The Environmental Management Consultancy

Hampshire Air Quality Group

CES

Stage 3 Air Quality Review and Assessment

Final Report

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1 INTRODUCTION

The Hampshire Air Quality Group commissioned CES to conduct a Stage 3 Air Quality Review and Assessment based on the findings of the Stage 1 and 2 review and assessments. All the pollutants outlined by the UK Government in the National Air Quality Strategy were reviewed as part of this Stage 3 review and assessment.

The aim of a Stage 3 air quality review is to act on the findings of the previous review and assessments by carrying out a more detailed study of air quality at locations which are suspected of failing to meet one or more of the air quality objectives.

1.1 An Overview of the Hampshire County Area

For the purposes of this report, the Hampshire Air Quality Group was considered to comprise all the local authorities in Hampshire with the exception of Hart District Council, Rushmoor Borough Council and Basingstoke and Deane Borough Council. The Hampshire County Area is, therefore, considered to be defined by the administrative boundaries of the ten remaining local authorities.

The county of Hampshire still retains a rural nature, especially away from the south coast. The two main cities, Southampton and Portsmouth, have populations of 215,000 and 190,000 respectively. The other main centres of population include Winchester, Havant, Romsey, Andover, Gosport and Petersfield. The total population of the Hampshire County Area is approximately 1,215,000.

1.2 Sources of Air Pollution

Line pollution sources cover all forms of transport, but it is road traffic, which is the major source of local air pollution. The main roads in the Hampshire County Area are the M3, M27, A3, A35 A303, A27 and A34. The Stage 1 of the review and assessment process indicated that there were several significant Part A or B processes in or surrounding the Area, mainly based in or close to Southampton and Portsmouth. These industrial sources include the refineries and power station at Fawley.

2 LITERATURE REVIEW

2.1 Overview of Recent Air Quality Legislation and Policy

Under the 1995 Environment Act and subsequent legislation, local authorities, with support from central government and the Environment Agency, play a major part in improving both local and national air quality. The 1997 Air Quality Regulations was built on existing policies of local environment control; for example, the Clean Air Acts and Local Authority Air Pollution Control (LAPC) under the Environmental Protection Act 1990 and Environment Act 1995, and empower local authorities with new responsibilities to assess and manage air quality in their respective area of jurisdiction. These regulations were subsequently superseded by the 2000 Air Quality Regulations.

In providing a nationally coherent framework for air quality assessment, the 2000 Air Quality Regulations specify new air quality standards and objectives. The objectives indicate the extent and timescale to which the Government intends to meet the standards - for example, it is intended that the standard for sulphur dioxide should be met 99.9% of the time by the end of the year 2005. The strategy makes clear that measures undertaken by central government should be sufficient to attain the objectives in most areas, though for some areas, additional measures may be required.

The requirement for regional air quality reviews aims to identify those potential problem areas or 'hot spots' in which local air quality is failing to meet the national air quality objectives set out in the 2000 Air Quality Regulations. Action at a local level must then be taken to ensure that air quality in the area will meet the appropriate objectives. This process is known as "local air quality management (LAQM)". The 2000 Air Quality Regulations will directly affect Hampshire Air Quality Group in that an air quality management plan will have to be drawn up in the event that air quality at any location within the region fails to meet the required national air quality objectives by the year specified.

2.2 United Kingdom National Air Quality Standards and Objectives

The National Air Quality Strategy (NAQS) identified eight ambient air pollutants that have the potential to cause harm to human health. These pollutants are all associated with local air quality problems, except ozone, which is a regional pollutant. The 2000 Air Quality Regulations therefore sets standards and objectives for the seven pollutants that are associated with local air quality. The objectives are aimed at reducing the health effects of the pollutants to negligible levels. Appendix B gives details of the objectives proposed by the Government in the 2000 Air Quality Regulations.

3 POLLUTANTS OF CONCERN

3.1 Nitrogen Dioxide

Oxides of nitrogen (NO_x) are primarily comprised of nitric oxide (NO) and nitrogen dioxide (NO_2), which are formed as a result of high temperature combustion. The majority of NO_x emitted from vehicles is in the form of NO, part 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. The effects of NO_2 exposure can be chronic and/or acute. Studies of artificial exposure have shown that chronic effects of the upper range of possible exposure concentrations might include changes in lung structure, metabolism and reduced resistance of the lungs to bacterial infection. No clear link between exposure to NO_2 from outdoor air and the above effects has been established. 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 at high temperatures 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.

The 2000 Air Quality Regulations has adopted, as objectives, an annual mean of 40 $\mu g/m^3$ (21 ppb) and an hourly objective of 200 $\mu g/m^3$ (105 ppb) not to be exceeded more than 18 times a year (equivalent to a 99.8th percentile). Both objectives are to be achieved by the end of 2005.

Estimates for 1995 show that road transport accounts for around 46% of total UK emissions of NO_x with the electricity supply industry and commercial sectors accounting for a further 22% and 12%, respectively. Figure C.1 in Appendix C shows that total national emissions of NO_x have decreased since 1989. This is due to legislation and emission control technology both for road traffic and industrial sources. Appendix F gives further information on the atmospheric chemistry of NO_x.

3.2 Particulate Matter

Particulate matter is composed of a wide range of materials arising from a variety of sources. Particulate matter is typically assessed as total suspended particulates or as a mass size fraction. The 2000 Air Quality Regulations has adopted the PM_{10} standard for the assessment of fine particulate matter. This expresses particulate levels as 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. 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 $\mu g/m^3$ respectively, although 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 also have a carcinogenic effect. This may be due to air stream-entrained particles carrying adsorbed carcinogens into the respiratory system. The true effects of PM_{10} are difficult to determine as they are masked by other parameters often associated with different PM_{10} exposure levels such as weather and lifestyle. The 2000 Air Quality Regulations has adopted objectives based on the EC Daughter objectives, which are an annual mean of 40 $\mu g/m^3$ and a 24 hour objective of 50 $\mu g/m^3$ (allowing 35 exceedances, equivalent to a 90th percentile) by the end of the year 2004.

Road transport accounts for the largest contribution to total national emissions of particulates at 26%. Other major sources include industrial processes at 13%, mining and quarrying at 13% and power stations at 15%. Figure C.2 in Appendix C shows that total national emissions of PM_{10} have decreased since 1970. This is due to legislation and emission control technology for both traffic and industrial sources.

3.3 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless gas formed by the incomplete combustion of carbon based fuels and is an indirect greenhouse gas. CO poses most threat to humans by acute poisoning of the haemoglobin in blood. Haemoglobin binds preferentially to CO over oxygen leading to an increasing inability to supply oxygen to maintain the biochemical processes of the body's cells. Very high levels of CO levels in the blood stream can cause permanent brain damage or death. The heart, like the brain, is heavily dependent on an uninterrupted supply of oxygen for its correct function. The levels of CO found in outdoor air are very unlikely to lead to detectable changes in heart performance. CO intake by smokers does have a measurable effect through increased arteriosclerosis, in turn leading to a higher rate of heart attacks. The 2000 Air Quality Regulations has adopted an objective of 11.6 mg/m^3 (10 ppm), expressed as the maximum of running 8 hour means, to be achieved by the end of the year 2003. Ambient levels below this threshold can be considered safe for non-smokers.

The primary source of carbon monoxide in the UK is road transport, which accounted for approximately 76% of total emissions, nationally in 1995. Carbon monoxide emissions from petrol vehicles account for 95% of the emissions due to road transport and some 71% of the total emissions. Figure C.3 shows that total national emissions of carbon monoxide have decreased since 1989. This is due to legislation and emission control technology.

3.4 Sulphur Dioxide

Sulphur dioxide is a gas at normal temperature and pressure, and dissolves in water to give an acidic solution which is readily oxidised to sulphuric acid. Due to its acidic nature it is an irritant when inhaled, causing breathing difficulties in high concentrations. Recent studies indicate that asthma sufferers have an increased susceptibility to the adverse effects caused during pollution episodes with exposure often leading to asthma attacks.

The 2000 Air Quality Regulations has adopted a 15-minute mean of 266 µg/m^3 (100 ppb) for the objective, not to be exceeded more than 35 times a year (equivalent to a 99.9th percentile) by the end of 2005. Two less stringent objectives are also outlined for the end of the year 2004: a 24 hour mean objective, not to be exceeded more than 3 times per year, of 125 µg/m^3 (46 ppb) and an hourly mean objective, not to be exceeded more than 24 times per year, of 350 µg/m^3 (129 ppb). The 15-minute objective is currently widely exceeded in the UK, at both urban and rural sites. These exceedances are associated with emissions from both large and small combustion plants and domestic burning.

Emissions of sulphur dioxide are dominated by coal-fired power stations, which contribute more than 65% of the UK total. There are also significant emissions from other industrial sources. Road transport contributes less than 2% of emissions.

3.5 Lead

Lead is the most widely used heavy metal both in its elemental form and in alloys. Most of the lead in the atmosphere occurs in the form of fine particles with an aerodynamic diameter of less than 1 µm. Direct human exposure tends to be through food, water, dust soil and air. Approximately 20% to 60% of lead is absorbed through the respiratory tract. Lead exhibits toxic biochemical effects in humans causing acute or chronic damage to the nervous system, kidneys, gastrointestinal tract, joints and reproductive system. Low-level long-term exposure may lead to subtle neuropsychological dysfunction, and critical effects to the nervous system and blood pressure. The 2000 Air Quality Regulations has adopted the WHO guideline of 0.5 µg/m^3 measured as an annual mean exposure level, to be achieved by the end of the year 2004. A further annual mean objective of 0.25 µg/m^3 has been adopted for the end of the year 2008.

The single largest application of lead on a global scale is in the manufacture of batteries, which uses around 60 - 70% of the worlds consumption of some 4 million tonnes of lead; other uses including pigment in paints and glazes, in alloy, in radiation shielding, tank lining and piping. The compound tetraethyl lead has been used in petrol as an additive to enhance the octane rating. This lead is released as particles during combustion. The principal atmospheric source of lead is road traffic with around 72% of total UK emissions in 1995. Lead levels in ambient air have decreased nationally by around 80% between 1980 and 1995. The increases used of catalytic converters and unleaded fuels have since led to a further reduction of lead emissions of nearly 50% of lead since 1995.

3.6 Benzene

Benzene is a known genotoxic carcinogen but at levels experienced in outdoor or normal workplace conditions, the risk is predominantly that of developing leukaemia. It has not been possible to demonstrate a level at which there is zero risk of exposure to benzene. A dose/risk relationship has been established and WHO states that for exposure to 0.3 ppb for 70 years the risk of leukaemia is about 1 in 100,000. The 2000 Air Quality Regulations has adopted an objective of 16.25 $\mu g/m^3$ (5 ppb), expressed as an annual running mean, based on the findings of the Expert Panel on Air Quality Standards (EPAQS). This objective is to be achieved by the end of the year 2003. The original EPAQS standard was derived on close examination of medical evidence concerning carcinogenic effects and seeks to establish a level of exposure below which the risk to health could be regarded as exceedingly small. Concentrations of benzene typically range from around 9.3 ppb in central London to 1.5 ppb in rural areas but it is not yet clear whether there is a linear relationship between dose and risk.

The main atmospheric source of benzene is from the combustion and distribution of petrol, of which it is a minor constituent. On a national basis, petrol driven motor vehicles are the single most important source of benzene and account for around 70% of the total emission in the UK in 1995. The refining, distribution and evaporation of petrol from vehicles account for about 10% of total emissions. Apart from the known carcinogenic effects of exposure to benzene, concern has been voiced on the role benzene plays in the production of photochemical smog. The photochemical ozone creation potential (POCP) of benzene has been estimated to be 18.8 based on a value for 100 for ethene. Although, the POCP of benzene is low in comparison with ethene, the volume of emissions of benzene from road traffic makes it an important contributor.

3.7 1,3-Butadiene

1,3-Butadiene is a gas at normal temperatures and pressures and is present in trace amounts in the atmosphere. Like benzene, 1,3-butadiene is a genotoxic carcinogen in that no absolutely safe level can be specified for ambient concentrations. Nevertheless a standard level of 1 ppb, expressed as a running annual mean, has been recommended by the EPAQS. The standard assumes that the risks associated with exposure to ambient levels of butadiene below this threshold are exceedingly small and are unlikely to pose any potential threat to health. This standard has been adopted as an objective by the 2000 Air Quality Regulations to be achieved by the end of the year 2003. 1,3-Butadiene is also a known photochemical precursor and contributes to the formation of photochemical smog.

1,3-Butadiene is used in industry, mainly for the production of synthetic rubber for tyres. Although neither petrol nor diesel fuel contain 1,3-butadiene it is formed in the combustion process from alkenes in the fuel. The proportion of these alkenes in the fuel has been increasing over the last decade so that it is likely that amounts of 1,3-butadiene emitted into the atmosphere have also increased. Motor vehicles contributed approximately 78% of the total emissions of 1,3 butadiene in the UK in 1995. Emissions of butadiene from industrial sources either manufacturing or using the compound contribute some 13% of the total emission at a national level.

4 AIR QUALITY MONITORING DATA

Air quality is measured using two broad techniques, continuous measuring instruments and non-continuous methods. Widespread continuous monitoring is a fairly recent development and so most historical data is based on non-continuous methods, and these continue to have a strong role to play. The UK National Air Quality Strategy is mainly based on the results of continuously measurements, the data from which is averaged over 15 minute intervals and which can then be further condensed into 1 hour or longer period averages.

The most sophisticated monitoring stations are those which are part of the National Automatic Urban and Rural Network (AURN) operated on behalf of the Department of the Environment, Transport and Regions (DETR). Raw data from these stations can be retrieved from the DETR home page on the Internet and are updated every four hours. The instruments are maintained and calibrated to high standards and while the raw data is reasonably accurate, it has to be ratified to take into account calibration errors and other anomalies. This ratification process can take several months.

Local authorities also operate continuous monitoring stations on their own behalf. They are maintained and calibrated to a recommended standard, but ratification of raw data is more limited, and tends to be restricted to obvious instrument errors that occur from time to time. The data from these stations is normally as good as raw data from the AURN stations, but is not necessarily as accurate as ratified data from the AURN stations.

The Hampshire Air Quality Group has eight continuous monitoring sites: six of which are fixed and two of which are mobile. Winchester City Council has two fixed sites in Winchester, one at a roadside site, the other in an urban background location. Portsmouth City Council has a mobile site, which it has used to monitor pollutant concentrations at a number of different sites in the last four years, and a newly commissioned fixed urban background site. Southampton City Council has two fixed and one mobile monitoring laboratories located in the city. One of the fixed laboratories is based at an intermediate site, near Six Dials, and is part of the AURN. The other, more recently established, fixed monitoring station is based at Redbridge School. The mobile station is presently based in the City Centre. Gosport Borough Council has also a recently established continuous monitoring site based in Gosport town centre.

Local authorities that cannot justify the cost of continuous monitoring stations rely on non-continuous measurement techniques to monitor air quality. These methods are also required, in conjunction with continuous monitoring equipment, in order to get a cost-effective indication of air quality across a wider geographical area. The most common form of non-continuous measurements is diffusion tubes. These are small stainless steel or plastic tubes, which are packed with an absorbent material sensitive to the pollutant being measured. The chemical is exposed to air at a given location for two to four week periods, after which analysis gives a measure of the average level of the pollutants for that period. Short-term peaks cannot be identified, but a comparison between locations can identify possible hotspots of pollution for further investigation, and the method identifies changes over a longer period of time. Nitrogen dioxide diffusion tube measurements have taken place across the Hampshire County Area for several years at numerous sites.

4.1 Nitrogen Dioxide

Once released into the atmosphere nitric oxide (NO) is rapidly oxidised to form nitrogen dioxide (NO_2) in a reaction with ozone. The availability of ozone 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. However, measurements of NO_2 taken at kerbside and roadside monitoring sites typically show higher concentrations than those observed at background monitoring sites.

Ambient NO_2 is the most widely monitored of all the criteria pollutants. This is primarily due to the availability of low cost monitoring techniques and the fact that there has been consistent and widespread exceedance of recent standards. Starting in 1993, a nationwide diffusion tube survey was commissioned with some 300 local authorities participating. Although less accurate than continuous monitoring methods, diffusion tube measurements have provided a detailed picture of the monthly and annual variation of NO_2 levels on local, regional and national scales of interest.

Of the six fixed continuous monitoring stations, there are data available from four sites. Three sites, two in Southampton and one in Portsmouth, have only been recently established and as such have limited datasets. A total of a month's continuous monitoring was also undertaken at four separate sites in the Test Valley Borough. The results are listed in Table 4.1. Numerous diffusion tube sites have also been established in the Hampshire County Area and example results are summarised in Table 4.2. These results show a general downward trend in NO_2 concentrations throughout the area since 1994.

In order to obtain a wider perspective, additional comparison has been made with data obtained from the nearest AURN sites at Southampton Centre and Reading Centre. Annual mean concentrations for 1999 were 42.0 $\mu g/m^3$ and 38.9 $\mu g/m^3$

respectively. The former location is an Urban Centre site; the latter is an Urban Background location.

Table 4.1: Annual Mean NO_2 (µg/m^3) Results: Continuous Monitoring Stations

Site	**Site Type**	**1996**	**1997**	**1998**	**1999**	**2000**
Southampton Centre AURN	U3	45.9	44.0	38.2	42.0	
St Georges St, Winchester	U1	-	82.3	53.2	60.2	
Friarsgate, Winchester	U4	-	33.4	39.7	31.2	
Fareham Rd/Tichbourne Way, Gosport	U2	-	-	-	-	23.1^{x}
Stanley Road, Portsmouth	U1	-	-	-	43.3*	
Estella Street, Portsmouth	U1	-	-	-	52.2+	
Bullington Cross Inn, Sutton Scotney	U2					38.0^{o}
Winchester Road, Andover	U2					16.6^{o}
Bracken Lodge, Southampton	U2					38.0^{o}
9 Park House, Romsey	U2					66.4^{o}

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background; * 10/9/1998 – 22/9/1998; + 1/4/1999 – 12/8/1999; x 4/2/2000 – 30/6/2000; ^{o} total study period 18/4/00 – 22/5/2000

On a national scale, annual mean NO_2 levels appear to be on a slight decline though this conclusion remains unsubstantiated at present. Seasonal trends for the period 1993 to 1996 show that on average levels of NO_2 during the winter months are higher than for the summer months.

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. Although NO_2 levels have increased by around 30% between 1986 and 1991, followed by perceived marginal decrease to 1996, future trends associated with NO_2 remain unclear at present. A variety of measures for reducing emissions of oxides of nitrogen (NO_x) from road traffic have already been introduced with further emissions controls planned for the future. The UKNAQS expects that these steps will lead to a reduction in NO_x emissions from vehicles of almost 45% by the year 2005 based on 1995 figures.

Table 4.2: Annual Mean NO_2 ($\mu g/m^3$) Diffusion Tube Measurements

Site	Site Type	1996	1997	1998	1999
Council Depot, Romsey	U4	-	32	27	24
Lyndhurst School	U4	29	28	20	19
Fawley Hall	U5	22	19	20	18
Bitterne Rd, Southampton	U1	63	54	57	-
Englefield Rd, Southampton	U3	31	27	31	-
West Street, Fareham	U1	42	34	39	30
Norton Drive, Fareham	U4	25	21	23	16
Horton Heath	R1	-	-	24	-
Police Station, Eastleigh	U1	-	-	35	-
London Road, Portsmouth	U1	51	48	55	59
Stroudley Av, Portsmouth	U4	24	17	21	22
Wickham Square, Wickham	U4	36	28	22	20
Winchester Rd, Denmead	U4	31	27	26	23

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background.

