12 AIR QUALITY

12.1 INTRODUCTION

An assessment has been undertaken to investigate the potential for air emissions from the construction and operation of the Queensland Curtis LNG (QCLNG) Project's proposed LNG Facility and associated infrastructure and the impact on the air quality of the Gladstone region. This assessment addresses the potential impacts from both normal and non-normal (upset) operations and includes:

- a description of plant processes associated with the generation of air emissions
- a description of normal and non-normal (upset) plant operating conditions and their relationship to the generation of air emissions
- a description of air pollutant source characteristics, concentrations and emission rates
- discussion of the local climate including the meteorological conditions important for the dispersion of air pollutants
- discussion of existing air quality including emission rates of air contaminants from background sources within the region and Department of Environment and Resource Management (DERM) monitoring data
- assessment of predicted impacts of air pollutants including Oxides of Nitrogen (NO_X) , carbon monoxide (CO) and particulate matter (PM_{10}) and hydrocarbons by comparison with air quality objectives
- discussion and assessment of the potential for the generation of photochemical smog
- assessment of vertical plume velocities associated with stack and flare emission sources during both normal and non-normal operating conditions, in relation to Civil Aviation Safety Authority (CASA) guidelines.

This chapter provides an overview of the existing air environment, assessment methodology and key findings of the air assessment, as summarised from the complete *Air Quality Impact Assessment* report included in full as *Appendix 5.13.*[1]

It should be noted that the air quality impact assessment, as summarised below and included as *Appendix 5.13,* does not address carbon dioxide (CO_2) emissions and greenhouse gas implications in detail. An assessment of greenhouse gas emissions for the LNG Facility and for the Project as a whole is provided in *Volume 7* of this EIS.

1 Katestone Environmental, 2009. *Air Quality Impact Assessment of the QCLNG Project, Gladstone, Queensland.*

12.2 DESCRIPTION OF PROJECT ENVIRONMENTAL OBJECTIVES

The Project environmental objective for air quality is: to preserve ambient air quality to the extent that ecological health, public amenity or safety is maintained.

12.3 LNG PROCESS INFRASTRUCTURE AND OPERATIONS

Project components that have the potential to affect environmental values assessed as part of the air quality study include:

- operation of the LNG Facility
- shipping activities
- construction activities including site clearing, road and LNG plant.

12.3.1 Normal and Non-Normal Operations

12.3.1.1 Normal Operations

For the purposes of the atmospheric dispersion modelling, normal operations refer to the day-to-day running of the LNG plant to produce LNG product. These production processes operate on a continual basis with static emission rates, and include emissions generated by the combustion of coal seam gas (CSG) and the processing of CSG feed gas for liquefaction. Emissions sources include:

- gas turbines to drive compressors
- gas turbines for power generation
- common hot oil and regeneration gas start up heaters
- acid gas removal unit
- nitrogen rejection unit
- dry gas flare (with lit pilot light)
- wet gas flare (with lit pilot light)
- marine flare (with lit pilot light).

Emissions from vehicles are transient, intermittent and spatially variable, and present only a very small incremental increase in the total emission of combustion-based air pollutants from the Project. Consequently, vehicle emissions from normal operations have not been included in this assessment.

12.3.1.2 *Non-normal Operations*

Non-normal operations refer to conditions at the LNG Facility that are outside the general operating parameters of the plant and occur intermittently for a short duration. Emission rates for these activities may also be variable and, consequently, do not impact air quality on a continual basis. The assessment of impacts from non-normal operations has been conducted selectively to identify worst-case conditions.

Potential emission sources include:

- dry gas flare (maintenance or upset conditions)
- wet gas flare (maintenance or upset conditions)
- marine flare (maintenance or upset conditions)
- LNG carrier exhaust emissions
- tug boat exhaust emissions
- variable emissions from normal operating equipment during start-up and shutdown
- construction activities
- vehicle emissions.

Emissions associated with the berthing, loading and unberthing of LNG carriers and the assisting tug boats are considered non-normal operations due to their discontinuous and variable operation. However, shipping activities will be undertaken during normal plant operations and consequently cumulative impacts arising from LNG shipping operations have been assessed.

Variations to source emission rates from plant processes during plant start-up and commissioning are likely to occur for a short duration and result in a ramping up of emissions. This scenario does not represent the worst-case impact and has therefore not been assessed for this study.

The generation of air emissions from construction activities will be short-term and intermittent. These emissions are generated through non-normal operations of the plant and, consequently, are discussed only in a qualitative manner. Mitigation strategies for dust management have been discussed.

12.3.2 *Process Units*

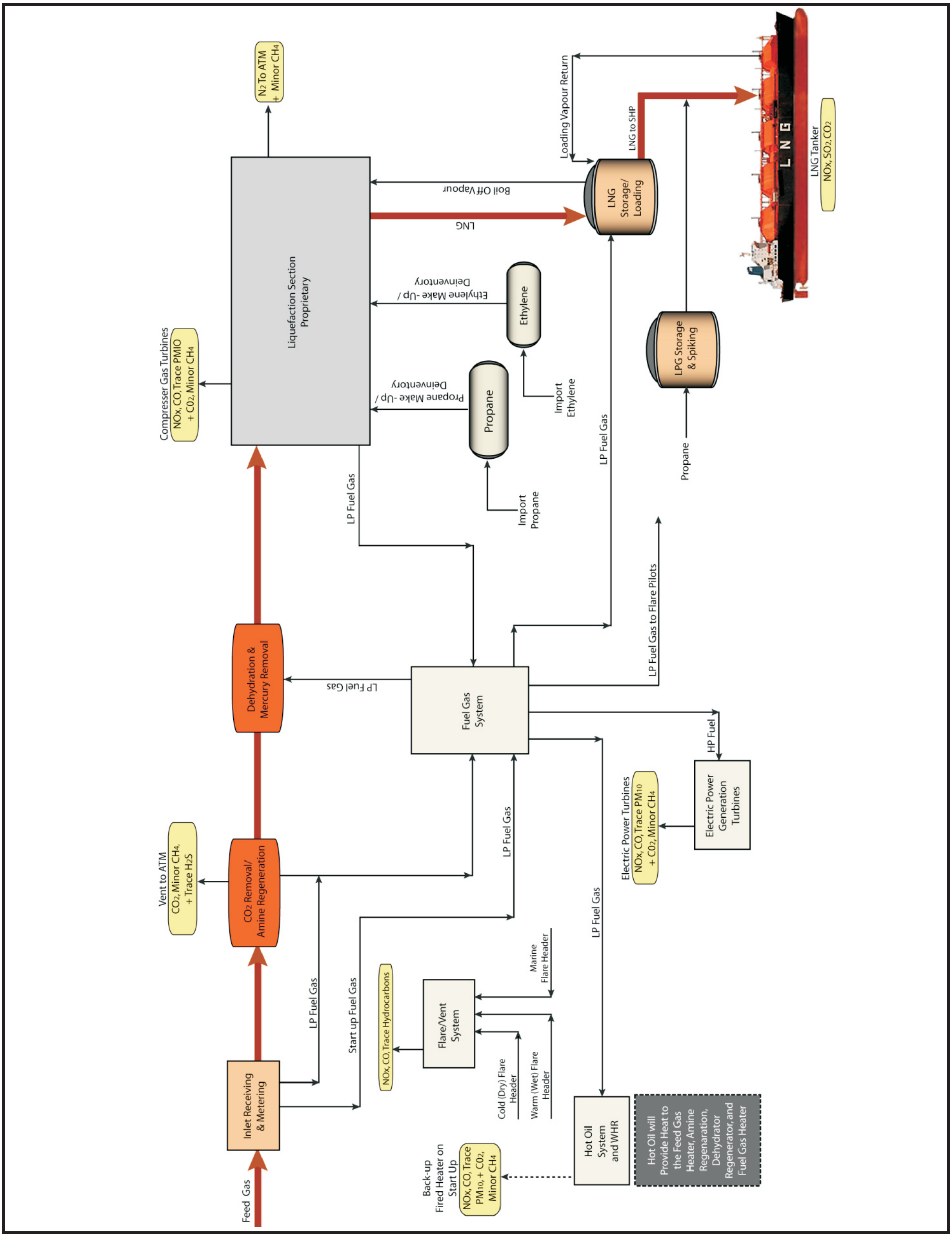
Process units associated with the production of LNG and their potential for the release of emissions to air are summarised in *Table 5.12.1*. Further description is included in *Appendix 5.13* as well as *Volume 2, Chapter 9*. A process flow diagram showing anticipated key emissions is included as *Figure 5.12.1*

Table 5.12.1 Summary of Process Units and Expected Emissions

Process Unit	Expected Emissions
Feed Gas Receiving and Metering	No emissions to air predicted during normal and non-normal operation.
Acid Gas Removal	The CSG is sweet (low sulfur) and no provisions are made for removal of significant levels of hydrogen sulfide or other sulfur components. The Acid Gas Regenerator is vented to the atmosphere without prior incineration. Emissions to air comprise primarily CO_2, with small quantities of methane (CH_4).
Dehydration and Mercury Removal	No emissions to air predicted during normal and non-normal operation, with the exception of possible flaring at start-up until the CO_2 and the water content specifications are met.
Nitrogen Removal	Nitrogen (N_2) will be rejected to meet LNG and fuel gas specifications. The nitrogen stream is vented to atmosphere. Emissions to air comprise primarily N_2, with small quantities of methane (CH_4).
Refrigeration Systems: Propane, Ethylene and Methane	No emissions to air are predicted during normal and non-normal operation other than releases from the gas turbine drivers, as described below.
Refrigeration Compressor Gas Turbine Drivers	Liquefaction system for each LNG process will utilise LM2500+G4 gas turbines to drive the compressor units. These will be arranged with: ▪ Two identical propane turbine/compressor sets in parallel ▪ Two identical ethylene turbine/compressor sets in parallel ▪ Two identical methane turbine/compressor sets in parallel Emissions to air comprise primarily NO_X, CO_2 and CO, small quantities of PM_{10} and trace quantities of hydrocarbons.

12.3.3 Support Facilities

Support facilities and their potential for the release of emissions to air are summarised in *Table 5.12.2*. They are further detailed in *Appendix 5.13* and *Volume 2, Chapter 9*.



QUEENSLAND CURTIS LNG
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Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	Volume 5	Figure 5.12.1
Approved	DS	File No: 0086165b_EIS_AQ_CDR001_F5.12.1	
Date	18/05/09	Revision 1	

Title **Process Flow Diagram with Key Emissions**

Table 5.12.2 Support Facilities

Support Facility	Expected Emissions
Dry and wet gas flare systems	Wet and Dry service flare systems support the emergency venting and flaring requirements of the process facilities: ▪ the wet gas flare system connected with the front end of the LNG train to process the blowdown of wet, heavy and warm hydrocarbon gases ▪ the dry gas flare system connected with the rear end of the LNG train to process the blowdown of dry, light and cold hydrocarbon gases. Emissions from the flares under emergency or maintenance conditions are considered to be non-normal in the context of the plant's operation and, consequently, have been assessed in isolation of the normal operating conditions at the facility. The impacts for the worst-case emergency scenario have been assessed, being blowdown of the dry gas flare. The physical arrangement of the dry and wet gas flares to treat heavy and light hydrocarbons from different process areas of the LNG trains means that blowdown is unlikely to both flares simultaneously. For the purposes of the dispersion modelling, it has been assumed that normal operations will be shutdown during gas venting to either of the flares. Emissions to air comprise primarily NO_X, CO, CO_2 and hydrocarbons. Smokeless flares will be installed resulting in near-zero particulate emissions in normal operations. On rare occasions when LPG from a vessel is flared through the marine flare smoke may occur, although this has not been modelled or assessed in detail due to the sporadic nature of this event.
Marine flare	A separate Cold Service Flare is provided to support the LNG Marine venting requirements. Boil-off gas generated on the LNG ships and during transfer will be returned to the plant for re-liquefaction via the boil-off gas compressors. Gas flaring will only be required in the event of a failure of the boil-off gas (BOG) compressors. The compressors are designed for an availability of 95 per cent. In the event of a Marine flare blowdown, ship loading can be postponed during maintenance to prevent the extended flaring of gas. Emissions to air comprise primarily NO_X, CO, CO_2, hydrocarbons and un-combustible methane. A smokeless flare will be installed resulting in near-zero particulate emissions.
Refrigerant storage	No emissions to air predicted during and non-normal operations.
Diesel Fuel	Diesel fuel will be used for emergency and critical service power generation, firewater pumping and instrument air compression. Diesel generators are primarily intended for backup and emergency use and therefore do not represent normal plant operations. No emissions to air are predicted during normal operation. Their use is anticipated to be intermittent and of limited duration, and consequently potential impacts have not been assessed. However, the generators will be run periodically for testing purposes, as required under relevant codes.
Fuel gas system	No emissions to air are predicted other than those released from combustion sources such as the gas turbines, heaters and flares during normal and non-normal operation.
LNG Storage and Loading	No emissions to air are predicted during normal operation NO_X, CO, and hydrocarbons during non-normal operation (boil-off gas flare). Some particulates may also be generated on rare

Support Facility	Expected Emissions
	occasions when LPG from a vessel is flared through the marine flare, although this has not been modeled or assessed in detail due to the sporadic nature of this event.
Propane Storage	No emissions to air predicted during normal operation. Failure of these boil-off gas compressors could result in propane vapour being flared by the plant flare system.

12.3.4 Utility Systems

Utility systems located at the LNG Facility and their associated expected emissions are summarised in *Table 5.12.3*. Refer to *Appendix 5.13* for additional detail.

Table 5.12.3 Utility Systems at the LNG plant

Utility System	Expected Emissions During Operation
Effluent Treatment	The wastewater treatment plant will be a closed tank system including an extended aeration-type activated sludge plant for treating the sanitary wastewater. The treated water will be routed to an ocean outfall. Digested sludge would be sent for disposal at an offsite landfill by a licensed contractor. There are two separate effluent treatment systems: one for oily/process waste water and the other for sanitary wastewater. Odorous air emissions generated by wastewater treatment processes will be collected and treated using an odour-control system designed to meet the requirements of the DERM Odour Guideline (2004). No emissions to air are predicted during normal and non-normal operations.
Electric Power	Power for the LNG plant is self-generated by the LM2500+G4 gas turbine generators. The main power generation units shall be centralised and common to all LNG trains. Open-cycle power generation will be used, with nominal configuration of three gas turbines including one non-running spare unit to deliver low heat rates. Turbines will be fitted with dry low NO_X burners Emissions to air comprise primarily NO_X and CO, small quantities of PM_{10} and trace quantities of hydrocarbons.
Firewater System	No emissions to air are predicted during normal operation. Use in non-normal operation is anticipated to be intermittent and of short duration and consequently impacts have not been assessed.
Hot Oil System	The hot oil system will be heated using the gas turbine waste heat recovery (WHR) units.

12.3.5 LNG Carriers and Tug Boats

LNG carriers and tug boats will be utilised for LNG transport operations. Some LNG vessels will have steam propulsion generated by liquid fuel boilers, with others based on dual-fuel diesel-electric propulsion generated from a combination of gas turbines and heavy fuel oil. Dual-fuel LNG ships tend to consume natural gas fuel under sail at sea, reverting to heavy fuel oil while berthed.

Their expected emissions are:

- LNG carriers: NO_X, sulfur dioxide (SO_2) and CO_2
- tug boats: NO_X, CO, SO_2, CO_2.

Details of proposed shipping operations are provided in *Volume 5*, *Chapter 15* and are further described in *Appendix 5.13*.

12.3.6 Construction Activities

Emissions generated during construction activities include engine exhausts from vehicles, construction equipment and diesel generators as well as dust from earthworks and vehicles movements. The composition of engine exhaust emissions is expected to be primarily NO_X and CO with small quantities of hydrocarbons.

Due to the relatively low emission rates of mobile vehicles in comparison to the LNG plant gas turbines, the short duration and transient nature of these emissions during construction in such an isolated area on Curtis Island is considered to be negligible. As a result, these emissions were not considered in the air assessment. It is not expected that gaseous emissions to the air during the construction phase will exceed those from the normal conditions of the full-scale operating three-train LNG Facility.

Control strategies to minimise the impacts from construction activities such as the generation of dust from vehicle movements and earthworks will be discussed as part of the Environmental Management Plan (EMP).

12.3.7 LNG Plant Production Efficiency

For the purposes of the air quality assessment, the QCLNG Project (including upstream gathering, the Pipeline and the LNG Facility) is assumed to operate with an availability of 93 per cent. Availability is a measure of efficiency and relates to the percentage of LNG production per annum, allowing for planned and unplanned shutdowns.

12.3.8 Feed Gas Composition

The CSG feed gas to the LNG Facility primarily comprises methane (CH_4), small quantities of nitrogen (N_2), carbon dioxide (CO_2) and ethane (C_2H_6), and trace quantities of other hydrocarbons.

Table 5.12.4 presents the composition of CSG extracted from the resource and as received at the LNG plant. The CSG does not comprise any sulfur compounds. The CO_2 content is likely to start at approximately 0.16 mol per cent and increase during the field life. Conservatively, the LNG plant has been designed for a 1.0 mol per cent peak.

Table 5.12.4 Composition of coal seam methane gas delivered to the LNG Facility (Major Components

Compound	Gas composition delivered to the LNG Facility (mole %)
Methane	97.80
Nitrogen	2.00
Ethane	0.02
Carbon Dioxide	0.16

12.4 EXISTING AIR ENVIRONMENT

The existing environment in the region surrounding the proposed LNG Facility area is discussed in terms of the background air quality and the geographical and meteorological conditions that are likely to influence the dispersion of air pollutants released by operations.

12.4.1 Background to the Gladstone Region

The coastal town of Gladstone is situated in a sub-tropical region comprising a flat coastal plain bordered by a range of mountains up to 600 m in elevation, typically 5 to 10 km from the coast but with a major off-shore island, Curtis Island, in the northern part.

The area for the proposed LNG Facility on Curtis Island and associated mainland facilities is a mixture of undeveloped rural land, native bushland and forest. The terrain is flat coastal plain, floodplain and mangrove with mildly undulating hills, with the exception of Mt Larcom. The relatively flat terrain and coastline location of the proposed LNG Facility and associated mainland facilities will influence the wind patterns observed on-site. Dominant meteorological conditions include sea and land breezes.

12.4.1.1 Surrounding Land Uses

The nearest industries to the proposed LNG Facility are Cement Australia and Queensland Energy Resources, on either side of Landing Road at Fisherman’s Landing adjacent to the wharf facilities. Further significant industries within the local area include Rio Tinto Aluminum (7 kilometres to the south-west), Orica (7.3 kilometres to the south-southwest) and the NRG Gladstone Power Station (9.3 kilometres to the south-southeast).

The LNG Facility will be situated approximately 4 km from the nearest single residence on islands in Port Curtis, 7.5 km from major residential areas in Gladstone City across Port Curtis and 9 km from the community at South End on Curtis Island. The location of residences in the region of the proposed LNG Facility that are considered and discussed in this assessment are shown in

Figure 5.12.2, with residences designated as a point labelled R#. It should be noted that residence ***R10*** is a vacated dwelling within the bounds of the Gladstone State Development Area (GSDA). While this dwelling is discussed as part of the air quality assessment, it is not a current or likely future residential dwelling for the life of the QCLNG Project.

