SINCLAIR KNIGHT MERZ
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SYDNEY PORTS
FIRST PORT, FUTURE PORT

Port Botany Expansion

AIR QUALITY STUDY

SYDNEY PORTS CORPORATION

- 5/06/2003

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Executive Summary

Sydney Ports Corporation (SPC) proposes to expand the capacity of its operations at Port Botany shipping terminals. The proposal involves the construction of a new terminal on land to be reclaimed from Port Botany, and would be situated between the existing Patrick Terminal and Sydney Airport's Parallel Runway. The expansion is required in order to handle the continuing growth in containerised cargo.

Sinclair Knight Merz has been commissioned to undertake the air quality impact assessment for the Environmental Impact Statement (EIS) for the proposed works. The study assesses air quality impacts from both the construction of the proposed expansion and from operation of the new terminal. The study provides:

- an overview of air quality issues and ambient air quality criteria relevant to the proposed construction and operation of the new terminal;
- a review of existing ambient air quality and meteorology in the Port Botany area;
- quantification and assessment of dust[1] emissions and air quality impacts from the site during construction. This includes dredging and reclamation, construction of the berth and deck/hardstand, and construction of the beach and recreational facilities;
- quantification and assessment of sulfur dioxide (SO_2), oxides of nitrogen (NO_x), particulate matter (PM_{10}), and carbon monoxide (CO) air quality impacts associated with operation of the terminal, as a result of ship, train, truck and dockside equipment emissions; and
- recommendations of monitoring requirements and mitigation measures to be implemented for safeguarding against adverse air quality impacts during construction and operation of the proposed new terminal.

Air Quality Issues Relevant to Proposal

The proposed development at Port Botany involves: (1) Reclamation of approximately 60 ha of land through dredging of some areas of Port Botany; (2) The provision of an additional 1.85 km of wharf face; (3) Up to 5 additional shipping and 6 tug berths; (4) Works along Foreshore Beach to include the construction of a boat ramp and recreational areas; and (5) Earthworks within Penrhyn Estuary. The air quality impact assessment assesses impacts from both construction of the proposed new terminal and these facilities, as well as an assessment of operational emissions from the anticipated numbers of ships whilst at berth, trucks and trains entering the site, and dockside equipment. This has been considered for all terminals operating at a forecast throughput of 3.2 million twenty-foot equivalent containers (TEUs).

The proposed construction works would be undertaken as a progression of various stages, primarily involving the following activities: boat ramp and tug berth construction, dredging and reclamation activities, wheel-generated dust from trucks, and beach enhancement. Three construction stages were identified as having the

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[1]In this report "dust" is defined to mean particles of all sizes, including: (1) The smaller respirable particles with diameters less than 10 μm, known as fine particulate matter (PM_{10}); and (2) Particles with diameter larger than 10 μm that contribute to dust deposition impacts.

potential to provide the most significant dust impacts on nearby residences. These stages were identified over 3-month work periods and will be detailed shortly.

The key pollutants associated with the construction works are the criteria pollutants, fine particulate matter (PM_{10}), total suspended particulate matter (TSP) and dust deposition. The New South Wales Environment Protection Authority (NSW EPA) criteria for these pollutants are outlined below.

The key local air emissions relating to the operation of the proposed new terminal and upgrade to the Patrick Terminal are nitrogen oxides (NO_x), sulfur dioxide (SO_2), fine particulate matter (PM_{10}) and carbon monoxide (CO). These pollutants are the key criteria pollutants considered by the NSW EPA as being relevant to assess this proposed activity. These emissions are from both ship main engines and auxiliary engines operating at berth, truck and train emissions whilst on site, and diesel operated dockside equipment emissions. Dockside equipment emissions are from rubber tyre gantries, straddle carriers and reach stackers.

Other pollutants such as greenhouse gases are assessed in terms of carbon dioxide (CO_2) emission.

Potential air quality impacts for both the construction and operational phases of the project have been assessed using the methodology of the NSW EPA document *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2001).

Air Quality Objectives

The NSW EPA has developed impact assessment criteria for pollutants in their *Approved Methods* document (mentioned above). These criteria have been based on the National Environment Protection Measure (NEPM) for Ambient Air Quality.

The air quality objectives used by the NSW EPA, which are relevant to assessing the construction and operational air quality impacts of this proposal are listed in **Table ES-1** and **Table ES-2** respectively. These criteria are listed in association with the results of the assessment such that a comparison of the air quality impacts with the relevant criteria can be made.

Existing Air Environment

Dispersion Meteorology

An assessment of the local environment and meteorological conditions was undertaken for Port Botany. This is important for describing the behaviour of plume dispersion within the local airshed (atmospheric environment) of Port Botany and surrounds.

The Port Botany terminals are located on the north-eastern shoreline of Botany Bay, approximately 5 km inland from the Tasman Sea. Botany Bay is located on the eastern fringe of the Sydney Basin, with the Port's location therefore lending itself to morning westerly winds (particularly during the cooler months) associated with morning drainage flows from the higher regions west of Sydney and across Parramatta. The local topography is generally flat with surrounding suburban areas rising to only 20-30 m above sea level. There is however an elevated area at the northern head of Botany

Bay, with relatively sharp land inclination rising up to the NSW Golf Club and coastal cliffs. The large surface area of Botany Bay (approximately 4,163 ha) immediately to the south/south-west of the Ports lends itself to afternoon winds blowing across the Bay due to differential air pressure gradients.

Meteorological data for use in the AUSPLUME dispersion modelling was obtained from the Bureau of Meteorology's monitoring station at Sydney Airport. AUSPLUME is a pollution dispersion model, suitable for industry and government to predict ground-level concentrations of pollutants from a variety of sources. It is a Gaussian model that assumes that, over time, the average concentration distribution of the plume is a Gaussian distribution. It is the regulatory model of the EPA and was approved for use in 2001.

Existing Air Quality

Site specific air quality criteria have been determined for this project, and are shown in **Table ES-1** and **Table ES-2** for construction and operational phases respectively along with the results of all assessments. These criteria have been determined from an assessment of the background air quality within the Port Botany region, such that the site specific criterion represents the difference between the NSW EPA ambient air objective and the existing background level.

For the purposes of this assessment, background air quality data has been made available from monitoring data collected at Sydney Airport's Mascot monitoring station during 2000-2002. This station is located approximately 2.7 km from the residential area closest to the site of the proposed new terminal.

Background air quality in the Port Botany region is largely influenced by operations of the Sydney (Kingsford Smith) Airport, located north-west of the port, with the Parallel Runway situated 1.1 km due west of the Patrick Terminal. Sydney's Central Business District (CBD) is located 11 km north of the terminals, with associated vehicular emissions influencing local air quality in the Port Botany area.

Construction Phase Air Quality Assessment

Sources of Dust Emission

The main air quality impacts considered for impact assessment (that is, included within the dispersion modelling of dust emissions) accounted for the above-water construction works and preliminary site stabilisation works. A worst-case scenario of construction activity (in terms of location of stages to residential receivers) was adopted for the purposes of the assessment.

There were three construction scenarios identified from the sequences detailed on the project plan as worst-case scenarios in terms of dust emission. These scenarios were defined over 3-month work periods, and the important construction activities within those periods are listed below:

- Construction Scenario 1 – Y1P2 ("Y1P2" stands for "Year 1, Period 2", where "Period 2" refers to the 2nd 3-month period of Year 1). Y1P2 includes the following activities judged important for dust emissions:
  - Boat Ramp / Tug Berth Construction;

  - Reclamation of the first works site area at western end of existing Patrick Terminal;
  - Rock Berm Placement; and
  - Wheel Generated Dust (WGD) on the main access road.
- Construction Scenario 2 – Y2P2, with the following activities considered important for dust emissions:
  - Reclamation of main berth areas (back tip of rock bund material for embankment);
  - Rock Armouring during Berth/Deck Construction and WGD from truck deliveries of pre-casts for berth construction; and
  - Estuary/beach Enhancement.
- Construction Scenario 3 – Y3P1, with the following activities considered important for dust emissions;
  - Reclamation (movement of pre-loading material) of new main berth areas (scraper, compactor and grader operations);
  - Rock Armouring during Berth/Deck Construction and WGD from truck deliveries of pre-casts for berth construction; and
  - Road and rail works.

Dust impacts were assessed for PM_{10} (24-hour) concentrations and monthly dust deposition levels.

Construction Phase Air Quality Assessment Results

A summary of the AUSPLUME air dispersion modelling results for dust emissions for the three scenarios listed above, is provided below. It is noted that the PM_{10} results predict the 6^{th}highest PM_{10} (24-hour) concentrations in order to provide direct comparisons with the NEPM PM_{10} objective that allows five PM_{10} (24-hour) exceedences of the 50 $\mu g/m^3$ criterion per year.

Dispersion modelling results for the construction phase are, for:

- Scenario Y1P2:

Predicted PM_{10} concentrations generated through site activity combined with existing background PM_{10} levels do not exceed the EPA criteria of 50$\mu g/m^3$ at any residential location.

Dust depositions predicted within residential areas do not exceed the project criterion of 2 g/m^2/month. The majority of houses to the north of Foreshore Road are well below this level, with levels predominantly from 0.1 to 0.2 g/m^2/month.

Predicted TSP concentrations emitted during construction are well below the EPA criteria of 90$\mu g/m^3$ beyond the site boundary.

- Scenario Y2P2:

During construction operations at the Port Botany site impact levels of PM_{10} will result in at most 2 additional exceedances of the EPA criteria of 50 $\mu g/m^3$. The NEPM for Ambient Air Quality allows for 5 exceedances of the 50 $\mu g/m^3$. As such this result is not considered significant given the annual average of 27 exceedances of the 50 $\mu g/m^3$ measured in the vicinity of the site in recent years.

In this case the dust depositions predicted within the residential area do not exceed the project criterion of 2 g/m^2/month. The highest modelled dust deposition in a residential area being between 1-2 g/m^2/month

Predicted annual TSP concentrations are significantly lower than the EPA criteria beyond the site boundary.

- Scenario Y3P1:

As for Y2P2 during construction operations at the Port Botany site impact levels of PM_{10} will result in at most 2 additional exceedances of the EPA criteria of 50 $\mu g/m^3$.

The dust deposition result for this scenario is similar to the previous scenario, with dust depositions predicted within the nearest residential areas of between 1-2 g/m^2/month.

TSP concentrations are again predicted to be well below the EPA criteria of 90$\mu g/m^3$ within residential areas surrounding the port.

The results are summarised below in **Table ES-1**. The maximum concentrations and depositions are impacts due to construction activities only, and do not include background pollutant levels. Therefore, the maximum concentrations/depositions should be compared with the criteria in the project criterion column.

- **Table ES-1 Results of Air Quality Assessment – Construction Phase**

Key Pollutant & Averaging Period	Scenario	NSW EPA Criterion ($\mu g/m^3$)	Average Background Conc* ($\mu g/m^3$)	Project Criterion ($\mu g/m^3$)	Max Conc at a Residential Receiver ($\mu g/m^3$)
PM_{10} (24-hour)	Y1P2	50 $\mu g/m^3$	34 $\mu g/m^3$	16 $\mu g/m^3$	≈ 2 $\mu g/m^3$
	Y2P2	50 $\mu g/m^3$	34 $\mu g/m^3$	16 $\mu g/m^3$	≈ 16 $\mu g/m^3$
	Y3P1	50 $\mu g/m^3$	34 $\mu g/m^3$	16 $\mu g/m^3$	≈ 16 $\mu g/m^3$
Dust Deposition (Annual)	Y1P2	4 g/m^2/mon	2 g/m^2/mon	2 g/m^2/mon	≈ 0·3 g/m^2/mon
	Y2P2	4 g/m^2/mon	2 g/m^2/mon	2 g/m^2/mon	≈ 2 g/m^2/mon
	Y3P1	4 g/m^2/mon	2 g/m^2/mon	2 g/m^2/mon	≈ 2 g/m^2/mon

* the combined average of monthly average and monthly maximum values

Operational Phase Air Quality Assessment

Sources of Emission and Methodology of Emission Estimation

The basis of the impact assessment of operational emissions was to assess air impacts for SO_2, NO_x, PM_{10} and CO emissions from three scenarios:

- Scenario 1 – existing case;
- Scenario 2 – the proposed terminal operating by itself at forecast demand (1.6 mill TEU); and
- Scenario 3 – all the terminals operating at a throughput of 3.2 mill TEU.

NO_x emissions have been modelled to provide ground level concentrations of NO_2, such that a comparison with the relevant NSW EPA ambient air objective could be made. This was undertaken by applying appropriate NO_x to NO_2 ratios to emissions estimates.

The modelling of CO emissions to predict ground level concentrations was not undertaken as part of the impact assessment. CO emissions represent either a lower quantity of emission (g/s) compared to NO_x and SO_2 emissions (for the case of ship emissions), or are not more than one order of magnitude greater than NO_x emissions. The NSW EPA impact assessment criteria for CO are significantly higher (3 orders of magnitude) than for NO_x and SO_2, and as such CO impacts expected at residential receivers would be much lower than the relevant criteria. Modelling of CO emissions was therefore not considered necessary.

'Peak' ship emissions were assessed by assuming a worst case scenario in any given hour, and a worst case positioning of ships whilst at berth at Port Botany was assessed (in terms of ship TEU size). The ship emissions inventory was developed by assuming all ships operate their auxiliary engines continuously whilst at berth at 100% maximum continuous rating (MCR), with the main engines also being on for half an hour (30 minutes) upon arrival and half an hour when departing at 30% MCR. Main engines have been assumed to be slow speed engines using Marine Diesel Oil (MDO) whilst at berth, which has an average fuel sulfur content of 1.5% weight of sulfur per weight of fuel (w/w).

'Annual' emissions were determined on the basis each ship will have it's auxiliary engines operating at 100% MCR for 32 hours at berth, with main engines operating at 30% MCR for half an hour each when arriving and departing the terminal.

'Peak' truck and train emissions have been determined from a 'peak week', which has been defined as 1.33 times the normal operational activity, in terms of truck and train arrivals. Trains have been modelled as being push-pull with a diesel locomotive at each end. Both trucks and trains are assessed whilst moving on-site and during idling operations.

Future emission factors take into account the expected improvements in diesel engine technology for ships, trucks, trains, and dockside equipment. These improvements are mostly due to the introduction of low NO_x combustion technology within diesel engines and the forecasted reduction in fuel sulfur content.

Operational Phase Air Quality Assessment Results

The results of dispersion modelling of operational emissions are shown in **Table ES-2**.

Impacts from SO_2 emissions were assessed from shipping emissions only, as the SO_2 contribution from ships to total SO_2 emission is significantly higher than from trucks and trains, and up to 2-3 times higher than dockside equipment for Scenario 1 and up to 5 times higher for the future scenarios (due to differing fuel types and diesel engine technology used between the various source groups). As such, SO_2 emissions from these other source groups are not considered to have any significant accumulative impact on air quality.

The results from **Table ES-2** indicate there are no exceedences of the site criteria for any of the pollutants within the residential area. The maximum predicted NO_2 (1-hour) concentration beyond the SPC boundary is 190 $\mu g/m^3$ and 186 $\mu g/m^3$ for Scenarios 1 and 3 respectively, which compare to the Project criterion of 182 $\mu g/m^3$ and the NSW EPA objective of 246 $\mu g/m^3$. These slight exceedences occur within Penrhyn Estuary for Scenario 1 and within Botany Cemetery for Scenario 3, both areas with no sensitive residential receivers.

- **Table ES-2 Operational Assessment Results**

Key Pollutant & Averaging Period	Scenario	NSW EPA Criterion ($\mu g/m^3$)	Average Background Conc* ($\mu g/m^3$)	Project criterion ($\mu g/m^3$)	Max Conc at a Residential Receiver ($\mu g/m^3$)	Max Conc Beyond SPC Boundary** ($\mu g/m^3$)
NO_2 (1-hour)	1 – Existing	246	64	246	200	220
	2 - New Terminal at Capacity	246	64	246	150	175
	3 - All Terminals at Capacity	246	64	246	210	230
NO_2 (Annual)	1 – Existing	62	24	62	35	40
	2 - New Terminal at Capacity	62	24	62	34	39
	3 - All Terminals at Capacity	62	24	62	35	40
PM_{10} (24-hour)	1 – Existing	50	34	16	4	9
	2 - New Terminal at Capacity	50	34	16	4	7
	3 - All Terminals at Capacity	50	34	16	7	13
PM_{10} (Annual)	1 – Existing	30	20	10	1	2
	2 - New Terminal at Capacity	30	20	10	1	2
	3 - All Terminals at Capacity	30	20	10	2	4
SO_2 (10-minute)	1 – Existing	712	N/A	712***	155	190
	2 - New Terminal at Capacity	712	N/A	712***	100	115
	3 - All Terminals at Capacity	712	N/A	712***	205	205
SO_2 (1-hour)	1 – Existing	570	27	543	145	245
	2 - New Terminal at Capacity	570	27	543	130	170
	3 - All Terminals at Capacity	570	27	543	210	270
SO_2 (24-hour)	1 – Existing	228	11	217	45	70
	2 - New Terminal at Capacity	228	11	217	45	65
	3 - All Terminals at Capacity	228	11	217	90	100
SO_2 (Annual)	1 – Existing	60	6	54	3	5
	2 - New Terminal at Capacity	60	6	54	3	5
	3 - All Terminals at Capacity	60	6	54	8	14

* the combined average of monthly average and monthly maximum values
** on land, that is not including within Botany Bay
*** background data for 10-minute averaging period is not available. As such, the NSW EPA ambient air objective for SO_2 (10-minute) of 712 $\mu g/m^3$ is used as the site specific criterion to assess impacts

Mitigation Measures and Monitoring Requirements

Mitigation of Construction Phase Dust Impacts

More than half of the impacts from dust emissions are attributable to wind generated dust from exposed work areas and stockpiled sands. Erosion control practices to minimise wind-generated dust can include:

- keeping the soil/sand wet;
- placement of grasses and other vegetation types that bind soils;
- wind breaks; and
- placement of a thin bituminous membrane.

Modelling of dust emissions has incorporated dust control measures that are likely to be used by SPC during construction activity. These include water sprays over active work areas and stockpiles, which generally provide 50% control efficiency, and wind breaks, which together with water sprays generally reduce dust emissions by up to 60-70%.

Wheel-generated dust from trucks accessing the Berth Construction Phase site area has been modelled as trucks moving on a gravel (unsealed) road surface along the site of the temporary bituminous emulsion, with level 2 watering (>2 $L/m^2/hr$). This achieves a 25% reduction of dust emissions from wheel-generated dust.

Mitigation of Operational Impacts

Irrespective of the fact that the expanded Port Botany is shown here to result in acceptable levels of air quality impact the development will result in increased numbers of trucks and trains using Sydney road and rail networks in the future. While the operations of these modes is not the direct responsibility of SPC nor do they have any control over truck and train operations it is considered prudent that SPC continually investigate all means available to reduce air emissions associated with their operations.

For example in the future SPC could consider alternative energy for ships at berth as opposed to operating auxiliary engines that use MDO. Options may include supply of shore power. Emissions from dockside equipment can be reduced by the installation of catalytic converters within diesel engines or the use of exhaust filtration devices and replacing existing equipment as new engine technology of alternative fuels to diesel becomes available.

Monitoring Requirements

It is recommended a high-volume air sampler and on-site meteorological station be used to monitor dust emissions (as PM_{10} and TSP) during construction of the proposed new terminal. Furthermore, three dust deposition gauges should be located in surrounding residential areas where dust impacts are likely to be greatest.

Conclusions

There are expected to be only marginal increases in ambient concentrations of $NO_{2,}$, SO_2, PM_{10} and CO as a result of operation of the proposed new terminal, with dispersion modelling of operational emissions showing no exceedences of the site criteria in residential areas.

The operation of the Port Botany expansion is expected to reduce greenhouse gas emissions by approximately 505,000 tonnes per annum in the long term when container volume in Sydney reaches approximately 3 million, when compared to the "do nothing" scenario. Construction of the new terminal and upgrade to existing terminals at Port Botany is therefore beneficial in terms of the large reduction of greenhouse gas emissions.

Acceptable levels of air quality impacts are predicted for the construction of the expanded Port Botany. Dust mitigation measures as set out above will, however, need to be incorporated into the project.

1. Introduction

1.1 General Introduction

Sydney Ports Corporation (SPC), a State-owned Corporation, established in 1995 to bring greater commercial and customer focus to the management of international shipping in Sydney, proposes to expand the existing port operations at Port Botany.

Studies carried out by Access Economics have forecast continued strong growth in both containerised and non-containerised cargo trade. Growth rates of between 4% and 6% per annum have been predicted, which indicates a trade throughput demand at Port Botany alone of some 1.6 million twenty-foot equivalent containers (TEU) by 2010. Capacity of the existing port facilities would be reached at about this time.

On the basis of this forecast growth, SPC have identified in their publication *First Port, Future Port* (2001) that sufficient capacity must be provided to accommodate continued trade growth. SPC is therefore proposing to expand the port facilities at Port Botany through land reclamation.

Port Botany's shipping terminals are located on the northern shores of Botany Bay, approximately 11 km south of Sydney's Central Business District (CBD) (refer to **Figure 1-1**). The proposed development at Port Botany involves the reclamation of approximately 60 ha of land in Botany Bay, extending north and west from the existing Patrick container terminal. The development includes preparation of the site for long-term use and the creation of up to 5 additional berths along an approximate 1.85 km additional wharf face. By 2025 the container handling capacity of the proposed terminal expansion is expected to be about 1.6 million TEU.

The proposed development involves a number of potential implications for air quality impacts. This report, has therefore been prepared, as part of the Environmental Impact Statement (EIS) process, to investigate the likely impacts on air quality during both the construction and operational phases of the project.

1.2 Study Objectives

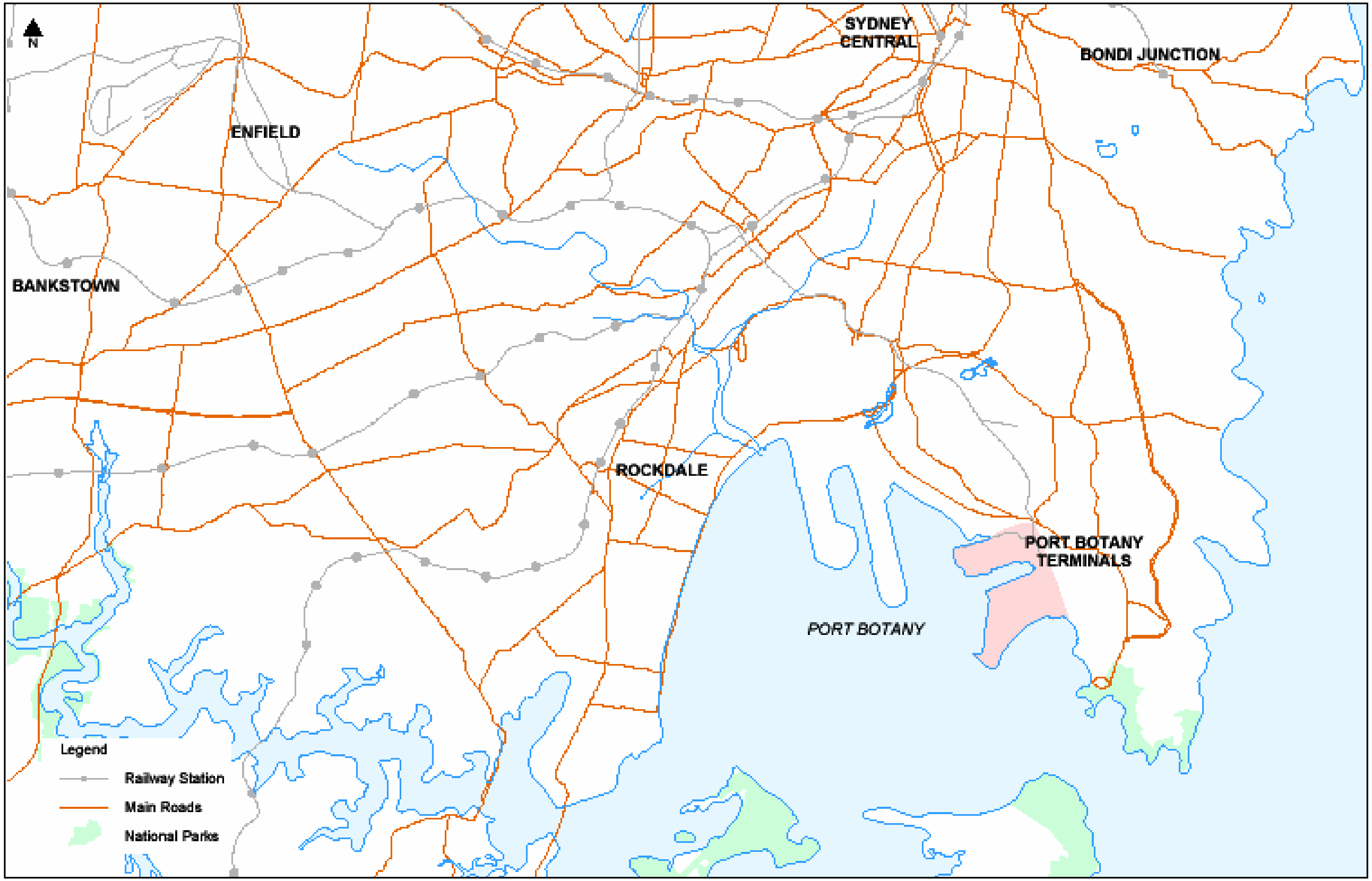
The objective of this air quality study is to review the existing air quality in the Port Botany area and to provide an assessment of the likely impacts on air quality during the construction and future operation of the proposal. To achieve these objectives the following tasks have been undertaken:

- a review of air quality issues as relevant to the construction and operation of the proposed new port facilities;
- an outline of the ambient air quality objectives relevant to the project;
- description of prevailing meteorology and existing ambient air quality in the Port Botany area;
- quantification and assessment of air quality impacts relating to dust emissions during the construction phases of the project, considering impacts from dredging, filling and compacting activities, and construction of the berths and hardstand;

- quantification and assessment of air quality impacts relating to train, truck, ship and terminal equipment emissions during the operational phase of the project, for the following scenarios:
  - existing case;
  - operation at new terminal on reclaimed land; and
  - operation at all terminals including proposed upgrade to Patrick terminal
- provision of general recommendations for the mitigation of any adverse air quality impacts and any on-going air quality monitoring requirements.

The development application also requests consent for the construction (and operation) of the individual terminal facilities. The construction activities would include road making, asphalting, construction of offices and other buildings, and so on. Each terminal operator would be required to show compliance with the studies of the EIS, and any relevant actions that may be required as stated in the EIS to reduce the potential for environmental and human impact.

■ Figure 1-1 Locality Map



2. Project Overview and Air Quality Issues

2.1 The Proposed Development

As outlined in **Section 1.1**, the proposed development at Port Botany involves land reclamation of approximately 60 ha, the provision of an additional 1.85 km of wharf face and up to 5 additional shipping and 6 tug berths. The development also includes works along Foreshore Beach and recreational areas, and Penrhyn Estuary. Imported rock bunds would be placed to form the boundary of the works, with material dredged from Botany Bay forming the majority of fill for the wharf-side hardstand area. A new ship-manoeuvring basin would be created within an area adjacent to the proposed new wharf face during the dredging process. Refer to **Figure 2-1** for a pictorial representation of proposed site layout.

A new shipping terminal area would eventually be created behind the wharf face. Potential air quality impacts associated with this proposal have been investigated for both the construction and operational phases of the works. As outlined in **Section 1.2**, the assessment also considers potential impacts from the construction of terminal facilities and infrastructure that would primarily be the responsibility of the individual terminal operators. A qualitative analysis is made of this stage of construction, as dust impacts are likely to be minimal in comparison to the stages assessed quantitatively as part of this investigation. Dust mitigation measures and environmental management procedures for this component of works would be the responsibility of the individual terminal operators, who would need to ensure appropriate environmental management plans (EMPs) are to put into place prior to construction commencing. The EMPs would be based on the findings and recommendations of this EIS.

2.2 Construction

2.2.1 Overview

The proposed construction works would be undertaken as part of several phases:

- underwater works, including underwater bund construction and infilling behind the retaining wall with dredge material; and
- above water works, including:
  - reclamation to a final level of 3.5 m above mean high water level, surface trimming, site compaction and temporary sealing / stabilisation works including staged pre-loading of the reclaimed area;
  - construction of marine structures including pile driving, construction of a hard rock berm, placement of retaining wall, infilling behind retaining wall above water level, rear rail crane beam, ship fendering and mooring units, and tug berth wharf/quay face;
  - beach enhancement and construction of public recreation areas along Foreshore Road including the construction of a boat ramp, cycleway and boardwalks, and new inter-tidal and saltmarsh areas at Penrhyn Estuary;
  - construction of port infrastructure including road and rail access and bridge construction, noise barriers and the provision of services; and

- terminal operator's construction activities including roads and pavement, buildings and amenities, and the installation of cranes and dockside equipment.

The following sections provide an overview of the likely construction techniques and sequencing expected during the construction works. The construction methodologies outlined are indicative only, as the techniques to be employed during actual construction would not be determined until the formal tendering process for construction commences. For a description of the worst-case construction scenarios considered in further detail for the impact assessment, refer to **Chapter 6**.

2.2.2 Underwater Works

The main air quality issues are expected to result from the transportation of rock material to the site for underwater berm construction, and are likely to be in the form of wheel generated dust, wind blown dust from stockpiles and vehicle engine emissions.

During the underwater works phase of the project, the majority of deliveries to the site would be rock bund material for the embankments (approximately 175,000 m^3), accounting for approximately 70 trucks/day and would be required over an estimated 48 week period. Trucks would enter the site from the Foreshore Road entrance over a gravel road, controlled with dust suppressants. The majority of these trucks would travel in the vicinity of the proposed boat ramp site for approximately 150 m, and dump their load at the proposed temporary stockpile site adjacent to the proposed boat ramp. A temporary barge loading ramp and pontoon would be erected adjacent to the stockpile site. Front end loaders (FELs) would transfer the stockpiled rock material onto flat decked barges for transport to the marine working face. An alternative rock loading point at the western end of the Patrick terminal ('works area') may also be utilised if necessary.

Transport and placement of rock material along the line of the perimeter quay faces would be undertaken using a fleet of several barges, forming a shuttle operation between the loading pontoon and a larger flat-topped barge, which would be moored at the site of the active construction face. The moored placement barge would be fitted with an underwater telescopic chute, capable of accurately directing rock to the portion of the rock face currently being constructed. A bobcat or FEL would be used to transfer rock from the shuttle barges to the placement barge and to push rock down the chute.

The proposed construction methodology, utilising a multi-terraced embankment approach, allows rock placement and dredging activities to proceed in parallel. As each of the rock bunds is completed, reclamation material would be pumped into position to form the base of the next rock bund. Dredged material would be cut from the area adjacent to the site of the proposed new wharf face using a cutter-suction dredger. The material would be transported through a floating pipeline behind the adjacent embankment for direct placement within the reclamation area. It is estimated that the project would involve dredging approximately 7.5 million m^3 of material from Botany Bay and using this as infill for land reclamation. Any dredged material that is unsuitable for use as part of the terminal area or proposed beach would be replaced in the dredge voids created, taken off site by truck or used in the estuary enhancement works.

Staging of dredging operations would predominantly be in a south to north direction, with dredging progressing inward from the southern and western embankments created.

2.2.3 Above Water Works

Above water works would initially include the final stage of reclamation above water level, surface trimming, site compaction and preliminary site stabilisation works including pre-loading. Berth and deck construction would begin to commence during the dredging and reclamation phases of the project.

Filling Area

The final stage of the reclamation phase of construction would involve bund construction and dredging infilling above water level. As mentioned above, a portion of the rock bund material delivered by truck would be to the works area at the western end of the Patrick Terminal. Trucks would cart the rock over the predominantly sand reclaimed material, to the progressive working face and end-tip their load behind the quay line.

After filling of the area with dredged material, dozers and graders would be used for trimming this material to form the final bund and surface.[2] Dust controls during this final bund forming would involve wetting the surface with water sprays.

Site Compaction, Stabilisation and Pre-loading

Hydraulically placed fill consisting predominantly of sand tends to self-compact fairly well on placement. However in order to enhance the bearing capacity and reduce long term settlement of the reclaimed material, pre-loading areas where the highest settlements are expected is often undertaken. This involves over-filling these areas for up to a year to accelerate initial settlement. Following forming the pre-loading material over the designated areas, progressive temporary sealing of the reclaimed land surface would be undertaken using a bituminous emulsion or hydromulch product. This would minimise the potential for blown dust emissions from the sandy surface.

Marine Structures and Berth Construction

The marine structures to be erected prior to bringing each berth on line include:

- wharf of quay-face structure;
- rear rail crane beam;
- ship fendering and mooring units; and
- tug berth wharf or quay-face.

Activities associated with construction of each berth are likely to include:

- procurement, joining and storage of piles;

[2] Relative Level (RL) of final reclamation would be 3.5 m above zero Fort Denison tide gauge. However pre-loading activity would require different earth elevations across the reclaimed site, ranging from RL 2.0 to RL 6.5.

- pile driving using floating plant, including some joining of piles in the pile driving plant;
- forming and pouring reinforced concrete pile caps, headstocks and decking;
- installation of underwater rock armouring berm by trucks and crane;
- infilling and compaction of sandfill (behind the retaining wall);
- installing the slab between retaining wall and wharf; and
- constructing the rear crane rail beam.

Piles are anticipated to be transported to the site by ship and/or barge in 12-metre sections, where they would then be welded into the required lengths. An epoxy or polyurethane compound would be applied before driving the piles in the section from seabed to deck.

Construction of the berths would require the importation of a total of approximately 200,000m^3 of hard igneous rock for creation of the rock armouring berm. These rocks would be of a maximum size of approximately 750 kg with a minimum of fine material being required. This equates to approximately 40 truck loads of rock per day over a period of approximately 18 months. These deliveries would be to areas adjacent to the wharf area being constructed at that time.

Concrete works would include the construction of the substructure and decking and would consist of pre-cast concrete units, with in-situ concrete work also being required for creation of the fender beam and the top half of the deck. Concrete trucks would be required for the duration of the concrete works program, where it is estimated 2 concrete trucks per hour would be required over 24 months.

2.2.4 Beach and Recreational Areas Construction

Construction of the beach and recreational areas would be over an approximately 11 ha area along Foreshore Road (refer to **Figure 2-1**). The anticipated activities associated with this construction include the spreading by dozer and landscaping of dredged sands and other off-site sand/topsoil where necessary. Other public recreation area works include the construction of a cycleway and boardwalks. Some rock material would also be required for rock revetment and landscaping purposes, however delivery of rock material is only likely to be for a few days.

Sand movement works will also be undertaken at Penrhyn Estuary along Foreshore Road for the creation of new inter-tidal and saltmarsh areas. This would involve sand being pushed into the water by dozer working during low tide periods. The sand would be significantly moist and is not expected to present an issue in terms of dust impact.

2.2.5 Construction Hours and Site Access

Site access arrangements during construction would be off Penrhyn Road, or via the short access road to the proposed boat ramp site (refer to **Figure 2-1**). All site roads have been assumed to have some form of gravel base and watering as a form of dust suppressant. The location of temporary vehicle routes within the site would be determined by the Site Manager during construction, and would frequently alter during the works.

Construction activities, including deliveries on-site would generally be restricted to 11 hours per day (0700 to 1800), 6 days a week. Dredging works would continue 24 hours, 7 days a week for a period of approximately 12 to 15 months. Some works may be required outside these times to minimise impacts on existing traffic/operations in the area.

2.2.6 Equipment Inventory

A summary of the equipment likely to be used during each phase of construction is shown in **Table 2-1**.

For the purposes of this impact assessment, ***Reclamation Phase*** refers to the reclamation and dredging phase of the project and associated works such as trimming, grading, and compacting activities. Beach construction has been assessed as if occurring simultaneously with the Reclamation Phase construction activity.

Berth Construction Phase refers to wharf and quay-face construction activities.

