Appendix C

Air Quality Impact Assessment

Newcastle Power Station

Air Quality Impact Assessment

29 April 2020

Project No.: 0468623/AQIA/R7

The business of sustainability

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29 April 2020

Newcastle Power Station

Air Quality Impact Assessment

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ABBREVIATIONS

Abbreviation	Meaning
Approved Methods	*The Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA, 2016)
AQIA	Air Quality Impact Assessment
AQMS	Air Quality Monitoring Station
Atm.	Atmosphere (unit of pressure)
B(a)P	Benzo(a)Pyrene
CO	Carbon Monoxide
DPIE	Department of Planning, Industry and the Environment (formerly OEH)
GJ	Gigajoule
GMR	Greater Metropolitan Region
g/s	grams/second
HAP	Hazardous Air Pollutant
ISR	In-Stack (NO_2:NO_x) Ratio
K	Degrees Kelvin
kV	Kilovolt
MAQS	Metropolitan Air Quality Study
mg/Nm^3	milligrams per normal cubic metre
MMBTU	Million British Thermal Units
MW	Megawatt
NGSF	Newcastle Gas Storage Facility
Nm^3	Normal cubic metre (i.e. 1 cubic metre at conditions of 273K and 1 atm)
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
O_2	Oxygen
OEH	Office of Environment and Heritage (now DPIE)
PAH	Polycyclic Aromatic Hydrocarbon
PM	Particulate Matter (general – inclusive of all size fractions)
PM_{10}	Particulate Matter less than 10 microns in aerodynamic diameter.
$PM_{2.5}$	Particulate Matter less than 2.5 microns in aerodynamic diameter.
ppb	Parts per billion
ppm	Parts per million
SCR	Selective Catalytic Reduction
SO_2	Sulfur dioxide
TAPM	The Air Pollution Model
$\mu g/m^3$	Microgram per cubic metre
US EPA	United States Environment Protection Agency
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

ERM Australia Pacific Pty Ltd (ERM) was commissioned by Aurecon Australasia Pty Ltd (Aurecon), on behalf of AGL, to undertake an Air Quality Impact Assessment (AQIA) for the AGL Newcastle Power Station (the Proposal), located near Tomago, NSW.

AGL is seeking to construct and operate a peaking power station of approximately 250 MW capacity, comprising either aeroderivative gas turbine (gas turbine) or reciprocating gas engine (reciprocating engine) generator technology.

The assessment considered potential air quality impacts associated with construction and operation of the Proposal. The assessment used a quantitative dispersion modelling analysis to estimate compliance of operational phase emissions with the New South Wales Environment Protection Authority (NSW EPA) impact assessment criteria.

The existing environment was characterised in terms of climate, meteorology and ambient air quality, with identification of key meteorological patterns, and the status of ambient air quality compliance:

- Ambient air quality standards for nitrogen dioxide (NO_2), carbon monoxide (CO) and sulphur dioxide (SO_2) are currently met at all Department of Planning, Industry and Environment (DPIE) ambient air quality monitoring locations across the last five years reviewed, with significant margin between peak measurements and the corresponding standards.
- Short term (24 hour average) ambient air quality standards for particulate matter (PM); i.e. particulate matter less than 2.5 micrometres in aerodynamic diameter ($PM_{2.5}$) and particulate matter less than 10 micrometres in aerodynamic diameter (PM_{10}) are exceeded at all locations across the five years reviewed.
- The long term (annual average) $PM_{2.5}$ ambient air quality standard[1] is reached at Wallsend, and exceeded at all other locations within the five years reviewed. The long term (annual average) PM_{10} ambient air quality standard is exceeded at Carrington, Stockton and Mayfield, and met at Wallsend, Beresfield and Newcastle. A review of these exceedances noted the dominance of extraneous events such as dust storms and bushfire activity.

Manufacturer data and United States Environmental Protection Agency (US EPA) emission factors were then used to estimate emissions for representative gas turbine and reciprocating engine technology options, Both natural gas and distillate fuels have been assessed resulting in a total of 4 assessment scenarios.

An evaluation of the power station's emission performance and control technologies concludes that the technologies currently proposed are consistent with Best Available Technology.

These emissions were applied on a continuous basis in the NSW EPA-approved CALPUFF dispersion modelling package, in conjunction with regional background air quality and meteorological datasets for the year 2018. Modelling predictions were processed into the concentration statistics required for assessment against NSW EPA impact assessment criteria.

Pollutants with a Proposal contribution in excess of 10% of relevant impact assessment criteria are confined to NO_2 and PM (both technology options), as well as acrolein and formaldehyde (reciprocating engine option only):

- Cumulative NO_2 predictions were estimated using the ozone limiting method, in conjunction with hourly time varying ozone and NO_2 concentrations sourced from the DPIE Beresfield air quality monitoring station. The maximum 1 hour average cumulative NO_2 prediction was 123 µg/m³, equal to 50% of the criterion.
- Peak 24 hour average $PM_{2.5}$ predictions were approaching criteria, with a peak incremental $PM_{2.5}$ prediction of 7.6 µg/m³. When added to the peak background concentration of 17.1 µg/m³, this

[1] Annual average standards apply on a calendar year basis.

results in a (maximum + maximum) cumulative concentration of 24.7 µg/m³, which is approaching the NSW EPA 24 hour criterion of 25 µg/m³. Refinement of the analysis through use of a time varying background would likely produce predictions well below those presented in this report.

- Exceedances of acrolein were predicted for the reciprocating engine option when operational on natural gas fuel, with the peak prediction across the modelling domain a factor of three times above the NSW EPA acrolein criterion. This prediction was based on US EPA emission factor-based estimates of acrolein emissions, for a 4-stroke lean burn gas engine in conjunction with a conservative estimate of oxidation catalyst control efficiency.

  To further investigate the potential for acrolein emissions to produce adverse air quality impacts, the following analysis was undertaken:

  - A review of the NSW EPA and international screening criteria was conducted. Based on assessment against these additional criteria, all predictions were estimated to be within respective screening criteria, as formulated to be protective of adverse public health outcomes.
  - A review of meteorological conditions conducive to acrolein exceedances was undertaken and identified that predicted exceedances were associated with high wind, moderate temperature daytime conditions and did not align with times at which the plant is most likely to operate. In this capacity, the assumption of continuous operation, as adopted within this assessment, is considered to provide a conservative assessment of peak acrolein predictions.

Accordingly, the analysis conducted within this assessment indicates that the potential for the Proposal to generate exceedances is low, and manageable through effective operation of the proposed emission controls.

Lastly, a review of potential cumulative impacts with other local sources of air emissions was conducted using the National Pollutant Inventory database. This review identified the Tomago Aluminium Smelter as the key emission source of interest in terms of potential localised cumulative impacts. Accordingly, an analysis of the smelter's local air quality monitoring data was conducted, with assessment of potential cumulative impacts resulting in no additional exceedances of SO_2 impact assessment criteria as a result of the Proposal.

1. INTRODUCTION

Environmental Resources Management Australia Pacific Pty Ltd (ERM) has been commissioned by Aurecon Australia Pty Ltd (Aurecon) on behalf of AGL, to undertake an air quality impact assessment (AQIA) for the Newcastle Power Station (the Proposal). AGL proposes to construct and operate a dual-fuel (gas/diesel) power station (approximately 250-megawatt (MW)) and associated infrastructure, including gas supply and electricity transmission connections.

This report provides an assessment of potential air quality impacts associated with the Proposal, in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA, 2016).

1.1 Proposal Location

The Proposal is proposed to be constructed at Tomago, approximately 14 km north-west of Newcastle within the Port Stephens Council Local Government Area (Figure 1.1) (the Proposal Area). The Proposal Area is approximately 96 ha in size and encompasses the following lots:

- Lot 2 DP1043561;
- Lot 3 DP1043561;
- Lot 4 DP1043561 (partial lot);
- Lot 202 DP1173564 (partial lot); and
- Lot 1203 DP1229590 (partial lot).

The north-west boundaries of Lot 2 DP1043561, Lot 3 DP1043561, and Lot 4 DP1043561 as well as the western boundary of Lot 1203 DP1229590 abut the Pacific Highway. The southern boundaries of Lot 2 DP1043561, Lot 3 DP1043561, and Lot 202 DP1173564 adjoin industrial estates. Lot 202 DP1173564 is bounded to the east and north by lots containing dense vegetation.

The power station aspect of the Proposal would be constructed on land within Lot 3, which is located within the western extent of the Proposal area.

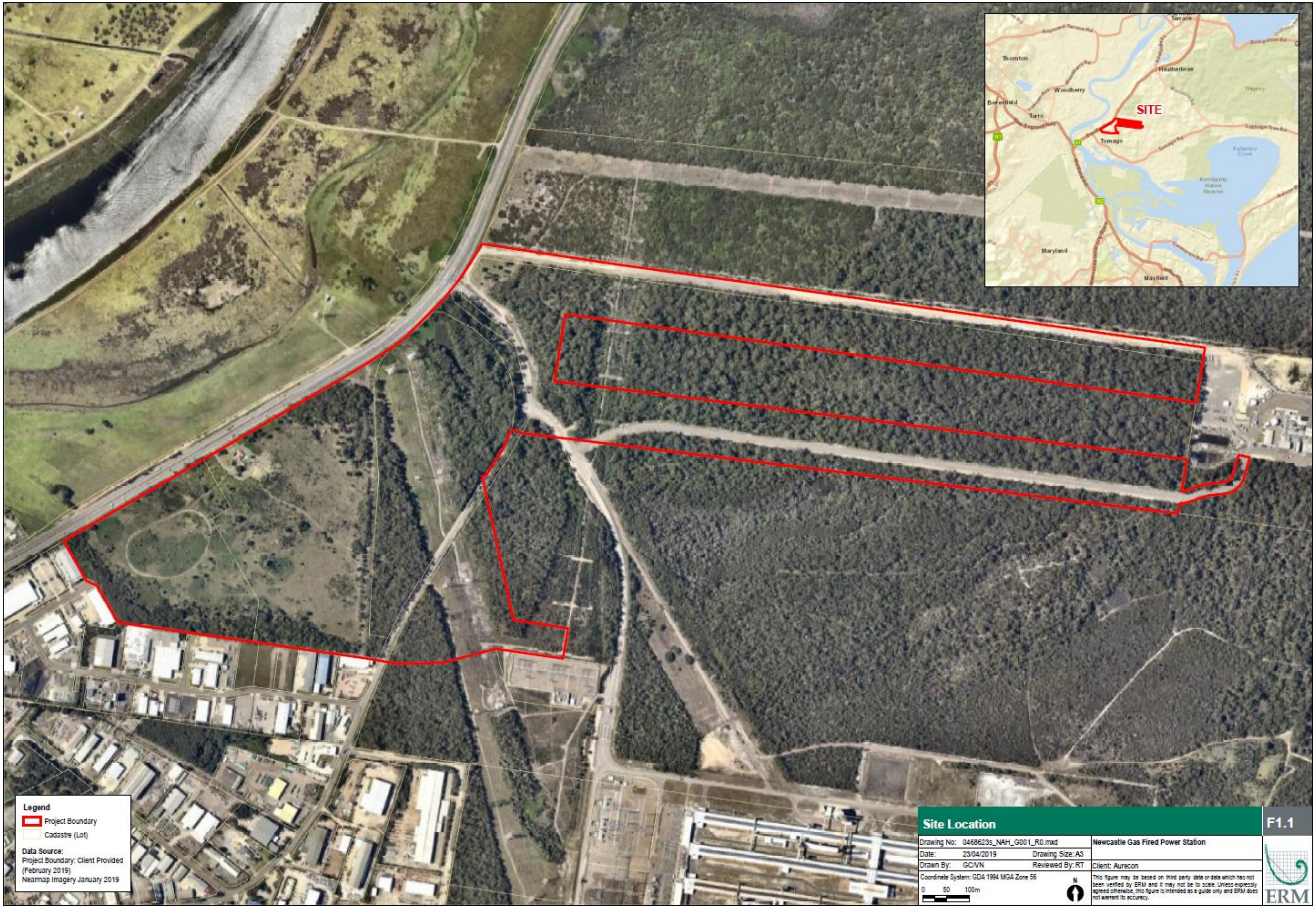
1.2 Assessment Scope

The Secretary's Environmental Assessment Requirements (SEARs) (Ref: SSI 9837) were issued by the NSW Department of Planning and Environment (DPE) on 18 February 2019 and form the basis of the environmental impact assessment for the Proposal.

Table 1.1 outlines the SEARs relevant to air quality, as well as the section of the report within which they have been addressed.

Table 1.1: SEARs relevant to air quality

Requirement	Section Addressed
An assessment of the likely air quality impacts of the project in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA, 2016);	This report
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.	Section 3



Legend

Project Boundary

Cadastre (Lot)

Data Source:
Project Boundary: Client Provided (February 2019)
Nearmap Imagery January 2019

Site Location

Drawing No:	0468623s_NAH_G001_R0.mxd		Newcastle Gas Fired Power Station
Date:	23/04/2019	Drawing Size: A3	
Drawn By:	GC/VN	Reviewed By: RT	Client: Aurecon
Coordinate System: GDA 1994 MGA Zone 56			This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.
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2. PROPOSAL DESCRIPTION

2.1 Overview

The Newcastle Power Station would be a dual fuel (gas and diesel) fast-start peaking power station with a nominal operating capacity of 250MW at Tomago in NSW. The Newcastle Power Station would supply electricity to the grid at short notice during periods of high electricity demand, and/or low supply, particularly during periods where intermittent renewable energy supply is low or during supply outages. This operation is aligned with AGL's move to a renewable energy mix. While the primary role of the Newcastle Power Station would be to provide firming or peaking capacity to the National Electricity Market, to maximise operational flexibility each unit of the power station would be designed for continuous operation. This impact assessment considers both the peaking load operation and the continuous operation.

The Proposal would also involve the construction and operation of gas pipelines and an electricity transmission line. The pipelines would supply the proposed power station with gas from the eastern Australia gas transmission pipelines via the Jemena network and, as an option, the Newcastle Gas Storage Facility (NGSF). A new electricity transmission line would transfer the electricity produced by the proposed power station to the national electricity network via connection to the existing 132kV Transgrid switchyard. The Proposal has a capital investment value of approximately $400 million and is anticipated to be operational in the year 2022.

The main elements of the Proposal are as follows:

- Power station, necessary supporting ancillary equipment and supporting infrastructure. The power station would be capable of operating with diesel fuel, if necessary.
- 132kV electricity transmission line to the existing TransGrid switching yard.
- Gas transmission pipelines and receiving station, compressor units, and ancillary infrastructure.
- Storage tanks and laydown areas.
- Water management infrastructure including pond(s), and a connection to Hunter Water potable service in line with Hunter Water requirements.
- Diesel storage and truck unloading facilities.
- Site access road.
- Office / administration, amenities, workshop / storage areas and car parking.

2.2 Power station

The power station would be a dual fuel power plant, capable of generating about 250 MW of electricity. The proposed power station would either consist of large reciprocating engine generators or aero-derivate gas turbine generators. Generation units would be dual fuel capable, meaning they would be able to be supplied by natural gas and/or liquid fuel.

The decision to install gas turbines or reciprocating engine technology will be made based on a range of environmental, social, engineering and economic factors that will be considered as the power station design progresses.

2.2.1 Gas Turbine Technology

Electricity would be generated by gas turbine technology through the combustion of natural gas and/or liquid fuel in turbines. With its heritage in the airline industry, aero derivative gas turbine units consist of a compressor, combustion chamber, turbine and generator. Air is compressed to a high pressure before being admitted into the combustion chamber. Fuel (natural gas or diesel as required) is injected into the combustion chamber where combustion occurs at very high temperatures and the gases expand. The resulting mixture of hot gas is admitted into the turbine causing the turbine to turn, generating power. In an open cycle configuration, hot exhaust gas is vented to the atmosphere through an exhaust stack, without heat recovery.

The turbines will be fitted with emission controls as required to meet regulatory emission limits under both natural gas and distillate oil (‘distillate’) operation.

2.2.2 Reciprocating Engine Technology

With its heritage in the shipping industry and a form of internal combustion engine, reciprocating engines used for power generation harness the controlled ignition of gas and/or diesel to drive a piston within a cylinder. A number of pistons move sequentially to rotate a crank shaft which turns the generator.

Manufacturers have identified the requirement for selective catalytic reduction (SCR) and oxidation catalysts in order to meet regulatory pollution control requirements.

2.2.3 Ancillary Facilities

The power station, regardless of chosen technology, would require supporting ancillary facilities. These would include:

- Natural gas reception yard potentially including gas metering, pressure regulation, compression, heating stations, pigging facilities and provision for flaring.
- Generator circuit breakers, generator step-up transformers and switchyard including overhead line support gantry.
- Water collection and treatment facilities.
- Water storage tanks and ponds.
- Truck loading/unloading facilities.
- Liquid fuel storage tanks.
- Emergency diesel generators with associated fuel storage.
- Closed circuit cooling systems.
- Control room.
- Offices and messing facilities.
- Electrical switch rooms.
- Occupational health and safety systems including an emergency warning and evacuation system.
- Workshop and warehouse.
- Firefighting system.
- Communication systems.
- Security fence, security lighting, stack aviation warning lights (if required) and surveillance system.
- Landscaped areas and staff parking areas.
- Concrete foundations, bitumen roadways, concrete pads in liquid fuel unloading station and gas turbine or engine unit maintenance areas.
- Concrete bund areas with drains for liquid fuel tanks, liquid chemicals store, oil filled transformers (if installed) and other facilities where contaminated liquids could leak.
- Level construction and laydown area.
- Engineered batters to support and protect the power plant platform.
- Sedimentation pond and associated diversion drain and earth bund.

2.3 Construction Activities and Construction Staging

Key construction activities for the Proposal would include:

- Clearing of vegetation at the proposed power station site and as required along the electrical transmission and gas pipeline(s) easements.
- Demolition of an existing house if not repurposed during construction and operation.

- Installation of gas pipeline(s) and electrical transmission line infrastructure.
- Earthworks to prepare the power station site and construction areas.
- Installation of foundations and underground services.
- Installation of aboveground civil, mechanical and electrical plant and equipment.
- Commissioning and testing.

2.4 Emissions to Air

Operational Phase

Potential air emission sources associated with operation of the Proposal include:

- Main generator plant (comprising either gas turbine or reciprocating technology).
- Distillate storage tanks.
- Gas reception infrastructure including heating stations, compressors (if not electrically powered) and flaring (if required).
- Emergency diesel generators.

The main generator plant forms the critical focus of this assessment. At the time of preparation, limited detail is available for gas reception and emergency diesel generators. Whilst potential air quality impacts from these sources are typically minor, consideration should be made as the plant design is progressed and such detail becomes available.

Emissions from distillate storage tanks would comprise volatile organic compounds. Distillate fuel used by the Proposal would be of conventional automotive diesel grade, and compliant with the *Fuel Quality Standards (Automotive Diesel) Determination 2019* (AG, 2019). Accordingly, emissions would be highest during tank filling, and would be similar in nature to those which occur during storage tank filling operations at a retail service station. Given the large buffer distance surrounding this infrastructure, potential air quality impacts are likely to be negligible, and have not been considered further within this assessment.

Construction Phase

During the construction phase, there is the potential for dust to be generated due to the excavation and handling of soils, site grading activities, and vehicle movements. Table 2.1 provides a summary of anticipated construction equipment by construction stage.

Table 2.1: Summary of anticipated construction equipment by construction stage

Construction Stage	Equipment
S1: Site Preparation and Earthworks	Excavator
	Bulldozer
	Grader
	Roller
	Loader
	Dump truck
S2: Concrete Foundation Works	Concrete truck
	Concrete mixer
	Compactor
	Crane
S3: Building Construction	Crane
	Delivery trucks
	Pneumatic tools

Construction Stage	Equipment
	Electric tools
	Power generators
	Hammers
S4: Pre-Pipeline Construction	Excavator
	Track trencher
	Crushing Machine
	Truck
	Crane
S5: Pipeline Construction	Welding/Bending Machine
	Pipe layer
	Bulldozer
	Padding machine
S6: Transmission Line Construction	Excavator
	Track trencher
	Crushing Machine
	Truck
	Crane

Noting the scale of construction and presence of buffers between the plant footprint and the site boundaries, it is considered appropriate that potential air quality impacts be addressed via the implementation of conventional management measures for construction operations. Specifically, the minimisation and control of dust emissions during the construction period should be detailed within the Construction Environmental Management Plan (CEMP) for the Proposal, through the implementation of measures that address the management and mitigation of potential air quality impacts.

2.4.1 Key Pollutants

The operational phase of the Proposal involves the combustion of natural gas and distillate fuels in either gas turbine or 4-stroke dual-fuel reciprocating engine technologies. Potential air emissions have been reviewed based on the Chapter 3 of the *US EPA AP-42 Compilation of Air Pollutant Emission Factors* (USEPA, 2005), as well as manufacturer information. From this review, the following key air pollutant emissions have been identified:

- Oxides of nitrogen (NO_x), inclusive of nitric oxide (NO) and nitrogen dioxide (NO_2).
- Carbon monoxide (CO)
- Sulfur dioxide (SO_2)
- Particulate matter (PM) including:
  - Particulate matter less than 2.5 µm in aerodynamic diameter ($PM_{2.5}$)
  - Particulate matter less than 10 µm in aerodynamic diameter (PM_{10}).
- Hazardous air pollutants (HAPs) including:
  - Acrolein, benzene, formaldehyde and other volatile organic compounds (VOCs).
  - polycyclic aromatic hydrocarbons (PAHs)
  - ammonia (residual from SCR).

Table 2.2 provides a summary of these key pollutants and their basis of formation

Table 2.2: Summary of key pollutants and basis of formation

Pollutant	Formation/Emission Basis
NO_x	Oxidation of atmospheric nitrogen in high temperature combustion reactions
CO	Incomplete oxidation of fuel-bound carbon
SO_2	Oxidation of fuel-bound sulfur
PM	- Incomplete oxidation of fuel-bound carbon. - Oxidation of fuel-bound sulfur to sulphate. - Emission of residual ash material within distillate fuel.
Acrolein	- Incomplete oxidation of fuel-bound carbon.
Formaldehyde	
Benzene	
PAHs	
Ammonia*	Residual ammonia from SCR operation.

Note: *Applicable to reciprocating engine option for which SCR is proposed.

3. REGULATORY FRAMEWORK

Potential air quality impacts from industrial sources are managed in NSW via a collection of regulatory instruments, which prescribe operating conditions, plant emission limits and ambient air quality criteria to be applied in the assessment and management of industrial operations.

These instruments include:

- The NSW *Protection of the Environment Operations Act (1997)* 'the POEO Act', which includes provisions for the minimisation of air pollution and odour, as well as specifying scheduled activities for which operators must carry an environment protection licence.
- The NSW *Protection of the Environment Operations (Clean Air) Regulation 2010* 'the Clean Air Regulation' (as amended January 2019), which provides statutory emission limits and operating requirements for industrial plant and activities.
- The *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA, 2017), 'the Approved Methods', which specify methods for the assessment of air emission sources and impact assessment criteria.

A summary of these instruments, as relevant to the Proposal, is provided in the following sections.

3.1 Regulatory Emission Limits

The Clean Air Regulation provides emission limits applicable to both the gas turbine and reciprocating engine plant options being considered for the Proposal. These emission limits apply to gases within the exhaust stack for operational periods in which the plant is operational, excluding plant start-up and shutdown.

Table 3.1 and Table 3.2 provide a summary of emission limits relevant to gas turbine and reciprocating engine options, respectively.

Table 3.1: Summary of Clean Air Regulation emission limits – Gas Turbine Option

Substance	Fuel Type		Units / Reference Conditions
	Natural Gas	Distillate	
Solid Particles (Total)	-	50	mg/m^3, dry, 273K, 101.3 kpa 15% O_2
Nitrogen dioxide (NO_2) or Nitric oxide (NO) or both, as NO_2 equivalent	70	90	
Smoke	-	Ringelmann 1 or 20% Opacity	-

Note: Limits do not apply to start-up and shutdown periods.

Table 3.2: Summary of relevant Clean Air Regulation emission limits – Reciprocating Engine Option

Substance	Fuel Type		Units / Reference Conditions
	Natural Gas	Distillate	
Solid Particles (Total)	50		mg/m^3, dry, 273K, 101.3 kpa 3% O_2
Nitrogen dioxide (NO_2) or Nitric oxide (NO) or both, as NO_2 equivalent	450		
Volatile organic compounds (VOCs), as n-propane,	40	1,140	
or Carbon Monoxide (CO)*	125	5,880	
Smoke	Ringelmann 1 or 20% Opacity		-

Notes: These limits do not apply to start-up and shutdown periods.
*The standard for volatile organic compounds *or* carbon monoxide is satisfied if either of those standards is met.

AGL proposes to procure plant that complies with the requirements of the POEO Act and Clean Air Regulation, and have sought manufacturer assurances on the capabilities of prospective plant options to address the requirements outlined in Table 3.1 and Table 3.2.

Within this assessment, the development of emission estimates has been undertaken within these requirements. Further discussion of this process is provided in Section 6.

3.2 Impact Assessment Criteria

The Approved Methods specify criteria relevant for the assessment of impacts from air pollution. These criteria form the basis for the quantitative aspect of this assessment.

The criteria are primarily human health-based (i.e. they are set at levels to protect against health effects) and also protect against adverse amenity and ecological impacts.

Table 3.3 summarises the air quality criteria for relevant to the Proposal.

Table 3.3: Summary of relevant air quality criteria

Pollutant	Assessment Statistic	Concentration (µg/m³)	Assessment Basis
NO_2	1 hour maximum	246	Cumulative (including background)
	Annual mean	62	
CO	15 minute maximum	100,000	
	1 hour maximum	30,000	
	8 hour maximum	10,000	
SO_2	10 minute maximum	712	
	1 hour maximum	570	
	24 hour maximum	228	
	Annual mean	60	
$PM_{2.5}$	24 hour maximum	25	
	Annual mean	8	
PM_{10}	24 hour maximum	50	
	Annual mean	25	
Formaldehyde	99.9th percentile, 1 hour maximum	20	Incremental (Proposal in isolation)
Acrolein		0.42	
Benzene		29	
PAHs (B[a]P TEQ)*		0.4	
Ammonia		330	

Note: *PAHs as benzo{a]pyrene equivalent.

4. AIR EMISSION CONTROL REVIEW

This section provides a review of the air emission controls being proposed for the four options for the Newcastle power station currently being considered.

The principal reference in the determination of Best Available Technology for emissions control for the Proposal has been the European Commission's *Best Available Techniques (BAT) Reference Document for Large Combustion Plants* ("the EU BREF"; IPPC, 2017). This document provides detailed descriptions of a range of emission control methodologies applied to large combustion processes.

4.1 Proposed Emission Controls for Gas Turbines

The EU BREF notes that there are three main techniques that have been used to prevent or reduce NO_x emissions from gas turbines, namely:

- Water or steam injection (often retrofitted to existing installations);
- Dry Low-NO_x Burners (DLN) widely applied for all kinds of gas turbines; and
- Catalytic solutions e.g. SCR.

For the current application, the turbine technology providers have elected to use water injection technology for NO_x control. The principal reason for this is the dual fuel (gas and diesel) nature of the Proposal, which makes the other two techniques unviable. The Proposal's stated emission performance through application of the water injection technology is to limit NO_x to 51 mg/Nm³ (at 15% oxygen) for natural gas, and 86 mg/Nm³ for distillate.

This performance is comparable to that quoted in Table 10.24 of the EU BREF which states Best Available Technology Achievable Emission Limits (BAT-AEL) in the range of 25-50 mg/Nm³ (daily average) for new open cycle gas turbines. No values are presented for BAT-AELs for turbines operating on distillate due to an absence of data.

4.2 Proposed Emission Controls for Reciprocating Engines

The EU BREF notes that the most important parameter governing the rate of NO_x formation in internal combustion engines is temperature, where the higher the temperature, the higher the NO_x in the exhaust gas.

While various techniques are noted for lowering combustion temperatures, the EU BREF additionally notes that "in some applications (e.g. larger plants in sensitive areas in the US), gas engines have been fitted with SCR for additional NO_x reduction".

For the Proposal, the reciprocating engines would use SCR technology for NO_x control, which involves the reaction of NOx and urea in the presence of a catalyst, to produce nitrogen and carbon dioxide. The stated emission performance through application of SCR technology is to limit NO_x to 150 mg/Nm³ (at 15% oxygen) for both natural gas and distillate fuel operation.

Table 7.6 of the EU BREF notes example NO_x emissions for dual fuel engines in the range of 147-380 mg/Nm³ in gas mode and 1,531-1,751 mg/Nm³ in distillate mode.

The Proposal would also use catalytic oxidation technology for VOC control in the reciprocating engines.

4.3 Benchmarking

Table 4.1 presents a benchmarking of the Proposal's NO_x emissions on a mass per unit output basis relative to other power stations in NSW. This information is presented graphically within Figure 4.1.

Table 4.1: Benchmarking of Proposal NO_x emissions on a mass per unit output basis

Reference	Plant Option	Fuel	NOx Emissions (kg/hr)	Output (MW)	NO_x Emission Intensity (kg/MWh)
Proposal	Gas Turbine	Natural Gas	108.0	264	0.4
		Distillate Oil	182.9	256	0.7
	Reciprocating Engine	Natural Gas	255.3	269	0.9
		Distillate Oil	276.5	269	1.0
Mt Piper CFPS	Existing	Coal	5120	1,320	3.9
	Proposed (2009)		3745	2,000	1.9
Eraring CFPS	Pre-upgrade		12,621	2,640	4.8
	Post-upgrade		9,835	3,000	3.3
Bayswater CFPS	Proposed (2009)		3,262	2000	1.6
NPI Emission Factor	Gas Turbine	Natural Gas (DLN)	-	-	0.4
		Distillate Oil (Water Injection)	-	-	1.0
	New Coal	Coal	-	-	1.9

Notes: References as cited within URS (2009), CFPS – Coal Fired Power Station. DLN – Dry Low NOx.

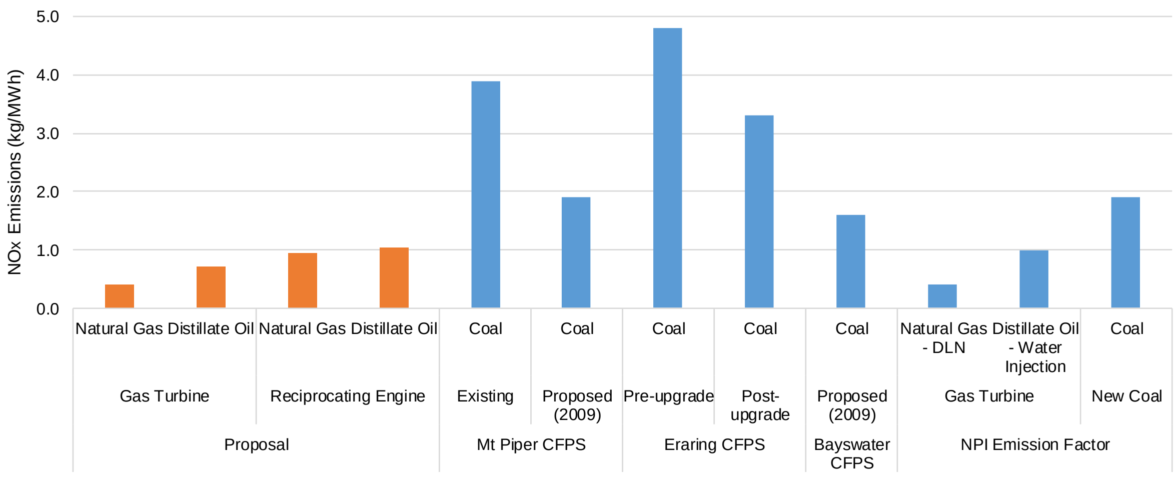


Figure 4.1: Benchmarking of Proposal NO_x emissions on a mass per unit output basis

As shown in these data, the NO_x emission intensity (kg NO_x/MWh) of the Proposal is lower than modern coal-fired generation technology. In addition, the selected gas turbine technology is also generally consistent with the corresponding NPI-derived NO_x emission intensity.

5. EXISTING ENVIRONMENT

This report section provides a summary of the existing environment including climate, meteorology and ambient air quality. These factors are relevant to the consideration of atmospheric dispersion, as well as the existing condition of the airshed, which forms an important consideration in the prediction of total pollutant concentrations, for assessment against cumulative air quality criteria.

5.1 Climate and Meteorology

The Newcastle region has a humid sub-tropical climate with warm summers and mild winters. Precipitation is typically heaviest in the first half of the year when east coast lows can bring very heavy falls and damaging winds. The region is influenced by land- and seabreeze flows, which have significant implications for air quality when extended anticyclonic conditions occur (PAE Holmes, 2011a).

Table 5.1 presents a summary of compiled climate statistics for the Bureau of Meteorology (BoM) Newcastle University Weather Station, which is located approximately 9 km to the south of the Proposal.

Table 5.1: Summary of climate statistics for Newcastle University weather station (#061390, Period: 1998 - 2018)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Twice daily temperature observations (°C)													
9am mean	23.3	22.6	20.7	18.5	14.8	12.3	11.3	13.0	16.7	19.3	20.2	22.3	17.9
3pm mean	27.3	26.5	25.0	22.1	19.5	17.0	16.6	18.2	21.1	22.7	23.7	26.0	22.1
Twice daily relative humidity observations (%)													
9am mean	72	78	78	77	78	79	77	69	65	62	71	70	73
3pm mean	57	62	60	61	59	60	54	48	48	50	58	58	56
Temperature Range (°C)													
Mean maximum	29.5	28.5	26.9	24.2	21.2	18.3	18.0	19.7	22.7	24.9	26.0	28.0	24.0
Mean minimum	19.5	19.4	17.6	14.1	10.5	8.8	7.3	8.0	10.7	13.4	15.9	17.9	13.6
Rainfall													
Mean Rainfall (mm)	84.5	133.1	124.4	127.3	88.3	131.7	54.8	57.5	66.9	66.2	109.2	69.4	1147.1
Mean rain days	10.2	12.3	12.1	11.8	10.7	12.7	10.7	8.9	8.5	9.5	11.8	11.1	130.3
Sky Condition													
Mean clear days	9.3	6.1	8.3	8.1	11.4	10.0	11.5	12.0	12.3	9.9	6.3	6.6	111.8
Mean cloudy days	9.8	10.9	8.9	8.0	7.8	7.9	8.0	5.8	5.4	8.2	11.5	9.5	101.7

Source: http://www.bom.gov.au/climate/averages/tables/cw_061390.shtml (accessed June 2019).

