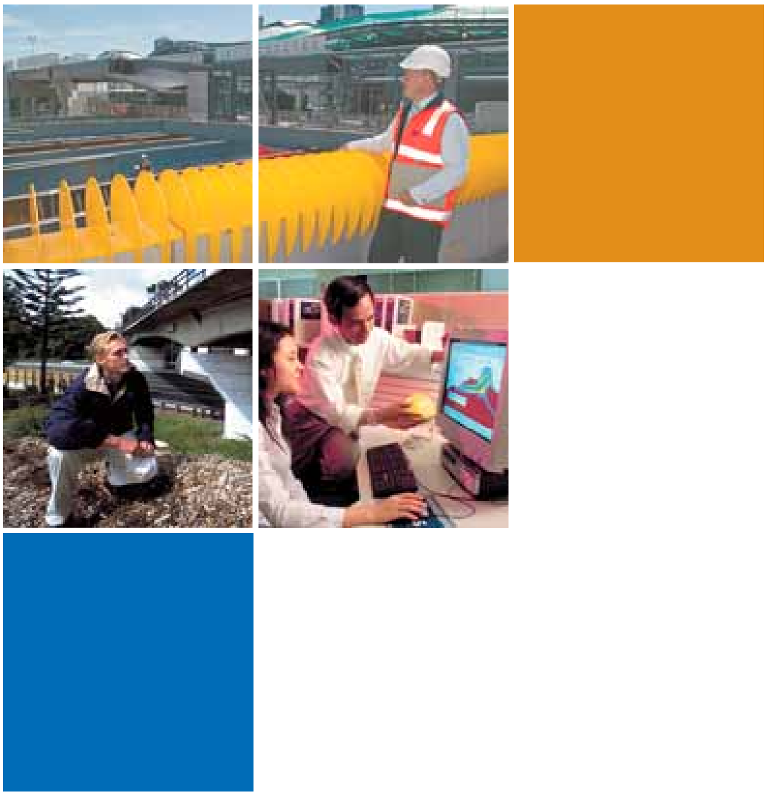
FINAL REPORT

GLNG Environmental Impact Statement - Air Quality



Prepared for

Santos Ltd

Santos House
Level 14
60 Edward Street
Brisbane QLD 4000

27 February 2009

42626222

Project Manager:

Abbie Brooke
Associate Environmental Engineer

URS Australia Pty Ltd

Level 16, 240 Queen Street
Brisbane, QLD 4000
GPO Box 302, QLD 4001
Australia
T: 61 7 3243 2111
F: 61 7 3243 2199

Project Director:

C M Pigott

Chris Pigott
Senior Principal

Author:

Li Fitzmaurice
Senior Environmental Scientist

Date: 27 February 2009

Status: Final

Table of Contents

Table of Contents

Table of Contents

Tables

Table of Contents

Figures

FIGURES ATTACHED SEPARATELY

Table of Contents

Table of Contents

Executive Summary

As discussed in the project description section, the GLNG project consists of the following three major project components:

- The Coal Seam Gas Fields (CSG Fields),
- The Gas Transmission Pipeline (The Pipeline), and
- The LNG Liquefaction and Export Facility (The LNG Facility).

Air quality impacts were independently assessed for the separate components of the project. Details regarding the existing conditions in each component study area have been assessed to characterise the baseline conditions and assess potential impacts from the GLNG Project. In addition, potential impacts on each component have been assessed and mitigation and monitoring measures have been identified to reduce the likelihood and or severity of the impacts identified. This report provides the details of this assessment for each of the three project components identified. Emissions modelled include criteria ambient air pollutants, namely nitrogen dioxide, sulphur dioxide, carbon monoxide, and particulate matter.

CSG Fields

Air quality impacts from the compressor stations in the field were modelled using a typical compressor station configuration located in the Roma or Fairview areas. Since the exact locations of future compressor stations are currently unknown, this generic modelling was used to evaluate air quality impacts with distance from the typical compressor station. Emissions from the other field operations such as drilling and well construction were not modelled since they are short-term activities spread over a large area, with only minor emissions to air. The modelling was conducted separately using meteorological data at Fairview and Roma.

Ground level nitrogen dioxide (NO_2) concentrations for a typical field compressor station have been modelled for 1 hour, 4 hour and annual averaging times at receptor distances of between 600 m and 2 km from the compressor station. The impacts were assessed with a conservatively estimated background NO_2 level of 41 µg/m^3 for 1 hour average, 35 µg/m^3 for 4 hour average, and 12 µg/m^3 for annual average.

The predicted results show that the NO_2 concentrations at these representative distances from the source comply with the Queensland air quality guidelines. Predicted results using either the Fairview or Roma meteorological data show a maximum of 20% of guideline for the one hour average, 59% for the 4-hour average and 49% for the annual average NO_2 concentration. Conservative assumptions were used throughout the assessment, for example assuming NO_x emissions are 35% NO_2 at all locations so that likely actual concentrations would be less than the predicted concentrations, particularly close to the source.

Air quality impacts of sulphur dioxide (SO_2), carbon monoxide (CO) and inhalable particulate matter with aerodynamic diameter less than 10 µm (PM_{10}) from the compressor stations were not modelled due to their low emission rates.

Gas Transmission Pipeline

The pipeline is not considered a significant source of air quality impacts as it is an underground welded pipe with no pumps, compressors or other source of air emissions along its length.

Queensland EPA does not operate any ambient air quality monitoring stations close to the Pipeline. The air quality along the Pipeline should be generally good as they are in remote areas.

Executive Summary

LNG Facility

The preliminary (pre-FEED) design that the EIS has assessed includes two LNG facility capacities, 3 Mtpa and 10 Mtpa, and two alternative LNG facility designs. Details of the air emissions from the Optimised Cascade LNG Process (OCP) and Propane Pre-cooled Mixed Refrigerant (C3MR) process designs were obtained from the process designers for 3 Mtpa and 10 Mtpa LNG facility configurations. Air quality impacts from the LNG facility were modelled using the Gladstone Airshed Modelling System (GAMS), which was developed for the Queensland EPA and contains modelled impacts for existing and approved industrial sources in Gladstone for the pollutants nitrogen dioxide (NO_2) and sulphur dioxide (SO_2).

The pollutants of most concern for a project of this type are nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and inhalable particulate matter (PM_{10}). The LNG facility will release methane (CH_4) and carbon dioxide (CO_2), which have been addressed in the separate greenhouse gas assessment report (Appendix T). Other volatile organic compounds (VOC) will only be released in very small amounts from the LNG facility as these are not present in the coal seam gas. Therefore VOC impacts have not been quantified for the LNG facility.

The LNG facility emissions were modelled both in isolation and combined with background sources. Background sources identified include currently existing industrial sources and planned future sources that have been approved or are currently seeking environmental approvals, and have publically available emissions data. These background sources, modelled in GAMS, contribute a baseline pollutant concentration of NO_2 or SO_2 that is added to the Project's predicted concentrations to determine a total projected air quality impact from all existing and known future sources.

To evaluate air quality impacts at sensitive receptor locations, approximately fifty sensitive receptors have been chosen to evaluate modelling results, in addition to predictions at the EPA air quality monitoring sites. These locations are within a 10 km radius of the LNG facility site, and are representative of residential locations on Curtis Island and Gladstone. These receptors are then grouped according to locations and land use and the maximum predicted concentration in each group is reported to provide a conservative estimate.

The key findings for the impacts from the LNG facility are listed below:

- Modelling results for NO_2 show that the impacts from the LNG facility combined with background sources are below the Queensland guideline for human health. Impacts at sensitive receptor locations due to the LNG facility plus background do not exceed 65 % of the Queensland guideline of 1-hour average ambient NO_2 concentration for human health, for either plant design;
- The Queensland guideline of 4-hour average NO_2 concentration for biological integrity are not exceeded over Curtis Island; however this guideline has been exceeded in Gladstone city due to impacts from existing industrial sources;
- The Queensland guideline of annual average NO_2 concentration for biological integrity are not exceeded; the maximum impacts from the combined impacts of the LNG facility and background sources do not exceed 30% of the annual average guideline for biological integrity;
- SO_2 emission rates are very small from this LNG facility and dispersion modelling results indicate that the LNG facility has a negligible impact on ambient SO_2 levels. Predicted SO_2 concentrations in Gladstone are dominated by existing industrial sources and the impacts from the LNG facility contribute little (less than 0.1 percent) to these levels;

Executive Summary

- CO emission rates and resultant impacts on ambient CO concentrations are low. These impacts are well below the assumed background level of CO and air quality guidelines. Impacts due to the LNG facility plus background do not exceed 25 % of the ambient 8-hour CO guideline for either plant design;
- Modelling results for particulate matter indicate that the impacts from the LNG facility in isolation are small for both plant designs. The highest impact of PM_{10} is located in the neighbouring Curtis Island Industry Precinct, with a predicted concentration of 2.3 μg/m³ for 24-hour averaging time and 0.5 μg/m³ for annual averaging time for the C3MR design and 2.0 μg/m³ for 24-hour averaging time and 0.7 μg/m³ for annual averaging time for the OCP design. Modelled cumulative impacts of PM_{10} do not exceed Queensland and national guidelines. Note that a constant background level of 30 μg/m³ is used for assessing cumulative impacts for 24-hour averaging time and 18 μg/m³ for annual averaging time, based on air quality measurements at Gladstone. Impacts at sensitive receptor locations due to the LNG facility plus background do not exceed 40 % of the ambient Queensland air quality guidelines, for either plant design; and
- During a scheduled maintenance, the LNG facility will be shut down and restarted, which leads to the flaring of the LNG facility gas for one LNG train for up to 3 hours. This scenario has comparable NO_2 impacts compared to normal operating conditions. This is due to the elevated stack height and high temperatures of emergency flares which provide greater dispersion than the compressor and power generation combustion sources that are part of normal LNG facility operations. The predicted concentrations of NO_2 due to the maintenance upset scenario satisfy short-term air quality guidelines when impacts of the LNG facility plus background sources are considered.

1.1 Existing Environment

1.1.1 Climate for the CSG Field region

Santos's proposed CSG fields extend from Roma to Emerald. They include a number of specific CSG fields including Denison, Mahalo, Comet, Acadia Valley, Fairview, Roma, Scotia, Eastern Surat Basin, Roma other, and some non-Santos operated fields. The total area of these fields is approximately 33,000 sq km. Of these fields, Fairview, Arcadia Valley and Roma fields are proposed to be developed initially, with expansion into other areas dictated by the success of this initial development program. A map of the study area is provided in Figure 1-1.

The CSG field study areas have an inland sub-tropical climate characterised by cool winters and hot summers, with the majority of the annual rainfall occurring during the summer months. In general the year round climate is dry (not humid) with the winter months being more arid than the summer months.

The Bureau of Meteorology operates several sites within or near the CSG field study area, which include Emerald, Springsure, Rolleston, Taroom, Brigalow, Injune, Roma Airport, Roma Post Office, Miles and Surat. The climate summary data from these sites are presented below.

Temperature

The average daily temperature range across all the sites is from 20.7 °C to 34.1 °C in summer (January) and from 5.1 °C to 21.0 °C in winter (July). Emerald is warmer than other sites in terms of both daily minimum and daily maximum temperature as it is the most northern site. Mean daily maximum and minimum temperature data at each site within the CSG field study area are presented in Figure 1-2.

Rainfall and Evaporation

The region experiences an average annual rainfall of 623 mm, with Brigalow reporting the highest annual average rainfall figure of 700 mm and Emerald reporting the lowest annual average rainfall figure of 515 mm. These data are shown in Figure 1-3.

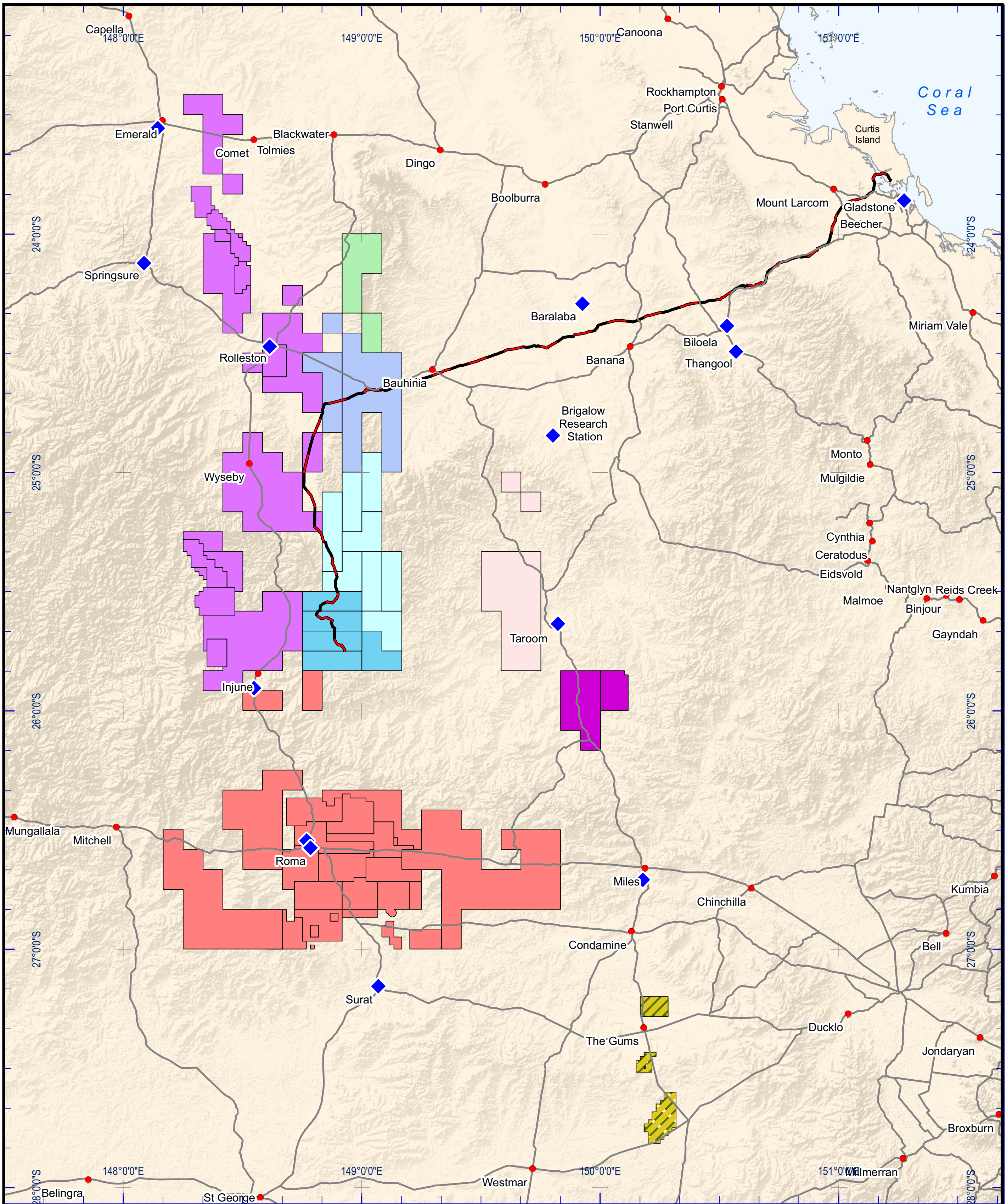
The summer months (December through to February) have the highest average monthly rainfall of over 80 mm per month (when averaged across all sites). Rainfall in the winter months (April to September) is approximately 30 mm per month.

Evaporation records are only available for three of the sites (Brigalow, Roma and Miles), as shown in Figure 1-4. The evaporation data is measured with evaporation pans filled with water. Evaporation is highest from November through to February, with a mean daily evaporation rate over 7.3 mm (approximately 219 per month). The winter three months, June through August, have daily evaporation rates of about 3 mm (approximately 90 mm per month).

Relative Humidity

Relative humidity is the term used to describe the amount of water vapour in the air relative to the saturation point at a given temperature. A graphical representation of the monthly average relative humidity data (at 9am and 3pm) for each of the air monitoring stations within the CSG field study area is shown in Figure 1-5. As is expected, the graph shows that relative humidity is higher at 9am (shown as dotted lines), ranging from 50% to 70% on average, and lower at 3pm (shown as solid lines), ranging from 30% to 45%. The diurnal temperature range from low temperature in the morning to high temperature in the afternoon is the primary reason for this variation through changing the water holding capacity.

For most sites, relatively humidity is higher in winter than in summer, with September and October (spring) reporting the lowest relative humidity levels.



N
W E
S

Kilometers
0 5 10 20 30 40 50

Scale 1:2 500 000
Datum : GDA 94

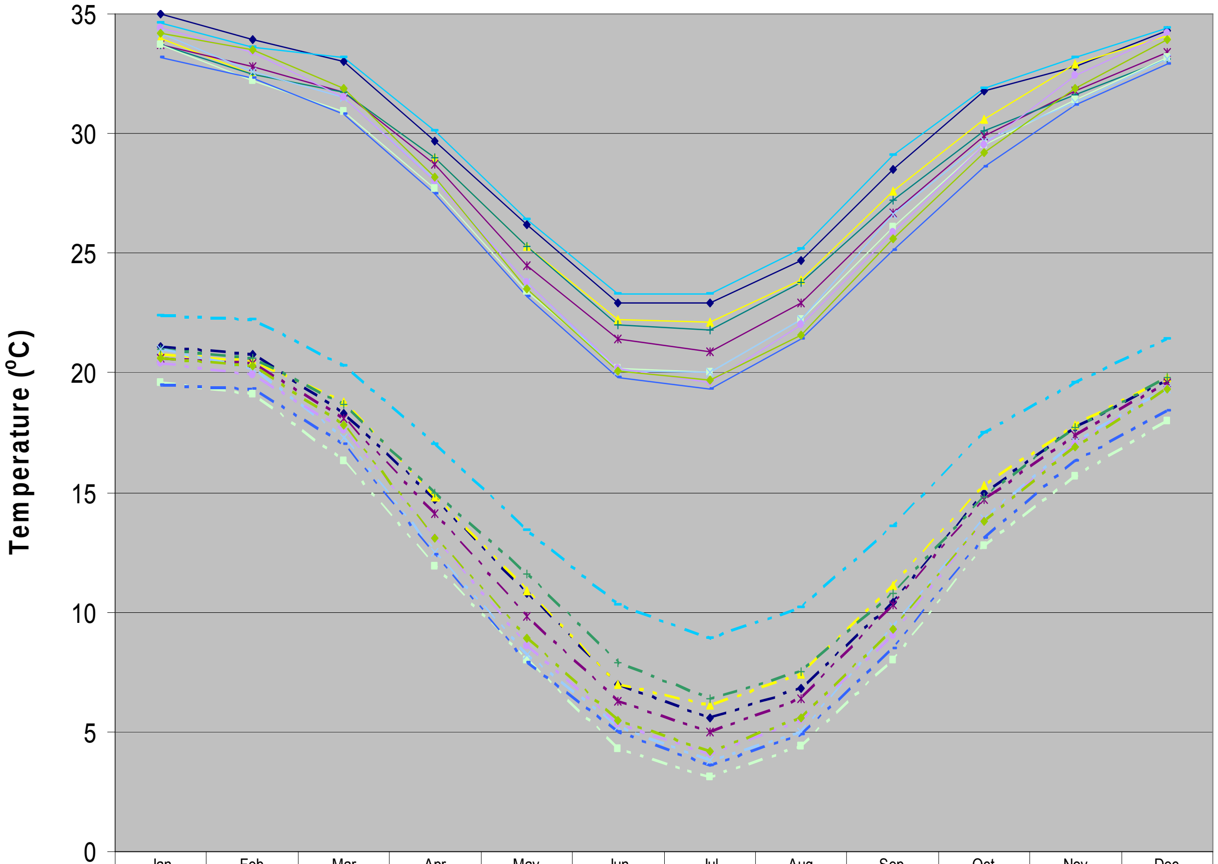
Meteorological Stations
Towns
Major Roads
Gas Transmission Pipeline

CSG FIELDS
Arcadia Valley
Comet
Dennison Trough
Fairview
Mahalo
Roma
Roma Other
Scotia
Eastern Surat

Source: This map may contain data which is sourced and Copyright. Refer to Secion 18.2 of the EIS for ownership and copyright details.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	**REGIONAL LOCATION OF METEOROLOGICAL STATIONS**

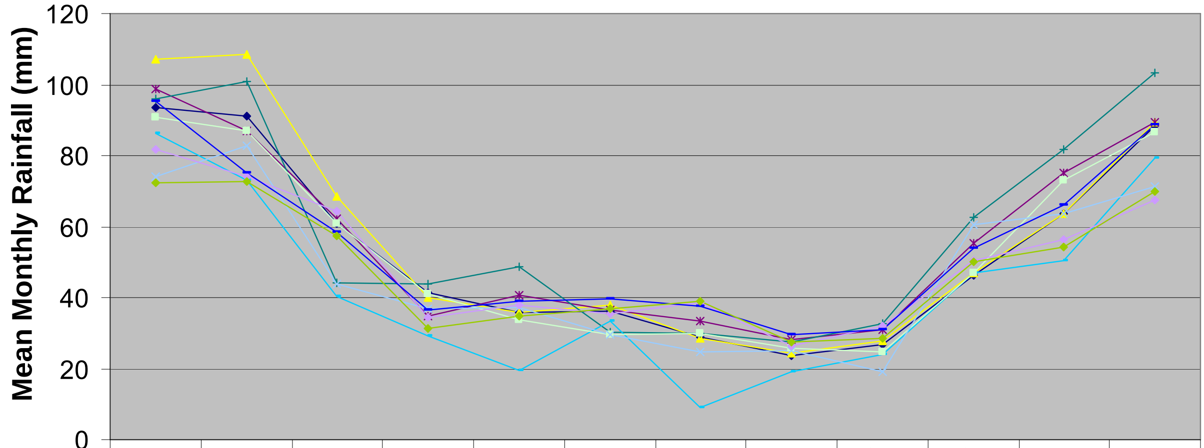
Drawn: MG	Approved: JB	Date: 27-02-2009	Figure: **1.1**	Rev. A
Job No.: 4262 6220	File No.: 42626220-g-796.mxd			A4



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rolleston Max	35.0	33.9	33.0	29.7	26.2	22.9	22.9	24.7	28.5	31.8	32.8	34.3
Rolleston Min	21.1	20.8	18.3	14.7	10.8	7.0	5.6	6.8	10.4	15.0	17.7	19.7
Springsure Max	34.0	32.5	31.7	29.0	25.3	22.2	22.1	23.9	27.6	30.6	32.9	34.1
Springsure Min	20.8	20.5	18.8	14.8	10.9	7.0	6.1	7.4	11.1	15.3	17.8	19.8
Taroom Max	33.7	32.8	31.7	28.7	24.5	21.4	20.9	22.9	26.7	29.9	31.8	33.4
Taroom Min	20.6	20.4	18.1	14.1	9.8	6.3	5.0	6.4	10.3	14.7	17.4	19.6
Brigalow Max	33.7	32.5	31.7	29.0	25.3	22.0	21.8	23.8	27.2	30.1	31.6	33.1
Brigalow Min	21.0	20.6	18.7	15.0	11.6	7.9	6.4	7.5	10.8	14.8	17.7	19.8
Emerald Max	34.6	33.6	33.2	30.1	26.4	23.3	23.3	25.2	29.1	31.9	33.2	34.4
Emerald Min	22.4	22.2	20.3	17.0	13.4	10.3	8.9	10.2	13.6	17.5	19.6	21.4
Injune Max	33.7	32.2	30.9	27.7	23.4	20.2	20.0	22.2	26.1	29.5	31.4	33.2
Injune Min	19.6	19.1	16.3	11.9	8.0	4.3	3.1	4.4	8.0	12.8	15.7	18.0
Roma Airport Max	34.2	32.6	31.5	28.1	23.8	20.1	20.0	22.2	26.6	29.7	31.3	33.1
Roma Airport Min	21.0	20.2	17.3	12.5	8.2	5.2	3.8	5.0	9.4	13.9	17.1	19.3
Roma Post Office Max	34.4	33.4	31.5	28.0	23.8	20.2	19.6	22.0	25.9	29.5	32.4	34.2
Roma Post Office Min	20.4	19.9	17.6	13.1	8.6	5.3	4.1	5.5	9.0	13.8	17.0	19.3
Miles Max	33.2	32.3	30.8	27.5	23.2	19.8	19.3	21.4	25.1	28.6	31.2	32.9
Miles Min	19.5	19.3	17.0	12.4	7.9	5.0	3.6	4.9	8.5	13.1	16.3	18.4
Surat Max	34.2	33.5	31.9	28.2	23.5	20.1	19.7	21.6	25.6	29.2	31.9	33.9
Surat Min	20.6	20.3	17.8	13.1	8.9	5.5	4.2	5.6	9.3	13.8	16.9	19.3

Time (Month)

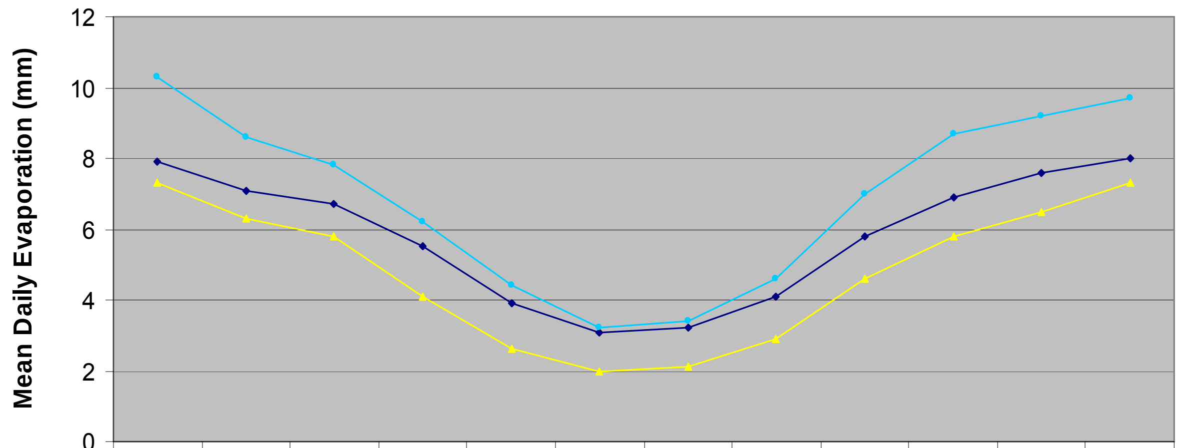
Figure 1-2 Mean daily maximum and minimum temperatures (°C) at sites within the CSG field study area



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rolleston	93.6	91.0	60.9	41.3	35.8	36.2	28.9	23.5	26.7	46.2	63.7	88.2
Springsure	107.3	108.4	68.4	40.1	35.9	38.0	28.6	24.3	27.8	47.1	63.8	89.4
Taroom	98.9	87.1	62.1	34.9	40.8	36.4	33.5	28.2	30.9	55.4	75.0	89.4
Brigalow	95.9	100.9	44.1	43.7	48.7	30.2	29.8	27.4	32.8	62.7	81.8	103.4
Emerald	86.1	73.0	40.3	29.3	19.5	33.4	9.1	19.2	24.1	47.1	50.5	79.4
Injune	90.9	86.8	61.0	40.9	33.7	29.7	29.9	25.6	24.7	47.1	73.1	86.6
Roma Airport	74.2	82.7	43.7	36.8	37.2	29.6	24.7	24.9	19.1	60.5	63.6	71.4
Roma Post Office	81.8	74.1	64.4	34.6	37.8	35.6	38.6	26.6	32.1	50.3	56.2	67.5
Miles	95.2	75.0	58.6	36.6	39.1	39.6	37.5	29.4	30.8	54.0	66.0	88.6
Surat	72.5	72.6	57.4	31.2	34.7	37.0	38.9	27.5	28.4	50.1	54.4	70.0

Time (Month)

Figure 1-3 Mean monthly rainfall (mm) at sites within the CSG field study area



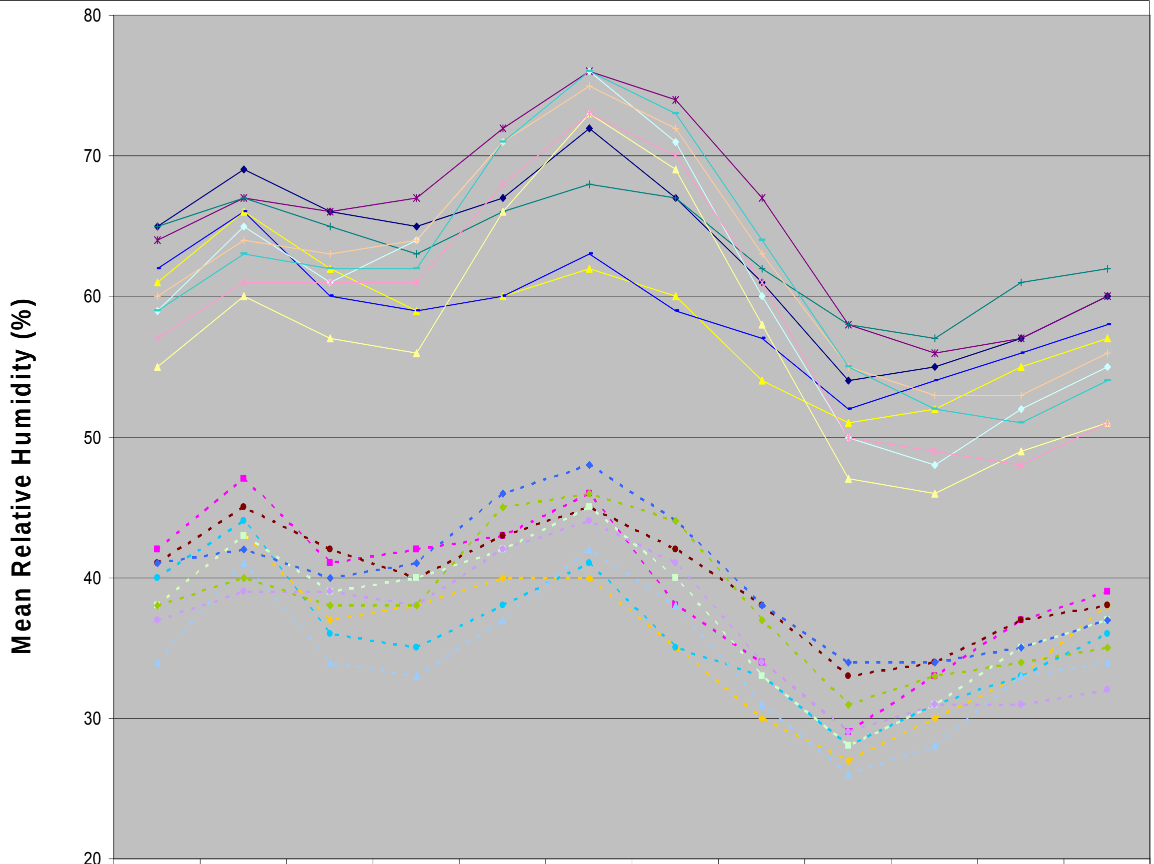
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Brigalow	7.9	7.1	6.7	5.5	3.9	3.1	3.2	4.1	5.8	6.9	7.6	8
Roma Airport	10.3	8.6	7.8	6.2	4.4	3.2	3.4	4.6	7	8.7	9.2	9.7
Miles	7.3	6.3	5.8	4.1	2.6	2	2.1	2.9	4.6	5.8	6.5	7.3

Time (Month)

Figure 1-4 Mean daily evaporation (mm) at sites within the CSG field study area

Section 1

Coal Seam Gas Field



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rolleston 9am	65	69	66	65	67	72	67	61	54	55	57	60
Rolleston 3pm	42	47	41	42	43	46	38	34	29	33	37	39
Springsure 9am	61	66	62	59	60	62	60	54	51	52	55	57
Springsure 3pm	38	43	37	38	40	40	35	30	27	30	33	38
Taroom 9am	64	67	66	67	72	76	74	67	58	56	57	60
Taroom 3pm	41	45	42	40	43	45	42	38	33	34	37	38
Brigalow 9am	65	67	65	63	66	68	67	62	58	57	61	62
Emerald 9am	62	66	60	59	60	63	59	57	52	54	56	58
Emerald 3pm	40	44	36	35	38	41	35	33	28	31	33	36
Injune 9am	59	65	61	64	71	76	71	60	50	48	52	55
Injune 3pm	38	43	39	40	42	45	40	33	28	31	35	37
Roma Airport 9am	55	60	57	56	66	73	69	58	47	46	49	51
Roma Airport 3pm	34	41	34	33	37	42	38	31	26	28	33	34
Roma Post Office 9am	57	61	61	61	68	73	70	61	50	49	48	51
Roma Post Office 3pm	37	39	39	38	42	44	41	34	29	31	31	32
Miles 9am	60	64	63	64	71	75	72	63	55	53	53	56
Miles 3pm	41	42	40	41	46	48	44	38	34	34	35	37
Surat 9am	59	63	62	62	71	76	73	64	55	52	51	54
Surat 3pm	38	40	38	38	45	46	44	37	31	33	34	35

Time (Month)

Figure 1-5 Mean 9am and 3pm relative humidity (%) at sites within the CSG field study area

Wind

Hourly records of wind speed and wind direction are available for Roma Airport, from the Bureau of Meteorology site. A wind rose plot derived from these observed data at Roma Airport for 2003 is presented in Figure 1-6.

At Fairview, no observation wind data are available, and meteorological modelling for 2006 has been undertaken to obtain meteorological data for dispersion modelling, as detailed in Section 1.2.2. A wind rose plot using the wind data extracted from the model output for Fairview is presented in Figure 1-7.

Figure 1-6 shows that for Roma Airport, the most dominant wind directions are from north and north-north-east. Figure 1-7 shows that for Fairview, the winds tend to arise mainly from the north-east. In general, wind speeds for Roma Airport are higher than those at Fairview. This wind speed difference may reflect influences of local terrain and surface roughness.

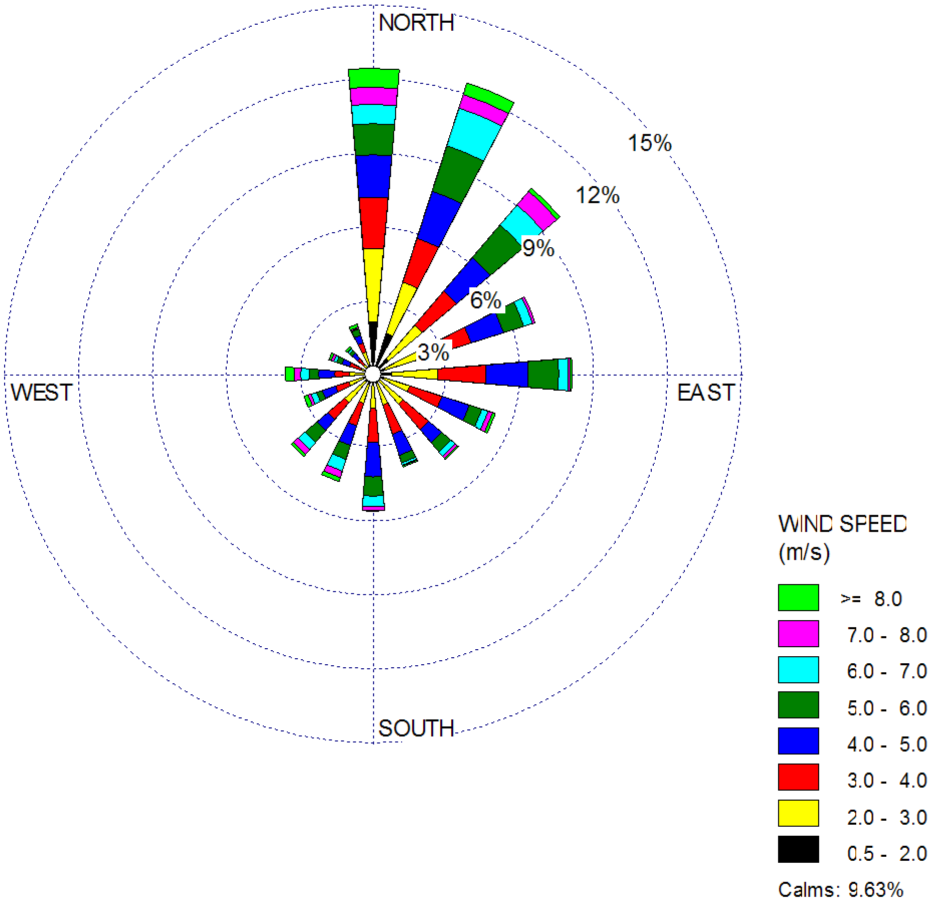


Figure 1-6 Wind rose for Roma Airport for 2003, derived from Bureau of Meteorology observational data

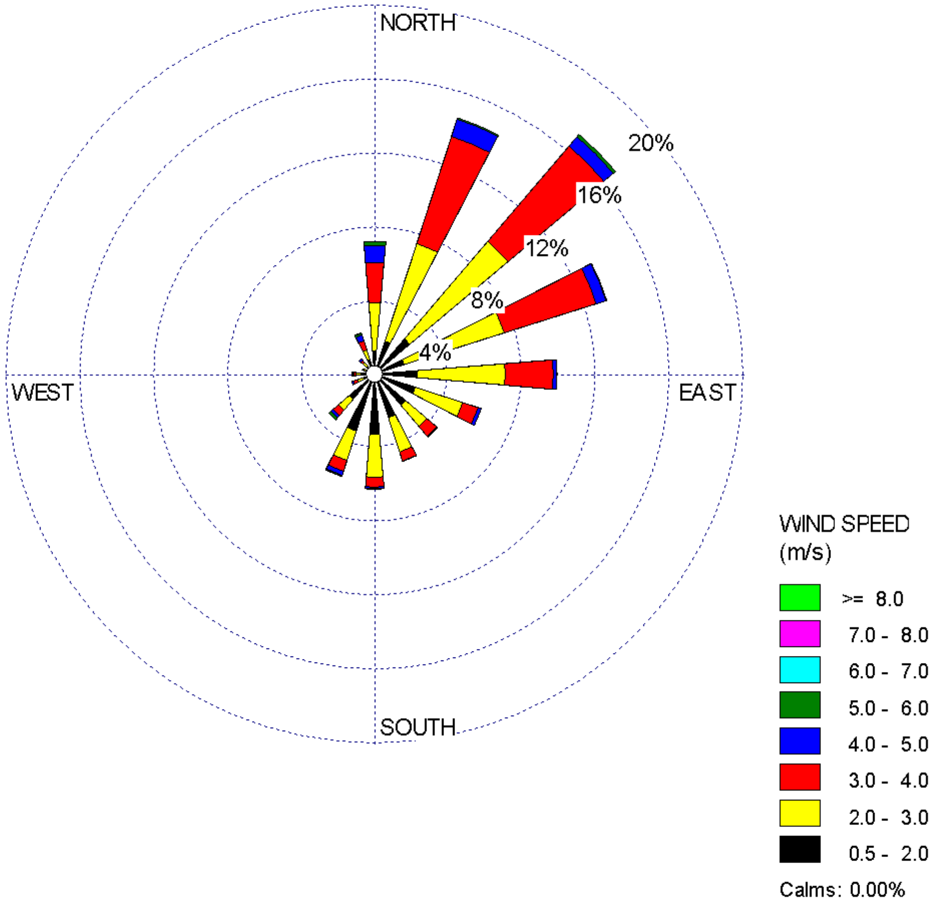


Figure 1-7 Wind rose at Fairview for 2006, derived from meteorological modelling data

Atmospheric Stability

Atmospheric stability is a parameter that is derived from wind and temperature profile data at a site. This data is used to characterise the conditions that lead to enhanced (unstable conditions) or poor atmospheric dispersion (stable conditions).

Table 1-1 shows the predicted percentages of stability classes for Roma and Fairview from the TAPM modelling data (at Roma for 2003 and Fairview for 2006), as detailed in Section 1.2.2. The stability categories indicate a high proportion of neutral conditions for Roma (34.9%), and a high proportion of stable conditions for Fairview (43.2% for slightly stable and stable categories combined).

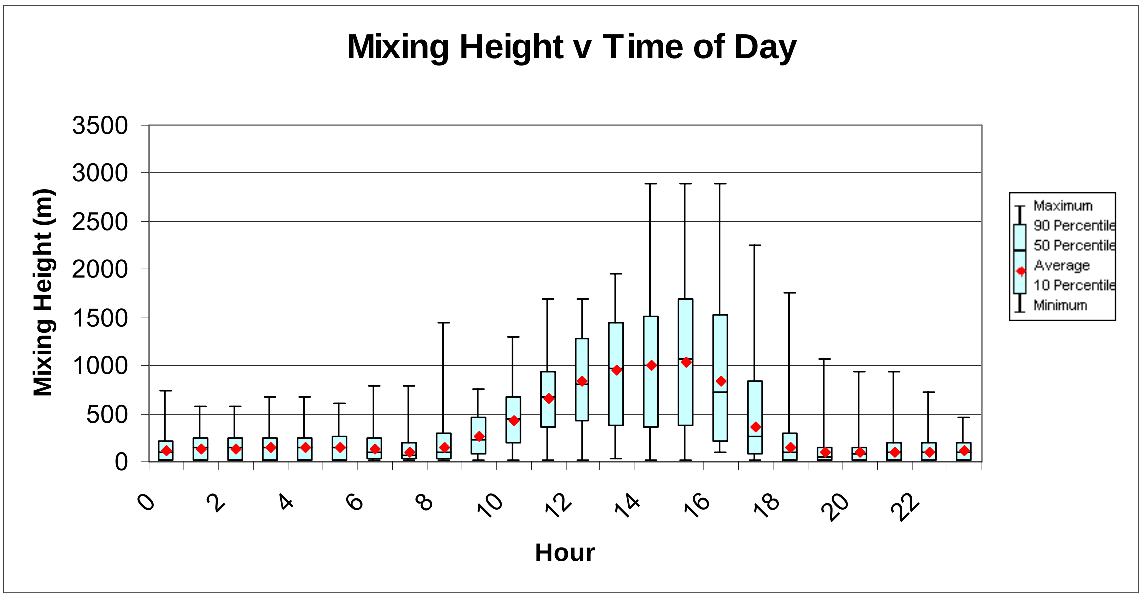
Table 1-1 Stability categories for Roma and Fairview predicted by TAPM for 2003 and 2006 respectively

Stability Category	Roma	Fairview	Description of Category
A	0.7%	3.5%	Extremely Unstable
B	12.4%	17.1%	Unstable
C	16.1%	12.8%	Slightly Unstable
D	34.9%	23.4%	Neutral
E	20.5%	15.4%	Slightly Stable
F	15.5%	27.8%	Stable

Mixing Height

Hourly mixing height data at the CSG field locations have been derived from TAPM modelling data (at Roma for 2003 and Fairview for 2006). Figure 1-8 presents this data as box-and-whisker plots by hour of day. Mixing heights at Roma are very low at night (mostly less than 100 m), but rise sharply after sunrise, peaking in the afternoon hours to altitudes between 400 m to 1700 m for the majority of the days (10 to 90 percentile). Daily maximum mixing height is lower in the winter than the summer due to reduced solar heating effects. At Fairview, mixing height data has a similar diurnal pattern to that of Roma, but peaks at lower altitudes (500 m to 1400 m) for the majority of the days (10 to 90 percentile).