- **Table 2-1 Equipment Inventory for Construction Phases**

Phase of Works	Equipment List	Number	Activity
Dredging & Reclamation – construction of embankment	Trucks	70 / day	Delivery of rock bund material and piles
	Front End Loader	2	Loading of rock bund materials onto shuttle barge
	Cutter-suction Dredge Rig	1	Dredging
	Bobcat / Front End Loader	2	Moving rock bund materials into chute on fixed barges
	Tugs	4	Towing rock transport barges
	Work Boats	2	Servicing dredging operation and general duties
	Barges	4	Rock transport
	Hopper Barges	2	Placing bund material
Dredging & Reclamation – site trimming and stabilisation	Dozer	1-2	Level finished (bulk fill) surface
	Water Truck	2	Aid in compaction and also for dust control
	Grader	1	Level finished (bulk fill) surface
	Rollers (Sheepsfoot & Steel Drum)	1-2	Compaction / Completion of finished surface
	Excavator	1-2	Trenching, trimming of embankments and placing temporary armour
Dredging & Reclamation – pre-loading	Scraper	6	Profile finished surface
	Water Truck	2	Aid in compaction and also for dust control
	Grader	1	Levelling finished surface
	Dozer / Compactor	1	Level finished surface and compaction
	Roller (Sheepsfoot)	1	Compaction / Completion of finished surface
Wharf Construction	Trucks	Up to 60 / day	Delivery of piles and hardrock berm material
	Piling Rig / Diesel Hammers	2-3	Install steel piles
	Large Crane	1-2	Placement of precast units during wharf construction
	Dozer	1-2	Moving stockpiled sand to fill behind precast retaining wall
	Grader	1	Level finished infilling area behind retaining wall
	Roller (vibratory)	1-2	Compaction / Completion of finished surface

Phase of Works	Equipment List	Number	Activity
	Road making equipment: Bitumen Spray Truck Rollers Trucks	 1 2 3	Temporary Sealing
	Concrete trucks	22 / day	Construction of wharf, bridges, drainage works, buildings etc
	Barges	3-4	Pile transport and driving
	Mobile Crane	1-2	Moving piles and pile sections for joining
Beach, Recreational Area and Penrhyn Estuary Enhancement	Trucks	Up to 30 / day	Delivery of hardrock for revetment and boat ramp, and later for extra beach sand and material as required
	Excavator	1	Placing and forming of rock revetment
	Dozer	1	Landscaping and spreading material for beach and estuary enhancement
	Front End Loader	1	Landscaping and spreading material for beach and estuary enhancement
	Dozer / Compactor	1	Profile finished beach area
Terminal Facilities	Trucks	80 / day	Delivery of construction materials
	Heavy Compacting Roller	2	Initial compaction of sub-grade
	Roller (Sheepsfoot)	2	Compaction of sub-grade/base/sub-base materials
	Dozer	2	Grading, profiling and spreading cement
	Asphalt Paving Machine	2	Levelling surface of asphalt
	Bitumen Spray Truck	1	Spraying asphalt over surface
	Roller (Steel Drum)	2	Compaction / Completion of finished surface
	Grader	1	Levelling surface
	Water Truck	1	Dust control
	Excavator	1-2	Excavation to install building foundations
	Backhoe	1	Excavation to install services, fencing and lighting
	Crane	1	Erecting lights, building assemblage and terminal equipment
	Concrete Truck	5 / day	Pouring of concrete for building foundations
Delivery of Terminal Facilities	Crane Transport Vessel	1	Delivery of fully assembled quay cranes
	Large Trucks	5	Delivery of partially assembled RMG sections
	Mobile Cranes	1	Erection of RMGs
	Transport Vessel	1	Delivery of Straddle Carriers/RTGs

mean vehicle speed on-site: 20 km/hour
mean truck GVM: loaded 30 tonnes, unloaded 15 tonnes

2.3 Operation

2.3.1 Sources of Emission

The key local air emissions relating to the operation of the proposed new terminal, existing terminals and the upgrade to the Patrick terminal are nitrogen oxides (NO_x), sulfur dioxide (SO_2), fine particulate matter (PM_{10}) and carbon monoxide (CO). These pollutants are the key criteria pollutants considered by the New South Wales Environment Protection Authority (NSW EPA) as being relevant for the assessment of the proposed activity.

Emissions including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) do not present a significant issue in terms of local air quality impact and are not considered by the dispersion modelling study. They are, however, important greenhouse gases and are considered as part of the overall assessment (refer to **Section 7.8**).

NO_x, SO_2, PM_{10} and CO emissions result from the following sources:

- ships at berth at the terminal wharves, with auxiliary engines operating at 100% MCR for 100% of the time;
- ships arriving and departing the terminals, with main engines operating at 30% MCR for half an hour on arrival and when departing;
- exhausts from trains entering, leaving and travelling around the site. Emissions would also be associated with trains while idling. Each train would be push-pull, having two locomotives;
- exhausts from container trucks entering the site, queuing (idling), travelling around the site to the various facilities, and then leaving the site;
- brake wear and tyre dust from trucks travelling at the site; and
- exhausts from diesel dockside equipment such as straddle carriers, reach stackers, and rubber tyre gantries.

2.3.2 Equipment and Transport Inventory

Table 2-2, **Table 2-3** and **Table 2-4** to follow set out an inventory of equipment and transport including ships (a conservative estimate of vessel visits is given), trucks and trains as well as dockside equipment associated with Port Botany operations for the three (3) scenarios under consideration.

■ Table 2-2 Scenario 1 Inventory – Existing Case (0.9 mill TEU)

Asset	Terminal	Number	Fuel Type	Comment / Activity
Ships, TEU size		**Visits/yr**		
<2000	Patrick, P&O	531	Diesel	Current ship numbers provided are shared between the two existing terminals (7 berths)
2000-2999		308	Diesel	
3000-3999		41	Diesel	
4000-4999		1	Diesel	
5000-5999		0	-	
6000-6999		0	-	
7000-7999		0	-	
Total		881	-	
Trucks		**Visits/day**		
	Brotherson North	1,602	Diesel	Impact assessment assumes all trucks are articulated. On-site travel speed 20 km/hr. Each truck spends 30 min idling on-site
	Brotherson South	1,311	Diesel	
	Total	2,913	-	
Trains		**Visits/day**		
	P&O	7	Diesel	300 m train length, 2 locos. Idle time 2 hours
	Patrick	6	Diesel	300 m train length, 2 locos. Idle time 2 hours
	P&O Trans	2	Diesel	300 m train length, 2 locos. Idle time 2 hours
	Total	15	-	-
Dockside Equipment				
Quay Cranes	P&O	6	Electric	No emissions
	Patrick	6	Electric	
Straddle Carriers	P&O	0	-	Operational 90% of time, 100% of time under load
	Patrick	26	Diesel	
Reach Stacker	P&O	0	-	Operational 60% of time, 100% of time under load
	Patrick	2	Diesel	
Rail Mounted Gantries	P&O	0	-	No emissions
	Patrick	2	Electric	
Rubber Tyre Gantries	P&O	20	Diesel	Operational 90% of time, 100% of time under load
	Patrick	0	-	

■ Table 2-3 Scenario 2 Inventory – Proposed New Terminal at Forecast Demand (1.6 mill TEU)

Asset	Terminal	Number	Fuel Type	Comment / Activity
Ships, TEU size		**Visits/yr**		
<2000	New Terminal	123	Diesel	5 berths
2000-2999		51	Diesel	
3000-3999		164	Diesel	
4000-4999		168	Diesel	
5000-5999		117	Diesel	
6000-6999		92	Diesel	
7000-7999		26	Diesel	
Total		741	-	
Trucks		**Visits/day**		
	New Terminal	1,882	Diesel	Impact assessment assumes all trucks are articulated. On-site travel speed 20 km/hr. Each truck spends 30 min idling on-site
Trains		**Visits/day**		
	New Terminal	18	Diesel	600 m train length, 2 locos. Idle time 2 hours
Dockside Equipment				
Quay Cranes	New Terminal	10	Electric	No emissions
Straddle Carriers	New Terminal	40	Diesel	Operational 90% of time, 100% of time under load
Reach Stacker	New Terminal	4	Diesel	Operational 60% of time, 100% of time under load
Rail Mounted Gantries	New Terminal	7	Electric	No emissions
Rubber Tyre Gantries	New Terminal	0	-	-

■ Table 2-4 Scenario 3 Inventory – All Terminals at throughput 3.2 mill TEU

Asset	Terminal	Number	Fuel Type	Comment / Activity
Ships, TEU size		**Visits/yr**		
<2000	Patrick, P&O, New Terminal	307	Diesel	Ship numbers represent total annual sailings over all terminals (12 berths)
2000-2999		127	Diesel	
3000-3999		409	Diesel	
4000-4999		421	Diesel	
5000-5999		293	Diesel	
6000-6999		229	Diesel	
7000-7999		66	Diesel	
Total		1852	-	
Trucks		**Visits/day**		
	Brotherson North	1,407	Diesel	Impact assessment assumes all trucks are articulated. On-site travel speed 20 km/hr. Each truck spends 30 min idling on-site
	Brotherson South	1,411	Diesel	
	New Terminal	1,882	Diesel	
	Total	4,700	-	
Trains		**Visits/day**		
	P&O	17	Diesel	300 m train length, 2 locos. Idle time 2 hours
	Patrick	14	Diesel	600 m train length, 2 locos. Idle time 2 hours
	P&O Trans	5	Diesel	300 m train length, 2 locos. Idle time 2 hours
	New Terminal	18	Diesel	600 m train length, 2 locos. Idle time 2 hours
	Total	54	-	-
Dockside Equipment				
Quay Cranes	P&O	8	Electric	No emissions
	Patrick	9	Electric	
	New Terminal	10	Electric	
Straddle Carriers	P&O	0	-	Operational 90% of time, 100% of time under load
	Patrick	37	Diesel	
	New Terminal	40	Diesel	
Reach Stacker	P&O	0	-	Operational 60% of time, 100% of time under load
	Patrick	0	-	
	New Terminal	4	Diesel	
Rail Mounted Gantries	P&O	0	-	No emissions
	Patrick	7	Electric	
	New Terminal	7	Electric	
Rubber Tyre Gantries	P&O	28	Diesel	Operational 90% of time, 100% of time under load
	Patrick	0	-	
	New Terminal	0	-	

- **Figure 2-1 Site Layout Map**

3. Air Pollution and Effects

3.1 Overview

This section of the report outlines the health effects of air pollutants.

Air borne particulate matter (PM_{10}) and deposited dust are considered to be associated with the construction of the upgrade facilities. Nitrogen oxides (NO_x), sulfur dioxide (SO_2), PM_{10} and carbon monoxide (CO) are considered to be the major pollutants impacting on the local air quality associated with operation of the terminals.

Due to the nature of the works to be undertaken during the overall development and operation of the terminals, these are considered the most relevant of the pollutants listed in the National Environment Protection Measure (NEPM) for Ambient Air Quality.

The aspects of the construction and operation of the proposal that are relevant to the assessment of air quality impacts are also detailed in this section.

3.2 Effects of Air Pollution

3.2.1 Airborne Particulate Matter

Airborne particulate matter is any material, except uncombined water, that exists in the solid or liquid state in the atmosphere or gas stream at standard condition. Airborne particles generally range in size from 0.001 to 500 μm, with the most significant particulate mass in the atmosphere ranging from 0.1 to 10 μm. A number of terms can be used to describe airborne particles and these are outlined in **Table 3-1**.

- **Table 3-1 Definition of Terms that Describe Airborne Particulate**

Term	Description
Particulate matter	Any material, except uncombined water, that exists in the solid or liquid state in the atmosphere or gas stream at standard condition
Aerosol	A dispersion of microscopic solid or liquid particles in gaseous media
Dust	Solid particles larger than colloidal size capable of temporary suspension in air
Fly Ash	Finely divided particles of ash entrained in flue gas. Particles may contain unburned fuel
Fog	Visible aerosol
Fume	Particles formed by condensation, sublimation, or chemical reaction, predominantly smaller than 1μm (tobacco smoke)
Mist	Dispersion of small liquid droplets of sufficient size to fall from the air
Particle	Discrete mass of solid or liquid matter
Smoke	Small gasborne particles resulting from combustion
Soot	An agglomeration of carbon particles

Source: Wark and Warner (1981)

Common size related terms are the classes Total Suspended Particulate Matter (TSP), PM_{10} and $PM_{2.5}$. TSP refers to the mass concentration of all suspended particles in the atmosphere. PM_{10} refers to all particles with aerodynamic sizes less than 10 μm, and $PM_{2.5}$ is all particles with aerodynamic sizes less than 2.5 μm.

Particulate matter is generated by industry, motor vehicles, refuse disposal, ocean salt, volcanic ash, products of wind erosion, roadway dust, bush fires and plant pollen and seed. Particulate matter presents a health hazard to the lungs, enhances chemical reactions in the atmosphere, reduces visibility, increases the possibility of precipitation, fog and clouds and reduces solar radiation.

The health effects of particles are largely related to the extent to which they can penetrate the respiratory tract. Larger particles (those greater than 10 μm) generally adhere to the mucus in the nose, mouth, pharynx and larger bronchi and are generally removed by swallowing or expectorating. Respirable particles are particles with an aerodynamic size less than about 3 μm. Particles below 2.5 μm can reach the deepest parts of the respiratory system, where they can only be removed by the body's cellular defence system. Respirable particles have been associated with a wide range of respiratory symptoms.

Dust deposition rates assess the effects of coarse particulate matter on amenity. The NSW EPA criteria for dust deposition and particulate matter concentration are outlined in the sections to follow.

3.2.2 Nitrogen Oxides

Oxides of nitrogen (NO_x) are dominated by nitric oxide (NO) and nitrogen dioxide (NO_2) which are important air pollutants. Lightning and the oxidation of ammonia can form oxides of nitrogen naturally. Combustion, however, is the main source of NO_x, with the burning of fossil fuels resulting in some atmospheric nitrogen being converted to oxides, mainly nitric oxide. The nitric oxide slowly oxidises to nitrogen dioxide. In the presence of sunlight and reactive organic compounds the oxidation to NO_2 and subsequently ozone (O_3) is much more rapid. This leads to what is termed photochemical smog.

Thus, oxides of nitrogen are an important contributor to the formation of photochemical pollution in Sydney. The Ambient Air Quality NEPM, developed by the National Environment Protection Council (NEPC), has established a 1-hour and a 4-hour standard for ozone (at ground level) of 0.10 and 0.08 parts per million respectively, since it is a major component of photochemical pollution with adverse effects on human health. In Sydney, particularly in the west and south-west, these standards are occasionally exceeded, sometimes by substantial amounts.

There is no NEPM standard for total oxides of nitrogen (NO_x) since only one of its constituents, NO_2, is directly of concern for health. The main health impact of excessive NO_2 exposure is a direct effect on respiratory function. Individuals with chronic inflammatory airway disease, such as bronchitis, are most at risk. The NEPM standard for NO_2 is 0.12 parts per million (246 $\mu g/m^3$) for a 1-hour averaging period, and 0.03 parts per million (62 $\mu g/m^3$) for an annual averaging period.

Nitrogen emissions can also increase nitrogen deposition into sensitive, already nitrogen-saturated coastal estuaries and ecosystems resulting in increased growth of algae and plants (Bluewater Network 2000).

Levels of nitrogen dioxide appear to have been declining over recent years with few exceedences of the standard now recorded in NSW. The reasons for this decline are not well understood, particularly since emissions of NO_x, of which NO_2 forms approximately 5-15%, have remained stable over the same period.

3.2.3 Photochemical Smog and Ozone

Nitrogen dioxide is an important contributor to the formation of ozone (O_3), a major component of photochemical smog. Oxides of nitrogen, in the presence of strong sunlight, follow a complex series of chemical reactions with reactive organic compounds to produce O_3. The amount of NO_x present and the availability of strong sunlight limit the total amount of O_3 formed during these reactions. It therefore follows that during the summer months, when there is an abundant supply of strong sunlight available to oxidise NO_x emissions within Sydney, higher O_3 concentrations occur.

Transport related air emissions within the Sydney airshed are primarily responsible for regional photochemical smog formation within the Sydney basin. Photochemical smog is not a localised phenomenon, in that O_3 is produced relatively slowly, over several hours, after exposure to sunlight has been sufficient for the series of reactions to be completed. Maximum O_3 concentrations therefore tend to occur downwind of the main source areas of precursor emissions, and can become re-circulated within local and regional circulation patterns.

Due to this dependence of photochemical smog formation on meteorology and length of exposure to sunlight and precursor emissions, areas remote from the source of emissions can be exposed to high O_3 concentrations. Consequently, an increase in precursor pollutant emissions within one area has the potential to increase O_3 levels in other regions remote from the sources.

While this air quality assessment provides a detailed analysis of NO_x emissions it is considered beyond the scope of the study's requirements to provide a quantitative assessment of O_3/ photochemical smog.

3.2.4 Sulfur Dioxide

Sulfur dioxide (SO_2) is a colourless pungent and irritating gas which, when present in sufficiently high concentrations, impacts directly on the upper airways in humans. SO_2 dissolves in the presence of moisture, forming an acidic solution in the lining of the airways which irritates the nose, throat, trachea and major bronchi and causes reactions such as coughing and wheezing in normal and susceptible groups such as asthmatics.

The high solubility of SO_2 means that it dissolves readily in the atmosphere to form acid. These solutions are corrosive and can have adverse impacts on the physical and biological environments. Studies have shown that sulphuric acid deposition can cause damage to buildings and certain fabric fibres.

3.2.5 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless gas formed from incomplete combustion of carbon in fuels. It is a common pollutant from industrial plant exhausts, but also is emitted from numerous consumer products/sources including woodstoves, exhausts from automobiles, internal combustion engines on lawnmowers and chainsaws, and charcoal grills. Fires of all types also contribute greatly to CO emission.

CO quickly enters the blood when inhaled into the lungs. Levels normally present in the atmosphere are unlikely to cause ill effect on humans, however low levels may cause poor concentration, memory and vision problems, and loss of muscle coordination. At higher levels (200 ppm for 2-3 hours) headaches, fatigue, and nausea can be experienced.

In terms of effects on the environment, CO is not considered a greenhouse gas, although it is a precursor to the generation of greenhouse gases, which is linked to global warming. CO elevates the concentrations of methane (a greenhouse gas) and ozone in the atmosphere. It eventually oxidises into carbon dioxide (CO_2). Very high levels of CO will cause the same problems to birds and animals that are experienced by people, although these levels are very unlikely to be encountered in the environment except during extreme events like bushfires.

3.2.6 Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is a colourless, odourless gas originating from many sources, including the respiration of living organisms and humans. The combustion of substances containing carbon (almost all combustible material) also produces CO_2.

While CO_2 can have some mild toxic effects such as eye irritation at concentrations exceeding 5,000 ppm (9,000 mg/m^3), it is most commonly associated with asphyxiation. The effect of asphyxiant gases is proportional to the extent to which they diminish the amount of oxygen in the air that is breathed. The oxygen may be diminished to two-thirds of its normal percentage in air before appreciable symptoms occur.

CO_2 is an important greenhouse gas. Research shows that atmospheric CO_2 is 30% higher today than in pre-industrial times and is higher than it has been for at least 420,000 years.

Burning fossil fuel is the greatest contributor to the continuing increase in atmospheric CO_2. The consensus among scientists is that the observed warming in surface temperature over the last 100 years is exceptional and unlikely to be explained solely by natural causes.

Observations including decreasing snow cover and sea ice, increasing sea level, increasing precipitation in mid- to high latitudes, changes in circulation patterns of the atmosphere and ocean and increasing intensity and frequency of El Nińo events point to a warming world.

4. NSW EPA Air Quality Objectives

4.1 Overview

This section of the report details air quality objectives relevant to the construction and operation of the proposal. The NSW EPA has developed impact assessment criteria for pollutants in their document *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2001).

4.2 Dust Deposition

Deposited dust, if present at sufficiently high levels, can reduce the amenity of an area. In NSW the EPA set limits on acceptable dust deposition levels. **Table 4-1** shows the maximum acceptable increase in dust deposition over the existing dust levels.

■ **Table 4-1 NSW EPA Criteria for Dust Fallout**

Existing dust fallout level ($g/m^2/month$)	Maximum acceptable increase over existing fallout levels ($g/m^2/month$)	
	Residential	**Other***
2	2	2
3	1	2
4	0	1

* Other refers to rural, semi-rural, urban commercial and industrial

The maximum acceptable increase in the mean annual dust deposition rate is 2 g/m^2/month in those areas where the existing dust deposition rate does not exceed 2 g/m^2/month. The aim of the dust deposition criteria is to limit the total dust deposition rate to 4 g/m^2/month in suburban residential areas and to 5 g/m^2/month in rural, semi-rural, commercial and industrial areas.

4.3 Concentration Based Ambient Air Quality Objectives

Table 4-2 sets out concentration based air quality criteria in NSW.

■ **Table 4-2 NSW EPA Impact Assessment Criteria**

Pollutant	Averaging Period	Concentration	
		pphm[1]	$\mu g/m^3$ [2]
SO_2	10-minute	25	712
	1-hour	20	570
	24-hour	8	228
	Annual	2	60
NO_2	1-hour	12	246
	Annual	3	62
O_3	1-hour	10	214
	4-hour	8	171
Lead	Annual	-	0.5
CO	15-minute	87*	100**
	1-hour	25*	30**
	8-hour	9*	10**

Pollutant	Averaging Period	Concentration	
		pphm[1]	$\mu g/m^3$ [2]
PM_{10}	24-hour	-	50
	Annual	-	30
TSP	Annual	-	90

[1] parts per hundred million
[2] at 273 K and 101.3 kPa
* ppm (parts per million)
** mg/m^3

The key air emissions relating to this project that have potential to impact on the local environment are fine particulate matter and dust (ground disturbance during construction earthworks, and from truck, train, ship and mobile equipment exhausts during operation of the upgraded port); NO_x emissions (from truck, train, ship and mobile equipment exhausts during operation); SO_2 emissions (from ship emissions whilst at berth); and CO emissions (from truck, train, ship and mobile equipment exhausts during operation). The air quality objectives noted by the NSW EPA, which are relevant to assessing the construction and operational air quality impacts of this proposal are listed in **Table 4-3**.

- **Table 4-3 NSW EPA Concentration Based Impact Assessment Criteria Relevant to Proposal**

Pollutant	Averaging Period	Criteria	Number of Allowable Exceedence Days/Year**
Nitrogen Dioxide (NO_2)	1-hour	12 pphm or 246 $\mu g/m^3$ *	1
	Annual	3 pphm or 62 $\mu g/m^3$ *	None
Sulfur Dioxide SO_2	10-minute	25 pphm or 712 $\mu g/m^3$ *	1
	1-hour	20 pphm or 570 $\mu g/m^3$ *	1
	24-hour	8 pphm or 228 $\mu g/m^3$ *	1
	Annual	2 pphm or 60 $\mu g/m^3$ *	None
Particulate Matter (PM_{10}) <10 μm	24-hour	50 $\mu g/m^3$ *	5
	Annual	30 $\mu g/m^3$ *	None
Carbon Monoxide (CO)	15-minute	87 ppm or 100 mg/m^3	1
	1-hour	25 ppm or 30 mg/m^3	1
	8-hour	9 ppm or 10 mg/m^3	1

* at 273 K and 101.3 kPa
** from the Ambient Air Quality National Environment Protection Measure (NEPM)

5. Existing Air Environment

5.1 Overview

This section of the report provides a description of the geography and topography of the surrounding area, as well as a study of the meteorological and air quality conditions in the Port Botany area.

5.2 Local Setting

5.2.1 Surrounding Geography and Topography

The SPC port site is located on the north-eastern shoreline of Botany Bay, approximately 5 km inland from the Tasman Sea (in a due east direction). Sydney (Kingsford Smith) Airport is located north-west of the port, with the Parallel Runway situated 1.1 km due west of the Patrick Terminal. The proposed terminal would be situated between the Patrick Terminal and the Parallel Runway on reclaimed land (refer to **Figure 2-1**).

Botany Bay is located on the eastern fringe of the Sydney Basin, with the Sydney Central Business District (CBD) located approximately 11 km north of the Port. The location therefore lends itself to morning westerly winds (particularly during the cooler months) associated with morning drainage flows from the higher regions west of Sydney and across Parramatta.

The local topography is generally flat with surrounding suburban areas rising to only 20-30 m above sea level. There is however an elevated area at the northern head of Botany Bay, with relatively sharp land inclination rising up to the NSW Golf Club. There are some small coastal cliffs with slight elevation in land around Little Bay, Tupia Head and Boora Point, which may provide some protection from off-shore winds heading to the site from the east and south-east.

The large surface area of Botany Bay (approximately 4,163 ha) immediately to the south/south-west of the Port lends itself to afternoon winds blowing across the Bay due to differential air pressure gradients. This is caused as a result of air above the land warming during the day with the cooler air above Botany Bay being drawn across the Bay.

5.2.2 Local Land Use

URS (2001) has identified the proposed site for the expansion of Port Botany facilities to be located within Botany Bay Council Local Government Area (LGA), in the suburb of Banksmeadow. The southern portion of the existing facilities at Port Botany lies within the LGA of Randwick City Council.

The predominant land use in the vicinity of the port facilities is the Sydney (Kingsford Smith) Airport located within 5 km from the Port.

The Botany Freight Rail line is to the north and north-east of the proposed development area, which is currently used for transportation of freight to/from the facilities at Port Botany. Botany Road (a major arterial road) passes over the top of the rail line at the intersection with Beauchamp Road at the north-east of the existing Patrick Terminal.

The major land use of the northern Botany Bay region around Banksmeadow and Matraville is predominantly industrial. The main industries within this area are:

- Orica Australia, Banksmeadow;
- Amcor Paper Mill, Botany;
- BP Oil Terminal, Botany;
- Mobil Oil Terminal, Botany;
- Caltex Terminal, Banksmeadow;
- Metal Recyclers;
- A.C Hatrick;
- Johnson & Johnson;
- Kelloggs;
- Port-Air Industrial Estate, Botany; and
- Caltex Refineries, Kurnell (southern shore of Botany Bay), and associated wharf/shipping operations.

Other land uses within the area are:

- commercial, mainly along the western shores of the Bay around Brighton-Le-Sands; and
- recreational uses, such as fishing (including beach fishing), picnicking, sight-seeing and bird watching in the many reserves around Phillip Bay and the Botany Bay National Park on the north head, boating, swimming, golf courses, water sports, and cycling.

There are residential areas around Port Botany. The suburb of Botany is closest to the site, located 0.5-1 km to the north. Southern Cross Drive, the Botany Freight Rail Line and Sir Joseph Banks Park bound the area. East Botany is approximately 2.5 km to the north of the site. To the east of the site, and extending to the coast, is a relatively large residential area consisting of Hillsdale, Matraville and Maroubra. This area is approximately 2.5 km from the proposed development area.

Sensitive receivers such as schools, hospitals, and sensitive populations within residential areas include:

- Banksmeadow Primary School (800 m north of the proposed development site);
- Botany Nursing Home (1.2 km north-west);
- Matraville Primary School (1.8 km north-east);
- Chifley Public School (2.5 km east);
- Catholic School on Bunnerong Road, Matraville (2.6 km east-north-east);

- Matraville High School (2.7 km east);
- Primary School on Menin Road, Matraville (2.8 km east-north-east);
- Botany Primary School (2.8 km north-west);
- Catholic School on Anzac Parade, Matraville (2.9 km east);
- Malabar Primary School (3 km east);
- Long Bay Correctional Centre, Malabar (3 km east-south-east);
- La Perouse Primary School (3.2 km south-east);
- University of NSW, Chifley campus (3.4 km south-east); and
- Prince Henry (The Coast) Hospital[3] and Primary School, Little Bay (3.5 km south-east).

5.3 Climatology and Dispersion Meteorology

The Bureau of Meteorology (BoM) operates an Automatic Weather Station (AWS) at Sydney Airport (Kingsford Smith) (BoM station ID 066037). It is located at 33856' S, 151810' E and at an elevation of 6 m. The following sections provide a summary of the climatic conditions recorded at this station since 1929, with a summary table shown in **Table 5-1**.

5.3.1 Temperature

The Bureau of Meteorology has recorded temperature at Sydney Airport over a period of at least 65 years. As shown in **Figure 5-1** the Botany area experiences a warm to mild climate with quite a mild range in temperatures throughout the year.

The 9am mean daily temperature range between 22.3°C in January to 10.5°C in July. The 3pm mean temperature range is between 24.7°C in February and 16.0°C in July. Overall, the warmest months of the year are January and February, which receive mean daily maximum temperatures of 26.3°C.

July is the coolest month, experiencing a mean daily maximum temperature of 16.9°C. These daily temperature ranges are indicative of a relatively mild climatic conditions experienced within the Botany area.

5.3.2 Rainfall and Evaporation

The rainfall data presented in **Figure 5-2** shows that the Botany area experiences a mild seasonal variation in the distribution of rain, with most rain falling during the late summer and autumn months. The mean annual rainfall at Sydney Airport is approximately 1,106 mm, which occurs over an average of approximately 129 days. The driest month is September, which receives a mean monthly rainfall of 62 mm. The wettest months of the year are March and June, receiving 122 mm and 123 mm respectively. Rain typically falls on at least 9 days per month throughout the year, with the highest number of rain days (12) occurring during March.

[3] All services to soon be relocated to Prince of Wales Hospital at Randwick

The monthly evaporation rates for Sydney Airport are also presented with the rainfall data in **Figure 5-2**. There is a strong seasonal pattern, with evaporation being strongest during the warm summer months and least during the cooler winter months. Mean monthly evaporation rates range from approximately 75 mm/month in June to 229 mm in December. Evaporation typically exceeds rainfall during all months except May and June.

5.3.3 Relative Humidity

The 9am and 3pm relative humidity readings recorded at Sydney Airport are shown in **Figure 5-3**. Relative humidity varies on both a daily and seasonal cycle. At 9am humidity is highest during the cooler months from April to July. The annual range in 9am humidity is between 75% in June to 61% in October. The 3pm relative humidity readings are typically lower than the 9am values, and are generally greatest during the warmer summer months. The 3pm readings range between 63% in February to 50% in August.

5.3.4 Wind Speed and Direction

A description of wind speed and direction has been provided from the wind roses generated from data collected at the Sydney Airport station since 1939. The 9am windroses are included in **Figure 5-4** and the 3pm windroses are in **Figure 5-5**.

Summer 9am winds are predominantly from the south (approximately 27% occurrence), however a full range of directions can be experienced. By mid afternoon (as seen from the 3pm windroses) winds tend to move to more easterly directions.

Late autumn and winter 9am windroses show a very high percentage of winds from the west (35% in July) and north-west (40%), with afternoon winds coming from a variety of directions but predominantly from the south to west. There are some afternoon winds that begin to come from the north-east by late winter.

The percentage of winds from the north-east during the afternoon increases to approximately 27% in spring, and then by summer this direction represents the highest percentage of wind directions during the afternoon.

Afternoon winds during autumn are from the north-east through to the south, with only a very small percentage of winds blowing from westerly directions. By late autumn, afternoon wind directions from these westerly (and other) directions increase in percentage occurrence, however winds from the south still dominate.

During winter, afternoon winds are generally either from the south or west, however winds from all directions are often experienced.

Wind speeds are greatest during spring, with the highest monthly mean 9am wind speed occurring during October of 4.4 m/s. November and December experience the highest mean 3pm wind speed, being 6.8 m/s. For all months of the year, wind speeds are lower in the morning, and then pick up in speed by the afternoon. This is as expected with air differentials increasing throughout the day due to heating of the land surface.

5.3.5 Meteorological Conditions Expected at the Site

The BoM AWS at Sydney Airport is located only 5 km north-west of the study area. The study site is in a similar topographical and geographical location as that of Sydney Airport. Both sites are located on the northern shoreline of Botany Bay, and hence a more coastal location providing meteorological data would not be appropriate to describe wind speed and direction, for example.

As such, the meteorological conditions experienced at Sydney Airport can sufficiently be used to describe the conditions expected at the proposed new terminal, Patrick and P&O terminals.

■ Table 5-1 Climatic Summary (Sydney Airport)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Daily Max Temp (°C)	26.3	26.3	25.2	22.8	19.9	17.4	16.9	18.1	20.2	22.3	23.9	25.6	22.1
Highest Max Temp (°C)	43	42.6	41.2	35.7	30	26.8	26.7	31.1	35.6	38.2	43.4	43.2	43.4
Mean Daily Min Temp (°C)	18.6	18.9	17.3	13.9	10.8	8.4	6.9	7.9	10.1	13	15.1	17.3	13.2
Lowest Min Temp (°C)	9.7	11.2	7.4	6.1	3	1	-0.1	1.2	2.3	4.8	5.9	8.2	-0.1
Mean 9am Air Temp (°C)	22.3	22.3	21.1	18.1	14.4	11.7	10.5	12.3	15.4	18.3	19.8	21.5	17.3
Mean 9am Dew Point Temperature (°C)	16.2	16.9	15.8	12.6	9.6	7.2	5.4	5.8	7.7	10.2	12.1	14.6	11.2
Mean 9am Relative Humidity (%)	70	73	73	72	74	75	72	66	62	61	63	66	69
Mean 9am Wind Speed (m/s)	3.9	3.7	3.5	3.4	3.3	3.5	3.5	3.8	4.1	4.4	4.3	4.0	3.8
Mean 3pm Air Temp (°C)	24.6	24.7	23.8	21.6	19	16.5	16	17.1	18.8	20.6	22	23.8	20.7
Mean 3pm Dew Point Temp (°C)	16.2	16.7	15.5	12.6	9.9	7.6	5.6	5.6	7.5	9.9	12.1	14.4	11.1
Mean 3pm Relative Humidity (%)	62	63	62	59	58	58	53	50	51	54	57	59	57
Mean 3pm Wind Speed (m/s)	6.5	6.2	5.8	5.1	4.5	4.8	4.9	5.6	6.2	6.6	6.8	6.8	5.8
Mean Rainfall (mm)	100.4	110.6	121.7	106.4	98.1	123	69.3	80.8	62.2	72.9	82	74.9	1102.4
Mean no. of Raindays	11.4	11.3	12.4	10.9	11.3	11.2	9.2	9.5	9.5	10.7	11.3	10.6	129.4
Highest Monthly Rainfall (mm)	400.4	596.9	393	476.2	421.7	465.9	253.7	387.8	249.4	271.3	396.1	359.2	-
Lowest Monthly Rainfall (mm)	5.4	2.5	6.4	8	2.9	2.5	0	0.2	1.6	0	5.7	4.8	-
Highest Daily Recorded Rain (mm)	157	216.2	202	174	165.9	151.2	132.6	207	115.4	112.3	143.3	182.1	216.2
Mean no. of Clear Days	6.5	5.7	7.6	8.8	8.8	8.9	11.9	13	10.8	7.9	6.2	6.3	102.4
Mean no. of Cloudy Days	13.4	12.2	12.2	10.6	11.2	10.8	8.4	8	8.6	11.3	11.7	12.4	130.7
Mean Daily Evaporation (mm)	7.1	6.5	5.3	4.1	2.9	2.5	2.7	3.7	4.7	5.7	6.5	7.4	4.9
Mean Daily Sunshine (hrs)	7.4	7.3	6.9	6.8	5.8	5.9	6.6	7.8	7.8	7.9	7.7	8	7.2
Maximum Wind Gust (km/hr)	151.9	107.6	127.8	122.4	129.6	129.6	109.4	114.8	111.2	126	151.9	126	151.9

Source: Bureau of Meteorology

Figure 5-1 Mean Monthly Temperature (Sydney Airport)

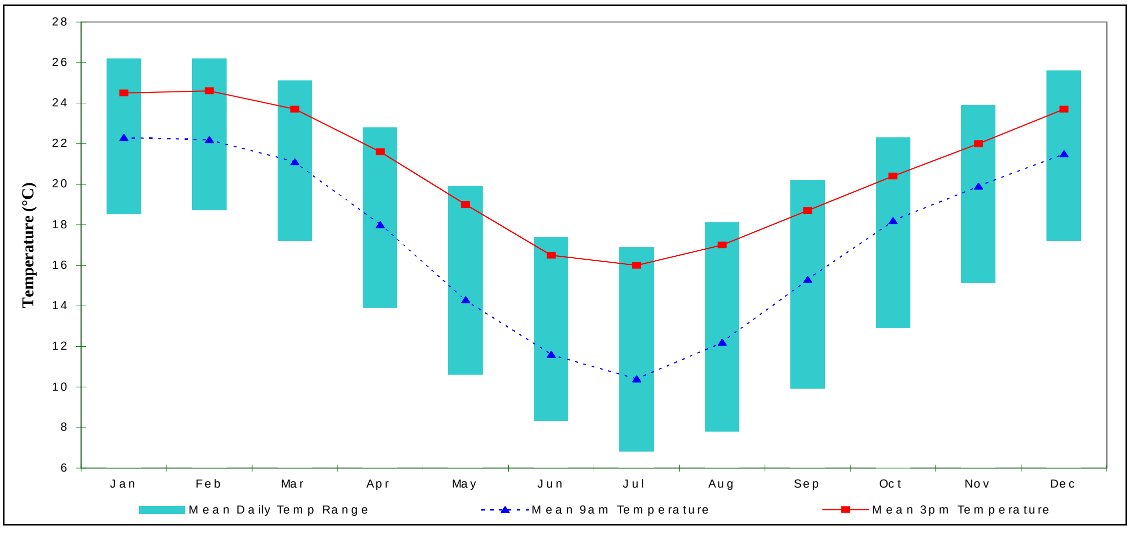


Figure 5-2 Mean Monthly Rainfall and Evaporation (Sydney Airport)

