Narrabri Special Activation Precinct

Final Air Quality Report

Prepared for NSW Government Department of Planning and Environment

June 2023

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June 2023

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Approved by

Scott Fishwick
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15 June 2023

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Acknowledgement of Country

We acknowledge country and pay respects to the Gomeroi/Gamilaroi/Gamilaraay/Kamilaroi people as the Traditional Owners and Custodians of the land and waters on which the Narrabri Special Activation Precinct is located.

We recognise their continued connection to Country and that this connection can be seen through stories of place and cultural practices such as art, songs, dances, storytelling and caring for the natural and cultural landscape of the area.

We also recognise the continuing living culture of Aboriginal people, and the significance of Narrabri in that living culture. We recognise the contemporary stories of displacement and the cultural significance of Narrabri in the continued journey of self-determination in Australia.

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1 Introduction

1.1 Background

EMM Consulting Pty Limited (EMM) has been commissioned by New South Wales (NSW) Government Department of Planning and Environment (DPE) to support the development of a Master Plan for the Narrabri Special Activation Precinct (SAP). EMM's role is to provide technical input with respect to potential air quality and odour impacts[1].

1.2 Narrabri SAP

The NSW Government, through its introduction of the SAPs, has identified six distinct areas for development throughout regional NSW. These areas facilitate planning and investment to stimulate economic growth across a range of industries, including freight and logistics, manufacturing, waste management and recycling, energy generation, agriculture and food processing. The planning and creation of these areas is partially facilitated and funded through the $4.2 billion Snowy Hydro Legacy Fund.

The establishment of SAPs is a joint initiative by the DPE, the Department of Regional Growth NSW, and the Regional Growth NSW Development Corporation (RGDC). It forms part of the 20-year economic vision for regional NSW. The DPE is responsible for preparing the planning framework, with the Department of Regional NSW managing each SAP.

In November 2020, Narrabri was declared as the sixth and final SAP, enabled by its strong reputation and location within Australia's highest productive grain region, as well as its strong transportation linkages including existing road and rail connections and the future Inland Rail.

Narrabri township is located within the Narrabri Shire local government area (LGA), 420 km north-northwest of Sydney. In the 2021 census, the population of Narrabri township was 6,898 persons, with 16% identifying as Aboriginal and/or Torres Strait Island Peoples. The township lies at the junction of the Newell and Kamilaroi Highways and has a direct rail connection to the Port of Newcastle via the Walgett branch of the Main North Line. Once completed, Narrabri will also have a direct connection to the new Inland Rail route which will connect Melbourne to Brisbane via new and upgraded track.

1.3 Master planning process

The master planning process for the Narrabri SAP involved the following main stages:

- Stage 1 – Analysis. This included a characterisation of the baseline conditions for the SAP and the surrounding area.
- Stage 2 – Identification of Options. This involved an options analysis of three possible scenarios for the SAP.
- Stage 3 – Draft Structure Plan. This involved the assessment of the land use Structure Plan for the SAP (the subject of this report).

As part of the master planning process, and to inform the supporting technical studies, two Enquiry by Design (EbD) workshops were organised. A preliminary EbD workshop was held on 29 and 30 March 2022 to develop three initial land use scenarios. Following an interdisciplinary assessment of the three scenarios, a final EbD workshop was held between 5 and 8 September 2022 to consider the constraints of the three scenarios and to identify and develop a preferred land use Structure Plan.

[1] EMM is also addressing noise impacts, although these are reported separately.

1.4 Previous air quality reports

The Stage 1 report for air quality and odour (EMM 2021) provided an overview of the regulations and guidance that are relevant to the management of these aspects in NSW, and identified the sensitive locations at which air quality and odour criteria would apply. Key existing and known future emissions sources were also identified for the Narrabri SAP and the surrounding area. A summary of the Stage 1 report is provided in Appendix A.

The Stage 2 report for air quality and odour (EMM 2022) presented an options analysis of three possible scenarios for the SAP. The approach was largely qualitative, based on key considerations such as the prevailing meteorology, the cumulative effects of industry interactions, and impacts on sensitive locations outside the SAP. The first step was to map the risk of impacts for each of the three scenarios, based on typical separation distances in the literature for specific activities. In the second step, each scenario was assessed at a high level using a SWOT analysis. The scenarios were compared using a star rating system, and opportunities were identified to help mitigate air quality and odour impacts. The Stage 2 report has now been superseded by the work presented in this report.

1.5 Purpose of this report

This report has been prepared for Stage 3 and completes step F.3.2 of the EMM scope of work (Air Quality and Odour Report). The report assesses the land use Structure Plan from the final EbD workshop from an air quality and odour perspective.

Through the use of air pollution modelling, the report evaluates potential impacts at sensitive locations inside and outside the SAP, and thus identifies areas of potential concern to further inform the layout of the SAP. The report focuses on the operational impacts of potential activities within the SAP. The construction of facilities is not taken into account, as construction impacts will tend to occur over relatively short timescales, and construction activities will be subject to best management practice for dust and odour.

NB: Only a single, hypothetical, 'typical use' scenario is considered for the SAP, based on broad-brush assumptions for proxy facilities. Given the uncertainty relating to the actual activities within the SAP, the results should be viewed as indicative, and the report does not provide a comprehensive assessment of likely compliance with air quality criteria.

2 Structure Plan for the SAP

The Narrabri SAP is located to the west of the existing township. The Structure Plan for the SAP, as finalised at the final EbD workshop, is shown in Figure 2.1. It should be noted that this figure does not necessarily represent the final SAP and land use boundaries, which may change throughout the master planning process.

The delivery of the SAP has been separated into two main stages:

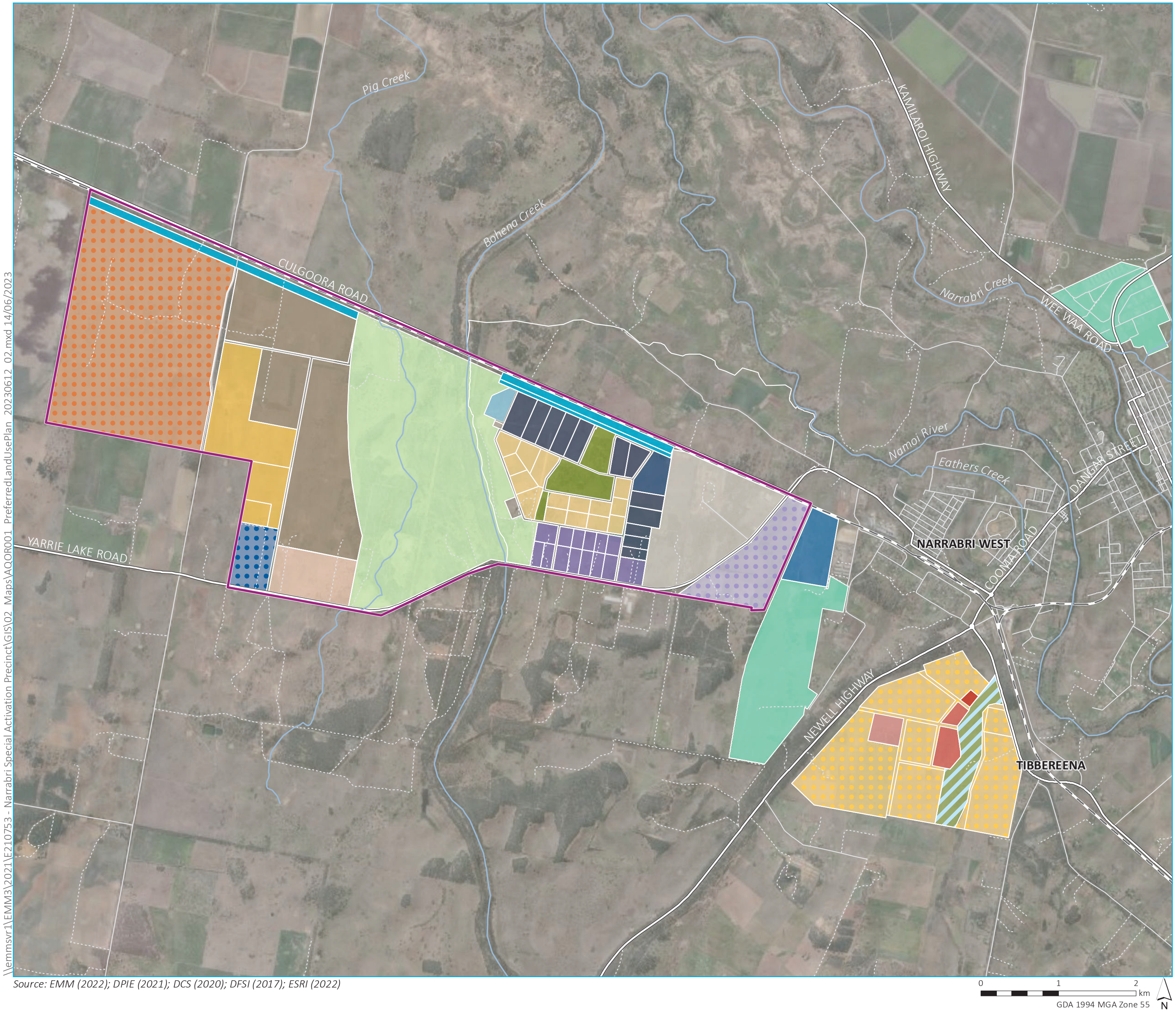
- Stage 1: Inland Port and Hub, at the east of the SAP
- Stage 2: Western SAP Extension, to support more hazardous and/or energy-intensive uses.

The combined area of Stage 1 and Stage 2 is approximately 1,205 ha. The two stages are separated by an environmental buffer zone.

The principal land uses in the SAP are labelled as follows:

- Stage 1:
  - transport and logistics
  - agriculture and food processing
  - manufacturing
  - interim hazardous uses
  - circular economy
  - waste management and recycling
- Stage 2:
  - grain production
  - fertiliser and chemicals
  - solar power
  - bioproducts
  - energy (gas power generation).

Figure 2.1 shows the land areas that are allocated to the above land uses at the time of reporting.



Source: EMM (2022); DPIE (2021); DCS (2020); DFSI (2017); ESRI (2022)

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KEY

Special Activation Precinct

Preferred SAP land use
- Agricultural and food processing area
- Bohnea Creek conservation area
- Byproducts
- Circular economy area
- Rail siding
- Energy
- Fertiliser and chemicals
- Green corridor
- High value vegetation to be retained
- Interim potential hazardous uses area
- Manufacturing
- Potential grain area
- Solar
- Stormwater basin
- Transport and logistics area
- Waste management and recycling area

Non-SAP land use
- Rail connection
- Light industrial
- Mount Kaputar precinct
- Indicative health precinct location
- Indicative neighbourhood centre location
- Indicative school location

Existing environment
- Rail line
- Major road
- Minor road
- Vehicular track
- Named watercourse

Narrabri SAP preferred land use plan

Narrabri Special Activation Precinct
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Figure 2.1

creating opportunities

3 Methodology

3.1 Overview

The assessment methodology involved the use of an atmospheric dispersion model, in conjunction with data on background air quality, to predict potential air pollution levels at sensitive locations inside and outside the SAP, and to identify possible areas (and activities) of concern. A single, hypothetical, 'typical use' scenario was investigated.

The atmospheric dispersion modelling for the assessment used the CALMET/CALPUFF system. The methodology was broadly in accordance with the NSW Environment Protection Authority (EPA) Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales ('Approved Methods for Modelling') (NSW EPA 2022).

The precise details of the facilities or activities within the SAP were not known at the time of the assessment. Therefore, several assumptions and simplifications were required.

It should be noted that the air quality modelling was not designed to address any statutory planning requirements for specific facilities, but provided information that could be used in a strategic context to further inform the layout of the SAP.

3.2 Policies and regulations

3.2.1 Ambient air quality

With respect to ambient air quality, the following general policies and regulations are relevant to the Narrabri SAP:

- National Environment Protection (Ambient Air Quality) Measure ('AAQ NEPM')[2]
- *Protection of the Environment Operations (POEO) Act 1997*
- Protection of the Environment (Clean Air) Regulation 2022
- The New South Wales (NSW) Environment Protection Authority (EPA) Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales ('Approved Methods for Modelling') (NSW EPA 2022).

It is likely that future industrial uses in the Narrabri SAP will require an Environment Protection Licence (EPL) under the POEO Act 1997. Air quality and odour management strategies for the SAP will need to be in accordance with the air quality and odour requirements for an EPL.

3.2.2 Odour

The POEO Act 1997 introduces the concept of 'offensive odour' for regulating odour from scheduled premises. Scheduled premises are regulated by the NSW EPA and Section 129 of the POEO Act prohibits the emission of offensive odour from scheduled premises.

[2] https://www.legislation.gov.au/Details/F2021C00475

In determining the offensiveness of an odour, it is relevant to consider the context in which an odour is perceived. Some odours, for example the smell of sewage, are likely to be judged offensive regardless of the context in which they occur. Other odours such as agricultural odours may be acceptable in a rural setting, but not in an urban setting. Whether or not an individual considers an odour to be a nuisance will depend on the frequency, intensity, duration, and offensiveness of the odour (the so-called FIDO factors).

Offensive odour is defined in the POEO Act as an odour:

a) that, by reason of its strength, nature, duration, character or quality, or the time at which it is emitted, or any other circumstances

   i. is harmful to (or is likely to be harmful to) a person who is outside the premises from which it is emitted, or

   ii. interferes unreasonably with (or is likely to interfere unreasonably with) the comfort or repose of a person who is outside the premises from which it is emitted, or

b) that is of a strength, nature, duration, character or quality prescribed by the regulations or that is emitted at a time, or in other circumstances, prescribed by the regulations.

Under the POEO Act, scheduled and non-scheduled premises are also required to prevent or minimise air pollution (including odour) using best management practices. It is an offence under the POEO Act, for scheduled and non-scheduled premises, to fail to operate plant in a proper and efficient manner or maintain the plant in an efficient condition.

In November 2006 the (then) NSW Department of Environment and Conservation published technical guidelines for the assessment and management of odour - Technical framework: Assessment and Management of Odour from Stationary Source in NSW (NSW DECC 2006a, 2006b). One of the key overlying principles in the Technical framework is ‘planning to prevent and minimise odour impacts’, that is, ‘at the planning stage, planners, proponents and regulators should consider the compatibility of a proposal with current and likely future land uses’.

There are a number of avoidance and mitigation strategies within the Technical framework which can be applied to minimise potential conflict between neighbouring land uses within the SAP.

3.3 Impact assessment criteria

3.3.1 Air quality

It is likely that future industrial uses in the Narrabri SAP will require an Environment Protection Licence (EPL) under the Protection of the Environment Operations Act 1997 (POEO Act 1997). Air quality and odour management strategies for the SAP will need to be in accordance with the air quality and odour requirements for an EPL.

Given the complex mix of emission sources in the SAP, and the associated range of pollutants, the air quality assessment was simplified by focussing on the following:

- nitrogen oxides (NO_X) and nitrogen dioxide (NO_2)
- particulate matter with an aerodynamic diameter of less than 10 µm (PM_{10})
- particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$).