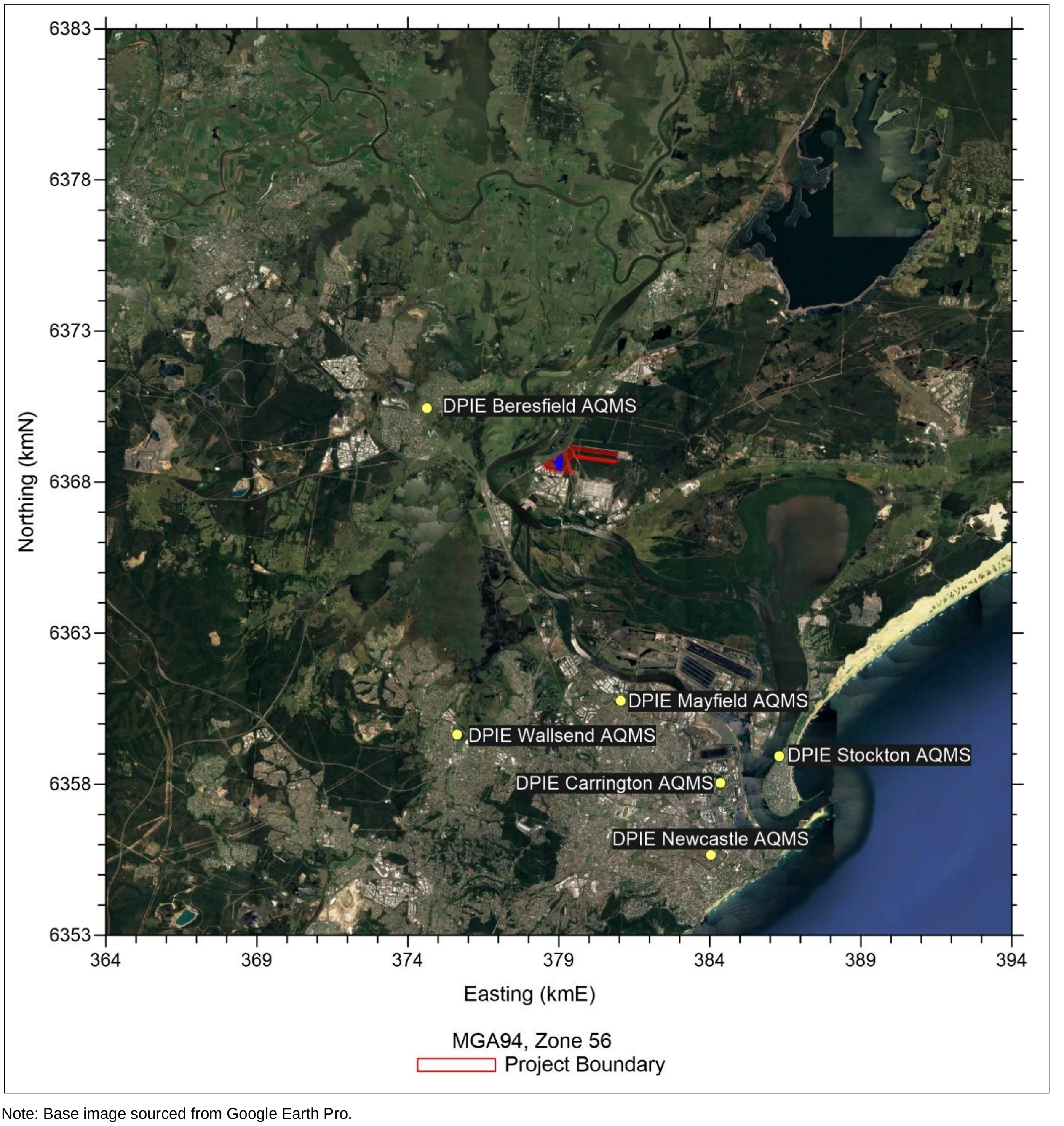
January is the warmest month with an average maximum temperature of 29.5°C. July is the coolest month with an average minimum temperature of 7.3°C. February through April produces the highest average monthly rainfall, whilst the number of rain days is relatively consistent across all months of the year. Winters are generally drier with the highest prevalence of clear conditions.

The NSW Department of Planning, Industry and the Environment (DPIE) operate 6 air quality monitoring stations (AQMS), within the Newcastle region, the closest of which is the Beresfield AQMS, located approximately 4.5 km WNW of the Proposal. These AQMS collect both meteorological and ambient air quality data. Table 5.2 presents a summary of these AQMS locations, with proximity to the Proposal, whilst Figure 5.1 shows these locations overlaid on aerial imagery.

Table 5.2: Summary of nearby AQMS and weather stations with proximity to Proposal

AQMS Location	Easting (kmE, MGA94)	Northing (kmN, MGA94)	Distance from Proposal / Bearing
Beresfield	374.627	6370.449	4.5 km WNW
Stockton	386.306	6358.923	12 km SE
Wallsend	375.623	6359.638	9.5 km WSW
Newcastle	384.038	6355.662	14 km SSE
Mayfield	381.057	6360.752	8.0 km SSE
Carrington	384.350	6358.050	12 km SSE

Figure 5.1: Location of DPIE AQMS' within the Newcastle region.



Note: Base image sourced from Google Earth Pro.

Table 5.3 presents a summary of wind monitoring parameters for the DPIE Beresfield AQMS over the most recent six years of monitoring.

Table 5.3: DPIE Beresfield - Summary of wind monitoring parameters (2013 – 2018)

Year	Average Wind Speed (m/s)	Percent Calms (wind speed < 0.5 m/s)	Data Completeness
2014	2.4	4.9%	99.1%
2015	2.5	4.0%	98.9%
2016	2.8	4.2%	98.6%
2017	2.3	4.7%	85.4%
2018	2.4	4.9%	99.7%
All Years (2014 – 2018)	**2.5**	**4.5%**	**95.6%**

Figure 5.2 through 5.4 provide annual and seasonal wind roses for the DPIE Beresfield AQMS across this period.

As shown in these figures and Table 5.3, winds are generally consistent between years, possessing an average wind speed of 2.5 m/s with calm conditions occurring approximately 5% of the time. Dominant winds on the north-westerly / south-easterly axis are consistent with those seen near to the Hunter River, and show the influence of the Hunter Valley topography. North-westerly winds are dominant during winter, whilst south-easterly winds are dominant during summer. Winds in autumn and spring are blended around the valley axis, with strong north-westerly winds present during early spring.

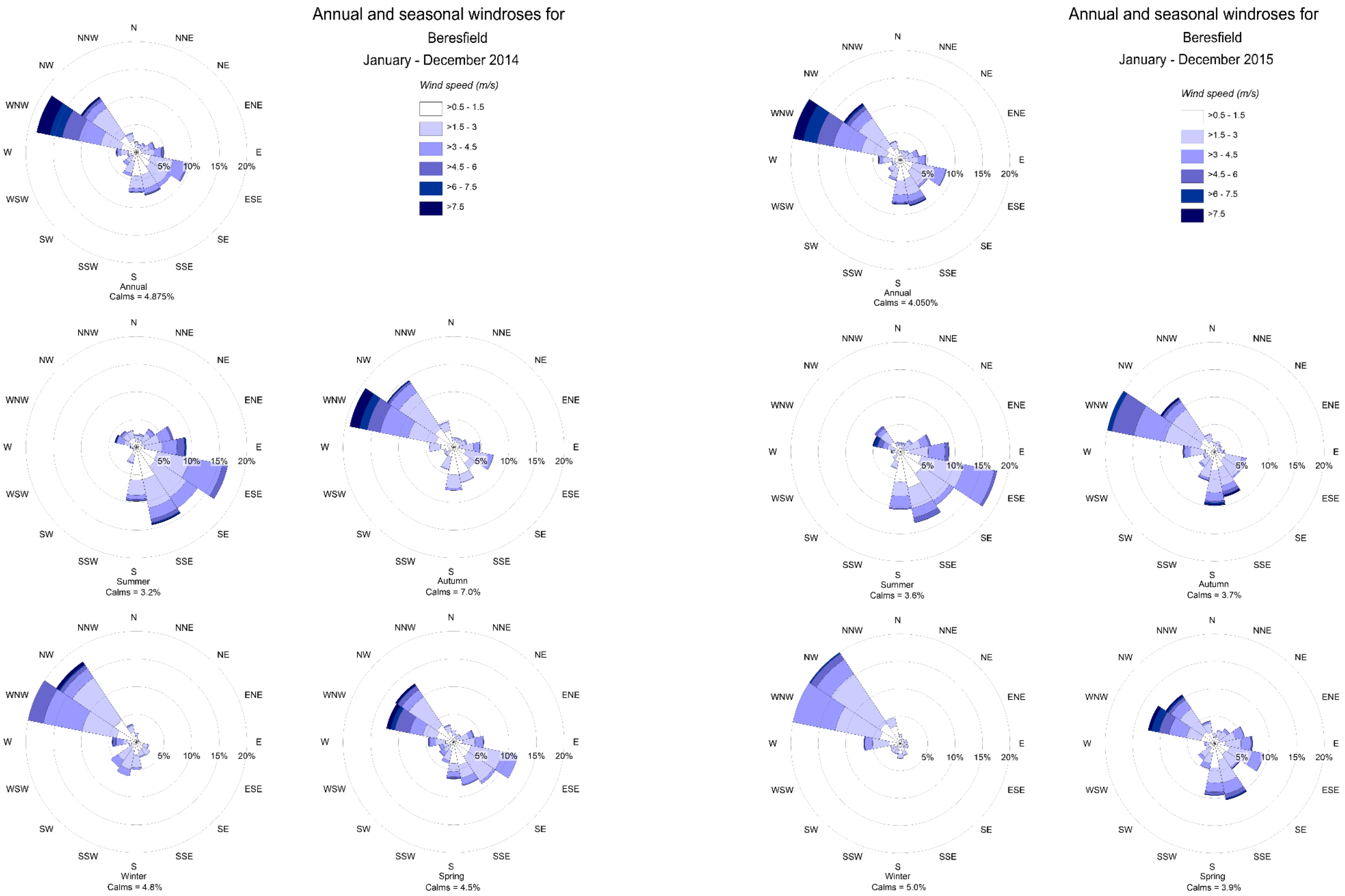


Figure 5.2: Annual and seasonal windroses - DPIE Beresfield 2014, 2015

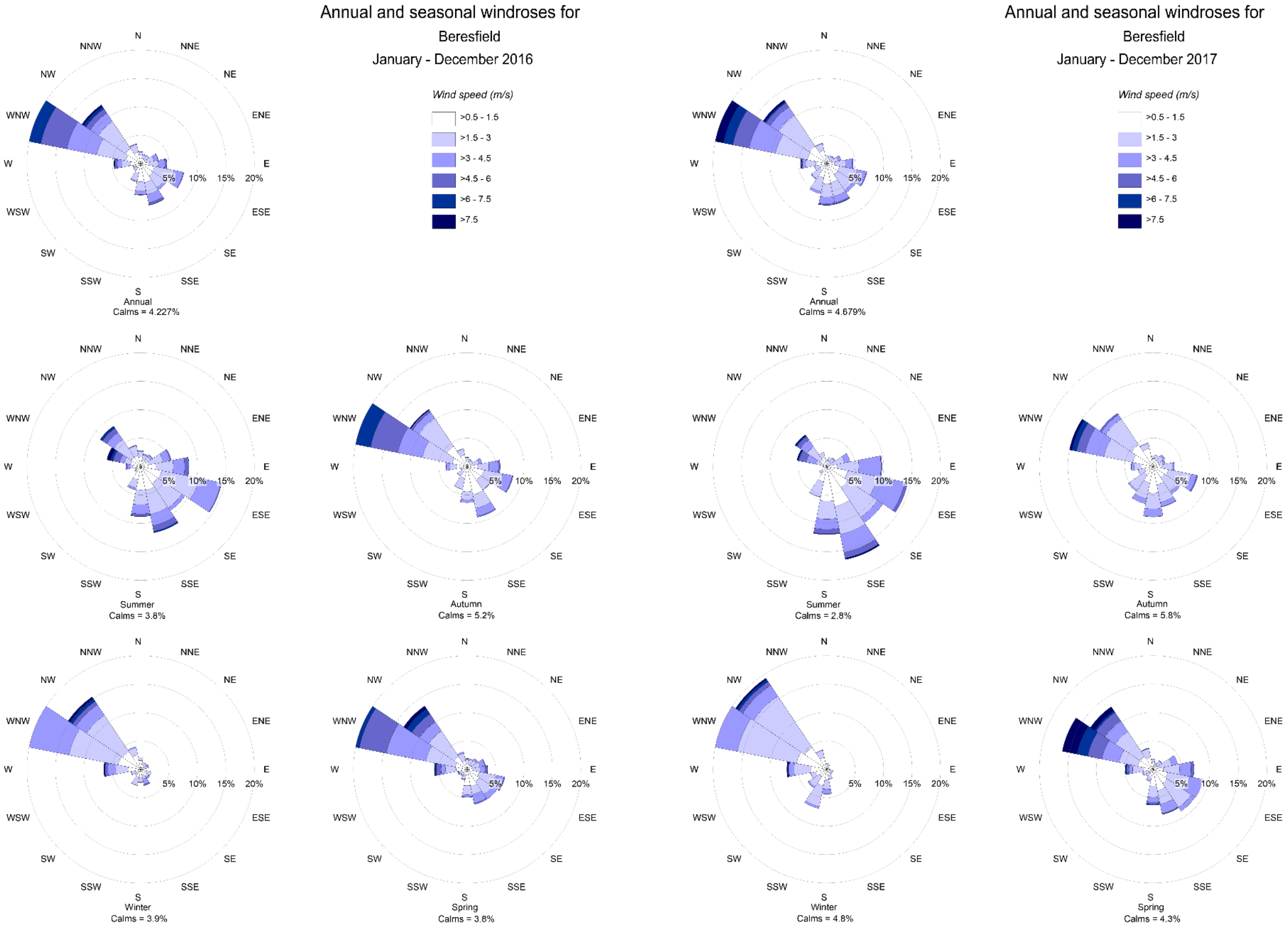


Figure 5.3: Annual and seasonal windroses - DPIE Beresfield 2016, 2017

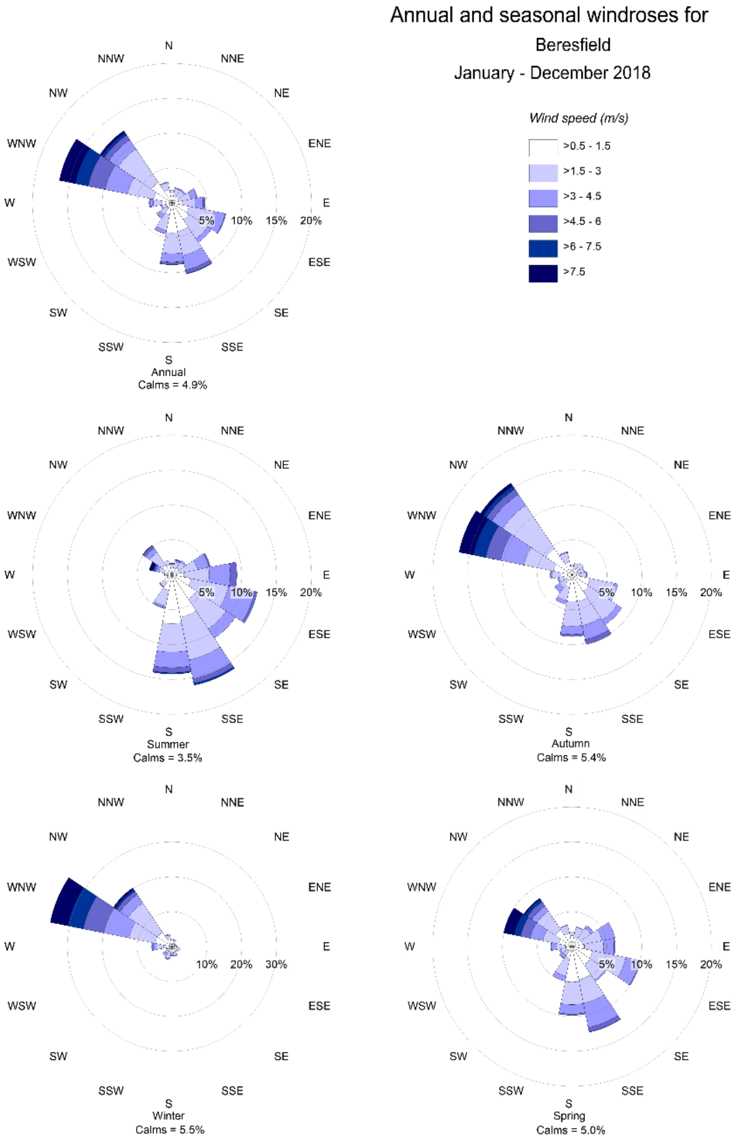


Figure 5.4: Annual and seasonal windroses - DPIE Beresfield, 2018

5.2 Ambient Air Quality

An understanding of existing ambient air quality is required to allow an estimate of total pollutant concentrations (i.e. inclusive of existing background and the Proposal), as required for assessment against cumulative air quality impact assessment criteria. Air quality within the region is considered typical of coastal settings, with influences from transport, industrial, domestic and biogenic sources contributing to total background pollutant levels.

This section provides a brief overview of ambient air quality monitoring data within the Newcastle region.

5.2.1 Nitrogen dioxide

Continuous hourly average ambient NO_2 concentrations are measured at six locations within the Newcastle region (Figure 5.1). Figure 5.5 provides a visual representation of these measurements over the period 2014 – 2018.

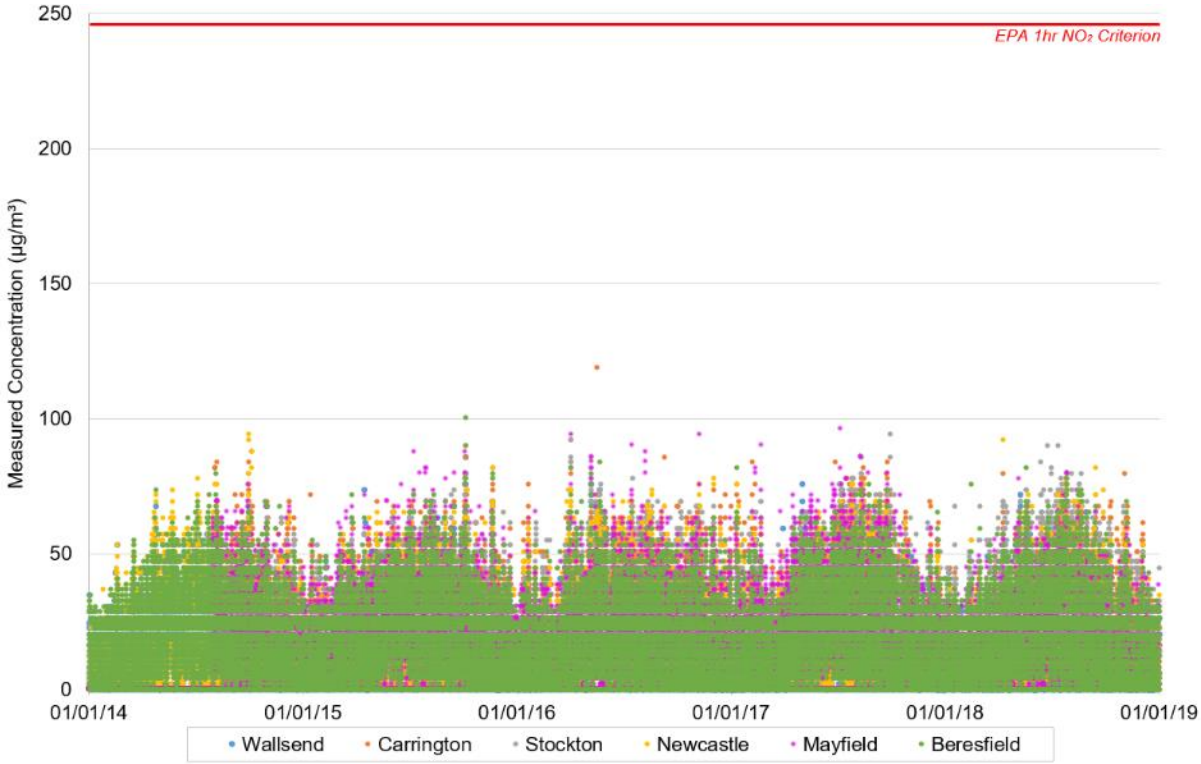


Figure 5.5: Time series plot of hourly ambient NO_2 measurements within the Newcastle region (2014-2018)

As shown in Figure 5.5, all measured concentrations are within the EPA 1hr NO_2 criterion of 246 µg/m³. With the exception of two measurements (out of approximately 200,000 measurements), peak concentrations are below 100 µg/m³, with higher measurements observed during the winter months.

Figure 5.6 provides a summary of NO_2 monitoring statistics for Newcastle region ambient NO_2 measurements (2014-2018).

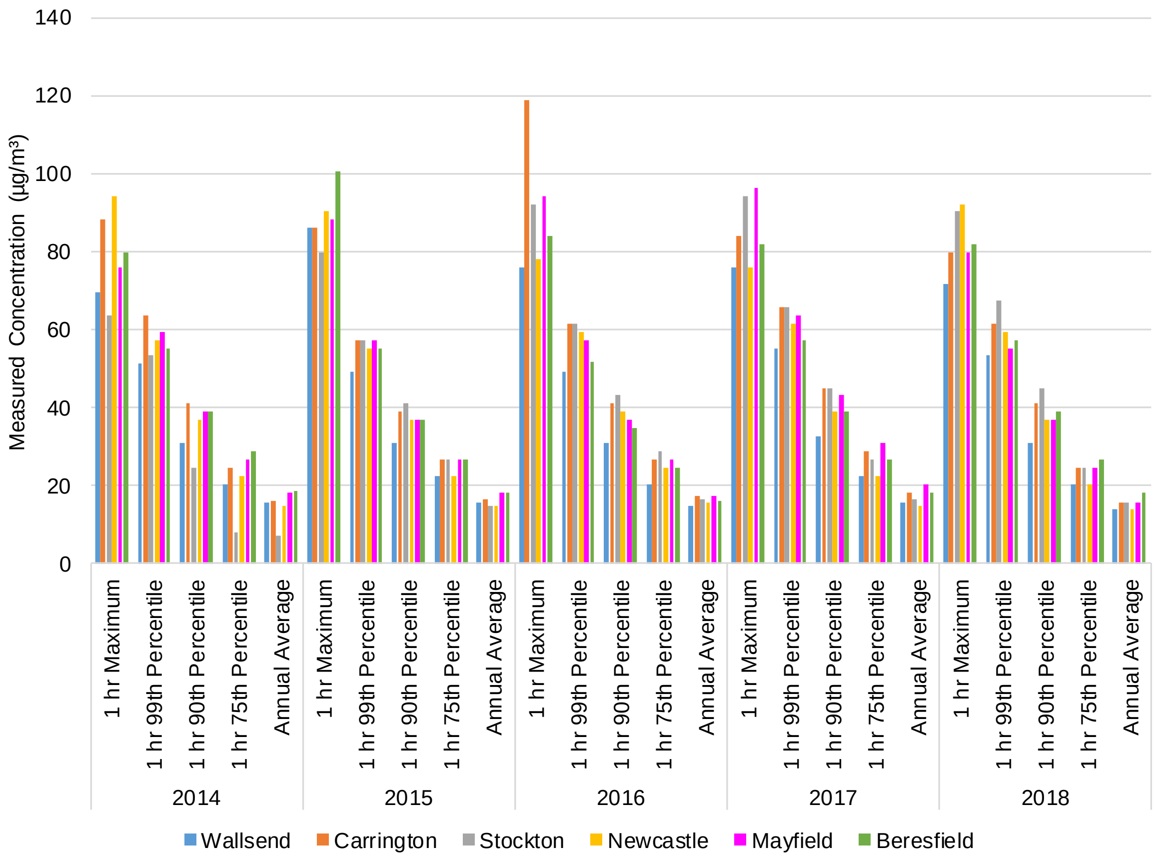


Figure 5.6: Summary statistics for Newcastle region ambient NO_2 measurements (2014-2018)

As shown in Figure 5.6, trends are generally consistent over the five year period, with peak concentrations being approximately five times higher than average concentrations. Five year average concentrations are highest at Mayfield (18.0 µg/m³), closely followed by Beresfield (17.9 µg/m³). Averages at other locations range from 14.2 µg/m³ (Stockton) to 16.8 µg/m³ (Carrington).

5.2.2 Carbon Monoxide

Continuous hourly average ambient CO concentrations are measured at the DPIE Newcastle AQMS (Figure 5.1), but not measured at other the other AQMS sites. Figure 5.7 provides a visual representation of these measurements over the period 2014 – 2018.

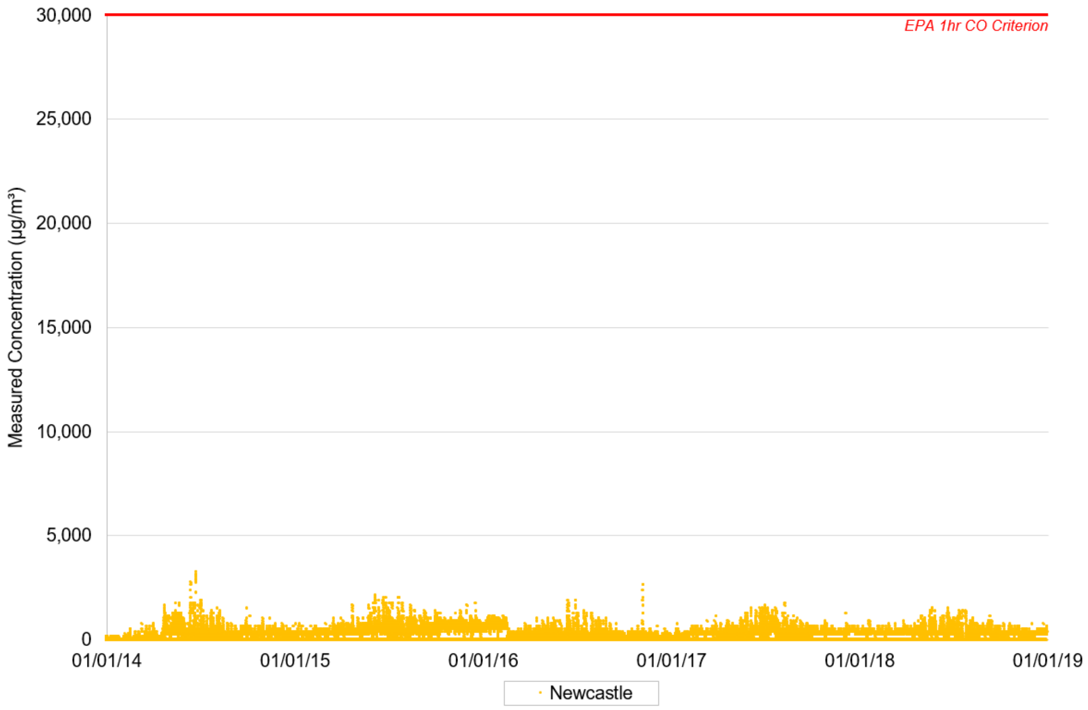


Figure 5.7: Time series plot of hourly ambient CO measurements at the Newcastle AQMS (2014-2018)

As shown in Figure 5.7, all measured concentrations are within the EPA 1 hour CO criterion of 30,000 µg/m³, with a maximum measured concentration of 3,250 µg/m³. Annual peak concentrations are generally below 2,500 µg/m³, with higher concentrations observed during the winter months.

Figure 5.8 shows a summary of CO monitoring statistics for Newcastle AQMS (2014-2018).

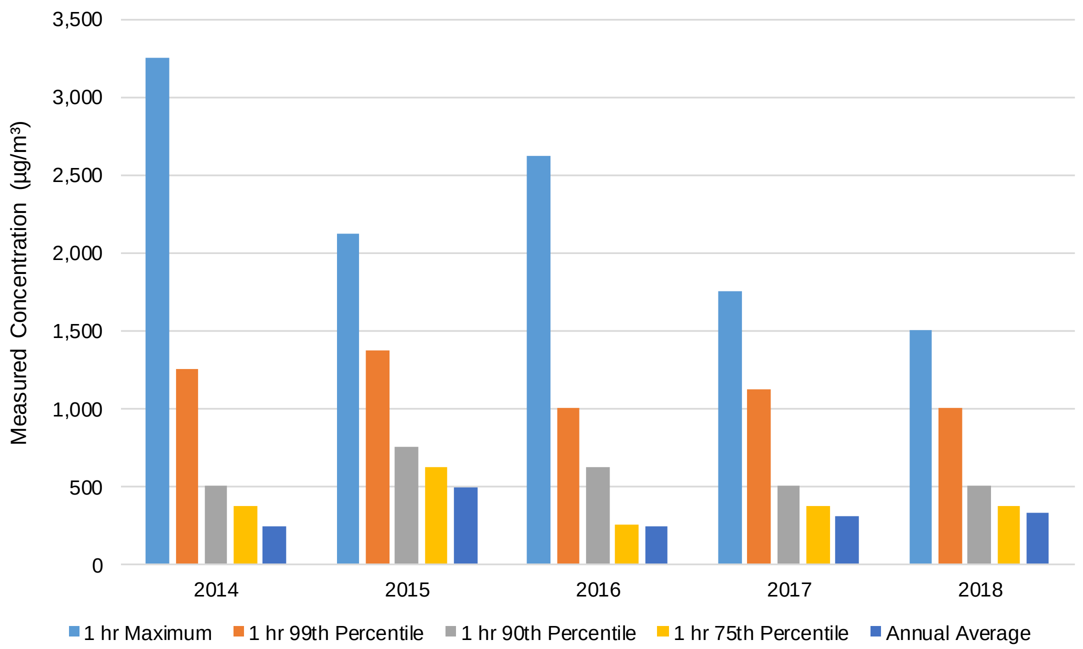


Figure 5.8: Summary statistics for Newcastle region ambient CO measurements (2014-2018)

As shown in Figure 5.8, trends in peak values possess a slight downward trend over the 5 years, whilst average values are variable between years.

5.2.3 Sulfur dioxide

Continuous hourly average ambient SO_2 concentrations are measured at six locations within the Newcastle region (Figure 5.1). Figure 5.9 provides a visual representation of these 1 hour average measurements over the period 2014 – 2018.

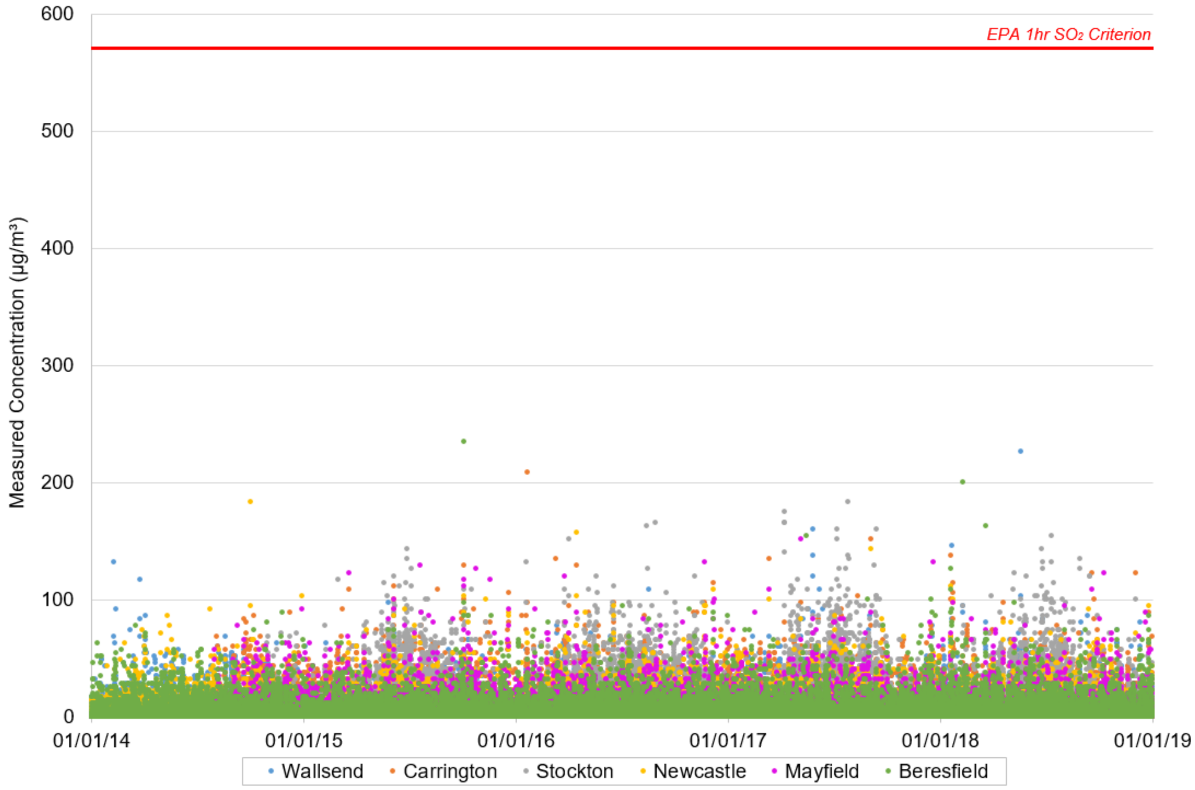


Figure 5.9: Time series plot of hourly ambient SO_2 measurements within the Newcastle region (2014-2018)

As shown in Figure 5.9, all measured concentrations are within the EPA 1 hour SO_2 criterion of 570 µg/m³. With the exception of three measurements (out of approximately 200,000 measurements), peak concentrations are below 200 µg/m³. The maximum measured 1 hour SO_2 concentration is 235 µg/m³.

