Appendix M

Air Quality and Greenhouse Gas Assessment

REPORT

Air and Greenhouse Gas Assessment

Prepared for

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1.1 Introduction

The potential air quality and greenhouse gas impacts from the Refinery are presented in this appendix. These have been assessed through the use of dispersion modelling, with results presented for the Refinery in isolation as well as the cumulative impacts of the Refinery and background industrial sources.

A summary of the climate in the Gladstone region is presented, addressing the typical temperatures. rainfall, evaporation, relative humidity, winds and extreme weather events that are measured in the region. Derived parameters such as atmospheric stability and temperature inversions are summarised for the project location.

Air quality impacts have been addressed by evaluating the current air quality in the Gladstone airshed due to existing industrial sources. The expected emissions of pollutants from the Refinery site are quantified, and discussed in relation to relevant emission standards and best practice design.

Greenhouse gas impacts have been evaluated based on the expected usage of electricity, petrol, diesel and process emissions of greenhouse gases.

1.2 Climate

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

Long-term climate records are available from the Bureau of Meteorology (BOM) for Gladstone Post Office (1872 to 1958) and Gladstone Radar (1957 to 2004). The records for Gladstone Radar, showing recent data for temperature, rainfall, evaporation and humidity, are presented in Table 1.1.

1.2.1 Temperature

The daily temperature variation in summer months is an average of 22.4 °C to 31.1 °C (January), with the coldest month of the year showing an average temperature range of 13.2 °C to 22.6 °C (July). The highest temperature recorded at the Gladstone Radar site is 40.1 °C, and the region has a mean number of 3.9 days per year when the temperature is over 35 °C. The lowest recorded temperature is 4.4 °C.

1.2.2 Rainfall and Evaporation

The region experiences an average annual rainfall of 918 mm, with an average of 97.5 raindays per year. Both the highest monthly rainfall (709.8 mm) and the highest daily rainfall (229.4 mm) were recorded in the month of February.

The summer months, November through to March, have high average monthly rainfalls, ranging from 78 to 154 mm per month. Rainfall during these months typically represents two-thirds of the annual total rainfall. Almost no rainfall is recorded in the months of May to September in some years.

Evaporation is highest from November through to February, with a mean daily evaporation rate of between 5.9 to 6.4 mm. The winter months have an evaporation rate of about 3 mm.

1.2.3 Relative Humidity

The relative humidity measured at the Gladstone Radar site at 9 am ranges from 63% (spring) to 72% (summer). Records of the relative humidity at 3 pm show that the lowest average relative humidity is in winter (53%), with the highest 3 pm humidity in summer (63%).

1.2.4 Winds

Records of winds in the Gladstone area are available from the BOM and Environmental Protection Agency (EPA) monitoring sites. Data for the year 2001 have been incorporated into the windfields 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 1.4. The windfields in GAMS were generated using Calmet, a three-dimensional meteorological modelling program (Scire, J. *et al*,2000a).

Winds for 2001 have been extracted from GAMS at the proposed location of the Project, and at a 10 m measurement height. Wind roses have been prepared from this data, and are presented in Figure 1.2.1. Figure 1.2.1a presents the wind rose for all hours of the year, which shows that the dominant wind direction at the site is from the east, with wind speeds reaching up to 10 m/s. Moderate winds (between 4 and 7 m/s) arise mainly from the north-east through to the south-east sector. Light winds can arise from any sector, but occur less frequently from the south-south west through to the north-west.

Figure 1.2.1b shows the distribution of winds in the early morning (midnight to 5am). These are heavily dominated by flows from the south-east to the south-west with wind speeds typically below 3 m/s, indicating that these are due to night-time drainage flows. Daytime wind patterns (Figure 1.2.1c) show light winds from the east through to the south-west, with an increasing proportion of winds with moderate strength from the east to the south-east. The distribution in the afternoon (Figure 1.2.1d) demonstrates that the seabreeze, from the north-east to east directions, creates stronger afternoon winds that dominate the wind pattern. By night-time (Figure 1.2.1e) the influence of the sea breeze decreases, and lighter winds from the north through to the south-south-east are seen.

The seasonal profile of winds at the site is illustrated in Figure 1.2.2, for all hours. The influence of the seabreeze from the east is most noticeable in the Summer (Figure 1.2.2a), with decreasing importance in the Spring (Figure 1.2.2d) when more moderate northerly winds occur. Autumn and Winter wind roses (Figure 1.2.2b and c) show that these times are characterised by low wind speeds, mainly from the southerly directions, with some moderate winds occurring from the east

Table 1.1 Long-term climate data for Gladstone Radar site (1957 to 2004)

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature - °C	31.1	30.9	30.2	28.3	25.5	23.1	22.6	23.9	26.3	28.3	29.8	30.9	27.6
Mean daily minimum temperature - °C	22.4	22.3	21.5	19.6	17.0	14.2	13.2	14.2	16.4	18.7	20.5	21.8	18.5
Mean 9am air temp - °C	27.1	26.6	25.7	23.6	20.4	17.3	16.4	18.0	21.3	24.1	26.0	27.1	22.8
Mean 9am relative humidity - %	70	72	71	69	71	68	67	66	63	63	64	67	68
Mean 9am wind speed - km/h	15.3	16.2	16.1	15.5	13.4	12.3	11.3	11.1	12.6	14.4	14.8	14.6	14.0
Mean 3pm air temp - °C	29.0	28.9	28.1	26.3	23.8	21.7	21.2	22.0	23.9	25.6	27.1	28.5	25.5
Mean 3pm relative humidity - %	64	64	63	61	60	55	53	54	56	60	62	63	60
Mean 3pm wind speed - km/h	23.1	22.8	22.8	21.2	17.6	15.4	15.7	18.0	20.9	22.1	23.0	22.7	20.5

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean monthly rainfall - mm	154.5	143.2	96.8	51.0	69.6	34.4	39.8	30.9	24.4	60.3	78.1	135.5	918.4
Mean no. of raindays	12.8	12.4	11.0	7.1	7.6	4.6	5.0	4.8	4.2	7.6	9.3	11.1	97.5
Highest monthly rainfall - mm	640.1	709.8	311.6	250.4	316.4	220.3	170.2	110.8	83.8	276.8	218.1	508.9	
Lowest monthly rainfall - mm	6.2	7.2	12.2	3.8	0.2	0	0	0.4	0	3.1	1.4	2.8	
Highest recorded daily rainfall - mm	196.8	229.4	112.3	93.4	178.0	62.5	92.7	78.2	75.0	149.4	84.2	196.0	229.4
Highest recorded wind gust - km/h	155.5	116.6	126.0	150.1	94.7	81.7	96.5	81.7	105.5	92.5	111.2	124.2	155.5
Mean daily evaporation - mm	6.4	5.9	5.4	4.5	3.4	3.0	3.1	3.5	4.3	5.4	6.0	6.3	4.8

1.2.5 Atmospheric Stability

Atmospheric stability is a parameter that is derived from data on the wind and temperature profile at the site. This data is 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, is presented in Table 1.2. This shows that the site is heavily influenced by stable atmospheric conditions (44 %), with only 19% of conditions being classified as Extremely Unstable or Unstable.

Table 1.2 Frequency of Atmospheric Stability Classes at the Project site

Atmospheric Stability Class	Frequency of Occurrence	Description of Category
A	3%	Extremely Unstable
B	16%	Unstable
C	17%	Slightly Unstable
D	17%	Neutral
E	3%	Slightly Stable
F	44%	Stable

1.2.6 Temperature Inversion

The temperature of air generally decreases with height above the ground, 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 trapping 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.

The frequency of temperature inversions at Gladstone has been determined from the Calmet modelled meteorological data for 2001. These data were extracted at all the vertical levels in the model (between 10 m and 2,750 m elevation above ground level). An inversion lasting at least one hour (the time-step that is used in Calmet) was found to occur for approximately 48% of hours in the year, or 449 separate inversion events that last up to 17 hours. Overall, inversions at night (the 8-hour period between 10pm and 6am) were found to occur for up to 29% of the time, or 379 separate inversion events, with 271 events lasting the whole night period.

1.2.7 Cyclones and Extreme Weather Events

An historical database of severe storm and disaster events is maintained by Emergency Management Australia (2006). 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) and 1997. 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.

1.3 Legislative Framework

1.3.1 Ambient Air Quality Guidelines

Queensland

In Queensland, air quality is managed under the Environment Protection Act 1994 (*the Act*), the *Environmental Protection Regulation 1998* (*the Regulation*) and the *Environmental Protection (Air) Policy 1997* (*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 are discussed later in this section.

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:

- 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. Relevant ambient air quality goals for this study are reproduced in Table 1.3.

The Queensland EPA has also adopted a guideline for dust deposition of 4 g/m²/month to ensure adequate protection from nuisance levels of dustfall. This level was derived from ambient monitoring of dust conducted in the Hunter Valley, NSW in the 1980's. The former NSW State Pollution Control Commission set the level to avoid a loss of amenity in residential areas, based on the levels of dust fallout that cause complaints. The current guideline level adopted in NSW (NSW Department of Environment and Conservation, 2005) is that the maximum total dust deposition level should not exceed 4 g/m²/month, and that the maximum increase in deposited dust is 2 g/m²/month.

Air quality guidelines for sulphur trioxide (SO_3) are not specified in Queensland legislation. Instead, reference has been made to the design criteria for sulphuric acid in the Victorian *State Environment Protection Policy (Air Quality Management)* (Vic SEPP) for ambient air quality management. Sulphur trioxide reacts with the water in ambient air to form sulphuric acid, which is classified as a Class 2 indicator for toxicity.

National

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

The NEPM (Ambient Air Quality) 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);
- particulates (as PM_{10} and $PM_{2.5}$); and
- lead (Pb).

In 2004 the NEPM (Air Toxics) was released which included monitoring investigation guidelines for five compounds classified as air toxics: benzene, benzo (a) pyrene, formaldehyde, toluene and xylenes. These toxic air pollutants are not released in significant quantities from the Project and have not been addressed in the air quality assessment. 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}.

National Health and Medical Research Council (NHMRC) air quality guidelines are referred to in the project's Terms of Reference. These guidelines addressed ambient air quality goals and emission concentrations for a range of pollutants; however these have now been rescinded (in 2002 and 2000). The NEPM guidelines are referred to instead for national air quality guidelines.

The NEPM and EPP (Air) standards that are relevant to the Project are included in Table 1.3. 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. For this reason, only the Queensland EPP (Air) guidelines have been used in evaluating air quality impacts from the Project. The EPP (Air) guidelines have been applied at residential locations near the Project.

International

International air quality guidelines are set out by the World Health Organisation (WHO) and were published in 2000 (WHO, 2000), with an update in 2005 (WHO, 2005). 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. The guideline values that apply to pollutants released from the Project are included in Table 1.3.

The 2005 update of the WHO guidelines has set very low goals for SO_2 and PM_{10}, which can often only be achieved through the stepped introduction of interim targets. The interim target for 24-hour average SO_2 from the guidelines released in 2000 was 125 µg/m^3, and should be easily achieved. A second interim target of 50 µg/m^3 for SO_2 was noted, to require jurisdictions to control emissions from motor vehicles, industrial emissions and/or power production. A similar approach has been adopted for PM_{10}, to gradually reduce the 24-hour average guideline value from an interim goal of 150 µg/m^3 to 50 µg/m^3, and to reduce the annual average from an interim target of 70 µg/m^3 to 20 µg/m^3. The WHO recommendations have not been adopted for implementation in Queensland, and the guidelines for SO_2, NO_2, and PM_{10} from the EPP (Air) have been used for this assessment.

The WHO guideline for nickel is presented as a lifetime exposure unit risk, as some compounds containing nickel are known human carcinogens (IARC Group 1). The use of this unit risk factor is different to other ambient air quality standards, as it requires the adoption of an acceptable level of risk. The WHO guidelines suggest that the acceptable risk should be considered as either $1x10^{-4}$, $1x10^{-5,}$ or $1x10^{-6}$. For this project, the acceptable risk level selected is the lowest and most conservative level of $1x10^{-6}$ for evaluation of health risk for the general population. The assessment of nickel exposure in this methodology is based on the conservative assumption of direct inhalation exposure to nickel for a lifetime, and is appropriate to protect sensitive individuals. An equivalent ground-level guideline concentration for nickel can be estimated by dividing the acceptable population exposure risk (1×10^{-6}) by the unit risk factor (0.0004 $[\mu g/m^3]^{-1}$) to give an effective guideline concentration of 0.0025 µg/m³.

The risk level has also been used as the trigger to determine whether a more detailed health risk assessment is required for the Environmental Impact Statement, which would account for the potential routes of exposure to nickel. Advice from the EPA (S. Hewton & R.Riese 2006, pers. comm., 9,23,24,27,31 March, 10,21, April) is that if the dispersion modelling demonstrates that the highest exposure at residential locations is below this risk factor, then a health risk assessment will not be required for the project.

Table 1.3 Australian and International Guidelines and Standards for Ambient Air

Pollutant	Averaging time	Guideline, Goal or Standard Value	Jurisdiction
Sulphur dioxide	10 minute	700 µg/m³ 500 µg/m³	EPP (Air) [1] WHO
	1 hour	570 µg/m³	EPP (Air)[1] , NEPM-Ambient Air
	24 hour	100 µg/m³ 230 µg/m³ 20 µg/m³	EPP (Air)[2] NEPM-Ambient Air WHO [3]
	Annual	60 µg/m³	EPP (Air) [1,2], NEPM-Ambient Air
Nitrogen dioxide	1 hour	320 µg/m³ 246 µg/m³ 200 µg/m³	EPP (Air) [1] NEPM-Ambient Air WHO
	4 hour	95 µg/m³	EPP (Air) [2]
	Annual	30 µg/m³ 62 µg/m³ 40 µg/m³	EPP (Air) [2] NEPM-Ambient Air WHO
Total suspended particulates	Annual	90 µg/m³	EPP (Air) [1]

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

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

[3] The WHO guidelines for SO_2 and PM_{10} have an implementation plan for their use as described in the report.

Pollutant	Averaging time	Guideline, Goal or Standard Value	Jurisdiction
PM$_{10}$	24 hour	150 µg/m^3 50 µg/m^3	EPP (Air) [1] NEPM-Ambient Air, WHO [3]
	Annual	50 µg/m^3 20 µg/m^3	EPP (Air) [1] WHO [3]
Dust deposition	Monthly	4 g/m^2/month	Queensland EPA
Hydrogen sulphide	30 minute (odour)	7 µg/m^3	EPP (Air) [4], WHO
	24 hour	150 µg/m^3	EPP (Air) [1], WHO
Sulphuric acid	3 min	33 µg/m^3	Vic SEPP
Nickel	Lifetime Exposure Risk - Carcinogen	0.0004 [µg/m^3]$^{-1}$	WHO
Cadmium	Annual	0.02 µg/m^3 (no increase above existing levels) 0.005 µg/m^3	EPP (Air) [1] WHO
Mercury	Annual	0.15 µg/m^3	WHO

1.3.2 Occupational Health and Safety Guidelines

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,n.d.). These are applicable to workplace exposure, and are defined by a Time Weighted Average (TWA) value or a Short Term Exposure Limit (STEL) value.

The TWA is based on long-term exposure of workers over an 8-hour working shift, 5 days per week. The STEL is based on a maximum 15-minute acute exposure, and is only applicable to some of the compounds that are released from this Project. TWA values for various compounds have been referenced from the NOHSC and are reported in Table 1.4. The TWA and STEL values are applied to workplace exposure at industrial locations near the refinery site, where ambient air quality guidelines are not applicable.

Sulphur dioxide, sulphur trioxide (reported as sulphuric acid), nitrogen dioxide, nitric oxide and hydrogen sulphide have potential health-related effects that are incorporated into the TWA and STEL exposure standards. Cadmium is noted by the NOHSC to be a probable human carcinogen (category 2). Some forms of mercury are noted to have skin absorption properties.

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[4] EPP (Air) Part 1, for protection of local amenity

Cobalt and nickel compounds are categorised as sensitisers due to their effect on human health, as repeated exposure may create a sensitivity to the substance. Nickel carbonyl is a probable human carcinogen (as noted by the National Pollutant Inventory), and may be a teratogen (cause harm to a foetus). Cobalt is needed in the human body in small amounts (for example, it forms part of Vitamin B-12), but is a possible human carcinogen at higher doses (International Agency for Research on Cancer).

Specific NOHSC exposure standards exist for particulate matter that are comprised of silica (crystalline or amorphous forms), asbestos or synthetic mineral fibre particles. Based on the available information, these forms of particulate matter will not be released from the refinery. The exposure standard for dusts that are not otherwise classified as containing hazardous components has been applied to particulate matter emissions from the refinery.

Table 1.4 Occupational Health and Safety guidelines for compounds emitted from the Refinery

Pollutant	Time Weighted Average (mg/m³)	Short Term Exposure Limit (mg/m³)
Sulphur Dioxide (SO_2)	5.2	13
Sulphuric Acid (SO_3)	1	3
Nitrogen Dioxide (NO_2)	5.6	9.4
Nitric Oxide (NO)	31	-
Particulate matter (not containing hazardous substances)	10	-
Hydrogen Sulphide (H_2S)	14	21
Cobalt (metal, dust and fume as Co)	0.05	-
Nickel (metal as Ni)	1	-
Nickel Carbonyl (as Ni)	0.12	-
Cadmium (as Cd)	0.01	-
Mercury (elemental vapour as Hg)	0.025	-
Mercury (inorganic monovalent compounds as Hg)	0.1	-

1.3.3 Emission Standards

General emission standards are not specified by either Queensland or national legislation. The NSW Department of Environment and Conservation (DEC) has specified limits on emissions from various activities, including non-ferrous primary metal production within the *Protection of the Environment Operations (Clean Air) Regulation*, 2002. The NSW DEC emission standards vary depending on the age of the plant, hence the standards for new plants built since 1 September 2005 have been used for this report. General emission standards are published in the Victorian *State Environmental Protection Policy* (SEPP) for Air Quality Management however these standards are not specifically for primary metal production.

The NSW emission standards have been referred to in this report for sources that are relevant to nickel production by the nickel smelting process. The Victorian SEPP emissions standards have been used for sulphuric acid mist and sulphur dioxide from the sulphuric acid plant, as well as nickel carbonyl emissions from the process.

International recommendations for emission standards are made by the World Bank. These are applied to projects that have World Bank funding. The Pollution Prevention and Abatement Handbook, released in 1998 (World Bank Group,1998), contains recommended emissions standards for nickel smelting and refining. The NSW DEC and World Bank emission concentration standards are presented in Table 1.5.

Table 1.5 Emission Concentration Standards for Nickel Smelting and Refining

Pollutant	Maximum Emission Concentration	Jurisdiction and applicable activity
Sulphur Dioxide	2 kg/t sulphuric acid	World Bank, Victorian SEPP (sulphuric acid plant)
Sulphuric Acid Mist	0.075 kg/t of 100% sulphuric acid (as H_2SO_4)	Victorian SEPP (sulphuric acid plant)
Nitrogen Dioxide	350 mg/Nm³	NSW DEC (sinter plant, smelting or refining process, alloying or casting process, fuel burning equipment)
Particulate Matter	50 mg/Nm³ 20 mg/Nm³	NSW DEC (sinter plant, smelting or refining process, alloying or casting process, fuel burning equipment) NSW DEC (crushing, grinding, separating or materials handling activity), World Bank
Nickel	1 mg/Nm³	World Bank
Nickel Carbonyl	0.5 mg/Nm³	Vic SEPP
Total of Antimony, Arsenic, Cadmium, Lead, Mercury, Beryllium, Chromium, Cobalt, Manganese, Nickel, Selenium, Tin, Vanadium or their compounds	1 mg/Nm³	NSW DEC (sinter plant, smelting or refining process, alloying or casting process)
Cadmium	0.2 mg/Nm³	NSW DEC (sinter plant, smelting or refining process, alloying or casting process)
Mercury	0.2 mg/Nm³	NSW DEC (sinter plant, smelting or refining process, alloying or casting process)

1.4 Existing Air Quality

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 SO_2, NO_2 and PM_{10}.

A summary of the ambient air quality monitoring data in Gladstone, for data recorded from 2001 to 2005, is presented in Table 1.6. These records show the highest concentrations of pollutants that were recorded at each site over the 5-year period, and were obtained from the EPA's monthly monitoring reports (EPA, 2001-2005). The records show that the existing levels of SO_2, NO_2 and ozone are well below the relevant EPP (Air) guideline, as detailed in Section 1.3 at all the monitoring sites.

Monitoring data for PM_{10} show that the highest records over this period sometimes exceed the air quality guideline of 150 µg/m³. The EPA monthly monitoring reports indicate that dust storms 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 PM_{10} levels.

Table 1.6 Ambient Air Quality Monitoring data for Gladstone region, 2001 to 2005.

Pollutant	Averaging time	Maximum pollutant concentration at monitoring location (µg/m³)				Guideline (µg/m³)
		Barney Point	South Gladstone	Clinton	Targinie	
Sulphur Dioxide	1 hour	351	240	377	349	570
Nitrogen Dioxide	1 hour	84	99	142	99	320
Ozone	1 hour	120	n/a	n/a	n/a	210
	4 hour	99	n/a	n/a	n/a	170
Particulate Matter (PM_{10})	24 hour [5]	82	83	83	93	150
	Annual	28	18	18	23	50

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

1.4.1 Modelled concentrations of SO_2 and NO_2

A detailed study of the industrial pollution sources in Gladstone was conducted for the baseline year 2001, as part of the Gladstone Airshed Study. Additional monitoring stations 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 is responsible for the creation and use of GAMS, with the current version available from 2004. GAMS was obtained from the EPA for this project to ensure that the existing industrial sources were included in the dispersion modelling for SO_2 and NO_2, and so that the modelling approach used in this assessment was consistent with previous work in the Gladstone region.

