Hunter Power Project - Response to Submissions

Air Quality Impact Assessment - Revised

Rev 1

30 July 2021

Hunter Power Project - Response to Submissions

Project No:	IS354500
Document Title:	Air Quality Impact Assessment - Revised
Document No.:	Hunter Power Project
Revision:	Rev 1
Date:	30 July 2021
Client Name:	Snowy Hydro Limited
Project Manager:	K Ivanusic
Author:	M Pickett
File Name:	IS354500_RtS_Air Quality Assessment_FinalDraft

Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Level 4, 12 Stewart Avenue
Newcastle West, NSW 2302
PO Box 2147
Dangar, NSW 2309
Australia
T +61 2 4979 2600
F +61 2 4979 2666
www.jacobs.com

Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
Rev 0	30/03/21	Final EIS	M Pickett	S Lakmaker, A Marshall	M Terei, M Luger	K Ivanusic
Rev 1	26/07/21	Final RtS	M Pickett	S Lakmaker	M Luger	K Ivanusic

Contents

List of figures

List of tables

Glossary

Abbreviation	Expansion / definition
AHD	Australian Height Datum
ANSTO	Australian Nuclear Science and Technology Organisation
B(a)P	Benzo(a)Pyrene, a commonly used indicator for Polycyclic Aromatic Hydrocarbons
CEMP	Construction Environment Management Plan
Diesel	The term ‘diesel’ was used given it will be the most likely fuel delivered to the Proposal Site, although the back-up fuel could be another form of distillate. The diesel fuel sulphur content used for this assessment is detailed in this report.
Distillate	The term ‘distillate’ includes various heating oils and diesel fuel. The main distillate classifications are Nos. 1, 2, and 4 fuel oils, and Nos. 1, 2, and 4 diesel fuels. Kerosene is also a distillate, similar to No. 1 oils, but is often listed separately for statistical purposes (PEI, 2021).
DLE	Dry Low Emission
DPIE	Department of Planning, Industry and Environment
EETM	Emissions Estimation Technique Manual, published by the NPI
EIS	Environmental Impact Statement
EPA	NSW Environment Protection Authority
EP&A Act	Environmental Planning and Assessment Act 1979 (NSW)
EP&A Regulation	Environmental Planning and Assessment Regulation (2000)
GDA	Geocentric Datum of Australia e.g. GDA 2020 and GDA 94
GLC	Ground Level Concentration
ISO	International Organization for Standardization
Jacobs	Jacobs Group (Australia) Pty Ltd
MW	MegaWatt (one million Watts) – a unit of power
NG	Natural Gas
OCGT	Open Cycle Gas Turbine
NMA	Newcastle Metropolitan Area
NO	Molecular formula for nitric oxide
NO_2	Molecular formula for nitrogen dioxide
NO_x	Molecular formula for oxides of nitrogen
NPI	National Pollutant Inventory
PAH	Polycyclic Aromatic Hydrocarbon(s) e.g. see B(a)P
PEOA	Protection of the Environment Operations Act
$PM_{2.5}$	Particulate Matter 2.5 – airborne particles with an equivalent aerodynamic diameter of <= 2.5 micron (μm)
PM_{10}	Particulate Matter 10 – airborne particles with an equivalent aerodynamic diameter of <= 10 micron (μm)
Proposal	Development of a gas-fired power station at Kurri Kurri NSW

Abbreviation	Expansion / definition
SEAR	Secretary's Environmental Assessment Requirements
Sensitive receptor	A location where people are likely to work or reside; this may include a dwelling, school, hospital, office or public recreational area (EPA, 2016).
Snowy Hydro	Snowy Hydro Limited
SO_2	Molecular formula for sulphur dioxide
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound – a hydrocarbon

Executive summary

An assessment of air pollutant emissions associated with the proposed Snowy Hydro Hunter Power Project (the 'Proposal') has been completed. The proposed development is an Open Cycle Gas Turbine power station located at Loxford, NSW which is approximately three kilometres north of Kurri Kurri in the Lower Hunter region. The chief objective of this assessment was to determine the potential air quality impacts that may occur as a result of power station operations.

The 'baseline' or existing air quality situation for this assessment does not include emissions from the former Kurri Kurri aluminium smelter with its associated effects on local air quality, that ceased production in 2012. The baseline for this assessment covered the post-smelter period of 2015 to 2019 (with 2019 heavily affected by bushfire smoke).

Air quality impacts from construction of the power station are expected to be insignificant and temporary. Commonly used dust and odour control measures will be used to minimise air emissions due to construction activities. The Proposal Site has good separation from sensitive receptors such as residential residences.

The Proposal is seeking approval for a capacity factor of up to 10 per cent of each year on natural gas fuel and two per cent on diesel fuel. However, it is expected that likely operations would result in a capacity factor of approximately two per cent. Modelling of continuous emissions from the Proposal was undertaken to test every hour of an annual meteorological simulation – this was a conservative approach taken for the assessment.

The key air pollutants associated with the Proposal are: carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter as $PM_{2.5}$ and the hydrocarbons or Volatile Organic Compounds (VOCs): formaldehyde and acrolein when the power station is fuelled by natural gas, and formaldehyde and Benzo(a)pyrene (B(a)P) when fuelled by diesel.

A detailed review of the existing environment was carried out including an analysis of measured concentrations of 'criteria' air pollutants and their indicators (CO, NO_2, SO_2 and $PM_{2.5}$), from representative monitoring stations. The following conclusions were made in relation to the existing air quality and meteorological conditions:

- Wind patterns in the vicinity of the Proposal Site are characteristic of the Lower Hunter Valley, with prevailing winds from the west-northwest.
- Measured CO, NO_2 and SO_2 concentrations have been consistently below NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) air quality impact assessment criteria.
- Measured ozone (O_3) concentrations occasionally exceed assessment criteria, with higher O_3 concentrations caused by mainly NO_x emissions from road traffic, bushfires and controlled burns and other sources, during warmer weather (sunny conditions); e.g., NSW DPIE (2020).
- Measured $PM_{2.5}$ levels increased across NSW and the Hunter region from 2017 to 2019 due to the effects of drought including dust storms, smoke from bushfires and hazard reduction burning. These events adversely influenced air quality with multiple days observed when $PM_{2.5}$ concentrations exceeded EPA assessment criteria.

Model predictions were assessed at selected sensitive receptors located near the Proposal Site, which were considered as representative of the worst case sensitive receptor locations. The key outcomes of the air quality assessment were:

- The Proposal will meet NSW Government, *Protection of the Environment Operations (Clean Air) Regulation 2010* requirements for air pollutant concentrations in the exhaust gases.
- Operation of the Proposal will lead to small increases of ambient (ground level) concentrations of the air pollutants: CO, NO_2, SO_2, $PM_{2.5}$ and the VOCs: formaldehyde, acrolein and Polycyclic Aromatic Hydrocarbons (as BaP); these small increases are predicted to not cause significant air quality impacts, by comparisons with their NSW EPA impact assessment criteria.

- The predicted changes in concentrations of key air quality indicators due to the Proposal are within the range of historically measured fluctuations in maximum concentrations for the region.
- The air pollutants of concern are those where background levels are already high; i.e., NO_2 (because O_3 levels are high) and $PM_{2.5}$. However, modelling showed that the Proposal would not cause additional exceedances of criteria.

Based on modelling, increases in NO_2 concentrations due to the Proposal are unlikely to cause exceedences of NO_2 criteria. However, O_3 background levels are high, and any additional NO_x emissions represent an increase to regional NO_x that contribute to the formation of O_3 in the wider region. A detailed photochemical modelling study was outside the scope of this assessment. However, it would be reasonable to assume the power station NO_x emissions would have the effect of slightly reducing O_3 levels in its immediate vicinity (O_3 destruction), but contributing to a very slight increase in regional O_3 levels.

The assessment demonstrated by modelling that $PM_{2.5}$ contributions due to the Proposal would be negligible relative to air quality criteria. Concentrations of $PM_{2.5}$, including with potential contributions from the Proposal, would continue to be within the range of historically measured fluctuations in maximum concentrations for the region. This means that in a year when the Hunter Valley is not affected by bushfires, emissions from the Proposal are very unlikely to cause exceedances of $PM_{2.5}$ criteria. In a year affected by bushfires, measurements of $PM_{2.5}$ in the Hunter Valley will reflect the influence of bushfire smoke.

The assessment demonstrated that Proposal operations, whether fuelled by natural gas or diesel, would not be expected to cause adverse air quality impacts in the vicinity of the Proposal Site nor in the wider Lower Hunter region. This conclusion was based on modelling procedures undertaken in accordance with NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) and which conservatively assumed that the power station would be operating continuously. The implementation of ‘best practice’ gas turbine engineering technology for the Proposal, such as using Dry Low Emission (DLE) combustion system when operating on gas and Water Injection (WI) control technology when operating on diesel will minimise NO_x emissions and air quality impacts.

1. Introduction

1.1 Proposal overview

Snowy Hydro Limited (Snowy Hydro) ('the Proponent') proposes to develop a gas fired power station near Kurri Kurri, NSW ('the Proposal'). Snowy Hydro is seeking approval from the NSW Minister for Planning and Public Spaces under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Proposal.

The Proposal Site is located in Loxford in the Hunter Valley within the Cessnock City Council local government area (LGA), approximately three km north of the town of Kurri Kurri, 30 km north-west of Newcastle CBD and 125 km north of Sydney. A regional map showing the Proposal's location is provided in Figure 2-1. The Proposal Site forms part of the decommissioned Kurri Kurri aluminium smelter site, owned by Hydro Aluminium Kurri Kurri Pty Ltd (Hydro Aluminium), that ceased operation in late 2012 and permanently closed in 2014. Demolition and site remediation works are ongoing, but would be completed prior to construction of the Proposal.

The Proposal involves the construction and operation of a open cycle gas turbine (OCGT) power station and electrical switchyard, together with other associated supporting infrastructure. The power station would have a capacity of up to approximately 750 Megawatts (MW) generated by two heavy duty gas turbines. Although primarily a natural gas fuelled power station, diesel operations are also expected as required if there were a constraint or unavailability in the natural gas system and there was a need to supply electricity to the National Electricity Market (NEM).

The Proposal would operate as a peak load generation facility supplying electricity at short notice when there is a requirement in the NEM. The major supporting infrastructure that is part of the Proposal would be a 132 kV electrical switchyard located within the Proposal Site. The Proposal would connect into existing 132 kV electricity transmission infrastructure located adjacent to the Proposal Site. A new gas lateral pipeline and gas receiving station will also be required and this would be developed by a third party and be subject to a separate environmental assessment and planning approval.

Other ancillary elements of the Proposal include:

- Storage tanks and other water management infrastructure for potable water and demineralised water
- Fire water storage tanks and firefighting equipment such as hydrants and pumps
- Maintenance laydown areas
- Stormwater basin
- Diesel fuel storage tanks and truck unloading facilities
- Site access roads and car parking
- Office/administration, amenities, workshop/storage areas.

Construction activities are anticipated to commence early 2022 and the Proposal is intended to be operational by the end of 2023, with some operation potentially commencing by August 2023.

1.2 Air quality context

The power station will be fuelled by natural gas normally, with diesel used as a backup fuel. This might include up to six months of diesel-only operation during 2023 before the natural gas supply to the Proposal Site is completed. The power output by the power station and air pollutant emissions profile will be different for each fuel type.

The Proposal is seeking approval for a capacity factor of up to 10 per cent of each year on natural gas fuel and two per cent on diesel fuel. However, it is expected that likely operations would result in a capacity factor of approximately two per cent. For the purpose of this assessment the predicted air emissions from the Proposal were assessed in accordance with Environment Protection Authority (EPA) modelling assessment requirements (EPA, 2016), which meant the effects of air emissions were tested for every hour of a simulated meteorological year; a conservative approach.

Typical air pollutants of concern for natural gas fuelled open cycle gas turbine power stations are: nitrogen dioxide (NO_2), and some hydrocarbons, known as Volatile Organic Compounds (VOCs). Indirectly, emissions of oxides of nitrogen (NO_x), VOCs, and carbon monoxide (CO), contribute to the photochemical formation of ozone (O_3) in the ambient atmosphere. Emissions of some other air pollutants, such as CO and sulphur dioxide (SO_2) are of less concern in that they are unlikely to lead to high concentrations relative to their corresponding ambient air quality standards / criteria.

Typical air pollutants of concern for diesel fuelled open cycle gas turbine power stations are: NO_2, some VOCs, and some small airborne particles or 'aerosols', measured in the ambient atmosphere as PM_{10} and $PM_{2.5}$. Emissions of SO_2 may be of concern depending on sulphur content of the fuel, and if background SO_2 levels are already high.

The Proposal Site is located in the small suburb of Loxford, north of Kurri Kurri, in the Lower Hunter Valley, with relatively flat terrain in the vicinity of the Proposal Site. Most of the sensitive receptors closest to the Proposal Site are isolated residences.

The nearest ambient air quality and meteorological monitoring station to the Proposal Site is EPA's Beresfield monitoring station, located approximately 16.7 km east of the Proposal Site. Review of the EPA Beresfield data, (refer Section 4.4), revealed higher risk air pollutant emissions for the Proposal were expected to be:

- NO_x – the formation of NO_2 will contribute to already high levels of O_3 (on both natural gas and diesel-fuelled operations)
- PM_{10} and $PM_{2.5}$ – existing levels of airborne particulate matter are high and exceed their air quality (monitoring) standards every year. The majority of the high PM_{10} and $PM_{2.5}$ levels were due to the effects of drought including due to dust storms, and smoke from bushfires and controlled burns (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*,). In particular, very high concentrations of PM_{10} and $PM_{2.5}$ were experienced in the last months of 2019 due to bushfires in the Lower Hunter Valley. Emissions from industry and road vehicles in the Newcastle and Lower Hunter regions also contribute to these high levels.

1.3 Performance outcome

The desired performance outcome for the Proposal relating to air quality is to minimise air quality impacts to reduce risks to human health and the environment to the greatest extent practicable through the design, construction and operation of the Proposal.

1.4 Secretary's Environmental Assessment Requirements (SEARs)

An Environmental Impact Statement (EIS) for the Proposal has been prepared under Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). This Air Quality Impact Assessment has been prepared to support the EIS. The purpose of this report is to address the relevant sections of the Secretary's Environmental Assessment Requirements (SEARs) issued on 5 February 2021 (SSI 12590060). The report preparation has also taken cognisance of any applicable agency comments. Table 1.1 outlines the SEARs relevant to this assessment.

Table 1.1: SEARs relevant to this assessment

Secretary's requirement
Air quality – including an assessment of likely air quality impacts of the project in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2016), including an assessment of scenarios where the project operates on diesel fuel
Air quality – including ability to comply with the relevant regulatory framework, specifically the *Protection of the Environment Operations Act 1997* and the *Protection of the Environment Operations (Clean Air) Regulation 2010*

1.5 Report structure

The report is structured by the sections listed in the following points:

- Section 1, Introduction – introduces the Proposal with a summary of the Proposal background, Proposal description, performance outcomes, and SEARs
- Section 2, Proposed Gas Turbine Power Station – sets out the predicted Proposal air emissions inventory, and selection of air pollutants for air quality impact assessment
- Section 3, Ambient Air Quality Standards – sets out the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) impact assessment criteria for the air pollutants identified in Section 2
- Section 4, Existing Environment – describes of key features of the existing environment including surrounding land uses, sensitive receptors, local meteorology, and existing air quality. The section sets out the results of a new review of background levels of hydrocarbons identified for this assessment
- Section 5, Assessment Methodology – overview of the methods used to assess the potential for air quality impacts due to the Proposal, based on modelling
- Section 6, Results – sets out the model results for 9600 grid receptors and 16 discrete receptors in accordance with the requirements of NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016)
- Section 7, Conclusion – provides a concise conclusion of the results of the assessment.

2. Proposed Gas Turbine Power Station

2.1 Overview

The Proposal Site is located in Loxford (as shown by the star symbol in Figure 2-1), which is approximately three km north of the township of Kurri Kurri, and approximately 14 km west of Beresfield and Thornton (see vector shown in Figure 2-1). Relatively shallow terrain exists across most of the local area, shown by the relief shading in the image.

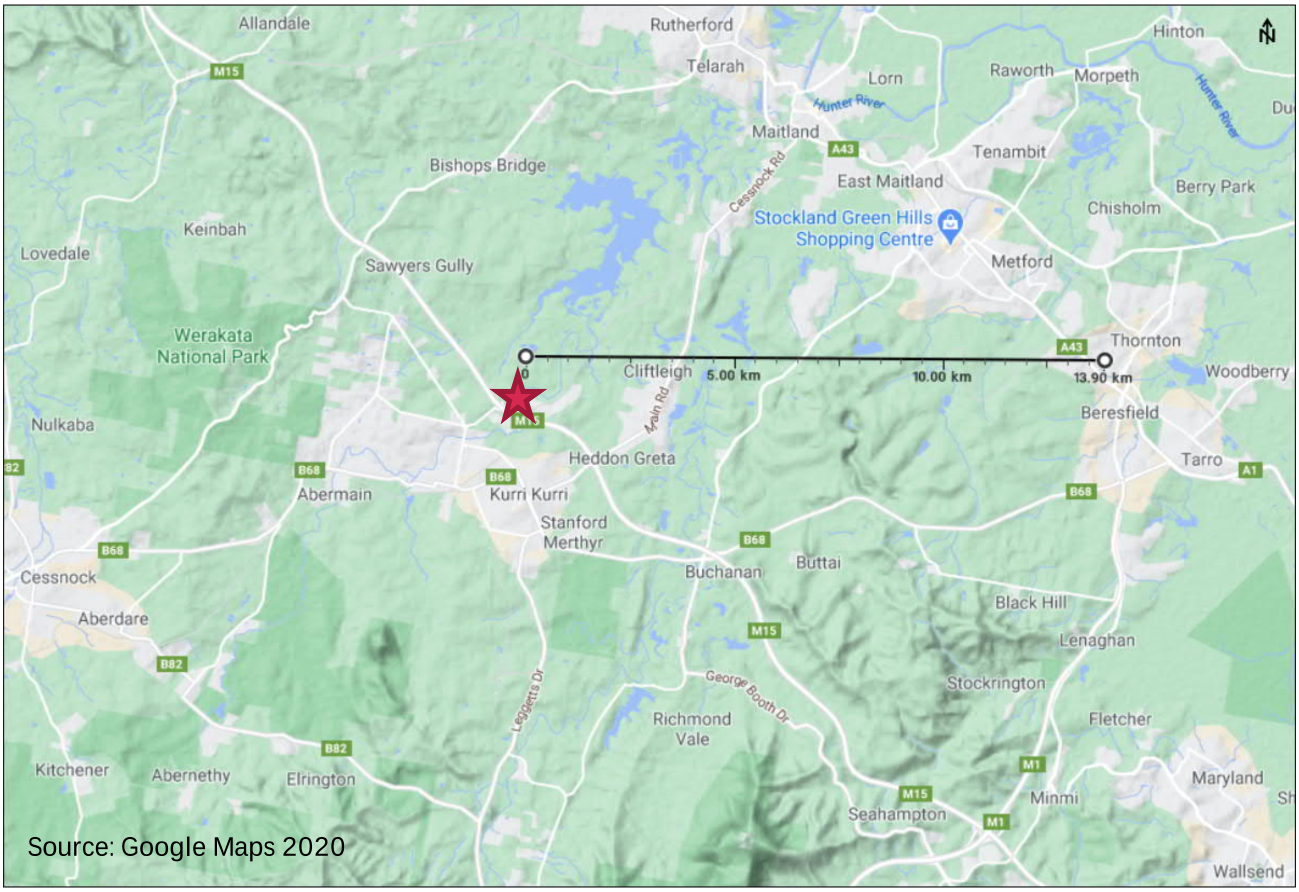


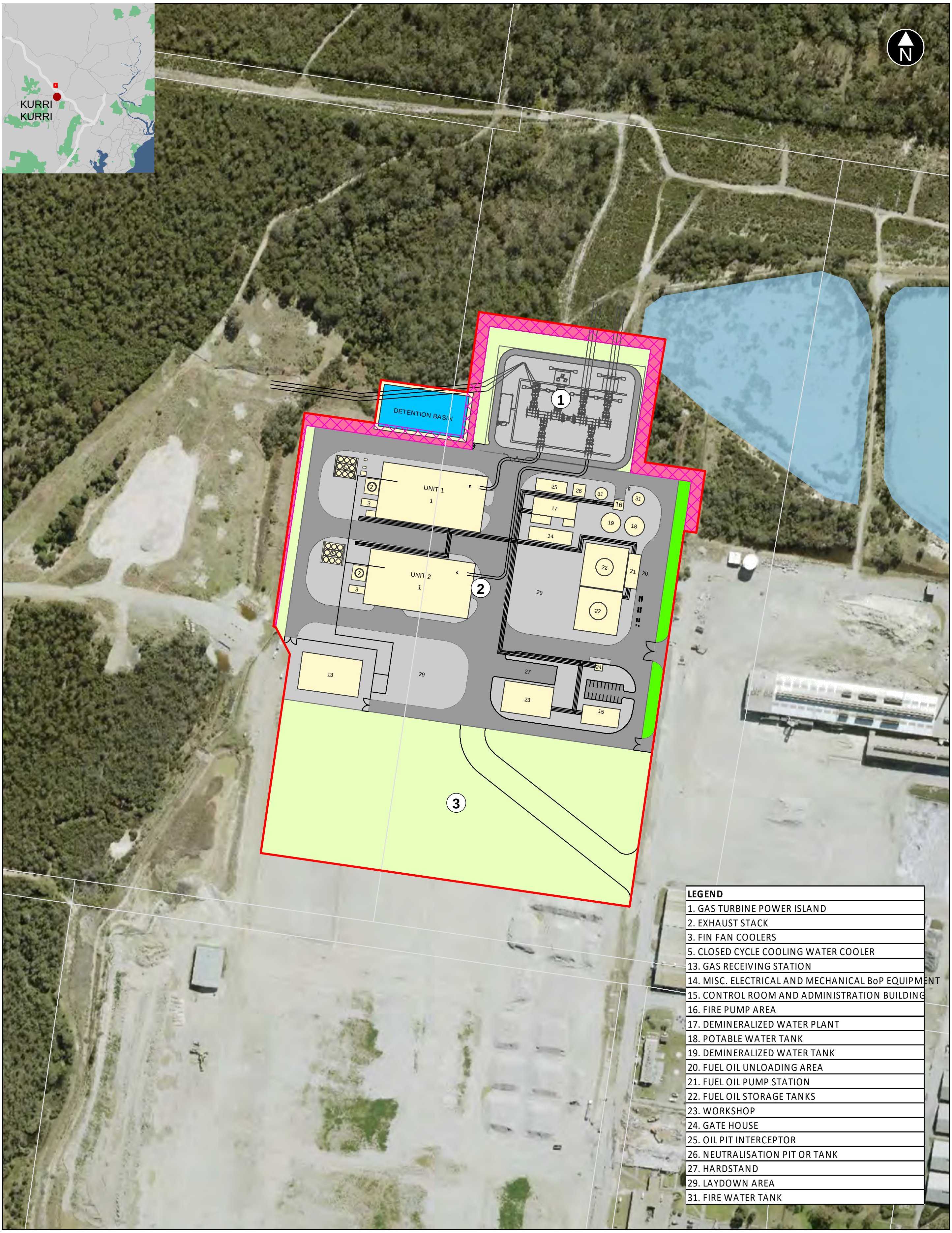
Figure 2-1: Regional Setting of Proposal (star indicates approximate location of the Proposal Site)

The remaining sub-sections of this section describe the Proposal including the Proposal air emissions estimates used for assessment by dispersion modelling, and explains the selection of pollutants for assessment.

2.2 Proposal site layout

A conceptual layout of the Proposal Site showing the indicative locations of the two OCGT stacks is provided in Figure 2-2. Additional details are provided in Appendix A.

The Proposal Site forms part of the former Hydro Aluminium Kurri Kurri Pty Ltd aluminium smelter site, which operated from 1969 to 2012, before closing in 2014. Figure 2-3 shows a historical aerial view of the aluminium smelter (M. Pickett, 6 March 2005). Since the closure of the aluminium smelter, extensive remediation works were undertaken including demolition of existing structures, asbestos removal and recycling of waste materials (Jacobs, 2020).



Proposal Site
Asset protection zone
Detention basin
Sealed roadway
Crushed rock
Landscaping
Grass / Road base
Existing waterbodies
Existing cadastre
1 Proposed Switchyard Area
2 Proposed Plant Area
3 Proposed Buffer Area

0 100 200 m

1:4,000 at A4
GDA2020 MGA Zone 56

Data sources:
Jacobs
Metromap (Aerometrex) 2020
NSW Spatial Services

Figure 2-2 Proposal Site Layout

snowy hydro renewable energy Jacobs

Figure 2-3: Aerial View of Aluminium Smelter prior to demolition to North-East (M. Pickett; 6 March 2005)

2.3 Site activity

2.3.1 Overview

The proposed gas turbine technology for the Proposal is two industrial frame heavy duty F-Class units in OCGT configuration. The nominal electrical output of the gas turbines is up to approximately 750 MW, depending on the eventual gas turbine selected. Key Proposal parameters include:

- The Proposal will be developed as two OCGT units with operations expected to commence by approximately August 2023 for the first unit, potentially on diesel fuel initially, with dual fuel and both units operational by December 2023
- Primarily the gas turbines will be fuelled by natural gas with the use of diesel fuel as a back-up (see Glossary for definitions for diesel and distillate).

2.3.2 Open cycle gas turbine operation

Open Cycle Gas Turbine operations generate electricity through the combustion of natural gas and/or diesel (or liquid distillate fuel) within a gas turbine. Gas turbines comprise a compressor, combustion chamber, turbine and electricity generator. Air is compressed to a high pressure before being admitted into the combustion chamber. Natural gas or diesel fuel is then injected into the combustion chamber where combustion occurs at high temperatures and the gases expand. The resulting mixture of pressurised hot gas is admitted to a turbine where aerodynamic blades cause a rotor to turn thus generating mechanical power, and subsequently, electrical power via the generator. In the open cycle configuration hot exhaust gases are vented directly to atmosphere through an exhaust stack. A schematic diagram of the process is provided in Figure 2-4 (Jacobs, 2020).

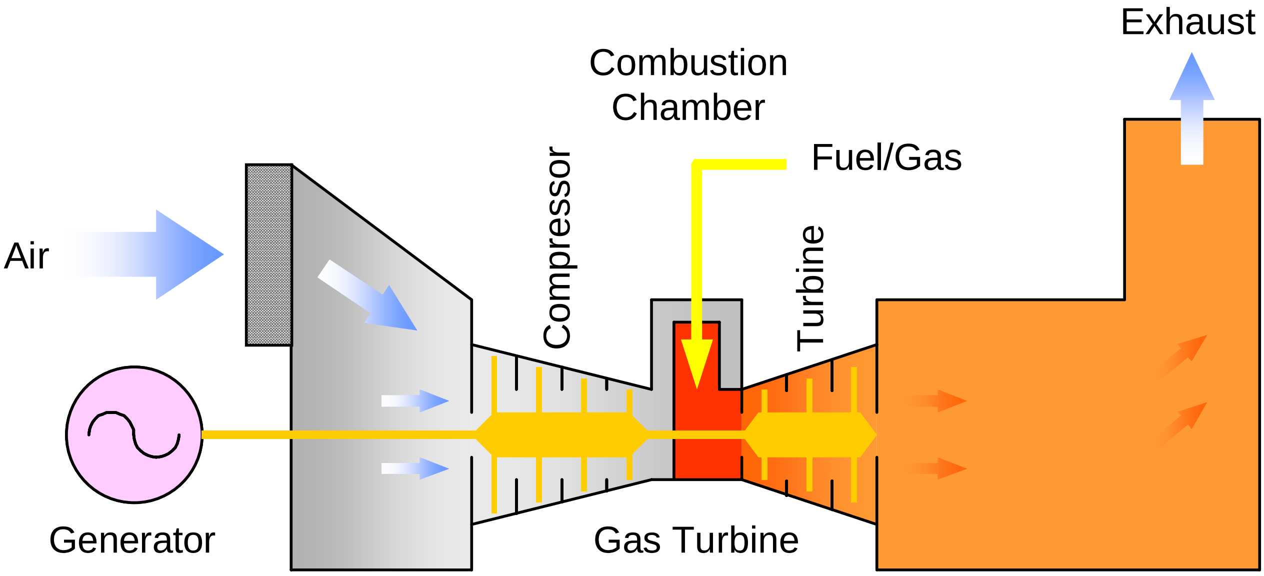


Figure 2-4: Schematic of Simple (or Open) Cycle Gas Turbine

2.3.3 Best practice technology

Snowy Hydro has considered the technologies available for controlling emissions from gas turbine plants of the size proposed in this Proposal. The best available and appropriate control technology for these units is to utilise Dry Low Emissions (DLE) burners on the gas turbines for use when firing natural gas fuel and using Water Injection (WI) control technology in the gas turbine burners when firing diesel fuel.

Post combustion technologies such as Selective Catalytic Reduction (SCR) have been installed on some combined cycle gas turbine plants, diesel power stations and even on certain open cycle gas turbine power stations. Coupling a F Class gas turbine in open cycle configuration with a SCR system is seen to be technically possible however presents some engineering, safety and commercial risks that would require very specific and detailed design and careful selection of materials mainly as a result of the high gas exhaust temperatures seen in F Class gas turbines. There is very limited successful operational experience using SCR technology with F Class open cycle gas turbines and commercially it is not considered feasible. The Proposal is already implementing the use of DLE burners which is considered a best practice approach and this technology would be able to comply with the emission requirements for the Proposal.

An overview of other control technologies (SCR, SNCR, $SCONO_X^{TM}$) is provided, however, are typically not technically and commercially practical for OCGT-plants for some of the below reasons. Similar conclusions were also drawn by the Proponents for the Newcastle Power Station EIS (AGL, 2019 Appendix C, April 2019) and the Tallawarra Stage B Gas Turbine Power Station Modification Environmental Assessment report (EnergyAustralia, June 2020).

