Derry City Council

Air Quality Review and Assessment:
Stage 3 Report

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Detailed Air Quality Modelling of Domestic Fuel Use and Road Traffic Emissions in Derry

Prepared for

Derry City Council

26th August 2004

CERC

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Table 8.10, Figs 8.18 to 8.31	Bunc05.upl, Creg05.upl, Dales05.upl, Dung05.upl, Glen05.upl, Penn05.upl, Stran05.upl
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Contents

1. Summary

Derry City Council (the council) has highlighted areas of possible exceedence of the Air Quality Strategy (AQS) objectives for:

- NO_2, due to road traffic emissions at seven junctions; and
- SO_2 and PM_{10}, due to domestic fuel use emissions at sixteen urban and ten rural locations.

CERC was commissioned by the council to undertake air quality modelling for these areas using the ADMS-Urban model (version 2.0).

The council provided all activity data for the study, including traffic flows, speeds and road characteristics for the traffic modelling, and domestic fuel use survey data for the domestic fuel use emissions modelling. Other sources of emissions of the modelled pollutants in the surrounding area were considered by modelling them as a set of 1km square grid sources. Gridded emissions data from the National Atmospheric Emissions Inventory (NAEI) were used to represent these emissions.

The modelling was carried out using hourly sequential meteorological data from Aldergrove, with wind data from Ballykelly, for the period April 2002 to March 2003.

Road traffic modelling

Traffic count data for each of the modelled roads were used to calculate emissions of nitrogen dioxide (NO_2). Concentrations of NO_2 have been calculated for comparison with the Air Quality Strategy (AQS) objectives.

There is a small area of predicted exceedence of the 2005 AQS objective for annual average NO_2 concentrations at the Creggan Road / Infirmary Road junction. The maximum predicted annual average concentration of NO_2 is 42.5µg/m^3, equivalent to 106% of the 2005 AQS objective. This area of exceedence is very small, and occurs only on the junction itself. However, the results of the model verification suggest that the model may be significantly underpredicting the concentrations at Creggan Road, and therefore this area of exceedence may cover a larger area.

There are no other predicted exceedences of either of the 2005 AQS objectives for NO_2 at the modelled junctions.

Domestic fuel use modelling

A domestic fuel use survey was carried out by Derry City Council to obtain information concerning the quantity and type of fuel used for domestic heating in representative areas. These data were used to calculate emissions of particulates (PM_{10}) and sulphur dioxide (SO_2) in each area. Concentrations of SO_2 and PM_{10} have been calculated for comparison with the Air Quality Strategy (AQS) objectives.

Model verification was carried out for the year April 2002 to March 2003. To ensure that predicted concentrations of PM_{10} and SO_2 were not being underestimated at any location, worst case adjustment factors were calculated based on the comparison between modelled and monitored concentrations at the Brandywell monitoring site. The adjustment was applied to the predicted concentrations across the whole of Derry. Applying this adjustment is likely to give a gross overestimate of the predicted concentrations at many sites.

There are no predicted exceedences of the 2004 annual average AQS objective for PM_{10} at any of the urban or rural locations.

The 90.41st percentile of daily average concentrations of PM_{10} is predicted to be exceeded in three of the modelled areas: Bogside (site b); Ballymagroarty; and Claudy. Concentrations across the whole of Derry were adjusted using factors derived from the Brandywell monitoring site, located in the Bogside area, so the exceedence in Bogside is supported by local monitoring data. The area of exceedence in Ballymagroarty is small, and the values only exceed by a small amount, so given the high adjustment factor used it is likely that this is not a cause for concern. At the rural location of Claudy, the high adjustment factor used across Derry is likely to lead to a gross overestimate of the impact, so it is unlikely that this predicted exceedence is a real one, however the modelled results do indicate that emissions in the Claudy area may be of more concern than in the other rural areas.

The provisional 2010 AQS annual average and 98.08th percentile of daily average concentrations of PM_{10} are predicted to be exceeded over an area covering most of the urban Derry area and in the rural area of Claudy.

There are two areas of predicted exceedence of the 2005 AQS objective for 15-minute average concentrations of SO_2 in the urban Derry area. There is a large area of predicted exceedence to the northeast of Derry, covering the Strathfoyle area, and a small area of predicted exceedence of on the edge of Shantallow. The maximum predicted 99.9th percentile of 15-minute average concentrations within the Strathfoyle area is 446μg/m^3, 168% of the AQS objective of 266μg/m^3. This area of predicted exceedence is due primarily to the estimated emissions from the two point sources in the area. This predicted area of exceedence is unlikely to represent a true exceedence because:

1. the emissions data represent an overestimate of current emissions, and
2. the predicted concentrations have been adjusted using a worst case adjustment factor based on the comparison between modelled and monitored concentrations at the Brandywell site.

2. Introduction

Derry City Council (the council) has highlighted areas of possible exceedence of the Air Quality Strategy (AQS) objectives for:

- NO_2, due to road traffic emissions at seven junctions; and
- SO_2 and PM_{10}, due to domestic fuel use emissions at sixteen urban and ten rural locations.

CERC was commissioned by the council to undertake air quality modelling for these areas using the ADMS-Urban model (version 2.0).

Details of the study areas are given in Section 3, and information concerning the meteorological data used is presented in Section 4. Section 5 presents the relevant limits and objectives. Section 6 gives details of the background concentrations assumed for the area, and details of the local monitoring data are presented in Section 7. Details of the traffic emissions modelling are presented in Section 8, and details of the urban and rural domestic fuel use emissions modelling are presented in Section 9. A discussion of the implications of the modelling is given in Section 10. Finally, a description of the ADMS model used in the study is included in Appendix A.

3. The Study Area

Certain parameters are used in air quality modelling to represent the physical characteristics of the area under consideration. A length scale parameter called the surface roughness length is used to characterise the study area in terms of the effects it will have on wind speed and turbulence, which are key factors in the modelling. For the road traffic emissions modelling, the study areas are predominantly urban and suburban, and so a surface roughness of 0.75m was used in the study to represent these regions: the same value has also been used for the urban locations considered in the domestic fuel use emissions modelling. A surface roughness of 0.5m was used to represent the rural areas considered in the domestic fuel use emissions modelling.

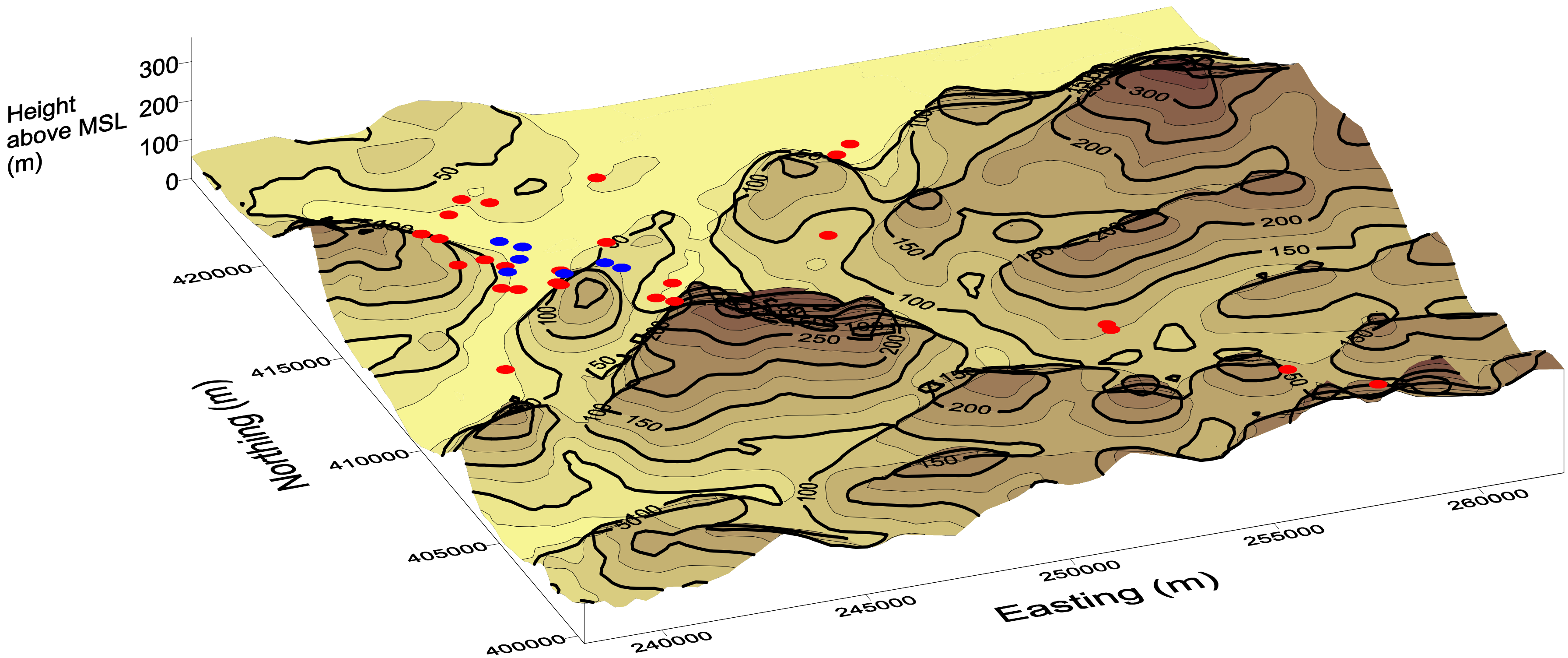
In urban areas, the significant amount of heat emitted by buildings and traffic warms the air within and above a city or large town. This is known as the urban heat island and its effect is to prevent the atmosphere from becoming very stable. In general, the larger the area the more heat is generated and the stronger the effect becomes. In the ADMS-Urban model, the stability of the atmosphere is represented by the Monin-Obukhov parameter, which has the dimension of length. The effect of the urban heat island is that, in stable conditions the Monin-Obukhov length will never fall below some minimum value; the larger the city, the larger the minimum value. A value of 30m, appropriate for large towns, has been used as the minimum Monin-Obukhov length for the modelling of urban and suburban areas in this study. No minimum Monin-Obukhov length has been specified in the modelling of rural areas.

3.1 Terrain data

The modelled areas are situated approximately 5km from the northern coast of Northern Ireland. The River Foyle runs through the centre of Derry, flanked by low hills on both sides. The hills to the south of the modelled area rise to a height of over 200m above sea level. The effect of local terrain on dispersion may be significant and hence has been included in the modelling.

Figure 3.1 shows a diagram of the local terrain. All heights are above Mean Sea Level (MSL).

Figure 3.1: Terrain map for Derry



Note that the height scale is exaggerated by a factor of 10

Location of domestic source

Location of modelled junction

4. Meteorological Data

For this study, meteorological data were obtained from Aldergrove for the period April 2002 to March 2003. Data covering this time period were used to allow modelled output to be compared with monitoring data collected over this time. The Aldergrove meteorological site is situated approximately 75 kilometres south east of the modelled area. Wind data are more subject to local variations, and so wind data from Ballykelly, situated approximately 10km north east of the modelled area, has been used, which will give a good representation of the wind conditions at the modelled areas.

92.8% of the total number of hours for the year was used in the analysis.

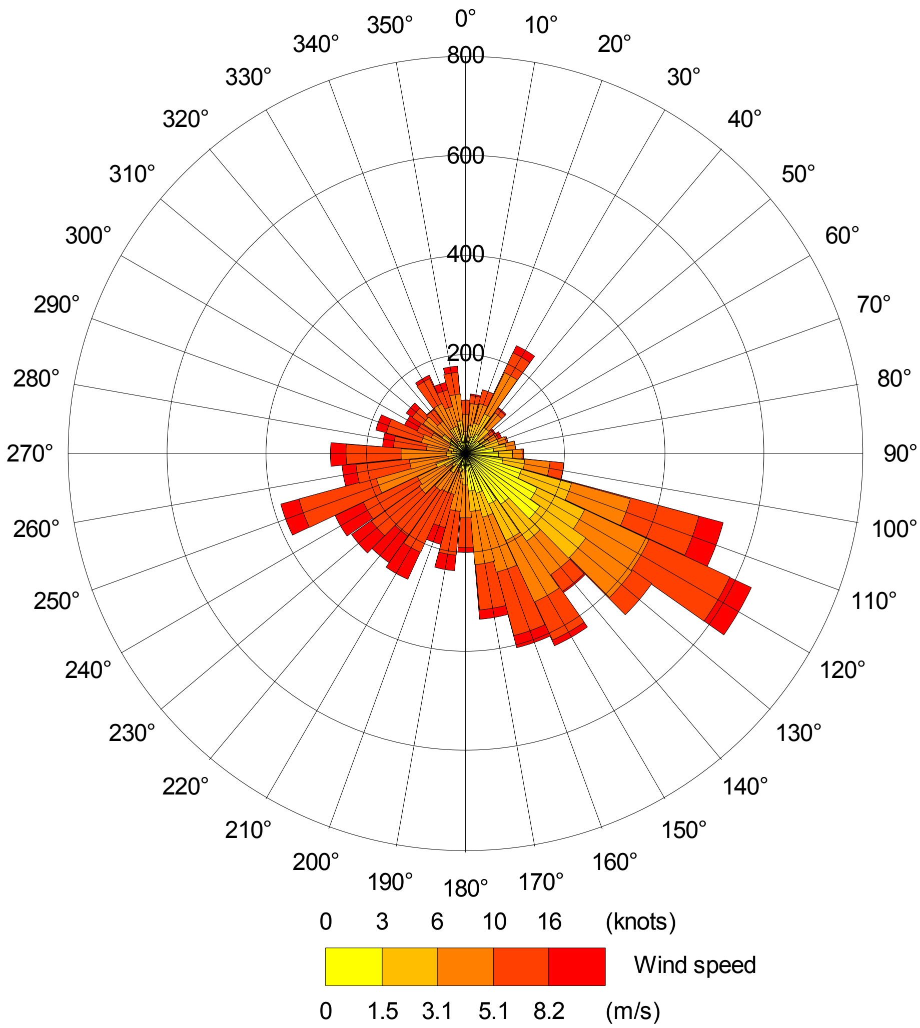
A summary of the meteorological data is given below in Table 4.1.

Table 4.1. Summary of meteorological data

	Minimum	Maximum	Mean
Temperature (°C)	-5.8	23.7	9.5
Wind speed (m/s)	0	15.5	4.3
Cloud cover (oktas)	0	8	5

The ADMS meteorological pre-processor, written by the Meteorological Office, uses these data to calculate the parameters required by the program. Figure 4.1 shows a wind rose of the site giving the frequency of occurrence of wind from different directions for a number of wind speed ranges.

Figure 4.1: Wind rose for Ballykelly, April 2002 to March 2003



5. Air Quality Standards

The Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland, Working Together for Clean Air, January 2000 defines air quality objective values for NO_2, PM_{10} and SO_2 to be achieved by 2004 or 2005, depending on the pollutant considered. These objectives are the subject of Statutory Rule 2003 No. 342, *Air Quality Regulations (Northern Ireland) 2003*, which came into force on 1st September 2003. Provisional AQS objective values for PM_{10} for 2010 also exist although these are not yet included in Regulations for the purposes of local air quality management.

The relevant AQS objectives are presented in Table 5.1.

Table 5.1 Air quality standards

	Value ($\mu g/m^3$)	Source	Description of standard	Date to be achieved
NO_2	200	AQS	Maximum hourly average (not to be exceeded more than 18 times per year, assumed equivalent to a 99.78th percentile)	2005
	40	AQS	Annual average	2005
PM_{10}	50	AQS	24 hour average (not to be exceeded more than 35 times per year, assumed equivalent to a 90.14th percentile)	2004
	40	AQS	Annual average	2004
	50	AQS (provisional)	24 hour average (not to be exceeded more than 7 times per year, assumed equivalent to a 98.08th percentile)	2010
	20	AQS (provisional)	Annual average	2010
SO_2	350	AQS	1 hour average (not to be exceeded more than 24 times a year, assumed equivalent to a 99.73rd percentile)	2004
	125	AQS	24 hour average (not to be exceeded more than 3 times per year, assumed equivalent to a 99.18th percentile)	2004
	266	AQS	15 minute average (not to be exceeded more than 35 times per year, assumed equivalent to a 99.9th percentile)	2005

Some of the standards considered are specified in terms of the number of times during a year that a concentration measured over a short period of time is permitted to exceed a specified value. For example, the concentration of NO_2 measured as the average value recorded over a one-hour period is permitted to exceed the concentration of 200μg/m^3 up to 18 times per year. Any more exceedences than this during a one-year period would represent a breach of the objective.

It is convenient to model objectives of this form in terms of the equivalent percentile concentration value. A percentile is the concentration below which lie a specified percentage of concentration measurements. For example, consider the 98th percentile of one-hour concentrations over a year. Taking all of the 8760 one-hour concentration values that occur in a year, the 98th percentile value is the concentration below which 98% of those concentrations lie. Or, in other words, it is the concentration exceeded by 2% (100 – 98) of those hours, that is, 175 hours per year. Taking the NO_2 objective considered above, allowing 18 exceedences per year is equivalent to not exceeding for 8742 hours or for 99.79% of the year. This is therefore equivalent to the 99.79th percentile value.

6. Background Data

The air entering Derry from outside the city contains a concentration of each pollutant being modelled. In this study, these background concentrations were estimated using measured data from rural monitoring sites.

For the inclusion of NO_x chemistry, as well as to account for background concentrations of NO_x and NO_2, hourly average monitored concentrations of NO_x, NO_2 and O_3 were input into the model. These data were downloaded from the National Air Quality Information Archive[1] from the rural monitoring site at Narberth, in south west Wales, between April 2002 and March 2003.

Hourly average background concentrations of SO_2 for this period were taken from the rural Ladybower site in the north of England. A study of the rural background sites in the UK showed that the annual average background in rural locations is approximately 2ppb. The Ladybower site has an annual average background of 2.2ppb, and so was chosen to represent a conservative estimate of the background concentrations. This site, although rural, is close to the cities of Sheffield and Manchester, and so the SO_2 concentrations at Ladybower may represent an overestimate of rural SO_2 concentrations. ADMS-Urban allows the contribution of SO_2 concentrations to the formation of secondary particulates to be taken into account.

Hourly average background concentrations of PM_{10} from Lough Navar between April 2002 and March 2003 were downloaded from the National Air Quality Information Archive. Lough Navar is located approximately 70km south west of Derry.

Some statistics calculated from the background data are shown in Table 6.1, to give an indication of the typical concentrations.

Table 6.1: Background concentration data for April 2002 to March 2003($\mu g/m^3$)

	NO_x	NO_2	O_3	PM_{10}	SO_2
Annual average	9.1	7.6	60.2	15.3	5.8
98^{th} percentile	33.7	28.7	100.0	41.6	29.3
Maximum hourly average	78.5	43.5	132.0	156.0	162.3

Rural concentrations of NO_x, NO_2, PM_{10} and SO_2 are predicted to decrease in future years compared to current levels. This was taken into account in the modelling. Hourly NO_x, PM_{10} and SO_2 concentrations for future years were estimated from the 2002 values according to the DEFRA guidance LAQM.TG(03)[2].

Hourly NO_2 concentrations were derived from the relationship between NO_x and NO_2 concentrations at the monitoring site, and O_3 concentrations were increased by the difference between the 2002 and future NO_2 concentrations.

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[1] http:\/\/www.airquality.co.uk/archive/data_and_statistics.php

[2] Local Air Quality Management Technical Guidance LAQM.TG(03), Part IV of the Environment Act 1995, DEFRA and devolved administrations, 2003

7. Local monitoring data

Derry City Council operates several pollutant monitoring sites in the areas covered by the modelling. The following monitoring data, recorded between April 2002 and March 2003, are available:

- Hourly concentrations of PM_{10} and NO_2 and 15-minute concentrations of SO_2 recorded at an urban background AURN (Automatic Urban and Rural Network) site in central Derry, operated on behalf of the Department for Environment, Food & Rural Affairs (DEFRA);
- Hourly concentrations of PM_{10} and 15-minute concentrations of SO_2 recorded at a continuous monitor at Brandywell;
- Monthly average concentrations of SO_2 recorded at 12 sites using SO_2 diffusion tubes; and
- Monthly average concentrations of NO_2 recorded at 8 sites using NO_2 diffusion tubes.

Receptor points located at the site of each monitor were included in the modelling so that the predicted concentrations from the modelling could be directly compared with the monitored concentrations.

The locations of the receptor points are shown in Figure 7.1, and details of each site are given in Table 7.1 overleaf.

A comparison of the monitored and predicted concentrations for April 2002 to March 2003 was carried out to verify the model. The results of the verification are presented in Sections 8.2 and 9.2, for the road traffic emissions modelling and the domestic fuel use emissions modelling, respectively.

7.1 Bias adjustment of NO_2 diffusion tube data

At the AURN site three NO_2 diffusion tubes have been co-located with the continuous monitor, to enable a comparison to be made between the two data sets. The annual average concentrations recorded over the time period April 2002 to March 2003 are presented in Table 7.2.

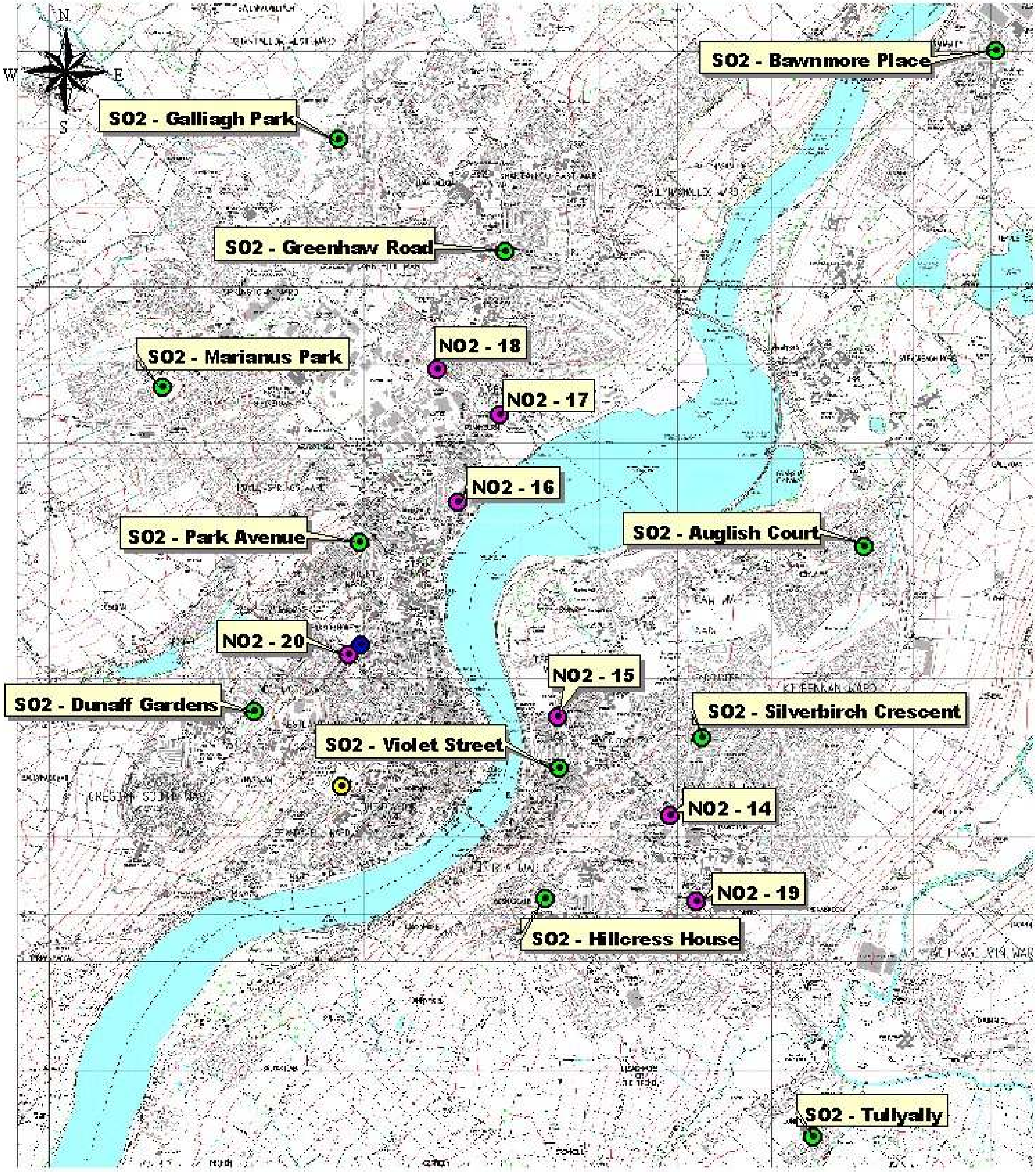
Table 7.2: Concentrations of NO_2 recorded at the AURN site (ppb)

Monitor type	**Annual average (April 2002 to March 2003)**
Continuous	8.3
Diffusion tube 1	8.6
Diffusion tube 2	8.5
Diffusion tube 3	9.0
Diffusion tube average	8.7

These data can be used to calculate a bias adjustment factor, A, for this time period:

$$A = Cm/Dm = 8.3/8.7 = 0.954$$

where Cm is the concentration recorded by the continuous monitor and Dm is the concentration recorded by the diffusion tubes. The concentrations of NO_2 recorded at each of the 8 diffusion tubes have been multiplied by this factor to account for the diffusion tube bias.



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- SO2 diffusion tube
- NO2 diffusion tube
- AURN site continuous monitor (PM10, NO2 and SO2)
- Brandywell continuous monitor (SO2 and PM10) and SO2 diffusion tube

0 1 2 3 Kilometers

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Monitoring sites

Figure 7.1

Table 7.1: Details of the monitoring sites

Name	Type	Pollutants	Averaging period	Location		
				X	Y	Height of inlet
AURN site	Continuous	PM_{10}, NO_2	1 hour	242991	417211	2.5
		SO_2	15 minutes			
Brandywell	Continuous	PM_{10}	1 hour	242866	416309	3
		SO_2	15 minutes			
Greenhaw Rd	Diffusion tube	SO_2	1 month	243908	419717	2.5
Silverbirch Crescent	Diffusion tube	SO_2	1 month	245166	416615	2.5
Tullyally	Diffusion tube	SO_2	1 month	245865	414078	2.5
Dunaff Gardens	Diffusion tube	SO_2	1 month	242313	416783	2.5
Auglish Court	Diffusion tube	SO_2	1 month	246193	417838	2.5
Bawnmore Place	Diffusion tube	SO_2	1 month	247031	420997	2.5
Hillcress House	Diffusion tube	SO_2	1 month	244163	415597	2.5
Violet Street	Diffusion tube	SO_2	1 month	244252	416419	2.5
Park Avenue	Diffusion tube	SO_2	1 month	242981	417859	2.5
Marianus Park	Diffusion tube	SO_2	1 month	241731	418849	2.5
Galliagh Park	Diffusion tube	SO_2	1 month	242852	420433	2.5
Brandywell	Diffusion tube	SO_2	1 month	242866	416309	3
Site 14: 26 Rossdowney Park	Diffusion tube	NO_2	1 month	244955	416127	2.5
Site 15: 5 Glendermot Road	Diffusion tube	NO_2	1 month	244242	416752	3
Site 16: 139c Strand Road	Diffusion tube	NO_2	1 month	243604	418118	3
Site 17: 3 Farren Park	Diffusion tube	NO_2	1 month	243877	418675	2
Site 18: 19 St Patrick's Terrace	Diffusion tube	NO_2	1 month	243480	418968	2.5
Site 19: 7 Haberton Park	Diffusion tube	NO_2	1 month	245131	415574	2.5
Site 20: 3 Creggan Road	Diffusion tube	NO_2	1 month	242907	417150	3
AURN site diffusion tube	Diffusion tube	NO_2	1 month	242991	417211	3.5

8. Modelling of road traffic emissions

8.1 Emissions data

All maps are orientated with north pointing up the page.

Seven road junctions were considered in this study:

1. Buncrana Road / Racecourse Road;
2. Pennyburn roundabout (Culmore Road / Buncrana Road);
3. Strand Road at Rockmills and Coppin House student accommodation;
4. Dales Corner;
5. Woodburn Park / Dungiven Road at the Irish Street lights;
6. Glenshane Road at Altnagelvin Hospital; and
7. Creggan Road / Infirmary Road.

The locations of these seven junctions are shown in Figure 8.1.

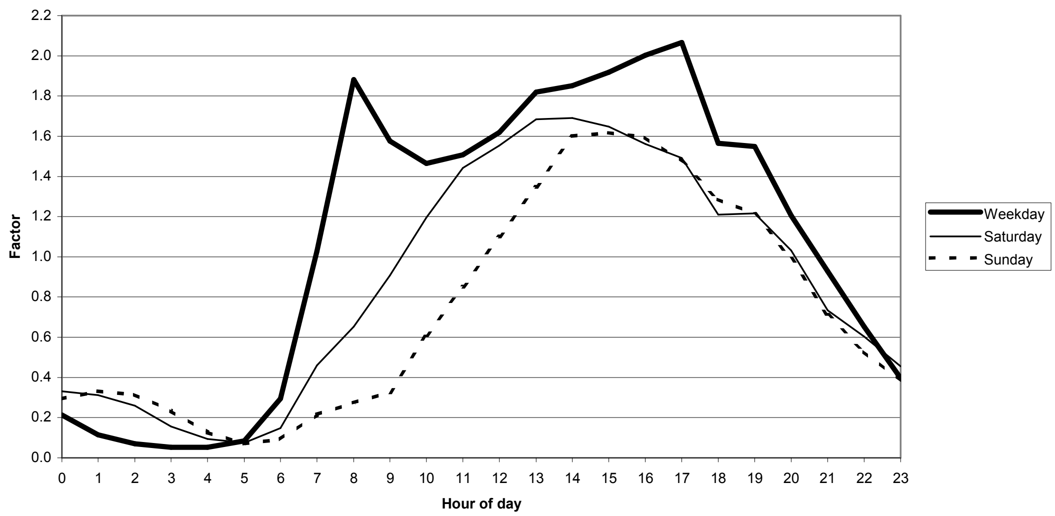
Traffic engineers from the local office of the Department of Regional Development (NI) provided traffic count data and speeds for each of the seven junctions. Peak hour turning count data, broken down into light and heavy vehicles, were provided for the year 2002. These data were converted to Annual Average Daily Totals (AADTs) using factors provided by the traffic engineers, as presented in Table 8.1. The traffic data were scaled to be appropriate to the modelled year using a growth factor of 2.6% per year, as advised by the traffic engineers.

Table 8.1: Factors used to convert peak hour flows to AADTs

	Junction	Factor	Estimated or calculated
1	Buncrana Road / Racecourse Road	16.67	calculated
2	Pennyburn roundabout (Culmore Road / Buncrana Road)	16.13	calculated
3	Strand Road at Rockmills and Coppin House student accommodation	16.67	estimated
4	Dales Corner	16.00	calculated
5	Woodburn Park / Dungiven Road at the Irish Street lights	16.00	estimated
6	Glenshane Road at Altnagelvin Hospital	12.99	calculated
7	Creggan Road / Infirmary Road	15.15	estimated

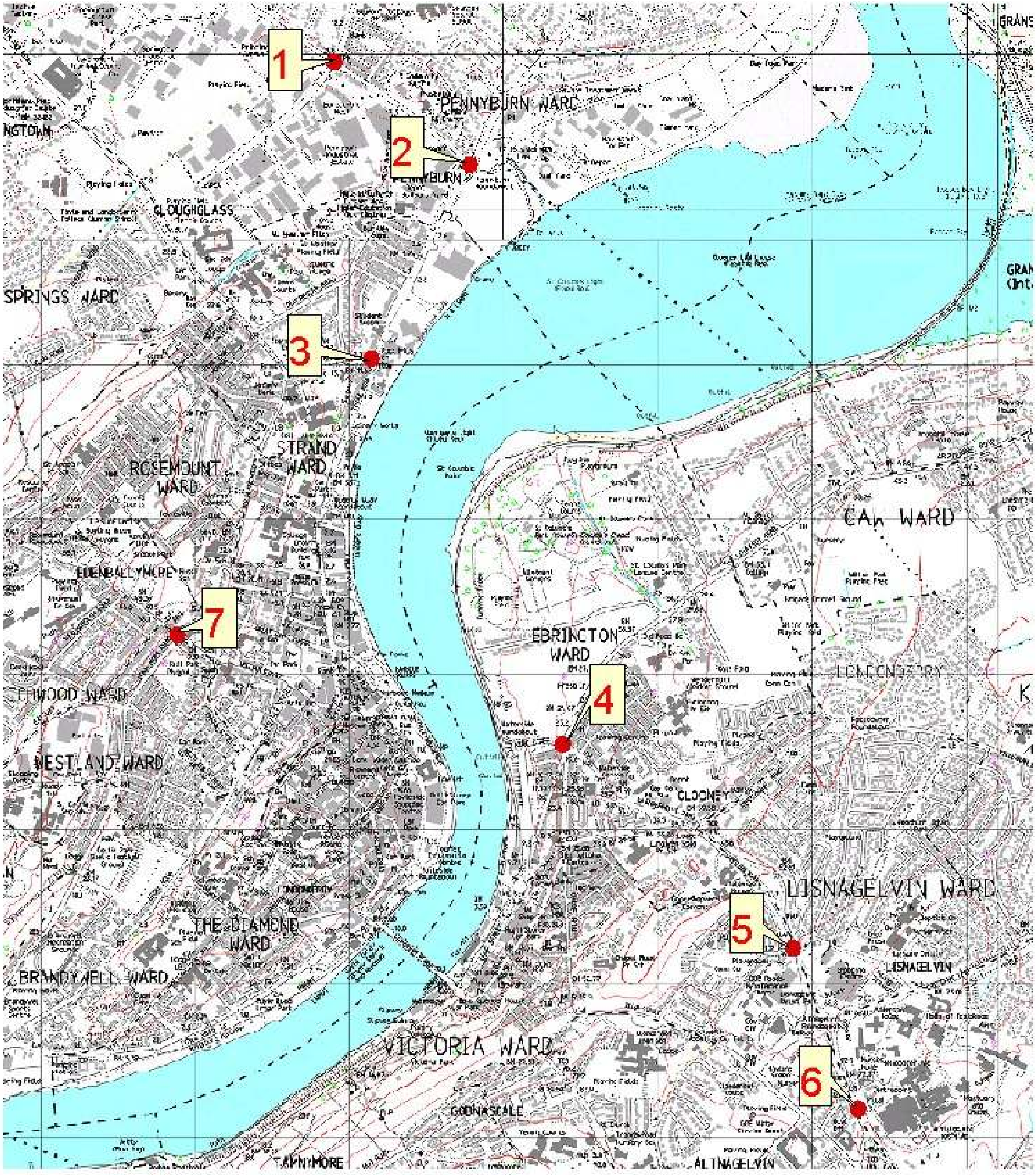
The width of each road was measured from a 1:10,000 scale map and canyon heights, where applicable, were estimated from photographs of each junction. The traffic engineers provided automatic 24-hour traffic count data from which diurnal profiles for a weekday, Saturday and Sunday were derived and applied to the modelled traffic emissions. These profiles are shown in Figure 8.3. The data for Buncrana Road was used to derive the profiles, as this gave the highest peaks.

Figure 8.2: Diurnal profiles for road traffic



The traffic engineers also provided diurnal patterns of queuing traffic at each junction, which are shown in the individual sections for each junction. Additional road sources were included to represent the increased emissions due to this queuing traffic.

Emissions from sources other than road traffic, and from road traffic outside the modelled areas, were represented by a set of 1km square grid sources with a depth of 10m. Gridded emissions data from the Data Warehouse section of the NAEI were used to represent these sources; the road traffic component of these data was scaled to be appropriate to the modelled year using a growth factor of 2.6% per year, as for the AADTs above. Note that this was also done for the emissions used in the domestic heating emissions modelling.



● Junction location

0 0.5 1 1.5 Kilometers

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Road junction locations
Figure 8.1

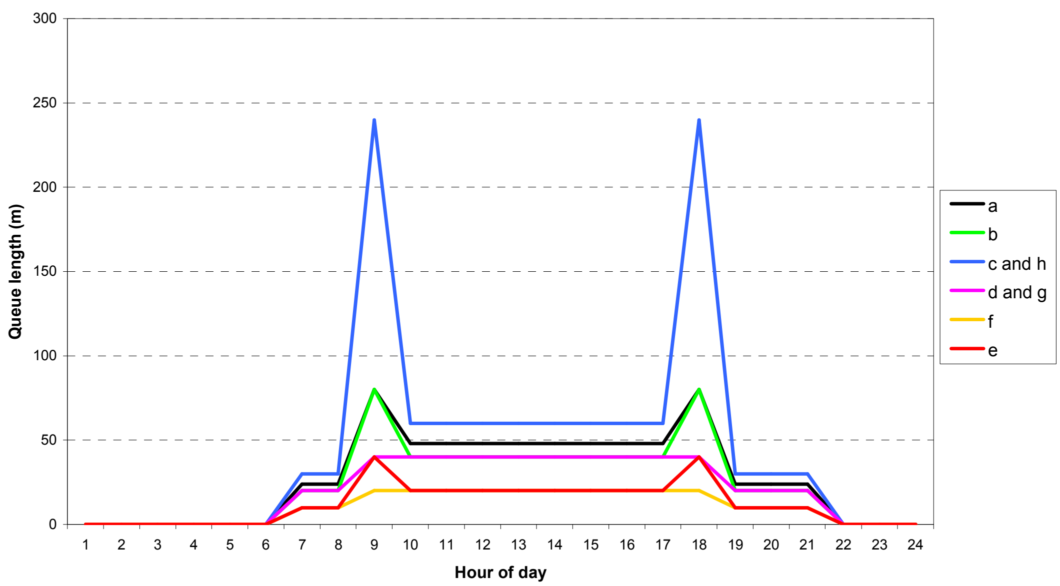
8.1.1 Buncrana Road / Racecourse Road

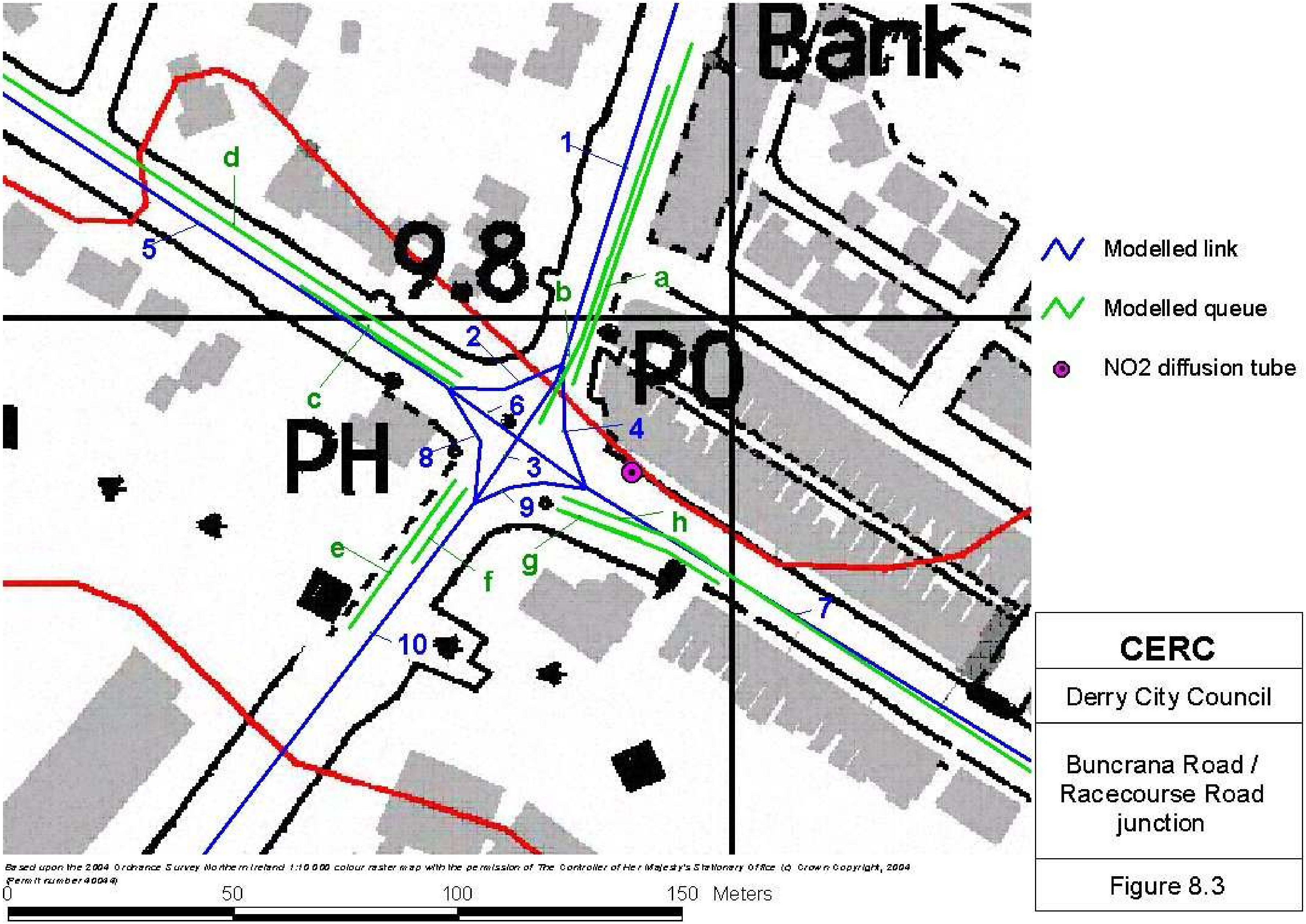
Figure 8.3 shows the modelled road links at the Buncrana Road / Racecourse Road junction. Table 8.2 presents the traffic data used in the modelling, and Figure 8.4 shows the diurnal profile applied to the length of each of the queues, which are labelled (a) to (h).