GAMS has been used as the modelling tool for this assessment, as it comprises the following industrial sources of air pollutants:

- Boyne Smelters Limited;
- Cement Australia;
- Comalco Alumina Refinery (Stage 1);
- Gladstone Power Station;
- Orica Chemical Complex;
- Queensland Alumina Limited;
- Stuart Oil Shale (Stage 1, approved but not fully operational); and
- Aldoga Aluminium Smelter (approved but not yet constructed)

Modelled concentrations of SO_2 and NO_2 are available in GAMS for a year of data (representing 2001 as the baseline year), and typical operations of the existing industries. Each of the industries noted above were included in the baseline impact assessment. The exception to this was Boyne Smelters Limited (BSL), which was modified from the original data in GAMS to account for the expansion that took place since 2001. The expansion of BSL increased the production capacity from 535,000 tpa to 708,000 tpa. The Environmental Impact Statement for the expansion states that SO_2 emissions from the site will increase by a factor of 35% due to the increased production of aluminium. Accordingly, the ground-level concentrations predicted by GAMS were scaled by URS on advice from the EPA by a factor of 135%, to represent the expansion of BSL.

Some verification studies were conducted for GAMS by the EPA, to determine how well it predicted the ground-level concentration of SO_2 and NO_2 from the industrial sources. This unpublished work, kindly made available by Ken Verrall of the EPA showed that the modelling predicts higher peak concentrations of pollutants compared to the ambient concentrations that have been measured at the EPA’s sites in Gladstone (K Verrall 2006, pers. comm., 4,19 May, 2 June). For example, predicted exceedances of the one-hour average guideline for SO_2 and NO_2 by GAMS, particularly in the vicinity of the Gladstone

Power Station, have not been substantiated by the monitoring data. The use of the data contained within GAMS to represent the air quality impacts of existing industrial sources is thus a conservative approach, and will over-estimate the actual impacts at the monitoring locations and residential areas.

Contour plots of the predicted 10-minute, 1-hour and 24-hour average concentration of SO_2 due to existing and approved background industrial sources in Gladstone are shown in Figures 1.4.1 to 1.4.3. The contours for the predicted concentrations of NO_2 (assuming 35% conversion from NO_x) are presented in Figure 1.4.4 for the 1-hour average, and Figure 1.4.5 for the 4-hour average concentration.

These figures demonstrate that the 10-minute, 1-hour and 24-hour SO_2 and 1-hour NO_2 concentrations are predicted to exceed the EPP (Air) guidelines in some non-residential locations due to current industrial sources. These effects are particularly seen close to the Gladstone Power Station.

Tabular data of the highest predicted air quality impacts of background sources of NO_2 and SO_2 on air quality at residential locations near the Gladstone Nickel Project and at the EPA's monitoring sites are presented in Table 1.7. The locations that have been evaluated for this assessment are shown on Figure 1.4.7. These results demonstrate that the modelled concentrations of both SO_2 and NO_2 approach the health-based ambient air quality guidelines at some locations. The residential locations that are analysed for this assessment are not predicted to be exposed to concentrations of SO_2 and NO_2 above the health-based guideline values. The 99.9th percentile of 1-hour average modelling results is generally used for evaluation of compliance with air quality guidelines, and the predictions of the concentrations at the EPA monitoring sites are below the monitoring data presented in Table 1.6.

The 4-hour NO_2 concentration is applicable for predicting impacts on vegetation, and is predicted to exceed the vegetation guideline over an extensive area that also covers the Nickel Refinery site due to the background sources of NO_2. These data are not confirmed by the related monitoring data at the EPA sites. A discussion of the potential vegetation impacts is included in Section 1.9.9.

Table 1.7 Modelled ground-level concentrations of SO_2 and NO_2 due to background industrial sources in the Gladstone region (µg/m³)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	EPP (Air) Guideline
Sulphur dioxide	10 minute 99.9th	617	262	495	470	700
	1 hour 99.9th	431	183	346	329	570
	24 hour	94	50	84	83	100
	Annual	12	12	13	12	60
Nitrogen dioxide (35% of NO_x concentration)	1 hour 99.9th	222	85	173	167	320
	4 hour	225	62	177	177	95[6]
	Annual	5	4	4	4	62 or 30 [6]

A comparison of measured and predicted concentrations of oxides of nitrogen at the EPA monitoring sites for 2001 is presented in Figure 1.4.6. The total oxides of nitrogen are the total of nitrogen dioxide, nitrous oxide and other chemical species, and have be used to evaluate the performance of GAMS. Results at South Gladstone and Clinton (Figure 1.4.6b and Figure 1.4.6c) show that the predicted 99.9th percentile results using GAMS (used for compliance with air quality guidelines) are higher than the measured concentrations. For Clinton in particular, the over-prediction of pollutant concentrations close to the Gladstone Power Station indicates that the model is not properly representing the peak impacts from industrial sources. The Barney Point and Targinie sites (Figure 1.4.6a and Figure 1.4.6d) show some predicted concentrations that are above the measured concentrations, with many predicted concentrations slightly below the monitoring data.

The comparison of predicted model results to the ambient measurements in the Gladstone area show that the modelling tends to over-predict the peak concentrations. This leads to the conclusion that modelling of SO_2 and NO_2 impacts from the Gladstone Nickel Project plus background industrial sources will also be over-predicted.

1.4.2 PM_{10}

Background concentrations of PM_{10} have been derived from the available monitoring data, as the background modelling in GAMS only includes the industrial sources of SO_2 and NO_x. These ambient measurements of PM_{10} incorporate the impacts from existing industrial, residential and natural sources of

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[6] EPP (Air) guideline for biological integrity

dust. Measurements at Targinie were used for the cumulative assessment of the project impacts with other sources of dust, as these measurements are the highest 24-hour concentrations (excluding months with dust storms). The 24-hour average concentration is 93 µg/m³ and the annual average concentration is 23 µg/m³ at Targinie. No data are available for the background concentration of TSP, hence these were assumed to be equal to the PM_{10} concentrations for this assessment.

1.4.3 Odour

Ambient measurements of odour near the Project site are not available. A site visit was conducted on 15 March 2006, during which time some field odour observations were made by URS staff [7] at the closest odour-generating industries. The observed odour on the western boundary of the Calliope Shire Sewage Treatment Plant on Reid Road ranged from 'not perceptible' to 'strong' over a 10-minute sampling period with odour observations every 10 seconds. The wind conditions were warm and breezy, with wind speeds of 2-4 m/s and variable wind directions either directly from the plant, or parallel to the plant boundary. The overall odour intensity was weak, and the character of the odour was consistent with sulphur dioxide or hydrogen sulphide. These observations imply that the odour from the sewage treatment plant would not affect amenity at the site or nearby residential locations under warm daytime conditions, however calm night-time conditions would also need to be observed for a full evaluation of odour from the plant.

The Gladstone Area Water Board plant did not emit a detectable odour during the site visit. Due to the prevailing wind direction from the east, odour observations from the Orica operations at the proposed Refinery site were not possible during the site visit.

1.4.4 Air Quality Complaints

The EPA in Gladstone has advised (D. Love, 2006, pers. comm.., 15 March 2006) that air quality complaints in the region over the last 5 years have been due to industrial operations around the Targinie region and port operations. Dust complaints have been noted that were due to Queensland Alumina Limited and port operations in Gladstone. The Barney Point terminal has received some dust complaints regarding the handling of magnesia. Three to four complaints are received per year due to coal dust. These short-term elevated dust events will not affect air quality at the Gladstone Nickel Refinery site as they are well removed from the Refinery operations (approximately 9 km away).

Operation of the Stuart Oil Shale project has sometimes raised in the order of tens of complaints per week due to odour impacts. This site is near Targinie (approximately 7 km from the Refinery), and thus odour impacts from the oil shale operation will not affect the local air quality near the Refinery site.

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[7] Abbie Brooke, Senior Environmental Engineer, URS, has been trained in field odour assessment. Her olfactory response and standard deviation of response to n-butanol falls within the allowable range under the Australian/New Zealand Standard, *Stationary source emissions Part 3: Determination of odour concentration by dynamic olfactometry,* AS/NZS 4323.3:2001.

1.5 Air Emissions from the Project

The estimates for air emissions from the proposed Refinery have been sourced from a combination of engineering design calculations by Aker Kvaerner (process engineers for the project) and Gladstone Pacific Nickel Limited, and information from other nickel projects utilising similar process technologies. Available design data for each process emission stream was compiled for the project for both 1a and Stage 2. Where the design had not progressed to a sufficient level of detail to estimate air emissions, information from other nickel projects utilising similar process technologies was used and adjusted based on plant throughput considerations. Detailed information on the process technologies used at each of these plants was required to select appropriate information for the GNP as no two nickel laterite plants are identical for all process stages.

Not all nickel plants that are in operation around Australia and the world use the same process technologies to that proposed for the Gladstone Nickel Project (refer to Section 5.7 of the EIS for information on available technologies). Nickel smelters process nickel sulphide ores that have a different chemical composition to the nickel laterite ores that are used in this project, and these are processed in three separate stages: Concentrating nickel sulphide ores includes crushing, floatation, thickening and drying of the ore; Smelting of the nickel sulphide concentrate in a flash furnace and separation of the nickel-rich matte product from the slag; Refining of the nickel matte to recover nickel metal. The potential for dust generation is greater for this process compared to a hydrometallurgical process such as the high pressure acid leach process (HPAL) proposed for the GNP refinery. HPAL is a ‘wet’ process, except for when the final metal products are dried and briquetted.

1.5.1 Process emissions

Air emissions from the proposed Gladstone Nickel Project have been identified by Gladstone Pacific Nickel to comprise sulphur dioxide (SO_2), sulphur trioxide (SO_3), oxides of nitrogen (NO_x), carbon dioxide (CO_2), hydrogen sulphide (H_2S), cobalt particulate (Co), nickel particulate (Ni), cadmium (Cd), mercury (Hg) and other metal particulates and particulate matter due to materials handling (as PM_{10}). Emissions of CO_2 are not considered an air quality pollutant and do not have health-based air quality guidelines, and have instead been dealt with as part of the greenhouse gas assessment (see Section 2).

The air quality impacts of the refinery have been considered for:

- Stage 1, representing a nickel production capacity of 60 ktpa, and
- Stage 2, representing a nickel production capacity of 126 ktpa.

The emissions from the refinery process, materials handling operations and the residue storage facility (RSF) are considered separately.

Source parameters for the air emission sources from the refinery are listed in Table 1.8, which notes the total number of stacks for Stage 1 and Stage 2, the stack height, diameter, exit velocity, exit temperature and flowrate per stack. The estimated mass emission rates for each compound released from the stack sources are presented in Table 1.9 for Stage 1 and in Table 1.10 for Stage 2. These tables show that each pollutant will be released only from selected sources, dependent on the process operation that the stack source relates to. Emissions from the nickel powder dryer are estimated to only comprise H_2S in negligible quantities (10,000 times lower emission rate than the neutralisation vent), and have not been included in the modelling.

Odour emissions (in terms of odour units) have not been quantified from the process emissions. The main odorous compound emitted is H_2S. The predicted off-site impacts of H_2S have been compared to the EPP (Air) guideline for protection of local amenity, which also addresses the odour impacts of H_2S.

Particulate matter is released in very small quantities from the Refinery process. Total particulate emissions have been estimated as the total of nickel, cobalt and other metal particulates.

Table 1.8 Source parameters for air emission points from the Refinery operations, Stage 1 and Stage 2

Source name	No. stacks, Stage 1	No. stacks, Stage 2	Stack height m	Stack diameter m	Stack exit velocity m/s	Stack exit temp °C	Normal flowrate per stack Nm³/s
Sulphuric Acid Plant	2	2	60	2.67	15	82	64.4
	-	1	60	2.81	15	82	71.7
Hydrogen Sulphide Incinerator	1	2	25	0.8	15	795	1.7
Power Plant	1	2	40	2.7	15	130	59.3
Hydrogen Plant	1	2	40	1.5	15	300	12.9
Neutralisation Vent	1	2	25	0.51	15	72	2.5
Cobalt Dryer Vent Gas	1	2	15	0.03	15	110	0.01
Cobalt Sinter Furnace Vent Gas	1	2	15	0.10	15	60	0.1
Ni Sinter Furnace Vent Gas	2	4	15	0.23	15	80	0.5

Table 1.9 Emission rate of pollutants released to air from the Refinery operations for Stage 1

Source name	Emission rate of pollutant per stack								
	SO_2 (g/s)	NO_x (g/s)	SO_3 (g/s)	H_2S (g/s)	Cobalt particulate (g/s)	Nickel particulate (g/s)	Nickel Carbonyl (g/s)	Cadmium (g/s)	Mercury (g/s)	Other metal particulates (g/s)
Sulphuric Acid Plant	45	-	2.6	-	-	-	-	-	-	-
Hydrogen Sulphide Incinerator	0.008	0.40	-	-	-	-	-	-	-	-
Power Plant	0.3	8.9	-	-	-	-	-	-	-	-
Hydrogen Plant	-	3.2	-	-	-	-	-	-	-	-
Neutralisation Vent	-	-	-	4.5E-04	-	-	-	-	-	-
Cobalt Dryer Vent Gas	-	-	-	1.8E-06	-	-	-	-	-	-
Cobalt Sinter Furnace Vent Gas	-	-	-	-	4.8E-06	-	-	1.9E-05	1.9E-05	9.5E-05
Ni Sinter Furnace Vent Gas	-	-	-	-	-	4.5E-04	2.2E-04	9.0E-05	9.0E-05	4.5E-04

Note: blank entry indicates that pollutant is not released in significant quantities from that source

Table 1.10 Emission rate of pollutants released to air from the Refinery operations for Stage 2

Source name	Emission rate of pollutant per stack									
	SO_2 (g/s)	NO_x (g/s)	SO_3 (g/s)	H_2S (g/s)	Cobalt particulate (g/s)	Nickel particulate (g/s)	Nickel Carbonyl (g/s)	Cadmium (g/s)	Mercury (g/s)	Other metal particulates (g/s)
Sulphuric Acid Plant	51	-	2.9	-	-	-	-	-	-	-
Hydrogen Sulphide Incinerator	0.0008	0.40	-	-	-	-	-	-	-	-
Power Plant	0.27	8.9	-	-	-	-	-	-	-	-
Hydrogen Plant	-	3.3	-	-	-	-	-	-	-	-
Neutralisation Vent	-	-	-	4.5E-04	-	-	-	-	-	-
Cobalt Dryer Vent Gas	-	-	-	1.9E-06	-	-	-	-	-	-
Cobalt Sinter Furnace Vent Gas	-	-	-	-	4.9E-06	-	-	2.0E-05	2.0E-05	9.8E-05
Ni Sinter Furnace Vent Gas	-	-	-	-	-	4.6E-04	2.3E-04	9.2E-05	9.2E-05	4.6E-04

Note: blank entry indicates that pollutant is not released in significant quantities from that source.

The emission concentrations of pollutants from the Refinery are compared to emissions concentration standards in Table 1.11 This table shows that the Refinery will meet or be well below the emissions standards outlined by the World Bank for nickel smelting and refining, and the NSW DEC standards for primary production of non-ferrous metals. Emissions of nickel, cadmium and mercury have been modelled at the allowable emission concentration for the purposes of this EIS, however it is expected that the plant will achieve a much lower emission of these compounds. The emissions of SO_2 from the acid plant are based on a typical conversion of 99.8% of sulphur to sulphuric acid, and show that the emissions are well below the allowable emission concentration.

Table 1.11 Comparison of Refinery Emissions to Emission Concentration Standards

Pollutant	Sources	Emission concentration from Refinery	Maximum Emission Concentration	Jurisdiction and applicable activity
Sulphur Dioxide	Sulphuric acid plant	1.3 kg/t acid	2 kg/t sulphuric acid	World Bank, Vic SEPP
Sulphuric Acid Mist (from SO_3)	Sulphuric acid plant	0.075 kg/t acid	0.075 kg/t acid	Vic SEPP
Nitrogen Dioxide	Hydrogen Sulphide Incinerator	235 mg/Nm³	350 mg/Nm³	NSW DEC (process plant)
	Power Plant	150 mg/Nm³ at 15% excess O_2		
	Hydrogen Plant	252 mg/Nm³ at 3% excess O_2		
Particulate Matter	Cobalt sinter furnace vent gas Nickel sinter furnace vent gas	10 mg/Nm³ (as metal particulate)	50 mg/Nm³	NSW DEC (process plant)
Nickel	Nickel sinter furnace vent gas	1 mg/Nm³	1 mg/Nm³	World Bank
Nickel Carbonyl	Nickel sinter furnace vent gas	0.5 mg/Nm³	0.5 mg/Nm³	Vic SEPP
Total of Antimony, Arsenic, Cadmium, Lead, Mercury,	Cobalt sinter furnace vent gas	1 mg/Nm³	1 mg/Nm³	NSW DEC (process plant)

Pollutant	Sources	Emission concentration from Refinery	Maximum Emission Concentration	Jurisdiction and applicable activity
Beryllium, Chromium, Cobalt, Manganese, Nickel, Selenium, Tin, Vanadium or their compounds	Nickel sinter furnace vent gas	1 mg/Nm³		
Cadmium	Cobalt sinter furnace vent gas	0.2 mg/Nm³	0.2 mg/Nm³	NSW DEC (process plant)
	Nickel sinter furnace vent gas	0.2 mg/Nm³		
Mercury	Cobalt sinter furnace vent gas	0.2 mg/Nm³	0.2 mg/Nm³	NSW DEC (process plant)
	Nickel sinter furnace vent gas	0.2 mg/Nm³		

1.5.2 Materials handling emissions

Solid materials that are required in the process and are delivered to the Refinery in bulk solid form are imported ore, sulphur and quicklime. Imported ore and sulphur will be unloaded through the proposed Wiggins Island Coal Terminal. The Refinery produces crystalline ammonium sulphate as a by-product, which is exported through the Fishermans Landing port. Potential dust emissions from handling of imported ore, sulphur and ammonium sulphate have been modelled.

Quicklime (calcium oxide) will be delivered by road tanker, and is kept in a storage bin with a dust collection system. The quicklime is recovered from the bin by an enclosed screw conveyor to the lime slaker, from where it is a wet process. Dust emissions from quicklime are expected to be very low, and the quantities handled are low relative to imported ore and sulphur, hence dust emissions for quick lime have not been modelled.

Dust emissions from materials handling operations for sulphur, imported ore and ammonium sulphate were estimated using the NPI Handbook for Nickel Concentrating, Smelting and Refining (DEH,1999), the NPI Handbook for Mining (DEH, 2001) (for front-end loader activities and emission control factors) and specified control efficiencies, and are discussed in more detail below. The NPI Handbook for Nickel is based on the nickel smelting process (for nickel sulphide ores) but also contains emission factors for dust generation from materials handling operations that are relevant to nickel refineries.

Sulphur will be delivered to the site as low dust-generating pastille or prill material (referred to collectively as prill). Sulphur will be transferred from the ships via a covered conveyor, and stored on a stockpile to the north-east of the processing plant. These activities will take place only on the days when a ship is at the wharf. The stockpile is expected to be approximately 200 m long. The sulphur is recovered from the stockpile with a front end loader, and it will be transferred to the site on a conveyor on an almost continuous basis (91% plant availability has been assumed).

The sulphur prill is formed as small granules (2 to 5 mm diameter) and is coated with a binding medium, hence is unlikely to generate significant dust during materials handling operations. However, there are no data available from the manufacturer that state how much dust may be generated by the sulphur. To represent the low generation of dust from the sulphur, dust control efficiencies of 90% were used (applicable for watering of the material with chemicals), and this has been applied to all sulphur handling operations.

Imported nickel laterite ore will be unloaded at Wiggins Island Coal Terminal, transferred from the ships via a covered conveyor and stockpiled to the north-east of the processing plant when a ship is at the wharf. The stockpile is expected to be approximately 700 m long. Ore will be recovered from the stockpile using a front-end loader, and transferred on a dedicated conveyor to the site on an almost continuous basis. The imported ore will also have a high moisture content of around 35%, and hence the emissions for conveying, handling and storage of ore on the stockpile have been reduced by a control efficiency of 90% to represent the high moisture content and the covered conveyor.

The conveyor from Wiggins Island to the site stockpiles will be shared between sulphur and imported ore. The number of days required to unload shipments for each material are noted in Table 1.12. The maximum transfer rate of 40,000 tonnes of ore per day has been used to derive the dust emissions from the conveyor, so that the dust modelling is representative of peak emissions from the conveyor.

Ammonium sulphate (amsul, as a flake crystal product) is produced in the process at a rate of 166,000 and 343,000 tonnes per year respectively for Stage 1 and Stage 2, and will be exported through the Fishermans Landing port facility. The amsul is stored on-site in silos, and will be loaded directly into covered B-double trucks for transport to the port. The trucks unload into a covered dump pit using bottom dump trailers to minimise dust, and the amsul transported into a storage shed at the port by a covered conveyor. The ammonium sulphate will be loaded by front-end loaders into mobile hoppers, and then into the covered load-out conveyor that connects to the port's ship loading conveyor system. Transfer of ammonium sulphate to the ships can only take place in dry weather, due to the soluble nature of the product. Dust from the handling of this material has been estimated from the site using the methodologies in the NPI Handbook for Nickel Concentrating, Smelting and Refining. The maximum transfer rate of 30,000 tonnes of amsul per day has been used to derive the dust emissions from the conveyor, so that the dust modelling is representative of peak emissions from the conveyor.

