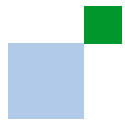


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## 5. Air Quality

### 5.1. Introduction

5.1.1 The proposed changes to the layout of the Pembroke CCGT power station since the submission of the 2005 ES, as described in Chapter 2, require a re-modelling and re-assessment of the air quality impacts of the proposals. This chapter presents the new air quality assessment based on the changed layout and using the most recent information available on the likely design of the plant obtained from the tenders of plant suppliers. Information on ambient air quality used in the assessment has also been updated.

5.1.2 Additional assessments were submitted to Pembrokeshire County Council's Public Protection Division in October 2005, in response to the Council's comments on the 2005 ES, and in April 2006, following the decision to re-site the plant but before detailed tender information was available (see Appendix AI.1.1 for a summary of issues addressed). The main results from these submissions, along with those contained in the 2005 ES, are presented in Appendix AI.5.1 for comparative purposes.

5.1.3 The new CCGT would be fired by natural gas only. The assessment of its impact on air quality considers each of the main gaseous emissions from the power station and their potential effects on both the local and the wider environment.

#### Natural Gas Combustion

5.1.4 The major component of natural gas is methane ( $\text{CH}_4$ ), typically present at 85-95 % by volume. Ethane ( $\text{C}_2\text{H}_6$ ), at 3-5 %, is the only other hydrocarbon present in significant amounts, with the bulk of the remaining volume comprising nitrogen gas ( $\text{N}_2$ ). Small concentrations of other hydrocarbons and carbon dioxide are normally also present. Unlike coal, or fuel oil, natural gas contains virtually no sulphur or inorganic material.

5.1.5 Combustion of natural gas in air results in primary emissions to the atmosphere of carbon dioxide, water vapour and nitrogen oxides ( $\text{NO}_x$ ), with  $\text{NO}_x$  being formed from nitrogen present in the combustion air as well as nitrogen present in the fuel. Of these combustion products, only  $\text{NO}_x$  has significance in terms of local air quality.  $\text{NO}_x$  emissions eventually contribute to the deposition of nitrogen species to the sea and to soil and vegetation, an issue of importance at the UK and European scale rather than at the local scale. The importance of carbon dioxide emissions relates to the global increase in greenhouse gas concentrations worldwide. There are negligible emissions of sulphur dioxide and particulate matter.

#### Air Quality Standards and Baseline Environment

5.1.6 In the United Kingdom the objectives for ambient air quality are defined in the Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland (DETR, 2000 and DEFRA, 2003a). The AQS outlines a national framework for reducing hazards to human health and to vegetation and ecosystems from air pollution in the UK. Most of the AQS objectives for the protection of health, including the objectives for nitrogen dioxide ( $\text{NO}_2$ ), have been included in the Air Quality (Wales) Regulations 2000 (as amended) ("the Air Quality Regulations") for the purposes of Local Air Quality Management. However the ozone objective for the protection of human health and the objectives for  $\text{NO}_x$  and sulphur dioxide to protect vegetation and ecosystems are to be treated as national objectives, against which compliance will be monitored at a national, rather than local authority, level.

5.1.7 Local authorities use the objectives of the AQS in determining whether it is necessary to manage air quality in specific areas. The AQS is also used by the

Environment Agency in regulating emissions to air from installations subject to integrated pollution prevention and control, including large combustion plants such as CCGT power stations.

5.1.8 For the purposes of this environmental statement, information on existing air quality monitoring has been obtained from two sources:-

- Pembrokeshire County Council Automatic Monitoring (Narberth)
- UK diffusion tube network Pembrokeshire

5.1.9 This chapter assesses the environmental impact of the following gaseous emissions in the context of existing background concentrations and an impact assessment of the new Pembroke power station:

- Nitrogen Oxides (NO<sub>x</sub>)
- Carbon Dioxide (CO<sub>2</sub>)
- Ozone (O<sub>3</sub>)
- Carbon Monoxide (CO)
- Unburnt Hydrocarbons
- Releases of methane (CH<sub>4</sub>) from the fuel gas system.

5.1.10 The predicted effects of changes to NO<sub>x</sub> concentrations as a result of the proposed power station's emissions are assessed in detail with reference to current levels in the area and with guidelines set for the protection of human health and vegetation. Changes in long-range nitrogen deposition to the UK and Europe as a consequence of the proposed development are assessed on the basis of deposition modelling by EMEP (UNECE's Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe).

5.1.11 The effects of increased NO<sub>x</sub> concentrations and nitrogen deposition on local nature conservation sites designated under the Habitats Directive (92/43/EEC) are not discussed in this chapter but are assessed in Chapter 8.

5.1.12 The significance of the projected carbon dioxide emissions from the new Pembroke power station is discussed in the context of the UK's recent record and future targets on greenhouse gas emissions. A brief assessment is also provided of minor combustion emissions (carbon monoxide and unburnt hydrocarbons), releases of methane from the fuel gas system and the potential for secondary production of ozone.

## 5.2. Nitrogen Oxides

### UK Air Quality Objectives for NO<sub>x</sub>

5.2.1 Concentrations of NO<sub>x</sub> include both nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>), but only the NO<sub>2</sub> component is considered relevant to human health. The NO<sub>2</sub> objectives for the protection of human health included in the AQS (DETR, 2000 and DEFRA, 2003a) are summarised in Table 5.1 and are included in the Air Quality Regulations for the purposes of Local Air Quality Management.

**Table 5.1: Air Quality Strategy objectives for the protection of human health**

Pollutant	Objective		To be achieved by
	Concentration	Measured as	
Nitrogen dioxide	200 µg m <sup>-3</sup> (105 ppb) not to be exceeded more than 18 times a year	1 hour mean	31 December 2005
	40 µg m <sup>-3</sup> (21 ppb)	Annual mean	31 December 2005

5.2.2 The AQS objectives are equivalent to the EU Air Quality Daughter Directive (1999/30/EC) limit values for NO<sub>2</sub>, although EU legislation does not require compliance with these limits until 1 January 2010. The limit values are based on the World Health Organisation (WHO) guidelines for 1 hour and annual average NO<sub>2</sub> concentrations (WHO, 2000).

5.2.3 The AQS also includes a national objective for total NO<sub>x</sub> for the protection of vegetation and ecosystems to be achieved by 31 December 2000. The objective concentration of 16 ppb or 30 µg m<sup>-3</sup> (as NO<sub>2</sub> equivalent) for the annual average is more stringent than the annual average NO<sub>2</sub> objective for the protection of human health. However, with the exception of sensitive sites designated under the Habitats Directive and sites of special scientific interest (SSSIs) designated under Part II of the Wildlife and Countryside Act 1981 (as amended by Part III of the Countryside and Rights of Way Act 2000) (see section 8.5), it only applies in areas which are:

- more than 20 km from an agglomeration (more than 250,000 population)
- more than 5 km away from industrial processes regulated under Part A of the Environmental Protection Act 1990 and the Pollution Prevention and Control (England and Wales) Regulations 2000 (as amended)
- more than 5 km away from motorways
- more than 5 km away from built up areas of more than 5,000 people

5.2.4 The AQS objective is based on the WHO guideline value for the long-term effect of NO<sub>x</sub> on general vegetation, which has been adopted as a European limit value in the Air Quality Daughter Directive.

#### Existing Local NO<sub>x</sub> Concentrations

5.2.5 Preparatory to an assessment of the impact of the new Pembroke power station on ground level air quality, it is necessary to establish the prevailing NO<sub>x</sub> concentrations in the area.

5.2.6 Monitoring of NO<sub>2</sub> and total NO<sub>x</sub> has been carried out in Pembrokeshire on a regular basis in recent years. Hourly concentrations of both NO<sub>2</sub> and NO<sub>x</sub> are available from the automatic monitoring station at Narberth (OS grid reference SN 146 127), which is a rural monitoring site operated by Pembrokeshire County Council on behalf of DEFRA. In addition, monthly mean NO<sub>2</sub> concentrations are measured at eight urban sites in Pembrokeshire as part of the UK NO<sub>2</sub> diffusion tube network. Data from these automatic and diffusion tube sites can be downloaded from the UK National Air Quality Information Archive ([www.airquality.co.uk](http://www.airquality.co.uk)).

5.2.7 Table 5.2 gives the annual average concentrations of NO<sub>2</sub> and NO<sub>x</sub> and the maximum and 99.8<sup>th</sup> percentiles of 1 hour NO<sub>2</sub> concentrations measured at the Narberth monitoring site for the years 1999 to 2005 inclusive, together with the availability of data from this site. The 99.8<sup>th</sup> percentile of 1 hour NO<sub>2</sub> concentrations is provided for comparison with the short-term AQS objective, as the objective of 105 ppb not to be exceeded more than 18 times per year is equivalent to a 99.8<sup>th</sup> percentile of 105 ppb. All the hourly data from Narberth for the period 1999 to 2005 inclusive have been ratified, but the availability of NO<sub>2</sub> and NO<sub>x</sub> data for the years 1999 to 2001 inclusive is poor (<75 %) and therefore the annual statistics for these years are relatively unreliable.

