AIR QUALITY MODELLING REPORT

PENGUINS REDEVELOPMENT PROJECT ENVIRONMENTAL STATEMENT

DECC Reference Number

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ACRONYMS

ADMS	Atmospheric Dispersion Modelling System
AQIA	Air Quality Impact Assessment
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EU	European Union
FPSO	Floating Production Storage and Offloading unit
IAQM	Institute of Air Quality Management
MDO	Marine Diesel Oil
PC	Process contribution
PEC	Predicted Environmental Concentration
SEPA	Scottish Environment Protection Agency
UKCS	UK Continental Shelf
VOCs	Volatile Organic Compounds

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1. INTRODUCTION

The Air Quality Impact Assessment (AQIA) has been undertaken for the operation of the Shell Penguin Floating Production, Storage and Offloading unit (FPSO), in the northern North Sea (Easting, 585438, Northing, 6823498)[1].

The site is located in the UK Continental Shelf (UKCS), adjacent to the UK/Norway marine border, approximately 160 km off the coast of the Shetland Islands.

The primary sources of emissions considered in the assessment are the continuous operation of combustion sources on the FPSO; namely the three gas turbine generators (19.7 MW_{th} combined) and the high pressure (HP) compressor (45.9 MW_{th}). Emergency flaring events have also been considered, in addition to other intermittent auxiliary combustion appliances, which use marine diesel oil (MDO) as fuel. These operational FPSO sources were considered to represent a worst-case assessment of the potential impact to air. Potential emissions from the drilling, commissioning and decommissioning phases, together with activities associated with shipping vessels and helicopters have been scoped out as they are not considered to be significant in air quality terms.

Due to the remote nature of the FPSO unit location, impacts on air quality have only been assessed in the context of human receptors, as there are no sensitive ecological sites in the vicinity.

The AQIA has been undertaken in a number of stages as follows.

- The legal framework was examined, focusing on the identification of applicable emissions limits and air quality standards;
- The receiving environment was characterised, including derivation of the existing baseline and meteorological conditions;
- An emissions inventory was built to quantify the emissions to air and characterise emission sources from the FPSO unit;
- Dispersion modelling using the ADMS 5 atmospheric dispersion model was used to quantify the maximum concentrations of pollutants of interest under three worst case operational scenarios;
- Impacts of emissions on air quality were quantified by comparison of the predicted maximum concentrations with the relevant air quality standards, with reference to the existing baseline conditions.

The three operational scenarios included in the assessment are namely; normal operations operating on gas; normal operations operating on gas with emergency flaring; and upset conditions operating with diesel gas turbine generator use and emergency flaring (as a worst-case potential scenario).

Total emissions of carbon dioxide (CO_2) have also been calculated for the proposed FPSO operations to show the cumulative greenhouse gases contribution of the Project.

The remainder of this section sets out the detailed approach to this process, the results of the AQIA, the identification of impacts and mitigation measures required, where appropriate.

[1] European Datum 50, 0 degrees

2. ASSESSMENT CRITERIA

2.1. OVERVIEW

The potential effects on human health of the emissions from the FPSO unit are assessed by comparison of the predicted pollutant concentrations arising around the FPSO to air quality standards and guidelines, taking into account the existing background.

2.2. REGULATORY FRAMEWORK

Whilst the Penguin FPSO unit site is located off-shore (160 km from the Shetland Islands), as it is located within the Scottish exclusive economic zone (EEZ), it is therefore still bound to European Union (EU) and Scottish Legislation.

Within Scotland the majority of the air quality standards relating to ambient air quality are based upon the EU directives (European Parliament, 2008). The relevant Scottish Legislation is The Air Quality Standards (Scotland) Regulations 2010. Scottish Statutory Instrument No. 204.

The EU and Scottish air quality standards include nitrogen oxides (NO_X) (which includes nitrogen dioxide (NO_2) and nitrogen oxide (NO)) and sulphur dioxide (SO_2), which are the primary pollutants of concern within this study. There will be emissions of other pollutants such as volatile organic compounds (VOCs); however, there is only one VOC with a mandatory standard in the EU and Scotland which is benzene. Predicted VOC concentrations have not been compared to the annual mean benzene standard as this is not considered appropriate for the assessment of short-term, emergency flaring emissions or VOCs emitted during intermittent upset conditions, neither of which is expected to involve significant quantities of benzene. VOC emissions from the gas-turbine generators and HP gas compressor have also been scoped out.

In addition, emissions of particulates (PM_{10} and $PM_{2.5}$) and carbon monoxide (CO) from combustion exhausts are not generally considered to be significant emissions for gas-fired sources and are therefore not included within the modelling assessment. PM_{10}, $PM_{2.5}$ and CO emissions from diesel generators and flaring activities have also not been included as their respective averaging periods within the Scottish air quality standards are not considered appropriate for the assessment of intermittent upset conditions and flaring events.

Total emissions of carbon dioxide (CO_2),have also been included in the assessment to show the cumulative greenhouse gas (GHG) contribution of the FPSO, in relation to the UK Continental Shelf (UKCS) annual CO_2 emissions. Further detail on the summary GHG calculations has been captured within the inventory for the Atmospheric Emissions chapter within the EIA.

2.3. REGULATORY GUIDELINES

The air quality standards for the protection of human health used in this assessment are set out in Table 2-1.

Table 2-1 Air Quality Standards for the Protection of Human Health

POLLUTANT	AVERAGING PERIOD AND STATISTIC	UNITS	VALUE	SOURCE
NO_2	Annual mean	$\mu g/m^3$	40	Scottish AQS / EU
NO_2	1 hour mean, not to be exceeded more than 18 times a year (99.79th percentile)	$\mu g/m^3$	200	Scottish AQS / EU
SO_2	24 hour mean, not to be exceeded more than 3times a year (99.9th percentile)	$\mu g/m^3$	125	Scottish AQS / EU
SO_2	1 hour mean, not to be exceeded more than 24 times a year (99.72nd percentile)	$\mu g/m^3$	350	Scottish AQS / EU
SO_2	15-minute mean, not to be exceeded more than 35 times a year (99.9th percentile)	$\mu g/m^3$	266	Scottish AQS

Horizontal Guidance H1 (SEPA, 2003), prepared jointly by Scottish Environment Protection Agency (SEPA), Environment Agency and Environment and Heritage Service, has also been used within the assessment[1].

[1] The Environment Agency for England have updated H1, with the most up to date version (v2.2) issued in 2012. In some circumstances SEPA advised that v2.2 may be more relevant. Where v2.2 has been cited, this is stated.

3. EXISTING ENVIRONMENT

The impacts on air quality arising from the FPSO unit are considered in the context of the existing environmental baseline conditions, in order to determine the overall significance.