12.4.2 Existing Industries in the Gladstone Region

The following industries are operating in the Gladstone regional airshed:

- a 1650 MW coal-fired power station
- two large alumina refineries
- an aluminium smelter
- an ammonium nitrate facility
- coal handling and port facilities
- a cement manufacturing facility.

Emissions from industry include NO_X, CO, PM_{10}, SO_2 and various hydrocarbons. Further sources of NO_X and SO_2 include vehicle traffic and shipping, while general sources of dust include bushfires, landfills, trains, exposed areas of land, construction activities and traffic. A summary of the currently operating industries reporting to the National Pollutant Inventory (NPI) is presented in *Table 5.12.5*, with their locations shown in *Figure 5.12.2.*

12.4.3 Other Proposed LNG Projects in the Gladstone Region

There are currently four proposed LNG projects in the planning stages for the Gladstone region. Two facilities, operated by Sunshine Gas (SUN LNG) and Gladstone LNG Pty Ltd (Gladstone LNG), are proposed for the reclaimed Fisherman's Landing site, while the QCLNG Project and the Santos LNG project are proposed for Curtis Island adjacent to the Fisherman's Landing area.

To assess the capacity of the Gladstone airshed for impacts of NO_2 from proposed LNG facilities, an assessment of the potential emissions from the SUN LNG, Gladstone LNG and Santos LNG projects was conducted. To achieve this, NO_X emissions from the primary NO_X source (the gas turbines and compressors) for each of these projects were scaled from the QCLNG NO_X emissions on the basis of published plant production capacity. *Table* 5.12.6 presents the assumed emission characteristics for each of the other three proposed LNG facilities. Indicative locations of these projects are shown in *Figure 5.12.2.*

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

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QUEENSLAND CURTIS LNG A BG Group business	Project Queensland Curtis LNG Project		Title **The Location of the Proposed QCLNG Project on Curtis Island and other existing, approved and proposed industries**
	Client QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	Volume 5 Figure 5.12.2	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR002_F5.12.2	
	Date 27/05/09	Revision 0	

Table 5.12.5 Existing Industries in the Gladstone Region for the 2006 to 2007 NPI Reporting Period.

Source	Oxides of nitrogen (kg/yr)	Carbon monoxide (kg/yr)	PM_{10} (kg/yr)	Total VOCs (kg/yr)	Sulfur Dioxide (kg/yr)
NRG Gladstone Operating Services (Gladstone Power Station)	45,000,000	1,200,000	870,000	130,000	31,000,000
Queensland Alumina Ltd (QAL) (alumina refinery)	8,800,000	1,400,000	530,000	85,000	3,800,000
Rio Tinto Aluminium Ltd, Yarwun (alumina refinery)	700,000	67,000	100,000	180,000	680,000
Boyne Smelters Ltd (aluminium smelter)	120,000	67,000,000	290,000	110,000	13,000,000
Cement Australia (Queensland) Pty Ltd, Gladstone	3,900,000	780,000	32,000	2,000	90,000
Orica Australia Pty Ltd, Yarwun (ammonium nitrate facility)	230,000	11,000	930	970	250
Austicks Pty Ltd	4,600	21,000	10,000	340	120
Callemondah Rail Yard	18,000	14,000	340	2,600	130
Queensland Energy Resources Limited (Stuart Oil Shale Facility)	Facility not operating during 2006-2007 period				

Table 5.12.6 Summary of emission characteristics for other LNG projects based on QCLNG emissions

Characteristics	Units	Santos LNG	Gladstone LNG	SUN LNG
Number of gas turbine and compressor stacks modelled	--	1 [2]	1 [2]	1 [2]
Base elevation	m	20	5	5
Stack height	m	28.3	28.3	28.3
Stack diameter	m	3	3	3
Exhaust temperature	K	607	607	607
Exit velocity	m/s	31	31	31
Total production capacity	Mtpa	10	3.2	1
Total NO_X from plant	g/s	52.83	16.90	5.28

[1] Gas turbine and compressor stack emission characteristics are shown for QCLNG.

[2] A single source was modelled for each of the other three LNG facilities.

12.4.4 Climate

Refer to *Volume 5, Chapter 2* for a general discussion on climate in the Gladstone region. The full air quality impact assessment report is included as *Appendix 5.13* with descriptions of specific parameters used in modelling.

12.4.5 Existing Air Environment – Summary of Results

The Gladstone region is highly industrialised and consequently the DERM operates a network of ambient air quality monitoring stations in the city and surrounding areas.

Table 5.12.7 summarises DERM monitoring stations, approximate distance from the proposed QCLNG Facility, pollutants measured and the recording period. The locations of these DERM monitoring stations are presented in *Figure 5.12.3*.

Table 5.12.7 DERM Monitoring Sites for Gladstone

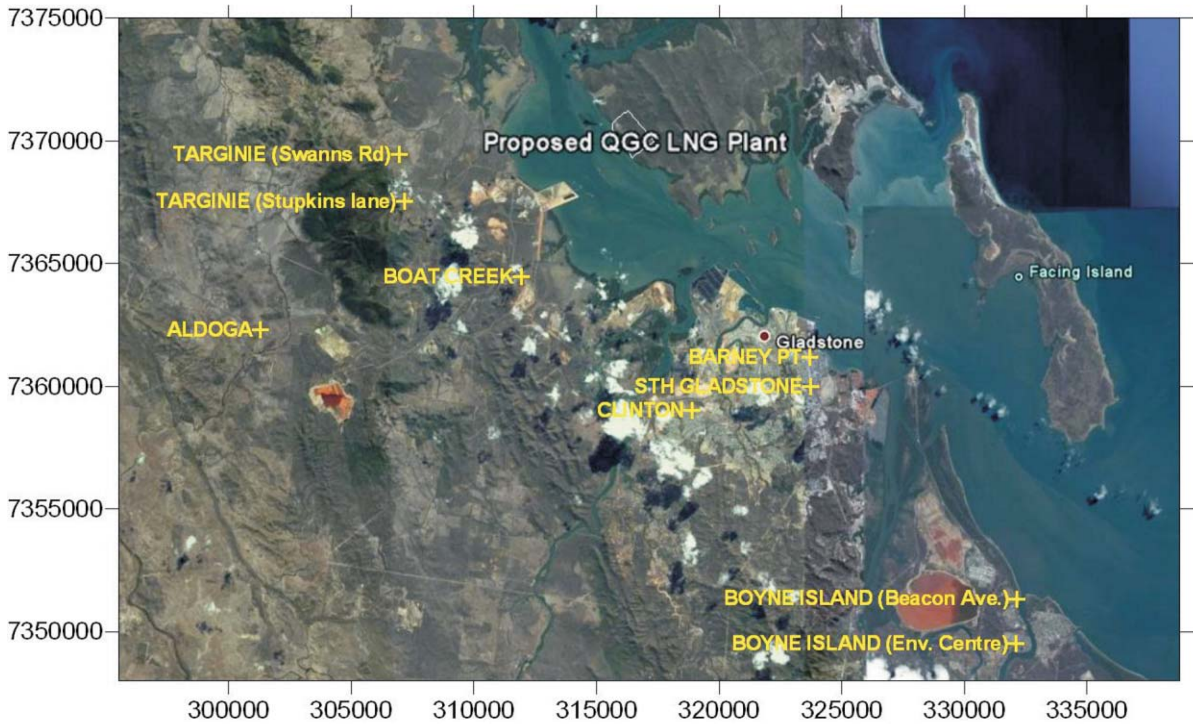
Site	Distance to Project site (km)	Record Period	Nitrogen dioxide	PM10	Sulfur dioxide	Carbon monoxide
Aldoga	17	2002 – present	No	No	No	No
Boat Creek	7	2008 – present	Yes	Yes	Yes	No
Clinton	11	2001 – present	Yes	Yes	Yes	No

Site	Distance to Project site (km)	Record Period	Nitrogen dioxide	PM10	Sulfur dioxide	Carbon monoxide
South Gladstone	12	2001 – present	Yes	Yes	Yes	No
Targinie (Stupkin Lane)	9	2001 – 2008	Yes	Yes	Yes	No
Targinie (Swans Road)	9	1997 – present	Yes	No	Yes	No
Boyne Island (Environment Centre)	25	2008 – present	Yes	No	Yes	No
Boyne Island (Beacon Ave)	24	2008 – present	Yes	No	Yes	Yes
Barney Point	11	1997 – 2003	Yes	No	Yes	No

The closest DERM monitoring stations to the proposed LNG Facility site are at Boat Creek and Targinie. The Swans Road station at Targinie has been operating since 1997 and monitors NO_2 and SO_2. The Stupkin Lane station at Targinie was operational between 2001 and 2008 and monitored NO_2 (until May 2006), PM_{10} (until June 2008) and SO_2 (until May 2006). The Targinie sites have been used to describe the background concentrations of NO_2, PM_{10} and SO_2 at the proposed QCLNG site.

12.4.5.1 *Nitrogen Dioxide*

The EPP (Air) air quality objective of 250 μg/m^3 for the 1-hour average concentrations was not exceeded at either of the Targinie monitoring stations for the years for which NO_2 data is available. Additionally, there were no exceedences of the EPP (Air) objective of 62 μg/m^3 for annual average concentrations of NO_2. The maximum 1-hour average and annual average results are shown in *Table 5.12.8*.



Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

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QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project	Title: **Location of DERM Ambient Air Quality Monitoring Stations in Gladstone Region**
	Client	QGC - A BG Group business	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**Volume 5** **Figure 5.12.3**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR003_F5.12.3	
	Date 10/06/09	Revision 0	

Table 5.12.8 Maximum 1-Hour Average And Annual Average Concentration Of Nitrogen Dioxide (µg/M³)

Year	Maximum 1-hour average		Annual average	
	Targinie (Stupkin Lane)	Targinie (Swans Road)	Targinie (Stupkin Lane)	Targinie (Swans Road)
1997	-	78.1	-	4.1
1998	-	90.4	-	6.2
1999	-	86.3	-	8.2
2000	-	78.1	-	6.2
2001	96.5	78.1	10.3	6.2
2002	98.6	80.1	16.4	6.2
2003	84.2	71.9	8.2	6.2
2004	90.4	61.6	8.2	6.2
2005	96.5	80.1	8.2	6.2
2006	-	84.2	-	8.2
2007	-	73.9	-	6.2
2008	-	65.7	-	6.4

EPP (Air) objective for 1-hour average: 250 µg/m³
EPP (Air) objective for annual average: 62 µg/m³

12.4.5.2 Carbon Monoxide

A monitoring station at Beacon Avenue, Boyne Island, has been recording carbon monoxide levels in the Gladstone region since October 1, 2008. The following 1-hour average CO concentrations were recorded:

- Minimum: 0.00 µg/m³
- Average: 60.7 µg/m³
- Maximum: 624.6 µg/m³

The maximum 8-hour average CO concentration during the monitoring period was 312.3 µg/m³, well below the EPP (Air) goal of 11,000 µg/m³. It should be noted that the QGC air standard for CO is 10,000 µg/m³

This monitoring station is predominantly upwind of the industrial activity in the Gladstone region and is therefore not representative of a background CO level for the location of the proposed LNG Facility on Curtis Island.

12.4.5.3 PM_{10}

The EPP (Air) objective for the 24-hour average concentrations of PM_{10} of 50 g/m³ was exceeded at Stupkin Lane monitoring station on 23 occasions between 2001 and 2008 during the following periods:

- October – November 2001
- July, October and December 2002
- December 2004

- January – February 2005
- November 2006
- March and April 2008.

Table 5.12.9 presents the maximum 24-hour average concentrations of PM_{10} from measurements at the Targinie Stupkin Lane monitoring station.

Table 5.12.9 Maximum and 95th Percentile 24-hour Average Concentrations of PM_{10} (µg/m^3) Measured at the Targinie Stupkin Lane Monitoring Site

Year	Maximum 24-hour average	95th percentile 24-hour average
2001	93	31
2002	204	39
2003	50	31
2004	50	30
2005	222	26
2006	79	25
2007	36	22
2008	62	25
EPP (Air) air quality objective	50[1]	--

[1] Five days of exceedences allowed per year

The uncharacteristically high events during 2002 were attributed to bushfires while those during 2005 were attributed to dust storms that occurred for 2-3 days over a significant portion of Queensland.

12.4.5.4 Sulfur Dioxide

The maximum 1-hour average and annual average concentrations for SO_2 at the Targinie Stupkin Lane and Swans Road monitoring stations are presented in *Table 5.12.10*.

The EPP (Air) goal of 570 µg/m^3 for the 1-hour concentration has not been exceeded at either of the Targinie monitoring stations for the years for which SO_2 data is available. Additionally, there were no exceedences of the 24-hour average SO_2 concentration EPP (Air) goal of 230 µg/m^3 or the annual average EPP (Air) goal of 57 µg/m^3.

Table 5.12.10 Summary of Annual Measurements of Sulfur Dioxide from the DERM Targinie Monitoring Sites (µg/m^3)

Year	Maximum 1-hour average		Maximum 24-hour average		Annual Average	
	Targinie (Stupkin Lane)	Targinie (Swans Road)	Targinie (Stupkin Lane)	Targinie (Swans Road)	Targinie (Stupkin Lane)	Targinie (Swans Road)
1997	-	118.7	-	51.2	-	10.3
1998	-	92.9	-	24.7	-	4.8
1999	-	118.7	-	21.7	-	6.0
2000	-	143.0	-	23.0	-	4.7
2001	19.5	266.0	2.4	25.4	0.6	3.7
2002	201.6	147.3	33.5	32.8	6.3	5.9
2003	235.9	291.7	44.9	48.0	6.7	6.3
2004	316.0	348.9	34.3	23.9	6.8	4.6
2005	147.3	121.5	36.2	32.6	6.7	4.4
2006	150.1	130.1	35.7	31.4	9.1	6.2
2007	-	204.5	-	24.3	-	4.7
2008	-	138.7	-	20.5	-	3.5
EPP (Air) objective	570		230		57	

12.5 AIR QUALITY CRITERIA

12.5.1 Queensland Environmental Protection Policies

The *Environmental Protection Act 1994* (EP Act) provides for the management of the air environment in Queensland. The legislation applies to government, industry and individuals and provides a mechanism for the delegation of responsibility to other government departments and local government and provides all government departments with a mechanism to incorporate environmental factors into decision-making.

The object of the *EP Act* is summarised as follows:

> *The object of the Environmental Protection Act 1994 is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends. (EPP (Air) Explanatory notes, General outline).*

The *EP Act* gives the Environment Minister the power to create Environmental Protection Policies (EPPs) that aim to protect the environmental values identified for Queensland. In accordance with the *EP Act*, the Environmental Protection (Air) Policy is to be reviewed every 10 years, with the initial EPP (Air) having been gazetted in 1997. Consequently, the revised EPP (Air) 2008 commenced on January 1, 2009.

The objective of the EPP (Air) 2008 is summarised as follows:

> *The objective of the Environmental Protection (Air) Policy 2008 is to identify the environmental values of the air environment to be enhanced or protected and to achieve the object of the Environmental Protection Act 1994, i.e. ecologically sustainable development.*

The application and purpose of the EPP (Air) 2008 is summarised as follows:

> *The purpose of the EPP (Air) is to achieve the object of the Act in relation to the air environment (EPP (Air) Part 2, Section 5).*
>
> *The purpose of this policy is achieved by:-*
>
> *a) Identifying environmental values to be enhanced or protected*
> *b) Stating indicators and air quality objectives for enhancing or protecting the environmental values*
> *c) providing a framework for making consistent, equitable and informed decisions about the air environment (EPP (Air) Part 2, Section 6).*
>
> *The environmental values to be enhanced or protected under the EPP (Air) are:*
>
> *a) the qualities of the air environment that are conducive to protecting the health and biodiversity of ecosystems*
> *b) the qualities of the air environment that are conducive to human health and wellbeing*
> *c) the qualities of the air environment that are conducive to protecting the aesthetics of the environment, including the appearance of buildings structures and other property*
> *d) the qualities of the air environment that are conducive to protecting agricultural use of the environment.*

The administering authority must consider the requirements of the EPP (Air) when it decides an application for an environmental authority, amendment of a licence or approval of a draft Environmental Management Plan. Schedule 1 of the EPP (Air) specifies air quality objectives for various averaging periods.

12.5.2 National Environment Protection Measure

The National Environment Protection Council defines national ambient air quality standards and goals in consultation – and agreement – with all State governments. These were first published in 1998 in the National Environment Protection (Ambient Air Quality) Measure (NEPM (Air)). Compliance with the NEPM (Air) standards are assessed via ambient air quality monitoring undertaken at locations prescribed by the NEPM (Air) and that are representative of large urban populations. The goal of the NEPM (Air) is for the ambient air quality standards to be achieved at these monitoring stations within 10 years of commencement (i.e. in 2008). The EPP (Air) 2008 has adopted the NEPM (Air) goals as air quality objectives.

12.5.3 Relevant Air Quality Goals for the Project

Table 5.12.11 presents a summary of the relevant ambient air quality goals for criteria pollutants adopted for the air assessment.

Table 5.12.11 Relevant Ambient Air quality Objectives for Criteria Air Pollutants (EPP (Air) 2008)

Indicator	Environmental value	Averaging period	Air quality objective[1] (µg/m³)	Number of days of exceedence allowed per year
Nitrogen dioxide	Health and wellbeing	1-hour	250	1
		1-year	62	N/A
	Health and biodiversity of ecosystems	1-year	33	N/A
CO	Health and wellbeing	8-hour	11,000	1
Particles as PM_{10}	Health and wellbeing	24-hour	50	5
Ozone	Health and wellbeing	1-hour	210	1
		4-hour	160	1
Sulfur dioxide	Health and wellbeing	1-hour	570	1
		24-hour	230	1
		1-year	57	N/A
	Protecting agriculture	1-year	32	N/A
	Health and biodiversity of ecosystems (for forests and natural vegetation	1-year	22	N/A

[1] Air quality objective at $0^{o}C$

N/A: Not applicable

In addition to the air pollutants detailed above, the combustion of coal seam gas in the gas turbines, gas-fired boilers and flares may also produce small quantities of hydrocarbons. For air quality assessments, it is common practice to consider, and where appropriate adopt, an air quality objective for a specific substance from another jurisdiction if information is not available in the EPP (Air). As a result, air quality objectives from the following guidelines and standards have been adopted where the EPP (Air) does not provide any assessment criteria for the hydrocarbons identified in this study:

- NSW Department of Environment and Climate Change (NSW DECC)

Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (2005)

- DERM Victoria (Vic SEPP) State Environment Protection Policy (Air Quality Management)
- World Health Organisation (WHO) Guidelines for Air Quality (*Chapter 3*) 2000
- National Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC:1003(1995))
- Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels 2008

Refer to *Table 39* in the Air Quality Impact Assessment Report appended as *Appendix 5.13* for a complete listing of relevant ambient air quality objectives and standards adopted for hydrocarbons.