Selective Catalytic Reduction (SCR)

- The technique is based on the reduction of NOx to nitrogen in a catalytic bed by reaction with ammonia (in a general aqueous solution). This is a post combustion control treatment.
- A SCR process requires additional land for the site and would produce additional noise and use of consumables
- The high velocity of the exhaust in an open cycle gas turbine is a significant technical difficulty for the removal of contaminants, compared to gas turbines in combined cycle configuration where the exhaust velocity and temperatures are reduced significantly

- The optimum operating temperature for SCR is 300-450°C. This is not suitable for the large industrial open cycle gas turbines proposed for this project as the exhaust temperature is well above this (typically 600°C-650°C).
- There are additional health and safety risks for storage, handling and emissions of ammonia and additional emissions of particulate matter (GER 4172 "Gas Turbine NOx Emissions Approaching Zero – Is it Worth the Price?")
- This technique may be costly in the case of plants operated between 500 h/yr and 1500 h/yr and even more so for plants operated <500 h/yr (European Commission, 2017). Considering this Proposal is expected to operate in the vicinity of 350 hours per year, which is below the lower threshold as indicated in the European Commission (2017), the commercial suitability for this technology reduces further.
- There is limited commercial experience of SCR on large frame OCGTs internationally and no experience of SCR on OCGTs in the Australian national electricity market.

Selective Non-catalytic reduction (SNCR)

- The technique is based on the reduction of NO_X to nitrogen by reaction with ammonia or urea at a high temperature, without the need of a catalyst. This is a post combustion control treatment
- The required operating temperature window is between 800°C and 1000°C for optimal reaction. This is not suitable for the OCGT proposed for this Project as the exhaust temperature is well below this (typically 600-650°C).
- This technology is not recommended by the European Commission (2017) for OCGTs
- No commercial experience of this technology on gas turbine installations in Australia or internationally

SCONOx™

- Use of a single catalyst that operates by simultaneously oxidising CO to CO_2, NO to NO_2, and then absorbing NO_2 onto its surface through the use of a potassium carbonate absorber coating. This technique does not require ammonia injection.
- The optimum operating temperature for SCONOx™ is 150-370°C. This is again not suitable for the open cycle gas turbines proposed for this Project as the exhaust temperature is well above this (typical 600-650°C).
- Performance is highly sensitive to even small amounts of sulphur in the gas fuel
- This technology is not recommended by the European Commission (2017) for OCGTs
- No commercial experience of this technology in gas turbines over 100MW globally

It's noted that all industrial frame open cycle gas fired power stations in Australia use Dry Low NOx when gas-fired and water injection when diesel fired, in the same manner as proposed for this Proposal.

2.3.4 Proposed operations and scenarios

The main operating parameters for the Proposal considered relevant for the air quality assessment are listed in Table 2.1.

Table 2.1: Proposal – Main Operating Parameters

Parameter	Value / Details	Comments
Plant Type	Open Cycle	-
Gas Turbine class	F Class industrial	Cold end drive, static starter
Number of gas turbines	Two	
Targeted Net Plant Capacity	Up to approximately 750 MW	Ambient conditions 15°C, 60% Relative Humidity (natural gas fuel)
Plant Operation	Peaking	ISO standard peak load rating to apply as per ISO 3977-2

Parameter	Value / Details	Comments
Facility load	Indicative minimum load 50% to maximum load (100%)	Indicative minimum load of 50% defined as a lower gas turbine load where reliable and safe operation occurs while still satisfying the required air emissions and noise limits for the plant. This will be dependent on the eventual gas turbine selected for the Proposal.
Capacity factor	Capacity factor being sought for approval: 10% on natural gas (approximately 1,051 hours per year); and 2% on diesel (approximately 175 hours per year) Total combined for Proposal: 12%	Normal operations will be fuelled by natural gas with diesel as backup fuel The Capacity Factors adopted assume 100% load operation. It is expected that likely operation of the Proposal would result in a total Capacity Factor of two per cent in any given year and some of this time at reduced load. Modelling of continuous emissions from the Proposal was undertaken to test every hour of an annual meteorological simulation.
Maximum likely diesel-fuelled operations	10 hours/day if required	At full load. Actual operation is expected to be less.
Emissions control	Yes	Dry-Low-Emission combustors on natural gas, water injection on diesel
Emergency diesel generator	Yes	
Design plant life	30 years	Minimum design life for Mechanical and Electrical components[1].
Cold start to full Load duration	Approximately 30 minutes	The NSW *Protection of the Environment Operations (Clean Air) Regulation* excludes concentration standards for start-up and shut-down periods (paragraph 56).

2.4 Gas Turbine air emissions

2.4.1 NO_x, CO and PM_{10}

The gas turbine (GT) technology option being considered for the Proposal will meet, and sometimes do better than, the NSW air emission limits when operating at maximum load (100 per cent), and indicative minimum load of 50 per cent, and between those loads. The GTs will be fitted with Dry Low Emissions combustors which result in low NO_x emissions (within the limits) when firing on natural gas. When operating on diesel fuel, the GTs will use water injection to assist with control of emissions of oxides of nitrogen (NO_x).

The Proposal GTs operating at maximum, stable operating load will meet the air emissions limits listed in Table 2.2. Note some of these are common technology limits used in industry and are better (lower) than NSW Government air emissions limits specified in the NSW *Protection of the Environment Operations (Clean Air) Regulation 2010*; see also Section 3.3.

[1] Note, civil and structural components will be designed for a 50 year life.

Table 2.2: Proposal – Air Emissions modelling inputs and regulatory limits

Substance and parameter	Proposal modelling inputs	Regulatory Limits*	Comments
Natural gas fuel			
Oxides of nitrogen (NO_x) 1-hour average	51 mg/Nm³ (25 ppm)	70 mg/Nm³ (34 ppm)	Dry Low Emissions (DLE). Subject to a minimum load (typically 50-55%). NO_x expressed as nitrogen dioxide (NO_2) based on 15% O_2, dry condition, temperature 0 °C and standard air pressure 1013 hPa.
Carbon monoxide (CO) 1-hour average	12.5 mg/Nm³ (10 ppm)	N/A	The *Protection of the Environment Operations (Clean Air) Regulation 2010* prescribes no limits for CO for GTs. 15% O_2, dry condition, temperature 0 °C and standard air pressure 1013 hPa.
Particulate Matter 10 (PM_{10})	5 mg/Nm³	N/A	
Diesel fuel			
NO_x, 1-hour average	86 mg/Nm³ (42 ppm)	90 mg/Nm³ (44 ppm)	Water-injected for NO_x management. NO_x expressed as nitrogen dioxide (NO_2) based on 15% O_2, dry condition, temperature 0 °C and standard air pressure 1013 hPa.
CO, 1-hour average	63 mg/Nm³ (50 ppm)	N/A	The *Protection of the Environment Operations (Clean Air) Regulation 2010* prescribes no limits for CO for GTs. 15% O_2, dry condition, temperature 0 °C and standard air pressure 1013 hPa.
Particulate Matter 10 (PM_{10})	10 mg/Nm³	50 mg/Nm³ (Total Particles)	

*NSW Government, *Protection of the Environment Operations (Clean Air) Regulation 2010*,.

2.4.2 NO_x emissions control by DLE

Gas turbine Dry Low Emission technology burns the majority of fuel at (relatively) cool, lean conditions to minimise NO_x production. The fuel-air mixture is pre-mixed before entering the combustion chamber, and the lean mixture lowers flame temperature and reduces NO_x emission (Boyce, 2012). This approach lowers the NO_x emissions from the GT without the need for water-injection or steam-injection when operating on natural gas. The use of DLE technology allows NO_x concentrations to be lowered to 25 ppm, as confirmed with the equipment manufacturers which might be selected for the Proposal.

2.4.3 Natural gas and diesel fuel sulphur content

Estimates for the sulphur contents of the natural gas and diesel fuels to be used by the Proposal were required for calculating exhaust emissions of sulphur dioxide (SO_2) by the GTs. As a conservative step in the assessment, the natural gas sulphur content adopted for this assessment was 50 mg/m³, which is the maximum total sulphur allowed in typical natural gas as specified in the Australian Standard *AS 4564:2011 – Specification for general purpose natural gas* and also as referenced in the Australian Energy Market Operator (AEMO) Gas Quality Guidelines. The actual sulphur content in typical natural gas used by Proposal is expected to be significantly less than this.

The sulphur limit for diesel fuel used by Proposal will be below 10 mg/kg, which is the maximum allowed for Automotive Diesel.

It is noted the *Protection of the Environment Operations (Clean Air) Regulation 2010* sulphur limit is much higher, 25 g/kg, for an in-stack emission limit applicable for outside the Newcastle Metropolitan Area. (The Proposal Site in Loxford is outside the Newcastle Metropolitan Area). However, such a high sulphur-content fuel is unlikely to be delivered to Australia in the future.

2.5 Air emissions inventory

This section outlines the air emissions inventory adopted for the assessment, based upon a review of the potential GT technology options for the Proposal. The air emissions parameters used as input parameters to the dispersion model, Calpuff, are detailed in Section 5 describing the assessment methodology.

Estimates for all the main air-release parameters for the Proposal OCGT stacks (such as exhaust temperature, exit velocity, stack dimensions, and air emissions concentrations and rates) are listed in Table 2.3. The gas turbine related input parameters were sourced from the OEMs that might be selected as gas turbine suppliers for the Proposal. The parameters that would result in the representative "worst case" air quality impacts from the potential F-class units were used in the modelling for the air quality impact assessment (Table 2.3). Consequently, each of the OEMs equipment that could be selected for the Proposal would have impacts equal to or better than those predicted in this assessment. Specific OEMs have not been identified with the respective data due to commercial confidentiality. Annual NO_x emissions can be of interest for a gas turbine proposal because of the potential to contribute to regional ozone formation. This regional ozone is created in the presence of sunlight and background air pollutants by the air emissions from many sources. Assuming a capacity factor of up to 10 per cent of each year on natural gas fuel and two per cent on diesel fuel, the annual NO_x emission is calculated to be 139 tonnes per annum.

Table 2.3: Proposal Air Emissions Parameters

Parameter	Units	Gas Fuel	Diesel Fuel	Comment
Gas Turbine Exhaust Stack				
Easting, GDA2020	m	Unit 1: 357,520 Unit 2: 357,510		Geocentric Datum of Australia 2020
Northing, GDA2020	m	Unit 1: 6,371,471 Unit 2: 6,371,402		Geocentric Datum of Australia 2020
Height above ground level of the top of the stack	m	36	36	
Estimated stack tip diameter	m	9.8	9.8	
Base elevation	m AHD	13	13	Estimated ground level at the exhaust stacks within the Proposal Site (metres above Australian Height Datum)

Parameter	Units	Gas Fuel	Diesel Fuel	Comment
Estimated Exhaust Gas Composition				
Oxygen (O_2)	wt%	12.75	13.86	Source: Approximate exhaust gas composition based on data received from potential OEM – 15°C @ 60% RH
Carbon Dioxide (CO_2)	wt%	6.89	7.61	
Water (H_2O)	wt%	5.99	5.33	
Nitrogen (N_2)	wt%	73.06	71.90	
Argon (Ar)	wt%	1.31	1.29	
Total	wt%	100.00	99.99	
GT Load	%	100	100	
Exhaust flow rate	m^3/s	1,884.5	1,666.6	Source: Approximate flow rate based on data received from potential OEM – 15°C @ 60% RH
Exhaust Temperature	°C	634.8	523.6	Source: Approximate temperature based on data received from potential OEM – 15°C @ 60% RH
Exhaust Velocity	m/s	25	22.1	Source: Approximate velocity based on assumed diameter and data received from potential OEM – 15°C @ 60% RH
Nitrogen Oxides (NO_x)	ppm	25	42	Maximum estimate from review of OEM data
	g/s	34.0	49.4	Calculated based on dry flue gas at actual O_2% (i.e. <15% O_2)
Carbon Monoxide (CO)	ppm	10	50	Source: Combination of OEM data
	g/s	8.3	35.8	Calculated based on dry flue gas at actual O_2% (i.e. <15% O_2)
Sulphur Dioxides (SO_x)	ppmvd	1.7 (dry, 0°C)	0.25 (dry, 0°C)	Fuel specifications used: natural gas sulphur max. 50 mg/Sm^3 and diesel sulphur max. 10 mg/kg (temps. 15°C and 60% relative humidity).
	g/s	2.61	0.36	For NG fuel use the SO_2 emission rate was calculated using the sulphur limit (above), gas density (0.7417 kg/Sm^3), and gas fuel consumption rate 19.38 kg/s. For diesel fuel use the SO_2 emission rate was calculated using the sulphur limit (above), distillate density (845 kg/Sm^3), and fuel consumption rate 18.05 kg/s.
Particulate Matter (PM_{10})	mg/Nm^3	5.0	10	Maximum estimate from review of OEM data
	g/s	3.3	5.7	Calculated based on dry flue gas at actual O_2% i.e. <15% O_2
GT Load	%	50	50	
Exhaust flow rate	m^3/s	1,298.9	1,223.0	Source: Approximate flow rate based on data received from potential OEM – 15°C @ 60% RH
Exhaust Temperature	°C	673.6	591.4	Source: Approximate temperature based on data received from potential OEM – 15°C @ 60% RH

Parameter	Units	Gas Fuel	Diesel Fuel	Comment
Exhaust Velocity	m/s	17.2	16.2	Source: Approximate velocity calculated based on assumed diameter and data received from potential OEM – 15°C @ 60% RH
Nitrogen Oxides (NO_x)	ppm	25	42	Maximum estimate from review of dataOEM data
	g/s	20.5	33.4	Calculated based on dry flue gas at actual O_2% i.e. <15% O_2
Carbon Monoxide (CO)	ppm	10	50	Source: Combination of OEM data
	g/s	5.0	24.2	Calculated based on dry flue gas at actual O_2% i.e. <15% O_2
Sulphur Dioxides (SO_x)	ppmvd	1.6	0.24	Limit as described in typical fuel specifications Gas Fuel: Sulphur max = 50 mg/m^3 Diesel Fuel: Sulphur max = 10 mg/kg
	g/s	1.61	0.25	
Particulate Matter (PM_{10})	mg/Nm^3	5.0	10	Maximum estimate from review of OEM data
	g/s	1.9	3.7	Calculated based on dry flue gas at actual O_2% i.e. <15% O_2

2.6 Construction activity

Construction of the Proposal will include temporary, localised air quality effects due to some dust emissions from construction activities and some engine exhaust emissions from construction vehicles and machinery. The engine exhaust emissions will be insignificant; comparable to public vehicle use on nearby roads and highways. For the control of dust (and potentially odour) emissions from the Proposal Site, management measures will be implemented and maintained throughout the construction phase as detailed in a Construction Environment Management Plan (CEMP).

Specifically, dust emissions are expected from the following construction activities:

- Vegetation clearing within the switchyard area
- Earthworks including site preparation and excavations
- Movement of spoil and fill around the Proposal Site
- Ground disturbance by movement of construction vehicles and heavy plant and machinery
- Concreting work
- Establishment of site landscaping.

A CEMP will detail the air emissions management measures commonly used to suppress dust (and potentially odour) to minimise air quality impacts. These measures will include preparation and implementation of a Soil and Water Management Plan, an Erosion and Sediment Control Plan, and dust suppression techniques such as progressive rehabilitation of disturbed ground and water sprays. In the event of air quality impacts being identified during construction, the CEMP is expected to rule that construction activities will be ceased until emissions are controlled.

Also, the CEMP will detail the air emissions management measures to minimise air emissions from vehicle and machinery engine exhaust emissions. Such measures will include, for example, requiring all construction vehicles, plant and machinery to be used on-site to be properly maintained including service records, and pre-start checklists completed.

In conclusion, air quality impacts due to construction of the Proposal are expected to be insignificant and temporary. Commonly used dust and odour control measures will be used to minimise air pollutant emissions. The construction site has good separation from sensitive receptors such as residences.

3. Air quality standards

3.1 Overview

The purpose of this section is to set out the NSW emissions limits and ambient air quality assessment criteria relevant to the Proposal. New national ambient air quality monitoring standards are also listed which may have a bearing on NSW emissions limits and assessment criteria in the future.

3.2 NSW Protection of the Environment Operations Act 1997

The NSW POEO Act 1997 is the primary piece of legislation for the regulation of potential pollution impacts associated with 'scheduled activities' in NSW. Scheduled activities are those defined in Schedule 1 of the Act. Clause 17 (Electricity generation) of the Act applies to electricity plant that uses a gas turbine and is situated in the metropolitan area or LGA of Port Stephens, Maitland, Cessnock, Singleton, Wollondilly or Kiama. The Proposal is located within the Cessnock LGA and so this schedule applies to the Proposal.

The Proposal is a scheduled activity because, as a metropolitan electricity works (gas turbines), it will burn more than 20 MegaJoule (MJ) of fuel per second. This means a licence is required for the premises (the activity is premises-based).

In relation to standards of air impurities not to be exceeded (Clause 128), air emissions at any point must be within concentrations prescribed by the regulations. The next sub-section sets out these concentrations relevant for the assessment.

3.3 NSW Protection of the Environment Operations (Clean Air) Regulation 2010

3.3.1 Air emissions limits

The NSW *Protection of the Environment Operations (Clean Air) Regulation 2010*, contains provisions for the regulation of emissions to air. The air emissions limits relevant for the Proposal are the 'Group 6 Standard' for scheduled premises; they are listed in Table 3.1. (Comparisons with the Proposal data were provided in Table 2.2).

Table 3.1: NSW Group 6 Standard for scheduled premises: air emissions limits for electricity generation

Substance	Natural Gas	Diesel
Solid Particles (Total)	--	50 mg/m^3
Nitrogen dioxide (NO_2)	70 mg/m^3	90 mg/m^3
Reference conditions	Dry, 273 K (0 °C), 1013 hPa	
Smoke	--	Ringelman 1 or 20% opacity; or, Ringelman 3 or 60% opacity

3.3.2 Fuel sulphur content

The Proposal is located within the Cessnock LGA; the relevant *Protection of the Environment Operations (Clean Air) Regulation 2010* fuel sulphur content limit is 2.5 per cent by weight (2.5 g/kg). This is substantially higher than the sulphur content expected for the fuels to be used by Proposal; see Section 2.4.3.

3.3.3 Exemptions

Exemptions to the *Protection of the Environment Operations (Clean Air) Regulation 2010* concentration standards include start-up and shutdown periods (paragraph 56), however practicable means must still be used to prevent and minimise air pollution.

3.4 NSW ambient air quality impact assessment criteria

This section sets out the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) ambient air quality assessment criteria relevant to the assessment; i.e., the air pollutants identified for assessment in Section 1.1. The criteria are listed in Table 3.2.

Table 3.2: NSW EPA air quality impact assessment criteria

Substance	Statistic	Concentration
Main air pollutants – from EPA (2016) Table 7.1, impact assessment criteria, inclusive of background levels		
Sulphur dioxide (SO_2)	Maximum 10-minute average	712 µg/m^3
	Maximum 1-hour average	570 µg/m^3
	Maximum 24-hour average	228 µg/m^3
	Maximum annual average	60 µg/m^3
Nitrogen dioxide (NO_2)	Maximum 1-hour average	246 µg/m^3
	Maximum 24-hour average	62 µg/m^3
Photochemical oxidants (as ozone; O_3)	Maximum 1-hour average	214 µg/m^3
	Maximum 4-hour average	171 µg/m^3
Particulate Matter as $PM_{2.5}$	Maximum 24-hour average	25 µg/m^3
	Maximum annual average	8 µg/m^3
Particulate Matter as PM_{10}	Maximum 24-hour average	50 µg/m^3
	Maximum annual average	25 µg/m^3
Carbon monoxide (CO)	Maximum 15-minute average	100 mg/m^3
	Maximum 1-hour average	30 mg/m^3
	Maximum 8-hour average	10 mg/m^3
Volatile Organic Compounds (VOCs) – from EPA (2016) Table 7.2a, principal toxic air pollutants, Proposal only contributions. Gas volumes expressed at 25°C and 1 atmosphere (101.325 kPa).		
Acrolein	99.9th percentile 1-hour average	0.42 µg/m^3
Formaldehyde	99.9th percentile 1-hour average	20 µg/m^3
Polycyclic Aromatic Hydrocarbons (PAH) as Benzo(a)Pyrene (B(a)P)	99.9th percentile 1-hour average	0.4 µg/m^3

3.5 National Environment Protection (Ambient Air Quality) Measure

The National Environment Protection Council (NEPC) produces National Environment Protection Measures (NEPMs). The national environment protection goals of the recently updated *National Environment Protection (Ambient Air Quality) Measure* (referred to in this report as 'the NEPM'), are to achieve the national environmental protection standards listed in Table 3.3 (NEPC, 2021a).

Table 3.3: National ambient air quality monitoring standards (2021)

Pollutant	Statistic	Maximum concentration standard
CO	Maximum 8-hour average (rolling 1hr. avg.)	9.0 ppm (11 mg/m^3 at 0^{o}C)
NO_2	Maximum 1-hour average	80 ppb (164 μg/m^3 at 0^{o}C)
	Annual average	15 ppb (31 μg/m^3 at 0^{o}C)
O_3	Maximum 8-hour average (rolling 1 hr. avg.)	65 ppb (139 μg/m^3 at 0^{o}C)
SO_2	Maximum 1-hour average	100 ppb (286 μg/m^3 at 0^{o}C)
	Annual average	20 ppb (57 μg/m^3 at 0^{o}C)
PM_{10}	Maximum 24-hour average	50 μg/m^3
	Annual average	25 μg/m^3
$PM_{2.5}$	Maximum 24-hour average	25 μg/m^3
	Annual average	8 μg/m^3

Additional tightening of standards for SO_2 and $PM_{2.5}$ applies from 1 January 2025 as listed in Table 3.4.

Table 3.4: National ambient air quality monitoring standards (from 2025)

Pollutant	Statistic	Maximum concentration standard
SO_2	Maximum 1-hour average	75 ppb (214 μg/m^3 at 0^{o}C)
$PM_{2.5}$	Maximum 24-hour average	20 μg/m^3
	Annual average	7 μg/m^3

It is noted the NEPM standards are not NSW impact assessment criteria – they are used by the participating jurisdictions to assess air quality in the regions using data acquired by performance monitoring stations. Also, from a Ministers notice about the changes (NEPC, 2021b):

"*…The Explanatory Statement clarifies this intent of the NEPM as a standard for reporting representative ambient air quality within an airshed, and not as a regulatory standard. The AAQ NEPM does not constrain a jurisdiction's ability to manage local or regional air quality issues.*"

However, air quality guidelines and policies developed by the states, in time, tend to align with the NEPM monitoring standards. As such these may have a bearing on NSW emissions limits and assessment criteria in the future.

4. Existing environment

4.1 Local setting

The Proposal Site is located at the former Kurri Kurri aluminium smelter site, which ceased operation in late 2012 and was permanently closed in 2014, and is now in the process of being demolished. The Proposal Site is approximately three km north of the township of Kurri Kurri, and approximately 15 km west of Beresfield (see Figure 2-1). The Proposal Site is bordered by forested areas to the north and west and small urban areas, each approximately three km away to the east and south: Cliftleigh to the east, and Heddon Greta to the south-east, the northern parts of Kurri Kurri south, and Weston south-west. There are a number of isolated residences within a 2.5 km radius of the Proposal Site, primarily in the southern half.

The terrain in the immediate vicinity of the Proposal Site is relatively flat, following the Swamp Creek river valley to the north-east towards Maitland. There are some hilly areas to the north-west and south-east. A 100 m high hill lies some 7.7 km south-southwest of the Proposal Site (see Figure 4-1). Figure 4-1 shows the location of the Proposal Site (yellow cross), terrain elevation contours (green, yellow and orange) and sensitive receptor locations identified for assessment (numbered green squares).

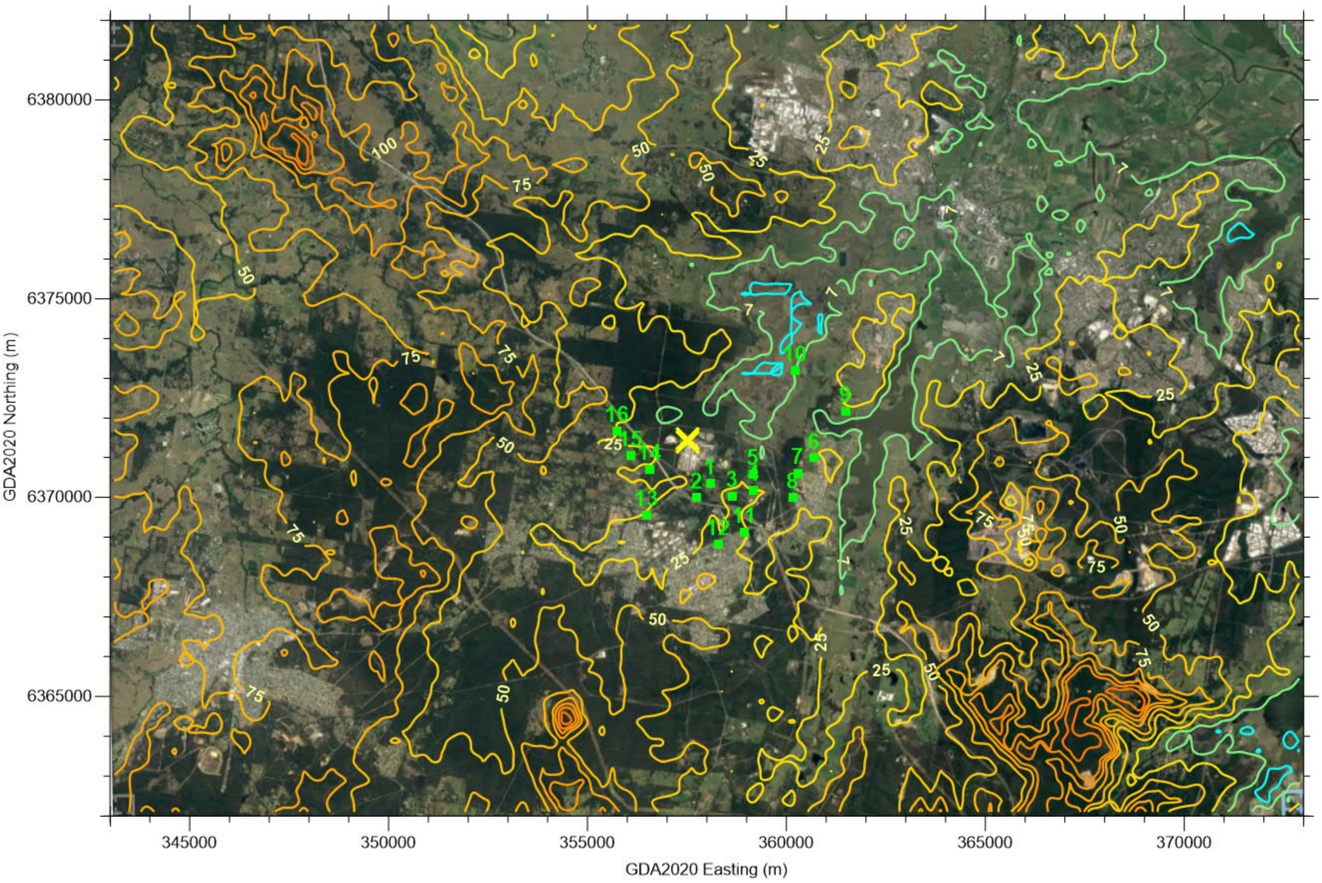


Figure 4-1: Air quality study area with terrain elevation contours and sensitive receptors

The 'base map' constructed for this assessment (Figure 4-1) is aligned north-south, with Geocentric Datum of Australia 2020 (GDA2020) northings (metres) labelled on the vertical axis, and eastings (metres) on the horizontal axis. Practically for this assessment there are no differences between GDA2020 and preceding GDA94 co-ordinate locations, which are only approximately 1-2 m apart in this study area. More details about the air quality study area are provided in Section 5.

4.2 Sensitive receptors

A sensitive receptor is where people are likely to work or reside and therefore have the potential to experience an air quality impact – the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) definition for a 'sensitive receptor' is provided in the Glossary. Potentially sensitive receptor locations, mainly isolated residences, were identified for use in this assessment using satellite imagery and are shown in Table 4.1 and Figure 4-1). These sensitive receptors were considered to be representative of locations potentially experiencing worst-case air quality impacts due to the Proposal because they were nearest to the proposed plant.

Table 4.1: Sensitive receptor locations (indicative) identified for assessment

No.	Easting (m)	Northing (m)	Description
1	358086	6370341	Residence
2	357748	6369983	Residence
3	358636	6370028	Residence
4	359178	6370182	School; TAFE NSW – Kurri Kurri
5	359161	6370579	Farmhouse; Bowditch Ave.
6	360689	6370984	Residence
7	360286	6370603	Residence
8	360157	6369986	Residence
9	361486	6372171	Residence
10	360220	6373188	Farmhouse
11	358945	6369119	Residence
12	358289	6368815	School; Kurri Kurri High School
13	356482	6369542	Residence; Amarillo
14	356566	6370702	Residence; Bishops Bridge Road
15	356089	6371047	Residence
16	355748	6371678	Residence

4.3 Local meteorology

Meteorological conditions are important for determining the direction and rate at which emissions from a source disperse. Key meteorological requirements of air dispersion models are, typically, hourly records of wind speed, wind direction, temperature and atmospheric stability. For air quality assessments, a minimum of one year of hourly data is usually required, which means that almost all possible meteorological conditions, including seasonal variations, are considered in the model simulations.

NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) prescribes the minimum requirements for meteorological data that are to be used in dispersion modelling. At least one year of 'site-specific' data should be used. If 'site-specific' data are not available then 'site-representative' data, correlated against at least five years of data, are acceptable. The meteorological data must also be at least 90 per cent complete. For this Proposal, meteorological data collected from the Department of Planning, Industry and Environment (DPIE) Beresfield air quality monitoring station were analysed in order to identify a representative year for this assessment (*Current and Forecast Air Quality* (NSW DPIE, 2021); see also Section 4.4.1. The process for identifying a representative meteorological year involved comparing hourly wind data and wind patterns over the 5-year period 2015 to 2019. The range of statistics from the data collected at

DPIE Beresfield from 2015 to 2019 are listed in Table 4.2. These data show that the wind speed statistics do not vary significantly from year to year.