Given the remote nature of the FPSO unit, site-specific ambient air quality data are not available. The most appropriate data source for off-shore applications is a representative 'rural' site from Defra's Automatic and Rural Network. Continuous background monitoring data from Defra's Strathvaich rural site has therefore been used in the assessment. The Strathvaich monitoring site was operated in a remote area of the Scottish Highlands and is considered to be the site which is most representative of the likely ambient concentrations at the FPSO unit and in the open North Sea.

It is acknowledged that Defra also operate a continuous monitoring site as part of the Automatic and Rural Network, at Lerwick, Shetland. The Lerwick site is also classified by Defra as 'Rural Background', however as the site is located with 150 m of a main road and on the outskirts of Lerwick town, it was considered that the Strathvaich site data was more closely matched to the proposed FPSO unit's location in terms of air quality.

For the pollutants of concern within this study, pollutant concentrations of NO_x, NO_2 and SO_2 were monitored at Strathvaich between 1990-1997. A summary of the monitored data over these periods is provided in Table 3-1 below.

It is acknowledged that the use of data from the historic closed site may not be considered to be ideal; however, as trends in the UK suggest a gradual improvement in background air quality concentrations since the 1990s, the use of the data in the assessment is considered to be robust.

Table 3-1 Strathvaich Rural Background Monitoring Data 1990 – 1997 (µg/m³)

POLLUTANT	1990	1991	1992	1993	1994	1995	1996	1997
Nitrogen dioxide (NO_2)								
Annual mean	1.81	3.53	1.30	1.89	2.02	0.92	1.44	1.02
1 hour max (99.79th percentile)	24.7	41.4	19.9	22.6	25.5	11.2	27.0	14.9
Data capture	16.6%	44.1%	85.3%	41.6%	68.1%	86.3%	84.6%	17.1%
Sulphur dioxide (SO_2)								
24hour max (99.19th percentile)	6.82	26.6	9.17	10.4	11.1	6.01	7.37	6.57
1 hour max (99.72nd percentile)	13.3	45.3	15.2	19.2	19.4	11.9	16.5	13.1
Data capture (%)	18.8%	56.1%	69.7%	77.4%	61.6%	94.4%	92.8%	17.2%

POLLUTANT	1990	1991	1992	1993	1994	1995	1996	1997

The data used in the assessment are also detailed in Table 3-2. Only recorded background concentrations, where data capture exceeded 75%, were considered in the assessment, in line with guidance (Defra, 2009).

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Table 3-2 Background Data used in Assessment (µg/m³)

POLLUTANT	AVERAGING PERIOD	VALUE	SOURCE
Nitrogen dioxide (NO_2)	Annual mean	1.44	Strathvaich 1996
	1-hour	2.88	2 x annual mean
Sulphur dioxide (SO_2)	1-hour	19.2	Strathvaich 1993
	15-minute	19.2	Assumed as 1-hour

4. ASSESSMENT METHODOLOGY

The scope of the assessment is summarised as follows

- Understand and quantify the potential sources of emissions on the FPSO unit;
- Identify potential operational emission scenarios;
- Identify sensitive receptors;
- Assess the potential impacts associated with the operational scenarios; and,
- Consider the magnitude and significance of the potential impacts.

4.1. Dispersion Modelling Inputs and Method

The operational impacts from the FPSO unit are assessed using the ADMS (Atmospheric Dispersion Modelling System) model. Its use is advocated by SEPA (SEPA, 2003) and the Environment Agency for industrial applications.

ADMS allows for the modelling of dispersion under convective meteorological conditions using a skewed Gaussian concentration distribution. It is able to simulate the effects of terrain and building downwash simultaneously. It can also calculate concentrations for direct comparison with air quality standards or guidelines.

A summary of the initial ADMS set up parameters are detailed in Table 4-1 below.

Table 4-1 ADMS 5 Model Set up Parameters

PARAMETER	UNIT	VALUE
Location of FPSO unit (easting, northing)	m, m	585438, 6823498
Coordinate reference system	-	European Datum 50, 0 degrees
Latitude	degrees	61.5
Surface Roughness	m	0.0001
Surface albedo	-	0.23
Minimum Monin-Obukhov length	m	1
Height of recorded wind	m	14
Assumed height of FPSO above sea level	m	30

4.1.1. Consideration of Building Downwash

When air flow passes over buildings, a phenomenon known as building downwash occurs where the air is entrained in the lee of the building and drawn down to ground level. This effect can bring the plume from the stack down to ground level quicker than would otherwise be the case, and therefore increase the ground level concentration relative to a case where there are no buildings or less tall buildings.

Building effects are typically a consideration where the buildings are greater than one third the height of the stacks. As detailed building information was not available at the time of

reporting, the inclusion of buildings within the modelling has not been carried out. In addition, given the likely close proximity of buildings on the FPSO unit, the ADMS model used is also not considered to be appropriate to assess the complex interactions of air flow in such near-field applications which typically require dedicated Computational Fluid Dynamics modelling and is beyond the scope of most environmental assessments.

4.1.1.1. Conversion of NOx to NO_2

Oxides of nitrogen (NO_x) are formed in the combustion process. In the exhaust gases from the stack, these are in the ratio of approximately 95% nitric oxide (NO) to 5% nitrogen dioxide (NO_2). With regard to the assessment of effect on human health, NO_2 is the pollutant of interest, as NO has far less pronounced health effects at ambient-type concentrations. In the atmosphere, various processes will oxidise NO to NO_2, but the process will not occur quickly or completely before the plume reaches ground level. It is therefore necessary to use a factor to estimate ground level concentrations of NO_2 based upon total NO_x emitted, because assuming 100% conversion is overly pessimistic. Based upon Environment Agency guidance (EA, 2005), it is assumed that, when assessing short term average concentrations, 35% of NO_x occurs as NO_2 and, for long term average concentrations, 70% of NO_x occurs as NO_2.

4.1.1.2. Operational Hours

Operational activities for the normal operational scenario are assumed to occur continuously over a full year i.e. 8760 hours, to provide a worst-case assessment of both short-term and long-term air quality impacts.

Operational activities for Scenarios 2 and 3, assessing the impacts of an emergency flaring event and potential upset conditions respectively, have been assessed against short-term air quality standards only, given the temporary nature of such emissions.

4.1.1.3. Assumptions and Limitations

- It is acknowledged that the absence of building data within the model is a limitation of the study as it may underestimate the maximum predicted impacts.
- The use of on-site plant operating on diesel will be minimised in line with industry best practice.
- Emergency flaring events will be minimised. A total of 12 events per year have been assumed for the assessment.