Details on the method of transport and daily tonnages of material handled from the ship, and to the site are presented in Table 1.12. These data were used, in conjunction with the relevant emission factors, to estimate the dust emission rates for TSP and PM_{10}, as presented in Table 1.13. These data were used for modelling of TSP and PM_{10} impacts due to the Refinery operations.

Table 1.12 Method of transport and throughputs for sulphur and imported ore

Materials handled on site	Transport and handling method	Material handling rate (tpd)		Number of days for ship unloading or loading (days/y)	
		Stage 1	Stage 2	Stage 1	Stage 2
Sulphur, prill form	Wiggins Island, conveyor, stacker to stockpile, reclaimed with front end loader, conveyor to process plant	30,000 from ship to stockpile 2,040 from stockpile to process plant	30,000 from ship to stockpile 3,360 from stockpile to process plant	22	37
Imported Ore	Wiggins Island, conveyor, stacker to stockpile, reclaimed with front end loader, conveyor to process plant	40,000 from ship to stockpile 10,560 from stockpile to process plant	40,000 from ship to stockpile 27,120 from stockpile to process plant	88	225
Ammonium Sulphate as flake crystal	Stored in on-site silo, front end loader to B-double truck, bottom dump trailers to stockpile in shed at Fishermans Landing, conveyor to ship (dry weather only)	510 from site 30,000 from stockpile to ship	1,060 from site 30,000 from stockpile to ship	6	11

Table 1.13 Emission rate of TSP and PM_{10} from materials handling operations, Stage 1 and Stage 2

Source	Type of material	Emission rate, Stage 1 (g/s)		Emission rate, Stage 2 (g/s)		Controls factors used
		TSP	PM_{10}	TSP	PM_{10}	
Ship unloader and conveyor [8]	Sulphur	0.35	0.14	0.35	0.14	90% - Water spray with chemicals (to represent coated prill material)
	Imported Ore	0.46	0.19	0.46	0.19	90% - Covered conveyor, wet ore/ water sprays
Stockpile	Sulphur	0.14	0.06	0.14	0.06	90% - Water spray with

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[8] Wharf and conveyor facilities are shared between the sulphur and imported ore shipments, hence modelling has addressed the highest emission rates due to these two materials.

Source	Type of material	Emission rate, Stage 1 (g/s)		Emission rate, Stage 2 (g/s)		Controls factors used
		TSP	PM_{10}	TSP	PM_{10}	
						chemicals (to represent coated prill material)
	Imported Ore	0.20	0.09	0.20	0.09	90% - Water spray with chemicals (for wet ore)
Conveyor to process plant	Sulphur	0.01	0.005	0.02	0.01	90% - Water spray with chemicals (to represent coated prill material)
	Imported Ore	0.06	0.02	0.16	0.06	90% - Covered conveyor, wet ore/ water sprays
Amsul loading to truck (on site)	Ammonium sulphate	0.02	0.01	0.03	0.01	70% - Enclosure
Amsul conveyor and loading to ship (Fishermans Landing)	Ammonium sulphate	0.95	0.38	0.95	0.38	70% - Covered conveyor
Total emissions from site (g/s)		**1.85**	**0.75**	**1.97**	**0.80**	
Total emissions per year (t/yr) [9]		**35.9**	**15.7**	**46.9**	**18.9**	

1.5.3 Emissions from the Residue Storage Facility

Residue is piped to the RSF as a wet slurry. Emissions to air from the RSF are expected to comprise only dust due to wind erosion from sections of the RSF surface that may dry out.

Estimates of the minimum wet surface area of the RSF have been made during the RSF design. The surface area of the RSF changes during its operation, and an average dry surface area of 3.4 km² has been estimated, corresponding to 43% of the total surface area of 7.9 km².

After the Refinery operations cease, the RSF will be rehabilitated by capping and re-vegetating the surface of the storage facility. The air quality impacts after rehabilitation are expected to be minimal, as wind erosion of the surface is prevented by rehabilitation.

Emissions of TSP and PM_{10} due to wind erosion have been estimated for the expected average dry surface area, based on emission factors in the NPI Handbook for Mining (DEH, 2001) The estimated emission rates are presented in Table 1.14 below, with the same exposed surface area and emission rates assumed for Stage 1 and Stage 2. No dust controls have been assumed for the RSF surface, and the modelling has assumed the worst-case scenario of dust emissions for every day of the year, neglecting the reduction in

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[9] Accounting for 91% availability of the plant, and the number of shipments for sulphur and imported ore per year

dust generation during and immediately following rain. Dust emissions from the RSF have been modelled from the whole surface of the RSF.

Table 1.14 Emission rate of TSP and PM_{10} from the RSF, Stage 1 and Stage 2

Source	Emission rate, Stage 1 and Stage 2 (g/s)	
	TSP	PM_{10}
Wind erosion from RSF	1.7	0.8

1.5.4 Emissions during construction

Emissions to air during construction of the Gladstone Nickel Refinery site will be primarily dust with some combustion pollutants due to diesel and petrol vehicles operating on site. Management of dust emissions is implemented through the Environmental Management Plan that will be prepared for the site. This will include strategies to prevent or minimise dust emissions during construction activities, outline methods to monitor the effects of construction activities, and document procedures that will be implemented to correct any adverse off-site impacts.

1.5.5 Emissions during upset conditions

The most likely, worse case upset condition for SO_2 emissions occurs when the H_2S scrubber is not operational and the vent gas is bypassed to the incinerator. This could occur for a period of days depending on the reason for bypassing the scrubber and scheduled maintenance time for repair.

Emission rates during upset conditions are shown in Table 1.15 and Table 1.16 for Stage 1 and Stage 2, respectively. These have been checked against recent data from an H_2S incinerator vendor and concluded that the assumptions for flow rate and SO_2 emission are conservative. .

One other possible upset emission scenario is the case when all all H_2S produced is vented directly to the incinerator. This would occur in the extremely rare case of both the H_2S pressure relief system and the H_2S scrubber not being operational. Although the incinerator is designed to handle this case due to the catastrophic safety consequences associated with a large release of H_2S, it is extremely unlikely and the duration of release would be about 10 minutes only.

Start-up and shutdown conditions for the acid plant have been investigated but the expected SO_2 emissions under these conditions are not expected to be as high as when the H_2S scrubber is off-line (Table 1.15 and Table 1.16), due to a lower overall gas throughput.

Table 1.15 Emission rate of pollutants released to air during upset conditions for Stage 1 (60 ktpa production)

Source name	Emission rate of pollutant per stack								
	SO_2 (g/s)	NO_x (g/s)	SO_3 (g/s)	H_2S (g/s)	Cobalt particulate (g/s)	Nickel particulate (g/s)	Nickel Carbonyl (g/s)	Cadmium (g/s)	Mercury (g/s)	Other metal particulates (g/s)
Sulphuric Acid Plant	45	-	2.6	-	-	-	-	-	-	-
Hydrogen Sulphide Incinerator	25	0.40	-	-	-	-	-	-	-	-
Power Plant	0.3	8.89	-	-	-	-	-	-	-	-
Hydrogen Plant	-	3.23	-	-	-	-	-	-	-	-
Neutralisation Vent	-	-	-	4.5E-04	-	-	-	-	-	-
Cobalt Dryer Vent Gas	-	-	-	1.8E-06	-	-	-	-	-	-
Cobalt Sinter Furnace Vent Gas	-	-	-	-	4.75.E-06	-	-	1.90E-05	1.90E-05	9.50.E-05
Ni Sinter Furnace Vent Gas	-	-	-	-	-	4.48.E-04	2.24.E-04	8.95E-05	8.95E-05	4.48.E-04

Note: blank entry indicates that pollutant is not released in significant quantities from that source

Table 1.16 Emission rate of pollutants released to air from during upset conditions for Stage 2 (120 ktpa production)

Source name	Emission rate of pollutant per stack									
	SO_2 (g/s)	NO_x (g/s)	SO_3 (g/s)	H_2S (g/s)	Cobalt particulate (g/s)	Nickel particulate (g/s)	Nickel Carbonyl (g/s)	Cadmium (g/s)	Mercury (g/s)	Other metal particulates (g/s)
Sulphuric Acid Plant	51		2.9	-	-	-	-	-	-	-
Hydrogen Sulphide Incinerator	25	0.40	-	-	-	-	-	-	-	-
Power Plant	0.27	8.89	-	-	-	-	-	-	-	-
Hydrogen Plant	-	3.25	-	-	-	-	-	-	-	-
Neutralisation Vent	-	-	-	4.5E-04	-	-	-	-	-	-
Cobalt Dryer Vent Gas	-	-	-	1.9E-06	-	-	-	-	-	-
Cobalt Sinter Furnace Vent Gas	-	-	-	-	4.90.E-06	-	-	1.96E-05	1.96E-05	9.81.E-05
Ni Sinter Furnace Vent Gas	-	-	-	-	-	4.62.E-04	2.31.E-04	9.25E-05	9.25E-05	4.62.E-04

Note: blank entry indicates that pollutant is not released in significant quantities from that source

1.6 Best Practice Design Controls

Gladstone Pacific Nickel has designed the proposed nickel refinery to meet the best practice environmental management for this type of plant.

The choice of the nickel *HPAL* process in preference to the nickel *smelting* process was the initial step in defining the project and its environmental impacts. The refining process used by Gladstone Pacific Nickel will result in the ore being processed as a wet material up until the cobalt and nickel drying stage. This greatly reduces the potential for dust to be released from the process.

Specific areas in which the plant has been designed to minimise air emissions, or has implemented controls on air emissions are discussed below.

- Steam boilers are gas-fired not coal-fired, and no coal is combusted in the process.
- The delivery of ore from Marlborough as a slurry, as well as the leaching and refining process for nickel and cobalt recovery are wet operations, and thus have negligible emissions of particulate matter. Dry operations are the drying, briquetting, sintering and packaging of the nickel and cobalt product. These dry operations take place in ventilated buildings that incorporate building dust capture. Air from the nickel and cobalt dryers is passed through a cyclone to remove particulate matter before being emitted. Fugitive emissions from briquetting machines, sintering furnaces and associated equipment are captured and vented to baghouses for dust collection.
- Imported ore is transferred from the port by a covered conveyor, and stored in on-site stockpiles. Reclamation of the ore is by front end loader, and no ore preparation steps are carried out before the leaching process.
- The acid plant operates on the double absorption principle, ensuring that the maximum conversion of SO_2 and SO_3 into sulphuric acid is obtained. Conversion efficiencies of over 99.7% are achieved in this type of plant, compared to 97% in single absorption plants. The selection of a high efficiency acid plant has a direct and beneficial effect in reducing the atmospheric emission rates of SO_2 from the acid plant.
- The acid plant also incorporates a candle filter system, to remove fine liquid droplets from the airstream prior to release to the atmosphere. This filter assists in removing any residual SO_3 from the exhaust.
- A scrubber will be installed on the hydrogen sulphide plant, to reduce the emissions of SO_2 from the hydrogen sulphide incinerator stack to less than 0.01 g/s for each stack.
- The Pressure Acid Leach process includes a scrubber to significantly reduce the emissions of entrained traces of sulphuric acid in uncondensed steam emitted from the HPAL process. The assumed efficiency of this scrubber is 99%.

- Dust suppressant is used when unloading sulphur from ships. This suppressant is a chemical spray that helps to bind the fine particles together, so that they drop out of the air at the source.
- Raw sulphur is delivered in the form of low dust-generating prill or pastille material. The size of the material is between 2 to 5 mm, and is designed to facilitate the easy handling and storage of sulphur.
- Belt washing will be installed on all sulphur and ore conveyor heads, to prevent carry back of product and possible contamination. Each conveyor transfer point will have spillage and belt washing contained in a collection tank. The tank contents will be pumped back to site for use in the process.
- Sulphur and ore conveyors will be covered to prevent wind-blown losses.
- Ammonium sulphate will be transported in covered B-double trucks that incorporate automatic tarping systems. The trucks will tip the ammonium sulphate into a covered dump pit to control dust during tipping,

The ammonium sulphate will be stockpiled in an enclosed storage shed to contain dust emissions. The conveyor from the silo to the ship will be covered to minimise dust emission

1.7 Meteorological Data

Meteorological data for 2001 is incorporated into the regional airshed model, GAMS. This modelling system contains three-dimensional windfields that represent the airflows in the region for the year that were generated using the meteorological model Calmet (Scire,J. *e. al.*, 2000a). These wind data in GAMS have also been used as the basis for dispersion modelling for this project.

Wind data extracted from GAMS at the Refinery site have been analysed and are discussed in Section 1.2 (Climate). The dominant wind direction at the site is from the east, with winds reaching up to 10 m/s. The seabreeze arises from the north-east to east directions in the afternoons, creating stronger winds. Night-time drainage flows are from the south-east through to the south-west.

The influences of climatic conditions on the air quality modelling results have been addressed by the use of the three-dimensional meteorological model data from Calmet. This accounts for all temperature inversion, stability class and worst-case meteorological conditions that were experienced during the modelled year.

1.8 Dispersion Modelling Methodology

The GAMS utility, described in more detail in Section 1.4 above, uses the Calpuff (Scire, 2000b) 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. Wind data for the year 2001 has been included in the GAMS program, and was generated using the Calmet meteorological model to simulate the wind flows over the Gladstone region for the year.

The version of Calpuff that comes with GAMS is version 5.4, which is an older version of the Calpuff code than is currently available. However, for compatibility with the Calmet windfields and the graphical user interface of GAMS, this older model version has been used for this project.

Each of the emission sources and pollutants were modelled using the Calpuff setup 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.

A modification of the Calpuff parameters that were specified in GAMS was made for this project, to remove the probability density function for convective conditions. This function is most appropriate for tall stack sources with high buoyancy, and is not appropriate for the shorter, wake-affected stacks that are proposed for the refinery site.

1.8.1 Oxides of nitrogen

The emissions of oxide of nitrogen from the refinery are assumed to contain only a small proportion of NO_2 at the point of emission. As the plume travels downwind, it mixes with ambient air and can react with photochemical precursors (such as ozone and reactive volatile organic compounds) to form more NO_2. The extent of this oxidation reaction is determined by the photochemical state of the air and the presence of sunlight. The GAMS has been set up to assume that up to 35% of the NO_x has been oxidised to NO_2 at the receptor location. This ratio of NO_2 to NO_x has also been adopted for this project.

1.8.2 Treatment of averaging times and percentiles for compliance

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

Some guidelines require the estimation of ground-level concentrations for averaging times of less than one hour. These results were extrapolated from the one hour average concentration by use of the Turner power law equation, with an exponent of 0.2 (Ministry for the Environment, New Zealand, 2004). Thus, the 1-hour average predictions were converted to an estimated 10-minute average by multiplying by 1.43, and to 30-minute average concentrations using a multiplier of 1.15. Fifteen-minute STEL concentrations were estimated by multiplying the 1-hour average concentration by 1.32.

1.8.3 Analysis of results

Results for SO_2 and NO_2 were analysed using GAMS. This allows the user to combine the predicted results from background sources with the results for the proposed project. In order to properly calculate the maximum and 99.9th percentile concentrations for each of the relevant averaging times, GAMS adds the model results on an hour-by-hour basis at each grid location. The combined concentrations at each model grid are then sorted to find the required rank. Due to the changing wind conditions for each hour of the year, the impact due to the refinery in isolation cannot be determined solely from the cumulative impact, and has thus been presented separately for Stage 2.

Results for other pollutants were extracted directly from the modelled Calpuff concentrations, as there is no background industrial data to include in the modelling. The only background measurement that was included in the results is that for PM_{10}, where monitoring data from Targinie was used to evaluate cumulative impacts.

The predicted dispersion modelling results due to operation of the refinery were evaluated at many residential and industrial locations around the refinery site, as shown on Figure 1.4.7 for each receptor type. The residential locations were identified from cadastral information in conjunction with digital aerial photography of the surrounding area that was taken on 19 December 2005. The ground-level concentrations have been presented at the residential locations of Clinton to the east, Yarwun to the west and south-west of the site, various rural-residential locations near Fisherman's Landing and Yarwun for comparison with health-based guidelines that are applicable at residential locations. In addition, results have been presented at the eight EPA monitoring sites that were operational in 2001 for comparison with the health-based air quality guidelines. Industrial locations that were assessed in the modelling included the Calliope Shire Sewage Treatment Plant, Gladstone Area Water Board treatment plant, Orica, Gladstone Power Station and others, and results at these locations were compared to the occupational health and safety guidelines. For each nominated receptor group, the results presented are the maximum concentration predicted by the modelling for any of the individual residential or industrial locations that fall into that group.

Air quality impacts due to the Residue Storage Facility were evaluated at rural-residential locations near the RSF and at the populated areas of Mt Larcom. Isolated rural-residential locations were identified to the south of the site at approximately 150 m and 3.3 km from the RSF boundary, 2.1 km to the south-east, 300 m to the west, 3.4 km to the north-west, 4.8 km to the north and a group of properties at over 3 km to the north-east. The closest residential locations at Mt Larcom are approximately 8.9 km from the closest boundary of the RSF.

1.9 Dispersion Modelling Results

1.9.1 Air Quality Impact from Project

The modelled concentrations of sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) were analysed for the refinery project in isolation and the refinery in conjunction with background industrial sources at residential locations near the refinery, as shown on Figure 1.4.7. Impacts due to the background industrial sources only are discussed in Section 1.3. Results for Stage 1 have been presented for only SO_2 and NO_2 for the Refinery impacts plus background industrial sources. The remaining results presented are for Stage 2, which is the final plant capacity that is addressed in this Environmental Impact Statement.

Predicted concentrations of SO_2 and NO_2 for Stage 1 are presented in Table 1.17, together with the impacts from background industrial sources. Likewise, the predicted results for Stage 2 of the development are presented in Table 1.18 including impacts from the background industrial sources. These results show that the EPP (Air) guidelines for SO_2 and NO_2 are satisfied for residential locations for both Stage 1 and Stage 2, where the EPP (Air) is applicable for human health.

The predicted ground-level impacts of SO_2 are shown graphically in Figure 1.9.1 to Figure 1.9.4 for Stage 2 with background industrial sources. The 10-minute, 1-hour and 24-hour average concentrations of SO_2 show that some non-residential areas in the immediate vicinity of the Gladstone Power Station, Stuart Oil Shale and the Refinery are predicted to exceed the relevant air quality guidelines for non-residential locations. As discussed in Section 1.4.1, this is largely due to the existing industrial sources of SO_2 and the over-prediction of ground-level impacts by the model. Predicted concentrations at residential locations comply with the air quality guidelines.

Contours of the ground-level concentrations of NO_2 for Stage 2 with background industrial sources are presented in Figure 1.9.5 to Figure 1.9.7. The 1-hour average concentration of NO_2 shows a small non-residential area that exceeds the EPP (Air) guideline, which is attributed to emissions from the existing Gladstone Power Station (as seen on Figure1.4.2 for background sources only). The annual average impacts are low.

The EPP (Air) guidelines for biological integrity are applicable where sensitive vegetation may occur. The predicted maximum 4-hour concentration of NO_2 may exceed this guideline off-site, however on comparison to the data presented in Table 1.7, it can be seen that these impacts are due to the existing industrial sources in the Gladstone region. The 4-hour average NO_2 contours shown in Figure 1.4.5 for the NO_2 impacts in the area prior to operation of the Refinery are very similar to those in Figure 1.9.6, showing that the area of impact for NO_2 is virtually unchanged when the refinery operations are considered. The NO_2 emissions from the operation of the Refinery contribute a small amount (up to 3.5 $\mu g/m^3$ at residential locations, or 3.7% of the guideline) to this maximum 4-hour average concentration for either Stage 1 or Stage 2.

To assist in the assessment, predicted SO_2 and NO_2 results for the Stage 2 development in isolation are presented in Table 1.19. These results illustrate that the operation of the Refinery in isolation will result in ground-level concentrations that are well below the EPP (Air) requirements for SO_2 and NO_2. The total impact of the Refinery emissions in conjunction with background industrial sources has to be taken into account in determining the overall compliance with air quality guidelines, together with the demonstrated over-prediction of GAMS when compared to existing EPA monitoring data.

Table 1.17 Modelled ground-level concentrations of SO_2 and NO_2 due to the Refinery (Stage 1) and background industrial sources (µg/m³)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	EPP (Air) Guideline
Sulphur dioxide	10 minute 99.9th	617	303	496	472	700
	1 hour 99.9th	432	212	347	330	570
	24 hour	96	57	85	84	100
	Annual	12	15	16	13	60
Nitrogen dioxide (35% of NO_x concentration)	1 hour 99.9th	222	87	173	167	320
	4 hour	225	64	177	177	95 [6]
	Annual	5	4	4	4	62 or 30 [6]

Table 1.18 Modelled ground-level concentrations of SO_2 and NO_2 due to the Refinery (Stage 2) and background industrial sources (µg/m³)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	EPP (Air) Guideline
Sulphur dioxide	10 minute 99.9th	618	350	497	473	700
	1 hour 99.9th	432	245	347	330	570
	24 hour	97	65	85	85	100
	Annual	12	17	17	14	60
Nitrogen dioxide (35% of NO_x concentration)	1 hour 99.9th	222	89	173	167	320
	4 hour	225	65	177	177	95 [6]
	Annual	5	4	4	4	62 or 30 [6]

Table 1.19 Modelled ground-level concentrations of SO_2 and NO_2 due to the Refinery (Stage 2) in isolation (µg/m³) [10]

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	EPP (Air) Guideline
Sulphur dioxide	10 minute 99.9th	71	169	183	213	700
	1 hour 99.9th	50	118	128	149	570
	24 hour	8	29	31	34	100
	Annual	1	5	4	2	60
Nitrogen dioxide (35% of NO_x concentration)	1 hour 99.9th	3	7	7	8	320
	4 hour	3	5	5	6	95[6]
	Annual	0.03	0.3	0.3	0.2	62 or 30[6]

Emissions of particulate matter from the Refinery process operations are small, and comprise particulate matter containing cobalt, nickel and other metals. The predicted impacts of particulate matter are addressed in conjunction with dust generated from materials handling in the section below.