Table 4.2: Annual statistics from DPIE Beresfield meteorological data 2015-2019

Statistic	2015	2016	2017	2018	2019
Fraction complete (%)	99	98	85	100	99
Mean wind speed (m/s)	2.5	2.8	2.3	2.4	2.4
99^{th} percentile 1-hour average wind speed (m/s)	9.6	11.2	8.9	9.8	10.2
Fraction of calms (%)	4.0	4.2	4.0	4.9	4.7
Fraction of winds >6 m/s (%)	5.9	9.9	3.8	5.1	6.5

The annual wind patterns for each year from 2015 to 2019 are shown by the wind roses in Figure 4-2; created using hourly average wind speed and wind direction data from DPIE Beresfield. From inspection of these wind roses the most common winds in the area are from the west-northwest. This pattern of winds is common for the Lower Hunter Valley and reflects the influence of the northwest to southeast alignment of the Hunter Valley. It is clear that the wind patterns were similar in all five years. This suggests that wind patterns do not vary significantly from year to year, and potentially the data from any of the years presented could be used as a representative year for assessment purposes.

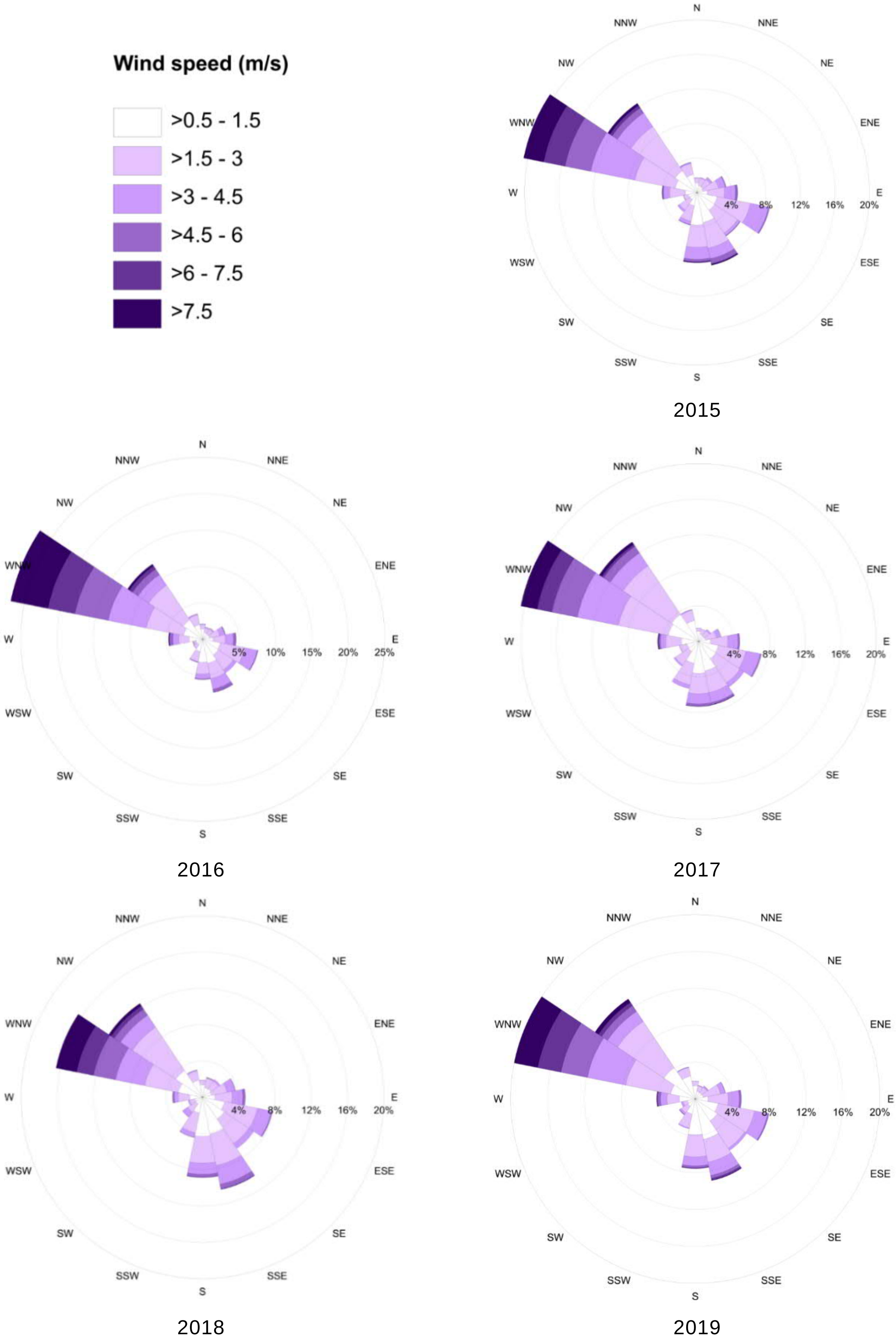


Figure 4-2: Annual wind roses: EPA Beresfield 2015-2019

4.4 Existing air quality

4.4.1 Overview

The DPIE established a network of monitoring stations across NSW to understand current air quality conditions and impacts, and to help identify programs to improve air quality (*Current and Forecast Air Quality* (NSW DPIE, 2021)). The nearest DPIE stations to the Proposal study area are illustrated in Figure 4-3 (from *Current and Forecast Air Quality* (NSW DPIE, 2021)); Beresfield is closest to Kurri Kurri. DPIE data from Beresfield were examined and compared with air quality (monitoring) standards to describe existing air quality conditions for key air pollutants relevant to this assessment.

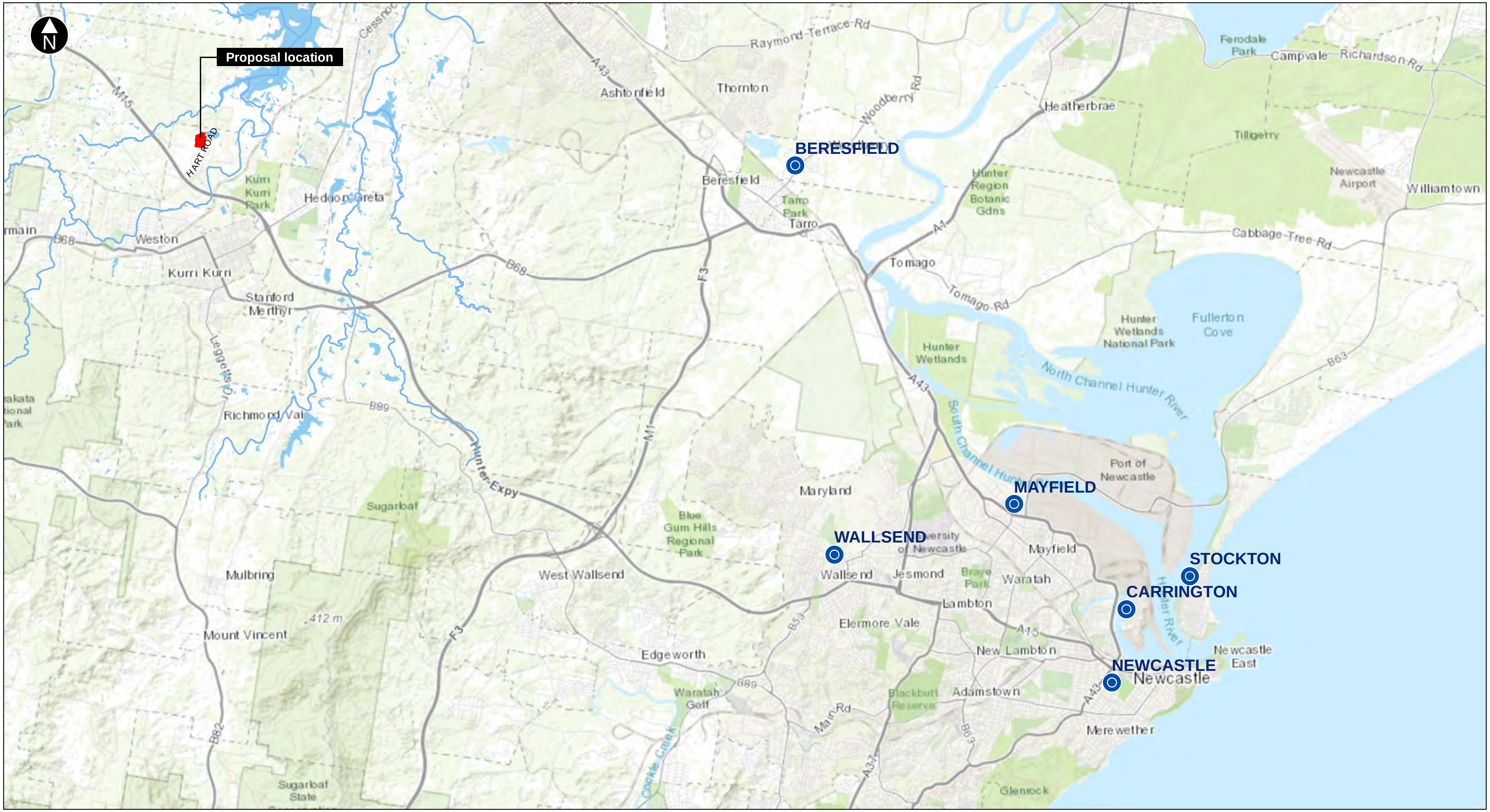
Parameters measured at DPIE Beresfield, Newcastle and Wallsend monitoring stations are listed in Table 4.3. Carbon monoxide (CO) is not measured at Beresfield, so the CO data used for this assessment were obtained from the next nearest station, Newcastle. It is noted Newcastle and Beresfield air quality monitoring data are affected more by emissions from road vehicles than the Kurri Kurri locality, so the selection of these data as representative of Kurri Kurri, is conservative (the concentrations at Newcastle and Beresfield are expected to be slightly higher than at Kurri Kurri).

Table 4.3: DPIE Beresfield, Newcastle and Wallsend air monitoring parameters

Air Monitoring Station	Distance and Direction	Measured Parameters
DPIE Beresfield	Approx. 17 km to east of Kurri Kurri	Meteorology, NO_2, O_3, SO_2, PM_{10}, $PM_{2.5}$
DPIE Newcastle	Approx. 27 km south-east of Kurri Kurri	Meteorology, NO_2, O_3, SO_2, PM_{10}, $PM_{2.5}$, CO
DPIE Wallsend	Approx. 21 km south-east of Kurri Kurri	Meteorology, NO_2, O_3, SO_2, PM_{10}, $PM_{2.5}$

Monitoring data completeness is important for assessment, with a 90 per cent capture rate preferred. DPIE data capture in the Lower Hunter has been excellent; capture rates for most national reporting parameters have been well in excess of 90 per cent since 2011 (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*). Over 2015-2019, only the hourly average data capture for CO in 2015 (Newcastle), was less than 90 per cent.

In this section, the units used for air pollutant concentrations were converted from volumetric units e.g. parts per billion (ppb), to mass units e.g. microgram per cubic metre ($\mu g/m^3$). The temperature used for the conversion was 25 degrees Celsius (25 ^oC), which is reflective of conditions in the Hunter Valley; e.g., mean minimum and maximum temperatures at Maitland are 12^oC and 25^oC.



- Proposal location
- Recreation areas
- Waterbodies
- DPIE air monitoring stations in Lower Hunter

0 5 10 km

1:150,000 at A4

Coordinate System: GDA2020 MGA Zone 56

Data sources:
Jacobs
NSW Spatial Services
DPIE (NSW Gov., 2021; 26 Jan., 2021)

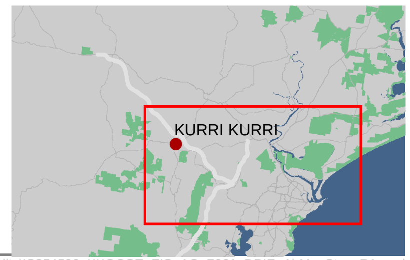


Figure 4-3 Map of DPIE air monitoring stations in Lower Hunter

4.4.2 Carbon monoxide

The nearest CO monitoring station to Kurri Kurri is DPIE Newcastle; a summary of CO concentrations from 2015 to 2019 is provided in Table 4.4. These results show that CO concentrations have been consistently below NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) impact assessment criteria. The trend in 8-hourly average CO has been slightly downwards since 2009 (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*,).

Table 4.4: Summary of measured CO concentrations: DPIE Newcastle (mg/m^3)

Statistic and criterion	2015	2016	2017	2018	2019
Max. 1-hour average; 30 mg/m^3	2.0	2.4	1.6	1.4	2.2
Max. 8-hour average; 10 mg/m^3	1.7	1.6	1.3	1.2	1.7

* Temperature 25^{o}C used to convert DPIE data to mass concentrations (see Section 4.4.1); reflective of Lower Hunter conditions.

4.4.3 Sulphur dioxide

A summary of SO_2 concentrations measured at DPIE Beresfield from 2015 to 2019 is provided in Table 4.5, from an analysis of results provided by *New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*. Normally background SO_2 concentrations are small, of the order 1 ppb; hence these results show that SO_2 concentrations in the Lower Hunter are likely influenced by industrial sources in the Hunter Valley, such as coal-fired power stations. However, at Beresfield the concentrations have been consistently below the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) impact assessment criteria each year. Analysis of the SO_2 trends in the Lower Hunter since 2009 shows no clear change in SO_2 levels over the past decade (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*,).

Table 4.5: Summary of measured SO_2 concentrations: DPIE Beresfield (μg/m^3)

Statistic and criterion	2015	2016	2017	2018	2019
Max. 1-hour average; 570 μg/m^3	215	86	141	183	178
Max. 24-hour average; 228 μg/m^3	21	21	21	18	24
Annual average; 60 μg/m^3	2.6	2.6	5.2	5.2	5.2

* Temperature 25^{o}C used to convert DPIE data to mass concentrations (see Section 4.4.1); reflective of Lower Hunter conditions.

4.4.4 Particulate matter as $PM_{2.5}$

A time-series of 24-hour average $PM_{2.5}$ concentrations measured at DPIE Beresfield over 2015–2019 is provided in Figure 4-4. The corresponding NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) assessment criterion of 25 µg/m^3, which came into effect on 20th January 2017, is also displayed (red-dashed line). The measured $PM_{2.5}$ exceeded the impact assessment criterion on some days over 2015–2019, with the increased exceedances in 2019 due to bushfire smoke and raised dust (*Fine particle pollution peaks during bushfires* (ANSTO, 2020) and *New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*). There are no clear trends in the $PM_{2.5}$ measurements in the Lower Hunter since 2009 (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*), which appear to have been heavily influenced by bushfire smoke in 2009, 2013, 2015, 2016 and 2019.

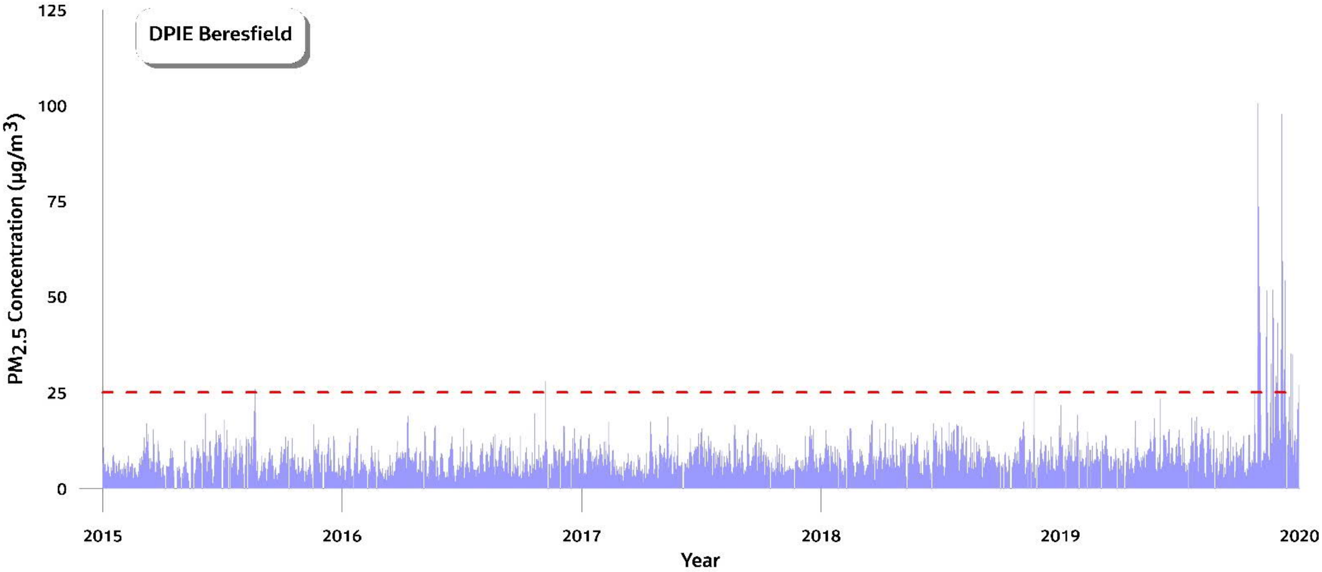


Figure 4-4: Measured 24-hour average $PM_{2.5}$ concentrations at Beresfield

A statistical summary of the $PM_{2.5}$ measurements at Beresfield over 2015 to 2019 is provided in Table 4.6.

Table 4.6: Summary of measured $PM_{2.5}$ concentrations: DPIE Beresfield (μg/m³)

Statistic and criterion	2015	2016	2017	2018	2019
Max. 24-hour average; 25 μg/m³	26	28	19	25	101
Number of days above 25 μg/m³	1	1	0	0	23
Annual average; 8 μg/m³ *	7.4	7.4	7.6	8.7	12.2

* Maximum annual average introduced by EPA for 2017 onwards.

4.4.5 Oxides of nitrogen

This assessment included dispersion modelling of NO_x emissions from the Proposal, however NO_2 is the pollutant of interest for comparison with the air quality criteria. A first step in the assessment was to determine the general NO_2 vs. NO_x relationship in the ambient air environment in the study area.

Inspection of ambient NO_x monitoring data shows that for most (possibly all) localities the NO_2 fraction is inversely proportional to the total NO_x. This means that maximum NO_x concentrations are associated with the lowest NO_2 concentrations. Typically as the NO_x concentration increases the NO_2/NO_x fraction decreases to a minimum. The NO_2/NO_x ratios for DPIE Beresfield, (hourly average data 2015-2019), are shown plotted against total NO_x in Figure 4-5; the plot includes an exponential fit. The average NO_2/NO_x fraction for these data is 68 per cent. For the highest NO_x concentrations greater than 300 μg/m³ the NO_2 concentration is less than 20 per cent.

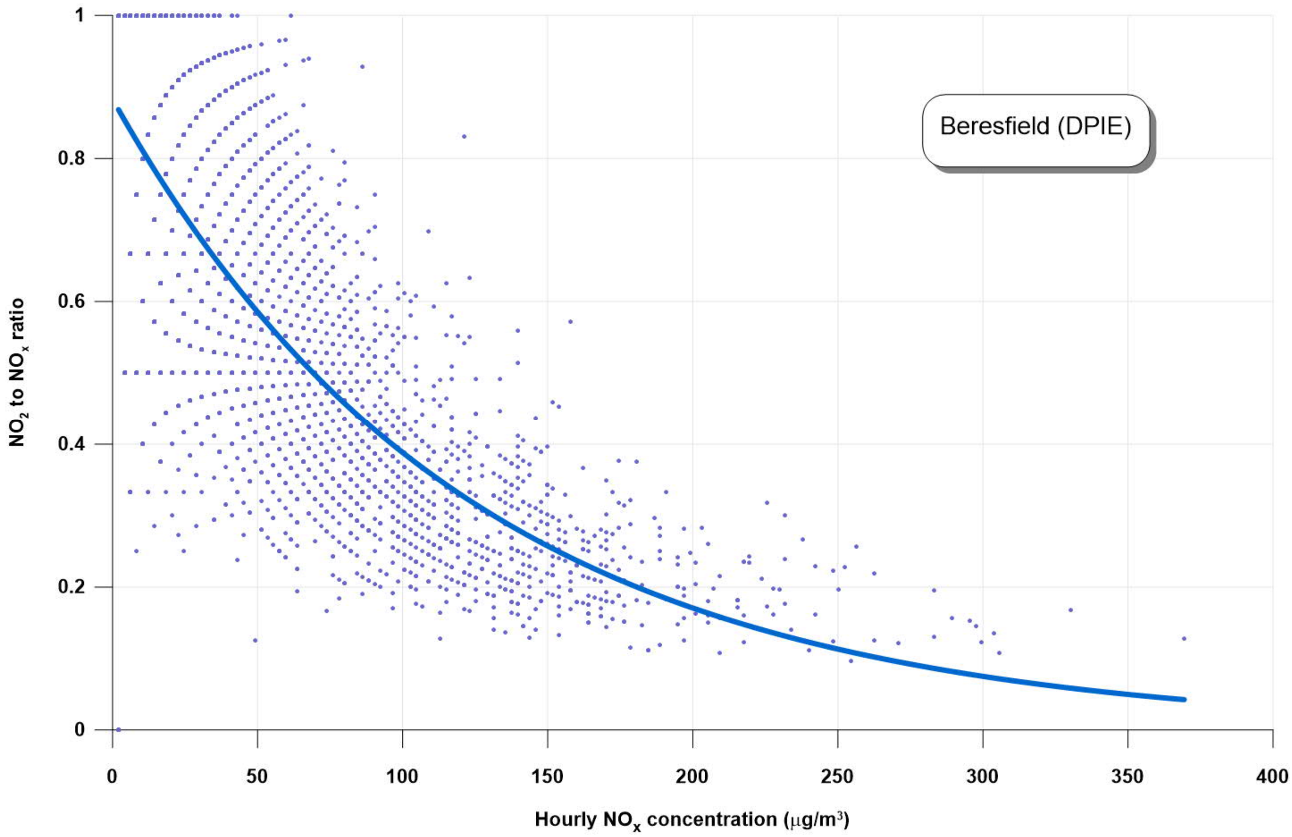


Figure 4-5: Measured NO_2 to NO_x ratios from hourly data collected at Beresfield (2015 to 2019)

An explanation for the pattern shown in Figure 4-5 is as follows: during the high-temperature combustion of fossil fuels such as natural gas and diesel there will be a variety of NO_x formed including NO and NO_2. At the point of emission, NO comprises the greatest proportion of the total NO_x. Typically NO comprises approximately 90 per cent by volume, the remainder being NO_2. The NO_2 is linked to adverse health effects, hence the assessment criteria for NO_2. Within a few hours however, in the presence of O_3 and sunlight, most of the NO converts to NO_2, but by the time this has occurred the NO_2 is likely well dispersed to lower, less harmful concentrations.

4.4.6 Nitrogen dioxide and ozone

A statistical summary of the measured NO_2 concentrations at DPIE Beresfield over 2015-2019 is provided in Table 4.7. These data show the NO_2 concentrations have been consistently below NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) impact assessment criteria. Analysis of the trends for NO_2 show no clear change since 2009 (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*).

Table 4.7: Summary of measured NO_2 concentrations: DPIE Beresfield

Statistic and criterion	2015	2016	2017	2018	2019
Max. 1-hour average; 246 $\mu g/m^3$	92	77	75	75	105
Annual average; 62 $\mu g/m^3$	17	15	16	17	15

* Temperature 25^oC used to convert DPIE data to mass concentrations (see Section 4.4.1); reflective of Lower Hunter conditions.

A marker for photochemical smog is ozone (O_3), which is formed from many air pollution sources in a region such as the Hunter Valley. Predictions of O_3 concentrations require regional photochemical modelling, which was outside the scope of this assessment. While O_3 was not required to be assessed for the Proposal, industrial emissions of NO_x and other pollutants contribute to the formation of O_3. As such a statistical summary of the Beresfield O_3 measurements is provided in Table 4.8, from an analysis of data provided by *Protection of the Environment Operations (Clean Air) Regulation 2010*. These results show that exceedences of the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) criteria for O_3 is a more significant air quality issue than for NO_2, and demonstrates why NO_x minimisation by industry is important even though exceedences of the NO_2 criteria are unlikely–at least in the Lower Hunter. Analysis of the trend data for O_3 (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*), and more recent monitoring data, shows an increase in O_3 levels. The most likely explanation is emissions from bushfires in 2018-2019 (*New South Wales Annual Compliance Report 2019, National Environment Protection (Ambient Air Quality) Measure*).

Table 4.8: Summary of measured O_3 concentrations: DPIE Beresfield

Statistic and criterion	2015	2016	2017	2018	2019
Max. 1-hour average; 214 $\mu g/m^3$	151	167	163	210	247
Max. 4-hour average; 171 $\mu g/m^3$	131	133	155	175	210

* Temperature 25°C used to convert DPIE data to mass concentrations (see Section 4.4.1); reflective of Lower Hunter conditions.

4.4.7 Hydrocarbons (VOCs) for assessment

The selection of VOCs for assessment is described in Section 5.2. The selected VOCs were, for the combustion of natural gas in gas turbines: formaldehyde and acrolein; and for the combustion of diesel fuel by gas turbines: PAHs as B(a)P and formaldehyde.

While NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) does not require background levels of individual VOCs to be included as part of cumulative impact assessments, reviews of the concentrations of VOCs selected for assessment were provided as additional information in the following sub-sections. These background concentrations assist with the interpretation of the assessment results.

4.4.8 VOCs: Formaldehyde

In Australia, formaldehyde is not measured very often, and generally only as part of a wider research campaign; e.g., Keywood et al. (2019), Guerette et al. (2019). A summary of a brief review of formaldehyde measurements focussing on NSW is provided in Table 4.9. The Measurements of Urban, Marine and Biogenic Air (MUMBA) monitoring campaign was undertaken in Wollongong over the 2012-2013 summer. The most detailed (hourly average) MUMBA dataset was identified as being most representative of formaldehyde concentrations in the Lower Hunter region.

Table 4.9: Summary of some NSW formaldehyde measurements

Parameter	Formaldehyde concentration	Source
MUMBA (Wollongong), 1025 hourly average measurements, Dec 2012 – Feb 2013 range mean	 0.09–8.69 ppb 1.19 ppb	Guerette et al. (2019) Calculated using MUMBA dataset
Sydney Particle Study I; summer 2011 1-hour average, typical low 1-hour average, typical high	 2–3 ppb 10–20 ppb	Keywood et al. (2019)
Sydney Particle Study II; autumn 2012 1-hour average, typical low	 0.5 ppb	Keywood et al. (2019)

Parameter	Formaldehyde concentration	Source
1-hour average, typical high	4–6 ppb	
EPA Sydney 2008-2009 Annual average (Rozelle and Turrella) Max. 24-hour average (Rozelle, Turella)	 1.6 ppb 3.2 ppb, 4.4 ppb	NEPC (2019)
Australia, general Natural background annual average Maximum 24-hour average	 1 ppb 2 ppb	Australian Government (2006)

4.4.9 VOCs: PAHs as B(a)P

Measurements of airborne Polycyclic Aromatic Hydrocarbons (PAHs) in Australia are rare, with results obtained only from relatively short measurement campaigns, generally undertaken many years apart. Commonly, PAH measurements are reported as Benzo(a)Pyrene (B(a)P) for comparisons with ambient air quality standards specified in this way. A summary of some relevant NSW measurements of PAHs as B(a)P is provided in Table 4.10. In winter, many localities in rural NSW, and parts of Sydney, are affected by smoke due to domestic wood burners, especially during temperature inversion conditions at night. This has the effect of elevating concentrations of PAHs in winter; e.g., *Ambient Concentrations of Polycyclic Aromatic Hydrocarbon Species in NSW* (NSW DEC, 2004).

Table 4.10: Summary of some NSW measurements of PAHs as B(a)P

Parameter	B(a)P concentration	Source
Sydney, Turrella Oct. 2008 – Sep. 2009 Annual average Maximum 24-hour average	 0.21 ng/m^3 0.40 ng/m^3	NEPC (2010); NEPC (2019)
Mayfield, Mar 2010 – Jan 2011 Annual average (56 meas.) Max. 24h avg.	 < 0.08 ng/m^3 < 0.08 ng/m^3	*Lower Hunter Ambient Air Quality Review of Available Data* (NSW OEH, 2012) No meas. above limit of detection. No meas. above limit of detection.
Beresfield, 1997–2001 winters (10 samples) Mean Max. 24h avg.	 0.15 ng/m^3 0.52 ng/m^3	*Ambient Concentrations of Polycyclic Aromatic Hydrocarbon Species in NSW* (NSW DEC, 2004)
Beresfield, 1997–2001 summers (3 samples) Mean Max. 24h avg.	 0.03 ng/m^3 0.05 ng/m^3	*Ambient Concentrations of Polycyclic Aromatic Hydrocarbon Species in NSW* (NSW DEC, 2004)

4.4.10 VOCs: Acrolein

The *Lower Hunter Ambient Air Quality Review of Available Data* (NSW OEH, 2012) recognised acrolein as a ‘priority industrial pollutant’ for the Newcastle Local Government Area, although ranked with a lower priority than PAHs, benzene and arsenic. Measurements of acrolein are rare in Australia and limited to relatively short measurement campaigns.

The CSIRO *Methane and Volatile Organic Compound Emissions in New South Wales* (2016) review of VOCs for the NSW EPA measured acrolein in a number of different environments, for which a typical background concentration was 1 ppb. However, these measurements were affected by sources such as vehicle traffic, wastewater treatment plants, and cattle feedlots. From the broader review of acrolein measurements by the U.S.

DHHS (2007), a better estimate for background acrolein levels in a rural environment is 0.1 ppb (0.23 μg/m^3 at 25^{o}C).

5. Assessment methodology

5.1 Overview

The potential air quality impacts of the Proposal were determined from results of computer-based dispersion modelling. This section describes important features and parameters used in the meteorological and air pollutant dispersion modelling that formed the basis of this assessment. This section provides a focus on site-specific parameters that affected the modelling. The assessment was undertaken in accordance with the procedures detailed in NSW *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* EPA (2016), which includes guidelines for the preparation of meteorological data, reporting requirements and the use of air quality assessment criteria to assess the significance of model-predicted air quality impacts. The modelling was based on the use of the Calmet and Calpuff models, with model settings following the guidance of *Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia'* (Barclay and Scire for NSW Office of Environment and Heritage (2011)).