4.2. Operational Scenarios

In order to provide a representative assessment of the likely operational conditions at the FPSO unit, the following scenarios have been considered in the study:

1. Normal operations (operating on gas)
   - Emission sources:
     - Three gas turbine generators (19.7MWth combined)
     - HP gas compressor (45.6MWth)
   - Pollutant Assessment:
     - Annual mean NO_2 concentrations
     - 1-hour NO_2 concentrations (99.79th percentile)
2. Normal operations (operating on gas) with emergency flaring

- Emission sources:
  - Three gas turbine generators (19.7MWth combined)
  - HP gas compressor (45.6MWth)
  - HP emergency flare
- Pollutant Assessment:
  - 1-hour NO_2 concentrations (99.79th percentile)
  - 1-hour SO_2 concentrations (99.72nd percentile)
  - 15-minute SO_2 concentration (99.9th percentile)

3. Upset conditions (diesel gas turbine generator use and emergency flaring)

- Emission sources:
  - Three gas turbine generators using marine-diesel-oil (19.7MWth combined)
  - HP emergency flare
- Pollutant Assessment:
  - 1-hour NO_2 concentrations (99.79th percentile)
  - 1-hour SO_2 concentrations (99.72nd percentile)
  - 15-minute SO_2 concentration (99.9th percentile)

4.3. Emissions Inventory

An inventory of data for the proposed operational plant on the FPSO unit was provided directly by Shell for the assessment. At the time of writing, due to on-going project developments, the exact model of the gas compressor and power generators to be utilised onsite were unknown. Multiple options were however provided by Shell and therefore the worst-case options, in terms of emissions, were selected for the assessment. Full details of the emissions parameters are provided in Table 4-2 below.

Additional auxiliary plant will also be utilised on-site (emergency generator and three fire pumps), however the potential impact of their emissions was not considered to be significant due to their non-continuous operational nature. Whilst the likely size of the auxiliary plant and hours of operation were provided by Shell, the exact models were unknown and therefore emissions parameters were reviewed from auxiliary plant considered to be representative to those likely to be installed at the FPSO.

Table 4-2 Emission Parameters

PARAMETER	UNITS	VALUE		
		GAS COMPRESSOR	POWER GENERATOR W. WHRU	FLARE (HP)
Assumed Model		General Electric PGT20	Solar Taurus 70	N/A

PARAMETER	UNITS	VALUE		
		GAS COMPRESSOR	POWER GENERATOR W. WHRU	FLARE (HP)
Location of flues (easting, northing)[a]		585400, 6823511	585398, 6823510 585400, 6823511 585402, 6823512	585460, 6823568
Number of units		1	3	1
Number of stacks		1	3	1
Number of flues per stack		1	1	1
Flue diameter	m	2.15	2.15 (x3)	1.65
Stack height	m	64.0	60	113
Flue gas temperature	Celsius	475	413	1000
Exit Velocity	m/s	15.5	7.04	200
Volumetric Flow Rate (per stack)	Nm^3/s	18.5	9.17	119
Volumetric Flow Rate (per stack)	Am^3/s	56.4	25.6	426
Emission rates				
NOx	g/s	0.95	0.47	143
SOx	g/s	n/a	n/a	3.27
VOCs	g/s	n/a	n/a	294

PARAMETER	UNITS	VALUE		
		GAS COMPRESSOR	POWER GENERATOR W. WHRU	FLARE (HP)
Emission rates (alternative fuel use – Marine Diesel Oil)				
NOx controlled	g/s	n/a	14.7	n/a
*SOx	g/s	n/a	13.7	n/a
VOCs	g/s	n/a	0.80	n/a

a Coordinate system - European Datum 50, 0 degrees

*Assumed max sulphur content in fuel in north sea (EU Directive 2005/33/EC) = 1.5%

4.4. METEOROLOGY

The meteorological data used in the model need to reflect local conditions. Given the off-shore location, in the absence of measurement station data in the area, prognostic MM5 data were used for the FPSO unit location (61.534108° N, 1.606761° E). The use of prognostic data is advocated for use particularly where measurement data are not readily available, such as remote locations and for off-shore applications. MM5 data are however ultimately based upon measured empirical data.

To ensure that meteorological variability was taking into account in the study, five years of hourly sequential data for 2010-2014 inclusive were used in the assessment. The wind roses for these data are illustrated in Figure 4-1.

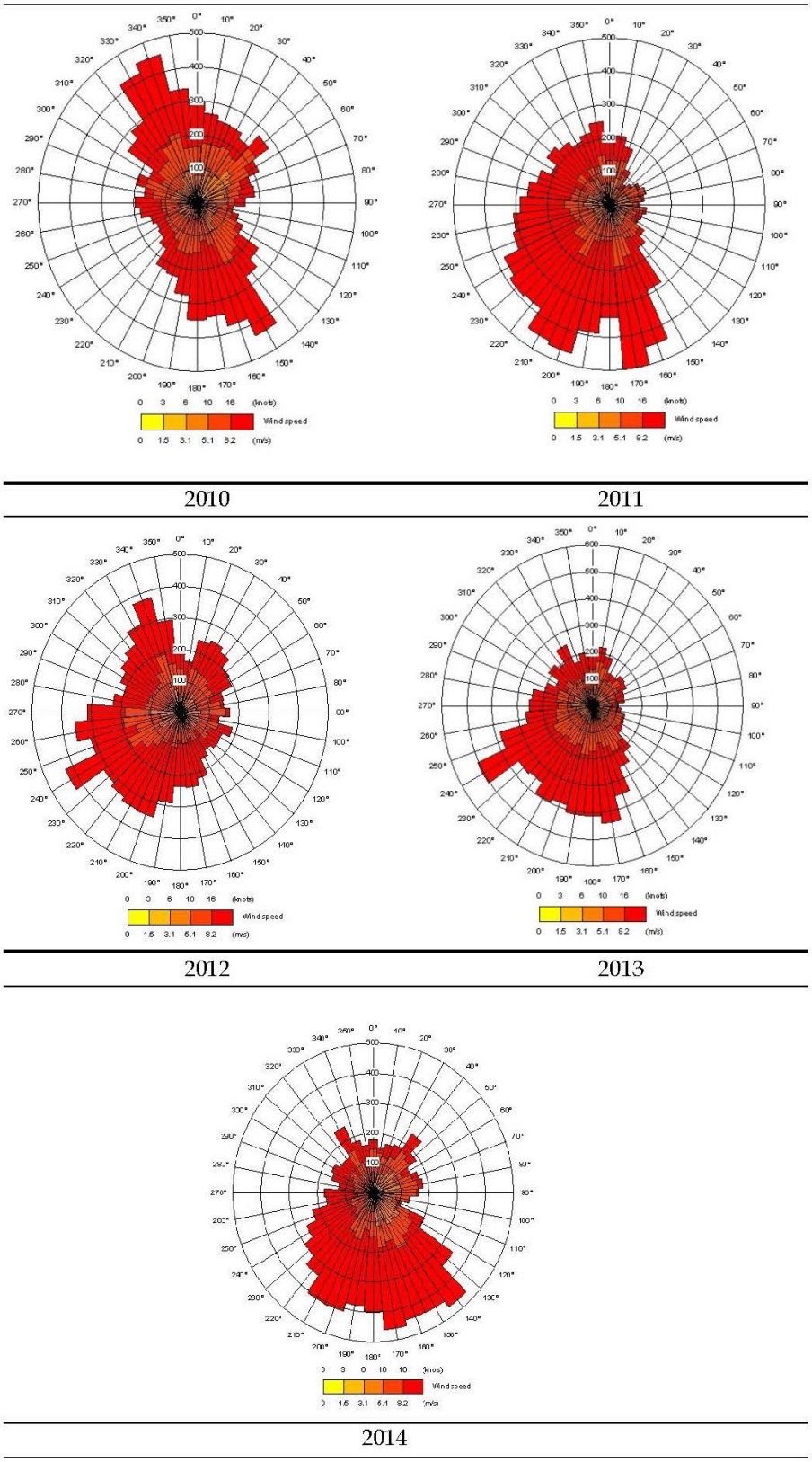

Figure 4-1 Wind Roses for Penguin FPSO (2010-2014)