(a) Roma



(b) Fairview

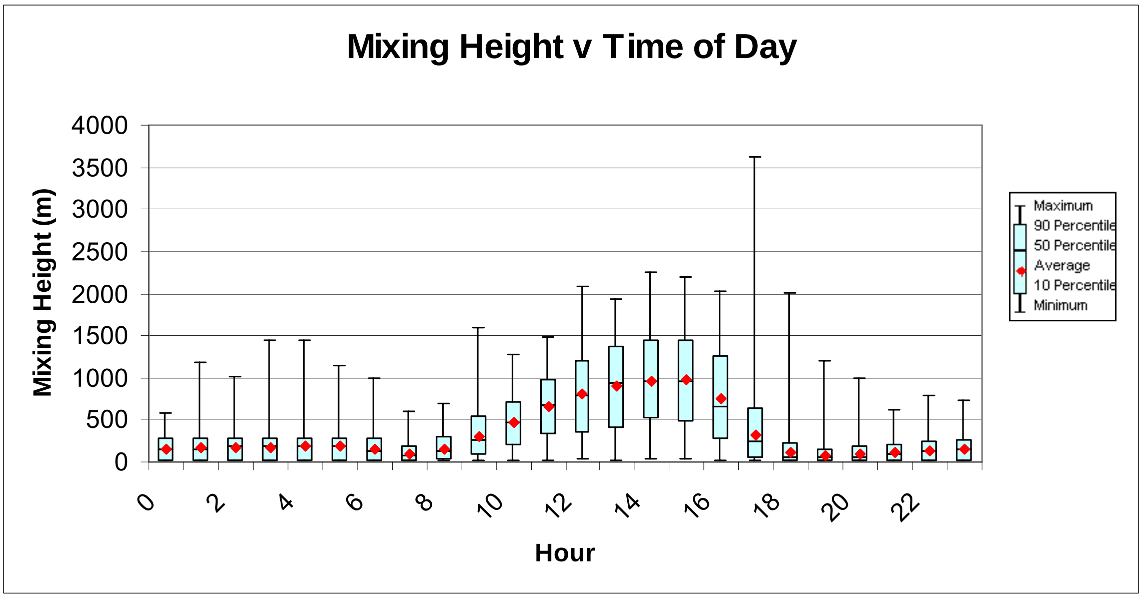


Figure 1-8 Mixing height data for (a) Roma, 2003, and (b) Fairview, 2006

1.1.2 Legislative Framework

The legislative framework that is applicable to the evaluation of air quality impacts on the CSG field study area is presented in Section 3.1.2. Relevant guidelines are presented below with measured air quality data and predicted air quality impacts.

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 have been adopted for this project. The relevant NSW DECC emission concentration standards are presented below in.

Table 1-2 NSW Department of Environment and Climate Change's Emission Concentration Standards related to the CSG field project

Pollutant	Maximum Emission Concentration	Applicable activity	Reference conditions
Nitrogen Oxides	450 mg/m^3	Stationary reciprocating internal combustion engines	Dry, 273 K, 101.3 kPa, 3% O_2

1.1.3 Existing Air Quality

The air monitoring network operated by Queensland EPA covers five regions comprising Mount Isa, Townsville, Mackay, Gladstone and Southeast Queensland region. The Toowoomba station (in the EPA's Southeast Queensland air monitoring region) is the closest air quality monitoring station to the GLNG coal seam gas fields at Arcadia Valley, Fairview and Roma. The monitoring site lies approximately 350 km ESE and 330 km SE of the Roma and Arcadia Valley CSG fields respectively, and is the furthest monitoring station away from emission sources in the Brisbane and Gold Coast metropolitan area.

The Toowoomba station began monitoring in August 2003. It is surrounded by light industry and residential areas and measures nitrogen dioxide (NO_2) and particulate matter with aerodynamic diameter less than 10 µm (PM_{10}). The air quality data at Toowoomba station is summarised in Table 1-3, and these data have been used as the background concentrations in evaluating air quality impacts due to CSG field activities. To represent short-term average background concentrations (1 hour, 4 hour, and 24 hour averages), the 95th percentile concentration has been used. This statistic is commonly used as it provides sufficiently conservative data to represent typical background concentrations, and is more stringent than the level recommended by the Victorian EPA of the 70th percentile concentration to represent background sources[1].

Table 1-3 Ambient nitrogen dioxide and PM_{10} concentration statistics for Toowoomba from 2003 – 2008

Pollutant	Averaging time	Pollutant concentration at monitoring location (µg/m^3)	Guideline (µg/m^3)
Nitrogen Dioxide	1 hour, 95th percentile	41	320 EPP (Air) 246 NEPM
	4 hour, 95th percentile	35	95 EPP (Air)

[1] Victorian State Environment Protection Policy (Air Quality Management), 2001.

Pollutant	Averaging time	Pollutant concentration at monitoring location (µg/m³)	Guideline (µg/m³)
	Annual	12	30 EPP (Air) 62 NEPM
PM_{10}	24 hour, maximum	140	150 EPP (Air) 50 NEPM
	24 hour,95th percentile	29	150 EPP (Air) 50 NEPM
	Annual	16	50 EPP (Air)

Overall, the measured levels of nitrogen dioxide at Toowoomba did not exceed the guidelines specified in the Queensland Environmental Protection (Air) Policy (EPP (Air)) 1997; and National Environmental Protection Measure (NEPM) guidelines for ambient air quality for both 1 hour and annual averaging times.

The PM_{10} levels have not exceeded the EPP (Air) 24-hour guideline for ambient air (150 µg/m^3). The more stringent NEPM 24-hour guideline of 50 µg/m^3 has been exceeded for years 2003, 2005 and 2006, but the number of exceedances was less than the maximum allowable number defined by NEPM, which is five days per annum. In 2005, the three days when 24-hour average PM_{10} levels exceeded the 50 µg/m^3 standard can be attributed to a dust storm in February. In both 2003 and 2006, the 24-hour average PM_{10} levels exceeded 50 µg/m^3 for one day per year. The 95th percentile value of 24-hour average PM_{10} levels at Toowoomba, 29 µg/m^3 can be used as the background 24-hour PM_{10} level for the CSG field, which is much lower than the EPP (Air) and NEPM guideline. The annual EPP (Air) guideline has not been exceeded.

As Toowoomba air quality monitoring station is surrounded by light industry and residential areas, the air quality would be somewhat different from the CSG field study area. The background nitrogen dioxide levels may be lower in the CSG field study area as lack of major emission sources (such as motor vehicles and other high temperature combustion activities). Whether the background PM_{10} levels from Toowoomba are representative of the CSG field locations would largely depend on the occurrence of natural wind blown soil dust and the impacts of motor vehicles and industrial pollution.

1.2 Potential Impacts and Mitigation Measures

1.2.1 Air Emissions from the Project

Emissions during Construction

Emissions to air during the construction phase of the CSG field development program will be primarily dust related, 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;
- Vehicles travelling on unpaved roads; and
- Vehicles and machinery exhausts.

The impacts of construction activities will be managed though the Environmental Management Plan. 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.

Emissions during Normal Operation

Emissions to the air environment from the GLNG CSG field operations include permanent and intermittent point source emissions, fugitive emissions, area source emissions and mobile source emissions. The main types of emissions from the CSG fields are summarised below:

- Emissions from coal seam gas combustion equipment, including compressor engines and generators;
- Emissions from diesel combustion associated with diesel generator sets and site vehicles used during construction;
- Emissions from cold vents, and fugitive emissions from wells; and
- Particulate emissions from traffic movements on unpaved roads.

The emissions from cold vents and fugitive emissions from wells will be predominantly methane, with minor releases of carbon dioxide and nitrogen, and trace releases of ethane and propane. Carbon dioxide and nitrogen are not considered as air pollutants. Methane, ethane and propane are not air pollutants in themselves, but propane may contribute to ozone formation as a volatile organic compound (VOC). Methane and ethane contribute little to ozone formation as they are not very reactive. As the release of propane is small and photochemical smog impacts are not an issue for the CSG fields, propane has not been assessed for air quality impacts. Methane released from cold vents and fugitive emissions has been addressed as a greenhouse gas in Appendix T.

Of the four emission sources listed above, the only significant continuous emission sources during the normal operations of the CSG field development are the combustion emissions from compressor engines at the compressor stations. It is not possible at the current stage of project development to know their specific locations. Therefore, impact assessment has been based on modelling known emissions from a typical compressor station in a generic location in the field area. Once the specific location of each compressor station has been identified, Santos will undertake site-specific dispersion modelling.

At the current state of project development, 12 compressor stations are proposed across the Fairview, Roma and Arcadia Valley CSG fields. Each compressor station will include an average of eight compressor units. All compressors will operate on coal seam gas as the fuel, and each unit will compress approximately 7 TJ of coal seam gas.

The source characteristics were taken from the manufacturer's specification sheet for a Caterpillar G3608 gas petroleum engine assuming 100% load at 1000 rpm. Further specifications and assumptions are as follows:

- Stack diameter of 0.45 m;
- Exhaust gas flow rate of 167 m^3/min;
- Exhaust velocity calculated to be 17 m/s;
- Stack height of 9.3 m above grade;
- Exhaust temperature of 470º C; and
- Fuel burnt is coal seam gas (methane).

NO_x is the main pollutant of concern from the compressor station, as gas engines emit very low quantities of particulate matter and carbon monoxide. The emission of sulphur oxides is also very low as there is a negligible amount of sulphur in the coal seam gas used as a fuel. The NO_x emission rate is estimated to be 0.461 g/s per compressor engine unit.

To compare with best practice emission standards, the in-stack NO_x emission concentration was calculated for the compressor engines. This emission concentration is 166 mg/m^3, calculated using the exhaust gas flow rate of 167 m^3/min. The emission concentration is much lower than the emission standard of 450 mg/m^3 presented in Section 1.1.2. Note that no corrections towards the reference conditions have been made when calculating in-stack emission concentrations as the emission data on moisture content and oxygen content are unavailable. The low in-stack emission concentrations reflect the use of low NO_x emission technologies in the engines.

Emissions during Upset Conditions

During upset conditions, the coal seam gas will be flared. The combustion product from burning coal seam gas will be predominantly carbon dioxide, which is not an air pollutant, with minor emissions of VOC. No modelling has been conducted for the upset conditions as these impacts are expected to be small and occur infrequently.

1.2.2 Dispersion Modelling Methodology

Air Dispersion Modelling

Ausplume was used to model the air quality impacts due to NO_x emissions from the compressors in the CSG fields. Ausplume is a steady-state Gaussian plume air dispersion model, used to predict ambient air concentrations of emissions using historic hourly meteorological data to calculate plume rise and dispersion. Ausplume was configured with eight engine sources and the provided operating characteristics. Radial receptors were used to model the impacts at various distances in any direction from the source. No terrain file was included in the model because the actual locations for compressor stations will not be known for a number of years.

The same configuration of the typical compressor station was modelled using meteorological data from the Fairview and Roma areas. In both cases, meteorological data for the site location was generated using The Air Pollution Model (TAPM), a three-dimensional prognostic meteorological model developed by the CSIRO. TAPM uses detailed synoptic analysis of all surface and upper air data collected in Australia to determine the wind flows over a chosen model domain. TAPM was set up for the Fairview and Roma areas to a 1 km inner-grid resolution for 2006 and 2003 respectively.

Results were extracted from TAPM and used as input for Ausplume dispersion modelling, in which an eight-unit compressor station is modelled, with total emissions as 3.688 g/s.

Emissions from the compressor stations are expressed in terms of oxides of nitrogen (NO_x), which describes a mixture of nitrogen dioxide (NO_2) and nitric oxide (NO). Emissions of NO_x from combustion sources are initially composed of approximately 90% NO and 10% NO_2. As the plume from the compressor leaves the site, the surrounding air will slowly oxidise the NO in the presence of sunlight to form more NO_2. Studies in regional cities such as Gladstone have shown that there is typically a ratio of approximately 35% NO_2 to NO_x under worst-case conditions. This ratio has been assumed for all distances from the compressor stations, although it is unlikely that 35% would be achieved at 600m or even 1 km from the compressor station, depending on weather conditions.

Limitations and accuracy of the models

The model limitations may include

- The limitations of TAPM to model local meteorology;
- The limitations of Ausplume to model dispersion;
- The limitations of not using local topography in the TAPM and Ausplume modelling, as the modelling is representative of impacts until specific sites are identified for the compressor stations; and
- The limitations of using preliminary design data for the compressor stations.

These limitations may lead to under or over prediction of impacts at ground level, which is largely unknown without actual monitoring data and source-specific emissions data for comparison. Hence, air dispersion modelling will be conducted later using local topography when actual locations of field compressor stations become known. A quantifiable monitoring and measuring program will be implemented through the Environmental Management Plan. Compliance with emission standards and ambient air quality standards will be ensured, as part of the Environment Management Plan.

1.2.3 Dispersion Modelling Results

Predicted NO_2 Concentrations

Table 1-4 shows predicted maximum NO_2 concentrations for the operation of the compressor station together with the estimated background concentration of NO_2 using the Fairview metrological data, with results using the Roma data presented in Table 1-5. Results for the 1 hour average concentration are presented as the 99.9th percentile for comparison with air quality guidelines. It was assumed that the compressor stations are sufficiently spaced such that there is no potential for cumulative effects from having multiple compressor stations in the area. Concentrations of NO_2 due to other sources are estimated from the monitoring data at Toowoomba.

Section 1 Coal Seam Gas Field

The predicted modelling results from Ausplume, together with the estimated NO_2 to NO_x ratio of 35%, result in values well below the guideline levels at all the distances modelled. Predicted results using the Fairview meteorological data show a maximum of 20% of guideline for the one hour average, 59% for the 4-hour average and 49% for the annual average. Results using the Roma meteorological data show a maximum of 20% of guideline for the one hour average, 56% for the 4-hour average and 48% for the annual average. The differences in results between Roma and Fairview cases are very small.

Table 1-4 Predicted NO_2 concentration with background concentration for Fairview

Distance from Source	Maximum NO_2 Concentrations (µg/m^3)		
	1 hour 99.9th percentile	4 hour	Annual
600 m	63	56	15
1 km	58	53	14
2 km	56	51	13
Background	**41**	**35**	**12**
EPP (Air) Guideline	**320 (for human health)**	**95 (for Biological Integrity)**	**30 (for Biological Integrity)**

Table 1-5 Predicted NO_2 concentration with background concentration for Roma

Distance from Source	Maximum NO_2 Concentrations (µg/m^3)		
	1 hour 99.9th percentile	4 hour	Annual
600 m	64	53	15
1 km	61	50	14
2 km	64.	52	13
Background	**41**	**35**	**12**
EPP (Air) Guideline	**320 (for human health)**	**95 (for Biological Integrity)**	**30 (for Biological Integrity)**

Cumulative Impacts and Air Shed Management

The cumulative impacts for the CSG fields are the combined impacts from Santos CSG development activities and from other background emissions in the areas. The other industrial emissions in the CSG fields are unavailable from public sources and hence cannot be assessed. Instead, the general background pollution level has been used from the Toowoomba air quality monitoring data, consistent with industry practice. Air dispersion model results have shown that predicted NO_2 levels from field compressors station reduce rapidly within a distance of several kilometres, and the actual distances between the 12 proposed field compressor stations within the extensive CSG fields will be large enough so that cumulative impact modelling assessment is deemed unnecessary.

In the CSG fields, there will be a large number of wells, varying with time, with the peak number over 2400. As the emission from wells are primary methane, with minor release of other chemicals that do not have air quality implications (See Section 1.2.1), cumulative impacts of wells on air quality have not been assessed.

The air quality in the air shed where the proposed Santos CSG fields are located is currently good and well below the EPA's guideline levels, due to the low level of industrial development in these regions. Hence currently no air shed management tools have been developed for these areas.

Human Health Risk Assessment

Potential human health impacts from activities in the CSG fields will come from NO_x, CO emissions from field compressor stations, dust emissions during the construction, exhaust fumes from field vehicles and diesel generators during construction and/or normal operation, and minor VOC emissions. Air dispersion modelling has predicted ground level NO_2 concentrations well below the EPP (Air) guidelines for human health at a distance of 600 m away from field compressor stations and hence NO_x emissions from field compressor stations are not of concern for human health. These low impacts indicate that a health risk assessment is not required.

The human health impacts from compressor CO emissions, from dust emissions during construction and from minor VOC emissions 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.

Odour Assessment

Odour is often of concern for industrial facilities. The coal seam gas and gas processing facilities in the CSG fields will not release strong odorous compounds. Minor odour associated with oxides of nitrogen (primarily due to NO) is not of concern for the pollutant concentrations that have been predicted in dispersion modelling. Fugitive emissions of non-methane VOC are not known to contain odorous compounds as there is no odorant added to the gas supply, hence no odour impacts are expected from the CSG fields.

1.2.4 Mitigation Measures

This project will comply with the Santos document *EHS Management System Hazard Standard, EHS05 Air Emissions.* Santos strives to meet air quality guidelines for a new facility through 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 the relevant environmental agency. Specific mitigation measures for each phase of the project development are discussed below.

Construction

Mitigation measures to reduce potential emissions during construction activities are listed below, and represent 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. This shall include minimising size of well leases and equipment lay-down/storage areas;
- The number and sizes of 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):

- 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.

Operational

Mitigation measures to reduce potential emissions during operational activities include:

- Implementation of a preventative maintenance program to ensure gas turbines are operating efficiently to minimise carbon monoxide emissions and uncombusted hydrocarbons (primarily methane, with minor VOC emissions);
- Optimisation of gas turbine operations to minimize time periods of operation at low efficiency levels that may result in excess GHG emissions and higher than normal levels of NO_x emissions; and
- Implementation of a quantifiable monitoring and measuring program.

In addition, comprehensive modelling will be conducted once the specific configuration and location of the compressor stations is known. This will include an assessment at residential locations that are identified within 5 km of each compressor station.

Decommissioning

Mitigation measures to reduce potential emissions during decommissioning activities are similar to requirements for construction:

- 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 decommissioning and earthworks 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):

- 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.

2.1 Existing Environment

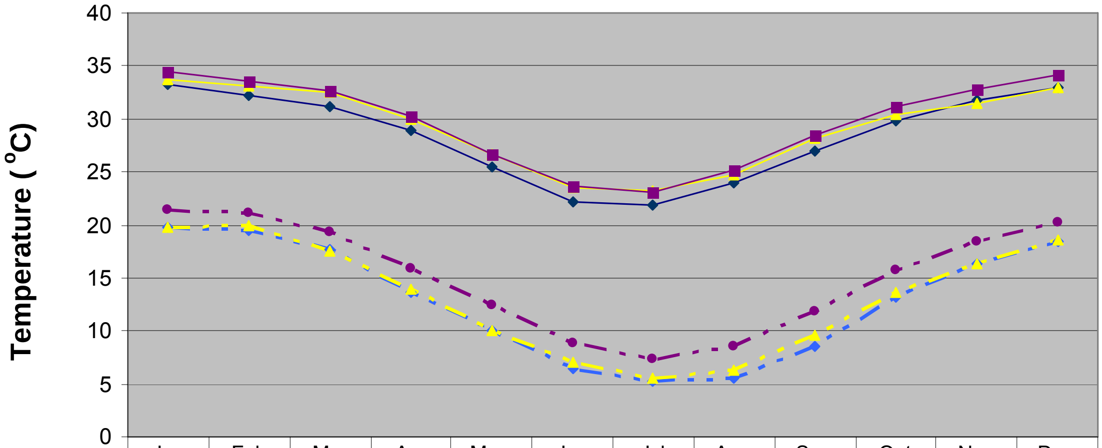
2.1.1 Climate along the Gas Transmission Pipeline

The Gas Transmission Pipeline connects the gas fields at Fairview with the LNG facility at Gladstone. The climate at either end of the Gas Transmission Pipeline is discussed in Section 1.1.1 and Section 3.1.1 respectively. This section considers meteorological data collected at Biloela DPI (a site operated by the Department of Primary Industry), Thangool Airport and Baralaba Post Office by the Bureau of Meteorology. These sites are located along the 425 km Gas Transmission Pipeline route. Biloela is approximately 100 km from Gladstone, located very close to the Gas Transmission Pipeline. Thangool is approximately 10 km south of Biloela, by the Burnett Highway; Baralaba is approximately 150 km from Gladstone, 50 km north of Banana and 30km north of the Gas Transmission Pipeline. The pipeline route and these meteorological sites are provided in the project map in Figure 1-1.

The climate summary for these monitoring sites is presented below.

Temperature

Mean maximum temperatures range from 21.9°C in July at Biloela DPI to 34.4°C in January at Baralaba Post Office. Mean minimum temperatures range from 5.2°C at Biloela DPI to 21.4°C in January at Baralaba Post Office. These data are shown in Figure 2-1.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Biloela DPI Max	33.2	32.2	31.2	28.9	25.4	22.2	21.9	23.9	27.0	29.8	31.7	32.9
Biloela DPI Min	19.8	19.5	17.7	13.7	10.1	6.5	5.2	5.6	8.6	13.2	16.4	18.4
Thangool Airport Max	33.7	33.1	32.5	29.9	26.6	23.5	23.2	24.7	28.1	30.4	31.5	33.0
Thangool Airport Min	19.8	19.9	17.6	13.9	10.1	7.0	5.5	6.3	9.6	13.7	16.3	18.6
Baralaba Post Office Max	34.4	33.5	32.7	30.3	26.6	23.6	23.1	25.1	28.4	31.2	32.8	34.1
Baralaba Post Office Min	21.4	21.1	19.3	15.9	12.4	8.9	7.4	8.6	11.8	15.7	18.4	20.2

Time (Month)

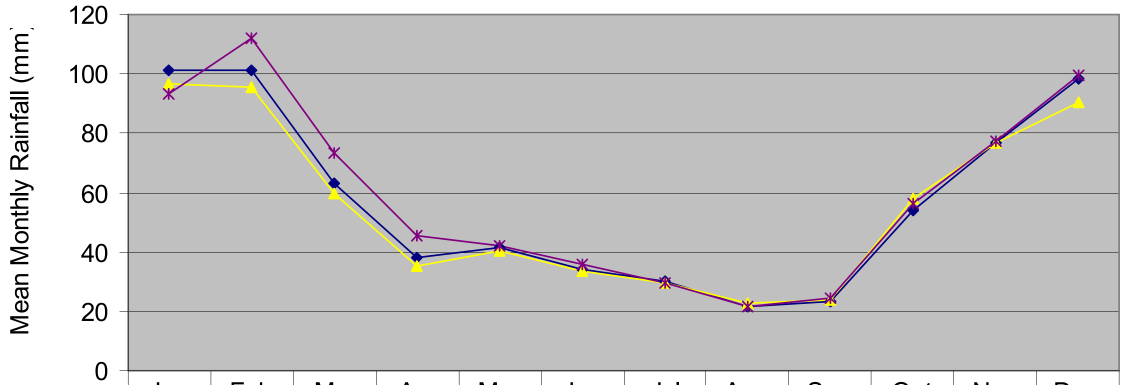
Figure 2-1 Mean monthly maximum and minimum temperature at sites near the Gas Transmission Pipeline

Rainfall and Evaporation

The sites at Biloela DPI, Thangool airport and Baralaba Post Office report similar annual rainfall statistics; average 661mm, 683mm and 709 mm respectively, as shown in Figure 2-2. The summer months (December to February), report the highest average monthly rainfalls figures (approximately 100 mm per month). Rainfall in the winter months (April to September) averages approximately 20 mm - 40 mm per month.

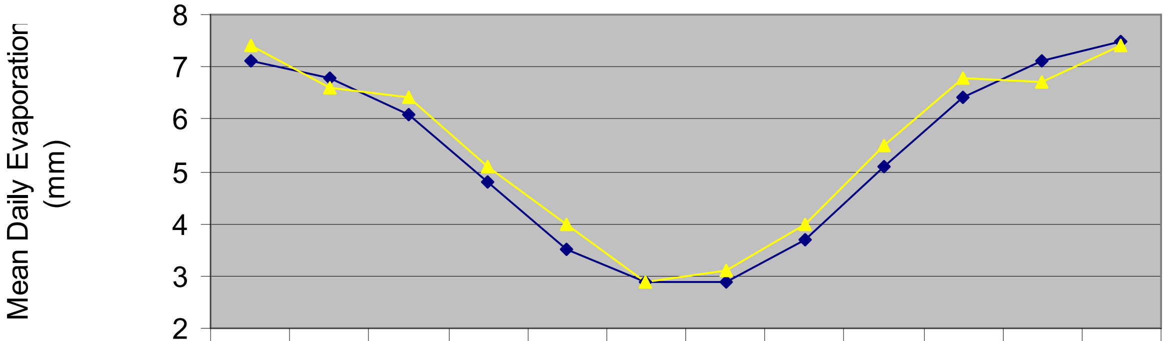
Evaporation records are only available for two of the three sites (Biloela DPI and Thangool airport) with data shown in Figure 2-3. Evaporation is highest from November through to February, with a mean daily potential evaporation rate of approximately 7 mm (approximately 210 per month). The winter months of June and July exhibit evaporation rates of approximately 3 mm (approximately 90 mm per month).

April and September may be the driest months as rainfall is low (average of about 40 mm for April and 20 mm for September), and evaporation demand is reasonably high (averagely about 5 mm for April and 5.5 mm for September).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Biloela DPI	101.3	101.4	63.1	38	41.4	34.4	30.1	21.4	23.3	54	76.5	98.6
Thangool Airport	96.5	95.4	59.9	35.2	40.5	33.3	29.5	22.9	24	57.8	77	90.4
Baralaba Post Office	93.1	112.3	73.2	45.5	42.1	35.6	29.7	21.4	24.6	56.3	77.1	99.7

Figure 2-2 Mean monthly rainfall at sites adjacent to the Gas Transmission Pipeline



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Biloela DPI	7.1	6.8	6.1	4.8	3.5	2.9	2.9	3.7	5.1	6.4	7.1	7.5
Thangool Airport	7.4	6.6	6.4	5.1	4	2.9	3.1	4	5.5	6.8	6.7	7.4

Time (Month)

Figure 2-3 Mean daily evaporation (mm) at sites adjacent to the Gas Transmission Pipeline

Relative Humidity

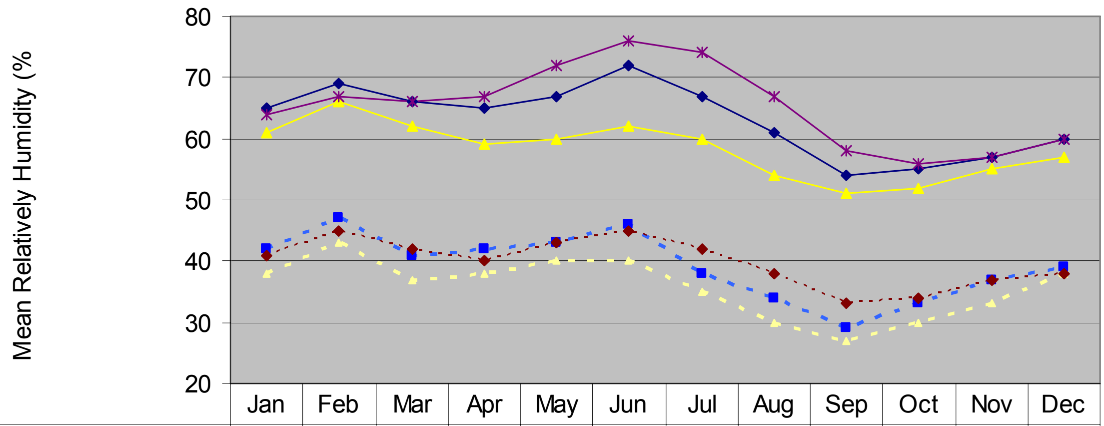
Relative humidity for all sites, as shown in Figure 2-4, is as follows:

- high at 9am, ranging from 50% to 75% on average, and
- low at 3pm, ranging from 27% to 47%.

This is primarily due to the low temperature in the morning and high temperature in the afternoon as the water holding capacity of the air increases with temperature.

For all sites, September has the lowest relative humidity, which is consistent with the rainfall and evaporation data.

Among all three sites, Thangool has the lowest relative humidity in general and Baralaba is slightly more humid than Biloela.



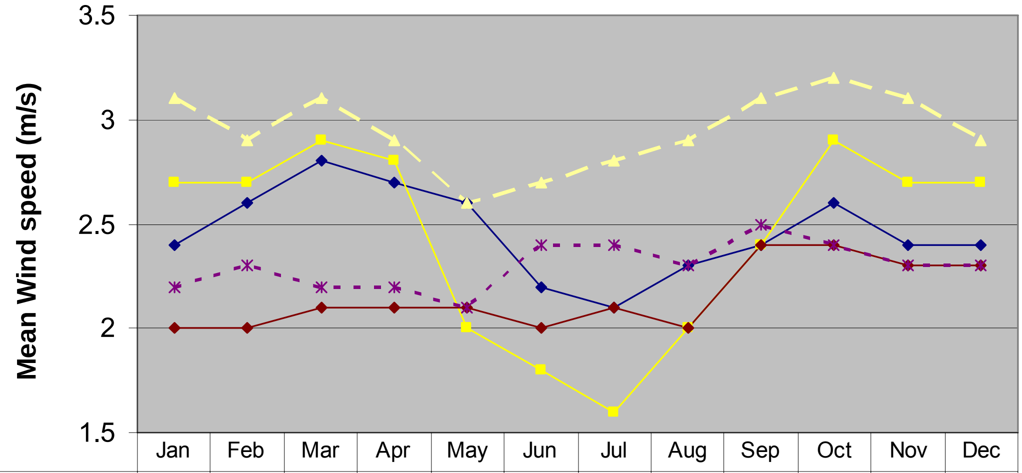
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Biloela DPI 9am	65	69	66	65	67	72	67	61	54	55	57	60
Biloela DPI 3pm	42	47	41	42	43	46	38	34	29	33	37	39
Thangool Airport 9am	61	66	62	59	60	62	60	54	51	52	55	57
Thangool Airport 3pm	38	43	37	38	40	40	35	30	27	30	33	38
Baralaba Post Office 9am	64	67	66	67	72	76	74	67	58	56	57	60
Baralaba Post Office 3pm	41	45	42	40	43	45	42	38	33	34	37	38

Time (Month)

Figure 2-4 Mean monthly relative humidity (%) at 9am and 3pm at sites near the Gas Transmission Pipeline

Wind

Figure 2-5 presents the monthly average wind speed at 9am and 3pm for three Bureau of Meteorology meteorological stations. For all three sites, monthly average wind speed ranges from 1.6 m/s to 3.1 m/s, with a site average of 2.5 m/s for Biloela, 2.7 m/s for Thangool, and 2.2 m/s for Baralaba.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Biloela DPI 9am	2.4	2.6	2.8	2.7	2.6	2.2	2.1	2.3	2.4	2.6	2.4	2.4
Thangool Airport 9am	2.7	2.7	2.9	2.8	2	1.8	1.6	2	2.4	2.9	2.7	2.7
Thangool Airport 3pm	3.1	2.9	3.1	2.9	2.6	2.7	2.8	2.9	3.1	3.2	3.1	2.9
Baralaba Post Office 9am	2	2	2.1	2.1	2.1	2	2.1	2	2.4	2.4	2.3	2.3
Baralaba Post Office 3pm	2.2	2.3	2.2	2.2	2.1	2.4	2.4	2.3	2.5	2.4	2.3	2.3

Figure 2-5 Mean monthly wind speed (m/s) at 9am and 3pm at sites near the Gas Transmission Pipeline

2.1.2 Legislative Framework

The legislative framework that is applicable to evaluation of air quality impacts from the Gas Transmission Pipeline is presented in Section 3.1.2.

2.1.3 Existing Air Quality

The existing air quality near the eastern end of the Gas Transmission Pipeline is represented by measurements taken at Gladstone, as presented in Section 3.1.3. The existing air quality near the western end of the Gas Transmission Pipeline is represented by measurements from Toowoomba, as presented in Section 1.1.3. There are no other sites that measure air quality in the vicinity of the Gas Transmission Pipeline route.

2.2 Potential Impacts and Mitigation Measures

The gas transmission pipeline will be a buried, high pressure steel pipeline. It is to be built entirely of welded pipes, with approximate nine buried mainline valves with an above-ground bypass valve and blowdown piping. Mainline valves are used for isolating sections of the pipeline and venting gas to enable maintenance activities or in the event of an incident. At this stage, no compressor stations are proposed along the pipeline route.

2.2.1 Air Emissions from the Project

Emissions during Construction

Air emissions during construction of the gas transmission pipeline will be primarily dust, with some minor sources of combustion pollutants such as nitrogen oxides due to diesel and petrol vehicles and machinery.

Emissions will be generated from a number of sources including:

- Clearing of vegetation and topsoil;
- Excavation and transport of earth material;
- Vehicles (including heavy vehicles delivering pipeline) travelling on unpaved roads; and
- Vehicles and construction equipment (such as excavators) exhausts.

The impacts of construction activities will be managed though the Environmental Management Plan. 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.

Emissions during Normal Operation

The gas transmission pipeline does not have any release points apart from mainline valves for use during maintenance activities or in the event of an incident. For this reason, potential air quality impacts are unlikely during routine operations, except for minor dust and exhaust emissions from pipeline maintenance vehicles.

Emissions during Upset Conditions

Potential gas release (i.e. gas venting) during emergencies or planned maintenance may occur via mainline valves. In case of such events, the air releases will be predominantly methane, with minor releases of carbon dioxide and nitrogen, and with trace releases of ethane and propane. Those gases are not considered as air pollutants and not listed in the key pollutants table in the Term of Reference, and hence they have not been assessed for air quality impacts. Methane releases during upset conditions have been addressed in Appendix T.

2.2.2 Dispersion Modelling

No air dispersion modelling has been conducted to assess air quality impacts from the pipelines during normal operation and upset conditions for reasons above. No modelling has been conducted to assess air quality impacts during pipeline construction because of the difficulty to model ever-changing construction location and the mobile nature of most sources during the construction. Rather, the impacts of construction activities on air quality will be managed through implementing best practice procedures to reduce air emissions as part of the Environmental Management Plan

Assessment of cumulative impacts from operation of the pipeline is not required, due to the low operational impacts and infrequent releases of gas from the pipeline under upset conditions.

As there are no known hazardous or toxic air pollutants from the pipeline during normal operation, a human health risk assessment has not been conducted. Potential human health impacts from dust and other pollutants during the construction will be minimised through implementing best practice procedures to reduce air emissions.

Due to the chemical composition of the coal seam gas, odour is not considered relevant to the proposed pipeline.

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.

2.2.3 Mitigation Measures

This project will comply with the Santos document *EHS Management System Hazard Standard, EHS05 Air Emissions.* Santos strives to meet air quality guidelines for a new facility through 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 the relevant environmental agency. Specific mitigation measures for each phase of the project development are discussed below.

Construction

Mitigation measures to reduce potential dust 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 cleared areas will be rehabilitated through revegetation.
- Minimise vehicle speeds.
- 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)

- 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.

Operational

During operation phase, mitigation measures include

- Minimising vehicle speeds for pipeline patrol vehicles, and
- Monitoring and maintenance programs to ensure good vegetation cover on the Right of Way areas along the pipeline.

Decommissioning

Mitigation measures to reduce potential emissions during decommissioning activities are similar to requirements for construction:

- 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 decommissioning and earthworks 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):

- 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.

3.1 Existing Environment

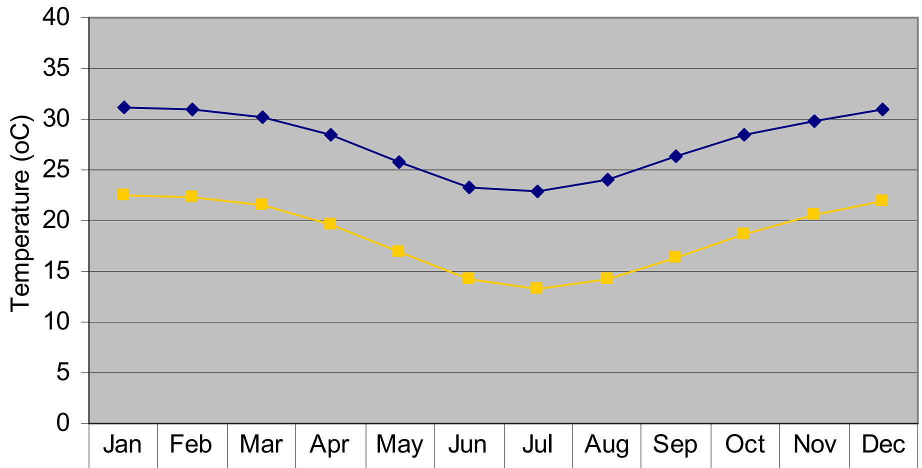
3.1.1 Climate at Gladstone

Gladstone has a sub-tropical coastal climate, characterised by increased rainfall and hot humid conditions in the summer months (November to March).

Long-term climate records are available from the Bureau of Meteorology for Gladstone Post Office (1872 to 1958) and Gladstone Radar (1957 to 2008). As the Gladstone Post Office is an old site that was closed half a century ago, only the Gladstone Radar data are presented below, showing recent data for temperature, rainfall, evaporation and humidity up to August of 2008.

Temperature

The mean daily maximum and minimum temperatures at Gladstone Radar are presented in Figure 3-1. On average, the daily temperature range in summer is from 22.5 °C to 31.2 °C (January), and in winter from 13.3 °C to 22.8 °C (July). The highest temperature recorded at the Gladstone Radar site is 42.0 °C, and the region has a mean number of 4.5 days per year when the temperature is over 35 °C. The lowest recorded temperature is 4.4 °C.



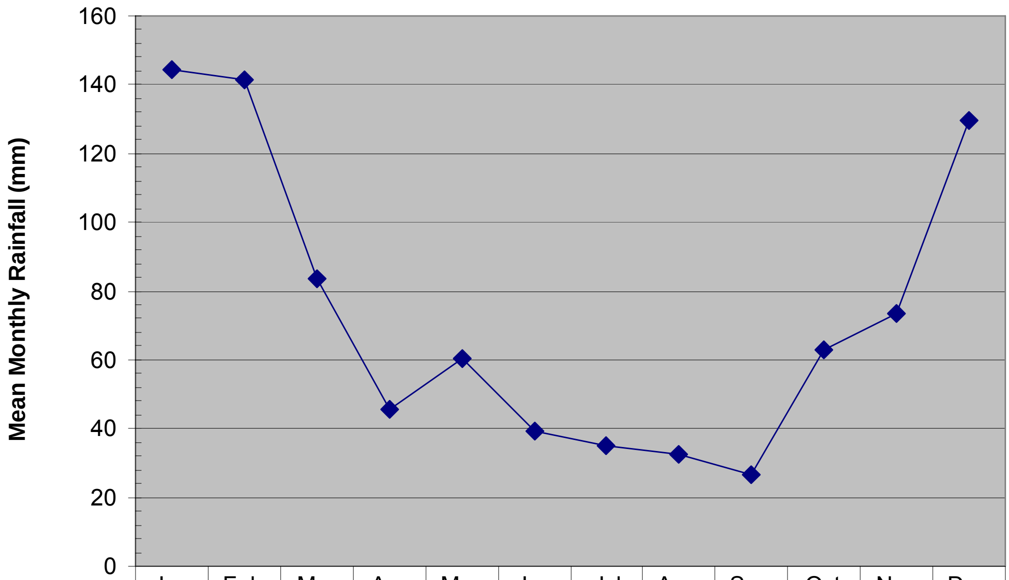
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temperature (°C)	31.2	30.9	30.2	28.4	25.7	23.2	22.8	24.0	26.4	28.4	29.9	31.0
Mean daily minimum temperature (°C)	22.5	22.4	21.5	19.6	17.0	14.3	13.3	14.2	16.4	18.7	20.5	21.9

Figure 3-1 Mean daily maximum and minimum temperature at the Gladstone Radar site

Rainfall and Evaporation

The Gladstone Radar site experiences an average annual rainfall of 878 mm, with an average of 97.6 rain days per year. The highest monthly rainfall (709.8 mm) and highest daily rainfall (248.0 mm) events were both recorded in February 2003.

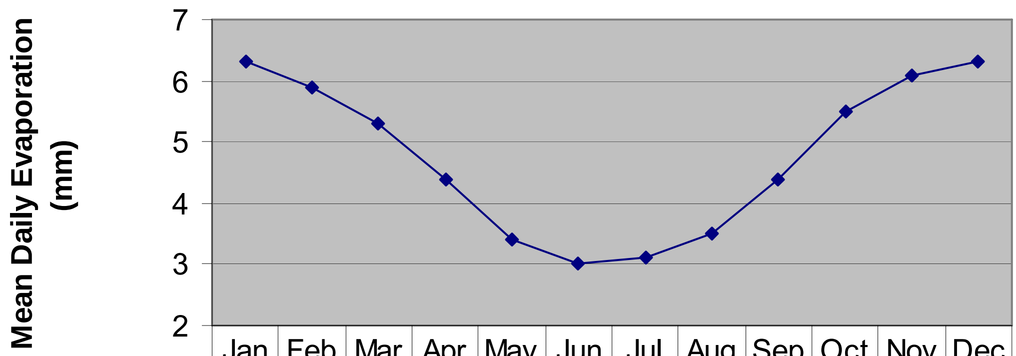
The mean monthly rainfall is presented in Figure 3-2. Rainfall generally occurs during the summer months (November to March), with monthly rainfall figures ranging from 76mm to 144 mm per month. Rainfall during these months typically represents two-thirds of the annual total rainfall. Typically little to no rainfall is recorded in the months of May to September.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	144.2	141.5	83.5	45.5	60.5	39.4	35.2	32.4	26.6	62.9	73.6	129.8

Figure 3-2 Mean monthly rainfall at the Gladstone Radar site

The mean daily evaporation rate is presented in Figure 3-3. Evaporation is highest from November through to February, with a mean daily potential evaporation rate of between 5.9 mm and 6.3 mm (approximately 177 to 189 mm per month). The winter months have an evaporation rate of about 3 mm (approximately 90 mm per month). Note that evaporation is measured using evaporation pans filled with water, and actual evaporation may be limited by water availability.