**Table 5.2: Summary of NO<sub>2</sub> and NO<sub>x</sub> measurements from Narberth for 1999-2005 inclusive**

Year	NO <sub>2</sub> concentration (ppb) <sup>†</sup>			NO <sub>x</sub> concentration (ppb) <sup>‡</sup>	Availability (%)
	Maximum 1 hour mean	99.8 <sup>th</sup> percentile 1 hour mean	Annual average	Annual average	
1999	23*	16*	3*	4*	64
2000	31*	27*	3*	4*	71
2001	34*	33*	4*	5*	64
2002	24	22	4	5	86
2003	31	26	5	6	79
2004	29	23	3	4	89
2005	30	22	3	4	92

<sup>†</sup> For NO<sub>2</sub>, 1 ppb = 1.91 µg m<sup>-3</sup> (conversion factor at 20°C, 1013 mb).

<sup>‡</sup> For NO<sub>x</sub> (as NO<sub>2</sub> equivalent), 1 ppb = 1.91 µg m<sup>-3</sup> (conversion factor at 20°C, 1013 mb).

\* Annual statistics relatively unreliable, as data capture <75%.

5.2.8 Table 5.3 provides the annual average NO<sub>2</sub> concentrations measured at the eight urban diffusion tube sites in Pembrokeshire for the years 1999 to 2005 inclusive. "Roadside" sites are 1-5 m from a busy road, whereas "Background" sites are >50 m from an equivalent road.

**Table 5.3: Annual average NO<sub>2</sub> concentrations measured in Pembrokeshire by UK diffusion tube network for 1999-2005 inclusive**

Site	Type	Grid reference	Annual average NO <sub>2</sub> concentration (ppb) <sup>†</sup>						
			1999	2000	2001	2002	2003	2004	2005
<u>Haverfordwest</u>									
1N	Roadside	SM 956	14	10	15	14	17	13	13
3N	Background	156	5	4	7	7	7	5	6
8N	Roadside	SM 958	-	-	19	21	25	21	18
9N	Background	169	-	-	-	5	7	4	4
		SM 949							
		152							
		SM 950							
		166							
<u>Pembroke</u>									
11N	Roadside	SM 984	19	18	17	19	28	19	17
13N	Background	015	5	4	6	7	7	5	5
14N	Background	SM 983	5	4	5	5	6	5	5
15N	Roadside	012	-	-	-	10	13	9	9
		SM 984							
		019							
		SM 981							
		014							

<sup>†</sup> For NO<sub>2</sub>, 1 ppb = 1.91 µg m<sup>-3</sup> (conversion factor at 20 °C, 1013 mb).

5.2.9 Table 5.3 shows that, as expected, levels of roadside air pollution are generally much higher than urban background concentrations. These data from the national network are consistent with the results of further diffusion tube measurements in the county undertaken by Pembrokeshire County Council (PCC, 2000, 2003 and 2006).

5.2.10 Comparison of Tables 5.2 and 5.3 indicates that annual average NO<sub>2</sub> concentrations at Narberth are lower than the urban background values, which is probably due to the influence of vehicle emissions in urban areas. However, it is not always possible to make direct comparisons between diffusion tube measurements and data from chemiluminescent analysers, such as that at Narberth, as diffusion tube results may exhibit systematic errors of up to 30%.

### Comparison of Local NO<sub>x</sub> Concentrations with AQS Objectives

5.2.11 Table 5.2 indicates that NO<sub>2</sub> concentrations at Narberth are well below the AQS objectives for the protection of human health: the maximum 99.8<sup>th</sup> percentile of 1 hour means for the years 1999-2005 inclusive is about 30 % of the short-term threshold concentration of 105 ppb and the maximum annual average is less than 25 % of the target annual mean. Furthermore, the maximum annual average NO<sub>x</sub> concentration is less than 40 % of the AQS objective for the protection of vegetation and ecosystems, suggesting that the likelihood of any adverse effect due to current NO<sub>x</sub> levels is very low.

5.2.12 Table 5.3 shows that the objective for annual NO<sub>2</sub> concentrations (21 ppb) may be exceeded at roadside sites. However, annual average objectives do not generally apply at roadside sites, as public exposure at such locations is expected to be short-term (DEFRA, 2003b). At the background sites, where members of the public may be regularly exposed, the measured annual mean NO<sub>2</sub> concentrations are less than 40 % of the AQS objective.

### NO<sub>x</sub> Emissions from the New Pembroke Power Station

5.2.13 In general, the maximum NO<sub>x</sub> concentration allowed by the Large Combustion Plant Directive (2001/80/EC) for new gas turbines above 50 MW<sub>th</sub> is 50 mg Nm<sup>-3</sup> (15%O<sub>2</sub>, dry) when burning natural gas. For a new CCGT having an annual average overall electrical efficiency greater than 55%, the NO<sub>x</sub> emission limit value for gas firing is 75 mg Nm<sup>-3</sup> (15% O<sub>2</sub>, dry). These limit values do not apply during start up and shut down periods.

5.2.14 Based on the latest tender specifications, a conservative NO<sub>x</sub> emission concentration of 36 mg Nm<sup>-3</sup> (15% O<sub>2</sub>, dry) has been assumed for the new Pembroke power station. During start-up, when the dry low NO<sub>x</sub> combustion system cannot operate, the gas turbine combustion system would operate in diffusion mode. Data from the most recent comparable CCGT plant currently operated by RWE npower (Module 6 of Didcot B Power Station, which uses a dry low NO<sub>x</sub> combustion system) indicates that the maximum NO<sub>x</sub> concentrations could reach about 120-150 mg Nm<sup>-3</sup> for 30-40 minutes, with a maximum half hour average of about 125 mg Nm<sup>-3</sup>. For a typical year on base load operation, about 20 such start-ups might occur for each gas turbine.

5.2.15 Emissions of NO<sub>x</sub> from power stations comprise a mixture of NO and NO<sub>2</sub>, with 5 % to 20 % by volume as NO<sub>2</sub> for gas combustion. The proportion of each depends on the characteristics of the combustion process and particularly the design of the gas turbine. At this stage it has been assumed for the purpose of air quality calculations that 20 % may be emitted as NO<sub>2</sub>.

5.2.16 The remaining NO<sub>x</sub> emitted as NO may be converted to NO<sub>2</sub> by reaction with ambient ozone (O<sub>3</sub>). In this assessment, the conversion of NO to NO<sub>2</sub> is calculated on an hour-by-hour basis in order to estimate ground level NO<sub>2</sub> concentrations during operation of the proposed CCGT.

5.2.17 It is conventional to express NO<sub>x</sub> emissions as an equivalent mass of NO<sub>2</sub>, irrespective of the proportions of NO and NO<sub>2</sub> present.

5.2.18 It is projected that the new Pembroke power station, a CCGT of around 2000 MW operating at base load with a NO<sub>x</sub> emission concentration of about 36 mg Nm<sup>-3</sup>, would emit about 3 ktonnes NO<sub>x</sub> per annum. The IPC Authorisation for the former Pembroke oil-fired power station allowed a total annual NO<sub>x</sub> emission of 13.9 ktonnes.

## Dispersion Modelling

### Model Used

5.2.19 The potential future impacts of the new Pembroke power station have been assessed using a plume dispersion model to calculate the dilution of the stack gases which occurs before contact with the ground under the full range of meteorological conditions which occur locally.

5.2.20 The Atmospheric Dispersion Modelling System, ADMS 3.3 (CERC, 2005), was used to assess plume dispersion on an hour-by-hour basis. This is a “new generation” dispersion model which takes account of the latest developments in atmospheric physics and which, unlike earlier models such as R91 (Clarke, 1979), does not characterise the boundary layer on the basis of Pasquill-Gifford stability classes. Instead, the stability of the atmosphere is defined in terms of a continuous scale based on the Monin-Obukhov length, which provides a measure of the relative importance of buoyancy generated by heating of the ground and mechanical mixing generated by the frictional effect of the earth’s surface. Thus, the different stability classes which may occur are inherently taken into account in the modelling procedure.

5.2.21 ADMS is widely used by industry, regulators and consultants in the UK and has undergone a number of validation studies (e.g. Futter, Webb, Hunter and Hill, 2001; Hunter, Webb and Milne, 2004). These studies indicate that the ADMS model gives sufficiently accurate predictions of the statistics relevant to the Air Quality Strategy for power station emissions.

### Modelling cases and Emission Parameters

5.2.22 The modelling study is based on tendered designs and is, therefore, the best representation possible of the plant that will ultimately be built. It is assumed that the plant will consist of five 400 MW single-shaft CCGT units, with horizontal steam generators and five separate 75 m single-flue stacks, one for each unit. The details of the assumed plant layout, configuration and emission parameters are presented in Table 5.4 (the impact of CO emissions is discussed in Section 5.4.2). The case with two stacks (comprising one two-flue stack and one three-flue stack, Case 2) is included to demonstrate the sensitivity of the air quality impacts to changes in stack configuration.

5.2.23 The initial modelling case presented in the Environmental Statement submitted in January 2005 assumed that the plant would consist of five 400 MW single-shaft CCGT units, with vertical steam generators and five separate 85 m single-flue stacks. Since then, modelling studies of four alternative configurations have been sent to Pembrokeshire County Council (PCC), following consultation with PCC on the original proposals and changes in the proposed layout of the plant on the site (see section 1.1 above). The details of these previous studies are presented in Appendix AI.5.1 for comparison with the results of the most recent modelling study.