Other pollutants that are expected to be released from the Refinery, and have impacts on human air quality guidelines, are addressed in Table 1.20. These pollutants are hydrogen sulphide, nickel, cadmium and mercury. The predicted maximum ground-level concentrations of hydrogen sulphide are less than 0.2% of the EPP (Air) 30-minute average guideline for amenity, and also well below the WHO guideline. Thus, the odour due to any hydrogen sulphide released from the process should not be detectable at residential locations.

Cadmium and mercury impacts are addressed through the use of annual average guidelines. The predicted concentrations of cadmium for Stage 2 operation are below 9% of the EPP (Air) guideline, and 35% of the WHO guideline. The predicted impact of mercury is less than 1% of the WHO guideline.

Predicted annual average impacts of nickel are presented in Table 1.20. These have been compared to the WHO risk criteria of 0.0004 $[\mu g/m^3]^{-1}$ and the acceptable population exposure risk of 1×10^{-6} (as discussed in Section 1.3.1) to give an effective ground-level concentration criteria of 0.0025 µg/m³. The predicted concentrations of nickel are well below the WHO risk criteria at residential locations, hence a more detailed health risk assessment is not required to be conducted for the project on this basis.

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[10] The incremental air quality impacts due to the Refinery in isolation cannot be compared to air quality guidelines without the inclusion of background sources

Table 1.20 Modelled ground-level concentrations of other pollutants due to the Refinery (Stage 2) in isolation (µg/m³)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	Guideline
Hydrogen sulphide	30 minute	0.002	0.007	0.007	0.011	7, EPP Air
	24 hour	0.0004	0.001	0.001	0.001	150, EPP Air
Sulphuric acid	3 minute	5	12	13	15	33, Vic SEPP
Nickel	Annual	0.0001	0.0005	0.0005	0.0005	0.0025, WHO[11]
Cadmium	Annual	0.00002	0.00012	0.00011	0.00011	0.02, EPP Air or 0.005 WHO
Mercury	Annual	0.00002	0.00012	0.00011	0.00011	0.15, WHO

1.9.2 Air Quality Impact from Materials Handling

Air quality impacts due to materials handling operations have been addressed through dispersion modelling for particulate matter. The ground-level concentration results for TSP and PM_{10} for Stage 2 of the Refinery operations are presented in Table 1.21. These results include the constant background concentration from measurements at Targinie of 93 µg/m³ for the 24-hour average concentrations, and 23 µg/m³ for annual average concentrations. The results show that the cumulative impact due to the Refinery and other sources of particulate matter is well below the EPP (Air) guidelines.

Contours of the predicted ground-level concentrations of TSP and PM_{10} with a constant background concentration are presented in Figure 1.9.8 to Figure 1.9.10 for Stage 2. These demonstrate that the dust concentrations are expected to be well below the EPP (Air) guideline values at any location on the modelling grid.

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[11] Lifetime exposure risk for nickel was converted to an air quality criteria for this assessment by dividing the acceptable population exposure risk by the WHO risk factor, ie $1x10^{-6}$ / 0.0004 [µg/m^{3}

Table 1.21 Modelled ground-level concentrations of TSP and PM_{10} due to the Refinery (Stage 2) with a constant background concentration [12](µg/m³)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	Guideline
TSP	Annual	23.1	23.1	23.2	23.2	90
PM_{10}	24 hour	94.8	95.8	97.0	98.3	150
	Annual	24.4	25.0	25.7	26.4	50

Dust deposition was also modelled using estimated TSP emissions from the Refinery. These results are presented in Table 1.22, and show that the Refinery in isolation is expected to cause minimal dust deposition impacts at residential locations. No background measurements of dust deposition are available, however the Refinery impacts are considered to be very small compared to other natural or man-made sources of dust.

Table 1.22 Modelled monthly deposition rate of dust (as TSP) due to the Refinery (Stage 2) in isolation (g/m²/month)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	Guideline
Dust deposition	Monthly	0.005	0.009	0.015	0.012	4

1.9.3 Air Quality Impact from RSF

Air quality impacts from dust erosion at the RSF are presented in Table 1.23 for TSP and PM_{10} concentrations, and dust deposition results are presented in Table 1.24. The impacts have been evaluated at rural-residential locations around the RSF site, and at the township of Mt Larcom. The predicted impacts are low at all locations, and are dominated by the assumed background concentrations of TSP and PM_{10}.

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[12] Background concentration is estimated to be 93 µg/m^3 for 24-hour average concentrations, and 23 µg/m^3 for annual average concentrations

Table 1.23 Modelled ground-level concentrations of TSP and PM_{10} due to the RSF (Stage 2) with a constant background concentration (µg/m³)

Pollutant	Averaging time	Mt Larcom area	Rural-residential	Guideline
TSP	Annual	23.2	23.5	90
PM_{10}	24 hour	93.9	95.3	150
	Annual	23.2	23.4	50

Table 1.24 Modelled monthly deposition rate of dust (as TSP) due to the RSF (Stage 2) in isolation (g/m²/month)

Pollutant	Averaging time	Mt Larcom area	Rural-residential	Guideline
Dust deposition	Monthly	0.010	0.025	4 g/m²/month

1.9.4 Air Quality Impact from Upset Conditions

The methodology for modelling upset emissions is described in detail in Section 1.9.

Predicted concentrations of SO_2 and NO_2 for Stage 1 upset conditions are presented in Table 1.25, together with the impacts from background industrial sources. Likewise, the predicted results for Stage 2 upset conditions of the development are presented in Table 1.26 including impacts from the background industrial sources. These results show that the EPP (Air) guidelines for SO_2 and NO_2 are satisfied for residential locations for both Stage 1 and Stage 2, where the EPP (Air) is applicable for human health.

Table 1.25 Modelled ground-level concentrations of SO_2 and NO_2 due to the Refinery upset conditions (Stage 1) and background industrial sources (µg/m³)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	EPP (Air) Guideline
Sulphur dioxide	10 minute 99.9th	618	327	496	472	700
	1 hour 99.9th	432	228	347	330	570
	24 hour	97	62	85	85	100
	Annual	12	17	17	14	60
Nitrogen	1 hour 99.9th	222	87	173	167	320

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	EPP (Air) Guideline
dioxide (35% of NO_x concentration)	4 hour	225	64	177	177	95
	Annual	5	4	4	4	62 or 30

Table 1.26 Modelled ground-level concentrations of SO_2 and NO_2 due to the Refinery upset conditons (Stage 2) and background industrial sources (µg/m³)

Pollutant	Averaging time	Clinton area	Yarwun Area	Rural-residential	EPA Monitoring sites	EPP (Air) Guideline
Sulphur dioxide	10 minute 99.9th	618	402	497	475	700
	1 hour 99.9th	432	281	347	332	570
	24 hour	99	87	88	88	100
	Annual	12	20	20	17	60
Nitrogen dioxide (35% of NO_x concentration)	1 hour 99.9th	222	89	173	167	320
	4 hour	225	65	177	177	95
	Annual	5	4	4	4	62 or 30

1.9.5 Occupational Health and Safety

Occupational health and safety (OH&S) impacts are addressed through the use of the 8-hour Time Weighted Average (TWA) and 15-minute Short Term Exposure Limit (STEL) at industrial locations (as shown on Figure 1.4.7). Predicted concentrations of pollutants have been evaluated at the nearby off-site industrial locations to determine whether the operation of the Refinery will cause adverse effects for industrial workers. The effects of the refinery in isolation are presented for all pollutants except sulphur dioxide, nitrogen dioxide and nitric oxide where the background industrial sources have been included in the assessment.

Occupational health and safety effects on workers on-site have not been evaluated in this assessment, as the modelling techniques used are designed to represent off-site impacts of the Refinery in isolation and with existing background sources. Refer to Section 13 of the EIS for details of managing occupational health and safety in the workplace.

The TWA results for all relevant pollutants are presented in Table 1.27 for Stages 1 and 2 of the Refinery operation. These results demonstrate that off-site impacts on workers will be well below the TWA, with the highest impact from sulphur dioxide, which represents up to 5% of the TWA guideline.

The 15-minute STEL results for all relevant pollutants are presented in Table 1.28. The highest short-term impacts are due to sulphur dioxide (11% of the STEL limit) and nitrogen dioxide (8% of the STEL), which also include the impacts from other industrial sources.

This assessment has shown that impacts on off-site workers due to the Refinery operations should be well below the relevant occupational health guidelines.

Table 1.27 Modelled ground-level concentrations of 8-hour average Time Weighted Average due to the Refinery (Stage 2) in isolation at off-site industrial locations (mg/m³)

Pollutant	Sources modelled	Stage 1	Stage 2	TWA Guideline
Sulphur dioxide	Refinery and Background	0.19	0.27	5.2
Sulphuric acid	Refinery in isolation	0.004	0.011	1
Nitrogen dioxide	Refinery and Background	0.14	0.14	5.6
Nitric oxide	Refinery and Background	0.3	0.3	31
Particulate matter (PM_{10})	Refinery with constant Background	0.098	0.102	10
Hydrogen sulphide	Refinery in isolation	2.9E-06	4.6E-06	14
Cobalt (as Co)	Refinery in isolation	2.5E-07	5.0E-07	0.05
Nickel (metal as Ni)	Refinery in isolation	3.9E-05	7.5E-05	1
Nickel carbonyl	Refinery in isolation	2.0E-05	3.7E-05	0.12
Cadmium	Refinery in isolation	8.1E-06	1.6E-05	0.01
Mercury (elemental vapour)	Refinery in isolation	8.1E-06	1.6E-05	0.025
Mercury (inorganic)	Refinery in isolation	8.1E-06	1.6E-05	0.1

Table 1.28 Modelled ground-level concentrations of 15-minute average Short Term Exposure Limit due to the Refinery (Stage 2) in isolation at off-site industrial locations (mg/m³)

Pollutant	Sources modelled	Stage 1a	Stage 1b	STEL Guideline
Sulphur dioxide	Refinery and Background	0.6	1.4	13

Pollutant	Sources modelled	Stage 1a	Stage 1b	STEL Guideline
Sulphuric acid	Refinery in isolation	0.01	0.03	3
Nitrogen dioxide	Refinery and Background	0.7	0.7	9.4
Hydrogen sulphide	Refinery in isolation	8.61E-06	1.31E-05	21

1.9.6 Photochemical Smog

Photochemical smog is currently not considered to be an issue in Gladstone. This is demonstrated by the EPA's monitoring records for ozone (a photochemical smog indicator) and nitrogen dioxide, which show that the highest ozone concentration is less than 60% of the EPP (Air) guideline value. Likewise, monitored concentrations of nitrogen dioxide indicate that the highest 1-hour average concentrations, measured at Clinton, are less than 45% of the guideline.

The Refinery project will not contribute much to the total concentrations of NO_2 in the Gladstone region, as the emissions of NO_x are relatively small compared to other industrial sources in Gladstone. This is demonstrated in Table 1.19, where the highest incremental increase of NO_2 concentration is predicted to be only 8 µg/m³ for a 1-hour average (assuming 35% of NO_x is oxidised to NO_2), which is well below the guideline value of 320 µg/m³. Thus, the small amount of NO_x emitted from the project will not affect the potential for photochemical smog in the Gladstone region.

1.9.7 Human Health Risk

A human health risk assessment would be required for the project if the predicted impacts of pollutants exceeded the ambient air quality guidelines for protection of human health. The predicted impacts of sulphur dioxide, nitrogen dioxide, hydrogen sulphide, sulphuric acid, nickel, cadmium, mercury and particulate matter have been quantified for this project. All predicted concentrations are well below the relevant health-based guidelines. Thus, a detailed human health risk assessment is not required.

1.9.8 Acid Rain

The Gladstone region currently does not experience acid rain impacts. A detailed monitoring program between 1991 and 1993 showed that acid rain was not a problem in Gladstone, as noted by the Minister of Environment and Heritage in 1994 (Queensland Legislative Assembly, 1994).

The Refinery will add SO_2 emissions into the Gladstone airshed that are equivalent to 7% of the total existing mass emissions from industrial sources (for Stage 2). This increase in SO_2 load to the airshed would not be expected to trigger an acid rain issue in the area. Thus, there is a very low risk that the Refinery operations will cause acid rain.

1.9.9 Impacts on vegetation

A qualitative discussion of the potential for adverse impacts on vegetation due to air pollutants that may be emitted from the Refinery is presented in Section 8.5of the EIS.

This notes that the vegetation types found in proximity to the Refinery are not sensitive to dust deposition, are hardy, and are well adapted to adverse conditions such as extended dry periods. The estimation of dust deposition (Section 1.9.2) at receptor locations near the Refinery has demonstrated that the potential impacts due to dust from materials handling operations is low. Thus, the vegetation near the site is expected to show no adverse impacts due to dust from the Refinery.

The site survey work that is discussed in Section 8.5 of the EIS notes that the vegetation at the Refinery site was generally healthy and showed no signs of adverse impacts that would be associated with poor air quality. Air dispersion modelling for the background industrial sources (Section 1.4.1) has predicted that the ground-level concentrations of NO_2 will exceed the 4-hour average EPP (Air) guideline for biological integrity. Since the vegetation on site shows no adverse impacts from existing pollution sources, and the impacts due to the Refinery are predicted to be small compared to existing sources (see Section 1.9), no additional impacts on the health of vegetation are anticipated from operation of the Refinery.

1.10 Conclusions

The air quality assessment has quantitatively assessed the existing air quality due to industrial sources in the region. The modelled concentrations of SO_2 and NO_2 due to existing industrial sources in the Gladstone area were found in some cases to exceed the relevant air quality guidelines at non-residential locations. These results are not substantiated by ambient air quality monitoring results, showing that the GAMS model used for impact assessment for this project is likely to over-predict the impacts of industrial sources in the region.

Emissions to air from the Refinery are expected to comprise sulphur dioxide, nitrogen dioxide, hydrogen sulphide, sulphuric acid, nickel, cobalt, cadmium, mercury and particulate matter. These emissions have been quantified and dispersion modelling has been carried out to determine the potential for adverse air quality impacts. Air dispersion modelling has shown that no adverse impacts on human health are anticipated at residential locations as a result of operation of Stage 2 of the Refinery.

Occupational health and safety impacts at other industrial locations due to operation of the Refinery were assessed. This work found that all levels of pollutants were well below the guidelines for occupational health.

2.1 Introduction

Greenhouse gases are naturally occurring gases in the earth’s atmosphere that absorb and radiate infrared radiation (heat) reflected from the earth’s surface. The most abundant of these gases are carbon dioxide (CO_2) and water (H_2O). Other naturally occurring greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) are present in much smaller amounts in the atmosphere. Naturally occurring greenhouse gases raise the Earth’s global average temperature to approximately 15°C, approximately 33°C higher than without their presence.

The less abundant greenhouse gases (eg CH_4 and N_2O) are much more efficient in trapping infrared radiation than CO_2. The measure of how “efficient” a greenhouse gas is in trapping infrared radiation is called the Global Warming Potential, defined as the ratio of infrared radiation trapped by one kilogram of non-CO_2 greenhouse gas compared to one kilogram of CO_2, over a defined time frame. For example, over a 100 year time-frame, methane traps approximately 21 times as much infrared radiation from the earth as CO_2 and nitrous oxide approximately 310 times as much infrared radiation as CO_2. When compiling greenhouse gas inventories, this difference in Global Warming Potential is accounted for by converting one tonne of non-CO_2 greenhouse gas into a CO_2 equivalent (CO_2-e) amount using the Global Warming Potential for that particular non-CO_2 gas.

Since greenhouse gases efficiently trap infrared radiation, scientists have suggested that there is a causal link between the rapid increases in the concentrations of greenhouse gases and the possibility of increased global temperatures. The best available scientific evidence suggests that the global average temperature has increased by approximately 0.6±0.2°C in the last 140 years. Because of this apparent link to climate change, the accounting and management of greenhouse gases is seen as an important issue by some governments and industrial companies. Furthermore, efficiencies in greenhouse gas emissions are often related to efficiencies in energy consumption.

2.2 Greenhouse Gas Policy Issues

Global and national greenhouse gas policy is complex and despite the Kyoto protocol coming into force in 2005, remains uncertain. This section briefly summarises the policy issues.

2.2.1 International Policy

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was signed in 1997 and entered into force in 2005. Its aim is to limit greenhouse gas emissions by countries by setting mandatory greenhouse gas emission targets relative to a country’s 1990 greenhouse gas emissions. It sets out three “flexibility mechanisms” to allow greenhouse gas targets to be met:

1. The Clean Development Mechanism.
2. Joint Implementation.

3. International emissions trading.

The definitions of the three mechanisms above are complex but effectively they allow greenhouse gas reductions to be made at the point where the marginal cost of that reduction is lowest. Essentially, an industrialised country sponsoring a greenhouse gas reduction project in a developing country can claim that reduction towards its Kyoto Protocol target and those greenhouse gas reductions can be traded.

2.2.2 Australian Policy

The Australian climate change program is managed by the Commonwealth Department of Environment and Heritage. Key features of the Australian climate change policy are:

- compiling and validating the National Greenhouse Gas Inventory;
- delivery of the voluntary based Greenhouse Challenge Plus program, a vehicle for companies to report their greenhouse gas emissions annually; and
- guiding a range of energy efficiency initiatives.

2.3 Greenhouse Gas Assessment Methodology

The greenhouse gas emission inventory for the Project is based on the methodology detailed in the World Business Council for Sustainable Development-Global Resources Institute Greenhouse Gas Protocol, www.ghg.protocol.org (GHG Protocol, 2004), and the relevant emission factors in the Australian Greenhouse Office “Factors and Methods Workbook” 2005 and the “Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2004 – Energy (Stationary Sources)”. The Protocol was first established in 1998 to develop internationally-accepted accounting and reporting standards for greenhouse gas emissions from companies.

The Greenhouse Gas Protocol is based on the concept of emission “scopes”.

- **Scope 1: Direct greenhouse gas emissions**. Direct greenhouse gas emissions occur from sources that are owned or controlled by the company, for example:
    - Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.;
    - Emissions from chemical production in owned or controlled process equipment.
- **Scope 2: Electricity indirect greenhouse gas emissions.** This accounts for greenhouse gas emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated.
- **Scope 3: Other Indirect greenhouse gas emissions.** This is an optional reporting class that accounts for all other indirect greenhouse gas emissions resulting from a company’s activities, but occurring from sources not owned or controlled by the company. Examples include extraction and

production of purchased materials; transportation of purchased fuels; and use of sold products and services.

2.4 Greenhouse Gas Inventory

The greenhouse gas inventory for the Project reports Scope 1 and Scope 2 emissions, to account for the on-site (Scope 1) and off-site (Scope 2) emissions from the project. For the purpose of this inventory, the operational boundary is defined as the boundary of the project site located in Gladstone as this is the main source of greenhouse gas emission. There are negligible greenhouse gas emissions from the RSF and from the port infrastructure.

The project generates a significant amount of its electricity demand (78% in Stage 1, and 61% in Stage 2) partly through the efficient use of heat released from process chemical reactions. The chemical reactions used to generate sulphuric acid on-site liberate substantial heat. This is used to generate high pressure steam which is used for process heating purposes. Excess steam is converted to electricity through a turbine.

The nickel refining process is a source of CO_2 emissions. The CO_2 emissions from these sources have been calculated by the Project proponents using chemical process simulation software. Process emissions of CO_2 are approximately 0.1% of the total Project greenhouse inventory.

Table 2.1 shows the energy consumption inputs to the Project’s greenhouse gas emissions inventory. Table 2.2 and Table 2.3 provide the greenhouse gas inventory for Stage 1 and Stage 2.