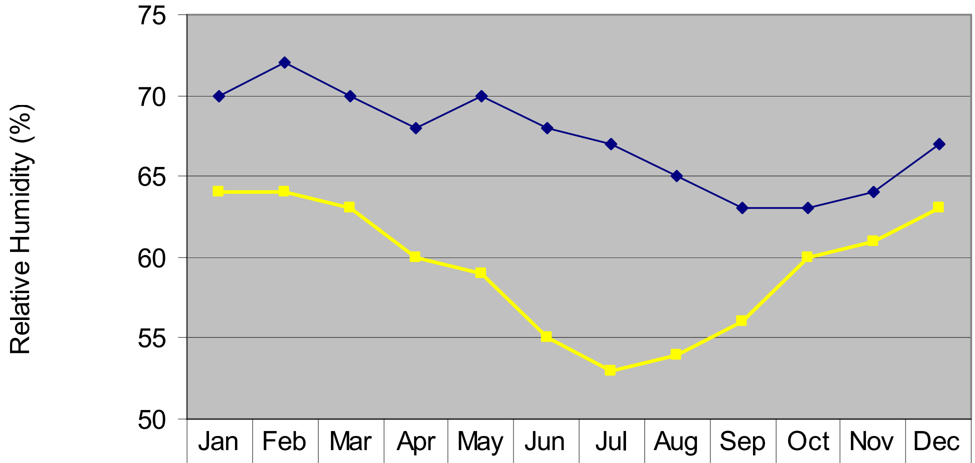


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily evaporation (mm)	6.3	5.9	5.3	4.4	3.4	3.0	3.1	3.5	4.4	5.5	6.1	6.3

Figure 3-3 Mean Daily Evaporation at the Gladstone Radar site

Relative Humidity

The relative humidity at 9am and 3pm is presented in Figure 3-4. The relative humidity measured at the Gladstone Radar site at 9 am ranges (on monthly averages) from 64% (spring) to 72% (summer). Records of the monthly average relative humidity indicate that at 3 pm the lowest value is 53% in winter and the highest value is 64% in summer.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean 9am relative humidity (%)	70	72	70	68	70	68	67	65	63	63	64	67
Mean 3pm relative humidity (%)	64	64	63	60	59	55	53	54	56	60	61	63

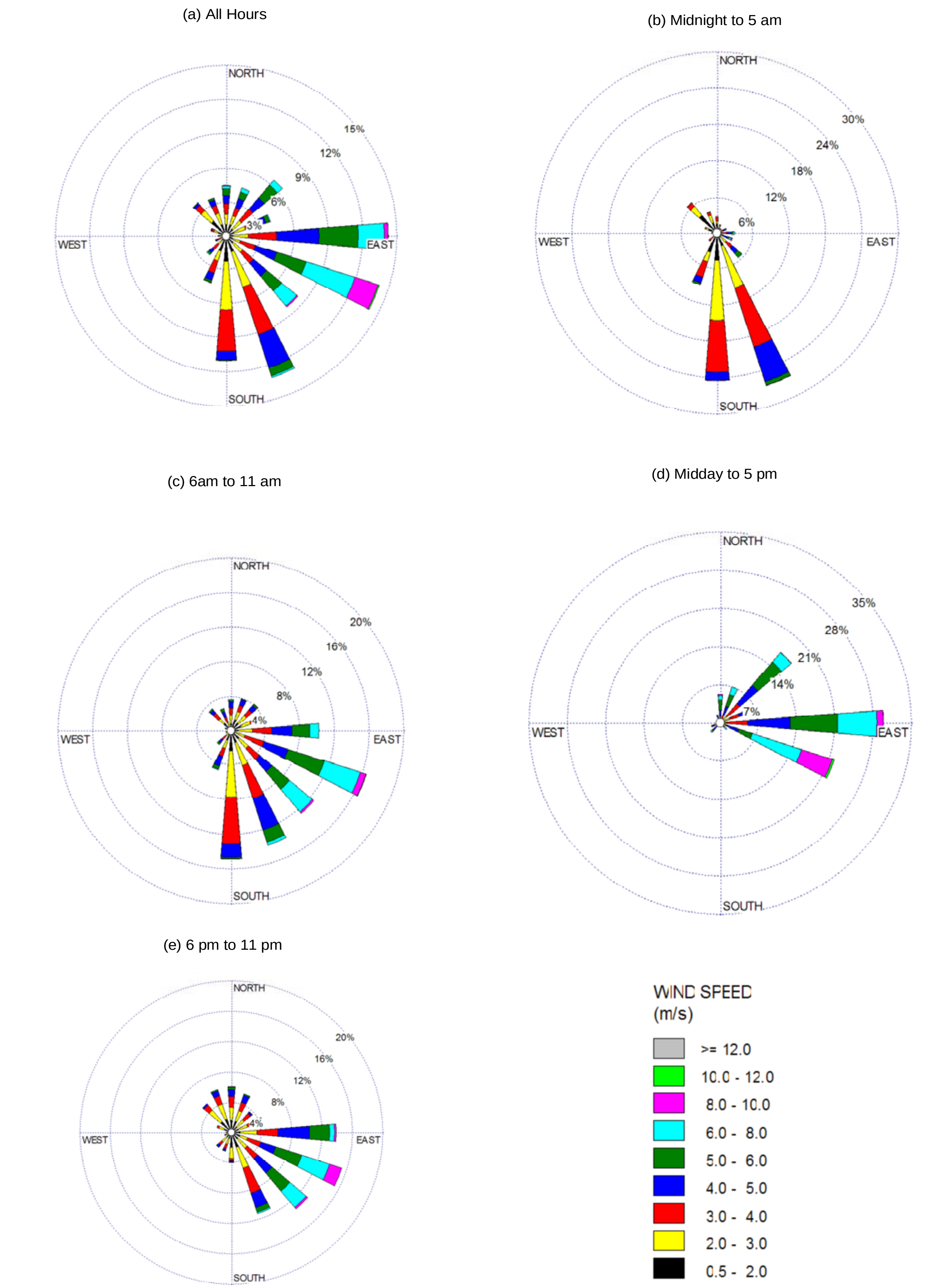
Figure 3-4 Mean 9am and 3pm relative humidity (%) at the Gladstone Radar site

Wind

Records of winds in the Gladstone area are available from the Bureau of Meteorology and EPA monitoring sites. Data for the year 2001 have been incorporated into the meteorological fields that are part of the Gladstone Airshed Modelling System (GAMS), a regional dispersion modelling tool that is available from the Queensland EPA. GAMS is described in more detail in Section 0. The wind fields in GAMS were generated using Calmet, a three-dimensional meteorological modelling program.

Wind data for 2001 has been extracted from GAMS for the proposed LNG facility location, based on a 10 m measurement height. The average wind speed for year 2001 is 3.7 m/s, which is a higher wind speed than experienced at Gladstone. Wind roses have been prepared from this data, and are presented in Figure 3-5. Figure 3-5a presents the wind rose for all hours of the year. This figure shows that the dominant wind direction at the site is from the east through to the south, with wind speeds reaching up to 12 m/s. In general, stronger winds originate from the east and east-south-east, and weaker winds from the south and south-south-east. Figure 3-5b shows the distribution of winds in the early morning (midnight to 5am). These are heavily dominated by flows from the south and south-south-east, with wind speeds typically below 5 m/s. Daytime wind patterns (Figure 3-5c and Figure 3-5d) indicate that throughout the day, the wind direction is increasingly from the east in the afternoon. Wind speeds during the day are much stronger than at night, due to the influence of the sea breeze. In the evening (Figure 3-5e), the wind speed and direction reverts back to the night conditions.

The seasonal profile of winds at the LNG facility site is illustrated in Figure 3-6, for all hours. The influence of the sea breeze from the east is most noticeable in the summer, dominated by strong easterlies (Figure 3-6a), with decreasing importance in the spring (Figure 3-6b) and autumn (Figure 3-6d). Winter wind roses (Figure 3-6c) are characterised by low wind speeds, mainly southerlies, with some moderate winds from the east-south-east.

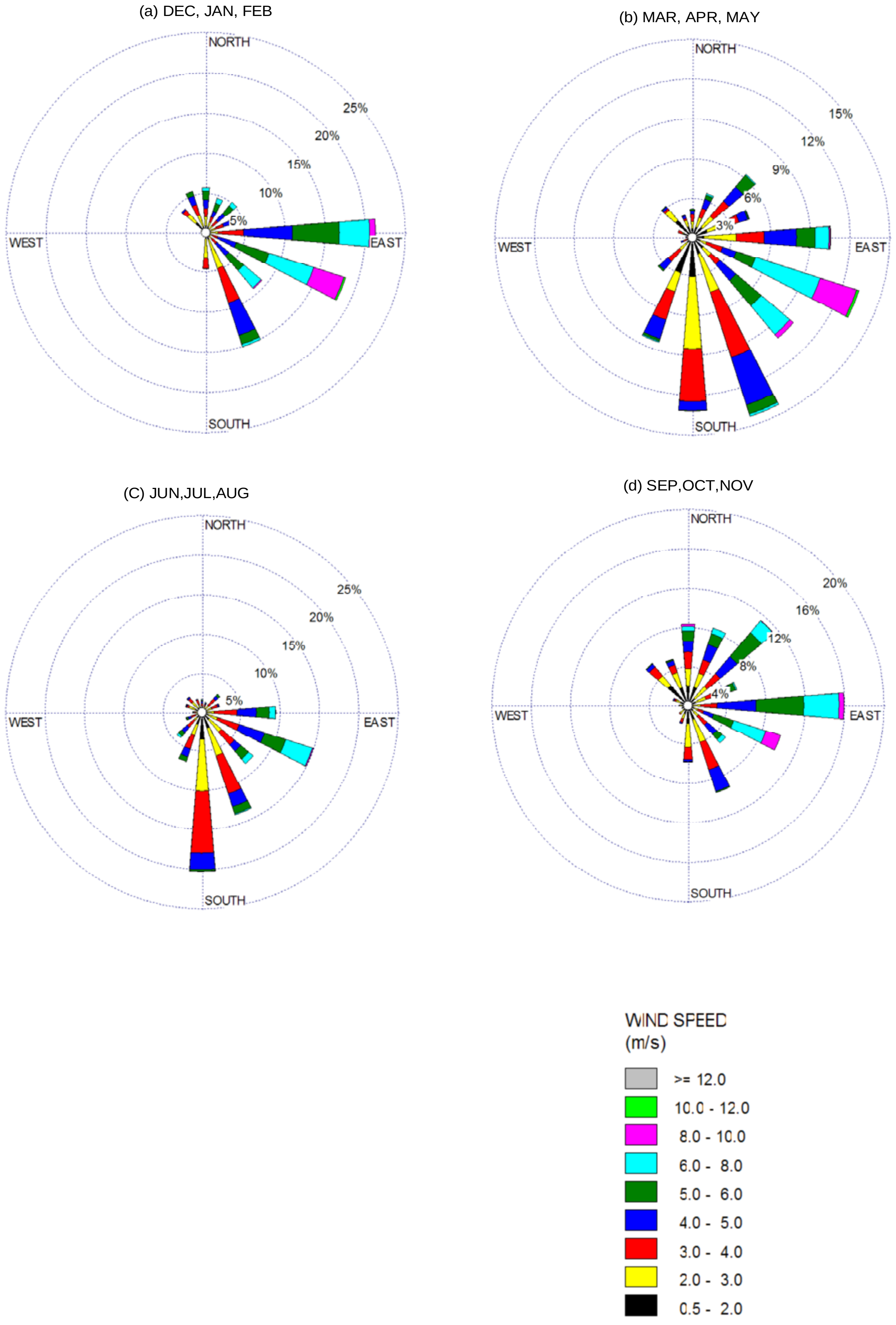


Client:

Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT

Title: **WIND ROSE PLOT AT THE LNG FACILITY BY HOUR OF THE DAY**

Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-5**
Job No: **4262 6220**	File: 42626220-g-615.srf		Rev B A4



Client: LNG

URS

Project: GLADSTONE LNG PROJECT
AIR QUALITY IMPACT ASSESSMENT

Title: **WIND ROSE PLOT AT THE LNG FACILITY BY SEASON**

Drawn: LF	Approved: JB	Date: 03-02-2009
Job No: **4262 6220**	File: 42626220-g-616.srf	

Figure: **3-6** | Rev B | A4

Atmospheric Stability

Atmospheric stability is a parameter that is derived wind and temperature profile data. These data are used to characterise the conditions that lead to enhanced (unstable conditions) or poor atmospheric dispersion (stable conditions).

The frequency of occurrence of the atmospheric stability classes, based on data derived from GAMS for 2001 at the project site, is presented in Table 3-1. This shows that the site is heavily influenced by stable (44%) and neutral atmospheric conditions (33 %), with only about 7% of conditions being classified as Extremely Unstable or Unstable.

Table 3-1 Frequency of Atmospheric Stability Classes at the Project site

Atmospheric Stability Class	Frequency of Occurrence	Description of Category
A	0.3%	Extremely Unstable
B	6.9%	Unstable
C	16.8%	Slightly Unstable
D	32.8%	Neutral
E	14.4%	Slightly Stable
F	29.1%	Stable

Mixing Height

Hourly mixing height data at the LNG facility site have been derived from GAMS for 2001, and are presented in Figure 3-7 as box-and-whisker plots. At night, the mixing height is very low and close to the lower limit of 50 m used in the model. The mixing height rises sharply after sunrise, and peaks at around 1,200 m to 2,000 m in the afternoon for the majority of the days (10 to 90th percentile). Daily maximum mixing height is lower in the winter than the summer due to less solar heating.

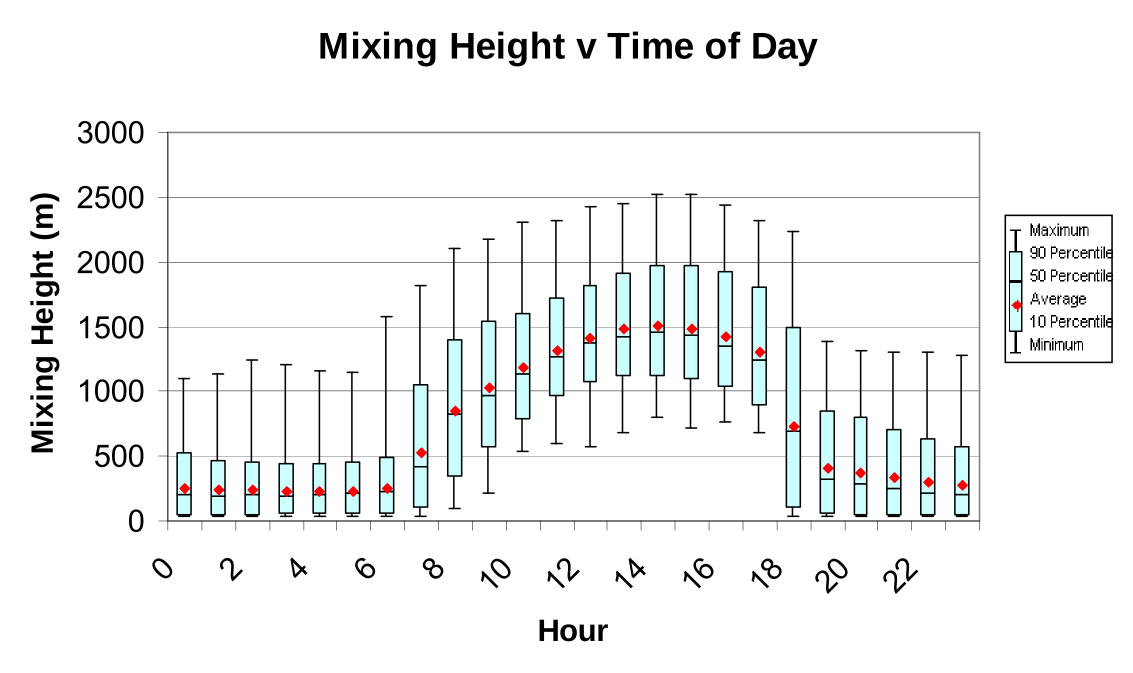


Figure 3-7 Mixing height by time of day for the LNG facility site at Curtis Island

Temperature Inversion

Air temperature generally decreases with altitude, with buoyancy causing the air to mix vertically. This is typical of sunny daytime conditions which are described as unstable. Temperature inversions occur when the temperature increases with height, which may only occur in a shallow band of air. This has the effect of trapping colder parcels of air below the warmer air above. Any pollution source that is emitted below this trapped inversion layer will have limited vertical mixing, and thus the pollutant will remain trapped and will have limited opportunity for dilution with fresh air. This effect also applies to ground-level noise sources. Inversions commonly develop at night, when the surface cools due to radiation heat loss to the atmosphere.

Temperature inversions often create the worst-case meteorological conditions for air dispersion, especially during the night-time period in winter (June, July and August).

The frequency of temperature inversions at Curtis Island has been determined from the Calmet modelled meteorological data for 2001. These data were extracted from all the vertical levels in the model (between 10 m and 2,750 m elevation above ground level) for June, July and August. The data showed the high occurrence of low-level inversion (less than 300 m height) from midnight to 6am, and some occurrence of these conditions from 8 to 11 pm. A summary of the occurrence of temperature inversions of varying inversion strength is presented in Table 3-2.

Four major inversion episodes with at least 1 hour with temperature inversion greater than 3 °C per 100 m occurred, on 16 June, 10 July, 15 July, and 26 July. These inversions lasted throughout the night, breaking up during the day time.

Table 3-2 Frequency of inversions for winter months at project site (2001 data)

Inversion strength	Total number of hours	Percent of winter hours
More than 3 °C/100 m	6	0.3%
More than 2 °C/100 m	87	4%
More than 1 °C/100 m	621	28%
More than 0 °C/100 m	1,188	54%

Cyclones and Extreme Weather Events

An historical database of severe storm and disaster events is maintained by Emergency Management Australia Disasters Database[2]. Records for the Rockhampton region (incorporating Gladstone) note that cyclones occurred in 1863, 1949, 1950, 1976 and 1990 (twice), with only the 1949 cyclone affecting Gladstone. Floods were noted in the Rockhampton region in 1959, 1990 (lasting over a month), 1997 and 2008. Other natural disasters reported in the Rockhampton region are an earthquake (1918), landslide (2000) and severe storms (2004). Many of the events reported had damage that spread over a wide geographical region.

3.1.2 Legislative Framework

Queensland ambient air quality guidelines

In Queensland, air quality is managed under the Environment Protection Act 1994 (the Act), the Environmental Protection Regulation 1998 [3] (the Regulation) and the Environmental Protection (Air) Policy 1997 [4] (the Policy).

The Act provides for long-term protection for the environment in Queensland in a manner that is consistent with the principles of ecologically sustainable development. The primary purpose of the Policy is to achieve the objectives of the Act in relation to Queensland's air environment. This objective is achieved by the Policy through:

- Identification of environmental values to be enhanced or protected;
- Specification of air quality indicators and goals to protect environmental values; and
- Provision of a framework for making consistent and fair decisions about managing the air environment and involving the community in achieving air quality goals that best protect Queensland's air environment.

The Policy applies "…to Queensland's air environment" but the air quality goals specified in the Policy do not extend to workplaces covered by the *Workplace Health and Safety Act (1995)*, or inside dwellings, hotels, education centres or hospitals (Section 9 of the Policy). Workplace health and safety exposure standards have not been addressed in this assessment.

Schedule 1 of the Policy, referred to as the EPP (Air) in this report, specifies the air quality indicators and goals that are to be achieved. The Schedule is divided into:

---

[2] Available at web site http://www.ema.gov.au/ema/emaDisasters.nsf

[3] Queensland Government, *Environmental Protection Regulation* 1998, Office of the Queensland Parliamentary Counsel.

[4] Queensland Government, *Environmental Protection (Air) Policy* 1997, Office of the Queensland Parliamentary Counsel

- Part 1 – Indicators and goals relevant to the aesthetic enjoyment of places and visual and local amenity;
- Part 2 - Indicators and goals relevant to biological integrity; and
- Part 3 – Other indicators and goals.

The goals in Part 3 are set for the protection of human health. EPP (Air) goals in Parts 1 and 3 are taken to be applicable to residential locations, while Part 2 goals are applicable to sensitive vegetation. Part 3 includes the guidelines for criteria pollutants such as nitrogen oxides, particulates (PM_{10}), sulphur dioxide, carbon monoxide and ozone, and toxic air pollutants such as formaldehyde and toluene. Relevant ambient air quality goals for this study are reproduced in Table 3-3.

National ambient air quality guidelines

National air quality guidelines are specified by the National Environment Protection Council (NEPC). The *National Environment Protection (Ambient Air Quality) Measure* (NEPM) was released in 1998 [5] (with an amendment in 2003), and sets standards for ambient air quality in Australia.

The NEPM specifies national ambient air quality standards and goals for the following common air pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), particulate matter with aerodynamic diameter less than 10 µm as (PM_{10}) and particulate matter with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) and lead (Pb). Relevant pollutants that are considered in this assessment are NO_2, SO_2, PM_{10} and CO.

Ambient concentrations of $PM_{2.5}$ are addressed only by advisory reporting standards in the NEPM, which are not applied as goals. Since detailed data on emissions of $PM_{2.5}$ are not available, emissions and impacts of $PM_{2.5}$ have not been addressed in this report. Potential particulate emissions and impacts are addressed through consideration of the impacts of total suspended particulates and PM_{10}.

In 2004 the *National Environment Protection (Air Toxics) Measure* was released which included monitoring investigation guidelines for five compounds classified as air toxics: benzene, benzo (a) pyrene, formaldehyde, toluene and xylene. These toxic air pollutants are not released in significant quantities from the Project and have not been quantified in the air quality assessment. See Section 3.2.4 for further discussion.

The NEPM and EPP (Air) standards that are relevant to the Project are included in Table 3-3. 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.

International ambient air quality guidelines

International air quality guidelines are set out by the World Health Organisation (WHO) and were published in 2000[6], with an update in 2005[7]. These ambient air quality guideline values are based on the health effects that have been ascertained for individual compounds. Individual jurisdictions can choose whether to adopt these guidelines as standards, hence they are intended to provide guidance on health effects.

---

[5] National Environmental Protection Council,*National Environment Protection Measure for Ambient Air Quality*, 1988, with amendment in 2003.

[6] World Health Organisation, *Air Quality Guidelines*, Second Edition, 2000 http://www.euro.who.int/air/activities/20050223_4, accessed July 2006

[7] World Health Organisation, *Air Quality Guidelines – Global Update 2005* http://www.euro.who.int/air/activities/20050624_2, accessed July 2006

The WHO recommendations have not been adopted for implementation in Queensland. Priority has been given to air quality guidelines that are enacted in Queensland, followed by national guidelines (NEPM). The guidelines for SO_2, NO_2, and PM_{10} from the EPP (Air) and NEPM have been used for this assessment as presented in Table 3-3.

Table 3-3 Australian and International Guidelines and Standards for Ambient Air Quality

Pollutant	Averaging time	Guideline, Goal or Standard Value	Jurisdiction
Sulphur dioxide	10 minutes	700 µg/m³	EPP (Air)[1]
	1 hour	570 µg/m³	EPP (Air)[1], NEPM-Ambient Air
	24 hours	100 µg/m³ 230 µg/m³	EPP (Air)[2] NEPM-Ambient Air
	Annual	60 µg/m³	EPP (Air)[1,2], NEPM-Ambient Air
Nitrogen dioxide	1 hour	320 µg/m³ 246 µg/m³	EPP (Air)[1] NEPM-Ambient Air
	4 hours	95 µg/m³	EPP (Air)[2]
	Annual	30 µg/m³ 62 µg/m³	EPP (Air)[2] NEPM-Ambient Air
Carbon Monoxide	8 hours	10000 µg/m³ 11200 µg/m³	EPP (Air)[1] NEPM-Ambient Air
Total suspended particulates	Annual	90 µg/m³	EPP (Air)[1]
PM_{10}	24 hours	150 µg/m³ 50 µg/m³	EPP (Air)[1] NEPM-Ambient Air
	Annual	50 µg/m³	EPP (Air)[1]
Ozone	1 hour	210 µg/m³	EPP (Air)[1] & NEPM-Ambient Air
	4 hour	170 µg/m³	EPP (Air)[1] & NEPM-Ambient Air

[1]EPP (Air) Part 3, for protection of human health

[2]EPP (Air) Part 2, for protection of biological integrity

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"[8] 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 have been adopted for this project. The relevant NSW DECC emission concentration standards are presented in Table 3-4, with reference conditions of dry, 273 K, 101.3 kPa, and 15% O_2 for gas turbines. There are no emission standards for SO_2 that are applicable to the LNG plant activities.

[8] http://www.environment.nsw.gov.au/air/poeoca2002.htm, access in December, 2008.

Table 3-4 NSW Department of Environment and Climate Change's Emission Concentration Standards related to this project

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	

3.1.3 Existing Air Quality

Existing air quality at Gladstone has been assessed through examining air quality monitoring data by the EPA and air dispersion modelling. Modelled impacts of existing and proposed industrial sources in Gladstone have been used for assessment of cumulative NO_2 and SO_2 impacts, as detailed in this section.

Air quality measurements at Gladstone

Air quality monitoring is currently undertaken in the Gladstone region by the EPA. Current monitoring sites are operated at Targinie, Clinton and South Gladstone, and measure ozone (Targinie), nitrogen dioxide (all three sites), sulphur dioxide (all three sites), PM_{10} (all three sites), visibility reducing particles (South Gladstone and Targinie), benzene (Targinie) and toluene (Targinie). An additional site at Barney Point was operational in 2001 and 2002, and monitored NO_2, SO_2, and PM_{10}.

A summary of the ambient air quality monitoring data in Gladstone, for NO_2, SO_2 and O_3 data recorded from 2001 to 2007, is presented in Table 3-5. The highest concentrations of pollutants that were recorded at each site over the 7-year period are summarised in the table. For PM_{10} 24-hour average concentrations, the 95th percentile value at Targinie is also presented in the table, to provide a more realistic background level for the cumulative impact assessment.

These values show that the existing levels of NO_2, SO_2, ozone and PM_{10} are well below the relevant EPP (Air) guidelines, as detailed in Section 2.1.2, at all the monitoring sites.

Monitoring data for PM_{10} shows that the highest records over the period from 2001-2007 occasionally exceeded the 24-hour ambient air quality guideline of 150 µg/m^3. The EPA monthly monitoring bulletins indicate that dust storms/bushfires were experienced across the region in October 2002 and February 2005, which clearly affected the monitored dust levels. The storm in October 2002 was rated as the worst in 30 years, and the elevated dust concentrations lasted for 3 days. The dust storm in February 2005 resulted in higher than normal dust levels for five days, but exceedances of the guideline were recorded only on one day. These two months with elevated dust concentrations were not included in the reported background PM10 levels. In 2006 and 2007, PM10 levels were only monitored at Clinton and Targinie, during which time the maximum recorded level at Clinton was 53 µg/m³. Exceedance of the NEPM 24-hour guideline of 50 µg/m³ only occurred on one day. The maximum recorded level at Targinie was 79 µg/m³, with only one exceedance of the NEPM 24-hour guideline recorded. These exceedance frequencies are all within the allowable 5 days per annum for the NEPM 24-hour PM10 guideline.

Table 3-5 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	1 hour	84	99	142	99	320 EPP (Air) 246 NEPM
Sulphur Dioxide	1 hour	351	240	377	349	570 EPP (Air) and NEPM
Ozone	1 hour	120	n/a	n/a	n/a	210 EPP (Air) and NEPM
	4 hour	99	n/a	n/a	n/a	170 EPP (Air) and NEPM
Particulate Matter (PM_{10})	24 hour, maximum [9]	82	83	83	93	150 EPP (Air) 50 NEPM
	24 hour, 95th percentile				30	150 EPP (Air) 50 NEPM
	Annual	28	18	18	18	50 EPP (Air)

Background pollution levels for cumulative impact assessment

To model the cumulative impacts for NO_2 and SO_2 from the LNG facility and other background sources, air dispersion modelling has been conducted for the background sources to account for the spatial and temporal nature of pollution levels in the Gladstone air shed. This is described in detail later in this section.

To model the cumulative impacts for PM_{10}, a different approach has been used. For Gladstone, comprehensive PM_{10} emission inventories are not available, and therefore impacts from background sources have been considered as a constant level through time and a uniform level through modelling domain. Monitoring data at Targinie from 2001 to 2007 has been used to extract this data as Targinie is the closest monitoring site to the LNG facility. The annual average PM_{10} concentration at Targinie is 18 µg/m³. For the 24-hour averaging time, this concentration is taken as 95% of the 24-hour average data for 2001-2007 at Targinie, which is 30 µg/m³. Detailed explanations for choosing these constant background PM_{10} levels are provided in Section 3.2.2.

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 chemical and physical properties of Australian fine particles (http://www.cmar.csiro.au/e-print/open/CSIRO_AFP.pdf). Based

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

on this relationship, annual average TSP levels are 47, 30, 30 and 30 µg/m³ respectively for the four monitoring sites shown in Table 3-5. All are well below the EPP (Air) guideline of 90 µg/m³. The value of 30 µg/m³ is used as background level for cumulative impact assessment.

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. 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) show a maximum 8-hour CO level of 1.1 ppm. Results collected from Toowoomba report a level of 2.2 ppm. Both sets of results are far less than the EPP (Air) guideline of 8 ppm, or 10,000 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 8-hour averaging duration.

Methodology for Modelling background concentrations of NO_2 and SO_2

A detailed study of the industrial pollution sources in Gladstone (for SO_2 and NO_2 impacts only) was conducted for the baseline year 2001, as part of the Gladstone Airshed Study. Additional air quality and meteorological monitoring stations in Gladstone were available for that period, and the resultant data for meteorology and air quality in the region were used to construct a regional modelling tool, known as the Gladstone Airshed Modelling System (GAMS). The EPA managed the creation and use of GAMS, with the version that is available to the public being released in 2004. GAMS was obtained from the EPA for this project to ensure that the existing industrial sources were included in the dispersion modelling for NO_2 and SO_2, and so that the modelling approach used in this assessment was consistent with previous work in the Gladstone region. Further details on GAMS are presented in Section 0.

GAMS has been used as the modelling tool for the assessment of background concentrations of NO_2 and SO_2. In this section, the background concentrations are referred to as those from the existing and approved industrial sources. The following existing industrial sources are included in the background modelling for this project (with acronyms used in GAMS provided in the brackets):

- 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);
- Queensland Energy Resources, formerly Southern Pacific Petroleum Oil Shale (SPP)

Based on advice from EPA, the Ticor chemical plant is closed and the proposed Aldoga Aluminium Smelter (AAS) was never built. Hence these two sources are not included in the background modelling.

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 future, with significant changes to the project operation proposed. No updated emissions inventory for the site is available however, so for conservatism the emissions data included in GAMS have been used for this assessment.

Additionally, the following proposed industrial sources are 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 of the proposed LNG projects are to be located at Fisherman's Landing at Gladstone. There are other proposed LNG projects for Curtis Island (for example the Queensland Curtis LNG project by QGC Ltd and BG Group), however no emissions data are publicly available for these projects (as of November 2008) and hence they are not included in the background modelling.

Modelled concentrations of NO_2 and SO_2 are available in GAMS for a year of data (representing 2001 as the baseline year), and for typical operations of the existing industries. For the existing sources listed above, EPA has provided the modelling results of NO_2 and SO_2 to URS. For the three proposed industrial sources listed above, URS has obtained the emissions data from their EIS reports and modelled the air quality impacts using GAMS.

The predictions of NO_2 concentration in GAMS assume a constant conversion of 35% of the total NO_x to NO_2. The use of this ratio is discussed further in Section 3.2.2. The use of the 99.9th percentile result for 1 hour average concentrations and maximum values for other averaging times is also presented in Section 3.2.2.

Modelling results for background NO_2 and SO_2

Contour plots of the predicted peak 1-hour, 4-hour and annual average concentration of NO_2 (assuming 35% conversion from NO_x) due to existing and approved background industrial sources in Gladstone are shown in Figure 3-8 to Figure 3-10.

Contour plots of the predicted 10-minute, 1-hour, and 24-hour average concentrations of SO_2 due to existing and approved background industrial sources in Gladstone are shown in Figure 3-11 to Figure 3-14. Note that the 10-minute data presented in Figure 3-11 are derived from 1-hour data using the method described in Section 0.

These figures demonstrate that the modelled 4-hour NO_2 concentrations exceed the EPP (Air) 4-hour guideline for vegetation in some areas at Gladstone due to current industrial sources. These effects are particularly evident close to the Gladstone Airport, Clinton Precinct, Yarwun Precinct and EPA monitoring sites. A discussion of the potential vegetation impacts is included in Section 3.2.3.

Tabular data of the highest modelled air quality impacts of background sources of NO_2 and SO_2 on air quality at receptors at various locations around Curtis Island and Gladstone and at the EPA's monitoring sites are presented in Table 3-6. The locations that have been evaluated for this assessment are shown in Section 0. For each receptor group, the highest value among all sites is presented.

These results at sensitive receptors demonstrate that:

- The modelled concentrations of both NO_2 and SO_2 are below the human health based ambient air quality guidelines at the above mentioned locations. For the model domain maximum, EPP (Air) 1-hour guideline is exceeded, which is located very close to a modelled industrial source.
- The maximum 4-hour average NO_2 levels are high at receptors located at Gladstone Airport, Clinton Precinct, Yarwun Precinct and EPA monitoring sites, with the highest value of 177 µg/m³ occurring at the EPA monitoring site at Clinton. These NO_2 levels exceed the EPP (Air) 4-hour guideline for biological integrity due to the proximity to several existing and approved industrial sources nearby. For the evaluation of cumulative impacts, these high predictions of NO_2 due to existing industrial sources dominate the predicted impacts. Note that some of the 4-hour average NO_2 levels at some receptors are higher than the 1-hour average NO_2 levels. This is because each 4-hour data is the maximum value, while the 1-hour data is the 99.9th percentile value. Note that the 4-hour average in the table is a rolling average; thus an exceedance episode may register more than once.
- At sensitive receptors, no SO_2 levels are predicted to exceed the guidelines. The maximum results on the model domain have exceeded the guidelines for 10 minute, 1 hour and 24 hour averaging times. These values are located very close to a modelled industrial source.

Limitations and accuracy of the background NO_2 and SO_2 modelling

It has been recognised that GAMS uses an older version of Calpuff (version 5.4) and hence the model updates and improvement in recent years since 2001 have not been incorporated. This compromise was made so that cumulative impacts can be assessed through modelling study using the database of impacts from industrial sources that are included in GAMS. It has also been recognised that the emission data used in GAMS as for 2001 may also need to be updated, and this can only be achieved with collective efforts of EPA and industries.

To assess the limitations and accuracy of the GAMS for modelling background NO_2 and SO_2 levels, model results have been compared with the monitoring data. However, the complex mix of factors that influences both the monitored and modelled data makes direct comparison of the modelling results to concurrent monitoring data difficult.

The modelled 99.9th percentile 1-hour average NO_2 concentrations at the EPA monitoring sites (167 µg/m³) are much higher than the monitored peak 1-hour average data (84 µg/m³) presented in Table 3-5. The modelled 99.9th percentile 1-hour average SO_2 concentration at the EPA monitoring sites (328 µg/m³) are slightly lower than the monitored peak 1-hour average data presented in Table 3-5 (351 µg/m³). Note that the monitored data are the peak values from many years, while the modelled data are only for year 2001. The monitored data also reflects impacts from existing sources, while modelled data reflects impacts from both existing and future proposed industrial sources. Additionally, the monitored data are affected by all pollution sources such as industrial, rural and motor vehicles while modelled data are impacted only by major industrial sources.

NO_2 concentrations have been estimated by assuming that 35% of the NO_x emitted from industrial sources is oxidised into NO_2, regardless of the distance from the emission source. Generally, NO_x emitted from combustion sources is approximately 10% NO_2 at the source, so this method results in an over-estimate of actual NO_2 concentrations close to industrial sources. Thus, predicted NO_2 impacts in GAMS would be over-predicted for receptors close to the sources.

At the time of its release in 2004, some verification studies were conducted for GAMS by the EPA (Verrall, K., 2004, unpublished) to determine how well it predicted the ground-level concentrations of NO_2 and SO_2 from the industrial sources. They showed that the model (for existing industrial sources only) predicts higher peak concentrations of pollutants compared to the ambient concentrations that have been measured at the EPA's sites in Gladstone. For example, predicted exceedances of the one-hour average guideline for NO2 and SO2 by GAMS, particularly in the vicinity of the Gladstone Power Station, have not been substantiated by the monitoring data. Thus, GAMS results must be used with caution, and needs to acknowledge the possible over-prediction of impacts from industrial sources, especially for the impacts of NO2.

Table 3-6 Modelled ground-level concentrations of NO_2 and SO_2 due to background industrial sources in the Gladstone region (µg/m³)

Receptor Group	NO_2 (µg/m³)			SO_2 (µg/m³)			
	1 hour, 99.9th	4 hour	Annual	10 min	1 hour, 99.9th	24 hour	Annual
Curtis South End & Quoin Island Community	25	29	0.4	105	73	18	2.3
Curtis Island Parkland	29	34	0.5	104	73	21	3.1
Curtis Island Industry Precinct	57	60	0.7	178	124	27	2.7
Gladstone	81	76	1.8	247	173	42	5.9
Gladstone Airport	163	172	2.8	459	321	85	7.3
Gladstone Industry	85	90	3.6	480	335	73	7.0
Gladstone Wetland areas	83	87	2.1	398	278	54	6.1
Clinton Precinct	195	171	1.8	567	396	71	5.1
Yarwun Precinct	112	103	8.0	385	269	64	19.2
Targinie Precinct	61	47	2.4	280	196	38	7.8
EPA monitoring sites	167	177	3.9	469	328	83	13.3
Model domain maximum	413	465	10	1191	832	173	48
EPP (Air) Guideline	**320**	**95**	**30**	**700**	**570**	**100**	**60**

3.2 Potential Impacts and Mitigation Measures

3.2.1 Air Emissions from the Project

Emissions during Construction

Emissions to air during construction of the LNG facility 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; and
- Vehicle and equipment exhaust.

The first three sources will emit particulate matter as coarse earth dust. Exhaust emissions will comprise particulate matter as well as VOCs, with emission profiles similar to mobile emissions on major roads; but the rate of emissions will be much lower than major roads as much lower number of sources are on the construction site.

The impacts of construction activities will be managed though the Environmental Management Plan. This will include strategies to prevent or minimise dust emissions and vehicle and machinery 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 mitigate any adverse off-site impacts.

Emissions during Normal Operation

This assessment comprises Phase 1 of a two phased assessment approach, with emission estimates reflecting the Pre-FEED (Front End Engineering Design) status of the project design. More detailed estimates of emissions will be developed during the FEED phase (Phase 2) when the process and engineering designs are developed.

For this project, there are two separate Pre-FEED facility designs, Optimised Cascade LNG Process (OCP) and Propane Pre-cooled Mixed Refrigerant (C3MR). Santos provided URS with the emission estimates for both designs, as emission inventory design document 25438-100-G65-GEH-00001 R00B for the OCP design and 3591-8150-RP-0003 Rev A2 for the C3MR design. Each facility design has considered the air emission sources from operation of the LNG facility at 3 Mtpa and 10 Mtpa production rates, equivalent to 1 and 3 LNG trains respectively.

The coal seam gas that flows to the LNG facility contains a high methane concentration, with very few impurities and no heavy hydrocarbons or water. On average, the CSG stream contains 94.95% methane, 4.0% nitrogen and 1.0% carbon dioxide, with trace amount of ethane (0.03%) and propane (0.02%). The LNG facility designs have incorporated mercury removal equipment to safeguard against trace levels of mercury which may damage the equipment, although no mercury is anticipated in the coal seam gas. Trace amounts of sulphur may also be present; no sulphur-containing odorants are added to the gas as it is not a retail pipeline.

The emissions for the C3MR design are provided in Table 3-7 for the 3 Mtpa and 10 Mtpa production cases, with a base elevation of 16 m above sea level, as included in the air dispersion modelling. The emissions have been qualified for NO_x, SO_2, PM_{10}, CO and CH_4. These emission quantities have been calculated from project-specific data and/or developed from the designers' in-house data. For emission sources included in Table 3-7, the emissions data for volatile organic compounds (VOC) were provided to URS as 100% methane because other forms of VOC in the proposed coal seam gas stream are small (as shown in the paragraph above).

Minor fugitive non-methane volatile organic compounds emissions sources, which are not included in Table 3-7, are listed here:

- Small amounts of non-methane VOC are emitted from mixed refrigerant compressor turbines, which use propane and ethane as well as methane and nitrogen as refrigerant, for which no emission data have been provided to URS.
- Small amounts of non-methane VOC are emitted from emergency diesel generators at a rate of 0.0053 g/s, and
- Small amounts of non-methane VOC are emitted from fugitive emission sources such as mixed solvent storage tanks, hot oil storage tanks and expansion tanks, slop oil tanks, and diesel fuel storage tanks, each having a VOC emission rate of 0.00032 g/s.

The emissions for the OCP design are provided in Table 3-8 for the 3 Mtpa and 10 Mtpa production. The emissions from refrigeration compressors with Dry-Low NO_x Emission technology and power generators were estimated based on vendors' data. The emissions for others were based on Australian National Pollutant Inventory (NPI) (Oil & Gas Exploration and Production) Emission Estimation Technique Manual and U.S. EPA "AP4-42-Compilation of Air Pollutant Emission Factors". In Table 3-8, all pilot flares are grouped as a single point source. The number of emission sources for the 10 Mtpa production is triple that of the 3 Mtpa production, except that 11 power generators will be installed for the 10 Mtpa capacity. For the OCP designs, the SO_2 emission rates for all sources (including refrigeration compressors and power generators) are so low that the impacts on ambient SO_2 levels are not modelled. The total fugitive non-methane VOC emissions for the OCP design were estimated based on NPI methods to be approximately 0.001 g/s for a single LNG train (3 Mtpa production; 10 Mtpa product uses three LNG trains); and the emission sources are valves, flanges, pump seals, connectors and others.

For the emissions of particulate matter from the LNG facility, the sources of dust are combustion sources which generate fine particles (10 µm diameter and smaller). Therefore the TSP emission rate and impacts from the LNG facility have been assumed to be equivalent to PM_{10} impacts.