The key part of the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) assessment process comprises comparisons of the model results for Ground Level Concentrations (GLCs) with the impact assessment criteria listed in Section 3.4.

5.2 Substances for assessment

The substances for assessment were selected by a review of National Pollutant Inventory (NPI) emissions factors (Australian Government, 2008), and corresponding U.S. EPA 'AP-42' data (U.S. EPA, 2004). The purpose of the review was to check (approximately) the air emissions data provided by the GT manufacturers, and to fill in some data gaps. The air emissions data were compared with the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) air quality assessment criteria to select the air pollutants for assessment. From this review the hydrocarbons selected for assessment were: formaldehyde and acrolein for natural gas-fuelled GTs and PAHs as B(a)P and formaldehyde for diesel-fuelled GTs.

5.3 Capacity factor

The proposed power station will not operate continuously throughout any year. The 'Capacity Factor' is an estimate of the fraction of time that a power station is expected to operate. The Capacity Factor for the Proposal, as a 'peaker plant', has been assumed to be 12 per cent for the purposes of assessment. However, it is expected that likely operation of the Proposal would result in a total Capacity Factor of two per cent in any given year, and some of this time at reduced load.

The air pollutant emission rates used as input to the modelling for this assessment were used to test every hourly condition of the simulated meteorological year. The purpose of this was to not limit the Proposal's operation to any particular season, month, or hour of the day. For that reason the assessment results for sub-hourly and hourly average assessment parameters, (such as maximum, ambient, hourly average NO_2 concentration), were conservative (high). Further, the Proposal is not expected to operate for a period as long as 24 hours in one instance, so the assessment results for 24-hour (daily) averages, such as the maximum 24-hour average $PM_{2.5}$ concentrations, were even more conservative. Similarly, the annual average assessment results due the Proposal were the most conservative of all the assessment results.

5.4 Meteorological modelling

5.4.1 Purpose

The main task of the meteorological modelling was to produce a three-dimensional, hourly-varying, meteorological database to be the foundation and input for the subsequent air pollutant dispersion modelling. Three-dimensional, hourly average wind vectors covering a large study area were key parameters. To assist with this process, high quality measurements of wind speed, wind direction and other meteorological parameters were available for the Lower Hunter (see Section 4.3). Some of these local observations were used to strongly influence the meteorological dataset created as input for dispersion modelling.

5.4.2 Selection of simulation year

In Section 4.3 it was determined the wind patterns in the Hunter Valley are similar each year – the data from any of the years analysed in detail (DPIE meteorological data 2015-2019), could have been used as a representative meteorological simulation year for the assessment. The simulation year selected for modelling was 2018, as the air quality monitoring data for 2019, (also required model inputs), were heavily affected by smoke from fires; e.g., see Figure 4-4.

5.4.3 TAPM and Calmet modelling

The Air Pollution Model (TAPM), developed at CSIRO Atmospheric Research, was used to generate, primarily, upper air data for the air quality study area. The significant and practical advantage of TAPM is that it eliminates the need for site-specific meteorological observations to be used as input to an air (pollutant) dispersion model. The model predicts surface and upper air flows important to local-scale air pollution, such as sea breezes and terrain-induced flows, against a background of larger-scale meteorology provided by synoptic analyses (Hurley, 2008a; Hurley et al. 2008b; Hurley et al. 2008).

For this air quality study, TAPM was used to generate hourly-varying surface and upper-air meteorological data over the Proposal study area, using the DPIE Beresfield surface measurements for 2018 as input. Modifications were made to default land use parameters for some grid cells in the Proposal study area to better reflect the local land use identified using vertical imagery, especially along Swamp Creek.

Hourly average wind speed and wind direction observational data from the DPIE Beresfield monitoring station were used in ‘data assimilation’ mode, to force TAPM to produce meteorological results to be similar to the observations at ground-level. The surface winds produced by TAPM for Beresfield were compared with the observational data to confirm proper assimilation. Subsequently these data were used as input to Calmet to produce an hourly-varying, three-dimensional, meteorological dataset for the air quality study area. (The air dispersion model used, Calpuff, required an input dataset from its meteorological model, Calmet).

Calmet is a meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded modelling domain. Atmospheric mixing (boundary) layer heights are calculated for each grid point, on an hourly basis. The diagnostic wind field generator accounts for slope flows, kinematic terrain effects, terrain blocking effects, and a micrometeorological model for overland and overwater boundary layers (Scire et al., 2000a). Summaries of some of the key input parameters used for the meteorological modelling are provided in Table 5.1 (TAPM) and Table 5.2 (Calmet).

Table 5.1: TAPM meteorological modelling parameters

Parameter	Value
Number of grids (spacing)	Four grids with horizontal resolution: 30 km, 10 km, 3 km, 1 km
Number of grid points	25 x 25 x 25: inner grid horizontal size 25 km x 25 km; and 25 vertical layers at the following heights (metres above ground leve): 10, 25, 50, 100, 150, 200, 250, 300, 400, 500, 600, 750, 1000, 1250, 1500, 1750, 2000, 2500, 3000, 3500, 4000, 5000, 6000, 7000, 8000
Year(s) of analysis	2018 & 2019 – 2018 was selected as the simulation year due air quality monitoring data affected by bushfire smoke late in 2019
Centre of analysis	Latitude 32.78333° S, Longitude 151.4833° E (near Proposal site) Easting 357.967 km; Northing 6371.714 km (practically GDA 2020)
Terrain data source	Default TAPM terrain data

Parameter	Value
Land use modifications	Land use codes modified to improve characterisation of Swamp Creek near site
Meteorological data assimilation	DPIE Beresfield meteorological data; measured hourly average wind speed and wind direction

Table 5.2: Calmet meteorological modelling parameters

Parameter	Value
Terrain data source(s)	1 second (30 metre) Shuttle Radar Topography Mission data
Land use data source(s)	Digitised using a vertical image
Meteorological grid domain	30 km x 20 km
Meteorological grid resolution	250 metres
Meteorological grid dimensions	120 x 80 horizontal grid points 9 vertical layers: 0, 20, 40, 80, 160, 320, 700, 1200, 1500 & 2000 metres
Meteorological grid origin	East 343.000 km; North 6362.000 km (MGA Zone 56)
RMAX1, RMAX2, RMAX3	Maximum radius of influence over land in: surface layer (RMAX1 = 5 km); aloft (RMAX2 = 20 km); and over water (RMAX3 = 20 km)
RMIN, R1, R2	Minimum radius of influence used in wind field interpolation (RMIN = 0.1 km) Relative weighting of first guess field and observations in surface layer (R1 = 0.5 km) Relative weighting of first guess field and observations in layers aloft (R2 = 1 km)
TERRAD	Radius of influence of terrain (TERRAD = 5.0 km)
Surface station	TAPM-generated surface and upper air station files output for Kurri: E 358.0 km, N 6371.7 km

Calmet results for the surface winds and other meteorological parameters were extracted at the Proposal Site location and compared with the Beresfield measurements, which confirmed the modelled data over the whole grid was of sufficient quality to used for the assessment. These comparisons are provided in Appendix B.

5.5 Calpuff modelling

The air dispersion model Calpuff, developed by Scire et al. (2000b), was selected for use for the air pollutant dispersion modelling for this Proposal. Calpuff is an air pollutant transport and dispersion model that advects puffs of material emitted from modelled sources, simulating the time evolution of dispersion and transformation processes. Calpuff is a non-steady-state Lagrangian Gaussian puff model including modules for: complex terrain effects, coastal interaction effects, building downwash, and wet and dry removal of pollutants as they contact the ground surface.

The model accounts for effects such as spatial variability of meteorological conditions, dispersion over a variety of spatially varying land surfaces, plume fumigation, and low wind speed dispersion (EPA, 2016). Calpuff includes algorithms for air pollutant dispersion including the use of turbulence-based dispersion coefficients derived from similarity theory or observations; e.g., *Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia'* (Barclay and Scire for NSW Office of Environment and Heritage (2011); NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016).

The key part of the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) assessment process comprises comparisons of the model results for Ground Level Concentrations (GLCs) with the impact assessment criteria listed in Section 3.4.

The Calpuff settings used for the Proposal followed the general guidance for using the model by Barclay and Scire (2011). Wake effects due to the layout and heights of the Proposal infrastructure were included. The Proposal gas turbine exhaust stacks were included as point sources (emissions parameters were detailed in Section 2.5).

Table 5.3: Calpuff air pollutant dispersion modelling parameters

Parameter	Value
Computational grid domain	30 km east-west by 20 km north-south 120 x 80 horizontal grid receptors, resolution 250 metres, giving 9600 grid receptors Additional 16 discrete receptors representing sensitive receptor locations 9 height layers: 0, 20 , 40, 80, 160, 320, 700, 1200, 1500, 2000 metres
Input surface meteorological data	Kurri Kurri surface location data produced by TAPM with assimilation of Beresfield surface wind measurements.
Input upper-air meteorological data	Kurri upper air station data produced by TAPM including with assimilation of Beresfield surface wind measurements. Vertical layer bias settings were biased towards the surface observations (settings: -1, -0.8, -0.6, -0.4, -0.2, 0, 0, 0, 0).
Simulation year	All hours of 2018 (except final hour – Calmet stop)
Chemical species modelled	NO_x, SO_2, CO, VOCs as xylene, $PM_{2.5}$, with gaseous dry deposition calculations included ($PM_{2.5}$ did not include deposition, so results for ground-level concentrations are conservative).
Building height profile wake effects	PRIME method used to simulate building downwash, and stack tip downwash activated
Dispersion option	Dispersion coefficients from internally calculated sigma-v, sigma-w using micrometeorological variables (u*, w*, L, etc.). Standard Calpuff routines to compute turbulence sigma-v and sigma-w using micrometeorological variables; for more details see Scire et al. (2000b)
Terrain adjustment	Partial plume path adjustment
Number of sources	Two point sources – GT stacks, heights 36 metres (see Section 2.5 for details).

5.6 Peak-to-mean ratio

The Calpuff modelling was limited to hourly average data; the main simulation involved the processing of a simulated year of meteorological and air dispersion data, or 8760 hours of simulations. Outputs from the modelling therefore were also limited to hourly averages, such as air pollutant concentrations. Some of the NSW EPA (2016) *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* air quality assessment criteria had sub-hourly averaging periods (Section 3.4), as such a method was needed to convert hourly-average GLCs due to point source emissions to a sub-hourly average GLC. Also, hourly-average concentrations for the ambient (separate) air pollutant concentrations, which could be from any source type (point, volume, etc.), were then converted to a sub-hourly average GLC. To do this Peak-to-Mean Ratios (PMR) were calculated using the peak concentration (C_p) and mean concentration (C_m) using equation (1),

$$C_p = C_m(t_p/t_m)^{-p}, \qquad (1)$$

where t_p is the averaging period of the peak concentration, and t_m is the averaging period of the 'mean' concentration (the latter all one-hour averages for the Proposal assessment), and *p* is an exponent determined by Borgas (2000). The values of the exponents and calculated PMRs used for this assessment are listed in Table 5.4.

Table 5.4: Calculated Peak-to-Mean Ratios used in assessment

Parameter	Point source	General source
Exponent 'p'	0.353	0.1
PMR: 10-minute average e.g. SO_2 (from mean 1-hour average)	1.88	1.20
PMR: 15-minute average e.g. CO (from mean 1-hour average)	1.63	1.15

5.7 NO_x to NO_2 conversion: OLM technique

Some background information to the air chemistry involved in the conversion of ambient NO_x to NO_2 was provided in Section 4.4.5 (ambient NO_x) and Section 4.4.6 (ambient O_3). This sub-section explains how model results for dispersed NO_x were converted to NO_2 GLCs using hourly background NO_2 and O_3 data; the technique is known as the Ozone Limiting Method (OLM), detailed in NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016).

The OLM was used to predict NO_2 GLCs. The method assumes all the available O_3 reacts with NO using all available (ambient) O_3 or NO. NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) warns the method assumes an instant reaction whereas in the atmosphere, the reaction takes place over a number of hours. The NO_2 concentration $[NO_2]$ at a point, in any hour, is determined by,

$$[NO_2] = 10\% \, [NO_x]^P + \text{minimum} \{90\% \, [NO_x]^P \text{ or } 46/48 \times [O_3]^B\} + [NO_2]^B, \qquad (2)$$

where $[NO_x]^P$ is the model-predicted NO_x concentration, $[O_3]^B$ is the background or measured O_3 concentration in that hour, and $[NO_2]^B$ the background NO_2 concentration in that hour (units all $\mu g/m^3$); e.g., NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016). The background NO_2 and O_3 data used for these calculations for the assessment were obtained from the DPIE Beresfield monitoring station.

5.8 NSW EPA ozone assessment

While the method described in Section 5.7 is adequate for estimating maximum NO_2 concentrations, the interplay between NO_2 and ozone (O_3) formation by photochemical processes in the ambient atmosphere is more complex. The photochemical production of O_3 involves many emissions sources, many air pollutants, and usually covers a large study area; e.g., see the modelling studies of the NSW Greater Metropolitan Region (GMR) by Duc et al. (2018), NSW DPIE (2020); and Duc et al. (2021).

Inspection of the NSW DPIE (2020) results for O_3 across the GMR indicates a single power generation source in the Lower Hunter region would contribute O_3 concentrations of up to approximately 1 ppb (e.g. 2 $\mu g/m^3$ at 20^{o}C), with typical background O_3 concentrations being approximately 20 ppb (e.g. 40 $\mu g/m^3$ at 20^{o}C). While a sophisticated photochemical modelling study of the Newcastle-Lower Hunter airshed was outside the scope of this study, increased O_3 concentrations associated with the Proposal were estimated using the NSW EPA's *Tiered Procedure for Estimating Ground-Level Ozone Impacts from Stationary Sources* (NSW EPA, 2011).

A summary of the NSW EPA (2011) procedure is provided in the following points:

- O_3 monitoring data for the region of interest (Lower Hunter for this Proposal), is used to determine whether the Proposal was in an 'Ozone Attainment Area' (affirmative in this case).

- If the source emissions are above an emission threshold a ‘Level 1’ screening assessment is triggered using the ‘Screening Tool’ (Microsoft spreadsheet) provided online: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/air/150507-ozone-procedure-tool.xls?la=en&hash=2FDD721DC550AB6E3B3560B8499FD475128ADF7A, accessed 18 July 2021.
- The Screening Tool estimates increases in 1-hour and 4-hour average ground-level O_3 concentrations for a source specified by its daily emissions of methane, CO, NO_x and/or VOCs, and using O_3 monitoring data.
- The resulting increases are compared with calculated maximum allowable O_3 increments, and a determination made if further more detailed studies are required.

The results of the NSW EPA (2011) ozone procedure are described in Section 6.7.

5.9 Airborne particulate matter

The results for airborne particulate matter as PM_{10} were not assessed as nearly all the particles are expected to be in the $PM_{2.5}$ size range (Australian Government, 2008). Also, the assessment of particulate emissions as $PM_{2.5}$ was more conservative than PM_{10} given that the $PM_{2.5}$ standards are lower (Section 3.4).

6. Results

6.1 Overview

This section provides the Calpuff results for Ground Level Concentrations as contour plots in accordance with NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016), and summary tables and discussions of results. The results are provided for the Proposal based on the maximum (100 per cent) load case, which was determined by sensitivity testing with Calpuff to be the worst-case operating scenario (i.e. the 50 per cent load case was tested by modelling also).

The Proposal is seeking approval for a capacity factor of up to 10 per cent on natural gas fuel and two per cent on diesel fuel. However, it is expected that likely operations would result in a capacity factor of approximately two per cent. Modelling of continuous emissions from the Proposal was undertaken to test every hour of an annual meteorological simulation – this was a conservative approach taken for the assessment.

Also, annual average GLCs were reported as calculated from the continuous emissions estimates; i.e. not reduced to account for the capacity factors. The reason for this was the annual averages were very small, and immaterial to the outcomes of the assessment.

A Level 2 air quality impact assessment was carried out for SO_2, NO_2, $PM_{2.5}$ and CO using contemporaneous measurements and model data in accordance with the NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) modelling assessment guideline. Level 2 assessments for these substances are conducted using the data and steps listed in the following points:

- Ambient air monitoring data (hourly averages) included at least one year of continuous measurements and were contemporaneous with the meteorological data used for dispersion modelling
- The dispersion model prediction for each receptor, for each hour, was added to the corresponding estimate for the background concentration in that hour to obtain the total concentration
- The maximum total concentrations in each hour, for each receptor, were compared with criteria for the substances tested.

For Level 2 assessment of the air pollutants, the model-predicted 99.9^{th}-percentile hourly average concentrations, (without background estimates), and these were compared with the impact assessment criteria at and beyond the Proposal boundaries (in this case at all 9600 grid receptor and 16 discrete receptor locations on the modelling grid). The 16 discrete receptor locations represent the 16 sensitive receptors identified in Section 4.2.

The modelling grid used to define the base map used for the contour plots was detailed in Section 5.5. The axes are labelled with GDA 2020 northings in units of metres (labelled in black on vertical axis), and eastings (m) on the horizontal axis. Units for the GLCs are mg/m^3 for the CO results, and $\mu g/m^3$ for all other results.

6.2 Calpuff results for carbon monoxide

6.2.1 Calpuff results: maximum 15-minute average CO GLC

The Calpuff results for maximum 15-minute average CO GLCs (mg/m^3) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

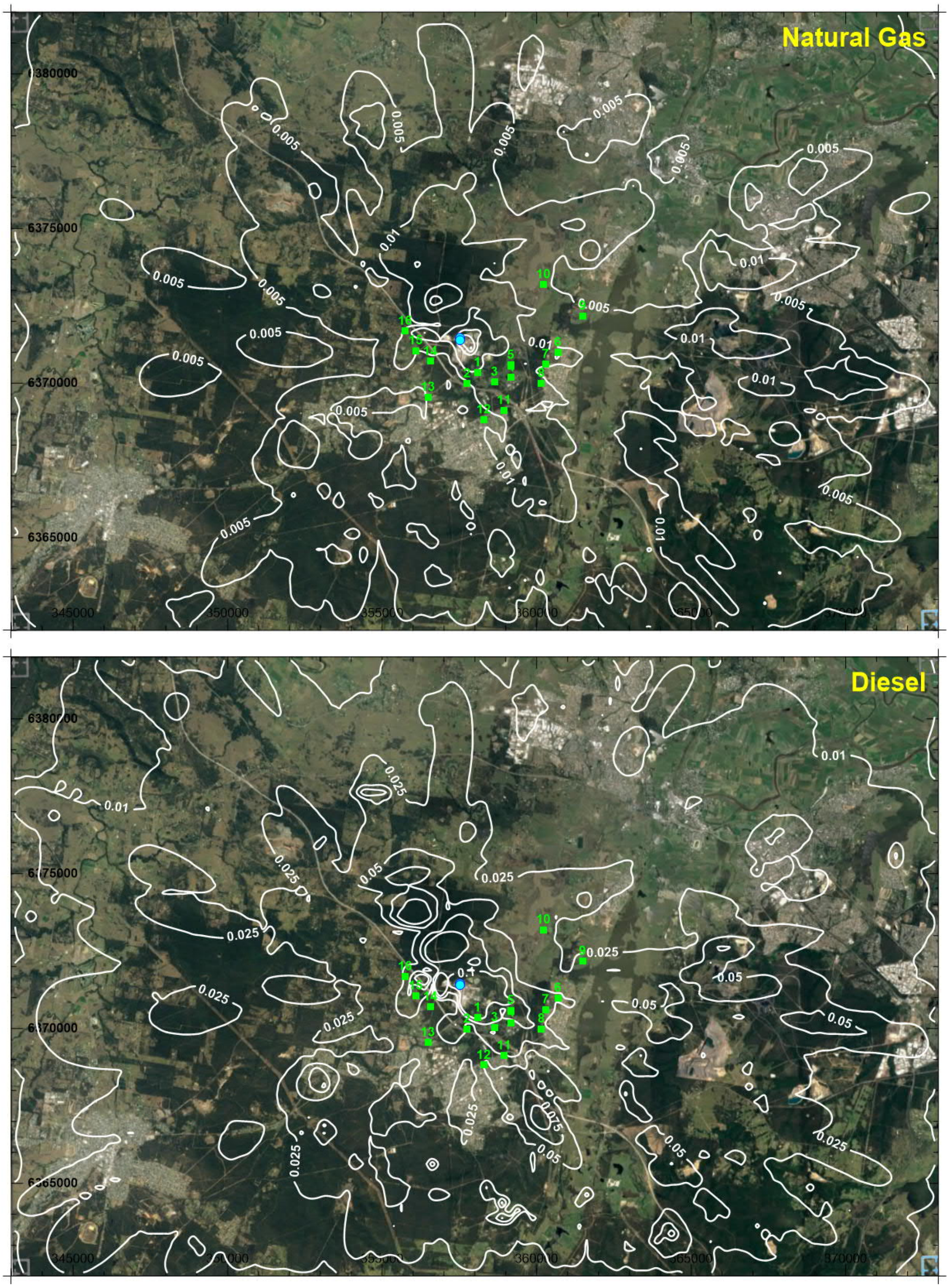


Figure 6-1: Maximum 15-minute average CO GLC (mg/m^3): natural gas (top) and diesel (bottom)

6.2.2 Calpuff results: maximum 1-hour average CO GLC

The Calpuff results for maximum 1-hour average CO GLCs (mg/m^3) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

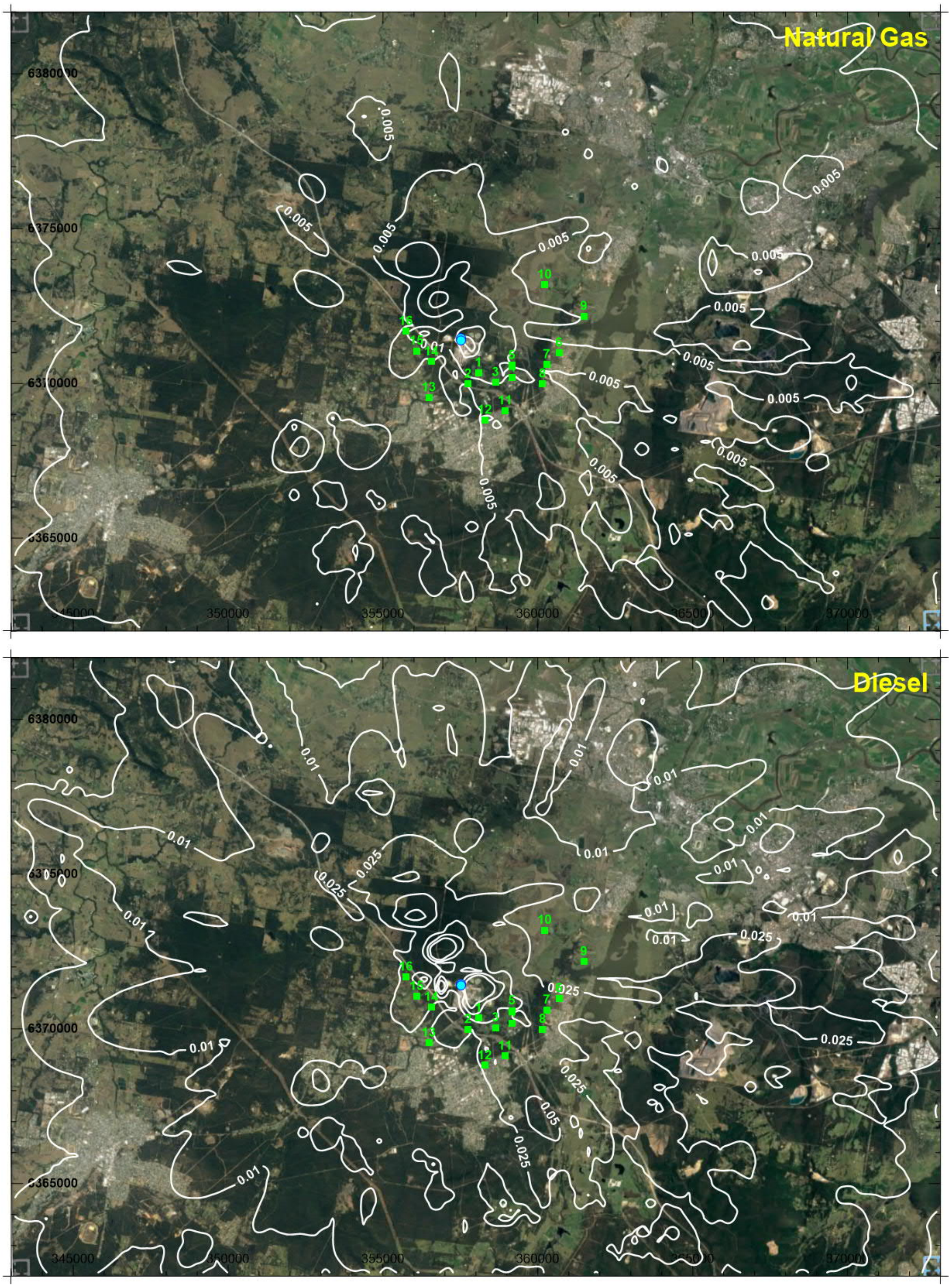


Figure 6-2: Maximum 1-hour average CO GLC (mg/m^3): natural gas (top) and diesel (bottom)

6.2.3 Calpuff results: maximum 8-hour average CO GLC

The Calpuff results for maximum eight-hour average CO GLCs (mg/m^3) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

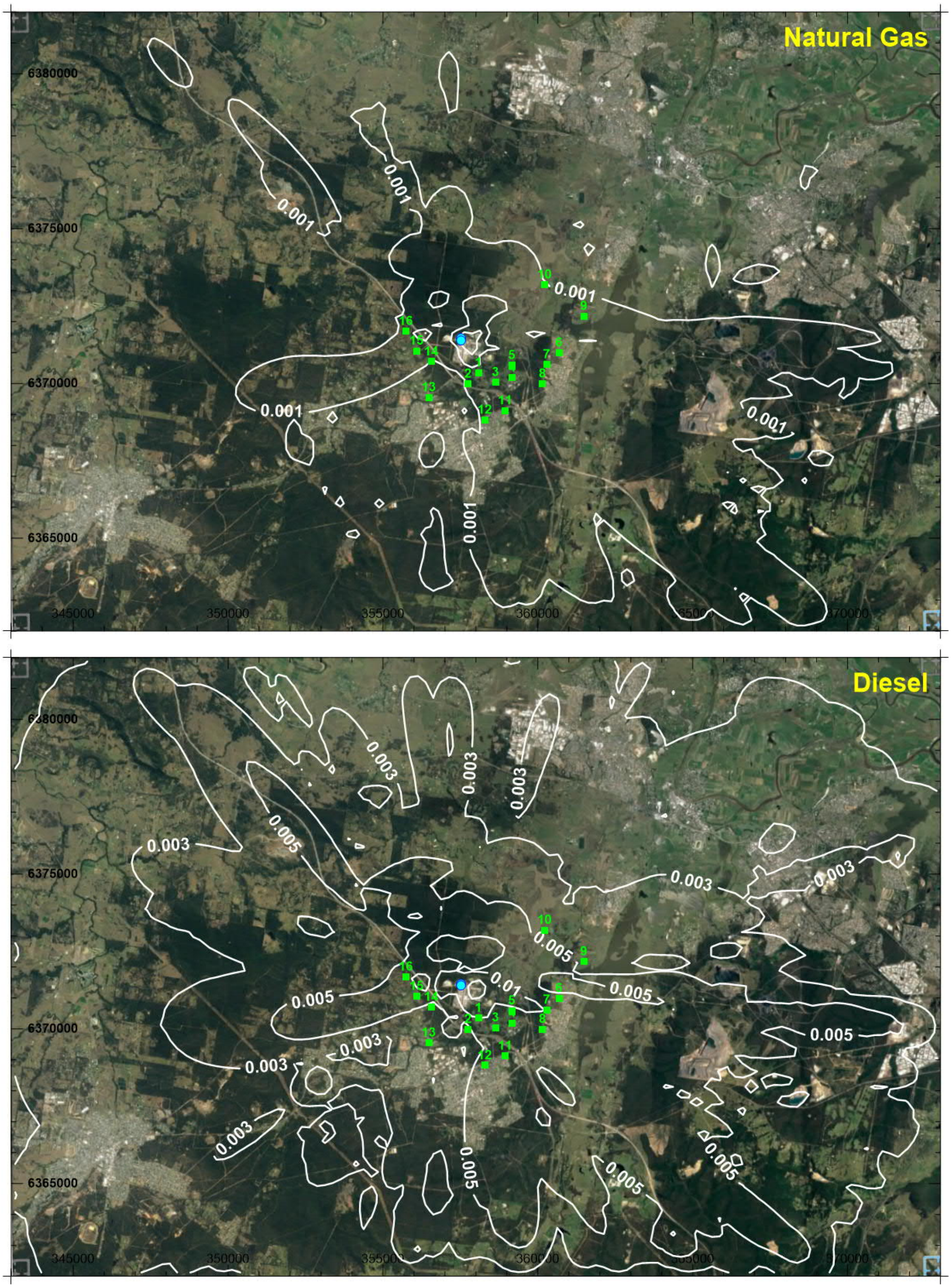


Figure 6-3: Maximum 8-hour average CO GLC (mg/m^3): natural gas (top) and diesel (bottom)

6.2.4 Summary and analysis of results: CO

This section provides a summary of all Calpuff results for CO for the 9600 Grid Receptors (GR) and the worst case (highest) results for the 16 Discrete Receptors (DR). Summaries of Calpuff results for CO for the OCGT's operating at 100 per cent load are provided in Table 6.1 (natural gas-fuelled case); and Table 6.2 (diesel-fuelled case). The units for all CO concentrations are mg/m^3. There were no CO measurements data available for EPA Beresfield, so EPA Newcastle data were used as background. The notes apply to both tables.

