Gloucestershire Joint Core Strategy

Strategic Air Quality Services

For Cheltenham Borough Council (on behalf of Gloucester City Council and Tewkesbury Borough Council)

27 June 2014

Plan Design Enable

Notice

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1. Introduction

Atkins were commissioned in relation to the Joint Core Strategy by Cheltenham Borough Council (on behalf of Gloucester City Council and Tewkesbury Borough Council) to assess the cumulative impacts on air quality of the development proposals identified in the Draft for Consultation Joint Core Strategy for 2031 (October 2013), which is currently at pre submission stage. The JCS includes major growth around Gloucester, Cheltenham and Tewksbury, providing around 30,000 homes and associated employment. It includes development at strategic allocation sites in rural areas around existing built up areas and development on brownfield sites in existing urban areas.

For strategic air quality the main potential effects of the JCS will be related to changes in emissions of road traffic as a result of changes to the local traffic network and this is the focus of the air quality assessment work.

This report presents a strategic level of assessment of air quality for the JCS, proportionate to the stage of development of the strategy using the current traffic model scenarios already available.

It was agreed that the air quality assessment would consider the following scenarios included in the Central Severn Vale (CSV) traffic model:

- 2012 base year – using the 2008 traffic model base year data;
- 2031 Do Minimum 1 (DM1) – JCS without nine strategic allocation sites, a “do nothing”; and
- 2031 Do Something 1 (DS1) – JCS with nine strategic allocation sites and sustainable transport measures (comprising a 6% demand reduction in strategic allocation sites, 3% demand reduction elsewhere within the CSV region).

The scope for air quality assessment was agreed to include the following:

- Review of the baseline air quality and constraints
- Strategic level assessment of changes in air pollutant emissions relative to the locations of air quality sensitive receptors to determine the overall effect on air quality of the Joint Core Strategy;
- Risk assessment of local air quality effects using illustrative air quality ‘headroom’ calculations at selected locations to determine outline risks to compliance with UK Air Quality Strategy (AQS) objectives and European Union (EU) limit value thresholds; and
- Recommendations of further work.

2. Methodology

2.1. Baseline & Constraints

Air Quality baseline and constraints data has been gathered from the following sources:

- Boundaries of air quality management areas (AQMA)[1];
- Defra Pollution Climate Mapping (PCM) model data for relevant years[2];
- Monitoring data from monitoring surveys carried by local authorities;
- Locations of sensitive receptors (residential properties, schools, hospitals and elderly care homes) from OS base mapping; and
- Boundaries of designated ecological sites[3].

2.2. Traffic Data

The air quality modelling has been undertaken using traffic data from the CSV traffic model to generate annual average daily traffic (AADT), proportion of heavy duty vehicles (HDV) and daily average speed for the following scenarios:

- 2012 base year – using the 2008 traffic model base year data;
- 2031 Do Minimum 1 (DM1) – JCS without nine strategic allocation sites, a “do nothing”; and
- 2031 Do Something 1 (DS1) – JCS with nine strategic allocation of sites and sustainable transport measures (comprising a 6% demand reduction in strategic allocation sites, 3% demand reduction elsewhere within the CSV region).

The CSV model is viewed as adequate for the strategic stage of air quality assessment, but it is recognised that further work will be undertaken on the SATURN traffic model outside of this stage of air quality work. This work (by Atkins) will expand the model in the Tewksbury and Ashchurch area as this is on the periphery of the current traffic model but includes areas critical to the JCS.

Traffic data for the 2008 base CSV traffic model was used to generate AADT, proportion of heavy duty vehicles (HDV) and daily average speed for 2012. Atkins have previously undertaken comparison of traffic count data for the period 2008 to 2012 across 16 Gloucestershire Automatic Traffic Count (ATC) sites, to ascertain whether adjustment of the 2008 traffic model was necessary. The analysis found both increases and decreases in flows across the network with an average 0.8 percent increase per year across all sites provided. As there was not a clear trend in traffic flows between 2008 and 2012 at all sites, the 2008 traffic data was therefore used without adjustment within the base case air quality model scenario for 2012. This approach has been used on other assessments undertaken by Atkins in the Gloucestershire area, and the approach was agreed in advance with the JCS team.

2.3. Air Quality Study Area

The air quality study area has been defined based on:

- The location of air quality constraints such as AQMA and monitored exceedances of UK AQS objectives and EU limit value thresholds; and

[1] http://aqma.defra.gov.uk/aqma/home.html
[2] http://uk-air.defra.gov.uk/data/gis-mapping/
[3] http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp

- Changes in traffic data as a result of the JCS DS1 scenario compared to the equivalent future year with current road conditions (i.e. JCS DM1 scenario) in the year of 2031.

The air quality study area has been determined in accordance with traffic change criteria set out in DMRB Volume 11 Section 3 Part 1[4] (HA207/07) which defines the air quality affected road network (ARN) for air quality assessments.

The air quality ARN for the purposes of the air quality assessment is defined as those roads that meet any of the traffic change criteria, whereby:

- Road alignment will change by 5 metres or more; or
- Daily traffic flows will change by 1,000 Annual Average Daily Traffic (AADT) or more; or
- Heavy Duty Vehicle (HDV) flows will change by 200 AADT or more; or
- Daily average speed will change by 10 km/hr or more; or
- Peak hour speed will change by 20 km/hr or more.

For the assessment of air quality at receptors sensitive in human health terms and at relevant ecological resources with statutory designation, the air quality study area is limited to 200 metres either side of each road carriageway section identified in the air quality ARN. This distance of 200 metres is industry best practice (specified in HA207/07) which has been derived from calculations using atmospheric dispersion modelling of dispersion profiles which have been reviewed in a series of field measurements[5]. In practice any air quality assessment is undertaken by identifying where there are relevant receptors adjacent to the air quality ARN and including all road sources within 200m of that receptor, whether in the air quality ARN or not.

The study area for the assessment of air pollutant emissions is shown in Figure 2-1. The study area was limited to the traffic model output within the boundaries of Gloucestershire. The road network includes major routes across Gloucestershire and the main road network within the towns of Tewkesbury, Cheltenham and Gloucester. Note that for strategic of the air quality assessment and given the extant proposals to improve the representation of the JCS within parts of the traffic model, the study area has not been limited to the usual “Traffic Reliability Area” or TRA – this should be borne in mind when interpreting the results (especially in the Tewkesbury and Ashchurch area).

For the illustrative air quality ‘headroom’ calculations, 12 locations where there were concerns about air quality effects were identified in discussion with the JCS team. These 12 locations were assigned a priority as presented in Table 2-1 and are shown in Figure 2-2. These were agreed in advance of any illustrative air quality ‘headroom’ calculations being undertaken.

Table 2-1 Locations Selected for Local Air Quality Modelling

Priority	Priority Description	Locations
Priority 1	Location where air quality monitoring shows an exceedance of government air quality standards and roads are in the air quality ARN. Or location has roads in the air quality ARN and the location is a stated area of concern for the Highways Agency as it may impact on a Highway Agency roads	• Around M5 Junction 9 • Around M5 Junction 11a • Around the junction of A4019 Tewkesbury Road/Poole Way and B4633 Gloucester Road in Cheltenham town centre • Around the junction of A46 Bath Road/ Berkley Street/College Road and A435 in Cheltenham town centre

[4] HA207/07 DMRB Volume 11 Section 3 Part 1, May 2007 http://www.standardsforhighways.co.uk/dmrb/
[5] HA207/07 DMRB Volume 11 Section 3 Part 1, May 2007 Paragraph C3.1 http://www.standardsforhighways.co.uk/dmrb/

Priority 2	Location where air quality monitoring shows an exceedance of government air quality standards and within an Air Quality Management Area, but does not include roads in the air quality ARN.	• Tewkesbury town centre • Around A417 St Oswald's Road and A430 Priory Road in Gloucester • B4073 Barton Street east of B430 Bruton Way in Gloucester • B4073 Painswick Road, west of A38 Eastern Avenue in Gloucester
Priority 3	Location within an Air Quality Management Area, and with roads in the air quality ARN, but no evidence of exceedance of government air quality standards (no monitoring data available).	• Around the junction of A4019 Tewkesbury Road and A4013 Princess Elizabeth Way in the Kingsditch area of Cheltenham • Around the junction of the A435 Evesham Road and B4075 New Barn Lane north of Cheltenham town centre • Around the junction of A46 Shurdington Road and Leckhampton Road, south of Cheltenham town centre • Around A4013 Princess Elizabeth Way and 40 Gloucester Road roundabout, near GCHQ, south west of Cheltenham town centre

Figure 2-1 Study Area for Strategic Air Pollutant Emissions Modelling

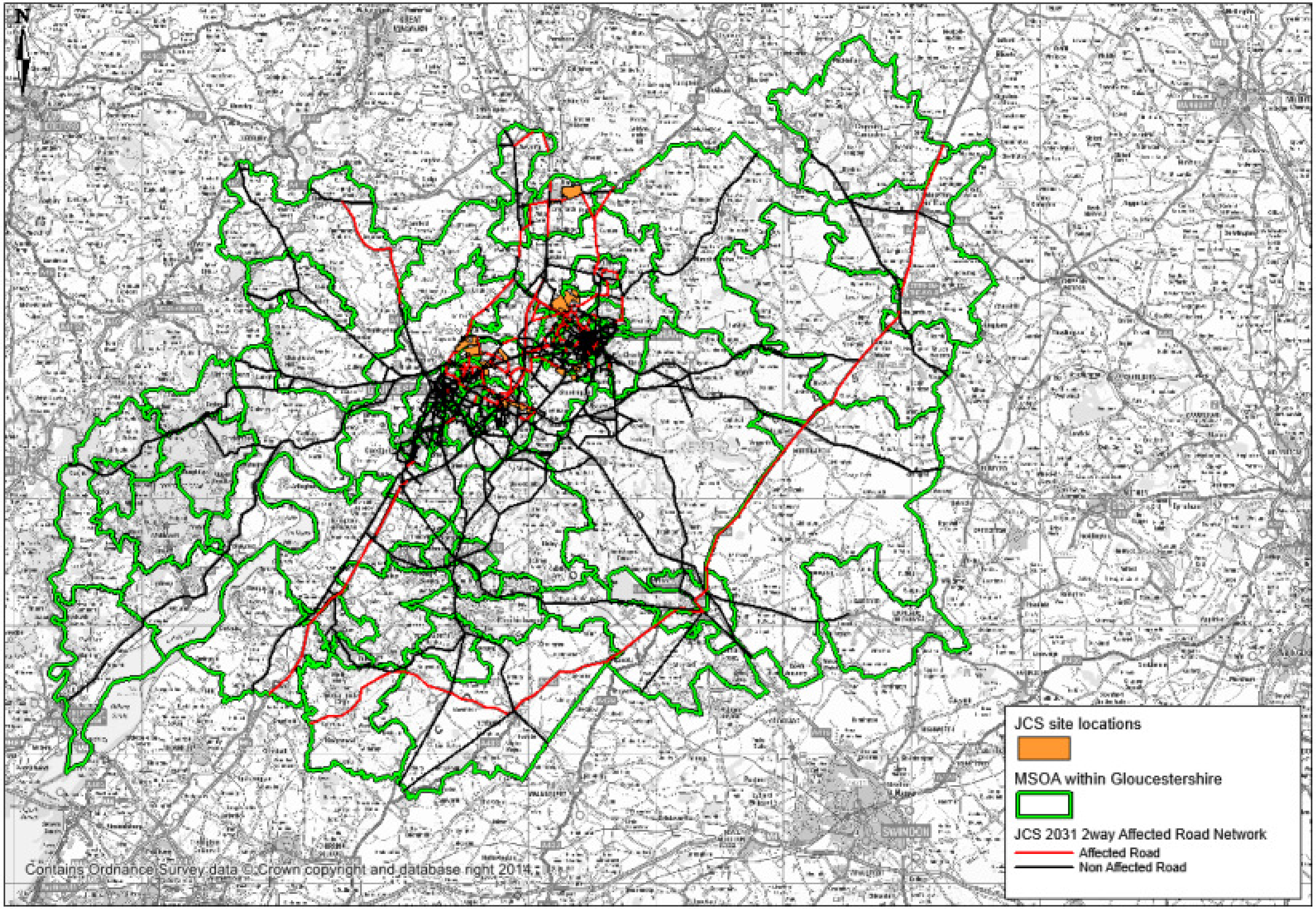
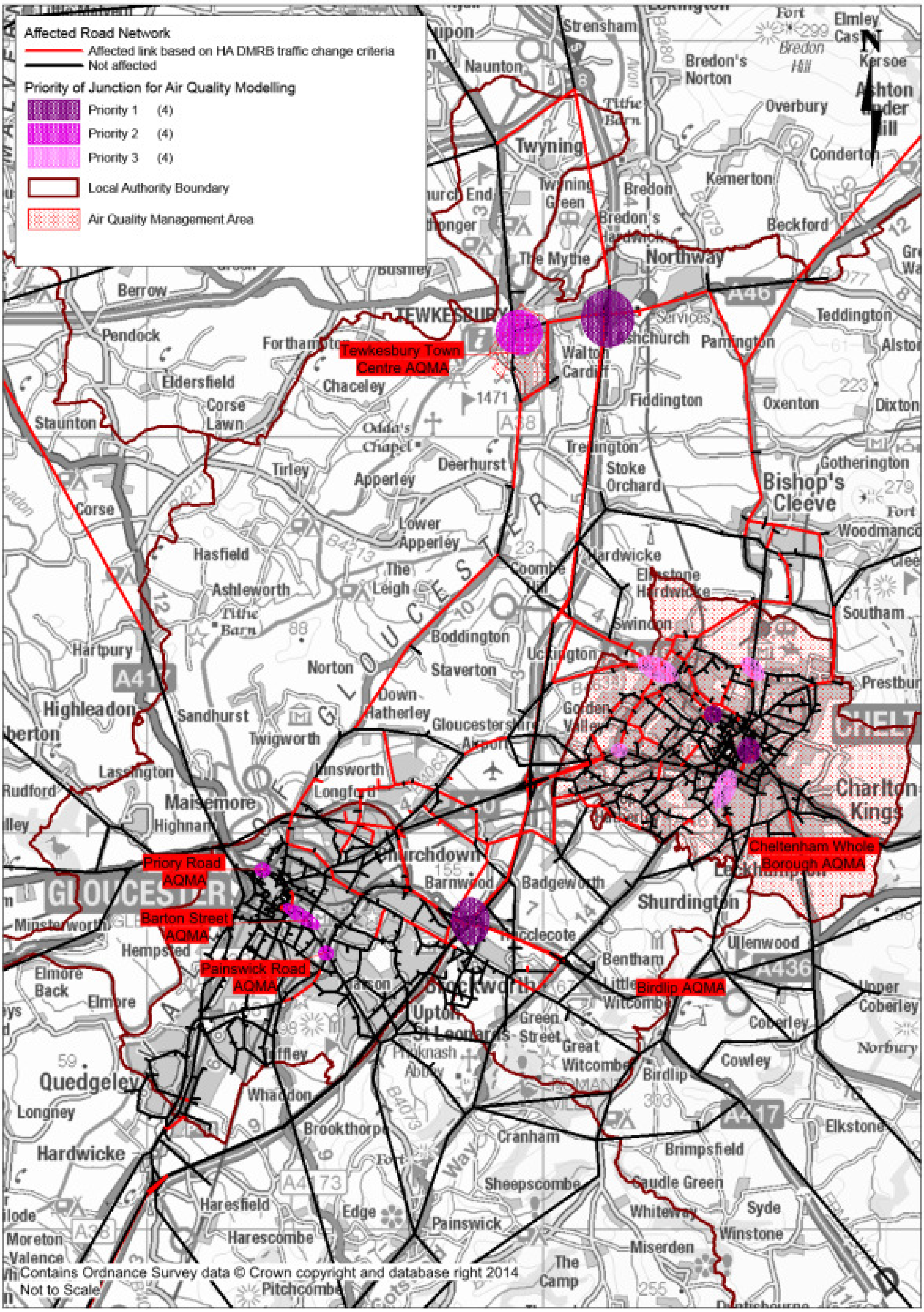


Figure 2-2 Locations Selected for Local Air Quality Modelling



2.4. Strategic Emissions Exposure Assessment

The assessment has been completed in general accordance with the methodology for strategic emissions described in Transport Appraisal Guidance (TAG) unit A3 environmental impact appraisal, May 2014. The total emissions for the emissions assessment study area have been estimated using the available traffic data and appropriate emission factors and combined with the number and location of air quality sensitive receptors (from OS Addresspoint data) to calculate an 'emissions exposure estimate'. The assessment has been undertaken for NOx only as a risk of exceedances of PM_{10} UK AQS objectives and EU limit value thresholds was not identified.

For the strategic emissions exposure assessment, the traffic data available from the CSV model for the 2031 DM1 and 2031 DS1 was used. Data represented Annual Average Daily Traffic flow over an average 24-hour period, maximum speed and the proportion of heavy duty vehicles per link.

The links represented in the model were separated into small zones across the emissions assessment study area using the boundary information provided in the Middle Layer Super Output Areas for England and Wales (MSOA). All links in the network were separated into zones by cutting longer links into sections within each MSOA so that only emissions within each MSOA are presented in the results. Population estimates for each MSOA were determined from OS Addresspoint data.

The steps to calculate the 'emissions exposure estimate' are described below. The first three steps were carried out for the 2031 DM1 and 2031 DS1 scenarios.

i. Calculate the total emissions (tonnes per year), for each zone, for NOx. Emissions for each link were calculated using the Emission Factor Toolkit v5.2c[6];
ii. Estimate the total population per zone;
iii. For each zone, multiply i) by ii) and divide the result by the area of the zone, expressed in square km;
iv. For each zone, subtract the value in iii) for the do-something (i.e. DS1) from the do-minimum (i.e. DM1);
v. Count the number of positive values in iv) - these are zones in which the scenario is unlikely to improve air quality over the do-minimum;
vi. Count the number of negative values in iv) - these are zones in which the scenario is likely to improve air quality over the do-minimum;
vii. Sum the values in iv) over all zones to create the emissions estimate.

2.5. Illustrative Air Quality 'Headroom' Calculations

Illustrative air quality 'headroom' calculations have been undertaken using the dispersion modelling software ADMS-Roads, version 3.2[7]. The model uses information on traffic flows, speeds and composition, vehicle emission rates, road alignment and width, and local meteorological data to estimate local air pollutant concentrations.

In summary the steps for undertaking the illustrative air quality 'headroom' calculations were as follows (further details are provided in the sub sections below):

- A simple[8] ADMS-Roads model was constructed to cover the 12 locations of air quality concern.
- A traffic model data was available from the CSV traffic model which covers the Gloucestershire area. Traffic data was extracted from the 2008 base (used to represent 2012), 2031 DM1 and 2031 DS1 scenarios for relevant road links. This provided annual average daily traffic (AADT), proportion of heavy duty vehicles (HDV) and speed limits (to be used to approximate daily average speed).
- The NOx road contributions (outputted directly from the model) and annual mean NO_2 background concentrations (determined using the Defra Technical Guidance LAQM.TG (09) tools[9]) were used to calculate total NO_2 concentrations for a selection of worst case receptors within 50m of the junction

[6] Emission Factor Toolkit, Defra, 2013. http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html/
[7] Atmospheric Dispersion Modelling System for Roads developed by Cambridge Environmental Research Consultants, http://www.cerc.co.uk/environmental-software/ADMS-Roads-model.html
[8] For this assessment a simple model was set up – Al roads were assumed to be at ground level and street canyons and queuing was not accounted for
[9] Defra Local Air Quality Management Technical Guidance published in 2009 (LAQM.TG(09)) and associated tools from 2013. Available at: http://laqm.defra.gov.uk/

locations. Verification of the 2012 modelling was undertaken against suitable air quality monitoring data for 2012.

