Cambridge
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Air quality assessment to support the permit variation for the proposed Energy Centre at Innospec, Ellesmere Port

Final report

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CERC

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Contents

1 Summary

Cambridge Environmental Research Consultants Ltd (CERC) was commissioned by Veolia Energy UK to carry out an air quality assessment to support the permit variation for a proposed Energy Centre at the Innospec site in Ellesmere Port, Cheshire.

The Energy Centre will comprise two CHP plant (2.5 MW and 1.5 MW) and two waste heat boilers, each with its own flue within a common stack.

A dispersion modelling assessment of emissions of nitrogen oxides (NO_x) was carried out using the ADMS 5 model (version 5.2.4.0), for impacts from the proposed Energy Centre and the existing lead furnace stack on the site. Innospec provided all site, stack and emissions data.

The Innospec site is located east of Ellesmere Port and south of the Mersey Estuary. Five years of hourly sequential meteorological data from Liverpool, 6 km north of the site, were used in the modelling, for the years 2016 to 2020 inclusive.

To assess impacts on human health, modelling was carried out to predict the Process Contribution (PC) to ground level concentrations of NO_2 for comparison with the UK air quality objectives. For impacts on protected conservation areas, modelling was carried out to predict the PC to ground level concentrations of NO_x, and nitrogen and acid deposition rates, for comparison with critical levels and critical loads, respectively.

1.1 Human health impacts

Process Contributions to NO_2 concentrations are not screened out, but the PECs are below the air quality objectives.

1.2 Ecological impacts

At Jack's Wood and Whitby Park, all NO_x PCs are screened out, as the annual average PCs are less than 1% of the critical level of 30 $\mu g/m^3$ and the daily average PCs are less than 10% of the critical level of 75 $\mu g/m^3$. At Mersey Estuary, within 500 m north of the modelled stack, neither annual nor daily average PCs are screened out, but the PECs are below the critical levels.

The maximum PCs to nitrogen deposition are screened out at Jack's Wood and Whitby Park, as they are less than 1% of the nitrogen critical load. At Mersey Estuary, the PC for one of the five modelled years of meteorological data is 1.1% of the lower end of the critical load range. The existing nitrogen deposition already exceeds the critical load.

According to the Critical Load Function Tool, the maximum PCs to acid deposition are screened out at Jack's Wood and Whitby Park. At Mersey Estuary, the PC is only 2% of the critical load function. However, the background acid deposition already exceeds the critical load function.

2 Introduction

Cambridge Environmental Research Consultants Ltd (CERC) was commissioned by Veolia Energy UK to carry out an air quality assessment to support the permit variation for a proposed Energy Centre at the Innospec site in Ellesmere Port, Cheshire.

Dispersion modelling of nitrogen oxides emissions to air was carried out to assess the impact of the site with the addition of the Energy Centre. The Energy Centre will comprise two CHP plant (2.5 MW and 1.5 MW) and two waste heat boilers, each with its own flue within a common stack. Emissions from an existing lead furnace stack were also taken into account in the modelling.

Section 3 presents the air quality standards relevant to this assessment. Details of the site location and surrounding area are given in Section 4, along with background concentrations for the area.

Section 5 presents the stack and building data used as input to the model, and Section 6 presents the meteorological data. Section 7 presents results for human health impacts, and Section 8 and Section 9 set out the concentration and deposition results, respectively, for impacts on habitats.

A discussion of the conclusions of the assessment is presented in Section 10. Finally, a description of the ADMS model used in the assessment is given in Appendix A.

3 Air quality standards

3.1 Protection of human health

UK air quality objectives for nitrogen dioxide (NO_2), set for the protection of human health, are summarised in Table 3.1. The objectives are taken from *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland*, July 2007, and are the subject of Statutory Instrument 2000 No. 928, *The Air Quality (England) Regulations 2000*, which came into force on 6th April 2000. The objective values are set at a European level, and take into account the effects of each pollutant on the health of those who are most sensitive to air quality.

Table 3.1: UK air quality objectives for the protection of human health (μg/m^3)

Substance	Limit value	Reference period and allowed exceedences
NO_2	200	hourly mean not to be exceeded more than 18 times a year (modelled as 99.79th percentile)
	40	annual mean

A number of the air quality objectives are specified in terms of the number of times during a year that a concentration measured over a short period of time (for example, 15 minutes, 1 hour or 24 hours, as appropriate) 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 200 μg/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.

3.2 Protection of vegetation and ecosystems

Critical levels for the protection of vegetation and ecosystems, as set out in the Environment Agency's guidance for environmental permits[1], are summarised in Table 3.2.

The guidance recommends the assessment of:

- Special Protection Areas (SPAs)[2], Special Areas of Conservation (SACs)[3] and Ramsar[4] sites within 10 km of the installation; and
- Sites of Special Scientific Interests (SSSIs)[5], National Nature Reserves (NNRs)[5], Local Nature Reserves (LNRs)[6], local wildlife sites and ancient woodland within 2 km of the installation.

Table 3.2: Critical levels for the Protection of Vegetation and Ecosystems (μg/m³)

Pollutant	Critical level	Comment
NO_x	30	annual mean
	75	daily mean

1 https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#screening-for-protected-conservation-areas

2 Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora

3 Council Directive 79/409/EEC on the conservation of wild birds

4 International Convention on Wetlands of International Importance especially as Waterfowl Habitat

5 Declared by the statutory country conservation agencies, which have a duty under the Wildlife and Countryside Act 1981

6 Declared under the National Parks and Access to the Countryside Act 1949 by local authorities after consultation with the relevant statutory nature conservation agency

4 Assessment area

4.1 Site location and surrounding area

The Innospec site is located west of Stanlow Refinery, close to the banks of the Mersey, east of Ellesmere Port. Figure 4.1 shows the location of the site. Designated conservation areas and Air Quality Management Areas (AQMAs) are also shown; these are described in subsections below.

A surface roughness length is used in the model to characterise the surrounding area in terms of the effects it will have on wind speed and turbulence, which are key components of the modelling. A surface roughness value of 0.5 metres was used for the modelled area, which represents the land use around the site. A surface roughness value of 0.2 metres was used for Liverpool Airport meteorological station. See Section 6 for further information regarding the meteorological data used in the modelling. In the ADMS 5 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 urban area, the larger the minimum value. A value of 30 metres was used in this modelling, which is suitable for a mixed urban and industrial area. The model default value of 1 metre was used for Liverpool Airport meteorological site.

The surrounding area is generally flat, and so the effects of terrain on dispersion were considered negligible and not taken into account in the modelling.

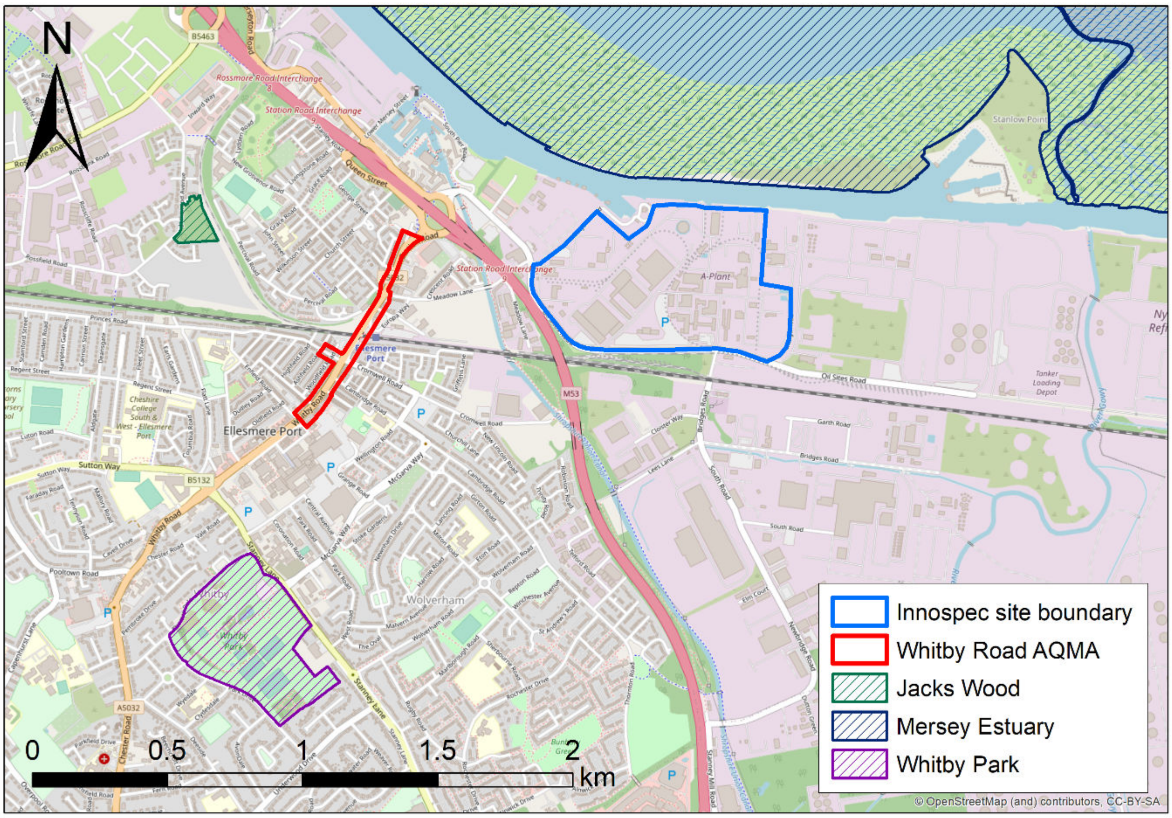

Figure 4.1: Location of Innospec site

4.2 Sensitive receptors for human health impact

Model output was generated at ground level on an output grid centred on the site, with concentration values calculated at points 20 m apart on this grid, capturing the maximum predicted concentrations across the modelled area.