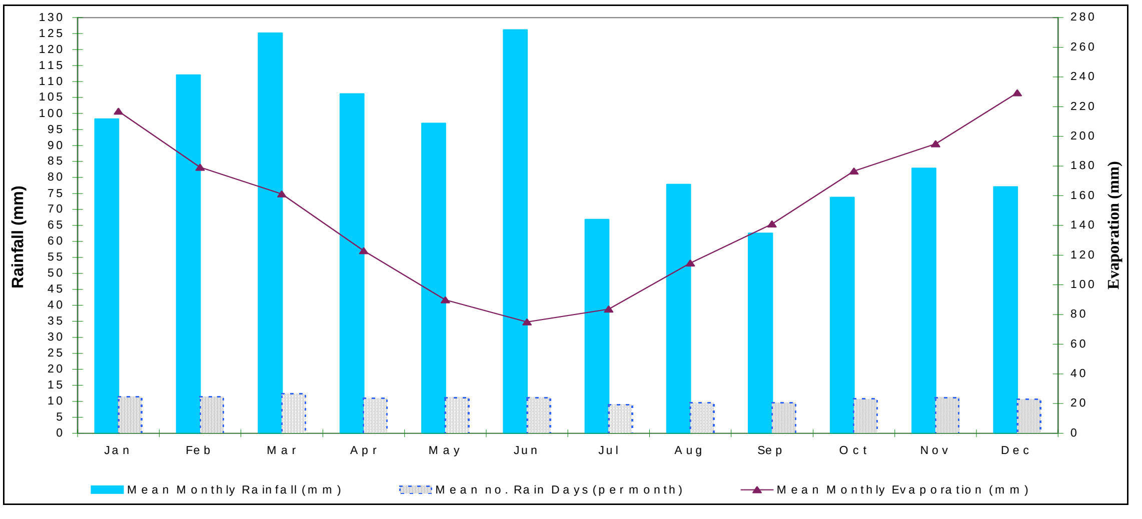
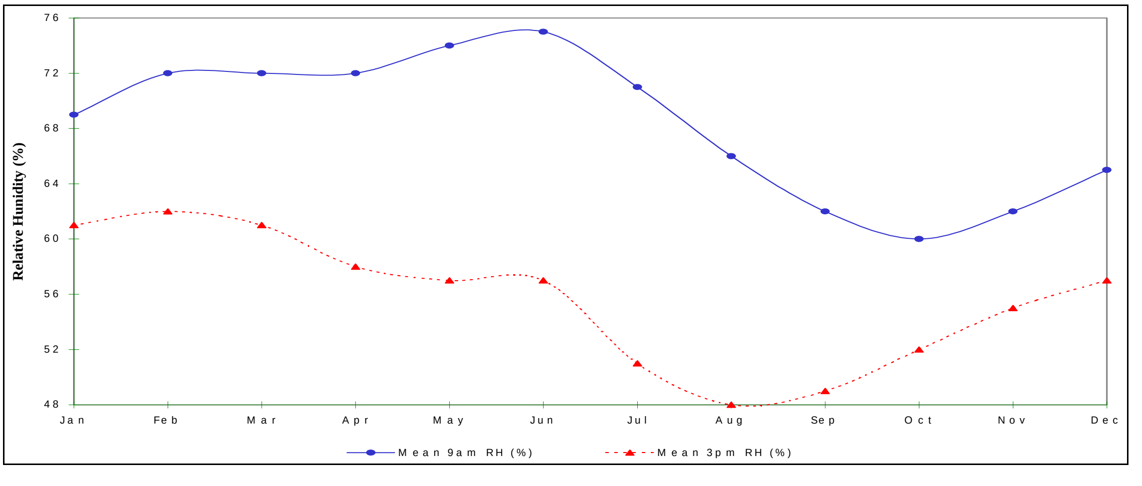
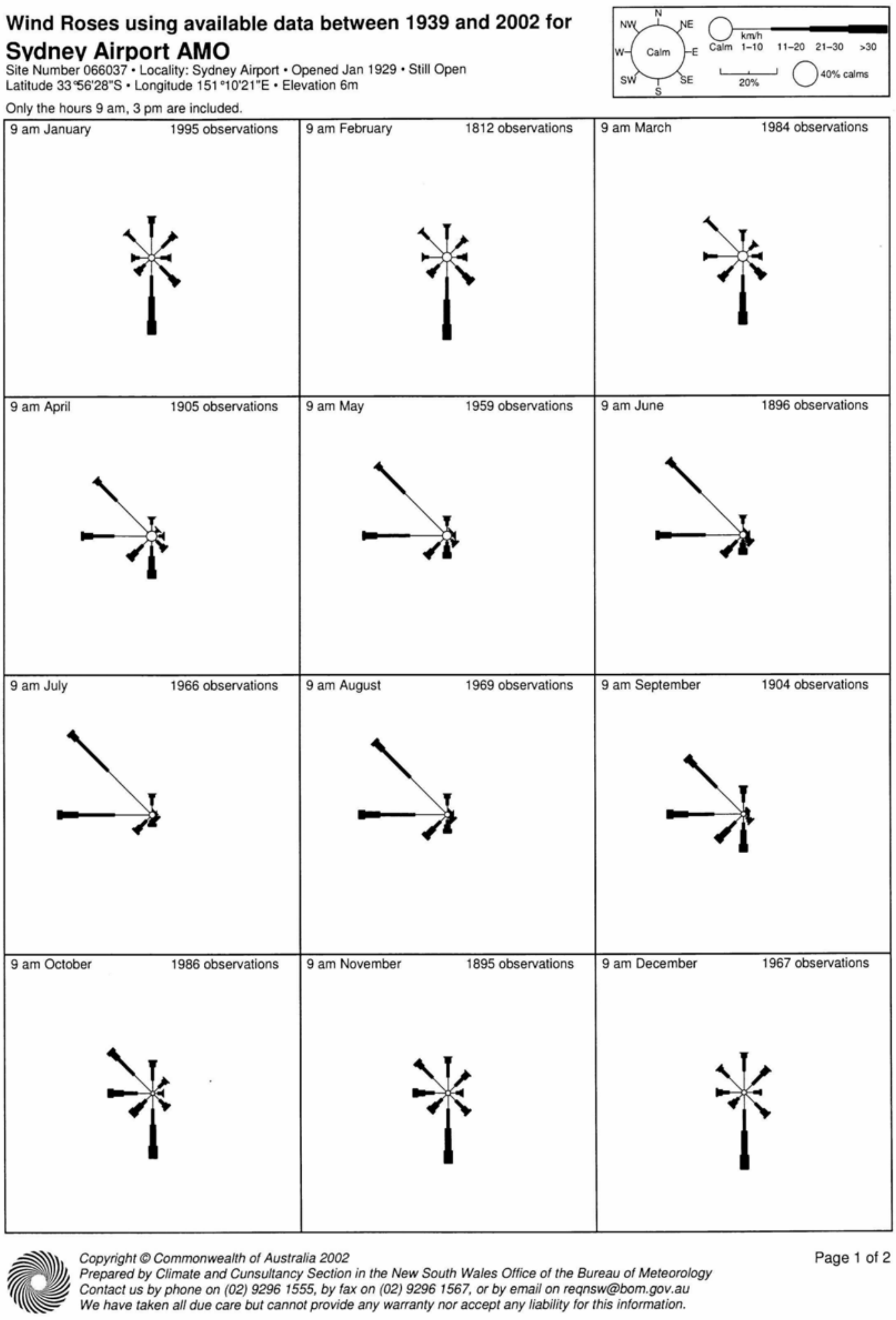


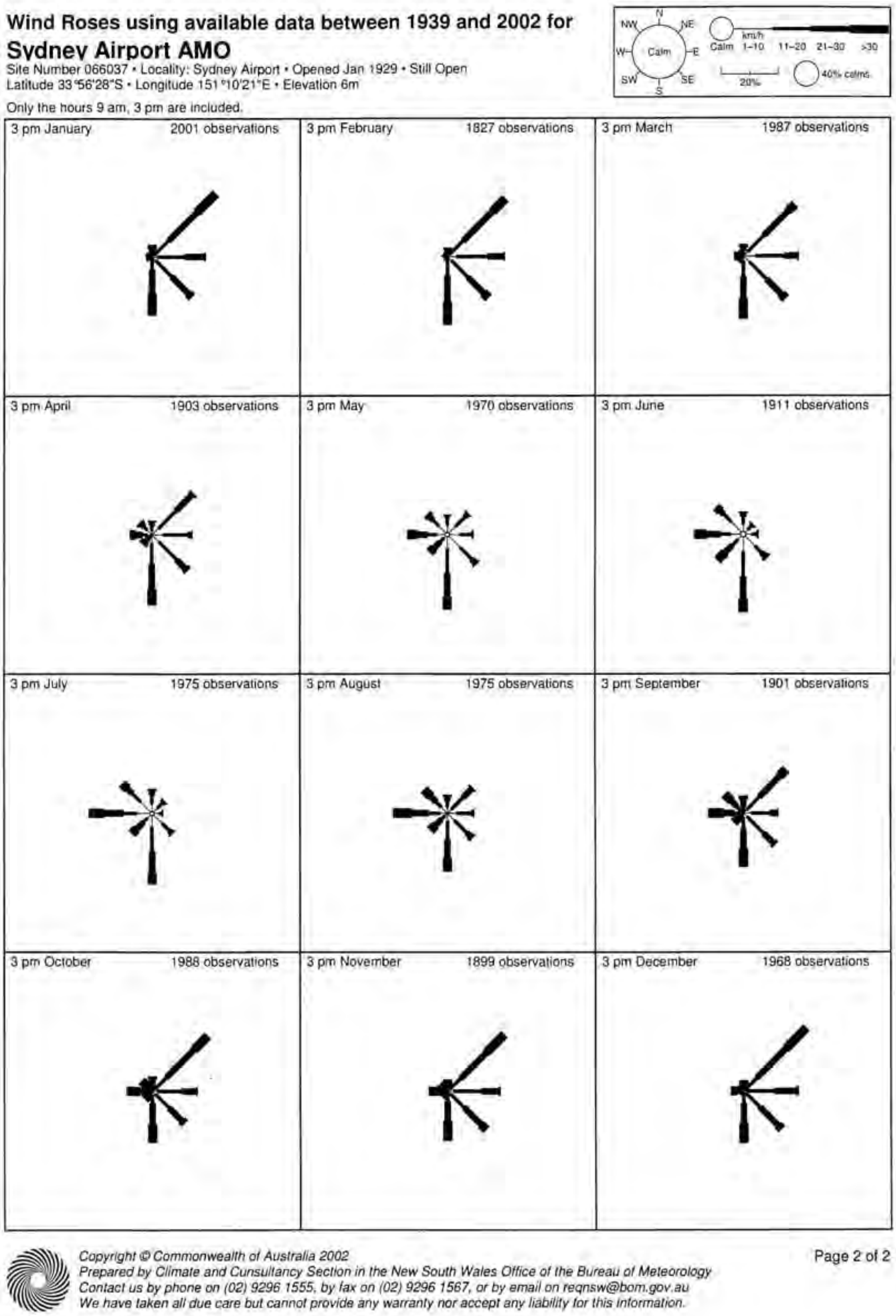
Figure 5-3 Mean Monthly Relative Humidity (Sydney Airport)



- **Figure 5-4 Long-term 9am Windroses for Sydney Airport**



■ **Figure 5-5 Long-term 3pm Windroses for Sydney Airport**



5.3.6 Meteorological Data for Dispersion Modelling

Meteorological data to be used for the dispersion modelling assessment has been obtained from data collected at Sydney Airport for the period January to December 2000. A full description of the meteorological data developed for modelling purposes is provided in **Appendix A**. The site provides three-hourly and hourly observations of wind speed/direction and temperature.

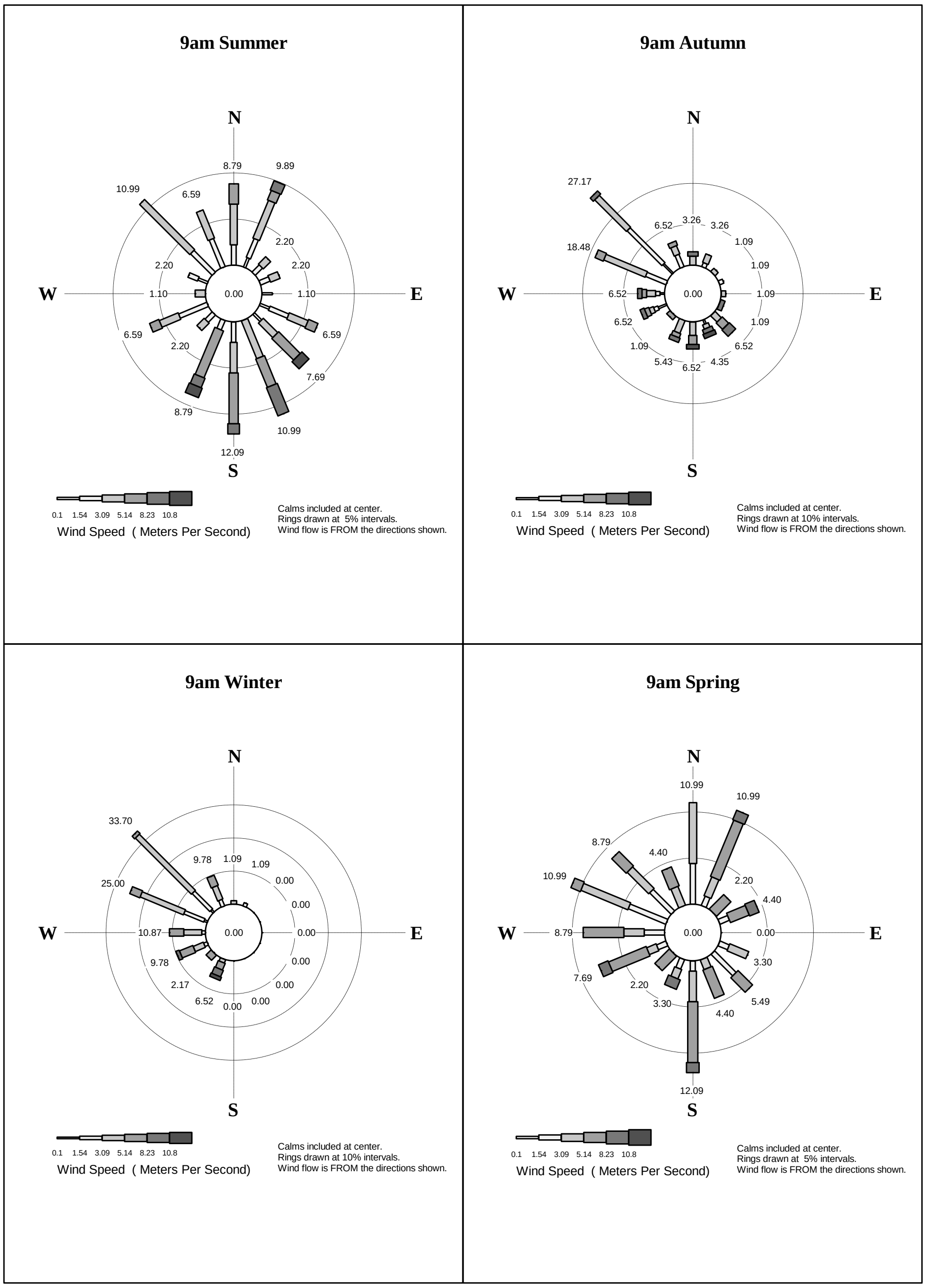
The monthly 9am and 3pm windroses for this set of data (year 2000) are shown in **Figure 5-6** and **Figure 5-7** respectively. The windroses are provided here for the purposes of comparison with the respective long-term windroses shown in **Figure 5-4** and **Figure 5-5** in order to assess the suitability of the wind data captured during the year of 2000.

An analysis of the windroses shows that the 2000 meteorological data collected at Sydney Airport generally compares very well with the longer-term data. 9am summer winds during 2000 showed 31% of all winds were from the south to south-east, comparing to similar proportions for the longer-term windroses. 9am autumn winds during 2000 are comparable, except that the high proportion of southerlies evident during March (long-term) did not occur to the same extent in 2000. 9am winter and spring winds correlate well with the longer term conditions, although the high proportion of 9am winds from the north-north-east during spring 2000 are not experienced to the same extent under normal spring conditions.

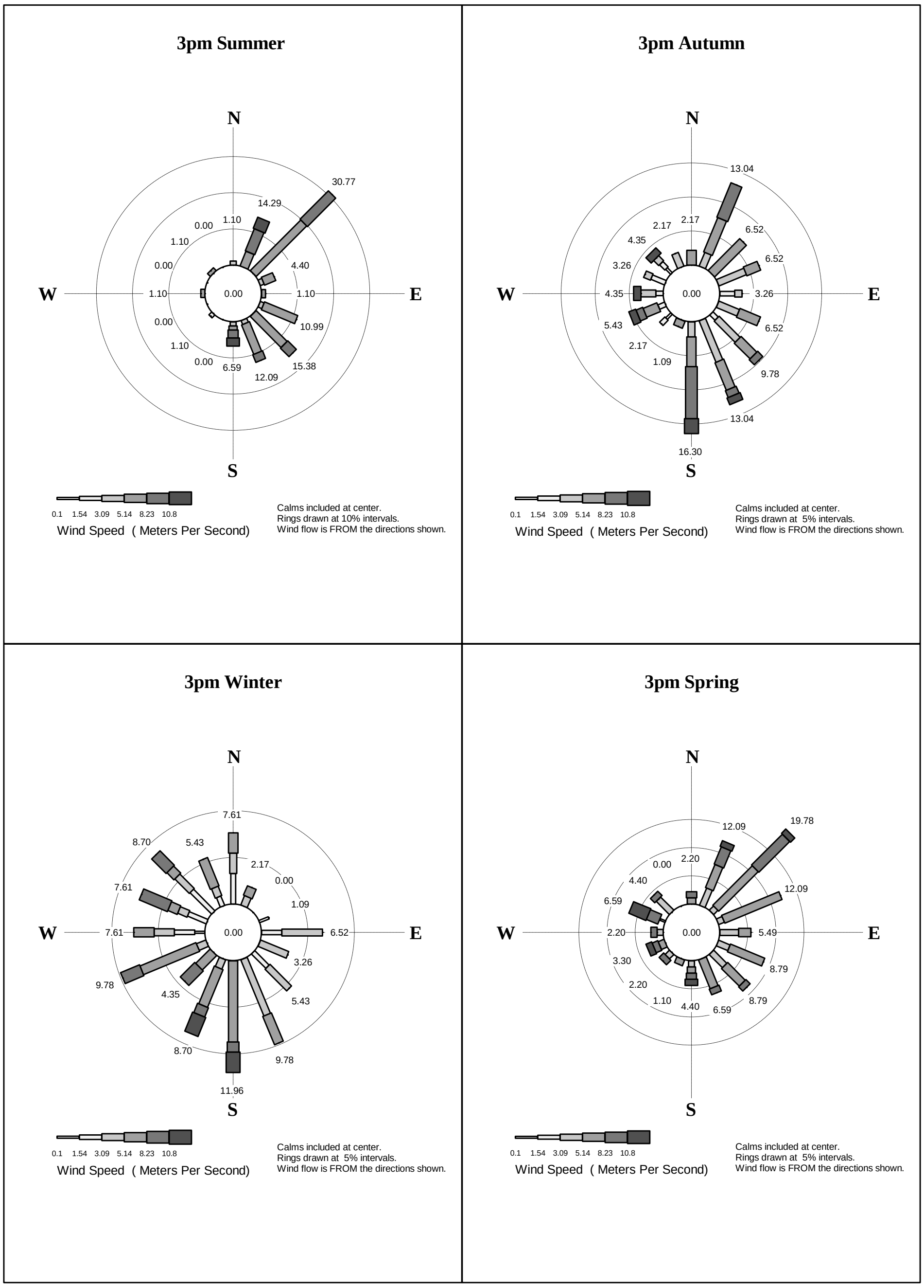
3pm windroses plotted from 2000 conditions correlate very well with the longer-term conditions, except that the longer-term spring windrose shows an approximate 18% occurrence of southerly winds for all spring months that only represent 4.4% occurrence during 2000.

The 2000 windroses are generally a very good representative of longer-term meteorological conditions expected at Sydney Airport and Port Botany. As such, the use of the 2000 data is sufficient for the purpose of undertaking the air dispersion modelling and impact assessment.

■ **Figure 5-6 9am Windroses for Sydney Airport (2000)**



■ Figure 5-7 3pm Windroses for Sydney Airport (2000)



5.4 Existing Ambient Air Quality

5.4.1 Overview

This section of the report provides a discussion of Port Botany's existing air quality using data collected from the nearby Sydney Airport monitoring site at Mascot (as shown in **Figure 5-8**). This is located approximately 2.7 km from the residential area closest to the site of the proposed new terminal.

Air quality within the area surrounding Port Botany is influenced by both local and regional pollutant sources, including road traffic, domestic sources, aircraft and a variety of industrial emissions. The proximity to local pollutant sources and the influence of sea breezes play significant roles in the dispersion of pollutants around Botany Bay.

As part of the NSW EPA's air quality monitoring network, PM_{10} (1-hour, TEOM[4]), SO_2 (1-hour) and NO_2 (1-hour) are monitored at the Randwick station, located approximately 4.2 km north-east of Port Botany at the Randwick Barracks.

Data from this station was obtained from the NSW EPA Quarterly Air Quality Monitoring Reports, and a comparison made to the Airport air quality data. SO_2 and NO_2 data from the Randwick station support the use of the Mascot data for the purposes of describing local air quality in the vicinity of Port Botany and surrounding residential area, with much consistency between the two data sets. With the PM_{10} (1-hour) raw data not being available for the Randwick site, a comparison for PM_{10} (24-hour) was not able to be determined.

Overall it was considered that use of the local Sydney Airport air monitoring data for this study would be representative of the background air quality in the Port Botany area, and is comparable to the NSW EPA monitoring data.

5.4.2 Air Quality Monitoring Results

Air quality monitoring data collected at Mascot (Sydney Airport) between July 2000 and August 2002 (26 months) was made available to Sinclair Knight Merz for the purpose of this assessment, and has been used to describe the existing air quality in Port Botany. Monthly average and monthly maximum NO_2, SO_2 and PM_{10} concentration data were graphed and compared with the relevant criteria outlined in **Table 4-2**.

Particulate Matter (PM_{10})

The monthly maximum and average PM_{10} (24-hour) concentration recorded at Mascot is displayed in **Figure 5-9**. The data for each individual year in the period is shown in **Table 5-2**.

It is evident in that the 50 $\mu g/m^3$ criteria was exceeded for all of the summer months where data was available. In December 2001 and January 2002, bushfires were most likely the cause of the exceedences, with severe bushfires in Sydney at this time. The exceedences of the criterion during the cooler months of the year may be a result of the use of solid fuel heaters during this time of the year.

[4] Tapered Element Oscillating Microbalance

- **Table 5-2 PM_{10} (24-hour) Concentrations at Mascot (2000-2002)**

Year	Average of Monthly Maximum (μg/m³)	Average of Monthly Average (μg/m³)
2000 (6 months)	50	21
2001 (12 months)	52	23
2002 (8 months)	37	15
Average	**47**	**20**

The NSW EPA has also adopted an annual (all hours) criterion for PM_{10} as 30 μg/m³. From the data obtained at Mascot for the period during 2000–2002, the PM_{10} (annual) average background is 20 μg/m³, as reported above in **Table 5-2**.

Dust Deposition

The NSW EPA criterion for dust deposition in residential areas is 4 g/m²/month. The existing background dust level in the Port Botany region is approximated at 1.5-2 g/m²/month, which allows an increment over existing levels of 2-2.5 g/m²/month. In order to be conservative and for the purposes of this study, the maximum acceptable increase over existing dust levels shall be taken as 2 g/m²/month, which has therefore been used as the site specific criterion for impact assessment.

Dust emission rates used in this assessment have been determined from TSP emission factors. The NSW EPA also adopts a concentration based TSP annual (all hours) criterion of 90 μg/m³. This criterion has not been assessed as part of this study as fine particulate matter (PM_{10}) is considered a more effective indicator of the impacts of dust on human health. Dust deposition (using TSP emission factors) is an effective indicator of impacts of dust emission in terms of human and environmental amenity. These impacts have been previously discussed in detail in **Section 3.2**.

Nitrogen Dioxide (NO_2)

The monthly maximum and monthly average 1-hour NO_2 concentration data for Mascot are displayed in **Figure 5-10**. The site did not record any exceedences of the 1-hour average NSW EPA criterion of 12 pphm at any time from July 2000 – August 2002. The data for each individual year in this period is shown in **Table 5-3**.

- **Table 5-3 NO_2 (1-hour) Concentrations at Mascot (2000-2002)**

Year	Average of Monthly Maximum (pphm)	Average of Monthly Average (pphm)
2000 (6 months)	6.8	1.2
2001 (12 months)	4.6	1.1
2002 (8 months)	4.5	1.2
Average (pphm)	**5.0**	**1.2**
Average (μg/m³)*	**103**	**24**

* at 273 K and 101.3 kPa

The annual (all hours) background NO_2 concentration recorded at the Mascot site from July 2000 – August 2002 is 1.2 pphm. This compares to the NSW EPA criterion of 3.0 pphm.

Sulfur Dioxide (SO_2)

The monthly maximum and average 1-hour and 24-hour SO_2 concentration for Mascot during 2000–2002 are presented graphically in **Figure 5-11** and **Figure 5-12** respectively.

As can be seen from the figures, there have been no exceedences of the NSW EPA 1-hour and 24-hour criterion of 20 pphm and 8 pphm respectively, with recorded concentrations well below the criteria. The maximum 1-hour SO_2 concentration recorded was 4.0 pphm. The maximum 24-hour SO_2 concentration recorded was 1.0 pphm.

The averages of the data recorded for each year are shown in **Table 5-4**.

- **Table 5-4 SO_2 (1-hour) and SO_2 (24-hour) Concentrations at Mascot (2000 – 2002)**

Year	Average of Monthly Maximum (pphm)		Average of Monthly Average (pphm)	
	1-hour	24-hour	1-hour	24-hour
2000 (6 months)	2.1	0.6	0.1	0.2
2001 (12 months)	2.0	0.5	0.2	0.2
2002 (8 months)	1.5	0.6	0.2	0.2
Average (pphm)	**1.9**	**0.5**	**0.2**	**0.2**
Average (μg/m^3)*	**49**	**16**	**6**	**6**

*at 273 K and 101.3 kPa

The annual (all hours) background SO_2 concentration recorded at the Mascot site from July 2000 – August 2002 is 0.2 pphm. This compares to the NSW EPA criterion of 2.0 pphm.

5.4.3 Relevance of Airport Data to Port Botany Expansion Project

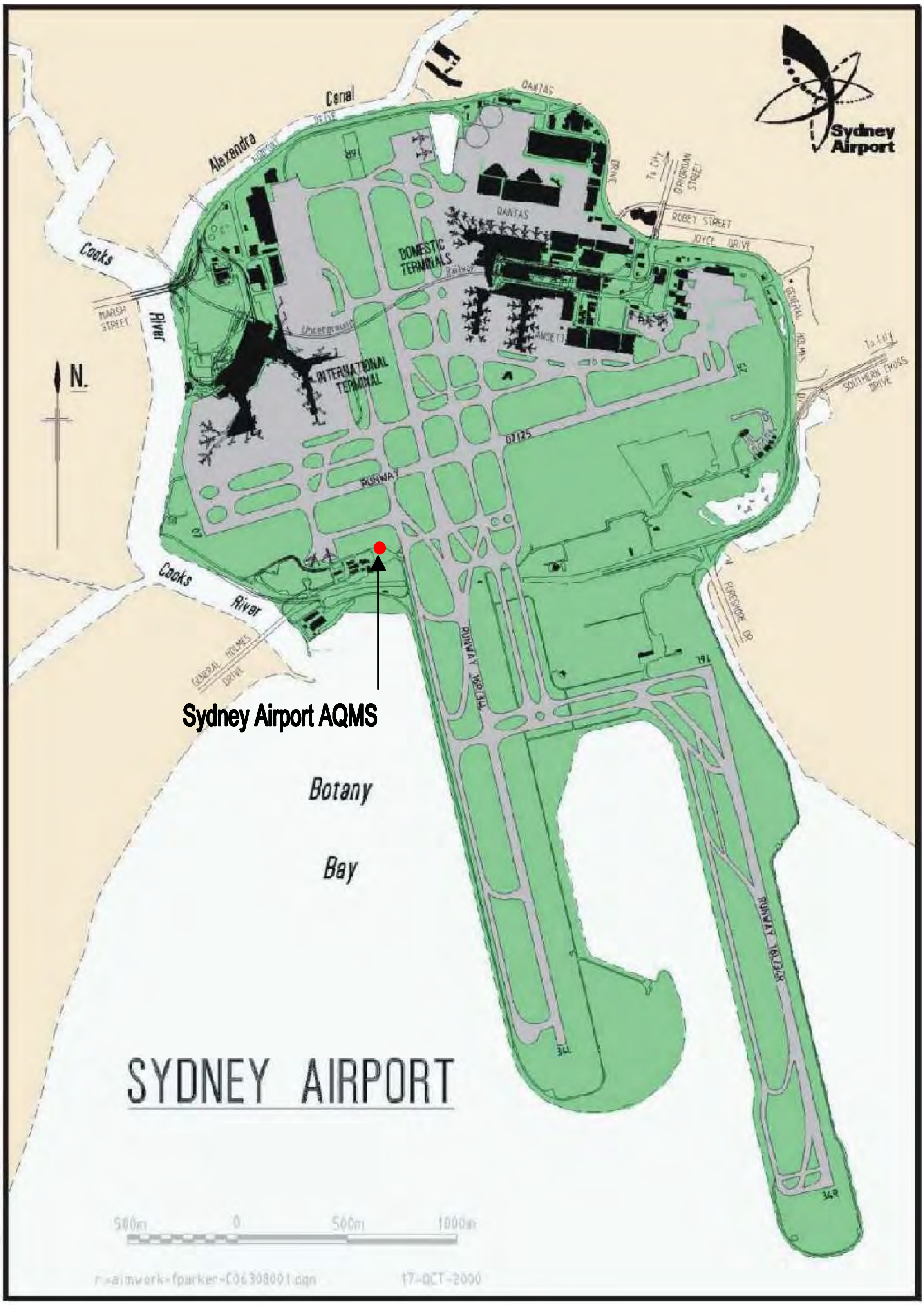
As discussed earlier, the data recorded at Sydney Airport during July 2000 – August 2002 adequately describes local air quality in the area immediately surrounding the Port Botany expansion project.

The land use within the vicinity of the Mascot air quality monitoring station is the Sydney Airport and associated aircraft runways. The areas of Botany, Banksmeadow and Matraville which surround Port Botany are slightly more industrial than the Airport, however the level of background pollution (particularly PM_{10}, which appears to be the only pollutant of concern within the area at particular times of the year) from aircraft operations and industrial activity are expected to be similar.

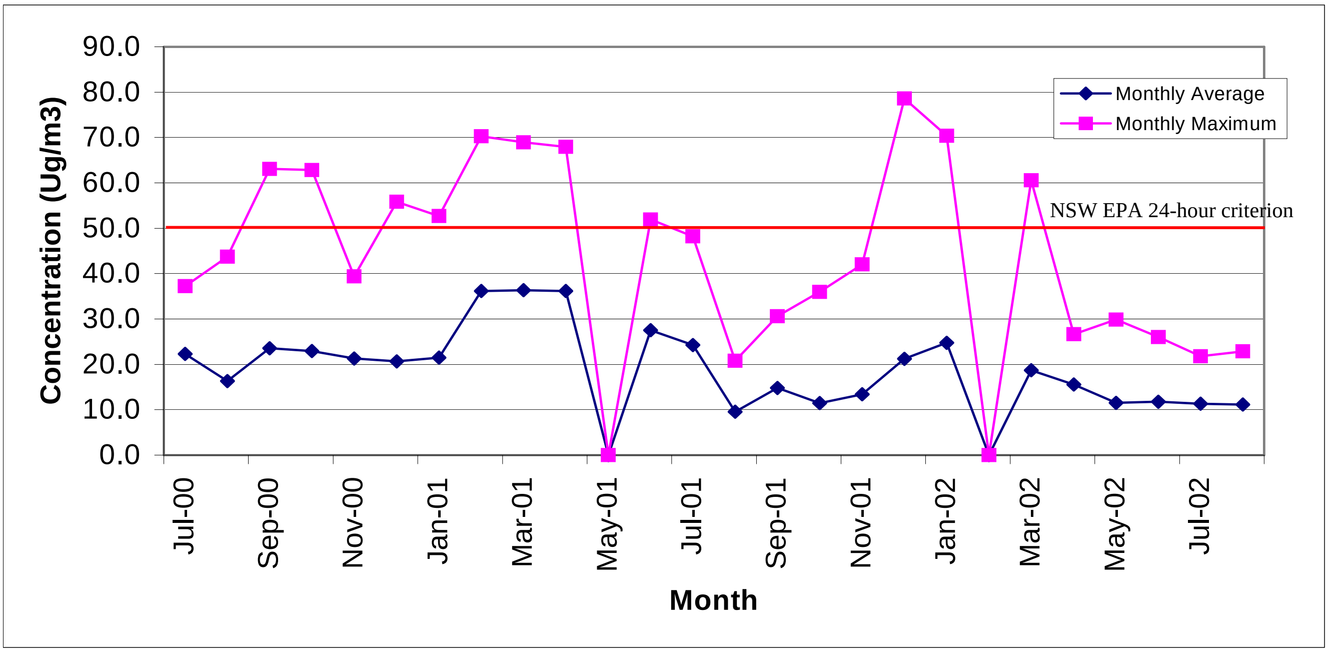
The most important feature of the monitoring data in terms of ambient air quality at Mascot is the exceedences of PM_{10}. The analysis presented above shows that the 24-hour PM_{10} criterion is most often exceeded during the warmer months of the year. The elevated background concentrations during these periods must therefore be given due attention. This may potentially be an issue for SPC during peak operational activity in the summer months, where under certain dispersion and meteorological conditions, the “room” for incremental impact of PM_{10} emissions from ships, dockside equipment, trains and trucks will become less. The implementation of dust mitigation measures during construction and whilst during periods of elevated background PM_{10} concentrations will also become more important. See **Section 6.7** for further comment.

The reasons for not including CO as part of the background air quality assessment are discussed in **Section 7.2.1**.

■ **Figure 5-8 Sydney Airport Air Quality Monitoring Station**

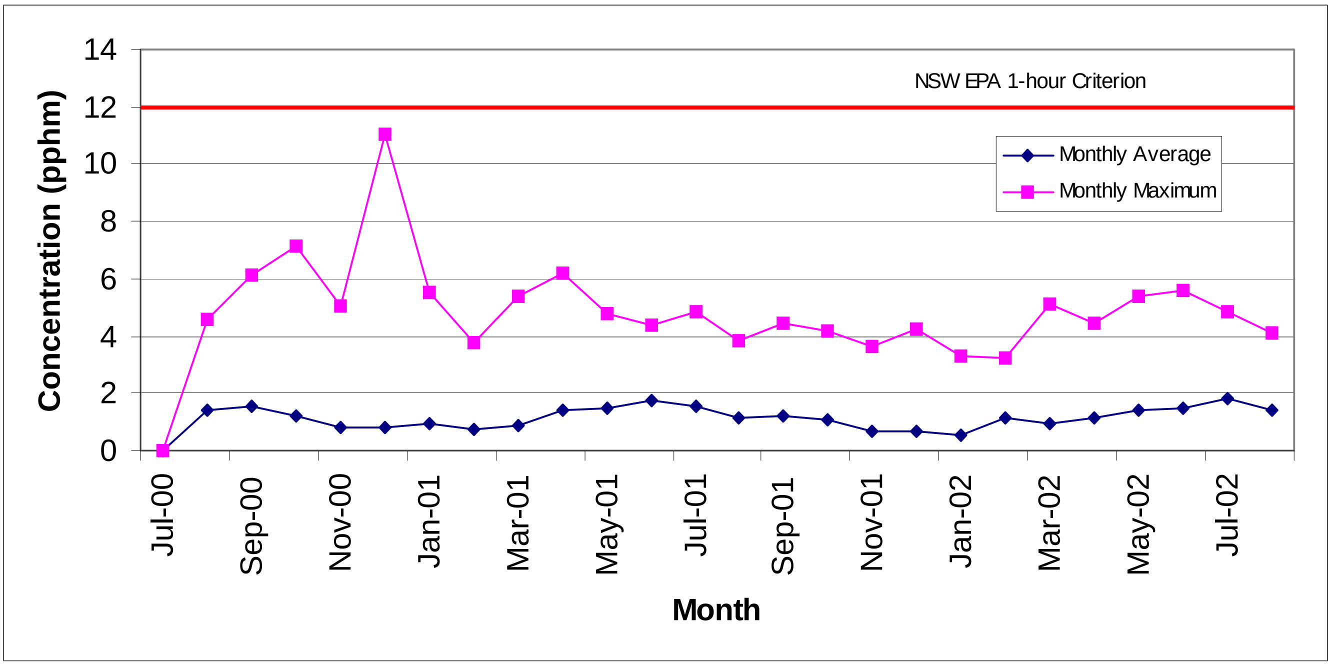


■ **Figure 5-9 Monthly Maximum and Average 24-hour PM_{10} Concentration at Mascot (2000–2002)**



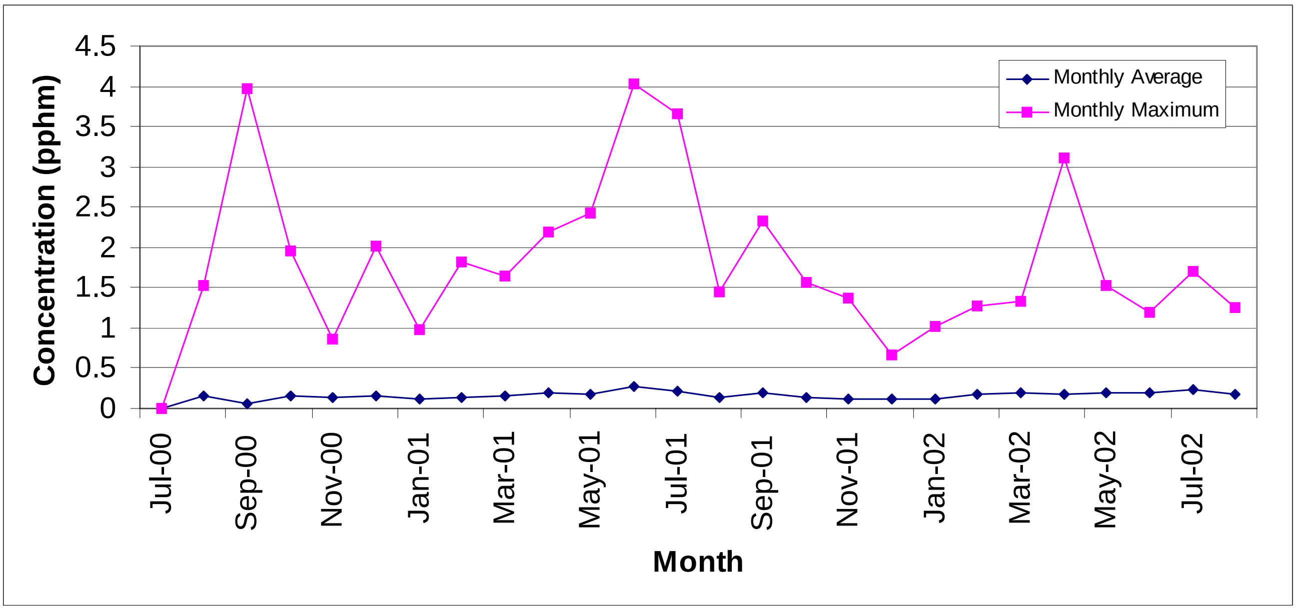
Note: Zero values indicate missing data

■ **Figure 5-10 Monthly Maximum and Average 1-hour NO_2 Concentration at Mascot (2000–2002)**



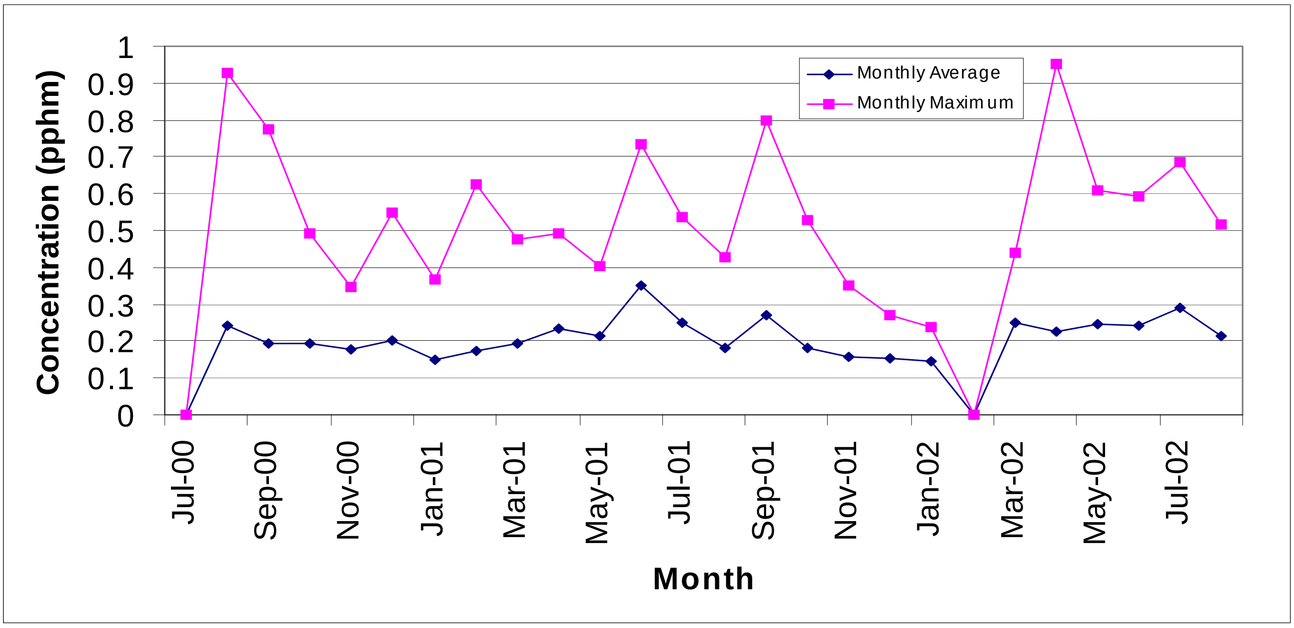
Note: Zero values indicate missing data

■ **Figure 5-11 Monthly Maximum and Average 1-hour SO_2 Concentration at Mascot (2000–2002)**



Note: Zero values indicate missing data. NSW EPA 1-hour criterion is 20 pphm.