Table 3-7 Air emissions from the C3MR design 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 per stack (g/s)				
	3 Mtpa	10 Mtpa					PM_{10}	SO_2	NO_x	CO	CH_4
MRC* Turbines Frame 6	2	6	40	5	823	15	0.6	0.01	6	11	0.01
MRC Turbines Frame 5	2	6	40	3.8	473	15	0.5	0.01	6.7	13	0.01
Power Gen.**	3	9	40	3.8	756	15	0.5	0.01	6.7	13	0.01
Cold Flare	1	1	80	0.61	296	4	0	0	0.1	0.1	0.1
Warm Flare	1	1	80	0.61	296	4	0	0	0.1	0.1	0.1
Low Pressure Flare	2	2	80	0.61	296	4	0	0	0.1	0.1	0.1
EMG	2	2	40	0.26	723	1.5	0.012	< 0.001	0.11	8.5	0
Acid Gas vent	1	1	40	0.4	323	15	0	0	0	0	22

*MRC: mixed refrigerant compressor ** Power Gen.: power generators using methane gas

*** EMG: emergency diesel generator at test load

Table 3-8 Air emissions from the OCP design 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 per stack (g/s)				
	3 Mtpa	10 Mtpa					PM_{10}	SO_2	NO_x	CO	CH_4
RC* Turbines	6	18	28.3	2.7	607	31	0.20	<0.001	3.23	1.94	0.86
Power Gen.**	5	11	36	1.1	811	38	0.04	<0.001	0.70	0.43	0.24
Pilot Flares	As 1	As 1	87	1.5	1,273	20	0.01	0	0.17	0.14	0.02
Nitrogen Vent	1	3	32	6.8	296	37	0	0	0	0	84
R. Gas Heater*	2	6	37	1	547	22	0.03	0	0.34	0.28	0.04
Hot Oil Heater	2	6	50	2.5	570	17	0.09	0	1.18	0.99	0.13
CO_2 Vent	1	3	16	0.84	296	13	0	0	0	0	14

* RC turbines: refrigeration compressor turbines ** Power Gen.: power generators using methane gas

*** R. Gas Heater: Regeneration Gas Heater

Control technologies

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:

- The on-site generation of power using clean methane gas for on-site requirements to avoid the use of coal-fired power from the Queensland power grid;
- To reduce NO_x emission, the compressors in both designs use Dry-Low NO_x technology;
- Air is injected into flares to make flares smokeless, thus reducing particulate matter emissions;

- During the carbon dioxide removal process, the solvent has been carefully selected to minimise the co-release of methane; and
- Boil off gas (BOG) is recycled to use as fuel rather than being flared to reduce emissions from flares.

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.

Comparison with emission standards

To compare these emissions with emission standards presented in Section 3.1.2, in-stack concentrations were calculated for the two facility designs. Whenever possible, these in-stack concentrations were converted to concentrations at the reference conditions that are specified for the emission standards (dry, 273 K, 101.3 kPa, and 15% O_2 for gas turbines).

For the C3MR design, for the MR turbine drivers and power generators, the NO_x emission rate of 25 ppmv at the reference condition was provided to URS by Santos, which is equivalent to 16 mg/m^3. For these emission sources, URS was also provided with the particulate matter emission concentration of 5 mg/m^3, and CO emission concentration of 100 mg/m^3 at the reference conditions.

For the OCP design, in-stack emission rates and reference conditions were not provided to URS. Hence, in-stack emission data were calculated based on based on exit velocity, temperature and assumed release pressure as 101.3 kPa, and then corrected to the reference conditions that are listed in Table 3-4. The in-stack oxygen and moisture contents are 14.9% and 5.8% respectively for the refrigeration turbines, and they are 14.1% and 6.2% respectively for power generators.

Table 3-9 presents the in-stack emission concentrations for major emission sources for the C3MR design. Table 3-10 presents those for the OCP design.

The emission standards presented in Table 3-4 for NO_x, particulate matter, and CO apply to the refrigeration compressor turbines and power generators, the major emission sources from the LNG facility. For the two designs, in-stack NO_x, particulate matter, and CO emission rates are well below the emission standards.

Table 3-9 In-stack emission concentrations for C3MR design

Emission concentrations	Particulate Matter (mg/m^3)	NO_x (mg/m^3)	CO (mg/m^3)
MRC Turbines Frame 6	5	16	37
MRC Turbines Frame 5	5	16	76
Power Generators	5	16	76
Relevant NSW emission standards	**50**	**350**	**125**

Table 3-10 In-stack emission concentrations for OCP design

Emission concentrations	Particulate Matter (mg/m^3)	NO_x (mg/m^3)	CO (mg/m^3)
Refrigeration Compressor Turbines	1.8	29	17
Power Generators	1.2	21	13
Relevant NSW emission standards	**50**	**350**	**125**

Emissions of Other Pollutants

As stated in the Term of Reference (ToR) for this project, emission estimates are required for a list of key pollutants. They are grouped into acidic/caustic aerosols, carbonyl compounds, coal and coal dust, criteria gaseous pollutants, fluorides, metals, particulate matter, polychlorinated biphenyls, polycyclic aromatic hydrocarbons (PAHs), radionuclides, and volatile organic compounds (VOC). Emissions from those groups of pollutants are discussed below.

- For the pollutants in the groups of acidic/caustic aerosols, carbonyl compounds, coal and coal dust, fluorides, metals, polychlorinated biphenyls and radionuclides, only trace amounts are expected to occur in the coal seam gas stream.
- Polycyclic aromatic hydrocarbons (PAHs) may be released in trace amounts through incomplete combustion of gas. The emissions of PAHs are very low and have not been modelled.
- There is very little sulphur in the coal seam gas. It is worth noting that the sulphur in general household gas is specifically added as an odorant (methyl mercaptan) so that it is easy to detect gas leakage. For this industrial pipeline, no sulphur is added to the coal seam gas.
- There is no mercury in the coal seam gas based on current knowledge of the gas composition. However the current LNG train designs do include the installation of a mercury removal unit. This unit is a contingency measure, in the case of the unlikely event of mercury being found in the gas stream. This should guarantee safety to the downstream industrial processing equipment.
- There will be no metal fumes emitted from the LNG facility during normal operations as there are no activities such as welding.
- Ozone is a secondary pollutant, which is not directly emitted from stacks.

- The VOC emissions for the LNG facility are mostly in the form of methane. Methane is not very active in the photochemical reactions that form ozone, which is of health concern. Methane itself is not of concern for human health either. But methane is a significant greenhouse gas and its emissions are discussed in more detail in the separate GHG report.
- Emissions of VOCs such as formaldehyde, benzene, toluene and xylene are very low and have not been modelled.
- As discussed earlier in this section (Section 3.2.1), small amounts of non-methane VOC's are emitted from mixed refrigerant compressor turbines, which use some non-methane VOC (propane and ethane) as well as methane and nitrogen as refrigerants, from emergency diesel generators, and from fugitive emission sources such as mixed solvent storage tanks, hot oil storage tanks and expansion tanks, slop oil tanks, and diesel fuel storage tanks for the C3MR design; and for the OCP design, non-methane VOC emission sources are valves, flanges, pump seals, connectors and others.
- The emission estimate for the particulate matter presented above in this section is for the total particulate matter. For the LNG facility, the particulate matter is mainly emitted from combustion processes, with small particle sizes (typically less than 1 µm in aerodynamic diameter). This assessment has assumed all the particulate matter emissions are in the form of PM_{10}. As there are no monitoring data for ambient $PM_{2.5}$ levels in the Gladstone region, the emissions have not been further broken down into $PM_{2.5}$.
- Odour is often of concern for industrial facilities. This LNG facility and the coal seam gas will not release strong odorous compounds. Some odour is associated with oxides of nitrogen, primarily due to NO. The odour related to non-methane VOC releases is not of concern either as their emissions are very low.

A health risk assessment is required for releases of hazardous or toxic material from the Facility. As noted above, the LNG facility is not expected to release significant amounts of hazardous or toxic materials from any part of the Facility. Known emissions of VOC such as methane and propane are not considered to be toxic. On this basis, a health risk assessment has not been conducted. Santos 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 health risk assessment.

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.

The following upset scenarios have been identified:

- **Scheduled maintenance:** scheduled shut-down and start-up for maintenance inspection, which occurs every three years, and lasts for 3 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 minutes duration). This scenario has not been modelled as its likelihood of occurring 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.

As indicated in the above list, only scheduled maintenance has been modelled. In addition, only 10 Mtpa production for each plant design has been modelled.

For the case of 10 Mtpa production, only one of the three compressor trains will be shut-down each time for maintenance, with the two other compressor trains operating normally. Table 3-11 and Table 3-12 present the emissions for the compressor train that undergoes scheduled maintenance.

Table 3-11 Upset emissions for one compressor train undergoing scheduled maintenance, for C3MR design

Source Name	Number of stacks	Stack height (m)	Stack diameter (m)	Temp (K)	Exit velocity (m/s)	Pollutant emission rate (g/s)				
						PM_{10}	SO_2	NO_x	CO	CH_4
Power Gen.	2	40	3.8	756	15	0.5	0.01	6.7	13	0.01
Cold flare[1]	1	80	0.61	1,273	20	0	0	17.9	97	37

[1.] The flare emission rates for the scheduled maintenance are not provided with C3MR design and they are assumed to be the dry flare emission rates for the OCP design.

Table 3-12 Upset emissions for one compressor train undergoing scheduled maintenance, for the OCP design

Source Name	Number of stacks	Stack height (m)	Stack diameter (m)	Temp (K)	Exit velocity (m/s)	Pollutant emission rate (g/s)				
						PM_{10}	SO_2	NO_x	CO	CH_4
Power Gen.	3	36	1.07	811	38	0.04	0	0.7	0.4	0.24
Dry flare	1	87	1.07	1273	20	0	0	17.9	97	37

3.2.2 Dispersion Modelling Methodology

Gladstone Airshed Model System (GAMS)

As noted in Sections 3.1.1 and 3.1.3, the GAMS modelling utility, which was developed for the Queensland EPA, has been used for modelling of pollutant dispersion from the site.

GAMS uses the Calpuff dispersion model to predict ground-level concentrations of pollutants. Calpuff was developed on behalf of the United States EPA, and is accepted by the Queensland EPA as a suitable model for predicting air quality impacts in the Gladstone region. The version of Calpuff that comes with GAMS is version 5.4, which has been superseded by version 6 that is currently available. However, for compatibility, this older model version has been used for this project.

Three-dimensional meteorological data for the year 2001 has been included in the GAMS program, and was pre-generated using the Calmet meteorological model to simulate the wind flows, temperature profiles, and other meteorological conditions over the Gladstone region for the year. Observed wind data from the sites around Gladstone were also incorporated into the modelling. Wind data extracted from GAMS at the project site have been analysed and are discussed in Section 3.1.1 (Climate).

For existing sources, EPA has modelled the air quality impacts using GAMS and estimated emissions obtained from the National Pollutant Inventory and individual industries. For future approved industrial sources, listed in Section 3.1.3, emissions data have been obtained from respective EIS reports, with air dispersion having been modelled by URS using GAMS.

To estimate air quality impacts from this project, each of the emission sources and pollutants were modelled using the Calpuff configuration that is included with GAMS. The point source configuration included all sources of a given pollutant in a single model run. The locations and heights of buildings around the site were entered into the model to enable the aerodynamic influence of building wake effects to be included.

Modelling Oxide of Nitrogen

The emissions of oxide of nitrogen (NOx) from the LNG facility contain only a small proportion of NO2, approximately 10%, at the point of emission. As the plume travels downwind, it mixes with ambient air and reacts with photochemical precursors (such as ozone and reactive volatile organic compounds) to form more NO2. The extent of this oxidation reaction is determined by the photochemical state of the air and the presence of sunlight. GAMS has been set up to model NOx dispersion without including photochemical reactions and it assumes that up to 35% of the NOx has been oxidised to NO2 at the receptor location. This ratio of NO2 to NOx has also been adopted by EPA to be used in GAMS based on long-term monitoring data for NO2 and NOx in Gladstone. The use of a fixed ratio of NO2 to NOx will over-estimate NO2 concentrations close to the source, as insufficient oxidation of NO takes place within 1-2 km of the source.

Modelling of Particulate Matter

The sources of particulate matter from the LNG facility site are primarily industrial combustion sources such as compressor turbines and power generators. These industrial combustion sources produce particles that are small in diameter, typically around 1 µm in aerodynamic diameter. On this basis, PM_{10} has been modelled for this project using GAMS with the assumption that all particulate matter emissions are present as PM_{10}. No dispersion modelling was done for total suspended particulates (TSP) as TSP emissions have been assumed to have the same emission rates, and therefore the same air quality impacts, as for PM_{10}. The mean geometric mass diameter of PM_{10} is set to be 1.0 µm and its standard deviation is set to be 2.0 µm.

Since GAMS does not contain predictions of PM_{10} due to the existing and approved industrial sources in Gladstone, a constant background concentration was used based on air quality monitoring data at Gladstone. There is no Queensland or national guideline on how the constant background concentration should be obtained from EPA monitoring data to assess cumulative air quality impacts. The Victorian State Environment Protection Policy (Air Quality Management) 1997 requires the use of 70th percentile to include background data where no appropriate hourly data exists. In this study, a more conservative percentile value was used: from daily records of PM_{10} measured at Targinie from 2001 to 2007, the 95th percentile 24-hour average concentration, which is 30 μg/m³, has been used as a constant background level. This more conservative choice of 95th percentile was chosen so that the extreme events such as bushfires and dust storms are excluded, which is more or less in line with the five allowable exceedances of the NEPM 24-hour guideline. The annual average concentration of 18 μg/m³ measured at Targinie was also used for evaluation of background dust concentrations for dispersion modelling. Targinie is the closest site to the Curtis Island area and has been used to represent all other sources of dust at residential receptor locations.

Photochemical Modelling

Photochemical modelling for Gladstone requires the use of a detailed emission inventory for industrial, commercial, domestic, biogenic and traffic related sources of nitrogen oxides and volatile organic compounds. No such inventory exists for Gladstone (as at November 2008) so detailed photochemical modelling has not been conducted.

Photochemical smog is currently not considered to be an issue in Gladstone. Limited short-term ozone monitoring data at Barney Point, as presented in Section 3.1.3, shows that ozone levels at Gladstone did not exceed any air quality guideline. In Australia, ozone is not considered a significant issue except in the major capital cities (Sydney and Melbourne particularly).

At stack tips, NO_x emitted is mainly in the form of NO, with an approximate NO_2 to NO_x ratio of 10%. After NO_x is emitted into the air it reacts with ozone and VOC, with some of NO gradually converted to NO_2. Currently, the GAMS assumes 35% percent of NO_x in the air is NO_2, which over-estimates NO_2 levels near emission sources. This constant ratio of NO_2 to NO_x has been used in the absence of sufficient data to conduct photochemical modelling.

Modelling Carbon Monoxide

Modelling of carbon monoxide was also undertaken using GAMS. A constant background concentration of 2,000 μg/m³ was used for evaluating the maximum 8-hour average concentration, as discussed in Section 3.1.3.

Modelling Flares for Upset Conditions

Flares operate with an exposed flame when used for upset conditions. As the flame length extends beyond the flare tip, they are not treated as normal point sources. Instead, equivalent stack height and equivalent flare diameters are calculated based on the formula provided in the *Air Dispersion Modelling Guidelines for Oklahoma Air Quality Permits, 2006.* The formulas used in this assessment are prescribed below.

$$H_{equiv} = H_{actual} + 0.00128 Q_c^{0.478} \quad \text{(Equation 1)}$$

$$D_{equiv} = 1.754 x 10^{-4} \sqrt{Q_c} \quad \text{(Equation 2)}$$

Where

H_{equiv} = equivalent height of the flare, m

H_{actual} = actual height of the stack from the ground, m

Q_c = flared gas heat release, Btu/hr

D_{equiv} = equivalent diameter of the flare, m

These formulas were initially published in an American Petroleum Institute (API) publication (API 1969), and then republished and modified by Beychok (1994)[10] in *Fundamentals of Stack Gas Dispersion* for a visible flame assumed to be tilted at a 45° angle regardless of wind speed.

Additional assumptions for these formulas as documented in *Air Dispersion Modelling Guidelines for Oklahoma Air Quality Permits, 2006,* are

- 55% of the heat lost due to radiation,
- an effective stack exit velocity of 20 meters per second, and
- an effective stack exit temperature of 1,273 Kelvin.

To use this formula, the value of Q_c is needed. The methane gas energy content of 54,837 kJ/kg has been used and converted to Btu/kg. Q_c is obtained by multiplying the gas energy content with the fuel flow rate (in kg/h). Fuel flow rates were estimated from the flare exhaust composition and the ratio of CO_2 in the exhaust to CH_4 in the feed gas.

Under normal operating conditions, the flares operate constantly with a pilot flame. This case has been included in the modelling for normal operations. Under upset conditions, such as during LNG facility maintenance, the equivalent height and diameter of the flare have been calculated. For the maintenance upset condition, a methane fuel flow rate of 42,281 kg/h was calculated based on the CO_2 emission rate of 32,298 g/s provided to URS. In the calculation, minor CO emissions were not considered and 100% combustion of methane was used. The equivalent flare height was calculated as 38.7 m and the equivalent flare diameter was calculated as 8.4 m.

Building Downwash Effects

The dispersion and buoyant rise of plumes released from stacks can be significantly modified by the presence of buildings nearby. In this study, building downwash has been modelled with the Calpuff model in GAMS using the PRIME method. The building height and width data have been extracted using the BPIP program and then imported into GAMS.

Note that for the OCP design, building height information was unavailable for the pre-FEED design. The building information for the C3MR design was used instead as it was the best available information at the time, but limited to no taller than the corresponding stack height.

Averaging Time

Different averaging times for pollutant concentrations are presented in this report. These averaging times reflect the time scales that have been used to develop the air quality guidelines that are presented in Section 3.1.2.

[10] Beychok, Milton R. 1994. Fundamentals of Stack Gas Dispersion. 3rd ed. Irvine, California: Milton Beychok

The Calpuff model used in GAMS predicts concentrations on a 1-hour average basis. Longer averaging times are then calculated from consecutive records and are displayed in GAMS.

Modelling results for ground level concentrations have been presented as 99.9th percentile for 1-hour averaging time, and for longer averaging durations, the maximum values have been used. The 99.5th percentile mentioned in the ToR is not applicable for the pollutants that have been modelled in this assessment.

The Queensland EPA specifies a guideline for SO_2 that is for a 10-minute averaging period. This concentration has been estimated from the 1-hour average concentration by assuming the Turner power law correction applies with an exponent of 0.2. The 10-minute average concentration is calculated from the 1-hour average (60 minute) concentration multiplied by a factor of $(60/10)^{0.2}$, or a factor of 1.43.

Percentiles for Compliance

Modelled predictions of air quality impacts can sometimes show high results due to spurious model results. These can grossly over-estimate the predicted concentrations, particularly for 1-hour average concentrations. To overcome this, the Queensland EPA recommends that the 99.9th percentile concentration be used to report modelled impacts of air pollutants for 1-hour and 10 minute averaging times (equivalent to the 9th highest hourly record over a 1 year period). For longer averaging times (4 hours, 8 hours, 24 hours, and annual average), the maximum predicted concentrations are reported.

Sensitive Receptor Locations

To evaluate air quality impacts at sensitive receptor locations, 51 sensitive receptors have been chosen to evaluate modelling results in addition to EPA's air quality monitoring sites, with their location shown in Figure 3-15. These locations are within a 10 km radius of the LNG facility site, and are representative of residential locations on Curtis Island and Gladstone. The land use covers residential, industrial, public use, commercial, state forest, wetland, and conservation areas. These receptors are then grouped according to locations and land use, as shown in Table 3-13.

Table 3-13 Sensitive receptor groups used for analysis of the LNG facility impacts

Group Name	Receptor Numbers	Land Use Description
Curtis & Quoin Island Community	33, 46, 52	Residential
Curtis Island Parkland	38, 51	Parkland
Curtis Island Industry Precinct	40, 42, 44, 45, 48	Industrial
Gladstone	1-12, 14-18, 20-25	Residential, industrial, park, commercial
Gladstone Airport	55	Airport
Gladstone Industry	28, 30, 34, 39, 41	Industrial
Gladstone Wetland Areas	26, 29, 43, 47	Wetland
Clinton Precinct	13, 19	Industrial
Yarwun Precinct	323, 27, 31, 32	Industrial, wetland
Targinie Precinct	35	residential
EPA monitoring sites	53-54, 56-61	Mix

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. 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 overcome these limitations, a quantifiable monitoring and measuring program will be implemented for operation of the LNG facility. This will be part of the Environment Management Plan.

3.2.3 Dispersion Modelling Results

Dispersion modelling results for each operating scenario are presented in this section. Results are presented as the highest predicted result at each group of sensitive receptors. Predicted results for the LNG facility, together with existing and approved sources in Gladstone, have been compared to the appropriate air quality guideline to determine the potential for adverse air quality impacts.

These predicted ground-level concentration results are presented as:

- the maximum value throughout the whole modelling domain (but outside the Santos LNG facility boundary),
- contour maps, and
- tabular data at sensitive receptor locations.

The modelling results in this assessment have not been presented as frequency contours of exceedances because the exceedances (as presented later) have been caused by background industrial sources with little impacts from the LNG facility.

In this section, the air quality impacts are presented as the modelling results from Santos' LNG facility (the LNG facility) emissions only (**the LNG facility in isolation**), and as those from the combined emissions of the LNG facility and the background industrial emission sources (**the LNG facility plus background**). The contribution from existing and approved sources to ambient air quality has been presented in Section 3.1.3 (**Background sources**).

The predicted results of air quality modelling presented in this analysis have been analysed for off-site impacts. The results are not applicable to evaluation of on-site air quality (related to compliance with occupational health and safety) due to the spatial resolution of the model predictions used.

The Overall Air Quality Impact from the LNG Facility and Background

The maximum values throughout the modelled domain but outside the boundary of the LNG facility have been extracted and presented in Table 3-14. It shows that due to the emissions from the LNG facility only, the domain maximum NO_2 levels for 1 hour averaging time is 54 µg/m³ for the OCP 3 Mtpa case, and 67 µg/m³ for the OCP 10 Mtpa case. Those values are slightly smaller for the C3MR design, 22 µg/m³ for 3 Mtpa case and 61 µg/m³ for 10 Mtpa case. These domain maximum values are located directly adjacent to the LNG facility boundary.

For comparison, domain maximum values due to combined impacts of background and the LNG facility impacts are also presented in Table 3-13. For the 99.9th percentile of 1-hour average NO_2 concentrations, the domain maximum is very similar among different LNG facility emission scenarios, about 413 – 414 µg/m³. These predicted impacts exceed the EPP (Air) guideline of 320 µg/m³ due to high background source impacts, demonstrated by the location of the impacts in Gladstone, as presented in Section 3.1.3. These values are similar to the background level because they are located in the city of Gladstone, whereas the impacts from the LNG facility are low. As discussed in Section 0, these predictions which are close to industrial sources are subject to over-prediction of NO_2 levels when a constant 35% conversion of NO_2 to NO_x is adopted.

For maximum 4-hour average NO_2 concentrations from the LNG facility in isolation, the domain maximum values are 53 µg/m³ for the OCP 3 Mtpa case, 64 µg/m³ for the OCP 10 Mtpa case, and 24 µg/m³ for the C3MR 3 Mtpa case, 57 µg/m³ for the C3MR 10 Mtpa case. None of these values have exceeded the EPP (Air) guideline of 95 µg/m³ for biological integrity. For the combined impacts from the LNG facility and the background industrial sources, the EPP (Air) guideline has been exceeded, occurring over Gladstone city due to the background sources.

No annual concentrations of NO_2 have exceeded the EPP (Air) guideline, both for predicted impacts due to the LNG facility only and for the LNG facility plus background sources. The highest predictions are 33% of the guideline.

The impacts from the LNG facility in isolation on SO_2 levels are very small, less than 0.1 µg/m³ for all scenarios for the C3MR design. The estimated emissions from the OCP design are essentially zero and have not been modelled. However, the background impacts are significant as the domain maximum values exceed 10-minute, 1-hour and 24-hour guidelines. Since the LNG facility emissions and air quality impacts for SO_2 are low, no further results will be presented for the impacts of SO_2 in this assessment.

The impacts of the LNG facility on 24 hour PM_{10} levels are similar for both OCP and C3MR designs, with a domain maximum of 5 µg/m³ for the OCP design and 3.7 µg/m³ for the C3MR design. When combined with assumed constant background level of 30 µg/m³, the impacts meet both the 24-hour EPP (Air) guideline of 150 µg/m³ and the national NEPM guideline of 50 µg/m³.

The impacts of the LNG facility on annual average PM_{10} levels are very small, with domain maximum of 0.6 µg/m³ for the OCP 10 Mtpa case and 0.7 µg/m³ for the C3MR 10 Mtpa case. Note that for PM_{10}, only the two 10 Mtpa production cases have been modelled. When combined with an assumed constant annual background level of 18 µg/m³, the annual EPP (Air) guideline of 50 µg/m³ is not exceeded.

It is worthwhile to note that this method of combining constant background levels with the LNG facility impacts is a likely over-estimate of the cumulative impacts as the maximum impacts from the LNG facility are not expected to occur at the same location and at the same time as the maximum background impact occurs.

The impacts of the LNG facility emissions on CO levels are very small, with a domain maximum of 92 µg/m³ for the OCP 10 Mtpa case and 202 µg/m³ for the C3MR 10 Mtpa case, compared with a guideline of 10,000 µg/m³. Note that for CO, only the 10 Mtpa cases have been modelled, and the background CO levels are neither monitored at Gladstone nor modelled by GAMS, but an 8-hour background level of 2,000 µg/m³ has been assumed as discussed in Section 2.1.3.

Due to the low predicted impacts of SO_2 and CO over the modelling domain, no further results are presented for these pollutants.

Table 3-14 Modelling results for NO_2, SO_2, CO and PM_{10}, presented as the maximum throughout the modelling domain but outside the LNG facility boundary

Design / Production	Scenario	NO_2 (µg/m³)			SO_2 (µg/m³)				CO (µg/m³)	PM_{10} (µg/m³)	
		1 hour, 99.9th	**4 hour**	**Annual**	**10 min**	**1 hour, 99.9th**	**24 hour**	**Annual**	**8 hour**	**24 hour**	**Annual**
OCP, 3 Mtpa	Isolation	54	53	2.6	Emissions provided to URS are so low that impacts from the LNG facility have not been modelled. Conservatively, we assumed impacts are the same as the C3MR design.				NM [1]	NM	NM
OCP, 3 Mtpa	With background	413	465	10					NM	NM	NM
OCP, 10 Mtpa	Isolation	67	64	3.3					92	5.0	0.6
OCP, 10 Mtpa	With background	413	465	10					2092	35.0	18.6
C3MR, 3 Mtpa	Isolation	22	24	1	0.1	0.1	<0.05	<0.05	NM	NM	NM
C3MR, 3 Mtpa	With background	413	465	10	1,191	832	173	48	NM	NM	NM
C3MR, 10 Mtpa	Isolation	61	57	3	0.4	0.3	0.1	<0.05	202	3.7	0.7
C3MR, 10 Mtpa	With background	414	465	10	1,191	832	173	48	2,202 [2]	33.7	18.7
Existing and approved sources	**Background only**	**413**	**465**	**10**	**1,191**	**832**	**173**	**48**	**2,000**	**30**	**18**
EPP (Air) guideline		320	95	30	700	570	100	60	10,000	150	50

Note: 1) NM stands for "not modelled";
2) Background CO is not measured at Gladstone, and a conservative background level of 2,000 µg/m³ is adopted as the background level based on CO measurement at other places in Queensland;
3) The background PM_{10} levels are taken from monitoring data, namely 18 µg/m³ for annual average and 30 µg/m³ for 24 hour average.

Modelling Results for NO_2 with the OCP Design

Modelled concentrations of NO_2 for the OCP design are analysed for the LNG facility in isolation and the LNG facility plus background. Impacts due to the background industrial sources only are discussed in Section 3.1.3.

For the 3 Mtpa production, the 1-hour average NO_2 concentration (defined as the 99.9th percentile of all hourly data during the modelling year of 2001) due to the LNG facility in isolation are presented as contour plots in

Figure 3-16 and the values due to the LNG facility plus background sources are presented in Figure 3-17. For the 10 Mtpa production scenarios, these figures are presented in Figure 3-18 and Figure 3-19.

Key observations from these OCP 1-hour NO_2 contour plots are made below:

- Figure 3-16 - For the LNG facility in isolation for 3 Mtpa production: NO_2 levels are approximately 10 µg/m³ near the LNG facility boundary and reduce quickly with distance away from the LNG facility, down to less than 2 µg/m³ at South End and Gladstone city.
- Figure 3-17 - For the LNG facility plus background sources: the highest NO_2 results across the modelling domain are over the city of Gladstone, peaking near the Gladstone Power Station, with 1-hour NO_2 guideline exceeded for a small area.
- Figure 3-18 - For the LNG facility in isolation for 10 Mtpa production: NO_2 levels are about 30 µg/m³ near the LNG facility boundary and reduce quickly with distance away from the LNG facility, down to less than 5 µg/m³ at South End and Gladstone city.
- Figure 3-19 - With 10 Mtpa production from the LNG facility plus background sources: over Gladstone city, the contour levels are similar to those in Figure 3-17 for the 3 Mtpa production, with a small area of exceedance near the Gladstone Power Station.

The maximum 4-hour average NO_2 concentrations are presented in Figure 3-20 to Figure 3-23. Key observations from these maximum 4-hour NO_2 contour plots are made below:

- Figures 3-20 and 3-22 - For the LNG facility in isolation: The NO_2 concentrations are far below the EPP (Air) 4-hour guideline of 95 µg/m³, approximately 10 µg/m³ for the 3 Mtpa case and 20 µg/m³ for the 3 Mtpa case near the LNG facility boundary.
- Figures 3-21 and 3-23 – For the LNG facility plus background sources: A large area over Gladstone city has exceeded the 4-hour guideline for biological integrity, reaching the peak at Gladstone Power Station. These exceedances are predominantly impacted by the background sources in that area. These high predicted concentrations are affected by the over-predicted NO_2 to NO_x ratio close to industrial sources and actual impacts are expected to be lower.

The annual average NO_2 concentrations are presented in Figure 3-24 to Figure 3-27. The key observation from these annual average NO_2 contour plots is that:

- The annual average NO_2 levels are very low, with the highest values being approximately 10 µg/m³ with combined impacts, well below the EPP (Air) guideline of 30 µg/m³.
- The highest impacts from the LNG facility in isolation, occurring at the boundary of the LNG facility, are approximately 1 µg/m³ for the 3 Mtpa production and 2 µg/m³ for the 10 Mtpa production.

At sensitive receptors, NO_2 concentrations are presented in Table 3-15 for 3 Mtpa production and Table 3-16 for 10 Mtpa. The tables show both air quality impacts due to the LNG facility in isolation and the LNG facility plus background sources.

Key conclusions from these tables are:

- The EPP (Air) 1-hour average guideline of 320 µg/m³ is not exceeded either for the LNG facility in Isolation or for the LNG facility plus background sources at any receptors, for both 3 Mtpa and 10 Mtpa production cases.

- The 4-hour average EPP (Air) guideline of 95 µg/m³ for biological integrity is exceeded at some receptors over the city of Gladstone for the LNG facility plus background sources, for both 3 Mtpa and 10 Mtpa production cases. These exceedances are overwhelmingly due to the background sources in the Gladstone area, as shown in Table 3-17, when background only and the LNG facility plus background impacts are listed side by side, which shows that the contribution from the LNG facility is less than 1 µg/m³ during these peak events for 10 Mtpa. This guideline is not exceeded for the LNG facility in isolation. There are no predicted exceedances at receptors over Curtis Island.
- The modelling results for annual average NO_2 concentrations are well below the EPP (Air) guideline of 30 µg/m³, for the LNG facility in Isolation or for the LNG facility plus background sources at any receptors, for both 3 Mtpa and 10 Mtpa production cases.
- The group of receptors that are most impacted by the LNG facility in isolation are on the proposed Curtis Island Industrial Precinct, which has been identified as the location for a future LNG plant.
- For the LNG facility in isolation, the results from the 10 Mtpa production are higher than the 3 Mtpa production, by about a factor of three for most receptors (except for the receptor at the Curtis Island Industrial Precinct, which is the closest to the LNG facility site). This reflects the proportionally increased number of emission sources for the larger capacity facility design.

Table 3-15 NO_2 modelling results at ground-level sensitive receptors, for the OCP 3 Mtpa production design

Receptor Group	NO_2 (µg/m³) the LNG facility in isolation			NO_2 (µg/m³) the LNG facility plus background		
	1 hour 99.9th	4 hour	Annual	1 hour 99.9th	4 hour	Annual
South End & Quoin Island Community	1.4	1.6	0.01	25	29	0.4
Curtis Island Parkland	2.4	3.2	0.02	29	34	0.6
Curtis Island Industry Precinct	16.7	15.4	0.94	57	60	1.7
Gladstone	1.6	2.1	0.02	81	76	1.8
Gladstone Airport	0.9	1.2	0.01	163	172	2.8
Gladstone Industry	3.7	3.4	0.06	85	90	3.6
Gladstone Wetland areas	4.2	4.0	0.15	83	87	2.1
Clinton Precinct	1.8	2.1	0.02	195	171	1.8
Yarwun Precinct	3.8	3.2	0.06	112	103	8.0
Targinie Precinct	1.1	1.0	0.02	61	47	2.4
EPA monitoring sites	1.9	2.9	0.03	168	178	4.0
EPP (Air) Guideline	**320**	**95**	**30**	**320**	**95**	**30**

Table 3-16 NO_2 modelling results at ground-level sensitive receptors, for the OCP 10 Mtpa production design

Receptor Group	NO_2 ($\mu g/m^3$) LNG facility in Isolation			NO_2 ($\mu g/m^3$) LNG facility plus Background		
	1 hour 99.9th	4 hour	Annual	1 hour 99.9th	4 hour	Annual
South End & Quoin Island Community	4.2	4.5	0.04	25	29	0.4
Curtis Island Parkland	6.4	6.6	0.06	29	34	0.6
Curtis Island Industry Precinct	30.5	30.0	2.12	58	60	2.8
Gladstone	5.0	6.2	0.06	82	77	1.9
Gladstone Airport	2.8	3.7	0.04	164	173	2.9
Gladstone Industry	10.4	10.0	0.21	85	90	3.7
Gladstone Wetland areas	10.7	10.1	0.37	83	87	2.2
Clinton Precinct	5.2	6.0	0.06	195	171	1.8
Yarwun Precinct	11.2	8.6	0.18	112	103	8.1
Targinie Precinct	3.2	2.8	0.06	61	47	2.5
EPA monitoring sites	5.6	8.4	0.09	168	178	4.0
EPP (Air) Guideline	**320**	**95**	**30**	**320**	**95**	**30**

Table 3-17 Predicted impact from the LNG facility with background, for OCP 10 Mtpa production design for the 4-hour average NO_2 concentration

Receptor Group	Maximum 4-hour NO_2 concentration (µg/m³)	
	LNG facility with background	Background Only
South End & Quoin Island Community	29	29
Curtis Island Parkland	34	34
Curtis Island Industry Precinct	60	60
Gladstone	77	76
Gladstone Airport	173	172
Gladstone Industry	90	90
Gladstone Wetland areas	87	87
Clinton Precinct	171	171
Yarwun Precinct	103	103
Targinie Precinct	47	47
EPA monitoring sites	178	177
EPP (Air) Guideline	**95**	**95**

Modelling Results for NO_2 with the C3MR Design

Results of NO_2 modelling for the C3MR design are similar to the results for the OCP design.

For the C3MR design, the 1-hour NO_2 modelling results are presented as contour plots in Figure 3-28 to Figure 3-31, the 4-hour NO_2 modelling results in Figure 3-32 to Figure 3-35, and annual NO_2 modelling results in Figure 3-36 to Figure 3-39. The modelled results at the sensitive receptors for the C3MR design are presented in Table 3-18 and Table 3-19. Overall, the impacts from the LNG facility in isolation are much smaller for the C3MR design than those for the OCP design.

The key observations from these concentration contour plots and receptor data are:

- The 1-hour average NO_2 guidelines have not been exceeded, with impact from the LNG facility in isolation near the LNG facility boundary approximately 10 µg/m³ for 3 Mtpa production and approximately 30 µg/m³ for 10 Mtpa production.
- The annual average NO_2 guidelines have not been exceeded, either for the LNG facility in isolation or for the LNG facility plus background sources. The annual average NO_2 levels due to the LNG facility in isolation are very low, with the highest value approximately 2 µg/m³ for the 10 Mtpa production at the LNG facility boundary, well below the EPP (Air) guideline of 30 µg/m³.
- The 4-hour average NO_2 guideline for biological integrity has not been exceeded for the LNG facility in isolation.

- The 4-hour average NO_2 guideline for biological integrity has been exceeded for the LNG facility plus background sources over Gladstone city, heavily impacted by background industrial sources (the contribution from the LNG facility is less than 1 µg/m³ during these peak events). NO_2 levels are over-estimated close to industrial sources due to the use of a constant NO_2 to NO_x ratio.

Table 3-18 NO_2 modelling results at ground-level sensitive receptors, for the C3MR 3 Mtpa production design

Receptor Group	NO_2 (µg/m³) LNG facility in Isolation			NO_2 (µg/m³) LNG facility and Background		
	1 hour 99.9th	4 hour	Annual	1 hour 99.9th	4 hour	Annual
South End & Quoin Island Community	3	3	0.0	25	29	0.4
Curtis Island Parkland	3	3	0.0	29	34	0.6
Curtis Island Industry Precinct	14	13	0.6	57	60	1.3
Gladstone	3	3	0.0	82	77	1.8
Gladstone Airport	2	4	0.0	164	172	2.8
Gladstone Industry	6	5	0.1	85	90	3.6
Gladstone Wetland areas	5	5	0.2	83	87	2.1
Clinton Precinct	3	3	0.0	195	171	1.8
Yarwun Precinct	6	5	0.1	112	103	8.0
Targinie Precinct	2	1	0.0	61	47	2.4
EPA monitoring sites	3	4	0.0	168	178	4.0
EPP (Air) Guideline	**320**	**95**	**30**	**320**	**95**	**30**

Table 3-19 NO_2 modelling results at ground-level sensitive receptors, for the C3MR 10 Mtpa production design

Receptor Group	NO_2 (µg/m³) LNG facility in Isolation			NO_2 (µg/m³) LNG facility and Background		
	1 hour 99.9th	4 hour	Annual	1 hour 99.9th	4 hour	Annual
South End & Quoin Island Community	8	8	0.1	25	29	0.4
Curtis Island Parkland	10	11	0.1	30	34	0.6
Curtis Island Industry Precinct	35	33	2.1	60	60	2.9
Gladstone	7	7	0.1	82	77	1.9
Gladstone Airport	5	11	0.1	165	173	2.9
Gladstone Industry	16	15	0.3	85	90	3.8
Gladstone Wetland areas	15	13	0.6	83	87	2.3
Clinton Precinct	9	10	0.1	195	171	1.9
Yarwun Precinct	17	15	0.3	112	103	8.1
Targinie Precinct	5	4	0.1	61	47	2.5
EPA monitoring sites	8	12	0.1	169	179	4.1
EPP (Air) Guideline	**320**	**95**	**30**	**320**	**95**	**30**

Discussions of NO_2 Impacts on Biological Integrity

It has been shown that in some areas of Gladstone the EPP (Air) 4-hour NO_2 guideline for biological integrity has been exceeded. The exceedances over Gladstone are due to the impacts from existing industrial sources in those areas. As discussed in Section 3.1.3, those predicted levels of exceedances of background NO_2 concentrations may be over-predicted by the model, particularly by the use of a constant NO_2 to NO_x ratio.

No exceedances have occurred over Curtis Island, where the LNG facility is located.

The 4-hour guideline is mainly for protecting plants, as plants' photosynthesis and other activities can be adversely impacted by high NO_2 levels. This Queensland EPP (Air) guideline is directly derived from the World Health Organisation air quality guideline[11], in which plants that were documented for NO_2 effects are predominantly crops. As the tolerance of plant species to NO_2 varies significantly, it is unknown how tolerant the protected Australian native plants are to the NO2 levels.

---

[11] World Health Organisation, *Air Quality Guidelines*, Second Edition, 2000 http://www.euro.who.int/air/activities/20050223_4, accessed July 2006

Modelling Results for Particulate Matter

Concentrations of PM_{10} have been modelled for the two 10 Mtpa production designs. As the background modelling in GAMS only includes the industrial sources of SO_2 and NO_x, the background concentrations of PM_{10} have been assumed to be constant, which are 30 µg/m³ for the 24-hour average and 18 µg/m³ for the annual average PM_{10} concentrations. These ambient measurements of PM_{10} incorporate the impacts from existing industrial, residential and natural sources of dust. As detailed in Section 3.1.3, the annual average TSP concentration has been estimated as 30 µg/m³.

For the emissions of particulate matter from the LNG facility, the sources of dust are combustion sources which generate fine particles (10 µm diameter and smaller). Therefore the TSP emission rate and impacts from the LNG facility have been assumed to be equivalent to PM_{10} impacts.

For the OCP design 10 Mtpa production scenarios, the maximum 24-hour and annual PM_{10} concentrations due to the LNG facility in isolation are presented as contour plots in Figure 3-40 and Figure 3-42. For the C3MR 10 Mtpa production scenario, these values are presented in Figure 3-41 and Figure 3-43. The cumulative impacts from both the LNG facility and the background sources are not presented here as contour plots because the assumed constant background level dominates the predicted impacts, and the spatial variation is very small.

These contour plots show that the impacts from the LNG facility on ambient PM_{10} levels are much smaller than the relevant EPP (Air) guidelines. The impact reduces quickly further away from the LNG facility boundary. When added the constant background levels of 30 µg/m³ to the 24-hour LNG facility impacts and 18 µg/m³ to the annual LNG facility impacts, cumulative impacts of the LNG facility and background sources are well below EPP (Air) guidelines of 150 µg/m³ for 24-hour averaging time and 50 µg/m³ for annual averaging time and also blow the NEPM guideline of 50 µg/m³ for 24-hour averaging time.

At sensitive receptors, PM_{10} concentrations for 24-hour and annual average and annual average concentrations of TSP are presented in Table 3-20 and Table 3-21. These tables show air quality impacts due both to the LNG facility in isolation and the LNG facility plus background sources.

Key conclusions from these tables are:

- In comparison with the assumed PM_{10} background concentration, the impacts from the LNG facility in isolation are small for both the C3MR and the OCP design. The highest impact of PM_{10} is located in the Curtis Island Industry Precinct, 2.3 µg/m³ for 24-hour averaging time and 0.47 µg/m³ for annual averaging time for the C3MR design and 2.0 µg/m³ for 24-hour averaging time and 0.69 µg/m³ for annual averaging time for the OCP design, which are much smaller than respective EPP (Air) guidelines.
- None of the EPP (Air) guidelines for PM_{10} and TSP are exceeded either for LNG facility impacts in isolation or for the combined LNG facility and background impacts, for both C3MR and OCP designs. The cumulative impacts for PM_{10} and TSP are less than 40% of the EPP (Air) guidelines. Likewise, the NEPM guideline of 50 µg/m³ for 24-hour average PM_{10} concentrations is satisfied for the LNG facility plus background impacts.