12.6 ATMOSPHERIC DISPERSION MODELLING METHODOLOGY

Air-dispersion modelling was conducted using a two-stage approach.

1. The CSIRO's meteorological model, TAPM (The Air Pollution Model) Version 3.0.7 (Hurley 2005), was used to simulate the regional meteorology in the Gladstone region. Further refinement of the wind field was then made through the CALMET Version 6.3 meteorological pre-processor.

2. The CALPUFF plume dispersion model was used to predict ground-level concentrations of air pollutants emitted from the QCLNG facility at Curtis Island. CALPUFF is a non-steady-state puff dispersion model, and is accepted for use by the DERM for application in environments where wind patterns and plume dispersion is strongly influenced by complex terrain and the land-sea interface.

For the assessment of impacts to air quality associated with NO_X emissions, a further two-level approach was adopted to predict the cumulative effect of emissions from the QCLNG facility and existing, approved and other potential industrial developments in the Gladstone region.

This assessment utilised the Gladstone Airshed Modelling System Version 3 (GAMSv3), a regional airshed dispersion modelling tool developed by Katestone Environmental for the Department of Infrastructure and Planning (DIP) for use in planning studies, to predict background levels for NO_X (and SO_2), and a fine resolution micro-scale dispersion model to predict impacts from the QCLNG facility. The approach provided for the accumulation of predicted gridded impacts on an hourly basis.

For the assessment of impacts associated with SO_2 emissions, the GAMSv3 has been used as a background to assess the impacts associated with the LNG carriers. For CO, PM_{10} and hydrocarbons, the fine resolution micro-scale dispersion model was used to predict ground-level concentrations, as these air pollutants are not included in the GAMSv3 emissions inventory. Background concentrations for CO and PM_{10} were based on DERM monitoring data in the region. No background concentrations were assumed for the assessment of hydrocarbons.

Refer to *Section 6.1* of the Air Quality Impact Assessment Report, appended as *Appendix 5.13*, for additional detail on these modelling methodologies, model configurations and specific meteorology simulations.

12.6.1 Analysis of Dispersion Meteorology

12.6.1.1 Wind Speed and Direction

Curtis Island is a low-lying barrier island dominated by coastal meteorology. Winds on the east coast of the island can be expected to be significantly stronger than those on the sheltered west coast. The small north-south ridge bisecting the island can generate light drainage winds at night under stable conditions. Terrain features can have an important influence on the dispersion of air pollutants and, as such, have been incorporated into the modelling.

The island is dominated primarily by winds from the east-to-southeast, with maximum sustained speed of 9 m/s. The seasonal distribution of winds is influenced by monsoonal and precipitation patterns. The diurnal wind pattern is dominated by the south-east trade winds, which usually begin to intensify by 9 am as a south-easterly flow and gradually rotate counter-clockwise to a north-easterly flow by mid-afternoon. Night-time flows predominantly consist of very light westerly drainage flows from the surrounding terrain and ever-present trade winds.

12.6.1.2 Atmospheric Stability and Mixing Height

Atmospheric stability refers to the vertical movement of the atmosphere and is therefore an important factor in the dispersion and transport of pollutants. Atmospheric stability is typically classified under the Pasquill-Gifford scheme and ranges from Class A, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to Class F, which represents very stable atmospheric conditions that typically occur during light wind conditions at night.

Table 5.12.12 shows the percentage distribution of stability classes for Curtis Island. There is a high percentage of D class stability (53 per cent), indicative of coastal sites. This is due to the high heat capacity of water dampening the development of a strong convective boundary layer. The water has a similar effect at night, where the warmth of the water prevents the development of any strong temperature inversions.

Table 5.12.12 Percentage Frequency Distribution For Atmospheric Stability Under The Pasquill-Gifford Stability Classification Scheme For The Project Area

Pasquill-Gifford Stability Class	Frequency (%)
A - Extremely unstable	2
B – Unstable	13
C - Slightly unstable	18
D – Neutral	53
E - Slightly stable	7
F – Stable	7

All stack emission points at the proposed LNG Facility are relatively tall and hot with a high vertical velocity, giving the plume enough thermal and mechanical buoyancy at the release point to generate sufficient momentum for it to penetrate any low night-time inversions, resulting in good dispersion conditions. These source characteristics also reduce the potential for building wake turbulence to affect plume dispersion.

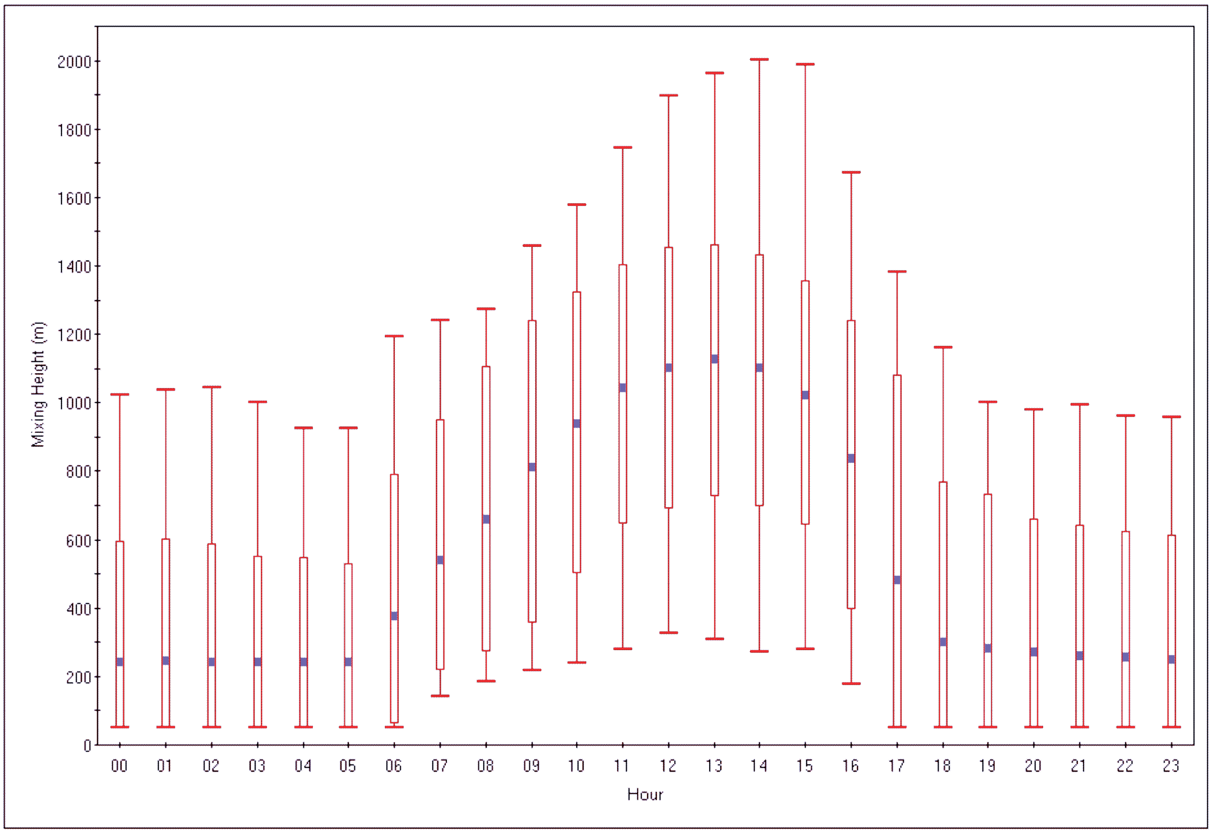
Mixing height refers to the height above ground within which the plume from the stack emission point can mix with the ambient air. During stable atmospheric conditions at night, the mixing height is often quite low. During the day, solar radiation heats the air at ground level and causes the mixing height to rise through the growth of convection cells. During strong wind speed conditions, the air will be well mixed, resulting in a high mixing height.

Figure 5.12.4 shows the profile for mixing height at Curtis Island extracted from the atmospheric dispersion model used. This shows that the mixing height tends to develop around 6-7am and peaks around 1-2pm before decreasing gradually around sunset (5-6pm).

Refer to the full Air Quality Impact Report appended in *Appendix 5.13* for more detailed discussion on the dispersion meteorology.

12.7 AIR QUALITY IMPACT ASSESSMENT SCENARIOS

An outline of modelling scenarios is provided below. For each of the scenarios, 24-hour/year-round facility operations were assumed. While this is a reasonable assumption, under normal conditions this is likely to overestimate impacts during non-normal and upset conditions, particularly when the flare is operating.



Legend

Whisker: Low=Min, High=Max; Box: Low=50%, High=95%

Middle: Mean

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**	Title **Daily Profile for mixing heights**
	Client **QGC - A BG Group business**	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB / Approved DS / Date 10/06/09	**Volume 5** **Figure 5.12.4** / File No: 0086165b_EIS_AQ_CDR004_F5.12.4 / Revision 0

12.7.1 *Modelling Scenarios – Normal Operations*

The modelling scenarios undertaken for the assessment of air quality impacts associated with emissions to air from the proposed LNG Facility during normal operations are summarised in *Table 5.12.13*.

Table 5.12.13 Modelling Scenario 1 – Normal Operations

Source unit	No. of units	Oxides of nitrogen	Carbon monoxide	PM10	Hydrocarbons
Train 1					
LM2500+G4 gas turbines for compressor drivers	6	Yes	Yes	Yes	Yes
LM2500+G4 gas turbines for power generation	1	Yes	Yes	Yes	Yes
Regeneration gas heater	1	Yes	Yes	Yes	Yes
Hot oil heater	2	Yes	Yes	Yes	Yes
Dry gas flare (pilot)	1	Yes	Yes	Yes	No
Wet gas flare (pilot)	1	Yes	Yes	Yes	No
Marine flare (pilot)	1	Yes	Yes	Yes	No
Train 2					
LM2500+G4 gas turbines for compressor drivers	6	Yes	Yes	Yes	Yes
LM2500+G4 gas turbines for power generation	1	Yes	Yes	Yes	Yes
Regeneration gas heater	1	Yes	Yes	Yes	Yes
Hot oil heater	2	Yes	Yes	Yes	Yes
Train 3					
LM2500+G4 gas turbines for compressor drivers	6	Yes	Yes	Yes	Yes
LM2500+G4 gas turbines for power generation	1	Yes	Yes	Yes	Yes
Regeneration gas heater	1	Yes	Yes	Yes	Yes
Hot oil heater	2	Yes	Yes	Yes	Yes
Dry gas flare (pilot)	1	Yes	Yes	Yes	No
Wet gas flare (pilot)	1	Yes	Yes	Yes	No

12.7.1.1 *Sensitivity Analysis for the Gas Turbines with Waste Heat Recovery Option*

A sensitivity analysis was conducted to determine whether there was a significant difference in predicted impacts of NO_2 due to the changed source characteristics as a result of the inclusion of a waste heat recovery (WHR) system on two out of six compressor driver gas turbines on each LNG train. This assessment included the dispersion modelling of NO_X emissions, as described for Scenario 1 (and presented in *Table 5.12.13*).

12.7.2 Modelling Scenarios – Non-normal Operations

As discussed previously, non-normal operations refer to non-continuous plant conditions that may occur due to upset or emergency, or operations relating to shipping and loading of LNG product onto ships. Consequently, these operations involve (potentially) flare and ship emissions. Notwithstanding this, the dispersion modelling for the short-term non-normal operations has been conducted for each hour of the year and 1-hour average ground-level concentrations have been assessed. This approach provides a conservative, worst-case assessment of impacts to air quality, as upset flare events are likely to be of less than one hour duration and occur only once a year.

Shipping emissions are based on the following assumptions:

- ships berthed at the wharf for less than 50 per cent of the year, with approximately 180 ship port calls proposed per year (for three operating LNG trains), at an average berthing duration of 24 hours
- for 16 hours of a 24-hour port call, Heavy Fuel Oil (HFO) is combusted in the LNG carrier's engines, while during the remaining eight hours, and while under sail, ships consume Natural Gas (NG) fuel. However, it should be noted that dual-fuel diesel engine ships will switch to ultra-low sulphur fuel while in port, although this has not been incorporated into the assessment
- estimated transit time between the proposed LNG wharf and the pilot station is approximately three hours. Consequently, the transfer of ships, under the assistance of two tug boats, from the pilot station to the wharf has not been assessed. The assessment of shipping emissions associated with an LNG carrier and tug boat at the wharf during each hour of the year, with the LNG carrier consuming primarily HFO, is considered to be a conservative estimate of the emissions from shipping activities.

The modelling scenarios investigated for the assessment of air quality impacts associated with emissions from the proposed LNG Facility during non-normal operations are summarised in *Table 5.12.14*, *Table 5.12.15* and *Table 5.12.6.*

Emissions from the dry gas flare under upset conditions represent the worst-case scenario, and consequently only an assessment of the dry gas flare has been made. It has been assumed that only one of the dry gas flares will operate at a time due to the configuration of the LNG trains.

A marine flare upset release event will only occur during loading of an LNG carrier. This has been predicted to occur at a frequency of 108 hours per year.

Table 5.12.14 Modelling Scenario 2 – Normal plant operations plus LNG carrier at wharf

Source unit	No. of units	Oxides of nitrogen	Carbon monoxide	PM_{10}	Hydrocarbons	Sulfur dioxide
Trains 1 – 3						
Scenario 1	--	Yes	Yes	Yes	Yes[1]	No
Shipping						
LNG Carrier at wharf	1	Yes	No	No	No	Yes
Tug boat on standby	1	Yes	No	No	No	Yes

[1] Hydrocarbons associated with flare pilot emissions not assessed

Table 5.12.15 Modelling Scenario 3 – Non-normal plant operations with dry gas flare upset conditions

Source unit	No. of units	Oxides of nitrogen	Carbon monoxide	PM_{10}	Hydrocarbons
Train 1					
Dry gas flare (upset)	1	Yes	Yes	No[1]	Yes

[1] No PM_{10} emissions due to smokeless flare

Note: during emergency release from the flares all normal emissions from the plant are assumed to cease.

Table 5.12.16 Modelling Scenario 4 – Non-normal plant operations with marine flare upset conditions

Source unit	No. of units	Oxides of nitrogen	Carbon monoxide	PM_{10}	Hydrocarbon s	Sulfur dioxide
Trains 1 - 3						
Scenario 1	--	Yes	Yes	Yes	Yes[1]	No
Train 1						
Marine flare (upset)	1	Yes	Yes	Yes	Yes	No
Shipping						
LNG carrier at wharf	1	Yes	No	No	No	Yes
Tug boat on standby	1	Yes	No	No	No	Yes

[1] Hydrocarbons associated with flare emissions not assessed

12.7.3 Air Pollutants and Averaging Periods

Section 6.4.3 of the Air Quality Impact Assessment Report, included as

Appendix 5.13, discusses modelled scenarios and averaging periods for:

- oxides of nitrogen
- CO
- PM_{10}
- hydrocarbon compounds
- photochemical smog
- odour.

12.8 SUMMARY OF RESULTS

This section presents the results of the air quality impact assessment for NO_2, PM_{10}, SO_2, CO, ozone, odour and all identified hydrocarbons for the normal and non-normal operating conditions.

12.8.1 Normal Operations – Scenario 1

As discussed, normal operations refers to emissions from the QCLNG Facility during the production of LNG product on a continuous basis.

12.8.1.1 Nitrogen Dioxide – Without Waste Heat Recovery

The assessment of the maximum 1-hour average ground-level concentrations of NO_2 has been made for the 99.9th percentile value, assuming no waste heat recovery (WHR) on compressors.

Figure 5.12.5 and *Figure 5.12.6* present the predicted maximum 1-hour and annual average ground-level concentrations of NO_2, respectively, for the proposed LNG Facility during normal operations and in isolation.

Figure 5.12.7 and Figure 5.12.8 present the predicted maximum 1-hour and annual average ground-level concentrations of NO_2, respectively, for the proposed LNG Facility during normal operations and including existing and approved industries (GAMSv3) and the other proposed LNG facilities in the Gladstone region.

Predicted maximum 1-hour and annual average ground-level concentrations of nitrogen dioxide within the modelling domain at sensitive receptors in isolation and including existing and approved industries (GAMSv3) are provided in *Table 5.12.17*.

Table 5.12.17 Predicted maximum 1-hour and annual average ground-level concentrations of nitrogen dioxide for the background, the QCLNG Facility in isolation and the plant and background combined (in µg/m3)

Location	GAMSv3 background		QCLNG facility in isolation		QCLNG facility with background	
	1-hour average	Annual average	1-hour average	Annual average	1-hour average	Annual average
R1	40.0	1.8	5.5	0.15	43.2	3.0
R2	42.3	2.5	6.3	0.08	44.5	3.1
R3	42.2	3.3	4.6	0.05	54.5	3.4
R4	51.5	3.3	4.9	0.05	66.1	4.2
R5	58.8	3.9	3.8	0.05	79.5	5.2
R6	75.4	5.0	3.6	0.05	84.5	5.7
R7	68.1	4.3	6.4	0.07	82.5	5.9
R8	71.5	4.8	2.8	0.04	67.7	4.6
R9	49.2	2.1	2.4	0.02	62.5	3.0
R10	40.3	0.8	7.2	0.05	36.3	1.0
R11	39.0	1.0	3.9	0.04	54.9	1.2
R12	43.8	0.9	3.5	0.03	54.2	1.2
R13	29.5	0.5	3.0	0.02	36.8	0.6
R14	30.3	0.5	3.0	0.02	39.6	0.6
R15	26.2	0.5	2.2	0.01	17.2	0.5
R16	17.0	0.5	2.3	0.01	22.8	0.5
R17	27.4	0.4	2.0	0.01	25.6	0.4
R18	19.8	0.3	1.8	0.01	23.1	0.4
R19	19.0	0.3	1.8	0.01	20.3	0.3
R20	18.4	0.3	1.8	0.01	17.2	0.3
Maximum on grid	118.6	0.8	24.4	0.84	302.1	9.5
Location of maximum[1]	317450, 7370350	315950, 7370650	309050, 7366150	315950, 7370650	317450, 7361050	315650, 7362550
Air quality objective	250	62/33	250	62/33	250	62/33

[1] Coordinates are in Australian Map Grip AGD66 Datum

The results indicate that:

- No exceedences of the EPP (Air) air quality objective are predicted for the 1-hour and annual average ground-level concentration of NO_2 due to the proposed LNG Facility, under normal operating conditions, assessed in isolation and including background concentrations.

