous projects the results have been imported into a GIS (e.g. ArcView and Map Info).

Currently AAQuIRE uses the CALINE4 model for the dispersion of road-traffic emissions and AERMOD for all other sources. Both these models are fully validated and have been extensively used worldwide. These are relatively complex models designed for detailed studies of local areas, which are used within AAQuIRE for both local and larger scale studies. This is considered necessary because of the frequent importance of local effects, such as traffic junctions, in properly assessing 'regional' effects. The modelling uncertainty for AAQuIRE is approximately ± 20%, which is well within the recommendations in technical guidance note LAQM.TG(03) [Ref 7].

Appendix D Traffic Data

Table 13 Traffic Data (AADTs and %HGV), Ipswich

Road*	AADT			%HGV		
	2004	2005	2010	2004	2005	2010
7Stoke St	11754	11871	12543	4.0	4.0	4.0
7Bridge St N	2464	2488	2637	15.9	15.9	15.9
7Bridge St S	7053	7123	7562	8.6	8.6	8.6
7Vernon St	6626	6693	7034	7.3	7.3	7.3
7Bridge St W	6626	6693	7104	7.3	7.3	7.3
7Bridge St E	6626	6693	7104	7.3	7.3	7.3
7Vernon St W	624	631	663	15.4	15.4	15.4
21Star Lane W	16510	16675	17526	5.1	5.1	5.1
21Star Lane E	14569	14715	15465	5.1	5.1	5.1
21Star Lane / Key St	1491	1506	1582	5.1	5.1	5.1
22College St E	20080	20280	21315	5.7	5.7	5.7
101Woodbridge Road E & W	3034	3064	3221	15.6	15.6	15.6
102Argyle St	5491	5546	5829	8.5	8.5	8.5
102St Helens St W	6633	6700	7041	7.8	7.8	7.8
102St Helens St E	9186	9278	9751	7.7	7.7	7.7
102Grimwade St	1825	1843	1937	13.8	13.8	13.8
209Fore St	25312	25565	26869	5.8	5.8	5.8
209Long St	1614	1631	1714	0.9	0.9	0.9
209Back Hamlet	4898	4947	5199	4.1	4.1	4.1
209Fore Hamlet	13439	13574	14266	3.2	3.2	3.2
209Duke St	10027	10127	10643	9.9	9.9	9.9
210Star Lane	10913	11022	11584	7.0	7.0	7.0
210Grimwade St N	8831	8919	9374	3.6	3.6	3.6
210Grimwade St S	19744	19941	20959	5.5	5.5	5.5
211Grimwade St	20001	20201	21232	5.4	5.4	5.4
211Fore St E	17022	17192	18069	11.2	11.2	11.2
211Fore St W	19705	19903	20918	5.8	5.8	5.8
211Grimwade St E	14549	14694	15444	5.8	5.8	5.8
211Grimwade St W	5453	5507	5788	4.2	4.2	4.2
212Greyfriars Road	16417	16581	17427	4.6	4.6	4.6
212Star Lane	18554	18740	19696	5.0	5.0	5.0
212College St	13181	13312	13992	6.9	6.9	6.9
212College St	5243	5295	5565	6.0	6.0	6.0
212College St	807	815	856	33.5	33.5	33.5
223Norwich Road S	7079	7150	7515	11.9	11.9	11.9
223Chevallier St	8367	8451	8882	7.6	7.6	7.6
223Norwich Road N	13720	13857	14564	10.4	10.4	10.4
223Valley Road	10474	10579	11119	4.3	4.3	4.3
217St Margaret's Green	4279	4322	4542	8.3	8.3	8.3
217St Margaret's St E	15430	15584	16379	6.6	6.6	6.6
217St. Margaret's St W	11720	11837	12441	7.1	7.1	7.1
301Star Lane W	8324	8407	8836	4.4	4.4	4.4
301Fore St N	947	956	1005	19.1	19.1	19.1
301Fore St S	389	393	413	27.1	27.1	27.1
301Star Lane E	8587	8673	9116	5.3	5.3	5.3
227Star Lane W	16980	17150	18025	4.5	4.5	4.5
227Star Lane N	2596	2622	2755	5.5	5.5	5.5
227Star Lane S	1657	1674	1759	1.7	1.7	1.7
227Foundation St S	428	432	454	6.2	6.2	6.2
227Lower Brook St	1871	1890	1987	3.0	1.7	3.0
227Foundation St N	2381	2405	2528	4.8	1.7	4.8
227Star Lane E	15614	15770	16575	4.0	4.0	4.0
18Crown St	9244	9337	9813	14.8	14.8	14.8
18Fonnereau Road	4938	4987	5242	7.9	7.9	7.9
18St Margarets Plain	11306	11419	12002	9.3	9.3	9.3