Table 8.2: Traffic data for Buncrana Road / Racecourse Road junction

	Road width (m)	Speed (km/h)	Street canyon height (m)	2002		2005	
				Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Link 1	12.9	20	0	10408	1286	11241	1389
Link 2	12.7	20	0	3384	390	3655	421
Link 3	12.9	20	0	2048	291	2212	314
Link 4	15.6	20	0	5044	537	5448	580
Link 5	13.4	20	0	11767	1250	12709	1350
Link 6	13.4	20	0	5993	588	6473	635
Link 7	17.3	20	0	14405	1338	15558	1445
Link 8	11.8	20	0	2343	318	2531	343
Link 9	17.0	20	0	3216	365	3473	394
Link 10	13.6	20	0	7328	1253	7915	1353

Figure 8.4: Diurnal profile of queues for Buncrana Road / Racecourse Road





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Buncrana Road / Racecourse Road junction

Figure 8.3

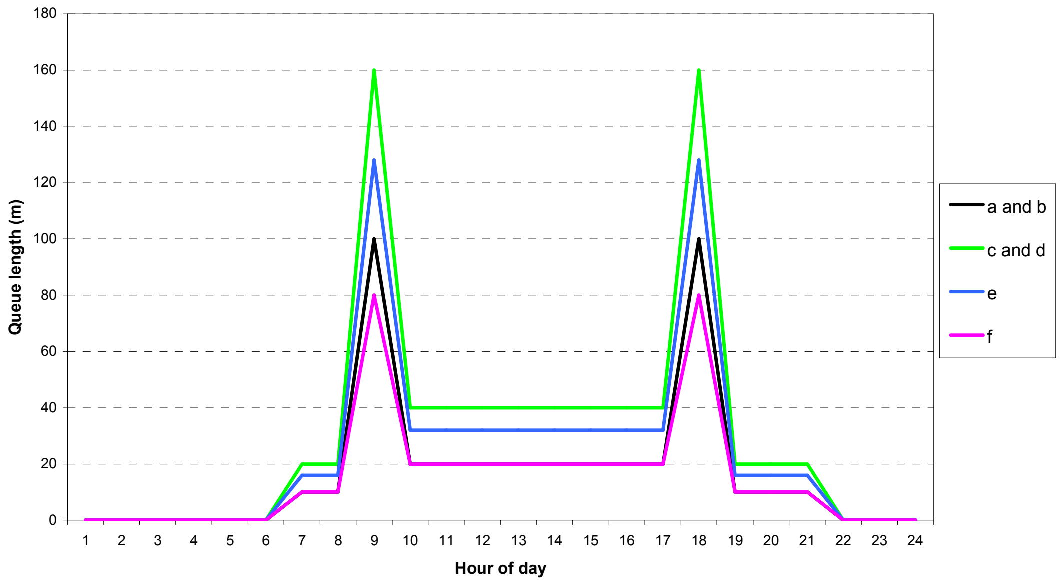
8.1.2 Pennyburn roundabout

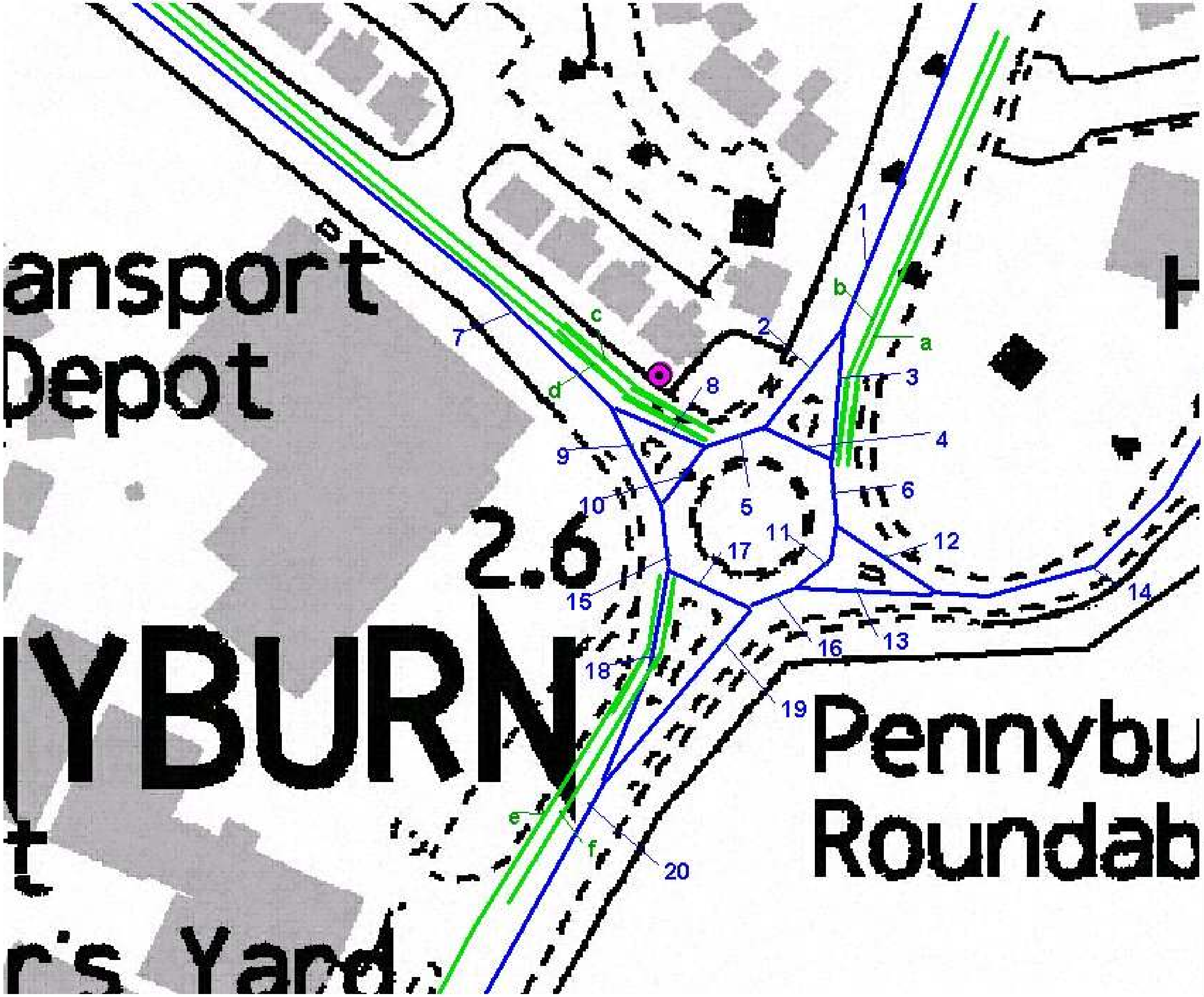
Figure 8.5 shows the modelled road links at Pennyburn roundabout. Table 8.3 displays the traffic data used in the modelling. Figure 8.6 shows the diurnal profile applied to the length of each of the queues, which are labelled (a) to (f).

Table 8.3: Traffic data for Pennyburn roundabout

	Road width (m)	Speed (km/h)	Street canyon height (m)	2002		2005	
				Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Link 1	20.0	20	0	26858	1714	29008	1851
Link 2	7.2	20	0	8540	545	9224	589
Link 3	6.8	20	0	18318	1169	19784	1263
Link 4	8.0	20	0	5828	690	6295	745
Link 5	8.2	20	0	14192	1411	15328	1524
Link 6	10.6	20	0	24145	1860	26078	2009
Link 7	16.8	20	0	14139	1748	15271	1888
Link 8	5.6	20	0	6439	796	6954	860
Link 9	5.9	20	0	7700	952	8316	1028
Link 10	9.1	20	0	7753	615	8375	664
Link 11	12.1	20	0	23099	1773	24948	1915
Link 12	6.7	20	0	907	227	980	245
Link 13	6.7	20	0	827	207	893	224
Link 14	6.7	20	0	1734	433	1873	468
Link 15	10.9	20	0	15778	1242	17041	1341
Link 16	10.2	20	0	23592	1980	25480	2138
Link 17	10.2	20	0	3438	313	3713	338
Link 18	7.2	20	0	12340	929	13328	1003
Link 19	6.8	20	0	20603	1551	22252	1675
Link 20	15.6	20	0	22944	2480	24781	2679

Figure 8.6: Diurnal profile of queues for Pennyburn roundabout





0 50 100 150 Meters

CERC
Derry City Council
Pennyburn roundabout
Figure 8.5

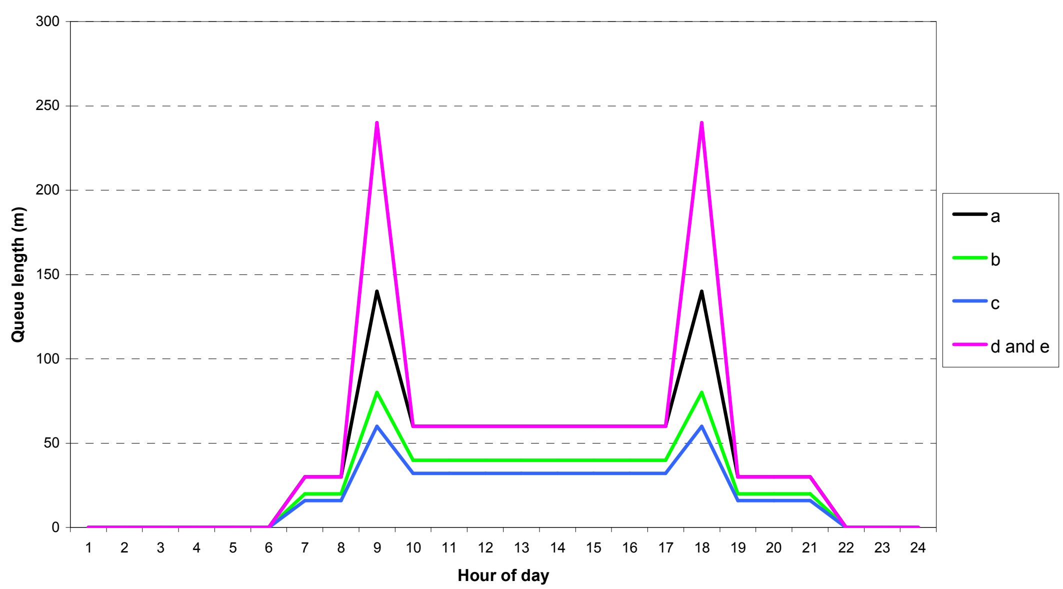
8.1.3 Strand Road at Rockmills and Coppin House

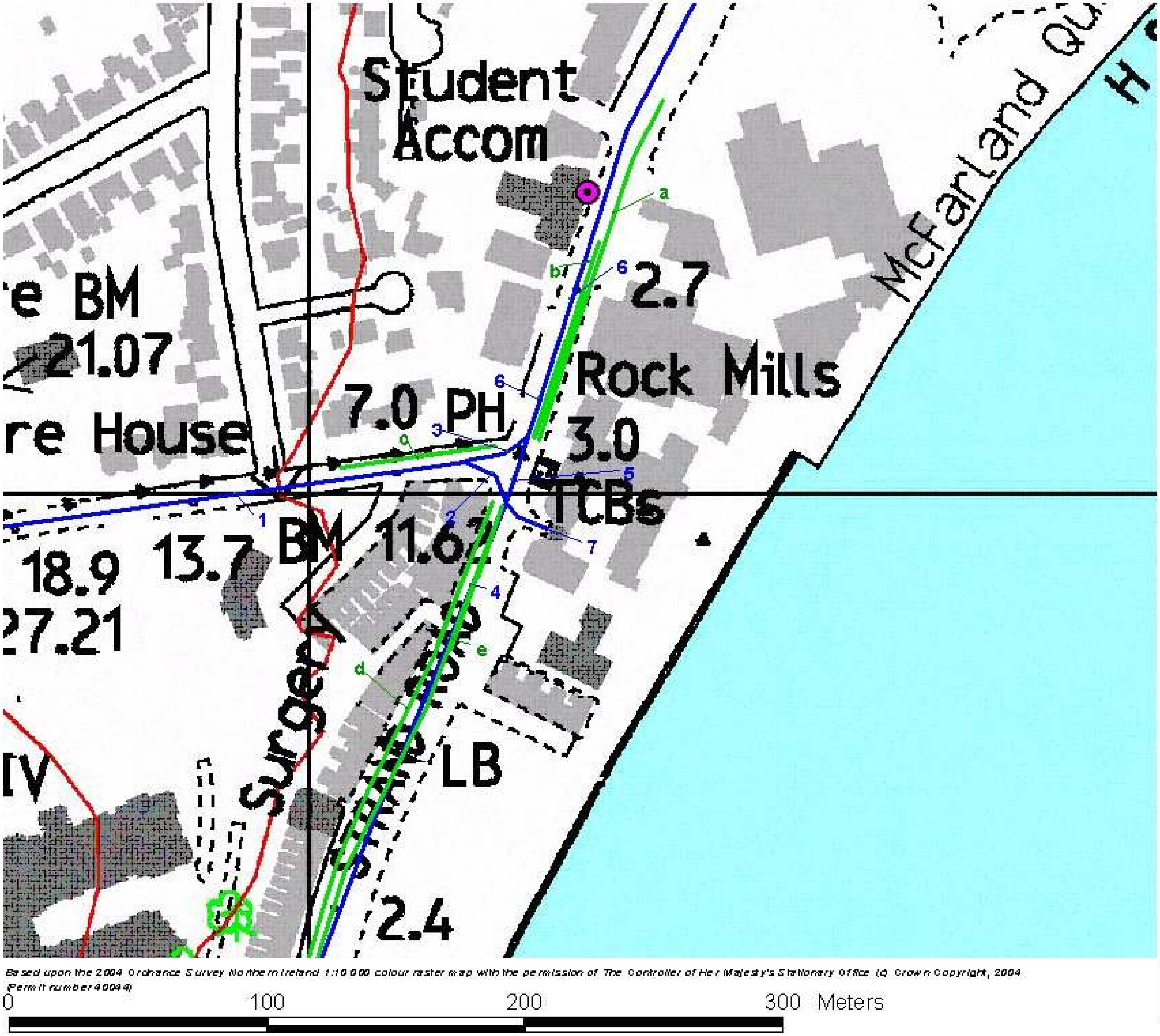
Figure 8.7 shows the modelled road links at Strand Road at Rockmills and Coppin House student accommodation. Table 8.4 displays the traffic data used in the modelling. Figure 8.8 shows the diurnal profile applied to the length of each of the queues, which are labelled (a) to (e).

Table 8.4: Traffic data for Strand Road junction

	Road width (m)	Speed (km/h)	Street canyon height (m)	2002		2005	
				Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Link 1	11.9	20	0	9539	295	8832	273
Link 2	8.0	20	0	6137	245	5682	227
Link 3	9.0	20	0	3289	164	3045	152
Link 4	12.7	20	0	38714	1996	35845	1848
Link 5	12.7	20	0	32250	1931	29860	1788
Link 6	17.5	20	0	35343	2291	32724	2121
Link 7	5.0	20	0	10	0	9	0

Figure 8.8: Diurnal profile of queues for Strand Road at Rockmills and Coppin House





Modelled link

Modelled queue

NO2 diffusion tube

CERC
Derry City Council
Strand Road at Rockmills and Coppin House junction
Figure 8.7

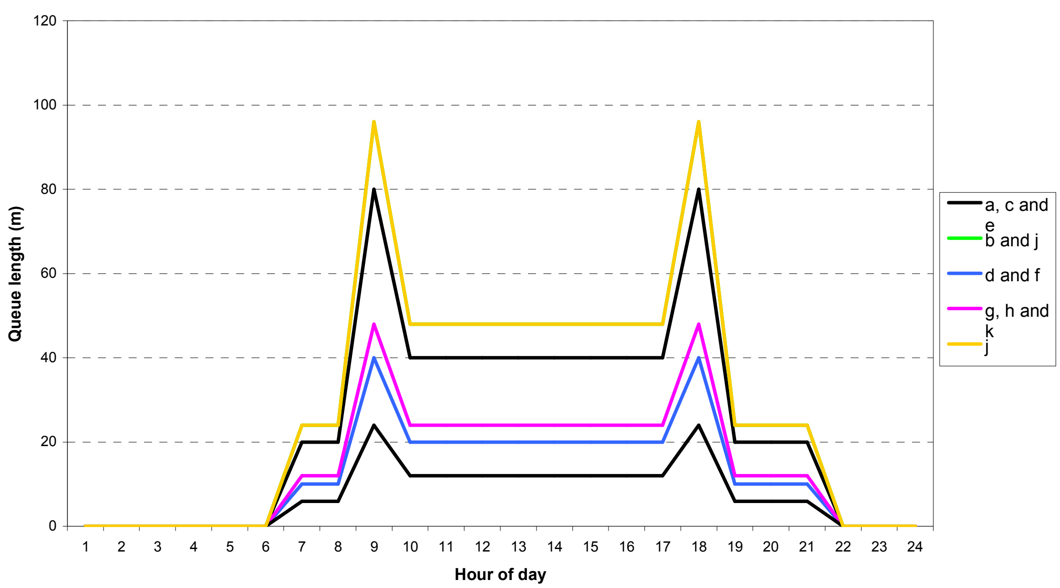
8.1.4 Dales Corner

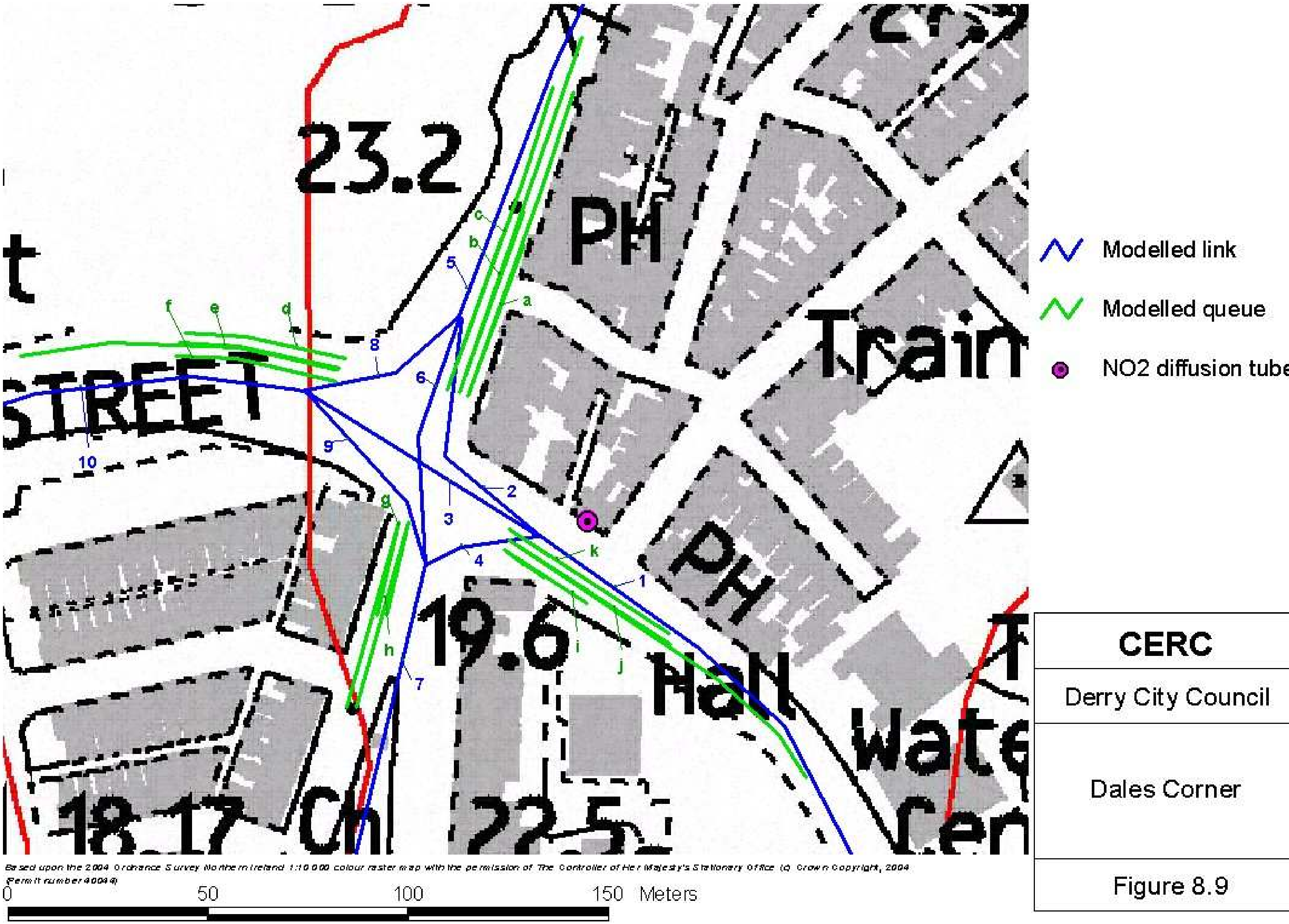
Figure 8.9 shows the modelled road links at Dales Corner. Table 8.5 displays the traffic data used in the modelling. Figure 8.10 shows the diurnal profile applied to the length of each of the queues, which are labelled (a) to (h).

Table 8.5: Traffic data for Dales Corner

	Road width (m)	Speed (km/h)	Street canyon height (m)	2002		2005	
				Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Link 1	20.3	20	0	18520	1480	20002	1598
Link 2	13.4	20	0	3556	268	3841	289
Link 3	20.3	20	0	13304	1112	14369	1201
Link 4	15.4	20	0	1658	102	1791	110
Link 5	17.9	20	0	23552	1664	25437	1797
Link 6	17.9	20	0	3639	233	3930	252
Link 7	23.7	20	0	7356	404	7945	436
Link 8	19.1	20	0	16275	1245	17478	1345
Link 9	13.3	20	0	1965	163	2122	176
Link 10	28.2	20	0	31324	2724	33831	2942

Figure 8.10: Diurnal profile of queues for Dales Corner





CERC

Derry City Council

Dales Corner

Figure 8.9

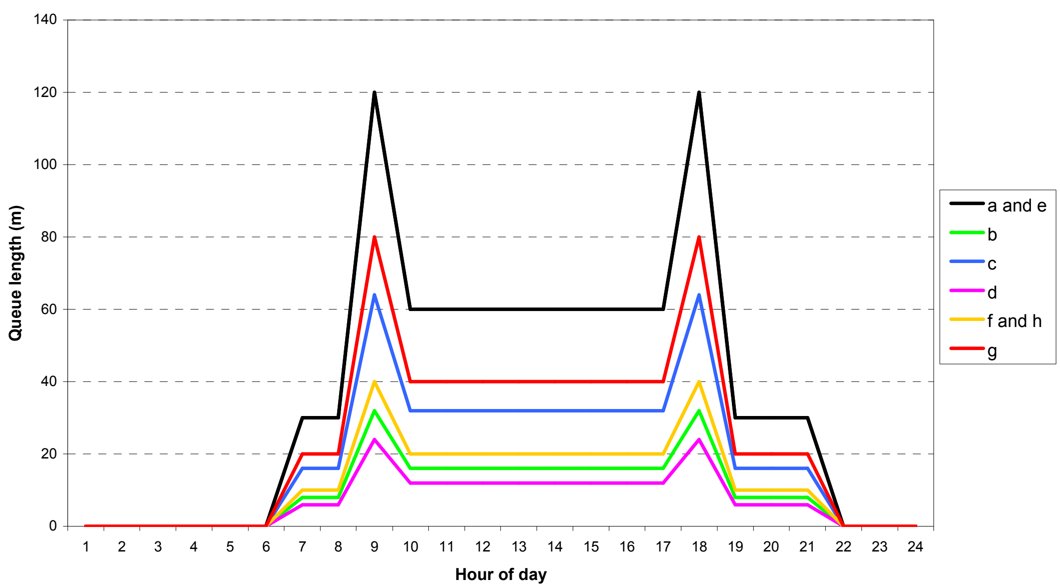
8.1.5 Woodburn Park / Dungiven Road at the Irish Street lights

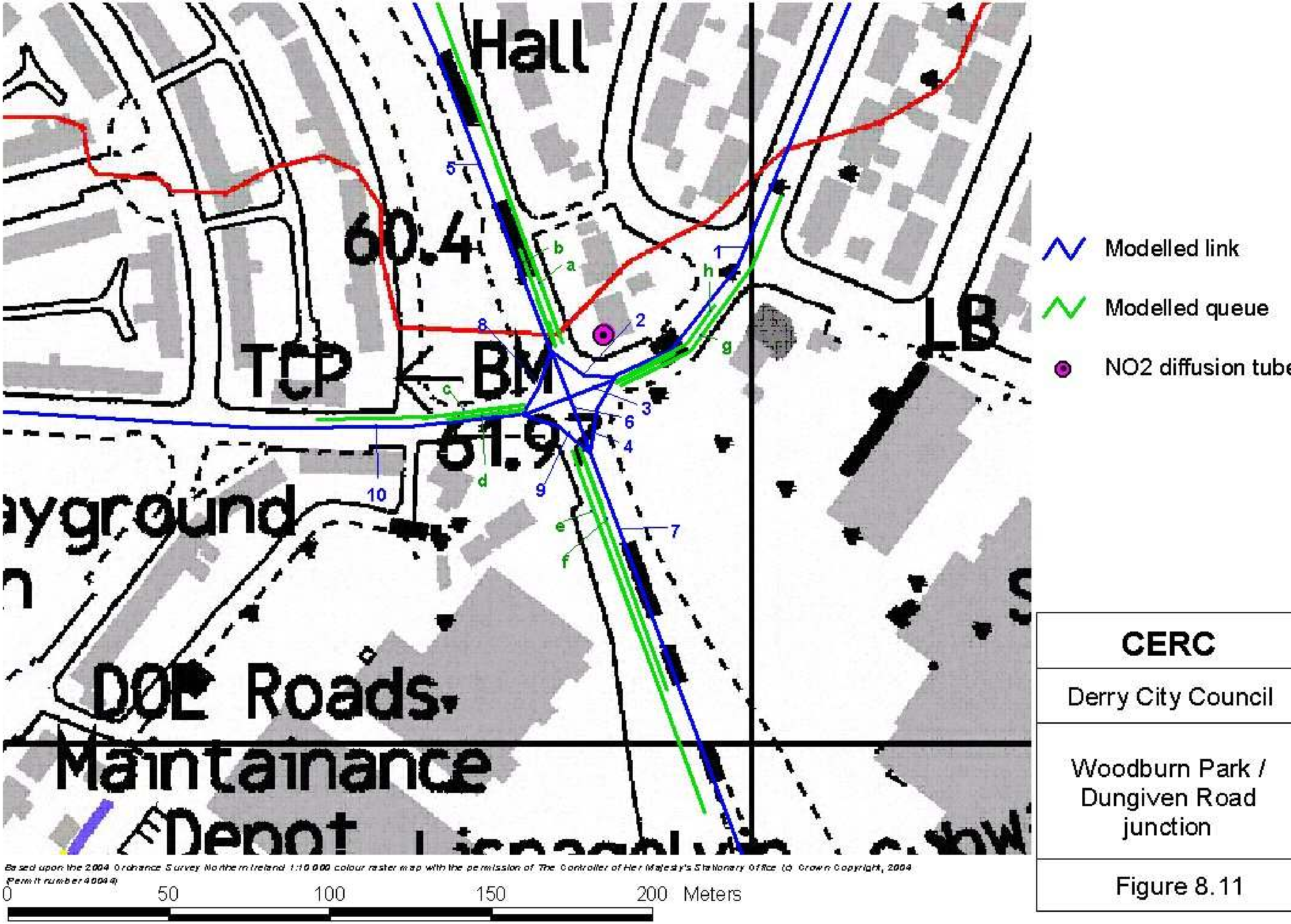
Figure 8.11 shows the modelled road links at the Irish Street lights on Dungiven Road. Table 8.6 displays the traffic data used in the modelling. Figure 8.12 shows the diurnal profile applied to the length of each of the queues, which are labelled (a) to (h).

Table 8.6: Traffic data for Woodburn Park / Dungiven Road at the Irish Street lights

	Road width (m)	Speed (km/h)	Street canyon height (m)	2002		2005	
				Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Link 1	11.3	20	0	8648	168	9340	181
Link 2	11.2	20	0	2224	96	2402	104
Link 3	11.3	20	0	3948	116	4264	125
Link 4	10.6	20	0	2368	64	2558	69
Link 5	15.9	20	0	25499	1685	27540	1820
Link 6	15.9	20	0	19598	1218	21167	1315
Link 7	14.5	20	0	22255	1345	24036	1453
Link 8	9.2	20	0	2346	102	2534	110
Link 9	9.5	20	0	338	14	365	15
Link 10	10.3	20	0	6617	247	7147	267

Figure 8.12: Diurnal profile of queues for Woodburn Park / Dungiven Road





CERC
Derry City Council
Woodburn Park / Dungiven Road junction
Figure 8.11

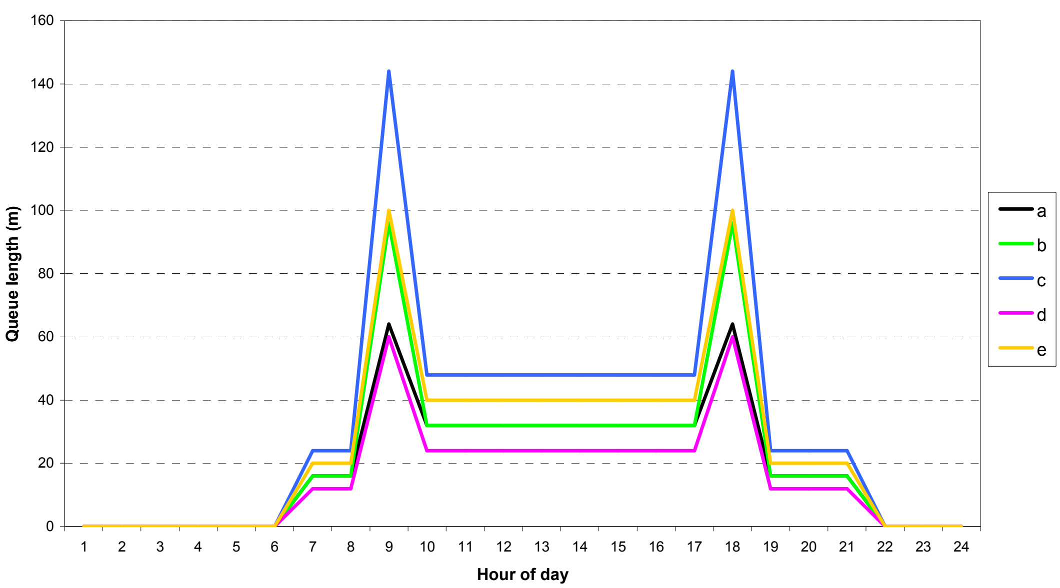
8.1.6 Glenshane Road at Altnagelvin Hospital

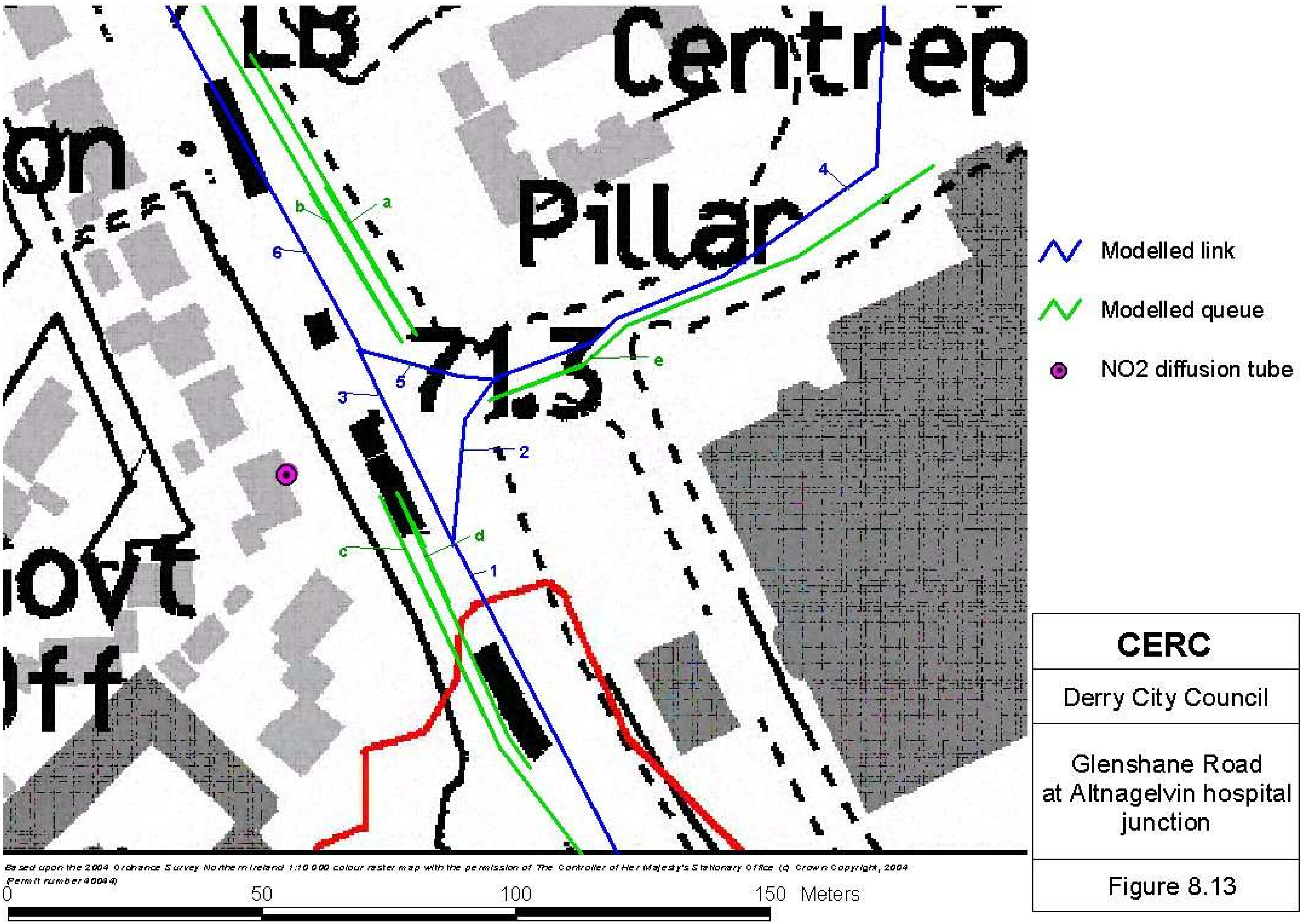
Figure 8.13 shows the modelled road links for Glenshane Road at Altnagelvin Hospital. Table 8.7 displays the traffic data used in the modelling. Figure 8.14 shows the diurnal profile applied to the length of each of the queues, which are labelled (a) to (d).

Table 8.7: Traffic data for Glenshane Road at Altnagelvin Hospital

	Road width (m)	Speed (km/h)	Street canyon height (m)	2002		2005	
				Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Link 1	26.0	20	0	23223	2185	25082	2360
Link 2	13.0	20	0	3127	263	3377	284
Link 3	26.0	20	0	20089	1942	21697	2097
Link 4	15.7	20	0	6607	304	7136	328
Link 5	10.7	20	0	3262	258	3523	279
Link 6	8.6	20	0	23200	2351	25057	2539

Figure 8.14: Diurnal profile of queues for Glenshane Road at Altnagelvin Hospital





CERC
Derry City Council
Glenshane Road at Altnagelvin hospital junction
Figure 8.13

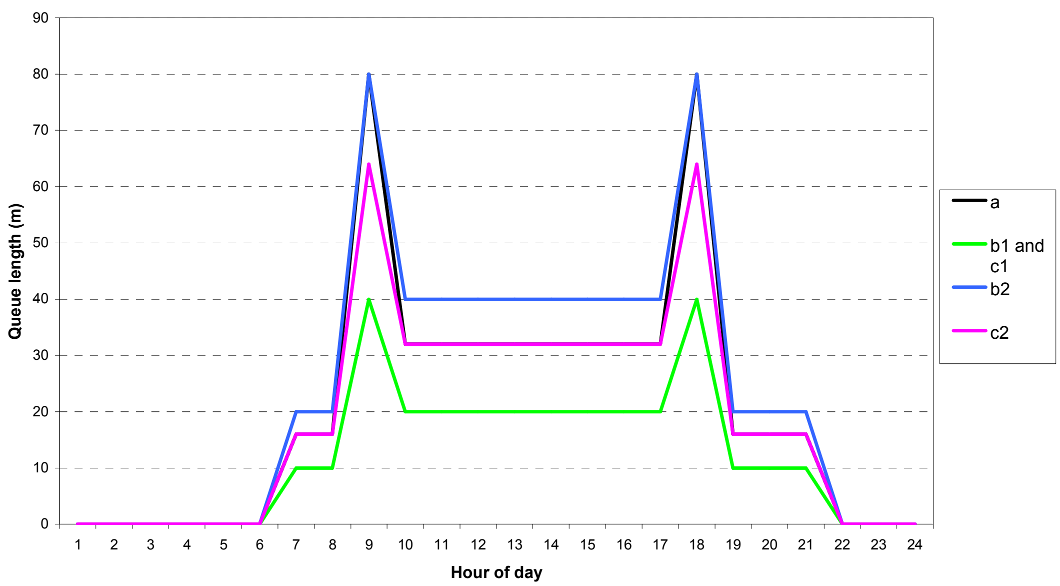
8.1.7 Creggan Road / Infirmary Road

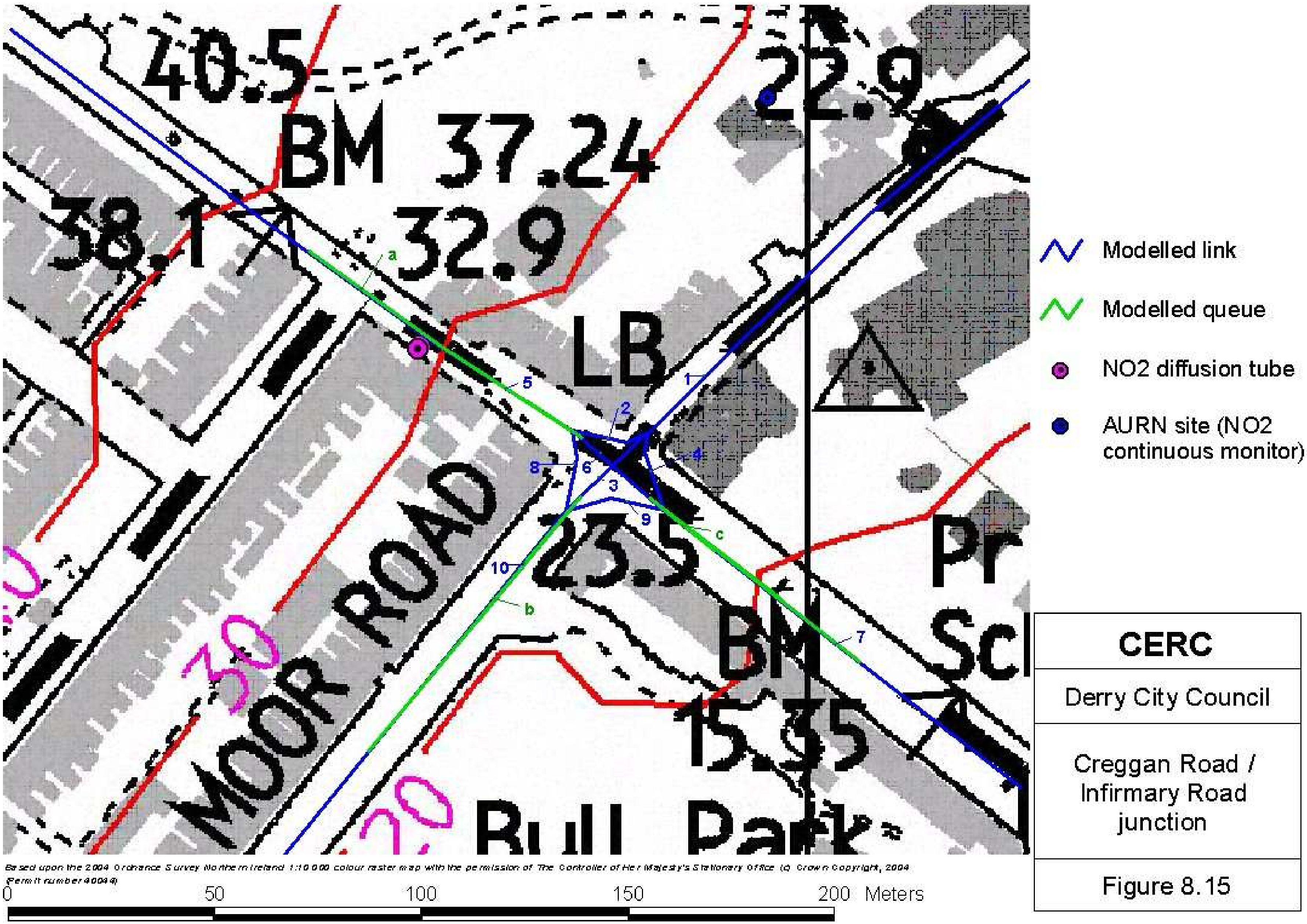
Figure 8.15 shows the modelled road links for Creggan Road / Infirmary Road. Table 8.8 displays the traffic data used in the modelling. Figure 8.16 shows the diurnal profile applied to the length of each of the queues, which are labelled (a) to (c).