These pollutants are important in terms of health, are emitted in substantial quantities, and can have ambient concentrations that are close to (or above) air quality criteria.

The air quality impact assessment criteria for these pollutants are set out in the Approved Methods for Modelling[3], and are identified in Table 3.1. As this report aimed to support strategic planning within the SAP, strict compliance (or non-compliance) with the criteria was not considered to be appropriate. Rather, the predicted concentrations from the modelling have been considered in terms of the risk of air quality impacts.

In addition, the focus was on **long-term (annual average) pollutant concentrations**, as these are most helpful in terms of understanding the general relationships between emission sources and ambient concentrations. The spatial distribution and timing of peak short-term concentrations (1-hour NO_2, 24-hour PM_{10} and 24-hour $PM_{2.5}$) are strongly influenced by short-term meteorological events, as well as the precise spatial relationship between sources and assessment locations[4]. It is our view that short-term predictions are, therefore, less helpful from a strategic planning perspective, and any planning decisions based on these could be undermined once the actual activities in the SAP are known (and modelled in more detail). Consequently, short-term concentrations have not been considered in the report, and the relevant criteria have only been included in Table 3.1 for completeness.

Table 3.1 Impact assessment criteria (NSW EPA 2022)

Pollutant	Averaging period	Impact assessment criterion
NO_2	1 hour	164 µg/m^3 [(a)]
	Annual	31 µg/m^3 [(a)]
PM_{10}	24 hours	50 µg/m^3
	Annual	25 µg/m^3 [(b)]
$PM_{2.5}$	24 hours	25 µg/m^3
	Annual	8 µg/m^3 [(b)]

Notes: a) Since the baseline air quality report, the criteria for NO2 have been reduced. The 1-hour and annual average criteria were previously 246 µg/m3 and 62 µg/m3 respectively.
b) The AAQ NEPM also includes 2025 goals for annual mean and 24-hour PM2.5 of 20 µg/m3 and 7 µg/m3 respectively.

The application of the assessment criteria in Table 3.1 is described in the Approved Methods for Modelling. The criteria are applied at the nearest existing or likely future 'off-site' sensitive assessment locations (referred to as 'receptors' in the Approved Methods for Modelling). The following must be reported for each metric, and in units and averaging periods consistent with the impact assessment criteria:

- the incremental impact (i.e. the predicted impact due to the pollutant source alone)
- the total impact (i.e. the incremental impact plus the existing background concentration).

3 The Approved Methods for Modelling also define carbon monoxide (CO), lead (Pb), total suspended particulate (TSP), deposited dust and hydrogen fluoride as criteria pollutants.

4 In addition, at some locations the short-term background concentrations can exceed the impact assessment criteria. This is most commonly the case for PM_{10} and $PM_{2.5}$, which are affected by events such as bushfires and dust storms. This adds further complexity to the assessment of short-term predictions, as the selection of the background data has a significant influence on the outcome.

3.3.2 Odour

There are no instrument-based methods that can measure an odour response in the same way as the human nose. Therefore, 'dynamic olfactometry' is typically used as the basis of odour quantification by regulatory authorities. Dynamic olfactometry is the measurement of odour by presenting a sample of odorous air to a panel of people with decreasing quantities of clean odour-free air. The panellists then note when the smell becomes detectable. The correlations between the known dilution ratios and the panellists' responses are then used to calculate the number of dilutions of the original sample required to achieve the odour detection threshold. The units for odour measurement using dynamic olfactometry are 'odour units' (OU) which are dimensionless and are effectively 'dilutions to threshold'.

The odour nuisance level can be as low as 2 OU and as high as 10 OU (for less offensive odours), whereas an odour assessment criterion of 7 OU is likely to represent the level below which 'offensive' odours should not occur. The Technical Framework recommends that, as a design criterion, no individual should be exposed to ambient odour levels of greater than 7 OU (NSW DECC 2006a; 2006b).

NSW EPA (2022) prescribes odour goals which take into account the population density for a particular area. A summary of the EPA's population-based odour assessment criteria is presented in Table 3.2. The most stringent odour goal of 2 odour units (OU) is acceptable for the whole population and is, therefore, appropriate for built-up areas.

Odour goals are only applied for Level 2 and Level 3 odour assessments (i.e. they apply to the 99th percentile of the dispersion modelling predictions) and are not used, for example, to determine compliance for an existing facility. Odour modelling is not applicable to annual average concentrations.

Table 3.2 Impact assessment criteria for complex mixtures of odorous air pollutants

Population of affected community (people)	Odour units (OU), nose response time average[(a)], 99th percentile
~ 2	7
~ 10	6
~ 30	5
~ 125	4
~ 500	3
Urban (2,000) and / or schools and hospitals	2

Notes: a) A nose response average refers to the instantaneous perception of odours by the human nose and is derived using peak-to-mean ratios.

3.4 Existing environment

The existing conditions for meteorology, air quality and odour were analysed by EMM (2021), and the findings are summarised in Appendix A. Based on the analysis, 2020 was selected as the representative year for the air quality modelling and background concentrations. Justification for this selection is provided in Appendix A.4.3.

3.4.1 Meteorology

An analysis of the data from the Narrabri Airport AWS – the closest Bureau of Meteorology (BoM) station to the project – was used to select a representative site year for meteorological data in the atmospheric dispersion modelling.

It was noted by EMM (2021) that the SAP will be located to the west of the Narrabri population. Westerly winds, which would transport emissions from the SAP to towards the population, were relatively infrequent overall. However, some westerly winds did occur in the afternoons.

3.4.2 Background air quality

The determination of background air quality for the assessment is described in EMM (2021), and the supporting analysis is provided in Appendix A. For PM_{10} and $PM_{2.5}$, background concentrations in 2020 were taken from the DPE monitoring station at Narrabri. For NO_X and NO_2, background concentrations were taken from DPE's Gunnedah station.

The analysis indicated that, in terms of annual average concentrations, there is significant capacity in the airshed to accommodate future development within the SAP. For example, the annual average concentrations of NO_2, PM_{10} and $PM_{2.5}$ (7, 12.4 and 5.5 µg/m^3) were well below the respective impact assessment criteria (31, 25 and 8 µg/m^3).

Peak short-term concentrations are highly dependent on background air quality and extreme events. The maximum 24-hour concentrations of both PM_{10} and $PM_{2.5}$ were above the corresponding criteria (50 µg/m^3 and 25 µg/m^3). There were eight exceedance days for PM_{10}, and one exceedance day for $PM_{2.5}$. Most of the exceedances were associated with the bushfires in January 2020.

3.4.3 Odour

The existing odour environment in the vicinity of the SAP is expected to be primarily influenced by the Narrabri Landfill which is located within the proposed SAP boundary. However, both the current and licenced filling rates are significantly lower than what is defined by NSW EPA as a large landfill, and a reduced buffer distance (significantly less than 1,000 metres) is likely to be applicable for future development within the SAP.

A Statement of Environment Effects (SEE) was prepared for a recent modification to the consent, to allow for the ongoing operation of the landfill by increasing the capacity (GHD 2020). The SEE found that odour was not a significant issue for existing sensitive locations in the vicinity of the site.

3.5 Modelling approach

3.5.1 Model domains and assessment locations

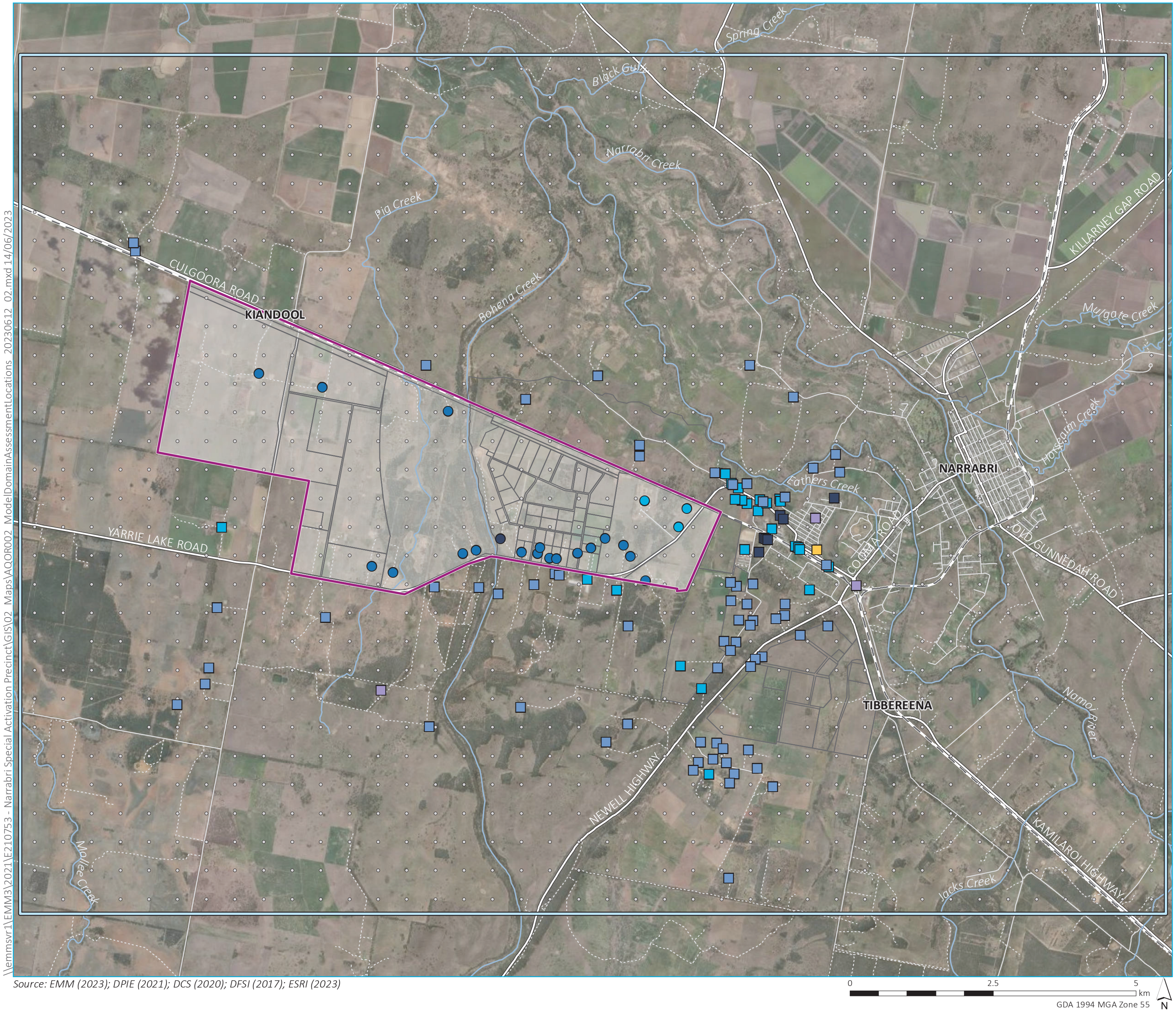
The domain and assessment locations (sensitive receptors) included in the dispersion modelling are illustrated in Figure 3.1. Further details are provided in Section 3.5.3.

To assess potential air quality and odour impacts, it was important to identify existing and likely future sensitive receptors in the vicinity of the Narrabri SAP. From an air quality perspective, the Approved Methods for Modelling defines sensitive receptors as:

> A location where people are likely to work or reside; this may include a dwelling, school, hospital, office or public recreational area.'

Section 5.2 of the Approved Methods for Modelling also describes 'particularly sensitive receptors' as 'residences, schools and hospitals'.

Based on discussions with DPE, Narrabri Shire Council (NSC) and NSW EPA, sensitive receptors were taken as existing or future dwellings, schools, childcare centres, hospitals, places of worship, public recreation, commercial offices and retail premises. Other commercial or industrial premises were considered for the purpose of the air quality and odour study.



KEY

- Special Activation Precinct
- SAP layout
- Model grid point
- Model grid extent

Assessment location

Inside SAP

- Commercial/Industrial
- Rural Residential
- Residential

Outside SAP

- Commercial/Industrial
- Rural Residential
- Suburban Residential
- School
- Playground

Existing environment

- Rail line
- Major road
- Minor road
- Vehicular track
- Named watercourse

Source: EMM (2023); DPIE (2021); DCS (2020); DFSI (2017); ESRI (2023)

Model domain and assessment locations

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Figure 3.1

creating opportunities

3.5.2 Meteorological modelling

The meteorological modelling for the assessment – which involved the use of CALMET – is described in EMM (2021). The performance of CALMET was also assessed.

CALMET was used to produce three-dimensional meteorological fields for use in the CALPUFF model. In the absence of upper air measurements, CALMET was run using prognostic upper air data (as a three-dimensional '3D.dat' file), which was used to derive an initial wind field (known as the Step 1 wind field in the CALMET model). The model then incorporated mesoscale and local scale effects, including surface observations, to adjust the wind field. This modelling approach is known as the 'hybrid' approach (TRC 2011) and was adopted for this assessment.

The Commonwealth Scientific and Industry Research Organisation (CSIRO) prognostic meteorological model TAPM was used to generate gridded upper air data for each hour of the model run period, for input into CALMET.