* the number before the road name refers to a specific traffic count

Table 14 Traffic Data (Speeds), Ipswich

Road*	Speed/kph		
	150m from junction	75m from junction	At Junction
7Stoke St	10	18	5
7Bridge St N	6	16	5
7Bridge St S	6	16	5
7Vernon St	8	18	5
7Bridge St W	6	16	5
7Bridge St E	6	16	5
7Vernon St W	8	18	5
21Star Lane W	20	18	14
21Star Lane E	23	20	12
21Star Lane / Key St	20	18	10
22College St E	20	20	20
101Woodbridge Road E & W	26	26	26
102Argyle St	15	15	5
102St Helens St W			5
102St Helens St E	25	20	5
102Grimwade St	15	15	5
209Fore St	25	18	15
209Long St	12	12	15
209Back Hamlet	25	20	14
209Fore Hamlet	22	17	12
209Duke St	26	26	11
210Star Lane	35	23	5
210Grimwade St N	33	10	5
210Grimwade St S	33	10	5
211Grimwade St	23	20	14
211Fore St E	16	16	16
211Fore St W	16	16	16
211Grimwade St E			14
211Grimwade St W			14
212Greyfriars Road	30	27	20
212Star Lane	30	27	20
212College St	27	13	17
212College St	37	20	19
212College St	37	20	17
223Norwich Road S	50	40	36
223Chevallier St	30	15	7
223Norwich Road N	17	17	5
223Valley Road	50	15	4
217St Margaret's Green	30	26	5
217St Margaret's St E	22	22	5
217St. Margaret's St W	31	27	5
301Star Lane W	24	22	21
301Fore St N	28	21	18
301Fore St S	25	20	20
301Star Lane E	24	22	21
227Star Lane W	29	28	20
227Star Lane N			5
227Star Lane S			5
227Foundation St S	40	30	5
227Lower Brook St	40	30	5
227Foundation St N	40	30	5
227Star Lane E	29	28	20
18Crown St	20	16	13
18Fonnereau Road	25	20	5
18St Margarets Plain	16	16	8