Table 8.8: Traffic data for Creggan Road / Infirmary Road

	Road width (m)	Speed (km/h)	Street canyon height (m)	2002		2005	
				Light vehicles	Heavy vehicles	Light vehicles	Heavy vehicles
Link 1	8.5	10	8	7648	237	8260	256
Link 2	6.6	10	8	3643	74	3935	80
Link 3	8.5	10	8	3712	155	4009	167
Link 4	7.4	10	8	285	15	308	16
Link 5	8.5	10	8	10505	214	11346	231
Link 6	13.1	10	8	3721	196	4019	212
Link 7	17.7	10	8	8932	470	9647	508
Link 8	9.8	10	8	3007	77	3248	83
Link 9	9.4	10	8	4925	259	5319	280
Link 10	8.5	10	8	11651	485	12584	524

Figure 8.16: Diurnal profile of queues for Creggan Road / Infirmary Road





CERC

Derry City Council

Creggan Road / Infirmary Road junction

Figure 8.15

8.2 Model verification

Receptor points located at the site of each monitor were included in the modelling so that the predicted concentrations from the modelling could be directly compared with the monitored concentrations. The locations of the receptor points are shown in Figure 7.1.

Predicted concentrations of NO_2 were compared with hourly monitoring data recorded at the AURN site and with annual average data recorded at the NO_2 diffusion tube locations. A comparison of the monitored and predicted concentrations of NO_2 for the period April 2002 to March 2003 is presented in Table 8.9. Figure 8.17 shows a comparison of the monitored and modelled annual average NO_2 concentrations.

Table 8.9: Comparison of monitored and modelled concentrations of NO_2 ($\mu g/m^3$), April 2002 to March 2003

	Annual average		**99.79^{th} percentile of hourly averages**	
	monitored	**modelled**	**monitored**	**modelled**
AURN site	15.9	15.4	35.0	62.3
DIFFUSION TUBES:				
Site 14: 26 Rossdowney Park	22.8	29.6	-	-
Site 15: 5 Glendermot Road	33.6	28.0	-	-
Site 16: 139c Strand Road	32.8	30.6	-	-
Site 17: 3 Farren Park	27.3	33.0	-	-
Site 18: 19 St Patrick's Terrace	38.1	34.2	-	-
Site 19: 7 Haberton Park	24.1	20.9	-	-
Site 20: 3 Creggan Road	46.6	26.9	-	-
AURN site diffusion tube	15.8*	15.4	-	-

* average from three co-located tubes

Table 8.9 and Figure 8.17 indicate that there is generally good agreement between the modelled and monitored concentrations.

The only exception is at Site 20, near the Creggan Road / Infirmary Road junction, where the modelled annual average concentration of NO_2 is much lower than the monitored value. The monitored concentration at this location may be unreliable; the annual average NO_2 concentration recorded at this site is 48.8$\mu g/m^3$, substantially higher than the values recorded elsewhere.

Alternatively, there may be local emission sources of NO_2 that are not fully represented in the modelling.

The monitoring site is located beside an uphill section of Creggan Road. The effect of this gradient on traffic emissions has been partially accounted for in the modelling by reducing the average speed across the junction to 10km/h, however, no quantitative correction is available to account for the increase in vehicle emissions resulting from the extra power required by vehicles to drive up this incline. The reduction in speed may be insufficient to represent actual emissions from vehicles travelling up Creggan Road.

In addition, there is a school and swimming pool nearby, and the boilers at these premises may be a significant source of NO_x emissions. Although it is likely that emissions from these sources are included in the NAEI gridded emissions, they were not explicitly modelled. Consequently, NO_2 emissions from these two sources have been distributed over the 1km grid rather than being focused at the locations of the school and swimming pool, near the junction.

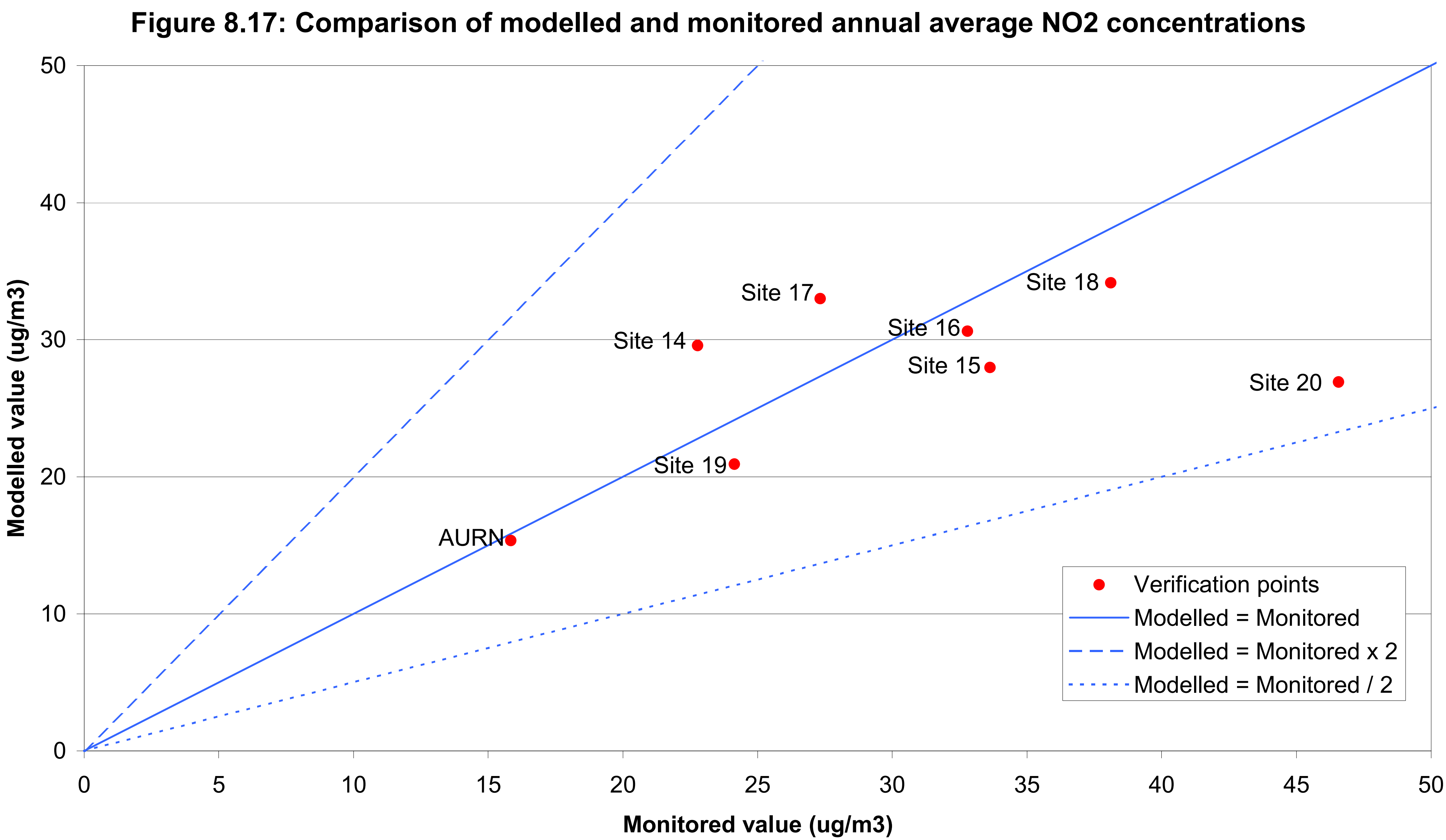


Figure 8.17: Comparison of modelled and monitored annual average NO2 concentrations
Modelled value (ug/m3)
Monitored value (ug/m3)
0
5
10
15
20
25
30
35
40
45
50
Site 17
Site 18
Site 14
Site 16
Site 15
Site 20
Site 19
AURN
Verification points
Modelled = Monitored
Modelled = Monitored x 2
Modelled = Monitored / 2

8.3 Predicted concentrations of NO_2

Ground level concentrations of NO_2 were calculated on a grid of receptor points covering the seven junctions, with extra receptor points added close to the modelled roads, where concentration gradients are highest.

All maps are orientated with north pointing up the page. Note that the red lines on the contour plots are part of the base map, and indicate the height contours of the land.

Maximum predicted NO_2 concentrations at each of the junctions are summarised in Table 8.10. A description of predicted concentrations at each of the junctions is given in Sections 8.3.1 to 8.3.7.

Table 8.10: Maximum predicted concentrations of NO_2 ($\mu g/m^3$), 2005

Junction	Maximum annual average		Maximum 99.79th percentile of hourly average	
	Predicted concentration ($\mu g/m^3$)	% of 2005 AQS objective	Predicted concentration ($\mu g/m^3$)	% of 2005 AQS objective
Buncrana Road / Racecourse Road	39.4	99	139.3	70
Pennyburn roundabout	37.0	93	138.1	69
Strand Road junction	38.6	97	141.2	71
Dales Corner	37.6	94	145.5	73
Woodburn Park / Dungiven Road	34.5	86	135.8	68
Glenshane Road at Altnagelvin Hospital	29.6	74	129.2	65
Creggan Road / Infirmary Road	42.5	106	146.3	73

8.3.1 Predicted Concentrations at Buncrana Road / Racecourse Road

Figures 8.18 and 8.19 show contour plots of the predicted annual average and 99.79th percentile of hourly average concentrations of NO_2 for 2005.

There are no predicted exceedences of either of the AQS objectives for NO_2 at the Buncrana Road / Racecourse Road junction in 2005. The maximum predicted annual average concentration of NO_2 is 39.4$\mu g/m^3$, 99% of the AQS objective of 40$\mu g/m^3$. Figure 8.19 shows that the maximum concentrations, above 35$\mu g/m^3$, are predicted to occur on the road junction itself; the highest predicted concentrations at the nearby houses are between 30$\mu g/m^3$ and 35$\mu g/m^3$.

The maximum predicted 99.79th percentile of hourly average concentrations is 139$\mu g/m^3$, 70% of the AQS objective value of 200$\mu g/m^3$.

8.3.2 Predicted Concentrations at Pennyburn roundabout

Figures 8.20 and 8.21 show contour plots of the predicted annual average and 99.79th percentile of hourly average concentrations of NO_2 for 2005.

There are no predicted exceedences of either of the AQS objectives for NO_2 at Pennyburn roundabout in 2005. The maximum predicted annual average concentration of NO_2 is 37.0µg/m^3, 93% of the AQS objective of 40µg/m^3. The maximum predicted 99.79th percentile of hourly average concentrations is 138.1µg/m^3, 69% of the AQS objective value of 200µg/m^3.

8.3.3 Predicted Concentrations at the Strand Road junction

Figures 8.22 and 8.23 show contour plots of the predicted annual average and 99.79th percentile of hourly average concentrations of NO_2 for 2005.

There are no predicted exceedences of either of the AQS objectives for NO_2 at the Strand Road junction in 2005. The maximum predicted annual average concentration of NO_2 is 38.6µg/m^3, 97% of the AQS objective of 40µg/m^3. Figure 8.22 shows that the maximum concentrations, above 35µg/m^3, are predicted to occur on the road junction itself; the highest predicted concentrations at the houses are between 30µg/m^3 and 35µg/m^3.

The maximum predicted 99.79th percentile of hourly average concentrations is 141.2µg/m^3, 71% of the AQS objective value of 200µg/m^3.

8.3.4 Predicted Concentrations at Dales Corner

Figures 8.24 and 8.25 show contour plots of the predicted annual average and 99.79th percentile of hourly average concentrations of NO_2 for 2005.

There are no predicted exceedences of either of the AQS objectives for NO_2 at Dales Corner in 2005. The maximum predicted annual average concentration of NO_2 is 37.6µg/m^3, 94% of the AQS objective of 40µg/m^3. The maximum predicted 99.79th percentile of hourly average concentrations is 145.5µg/m^3, 73% of the AQS objective value of 200µg/m^3.

8.3.5 Predicted Concentrations at Woodburn Park / Dungiven Road junction

Figures 8.26 and 8.27 show contour plots of the predicted annual average and 99.79th percentile of hourly average concentrations of NO_2 for 2005.

There are no predicted exceedences of either of the AQS objectives for NO_2 at the Woodburn Park / Dungiven Road junction in 2005. The maximum predicted annual average concentration of NO_2 is 34.5µg/m^3, 86% of the AQS objective of 40µg/m^3. The maximum predicted 99.79th percentile of hourly average concentrations is 135.8µg/m^3, 68% of the AQS objective value of 200µg/m^3.

8.3.6 Predicted Concentrations at Glenshane Road at Altnagelvin hospital

Figures 8.28 and 8.29 show contour plots of the predicted annual average and 99.79th percentile of hourly average concentrations of NO_2 for 2005.

There are no predicted exceedences of either of the AQS objectives for NO_2 at the Glenshane Road with Altnagelvin hospital in 2005. The maximum predicted annual average concentration of NO_2 is 29.6µg/m^3, 74% of the AQS objective of 40µg/m^3. The maximum predicted 99.79th percentile of hourly average concentrations is 129.2µg/m^3, 65% of the AQS objective value of 200µg/m^3.

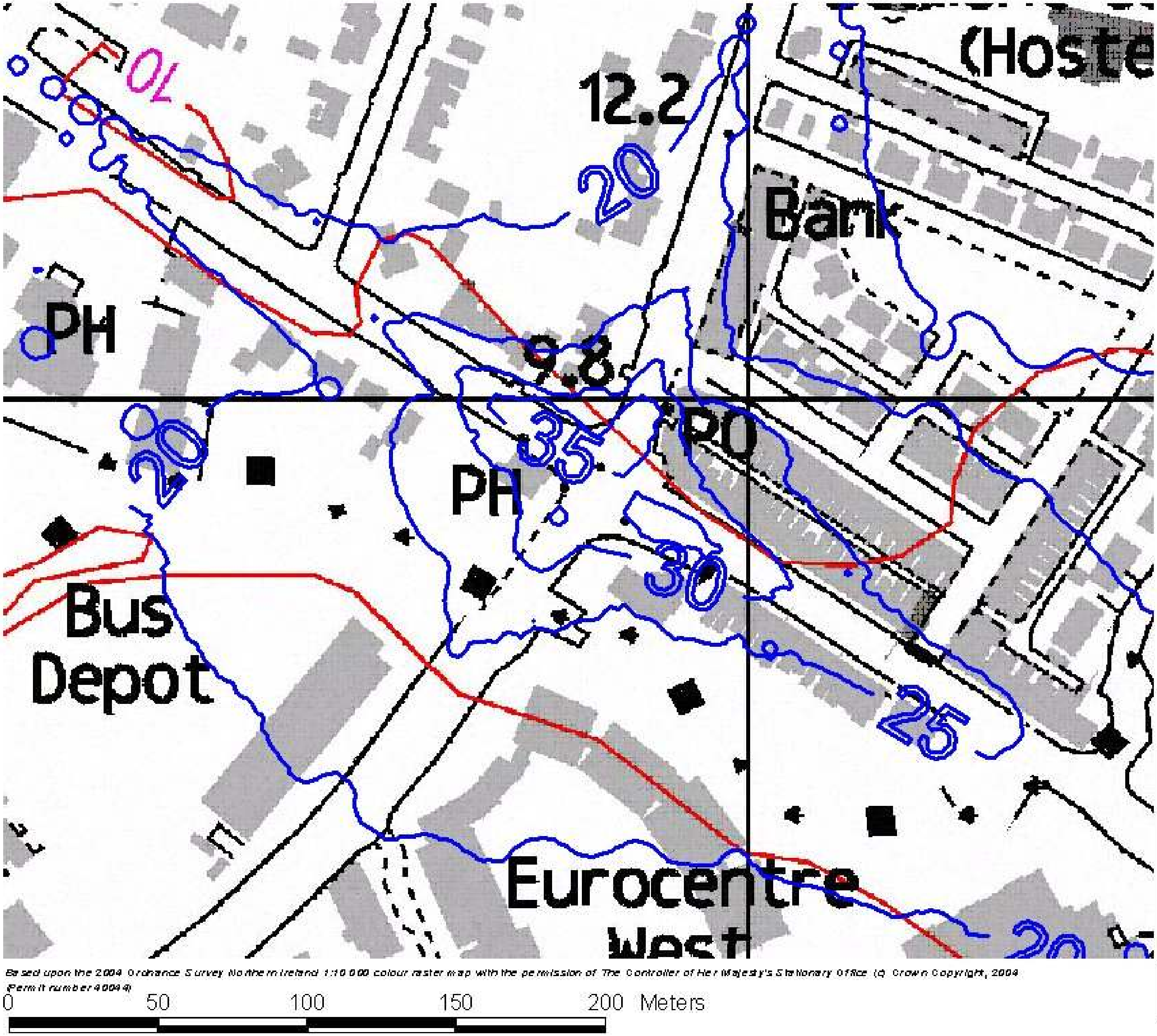
8.3.7 Predicted Concentrations at Creggan Road / Infirmary Road

Figures 8.30 and 8.31 show contour plots of the predicted annual average and 99.79th percentile of hourly average concentrations of NO_2 for 2005.

The maximum predicted annual average concentration of NO_2 is 42.5µg/m^3, which exceeds the AQS objective of 40µg/m^3. Figure 8.30 shows that the predicted area of exceedence is very small, and occurs only on the junction itself. However, as discussed in Section 8.2, the results of the model verification suggest that the model may be significantly underpredicting the concentrations at Creggan Road, and therefore it is possible that the area of exceedence may cover a larger area.

The monitored concentration of NO_2 is approximately 1.7 times larger than the modelled value. In order to give some indication of the worst case area of exceedence a contour was added to Figure 8.30 to represent the area where an exceedence would occur if the concentrations of NO_2 were 1.7 times larger than those predicted. This corresponds to a contour level of 23.5µg/m^3, and is shown by an orange line.

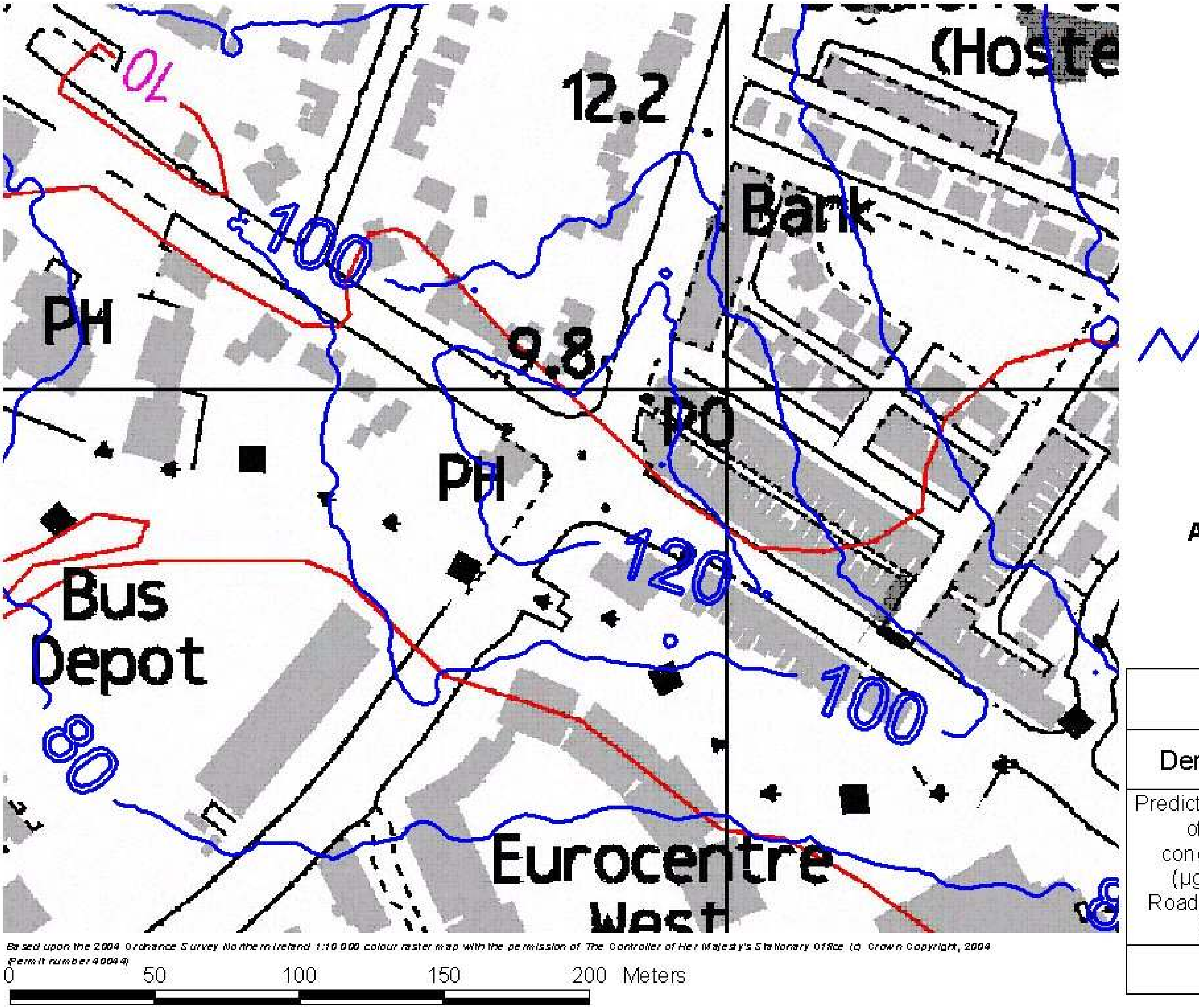
There are no predicted exceedences of the 99.79th percentile of hourly average AQS objective. The maximum predicted 99.79th percentile of hourly average concentrations is 146µg/m^3, 73% of the AQS objective value of 200µg/m^3.



Concentration of NO_2 (µg/m³)

AQS objective = 40µg/m³

CERC
Derry City Council
Predicted annual average concentrations of NO_2 (µg/m³) at Buncrana Road / Racecourse Road junction, 2005
Figure 8.18



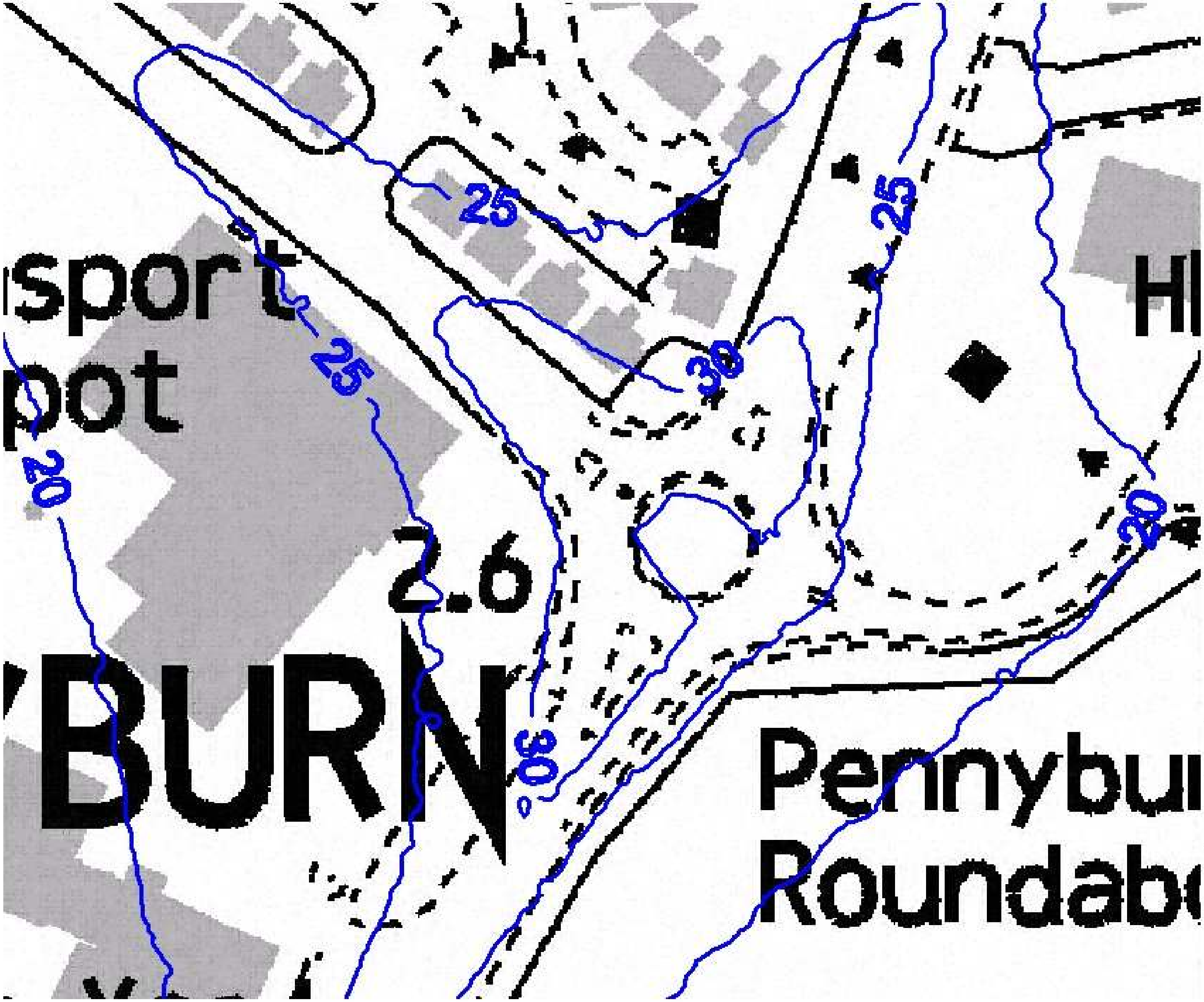
AQS objective = 200µg/m³

CERC

Derry City Council

Predicted 99.79th percentile of hourly average concentrations of NO2 (µg/m³) at Buncrana Road / Racecourse Road junction, 2005

Figure 8.19



Based upon the 2004 Ordnance Survey Northern Ireland 1:10 000 colour raster map with the permission of The Controller of Her Majesty's Stationary Office (c) Crown Copyright, 2004 (Permit number 40044)

0 50 100 150 Meters

Concentration of NO2 (µg/m³)

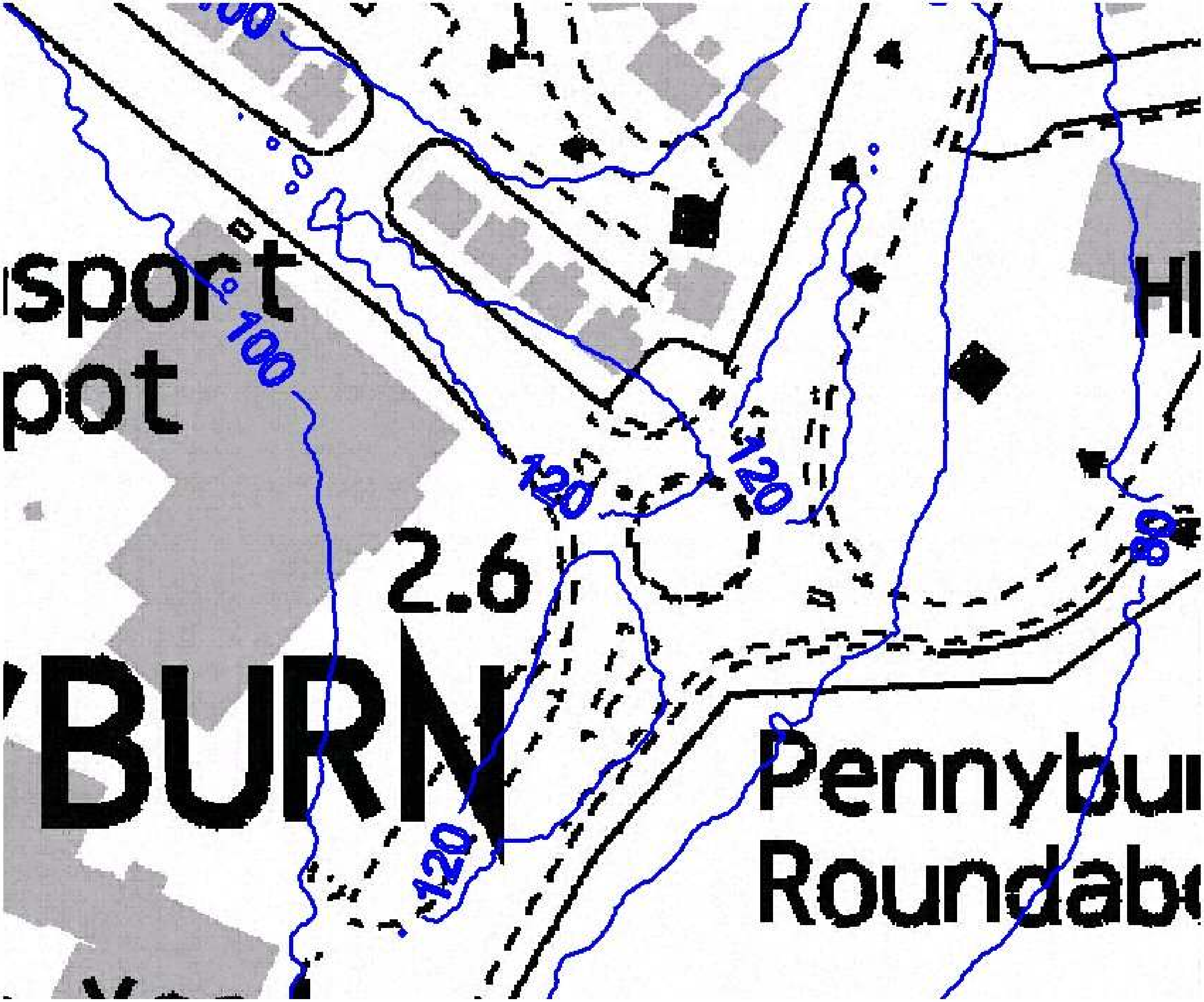
AQS objective = 40µg/m³

CERC

Derry City Council

Predicted annual average concentrations of NO2 (µg/m³) at Pennyburn roundabout, 2005

Figure 8.20



0 50 100 150 Meters

Concentration of NO2 (µg/m³)

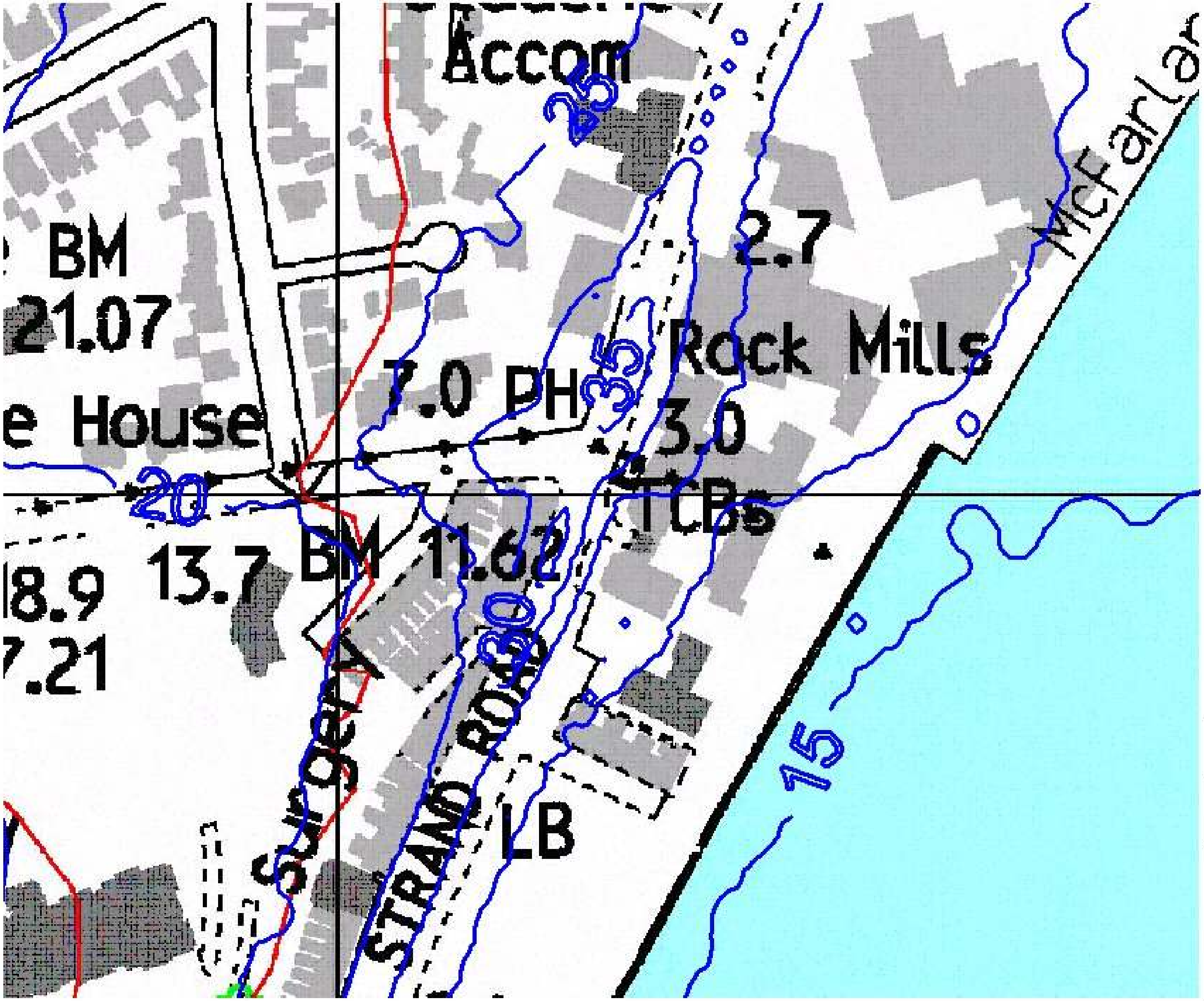
AQS objective = 200µg/m³

CERC

Derry City Council

Predicted 99.79th percentile of hourly average concentrations of NO2 (µg/m³) at Pennyburn roundabout, 2005

Figure 8.21



0 50 100 150 200 250 Meters

Concentration of NO2 (µg/m³)

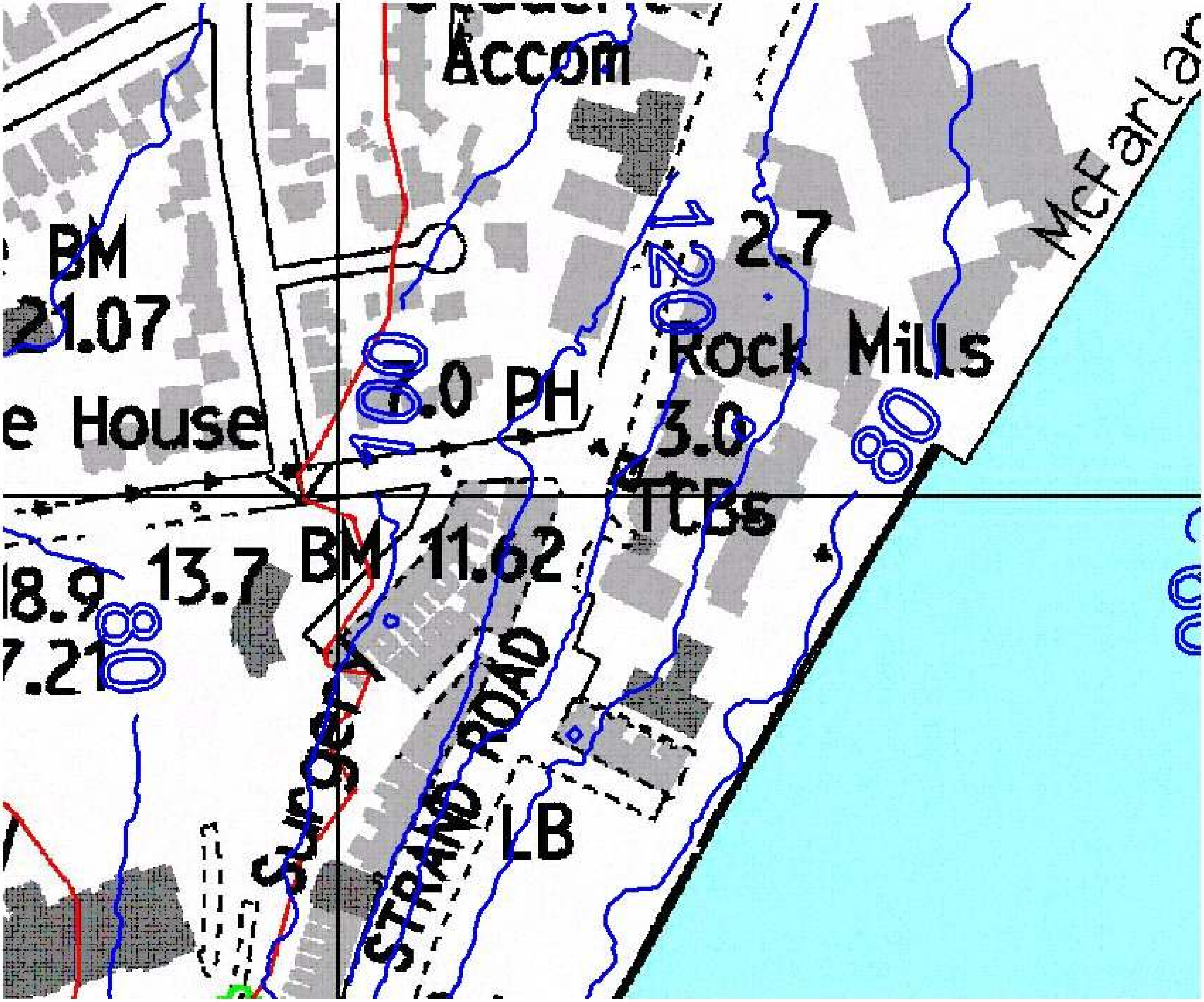
AQS objective = 40µg/m³

CERC

Derry City Council

Predicted annual average concentrations of NO2 (µg/m³) at the Strand Road junction, 2005

Figure 8.22



0 50 100 150 200 250 Meters

Concentration of NO2 (µg/m³)