- The predicted maximum incremental 1-hour and annual average ground-level concentrations of NO_2 anywhere across the modelling domain for the proposed LNG Facility during normal operating conditions, and in isolation, are 24.4 µg/m^3 and 0.8 µg/m^3, respectively, which are 9.8 per cent and 1.35 per cent of the EPP (Air) air quality objectives of 250 µg/m^3 (1-hour) and 62 µg/m^3 (annual).
- The predicted maximum incremental 1-hour and annual average ground-level concentrations of NO_2 at any sensitive place for the proposed LNG Facility during normal operating conditions, and in isolation, are 7.2 µg/m^3 at R10 and, 0.15 µg/m^3 at R1, respectively, which are 2.9 per cent and 0.2 per cent of the EPP (Air) air quality objectives of 250 µg/m^3 (1-hour) and 62 µg/m^3 (annual).
- The predicted maximum 1-hour and annual average ground-level concentrations of NO_2 at any sensitive place for the proposed LNG Facility during normal operating conditions, and including the background, are 84.5 µg/m^3 at R6 and 5.9 µg/m^3 at R7, respectively, which are 33.8 per cent and 9.5 per cent of the EPP (Air) air quality objectives of 250 µg/^{m3} (1-hour) and 62 µg/m^3 (annual).
- Predicted elevated concentrations of NO_2 in the Gladstone region that cause an exceedence of the EPP (Air) 1-hour average air quality objective of 250 µg/m^3 are situated in close proximity to the power station stacks and are a result of emissions from the power station. The location of these high concentrations is approximately nine kilometres to the south-southeast of the QCLNG Facility.

12.8.1.2 *Nitrogen Dioxide – Sensitivity Analysis for the Gas Turbine with Waste Heat Recovery*

A sensitivity analysis has been conducted to evaluate the change in ground-level concentrations of NO_2 associated with the lower temperature and exit velocity that is characteristic of WHR. The analysis found that there was an insignificant change in the predicted ground-level concentrations of NO_2 for the "with WHR system" option in comparison with the Scenario 1 base case of "without WHR system". The assessment found that the predicted change in ground-level concentrations of NO_2 ranged between a 2 µg/m^3 decrease and a 5 µg/m^3 increase across the modelling domain, depending on the distance from the source and the elevation of the terrain.

- Further detail on predicted maximum 1-hour and annual average ground-level concentrations of NO_2 for the QCLNG with background for the "with WHR system" option is provided in *Appendix 5.13*.

TYPE: NO_2 maximum (99.9th percentile) 1-hour average contour plot

Averaging Period: 1-hour

Air Quality Objective: Health and wellbeing: 250 $\mu g/m^3$

Units: $\mu g/m^3$

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N.T.S

N

QUEENSLAND CURTIS LNG A BG Group business	Project: **Queensland Curtis LNG Project**		Title: **Scenario 1 - Predicted maximum 1-hour average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations, in isolation**
	Client: **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**Volume 5** **Figure 5.12.5**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR005_F5.12.5	
	Date 10/06/09	Revision 0	

TYPE: Maximum Contour Plot

Averaging Period: Annual

Air Quality Objective: Health and wellbeing: 62μg/m^3

Health and Biodiversity of Ecosystems: 33μg/m^3

Units: μg/m^3 and meters

Source Note

Katestone Environmental Pty Ltd

Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

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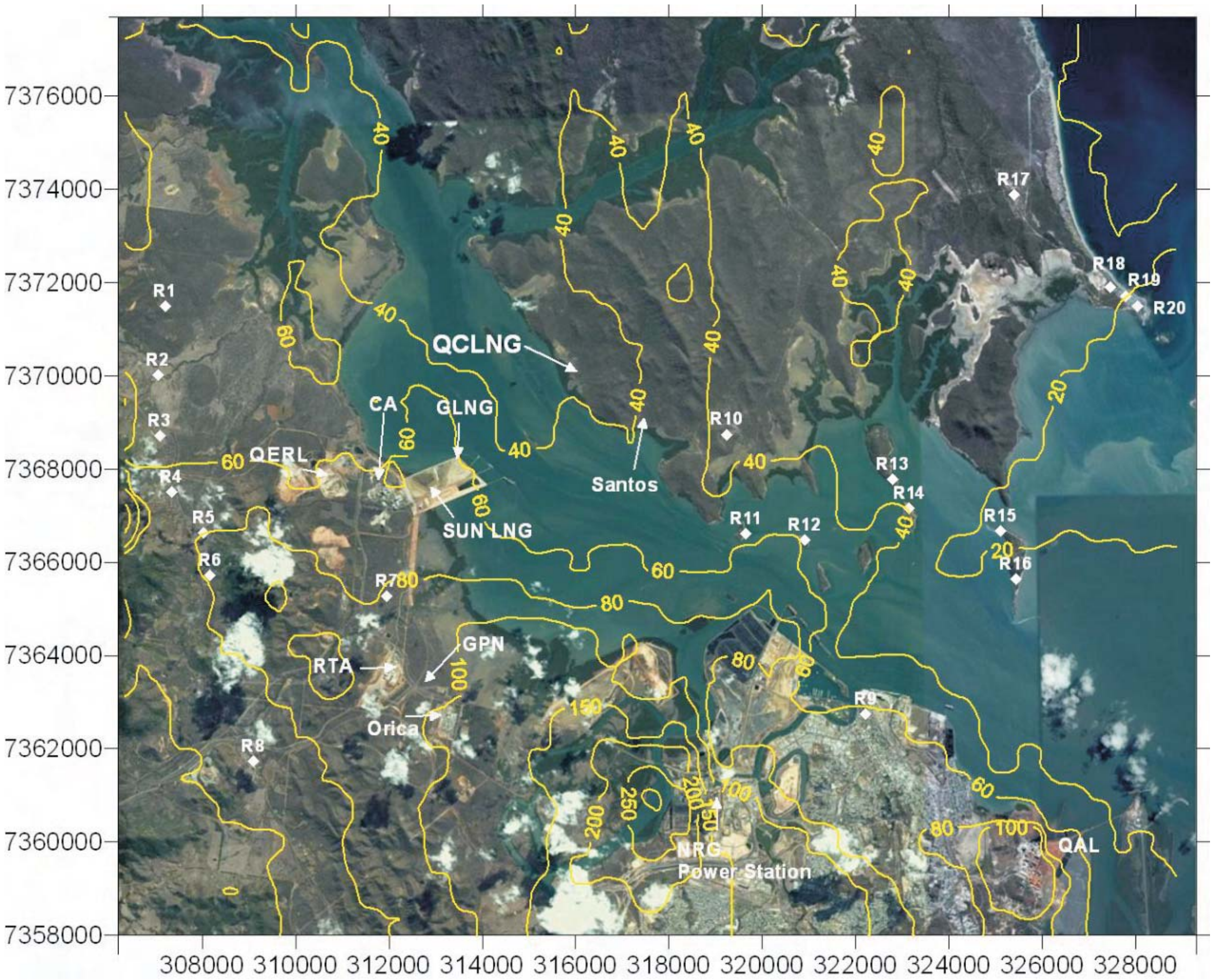
QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project	Title **Scenario 1 - Predicted annual average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations, in isolation**
	Client	QGC - A BG Group business	
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**Volume 5** **Figure 5.12.6**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR006_F5.12.6	
	Date 10/06/09	Revision 0	



TYPE: Maximum 99.9th percentile)

Averaging Period: 1-hour

Air Quality Objective: Health and wellbeing: 250μg/m^3

Health and Biodiversity of Ecosystems: 33μg/m^3

Units: μg/m^3

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	Volume 5	Figure 5.12.7
Approved	DS	File No: 0086165b_EIS_AQ_CDR007_F5.12.7	
Date	10/06/09	Revision 0	

Title **Scenario 1 - Predicted maximum 1-hour average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations, with background**

Disclaimer:
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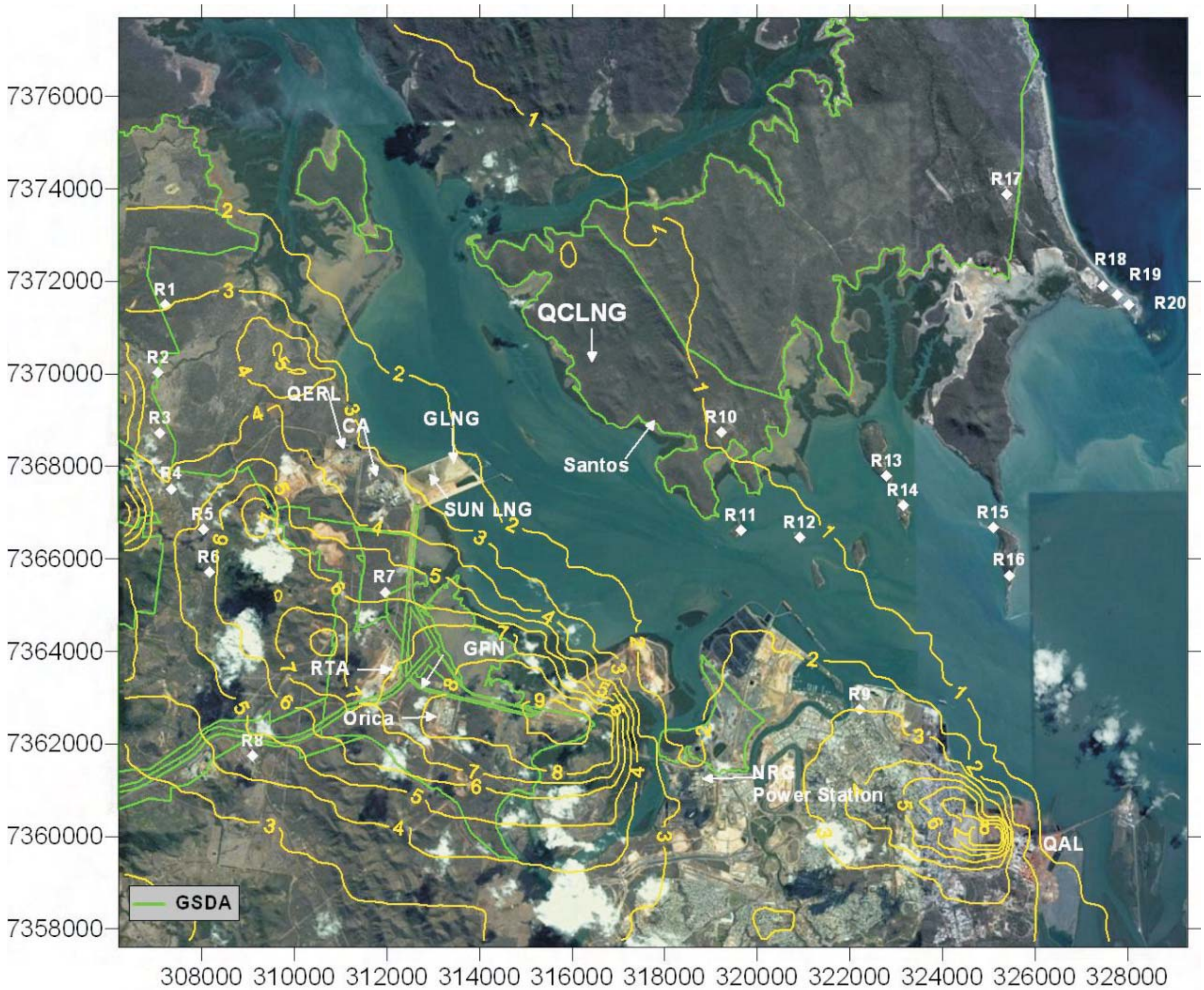

TYPE: Maximum Contour Plot

Averaging Period: Annual

Air Quality Objective: Health and wellbeing: 62μg/m^3

Health and Biodiversity of Ecosystems: 33μg/m^3

Units: μg/m^3

Source Note

Katestone Environmental Pty Ltd

Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

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QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Scenario 1 - Predicted annual average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations, with background
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB	Volume 5 Figure 5.12.8	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: DS	File No: 0086165b_EIS_AQ_CDR008_F5.12.8	
	Date: 10/06/09	Revision: 0	

12.8.1.3 *Carbon Monoxide*

The assessment of the maximum 8-hour average ground-level concentrations of CO has been made for the 100th percentile value. The maximum 8-hour average ground-level concentrations of CO of 312 μg/m^3, measured at the Beacon Avenue, Boyne Island, monitoring station, has been included as the background concentration.

Figure 5.12.9 presents the predicted maximum 8-hour average ground-level concentrations of CO for the QCLNG Facility during normal operations and including background. Predicted concentrations at sensitive receptors are tabulated in *Appendix 5.13*.

The results indicate that:

- there are no anticipated exceedences of the EPP (Air) air quality objectives for the 8-hour average ground-level concentration of CO due to the proposed LNG Facility, under normal operating conditions, assessed in isolation and including background.
- the predicted maximum 8-hour average ground-level concentration of CO at any location within the modelling domain due to the proposed LNG Facility, under normal operating conditions and including background, is 365.4 μg/m^3, which is 3.32 per cent of the EPP (Air) air quality objective of 11,000 μg/m^3.
- The predicted maximum 8-hour average ground-level concentration of CO at any sensitive receptor due to the proposed LNG Facility, under normal operating conditions and including background, is 328.1 μg/m^3, which is 2.98 per cent of the EPP (Air) air quality objective of 11,000 μg/m^3.

12.8.1.4 *PM_{10} and $PM_{2.5}$*

The assessment of the maximum 24-hour average ground-level concentrations of PM_{10} has been made for the 100th percentile value. A background level for PM10 of 29 μg/m^3 has been included in this assessment based on measurements at the Targinie Stupkin Lane monitoring station.

- *Figure 5.12.10* presents the predicted maximum 24-hour average ground-level concentrations of PM_{10} for the proposed LNG Facility, during normal operations and including background. Predicted concentrations at sensitive receptors are tabulated in *Appendix 5.13.*

TYPE: Maximum Contour Plot

Averaging Period: 8-hour

Air Quality Objective: Health and wellbeing: 11,000μg/m^3

Units: μg/m^3

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Scenario 1 - Predicted maximum 8-hour average ground - level concentrations of carbon monoxide for the QCLNG Plant during normal operations, with background
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB	Volume 5 Figure 5.12.9	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: DS	File No: 0086165b_EIS_AQ_CDR09_F5.12.9	
	Date: 10/06/09	Revision: 0	

TYPE: Maximum Contour Plot

Averaging Period: 24-hour

Air Quality Objective: Health and wellbeing: 50μg/m^3

Units: μg/m^3

Source Note

Katestone Environmental Pty Ltd

Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business		Title: Scenario 1 - Predicted maximum 24-hour average ground - level concentrations of PM_{10} for the QCLNG Plant during normal operations, with background
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB Approved DS Date 10/06/09	Volume 5 Figure 5.12.10 File No: 0086165b_EIS_AQ_CDR010_F5.12.10 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

The results indicate that:

- there are no predicted exceedences of the EPP (Air) air quality objectives for the 24-hour average ground-level concentration of PM_{10} due to the proposed LNG Facility, under normal operating conditions, assessed in isolation and including background.
- the predicted maximum 24-hour average ground-level concentration of PM_{10} at any sensitive receptor due to the proposed LNG Facility, under normal operating conditions and in isolation, is 0.6 µg/m_3 at Receptor 10. With the inclusion of the background, the maximum is 29.6 µg/m^3, which is 59 per cent of the EPP (Air) air quality objective of 50 µg/m^3.
- the predicted maximum 24-hour average ground-level concentration of PM_{10} at any location within the modelling domain due to the proposed LNG Facility, under normal operating conditions and in isolation, is 1.8 µg/m^3. With the inclusion of the background, the maximum is 30.8 µg/m^3, which is 61.6 per cent of the EPP (Air) air quality objective of 50 µg/m^3.

For the assessment of $PM_{2.5}$, a conservative approach has been adopted whereby the ground-level concentration of PM_{10} has been compared with the $PM_{2.5}$ air quality objective. This assumes the total mass of fine particulate matter emitted from the QCLNG Facility has an aerodynamic diameter less than 2.5 microns. There is no objective for PM_1 and therefore no assessment was made.

On this basis, for the assessment of $PM_{2.5}$ the results indicate that, assuming 100 per cent of the particulate matter emitted from the QCLNG facility is $PM_{2.5}$, the maximum ground-level concentration at any location across the modelled domain is 1.8 µg/m^3. This is less than 7.2 per cent of the EPP (Air) air quality objective of 25 µg/m^3. Ambient monitoring for $PM_{2.5}$ is not conducted at the Targinie DERM monitoring stations and therefore a cumulative assessment has not been provided.

12.8.1.5 Hydrocarbons

Modelling of maximum ground-level concentrations of specific non-methane hydrocarbons (expressed as methane equivalents, across the modelling domain and at sensitive receptors associated with emissions to air from the proposed LNG Facility under normal operations) indicates that the most affected sensitive receptor is Receptor 10.

In order to determine the concentrations of specific hydrocarbon compounds that comprise the total hydrocarbon content at Receptor 10, the percentage of each compound identified (per USDERM AP-42) to the Total Organic Compound (TOC) content has been applied. On this basis, *Table 5.12.18* presents a summary of the predicted maximum ground-level concentrations of each hydrocarbon at Receptor 10, associated with emissions from the QCLNG Facility under normal operations.

Table 5.12.18 Predicted maximum ground-level concentrations of specific species of non-methane hydrocarbons at Receptor 10

Hydrocarbon	Air quality objective used for Assessment[1] (µg/m^3)	Percentage of Air quality objective (%)	Predicted maximum ground-level concentration[2] (µg/m^3)
1,3-Butadiene	40	1.24E-02	4.94E-03
2-Methylnaphthalene	60	4.00E-05	2.40E-05
3-Methylchloranthrene	60	3.00E-06	1.80E-06
7,12-Dimethylbenz(a)anthracene	0.5	3.20E-03	1.60E-05
Acenaphthene	1	1.80E-04	1.80E-06
Acenaphthylene	1	1.80E-04	1.80E-06
Acetaldehyde	42.00	1.10E+00	4.60E-01
Acrolein	0.42	1.75E+01	7.36E-02
Anthracene	0.5	4.80E-04	2.40E-06
Benz(a)anthracene	0.5	3.60E-04	1.80E-06
Benzene	29	4.83E-01	1.40E-01
Benzo(a)pyrene3	Annual average		1.20E-06
Benzo(b)fluoranthene	0.5	3.60E-04	1.80E-06
Benzo(g,h,i)perylene	0.5	2.40E-04	1.20E-06
Benzo(k)fluoranthene	0.5	3.60E-04	1.80E-06
Butane	19,000	1.10E-02	2.10E+00
Chrysene	0.5	3.60E-04	1.80E-06
Dibenzo(a,h)anthracene	0.5	2.40E-04	1.20E-06
Dichlorobenzene	600	2.00E-04	1.20E-03
Ethane	12,000	2.58E-02	3.10E+00
Ethylbenzene	8,000	4.60E-03	3.68E-01
Fluoranthene	0.5	6.00E-04	3.00E-06
Fluorene	0.5	5.60E-04	2.80E-06
Formaldehyde	20	4.12E+01	8.24E+00
Hexane	3,200	5.62E-02	1.80E+00
Indeno(1,2,3-cd)pyrene	0.5	3.60E-04	1.80E-06
Naphthalene	52,000	2.99E-05	1.56E-02
Pentane	33,000	7.87E-03	2.60E+00
Phenanathrene	0.5	3.40E-03	1.70E-05
Propane	18,000	8.88E-03	1.60E+00
Propylene Oxide	90	3.70E-01	3.33E-01
Pyrene	0.5	9.99E-04	5.00E-06
Toluene	360	4.16E-01	1.50E+00
Xylene	190	3.87E-01	7.36E-01

1 Air quality objectives for varying averaging periods have been converted to a 1-hour average for assessment.

2 The predicted maximum ground-level concentration is at the most affected sensitive receptor.

3 Benzo(a)pyrene is assessed as an annual average for its chronic health risk and consequently has not been converted to a 1-hour average. However, the predicted maximum 1-hour average is well below the annual average and therefore will be below the air quality objective.