4.2 Particulate Matter (PM_{10})

Fine particulate matter (PM_{10}) is currently measured at 50 AURN sites throughout the UK with annual urban mean concentrations varying between 15 $\mu g/m^3$ and 35 $\mu g/m^3$. Rural annual mean concentrations tend to be somewhat lower at around 10 $\mu g/m^3$ to 15 $\mu g/m^3$. The diurnal variation of PM_{10} typically depends on a combination of large-scale processes and the degree of local anthropogenic activity. Elevated levels of PM_{10} tend to occur between 06:00 hrs and 23:00 hrs. Where monitoring sites have been located close to roads, a positive correlation with traffic levels has been observed.

In urban areas the annual mean value of PM_{10} remains fairly uniform across the United Kingdom. PM_{10} measurements at the continuous monitoring sites are listed in Table 4.3. This compares with the AURN sites at Southampton Centre and Reading Centre, which have measured annual mean concentrations in 1999 of 25.6 $\mu g/m^3$ (gravimetric) and 21.2 $\mu g/m^3$ (gravimetric) respectively.

Examination into seasonal variations of PM_{10} levels tend to demonstrate higher concentrations over the winter periods than those of the summer due to the existence in the summer of meteorological conditions more favourable to dispersion.

Future trends are likely to show a decrease in ambient PM_{10} levels. A variety of measures for reducing PM_{10} emissions from road traffic has already been introduced. The UKNAQS expects a reduction in PM_{10} emissions from vehicles of almost 40% by the year 2005 based on 1995 figures.

Table 4.3: Annual Mean Gravimetric PM_{10} (μg/m^3) Results

Site	Site Type	1997	1998	1999	2000
Southampton Centre AURN	U3	-	-	25.6	-
St Georges St, Winchester	U1	31.8	26.2	24.9	-
Friarsgate, Winchester	U4	22.1	20.5	21.4	-
Fareham Rd/Tichbourne Way, Gosport	U2				24.8^x
Stanley Road, Portsmouth	U1	-	-	26.5*	-
Estella Street, Portsmouth	U1	-	-	30.1+	-

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background. * 10/9/1998 – 22/9/1998; + 1/4/1999 – 12/8/1999; x 4/2/2000 - 30/6/2000.

4.3 Carbon Monoxide

Measurements of carbon monoxide (CO) levels have been available on a national scale for many years. The AURN currently monitors CO at a total of 61 sites through out the United Kingdom using infra-red continuous monitors. Given that motor vehicles are the primary source of CO, it is expected that the diurnal variation of the pollutant is likely to mirror local traffic patterns. This effect has been widely confirmed particularly where CO is being monitored close to heavily trafficked roads.

CO monitoring data from the continuous monitoring sites are listed in Table 4.4. The nearest AURN sites at Southampton Centre and Reading Centre determined maximum 8-hour concentrations of 4.4 mg/m^3 and 5.5 mg/m^3 in 1998.

Table 4.4: Maximum Running 8-Hour Mean CO (mg/m^3) Measurements

Site	Site Type	1996	1997	1998	1999
Southampton Centre AURN	U3	7.6	10.7	4.4	-
St Georges St, Winchester	U1	-	5.0	5.0	1.0
Friarsgate, Winchester	U4	-	3.5	3.1	0.5
Stanley Road, Portsmouth	U1	-	-	-	1.4*
Estella Street, Portsmouth	U1	-	-	-	2.1+

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background. * 10/9/1998 – 22/9/1998; + 1/4/1999 – 12/8/1999.

Seasonal variations of CO levels tend to produce higher concentrations over the winter periods than those of the summer due to the existence in the summer months of meteorological conditions more favourable to dispersion. This effect is enhanced by the influence of cold start emissions (see Section 5.1).

The UKNAQS reports that national trends indicate a decline in levels CO since 1989 by around 10-50% depending on the location of the monitoring site. Further emission control measures are set to be introduced in an attempt to CO emissions from road vehicles (i.e. a 48% reduction by the year 2005 based on 1995 data). This will make any exceedance of the CO air quality objectives very unlikely.

4.4 Sulphur Dioxide

National emissions of sulphur dioxide (SO_2) have decreased by 63% since 1970 and by 52% since 1980. National emissions are dominated by fossil fuel power stations, which currently account for around 67% of the national total. Industrial combustion plants comprise the second largest source of SO_2 at 19%. Since the 1960's, ambient SO_2 has been monitored at a number of sites cross the United Kingdom. Currently four networks monitor nationwide levels of SO_2: the Basic Network (BUN), the Automatic Urban and Rural Network (AURN), the EC Directive Network and the Rural Network. Only the 28 sites of the AURN network provide continuous monitoring results that can be compared with the UKNAQS short-term health-based objective. Diurnal variations in SO_2 levels are unclear and ultimately depend on prevailing meteorology and the location of receptors in relation to known sources.

The only continuous data available for the Hampshire County Area for SO_2 is at the Southampton Centre AURN site (see Table 4.5). The nearest AURN sites at Southampton Centre and Reading Centre observed concentrations, as a 99.9th percentile of 15 minute means, in 1999 of 59.5 $\mu g/m^3$ and 64.9 $\mu g/m^3$, respectively. There have also been diffusion tube surveys in the County, which are listed in Table 4.6.

Table 4.5: SO_2 ($\mu g/m^3$) Measurements: Southampton Centre

Parameter	Site Type	1996	1997	1998	1999
Annual Mean	U3	10.8	8.1	8.1	6.5
Maximum 15 Minute	U3	406	230	132	59.5

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background.

Ambient levels of SO_2 have decreased significantly since 1960 due to the shift from coal and oil towards gas as the main source of domestic heating and a decrease in power station emissions. Recent data suggest that in some cases this downward trend will continue, although for a number of monitoring sites this trend appears to have levelled off.

Table 4.6: Annual Mean SO_2 (μg/m^3) Measurements

Site	1996	1997	1998	1999
Portsmouth*	30	31	26	19
New Road, Netley+	-	-	7	-
Lyndhurst School+	10.9	16.3	11.4	6.6
Fawley Hall+	10.2	13.4	3.9	6.3
Havant+	19	-	14	-

* Measured with a 8 port bubbler; + Measured using diffusion tubes.

Seasonal variations of SO_2 levels tend to show higher concentrations over the winter periods than those of the summer due to the existence in the summer of meteorological conditions more favourable to dispersion. This effect is enhanced by the higher demand for electricity and increased domestic burning in the winter, leading to increased SO_2 emissions over the winter months.

Industrial emissions of SO_2 including those made by the electricity supply industry currently account for around 91% of total national SO_2 emissions. Future trends are likely to show a continued decrease in ambient SO_2 levels due to the introduction of a number of measures aimed at reducing emissions from both road traffic and industrial sources. The UKNAQS anticipates a reduction in SO_2 emissions of almost 70% by the year 2005 based on 1980 figures.

4.5 Lead

Lead concentrations have decreased by up to a factor of 10 since 1985 due mainly to the reduction of lead in petrol in 1986. The subsequent ban of lead in petrol at the end of 1999 should see lead levels in air drop further still. The only sources of concern are now industrial plants. Measured data for lead in Hampshire is therefore not extensive. Monitoring was undertaken for a number of years at St John's Court and Milton Middle School until 1995, when annual mean levels were approximately between <0.2-0.4 μg/m^3. Monitoring was also undertaken in Eastleigh between 1989 and 1991, where annual means of between 0.1-0.3 μg/m^3 were detected.

The only available current monitoring data for lead is done at Lyndhust and Fawley in the New Forest. The data are listed in Table 4.7.

Table 4.7: Annual Mean Lead (µg/m^3) Results: Diffusion Tube Results

Site	1996	1997	1998	1999
Lyndhurst School	0.08	0.02	0.03	0.02
Fawley Hall	0.04	0.01	0.02	0.02

4.6 Benzene

Spot measurements of benzene in ambient air for the UK have been recorded since the 1970's. More extensive, nation-wide measurements of ambient benzene levels have only recently been available since the advent of the Automatic Hydrocarbon Network (AHN) consisting of 12 independent fixed monitoring sites.

The only continuous data available for the Hampshire County Area for benzene is at the Southampton Centre AURN site (see Table 4.8).

Table 4.8: Annual Mean Benzene (µg/m^3) Measurements: Southampton Centre

Site	Site Type	1996	1997	1998	1999
Southampton Centre	U3	6.2	5.8	5.2	4.2

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background.

Since motor vehicles are known to be a major source of benzene, it is expected that the diurnal variation of the pollutant is likely to mirror local traffic patterns. This effect has been widely confirmed, particularly where benzene is being monitored close to heavily trafficked roads. Investigations have shown that benzene concentrations decrease with increasing distance from the road, with exceedances of the UKNAQS air quality standard often occurring at the kerbside.

National annual trends indicate a decrease in benzene levels of around 20% between 1992 and 1995, although many roadside sites still recorded exceedances of the UKNAQS air quality standard. Seasonal variations of benzene levels are likely to produce marginally higher concentrations over the winter periods than those of the summer due to the existence in the summer of meteorological conditions more favourable to atmospheric dispersion. This effect is enhanced by the increased reaction of benzene with the OH radical during the summer months where OH concentrations tend to be higher and consequently more likely to lead to lower benzene levels.

4.7 1,3-Butadiene

Extensive measurements of ambient levels of 1,3-butadiene have only recently been available since the establishment of the Automatic Hydrocarbon Network (AHN) in 1993. Currently, ambient concentrations of butadiene are monitored at 12 AHN sites throughout the UK. The only continuous data available for the Hampshire County Area for 1,3-butadiene is at the Southampton Centre AURN site (see Table 4.9).

Table 4.9: Annual Mean 1,3-Butadiene (μg/m^3) Measurements: Southampton Centre

Site	Site Type	1996	1997	1998	1999
Southampton Centre	U3	0.81	0.74	0.56	0.52

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background

Since motor vehicles are a major source of 1,3-butadiene, comprising 78% of national annual emissions, it is expected that the diurnal variation of the pollutant is likely to mirror that of local traffic patterns. Due to the low concentrations measured, the diurnal pattern for 1,3-butadiene is not as clear as for other traffic related pollutants, for example, carbon monoxide. Despite this general observation, studies have correlated measurements of 1,3 butadiene concentrations taken near to kerbside locations with daily traffic flows. Annual mean concentrations of 1,3-butadiene recorded within urban areas, range from 0.25 μg/m^3 to 1.3 μg/m^3 with rural concentrations being generally lower.

Drawing on national data, a marginal decrease in 1,3-butadiene levels of between 5% to 20% can be observed for most of the AHN sites across the UK between 1994 and 1997. Although absolute values of 1,3-butadiene may frequently exceed 2.25 μg/m^3 at roadside sites, it is unlikely that the UKNAQS air quality standard is exceeded. During 1994 and 1995 no exceedances of 1,3-butadiene were recorded for any of the AHN sites. Seasonal variations of 1,3-butadiene levels, like many other air pollutants, tend to result in marginally higher concentrations over the winter period than over the summer period due to the occurrence in the summer periods of meteorological conditions that are potentially more favourable to dispersion.

5 MODELLING METHODOLOGY

The AAQuIRE 2000 regional air quality model was used to predict nitrogen dioxide (NO_2), PM_{10} for road traffic and industrial sources, and carbon monoxide (CO), sulphur dioxide (SO_2), lead, benzene and 1,3-butadiene concentrations for industrial sources, in the base year (1999) and the relevant objective year (2003/2004/2005). The AAQuIRE regional dispersion model, which was developed by CES and has been used throughout the world for the past 9 years, uses dispersion algorithms which have been independently and extensively validated. A description of AAQuIRE and the stages required in any detailed modelling study are given in Appendix D.

There are 4 main categories of air pollutant sources including road traffic, industrial processes (i.e. Part A and B's) diffuse sources (e.g. domestic heating) and mobile sources (e.g. airports, rail and shipping). The conclusions from the Stage 1 review and assessment suggested that road traffic and several industrial sources needed to be investigated further. Contributions from the other pollutant sources were amalgamated into the background concentration.

5.1 Emissions Data

Road transport represents the major source of pollution in the study area and it was therefore imperative that the emission data was as accurate as possible. Speed related emission factors for 1999 were provided by the London Research Centre (LRC), based on models produced by NETCEN and TRL. The figures for 2003/2004/2005 were derived from the 1999 speed related emission factors using a year correction factor. This factor was determined from emissions data provided by the Highways Agency for the T5 Public Inquiry. The emission rates are given in Appendix E.

The vehicle fleet was classified into four categories of vehicles: petrol-engined vehicles without catalysts, petrol-engined vehicles with catalysts, diesel-engined light duty vehicles (LDV) and heavy duty vehicles (HDV). The vehicle fleet composition was different for each of the years assessed. This was due to an increase in the number of petrol-engined vehicles fitted with catalysts and an increase in the proportion of diesel LDVs, in later years.

The particulate emission rates include all sizes of particles. A small proportion of the particulate matter emitted from vehicle exhausts may be larger than 10 µm. As a worst case, it is assumed that all of the exhaust particulates produced are PM_{10}. PM_{10} will also be produced by vehicles from tyre wear, brake linings and resuspension of dust from the road. The PM_{10} contribution from these three sources was estimated to be 0.01 g/km for LDVs and 0.02 g/km for HDVs.

Emissions of some pollutants are higher when the engine is cold. Cars take about 3 minutes or 1.6 km before the engine is hot. This was accounted for by using a variable vehicle composition profile for each road. This information was taken from the LRC emissions inventory. Enhancement of pollutant emissions due to cold starts is given in Table 5.1.

Table 5.1: Ratio of Emissions from Cold:Hot Cars

LDV Category	NO_x	CO	PM_{10}
Non catalyst petrol	1.0	1.6	1.0
Catalyst petrol	1.3	9.6	1.0
Diesel	1.2	1.6	2.0

It is likely that a small proportion of catalysts in the LDV fleet will not be functioning at any one time. This proportion was taken to be 3% of the catalyst vehicles. The emissions from failed catalyst vehicles were taken to be the same as those from non-catalyst vehicles.

5.2 Traffic Data

Road traffic flow, speed and HGV proportions were based on data provided by the local authorities in the Hampshire Air Quality Group and Hampshire County Council. Where speed and HGV proportion data were not available, default values detailed in 'Transport Statistics Great Britain 1998 Edition' were used. Future case flows, where unavailable, were determined using the National Road Traffic Forecasts.

Modelling of emissions from traffic was only carried out for NO_2 and PM_{10}, as established in the Stage 1 review and assessments. Four separate diurnal profiles were used: the first for motorways; the second for dual carriageways; the third for A roads; and the fourth for B roads and unclassified roads. These profiles were taken from the Highways Agency counting sites which include hourly breakdowns of flow and are represented graphically in Figure 5.1.

5.3 Industrial Sources

The Stage 1 review and assessments indicated that there were several significant industrial sources in the Hampshire County Area. The Environment Agency provided the emissions data for these industrial sources. These data have recently been revised as Esso Petroleum Plc has altered the gas exit temperatures from its Fawley refinery processes. These changes are being modelled by the Environment

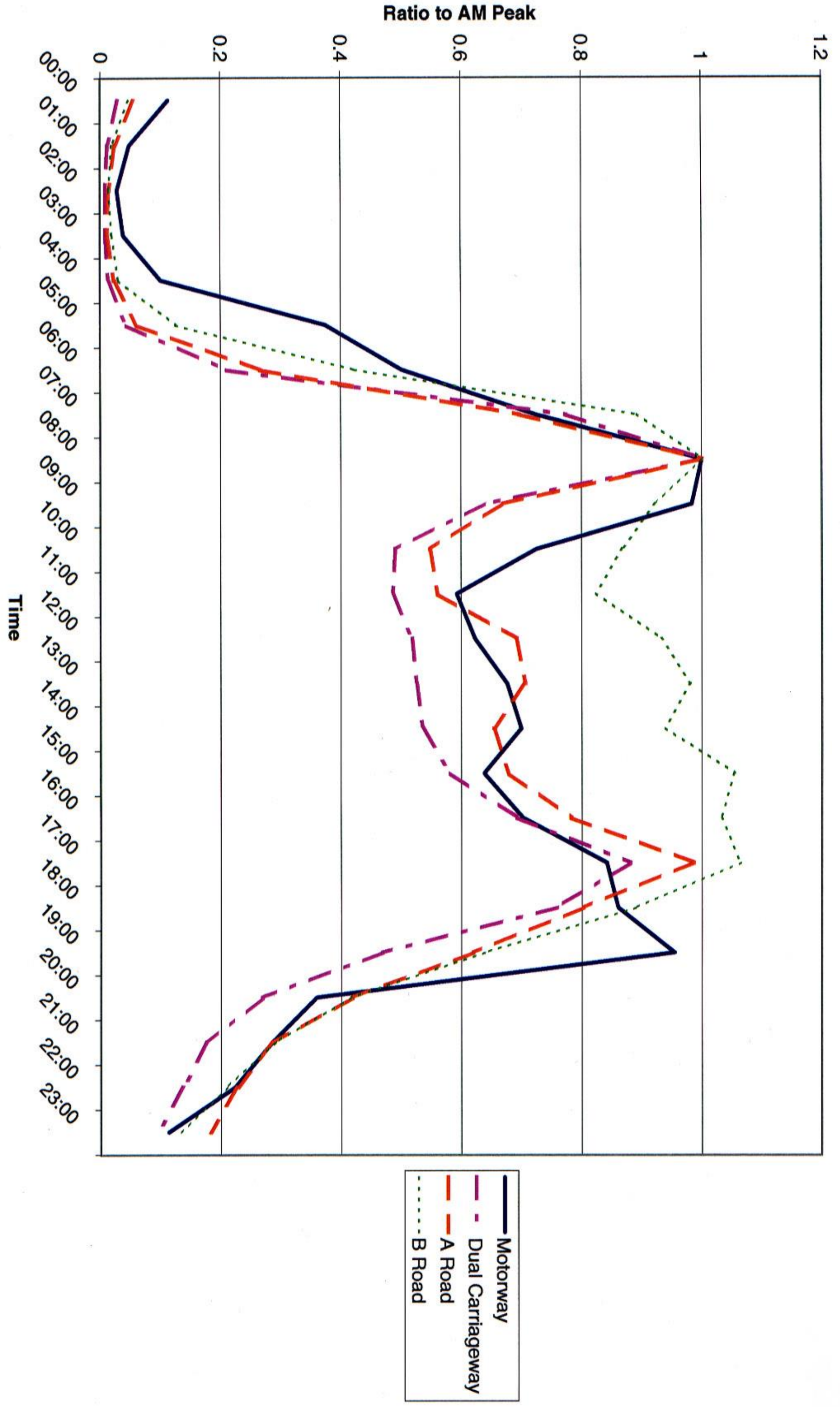

Figure 5.1: Diurnal Profiles

Agency to determine whether they will significantly alter the Local Authority modelled concentrations.

5.4 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. This was achieved by including background contributions, which are given in Table 5.2. These were based on data from the National Air Quality Archive (see Appendix H) and local monitoring data. The background concentrations for future years were determined from the relevant base case value by applying a scaling factor as outlined in 'Review and Assessment: Pollutant Specific Guidance' (LAQM.TG4(00)).