4.5. RECEPTORS

Due to the remote location of the FPSO unit, there are no specific human receptors within 10 km of the FPSO and therefore discrete receptors have not been included within the modelling exercise. In order to ascertain the maximum potential impacts off-site, a receptor grid has been used in the assessment. A grid of receptors measuring 20 km by 20 km centred on the FPSO unit site (i.e. a 10 km radius), is defined in the model in line with UK guidance (SEPA, 2003)[1].

This grid is considered to be appropriate to assess the worst-case impacts at all potential sensitive human receptors in the vicinity of the Penguin FPSO unit location.

(1)The Environment Agency for England have updated H1, with the most up to date version (v2.2) issued in 2012. In some circumstances SEPA advised that v2.2 may be more relevant. Where v2.2 has been cited, this is stated.

5. SIGNIFICANCE CRITERIA

In relation to effects on sensitive human receptors, the significance of effects used in the EIA process is determined based on guidance developed jointly by Environmental Protection UK (EPUK) and the UK Institute of Air Quality Management (IAQM) (Environmental Protection (UK), 2010). The significance is determined in terms of:

- Process Contribution (PC), this is the impact associated with emissions from the Project only; and
- Predicted Environmental Concentration (PEC), this is the impact associated with PC added to the existing background conditions.

The criteria presented in Table 5-1 have been used to assess the significance of effects on sensitive human receptors. The process is in two stages:

- Screening stage, to determine the magnitude of impacts of the PC as a percentage of the air quality standard or guideline; and
- Second stage, to determine the significance of effects in terms of the magnitude of impacts identified from the screening stage, considered alongside the PEC.

Table 5-1 Significance Criteria for Assessing Impacts at Human Sensitive Receptors (EPUK, 2010)

DETERMINATION OF MAGNITUDE	
Magnitude of impact	***PC as a percentage of air quality standard or guideline***
Large	PC >10%of AQS
Medium	PC 5% - 10% of AQS
Small	PC 1% - 5% of AQS
Negligible	PC <1% of AQS

DETERMINATION OF SIGNIFICANCE				
Magnitude of Impact	***Negligible***	***Small***	***Medium***	***Large***
PEC above air quality standard or guideline with or without scheme	Not significant	Minor adverse	Moderate adverse	Major adverse
PEC below air quality standard or guideline without scheme and PEC above air quality standard with scheme	Not significant	Minor adverse	Moderate adverse	Moderate adverse

DETERMINATION OF MAGNITUDE				
PEC below air quality standard or guideline with scheme (75%-90% of air quality standard or guideline)	Not significant	Not significant	Minor adverse	Minor adverse
PEC well below air quality standard or guideline with scheme (<75% of air quality standard or guideline)	Not significant	Not significant	Not significant	Minor adverse

6. ASSESSMENT RESULTS

The PC and PEC for NO_2 and SO_2 have been calculated for comparison with the relevant Scottish Air Quality Standards, based on the emissions inventory detailed in Section 4.3. The results for each of the investigated scenarios identify the maximum concentrations (as relevant percentiles) predicted over a period of five years 2010 – 2014 on a sea level receptor grid, as discussed in Section 4. This approach therefore presents the worst case impact for the pollutants of interest anywhere in the study area at sea level. The overall significance for each Scenario is then determined on the basis of the approach outlined in Section 5.

The modelling has also been undertaken based on historic background monitoring data from Strathvaich, given the remote locations of the FPSO unit, as these were the data considered to be most appropriate at the time of writing. It is not expected however that the conclusions of the assessment would be substantially different should site specific ambient air quality data for the vicinity of the FPSO unit ever be available for use.

The predicted impact of FPSO operations on CO_2 emissions are also detailed in Section 5.5.

6.1. SCENARIO 1 – NORMAL OPERATIONS

This scenario has been modelled based on the operation and associated emissions from the HP gas compressor and three gas turbine generators for NO_2. The modelling has been based on the source parameters and emissions inventory detailed in Section 4.3.

A summary of the maximum short-term and long-term NO_2 concentrations arising anywhere on the modelled receptor grid is presented in Table 6-1 below, together with the overall significance of the predicted impacts when compared to the relevant air quality standards

Table 6-1 Maximum Predicted Pollutant Concentrations (µg/m³) – Scenario 1 (Normal Operations)

POLLUTANT	AVERAGING PERIOD	AQS	BACKGROUND	PC	PC/AQS	PEC	PEC/AQS	SIGNIFICANCE
Nitrogen dioxide (NO_2)	Annual mean	40	1.44	7.28×10^{-2}	0.18%	1.51	3.78%	Not significant
	1 hour (99.79th percentile)	200	2.88	2.66	1.33%	5.54	2.77%	Not significant

KEY	
Major adverse impacts	
Moderate adverse impacts	
Minor adverse impacts	

KEY	
Not significant	

6.1.1. Scenario 1 Findings

When considering the PC and PEC for the normal operation of the Penguin FPSO unit, not significant impacts are predicted at all locations for both annual mean and 1-hour NO_2 concentrations against the Scottish Air Quality Standards.

Predicted pollutant contours have also been prepared and are illustrated in Figure 6-1 and Figure 6-2.