A clear seasonal or temporal trend is not apparent. Figure 5.10 shows a summary of SO_2 monitoring statistics for Newcastle region (2014-2018).

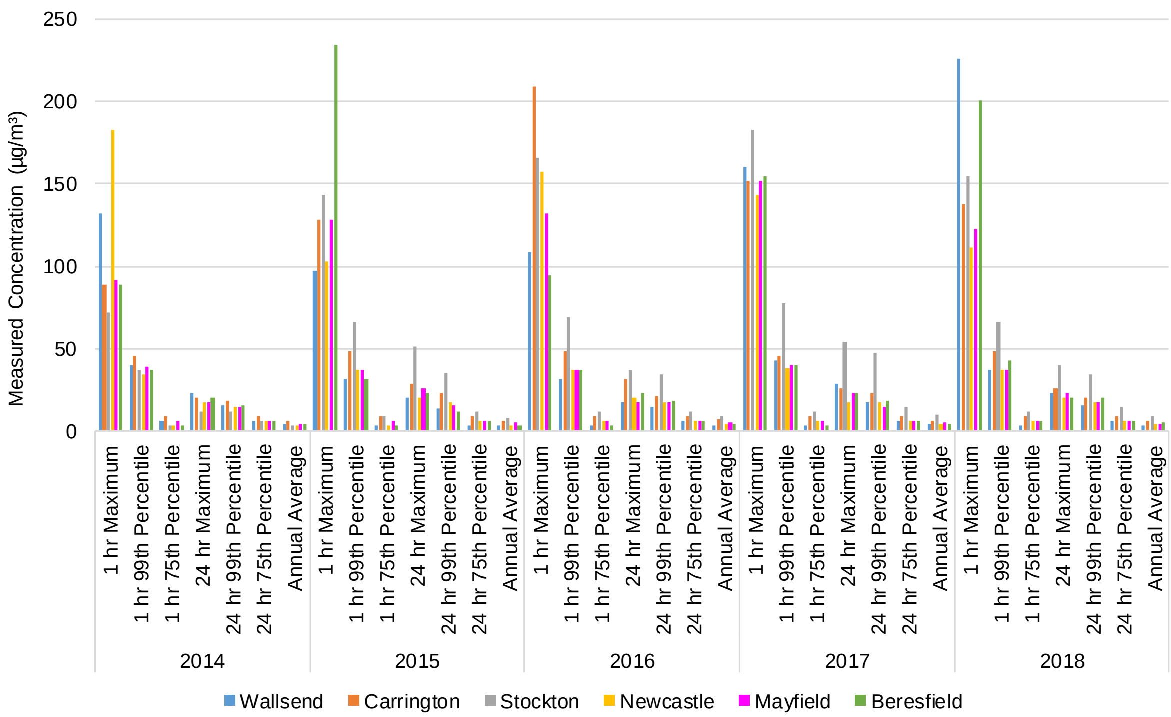


Figure 5.10: Summary statistics for Newcastle region ambient SO_2 measurements (2014-2018)

As shown in Figure 5.10, trends are generally consistent within the five year period, with peak concentrations being approximately 30 times higher than average concentrations. Five year average concentrations are highest at Stockton (7.7 µg/m³), followed by Carrington (6.3 µg/m³), which is possibly due to an influence from shipping emissions. The five year average at Beresfield (4.0 µg/m³) is equal to that at Newcastle, and slightly higher than that at Wallsend (3.6 µg/m³).

5.2.4 Particulate matter less than 2.5 micrometres

Continuous hourly average ambient $PM_{2.5}$ concentrations are measured at six locations within the Newcastle region (Figure 5.1). Figure 5.11 provides a visual representation of 24 hour average measurements over the period 2014 – 2018.

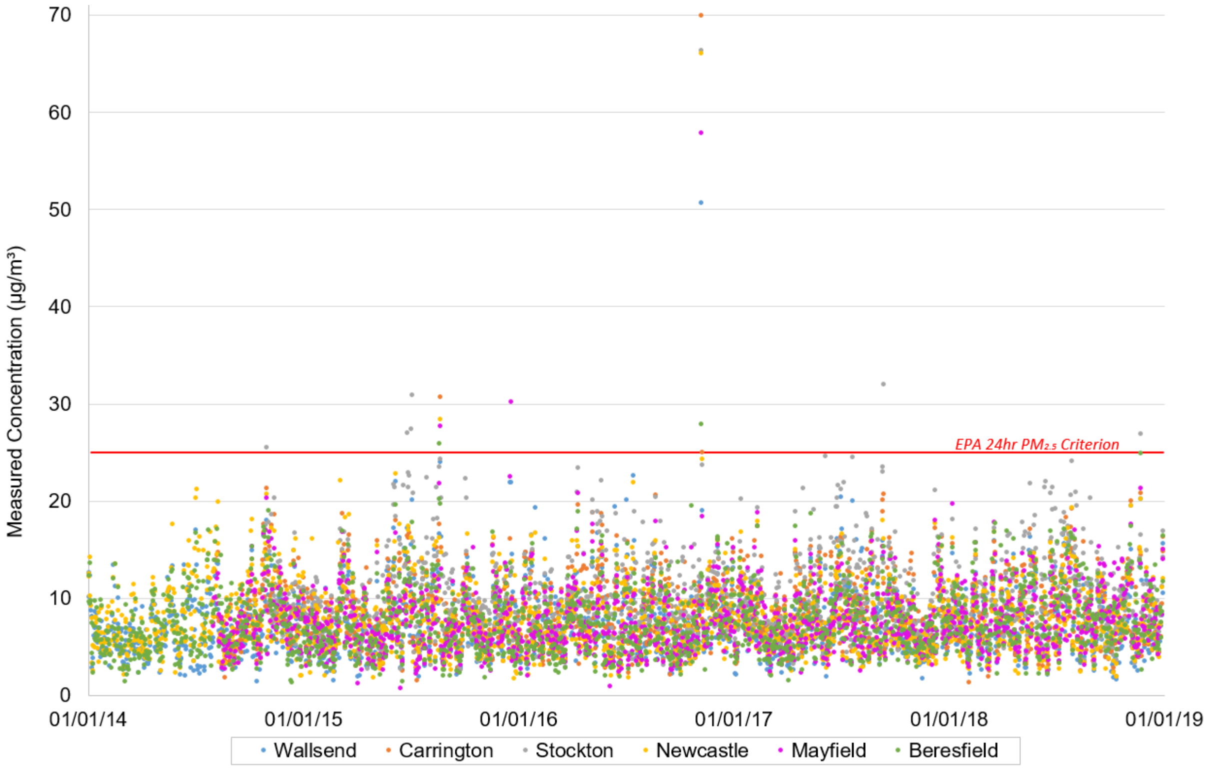


Figure 5.11: Time series plot of 24 hour average ambient $PM_{2.5}$ measurements within the Newcastle region (2014-2018)

As shown in Figure 5.11, peak measurements exceed the EPA 24 hour $PM_{2.5}$ criterion of 25 µg/m³ at all locations. These measurements primarily relate to interregional dust storms, hazard reduction burns, and bushfire events. Figure 5.12 shows a corresponding summary of $PM_{2.5}$ monitoring statistics for Newcastle region (2014-2018).

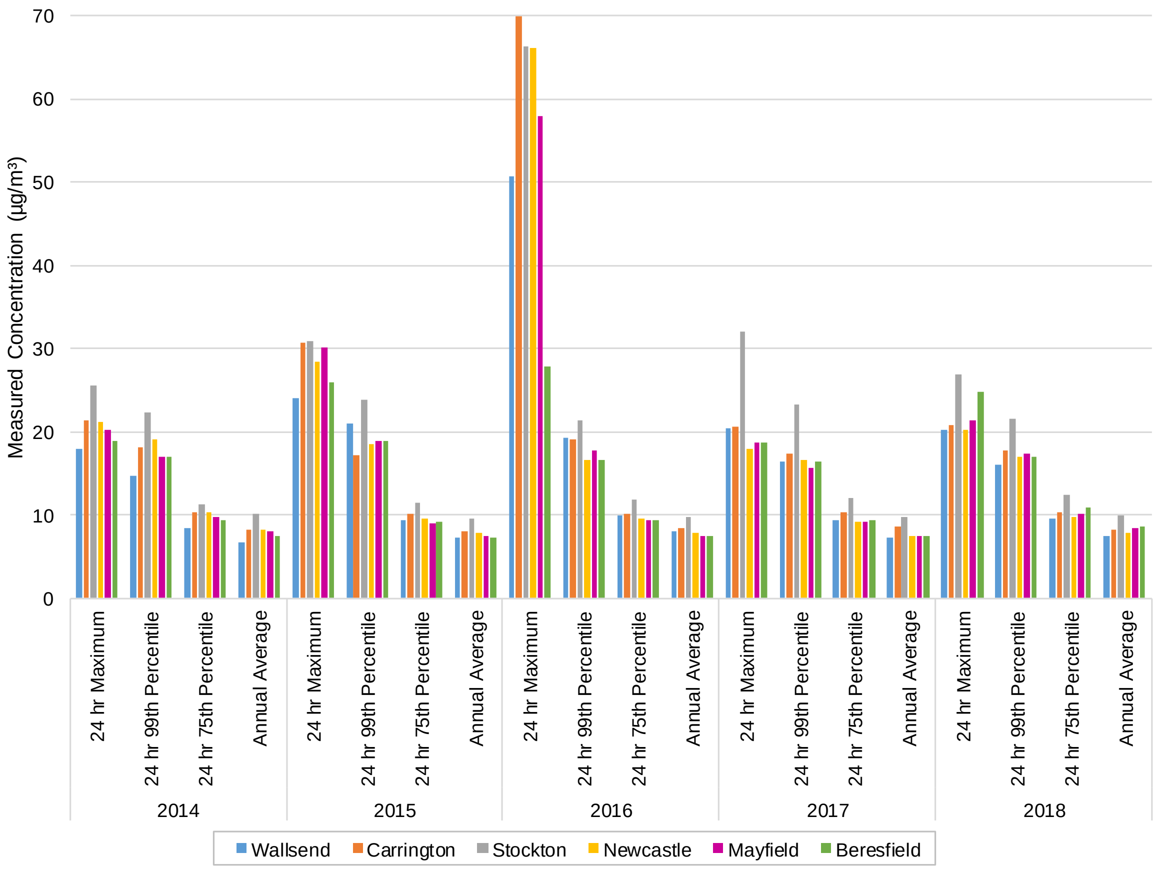


Figure 5.12: Summary statistics for Newcastle region ambient $PM_{2.5}$ measurements (2014-2018)

As shown in Figure 5.12, trends are varied within the five year period, with peak concentrations being approximately four times higher than average concentrations. Inter-annual variability in peak statistics is primarily driven by the influence of exceptional events such as dust storms and bushfire activity

In 2016, extensive hazard reduction burns were the major influences on elevated $PM_{2.5}$ concentrations throughout NSW. All exceedances of the 24 hour average $PM_{2.5}$ were linked to hazard reduction burns (OEH, 2018).

Five year average concentrations are highest at Stockton (9.8 µg/m³), followed by Carrington (8.3 µg/m³). The five year average at Beresfield (7.7 µg/m³) is near to that at Newcastle and Mayfield (7.8 µg/m³), and slightly higher than Wallsend (7.3 µg/m³).

5.2.5 Particulate matter less than 10 micrometres

Continuous hourly average ambient PM_{10} concentrations are measured at six locations within the Newcastle region (Figure 5.1). Figure 5.13 provides a visual representation of 24 hour average measurements over the period 2014 – 2018.

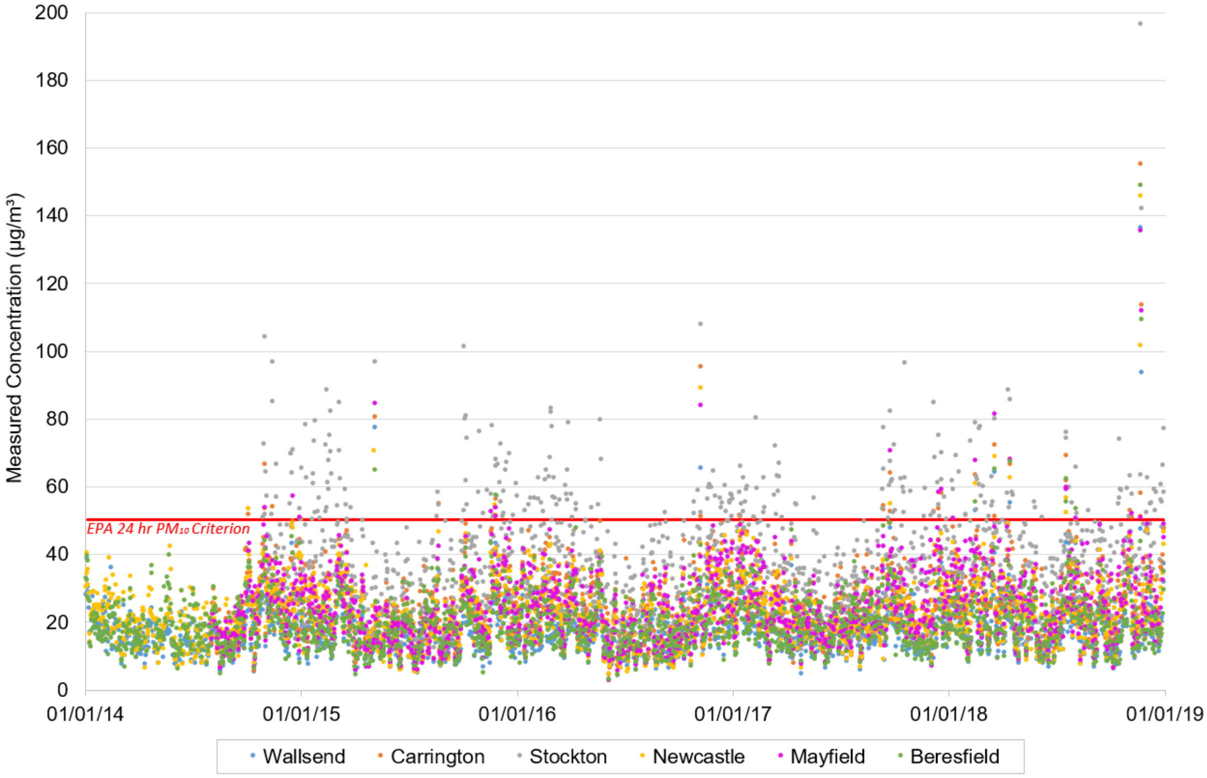


Figure 5.13: Time series plot of 24 hour average ambient PM_{10} measurements within the Newcastle region (2014-2018)

As shown in Figure 5.13, peak measurements exceed the EPA 24 hour PM_{10} criterion of 50 µg/m³ at all locations. These measurements primarily relate to interregional dust storms, hazard reduction burns, and bushfire events.

Of interest, the Office of Environment and Heritage (OEH), (now DPIE) Lower Hunter Particle Characterisation Study (OEH, 2016) identifies that samples collected at Stockton contained approximately 12 µg/m³ more annual average PM_{10} sea salt than Mayfield, with differences most prevalent during the summer months when onshore winds are present. The effect is less pronounced in $PM_{2.5}$ due to the coarser makeup of coastal sea salt.

Figure 5.14 shows a corresponding summary of PM_{10} monitoring statistics for Newcastle region (2014-2018).

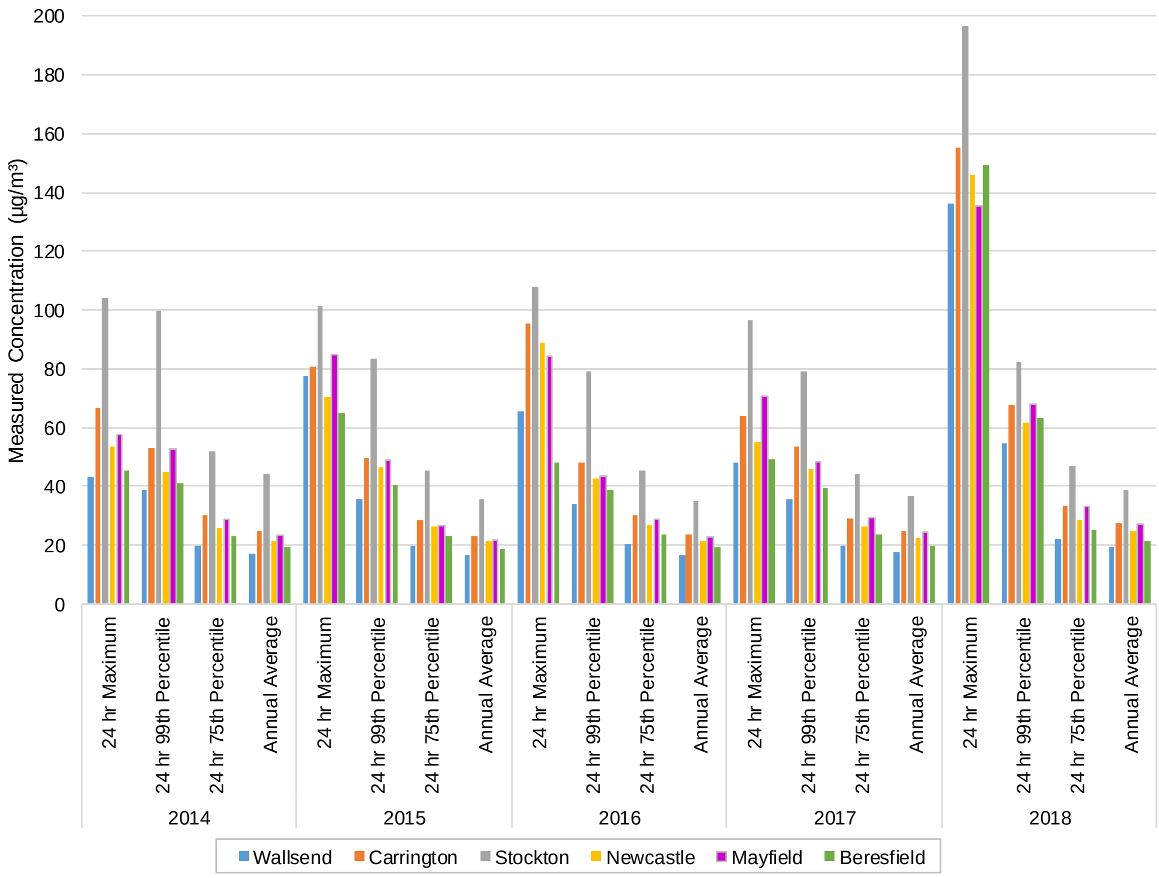


Figure 5.14: Summary statistics for Newcastle region ambient PM_{10} measurements (2014-2018)

As shown in Figure 5.14, trends are varied within the five-year period, with peak concentrations being approximately four times higher than average concentrations. Five year average concentrations are highest at Stockton (38 µg/m³), followed by Carrington (24 µg/m³), and Mayfield (24 µg/m³). The five year average at Beresfield (20 µg/m³) is near to that at Newcastle (22 µg/m³), and higher than Wallsend (17 µg/m³). Inter-annual variability in peak statistics is primarily driven by the influence of exceptional events such as dust storms and bushfire activity. A detailed review of these events is provided in Section 5.8.

5.3 Summary

Based on this review the following

- Ambient air quality standards for NO_2, CO and SO_2 are met at all locations across the 5 years reviewed, with significant margin between peak measurements and the relevant standards.
- Short term (24 hour average) ambient air quality standards for PM ($PM_{2.5}$ and PM_{10}) are exceeded at all locations across the 5 years reviewed, due to environmental events; such as, dust storms and bushfires.
- The long term (annual average) $PM_{2.5}$ ambient air quality standard is reached at Wallsend, and exceeded at all other locations within the 5 years reviewed. The long term (annual average) PM_{10} ambient air quality standard is exceeded at Carrington, Stockton and Mayfield, and met at Wallsend, Beresfield and Newcastle.
- Ambient air quality is generally consistent within the region, with influence of sources such as shipping and coastal sea salt evident in the data.

6. ASSESSMENT METHODOLOGY

This section provides an overview of the technical approaches applied within the assessment.

6.1 Model Selection

Given the presence of buoyant air emissions within a coastal region, the use of a non-steady-state model such as CALPUFF provides a distinct advantage in the treatment of calm conditions over steady-state models (such as AERMOD or AUSPLUME), and is also able to address changes in meteorology that occur with changing land use, including coastal fumigation.

The height of the atmospheric boundary layer is driven by turbulence, which is generated either mechanically via air motion over rough obstacles, or convectively, through heating of the earth’s surface. Noting the low surface roughness of water, and the ability of water to absorb and distribute solar radiation, the levels of atmospheric turbulence are lower over water. CALPUFF addresses this through the incorporation of algorithms that are able to treat these effects.

6.2 Dispersion Meteorology

The regional meteorology has been modelled using CALMET. CALMET is a meteorological pre-processor that includes a wind field generator containing objective analysis and parameterised treatments of slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables to produce the three-dimensional meteorological fields that are utilised in the CALPUFF dispersion model (i.e. the CALPUFF dispersion model requires meteorological data in three dimensions). CALMET uses the meteorological inputs in combination with land use and geophysical information for the modelling domain to predict gridded meteorological fields for the region.

A one year meteorological dataset was compiled for CALPUFF for the calendar year 2018. The year 2018 has been selected based on a review of the last 5 years of meteorological data for DPIE Beresfield AQMS (Section 4). 2018 was noted to be the most consistent with the 5 year average wind speed and percent calms, whilst also exhibiting data completeness above 90% required for use in dispersion modelling (99.7% complete). Ambient air quality data for this year is also generally consistent with other years.

The compiled dataset includes hourly spatially-varying fields of meteorological variables relevant to the estimation of pollutant dispersion.

CALMET has been run using six surface stations each augmented by corresponding upper air pseudo-stations from the Commonwealth Scientific and Industrial Research Organisation’s (CSIRO’s) ‘The Air Pollution Model’ (TAPM). These TAPM runs have incorporated assimilation into the lowest 3 layers in order to control winds within the surface layer to reflect observed values, whilst providing vertical blending of the surface observations with the TAPM upper air predictions. TAPM surface observations have then been discarded within CALPUFF in place of actual observations.

This approach ensures the appropriate weighting of measured data, and addresses the spatial variability in meteorology and boundary layer development across the domain. Most importantly, this approach also minimises the production of assimilation boundaries that are a critical limitation of a hybrid approach involving the incorporation of 3-dimensional prognostic wind fields alongside surface observations. A summary of this meteorological modelling methodology is provided in Appendix A.

6.3 Model Receptors

The model configuration requires designation of the spatial location of model receptors, which are points at which model concentration outputs are generated. The model has used both gridded and discrete receptors as per the following:

- Gridded receptors have been incorporated on a 30 x 30 km receptor grid equating to a total of 14,641 gridded receptors across 900 square kilometres. This domain extent is considered adequate for the capture of peak model predictions.
- 36 discrete receptors have been allocated to localities across the gridded modelling domain.

Table 6.1 lists the discrete receptors with corresponding coordinates. Figure 6.1 shows the gridded receptor domain extent and corresponding discrete receptor locations.

Table 6.1: Summary of discrete receptors

Receptor	Locality	Easting (kmE)	Northing (kmN)
01	Tomago	379.326	6367.022
02	Hexham	376.901	6367.022
03	Beresfield	374.324	6369.986
04	Heatherbrae	381.323	6371.779
05	Williamtown	392.366	6369.398
06	Fullerton Cove	391.008	6365.382
07	Fern Bay	387.228	6362.173
08	Kooragang	385.102	6360.795
09	Stockton	386.134	6358.129
10	Carrington	384.556	6357.861
11	Mayfield	382.100	6359.338
12	Hamilton	383.027	6356.672
13	Newcastle	385.895	6356.151
14	Merewether	383.491	6354.499
15	Adamstown	381.231	6354.847
16	New Lambton	379.927	6356.614
17	Jesmond	377.725	6358.787
18	Warabrook	380.227	6360.347
19	Sandgate	379.360	6362.211
20	Maryland	374.470	6360.837
21	Cameron Park	370.071	6357.697
22	Cardiff	374.701	6354.655
23	Glendale	372.825	6355.473
24	Black Hill	370.379	6365.841
25	Thornton	372.524	6372.596
26	Ashtonfield	369.596	6372.990
27	East Maitland	367.807	6375.432
28	Millers Rest	379.546	6374.370
29	Raymond Terrace	382.306	6374.446
30	Maitland	364.839	6377.335
31	Morpeth	371.583	6378.304
32	Osterley	378.130	6378.482
33	Medowie	393.082	6376.761
34	Largs	369.012	6380.994
35	Brandy Hill	377.714	6381.904
36	Eagleton	383.569	6380.321

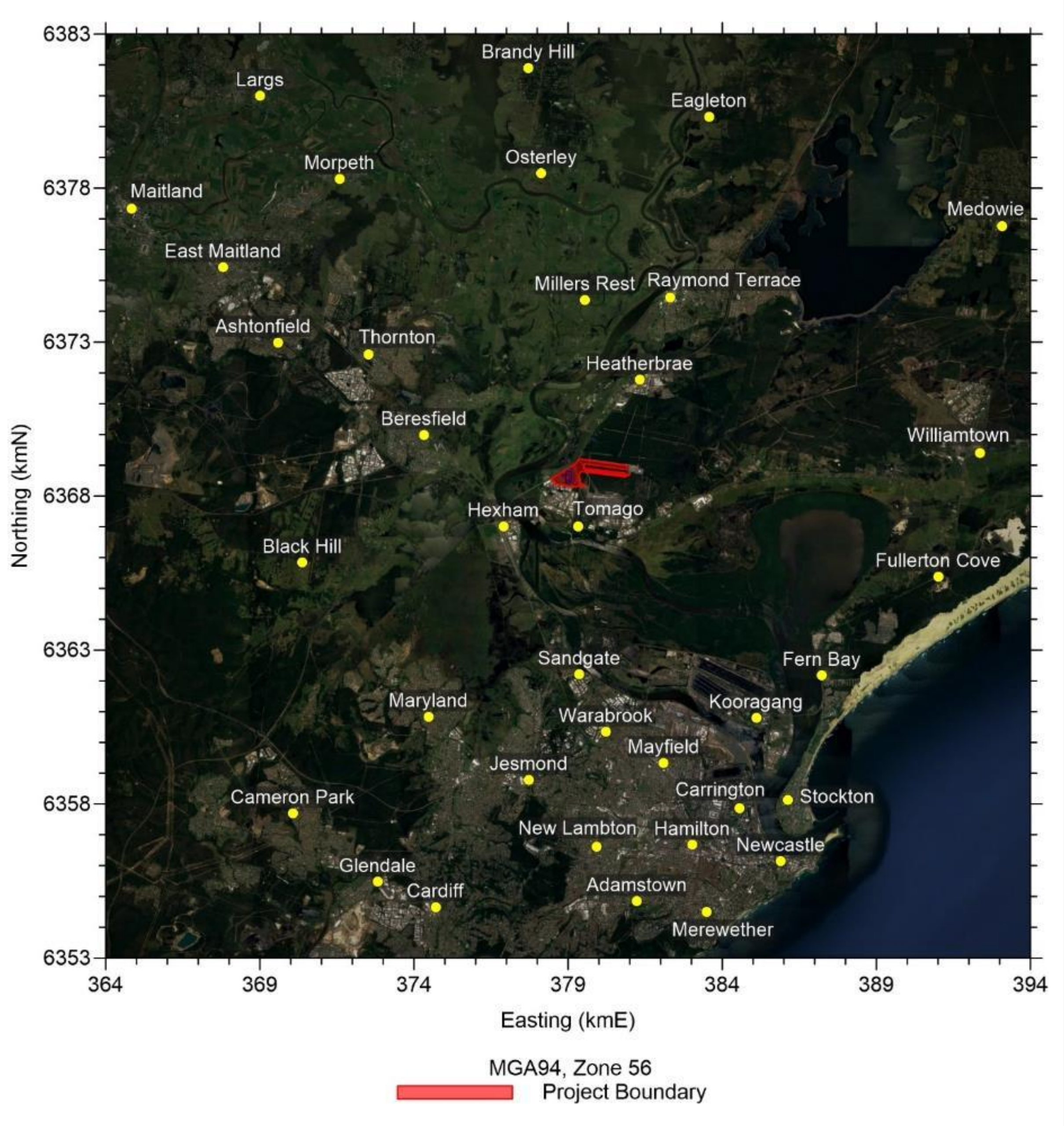


Figure 6.1: Aerial image showing discrete receptors, gridded receptor domain extent and Proposal boundary

6.4 Emission Parameters

Emission parameters have been compiled based on indicative manufacturer information for the modelled plant options. Indicative stack locations have been estimated for both engine types, by overlaying selected generic plant layouts onto the centre of the generator yard within the site layout.

Adjustment to stack design and locations will occur with progression of the design due to detailed consideration of spatial requirements, and/or adoption of alternative vendor options. The influence of design or location changes within the generator yard area are unlikely to be material when considered in the context of source-receptor distances of interest.

Table 6.2 presents a summary of modelled emission parameters adopted for each plant option.

Table 6.2: Summary of modelled emission parameters

Emission Source	Stacks per Cluster[1]	Stack Height (mAGL)	Effective Diameter (m)	Exit Velocity (m/s) NG / DO	Exit Temperature (K) NG / DO	Easting (kmE MGA94)	Northing (kmN MGA94)
Gas Turbine Option							
Gas turbine exhaust 1	N/A	20	2.782	60 / 59	679 / 681	378.984	6368.576
Gas turbine exhaust 2		20	2.782	60 / 59	679 / 681	378.985	6368.598
Gas turbine exhaust 3		20	2.782	60 / 59	679 / 681	378.987	6368.620
Gas turbine exhaust 4		20	2.782	60 / 59	679 / 681	378.988	6368.642
Reciprocating Engine Option							
Exhaust stack cluster 1	4	32	3.6	26 / 30	593 / 561	378.949	6368.561
Exhaust stack cluster 2	4	32	3.6	26 / 30	593 / 561	378.951	6368.597
Exhaust stack cluster 3	5	32	4.025	26 / 30	593 / 561	378.956	6368.659

Note:
- [1]Reciprocating engine stacks merged to a single effective source per stack cluster and modelled with unity emission rate assumptions corrected to the stack / cluster values (i.e. 4, 4 and 5 g/s for each respective cluster, thus allowing scaling using individual stack emission rates.
- 'NG / DO': Natural Gas / Distillate Oil values (respectively).
- mAGL: metres above ground level.
- All sources modelled at a base elevation of 15 mAHD (m Australian Height Datum).

6.5 Building Downwash Effects

Aerodynamic wakes are produced as air travels over irregular objects such as building structures. Within these wakes, there is a high level of turbulence and vertical mixing. In instances where exhaust plumes interact with these wakes, pollutants can be mixed downward to ground level, producing locally elevated concentrations, and otherwise reducing the scale of plume rise at distances downwind of the source. Within dispersion modelling, this effect is referred to as building downwash.

For this study, emission sources were screened for potential interaction with building wakes, where wakes extend:

- by a distance of 5 x L from the leeward edge of a wake producing structure, where L is the lesser of the structure height or the projected structure width.
- to a height of 2.5 times the height of the structure.

Based on generic site layouts, the reciprocating engine plant emission stacks (~30 m high) will be located within the zone of influence of the generator hall, which is approximately 18 m high at its peak. Figure 6.2 shows the proximity of these structures, as represented within the building downwash model.

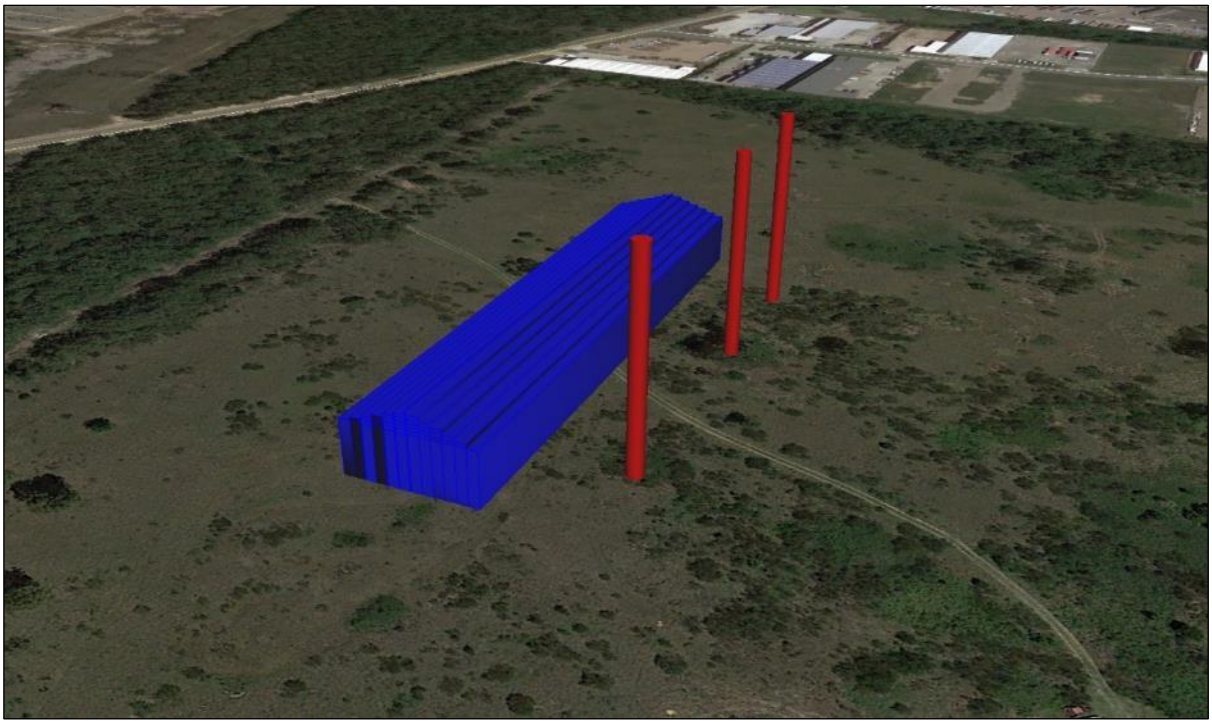


Image sourced from Google Earth Pro.

Figure 6.2: Aerial image showing reciprocating engine building representation (blue) and point sources (red).