As the local authority has some control over emissions of NO_x but little or no control over the atmospheric oxidants that oxidise the NO to NO_2, it is more appropriate to review NO_2 by first reviewing NO_x. It is for this reason that a NO_x background is applied to the modelled NO_x concentration before a variable NO_2/NO_x is applied (see Appendix F).

Table 5.2: Background Concentrations for Stage 3 Review and Assessment

Pollutant	**Base Case (1999)**	**Objective Year (2003/2004/2005)**
NO_x (µg/m^3)	26.7	19.8
PM_{10} (µg/m^3)	24.1	22
CO (mg/m^3)	0.26	0.14
SO_2 (µg/m^3)	5.7	2.8
Lead (µg/m^3)	0.015	0.008
Benzene (µg/m^3)	0.97	0.32
1,3-Butadiene (µg/m^3)	0.45	0.19

5.5 Meteorological Data

After due consultation with the Meteorological Office, a meteorological dataset was compiled using data from the three nearest suitable stations. Data from Gatwick Airport were used for the eastern inland areas of the county; data from Southampton Weather Centre were employed for modelling the coastal areas; and data from RAF

Lyneham were used for the western inland areas. There are other stations nearer to the Hampshire County Area, but the data are either too old or the stations do not measure essential meteorological parameters for dispersion modelling such as mixing height and stability class.

The windroses for these three locations are shown in Figures G.1-G.3 in Appendix G.

6 PREDICTED LEVELS

6.1 Nitrogen Dioxide

This assessment considers two air quality standards for nitrogen dioxide (NO_2): a 99.8th percentile of hourly means of 200 μg/m^3 (105 ppb) and the annual mean of 40 μg/m^3 (21 ppb). The series of contour plots in Appendix A show the predicted NO_2 concentrations during the base case and the year 2005.

Figures 1.1.a/b - 1.2.a/b in Appendix A show the predicted annual mean and 99.8th percentile concentrations for base case (1999) and the year 2005. The highest concentrations clearly follow the major roads, especially the M3. Figure 1.1.a indicates that annual mean standard was likely to be exceeded throughout large parts of the Hampshire County Area in the year 1999. The majority of the exceedances were predicted in the vicinity of the M3, the M27, the M275 and the A33/A35. In contrast, the hourly objective (see Figure 1.1.b) was not predicted to be exceeded in the Hampshire County Area.

Figure 1.2.a show that the predicted annual mean concentrations in the year 2005 did not exceed the objective in the Hampshire County Area. Levels in excess of 35 μg/m^3 were predicted at locations in Portsmouth, Southampton and Eastleigh. Emphasis in the guidance has been placed on non-occupational, near ground level outdoor locations where the public might be exposed for a substantial part of the day. Locations where people may be exposed to annual average concentrations that exceed the objective include:

- residential properties
- shopping areas
- recreational facilities
- schools and hospitals

No exceedances of the hourly objective are predicted for 2005.

Table 6.1 compares the measured and predicted NO_2 concentrations for the base year to enable the accuracy of the results to be illustrated. The accuracy of the future year modelling results are relative to the accuracy of the base year results. This means that the same degree of confidence can be placed in the future year concentrations when comparing them with the air quality objectives. The majority of the modelled results are within +/- 20%, including all the continuous monitoring site measurements, which is well within the expected accuracy of the AAQuIRE model. All the results are within +/- 42%, the extreme differences being between diffusion tube measurements and modelled results. In this evaluation, it is also necessary to consider that the monitoring data has an uncertainty attached to it as well, especially those measurements undertaken with diffusion tubes. Monitoring locations based in town centres are also prone to local impacts, for example the restriction of dispersion due to tall buildings or by proximity to traffic lights, which are not covered in a regional modelling study of this nature.

Table 6.1: Nitrogen Dioxide Concentration Validation Results

			Annual Mean ($\mu g/m^3$)		
Site Location	*Site Type*	*Year of Measurement*	*Measured*	*Predicted*	*Percentage difference*
West Street, Fareham	U1 (DT)	1999	29.7	33	11.1%
London Rd, Portsmouth	U2 (DT)	1999	58.7	44.7	-23.9%
Stanley Rd, Portsmouth	U2 (CM)	1998*	43.3	36	-16.9%
AURN, Southampton	U3 (CM)	1999	42	41	-2.4%
Police Station, Eastleigh	U1 (DT)	1998	35	35.6	1.7%
Friarsgate, Winchester	U4 (CM)	1999	31.2	28.4	-9.0%
Wickham Square, Wickham	U2 (DT)	1999	23.1	26.6	15.2%
Winchester Rd, Denmead	U2 (DT)	1999	20.4	26.2	28.4%
Lyndhurst School	U4 (DT)	1999	19	27	42.1%
Council Depot, Romsey	U4 (DT)	1999	24.3	24.1	-0.8%

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background. (DT) – diffusion tube measurement; (CM) – continuous monitoring measurement. * Monitoring not undertaken for entire year.

6.2 Particulate Matter (PM_{10})

This assessment considers two air quality standards for PM_{10}: a 24 hour mean to be exceeded not more than 35 times a year (the 90th percentile) and an annual mean of 40 $\mu g/m^3$. The figure 2 series of contour plots in Appendix A show the predicted PM_{10} concentrations for the base case and the year 2004.

Figures 2.1.a/b show the predicted concentrations in the base case (1999) for both the annual mean and 90th percentile standards. The highest concentrations follow the major roads in the Hampshire County Area with the greatest concentration being predicted along the M27 in Eastleigh.

Figures 2.2.a/b show the predicted concentrations in the year 2004, for both the annual mean and 90th percentile objectives, respectively. No areas of exceedance of either objective were predicted in the Hampshire County Area for 1999 or 2004.

Table 6.2 compares the measured and predicted PM_{10} concentrations for the base year to enable the accuracy of the results to be illustrated. The accuracy of the future year modelling results are relative to the accuracy of the base year results. This means that the same degree of confidence can be placed in the future year concentrations when comparing them with the air quality objectives. The agreement of the modelled and the measured concentration is good, within +/- 13%.

Table 6.2: PM_{10} Concentration Validation Results

		Annual Mean (μg/m^3, gravimetric)		
Site Location	*Site Type*	*Measured*	*Predicted*	*Percentage difference*
Stanley Rd, Portsmouth*	U2	26.5	24.4	-7.9%
AURN, Southampton	U3	25.6	24.2	-5.5%
Friarsgate, Winchester	U4	21.4	24.1	12.6%
St Georges Street	U2	24.9	24.1	-3.2%

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background. * Monitoring not undertaken for entire year (1998 values)

6.3 Carbon Monoxide

The modelling study makes predictions for industrial sources of the maximum 8 hourly running mean for carbon monoxide (CO) in the Hampshire County Area for the years 1999 and 2003. The contour plots for these scenarios are shown in Appendix A in Figure 3.1. No exceedances of the CO standard due to industrial sources were predicted for either year and it is considered very unlikely that any exceedances of the CO objective will occur.

6.4 Sulphur Dioxide

Sulphur dioxide (SO_2) concentrations were predicted for the most stringent SO_2 objective, the 15-minute standard, in 2005 to see if the industrial sources in the region had the potential to cause exceedance. The modelling results are shown in Figure 4.1 in Appendix A. The only exceedances of this objective were predicted close to the refineries and power station at Fawley.

Validation of the modelling was only possible with the AURN continuous monitoring site in Southampton due to the parameters of the objective. A reasonable agreement was obtained with this site (see Table 6.3).

Table 6.3: SO_2 Concentration Validation Results

		99.9th Percentile of 15 Minute Means (μg/m^3)		
Site Location	*Site Type*	*Measured*	*Predicted*	*Percentage difference*
AURN, Southampton	U3	161	143	-11.2%

U1 – kerbside; U2 – roadside; U3 – Intermediate; U4 – Urban Background; U5 – Urban Industrial; R1 – Rural Background

The 15-minute objective is widely considered to be the most stringent of the three objectives outlined in the 2000 Air Quality Regulations and so it follows that there should no potential for exceedance of the other two objectives.

6.5 Lead

Lead emissions were modelled for 2004 in order to predict concentrations for comparison with the annual mean objective of 0.5 μg/m^3. There were no predicted exceedances of this objective (see Figure 5.1). The maximum concentration predicted was 0.0082 μg/m^3 near Fawley.

6.6 Benzene

Industrial sources of benzene were modelled for the Hampshire County Area for 2003, in order that comparison could be made with the UKNAQS objective. The results are shown in Figure 6.1 in Appendix A. No exceedances of the annual mean objective of 16.25 μg/m^3 were predicted. The highest concentration predicted for 2003 was 0.47 μg/m^3 near Fawley.

6.7 1,3-Butadiene

1,3-Butadiene emissions from industrial sources were modelled in the Hampshire County Area for the objective year, 2003. The results are shown in Figure 7.1 in Appendix A. No exceedances of the annual mean objective of 2.25 μg/m^3 were predicted with the highest concentration, 0.207 μg/m^3, near Fawley.

6.8 Proposed Industrial Sources

There were two proposed industrial sources, which were modelled independently of the existing concerns. These sites are proposed by Onyx: one, an energy recovery facility, is situated in Hilsea, Portsmouth; the other, an incinerator, is located near Marchwood, Southampton. The modelled predictions, including the relevant background concentrations, are shown in Figures 8.1-8.6 and Figures 9.1-9.6. The impacts of both proposed industrial plants are very small and examined in isolation give no reason for concern. However, both proposed plants are located near to major roads, and near to areas where exceedances of the annual mean NO_2 standard are currently predicted. Therefore, any impact, despite its small magnitude, may be considered to be a problem in such areas.

7 CONCLUSIONS

Predicted levels of nitrogen dioxide and PM_{10} compared reasonably well with measured concentrations across the Hampshire County Area. Levels of nitrogen dioxide and PM_{10} were predicted to meet the air quality objectives throughout the Hampshire County Area in the future cases. There were significant areas of exceedance of the annual mean objective for nitrogen dioxide in 1999 along the major roads, but due to improved emissions controls and lower background concentrations, no exceedances were predicted for the year 2005. The highest nitrogen dioxide levels occur next to the junction of the A334 with the M27 in Eastleigh.

No exceedances of the carbon monoxide, lead, benzene and 1,3-butadiene objectives were predicted in the Hampshire County Area. There is a small level of exceedance of the sulphur dioxide 15-minute mean objective near Fawley. The exceedance area is mostly within the boundaries of the refinery, but there may be a small area of exposure in Fawley village. Continuous monitoring should be considered in this area, as present diffusion tube measurements, although showing low annual mean concentrations, do not indicate the presence of the peak concentrations required by the objective.

8 RECOMMENDATIONS

The current monitoring programmes should be continued, following quality assurance and control procedures outlined in the technical guidance notes. The main priorities are the monitoring of nitrogen dioxide, near areas of high traffic flows, and sulphur dioxide in Fawley close to the refineries. The siting of a continuous sulphur dioxide monitoring station is therefore highly recommended in the Fawley area.

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APPENDIX A

CONTOUR PLOTS

Figure 1.1.a: Nitrogen Dioxide Concentrations ($\mu g/m^3$)
Annual Mean: 1999

National Air Quality Objective 40 $\mu g/m^3$

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Figure 1.1.b: Nitrogen Dioxide Concentrations ($\mu g/m^3$)
99.8th Percentile of Hourly Means: 1999

National Air Quality Objective 200 $\mu g/m^3$

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Figure 1.2.a: Nitrogen Dioxide Concentrations (µg/m^3)
Annual Mean: 2005

National Air Quality Objective 40 µg/m^3

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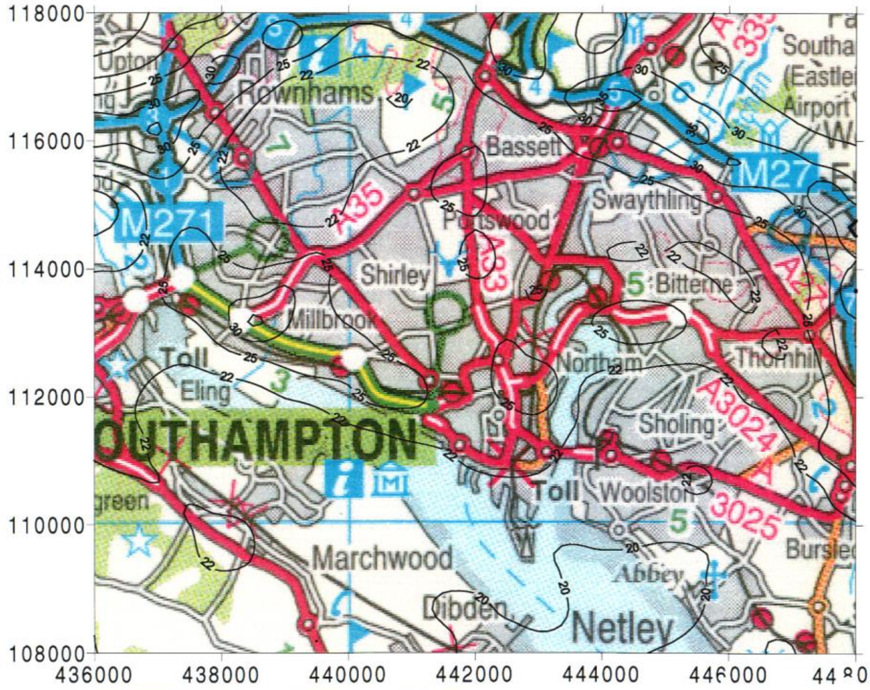
Figure 1.2.b: Nitrogen Dioxide Concentrations ($\mu g/m^3$)
99.8th Percentile of Hourly Means: 2005

Figure 1.3.a: Nitrogen Dioxide Concentrations ($\mu g/m^3$)
Annual Mean: 2005



National Air Quality Objective 40 $\mu g/m^3$

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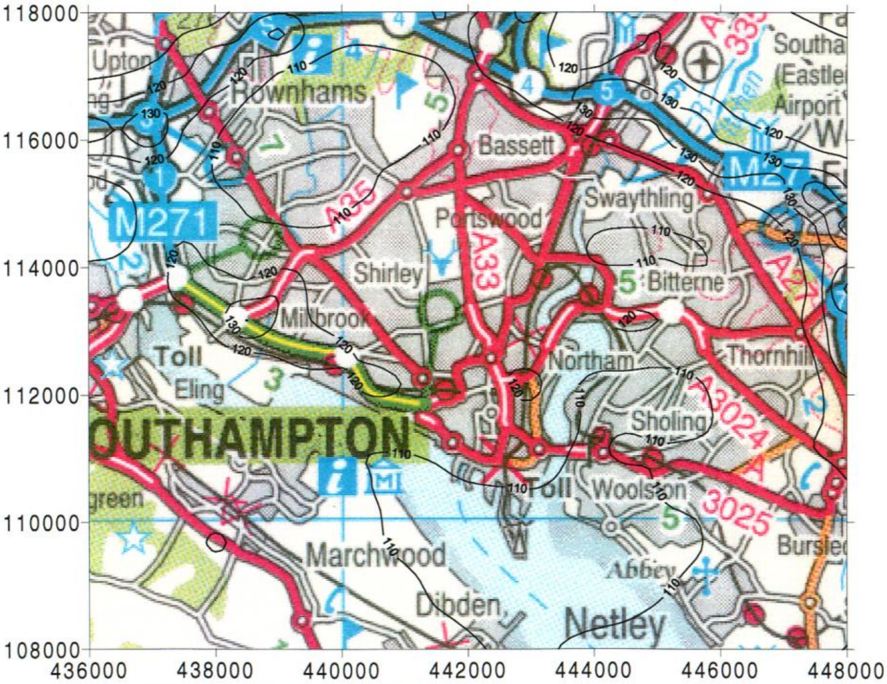
Figure 1.3.b: Nitrogen Dioxide Concentrations (µg/m^3)
99.8th Percentile of Hourly Means: 2005



National Air Quality Objective 200 µg/m^3

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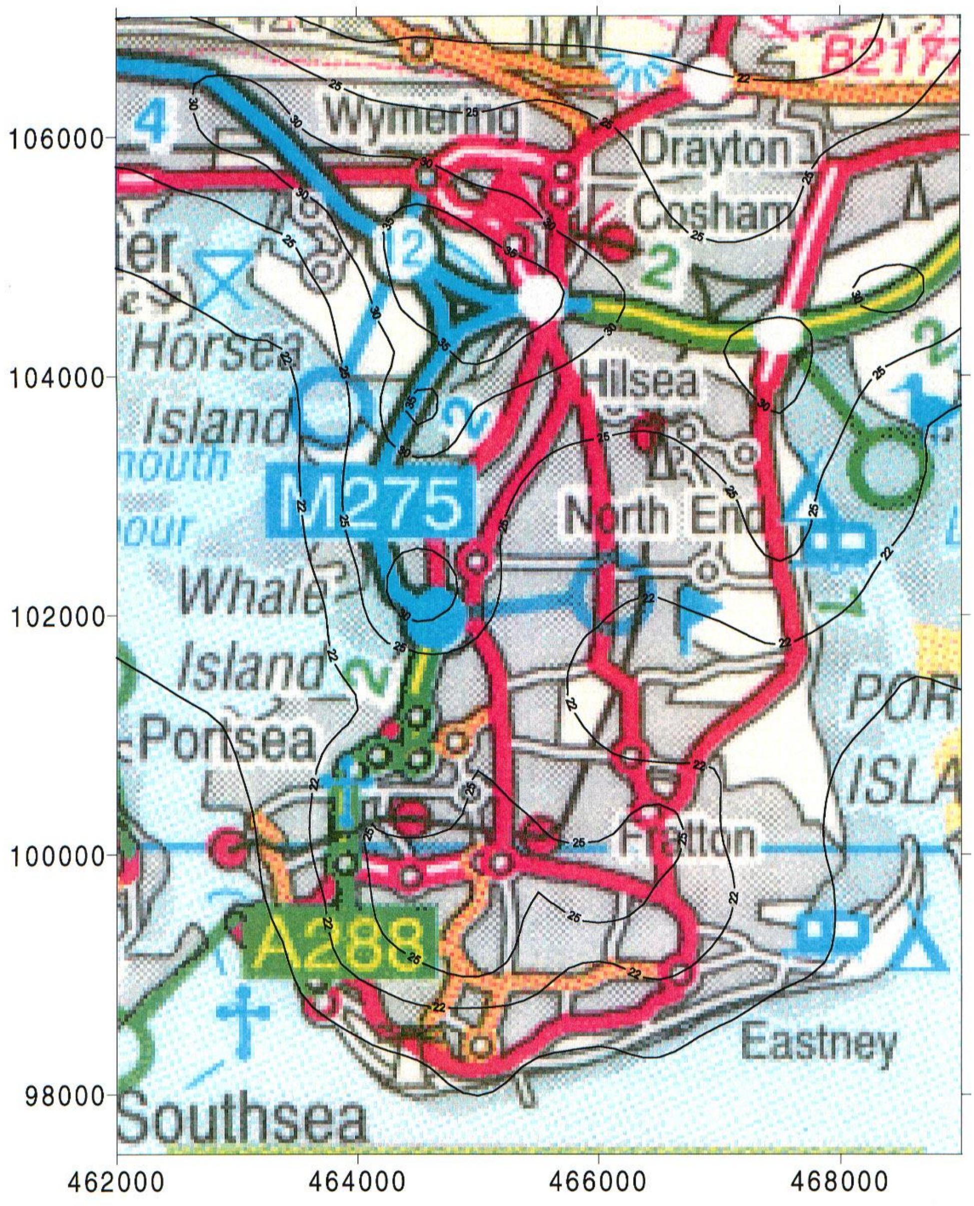
Figure 1.4.a: Nitrogen Dioxide Concentrations ($\mu g/m^3$) Annual Mean: 2005



