8.8 Air Quality

8.8.1 Introduction

An air quality impact assessment of the proposed LNG facility was conducted to address the Term of Reference (ToR) requirements for the EIS relating to air quality. The assessment considered the potential air quality impacts at ground level associated with the construction and operational phases of the facility.

Key findings of the air quality assessment for the proposed LNG facility are described below, with a full copy of the assessment report provided in Appendix S.

8.8.2 Methodology

The air quality assessment included:

- Description of the existing air quality across the study area of the proposed LNG facility;
- An overview of applicable air quality criteria based on relevant Queensland and national legislation and guidelines;
- Estimation of air emissions during the construction and operational phases of the LNG facility development;
- Air quality modelling to predict the potential impacts at sensitive receptors during the operational phases of the LNG facility; and
- A summary of possible mitigation measures which could be incorporated into the LNG facility development to minimise the potential for impacts.

A full description of the LNG facility used as the basis for the assessment is provided in Section 3.

8.8.3 Regulatory Framework

For information on the *Environmental Protection Act 1994* (EP Act) and *Environmental Protection (Air) Policy 2008* (EPP (Air)) refer to Section 6.8.3.

8.8.3.1 National Air Quality Guidelines

National air quality guidelines are specified by the National Environment Protection Council (NEPC). The National Environmental Protection Measure (NEPM) for Ambient Air Quality was released in 1998 (with an amendment in 2003) (NEPC, 2003) and sets standards for ambient air quality in Australia.

The NEPM and EPP (Air) 2008 standards relevant to the project are included in Table 8.8.1. The NEPM standards are intended to be applied at monitoring locations that represent air quality for a region or sub-region of more than 25,000 people and are not used as recommendations for locations near industrial facilities. For this reason, only the EPP (Air) 2008 guidelines have been used in evaluating air quality impacts from the LNG facility.

Table 8.8.1 Relevant Queensland and Australian Guidelines and Standards for Ambient Air Quality

Pollutant	Averaging time	Guideline, Goal or Standard Value	Jurisdiction	Allowable Exceedances
Sulphur dioxide (SO_2)	1 hour	570 µg/m³	EPP (Air) 2008[1], NEPM-Ambient Air	1 day each year
	24 hours	230 µg/m³	EPP (Air) 2008[1] & NEPM-Ambient Air	
	Annual	57 µg/m³	EPP (Air) 2008[1]& NEPM-Ambient Air	
		32 µg/m³	EPP (Air) 2008[3]	
		22 µg/m³	EPP (Air)[2] 2008	
Nitrogen dioxide (NO_2)	1 hour	250 µg/m³ 246 µg/m³	EPP (Air) 2008[1] NEPM-Ambient Air	1 day each year
	Annual	62 µg/m³	EPP (Air) 2008[1] & NEPM-Ambient Air	
		33 µg/m³	EPP (Air) 2008[2]	
Carbon Monoxide (CO)	8 hours	11,000 µg/m³ 11,200 µg/m³	EPP (Air) 2008[1] NEPM-Ambient Air	1 day each year
Total suspended particulates	Annual	90 µg/m³	EPP (Air) 2008[1]	-
PM_{10}	24 hours	50 µg/m³	EPP (Air) 2008[1] & NEPM-Ambient Air	5 days each year
$PM_{2.5}$	24 hours	25 µg/m³	EPP (Air) 2008[1]	-
	Annual	8 µg/m³	EPP (Air) 2008[1]	
Ozone	1 hour	210 µg/m³	EPP (Air) 2008[1] & NEPM-Ambient Air	1 day each year
	4 hour	160 µg/m³ 170 µg/m³	EPP (Air) 2008[1] NEPM-Ambient Air	1 day each year

[1] EPP (Air) 2008 Guideline for human health and wellbeing.
[2] EPP (Air) 2008 Guideline for ecological health and biodiversity (for forests and natural vegetation).
[3] EPP (Air) 2008 Guideline for agriculture.

8.8.3.2 Emission Standards

General emission standards are not specified in either Queensland or national legislation. The NSW Department of Environment and Climate Change (DECC)'s legislation "*Protection of the Environment Operations (Clean Air) Regulation, 2002*" has specified limits on emissions from various activities, including general activities and plants. The NSW DECC emission standards vary depending on the age of the plant. The standards for new plants built since 1 September 2005 has been adopted for this project. The relevant NSW DECC emission concentration standards are presented below in Table 8.8.2. In the table, a reference conditions for the emission standards are provided, only applicable to gas turbines.

Table 8.8.2 NSW Department of Environment and Climate Change's Emission Concentration Standards related to the LNG Facility

Pollutant	Maximum Emission Concentration	Applicable activity	Reference conditions
Nitrogen Oxides	350 mg/m^3	Any activity or plan (with exceptions – many and so not listed here)	Dry, 273 K, 101.3 kPa, and 15% O_2 for gas turbines
Particulate Matter (solid particles)	50 mg/m^3	Any activity or plant, except plant for heating metals, crushing, grinding, separating or material handling	
Carbon Monoxide	125 mg/m^3	Any activity or plant involving combustion except stationary reciprocating internal combustion engine using a gaseous or liquid fuel	

8.8.4 Existing Environmental Values

8.8.4.1 Climate

See Section 8.2 for the climate summary of temperature, rainfall, evaporation, relative humidity, wind speed and wind direction, atmospheric stability, mixing height and temperature inversions.

8.8.4.2 Existing Ambient Air Quality

The existing air quality of the LNG facility study area has been derived from a number of sources including air quality monitoring data from the Environmental Protection Agency (EPA) and other modelling sources. The existing air quality parameters have been used to model impacts of existing and proposed industrial sources in Gladstone to derive cumulative NO_2 and SO_2 impacts.

Gladstone Air Monitoring Data

Air quality monitoring is currently undertaken in the Gladstone region by the EPA, with long-term monitoring sites operated at Targinie, Clinton and South Gladstone. Additional stations have been installed recently as part of the Clean and Healthy Air for Gladstone program. Boat Creek commenced operation in June 2008, Boyne Island (Malpas Street) in August 2008 and Boyne Island (Beacon Avenue) commenced in October 2008. Parameters measured at each of the sites are shown in Table 8.8.3.

Table 8.8.3 Queensland EPA Monitoring Stations in the Gladstone Region

Pollutant	Targinie	Clinton	South Gladstone	Boat Creek	Boyne Island (Malpas Street)	Boyne Island (Beacon Avenue)
Nitrogen oxides (NO_X)	Y	Y	Y	Y	Y	Y
Sulphur dioxide (SO_2)	Y	Y	Y	Y	Y	Y
PM_{10}	Y	Y	Y	Y	Y	Y
$PM_{2.5}$	-	-	Y	Y	Y	Y
Visibility-reducing particles	Y	-	Y	Y	Y	Y
Ozone (O_3)	Y	-	-	-	-	-
Benzene and toluene	Y	-	-	-	-	-

An additional site at Barney Point was operational from 2000 to 2003, monitoring NO_2, SO_2 and PM_{10}.

A summary of the ambient air quality monitoring data in Gladstone, for NO_2, SO_2, O_3 and PM_{10} is provided in Table 8.8.4.

The monitoring results show that the existing levels of NO_2, SO_2 and ozone are well below the relevant EPP (Air) 2008 guidelines at all monitoring sites.

With dust storms in October 2002 and February 2005 excluded, PM_{10} levels from 2001-2007 were below the historical EPA (Air) guideline of 150 µg/m³ (applicable to 31 December 2008) for the 24-hour average concentration, however higher than the new air quality objective of 50 µg/m³ specified in the EPP (Air) 2008.

Table 8.8.4 Air Quality Monitoring Data for Gladstone Region: 2001 to 2007

Pollutant	Averaging time	Maximum pollutant concentration at monitoring location (µg/m³)				Guideline (µg/m³)
		Barney Point	South Gladstone	Clinton	Targinie	
Nitrogen Dioxide (NO_2)	1 hour	84	99	142	99	250 EPP (Air) 2008 246 NEPM
Sulphur Dioxide (SO_2)	1 hour	351	240	377	349	570 EPP (Air) 2008 and NEPM
Ozone (O_3)	1 hour	120	n/a	n/a	n/a	210 EPP (Air) 2008 and NEPM
	4 hour	99	n/a	n/a	n/a	160 EPP (Air) 2008 179 NEPM
Particulate Matter (PM_{10})	24 hour, maximum[1]	82	83	83	93	50 EPP (Air) 2008 and NEPM
	24 hour, 95^{th} percentile				30	50 EPP (Air) 2008 and NEPM

[1] PM_{10} monitoring data, excluding months with dust storms (October 2002 and February 2005)

To model the cumulative impacts for PM_{10} at Gladstone, impacts from background sources are considered as one single, constant level as comprehensive PM_{10} inventories are not available to do air dispersion modelling. The closest monitoring site to the LNG facility (Targinie) has been used to extract information for this constant background PM_{10} level. For the 24-hour averaging time, this constant is taken as 95% of the 24-hour average data for 2001-2007 at Targinie, which is 30 µg/m³.