Table 3-20 Maximum PM_{10} and TSP modelling results at ground-level sensitive receptors, for the C3MR 10 Mtpa design (µg/m³)

Receptor Group	PM_{10}		TSP[1]	PM_{10}		TSP
	LNG facility in Isolation			LNG facility and Background		
	24 hour	Annual	Annual	24 hour	Annual	Annual
South End & Quoin Island Community	0.4	0.01	0.02	30	18	30
Curtis Island Parkland	0.6	0.02	0.03	31	18	30
Curtis Island Industry Precinct	2.3	0.47	0.78	32	18	31
Gladstone	0.3	0.02	0.03	30	18	30
Gladstone Airport	0.4	0.02	0.03	30	18	30
Gladstone Industry	0.8	0.06	0.11	31	18	30
Gladstone Wetland areas	0.9	0.13	0.21	31	18	30
Clinton Precinct	0.5	0.02	0.03	31	18	30
Yarwun Precinct	0.9	0.07	0.11	31	18	30
Targinie Precinct	0.2	0.02	0.03	30	18	30
EPA monitoring sites	0.6	0.03	0.05	31	18	30
EPP (Air) Guideline	**150**	**50**	**90**	**150**	**50**	**90**

Table 3-21 PM_{10} and TSP modelling results at ground-level sensitive receptors, for the OCP 10 Mtpa design (µg/m³)

Receptor Group	PM_{10}		TSP	PM_{10}		TSP
	LNG facility in Isolation			LNG facility and Background		
	24 hour	Annual	Annual	24 hour	Annual	Annual
South End & Quoin Island Community	0.2	0.03	0.05	30	18	30
Curtis Island Parkland	0.3	0.02	0.03	30	18	30
Curtis Island Industry Precinct	2.0	0.69	1.15	32	19	31
Gladstone	0.2	0.22	0.37	30	18	30
Gladstone Airport	0.1	0.01	0.02	30	18	30
Gladstone Industry	0.4	0.10	0.16	30	18	30
Gladstone Wetland areas	0.5	0.18	0.29	31	18	30
Clinton Precinct	0.3	0.02	0.03	30	18	30
Yarwun Precinct	0.4	0.09	0.14	30	18	30
Targinie Precinct	0.1	0.01	0.02	30	18	30
EPA monitoring sites	0.3	0.09	0.15	30	18	30
EPP (Air) Guideline	**150**	**50**	**90**	**150**	**50**	**90**

Air Quality Impact from Upset Conditions

The methodology for modelling upset emissions is described in detail in Section 3.2.2. Scenarios for a scheduled shut-down and start-up for maintenance inspection have been modelled for C3MR 10 Mtpa production and OCP 10 Mtpa production. These upset conditions are expected to occur once every three years and to last for 3 hours. During the scheduled maintenance, one compressor train with its associated turbines and power generators is taken offline.

Contour plots of the modelled maximum 1-hour average concentration of NO_2 (assuming 35% conversion from NO_x) due to the LNG facility are shown in Figure 3-44 and Figure 3-45. Combined with the impacts from background industrial sources, modelled 1-hour NO_2 concentrations for scheduled maintenance are presented in Figure 3-46 and Figure 3-47.

The modelling results at ground-level sensitive receptors are presented in Table 3-22, for the 1-hour NO_2 concentrations. This table shows that the EPP (Air) 1-hour NO_2 guideline of 320 µg/m³ has not been exceeded for any emission scenario, no matter whether the LNG facility emissions are considered in isolation or combined with the background emission sources in Gladstone. Comparing data in this table with data for 10 Mtpa normal operations in Table 3-19 for C3MR and in Table 3-16 for OCP, the 1-hour NO_2 concentrations due to the upset emissions are very similar to or slightly lower than those due to the 10 Mtpa emissions under normal operation.

This is due to the improved plume dispersion from the tall, hot buoyant flare sources compared to the refrigeration compressor turbines and power generators.

Table 3-22 Modelling results for the maintenance scenario: 1-hour NO_2 concentrations at the ground level sensitive receptors

Receptor Group	NO_2 (µg/m³) LNG facility in Isolation 1 hour 99.9th percentile		NO_2 (µg/m³) LNG facility and Background 1 hour 99.9th percentile	
	C3MR 10 Mtpa	OCP 10 Mtpa	C3MR 10 Mtpa	OCP 10 Mtpa
South End & Quoin Island Community	6	3	25	25
Curtis Island Parkland	8	5	30	29
Curtis Island Industry Precinct	30	26	58	57
Gladstone	6	3	82	82
Gladstone Airport	4	2	165	164
Gladstone Industry	13	7	85	85
Gladstone Wetland areas	12	8	83	83
Clinton Precinct	7	4	195	195
Yarwun Precinct	14	8	112	112
Targinie Precinct	4	2	61	61
EPA monitoring sites	6	4	169	168
EPP (Air) Guideline	**320**			

Air Quality Impact during Construction

The 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. These impacts are difficult to assess as they are shifting constantly. As a consequence, the air quality impacts during construction have not been modelled. A Construction Environmental Management Plan will be prepared for the site to manage dust emissions during construction activities.

3.2.4 Discussion of results

Cumulative impacts and airshed management, human health risk assessment and odour assessment are discussed below to address relevant requirements in the ToR.

Cumulative Impacts and Airshed 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. Cumulative airshed 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 above in this report.

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. Further expansion of GAMS capability by EPA to include modelling of particulate matter will be beneficial.

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 the normal operation, dust emissions during the construction, and minor VOC emissions.

This report has assessed human health risk for criteria pollutants including carbon monoxide, particulate matter (specifically PM_{10}), sulphur dioxide and nitrogen dioxide. Modelling results show that both for the LNG facility in isolation and for the cumulative impacts which combine impacts from the LNG facility and background sources, NEPM and EPP (Air) human health based guidelines have not been exceeded. For ozone, another criteria air pollutant, no modelling has been conducted for reasons provided in Section 3.2.2. Monitoring results in Gladstone, though limited, have indicated no exceedances of NEPM and EPP (Air) guidelines.

A health risk assessment was considered for potential releases of hazardous or toxic material 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 are not considered to be toxic. The LNG facility will emit very small amounts of non-methane VOC as provided in Section 3.2.1, some of which may be toxic to human health. The expected non-methane VOC emissions will include:

- Ethane and propane from the fugitive emissions of coal seam gas and refrigerants (used by refrigeration compressors), and
- A variety of non-methane VOC emissions from vehicles and machinery operating on gasoline or diesel fuel during construction stage and for emergency diesel generators.

However, the amount of non-methane VOC emission from this project is small, as shown in Section 3.2.1, and will not cause any adverse health impacts. 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 for reasons described above. However, best-practice mitigation measures will be in place to minimise their impacts.

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 concentrations, as well as meet or surpass ambient air quality guidelines. Thus the final FEED design will ensure that no significant human health risk occurs through impact assessment of the air emissions.

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.

Occupational Health and Safety

Occupational health and safety exposure standards are specified by the Australian Government's National Occupational Health and Safety Commission (NOHSC), and published in the Hazardous Substances Information System (HSIS). The safety standards are higher than ambient air quality standards, designed to protect workers on site. However, the air quality dispersion modelling results are not applicable to evaluation of on-site air quality due to the resolution of the model predictions used, which is 500 m in horizontal modelling domain.

Odour Assessment

Odour is not a concern for the LNG facility. The LNG facility and the coal seam gas will not release strong odorous compounds, as no odorant is added to the gas since it is a dedicated industrial pipeline. 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.

3.2.5 Conclusions

Based on emission estimates and dispersion modelling results, it has been found that the impacts from the LNG facility for SO_2, CO and particulate matter are small, as summarised below.

- SO_2 emission rates are very small from this LNG facility and dispersion modelling results indicate that the LNG facility has a negligible impact on ambient SO_2 levels. Predicted SO_2 concentrations in Gladstone are dominated by existing industrial sources and the impacts from the LNG facility contribute little (less than 0.1 percent) to these levels;
- CO emission rates and resultant impacts on ambient CO concentrations are low. These impacts are well below the assumed background level of CO and air quality guidelines. Impacts due to the LNG facility plus background do not exceed 25 % of the ambient 8-hour CO guideline for either plant design;
- Modelling results for particulate matter indicate that the impacts from the LNG facility in isolation are small for both plant designs. The highest impact of PM_{10} is located in the neighbouring Curtis Island Industry Precinct, with a predicted concentration of 2.3 µg/m³ for 24-hour averaging time and 0.5 µg/m³ for annual averaging time for the C3MR design and 2.0 µg/m³ for 24-hour averaging time and 0.7 µg/m³ for annual averaging time for the OCP design. Modelled cumulative impacts of PM_{10} do not exceed Queensland and national guidelines. Note that a constant background level of 30 µg/m³ is used for assessing cumulative impacts for 24-hour averaging time and 18 µg/m³ for annual averaging time, based on air quality measurements at Gladstone. Impacts at sensitive receptor locations due to the LNG facility plus background do not exceed 40 % of the ambient Queensland air quality guidelines, for either plant design;

Based on emission estimates of NO_x and a conservative NO_2/NO_x ratio in the dispersion modelling results, the impacts of NO_2 from the LNG facility are not of concern for human health, and cumulative impacts of NO_2 is not of concern over Curtis Island, as summarised below.

- Modelling results for NO_2 show that the impacts from the LNG facility combined with background sources are below the Queensland guideline for human health. Impacts at sensitive receptor locations due to the LNG facility plus background do not exceed 65 % of the Queensland guideline of 1-hour average ambient NO_2 concentration for human health, for either facility design;

- The Queensland guideline of 4-hour average NO_2 concentration for biological integrity are not exceeded over Curtis Island; however this guideline has been exceeded in Gladstone city due to impacts from existing industrial sources;
- The Queensland guideline of annual average NO_2 concentration for biological integrity are not exceeded. The maximum impacts from the combined impacts of the LNG facility and background sources do not exceed 30% of the annual average guideline for biological integrity.

During a scheduled maintenance, the LNG facility will be shut down and restarted, which leads to the flaring of the LNG facility gas for one LNG train for up to 3 hours. This scenario has comparable NO_2 impacts at ground level receptors compared to normal operating conditions. This is due to the elevated stack height and high temperatures of emergency flares which provide greater dispersion than the compressor and power generation combustion sources that are part of normal LNG facility operations. The predicted concentrations of NO_2 due to the maintenance upset scenario satisfy short-term air quality guidelines when impacts of the LNG facility plus background sources are considered.

3.2.6 Mitigation Measures

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.

Construction

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.
- 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)

- 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.

Operation

The LNG facility designs assessed for the Santos GLNG project incorporate mitigation measures in the equipment design, as discussed in Section 3.2.1. 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.

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 implementation of in-stack NO_x testing to characterise actual emissions during the operational phase of the project will enable NO_x impacts to be more accurately determined.

To address concerns of residents regarding health impacts, Santos GLNG 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 and will inform any required changes to the LNG facility design for incorporation into the more detailed FEED design.

Decommissioning

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.

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

- 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.

Section 4 References

Beychok, Milton R. 1994. *Fundamentals of Stack Gas Dispersion*. 3rd ed. Irvine, California.

CSIRO, *Chemical and Physical Properties of Australian Fine Particles: A Pilot Study*, with web access as http://www.cmar.csiro.au/e-print/open/CSIRO_AFP.pdf.

National Environmental Protection Council: *National Environment Protection (Ambient Air Quality) Measure 1988*, with amendment in 2003.

National Environmental Protection Council: *National Environment Protection (Air Toxics) Measure* 2004.

National Pollutant Inventory (NPI) 2005, *Emission Estimation Technique Manual for Oil & Gas Exploration & Production*, version 1.1. Web access is http://www.npi.gov.au.

NSW Department of Environment and Climate Change 2005, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*.

NSW Department of Environment and Climate Change 2003, *Protection of the Environment Operations (Clean Air) Regulation*.

Queensland Government, *Environmental Protection Act 1994*

Queensland Government, *Environmental Protection (Air) Policy 1997*

Queensland Government, *Environmental Protection Regulation 1998*

Queensland Government, *Workplace Health and Safety Act 1995*

Queensland Environmental Protection Agency, 2001-2005, *Air Quality Bulletin, Central Queensland.* (available on web site http://www.epa.qld.gov.au)

Santos, 2005, *EHS MANAGEMENT SYSTEM HAZARD STANDARD, EHS05 Air Emissions*.

U.S. EPA: *AP-42 - Compilation of Air Pollutant Emission Factors, Fifth Edition*, Volume 1. Web access is http://www.epa.gov/ttn/chief/ap42/.

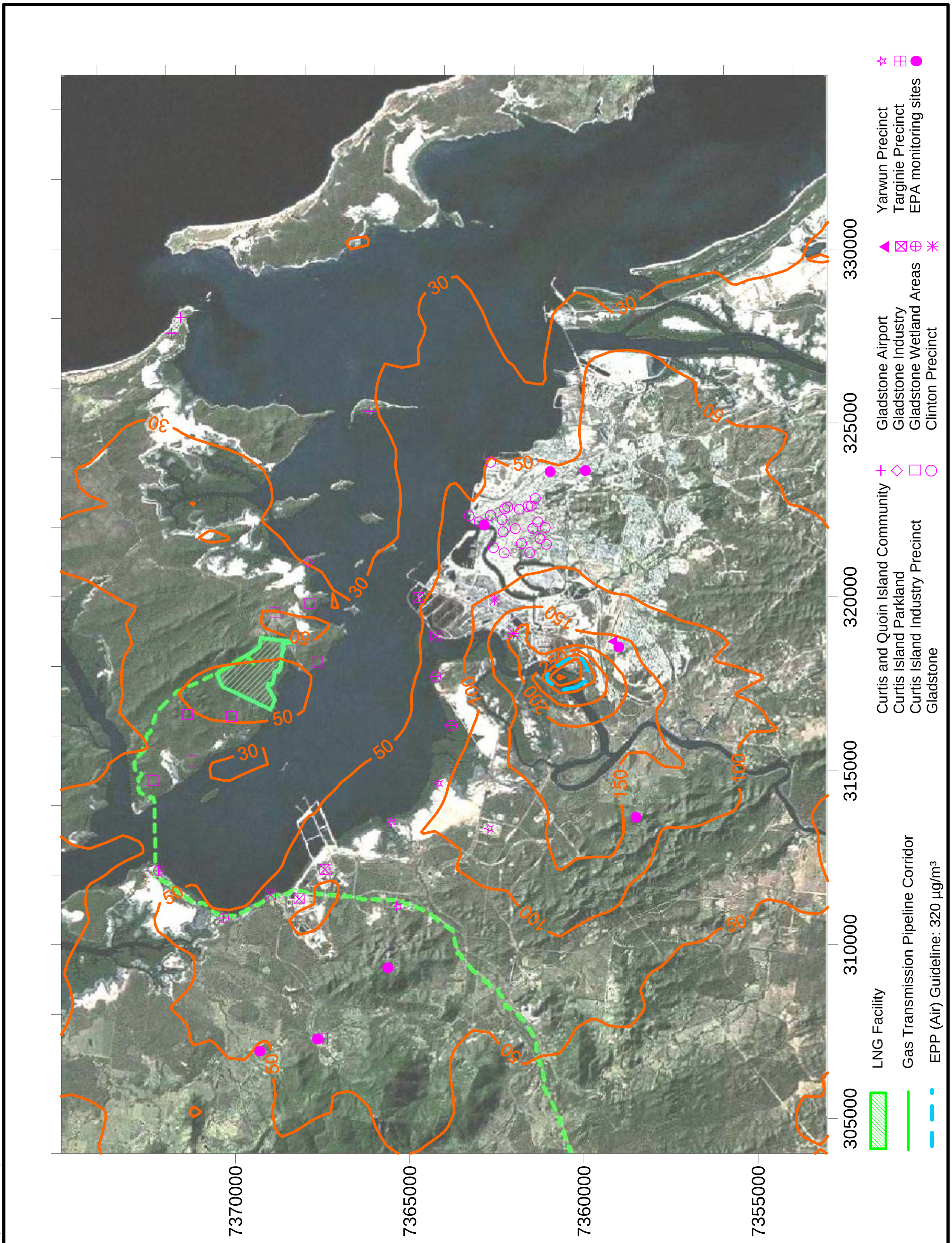
Victoria Environment Protection Authority 1996, *Best Practice Environmental Management - Environmental Guidelines for Major Construction Sites*.

Victorian *State Environment Protection Policy (Air Quality Management)*, 2001.

World Health Organisation 2000, *Air Quality Guidelines*, Second Edition, http://www.euro.who.int/air/activities/20050223_4, accessed July 2006

World Health Organisation, *Air Quality Guidelines – Global Update 2005* http://www.euro.who.int/air/activities/20050624_2, accessed July 2006.

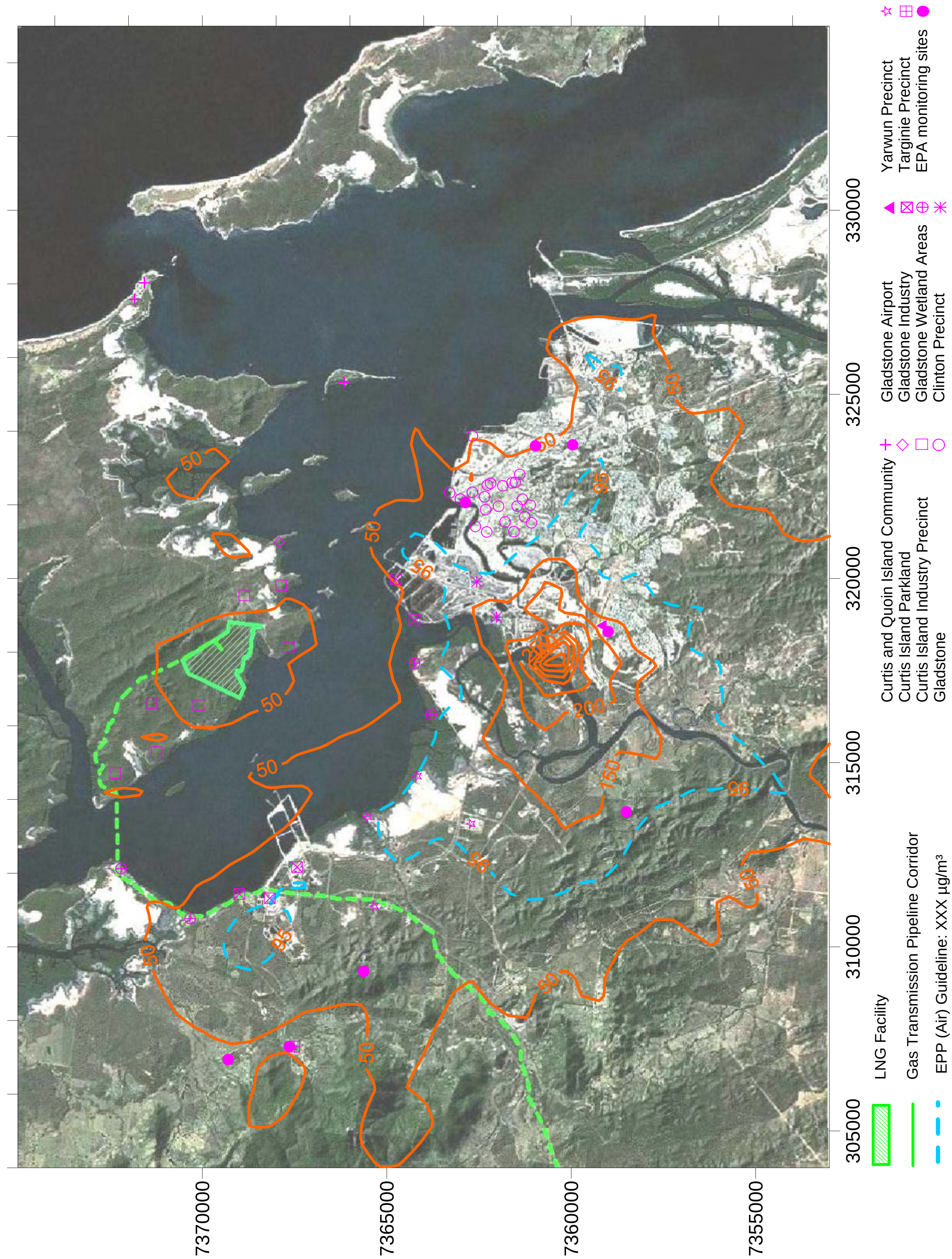
Figures



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

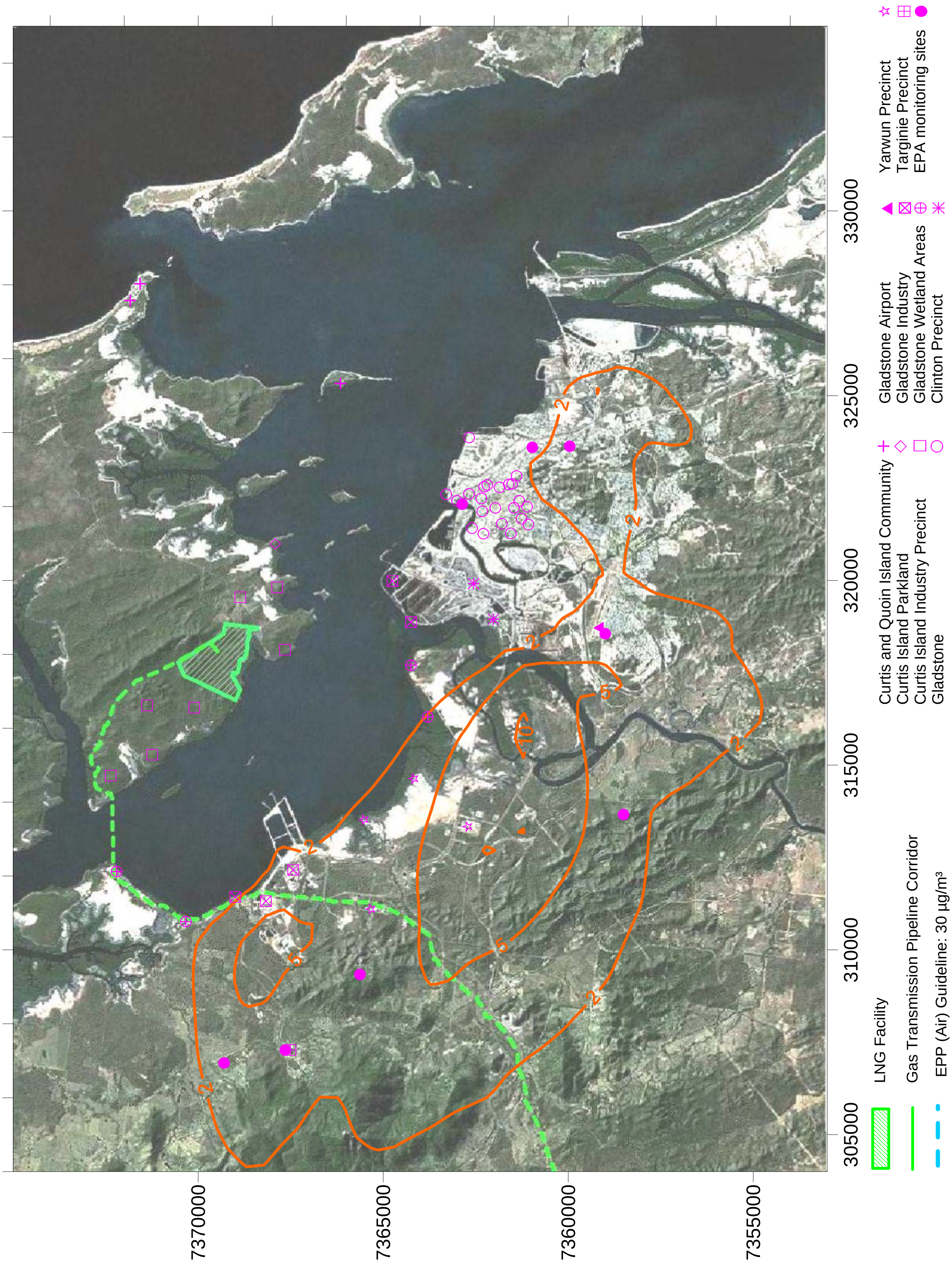
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: **99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO BACKGROUND SOURCES**	
	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-8**	Rev B
	Job No: **4262 6220**	File: 42626220-g-617.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

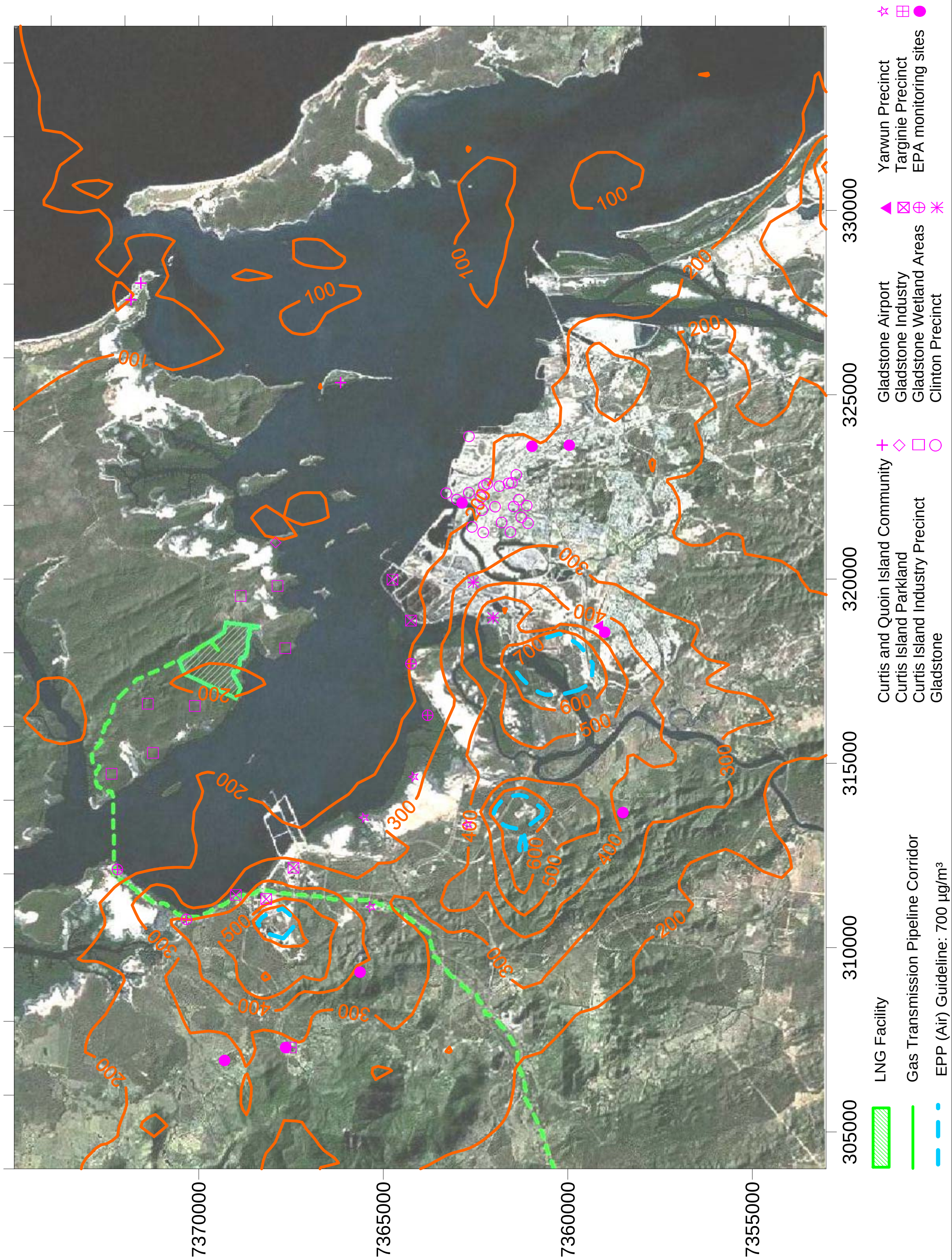
Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO BACKGROUND SOURCES	
LNG / URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-9**	Rev B
	Job No: **4262 6220**	File: 42626220-g-618.srf			A4



Datum: MGA94, Zone 55

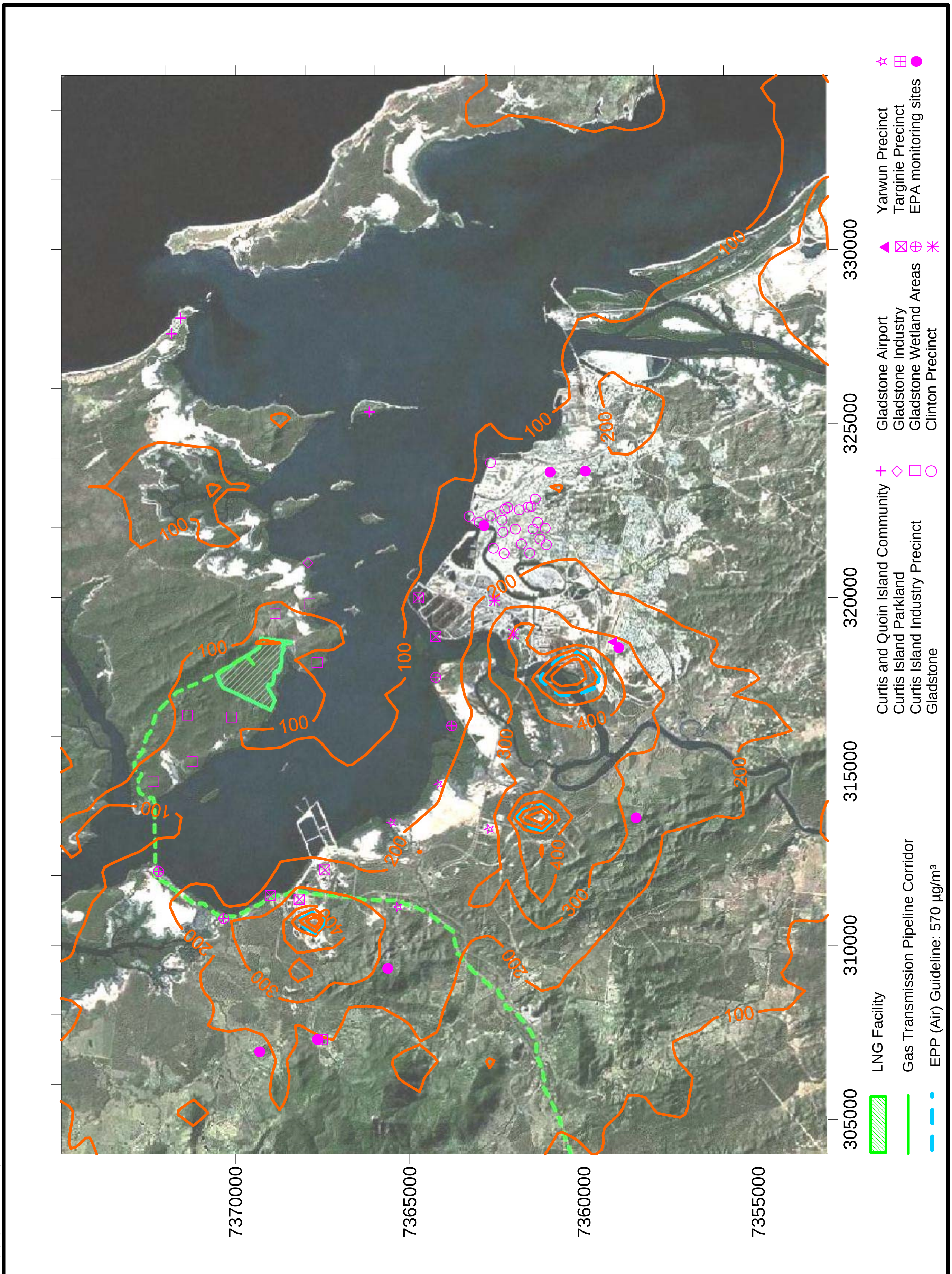
Client: LNG / URS	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO BACKGROUND SOURCES	
	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-10**	Rev B
	Job No: **4262 6220**	File: 42626220-g-619.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

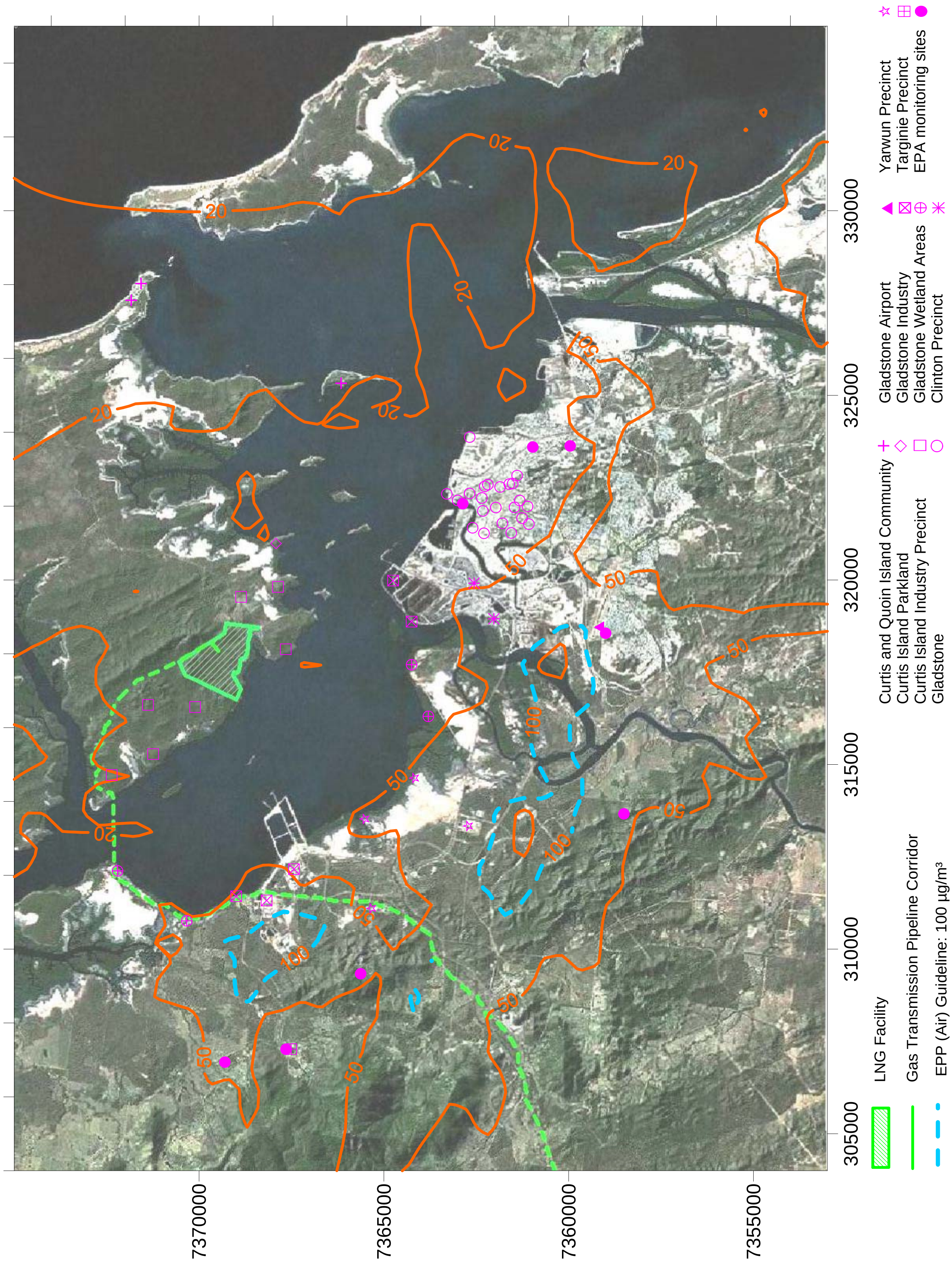
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: 99.9TH PERCENTILE 10 MINUTE AVERAGE CONCENTRATION OF SO2 (µg/m³) DUE TO BACKGROUND SOURCES	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-11**	Rev B
	Job No: **4262 6220**	File: 42626220-g-620.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

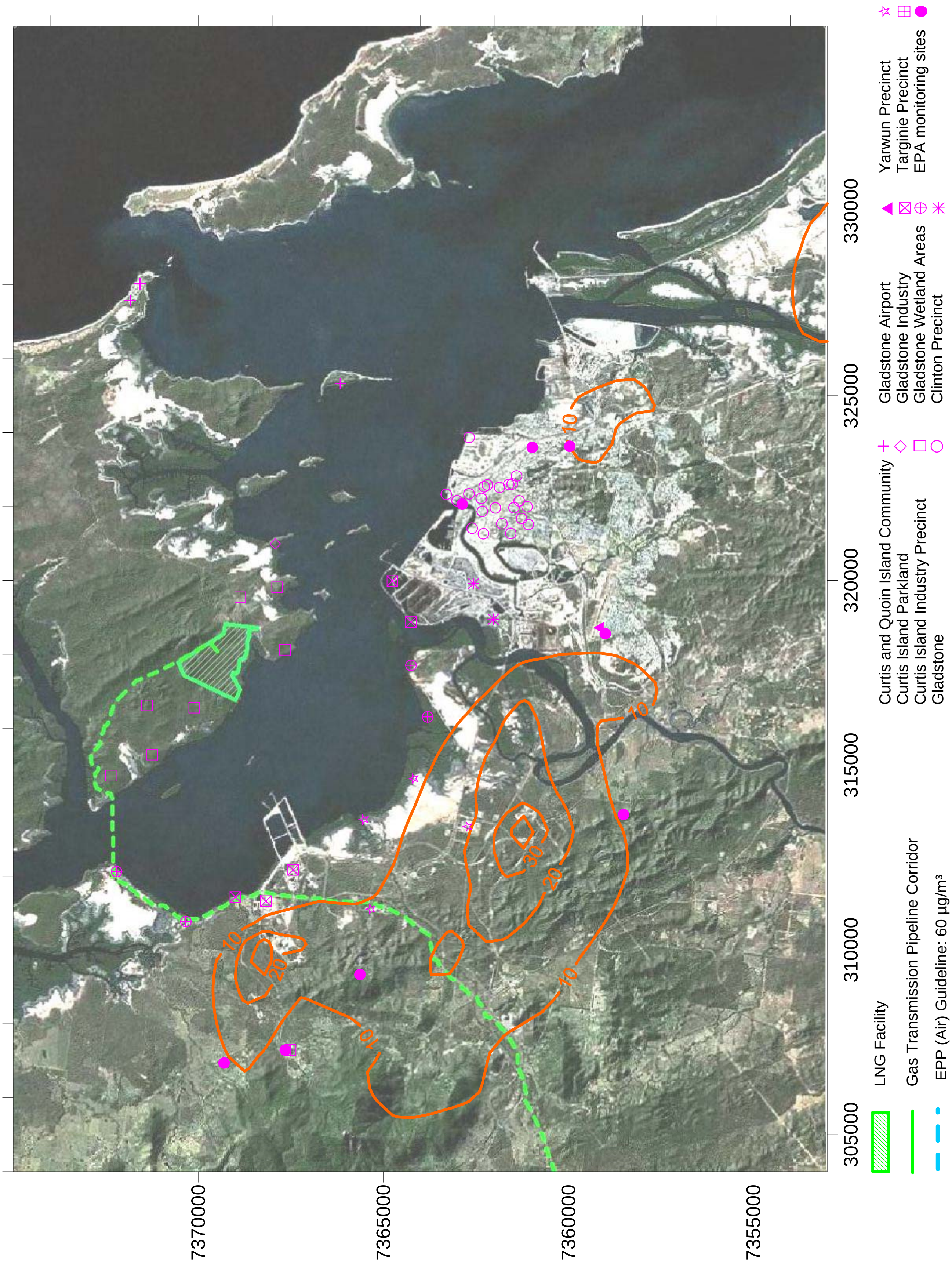
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: 99.9TH PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF SO2 (µg/m³) DUE TO BACKGROUND SOURCES	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-12**	Rev B
	Job No: **4262 6220**	File: 42626220-g-621.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

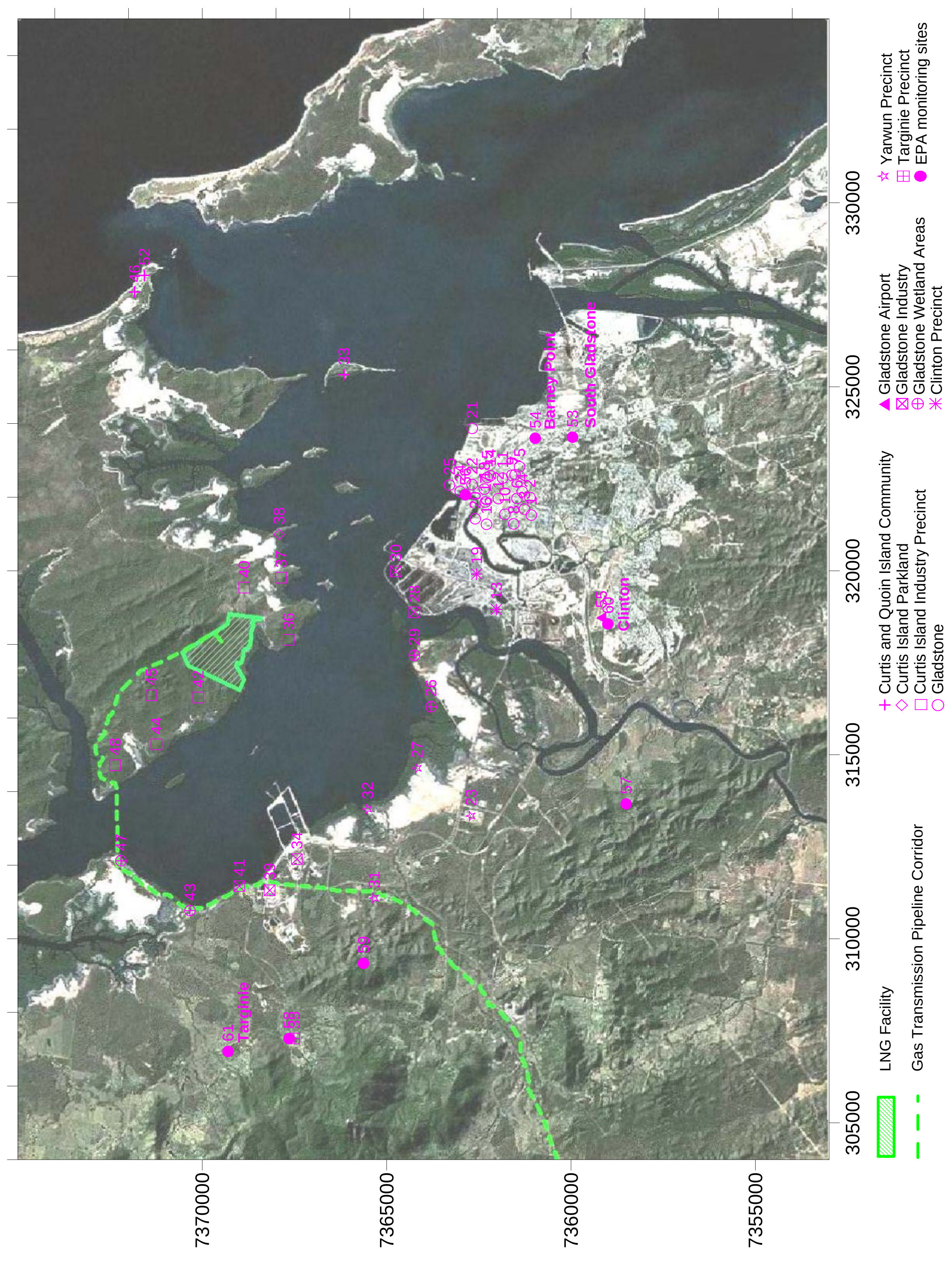
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: MAXIMUM 24 HOUR AVERAGE CONCENTRATION OF SO2 (µg/m³) DUE TO BACKGROUND SOURCES	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-13**	Rev B
	Job No: **4262 6220**	File: 42626220-g-622.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