Table 6.1: Summary of Calpuff results for CO: natural gas-fuelled and 100% load (mg/m^3)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
15-minute[1]	100	1.578	1.578	1.578	1.58%
1 hour	30	1.374	1.374	1.374	4.58%
8 hour[2]	10	0.987	1.059	0.987	10.59%

Table 6.2: Summary of Calpuff results for CO: diesel-fuelled; 100% load (mg/m^3)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
15-minute[1]	100	1.578	1.578	1.578	1.58%
1 hour	30	1.374	1.374	1.374	4.58%
8 hour[2]	10	0.987	1.059	0.987	10.59%

1. 15-minute averages for CO estimated from hourly averages using Peak-to-Mean Ratios (PMR): 1.63 (point sources, from Calpuff results for hourly average GLCs); and 1.20 (volume sources, from monitoring results for hourly average GLCs); see Section 5.6.

2. NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) assessment criterion is a standard (step-wise) 8-hour average. The corresponding NEPM standard is a rolling 8-hour average (NEPC, 2016).

The Calpuff results for cumulative, ambient CO concentrations due to emissions from the Proposal including background CO are low in comparison to the impact assessment criteria. The results for maxima (columns four and five) are very similar to background (column three) because the modelled contributions due to the Proposal were very small. The results indicate there is no significant risk of air quality impacts due to CO emissions from the Proposal operating at 100 per cent load, whether fuelled by natural gas or diesel, at any time of the year.

6.3 Calpuff results for sulphur dioxide

6.3.1 Calpuff results: maximum 10-minute average SO_2 GLC

The Calpuff results for maximum 10-minute average SO_2 GLCs ($\mu g/m^3$) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

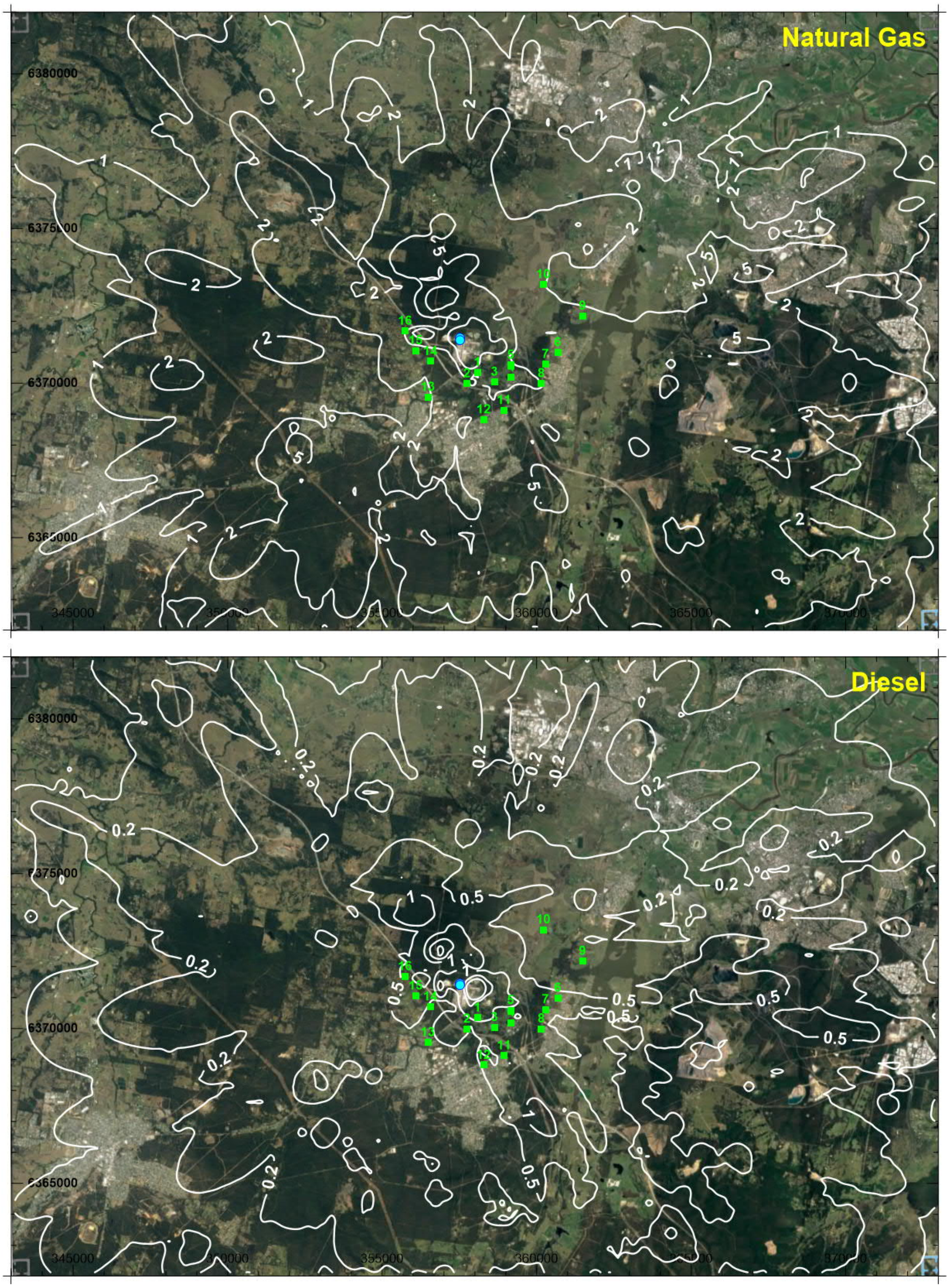


Figure 6-4: Maximum 10-minute average SO_2 GLC ($\mu g/m^3$): natural gas (top) and diesel (bottom)

6.3.2 Calpuff results: maximum 1-hour average SO_2 GLC

The Calpuff results for maximum one-hour average SO_2 GLCs ($\mu g/m^3$) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

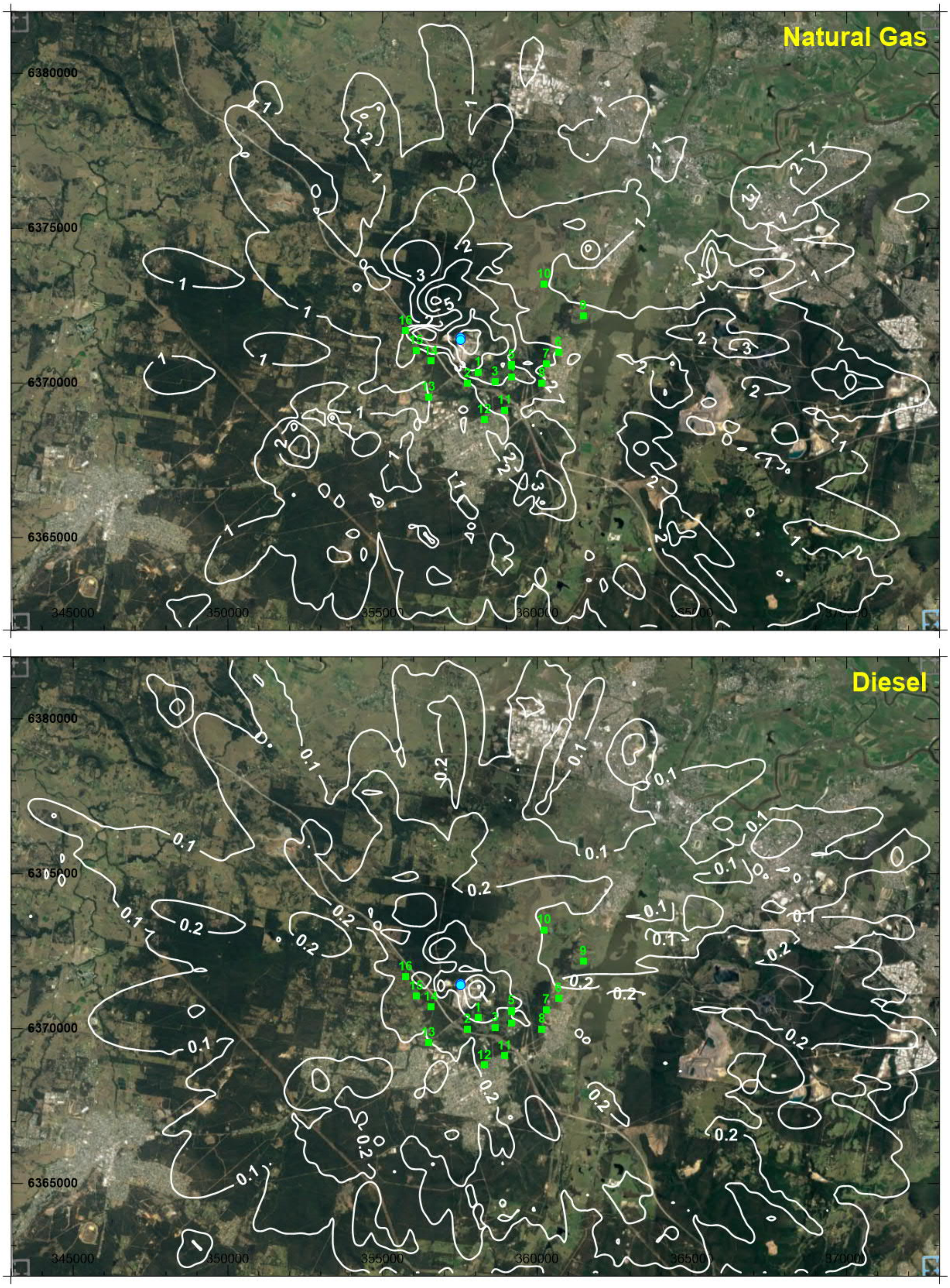


Figure 6-5: Maximum 1-hour average SO_2 GLC ($\mu g/m^3$): natural gas (top) and diesel (bottom)

6.3.3 Calpuff results: maximum 24-average SO_2 GLC

The Calpuff results for maximum 24-hour average SO_2 GLCs (µg/m^3) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

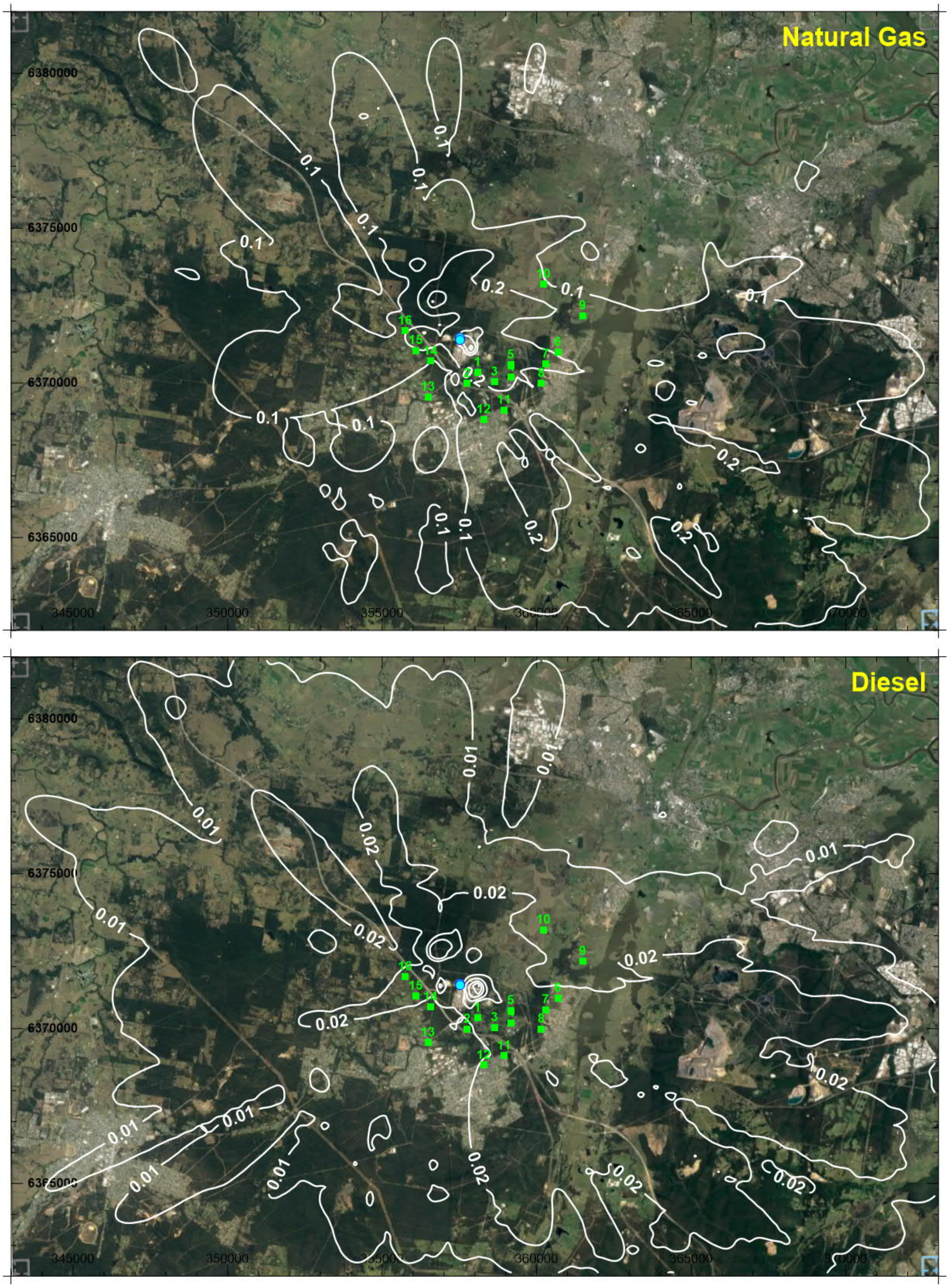


Figure 6-6: Maximum 24-hour average SO_2 GLC (µg/m^3): natural gas (top) and diesel (bottom)

6.3.4 Calpuff results: annual average SO_2 GLC

The Calpuff results for annual average SO_2 GLCs (μg/m^3) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

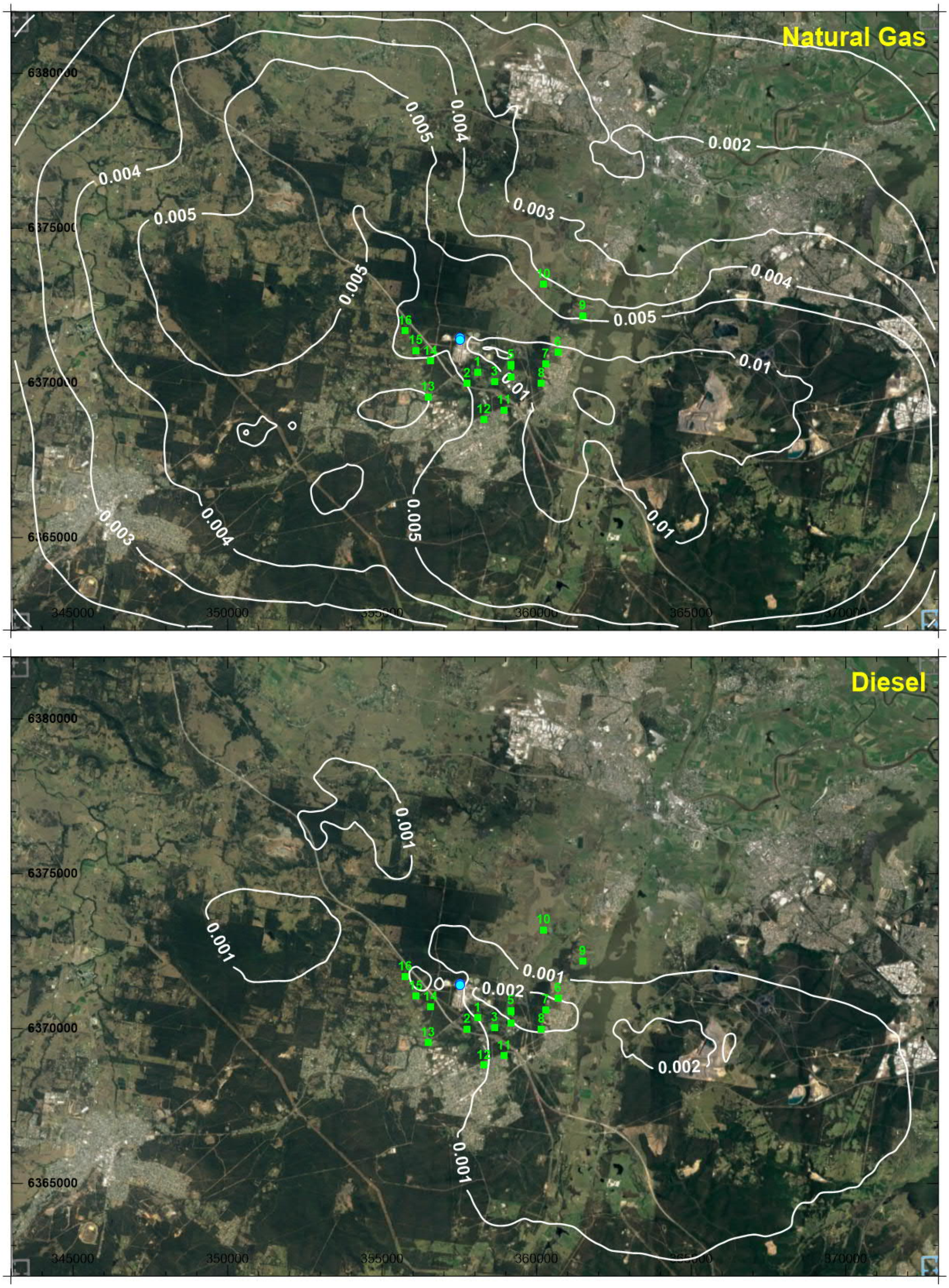


Figure 6-7: Annual average SO_2 GLC (μg/m^3): natural gas (top) and diesel (bottom)

6.3.5 Summary and Analysis of results: SO_2

This section provides a summary of all Calpuff results for SO_2 for the 9600 Grid Receptors (GR) and the worst case (highest) results for the 16 sensitive receivers (referred to in the model as Discrete Receptors (DR). Summaries of Calpuff results for SO_2 for the OCGT's operating at 100 per cent load are provided in Table 6.3 (natural gas-fuelled); and Table 6.4 (diesel-fuelled). The units for all SO_2 concentrations are $\mu g/m^3$. The notes apply to both tables.

Table 6.3: Summary of Calpuff results for SO_2: natural gas-fuelled; 100% load ($\mu g/m^3$)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
10 minute[1]	712	219.257	219.508	219.270	30.83%
1 hour	570	183.290	183.500	183.301	32.19%
24 hour	228	18.765	18.551	18.803	8.25%
annual	60	4.204	4.211	4.218	7.03%

Table 6.4: Summary of Calpuff results for SO_2: diesel-fuelled; 100% load ($\mu g/m^3$)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
10 minute[1]	712	219.257	219.520	219.259	30.83%
1 hour	570	183.290	183.510	183.292	32.19%
24 hour	228	18.765	18.555	18.770	8.23%
annual	60	4.204	4.213	4.207	7.02%

1. 10-minute averages for SO_2 estimated from hourly averages using Peak-to-Mean Ratios (PMR): 1.88 (point sources, from Calpuff results for hourly average GLCs); and 1.20 (volume sources, from monitoring results for hourly average GLCs); see Section 5.6.

Note: Temperature 25^oC.

The Calpuff results for cumulative, ambient SO_2 concentrations due to emissions from the Proposal, including estimates for background SO_2, are low in comparison to the impact assessment criteria. The results for maxima (columns 4 & 5) are very similar to background (columns 3) because the modelled contributions due to the Proposal were very small. The results indicate there is no significant risk of air quality impacts due to SO_2 emissions from the Proposal operating at 100 per cent load, whether natural gas-fuelled or diesel-fuelled, at any time of the year.

6.4 Calpuff results for particulate matter as $PM_{2.5}$

6.4.1 Calpuff results: maximum 24-hour average $PM_{2.5}$ GLC

The Calpuff results for maximum 24-hour average $PM_{2.5}$ GLCs ($\mu g/m^3$) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

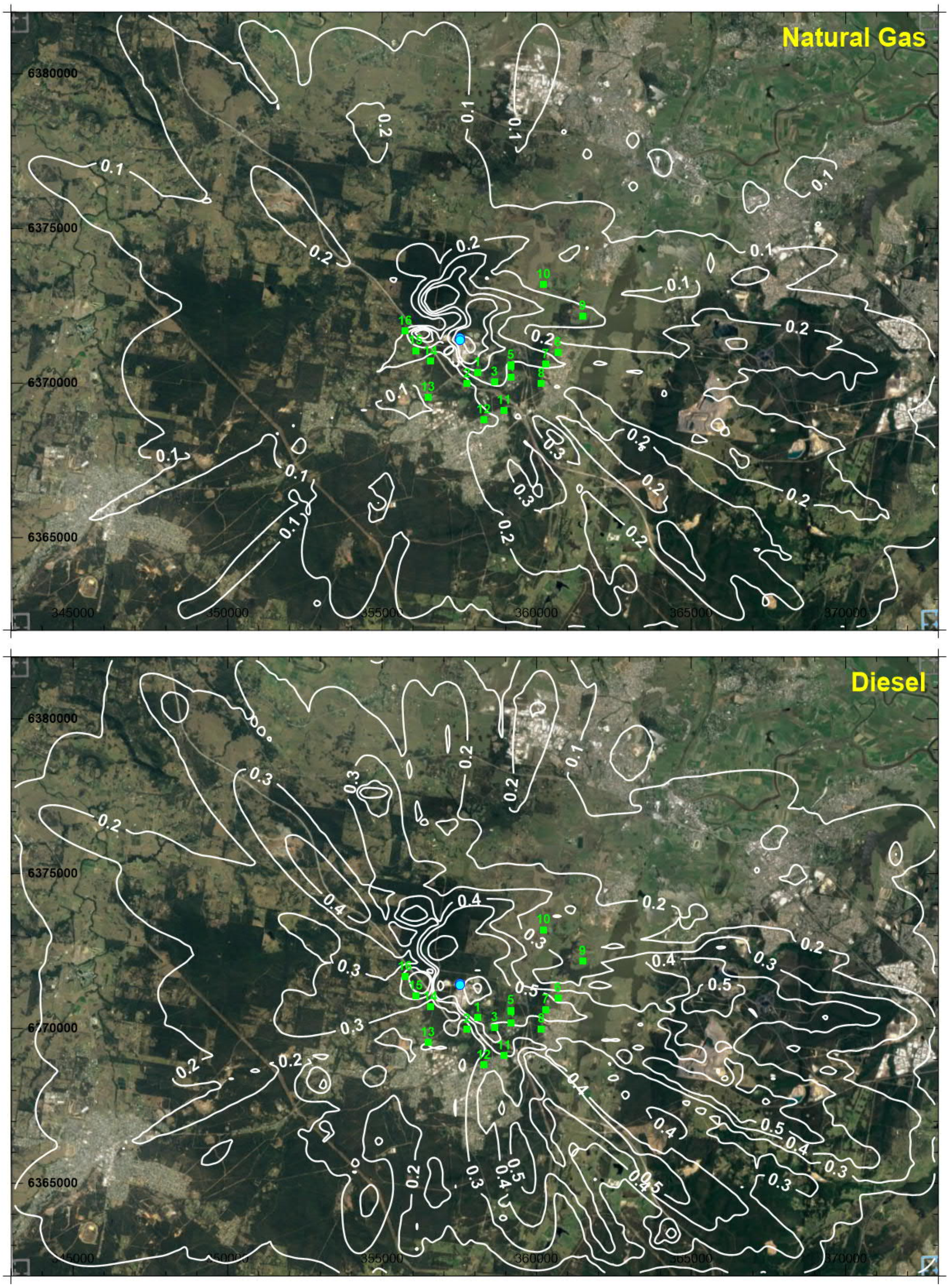


Figure 6-8: Maximum 24-hour average $PM_{2.5}$ GLC ($\mu g/m^3$): natural gas (top) and diesel (bottom)

6.4.2 Calpuff results: annual average $PM_{2.5}$ GLC

The Calpuff results for annual average $PM_{2.5}$ GLCs ($\mu g/m^3$) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

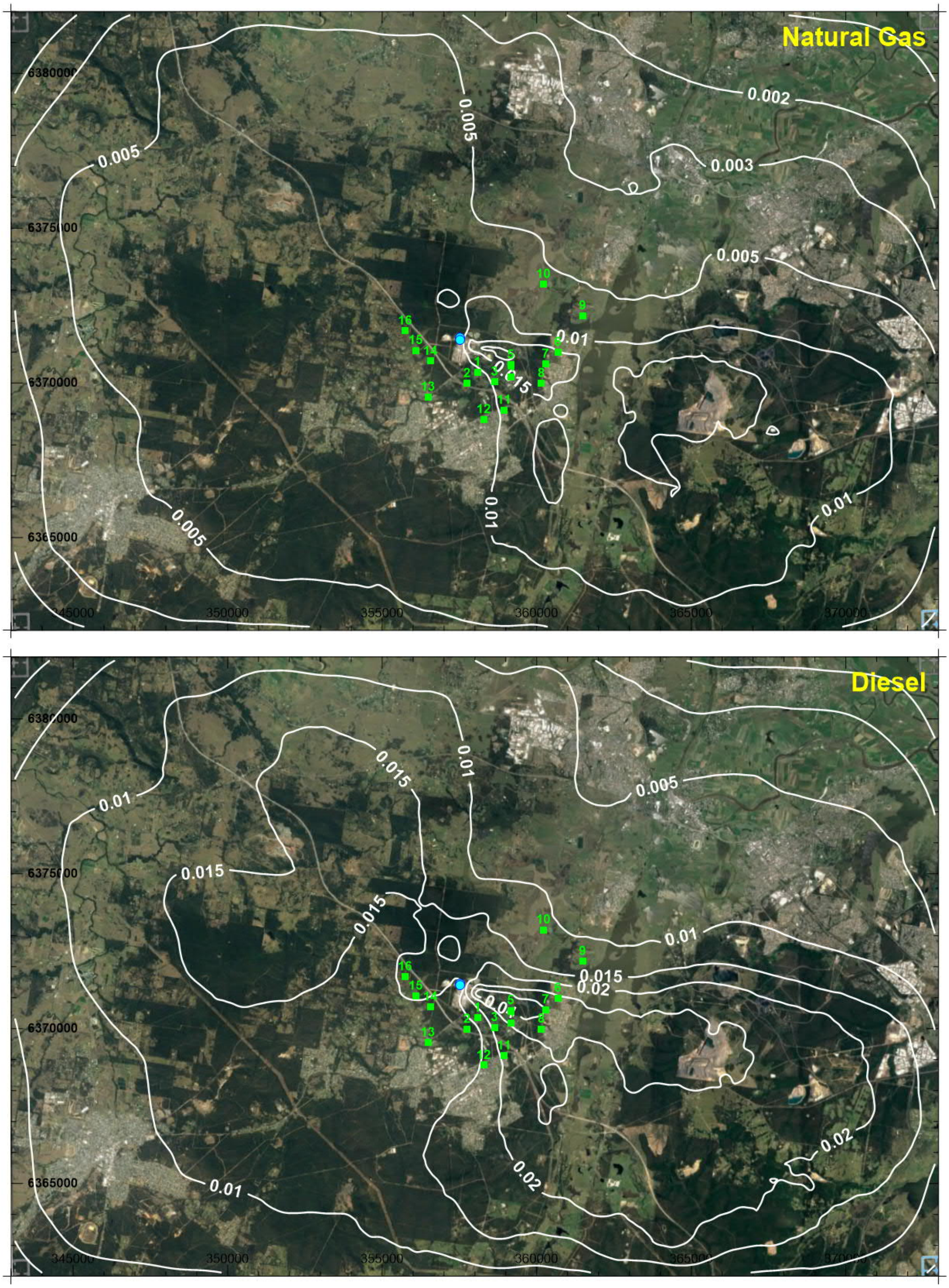


Figure 6-9: Annual average $PM_{2.5}$ GLC ($\mu g/m^3$): natural gas (top) and diesel (bottom)

6.4.3 Summary and analysis of results: $PM_{2.5}$

This section provides a summary of all Calpuff results for $PM_{2.5}$ for the 9600 Grid Receptors (GR) and the worst case (highest) results for the 16 sensitive receivers (referred to in the model as Discrete Receptors (DR). Summaries of Calpuff results for $PM_{2.5}$ for the OCGT's operating at 100 per cent load are provided in Table 6.5 (natural gas-fuelled); and Table 6.6 (diesel-fuelled). The units for all $PM_{2.5}$ concentrations are $\mu g/m^3$. The notes apply to both tables.

Table 6.5: Summary of Calpuff results for $PM_{2.5}$: natural gas-fuelled; 100% load ($\mu g/m^3$)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
24 hours	25	24.917	25.255	25.075	101.02%
Annual	8	8.670	8.691	8.688	108.64%

Table 6.6: Summary of Calpuff results for $PM_{2.5}$: diesel-fuelled; 100% load ($\mu g/m^3$)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
24 hours	25	24.917	25.828	25.262	103.31%
Annual	8	8.670	8.718	8.711	108.97%

1. Note the results for $PM_{2.5}$ are high due to existing, high background levels. The contributions due to the Proposal are 'very small' (annual averages), and 'small' (maximum 24-hour averages), relative to the criteria.

As can be seen from the model results, $PM_{2.5}$ contributions due to the Proposal would be negligible relative to air quality criteria and background concentrations. Concentrations of $PM_{2.5}$, including with potential contributions from the Proposal, would continue to be within the range of historically measured fluctuations in maximum concentrations for the region. Table 4.6 and Figure 4-4 showed the 24-hour average $PM_{2.5}$ concentrations measured at DPIE Beresfield monitoring station over 2015–2019. Over this 5-year period, exceedences of the $PM_{2.5}$ criteria occurred in all years except 2017. Reasons for the higher measured concentrations over this 5-year period were bushfire smoke and raised dust (the latter due to periods of higher wind speeds). All the predicted increases due to the Proposal are insignificant in relation to these background concentrations.