- The output of the above steps were illustrative annual mean NO_2 concentrations for the 2012 base case, 2031 DM1 and 2031 DS1.
- The change in total NO_2 concentrations due to the DS1 compared to the DM1 was calculated to determine a magnitude of impact at each receptor in accordance with Highways Agency IAN 174/13 (large is a change in concentrations >4 µg/m^3, medium is 2 to 4 µg/m^3, small is 0.4 to 2 µg/m^3 and imperceptible is a change <0.4 µg/m^3).

2.5.1.1. Traffic Sources Input Data

For the illustrative air quality 'headroom' calculations, the traffic data available from the CSV model for 2008 (to represent 2012), 2031 DM1 and 2031 DS1 was used. Data represented Annual Average Daily Traffic flow over an average 24-hour period, maximum speed and the proportion of heavy duty vehicles per link. An overview of the road links included in the air quality model is shown in Figure 2-3. More detailed images for each of the 12 locations modelled are shown in Section A.1 of Appendix A.

An average 24-hour traffic flow profile for weekdays, Saturday and Sundays was derived based on averaging the traffic count data from ATC sites and this is shown in Figure 2-4.

Figure 2-3 Roads Included in the Air Quality Model

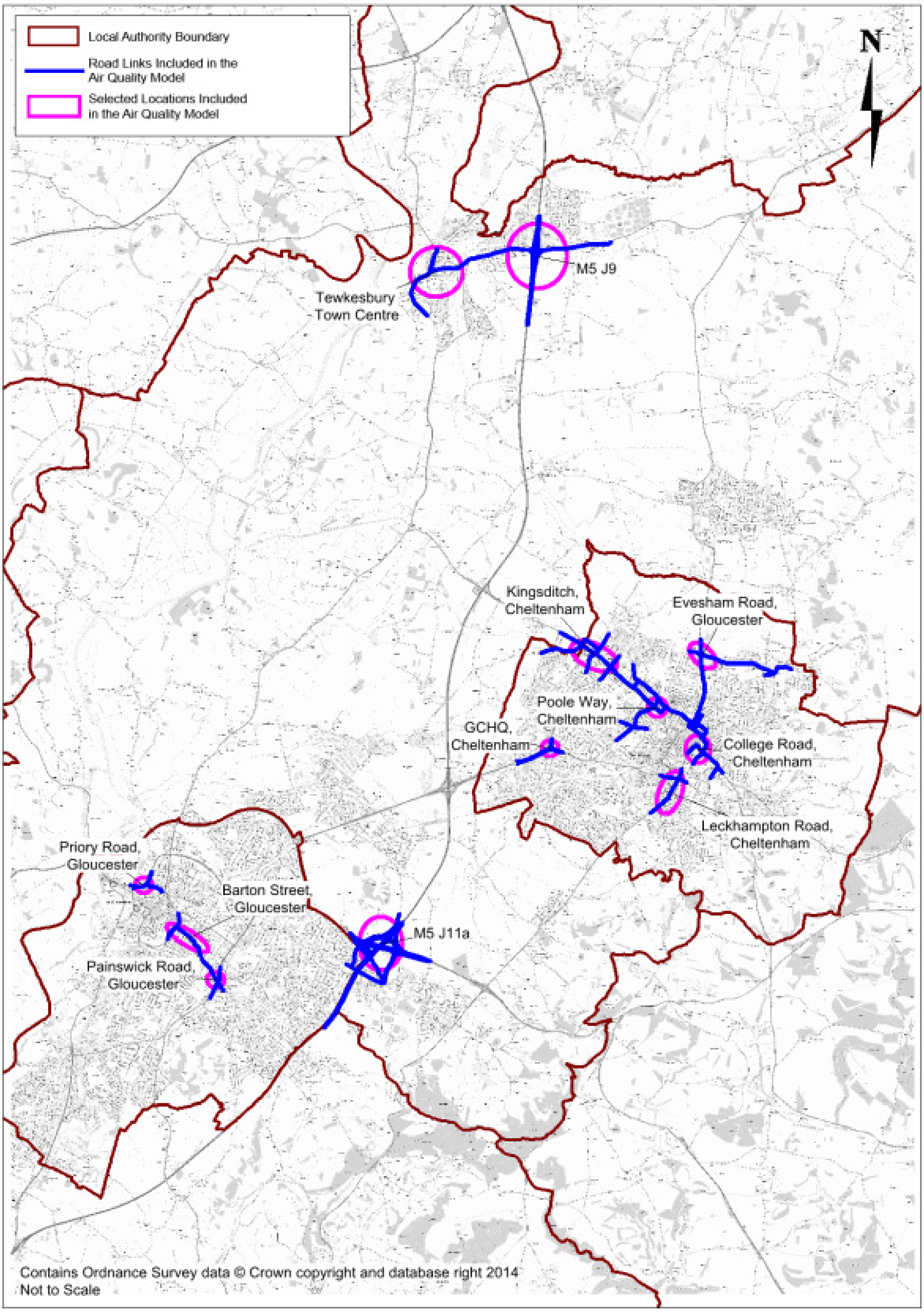
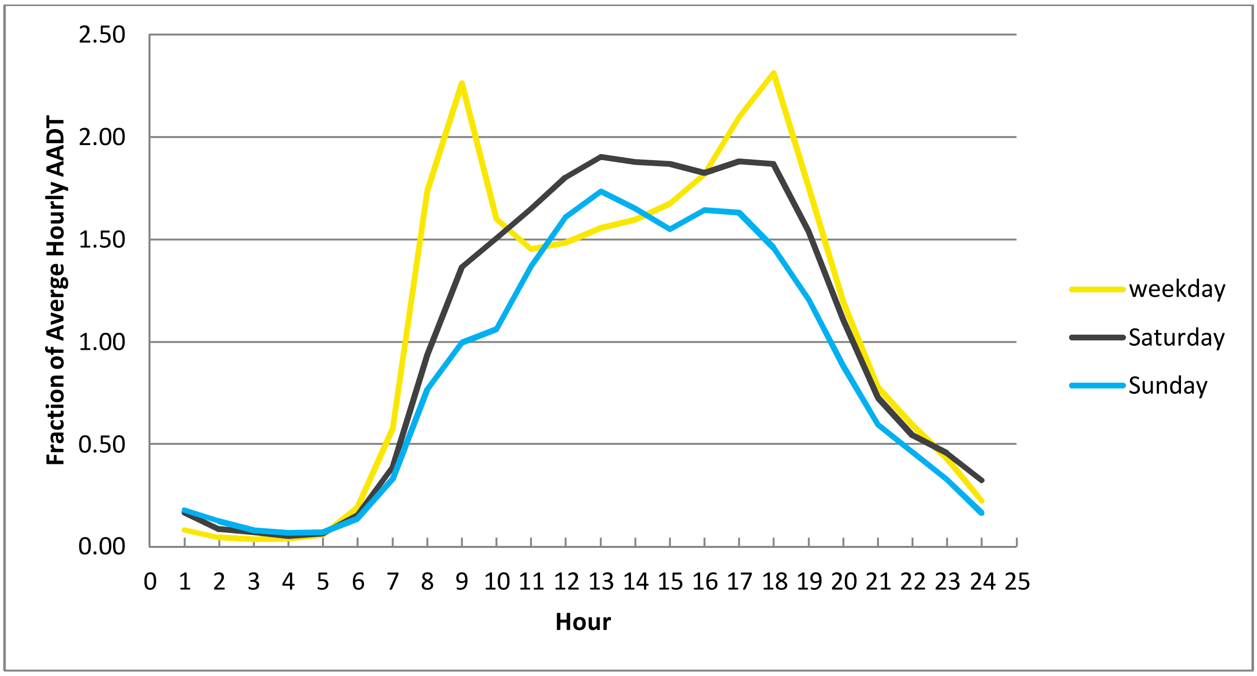


Figure 2-4 24-Hour Traffic Flow Profile used in the Air Quality Model



2.5.1.2. Emission Factors

Vehicle exhaust emissions of NOx for light duty vehicles (LDV) and HDV were calculated within ADMS-Roads using Defra's Emission Factor Toolkit (EFT), version 5.2c[10], for each road link in each modelled scenario. Road links were assigned a fleet mix based on whether the road link was a Motorway, urban or rural road.

2.5.1.3. Receptors

A total of 59 discrete receptors were included in the air quality model. 56 receptors were those representing human health receptors within 50 metres of the 12 selected locations and 3 were receptors representing ecological resources. In addition, 64 monitoring locations, within 50 metres of the junctions or surrounding roads were included (for use in the verification of the air quality model). The modelled receptors are presented in Appendix A in Table A-2, and are determined from OS AddressPoint data provided by Gloucestershire. The height of all human health receptors was set at 1.5 metres above ground level to represent breathing height and ecological receptors were set at ground level, while the height of the monitoring sites was set at the sampling height reported by the relevant local authority (a height of 2 metres was assumed where the height was not reported).

2.5.1.4. Background Concentrations

The air quality modelling provides an estimate of the contribution of a road to total pollutant concentrations; it does not take into account the existing background concentrations. A background contribution must therefore be added to the modelled road contribution in order to derive the total pollutant concentration.

Background pollutant concentration maps are provided on the Defra UK-AIR website[11]. These data are based on the extrapolation and interpolation of empirical measurements and modelled dispersion of, amongst others, transport and industrial sources. The latest background concentrations for every one kilometre grid square in the UK provided are based on 2010 monitoring data. The data have concentrations split according to the proportion of emissions from in-square and out-of-square sources and are available for future years up to 2030.

Background annual mean concentrations for 2012 and 2030 (used for 2031) at the receptors included in modelling are shown in Table A-3 in Appendix A. The in–square motorway sector was removed from background concentrations using the Defra NO_2 Adjustment for NOx Sector Removal tool version 3.1[12] to

[10] Emission Factor Toolkit, Defra, 2013. http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html/
[11] Defra 2010 base year background maps http://laqm.defra.gov.uk/maps/maps2010.html
[12] Defra NO_2 Adjustment for NOx Sector Removal tool, version 3.1 http://laqm.defra.gov.uk/maps/maps2010.html#NO2adj

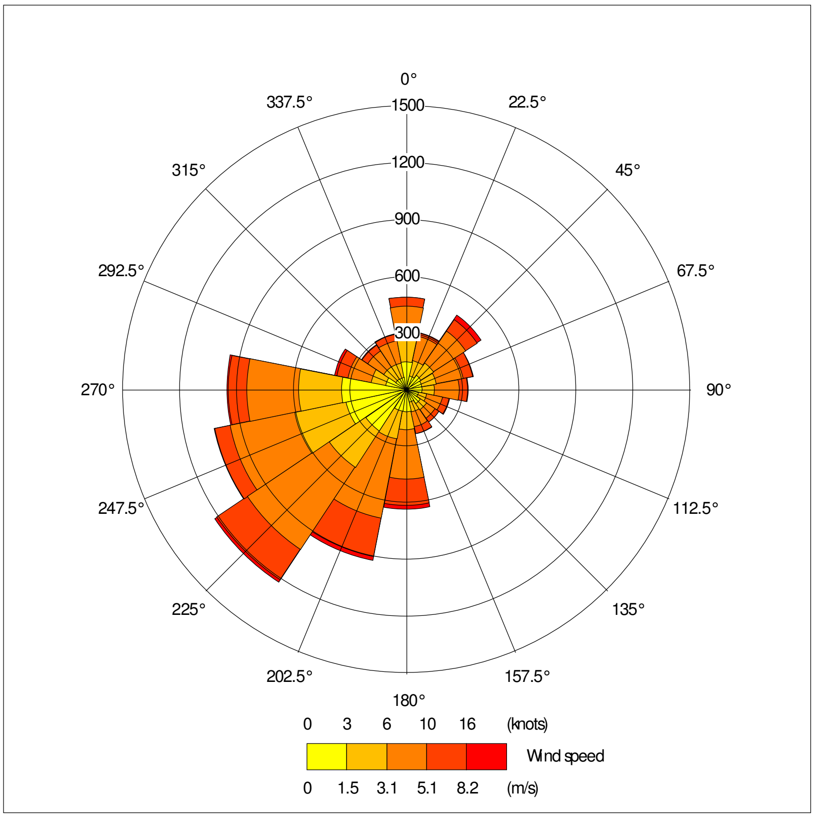
avoid double counting of emission sources that were included explicitly in the air quality model. Sector removal of trunk or primary A-roads was not undertaken as the junction modelling only included sections of these types of roads.

2.5.1.5. Air Quality Model Inputs and Assumptions

The modelled scenarios were based on the following key inputs and assumptions. Note that for the strategic air quality assessment all areas are modelled with the same limiting assumptions (the assumptions are consistent with previous work for GCC in same area):

- Traffic conditions vary throughout the day; hence 24-hour profiles have been applied in the model to improve approximation of vehicle emissions in each hour of the year.
- The emission factor toolkit (EFT) Version 5.2c has been used for obtaining speed-dependent emission factors for both LDV – cars and vans under 3.5 tonnes gross and HDV – all vehicles over 3.5 tonnes gross vehicle types;
- 1:10,000 Ordnance Survey base mapping was used to define road geometry;
- Hourly sequential meteorological data for 2012 was taken from Gloucester Airport meteorological station, including: date, time, wind direction (angle wind blowing from), wind speed (in metres per second, at 10 metres above ground level), surface air temperature (degrees Celsius), cloud cover (oktas – or eighths of sky covered). This site is located between Gloucester and Cheltenham, west of M5 junction 11. Wind speed and direction data for the Gloucester Airport meteorological station are presented as a wind rose in Figure 2-5;
- A Latitude of 51.9 degrees was selected. This determines times of sunrise and sunset for each day throughout the year, which in turn affects stability calculations;
- Surface roughness coefficients have been defined as 0.5 metres (representative of parkland, open suburbia) for the air quality model area. This is generally representative of the model area, which includes a mix of open and predominantly low structures (buildings of ~2 to 3 storeys). For the meteorological station a surface roughness of 0.5 metres was also used. The surface roughness parameter is important in the approximation of turbulent conditions within the atmospheric boundary layer and thus in the estimation of pollutant concentrations at receptors;
- Minimum Monin-Obukhov length (to reasonably limit the occurrence of very stable atmospheric conditions) has been defined as 30 metres (mixed urban areas – considered reasonable representative of the model area). This parameter limits the occurrence of very stable boundary layer conditions (i.e. when the air is still) to a degree that is appropriate to the general land-use. In general, the potential for very stable conditions is lowest in large urban areas where the ‘heat island’ effect promoting turbulent motion in the boundary layer is strongest;
- A single centreline was entered in the model for modelled roads, other than for the M5, where there is separation between carriageways; and
- Road widths were taken to be 3.65 metres per lane.

Figure 2-5 Wind rose for Gloucester Airport Meteorological Station, 2012



2.5.1.6. Model Uncertainty

Any dispersion model has inherent areas of uncertainty, including:

- Traffic data;
- Appropriateness of emissions data;
- Simplifications in model algorithms and empirical relationships that are used to simulate complex physical and chemical processes in the atmosphere;
- Appropriateness of background concentrations; and
- Appropriateness of meteorological data.

Uncertainty associated with traffic data has been minimised by using a validated traffic model and 24-hour profiles from traffic data counts, although it is recognised that the CSV traffic model will be subject to further improvements especially around the Tewkesbury and Ashchurch area.

Uncertainties associated with emissions and background concentration data have been minimised by using the most recent appropriate published data from Defra, and for background data by comparison with available local monitoring data.

Uncertainties associated with model algorithms and empirical relationships have been minimised by using algorithms and relationships that have been independently validated and judged as fit for purpose.

Another uncertainty is with using historical meteorological data to estimate future concentrations. The key limiting assumption is that conditions in the future will be the same as in the past; however, in reality no two years are - or will be - the same. Defra's Technical Guidance LAQM.TG (09) reviews a number of studies examining inter-annual variability of meteorological data and the effect on dispersion model output; it is suggested that variability in source contribution should be no more than 30% between any two years.

2.5.1.7. Comparison with Air Quality Criteria

To derive total NO_2 concentrations from the modelled road NOx concentrations, and hence to allow a comparison with the air quality criteria, the method described in Defra's Technical Guidance LAQM.TG (09) was used. The total annual mean NO_2 is calculated from the modelled road NOx and background NO_2. The conversion was carried out using the latest revised 'NOx to NO_2 conversion spreadsheet' Version 3.2 available from the tools on the Defra UK-AIR website[13].

In addition to the modelled road NOx and background NO_2 data, the NOx to NO_2 conversion spreadsheet requires a local authority area to be specified to determine regional oxidant concentrations, and a traffic mix to determine the proportion of primary NO_2. The local authority used was selected based on receptor location and the traffic mix was "All urban UK traffic" for receptors in urban areas and "All non-urban UK traffic" for other areas.

2.5.1.8. Model Verification

It is good practice to compare modelled estimates of pollutant concentrations with real-world monitoring to assess a model's performance for a base year and to then inform the interpretation of model results for future years. There are 64 monitoring sites in the air quality study area which were suitable for comparison against modelled results. Air quality monitoring data was not available in all of the 12 selected modelling locations, so for the purposes of model verification the areas were split as shown in Table 2-2. Verification tables are presented in Section A.4 of Appendix A.

Table 2-2 Air Quality Model Verification Areas

Junction Location Abbreviation	Model Verification Area
M5 J9	Tewkesbury urban area
Tewkesbury town centre	
Kingsditch, Cheltenham	Cheltenham urban area
Poole Way, Cheltenham	
College Road, Cheltenham	
Evesham Road, Cheltenham	
Leckhampton Road, Cheltenham	
GCHQ, Cheltenham	
M5 J11a	M5 J11a
Priory Road Gloucester	Gloucester urban area
Barton Street, Gloucester	
Painswick Road, Gloucester	

A comparison of modelled and measured annual mean NO_2 concentrations for 2012 is presented in Table A-4 in Appendix A. When compared to the measured values, prior to any adjustment the air quality model was found to:

[13] NO_x to NO_2 Calculator, Version 3.2, Defra, 2012. http://laqm.defra.gov.uk/tools-monitoring-data/no-calculator.html/

- Show substantial under estimation of total NO_2 in Tewkesbury;
- Show predominant under estimation of total NO_2 in Cheltenham;
- Show general over estimation of total NO_2 around M5 J11a.
- Show substantial under estimation of total NO_2 in Gloucester; and

The model was adjusted and the adjusted total NO_2 concentrations verified to determine if the model had appropriate performance. Further details are provided in Table A-5 in Appendix A. Adjustment factors greater than four were required in urban areas, where there tended to be underestimation of concentrations. This is not unexpected given the simple modelling approach used for the strategic risk assessment.

Model statistics used to determine model performance post-adjustment are:

- Root mean square error (RMSE) – It is required that the RMSE is below 25% of the UK AQS objective or EU limit value threshold (i.e. an RMSE of 10ug/m^3).), and ideal if it is below 10% of the UK AQS objective or EU limit value threshold (i.e. an RMSE of 4ug/m^3).
- Fractional Bias (FB) – the ideal value is zero.
- In addition an air quality model can be considered to have appropriate performance where modelled concentrations are within 25% of monitored concentrations at 95% of sites, in accordance with Defra's Technical Guidance LAQM.TG (09)).