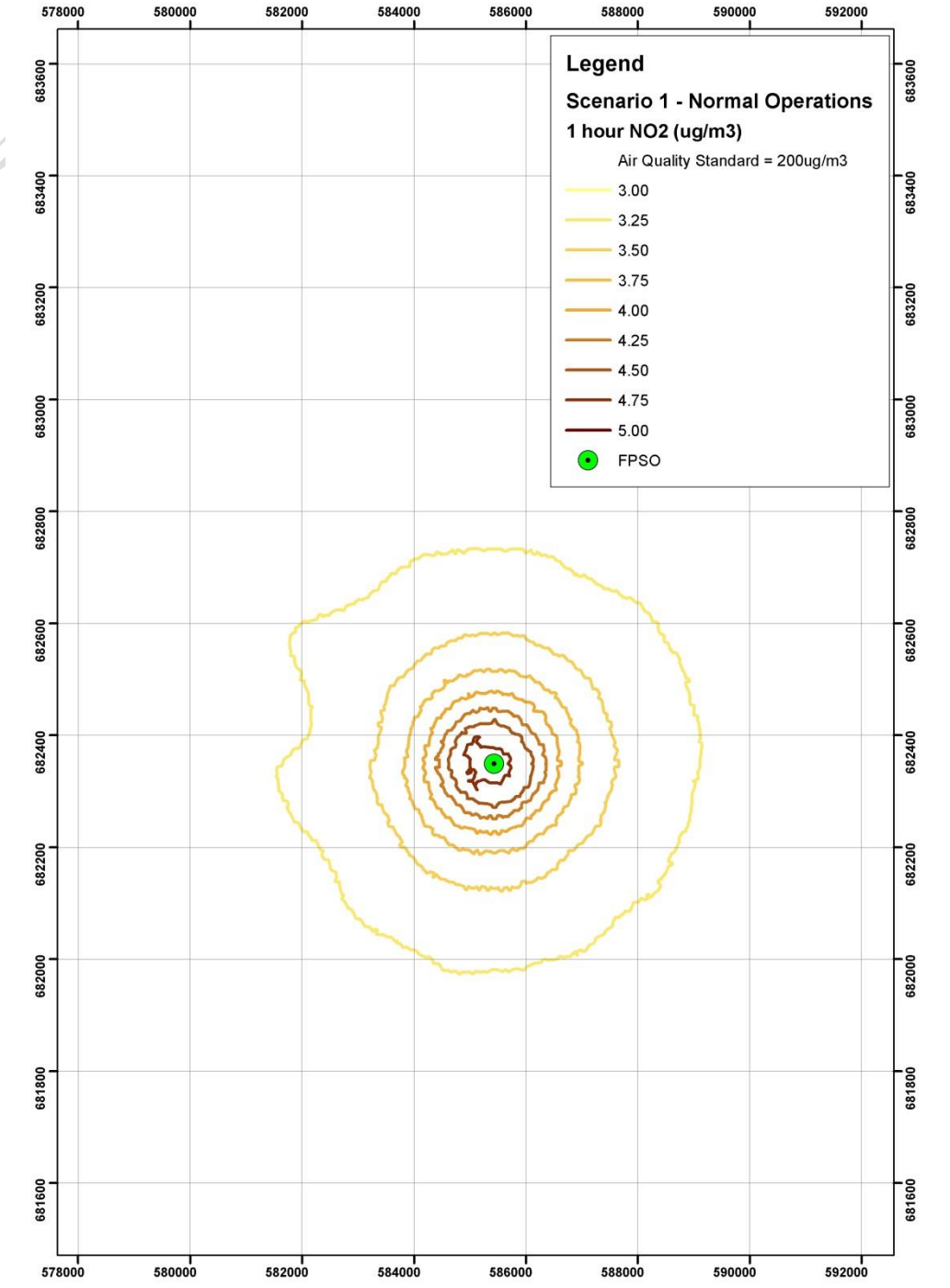

Figure 6-1 Maximum Predicted 1-hour NO_2 Concentrations - Scenario 1 - Normal Operations

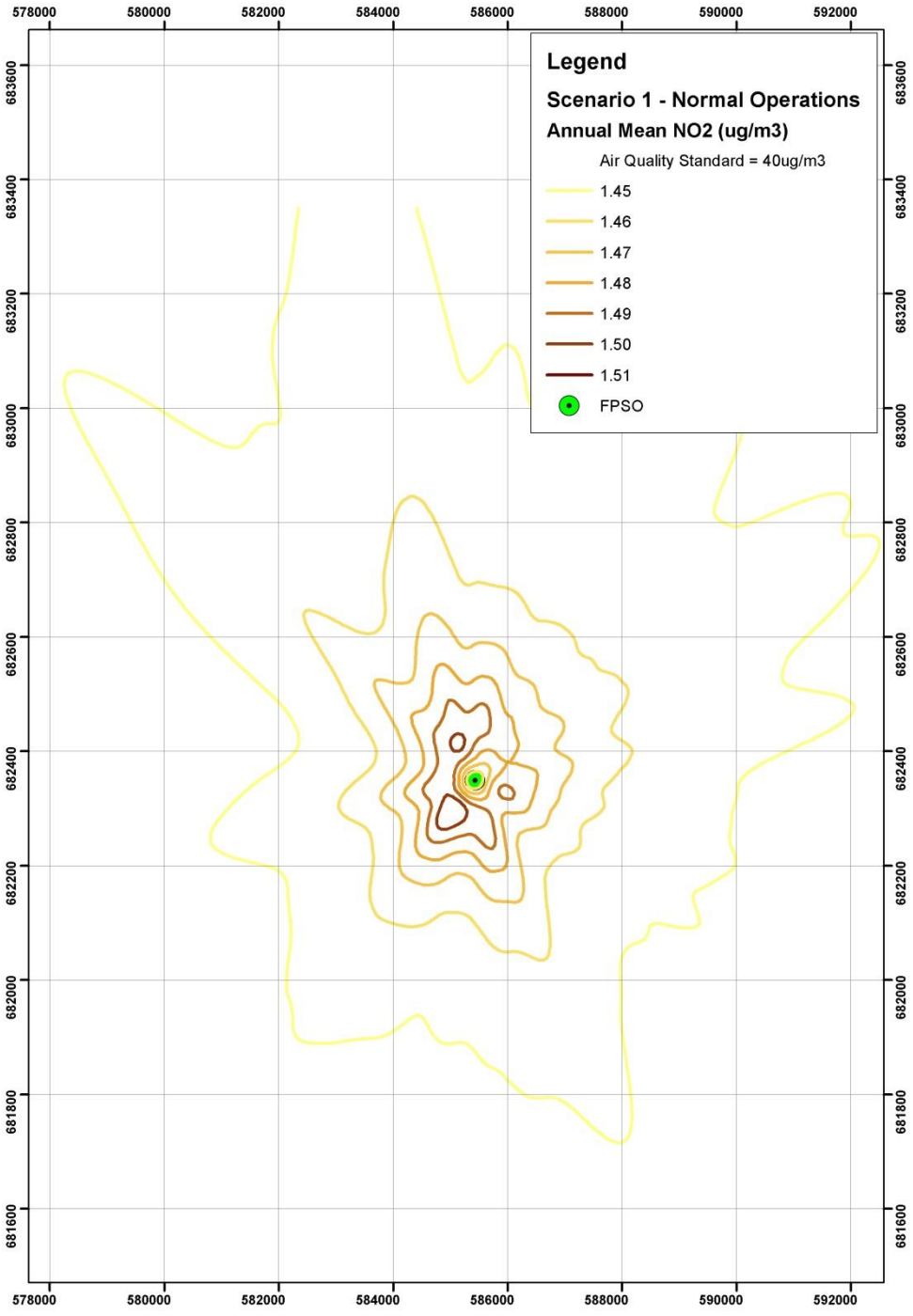

Figure 6-2 Maximum Predicted Annual Mean NO_2 Concentrations - Scenario 1 - Normal Operations

6.2. Scenario 2 – Normal Operations with Emergency Flaring

This scenario has been modelled based on the operation and associated emissions from the gas compressor and three gas turbine generators, in addition to an emergency flaring event for the pollutants of concern from the FPSO unit. The modelling has been based on the source parameters and emissions inventory detailed in Section 4.3.