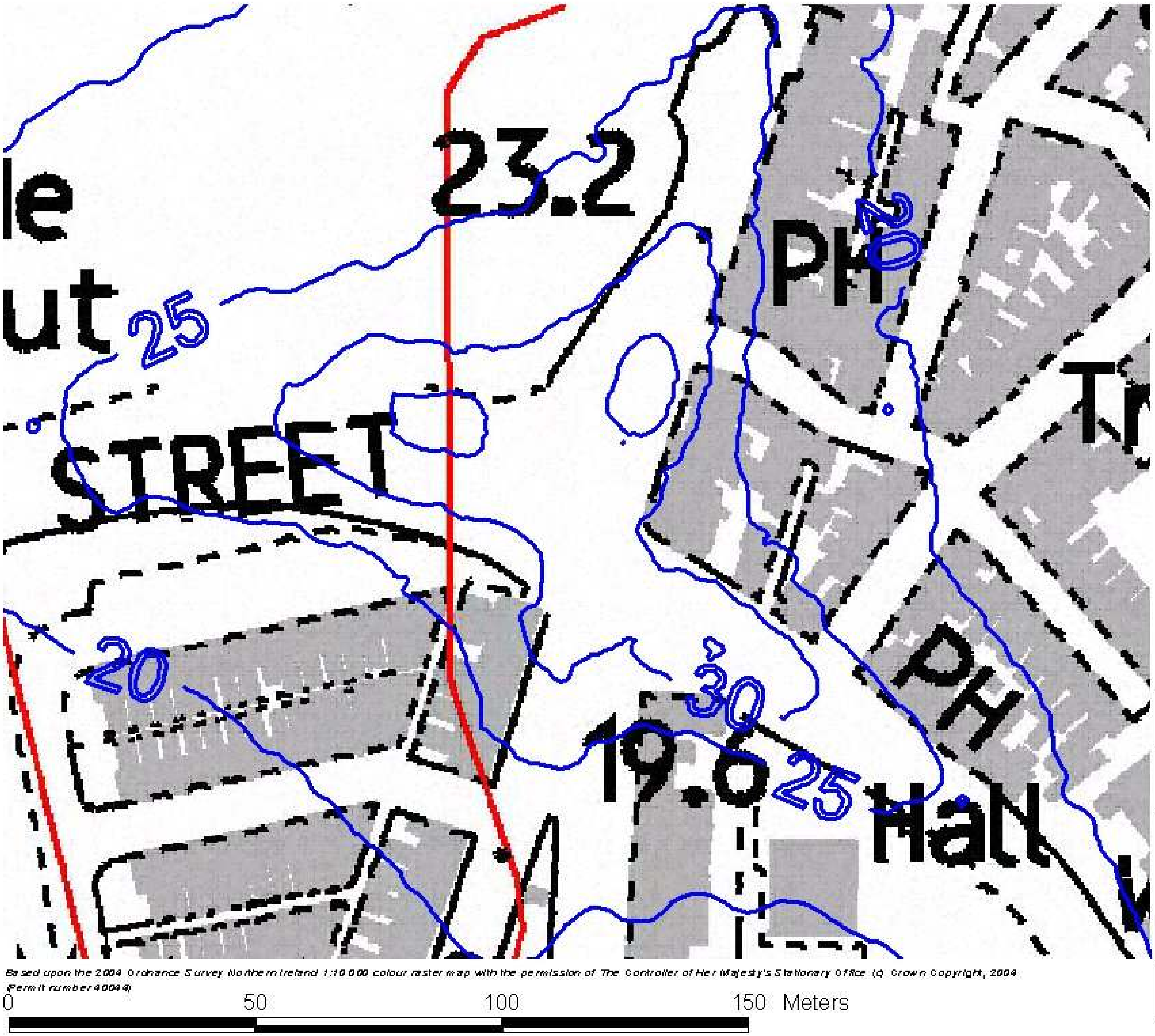
AQS objective = 200µg/m³

CERC

Derry City Council

Predicted 99.79th percentile of hourly average concentrations of NO2 (µg/m³) at the Strand Road junction, 2005

Figure 8.23



Concentration of NO2 (μg/m³)

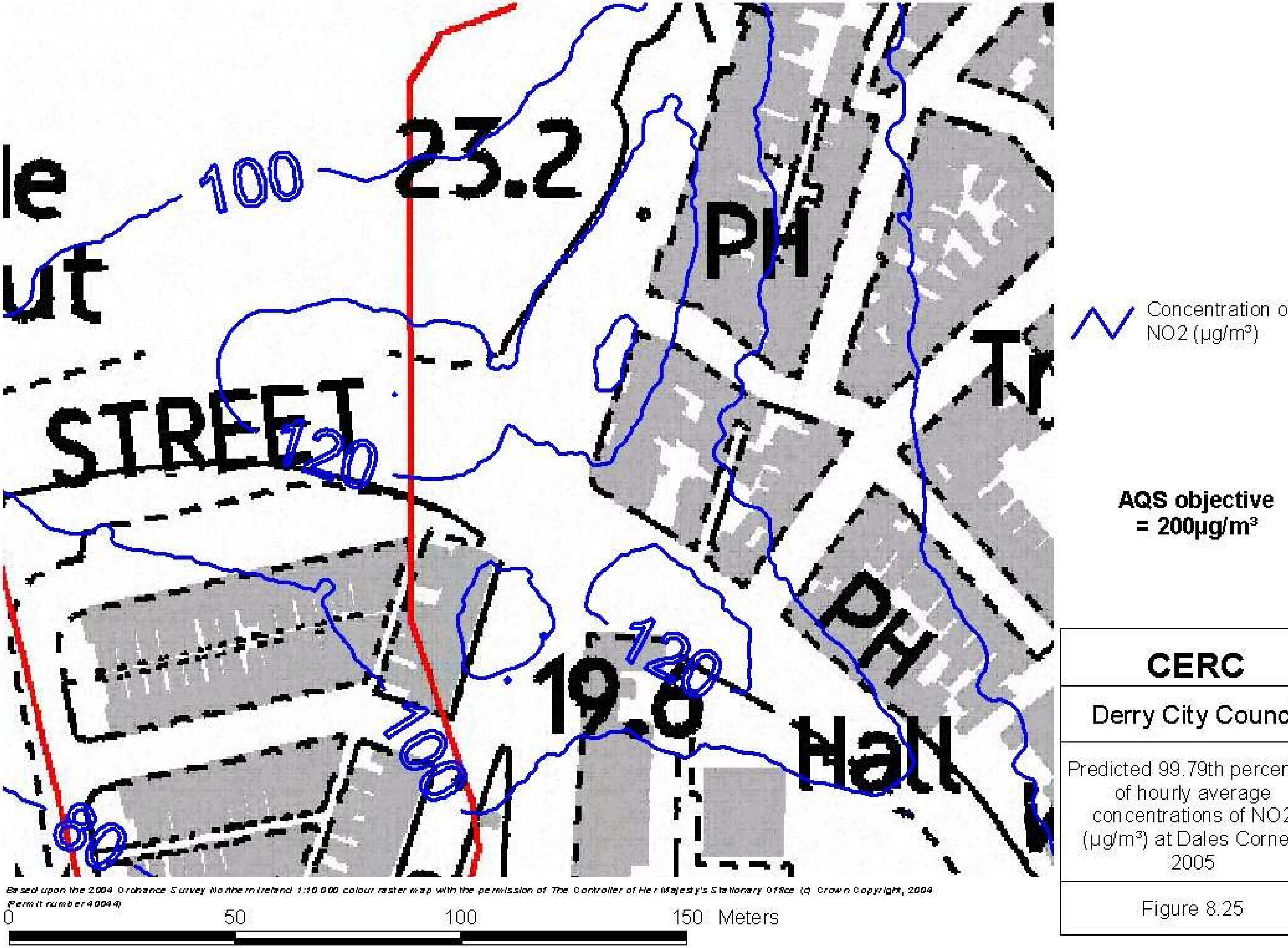
AQS objective = 40μg/m³

CERC

Derry City Council

Predicted annual average concentrations of NO2 (μg/m³) at Dales Corner, 2005

Figure 8.24

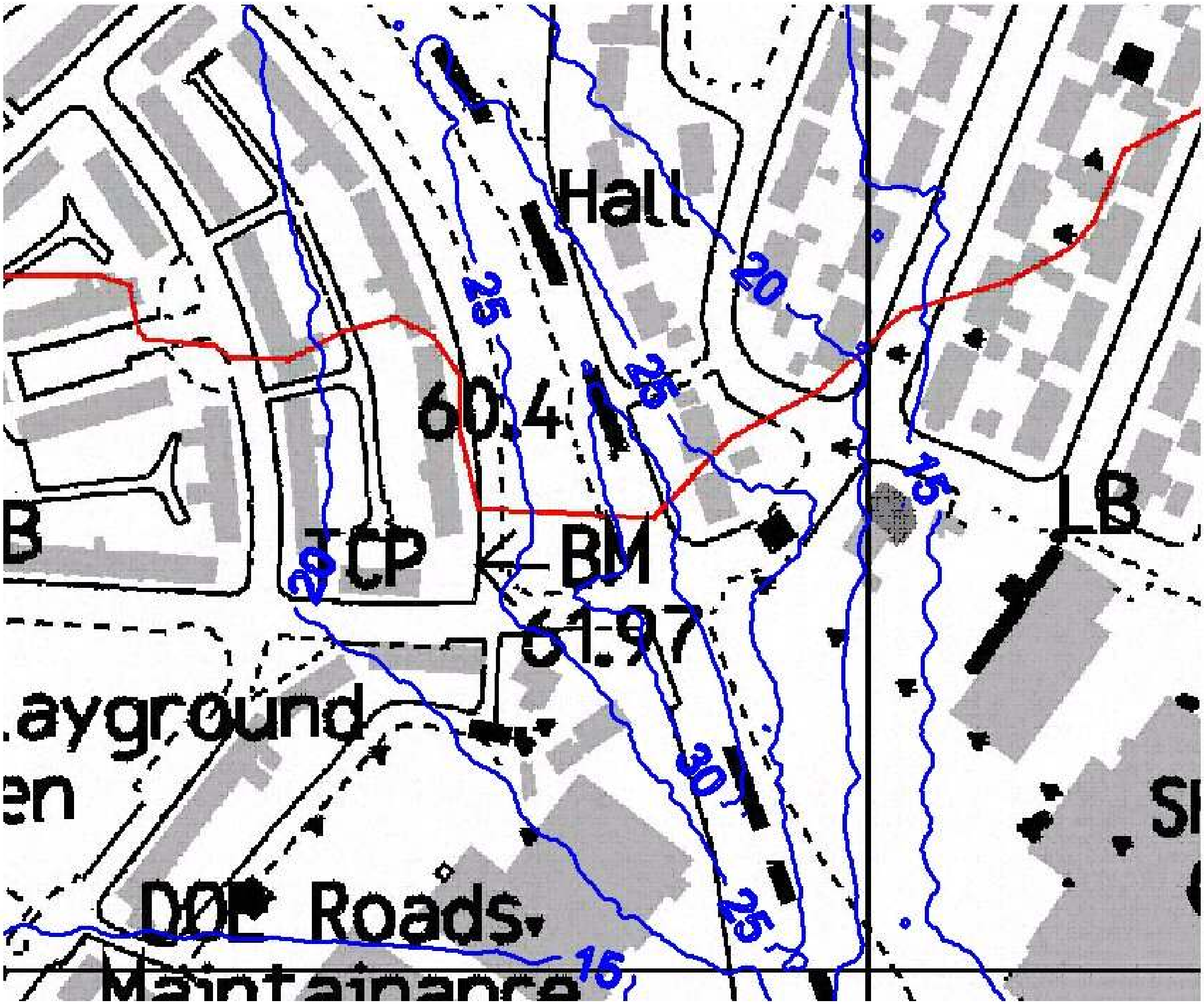


CERC

Derry City Council

Predicted 99.79th percentile of hourly average concentrations of NO2 (µg/m³) at Dales Corner, 2005

Figure 8.25



0 50 100 150 200 Meters

Concentration of NO2 (µg/m³)

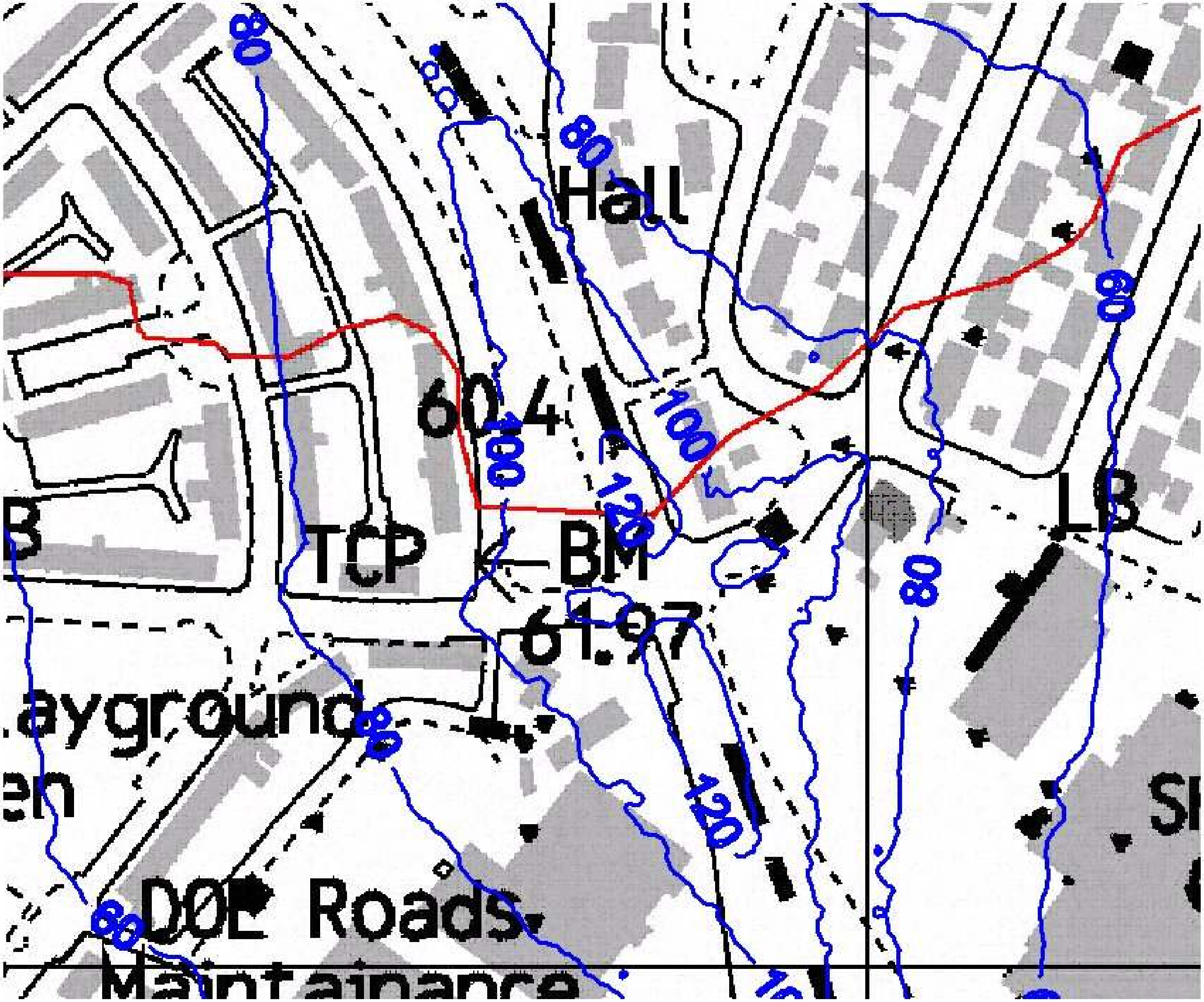
AQS objective = 40µg/m³

CERC

Derry City Council

Predicted annual average concentrations of NO2 (µg/m³) at Woodburn Park / Dungiven Road junction, 2005

Figure 8.26



Concentration of NO2 (µg/m³)

AQS objective = 200µg/m³

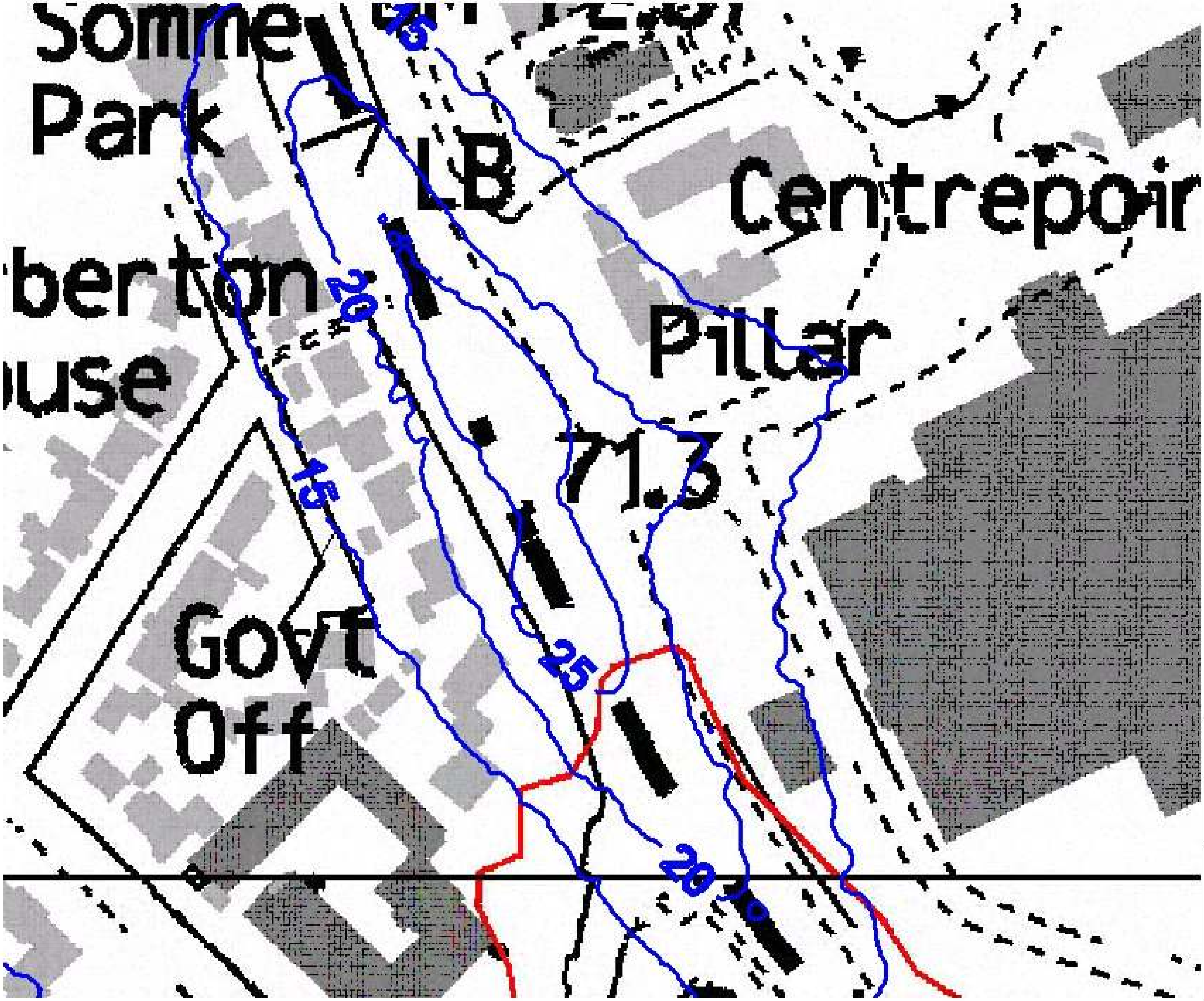
0 50 100 150 200 Meters

CERC

Derry City Council

Predicted 99.79th percentile of hourly average concentrations of NO2 (µg/m³) at Woodburn Park / Dungiven Road junction, 2005

Figure 8.27

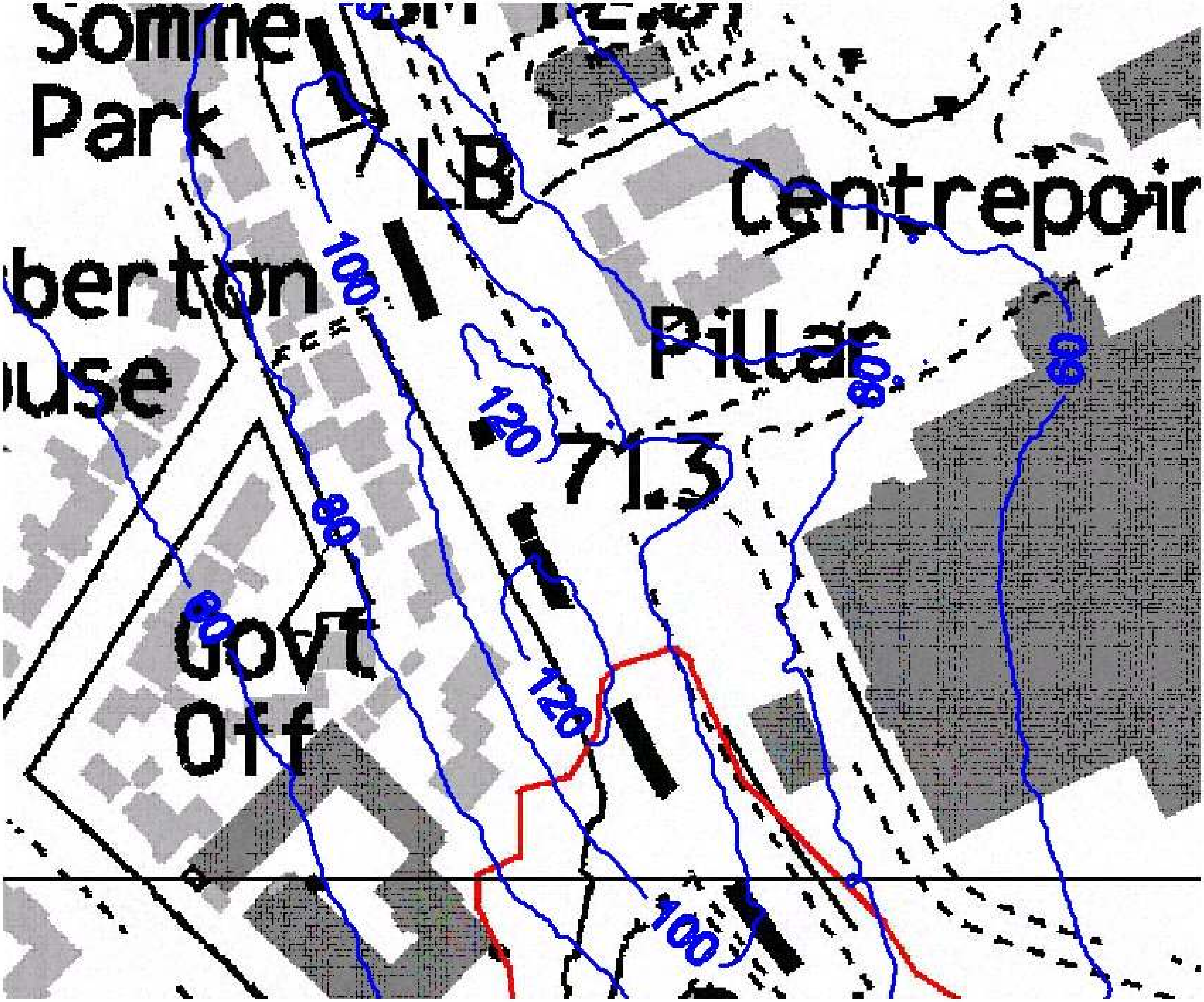


0 50 100 150 Meters

Concentration of NO_2 (µg/m³)

AQS objective = 40µg/m³

CERC
Derry City Council
Predicted annual average concentrations of NO_2 (µg/m³) at Glenshane Road junction, 2005
Figure 8.28



0 50 100 150 Meters

Concentration of NO2 (µg/m³)

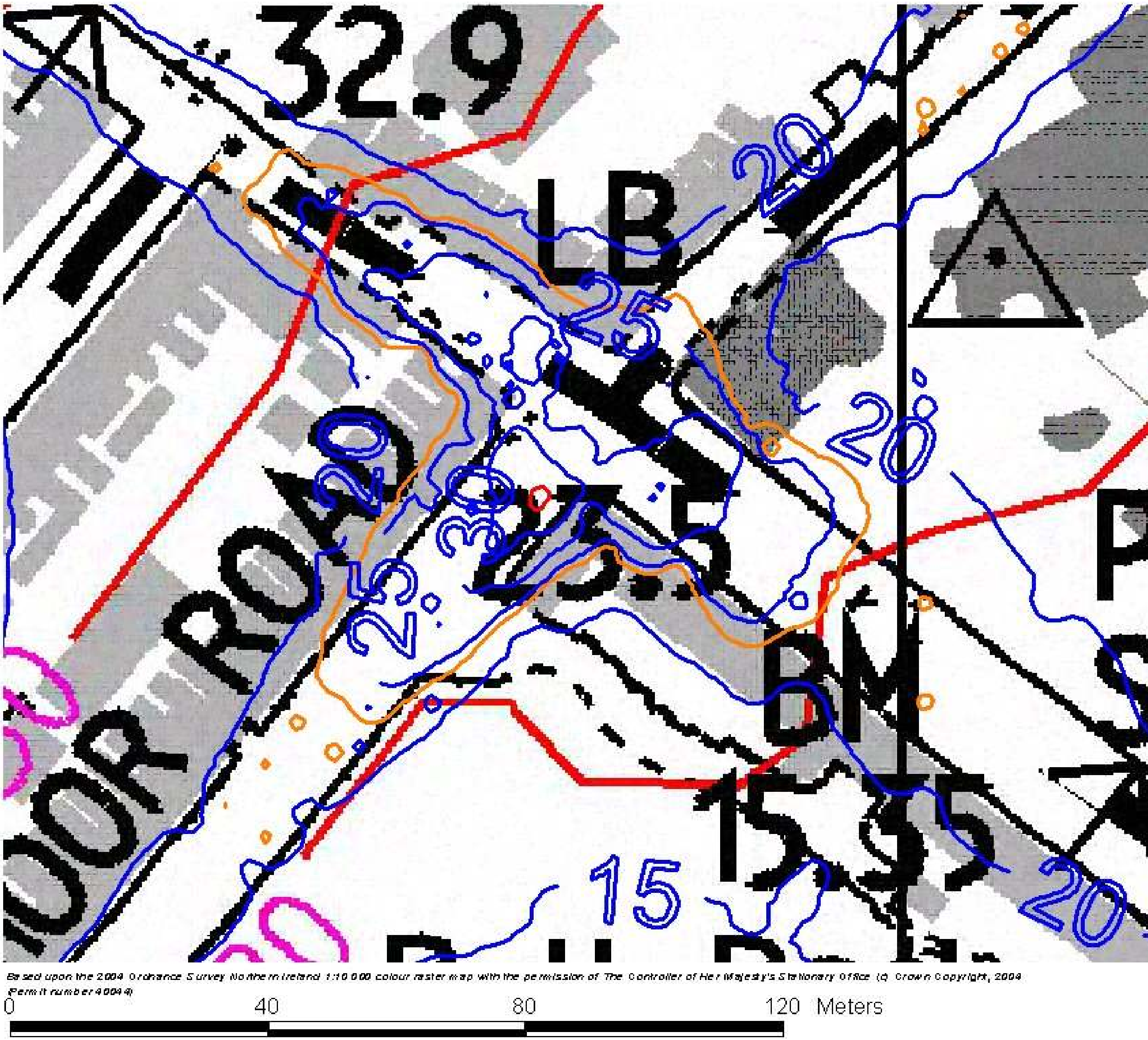
AQS objective = 200µg/m³

CERC

Derry City Council

Predicted 99.79th percentile of hourly average concentrations of NO2 (µg/m³) at Glenshane Road junction, 2005

Figure 8.29



Concentration of NO2 (µg/m³)

Predicted exceedence of NO2 AQS objective

Estimate of worst case area of exceedence of NO2 AQS objective

AQS objective = 40µg/m³

CERC

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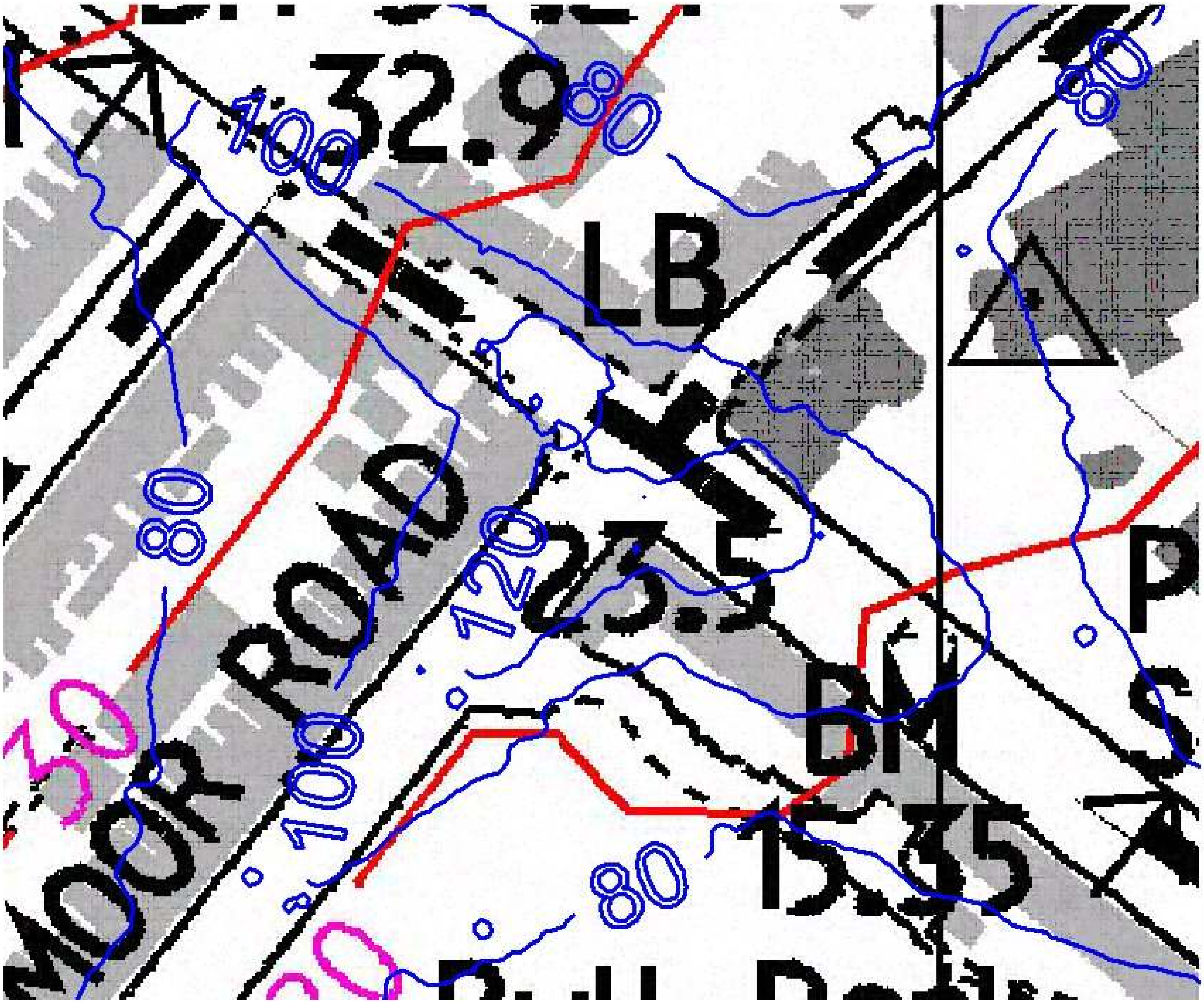
Predicted annual average concentrations of NO2 (µg/m³) at Creggan Road / Infirmary Road junction, 2005

Figure 8.30



0 50 100 Meters

Concentration of NO_2 ($\mu g/m^3$)

AQS objective = 200µg/m³

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Predicted 99.79th percentile of hourly average concentrations of NO_2 ($\mu g/m^3$) at Creggan Road / Infirmary Road junction, 2005

Figure 8.31

9. Modelling of domestic fuel use emissions

9.1 Emissions data

Figure 9.1 shows the locations of the sixteen 500m-square areas of dense urban housing and the ten 500m-square areas of rural housing considered in this study. Also shown on this figure are the locations of two major industrial point sources included in the modelling; more details of these are given later on in this section.

An initial fuel use survey was conducted by Derry City Council in 2003 to obtain information concerning the type and quantity of domestic solid fuel used in twelve 1km-square areas in the central Derry area. Average fuel consumption per week was provided for winter (October to March) and summer (April to September).

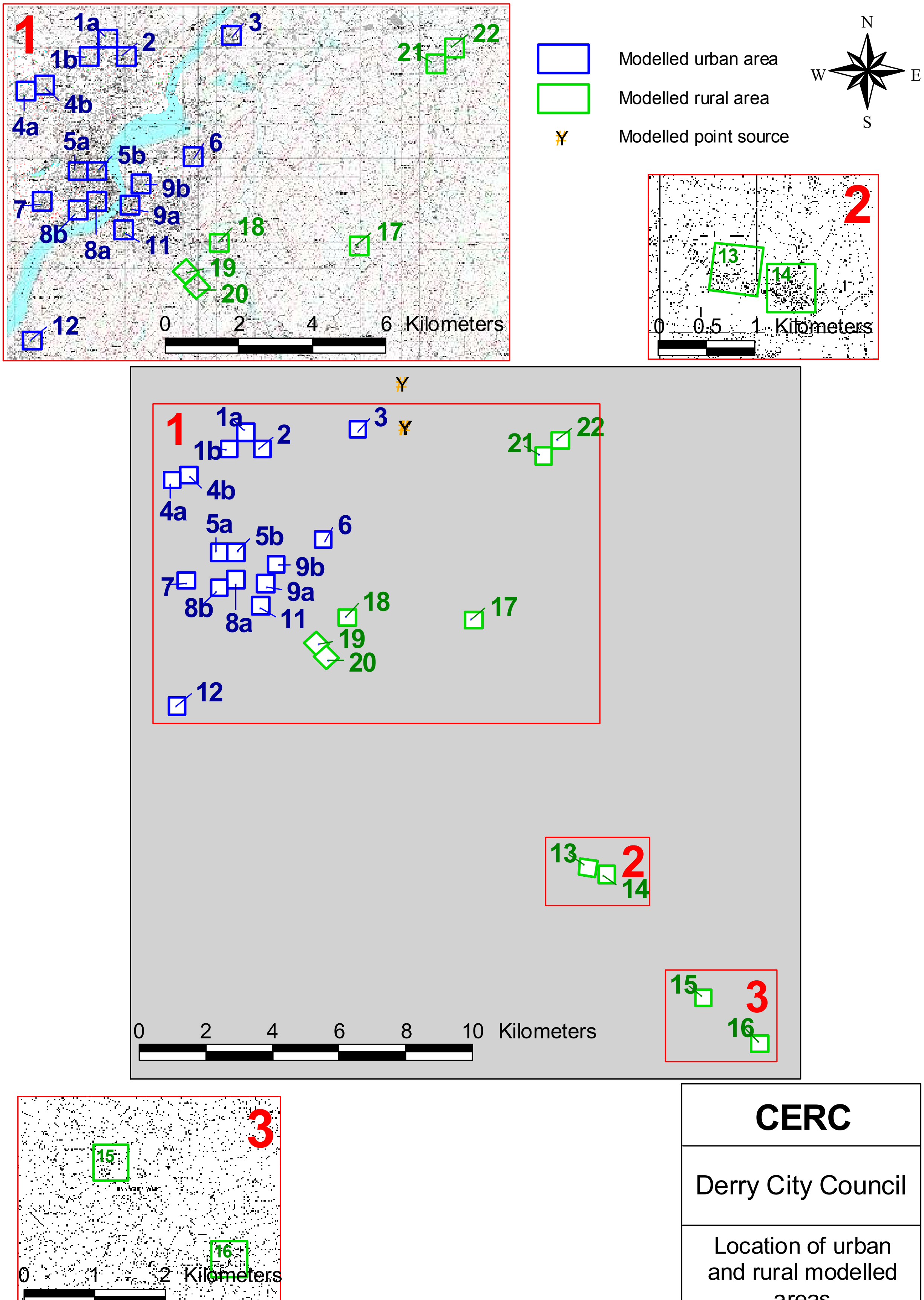
Each of the sixteen 500m-square areas of urban housing considered in this study falls within one of the twelve 1km-square areas within which the original domestic fuel use survey was carried out. To calculate the fuel use within each 500m-square area, the proportion of each 500m-square area covered by housing has been compared to the proportion of the corresponding 1km-square area covered by housing, and the fuel use data apportioned accordingly.

A second domestic fuel use survey was carried out by Derry City Council in 2003 to provide an estimate of the consumption of domestic solid fuel in the Faughanview Park area. Extrapolating from the results of this survey, the council estimated the solid fuel use in each of the other nine rural areas.

The survey data were used to calculate emissions of PM_{10} and SO_2 due to domestic solid fuel use within each of the 500m-square areas, using emission factors from the UK Emission Factors Database (UKEFD)[3]. Turf was used as the fuel in some areas, but since no emission factors are available for this fuel, emission factors for coal have been used instead, as these are the most conservative (overestimating) emission factors for solid fuel burning.

Table 9.1 presents the calculated emission rates of PM_{10} and SO_2 due to domestic solid fuel use for each of the study areas in winter and in summer.

[3] http://www.naei.org.uk/emissions/index.php



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Location of urban and rural modelled areas

Figure 9.1

Based upon the 2004 Ordnance Survey Northern Ireland 1:10 000 colour raster map with the permission of The Controller of Her Majesty's Stationary Office (c) Crown Copyright, 2004 (Permit number 40044)

Table 9.1: Emission rates due to domestic solid fuel use for winter and summer

Survey area			**Emission rate of PM_{10} (g/s)**		**Emission rate of SO_2 (g/s)**	
Type	**No.**	**Name**	**Winter**	**Summer**	**Winter**	**Summer**
Urban	1a	Galliagh a	0.11	0.05	0.39	0.18
Urban	1b	Galliagh b	0.14	0.07	0.52	0.24
Urban	2	Shantallow	0.15	0.05	0.50	0.18
Urban	3	Strathfoyle	0.10	0.05	0.35	0.19
Urban	4a	Ballymagroarty a	0.09	0.04	0.31	0.15
Urban	4b	Ballymagroarty b	0.15	0.07	0.54	0.26
Urban	5a	Rosemount a	0.11	0.03	0.24	0.07
Urban	5b	Rosemount b	0.11	0.03	0.24	0.07
Urban	6	Caw	0.08	0.04	0.27	0.13
Urban	7	Creggan	0.48	0.20	1.16	0.49
Urban	8a	Bogside a	0.16	0.07	0.45	0.19
Urban	8b	Bogside b	0.14	0.06	0.39	0.16
Urban	9a	Waterside a	0.08	0.04	0.20	0.11
Urban	9b	Waterside b	0.08	0.04	0.20	0.11
Urban	11	Gobnascale	0.18	0.05	0.39	0.12
Urban	12	Newbuildings	0.12	0.06	0.30	0.14
Rural	13	Claudy 1	0.04	0.01	0.13	0.05
Rural	14	Claudy 2	0.06	0.02	0.12	0.03
Rural	15	Slieveboy Park	0.03	0.01	0.05	0.01
Rural	16	Faughanview Park	0.09	0.02	0.18	0.05
Rural	17	Lettershendony	0.05	0.02	0.18	0.07
Rural	18	Ardnabrockie	0.08	0.02	0.16	0.04
Rural	19	Tullyalley	0.12	0.05	0.43	0.18
Rural	20	Currynairn	0.11	0.04	0.39	0.16
Rural	21	Dunverne Gardens	0.04	0.01	0.08	0.02
Rural	22	St Canice's Park	0.10	0.02	0.19	0.05

Emissions of PM_{10} and SO_2 due to domestic solid fuel use from each survey area have been modelled as volume sources, each with an area of 500m by 500m and a height of 10m. Different emission rates have been used for winter and summer, as appropriate.

Gridded emissions from the NAEI have been used to represent emissions from sources other than those represented by the emissions in Table 9.1, that is:

- domestic fuel use emissions from outside the study areas; and
- emissions from all other source types in the Derry area, with the exception of two explicitly modelled point sources.

These emissions data have been represented by a set of 1km square grid sources with a depth of 10m. The road traffic component of the data was scaled to be appropriate to each modelled year using a traffic growth factor of 2.6% per year, as for the NO_x emissions (see Section 8.1).

Emissions of PM_{10} and SO_2 from the survey areas and from the NAEI grids are shown in Figures 9.2 to 9.5, respectively.