National Air Quality Objective 40 $\mu g/m^3$

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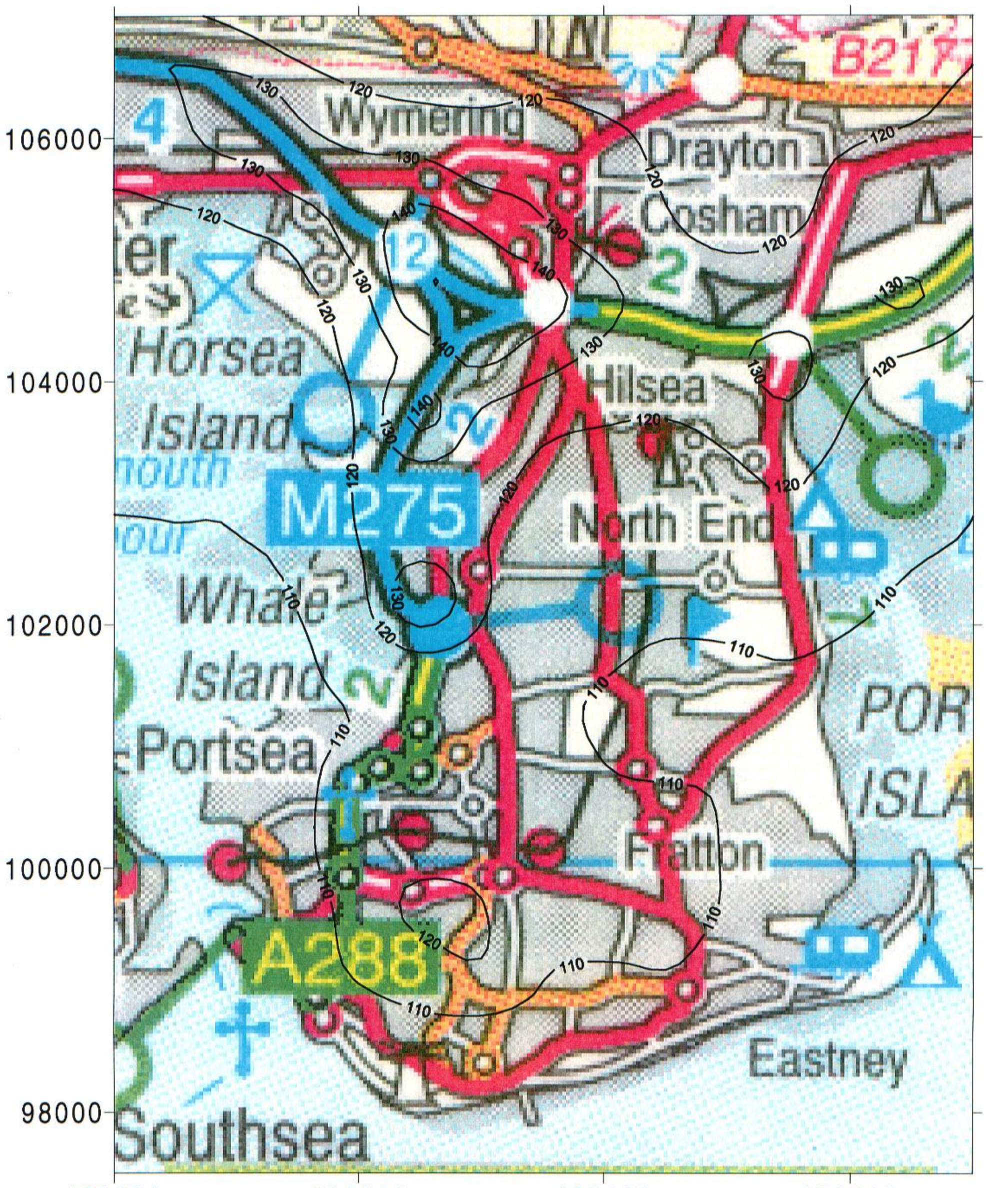
Figure 1.4.b: Nitrogen Dioxide Concentrations ($\mu g/m^3$)
99.8th Percentile of Hourly Means: 2005



National Air Quality Objective 200 $\mu g/m^3$

Figure 2.1.a: PM_{10} Concentrations ($\mu g/m^3$)
Annual Mean: 1999

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Figure 2.1.b: PM$_{10}$ Concentrations ($\mu g/m^3$)
90th Percentile of 24 Hour Means: 1999

National Air Quality Objective 50 $\mu g/m^3$

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Figure 2.2.a: PM$_{10}$ Concentrations ($\mu g/m^3$)
Annual Mean: 2004

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Figure 2.2.b: PM_{10} Concentrations ($\mu g/m^3$)
90th Percentile of 24 Hour Means: 2004

National Air Quality Objective 50 $\mu g/m^3$

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Figure 2.3.a: PM$_{10}$ Concentrations (µg/m^3)
Annual Mean: 2004

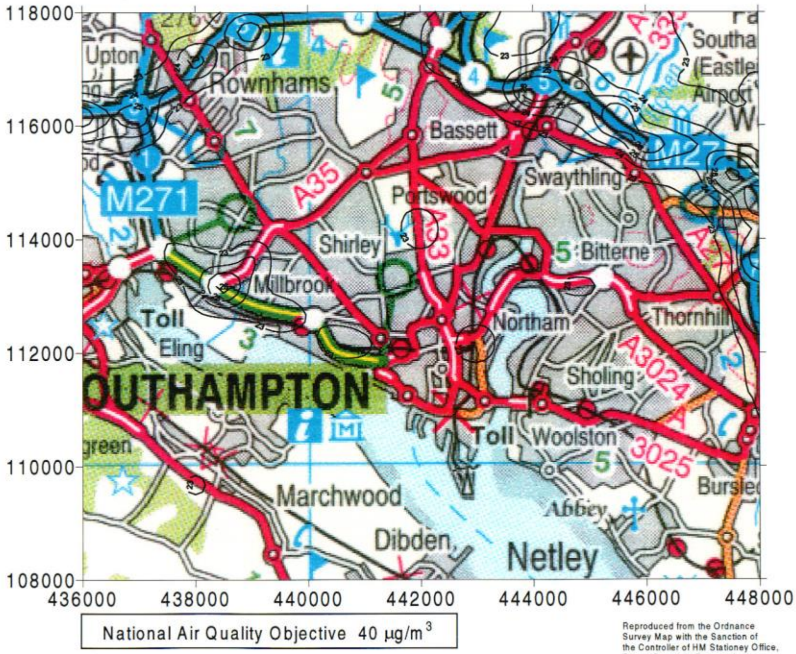

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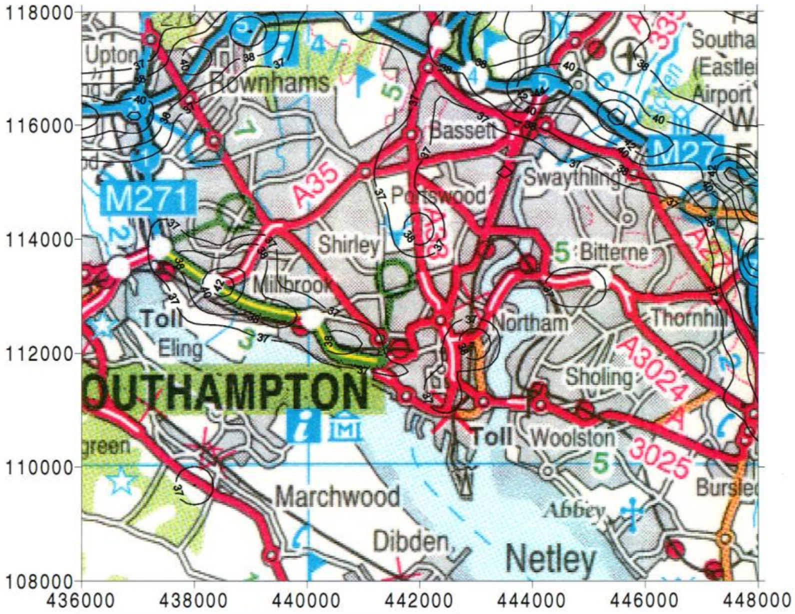
Figure 2.3.b: PM$_{10}$ Concentrations ($\mu g/m^3$)
90th Percentile of 24 Hour Means: 2004



National Air Quality Objective 50 $\mu g/m^3$

Figure 3.1: Carbon Monoxide Concentrations (mg/m^3)
Maximum 8 Hour Mean: 2003

National Air Quality Objective 11.6 mg/m^3

Figure 4.1: Sulphur Dioxide Concentrations (mg/m^3)
99.9th Percentile of our Mean: 2003

National Air Quality Objective 266 µg/m^3

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Figure 5.1: Lead Concentrations ($\mu g/m^3$)
Annual Mean: 2004

National Air Quality Objective 0.5 $\mu g/m^3$

Figure 6.1: Benzene Concentrations ($\mu g/m^3$)
Running Annual Mean: 2004

National Air Quality Objective 16.25 ($\mu g/m^3$)

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Figure 7.1: 1,3 Butadiene Concentrations (μg/m^3)
Running Annual Mean: 2003

Figure 8.1: Onyx Energy Recovery Facility
Nitrogen Dioxide Concentrations ($\mu g/m^3$)
Annual Mean: 2005

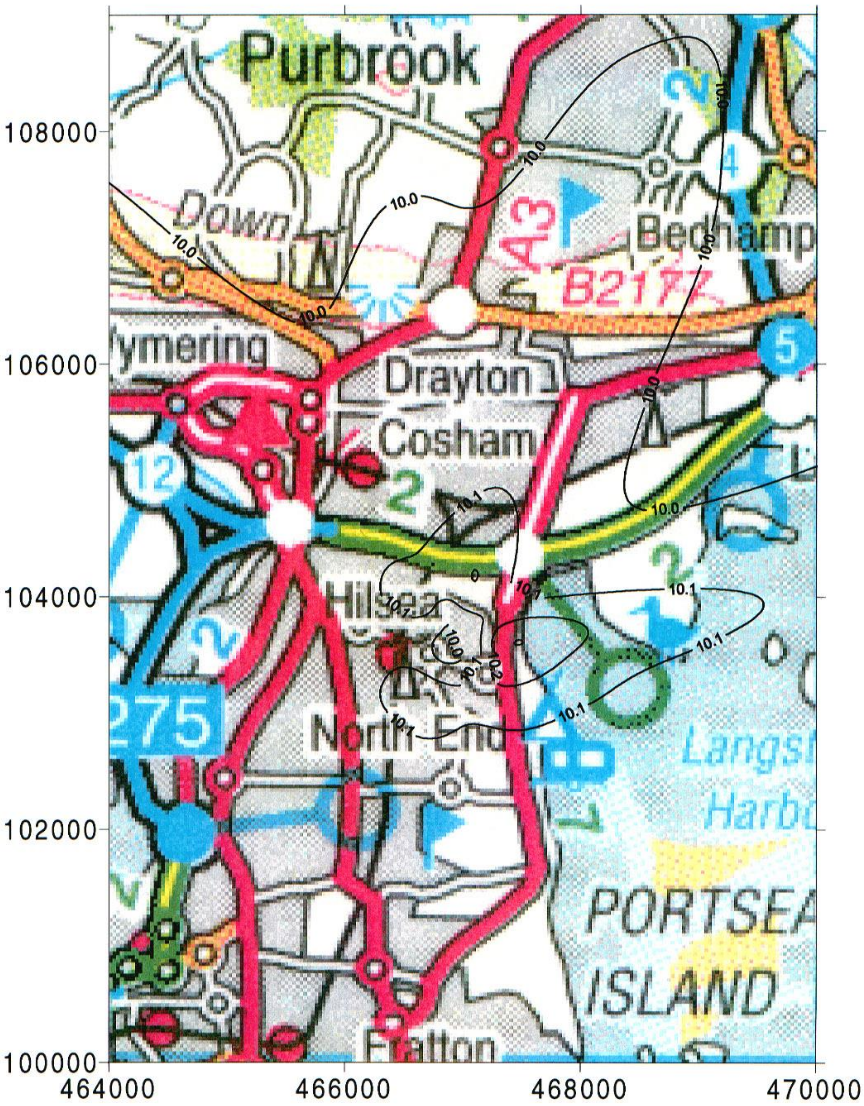


Figure 8.2: Onyx Energy Recovery Facility Nitrogen Dioxide Concentrations (μg/m^3) 99.8th Percentile of Hourly Means: 2005

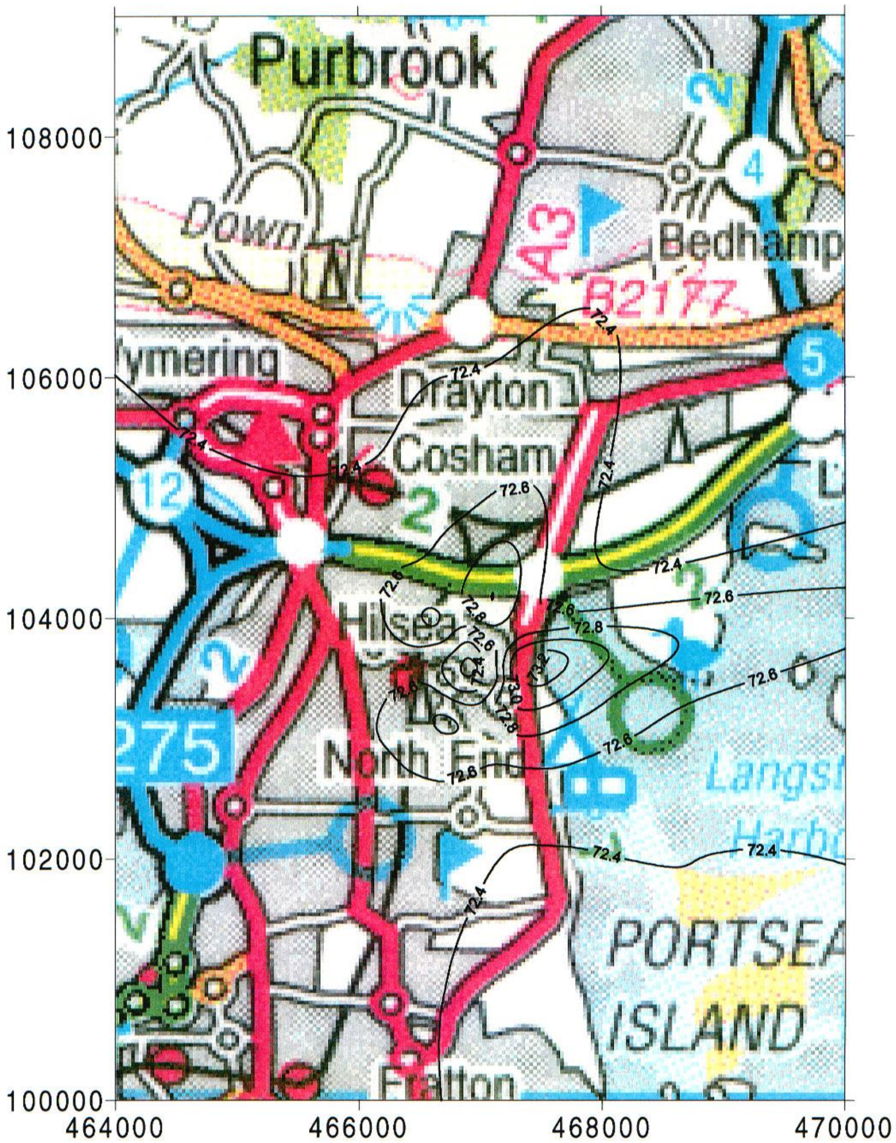


Figure 8.3: Onyx Energy Recovery Facility
Carbon Monoxide Concentrations (mg/m^3)
Maximum 8 Hour Mean: 2003

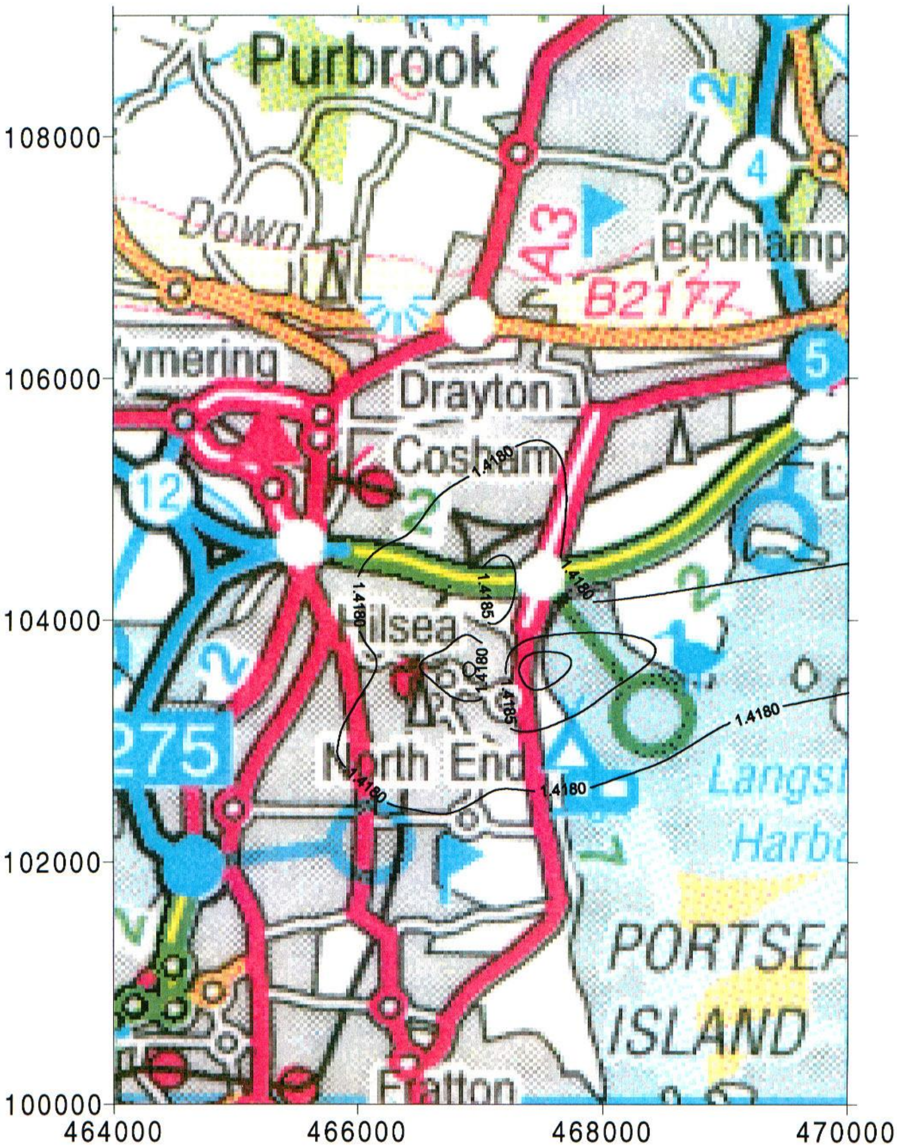


Figure 8.4: Onyx Energy Recovery Facility

PM_{10} Concentrations (μg/m^3)