Model output was also generated at locations of specific sensitive receptors. The locations of these receptors are described in Table 4.1 and shown in Figure 4.2. All sensitive receptors were modelled at ground level.

Table 4.1: Sensitive human health receptors

Id	Name	Type	Location (X, Y)
1	Wolverham Primary and Nursery School	School	340750, 375776
2	The Oaks Community Primary School	School	340767, 375059
3	St Bernard's Roman Catholic Primary School	School	340784, 375323
4	Oval Crescent	Residential	341443, 375349
5	Robinson Road	Residential	341086, 375952
6	Griffiths Lane	Residential	340689, 376359
7	Shephard Close	Residential	340742, 376708

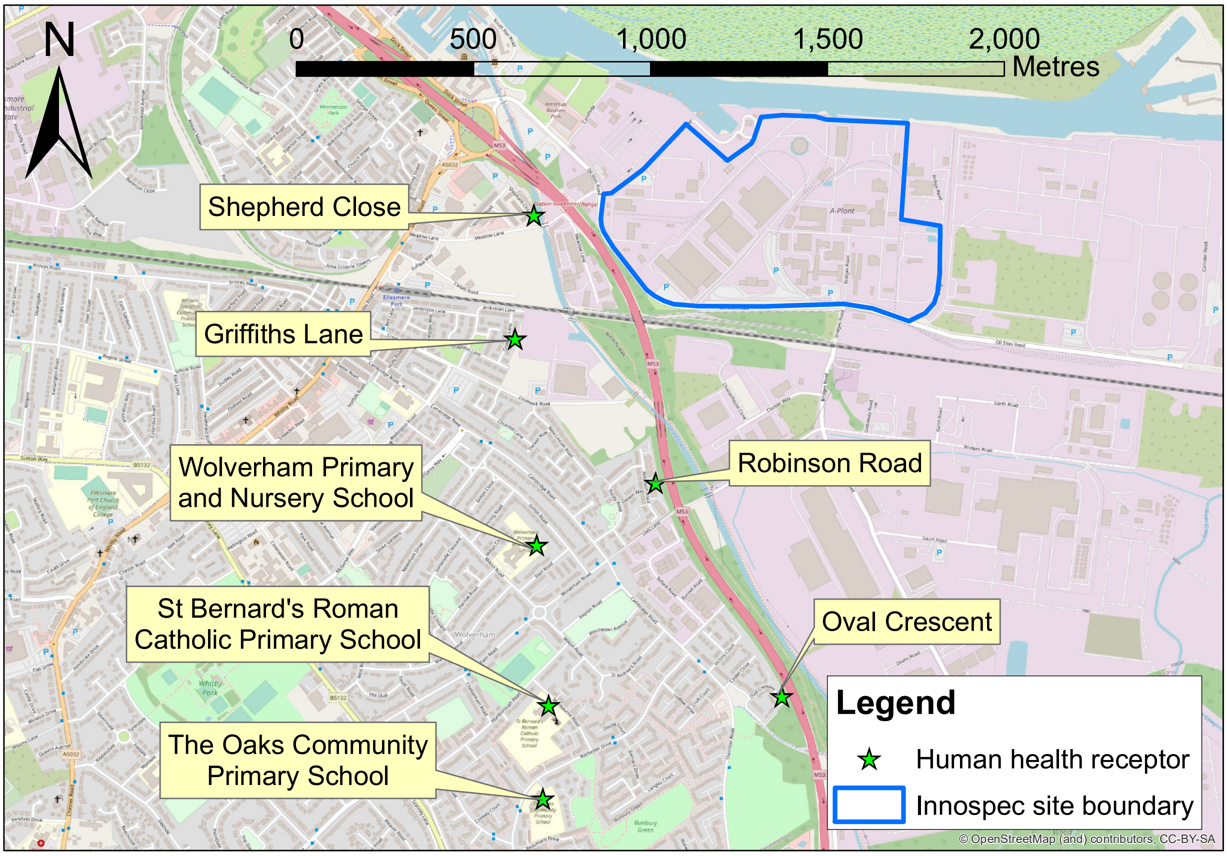

Figure 4.2: Location map of human health receptors

4.3 Sensitive receptors for the protection of vegetation and ecosystems

Following guidance set out by the Environment Agency, as discussed in Section 3.2, model output was calculated at designated sites within appropriate distances of the modelled stacks, at which potentially sensitive ecosystems were identified.

Three designated sites were considered, as detailed in Table 4.2 and shown in Figure 4.1.

Table 4.2: Designated sites

Name	Designation	Distance from site boundary
Mersey Estuary	SPA, Ramsar, SSSI	100 m north
Whitby Park	LNR	1.4 km south west
Jack's Wood	LWS	1.2 km west

4.4 Local air quality

4.4.1 AQMAs

Cheshire West and Chester Council have declared three Air Quality Management Areas (AQMAs) for NO_2 concentrations. The closest is approximately 500 m west of the site, an area incorporating residential properties on Whitby Road, in Ellesmere Port. The location of this AQMA is shown in Figure 4.1.

The Council has also declared an AQMA for SO_2 concentrations, which includes an area encompassing the entire village of Thornton le Moors and parts of Stanlow Refinery.

4.4.2 Monitoring sites

Monitoring data for the years 2018 to 2021 were obtained from Cheshire West and Chester Air Quality Annual Status Reports[7] and directly from Cheshire West and Chester Council. Monitoring sites within 2 km of the site boundary are summarised in Table 4.3.

Figure 4.3 shows the locations of these sites.

[7] https://www.cheshirewestandchester.gov.uk/residents/pests-pollution-food-safety/pollution-and-air-quality/air-quality-review-and-assessment

Table 4.3: NO_2 monitoring sites, 2018-2021

ID	Monitor	Name	Type	Location (X,Y)
LR-JG	Automatic	Library	Urban background	339947, 375889
WH	Automatic	Whitby Road	Roadside	340197, 376363
NS	Diffusion tube	Newsagent Station Rd	Roadside	340406, 376724
RR	Diffusion tube	Richfield Recruitment	Roadside	340180, 376338
SLW	Diffusion tube	Stanney Lane	Roadside	339889, 375755
SR	Diffusion tube	Station Road	Roadside	340435, 376790
UCA	Diffusion tube	U of C Academy	Roadside	339687, 375972
WH1-3	Diffusion tube	Whitby Road [8]	Roadside	340196, 376363