Model statistics post-adjustment are shown in Table 2-3. The RMSE and FB values are acceptable. 56 out of 64 monitoring sites have adjusted modelled total NO_2 concentrations within 25% of monitored concentrations (see Table A-6 in Appendix A), which is less than the 95% expected by Defra TG(09) for formal assessments (this is a strategic assessment). This is not unexpected given that a simple modelling approach was applied for the strategic risk assessment, which did not include modelling of street canyons, congested speeds or queuing at junctions in urban areas. Note that the consequence of a strategic approach is that post-adjustment the model generally overestimates, which accounts for most of the remaining differences greater than 25%.

Further work would be required to refine the air quality model for any formal impact assessment. However for the purposes of the strategic risk assessment, which is intended to be a strategic level assessment, the air quality model performance is considered to be proportionate and sufficient. The adjustment factors derived have been applied to the modelling results for the human health and ecological receptors in the base and future years, with and without the JCS.

Table 2-3 Air Quality Model Statistics, Post Adjustment

RMSE µg/m^3	FB
6.64	0.02
Notes: Root Mean Square Error: RMSE is used to define the average error or uncertainty of the model (µg/m^3). In the case of modelled annual mean NO_2 a value of less than 10 is acceptable Fractional Bias: FB is used to identify if the model shows a systematic tendency to over or under estimate. Ideal value is 0	

3. Baseline & Constraints

3.1. Local Air Quality Management Review and Assessment

The assessment has considered air quality within the boundaries of Tewksbury Borough Council, Cheltenham Borough Council, Gloucester City Council, Cotswolds District Council and Forest of Dean District Council.

These local authorities have carried out regular reviews and assessments of local air quality, in common with many other authorities across the UK, the councils have shown that the UK AQS objective and EU limit value thresholds most likely to be exceeded are for NO_2 due to road traffic emissions. The UK AQS objective and EU limit value thresholds for human health are presented in Table 3-1 for reference.

Table 3-1 Relevant Local Air Quality Criteria for Protection of Human Health

Pollutant	Criteria
NO_2	Annual mean concentration should not exceed 40 µg/m^3
	Hourly mean concentration should not exceed 200 µg/m^3 more than 18 times a year

National assessments have demonstrated that there is no risk of carbon monoxide, 1,3-butadiene or benzene concentrations exceeding relevant UK AQS objective and EU limit value thresholds for human health due to emissions from traffic anywhere in the UK. The pollutants carbon monoxide, 1,3-butadiene and benzene are therefore not considered further. Based on available review and assessments, local authorities covering the air quality study do not expect PM_{10} UK AQS objective and EU limit value thresholds for human health to be exceeded and this pollutant is not considered further.

The EU has set limit values for the protection of vegetation for NOx based on the work of the United Nations Economic Commission for Europe (UNECE) and World Health Organisation (WHO). The EU limit value for annual mean NOx for the protection of vegetation is 30 µg/m^3.

The Local Air Quality Management page of Defra's UK-Air website[14] has been reviewed to identify the AQMAs within the air quality study area. An AQMA is declared by the local authority where a breach of one or more UK AQS objective or EU limit value thresholds is likely.

There are seven AQMAs within the Gloucestershire area. These AQMA are as follows:

- Tewkesbury Town Centre AQMA - Tewkesbury Borough Council has designated the town centre as AQMA, an area encompassing parts of Tewkesbury town centre, including parts of High Street, Barton Street Church Street and the Eastern Relief Road.

- Cheltenham Whole Borough AQMA – Covering the whole area within the boundaries of Cheltenham Borough Council.

- Barton Street AQMA – An area encompassing Barton Street, Gloucester from its junction with Trier Way/Bruton Way to the north west and Upton Street to the south east, within the boundaries of Gloucester City Council.

- Painswick Road AQMA – An area encompassing a number of properties on either side of Painswick Road, Gloucester, within the boundaries of Gloucester City Council;

- Priory Road AQMA – An area encompassing the junction of St Oswald's Road and Priory Road, within the boundaries of Gloucester City Council;

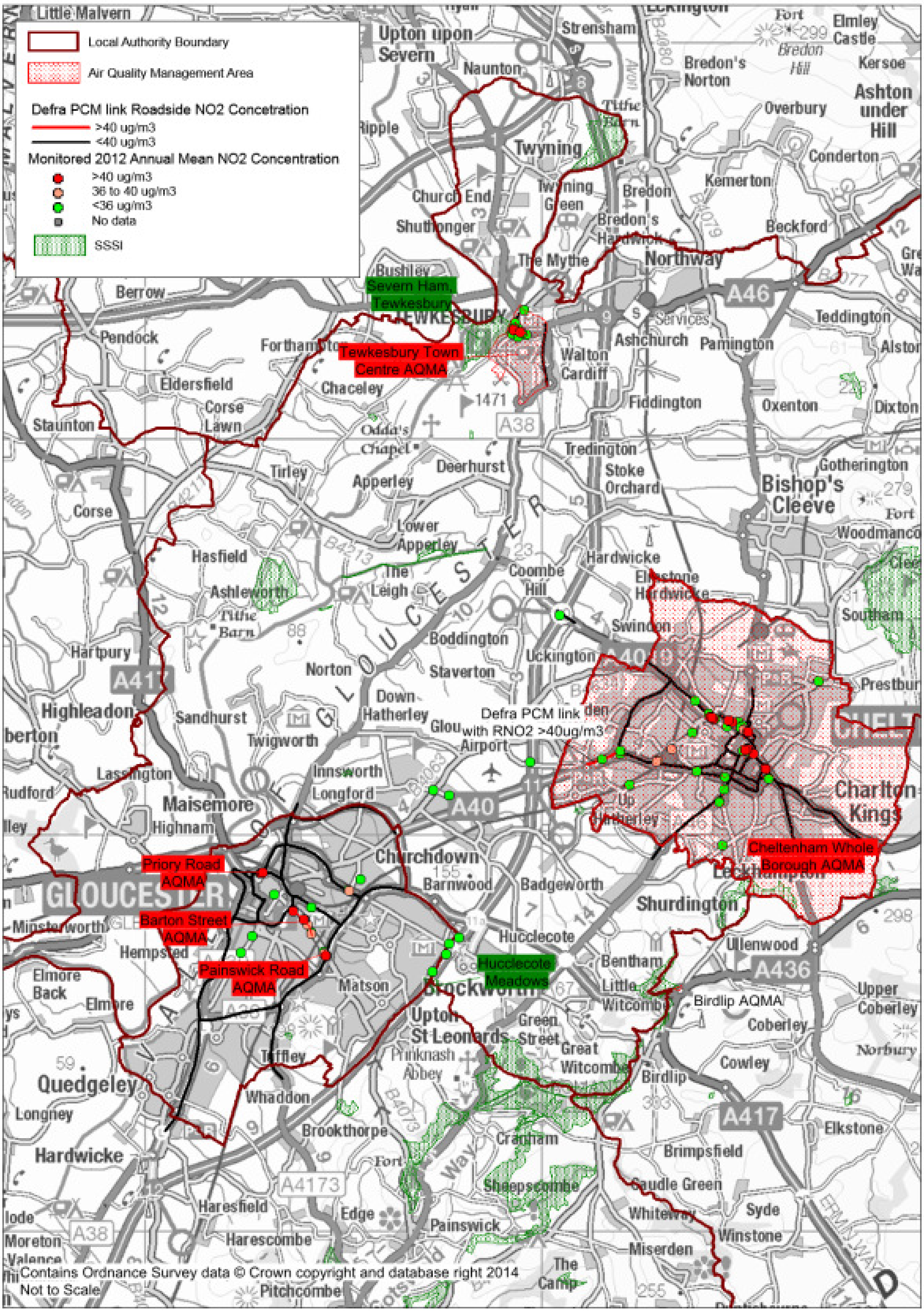
- Birdlip AQMA – An area encompassing the junction of the A417 and A436 at the Birdlip Roundabout, including nearby properties, within the boundaries of Cotswold District Council; and

[14] http://uk-air.defra.gov.uk/

- Lydney AQMA - An area in Lydney along parts of the B4231 (High Street, Hill Street and Newerne Street) and parts of Bream Road and Forest Road within the boundaries of Forest of Dean District;

All of these areas have been designated due to exceedances of the annual mean NO_2 UK AQS objective and EU limit value threshold of 40 $\mu g/m^3$. The AQMA within the boundaries of Tewksbury Borough Council, Cheltenham Borough Council and Gloucester City Council are considered to be most relevant to the JCS and are shown in Figure 3-1.

Figure 3-1 Constraints (AQMA, Defra PCM Links and Ecological Sites) within the Air Quality Study Area



3.2. Defra PCM Model Links

Further information on areas exceeding UK AQS objective or EU limit value thresholds are available from Defra's Pollution Climate Mapping (PCM) model[15]. The Defra PCM mapping provides 'road contributed' concentrations of pollutants, including annual mean NO_2.

Defra PCM mapping of roadside NO_2 concentrations in 2012 indicates exceedances of the annual mean NO_2 UK AQS objective and EU limit value thresholds on a section of the A40 between the A4013 and the Arles Court park and ride site. The location of these roads is shown in Figure 3-1.

3.3. Air Quality Monitoring

Air quality monitoring is undertaken by the local authorities in the air quality study area. This information has been collated to consider baseline local air quality conditions and where relevant has been used in the verification of the illustrative 'headroom' calculations. The monitoring data for Tewksbury Borough Council, Cheltenham Borough Council and Gloucester City Council are considered to be most relevant to the JCS and as such data has been collated for these local authorities only.

The monitoring techniques used for nitrogen dioxide (NO_2) are both continuous and passive. Continuous monitoring methods are generally more accurate than passive techniques so consideration of the associated uncertainties will be important when undertaking air quality modelling and verification.

3.3.1. Local Authority Monitoring

Local authority monitoring data has been collated for relevant monitoring sites within Cheltenham Borough Council, Tewksbury Borough Council, Gloucester City Council, and Stroud District Council. Figure 3-1shows monitored annual mean NO_2 concentrations for 2012 at relevant sites. Data tables are presented in Appendix B. There were exceedances of the annual mean NO_2 UK AQS objective and EU limit value threshold of 40 $\mu g/m^3$ in 2012 at the following locations:

- In Tewkesbury town centre (within the Tewkesbury Town Centre AQMA)
- In Cheltenham town centre (within the Cheltenham Whole Borough AQMA):
  - Along the A4019 Tewkesbury Road at the junction with A4019 Poole Way
  - Along A4019 Swindon Road
  - Along A46 Fairview Road
  - Around the junction of A46 Bath Road/ Berkley Street/College Road and A435
- In Gloucester town centre:
  - Along the A430 Priory Road in Gloucester (within the Priory Road AQMA)
  - Along the B4073 Barton Street east of B430 Bruton Way in Gloucester (within the Barton Street AQMA)
  - Along the B4073 Painswick Road, west of A38 Eastern Avenue in Gloucester (within the Painswick Road AQMA)

3.4. Receptors

There are two types of receptors considered for air quality:

- Human health related receptors - properties where relevant exposure for the air quality criteria being assessed could occur (defined in Defra Technical Guidance LAQM.TG(09)) as residential premises,

[15] http://uk-air.defra.gov.uk/data/gis-mapping

schools, hospitals and other community facilities where there is routine public access; places of work and most pedestrian areas can generally be excluded); and
- Designated ecological areas - including internationally designated ecological sites (such as Sites of Special Scientific Interest (SSSI), Special Areas of Conservation (SAC), Special Protection Areas (SPA) and sites listed under the Convention on Wetlands and Wildfowl (Ramsar).

3.4.1. Human Health related Receptors

There are numerous human receptors located in the Tewkesbury, Cheltenham and Gloucester urban areas. Worst case receptors within 50 metres of locations where there were concerns about air quality effects have been included in the local air quality the illustrative air quality ‘headroom’ calculations. These receptor locations are discussed in Section 2.5.1.3.

3.4.2. Designated Ecological Sites

There are two designated ecological site within 200 metres of the junctions identified for assessment in local air quality study area, shown in Figure 3-1. These are:

- Severn Ham, Tewkesbury SSSI, west of the A38 in Tewkesbury town centre; and
- Hucclecote Meadows SSSI, south of M5 J9.

The Severn Ham, Tewkesbury SSSI is designated as it is one of the last remaining traditionally managed ham meadows overlying the alluvium in the Severn Vale. The major habitat represented is that of neutral grassland, much of which has been semi improved. The Hucclecote Meadows SSSI is part of a series of lowland meadows overlying Lower Lias clays in the Severn Vale and represents one of the few remaining areas of such herb-rich ancient pastures. Both these area will be considered as sensitive receptors in the local air quality illustrative air quality ‘headroom’ calculations, due to their sensitivity to nitrogen.

4. Assessment Results

4.1. Strategic Emissions Exposure Assessment

A summary of the results of the strategic emissions exposure assessment are presented in Table 4-1.

Table 4-1 Summary of Strategic Emissions Exposure Assessment

Local Authority Area	DM1 NOx (Tonnes per Year)	DS1 NOx (Tonnes per Year)	Change in NOx (Tonnes per Year)	Change in Emissions Exposure (Tpy*population/km^2)
Cheltenham	54	57	+3	+9032
Cotswold	93	100	+7	+697
Forest of Dean	39	39	<1	+27
Gloucester	93	93	<1	-617
Stroud	211	207	-4	-639
Tewkesbury	240	249	+9	+3952
All model links within Gloucestershire	**730**	**745**	**+15**	**+12452**

The change in the modelled emission exposure estimate across the Gloucestershire area is positive indicating an increase in exposure to road traffic emissions as a result of the JCS. The breakdown into local authority areas indicates that the largest change in emissions exposure by far occurs in Cheltenham. Cheltenham has the second highest population in Gloucestershire (Gloucester has the highest population) which when combined with a 6% increase in emissions across the Cheltenham Borough Council authority results in the largest change in emissions exposure.

The largest increase in total NOx emissions occurs within Tewkesbury but results in the second highest change in emissions exposure as the affected population is much lower than in Cheltenham, (Tewkesbury has the second lowest population in Gloucestershire).

The total change in NOx emissions on road links across Gloucester appear to be less than one tonne per year, this is a result of ten MSOA areas with decreases in emissions in the south west of Gloucester and five areas with increases in emissions in the north west of Gloucester, as can be seen in Figure 4-2 below. The overall change across the Gloucester City Council authority balances out these localised effects.

Figure 4-1 presents the change in NOx emissions in kg per year as a result of implementing the DS1 as a thematic map, identifying the locations where NOx emissions from links within the MSOA are expected to increase and decrease. The majority of increases in emissions, represented in purple, are to the north and east of the county. MSOAs with decreases in NOx emissions, represented in green, are mostly located to the south west of the county and result mainly from expected decrease in traffic on the M5 in this area.

Note that the comparison in the strategic air quality assessment is between the 2031 Do Minimum 1 (DM1) – JCS without nine strategic allocation sites, a “do nothing”; and 2031 Do Something 1 (DS1) – JCS with nine strategic allocation sites and sustainable transport measures (comprising a 6% demand reduction in strategic allocation sites, 3% demand reduction elsewhere within the CSV region). As such it is prior to any emission-impact driven mitigation of the consequences of the JCS (that is, no road traffic alleviation measures), and as such does not represent the residual impacts. This is a strategic assessment proportionate to the current status of the JCS and to readily available pre-existing data, all prior to already required traffic model changes.

Figure 4-1 Thematic Map of Change in NOx Emission for JCS

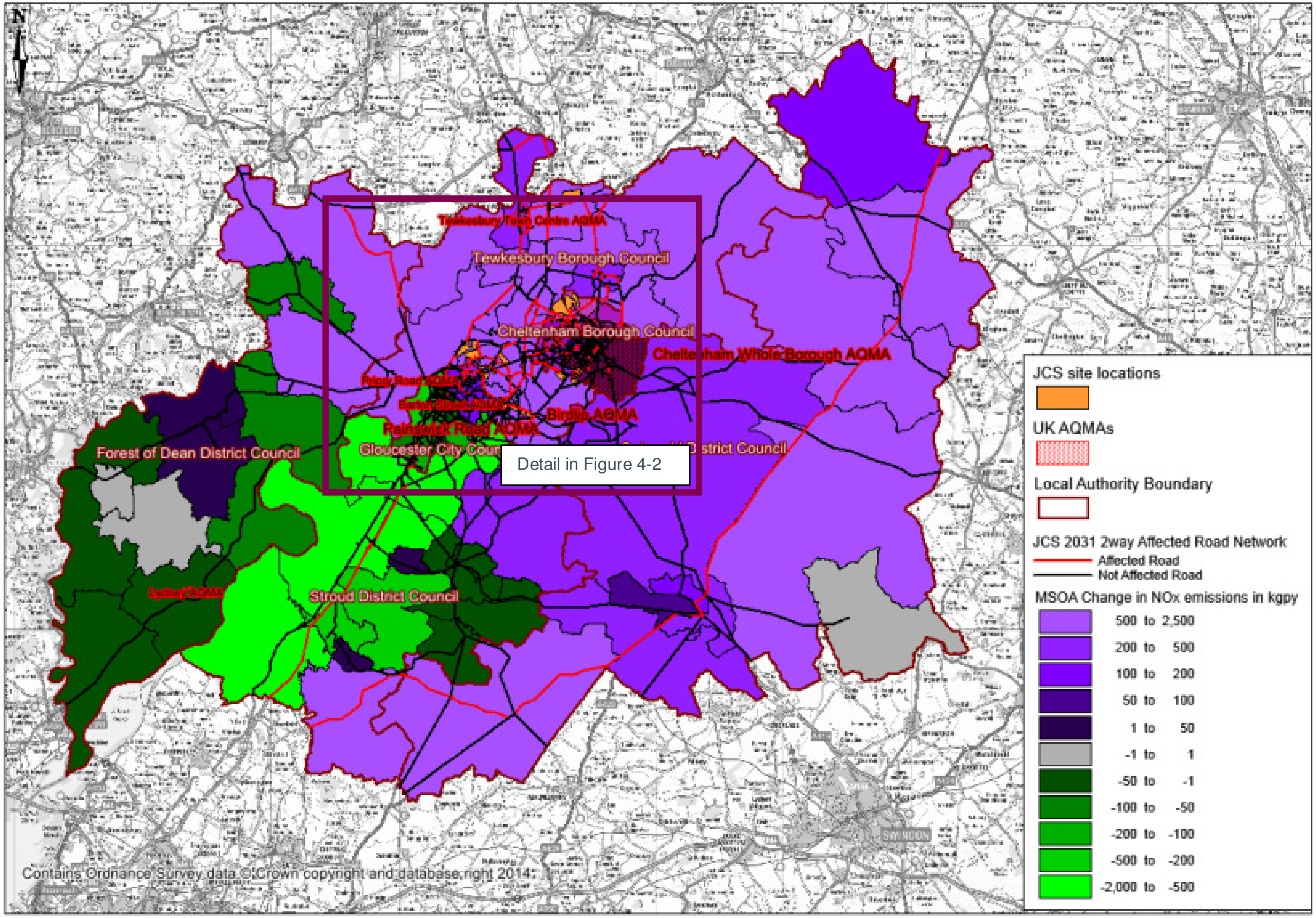
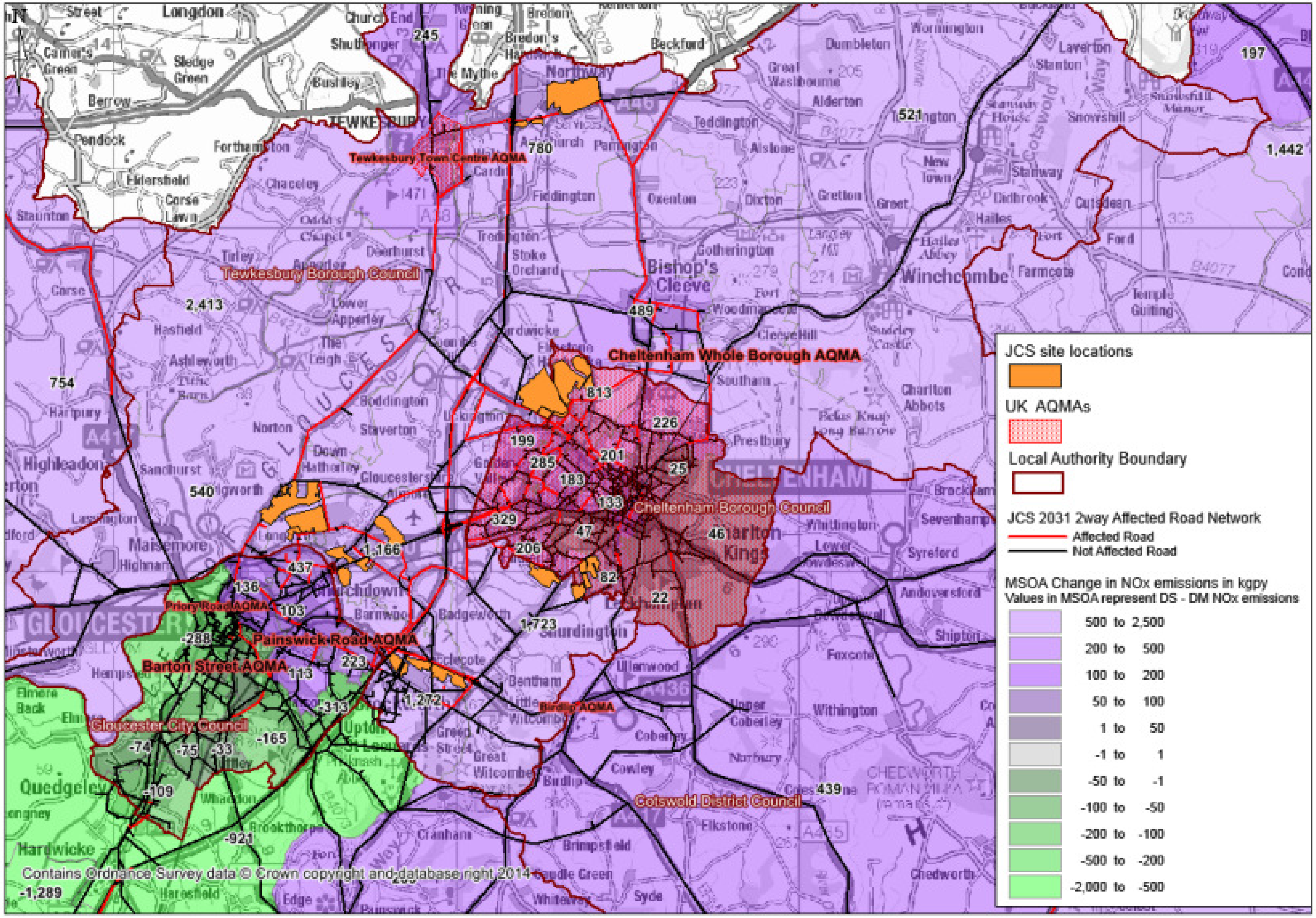