The worst-case DR results for 24-hour average $PM_{2.5}$ were obtained for the diesel-fuelled case; these are illustrated further by the time series plot shown in Figure 6-10. (The corresponding worst case DR results for the natural gas-fuelled case have a very similar appearance when plotted in this way). The plot shows results for 24-hourly average $PM_{2.5}$ concentrations ($\mu g/m^3$) for all 365 days of 2018: modelled results of the Proposal concentrations are shown in blue (without background); the background (EPA Beresfield) results are shown in yellow, which clearly dominate the results, and the NSW Assessment Criterion is shown in red (25 $\mu g/m^3$).

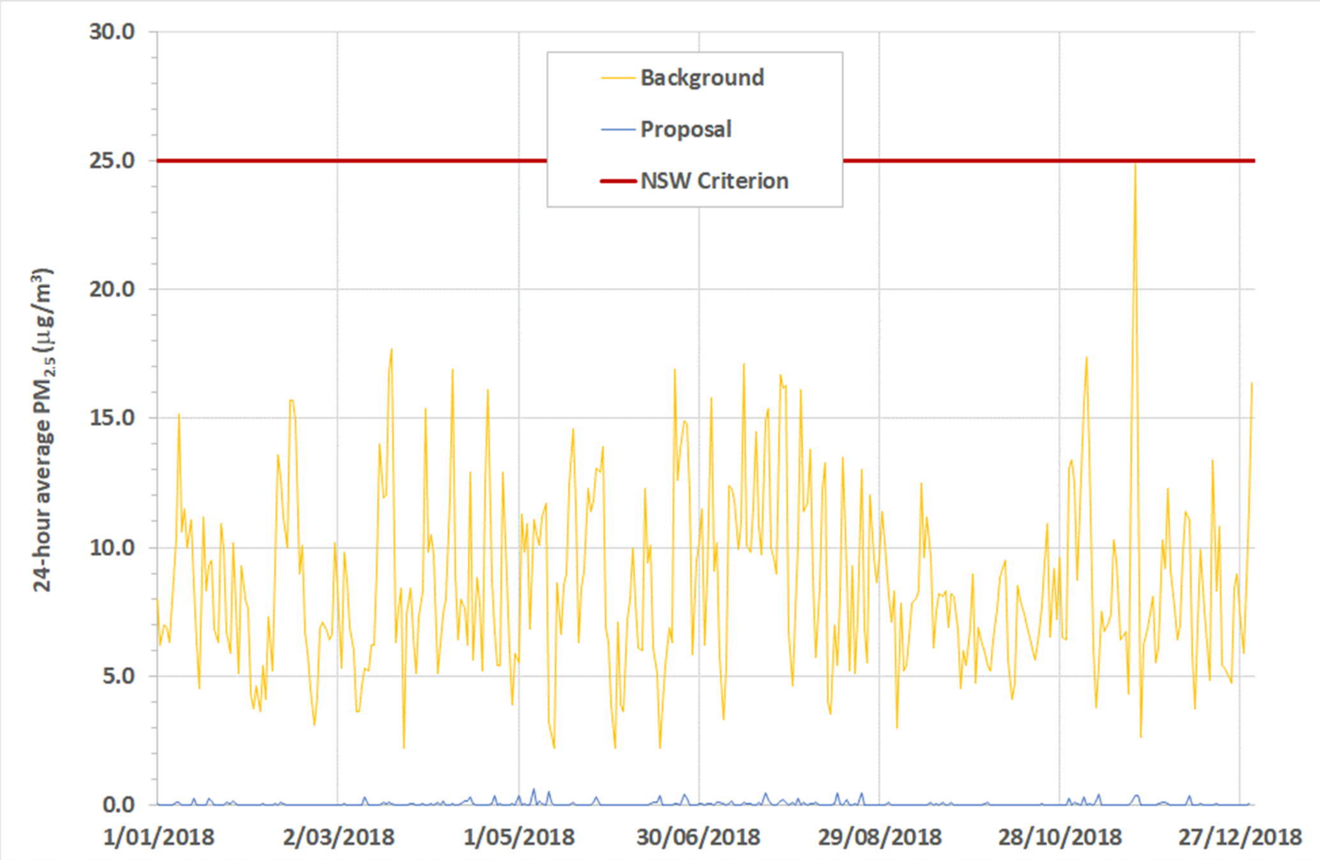


Figure 6-10: 24-hour average $PM_{2.5}$ background and modelled Proposal concentrations for worst case discrete receptor (diesel-fuelled case)

6.5 Calpuff results for nitrogen dioxide

6.5.1 Calpuff results: maximum 1-hour average NO_2 GLC

The Calpuff results for maximum hourly average NO_2 GLCs ($\mu g/m^3$) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only. Further analysis of the modelled NO_x results is provided in Section 6.5.3.

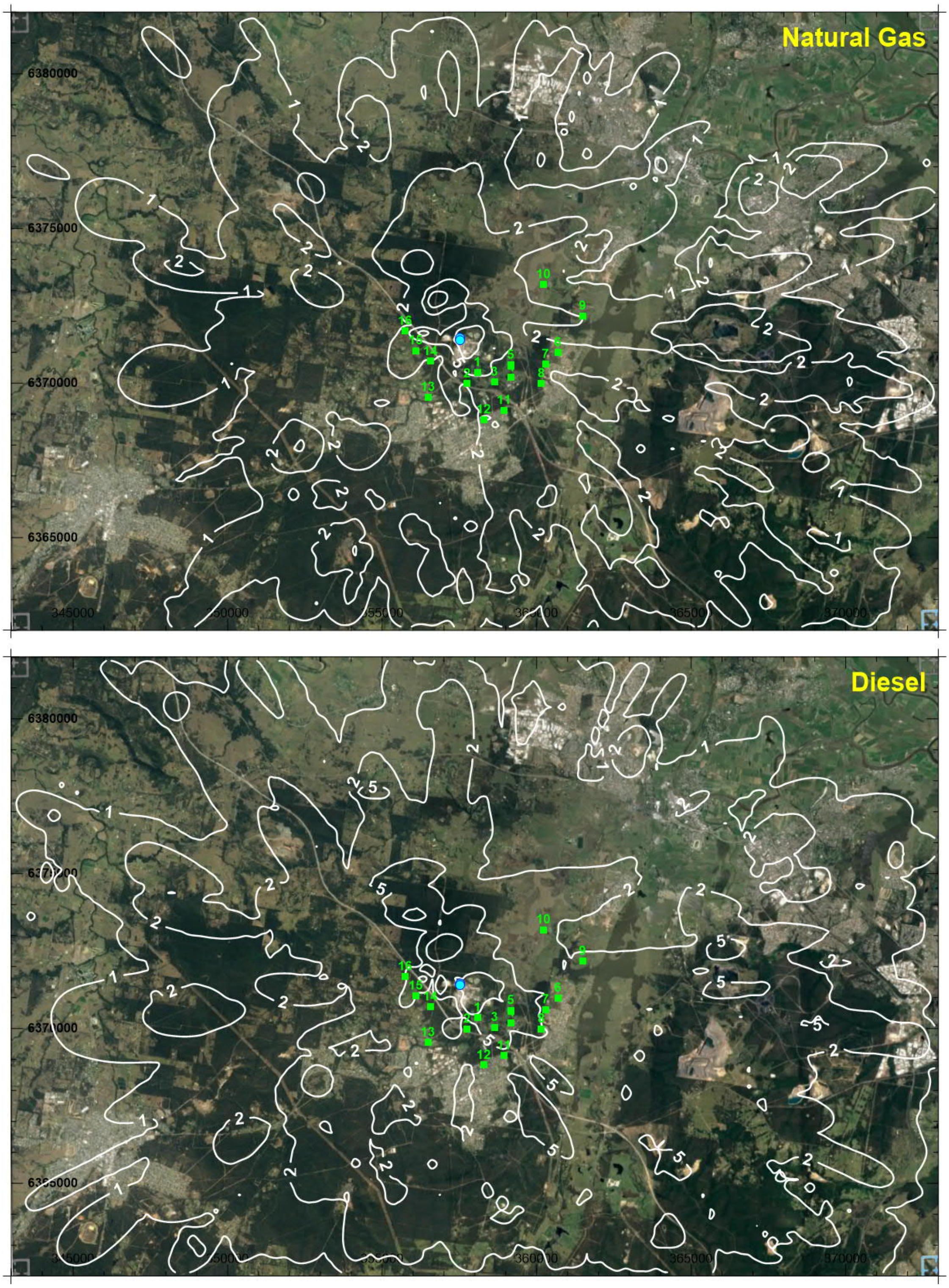


Figure 6-11: Maximum 1-hour average NO_2 GLC ($\mu g/m^3$): natural gas (top) and diesel (bottom)

6.5.2 Calpuff results: annual average NO_2 GLC

The Calpuff results for annual average NO_2 GLCs (μg/m^3) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only. Further analysis of the modelled NO_x results is provided in Section 6.5.3.

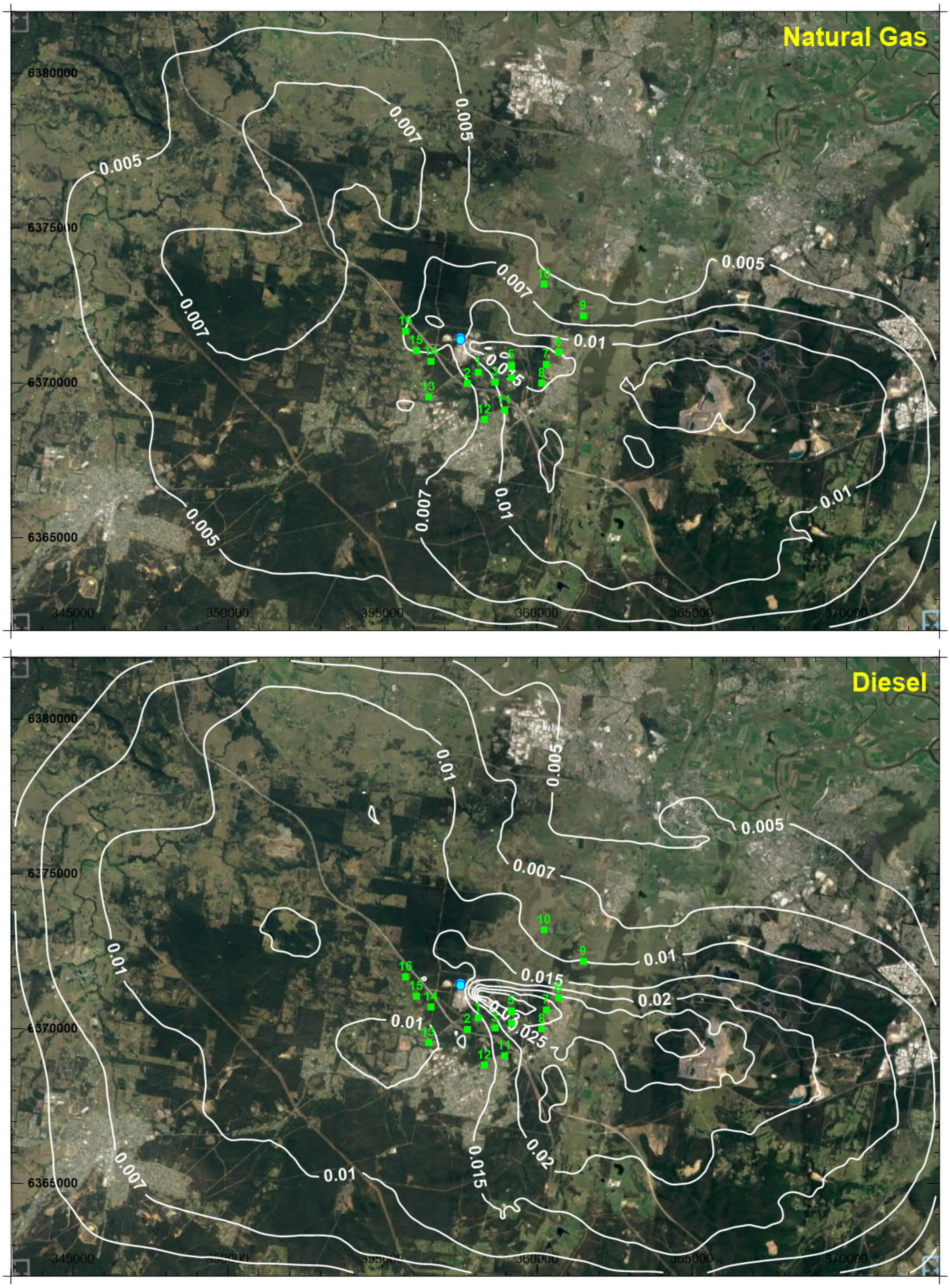


Figure 6-12: Annual average NO_2 GLC (μg/m^3): natural gas (top) and diesel (bottom)

6.5.3 Summary and Analysis of results: NO_2

This section provides a summary of all Calpuff results for NO_2 for the 9600 Grid Receptors (GR) and the worst case (highest) results for the 16 sensitive receivers (referred to in the model as Discrete Receptors (DR)). Summaries of Calpuff results for NO_2 for the OCGT's operating at 100 per cent load are provided in Table 6.7 (natural gas-fuelled); and Table 6.8 (diesel-fuelled). The notes apply to both tables.

Table 6.7: Summary of Calpuff results for NO_2: natural gas-fuelled; 100% load ($\mu g/m^3$)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
1h	246	75.209	78.387	75.290	31.86%
Annual	62	16.054	16.074	16.210	26.15%

Table 6.8: Summary of Calpuff results for NO_2: diesel-fuelled; 100% load ($\mu g/m^3$)

Average period	NSW Assessment Criterion	Max. background	Proposal max. GR result including background	Proposal max. DR result including background	Max. assessment result as fraction of Criterion
1h	246	75.209	95.876	75.328	38.97%
Annual	62	16.054	16.094	16.338	26.35%

1. The estimate of the NO_2/NO_x ratio (10%) used to analyse the GR results was determined by tuning the results for the GRs plus a statistical estimate for background NO_2 to the results obtained by the more involved OLM Level 2 assessment method. The tuning led to the selection of a NO_2/NO_x ratio of 10% for the Proposal contributions with the 99th percentile 1-hour average background NO_2 concentration. The purpose of this tuning procedure was to select a NO_2/NO_x ratio for plotting the Proposal NO_2 contributions; i.e., the contour plots in this section. Note that this ratio is different to the NO_2/NO_x ratio of around 20%-30% generally observed for higher NO_x concentrations.

The results for NO_2 were determined using the Ozone Limiting Method (refer Section 5.7), which combined the Calpuff results for NO_x dispersion at ground level with EPA Beresfield monitoring data for NO_2 and O_3. There were no predicted exceedances of the impact assessment criteria for NO_2. Many of the results for maxima (columns four and five) were very similar to background (column three) because most of the modelled contributions due to the Proposal were small.

The worst-case DR results for hourly average NO_2 were obtained for the diesel-fuelled case; these are illustrated further by the time series plot shown in Figure 6-13. (The corresponding worst case DR results for the natural gas-fuelled case have a very similar appearance when plotted in this way). The plot shows results for hourly average NO_2 concentrations ($\mu g/m^3$) for all 8760 hours of 2018: modelled results of the Proposal concentrations are shown in blue (without background); background (EPA Beresfield) concentrations are shown in yellow, which clearly dominate the results, and the NSW Assessment Criterion is shown in red (246 $\mu g/m^3$).

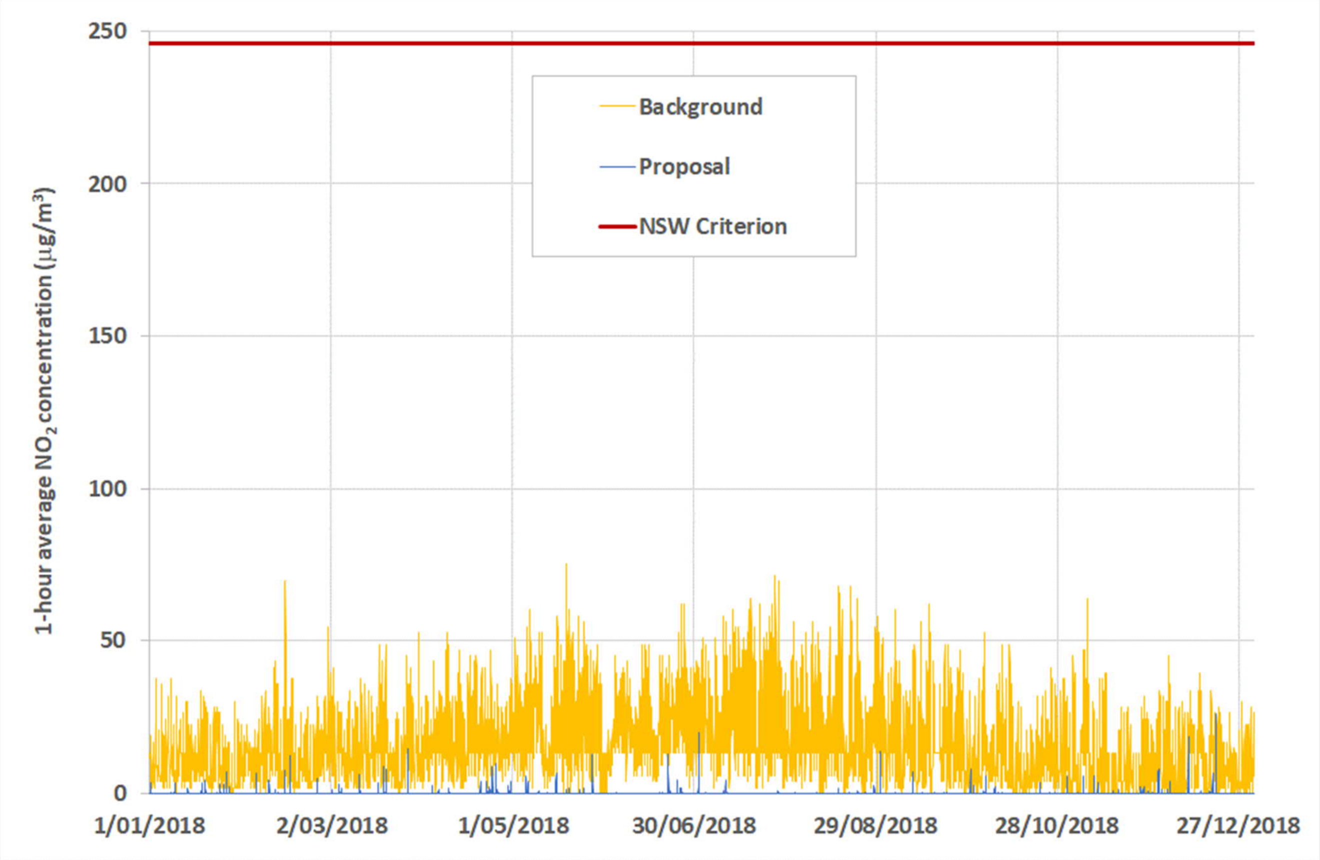


Figure 6-13: Hourly average NO_2 background and modelled Proposal concentrations for worst case discrete receptor (diesel-fuelled case)

6.6 Calpuff results for hydrocarbons (VOCs)

6.6.1 Calpuff results: 99.9th percentile one-hour average CH_2O GLC

The Calpuff results for 99.9th percentile (PC) one-hour average formaldehyde (CH_2O) GLCs (μg/m^3) for the 9600 grid receptors are depicted in the figures below (natural gas–top; diesel–bottom); Proposal contributions only.

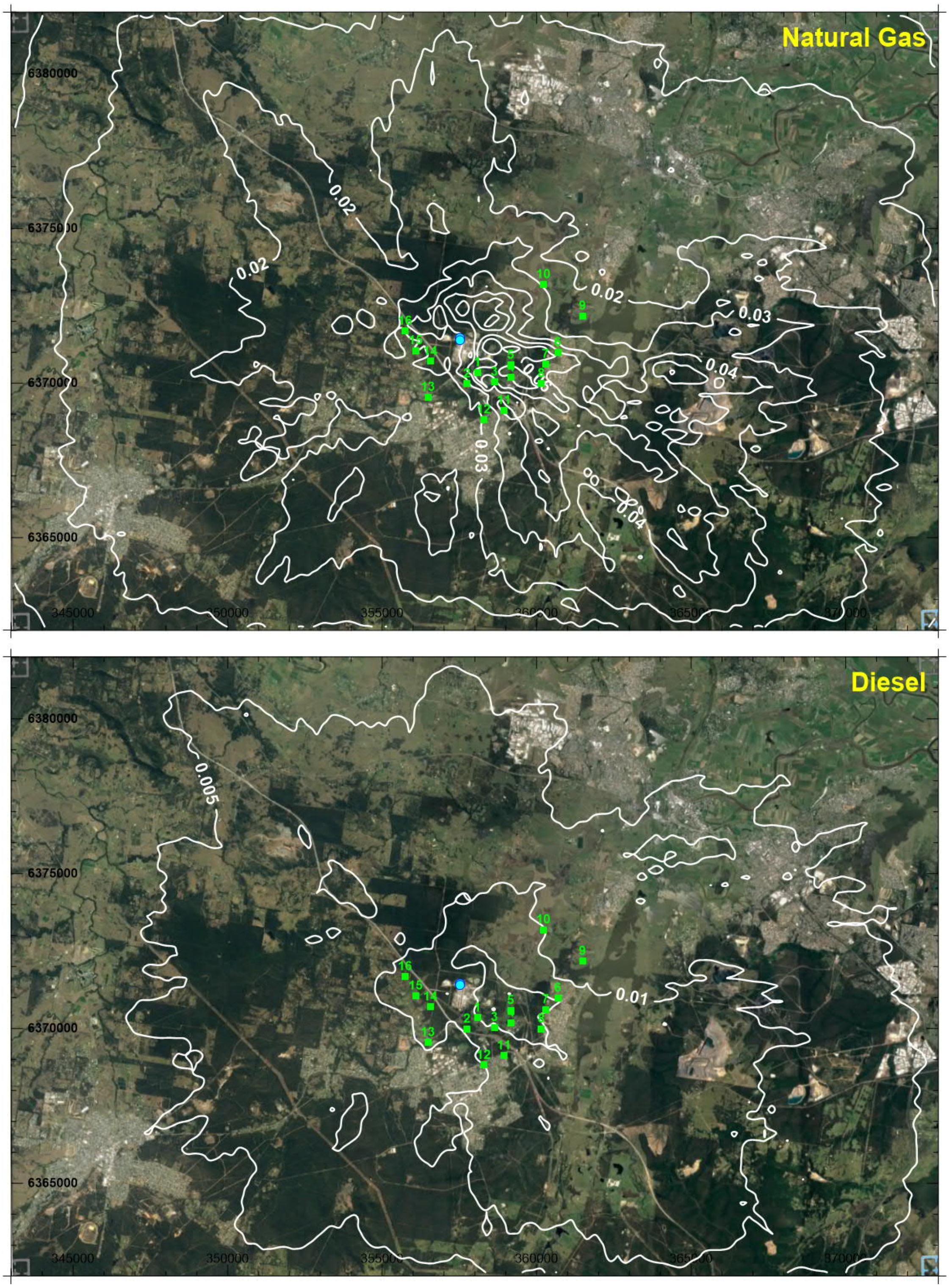


Figure 6-14: 99.9th PC 1-hour average CH_2O GLC (μg/m^3): natural gas (top) and diesel (bottom)

6.6.2 Calpuff results: 99.9th percentile 1-hour average acrolein and B(a)P GLC

The Calpuff results for the 9600 grid receptors for the following two cases are depicted in the figure below, for the Proposal contributions only: (1) 99.9th percentile (PC) one-hour average acrolein GLCs (μg/m^3) for the natural gas fuel case only; and (2) 99.9th percentile (PC) one-hour average B(a)P GLCs (μg/m^3) for the diesel fuel case only.

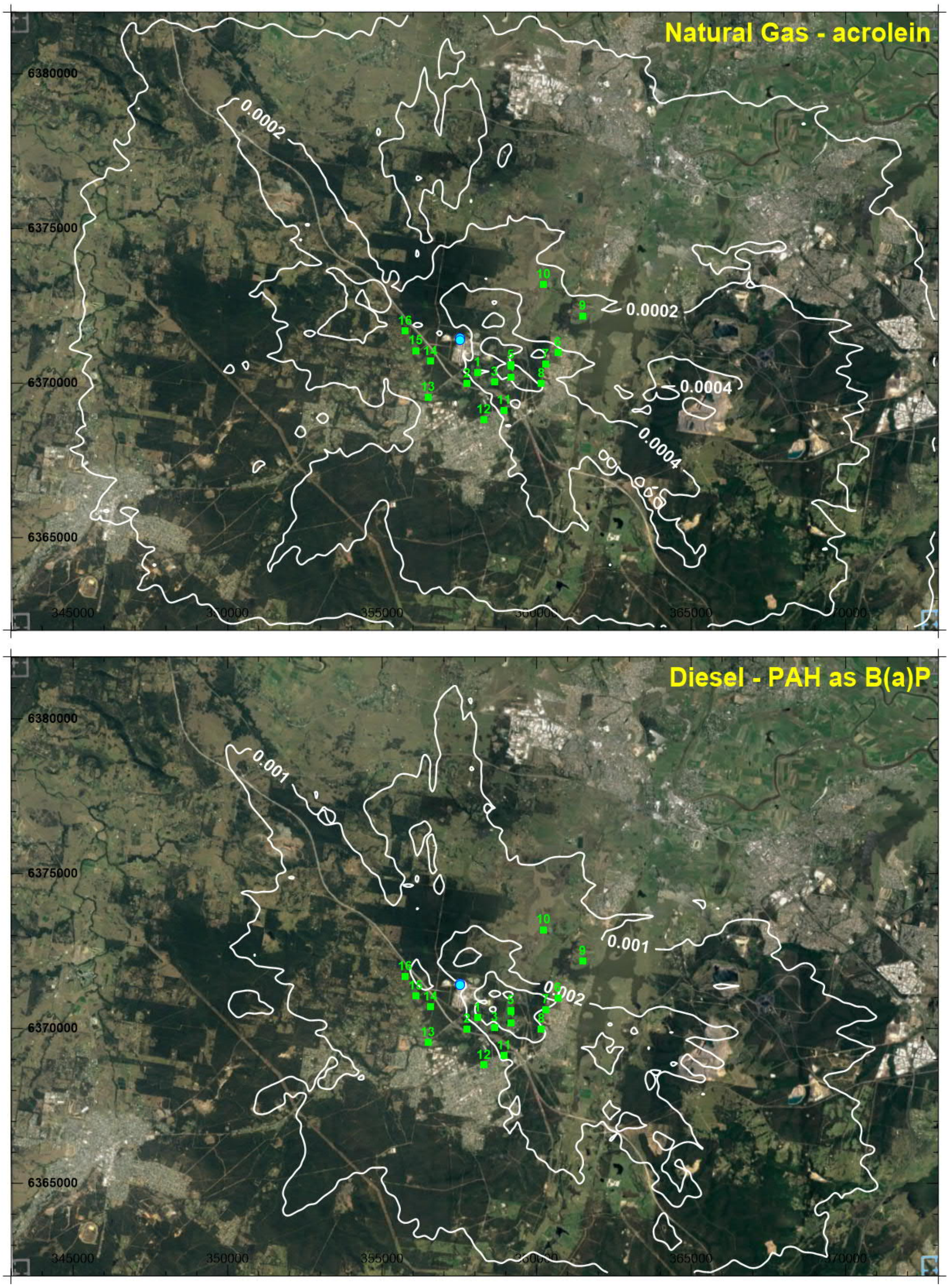


Figure 6-15: 99.9th PC one-hour average GLCs: natural gas–acrolein (μg/m^3) (top); and B(a)P–diesel (μg/m^3) (bottom)

6.6.3 Summary and analysis of VOCs results

This section provides a summary of Calpuff results for the 9600 Grid Receptors (GR) and the worst case (highest) results for the 16 sensitive receivers (referred to in the model as Discrete Receptors (DR)), for the highest risk VOCs identified for the Proposal: formaldehyde (CH_2O) and acrolein for the natural gas fuel case (Table 6.9), and CH_2O and PAH as B(a)P for the diesel fuel case (Table 6.10). The units for all VOC concentrations are $\mu g/m^3$.

In accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* Level 2 assessment method, comparisons of model results with criteria for the VOCs do not include estimates for background i.e. is not 'cumulative'. (The estimates for background VOC concentrations in Section 0 provided context only for this assessment).

Table 6.9: Summary of Calpuff results: 99.9th percentile 1h-average VOCs: natural gas-fuelled case ($\mu g/m^3$)

VOC	NSW Assessment Criterion	Estimated background	Proposal GR result excluding background	Proposal DR result excluding background	Max. assessment result (Proposal); fraction of Criterion
formaldehyde	20	2.7	0.080	0.067	0.40%
acrolein	0.42	0.3	0.001	0.001	0.17%

Table 6.10: Summary of Calpuff results for 99.9th percentile 1h-average VOCs: diesel-fuelled case ($\mu g/m^3$)

VOC	NSW Assessment Criterion	Estimated background	Proposal GR result excluding background	Proposal DR result excluding background	Max. assessment result (Proposal); fraction of Criterion
formaldehyde	20	2.7	0.031	0.027	0.15%
PAH as B(a)P	0.4	0.001	0.004	0.004	1.09%

There were no predicted exceedances of the impact assessment criteria for formaldehyde (20 $\mu g/m^3$). The background formaldehyde concentrations are significantly higher than predicted contributions due to the Proposal.

There were no predicted exceedances of the impact assessment criteria for acrolein (0.42 $\mu g/m^3$) and B(a)P (0.4 $\mu g/m^3$). The background acrolein concentrations are significantly higher than predicted contributions due to the Proposal. Proposal contributions of B(a)P are greater than background, but overall the B(a)P concentrations are very low, of the order one per cent of the criteria.

In summary, the risk of air quality impacts due to VOC emissions from the Proposal is very low.

6.7 Ozone assessment

This section describes the results of an O_3 assessment undertaken using the NSW EPA's *Tiered Procedure for Estimating Ground-Level Ozone Impacts from Stationary Sources* (NSW EPA, 2011); see Section 5.8. The conclusion is the O_3 contributions caused by the Proposal are predicted to be negligible.

Comparisons of maximum O_3 concentrations measured by DPIE Beresfield over 2016-2020 inclusive were used to determine that the Proposal Site is in an NSW EPA (2011)-specified ozone non-attainment area; i.e., the background O_3 levels are relatively high; a summary of the results is provided in Table 6.11.