No data are available for the background concentration of total suspended particulates (TSP), therefore TSP is calculated based on the assumed ratio: PM_{10} /TSP = 60% based on a CSIRO pilot study on Australian fine particles (http://www.cmar.csiro.au/e-print/open/CSIRO_AFP.pdf). Based on this relationship, the annual average TSP level was 30 µg/m³ for Targinie during 2001-2007 (based on the annual average PM_{10} level of 18 µg/m³), which is used as the background level for the cumulative impact assessment.

The records of $PM_{2.5}$ concentration from the Boat Creek and South Gladstone sites are most representative of the project location. There is a limited data set available for $PM_{2.5;}$ five months of data for Boat Creek and one month at South Gladstone. The maximum 24 hour $PM_{2.5}$ concentration recorded during the period June to November 2008 is 20 µg/m³ which will be used as a conservative background level for evaluation of cumulative impacts of $PM_{2.5}$ from the LNG facility and background sources at Gladstone. The annual average concentration cannot be determined from this short monitoring period.

No monitoring is conducted by Queensland EPA in the Gladstone region for carbon monoxide (CO). However, based on results of CO monitoring elsewhere in Queensland, background CO levels are generally very low in comparison to air quality standards. Results indicate CO levels are slightly elevated in areas extremely close to major roadways as motor vehicles are the major emission sources of CO in urban areas. In Queensland, CO is monitored only at selected sites. Monitoring results collected at Woolloongabba in 2007 (sampled within a few metres of major roadways) showed a maximum 8-hour CO level of 1.1 ppm. Results collected from Toowoomba reported a level of 2.2 ppm. Both sets of results are far less than the EPP (Air) guideline of 9.0 ppm, or 11,000 µg/m³. Hence a conservative background CO level of 1.65 ppm (the average of 1.1 and 2.2), or 2,000 µg/m³, is adopted for the 8-hour average concentration.

Modelled Concentration - SO_2 and NO_2

A detailed study of the industrial pollution sources in Gladstone was conducted for the baseline year 2001, as part of the Gladstone Airshed Study. The year 2001 was chosen by EPA as the base year for this study, as detailed databases of industrial emissions, local meteorology and ambient pollutant monitoring were available in the Gladstone region. Air quality and meteorological monitoring stations in Gladstone were used to construct a regional modelling tool, known as the Gladstone Airshed Modelling System (GAMS), to ensure that the existing and approved industrial sources were included in the dispersion modelling for NO_2 and SO_2. Further details on GAMS and the industrial sources are provided in the full air quality impact assessment study in Appendix S.

The following existing industrial sources were included in the GAMS model:

- Boyne Smelters Limited (BSL);
- Cement Australia, formerly Queensland Cement Limited (QCL);
- Rio Tinto Aluminium Yarwun, formerly Comalco Alumina Refinery (CAR);
- Gladstone Power Station (NRG);
- Orica Chemical Complex (Orica);
- Queensland Alumina Limited (QAL); and
- Queensland Energy Resources, formerly Southern Pacific Petroleum Oil Shale (SPP).

The concentration data predicted by GAMS for Boyne Smelters Limited (BSL) were scaled up by a factor of 40 % to account for the expansion of the smelter that took place since the emissions inventory used in GAMS was prepared for 2001 data. The impacts predicted in GAMS for CAR are based on Stage 1 of the project as predicted impacts for Stage 2 of the project are currently not available.

The former SPP project is scheduled to restart in the near future, with significant changes to the project operation proposed. No updated emissions inventory for the site is available so for conservatism the emissions data included in GAMS have been used for this assessment as suggested by EPA.

Additionally, the following proposed industrial sources were included in the background modelling:

- Gladstone Pacific Nickel Refinery, proposed by Gladstone Pacific Nickel;
- Sun LNG Project, proposed by Sunshine Gas and Sojitz Corp; and
- Gladstone LNG Project, proposed by Arrow Energy and LNG Ltd.

Both the Sun and Gladstone LNG projects are proposed to be located at Fisherman's Landing at Gladstone. There are other proposed LNG projects for Curtis Island, however emissions data is not publicly available for these projects (as of November 2008) and hence has not been included in the background modelling.

A summary of the highest modelled air quality impacts of background sources of NO_2 and SO_2 at various sensitive receptor locations around Curtis Island and Gladstone and at the EPA's monitoring sites are presented in Table 8.8.5. The sensitive receptors evaluated in the assessment are located within a 10 km radius of the LNG facility study area and are representative of residential locations on Curtis Island and Gladstone. The locations of the sensitive receptors are shown in Figure 8.8.1.

Table 8.8.5 shows that the modelled background NO_2 and SO_2 concentrations were below the Queensland EPA ambient air quality guidelines at all sensitive receptor locations. A comparison to monitoring data shows that the model over-predicts ambient air quality impacts of NO_2 near industrial sources and will therefore over-predict potential NO_2 impacts near the LNG facility.

Table 8.8.5 Modelled Ground Level Concentrations of NO_2 and SO_2 due to Existing and Proposed Industrial Sources in the Gladstone Region (excluding GLNG Project)

Receptor Group	NO_2 (µg/m³)		SO_2 (µg/m³)		
	1 hour, 99.9th	Annual	1 hour, 99.9th	24 hour	Annual
Curtis South End & Quoin Island Community	25	0.4	73	18	2.3
Curtis Island Parkland	29	0.5	73	21	3.1
Curtis Island Industry Precinct	57	0.7	124	27	2.7
Gladstone	81	1.8	173	42	5.9
Gladstone Airport	163	2.8	321	85	7.3
Gladstone Industry	85	3.6	335	73	7.0
Gladstone Wetland areas	83	2.1	278	54	6.1
Clinton Precinct	195	1.8	396	71	5.1
Yarwun Precinct	112	8.0	269	64	19.2
Targinie Precinct	61	2.4	196	38	7.8
EPA monitoring sites	167	3.9	328	83	13.3
EPP (Air) 2008 Guideline	**250**	**62[1] , 33[2]**	**570**	**230**	**57[1], 32[3], 22[2]**

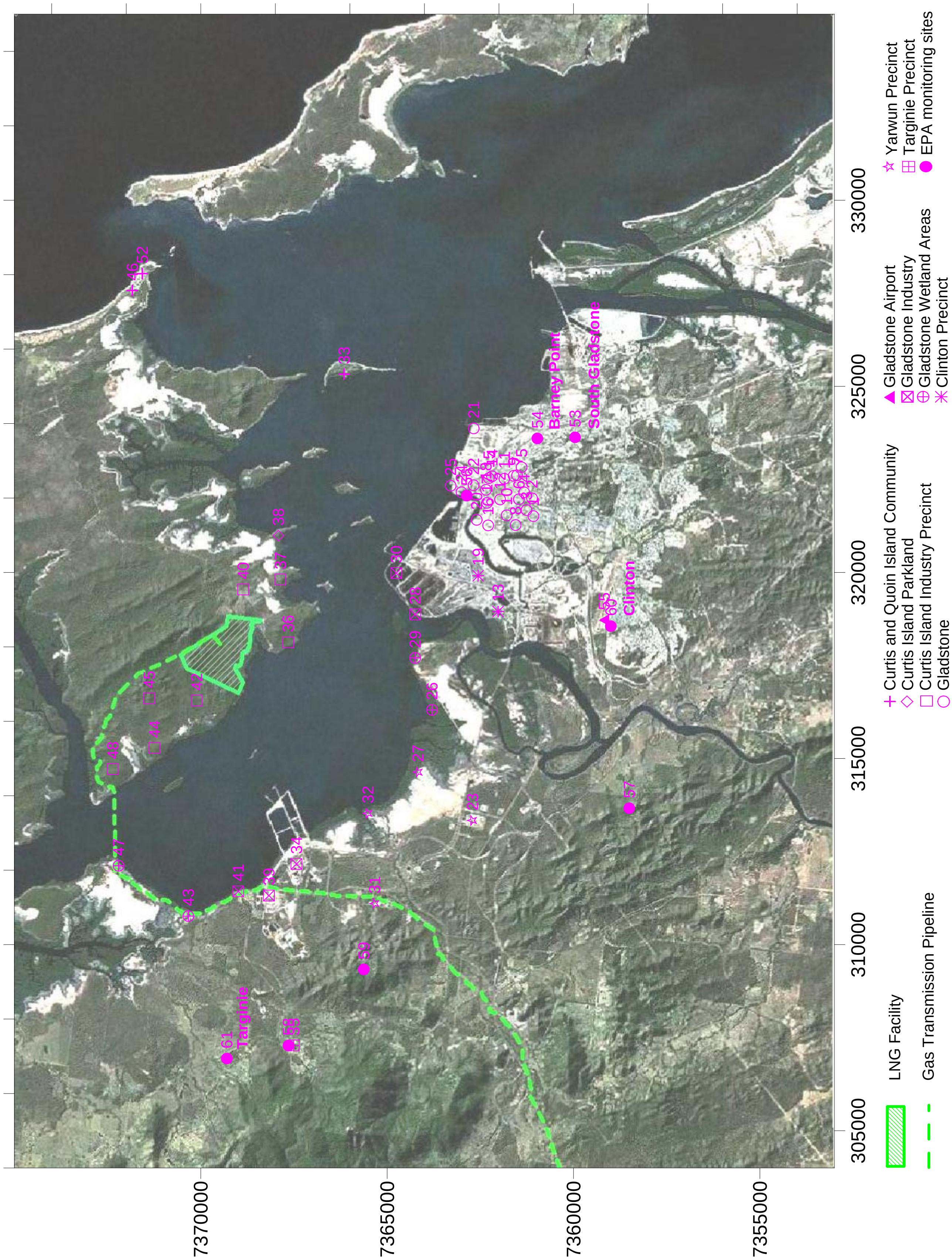
[1] For human health and wellbeing
[2] For the health and biodiversity of ecosystems (protecting forests and natural vegetation)
[3] For protecting agriculture