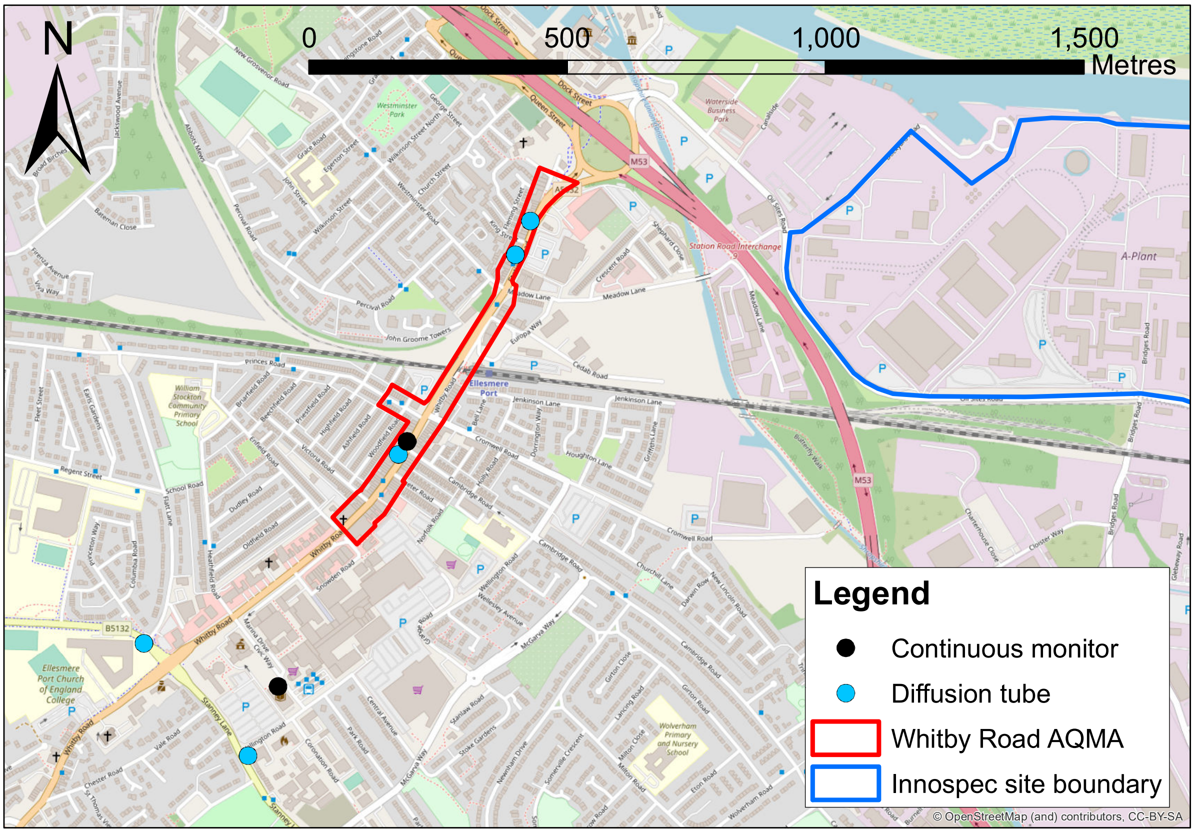

Figure 4.3: Locations of nearby monitoring sites

Table 4.4 and Table 4.5 provide the monitored concentrations of NO_2 for the years 2018 to 2021. There are no monitored exceedences of the NO_2 objectives.

Table 4.4: Continuous monitoring data for NO_2, 2018-2021 ($\mu g/m^3$)

ID	2018		2019		2020		2021	
	Annual average	1-hour means > 200	Annual average	1-hour means > 200	Annual average	1-hour means > 200	Annual average	1-hour means > 200
LR-JG	19	0	-	-	-	-	-	-
WH	37	0	35	0	28	0	29	0

[8] Co-located with the automatic Whitby Road site

Table 4.5: Diffusion tube monitoring data for NO_2, 2018-2021 (µg/m³)

ID	NO_2 annual mean			
	2018	2019	2020	2021
NS	32.4	-	-	-
RR	36.5	35.2	30.0	31.4
SLW	-	-	16.8	18.3
SR	33.8	31.0	26.3	29.3
UCA	28.6	24.9	-	-
WH1-3	37.0	31.4	25.8	27.4

4.4.3 Mapped background data

Human health impacts

Background concentrations of NO_2 were obtained from the UK AIR Air Information Resource background mapping[9]. The tool provides national modelled background maps on a 1 km resolution; the latest data available are for the year 2021.

Table 4.6 provides the background concentrations for the grid squares around the site.

These values were used as an estimate of background concentration in order to calculate total concentrations of NO_2, referred to as Predicted Environmental Concentrations (PECs).

Table 4.6: Background concentrations of NO_2 (µg/m³)

Grid square (x, y)	Description	NO_2
340500, 375500	Residential areas to west/south of site	11.1
340500, 376500		13.9
341500, 375500		13.1
341500, 376500	Industrial area adjacent to site	15.7

Ecological impacts

Mapped background data for NO_x at the location of each designated conservation area, taken from the Air Pollution Information System (APIS) website,[10] are shown in Table 4.7. These values represent three year averages, over the period 2018 to 2020.

Table 4.7: Background concentrations for habitat sites from APIS website (µg/m³)

Habitat Site	Site Type	NO_x
Mersey Estuary	SPA, Ramsar, SSSI	20.2
Whitby Park	LNR	16.6
Jack's Wood	LWS	17.9

[9] https://uk-air.defra.gov.uk/data/gis-mapping/
[10] http://www.apis.ac.uk/search-location

5 Modelled stacks and emissions data

5.1 Modelled stacks

Table 5.1 and Table 5.2 present the modelled stack parameters and emissions data, respectively.

Figure 5.1 presents the locations of the modelled stacks and the site buildings. Site buildings are described in Section 5.2.

Table 5.1: Modelled stack details

	Energy Centre			Lead furnace
	2.5 MW CHP	1.5 MW CHP	Waste heater boiler (x2)	
Location (x,y)	341667.3, 376589.6			341677, 376760
Height (m)	17.0			91.4
Diameter (m)	0.6	0.5	0.61	4.0
Normalised volume flow rate - dry (Nm^3/h)	9442	5748	7452	27924
Normalised volume flow rate - wet (Nm^3/h)	10546	6404	-	27924
Actual volume flow rate (Am^3/h)	15182 [11]	9219 [11]	11273	30529
Velocity [12] (m/s)	14.9	13.0	13.12	0.7
Temperature (°C)	120	120	140	29

Table 5.2: Emission rates of NO_x

	2.5 MW CHP	1.5 MW CHP	Waste heater boiler (x2)	Lead furnace
Emission concentration [13] (mg/Nm^3)	250	250	100	15.3
Emission rate [14] (g/s)	0.660	0.440	0.207	0.118

[11] Calculated from 'Normalised volume flow rate – wet', adjusting for temperature only
[12] Calculated from 'Actual volume flow rate' and diameter
[13] Quoted at 5% oxygen for the CHP plant and 3% oxygen for the boilers
[14] Calculated from 'Normalised volume flow rate – dry' and emission concentration

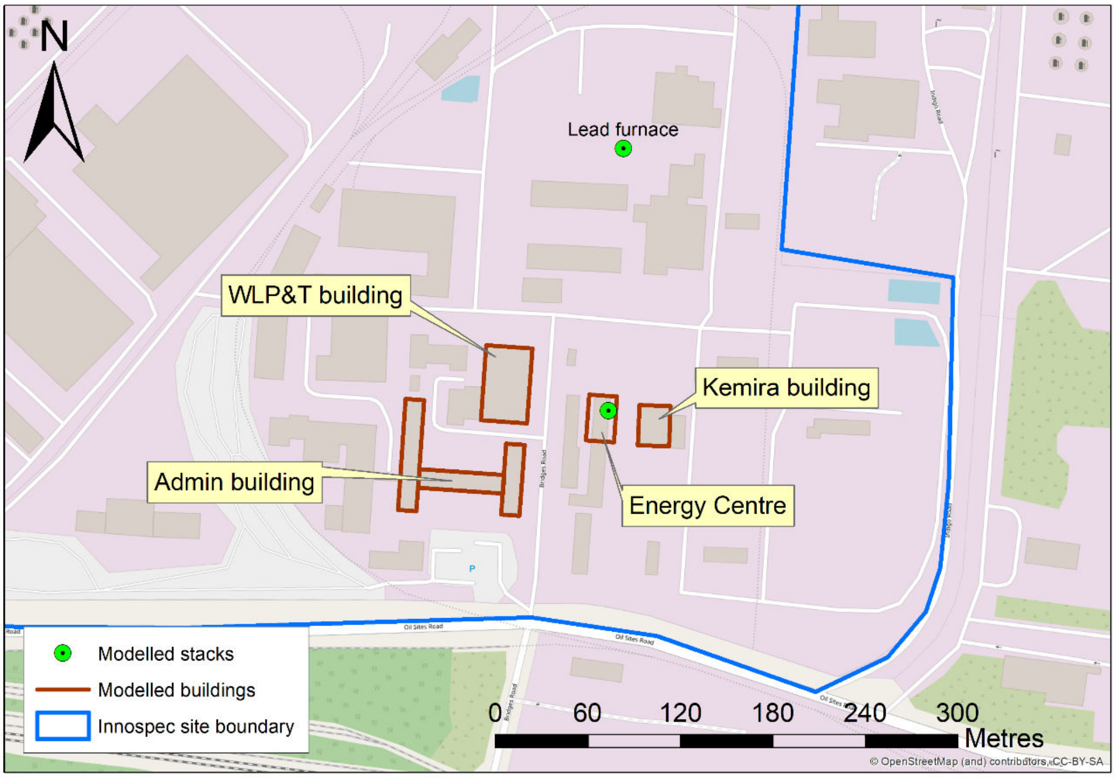

Figure 5.1: Locations of modelled stack and buildings

5.2 Modelled buildings

Buildings that are relatively close to the modelled stacks and higher than one third of the stack height can have an effect on dispersion, by disturbing wind flows and increasing turbulence. Increased concentrations can also occur when pollutants are entrained into the region downwind of a building, but concentrations can be consequently decreased further away as the plume, travelling downstream, is further diluted.

Veolia provided building heights and a plan of the site layout. Table 5.3 presents the buildings data used and Figure 5.1 shows the locations of the modelled buildings and stacks. As the combined CHP and boiler stack is located on the Energy Centre building, this was selected as the Main Building in its modelling. As the lead furnace stack height is 91.4 m, no buildings were considered to impact dispersion from this stack.

Table 5.3: Site buildings data

Name	Coordinates of building centre (x,y)	Height (m)	Length (m)	Width (m)	Angle of length to north (°)
Energy Centre	341662.5, 376584.8	9.9	29.7	18.2	4
Kemira building	341696.7, 376580.1	11.5	26.0	20.25	2
WLP&T building	341601.0, 376607.0	13.0	49.0	30.0	4
Admin – east wing	341605.0, 376545.0	11	46.0	12.0	4
Admin – west wing	341539.0, 376561.0	11	72.0	12.0	4
Admin – main	341571.6, 376544.0	11	12.0	55.0	4

6 Meteorological data

Modelling was carried out using hourly sequential meteorological data obtained from Liverpool Airport for the five years 2016 to 2020 inclusive. Liverpool Airport is located approximately 6 km north of the modelled stack.