Figure 4-2 Thematic Map of Change in NOx Emissions for Tewkesbury, Cheltenham and Gloucester



In accordance with the methodology for strategic emissions exposure given in The TAG guidance, a comparison of MSOA areas within each local authority area where emissions are estimated to increase and decrease as a result of the DS1 are also summarised in the Table 4-2, with an indication of where AQMAs are present. The strategic emissions exposure methodology does not however indicate whether the local air quality in these AQMAs will be affected as it sums emissions from all traffic model links within each MSOA.

Table 4-2 Summary of Number of MSOA Areas with Increases and Decreases in Emissions and AQMAs Affected

Local Authority Area	No. MSOAs with Increase in Emissions	No. MSOAs with Decrease in Emissions	AQMA Affected
Cheltenham	15	0	Increase in emissions in the MSOAs within Cheltenham Whole Borough Council AQMA
Cotswold	10	1	Increase in emissions in the MSOA containing Birdlip AQMA
Forest of Dean	3	6	Decrease in emissions in MSOA containing Lydney AQMA
Gloucester	5	10	Decrease in emissions in MSOAs containing Priory Road AQMA and Barton Street AQMA. Increase in emissions in MSOA containing Painswick Road AQMA
Stroud	4	11	No AQMAs present
Tewkesbury	9	0	Increase in emissions in the MSOA containing Tewkesbury Town Centre AQMA
All model links within JCS area	**46**	**28**	**7 AQMAs identified, 4 show increase in emissions, 3 MSOAs show decreases in emissions**

4.2. Illustrative Air Quality ‘Headroom’ Calculations

Illustrative air quality ‘headroom’ calculations were undertaken for 2012 base year, 2031 DM1 and 2031 DS1 at selected human receptors and ecological receptors around 12 selected locations. The magnitude of impact of changes in concentrations in 2031 as a result of the JCS was calculated to determine the effect of the JCS on air quality. In accordance with Highways Agency IAN 174/13 ‘large’ is a change in concentrations >4 $\mu g/m^3$, ‘medium’ is 2 to 4 $\mu g/m^3$, ‘small’ is 0.4 to 2 $\mu g/m^3$ and ‘imperceptible’ is a change <0.4 $\mu g/m^3$).The results of these calculations are presented in Appendix C and discussed below.

For the whole study area, in 2031 concentrations are expected to be below the annual mean NO_2 UK AQS objective and EU limit value thresholds at all human health receptors for the DM1 and DS1. This is a product of year on year reductions in vehicle emissions arising from fleet replacement rates using central Government assessment methods.

Around M5 J9, Tewkesbury:

- In 2012 modelled concentrations were above the annual mean NO_2 UK AQS objective and EU limit value thresholds at the human health receptors within 50 metres of the A438. No monitoring data was available for this location and the modelled concentrations were adjusted using monitoring sites in Tewkesbury town centre, which possibly resulted in over adjustment and therefore over estimation of concentrations around M5 J9.

- With DS1 there is a ‘small’ reduction in concentrations of annual mean NO_2 at the human health receptor on Milne Pastures, north of the A438, but ‘imperceptible’ elsewhere.

In Tewkesbury town centre:

- In 2012 modelled concentrations were above the annual mean NO_2 UK AQS objective and EU limit value thresholds at the human health receptor located at 1 Barton Terrace, but below the thresholds elsewhere.

- With DS1 there is an 'imperceptible' change in concentrations of annual mean NO_2 at all human health receptors.

- At the ecological receptor the NOx threshold for the protection of vegetation is not exceeded in 2012 or in 2031.

In Cheltenham:

- In 2012 modelled concentrations were above the annual mean NO_2 UK AQS objective and EU limit value thresholds at the human health receptor located around the Poole Way and College Road junction locations, but below the thresholds at human health receptors elsewhere.

- With DS1 there is are 'small' increases in concentrations of annual mean NO_2 at the human health receptor around the Kingsditch, Poole Way and College Road junction locations. There is an 'imperceptible' change in concentrations of annual mean NO_2 at all human health receptors elsewhere.

Around M5 J11a, Gloucester:

- In 2012 modelled concentrations were below the annual mean NO_2 UK AQS objective and EU limit value thresholds at all human health receptors.

- With DS1 there is an 'imperceptible' change in concentrations of annual mean NO_2 at all human health receptors.

- At the ecological receptors the NOx threshold for the protection of vegetation is exceeded in 2012, but below the threshold in 2031.

In Gloucester:

- In 2012 modelled concentrations were above the annual mean NO_2 UK AQS objective and EU limit value thresholds at the human health receptors located along Painswick Road, but below the thresholds elsewhere. Modelled concentrations were in the range 39 to 40 $\mu g/m^3$ at the human health receptor at 34 Mount Street, in the Priory Road junction location and also at a human heath receptor within the Painswick Road junction location.

- With DS1 there is an 'imperceptible' change in concentrations of annual mean NO_2 at all human health receptors.

5. Conclusions

This report presents the strategic air quality assessment for the JCS. For air quality the main potential effects of the JCS will be related to changes in emissions of road traffic as a result of changes to the local traffic network and this is the focus of the air quality assessment work. A strategic level of assessment of air quality, proportionate to the stage of development of the strategy has been undertaken using readily available pre-existing current traffic model scenarios, all prior to the already required traffic model changes.

The assessment has considered the following scenarios:

- 2012 base year – using the 2008 traffic model base year data;
- 2031 Do Minimum 1 (DM1) – JCS without nine Strategic Allocation Sites, a “do nothing” scenario; and
- 2031 Do Something 1 (DS1) – JCS full allocation and sustainable transport measures (comprising a 6% demand reduction in Strategic Allocation Sites, 3% demand reduction elsewhere within the CSV region).

Given the basis of this comparison, it is prior to any emission-impact driven mitigation of the consequences of the JCS (that is, no road traffic alleviation measures), and as such does not represent the residual impacts.

A Strategic level assessment of changes in air pollutant emissions was undertaken, covering the whole JCS area to determine the overall effect on air quality exposure of the JCS in the year 2031. This assessment indicated that there would be an **overall increase in emissions exposure as a result of the JCS**. This is commensurate with increasing the population and numbers of private vehicles in an area, prior to developing emissions-related mitigation measures which were outside of the brief (given the proportionate approach at this stage of the JCS development). The largest change in emissions exposure is expected to occur in Cheltenham – a combination of the second highest population in Gloucestershire and a 6% increase in emissions across the Borough. The largest increase in total NOx emissions occurs within Tewkesbury but the affected population is much lower than in Cheltenham. The total change in NOx emissions on road links across Gloucester appears to be less than one tonne per year.

The assessment of local air quality effects using illustrative air quality ‘headroom’ calculations indicated at the 12 locations selected for assessment there would be **no exceedances of annual mean NO_2 UK AQS objectives and EU limit value thresholds in 2031 at human health receptors**. There would also be compliance with EU limit value threshold for the protection of vegetation at designated ecological sites within 200 metres of the locations assessed. This is a product of year on year reductions in vehicle emissions arising from fleet replacement rates using Defra TG (09) assessment methods. Assessments accounting for reduced levels of actual improvements in vehicle emission technology (such as using Defra 2012 guidance or Highways Agency interim advice note 170) were outside of the brief, given the proportionate approach at this stage of the JCS development. There would be ‘small’ increases in concentrations of annual mean NO_2 at the human health receptor around the Kingsditch, Poole Way and College Road junction locations in Cheltenham in 2031 and a ‘small’ reduction in concentrations of annual mean NO_2 at the human health receptor on Milne Pastures, north of the A438. All other locations would have an ‘imperceptible’ change in 2031.

6. Further Work

Prior to discussion with the JCS team, based on the approach adopted for the strategic assessment and the findings, the following further work is recommended:

- Rerun of the air quality assessment using updated CSV traffic model, especially for the Tewkesbury and Ashchurch area – both for emissions and local air quality given the proposed more detailed traffic model zoning in this area;
- Investigation of apparent re-routing with JCS in place off M5 and A38 bypassing Gloucester and Cheltenham;
- Potential assessment of DS2 (JCS with additional infrastructure schemes) if/when these are agreed and assessment of differences in air quality and emissions between the DM2 and DS1 to differentiate impacts of each and highlight benefits of interventions;
- Improvements to air quality model adjustment to achieve Defra TG(09) guidance of 95% of verification sites within 25% of monitoring values, including variable air quality model setup by development site to better reflect locale (and accounting for known updates to the traffic model;
- Assessments prior to 2031, such as phased opening years;
- Analysis of JCS impacts under long term trend methods such as provided in HA IAN 173 and Defra Note on Projecting NO_2 April 2012, to account for reduced levels of actual improvements in vehicle emission technology – the strategic air quality assessment assumes Defra TG(09) standard rates of improvement;
- Assessment of nitrogen deposition changes in the SSSIs; and
- Compliant webTAG assessment to support JCS business case.

Appendices

Appendix A. Illustrative Air Quality 'Headroom' Calculations Modelling Data

A.1. Junction Locations Included in the Air Quality Model

Table A-1 Summary of Junction Locations Included in the Air Quality Model

Local Authority	Junction Location Abbreviation	Priority	Junction Location Description
Tewkesbury	M5 J9	1	Around M5 Junction 9
Tewkesbury	Tewkesbury town centre	2	Tewkesbury town centre
Cheltenham	Kingsditch, Cheltenham	3	Around the junction of A4019 Tewkesbury Road and A4013 Princess Elizabeth Way in the Kingsditch area of Cheltenham
Cheltenham	Poole Way, Cheltenham	1	Around the junction of A4019 Tewkesbury Road/Poole Way and B4633 Gloucester Road in Cheltenham town centre
Cheltenham	College Road, Cheltenham	1	Around the junction of A46 Bath Road/ Berkley Street/College Road and A435 in Cheltenham town centre
Cheltenham	Evesham Road, Cheltenham	3	Around the junction of the A435 Evesham Road and B4075 New Barn Lane north of Cheltenham town centre
Cheltenham	Leckhampton Road, Cheltenham	3	Around the junction of A46 Shurdington Road and Leckhampton Road, south of Cheltenham town centre
Cheltenham	GCHQ, Cheltenham	3	Around A4013 Princess Elizabeth Way and 40 Gloucester Road roundabout, near GCHQ, south west of Cheltenham town centre
Gloucester	M5 J11a	1	Around M5 Junction 11a
Gloucester	Priory Road Gloucester	2	Around A417 St Oswald's Road and A430 Priory Road in Gloucester
Gloucester	Barton Street, Gloucester	2	B4073 Barton Street east of B430 Bruton Way in Gloucester
Gloucester	Painswick Road, Gloucester	2	B4073 Painswick Road, west of A38 Eastern Avenue in Gloucester

Figure A-1 Location of Receptors Modelled in the Air Quality Assessment - Tewkesbury Town Centre

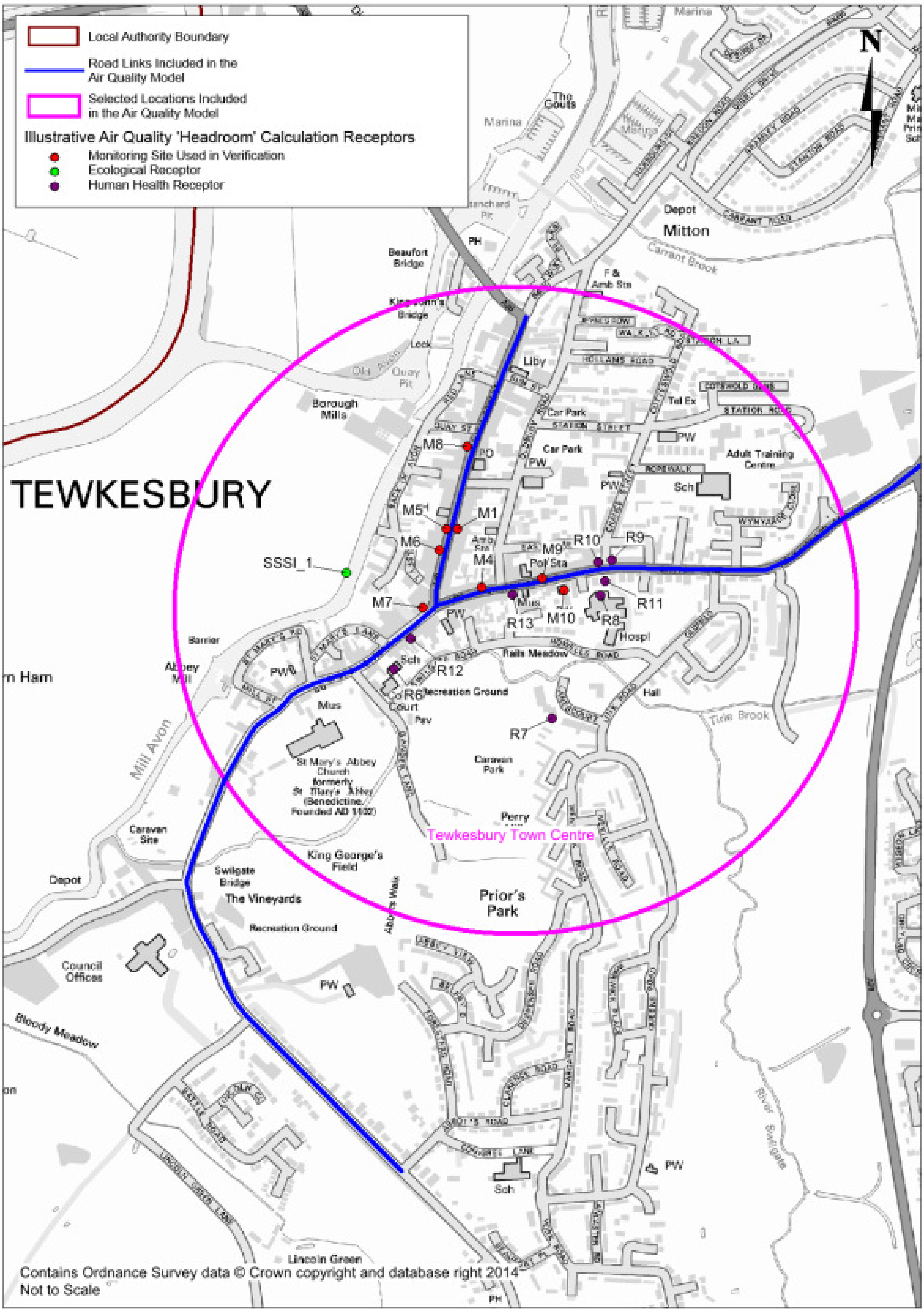


Figure A-2 Location of Receptors Modelled in the Air Quality Assessment - Tewkesbury M5 J9