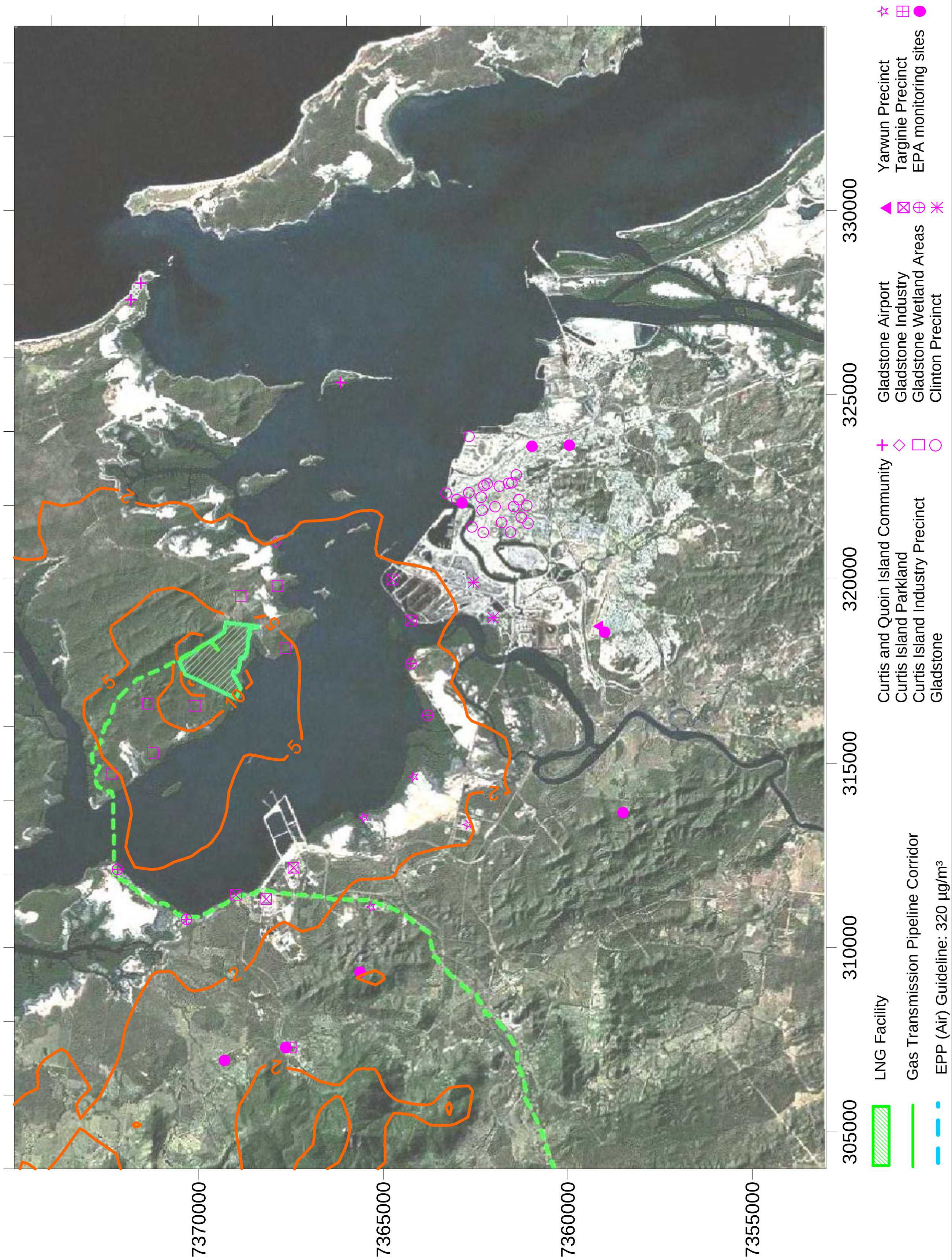
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: **ANNUAL AVERAGE CONCENTRATION OF SO2 (µg/m³) DUE TO BACKGROUND SOURCES**	
LNG / URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-14**	Rev B
	Job No: **4262 6220**	File: 42626220-g-623.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

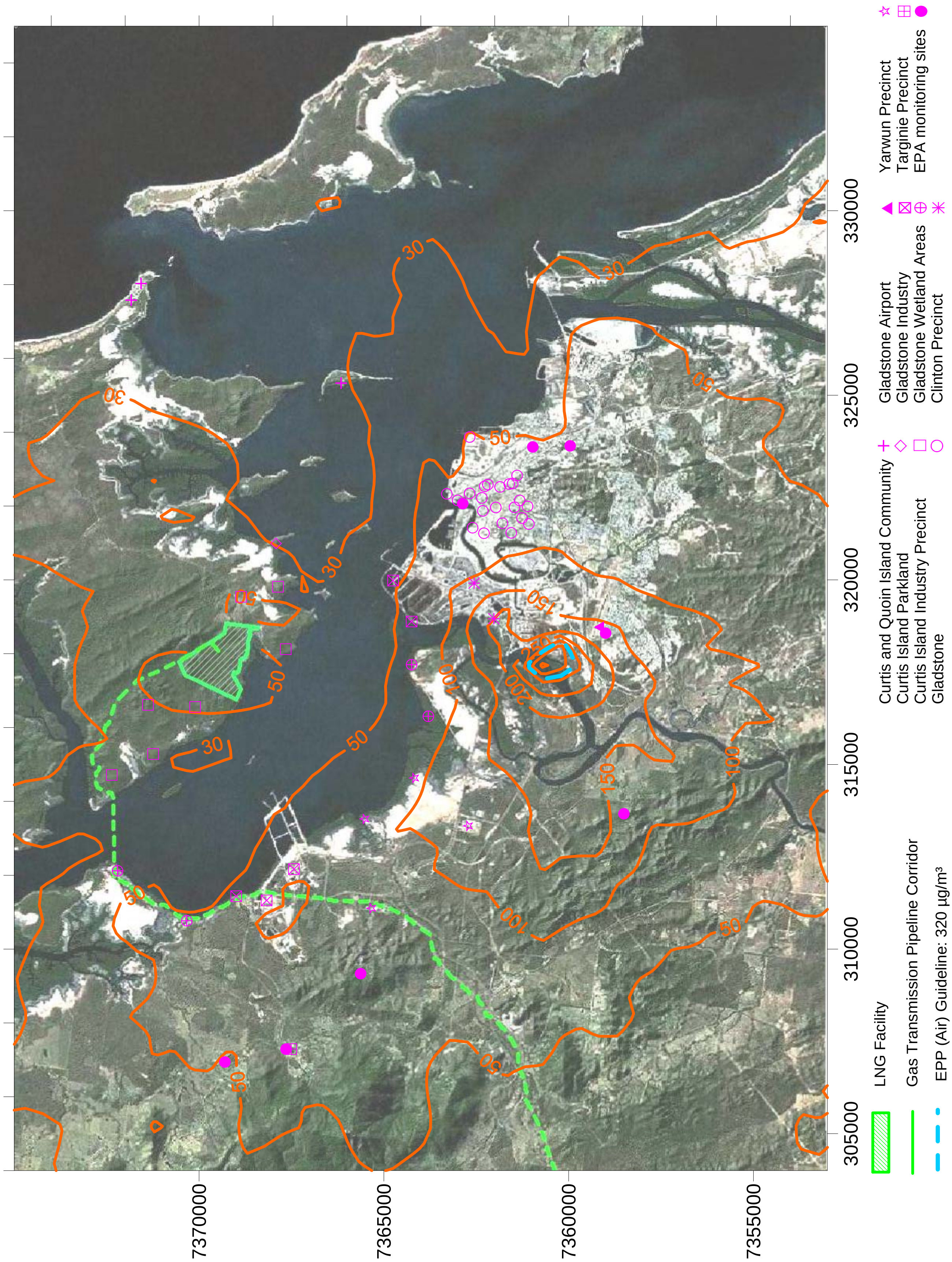
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: SENSITIVE RECEPTOR LOCATIONS IN GLADSTONE AREA USED IN AIR QUALITY MODELLING	
LNG / URS	Drawn: LF	Approved: JB	Date: 26-02-2009	Figure: **3-15**	Rev C
	Job No: **4262 6220**	File: 42626220-g-654.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

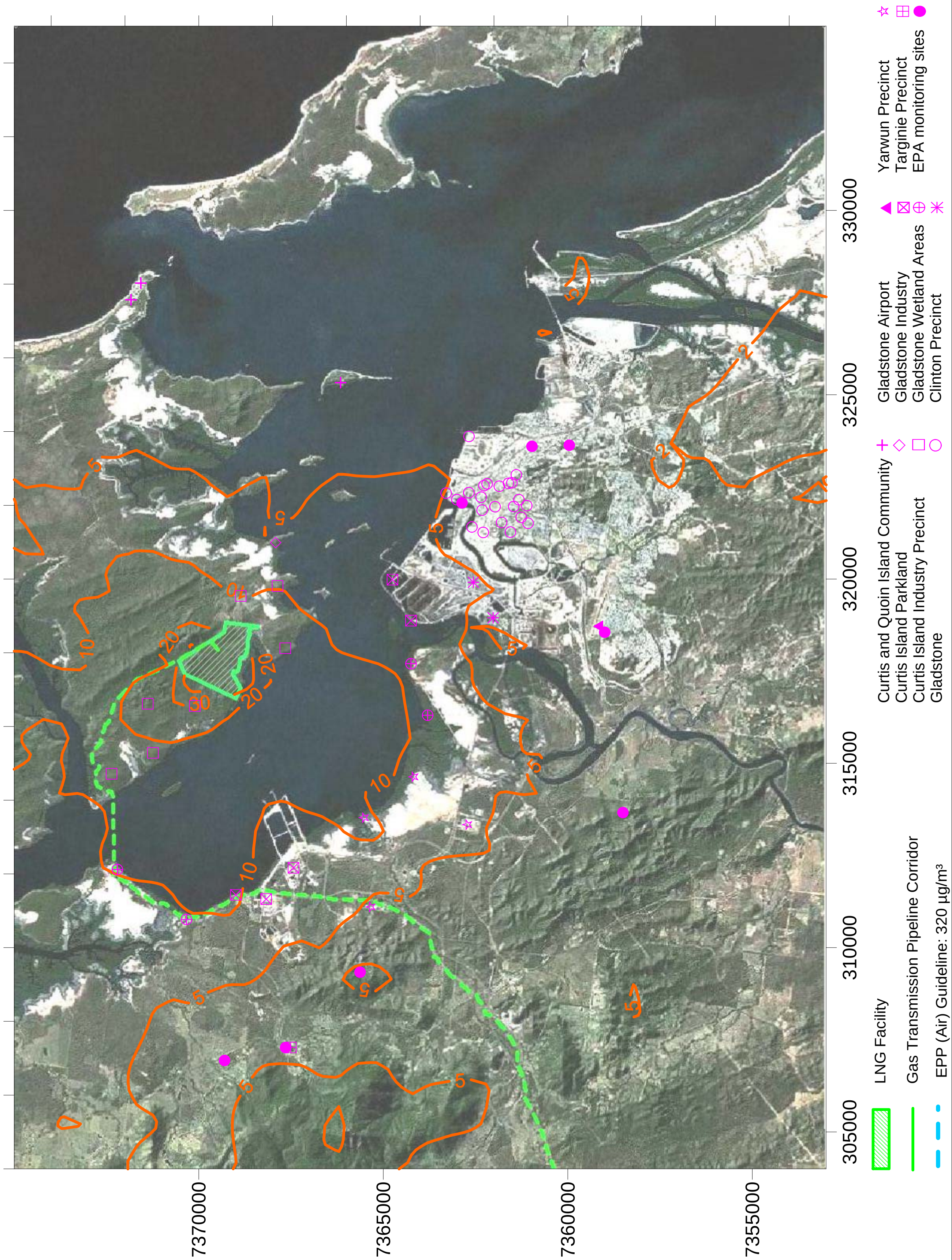
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR OCP 3 MTPA
URS	Drawn: LF / Approved: JB / Date: 03-02-2009	Figure: 3-16 / Rev B
	Job No: **4262 6220** / File: 42626220-g-624.srf	A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

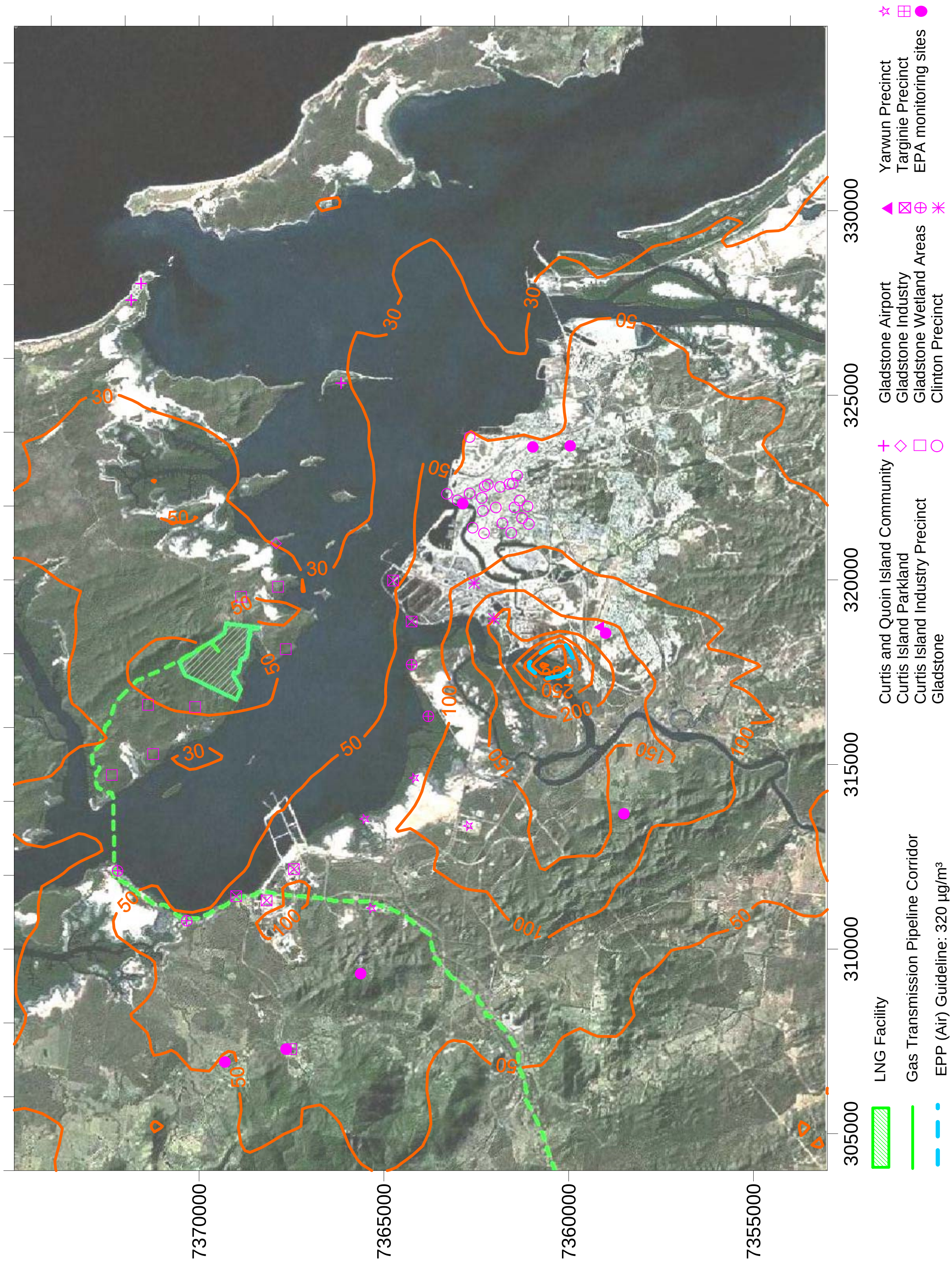
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR OCP 3 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-17**	Rev B
	Job No: **4262 6220**	File: 42626220-g-625.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR OCP 10 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-18**	Rev B
	Job No: **4262 6220**	File: 42626220-g-626.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS Ownership and Copyright.

Datum: MGA94, Zone 55

Client:

URS

Project:

GLADSTONE LNG PROJECT
AIR QUALITY IMPACT ASSESSMENT

Title:

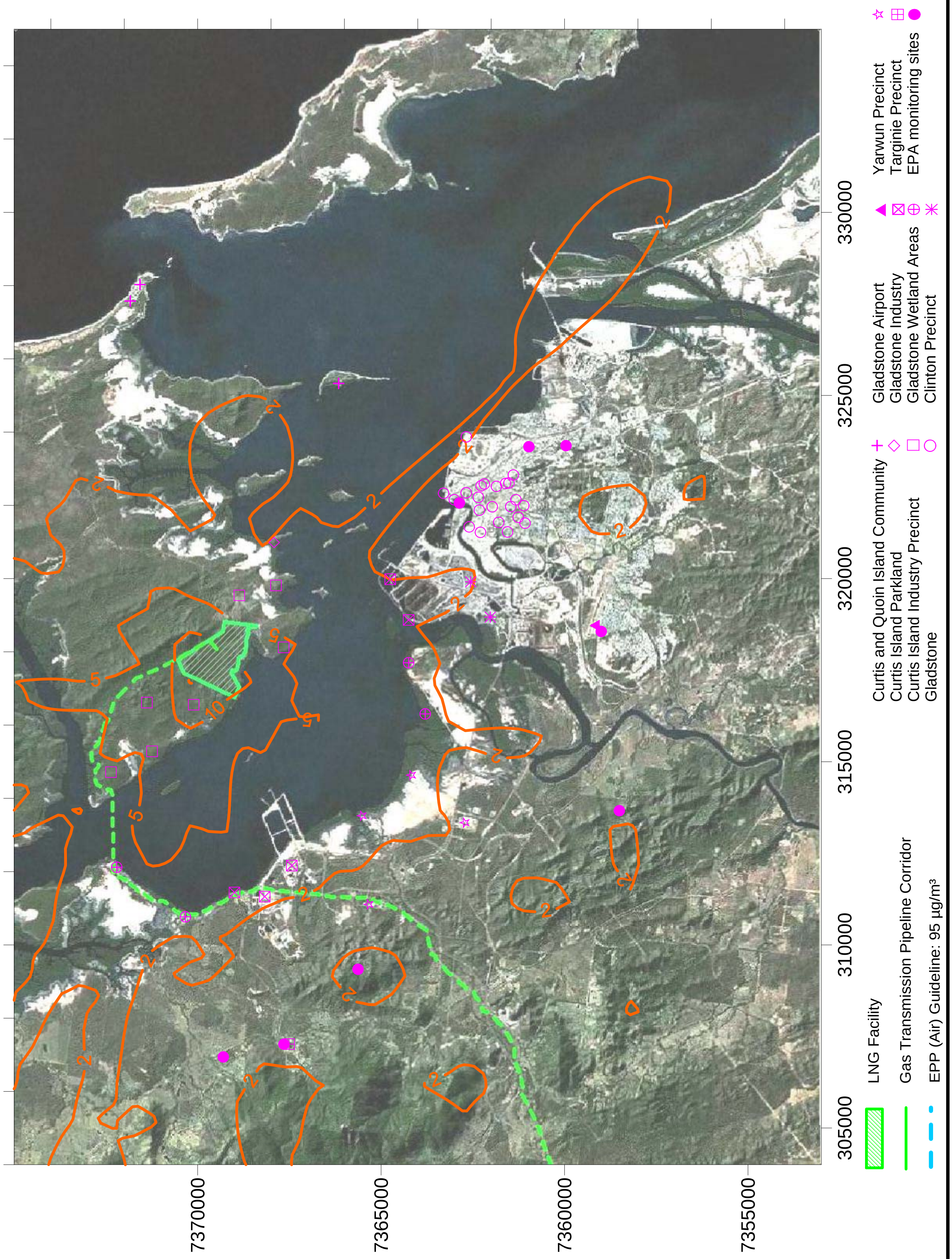
99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR OCP 10 MTPA

Drawn: LF	Approved: JB	Date: 03-02-2009
Job No: **4262 6220**	File: 42626220-g-627.srf	

Figure: **3-19**

Rev B

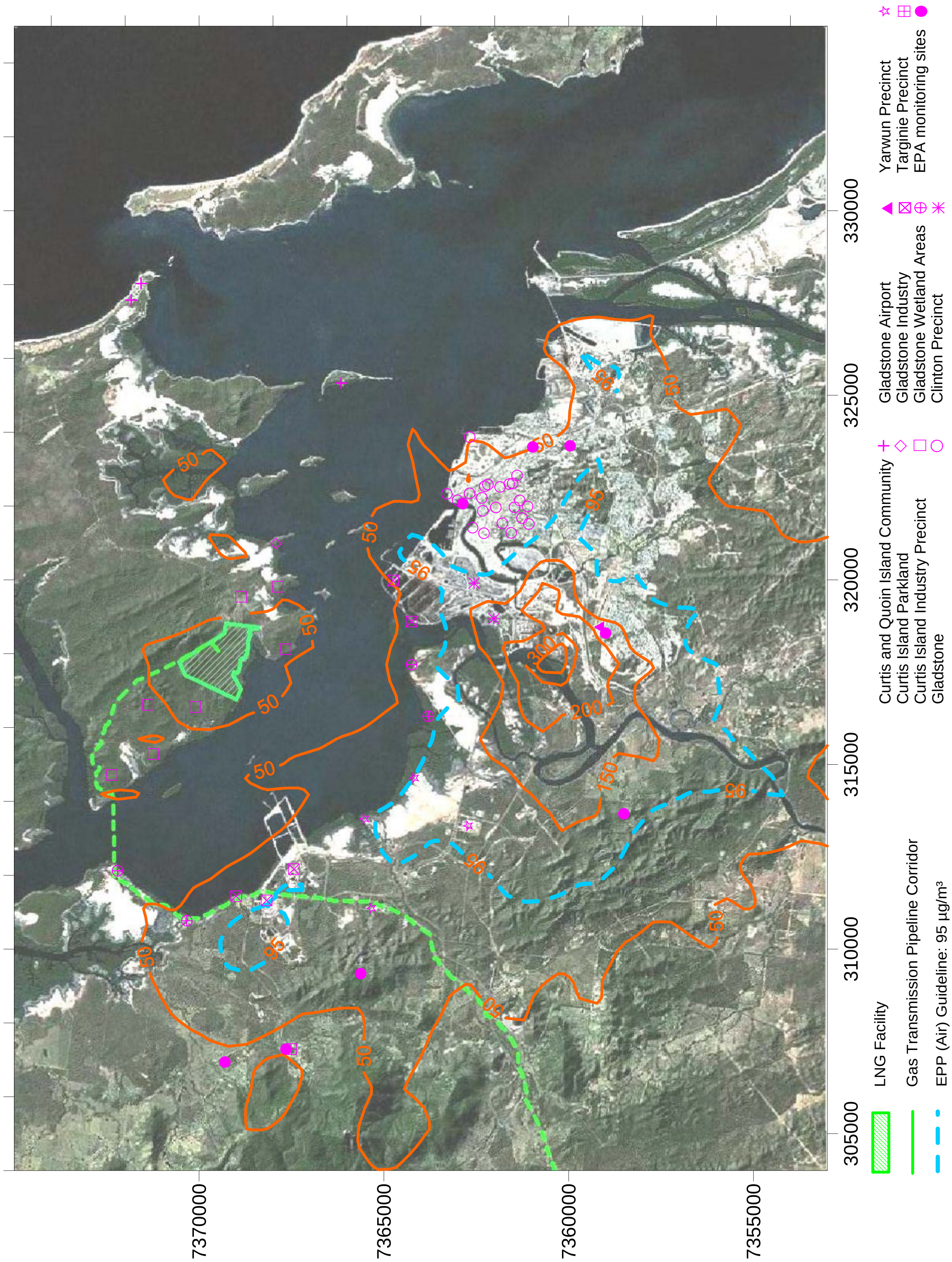
A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR OCP 3 MTPA
LNG / URS	Drawn: LF; Approved: JB; Date: 03-02-2009	Figure: **3-20**
	Job No: **4262 6220**; File: 42626220-g-628.srf	Rev B; A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

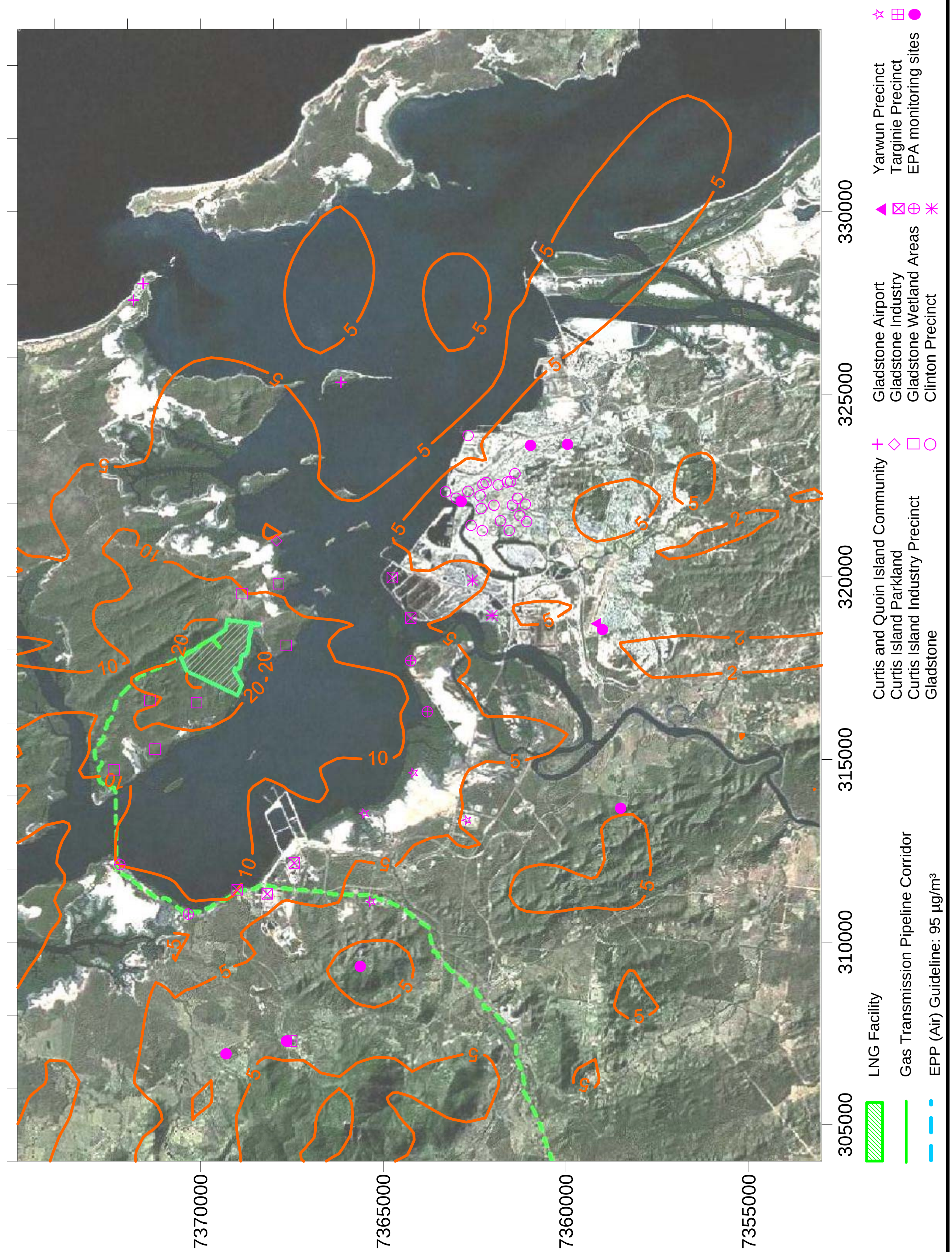
Client: LNG

URS

Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT

Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR OCP 3 MTPA

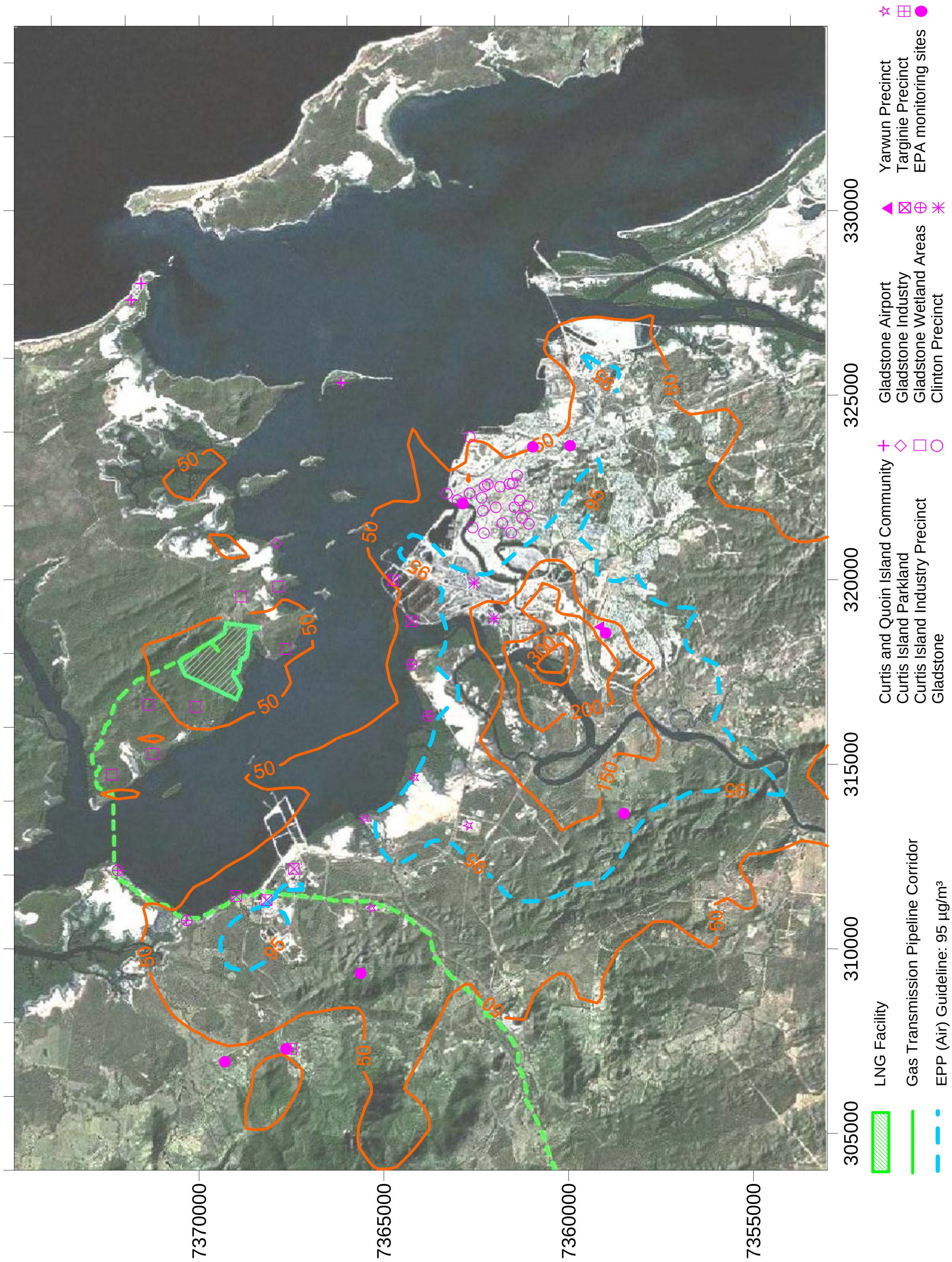
Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-21**	Rev B
Job No: **4262 6220**	File: 42626220-g-629.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

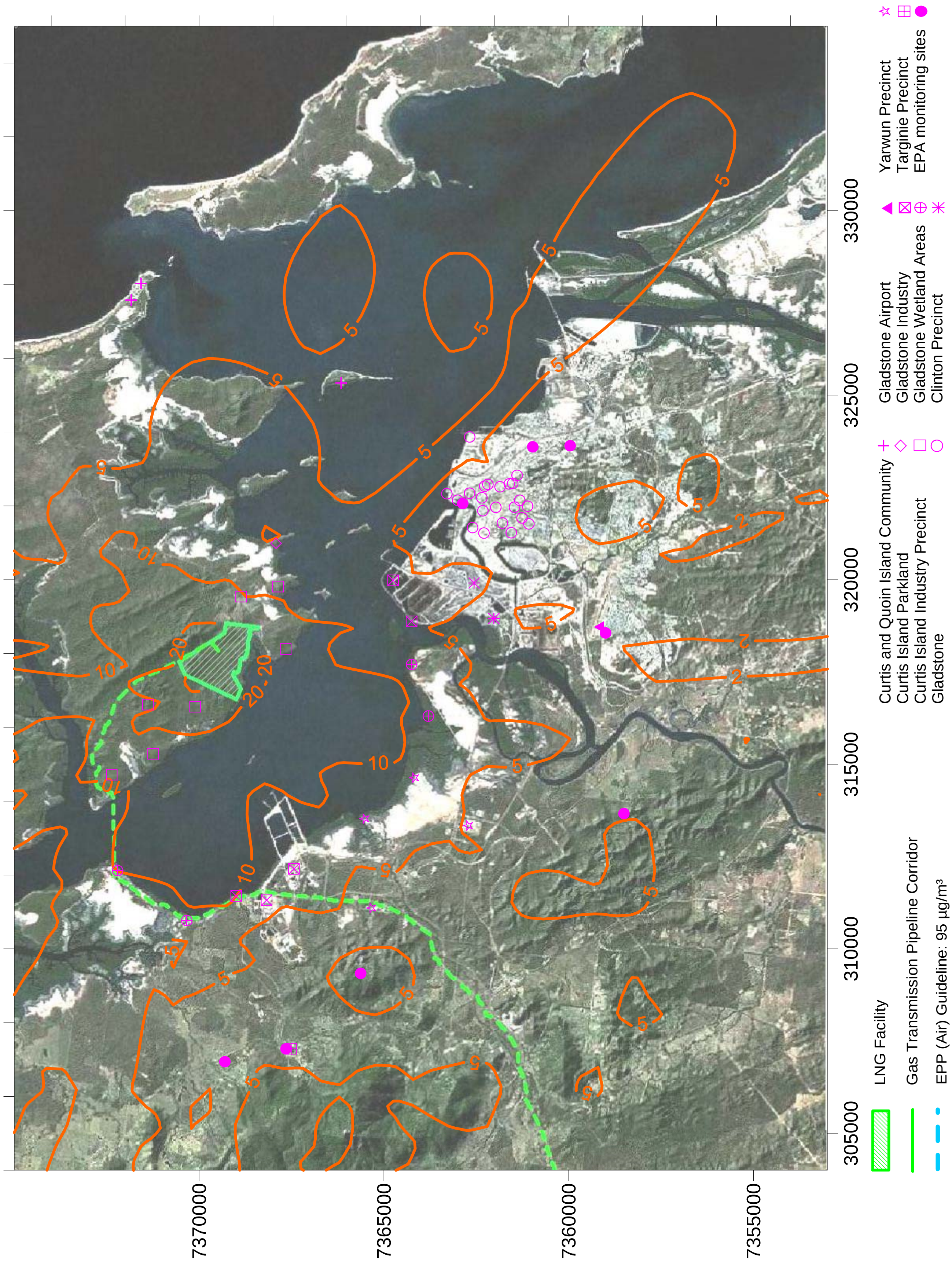
Client: LNG / URS	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: **MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO THE PLANT IN ISOLATION FOR OCP 10 MTPA**	
	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-22**	Rev B
	Job No: **4262 6220**	File: 42626220-g-630.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

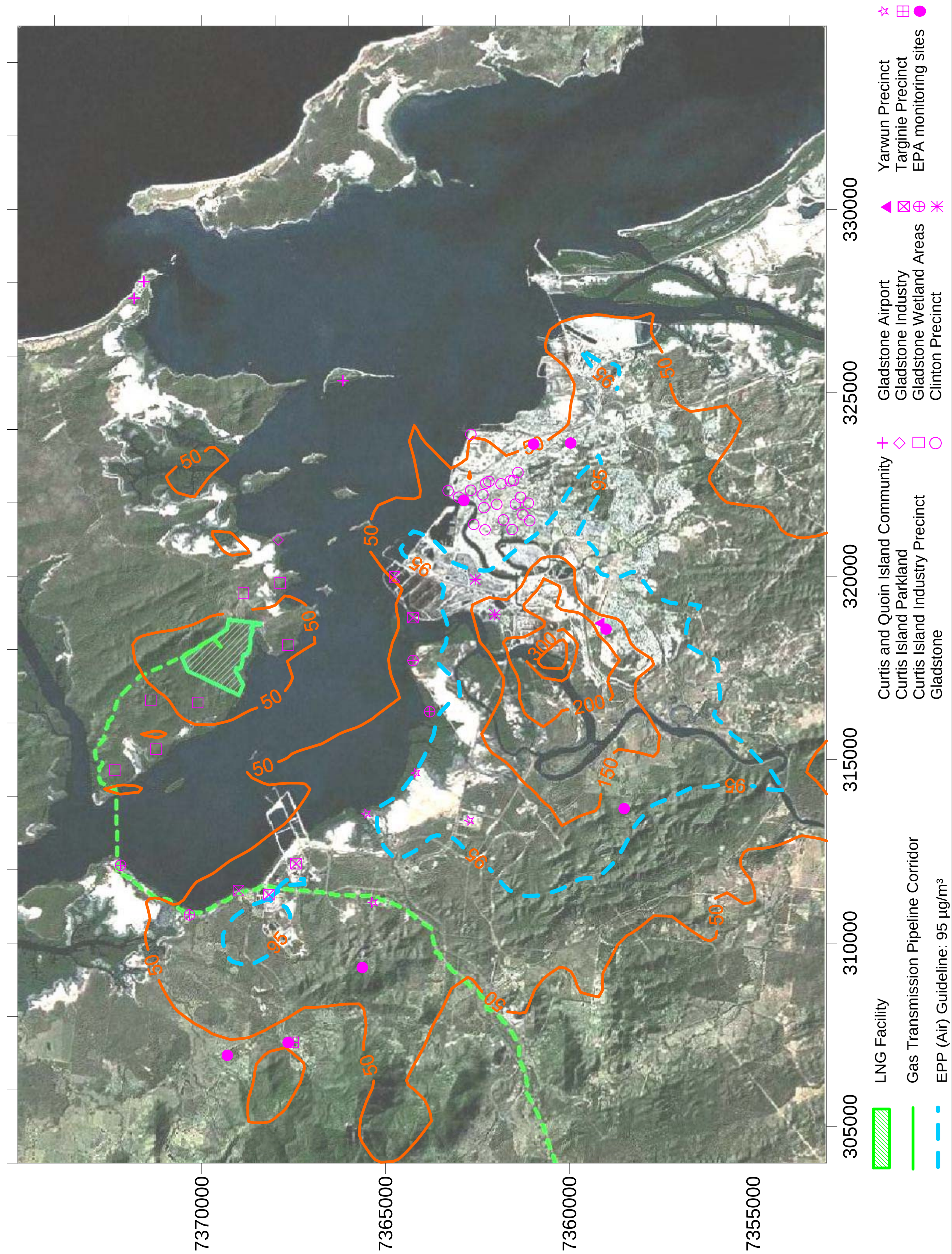
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR OCP 3 MTPA
LNG / URS	Drawn: LF — Approved: JB — Date: 03-02-2009	Figure: **3-21** — Rev B
	Job No: **4262 6220** — File: 42626220-g-629.srf	A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

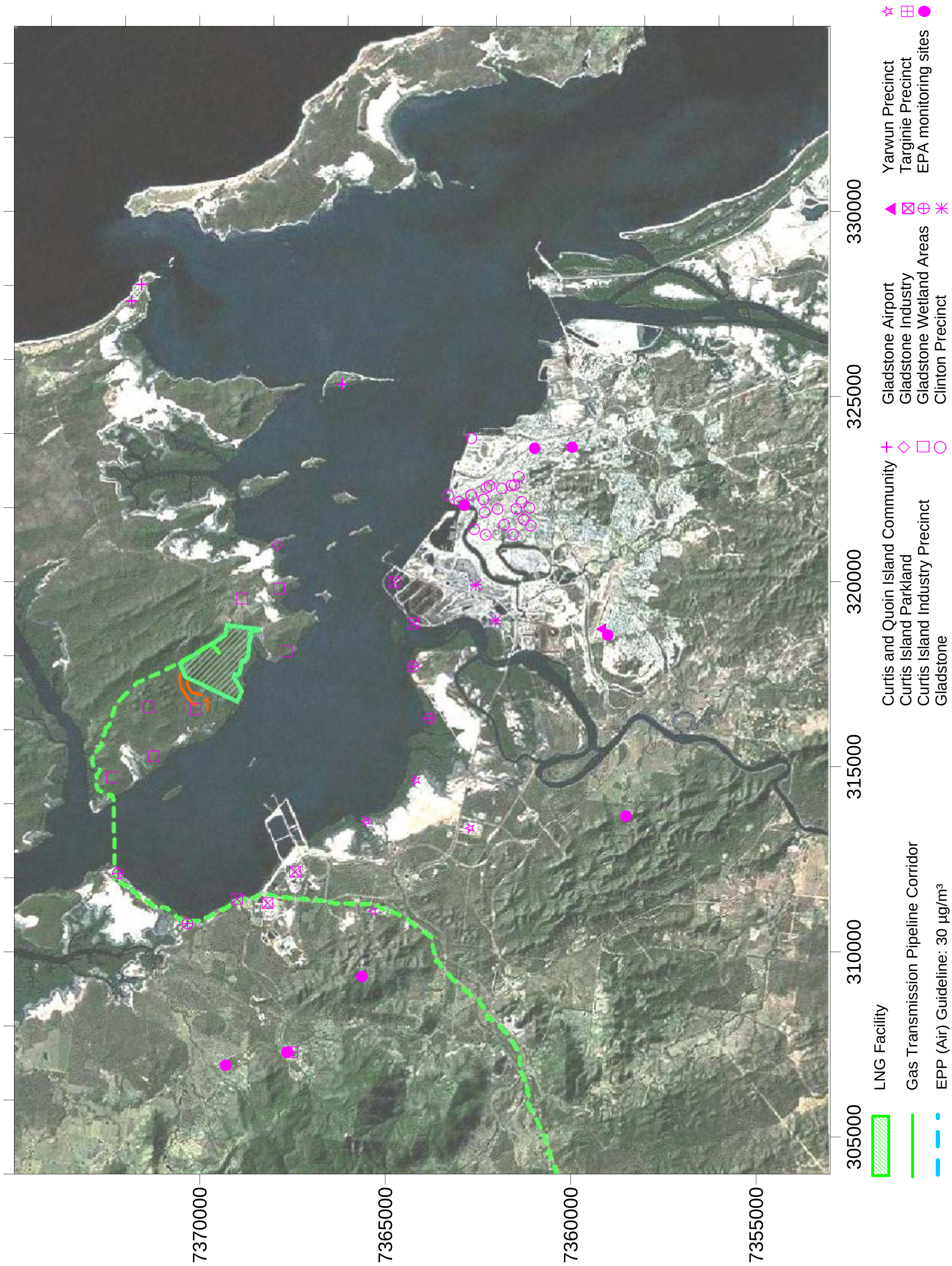
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO THE PLANT IN ISOLATION FOR OCP 10 MTPA
URS	Drawn: LF / Approved: JB / Date: 03-02-2009	Figure: **3-22** / Rev B
	Job No: **4262 6220** / File: 42626220-g-630.srf	A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