Table 2.1 Greenhouse Gas Inventory Inputs – Energy Consumption

Parameter	Value		Units
	Stage 1	Stage 2	
Electricity– process generated	384,000	599,000	MWh/year
Electricity – from grid	104,000	376,000	MWh/year
Natural Gas consumption – power generation and process use	2,174	3,994	TJ/year
LPG – transport	130	260	kL/year
Diesel – transport, emergency power	930	1,930	kL/year

Table 2.2 Greenhouse Gas Inventory – Stage 1

Emission Scope	Parameter	Value	Units	Emission Factor	EF Units	kg CO2-e emitted	Reference
2 - Off Site	Electricity – from grid	104,000	MWh/year	1.03	kg CO2-e / kWh	107,120,000	1
1 - On Site	Natural Gas consumption – power generation and process use	2,174	TJ/year	52.6	kg CO2-e / GJ	114,356,225	2
1 - On Site	LPG – transport	130	kL/year	1.6	t CO2-e / kL	208,000	3
1 - On Site	Diesel – transport, emergency power	930	kL/year	2.8	t CO2-e / kL	2,604,000	4
	Process emissions			No. Stacks			
1 - On Site	PAL Vent Scrubber Off-gas	0.09	g CO2 / second / stack	2	-	5,546	5
1 - On Site	Saprolite Neutralisation Vent Gas	0.05	g CO2 / second / stack	1	-	1,614	5
1 - On Site	Solution Neutralisation Vent Scrubber Offgas	3.12	g CO2 / second / stack	1	-	98,467	5
1 - On Site	Neutralisation Vent	1.51	g CO2 / second / stack	1	-	47,628	5
1 - On Site	Final Neutralisation 1 Vent	1.56	g CO2 / second / stack	1	-	49,225	5
				Total kg CO2-e		224,571,123	
				Total Mt CO2-e		0.225	

1 Table 5, Column A (Qld) AGO Factors and Methods Workbook (December 2005)

2 Table 2, Scope 1 (Qld) AGO Factors and Methods Workbook (December 2005)

3 Table 3, Column C, LPG, AGO Factors and Methods Workbook (December 2005)

4 Table 3, Column C, Industrial Diesel Fuel, AGO Factors and Methods Workbook (December 2005)

5 Gladstone Pacific Nickel Limited quoted figure, from process simulation. Assumes 100% operation per year.

Table 2.3 Greenhouse Gas Inventory – Stage 2

Emission Scope	Parameter	Value	Units	Emission Factor	EF Units	kg CO2-e emitted	Reference
2 - Off Site	Electricity – from grid	376,000	MWh/year	1.03	kg CO2-e / kWh	387,280,000	1
1 - On Site	Natural Gas consumption – power generation and process use	3,994	TJ/year	52.6	kg CO2-e / GJ	210,084,419	2
1 - On Site	LPG – transport	260	kL/year	1.6	t CO2-e / kL	416,000	3
1 - On Site	Diesel – transport, emergency power	1,930	kL/year	2.8	t CO2-e / kL	5,404,000	4
	Process emissions			No. Stacks			
1 - On Site	PAL Vent Scrubber Off-gas	0.09	g CO2 / second / stack	4	-	11,093	5
1 - On Site	Saprolite Neutralisation Vent Gas	0.05	g CO2 / second / stack	2	-	3,228	5
1 - On Site	Solution Neutralisation Vent Scrubber Offgas	6.24	g CO2 / second / stack	2	-	196,934	5
1 - On Site	Neutralisation Vent	1.51	g CO2 / second / stack	2	-	95,256	5
1 - On Site	Final Neutralisation 1 Vent	3.12	g CO2 / second / stack	2	-	98,450	5
				Total kg CO2-e		603,750,214	
				Total Mt CO2-e		0.604	

1 Table 5, Column A (Qld) AGO Factors and Methods Workbook (December 2005)

2 Table 2, Scope 1 (Qld) AGO Factors and Methods Workbook (December 2005)

3 Table 3, Column C, LPG, AGO Factors and Methods Workbook (December 2005)

4 Table 3, Column C, Industrial Diesel Fuel, AGO Factors and Methods Workbook (December 2005)

5 Gladstone Pacific Nickel Limited quoted figure, from process simulation. Assumes 100% operation per year.

The State and Territories Greenhouse Gas Inventories 2004, published by the Australian Greenhouse Gas Office in 2006, lists Australian GHG emissions from each of the states and territories, and by industry sector. In 2004, Australia's total GHG emissions were 564.7 million tonnes CO_2-e, and Queensland's emissions were 158.5 million tonnes CO_2-e. Assuming full production for Stage 2 of the project, then the Project represents 0.11% of Australia's 2004 GHG emissions, and 0.38% of Queensland's 2004 emissions. This is an insignificant additional increase to current Australian and Queensland greenhouse gas emissions.

2.5 Mitigation Measures

The following options that are being investigated by GPNL to manage the refinery's greenhouse impacts:

- The Stage 2 production rate will consume more than 0.5 PJ of energy through its purchase of natural gas and consumption of electricity. Consumption of more than 0.5 PJ is the trigger for participation in the mandatory, national energy efficiency assessment and public reporting program called Energy Efficiency Opportunities (EEO). This program was first announced in the 2004 Energy White Paper and is administered by the Department of Industry, Tourism and Resources (DITR). As part of this program, GPNL will conduct rigorous and comprehensive assessments to identify energy efficiency programs and outcomes, with the overall effect of reducing energy consumption and GHG emissions.
- The use of the HPAL refining technology rather than the alternative smelting technology will significantly reduce greenhouse emissions. The HPAL process requires less energy per tonne of metal produced than pyrometallurgical processes or the ammonia leach process. Energy released from the exothermic reaction which produces sulphur dioxide for sulphuric acid manufacture is recovered as steam and used within the HPAL process for heating purposes or to generate power. By contrast, the smelting process requires more energy input per tonne of nickel as the ability to use waste heat for electricity generation is not available.

2.6 Comparison to alternative technologies

The Project will use a hydrometallurgical process - high pressure acid leach (HPAL) - to extract nickel from laterite ore. The HPAL process is discussed elsewhere in this EIS (Section 2 of the EIS).

One benefit of the HPAL process compared to smelting alternatives is the reduced consumption of energy. The chemical reactions used to generate sulphuric acid on-site liberate substantial heat. This is used by the Project to generate high pressure steam which is used for process heating, with the surplus converted to electricity through a turbine. The project generates a significant amount of its electricity demand (78% in Stage 1, and 61% in Stage 2).

By contrast, a smelting process requires more energy input per tonne of nickel produced (refer to Section 2 of the EIS for further details). The selection of the HPAL process minimises the amount of GHG emissions resulting from nickel production.

Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Gladstone Pacific Nickel Limited and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 21st October 2005.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between May and July 2006 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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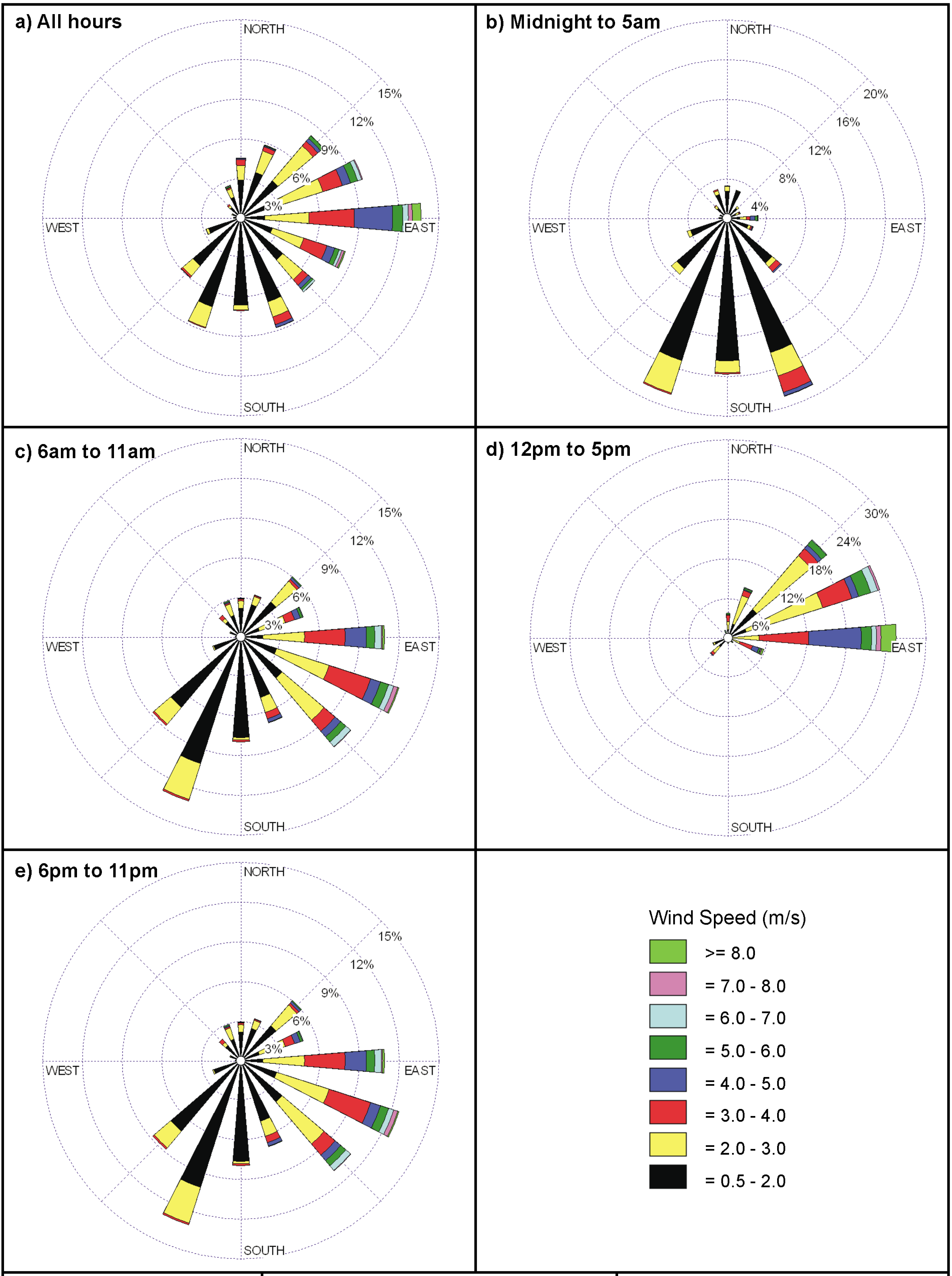
Figures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b) Midnight to 5am

c) 6am to 11am

d) 12pm to 5pm

e) 6pm to 11pm

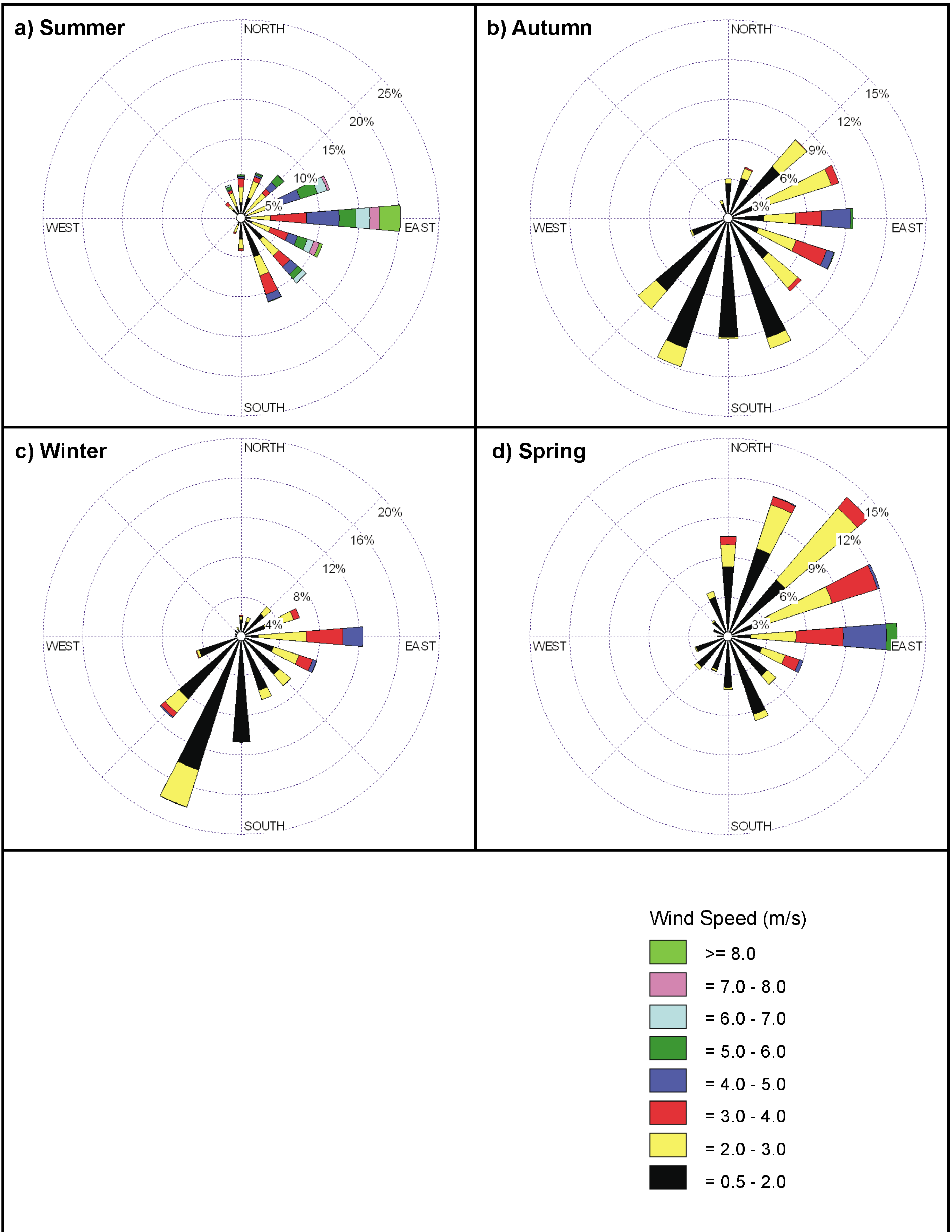
Client
Gladstone Pacific Nickel Ltd

URS

Project
GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Title
WIND ROSES FOR 2001
BY TIME OF DAY
EXTRACTED FROM GAMS DATA

Drawn: TN
Approved: CMP
Date: 12/09/2006
Job No.: **4262 5791**
File No. 42625791-g-073.cdr
Figure: **1.2.1**
Rev. A
A4



Client

Gladstone Pacific Nickel Ltd

URS

Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Title

WIND ROSES FOR 2001
BY SEASON
EXTRACTED FROM GAMS DATA

Drawn: TN	Approved: CMP	Date: 12/09/2006	Figure: **1.2.2**	Rev. A
Job No.: **4262 5791**	File No. 42625791-g-074.cdr			A4

URS

Client

Gladstone Pacific Nickel Ltd

Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: **4262 5791**
File No: 42625791-g-075.wor

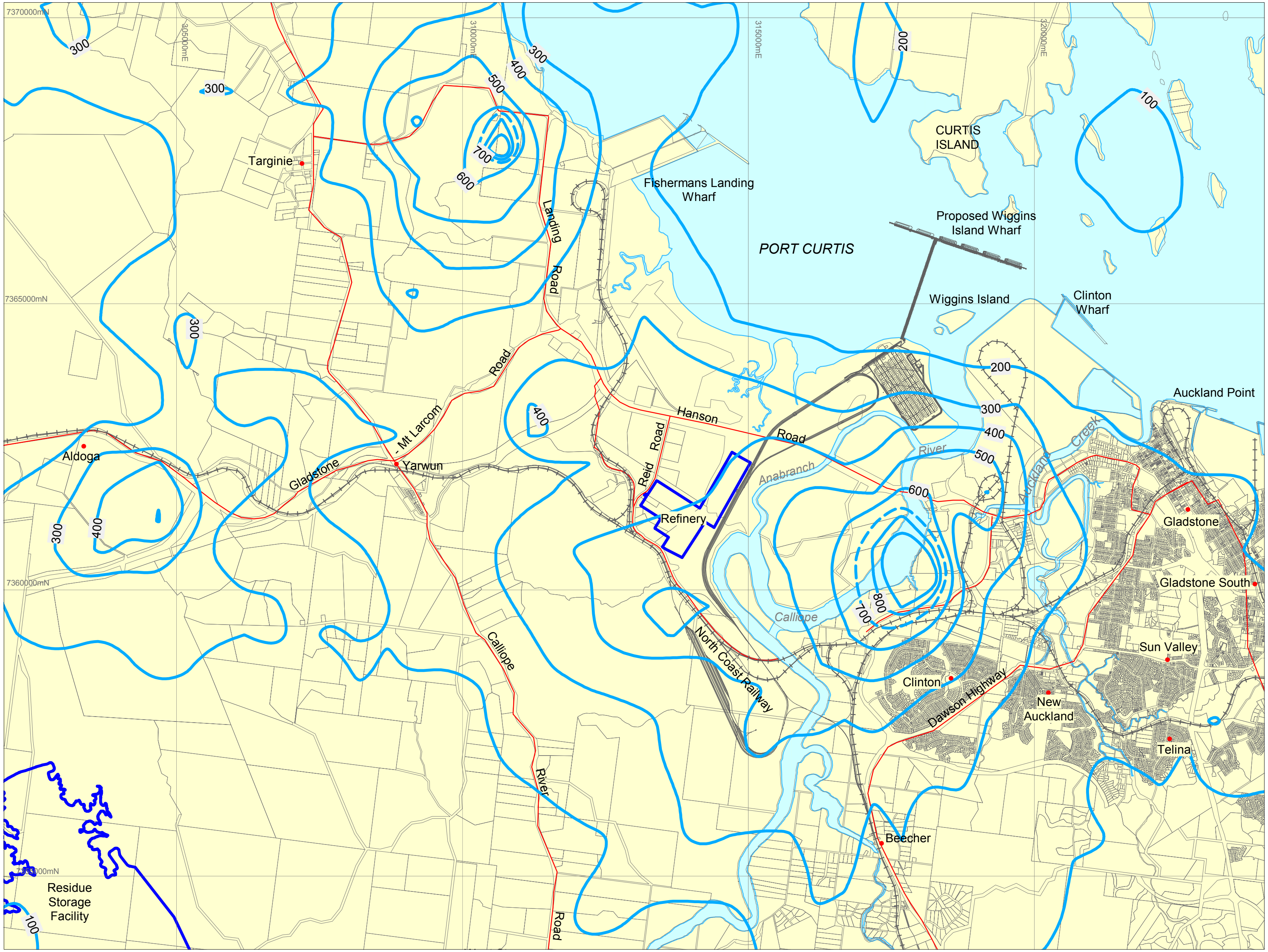
Title

99.9th PERCENTILE 10 MINUTES AVERAGE CONCENTRATION OF SO_2 DUE TO BACKGROUND INDUSTRIAL SOURCES FROM GAMS (µg/m³)

Figure: **1.4.1**

Rev: A

A4



N

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Scale 1:100,000 (A4)

MGA Z56, GDA94

—200— SO_2 Concentration Contours (µg/m³)

- -700- - Air Quality Guideline

URS

Client

Gladstone Pacific Nickel Ltd

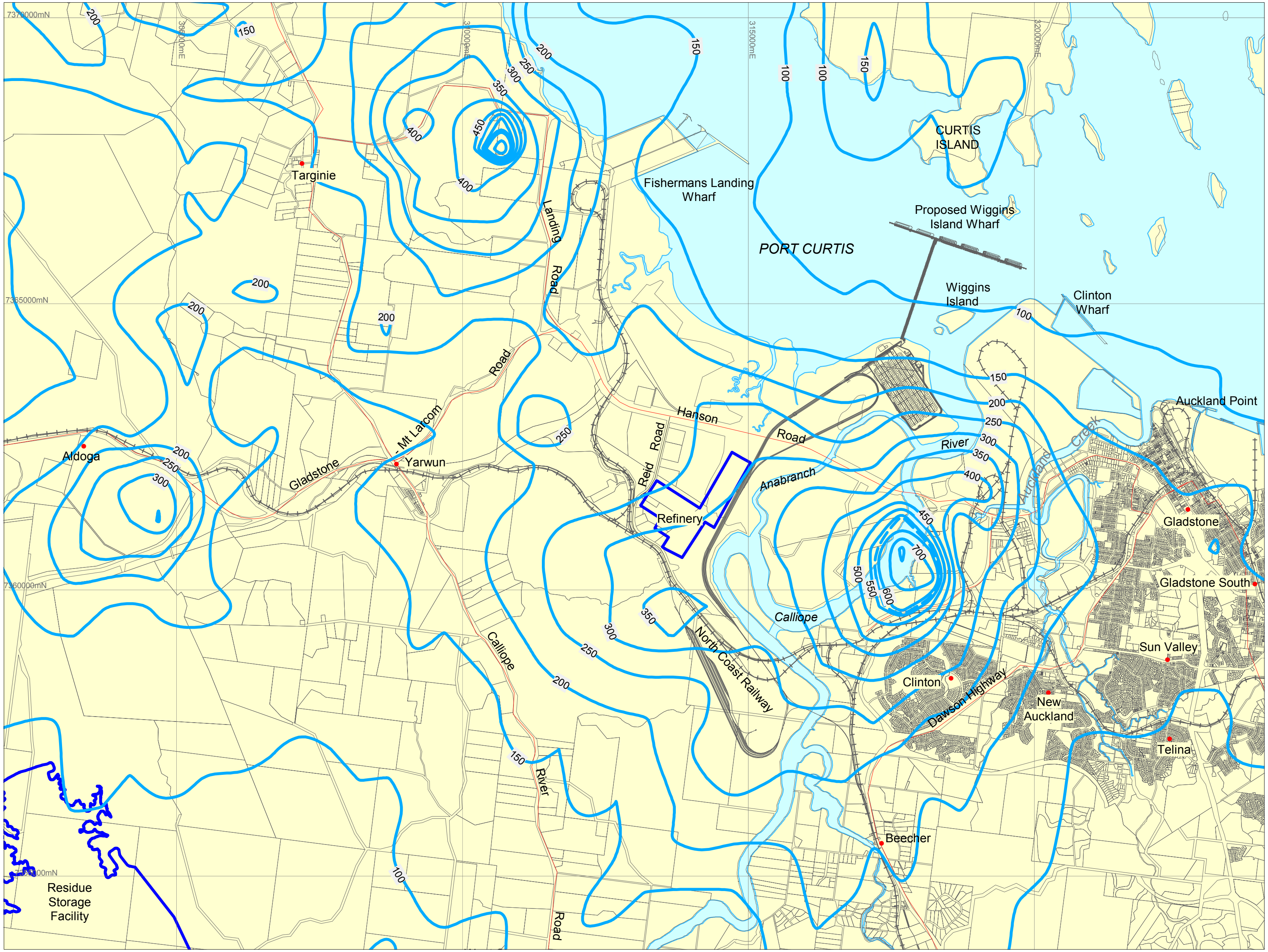
Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Title