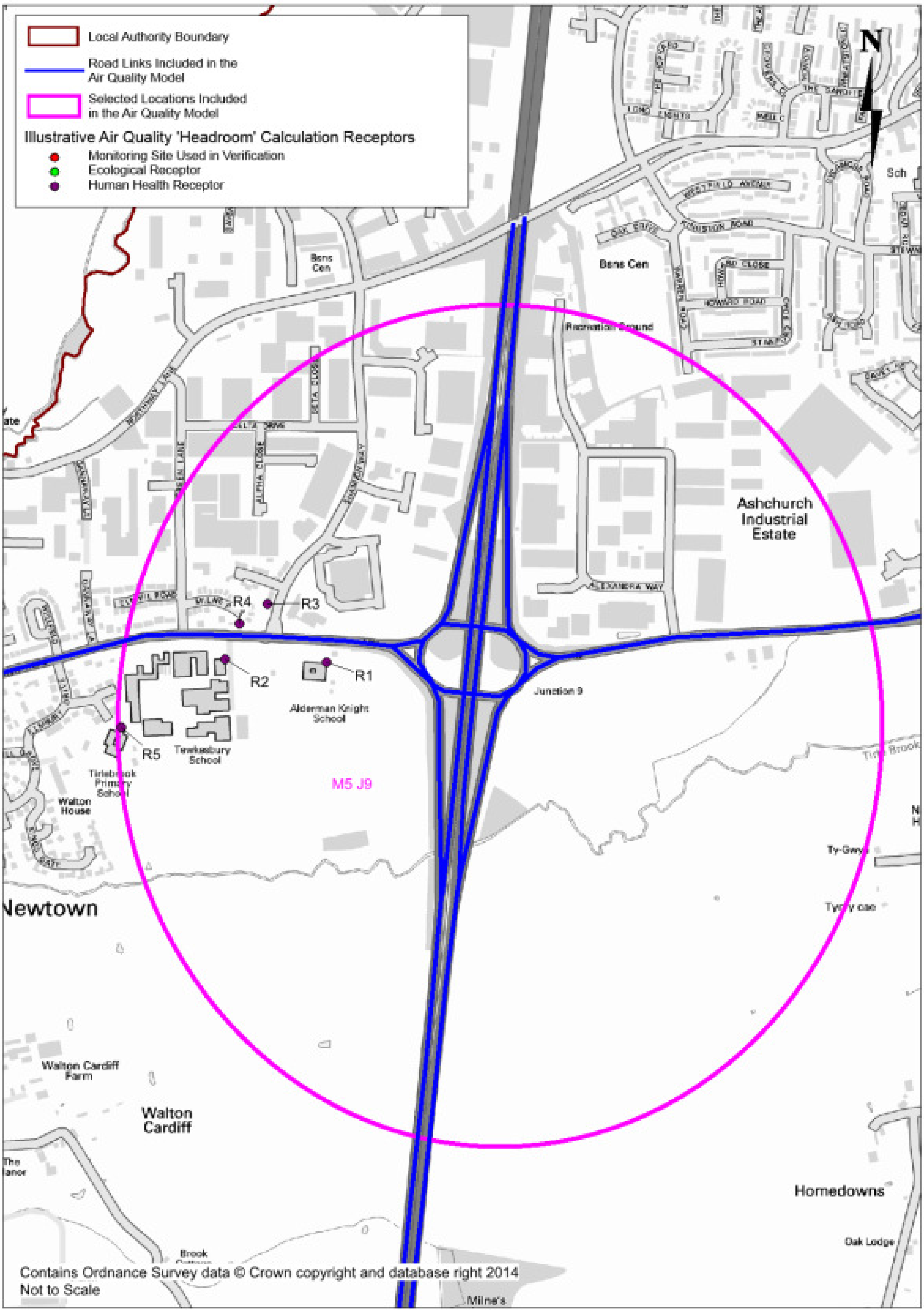


Figure A-3 Location of Receptors Modelled in the Air Quality Assessment – Cheltenham Kingsditch

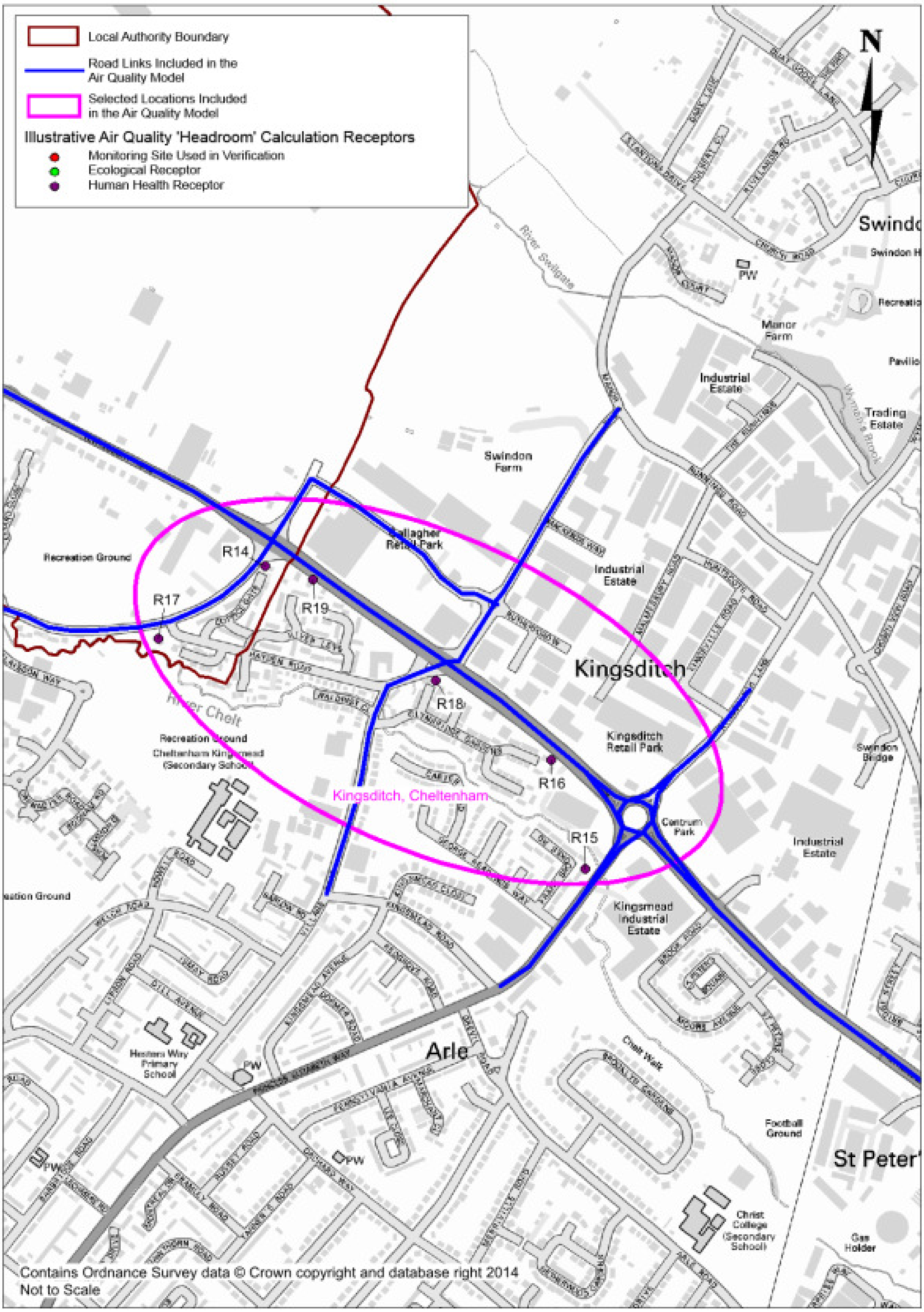


Figure A-4 Location of Receptors Modelled in the Air Quality Assessment – Cheltenham Poole Way

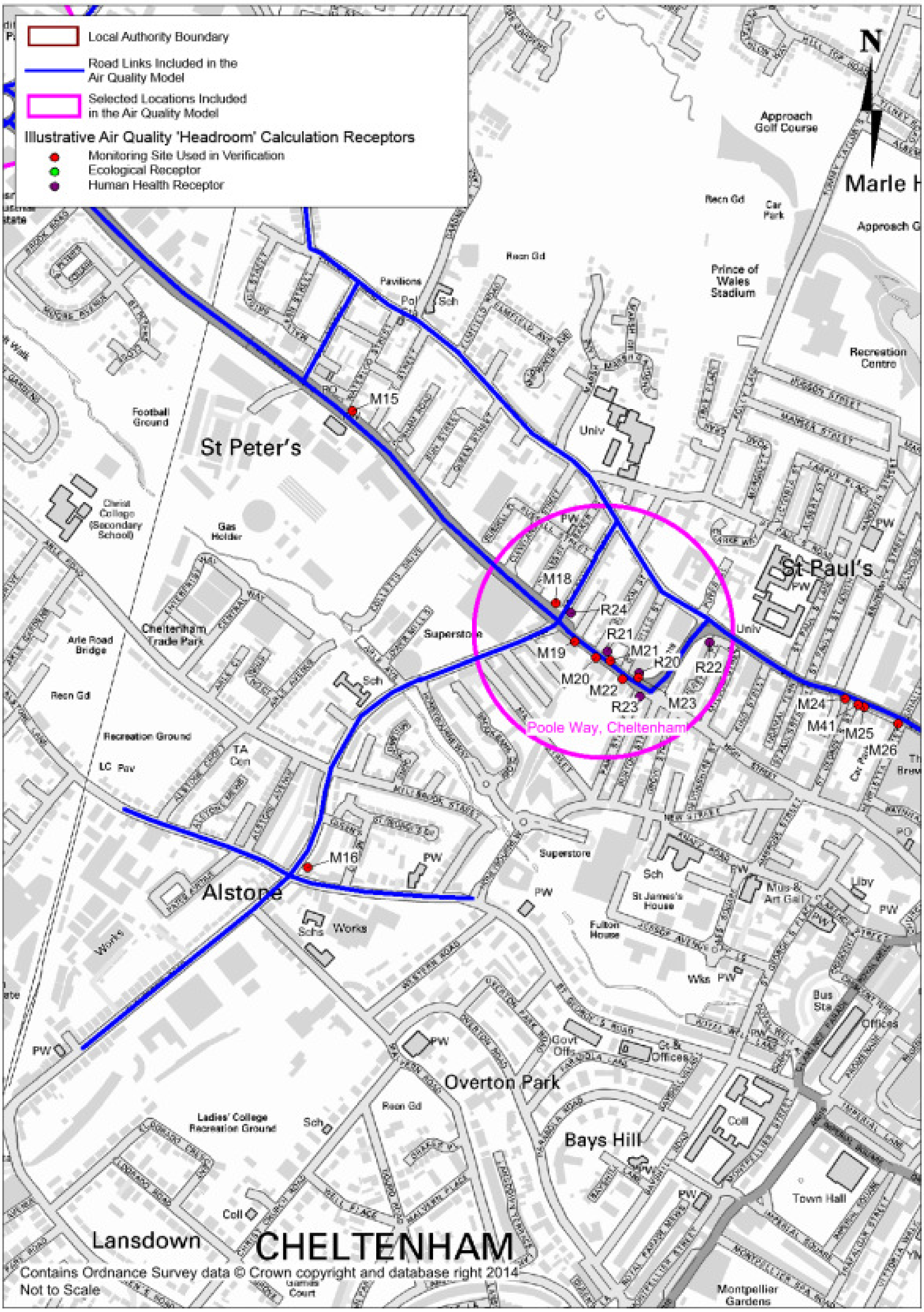


Figure A-5 Location of Receptors Modelled in the Air Quality Assessment – Cheltenham College Road

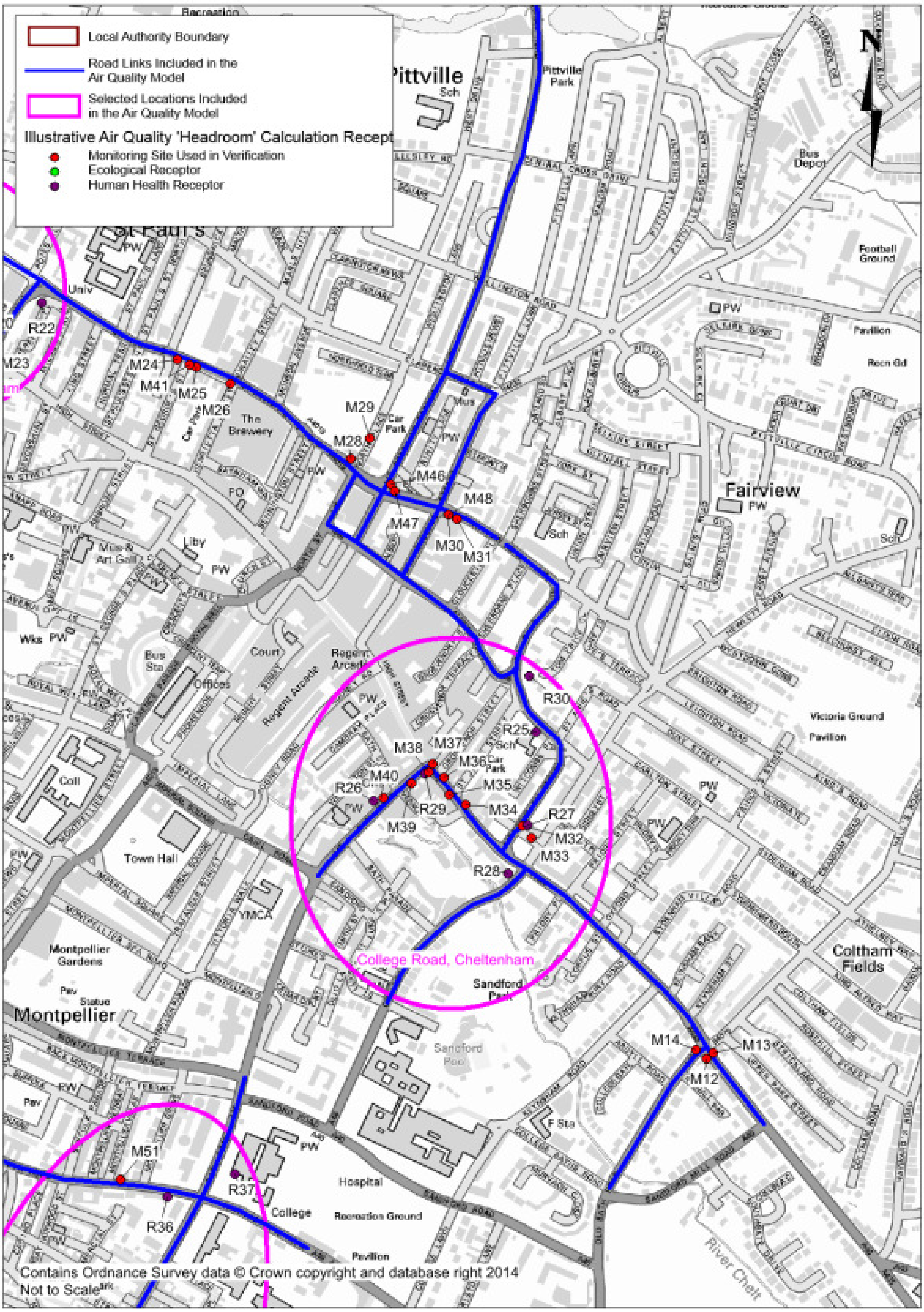


Figure A-6 Location of Receptors Modelled in the Air Quality Assessment – Cheltenham Evesham Road

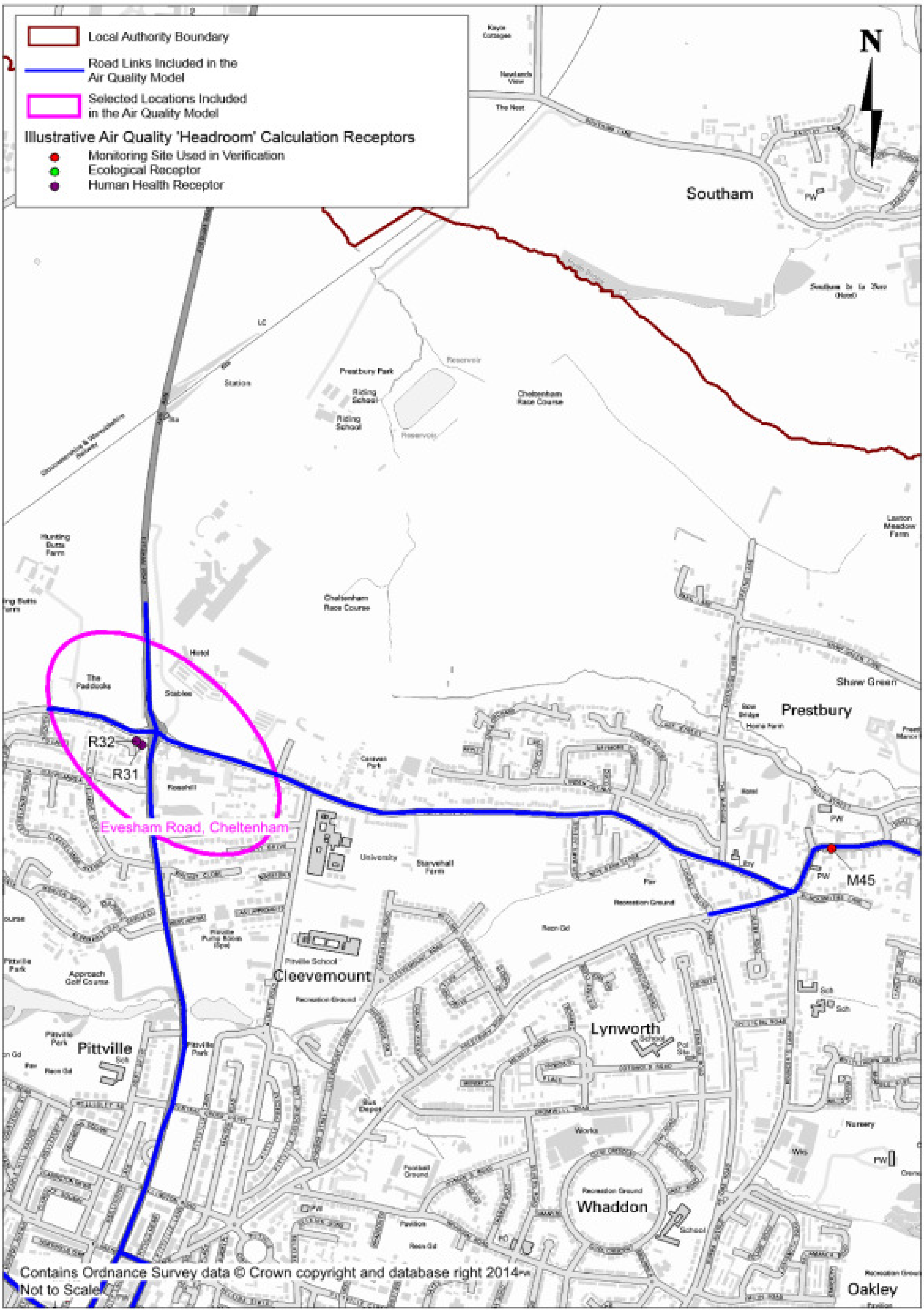


Figure A-7 Location of Receptors Modelled in the Air Quality Assessment – Cheltenham Leckhampton Road