6.6 NO_2 Conversion

Oxides of nitrogen (NO_x) are emitted primarily as nitric oxide (NO) and nitrogen dioxide (NO_2). At the point of emission, NO_x will primarily comprise NO which has the ability to be progressively oxidised to NO_2 by atmospheric ozone over periods in the time scale of hours. Given that NO_2 is the principal species in terms of potential human health effects, a method for the estimation of NO_2 conversion is required.

Several approaches are available to estimate the transformation of NO to NO_2. The Approved Methods provide the following techniques, in descending order of conservatism:

- *Method 1: 100% conversion of NO to NO_2.*
- *Method 2: NO to NO_2 conversion limited by ambient ozone concentration (OLM)*
- *Method 3: NO to NO_2 conversion using empirical relationship.*

For this assessment, the Ozone Limiting Method (OLM) (Method 2) has been used to estimate NO_2 concentrations, as this allows a conservative representation of conversion, whilst also refining predictions beyond Method 1.

6.6.1 Ozone Limiting Method

In its default form, the OLM assumes that 10% of the NO_x emissions occur as NO_2, with the remaining NO being converted over to NO_2 until all of the ambient ozone is consumed. In this respect, the conversion is limited by the availability of ozone. Equation 6.1 provides the basis for the OLM calculation applied in this assessment:

$$NO_2total = \{ISR \times NO_xp\} + minimum\{\,[(1 - ISR) \times NO_xp]\ or\ [(46/48) \times\ O_3bg]\} + NO_2bg$$

Equation 6.1

Where:

NO_2total	=	total NO_2 concentration inclusive of project and background (µg/m³)
ISR	=	in-stack NO_2:NO_x ratio
NO_xp	=	predicted NO_x concentration (µg/m³)
O_3bg	=	measured background ozone concentration (µg/m³)
NO_2bg	=	background NO_2 concentration (µg/m³)

The ozone concentrations applied were based on hourly monitoring data from the Beresfield AQMS. Ozone and NO_2 data were 93% and 94% complete (respectively) for the year 2009. Data gaps of up to two hours were filled by linear interpolation which brought the data availability to 98%. Remaining missing values were substituted with data from Wallsend to provide a complete dataset.

The OLM calculations were performed on an hourly basis for each of the 8,760 hours of the model run. Hourly NO_2 predictions were processed using the OLM in conjunction with corresponding hourly ozone and NO_2 background data.

6.6.2 In-Stack NO_2:NO_x Ratio

As outlined in Section 5.6.1 the default OLM contains the implicit assumption that 10% of NO_x emissions exist as NO_2 at the point of release, i.e. the emissions possess an in-stack NO_2:NO_x ratio (ISR) of 0.1. This ISR is generally appropriate for combustion sources, which typically feature ISRs of 0.05 to 0.1. Manufacturer information for the reciprocating engines indicates that this assumption may not be appropriate for lean burn gas engines using SCR to control NO_x emissions to low levels.

To estimate an ISR suitable for application in this assessment, a review of the US EPA In-Stack Ratio (ISR) database (US EPA, 2017) was undertaken. This database consists of over 2,000 source tests across a range of combustion plant types, with detail of a range of emission and test parameters. The database was filtered for the following properties:

- Reciprocating internal combustion engines
- 4-stroke lean burn combustion
- Natural gas fuel
- Emission concentration less than 150 mg/Nm³ at 15% O_2 (equivalent to 450 mg/Nm³ a 3% O_2).
- Catalytic emission control with exhaust oxygen content > 8%[2].

In addition, a range of anomalous results were removed (such as oxygen content greater than 20% or discrepancies in NO_x addition). This results in a dataset of approximately 391 ISR measurements, which are presented in Figure 6.3.

[2] Oxygen criterion applied to remove any inadvertently included rich burn engines with 3-way catalysts, or samples for which oxygen was not reported.

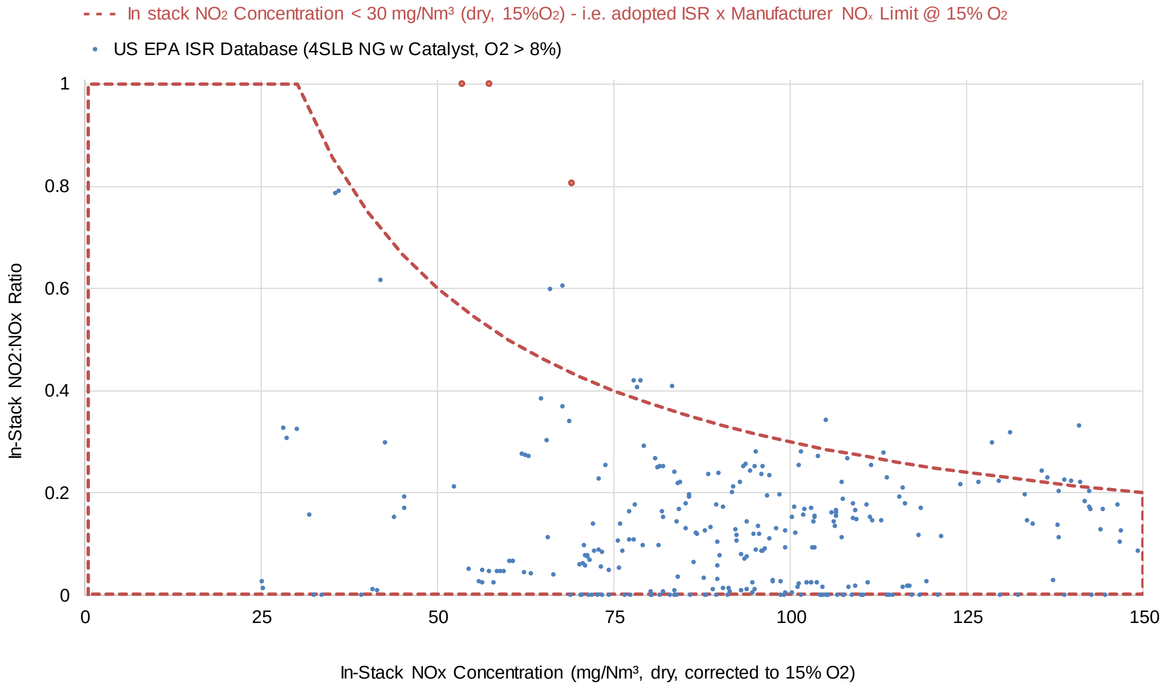


Figure 6.3: ISR vs in-stack NO_x concentration from filtered US EPA ISR database

These data show that for in-stack NO_x values within the manufacturer specification of 150 mg/Nm³, ISRs are generally below 0.2, averaging 0.11 across the filtered dataset. It is noted that the three highest values (shown in maroon) are from a single set of three consecutive tests performed on the same unit within one day, and are suspected to be erroneous (with two of three test results reporting NO of 0.0 ppm). These values have been retained for clarity.

Across the dataset, over 90% of ISR values below this concentration fall within a 30 mg/Nm³ in-stack NO_2 concentration (i.e. the area bounded by the red dashed line). This indicates that the assumption of emissions occurring at the manufacturer specification with an ISR of 0.2 would accommodate variability against the average ISR of 0.11, and also higher ISRs that may be present at lower NOx ranges, under which case a conservative representation of available NO is implied.

Accordingly, an ISR of 0.2 has been adopted for reciprocating engines operating on natural gas, and the default of 0.1 applied for other sources. Manufacturer information indicates that an ISR of 0.1 is appropriate for reciprocating engines operating on distillate fuel.

6.7 Predictions for Sub-hourly Averaging Periods

Where required, hourly averaged model predictions and background data have been converted to sub-hourly averaging periods using the power law conversion provided in the EPA Victoria draft guideline *Guidance notes for using the regulatory air pollution model AERMOD in Victoria* (EPAV, 2013). This conversion accounts for fluctuations in pollutant levels within the larger averaging period, and is provided in Equation 5.2.

$$C_{n\,min} = C_{1\,hour} \times \left(\frac{60}{n}\right)^{0.2}$$

Equation 6.2

Where: $C_{1\,hour}$ is the 1 hour average prediction.

$C_{n\,min}$ is the n minute average prediction.

6.8 Background Air Quality Dataset

Background data has been sourced from the DPIE Beresfield AQMS based on the data presented in Section 4. This station has been selected given proximity to the Proposal, and representativeness within the surrounding modelling domain in terms of surrounding land uses, separation from the coast and alignment within the Hunter Valley axis.

Particulate matter data have been reviewed to remove exceptional events, based on information provided in OEH quarterly air quality monitoring summaries for the Newcastle region (OEH, 2018b; 2018c; 2018d; 2018e; 2018f). This allows the assessment of the Proposal excluding extraneous events.

The quarterly reports were reviewed with identification of a total of seven exceptional events relating to bushfire and dust storm activity. The remaining peak 24 hour $PM_{2.5}$ concentration was measured on 15 July 2018, at a time when regional dust events were reported. The retention of this data point is considered conservative to the assessment.Table 6.3 provides a summary of excluded PM events.

Table 6.3: Summary of excluded PM events

Date/s	Description	Reference
14-16/02/2018	Interregional dust storm, bushfire activity at Wollemi National Park	OEH (2018b)
19-20/03/2018	Long range dust transport	OEH (2018c)
15/04/2018		
18-19/07/2018	Long range dust transport (Victorian Mallee region)	OEH (2018d)
04/08/2018	Long range dust transport	
6/11/2018	Long-range dust transport from north-western NSW	
21-23/11/2018	Long range dust transport (South Australia), Port Stephens bushfire activity.	OEH (2018e)

Table 6.4 presents a summary of adopted 2018 pollutant background concentrations, as based on data from the DPIE Beresfield AQMS.

Table 6.4: Summary of adopted 2018 pollutant background concentrations.

Pollutant	Assessment Statistic	Adopted Background Concentration (µg/m³)	Impact Assessment Criterion (µg/m³)
NO_2	1 hour maximum	*82**	246
	Annual mean	18.1	62
CO	15 minute maximum	1,980**	100,000
	1 hour maximum	1,500	30,000
	8 hour maximum	1,125	10,000
SO_2	10 minute maximum	286	712
	1 hour maximum	200	570
	24 hour maximum	20	228
	Annual mean	4.7	60
$PM_{2.5}$	24 hour maximum	17.1	25
	Annual mean	8.1	8
PM_{10}	24 hour maximum	40.6	50
	Annual mean	20.0	25

Note: *Maximum hourly value shown. Time varying background concentration applied in analysis.
**Value converted using power law.
Adopted PM background concentrations exclude 7 exceptional events when interregional dust storms and/or bushfires were present.

7. EMISSION ESTIMATION

7.1 Overview

Proposal emissions have been estimated using manufacturer data supplemented by US EPA AP-42 emission factors (US EPA, 2006) and fuel specifications. For pollutants where manufacturer information is not available, emission factors allow the estimation of individual pollutant emissions on the basis of fuel consumption and generator technology.

AGL is proposing to employ either gas turbine or reciprocating engine generation technology for the Proposal. ERM has been provided with vendor specifications for a range of gas turbine and reciprocating engine options being considered for the Proposal. ERM has reviewed the technical data for these options, and progressed detailed modelling of one gas turbine and one reciprocating engine option, as representative of the proposed generator technologies and the scale of the Proposal output.

In addition, all emission estimates have been scaled upward by 10% to accommodate minor variability in plant specifications that may exist within each technology option.

7.2 Estimation Methods

Manufacturer data has been used to estimate NO_x and CO emissions (both plant options), as well as formaldehyde and SO_2 emissions for reciprocating engines. Where based on manufacturer data, the modelled emissions reflect control of emissions either to, or within POEO limits, which the plant will be designed to meet during routine operation.

It is noted that quantitative POEO limits do not apply during start-up or shutdown of the plant. A discussion of start-up and shutdown emissions is provided in Appendix B. In addition, it is noted that whilst POEO limits may not be met during part load operation, (e.g. where an individual generator is run at low loads typically less than 40% - 50% of maximum output), AGL do not propose to operate generators at part loads.

Manufacturer emission data for PM is limited to filterable particulate. Accordingly, PM emissions for reciprocating engines have been estimated based on manufacturer's data for the filterable fraction, and supplemented by the US EPA AP-42 PM emission factors, (which represent an average of test data), for the condensable fraction.

The use of oxidation catalysts on the reciprocating engines is anticipated to provide a reduction of condensable material through oxidation of soluble organic fraction PM (MECA, 2015), thus resulting in a reduction against the uncontrolled emissions factors featured in the US EPA (2006). As a conservative measure, this effect has not been incorporated into the emission estimation.

A control efficiency of 40% has been incorporated into the estimation of acrolein emissions for reciprocating engines under natural gas operation. This is based on a theoretical estimate from the manufacturer which includes conservatism to reflect uncertainty in measurement of post-control concentrations near to method detection limits.

Table 7.1 outlines the basis of pollutant emission estimates by technology and pollutant.

Table 7.1: Summary of emission estimation basis by pollutant and technology type

Parameter	Technology Type	
	Gas Turbine Option	Reciprocating Engine Option
NO_x as NO_2	Manufacturer data	
CO		
SO_2	Fuel specification	Manufacturer data
PM	Manufacturer data (filterable fraction), US EPA AP-42 Emission Factors (condensable fraction)	
Acrolein	US EPA AP-42 Emission Factors*	

Benzene		
Formaldehyde	US EPA AP-42 Emission Factors	Manufacturer data
PAH	US EPA AP-42 Emission Factors	

Notes: *Vendor estimate of oxidation catalyst efficiency incorporated into reciprocating engine estimate (natural gas fuel).

7.3 Fuel Consumption

Fuel consumption estimates have been provided by Aurecon and are detailed in Table 7.2. These values have been converted to units of million British thermal units per second (mmBTU/s) on a higher heating value (HHV) basis, for use in conjunction with the US EPA AP-42 emission factors, which apply on this basis.

Table 7.2: Summary of fuel emission estimates

Parameter	Gas Turbine		Reciprocating Engine		Units / Basis
	Natural Gas	Distillate	Natural Gas	Distillate	
Fuel Consumption	2272	2265	2071	2168	GJ/hr (LHV, Plant)
	158	157	44	46	MW_{th} (LHV, Unit*)
HHV / LHV Conversion	1.10	1.07	1.10	1.07	-
Fuel Consumption	174	168	49	50	MW_{th} (HHV, Unit*)
	0.174	0.157	0.049	0.050	GJ/s (HHV, Unit*)
	0.165	0.149	0.046	0.047	mmBTU/s (HHV)

Notes:
- LHV: Lower Heating Value,
- HHV: Higher Heating Value,
- GJ: Gigajoules, MW_{th} – megawatt (thermal).
- *Refers to a single generator unit (i.e. an individual turbine/reciprocating engine).

7.4 US EPA AP-42 Emission Factors

The US EPA AP-42 database has been referenced for the emission factors outlined in Table 7.3.

Table 7.3: Summary of adopted US EPA AP-42 emission factors (lb/MMBTU)

Substance	Gas Turbine Option (a)		Reciprocating Engine Option	
	Natural Gas	Distillate	Natural Gas (b)	Distillate (c)
$PM_{2.5}$, PM_{10} (condensable)	4.70E x 10^{-03}	7.20E x 10^{-03}	9.91E x 10^{-03}	7.70E x 10^{-03}
Acrolein	6.40 x 10^{-06}	6.4 x 10^{-06}	5.14 x 10^{-03}	7.88 x 10^{-06}
Benzene	1.20 x 10^{-05}	5.50 x 10^{-05}	4.40 x 10^{-04}	7.76 x 10^{-04}
Formaldehyde	7.10 x 10^{-04}	2.80 x 10^{-04}	N/A	
PAHs (B[a]P TEQ)(d)	9.00 x 10^{-07} (e)	5.00 x 10^{-06} (e)	1.67 x 10^{-07}(d)	1.39 x 10^{-04}(d)

Notes:
(a) US EPA (2006) – 3.1 Stationary Gas Turbines
(b) US EPA (2006) – 3.2 Natural Gas-Fired Reciprocating Engines (4 stroke lean burn values adopted) in absence of dual-fuel factors.
(c) US EPA (2006) – 3.4 Large Stationary Diesel and All Dual-Fuel Reciprocating Engines.
(d) PAH value converted to B(a)P equivalent using the Potency Equivalent Factors (PEFs) from the Approved Methods (Table 7.2c)
(e) In absence of speciated PAHs or B(a)P TEQ, emission factor estimated as Total PAHs minus naphthalene.
N/A – Not Applicable: Emission estimate based on manufacturer data.

7.5 Sulfur Dioxide Emission Factors

SO_2 emission factors have been prepared based on conservation of mass principles, assuming the complete oxidation of fuel-bound sulfur into SO_2. Fuel-bound sulfur content has been defined by the following relevant fuel specifications:

- AEMO 2017, *Gas Quality Guidelines, (Network notification threshold adopted).*
- AG 2019, *Fuel Quality Standards (Automotive Diesel) Determination 2019,* (*Fuel standard maximum value adopted).*

Table 7.4 and Table 7.5 provide detail of the derivation of fuel-specific SO_2 emission factors for natural gas and distillate operation (respectively).

Table 7.4: Derivation of fuel-specific SO_2 emission factor for natural gas operation

Parameter	Value	Units	Source / Basis
Sulfur content	50	mg/m³@15°C, 1 atm.	AEMO, 2017
Gas density	0.755	kg/m³	AGL, 1995
Sulfur content	66.2	mg/kg	Calculated
Energy density	51.4	MJ/kg	AGL, 1995
Sulfur content	1.29	mg/MJ	Calculated
Sulfur dioxide emissions	2.57	g/GJ	

AGL 1995, Natural Gas Technical Data Handbook, AGL 1995.

Table 7.5: Derivation of fuel-specific SO_2 emission factor for distillate operation

Parameter	Value	Units	Source / Basis
Energy density	45.6	MJ/kg (HHV)	ABARE, 2008
Sulfur content	10.0	mg/kg	AG, 2019
	0.22	mg/MJ (HHV)	Calculated
Sulfur dioxide emissions	0.44	g/GJ (HHV)	

7.6 Summary of Modelled Emission Rates

Table 7.6 presents a summary of modelled emission rates by technology, fuel type and pollutant. Emission rates have been applied on a continuous basis for the 2018 meteorological dataset.

Table 7.6: Summary of modelled emission rates

Substance	Modelled Emission Rate (g/s - stack)			
	Gas Turbine Option		Reciprocating Engine Option	
	Natural Gas	Distillate	Natural Gas	Distillate
NO_x	8.3	14.0	6.0	6.5
CO	15.7	36.3	1.7	1.8
SO_2	0.5	0.1	0.49	0.48
PM	1.046	2.626	0.511	0.8998
Acrolein	0.0005	0.0005	0.071	0.0002
Benzene	0.001	0.004	0.010	0.018
Formaldehyde	0.0583	0.0208	0.602	0.652
PAHs (B[a]P TEQ)*	0.00007	0.00037	0.000001	0.000015
Ammonia	N/A		0.457	0.476

Note: - N/A – Not applicable as ammonia/urea injection within SCR-based NOx emission controls is limited to reciprocating engine plant.
- Modelled gas turbine plant comprises 4 stacks. Modelled reciprocating engine plant comprises 13 stacks.

7.7 Annualised Emission Estimates

Table 7.7 and Table 7.8 present annualised emission estimates for the Proposal on the basis of 14% and 100% operation, (respectively). These emission estimates are based on the modelled emission rates shown in Table 7.6.

Table 7.7: Annualised emission estimates – 100% Operation

Substance	Annualised Emission Estimate (t/annum) – 14% Operation			
	Gas Turbine Option		Reciprocating Engine Option	
	Natural Gas	Distillate	Natural Gas	Distillate
NO_x	146	247	346	374
CO	277	641	98	103
SO_2	8.8	1.8	28	28
PM	18	46	29	52
Acrolein	0.01	0.01	4.1	0.01
Benzene	0.02	0.07	0.6	1.0
Formaldehyde	1.0	0.4	35	37
PAHs (B[a]P TEQ)*	0.001	0.007	0.0001	0.001
Ammonia	N/A		26	27

Note: N/A – Not applicable as ammonia/urea injection within SCR-based NOx emission controls is limited to reciprocating engine plant.

Table 7.8: Annualised emission estimates – 100% Operation

Substance	Annualised Emission Estimate (t/annum) – 100% Operation			
	Gas Turbine Option		Reciprocating Engine Option	
	Natural Gas	Distillate	Natural Gas	Distillate
NO_x	1,041	1,762	2,469	2,672
CO	1,980	4,579	697	738
SO_2	63	13	201	197
PM	132	331	209	369
Acrolein	0.1	0.1	29	0.1
Benzene	0.1	0.5	4.1	7.4
Formaldehyde	7	3	247	267
PAHs (B[a]P TEQ)*	0.009	0.047	0.0004	0.006
Ammonia	N/A		187	195

Note: N/A – Not applicable as ammonia/urea injection within SCR-based NOx emission controls is limited to reciprocating engine plant.

8. RESULTS

This section provides a summary of the results of the dispersion modelling, with comparison against NSW EPA air quality impact assessment criteria. Assessment results have been provided in both tabulated form, and as contour isopleths for select modelling scenarios.

The dispersion modelling has considered the following operational scenarios:

1. Gas turbine option – Natural Gas Fuel
2. Gas turbine option – Distillate Fuel
3. Reciprocating Engine option – Natural Gas Fuel
4. Reciprocating Engine option – Distillate Fuel.

Modelling predictions for these scenarios have been screened for all pollutants assessed, on the basis of maximum values at discrete and gridded receptors within an assessment summary.

Based on the scale of these predictions, contour isopleths and receptor lists of modelling results have been prepared across these four scenarios for the following pollutant and averaging period combinations:

- NO_2:
  - maximum 1 hour average
  - annual average
- $PM_{2.5}$:
  - maximum 24 hour average
  - annual average
- Acrolein: 99.9th percentile 1 hour average
- Formaldehyde: 99.9th percentile 1 hour average.

All results have presented in the mass-based units of micrograms per cubic metre (µg/m^3). Contour isopleths have been prepared using geometric spacing (e.g. 1, 2, 5, 10, 20, 50 µg/m^3).

Incremental predictions represent the influence of emissions from the Proposal in absence of background sources. Cumulative predictions represent the combined influence of the Proposal and existing background concentrations.

8.1 Assessment Summary

Table 8.1 and Table 8.2 present a summary of maximum gridded and discrete receptor predictions for gas turbine and reciprocating engine options (respectively), for all pollutants and scenarios. All predictions are compliant with assessment criteria with the exception of the VOC acrolein (reciprocating engine option under natural gas operation; shown in bold) and annual average $PM_{2.5}$, due to elevated background levels.

To further investigate the potential for acrolein emissions to produce adverse air quality impacts, the following analysis was undertaken:

- Additional assessment was conducted incorporating a range of international health risk screening criteria and is documented in Appendix C. All predictions are estimated to be within respective screening criteria.
- A review of meteorological conditions conducive to acrolein exceedances was undertaken, and is documented in Appendix D. This review identified that predicted exceedances were associated with high wind, moderate temperature daytime conditions and did not align with times at which the plant is more likely to operate. In this capacity, the assumption of continuous operation, as adopted within this assessment, is considered to provide a conservative assessment of peak acrolein predictions.

Table 8.1: Assessment Summary – Gas Turbine Option

Substance	Averaging Period	Prediction at Maximum Impacted Receptor (µg/m³)				Maximum Incremental Prediction (µg/m³)	Background* (µg/m³)	Maximum Cumulative Prediction (µg/m³)	Criterion (µg/m³)
		Natural Gas Fuel		Distillate Fuel					
		Discrete	Gridded	Discrete	Gridded				
NO_2	1 hour maximum	58	61	63	84	84	82*	100	*246*
	Annual mean	0.2	0.3	0.4	0.4	0.4	18.1	18.5	*62*
CO	15 minute maximum	139	535	292	1,198	1,198	1,980	3,178	*100,000*
	1 hour maximum	174	669	365	1,498	1,498	1,500	2,998	*30,000*
	8 hour maximum	63	133	139	295	295	1,125	1,420	*10,000*
SO_2	10 minute maximum	8	30	1	4	30	286	316	*712*
	1 hour maximum	5	21	1	3	21	200	221	*570*
	24 hour maximum	0.8	1.5	0.1	0.2	1.5	20	21	*228*
	Annual mean	0.01	0.02	0.002	0.003	0.02	4.7	4.7	*60*
$PM_{2.5}$	24 hour maximum	1.6	3.1	3.9	7.6	7.6	17.1	24.7	*25*
	Annual mean	0.03	0.04	0.08	0.10	0.10	**8.1***	**8.2***	*8.0*
PM_{10}	24 hour maximum	1.6	3.1	3.9	7.6	7.6	40.6	48.0	*50*
	Annual mean	0.03	0.04	0.08	0.10	0.10	20.0	20.1	*25*
Acrolein	1 hour 99.9th percentile	0.002	0.003	0.002	0.002	0.003	-	0.003	*0.42*
Benzene	1 hour 99.9th percentile	0.002	0.005	0.01	0.02	0.02	-	0.02	*29*
Formaldehyde	1 hour 99.9th percentile	0.2	0.3	0.1	0.1	0.3	-	0.3	*20*
PAHs	1 hour 99.9th percentile	0.0003	0.0004	0.001	0.002	0.002	-	0.002	*0.4*

Note: Totals may appear non-additive due to rounding of reported intermediate values.
*Time varying background concentration applied in contemporaneous analysis. Maximum 1 hour background value shown.

Table 8.2: Assessment Summary – Reciprocating Engine Option

Substance	Averaging Period	Prediction at Maximum Impacted Receptor (µg/m³)				Maximum Incremental Prediction (µg/m³)	Background* (µg/m³)	Maximum Cumulative Prediction (µg/m³)	Criterion (µg/m³)
		Natural Gas Fuel		Distillate Fuel					
		Discrete	Gridded	Discrete	Gridded				
NO_2	1 hour maximum	76	113	71	95	113	82[1]	123	*246*
	Annual mean	0.6	1.0	0.6	1.0	1.0	18.0	19.1	*62*
CO	15 minute maximum	21	98	26	104	104	1,980	2,084	*100,000*
	1 hour maximum	26	123	32	130	130	1,500	1,630	*30,000*
	8 hour maximum	8	30	11	29	30	1,125	1,155	*10,000*
SO_2	10 minute maximum	11	52	12	50	52	286	338	*712*
	1 hour maximum	8	36	9	35	36	200	236	*570*
	24 hour maximum	1.0	4.3	1.3	3.4	4.3	20	24	*228*
	Annual mean	0.05	0.10	0.05	0.08	0.10	4.7	5	*60*
$PM_{2.5}$	24 hour maximum	1.1	4.5	2.5	6.4	6.4	17.1	23	*25*
	Annual mean	0.05	0.10	0.09	0.16	0.16	**8.1***	**8.3***	*8*
PM_{10}	24 hour maximum	1.1	4.5	2.5	6.4	6.4	40.6	47.0	*50*
	Annual mean	0.05	0.10	0.09	0.16	0.16	20.0	20	*25*
Acrolein	1 hour 99.9th percentile	**0.68***	**1.25***	0.001	0.003	**1.25***	-	**1.25***	*0.42*
Benzene	1 hour 99.9th percentile	0.1	0.2	0.1	0.3	0.3	-	0.3	*29*
Formaldehyde	1 hour 99.9th percentile	6	11	5	9	11	-	11	*20*
PAHs	1 hour 99.9th percentile	0.00001	0.00001	0.0001	0.0002	0.0002	-	0.0002	*0.4*
Ammonia	1 hour 99.9th percentile	4	9	4	7	9	-	9	*330*

Notes: Exceedances shown in **bold font** and marked with an asterisk.
Totals may appear non-additive due to rounding of reported intermediate values.
[*]Time varying background concentration applied in contemporaneous analysis. Maximum 1 hour background shown.

8.2 NO_2

Table 8.3 and Table 8.4 present a summary of maximum 1 hour and annual average NO_2 predictions (respectively). Figure 8.1 through Table 8.4 present contour isopleths for the corresponding incremental predictions. All NO_2 predictions are within relevant impact assessment criteria.

Table 8.3: Summary of model predictions - Maximum 1 hour average NO_2 (µg/m³)

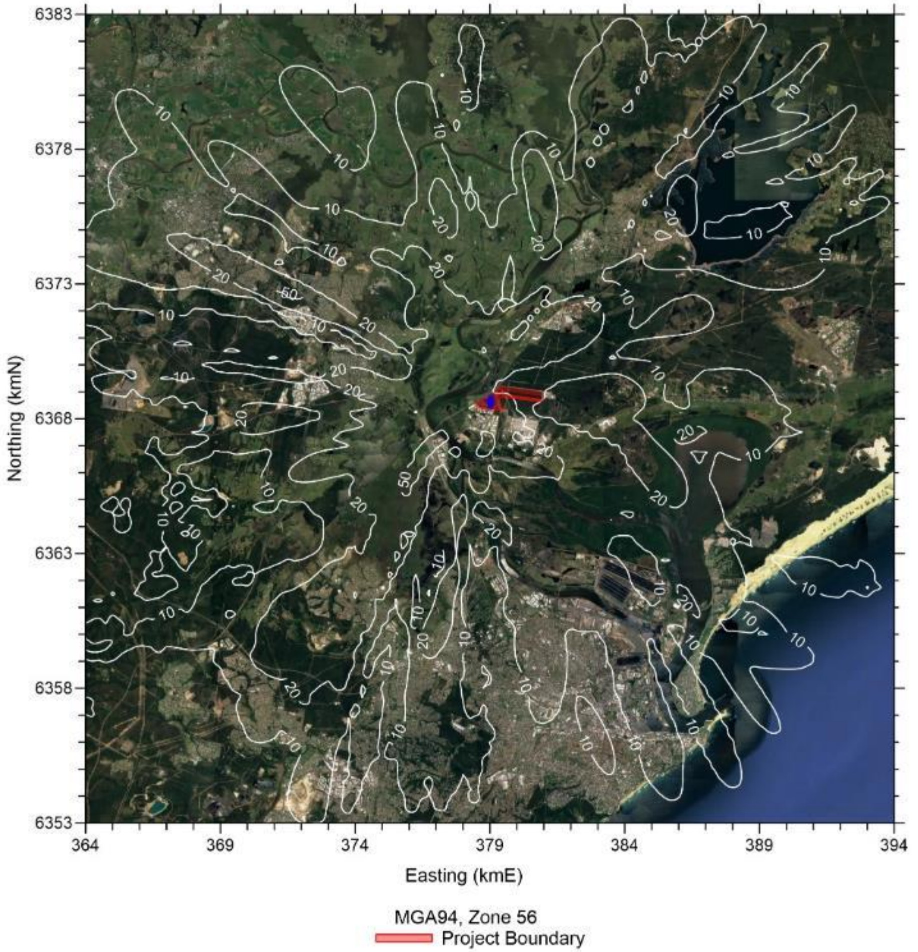
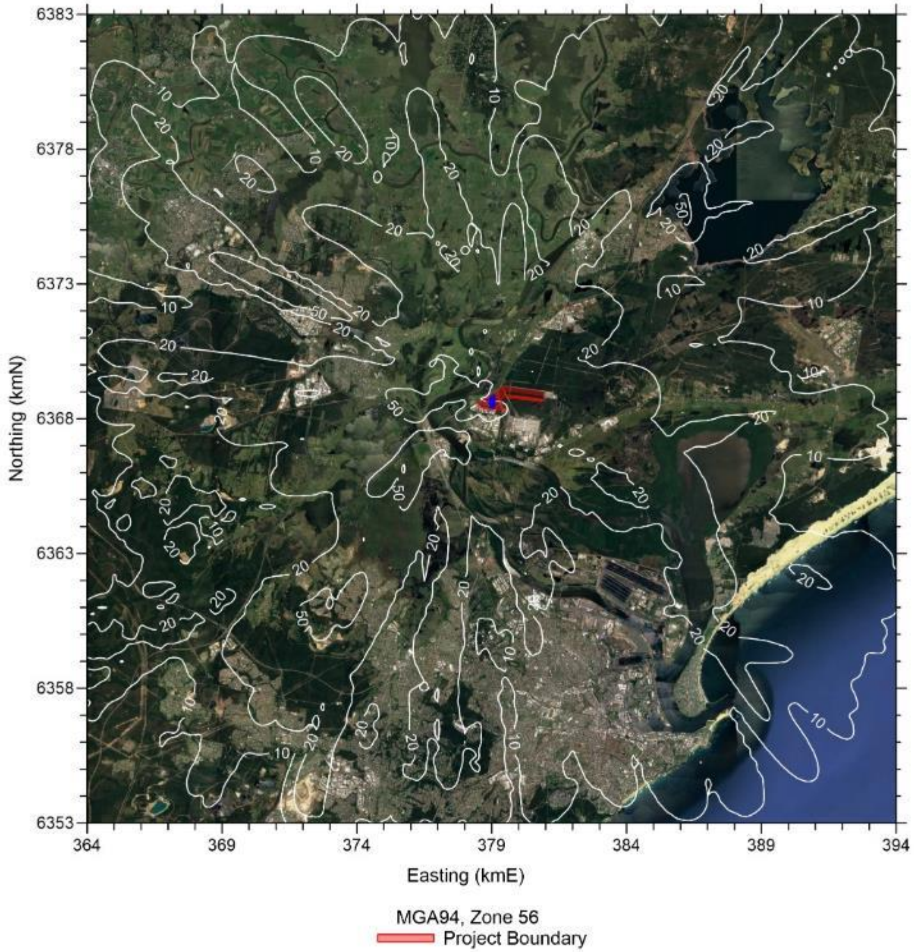
Receptor	Locality	Gas Turbine Option				Reciprocating Engine Option			
		Natural Gas		Distillate		Natural Gas		Distillate	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
01	Tomago	24	82	37	82	46	82	52	82
02	Hexham	58	82	63	82	76	82	71	82
03	Beresfield	16	82	23	82	28	82	32	82
04	Heatherbrae	24	82	27	82	39	82	32	82
05	Williamtown	5	82	9	82	17	82	19	82
06	Fullerton Cove	7	82	8	82	14	82	16	82
07	Fern Bay	14	82	26	82	37	82	38	82
08	Kooragang	10	82	19	82	27	82	22	82
09	Stockton	11	82	12	82	18	82	18	82
10	Carrington	14	82	16	82	21	82	18	82
11	Mayfield	9	82	16	82	15	82	17	82
12	Hamilton	11	82	15	82	12	82	16	82
13	Newcastle	12	82	14	82	19	82	16	82
14	Merewether	9	82	15	82	12	82	17	82
15	Adamstown	8	82	11	82	17	82	15	82
16	New Lambton	7	82	11	82	16	82	20	82
17	Jesmond	12	82	23	82	15	82	15	82
18	Warabrook	15	82	21	82	43	82	47	82
19	Sandgate	8	82	14	82	20	82	27	82
20	Maryland	28	82	41	82	13	82	28	82
21	Cameron Park	11	82	21	82	25	82	40	82
22	Cardiff	8	82	14	82	12	82	14	82
23	Glendale	15	82	25	82	13	82	14	82
24	Black Hill	9	82	15	82	35	82	36	82
25	Thornton	31	82	59	82	30	82	34	82
26	Ashtonfield	20	82	32	82	70	84	56	82
27	East Maitland	17	82	30	82	38	82	43	82
28	Millers Rest	16	82	28	82	31	82	38	82
29	Raymond Terrace	20	82	22	82	33	82	30	82
30	Maitland	9	82	16	82	24	82	29	82
31	Morpeth	5	82	9	82	30	82	27	82
32	Osterley	8	82	14	82	25	82	25	82
33	Medowie	11	82	14	82	18	82	19	82
34	Largs	8	82	11	82	15	82	18	82
35	Brandy Hill	9	82	16	82	29	82	33	82
36	Eagleton	12	82	14	82	17	82	25	82
Maximum by Receptor Type									
Discrete	-	58	82	63	82	76	84	71	82
Gridded	-	61	82	84	100	113	123	95	119
Criterion	-	-	*246*	-	*246*	-	*246*	-	*246*