The results indicate that none of the 35 identified hydrocarbon species potentially associated with emissions from the proposed LNG Facility was found to exceed the ambient air quality objectives at the most affected sensitive receptor (Receptor 10).

12.8.1.6 Photochemical Smog

The assessment of photochemical smog impacts has been conducted based on 100 per cent conversion of NO_2 to ozone. This is an extremely conservative assumption.

The current atmospheric environment in Gladstone receives very low ozone levels, with only a few hours per year receiving levels slightly above background concentrations. The peak contribution of the proposed LNG Facility to levels of NO_2 at a sensitive receptor is 24.4 µg/m^3, with a predicted maximum incremental increase of ozone at this location of 22.9 µg/m^3.

Adding the maximum contribution due to the proposed QCLNG Facility at the most affected sensitive receptor to the maximum ozone recorded at the Targinie monitoring station results in a maximum ozone concentration of 132.7 µg/m^3, which is 63 per cent of the ambient air quality objective of 210 µg/m^3 for a 1-hour average.

Therefore, the contribution of the proposed Project to regional photochemical activity is, at worst, minor and unlikely to be of any cause for concern or require further assessment.

12.8.1.7 Odour

A qualitative assessment of the potential for odour impacts has been conducted based on thresholds for individual compounds. The assessment was based on the predicted maximum ground-level concentration at the most affected sensitive receptor. Pollutants assessed were NO_2 and odorous hydrocarbons with a maximum ground-level concentration of greater than 1 per cent of their air quality objective.

The results indicate that the predicted maximum (100th percentile) 1-hour average ground-level concentration of each odorous compound at the most affected receptor is well below both the odour threshold and ambient air quality objective.

Consequently, it is unlikely that the ground-level odour concentration at R10, as a result of air emissions from the proposed LNG Facility in isolation, will exceed the DERM odour guideline of 2.5 ou (99.5th percentile) at any location.

12.8.2 Non-normal Operations – Scenario 2

As described in *Section 12.7*, non-normal operations in Scenario 2 refer to normal operations at the proposed LNG Facility plus non-continuous shipping emissions.

12.8.2.1 Nitrogen Dioxide

The assessment of the maximum 1-hour average ground-level concentrations of NO_2 for the proposed LNG facility in isolation and with background has been made for the 99.9th percentile value.

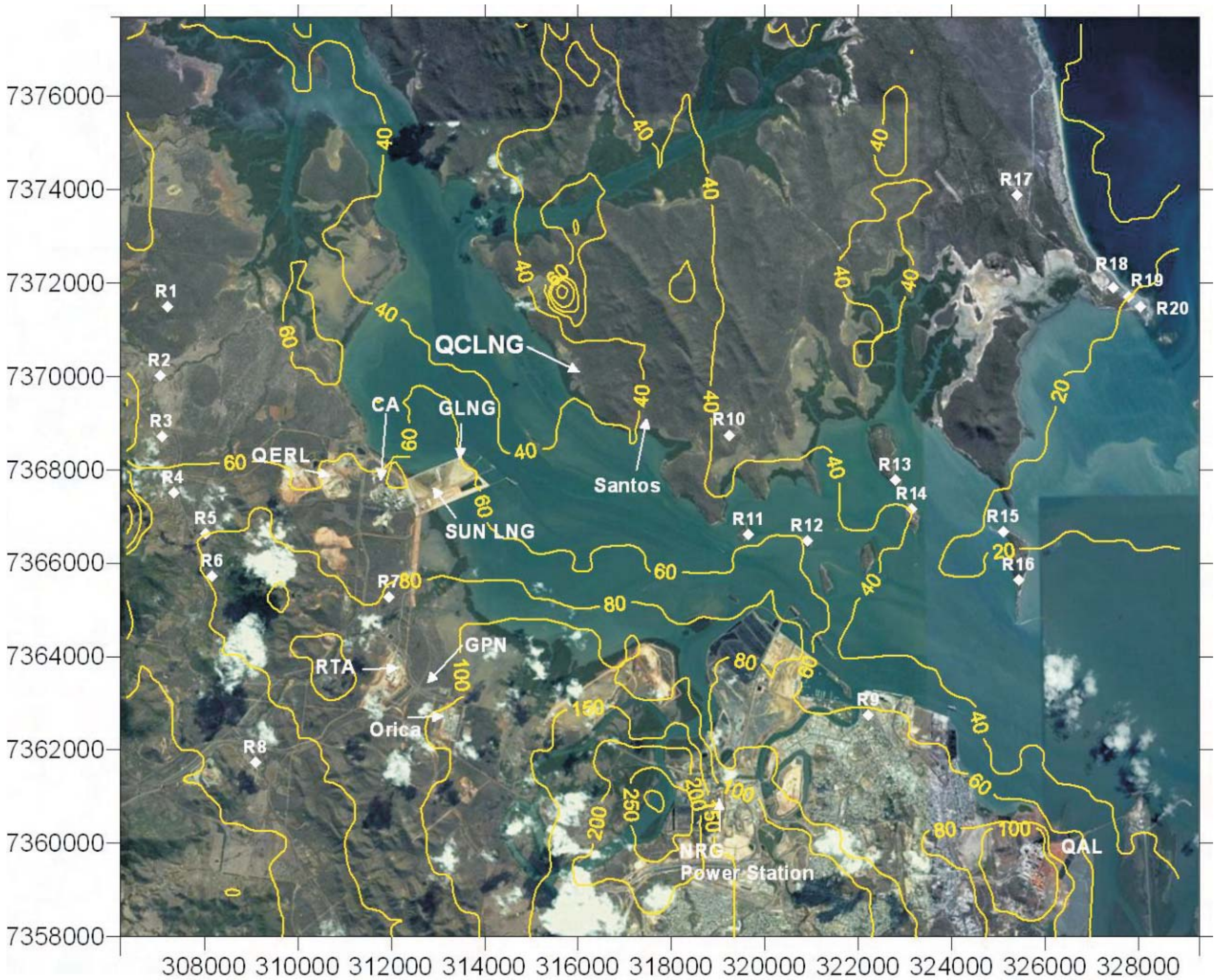
Figure 5.12.11 and *Figure 5.12.12* present the predicted maximum 1-hour and annual average ground-level concentrations of NO_2, respectively, for the proposed LNG Facility during normal operations, plus shipping activities and approved industries (GAMSv3) and the background in the Gladstone region. Predicted concentrations at sensitive receptors are tabulated in *Appendix 5.13.*

The results show the following:

- There are no exceedences predicted of the EPP (Air) air quality objective for the 1-hour and annual average ground-level concentration of NO_2 due to the proposed LNG Facility, under normal operating conditions, assessed in isolation and including background concentrations at any sensitive place.
- The predicted maximum incremental 1-hour and annual average ground-level concentrations of NO_2 at any sensitive place for the proposed LNG Facility during normal operating conditions, and in isolation, is 19.4 µg/m^3 at R4 and, 0.4 µg/m^3 at R1, respectively, which are 7.8 per cent and 0.6 per cent of the EPP (Air) air quality objectives of 250 µg/m^3 (1-hour) and 62 µg/m^3 (annual).
- The predicted maximum 1-hour and annual average ground-level concentrations of NO_2 at any sensitive place for the proposed LNG Facility during normal operating conditions, and including background, is 84.5 µg/m^3 at R6 and 5.9 µg/m^3 at R7, respectively, which are 33.8 per cent and 9.5 per cent of the EPP (Air) air quality objectives of 250 µg/m^3 (1-hour) and 62 µg/m^3 (annual).
- Predicted elevated concentrations of NO_2 that cause an exceedence of the EPP (Air) 1-hour average air quality objective of 250 µg/m^3 for the proposed LNG Facility, in isolation, occur near the wharf on the QCLNG site and are caused by emissions from the LNG carrier engines.

12.8.2.2 Sulfur Dioxide

The assessment of the maximum 1-hour average ground-level concentrations of SO_2, for the proposed LNG Facility in isolation and the GAMSv3 background, has been made for the 100th percentile.



TYPE: Maximum (99th percentile) Contour Plot

Averaging Period: 1-hour

Air Quality Objective: Health and wellbeing: 250μg/m^3

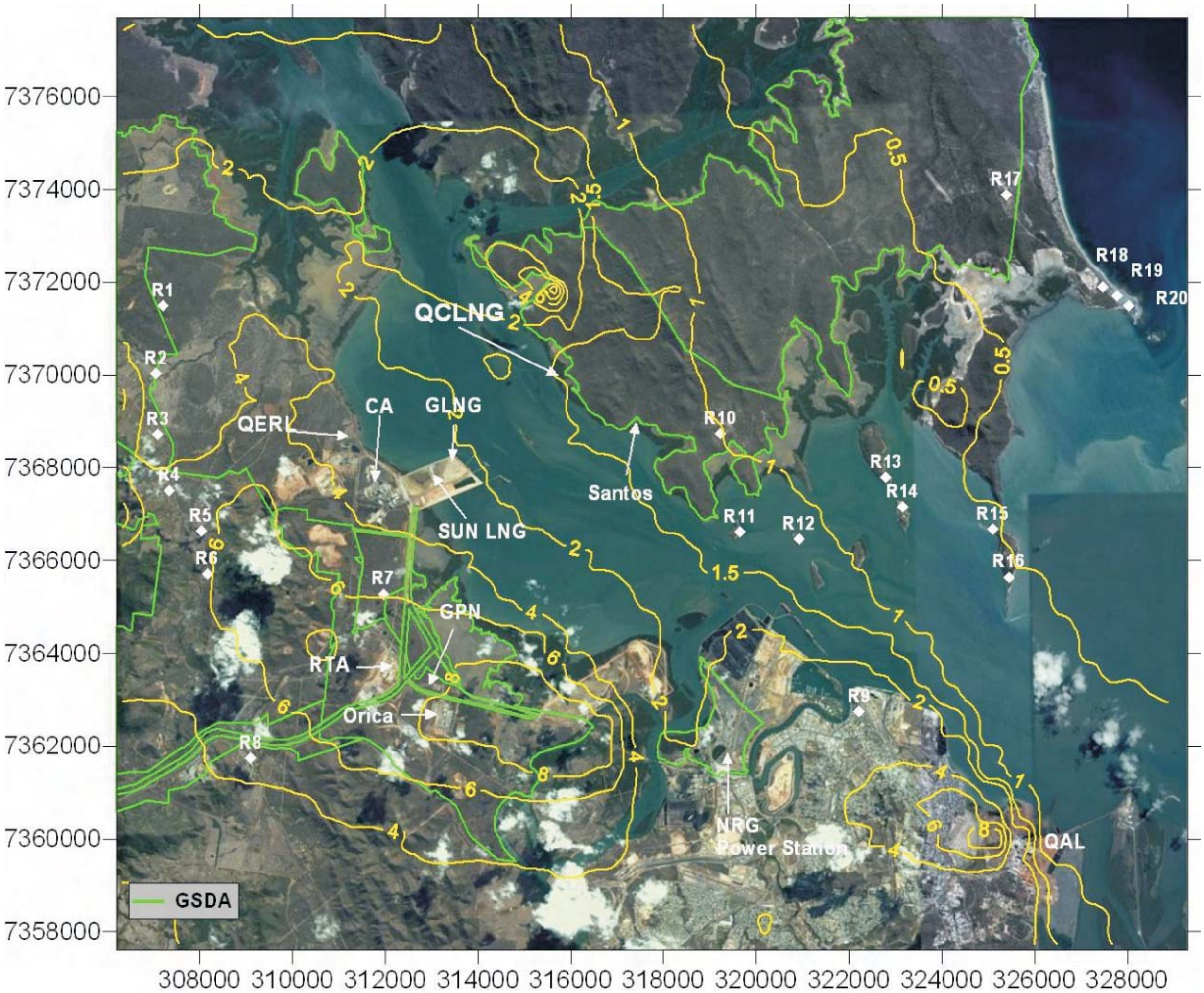
Units: μg/m^3

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project **Queensland Curtis LNG Project**		Title **Scenario 2 - Predicted maximum 1-hour average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations and the LNG Carrier during cargo transfer, with background**
	Client **QGC - A BG Group business**		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	**Volume 5** **Figure 5.12.11**	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR011_F5.12.11	
	Date 10/06/09	Revision 0	



TYPE: Maximum Contour Plot

Averaging Period: Annual

Air Quality Objective: Health and wellbeing: 62μg/m^3

Health and Biodiversity of Ecosystems: 33μg/m^3

Units: μg/m^3

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Scenario 2 - Predicted annual average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations and the LNG Carrier during cargo transfer, with background
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	Volume 5 Figure 5.12.12	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR012_F5.12.12	
	Date 10/06/09	Revision 0	

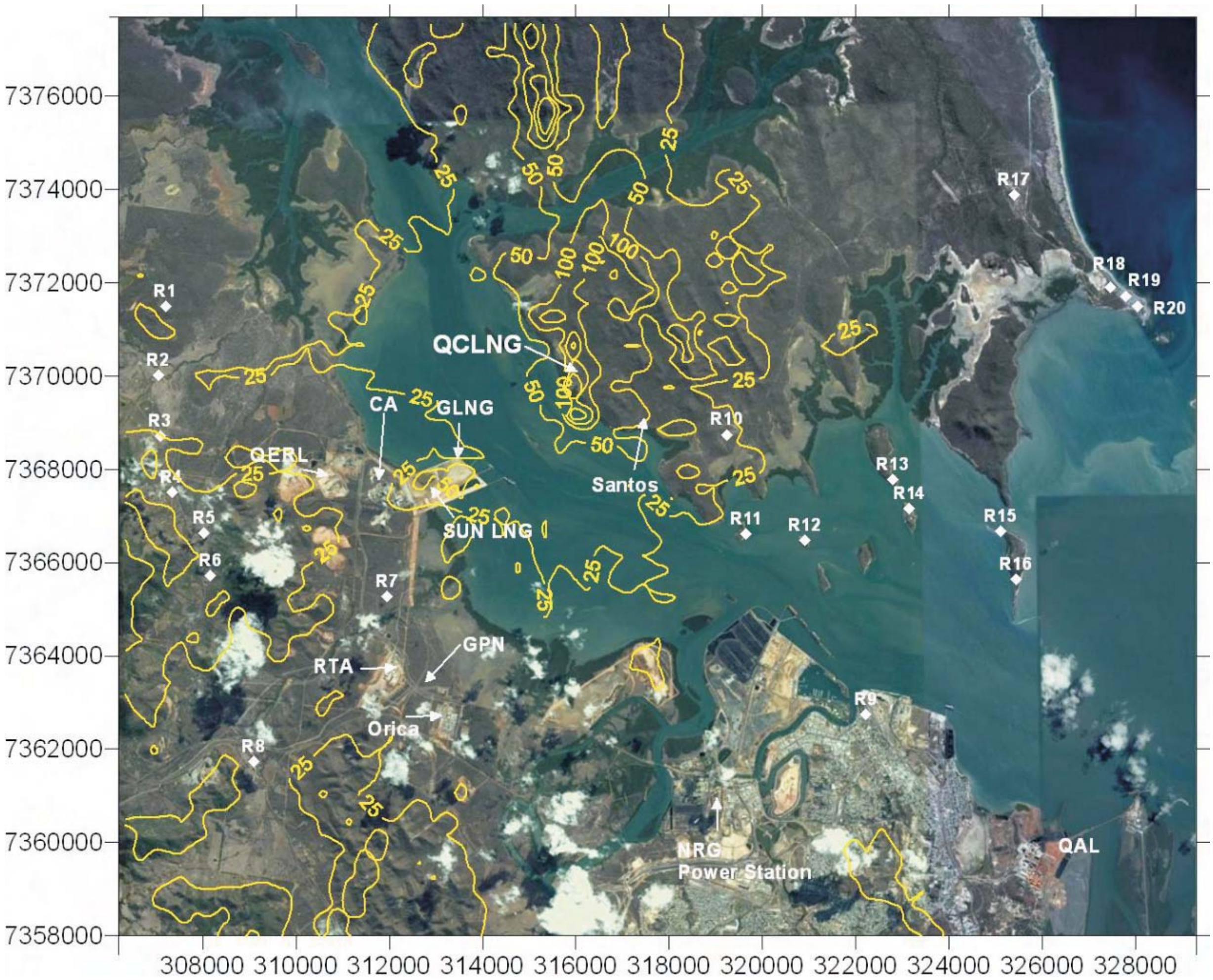
Figure 5.12.13 and *Figure 5.12.14* present the predicted maximum 1-hour average ground-level concentrations of SO_2 for the proposed LNG facility during normal operations, plus shipping activities in isolation and including background in the Gladstone region, respectively.
Figure 5.12.15 and *Figure 5.12.16* present the predicted maximum 24-hour average ground-level concentrations of SO_2 for the proposed LNG facility during normal operations plus shipping activities in isolation including background in the Gladstone region, respectively.

Figure 5.12.17 and *Figure 5.12.18* present the predicted maximum annual average ground-level concentrations of SO_2 for the proposed LNG facility during normal operations plus shipping activities in isolation including background in the Gladstone region, respectively.

Predicted concentrations at sensitive receptors are tabulated in *Appendix 5.13.*

The results indicate that:

- There are no predicted exceedences of the EPP (Air) air quality objective for the 1-hour, 24-hour and annual average ground-level concentrations of SO_2 due to the proposed shipping activity by the proposed LNG Facility, when assessed in isolation.
- The predicted maximum incremental 1-hour, 24-hour and annual average ground-level concentrations of SO_2 anywhere across the modelling domain for shipping emissions, and in isolation, are 61.2 per cent, 13.9 per cent and 11.4 per cent of the EPP (Air) air quality objectives for health and wellbeing.
- The predicted maximum 1-hour, 24-hour and annual average ground-level concentrations of SO_2 at any sensitive place for the shipping activities in isolation are 7 per cent, 2 per cent and 1 per cent of the respective EPP (Air) air quality objectives.
- The predicted maximum 1-hour, 24-hour and annual average ground-level concentrations of SO_2 at any sensitive place for the shipping activities including background are 65 per cent, 55 per cent and 33 per cent of the respective EPP (Air) air quality objectives.
- Predicted ground-level concentrations in exceedence of the 1-hour, 24-hour and annual average EPP (Air) air quality objectives for the proposed LNG facility plus background case are located in close proximity to the power station and due to power station emissions. Predicted ground-level concentrations of SO_2 in the vicinity of the proposed LNG facility are well below the EPP (Air) air quality objectives.