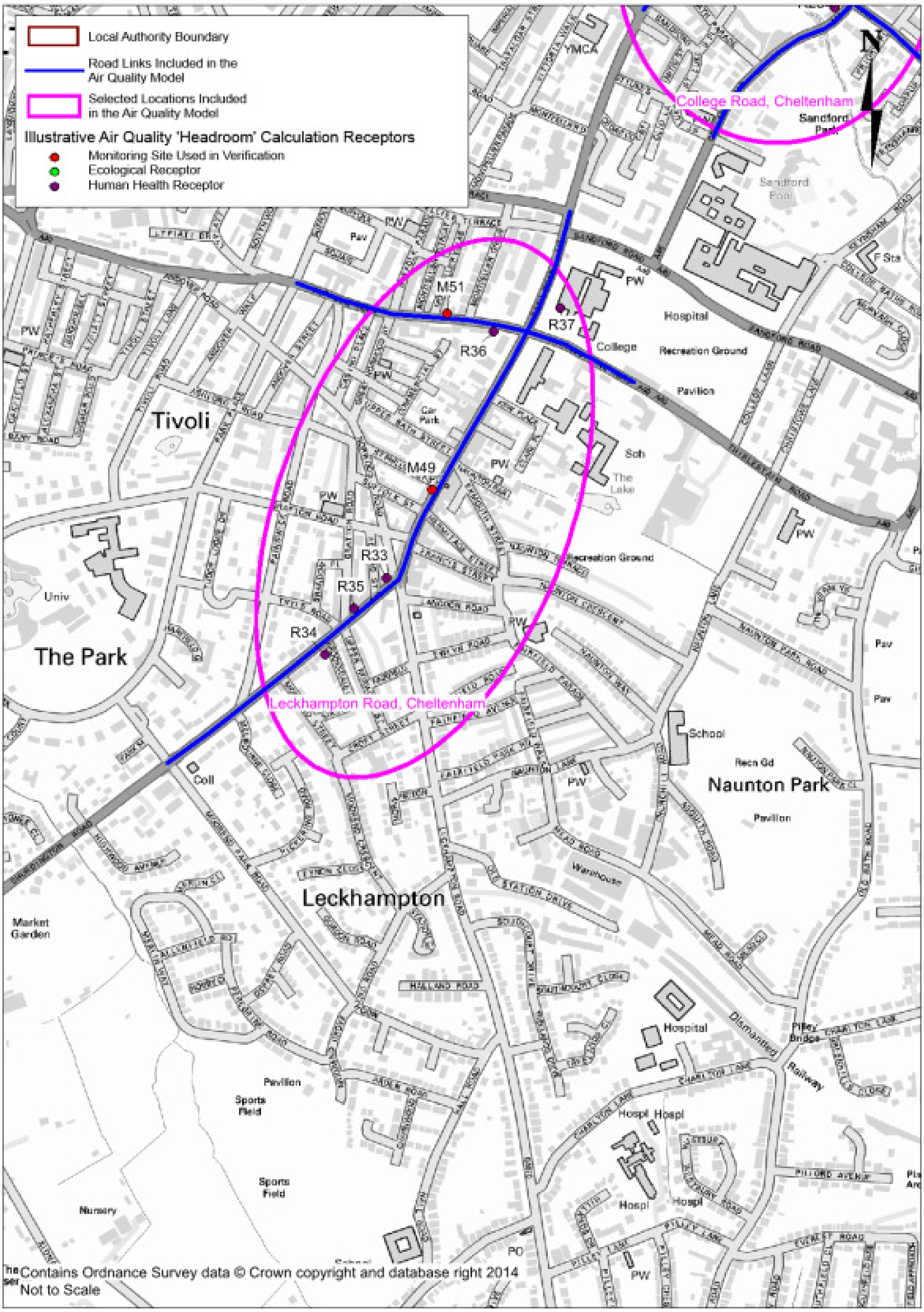


Figure A-8 Location of Receptors Modelled in the Air Quality Assessment – Cheltenham GCHQ

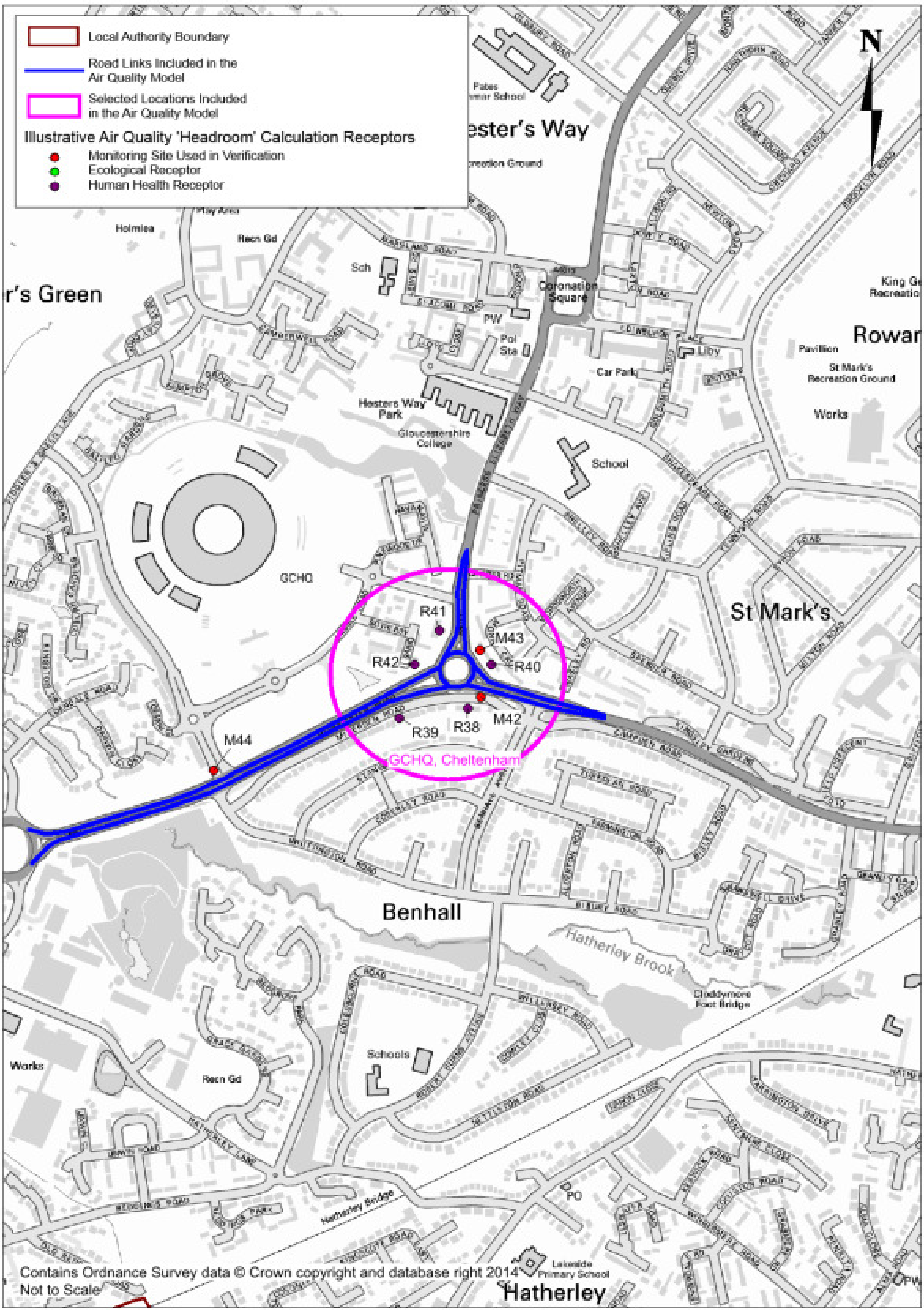


Figure A-9 Location of Receptors Modelled in the Air Quality Assessment – Gloucester M5 J11a

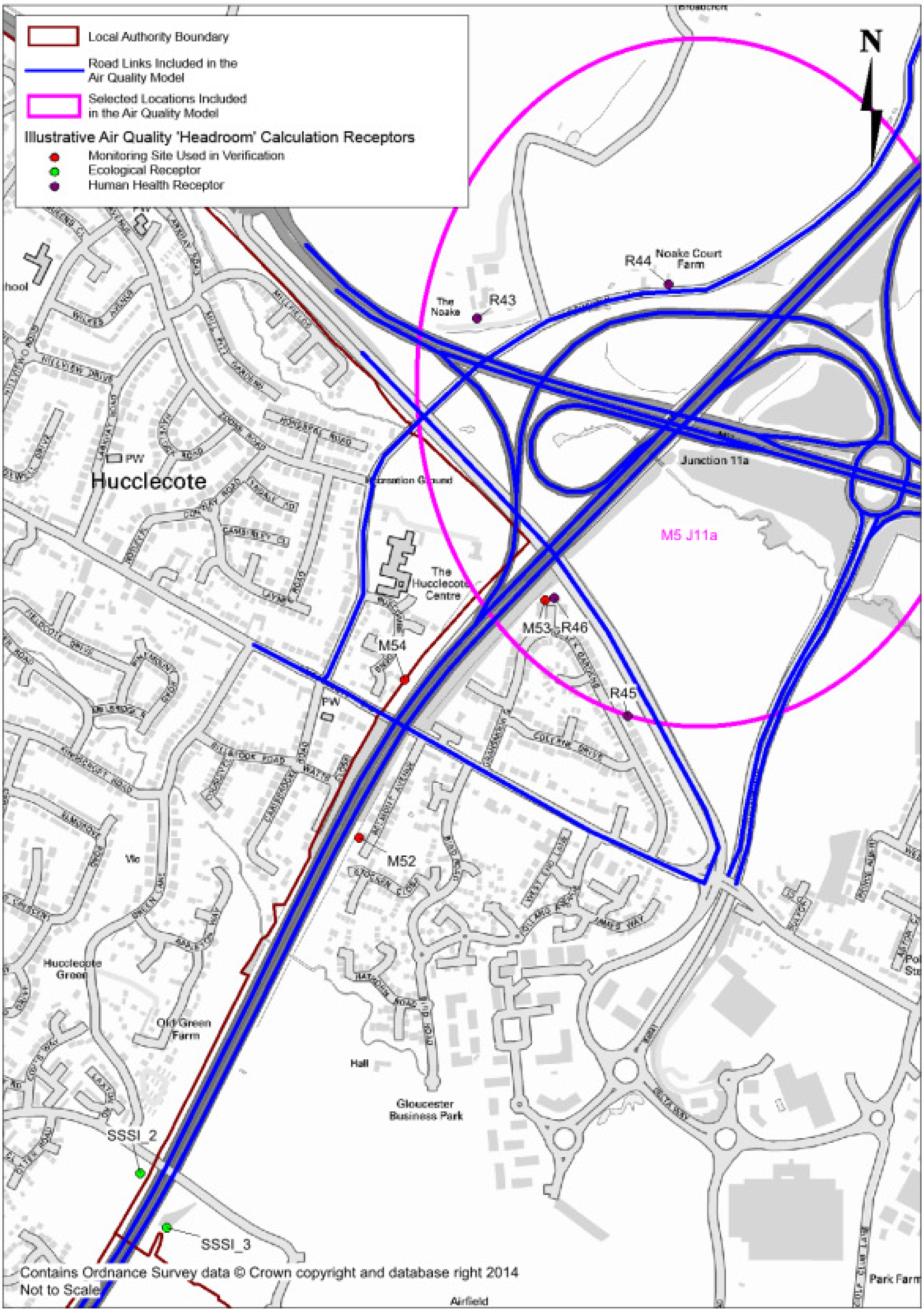


Figure A-10 Location of Receptors Modelled in the Air Quality Assessment – Gloucester Priory Road

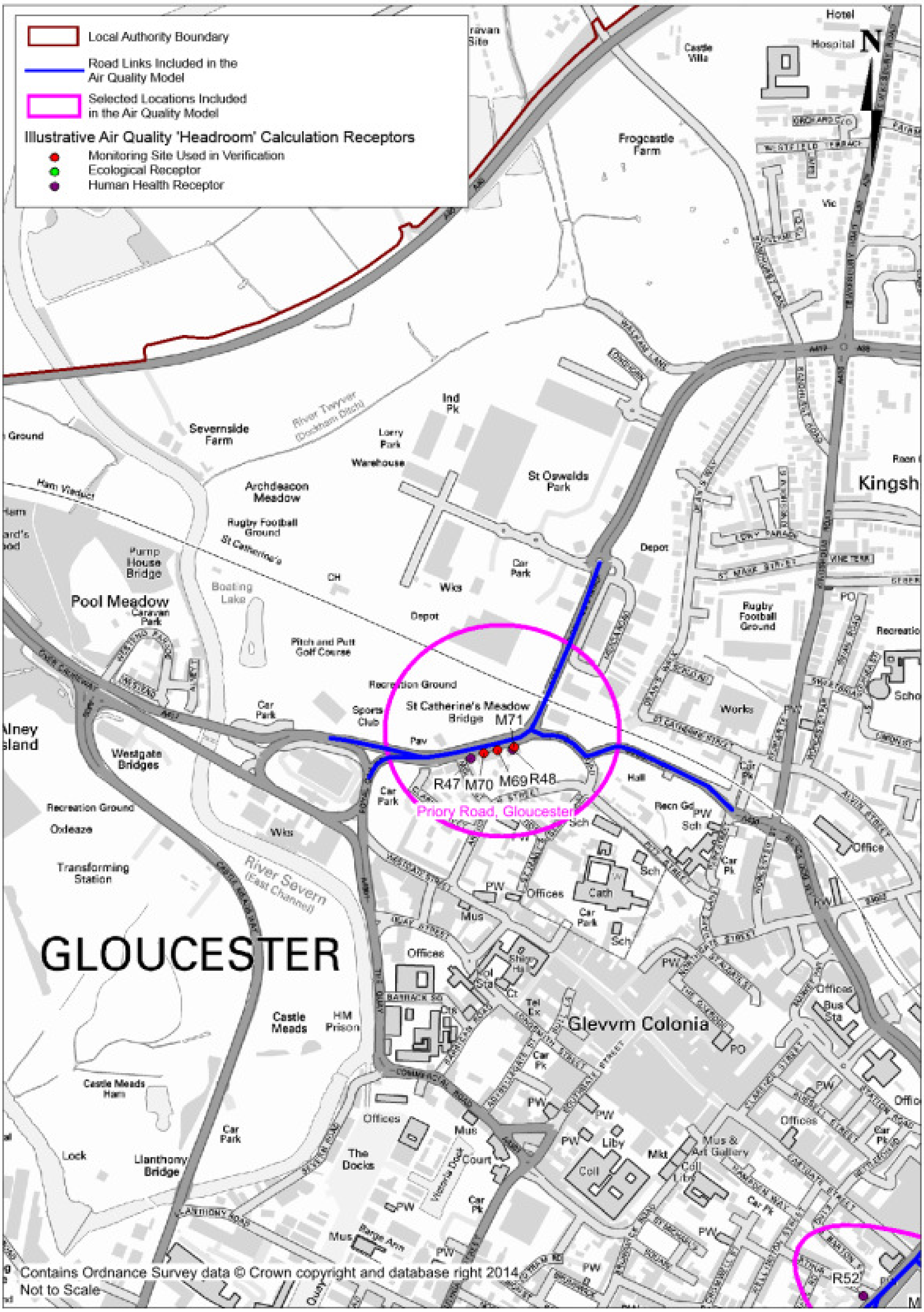
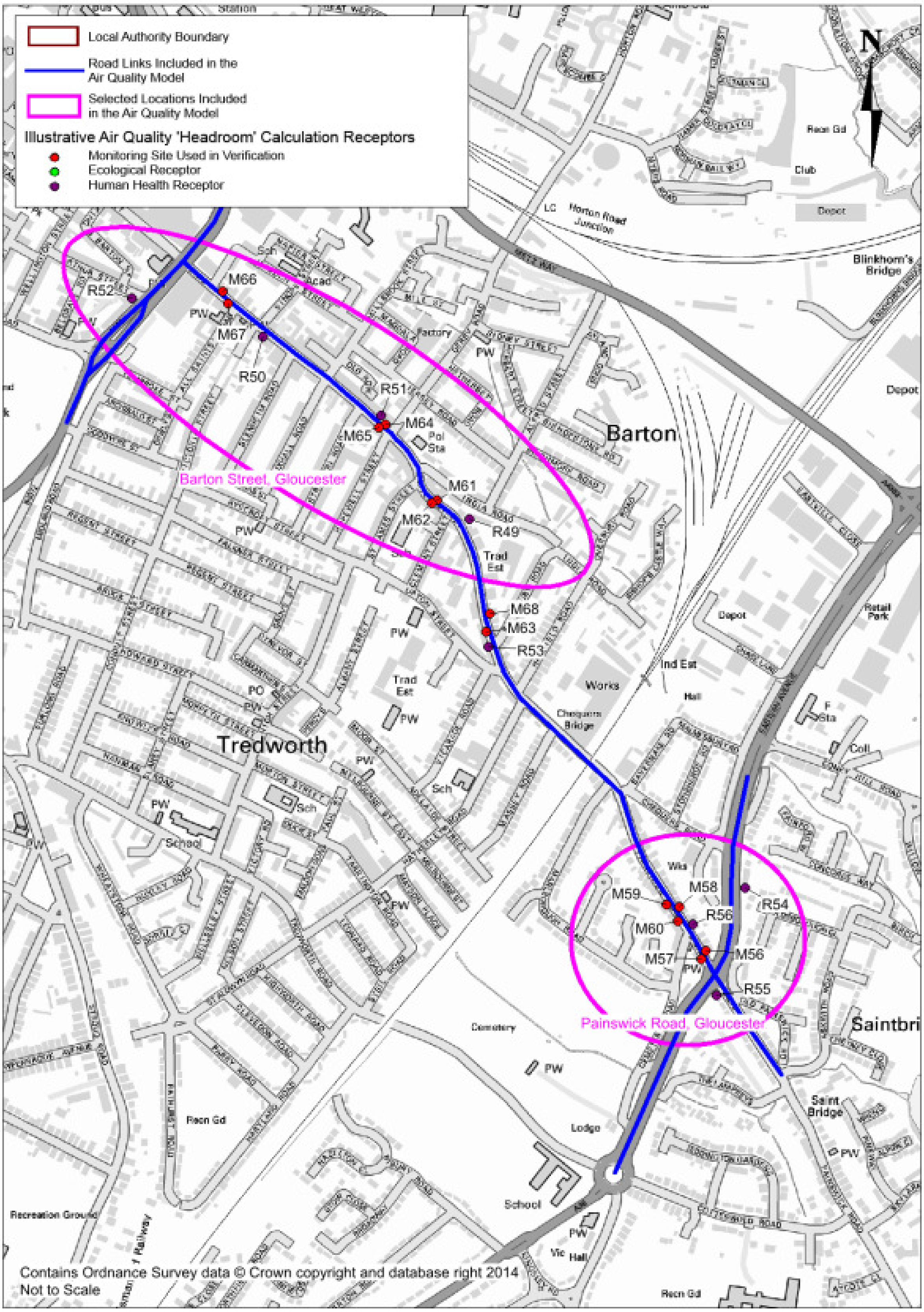


Figure A-11 Location of Receptors Modelled in the Air Quality Assessment – Gloucester Barton Street and Painswick Road