Annual Mean: 2004

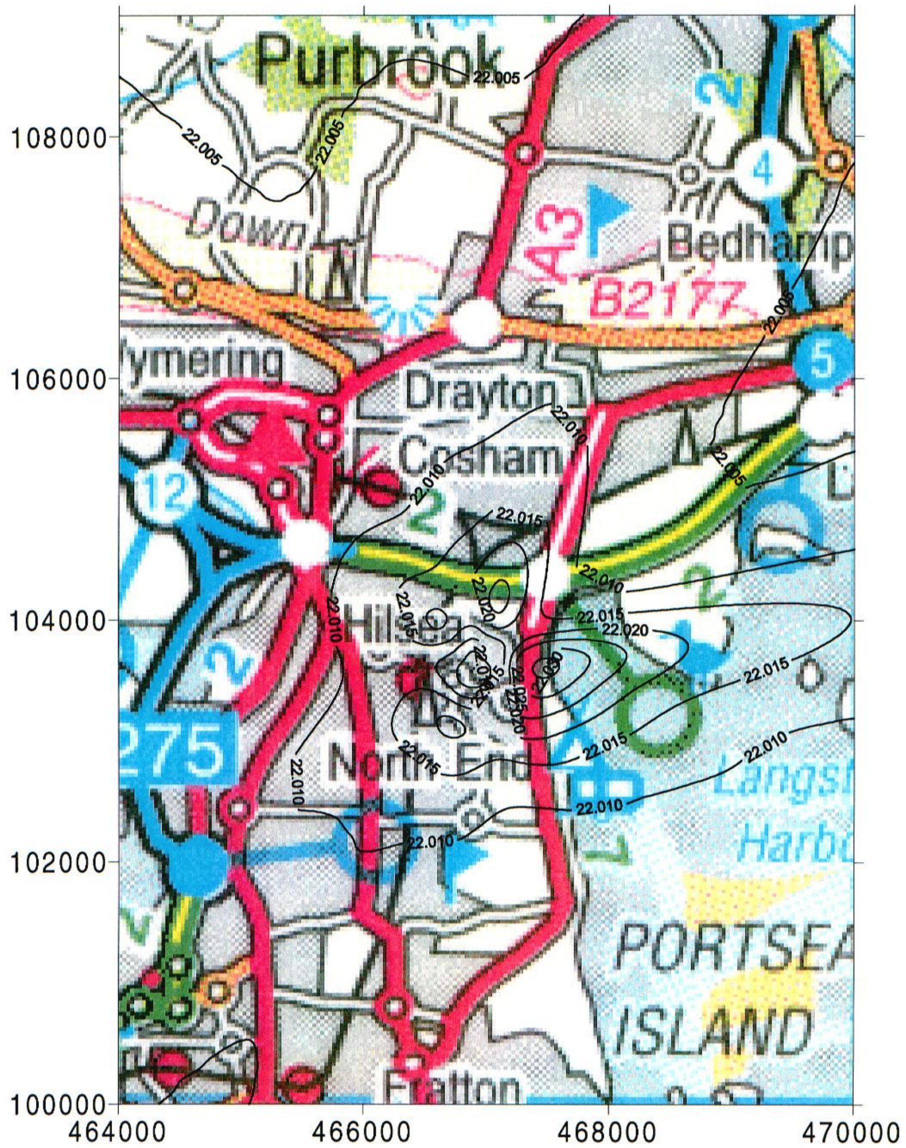


Figure 8.5: Onyx Energy Recovery Facility
PM$_{10}$ Concentrations ($\mu g/m^3$)
90th Percentile of 24 Hour Means: 2004

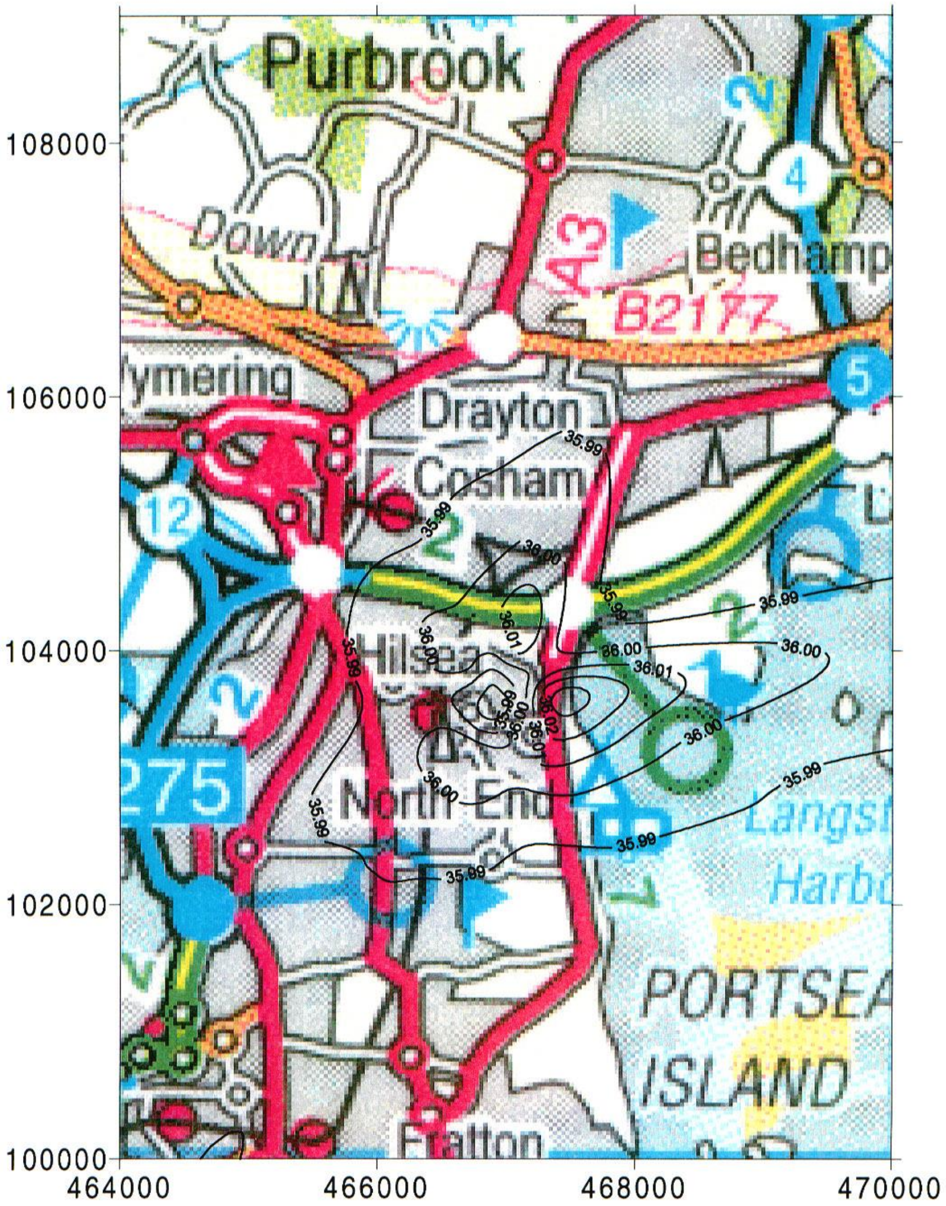


Figure 8.6: Onyx Energy Recovery Facility
Sulphur Dioxide Concentrations ($\mu g/m^3$)
99.9th Percentile of 15 Minute Means: 2005

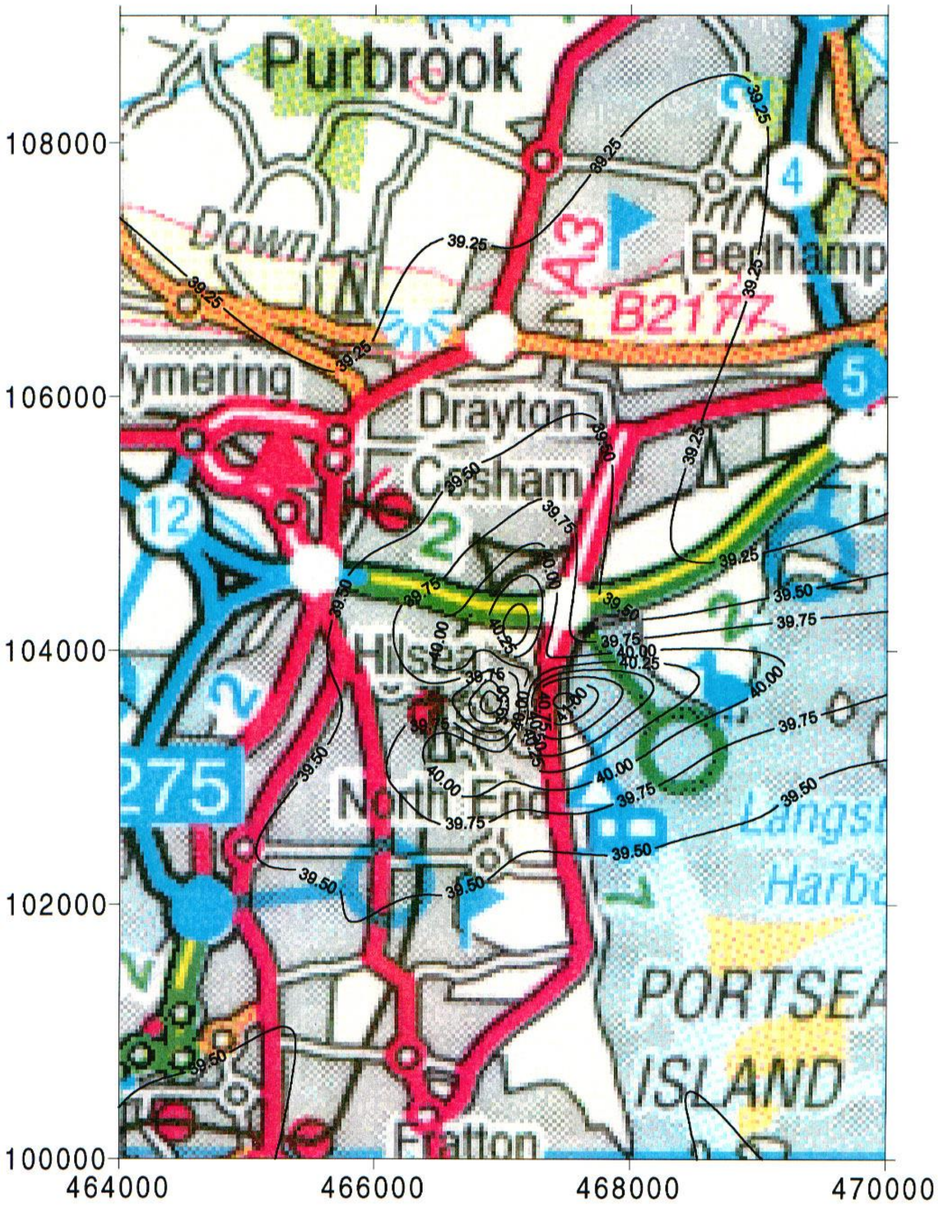


Figure 9.1: Onyx Marchwood Incinerator
Nitrogen Dioxide Concentrations ($\mu g/m^3$)
Annual Mean: 2005

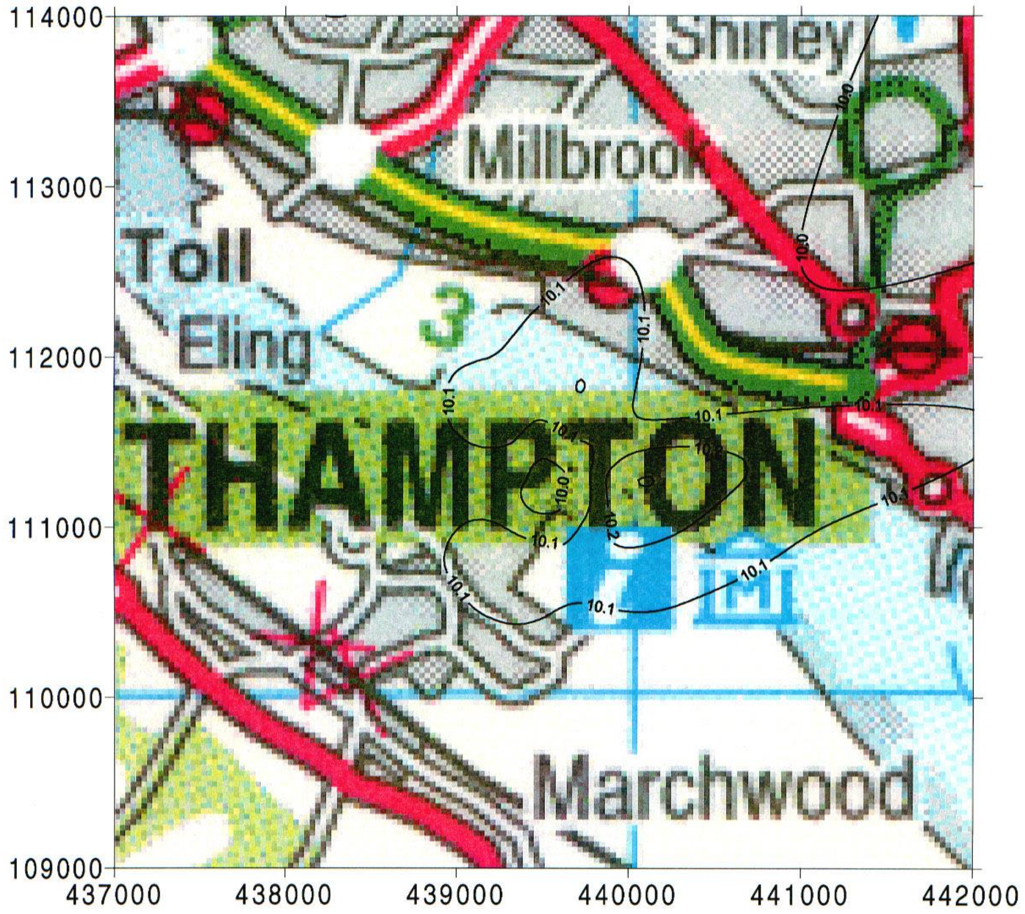


Figure 9.2: Onyx Marchwood Incinerator
Nitrogen Dioxide Concentrations ($\mu g/m^3$)
99.8th Percentile of Hourly Means: 2005

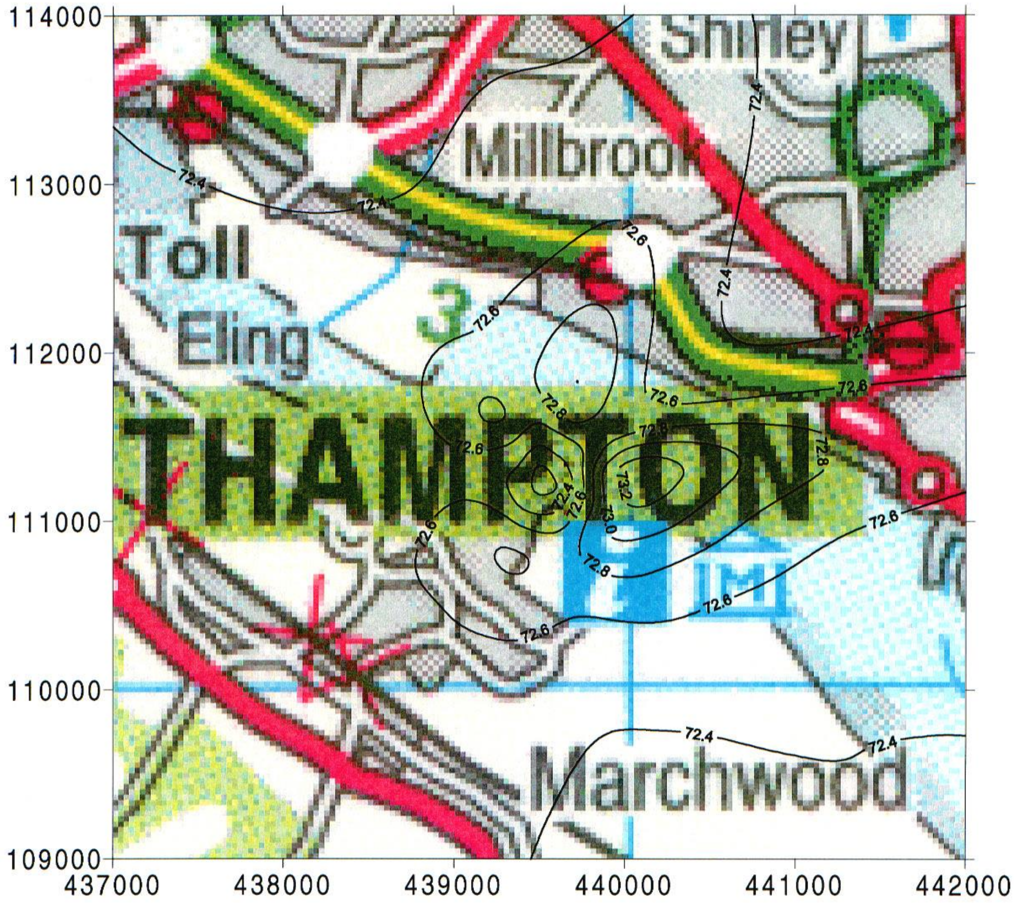


Figure 9.3: Onyx Marchwood Incinerator
Carbon Monoxide Concentrations (mg/m^3)
Maximum 8 Hour Mean: 2003

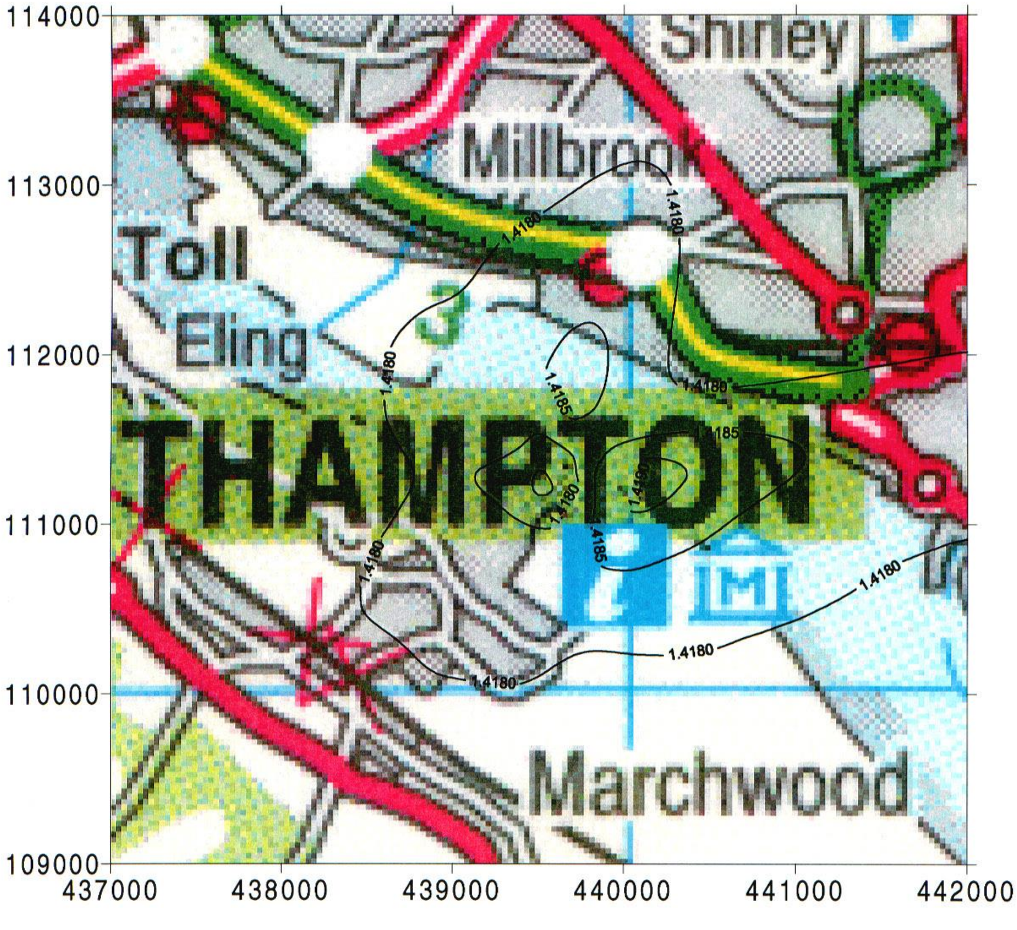


Figure 9.4: Onyx Marchwood Incinerator
PM_{10} Concentrations ($\mu g/m^3$)
Annual Mean: 2004