■ **Figure 5-12 Monthly Maximum and Average 24-hour SO_2 Concentration at Mascot (2000–2002)**



Note: Breaks indicate missing data. NSW EPA 24-hour criterion is 8 pphm.

5.5 Project Specific Air Quality Objectives

The *Approved methods and guidance for the modelling and assessment of air pollutants in NSW* (NSW EPA 2001) states background air quality must be taken into consideration when undertaking air quality impact assessments. The basis for this is such that cumulative impacts from a variety of sources should not exceed the NSW EPA ambient air quality objectives, as discussed earlier in **Chapter 4**.

Having set out the recognised NSW EPA ambient air quality criteria (**Chapter 4**) and summarised existing ambient air quality in **Section 5.4**, it is now possible to set out project-specific ambient air criteria for key pollutants associated with the construction and operation of the New Port Botany Terminal. The proposed project's specific air quality criteria are the difference between the NSW EPA objectives and the background level for the respective pollutants. This is shown in **Table 5-5**.

- **Table 5-5 Site Specific Air Quality Criteria**

Pollutant	Averaging Period	Monthly Average Background*	Monthly Maximum Background*	Average Background for Impact Assessment**	Current Criterion	
					NSW EPA Criterion	Project Specific Criterion
Particulate Matter (PM_{10})	24-hour	20 µg/m^3	47 µg/m^3	34 µg/m^3	50 µg/m^3	16 µg/m^3
	Annual	-	-	20 µg/m^3	30 µg/m^3	10 µg/m^3
Dust Deposition	-	-	-	1.5 – 2 g/m^2/month	4 g/m^2/month	2 g/m^2/month
SO_2	10-minute	N/A	N/A	N/A	712 µg/m^3	712 µg/m^3 ***
	1-hour	4 µg/m^3 (0.2 pphm)	49 µg/m^3 (1.9 pphm)	27 µg/m^3 (1.0 pphm)	570 µg/m^3 (20 pphm)	543 µg/m^3 (19 pphm)
	24-hour	6 µg/m^3 (0.2 pphm)	16 µg/m^3 (0.5 pphm)	11 µg/m^3 (0.4 pphm)	228 µg/m^3 (8 pphm)	217 µg/m^3 (7.6 pphm)
	Annual	-	-	6 µg/m^3 (0.2 pphm)	60 µg/m^3 (2 pphm)	54 µg/m^3 (1.8 pphm)
NO_2	1-hour	24 µg/m^3 (1.2 pphm)	103 µg/m^3 (5.0 pphm)	64 µg/m^3 (3.1 pphm)	246 µg/m^3 (12 pphm)	182 µg/m^3 (8.9 pphm)
	Annual	-	-	24 µg/m^3 (1.2 pphm)	62 µg/m^3 (3 pphm)	38 µg/m^3 (1.8 pphm)

* Average for all months July 2000 – August 2002
** The combined average of monthly average and monthly maximum values
N/A = data not available
*** background data for 10-minute averaging period is not available. As such, the NSW EPA ambient air objective for SO_2 (10-minute) of 712 µg/m^3 is used as the site specific criterion to assess impacts

It can be seen from the above data that existing ambient PM_{10} and NO_2 concentrations make up a moderate proportion of the relevant NSW EPA criterion while ambient SO_2 concentrations are only a fraction of the criterion values. As such using a project specific criterion which is based on the average of average and maximum ambient air quality data, has in some cases the potential to underestimate predicted PM_{10} and NO_2 impacts from the AUSPLUME modelling.

As such for modelling these pollutants an hourly background air quality data file has been input to the model such that the modelling predicts hourly impacts including both background and impact levels of air pollution. The meteorological data file used for modelling covers the same time period as the ambient air quality data.

6. Construction Air Quality Assessment

6.1 Overview

The Port Botany expansion construction activities, which primarily involve the movement of many tonnes of material and heavy vehicles on the various work sites, will produce PM_{10} and dust deposition impacts on the sites and surrounding region.

An overview of the construction activities was provided in **Section 2.2**. The following sections outline the main sources of PM_{10} and dust deposition and estimate the level of impact generated during the construction works by air dispersion modelling with AUSPLUME.

6.2 Methodology of Air Quality Assessment

The methodology employed for assessing dust impacts from construction of the proposed Port Botany expansion is based on the NSW EPA guidelines "*Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW*" (Aug 2001). The basis of this methodology is to prepare an inventory of the expected dust emissions from the dust generating activities that are described in this chapter. Emissions are then modelled making use of air dispersion modelling software. For this study the Gaussian plume dispersion model, AUSPLUME (V5.4), was used to model dust emissions from construction activities. Impacts at sensitive receivers and at residential areas were then compared to NSW EPA air quality objectives and criteria, as discussed previously in **Chapter 4**.

Modelled air quality for the construction of the proposed Port Botany upgrade takes into account existing air quality. To do this air quality impacts determined by AUSPLUME include background PM_{10} concentrations. Hourly average background PM_{10} data were available over a period of 3 years from 2000 through to 2002, however, gaps existed in the database for each year. Therefore a database of hourly average background PM_{10} data was created using data from each of the three years.

The primary blocks of data forming the new annual databases are shown as follows:

- 1/01/2001 0:00 – 1/05/2001 3:00
- 1/05/2002 4:00 – 6/06/2002 18:00
- 6/06/2001 19:00 – 13/06/2001 14:00
- 13/06/2002 15:00 – 18/06/2002 16:00
- 18/06/2001 17:00 – 1/07/2001 23:00
- 1/07/2000 0:00 – 24/07/2000 10:00
- 25/07/2002 10:00 – 3/08/2002 9:00
- 2/08/2000 10:00 – 31/12/2000 23:00

Hourly meteorological data were also available for 2000-2002 to provide a time match of meteorological data to pollutant data.

In the period of assessment the background PM_{10} data revealed 27 exceedances of the PM_{10} (24 hour) criteria of 50 $\mu g/m^3$. As such we have assessed construction phase PM_{10} impacts by predicting the number of additional exceedances of 50 $\mu g/m^3$ over the 12 month assessment period.

6.3 Main Construction Activities and Site Areas

6.3.1 Selection of Three Intensive Construction Activity Periods

SPC has divided the proposed construction activities generally into 3-month work segments, or blocks. The proposed schedule of construction activity is provided in **Table 6-1**.

- **Table 6-1 Proposed Construction Schedule**

Activity	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
Establishment	X																							
Tug Berth Construction	X	X																						
Dredging & Reclamation		X	X	X	X	X																		
Rock Berm Placement		X	X	X	X																			
Pile Driving				X	X	X	X	X	X															
Rock Armouring					X	X	X	X	X	X														
Wall Unit Placement										X	X	X	X											
Deck Construction							X	X	X	X	X	X	X											
Road & Rail Works						X	X	X	X	X	X	X	X	X	X	X								
Boat Ramp Relocation					X																			
Estuary Development						X	X																	
Beach Enhancement						X	X																	
Operator Works														X	X	X	X	X	X	X	X	X	X	X

Three of the most intensive of these 3-month periods were selected for air dispersion modelling scenarios, with the primary reference for the details of the construction activities being the 'Microsoft Project' planning schedule supplied by SPC. The three 3-month periods selected for the modelling scenarios, and the corresponding construction activities found within those periods that were considered to have potential PM_{10} and dust deposition impacts, are shown in **Table 6-2**.

- **Table 6-2 Three Intensive Construction Activity Periods**

3-Month Period	Construction Activities
Year 1 Period 2 (Y1P2)	Boat Ramp/ Tug Berth Construction, Dredging & Reclamation, Rock Berm Placement
Year 2 Period 2 (Y2P2)	Tug Berth Construction (Truck Deliveries, Retaining Wall), Dredging & Reclamation, Rock Armouring (Wharf/Deck Construction), Beach Enhancement
Year 3 Period 1 (Y3P1)	Boat Ramp Construction (WGD* by trucks), Dredging & Reclamation (Pre-loading), Rock Armouring (Wharf/Deck Construction)

* WGD = Wheel Generated Dust

6.3.2 Site Areas

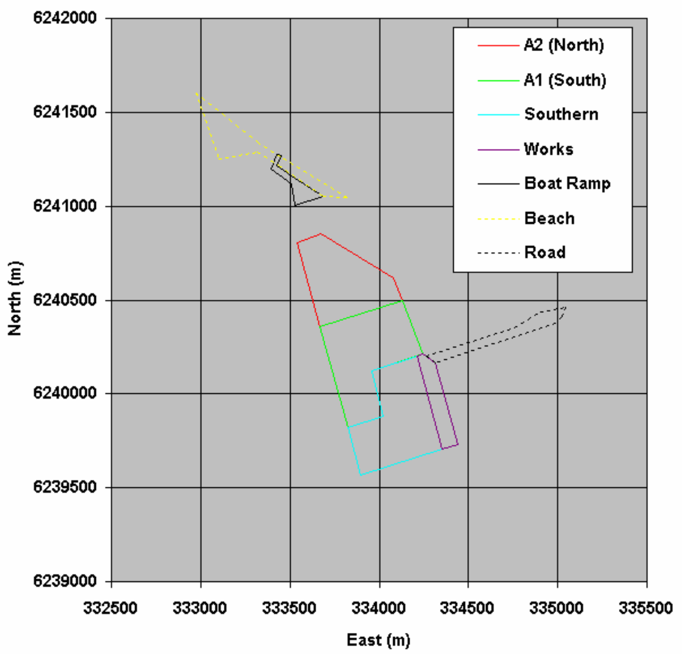
The site areas specified by SPC and used for the modelling were, (refer to **Figure 6-1**):

- A2 (North) 15.0 ha;
- A1 (South) 15.0 ha; and
- Southern 15.0 ha.

The other site areas were measured using the Sinclair Knight Merz Geographical Information System "ERDAS", and found to be approximately (refer to **Figure 6-1**):

- Works 4.0 ha;
- Road 3.6 ha;
- Beach 7.0 ha; and
- Boat Ramp 2.0 ha.

■ **Figure 6-1 Construction Activity Site Areas**



Each of the construction activities listed in **Table 6-2** was associated with one of the activity areas defined by the boundaries shown in **Figure 6-1**. The areas shown here defined the boundaries for the PM_{10} and Total Suspended Particulate (TSP)[5] area sources for AUSPLUME. The associations between these site areas and the construction activities will become apparent in the next section.

[5] The TSP emission factors were used by AUSPLUME to calculate dust deposition.

6.3.3 Calculated PM_{10} and TSP Emission Factors

The calculated emission rates for PM_{10} and Total Suspended Particulate (TSP) are shown in **Table 6-3** for period 'Y1P2', **Table 6-4** for period 'Y2P2' and **Table 6-5** for period 'Y3P1'. These emission rates include correction factors that account for the appropriate dust controls, such as, Level 2 Watering for Wheel-Generated Dust (WGD) from trucks, and a Reduction Factor (RF) of 35% for the application of water sprays and wind breaks to the beach enhancement modelling scenario.[6]

- **Table 6-3 PM_{10} and TSP Emission Rates for Modelling Scenario 'Y1P2'**

Activity and Source of Dust Emission	Emission Rate PM_{10}	Emission Rate TSP
Tug Berth Construction – Area 'Boat Ramp'		
Truck WGD, 30 trips per day	0·018 kg/hr	0·082 kg/hr
Truck Dump	0·012 kg/hr	0·037 kg/hr
Total Areal Emission Rate 'Boat Ramp'	4·19E-07 g/m^2/sec	1·65E-06 g/m^2/sec
Dredging & Reclamation – Area 'Works'		
Truck WGD (See below, Area 'Road')	(See below, Area 'Road')	(See below, Area 'Road')
Truck dump/unload	0·053 kg/hr	0·147 kg/hr
Bulldozers (2)	0·113 kg/hr	0·820 kg/hr
Compactor (1)	0·056 kg/hr	0·410 kg/hr
Total Areal Emission Rate 'Works'	1·54E-06 g/m^2/sec	9·57E-06 g/m^2/sec
Rock Berm Placement – Area 'Road'		
Truck WGD from Dredging & Reclamation activities, 30 trips per day	0·179 kg/hr	0·818 kg/hr
Truck WGD only from dumping rocks underwater, 40 trips per day	0·239 kg/hr	1·09 kg/hr
Total Areal Emission Rate 'Road'	3·22E-06 g/m2/sec	1·47E-05 g/m2/sec

- **Table 6-4 PM_{10} and TSP Emission Rates for Modelling Scenario 'Y2P2'**

Activity and Source of Dust Emission	Emission Rate PM_{10}	Emission Rate TSP
Dredging & Reclamation – Areas A1 (South), A2 (North), but consider worst case A2 (North) Only		
Truck WGD, 100 trips per day	1·42 kg/hr	4·78 kg/hr
Total Areal Emission Rate 'A2 (North)'	2·62E-06 g/m^2/sec	8·86E-06 g/m^2/sec
Rock Armouring – Areas 'A1 (South)', 'Road' + 'Works'		
Truck WGD, 40 trips/day + 22/day deliveries	0·71 kg/hr	2·40 kg/hr
Total Areal Emission Rate A1+Works+Road	8·73E-07 g/m^2/sec	2·95E-06 g/m^2/sec
Beach Enhancement – Area 'Beach'		
Truck WGD, 30 trips per day	0·092 kg/hr	0·32 kg/hr
Truck Dump	0·053 kg/hr	0·15 kg/hr
Dozers (2) on Sand	0·17 kg/hr	1·21 kg/hr
Loaders (2)	0·00052 kg/hr	0·0011 kg/hr
Total Areal Emission Rate A1+Works+Road	1·26E-06 g/m2/sec	6·66E-06 g/m2/sec

[6] Source: Environment Australia (Dec 2001) *National Pollutant Inventory (NPI) Emission Estimation Technique Manual for Mining*, Table 3

■ **Table 6-5 PM_{10} and TSP Emission Rates for Modelling Scenario 'Y3P1'**

Activity and Source of Dust Emission	Emission Rate PM_{10}	Emission Rate TSP
Dredging & Reclamation – Areas A1 (South), A2 (North), but consider worst case A2 (North) Only		
Scrapers (6)	0·94 kg/hr	3·58 kg/hr
Compactor	0·028 kg/hr	0·205 kg/hr
Grader	0·045 kg/hr	0·074 kg/hr
Total Areal Emission Rate 'A2 (North)'	2·0E-06 g/m^2/sec	7·9E-06 g/m^2/sec
Rock Armouring – Areas 'A1 (South)', 'Road' + 'Works'		
Truck WGD, 60 trips per day	1·66 kg/hr	5·86 kg/hr
Total Areal Emission Rate A1+Works+Road	2·04E-06 g/m^2/sec	7·21E-06 g/m^2/sec

The calculated emission factors accounting for wind erosion of the exposed areas (average wind speed) are shown in **Table 6-6**.

■ **Table 6-6 Emission Rates Assumed for the PM_{10} and TSP Area Sources**

Area	PM_{10} (g/m^2/s)	TSP (g/m^2/s)	Control
All areas except 'Beach'	2.58E-06	5.16E-06	Water sprays (RF=50%)
'Beach'	1.81E-06	3.61E-06	Water sprays & wind breaks (RF=35%)

The input emissions factors input to AUSPLUME were varied according to a wind speed-cubed law, to account for the greater emissions expected during windier conditions, and lesser emissions during calmer conditions. In the variable emissions source files, the wind erosion of the relevant area sources were 'switched on' for 24 hours a day, whereas the construction activity area sources were 'switched on' only for the 11 working hours in a day. The emission factors in the dust deposition modelling runs were reduced by a factor of $^6/_7$ to account for the deposition of dust resulting from 6 working days in a 7-day week. This scheme was not necessary for the PM_{10} modelling runs as the purpose of those was to determine a maximum 24-hour impact.

6.4 Dispersion Modelling Results

Results showing modelling contour plots are provided in
Figure 6-2 to **Figure 6-9**. These plots have been drawn using the plotting software *Surfer for Windows*.

6.4.1 Modelling Results for Scenario 'Y1P2'

The results from modelling showing PM_{10} criteria exceedences for the scenario 'Y1P2' are shown in **Figure 6-2** . These results show that site activity does not result in any additional (above 27) exceedances of the PM_{10} criteria within the nearest residential areas to the construction area.

Monthly dust depositions for the period 'Y1P2' are shown in **Figure 6-3**. Incremental dust deposition levels predicted within residential areas do not exceed the project criterion of 2 g/m^2/month, with residences closest to the work sites experiencing maximum dust depositions of 0.3 g/m^2/month. The majority of houses to the north of Foreshore Road are well below this level, with levels predominantly from 0.1 to 0.3 g/m^2/month.

Annual TSP concentrations for the period 'Y1P2' are shown in **Figure 6-4**. The results show that annual TSP is substantially lower than the EPA criteria of 90µg/m^3 at all locations beyond the site boundary.

6.4.2 Modelling Results for Scenario 'Y2P2'

The modelling results showing PM_{10} criteria exceedances for the scenario 'Y2P2' is shown in **Figure 6-5**. These results indicate that during this phase of construction the operations at Port Botany has the potential to result in 2 additional exceedances of the PM_{10} criteria within the nearest residential areas to the construction area. The NEPM for Ambient Air Quality allows for 5 exceedances of the 50 µg/m^3. As such this result is not considered significant given the annual average of 27 exceedances of the 50 µg/m^3 measured in the vicinity of the site in recent years.

Monthly dust depositions for the period 'Y2P2' are shown in **Figure 6-6**. In this case there are no modelled exceedances of the 2 g/m^2/month within any of the surrounding residential areas.

Annual TSP concentrations for the period 'Y2P2' are shown in **Figure 6-7**. The results indicate that annual TSP is substantially lower than the EPA criteria of 90µg/m^3 at all locations beyond the site boundary.

6.4.3 Modelling Results for Scenario 'Y3P1'

The modelling results for PM_{10} (24-hour) impacts for the scenario 'Y3P1' are shown in **Figure 6-8**, and are similar to the Y2P2 scenario result. As with Y2P2 the modelling results indicate that construction operations at Port Botany has the potential to result in 2 additional exceedances of the PM_{10} criteria within the nearest residential area to the construction area.

Monthly dust depositions for the period 'Y3P1' are shown in **Figure 6-9**. Modelling results indicate that a monthly dust deposition criteria of 2 g/m^2/month is not exceeded in the residential areas surrounding the construction area.

Annual TSP concentrations for the period 'Y3P1' are shown in **Figure 6-10**. The results of the modelling indicate TSP impacts do not exceed the EPA criteria of 90µg/m^3 at any location beyond the site boundary.

6.4.4 Summary of Results

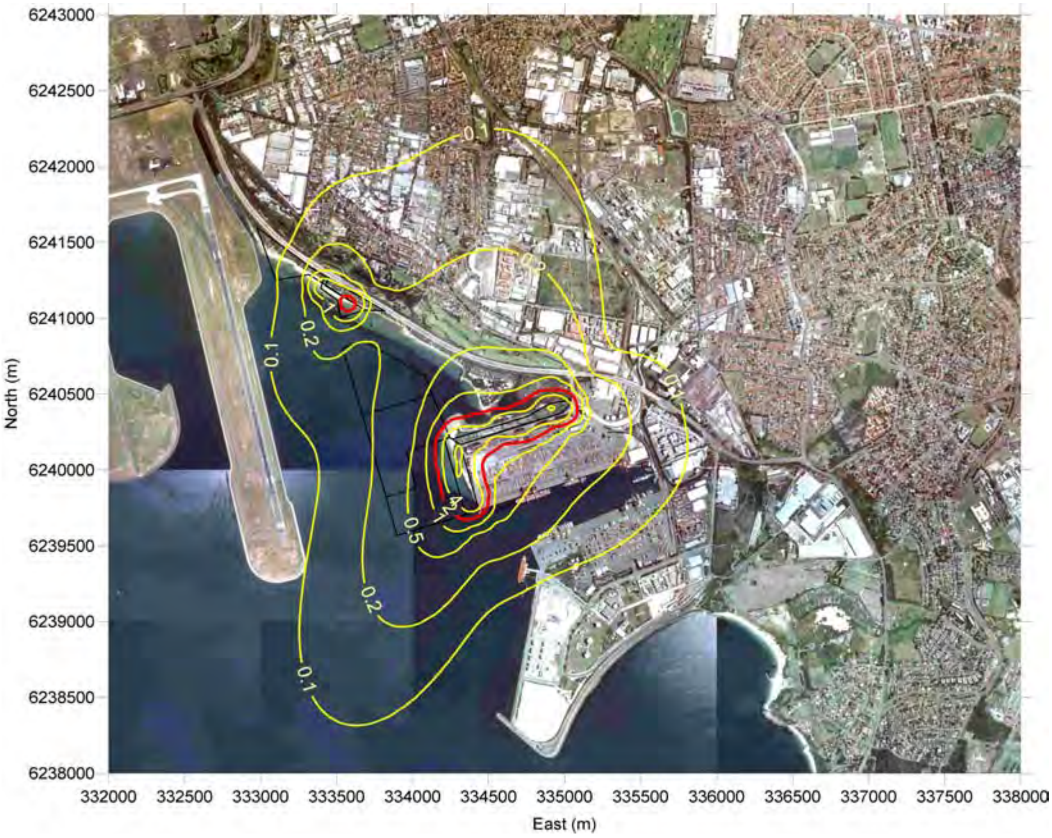
A summary of dispersion modelling results for the construction phase air quality assessment is provided in **Table 6-7** below.

- **Table 6-7 Summary of Key Construction Impact Assessment Results**

Key Pollutant & Averaging Period	Scenario	NSW EPA Criterion (µg/m^3)	Average Background Conc* (µg/m^3)	Project criterion (µg/m^3)	Max Conc at a Residential Receiver (µg/m^3)
PM_{10} (24-hour)	Y1P2	50 µg/m^3	34 µg/m^3	16 µg/m^3	≈ 2 µg/m^3
	Y2P2	50 µg/m^3	34 µg/m^3	16 µg/m^3	≈ 16 µg/m^3
	Y3P1	50 µg/m^3	34 µg/m^3	16 µg/m^3	≈ 16 µg/m^3
Dust Deposition (Annual)	Y1P2	4 g/m^2/mon	2 g/m^2/mon	2 g/m^2/mon	≈ 0·3 g/m^2/mon
	Y2P2	4 g/m^2/mon	2 g/m^2/mon	2 g/m^2/mon	≈ 2 g/m^2/mon
	Y3P1	4 g/m^2/mon	2 g/m^2/mon	2 g/m^2/mon	≈ 2 g/m^2/mon

■ **Figure 6-2 PM_{10} Impacts Construction Y1P2, Exceedences of 50µg/m^3**

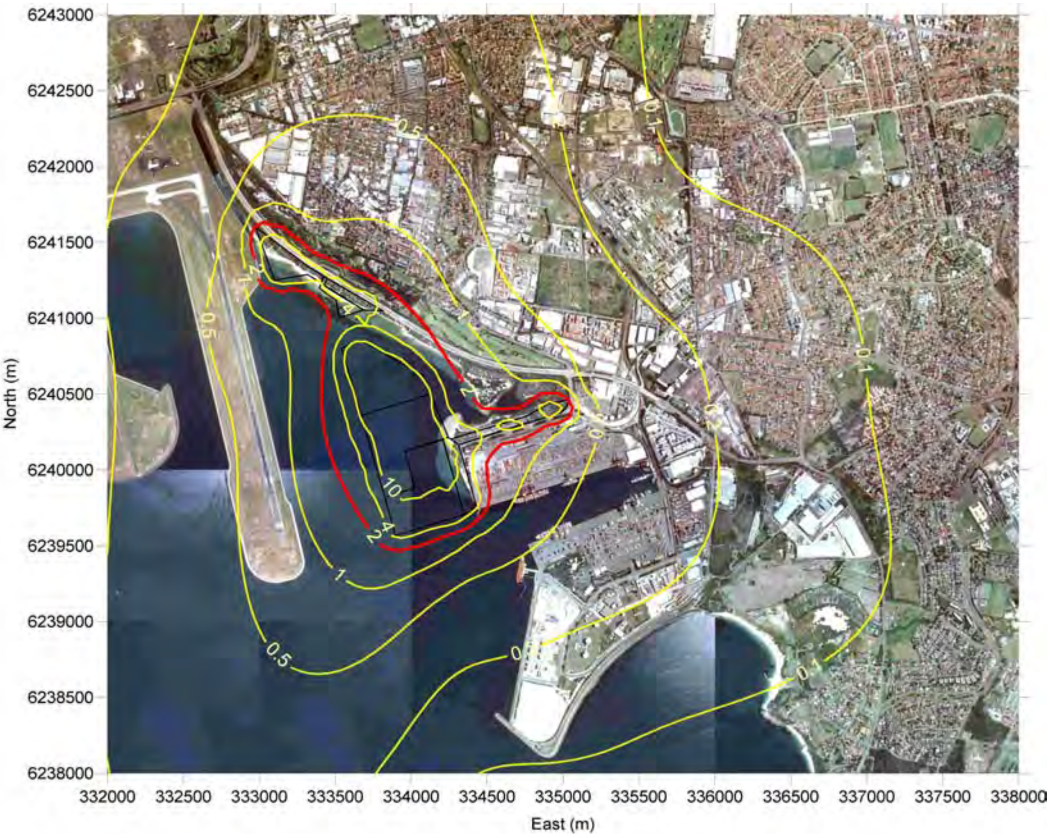
- **Figure 6-3 Dust deposition Impacts Construction Y1P2 (g/m^2/month)**



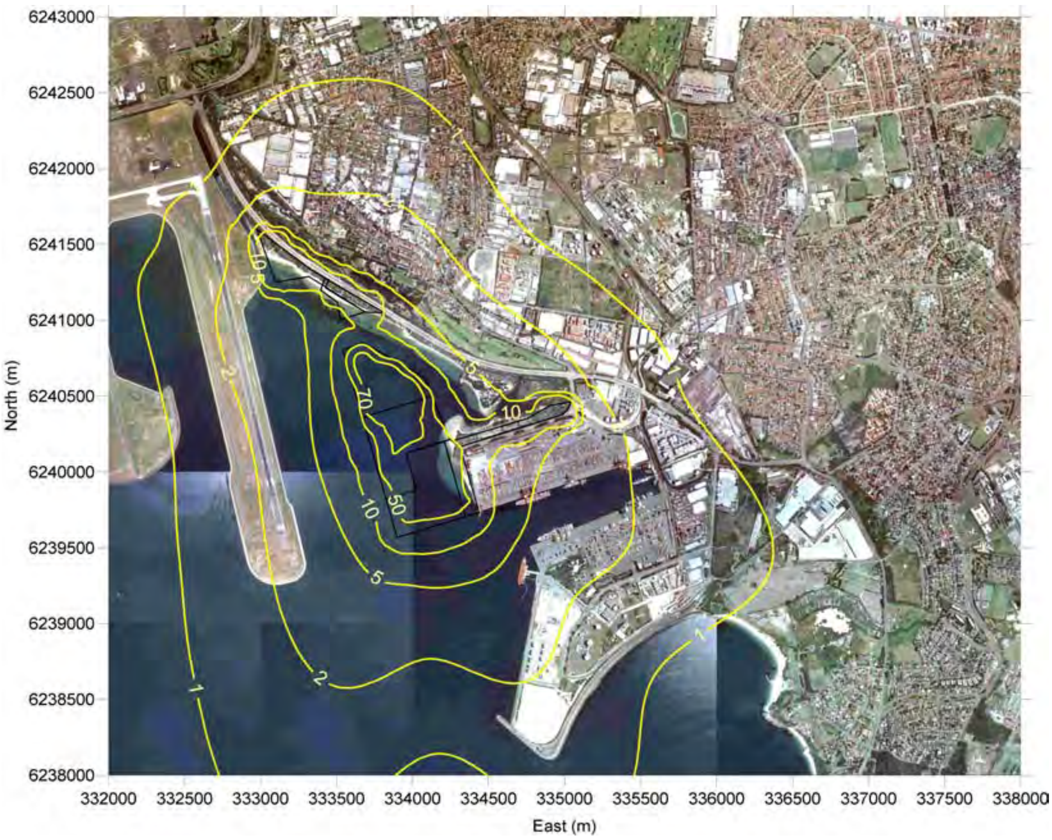
- **Figure 6-4 TSP Impacts Construction Y1P2 Annual Average (μg/m³)**

■ **Figure 6-5 PM_{10} Impacts Construction Y2P2, Exceedences of 50μg/m^3**

- **Figure 6-6 Dust Deposition Impacts Construction Y2P2 (g/m²/month)**

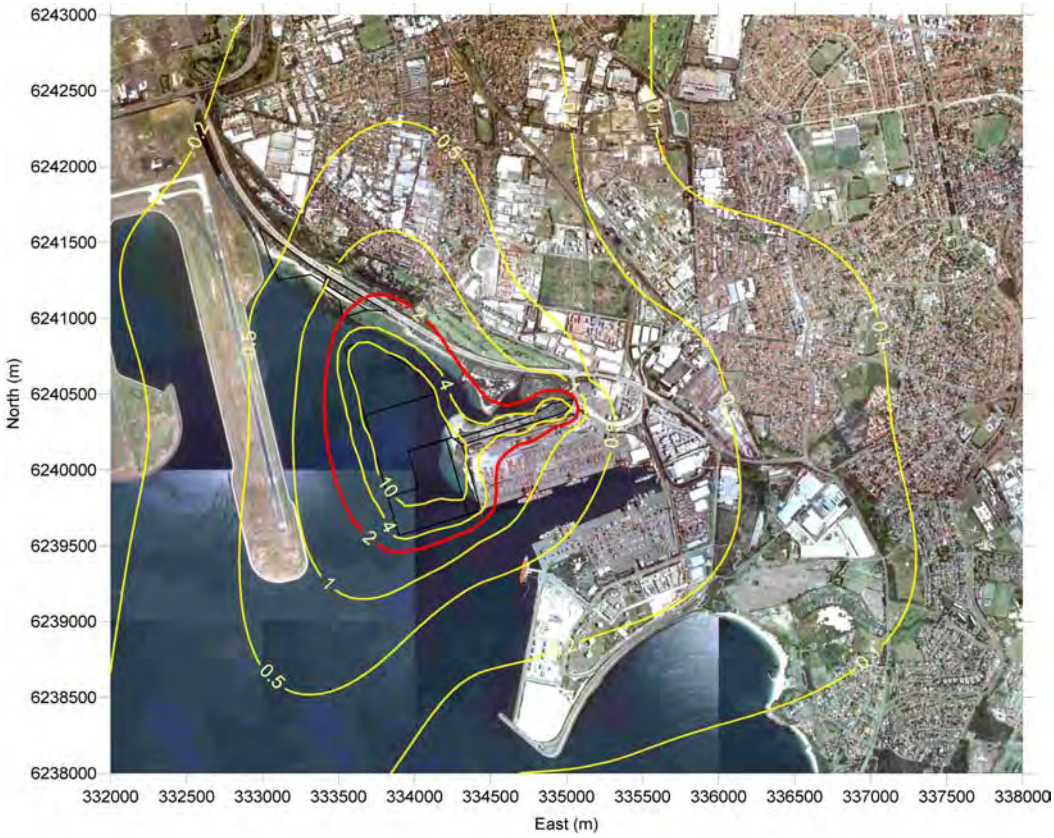


- **Figure 6-7 TSP Impacts Construction Y2P2 Annual Average ($\mu g/m^3$)**

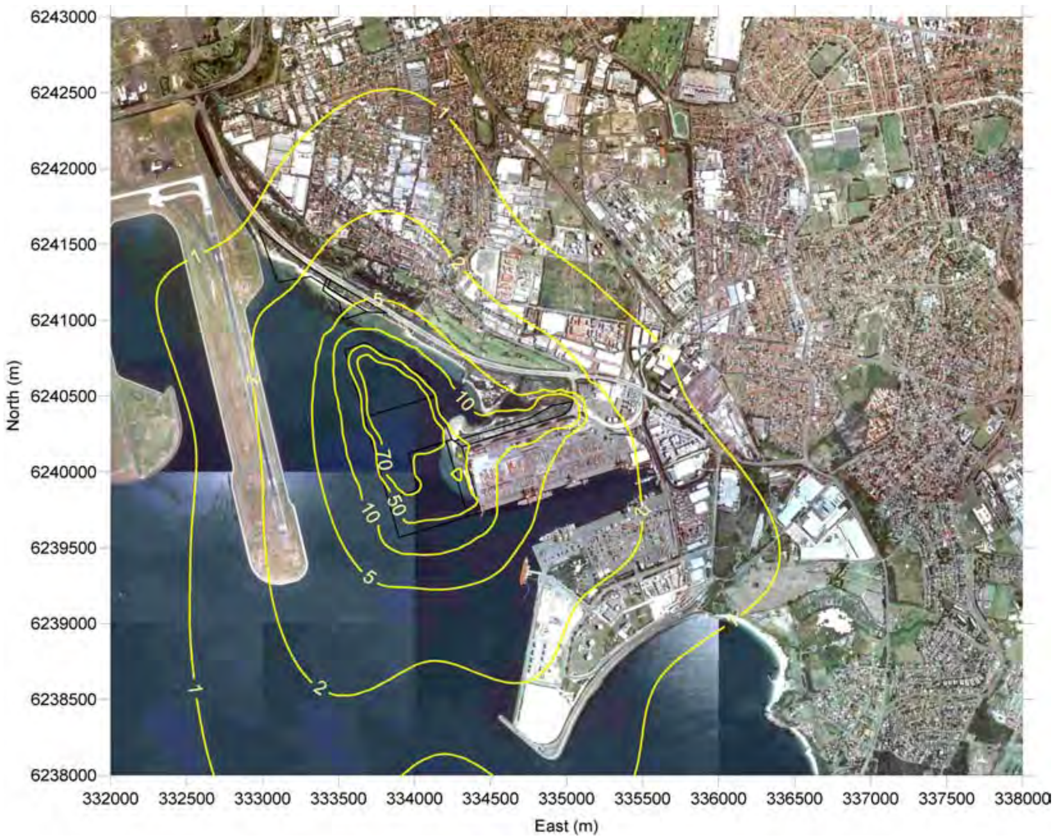


■ **Figure 6-8 PM_{10} Impacts Construction Y3P1, Exceedences of 50$\mu g/m^3$**

■ **Figure 6-9 Dust Deposition Impacts Construction Y3P1 (g/m²/month)**



- **Figure 6-10 TSP Impacts Construction Y3P1 Annual Average (μg/m³)**



6.4.5 General Implications of Results

The air dispersion modelling results indicate that construction activities may result in the 24-hour PM_{10} criteria of 50μg/m^3 being exceeded within nearest residential areas on a maximum of 2 additional days in each of construction periods Y2P2 and Y3P1. The NEPM for Ambient Air Quality allows for 5 exceedances of the 50 μg/m^3 criterion. As such this result is not considered significant given the annual average of 27 exceedances of the 50 μg/m^3 measured in the vicinity of the site in recent years.

Dust deposition impacts are not predicted to exceed the project criterion of 2 g/m^2/month within any surrounding residential area during the course of construction. The modelling results indicate that for all construction scenarios annual TSP impacts are substantially lower than the EPA criteria of 90μg/m^3 at all locations beyond the site boundary.

The results obtained are for modelling dust emissions with no dry depletion. Modelling emissions with dry depletion provides a more realistic interpretation of dust plume dispersion and settling, where the mass of particles deposited on the surface from gravitational settling is removed from the plume. Had modelling been undertaken with dry depletion of dust particles, dust impacts would have been less than that predicted in the results described above. Unfortunately long model run times preclude the practical application of dry depletion within the modelling for detailed studies such as the one presented here.