A.2. Receptors Used in the Air Quality Model

Table A-2 Receptors included in the Air Quality Model

ID	Description	Junction Location Abbreviation	OS Grid Reference
Human Receptors			
R1	Alderman Knight School, Tewkesbury	M5 J9	391356, 233122
R2	Tewkesbury Grant Maintained Comprehensive School, Tewkesbury	M5 J9	391179, 233127
R3	1 Furrowfield Park, Tewkesbury	M5 J9	391253, 233224
R4	17 Milne Pastures, Tewkesbury	M5 J9	391204, 233189
R5	Tirlebrook Primary School, Tewkesbury	M5 J9	390998, 233009
R6	The Abbey School, Tewkesbury	Tewkesbury town centre	389203, 232562
R7	Tewkesbury Community Hospital, Tewkesbury	Tewkesbury town centre	389479, 232477
R8	Tewkesbury Hospital, Tewkesbury	Tewkesbury town centre	389563, 232691
R9	1 Barton Terrace, Tewkesbury	Tewkesbury town centre	389583, 232752
R10	47 Barton Street, Tewkesbury	Tewkesbury town centre	389560, 232749
R11	49 Barton Street, Tewkesbury	Tewkesbury town centre	389571, 232716
R12	14 Church Street, Tewkesbury	Tewkesbury town centre	389232, 232615
R13	67 Barton Street, Tewkesbury	Tewkesbury town centre	389410, 232692
R14	8 Coppice Gate, Cheltenham	Kingsditch, Cheltenham	392626, 224357
R15	29 Frank Brookes Road, Cheltenham	Kingsditch, Cheltenham	393183, 223830
R16	69 Glynbridge Gardens, Cheltenham	Kingsditch, Cheltenham	393124, 224020
R17	Sorrel, Hayden Road, Cheltenham	Kingsditch, Cheltenham	392440, 224230
R18	10 Patterdale Close, Cheltenham	Kingsditch, Cheltenham	392922, 224158
R19	11 Yeend Close, Cheltenham	Kingsditch, Cheltenham	392708, 224333
R20	433-435 Churchill Court, Cheltenham	Poole Way, Cheltenham	394380, 222934
R21	445 High Street, Cheltenham	Poole Way, Cheltenham	394324, 222970
R22	1 Nailsworth Terrace, Cheltenham	Poole Way, Cheltenham	394502, 222986
R23	5 Burton Towers, Park Street	Poole Way, Cheltenham	394381, 222892
R24	3 Townsend Street, Cheltenham	Poole Way, Cheltenham	394261, 223037
R25	St. Johns Primary School, Cheltenham	College Road, Cheltenham	395363, 222239
R26	25 Bath Road, Cheltenham	College Road, Cheltenham	395080, 222119
R27	9 Berkeley Place, Cheltenham	College Road, Cheltenham	395349, 222077
R28	6 High Street, Cheltenham	College Road, Cheltenham	395315, 221993
R29	68 High Street, Cheltenham	College Road, Cheltenham	395169, 222167
R30	65 Tom Price Close, Cheltenham	College Road, Cheltenham	395351, 222336
R31	52 Cleevelands Drive, Cheltenham	Evesham Road, Cheltenham	395261, 224152
R32	50 Cleevelands Drive, Cheltenham	Evesham Road, Cheltenham	395247, 224162
R33	5 , Shurdington Road, off Bath Road, Cheltenham	Leckhampton Road, Cheltenham	394534, 220998
R34	12 Shurdington Road, Cheltenham	Leckhampton Road, Cheltenham	394428, 220866
R35	29 Shurdington Road, Cheltenham	Leckhampton Road, Cheltenham	394478, 220946
R36	2 Suffolk Road, Cheltenham	Leckhampton Road, Cheltenham	394721, 221429
R37	Cheltenham College, Cheltenham	Leckhampton Road, Cheltenham	394838, 221469

ID	Description	Junction Location Abbreviation	OS Grid Reference
R38	7 Miserden Road, Cheltenham	GCHQ, Cheltenham	391975, 222031
R39	16 Miserden Road, Cheltenham	GCHQ, Cheltenham	391855, 222015
R40	64 Monkscroft, Cheltenham	GCHQ, Cheltenham	392016, 222108
R41	Corine Court, Sotherby Drive, Cheltenham	GCHQ, Cheltenham	391924, 222167
R42	Aston Court Sotherby Drive, Cheltenham	GCHQ, Cheltenham	391881, 222108
R43	The Noake, Gloucester	M5 J11a	387797, 217879
R44	Noake Court Farm, Gloucester	M5 J11a	388130, 217938
R45	119 Sussex Grds, Gloucester	M5 J11a	388059, 217187
R46	73 Sussex Grds, Gloucester	M5 J11a	387931, 217392
R47	34 Mount Street, Gloucester	Priory Road, Gloucester	382876, 219020
R48	66 Priory Road, Gloucester	Priory Road, Gloucester	382948, 219035
R49	261 Barton Street, Gloucester	Barton Street, Gloucester	384147, 217698
R50	144 Barton Street, Gloucester	Barton Street, Gloucester	383787, 218015
R51	215 Barton Street, Gloucester	Barton Street, Gloucester	383993, 217879
R52	18 Trier Way, Gloucester	Barton Street, Gloucester	383559, 218083
R53	232 Barton Street, Gloucester	Barton Street, Gloucester	384180, 217475
R54	40 Eastern Avenue, Gloucester	Painswick Road, Gloucester	384627, 217056
R55	120 Painswick Road, Gloucester	Painswick Road, Gloucester	384576, 216868
R56	79 Painswick Road, Gloucester	Painswick Road, Gloucester	384536, 216992
Ecological Receptors			
SSSI_1	Severn Ham, Tewkesbury	Tewkesbury Town centre	389121, 232730
SSSI_2	Hucclecote Meadows, west of M5	M5 J11a	387210, 216390
SSSI_3	Hucclecote Meadows, east of M5	M5 J11a	387256, 216295
Monitoring Site Used For Verification			
M1	Tewke_1N	n/a	389314, 232807
M4	Tewke_5N	n/a	389356, 232705
M5	Tewke_6N	n/a	389294, 232806
M6	Tewke_35N	n/a	389283, 232769
M7	Tewke_37N	n/a	389254, 232670
M8	Tewke_38N	n/a	389331, 232950
M9	Tewke_41N	n/a	389462, 232721
M10	Tewke_45N	n/a	389500, 232700
M12	Chelt_5	n/a	395660, 221670
M13	Chelt_6	n/a	395672, 221680
M14	Chelt_7	n/a	395642, 221685
M15	Chelt_10	n/a	393880, 223390
M16	Chelt_11	n/a	393802, 222595
M18	Chelt_21	n/a	394235, 223055
M19	Chelt_22	n/a	394268, 222988
M20	Chelt_23	n/a	394305, 222960
M21	Chelt_24	n/a	394330, 222955
M22	Chelt_25	n/a	394350, 222923
M23	Chelt_26	n/a	394378, 222925
M24	Chelt_27	n/a	394738, 222888
M25	Chelt_28	n/a	394771, 222874

ID	Description	Junction Location Abbreviation	OS Grid Reference
M26	Chelt_29	n/a	394830, 222845
M28	Chelt_31	n/a	395040, 222715
M29	Chelt_32	n/a	395073, 222750
M30	Chelt_35	n/a	395210, 222618
M31	Chelt_36	n/a	395225, 222610
M32	Chelt_37	n/a	395340, 222075
M33	Chelt_38	n/a	395355, 222055
M34	Chelt_39	n/a	395240, 222112
M35	Chelt_40	n/a	395212, 222130
M36	Chelt_41	n/a	395202, 222160
M37	Chelt_42	n/a	395182, 222183
M38	Chelt_43	n/a	395176, 222169
M39	Chelt_44	n/a	395146, 222149
M40	Chelt_45	n/a	395097, 222124
M41	Chelt_48	n/a	394760, 222878
M42	Chelt_15	n/a	391997, 222051
M43	Chelt_16	n/a	391996, 222133
M44	Chelt_17	n/a	391532, 221923
M45	Chelt_9	n/a	397009, 223888
M46	Chelt_33	n/a	395110, 222670
M47	Chelt_34	n/a	395117, 222658
M48	Chelt_35	n/a	395210, 222618
M49	Chelt_2	n/a	394614, 221153
M51	Chelt_19	n/a	394640, 221460
M52	Tewke_12N	n/a	387591, 216975
M53	Tewke_14N	n/a	387915, 217389
M54	Glouc_9	n/a	387670, 217250
M56	Glouc_18	n/a	384558, 216946
M57	Glouc_19	n/a	384550, 216932
M58	Glouc_22	n/a	384512, 217023
M59	Glouc_23	n/a	384490, 217027
M60	Glouc_24	n/a	384509, 216998
M61	Glouc_10	n/a	384090, 217731
M62	Glouc_12	n/a	384081, 217725
M63	Glouc_13	n/a	384175, 217501
M64	Glouc_14	n/a	384000, 217863
M65	Glouc_15	n/a	383989, 217857
M66	Glouc_16	n/a	383717, 218094
M67	Glouc_17	n/a	383726, 218074
M68	Glouc_21	n/a	384182, 217533
M69	Glouc_5	n/a	382921, 219034
M70	Glouc_6	n/a	382898, 219029
M71	Glouc_7	n/a	382950, 219040

A.3. Background Concentrations Used in the Air Quality Model

Table A-3 Receptors Background Concentrations

ID	Junction Location Abbreviation	2012 Background Concentration (μg/m^3)	2030 Background Concentration (μg/m^3)
Human Receptors (NO_2 background concentration)			
R1	M5 J9	25.1	18.2
R2	M5 J9	25.1	18.2
R3	M5 J9	25.1	18.2
R4	M5 J9	25.1	18.2
R5	M5 J9	18.3	12.2
R6	Tewkesbury town centre	14.0	9.3
R7	Tewkesbury town centre	14.0	9.3
R8	Tewkesbury town centre	14.0	9.3
R9	Tewkesbury town centre	14.0	9.3
R10	Tewkesbury town centre	14.0	9.3
R11	Tewkesbury town centre	14.0	9.3
R12	Tewkesbury town centre	14.0	9.3
R13	Tewkesbury town centre	14.0	9.3
R14	Kingsditch, Cheltenham	16.9	11.4
R15	Kingsditch, Cheltenham	23.3	17.5
R16	Kingsditch, Cheltenham	21.2	15.8
R17	Kingsditch, Cheltenham	16.9	11.4
R18	Kingsditch, Cheltenham	16.9	11.4
R19	Kingsditch, Cheltenham	16.9	11.4
R20	Poole Way, Cheltenham	27.8	22.2
R21	Poole Way, Cheltenham	27.8	22.2
R22	Poole Way, Cheltenham	27.8	22.2
R23	Poole Way, Cheltenham	27.8	22.2
R24	Poole Way, Cheltenham	20.6	15.2
R25	College Road, Cheltenham	22.0	16.4
R26	College Road, Cheltenham	22.0	16.4
R27	College Road, Cheltenham	22.0	16.4
R28	College Road, Cheltenham	19.6	14.3
R29	College Road, Cheltenham	22.0	16.4
R30	College Road, Cheltenham	22.0	16.4
R31	Evesham Road, Cheltenham	14.7	10.1
R32	Evesham Road, Cheltenham	14.7	10.1
R33	Leckhampton Road, Cheltenham	16.5	11.6
R34	Leckhampton Road, Cheltenham	16.5	11.6
R35	Leckhampton Road, Cheltenham	16.5	11.6
R36	Leckhampton Road, Cheltenham	21.7	16.0
R37	Leckhampton Road, Cheltenham	21.7	16.0
R38	GCHQ, Cheltenham	15.8	10.2
R39	GCHQ, Cheltenham	15.8	10.2
R40	GCHQ, Cheltenham	18.2	12.3
R41	GCHQ, Cheltenham	15.8	10.2
R42	GCHQ, Cheltenham	15.8	10.2
R43	M5 J11a	17.5	11.5

R44	M5 J11a	17.3	10.5
R45	M5 J11a	17.3	10.5
R46	M5 J11a	17.5	11.5
R47	Priory Road, Gloucester	15.9	10.4
R48	Priory Road, Gloucester	15.9	10.4
R49	Barton Street, Gloucester	20.9	15.1
R50	Barton Street, Gloucester	20.3	15.2
R51	Barton Street, Gloucester	19.0	13.4
R52	Barton Street, Gloucester	20.3	15.2
R53	Barton Street, Gloucester	20.9	15.1
R54	Painswick Road, Gloucester	20.9	15.1
R55	Painswick Road, Gloucester	17.2	11.8
R56	Painswick Road, Gloucester	17.2	11.8
Ecological Receptors (NOx background concentration)			
SSSI_1	Tewkesbury Town centre	19.4	12.4
SSSI_2	M5 J11a	21.5	17.2
SSSI_3	M5 J11a	21.5	17.2
Monitoring Site Used For Verification (NO_2 background concentration)			
M1	n/a	14.0	-
M4	n/a	14.0	-
M5	n/a	14.0	-
M6	n/a	14.0	-
M7	n/a	14.0	-
M8	n/a	14.0	-
M9	n/a	14.0	-
M10	n/a	14.0	-
M12	n/a	19.6	-
M13	n/a	19.6	-
M14	n/a	19.6	-
M15	n/a	23.3	-
M16	n/a	21.8	-
M18	n/a	20.6	-
M19	n/a	27.8	-
M20	n/a	27.8	-
M21	n/a	27.8	-
M22	n/a	27.8	-
M23	n/a	27.8	-
M24	n/a	27.8	-
M25	n/a	27.8	-
M26	n/a	27.8	-
M28	n/a	22.0	-
M29	n/a	22.0	-
M30	n/a	22.0	-
M31	n/a	22.0	-
M32	n/a	22.0	-
M33	n/a	22.0	-
M34	n/a	22.0	-
M35	n/a	22.0	-
M36	n/a	22.0	-
M37	n/a	22.0	-

M38	n/a	22.0	-
M39	n/a	22.0	-
M40	n/a	22.0	-
M41	n/a	27.8	-
M42	n/a	15.8	-
M43	n/a	15.8	-
M44	n/a	18.3	-
M45	n/a	14.4	-
M46	n/a	22.0	-
M47	n/a	22.0	-
M48	n/a	22.0	-
M49	n/a	21.7	-
M51	n/a	21.7	-
M52	n/a	15.2	-
M53	n/a	17.5	-
M54	n/a	17.5	-
M56	n/a	17.2	-
M57	n/a	17.2	-
M58	n/a	20.9	-
M59	n/a	20.9	-
M60	n/a	17.2	-
M61	n/a	20.9	-
M62	n/a	20.9	-
M63	n/a	20.9	-
M64	n/a	19.0	-
M65	n/a	19.0	-
M66	n/a	20.3	-
M67	n/a	20.3	-
M68	n/a	20.9	-
M69	n/a	15.9	-
M70	n/a	15.9	-
M71	n/a	15.9	-

A.4. Air Quality Model Verification

Comparison of modelled and measured annual mean NO_2 concentrations for 2012 is presented in Table A-4.

Table A-4 Comparison of Monitored and Modelled Annual Mean NO_2 (µg/m^3)

Site Name	Model Area	Monitored Annual Mean Total NO_2 (µg/m^3)	Modelled Annual Mean Total NO_2 (µg/m^3)	% Difference (unadjusted modelled NO_2 - monitored NO_2) / monitored NO_2 * 100
M1	Tewkesbury urban area	32.2	17.1	-47%
M4		29.0	16.8	-42%
M5		35.2	16.2	-54%
M6		40.8	16.7	-59%
M7		30.4	15.9	-48%

Site Name	Model Area	Monitored Annual Mean Total NO_2 ($\mu g/m^3$)	Modelled Annual Mean Total NO_2 ($\mu g/m^3$)	% Difference (unadjusted modelled NO_2 - monitored NO_2) / monitored NO_2 * 100
M8		30.9	16.4	-47%
M9		41.0	18.6	-55%
M10		29.8	15.9	-47%
M12	Cheltenham urban area	42.5	23.0	-46%
M13		39.0	25.9	-34%
M14		39.4	22.3	-43%
M15		31.0	27.7	-11%
M16		30.5	24.9	-19%
M18		35.9	24.9	-31%
M19		44.3	31.2	-29%
M20		45.1	31.0	-31%
M21		39.1	31.8	-19%
M22		49.8	30.3	-39%
M23		30.4	31.3	+3%
M24		43.3	30.2	-30%
M25		41.3	30.2	-27%
M26		40.3	29.6	-26%
M28		35.2	25.6	-27%
M29		33.0	23.5	-29%
M30		37.7	25.5	-32%
M31		42.0	24.9	-41%
M32		31.3	26.8	-14%
M33		40.3	24.9	-38%
M34		30.8	26.3	-15%
M35		33.1	24.7	-25%
M36		40.5	25.7	-36%
M37		38.0	25.5	-33%
M38		37.9	25.4	-33%
M39		42.0	25.6	-39%
M40		35.0	24.7	-30%
M41		34.7	31.1	-10%
M42		27.7	19.5	-30%
M43		28.7	20.8	-28%
M44		35.4	23.2	-34%
M45		35.5	17.7	-50%
M46		37.7	26.1	-31%
M47		33.5	26.1	-22%
M48		37.7	25.5	-32%

Site Name	Model Area	Monitored Annual Mean Total NO_2 ($\mu g/m^3$)	Modelled Annual Mean Total NO_2 ($\mu g/m^3$)	% Difference (unadjusted modelled NO_2 - monitored NO_2) / monitored NO_2 * 100
M49		30.8	24.4	-21%
M51		31.6	24.5	-22%
M52	M5 J11a	27.8	31.2	+12%
M53		25.9	29.0	+12%
M54		30.5	28.7	-6%
M56	Gloucester urban area	30.3	23.9	-21%
M57		40.1	22.0	-45%
M58		29.0	25.6	-12%
M59		32.9	24.0	-27%
M60		36.7	20.5	-44%
M61		33.2	25.6	-23%
M62		36.0	23.7	-34%
M63		39.9	23.3	-42%
M64		40.8	23.2	-43%
M65		43.1	21.7	-50%
M66		40.8	23.8	-42%
M67		48.0	22.8	-53%
M68		28.7	24.6	-14%
M69		47.4	21.8	-54%
M70		45.9	21.9	-52%
M71		52.5	21.4	-59%

Table A-5 presents the determination of the model adjustment. Adjustment factors greater than four were required in urban areas. This is not unexpected given that a simple modelling approach was applied for the strategic assessment which did not include modelling of street canyons, congested speeds or queuing at junctions in urban areas. A comparison of adjusted modelled annual mean NO_2 concentrations with measured annual mean NO_2 concentrations for 2012 is presented in Table A-6.