**Table 5.4: Emission and layout parameters assumed for plume dispersion modelling**

Case number	Number of stacks	Effective flue diameter (m)	Height of stacks (m)	Layout	Stack locations
1	5 single-flue	7	75	Stacks on NORTH side of building complex	SM 9284 0274 SM 9290 0274 SM 9295 0274 SM 9300 0274 SM 9306 0274
2	2 multi-flue (one 3-flue, one 2-flue)	12.1 (3-flue) 9.9 (2-flue)	75	As above	SM 9290 0274 SM 9303 0274
<b>Common parameters used for both modelling cases</b>					
<b>Parameter</b>			<b>Value</b>		
Flue gas NO <sub>x</sub> concentration			36 mg/m <sup>3</sup>		
Flue gas CO concentration			65 mg/m <sup>3</sup>		
Emission temperature			78°C		
NO <sub>2</sub> emission rate per flue			4.6 g/s		
NO emission rate per flue			11.9 g/s		
CO emission rate per flue			41.3 g/s		
Exit velocity of flue gas			16 m/s (full load)		
Hours of operation			8760 hours/year (100% load factor)		

5.2.24 The NO<sub>2</sub> and NO emission rates are based on a NO<sub>x</sub> release concentration of 36 mg Nm<sup>-3</sup> (15 % O<sub>2</sub>, dry), with 20 % by volume of the NO<sub>x</sub> present as NO<sub>2</sub> and flue gases containing 14.3 % O<sub>2</sub> and having a moisture content of 7.7 %. The values for oxygen and moisture content are based on data from RWE npower's Didcot B CCGT.

5.2.25 The stack height of 75 m is comfortably above the minimum required stack height of 67 m determined by the methodology in Technical Guidance Note (Dispersion) D1 (HMIP, 1993).

### Local Building Effects

5.2.26 Large buildings (with heights greater than approximately one third of the stack height) in the vicinity of discharge stacks have the potential to increase ground level concentrations by causing the plume to “downwash” into the building wakes.

5.2.27 The modelling studies assumed that the buildings close to the CCGT stacks can be represented by a combined building with the dimensions detailed in Table 5.5. These dimensions are based on the likely dimensions of HRSGs and turbine houses for the tendered CCGT plant designs.

5.2.28 The existing 400 kV substation building could also be included in the modelling of site buildings. However initial scoping studies indicated that using a single block representing the HRSGs and turbine houses gave the highest ground level concentrations and was therefore a more conservative approach to representing the effects of the plant's buildings.



**Table 5.5: Building dimensions assumed for plume dispersion modelling**

Building	Height (m)	x-length (m)	y-length (m)	Angle of y-length from north (°)	Grid reference of centre (m)
HRSGs and turbine houses CASES 1&2	34	259	96	0	SM 9295 0269

### Meteorological Data and Roughness Length

5.2.29 The model runs described here used hourly sequential meteorological data from the Met Office site at Milford Haven. Milford Haven is about 4 km north-west of the proposed power station site and is in an area generally representative of the modelled site.

5.2.30 Using three years of meteorological data is generally regarded as the minimum acceptable for air quality modelling. In this study, the meteorological data used were those for the five years 1999 to 2003 inclusive and also for 2005. The data for 2004 were not included, as no background ozone concentration data are available for this year (see subsection below on “NO<sub>x</sub> Chemistry”).

5.2.31 There is no official surface roughness length recommended by the Met Office for use at Milford Haven. The roughness length was set to 0.3 m, which is the maximum value suggested by ADMS for agricultural land and is considered appropriate for an industrial site set in a mainly rural environment close to an area of open water.

### Output Grids

5.2.32 A 3 km x 3 km output grid with a node spacing of 100 m was used for the modelling, as this proved to be sufficiently fine to resolve the magnitude of the peaks in the distribution of concentrations. The grid was centred on the middle stack modelled in Case 1 (grid reference SM 9295 0274).

5.2.33 Further modelling on a 9 km x 9 km output grid with a node spacing of 300 m was used to investigate the impacts of the station on air quality over a wider area, and the effects on designated conservation sites within 10 km of the power station (Chapter 8) were examined using receptor points on a 20 km x 20 km grid with a node spacing of 500 m.

### NO<sub>x</sub> Chemistry

5.2.34 ADMS 3.1 contains a simple NO<sub>x</sub> chemistry module which can be used to predict NO<sub>2</sub> concentrations taking into account the photostationary equilibrium between NO, NO<sub>2</sub> and ozone (O<sub>3</sub>) and the reaction timescales. This module has been tested and has been shown to function satisfactorily (Hunter, 2003) and is likely to give a more robust assessment of power station contributions to NO<sub>2</sub> concentrations than simpler methods, such as the use of conversion factors. Hence this module has been used to assess the impact of the proposed new Pembroke power station on local NO<sub>2</sub> concentrations.

5.2.35 The background concentrations used by the module were hourly varying concentrations of O<sub>3</sub>, NO<sub>x</sub> and NO<sub>2</sub> obtained from the rural monitoring site at Narberth for the years 1999 to 2005 inclusive. A summary of the NO<sub>2</sub> and NO<sub>x</sub> measurements from Narberth during this time period is given in Table 5.2. The annual average O<sub>3</sub> concentrations measured at Narberth between 1999 and 2005 and the availability of these data are given in Table 5.6.

5.2.36 In order to model the station-only contribution to NO<sub>2</sub> deposition at nature conservation sites local to Pembroke (Chapter 8), further runs were performed in which just hourly ambient O<sub>3</sub> concentrations were supplied to the model, i.e. background NO<sub>x</sub> concentrations were excluded.

**Table 5.6: Annual average O<sub>3</sub> concentrations measured at Narberth for 1999- 2005 inclusive**

Year	Annual average O <sub>3</sub> concentration (ppb) <sup>†</sup>	Availability of hourly data (%)
1999	33	84
2000	34*	72
2001	31	94
2002	30	91
2003	28	89
2004	N/A	0
2005	31*	60

<sup>†</sup> For O<sub>3</sub>, 1 ppb = 2.00 µg m<sup>-3</sup> (conversion factor at 20°C, 1013 mb).

\* Annual statistics relatively unreliable, as data capture <75%.

N/A No data available, as site non-operational or data erroneous for this period.

### Deposition

5.2.37 Only deposition of NO<sub>2</sub> was considered, as there is negligible wet or dry deposition of NO. Also, in accordance with the agreed methodology for the assessment of impacts from large coal- and oil-fired power stations in England and Wales (Brooke, Griffiths, Sadler and Lennard, 2006), the wet deposition of NO<sub>2</sub> was neglected, as detailed studies of the chemical and physical behaviour of NO<sub>2</sub> uptake by drops falling through a plume (Cocks, 2005) have indicated that the wet deposition of NO<sub>2</sub> is minimal compared to dry deposition.

5.2.38 The dry deposition of NO<sub>2</sub> was estimated from the ground-level NO<sub>2</sub> concentration and the site-relevant dry deposition velocity for NO<sub>2</sub>. Plume depletion was ignored as the dry deposition module in ADMS was not used. Thus, the estimates of NO<sub>2</sub> deposition are likely to represent a conservative assessment.

5.2.39 The dry deposition velocity for NO<sub>2</sub> deposition on low-lying vegetation was assumed to be 1.5 mm s<sup>-1</sup> and that for woodland was assumed to be 3.0 mm s<sup>-1</sup>. These dry deposition velocities are based on reviews of published values from monitored data and the results of theoretical modelling studies, and have been agreed with the EA for use in the impact assessment of atmospheric emissions from coal- and oil-fired power stations (Brooke et al, 2006).

### Terrain Effects

5.2.40 It is generally considered that terrain will not have a significant effect on plume dispersion unless slopes have a gradient of greater than 1 in 10. Examination of the terrain around the proposed power station site indicates that, over the distance scales in which the power station plume has its greatest impact, there are some gradients above this threshold. Therefore, modelling runs were performed using the complex terrain module.

5.2.41 For the 3 km x 3 km output grid, OS Landform PANORAMA data were used to create a 5 km x 5 km ADMS terrain grid centred on the middle stack modelled in Case 1 as described above in the subsection on "Output Grids". A 13.4 km x 13.4 km terrain grid was created for modelling on the 9 km x 9 km output grid, and a 30 km x 30 km terrain grid was used for modelling at the receptor points in the designated conservation sites. The standard ADMS terrain grid resolution of 32 points x 32 points was selected in all cases.

### Modelled Ground Level Concentrations of NO<sub>x</sub>

5.2.42 The modelled ground level NO<sub>x</sub> concentrations from the proposed CCGT, including rural background NO<sub>x</sub>, are presented below. These results are discussed in terms of current concentrations in the area and comparisons with air quality guidelines and limit values for the protection of health and ecology.

5.2.43 Table 5.7 gives the highest values of annual average NO<sub>x</sub> and NO<sub>2</sub> concentrations and the highest maximum and 99.8<sup>th</sup> percentiles of 1 hour NO<sub>2</sub> concentrations calculated anywhere on the 3 km x 3 km output grid for both of the modelling scenarios. By calculating the results for six different annual meteorology and chemistry datasets, an illustration of the variability from year to year that can be expected is provided. (see paragraph 5.2.30).