Table 8.4: Summary of model predictions - Annual average NO_2 (µg/m³)

Receptor	Locality	Gas Turbine Option				Reciprocating Engine Option			
		Natural Gas		Distillate		Natural Gas		Distillate	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
01	Tomago	0.2	18.2	0.3	18.3	0.5	18.6	0.6	18.6
02	Hexham	0.2	18.3	0.4	18.4	0.6	18.6	0.6	18.7
03	Beresfield	0.1	18.1	0.2	18.2	0.3	18.3	0.3	18.4
04	Heatherbrae	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.2
05	Williamtown	0.0	18.1	0.1	18.1	0.1	18.2	0.1	18.2
06	Fullerton Cove	0.1	18.1	0.1	18.2	0.2	18.3	0.2	18.3
07	Fern Bay	0.1	18.1	0.2	18.2	0.2	18.3	0.2	18.3
08	Kooragang	0.1	18.1	0.1	18.2	0.2	18.3	0.2	18.3
09	Stockton	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.2
10	Carrington	0.1	18.1	0.1	18.1	0.2	18.2	0.2	18.2
11	Mayfield	0.1	18.1	0.1	18.1	0.2	18.2	0.2	18.2
12	Hamilton	0.1	18.1	0.1	18.1	0.1	18.2	0.2	18.2
13	Newcastle	0.1	18.1	0.1	18.1	0.1	18.2	0.1	18.2
14	Merewether	0.0	18.1	0.1	18.1	0.1	18.1	0.1	18.2
15	Adamstown	0.0	18.1	0.1	18.1	0.1	18.1	0.1	18.2
16	New Lambton	0.1	18.1	0.1	18.1	0.1	18.2	0.1	18.2
17	Jesmond	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.2
18	Warabrook	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.2
19	Sandgate	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.3
20	Maryland	0.1	18.1	0.2	18.2	0.2	18.3	0.3	18.3
21	Cameron Park	0.1	18.1	0.1	18.1	0.2	18.2	0.2	18.2
22	Cardiff	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.2
23	Glendale	0.1	18.1	0.1	18.1	0.2	18.2	0.2	18.2
24	Black Hill	0.1	18.1	0.1	18.2	0.2	18.3	0.3	18.3
25	Thornton	0.1	18.1	0.2	18.2	0.3	18.3	0.3	18.3
26	Ashtonfield	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.3
27	East Maitland	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.3
28	Millers Rest	0.1	18.1	0.1	18.2	0.2	18.3	0.3	18.3
29	Raymond Terrace	0.1	18.1	0.1	18.2	0.2	18.2	0.2	18.3
30	Maitland	0.1	18.1	0.1	18.1	0.1	18.2	0.2	18.2
31	Morpeth	0.1	18.1	0.1	18.1	0.1	18.2	0.2	18.2
32	Osterley	0.1	18.1	0.1	18.1	0.2	18.2	0.2	18.2
33	Medowie	0.1	18.1	0.1	18.1	0.1	18.2	0.1	18.2
34	Largs	0.0	18.1	0.1	18.1	0.1	18.1	0.1	18.2
35	Brandy Hill	0.0	18.1	0.1	18.1	0.1	18.1	0.1	18.2
36	Eagleton	0.1	18.1	0.1	18.1	0.1	18.2	0.1	18.2
Maximum by Receptor Type									
Discrete	-	0.2	18.3	0.4	18.4	0.6	18.6	0.6	18.7
Gridded	-	0.3	18.3	0.4	19	1.0	19.1	1.0	19.1
Criterion	-	-	*62*	-	*62*	-	*62*	-	*62*

Notes: - Predictions based on continuous operation. Annual average predictions at estimated (14%) operating duty would be approx. 7 times lower than those presented.

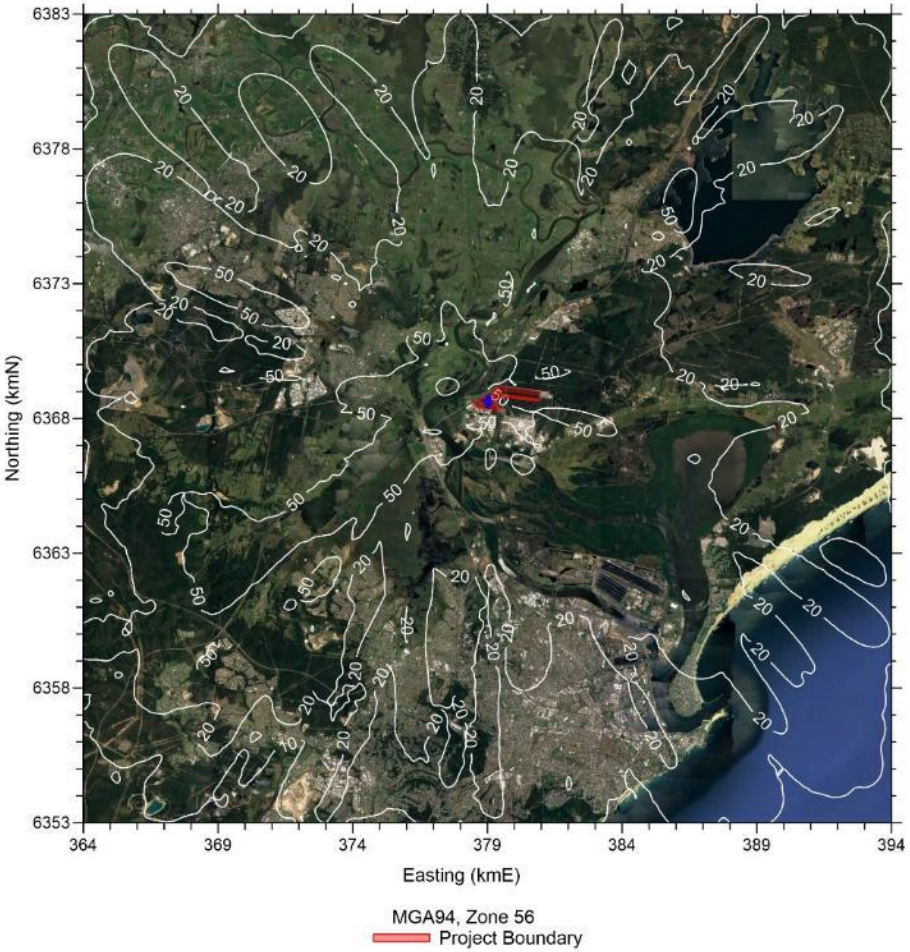
Figure 8.1: Maximum incremental 1 hour average NO_2 predictions – Gas Turbine Option (µg/m³)

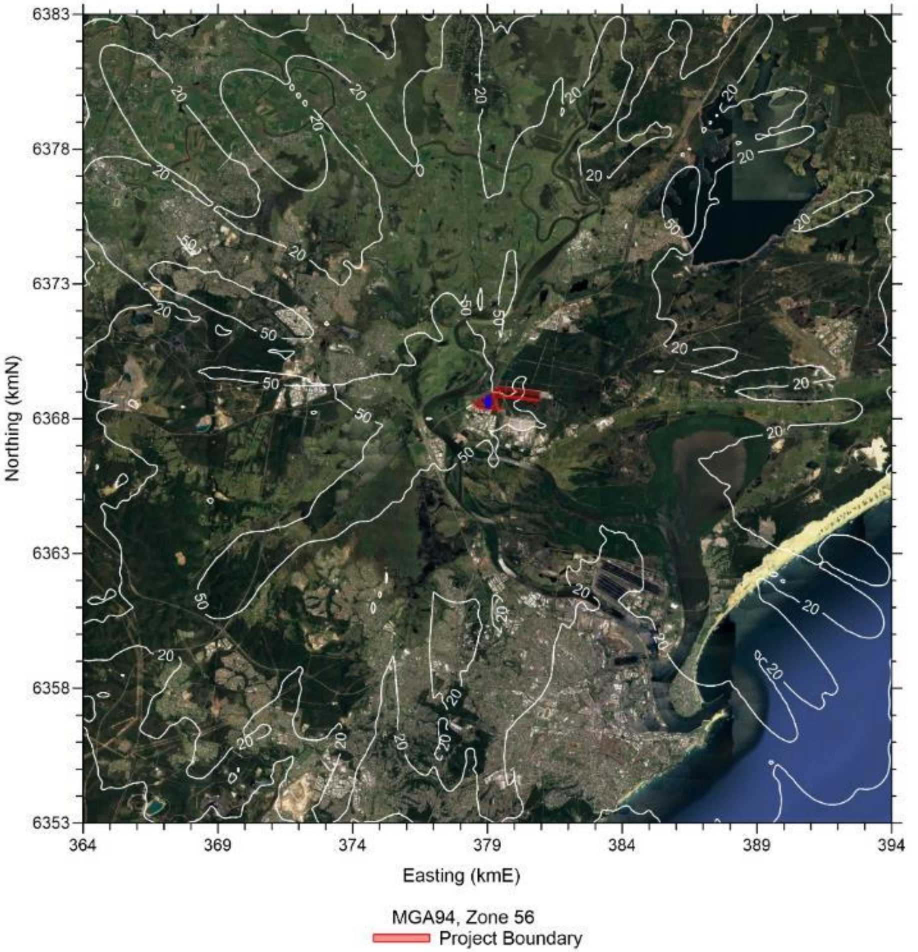
Natural Gas	Distillate
	

Notes: - Base image sourced from Google Earth Pro.
- Contour Levels: 10, 20, 50, 100 µg/m³.

Figure 8.2: Maximum incremental 1 hour average NO_2 predictions – Reciprocating Engine Option (µg/m³)

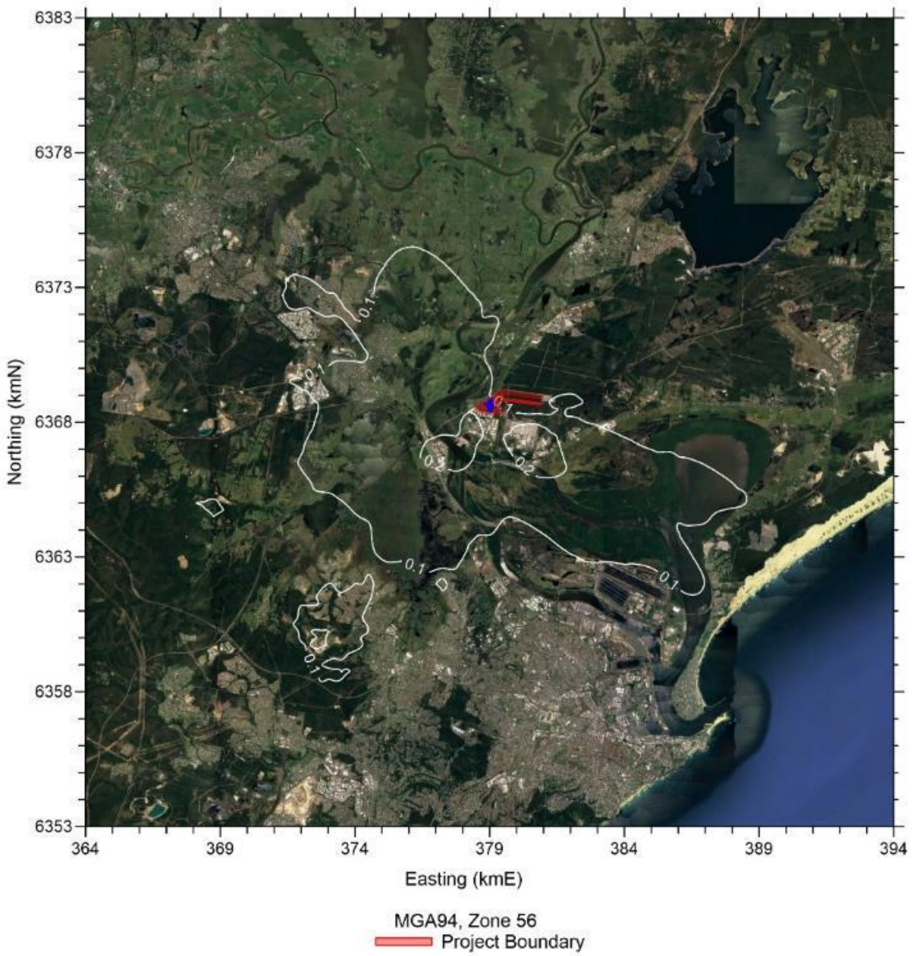
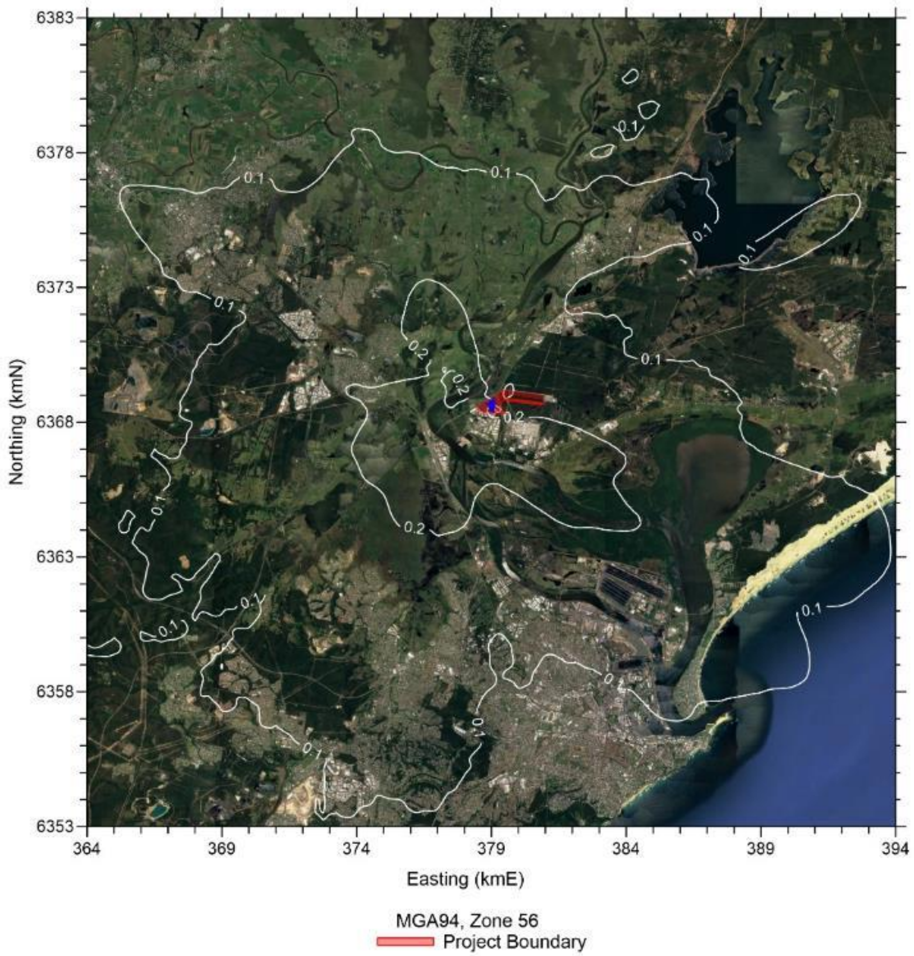
Natural Gas	Distillate





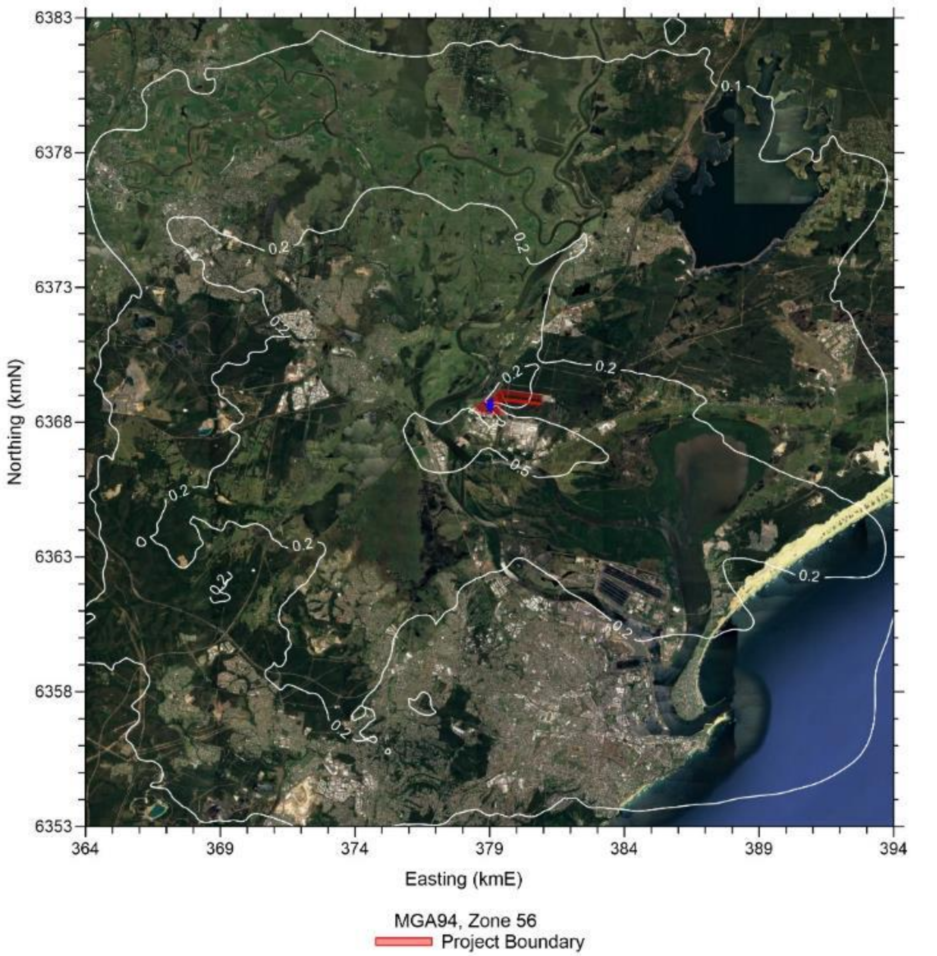
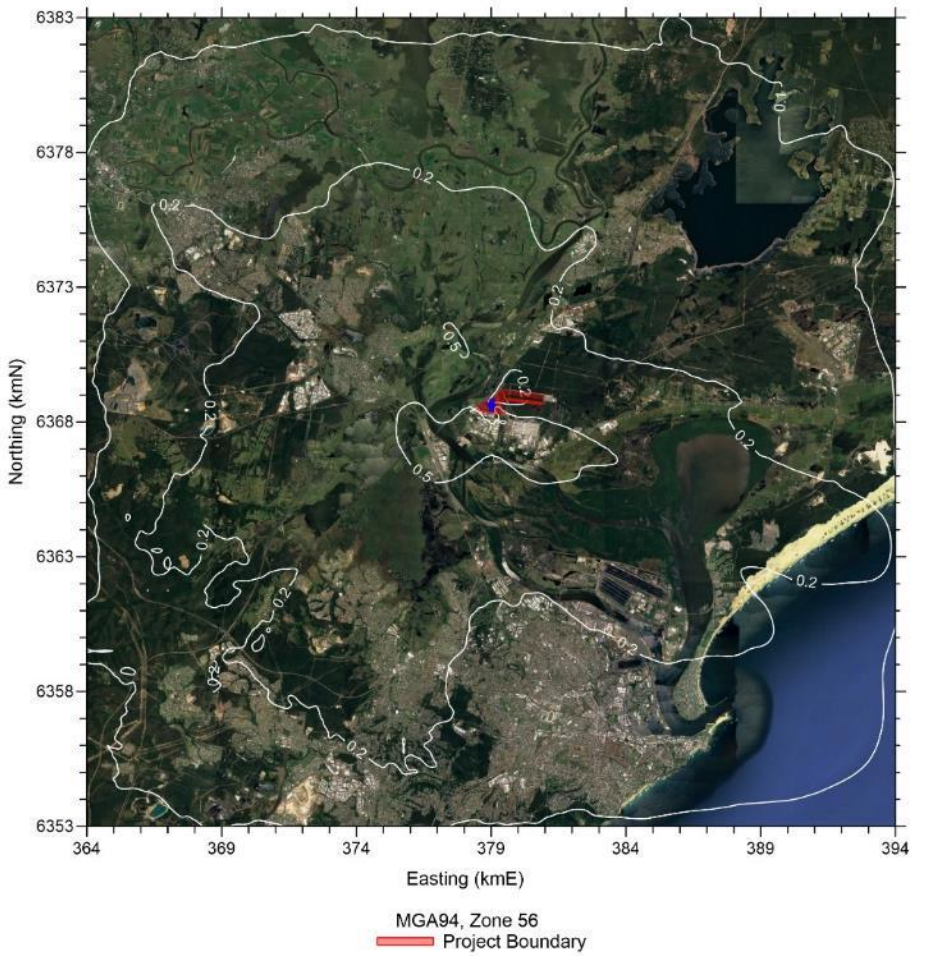
Notes: - Base image sourced from Google Earth Pro.
- Contour Levels: 10, 20, 50, 100 µg/m³.

Figure 8.3: Annual average incremental NO_2 predictions – Gas Turbine Option (µg/m³)

Natural Gas	Distillate
	

Notes:
- Base image sourced from Google Earth Pro.
- Contour Levels: 0.1, 0.2, 0.5, 1.0 µg/m³.
- Predictions based on continuous operation. Annual average predictions at estimated (14%) operating duty would be approx. 7 times lower than those presented.

Figure 8.4: Annual average incremental NO_2 predictions – Reciprocating Engine Option (µg/m³)

Natural Gas	Distillate
	

Notes: - Base image sourced from Google Earth Pro.
- Contour Levels: 0.1, 0.2, 0.5, 1.0 µg/m³.
- Predictions based on continuous operation. Annual average predictions at estimated (14%) operating duty would be approx. 7 times lower than those presented.

8.3 $PM_{2.5}$

Table 8.5 and Table 8.6 present a summary of maximum 24 hour and annual average $PM_{2.5}$ predictions (respectively). Figure 8.5 through Figure 8.8 present corresponding contour isopleths for incremental $PM_{2.5}$ predictions.

Table 8.5: Summary of model predictions – Maximum 24 hour average $PM_{2.5}$

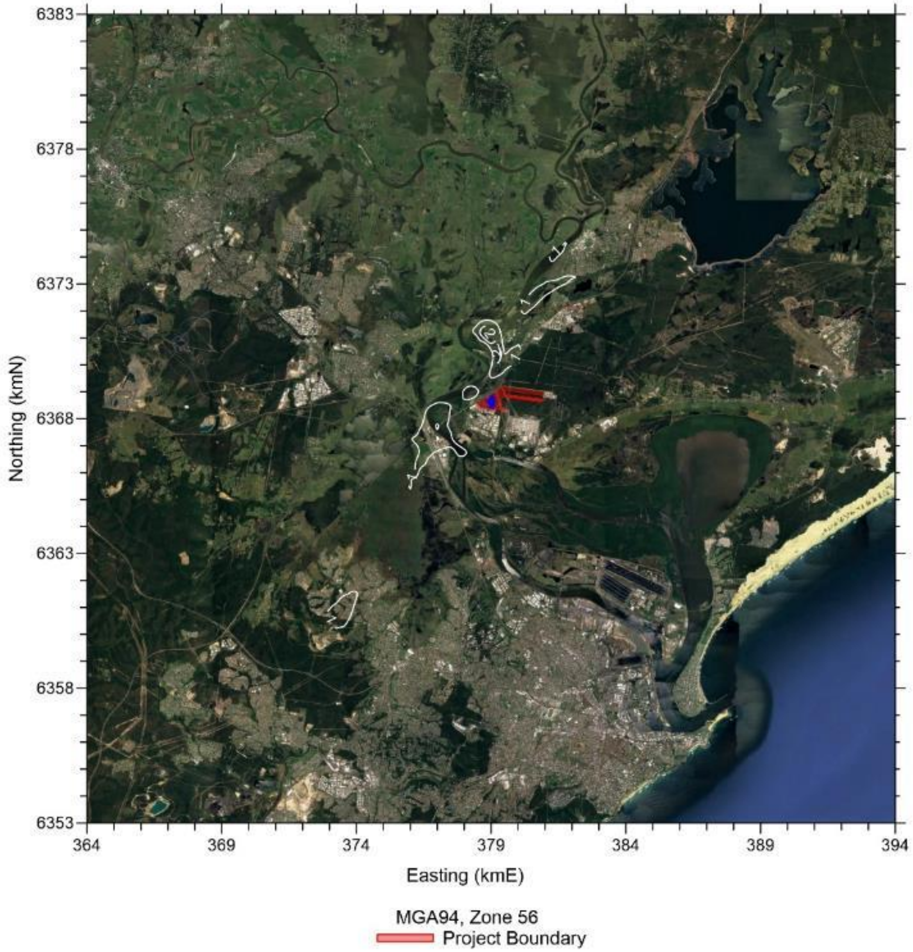
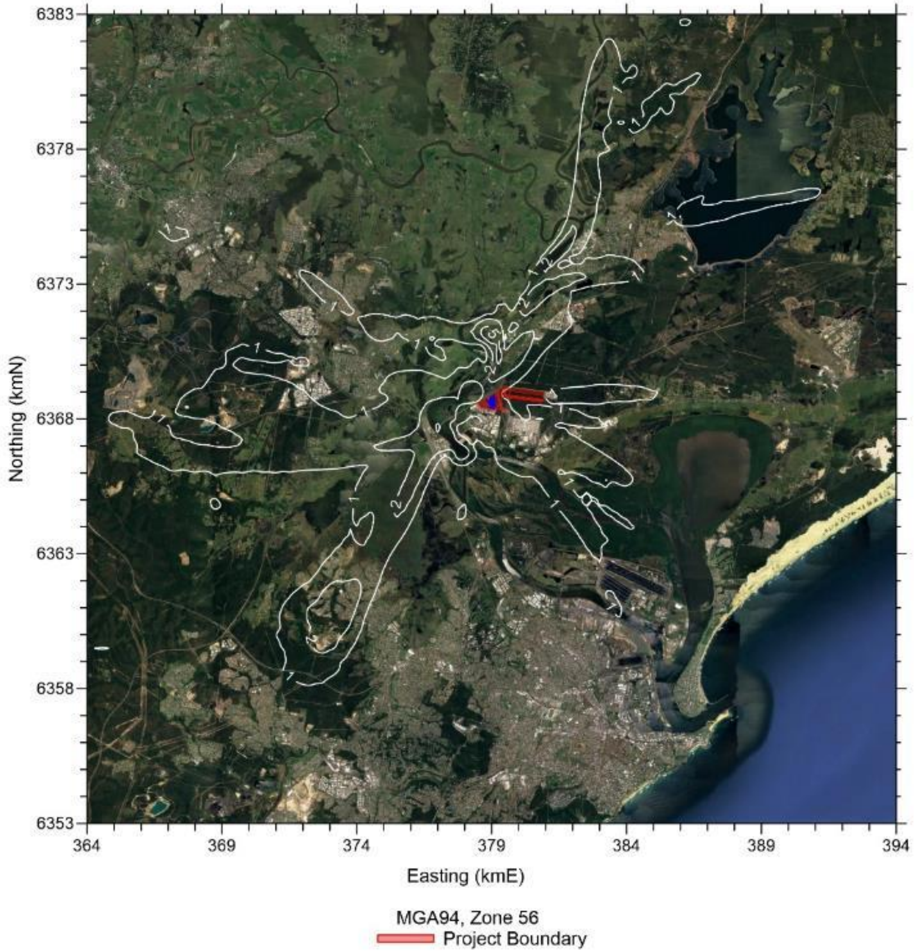
Receptor	Locality	Gas Turbine Option				Reciprocating Engine Option			
		Natural Gas		Distillate		Natural Gas		Distillate	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
01	Tomago	0.4	17.8	1.2	18.6	0.8	18.2	1.3	18.7
02	Hexham	1.6	19.0	3.9	21.3	1.1	18.5	2.5	19.9
03	Beresfield	0.3	17.7	0.7	18.1	0.6	18.0	1.0	18.4
04	Heatherbrae	0.5	17.9	1.4	18.8	0.9	18.3	1.6	19.0
05	Williamtown	0.2	17.6	0.4	17.8	0.4	17.8	0.7	18.1
06	Fullerton Cove	0.2	17.6	0.5	17.9	0.5	17.9	0.8	18.2
07	Fern Bay	0.3	17.7	0.7	18.1	0.6	18.0	1.0	18.4
08	Kooragang	0.3	17.7	0.8	18.2	0.5	17.9	0.8	18.2
09	Stockton	0.2	17.6	0.6	18.0	0.3	17.7	0.5	17.9
10	Carrington	0.2	17.6	0.6	18.0	0.3	17.7	0.6	18.0
11	Mayfield	0.1	17.5	0.4	17.8	0.2	17.6	0.3	17.7
12	Hamilton	0.1	17.5	0.4	17.8	0.2	17.6	0.3	17.7
13	Newcastle	0.2	17.6	0.4	17.8	0.3	17.7	0.4	17.8
14	Merewether	0.1	17.5	0.4	17.8	0.2	17.6	0.3	17.7
15	Adamstown	0.1	17.5	0.3	17.7	0.2	17.6	0.3	17.7
16	New Lambton	0.1	17.5	0.2	17.6	0.2	17.6	0.4	17.8
17	Jesmond	0.2	17.6	0.6	18.0	0.2	17.6	0.4	17.8
18	Warabrook	0.1	17.5	0.3	17.7	0.3	17.7	0.5	17.9
19	Sandgate	0.1	17.5	0.4	17.8	0.2	17.6	0.4	17.8
20	Maryland	0.4	17.8	0.8	18.2	0.2	17.6	0.5	17.9
21	Cameron Park	0.2	17.6	0.5	17.9	0.2	17.6	0.4	17.8
22	Cardiff	0.1	17.5	0.3	17.7	0.2	17.6	0.3	17.7
23	Glendale	0.1	17.5	0.3	17.7	0.1	17.5	0.2	17.6
24	Black Hill	0.3	17.7	0.7	18.1	0.3	17.7	0.5	17.9
25	Thornton	0.4	17.8	1.0	18.4	0.5	17.9	0.8	18.2
26	Ashtonfield	0.3	17.7	0.7	18.1	0.3	17.7	0.5	17.9
27	East Maitland	0.3	17.7	0.7	18.1	0.6	18.0	1.0	18.4
28	Millers Rest	0.2	17.6	0.5	17.9	0.3	17.7	0.5	17.9
29	Raymond Terrace	0.5	17.9	1.1	18.5	0.4	17.8	0.7	18.1
30	Maitland	0.2	17.6	0.5	17.9	0.4	17.8	0.7	18.1
31	Morpeth	0.2	17.6	0.4	17.8	0.2	17.6	0.3	17.7
32	Osterley	0.2	17.6	0.4	17.8	0.3	17.7	0.5	17.9
33	Medowie	0.2	17.6	0.6	18.0	0.3	17.7	0.5	17.9
34	Largs	0.1	17.5	0.3	17.7	0.2	17.6	0.3	17.7
35	Brandy Hill	0.1	17.5	0.4	17.8	0.3	17.7	0.5	17.9
36	Eagleton	0.4	17.8	1.1	18.5	0.2	17.6	0.3	17.7
Maximum by Receptor Type									
Discrete	-	1.6	19.0	3.9	21.3	1.1	18.5	2.5	19.9
Gridded	-	3.1	20.5	7.6	25.0	4.5	21.9	6.4	23.8
Criterion	-	-	*25*	-	*25*	-	*25*	-	*25*

Table 8.6: Summary of model predictions – Annual average $PM_{2.5}$

Receptor	Locality	Gas Turbine Option				Reciprocating Engine Option			
		Natural Gas		Distillate		Natural Gas		Distillate	
		Inc.	Cum.	Inc.	Cum.	Inc.	Cum.	Inc.	Cum.
01	Tomago	0.02	**8.1***	0.06	**8.2***	0.05	**8.1***	0.08	**8.2***
02	Hexham	0.03	**8.1***	0.08	**8.2***	0.05	**8.2***	0.09	**8.2***
03	Beresfield	0.01	**8.1***	0.03	**8.1***	0.03	**8.1***	0.04	**8.1***
04	Heatherbrae	0.01	**8.1***	0.02	**8.1***	0.02	**8.1***	0.03	**8.1***
05	Williamtown	0.01	**8.1***	0.01	**8.1***	0.01	**8.1***	0.02	**8.1***
06	Fullerton Cove	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
07	Fern Bay	0.01	**8.1***	0.04	**8.1***	0.02	**8.1***	0.04	**8.1***
08	Kooragang	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.04	**8.1***
09	Stockton	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
10	Carrington	0.01	**8.1***	0.02	**8.1***	0.02	**8.1***	0.03	**8.1***
11	Mayfield	0.01	**8.1***	0.02	**8.1***	0.02	**8.1***	0.03	**8.1***
12	Hamilton	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
13	Newcastle	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
14	Merewether	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
15	Adamstown	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
16	New Lambton	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
17	Jesmond	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
18	Warabrook	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
19	Sandgate	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
20	Maryland	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
21	Cameron Park	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
22	Cardiff	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
23	Glendale	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
24	Black Hill	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
25	Thornton	0.02	**8.1***	0.04	**8.1***	0.02	**8.1***	0.04	**8.1***
26	Ashtonfield	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
27	East Maitland	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
28	Millers Rest	0.01	**8.1***	0.03	**8.1***	0.02	**8.1***	0.03	**8.1***
29	Raymond Terrace	0.02	**8.1***	0.04	**8.1***	0.02	**8.1***	0.04	**8.1***
30	Maitland	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
31	Morpeth	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
32	Osterley	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
33	Medowie	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
34	Largs	0.01	**8.1***	0.01	**8.1***	0.01	**8.1***	0.02	**8.1***
35	Brandy Hill	0.01	**8.1***	0.01	**8.1***	0.01	**8.1***	0.01	**8.1***
36	Eagleton	0.01	**8.1***	0.02	**8.1***	0.01	**8.1***	0.02	**8.1***
Maximum by Receptor Type									
Discrete	-	0.03	**8.1***	0.08	**8.2***	0.05	**8.2***	0.09	**8.2***
Gridded	-	0.04	**8.1***	0.10	**8.2***	0.10	**8.2***	0.16	**8.3***
Criterion	-	-	*8.0*	-	*8.0*	-	*8.0*	-	*8.0*

Notes: - Exceedances shown in **bold font** and marked with an asterisk. Background exceedances result in exceedances for all predictions.
- PM emissions assumed to occur as $PM_{2.5}$, hence incremental $PM_{2.5}$ results are equal to incremental PM_{10} results.
- Predictions based on continuous operation. Annual average predictions at estimated (14%) operating duty would be approx. 7 times lower than those presented.