Estimated missions from two major industrial point sources have been modelled explicitly, as to model these emissions as grid sources would lead to a gross overestimate of concentrations. The modelled stack and emission parameters of these sources, Coolkeeragh power station and Invista (UK) Ltd, are given in Table 9.2. The stack parameters were taken from data supplied by the council, and the average emissions were estimated from the emissions data included in the NAEI gridded data.

Table 9.2: Stack and emissions data for explicitly modelled point sources

	Coolkeeragh power station	**Invista (UK) Ltd**
Stack height (m)	70	42.1
Diameter (m)	6	1.1
Temperature (°C)	122	150
Exit velocity (m/s)	15.9	14.4
Emission rate of PM_{10} (g/s)	4.2	-
Emission rate of SO_2 (g/s)	168	23.5

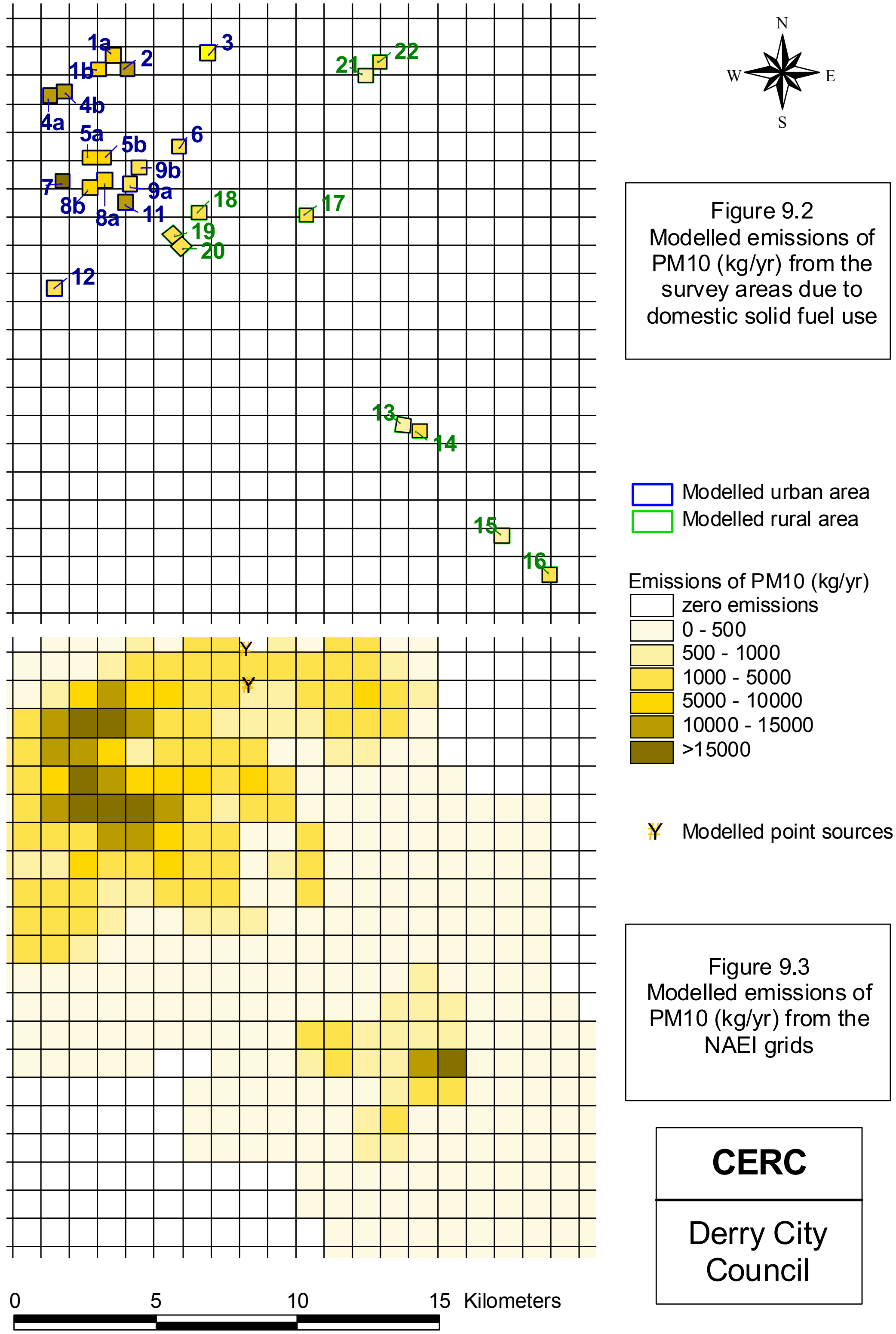

Figure 9.2
Modelled emissions of PM10 (kg/yr) from the survey areas due to domestic solid fuel use

Figure 9.3
Modelled emissions of PM10 (kg/yr) from the NAEI grids

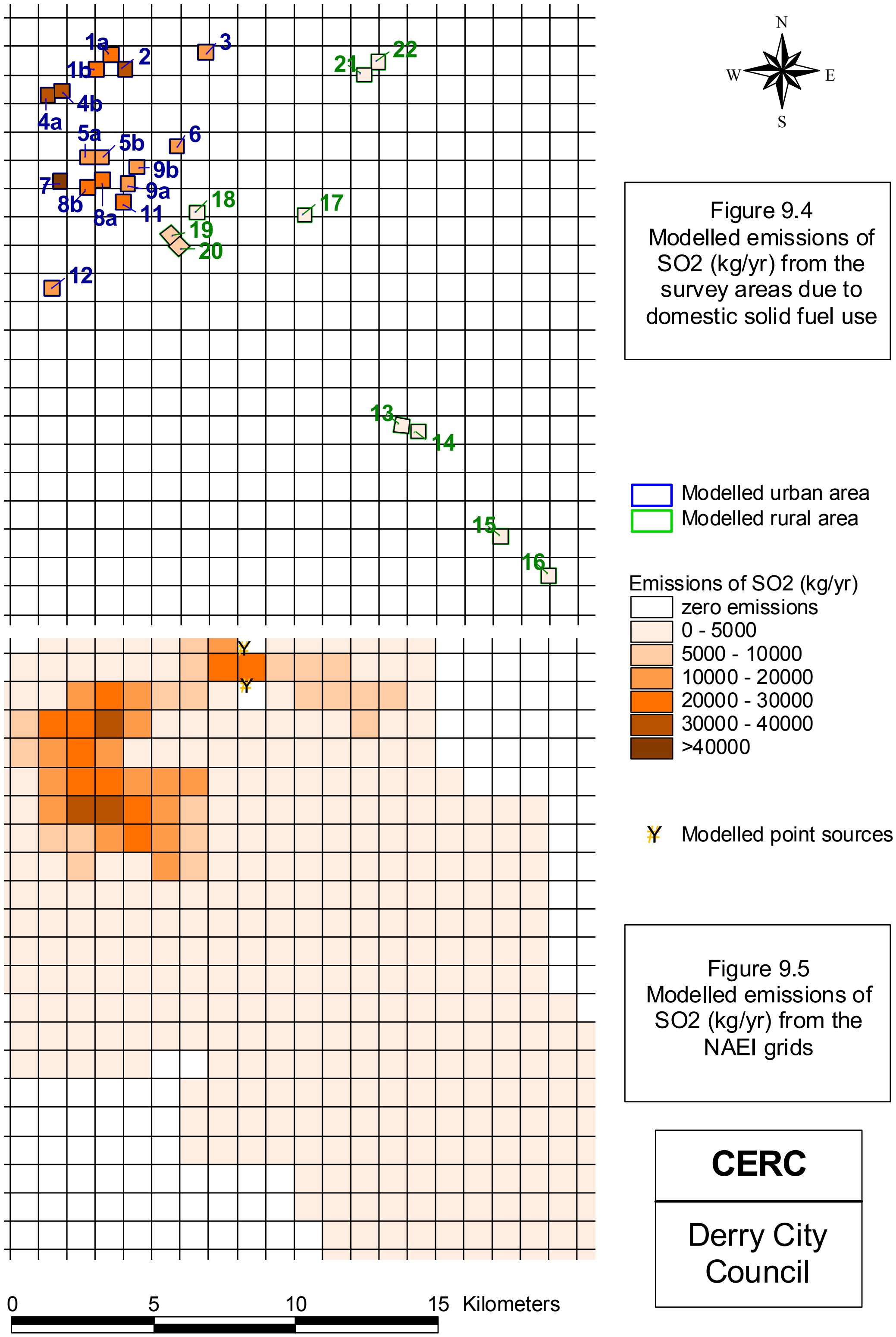

Figure 9.4
Modelled emissions of SO2 (kg/yr) from the survey areas due to domestic solid fuel use

Figure 9.5
Modelled emissions of SO2 (kg/yr) from the NAEI grids

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9.2 Model Verification

Receptor points located at the site of each monitor were included in the modelling so that the predicted concentrations from the modelling could be directly compared with the monitored concentrations. The locations of the receptor points are shown in Figure 7.1.

9.2.1 Model verification for PM_{10}

Predicted concentrations of PM_{10} were compared with monitoring data recorded at the AURN site and at the continuous monitor at Brandywell. Note that all PM_{10} data are expressed as gravimetric equivalent. A comparison of the monitored and predicted concentrations of PM_{10} for the period April 2002 to March 2003 is presented in Table 9.3.

Table 9.3: Comparison of monitored and modelled concentrations of PM_{10} ($\mu g/m^3$) (April 2002 to March 2003)

	Annual average		90.41^{st} percentile of 24-hour averages		98.08^{th} percentile of 24-hour averages	
	monitored	**modelled**	**monitored**	**modelled**	**monitored**	**modelled**
AURN site	22.4	22.9	40.8	34.0	66.3	50.5
Brandywell	27.5	22.6	50.8	34.5	77.0	50.0

Table 9.3 shows that there is good agreement between the modelled and monitored annual average concentrations of PM_{10}, and reasonable agreement between the modelled and monitored percentile statistics of concentrations of PM_{10} at the AURN site. The model tends to underpredict the percentile values; this is likely to be because peak emissions are not represented in the emissions data. Emissions data for the domestic sources are winter and summer average emissions, and there is no representation of times when emissions may be above average, for example during a cold spell.

Agreement between modelled and monitored concentrations at the Brandywell site is less good. The modelled concentrations at the AURN site and at Brandywell are very similar, indicating that better agreement at the Brandywell site cannot be obtained by making alterations to the model parameters or modelling methodology. Table 9.4 shows a breakdown of the contributions to the modelled annual average concentration of PM_{10} at each of the monitoring sites.

Table 9.4: Contributions to the modelled annual average concentration of PM_{10} ($\mu g/m^3$)

	Modelled annual average	Contribution from explicitly modelled sources	Contribution from gridded emissions	Background concentration
AURN site	22.9	0.8	6.8	15.3
Brandywell	22.6	1.1	6.2	15.3

Table 9.4 shows that the contribution from the explicitly modelled sources, that is the volume sources used to represent the domestic heating emissions, is similar at both sites. This is to be expected, as the level of fuel use in these areas is similar. This suggests that the higher concentrations recorded at Brandywell are due to some other source of emissions local to the monitor. Within 200m of the Brandywell monitor there are two schools and a football stadium, which may be significant sources of particulates. Although emissions from these sources may be included in the NAEI gridded emissions, they were not explicitly modelled. Consequently, emissions from these sources have been distributed over the 1km grid rather than being focused at the source locations.

To ensure that predicted concentrations of PM_{10} are not being underestimated at any location, a worst case adjustment was calculated, and applied to the non-background component of the predicted modelled concentrations. The adjustment factor (A) was calculated from the comparison between modelled and monitored concentrations at the Brandywell site, as this site showed the greatest difference between modelled and monitored concentrations. Table 9.5 shows the adjustment factor applied to each modelled statistic.

Table 9.5: Calculation of adjustment factors for PM_{10} at Brandywell

	Annual average	**90.41st percentile of 24-hour averages**	**98.08th percentile of 24-hour averages**
Monitored concentration (µg/m^3)	27.5	50.8	66.3
Modelled concentration (µg/m^3)	22.6	34.5	50.5
Background concentration (µg/m^3)	15.3	15.3	15.3
Monitored – background concentration (µg/m^3) (X)	12.2	35.5	51.0
Modelled – background concentration (µg/m^3) (Y)	7.3	19.2	35.2
Adjustment factor (=X/Y)	**1.7**	**1.8**	**1.4**

The adjusted concentration for each of the modelled objectives was calculated as follows:

Adjusted concentration = A*(modelled concentration – B) + B

where A is the adjustment factor and B is the background concentration.

It should be noted that these adjustment factors are based on the comparison between modelled and monitored concentrations at the Brandywell site only, and represent a worst case. It is likely that the future concentrations at most locations will be lower than the concentrations calculated by applying this adjustment.

9.2.2 Model verification for SO_2

Predicted concentrations of SO_2 were compared with hourly and 15-minute monitoring data recorded at the AURN site and at Brandywell, and with monthly data recorded at the SO_2 diffusion tube locations. A comparison of the monitored and predicted concentrations of SO_2 for the period April 2002 to March 2003 is presented in Table 9.6 (overleaf). Figure 9.1 shows a comparison of the monitored and modelled annual average SO_2 concentrations.

Table 9.6 and Figure 9.1 show that the monitored and modelled annual average concentrations of SO_2 agree to within a factor of two. This comparison is useful, in that good agreement lends confidence to the model inputs. However, all of the objectives for SO_2 are short-term objectives, and so good agreement with percentile values is of most concern.

Table 9.6 shows that at the AURN site the model overpredicts the percentile values compared to the monitoring data, whereas at the Brandywell site the model underpredicts the percentile values.

As was done for PM_{10}, to ensure that predicted concentrations of SO_2 are not being underestimated at any location, a worst case adjustment was made to the predicted modelled concentrations. The adjustment factor was calculated from the comparison between modelled and monitored concentrations at the Brandywell site. Table 9.7 shows the adjustment factor applied to each modelled statistic.

Table 9.7: Calculation of adjustment factors for SO_2

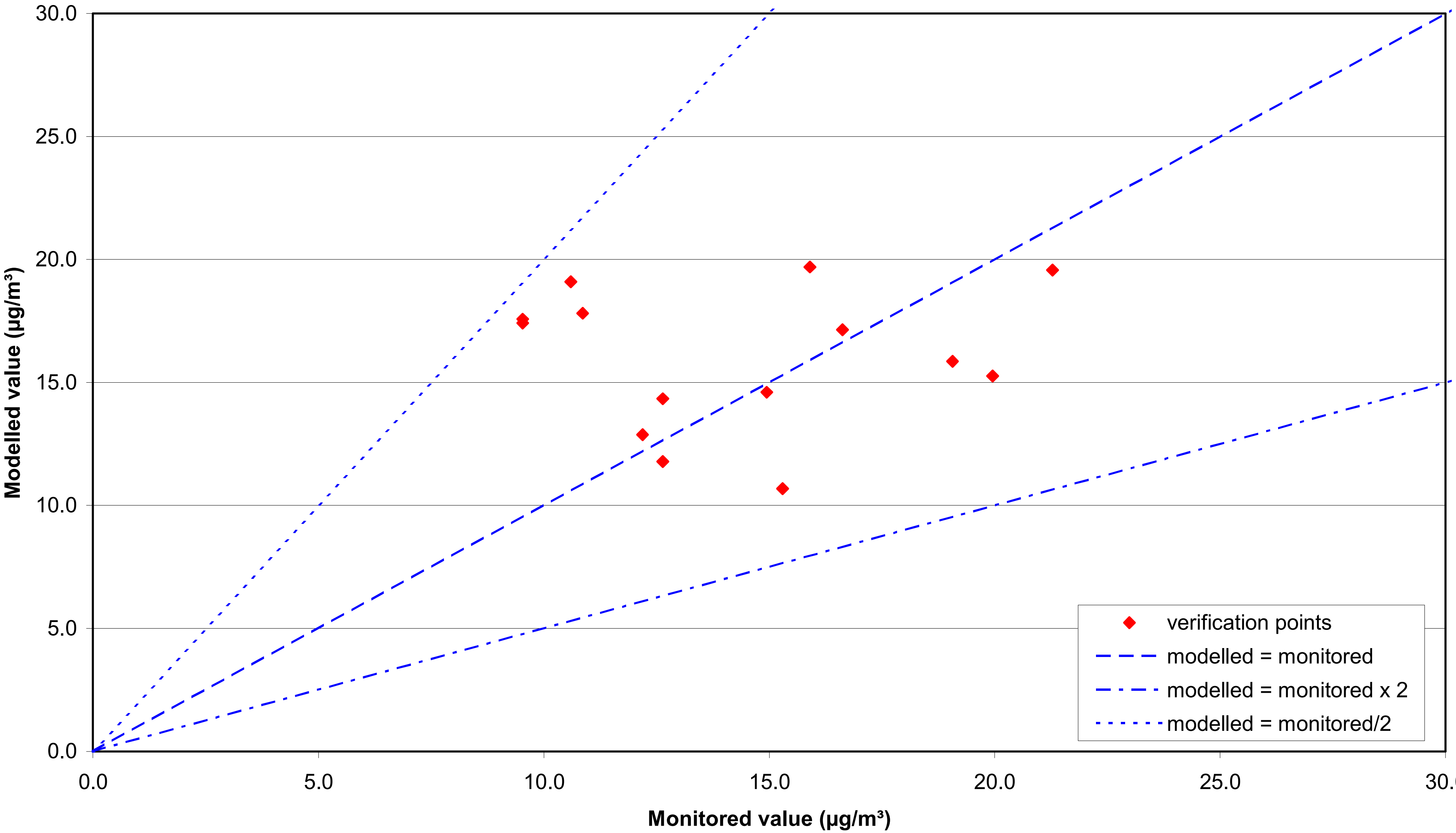
	99.73rd percentile of hourly averages	**99.18th percentile of 24-hour averages**	**99.9th percentile of 15-minute averages**
Monitored concentration (µg/m^3)	133.0	68.2	192.4
Modelled concentration (µg/m^3)	95.4	51.0	117.1
Background concentration (µg/m^3)	5.8	5.8	5.8
Monitored – background concentration (µg/m^3) (X)	127.2	62.4	186.6
Modelled – background concentration (µg/m^3) (Y)	59.6	45.2	111.3
Adjustment factor (X/Y)	**2.1**	**1.4**	**1.7**

It should be noted that these adjustment factors are based on the comparison between modelled and monitored concentrations at the Brandywell site only, and represent a worst case. It is likely that the future concentrations at most locations will be lower than the concentrations calculated by applying this adjustment, especially given that the model overpredicts concentrations at the AURN site, and applying this worst case adjustment will give an even greater overprediction.

Table 9.6: Comparison of monitored and modelled concentrations of SO_2 ($\mu g/m^3$) (April 2002 to March 2003)

	Annual average		**99.73rd percentile of hourly averages**		**99.18th percentile of 24-hour averages**		**99.9th percentile of 15-minute averages**	
	monitored	**modelled**	**monitored**	**modelled**	**monitored**	**modelled**	**monitored**	**modelled**
AURN site	10.6	19.1	66.5	87.2	35.0	46.8	91.2	105.5
Brandywell	15.9	19.7	133.0	95.4	68.2	51.0	192.4	117.1
Greenhaw Road	9.5	17.6	-	-	-	-	-	-
Silverbirch Crescent	12.6	14.3	-	-	-	-	-	-
Tullyally	15.3	10.7	-	-	-	-	-	-
Dunaff Gardens	9.5	17.4	-	-	-	-	-	-
Auglish Court	12.6	11.8	-	-	-	-	-	-
Bawnmore Place	12.2	12.9	-	-	-	-	-	-
Hillcress House	14.9	14.6	-	-	-	-	-	-
Violet Street	16.6	17.1	-	-	-	-	-	-
Park Avenue	10.9	17.8	-	-	-	-	-	-
Marianus Park	20.0	15.3	-	-	-	-	-	-
Galliagh Park	19.1	15.9	-	-	-	-	-	-
Brandywell	21.3	19.6	-	-	-	-	-	-

Figure 9.1: Comparison of modelled and monitored annual average SO2 concentrations



9.3 Predicted Concentrations for PM_{10} and SO_2

All results presented in this section have been adjusted as discussed in Section 9.2. All maps are orientated with north pointing up the page.

9.3.1 Predicted concentrations of PM_{10}, 2004

Figures 9.7 to 9.16 show the predicted annual average concentrations of PM_{10} and the predicted 90.41^{st} percentile of daily average concentrations of PM_{10} for 2004 across the twenty-six modelled squares.

Figures 9.7 and 9.8a show predicted concentrations for the sixteen squares of dense urban housing plus the three rural squares covering Ardnabrockie, Tullyalley and Currynairn. Figure 9.8b shows the predicted area of possible exceedence of the 90.41^{st} percentile of daily average concentrations of PM_{10}. The predicted concentrations over the outlying rural squares are shown in Figures 9.9 to 9.16.

Table 9.8 summarises the maximum predicted annual average concentrations of PM_{10} and the maximum predicted 90.41^{st} percentile of daily average concentrations of PM_{10} for 2004 within each of the squares. Exceedences of the AQS objectives are shown in red.

Figures 9.7 to 9.16 and Table 9.8 show that there are no predicted exceedences of the 2004 annual average AQS objective for PM_{10} at any of the urban or rural locations. The maximum predicted annual average concentration of PM_{10} of 30.7$\mu g/m^3$ occurs at Ballymagroarty (site b), equivalent to 77% of the 2004 AQS objective.

The 90.41^{st} percentile of daily average concentrations of PM_{10} is predicted to be exceeded in three of the modelled areas, Bogside (site b), Ballymagroarty (site b) and Claudy.

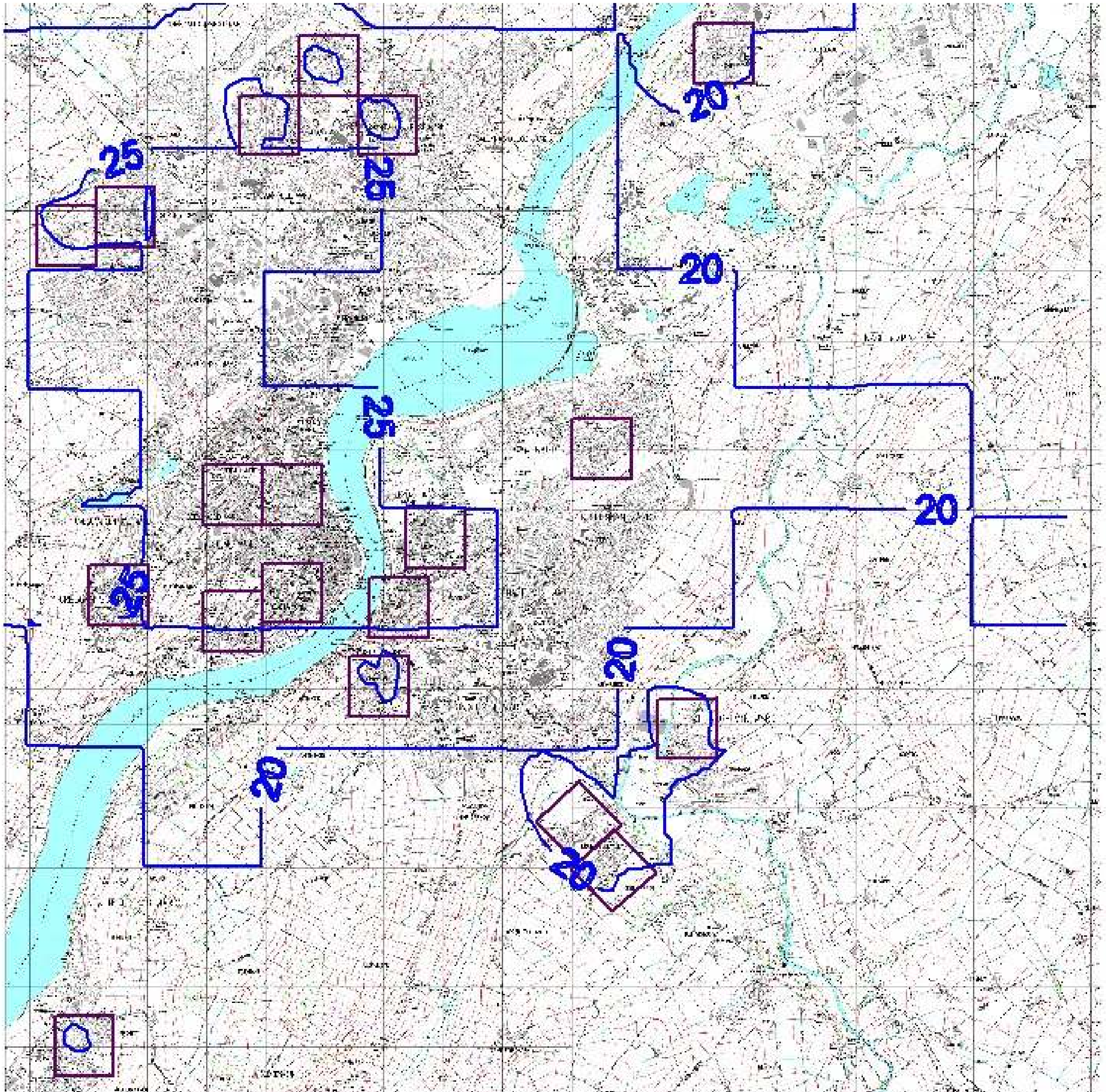
Figure 9.8b shows the predicted area of possible exceedence at Bogside (site b). Concentrations across the whole of Derry were adjusted using factors derived from the Brandywell monitoring site, located in the Bogside area, so the exceedence at this location is supported by local monitoring data.

Figure 9.8c shows the predicted area of possible exceedence at Ballymagroarty (site b). The exceedence is marked in pink, rather than red, to avoid confusion with the height contours on the map. The exceedence covers a small area, which coincides with the area where two squares of gridded emissions data meet. As Table 9.8 shows, the adjusted figures in the Ballymagroarty area only just exceed the objective value; concentrations across the whole of Derry were adjusted using factors derived from the Brandywell monitoring site, and at this location this high adjustment may lead to an overestimate of the impact. The area of exceedence is small, and the values only exceed by a small amount, so given the high adjustment factor it is likely that this is not a cause for concern.

Figure 9.10 shows a predicted exceedence in the Claudy area. The boundary of the predicted area of exceedence coincides with the edge of a square of the gridded emissions data, indicating that this exceedence is caused by high levels of emissions from the grid squares, rather than from the domestic heating emissions in Claudy. Concentrations across the whole of Derry were adjusted using factors derived from the Brandywell monitoring site, and at this rural location this high adjustment is likely to lead to a gross overestimate of the impact. It is unlikely that this predicted exceedence is a real one, however the modelled results do indicate that emissions in the Claudy area may be of more concern than in the other rural areas.

Table 9.8: Maximum predicted concentrations of PM_{10} ($\mu g/m^3$), 2004

Survey area			Maximum annual average		Maximum 90.41st percentile of daily average	
Type	**No.**	**Name**	**Predicted concentration ($\mu g/m^3$)**	**% of 2004 AQS objective**	**Predicted concentration ($\mu g/m^3$)**	**% of 2004 AQS objective**
Urban	1a	Galliagh a	25.4	64	42.9	86
Urban	1b	Galliagh b	29.8	75	49.1	98
Urban	2	Shantallow	29.3	73	47.6	95
Urban	3	Strathfoyle	22.0	55	38.3	77
Urban	4a	Ballymagroarty a	26.1	65	44.7	89
Urban	4b	Ballymagroarty b	30.7	77	50.2	100
Urban	5a	Rosemount a	29.7	74	49.9	100
Urban	5b	Rosemount b	28.7	72	47.7	95
Urban	6	Caw	24.0	60	40.0	80
Urban	7	Creggan	30.1	75	49.7	99
Urban	8a	Bogside a	29.6	74	49.9	100
Urban	8b	Bogside b	29.8	75	50.8	102
Urban	9a	Waterside a	27.7	69	45.4	91
Urban	9b	Waterside b	27.6	69	45.3	91
Urban	11	Gobnascale	25.8	65	43.0	86
Urban	12	Newbuildings	20.2	51	36.2	72
Rural	13	Claudy 1	31.6	79	62.7	125
Rural	14	Claudy 2	31.7	79	62.6	125
Rural	15	Slieveboy Park	18.2	46	33.1	66
Rural	16	Faughanview Park	19.0	48	34.5	69
Rural	17	Lettershendony	21.5	54	37.4	75
Rural	18	Ardnabrockie	20.7	52	36.8	74
Rural	19	Tullyalley	22.1	55	38.1	76
Rural	20	Currynairn	21.8	55	37.9	76
Rural	21	Dunverne Gardens	23.0	58	39.9	80
Rural	22	St Canice's Park	23.7	59	40.7	81



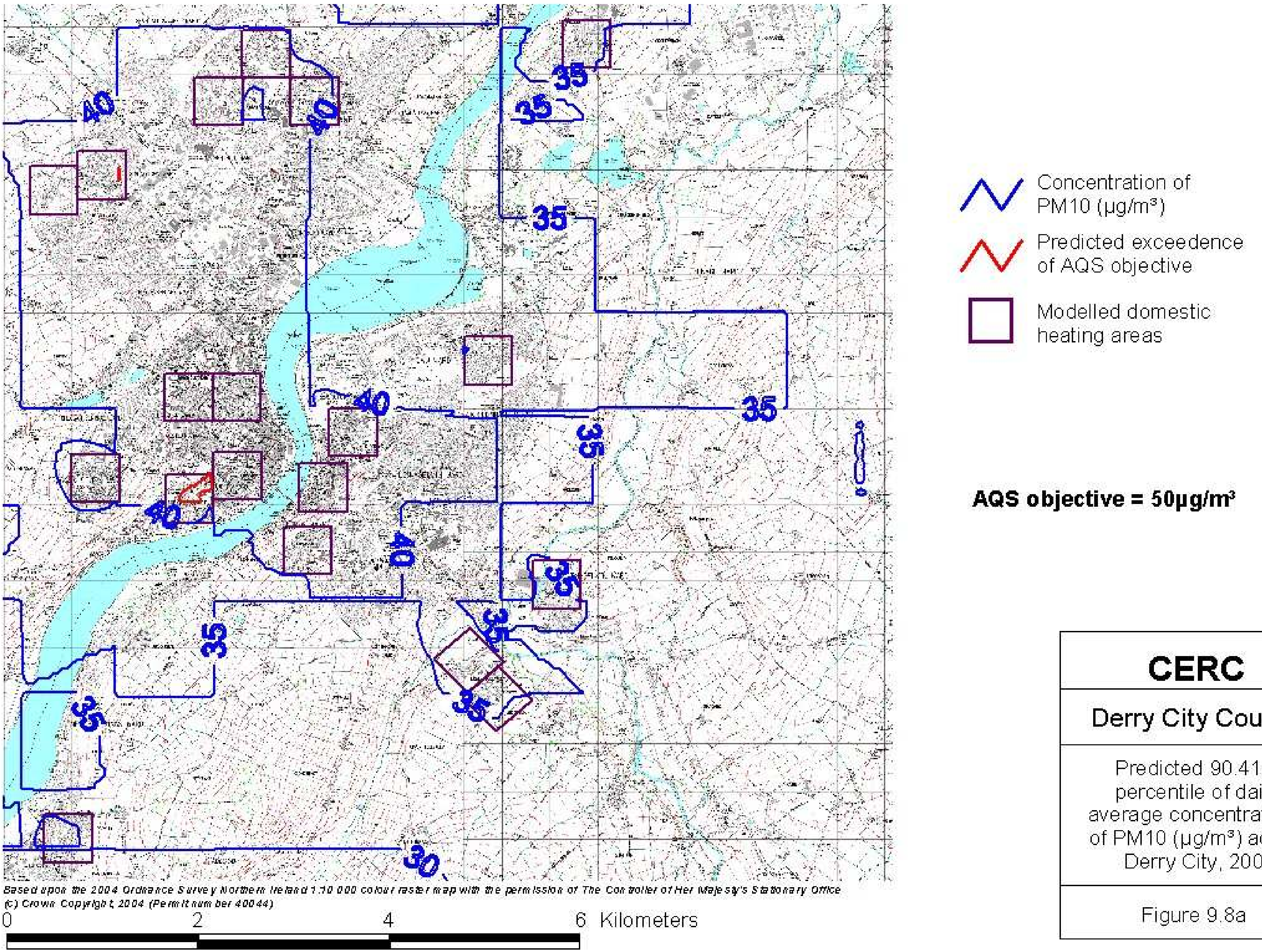
0 2 4 6 Kilometers

Concentration of PM10 (µg/m³)

Modelled domestic heating areas

AQS objective = 40µg/m³

CERC
Derry City Council
Predicted annual average concentrations of PM10 (µg/m³) across Derry City, 2004
Figure 9.7

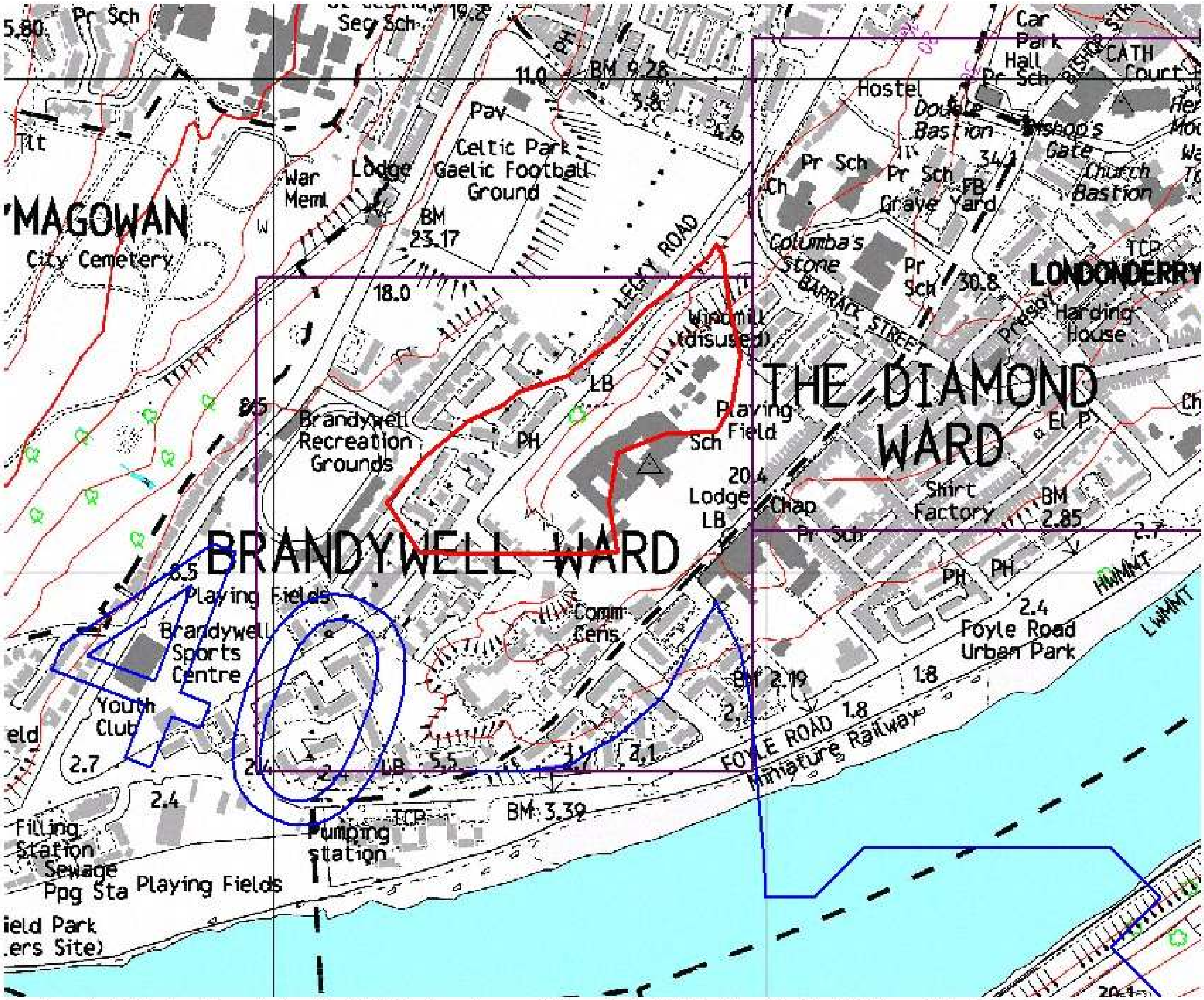


CERC

Derry City Council

Predicted 90.41st percentile of daily average concentrations of PM10 (µg/m³) across Derry City, 2004

Figure 9.8a



0 0.2 0.4 0.6 0.8 Kilometers

Concentration of PM10 (µg/m³)

Predicted exceedence of AQS objective

Modelled domestic heating areas

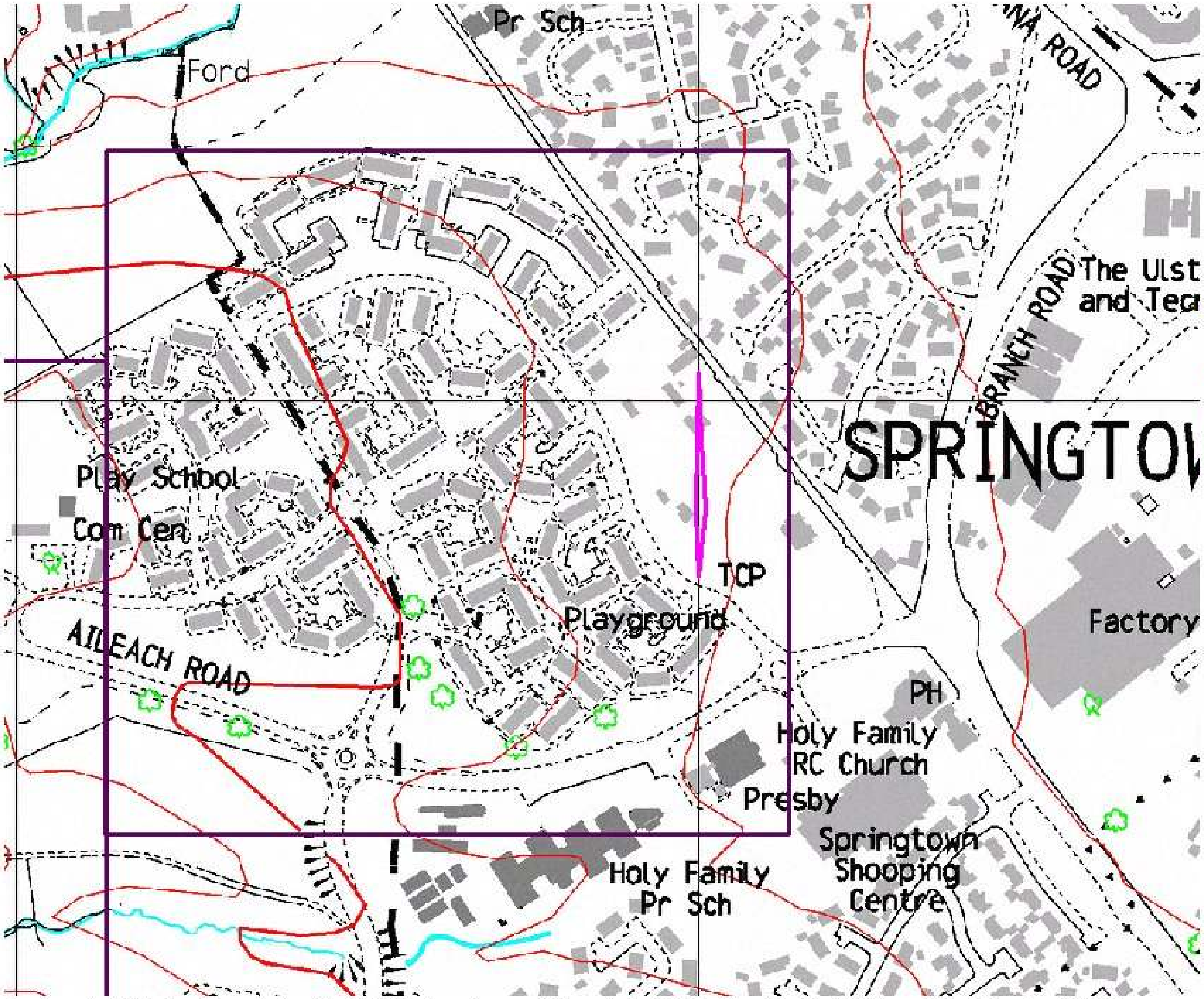
AQS objective = 50µg/m³

CERC

Derry City Council

Predicted 90.41st percentile of daily average concentrations of PM10 (µg/m³) at Bogside, 2004