**Table 5.7: Maximum NO<sub>2</sub> and NO<sub>x</sub> concentrations predicted for the operation of the new Pembroke power station at full load using 6 years' meteorology and chemistry data**

CASE 1 (5 stacks)	NO <sub>2</sub> concentration (ppb)			NO <sub>x</sub> concentration (ppb)
	Maximum 1 hour mean	Maximum 99.8 <sup>th</sup> percentile 1 hour mean	Maximum annual average	Maximum annual average
Year (Meteorology and background chemistry data)				
1999	81	57	7	13
2000	94	55	7	15
2001	72	54	6	12
2002	80	58	7	15
2003	89	66	7	13
2005	82	63	5	12

CASE 2 (2 stacks)	NO <sub>2</sub> concentration (ppb)			NO <sub>x</sub> concentration (ppb)
	Maximum 1 hour mean	Maximum 99.8 <sup>th</sup> percentile 1 hour mean	Maximum annual average	Maximum annual average
Year (Meteorology and background chemistry data)				
1999	72	50	5	9
2000	61	51	5	10
2001	66	51	5	8
2002	72	53	6	10
2003	75	56	6	9
2005	66	50	4	8

5.2.44 The results in Table 5.7 show the expected lower annual average NO<sub>2</sub> and NO<sub>x</sub> ground level concentrations for Case 2 as a result of the enhanced plume buoyancy obtained from multi-flue stacks. The differences between the two cases for the maximum and 99.8<sup>th</sup> percentile 1-hour mean NO<sub>2</sub> concentrations are, however, proportionally smaller than for the means and are less consistent from year to year as NO to NO<sub>2</sub> conversion is dependent upon, and limited by, the amount of O<sub>3</sub> available.

5.2.45 It is evident that, for both modelling cases, the NO<sub>2</sub> concentrations calculated around the Pembroke site when the CCGT is running at full load remain well below the AQS objectives for the protection of human health. The maximum 99.8<sup>th</sup> percentile 1-hour means for Case 1 are about 2-3 times the current background levels (Table 5.2) but are only about 60% of the AQS objective of 105 ppb. The maximum 1-hour means

indicate that there would be no expected exceedances of the 105 ppb threshold concentration.

5.2.46 Given that Case 1 relates to the proposed stack configuration, further analysis of the air quality impacts of the proposals is based on this case. Figures 5.1 and 5.2 show contour plots of the predicted annual average concentrations of NO<sub>x</sub> and NO<sub>2</sub> respectively for the station operating at full load with 2002 meteorological and background chemistry data on the 9 km x 9 km output grid for Case 1; Figure 5.3 shows the corresponding contour plot of 99.8<sup>th</sup> percentile 1 hour NO<sub>2</sub> concentrations. Note in Table 5.7 that the maxima for each statistic derived do not all occur for the same data year. The year 2002 chosen for the plots in Figure 5.3 was considered representative in that modelled concentrations were equal highest for annual means and mid range for 1-hour mean and 99.8<sup>th</sup> percentile.

5.2.47 The maximum annual average NO<sub>2</sub> concentrations when the station is running at full load remain less than 40 % of the annual average AQS objective (21 ppb) for the protection of human health. Compared to current background levels (Table 5.2), annual average NO<sub>2</sub> concentrations are predicted to increase by a factor of up to about two. The highest annual average NO<sub>2</sub> concentrations are generally predicted to be to the north-east of the station stacks, within a distance of about 0.5 km (Figure 5.2).

5.2.48 The maximum annual average NO<sub>x</sub> concentrations are typically about three times the current background values (Table 5.2), but remain below the AQS objective for the protection of vegetation and ecosystems (16 ppb). The highest annual average NO<sub>x</sub> concentrations were predicted to be less than 0.5 km from the stacks (Figure 5.1).

#### **Start-up, Shut-down and Part-Load Operation**

5.2.49 During the start up of a gas turbine, hourly average NO<sub>x</sub> emission concentrations may rise to about 100 mg Nm<sup>-3</sup> (Section 5.2.3). For a typical year on baseload operation, about 20 such start-ups might occur for each of the five gas turbines (5.2.14 above). If it is assumed that no two gas turbines will start in the same hour, the maximum increase in average NO<sub>x</sub> emissions from the power station in any given hour will be about 40 % (i.e. from about 36 to about 50 mg Nm<sup>-3</sup>).

5.2.50 For Case 1, the maximum 99.8<sup>th</sup> percentile of 1-hour mean NO<sub>2</sub> concentrations at ground level for power station NO<sub>x</sub> emissions of 36 mg Nm<sup>-3</sup> in combination with rural background levels of pollution is 66 ppb (Table 5.7). Assuming (pessimistically) that the highest hourly NO<sub>2</sub> concentrations are solely due the impact of the power station plume (with no impact from background NO<sub>x</sub>) and that NO<sub>2</sub> formation is not limited by ambient O<sub>3</sub> concentrations, the maximum possible increase in 99.8<sup>th</sup> percentiles due to start-up operation would be about 40 %. Thus the maximum predicted 99.8<sup>th</sup> percentile of 1-hour NO<sub>2</sub> concentrations would be about 92 ppb and would remain below the AQS objective of 105 ppb.

5.2.51 The start-up situation would typically occur in 100 hours in the year, i.e. 1.1 % of hours. As the wind direction at Milford Haven typically lies within any given 10° sector for less than 10 % of hours in a year, the impact of start-ups on air quality at any given location will only occur for a maximum of about 0.1 % of hours in a year. Thus start-up will have little impact on annual average NO<sub>x</sub> and NO<sub>2</sub> concentrations and is very unlikely to have a substantial effect on 99.8<sup>th</sup> percentile 1-hour NO<sub>2</sub> concentrations.

5.2.52 In the case of emergency shut-down, by definition the gas turbine(s) concerned would be shut down and there would be no increase in NO<sub>x</sub> emissions as a result.

5.2.53 With regard to part-load operation, gas turbines equipped with dry low NO<sub>x</sub> combustion systems generally operate in two distinct combustion modes – “diffusion mode” for start up and at low loads and “premixed mode” at higher loads. The names given to these vary depending on the particular proprietary technology used but the principle is similar in all cases. Premixed mode results in much lower NO<sub>x</sub> concentrations, but is unstable below a certain percentage load (usually around 50 %, but varies depending on the design). Diffusion mode is therefore used for start-up and at low loads, which is why hourly average NO<sub>x</sub> concentrations from a turbine during start-up are predicted to rise to about 100 mg Nm<sup>-3</sup>.

5.2.54 Even if there was a gas turbine operating in diffusion mode during all hours of the year, annual average concentrations of NO<sub>x</sub> and NO<sub>2</sub> at ground level would rise by less than 40 % due to the contribution from background pollutant concentrations. For Case 1, the maximum predicted annual average concentrations of NO<sub>x</sub> and NO<sub>2</sub> arising during normal operation are 15 ppb and 7 ppb respectively (Table 5.7). Therefore, it is predicted that there will be no exceedance of the annual average AQS objective of 21 ppb for NO<sub>2</sub> due to increased NO<sub>x</sub> emissions arising from running a unit on low load.

5.2.55 It is theoretically possible that the AQS objective for the protection of vegetation of 16 ppb for annual average NO<sub>x</sub> could be exceeded at the point of maximum plume impact if a gas turbine operated in diffusion mode for more than about 25 % of hours in a year (resulting in an increase in station NO<sub>x</sub> contribution of about 10 %). However, such a situation is purely hypothetical. Because of the higher NO<sub>x</sub> levels arising from diffusion mode operation, it is usual for Integrated Pollution Control Authorisations/PPC Permits covering such gas turbines on CCGT power stations to include a condition prohibiting sustained operation in diffusion mode and/or requiring periods of operation in diffusion mode to be minimised. RWE npower expects this would be the case at Pembroke and would in any case seek to minimise diffusion mode operation.

5.2.56 The above discussion takes no account of the reduced plume buoyancy and momentum due to the decrease in volume flux during part-load operation. However, the decrease in volume flux is counteracted by a decrease in NO<sub>x</sub> emission rate and, overall, it is expected that there would be little or no increase in the power station contributions to ground level concentrations of NO<sub>2</sub> and NO<sub>x</sub> arising from a gas turbine running at part load.

#### **In-combination effects**

5.2.57 Table 5.7 gives the maximum ground-level NO<sub>2</sub> and NO<sub>x</sub> concentrations predicted for the operation of the new Pembroke Power Station at full load in combination with the existing background concentrations of NO<sub>x</sub>, NO<sub>2</sub> and O<sub>3</sub> measured at a typical rural site in Pembrokeshire (the DEFRA automatic monitoring site at Narberth). However, there will be additional contributions to background NO<sub>x</sub> concentrations due to urban and industrial sources, and these are considered below.

#### Urban background

5.2.58 Background concentrations of NO<sub>x</sub> and NO<sub>2</sub> are higher in urban areas than at Narberth due to vehicle emissions. Annual average urban background concentrations of NO<sub>2</sub> measured in Pembroke and Haverfordwest by the UK NO<sub>2</sub> diffusion tube survey are shown in Table 5.3. These data are consistent with the results of further diffusion tube measurements undertaken in Pembrokeshire by Pembrokeshire County Council (PCC, 200, 2003 and 2006).