Table 6.11: Ozone attainment area determination

Parameter	Max. 1h O_3 (ppb)	Max. 4h O_3 (ppb)	Notes
Average of maxima 2016-2020	98.9	83.8	Bushfire emissions affect high results
NEPM standards (NEPC, 2016) x82%	82	65.6	EPA (2011) referred to the equivalent of NEPC (2016) standards
Result	Project air quality study area in Lower Hunter is an ozone non-attainment area because the concentrations exceeded the NSW EPA (2011) thresholds (82% of NEPM standards).		

The second step was to compare the Proposal's annual NO_x/VOC emissions with the threshold of 90 tonnes/year. The NO_x emission from the Proposal might be up to 139 tonnes per year using a capacity factor of 10%, (the capacity factor estimate used here was for this calculation only), which triggered a 'Level 1' assessment using the Level 1 screening tool. DPIE measurements of O_3 from Beresfield, Newcastle and Wallsend over a five-year period, 2016-2020 inclusive, were used as input to the tool; the results are detailed in Table 6.12.

Table 6.12: Results from Level 1 screening assessment tool

Parameter	Proposal result, NG fuel	Proposal result, diesel fuel	Assessment result
Maximum 1-hour average O_3 increment	1.9 ppb	2.7 ppb	Greater than screening impact level (0.5 ppb)
Maximum 4-hour average O_3 increment	1.2 ppb	1.7 ppb	Greater than screening impact level (0.5 ppb)

The results for the maximum increments listed in Table 6.12 exceed the screening impact levels of 0.5 ppb, and also the maximum allowable increment for ozone non-attainment areas, which is 1 ppb. As such some further investigations were carried out.

First, to place these increments determined for the Proposal into context, recent NSW DPIE (2020) results for O_3 in the NSW GMR, using sophisticated photochemical modelling techniques, are shown in Figure 6-16. These show that even in the power generation intensive regions of Sydney and Wollongong, power stations cause increases in the O_3 concentrations of approximately 1 ppb only over the study area; i.e., small concentrations similar to those determined for this project. In Figure 6-16, note the contributions from power stations (approx. 0.1-1 ppb) and other human-made sources (approx. 1-10 ppb) are lower than typical values background values (natural sources, approx. 18.4-22.0 ppb). These model results by DPIE (2020) are assumed to provide more accurate O_3 concentrations than the results of the EPA NSW (2011) tool listed in Table 6.12.

It is noted that the new NEPM replaces the maximum hourly and 4-hourly average O_3 standards with a single maximum 8-hour average (see Section 3.5). Measurements of 8-hour average O_3 concentrations at the DPIE Beresfield monitoring station exceed the new standard (65 ppb), due to bushfires, road traffic, other industrial sources, and the natural background. These exceedences can be expected to continue in future, but the current Beresfield dataset shows they should be rare; i.e., approximately 1-2 exceedences per year. Again using the NSW EPA (2011) method it is expected the 8-hour average O_3 contribution from the project will be less than 1 ppb (approximately 2 $\mu g/m^3$); in summary, a minimal increase in O_3 levels is expected in future due to the Proposal.

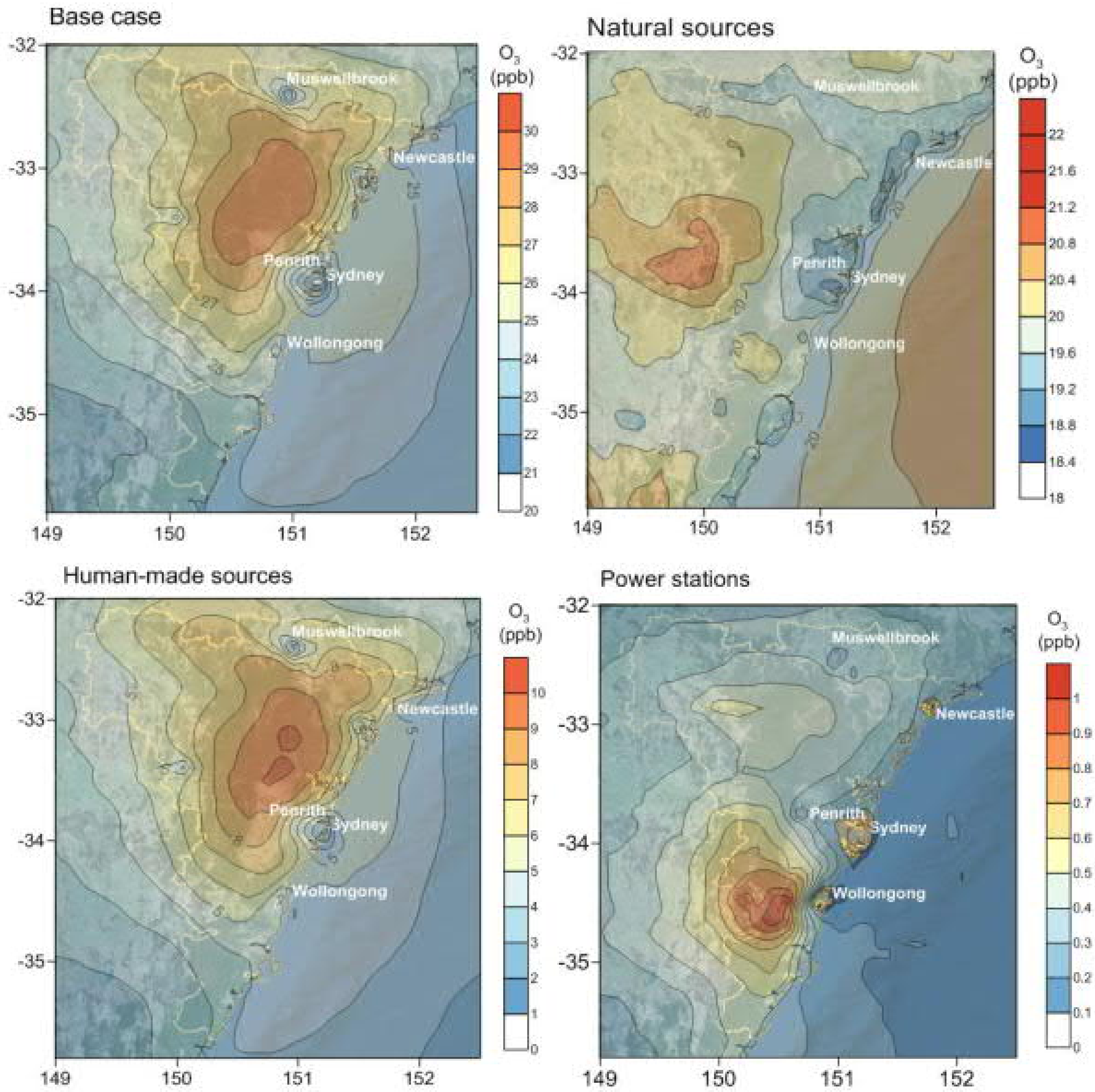


Figure 6-16: NSW DPIE (2020) results for daily maximum 1-hour average O_3 concentration (ppb)

As a final illustration, the O_3 measurements at DPIE Beresfield over 2016-2020 are shown in Figure 6-17 (1-hour and 4-hour averages); and Figure 6-18 (rolling 8-hour averages). These results are typical of the variations in O_3 concentrations throughout the Lower Hunter. The peaks in the O_3 concentrations that can be clearly seen to occur in the summer months are very likely due to emissions from bushfires, road traffic, and other sources, superimposed on background levels typically around 20 ppb. Variations in the O_3 concentrations such as these occur all over the Lower Hunter region, and other parts of the NSW GMR. In comparison the maximum O_3 contributions calculated for the Proposal (0-3 ppb), are small, rare, and will occur in very few locations in comparison. In addition, these Proposal increments are not at levels to cause additional exceedances over background levels.

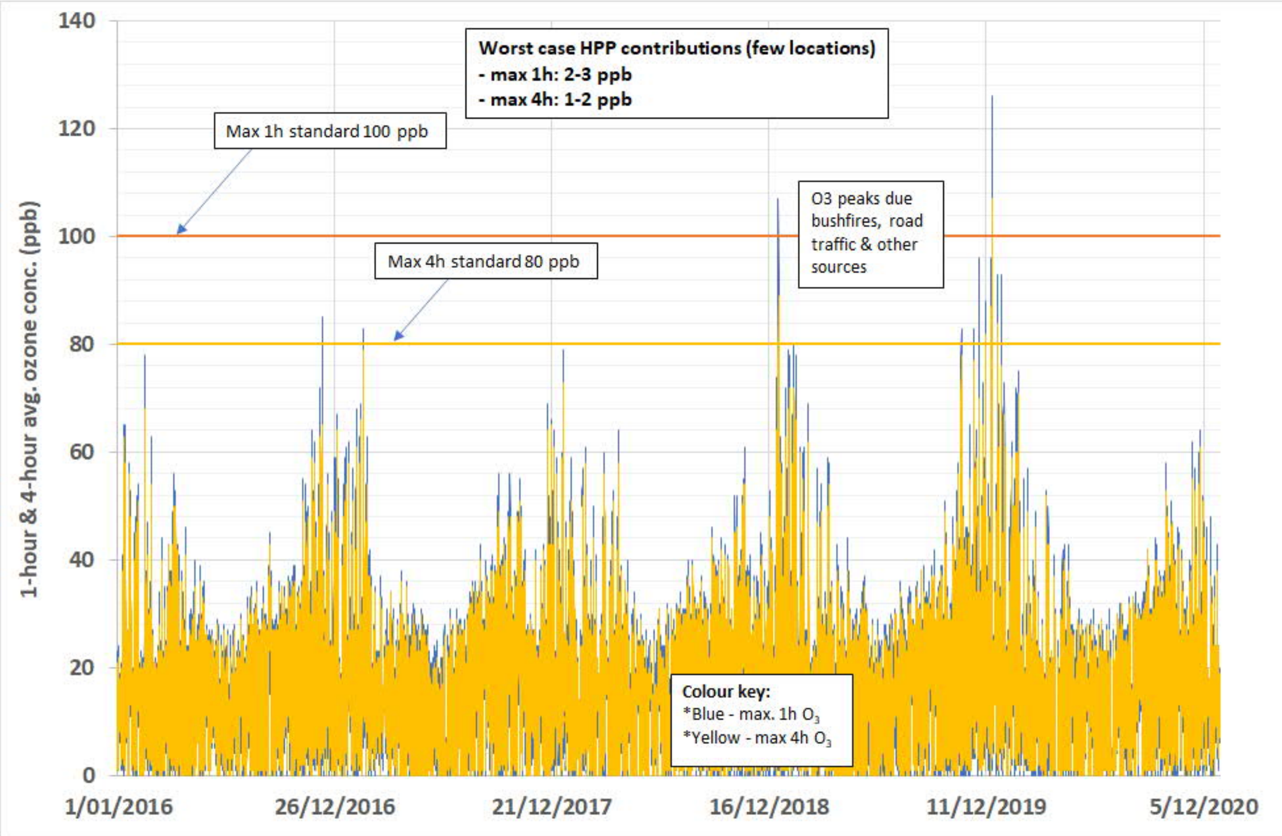


Figure 6-17: DPIE Beresfield maximum 1-hour and 4-hour average O_3 concentration (ppb)

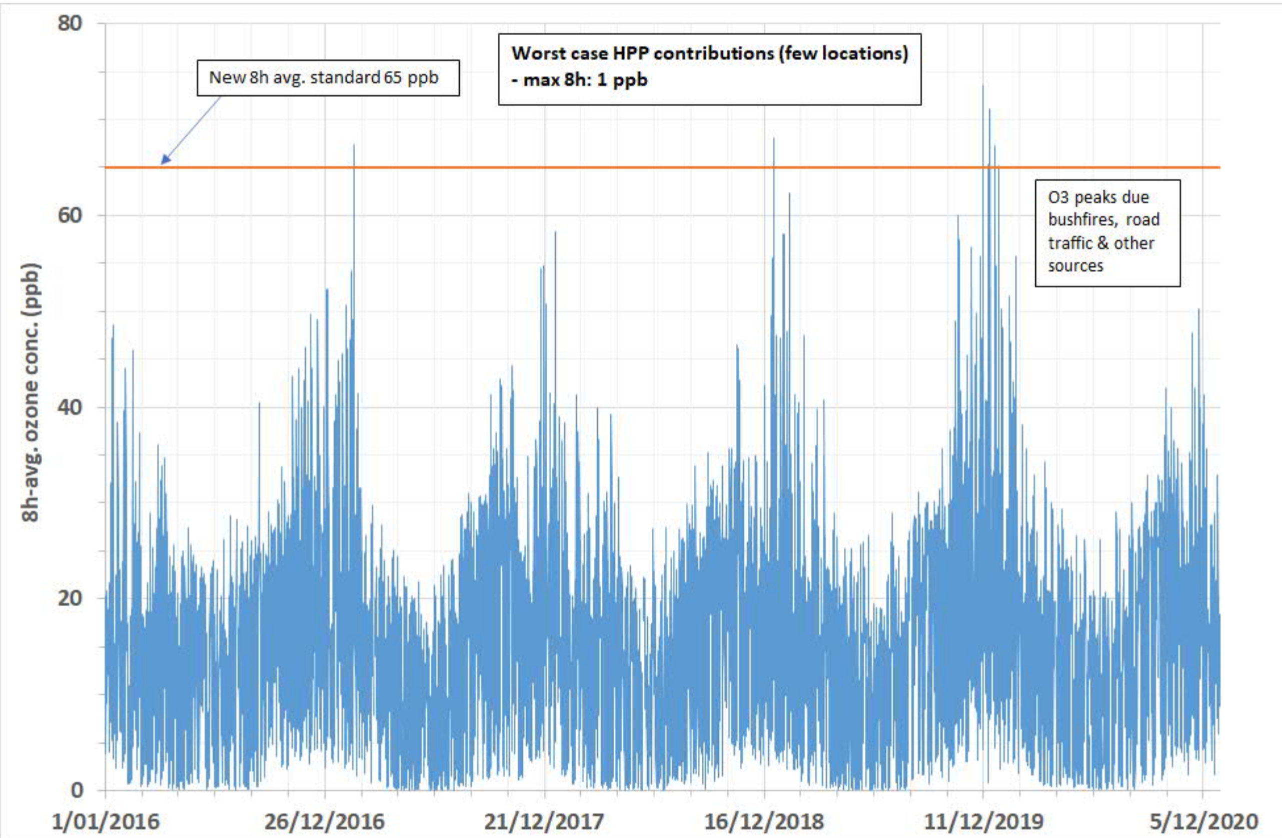


Figure 6-18: DPIE Beresfield maximum 8-hour average O_3 concentration (ppb)

6.8 Plant start-up and shut-down

The purpose of this section is to provide an assessment of the likely plant start-up and shut-down, and variable load operations.

For this peaker power station, the OCGT starts will occur for a fraction of the year. For example, based on 1000 operating hours in a year and run-times including start-ups varying from say between 1-4 hours, the number of starts would be between approximately 250 and 1000 per year. With a start-up duration to full load of approximately 30 minutes, the time spent on starts (and with corresponding start-up emissions) equates to between 1% and 6% of a year (NG and diesel use). For lower plant operating hours, the percentage of the year which is spent on start-ups and shut-downs is even further reduced.

A representative F-Class GT ramp-up time from start initiation to maximum speed is approximately 20 minutes, at which point the GT is placed under load. From the 20-minute mark, the time to ramp up from zero to full load is approximately 10 minutes, making a total of approximately 30 minutes from engine start to full load.

A summary of typical air emissions behaviour (i.e. mass emission rates) during start-up of a typical F Class GT assessed for this Proposal is provided in the following points:

- For a natural gas-fuelled GT, start-up behaviour over 60 minutes would typically involve:
  - CO emission increases to a peak approximately 15 minutes after ignition, then drops back rapidly to its 100% load value at approximately 20 minutes after ignition. The start-hour average CO concentration is expected to be greater than the 100% load value, however in relation to air quality impact this will be insignificant as the ambient air quality standard for CO is a rolling 8-hour average, and the predicted ambient CO concentrations are low in any case (see summary of results in Section 6.2.4).
  - NO_x emission rate ramps approximately linearly to its 100% load value, potentially with some peaks in the NO_x in the first 30 minutes. The start-hour average NO_x concentration is expected to be less than or approximately equal to the 100% load value (immaterial to this assessment).
  - The SO_x and PM_{10} emissions ramp up approximately linearly to their maximum load values, so the emissions are low during start-up. The start-hour average concentrations for both substances are less than their 100% load values (immaterial to this assessment).
- For a diesel-fuelled GT, start-up behaviour over 60 minutes would typically involved:
  - CO emission increases to a peak approximately 15 minutes after ignition, then drops back rapidly to its 100% load value at approximately 20 minutes after ignition. The start-hour average CO concentration is expected to be greater than the 100% load value, however in relation to air quality impact this will be insignificant as the ambient air quality standard for CO is a rolling 8-hour average, and the predicted ambient CO concentrations are low in any case (see summary of results in Section 6.2.4), and diesel fuel starts will be rare (2% capacity factor vs. 10% capacity factor for NG).
  - NO_x emission increases to a peak approximately 20 minutes after ignition, then drops back rapidly to its 100% load value about 5 minutes later. In this case the start-hour average NO_x concentration is expected to be higher than the 100% load value, however this represents a low risk of air quality impact because the predicted ambient NO_2 concentrations are low (see summary of results for NO_2 in Section 6.5.3), and diesel fuel starts will be rare (2% capacity factor vs. 10% capacity factor for NG).
  - The SO_x and PM_{10} emissions ramp up approximately linearly to their maximum load values, so the emissions are low during start-up. The start-hour average concentrations for both substances are less than their 100% load values (immaterial to this assessment).

Calpuff sensitivity testing was undertaken for the OCGT emissions characteristics for a 50% load case to investigate the air quality effects associated with (1) plant start-up; and (2) running the plant continuously at half-load (Section 2.3.4). The emissions parameters for the GTs at 100% load and 50% load were detailed in Section 2.5; a summary of some of the main differences between these two scenarios is provided in Table 6.13.

Table 6.13: Gas turbine operating and air emissions parameters: 50% and 100% loads

Fuel scenario and parameter	50% load	100% load
NG fuelled GT		
Exhaust flow rate at exhaust temperature	1,298.9 m^3/s	1884.5 m^3/s
Exhaust temperature	673.6 °C	634.8 °C
Exhaust velocity	17.2 m/s	25.0 m/s
NO_x emission rate	20.5 g/s	34.0 g/s
CO emission rate	5.0 g/s	8.3 g/s
SO_x (as SO_2) emission rate	1.61 g/s	2.61 g/s
PM_{10} emission rate	1.9 g/s	3.3 g/s
Diesel fuelled GT		
Exhaust flow rate at exhaust temperature	1,223.0 m^3/s	1666.6 m^3/s
Exhaust temperature	591.4 °C	523.6 °C
Exhaust velocity	16.2 m/s	22.1 m/s
NO_x emission rate	33.4 g/s	49.4 g/s
CO emission rate	24.2 g/s	35.8 g/s
SO_x (as SO_2) emission rate	0.25 g/s	0.36 g/s
PM_{10} emission rate	3.7 g/s	5.7 g/s

The Calpuff sensitivity tests showed the model-predicted GLCs for the 50% load case were lower than for the full-load case, even though the exit velocities were lower for half-load (Table 6.13). As such the main focus of this assessment was on the worst case operation; i.e., the 100% load case. The results of the sensitivity tests for the worst case grid receptor are provided in Table 6.14.

Table 6.14: Results of Calpuff sensitivity tests: 50% and 100% loads

Fuel scenario and parameter	50% load	100% load
NG fuelled GT – Calpuff results for max. 1h-average GLC		
CO (mg/m^3)	0.03	0.063
SO_2 ($\mu g/m^3$)	9.72	19.7
Diesel fuelled GT – Calpuff results for max. 1h-average GLC		
CO (mg/m^3)	0.143	0.313
SO_2 ($\mu g/m^3$)	1.47	3.2

OCGT plant shut-down involves reducing then cutting the fuel supply to the gas turbines, with shut-down duration estimated to be approximately 20 minutes from full-load to 'flame-off'. The emissions during shut-down are expected to be insignificant in comparison with other operating modes; i.e., causing ground-level concentrations of air pollutants lower than predicted by modelling for this assessment, and were not considered further for this assessment.

7. Recommendations

This section sets out recommended air emissions (stack) monitoring for the power station, based on the results of this assessment.

A meteorological monitoring station would provide valuable real-time data to the operator in relation to the potential for air quality impacts at sensitive receptor locations. As such a meteorological monitoring station is recommended to be operated when the power station is generating electricity, with at least the following measurement parameters acquired in accordance with Australian Standards:

- Five-minute average wind speed and wind direction
- Five-minute average temperature.

For each gas turbine exhaust stack, it is recommended oxides of nitrogen be measured continuously when the plant is generating electricity.

The following air quality measurement parameters are recommended for monitoring once per year:

- Carbon dioxide
- Dry gas density
- Moisture content
- Molecular weight of stack gases
- Oxygen
- Temperature
- Velocity
- Volumetric flowrate.

8. Conclusion

An assessment of air pollutant emissions associated with the Proposal has been completed. The Proposal is an open cycle gas turbine power station to be fuelled primarily by natural gas, and diesel as a backup. The key objective of the assessment was to determine the potential change in ambient air quality that may occur as a result of operation of the Proposal.

The key air pollutants associated with the Proposal are: carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter as $PM_{2.5}$ and the hydrocarbons or Volatile Organic Compounds (VOCs): formaldehyde and acrolein when the power station is fuelled by natural gas, and formaldehyde and Benzo(a)pyrene (B(a)P) when fuelled by diesel.

In relation to air emissions from the Proposal, the key air quality issues identified were due to existing high background levels of $PM_{2.5}$ and O_3.

A detailed review of the existing environment was carried out including an analysis of measured concentrations of key air quality indicators (CO, NO_2, and $PM_{2.5}$) from representative monitoring stations. The following conclusions were made in relation to the existing air quality and meteorological conditions:

- Wind patterns in the vicinity of the Proposal are characteristic of the Lower Hunter Valley, with the prevailing winds being from the west-northwest
- Measured CO, NO_2 and SO_2 concentrations have been consistently below NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) air quality impact assessment criteria
- Measured O_3 occasionally exceed assessment criteria nearly every year, typically due to emissions from bushfires and controlled burns
- Measured $PM_{2.5}$ levels increased across NSW and the Hunter region from 2017 to 2019 due to dust from the widespread intense drought, and smoke from bushfires and hazard reduction burning. These events adversely influenced air quality with multiple days observed when $PM_{2.5}$ concentrations exceeded EPA assessment criteria.

Model predictions were assessed at selected sensitive receptors located near the Proposal Site, and these were considered as representative of the worst case sensitive receptor locations in the Lower Hunter. The key outcomes of the air quality assessment were:

- The Proposal will meet NSW Government requirements for air pollutant concentrations in the exhaust gases
- Operation of the proposed power station will lead to small increases, relative to air quality criteria, in ambient (ground level) concentrations of the air pollutants: CO, NO2, SO2, $PM_{2.5}$ and the VOCs: formaldehyde, acrolein and PAHs as B(a)P
- The air pollutants of concern are those where background levels are already high; i.e., NO_2 (because O_3 levels are high) and PM2.5
- Modelling predicts the Proposal will meet NSW Government requirements for ground level concentrations for air pollutants CO, NO2, SO2, PM2.5 and the VOCs: formaldehyde, acrolein and PAHs as B(a)P
- While during extreme events, such as bushfires, there is the potential for ground level concentrations of PM2.5 to be above the GLC criteria, the Proposal is not predicted to cause any additional exceedances due to its negligible contribution.

Based on modelling, increases in NO_2 concentrations due to the Proposal are unlikely to cause exceedences of NO_2 criteria. However, O_3 background levels are high, and any additional NO_x emissions represent an increase to regional NO_x that contribute to the formation of O_3 in the wider region. A detailed photochemical modelling study was outside the scope of this study. However, it would be reasonable to assume the power station NO_x emissions would have the effect of slightly reducing O_3 levels in its immediate vicinity (O_3 destruction), but contributing to a very slight increase in regional O_3 levels.The model results show that $PM_{2.5}$ contributions due to the Proposal would be negligible relative to air quality criteria. Concentrations of $PM_{2.5}$, including with potential contributions from the Proposal, would continue to be within the range of historically measured fluctuations in maximum concentrations for the region. This means that in a year not affected by bushfires, emissions from the Proposal are very unlikely to cause exceedances of $PM_{2.5}$ criteria. In a year affected by bushfires, measurements of $PM_{2.5}$ will be representative of the high concentrations due to bushfire smoke.

The assessment demonstrated the Proposal's operations, whether fuelled by natural gas or diesel, are not expected to cause adverse air quality impacts in the vicinity of the Proposal Site nor in the wider Lower Hunter region. This conclusion was based on modelling procedures undertaken in accordance with NSW EPA *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016) and which conservatively assumed that the power station would be operating continuously, which is not what approval is being sought for. The implementation of 'best practice' gas turbine engineering technology for the Proposal, such as Dry Low Emission (DLE) combustion system to minimise NO_x emissions, will minimise air quality impacts.

9. References

AGL, (2019) *Newcastle Power Station Project EIS*. Available at : https://www.agl.com.au/-/media/aglmedia/documents/about-agl/how-we-source-energy/newcastle-power-station/agl-newcastle-power-station-executive.

Australian Government (2006): Australian Government, Department of Health and Aging, *Priority Existing Chemical Assessment Report No. 28, Formaldehyde*, National Industrial Chemicals Notification and Assessment Scheme, November 2006.

Australian Government (2008): Australian Government, National Pollutant Inventory, *Emission Estimation Technique Manual for Combustion Engines*, Version 3.0, Department of the Environment, Water, Heritage and the Arts, 2008.

ANSTO (2020): Australian Nuclear Science and Technology Organisation, *Fine particle pollution peaks during bushfires*, Published 12th May 2020 by ANSTO Staff, https://www.ansto.gov.au/news/fine-particle-pollution-peaks-during-bushfires, web page accessed by Jacobs 29 Jan 2021.

J. Barclay and J. Scire, *Generic Guidance and Optimum Model Settings for the CALPUFF Modeling System for Inclusion into the 'Approved Methods for the Modeling and Assessments of Air Pollutants in NSW, Australia'*, Prepared For: NSW Office of Environment and Heritage, Sydney Australia, Atmospheric Studies Group, TRC Environmental Corporation, March 2011.

Borgas (2000): M. Borgas, *The mathematics of whiffs and pongs*, presented at Enviro2000 Odour Conference, Clean Air Society of Australia and New Zealand, Sydney, 9-13 April 2000.

Boyce (2012): Meherwan P. Boyce, *Gas Turbine Engineering Handbook*, Fourth Edition, Elsevier, 2012.

CSIRO (2016): Day, S., Tibbett, A., Sestak, S., Knight, C., Marvig, P., McGarry, S., Weir, S., White, S., Armand, S., van Holst, J., Fry, R., Dell'Amico, M., Halliburton, B., Azzi, M. *Methane and Volatile Organic Compound Emissions in New South Wales*. CSIRO, Australia, 2016.H. N. Duc, L.T.-C. Chang, T. Trieu, D. Salter and Y. Scorgie, *Source Contributions to Ozone Formation in the New South Wales Greater Metropolitan Region, Australia*. Atmosphere, 9, 443 (32 pages), 13 November 2018.

H. Duc, D. Salter, M. Azzi, N. Jiang, L. Warren, M. Riley, S. White, T. Trieu, L. Chang, and X. Barthelemy, *The Effect of Lockdown Period during CoViD-19 Pandemic on Air Quality in Sydney Region*. Department of Planning, Industry and Environment NSW, Australia, CASANZ 2021 – Online, 17-21 May 2021.

Energy Australia (2020) Tallawarra Stage B Gas Turbine Power Station Modification Environmental Assessment report. Available at:
https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=MP07_0124-MOD-2%2120200629T062951.075%20GM

Environ (2011): ENVIRON Australia Pty Ltd., *Tiered Procedure for Estimating Ground-Level Ozone Impacts from Stationary Sources*, Prepared for: Office of Environment and Heritage, September 2011.

EPA (2016): NSW Environment Protection Authority, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*, State of NSW and Environment Protection Authority, August 2005, minor revisions November 2016, published January 2017.

EPA (2019): NSW Environment Protection Authority, *About air pollution*, https://www.epa.nsw.gov.au/your-environment/air/air-nsw-overview/about-air-pollution, July 2019 (web page accessed 21 January 2021).

EPA (2021): NSW Environment Protection Authority, *NSW State of Environment, Air Quality*, (Current), https://soe.epa.nsw.gov.au/all-themes/climate-and-air/air-quality, accessed 22 January 2021.

European Commission (2017): Best Available Techniques (BAT) reference Document for Large Combustion Plants [LCP BREF 2017]; EUR 28836 EN; doi:10.2760/949. Prepared by the European Integrated Pollution Prevention and Control Bureau. Available at: http://www.eipie.eu/the-sevilla-process/lcp-bref and http://www.eipie.eu/storage/files/Ref%204.pdf

Guerette, E., Paton-Walsh, C., Galbally, I., Molloy, S., Lawson, S., Kubistin, D., Buchholz, R., Griffith, D. W.T., Langenfelds, R. L., Krummel, P. B., Loh, Z., Chambers, S., Griffiths, A., Keywood, M., Selleck, P., Dominick, D., Humphries, R. & Wilson, S. R., *Composition of clean marine air and biogenic influences on VOCs during the MUMBA campaign*. Atmosphere, 10 (7), 383-1-383-30, 2019.

Hurley (2008a). P. Hurley, *TAPM V4. User Manual*, CSIRO Marine and Atmospheric Research Internal Report No. 5, October 2008.

Hurley (2008b). P. Hurley, *TAPM V4. Part 1: Technical Description*, CSIRO Marine and Atmospheric Research, Paper No. 25, October 2008.

Hurley, P., M. Edwards and A. Luhar, *TAPM V4. Part 2: Summary of Some Verification Studies*, CSIRO Marine and Atmospheric Research Paper No. 26, October 2008.