The hours of meteorological data used in the analysis exclude hours of calm, hours of variable wind direction and unavailable data, for example due to issues with the instrumentation. A summary of the data used is given in Table 6.1. The ADMS meteorological pre-processor, written by the Met Office, uses the meteorological data to calculate the parameters required by the model.

Figure 6.1 shows wind roses for Liverpool Airport, giving the frequency of occurrence of wind from different directions for a number of wind speed ranges, for the five years 2016 to 2020.

Table 6.1: Summary of meteorological data used

Year	Percentage used	Parameter	Minimum	Maximum	Mean
2016	95.9	Temperature (°C)	-3.0	30.0	10.8
		Wind speed (m/s)	0	17.5	4.5
		Cloud cover (oktas)	0	8	3.6
2017	95.5	Temperature (°C)	-3.0	28.0	11.2
		Wind speed (m/s)	0	22.7	4.8
		Cloud cover (oktas)	0	8	4.2
2018	93.9	Temperature (°C)	-5.0	30.0	11.2
		Wind speed (m/s)	0	22.1	4.6
		Cloud cover (oktas)	0	8	3.9
2019	95.3	Temperature (°C)	-4.0	31.0	11.1
		Wind speed (m/s)	0	18.0	4.6
		Cloud cover (oktas)	0	8	3.8
2020	96.6	Temperature (°C)	-1.0	30.0	11.5
		Wind speed (m/s)	0	16.5	4.9
		Cloud cover (oktas)	0	8	4.0

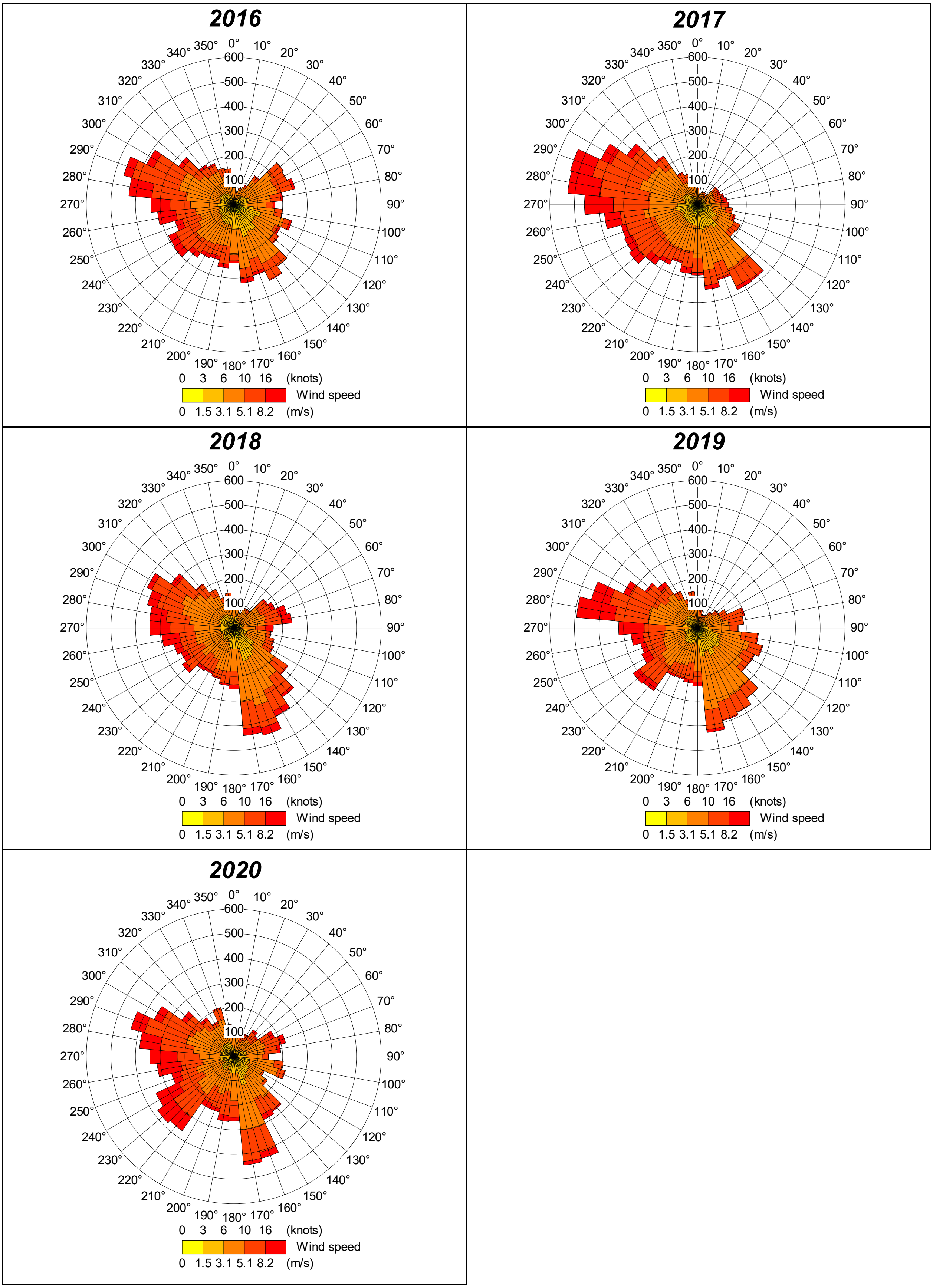

Figure 6.1: Wind roses for Liverpool Airport

7 Impact of emissions on human health

Nitrogen oxides (NO_x) comprise nitric oxide (NO) and nitrogen dioxide (NO_2). Only NO_2 is considered in statutory air quality objectives for the protection of human health; the NO_x critical levels for the Protection of Vegetation and Ecosystems are considered in Section 8.

The PC to NO_2 concentrations depends on the concentrations of NO_x due to other sources in the area and the chemical reactions taking place between NO and NO_2.

For direct comparison against the objectives for NO_2, an empirical relationship defined by the Environment Agency was therefore used to calculate the NO_2 PEC. This method assumes that a fixed proportion of the PC of NO_x is NO_2 (70% for the annual average and 35% for the 99.79th percentile of hourly averages). The NO_2 PEC is calculated by adding the annual average NO_2 background concentration to the annual average concentration, and twice the annual average background concentration of NO_2 to the 99.79th percentile of hourly average concentrations.

Table 7.1 shows the maximum predicted annual average offsite concentrations of NO_2, calculated using meteorological data for the five years 2016 to 2020.

The maximum annual average offsite NO_2 PC is 4.1 µg/m^3, 10% of the air quality objective of 40 µg/m^3, calculated using meteorological data for the year 2020. Including the background concentration of 15.7 µg/m^3, maximum predicted offsite PEC is 50% of the air quality objective.

Figure 7.1 shows a contour plot of annual average NO_2 PC concentrations, based on meteorological data for the year 2020, the year giving the highest predicted annual average concentrations.

Table 7.2 shows the maximum predicted hourly average offsite concentrations of NO_2, calculated using meteorological data for the five years 2016 to 2020.

The maximum offsite 99.79th percentile of hourly average NO_2 PC concentration is 25 µg/m^3, 13% of the air quality objective of 200 µg/m^3, calculated using meteorological data for the year 2019. Including the background concentration, maximum predicted offsite PECs are 28% of the air quality objective.

Figure 7.2 shows a contour plot of the 99.79th percentile of hourly average NO_2 PC concentrations, based on meteorological data for the year 2019, the year giving the highest predicted hourly average concentrations.