8.8.5 Potential Impacts and Mitigation Measures

For the LNG facility (as part of a dual pre-FEED (Front End Engineering Design) process), two separate engineering designs were initially evaluated for the air quality impacts as presented in Appendix S. In late 2008 Santos selected the Optimised Cascade Process (OCP) design as the preferred technology to be used for the LNG facility. Subsequently, only assessment for this design is presented in this section.

8.8.5.1 Description of Activities

Construction will include site preparation, the construction of LNG trains and storage facility, product loading facility (PLF), materials offloading facility (MOF), potential bridge and general infrastructure (i.e. roads, temporary buildings, bunds). During normal operations activities will include removal of CO_2 and trace sulfur-containing compounds (collectively called acid gas), gas liquefaction using refrigeration compressor gas turbines, and nitrogen removal, LNG gas storage, and transfer to ship loading facilities. Gas-fired power generators will be used to provide power for the LNG facility. Flaring will occur during plant upset conditions or scheduled shut down and start up for maintenance, with flare pilots on during normal operation. See Section 3.8 for a full description of the LNG facility and conceptual process flow diagram during normal operation.



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Datum: MGA94, Zone 56

Client: LNG / URS	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT		Title: **AIR QUALITY SENSITIVE RECEPTOR LOCATIONS IN GLADSTONE AREA**
Drawn: LF	Approved: JB	Date: 27-02-2009	Figure: **8.8.1** Rev B
Job No: **4262 6220**	File: 42626220-g-880b.srf		A4

This project will comply with the Santos document *EHS Management System Hazard Standard, EHS05 Air Emissions.* Santos strives to meet air quality guidelines through new facility EIS assessment, qualifying emissions through direct monitoring or estimation techniques, recording external and internal complaints related to offensive air emissions or odour, and establishing and maintaining an air quality monitoring program if required by relevant environmental agency.

8.8.5.2 Emission Rates

Emissions During Construction

Emissions

Emissions to air during construction and decommissioning of the LNG facility and associated infrastructure will be primarily dust, with some minor sources of combustion pollutants such as NO_x due to diesel and petrol vehicles operating on site.

Emissions will be generated from a number of sources including:

- Clearing of vegetation and topsoil;
- Excavation and transport of earth material;
- Vehicle travelling on unpaved roads;
- Vehicle exhaust; and
- Barge and ferry exhaust.

Mitigation Measures

The impacts of construction activities will be managed though the Environmental Management Plan (EMP). This will include strategies to prevent or minimise dust emissions during construction activities, an outline of methods to monitor the effects of construction activities, and documentation of procedures that will be implemented to mitigate any adverse off-site impacts.

Mitigation measures to reduce potential emissions during construction activities are listed below. They are best practice management tools for construction site dust control.

- The land cleared for construction purposes will be kept to the minimum necessary, especially during the drier months of the year;
- The number and sizes stockpiles should be kept to minimum;
- The cleared areas and stockpiles will be progressively rehabilitated through revegetation and/or mulching; and
- Dust suppression shall be undertaken during construction and clearing activities, particularly during high wind conditions. Haul roads and other unsealed areas may be watered to suppress dust.

Mitigation measures to reduce vehicle and machinery exhaust emissions include, as suggested by Victoria EPA (1996) include:

- Ensure that all vehicles and machinery are fitted with appropriate emission control equipment, maintained frequently and serviced to the manufacturers' specifications; and
- Smoke from internal combustion engines should not be visible for more than ten seconds.

Mitigation measures to reduce potential emissions during decommissioning activities are similar to requirements for construction, and are listed below.

- The number and sizes of stockpiles should be kept to minimum;
- Rehabilitation of disturbed areas shall be undertaken to the maximum extent possible through revegetation and/or mulching; and

- Dust suppression shall be undertaken during construction and clearing activities, particularly during high wind conditions. Haul roads and other unsealed areas may be watered to suppress dust.

Emissions During Normal Operation

Emissions

Emission sources identified for the LNG facility during normal operation include:

- Refrigeration compressor gas turbines;
- Power generators (gas turbines);
- Flare pilots;
- Nitrogen vent;
- Regeneration gas heater;
- Hot oil heater;
- CO_2 vent, and
- Fugitive emission sources such as valves, flanges, pump seals, connectors, compressors and vents.

As presented in Table 8.8.6, emissions from the LNG facility were considered for the operational capacities of 3 Mtpa and 10 Mtpa, with a detailed emission inventory provided in Appendix S. Emission quantities were estimated based on vendor's data and the Australian National Pollutant Inventory (Oil & Gas Exploration and Production) Emission Estimation Technique Manual.

Emissions of $PM_{2.5}$ were not provided by the equipment vendor. Since this facility will be burning only CSG in combustion sources, the particulate matter emitted will consist of aerodynamic diameter particles (typically less than 1 μm) and hence the $PM_{2.5}$ emissions have been assumed to be equivalent to the PM_{10} emissions.

The total non-methane VOC emissions, not listed in Table 8.8.6, were estimated to be approximately 0.95 g/s for a single LNG train (3 Mtpa production), based on National Pollutant Inventory (NPI) methods.

The emissions from refrigeration compressor turbines and power generators were compared with in-stack emission standards as presented in Table 8.8.7, for NO_x, particulate matter, and CO emission rates. Their emissions are all under the emission standards.

Emission estimates for minor emission sources not detailed above for each of the key pollutants groups (required by the ToR) are provided below in Table 8.8.8.

Table 8.8.6 Continuous Air Emissions from the LNG Facility for 3 Mtpa and 10 Mtpa Cases (emission parameters per stack)

Source Name	Number of stacks		Stack height (m)	Stack diameter (m)	Temp (K)	Exit velocity (m/s)	Pollutant emission rate (g/s) per equipment			
	3 Mtpa	10 Mtpa					PM_{10}	SO_2	NO_x	CO
Refrigeration Compressor Turbines	6	18	28.3	2.7	607	31	0.20	<0.001	3.23	1.94
Power Generators	5	11	36	1.1	811	38	0.04	<0.001	0.70	0.43

Source Name	Number of stacks		Stack height (m)	Stack diameter (m)	Temp (K)	Exit velocity (m/s)	Pollutant emission rate (g/s) per equipment			
	3 Mtpa	10 Mtpa					PM_{10}	SO_2	NO_x	CO
Flare pilots	As 1[*]	As 1[1]	87	1.5	1273	20	0.01	0	0.17	0.14
Nitrogen Vent	1	3	32	6.8	296	37	0	0	0	0
Regeneration Gas Heater	2	6	37	1	547	22	0.03	0	0.34	0.28
Hot Oil Heater	2	6	50	2.5	570	17	0.09	0	1.18	0.99
CO_2 Vent	1	3	16	0.84	296	13	0	0	0	0