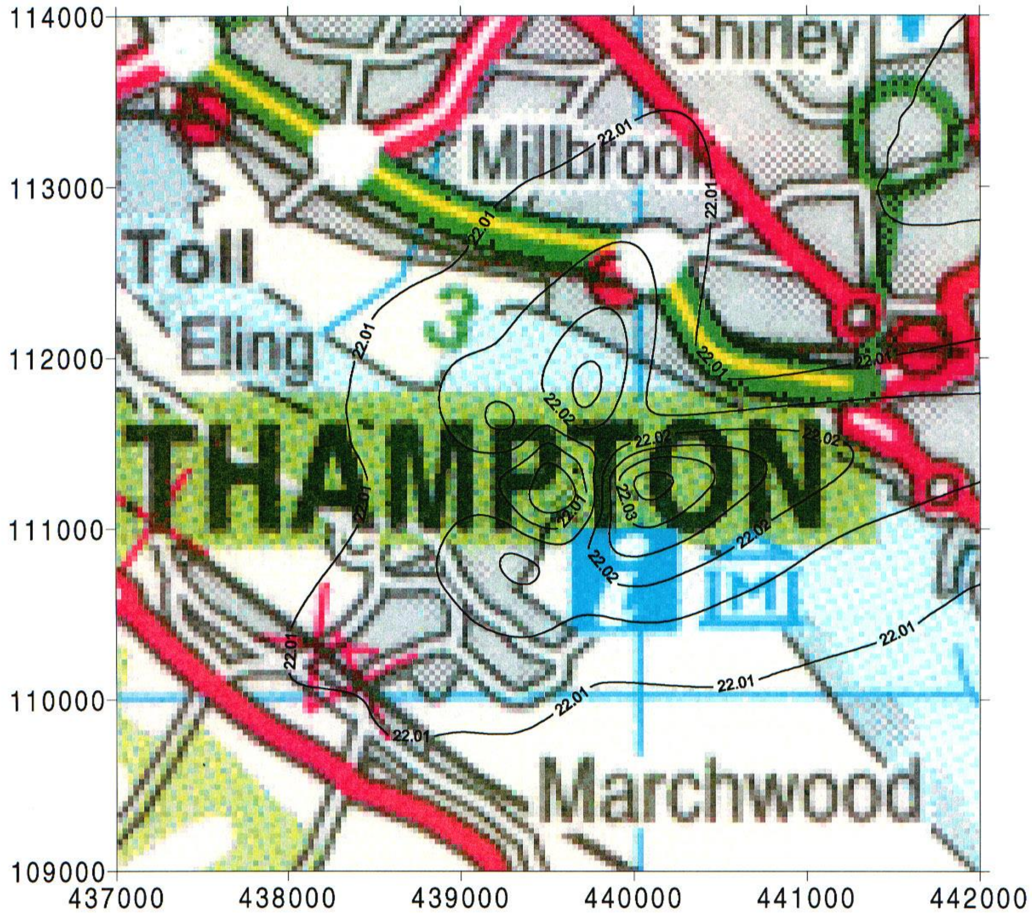


Figure 9.5: Onyx Marchwood Incinerator
PM_{10} Concentrations ($\mu g/m^3$)
90th Percentile of 24 Hour Means: 2004

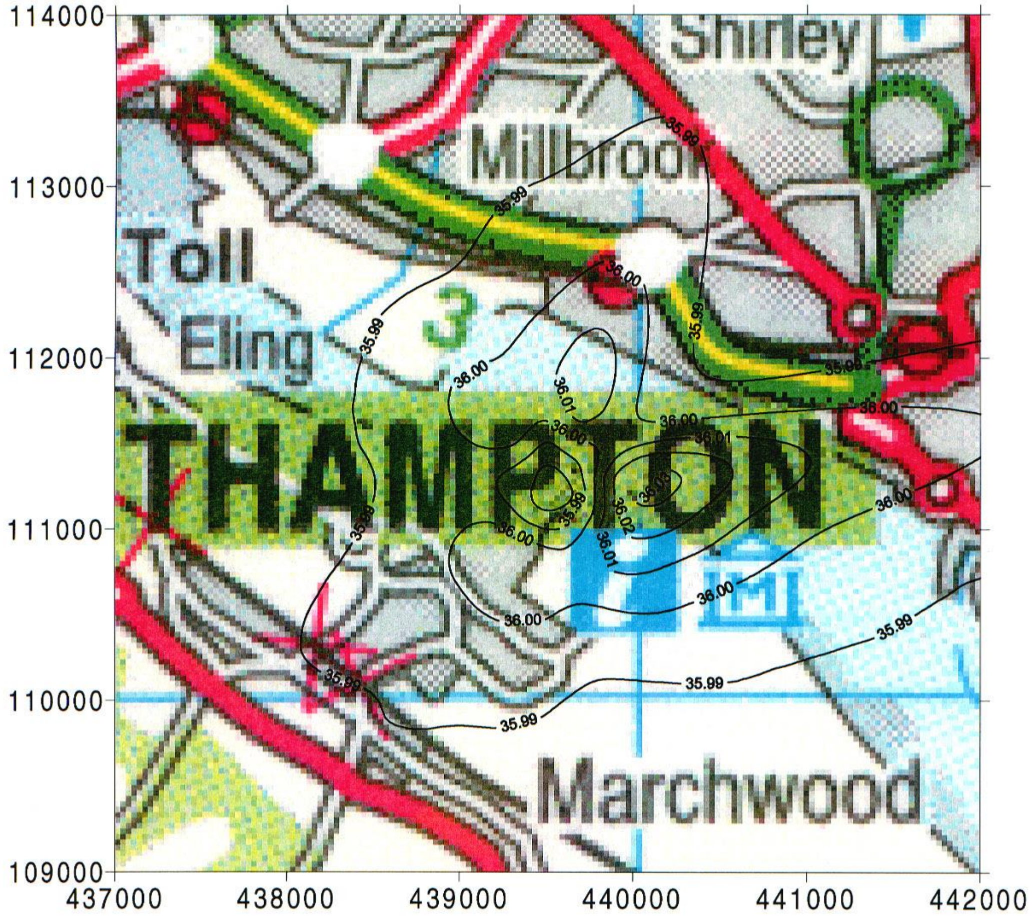
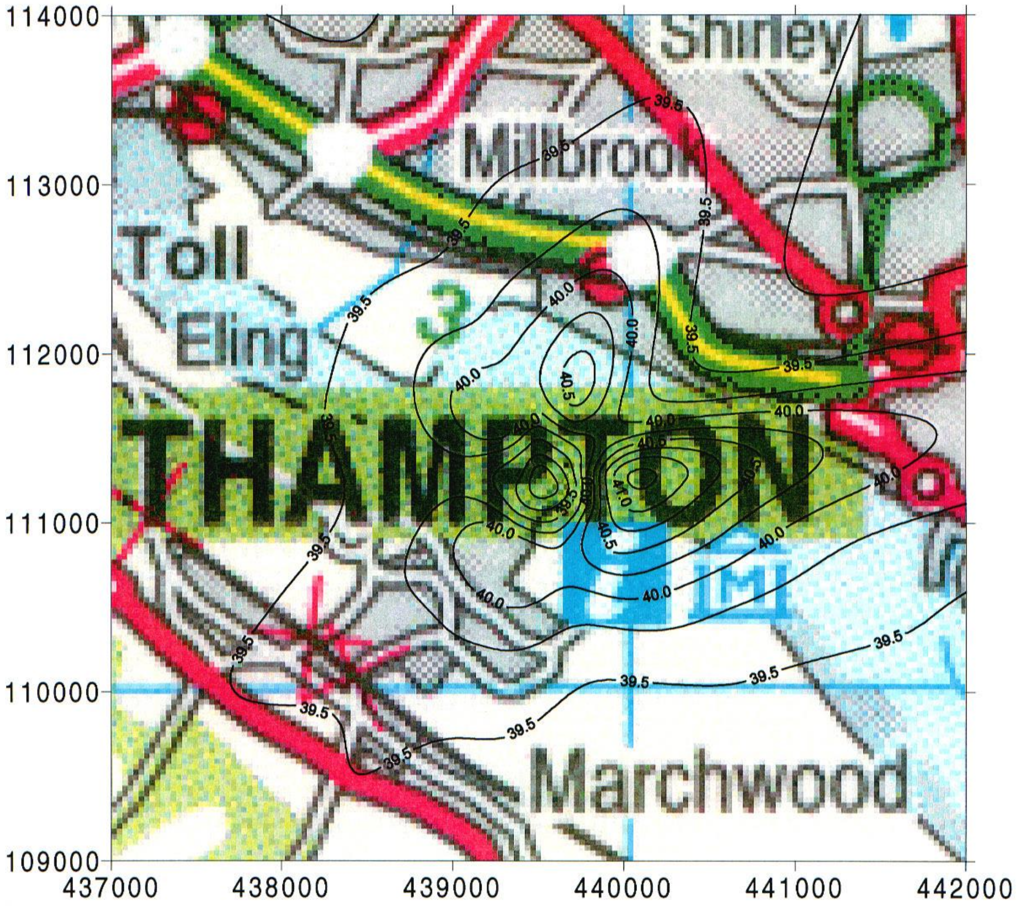


Figure 9.6: Onyx Marchwood Incinerator
Sulphur Dioxide Concentrations (μg/m^3)
99.9th Percentile of 15 Minute Means: 2005



APPENDIX B

AIR QUALITY CRITERIA

Summary of the revised objectives adopted in the 2000 National Air Quality Strategy

Pollutant	**Objective**		**Date to be achieved by**	**Change over previous (1997) strategy objective**
	Concentration	Measured as		
Benzene	16.25µg/m^3 (5ppb)	running annual mean	December 31, 2003	Tougher: ie same numbers, target date brought forward two years
1,3-Butadiene	2.25µg/m^3 (1ppb)	running annual mean	December 31, 2003	Tougher: ie same numbers, target date brought forward two years
Carbon monoxide	11.6mg/m^3 (10ppm)	running 8 hour mean	December 31, 2003	Tougher: ie same numbers, target date brought forward two years
Lead	0.5µg/m^3	annual mean	December 31, 2004	Tougher: ie same numbers, target date brought forward two year
	0.25µg/m^3	annual mean	December 31, 2008	New objective
Nitrogen dioxide	200µg/m^3 (105ppb)	1 hour mean not to be exceeded more than 18 times a year	December 31, 2005	Tighter limit, dropping from 286mgm^3 (150ppb), same target date, remains provisional
	40µg/m^3 (21ppb)	annual mean	December 31, 2005	Unchanged: same numbers, same target date, remains provisional
Particles (PM$_{10}$)	50µg/m^3	24 hour mean not to be exceeded more than 35 times a year	December 31, 2004	Relaxed: more exceedances allowed, target date brought forward one year
	40µg/m^3	annual mean	December 31, 2004	New objective
Sulphur dioxide	350µg/m^3 (132ppb)	1 hour mean not to be exceeded more than 24 times a year	December 31, 2004	New objective
	125µg/m^3 (47ppb)	24 hour mean not to be exceeded more than 3 times a year	December 31, 2004	New objective
	266µg/m^3 (100ppb)	15 minute mean not to be exceeded more than 35 times a year	December 31, 2005	Unchanged, same numbers, same target date, but no longer provisional

APPENDIX C

EMISSION TRENDS

Figure C.1: Variation of Total UK NO_x Emissions with Time

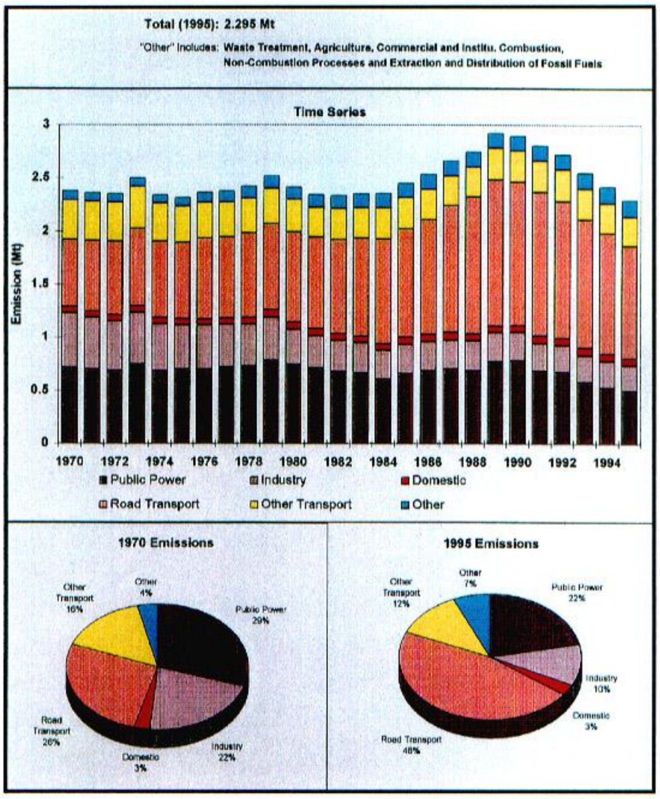


Figure C.2: Variation of Total UK PM_{10} Emissions with Time

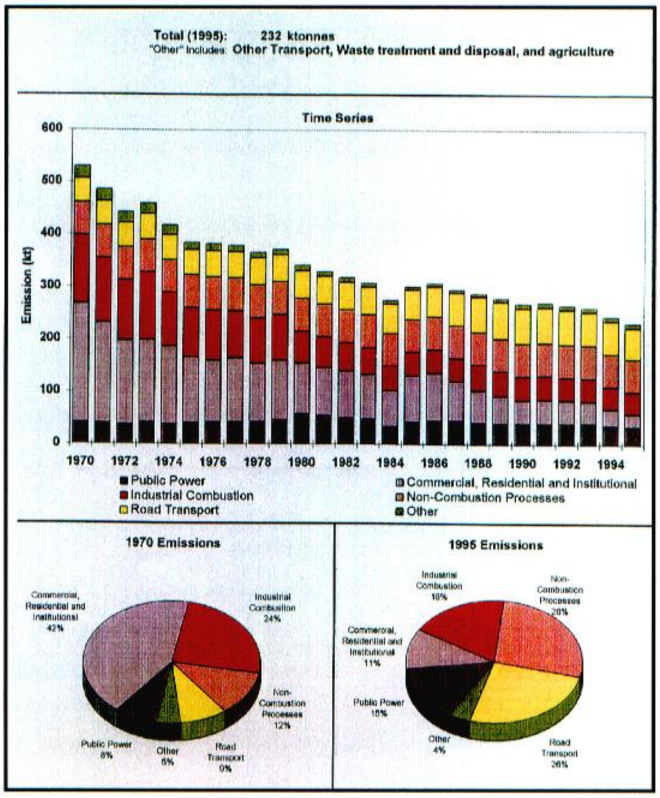
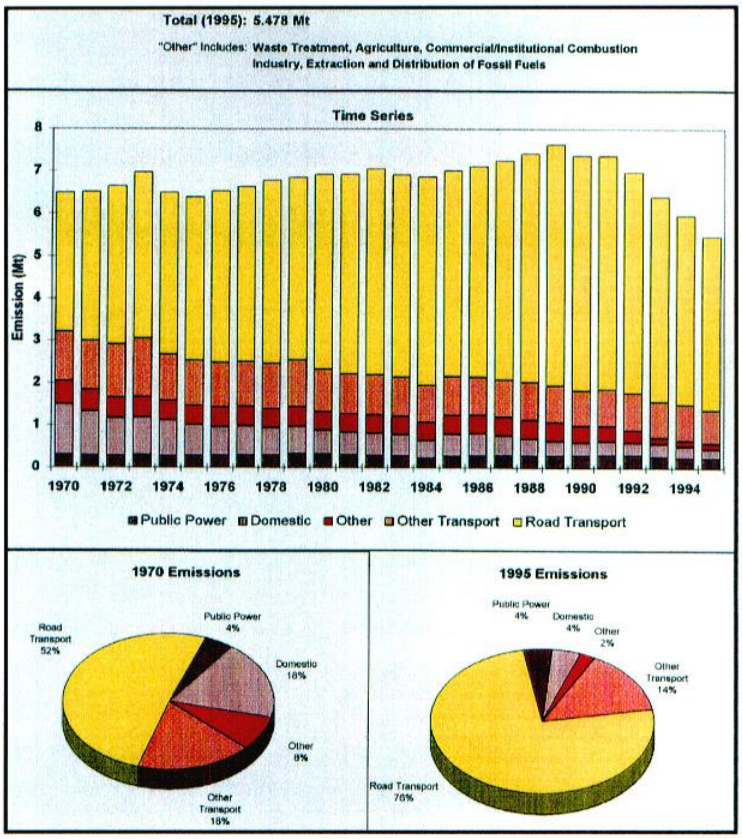


Figure C.3: Variation of Total UK CO Emissions with Time



APPENDIX D

AAQUIRE DESCRIPTION

The AAQuIRE 2000 software is a system to predict Ambient Air Quality in Regional Environments and comprises a regional air quality model and statistical package.

AAQuIRE was developed by Consultants in Environmental Sciences Ltd (CES) to meet three requirements in predictive air quality studies. The first requirement was an immediate need for a system which produced results which 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 50 µg/m^3 is expressed as a 90th percentile of hourly means. This is usually considered by predicting for all points within a study area the percentage frequency of exceedance of a 50 µg/m^3 level. This approach is clearer and far simpler than the direct calculation of percentile values. 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, no to be exceeded more then 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 way in which AAQuIRE operates and the models currently available within it are discussed below.

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

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

Both the second (file generation) and fourth (statistical interpretation) stages produce log files which record all the input file names and other data required in the processing. These form a record of a study and can be utilised directly by the appropriate stages of AAQuIRE to repeat exactly previous studies. Additionally, during the statistical interpretation stage the log data for the dispersion modelling inputs are checked to ensure that only appropriate data are combined.

The first step in operating AAQuIRE was to prepare the input data. Data was 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 Hampshire County study area;
- grid of model prediction locations (receptors);
- traffic emissions data; and

The modelling is always carried out to give annual average results from which appropriate shorter period concentrations can be derived. These relationships are given in Table D.1.

The second stage is the generation of all the model input files and control files required for a study. A concentration is calculated at each receptor, for each of the categories included in the meteorological data file for each of the pollutant sources.

The third stage is executing the models. A sophisticated management system allows the dispersion modelling to be carried out simultaneously on a number of machines linked by a suitable network. Also at this stage, where an input file has been split across a number of runs because of runtime constraints, the separate results files are combined into one file per category.