Figure 9.8b



Concentration of PM10 (µg/m³)

Predicted exceedence of AQS objective

Modelled domestic heating areas

AQS objective = 50µg/m³

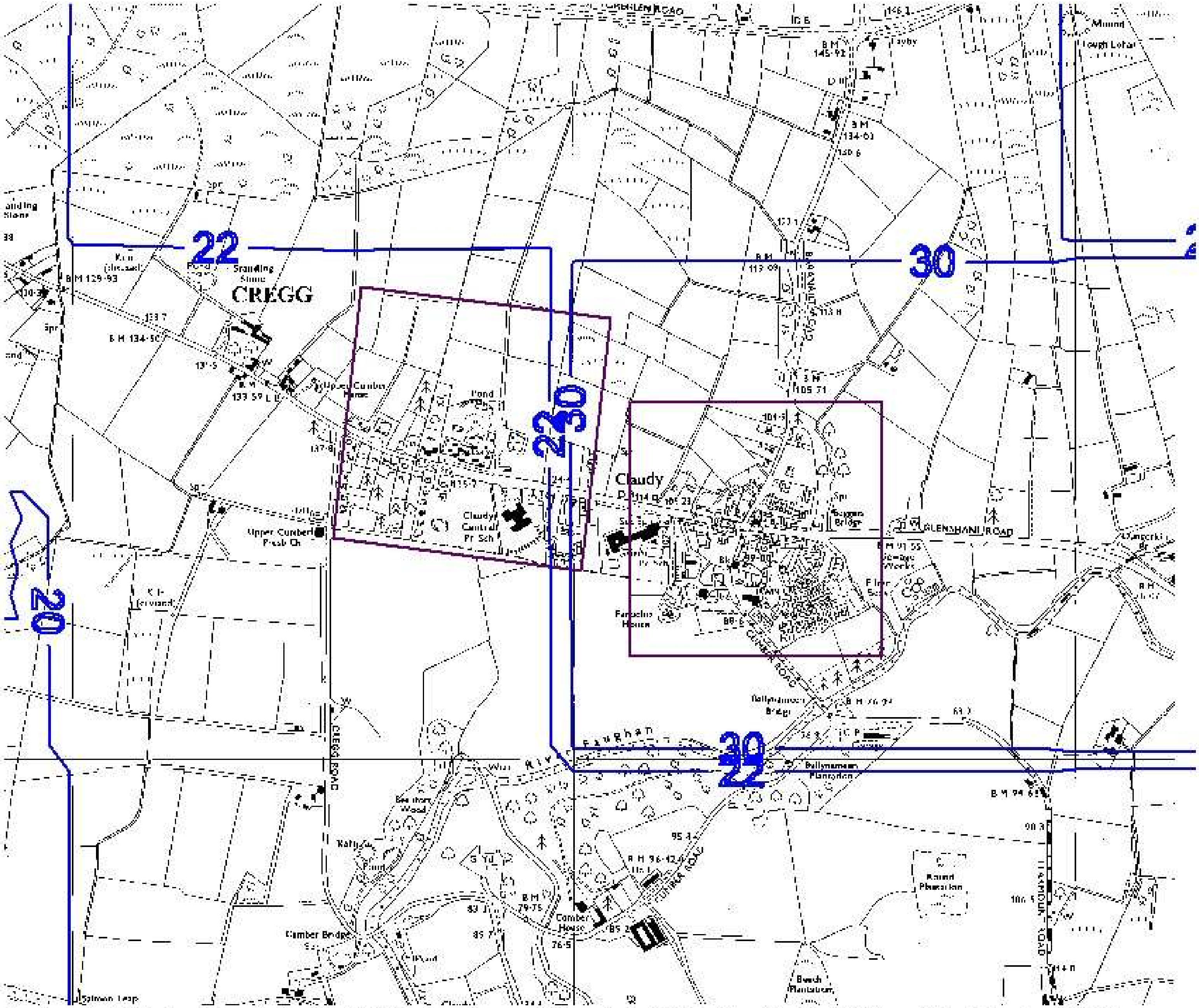
0 0.2 0.4 0.6 0.8 Kilometers

CERC

Derry City Council

Predicted 90.41st percentile of daily average concentrations of PM10 (µg/m³) at Ballymagroarty, 2004

Figure 9.8c



Concentration of PM10 (µg/m³)

Modelled domestic heating areas

AQS objective = 40µg/m³

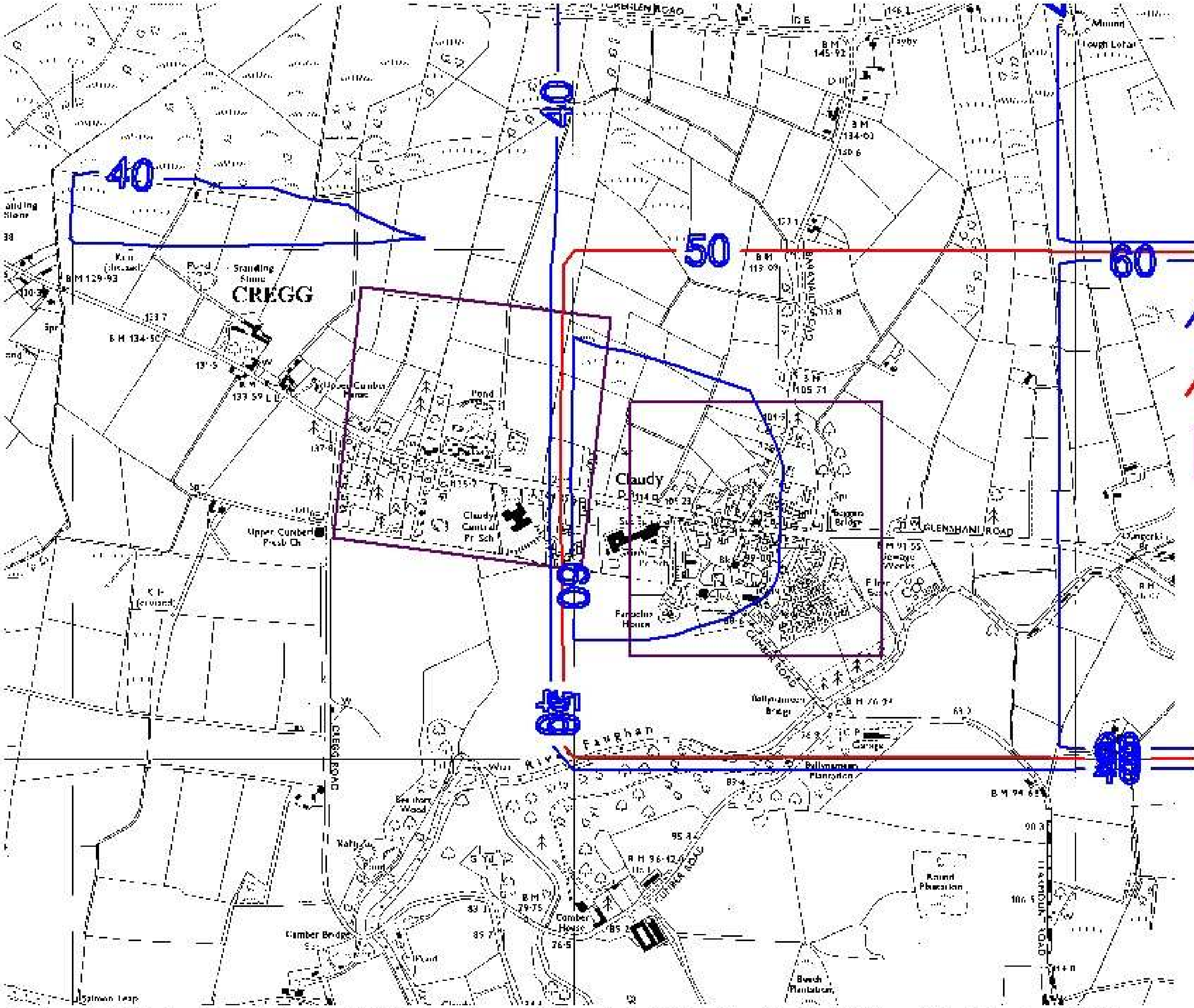
0 0.4 0.8 1.2 1.6 Kilometers

CERC

Derry City Council

Predicted annual average concentrations of PM10 (µg/m³) at Claudy, 2004

Figure 9.9



0 0.4 0.8 1.2 1.6 Kilometers

Concentration of PM10 (µg/m³)

Predicted exceedence of AQS objective

Modelled domestic heating areas

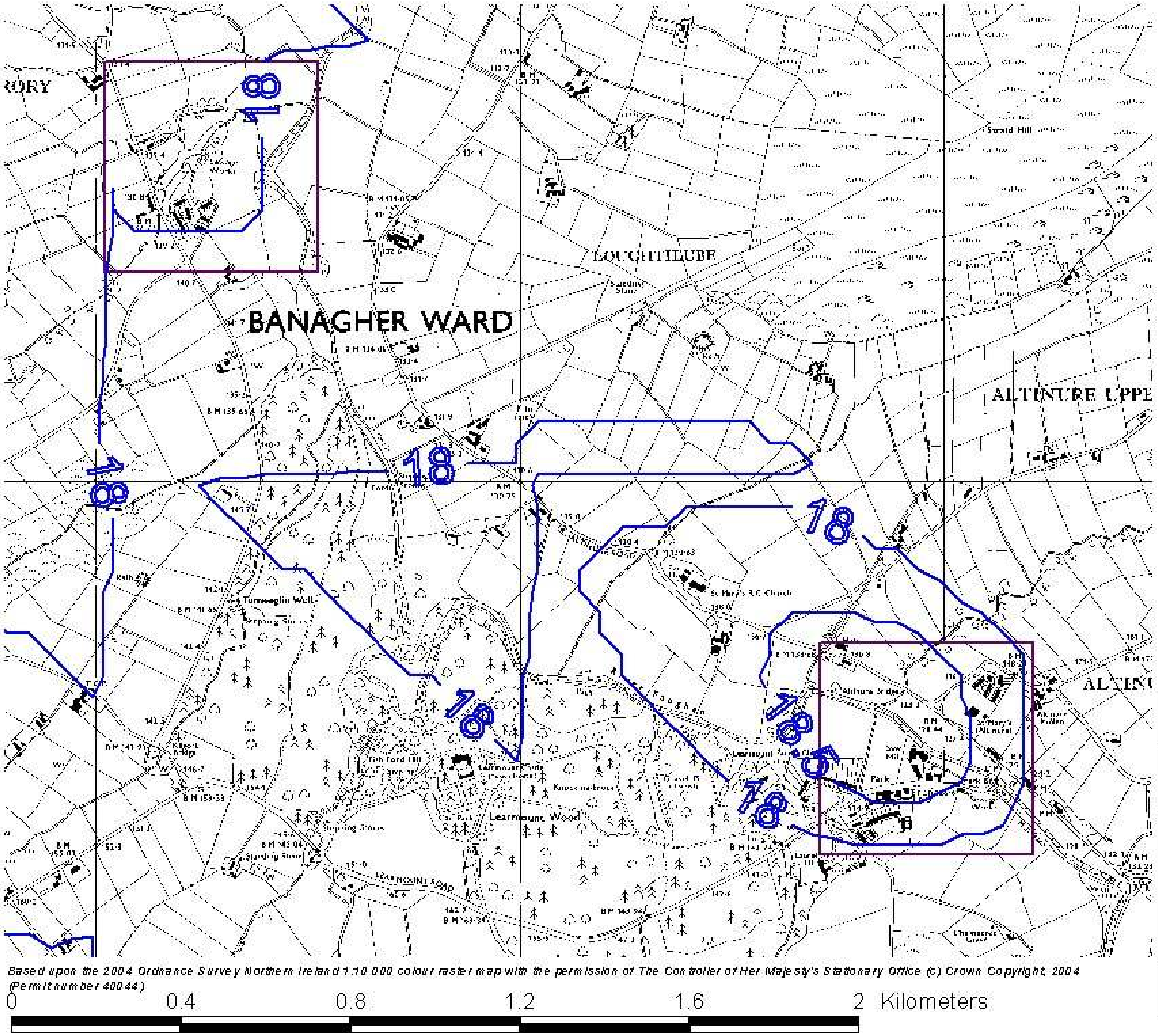
AQS objective = 50µg/m³

CERC

Derry City Council

Predicted 90.41st percentile of daily average concentrations of PM10 (µg/m³) at Claudy, 2004

Figure 9.10



Concentration of PM10 (µg/m³)

Modelled domestic heating areas

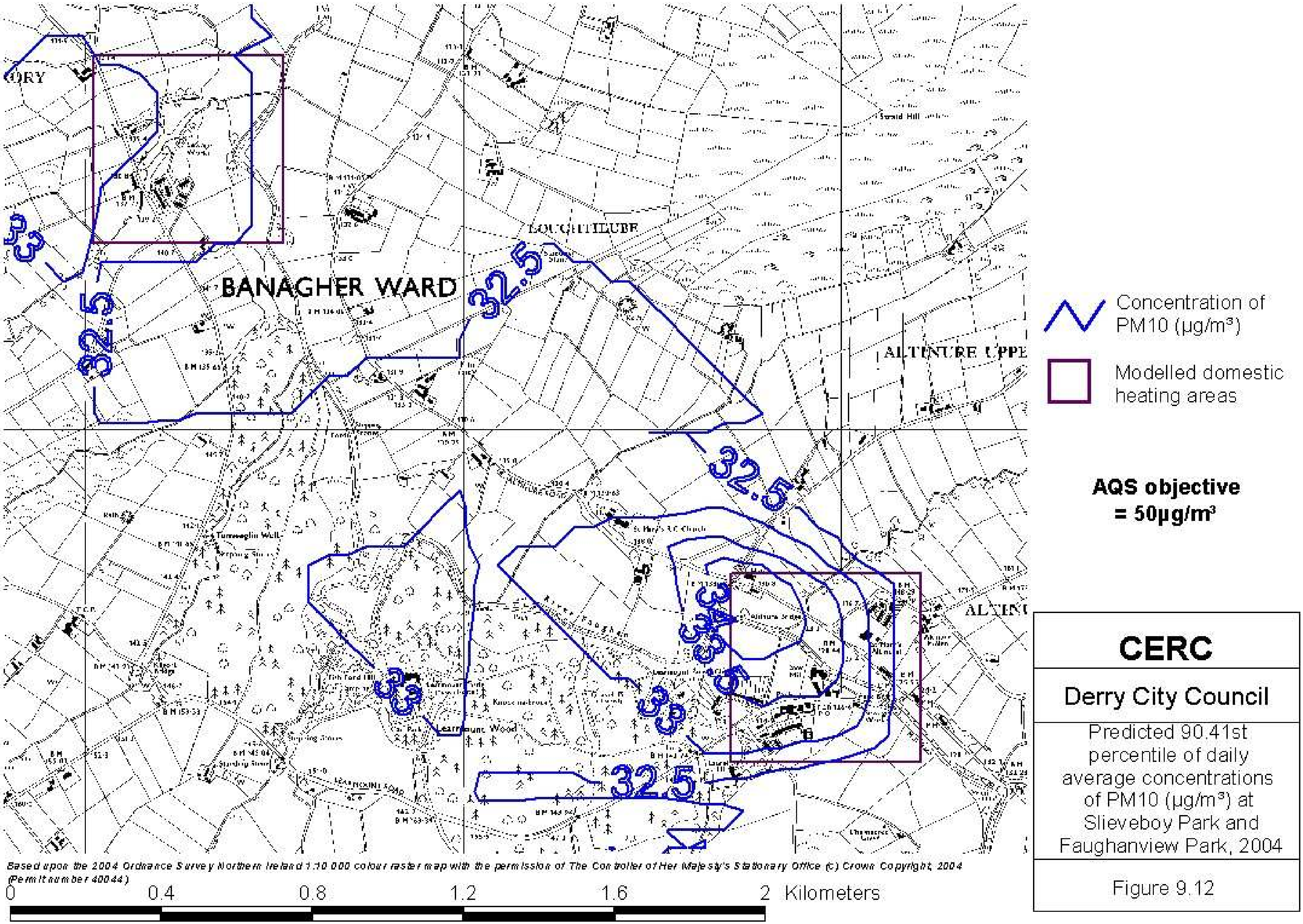
AQS objective = 40µg/m³

CERC

Derry City Council

Predicted annual average concentrations of PM10 (µg/m³) at Slieveboy Park and Faughanview Park, 2004

Figure 9.11

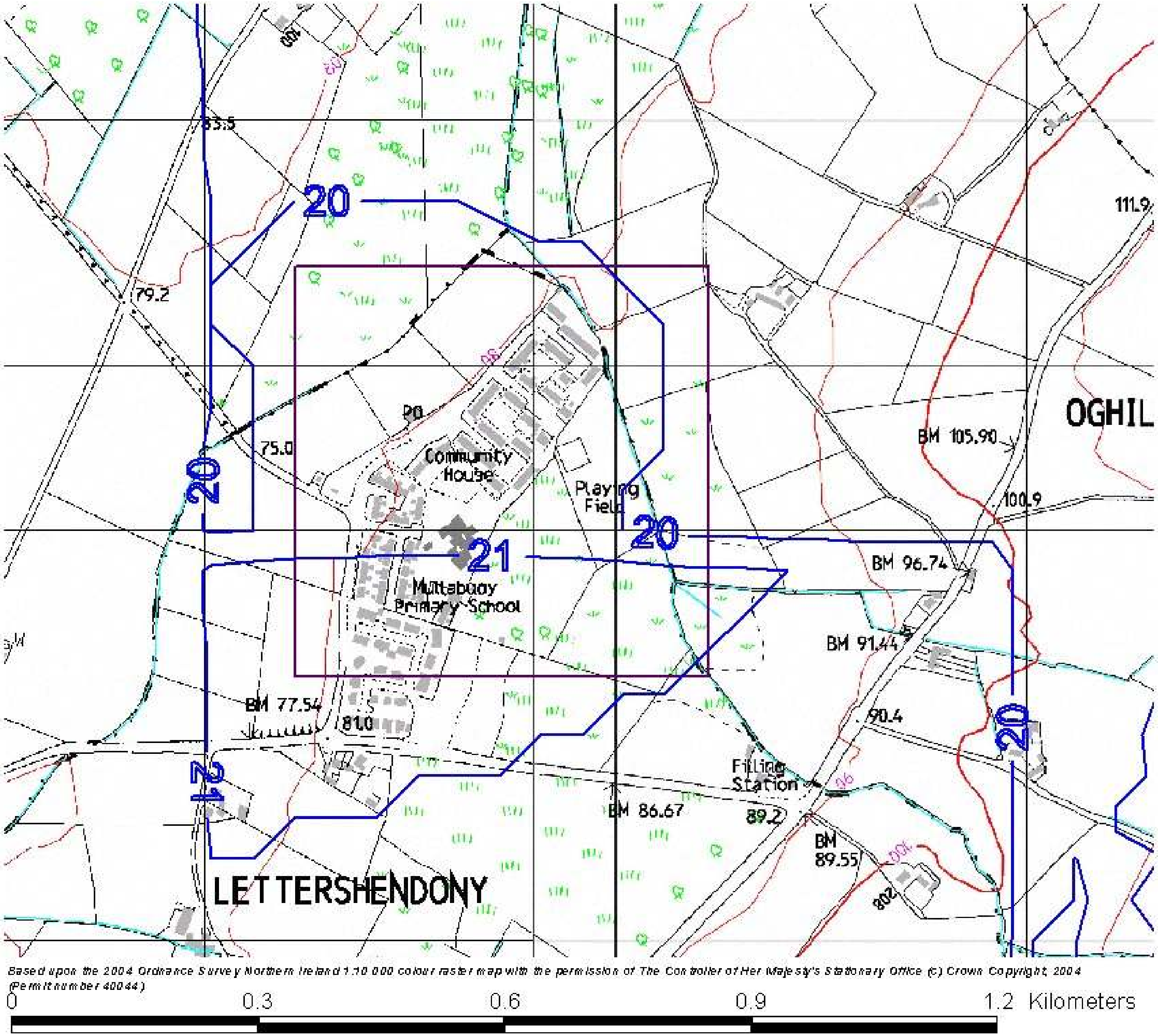


CERC

Derry City Council

Predicted 90.41st percentile of daily average concentrations of PM10 (µg/m³) at Slieveboy Park and Faughanview Park, 2004

Figure 9.12



Concentration of PM10 (µg/m³)

Modelled domestic heating areas

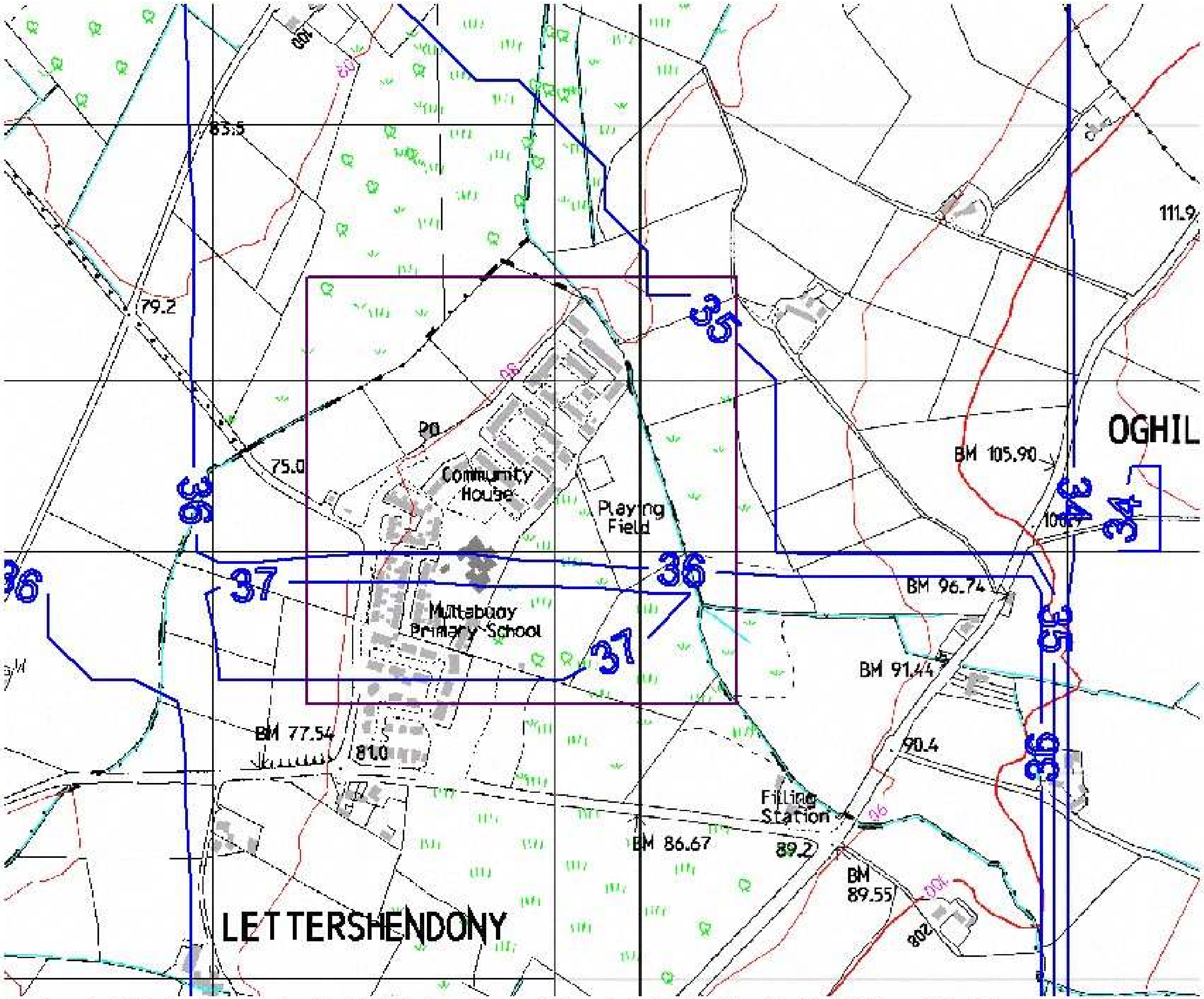
AQS objective = 40µg/m³

CERC

Derry City Council

Predicted annual average concentrations of PM10 (µg/m³) at Lettershendony, 2004

Figure 9.13



Concentration of PM10 (µg/m³)

Modelled domestic heating areas

AQS objective = 50µg/m³

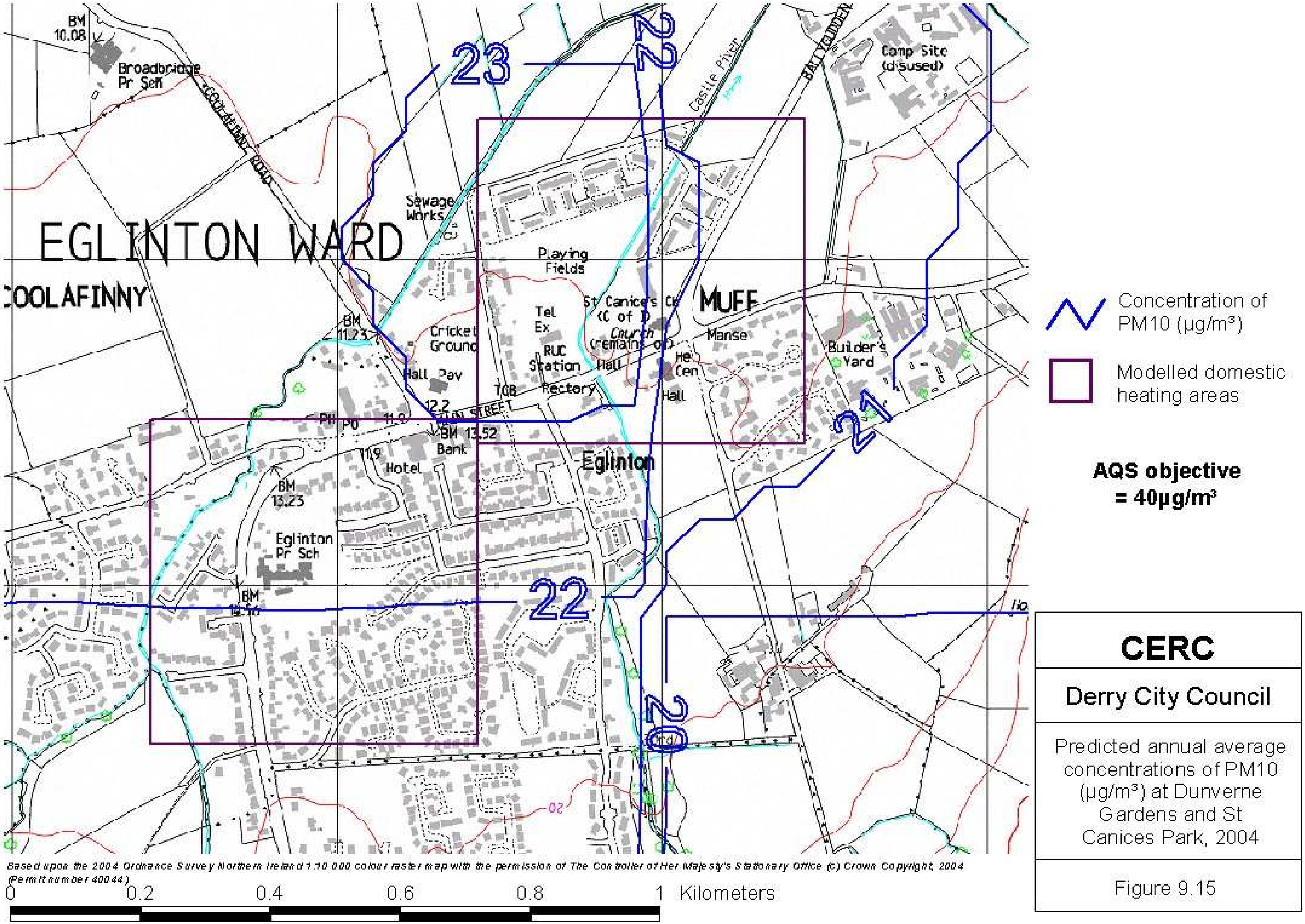
0 0.2 0.4 0.6 0.8 1 Kilometers

CERC

Derry City Council

Predicted 90.41st percentile of daily average concentrations of PM10 (µg/m³) at Lettershendony, 2004

Figure 9.14



Based upon the 2004 Ordnance Survey Northern Ireland 1:10 000 colour raster map with the permission of The Controller of Her Majesty's Stationary Office (c) Crown Copyright, 2004 (Permit number 40044)

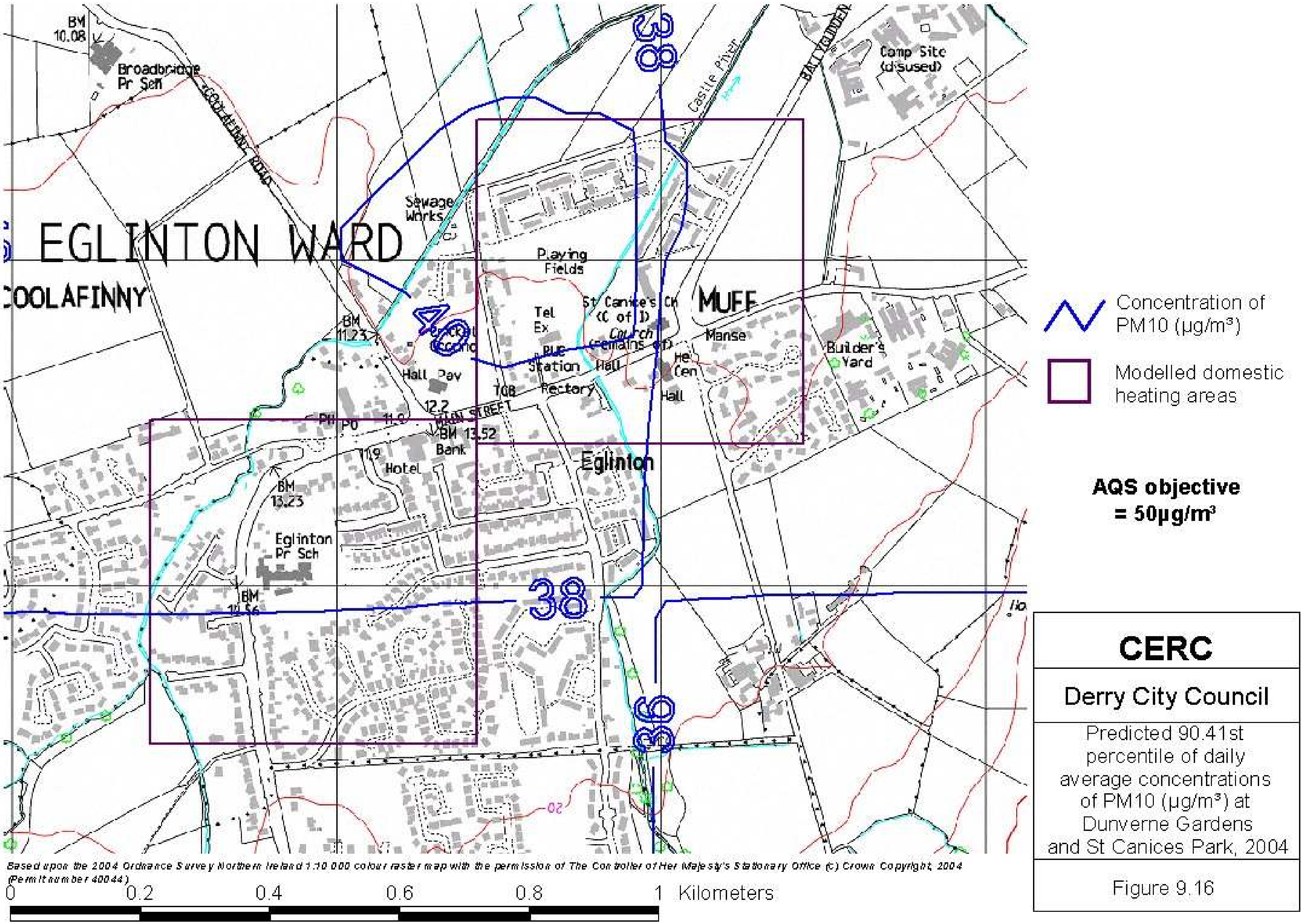
0 0.2 0.4 0.6 0.8 1 Kilometers

CERC

Derry City Council

Predicted annual average concentrations of PM10 ($\mu g/m^3$) at Dunverne Gardens and St Canices Park, 2004

Figure 9.15



CERC

Derry City Council

Predicted 90.41st percentile of daily average concentrations of PM10 (µg/m³) at Dunverne Gardens and St Canices Park, 2004

Figure 9.16

9.3.2 Predicted concentrations of PM_{10}, 2010

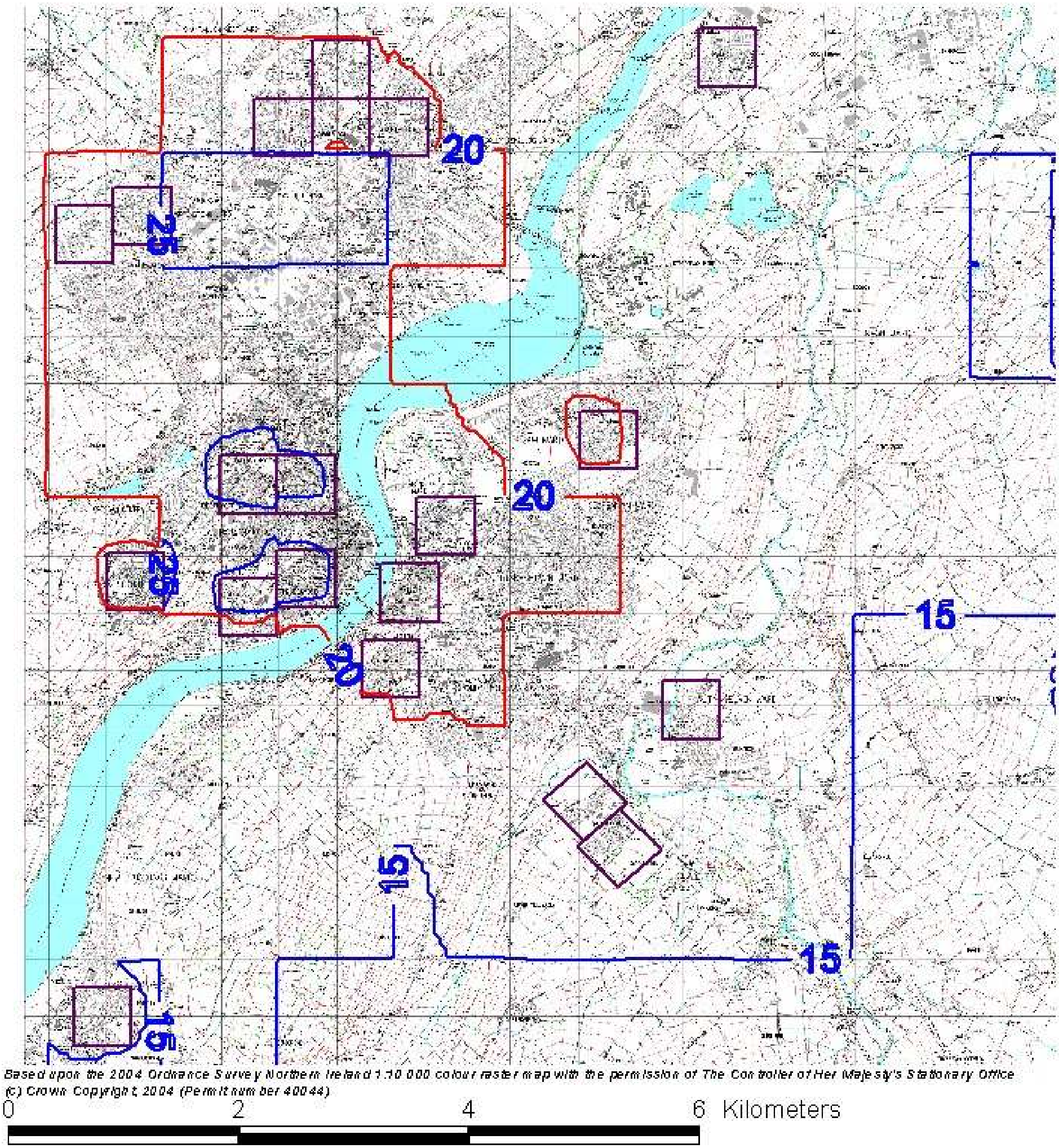
Figures 9.17 to 9.26 show the predicted annual average concentrations of PM_{10} and the predicted 98.08th percentile of daily average concentrations of PM_{10} for 2010 across the twenty-six modelled squares. Figures 9.17 and 9.18 show predicted concentrations for the sixteen squares of dense urban housing plus the three rural squares covering Ardnabrockie, Tullyalley and Currynairn. The predicted concentrations over the outlying rural squares are shown in Figures 9.19 to 9.26. Table 9.9 summarises the maximum predicted annual average concentrations of PM_{10} and the maximum predicted 98.08th percentile of daily average concentrations of PM_{10} for 2010 within each of the squares.

Figure 9.17 shows a predicted area of exceedence of the provisional 2010 AQS annual average objective value of 20µg/m^3 covering most of the urban Derry area. The values in the urban area of Derry reach a maximum of 27.5µg/m^3 in Ballymagroarty (site b), equivalent to 138% of the objective value. Figure 9.19 shows that the provisional annual average objective is also predicted to be exceeded in the rural area of Claudy, where values reach a maximum of 28.5 µg/m^3, 143% of the objective value, in Claudy 2. There are no predicted exceedences of the annual average objective in any of the other modelled rural areas. The annual average values in Table 9.9 that exceed the objective are highlighted in red.

Figure 9.18 shows a predicted area of exceedence of the provisional 2010 AQS objective for 98.08th percentile of daily average concentrations of PM_{10} of 50µg/m^3 covering most of the urban Derry area. The values in the urban area of Derry reach a maximum of 60.6µg/m^3 in Creggan and Bogside (site b), equivalent to 121% of the objective value. Figure 9.20 shows that the provisional objective for 98.08th percentile of daily average concentrations is also predicted to be exceeded in the rural area of Claudy, where values reach a maximum of 68.7µg/m^3, 137% of the objective value, in Claudy 1 and 2. There are no predicted exceedences of the objective in any of the other modelled rural areas. The 98.08th percentile of daily average concentrations in Table 9.9 that exceed the objective are highlighted in red.