The impacts from sedimentation of dust emissions within Penrhyn Estuary and the shallow waters of Botany Bay are considered to be minimal. This area is approximately 34 ha in size, with worst case dust deposition levels in this vicinity of approximately 4 g/m^2/month being deposited during construction stages closer to the estuary habitat. To ensure minimal impact on sensitive habitats and to minimise the potential for sedimentation in shallow waters, monitoring of sediment levels during construction within these sensitive areas is recommended.

In the Director General’s comments on requirements for the EIS, mention was to be made in relation to the implications of dust emissions on visibility for aircraft operations. The air dispersion modelling results shown here indicate that there is not likely to be a significant impact on visibility, with only low particle concentrations and dust deposition levels predicted for the areas surrounding all runways and approaches.

6.5 Cumulative Impacts

Due to the nature of the staged project works, with the final staging of construction likely to occur around 2009 (buildings and terminal operator works), each stage of construction works should be timed such that cumulative dust impacts are considered in respect to any other construction activity or dust-generating activity within the Port Botany area at the particular point in time.

6.6 Sources of Dust not included in Dispersion Modelling

6.6.1 Reclamation and Berth Construction

The dust dispersion modelling section of the impact assessment aims to provide an indication of likely worst case scenario dust impacts on sensitive receivers and residential areas. Minor sources of dust emission occurring at other stages of the construction work would generate from those activities described earlier in **Table 2-1** and not modelled in the impact assessment. Particularly, these sources include:

- dust from the dumping of rock to the temporary stockpile area, located adjacent to the future boat ramp, and transfer to barge (emissions from truck wheel-generated dust have been included in the dispersion modelling);
- *placement* of dredged material above water level is not expected to have a significant impact on air quality, given the fact that the material would be placed in the saturated state, placed by discharging through the end of a moveable pipeline (refer **Section 2.2**). *Wind erosion* from this area is considered however; and
- truck unloading of rock material associated with direct end tipping of rock material in "Stage 6" of the Reclamation Phase (above water level). Note truck wheel-generated dust has been included in the dispersion modelling.

6.6.2 Infrastructure and Terminal Operator's Construction Activities

The construction of road access and the rail bridge and access are likely to have very low levels of dust emission. Dust emissions would most likely be limited to wheel-generated dust from trucks entering and leaving work construction zones, particularly on unsealed roads.

Potential dust impacts during these stages of construction are expected to be minimal, and significantly lower in comparison to the stages of the construction works assessed by dispersion modelling. However, the sources of dust emission could include:

- dust from typical road making and pavement laying machinery and traffic;
- exposed ground for the installation of internal power, water and wastewater services;
- construction activity for installation of rail mounted gantries and main crane rails; and
- construction of site buildings (would involve truck deliveries of approximately 8 trucks per day).

Appropriate dust control methods such as a truck wheel wash should be put in place for these types of activity, where appropriate, to ensure visible dust emissions are not carried off the site by trucks. The extent of dust control practises will depend on the type of the site roads (sealed, gravel, or dirt) and important meteorological conditions such as wind speed and direction.

6.7 Mitigation of Dust Impacts

More than half of the impacts from dust emissions are attributable to wind generated dust from exposed work areas and stockpiled sands. Erosion control practices to minimise wind-generated dust can include:

- moistening exposed areas of soil and sand;
- placement of grasses and other vegetation types that bind soils;

- wind breaks; and
- placement of a thin bituminous membrane.

Modelling of dust emissions has incorporated dust control measures that are likely to be used by SPC during construction activity. These are predominantly water sprays over active works areas and stockpiles. In terms of wind erosion from stockpiles, a 50% control efficiency is achieved with the use of water sprays (as modelled). Wind blown dust emissions during beach construction have been modelled with both water sprays of 50% control efficiency, and the use of wind breaks along Foreshore Road. Wind breaks usually consist of hessian material tied to typical cyclone-wire construction fences at the boundary of the construction zone, and are approximately 2 m in height. The location of these wind breaks would ideally be located along the work site at the appropriate section of Foreshore Road. Maintenance of the wind breaks would be required on a regular basis, which would include repairing torn material, and replacing material once they become ‘saturated’ with dust and no longer appear to be acting as a form of dust control.

The combined dust control of using water sprays and wind breaks along Foreshore Road during beach construction would reduce wind blown dust emissions from the beach by 65% of uncontrolled dust emissions.

Wheel-generated dust from trucks accessing the Berth Construction phase site area has been modelled as trucks moving on a gravel (unsealed) road surface along the works site, with level 2 watering (>2 L/m^2/hr). This achieves a 75% reduction of dust emissions from wheel-generated dust. It is important to keep these roads wet due to the high number of trucks expected to the visit the site each day. A temporary bituminous road seal for heavily trafficked areas would be desirable.

Controlling dust emissions from dozer unloading of sand into the Berth Construction phase hardstand construction area can be achieved with water sprays being utilised in the dump areas whilst in the above water level stages.

Due to some sections of the reclaimed area not being used for considerable periods of time between the various construction phases, SPC has indicated that the area would need to be stabilised to reduce wind blown dust emissions from the area. Where subsequent construction activities are to take place on the site, a bituminous membrane is often the preferred option. This is proposed to be a grade ASS/170-60 bitumen emulsion in accordance with AS 1160-1988 (Baggerman 2002).

For recommendations relating to the monitoring of dust emissions during construction, refer to **Section 8**. A summary of the dust mitigation measures that would be required by SPC to implement during construction (and further recommendations) is detailed in **Table 6-8**.

■ Table 6-8 Summary of Dust Mitigation Measures

Activity	Required Control	Further Control (not required but recommended to further reduce dust emissions)
Trucks arriving/leaving Tug Berth Works Area	Level 2 watering (>2 L/m^2/hr)	Temporary sealing of road
	Coarse gravel to be laid over site road	Temporary sealing of site road
		Truck wheel wash at Foreshore Road site gate – reduces wheel-generated dust and silt loading on Foreshore Road
Trucks arriving/leaving Main Works Area (western end Patrick Terminal)	Level 2 watering (>2 L/m^2/hr). achieves 75% dust emission reduction	Temporary sealing of road
	Coarse gravel to be laid over site road (parallel to northern boundary of Patrick Terminal)	Temporary sealing of site road
		Truck wheel wash at Penrhyn Road site gate – reduces wheel-generated dust and silt loading on Foreshore Road
Filling for Pre-loading (“Stage 6”)	Level 2 watering (>2 L/m^2/hr). During filling stages if fill material becomes no longer naturally moist (prior to bituminous emulsion application)	-
	Temporary sealing of all pre-loaded areas (Southern Area, Area 1 and Area 2) using bituminous emulsion (or equivalent)	-
Movement of pre-loading fill from one area to another (scrapers) and subsequent trimming/compaction	Level 2 watering (2 L/m^2/hr)	-
All exposed work areas. Wind erosion control	Level 2 watering (2 L/m^2/hr)	-
Beach construction/ Enhancement	Level 2 watering (2 L/m^2/hr)	-
	Wind breaks along appropriate work zone on Foreshore Road – increases dust emission reduction to 65%	-

7. Operational Air Quality Assessment

7.1 Overview

Air quality impacts from the operation of the proposed new terminal and expanded terminals would result from an increase in the transport of containerised cargo into and out of Port Botany. There would be an increase in the number and size of ships entering and leaving the Port, as well as an increase in the number of trucks and trains accessing the terminals, and an increase in associated dockside equipment.

Air quality impacts from all potential polluting sources need to be assessed not just in terms of the proposed new terminal, but also in terms of cumulative impacts from all terminals at Port Botany under the responsibility of SPC. Quantitative impacts have been considered at a local level, and assessment of emissions has been undertaken only relating to transport movement within the SPC site boundaries, and from ship emissions during immediate arrival, departure, and berthing operations at the terminals.

7.2 Methodology of Assessment

7.2.1 General

The methodology used for assessing operational impacts from the proposed Port Botany expansion is similar to that of the methodology used for construction impacts, and is based on the NSW EPA guidelines *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW* (Aug 2001).

The basis of the methodology is to assess air impacts (SO_2, NO_x, PM_{10} and CO) from three scenarios:

- Scenario 1 - existing case;
- Scenario 2 - the proposed terminal operating by itself at forecast demand (1.6 mill TEU); and
- Scenario 3 - all the terminals operating at a throughput of 3.2 mill TEU.

Air quality impacts were assessed by developing an emissions inventory for both 'peak' and 'normal' operations at the terminals, and include the consideration of emissions from ships, trains, trucks, and dockside equipment. Emissions inventories are shown in later sections of this chapter, with emissions reported in tonnes per year. This has been done for comparative purposes between the various sources of emission.

SO_2, NO_x, and PM_{10} emissions were modelled using AUSPLUME (V5.4) air dispersion modelling and assessed in relation to the project specific air quality criteria described in **Table 5-5**. Operations were modelled 24 hours a day, 7 days a week. The modelling results are presented graphically and discussed in **Section 7.7**.

Impacts from SO_2 emissions were assessed from shipping emissions only, as the SO_2 contribution from ships to total SO_2 emission is significantly higher than from trucks and trains, and up to 2-3 times higher than dockside equipment for Scenario 1 and up to 5 times higher for the future scenarios (refer to **Table 7-12**). As such, SO_2 emissions from these other source groups are not considered to have any significant accumulative impact on air quality. This is due to the differing fuel types used between the various source groups, with ship fuel oil being of much poorer grade (in terms of sulfur content) than for truck, train, and dockside equipment diesel. The engine combustion technology in ship engines (particularly slow speed main engines) is also of a lesser efficiency than that of other diesel engines in other transport modes.

No modelling of CO emissions has been undertaken as part of the impact assessment. It is evident from the following emissions summary tables that CO emissions represent either a lower quantity of emission (tonnes/year) compared to NO_x and SO_2 emissions (for the case of ship emissions), or are not more than one order of magnitude greater than NO_x emissions. The NSW EPA impact assessment criteria for CO are shown in **Table 4-2**. These criteria are significantly higher (3 orders of magnitude) than for NO_x and SO_2, and as such from the results shown later in this section it can be deduced that CO impacts expected at residential receivers would be much lower than the relevant criteria. Modelling of CO emissions was therefore not considered necessary.

7.2.2 NO_x to NO_2 Ratios

In terms of considering NO_2 impacts from NO_x emission estimates, ground level concentrations are predicted as NO_2 to allow for comparison with NSW EPA air quality objectives. In considering a suitable NO_x to NO_2 conversion factor it is expected that the principal components of NO_x emitted from these sources will be nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is mostly emitted in the form of NO (approximately 90%), with typically less than 10% in the form of NO_2. As the plume grows from the point of emission and reacts with the surrounding atmosphere, in particular ozone (O_3), more of the NO is converted to NO_2. The O_3 reaction is a titration reaction where the amount of NO_2 formed equals the amount of O_3 lost. Thus the concentration of NO_2 formed via O_3 oxidation can never exceed the concentration of O_3 in the ambient air.

A Dutch report by Janssen et al (1988) provides a relation for the development of a NO_2/NO_x ratio for each season of the year that predicts the conversion of NO_x emissions to NO_2 over a downwind distance from the source of emission. As mentioned above, in general less than 10% of the NO_x emission is emitted directly as NO_2 from the source. In order to be conservative, an initial 10% NO_2 is assumed at the release point. This is added to the extra NO_2 formed from oxidised NO as the plume travels downwind. As such, the following NO_2/NO_x ratios were calculated for each season of the year, and used in the dispersion modelling of operational NO_x emissions for all wind speeds:

- Summer: 0.22
- Autumn: 0.22
- Winter: 0.20
- Spring: 0.22

These ratios are predicted for a 2 km downwind distance from the source, based on the average O_3 background concentration in the Port Botany region being 1.0 – 2.5 pphm. A distance of 2 km represents a reasonable distance that encompasses nearest sensitive receivers likely to receive maximum NO_2 impacts.

NO_2 impacts were assessed for both 1-hour and annual averaging periods, and results compared to their respective site criteria.

The emissions inventories for each of the source group are summarised in the following sections. The emissions tables present NO_x emissions as NO_2, that is the NO_2/NO_x ratios from above have already been applied to the emission rate. This is to represent the actual NO_2 emission rate that has been entered into the AUSPLUME model.

7.3 Ship Emissions

7.3.1 Ship Emission Factors

Ship emissions for the existing scenario have been determined from emission factors developed by a study undertaken by the Lloyd's Register (1995) and annual ship visitation numbers provided by SPC. Ship emissions are largely determined as a function of main engine and auxiliary engine size (kW or rpm), and for SO_2 emissions, the sulfur content in the fuel.

The ship emissions inventory was developed by assuming all ships operate their auxiliary engines continuously whilst at berth at 100% MCR, with the main engines also being on for half an hour (30 minutes) upon arrival and half an hour when departing at 30% MCR. Main engines have been assumed to be slow speed engines using Marine Diesel Oil (MDO) whilst at berth.

MDO generally has a fuel sulfur content of approximately 1.5% w/w and below (Rauta, Port Technology International). The Lloyd's Register study has estimated emission factors that are based on main and auxiliary engines using fuel of 2.7% w/w sulfur content.[7] As such, ship SO_2 emissions for the existing case (Scenario 1) have been scaled based on stoichiometric relationships to represent a fuel sulfur content of 1.5% w/w, that is, SO_2 emissions have been multiplied by a factor of 0.56 (1.5%/2.7%).

Ship NO_x and SO_2 emissions for Scenarios 2 and 3 have been determined from the expected emissions predicted from ship engines built in compliance with Annex VI of the MARPOL Protocol, established by the International Maritime Organisation (IMO). Annex VI, the *Prevention of Air Pollution from Ships*, was added to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78).

Regulation 13 of Annex VI represents the NO_x Technical Code: *Technical Code on Control of Emissions of Nitrogen Oxides from Marine Diesel Engines*. The Code applies to all engines installed on ships constructed after 1 January 2000 or engines which undergo a major conversion after 1 January 2000. Ship engines are required to operate such that NO_x emissions are within the following limits:

- 17.0 g/kWh for engines less than 130 rpm (slow speed engines);

[7] All slow speed engines and medium speed engines greater than or equal to 2,000 kW were assumed in the Lloyd's Register study to be burning fuel of sulfur content 2.7% w/w. Auxiliary power was assumed to be provided by medium speed diesel engines on all ships.

- $45.0*n^{(-0.2)}$ g/kWh, when 130 < n (engine rating) < 2,000 rpm; and
- 9.8 g/kWh for engines greater than 2,000 rpm (high speed engines).

From a review of ship TEU size versus engine rating (JSEA 2001), all ships expected to arrive at Port Botany in 2021 would have main engines of less than 130 rpm, and auxiliary engines in the second range as defined above. In order to be conservative the NO_x limit, as provided by these equations, has been used as the NO_x emission factor to estimate NO_x emissions from each ship for Scenarios 2 and 3. For Scenario 1, NO_x emissions have been based on the Lloyd's Register shipping emission factors, as mentioned previously. These equate to NO_x emissions of 17.5 g/kWh for all slow speed main engines, which are not significantly higher than the future MARPOL NO_x limit.

SO_2 emissions for Scenarios 2 and 3 have been determined from the IMO Annex VI limits for fuel sulfur content, with the expectation that ships arriving at Port Botany in 2021 would be in compliance with the Protocol. **Table 7-1** defines the limits of fuel sulfur content proposed for future shipping operations. The table compares the IMO/MARPOL limits with those proposed by the European Union (EU) and the International Specification Limit.

- **Table 7-1 Limits of Sulfur Content in Ship Fuel Oils**

Fuel Type	International Specification Limit (ISO 8217)	IMO/MARPOL Annex VI	EU Proposal
Marine Diesel Oil (MDO)	1.5 – 2.0%	1.5%	0.2%
Intermediate Fuel Oil (IFO), Heavy Fuel Oil (HFO)	3.5 – 5.0%	4.5%	0.5 – 1.5%

A fuel sulfur content of 1.5% w/w has therefore been used to estimate SO_2 emissions from ships in 2021 (main and auxiliary engines) whilst at berth. It should therefore be noted SO_2 emission factors for the existing scenario are equivalent to those used for the 'at capacity' scenarios (assumes no improvement in fuel sulfur content).

PM_{10} and CO emission factors for the existing case have been used to estimate emissions for the future throughput scenarios due to the lack of available published data relating to the expected reduction in these emissions from ship engine technology improvements. A conservative approach was adopted and no assumptions were made in this regard. A similar approach was adopted to determine NO_x emissions for Scenarios 2 and 3, whereby the maximum limit of NO_x emissions defined by MARPOL Annex VI was used to estimate ship emissions.

7.3.2 Assessment Approach

Depending on the pollutant and the respective averaging period, 'peak' (10-minute, 1-hour and 24-hour) impacts were assessed by assuming a worst case scenario in any given hour, and assumes a worst case positioning of ships while at berth at Port Botany (in terms of ship TEU size). Peak emissions for Scenario 3 have been determined assuming that there would be ten ships docked amongst the three terminals with auxiliary engines operating continuously at 100% MCR, and two of the ships operating their main engines at 30% MCR for half an hour during the 1-hour and 24-hour period. This was to represent the scenario of a ship just arriving and a ship simultaneously just ready to depart.

‘Annual’ emissions were determined on the basis each ship would have it’s auxiliary engines operating at 100% MCR for 32 hours at berth, with main engines also operating at 30% MCR for half an hour each when arriving and departing the terminal. Impacts were assessed by distributing the total annual ship emissions amongst all berths.

Ship stack parameters used in AUSPLUME modelling are summarised in **Table 7-2**. Stack heights have been determined from scale drawings of containers ships provided in JSEA (2001). Ship stack diameter and gas exit velocity has been determined from exhaust air flow rates, based on the physical-chemical relationships of quantity of exhaust air produced from rate of fuel usage. Fuel usage is based on 0.26 L/kWh, which equates to 0.221 kg/kWh. Exhaust air is based on a production rate of 30 Nm^3/kg diesel consumed.

Each ship at berth was considered as a building for the purposes of modelling building wake effects. Each ship was set up in the US Building Profile Input Program (BPIP), run as a utility within AUSPLUME using the PRIME building wake algorithm. Each ship was defined as having a single tier of average height 18.3 m above sea level.

- **Table 7-2 Ship Engine and Stack Parameters**

Ship TEU Category	Engine size (kW)		Exit velocity (m/s)		Stack diameter (m)		Stack height (m), ASL*	Exit temp (°C)
	Main (30% MCR)	Aux (100% MCR)	Main (30% MCR)	Aux (100% MCR)	Main	Aux		
<2000	3,600	2,430	19.3	13.0	1.0	1.0	32.2	350
2000-2999	6,230	3,650	21.3	19.6	1.25	1.0	30.9	350
3000-3999	8,870	5,400	21.1	28.9	1.5	1.0	36.7	350
4000-4999	11,490	6,140	27.3	32.8	1.5	1.0	38.9	350
5000-5999	15,210	7,420	26.6	39.7	1.75	1.0	38.9	350
6000-6999	18,080	9,820	24.2	23.4	2.0	1.5	45.1	350
7000-7999	20,580	12,050	27.5	28.7	2.0	1.5	45.1	350

* above sea level

The emissions inventory used in the impact assessment for Scenario 1 for both peak and normal activity is provided in **Table 7-3**. ‘Normal’ activity emissions are estimated from annual averaged emissions estimates. The existing case considers ships arriving at both the existing Brotherson Dock North Terminal (Patrick) and Brotherson Dock South Terminal (P&O Ports).

In terms of assessing the air quality impacts from the proposed new terminal, emissions have been calculated on the forecasted shipping numbers provided by SPC for the new terminal at maximum capacity (1.6 million TEU). Impact assessment has been undertaken for emissions from the proposed new reclamation terminal alone (Scenario 2), as well as including a cumulative impact assessment of estimated air emissions from all terminals at Port Botany for the future scenario (3.2 million TEU, Scenario 3). Air emissions based on numbers of ships at the new terminal at forecast demand are detailed in **Table 7-4**.

Emissions from ships at all terminals when at capacity (Scenario 3) is provided in **Table 7-5**. It is noted that, for the purposes of this assessment, the maximum number of ships expected to be at the terminals at any one time is 10 ships, whilst there are 12 berths. This is due to the possible ship alignment arrangements at the terminals in relation to ship length, when large ships are present. It is possible that 12 smaller ships could be berthed at the terminals at any one time, however the scenario modelled is considered a worst case. The largest 10 ships possible at any given time have been considered for the impact assessment.

Emissions from tugs have not been included in the assessment due to their emissions being very low compared to container ship emissions. Emissions from tugs are unlikely to make any significant difference to the results of air dispersion modelling.

Table 7-3 Scenario 1 - Existing Case Ship Emissions

Ship TEU	Peak Scenario Emissions, per source (g/s)					Annual No. of Sailings	Annual Average Emission (per source) for normal' conditions model (g/s)				Annual Emission (tonne/year)			
	No. of ships at berth in Worst Case Peak Model	SO_2	NO_2	PM_{10}	CO		SO_2	NO_2	PM_{10}	CO	SO_2	NO_2	PM_{10}	CO
Auxiliary Engine														
<2000	2	2.7	2.0	0.07	0.9	531	1.7	1.3	0.05	0.6	162.5	119.9	4.54	52.2
2000-2999	2	5.3	3.1	0.11	1.1	308	3.0	1.8	0.06	0.6	188.9	111.1	3.96	40.0
3000-3999	1	7.9	4.9	0.17	1.5	41	1.2	0.7	0.03	0.2	37.2	23.2	0.78	6.9
4000-4999	1	8.9	5.7	0.19	1.6	1	0.03	0.02	0.001	0.01	1.0	0.7	0.02	0.2
5000-5999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6000-6999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7000-7999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**6**	**32.8**	**20.7**	**0.72**	**7.0**	**881**	**12.4**	**8.1**	**0.30**	**3.1**	**389.5**	**254.9**	**9.3**	**99.3**
Main Engine														
<2000	1	0.1	0.1	0.01	0.03	531	0.40	0.07	0.01	0.07	12.6	6.5	0.99	2.3
2000-2999	0	0	0	0	0	308	0.38	0.11	0.03	0.08	12.1	7.1	1.79	2.6
3000-3999	0	0	0	0	0	41	0.07	0.04	0.01	0.02	2.3	1.4	0.34	0.5
4000-4999	1	0.4	0.2	0.06	0.10	1	0.002	0.001	0.0003	0.0005	0.1	0.04	0.01	0.02
5000-5999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6000-6999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7000-7999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**2**	**0.6**	**0.3**	**0.07**	**0.1**	**881**	**0.9**	**0.5**	**0.10**	**0.17**	**27.1**	**15.0**	**3.1**	**5.5**
GRAND TOTAL	**-**	**33.3**	**21.0**	**0.8**	**7.1**	**881**	**13.2**	**8.6**	**0.4**	**3.3**	**416.6**	**269.9**	**12.4**	**104.8**

Note: NO_2 emissions represent the average emission from each of summer, autumn, winter and spring emissions

■ **Table 7-4 Scenario 2 - New Terminal Ship Emissions at Forecast Demand, 1.6 mill TEU**

Ship TEU	Peak Scenario Emissions, per source (g/s)					Annual No. of Sailings	Annual Average Emission (per source) for 'normal' conditions model (g/s)**				Annual Emission (tonne/year)			
	No. of ships at berth in Worst Case Peak Model	SO_2	NO_2	PM_{10}	CO		SO_2	NO_2	PM_{10}	CO	SO_2	NO_2	PM_{10}	CO
Auxiliary Engine														
<2000	0	0	0	0	0	123	2.2	1.2	0.05	0.6	37.6	22.9	1.05	12.1
2000-2999	0	0	0	0	0	51	0	0	0	0	31.1	14.5	0.65	6.6
3000-3999	0	0	0	0	0	164	0	0	0	0	148.3	77.9	3.11	27.7
4000-4999	1	8.9	4.4	0.19	1.6	168	10.2	5.2	0.21	1.9	173.4	84.7	3.64	31.1
5000-5999	1	10.8	5.5	0.23	1.8	117	4.6	2.3	0.10	0.8	145.9	73.6	3.1	24.6
6000-6999	1	14.3	7.5	0.30	2.2	92	4.8	2.5	0.10	0.7	151.0	79.3	3.2	23.3
7000-7999	1	21.9	9.2	0.37	2.5	26	2.1	0.9	0.04	0.2	66.7	28.0	1.1	7.7
Total	**4**	**56.0**	**26.5**	**1.43**	**8.2**	**741**	**23.9**	**12.1**	**0.50**	**4.2**	**754.1**	**381.0**	**15.8**	**133.0**
Main Engine														
<2000	0	0	0	0	0	123	0.16	0.09	0.02	0.03	2.9	1.6	0.2	0.5
2000-2999	0	0	0	0	0	51	0	0	0	0	2.0	1.1	0.3	0.4
3000-3999	0	0	0	0	0	164	0	0	0	0	9.1	5.2	1.3	2.0
4000-4999	0	0	0	0	0	168	0.68	0.39	0.10	0.15	12.2	7.0	1.8	2.8
5000-5999	0	0	0	0	0	117	0.36	0.20	0.05	0.08	11.2	6.4	1.7	2.6
6000-6999	0	0	0	0	0	92	0.33	0.19	0.05	0.08	10.4	6.0	1.5	2.5
7000-7999	1	0.8	0.4	0.11	0.2	26	0.11	0.06	0.02	0.03	3.4	2.0	0.5	0.8
Total	**1**	**0.8**	**0.4**	**0.11**	**0.2**	**741**	**1.63**	**0.93**	**0.23**	**0.37**	**51.3**	**29.3**	**7.4**	**11.7**
GRAND TOTAL	**-**	**56.8**	**26.9**	**1.5**	**8.4**	**741**	**25.5**	**13.0**	**0.7**	**4.6**	**805.4**	**410.3**	**23.2**	**144.7**

Note: NO_2 emissions represent the average emission from each of summer, autumn, winter and spring emissions
* Proposed new terminal represents 40% of all shipping movements into Port Botany
** Total emissions distributed on a proportionate basis over 5 berths for modelling purposes

Table 7-5 Scenario 3 - Cumulative Ship Emissions from All Terminals, 3.2 mill TEU

Ship TEU	Peak Scenario Emissions, per source (g/s)					Annual No. of Sailings	Annual Average Emission (per source) for 'normal' conditions model (g/s)**				Annual Emission (tonne/year)			
	No. of ships at berth in Worst Case Peak Model	SO_2	NO_2	PM_{10}	CO		SO_2	NO_2	PM_{10}	CO	SO_2	NO_2	PM_{10}	CO
Auxiliary Engine														
<2000	0	0	0.0	0	0	307	1.5	0.9	0.04	0.5	93.9	57.3	2.63	30.2
2000-2999	0	0	0.0	0	0	127	2.5	1.2	0.05	0.5	77.9	36.4	1.63	16.5
3000-3999	1	7.9	4.1	0.17	1.5	409	5.9	3.1	0.12	1.1	370.8	194.7	7.78	69.2
4000-4999	3	8.9	4.4	0.19	1.6	421	6.9	3.4	0.14	1.2	433.6	211.7	9.09	77.7
5000-5999	3	10.8	5.5	0.23	1.8	293	11.6	5.8	0.24	2.0	364.8	184.1	7.7	61.5
6000-6999	2	14.3	7.5	0.30	2.2	229	12.0	6.3	0.25	1.8	377.4	198.2	7.9	58.2
7000-7999	1	21.9	9.2	0.37	2.5	66	5.3	2.2	0.09	0.6	166.8	70.1	2.8	19.3
Total	**10**	**117.7**	**57.8**	**2.38**	**18.7**	**1,852**	**59.8**	**30.2**	**1.25**	**10.5**	**1,885.3**	**952.4**	**39.5**	**332.6**
Main Engine														
<2000	0	0	0	0	0	307	0.12	0.06	0.01	0.02	7.3	4.0	0.6	1.3
2000-2999	0	0	0	0	0	127	0.16	0.09	0.02	0.03	5.0	2.9	0.7	1.1
3000-3999	1	0.3	0.2	0.05	0.07	409	0.36	0.21	0.05	0.08	22.9	13.1	3.4	5.1
4000-4999	0	0	0	0	0	421	0.48	0.28	0.07	0.11	30.5	17.44	4.5	6.9
5000-5999	0	0	0	0	0	293	0.89	0.51	0.13	0.21	28.1	16.1	4.1	6.5
6000-6999	0	0	0	0	0	229	0.83	0.47	0.12	0.20	26.1	14.9	3.9	6.2
7000-7999	1	0.8	0.4	0.11	0.18	66	0.27	0.16	0.04	0.06	8.6	4.9	1.3	2.0
Total	**2**	**1.1**	**0.6**	**0.16**	**0.25**	**1,852**	**4.07**	**2.32**	**0.58**	**0.93**	**128.3**	**73.3**	**18.4**	**29.2**
GRAND TOTAL	**-**	**118.8**	**58.4**	**2.5**	**19.0**	**1,852**	**63.9**	**32.3**	**1.8**	**11.4**	**2,013.6**	**1,025.7**	**57.9**	**361.8**

Note: NO_2 emissions represent the average emission from each of summer, autumn, winter and spring emissions
** Emissions distributed over 10 berths: <2000 TEU x 2, 2000-3000 TEU x 1, 3000-4000 TEU x 2, 4000-5000 TEU x 2, 5000-6000 TEU x 1, 6000-7000 TEU x 1, 7000-8000 x 1

7.4 Traffic (Road and Rail) Emissions

Traffic emissions have been based on a traffic and transport study prepared by Maunsell (Nov 2002) for the proposed Port Botany Expansion. The study predicts road and rail visitations to each of the terminals at Port Botany for the existing Scenario and for each five-year period up to 2021, with the Port having a throughput of 3.2 mill TEU.

The road and rail numbers presented in the traffic study have been used to determine 'peak' and annual average emissions of NO_x, PM_{10} and CO based on emissions factors which estimate emissions from the vehicle kilometres travelled (VKT) and fuel consumption rates of trucks and train locomotives. These emission factors are detailed further in the following sections.

For the purposes of assessing 'peak' emissions, Maunsell state a factor of 1.33 can be multiplied to normal traffic numbers to estimate traffic numbers that might be expected in a 'peak week'. A peak day (24-hour period) was then able to be determined for the purpose of the air quality impact assessment from the peak week traffic numbers.

The impact assessment is based on "Market Share Scenario 1" from Maunsell's study, which maximises the number of road and rail trips to/from the proposed new terminal. The rail/road ratio of 25%/75% is used for the existing case, and 40%/60% for the 2021 case. The scenario also assumes the proposed new terminal captures 30% of total container traffic by 2011 and 40% in 2016 and 2021.

7.4.1 Truck Emissions

Truck emissions include PM_{10}, NO_x and CO emissions from trucks while moving, determined as a function of truck VKT, and during idling periods at the terminals, which are a function of the time spent idling (grams pollutant per minute). PM_{10} emissions also include brake and tyre dust, which are a function of VKT.

Differing truck exhaust emission factors were used for the existing and future scenarios respectively, with the basis being improved diesel engine technology for 2021 (pers comm Xu, NSW EPA 2001). All trucks have been assumed to be articulated trucks travelling on 'congested arterial' roads (most conservative). PM_{10} exhaust emissions are based on a fuel sulfur content of 50 ppm.

For all terminals, it has been assumed that trucks travel at speeds of approximately 20 km/hr, and each truck spends approximately 30 minutes idling with engines on whilst on-site. Modelling of truck emissions was undertaken by dividing the total emission from each terminal by a number of trucks fixed around the terminal along the truck route, thus representing stationary stack (point) sources. The truck stack exhaust parameters used in the dispersion modelling are summarised below in **Table 7-6**.

▪ **Table 7-6 Truck Engine Exhaust Parameters**

Source Characteristics	
Height of exhaust	4 m
Diameter of exhaust	0.1 m
Exhaust exit temperature	75°C
Exhaust exit velocity	10 m/s

The assessment considers truck emissions from Brotherson Dock North (Patrick and P&O Trans), Brotherson Dock South (P&O Ports), and the proposed new terminal. These emissions are detailed in **Table 7-7**.

▪ **Table 7-7 Peak and 'Normal' Truck Emissions**

Terminal	Truck Visits on a normal day	Peak Scenario Emissions, per model source* (g/s)				Annual Average Emission (per model source)* for 'normal' conditions model (g/s)				Annual Emission** (tonne/year)			
		NO_2	PM_{10}	CO	SO_2	NO_2	PM_{10}	CO	SO_2	NO_2	PM_{10}	CO	SO_2
EXISTING CASE													
Brotherson North	1,602	0.042	0.010	0.177	0.014	0.031	0.007	0.133	0.011	8.9	2.1	37.7	3.1
Brotherson South	1,311	0.043	0.010	0.162	0.017	0.033	0.008	0.122	0.013	9.3	2.2	34.6	3.7
Total	**2,913**	**0.77**	**0.178**	**3.05**	**0.284**	**0.58**	**0.134**	**2.29**	**0.214**	**18.2**	**4.2**	**72.3**	**6.7**
Throughput of 3.2 mill TEU													
Brotherson North	1,407	0.025	0.004	0.131	0.000	0.019	0.003	0.098	0.000	5.3	0.9	27.9	0.1
Brotherson South	1,411	0.030	0.005	0.139	0.001	0.023	0.003	0.104	0.001	6.4	1.0	29.6	0.1
New Terminal	1,882	0.037	0.005	0.150	0.001	0.028	0.004	0.113	0.001	10.6	1.5	42.8	0.3
Total	**4,700**	**0.94**	**0.141**	**4.23**	**0.020**	**0.71**	**0.106**	**3.18**	**0.015**	**22.4**	**3.4**	**100.3**	**0.5**

Note: NO_2 emissions represent the average emission from each of summer, autumn, winter and spring emissions
* For the purposes of modelling truck emissions, total truck emissions were divided over 9 stationary truck sources for each of Brotherson North and Brotherson South, and 12 stationary truck sources for the proposed new terminal. "Total" (emission) refers to the total mass emission rate over entire SPC site for all trucks.
** Annual emission in tonnes per year represents the mass emission from all trucks over the entire terminal, not per model source

It can be seen from the PM_{10} emission inventory above that there would in fact be an improvement in the total quantity of PM_{10} and SO_2 emission. This is due to the well-established forecasts of improvements in truck engine technology and engine/exhaust efficiency, and for the case of SO_2 emissions, a significant reduction in the fuel sulfur content for use in trucks.

SPC has identified that there will be also be 'stack runs' to move various containers around and between terminals. Stack runs could account up to 300 vehicles per day for the Patrick Terminal, up to 200 vehicles per day for the P&O Ports Terminal, and up to 300 vehicles per day for the proposed new terminal. Emissions from these trucks have not been included in the dispersion modelling of 'peak' emissions as the stack runs are most likely to occur on quieter days, and as such there would be no significant change in the number of daily truck visits.

7.4.2 Train Emissions

Emissions from trains include NO_x, PM_{10} and CO emissions from train locomotives while travelling on-site and during idling operations on rail sidings.

It has been assumed that two trains would be present on the new terminal.[8] Each train would have two locomotives, with trains being push-pull (one locomotive at each end). Emission factors for diesel locomotives whilst travelling on-site (grams per litre fuel consumed) were from the *NPI Emission Estimation Technique Manual for Aggregated Emissions from Railways* (1999) sourced from USEPA (1991) and work undertaken by the California Air Resources Board (CARB, 1991). Emission factors for determining NO_x and PM_{10} emissions in 2021 are less than those used for the existing case, similar to reasons mentioned above for truck emissions in 2021. Locomotive fuel consumption rate has been estimated at 5 L/km/loco (Rail Access Australia 2001).

An idling diesel fuel consumption rate of 18.9 L/hr has been used to determine emissions from train locomotives whilst idling (Environment Canada et al 2000, Clyde Engineering 1997 & ZTR Control Systems 2002). Based on the average turnaround time provided by SPC, it has been assumed each locomotive idles for 2 hours on-site per visit. The locomotive stack exhaust parameters used in the dispersion modelling are detailed below in **Table 7-8**.

■ Table 7-8 Locomotive Stack Exhaust Parameters

Source Characteristics	
Height of exhaust	3 m
Diameter of exhaust	0.3 m
Exhaust exit temperature	200°C
Exhaust exit velocity	10 m/s

The train locomotive emissions from each of the terminals for both the existing and future cases are presented in **Table 7-9**.

■ Table 7-9 Peak and 'Normal' Train Locomotive Emissions

Terminal	Train Visits on a normal day	Peak Scenario Emissions, per loco* (g/s)				Annual Average Emission (per loco)* for 'normal' conditions model (g/s)				Annual Emission** (tonne/year)			
		NO_2	PM_{10}	CO	SO_2	NO_2	PM_{10}	CO	SO_2	NO_2	PM_{10}	CO	SO_2
EXISTING CASE													
P&O	7	0.063	0.007	0.038	0.013	0.047	0.005	0.028	0.010	3.0	0.3	1.8	0.6
Patrick	6	0.056	0.006	0.033	0.011	0.042	0.005	0.025	0.009	2.6	0.3	1.6	0.5
P&O Trans	2	0.016	0.002	0.010	0.003	0.012	0.001	0.007	0.002	0.8	0.1	0.5	0.2
Total	**15**	**0.27**	**0.030**	**0.16**	**0.055**	**0.20**	**0.022**	**0.12**	**0.042**	**6.4**	**0.7**	**3.8**	**1.3**
Throughput of 3.2 mill TEU													
P&O	17	0.082	0.012	0.100	0.001	0.062	0.009	0.075	0.001	3.9	0.6	4.7	0.1
Patrick	14	0.064	0.010	0.077	0.001	0.048	0.007	0.058	0.001	3.0	0.5	3.7	0.04
P&O Trans	5	0.020	0.003	0.024	0.000	0.015	0.002	0.018	0.000	0.9	0.1	1.1	0.01
New Terminal	18	0.051	0.008	0.062	0.001	0.038	0.006	0.046	0.001	4.8	0.7	5.9	0.1
Total	**54**	**0.53**	**0.080**	**0.65**	**0.007**	**0.40**	**0.060**	**0.49**	**0.006**	**12.7**	**1.9**	**15.4**	**0.2**

Note: NO_2 emissions represent the average emission from each of summer, autumn, winter and spring emissions
* 2 locos were modelled for each of the existing terminals and 4 locos (2 trains) modelled for the New Terminal. "Total" refers to the total mass emission rate over the entire terminal for all train locos
** Annual emission in tonnes per year represents the mass emission from all locos over the entire terminal, not per model source

[8] Note that the proposed development includes the construction of three rail lines on the new terminal, however, it is anticipated that only two trains would be present on the site at any one time. The third line is a run around.