Jacobs (2020): Jacobs, *Kurri Kurri OCGT Gas Fired Power Station*, Environmental and Planning Scoping Report, 18 December 2020.

Keywood, M., Selleck, P., Reisen, F., Cohen, D., Chambers, S., Cheng, M., Cope, M., Crumeyrolle, S., Dunne, E., Emmerson, K., Fedele, R., Galbally, I., Gillett, R., Griffiths, A., Guerette, E.-A., Harnwell, J., Humphries, R., Lawson, S., Miljevic, B., Molloy, S., Powell, J., Simmons, J., Ristovski, Z., and Ward, J. *Comprehensive aerosol and gas data set from the Sydney Particle Study*, Earth Syst. Sci. Data, 11, pp.1883–1903, 2019.

NEPC (2016): National Environment Protection Council, *National Environment Protection (Ambient Air Quality) Measure*, prepared by the Department of the Environment, Federal Register of Legislative Instruments F2016C00215, prepared 25/02/2016.

NEPC (2019): National Environment Protection Council, *Annual Report 2017-2018*, Commonwealth of Australia and each Australian state and territory, 2019.

NEPC (2021a): National Environment Protection Council, *National Environment Protection (Ambient Air Quality) Measure*, prepared by the Office of Parliamentary Counsel, Canberra, Authorised Version F2021C00475, registered 26/05/2021.

NEPC (2021b): National Environment Protection Council, *Key Changes to the Ambient Air Quality Measure agreed by Ministers April 2021*, http://www.nepc.gov.au/nepms/ambient-air-quality/variation-ambient-air-quality-nepm-ozone-nitrogen-dioxide-and-sulfur, accessed 16 July 2021.

NSW DPEI (2020): NSW Department of Planning, Industry and Environment, *Air Quality Study for the NSW Greater Metropolitan Region, A Sydney Air Quality Study Program Report*. Environment, Energy and Science, DPIE, EES 2020/0488, November 2020.

NSW EPA (2016): NSW Environment Protection Authority, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*, EPA 2016/0666, August 2005, minor revisions November 2016, published January 2017.

NSW Gov. (2004): NSW Government, *Ambient Concentrations of Polycyclic Aromatic Hydrocarbon Species in NSW*, Ambient Air Quality Research Project (1996–2001), Internal working paper no. 3, Atmospheric Science Section, Department of Environment and Conservation (NSW), December 2004.

NSW Gov. (2012): NSW Government, *Lower Hunter Ambient Air Quality Review of Available Data*, State of NSW and Office of Environment and Heritage, 2012.

NSW Gov. (2020a): NSW Government, *Protection of the Environment Operations (Clean Air) Regulation 2010*, Current version 8 January 2019, file last modified 25 March 2020, accessed by Jacobs 12 November 2020.

NSW Gov. (2020b): NSW Government, Department of Planning, Industry and Environment, *New South Wales Annual Compliance Report 2018, National Environment Protection (Ambient Air Quality) Measure*, 2020.

NSW Gov. (2020c): NSW Government, Department of Planning, Industry and Environment, *New South Wales Annual Compliance Report 2019,* 12 November 2020, https://www.environment.nsw.gov.au/topics/air/nsw-air-quality-statements/annual-air-quality-statement-2019, website accessed by Jacobs 29 Jan 2021.

NSW Gov. (2021): NSW Government, Department of Planning, Industry and Environment, *Current and Forecast Air Quality*, https://www.dpie.nsw.gov.au/air-quality, website accessed Dec 2020 and Jan 2021.

PEI (2021): Petroleum Equipment Institute, *Distillate*, www.pei.org/wiki/distillate, accessed 23 Jan 2021.

Scire et al. (2000a): J.S. Scire, F.R. Robe, M.E. Fernau., R.J. Yamartino, *A User's Guide for the CALMET Meteorological Model (Version 5)*, Earth Tech Inc., January 2000.

Scire et al. (2000b): J.S. Scire, D.G. Strimaitis, R.J. Yamartino, *A User's Guide for the CALPUFF Dispersion Model (Version 5)*, Earth Tech Inc., January 2000.

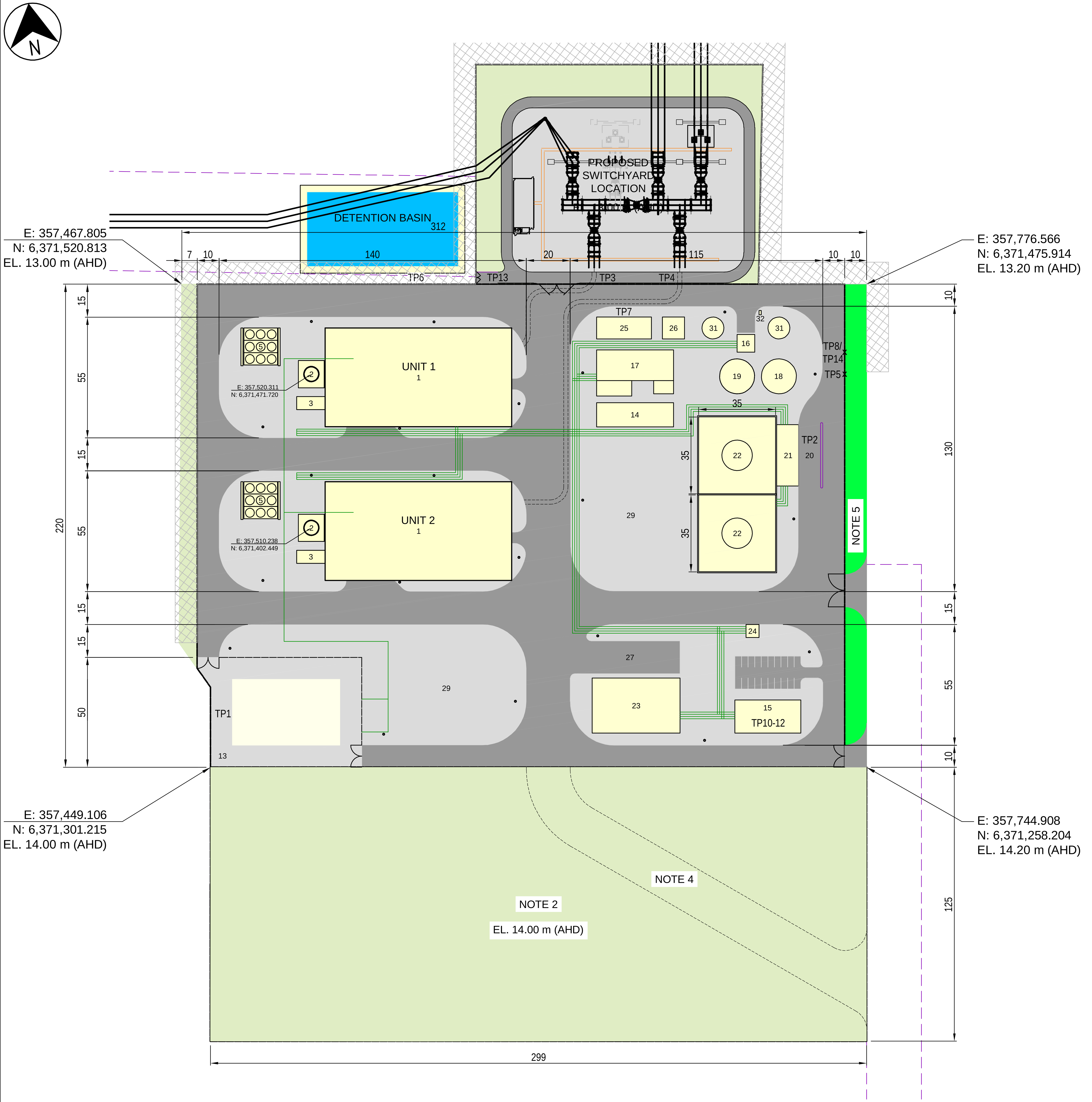
Teal Group Corporation, *Mitsubishi Hitachi Power Systems M501/M701*, Heavy Industrial Gas Turbines, November 2019.

U.S. DHHS (2004): U.S. Department of Health and Human Services, *Toxicological Profile for Acrolein*, Public Health Service, Agency for Toxic Substances and Disease Registry, August 2007.

U.S. EPA (2004): U.S. Environmental Protection Agency, AP-42, Vol. I, *3.1: Stationary Gas Turbines*, Final Section - Supplement F, April 2000, https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-fifth-edition-volume-i-chapter-3-stationary-0, accessed 24 January 2021.

Appendix A. Power Station Concept Arrangement – OCGT F-Class Layout

DATE: 24/03/2021 3:44:50 PM NAME: INCAMPO, ROBERTO
LOCATION: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IS354500\01 Design\DRAWINGS\IS354500-0000-MC-DRG-000X.dwg



PLANT LAYOUT
SCALE 1:1000

NOTES:

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS & ARE APPROXIMATE ONLY.
2. POWER STATION BUFFER ZONE.
3. DELETED.
4. INDICATIVE ROADWAY SHOWN ON ADJACENT LOT FOR HEAVY VEHICLE TRANSPORT TO SITE.
5. AREA IDENTIFIED FOR LANDSCAPE SETBACK.
6. COORDINATES BASED ON GDA2020 GIS DATUM.

TERMINAL POINTS:

TP1 GAS FUEL
TP2 DISTILLATE FUEL
TP3 HIGH VOLTAGE CONNECTION 1
TP4 HIGH VOLTAGE CONNECTION 2
TP5 POTABLE WATER
TP6 CLEAN PROCESS AND STORMWATER
TP7 WASTE OIL
TP8 SEWAGE
TP9 WASH WATER WASTE
TP10 COMMUNICATIONS
TP11 COMMUNICATIONS
TP12 COMMUNICATIONS
TP13 AUXILIARY & CONSTRUCTION POWER
TP14 TRADEWASTE WATER

NOTE: FINAL TERMINAL POINT LOCATIONS ARE YET TO BE CONFIRM

LEGEND:

1. GAS TURBINE POWER ISLAND
2. EXHAUST STACK
3. FIN FAN COOLERS
5. CLOSED CYCLE COOLING WATER COOLER
13. GAS RECEIVING STATION
14. MISC. ELECTRICAL AND MECHANICAL BoP EQUIPMENT
15. CONTROL ROOM AND ADMINISTRATION BUILDING
16. FIRE PUMP AREA
17. DEMINERALIZED WATER PLANT
18. POTABLE WATER TANK
19. DEMINERALIZED WATER TANK
20. FUEL OIL UNLOADING AREA
21. FUEL OIL PUMP STATION
22. FUEL OIL STORAGE TANKS
23. WORKSHOP
24. GATE HOUSE
25. OIL PIT INTERCEPTOR
26. NEUTRALISATION PIT OR TANK
27. HARDSTAND
29. LAYDOWN AREA
31. FIRE WATER TANK

SEALED ROADWAY
CRUSHED ROCK
LANDSCAPING
GRASS / ROAD BASE
BURIED SERVICES
FIRE HYDRANT

SCALE 1:1000 (A1) 20 10 0 20 40 60 80 100m

CONCEPT

REV	DATE	APP'D	REVISION	DRAWING NUMBER	REFERENCE DRAWING TITLE
A	XX.XX.21		ISSUED FOR INFORMATION		

Jacobs
ABN 37 001 024 095 and ACN 001 024 095
Jacobs Group (Australia) Pty Ltd
Level 7, 177 Pacific Highway
North Sydney, NSW 2060
AUSTRALIA
Tel: +61 2 9928 2100
Fax: +61 2 9928 2500
Web: www.jacobs.com

CLIENT: SNOWY HYDRO
PROJECT: KURRI KURRI POWER STATION STUDY

DRAWN	DRAWING CHECK	REVIEWED	APPROVED
R. INCAMPO		K. IVANUSIC	
DESIGNED: R. INCAMPO	DESIGN REVIEW: A. MARSHALL	DATE: XX.XX.21	DATE

TITLE: KURRI KURRI POWER STATION
CONCEPT ARRANGEMENT
SCGT F-CLASS LAYOUT

SCALE: 1:1000 | DRAWING No: IS354500-0000-MC-DRG-0003 | REV: A

A1

Appendix B. Comparisons of Meteorological Data

The purpose of this Appendix is to provide some of the key results of comparisons between modelled and measured meteorological data. The purpose was to confirm the Calmet data were of appropriate quality for use as input to the air pollutant dispersion model, Calpuff, for the air quality impact assessment (see Section 5.4.3).

Calmet meteorological model results for surface winds and other meteorological parameters for the Proposal Site location were compared with measurements at the DPIE Beresfield monitoring station, for the simulation year, 2018.

Annual and seasonal wind roses created from Calmet results for hourly average wind speed and wind direction, extracted from a point near the Proposal Site location, are provided in Figure B.1. The corresponding wind roses created from hourly average measurements at Beresfield, are shown in Figure B.2. While there are some differences, some of which can be explained by variations in land use and terrain between Beresfield and Kurri, Calmet has captured the annual and seasonal wind patterns very well. Differences between conditions at the Proposal site and Beresfield would be expected based on the separation (approximately 17 km) and differences in local terrain and landuse.

A statistical summary of wind speed and temperature statistics is provided in Table B1. Calmet has modelled the hourly average temperatures accurately, except underestimated the higher temperatures, which would have no significant effect on the assessment results. The Calmet results for wind speed at Kurri also compare well with the Beresfield measurements, except the higher wind speeds have been underestimated. Some underestimation of wind speed is acceptable for an air quality assessment as lower wind speeds are worse for air pollutant dispersion. However, overall, the Calmet results for wind speed, which were based on TAPM modelling with data assimilation from Beresfield, were as expected; i.e., reflective of the measurements.

Table B1. Statistical summary of hourly average temperature and wind speed: Calmet and measurements

Parameter (1-hour averages)	Calmet Temperature for Proposal site (^oC)	Measured Temperature at Beresfield (^oC)	Calmet wind speed for Proposal site (m/s)	Measured wind speed at Beresfield (m/s)
No. of records	8759	8673	8759	8733
Data capture	100.0%	99.0%	100.0%	99.7%
Maximum	39.9	43.9	9.8	13.1
99^{th} percentile	32.4	35.0	7.6	9.8
90^{th} percentile	25.6	26.5	4.2	4.5
70^{th} percentile	21.0	21.5	2.8	2.8
Median	18.1	18.2	2.0	1.9
Average	18.0	18.2	2.4	2.4
minimum	3.5	1.5	0.1	0.0

The atmospheric boundary layer height or Mixing Layer Height (MLH) is the lowest layer of the troposphere in contact with the ground, characterised by turbulence and mixing. The MLH is important for air pollutant dispersion modelling, as the top of the mixing layer essentially forms the lid on the atmospheric volume available for dispersion of air pollutants. In summer, due to solar heating and convection, a typical MLH is approximately 2000-3000 metres, whereas in winter a typical MLH is much lower; e.g., 1000 metres is typical. Models such as Calmet calculate the MLH, so these may be reviewed as a check on data quality.

Examples of Calmet results for hourly average MLH produced for this assessment are shown in Figure B3 (mid-summer), and Figure B4 (mid-winter). As expected, the summer MLH are in an appropriate range, 2000-3000 metres, and the winter MLH are lower. Also as expected, the calculated MLH increases during daylight hours, and nearly vanishes at night, and increases with increasing temperatures and wind speeds. To conclude, reviews of the meteorological data such as these, and others (not shown in this report), demonstrated that the Calmet results did not exhibit any anomalies that would compromise the dispersion modelling. The meteorological data from Calmet were therefore determined to be of sufficient quality to be used as input to Calpuff for the air quality assessment.

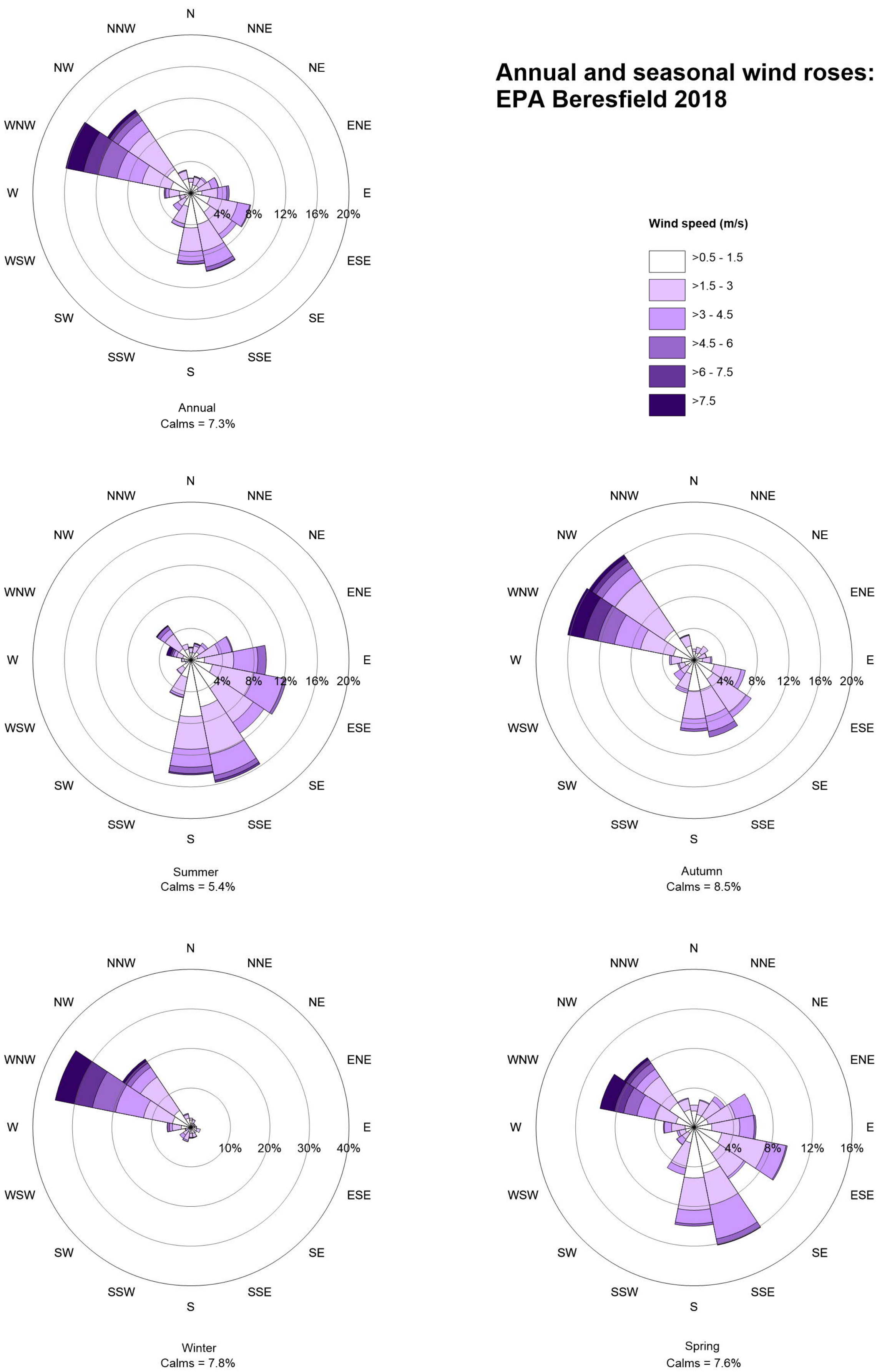


Figure B1. Annual and seasonal wind roses – Beresfield 2018 observations

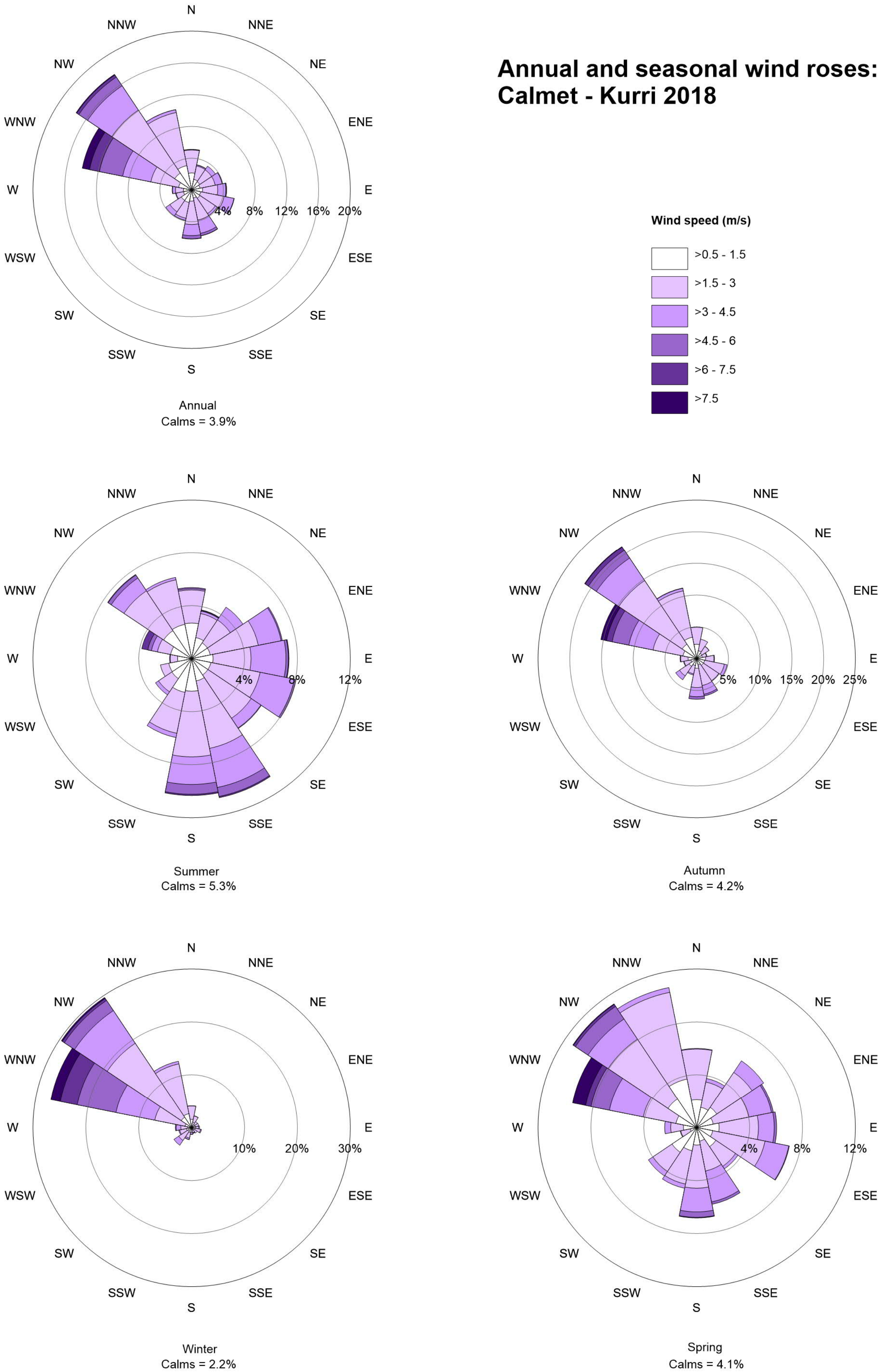


Figure B2. Annual and seasonal wind roses: Kurri 2018 – Calmet model results

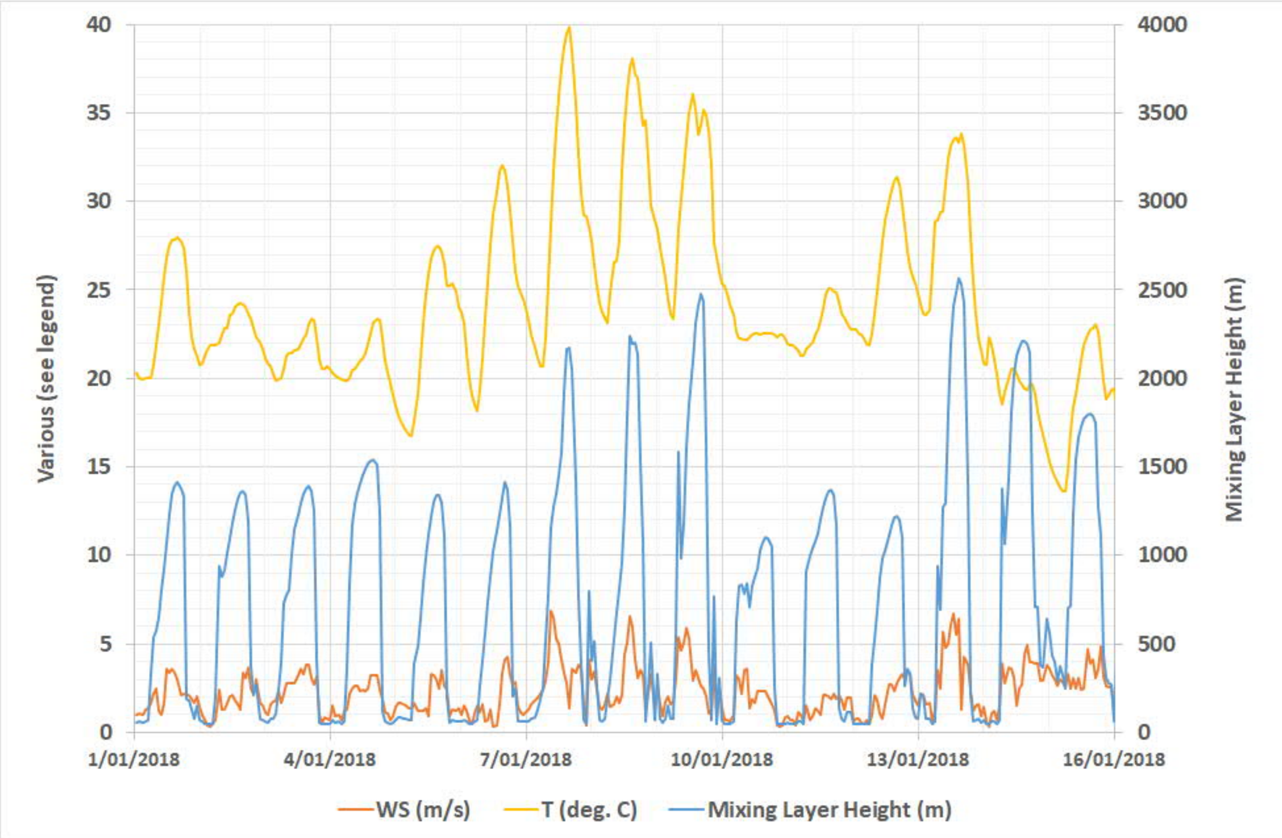


Figure B3. Summer example, Kurri: Calmet results for hourly average temperature, wind speed and MLH

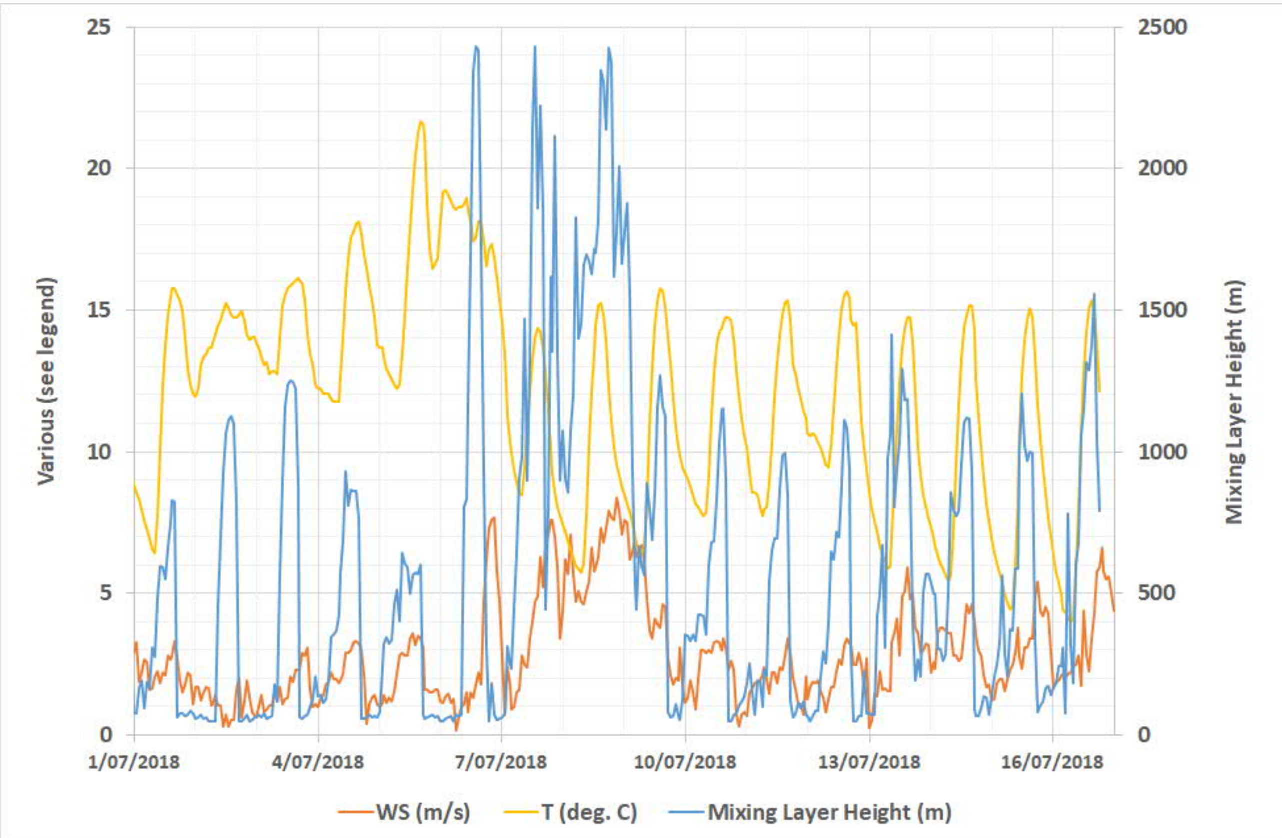


Figure B4. Winter example, Kurri: Calmet results for hourly average temperature, wind speed and MLH