3.5.3 Dispersion modelling

i General model set-up

The CALPUFF model (Version 7) was used for the dispersion modelling. CALPUFF was configured in accordance with the recommended settings of TRC Environmental Corporation (TRC 2011) where relevant to do so. Pollutant concentrations were predicted across the 20 km (x axis) by 15 km domain (y axis) centred over the SAP with a 500 m resolution, as well as at 126 individual assessment locations (see below). Concentrations were predicted for the 12-month period of 2020.

ii Assessment locations

A mixture of rural residential, suburban residential, educational, recreational, commercial and industrial assessment locations were selected. Further details of the assessment locations are provided in Appendix B. Pollutant concentrations were predicted for every hour of the year at each assessment location.

iii Emission sources and assumptions

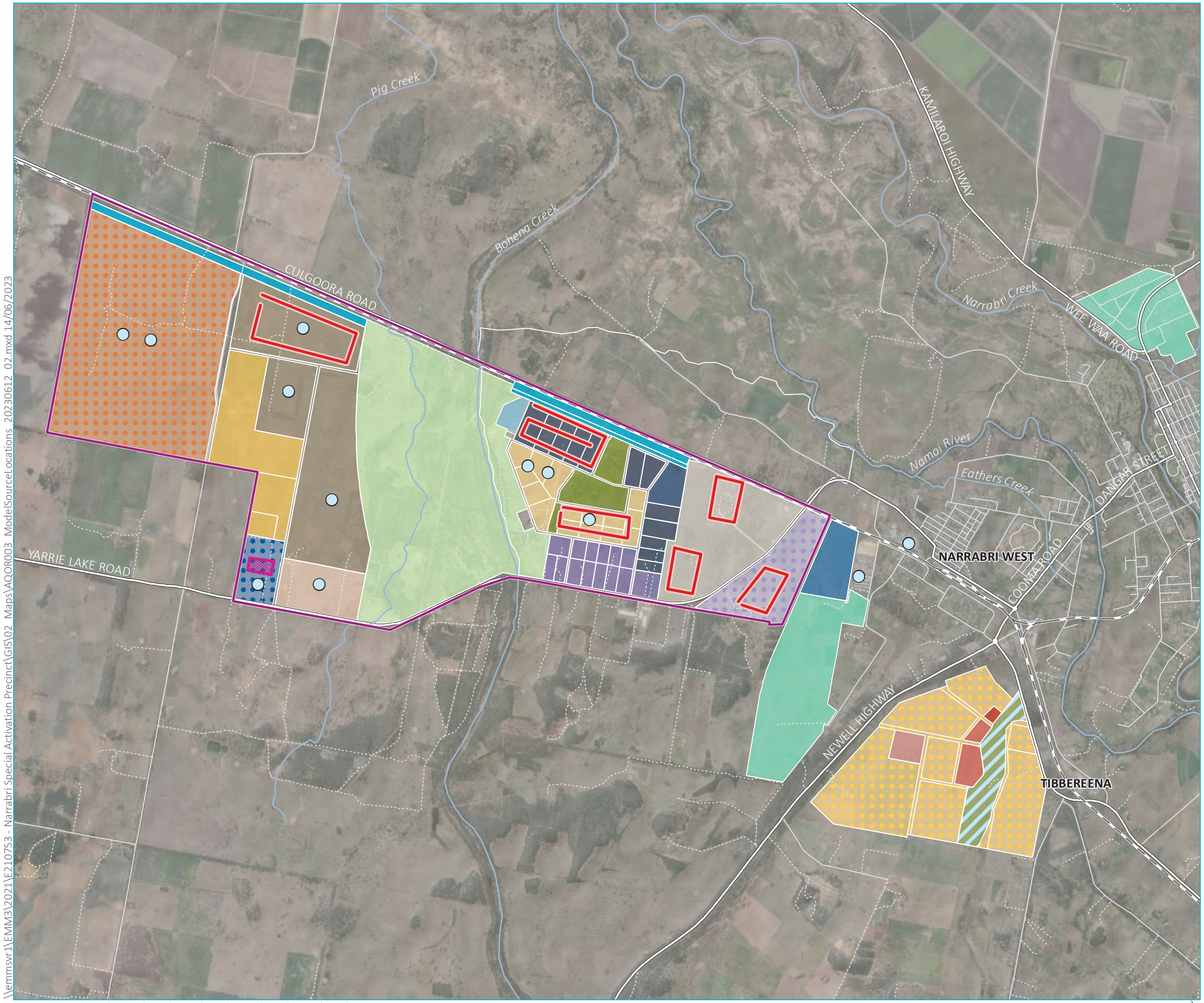
The nominal emission source locations adopted in the model for activities inside and outside the SAP are shown in Figure 3.2.

The emission sources in the model domain were categorised as follows:

- existing facilities
- new land uses in the Structure Plan for the SAP (Stage 1)
- new land uses in the Structure Plan for the SAP (Stage 2).

In order to simplify the assessment, road and rail traffic were excluded from the modelling, other than where they were already included in the assumptions for specific land uses (see below). It is likely that any material air quality impacts associated with road and rail operation will be restricted to within a few hundred metres of the operations and will be relatively small, apart from at locations very close to transport corridors.

The assumptions for the various emission sources that were included in the modelling are summarised in Appendix C. As noted earlier, the precise details of the facilities or activities within the SAP were not known at the time of the assessment. For each type of land use in the Structure Plan, the characteristics of the emission sources were therefore assumed using surrogate variables in combination with data from previous air quality impact assessments (AQIAs) – referred to here as 'proxy facilities'.



KEY

- Special Activation Precinct
- Point source
- Line source
- Area source

Preferred SAP land use

- Agricultural and food processing area
- Bohnea Creek conservation area
- Byproducts
- Circular economy area
- Rail siding
- Energy
- Fertiliser and chemicals
- Green corridor
- High value vegetation to be retained
- Interim potential hazardous uses area
- Manufacturing
- Potential grain area
- Solar
- Stormwater basin
- Transport and logistics area
- Waste management and recycling area

Non-SAP land use

- Rail connection
- Light industrial
- Mount Kaputar precinct
- Indicative health precinct location
- Indicative neighbourhood centre location
- Indicative school location

Existing environment

- Rail line
- Major road
- Minor road
- Vehicular track
- Named watercourse

Model source locations

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Figure 3.2

EMM creating opportunities

Source: EMM (2022); DPIE (2021); DCS (2020); DFSI (2017); ESRI (2022)

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The source characteristics included:

- type (e.g. point, line, area)
- location
- dimensions (e.g. stack height)
- emission parameters (e.g. air flow rate, emission rate, temperature).

For some land uses, several different source types were relevant.

The proxy facilities that were used to characterise emissions within the SAP (Stages 1 and 2) are summarised in Table 3.3. The proxy facilities were either already known to EMM (e.g. previous EMM AQIAs) or were identified in an online search of AQIAs.

3.5.4 Post-processing

The model predictions for annual mean NO_X, PM_{10} and $PM_{2.5}$ were combined with the measurements of background concentrations to determine the total pollutant concentrations (also referred to as 'cumulative impacts').

Odour modelling results are presented as the 99th percentile 1-second (nose response) odour concentration to provide an indicative odour impact in the surrounding environment. Odour concentrations were derived from predicted 1-hour average odour concentrations with a peak-to-mean ratio of 2.3 applied, consistent with the Approved Methods for Modelling recommendations for volume sources.

The calculation of NO_2 concentrations from the predicted NO_X concentrations was considered unnecessary. This is explained later in the report.

Table 3.3 Proxy facilities for emissions

SAP stage	Land use	Facility type	Proxy facility	Reference	Notes
1	Transport and logistics	-	Moorebank Intermodal Terminal, Stage 1 and Stage 2	ENVIRON (2015) and Ramboll (2016)	Broadly representative of typical activities at intermodal terminals.
	Agriculture and food processing	Grain processing	Selby Wheat Processing Facility	Hydrock (2019)	Only grain processing facility found with an online AQIA.
		Cotton gin	Carrathool Cotton Gin	PEL (2014)	Only cotton gin found with an online AQIA.
	Manufacturing	Excluded. Unlikely to feature significant emission sources.			
	Interim hazardous uses	Excluded. Unlikely to feature significant emission sources.			
	Circular economy		Melbourne Regional Landfill	PEL (2016)	Facility with online AQIA.
	Waste management and recycling		Girraween Resource Recovery Facility	EMM (2019)	Facility with online AQIA.
2	Grain production		Selby Wheat Processing Facility	Hydrock (2019)	Only grain processing facility found with an online AQIA.
	Fertiliser and chemicals	Ammonium nitrate plant	Kooragang Island Ammonium Nitrate Facility	URS (2012)	Facility with online AQIA.
		Sodium bicarbonate plant	No AQIA. USEPA AP-42 sodium carbonate production emission factors in kg/hour adopted.	Pacific Environment Services (1993)	USEPA published emission factors for sodium carbonate production.
		Methanol plant	Burrup Peninsula Methanol Complex	WA EPA (2002)	Facility with online AQIA.
	Solar power	Excluded. Unlikely to feature significant emission sources			
	Bioproducts		Wagga Wagga Biodiesel Plant	The Odour Unit (2008)	Facility with online AQIA. Included as example of bioproduct.
	Energy		Newcastle Power Station (gas)	ERM (2019)	Facility with online AQIA.

4 Results

The air quality modelling focussed on annual average concentrations of NO_X (as a proxy for NO_2), PM_{10} and $PM_{2.5}$, as well as short-term odour impacts. The results of the modelling are presented in the following sections. Section 4.1 considers the results for the individual assessment locations, including the various source contributions, and Section 4.2 considers the spatial distribution of the total concentrations in the model domain, presented as contour plots.

Given the uncertainty concerning the development of the SAP, and the assumptions required for the modelling, the results should only be considered to provide an indication of potential air quality impacts and constraints to development.

4.1 Concentrations at assessment locations

4.1.1 Comparison with impact assessment criteria

i Air quality

The cumulative results for annual average NO_X, PM_{10} and $PM_{2.5}$ at the 126 individual assessment locations are shown in Figure 4.1 to Figure 4.3. In each figure, the assessment locations have been grouped as follows:

- residences or other sensitive locations inside the SAP: chart (a)
- commercial or industrial locations inside the SAP: chart (b)
- residences or other sensitive locations outside the SAP: chart (c)
- commercial or industrial locations outside the SAP: chart (d).

Each chart includes the corresponding annual average background concentration for each pollutant.

For each pollutant, the total concentration was generally well below the corresponding air quality impact assessment criterion. For example:

- for PM_{10} the highest total concentration was around 18 µg/m^3, compared with a criterion of 25 µg/m^3
- for $PM_{2.5}$ the highest total concentration was around 6.5 µg/m^3, compared with a criterion of 8 µg/m^3.

In the case of NO_X, there is no corresponding criterion. However, the annual average criterion for NO_2 is 31 µg/m^3. With the exception of assessment location RR_17, the highest total NO_X concentration (14.5 µg/m^3) was well below this criterion. Ambient concentrations of NO_2 are lower than those of NO_X, and an exceedance of the NO_2 criterion would usually require a NO_X concentration of around 80 µg/m^3. It is, therefore, unlikely that annual average NO_2 will be a major constraint to development in the SAP.

The predicted NO_x concentrations at assessment location RR_17 are influenced directly by emissions from the potential transport and logistics area. Emissions from this area were estimated based on an air quality impact assessment for a large scale intermodal facility located in Sydney. Consequently, the predicted results should be viewed as conservative.