Table 7.1: Maximum predicted offsite annual average concentrations of NO_2 ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC (NO_x)	PC (NO_2)[15]	PC % of objective	Background NO_2	PEC (NO_2)	PEC % of objective	Location	
										x	y
2016	Long-term AQO	Annual average	40	4.8	3.4	9	15.7	19.1	48	341900	376530
2017				5.6	3.9	10		19.6	49	341900	376550
2018				4.3	3.0	8		18.7	47	341820	376690
2019				4.8	3.4	9		19.1	48	341800	376710
2020				5.8	4.1	10		19.8	50	341800	376710

Table 7.2: Maximum predicted offsite hourly average concentrations of NO_2 ($\mu g/m^3$)

Year	Standard	Measured as	Objective value	PC (NO_x)	PC (NO_2)[16]	PC % of objective	Background NO_2[17]	PEC (NO_2)	PEC % of objective	Location	
										x	y
2016	Short-term AQO	99.79th percentile of hourly averages	200	69	24	12	31.4	55	28	341800	376710
2017				68	24	12		55	28	341800	376710
2018				68	24	12		55	28	341800	376710
2019				70	25	13		56	28	341800	376710
2020				69	24	12		55	28	341800	376710

[15] 70% of long term NO_x PC
[16] 35% of short-term NO_x PC
[17] Adding double the annual average background concentration to the 99.79th percentile of hourly averages

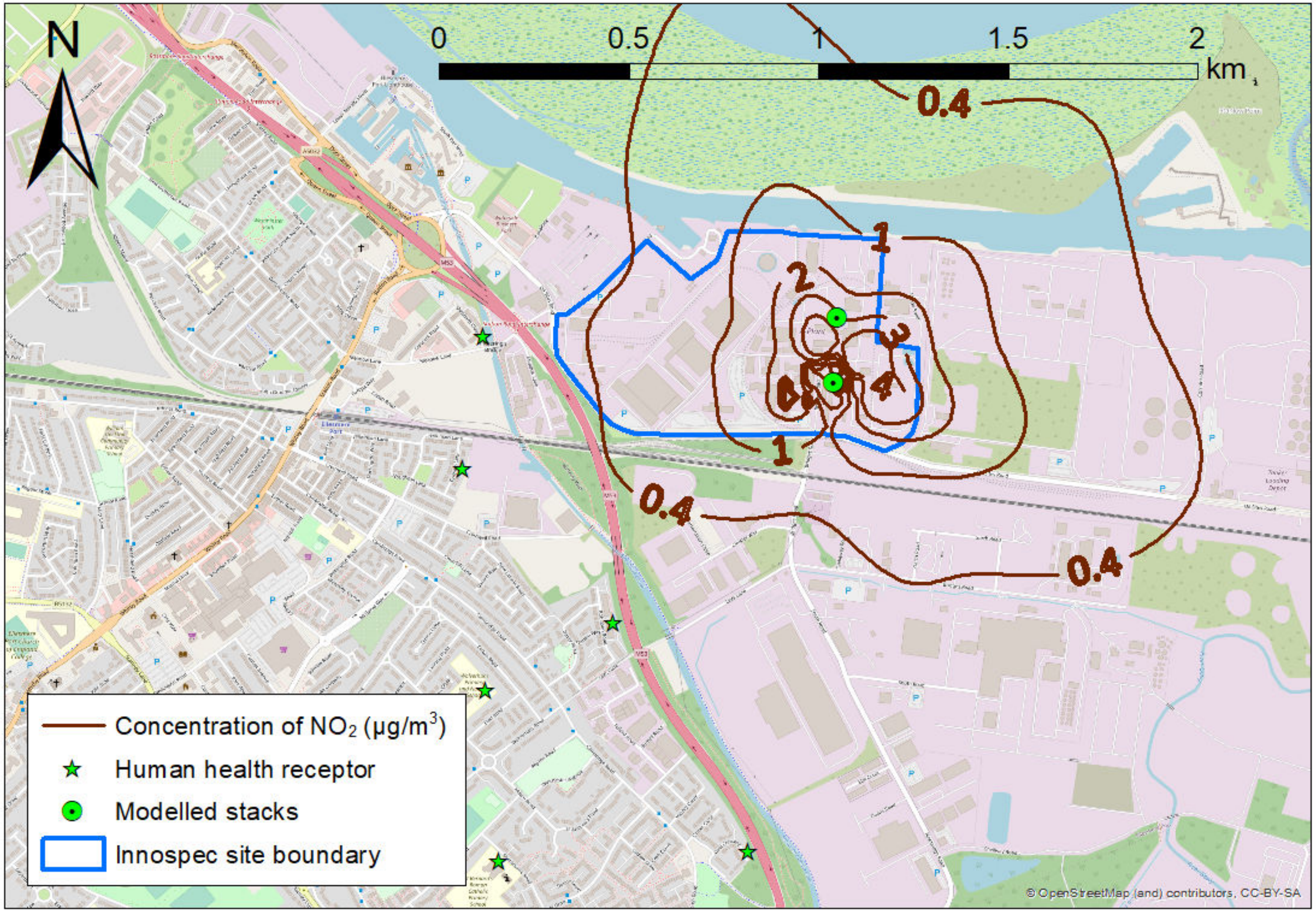

Figure 7.1: Contour plot of the PC to annual average NO_2 concentration, using meteorological data for the year 2020

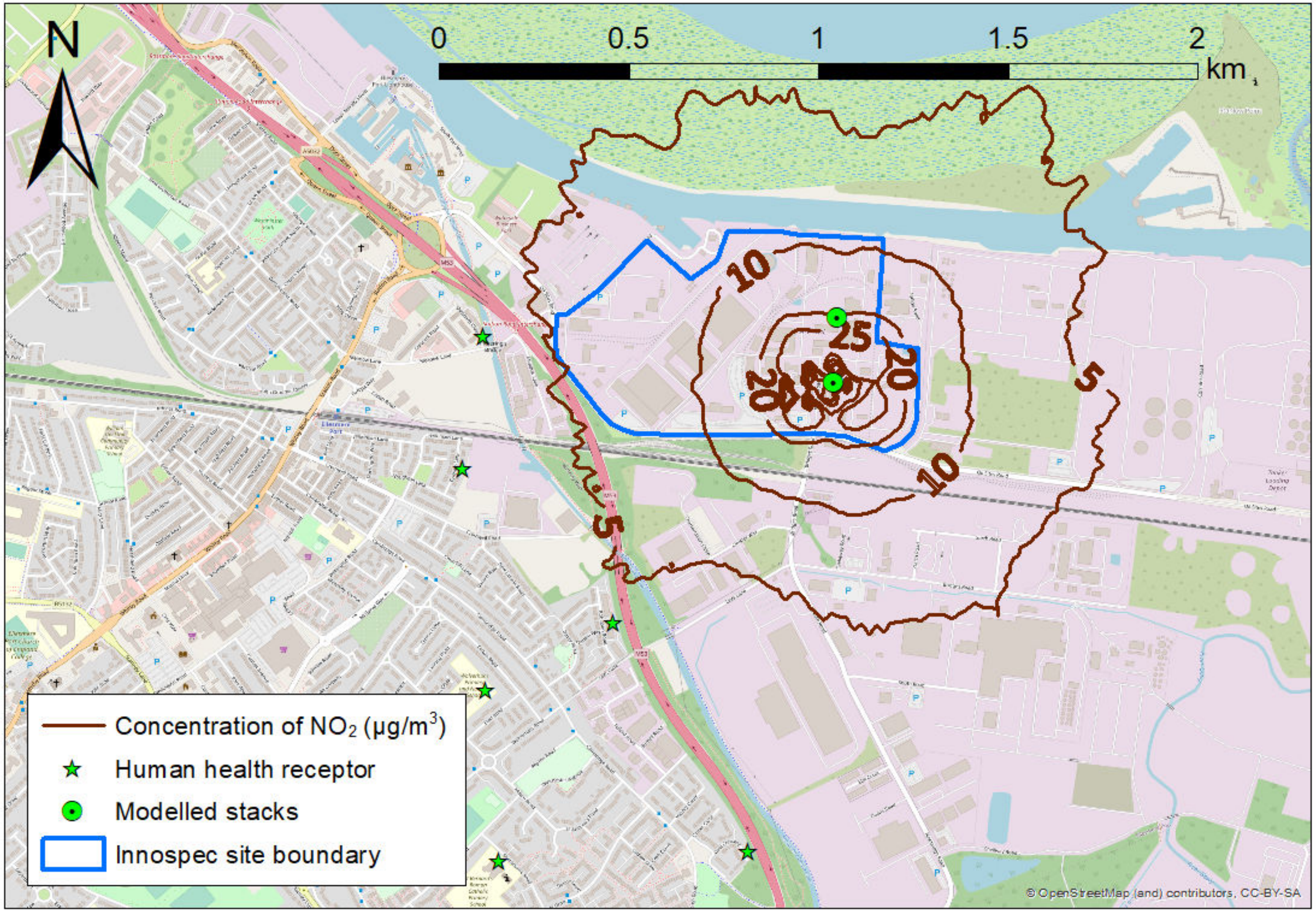

Figure 7.2: Contour plot of the PC to 99.79th percentile of hourly average NO_2 concentration, using meteorological data for the year 2019

Table 7.3 shows the calculated annual average PCs of NO_2 at the receptor points. At each receptor point, the maximum value over all five years of meteorological data is presented.

The maximum calculated PCs to annual average NO_2 concentration are screened out as they are less than 1% of the annual average air quality objective.

Table 7.3: PCs to annual average NO_2 concentrations (µg/m^3) at receptors

ID	Receptor	AQO	PC		
			NO_x	NO_2	% of AQO
1	Wolverham Primary and Nursery School	40	0.31	0.22	0.6
2	The Oaks Community Primary School		0.10	0.07	0.2
3	St Bernard's Roman Catholic Primary School		0.15	0.11	0.3
4	Oval Crescent		0.14	0.10	0.3
5	Robinson Road		0.41	0.29	0.7
6	Griffiths Lane		0.37	0.26	0.7
8	Shephard Close		0.46	0.32	0.8

Table 7.4 shows the calculated hourly average PCs of NO_2 at the receptor points. At each receptor point, the maximum value over all five years of meteorological data is presented.