TYPE: Maximum (99.9th percentile) Contour Plot

Averaging Period: 1-hour

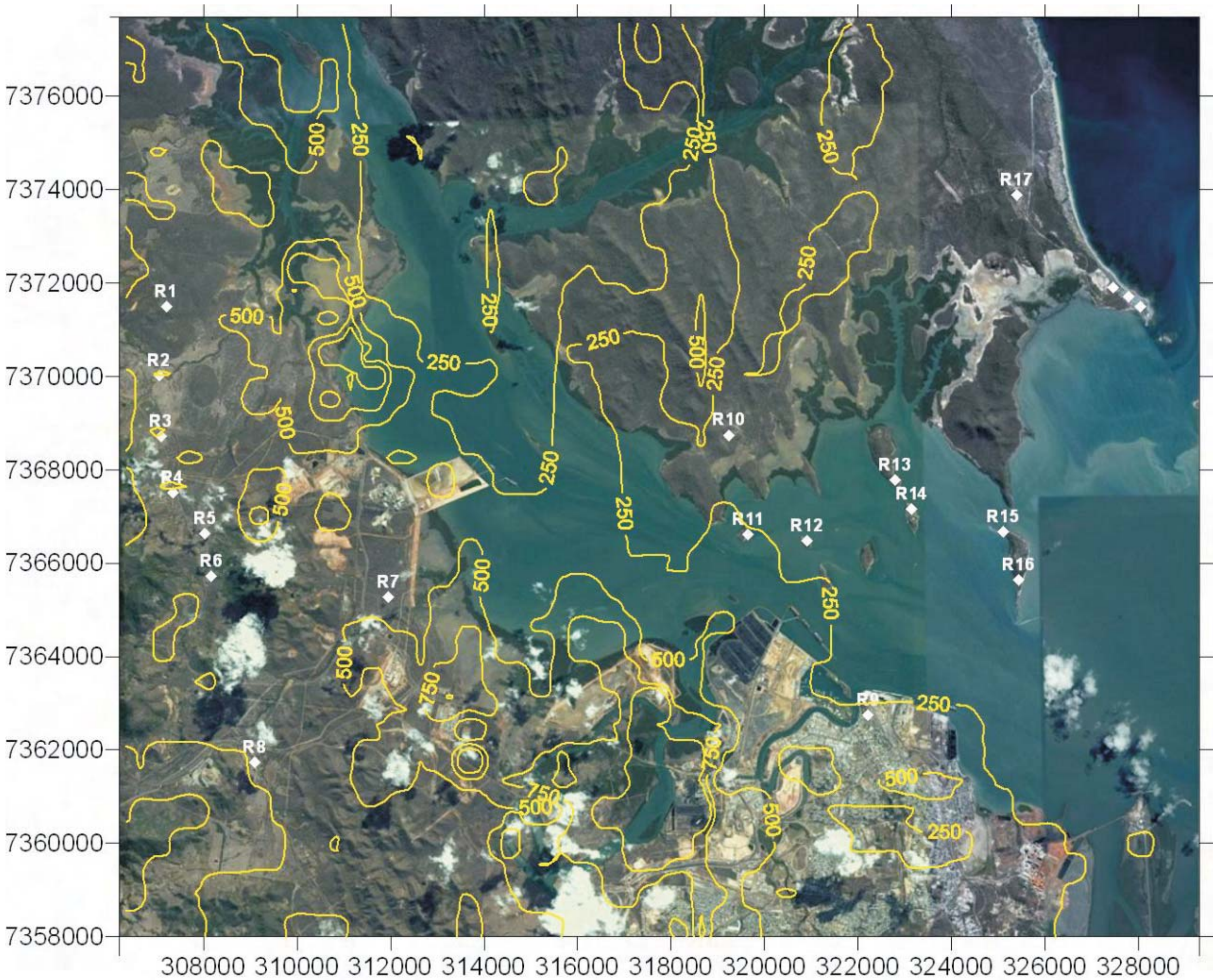
Air Quality Objective: Health and wellbeing: 570μg/m^3

Units: μg/m^3

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project		Title	Scenario 2 - Predicted maximum 1-hour average ground - level concentrations of sulfur dioxide for the LNG Carrier during cargo transfer, in isolation
	Client	QGC - A BG Group business			
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	Volume 5	Figure 5.12.13	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.	
	Approved DS	File No: 0086165b_EIS_AQ_CDR013_F5.12.13			
	Date 10/06/09	Revision 0			



TYPE: Maximum (100th percentile) Contour Plot

Averaging Period: 1-hour

Air Quality Objective: Health and wellbeing: 570μg/m^3

Units: μg/m^3

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Scenario 2 - Predicted maximum 1-hour average ground - level concentrations of sulfur dioxide for the LNG Carrier during cargo transfer, with background
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn: JB	Volume 5 Figure 5.12.14	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved: DS	File No: 0086165b_EIS_AQ_CDR014_F5.12.14	
	Date: 10/06/09	Revision: 0	

TYPE: Maximum (100th percentile) Contour Plot

Averaging Period: 24-hour

Air Quality Objective: Health and wellbeing: 230μg/m^3

Units: μg/m^3

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project, Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project	Title	**Scenario 2 - Predicted maximum 24-hour average ground - level concentrations of sulfur dioxide for the LNG Carrier during cargo transfer, in isolation**
Client	QGC - A BG Group business		
Drawn JB	Volume 5	Figure 5.12.15	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
Approved DS	File No: 0086165b_EIS_AQ_CDR015_F5.12.15		
Date 10/06/09	Revision 0		

TYPE: Maximum (100th percentile) Contour Plot

Averaging Period: 24-hour

Air Quality Objective: Health and wellbeing: 230μg/m^3

Units: μg/m^3

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project Queensland Curtis LNG Project Client QGC - A BG Group business	Title Scenario 2 - Predicted maximum 24-hour average ground - level concentrations of sulfur dioxide for the LNG Carrier during cargo transfer, with background
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB Approved DS Date 10/06/09 Volume 5 Figure 5.12.16 File No: 0086165b_EIS_AQ_CDR016_F5.12.16 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

TYPE: Maximum Contour Plot

Averaging Period: Annual

Air Quality Objective: Health and wellbeing: 57μg/m^3

Protecting Agriculture: 32μg/m^3

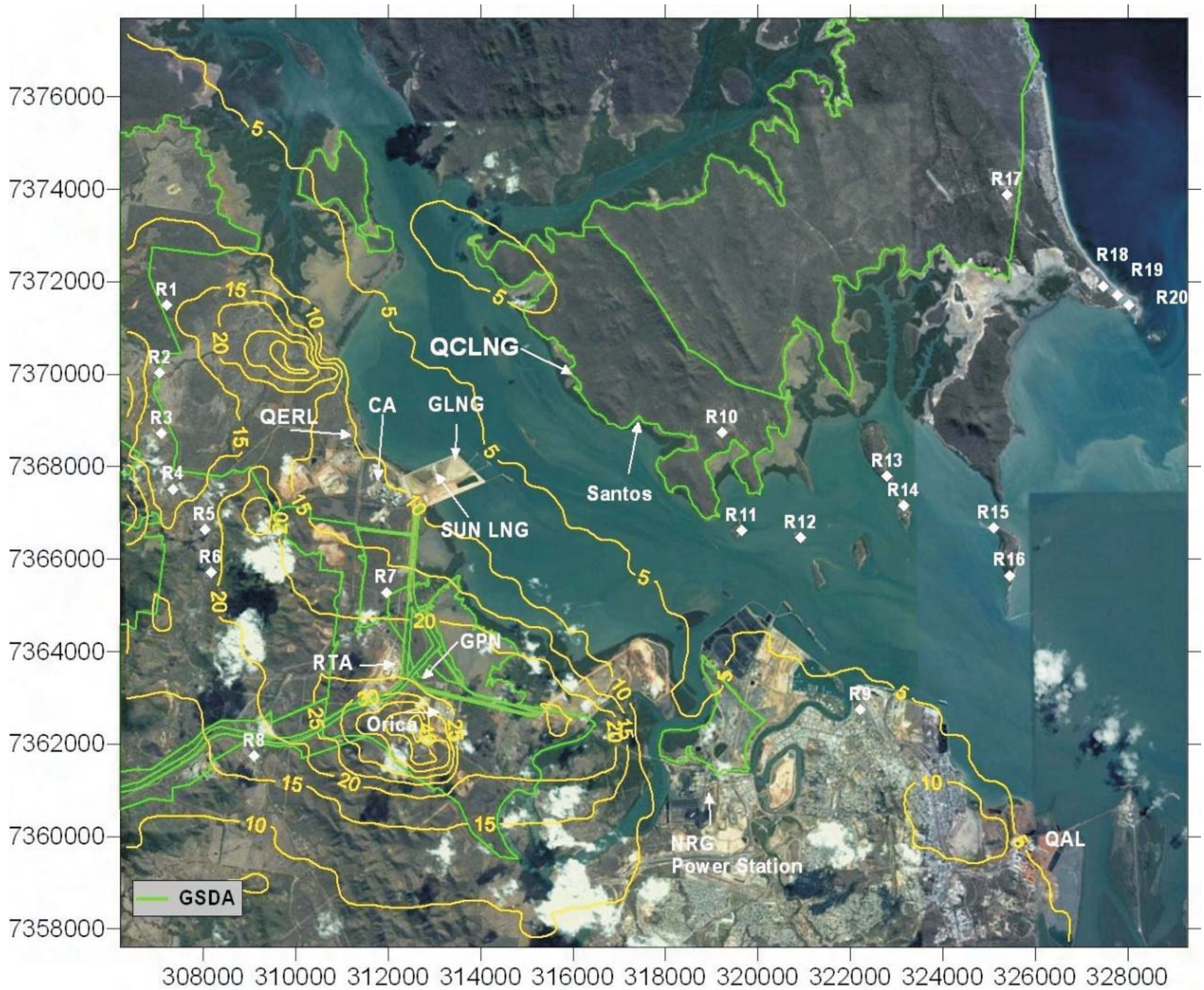
Health and Biodiversity of Ecosystems: 22μg/m^3

Units: μg/m^3

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project Queensland Curtis LNG Project		Title **Scenario 2 - Predicted annual average ground - level concentrations of sulfur dioxide for the LNG Carrier during cargo transfer, in isolation**
	Client QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	Volume 5 Figure 5.12.17	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR017_F5.12.17	
	Date 10/06/09	Revision 0	



TYPE: Maximum Contour Plot

Averaging Period: Annual

Air Quality Objective: Health and wellbeing: 57μg/m^3

Protecting Agriculture: 32μg/m^3

Health and Biodiversity of Ecosystems: 22μg/m^3

Units: μg/m^3

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project Client: QGC - A BG Group business		Title: Scenario 2 - Predicted annual average ground - level concentrations of sulfur dioxide for the LNG Carrier during cargo transfer, with background
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB Approved DS Date 10/06/09	Volume 5 Figure 5.12.18 File No: 0086165b_EIS_AQ_CDR018_F5.12.18 Revision 0	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.

12.8.3 *Non-normal Operations – Scenario 3*

As described previously, non-normal operations in Scenario 3 refer to releases from the dry gas flare only, during plant upset or emergency conditions.

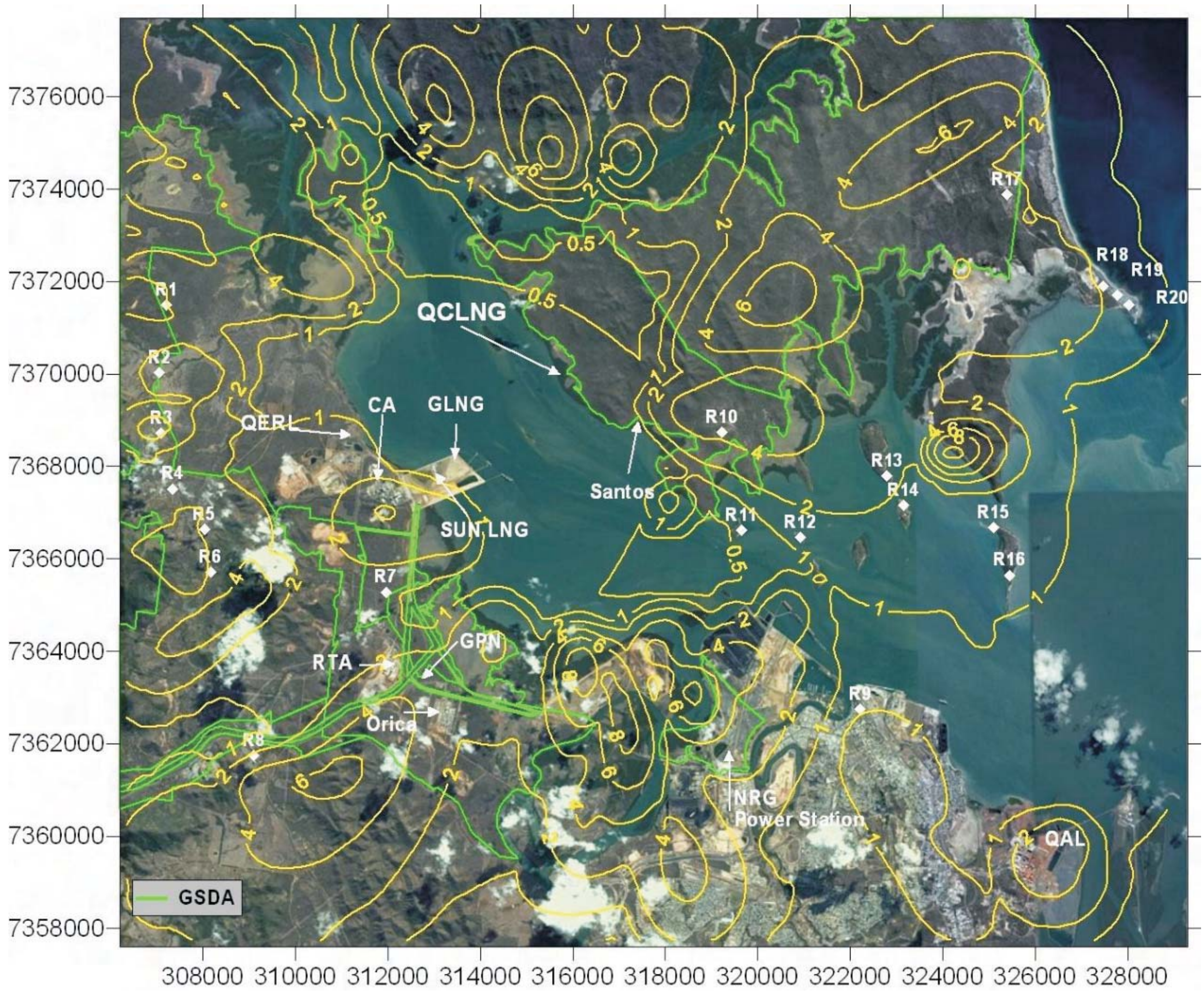
12.8.3.1 *Nitrogen Dioxide*

The assessment of the maximum 1-hour average ground-level concentrations of NO_2 for the dry gas flare has been made for the 100th percentile, while for the proposed facility plus background the 99.9th percentile value has been assessed.

Figure 5.12.19 and *Figure 5.12.20* present the predicted maximum 1-hour average ground-level concentrations of NO_2, for the QCLNG facility for non-normal operations when the plant is shutdown and the dry gas flare operates during an upset blowdown event, in isolation and with background, respectively.

Predicted concentrations at sensitive receptors are tabulated in *Appendix 5.13.* The results include the following:

- There are no predicted exceedences of the EPP (Air) air quality objective for the 1-hour average ground-level concentration of NO_2 due to a dry gas flare event, when assessed in isolation.
- Predicted exceedences of the 1-hour average ground-level concentration EPP (Air) air quality objective for NO_2 are located in close proximity to the power station and due to power station emissions. Predicted ground-level concentrations of NO_2 in the vicinity of the proposed LNG Facility are well below the EPP (Air) air quality objectives.
- The predicted maximum incremental 1-hour average ground-level concentration of NO_2 anywhere across the modelling domain for the proposed LNG facility during a dry gas flare upset blowdown, and in isolation, is 10.4 $\mu g/m^3$, which is 4.2 per cent of the EPP (Air) air quality objectives of 250 $\mu g/m^3$.
- The predicted maximum incremental 1-hour average ground-level concentration of NO_2 at any sensitive place for the proposed LNG facility during a dry gas flare event, in isolation and with background, is 6.0 $\mu g/m^3$ and 84.5 $\mu g/m^3$, respectively, which is 2.4 per cent and 33.8 per cent of the EPP (Air) air quality objective of 250 $\mu g/m^3$.