7.5 Dockside Equipment Emissions

Dockside equipment that would be used at the terminals includes rubber tyre gantries, fork lifts, reach stackers and straddle carriers – all being diesel operated. Quay cranes and rail mounted gantries would also be used, however these equipment are electrically operated and would have no on-site emissions.

Rubber tyre gantries and straddle carriers have been assumed to be operating 90% of the time, with reach stackers operating 60% of the time. Emissions are a function of the horsepower rating of each equipment type (g/hp-hr) and are sourced from the USEPA NONROAD Model (1998). Emission factors incorporate an in-use adjustment factor derived from emission testing designed to represent operational behaviour of nonroad equipment, and for the use in steady-state modelling. Similar to trucks and trains, nonroad emission factors assume improved diesel engine efficiency for the year 2021. SO_2 emission factors are based on the default weight fraction of sulfur in nonroad diesel fuel, being 0.33% w/w.

Due to the complex nature of modelling the constant stop-go and accelerating-decelerating nature of the equipment, and in order to be conservative, emissions have been assessed assuming the equipment is under maximum load 100% of its operating time.

The engine and stack exhaust parameters that have been used in the dispersion modelling for all dockside equipment are included in **Table 7-10**. The exhaust exit velocity provided below is determined from the dockside equipment exhaust air flow rates based on a fuel consumption of 0.2-0.3 L/kWh, and an exhaust temperature of 3508C.

Table 7-10 Dockside Equipment Engine and Stack Exhaust Parameters

Equipment Type	Engine Size (hp)	% time operating	Height of exhaust (m)	Diameter of exhaust (m)	Exhaust exit temp (°C)	Exhaust exit velocity (m/s)
Rubber Tyre Gantries	535*	90	24*	0.3	350	23.7
Reach Stackers	330*	60	3.4*	0.3	350	14.6
Straddle Carriers	181*	90	24**	0.2	350	18.1
Quay Cranes	Electric – no on-site emissions					
Rail Mounted Gantries	Electric – no on-site emissions					

* provided from supplier of equipment to Patrick Terminal
** assumed to be 6th Generation straddle carrier

The number of each type of dockside equipment, and the NO_2, PM_{10}, SO_2 and CO emissions, are summarised in **Table 7-11**. For this source group, there was no distinction made between peak operating conditions and normal operating conditions of dockside equipment. Equipment operating for all conditions under 100% load is a conservative estimate of emissions.

■ **Table 7-11 Dockside Equipment Emissions**

Equipment	Terminal	Number	Emission, per model source* (g/s)				Annual Emission** (tonne/year)			
EXISTING CASE			**NO_2**	**PM_{10}**	**CO**	**SO_2**	**NO_2**	**PM_{10}**	**CO**	**SO_2**
Rubber Tyre Gantries	P&O	20 (10)*	0.388	0.129	0.340	1.167	122.2	40.8	107.1	368.1
Reach Stackers	Patrick	2 (2)	0.054	0.045	0.127	0.069	3.4	2.8	8.0	4.4
Straddle Carriers	Patrick	26 (10)	0.177	0.096	0.272	0.148	55.9	30.3	85.7	46.8
Quay Cranes	Patrick, P&O	6, 6	Electric – no on-site emissions							
Rail Mounted Gantries	Patrick	2	Electric – no on-site emissions							
Total	**All**	**-**	**5.76**	**2.34**	**6.37**	**13.30**	**181.6**	**73.9**	**200.9**	**419.3**
Throughput of 3.2 mill TEU										
Rubber Tyre Gantries	P&O	28 (10)	0.220	0.181	0.476	1.636	69.4	57.2	150.0	516.0
Reach Stackers	New Terminal	4 (4)	0.034	0.045	0.127	0.070	4.2	5.7	16.0	8.8
Straddle Carriers	Patrick	37 (10)	0.102	0.137	0.387	0.212	32.3	43.1	122.0	66.8
	New Terminal	40 (10)	0.111	0.148	0.418	0.229	34.9	46.6	131.9	72.2
Quay Cranes	Patrick, P&O, New Terminal	9, 8, 10	Electric – no on-site emissions							
Rail Mounted Gantries	Patrick, New Terminal	7, 7	Electric – no on-site emissions							
Total			**2.13**	**4.84**	**13.31**	**21.05**	**140.9**	**152.5**	**419.8**	**663.8**

* For the purposes of modelling dockside equipment emissions, total emissions were divided by the number of sources included in the AUSPLUME modelling (shown in brackets)
** Annual emission in tonnes per year represents the mass emission from all equipment sources over the entire terminal, not per model source

It can be seen from **Table 7-11** that there would be an overall reduction in NO_2 emissions in the year 2021, when compared to the existing case, despite the increase in dockside equipment. This is due to the expected improvements in diesel engine technology with the introduction of low NO_x combustion technology within diesel engines.

7.6 Summary of Total Emissions

It can be seen from the emissions inventories presented in the tables above that the ship emissions contribute significantly to total air emissions and thus air quality impacts in surrounding areas. NO_2 emissions from ships, for example, for Scenario 3 represent approximately 1,030 tonnes/yr. Dockside equipment NO_2 emissions provide for 140 tonnes/yr, whereas truck and train NO_2 emissions are only 22 tonnes/yr and 13 tonnes/yr respectively.

A summary of total emissions for each source group and scenario is provided below as **Table 7-12**. The summary shows a comparison of actual emission rate (g/s) between the various source groups and the total mass emission in any year (tonnes/yr).

Table 7-12 Summary of Emissions for All Source Groups

Source Group	Peak Model (g/s)				Annual Model (g/s)				Annual Emission (tonne/year)			
	CO	**NO_2**	**PM_{10}**	**SO_2**	**CO**	**NO_2**	**PM_{10}**	**SO_2**	**CO**	**NO_2**	**PM_{10}**	**SO_2**
Total emissions Scenario 1 (Existing Case)												
Ships	7.2	21.1	0.8	33.3	3.3	8.6	0.4	13.2	104.8	269.9	12.4	416.6
Trains	0.2	0.3	0.03	0.06	0.1	0.2	0.02	0.04	3.8	6.4	0.7	1.3
Trucks	3.1	0.8	0.2	0.3	2.3	0.6	0.1	0.2	72.3	18.2	4.2	6.7
Dockside	6.4	5.8	2.3	13.3	6.4	5.8	2.3	13.3	200.9	181.6	73.9	419.3
TOTAL	**16.7**	**27.9**	**3.4**	**47.0**	**12.1**	**15.1**	**2.9**	**26.8**	**381.7**	**476.0**	**91.3**	**844.0**
Total emissions Scenario 2 (New Terminal Only at Forecast Capacity)												
Ships	8.4	27.0	1.2	8.9	4.6	13.0	0.7	25.5	144.7	410.3	23.2	805.5
Trains	0.3	0.2	0.03	0.003	0.2	0.2	0.02	0.002	5.9	4.8	0.7	0.1
Trucks	1.8	0.5	0.06	0.01	1.4	0.3	0.05	0.01	42.8	10.6	1.5	0.3
Dockside	4.7	1.2	1.7	2.6	4.7	1.2	1.7	2.6	147.9	39.2	52.2	81.0
TOTAL	**15.1**	**28.9**	**2.9**	**11.5**	**10.8**	**14.7**	**2.5**	**28.1**	**341.3**	**464.9**	**77.6**	**886.8**
Total emissions Scenario 3 (All Terminals at Forecast Demand of 3.2 mill TEU)												
Ships	18.9	58.5	2.5	118.7	11.5	32.5	1.8	63.9	361.9	1025.7	57.9	2013.6
Trains	0.7	0.5	0.08	0.01	0.5	0.4	0.06	0.01	15.4	12.7	1.9	0.2
Trucks	4.2	0.9	0.1	0.02	3.2	0.7	0.1	0.02	100.3	22.4	3.4	0.5
Dockside	13.3	4.5	4.8	21.1	13.3	4.5	4.8	21.1	419.8	140.9	152.5	663.8
TOTAL	**37.1**	**64.4**	**7.6**	**139.8**	**28.5**	**38.1**	**6.8**	**84.9**	**897.4**	**1201.6**	**215.7**	**2678.1**

The table shows SO_2 emissions are higher than the emissions of the other key pollutants (CO, NO_2 and PM_{10}) for Scenarios 1 and 3. It can be seen that ships have by far the greatest contribution to the total SO_2 emission from the site.

The lower contribution of SO_2 emissions for Scenario 2 is suggested by the dockside equipment emissions at the proposed New Terminal. There are no rubber tyre gantries planned for use at the New Terminal, which represent a significant quantity of SO_2 emissions from the P&O Terminal (high-powered engines). For further detail, refer to **Table 7-10** and **Table 7-11**.

7.7 Impact Assessment Results

The results of dispersion modelling of operational emissions are summarised below. The results have been summarised in tabular form, which provides comparison between the existing and future scenarios respectively, as well as comparison with the site criteria as described in **Section 5.5**. Incremental ground level concentration plots are also shown for each pollutant and for various averaging periods. These plots have been drawn using the plotting software *Surfer for Windows*, and are included in **Figure 7-1** to **Figure 7-24**. In each of these plots, the Project criterion is shown by a red contour line.

Results of NO_x emissions (modelled to predict total NO_2 ground level concentrations, background plus impact) are summarised in **Table 7-13**. Total NO_2 impacts are predicted in a similar manner to construction phase PM_{10} impacts (refer to **Section 6.2**) by using an hourly background NO_2 file as input to the modelling. Incremental PM_{10} ground level concentrations are summarised in **Table 7-14**, while incremental SO_2 concentrations from ship emissions are summarised in **Table 7-15**. It is noted 10-minute, 1-hour and 24-hour averaging period model predictions are for ‘peak’ emission rates from ‘peak’ operations at the terminals, whilst annual averaging period model predictions are for normal annual averaged operation activity.

Results are presented for both maximum concentrations predicted at a residential receiver, and the maximum concentration predicted beyond the SPC boundary. The latter is not considered to be as critical as the former, due to the fact that the NSW EPA concentration based ambient air criteria are set based on sound research relating to the pollutant’s effects on human health. Where there may be a receiver beyond the boundary that is not a residential receiver (such as workers in an industrial zone), occupational health and safety exposure criteria are a more efficient set of criteria to assess against rather than the NSW EPA ambient air criteria, given there is usually only an 8-hour exposure (averaging period).

7.7.1 Results of NO_2 Impact Assessment

Table 7-13 below summarises the total NO_2 impacts (ambient plus impact) from operational emissions.

- **Table 7-13 Predicted Total NO_2 Ground Level Concentrations**

Averaging Period	Scenario	EPA Criterion ($\mu g/m^3$)	Max Conc at a Residential Receiver ($\mu g/m^3$)	Max Conc Beyond SPC Boundary* ($\mu g/m^3$)
1-hour	1 – Existing	246	200	220
	2 – New Terminal at Capacity	246	150	175
	3 - All Terminals at Capacity	246	210	230
Annual	1 – Existing	62	35	40
	2 – New Terminal at Capacity	62	34	39
	3 - All Terminals at Capacity	62	35	40

* on land, that is not including within Botany Bay

Operational phase NO_2 impacts have been assessed in a similar method to construction phase PM_{10} impacts by considering hourly background NO_2 levels. In this situation it can be seen that total NO_2 impacts do not exceed EPA criteria under any Scenario for either 1 hour or annual averaging periods.

The results of modelling NO_2 (1-hour) impacts are shown in **Figures 7-1** to **7-3**, while annual impacts are shown in **Figures 7-4** to **7-6**.

It can be seen from the results of modelling that the operational NO_2 impacts do not at present or will not in the future cause any exceedance of EPA criteria when existing background levels are considered on an hourly basis.

7.7.2 Results of PM_{10} Impact Assessment

Table 7-14 below summarises the PM_{10} impacts from operational emissions.

- **Table 7-14 Predicted PM_{10} Ground Level Concentrations**

Averaging Period	Scenario	Project Criterion (μg/m³)	Max Conc at a Residential Receiver (μg/m³)	Max Conc Beyond SPC Boundary* (μg/m³)
24-hour	1 – Existing	16	4	9
	2 – New Terminal at Capacity	16	4	7
	3 - All Terminals at Capacity	16	7	13
Annual	1 – Existing	10	1	2
	2 – New Terminal at Capacity	10	1	2
	3 - All Terminals at Capacity	10	2	4

* on land, that is not including within Botany Bay

The NEPM for Ambient Air Quality permits 5 exceedences per year of the PM_{10} (24-hour) criterion of 50 μg/m³. As such, the incremental concentrations shown above represent the 6th highest concentration predicted over a year. The results indicate there are no exceedences of the project criteria for 24-hour and annual averaging periods for any of the scenarios.

The addition of the proposed new terminal would only provide a marginal increase in PM_{10} concentrations within neighbouring residential areas. The residential area most impacted by the addition of the proposed terminal (in terms of PM_{10} 24-hour impacts) is that around Phillip Bay and La Perouse, and is best seen in **Figure 7-9**. The maximum predicted incremental PM_{10} (24-hour) concentration in residential area is 7 μg/m³ (for Scenario 3), which compares to the project criterion of 16 μg/m³ and the NSW EPA ambient air objective of 50 μg/m³.

7.7.3 Results of SO_2 Impact Assessment

Table 7-15 summarises the SO_2 impacts from operational emissions.

- **Table 7-15 Predicted SO_2 Ground Level Concentrations**

Averaging Period	Scenario	Project Criterion (μg/m³)	Max Conc at a Residential Receiver (μg/m³)	Max Conc Beyond SPC Boundary* (μg/m³)
10-minute	1 – Existing	712**	155	190
	2 – New Terminal at Capacity	712**	100	115
	3 - All Terminals at Capacity	712**	205	205
1-hour	1 – Existing	543	145	245
	2 – New Terminal at Capacity	543	130	170
	3 - All Terminals at Capacity	543	210	270
24-hour	1 – Existing	217	45	70
	2 – New Terminal at Capacity	217	45	65
	3 - All Terminals at Capacity	217	90	100
Annual	1 – Existing	54	3	5
	2 – New Terminal at Capacity	54	3	5
	3 - All Terminals at Capacity	54	8	14

* on land, that is not including within Botany Bay
** background data for 10-minute averaging period is not available. As such, the NSW EPA ambient air objective for SO_2 (10-minute) of 712 μg/m³ is used to assess impacts

The results shown above taken from contour plot diagrams – **Figure 7-13** to **Figure 7-24** indicate incremental SO_2 concentrations for all averaging periods do not exceed the site criteria. The maximum incremental SO_2 (1-hour) concentration experienced beyond the boundary is 270 $\mu g/m^3$ (for Scenario 3), which is less than half the Project criterion of 543 $\mu g/m^3$. The maximum incremental SO_2 (1-hour) concentration experienced at a residential receiver (210 $\mu g/m^3$ for Scenario 3) is at houses immediately due east of Amcor.

7.7.4 Results of CO Impact Assessment

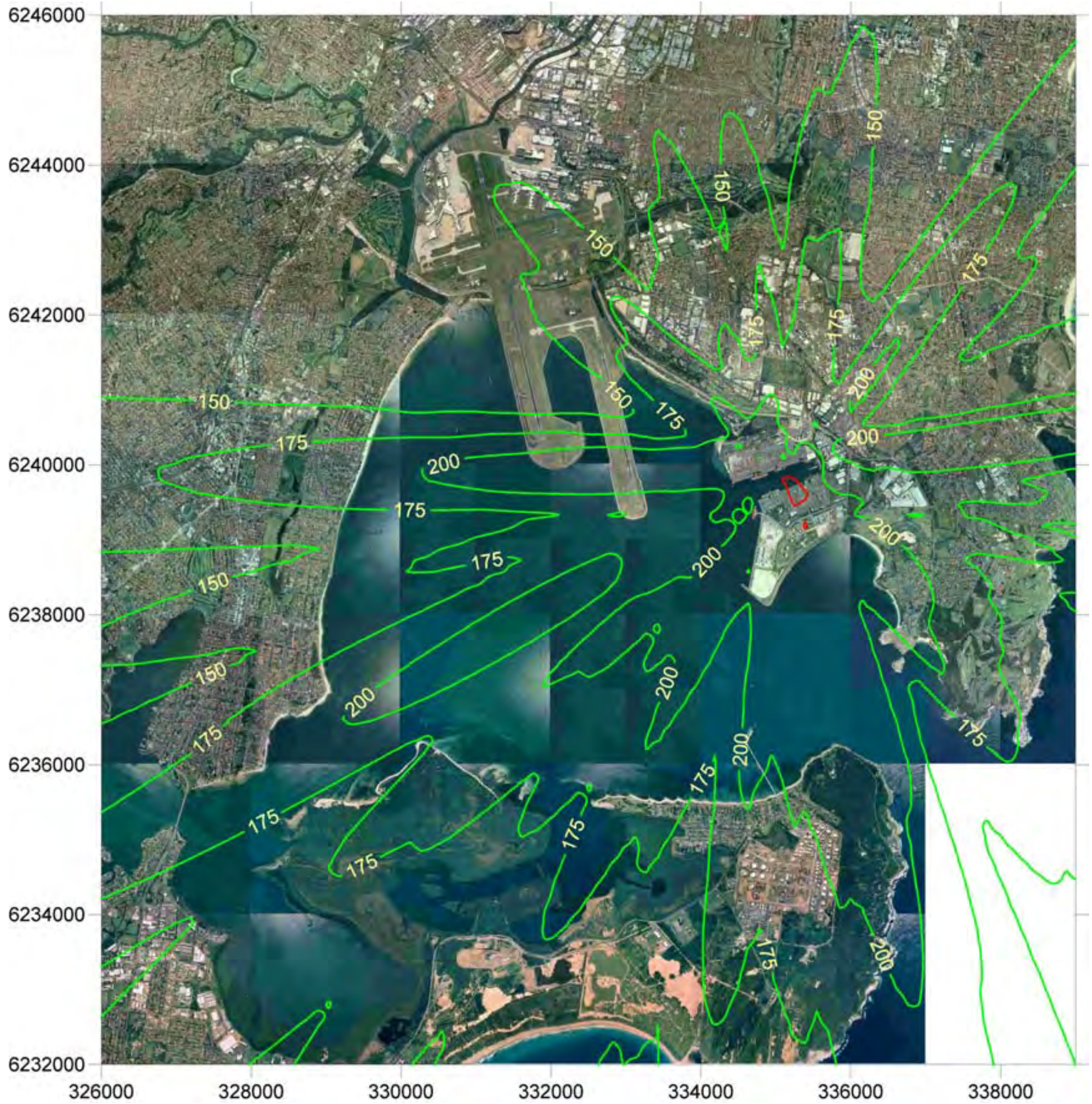
As discussed in **Section 7.2** no dispersion modelling assessment of CO is warranted.

The reason for this that CO emissions from port operations are similar in magnitude to other gaseous emissions eg. NO_2 and SO_2 yet CO is much less harmful than these other pollutants at equivalent concentrations.

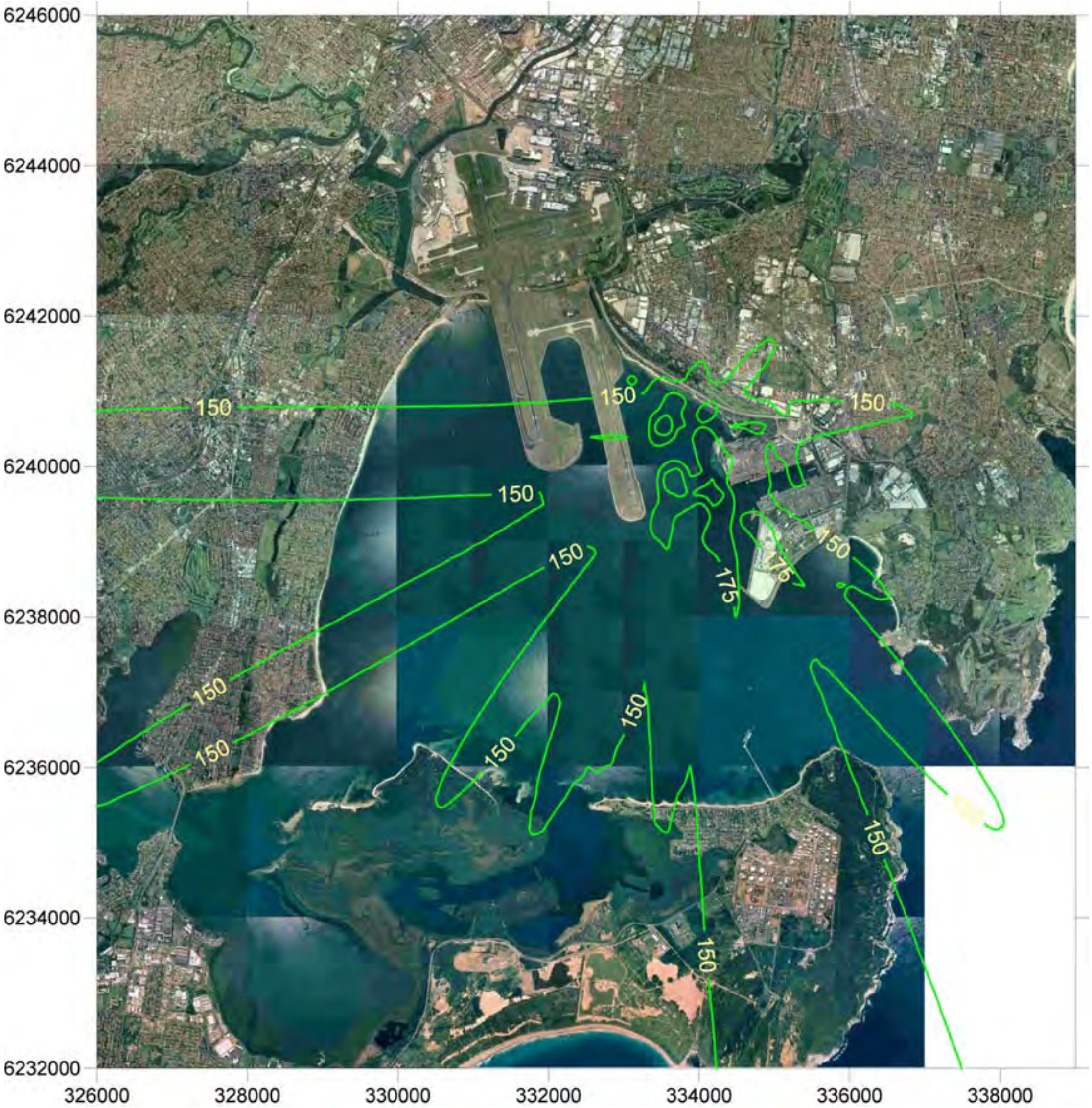
By way of example it can be seen from **Table 7-12** that in all Scenarios total CO emissions are lower than NO_2 emissions. Given that 1-hour NO_2 impacts comply with the EPA criteria of 246 $\mu g/m^3$ in all cases, it is automatically follows that 1-hour CO impacts will also comply with the relevant criteria of 30 mg/m^3 (30 000 $\mu g/m^3$).

While it is acknowledged that similar comparisons cannot be made for other CO averaging periods, eg 15 minutes and 8 hours, the above comparison provides sufficient justification that CO impacts are a non-issue for the Port Botany expansion, and as such no detailed dispersion modelling assessment is considered necessary.

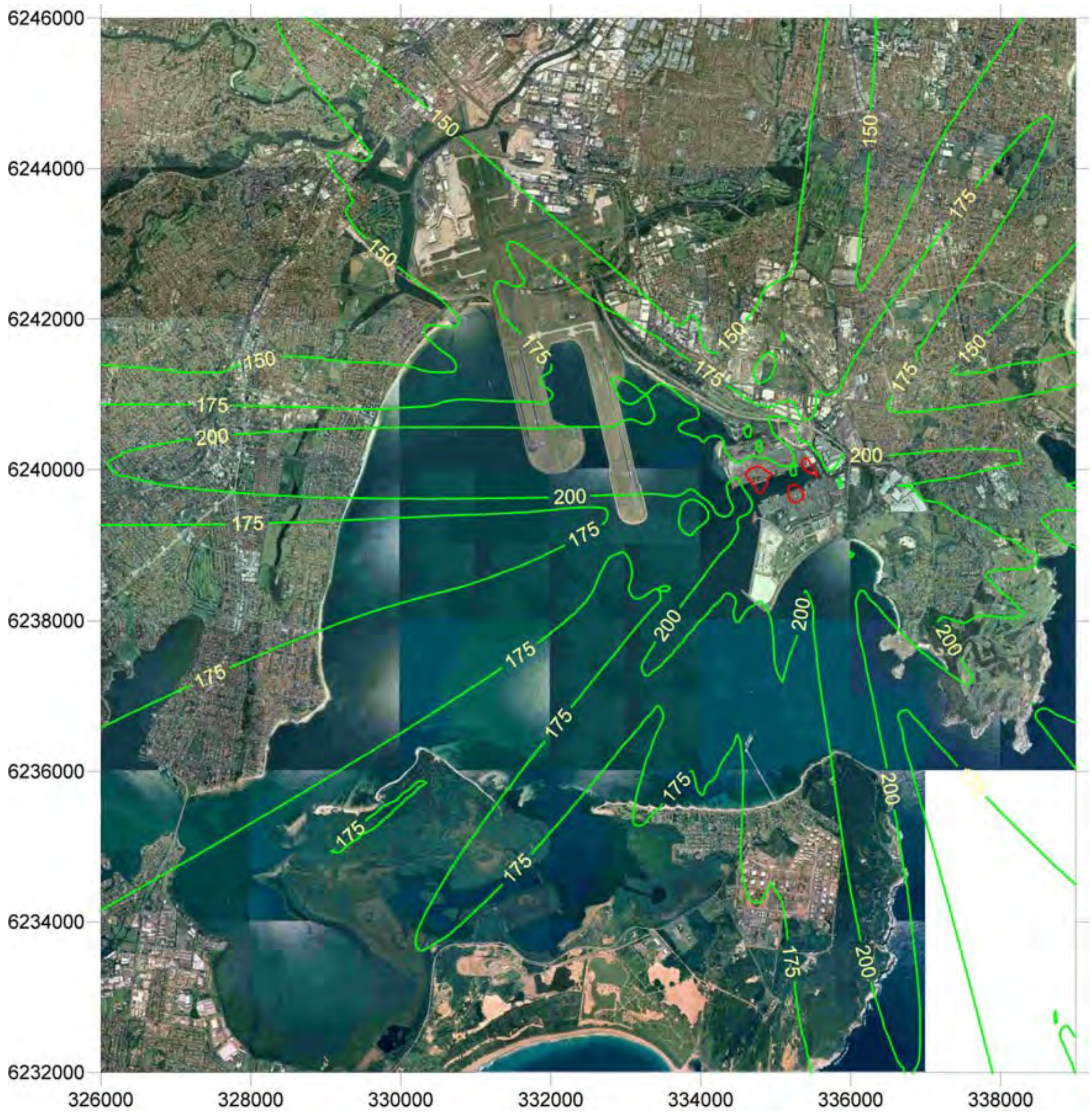
■ **Figure 7-1 Scenario 1 – 1-hour NO_2 Impacts (Existing Terminal) ($\mu g/m^3$)**



- **Figure 7-2 Scenario 2 – 1-hour NO_2 Impacts (New Terminal) ($\mu g/m^3$)**



- **Figure 7-3 Scenario 3 – 1-hour NO_2 Impacts (All Terminals) ($\mu g/m^3$)**



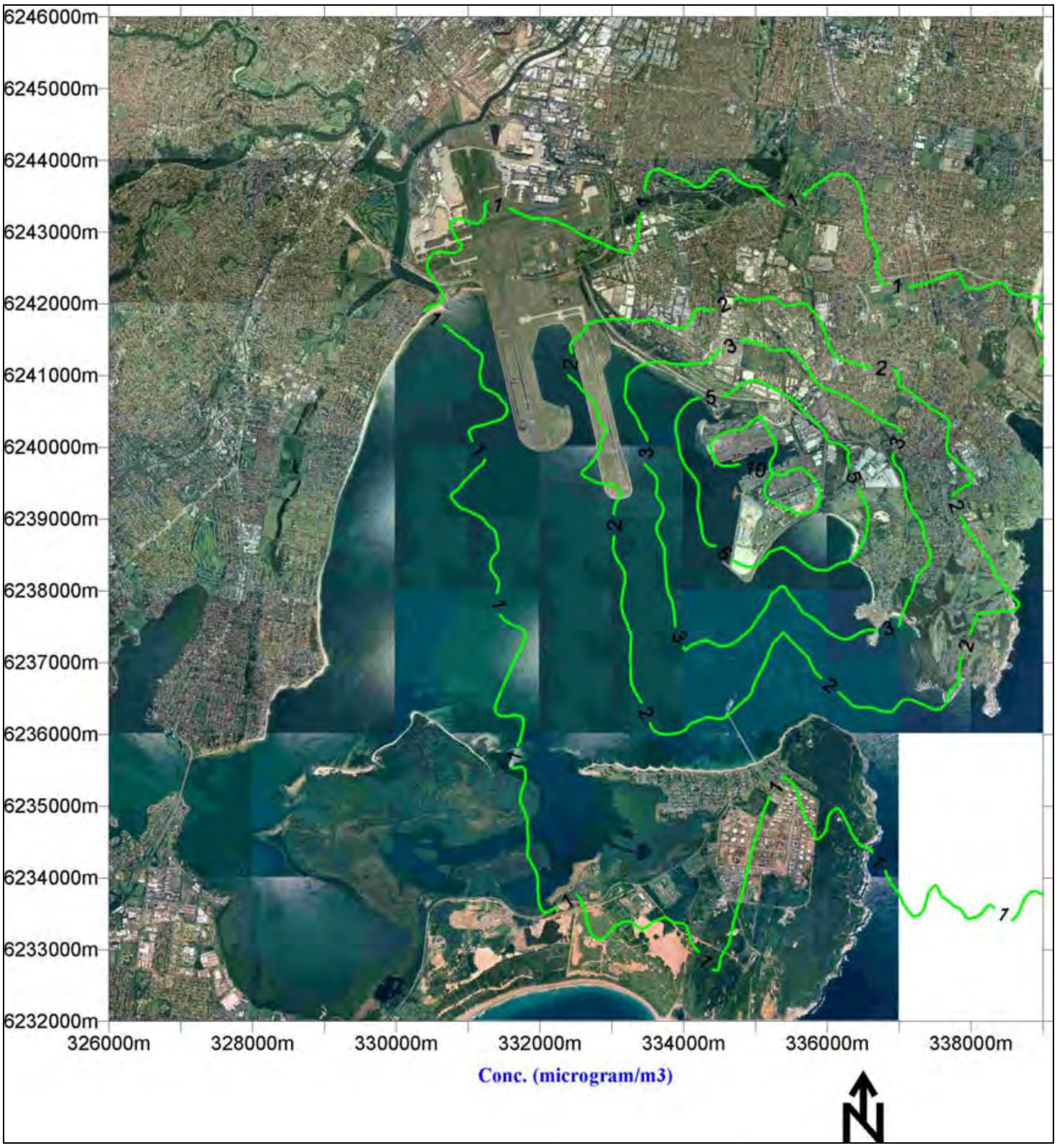
■ **Figure 7-4 Scenario 1 - Annual Ave. NO_2 Impacts (Existing Terminals) ($\mu g/m^3$)**

SKM

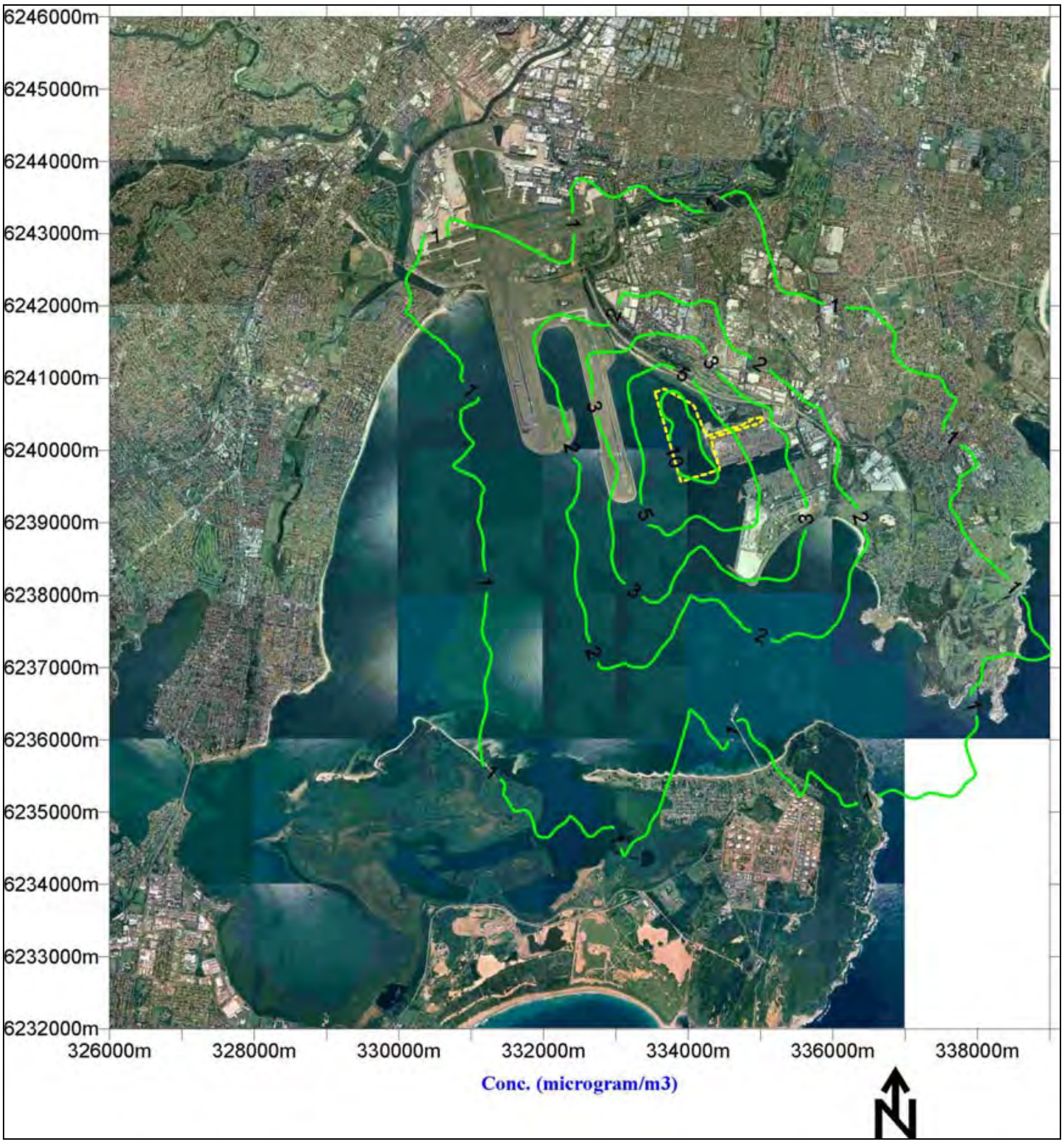
- **Figure 7-5 Scenario 2 - Annual Ave. NO_2 Impacts (New Terminals) ($\mu g/m^3$)**

Figure 7-6 Scenario 3 - Annual Ave. NO_2 Impacts (All Terminals) ($\mu g/m^3$)

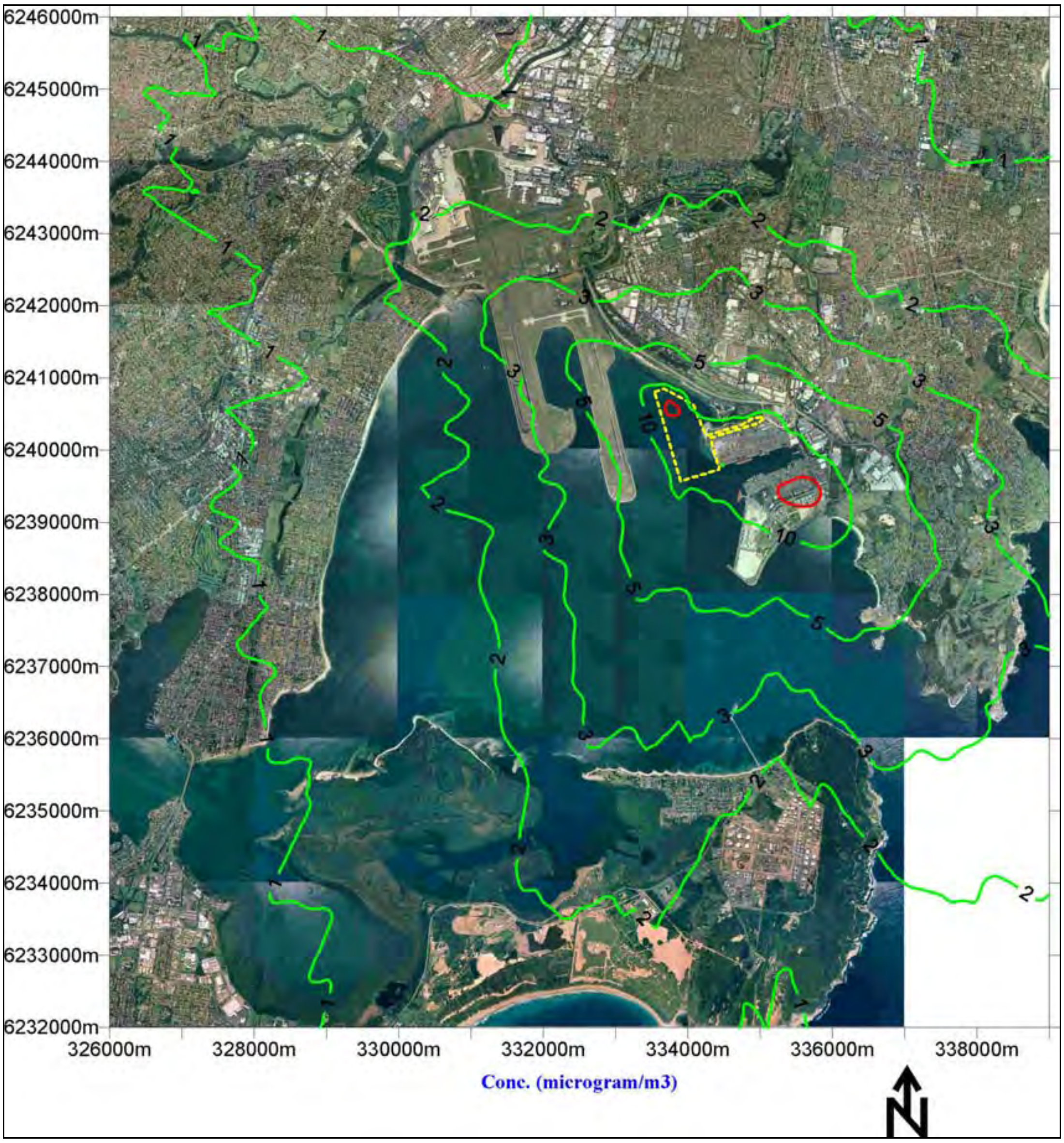
■ **Figure 7-7 Scenario 1 – 24-hour PM_{10} Impacts (Existing Terminals) ($\mu g/m^3$)**