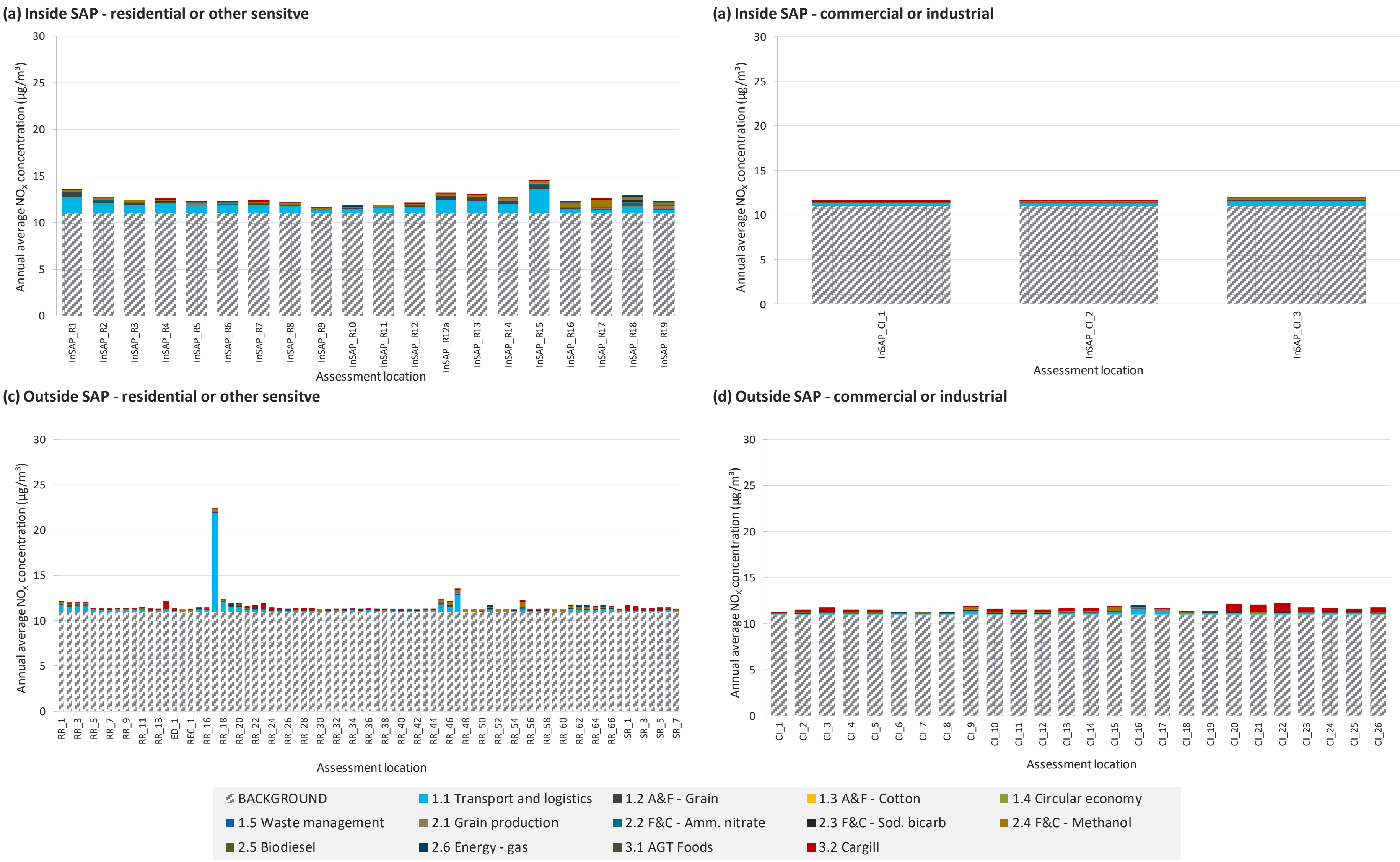


Figure 4.1 Annual mean NO_X concentrations at assessment locations

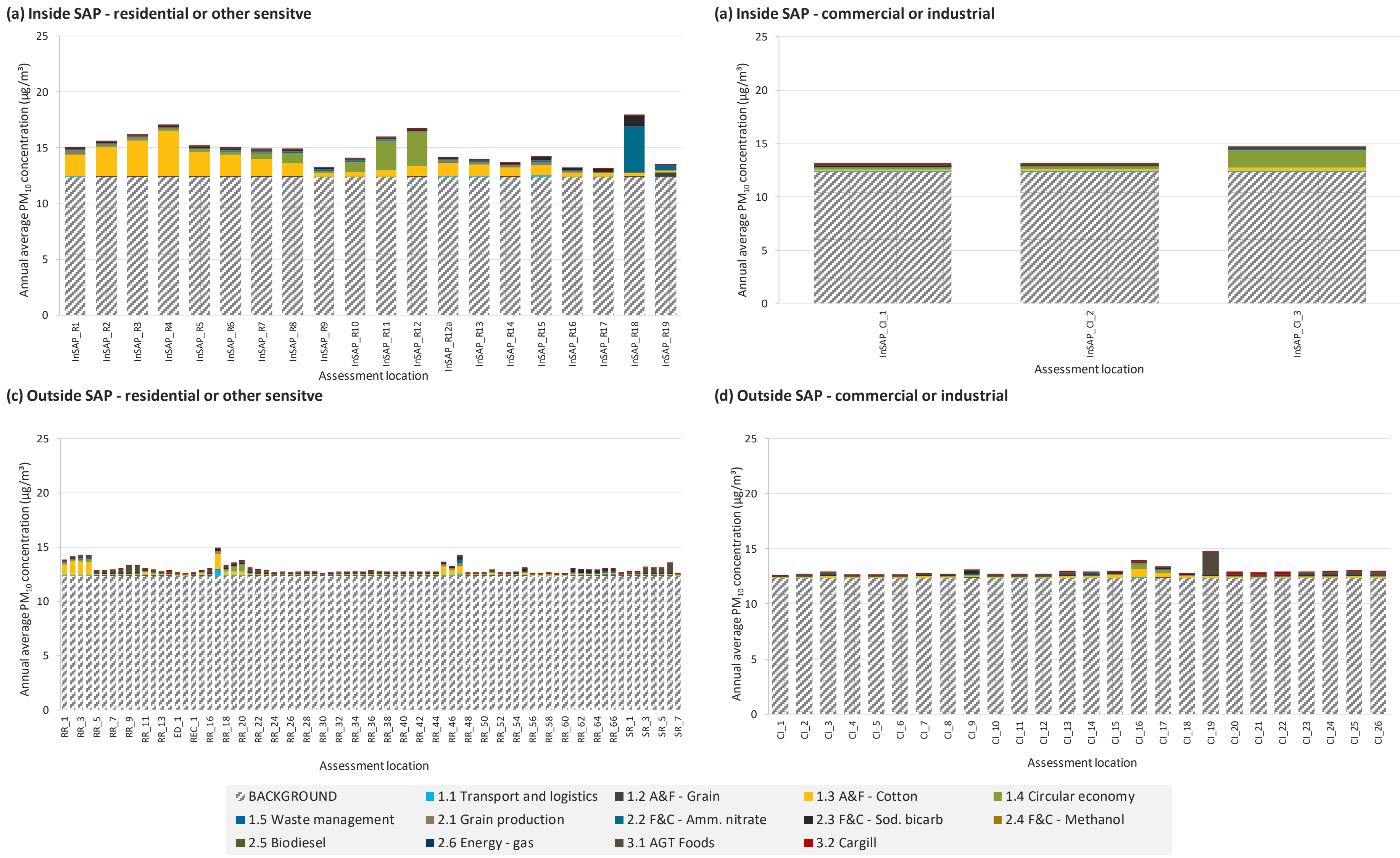


Figure 4.2 **Annual mean PM_{10} concentrations at assessment locations**

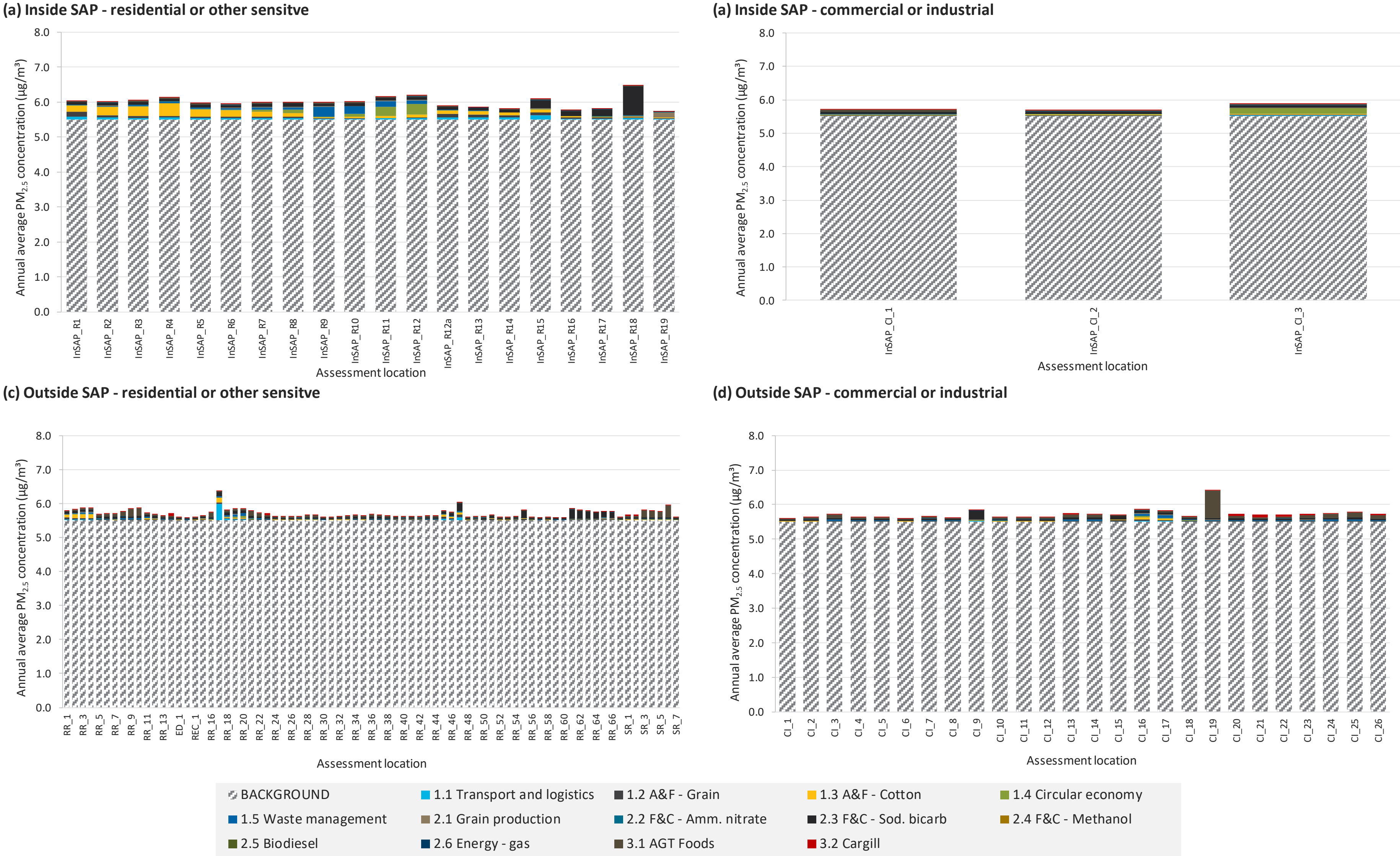


Figure 4.3 Annual mean $PM_{2.5}$ concentrations at assessment locations

ii Odour

As discussed in Section 3.3.2, the applicable odour criteria for sensitive assessment locations **outside the SAP** will vary depending on the location and population size. For individual rural properties, the odour criterion will be 7 odour units (OU) whereas for more densely populated areas like the suburban areas of Narrabri, the odour criterion will be 2 OU. The predicted odour concentrations were below the applicable odour criterion at all locations outside the SAP. The highest odour concentrations outside the SAP occurred at rural residential locations RR_19 and RR_20 (3 OU and 4 OU respectively). These assessment locations are in close proximity to the circular economy area of the SAP, with odour impacts being driven by landfilling sources.

Odour is potentially a significant issue for some receptors **inside the SAP**. The Delivery Plan for the SAP should require early engagement with NSW EPA if an activity in the SAP is likely to require an EPL.

4.1.2 Source contributions

i Air quality

From Figure 4.1 to Figure 4.3, it can be seen that, for each pollutant, the background concentration was the dominant contributor at almost all assessment locations. In the case of NO_X, it accounted for between around 95% and 98% of the total concentration. The exception to this was assessment location RR_17, where the background accounted for 50% of the total concentration. For PM_{10} the background accounted for between 70% and 99% of the total concentration, and for $PM_{2.5}$ it accounted for between 85% and 99%.

In terms of the main contributions (in proportional terms) from activities within the SAP and existing facilities to the total model predictions (excluding background), the results are summarised in Table 4.1.

Table 4.1 Summary of main contributing activities to modelled annual average concentrations

Pollutant	Location	Assessment location group	Main contributing activities
NO_X	Inside SAP	Residence/sensitive	Transport and logistics; methanol
		Commercial/industrial	Transport and logistics
	Outside SAP	Residence/sensitive	Transport and logistics; methanol; Cargill
		Commercial/industrial	Cargill; transport and logistics; methanol
PM_{10}	Inside SAP	Residence/sensitive	Cotton gin; circular economy; ammonium nitrate; sodium bicarbonate
		Commercial/industrial	Circular economy; cotton gin; AGT foods
	Outside SAP	Residence/sensitive	Cotton gin; AGT foods; sodium bicarbonate; circular economy
		Commercial/industrial	AGT foods; cotton gin; Cargill
$PM_{2.5}$	Inside SAP	Residence/sensitive	Cotton gin; sodium bicarbonate; circular economy; waste management and recycling
		Commercial/industrial	Waste management and recycling; circular economy
	Outside SAP	Residence/sensitive	Sodium bicarbonate; AGT foods
		Commercial/industrial	AGT foods; sodium bicarbonate; Cargill

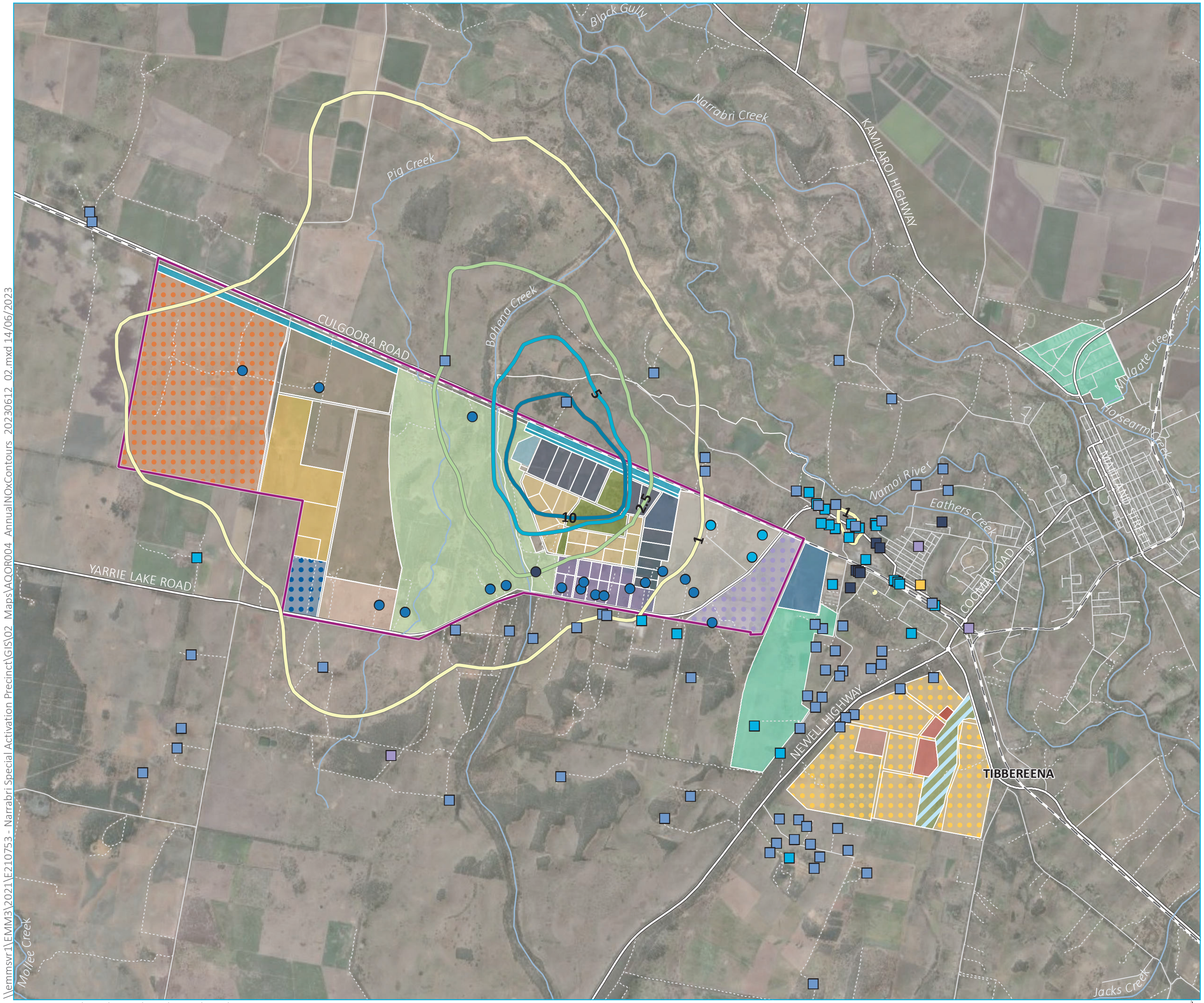
When assessing actual future developments, sensitive locations outside the SAP are likely to be the most relevant. For NO_X, the main activities that contributed to the concentrations at these locations were transport and logistics, methanol production and Cargill. For PM_{10} the activities were the cotton gin, AGT Foods, sodium bicarbonate production and the circular economy land use. For $PM_{2.5}$ the activities were AGT Foods and sodium bicarbonate production.

ii Odour

The main contributions from activities in the SAP (and existing facilities) to the total model predictions for odour are the circular economy and biodiesel plant. Between the two categories, the circular economy area has the most influence on predicted odour concentrations at assessment locations beyond the SAP. However, it is noted that the modelling conservatively assumes that the entire area is associated with landfill operations.

4.2 Contour plots

CALPUFF-predicted concentrations of annual average NO_x, PM_{10} and $PM_{2.5}$ from the modelled SAP activities are presented in Figure 4.4, Figure 4.5 and Figure 4.6 respectively. Predicted 99th percentile 1-second average odour concentrations from the SAP are illustrated in Figure 4.7.