99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF SO_2 DUE TO BACKGROUND INDUSTRIAL SOURCES FROM GAMS (µg/m³)

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: **4262 5791**
File No: 42625791-g-042.wor
Figure: **1.4.2**
Rev: A
A4



N

0 1.25 2.5km
Scale 1:100,000 (A4)
MGA Z56, GDA94

150 SO_2 Concentration Contours (µg/m³)
570 Air Quality Guideline

Client

Gladstone Pacific Nickel Ltd

Project

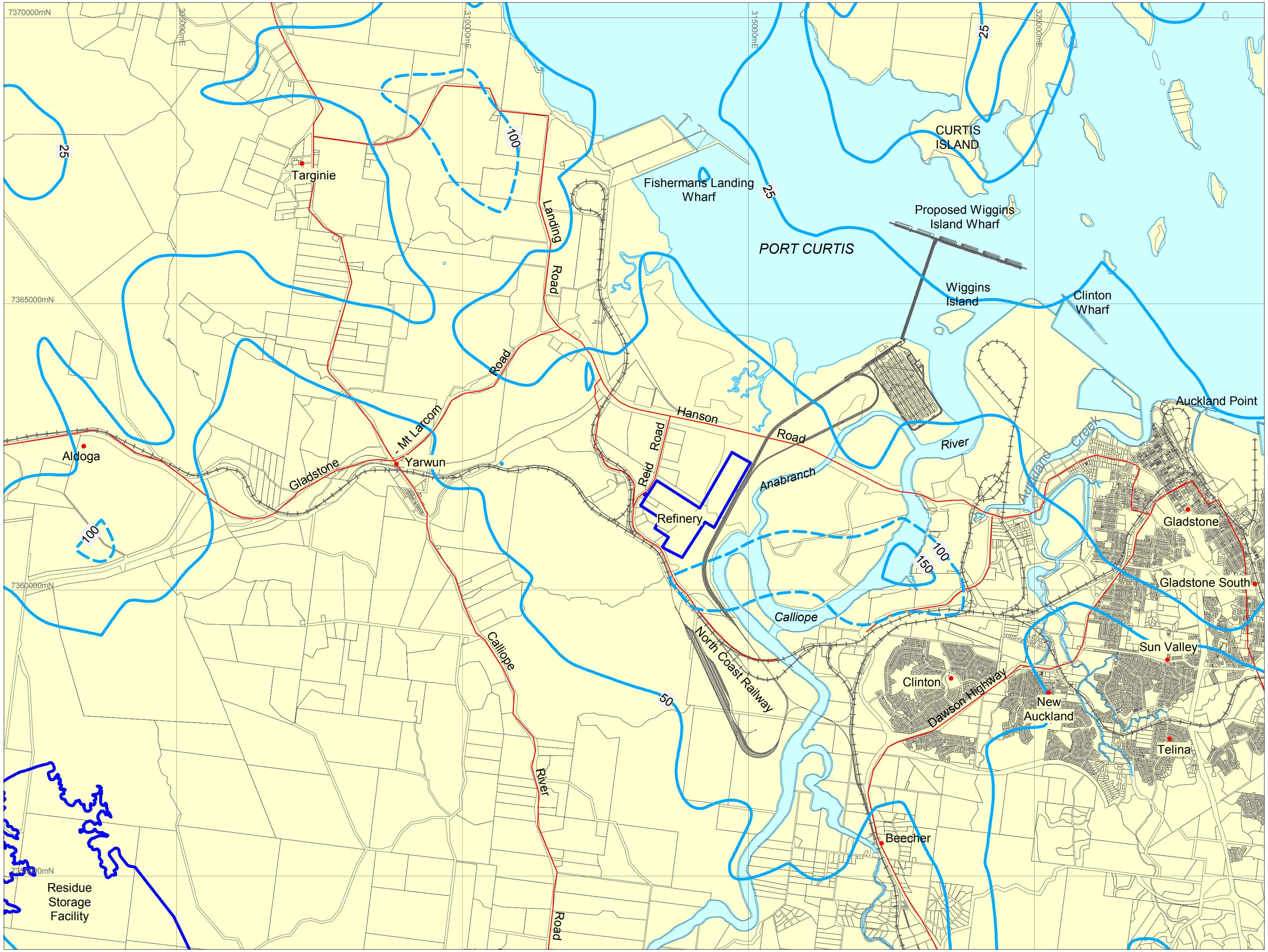
GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: 4262 5791
File No: 42625791-g-078.wor

Title

MAXIMUM 24 HOUR AVERAGE CONCENTRATION OF SO_2 DUE TO BACKGROUND INDUSTRIAL SOURCES FROM GAMS (µg/m³)

Figure: 1.4.3
Rev: A
A4



N

0 1.25 2.5km

Scale 1:100,000 (A4)

MGA Z56, GDA94

150	SO_2 Concentration Contours (µg/m³)
100	Air Quality Guideline

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Gladstone Pacific Nickel Ltd

Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: **4262 5791**
File No: 42625791-g-043.wor

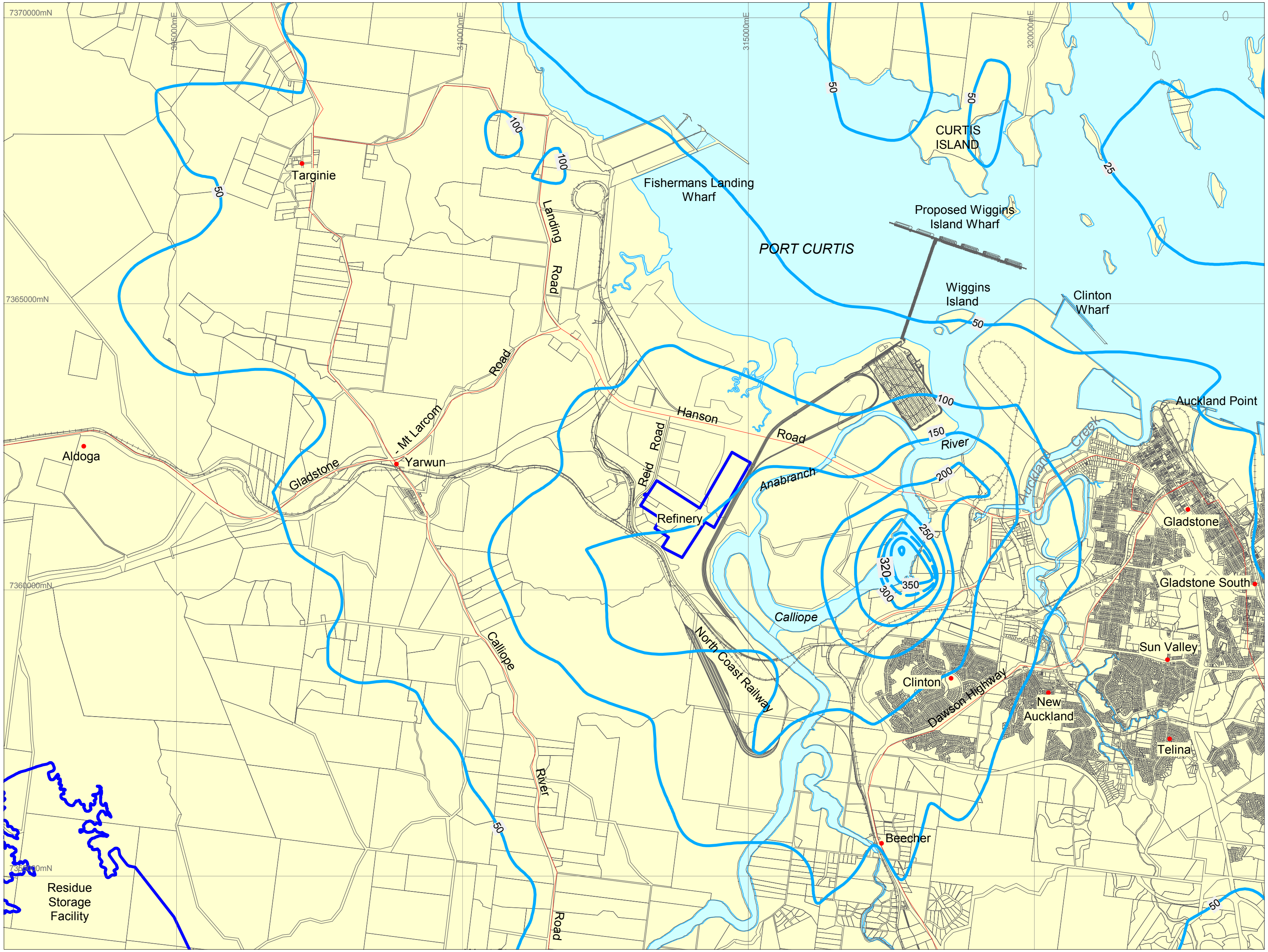
Title

99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO_2 DUE TO BACKGROUND INDUSTRIAL SOURCES FROM GAMS (µg/m³)

Figure: **1.4.4**

Rev: A

A4



N

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Scale 1:100,000 (A4)

MGA Z56, GDA94

150 NO_2 Concentration Contours (µg/m³)

320 Air Quality Guideline

Client

URS

Gladstone Pacific Nickel Ltd

Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: 4262 5791
File No: 42625791-g-076.wor

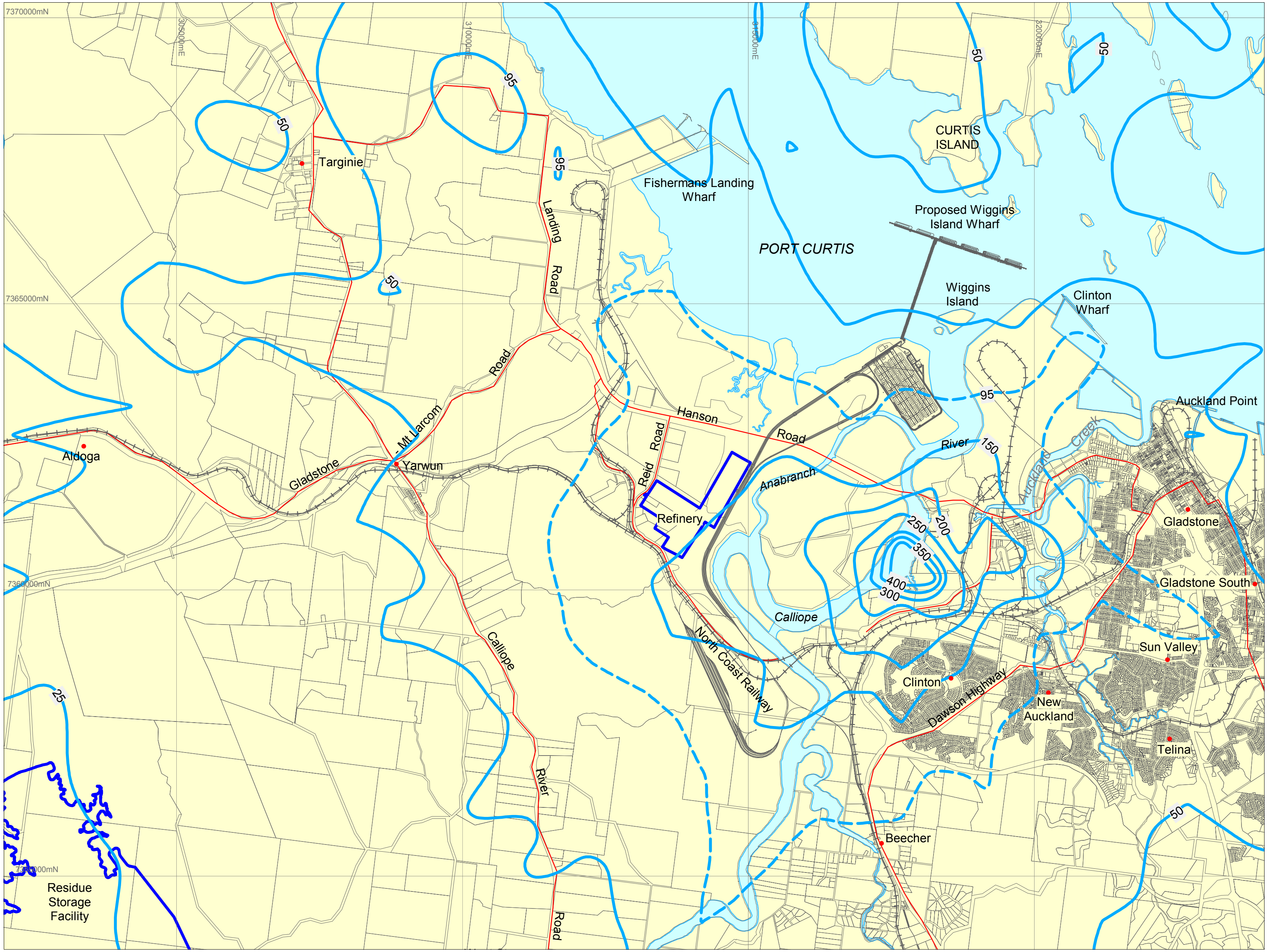
Title

MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO_2 DUE TO BACKGROUND INDUSTRIAL SOURCES FROM GAMS ($\mu g/m^3$)

Figure: 1.4.5

Rev: A

A4



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Scale 1:100,000 (A4)
MGA Z56, GDA94

N

150 NO_2 Concentration Contours ($\mu g/m^3$)
95 Air Quality Guideline

URS

Client

Gladstone Pacific Nickel Ltd

Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 29/09/2006
Job No.: **4262 5791**
File No.: 42625791-g-087.cdr

Title

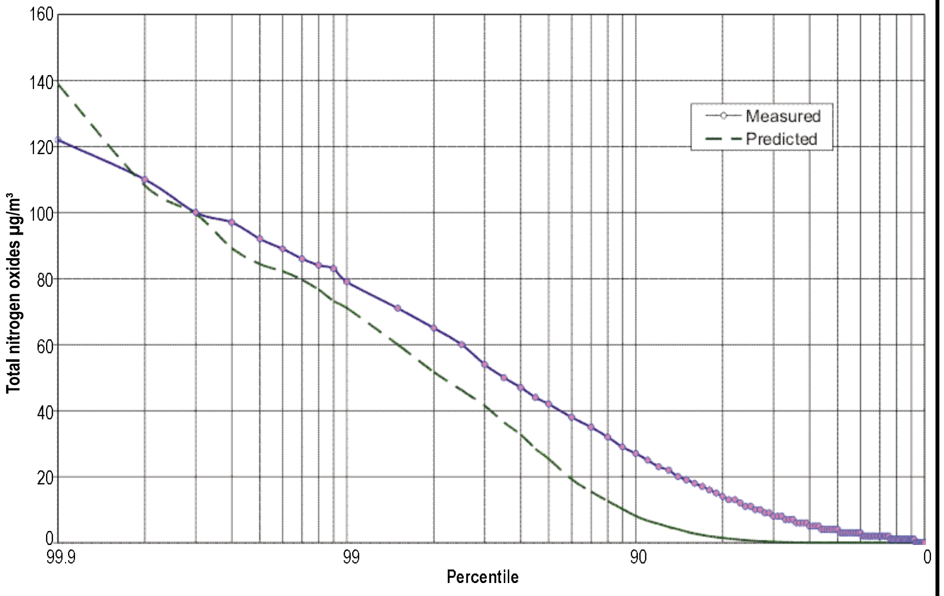
COMPARISON OF MEASURED AND PREDICTED CONCENTRATIONS OF TOTAL OXIDES OF NITROGEN AT EPA MONITORING LOCATIONS (µg/m³)

Figure: **1.4.6**

Rev. A

A4

a) Barney Point



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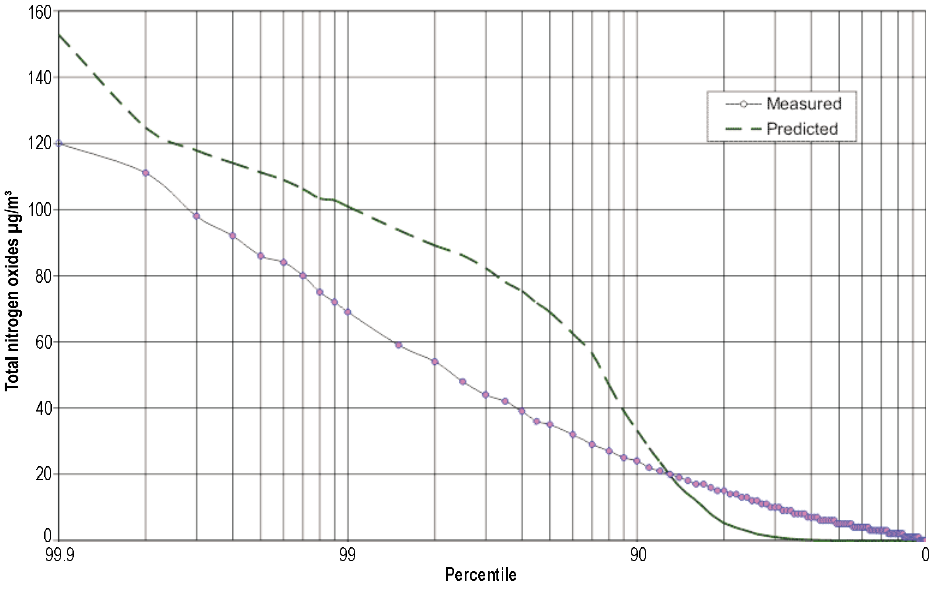
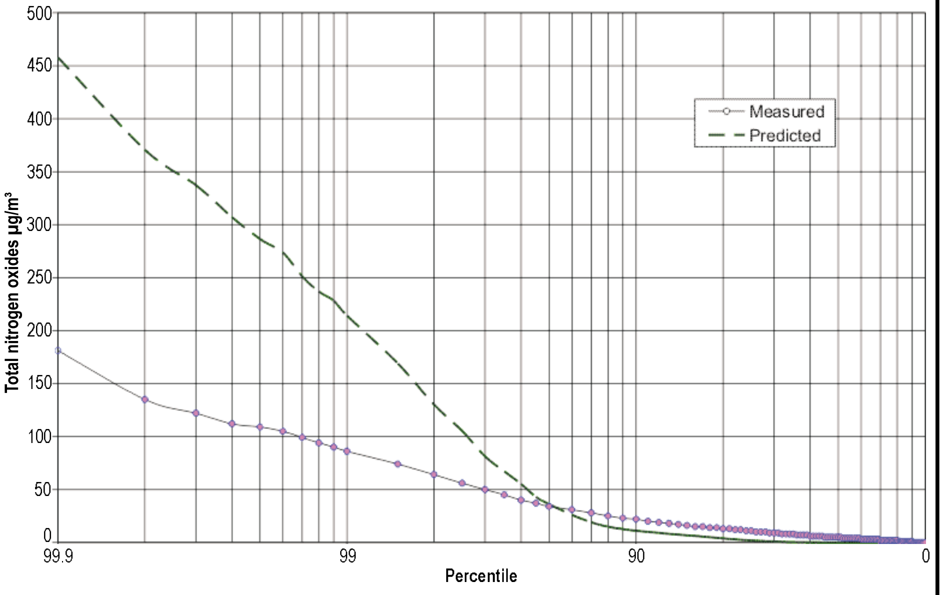


c) Clinton



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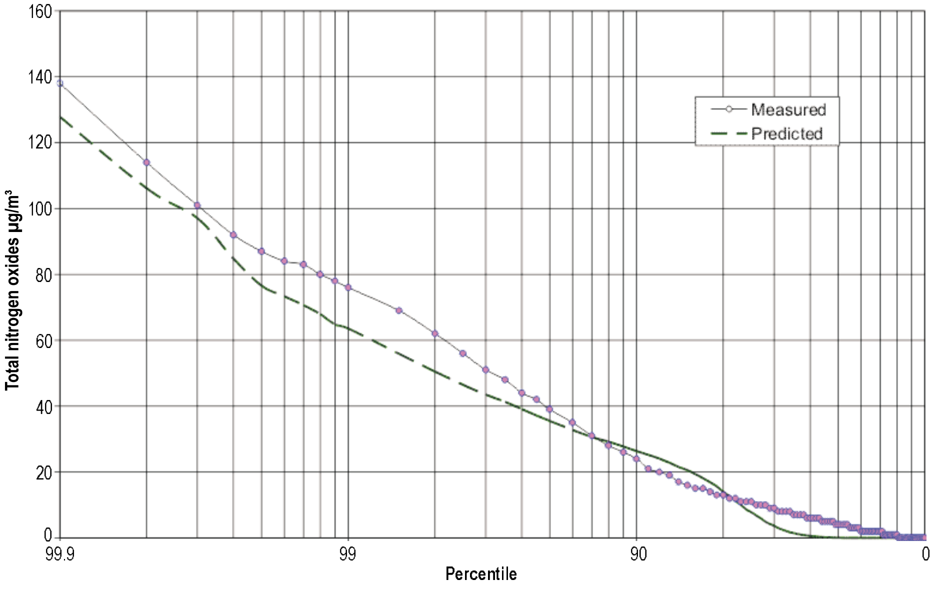