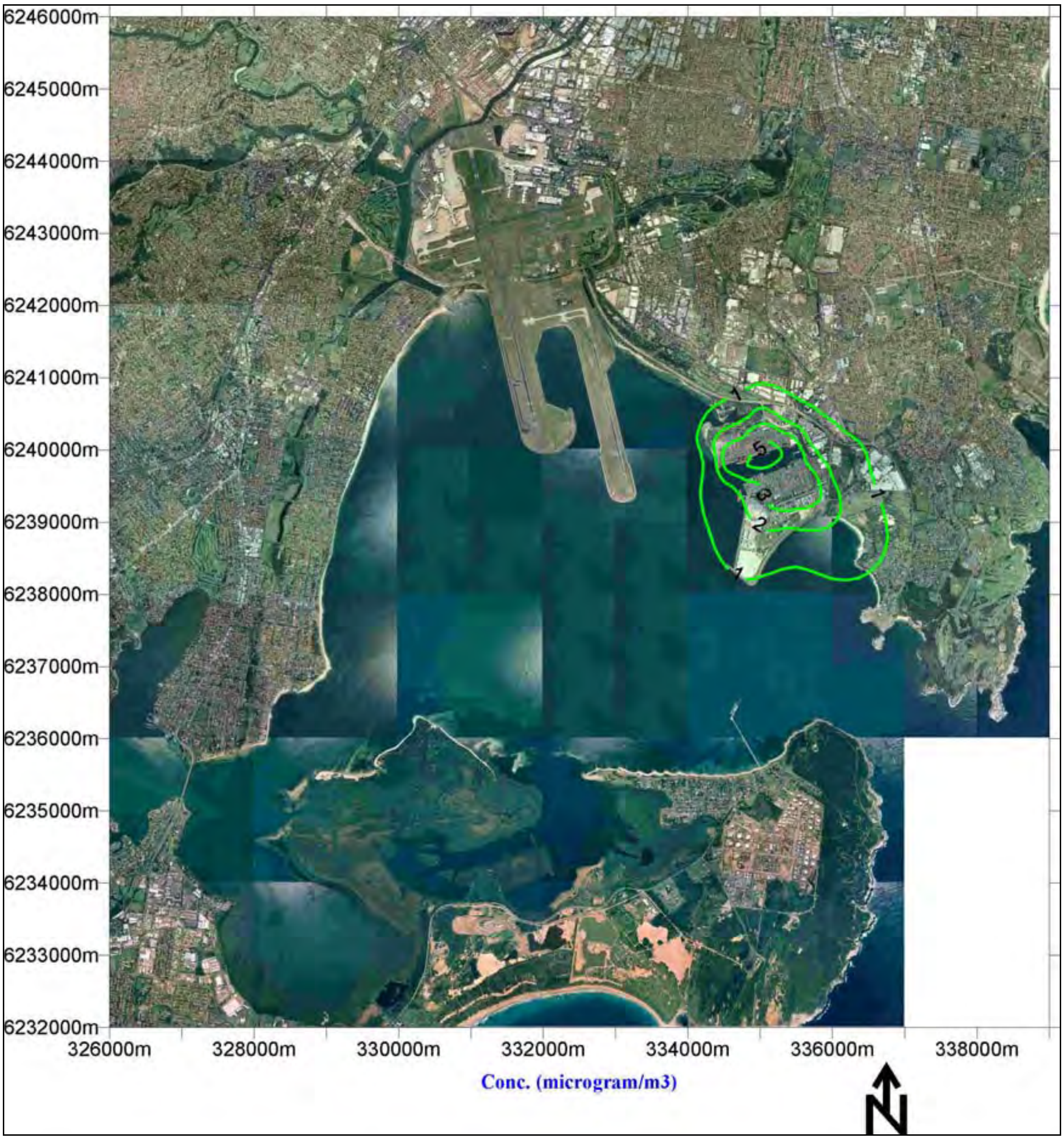
■ **Figure 7-8 Scenario 2 – 24-hour PM_{10} Impacts (New Terminals) ($\mu g/m^3$)**



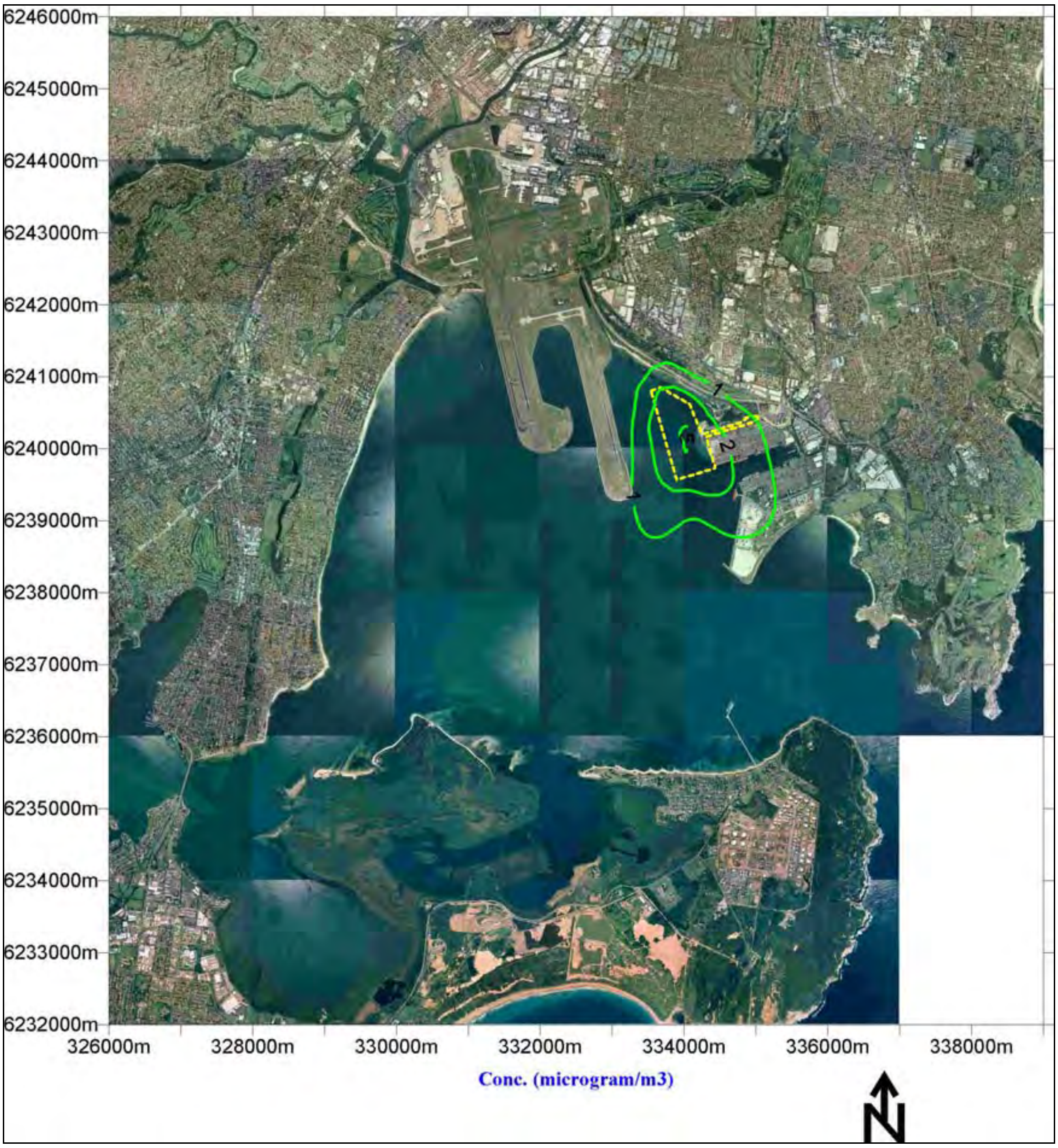
■ **Figure 7-9 Scenario 3 – 24-hour PM_{10} Impacts (All Terminals) ($\mu g/m^3$)**



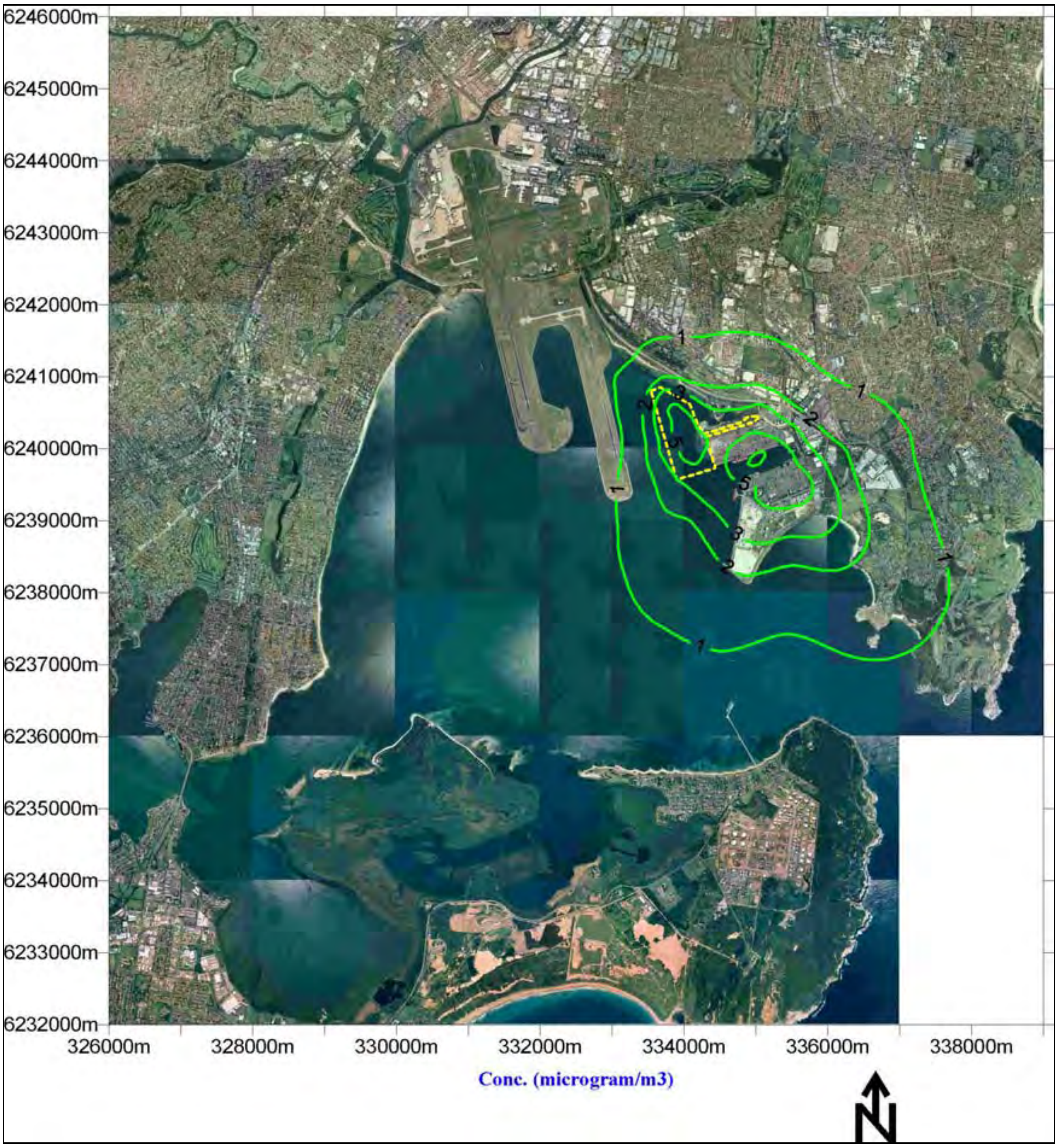
- **Figure 7-10 Scenario 1 – Annual Ave. PM_{10} Impacts (Exist. Terminals) ($\mu g/m^3$)**



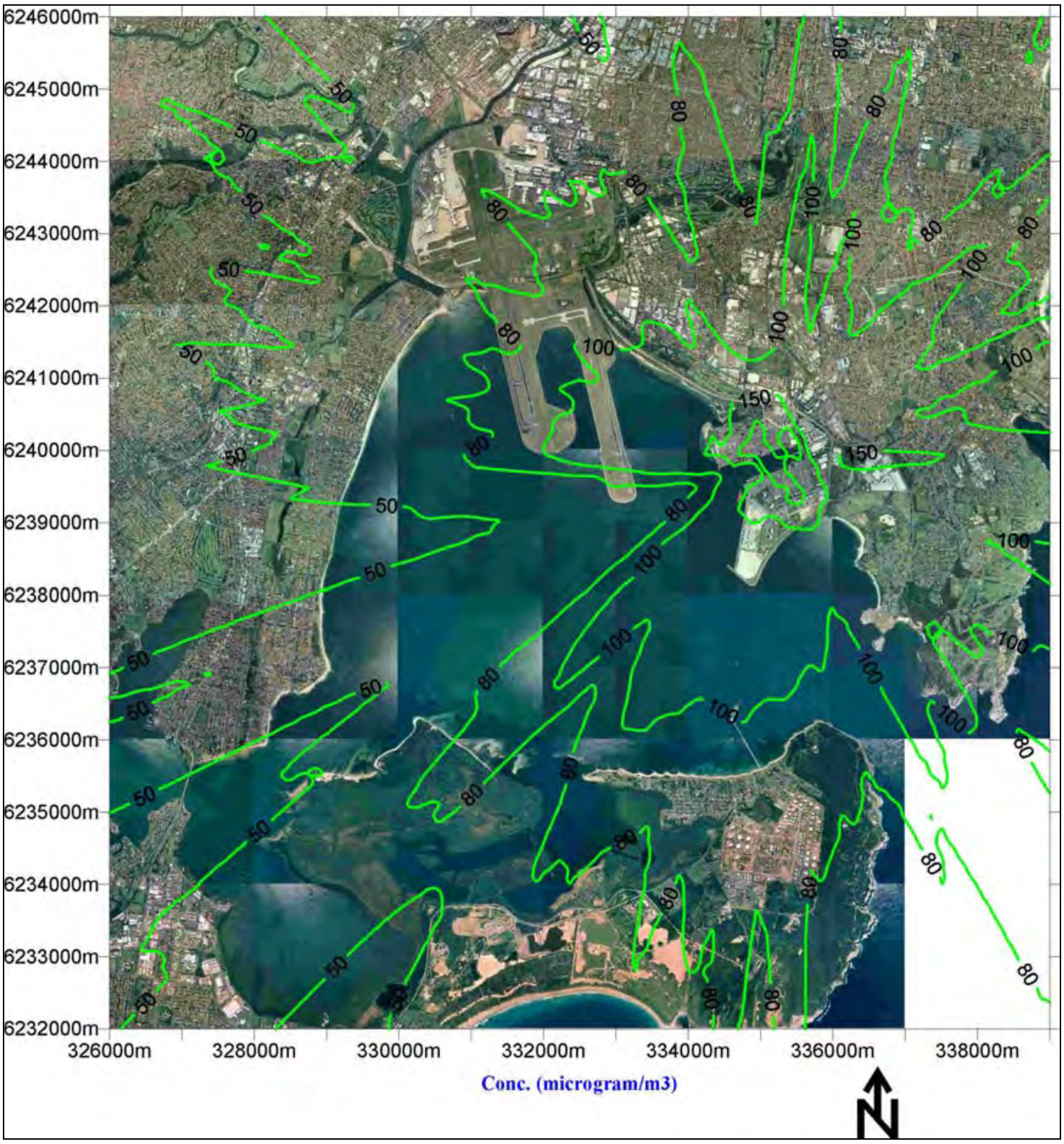
■ **Figure 7-11 Scenario 2 – Annual Ave. PM_{10} Impacts (New Terminals) ($\mu g/m^3$)**



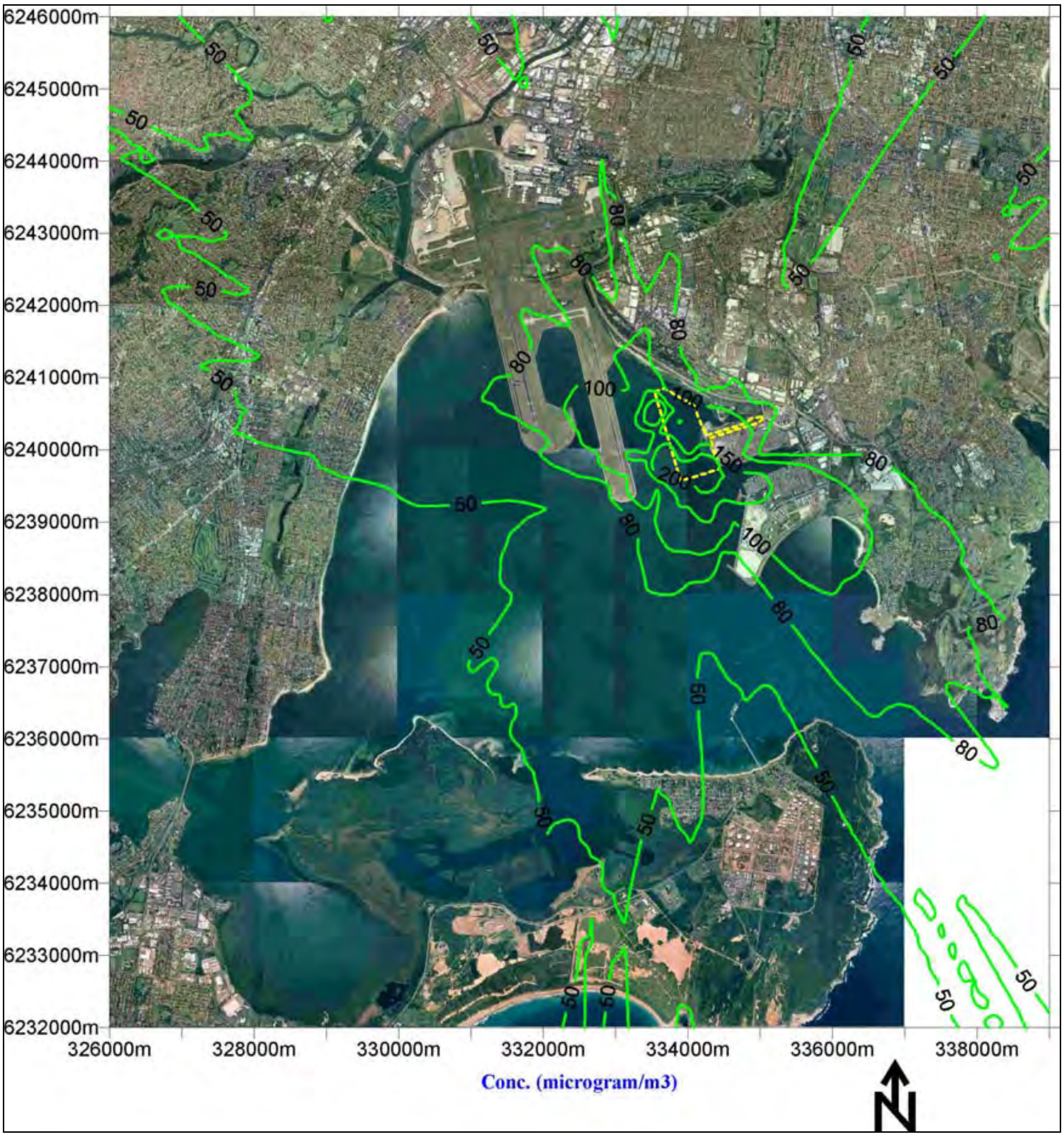
- **Figure 7-12 Scenario 3 – Annual Ave. PM_{10} Impacts (All Terminals) ($\mu g/m^3$)**



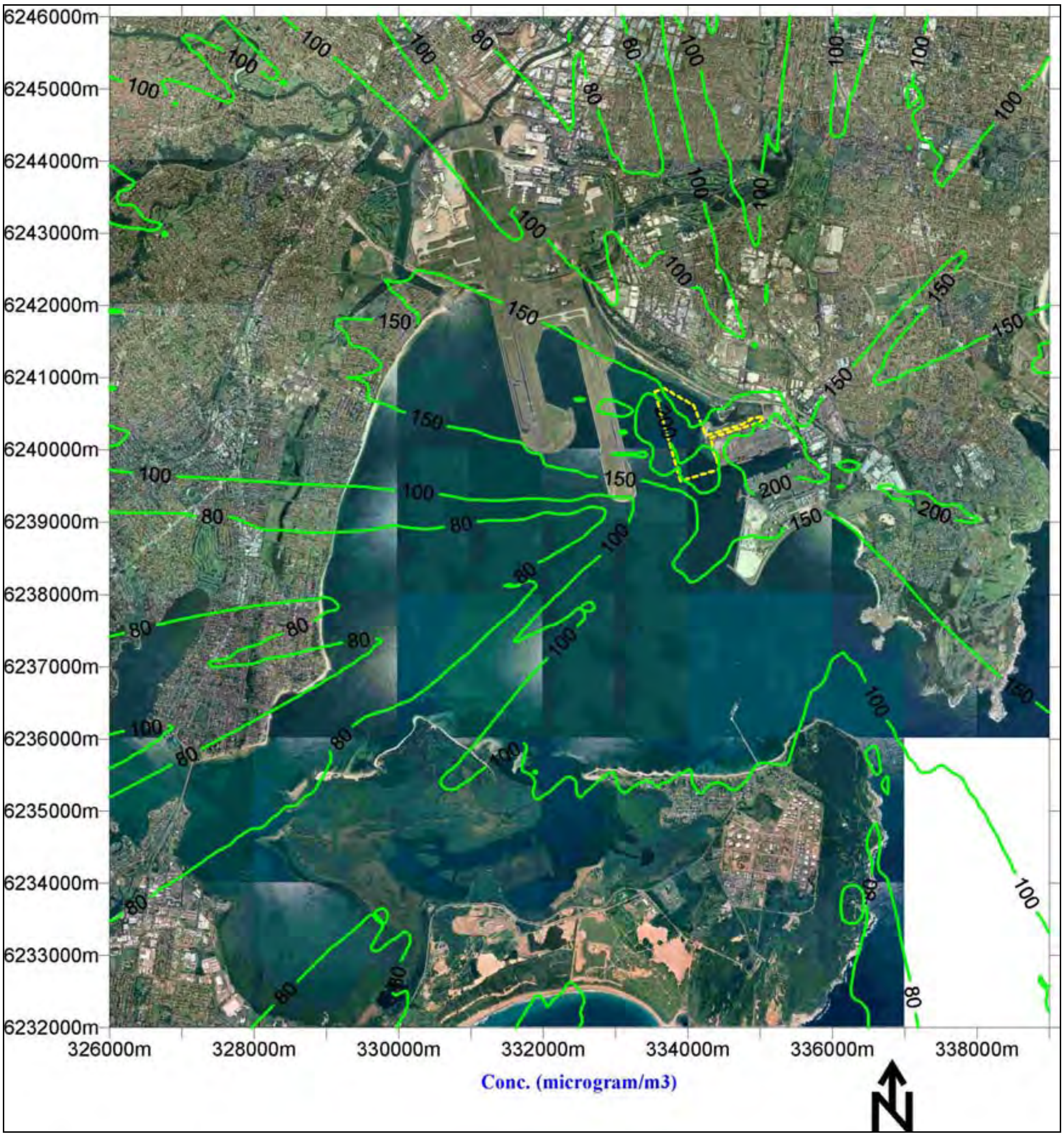
- **Figure 7-13 Scenario 1 – 10-min SO_2 Impacts (Existing Terminals) ($\mu g/m^3$)**



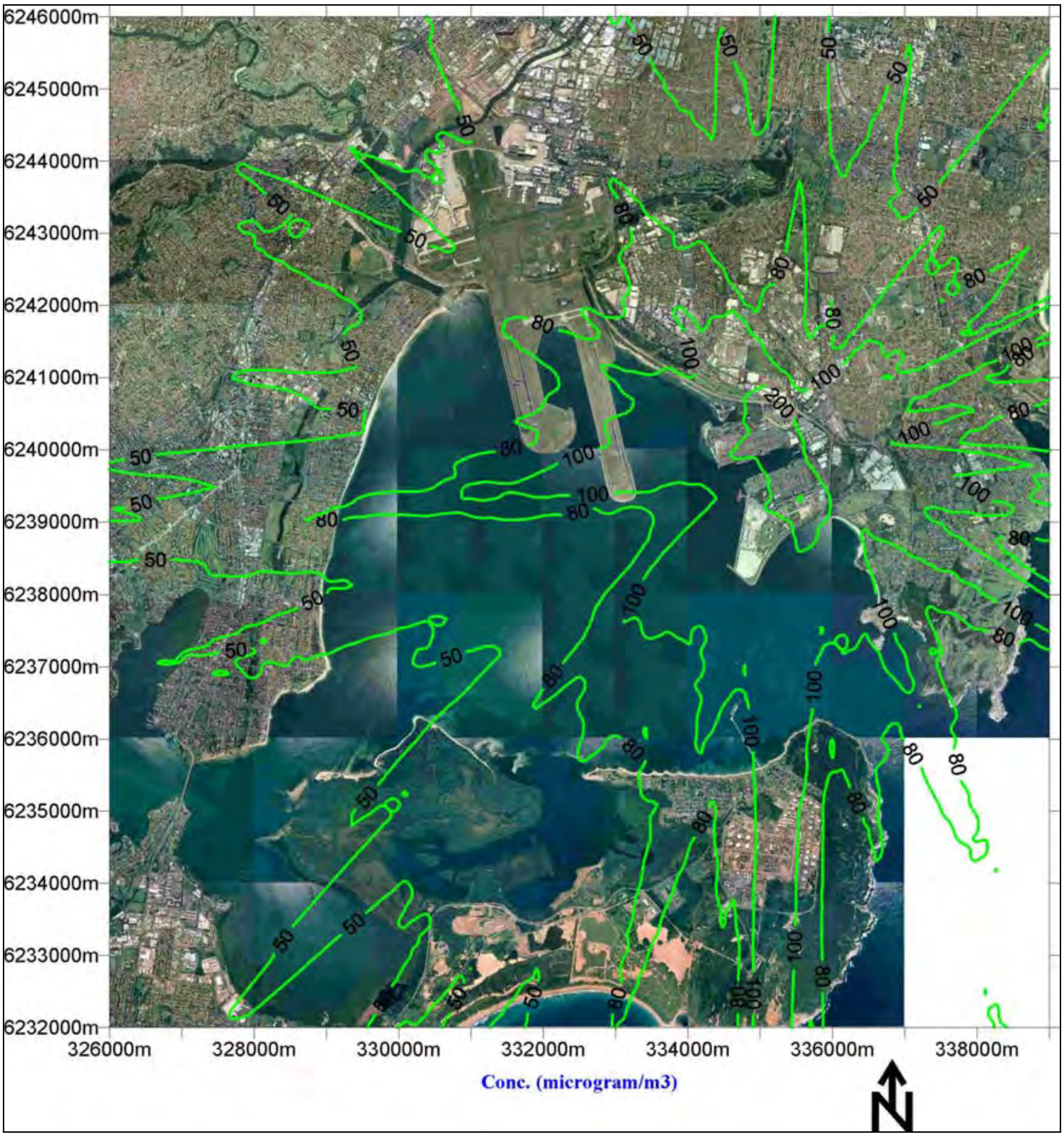
- **Figure 7-14 Scenario 2 – 10-min SO_2 Impacts (New Terminals) ($\mu g/m^3$)**



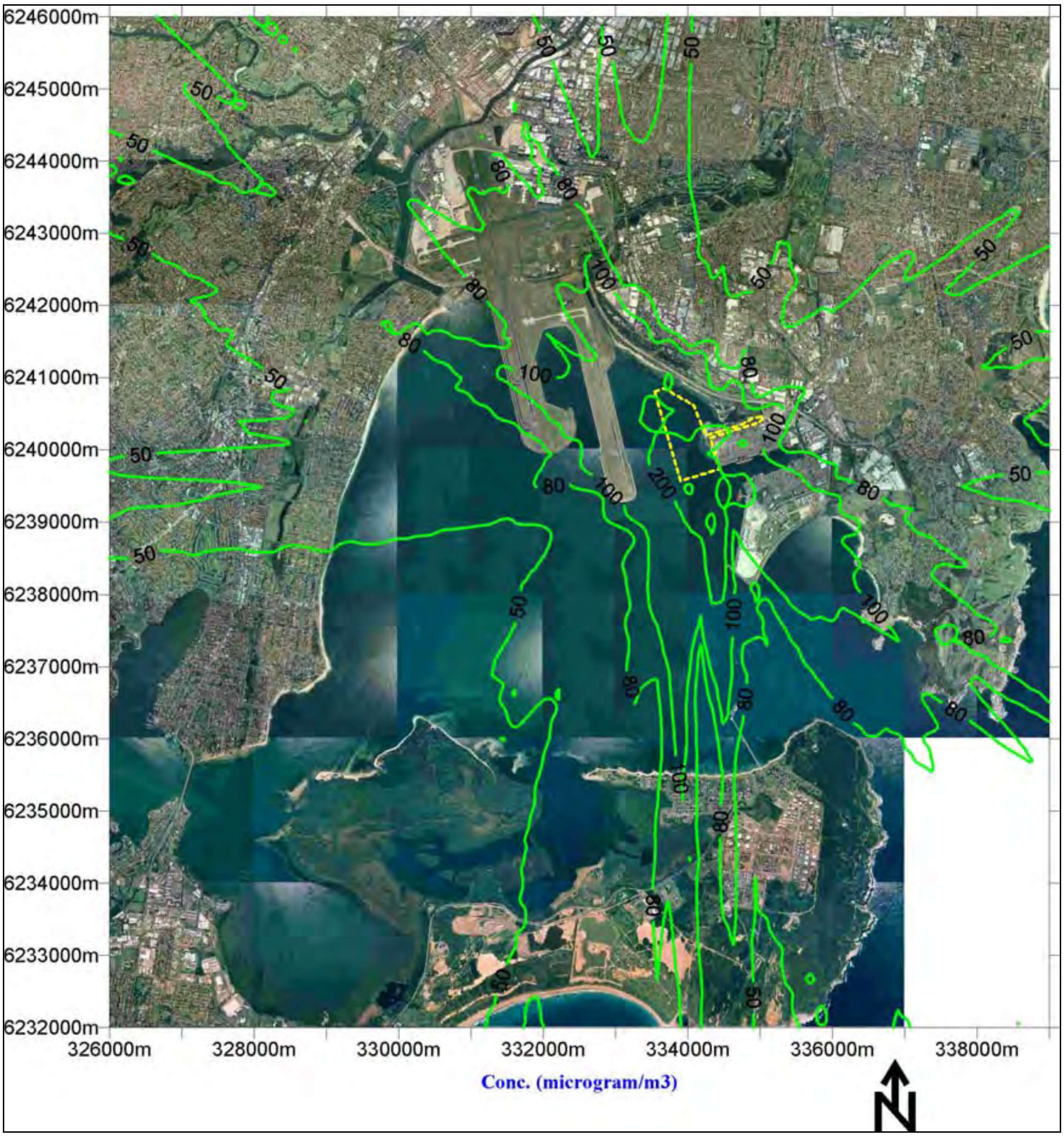
- **Figure 7-15 Scenario 3 – 10-min SO_2 Impacts (All Terminals) ($\mu g/m^3$)**



- **Figure 7-16 Scenario 1 – 1-hour SO_2 Impacts (Existing Terminals) ($\mu g/m^3$)**