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Source: EMM (2023); DFSI (2017); ESRI (2023)

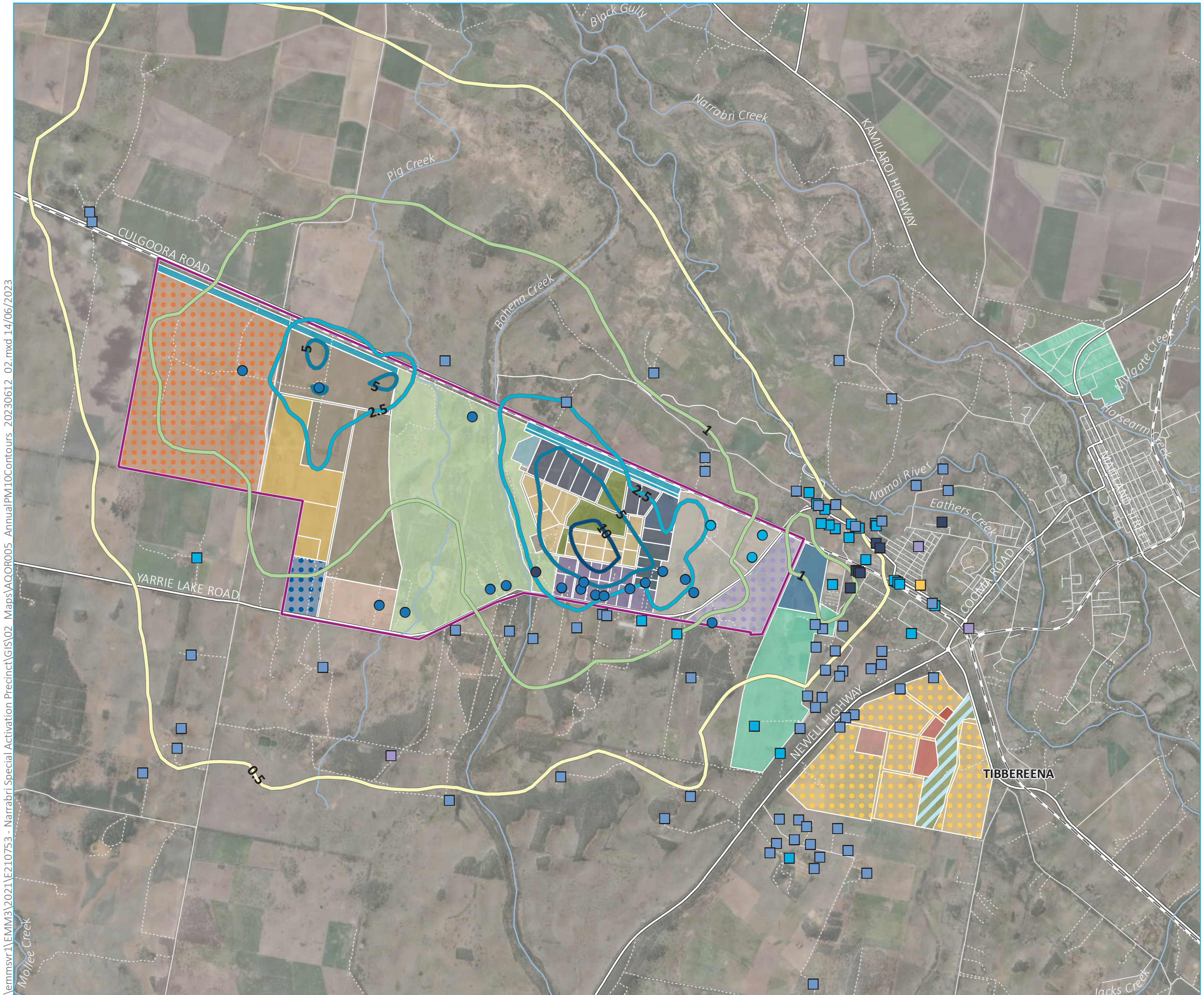
KEY

- Special Activation Precinct
- Annual mean NO_x concentration contour (µg/m³)
  - 1
  - 2.5
  - 5
  - 10
- Assessment location
- Inside SAP
  - Commercial/Industrial
  - Rural Residential
  - Residential
- Outside SAP
  - Commercial/Industrial
  - Rural Residential
  - Suburban Residential
  - School
  - Playground
- Preferred SAP land use
  - Agricultural and food processing area
  - Bohnea Creek conservation area
  - Byproducts
  - Circular economy area
  - Rail siding
  - Energy
  - Fertiliser and chemicals
  - Green corridor
  - High value vegetation to be retained
  - Interim potential hazardous uses area
  - Manufacturing
  - Potential grain area
  - Solar
  - Stormwater basin
  - Transport and logistics area
  - Waste management and recycling area
- Non-SAP land use
  - Rail connection
  - Light industrial
  - Mount Kaputar precinct
  - Indicative health precinct location
  - Indicative neighbourhood centre location
  - Indicative school location
- Existing environment
  - Rail line
  - Major road
  - Minor road
  - Vehicular track
  - Named watercourse

Contour plot for annual mean NO_x concentrations (µg/m³)

Narrabri Special Activation Precinct
Final Air Quality and Odour Report
Figure 4.4

EMM creating opportunities

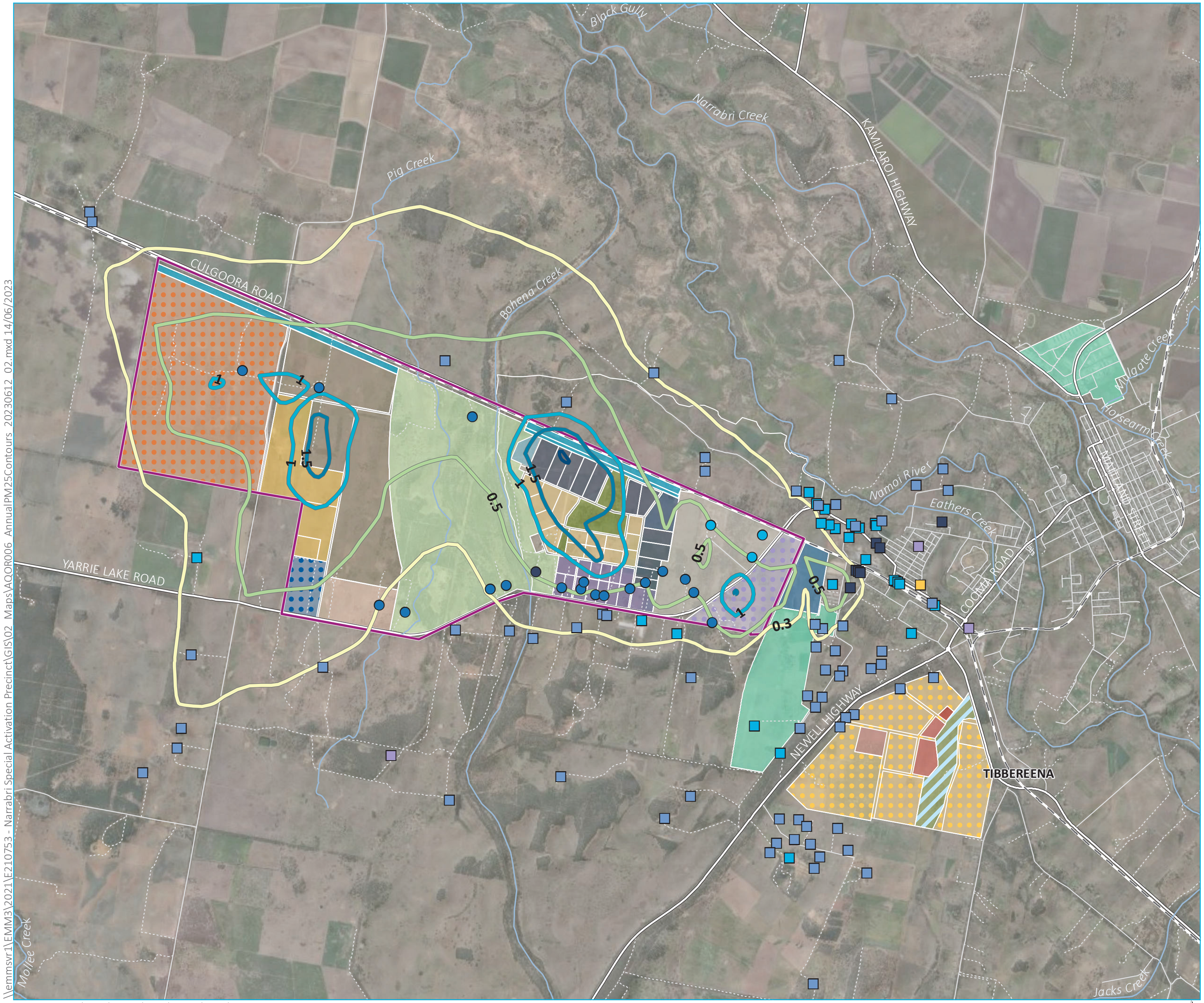


Source: EMM (2023); DFSI (2017); ESRI (2023)

Contour plot for annual mean PM_{10} concentrations (µg/m³)

Narrabri Special Activation Precinct
Final Air Quality and Odour Report
Figure 4.5

EMM creating opportunities



KEY

Special Activation Precinct

Annual $PM_{2.5}$ concentrations (µg/m³)
- 0.3
- 0.5
- 1
- 1.5
- 2.5

Assessment location

Inside SAP
- Commercial/Industrial
- Rural Residential
- Residential

Outside SAP
- Commercial/Industrial
- Rural Residential
- Suburban Residential
- School
- Playground

Preferred SAP land use
- Agricultural and food processing area
- Bohnea Creek conservation area
- Byproducts
- Circular economy area
- Rail siding
- Energy
- Fertiliser and chemicals
- Green corridor
- High value vegetation to be retained
- Interim potential hazardous uses area
- Manufacturing
- Potential grain area
- Solar
- Stormwater basin
- Transport and logistics area
- Waste management and recycling area

Non-SAP land use
- Rail connection
- Light industrial
- Mount Kaputar precinct
- Indicative health precinct location
- Indicative neighbourhood centre location
- Indicative school location

Existing environment
- Rail line
- Major road
- Minor road
- Vehicular track
- Named watercourse

Contour plot for annual mean $PM_{2.5}$ concentrations (µg/m³)

Narrabri Special Activation Precinct
Final Air Quality and Odour Report
Figure 4.6

creating opportunities

\\emmsvr1\EMM3\2021\E210753 - Narrabri Special Activation Precinct\GIS\02_Maps\AQOR006_AnnualPM25Contours_20230612_02.mxd 14/06/2023

Source: EMM (2023); DFSI (2017); ESRI (2023)

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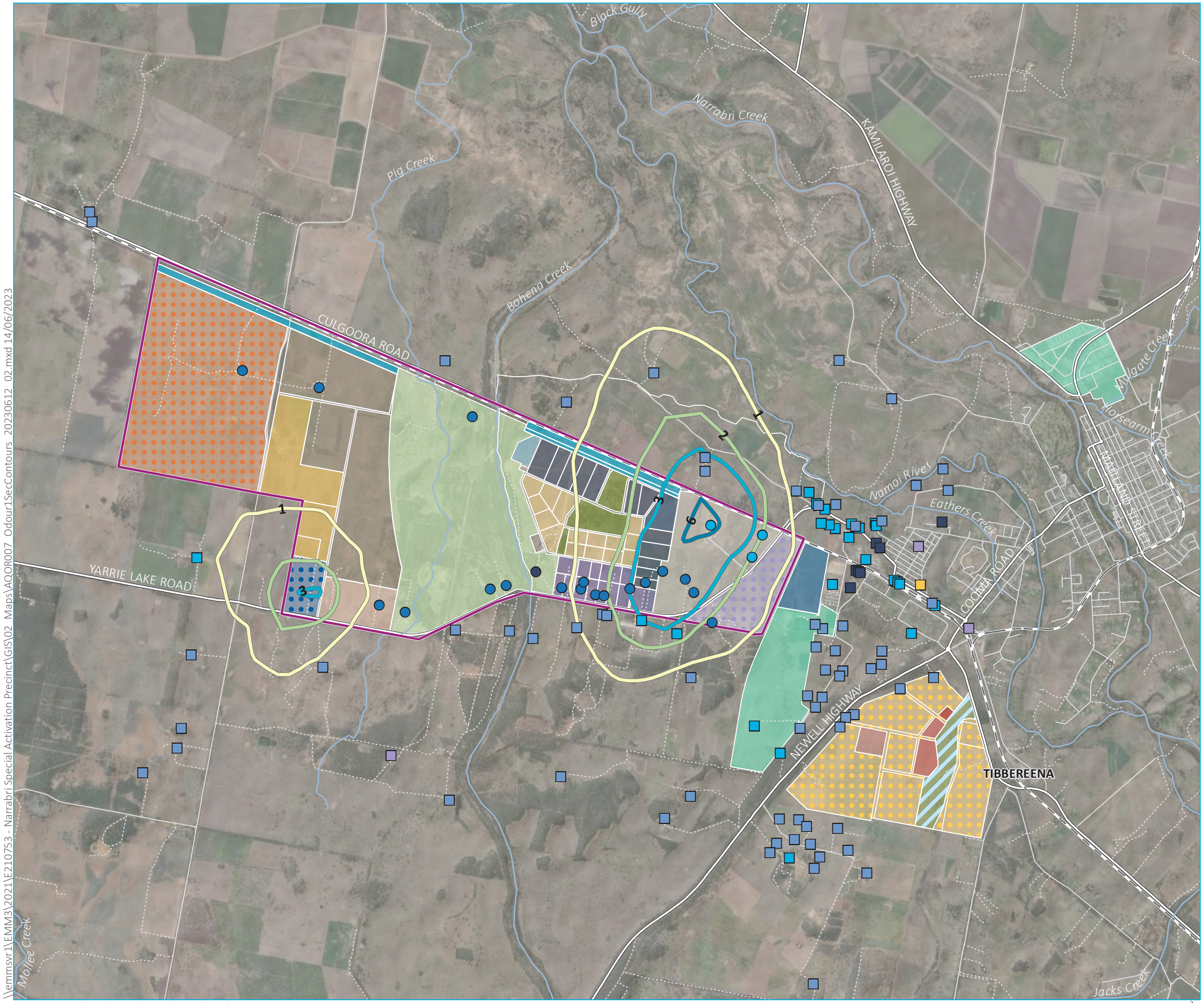

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Source: EMM (2023); DFSI (2017); ESRI (2023)

KEY

Special Activation Precinct

1-second odour concentration contours (odour units)
- 1
- 2
- 3
- 6

Assessment location

Inside SAP
- Commercial/Industrial
- Rural Residential
- Residential

Outside SAP
- Commercial/Industrial
- Rural Residential
- Suburban Residential
- School
- Playground

Preferred SAP land use
- Agricultural and food processing area
- Bohnea Creek conservation area
- Byproducts
- Circular economy area
- Rail siding
- Energy
- Fertiliser and chemicals
- Green corridor
- High value vegetation to be retained
- Interim potential hazardous uses area
- Manufacturing
- Potential grain area
- Solar
- Stormwater basin
- Transport and logistics area
- Waste management and recycling area

Non-SAP land use
- Rail connection
- Light industrial
- Mount Kaputar precinct
- Indicative health precinct location
- Indicative neighbourhood centre location
- Indicative school location

Existing environment
- Rail line
- Major road
- Minor road
- Vehicular track
- Named watercourse

Contour plot for 99th percentile 1-second (nose response) odour concentrations (odour units)

Narrabri Special Activation Precinct
Final Air Quality and Odour Report
Figure 4.7

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5 Conclusions and recommendations

5.1 Conclusions

Air quality and odour were modelled for a single, hypothetical scenario relating to the potential development of the Narrabri SAP. Various proxy facilities were used to characterise emission sources for the land uses in the Structure Plan for the SAP.

The conclusions of this work are summarised below:

Air quality

- For each modelled pollutant (NO_X/NO_2, PM_{10}, $PM_{2.5}$), the total annual mean concentration was generally well below the corresponding air quality impact assessment criterion. This suggests that there is capacity for the development of the SAP based on 'typical' facilities for the land uses in the Structure Plan.
- For each pollutant, the background was the dominant contributor at almost all assessment locations.
- For sensitive locations outside the SAP, the activities that contributed the most to NO_X concentrations were transport and logistics, methanol production and Cargill. For PM_{10} the main activities were the cotton gin, AGT Foods, sodium bicarbonate production and the circular economy land use. For $PM_{2.5}$ the main activities were AGT Foods and sodium bicarbonate production.