Client

Gladstone Pacific Nickel Ltd

Project

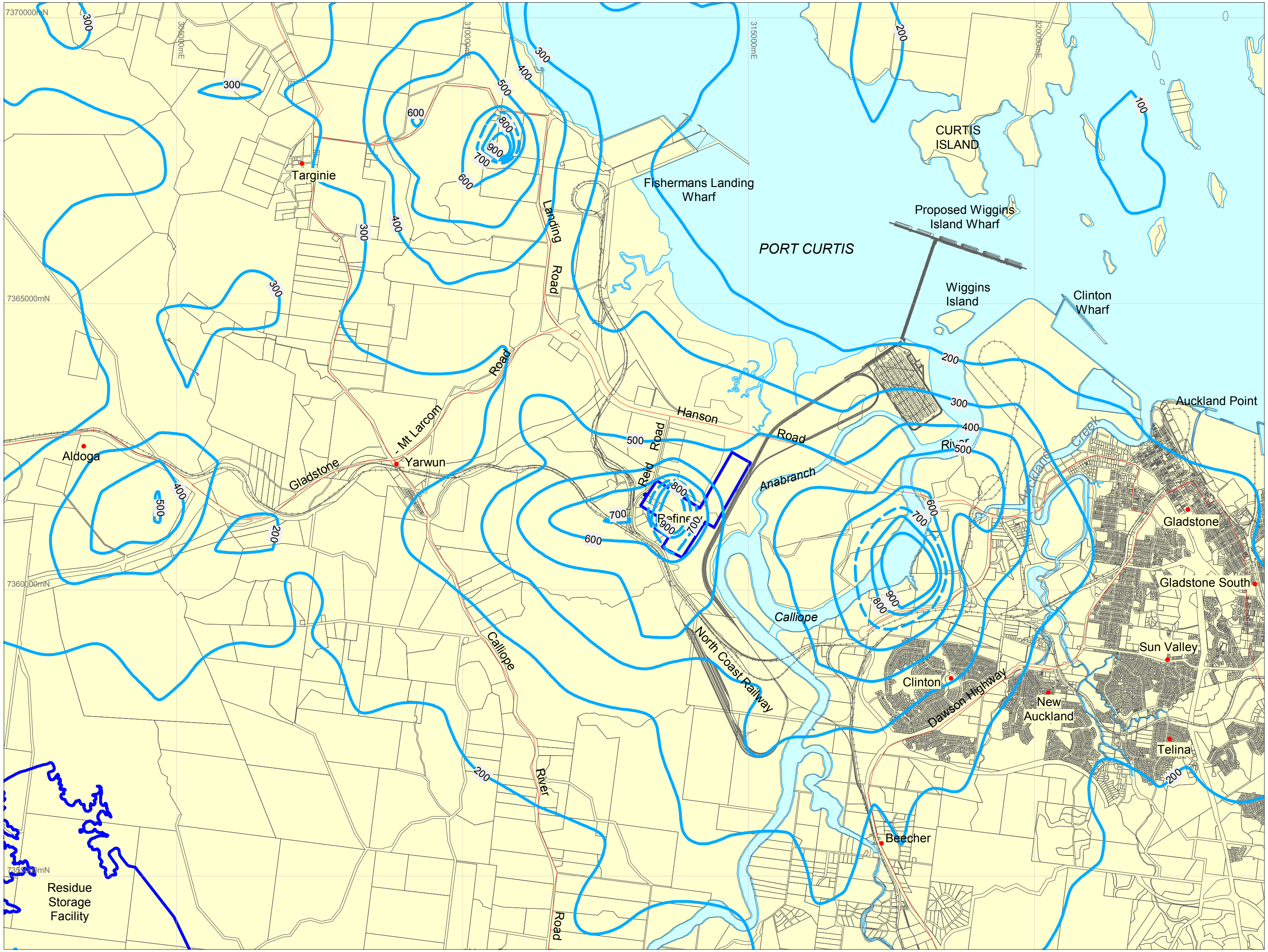
GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Title

LOCATION OF RESIDENTIAL AND INDUSTRIAL RECEPTORS USED FOR AIR QUALITY MODELLING

Drawn: TN
Approved: CMP
Date: 23-10-06
Job No: **4262 5791**
File No: 42625791-g-107.wor

Figure: **1.4.7**
Rev: A
A4



N

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Scale 1:100,000 (A4)

MGA Z56, GDA94

—200— SO_2 Concentration Contours (µg/m³)

- -700- - Air Quality Guideline

Client

Gladstone Pacific Nickel Ltd

URS

Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: **4262 5791**
File No: 42625791-g-044.wor

Title

99.9th PERCENTILE 10 MINUTE AVERAGE CONCENTRATION OF SO_2 DUE TO REFINERY (Stage 2) WITH BACKGROUND INDUSTRIAL SOURCES (µg/m³)

Figure: **1.9.1**
Rev: A
A4

URS

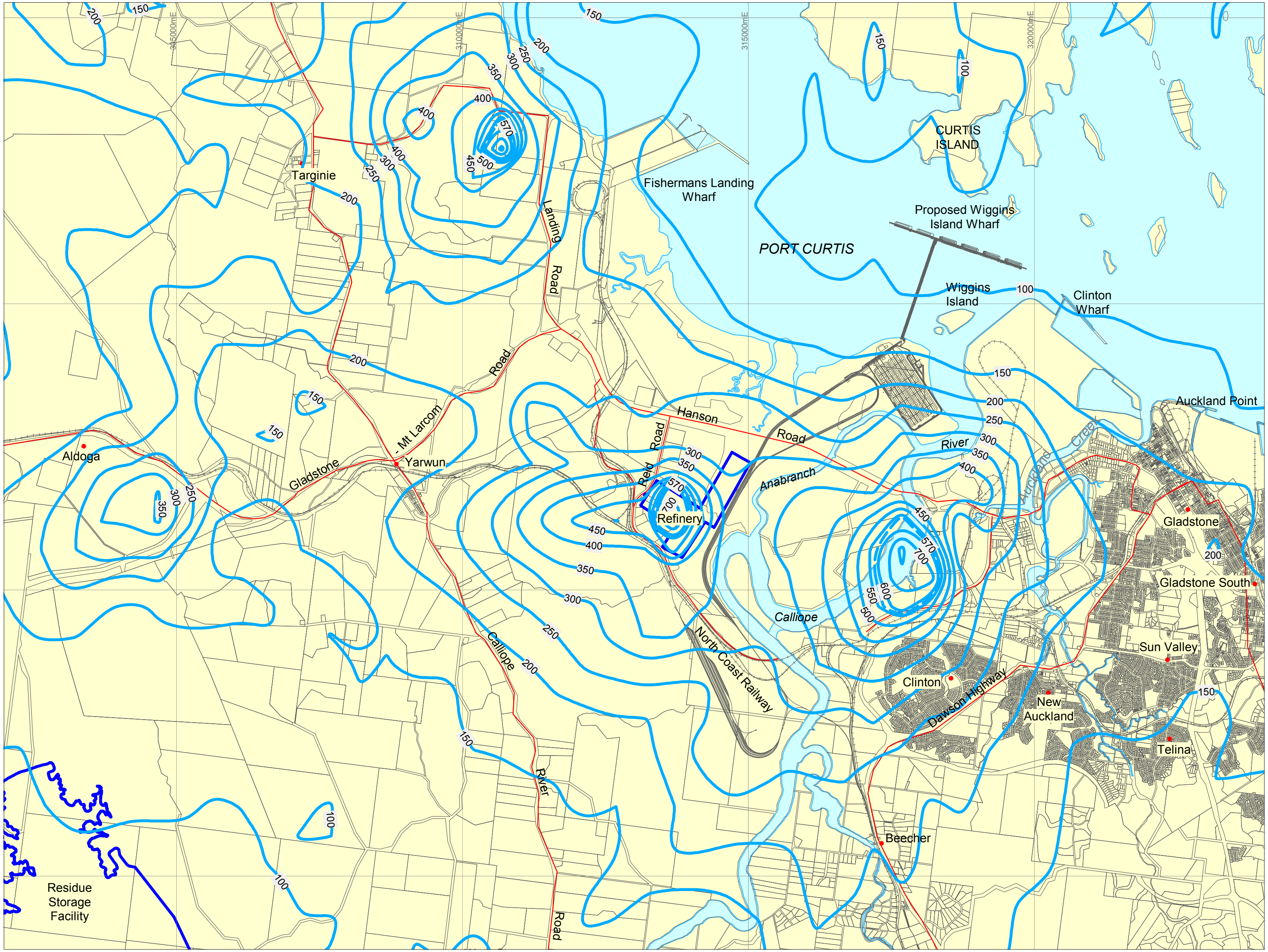
Client
Gladstone Pacific Nickel Ltd

Project
GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: 4262 5791
File No: 42625791-g-045.wor

Title
99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF SO_2 DUE TO REFINERY (Stage 2) WITH BACKGROUND INDUSTRIAL SOURCES (µg/m³)

Figure: 1.9.2
Rev: A
A4



N

0 1.25 2.5km
Scale 1:100,000 (A4)
MGA Z56, GDA94

200 SO_2 Concentration Contours (µg/m³)
570 Air Quality Guideline

Client

Gladstone Pacific Nickel Ltd

Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: **4262 5791**
File No: 42625791-g-046.wor

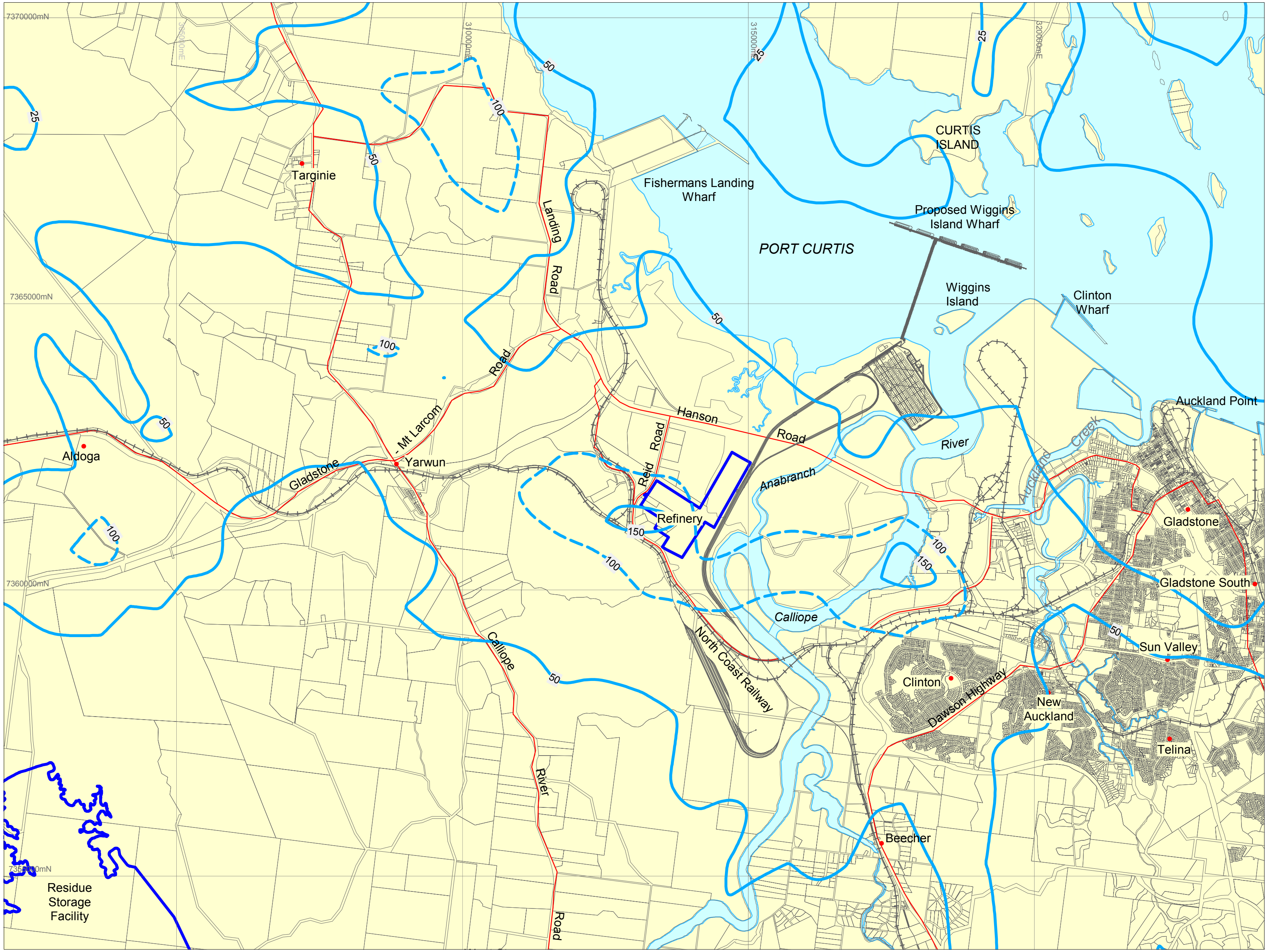
Title

MAXIMUM 24 HOUR AVERAGE CONCENTRATION OF SO_2 DUE TO REFINERY (Stage 2) WITH BACKGROUND INDUSTRIAL SOURCES (µg/m³)

Figure: **1.9.3**

Rev: A

A4

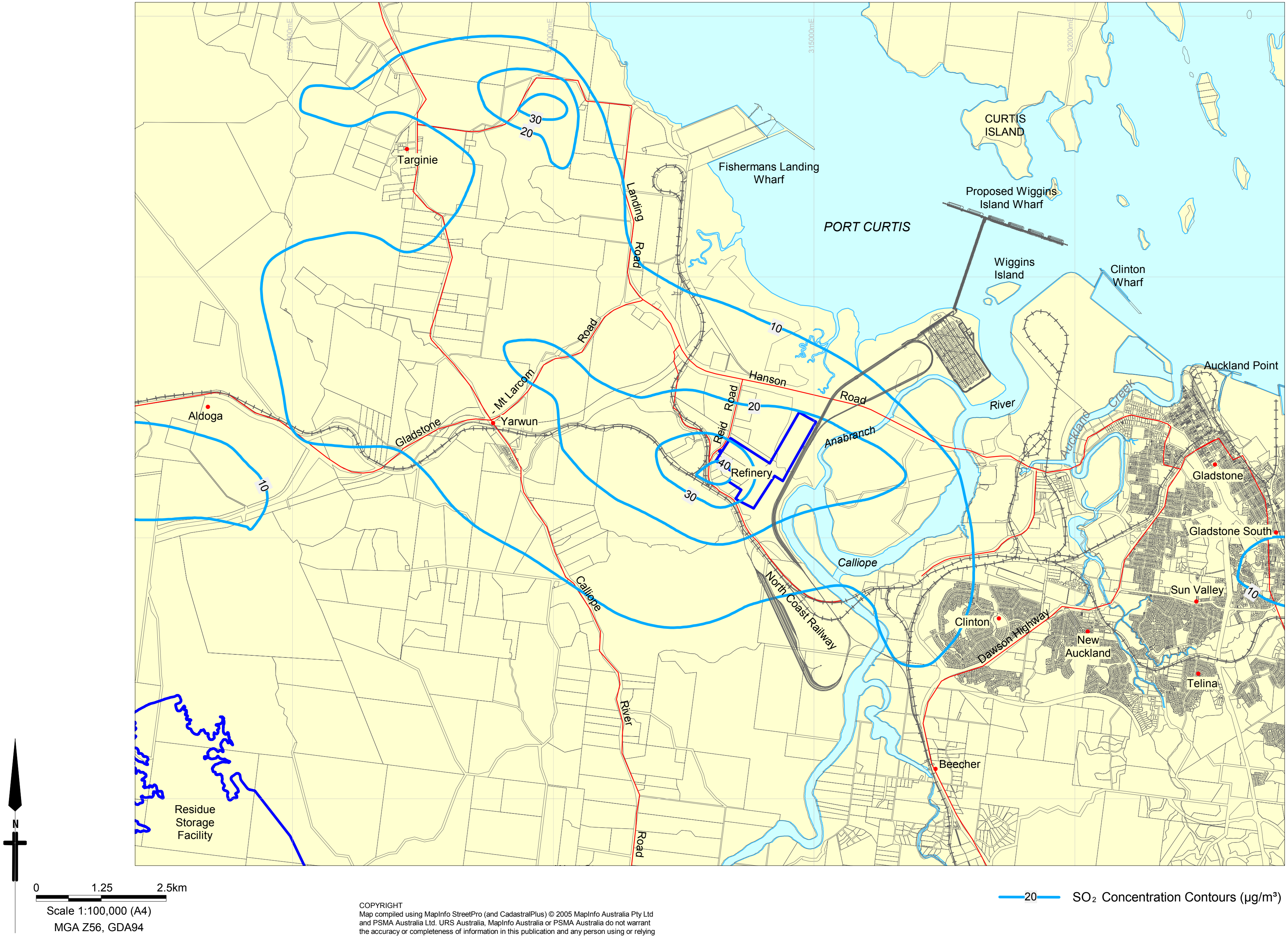


N

0 1.25 2.5km
Scale 1:100,000 (A4)
MGA Z56, GDA94

—200— SO_2 Concentration Contours (µg/m³)

- -100- - Air Quality Guideline



Client
Gladstone
Pacific Nickel Ltd

Project
GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 31-08-06
Job No: **4262 5791**
File No: 42625791-g-068.wor

Title
ANNUAL AVERAGE CONCENTRATION OF SO_2 DUE TO REFINERY (Stage 2) WITH BACKGROUND INDUSTRIAL SOURCES (µg/m³)

Figure: **1.9.4**
Rev: A
A4

URS

Client

Gladstone Pacific Nickel Ltd

Project

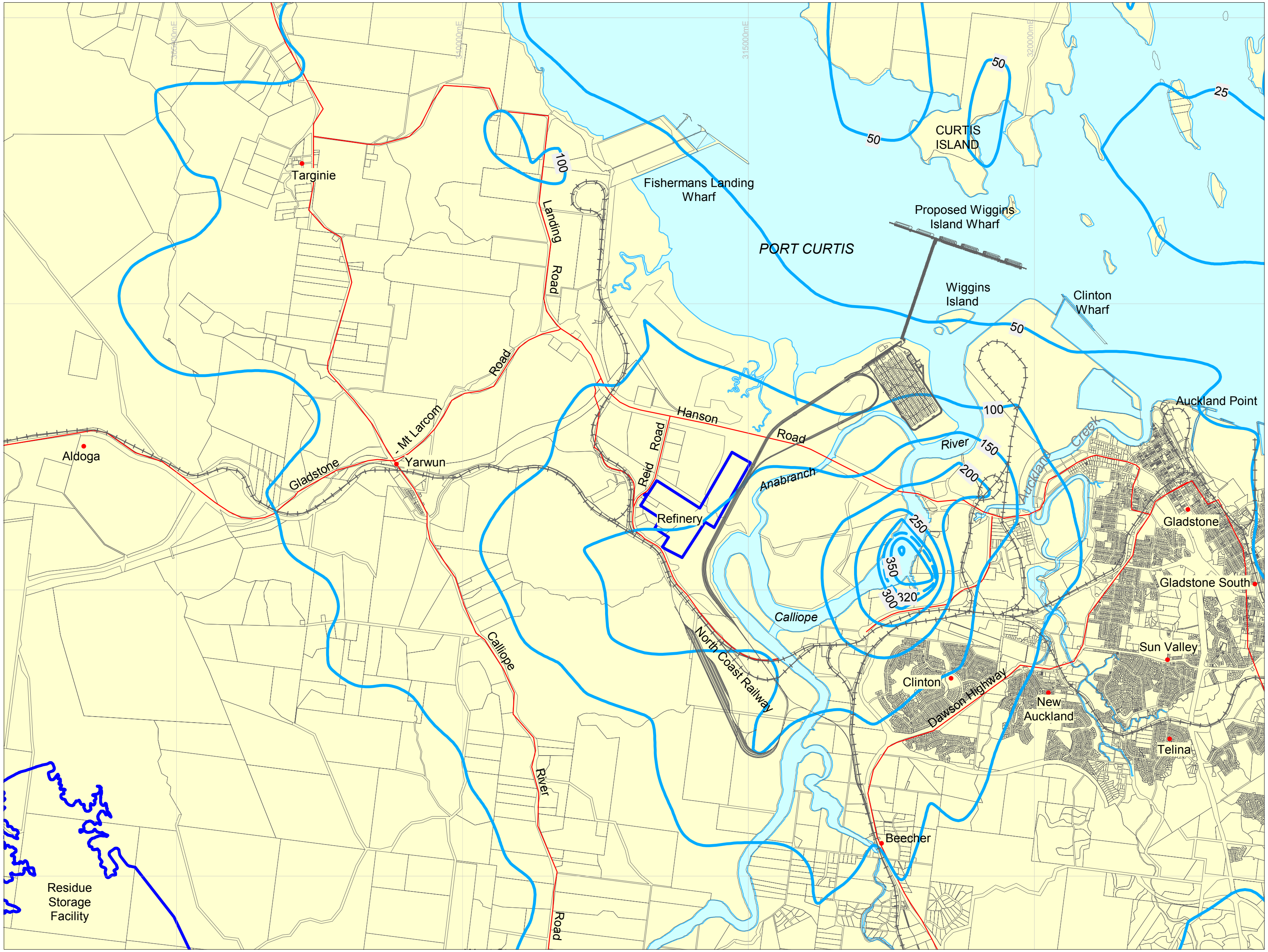
GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
Approved: CMP
Date: 31-08-06
Job No: **4262 5791**
File No: 42625791-g-047.wor

Title

99.9th PERCENTILE 1 HOUR AVERAGE CONCENTRATION OF NO_2 DUE TO REFINERY (Stage 2) WITH BACKGROUND INDUSTRIAL SOURCES (µg/m³)

Figure: **1.9.5**
Rev: A
A4



N

0 1.25 2.5km

Scale 1:100,000 (A4)

MGA Z56, GDA94

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200 NO_2 Concentration Contours (µg/m³)
320 Air Quality Guideline

Client

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Gladstone Pacific Nickel Ltd