Table D.1: Short Term Averaging Conversions

Pollutant	Relationship
Nitrogen dioxide	99.8th Percentile of 1 Hour Means = 12.8365*(Annual Mean $NO_{x)}$)$^{0.4604}$
PM_{10}	90th Percentile of 24 Hour Means = 1.4991*(Annual Mean $PM_{10)}$)$^{1.0281}$
Sulphur dioxide	99.9th Percentile of 15 minute means = 13.6818*(Annual Mean SO_{2})
Carbon Monoxide	Maximum 8 Hour Mean = 10.4244*(Annual Mean CO)-2.4052*(Annual Mean CO)^2+0.2288*(Annual Mean CO)^3

The fourth stage is the statistical combination of the dispersion results and the specification of the relevant averaging period. More than one profile is required because not all emission sources will behave the same way during a day. For example traffic normally has a very clear variation during a day which differs from that for urban heating or industrial emissions.

The final results can be processed in two ways, according to the available meteorological data. Where summary annual data, determined over a period of several years, are used then the total day - profile of concentration is determined for each meteorological category at each receptor point. This will either be a mean value or determination of the exceedance or non-exceedance of a standard. This value is then weighted by the occurrence frequency of the meteorological category in question and combined with the results for all other categories, each weighted for frequency of occurrence, to give the required statistic for each receptor point.

Using the hourly or 15-minute meteorological data, and diurnal profile, pollutant concentrations can be predicted for each hour/ quarter hour of the year and the required statistics calculated for each receptor point in the study area.

The final stage is presentation of results. Currently the results 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 (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 individual major roads, in properly assessing `regional' effects.

APPENDIX E

VEHICLE EMISSIONS

Table E.1: Emission Rates of NO_x (g/km) from the Vehicle Fleet

Speed km/h	Petrol Cars		Diesel Cars		Petrol LGV		Diesel LGV		Rigids		Artics		Buses		M'cycles	
	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005
5	1.0008	0.4705	0.7604	0.3575	1.5743	0.7402	1.3420	0.6309	10.6562	5.0100	21.0318	9.8880	17.7735	8.3561	0.1998	0.0939
10	0.9997	0.3599	0.6987	0.2516	1.5673	0.5643	1.2531	0.4512	10.1674	3.6606	20.0174	7.2070	16.4280	5.9146	0.1998	0.0719
15	1.0044	0.3122	0.6413	0.1993	1.5676	0.4872	1.1713	0.3641	9.7184	3.0207	19.0490	5.9209	15.1854	4.7200	0.1998	0.0621
20	1.0148	0.2870	0.5882	0.1663	1.5752	0.4454	1.0966	0.3101	9.3094	2.6324	18.1265	5.1255	14.0458	3.9716	0.1998	0.0565
25	1.0310	0.2728	0.5394	0.1427	1.5902	0.4208	1.0290	0.2723	8.9404	2.3657	17.2498	4.5644	13.0092	3.4423	0.1998	0.0529
30	1.0529	0.2653	0.4948	0.1247	1.6125	0.4063	0.9685	0.2440	8.6113	2.1696	16.4191	4.1368	12.0756	3.0424	0.1998	0.0503
35	1.0806	0.2623	0.4546	0.1103	1.6421	0.3986	0.9151	0.2221	8.3221	2.0199	15.6343	3.7947	11.2449	2.7293	0.1998	0.0485
40	1.1140	0.2625	0.4187	0.0987	1.6791	0.3957	0.8687	0.2047	8.0728	1.9024	14.8954	3.5103	10.5172	2.4785	0.1998	0.0471
45	1.1531	0.2655	0.3870	0.0891	1.7234	0.3968	0.8294	0.1910	7.8635	1.8105	14.2025	3.2701	9.8925	2.2777	0.1998	0.0460
50	1.1980	0.2708	0.3597	0.0813	1.7751	0.4013	0.7972	0.1802	7.6941	1.7394	13.5554	3.0644	9.3708	2.1184	0.1998	0.0452
55	1.2486	0.2782	0.3366	0.0750	1.8341	0.4086	0.7721	0.1720	7.5646	1.6854	12.9542	2.8862	8.9520	1.9945	0.1998	0.0445
60	1.3050	0.2874	0.3178	0.0700	1.9004	0.4185	0.7540	0.1661	7.4750	1.6462	12.3989	2.7305	8.6362	1.9019	0.1998	0.0440
65	1.3671	0.2981	0.3033	0.0662	1.9741	0.4305	0.7431	0.1620	7.4254	1.6193	11.8896	2.5929	8.4234	1.8370	0.1998	0.0436
70	1.4350	0.3108	0.2931	0.0635	2.0551	0.4452	0.7392	0.1601	7.4157	1.6064	11.4261	2.4751	8.3136	1.8009	0.1998	0.0433
75	1.5086	0.3250	0.2872	0.0619	2.1435	0.4617	0.7424	0.1599	7.4460	1.6039	11.0086	2.3713	8.3067	1.7893	0.1998	0.0430
80	1.5880	0.3405	0.2856	0.0613	2.2392	0.4802	0.7527	0.1614	7.5162	1.6118	10.6370	2.2810	8.4028	1.8019	0.1998	0.0428
85	1.6731	0.3576	0.2883	0.0616	2.3422	0.5007	0.7700	0.1646	7.6263	1.6303	10.3112	2.2042	8.6019	1.8388	0.1998	0.0427
90	1.7639	0.3760	0.2953	0.0629	2.4526	0.5228	0.7945	0.1694	7.7763	1.6577	10.0314	2.1384	8.9040	1.8981	0.1998	0.0426
95	1.8605	0.3955	0.3066	0.0652	2.5703	0.5465	0.8260	0.1756	7.9663	1.6937	9.7975	2.0830	9.3090	1.9791	0.1998	0.0425
100	1.9628	0.4168	0.3221	0.0684	2.6953	0.5723	0.8646	0.1836	8.1962	1.7403	9.6095	2.0404	9.8170	2.0844	0.1998	0.0424
105	2.0709	0.4388	0.3420	0.0725	2.8277	0.5992	0.9103	0.1929					10.4280	2.2097	0.1998	0.0423
110	2.1847	0.4624	0.3661	0.0775	2.9674	0.6280	0.9631	0.2038					11.1420	2.3580	0.1998	0.0423
115	2.3043	0.4871	0.3945	0.0834	3.1145	0.6584	1.0229	0.2162					11.9589	2.5281	0.1998	0.0422

Table E.2: Emission Rates of CO (g/km) from the Vehicle Fleet

Speed km/h	Petrol Cars		Diesel Cars		Petrol LGV		Diesel LGV		Rigids		Artics		Buses		M'cycles	
	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005
5	15.7990	4.0006	0.9054	0.2293	48.2843	12.2266	1.9324	0.4893	5.9464	1.5058	5.8775	1.4883	16.2457	4.1138	16.5307	4.1859
10	14.3285	3.7440	0.8298	0.2168	41.6621	10.8861	1.7607	0.4601	5.2871	1.3815	5.2551	1.3731	14.1887	3.7074	16.5307	4.3194
15	12.9607	3.4564	0.7589	0.2024	35.6185	9.4989	1.6020	0.4272	4.6840	1.2492	4.6840	1.2492	12.2900	3.2776	16.5307	4.4085
20	11.6954	3.1610	0.6927	0.1872	30.1534	8.1497	1.4564	0.3936	4.1372	1.1182	4.1642	1.1255	10.5496	2.8513	16.5307	4.4678
25	10.5328	2.8735	0.6311	0.1722	25.2669	6.8931	1.3238	0.3611	3.6467	0.9949	3.6955	1.0082	8.9676	2.4465	16.5307	4.5098
30	9.4727	2.5969	0.5742	0.1574	20.9589	5.7459	1.2042	0.3301	3.2124	0.8807	3.2781	0.8987	7.5438	2.0681	16.5307	4.5319
35	8.5153	2.3390	0.5219	0.1434	17.2295	4.7326	1.0977	0.3015	2.8343	0.7785	2.9118	0.7998	6.2783	1.7245	16.5307	4.5407
40	7.6604	2.1045	0.4743	0.1303	14.0786	3.8677	1.0042	0.2759	2.5126	0.6902	2.5968	0.7134	5.1712	1.4206	16.5307	4.5413
45	6.9082	1.8908	0.4314	0.1181	11.5063	3.1493	0.9238	0.2528	2.2470	0.6150	2.3331	0.6386	4.2223	1.1557	16.5307	4.5245
50	6.2585	1.7018	0.3932	0.1069	9.5125	2.5866	0.8564	0.2329	2.0378	0.5541	2.1205	0.5766	3.4318	0.9331	16.5307	4.4949
55	5.7115	1.5371	0.3596	0.0968	8.0973	2.1792	0.8020	0.2158	1.8847	0.5072	1.9592	0.5273	2.7995	0.7534	16.5307	4.4489
60	5.2670	1.4046	0.3308	0.0882	7.2606	1.9362	0.7606	0.2028	1.7880	0.4768	1.8490	0.4931	2.3256	0.6202	16.5307	4.4083
65	4.9252	1.2920	0.3065	0.0804	7.0025	1.8369	0.7324	0.1921	1.7474	0.4584	1.7901	0.4696	2.0099	0.5272	16.5307	4.3364
70	4.6859	1.2075	0.2870	0.0740	7.3229	1.8871	0.7171	0.1848	1.7632	0.4544	1.7825	0.4593	1.8526	0.4774	16.5307	4.2599
75	4.5493	1.1510	0.2721	0.0688	8.2219	2.0802	0.7149	0.1809	1.8352	0.4643	1.8260	0.4620	1.8536	0.4690	16.5307	4.1823
80	4.5152	1.1275	0.2619	0.0654	9.6994	2.4220	0.7257	0.1812	1.9634	0.4903	1.9208	0.4796	2.0128	0.5026	16.5307	4.1278
85	4.5838	1.1327	0.2563	0.0633	11.7555	2.9050	0.7496	0.1852	2.1479	0.5308	2.0667	0.5107	2.3304	0.5759	16.5307	4.0850
90	4.7549	1.1708	0.2555	0.0629	14.3901	3.5434	0.7865	0.1937	2.3887	0.5882	2.2639	0.5575	2.8063	0.6910	16.5307	4.0705
95	5.0287	1.2365	0.2593	0.0637	17.6033	4.3284	0.8364	0.2057	2.6857	0.6604	2.5124	0.6178	3.4405	0.8460	16.5307	4.0646
100	5.4050	1.3434	0.2677	0.0665	21.3950	5.3178	0.8994	0.2235	3.0390	0.7554	2.8120	0.6989	4.2330	1.0521	16.5307	4.1088
105	5.8840	1.4761	0.2809	0.0705	25.7653	6.4636	0.9754	0.2447					5.1838	1.3004	16.5307	4.1470
110	6.4655	1.6503	0.2987	0.0762	30.7141	7.8395	1.0645	0.2717					6.2929	1.6062	16.5307	4.2193
115	7.1497	1.8542	0.3212	0.0833	36.2415	9.3989	1.1666	0.3025					7.5603	1.9607	16.5307	4.2871

Table E.3: Emission Rates of PM_{10} (g/km) from the Vehicle Fleet

Speed km/h	Petrol Cars		Diesel Cars		Petrol LGV		Diesel LGV		Rigids		Artics		Buses		M'cycles	
	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005	1996	2005
5	0.0292	0.0347	0.1604	0.1905	0.0456	0.0541	0.4794	0.5693	1.4694	0.8346	1.5172	0.8618	1.1714	1.3911	0.0874	0.1038
10	0.0292	0.0322	0.1456	0.1604	0.0456	0.0502	0.4389	0.4836	1.3123	0.7419	1.3571	0.7672	1.1216	1.2358	0.0874	0.0963
15	0.0292	0.0308	0.1320	0.1391	0.0456	0.0480	0.4018	0.4233	1.1687	0.6590	1.2097	0.6821	1.0720	1.1294	0.0874	0.0921
20	0.0292	0.0296	0.1196	0.1213	0.0456	0.0462	0.3679	0.3732	1.0384	0.5895	1.0750	0.6102	1.0224	1.0371	0.0874	0.0887
25	0.0292	0.0287	0.1083	0.1063	0.0456	0.0447	0.3374	0.3312	0.9215	0.5165	0.9529	0.5341	0.9730	0.9551	0.0874	0.0858
30	0.0292	0.0278	0.0982	0.0935	0.0456	0.0434	0.3101	0.2951	0.8180	0.4506	0.8436	0.4648	0.9236	0.8791	0.0874	0.0832
35	0.0292	0.0270	0.0893	0.0826	0.0456	0.0421	0.2861	0.2646	0.7279	0.4007	0.7470	0.4113	0.8743	0.8087	0.0874	0.0809
40	0.0292	0.0263	0.0815	0.0735	0.0456	0.0411	0.2653	0.2392	0.6511	0.3711	0.6631	0.3779	0.8251	0.7440	0.0874	0.0788
45	0.0292	0.0257	0.0749	0.0659	0.0456	0.0401	0.2479	0.2181	0.5878	0.3553	0.5918	0.3577	0.7760	0.6828	0.0874	0.0769
50	0.0292	0.0251	0.0695	0.0598	0.0456	0.0393	0.2337	0.2013	0.5379	0.3454	0.5333	0.3425	0.7270	0.6263	0.0874	0.0753
55	0.0292	0.0247	0.0652	0.0551	0.0456	0.0385	0.2228	0.1884	0.5013	0.3410	0.4875	0.3316	0.6781	0.5732	0.0874	0.0739
60	0.0292	0.0243	0.0621	0.0518	0.0456	0.0380	0.2152	0.1794	0.4781	0.3465	0.4543	0.3293	0.6293	0.5246	0.0874	0.0729
65	0.0292	0.0242	0.0602	0.0498	0.0456	0.0377	0.2109	0.1746	0.4683	0.3597	0.4339	0.3333	0.5806	0.4806	0.0874	0.0724
70	0.0292	0.0240	0.0595	0.0490	0.0456	0.0375	0.2098	0.1728	0.4719	0.3857	0.4261	0.3483	0.5319	0.4381	0.0874	0.0720
75	0.0292	0.0241	0.0599	0.0494	0.0456	0.0376	0.2121	0.1750	0.4889	0.4261	0.4311	0.3757	0.4834	0.3989	0.0874	0.0722
80	0.0292	0.0242	0.0615	0.0510	0.0456	0.0378	0.2176	0.1804	0.5193	0.4750	0.4487	0.4105	0.4350	0.3606	0.0874	0.0725
85	0.0292	0.0244	0.0642	0.0537	0.0456	0.0381	0.2264	0.1893	0.5630	0.5347	0.4791	0.4550	0.3866	0.3233	0.0874	0.0731
90	0.0292	0.0248	0.0681	0.0579	0.0456	0.0387	0.2385	0.2025	0.6202	0.5957	0.5221	0.5016	0.3383	0.2873	0.0874	0.0742
95	0.0292	0.0253	0.0732	0.0634	0.0456	0.0394	0.2538	0.2196	0.6907	0.6611	0.5779	0.5531	0.2902	0.2511	0.0874	0.0757
100	0.0292	0.0257	0.0795	0.0700	0.0456	0.0401	0.2725	0.2399	0.7746	0.7412	0.6463	0.6184	0.2421	0.2131	0.0874	0.0770
105	0.0292	0.0263	0.0869	0.0784	0.0456	0.0411	0.2944	0.2654							0.0874	0.0788
110	0.0292	0.0270	0.0955	0.0883	0.0456	0.0421	0.3196	0.2953							0.0874	0.0808
115	0.0292	0.0276	0.1053	0.0995	0.0456	0.0431	0.3481	0.3290							0.0874	0.0826

APPENDIX F

ATMOSPHERIC CHEMISTRY OF NOx

NITROGEN DIOXIDE AND OXIDES OF NITROGEN

Oxides of nitrogen (NO_x) is a collective term used to refer to the two chemical species: nitric oxide (NO) and nitrogen dioxide (NO_2). These two oxides are grouped together because most anthropogenic NO_2 is derived from emissions of NO.

The majority of NO_2 emitted in motor vehicles is in the form of NO which is thought to be harmless at ambient concentrations. However, it is oxidised in the atmosphere to produce NO_2, which is harmful to human health. The UK has air quality standards NO_2 to protect human health.

The Advisory Group on the Medical Aspects of Air Pollution Episodes (Department of Health Advisory Group on the Medical Aspects of Air Pollution Episodes. Oxides of Nitrogen - Third Report. HMSO, 1993) described NO_x chemistry in the following way:

During its atmosphere lifetime, the dominant oxide of nitrogen, NO, is progressively oxidised to NO_2, largely by reaction with ozone.

$NO + O_3 \rightarrow NO_2 + O_2$

The consequence of this reaction is that the amount of the total NO_x emitted which is oxidised to NO_2 is often limited by the availability of ozone. Closes to sources, the fraction of the NO_x present as NO_2 will, in general, be low. Further from the source, in conditions of vigorous atmosphere mixing the initial NO_x plume will be diluted with fresh, unreacted ozone, and the proportions of NO_x, which is NO_2, will be higher. The relationship between NO, NO_2 and O_3 is complicated by the back reaction which occurs during daylight as NO_2 is photolysed by short wavelength light (> 400 nm).

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

$O + O_2 \rightarrow O_3$

The Quality of Urban Air Research Group (Department of the Environment, Quality of Urban Air Research Group, Urban Air Quality in the UK 1993) add that "In polluted atmospheres other reactions take place involving hydrocarbons, aldehydes, CO and other compounds".

The proportion of NO_x, which is NO_2, varies greatly with location and time. For this reason DETR Guidance suggests that it is more appropriate to first model NO_x and then apply a factor to estimate the NO_2 concentration. This is because a local authority has some control over the emissions of NO_x but little or no control over atmospheric oxidants that oxidise NO to NO_2. However, the proportion of NO_x that is NO_2 varies according to a number of factors including the amount of ozone available and the distance from the emission source. A variable NO_2/NO_x relationship was therefore used to convert annual average NO_x to annual average NO_2, as given in Table F.1. This relationship was taken from the DMRB (May 1999).

Table F.1: Relationship between annual mean concentrations of NO_x and NO_2

NO_x (ppb)	NO_2 (ppb)
10	8.3
20	15.2
30	20.3
40	24.3
50	27.5
60	30.1
70	32.4
80	34.4
90	36.1
100	37.7
110	39.1
120	40.4
130	41.6
140	42.7
150	43.7
160	44.7
170	45.6
180	46.4
190	47.2
200	47.9
210	48.6
220	49.3
230	49.9
240	50.5
250	51.1

This relationship was used for both the base and future case years as the best representation of the NO_2/NO_x relationship. It should also be noted that as NO_x concentrations are expected to decline in future years the NO_2 will not be limited as much by O_3. This means that the future year NO_2/NO_x ratio is likely to increase.

The short-term averaging periods were derived by applying an empirical relationship to the annual average NO_2 concentrations, as given in Appendix D.