Figure 8.5: Maximum incremental 24 hour average $PM_{2.5}$* predictions – Gas Turbine Option (µg/m³)

Natural Gas	Distillate
	

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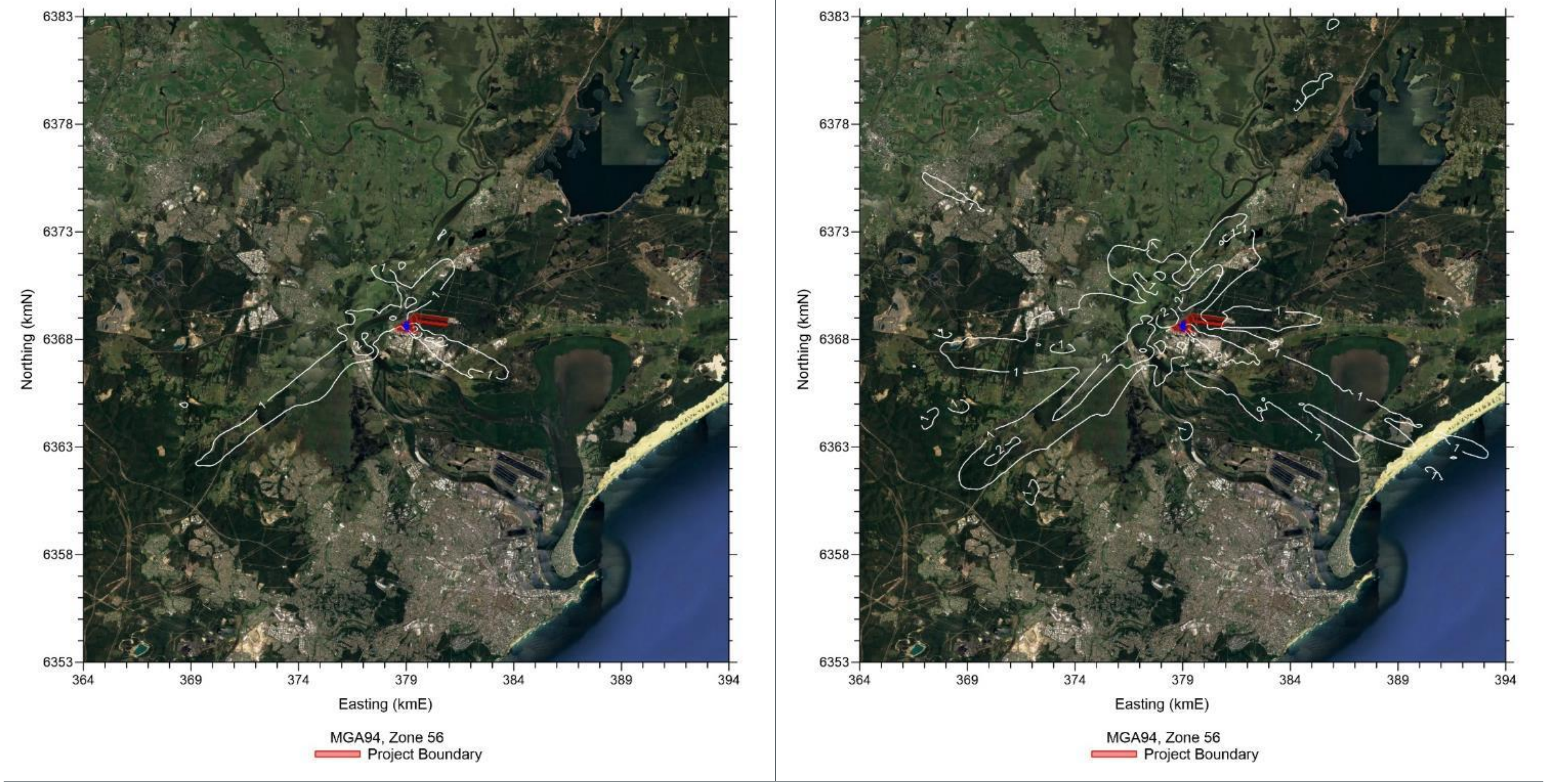
Notes: - Base image sourced from Google Earth Pro.
- Contour Levels: 1, 2, 5 µg/m³.
- Noting that all PM emissions have been assumed to occur as $PM_{2.5}$, these contour isopleths are also representative of incremental PM_{10} predictions.

Figure 8.6: Maximum incremental 24 hour average $PM_{2.5}$ predictions – Reciprocating Engine Option (µg/m³)

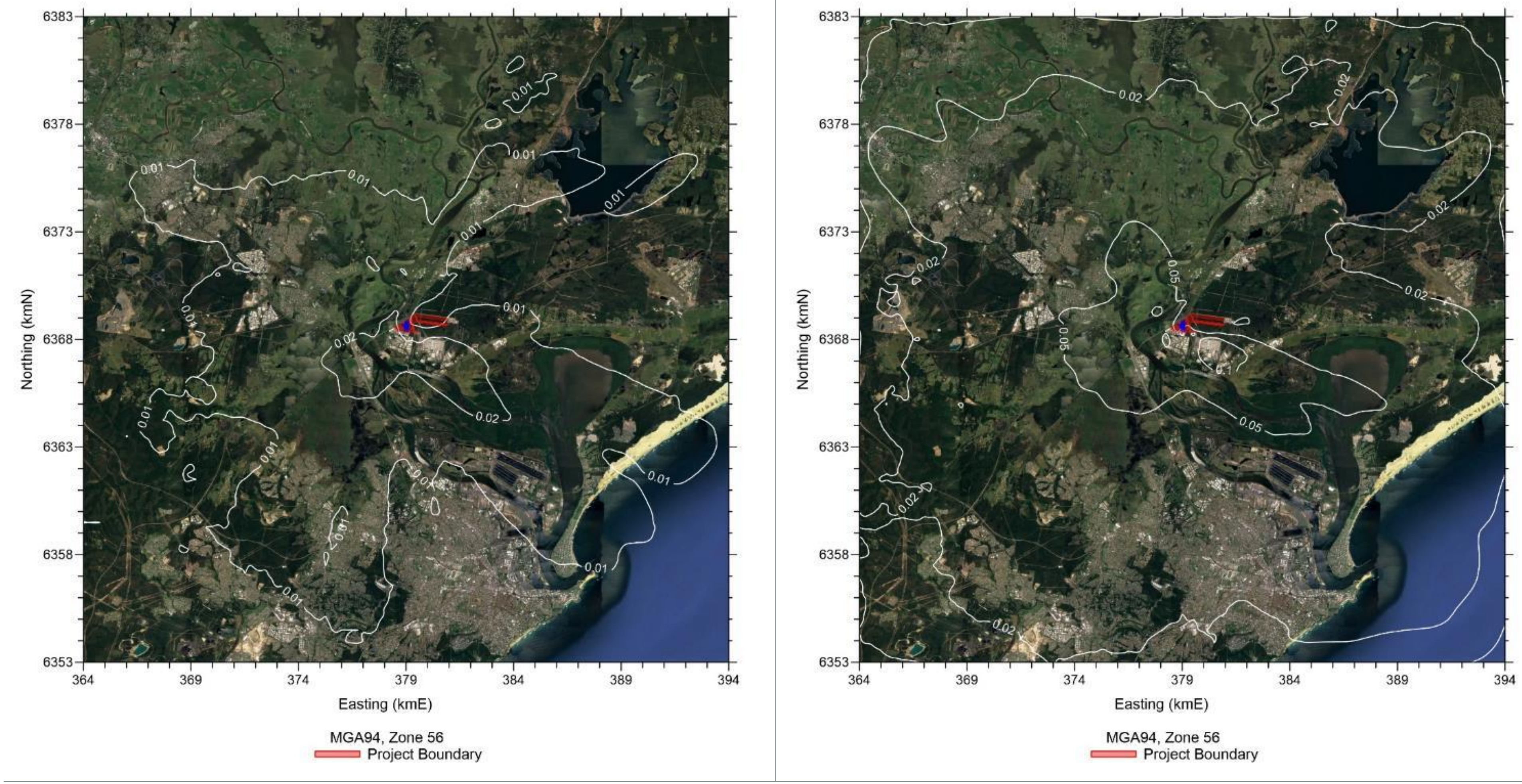
Natural Gas	Distillate



Notes:
- Base image sourced from Google Earth Pro.
- Contour Levels: 1, 2, 5 µg/m³.
- All PM emissions have been assumed to occur as $PM_{2.5}$, hence these contour isopleths also represent of incremental PM_{10} predictions.

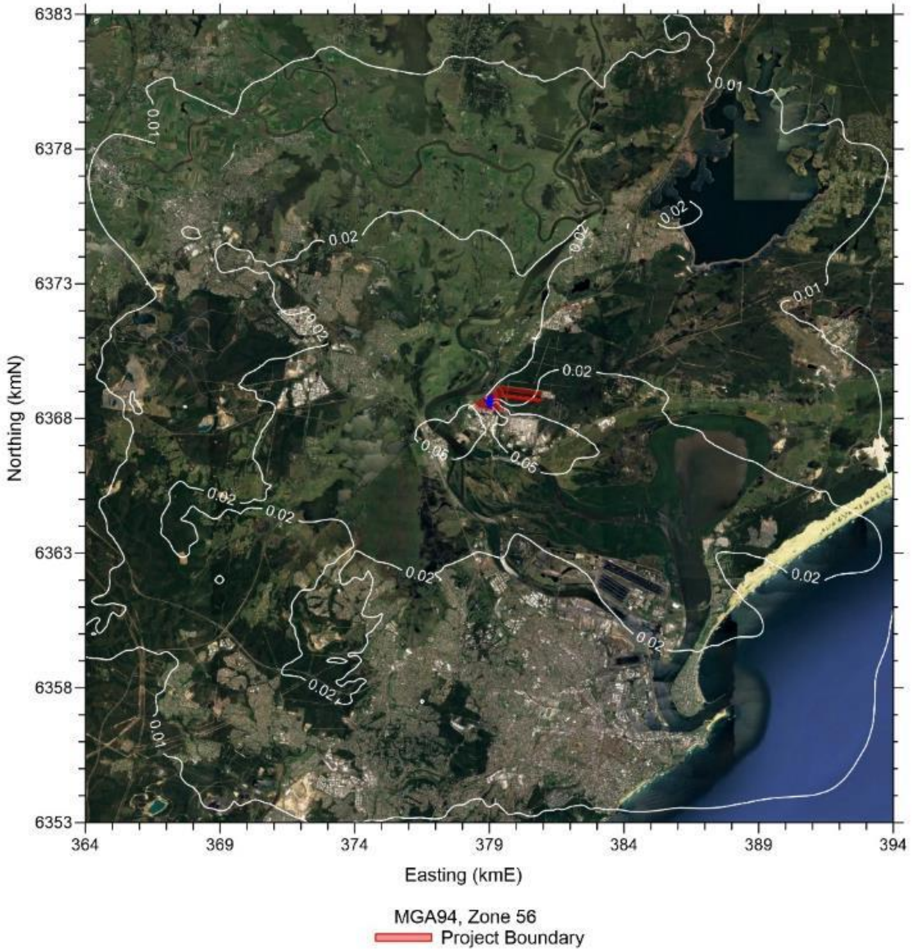
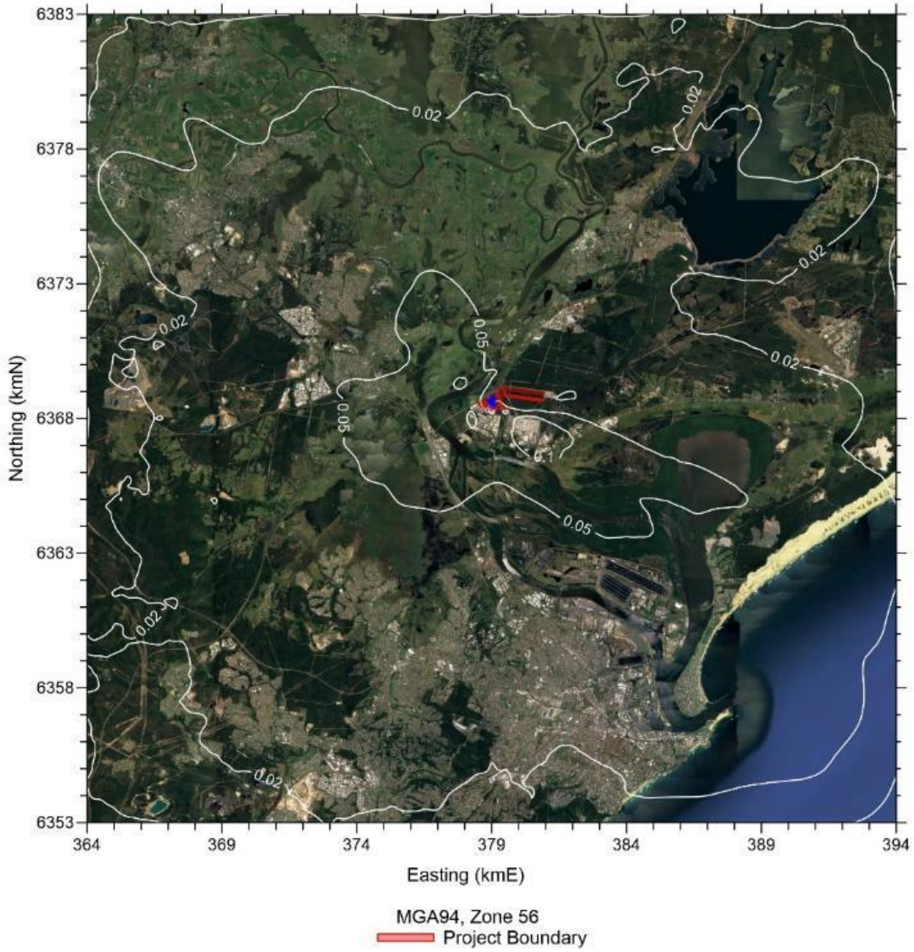
Figure 8.7: Incremental annual average $PM_{2.5}$ predictions – Gas Turbine Option (µg/m³)

Natural Gas	Distillate



Notes:
- Base image sourced from Google Earth Pro.
- Contour Levels: 0.1, 0.2, 0.5, 1.0 µg/m³.
- All PM emissions have been assumed to occur as $PM_{2.5}$, hence these contour isopleths also represent of incremental PM_{10} predictions.
- Predictions based on continuous operation. Annual average predictions at estimated (14%) operating duty would be approx. 7 times lower than those presented.

Figure 8.8: Incremental annual average $PM_{2.5}$ predictions – Reciprocating Engine Option (µg/m³)

Natural Gas	Distillate
	

Notes:
- Base image sourced from Google Earth Pro.
- Contour Levels: 0.1, 0.2, 0.5, 1.0 µg/m³.
- Predictions based on continuous operation. Annual average predictions at estimated (14%) operating duty would be approx. 7 times lower than those presented.

8.4 Acrolein and Formaldehyde

Table 8.7 presents a summary of 99.9th percentile 1 hour average acrolein and formaldehyde predictions. Figure 8.9 and Figure 8.10 present contour isopleths of these predictions. Appendix C and Appendix D provide additional assessment and review of potential acrolein impacts.

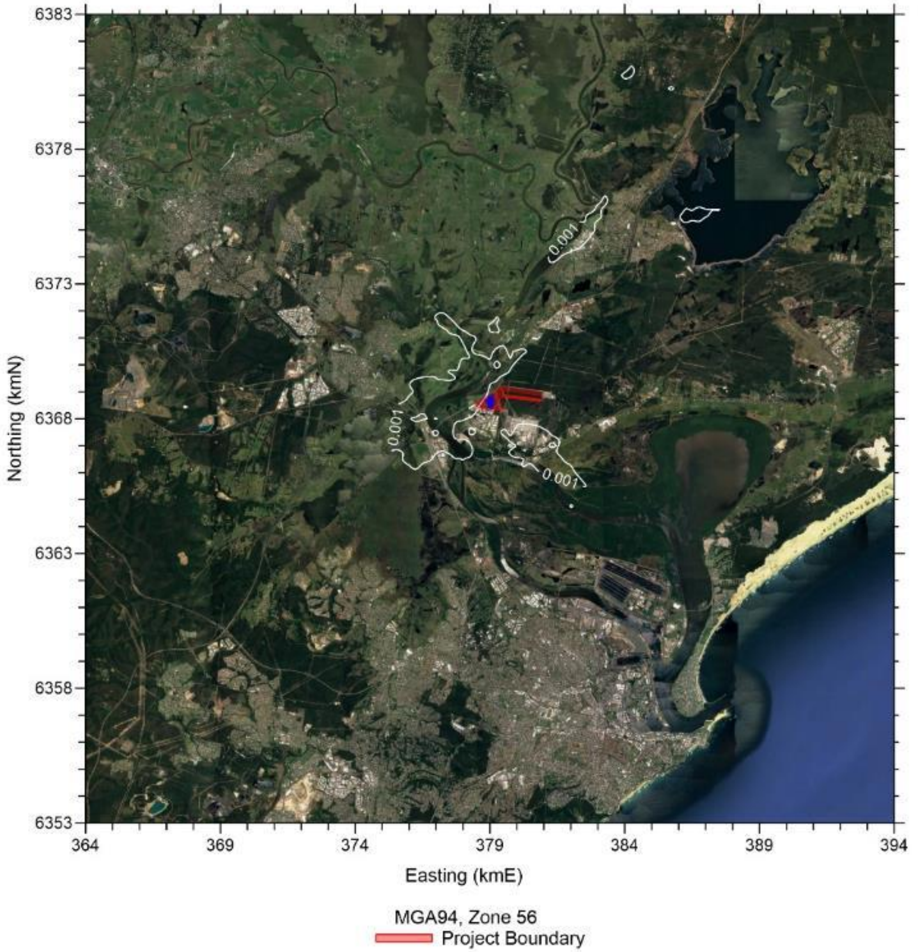
Table 8.7: Summary of model predictions – 99.9th percentile 1 hour average acrolein and formaldehyde

Receptor	Locality	Acrolein				Formaldehyde			
		Gas Turbine Option		Reciprocating Engine Option		Gas Turbine Option		Reciprocating Engine Option	
		Natural Gas	Distillate	Natural Gas	Distillate	Natural Gas	Distillate	Natural Gas	Distillate
01	Tomago	0.001	0.001	**0.48***	0.001	0.1	0.0	4.1	4.3
02	Hexham	0.002	0.002	**0.68***	0.001	0.2	0.1	5.8	5.2
03	Beresfield	0.001	0.000	0.28	0.001	0.1	0.0	2.4	2.4
04	Heatherbrae	0.001	0.000	0.24	0.001	0.1	0.0	2.0	2.1
05	Williamtown	0.000	0.000	0.13	0.000	0.0	0.0	1.1	1.1
06	Fullerton Cove	0.000	0.000	0.13	0.000	0.0	0.0	1.1	1.1
07	Fern Bay	0.001	0.001	0.25	0.001	0.1	0.0	2.1	2.2
08	Kooragang	0.001	0.000	0.22	0.001	0.1	0.0	1.9	2.0
09	Stockton	0.000	0.000	0.16	0.000	0.0	0.0	1.4	1.6
10	Carrington	0.000	0.000	0.13	0.000	0.0	0.0	1.1	1.1
11	Mayfield	0.000	0.000	0.14	0.000	0.0	0.0	1.2	1.3
12	Hamilton	0.000	0.000	0.11	0.000	0.0	0.0	0.9	1.1
13	Newcastle	0.000	0.000	0.13	0.000	0.0	0.0	1.1	1.1
14	Merewether	0.000	0.000	0.11	0.000	0.0	0.0	0.9	1.0
15	Adamstown	0.000	0.000	0.14	0.000	0.0	0.0	1.2	1.3
16	New Lambton	0.000	0.000	0.15	0.000	0.0	0.0	1.3	1.3
17	Jesmond	0.000	0.000	0.12	0.000	0.0	0.0	1.0	1.1
18	Warabrook	0.000	0.000	0.20	0.000	0.1	0.0	1.7	1.5
19	Sandgate	0.000	0.000	0.15	0.000	0.0	0.0	1.3	1.5
20	Maryland	0.000	0.000	0.11	0.000	0.0	0.0	1.0	1.0
21	Cameron Park	0.000	0.000	0.09	0.000	0.0	0.0	0.7	0.9
22	Cardiff	0.000	0.000	0.09	0.000	0.0	0.0	0.8	0.8
23	Glendale	0.000	0.000	0.09	0.000	0.0	0.0	0.7	0.9
24	Black Hill	0.000	0.000	0.14	0.000	0.0	0.0	1.2	1.3
25	Thornton	0.001	0.000	0.20	0.001	0.1	0.0	1.7	2.0
26	Ashtonfield	0.001	0.001	0.16	0.000	0.1	0.0	1.3	1.7
27	East Maitland	0.000	0.000	0.22	0.001	0.1	0.0	1.9	1.9
28	Millers Rest	0.000	0.000	0.15	0.000	0.0	0.0	1.3	1.4
29	Raymond Terrace	0.001	0.001	0.41	0.001	0.1	0.0	3.4	3.0
30	Maitland	0.000	0.000	0.19	0.000	0.0	0.0	1.6	1.5
31	Morpeth	0.000	0.000	0.10	0.000	0.0	0.0	0.8	0.8
32	Osterley	0.000	0.000	0.13	0.000	0.0	0.0	1.1	0.9
33	Medowie	0.000	0.000	0.17	0.000	0.1	0.0	1.5	1.5
34	Largs	0.000	0.000	0.07	0.000	0.0	0.0	0.6	0.7
35	Brandy Hill	0.000	0.000	0.09	0.000	0.0	0.0	0.7	0.7
36	Eagleton	0.001	0.000	0.13	0.000	0.1	0.0	1.1	0.9
Maximum by Receptor Type									
Discrete	-	0.002	0.002	**0.68***	0.001	0.2	0.1	5.8	5.2
Gridded	-	0.003	0.002	**1.25***	0.003	0.3	0.1	10.6	9.3
Criterion	-	*0.42*				*20*			

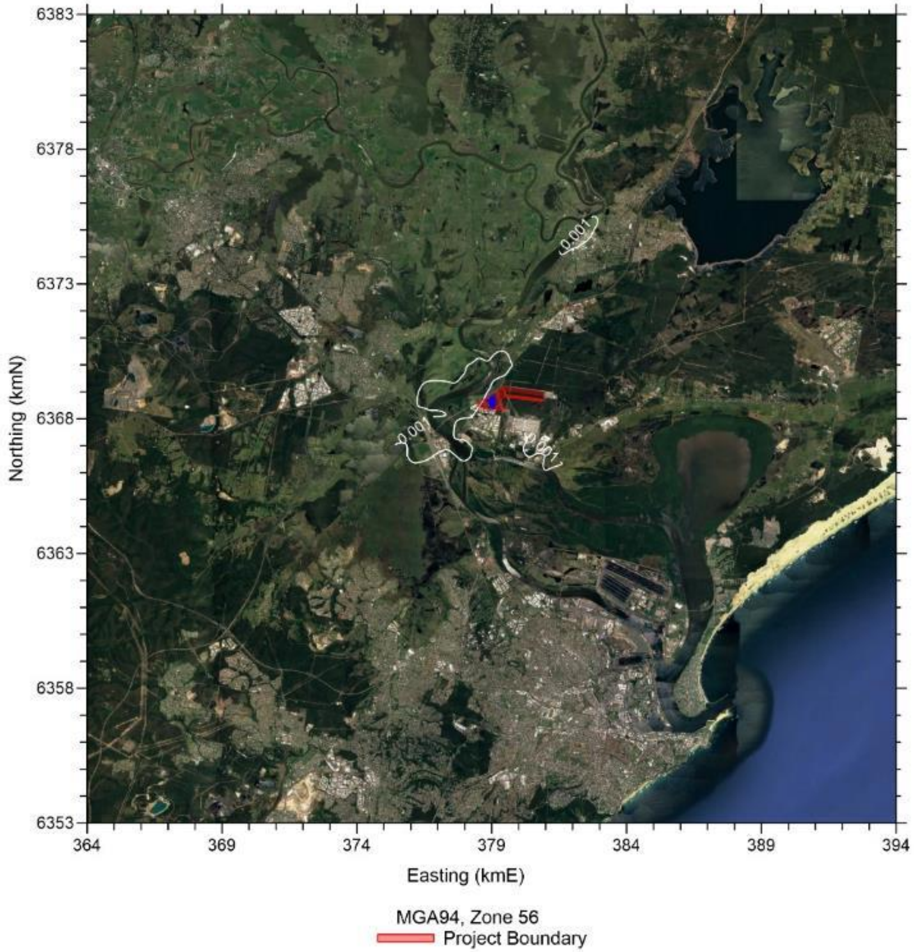
Note: Exceedances shown in **bold font** and marked with an asterisk.

Figure 8.9: 99.9th percentile incremental 1 hour average acrolein predictions – Gas Turbine Option (µg/m³)

Natural Gas



Distillate

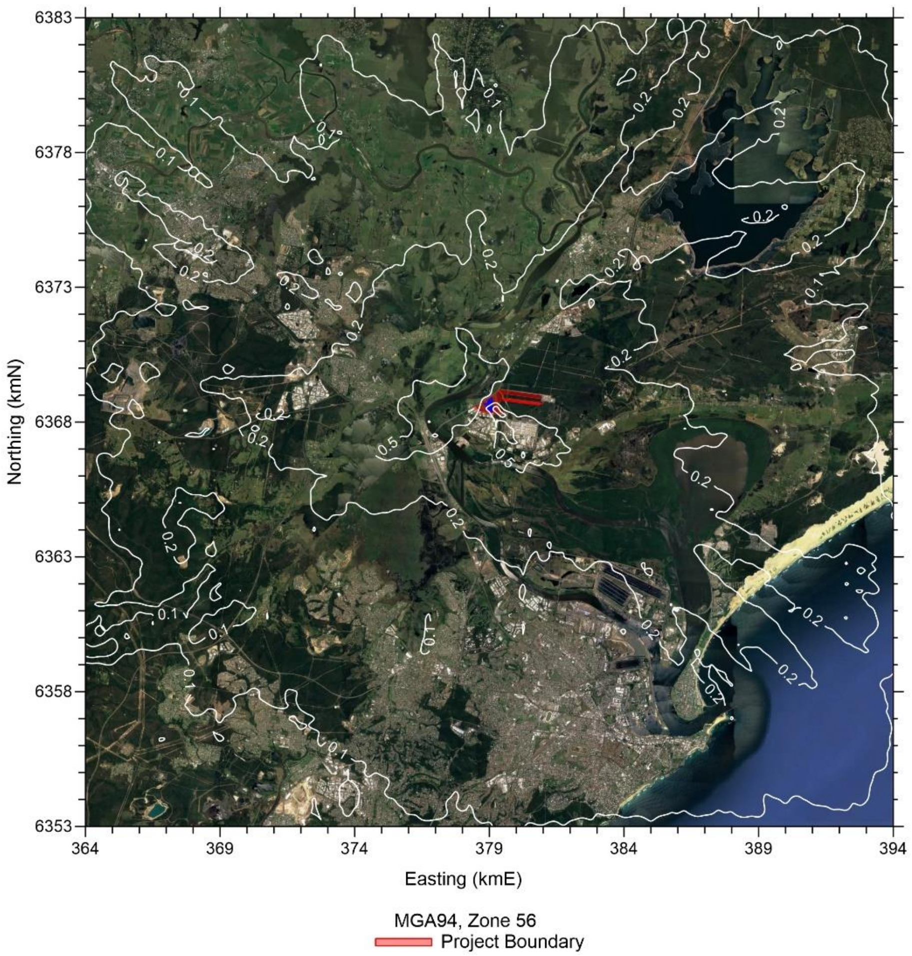


Notes: - Base image sourced from Google Earth Pro.
- Contour Levels: 0.001, 0.002, 0.005 µg/m³.

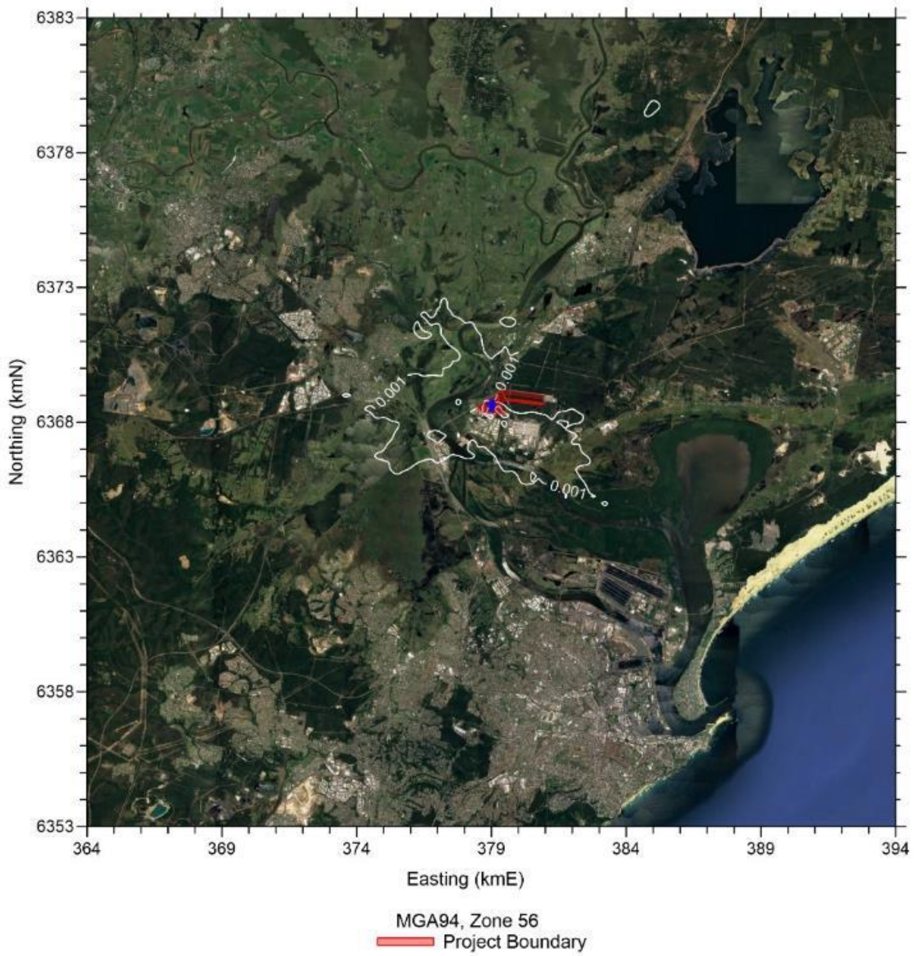
Figure 8.10: 99.9th percentile incremental 1 hour average acrolein predictions – Reciprocating Engine Option (µg/m³)

Natural Gas	Distillate

Natural Gas



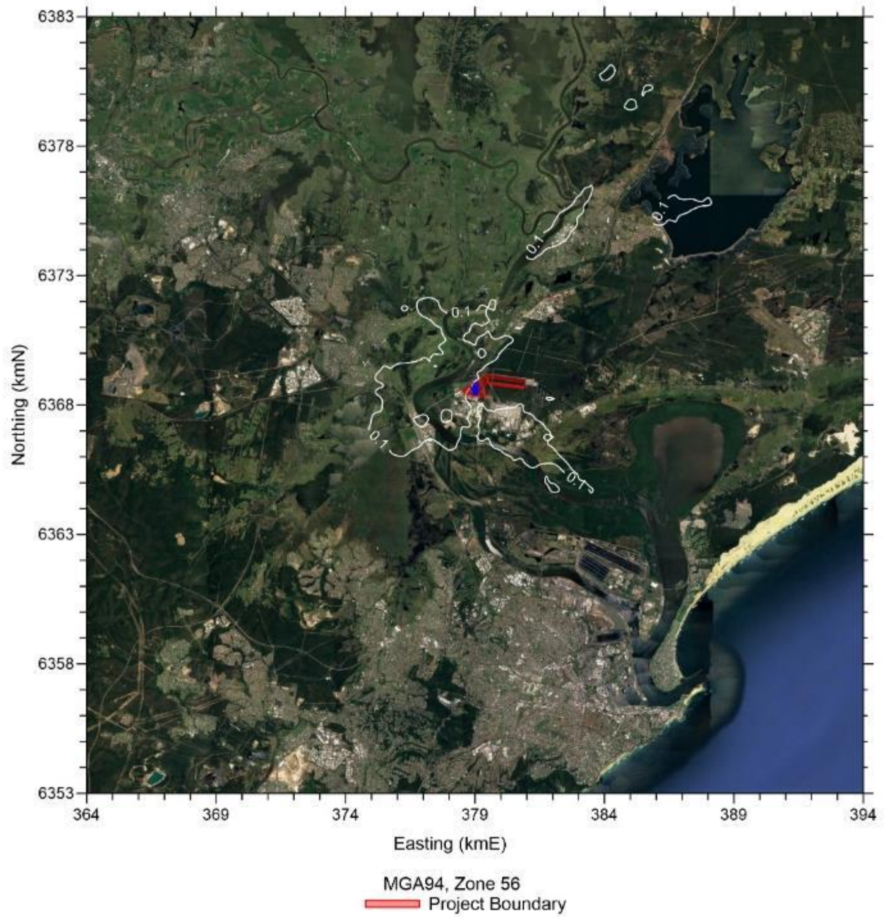
Distillate



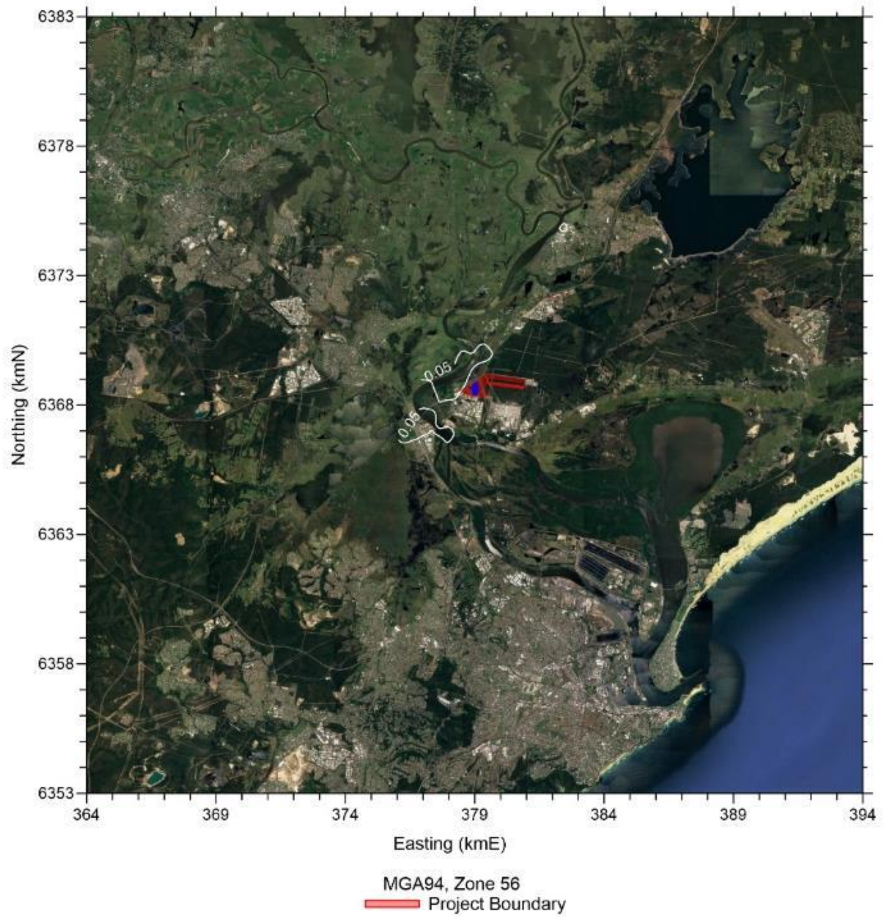
Notes:
- Base image sourced from Google Earth Pro.
- Contour Levels: 0.001, 0.002, 0.005, 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1 µg/m³.