TYPE: NO_2 maximum (100th percentile)
1-hour average contour plot

Averaging Period: 1-hour

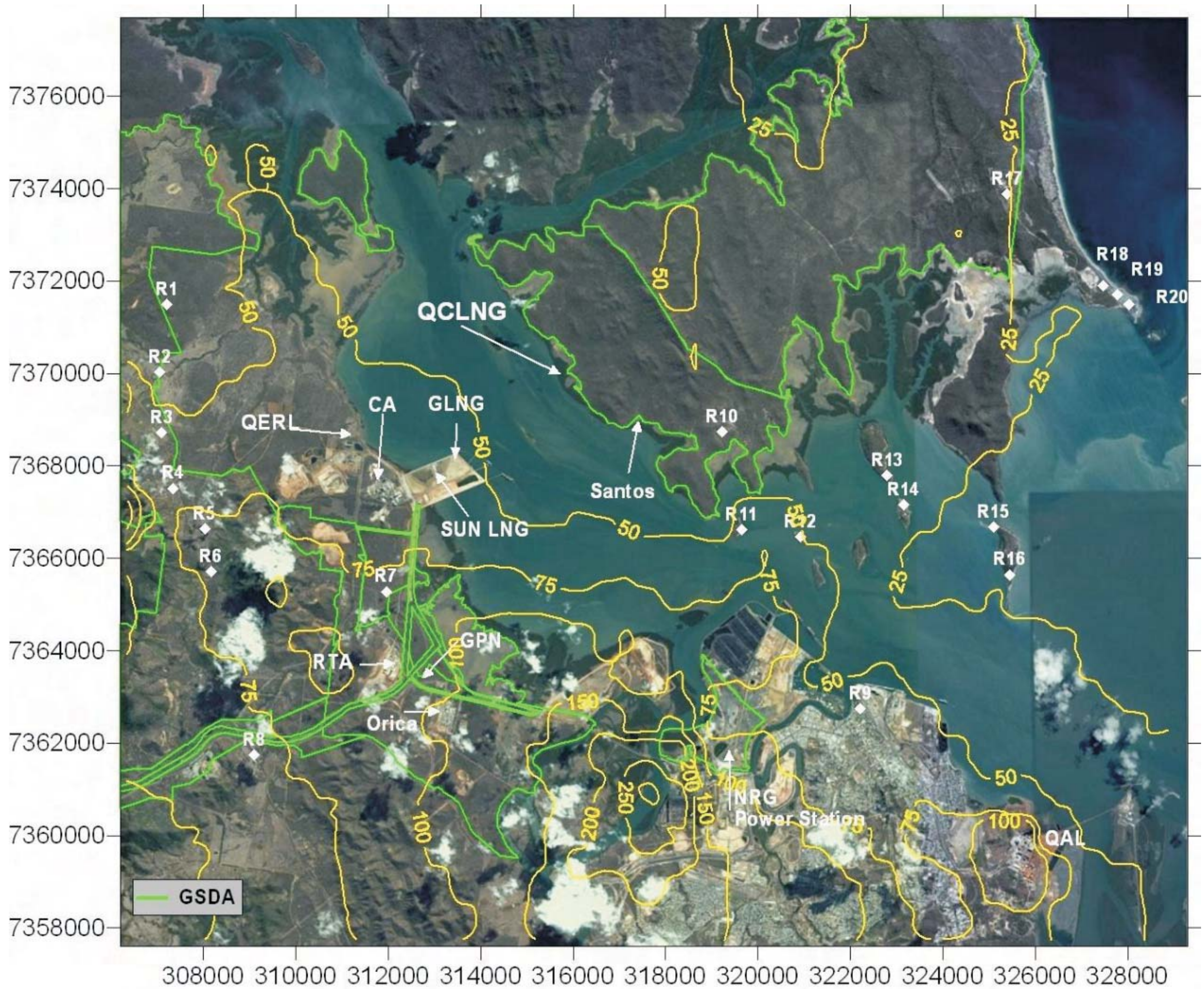
Air Quality Objective: Health and wellbeing: 250 $\mu g/m^3$

Units: $\mu g/m^3$

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project	Queensland Curtis LNG Project	Title	Scenario 3 - Predicted maximum 1-hour average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during a non-normal Dry Gas Flare release, in isolation
	Client	QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	Volume 5 Figure 5.12.19	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.	
	Approved DS	File No: 0086165b_EIS_AQ_CDR019_F5.12.19		
	Date 10/06/09	Revision 0		



TYPE: NO_2 maximum (99.9th percentile)
1-hour average contour plot

Averaging Period: 1-hour

Air Quality Objective: Health and wellbeing: 250 $\mu g/m^3$

Units: $\mu g/m^3$

Source Note
Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

N

QUEENSLAND CURTIS LNG A BG Group business	Project: Queensland Curtis LNG Project		Title: Scenario 3 - Predicted maximum 1-hour average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during a non-normal Dry Gas Flare release, with background
	Client: QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	Volume 5 Figure 5.12.20	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR020_F5.12.20	
	Date 10/06/09	Revision 0	

12.8.3.2 *Carbon Monoxide*

The assessment of the maximum 8-hour average ground-level concentrations of CO for the dry gas flare has been made for the 100th percentile. Predicted concentrations at sensitive receptors are tabulated in *Appendix 5.13.* The results show:

- There are no predicted exceedences of the EPP (Air) air quality objective for the 8-hour average ground-level concentration of CO due to a dry gas flare event, when assessed in isolation and with background.
- The predicted maximum incremental 8-hour average ground-level concentration of CO_2 anywhere across the modelling domain for the LNG plant during a dry gas flare upset blowdown, in isolation and with background, is 56.1 µg/m^3 and 368.1 µg/m^3, which is 0.51 per cent and 3.3 per cent, respectively, of the EPP (Air) air quality objective of 11,000 µg/m^3.
- The predicted maximum incremental 8-hour average ground-level concentration of CO_2 anywhere across the modelling domain for the LNG plant during a dry gas flare upset blowdown, in isolation and with background, is 22.3 µg/m^3 and 334.3 µg/m^3 at Receptor 3, which is 0.2 per cent and 3 per cent, respectively, of the EPP (Air) air quality objective of 11,000 µg/m^3.

12.8.3.3 *Hydrocarbons*

Emissions of hydrocarbons from the dry gas flare during non-normal upset blowdown conditions have been estimated from the emission rate of total hydrocarbons from the proposed LNG Facility and from the breakdown of specific hydrocarbons as outlined in the US DERM's AP-42 Industrial Flares[2] document.

Issue Identification

It is anticipated the Project will emit a suite of hydrocarbons, which available published information suggests are recognised asphyxiants. The potential risk to persons living and working in the surrounding area that could be associated with exposure to these hydrocarbons due to their release from the proposed LNG Facility has been assessed.

The following hydrocarbons have been identified as those potentially emitted from the flare:

- Methane
- Ethane/ethylene
- Acetylene
- Propane
- Propylene

2 USDERM, 1991. - AP42, *Fifth Edition, Volume 1*: "Miscellaneous Sources", Chapter 13.5 "Industrial Flares".

Hazard Identification/Dose Response Assessment

A summary of health and safety data relating to each of the hydrocarbons is included in *Table 5.12.19*. It is noted that while there are no design standards for these hydrocarbons that are published by the Victorian DERM, the NSW Department of Environment and Climate Change or the National Environment Protection Council (NEPC), the Texas Commission on Environmental Quality has published air quality guidelines for some of the organic species. These are shown in *Table 5.12.19*.

Safe Work Australia publishes Hazardous Substances Information System (HSIS) exposure standards for atmospheric contaminants in the occupational environment[3].

Each of the compounds that are likely to be emitted from the LNG flare is characterised as non-irritating to eyes and skin or if inhaled. However, inhalation at high concentrations can act as an asphyxiant. The HSIS exposure standards do not make recommendations as to the concentration of each compound that could cause asphyxiation, rather, the reader is referred to *Chapter 10* of the Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment NOHSC 3008 (1995) 3rd Edition, which states that:

"Simple asphyxiants are gases which, when present in an atmosphere in high concentrations, lead to a reduction of oxygen concentration by displacement or dilution. It is not appropriate to recommend an exposure standard for each simple asphyxiant, rather, it should be required that a sufficient oxygen concentration be maintained.

The minimum oxygen content in air should be 18 per cent by volume under normal atmospheric pressure. This is equivalent to a partial pressure of oxygen (PO2) of 18.2 kPa (137 mm Hg). At pressures significantly higher or lower than the normal atmospheric pressure, expert guidance should be sought."

Exposure Assessment

The dispersion modelling predicted that the maximum 1-hour average combined concentration of total hydrocarbons across the modelling domain would be 34.77 µg/m³ (as methane). *Table 5.12.20* provides estimates of ground-level concentrations of speciated hydrocarbons based on the maximum prediction ground-level concentration across the modelling domain, and at the most affected sensitive receptor. These predictions are presented as a mass concentration for comparison with the TCEQ air quality standards. The predictions are also presented as a volume percentage in air.

3 National Occupational Health and Safety Commission, 1995. Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC:1003 (1995))

Risk Characterisation

The findings of the dispersion modelling assessment summarised in *Table* 5.12.20 indicates that the predicted ground-level concentration of each hydrocarbon is very low. None of these hydrocarbons is likely to be present in sufficient quantities to displace oxygen to the extent that asphyxiation could occur, indicating a negligible risk.

The predicted maximum concentration of each hydrocarbon is also very low compared to the TCEQ standards at the maximum concentration anywhere across the modelling domain.

The predicted concentration of each hydrocarbon is very low when compared with its lower explosive limit, indicating a very low risk of explosion. There is a negligible risk that these compounds could concentrate in low-lying areas and cause an explosion or asphyxiation.

12.8.4 Non-Normal Operations – Scenario 4

Non-normal operations in Scenario 4 refer to the normal operations at the proposed LNG Facility, non-continuous shipping emissions and releases from the marine flare during upset conditions.

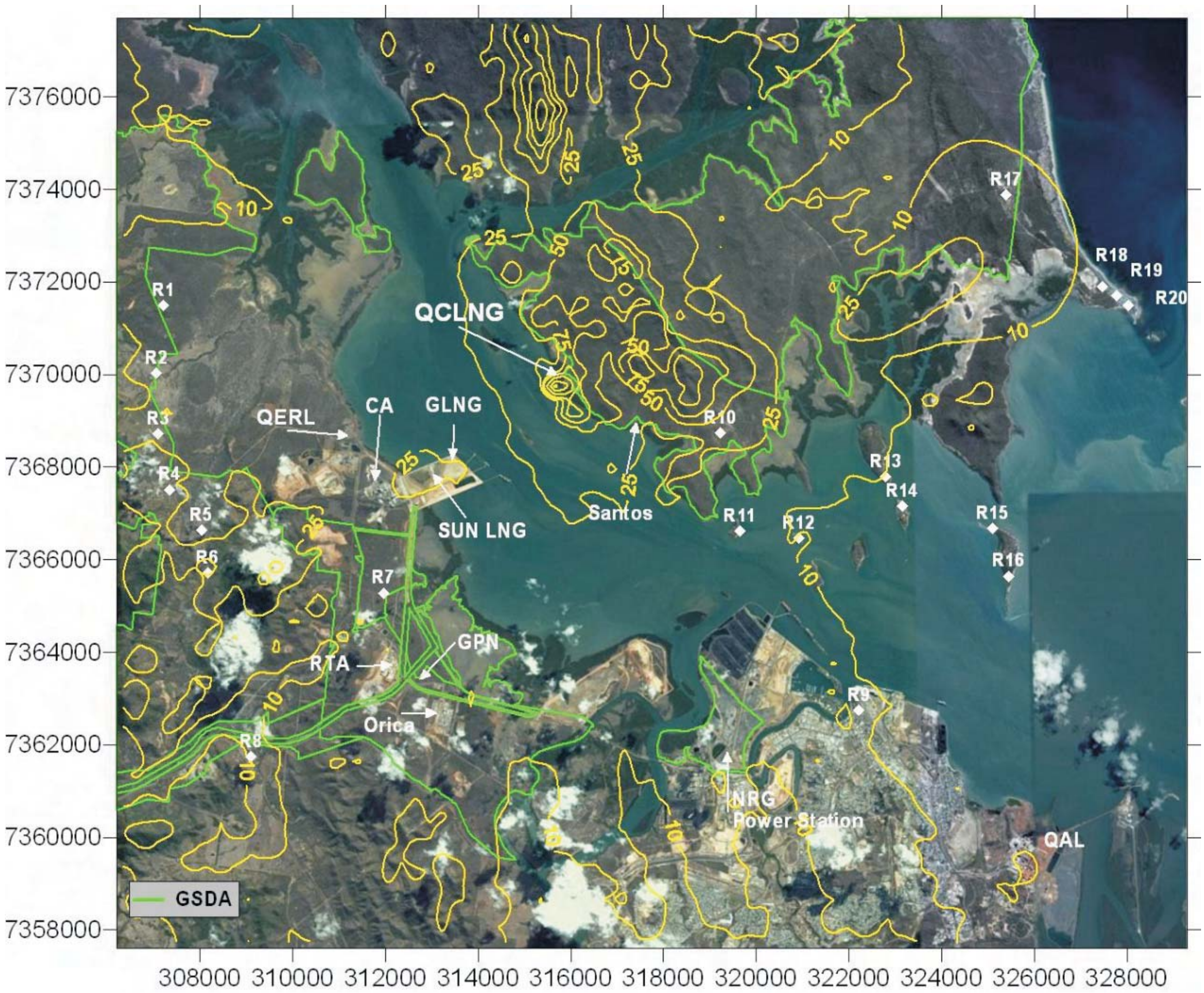
12.8.4.1 Nitrogen Dioxide

The assessment of the maximum 1-hour average ground-level concentrations of NO_2 for the emissions from the proposed LNG Facility during normal operations, plus shipping emissions and an upset conditions blowdown from the marine flare, has been made for the 100th percentile. For the LNG Facility with background, the 99.9th percentile has been assessed.

Figure 5.12.21 and *Figure 5.12.22* present the predicted maximum 1-hour average ground-level concentrations of NO_2, for the proposed LNG Facility during normal operations, plus shipping emissions and an upset conditions blowdown from the marine flare, in isolation and with background, respectively.

Predicted concentrations at sensitive receptors are tabulated in *Appendix 5.13.* The results show:

- There are no predicted exceedences of the EPP (Air) air quality objective for the 1-hour average ground-level concentration of NO_2 due to the combination of the proposed LNG Facility during normal operations, plus shipping activities and an upset blowdown event at the marine flare, when assessed in isolation and with background at any sensitive receptor location.



TYPE: Maximum Contour Plot

Averaging Period: 1-hour

Air Quality Objective: Health and wellbeing: 250 $\mu g/m^3$

Units: $\mu g/m^3$

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

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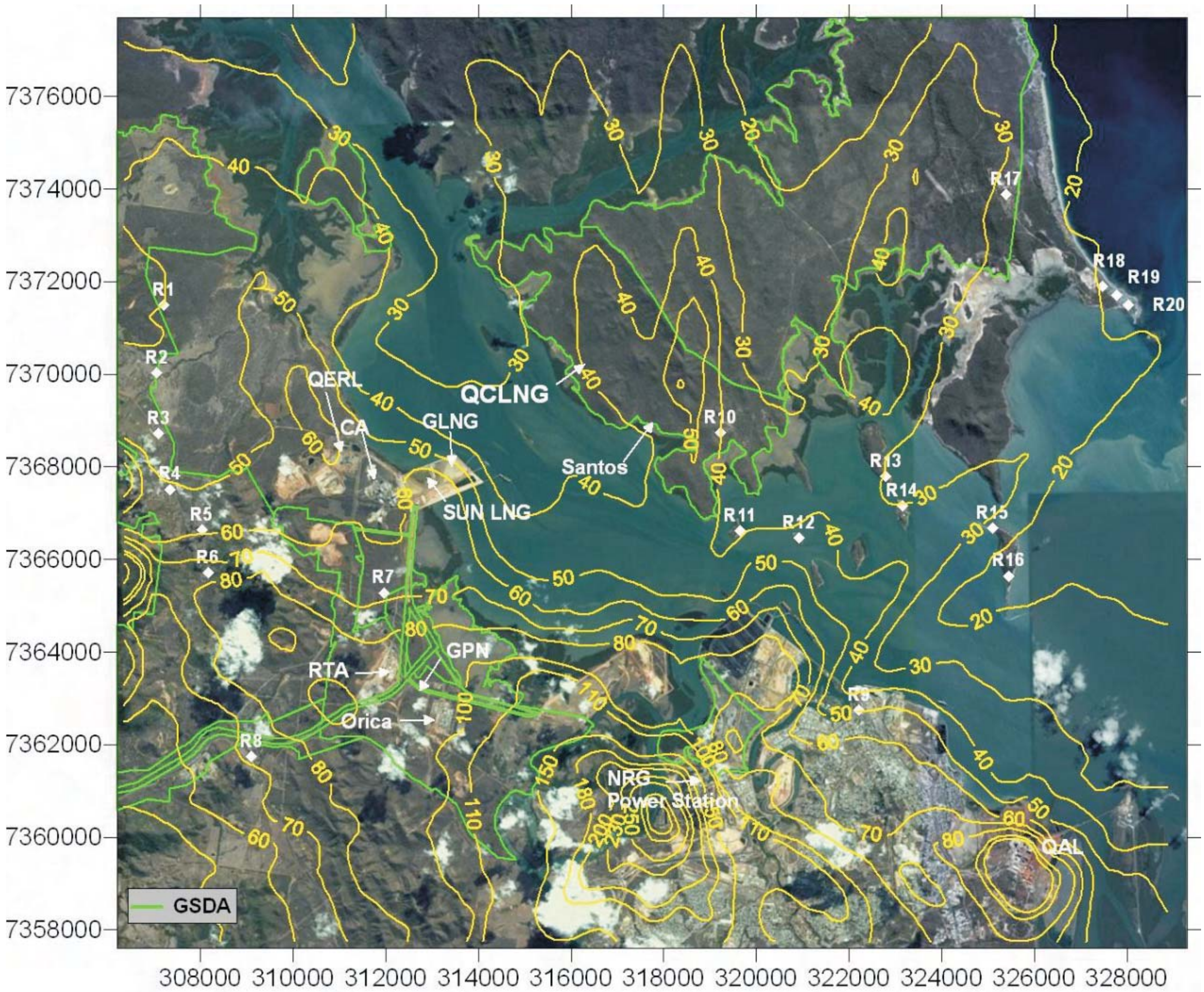
QUEENSLAND CURTIS LNG A BG Group business	Project Queensland Curtis LNG Project		Title Scenario 4 - Predicted maximum 1-hour average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations, including an LNG Carrier at the wharf and an upset release of the Marine Flare, in isolation
	Client QGC - A BG Group business		
ERM Environmental Resources Management Australia Pty Ltd	Drawn JB	Volume 5 Figure 5.12.21	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.
	Approved DS	File No: 0086165b_EIS_AQ_CDR021_F5.12.21	
	Date 10/06/09	Revision 0	



TYPE: Maximum (99.9th percentile) Contour Plot

Averaging Period: 1-hour

Air Quality Objective: Health and wellbeing: 250 $\mu g/m^3$

Units: $\mu g/m^3$

Source Note

Katestone Environmental Pty Ltd
Air Quality Impact Assessment Of The QCLNG Project,
Gladstone, Queensland - June 2009.

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QUEENSLAND CURTIS LNG
A BG Group business

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Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	JB	Volume 5	Figure 5.12.22
Approved	DS	File No: 0086165b_EIS_AQ_CDR022_F5.12.22	
Date	10/06/09	Revision 0	

Title **Scenario 4 - Predicted maximum 1-hour average ground - level concentrations of nitrogen dioxide for the QCLNG Plant during normal operations, including an LNG Carrier at the wharf and an upset release of the Marine Flare, with background**

Disclaimer:
Maps and Figures contained in this Report may be based on Third Party Data, may not to be to scale and are intended as Guides only.
ERM does not warrant the accuracy of any such Maps and Figures.