Odour

- The main contributions from activities within the SAP (and existing facilities) to the total model predictions for odour are the circular economy and biodiesel plant. Between the two categories, the circular economy area has the most influence on predicted odour concentrations at assessment locations beyond the SAP; however, it is noted that the modelling conservatively assumes that the entire area is associated with landfill operations.
- Predicted odour concentrations are below the applicable odour criterion at all locations outside the SAP.
- Odour is potentially a significant issue for some receptors inside the SAP. The Delivery Plan for the SAP should require early engagement with NSW EPA if an activity in the SAP is likely to require an EPL.
- The assessment locations in close proximity to the circular economy area of the SAP have the greatest potential for odour impacts. Odour impacts are driven by landfilling sources.

5.2 Recommendations

The recommendations of this work are summarised below.

Reassessment as the SAP evolves

The modelling suggests that there are not likely to be any major constraints on development in the SAP in terms of air quality and odour, noting that short-term impacts on air quality have not been considered.

Nevertheless, as the SAP evolves, there will be a need to ensure that each new development that is added complies with any applicable regulations and criteria, and in particular:

- the prescribed discharge concentrations in the Protection of the Environment Operations (Clean Air) Regulation 2012
- the impact assessment criteria in the Approved Methods for Modelling.

As a first approximation of the impacts of new developments, and a potential screening step, the scale of any proposed development can be compared with the corresponding assumptions in this report. However, it is recommended that, as each new major development is proposed for the SAP, the air quality modelling is updated based on detailed design data, and the cumulative impacts on air quality and odour are re-evaluated. This will enable the cumulative impacts of the SAP, and the capacity for further development, to be tracked over time. The procedure for reassessment, including the air quality and odour criteria for developments in the SAP, will be defined in the Master Plan and Delivery Plan.

Management/mitigation of air quality and odour

As a general rule, high-risk developments should be located as far from sensitive receptors as possible, which generally means towards the centre of the Inland Port area or in the Western Extension.

In terms of specific measures, developments within the SAP should follow best practice with respect to the management of air quality and odour[5]. There are some existing commitments in this respect; for example, the ammonium nitrate plant will use low-emissions technology. However, given the current uncertain nature of these developments at present, it is not possible to provide specific guidance on management and mitigation. There are a number of general reference documents that should be considered, such as international examples of best practice (e.g. EU Best Available Techniques reference documents (BREFs)), state and national guidance documents, and industry-prepared management guidance.

Although odour does not appear to be a significant issue for the existing landfill, appropriate odour buffer zones and other avoidance and mitigation strategies should be considered for development within the SAP.

Operational Environmental Management Plan (OEMPs) should outline mitigation measures to manage the air quality impacts associated with specific operations.

Monitoring and reporting

The Master Plan and Delivery Plan will provide procedures for ongoing monitoring of air quality and reporting.

At this stage it is not possible to provide detailed guidance on monitoring, as this would again be dependent on the nature of the specific developments inside the SAP.

[5] Some effects of mitigation measures have been built into the modelling, including those that were assumed in the AQIAs for the proxy facilities.

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Abbreviations

AAQ NEPM	National Environment Protection (Ambient Air Quality) Measure
AHD	Australian Height Datum
AWS	Automatic Weather Station
BoM	Bureau of Meteorology
CO	carbon monoxide
DPE	(NSW) Department of Planning and Environment
EIS	environmental impact statement
EPA	(NSW) Environment Protection Authority
EPL	Environment Protection Licence
NARCliM	NSW and ACT Regional Climate Modelling
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
NPI	National Pollutant Inventory
NSC	Narrabri Shire Council
NSW	New South Wales
O_3	ozone
OU	odour unit
PM	particulate matter
$PM_{2.5}$	particulate matter with an aerodynamic diameter of less than 2.5 µm
PM_{10}	particulate matter with an aerodynamic diameter of less than 10 µm
POEO	Protection of the Environment Operations (Act)
SAP	Special Activation Precinct
TSP	total suspended particulate

Appendix A

Summary of Stage 1 report for air quality and odour

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A.1 Background

The first main stage in the air quality assessment was the characterisation of the baseline conditions in and around the Narrabri SAP, and the findings of the baseline study for air quality and odour were contained in the report by EMM (2021). The findings of the baseline study are summarised here.

This baseline study analysed the existing and potential air quality and odour issues that may arise from within the Narrabri SAP, or be affected by existing uses outside it, to establish an environmental baseline.

The aims of the baseline study for air quality and odour were to:

- identify the policies, regulations and impact assessment criteria for air quality and odour that were applicable to the Narrabri SAP
- identify key sensitive receptor locations and land uses, taking into account future residential land releases
- identify all significant existing and proposed sources of air pollutants, including odour, in and around the Narrabri SAP
- collate all publicly available air quality and meteorological monitoring data from the Narrabri region, identifying trends, key statistics and data gaps
- provide a detailed discussion of background air quality and meteorological conditions
- develop a meteorological dataset suitable for use in an atmospheric dispersion model
- provide recommendations on the existing and future constraints for the Narrabri SAP.

A.2 Land use and terrain

Narrabri is a traditional agricultural community focused on cotton and wheat. Land use change over the past 50 years has seen the intensification of the cotton industry and the expansion of coal mining and coal seam gas exploration in the Shire. Land use is characterised by large and small agricultural producers, research facilities, extractive industry projects, parks of national and state significance, and a rich Aboriginal heritage.

The Narrabri SAP is located within previously cleared agricultural areas. Large areas of native vegetation exist to the south (Pilliga National Park, Jacks Creek State Forest and the Bibblewindi State Forest). To the east/northeast is the Mount Kaputar National Park.

The elevation of Narrabri SAP varies very little, from approximately 215 m Australian Height Datum (AHD) in the northern area to around 230 m AHD in the southern area. Regional topography is also very flat, as shown in the three-dimensional representation in Figure A.1. The elevated ridgeline of Mount Kaputar to the east /northeast is also shown in Figure A.1, rising to an elevation of over 1,000 m AHD and playing an important role in regional wind patterns.

Figure A.1 Three-dimensional representation of regional topography

A.3 Climate and meteorology

A.3.1 Introduction

Meteorological mechanisms influence the generation, dispersion, transformation and eventual removal of pollutants from the atmosphere. To adequately characterise the dispersion of air pollutant emissions, information is needed on the prevailing wind regime, ambient temperature, rainfall, relative humidity, mixing depth, and atmospheric stability.

A.3.2 Monitoring stations

The analysis of climate and meteorology for the area was based on the following monitoring sites:

- the Bureau of Meteorology (BoM) automatic weather station (AWS) at Narrabri Airport, located approximately 8 km north-east of the Narrabri SAP boundary
- the DPE Narrabri air quality monitoring station (AQMS), also located at Narrabri Airport, approximately 8 km north-east of the Narrabri SAP boundary
- the BoM long-term temperature station at Narrabri West, approximately 800 m to the east of the Narrabri SAP boundary
- the BoM long-term rainfall station at Mollee, approximately 6 km to the north of the Narrabri SAP boundary.

The locations of these monitoring sites, in relation to the Narrabri SAP, are presented in Figure 3.1.

A.3.3 Historical climate

i Temperature

Temperature has been measured at the Narrabri Airport site since 2001. A longer historical time series of temperature was available for the BoM station at Narrabri West Post Office, around 800 m to the east of the Narrabri SAP boundary. Although the Narrabri West site closed in 2002, measurements are available for download dating back to 1962.

Figure A.2 shows the annual mean maximum and minimum temperatures at the two stations. The values are calculated from the monthly mean maximum and minimum temperatures. The record shows a gradual increase in temperature with time. The increases at Narrabri Airport are around 0.4°C per decade for the minimum, and 0.5°C per decade for the maximum, whereas at Narrabri West they are around 0.3°C per decade for the minimum, and 0.4°C per decade for the maximum.

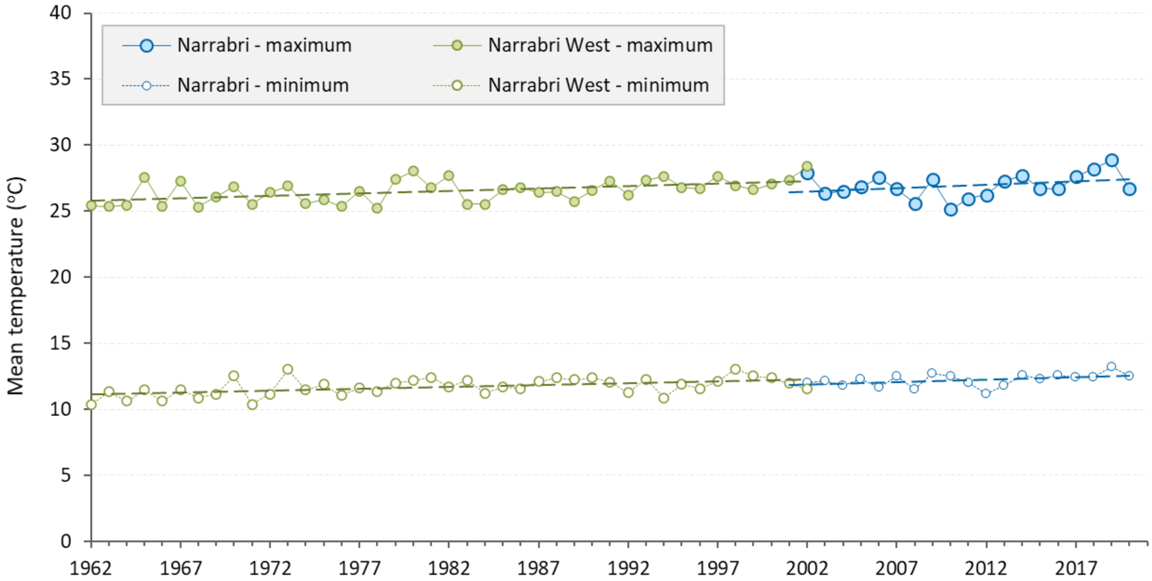


Figure A.2 Historical temperature data for the BoM stations at Narrabri Airport and Narrabri West

Table A.1 shows the average temperature statistics for each month at Narrabri Airport. The region experiences hot summers, with a mean maximum temperature in the summer months of 33–35°C. Winters are cool, with a mean minimum temperature of 4–6°C. The temperature extremes are also presented in the table. The highest and lowest temperatures on record were 47.8°C and -6°C.

Table A.1 Temperature statistics, BoM Narrabri Airport AWS (2001-2021)

Statistic	Temperature (°C)												
	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum	34.9	33.6	30.9	26.9	22.4	18.5	18.1	20.1	24.2	28.3	31.3	33.2	26.9
Highest	47.8	46.5	40	34.8	29.7	26	26.5	31.7	34.9	40.8	44	44.4	47.8
Mean minimum	20.5	19.5	16.7	12.3	7.4	5.8	4.1	4.6	8.1	12.3	16.1	18.6	12.2
Lowest	8.4	9.2	4.1	0.3	-3	-4.6	-6	-3.6	-1.2	2.1	4.3	6.9	-6

ii Rainfall

Rainfall has been measured at Narrabri Airport AWS since 2001. A much longer historical time series of rainfall data, dating back to 1926, is available for the BoM station at Mollee, 6 km to the north of the SAP boundary.

Figure A.3 shows the annual total rainfall at the two stations. The long-term record from Mollee shows that there has been no strong upward or downward trend in rainfall. The Mollee area receives, on average, approximately 600 mm per year. The average annual rainfall at Narrabri is slightly lower (around 550 mm).

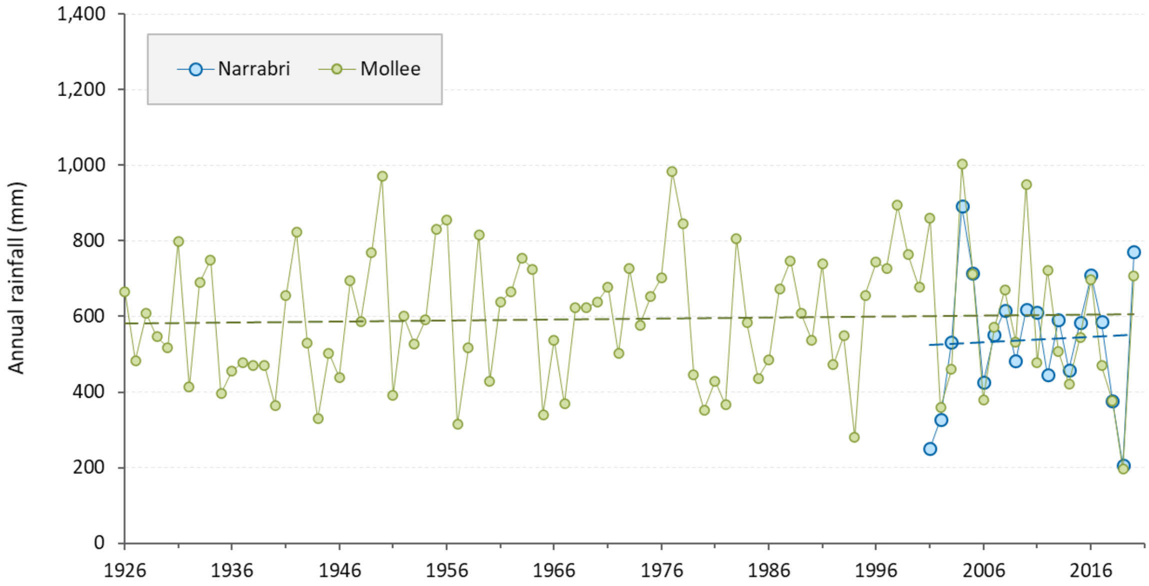


Figure A.3 Historical rainfall data for the BoM stations at Narrabri Airport and Mollee

Table A.2 shows the average rainfall statistics for each month at Narrabri Airport. Rainfall is generally highest in summer, with December being the wettest month. Rainfall is usually lowest in winter, with May and July being the driest month, although there is a peak in June.

Table A.2 Rainfall statistics, BoM Narrabri Airport AWS (2001-2021)

Statistic	Rainfall (mm)												
	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	67.3	62.6	64.3	27.4	25.2	51.1	29.9	29.7	31.5	39.2	67.7	69.7	552.7
Highest	196	176.6	192.8	107	57.4	186.4	74.6	102.8	123.4	88.2	200	247.4	891.4
Lowest	5	3.2	2.2	0	0	0.6	0.6	1	0.2	3.6	7	6.8	206.2
Highest daily	100.4	72.8	78.6	60.6	32	58	30.6	40.4	41.4	43.2	73.6	125.2	125.2

A.3.4 Future climate

i Introduction

A climate change adaptation report has been prepared for the Narrabri SAP, providing a high-level overview of potential climate change risks and adaptation measures across the investigation area (Umwelt 2021). Climate change projections reported in Umwelt (2021) are based on a regional snapshot for New England North West region, prepared by AdaptNSW[6]. The regional climate change projections include:

- an increase in average and extreme temperature events
- an increase in number of hot day (above 35°C)
- an increase in rainfall during autumn
- an increase in bushfire risk and intensity
- a decrease in rainfall during winter
- a decrease in number of cold night (below 2°C).