Figure 8.11: 99.9th percentile incremental 1 hour average formaldehyde predictions – Gas Turbine Option (µg/m³)

Natural Gas



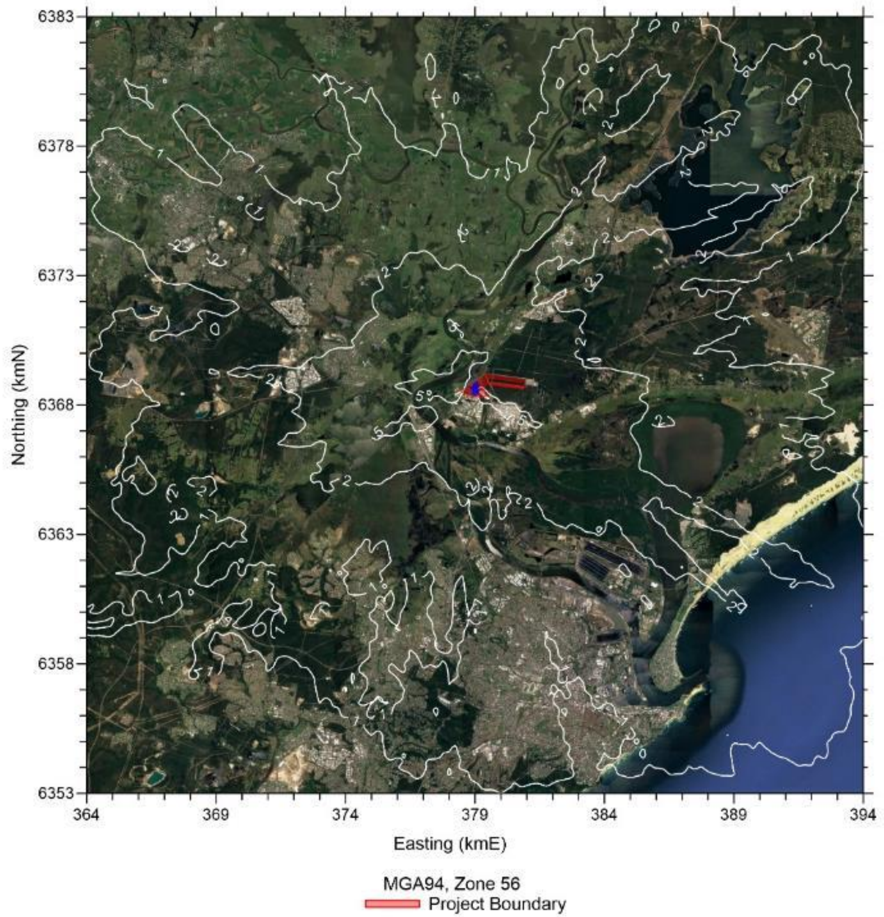
Distillate



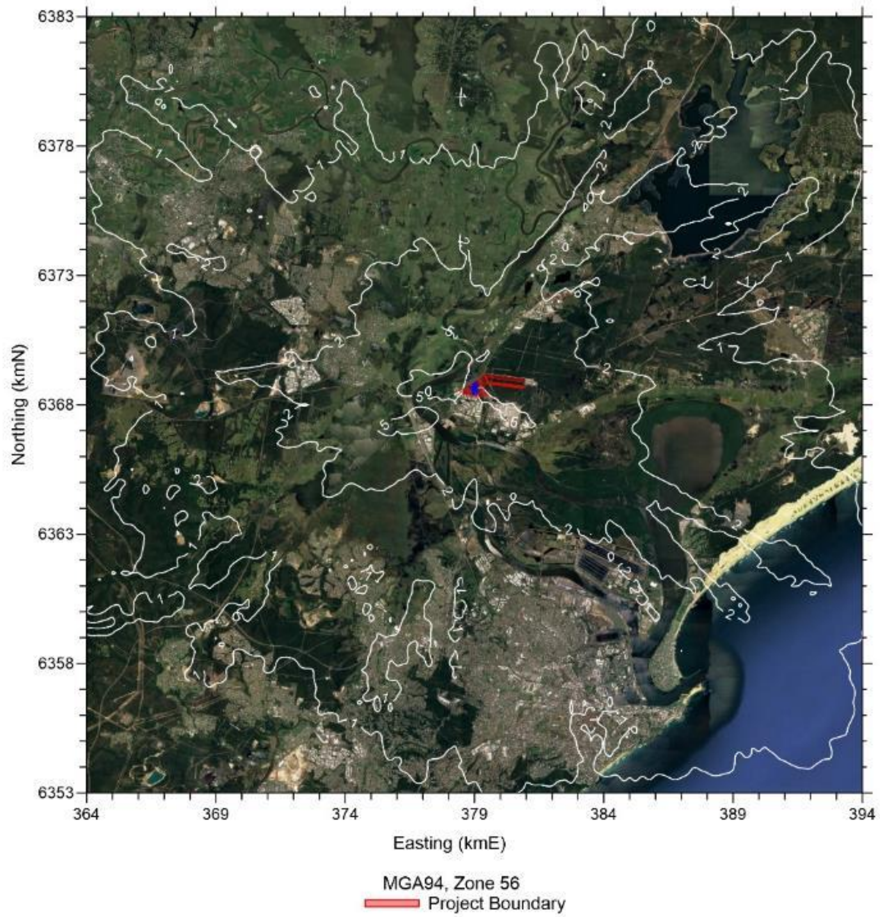
Notes:
- Base image sourced from Google Earth Pro.
- Contour Levels: 0.05, 0.1, 0.2 µg/m³.

Figure 8.12: 99.9th percentile incremental 1 hour average formaldehyde predictions – Reciprocating Engine Option (µg/m³)

Natural Gas



Distillate



Notes: - Base image sourced from Google Earth Pro.
- Contour Levels: 1, 2, 5, 10 µg/m³.

9. OZONE AND INTERREGIONAL TRANSPORT

Emissions from combustion sources can interact in the atmosphere to generate photochemical smog and ozone. The process involves a range of chemical reactions which occur on time scales ranging from several hours to several days, producing ozone, nitric oxide, peroxyacetyl nitrate and aldehydes.

This phenomenon is typically most prevalent during extended periods of light winds accompanied by higher temperature and strong sunlight, in places where anthropogenic emissions of precursor pollutants are significant on a regional basis, and where terrain features and/or meteorological patterns promote the trapping or recirculation of pollutants.

This section provides a screening level assessment of potential ozone impacts, with consideration of the potential for interregional transport of air emissions from the Proposal. The approach to undertaking this assessment has incorporated the outcomes of discussions with NSW EPA.

9.1 Ozone Screening Assessment

This ozone screening assessment has been prepared using the *NSW Tiered Procedure for Estimating Ground-Level Ozone Impacts from Stationary Sources* (Environ, 2011), implemented by the NSW EPA in 2015 in conjunction with an existing investigation of photochemical impacts for the Site.

An overview of the tiered ozone procedure framework is shown in Figure 9.1. The Proposal requires consideration of ozone impacts as it satisfies all the following:

- It is an activity listed under Schedule 1 of the POEO Act.
- It will release ozone precursors as part of the Proposal's proposed operations.
- It is located within the NSW Greater Metropolitan Region (GMR) as defined within the Clean Air Regulation.

An assessment of ozone impact that follows the steps outlined in the framework (Figure 9.1) is discussed in the sections below.

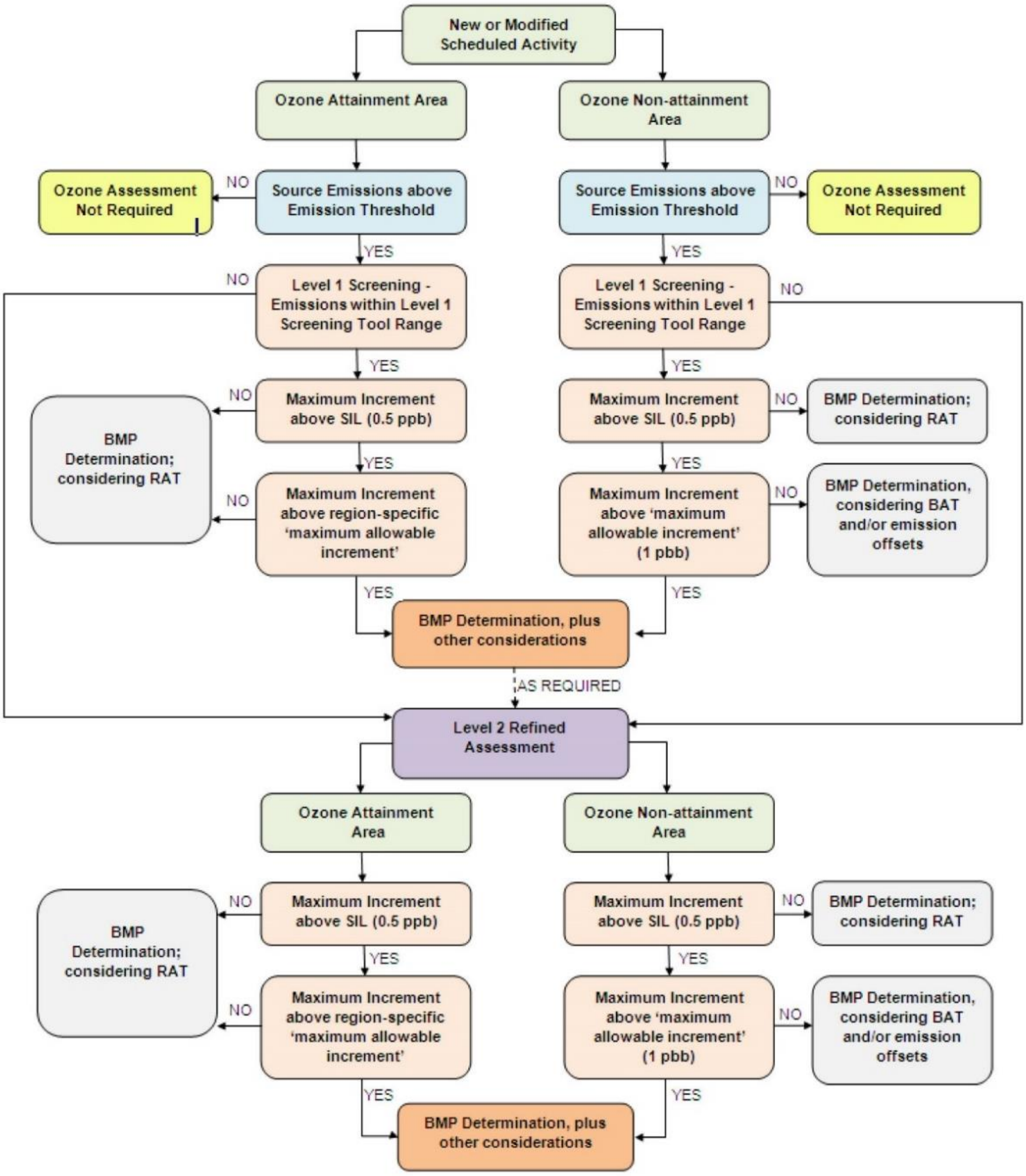


Figure 9.1: Ozone impact assessment procedure and current assessment pathway (Environ, 2011)

9.1.1 Classification as ozone attainment or ozone non-attainment area

The first step in the process is to determine if the project is located within an “attainment area” or “non-attainment area”. Ozone attainment and non-attainment areas are defined based on comparison with the ambient air quality (NEPM) goals (NEPC, 1998). The five year average maximum 1 hour and 4 hour ozone concentrations for the region are compared against a screening “acceptance limit” which is expressed as 82% of the NEPM goal (NEPC, 2007).

The maximum 1 hour and 4 hour ozone concentrations have been summarised for the Newcastle region for the period 2014-2018, as presented in Table 9.1.

It is noted that whilst available, the 2019 dataset has not yet been fully validated, and has therefore been excluded from this analysis.

Table 9.1: 1 hour and 4 hour maximum ozone concentrations in the Newcastle region (ppm)

Location	Annual maximum					5-year average maximum
	2014	2015	2016	2017	2018	
1 hour average						
Beresfield	0.090	0.077	0.085	0.083	0.107	**0.088**
Newcastle	0.065	0.074	0.077	0.086	0.067	0.074
Wallsend	0.087	0.071	0.086	0.106	0.086	0.087
4 hour average						
Beresfield	0.077	0.067	0.068	0.079	0.089	**0.076**
Newcastle	0.056	0.066	0.069	0.073	0.058	0.064
Wallsend	0.065	0.062	0.078	0.097	0.068	0.074

Note: The highest five year average maximum value recorded across monitoring stations in the region is shown in bold font.

The classification scheme used to determine if a region is an attainment or non-attainment area is provided in Table 9.2, as based on the relevant five yearly average annual maximum ozone concentrations shown in bold font in Table 9.1.

Table 9.2: Classification of ozone attainment or non-attainment area

Regional Airshed Status	Five Yearly Average Annual Maximum Ozone Concentration Thresholds	
	1 hour average	4 hour average
Attainment	< 0.082	< 0.0656
Non-attainment	*>= 0.82 and < 0.130*	*>= 0.0656 and < 0.110*
Non-attainment - Serious	>= 0.130 and < 0.150	>= 0.110 and < 0.120
Non-attainment - Severe	>= 0.150 and < 0.230	>= 0.120 and < 0.190
Non-attainment - Extreme	>= 0.230	>= 0.190

Note: Attainment status highlighted in yellow.

Based on the most recent five years of data, the Newcastle region is classified as an ozone non-attainment area, hence the right-hand side of the ozone assessment pathway applies (Figure 9.1).

9.1.2 Emissions Threshold

The second step evaluates the total annual NO_x and VOC emissions from the project against the emission thresholds shown in Table 9.3. If the emissions from scheduled activities exceed either of the thresholds, an ozone impact assessment is required to determine the significance of the incremental ozone contributions. It is noted that different thresholds apply for 'serious', 'severe' and 'extreme' non-attainment areas.

Table 9.3: Emission thresholds for Schedule 1 activities located in non-attainment areas

Activity	Source type	NO_x / VOC Emission Threshold (tonnes/year)
Any scheduled activity listed in Schedule 1 of the POEO Act (2007)	New	>90
	Modified	>35

The annual NO_x emissions for the Proposal have been estimated for both 14% and 100% (continuous) operating duty as shown in Table 9.4.

Table 9.4: Estimate of annual NO_x emissions at 14% and 100% operating duty

Plant Option	Fuel	Annual NO_x emissions (tonnes/year)	
		14% Operating Duty	100% Operating Duty
Gas Turbine	Natural gas	146	1,041
	Diesel oil	247	1,762
Reciprocating Engine	Natural gas	346	2,469
	Diesel oil	374	2,672

Under both the 14% and 100% operation, the ozone impact assessment is triggered, hence the next step in the framework is a Level 1 screening assessment.

9.1.3 Level 1 Ozone Screening Assessment

The EPA's Level 1 screening tool accompanies the NSW Ozone Procedure. This assessment has used Version 3.0 of the screening tool (Environ, 2015), with inclusion of 2014-2018 ozone data, and user specified speciated VOC emissions.

The Level 1 screening tool is primarily intended for continuous emission sources. Noting that the Proposal would operate typically intermittently, but may operate continuously in some circumstances, this analysis has considered two operating scenarios:

- Operation 24 hours per day
- Operation 6 hours per day.

Table 9.5 provides a summary of daily NO_x and CO inputs as entered into the Level 1 screening tool. Methane and speciated (i.e. user-specified) VOC emission estimates were also entered into the tool using US EPA default emission factors (US EPA, 2006).

Table 9.5: Summary of daily NO_x and CO estimates (tonnes/day)

Plant Option	Fuel	24 hours / day Operation		6 hours / day Operation	
		NOx	CO	NOx	CO
Gas Turbine	Natural gas	2.9	5.4	0.7	1.4
	Distillate	4.8	12.5	1.2	3.1
Reciprocating Engine	Natural gas	6.8	1.9	1.9	2.0
	Distillate	7.3	2.0	3.0*	0.6*

Note: *Includes allowance for elevated emissions during start-up (assuming 1 start-up per 6 hours operation).

The NSW EPA's ozone assessment framework defines criteria for assessment of increments to ground level ozone concentrations in the GMR. For non-attainment areas, the NSW Ozone Procedure defines a screening impact level (SIL) and maximum allowable increment as follows:

- Screening impact level (SIL) of 0.5 ppb
- Maximum allowable increment of 1 ppb

Table 9.6 shows the Level 1 screening tool incremental ozone predictions for these scenarios.

Table 9.6: Summary of Level 1 ozone screening tool results – Incremental ozone concentration (ppb)

Plant Option	Fuel	24 hours / day Operation		6 hours / day Operation	
		1 hour	4 hour	1 hour	4 hour
Gas Turbine	Natural gas	1.9	1.2	0.5	0.3
	Distillate	3.1	2.0	0.8	0.5
Reciprocating Engine	Natural gas	4.3	2.7	1.2	0.8
	Distillate	4.6	2.8	2.0	1.3

As shown in Table 9.6, the SIL and maximum allowable increment are met for the natural gas-fired gas turbine option under a 6 hour per day operating scenario, whilst these criteria are exceeded for all other scenarios.

Ordinarily, if the predicted incremental ozone concentration is above the SIL, the NSW EPA's ozone assessment procedure (Figure 9.1) would then require a Level 2 Refined Assessment to be conducted. However, as discussed below an alternative approach has been adopted in this instance.

9.2 Previous Studies Considering Ozone and Interregional Transport

An independent assessment of photochemical smog generation was undertaken for a previous project located on the Proposal Area in 2003 (CSIRO, 2003), comprising the staged development of a dual-fuel gas turbine power plant ranging from 260 MW to 790 MW in capacity.

For this development, CSIRO conducted modelling of potential smog generation using a three-dimensional modelling system, including a TAPM numerical weather prediction system, the Carnegie Mellon California Institute of Technology chemical transport model, and the NSW Metropolitan Air Quality Study (MAQS) emissions inventory.

The modelling featured specific ozone event periods, which were selected on the basis of having high ozone concentrations, and meteorological conditions suitable for the interregional transport between the power stations and the Sydney region (CSIRO, 2005).

The results of the modelling indicated that the proposed development would have only had a minor positive or negative effect on peak 1 hour and 4 hour ozone concentrations, depending on the scenario considered. Net increases in ozone were predicted to be of the order of 0.2% for all scenarios considered in the modelling. The assessment recognised that the NEPM ambient air quality standards for ozone are exceeded on occasion in the Metropolitan Air Quality Study Region, but the development was found to be very unlikely to cause any exacerbation of this situation (DIPNR, 2003).

The following key comparisons between (CSIRO, 2003) and the Proposal are considered:

- Similar NO_x emission intensity (kg/MWh) technologies considered for the two projects[3].
- Smaller scale of the Proposal (~250 MW versus up to 790 MW capacity)
- The presence of occasional ozone exceedances (i.e. non-attainment) noted within the MAQS; and

In view of the above, it is considered that the conclusions of the previous CSIRO modelling are anticipated to remain valid for the Proposal. Namely, that net increases in ozone generation as a result of the Proposal are anticipated to be minor.

Additional support to the above is provided within (CSIRO, 2005); an ozone impact assessment for the proposed 660 MW Munmorah Power Station on the Central Coast, south of Newcastle.

[3] CSIRO (2003) assessed a dual-fuel gas turbine-based plant, whilst the Proposal comprises dual fuel gas turbine or reciprocating engine technologies. Respective NO_x emission intensities are presented in Table 4.1.

(CSIRO, 2005) employed similar modelling techniques to that described within CSIRO (2003) and concludes "*emissions from the proposed gas turbine are predicted to result in no exceedances of air quality goals and standards for* NO_2 *and* O_3*. Emissions from the gas turbine are predicted to have no adverse effect on concentrations of nitrogen dioxide and ozone in the Sydney basin region*".

In view of the above commentary on both ozone impacts and inter-regional transport associated with power station assessments in the region, it is not considered that a Level 2 Refined Assessment is merited for what is a lesser output proposal.

10. LOCAL CUMULATIVE ASSESSMENT

The assessment has addressed potential air quality impacts across a 30 x 30 km region. The cumulative contribution of regional air pollution sources has been addressed at a broad scale through the review and incorporation of regional ambient air quality data into the assessment predictions.

To understand potential isolated impacts from the cumulative impact of the Proposal and existing local emission sources, a review of local air emission sources was conducted. The National Pollutant Inventory (NPI) air emission database[4] was reviewed in order to identify the presence and relative scale of air emission sources with pollutants common to the Proposal.

Table 10.1 shows a summary of these sources, with proximity to the Proposal, and annualised emission quantities for relevant pollutants.

Table 10.1: Annualised air emission quantities for sources near to the Proposal

Facility	Distance / Bearing from Proposal	Annualised Air Emissions – NPI 2017/18 Reporting Year (kg)			
		NO_x	CO	SO_2	$PM_{2.5}$
Hunter Galvanising	1 km SSE	2,500	2,400	27	200
Tomago Aluminium Smelter	1.5 km SE	350,000	47,000,000	11,000,000	53,000
Newcastle Gas Storage Facility	2 km E	2,900	3,200	29	34
Proposal*	-	49,000	115,000	2,100	8,100

Note: *Assuming 14% annual average operating duty, maximum of both technology options, 50/50 fuel mix (natural gas/distillate).

These inventories identify the Tomago Aluminium Smelter ('the smelter') as a key existing emission source of interest in terms of potential localised cumulative air quality impacts. The smelter is operated by Tomago Aluminium Corporation (TAC).

Emissions from the NGSF have been assessed within the Project Approval and subsequent modifications (PAEH, 2011b), and been shown to be minor including:

- Maximum (non-emergency) incremental 1 hour average NO_2 sensitive receptor predictions of approximately 2 µg/m³ (assuming a NO_2:NO_x ratio of 0.2).
- Peak 1 hour average SO_2 sensitive receptor predictions of approximately 1 µg/m³.
- Peak 24 hour average $PM_{2.5}$ sensitive receptor predictions of approximately 0.1 µg/m³.

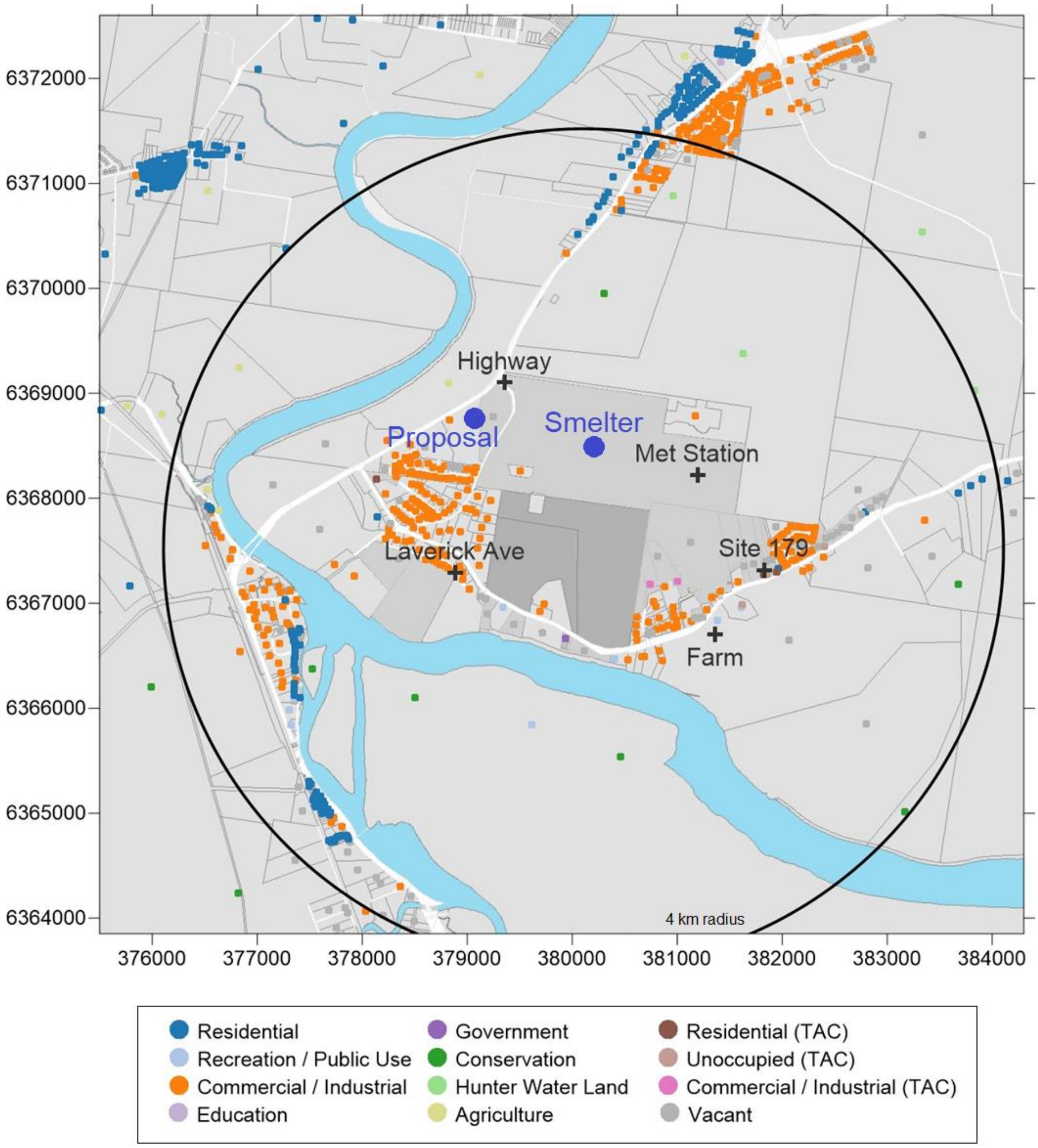
These incremental contributions are all less than 1% of their respective criteria, and hence are not considered material in terms of potential cumulative impacts. Emissions from the Hunter Galvanising facility are anticipated to be of a similar level of significance.

To gain understanding of potential scale of cumulative impacts with the smelter, ERM has been provided with ambient monitoring data from the local SO_2 monitoring network operated by TAC. These data include annualised summaries of monitoring data collected at five sites within the network dating back to 2009, and include the following:

- Maximum, 99th, 90th and 75th percentile statistics
- 10 minute, 1 hour and 24 hour averages
- Annual number of exceedances.

Figure 10.1 shows the location of the five continuous real-time ambient air quality monitoring stations at which SO_2 monitoring is currently undertaken, whilst Table 10.2 through Table 10.4 provide the annual maximum monitoring results for 10 minute, 1 hour and 24 hour averages (respectively).

[4] http://www.npi.gov.au/npidata/action/load/map-search (accessed June 2019).



Source: Adapted from TAC provided image.

Figure 10.1: Location of TAC SO_2 monitoring stations in the local vicinity of the smelter.

Table 10.2: Annual maximum 10 minute average SO_2 concentrations from TAC monitoring network

Year	Maximum 10 minute average SO_2 Measurement (µg/m³)				
	Farm	Highway	Laverick Ave	Met Station	Site 179
2014	561	314	361	423	364
2015	554	308	304	356	543
2016	448	324	320	344	437
2017	576	280	463	403	402
2018	553	320	365	367	384
Criterion	712				

Table 10.3: Annual maximum 1 hour average SO_2 concentrations from TAC monitoring network

Year	Maximum 1 hour average SO_2 Measurement (µg/m³)				
	Farm	Highway	Laverick Ave	Met Station	Site 179
2014	454	239	263	320	273
2015	480	299	232	284	349
2016	405	265	241	276	320
2017	433	171	252	296	294
2018	498	248	248	318	295
Criterion	570				

Table 10.4: Annual maximum 24 hour average SO_2 concentrations from TAC monitoring network

Year	Maximum 24 hour average SO_2 Measurement (µg/m³)				
	Farm	Highway	Laverick Ave	Met Station	Site 179
2014	225	82	76	174	44
2015	217	113	82	126	140
2016	248 *(2)*	131	84	73	128
2017	**237** *(1)*	52	109	151	96
2018	**269** *(2)**	97	88	206	99
Criterion	228				

Note: Exceedances shown in **bold text**. Number of exceedances shown in italicised brackets. *Value updated from previous draft based on 2018 monitoring records provided by TAC.

As shown in Table 10.2 through Table 10.4, ambient SO_2 concentrations are higher than the concentrations measured at Beresfield, but within NSW EPA impact assessment criteria, with the exception of years 2016, 2017 and 2018, which contain a total of five recorded exceedances of the 24 hour average criterion[5].

Maximum Cumulative SO_2 Concentrations

In order to assess the potential for the Proposal to produce exceedances of SO_2 criteria in the local vicinity of the smelter, a simplistic assessment of potential cumulative impacts has been undertaken. This has involved addition of peak Proposal model predictions (Reciprocating Engine option, natural gas operation, continuous operation all hours of the year) to peak measured concentrations within the TAC monitoring network for the assessment year (2018).

This approach does not necessarily reflect a realistic estimate of potential cumulative concentrations, given that peak model predictions and peak TAC SO_2 data are unlikely to be coincident in either space or time[6]. However this approach is instructive in screening against the NSW EPA SO_2 impact assessment criteria.

Table 10.5 presents this analysis, with comparison of maximum cumulative concentrations against relevant criteria.

[5] 2018 value updated from previous draft based on analysis of 2018 monitoring records as provided by TAC in February 2020.
[6] The peak 24 hour model prediction in the vicinity of the Farm monitoring site is approximately 1 µg/m³.

Table 10.5: Screening for potential of the Proposal to produce localised SO_2 exceedances

Statistic	Maximum Measurement (All TAC Stations, 2018)	Maximum Proposal Increment[1]	Maximum Cumulative Concentration	Criterion
10 minute	553	52	605	712
1 hour	498	36	534	570
24 hour	**269** *(205)*	4.3	**273** *(209)*	228
Annual	24.3	0.1	24.4	60

Notes: Exceedances shown in bold font and marked with an asterisk.
Highest non-exceedance value shown in italicised font in brackets.
[1]Reciprocating engine option, natural gas fuel.