The maximum calculated PCs hourly annual average NO_2 concentration are screened out as they are less than 10% of the hourly average air quality objective.

Table 7.4: PCs to 99.79th percentile of hourly average NO_2 concentrations (µg/m^3) at receptors

ID	Receptor	AQO	PC		
			NO_x	NO_2	% of AQO
1	Wolverham Primary and Nursery School	200	9.6	3.4	2
2	The Oaks Community Primary School		6.5	2.3	1
3	St Bernard's Roman Catholic Primary School		7.7	2.7	1
4	Oval Crescent		8.9	3.1	2
5	Robinson Road		13.8	4.8	2
6	Griffiths Lane		11.2	3.9	2
8	Shephard Close		12.3	4.3	2

8 Impact on vegetation and ecosystems

Modelling was carried out to predict the maximum PC to concentrations of nitrogen oxides (NO_x) at the designated conservation areas. Note that the maximum concentrations quoted are the maximum values occurring at locations relevant to the standard under consideration. This means that, for comparison against critical levels for the Protection of Vegetation and Ecosystems, only those values predicted within the sensitive habitat sites were included.

The significance of the total pollutant release was assessed by comparing the PC to the relevant critical level. For long-term critical levels, the Environment Agency considers the release to be insignificant if the PC is less than 1% of the critical level. For short-term critical levels, the Agency considers the release to be insignificant if the PC is less than 10% of the critical level. Where a release is insignificant the pollutant is screened out and no further assessment undertaken.

Table 8.1 and Table 8.2 show the maximum predicted annual and daily average PCs to concentrations of NO_x at the designated sites, using meteorological data for the five years 2016 to 2020.

At Jack's Wood and Whitby Park, all NO_x PCs are screened out, as the annual average PCs are less than 1% of the critical level of 30 $\mu g/m^3$ and the daily average PCs are less than 10% of the critical level of 75 $\mu g/m^3$.

At Mersey Estuary, which is within 500 m north of the modelled stack, neither annual nor daily average PCs are screened out, but the annual and daily average PECs are below the critical levels.

Table 8.1: Predicted annual average NO_x concentrations at designated conservation areas (µg/m³)

Site name	Critical level	Year	PC			Background	PEC	
			NO_x	% of critical level	Screened out?		NO_x	% of critical level
Mersey Estuary	30	2016	1.0	3	No	20.2	21.2	71
		2017	1.3	4			21.5	72
		2018	1.6	5			21.8	73
		2019	1.5	5			21.7	72
		2020	1.5	5			21.7	72
Jack's Wood		2016	0.17	0.6	Yes	-	-	-
		2017	0.12	0.4				
		2018	0.13	0.4				
		2019	0.18	0.6				
		2020	0.14	0.5				
Whitby Park		2016	0.18	0.6	Yes	-	-	-
		2017	0.08	0.3				
		2018	0.12	0.4				
		2019	0.11	0.4				
		2020	0.12	0.4				

Table 8.2: Predicted daily average NO_x concentrations at designated conservation areas (µg/m³)

Site name	Critical level	Year	PC				PEC	
			NO_x	% of critical level	Screened out?	Background	NO_x	% of critical level
Mersey Estuary	75	2016	10.3	14	No	20.2	30.5	41
		2017	10.0	13			30.2	40
		2018	11.7	16			31.9	43
		2019	11.6	15			31.8	42
		2020	13.5	18			33.7	45
Jack's Wood		2016	1.7	2	Yes	-	-	-
		2017	1.6	2				
		2018	3.3	4				
		2019	1.8	2				
		2020	1.7	2				
Whitby Park		2016	1.6	2	Yes	-	-	-
		2017	1.5	2				
		2018	1.2	2				
		2019	2.1	3				
		2020	2.0	3				

9 Impact on deposition rates

Material from a plume can be lost to the ground, at the surface of the ground (dry deposition), and through wash out with precipitation (wet deposition). Deposition of pollutants may lead to detrimental effects at sensitive habitats due to acidification and nitrogen eutrophication.

Modelling was carried out to predict the PC to the nitrogen and acid deposition rates from the proposed Energy Centre and existing lead furnace over the designated conservation areas. The significance of the total pollutant release was assessed by comparing the PC to the relevant critical loads. For long-term impacts, as in the case of deposition, the Environment Agency considers the release to be insignificant if the PC is less than 1% of the critical load. Where a release is insignificant the impact is screened out and no further assessment undertaken.

9.1 Nitrogen deposition

9.1.1 Critical loads and existing levels of nitrogen deposition

The Air Pollution Information System (APIS) website[10] gives critical load values for specific SACs, SPAs and Ramsars. For sites such as LNRs or LWSs, critical load values can be found by location.

Table 9.1 shows the habitat types, critical loads and total nitrogen deposition values at the designated conservation areas identified in Section 4.3.

The total nitrogen deposition values presented are specific to habitat types at each designated conservation area. The total nitrogen deposition values presented represent the average deposition over the years 2018 to 2020, due to existing local sources and background contributions. In some cases, the existing total nitrogen deposition rate exceeds the relevant critical load range.

Table 9.1: Total nitrogen deposition (kg N ha^{-1} yr^{-1})

Site name	Habitat type	Relevant Nitrogen critical load class	Critical load	Total nitrogen deposition
Mersey Estuary	Fen, marsh and swamp	Rich fens	15 - 30	32.6
	Littoral sediment	Pioneer, low-mid mid-upper saltmarshes	20 - 30	
Whitby Park	Neutral grassland	Low and medium altitude hay meadows	20 - 30	30.0
Jack's Wood	Broadleaved, mixed and yew woodland	Broadleaved deciduous / Fagus woodland	10 - 20	51.0

9.1.2 Process contribution to nitrogen deposition

The deposition of nitrogen from concentrations of NO_2 (assumed to be 70% of NO_x) was considered.

The Environment Agency Air Quality Modelling and Assessment Unit (AQMAU)[18] recommend dry deposition velocities for grassland and forest. NO_2 dry deposition velocities of 0.003 m/s for forest and of 0.0015 for grassland were assumed. The forest value was assumed for Jack's Wood and the grassland value was assumed for Mersey Estuary and Whitby Park.

The maximum predicted annual PC to deposition rates of nitrogen at each designated conservation area is presented in Table 9.2, together with the PC as a percentage of the most stringent critical load applicable to each designated conservation area.

The maximum PCs to nitrogen deposition are screened out at Jack's Wood and Whitby Park, as they are less than 1% of the nitrogen critical load.

At Mersey Estuary, the PC for one of the five modelled years of meteorological data is 1.1% of the lower end of the critical load range. The existing nitrogen deposition already exceeds the critical load.

Table 9.2: Maximum nitrogen deposition (kg N ha^{-1} yr^{-1}) at designated conservation areas

Site name	Critical load class	Critical load	Year	PC	PC as % of critical load
Mersey Estuary	Rich fens	15 – 30	2016	0.111	0.7
			2017	0.130	0.9
			2018	0.159	1.1
			2019	0.147	1.0
			2020	0.150	1.0
Whitby Park	Low and medium altitude hay meadows	20 – 30	2016	0.017	< 0.1
			2017	0.008	< 0.1
			2018	0.012	< 0.1
			2019	0.010	< 0.1
			2020	0.011	< 0.1
Jack's Wood	Broadleaved deciduous / Fagus woodland	10 – 20	2016	0.031	0.3
			2017	0.021	0.2
			2018	0.023	0.2
			2019	0.032	0.3
			2020	0.026	0.3

[18]AQTAG 06, *Technical Guidance on detailed modelling approach for an appropriate assessment for emissions to air*, Environment Agency, March 2014

9.2 Acid deposition

9.2.1 Critical loads and existing levels of acid deposition

The APIS website[10] gives critical load values for specific SACs, SPAs and Ramsars. For sites such as LNRs or LWSs, critical load values can be found by location.

Table 9.3 shows the habitat types, critical loads and total acid deposition values at the designated conservation areas identified in Section 4.3. The critical loads presented are specific to each designated conservation area.

The Critical Load Function is defined by three quantities to account for the contribution of different species to total acid deposition[10]. CLmaxS is the maximum critical load for acidity expressed in terms of sulphur i.e. when nitrogen deposition is zero; this value also considers non-marine chloride deposition[18]. Similarly, CLmaxN is the maximum critical load of acidity expressed in terms of nitrogen only i.e. when sulphur and non-marine chloride deposition is zero. Finally, CLminN defines a nitrogen deposition level below which additional nitrogen will not acidify the system, due to long-term nitrogen losses in the soil, e.g. nitrogen uptake by vegetation.

The total acid deposition values presented represent the average deposition over the years 2018 to 2020, due to existing local sources and background contributions. The nitrogen (N) and sulphur (S) contributions are presented.