A summary of the maximum short-term NO_2 and SO_2 concentrations arising anywhere on the modelled receptor grid is presented in Table 6-2 below, together with the overall significance of the predicted impacts when compared to the relevant air quality standards.

Table 6-2 Maximum Predicted Pollutant Concentrations (µg/m³) - Scenario 2 (Normal Operations Including Flaring)

POLLUTANT	AVERAGING PERIOD	AQS	BACKGROUND	PC	PC/AQS	PEC	PEC/AQS	SIGNIFICANCE
Nitrogen dioxide (NO_2)	1 hour (99.79th percentile)	200	2.88	2.66	1.33%	5.54	2.77%	Not significant
Sulphur dioxide (SO_2)	1 hour (99.72nd percentile)	350	19.2	1.94 x10-03	0.001%	19.2	5.49%	Not significant
	15-minute (99.9th percentile)	266	19.2	3.49 x10-3	0.001%	19.2	7.22%	Not significant

KEY	
Major adverse impacts	
Moderate adverse impacts	
Minor adverse impacts	
Not significant	

6.2.1. Scenario 2 Findings

When considering the PC and PEC for the normal operation (including emergency flaring) of the Penguin FPSO unit, not significant impacts are predicted at all locations for 1-hour NO_2 concentrations, together with 1-hour and 15-minute SO_2 concentrations against the Scottish Air Quality Standards. Due to the low predicted pollutant concentrations, the preparation of contour plots for Scenario 2 has not been considered necessary.

6.3. Scenario 3 – Upset Conditions (Diesel Gas Turbine Generator use and Emergency Flaring)

This scenario has been modelled based on the operation and associated emissions from the three gas turbine generators operating on marine diesel oil, in addition to an emergency flaring event, for the principal pollutants of concern on the FPSO unit. The modelling has been based on the source parameters and emissions inventory detailed in Section 4.3.

A summary of the maximum short-term NO_2 and SO_2 concentrations arising anywhere on the modelled receptor grid is presented in
Table **6-3** below, together with the overall significance of the predicted impacts when compared to the relevant air quality standards.

Table 6-3 Maximum Predicted Pollutant Concentrations (µg/m3) - Scenario 3 (Upset conditions)

POLLUTANT	AVERAGING PERIOD	AQS	BACKGROUND	PC	PC/AQS	PEC	PEC/AQS	SIGNIFICANCE
Nitrogen dioxide (NO_2)	1 hour (99.79th percentile)	200	2.88	69.6	34.8%	72.5	36.2%	Minor adverse
Sulphur dioxide (SO_2)	1 hour (99.72nd percentile)	350	19.2	155	44.2%	174	49.7%	Minor adverse
	15-minute (99.9th percentile)	266	19.2	204	76.6%	223	83.8%	Minor adverse

KEY	
Major adverse impacts	
Moderate adverse impacts	
Minor adverse impacts	
Not significant	

6.3.1. Scenario 3 Findings

When considering the PC and PEC for the Upset conditions (gas turbine generators using marine diesel oil (MDO) and an emergency flaring event) of the Penguin FPSO unit, minor adverse impacts are predicted with regards to both 1-hour NO_2 and SO_2 averaging periods, as well as 15-minute SO_2 concentrations. Predicted PCs are all considered to be Large (>10% of

the relevant Scottish Air Quality Standard), however the PEC is not predicted to exceed any of the relevant criteria.

The use of all three gas turbine generators on 100% load using MDO is considered to be highly unlikely, in addition to an emergency flaring event occurring simultaneously, however it has been presented as a worst-case scenario in terms of the potential non-routine emissions from the FPSO unit.

Predicted pollutant contours have also been prepared and are illustrated in Figure 6-3, Figure 6-4 and Figure 6-5.