Table 9.9: Maximum predicted concentrations of PM_{10} ($\mu g/m^3$), 2010

Survey area			Maximum annual average		Maximum 98.08th percentile of daily average	
Type	**No.**	**Name**	**Predicted concentration ($\mu g/m^3$)**	**% of 2010 AQS objective**	**Predicted concentration ($\mu g/m^3$)**	**% of 2010 AQS objective**
Urban	1a	Galliagh a	22.1	111	53.3	107
Urban	1b	Galliagh b	26.6	133	57.8	116
Urban	2	Shantallow	26.1	131	56.5	113
Urban	3	Strathfoyle	18.8	94	46.2	92
Urban	4a	Ballymagroarty a	22.9	115	56.4	113
Urban	4b	Ballymagroarty b	27.5	138	59.2	118
Urban	5a	Rosemount a	26.5	133	59.2	118
Urban	5b	Rosemount b	25.6	128	56.5	113
Urban	6	Caw	20.8	104	48.2	96
Urban	7	Creggan	26.9	135	60.6	121
Urban	8a	Bogside a	26.5	133	59.0	118
Urban	8b	Bogside b	26.6	133	60.6	121
Urban	9a	Waterside a	24.6	123	53.5	107
Urban	9b	Waterside b	24.5	123	53.3	107
Urban	11	Gobnascale	22.6	113	52.5	105
Urban	12	Newbuildings	15.6	78	44.3	89
Rural	13	Claudy 1	28.4	142	68.7	137
Rural	14	Claudy 2	28.5	143	68.7	137
Rural	15	Slieveboy Park	14.9	75	41.1	82
Rural	16	Faughanview Park	15.7	79	43.6	87
Rural	17	Lettershendony	18.2	91	47.0	94
Rural	18	Ardnabrockie	17.5	88	44.4	89
Rural	19	Tullyalley	18.9	95	47.1	94
Rural	20	Currynairn	18.6	93	45.5	91
Rural	21	Dunverne Gardens	19.8	99	50.5	101
Rural	22	St Canice's Park	20.5	103	52.0	104



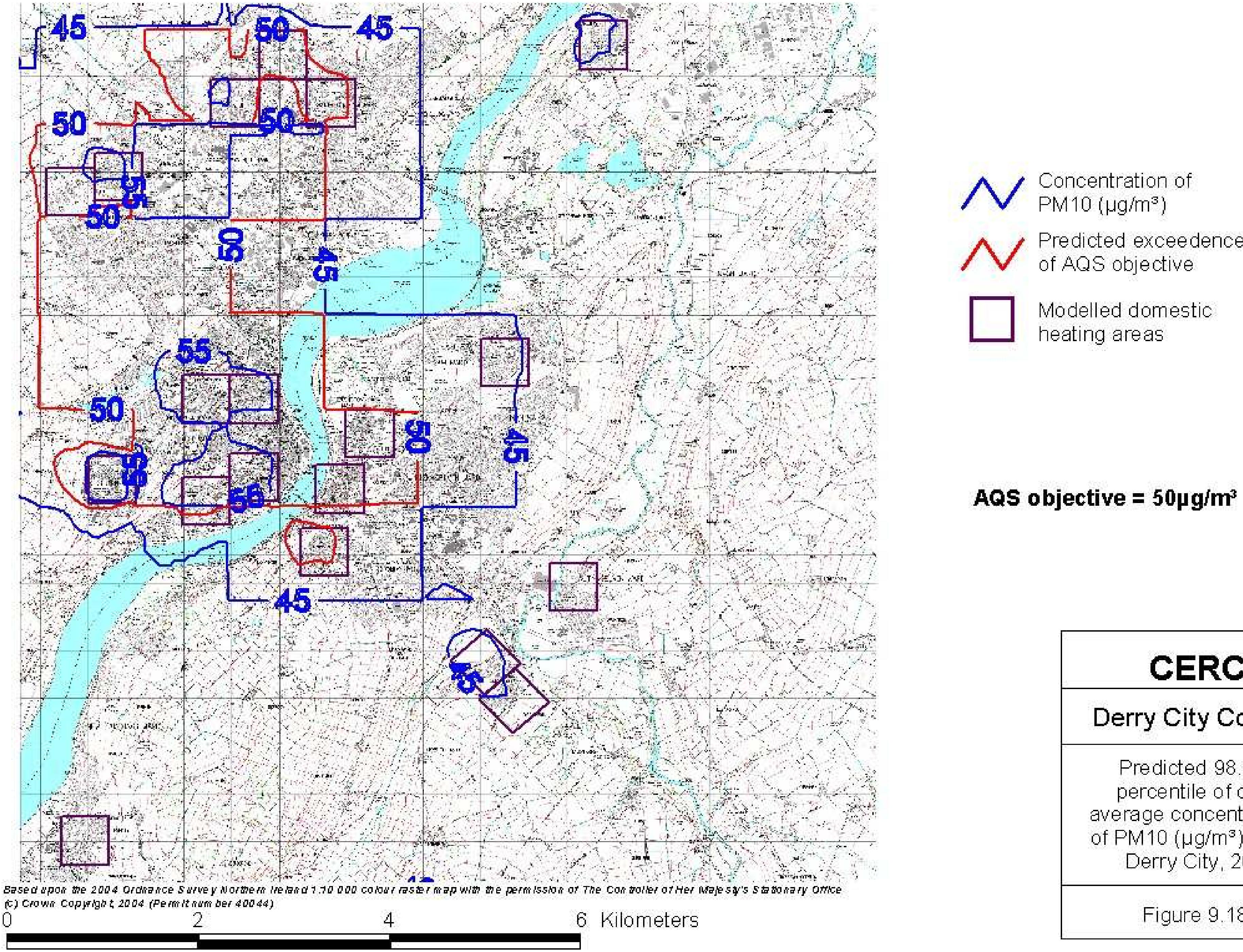
Concentration of PM10 (µg/m³)

Predicted exceedence of AQS objective

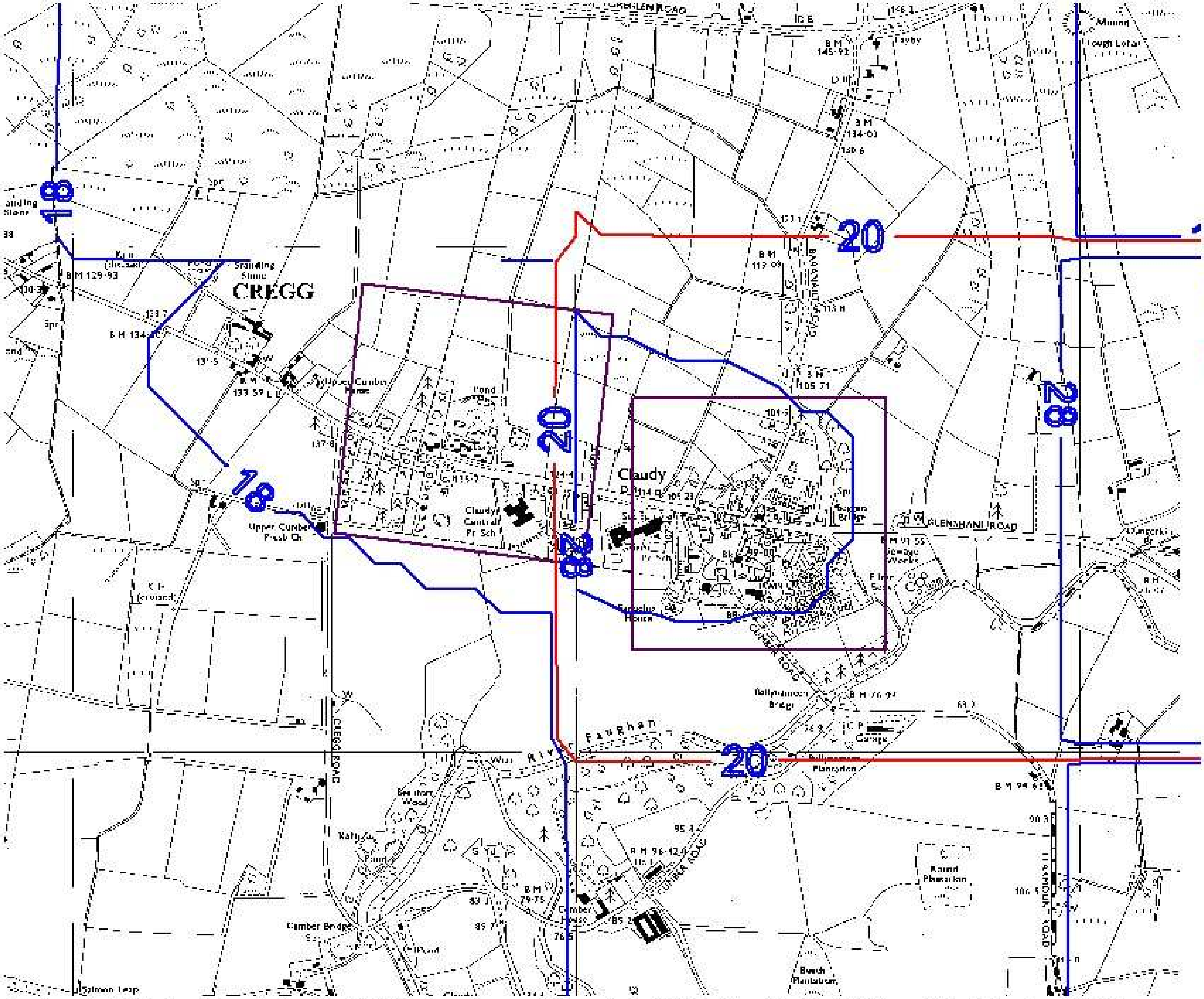
Modelled domestic heating areas

AQS objective = 20µg/m³

CERC
Derry City Council
Predicted annual average concentrations of PM10 (µg/m³) across Derry City, 2010
Figure 9.17



CERC
Derry City Council
Predicted 98.08th percentile of daily average concentrations of PM10 (µg/m³) across Derry City, 2010
Figure 9.18



Concentration of PM10 (µg/m³)

Predicted exceedence of AQS objective

Modelled domestic heating areas

AQS objective = 20µg/m³

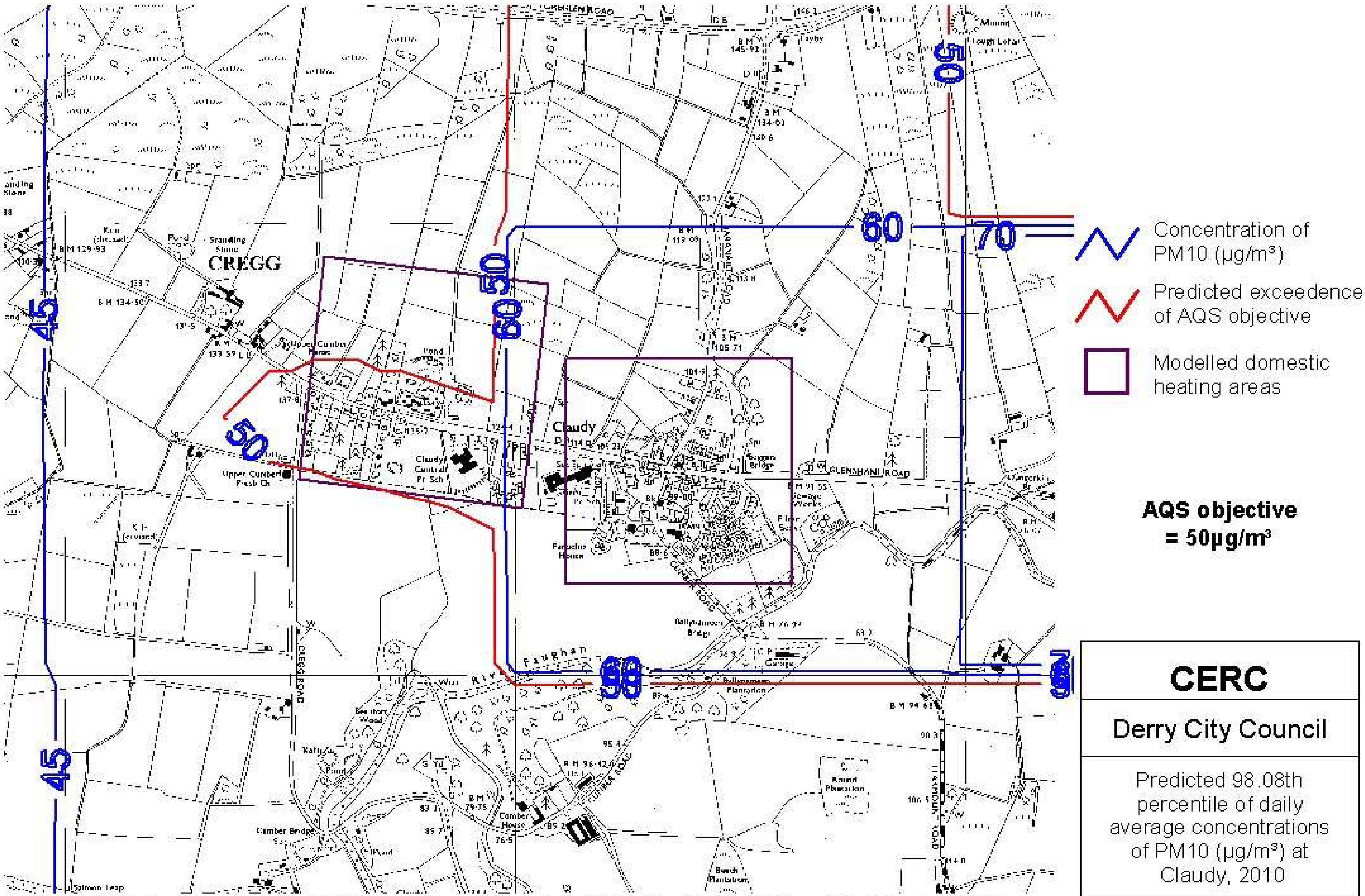
0 0.4 0.8 1.2 1.6 Kilometers

CERC

Derry City Council

Predicted annual average concentrations of PM10 (µg/m³) at Claudy, 2010

Figure 9.19



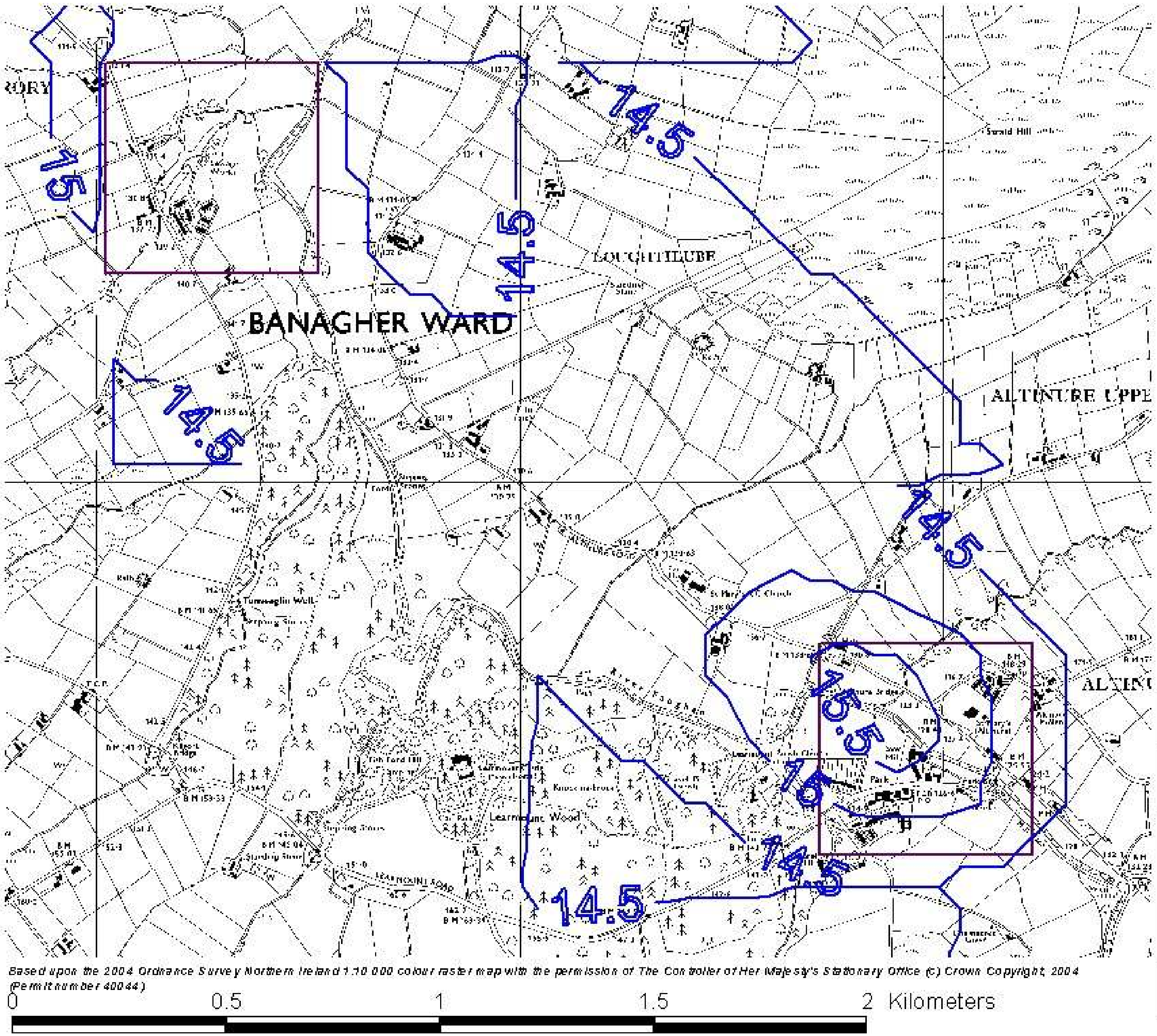
0 0.4 0.8 1.2 1.6 Kilometers

CERC

Derry City Council

Predicted 98.08th percentile of daily average concentrations of PM10 (µg/m³) at Claudy, 2010

Figure 9.20



Concentration of PM10 (µg/m³)

Modelled domestic heating areas

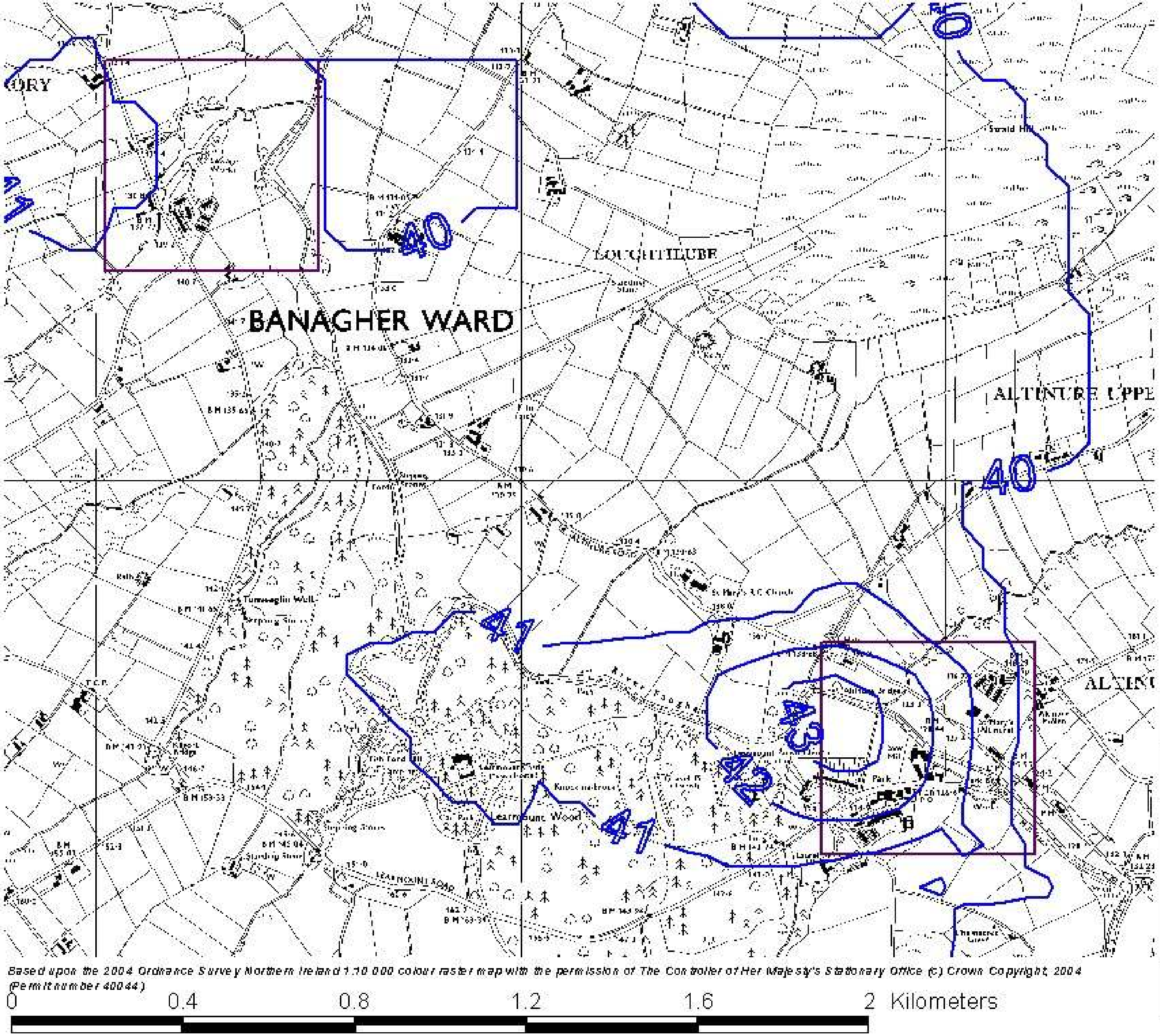
AQS objective = 20µg/m³

CERC

Derry City Council

Predicted annual average concentrations of PM10 (µg/m³) at Slieveboy Park and Faughanview Park, 2010

Figure 9.21



Concentration of PM10 (µg/m³)

Modelled domestic heating areas

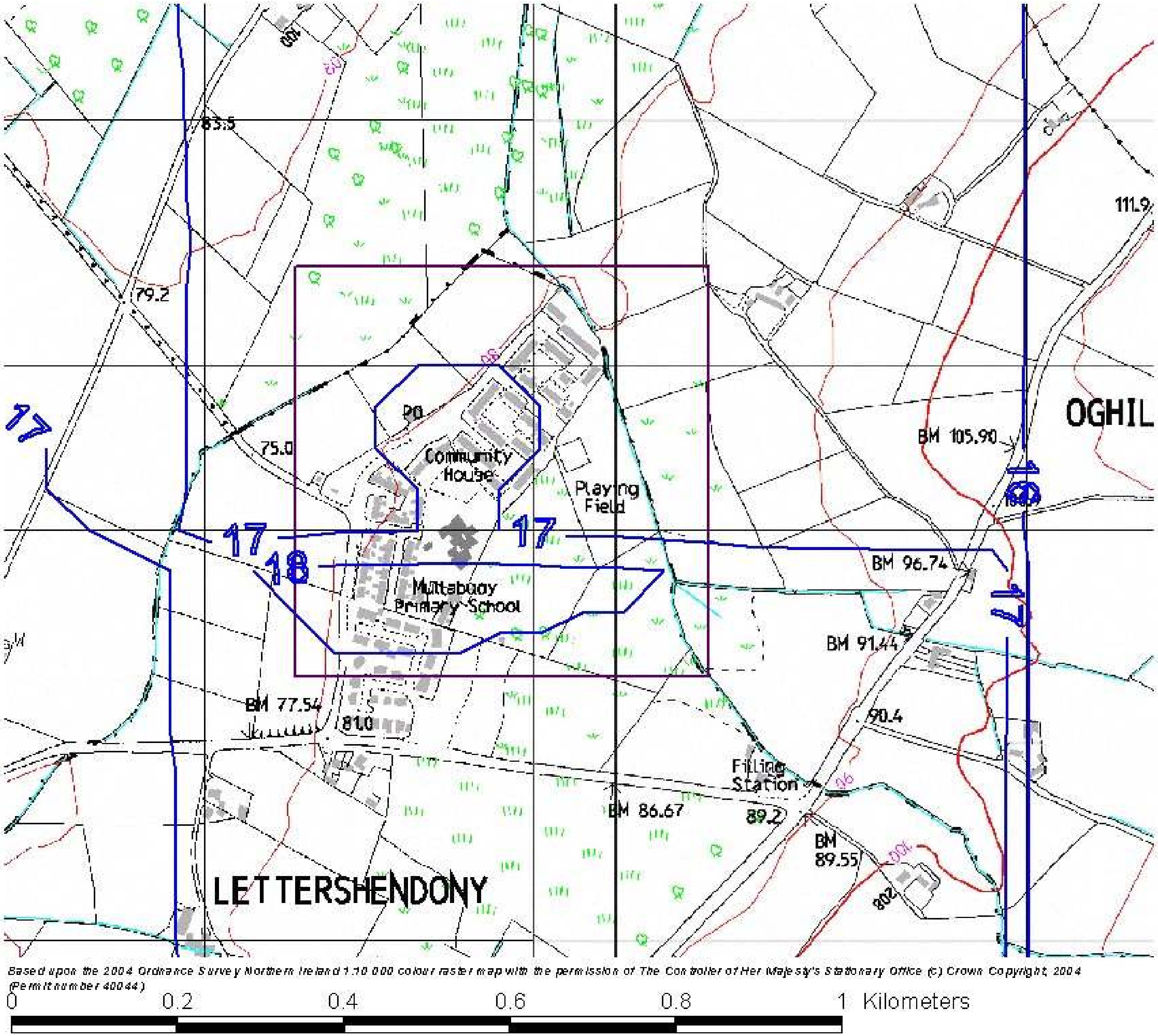
AQS objective = 50µg/m³

CERC

Derry City Council

Predicted 98.08th percentile of daily average concentrations of PM10 (µg/m³) at Slieveboy Park and Faughanview Park, 2010

Figure 9.22

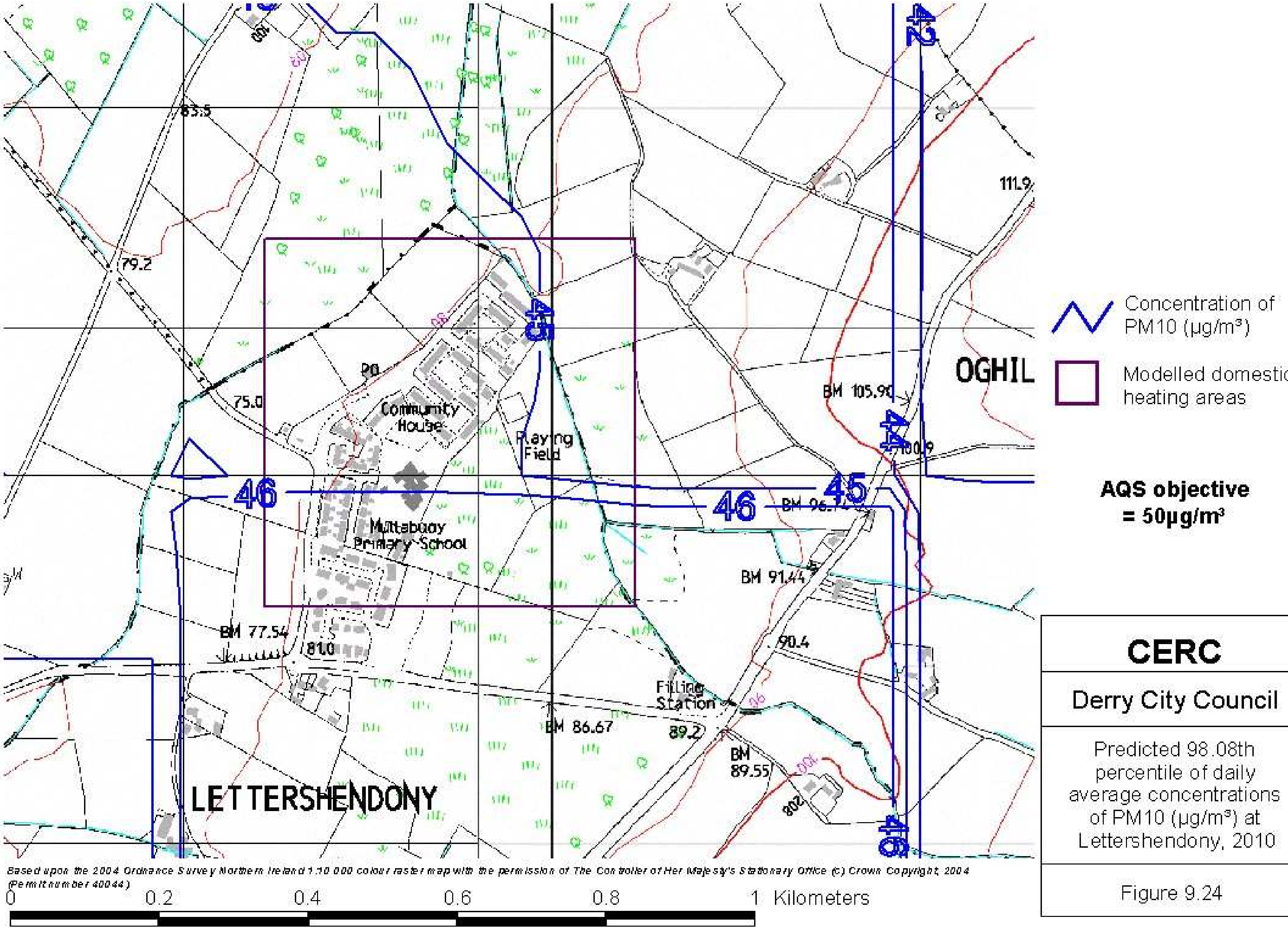


Concentration of PM10 (µg/m³)

Modelled domestic heating areas

AQS objective = 20µg/m³

CERC
Derry City Council
Predicted annual average concentrations of PM10 (µg/m³) at Lettershendony, 2010
Figure 9.23

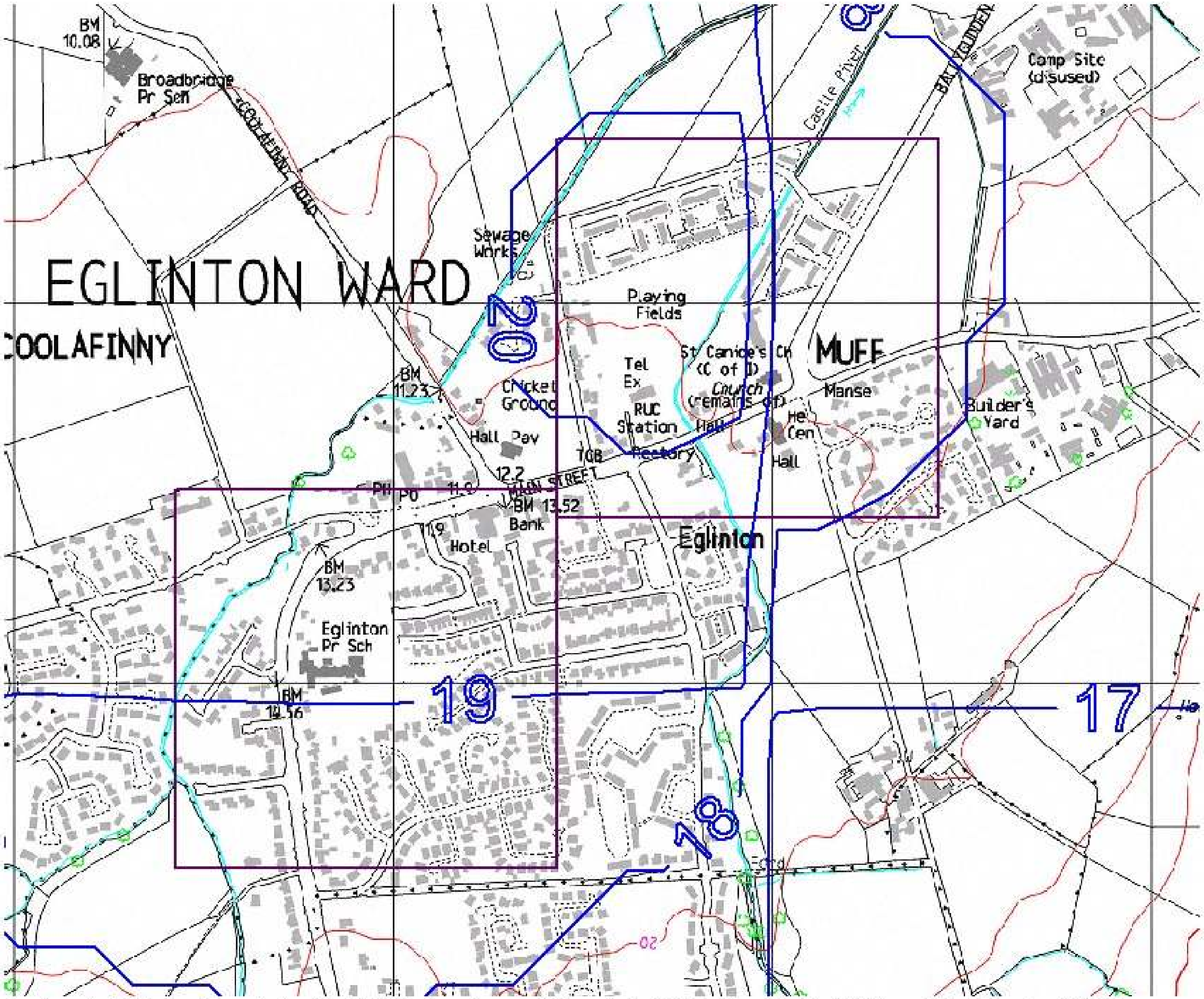


CERC

Derry City Council

Predicted 98.08th percentile of daily average concentrations of PM10 (µg/m³) at Lettershendony, 2010

Figure 9.24



Concentration of PM10 (µg/m³)

Modelled domestic heating areas

AQS objective = 20µg/m³

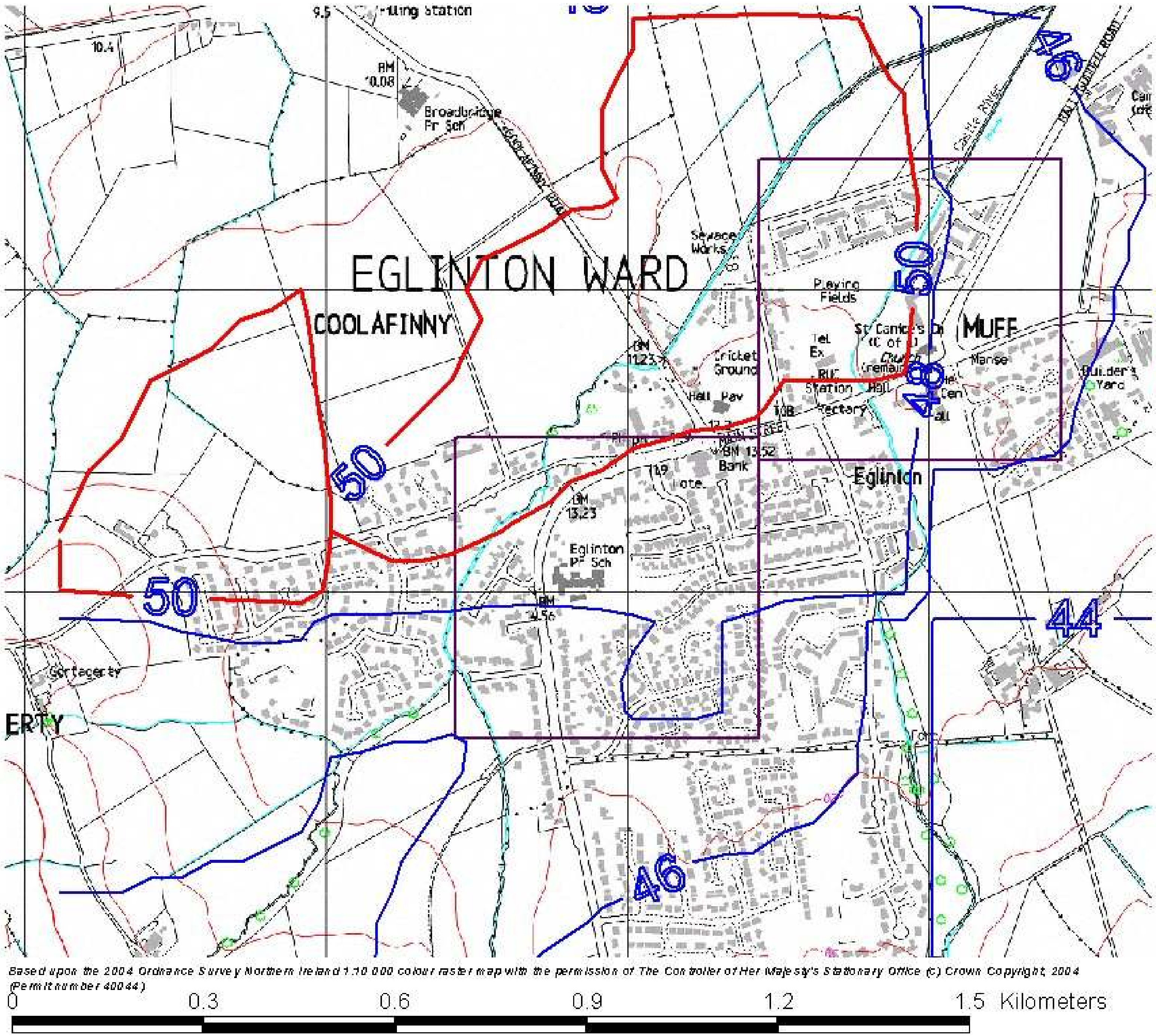
CERC

Derry City Council

Predicted annual average concentrations of PM10 (µg/m³) at Dunverne Gardens and St Canices Park, 2010

Figure 9.25

0 0.2 0.4 0.6 0.8 1 Kilometers



Concentration of PM10 (µg/m³)

Predicted exceedence of AQS objective

Modelled domestic heating areas

AQS objective = 50µg/m³

CERC

Derry City Council

Predicted 98.08th percentile of daily average concentrations of PM10 (µg/m³) at Dunverne Gardens and St Canices Park, 2010

Figure 9.26

9.3.3 Predicted concentrations of SO_2

The most stringent of the three objectives for SO_2 is the objective for the 99.9th percentile of 15-minute average concentrations of SO_2.

Figures 9.27 to 9.31 show the predicted 99.9th percentile of 15-minute average concentrations of SO_2 for 2005 across the twenty-six domestic squares. Figures 9.27a and 9.28 show predicted concentrations for the sixteen squares of dense urban housing plus the three rural squares covering Ardnabrockie, Tullyalley and Currynairn. The predicted concentrations over the outlying rural squares are shown in Figures 9.29 to 9.31. Table 9.10 summarises the maximum predicted 99.9th percentile of 15-minute average concentrations of SO_2 within each of the squares. The values in Table 9.10 that exceed the objective are highlighted in red.

Figure 9.27a shows an area of predicted exceedence of the AQS objective for 15-minute average concentrations of SO_2 to the northeast of Derry, covering the Strathfoyle area. This area of exceedence is shown in more detail in Figure 9.27b. The maximum predicted 99.9th percentile of 15-minute average concentrations within the Strathfoyle area is 446μg/m^3, 168% of the AQS objective.

There are several reasons why this predicted area of exceedence is unlikely to represent a true exceedence of the 99.9th percentile of 15-minute average concentrations of SO_2. This area of predicted exceedence is due primarily to the estimated emissions from the two point sources, Coolkeragh power station and Invista (UK) Ltd (formerly DuPont Cogen), located approximately 1500m to the east and northeast of this square. The emissions from these sources were estimated using data included in the NAEI gridded data, representing the year 2000. Emissions data for these sources collected during 2003 shows that the emissions from Coolkeragh power station have been reduced by over 70% and emissions from Invista (UK) Ltd have reduced by approximately 11%. It should also be noted that Coolkeragh power station is due to convert to gas-fired operation in late 2004, and this is likely to further reduce emissions. Furthermore, detailed dispersion modelling studies to model emissions from these sources have been carried out, and no exceedences were predicted[4,5].

It should also be noted that the predicted 99.9th percentile of 15-minute average concentrations of SO_2 over the whole of the Derry area were scaled using adjustment factors based on the comparison between modelled and monitored concentrations at the Brandywell site. The model overpredicts concentrations at the AURN site, and so applying this worst case adjustment over the whole of Derry will give a gross overprediction at most locations.

In the case of the exceedence seen on Figure 9.27b, the predicted concentrations represent an overestimate:

- firstly because the emissions data are higher than current emissions data, and
- secondly because the resulting concentrations have been increased using a worst case adjustment factor.