* the number before the road name refers to a specific traffic count

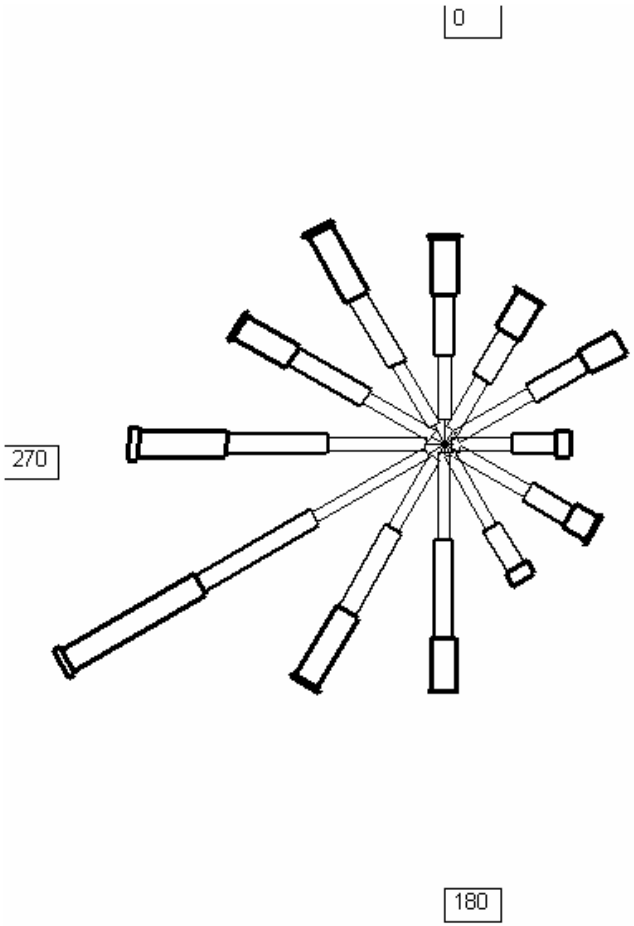
Appendix E Meteorological Data

Meteorological data measured at Wattisham were used in this modelling study. The data consisted of the frequencies of occurrence of wind speed (0 – 2, 2 – 4, 4 – 6, 6 – 10, 10+ m/s), wind direction (30° resolution) and Pasquill stability classes. Pasquill stability classes categorise the stability of the atmosphere from A (very unstable) through D (neutral) to G (very stable).

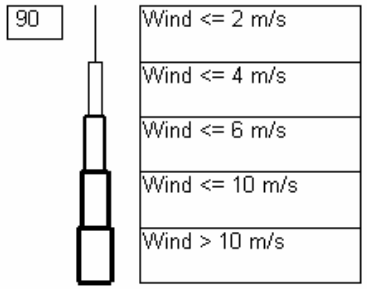
Calm winds were distributed evenly between the wind direction sectors in the 1 m/s category. The stability classes used were C, D and E where all of the unstable classes were grouped in C and all of the stable classes in E.

The meteorological data were used to produce a wind/stability rose: see the figure on the following page. Each wind rose bar is designed to illustrate three wind properties: the direction the wind is coming from; the relative number of hours the wind is from this direction; and the magnitude of the wind speeds. These data are also tabulated to show the total number of hours and the wind speed split for each wind direction sector.

Table 15 Meteorological Data, Wattisham, 2001



	Wind <= 2 m/s	Wind <= 4 m/s	Wind <= 6 m/s	Wind <= 10 m/s	Wind > 10 m/s	Total
D >= 345 or D < 15	68	174	166	150	8	566
15 <= D < 45	43	158	143	116	5	465
45 <= D < 75	38	231	165	113		547
75 <= D < 105	23	163	116	38		340
105 <= D < 135	47	213	128	74	4	466
135 <= D < 165	33	227	127	38		425
165 <= D < 195	25	237	261	142	1	666
195 <= D < 225	45	221	255	217	9	747
225 <= D < 255	54	347	357	410	19	1187
255 <= D < 285	48	265	273	235	26	847
285 <= D < 315	37	205	229	160	13	644
315 <= D < 345	56	199	205	203	12	675
Total	517	2640	2425	1896	97	7575



Appendix F Stack Diameter at the Tarmac Site

Following the completion of the modelling study of PM_{10} emissions from the industrial site operated by Tarmac, it was discovered that the stack diameter of 0.12m used in the model was incorrect. The correct diameter is 1.2m. To determine the effects of using the incorrect diameter on the predicted PM_{10} concentrations, the 2004 model was re-run with the correct diameter and concentrations were predicted at three receptors in the study area. The results are listed in Table 16.

Table 16 Effect of Stack Diameter on Predicted PM_{10} Concentrations

Receptor Location	2004 Annual Mean PM_{10} Concentration/µg/m^3		
	Stack Diameter = 0.12m	Stack Diameter = 1.2m	Difference
617050, 243300	20.1017	20.1006	0.0011
617050, 243400	20.1020	20.1006	0.0014
617050, 243500	20.1022	20.1009	0.0013

It can be seen that the effect of using the incorrect diameter is to over predict the 2004 annual mean PM_{10} concentrations by 0.0010 to 0.0015 µg/m^3 at the three receptors. As this impact is small it was deemed unnecessary to correct the modelling study presented in the rest of this report.