When peak 10 minute, 1 hour and annual average model predictions are assessed in conjunction with peak TAC measurements, the maximum cumulative predictions are within respective criteria. Noting that the 24 hour average TAC measurements is greater than the criterion, the highest non-exceeding background concentration has also been presented (value shown in brackets). Adding the highest predicted 24 hour concentration to this value does not exceed the criterion, thus the Proposal is not predicted to produce additional exceedances of the 24 hour average criterion.

11. CONCLUSIONS

This assessment has considered potential air quality impacts associated with construction and operation of the AGL Newcastle Power Station. The assessment has used a quantitative dispersion modelling analysis to estimate compliance of operational phase emissions with the NSW EPA impact assessment criteria.

The existing environment has been characterised in terms of climate, meteorology and ambient air quality, with identification of key meteorological patterns, and the status of ambient air quality compliance:

- Ambient air quality standards for NO_2, CO and SO_2 are currently met at all DPIE monitoring locations across the 5 years reviewed, with significant margin between peak measurements and the corresponding standards.
- Short term (24 hour average) ambient air quality standards for PM (i.e. $PM_{2.5}$ and PM_{10}) are exceeded at all locations across the 5 years reviewed.
- The long term (annual average) $PM_{2.5}$ ambient air quality standard is met at Wallsend, and exceeded at all other locations within the 5 years reviewed. The long term (annual average) PM_{10} ambient air quality standard is exceeded at Carrington, Stockton and Mayfield, and met at Wallsend, Beresfield, and Newcastle. A review of these exceedances noted the dominance of extraneous events such as dust storms and bushfire activity.

An evaluation of the Proposal's emission performance and control technologies concludes that the technologies currently proposed are consistent with Best Available Technology.

Manufacturer data and US EPA emission factors have been used to estimate emissions for representative gas turbine and reciprocating engine technology options. Both natural gas and distillate fuels have been assessed resulting in a total of 4 assessment scenarios. These emissions were applied on a continuous basis in the NSW EPA-approved CALPUFF dispersion modelling package, in conjunction with regional background air quality and meteorological datasets for the year 2018.

Modelling predictions were processed into the concentration statistics required for assessment against NSW EPA impact assessment criteria.

Pollutants with a Proposal contribution in excess of 10% of relevant impact assessment criteria are confined to NO_2 and particulate matter (both technology options), as well as acrolein and formaldehyde (reciprocating engine option only):

- Cumulative NO_2 predictions were estimated using the ozone limiting method, in conjunction with hourly time varying ozone and NO_2 concentrations sourced from the DPIE Beresfield AQMS. The maximum 1 hour average cumulative NO_2 predictions was 123 µg/m³, equal to 50% of the criterion.
- Peak $PM_{2.5}$ predictions were approaching criteria, with a peak incremental $PM_{2.5}$ prediction of 7.6 µg/m³. When added to the peak background concentration of 17.1 µg/m³, results in a (maximum + maximum) cumulative concentration of 24.7 µg/m³, which is approaching the NSW EPA criterion of 25 µg/m³ Refinement of the analysis through the use of a time varying background would likely produce predictions well below those presented in this report.
- Exceedances of acrolein were predicted for the reciprocating engine option when operational on natural gas fuel, with the peak prediction across the modelling domain a factor of three times above the NSW EPA acrolein criterion. This prediction is based on US EPA emission factor-based estimates of acrolein emissions, for a 4-stroke lean burn gas engine with a conservative estimate of oxidation catalyst control efficiency.

  To further investigate the potential for acrolein emissions to produce adverse air quality impacts, the following analysis was undertaken:

- A review of the NSW EPA and international screening criteria was conducted. Based on assessment against these additional criteria, all predictions were estimated to be within respective screening criteria, as formulated to be protective of adverse public health outcomes.
- A review of meteorological conditions conducive to acrolein exceedances was undertaken and identified that predicted exceedances were associated with high wind, moderate temperature daytime conditions and did not align with times at which the plant is more likely to operate. In this capacity, the assumption of continuous operation, as adopted within this assessment, is considered to provide a conservative assessment of peak acrolein predictions.

Accordingly, the analysis conducted within this assessment indicates that the potential for the Proposal to cause exceedances is low, and manageable through effective operation of the proposed emission controls.

Commentary provided on both ozone impacts and inter-regional transport associated with other power station assessments in the region indicates that net increases in ozone generation as a result of the Proposal are anticipated to be minor.

Lastly, a review of potential cumulative impacts with other local sources of air emissions was conducted using data from the National Pollutant Inventory. This review identified the Tomago Aluminium Smelter as the key emission source of interest in terms of potential localised cumulative impacts. Accordingly, an analysis of the smelter's local air quality monitoring data was conducted, with assessment of potential cumulative impacts concluding that additional exceedances of SO_2 impact assessment criteria are not predicted to occur as a result of the Proposal.

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APPENDIX A METEOROLOGICAL MODELLING

A.1 TAPM

TAPM is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research (Hurley, 2002a, 2002b; Hurley et al., 2002a, 2002b; Hibberd et al., 2003; Luhar & Hurley, 2003). TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution dispersion components.

TAPM has been used to provide upper-air meteorological for the CALMET meteorological pre-processor. TAPM incorporates the following databases for input to its computations:

- Gridded database of terrain heights on a latitude/longitude grid of 30 second grid spacing, (around one kilometre). This default dataset is supplemented by a finer resolution dataset at nine second spacing (around 270 metres) for this assessment.
- Australian vegetation and soil type data at three minute grid spacing, (around five kilometres).
- Rand's global long term monthly mean sea-surface temperatures on a longitude/latitude grid at one degree grid spacing (around 100 kilometres).
- Six-hourly synoptic scale analyses on a latitude/longitude grid at 0.75-degree grid spacing, (around 75 kilometres), derived from the local analysis and prediction system (LAPS) data from the Bureau of Meteorology.

TAPM (V4.0.5) was run as per the configuration outlined in Table 4.1.

Table A.1: Summary of TAPM model configuration

Parameter	Value
Centre of TAPM Analysis	151.7167 °E, 32.825 °S
	379 876 mE, 6367 384 mN (MGA94, Zone 56H)
Number of grids	4
Grid spacing	30 km, 10 km, 3 km, 1km
Number of grid points	33 x 33 x 25
Period of analysis	29/12/2017 – 01/01/2019
Terrain information	AUSLIG 9 second DEM data
Mode	Meteorology
Wind assimilation	6 Sites influencing 3 levels, with a 7,500 m radius of influence: Beresfield, Williamtown, Stockton, Newcastle, Mayfield, Wallsend.
Data export	Data extracted as upper air format (UP.DAT) at all 6 assimilation sites.

A.2 CALMET

CALMET V6.5.0 was configured as detailed below:

- Grid dimensions: 121 x 121 points at 250 m resolution (30 x 30 km), with grid origin: 363.875 kmE, 6352.875 kmN (MGA 94).
- Cell faces at: 0, 20, 30, 70, 130, 270, 530, 970, 1,530, 2,470, 3,530, 4,970 mAGL.
- Terrain information sourced from the 3 arc-second NASA SRTM terrain database.
- Land use data manually generated from aerial photography (see Figure A.1).
- Temperature from surface and upper air stations.
- Diagnostic wind module used with:
  - Extrapolation of winds using similarity theory.

- Horizontally and vertically varying winds with divergence minimisation. Froude number adjustment and slope flows incorporated with a radius of influence (TERRAD) of 3 km.
- No calculation of kinematic effects.
- R1 = 3 km, R2 = 40 km.

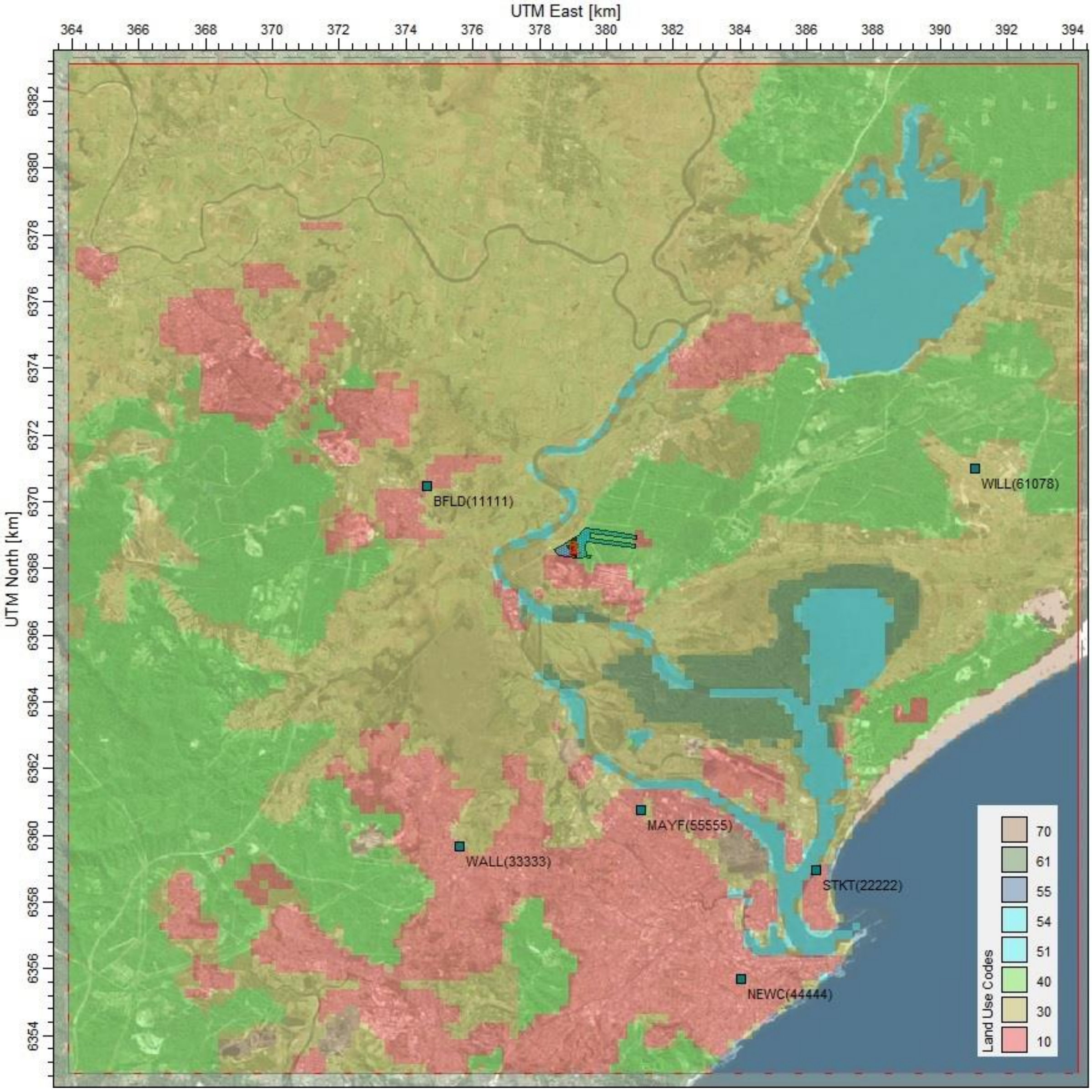

Figure A.1: Aerial image showing land use codes

Table A.2: Summary of land use types

Land Use Code	Description
10	Urban or built up land
30	Rangeland
40	Forest land
51	Streams and canals
54	Bays and estuaries
55	Oceans and seas
61	Forested wetland
70	Barren land

APPENDIX B REVIEW OF EMISSIONS DURING START-UP AND SHUTDOWN

This section provides a brief review of start-up emissions associated with both gas turbine and reciprocating engine plant options.

B.1 Gas Turbine Option

During operation, gas turbines are designed to oxidise fuel into carbon dioxide and water in an efficient manner, with effective control of NOx, CO and HAP emissions. This differs from the start-up period, where generally lower combustion temperatures and transient changes in combustion parameters can restrict the application of air emission controls (specifically water injection), resulting in short periods during which oxygen-corrected exhaust pollutant concentrations are higher than those experienced during operation.

Aeroderivative gas turbines of the scale proposed are capable of progressing from rest to full load on time scales in the order of 5 - 10 minutes. These durations are inclusive of the period prior to ignition (e.g. purging of the turbine), and the time during which the turbines are ramping up to full output, i.e. after which emission controls have become effective. This is in contrast with large industrial (frame) turbines, for which open cycle start-up durations can be in the vicinity of 15 to 45 minutes (URS, 2011).

Emission estimates for turbine start-up are limited. CH2MHILL (2010) provides start-up and shutdown pollutant emission estimates for a gas-fired LM6000PC gas turbine, which is a water-injected aeroderivative turbine of the scale of those being considered for the Proposal.

Over an 8 minute period (from ignition to 100% load), NO_x and CO emissions are estimated at 3.5 and 3 pounds (lb) respectively, equating to average emission rates of 3.3 and 2.8 g/s over this period. These emission rates are similar in scale (slightly lower) to operational NO_x and CO emission rates of approximately 5.4 and 3.3 g/s. Over an 8 minute shutdown period, NO_x and CO emission estimates are 2.7 and 2.4 lb (respectively), which are lower than those during operation, as well as those estimated over a corresponding 8 minute start-up period, and consequently of lesser significance than operational emissions.

Emission estimates were not able to be sourced for liquid fuel start-up, however it is anticipated that these would be similar in scale to operational emissions, especially when weighted into an hourly average emission rate as relevant to the dispersion modelling interval and the short-term nitrogen dioxide standard.

Accordingly, given the short duration, reduced exhaust mass flow rates and infrequent nature of start-up and shutdown conditions (relative to either operation or rest), the potential for these emissions to produce adverse air quality impacts is considered minor.

B.2 Reciprocating Engine Option

Emissions from reciprocating engines vary during start-up in a similar capacity to those from gas turbines. Noting this, reciprocating engines employ post-combustion controls (SCR and oxidation catalysts) which require additional time beyond the engine start-up to reach optimal operating conditions. Table C.1 provides a summary of manufacturer estimates of NO_x emissions for a start-up hour. As shown in the Table C.1, with the exception of NO_x emissions under distillate operation, emissions during start-up are similar in scale to those under continuous operation.

Table B.1: Comparison of Reciprocating Engine emissions under start-up and operation

Emission Scenario	NOx		CO		Units
	NG	DO	NG	DO	
Operation (full load)	22	23	6	6	kg/hr
Start-up	23	116	6	14	kg/hr
Proportion: Start-up vs Operation	125%	573%	119%	252%	-

In the case of diesel operation, whilst the engines are capable of reaching full operating load in 5 minutes, elevated NO_x emissions are estimated to continue for a period of up to 30 minutes after commencement of start-up. The duration of this condition is dependent on the pre-starting temperature of the catalyst bed, which in turn is a function of time since the given unit was last operational. Noting the anticipated infrequent nature of start-up events, and operation on distillate fuel, the combined risk of adverse air quality impacts resulting from start-up using distillate fuel (under adverse dispersion conditions) are considered to be low.

APPENDIX C DETAILED ACROLEIN ASSESSMENT

C.1 OVERVIEW

The dispersion modelling has predicted that maximum offsite 1 hour average 99.9th percentile acrolein predictions would result in a threefold exceedance of the NSW EPA impact assessment criterion. In order to permit a more refined assessment of potential adverse air quality impacts, additional acrolein assessment has been undertaken, involving the following tasks:

- A review of the background and basis of derivation for the NSW EPA acrolein criterion.
- A review of contemporary public health-endpoint based screening criteria.
- An expanded assessment of acrolein predictions against alternative screening criteria.

Detail of this analysis is provided in the following sections.

C.2 NSW APPROVED METHODS ACROLEIN CRITERION

The Approved Methods provide a range of air quality impact assessment criteria for application in the assessment of air emissions from new or modified pollutant sources. The document contains criteria for 'principal toxic pollutants', inclusive of acrolein, which are to be applied against the incremental 99.9th percentile 1 hour average predictions for the facility of interest, in isolation. These criteria are applicable at and beyond the boundary of the facility under assessment.

These criteria have been referenced from EPA Victoria "design criteria" for Class 3 indicator pollutants (GoV, 2001) which in turn, were developed from (current as of 2001) occupational exposure standards as per the following process:

> "*Design Criteria…* (for Class 2 indicator pollutants) *…have been derived from the current Worksafe Australia Occupational Health and Safety TWA values divided by a safety factor of 30. This safety factor accounts for extrapolation from a healthy adult exposed over their working life to the general population potentially exposed over a lifetime. This extrapolation takes into account the protection of sensitive groups including the elderly and children."*
>
> *"Design criteria for Class 3 indicators are derived in a similar manner to those for toxicity based Class 2 indicators. An additional safety factor of 10 is applied due to the seriousness of the potential health effects arising from exposure to these pollutants"*

Table C.1 shows the basis derivation for the NSW EPA acrolein criterion from the corresponding occupational criterion.

Table C.1: Basis of derivation for NSW EPA acrolein impact assessment criterion

Parameter	Value	Units	Source
Australian 8 hour occupational standard (TWA) – Circa. 2001*	100	ppb	(SWA, 2019)
VIC EPA design criterion TWA conversion (safety) factor	300	-	(GoV, 2001)
VIC EPA design criterion (3 minute average)	0.33	ppb	
Conversion factor (3 minute to 1 hour)	1.82	-	(EPAV, 2005)
NSW EPA impact assessment criterion	0.18	ppb	(EPA, 2017)
	0.42	µg/m³	

Note: *This standard is current, has been in place since 1991 and is understood to be under review (SWA, 2019).

C.3 REVIEW OF ADDITIONAL ACROLEIN SCREENING CRITERIA

A brief review of contemporary public health endpoint-based assessment standards has been undertaken in order to provide a more consolidated range of criteria for consideration in the assessment of potential acrolein impacts.

Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (TCEQ; 2018, 2019)

The Texas Commission on Environmental Quality (TCEQ) provide a diverse range of Effects Screening Levels (ESLs) for use in dispersion modelling assessment of new and modified sources of air pollution. TCEQ (2018) provides the following context on the ESLs.

> *"Effects Screening Level (ESL): Guideline concentrations derived by the Texas Commission on Environmental Quality (TCEQ) and used to evaluate ambient air concentrations of constituents. Based on a constituent's potential to cause adverse health effects, odor nuisances, vegetation effects, or materials damage. Health-based screening levels are set at levels lower than those reported to produce adverse health effects, and are set to protect the general public, including sensitive subgroups such as children, the elderly, or people with existing respiratory conditions. If an air concentration of a constituent is below the screening level, adverse effects are not expected. If an air concentration of a constituent is above the screening level, it is not indicative that an adverse effect will occur, but rather that further evaluation is warranted."*

TCEQ (2019) also outlines a tiered methodology for the application of the ESL's. Of these, Tier II represents an intermediate (screening level) which involves assessment of maximum 1 hour average sensitive receptor predictions (e.g. a residence) against the ESL, and assessment of maximum 1 hour average industrial receptor predictions against a level equal to double that of the ESL. The guidance also outlines a Tier III assessment, which involves more detailed consideration of potential impacts should exceedances be predicted within the Tier II assessment.

The 1 hour average and annual average acrolein ESLs are 3.2 µg/m³ and 0.82 µg/m³ (respectively).

Ontario Ministry of the Environment and Climate Change Ambient Air Quality Criteria (MoE, 2019)

The Ontario Ambient Air Quality Criteria (AAQCs) comprise air quality criteria intended for use in environmental assessment and assessment of ambient air quality data, where an AAQC is defined as "*a desirable concentration of a contaminant in air and is used to assess general air quality resulting from all sources of a contaminant to air*" (MoE, 2019).

The 1 hour average and 24 hour average acrolein AAQCs are 4.5 µg/m³ and 0.4 µg/m³ (respectively).

Agency for Toxic Substances and Diseases Registry (ATSDR) Minimal Risk Levels (MRLs), (ATSDR, 2019)

ATSDR MRLs are provided as a human health risk assessment screening tool for assessing cases where potential health effects should be considered more closely. They are based on the '*no observed adverse effect level/uncertainty factor'* (NOAEL/UF) approach to derivation MRLs for hazardous substances.

They are set below levels that, based on current information "*might cause adverse health effects in the people most sensitive to such substance-induced effects*." MRLs are derived for acute (1-14 days), intermediate (>14-364 days), and chronic (365 days and longer) exposure durations, and for both oral and inhalation exposure routes.

The acute and intermediate MRLs for acrolein are 7.0 µg/m³ and 0.1 µg/m³ (respectively).

California EPA Air Toxics Hot Spots Program – Reference Exposure Levels (OEHHA, 2015)

The Air Toxics Hot Spots Information and Assessment program provides a framework for the assessment of extent of airborne emissions from stationary sources and the potential public health impacts of those emissions.

This framework includes an acute, 8 hour and chronic Reference Exposure Levels (RELs) for a range of substances as per the following (respective) definitions:

- "*an acute REL is an exposure that is not likely to cause adverse health effects in a human population, including sensitive subgroups, exposed to that concentration (in units of micrograms per cubic meter or µg/m³) for the specified exposure duration on an intermittent basis."*
- *"an 8 hour REL is an exposure that is not likely to cause adverse health effects in a human population, including sensitive subgroups, exposed to that concentration (in units of micrograms per cubic meter or µg/m³) for an 8 hour exposure duration on a regular (including daily) basis*
- *"A chronic REL is a concentration level (expressed in units of micrograms per cubic meter (µg/m³) for inhalation exposure… …at or below which no adverse health effects are anticipated following long-term exposure."*

The acute, 8 hour and chronic acrolein RELs are 2.5 µg/m³, 0.7 µg/m³ and 0.35 µg/m³ (respectively).

Summary of Screening Criteria

Table C.2 presents a summary of acrolein screening criteria identified as relevant to this assessment.

Table C.2: Summary of acrolein criteria

Default Application	Exposure Duration	Criterion Type	Value	Assessment Statistic	Applicability
Dispersion Modelling Assessment	Acute	NSW EPA IAC	0.42	1 hour (99.9th percentile)	At and beyond boundary
		TCEQ ESL	3.2	1 hour (maximum)	At sensitive receptors**
		Ontario AAQC	4.5	1 hour	
	Sub-Acute		0.4	24 hour	
	Chronic	TCEQ ESL	0.82	Annual	
Human Health Risk Assessment – Screening*	Acute	OEHHA REL	2.5	1 hour	
	Sub-Acute / Intermediate		0.7	8 hour	
		ATSDR MRL	7.0	24 hour	
			0.1	1 – 14 day	
	Chronic	OEHHA REL	0.35	Annual	

*For cases where an emission source is not pre-existing, these figures are regularly used in the evaluation of dispersion modelling results.

**In the case of TCEQ-ESLs, Tier II assessment requires application of the ESL at residential receptors, with a doubling of the ESL at off-site industrial receptors (OEHHA, 2019).

C.4 ACROLEIN ASSESSMENT

Table C.3 presents the results of the Proposal dispersion modelling (reciprocating engine, natural gas option) against the range of criteria identified in Section A3.1.

A contour isopleth of the maximum 1 hour average acrolein prediction is also provide in Figure A.1.

Table C.3: Assessment of model predictions against reviewed acrolein criteria

<table>
<tr><th>Criterion Type</th><th>Model Prediction (µg/m³)</th><th>Criterion (µg/m³)</th><th>Assessment Statistic</th><th>Applicable Result</th></tr>
<tr><td>NSW EPA IAC</td><td>1.25</td><td>0.42</td><td>1 hour (99.9th percentile)</td><td>Grid Maximum</td></tr>
<tr><td>TCEQ ESL</td><td rowspan="3">2.0</td><td>3.2</td><td rowspan="3">1 hour maximum</td><td rowspan="9">Maximum Residential Receptor*</td></tr>
<tr><td>Ontario AAQC</td><td>4.5</td></tr>
<tr><td rowspan="2">OEHHA REL</td><td>2.5</td></tr>
<tr><td>0.5</td><td>0.7</td><td>8 hour maximum</td></tr>
<tr><td>Ontario AAQC</td><td rowspan="2">0.2</td><td>0.4</td><td>24 hour maximum</td></tr>
<tr><td rowspan="2">ATSDR MRL</td><td>7.0</td><td>24 hour maximum</td></tr>
<tr><td>0.05</td><td>0.1</td><td>7 day maximum**</td></tr>
<tr><td>TCEQ ESL</td><td rowspan="2">0.01</td><td>0.82</td><td rowspan="2">Annual</td></tr>
<tr><td>OEHHA REL</td><td>0.35</td></tr>
</table>

Note: *Maximum residential receptor results interpolated from gridded receptor predictions.
**1 – 14 day MRL treated as applicable to maximum 7 day average prediction.

These results indicate the following:

- As shown in Table C.3, with exception of the NSW EPA criterion, all other predictions are within respective assessment criteria, as formulated to be protective of adverse public health outcomes.
- Model predictions are approaching both acute and sub-acute OEHHA RELs.
- Annual average model predictions are significantly lower than respective (chronic) criteria.

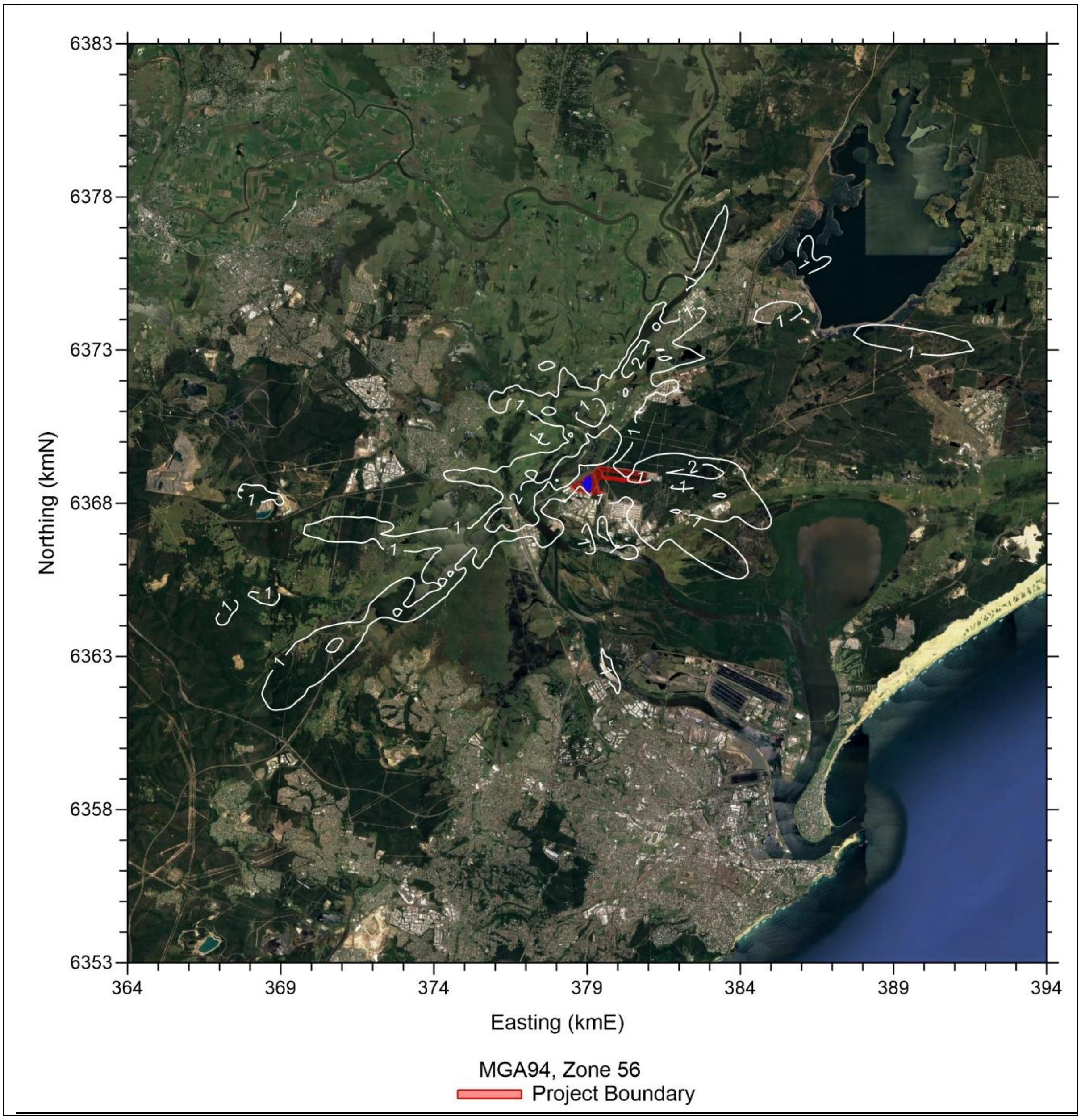

Figure C.1: Maximum 1 hour average acrolein prediction (µg/m³)

APPENDIX D METEOROLOGICAL ANALYSIS OF PEAK ACROLEIN PREDICTIONS

D.1 Meteorological Analysis

A review of modelling data was undertaken in order to identify meteorological conditions that are associated with peak acrolein predictions. This involved processing a time series of modelled meteorological and concentration data at the peak model receptor, which was located immediately to the south east of the Proposal (MGA coordinates 379 500 mE, 6368 250 mN). Meteorological conditions and concentration data at this model receptor were analysed and found to indicate the following:

- At the peak 99.9th percentile receptor, concentrations in excess of the 0.42 µg/m^3 acrolein criterion were predicted during a total of 72 hours within the 8,760 hour meteorological dataset[7].
- Peak predictions are primarily aligned with daytime conditions– 70% of exceedances were predicted to occur during between the hours of 8 am and 3 pm.
- Peak predictions are confined to neutral conditions (C and D class atmospheric stability).
- Peak predictions are aligned with strong winds - 97% of exceedances were predicted for wind speeds greater than 6.5 m/s.
- Peak predictions are aligned with moderate temperatures, primarily occurring between 10°C and 30°C.

A visual representation of the data supporting these findings is shown in Figure D.1 (overleaf).

It is noted that the plant is proposed to operate in a peaking capacity, primarily serving periods of peak demand, or when renewable capacity is limited. It is noted that acrolein exceedances do not align with the evening peak or temperature extremes (as relevant to peak reverse cycle air conditioning demand), and are primarily confined to high wind daytime conditions that are typically associated with higher output from wind and solar generation.

On this basis, it is considered that meteorological conditions conducive to acrolein exceedances do not align with times at which the plant is more likely to operate. In this capacity, the assumption of continuous operation, as adopted within this assessment provides a conservative representation of peak acrolein predictions.

[7] The acrolein criterion applies as a 99.9th percentile concentration, and thus applies to the 9th highest modelling result across an 8,760 hour annual modelling period.

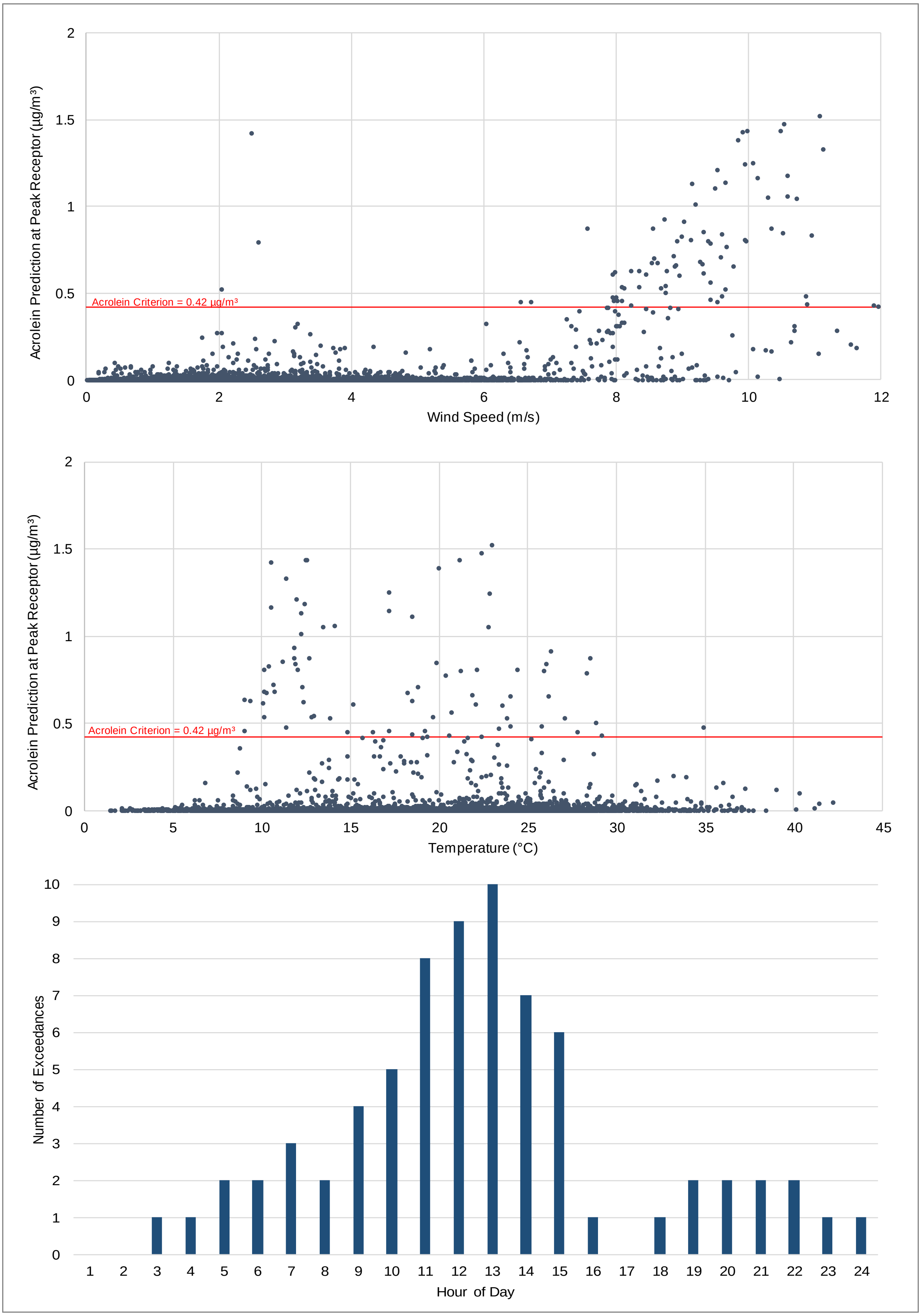

Figure D.1: Review of acrolein exceedances against local wind speed, temperature and hour of day

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