5.2.59 The annual average NO<sub>2</sub> concentrations measured in urban areas are between 1 and 3 ppb higher than those measured at Narberth (4-6 ppb, Table 5.2). Thus, as the maximum annual average NO<sub>2</sub> concentration for Pembroke Power Station NO<sub>x</sub> emissions in combination with rural background pollutant levels is only 7 ppb (Table 5.7), it seems very unlikely that the power station would give rise to an exceedance of the AQS objective of 21 ppb for annual average NO<sub>2</sub> when in combination with urban levels of NO<sub>x</sub>.

5.2.60 The maximum predicted hourly average NO<sub>2</sub> concentration for Pembroke Power Station in combination with rural background is 94 ppb (Table 5.7) and, therefore, below the AQS threshold level of 105 ppb for the 99.8<sup>th</sup> percentile of hourly concentrations. The maximum hourly average background NO<sub>x</sub> concentrations in urban areas of Pembrokeshire are likely to be higher than those at Narberth. However, for the meteorological conditions when the power station impact on ground level concentrations is likely to be greatest (e.g. high wind speeds), background concentrations of NO<sub>x</sub> from low level sources (such as traffic) are likely to be low. Therefore, prevailing background NO<sub>x</sub> concentrations will make little difference to the maximum short-term peak concentrations arising from the impact of power station plumes. In addition, urban areas do not coincide with the areas of maximum short-term plume impact (Figure 5.3).

Existing point sources

5.2.61 The most significant point sources of NO<sub>x</sub> within the vicinity of the proposed Pembroke Power Station are the Chevron Texaco and Total oil refineries, about 2 km to the west and 6.5 km to the northwest of Pembroke Power Station respectively. The plumes of emissions from these elevated sources may have an impact on ground level concentrations at the same time as the plume from Pembroke Power Station, and so the effects of plume overlap from these sources may lead to increased short-term, as well as long-term, NO<sub>x</sub> and NO<sub>2</sub> concentrations.

5.2.62 The results of plume dispersion modelling for the Chevron Texaco and Total oil refineries have been provided to Pembrokeshire County Council by the Environment Agency for the Second Stage Air Quality Review and Assessment (PCC, 2000). The results assume all NO<sub>x</sub> emissions from the refineries take the form of NO<sub>2</sub> and the maximum ground level concentrations (in ppb rather than µg m<sup>-3</sup>) are given in Table 5.8. There had been no changes in the release details at the refineries at the time of the April 2006 update of the Review and Assessment (PCC, 2006).

**Table 5.8: Maximum contributions to ground level NO<sub>x</sub> concentrations from operation of Chevron Texaco and Total refineries**

Site	NO <sub>x</sub> concentration (ppb)	
	Maximum annual average	Maximum 99.95 <sup>th</sup> percentile 1-hour mean
Chevron Texaco refinery	1.0	27
Total (formerly Elf) refinery	0.6	31

5.2.63 The maximum increase in annual average NO<sub>x</sub> concentration arising from operations at each of the refineries would be only about 1 ppb. Thus, it seems very unlikely that increases in annual average NO<sub>2</sub> concentration resulting from the overlap of plumes from the power station and the refineries would lead to an exceedance of the AQS annual average objective of 21 ppb.

*Chevron Texaco oil refinery*

5.2.64 With regards to the effects of plume overlap on short-term concentrations, the greatest interactions will be between the plumes from the Chevron Texaco oil refinery and Pembroke Power Station when the winds are from the east or from the west. For

winds blowing from west to east (from the refinery towards the CCGT), the maximum 99.8<sup>th</sup> percentile 1-hour NO<sub>2</sub> concentration associated with power station emissions (in the downwind direction east of the power station) is about 35 ppb (Figure 5.3). As the maximum 99.95<sup>th</sup> percentile of 1-hour NO<sub>x</sub> concentrations associated with the Chevron Texaco refinery at any location is only 27 ppb, it seems unlikely that the AQS objective of 105 ppb for the 99.8<sup>th</sup> percentile of hourly NO<sub>2</sub> concentrations will be exceeded.

5.2.65 For winds blowing from east to west (from the CCGT towards the refinery), the maximum 99.8<sup>th</sup> percentile 1-hour NO<sub>2</sub> concentration arising from Pembroke Power Station (in the downwind direction west of the refinery) is about 25 ppb. Thus again it seems unlikely that the AQS objective for the 99.8<sup>th</sup> percentile of NO<sub>2</sub> concentrations will be exceeded due to an overlap between plumes from the proposed Pembroke CCGT and the Chevron Texaco refinery.

#### *Total oil refinery*

5.2.66 Figure 5.3 indicates that the 99.8<sup>th</sup> percentile 1-hour NO<sub>2</sub> concentrations arising from Pembroke Power Station emissions in the vicinity of the Total refinery will be less than 25 ppb. The maximum 99.95<sup>th</sup> percentile of 1-hour NO<sub>x</sub> concentrations associated with the Total refinery is 31 ppb. It therefore seems unlikely that the AQS objective of 105 ppb for the 99.8<sup>th</sup> percentile of hourly NO<sub>2</sub> concentrations will be exceeded when the wind is blowing from the power station towards the Total refinery.

5.2.67 Similarly, when the wind is blowing from the northwest (from the Total refinery towards the power station), it seems unlikely that the small contribution from the Total refinery in the vicinity of the power station will lead to an exceedance of the short-term AQS objective for NO<sub>2</sub>.

#### Permitted developments

5.2.68 In addition to the existing sources of NO<sub>x</sub> emissions, there are two developments within 10 km of the proposed Pembroke Power Station which have been permitted and are under construction:

- Dragon liquid natural gas (LNG) terminal
- South Hook LNG terminal

5.2.69 Both of these are associated with significant NO<sub>x</sub> emissions, and the possible impacts of these new developments on local air quality in combination with the impact of the proposed power station, are considered below.

#### *Dragon LNG terminal*

5.2.70 The Dragon LNG terminal is being developed on land adjacent to the southwest part of the existing SemGroup (formerly Petroplus) bulk liquid storage terminal and is about 2.5 km north of the proposed Pembroke CCGT.

5.2.71 Before the LNG can be exported to the national gas transmission system it must be converted back to natural gas. It is intended that heat generated by the existing Haven Energy CHP plant will be used as the main source of energy for the regasification process. However, to achieve peak gasification capacity and to provide standby facilities should the CHP plant be unavailable, the terminal will also have 12 Submerged Combustion Vaporisers (SCVs) fuelled by the combustion of natural gas.

5.2.72 Air quality modelling of a range of operational scenarios (Dragon LNG Terminal Environmental Statement) has indicated that the highest impacts on ground

level NO<sub>x</sub> concentrations in residential areas around the Dragon LNG terminal will occur at Waterston, about 1 km northeast of the LNG terminal. At Waterston, the maximum predicted annual average concentration of total NO<sub>x</sub> arising from the LNG terminal was about 1.6 ppb. As the maximum contribution to annual average NO<sub>2</sub> concentrations from Pembroke Power Station in combination with rural background pollutant levels is only about 7 ppb, it is unlikely that there will be any exceedance of the annual average AQS objective for NO<sub>2</sub> of 21 ppb due to the Dragon LNG terminal in combination with Pembroke Power Station and background levels.

5.2.73 The maximum 99.8<sup>th</sup> percentile of 1-hour concentrations of total NO<sub>x</sub> at Waterston arising from the LNG terminal was predicted to be about 56 ppb. The plume impacts from Pembroke Power Station and the LNG terminal may overlap in the general vicinity of Waterston when the wind is blowing in a southerly direction from the power station towards the LNG terminal. However, for Pembroke Power Station in combination with rural background pollution levels, the 99.8<sup>th</sup> percentiles of 1-hour NO<sub>2</sub> concentrations north of the Haven are estimated to be less than 25 ppb. Thus, it is unlikely there will be an exceedance of the AQS objective of 105 ppb for the 99.8<sup>th</sup> percentile of 1-hour NO<sub>2</sub> concentrations due to the power station in combination with the LNG terminal.

5.2.74 When the wind is blowing from the north, from the LNG terminal towards the proposed Pembroke Power Station, the maximum 99.8<sup>th</sup> percentile of hourly NO<sub>2</sub> concentrations arising from power station NO<sub>x</sub> emissions downwind to the south is predicted to be about 25 ppb. South of the Haven, the 99.8<sup>th</sup> percentiles of 1-hour NO<sub>x</sub> concentrations associated with emissions from the Dragon LNG terminal reach a maximum of about 50 ppb. Thus, once again, it is unlikely that the AQS objective of 105 ppb for the 99.8<sup>th</sup> percentile of 1-hour NO<sub>2</sub> concentrations will be exceeded when the plume impacts from the LNG terminal and the power station overlap.

5.2.75 Later modelling of the LNG terminal for a PPC application (PCC, 2006) has concluded that the greatest impacts on NO<sub>2</sub> concentrations will be a 9 % contribution to the hourly Environmental Quality Standard (EQS) and that process contributions to the annual EQS will be less than 1%. As the predicted annual average process contribution (<2.1 ppb) is similar to that estimated in the original Environmental Statement for the LNG terminal (1.6 ppb) and the maximum 1 hour impact (about 9.5 ppb) is less than 20 % of that estimated in the Environmental Statement (56 ppb), it remains unlikely that the AQS objectives for NO<sub>2</sub> will be exceeded due to the operation of the proposed Pembroke CCGT in combination with the Dragon LNG terminal.