Table A-5 Comparison and Adjustment of Monitored and Modelled Roads NOx ($\mu g/m^3$)

Site Name	Monitored Annual Mean Roads NOx ($\mu g/m^3$)	Modelled Annual Mean Roads NOx ($\mu g/m^3$)	Modelled Roads NOx / Monitored Roads NOx	Adjustment Factor [i]	Adjusted Modelled Annual Mean Roads NOx ($\mu g/m^3$)
M1	38.3	5.9	6.5	7.83	46.1
M4	31.0	5.4	5.7		42.4
M5	45.5	4.3	10.6		33.4
M6	59.6	5.1	11.7		39.8
M7	34.1	3.7	9.2		29.0
M8	35.3	4.5	7.8		35.3
M9	60.2	8.9	6.8		69.3
M10	32.8	3.6	9.2		27.8

Site Name	Monitored Annual Mean Roads NOx ($\mu g/m^3$)	Modelled Annual Mean Roads NOx ($\mu g/m^3$)	Modelled Roads NOx / Monitored Roads NOx	Adjustment Factor [i]	Adjusted Modelled Annual Mean Roads NOx ($\mu g/m^3$)
M12	51.7	6.9	7.5	4.14	28.4
M13	42.8	12.9	3.3		53.2
M14	43.8	5.4	8.1		22.3
M15	16.0	9.0	1.8		37.4
M16	18.2	6.2	2.9		25.7
M18	33.0	8.5	3.9		35.3
M19	37.6	7.3	5.2		30.1
M20	39.6	6.6	6.0		27.3
M21	24.9	8.5	2.9		35.2
M22	52.0	5.3	9.8		22.0
M23	5.5	7.5	0.7		30.9
M24	35.1	5.0	7.0		20.7
M25	30.1	5.0	6.1		20.6
M26	27.7	3.9	7.2		16.0
M28	28.3	7.4	3.8		30.4
M29	23.3	2.9	8.1		11.9
M30	34.2	7.0	4.9		28.9
M31	44.9	5.9	7.6		24.4
M32	19.5	9.8	2.0		40.5
M33	40.6	5.9	6.9		24.3
M34	18.4	8.7	2.1		36.2
M35	23.5	5.5	4.3		22.6
M36	41.1	7.5	5.4		31.2
M37	34.9	7.1	4.9		29.4
M38	34.7	6.8	5.1		28.1
M39	44.9	7.3	6.1		30.3
M40	27.8	5.4	5.2		22.1
M41	14.8	7.0	2.1		28.9
M42	24.4	7.2	3.4		29.8
M43	26.6	9.8	2.7		40.5
M44	36.9	10.0	3.7		41.3
M45	45.5	6.3	7.2		26.1
M46	34.2	8.3	4.1		34.5
M47	24.4	8.3	2.9		34.3
M48	34.2	7.0	4.9		28.9
M49	18.9	5.4	3.5		22.5
M51	20.7	5.5	3.7		23.0
M52	25.9	33.5	0.8	No adjustment applied	33.5
M53	17.0	23.8	0.7		23.8
M54	27.2	23.2	1.2		23.2

Site Name	Monitored Annual Mean Roads NOx ($\mu g/m^3$)	Modelled Annual Mean Roads NOx ($\mu g/m^3$)	Modelled Roads NOx / Monitored Roads NOx	Adjustment Factor [i]	Adjusted Modelled Annual Mean Roads NOx ($\mu g/m^3$)
M56	27.3	13.6	2.0	5.22	70.7
M57	50.9	9.6	5.3		50.1
M58	16.7	9.5	1.8		49.6
M59	25.3	6.2	4.1		32.2
M60	42.4	6.6	6.5		34.2
M61	26.0	9.4	2.8		48.8
M62	32.5	5.5	5.9		28.6
M63	42.0	4.7	8.9		24.6
M64	48.6	8.4	5.8		43.8
M65	54.5	5.4	10.1		28.2
M66	59.9	7.0	8.5		36.6
M67	79.9	5.0	16.1		26.0
M68	30.4	7.3	4.2		38.0
M69	78.2	11.7	6.7		61.1
M70	60.8	11.9	5.1		62.1
M71	79.7	10.9	7.3		56.6
Notes					
[i] Adjustment factor has been derived using Excel LINEST (linear regression) function. The factor represents the slope ('A') of a straight fitted line y = Ax + B, where B = 0 [i] Adjustment factor has been derived using Excel LINEST (linear regression) function. The factor represents the slope ('A') of a straight fitted line y = Ax + B, where B = 0					

Table A-6 Comparison of Monitored and Adjusted Modelled Annual Mean NO_2 ($\mu g/m^3$)

Site Name	Model Area	Monitored Annual Mean Total NO_2 ($\mu g/m^3$)	Modelled Annual Mean Total NO_2 ($\mu g/m^3$)	% Difference (unadjusted modelled NO_2 - monitored NO_2) / monitored NO_2 * 100
M1	Tewkesbury urban area	32.2	35.5	+10%
M4		29.0	33.9	+17%
M5		35.2	30.1	-14%
M6		40.8	32.8	-20%
M7		30.4	28.1	-7%
M8		30.9	30.9	0%
M9		41.0	44.4	+8%
M10		29.8	27.6	-7%
M12	Cheltenham urban area	42.5	33.0	-22%
M13		39.0	43.1	+10%
M14		39.4	30.3	-23%
M15		31.0	40.2	+30%

Site Name	Model Area	Monitored Annual Mean Total NO_2 ($\mu g/m^3$)	Modelled Annual Mean Total NO_2 ($\mu g/m^3$)	% Difference (unadjusted modelled NO_2 - monitored NO_2) / monitored NO_2 * 100
M16		30.5	33.8	+11%
M18		35.9	36.9	+3%
M19		44.3	41.3	-7%
M20		45.1	40.1	-11%
M21		39.1	43.4	+11%
M22		49.8	37.9	-24%
M23		30.4	41.6	+37%
M24		43.3	37.3	-14%
M25		41.3	37.3	-10%
M26		40.3	35.2	-13%
M28		35.2	36.1	+3%
M29		33.0	27.8	-16%
M30		37.7	35.5	-6%
M31		42.0	33.5	-20%
M32		31.3	40.3	+29%
M33		40.3	33.4	-17%
M34		30.8	38.5	+25%
M35		33.1	32.7	-1%
M36		40.5	36.4	-10%
M37		38.0	35.7	-6%
M38		37.9	35.1	-7%
M39		42.0	36.1	-14%
M40		35.0	32.5	-7%
M41		34.7	40.8	+18%
M42		27.7	30.1	+9%
M43		28.7	34.7	+21%
M44		35.4	37.2	+5%
M45		35.5	27.2	-23%
M46		37.7	37.8	+0%
M47		33.5	37.7	+13%
M48		37.7	35.5	-6%
M49		30.8	32.4	+5%
M51		31.6	32.6	+3%
M52	M5 J11a	27.8	31.2	12%
M53		25.9	29.0	+12%
M54		30.5	28.7	-6%
M56	Gloucester urban area	30.3	47.4	+57%
M57		40.1	39.8	-1%

Site Name	Model Area	Monitored Annual Mean Total NO_2 ($\mu g/m^3$)	Modelled Annual Mean Total NO_2 ($\mu g/m^3$)	% Difference (unadjusted modelled NO_2 - monitored NO_2) / monitored NO_2 * 100
M58		29.0	42.9	+48%
M59		32.9	35.9	+9%
M60		36.7	33.3	-9%
M61		33.2	42.6	+28%
M62		36.0	34.3	-5%
M63		39.9	32.6	-18%
M64		40.8	38.9	-5%
M65		43.1	32.4	-25%
M66		40.8	31.4	-23%
M67		48.0	26.7	-44%
M68		28.7	32.0	+12%
M69		47.4	41.3	-13%
M70		45.9	46.4	+1%
M71		52.5	44.4	-16%

Appendix B. Baseline Air Quality Monitoring Data

Table B-1 Continuous Monitoring Results (μg/m^3)

Site Description	Grid Ref	Site Type	Local Authority	2008	2009	2010	2011	2012
Barton Street	383700, 218000	Urban Background	Gloucester	Closed	Closed	46	44	Not available
St Georges Street	394760, 228878	Roadside	Cheltenham	Closed	Closed	Closed	35*	37
*Annualised by Cheltenham Borough Council								

Table B-2 Local Authority Annual Mean Nitrogen Dioxide Diffusion Tube Monitoring Results (μg/m^3) (Bias Adjusted)

Site ID	Site Description	Grid Ref	Site Type	Local Authority	2008	2009	2010	2011	2012
M1	Tewke_1N	389314, 232807	Roadside	Tewkesbury	36.3	35.8	34.4	33.0	32.2
M2	Tewke_2N	389399, 232788	Roadside	Tewkesbury	26.5	27.0	24.5	23.5	24.3
M3	Tewke_3N	389611, 232660	Urban Background	Tewkesbury	15.8	15.6	16.9	14.0	13.6
M4	Tewke_5N	389356, 232705	Roadside	Tewkesbury	33.5	31.8	33.2	29.3	29.0
M5	Tewke_6N	389294, 232806	Roadside	Tewkesbury	40.0	37.4	35.3	36.2	35.2
M6	Tewke_35N	389283, 232769	Roadside	Tewkesbury	45.2	43.7	40.5	35.7	40.8
M7	Tewke_37N	389254, 232670	Roadside	Tewkesbury	34.2	30.3	30.9	28.9	30.4
M8	Tewke_38N	389331, 232950	Roadside	Tewkesbury	36.8	31.4	32.4	31.8	30.9
M9	Tewke_41N	389462, 232721	Roadside	Tewkesbury	closed	45.4	41.7	41.4	41.0
M10	Tewke_45N	389500, 232700	Roadside	Tewkesbury	closed	closed	35.1	26.7	29.8
M11	Tewke_47N	389400, 232600	Roadside	Tewkesbury	closed	closed	39.0	30.5	32.2
M12	Chelt_5	395660, 221670	Roadside	Cheltenham	closed	closed	45.5	42.5	42.5
M13	Chelt_6	395672, 221680	Roadside	Cheltenham	closed	closed	closed	39.3	39.0

Site ID	Site Description	Grid Ref	Site Type	Local Authority	2008	2009	2010	2011	2012
M14	Chelt_7	395642, 221685	Roadside	Cheltenham	closed	closed	closed	closed	39.4
M15	Chelt_10	393880, 223390	Roadside	Cheltenham	closed	closed	31.9	27.6	31.0
M16	Chelt_11	393802, 222595	Roadside	Cheltenham	31.2	29.8	34.0	29.6	30.5
M17	Chelt_20	394695, 222733	Kerbside	Cheltenham	31.6	30.4	32.8	31.5	31.6
M18	Chelt_21	394235, 223055	Roadside	Cheltenham	closed	closed	closed	33.7	35.9
M19	Chelt_22	394268, 222988	Roadside	Cheltenham	closed	closed	closed	32.5	44.3
M20	Chelt_23	394305, 222960	Roadside	Cheltenham	closed	closed	closed	43.5	45.1
M21	Chelt_24	394330, 222955	Roadside	Cheltenham	closed	closed	41.4	34.8	39.1
M22	Chelt_25	394350, 222923	Roadside	Cheltenham	closed	closed	closed	46.7	49.8
M23	Chelt_26	394378, 222925	Roadside	Cheltenham	closed	closed	closed	28.3	30.4
M24	Chelt_27	394738, 222888	Roadside	Cheltenham	closed	closed	closed	44.0	43.3
M25	Chelt_28	394771, 222874	Roadside	Cheltenham	closed	closed	closed	40.2	41.3
M26	Chelt_29	394830, 222845	Kerbside	Cheltenham	closed	closed	45.7	40.0	40.3
M27	Chelt_30	394975, 222855	Urbancentre	Cheltenham	closed	closed	closed	closed	27.8
M28	Chelt_31	395040, 222715	Roadside	Cheltenham	closed	closed	closed	35.6	35.2
M29	Chelt_32	395073, 222750	Roadside	Cheltenham	closed	closed	closed	closed	33.0
M30	Chelt_35	395210, 222618	Roadside	Cheltenham	closed	closed	39.6	37.1	37.7
M31	Chelt_36	395225, 222610	Roadside	Cheltenham	closed	closed	closed	41.8	42.0
M32	Chelt_37	395340, 222075	Roadside	Cheltenham	closed	closed	38.2	29.6	31.3
M33	Chelt_38	395355, 222055	Roadside	Cheltenham	closed	closed	47.9	38.9	40.3
M34	Chelt_39	395240, 222112	Roadside	Cheltenham	closed	32.4	35.8	31.0	30.8
M35	Chelt_40	395212, 222130	Roadside	Cheltenham	closed	34.6	36.2	32.8	33.1
M36	Chelt_41	395202, 222160	Roadside	Cheltenham	closed	38.6	42.0	37.3	40.5
M37	Chelt_42	395182, 222183	Roadside	Cheltenham	closed	40.3	45.1	37.0	38.0
M38	Chelt_43	395176, 222169	Roadside	Cheltenham	closed	45.6	47.3	39.9	37.9

Site ID	Site Description	Grid Ref	Site Type	Local Authority	2008	2009	2010	2011	2012
M39	Chelt_44	395146, 222149	Roadside	Cheltenham	44.0	43.5	46.3	43.1	42.0
M40	Chelt_45	395097, 222124	Roadside	Cheltenham	closed	34.8	39.8	34.2	35.0
M41	Chelt_48	394760, 222878	Roadside	Cheltenham	closed	closed	closed	closed	34.7
M42	Chelt_15	391997, 222051	Roadside	Cheltenham	31.4	28.5	32.7	28.2	27.7
M43	Chelt_16	391996, 222133	Roadside	Cheltenham	30.0	29.3	30.4	28.3	28.7
M44	Chelt_17	391532, 221923	Kerbside	Cheltenham	closed	closed	36.5	33.9	35.4
M45	Chelt_9	397009, 223888	Roadside	Cheltenham	34.4	35.0	37.0	35.7	35.5
M46	Chelt_33	395110, 222670	Roadside	Cheltenham	closed	closed	41.8	38.2	37.7
M47	Chelt_34	395117, 222658	Kerbside	Cheltenham	closed	closed	closed	32.3	33.5
M48	Chelt_35	395210, 222618	Roadside	Cheltenham	closed	closed	39.6	37.1	37.7
M49	Chelt_2	394614, 221153	Roadside	Cheltenham	32.7	32.2	34.7	33.2	30.8
M50	Chelt_3	394494, 220823	Background	Cheltenham	closed	closed	closed	closed	18.8
M51	Chelt_19	394640, 221460	Roadside	Cheltenham	closed	closed	40.1	31.0	31.6
M52	Tewke_12N	387591, 216975	Urban	Tewkesbury	29.5	29.2	26.2	24.9	27.8
M53	Tewke_14N	387915, 217389	Urban	Tewkesbury	29.2	29.4	27.1	25.4	25.9
M54	Glouc_9	387670, 217250	Background	Gloucester	33.7	31.4	29.9	29.0	30.5
M55	Glouc_11	387250, 216530	Background	Gloucester	closed	closed	closed	22.6	26.8
M56	Glouc_18	384558, 216946	Roadside	Gloucester	36.6	34.8	32.2	29.6	30.3
M57	Glouc_19	384550, 216932	Roadside	Gloucester	49.9	43.7	41.0	40.9	40.1
M58	Glouc_22	384512, 217023	Roadside	Gloucester	33.3	30.8	31.5	26.8	29.0
M59	Glouc_23	384490, 217027	Roadside	Gloucester	38.6	37.2	33.7	32.4	32.9
M60	Glouc_24	384509, 216998	Roadside	Gloucester	44.3	39.8	37.6	36.9	36.7
M61	Glouc_10	384090, 217731	Roadside	Gloucester	33.2	32.6	33.9	27.6	33.2
M62	Glouc_12	384081, 217725	Roadside	Gloucester	42.4	40.8	37.2	32.1	36.0
M63	Glouc_13	384175, 217501	Roadside	Gloucester	44.2	40.9	41.1	36.6	39.9

Site ID	Site Description	Grid Ref	Site Type	Local Authority	2008	2009	2010	2011	2012
M64	Glouc_14	384000, 217863	Roadside	Gloucester	42.5	37.4	43.3	35.2	40.8
M65	Glouc_15	383989, 217857	Roadside	Gloucester	44.6	37.5	40.7	39.9	43.1
M66	Glouc_16	383717, 218094	Roadside	Gloucester	42.2	39.1	41.3	37.2	40.8
M67	Glouc_17	383726, 218074	Roadside	Gloucester	52.6	51.6	48.2	46.2	48.0
M68	Glouc_21	384182, 217533	Roadside	Gloucester	28.3	29.7	27.1	24.1	28.7
M69	Glouc_5	382921, 219034	Roadside	Gloucester	53.2	55.0	48.6	45.4	47.4
M70	Glouc_6	382898, 219029	Roadside	Gloucester	48.7	47.7	43.2	43.0	45.9
M71	Glouc_7	382950, 219040	Roadside	Gloucester	57.8	56.0	55.8	49.1	52.5

Appendix C. Illustrative Air Quality 'Headroom' Calculation Results

Table C-1 Adjusted Modelled NO_2 Concentrations at Human Health Receptors (µg/m^3)

Receptor ID	2021 Base	2031 DM1	2031 DS1	Change	Magnitude of Impact
R1	**45.5**	24.2	24.0	-0.2	Imperceptible
R2	**41.1**	22.8	22.6	-0.2	Imperceptible
R3	**42.4**	23.2	23.0	-0.2	Imperceptible
R4	**54.1**	27.1	26.5	-0.6	Small
R5	26.2	14.4	14.3	-0.1	Imperceptible
R6	20.1	11.0	11.1	+0.1	Imperceptible
R7	16.6	10.1	10.1	0.0	Imperceptible
R8	23.4	12.1	12.0	-0.1	Imperceptible
R9	**41.6**	17.8	17.7	-0.1	Imperceptible
R10	38.7	17.2	17.2	0.0	Imperceptible
R11	31.1	14.4	14.4	0.0	Imperceptible
R12	27.1	13.0	13.3	+0.3	Imperceptible
R13	33.8	15.6	15.6	0.0	Imperceptible
R14	26.4	15.7	16.3	+0.6	Small
R15	33.7	21.9	22.2	+0.3	Imperceptible
R16	32.6	19.6	20.2	+0.6	Small
R17	22.1	13.4	13.7	+0.3	Imperceptible
R18	29.0	15.5	16.3	+0.8	Small
R19	30.4	16.2	17.0	+0.8	Small
R20	**40.7**	25.3	25.5	+0.2	Imperceptible
R21	**42.9**	25.9	26.0	+0.1	Imperceptible
R22	35.6	24.5	24.7	+0.2	Imperceptible
R23	35.6	24.2	24.3	+0.1	Imperceptible
R24	39.0	21.7	22.5	+0.8	Small
R25	30.5	19.0	19.3	+0.3	Imperceptible
R26	30.6	19.2	19.3	+0.1	Imperceptible
R27	**42.9**	23.6	24.0	+0.4	Imperceptible
R28	31.1	18.4	18.7	+0.3	Imperceptible
R29	**42.5**	23.3	23.5	+0.2	Imperceptible
R30	33.4	20.1	20.4	+0.3	Imperceptible
R31	22.8	13.0	13.3	+0.3	Imperceptible
R32	23.6	13.5	13.8	+0.3	Imperceptible
R33	24.6	14.6	14.8	+0.2	Imperceptible
R34	23.3	14.3	14.4	+0.1	Imperceptible
R35	26.0	15.4	15.6	+0.2	Imperceptible
R36	32.6	19.6	19.5	-0.1	Imperceptible

Receptor ID	2021 Base	2031 DM1	2031 DS1	Change	Magnitude of Impact
R37	29.2	18.5	18.6	+0.1	Imperceptible
R38	25.2	12.8	12.9	+0.1	Imperceptible
R39	30.2	13.9	14.1	+0.2	Imperceptible
R40	36.6	17.7	17.9	+0.2	Imperceptible
R41	26.8	13.2	13.3	+0.1	Imperceptible
R42	32.4	14.5	14.8	+0.3	Imperceptible
R43	20.8	12.9	13.0	+0.1	Imperceptible
R44	22.3	12.7	12.9	+0.2	Imperceptible
R45	19.8	11.4	11.4	0.0	Imperceptible
R46	27.5	14.8	14.8	0.0	Imperceptible
R47	39.4	20.0	19.8	-0.2	Imperceptible
R48	37.6	19.1	18.9	-0.2	Imperceptible
R49	31.8	16.9	17.0	+0.1	Imperceptible
R50	28.6	18.1	18.0	-0.1	Imperceptible
R51	33.7	18.2	18.2	0.0	Imperceptible
R52	32.4	20.9	20.7	-0.2	Imperceptible
R53	31.4	16.9	17.0	+0.1	Imperceptible
R54	**44.4**	23.6	23.7	+0.1	Imperceptible
R55	**41.3**	18.9	19.0	+0.1	Imperceptible
R56	39.3	18.6	18.8	+0.2	Imperceptible

Table C-2 Adjusted Modelled NOx Concentrations at Ecological Receptors (µg/m^3)

Receptor	Base 2012	DM 2031	DS 2031	Change
SSSI_1	20.1	12.6	12.6	0.0
SSSI_2	42.3	23.7	23.6	-0.1
SSSI_3	48.3	25.8	25.6	-0.2