Table 9.3: Total acid deposition (keq ha^{-1} yr^{-1})

Site name	Habitat type	Relevant acidity critical load class	Critical load (keq)	Total acid deposition N|S
Mersey Estuary	Neutral grassland	Acid grassland	MaxCLminN: 0.438 MaxCLmaxN: 4.548 MaxCLmaxS: 4.110 MinCLminN: 0.223 MinCLmaxN: 0.556 MinCLmaxS: 0.190	2.33|0.21
		Calcareous grassland	MaxCLminN: 1.071 MaxCLmaxN: 5.071 MaxCLmaxS: 4.000 MinCLminN: 0.856 MinCLmaxN: 4.856 MinCLmaxS: 4.000	
	Bogs	Bogs	MaxCLminN: 0.321 MaxCLmaxN: 0.528 MaxCLmaxS: 0.207 MinCLminN: 0.321 MinCLmaxN: 0.498 MinCLmaxS: 0.177	
	Dwarf shrub heath	Dwarf shrub heath	MaxCLminN: 0.892 MaxCLmaxN: 4.824 MaxCLmaxS: 4.110 MinCLminN: 0.642 MinCLmaxN: 0.832 MinCLmaxS: 0.190	
Whitby Park	Neutral grassland	Calcareous grassland	CLminN: 1.071 CLmaxN: 4.000 CLmaxS: 5.071	2.11|0.21
Jack's Wood	Broadleaved, mixed and yew woodland	Broadleaved / coniferous unmanaged woodland	CLminN: 0.357 CLmaxN: 1.359 CLmaxS: 1.716	3.64|0.25

9.2.2 Process contribution to acid deposition

The rate of acid deposition calculated in this assessment is based on the PC to acid deposition from nitrogen, presented in Section 9.1. The dry deposition velocities used are provided in Section 10.1.2.

The APIS Critical Load Function Tool[19] was used to assess the impact of the nitrogen contribution to acid deposition at each of the designated conservation areas.

For each identified habitat, minCLmaxS, minCLmaxN and minCLminN were input to the tool, along with the maximum background deposition, presented in Table 9.3. The maximum PCs to the nitrogen contribution were also input to the tool.

Table 9.4 presents the maximum predicted contributions from nitrogen to the acid deposition rates at each designated conservation area.

Table 9.4: Contributions to acid deposition (keq ha^{-1} yr^{-1}) at designated conservation areas

Site name	Critical load class	Year	PC (N)
Mersey Estuary	Bogs	2016	0.0079
		2017	0.0093
		2018	0.0114
		2019	0.0105
		2020	0.0107
Whitby Park	Low and medium altitude hay meadows	2016	0.0012
		2017	0.0006
		2018	0.0008
		2019	0.0007
		2020	0.0008
Jack's Wood	Broadleaved / coniferous unmanaged woodland	2016	0.0022
		2017	0.0015
		2018	0.0016
		2019	0.0023
		2020	0.0019

Table 9.5 presents the PC as a percentage of the Critical Load (CL) function, as output from the APIS Critical Load Function Tool, for each identified habitat at each designated conservation area.

According to the Critical Load Function Tool, the maximum PCs to acid deposition are screened out at all designated conservation areas except Mersey Estuary.

At Mersey Estuary, the PC is only 2% of the CL function. However, the background acid deposition already exceeds the CL function.

[19] http://www.apis.ac.uk/critical-load-function-tool

Table 9.5: Results from APIS Critical Load Function Tool

Site name	Acidity critical load class	PC as % of CL function	Screened out?	Background (keq/ha/yr)	PEC (keq/ha/yr)	PEC as % of CL function
Mersey Estuary	Bogs	2	No	2.04	2.05	512
Whitby Park	Low and medium altitude hay meadows	0	Yes	-	-	-
Jack's Wood	Broadleaved / coniferous unmanaged woodland	0	Yes	-	-	-

10 Discussion

An air quality assessment was carried out to support the permit variation for a proposed Energy Centre at the Innospec site in Ellesmere Port, Cheshire. The dispersion modelling assessment included emissions from two CHP plant and two waste heat boilers, in addition to the existing lead furnace on the site.

10.1 Human health impacts

Process Contributions to NO_2 concentrations are not screened out, but the PECs are below the air quality objectives.

10.2 Ecological impacts

At Jack's Wood and Whitby Park, all NO_x PCs are screened out, as the annual average PCs are less than 1% of the critical level of 30 µg/m^3 and the daily average PCs are less than 10% of the critical level of 75 µg/m^3. At Mersey Estuary, within 500 m north of the modelled stack, neither annual nor daily average PCs are screened out, but the PECs are below the critical levels.

The maximum PCs to nitrogen deposition are screened out at Jack's Wood and Whitby Park, as they are less than 1% of the nitrogen critical load. At Mersey Estuary, the PC for one of the five modelled years of meteorological data is 1.1% of the lower end of the critical load range. The existing nitrogen deposition already exceeds the critical load.

According to the Critical Load Function Tool, the maximum PCs to acid deposition are screened out at Jack's Wood and Whitby Park. At Mersey Estuary, the PC is only 2% of the critical load function. However, the background acid deposition already exceeds the critical load function.

APPENDIX A: Summary of ADMS 5

ADMS, the Atmospheric Dispersion Modelling System, has been developed to make use of the most up-to-date understanding of the behaviour of the lower levels of the atmosphere in an easy-to-use computer modelling system for atmospheric emissions. This allows the impacts of emissions from industrial and other facilities to be thoroughly investigated as part of an environmental assessment or for other regulatory purposes. The following is a summary of the capabilities and validation of ADMS 5. More details can be found on the CERC web site at www.cerc.co.uk.

The core model calculates the average concentration arising from an emission for a given meteorological condition (for example, wind speed and direction), taking account of plume rise and stack downwash where required. The emission may be released from a single source or from a number of sources. In addition, ADMS is able to:

- calculate long-term concentration statistics, typically for a period of one year, for direct comparison with air quality standards and objectives;
- take into account the often very significant effects that a nearby building can have on the dispersion of emissions;
- model the chemical conversions that occur in the atmosphere between nitric oxide (NO), nitrogen dioxide (NO_2) and ozone (O_3);
- include background concentrations in concentration statistics;
- allow for the effects of complex terrain and changes in surface roughness on wind speed and direction, and on the levels of turbulence in the atmosphere;
- determine the quantities of an emission deposited to the ground by both dry and wet deposition processes;
- include the decay of radioactive emissions and determine the gamma dose at a location received from passing material;
- report the extent to which a moist plume will be visible;
- model sources over the sea, such as oil platforms, using special calculations of surface roughness and heat fluxes; and
- output temperature, relative and/or specific humidity, as well as exceedences of temperature and/or humidity thresholds and simultaneous exceedences of temperature and humidity threshold values.

More details of these processes are given below.

ADMS runs in Windows 8, Windows 7, Windows Vista and XP environments. It has been developed by CERC in conjunction with the UK Meteorological Office and the Department of Mechanical Engineering at the University of Surrey. In its earlier stages, ADMS was developed with contributions from a number of sponsors, including the Environment Agency (originally under HMIP), the Health and Safety Executive and a number of the successor companies of the CEGB.

Dispersion Modelling

ADMS uses boundary layer similarity profiles 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 ground. This has significant advantages over earlier methods in which the dispersion parameters did not vary with height within the boundary layer.

In stable and neutral conditions, dispersion is represented by a Gaussian distribution. In convective conditions, the vertical distribution takes account of the skewed structure of the vertical component of turbulence. This is necessary to reflect the fact that, under convective conditions, rising air is typically of limited spatial extent but is balanced by descending air extending over a much larger area. This leads to higher ground-level concentrations than would be given by a simple Gaussian representation.

The formulation of ADMS means that, for a given meteorological condition, as well as determining average concentrations the model is also able to provide statistical information on concentration fluctuations. This can be particularly important in applications such as, for example, determining whether or not a dispersing material exceeds flammability or odour detection thresholds.

Emissions

Buoyant emissions, and those with vertical momentum, rise in the atmosphere after emission. This movement, which is referred to as *plume rise*, also results in additional dilution and can result in the emission penetrating the top of the atmospheric boundary layer and being lost from the local area. These effects are included in the modelling using an integral solution of the conservation equations for the plume's mass, momentum and heat. The possibility of entrainment behind the stack, known as *downwash*, which can lower the effective height of the emission, is also included in the calculation.

ADMS can also model emissions represented as:

- lines – for linear sources;
- areas – to represent situations where a source can best be represented as uniformly spread over an area, such as evaporation from an open tank;
- volumes – to represent situations where a source can best be represented as uniformly spread throughout a volume, such as fugitive emissions from a factory complex; and
- jets – to represent situations where emissions are not emitted vertically upwards.

Presentation of Results

For most situations ADMS is used to model the fate of emissions for a large number of different meteorological conditions. Typically, meteorological data are input for every hour during a year or for a set of conditions representing all those occurring at a given location. ADMS uses these individual results to calculate statistics for the whole data set. These are usually average values, including rolling averages, percentiles and the number of hours for which specified concentration thresholds are exceeded. This allows concentrations to be calculated for direct comparison with air quality limits, guidelines and objectives, in whatever form they are specified.

Results can be presented as numerical values at specified locations. In addition, by calculating concentrations over a grid of locations, results can be presented graphically as concentration contours or isopleths. This can be done using the ADMS-Mapper, and is also facilitated by a link with GIS[20] ESRI ArcGIS.