Table 8.8.7 In Stack Emission Concentrations for the LNG Facility

Emission concentrations	Particulate Matter (mg/m³)	NO_x (mg/m³)	CO (mg/m³)
Refrigeration Compressor Turbines	1.8	29	17
Power Generators	1.2	21	13
Relevant NSW emission standards	**50**	**350**	**125**

Table 8.8.8 Other Emission Sources and Quantities

Pollutant Group	Emission Quantity	Comment
Acidic/caustic aerosols	Not Applicable (N/A)	Not present or trace amounts in CSG.
Carbonyl compounds		
Coal and coal dust		
Fluorides		
Metals		
Polychlorinated biphenyls (PCB)		
Radionuclides		
Polycyclic aromatic hydrocarbons (PAHs)	Released in trace amounts through incomplete combustion of gas.	Emissions of PAHs are very low and have not been modelled.
Sulphur	N/A	Very little sulphur content in CSG. No sulphur added during industrial process.
Mercury	N/A	No mercury in CSG based on gas composition data.
Metal fumes	N/A	No welding- which is key source of metal fumes
Ozone	N/A	Secondary pollutant, which is not directly emitted from stacks
VOC	Most VOC emissions are in the form of methane (as 96.9% of CSG is methane)	Methane in CSG is key source of VOC. Minor sources are fugitive emission sources such as valves, flanges, pump

[1] Dry and wet flare stacks have been modelled as one effective stack.

Pollutant Group	Emission Quantity	Comment
	Negligible amounts of other VOCs released through incomplete combustion of gas	seals, connectors and others. Methane is addressed in Section 6.9. Emissions of VOCs (e.g. formaldehyde, benzene, toluene and xylene) are very low and have not been modelled.
Odour	Minor	Minor odour associated with oxides of nitrogen (NO_x), and to a lesser extent due to non-methane VOCs.

Carbon dioxide and methane emissions are discussed in Section 8.9.

Emissions During Upset Conditions

The LNG facility will be designed in accordance with applicable safety standards and guidelines to minimise the likelihood of plant upset conditions occurring. The design uses the operating principle that the flares on site act as the back-up measure for releases of gas or refrigerants from the site in the event of a process or equipment failure. For further information refer to Section 10.4.8.

Emissions

Upset scenarios were provided by Santos to represent the possible situations that may lead to gas release through the flares. These include the following scenarios:

- **Scheduled maintenance**: scheduled shut-down and start-up for maintenance inspection, which occurs every three years, and lasts for three hours. This upset condition has been modelled by assuming that the refrigeration compressors and power generation turbines for one train are taken off-line during maintenance, and the gas for this train is diverted to the emergency flare.
- **Controlled relief**: due to blocked outlets to the propane compressors (typically approximately 15 minute duration). This scenario has not been modelled as likelihood of occurrence is rare, and may never happen during the lifetime of the facility's operation.
- **Emergency shut down**: rare or may never happen during the lifetime of the project. This scenario has not been modelled.
- **Warm ship load out**: load-out of LNG to a ship when the ship is warm, occurring probably once in three years. It will take approximately 24 hours to cool the ship down using LNG, much of which will be boiled off and recycled back to the LNG facility for re-liquefaction. This scenario has not been modelled as much of the methane gas is recycled back to the LNG facility.

Only scheduled maintenance has been modelled for compressor train emissions, with emission rates detailed in Table 8.8.9 for one compressor train undergoing scheduled maintenance. For the 10 Mtpa case, only one compressor train will be under scheduled maintenance at any one time, with the other two compressor trains operating normally as detailed in Table 8.8.6.

Table 8.8.9 Upset Emissions for one Compressor Train Undergoing Scheduled Maintenance

Source Name	Number of stacks	Stack height (m)	Stack diameter (m)	Temp (K)	Exit velocity (m/s)	Pollutant emission rate (g/s) per equipment			
						PM_{10}	SO_2	NO_x	CO
Power Gen.	3	36	1.1	811	38	0.04	0	0.7	0.4
Dry flare	1	126[1]	8.4[1]	1,273	20	0	0	17.9	97

[1]The effective stack height and diameter (accounting for flame length and diameter during scheduled maintenance event) were used to model flares, as detailed in Appendix S.

Emission Controls

The design of the LNG facility is based on the philosophy of minimising air emissions through efficient, low emissions equipment design, instead of relying on end-of-pipe process controls to achieve the required levels of emission reduction for the plant equipment. Design measures that have been incorporated in the equipment specification to reduce air quality emissions include the following:

- Generation of onsite power using clean methane gas for plant requirements to avoid reliance on coal-fired power sources from the Queensland power grid;
- Use of Dry-Low NO_x technology in refrigeration compressors and power generation turbines to reduce NO_x emissions;
- Injection of air into elevated flares to produce smokeless flares, thereby reducing particulate matter emissions;
- As part of the carbon dioxide removal process, careful selection of solvent to minimise the co-release of methane; and
- The use of boil off gas (BOG) as fuel rather than flaring to reduce emissions from flares and to improve overall plant energy efficiency.

The design philosophy adopted for the LNG facility encompasses the use of Best Available Technology Not Entailing Excessive Cost (BATNEEC). In addition, the GLNG Project policy is for minimal discharge of all wastes. Environmental considerations will be included throughout the LNG facility's construction, operations and decommissioning phases.

Further refinement of the facility design is currently underway as part of the FEED process, with consideration being given to the use of the following technologies:

- Incorporation of waste heat recovery units on gas turbine exhausts to provide process heat for use elsewhere in facility and to reduce the operational requirements for gas-fired heaters; and
- Evaluation of a thermal oxidiser for the nitrogen removal unit to combust traces of methane that escape with this vent if demonstrated to result in a net energy efficiency and greenhouse gas reduction for the project.

Other opportunities for reduction in plant emissions will be identified through the detailed FEED design, with cost-effective and energy-efficient measures implemented in the project.

Mitigation Measures

The LNG facility incorporates mitigation measures in the equipment design and these have previously been described in Section 8.8.5.2. Additional measures to reduce impacts of SO_2, CO and particulate matter are not required for the project, as demonstrated by the low impacts of these pollutants.

To address concerns of residents regarding health impacts, Santos will provide relevant data to Queensland EPA on the LNG facility emissions, for use in the Queensland EPA's "Clean and Healthy Air for Gladstone" project. This information will form part of the cumulative health risk assessment that Queensland Health is conducting.

NO_x emissions are the primary air quality concern for this project despite the inclusion of low NO_x emission technologies in the equipment designs. The installation of in-stack NO_x monitoring to characterise actual emissions during the operational phase of the project will enable NO_x concentrations outside the site boundary to be determined given the likely overestimations of NO_x during modelling.

8.8.5.3 Air Dispersion Modelling

Methodology

GAMS uses the Calpuff dispersion model (Scire, 2000) to predict ground-level concentrations of emissions. Calpuff was developed for the United States EPA and is accepted by Queensland's EPA as a suitable model for predicting air quality impacts in the Gladstone region. Wind data for the year 2001 have been used and were generated using the Calmet meteorological model to predict the wind flows over the Gladstone region.

Emission modelling was undertaken for NO_x, particulate matter (as TSP, PM_{10} and $PM_{2.5}$) and CO for normal and upset conditions at 51 sensitive receptors (refer to Figure 8.8.1).

No modelling was undertaken for photochemical smog as there are no comprehensive volatile organic compounds (VOC) emission inventories in Gladstone. In addition, photochemical smog is currently not considered to be an issue in Gladstone as ozone monitoring data at Barney Point (Table 8.8.4) shows that ozone levels at Gladstone did not exceed any air quality guidelines.

The parameters of the model are provided in detail in Appendix S including all environmental and modelling considerations such as building downwash effects.

The emissions of NO_x from the LNG facility were estimated to contain only a small proportion of NO_2 (~10%) at the point of emission. As the plume travels downwind, it mixes with ambient air and can react with photochemical precursors (such as ozone and reactive VOC) to form more NO_2. The extent of this oxidation reaction is determined by the photochemical state of the air and the presence of sunlight. GAMS has assumed that up to 35% of the NO_x has been oxidised to NO_2 at the receptor location, based on analysis of long-term ambient monitoring data. This ration has also been used in evaluation of modelling results.

Results for averaging times of 1-hour or less are presented as the 99.9^{th} percentile of the hourly data. This is the same as the ninth-highest hour of predicted model results for the year of modelling, and is used to accommodate spurious model results that can over-estimate the 1-hour average concentration. Results for other averaging times are reported as the maximum concentration.