Project

GLADSTONE NICKEL PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Drawn: TN
Approved: CMP
Date: 22-08-06
Job No: **4262 5791**
File No: 42625791-g-077.wor

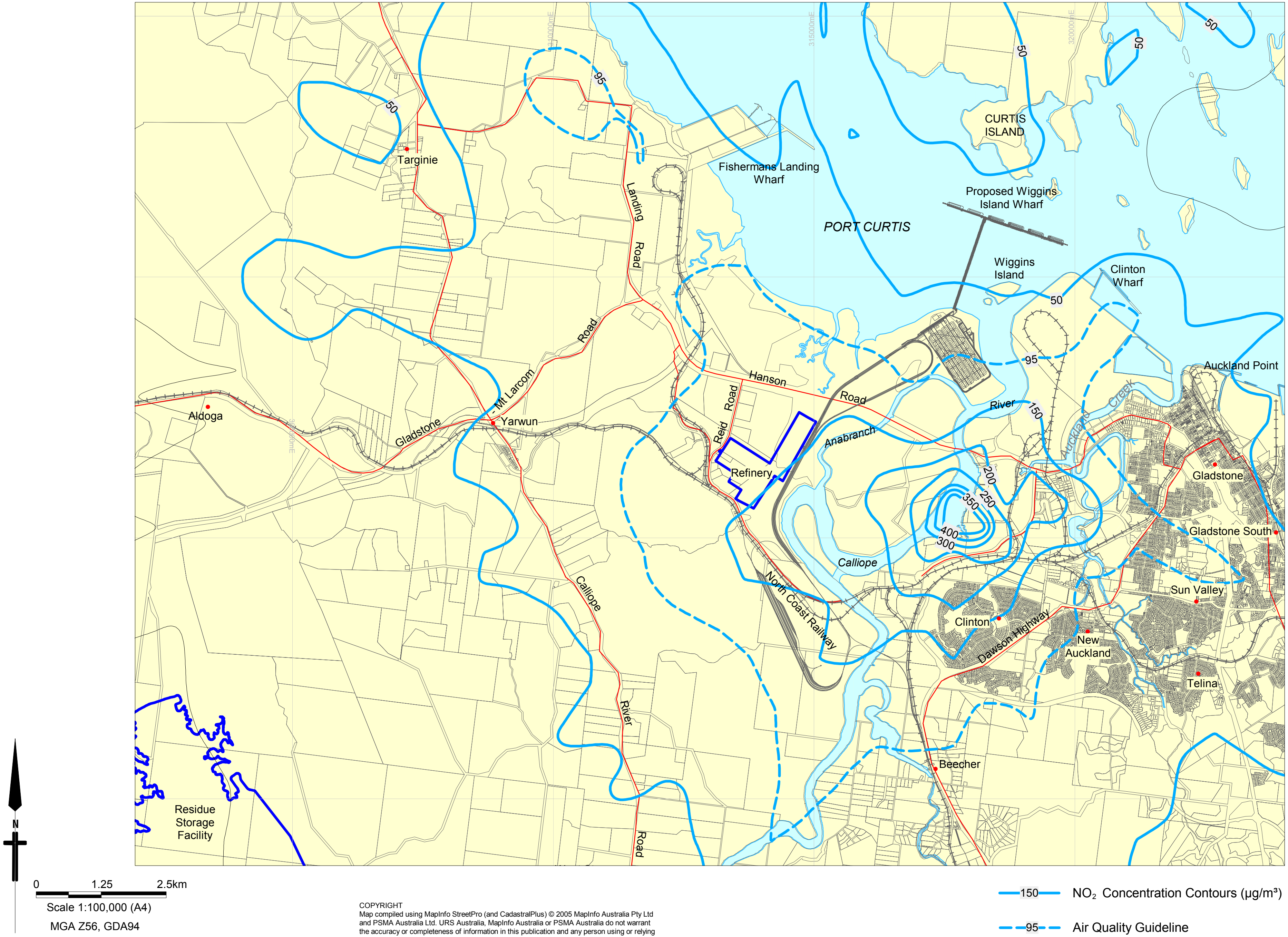
Title

MAXIMUM 4 HOUR AVERAGE CONCENTRATION OF NO $_2$ DUE TO REFINERY (STAGE 2) WITH BACKGROUND INDUSTRIAL SOURCES (µg/m³)

Figure: **1.9.6**

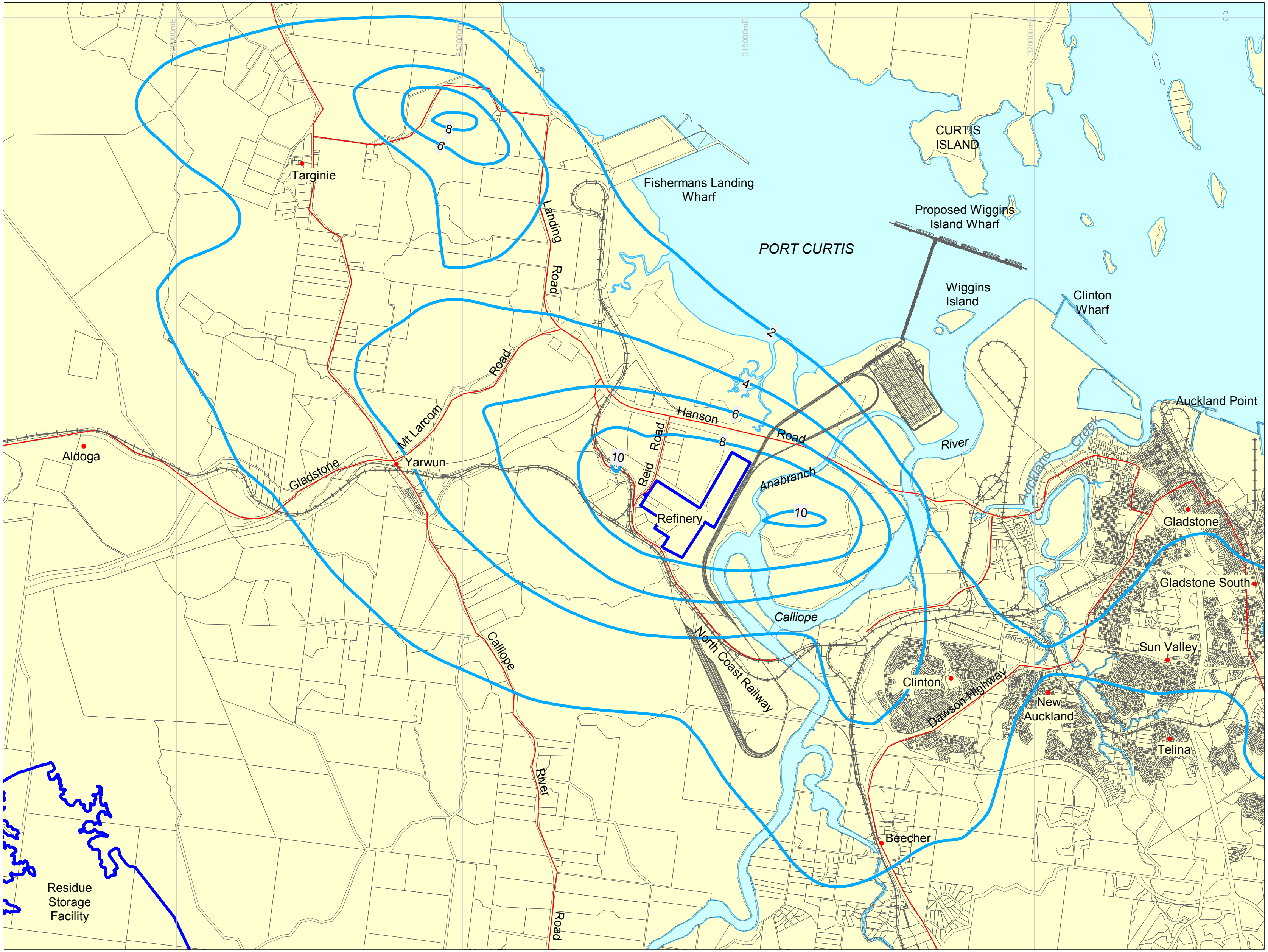
Rev: A

A4



150 NO $_2$ Concentration Contours (µg/m³)

95 Air Quality Guideline



0 1.25 2.5km

Scale 1:100,000 (A4)

MGA Z56, GDA94

2 NO_2 Concentration Contours (µg/m³)

Client

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Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
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File No: 42625791-g-067.wor

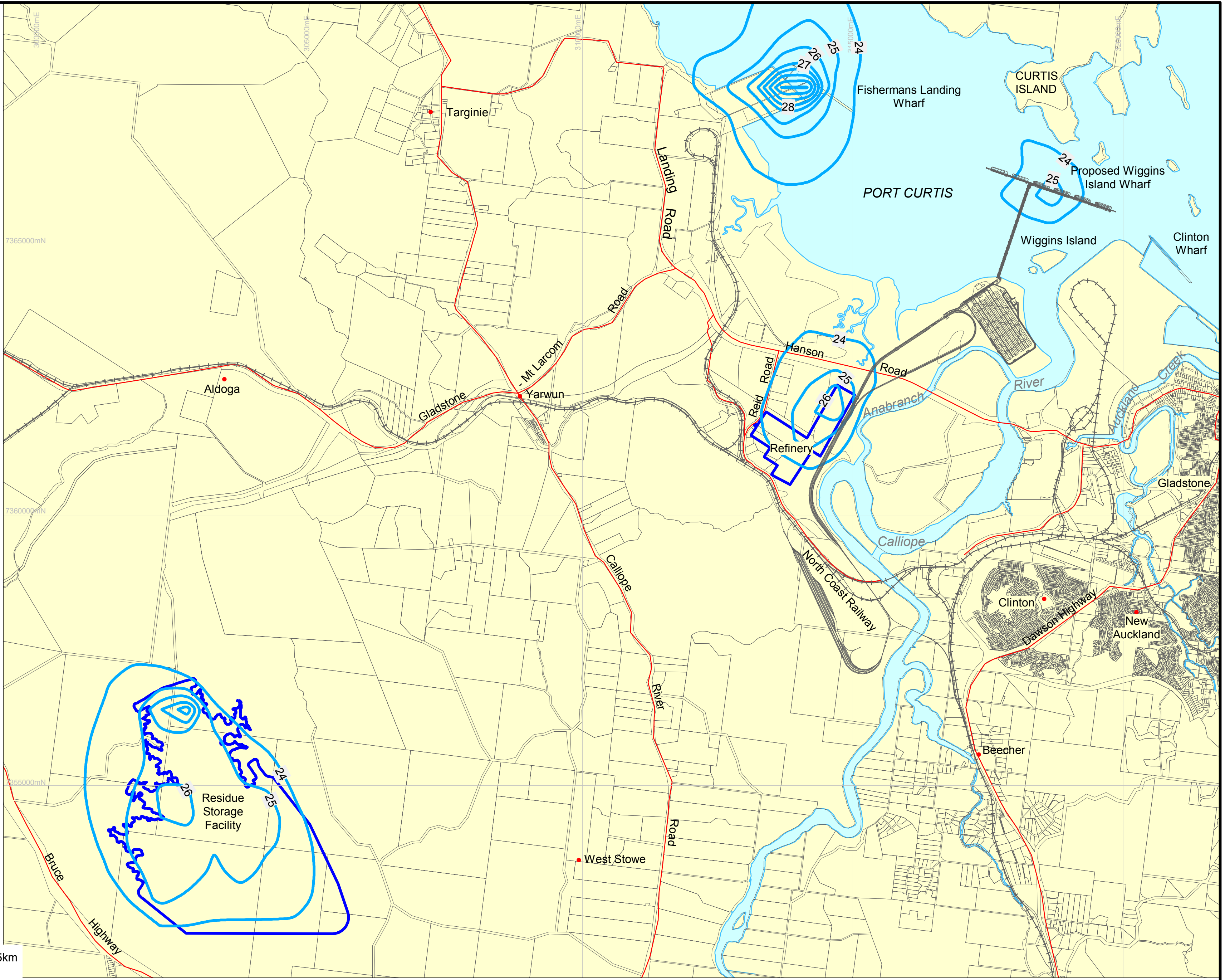
Title

ANNUAL AVERAGE CONCENTRATION OF NO_2 DUE TO REFINERY (Stage 2) WITH BACKGROUND INDUSTRIAL SOURCES (µg/m³)

Figure: **1.9.7**

Rev: A

A4



0 1.25 2.5km

Scale 1:100,000 (A4)

MGA Z56, GDA94

24 TSP Concentration Contours (µg/m³)

Client

Gladstone Pacific Nickel Ltd

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File No: 42625791-g-069b.wor

Title

ANNUAL AVERAGE CONCENTRATION OF TSP DUE TO REFINERY AND MATERIALS HANDLING (Stage 2) AND CONSTANT BACKGROUND CONCENTRATION (µg/m³)

Figure: **1.9.8**
Rev: B
A4

Client

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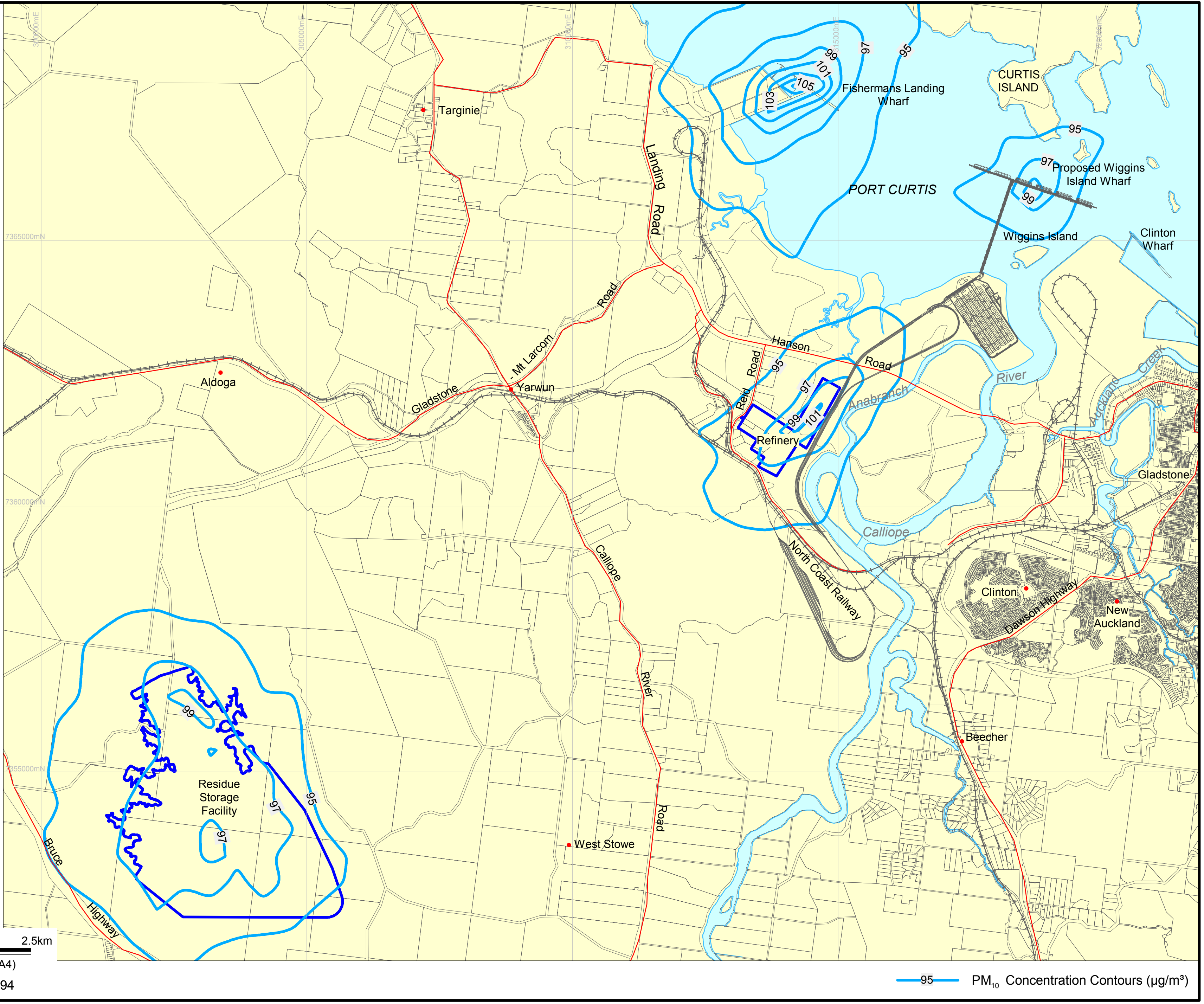
Project

GLADSTONE NICKEL PROJECT
AIR AND GREENHOUSE GAS ASSESSMENT

Title

MAXIMUM 24 HOUR AVERAGE CONCENTRATION OF PM_{10} DUE TO REFINERY AND MATERIALS HANDLING (Stage 2) AND CONSTANT BACKGROUND CONCENTRATION (µg/m³)

Drawn: TN
Approved: CMP
Date: 05-09-06
Job No: **4262 5791**
File No: 42625791-g-070b.wor
Figure: **1.9.9**
Rev: B
A4



N

0 1.25 2.5km
Scale 1:100,000 (A4)
MGA Z56, GDA94

Client

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AIR AND GREENHOUSE GAS ASSESSMENT

Drawn: TN
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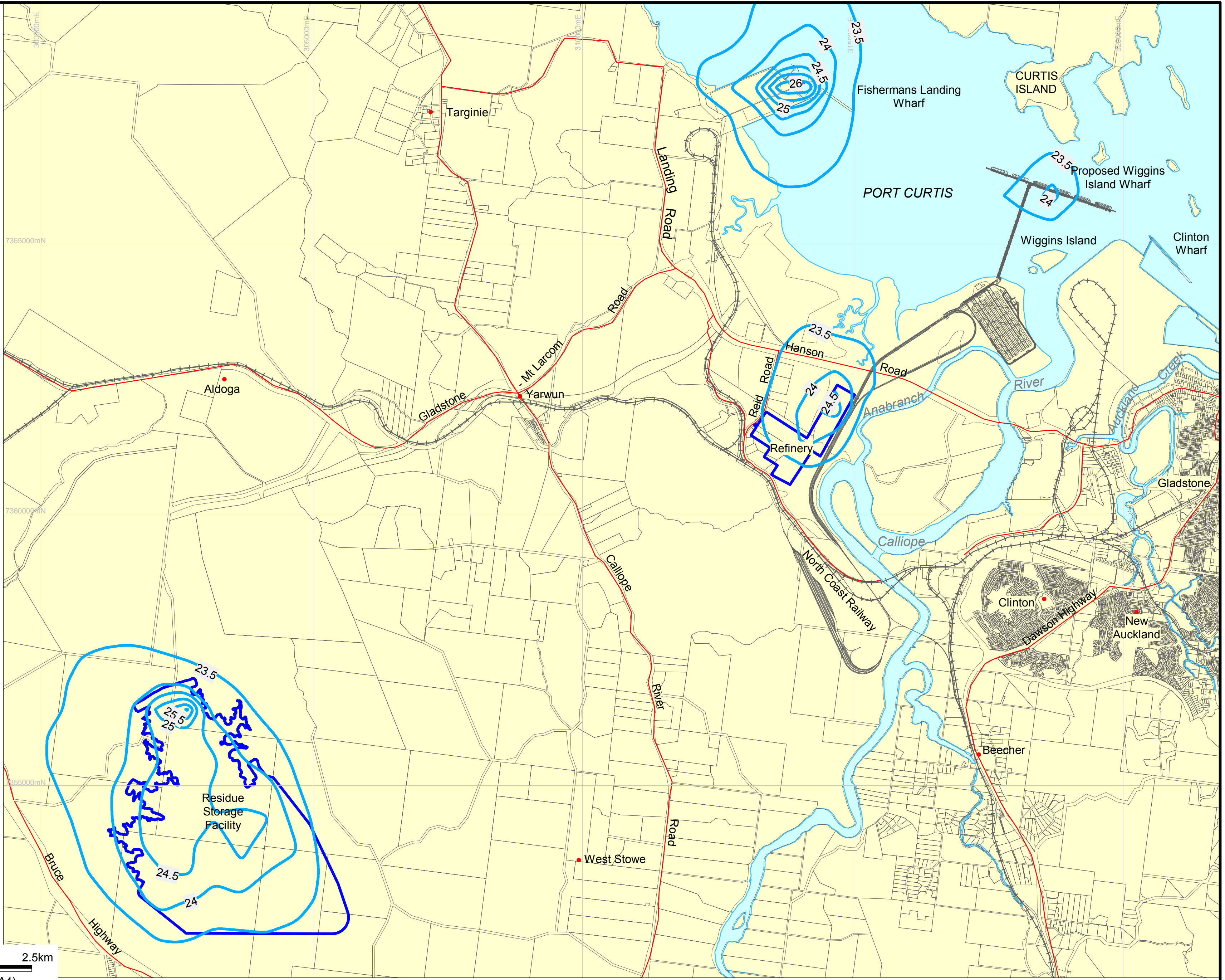
Date: 05-09-06
Job No: **4262 5791**
File No: 42625791-g-071b.wor

Title
ANNUAL AVERAGE CONCENTRATION OF PM_{10} DUE TO REFINERY AND MATERIALS HANDLING (Stage 2) AND CONSTANT BACKGROUND CONCENTRATION (µg/m³)

Figure: **1.9.10**
Rev: A
A4



N

0 1.25 2.5km
Scale 1:100,000 (A4)
MGA Z56, GDA94

24 TSP Concentration Contours (µg/m³)