#### *South Hook LNG terminal*

5.2.76 The South Hook LNG terminal is a permitted development to unload, store and regasify LNG at the site of the former Esso oil refinery, about 6 km west-northwest of the proposed Pembroke Power Station. The terminal is larger than the one permitted adjacent to the SemGroup (formerly Petroplus) site, with NO<sub>x</sub> emissions from up to 20 SCVs which will discharge continuously below water. For safety purposes, there will be two flare systems installed on site: one for low pressure discharges and the other for high pressure systems.

5.2.77 A typical operating scenario of 16 active SCVs was modelled for the South Hook Environmental Statement. The results indicated that increases in annual average NO<sub>2</sub> concentrations beyond the site boundary would, in general, be less than 1 ppb. Thus the effects of the South Hook LNG terminal in combination with Pembroke Power Station and other sources would be unlikely to lead to an exceedance of the AQS objective for annual average NO<sub>2</sub> concentrations.



5.2.78 The short-term plume impacts arising from typical operations at South Hook LNG terminal result in 99.8<sup>th</sup> percentile hourly NO<sub>2</sub> concentrations of less than 26 ppb at locations east of Hubberston, about 1.5 km east of the LNG terminal. Similarly, the 99.8<sup>th</sup> percentile hourly NO<sub>2</sub> concentrations associated with emissions from Pembroke Power Station are predicted to be less than 25 ppb at distances beyond about 3.5 km west-northwest of the power station site. These results indicate that the short-term impacts from the LNG terminal near the power station are likely to be small, as are the short-term impacts of the power station in the vicinity of the LNG terminal. It is therefore unlikely that overlap of the plumes from these two sources will cause an exceedance of the AQS objective of 105 ppb for the 99.8<sup>th</sup> percentile of 1-hour average NO<sub>2</sub> concentrations during normal operations.

5.2.79 Modelling of a flare release (less than once in 5 years during normal operation) indicated that the ground level contribution to NO<sub>2</sub> concentrations at the nearest sensitive receptors during a flare event would be negligible, being less than 3 % of the AQS threshold concentration for short-term impacts.

### NO<sub>x</sub> Compliance Monitoring

5.2.80 RWE npower's previous practice (e.g. at Didcot B) has been to carry out continuous NO<sub>x</sub> and NO<sub>2</sub> monitoring at two locations for at least 12 months prior to commissioning of the first unit and continuing for at least 12 months after the power station is fully commissioned. As far as the availability of suitable sites permits (they need a permanent shelter, and therefore require planning permission, and need a power supply), they are usually located where the highest average impacts from the power station are predicted. These may be supplemented by diffusion tube measurements which provide monthly average NO<sub>2</sub> data at a wider range of locations and are a much more cost-effective way of confirming the longer-term impacts of the power station on NO<sub>2</sub> levels at a wider range of locations.

5.2.81 RWE npower proposes a similar approach at Pembroke and intends to discuss the location of monitoring stations with PCC.

### Long-range Nitrogen Deposition

5.2.82 In addition to the effects on local air quality, NO<sub>x</sub> emissions contribute to the deposition of nitrogen which is associated with the following mechanisms for ecosystem harm:

- Acidification of freshwaters and terrestrial ecosystems
- Eutrophication, i.e. over-enrichment with nitrogen, which may lead to changes in biodiversity

5.2.83 Nitrogen oxides are removed from the atmosphere by two principal mechanisms: dry deposition, resulting from direct contact of pollutants with plant and soil surfaces, and wet deposition, resulting from removal via rain, snow and mist. The deposition processes for the removal of NO and NO<sub>2</sub> tend to be less efficient than those for the removal of oxidised nitrates. As the chemical conversion of NO<sub>x</sub> to nitrate is relatively slow, this means that the effects of deposition are of concern on a UK and European scale, rather than just at a local level. (The effects of nitrogen deposition on local nature conservation sites are considered in Chapter 8.)

5.2.84 The results of EMEP deposition modelling (EMEP, 2005) predict that the total deposition of NO<sub>x</sub> (and its oxidation products) in the UK for a 2010 emissions scenario would be about 262 ktonnes (as NO<sub>2</sub> equivalent), of which about 91 ktonnes – or 35 % – would be associated with UK emissions. The predicted annual NO<sub>x</sub> emissions from the Pembroke CCGT operating at full load are about 3 ktonnes (5.2.18 above), which is

equivalent to about 0.3 % of the predicted UK emissions for 2010 (1,090 ktonnes). Thus, in 2010, the contribution of Pembroke to UK NO<sub>x</sub> deposition would be < 0.2 % and so the impact on UK deposition would be negligible. It is likely that Pembroke, as a new efficient station, would displace older, less efficient power stations which emit substantially more NO<sub>x</sub> per unit of electricity generated. The impact on the UK deposition would therefore be a net reduction of NO<sub>x</sub> deposition.

5.2.85 Beyond the UK, the EMEP results predict that Ireland is the EU Member State to which UK emissions make the greatest contribution to deposition of NO<sub>x</sub> (about 24 % for 2010 emissions). In 2010, the contribution of Pembroke to total deposition of NO<sub>x</sub> in Ireland would be about 0.1 %.

### 5.3. Carbon Dioxide Emissions

5.3.1 Carbon dioxide (CO<sub>2</sub>) emissions have no significant local impact. Interest in CO<sub>2</sub> emissions arises from their contribution to global atmospheric concentrations.

5.3.2 Global atmospheric CO<sub>2</sub> concentrations have risen steadily by about 30 % since the industrial revolution, almost certainly as a result of burning fossil fuels and deforestation. There is concern that continued increases in CO<sub>2</sub> and other greenhouse gases might lead to significant changes in global climate later this century, although there is uncertainty about the local and regional magnitude and timing of any such changes.

5.3.3 Under the 1997 Kyoto Protocol of the UN Framework Convention on Climate Change, the EU has agreed to reduce emissions of a “basket” of six greenhouse gases – including CO<sub>2</sub> – to 8 % below 1990 levels for the period 2008-2012. This target was shared among the EU Member States according to their economic circumstances, with the UK agreeing to reduce emissions by 12.5 % over the same time period. The UK currently appears to be on course to meet this target, largely as a result of the decline in CO<sub>2</sub> emissions from the power industry associated with the switch from coal- to gas-firing. Typically, a CCGT firing natural gas emits less than half of the CO<sub>2</sub> per unit of electricity generated compared with the coal-fired generation it displaces. CO<sub>2</sub> emissions from a CCGT power station are typically below 400 g per kilowatt hour (kWh) of electricity generated, compared with approximately 900 g per kWh for a coal-fired station.

5.3.4 The UK Government aimed to move beyond the Kyoto target and reduce CO<sub>2</sub> emissions to 20 % below 1990 levels by 2010, although it is unlikely to achieve this extended target. The introduction of a CCGT at Pembroke would be likely to assist in the reduction of CO<sub>2</sub> emitted per kWh of electricity generated by RWE npower plant and would be beneficial in terms of helping to meet the UK’s greenhouse gas commitments.

5.3.5 It is estimated that the Pembroke CCGT, if operated at full capacity throughout the year, would emit approximately 5.8 million tonnes of CO<sub>2</sub> per annum.

5.3.6 Total UK greenhouse gas emissions in 2005 were 654 million tonnes CO<sub>2</sub> equivalent, to which carbon dioxide emissions contributed 556 million tonnes (DEFRA, 2007), little changed from the 2004 figure of 557 million tonnes. In that year power stations in the UK emitted some 172 million tonnes CO<sub>2</sub>, approximately 30% of UK total CO<sub>2</sub> emissions (AEP, 2007).

5.3.7 Based on these figures, the annual contribution of the new Pembroke power station would be less than 4 % of UK power station CO<sub>2</sub> emissions and about 1 % of total UK greenhouse gas emissions. It is likely that Pembroke as a new efficient station would displace older, less efficient power stations emitting more CO<sub>2</sub> per unit of

electricity generated. The impact on the UK deposition would therefore be a net reduction of CO<sub>2</sub> emissions. If the new Pembroke power station were to displace generation from coal-fired plant, the resultant net reduction in carbon dioxide emissions would be approximately 7.2 million tonnes per annum.

#### 5.4. Other Gaseous Emissions

##### Ozone

5.4.1 The national AQS objective for ozone, to be achieved by 31 December 2005, is that the daily maximum of running 8-hour means should not exceed 50 ppb (100 µg m<sup>-3</sup>) on more than 10 days per year. Prior to the required achievement date, this objective was exceeded at the Narberth monitoring site, about 24 km from the proposed Pembroke CCGT, for all years between 1999 and 2003 inclusive as shown in Table 5.9.

**Table 5.9: Number of days at Narberth with maximum running 8 hour mean for O<sub>3</sub> greater than 50 ppb, 1999- 2005 inclusive**

Year	Number of days with 8h O <sub>3</sub> concentration >50 ppb	Availability of hourly data (%)
1999	28	84
2000	12*	72
2001	19	94
2002	13	91
2003	32	89
2004	N/A	0
2005	2*	60

\* Annual statistics unreliable, as data capture <75%.