Limitations and Accuracy of the Models

The model limitations may include

- The limitations of GAMS;
- The limitations of using a constant NO_2/NO_x ratio;
- The limitations of using constant background levels for particulate matter and CO; and
- The limitations of using pre-FEED emissions rather than FEED emission estimates.

GAMS tends to over-predict peak ambient NO_2 concentrations at ground level for the existing industrial sources (see Appendix S for details). The use of constant NO_2/NO_x ratio of 35% will significantly over-predict NO_2 concentrations for receptors that are located close to the facility, which is also applicable to the existing industrial sources that have been modelled in GAMS. The conservative choice of constant background levels of particulate matter and CO will result in over-prediction of cumulative impacts, particularly for receptors at Curtis Island that are not immediately adjacent to industrial activities.

To confirm the accuracy of the model predictions, a monitoring program will be implemented for operation of the LNG facility. The monitoring program will be part of the EMP.

Predicted Ground Level Concentrations - Normal Operations

At sensitive receptors, the maximum modelled values for NO_2, are provided in Table 8.8.10 and Table 8.8.11 for the 3 Mtpa and 10 Mtpa LNG facility scenarios. The NO_2 concentration for the LNG facility in isolation is predicted to be well below guidelines, and the cumulative impacts are also below the EPP (Air) 2008 guidelines at sensitive receptor locations. The predicted 1-hour and annual NO_2 concentrations impacted the LNG facility in isolation for the 10 Mtpa case are presented in Figure 8.8.2 and Figure 8.8.3 as contour plots; and the predicted cumulative impacts are presented in Figure 8.8.4 and Figure 8.8.5. In Figure 8.8.4, the cumulative impacts of 1-hour NO_2 concentrations exceed the EPP (Air) 2008 guideline of 250 µg/m³ for human health and wellbeing, but only in the area very close to an existing industrial source at Gladstone. This exceedance, which may only occur within that industrial facility, is over-predicted due to the use of 35 % as ratio of NO_2 to NO_x.

The SO_2 impacts from the LNG facility were predicted using the alternative pre-FEED design as more conservative emission estimates were provided for the alternative design (see details in Appendix S). The predicted impacts in isolation are very low, with maximum impacts of 0.3 µg/m³ for 1-hour averaging time, 0.1 µg/m³ for 24-hour averaging time, and less than 0.05 µg/m³ for the annual average concentration. Those are the maximum impacts for all scenarios and for any locations outside the LNG facility boundary, and are less than 0.1 % of respective guidelines for the facility in isolation. Cumulative impacts of SO_2 are dominated by the existing industrial sources of SO_2, and are not appreciably affected by the operation of the LNG facility.

The predicted PM_{10} impacts of the LNG facility were low, with the maximum 24-hour average PM_{10} of 2.0 µg/m³ among all sensitive receptors due to the facility in isolation. When combined with the constant background level of 30 µg/m³, the cumulative impacts meet the 24-hour EPP (Air) 2008 guideline of 50 µg/m³. Emissions of TSP and $PM_{2.5}$ were assumed to be equivalent to PM_{10}, resulting in the same incremental impact of these pollutants. The predicted maximum impact of annual average TSP from the LNG facility in isolation is 0.8 µg/m³, and the maximum cumulative impact is 31 µg/m³, well below the EPP (Air) 2008 guideline of 90 µg/m³. The maximum predicted 24 hour average concentration of $PM_{2.5}$ is 22 µg/m³, below the EPP (Air) 2008 guideline of 25 µg/m³ and governed by the background concentration. The annual average $PM_{2.5}$ concentration cannot be combined with a background level, as no relevant data are available, however the incremental concentration of 0.8 µg/m³ is only 10 % of the guideline of 8.0 µg/m³ and so would not cause exceedance of the guideline. Further details on the predicted dust impacts are presented in Appendix S.

Full assessment of $PM_{2.5}$ has not been conducted due to the lack of sufficient air quality monitoring data at Gladstone that can be used to derive realistic background level. The particulate emissions from the LNG facility are small in size as they are mainly from gas turbines and hence conservatively we assume that all PM_{10} are $PM_{2.5}$. Hence, impacted by the LNG facility alone, the maximum 24-hour average $PM_{2.5}$ concentration at ground level among all sensitive receptors is 2.0 µg/m³. When combined with the constant background level of 20 µg/m³, the cumulative impacts meet the 24-hour EPP (Air) 2008 guideline of 25 µg/m³.

The predicted CO impacts of the LNG facility emissions were very low, with a domain maximum 8-hour average CO concentration of 92 µg/m³ for the 10 Mtpa scenario. The cumulative impacts of CO meet the guideline of 11,000 µg/m³, however it should be noted that background CO levels are neither monitored at Gladstone nor modelled by GAMS and were based on an assumed 8-hour background level of 2,000 µg/m³ (refer Appendix S).

Table 8.8.10 Maximum Modelling Results at Ground Level Sensitive Receptors for 3 Mtpa Production for NO_2 (µg/m³)

Receptor Group	Due to the LNG Facility in isolation		Due to the LNG Facility plus background	
	1 hour 99.9th	Annual	1 hour 99.9th	Annual
South End & Quoin Island Community	1.4	0.01	25	0.4
Curtis Island Parkland	2.4	0.02	29	0.6
Curtis Island Industry Precinct	16.7	0.94	57	1.7
Gladstone	1.6	0.02	81	1.8
Gladstone Airport	0.9	0.01	163	2.8
Gladstone Industry	3.7	0.06	85	3.6
Gladstone Wetland areas	4.2	0.15	83	2.1
Clinton Precinct	1.8	0.02	195	1.8
Yarwun Precinct	3.8	0.06	112	8.0
Targinie Precinct	1.1	0.02	61	2.4
EPA monitoring sites	1.9	0.03	168	4.0
EPP (Air) 2008 Guideline	**250**[1]	62[1] **33**[2]	**250**[1]	62[1] **33**[2]

[1] Guideline for Human Health
[2] Guideline for Ecological Health

Table 8.8.11 Maximum Modelling Results at Ground Level Sensitive Receptors for 10 Mtpa Production for NO_2 (µg/m³)

Receptor Group	Due to the LNG Facility in isolation		Due to the LNG Facility plus background	
	1 hour 99.9th	Annual	1 hour 99.9th	Annual
South End & Quoin Island Community	4.2	0.04	25	0.4
Curtis Island Parkland	6.4	0.06	29	0.6
Curtis Island Industry Precinct	30.5	2.12	58	2.8
Gladstone	5.0	0.06	82	1.9
Gladstone Airport	2.8	0.04	164	2.9
Gladstone Industry	10.4	0.21	85	3.7
Gladstone Wetland areas	10.7	0.37	83	2.2
Clinton Precinct	5.2	0.06	195	1.8
Yarwun Precinct	11.2	0.18	112	8.1
Targinie Precinct	3.2	0.06	61	2.5
EPA monitoring sites	5.6	0.09	168	4.0
EPP (Air) 2008 Guideline	**250**[1]	**62**[1] **33**[2]	**250**[1]	**62**[1] **33**[2]

[1] Guideline for Human Health
[2] Guideline for Ecological Health

Predicted Ground Level Concentrations - Upset Conditions

The maximum modelling results at sensitive receptors for the maintenance upset condition are provided in Table 8.8.12. Results indicate that the EPP (Air) 2008 1-hour NO_2 guideline of 250 µg/m³ will not be exceeded for any emission scenario as a stand alone industrial facility or with consideration of background emission sources in Gladstone, for any sensitive receptors. The predicted 1-hour NO_2 concentrations due to the LNG facility and background sources, for the 10 Mtpa case and for the maintenance upset condition are presented in Figure 8.8.6. The predicted impacts for this upset condition are similar to or slightly lower than normal operating conditions. Further discussion on this is presented in Appendix S.