---

[4] Coolkeragh ESB CCGT Power Project, *Application for Variation of IPC Authorisation No. 007/98A, Additional Information Note*, P004K002-R1-002, September 2001

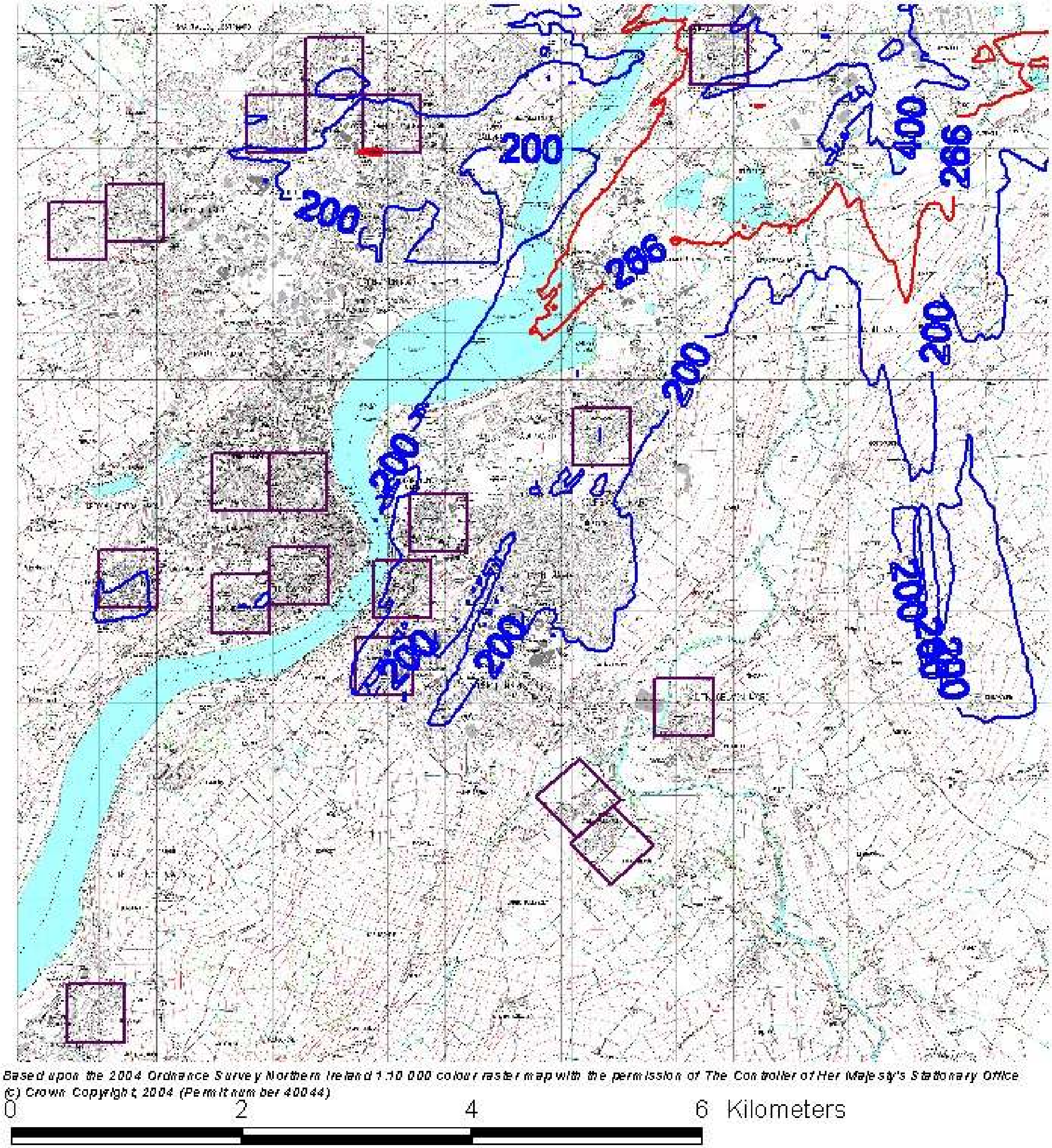
[5] *Application for Authorisation, COGEN Plant*, DuPont (UK) Ltd, Maydown Works, 21 December 1998

In summary, any conclusions about possible exceedences due to the power station emissions should be drawn from detailed dispersion modelling studies of these sources, and the areas of exceedence shown here are not a cause for concern.

Figure 9.27a also shows a small area of predicted exceedence of the AQS objective for 15-minute average concentrations of SO_2 on the edge of Shantallow; this area of exceedence is shown in more detail in Figure 9.27c. The maximum predicted 99.9th percentile of 15-minute average concentrations within the Shantallow square is 273µg/m^3, 103% of the AQS objective. As discussed above, the predicted 99.9th percentile of 15-minute average concentrations of SO_2 were scaled using adjustment factors based on the comparison between modelled and monitored concentrations at the Brandywell site and this worst case adjustment will give a gross overprediction at some locations. The area of exceedence is small, and the values only exceed by a small amount, so given the high adjustment factor it is likely that this is not a cause for concern.

Table 9.10: Maximum predicted concentrations of SO_2 ($\mu g/m^3$)

Survey area			Maximum 99.9th percentile of 15-minute average concentrations	
Type	**No.**	**Name**	**Predicted concentration ($\mu g/m^3$)**	**% of AQS objective**
Urban	1a	Galliagh a	208	78
Urban	1b	Galliagh b	223	84
Urban	2	Shantallow	273	103
Urban	3	Strathfoyle	446	168
Urban	4a	Ballymagroarty a	174	65
Urban	4b	Ballymagroarty b	183	69
Urban	5a	Rosemount a	184	69
Urban	5b	Rosemount b	168	63
Urban	6	Caw	218	82
Urban	7	Creggan	226	85
Urban	8a	Bogside a	195	73
Urban	8b	Bogside b	206	77
Urban	9a	Waterside a	219	82
Urban	9b	Waterside b	229	86
Urban	11	Gobnascale	205	77
Urban	12	Newbuildings	151	57
Rural	13	Claudy 1	126	47
Rural	14	Claudy 2	127	48
Rural	15	Slieveboy Park	121	45
Rural	16	Faughanview Park	123	46
Rural	17	Lettershendony	201	76
Rural	18	Ardnabrockie	147	55
Rural	19	Tullyalley	174	65
Rural	20	Currynairn	159	60
Rural	21	Dunverne Gardens	183	69
Rural	22	St Canice's Park	195	73



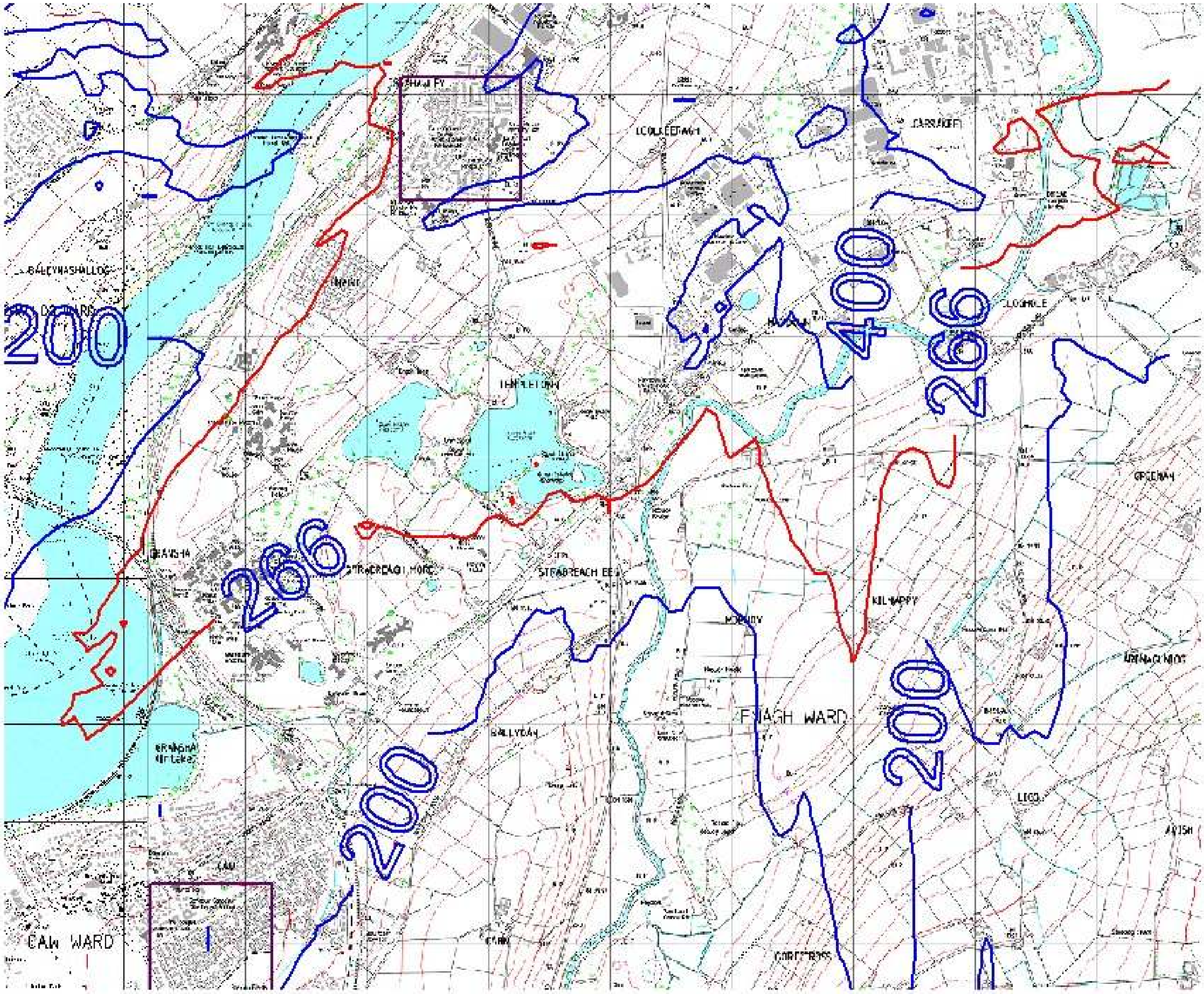
Concentration of SO2 (µg/m³)

Predicted exceedence of SO2 AQS objective

Modelled domestic heating areas

AQS objective = 266µg/m³

CERC
Derry City Council
Predicted 99.9th percentile of 15 minute average concentrations of SO2 (µg/m³) across Derry City, 2005
Figure 9.27a



Based upon the 2004 Ordnance Survey Northern Ireland 1:10 000 colour raster map with the permission of The Controller of Her Majesty's Stationary Office (c) Crown Copyright, 2004 (Permit number 40044)

0 0.7 1.4 2.1 2.8 3.5 Kilometers

Concentration of SO2 (µg/m³)

Predicted exeedence of AQS objective

Modelled domestic heating areas

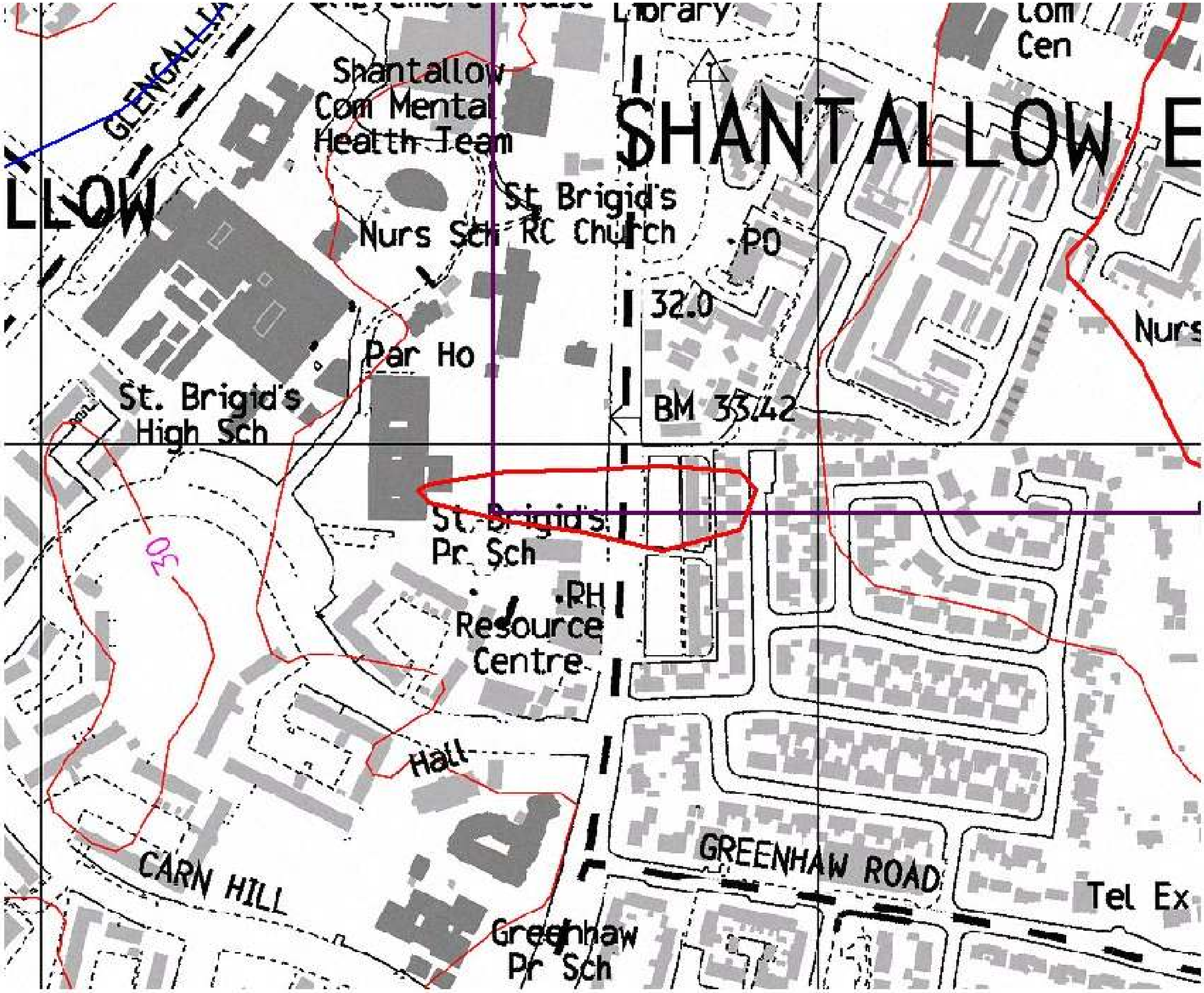
AQS objective = 266 µg/m³

CERC

Derry City Council

Predicted 99.9th percentile of 15 minute average concentrations of SO2 (µg/m³) at Strathfoyle, 2005

Figure 9.27b



0 0.1 0.2 0.3 0.4 0.5 Kilometers

Concentration of SO_2 (µg/m³)

Predicted exeedence of AQS objective

Modelled domestic heating areas

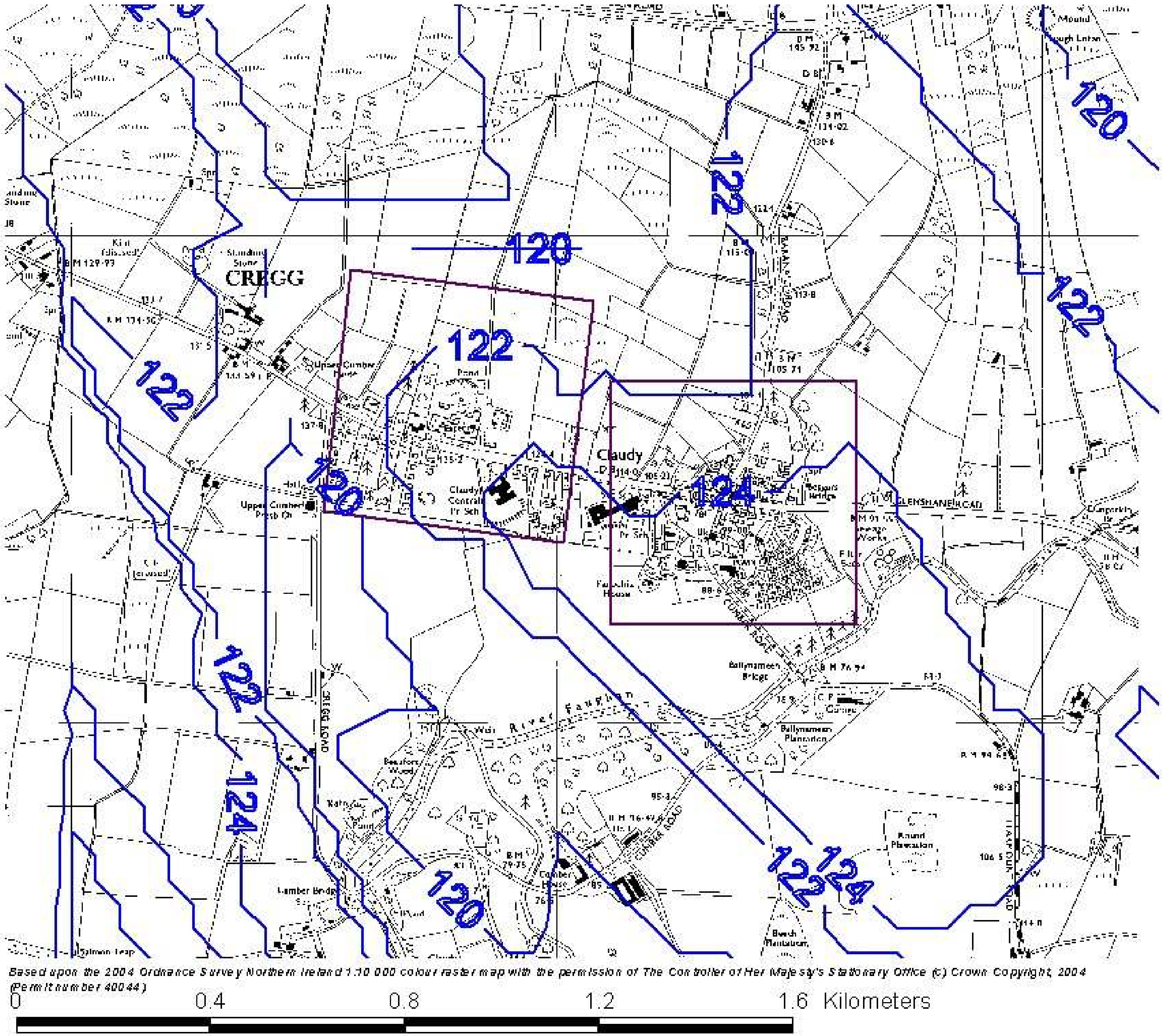
AQS objective = 266 µg/m³

CERC

Derry City Council

Predicted 99.9th percentile of 15 minute average concentrations of SO_2 (µg/m³) at Shantallow, 2005

Figure 9.27c



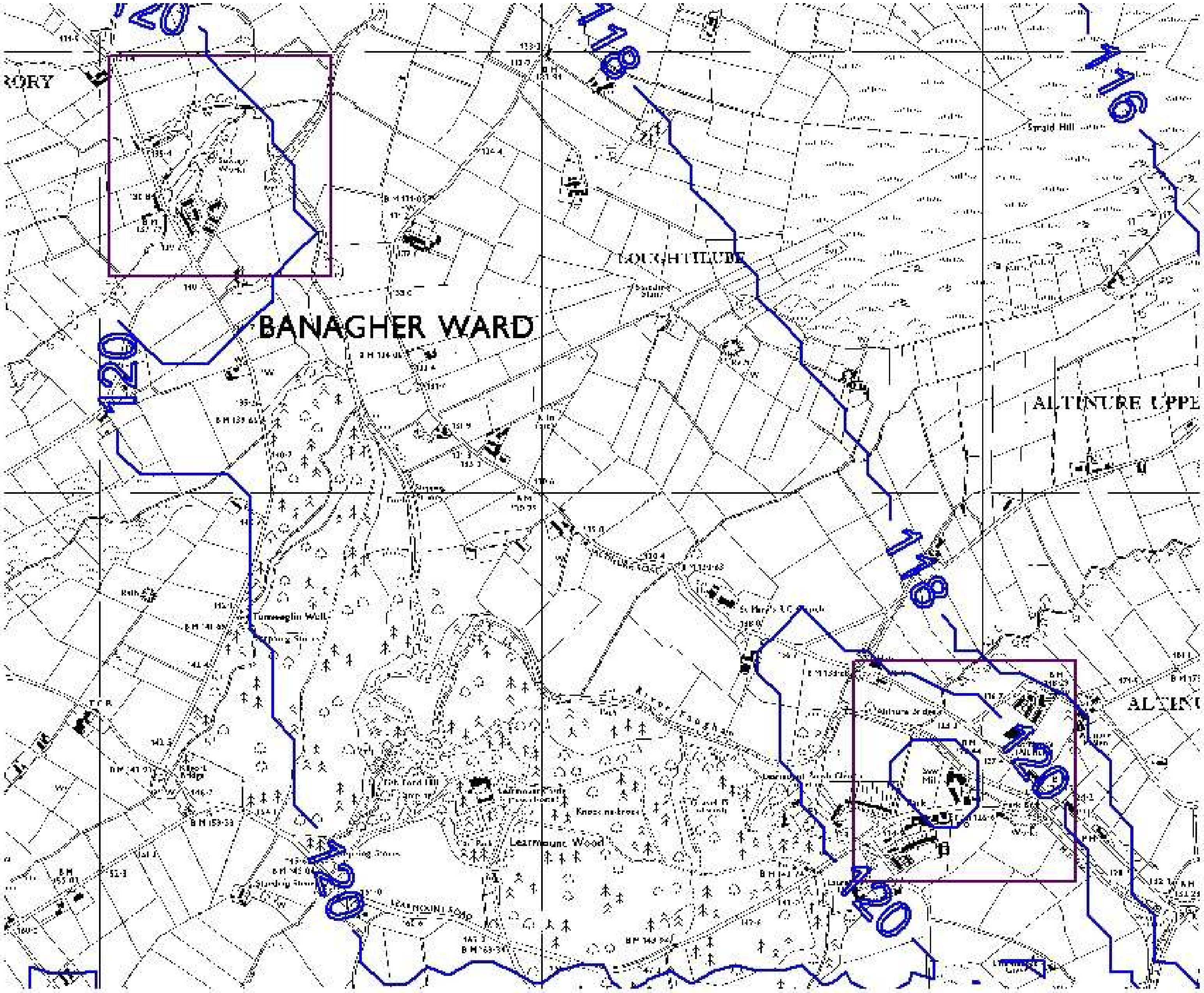
Based upon the 2004 Ordnance Survey Northern Ireland 1:10 000 colour raster map with the permission of The Controller of Her Majesty's Stationary Office (c) Crown Copyright, 2004 (Permit number 40044)

CERC

Derry City Council

Predicted 99.9th percentile of 15 minute average concentrations of SO2 (µg/m³) at Claudy, 2005

Figure 9.28



Concentration of SO2 (µg/m³)

Modelled domestic heating areas

AQS objective = 266 µg/m³

Based upon the 2004 Ordnance Survey Northern Ireland 1:10 000 colour raster map with the permission of The Controller of Her Majesty's Stationary Office (c) Crown Copyright, 2004 (Permit number 40044)

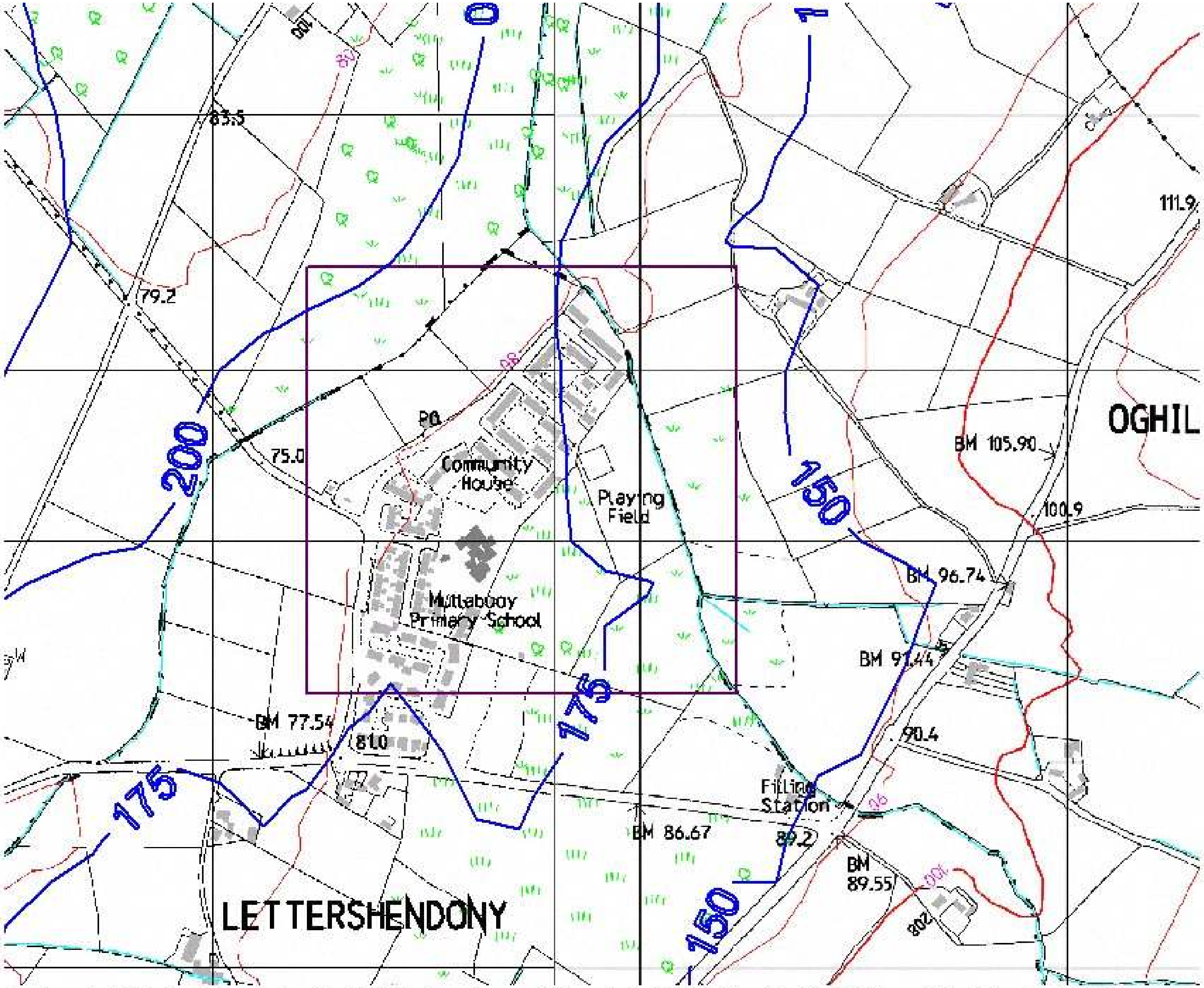
0 0.3 0.6 0.9 1.2 1.5 Kilometers

CERC

Derry City Council

Predicted 99.9th percentile of 15 minute average concentrations of SO2 (µg/m³) at Slieveboy Park and Faughanview Park, 2005

Figure 9.29



Concentration of SO_2 (µg/m³)

Modelled domestic heating areas

AQS objective = 266 µg/m³

Based upon the 2004 Ordnance Survey Northern Ireland 1:10 000 colour raster map with the permission of The Controller of Her Majesty's Stationary Office (c) Crown Copyright 2004 (Permit number 40044)

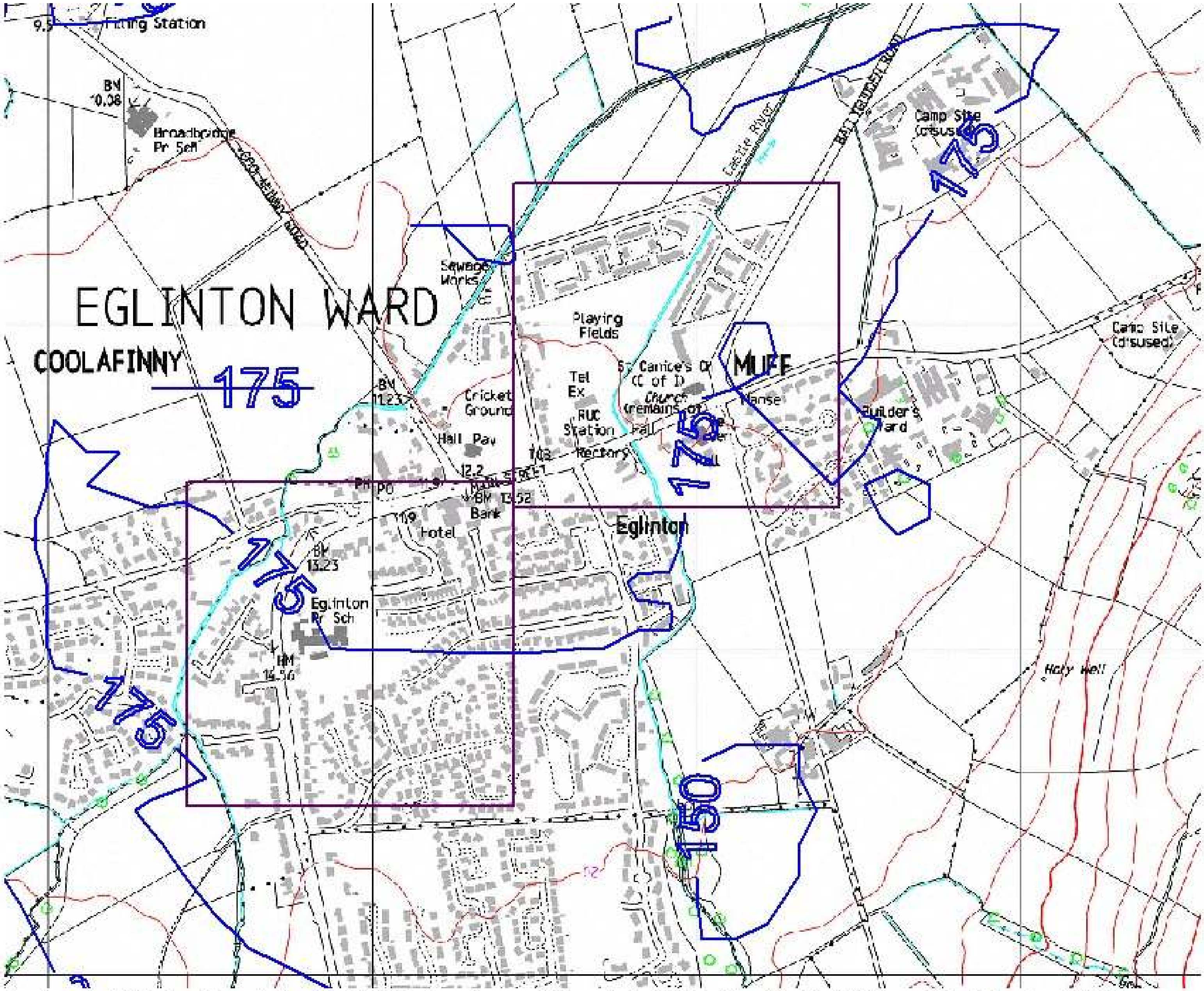
0 0.2 0.4 0.6 0.8 1 Kilometers

CERC

Derry City Council

Predicted 99.9th percentile of 15 minute average concentrations of SO_2 (µg/m³) at Lettershendony, 2005

Figure 9.30



0 0.2 0.4 0.6 0.8 1 Kilometers

Concentration of SO_2 (µg/m³)

Modelled domestic heating areas

AQS objective = 266 µg/m³

CERC

Derry City Council

Predicted 99.9th percentile of 15 minute average concentrations of SO_2 (µg/m³) at Dunverne Gardens and St Canices Park, 2005

Figure 9.31

10. Discussion

Derry City Council (the council) has highlighted areas of possible exceedence of the Air Quality Strategy (AQS) objectives for:

- NO_2, due to road traffic emissions at seven junctions; and
- SO_2 and PM_{10}, due to domestic fuel use emissions at sixteen urban and ten rural locations.

CERC was commissioned by the council to undertake air quality modelling for these areas using the ADMS-Urban model (version 2.0).

Road traffic modelling

Traffic count data for each of the modelled roads were used to calculate emissions of nitrogen dioxide (NO_2). Concentrations of NO_2 have been calculated for comparison with the Air Quality Strategy (AQS) objectives.

There is a small area of predicted exceedence of the 2005 AQS objective for annual average NO_2 concentrations at the Creggan Road / Infirmary Road junction. The maximum predicted annual average concentration of NO_2 is 42.5µg/m^3, equivalent to 106% of the 2005 AQS objective. This area of exceedence is very small, and occurs only on the junction itself. However, the results of the model verification suggest that the model may be significantly underpredicting the concentrations at Creggan Road, and therefore this area of exceedence may cover a larger area.

There are no other predicted exceedences of either of the 2005 AQS objectives for NO_2 at the modelled junctions.

Domestic fuel use modelling

A domestic fuel use survey was carried out by Derry City Council to obtain information concerning the quantity and type of fuel used for domestic heating in representative areas. These data were used to calculate emissions of particulates (PM_{10}) and sulphur dioxide (SO_2) in each area. Concentrations of SO_2 and PM_{10} have been calculated for comparison with the Air Quality Strategy (AQS) objectives.

Model verification was carried out for the year April 2002 to March 2003. To ensure that predicted concentrations of PM_{10} and SO_2 were not being underestimated at any location, worst case adjustment factors were calculated based on the comparison between modelled and monitored concentrations at the Brandywell monitoring site. The adjustment was applied to the predicted concentrations across the whole of Derry. Applying this adjustment is likely to give a gross overestimate of the predicted concentrations at many sites.

There are no predicted exceedences of the 2004 annual average AQS objective for PM_{10} at any of the urban or rural locations.

The 90.41st percentile of daily average concentrations of PM_{10} is predicted to be exceeded in three of the modelled areas: Bogside (site b); Ballymagroarty; and Claudy. Concentrations across the whole of Derry were adjusted using factors derived from the Brandywell monitoring site, located in the Bogside area, so the exceedence in Bogside is supported by local monitoring data. The area of exceedence in Ballymagroarty is small, and the values only exceed by a small amount, so given the high adjustment factor used it is likely that this is not a cause for concern. At the rural location of Claudy, the high adjustment factor used across Derry is likely to lead to a gross overestimate of the impact, so it is unlikely that this predicted exceedence is a real one, however the modelled results do indicate that emissions in the Claudy area may be of more concern than in the other rural areas.

The provisional 2010 AQS annual average and 98.08th percentile of daily average concentrations of PM_{10} are predicted to be exceeded over an area covering most of the urban Derry area and in the rural area of Claudy.

There are two areas of predicted exceedence of the 2005 AQS objective for 15-minute average concentrations of SO_2 in the urban Derry area. There is a large area of predicted exceedence to the northeast of Derry, covering the Strathfoyle area, and a small area of predicted exceedence of on the edge of Shantallow. The maximum predicted 99.9th percentile of 15-minute average concentrations within the Strathfoyle area is 446µg/m^3, 168% of the AQS objective of 266µg/m^3. This area of predicted exceedence is due primarily to the estimated emissions from the two point sources in the area. This predicted area of exceedence is unlikely to represent a true exceedence because:

1. the emissions data represent an overestimate of current emissions, and
2. the predicted concentrations have been adjusted using a worst case adjustment factor based on the comparison between modelled and monitored concentrations at the Brandywell site.

APPENDIX A: Summary of ADMS-Urban

ADMS-Urban is a practical air pollution modelling tool, which has been developed to provide detailed predictions of pollution concentrations for all sizes of study area. The model can be used to look at concentrations near a single road junction or over a region extending across the whole of a major city. ADMS-Urban has therefore been extensively used for Stage 3 of the Review and Assessment of Air Quality carried out by Local Authorities in the UK, and for the follow-up work required in Stage 4 and the development of Action Plans for improving air quality. The following is a summary of the capabilities and validation of ADMS-Urban. More details can be found on the CERC web site at www.cerc.co.uk.

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS) which has been developed to investigate the impacts of emissions from industrial facilities. ADMS-Urban allows full characterisation of the wide variety of emissions in urban areas, including an extensively validated road traffic emissions model. It also boasts a number of other features, which include consideration of:

- the effects of vehicle movement on the dispersion of traffic emissions;
- the behaviour of material released into street-canyons;
- the chemical reactions occurring between nitrogen oxides, ozone and Volatile Organic Compounds (VOCs);
- the pollution entering a study area from beyond its boundaries;
- the effects of complex terrain on the dispersion of pollutants; and
- the effects of a building on the dispersion of pollutants emitted nearby.

More details of these features are given below.

Studies of extensive urban areas are necessarily complex, requiring the manipulation of large amounts of data. To allow users to cope effectively with this requirement, ADMS-Urban has been designed to operate in the widely familiar PC environment, under Windows NT. The manipulation of data is further facilitated by the possible integration of ADMS-Urban with a Geographical Information System (GIS) such as MapInfo or ArcView, and with the CERC Emissions Inventory Toolkit, EMIT.

Dispersion Modelling

ADMS and ADMS-Urban use boundary layer similarity profiles to parameterise the variation of turbulence with height within the boundary layer, and the use of a skewed-Gaussian distribution to determine the vertical variation of pollutant concentrations in the plume under convective conditions.

The main dispersion modelling features of ADMS-Urban are as follows:

- ADMS-Urban is an **advanced dispersion model** in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the surface. This method supercedes methods based on Pasquill Stability Categories, as used in, for example, Caline and ISC. Concentrations are calculated hour by hour and are fully dependent on prevailing weather conditions.
- For convective conditions, a **non-Gaussian vertical profile of concentration** allows for the skewed nature of turbulence within the atmospheric boundary layer, which can lead to high concentrations near to the source.
- A **meteorological pre-processor** calculates boundary layer parameters from a variety of input data, typically including date and time, wind speed and direction, surface temperature and cloud cover. Meteorological data may be raw hourly averaged or statistically analysed data.

Emissions

Emissions into the atmosphere across an urban area typically come from a wide variety of sources. There are likely to be industrial emissions from chimneys as well as emissions from road traffic and domestic fuel use systems. To represent the full range of emissions configurations, the explicit source types available within ADMS-Urban are:

- **Industrial points**, for which plume rise and stack downwash are included in the modelling.
- **Roads**, for which emissions are specified in terms of vehicle flows and the additional initial dispersion caused by moving vehicles is also taken into account.
- **Areas**, where a source or sources is best represented as uniformly spread over an area.
- **Volumes**, where a source or sources is best represented as uniformly spread throughout a volume.

In addition, sources can also be modelled as a regular grid of emissions. This allows the contributions of large numbers of minor sources to be efficiently included in a study while the majority of the modelling effort is used for the relatively few significant sources.

ADMS-Urban can be used in conjunction with CERC's Emissions Inventory Toolkit, EMIT, which facilitates the management and manipulation of large and complex data sets into usable emissions inventories.

Presentation of Results

The results from the model can be based on a wide range of averaging times, and include rolling averages. Maximum concentration values and percentiles can be calculated where appropriate meteorological input data have been input to the model. This allows ADMS-Urban to be used to calculate concentrations for direct comparison with existing air quality limits, guidelines and objectives, in whatever form they are specified.

ADMS-Urban can be integrated with the ArcView or MapInfo GIS to facilitate both the compilation and manipulation of the emissions information required as input to the model and the interpretation and presentation of the air quality results provided.

Complex Effects - Street Canyons

The *Operational Street Pollution Model (OSPM)*[6], developed by the Danish National Environmental Research Institute (NERI), has been incorporated within ADMS-Urban. The OSPM uses a simplified flow and dispersion model to simulate the effects of the vortex that occurs within street canyons when the wind-flow above the buildings has a component perpendicular to the direction of the street. The model takes account of vehicle induced turbulence. The model has been validated against Danish and Norwegian data.

Complex Effects - Chemistry

ADMS-Urban includes the *Generic Reaction Set (GRS)*[7] atmospheric chemistry scheme. The original scheme has seven reactions, including those occurring between nitrogen oxides and ozone. The remaining reactions are parameterisations of the large number of reactions involving a wide range of Volatile Organic Compounds (VOCs). In addition, an eighth reaction has been included within ADMS-Urban for the situation when high concentrations of nitric oxide (NO) can convert to nitrogen dioxide (NO_2) using molecular oxygen.

In addition to the basic GRS scheme, ADMS-Urban also includes a trajectory model[8] for use when modelling large areas. This permits the chemical conversions of the emissions and background concentrations upwind of each location to be properly taken into account.

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[6] Hertel, O., Berkowicz, R. and Larssen, S., 1990, 'The Operational Street Pollution Model (OSPM).' *18th International meeting of NATO/CCMS on Air Pollution Modelling and its Applications.* Vancouver, Canada, pp741-749.

[7] Venkatram, A., Karamchandani, P., Pai, P. and Goldstein, R., 1994, 'The Development and Application of a Simplified Ozone Modelling System.' *Atmospheric Environment,* Vol 28, No 22, pp3665-3678.

[8] Singles, R.J., Sutton, M.A. and Weston, K.J., 1997, 'A multi-layer model to describe the atmospheric transport and deposition of ammonia in Great Britain.' In: *International Conference on Atmospheric Ammonia: Emission, Deposition and Environmental Impacts. Atmospheric Environment*, Vol 32, No 3.

Complex Effects - Terrain

As well as the effect that complex terrain has on wind direction and, consequently, pollution transport, it can also enhance turbulence and therefore increase dispersion. These effects are taken into account in ADMS-Urban using the FLOWSTAR[9] model developed by CERC.

Data Comparisons – Model Validation

ADMS-Urban is a development of the Atmospheric Dispersion Modelling System (ADMS), which is used throughout the UK by industry and the Environment Agency to model emissions from industrial sources. ADMS has been subject to extensive validation, both of individual components (e.g. point source, street canyon, building effects and meteorological pre-processor) and of its overall performance.

ADMS-Urban has been extensively tested and validated against monitoring data for large urban areas in the UK, including Central London and Birmingham, for which a large scale project was carried out on behalf of the DETR (now DEFRA).

Further details of ADMS-Urban and model validation, including a full list of references, are available from the CERC web site at www.cerc.co.uk.

[9] Carruthers D.J., Hunt J.C.R. and Weng W-S. 1988. 'A computational model of stratified turbulent airflow over hills – FLOWSTAR I.' Proceedings of Envirosoft. In: *Computer Techniques in Environmental Studies,* P. Zanetti (Ed) pp 481-492. Springer-Verlag.