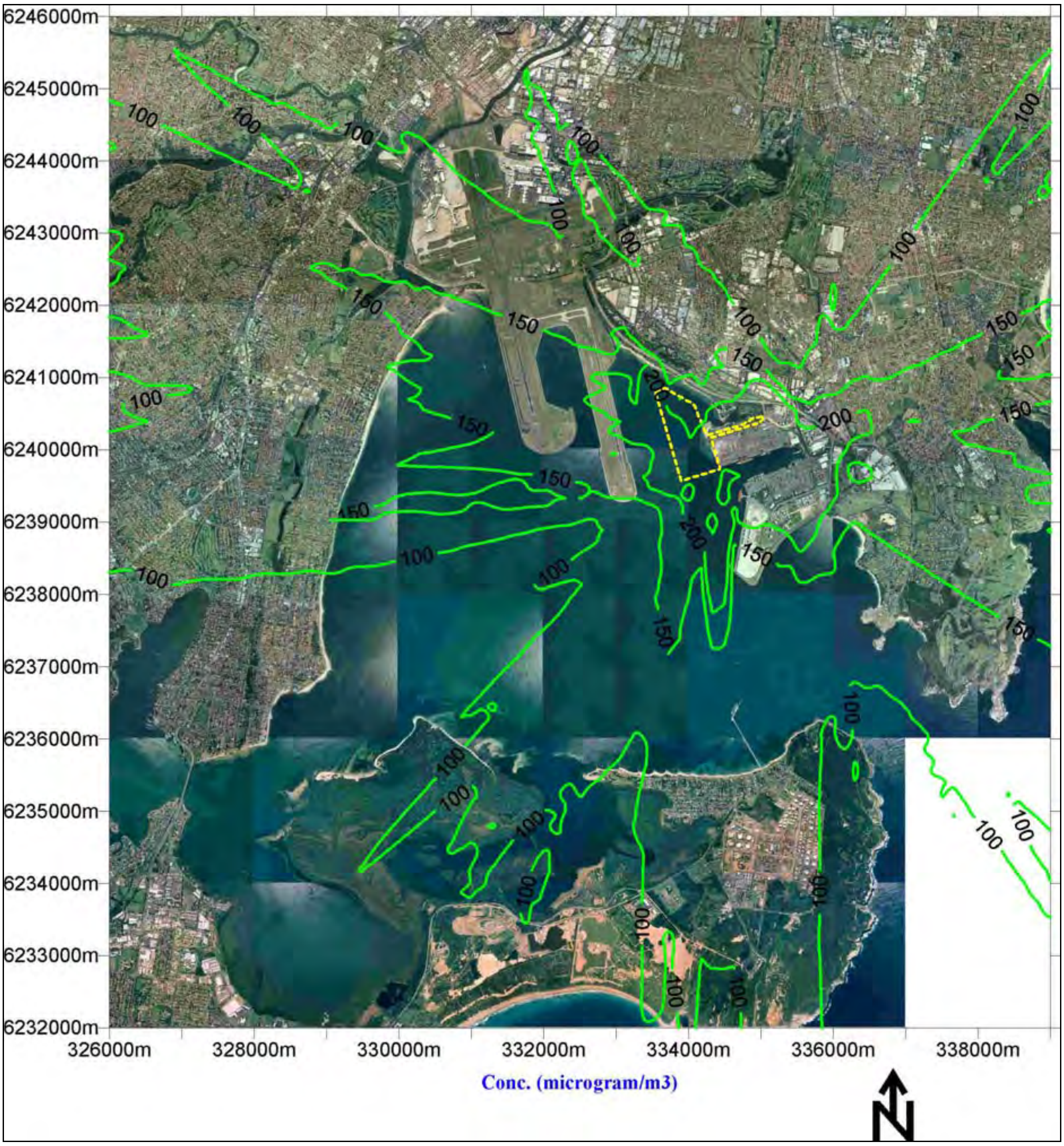


■ **Figure 7-17 Scenario 2 – 1-hour SO_2 Impacts (New Terminals) ($\mu g/m^3$)**

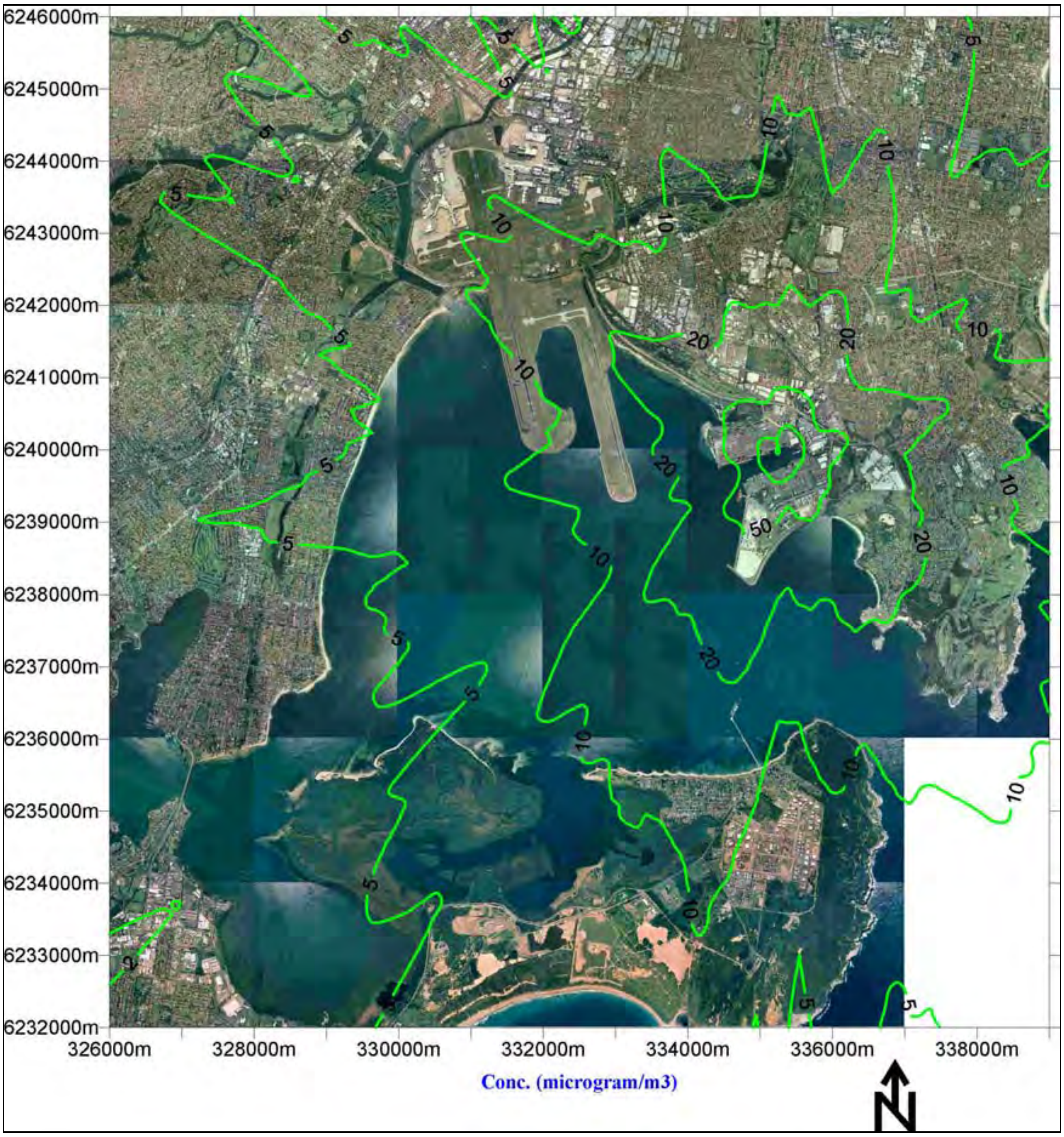


SKM

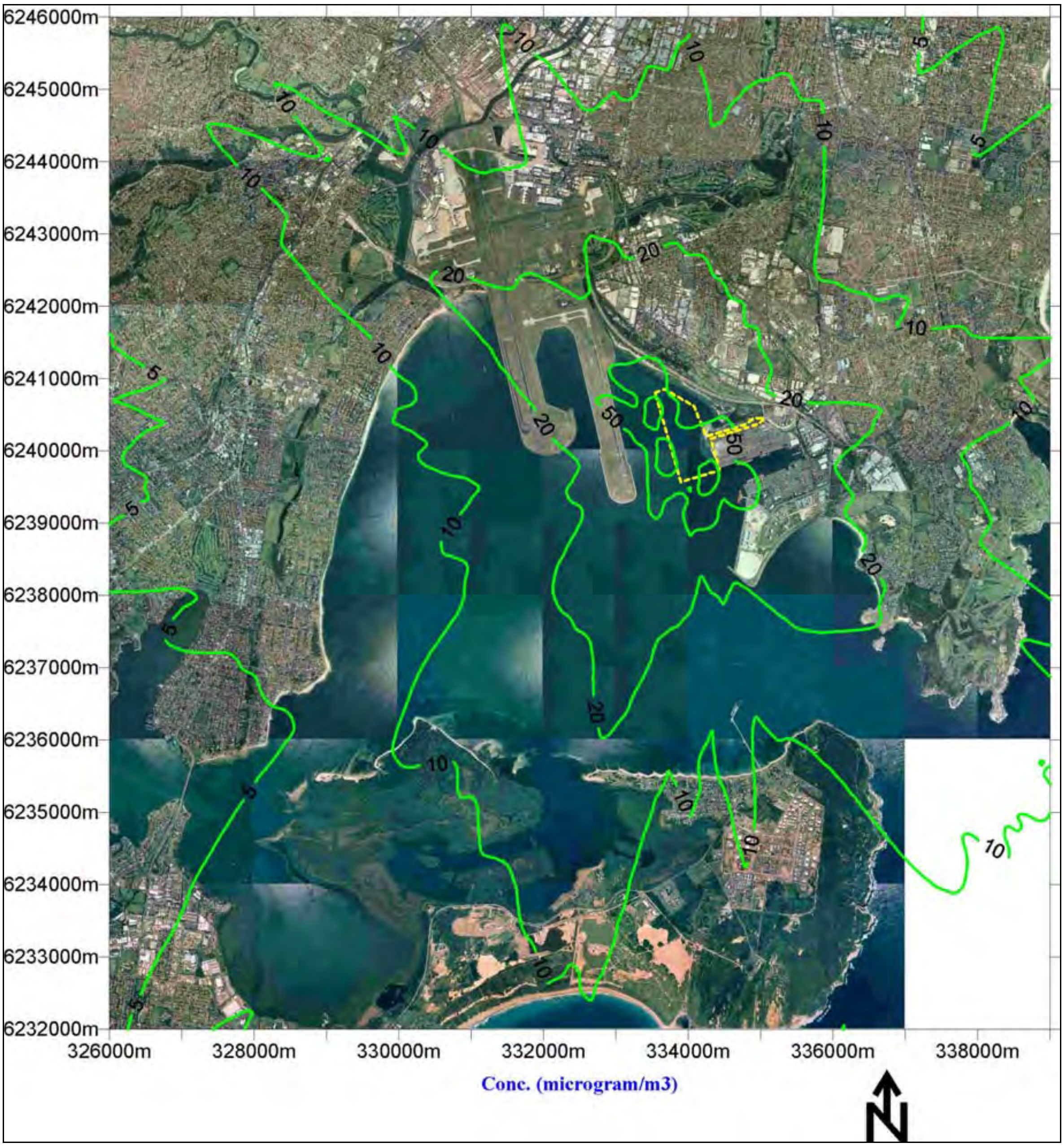
■ **Figure 7-18 Scenario 3 – 1-hour SO_2 Impacts (All Terminals) ($\mu g/m^3$)**



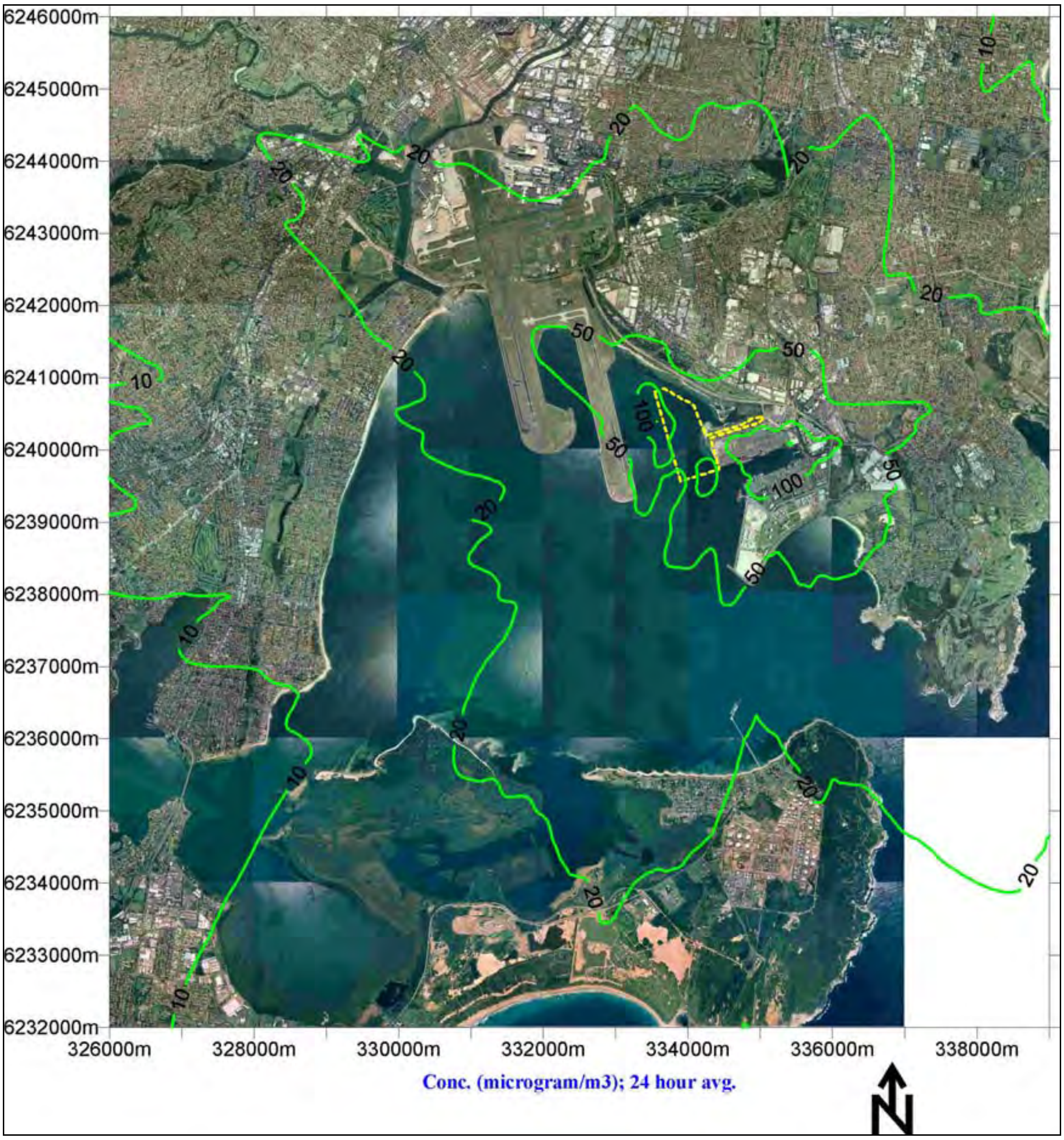
■ **Figure 7-19 Scenario 1 – 24-hour SO_2 Impacts (Existing Terminals) ($\mu g/m^3$)**



- **Figure 7-20 Scenario 2 – 24-hour SO_2 Impacts (New Terminals) ($\mu g/m^3$)**

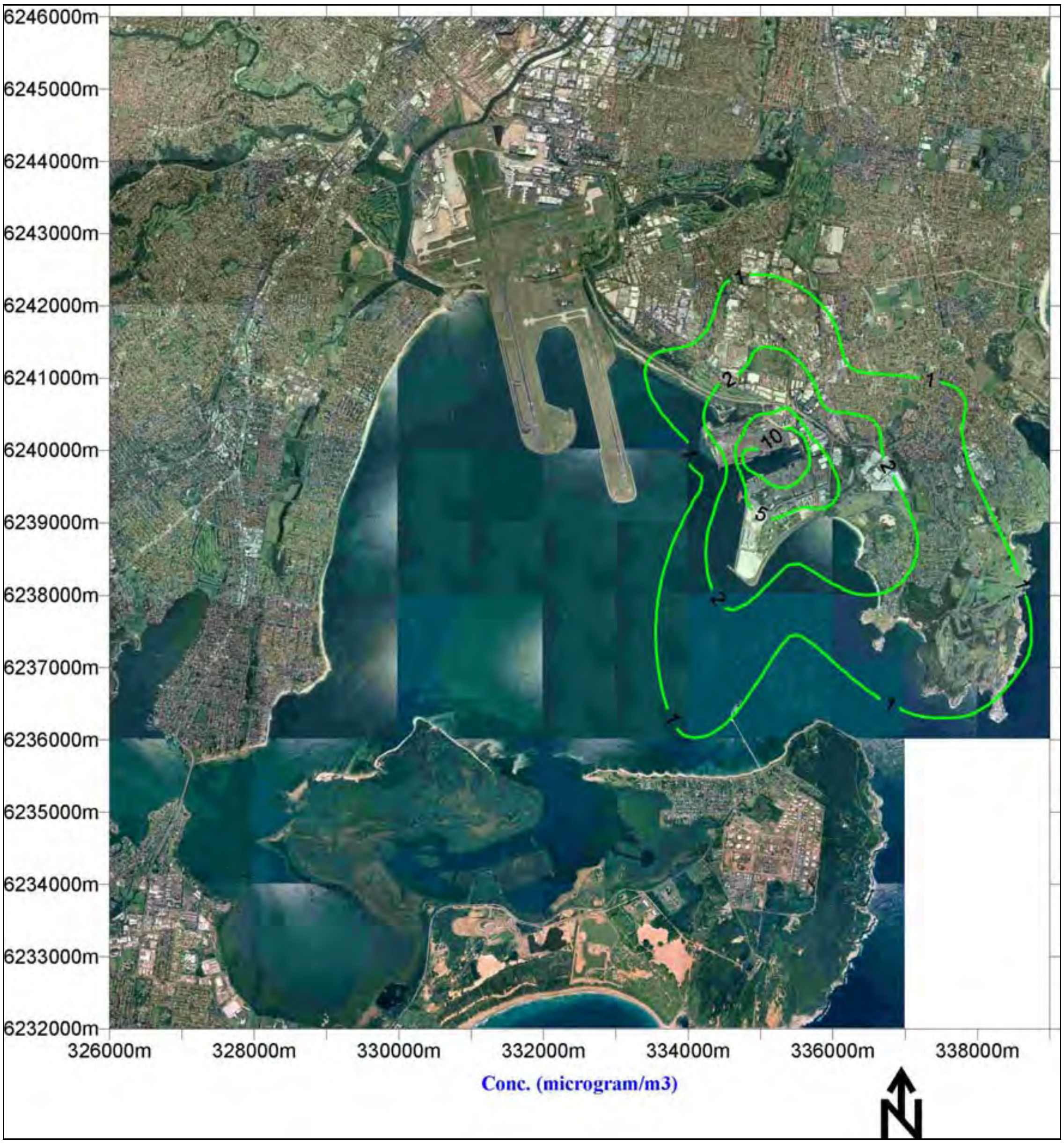


- **Figure 7-21 Scenario 3 – 24-hour SO_2 Impacts (All Terminals) ($\mu g/m^3$)**

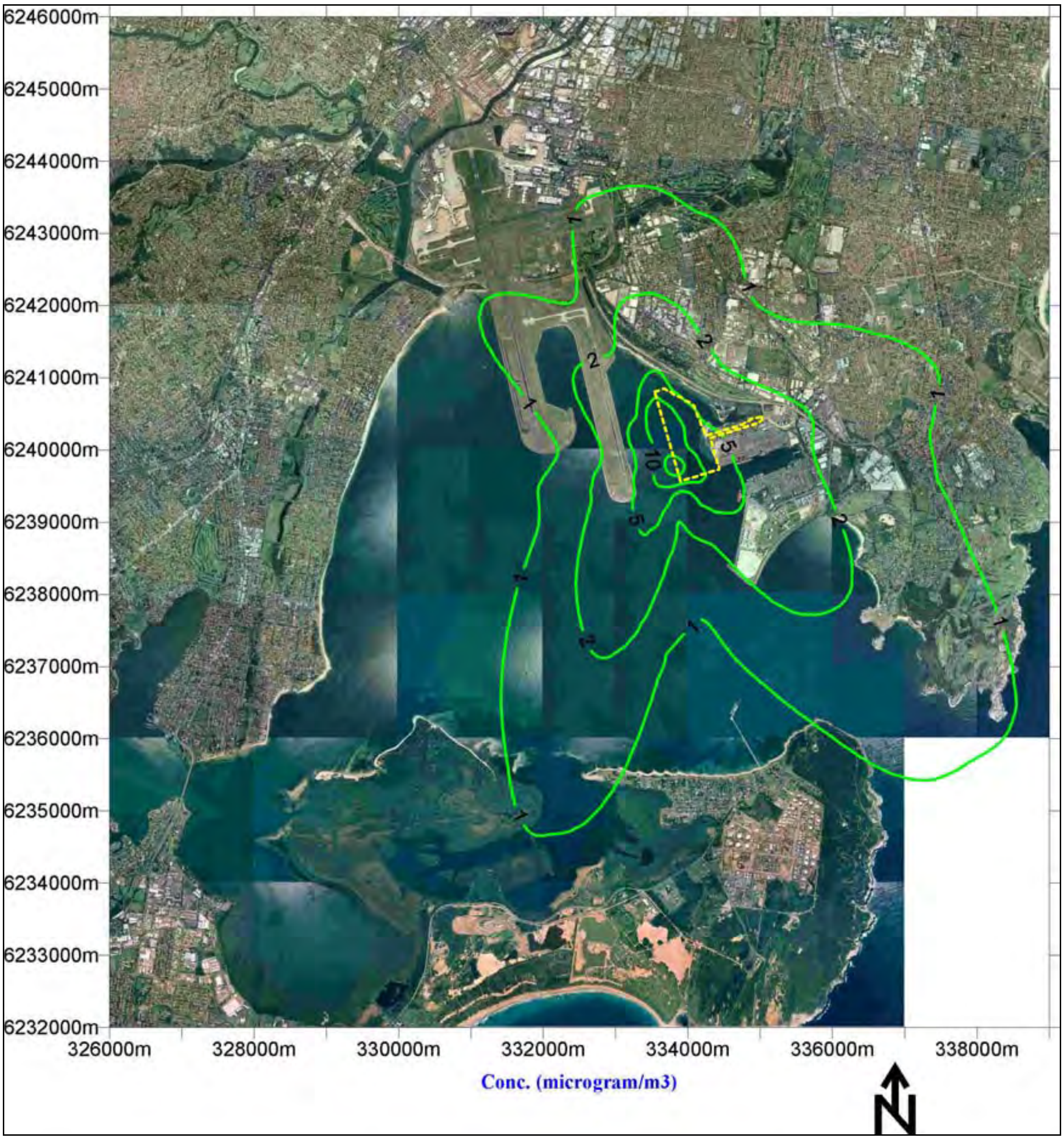


SKM

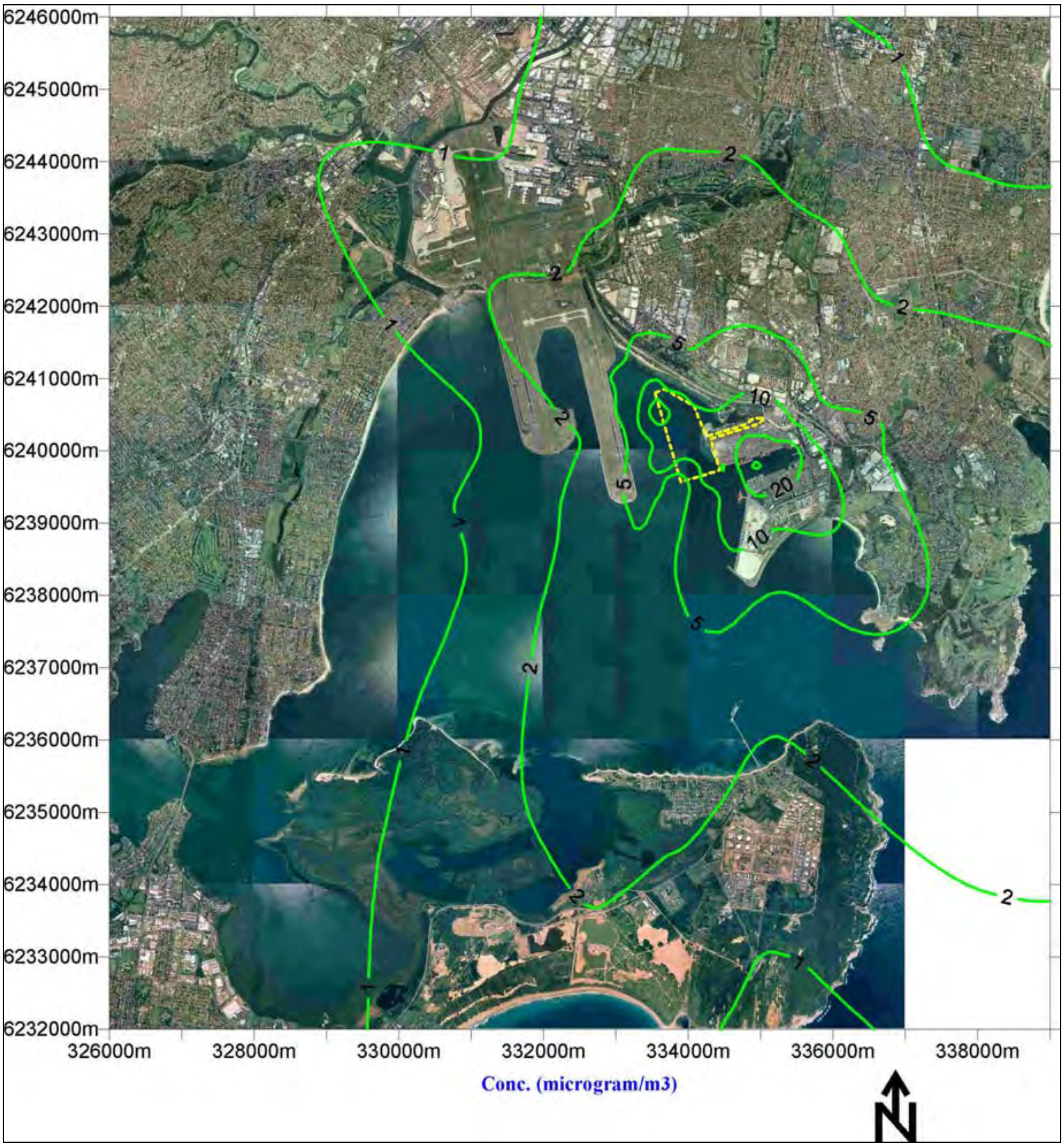
■ **Figure 7-22 Scenario 1 – Ann. Ave. SO_2 Impacts (Existing Terminals) ($\mu g/m^3$)**



■ **Figure 7-23 Scenario 2 – Annual Ave. SO_2 Impacts (New Terminals) ($\mu g/m^3$)**



- **Figure 7-24 Scenario 3 – Annual Ave. SO_2 Impacts (All Terminals) ($\mu g/m^3$)**



7.8 ESD / Greenhouse Considerations

In an earlier study, Sinclair Knight Merz (2002) undertook an assessment investigating several potential future operating scenarios for the transport of container cargo through Sydney in both the intermediate (approximately 2008 to 2010), and the long-term (approximately 2020 to 2025).

The options included the "Do Nothing" scenario. The various options were assessed in terms of Ecological Sustainable Development (ESD), measured by greenhouse gas (CO_2) emissions generated by road, rail and shipping transport of containers to and from Sydney. The assessment also included comparison of the scenarios in terms of each scenario's contribution to regional (Sydney metropolitan airshed) emissions of PM_{10}, NO_x, CO and SO_2.

The study found that construction and operation of the Port Botany expansion alone, without the operation of any new intermodal terminals within the Sydney metropolitan area, is expected to reduce greenhouse gas emissions by approximately 505,000 tonnes per annum by the year 2020-2025, when compared to the "do nothing" scenario. These reductions are largely a result of a decrease in the total kilometres travelled by trucks and trains which would otherwise have to travel interstate and intrastate, in the absence of any Port Botany expansion. For further details of the methods and results of this study, refer to **Appendix B**.

Overall, the Sinclair Knight Merz (2002) study has shown that the construction of the new terminal and upgrade to existing terminals at Port Botany is beneficial in terms of the large reduction of greenhouse gas emissions, when compared to the "Do Nothing" scenario. It can therefore be seen there are significant environmental (greenhouse) advantages of locating an additional terminal within the Sydney metropolitan area.

7.9 Mitigation of Operational Impacts and Green Offsets

The results of this assessment show that operational impacts on air quality associated with the expansion of Port Botany are acceptable. On a local scale the incremental increase in emissions of NO_2, PM_{10}, CO and SO_2 do not result in any exceedence of the previously specified EPA air quality objectives.

In terms of greenhouse gases, the future operation of an expanded Port Botany is shown to result in lower emissions (quantified as CO_2) when compared with the Do Nothing Scenario.

7.9.1 Impact Mitigation

Irrespective of the fact that the expanded Port Botany is shown here to result in acceptable levels of air quality impact, the development will result in increased numbers of trucks and trains using Sydney road and rail networks in the future. While the operations of these modes is not the direct responsibility of SPC nor do they have any control over truck and train operations it is considered prudent that SPC continually investigate all means available to reduce air emissions associated with port operations.

For example in the future SPC could consider (support the use of) alternative energy for ships at berth as opposed to operating auxiliary engines that use Marine Diesel Oil (MDO). Options may include supply of shore power should ships be able to accept such power. Emissions from dockside equipment can be reduced by the installation of catalytic converters within diesel engines or the use of exhaust filtration devices and replacing existing equipment as new engine technology of alternative fuels to diesel becomes available.

8. Air Monitoring Requirements

8.1 Overview

This section of the report sets out air quality and meteorological monitoring required during the construction stage of the development.

8.2 Construction Phase Monitoring

8.2.1 Air Quality Monitoring

Prior to and during construction, it is recommended to undertake monitoring in areas that are most likely to receive dust impacts during the construction period. All monitoring should be undertaken in accordance with the NSW EPA *Approved methods for the sampling and analysis of air pollutants in New South Wales* (2001). All monitoring devices would be located in accordance with AS 2922-1987 – *Ambient Air - Guide for Siting of Sampling Units*.

In particular, one high-volume air sampler (HVAS) should be installed within the residential area to the north of Foreshore Road and preferably to the south of Botany Road. This location is shown by dispersion modelling (refer to **Section 6.4**) to receive the greatest dust impacts during construction. This HVAS should monitor PM_{10} on a six-day cycle in accordance with:

- AS 3580.9.6-1990 – Particulate matter – PM_{10} – high-volume sampler with size-selective inlet

It is also recommended three dust deposition gauges be installed within residential areas – preferably two in the residential area north of Foreshore Road, and one in the Matraville residential area immediately east of Amcor. An additional dust deposition gauge should also be located in Penrhyn Estuary. Dust depositions in this vicinity are likely to be 1-10 g/m^2/month during construction stages closer to the wetland habitat. To ensure minimal impact on sensitive habitats and to minimise the potential for sedimentation in shallow waters, on going monitoring of sediment levels within these sensitive areas is recommended.

Sampling should be undertaken in accordance with:

- AS 3580.10.1-1991 – Particulates – deposited matter (gravimetric method).

Monitoring should commence 6-12 months prior to the commencement of construction. The purpose of the initial monitoring would be to determine if the background PM_{10} and dust deposition levels are over and above the pre-determined background levels set out in this report. Once construction commences, monitoring would assist in identifying any exceedences of the PM_{10} (24-hour) criterion of 50 $\mu g/m^3$, and where these episodes are reported and shown to be attributed to the earthworks at the site, dust management measures can be implemented.

8.2.2 Meteorological Monitoring

A meteorological monitoring station should be installed at one of the existing terminals, if not already installed. The meteorological station should be installed in accordance with:

- AS 2922-1987 – Ambient Air – Guide for Siting of Sampling Units; and
- AS 2923-1987 – Ambient Air – Guide for the Measurement of Horizontal Wind for Air Quality Applications.

Parameters to be collected should include:

- wind speed;
- wind direction;
- temperature;
- humidity;
- solar radiation; and
- rainfall.

The primary purpose of the meteorological monitoring station is to collect data sufficient to identify adverse air quality impacts within nearest residential areas that could potentially be caused by construction works or operation of the terminals.

9. Conclusions and Recommendations

This report has provided a comprehensive air quality impact assessment of the proposed upgrade to Port Botany terminal operations, including a proposed new terminal to be constructed from land reclamation.

An assessment of the existing ambient air quality within the Port Botany local area was made, as well as an air quality impact assessment of both the proposed reclamation and construction works, and of the operation of the terminals for both existing and future scenarios. Impacts were compared to the NSW EPA ambient air quality objectives, taking into account the existing air quality.

AUSPLUME dispersion modelling of dust emissions from construction of the proposed new terminal shows that there are low risks that incremental PM_{10} (24-hour) concentrations and monthly dust depositions will exceed the site criteria of 16 $\mu g/m^3$ and 2 g/m^2/month respectively. These results were achieved assuming high-level dust mitigation practices incorporated into the earthworks and construction procedures. These measures include the use of wind breaks along the northern edge of the beach on Foreshore Road, and dust suppressant practices including regular watering of temporary access roads and exposed work areas. During the stabilisation of the reclaimed area, wind blown dust emissions would need to be controlled with the placement of a temporary bituminous membrane emulsion (or equivalent).

Each stage of the construction works should be timed such that cumulative dust impacts are considered in respect to any other construction activity or dust-generating activity within the area.

Air quality impacts from the Port's current and estimated future operations were assessed by AUSPLUME dispersion modelling of both 'peak' and 'annual averaged' (normal) operation. The potential for adverse air quality impacts from the operation of the Port's proposed new terminal, combined with the P&O Ports and Patrick Terminals, when at throughput of 3.2 million TEU, is minimal. There are expected to be only marginal increases in CO, $NO_{2,}$, SO_2 and PM_{10} concentrations in surrounding area, with modelling results showing no exceedences of the site criteria within residential areas or at sensitive receivers.

A conservative approach has been taken to estimate ship emissions for the future scenarios, and are based on the maximum NO_x and SO_2 limits proposed by the MARPOL 73/78 Protocol. It is likely that ship engines being built in compliance with the Protocol will have a level of safeguard in order that they do not emit the emission 'limits'. As such, impacts presented in this study may well be less depending on the extent of which this philosophy is practised, and the extent to which these ships are used in Australian ports.

It is recommended a high-volume air sampler and on-site meteorological station be used to monitor dust impacts (as PM_{10}) during construction of the proposed new terminal. Furthermore, during construction four dust deposition gauges should be located in surrounding residential areas and Penrhyn Estuary where dust impacts are likely to be greatest. In further reducing operational emissions, particularly in mitigating emissions from ships, SPC should support ship designs that consider alternative energy for ships at berth as opposed to operating auxiliary engines that use

Marine Diesel Oil (MDO). Options may include using power connected to the terminal. SPC should make provision for shore power connections in the future.

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Appendix A Met Data File Development

AUSPLUME Meteorological File for Sydney Airport

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A.1 Source of Data

Meteorological observations have been taken at Sydney Airport for many years, however the data used for dispersion modelling in this air quality impact assessment covers the period from January 2000 to January 2001 inclusive. The site (Bureau of Meteorology station number 066037) has an Automatic Weather Station that provides three-hourly "SYNOP" and hourly or better "METAR" observations of wind and temperature. The SYNOP data also include manual observations of cloud amounts and heights. The SYNOP data are stored in ADAM, the Bureau of Meteorology's climate data archive. METAR data are stored in the Bureau's NSW Regional Office. The AWS also provides observations every minute of temperature, wind speed, wind direction and sigma-theta (the standard deviation of wind direction). The Bureau's NSW Regional Office also stores these data.

A.2 Treatment of Data

The SYNOP and METAR data were combined into a single data set. When observations were from the same time, preference was given to the SYNOP data as it has undergone slightly more quality control as a result of being ingested into ADAM.
No gaps in the observations exceeding 3 hours were found in the period investigated.
The one-minute data (and to a lesser extent the METAR and SYNOP data) were known to contain errant values. These were checked for quality by looking for outliers and for events when the value changed very rapidly.

A.3 Estimation of Pasquill Stability Class

Pasquill stability class was estimated using the method described by D. Bruce Turner in *A Diffusion Model for an Urban Area*, Journal of Applied Meteorology, Volume 3, Feb 1964, pp83-91. This method has been modified slightly to accommodate the cloud observations as stored in ADAM.

The method involves determining an "insolation correction" from the amount and disposition of cloud. This is added to an "insolation index", determined from the solar position (itself dependent on the time of day and the date) to yield a "Net Radiation Index". This is then combined with wind speed to estimate stability class.

A.4 Estimation of Mixing Depth

The wind speed and the surface roughness determine the depth of the mechanically mixed layer. E.J. Plate describes the method in *Aerodynamic characteristics of atmospheric boundary layers*, a 1971 U.S. Department of Commerce report numbered NTIS TID-254.65.

The mixing depth M is estimated to be

$$M = \frac{0.185\,u^*}{2\Omega \sin\theta}$$

where Ω is the angular rate of rotation of the earth, and θ the latitude. u^* is the "friction velocity",

$$u^* = \frac{0.35\,u}{\ln\left(z_w / z_0\right)}$$

u being the measured wind speed, z_w the height of the anemometer and z_0 the roughness length (also known as roughness height).

As only mechanical mixing is considered (the effects of convection are ignored), the mixing depths derived will generally be low estimates. This method yields mixing depths that are generally lower than those from the method suggested in the NSW EPA's *Approved methods and guidance for the modelling and assessment of air pollutants in NSW* (Aug 2001). These lower mixing depths will tend to favour higher ground-level concentrations.

To prevent the unrealistic case of the mixed depth falling to zero, u is limited to the stall speed of the anemometer, 0.5 m/s. Three versions of the data are provided, with roughness lengths of 20 cm, 40 cm and 80 cm.

A.5 Estimation of Hourly Mean Values

AUSPLUME requires hourly mean values of various meteorological parameters. The timestamp that is placed on the value is taken to be the time at the *end* of the hour.

If at least 30 one-minute observations of temperature were available for the hour under consideration, their mean value is determined and used. If there is insufficient one-minute data (or none), recourse is made to the combined METAR and SYNOP temperatures. The temperature at the start of the hour is estimated by linear interpolation, as is that at the end of the hour. A weighted mean of the temperatures observed in the hour is then calculated.

Wind speed is handled in an identical fashion to temperature. Wind direction is handled similarly, with care taken to eliminate the discontinuity at north (where the direction jumps from 1° to 360°). Observations with zero wind speed are excluded from the calculation of mean wind direction.

Sigma-theta is calculated only from the one-minute data, taking into account the variances within the individual observations, and the variance of the set of directions for the hour.

To avoid problems associated with observation times during daylight saving, the "insolation correction" is calculated when cloud observations are available, and then hourly mean values derived (in the same way as temperature means are). The stability class for the hour is then a function of the insolation correction, the actual insolation at the halfway mark in the hour, and the mean wind speed for the hour.

Mixing depth is calculated from the calculated mean wind speed for the hour.

Appendix B Results of ESD Study

B.1 Overview

This section of the report provides detailed and summarised CO_2 emissions estimates for transport scenarios considered as part of a Sinclair Knight Merz study undertaken for SPC.

The total vehicle kilometres travelled (VKT) by trucks for each scenario was multiplied by the emission factors for the various road types within the Sydney metropolitan area (same source as those used for the Port Botany expansion local air quality study). This resulted in an estimate of CO_2 emissions from road container movements for each scenario.

The emissions of CO_2 from rail container movements were calculated for each scenario using the emission factors in the Port Botany local air quality study. The rural rail emissions are determined for the entire length of the trip, and include the corresponding movement of empty containers out to the rural regions for export.

The duration the main and auxiliary engines are operating during each phase of the journey for each ship visiting Port Botany during the 2000/2001 financial year was calculated. Emissions of CO_2 were determined for each ship using the emission factors outlined in **Section 7.3.1**.

The 'intermediate' term (medium-term) refers to predictions just before the current facilities at Port Botany reach capacity (estimated in approximately 2008-2010). 'Long-term' refers to the Port at forecast demand (approximately 2020-2025) when throughput in Sydney reaches approximately 3 million TEU.

B.2 Results of ESD Assessment

B.2.1 Scenario 1 – Existing

The estimated annual CO_2 emissions from the transport of containerised cargo by truck, rail and ship for the Existing Scenario is summarised in **Table B-1**.

- **Table B-1 Summary of Existing Estimated CO_2 Emissions**

Transport Mode	Annual CO_2 Emission (tonnes/year)
Road	30,110
Metropolitan Rail	4,080
Rural Rail	60,955
Ship and Tug	61,140
Total	**156,285**

B.2.2 Scenario 2 – Do Nothing (Long-Term)

The estimated annual CO_2 emissions from the transport of containerised cargo by truck, rail and ship for the Do Nothing Scenario in the long-term are summarised in **Table B-2**.

■ **Table B-2 Summary of Estimated CO_2 Emissions – Do Nothing (Long-term)**

Transport Mode	Annual CO_2 Emission (tonnes/year)
Road	54,189
Metropolitan Rail	13,344
Rural Rail	313,087
Rail Other Port	407,782
Ship and Tug	115,817
Total	**904,219**

B.2.3 Scenario 3 – Botany Upgrade (Long-Term)

The estimated annual CO_2 emissions from the transport of containerised cargo by truck, rail and ship for the Botany Upgrade Scenario in the long-term is summarised in **Table B-3**.

■ **Table B-3 Summary of Estimated CO_2 Emissions – Botany Upgrade (Long-term)**

Transport Mode	Annual CO_2 Emission (tonnes/year)
Road	54,149
Metropolitan Rail	18,358
Rural Rail	209,494
Ship and Tug	117,330
Total	**399,330**

B.3 Discussion of ESD Calculations for Future Scenarios

Table B-4 provides a summary of expected CO_2 emissions generated from the future long-term operating scenarios.

■ **Table B-4 Summary – Long-Term CO_2 Emissions (tonnes/year)**

Transport Mode	Scenario 2 – Do Nothing	Scenario 3 – Botany Upgrade
Road	54,189	54,149
Metropolitan Rail	13,344	18,358
Rural Rail	313,087	209,494
Rail Other Ports	407,782	-
Ship and Tug	115,817	117,330
Total	**904,219**	**399,330**

As shown above, the operating scenario producing the lowest emission of CO_2 is the Botany Upgrade, as assessed under Scenario 3. The Do Nothing scenario, which would involve diversion of ships to other ports outside Sydney and rail transport of containers to Sydney, would generate the greatest emission of CO_2 of the options assessed.