Climate effects, such as El Niño Southern Oscillation (ENSO), and longer-term climate change may influence the ambient background air quality. For example, variations in annual rainfall related to ENSO cycles may influence background PM_{10} concentrations in rural areas of NSW, while future climate change (higher temperatures, reduced rainfall, increased bushfire risk) can also influence background PM_{10}, $PM_{2.5}$ concentrations.

For the purposes of this report, climate change projections for mean temperature and accumulated rainfall are presented, to provide some context around how the future ambient background air quality may be affected.

Climate change projections for Narrabri were obtained from the NSW and ACT Regional Climate Modelling (NARCliM) project[7], extracted for an area representative of the Narrabri SAP. These data are a subset of the data used in the regional snapshots and are consistent with the projections reported in Umwelt (2021), both in terms of magnitude and the direction of change.

ii Projected changes in temperature and rainfall

NARCliM provides data for twelve different regional climate projections, based on four global climate models (GCMs) which are downscaled using three different regional climate models (RCMs). The GCMs are based on the phase 3 of the Coupled Model Intercomparison Project (CMIP) which informed the IPCC Fourth Assessment Report (AR4, published in 2007)[8]. All models were run for the same representative emissions scenario (the IPCC high emission scenario known as A2), which, at the time, was considered the most likely emission trajectory scenario. NARCliM climate projections are available for south-east Australia at a fine resolution (10 km and hourly intervals). Data are available for three distinct 20-year periods; baseline (1990–2009), near future (2020–2039) and far future (2060–2079).

Each of the different models will produce a range of different projections or outcomes. To reduce the bias and uncertainty from looking at a single model prediction, the approach for this analysis is to combined data from the 12 regional climate models to produce a 'model ensemble average'. The projected mean monthly temperature for the baseline, near future and far future scenarios is presented in Figure A.4.

6 https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW

7 https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM

8 Climate projections in the IPCC Fifth Assessment Report (AR5, published in 2013) are based mainly on the fifth phase of CMIP but were not available for this version of NARCliM.

There is a consistent increase in monthly mean temperature projected for both the near future and far future scenarios. On an annual basis, mean monthly temperatures are projected to increase by 0.7°C in the near future and by 2.2°C in the far future and the magnitude of change is similar across all seasons (see Figure A.5).

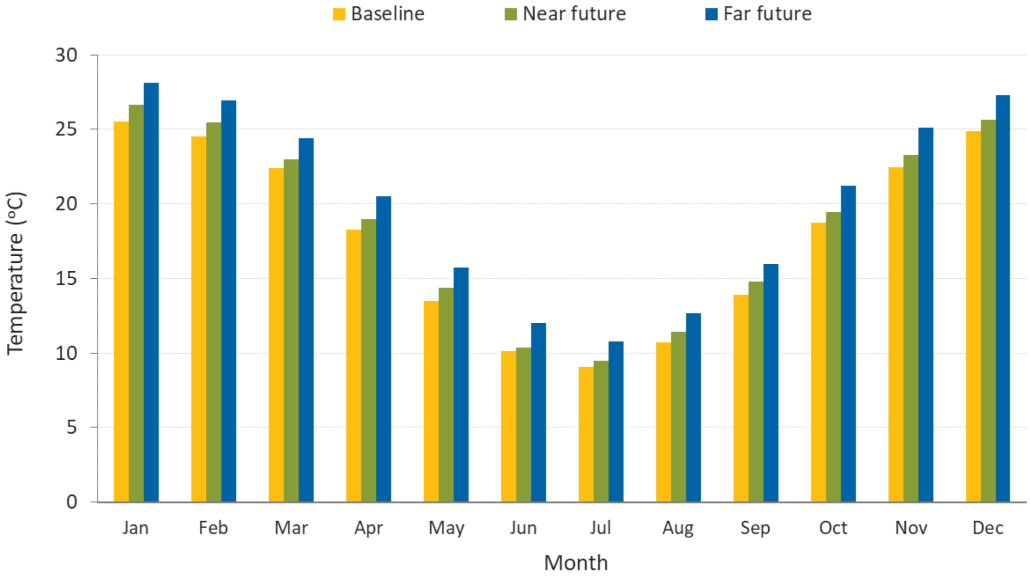


Figure A.4 Projected monthly mean temperature

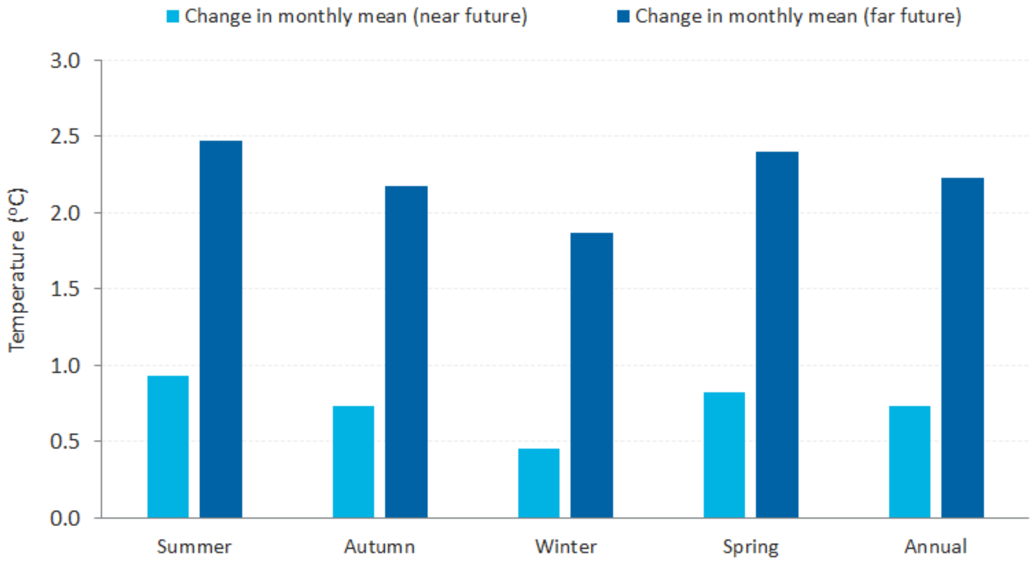


Figure A.5 Projected change in mean temperature by season

The projected seasonal and annual changes in rainfall for the near future and far future are shown in Figure A.6, based on a model ensemble average for a single point in the vicinity of the project. The percentage change is expressed relative to the modelled baseline period (1990–2009). On an annual basis, rainfall is projected to increase slightly (1.3%) in the near future and increase more substantially (10%) in the far future. In summer and winter, rainfall is projected to decrease in the near future and increase in the far future. The changes in spring are relatively small, but there are marked increases in autumn for both scenarios.

On the basis of the information presented above, it is reasonable to assume that the trends beyond the far future scenario would continue beyond 2079.

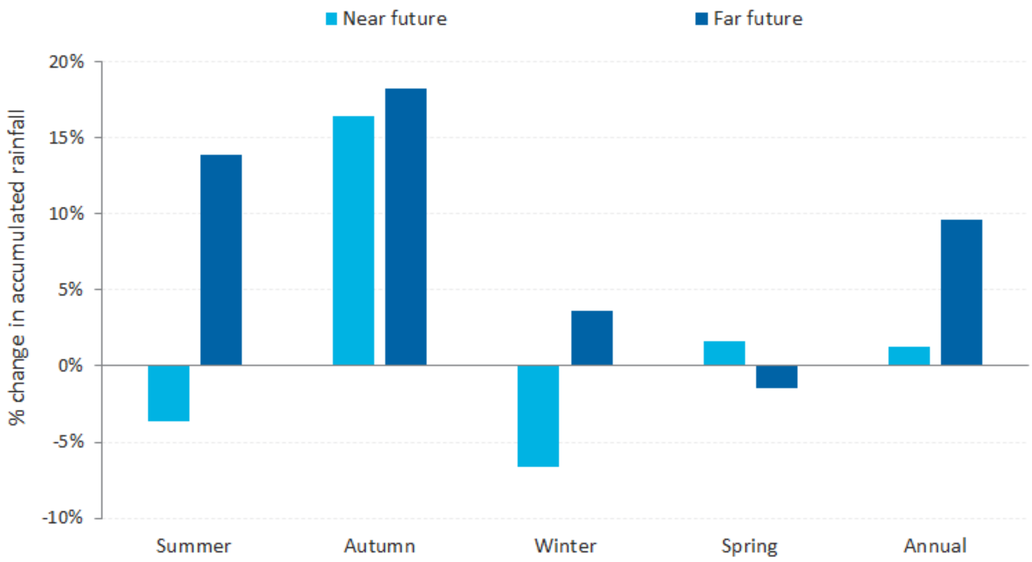


Figure A.6 Projected change in accumulated rainfall for near and far future

A.3.5 Dispersion meteorology

i Overview

The closest BoM monitoring site to the SAP was the AWS at Narrabri Airport (see Table A.3). An analysis of the data from the Narrabri Airport AWS was used to select a representative site year for meteorological data in the atmospheric dispersion modelling. The monitoring station has been operational since 2001, and data for the five-year period between 2016 and 2021 were analysed for the assessment. Data availability for all parameters and all years was very high, at between 98.3% and 99.9%.

Table A.3 Meteorological monitoring station

Item	Description
Station name	Narrabri Airport AWS
BoM site number	054038
Location	Lat: -30.3154 ; Long: 149.8302
Elevation (m, AHD)	229
Distance from project (km)	11.5
Start of operation	2001
Monitoring period included in assessment	2016 to 2020
Parameters measured	Temperature, relative humidity, pressure, wind speed, wind direction, sigma theta, rainfall, cloud height, visibility.

ii Between-year comparison

Inter-annual diurnal profiles for wind speed, wind direction, temperature and relative humidity are shown as box-and-whisker plots in Figure A.7 to Figure A.10. For each data series, the box is bounded on the top by the third quartile, and on the bottom by the first quartile. The median is represented by a horizontal line through the box. The whiskers (vertical lines) extend from the ends of the box to the minimum and maximum values. The profiles were generally very similar from year to year.

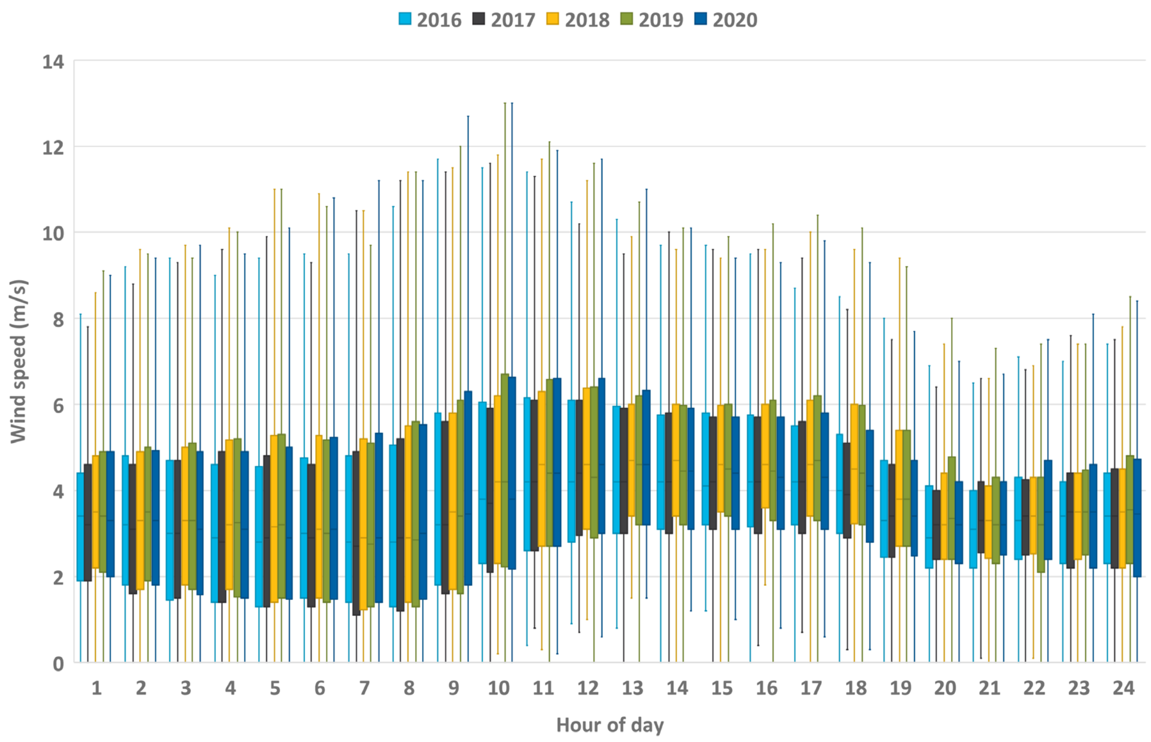


Figure A.7 Inter-annual variability in diurnal wind speed (BoM Narrabri Airport AWS, 2016-2020)

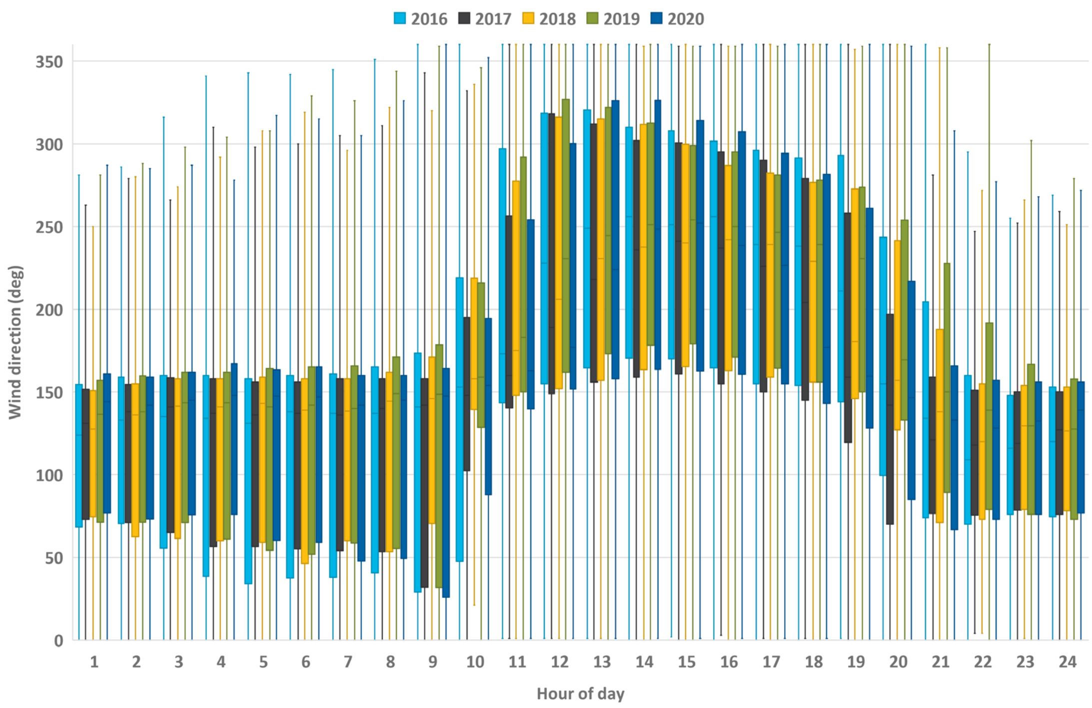


Figure A.8 Inter-annual variability in diurnal wind direction (BoM Narrabri Airport AWS, 2016-2020)