N/A No data available, as site non-operational or data erroneous for this period.

5.4.2 Ozone is not a direct emission from combustion processes but forms in the atmosphere at ground level as a result of reactions between nitrogen oxides and volatile organic compounds (VOCs) in the presence of sunlight. In general, the highest ozone concentrations are typically found at distances of the order of 100 km downwind of major precursor source areas, reflecting the nature of the atmospheric chemistry involved in its production.

5.4.3 Road transport and power plant are the major contributors to NO<sub>x</sub> emissions in the UK - 36 % and 21 % respectively in 2003 – whereas solvent use and road vehicles (including petrol evaporation) are the major sources of VOCs – 34 % and 16 % respectively for non-methane VOCs in 2003. Thus, arguably, road transport is the main source of ground-level ozone, since motor vehicles emit both the gaseous components required for its production, simultaneously and in the same location.

5.4.4 Modelling of ozone in the plume of a 1500 MW CCGT (Wright, 2000) has shown that, as expected, ozone concentrations are generally decreased downwind of the power station, due to the reaction of NO in the plume with ambient ozone to form NO<sub>2</sub>. However, there may be some very small increases in ozone concentration (up to about 0.05 ppb) at distances beyond about 100 km, where NO levels in the plume approach those in the surrounding atmosphere.

5.4.5 It is predicted that ozone concentrations would be likely to be reduced in Pembrokeshire in the presence of power station emissions, and any small increases at distances beyond about 100 km are likely to be insignificant.

##### Carbon Monoxide

5.4.6 Small amounts of carbon monoxide (CO) may be formed instead of CO<sub>2</sub> when combustion of the fuel is incomplete. CO ultimately oxidises to CO<sub>2</sub>. Formation of CO will be minimised by design of the combustion chamber and the burners. Based on

tender specifications, a flue gas CO concentration of 65 mg Nm<sup>-3</sup> was assumed in the Pembroke CCGT plume dispersion modelling described at 5.2.19 *et seq.* above..

5.4.7 The AQS objective for ground-level CO concentrations, to be achieved by 31 December 2003, is that running 8-hour means should not exceed 8.6 ppm (10 mg m<sup>-3</sup>). Table 5.10 shows that the maximum predicted station contribution to an 8-hour mean CO concentration is only 0.5 ppm and, therefore, the impact of the station on short-term CO concentrations is insignificant compared to the AQS objective.

**Table 5.10: Maximum CO concentrations predicted for the operation of the new Pembroke power station at full load**

Year (Meteorology and background chemistry data)	Maximum running 8-hour mean (ppm)	
	CASE 1 (5 single-flue stacks)	CASE 2 (2 multi-flue stacks)
1999	0.4	0.4
2000	0.4	0.4
2001	0.5	0.4
2002	0.4	0.4
2003	0.5	0.4
2005	0.4	0.4

#### Unburnt Hydrocarbons

5.4.8 The combustion systems of the gas turbines will be designed to minimise emissions of unburnt hydrocarbons.

#### Releases of methane from the fuel gas system

5.4.9 During shutdown of a gas turbine, the fuel gas vent valve would be opened after the emergency stop and isolating valves were closed, in order to prevent leakages into the combustion chambers. The gas would be released into the atmosphere through a vent at building roof level. The quantity of gas released would be dependent on the detailed plant design but for similar plant it is approximately 17 kg (30.6 Nm<sup>3</sup>) for each gas turbine shutdown.

5.4.10 For inspection and maintenance of the high pressure gas pipework between the above-ground installation (AGI) and the power plant, it would be necessary to vent this pipework to atmosphere. This would only occur very infrequently, typically once every 10 years. The exact quantity of gas which would be released would depend on the final design and volume of the gas pipework, but is expected to be about 1.5 tonnes (2,000 Nm<sup>3</sup>). Smaller volumes of gas would be vented from sections of pipe supplying individual gas turbines when required for maintenance.

5.4.11 The total amount of fuel gas vented to atmosphere is expected to be less than 3 tonnes (4,000 Nm<sup>3</sup>) per year in normal operation, except in years when the high pressure gas pipework has to be vented for maintenance. It would be possible to assess the actual volume of gas vented by reference to the volume and working pressure of each section of the fuel gas system, and operational records of gas turbine shutdowns and maintenance activities involving gas venting.

5.4.12 Fuel gas is almost entirely comprised of methane. Methane (CH<sub>4</sub>) is not considered to have significant toxicological properties and so is not of concern with respect to local air quality, but it is a greenhouse gas and emissions should be viewed in terms of total UK releases. In 2005, estimated methane releases for the UK were approximately 2.3 million tonnes CH<sub>4</sub> (DEFRA, 2007) and hence the potential emissions from the Pembroke CCGT (3 tonnes) can be considered insignificant.

## 5.5. Summary

### Nitrogen Oxide Emissions

#### Local Air Quality

5.5.1 Estimates of the effect that the proposed CCGT station would have on prevailing ground level NO<sub>2</sub> and NO<sub>x</sub> concentrations show that, although maximum 99.8<sup>th</sup> percentile 1 hour NO<sub>2</sub> concentrations of approx 66 ppb and annual average concentrations of NO<sub>2</sub> and NO<sub>x</sub> of approx 7 and 15 ppb respectively are possible when the station is operating at full load, all NO<sub>2</sub> concentrations would remain well within the Air Quality Strategy objectives of 105 ppb (99.8<sup>th</sup> percentile 1 hour) and 21 ppb (annual average) for the protection of human health. Also, NO<sub>x</sub> concentrations would remain below the annual average objective of 16 ppb for the protection of vegetation. These maximum concentrations would generally occur less than 0.5 km from the stacks, often within RWE npower land.

#### Long-range Nitrogen Deposition

5.5.2 Deposition modelling by EMEP for a 2010 emissions scenario suggests that the NO<sub>x</sub> emissions from the new Pembroke power station are likely to have a very small impact on total NO<sub>x</sub> deposition in the UK and on NO<sub>x</sub> deposition in other EU Member States.

#### Carbon Dioxide Emissions

5.5.3 CCGT power stations firing natural gas emit less than half of the CO<sub>2</sub> emitted by existing coal-fired power plant, and the former oil-fired power station at Pembroke, per unit of electricity generated. The increase in the use of natural gas for power generation has made the major contribution to the UK's reduction in greenhouse gas emissions in recent years, enabling it to meet its Kyoto target under the UN Framework Convention on Climate Change. The introduction of Pembroke would be likely to assist the reduction of RWE npower's overall UK CO<sub>2</sub> emissions per unit generated and would be beneficial in terms of helping to meet the UK's domestic greenhouse gas emission reduction commitments.

## 5.6. References

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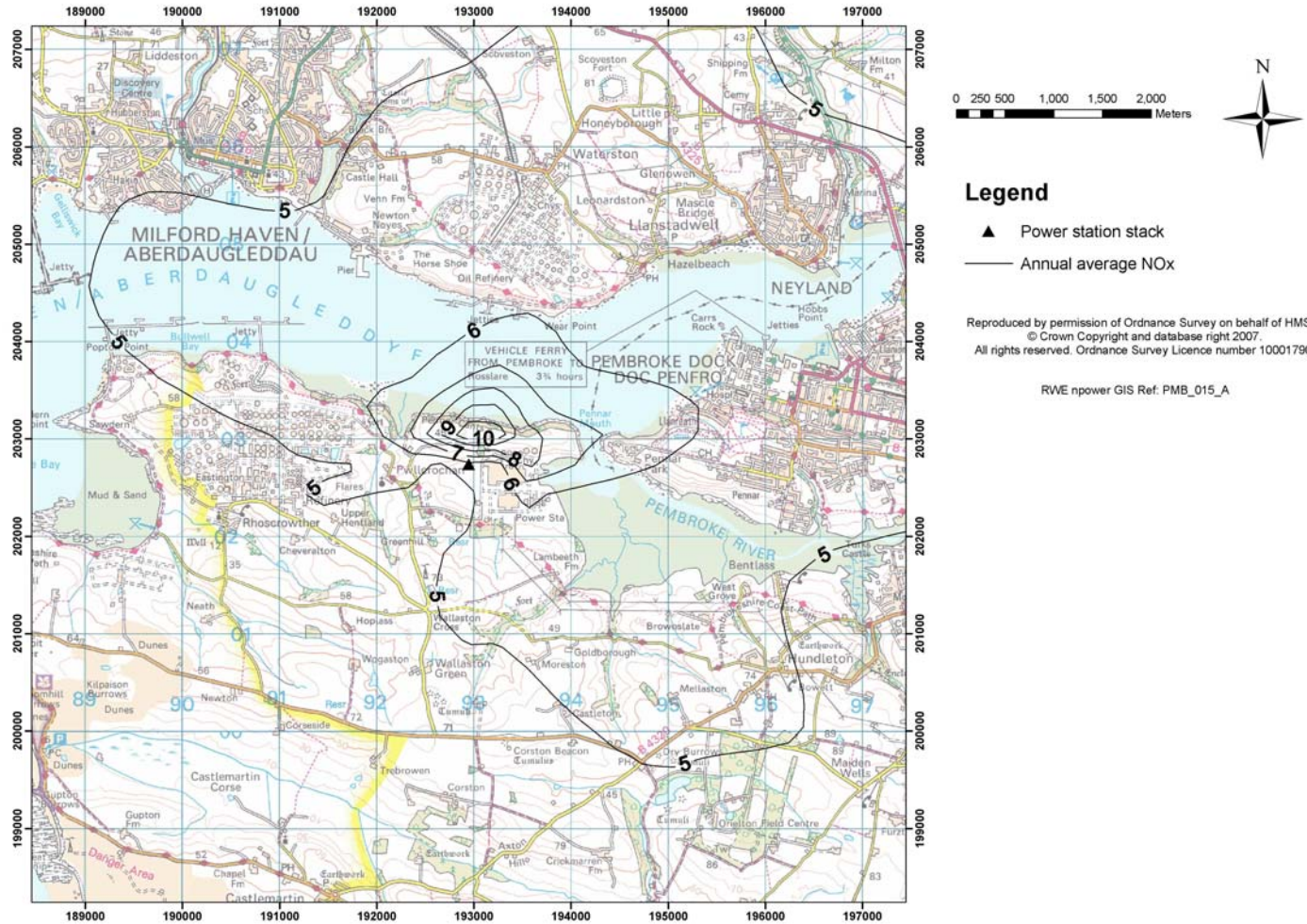