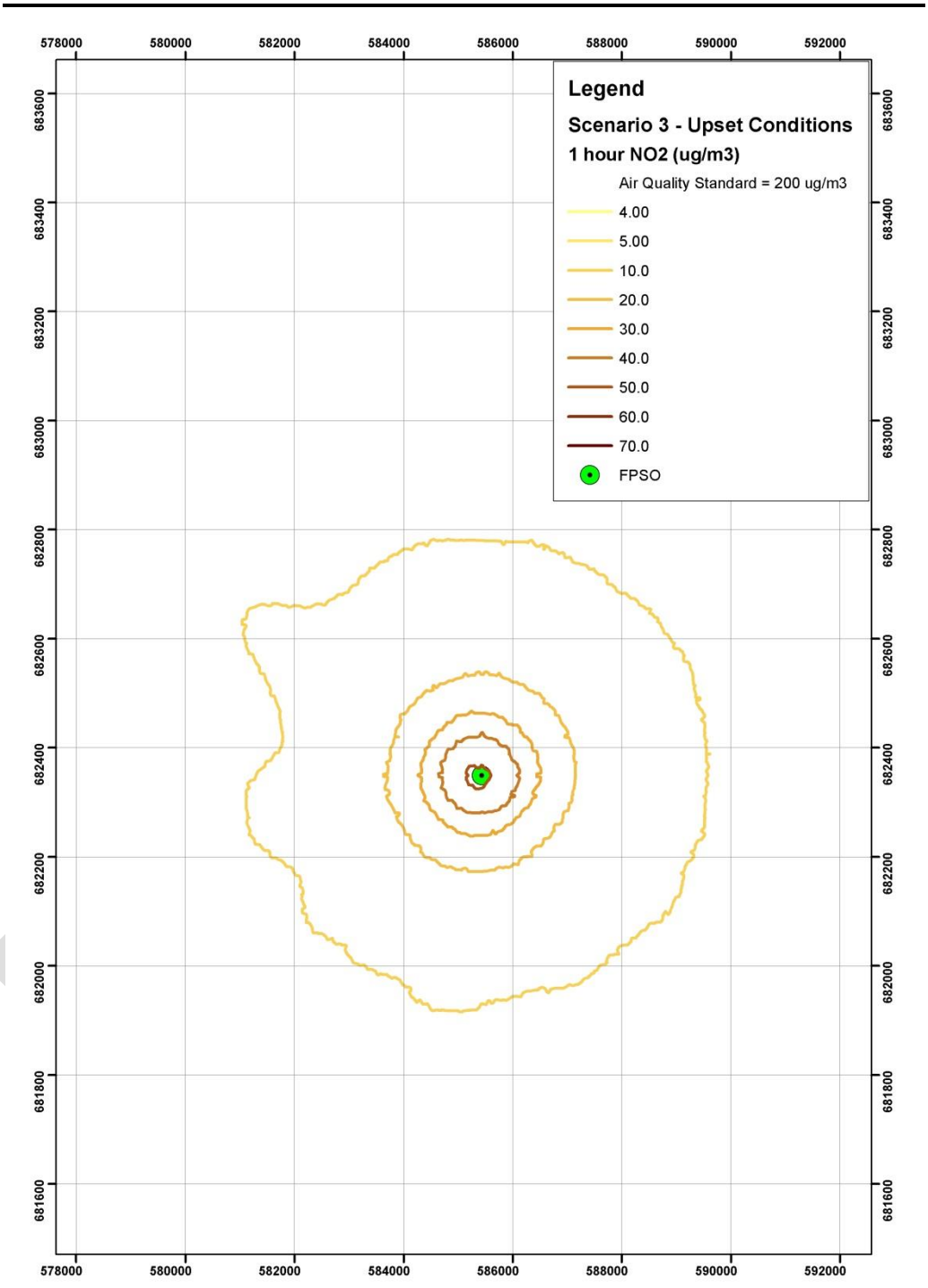

Figure 6-3 Maximum Predicted 1-hour NO_2 Concentrations - Scenario 3 - Upset Conditions

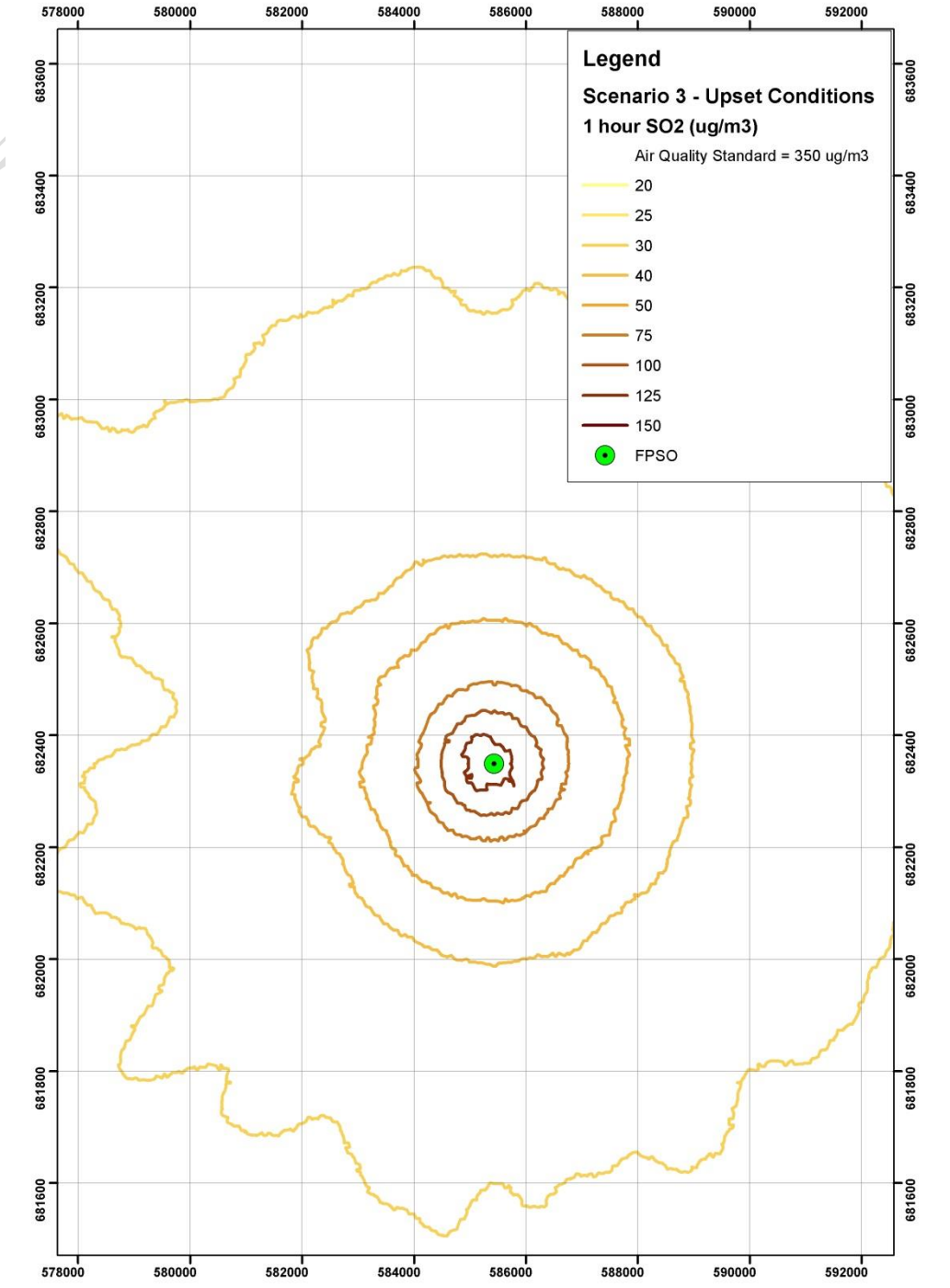

Figure 6-4 Maximum Predicted 1-hour SO_2 Concentrations - Scenario 3 - Upset Conditions