APPENDIX G

METEOROLOGICAL DATA

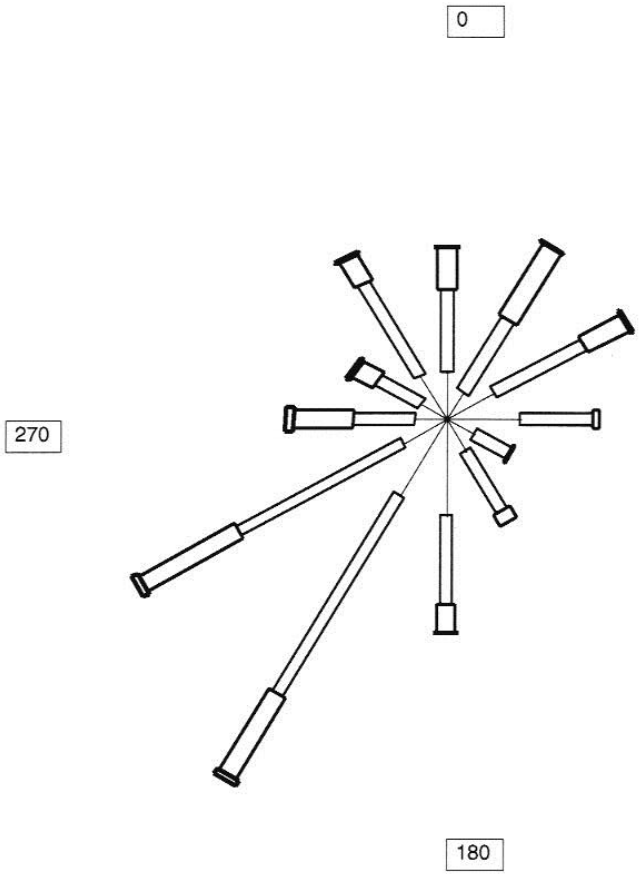
METEOROLOGICAL DATA

Meteorological data measured at Gatwick Airport was used for the eastern inland areas of Hampshire in the modelling study. The coastal regions were modelled using meteorological data from Southampton Weather Centre and the western inland areas were modelled using data from RAF Lyneham. In each case, the data consisted of the frequencies of occurrence of wind speed (0-2, 3-4, 6-10, 10+ m/s), wind direction (30^{o} 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).

The meteorological data was used to produce a wind/stability rose. The rose consisted of 12 wind direction sectors of 30°, 4 wind speed bands and 3 stability classes.

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 windroses are shown in Figures G.1-G.3.

Figure G.1: Windrose for Meteorological Data for Gatwick Airport



	Wind <= 2 m/s	Wind <= 5 m/s	Wind <= 10 m/s	Wind > 10 m/s	Total
D >= 345 or D < 15	181	315	160	4	660
15 <= D < 45	114	326	312	5	757
45 <= D < 75	200	369	170	5	744
75 <= D < 105	263	262	27		552
105 <= D < 135	115	147	5		267
135 <= D < 165	145	255	52		452
165 <= D < 195	366	337	105	4	812
195 <= D < 225	335	867	357	20	1579
225 <= D < 255	182	671	395	22	1270
255 <= D < 285	113	217	217	29	576
285 <= D < 315	106	176	86	13	381
315 <= D < 345	189	404	111	6	710
Total	2309	4346	1997	108	8760

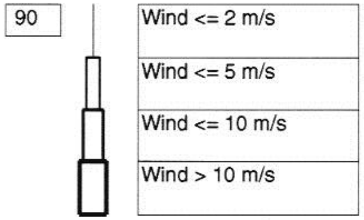
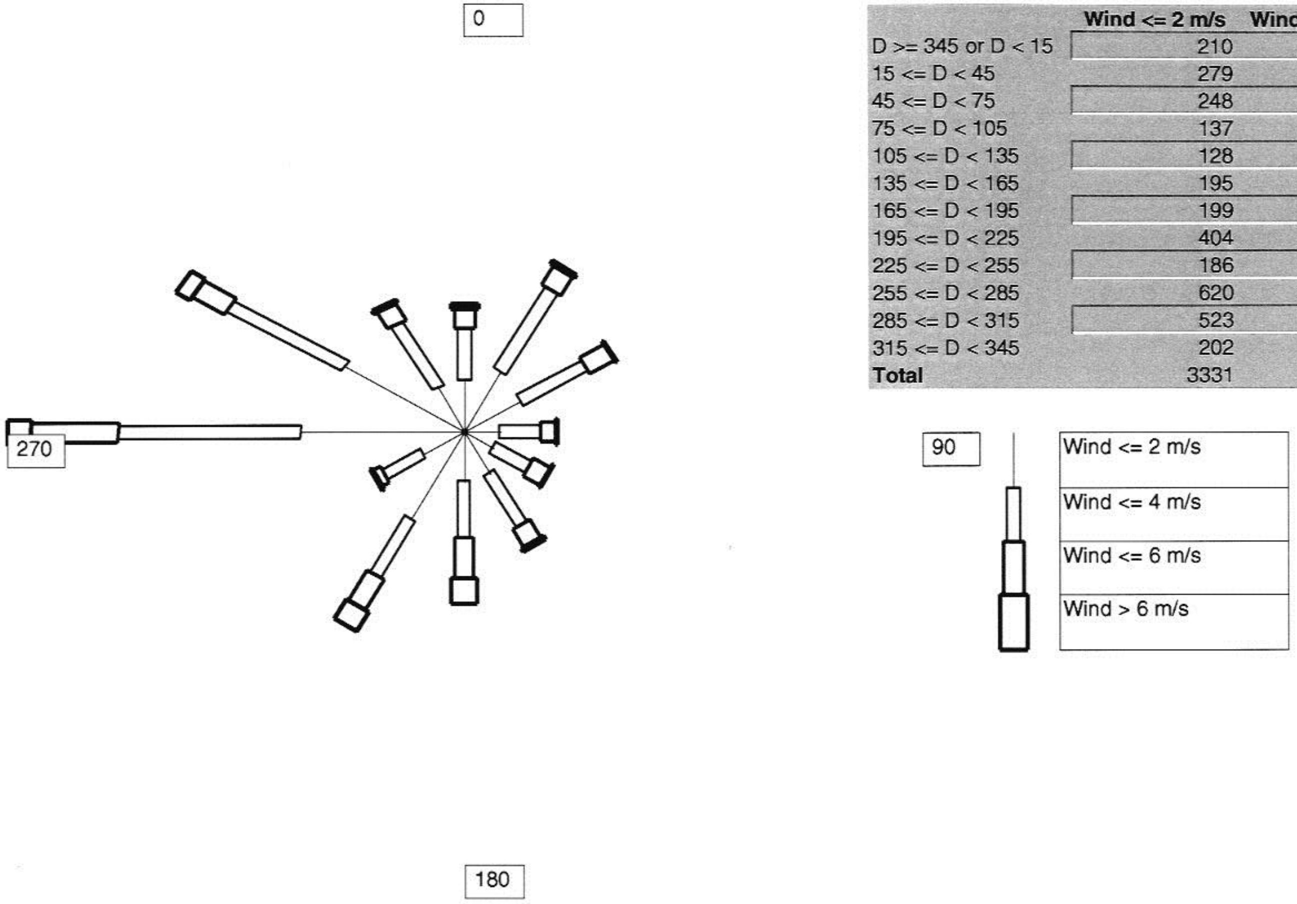
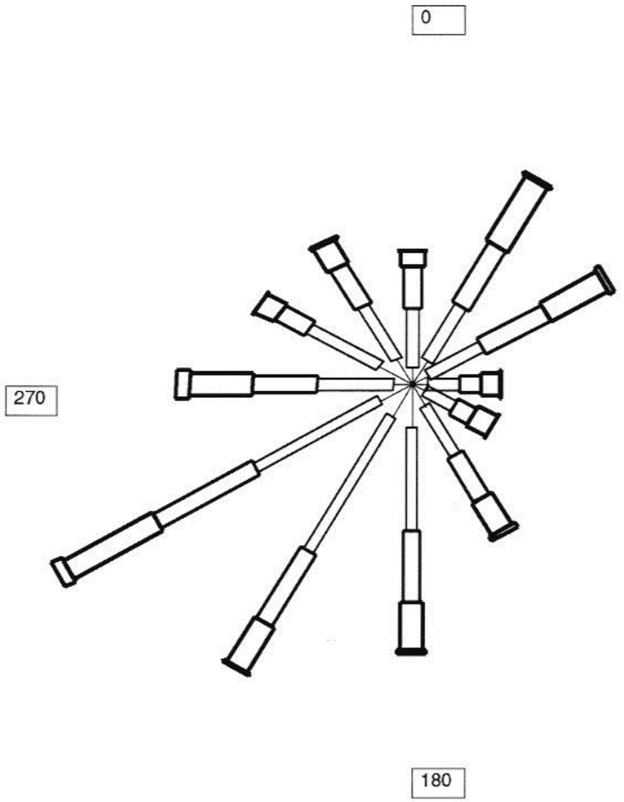


Figure G.2: Windrose for Meteorological Data for Southampton Weather Centre

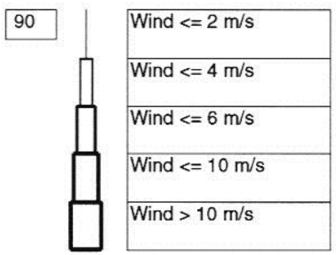


	Wind <= 2 m/s	Wind <= 4 m/s	Wind <= 6 m/s	Wind > 6 m/s	Total
D >= 345 or D < 15	210	217	77	19	523
15 <= D < 45	279	390	91	9	769
45 <= D < 75	248	287	106	7	648
75 <= D < 105	137	156	60	5	358
105 <= D < 135	128	157	78	3	366
135 <= D < 165	195	243	83	14	535
165 <= D < 195	199	232	163	104	698
195 <= D < 225	404	266	144	93	907
225 <= D < 255	186	162	28	8	384
255 <= D < 285	620	694	338	92	1744
285 <= D < 315	523	503	146	58	1230
315 <= D < 345	202	304	80	12	598
Total	3331	3611	1394	424	8760

Figure G.3: Windrose for Meteorological Data for RAF Lyneham



	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	63	212	150	54	3	482
15 <= D < 45	98	224	248	269	10	849
45 <= D < 75	63	208	243	222	19	755
75 <= D < 105	55	105	74	62	4	300
105 <= D < 135	51	110	72	75	1	309
135 <= D < 165	92	200	177	130	16	615
165 <= D < 195	156	367	254	171	16	964
195 <= D < 225	135	552	293	184	9	1173
225 <= D < 255	123	477	379	340	40	1359
255 <= D < 285	61	256	216	209	42	784
285 <= D < 315	125	269	115	72	2	583
315 <= D < 345	99	225	162	92	9	587
Total	1121	3205	2383	1880	171	8760



APPENDIX H

BACKGROUND CONCENTRATIONS

Figure H.1: NO_x Background Concentrations for 1996

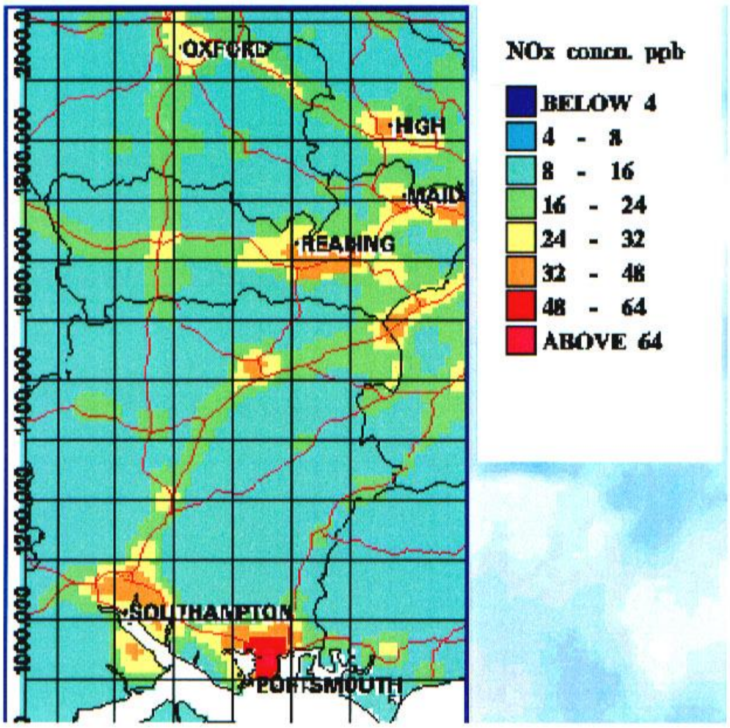


Figure H.2: PM_{10} Background Concentrations for 1996

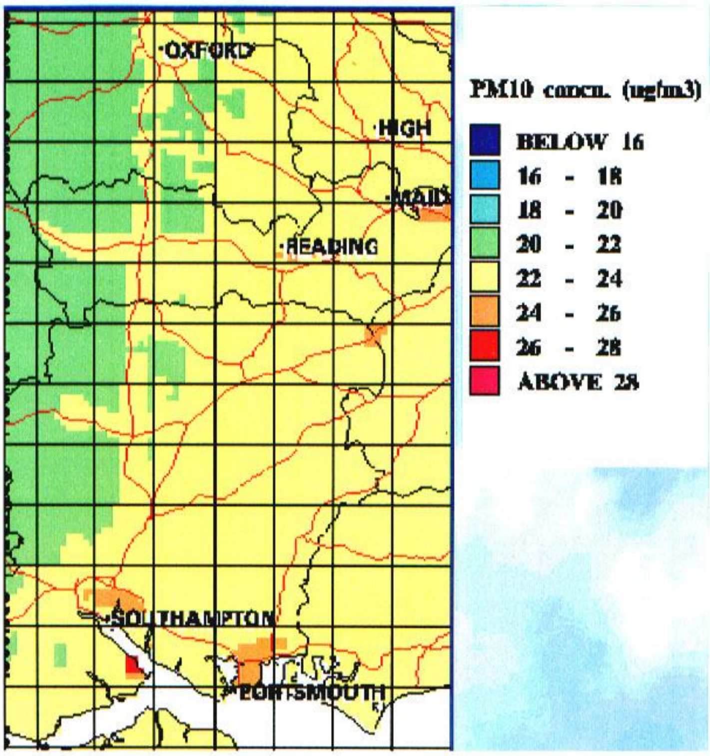


Figure H.3: CO Background Concentrations for 1996

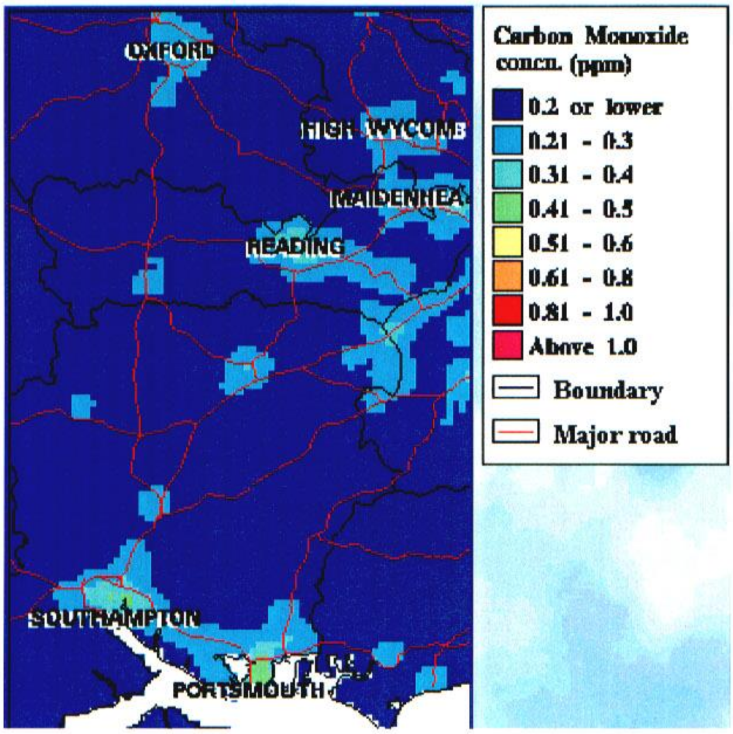


Figure H.4: SO_2 Background Concentrations for 1996

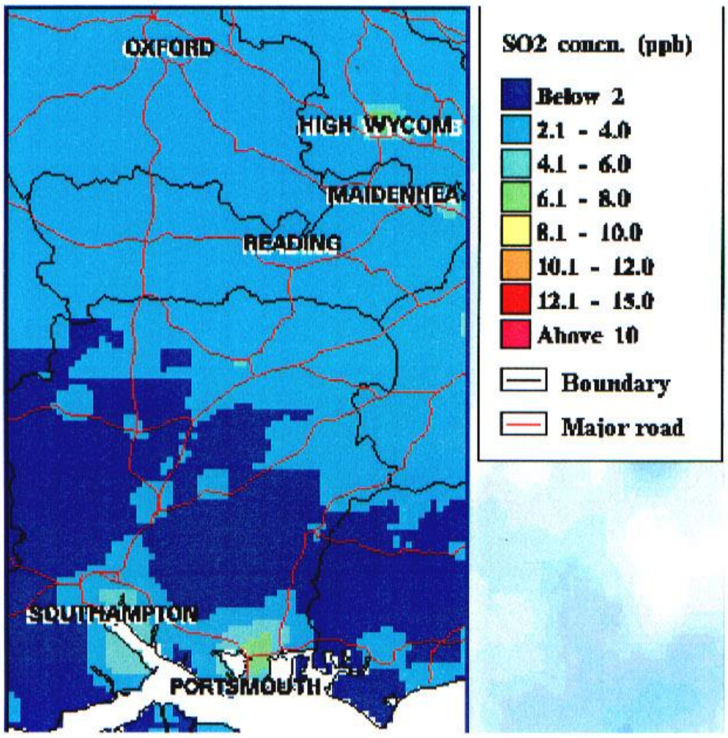


Figure H.5: Lead Background Concentrations for 1996

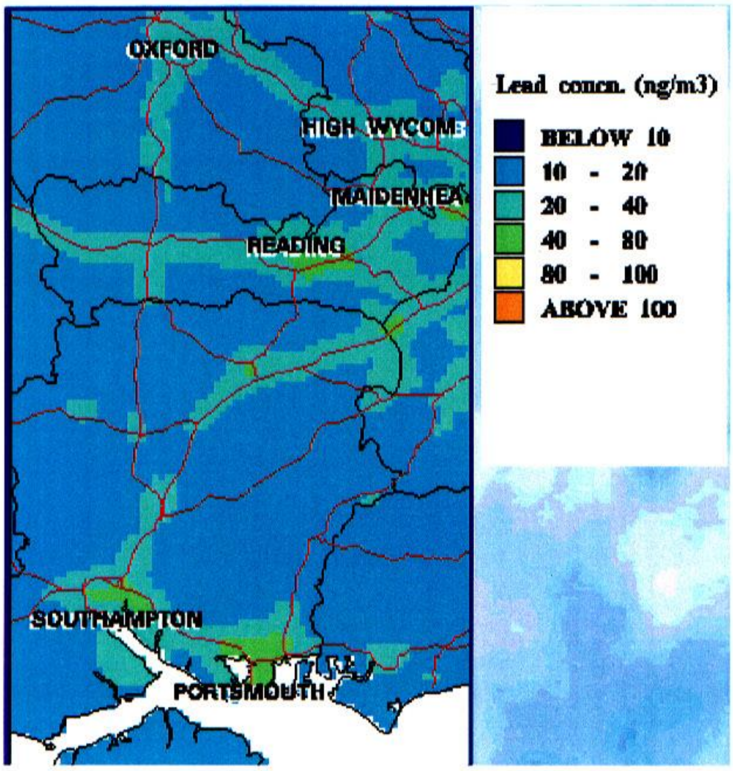


Figure H.6: Benzene Background Concentrations for 1996