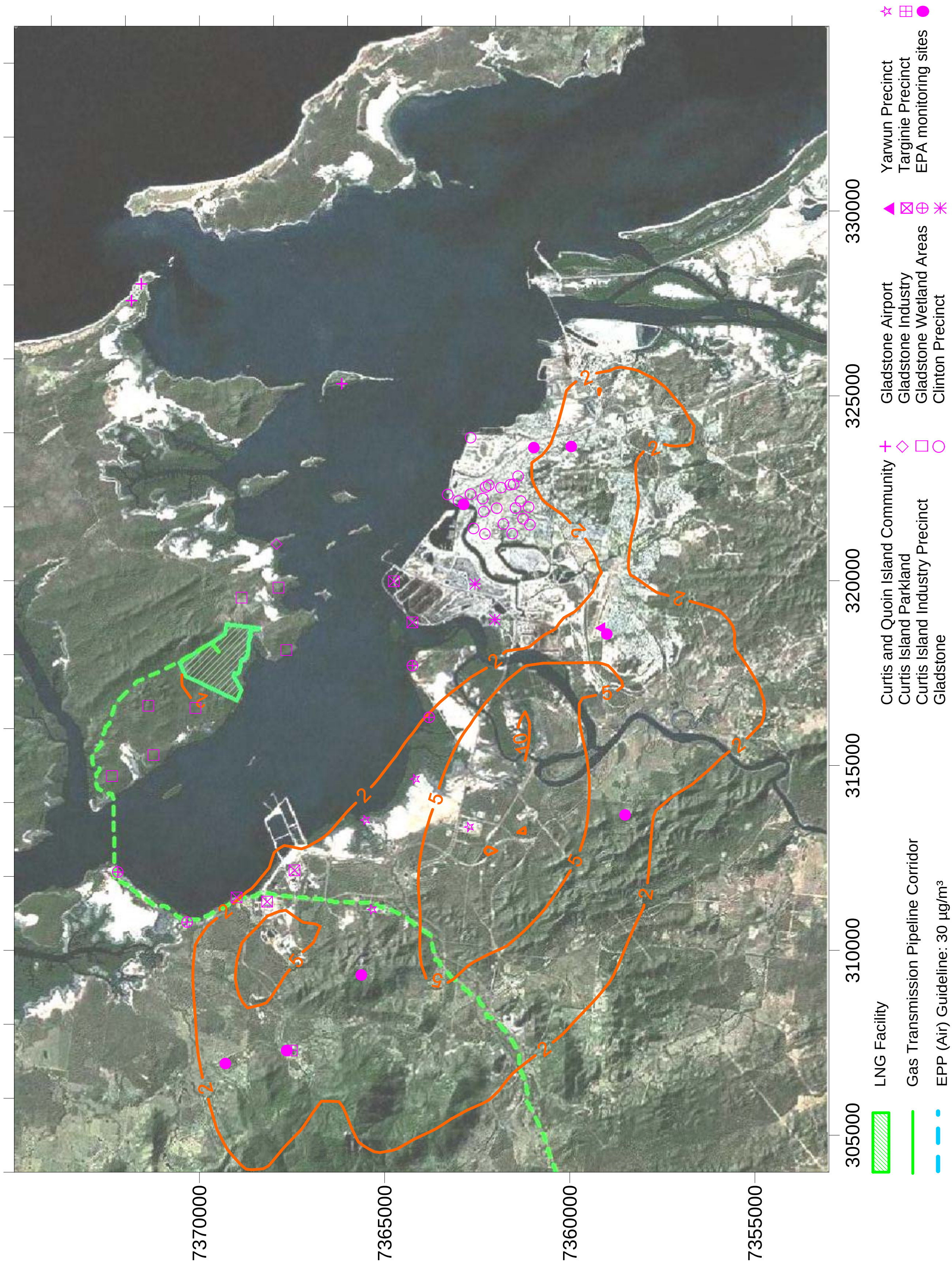
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: **MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO THE PLANT PLUS BACKGROUND FOR OCP 10 MTPA**	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-23**	Rev B
	Job No: **4262 6220**	File: 42626220-g-631.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

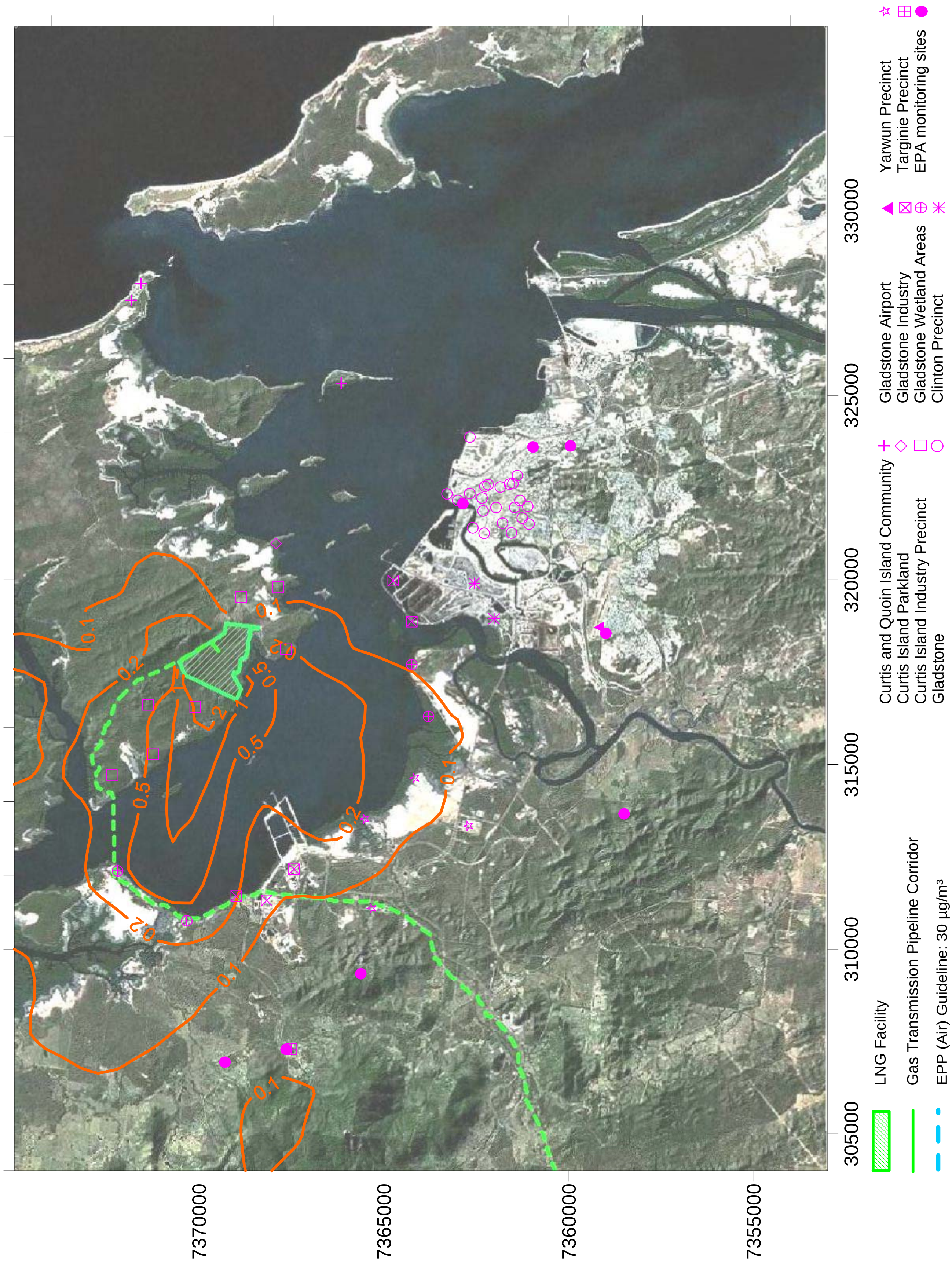
Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR OCP 3 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-24**	Rev B
	Job No: **4262 6220**	File: 42626220-g-632.srf			A4



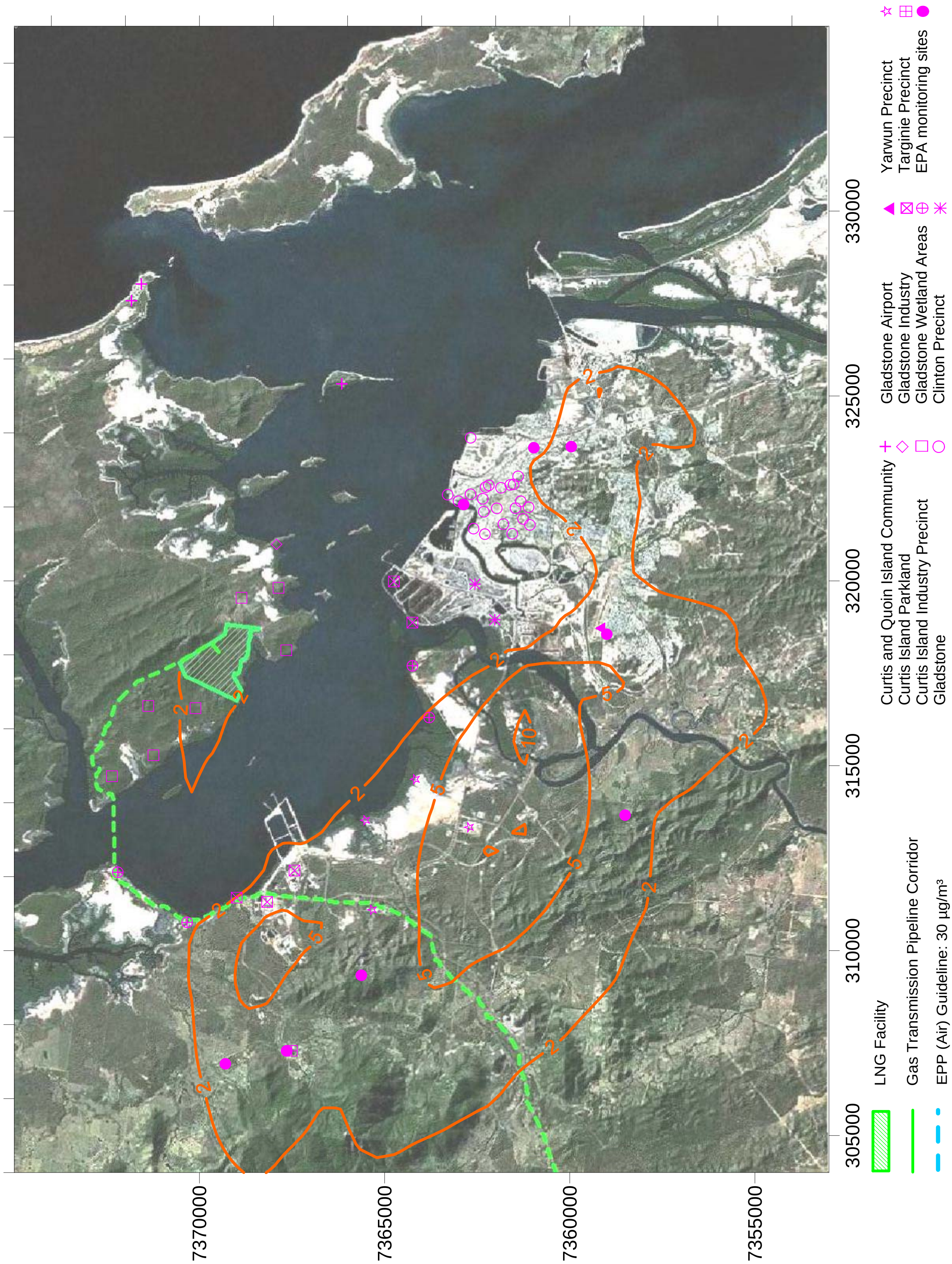
Datum: MGA94, Zone 55

Client:	Project:	Title:
LNG / URS	GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	**ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR OCP 3 MTPA**
	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-25**	Rev B
	Job No: **4262 6220**	File: 42626220-g-633.srf	A4



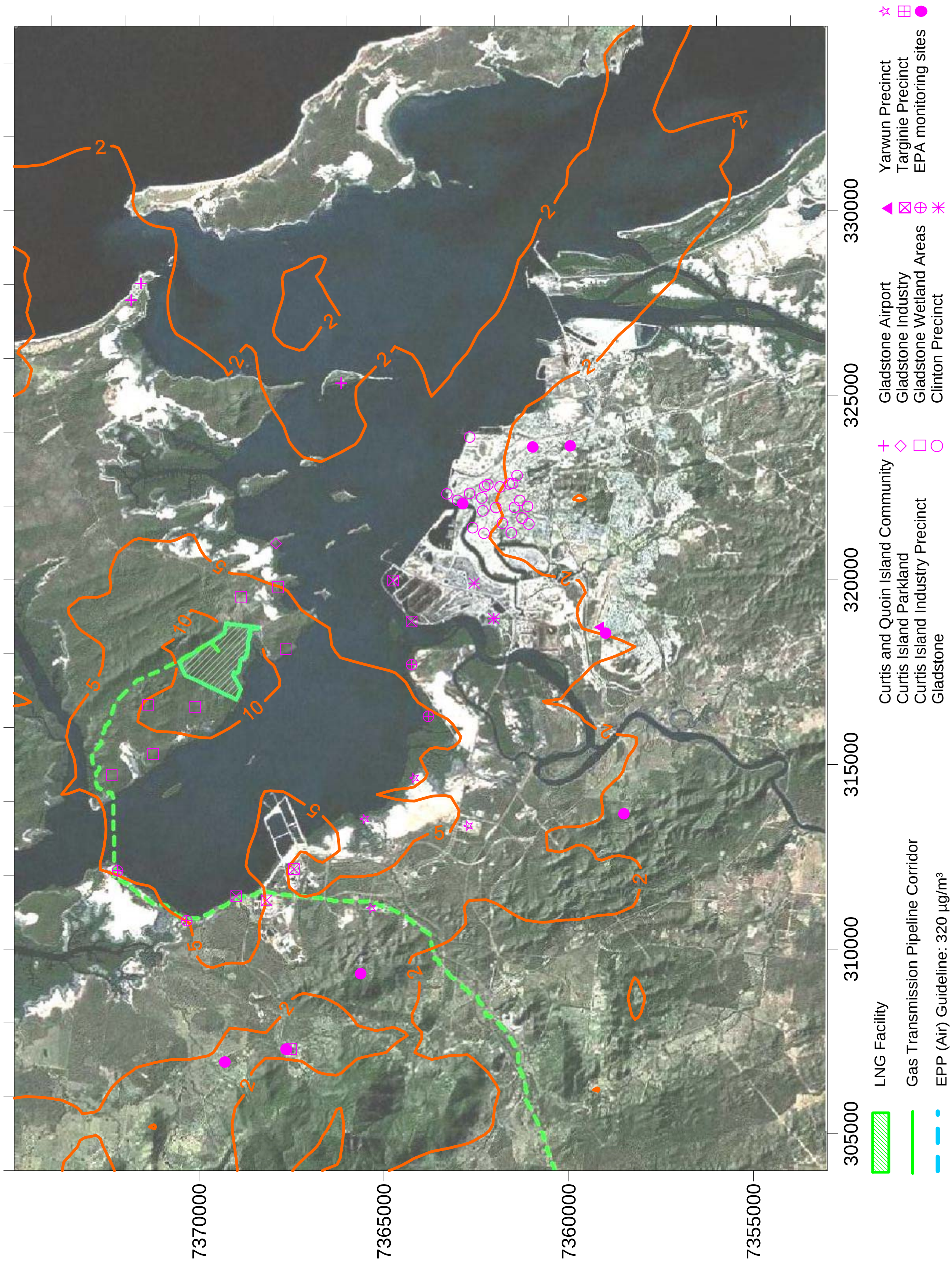
Datum: MGA94, Zone 55

Client: LNG / URS	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT		Title: **ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR OCP 10 MTPA**
	Drawn: LF	Approved: JB	Date: 03-02-2009
	Job No: **4262 6220**	File: 42626220-g-634.srf	Figure: **3-26** — Rev B — A4



Datum: MGA94, Zone 55

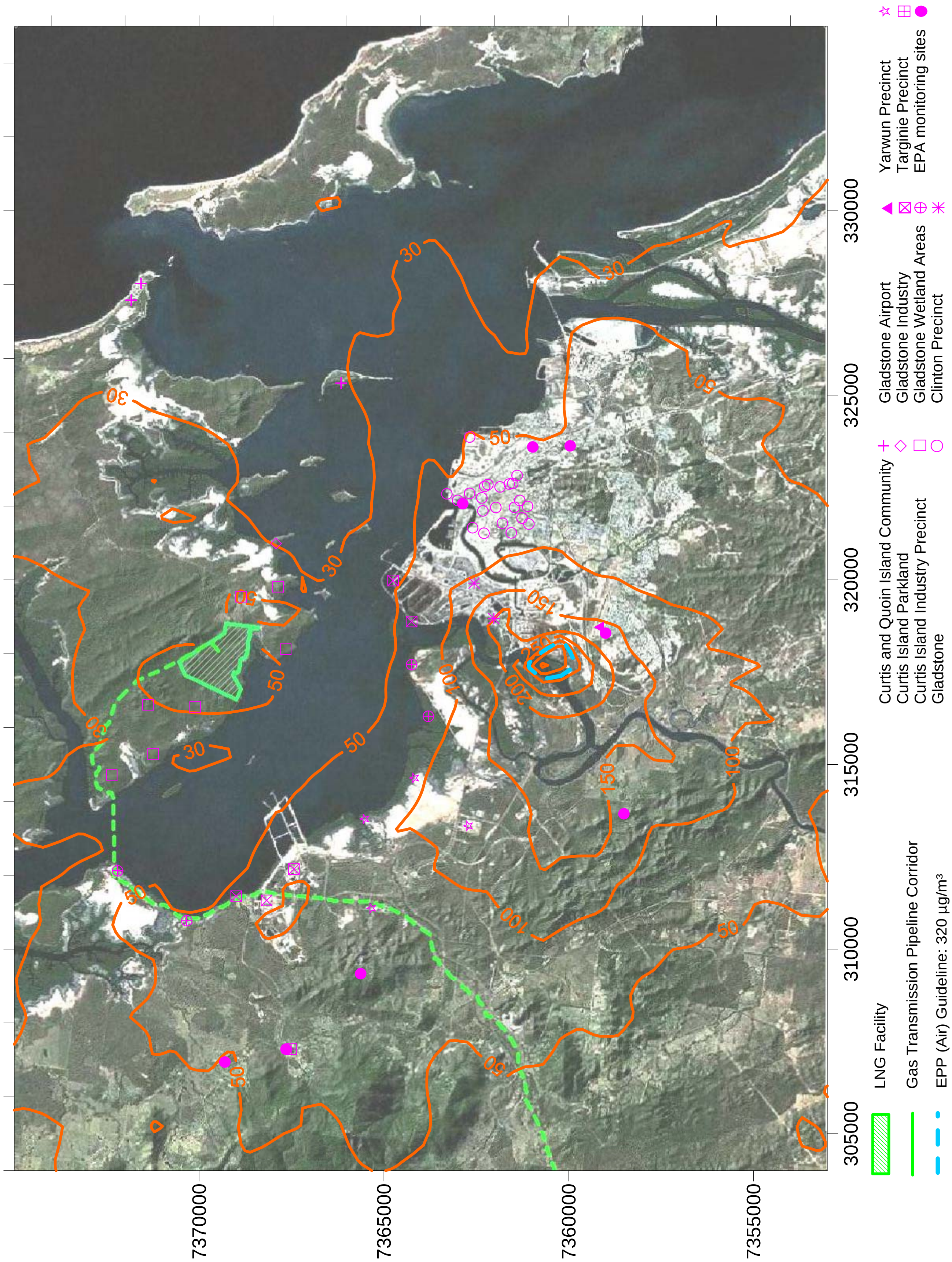
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	Title: ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR OCP 10 MTPA
LNG / URS	Drawn: LF — Approved: JB — Date: 03-02-2009	Figure: **3-27** — Rev B
	Job No: **4262 6220** — File: 42626220-g-635.srf	A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

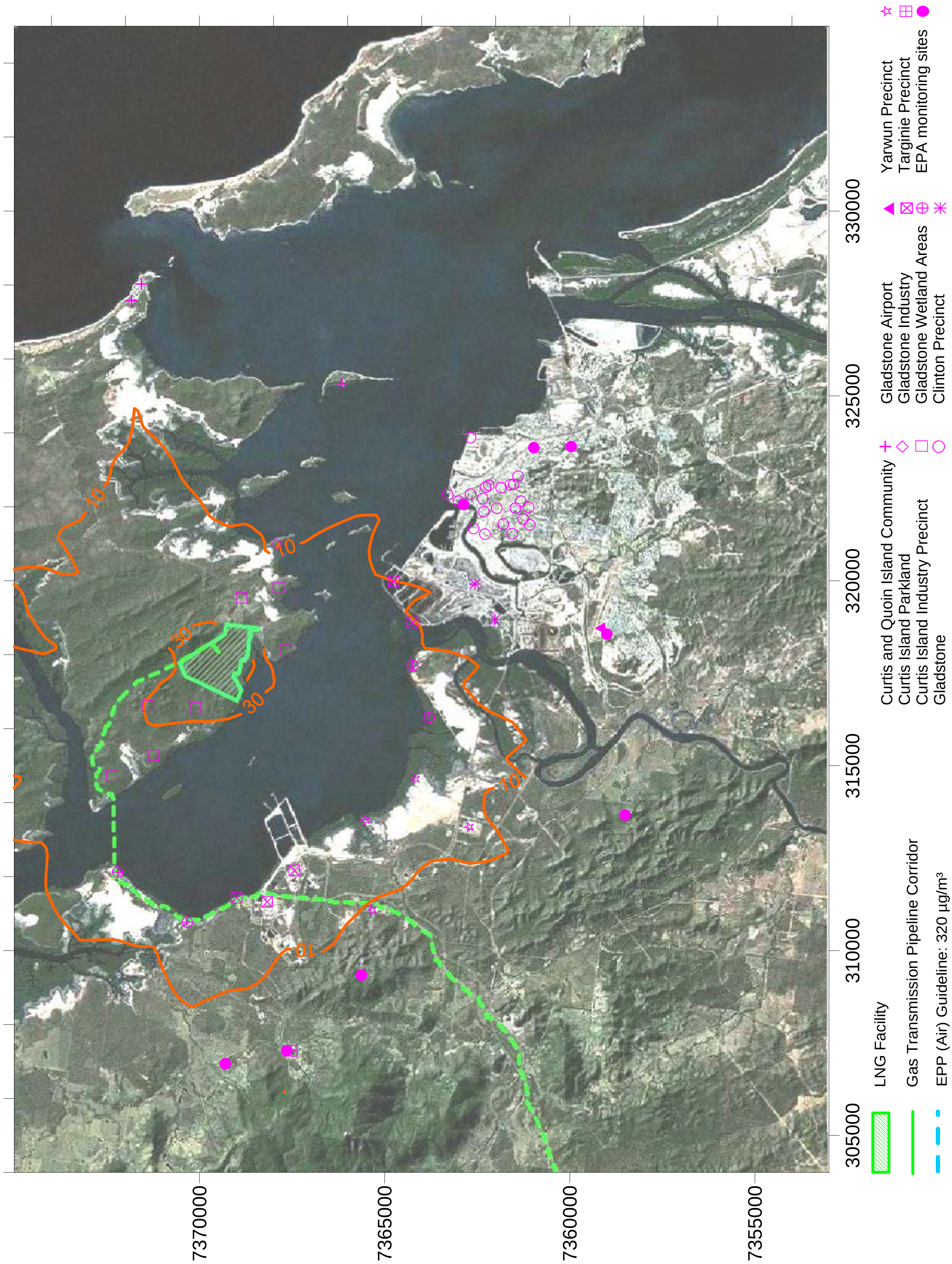
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 3 MTPA
URS	Drawn: LF / Approved: JB / Date: 03-02-2009	Figure: 3-28 / Rev B
	Job No: **4262 6220** / File: 42626220-g-636.srf	A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

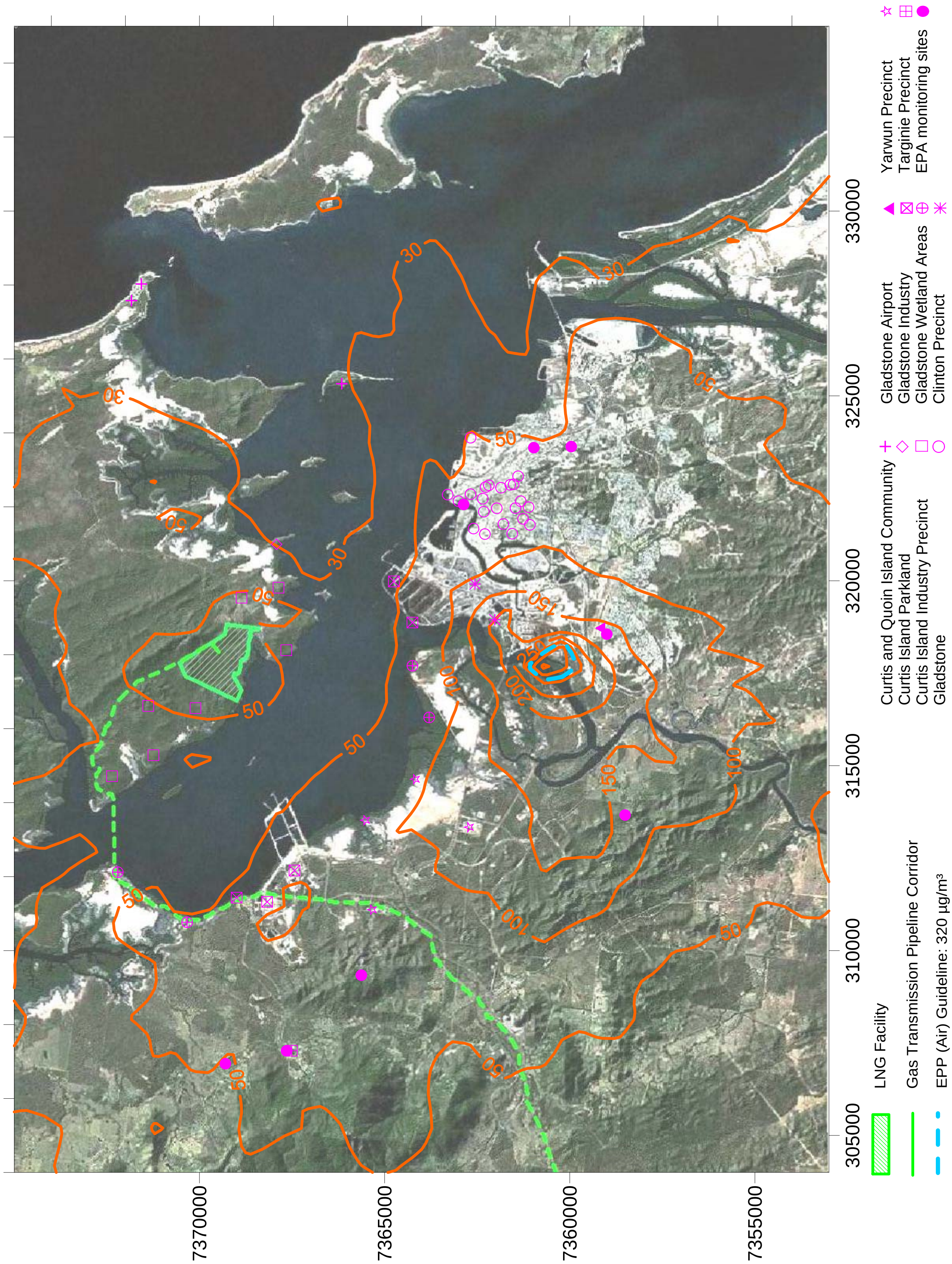
Client: LNG / URS	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR C3MR 3 MTPA	
	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-29**	Rev B
	Job No: **4262 6220**	File: 42626220-g-637.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

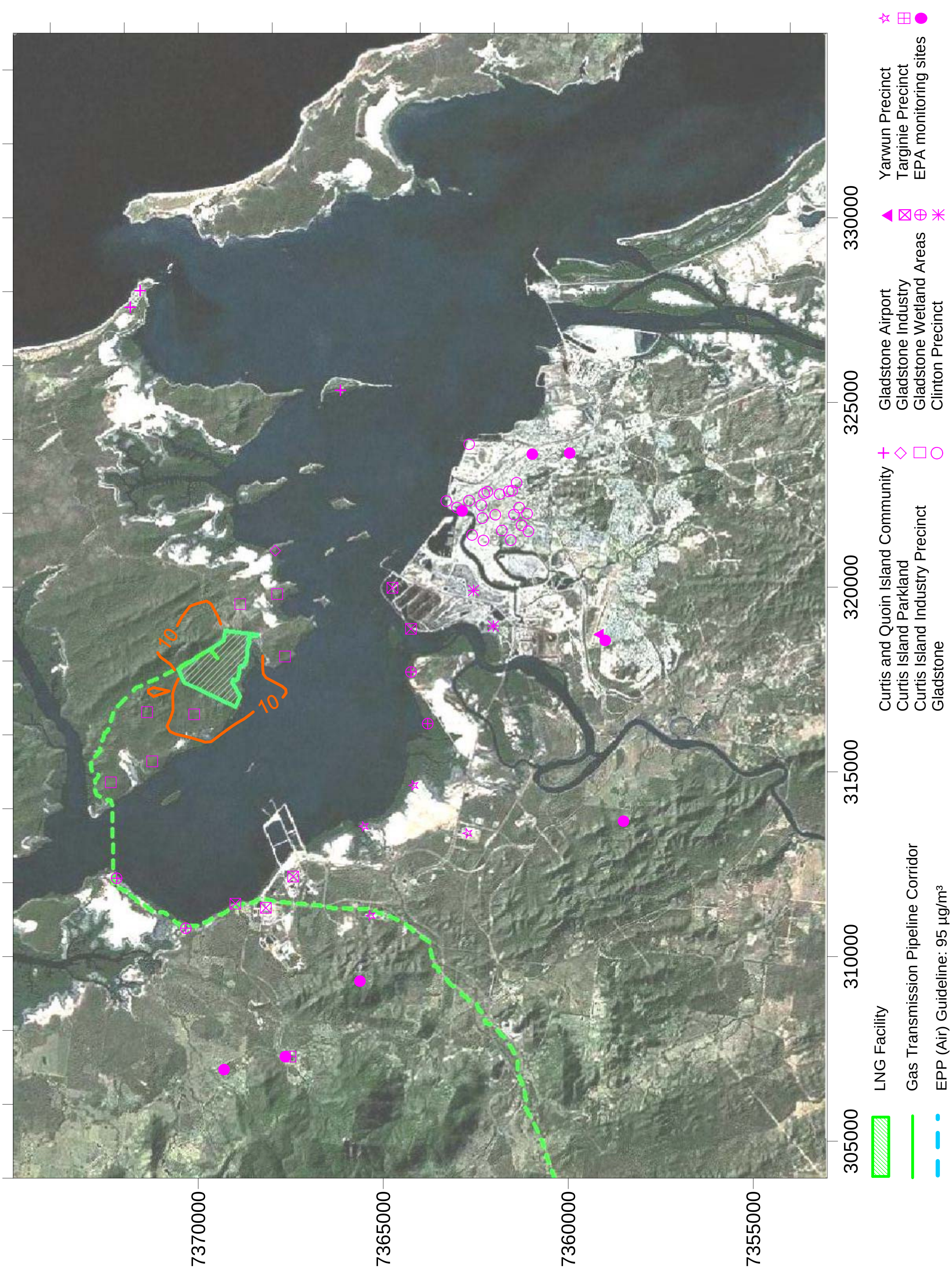
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 10 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-30**	Rev B
	Job No: **4262 6220**	File: 42626220-g-638.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

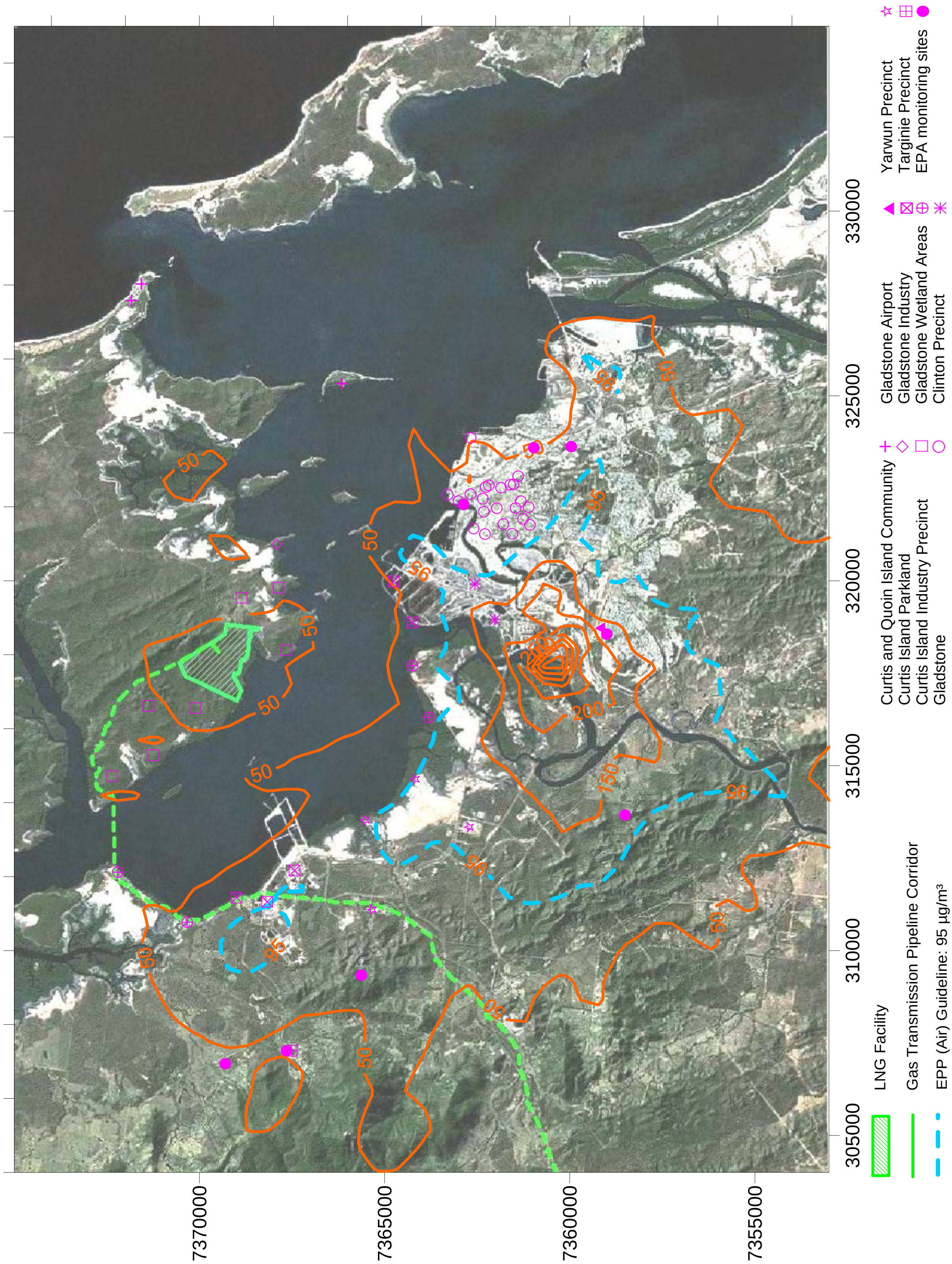
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT	Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR C3MR 10 MTPA
LNG	Drawn: LF / Approved: JB / Date: 03-02-2009	Figure: **3-31**
URS	Job No: **4262 6220** / File: 42626220-g-639.srf	Rev B / A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

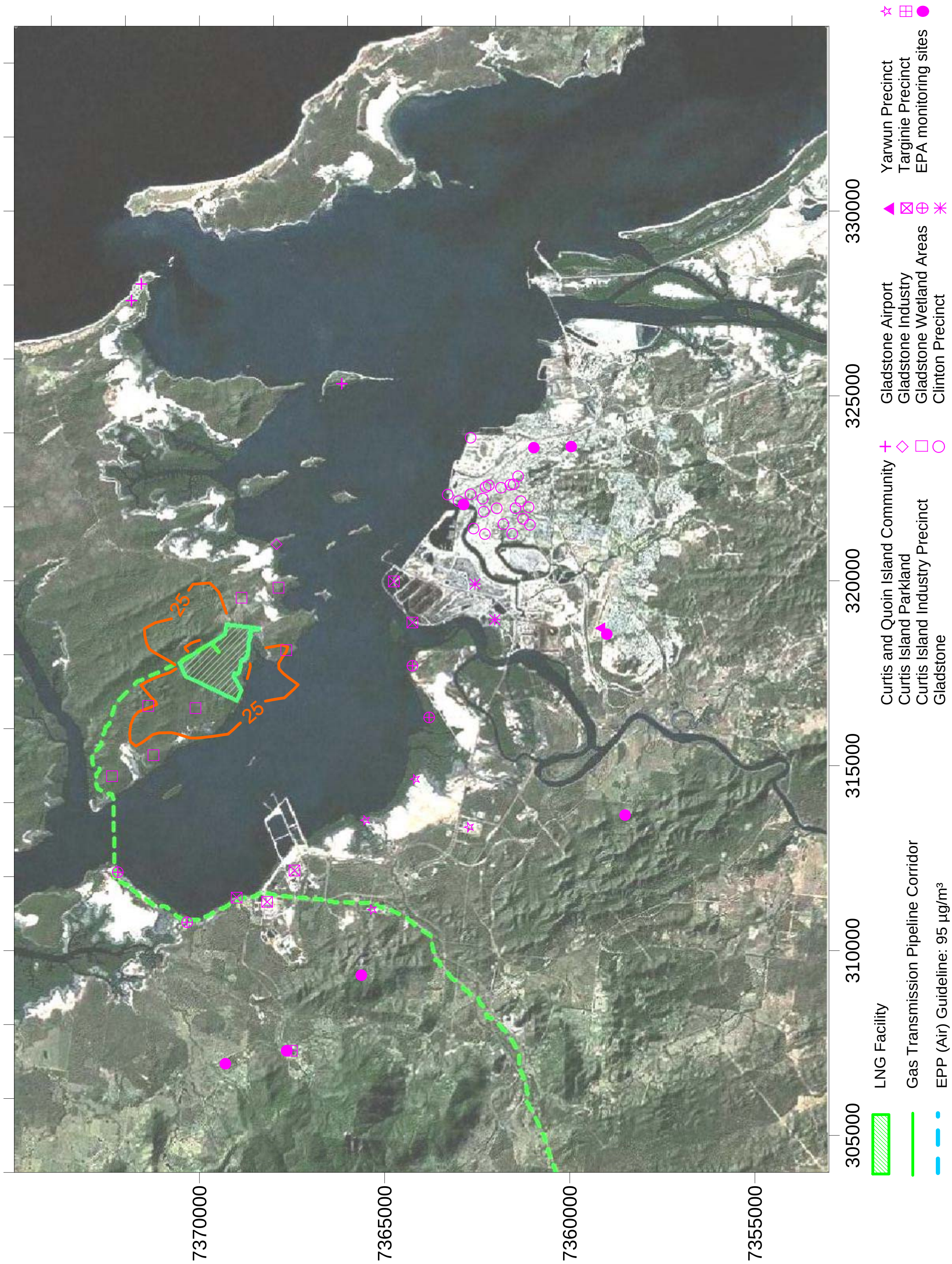
Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: **MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 3 MTPA**	
LNG					
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-32**	Rev B
	Job No: **4262 6220**	File: 42626220-g-640.srf			A4