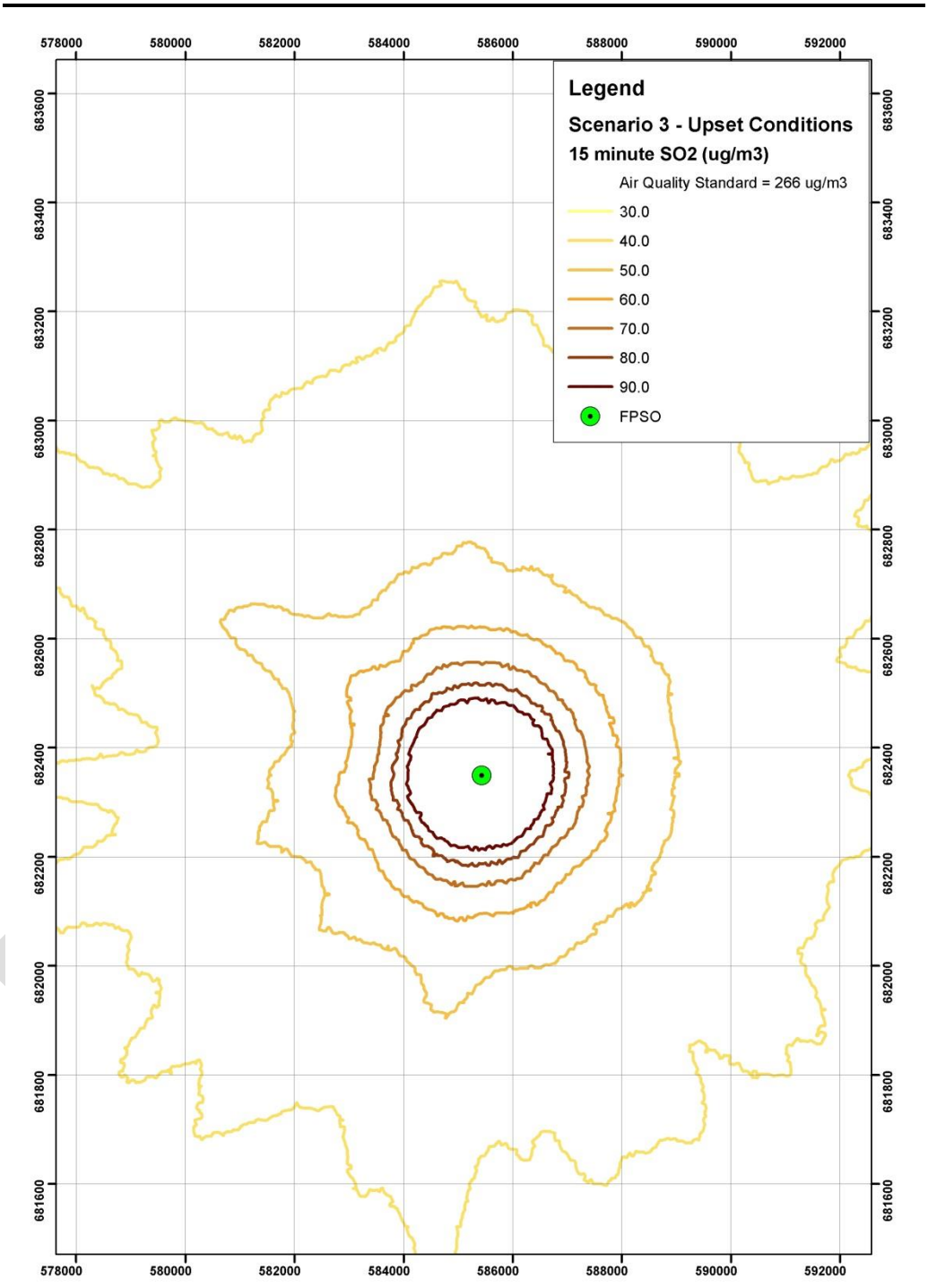

Figure 6-5 Maximum Predicted 15-minute SO_2 Concentrations - Scenario 3 - Upset Conditions

6.4. Discussion of Uncertainties

It is acknowledged that uncertainties exist within dispersion modelling, in terms of both of data input and subsequently the results output.

The following points have been discussed to acknowledge the potential effect of any modelling limitations and the effect these may have on the overall assessment conclusions.

The omission of building downwash from the modelling assessment was noted as a limitation in the study, in terms of identifying the maximum potential impact. Were the PCs for each pollutant in each scenario to be conservatively doubled (allowing for any underestimation), overall the significance of impacts for both Scenarios 1 and 2 - Normal operations on gas; and, normal operations on gas, with an emergency flaring event, respectively, would not change from those concluded in the assessment i.e. not significant impacts.

Theoretically also doubling the PCs for Scenario 3 (upset conditions) however, would result in an increased significance rating for both SO_2 averaging periods (1-hour and 15-minute), increasing impacts to moderate and major adverse, respectively. It is considered however that the likelihood of this very much worst-case upset scenario occurring is low.

The remote location of the FPSO unit also presents uncertainty with regards to understanding the existing baseline concentrations. Defra's rural site at Strathvaich in the Scottish Highlands was selected as the most representative of conditions in the North Sea. It is likely however that ambient air quality conditions at sea would be lower than even a remote onshore environment for both NO_2 and SO_2 and therefore the assessment approach is considered to be robust.

Five sequential years of meteorological data were also included in the modelling to present a robust assessment. Using the 'best-case' meteorological year, only the significance of the 1-hour NO_2 impacts is reduced from minor adverse impacts to not significant. The significance of all pollutants in all other scenarios would remain the same as reported, albeit with lesser concentrations.

With regards to potential uncertainties associated with the meteorological data used in the assessment, whilst the data used was that of prognostic MM5 data (due to the absence of a meteorological station in the remote study area), it is considered that the environment surrounding the FPSO site is relatively straightforward to simulate, and therefore the meteorological data used are likely to be representative of the site conditions.

6.5. Cumulative FPSO Greenhouse Gas Emissions

The cumulative operational combustion emissions from the FPSO have been calculated and are detailed in Table 6.4. .Comparison has been made between the total greenhouse gas (CO_2 emissions and the reported 2013 UKCS total CO_2 emissions from offshore fixed installations (ie platforms and FPSOs)[1].

The total cumulative CO_2 emissions from FPSO combustion sources are calculated to represent 0.17%, which is not considered to be significant in relation to the reported 2013 UKCS total CO_2 emissions from fixed installations.

[1]Total CO_2 2013 emissions from fixed installations (EEMS, 2014) tonnes 137,000,680

Table 6.4 Cumulative Combustion Emissions

Parameter	Unit	Value
CO_2 emissions per annum	tonnes	230,000
NO_x emissions per annum	tonnes	489
SO_2 emissions per annum	tonnes	11.6

7. CONCLUSIONS

An assessment of impacts using dispersion modelling was undertaken for the operational stages of the Project to quantify the predicted concentrations of NO_2 and SO_2. VOC emissions (such as benzene) were not included in the modelling, as the annual mean averaging period within the Air Quality Standards does not reflect the likely short-term time period when VOC emissions are likely to occur. Overall, there were no predicted exceedances of any of the relevant Air Quality Standards for the pollutants of concern, for any of the modelled scenarios at any location.

Slight adverse impacts for both 1-hour NO_2 and SO_2 concentrations, together with 15-minute SO_2 concentrations, were predicted under Scenario 3 (upset conditions) through the use of the three gas turbines generators operating on marine diesel oil, together with an emergency flaring event occurring simultaneously. However, none of the Air Quality Standards were exceeded. This scenario is considered to be highly unlikely, but was presented as a worst-case scenario in terms of the potential non-routine emissions from the FPSO unit.

The total cumulative CO_2 emissions from FPSO combustion sources are calculated to represent 0.17%, of the reported 2013 UKCS total CO_2 emissions from fixed installations, which is not considered to be significant.

On the basis of the impact assessment, mitigation measures for reducing emissions and reducing impacts are not considered necessary. However, in line with industry best practice, flaring events and the use of plant operating on diesel will be minimised, with an overall focus on energy efficiency.

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8. REFERENCES

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