Table 8.8.12 Maximum Modelling Results at Ground Level Sensitive Receptors for 10 Mtpa Production for NO_2, for the Maintenance Upset Condition

Receptor Group	NO_2 (µg/m³) 1-hour 99.9th percentile	
	LNG Facility in Isolation	LNG Facility plus Background
South End & Quoin Island Community	3	25
Curtis Island Parkland	5	29
Curtis Island Industry Precinct	26	57
Gladstone	3	82
Gladstone Airport	2	164
Gladstone Industry	7	85
Gladstone Wetland areas	8	83
Clinton Precinct	4	195
Yarwun Precinct	8	112
Targinie Precinct	2	61
EPA monitoring sites	4	168
EPP (Air) 2008 Guideline	**250 (for human health)**	

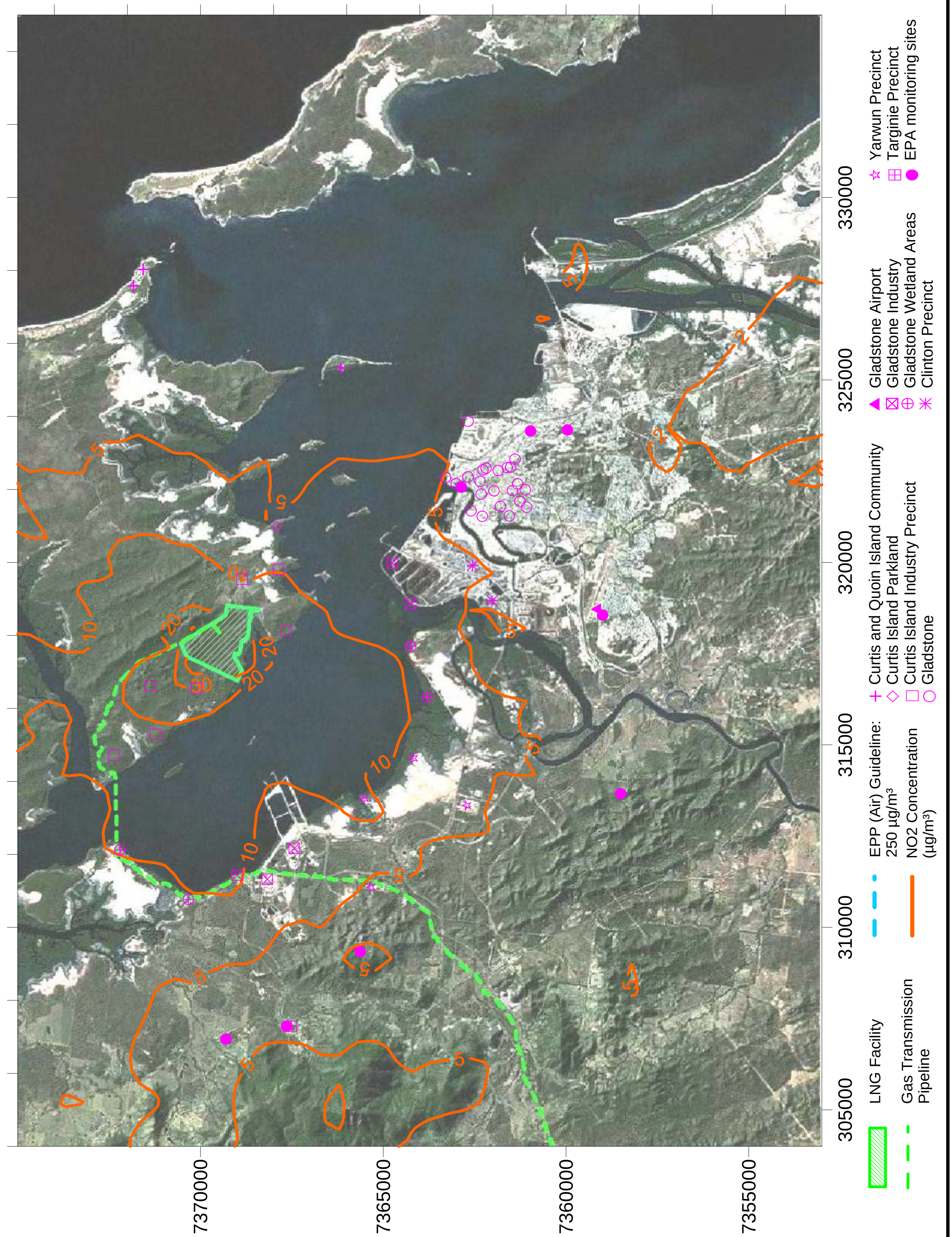
Human Health Risk Assessment

Potential human health impacts from activities at the LNG facility will come from NO_x, SO_2, CO, and particulate matter emissions from the LNG compressor trains during normal operation, dust emissions during construction, and minor VOC emissions.

Air dispersion modelling has predicted ground level NO_2 concentrations below the EPP (Air) 2008 guidelines for human health. Modelling results also show that the impacts from the facility's SO_2, CO, and particulate emissions are negligible. These results demonstrate that a human health risk assessment for these pollutants is not required, as the pollutant impacts satisfy air quality guidelines that are intended to protect human health.

A health risk assessment was considered for potential releases of hazardous or toxic materials from the LNG facility. The LNG facility is not expected to release significant amounts of hazardous or toxic materials. Known major emissions of VOCs such as methane and ethane are not considered to be toxic. On this basis, a health risk assessment of VOCs has not been conducted.

The human health impacts from dust emissions during the construction of the LNG facility have not been assessed through air dispersion modelling as their impacts are expected to be low. However, mitigation measures will be in place to minimise their impacts.



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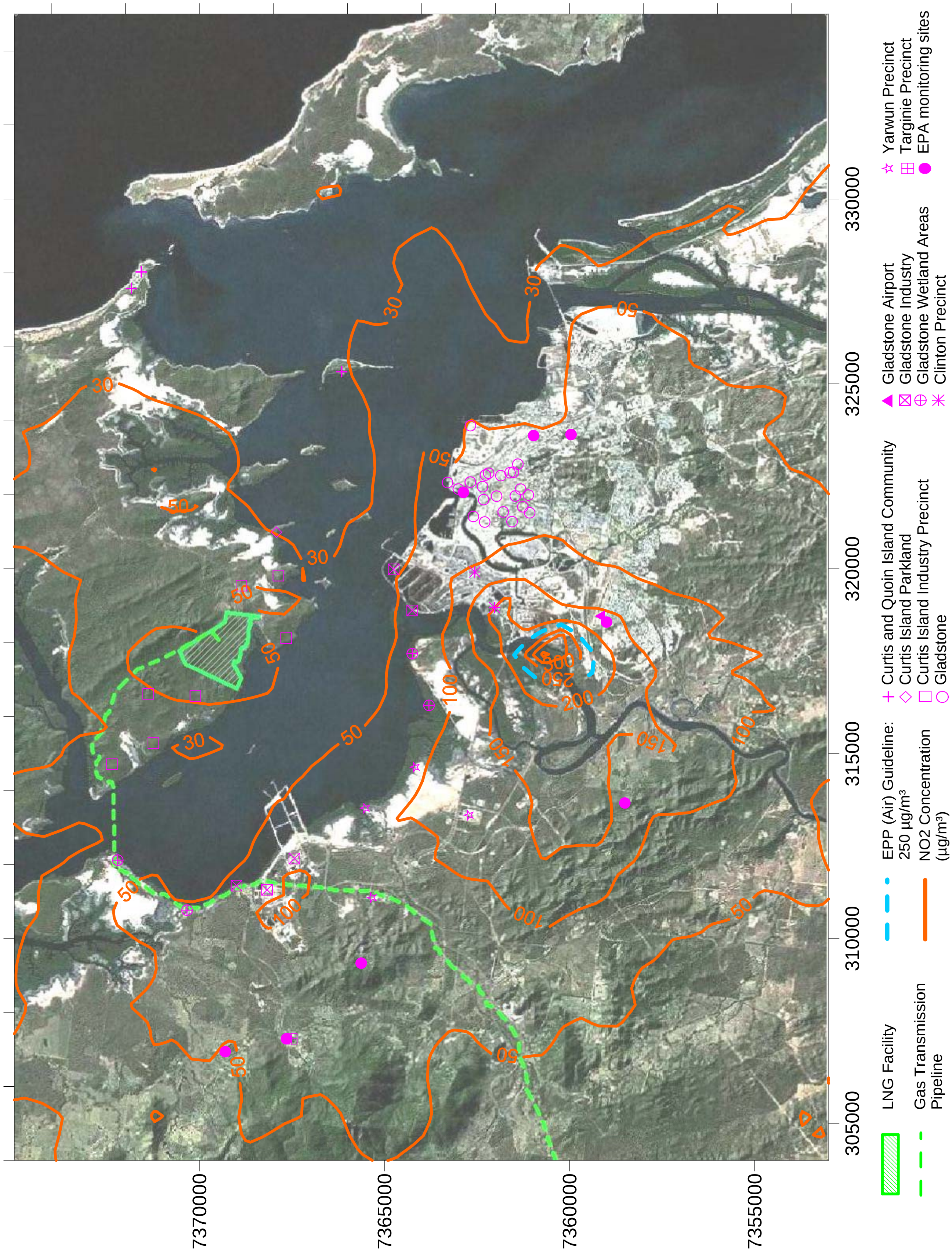
Datum: MGA94, Zone 56

Client: LNG URS

Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT

Title: **99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO THE LNG FACILITY IN ISOLATION FOR 10 MTPA PRODUCTION**

Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **8.8.2** Rev A
Job No: **4262 6220**	File: 42626220-g-881.srf		A4



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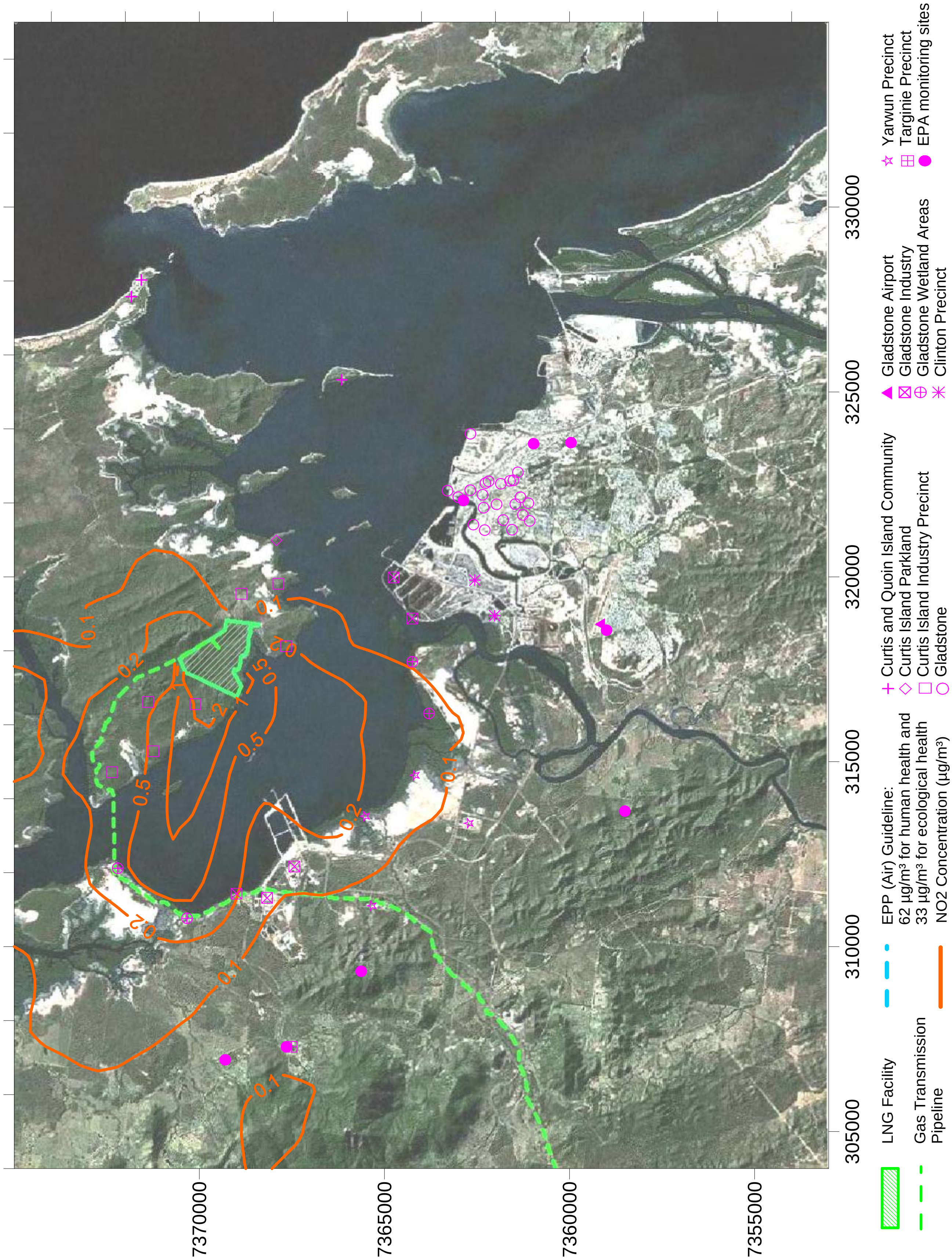
Datum: MGA94, Zone 56

Client:	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT			Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO The LNG FACILITY PLUS BACKGROUND SOURCES FOR 10 MTPA PRODUCTION	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **8.8.3**	Rev A
	Job No: **4262 6220**	File: 42626220-g-882.srf			A4



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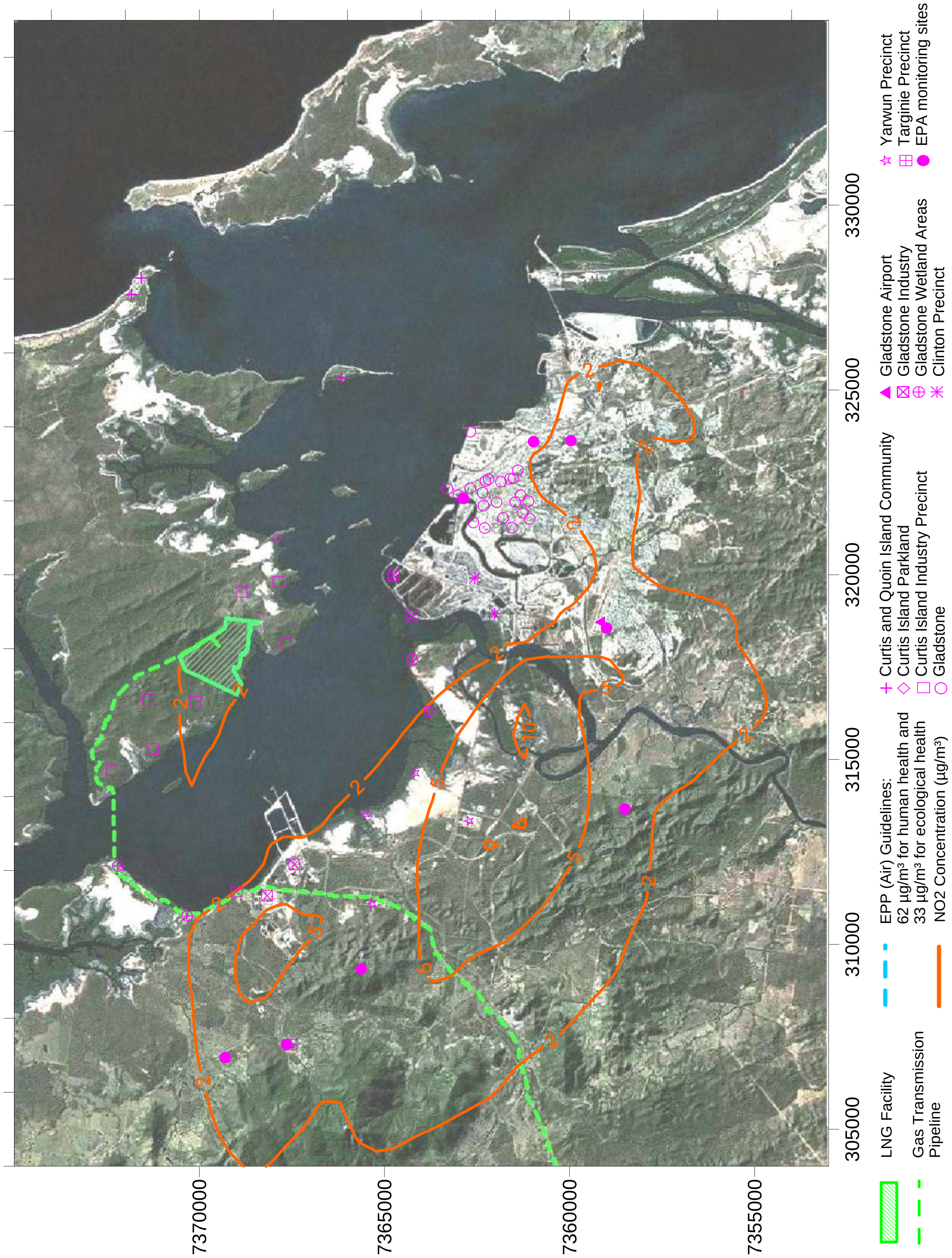
Datum: MGA94, Zone 56

Client:	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT			Title: **ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO THE LNG FACILITY IN ISOLATION FOR 10 MTPA PRODUCTION**
LNG / URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **8.8.4** — Rev A
	Job No: **4262 6220**	File: 42626220-g-883.srf		A4



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Datum: MGA94, Zone 56

Client:	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT			Title: ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO THE LNG FACILITY PLUS BACKGROUND SOURCES FOR 10 MTPA PRODUCTION	
URS	Drawn: LF	Approved: JB	Date: 20-01-2009	Figure: **8.8.5**	Rev A
	Job No: **4262 6220**	File: 42626220-g-884.srf			A4

This report is based on the preliminary Pre-FEED data and thus cannot be reasonably compared to best practice operations. Design specifications for the FEED design are to surpass the NSW DECC emission standards, as well as meet or surpass ambient air quality standards. Thus the final FEED design will ensure no significant human health risks.