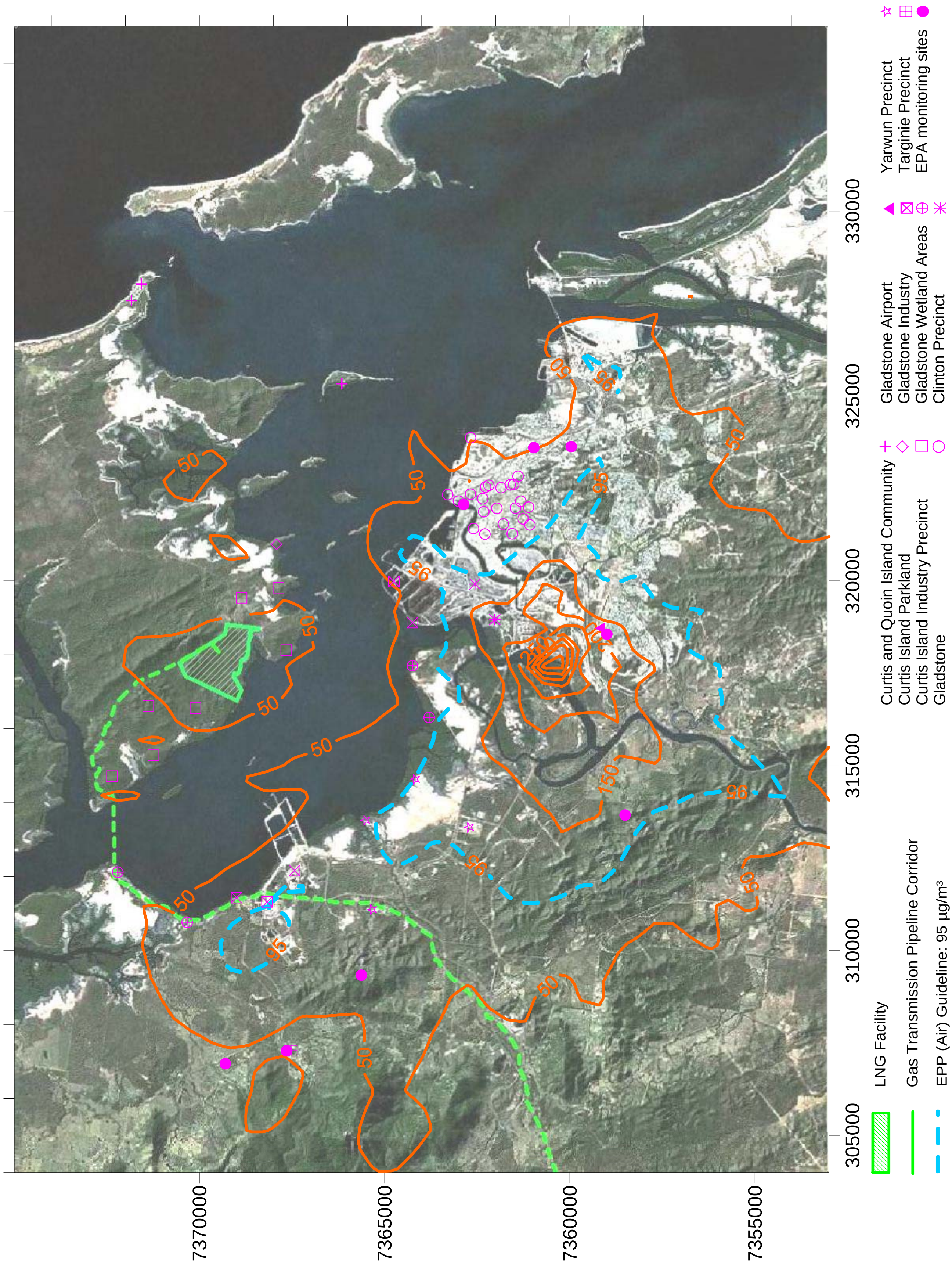
Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR C3MR 3 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-33**	Rev B
	Job No: **4262 6220**	File: 42626220-g-641.srf			A4



Datum: MGA94, Zone 55

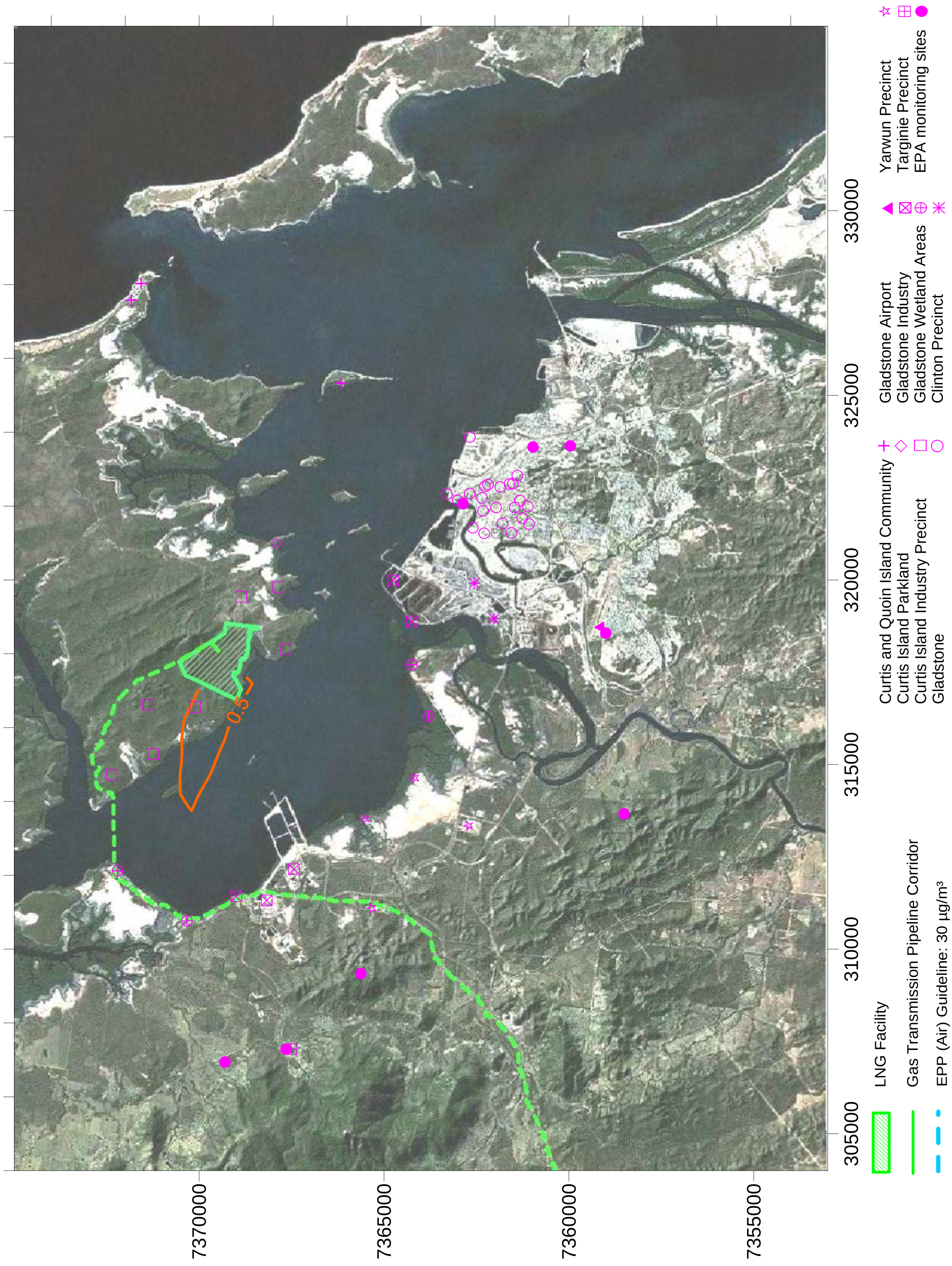
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 10 MTPA	
LNG / URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-34**	Rev B
	Job No: **4262 6220**	File: 42626220-g-642.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR C3MR 10 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-35**	Rev B
	Job No: **4262 6220**	File: 42626220-g-643.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

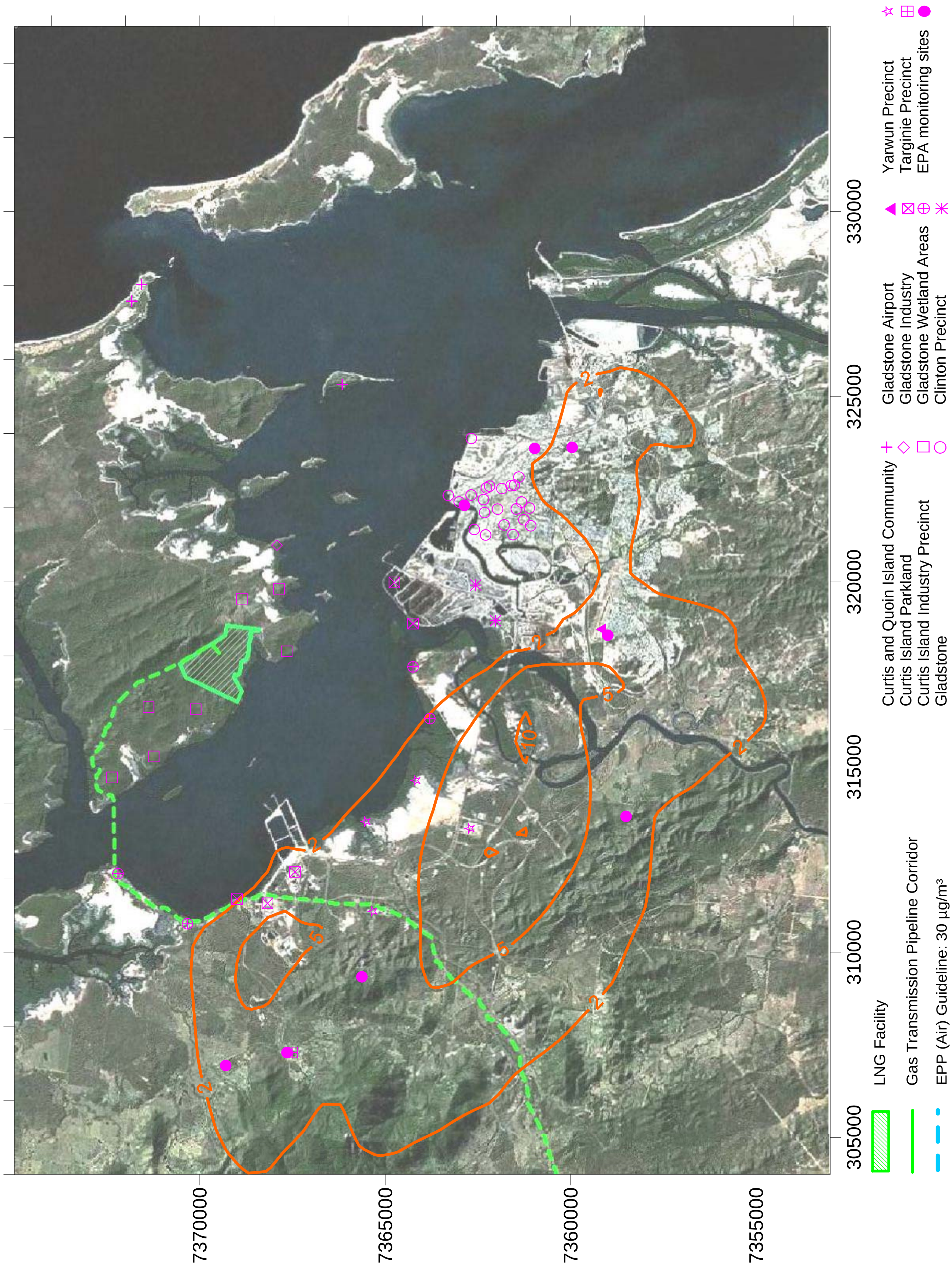
Client:

URS

Project:
GLADSTONE LNG PROJECT
AIR QUALITY IMPACT ASSESSMENT

Title:
ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 3 MTPA

Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-36**	Rev B
Job No: **4262 6220**	File: 42626220-g-644.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

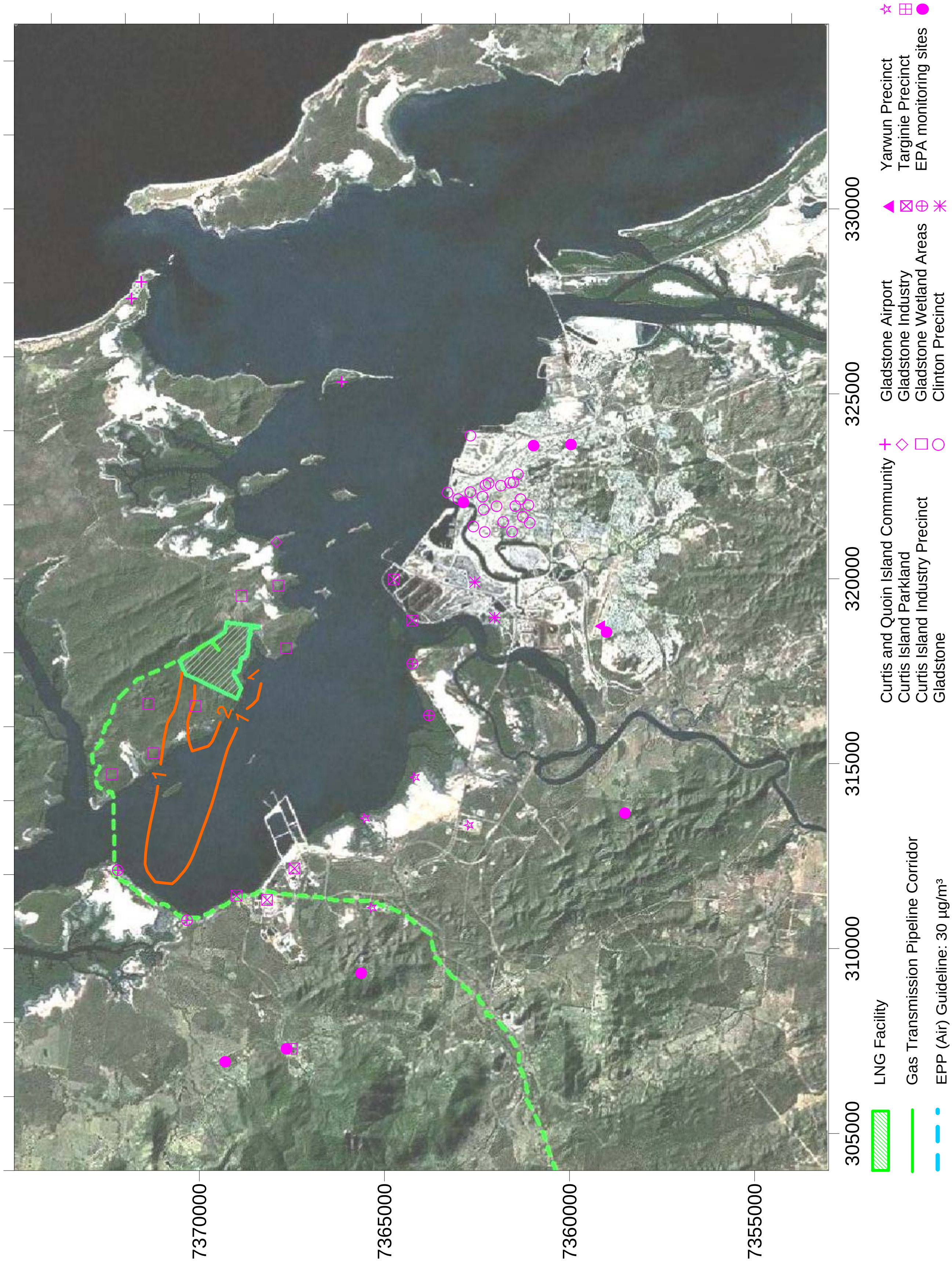
Datum: MGA94, Zone 55

Client: LNG URS

Project: GLADSTONE LNG PROJECT
AIR QUALITY IMPACT ASSESSMENT

Title: **ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR C3MR 3 MTPA**

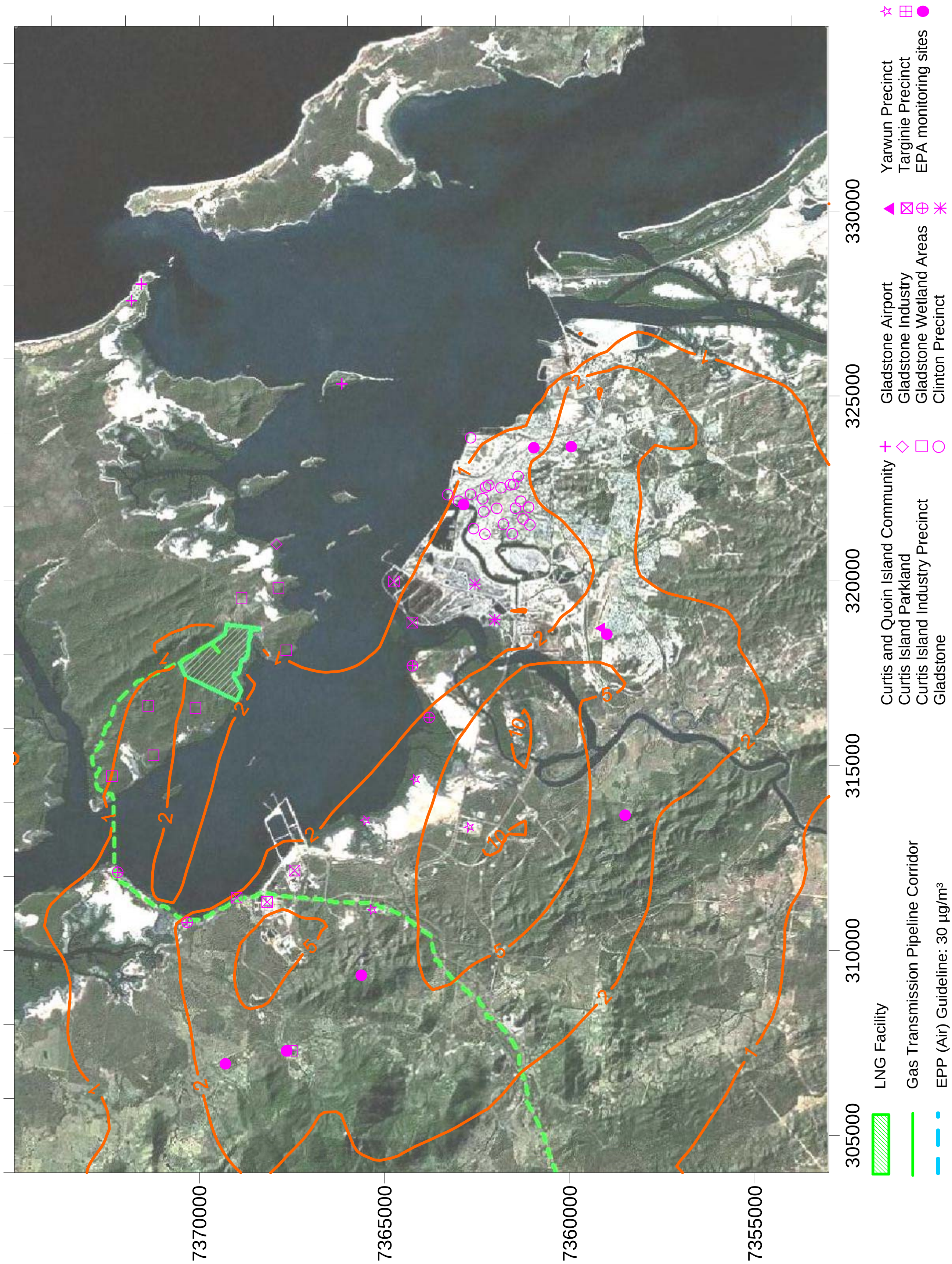
Drawn: LF	Approved: JB	Date: 03-02-2009	Rev B
Job No: **4262 6220**	File: 42626220-g-645.srf	Figure: **3-37**	**A4**



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

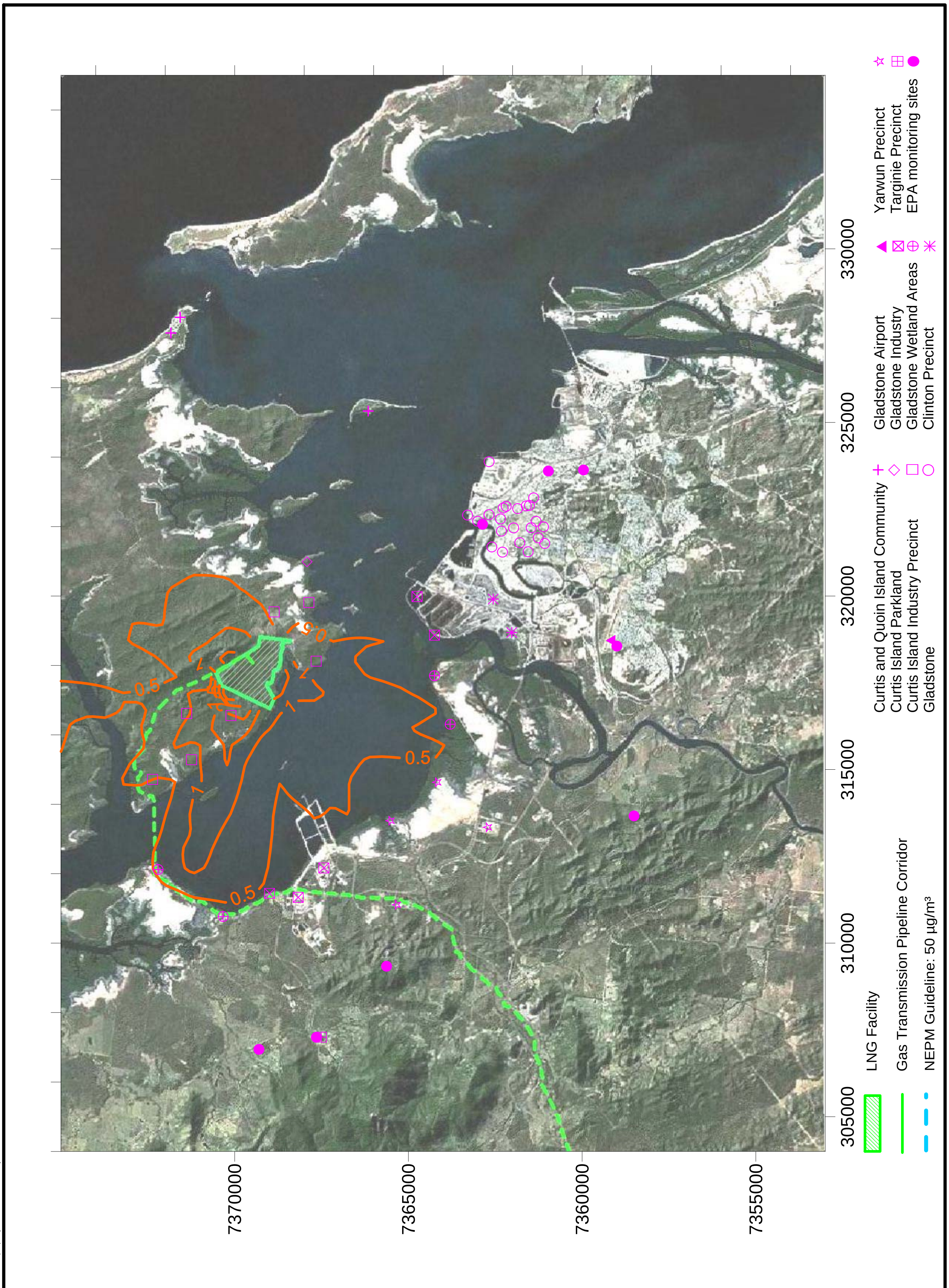
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 10 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: 3-38	Rev B
	Job No: **4262 6220**	File: 42626220-g-646.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

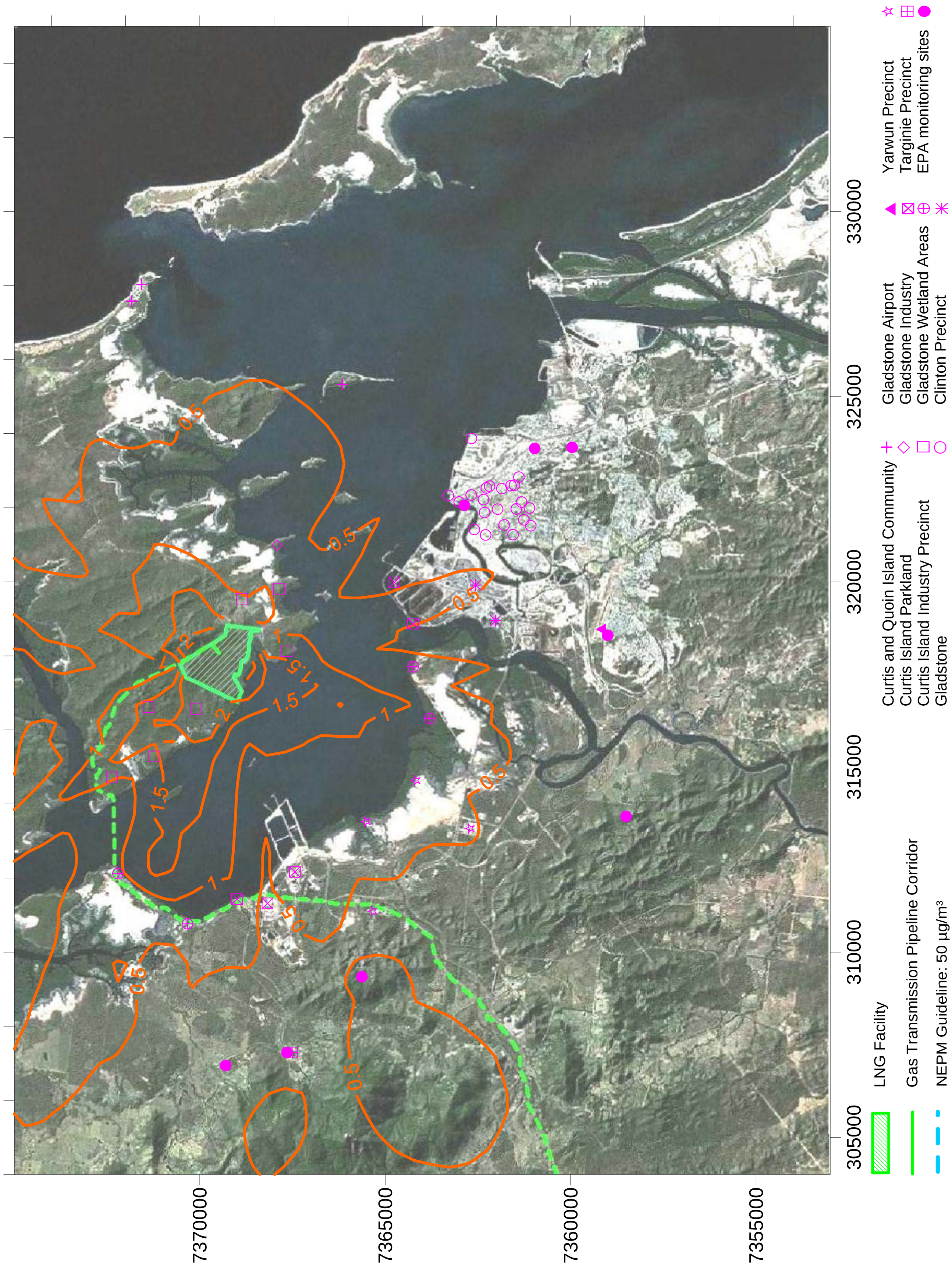
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: ANNUAL AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR C3MR 10 MTPA	
LNG / URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: 3-39	Rev B
	Job No: 4262 6220	File: 42626220-g-647.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

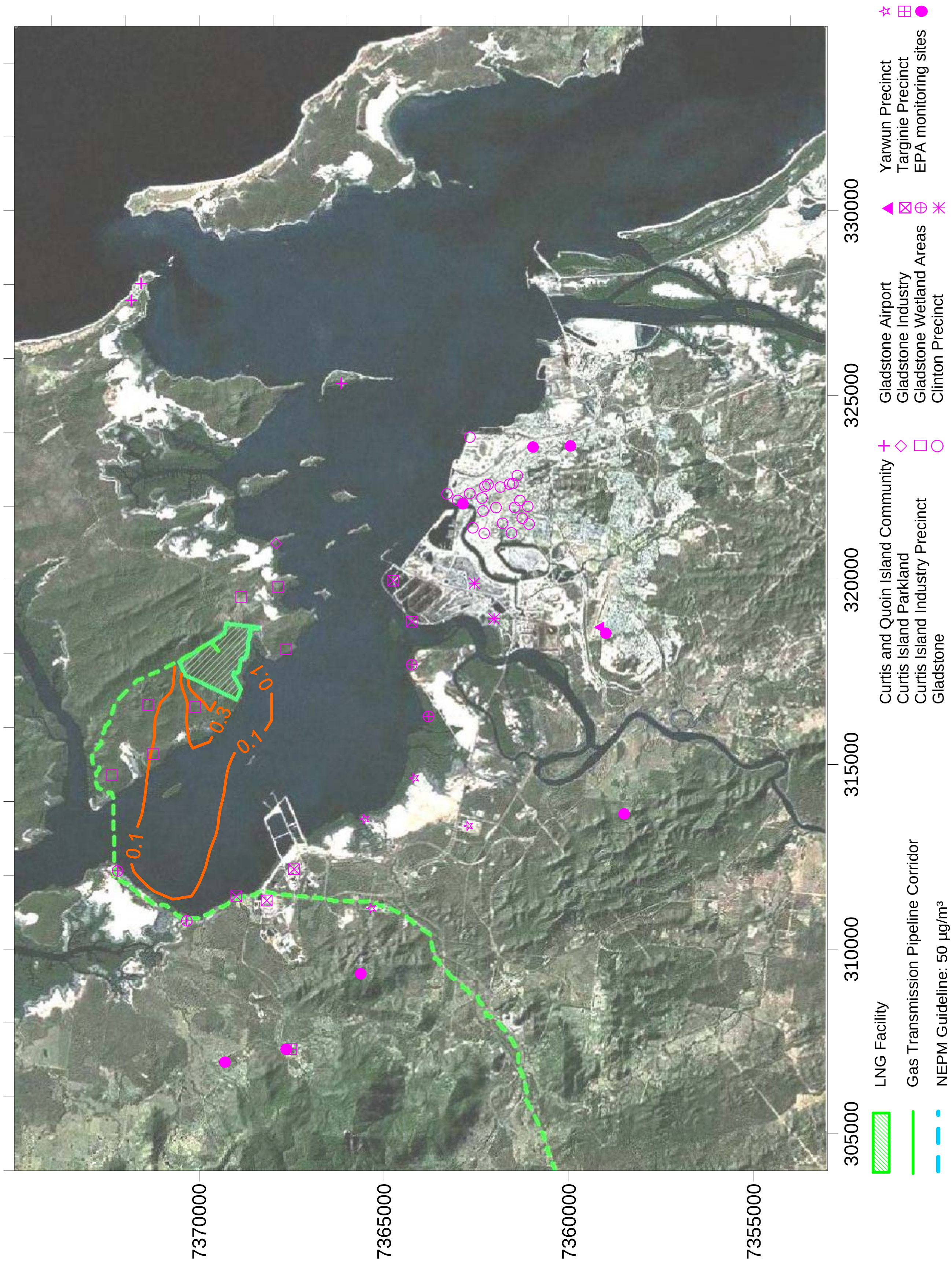
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: MAXIMUM 24 HOUR AVERAGE CONCENTRATION OF PM10 (µg/m³) DUE TO PLANT IN ISOLATION FOR OCP 10 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-40**	Rev B
	Job No: **4262 6220**	File: 42626220-g-648.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

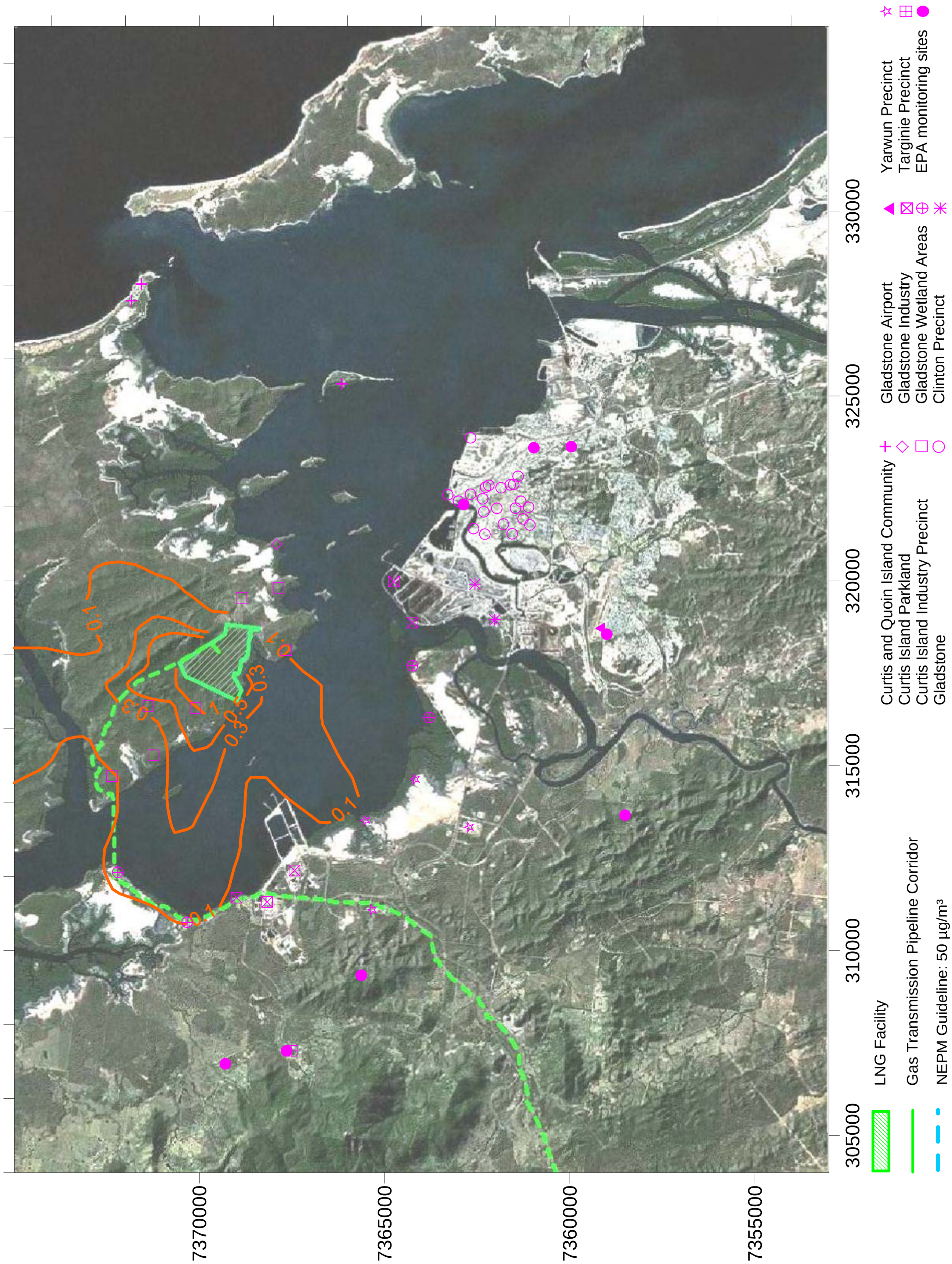
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT		Title: MAXIMUM 24-HOUR AVERAGE CONCENTRATION OF PM10 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 10 MTPA	
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Rev B
	Job No: **4262 6220**	File: 42626220-g-649.srf	Figure: **3-41**	A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

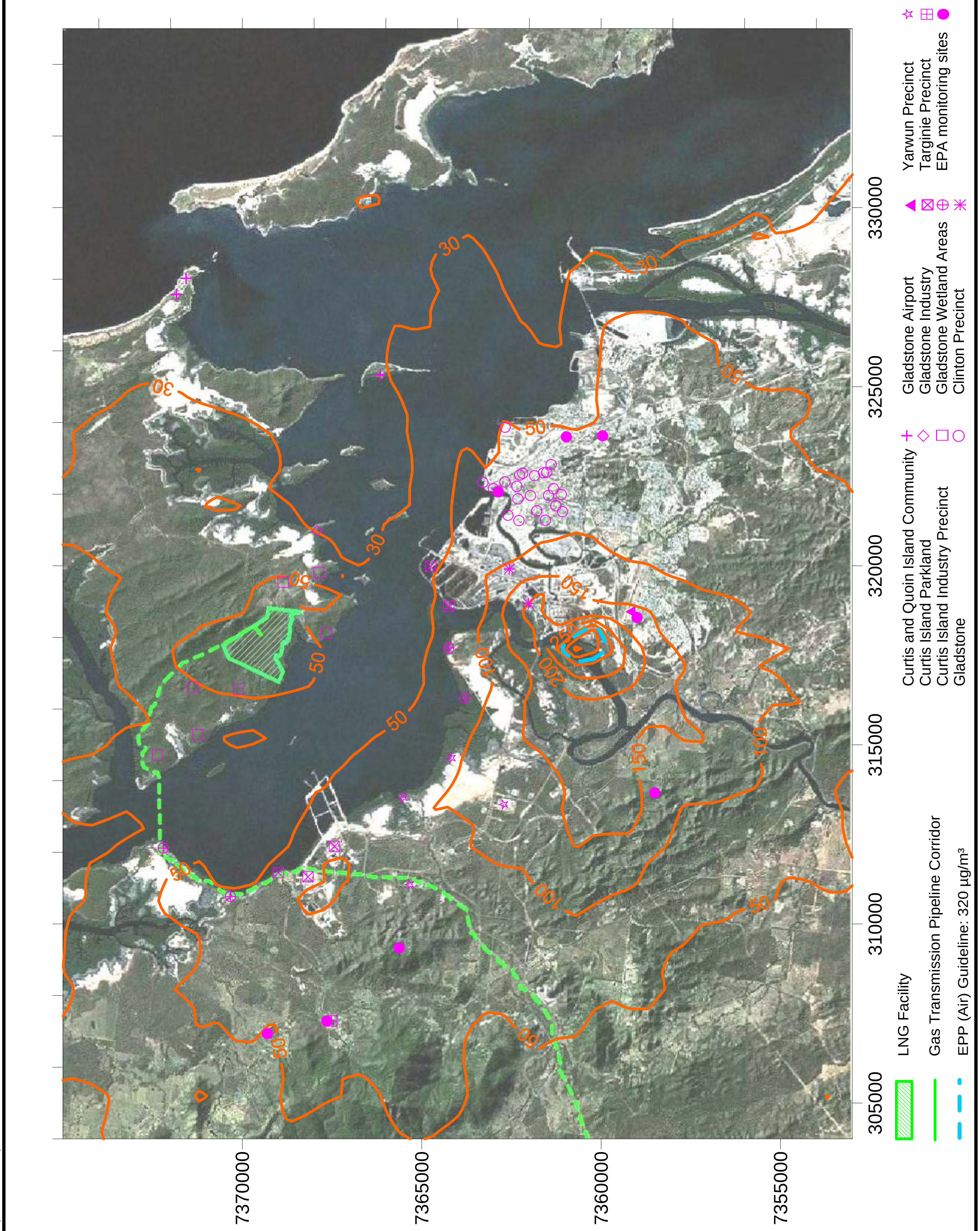
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: ANNUAL AVERAGE CONCENTRATION OF PM10 (µg/m³) DUE TO PLANT IN ISOLATION FOR OCP 10 MTPA	
LNG / URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-42**	Rev B
	Job No: **4262 6220**	File: 42626220-g-650.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

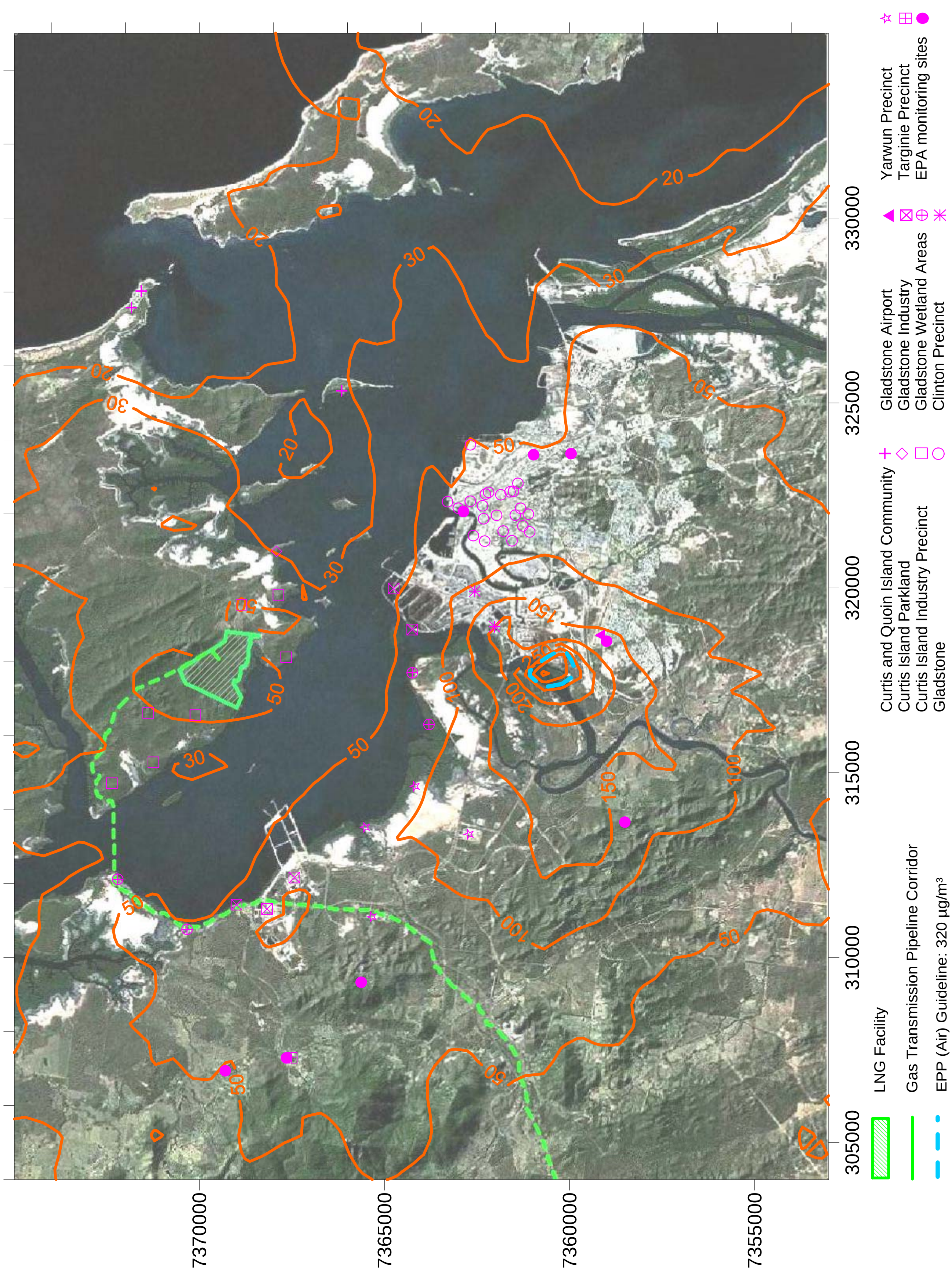
Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: ANNUAL AVERAGE CONCENTRATION OF PM10 (µg/m³) DUE TO PLANT IN ISOLATION FOR C3MR 10 MTPA	
LNG / URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: 3-43	Rev B
	Job No: **4262 6220**	File: 42626220-g-651.srf			A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

Client: LNG / URS	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT		Title: **99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR C3MR 10 MTPA WITH UPSET CONDITIONS**
	Drawn: LF	Approved: JB	Date: 03-02-2009
	Job No: **4262 6220**	File: 42626220-g-652.srf	Figure: **3-44** Rev B A4



Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Datum: MGA94, Zone 55

Client:	Project: GLADSTONE LNG PROJECT AIR QUALITY IMPACT ASSESSMENT			Title: 99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO2 (µg/m³) DUE TO PLANT PLUS BACKGROUND FOR OCP 10 MTPA WITH UPSET CONDITIONS
URS	Drawn: LF	Approved: JB	Date: 03-02-2009	Figure: **3-45** Rev B
	Job No: **4262 6220**	File: 42626220-g-653.srf		A4