Table 5.12.19 Health and Safety data relevant to speciated VOCs Potentially emitted During Emergency Flaring

Compound	CAS Number	Mass relative to air	Lower explosive limit (per cent)	HSIS Exposure Standards (TWA, STEL)	Victorian DERM/NSW DECC design standards	Texas (TCEQ) 1-hour average (µg/m³)	BOC MSDS		
							Eye	Inhalation	Skin
Methane	74-82-8	0.55	5	No values assigned.	-	-	Non-irritating	Non-irritating - Asphyxiant. Effects are proportional to oxygen displacement	Non-irritating
Ethane	74-84-0	1.04	3	No values assigned.	-	12,000	Non-irritating	Non-irritating - Asphyxiant. Effects are proportional to oxygen displacement	Non-irritating
Ethylene	74-85-1	0.97	2.7	No values assigned.	-	-	Non-irritating	Non-irritating - Asphyxiant. Effects are proportional to oxygen displacement	Non-irritating
Acetylene	74-86-2	0.90	2.5	No values assigned.	-	26,600	Non-irritating	Non-irritating - Asphyxiant. Effects are proportional to oxygen displacement	Non-irritating
Propane	74-98-6	1.52	2.2	No values assigned.	-	18,000	Non-irritating	Non-irritating - Asphyxiant. Effects are proportional to oxygen displacement	Non-irritating
Propylene	115-07-1	1.45	2.4	No values assigned.	-	8,750	Non-irritating	Non-irritating - Asphyxiant. Effects are proportional to oxygen displacement	Non-irritating

Table 5.12.20 Maximum ground-level concentrations of methane, ethane, ethylene, acetylene, propane and propylene across the modelling domain and at the most affected sensitive receptor due to dry gas flare emissions

Compound	MW	% v/v of total VOCs emitted	Texas (TCEQ) 1-hour average (µg/m³)	Predicted maximum concentrations across modelling domain			Predicted maximum concentrations at most affected sensitive receptor		
				ppb	% v/v in air	µg/m³	ppb	% v/v in air	µg/m³
Methane	16.04	55	-	29.16	2.9E-06	19.1	13.75	1.4E-06	9.0
Ethane	30.07	8	12000	4.24	4.2E-07	5.2	2.00	2.0E-07	2.5
Ethylene	28.05	8	-	4.24	4.2E-07	4.9	2.00	2.0E-07	2.3
Acetylene	26.04	5	26600	2.65	2.7E-07	2.8	1.25	1.2E-07	1.3
Propane	44.09	7	18000	3.71	3.7E-07	6.7	1.75	1.7E-07	3.2
Propylene	42.08	25	8750	13.25	1.3E-06	22.8	6.25	6.2E-07	10.7

- An exceedence of the 1-hour average ground-level concentration EPP (Air) air quality objective for NO_2 is predicted in the proximity of the marine flare and wharf facilities. Predicted ground-level concentrations of NO_2 beyond the proposed LNG Facility operations area are well below the EPP (Air) air quality objectives.
- The predicted maximum incremental 1-hour average ground-level concentration of NO_2 at a sensitive receptor location for the proposed LNG Facility during normal operations, plus shipping activities and an upset blowdown event at the marine flare, and in isolation, is 38.0 µg/m^3 at Receptor 10, which is 15.2 per cent of the EPP (Air) air quality objectives of 250 µg/m^3.

The predicted maximum incremental 1-hour average ground-level concentration of NO_2 at a sensitive receptor location for the proposed LNG Facility during normal operations, plus shipping activities and an upset blowdown event at the marine flare, including background, is 84.5 µg/m^3 at Receptor 6, which is 33.8 per cent of the EPP (Air) air quality objectives of 250 µg/m^3.

12.8.4.2 *Carbon Monoxide*

The assessment of the maximum 8-hour average ground-level concentrations of CO for the emissions from the proposed LNG Facility during normal operations, plus shipping emissions and an upset conditions blowdown from the marine flare, has been made for the 100th percentile.

The results show:

- There are no predicted exceedences of the EPP (Air) air quality objective for the 8-hour average ground-level concentration of CO due to the combination of the proposed LNG Facility during normal operations, plus shipping activities and an upset blowdown event at the marine flare, when assessed in isolation and with background at any location across the modelling domain.
- The predicted maximum incremental 1-hour average ground-level concentration of CO anywhere across the modelled domain for the proposed LNG Facility during normal operations, plus shipping activities and an emergency event at the marine flare, in isolation and with background, is 165.4 µg/m^3 and 477.4 µg/m^3, respectively, which is 1.5 per cent and 4.3 per cent of the EPP (Air) air quality objective of 11,000 µg/m^3.

The predicted maximum incremental 1-hour average ground-level concentration of CO at a sensitive receptor location for the proposed LNG Facility during normal operations, plus shipping activities and an emergency event at the marine flare, in isolation and with background, is 16.7 µg/m^3 and is 328.7 µg/m^3, respectively, at Receptor 10, which is 0.15 per cent and 3 per cent of the EPP (Air) air quality objective of 11,000 µg/m^3.

12.8.4.3 Hydrocarbons

As outlined in *Section 12.8.3.3,* the following hydrocarbons have been identified as those potentially being emitted from the flare:

- Methane
- Ethane/ethylene
- Acetylene
- Propane
- Propylene

Exposure Assessment

The dispersion modelling predicted that the maximum 1-hour average combined concentration of total hydrocarbons across the modelling domain and at the most affected sensitive place would be 460.1 µg/m³ and 4.1 µg/m³ (as methane), respectively.

Risk Characterisation

The findings of the dispersion modelling assessment indicates that the predicted ground-level concentration of each hydrocarbon is very low. None of these hydrocarbons is likely to be present in sufficient quantities to displace oxygen to the extent that asphyxiation could occur. The predicted maximum concentration of each hydrocarbon is also very low compared to the TCEQ standards (maximum of 3.4 per cent for propylene).

12.9 ASSESSMENT OF VERTICAL PLUMES FOR AVIATION SAFETY

The proposed LNG Facility consists of a number of stacks that emit industrial exhausts with the potential to generate significant vertical plume velocities above the proposed LNG Facility, as well as potential vertical plumes arising from flaring events. As the Gladstone Airport is located approximately 10.3 km to the south of the proposed LNG Facility, these vertical plumes pose a potential aviation safety risk.

An assessment of the vertical velocities associated with stack exhaust plumes at the proposed QCLNG Facility on Curtis Island was carried out, based on the guidelines for aviation safety published by the Australian Civil Aviation Safety Authority (CASA) in Guidelines For Conducting Plume Rise Assessments (2004). This assessment (including detailed methodology and findings) is provided in full as Appendix C of the *Air Quality Impact Assessment* included as *Appendix 5.13*. A summary is provided below.

The aim of the assessment was to investigate the vertical and horizontal extent of the plume from various sources at the facility, and to estimate the height and downwind distance at which the average vertical plume velocities diminish to the critical value of 4.3 m/s.

The Gladstone Airport Development Plan describes a PANS-OPS (Procedures for Air Navigation Services – Aircraft Operations) over the QCLNG facility of 300 to 350 m above-ground. The frequencies with which the plume exhaust velocities under normal and non-normal operating conditions achieve or exceed the PANS-OPS above the proposed LNG Facility have been assessed.

12.9.1 Summary of Assessment Findings

12.9.1.1 Plume heights for normal operations

For normal operating conditions, there is a potential for the average plume vertical velocity to exceed 4.3 m/s up to a maximum height of approximately 500 m above ground-level, at a maximum downwind distance of approximately 200 m.

A plume with vertical velocity above 4.3 m/s is likely to exceed the PANS-OPS (300 m) for 29 hours per year or 0.33 per cent of the time.

Of all the sources assessed for normal operations, the highest critical height for the 0.1 percentile is approximately 400 m above ground-level.

12.9.1.2 Plume heights for non-normal operations (planned events)

Each LNG train will have a planned shutdown every 3-4 years with associated maintenance and start-up flaring.

For non-normal operating conditions (planned events during maintenance and start-up), the operating condition likely to generate the highest plume is the dry gas flare release during start-up. This event is estimated to occur 2-4 times per year for 12 to 24 hours, but with much smaller events during start-up which may involve periodic flaring for up to five days.

During start-up conditions the plume generated by the flare is expected to penetrate the PANS-OPS for half the time at a vertical velocity above 4.3 m/s. Therefore it can be expected that during planned maintenance and start-up use of the flare the PANS-OPS at the site will be exceeded for an average vertical velocity of 4.3 m/s. This could occur sporadically for up to five days every three to four years per train (note the current proposed LNG Facility is planned for three-train capacity).

The 0.1 percentile critical plume height (when operation for all year is assumed) is almost 1,500 m above ground-level.

Taking into account the expected hours of operation of the flare, the plume is expected to penetrate the PANS-OPS approximately 50 hours per year and the 0.1 percentile is reduced to approximately 550 m.

The horizontal extent of the plume that exceeds a vertical velocity of 4.3 m/s is expected to be, on average, approximately 450 m (and up to 650 m).

12.9.1.3 Plume heights for non-operations (unplanned events)

For non-normal operating conditions (unplanned events or emergency releases), the operating condition likely to generate the highest plume is the emergency operation of the dry gas flare. This event is likely to occur less than once per year and last for approximately 20 minutes.

Smaller flaring events may occur throughout the year due to minor process upsets.

During the unscheduled emergency operation of the dry gas flare, the vertical velocities generated by the extremely buoyant plume are expected to exceed the PANS-OPS height of 300 m under almost all meteorological conditions to a maximum height of 1921 m above ground-level. However, as the expected frequency of this event is once per year for less than one hour, the 0.1 percentile is actually below the PAN-OPS criteria due to the extreme unlikely occurrence of an emergency flare event.

The horizontal extent of the plume that exceeds a vertical velocity of 4.3 m/s is expected to be, on average, approximately 500 m (and up to 719 m).

The flare flame height is expected to be less than 250 m above ground-level during worst-case meteorological conditions.

12.9.2 Management of Impacts

QGC will work with appropriate authorities to develop and implement appropriate management measures to address the identified issues associated with vertical plumes for aviation safety.

12.10 MANAGEMENT AND MITIGATION MEASURES

The air quality impact assessment was undertaken with consideration to management of a range of mitigation measures that have been implemented for the proposed LNG Facility. These have been incorporated throughout the design process based on assessment of a range of potential technologies for key emissions sources, as part of the internal QGC Group Best Available Techniques assessment. These are summarised below (as described also in *Volume 2, Chapter 9*) with additional detail also provided in *Table 5.12.21*[4]. Key outcomes include:

4 BG: Queensland Curtis LNG Project, 2008. *LNG Facility BAT Justification Report - Select Phase*

- Adoption of WHR to reduce requirement for use of fuel gas burners associated with the dehydration and CO_2 removal components of the LNG process. Use of fuel gas burners is estimated to result in emission of approximately 10,800 tonnes of CO_2 per annum per LNG train, with WHR to reduce this to approximately 365 tonnes[5] CO_2 per annum
- A variety of refrigeration compressor drivers were considered for the Project. The aero-derivative LM2500+G4s with Dry Low Emissions (DLE) were selected in a 2+2+2 configuration for each LNG process train (a total of six compressor drivers per train). Design NO_x emissions from this configuration of LM2500+G4s + DLE are as low as or lower than any of the other options considered in detail (although electric motor drives were not considered in detail due to being unproven technology for the required drive size and electrical stability analysis). The initial template design of the facility assumed use of 2+2+2 (per LNG train) Frame 5D Gas Turbine Drivers, and selection of the LM2500+G4s will result in a reduction of:
  - annual NO_X emissions from approximately 975 tpa per LNG train (for the Base Case of the Frame 5D) to approximately 580 tpa per LNG train and
  - annual CO_2 emissions from approximately 1,020 Mtpa per LNG train (for the Base Case of the Frame 5D) to approximately 730 Mtpa per LNG train.
- Optimisation of power generation, with a range of turbine configurations assessed for 1, 2 and 3 train operation. Aero-derivative LM2500+G4s with DLE were also selected for power generation, with 2 operating + 1 spare (for 2 Train operation). For the third train it is assumed that Inlet Air Chilling (IAC) has been applied (see below), allowing two operating LM2500+G4 units to run all three trains. Use of the LM2500+G4 is calculated to result in the lowest NO_X and CO_2 emissions of all the options considered
- Inlet air chilling (IAC) on the main refrigeration turbines optimises the efficiency of the turbines over a range of ambient temperatures and humidity, improving annual LNG production. The use of IAC can provide additional power per train to the liquefaction Refrigeration Compressors on a warm day for an investment of less power to the IAC utility plant.

  IAC provide an operational benefit for Upstream operations, as it can provide a stable feed demand throughout daily temperature swings, thus improving the efficiency of upstream operations by reducing personnel and transportation resources through steady operations rather than continually cycling the production flow rates.

5 Bechtel Oil, Gas and Chemicals, Inc. 2008. *BG Queensland Curtis LNG Project: Study Report For CTR #42 – Waste Minimization*

Table 5.12.21 Summary of Best Available Techniques Assessment Outcomes as Applicable to Air Quality (assessment per LNG Train)

Component	Environmental Issue / Constraint	Base Case	BAT Assessment Summary	BAT Outcome
Acid Gas Removal	H_2S	Venting off acid gas: - no incinerator.	Negligible H_2S present in feed gas. Also, given concentration of CO2, additional hydrocarbons would need to be added to incinerator to make it burn, resulting in increased emissions.	Base case retained.
Dehydration and Mercury Removal	TOC/CH_4 emissions arising from operation of fuel gas burner	Fuel gas burner (H-1301). 3 beds, 2 beds on 24 hr adsorption, 1 bed on 12 hrs regeneration/standby with 3.5 hours heating.	WHR to reduce burner requirement. - 3 beds, burner only required on restart. Assume WHR reduces requirement to 5 per cent of year (ie, 95 per cent reduction emissions from base case)	WHR adopted.
Refrigeration gas turbines	NOx	2+2+2 Frame 5D Gas Turbine Drivers	Options considered: • Option 1 2+2+2 Frame 5D Gas Turbine Drivers • Option 2 **2+2+2 LM2500+G4 Gas Turbine Drivers** • Option 3 2+2+2 Electric Motor Drives with LMS100 Power Station Drivers (Simple Cycle) • Option 4 2+2+2 Electric Motor Drives with LMS100 Power Station Drivers (CCGT) NOx discharges of each turbine: Aero derivative engines will be guaranteed at around 25 ppmv NOx. The Frame 5D LHE combustor will operate at around 121 ppm NOx, and the Frame 5D with a DLN1 combustor will produce 42 ppmv NOx. Electric drives partially rejected due to limited reliability and proven technology data.	LM2500+G4 aero-derivative refrigeration driver with Dry Low Emissions (DLE) combustion system selected for the Project, utilising 6 x LM2500+G4s, in 2:2:2 configuration for each 3.8 mtpa LNG train. Estimated reduction in annual NOx emissions from approximately 975 tpa per LNG train (for the Base Case of the Frame 5D) to approximately 580 tpa per LNG train.
Electric Power	NOx	Power generation using Solar Taurus 70's with Solonox. Five operational generators required for Train 1 (plus one spare, for a 5+1 configuration), with an additional three	Options considered on a 2 train basis with Inlet Air Chilling. - Option 1: LM2500+ G4s - 2 Units Online - Option 2: Taurus 70 - 8 Units Online - Option 3: Mars 100: - 6 Units Online - Option 4: Titan 130 - 4 Units Online	LM2500+g4s: 2 operating 1 spare (for 2 Trains or 3 Trains with IAC). Estimated reduction in annual NOx emissions for 2 trains from approximately

Component	Environmental Issue / Constraint	Base Case	BAT Assessment Summary	BAT Outcome
		operational generators required per additional LNG train	LM2500+G4 option results in the lowest NOx emissions.	145 tpa (for the base case) to approximately 124 tpa (for the LM2500+G4 option).
Hot Oil System	CO_2, TOC/CH_4 and NO_x	Heater 3401 - 2 per train. Estimated emissions per train: 83,000 tpa CO_2, 7 tpa TOC/CH_4, 64 tpa NO_x.	WHR would allow reduction of heaters to 1 heater per train, with operation required only on start-up. Assume WHR reduces requirement to 5 per cent of year, this would indicate 95 per cent reduction in emissions from base case.	Waste Heat Recover adopted.
Inlet Air Chilling (IAC)	IAC on refrigeration turbines reduces power requirements and potentially allows for increase in LNG production without an increase in the PFD flow rates. However, reduced power requirement on the refrigeration turbines and increased LNG production is offset by increased demand in electric power. Hence, IAC has the potential to increase emissions (primarily NOx and CO2) associated with turbine operation	No inlet air chilling	Estimates indicate that IAC potentially provides a marginal increase (3.8 per cent) in LNG production per total unit of power generation for the 1 train case, and a slightly greater increase (5.1 per cent) in LNG production per total unit power generation for the 2 train case.	IAC adopted.

12.11 CONCLUSION

The key emissions from the Queensland Curtis LNG (QCLNG) Project's proposed LNG Facility during the operation phase are nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter (PM_{10}). Emissions from LNG carriers also include sulfur dioxide (SO_2).

Air quality modelling took into account predicted operation phase emissions from the proposed LNG Facility, associated shipping, existing emission sources within Gladstone and emissions estimated for the three other proposed LNG projects within Gladstone.

During normal operation, the air quality assessment predicts that there will be no exceedence of the Queensland Environmental Protection (Air) Policy objectives for NO_2, CO, PM_{10}, hydrocarbon species and odorous compounds at any sensitive receptor. The contribution of the LNG Facility to photochemical activity in the Gladstone region was assessed to be, at worst, minor and unlikely to be of concern.

No exceedence of EPP (Air) air quality objectives are predicted for SO_2 emissions from the LNG carriers at any sensitive receptor. However, predicted 1-hour, 24-hour and annual average ground-level SO_2 concentrations exceed air quality objectives in close proximity to the Gladstone Power Station due to power station emissions. Predicted ground-level SO_2 concentrations in close proximity to the LNG Facility fall well below air quality objectives.

During non-normal plant operations (i.e. upset conditions) requiring dry gas flaring, the 1-hour average ground-level concentration of NO_2 is exceeded in close proximity to the Gladstone Power Station when existing emission sources within the Gladstone region are taken into consideration. This is largely attributed to NO_2 emissions from the power station. Predicted ground-level NO_2 concentrations in close proximity to the LNG Facility fall well below air quality objectives.

During non-normal plant operations requiring marine gas flaring, there are no exceedences of air quality objectives for predicted 1-hour average ground-level concentration of NO_2 beyond the boundary of the LNG Facility, taking into account existing emission sources within the Gladstone region. However, the predicted 1-hour average ground-level concentration for NO_2 does exceed the air quality objective in close proximity to the marine flare and wharf facilities.

For both the dry gas flaring and marine gas flaring scenarios, maximum concentrations of CO do not exceed air quality objectives across the modelling domain. Furthermore, predicted ground-level concentrations of hydrocarbons are very low and none are likely to be present in sufficient quantities to cause asphyxiation.

Emissions generated during construction activities are likely to consist of engine exhausts from vehicles and diesel generators (mainly NO_x and CO, with small quantities of hydrocarbons) and from dust generated by earthworks and vehicle movements on sealed and unsealed roads. The generation of air emissions from construction activities will be short-term and intermittent, and can be relatively well managed through the implementation of an Environmental Management Plan (refer Volume 11 for draft EMPs). It is not expected that construction phase emissions will exceed those from normal conditions. A summary of the impacts outlined in this chapter is provide in *Table 5.12.22*.

Table 5.12.22 Summary of Impacts for Air Quality

Impact assessment criteria	**Assessment outcome**
Impact assessment	Negative.
Impact type	Direct.
Impact duration	Long-term for emissions during normal operations. Short-term for emissions during construction, non-normal operations and from LNG carriers.
Impact extent	Local.
Impact likelihood	High for normal operations and shipping. Low for non-normal operations.

Overall assessment of impact significance: minor, for both construction and operations phases.

No exceedences of EPP (Air) air quality objectives are predicted for emissions from the LNG Facility during normal operations, taking into account background levels and other proposed LNG projects. Predicted exceedences of air quality objectives from dry or marine gas flaring during non-normal operations and from LNG carriers are of short duration and are not predicted to occur at sensitive receptors.