Currently the EPA is conducting a comprehensive health risk assessment in the Gladstone region. This study is expected to provide a much broader picture on the cumulative health risks in the Gladstone region. Santos GLNG will participate in the Queensland EPA's "Clean and Healthy Air for Gladstone" project and will provide site emissions data as appropriate for use in the EPA's health risk assessment.

Odour Assessment

Odour is often of concern for industrial facilities. Coal seam gas and LNG do not contain strong odorous compounds. Minor odour associated with oxides of nitrogen (primarily due to NO) is not a concern due to the relatively low levels of these pollutants released and the distance from the facility to residential locations. The odour related to non-methane VOC releases is not of concern either as their emissions from the LNG facility are very low, and emissions such as ethane and propane are odourless.

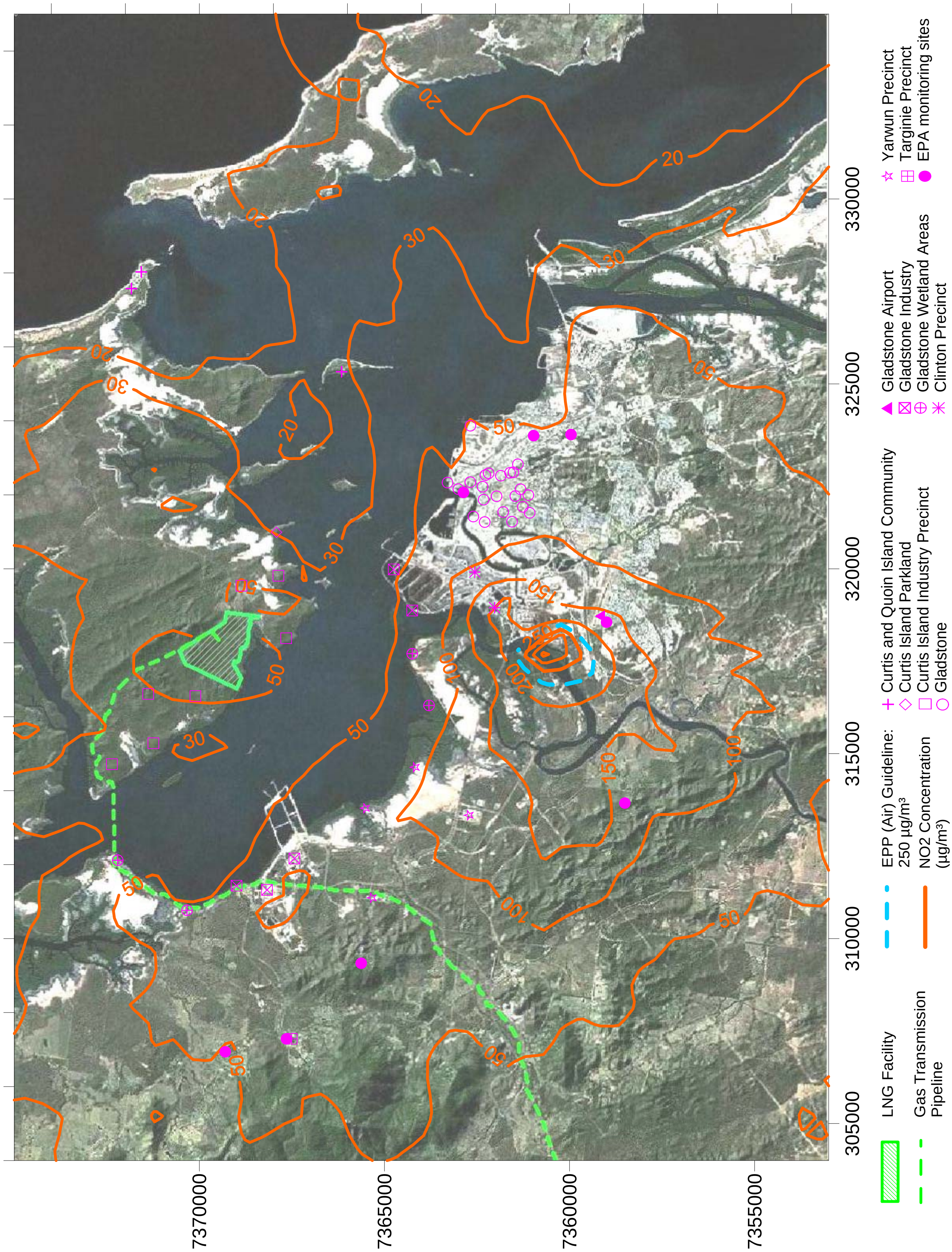
8.8.5.4 Cumulative Impacts and Air Shed Management

The cumulative impacts for the LNG facility are the combined impacts from LNG facility and from other existing and future proposed industrial sources in the area. As listed in Section 8.8.4, existing background industrial sources, proposed Gladstone Pacific Nickel Refinery, and proposed Sun LNG Project and Gladstone LNG Project on Fisherman's Landing at Gladstone have been incorporated in the cumulative impact assessment. There are other proposed LNG projects for Curtis Island, however no emissions data are publicly available for these projects at the time of writing the assessment and hence they have not been included in the background modelling.

The cumulative air shed modelling has been conducted using GAMS for NO_x and SO_2. For other pollutants, constant background pollution levels have been used based on air quality monitoring data in Gladstone to represent the existing background sources. The results of cumulative impacts have been presented in this assessment, and show that the proposed LNG facility will result in low incremental impacts to the Gladstone airshed, and acceptable cumulative impacts. These impacts are sufficiently below the air quality guidelines, that the operation of the GLNG Project will not restrict the development of other potential industries in the Gladstone region.

The air quality in the Gladstone air shed has been of concern due to the large number of industrial sources, and hence GAMS was developed for air shed management by EPA. However GAMS has so far been limited to the modelling of NO_x and SO_2.

Table 8.8.13 provides a summary of potential air quality impacts and mitigation measures for the LNG facility.



Datum: MGA94, Zone 56

Client: LNG / URS	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT			Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR 10 MTPA WITH UPSET CONDITIONS	
	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **8.8.6**	Rev A
	Job No: **4262 6220**	File: 42626220-g-885.srf			A4

Table 8.8.13 Potential Air Quality Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Construction			
Dust emissions.	Dust can potentially impact on human and vegetation health.	• Implement appropriate engineering design to minimise dust emissions. • Minimise areas cleared. • Use dust suppression controls. • Implement quantified monitoring and measuring program. • Educate community on GLNG emissions and their impacts.	Reduce impact of dust.
Operation			
NO_2 emissions	NO_2 generated from refrigeration compressors and power generation turbines can potentially impact on human and vegetation health	• Integrate "Clean and healthy air for Gladstone" program into GLNG project. • Implement appropriate engineering design to minimise air emissions. • Implement quantified monitoring and measuring program. • Educate community on GLNG emissions and their impacts.	Reduce impact of NO_2 emissions.
Decommissioning			
Dust emissions	Dust can potentially impact on human and vegetation health.	• Implement appropriate engineering design to minimise dust emissions. • Minimise areas cleared • Use dust suppression controls. • Implement quantified monitoring and measuring program.	Reduce impact of dust.

8.8.6 Summary of Findings

The air quality assessment considered potential impacts during the construction and operational phases of the LNG facility.

Emissions to air during construction of the LNG facility will be primarily dust, with some minor sources of combustion pollutants due to diesel and petrol vehicles operating on site. Management of these emissions will be implemented through the EMP that will be prepared for the site. This will include strategies to prevent or minimise dust and exhaust emissions during construction activities, an outline of methods to monitor the effects of construction activities, and documentation of procedures that will be implemented to correct any adverse off-site impacts.

Potential emission sources associated with the operational phase primarily relate to $NO_{2.}$ The air quality assessment predicted no exceedances of the EPP (Air) 2008 NO_2 guidelines at any sensitive receptors, with cumulative impacts from the LNG facility and other existing and proposed major industrial sources included. The predicted impacts of SO_2 due to the LNG facility in isolation are extremely low because of the negligible amount of trace sulphur content in the coal seam gas. Impacts on ambient TSP, PM_{10}, $PM_{2.5}$ and CO concentrations due to the LNG facility are low, with no predicted cumulative impacts above EPP (Air) 2008 guidelines.