Complex Effects - Buildings

A building or similar large obstruction can affect dispersion in three ways:

1. It deflects the wind flow and therefore the route followed by dispersing material;
2. This deflection increases levels of turbulence, possibly enhancing dispersion; and
3. Material can become entrained in a highly turbulent, recirculating flow region or cavity on the downwind side of the building.

The third effect is of particular importance because it can bring relatively concentrated material down to ground level near to a source. From experience, this occurs to a significant extent in more than 95% of studies for industrial facilities.

The buildings effects module in ADMS has been developed using extensive published data from scale-model studies in wind-tunnels, CFD modelling and field experiments on the dispersion of pollution from sources near large structures. It operates out to a distance of about 30 building heights from the building and has the following stages:

(i) A complex of buildings is reduced to a single rectangular block with the height of the dominant building and representative streamwise and crosswind lengths.

(ii) The disturbed flow field consists of a recirculating flow region in the lee of the building with a diminishing turbulent wake downwind, as shown in Figure A1.

(iii) Concentrations within the well-mixed recirculating flow region are uniform and based upon the fraction of the release that is entrained.

(iv) Concentrations further downwind in the main wake are the sum of those from two plumes: a ground-level plume from the recirculating flow region and an elevated plume from the non-entrained remainder.

[20] Geographical Information System

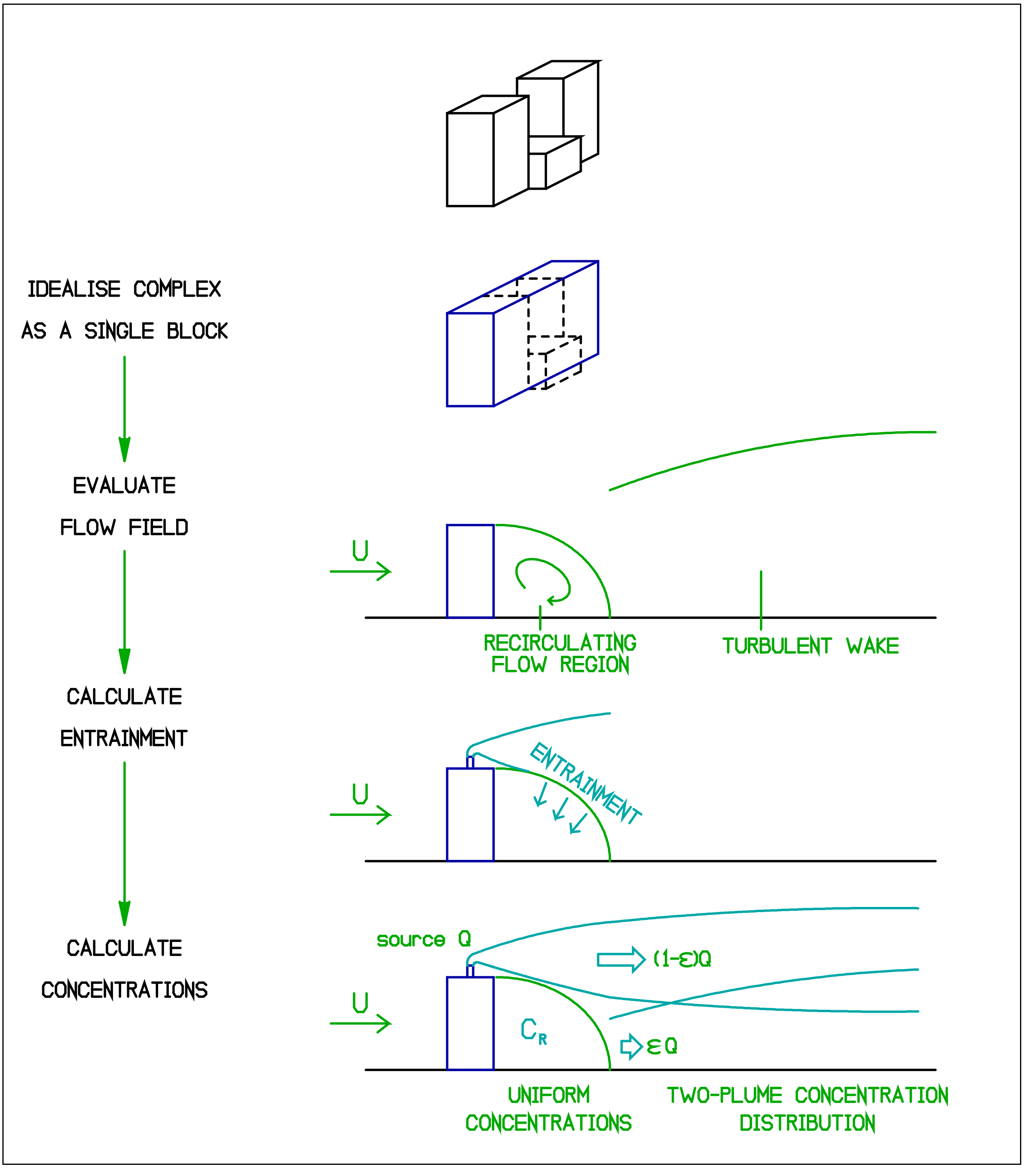

Figure A1: Stages in the modelling of building effects

Complex Effects – NO_x Chemistry

Nitrogen oxides (NO_x) emitted from combustion processes are typically only 5% to 10% nitrogen dioxide (NO_2), with the remainder as nitric oxide (NO). After emission, the NO combines with the ozone (O_3) present in the atmosphere to increase the proportion of NO_2. The key features of the two processes involved can be represented by:

(1) $NO + O_3 \rightarrow NO_2$

(2) $NO_2 + h\nu \rightarrow NO + O_3$

where the role played by oxygen (O and O_2) has been omitted for clarity and $h\nu$ represents ultra violet radiation. Both of these reactions, which can proceed relatively rapidly, are modelled by ADMS, which only allows the second reaction to occur in daylight. Other reactions that involve O_3 and NO_2, such as those with Volatile Organic Compounds (VOCs), have not been included because their reaction times are significantly longer. They would not have any significant effect on concentrations arising from specific industrial emissions.

Complex Effects – Terrain and Roughness

Complex terrain can have a significant impact on wind-flow and consequently on the fate of dispersing material. Primarily, terrain can deflect the wind and therefore change the route taken by dispersing material. Terrain can also increase the levels of turbulence in the atmosphere, resulting in increased dilution of material. This is of particular significance during stable conditions, under which a sharp change with height can exist between flows deflected over hills and those deflected around hills or through valleys. The height of dispersing material is therefore important in determining the route it takes. In addition areas of reverse flow, similar in form and effect to those occurring adjacent to buildings, can occur on the downwind side of a hill.

Changes in the surface roughness can also change the vertical structure of the boundary layer, affecting both the mean wind and levels of turbulence.

The ADMS Complex Terrain Module models these effects using the wind-flow model FLOWSTAR. This model uses linearised analytical solutions of the momentum and continuity equations, and includes the effects of stratification on the flow. Ideally hills should have moderate slopes (up to 1 in 2 on upwind slopes and hill summits, up to 1 in 3 in hill wakes), but the model is useful even when these criteria are not met. The terrain height is specified at up to 66,000 points that are interpolated by the model onto a regular grid of up to 256 by 256 points. The best results are achieved if the specified data points are regularly spaced. FLOWSTAR has been extensively tested with laboratory and field data.

Regions of reverse flow are treated by assuming that any emissions into the region are uniformly mixed within it. Material then disperses away from the region as if it were a virtual point source. Material emitted elsewhere is not able to enter reverse flow regions.

Deposition

Material in a plume that is close to the ground can be lost to the ground by dry deposition. This process is included in ADMS by using a gravitational settling velocity for particles, and a deposition velocity based on aerodynamic, sub-layer and surface-layer resistance values for gases. The concentration profile within a dispersing plume is then adjusted to take account of the losses at the surface. Dry and wet deposition parameters can be varied spatially, to take into account changes in land use across the modelled area.

Wet deposition is included via a washout coefficient to control the quantity of material incorporated into rain. In addition, for SO_2 and HCl emitted from point sources, the 'Falling Drop' model is available, which includes the kinetics of the uptake of gases, as well as the thermodynamics and chemistry of the dissolution of gases in raindrops.

Radioactivity

For radioactive releases ADMS calculates the transformations within the plume of one isotope into another by radioactive decay. ADMS can also determine the gamma dose received at a location from a dispersing plume.

Visible Plumes

For moist emissions ADMS determines the section of the plume where the liquid water content is sufficient for the plume to be visible. This allows statistics of the frequency and lengths of visible plumes to be calculated.

Data Comparisons – Model Validation

The individual components of ADMS, for example the Buildings Module, have been developed using published scientific data and each component extensively tested to ensure that it provides reliable results. In addition, a very large number of studies have been performed on the accuracy of ADMS for point source emissions.

Among other validation studies, ADMS output has been compared with three flat terrain data sets known as Kincaid, Indianapolis and Prairie Grass, which are available from the US Modellers Data Archive. Each of these datasets has been generally accepted as containing enough measurements of sufficient quality for meaningful validation.

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