Figure 5.1: Predicted annual average NO<sub>x</sub> concentrations (ppb) based on 2002 meteorology and background chemistry data

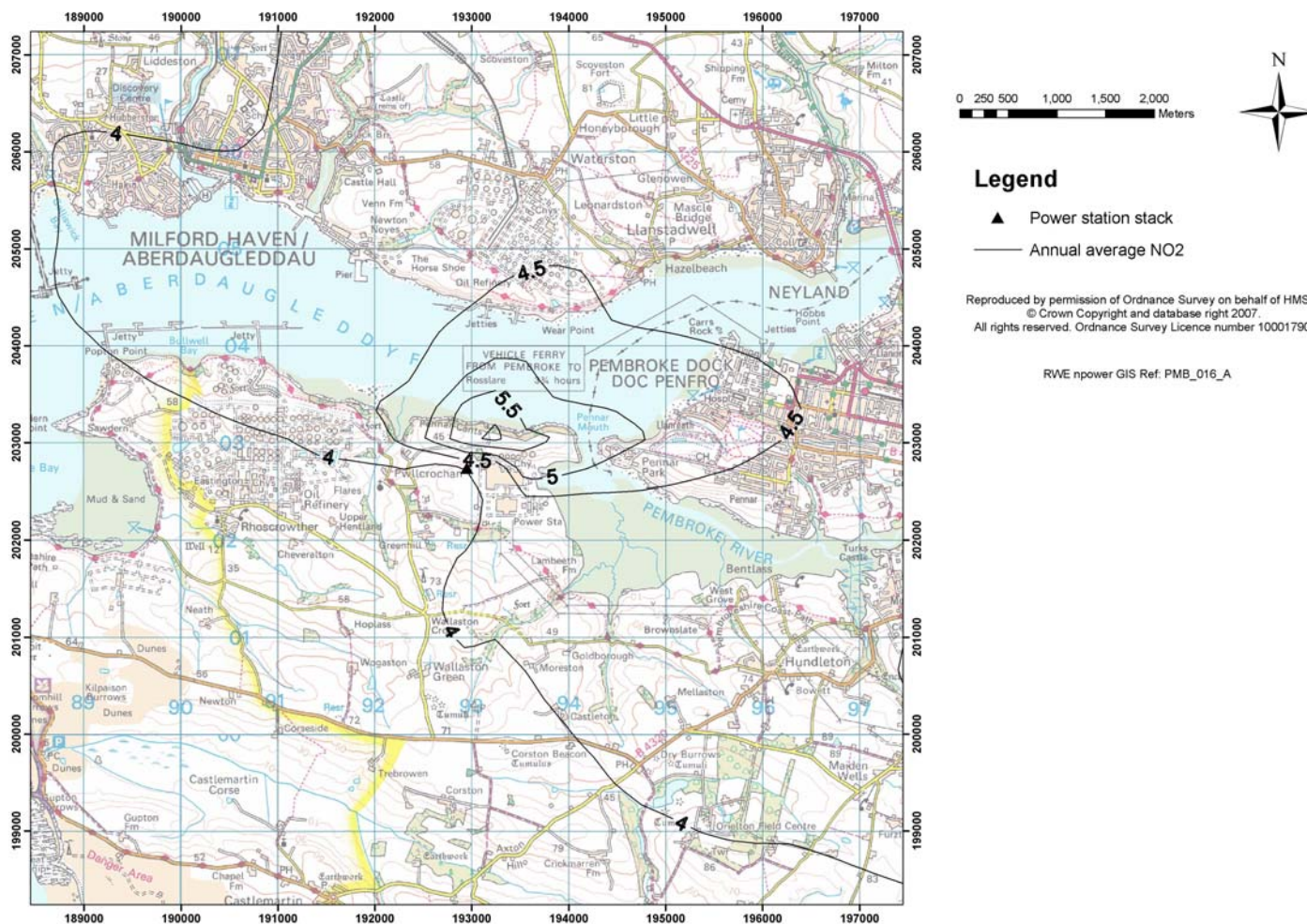


Figure 5.2: Predicted annual average NO<sub>2</sub> concentrations (ppb) based on 2002 meteorology and background chemistry data



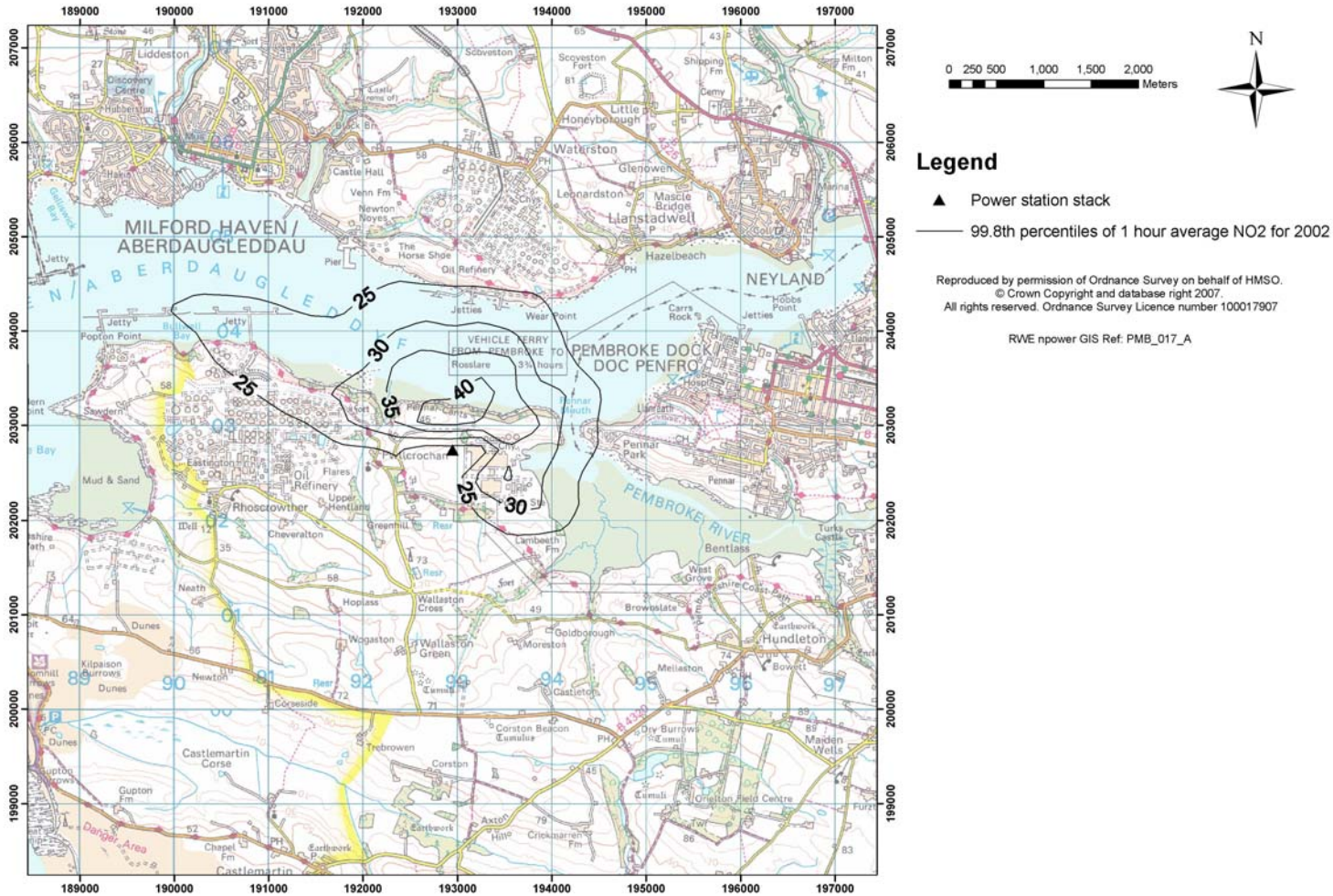


Figure 5.3: Predicted 99.8<sup>th</sup> percentile 1 hour NO<sub>2</sub> concentrations (ppb) based on 2002 meteorology and background chemistry data