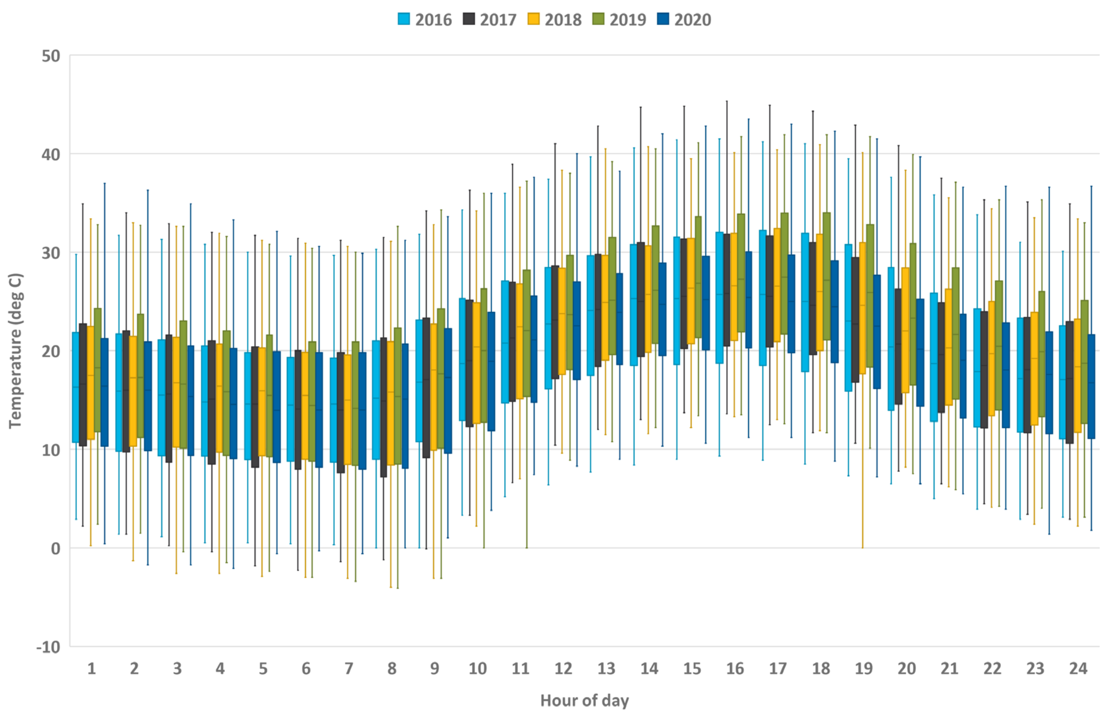


Figure A.9 Inter-annual variability in diurnal temperature (BoM Narrabri Airport AWS, 2016-2020)

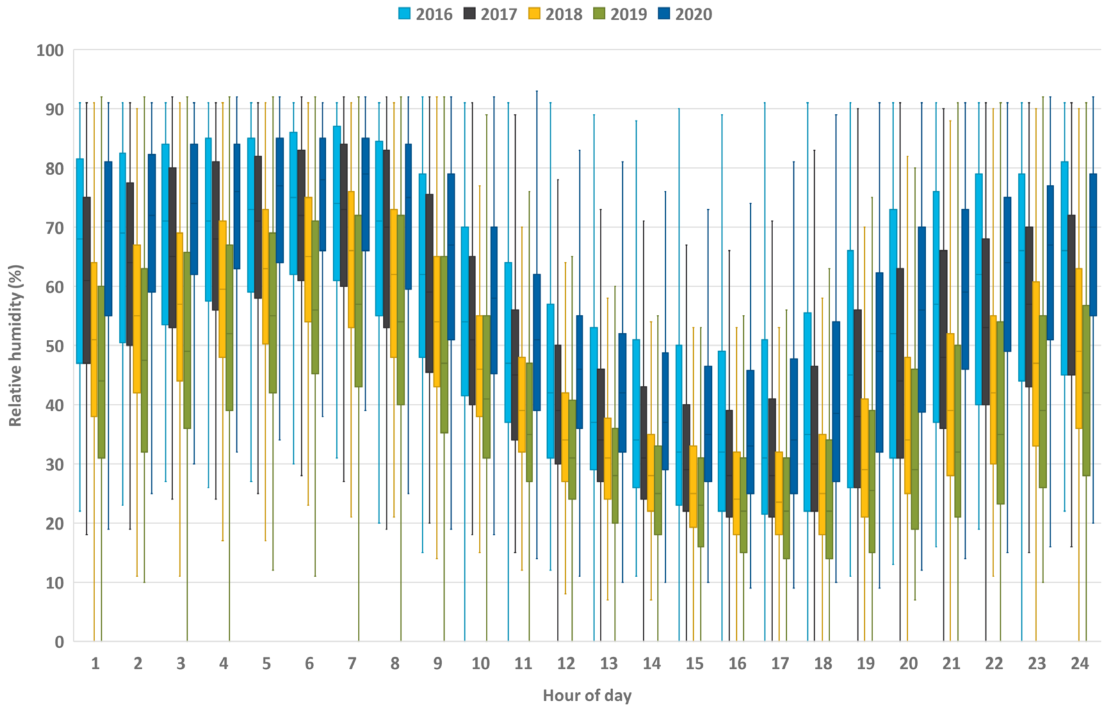


Figure A.10 Inter-annual variability in diurnal relative humidity (BoM Narrabri Airport AWS, 2016-2020)

iii Wind speed and direction

Annual wind roses at the BoM Narrabri Airport AWS – created from the wind speed and wind direction data – are presented in Figure A.11. There was a high degree of consistency in wind direction, average wind speed, and percentage occurrence of calm winds (defined as wind speeds <= 0.5 m/s) across the five-year period. The prevailing winds in all years were from the south-eastern quadrant, with a smaller percentage of winds from the north. Annual average wind speeds ranged between 3.8 m/s and 4.1 m/s. The annual average frequency of calm conditions ranged between 3.2% and 3.8%.

Seasonal wind roses (averaged across all years) are shown in Figure A.12. The mean seasonal wind speed ranged from 3.4 m/s in winter to 4.5 m/s in summer. The seasonal average percentage of calm conditions ranged from 1.2% in summer to 5.9% in winter. The wind patterns in all four seasons were similar, with winds from the south-eastern quadrant being the most common. The main seasonal difference was that northerly winds were more common in spring and summer than in autumn and winter.

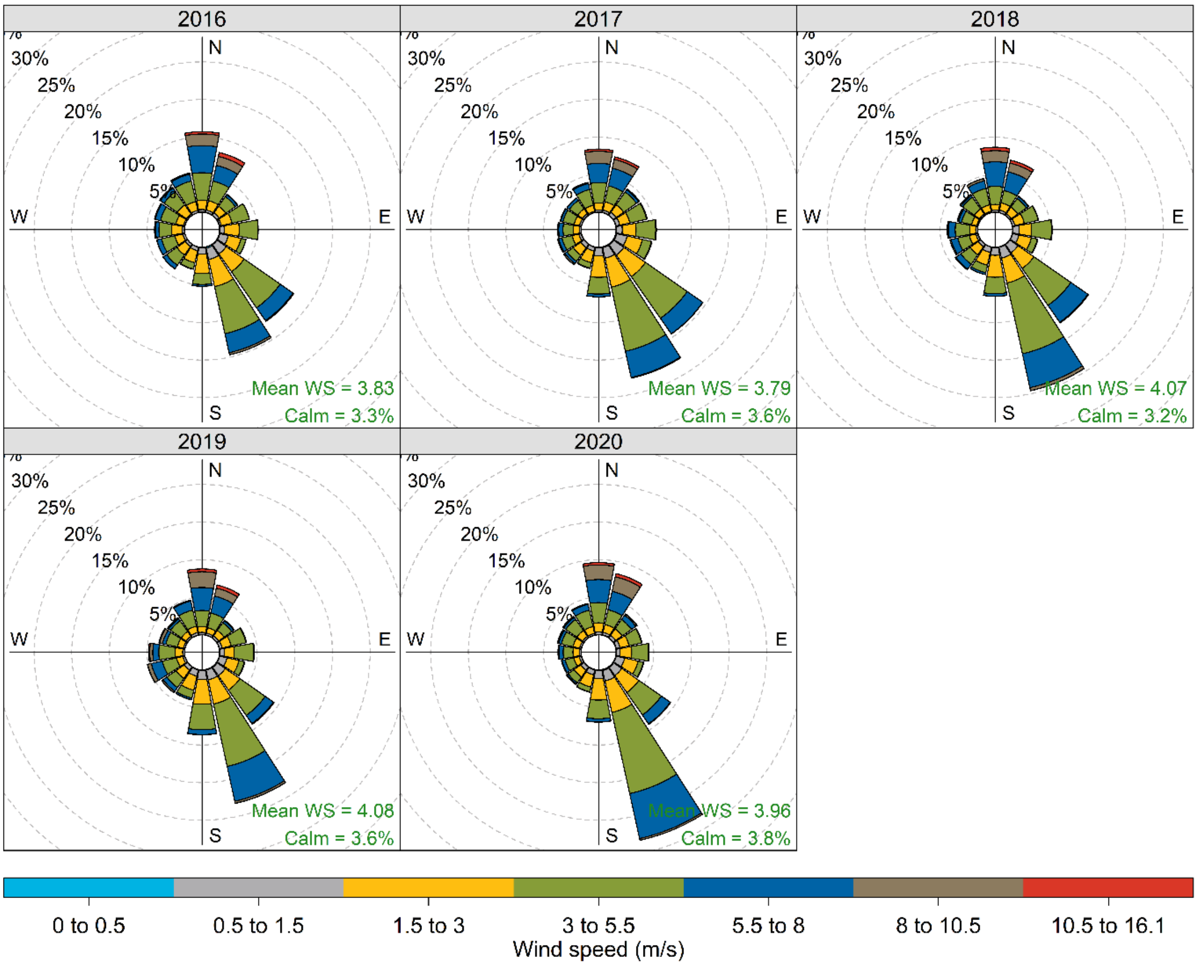


Figure A.11 Annual wind roses (BoM Narrabri Airport AWS, 2016–2020)

Wind roses for each hour of the day (averaged across all years) are shown in Figure A.13. From midnight to 8:00 am (hours 00 to 07), the winds were mostly from the south-east quadrant, with an increasing north-north-easterly component. Between 8:00 am and 1:00 pm (hours 08 to 12), the winds were mainly from the south-east and the north. In the afternoon (hours 13 to 18), winds from the south-south-east remained prominent. The SAP will be located to the west of the Narrabri population. The proportion of the year when winds were blowing from the west to towards the population was quite low overall. However, westerly winds did occur in the afternoon, peaking in frequency between around 3:00 pm and 5:00 pm. From 7:00 pm to midnight the winds from the south-east quadrant became increasingly dominant.

The highest wind speeds typically occurred in the mid-late morning. The average wind speed overnight was around 3.5 m/s and peaked at 4.8 m/s around mid-day. The proportion of calm winds during the night peaked at around 9%, whereas during the day it was much lower, and close to 0% between 10:00 am and 5:00 pm.

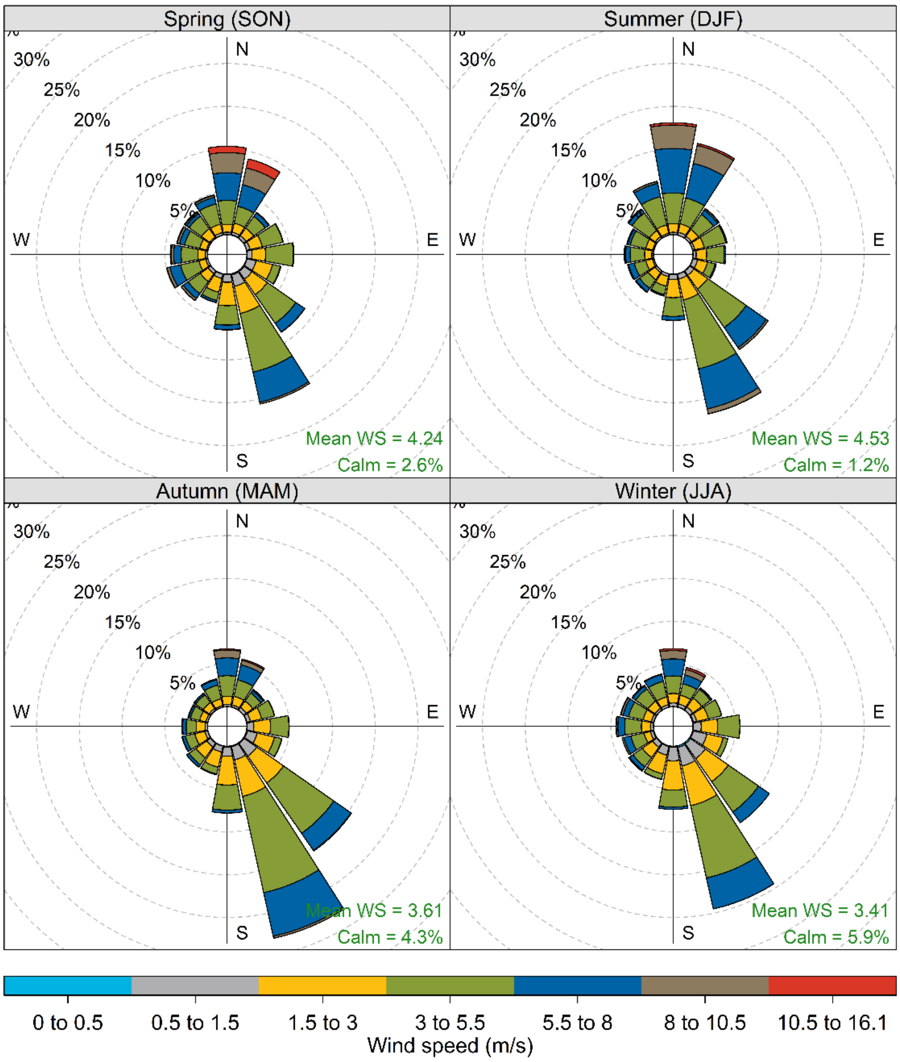


Figure A.12 Seasonal wind roses (BoM Narrabri Airport AWS, 2016-2020)

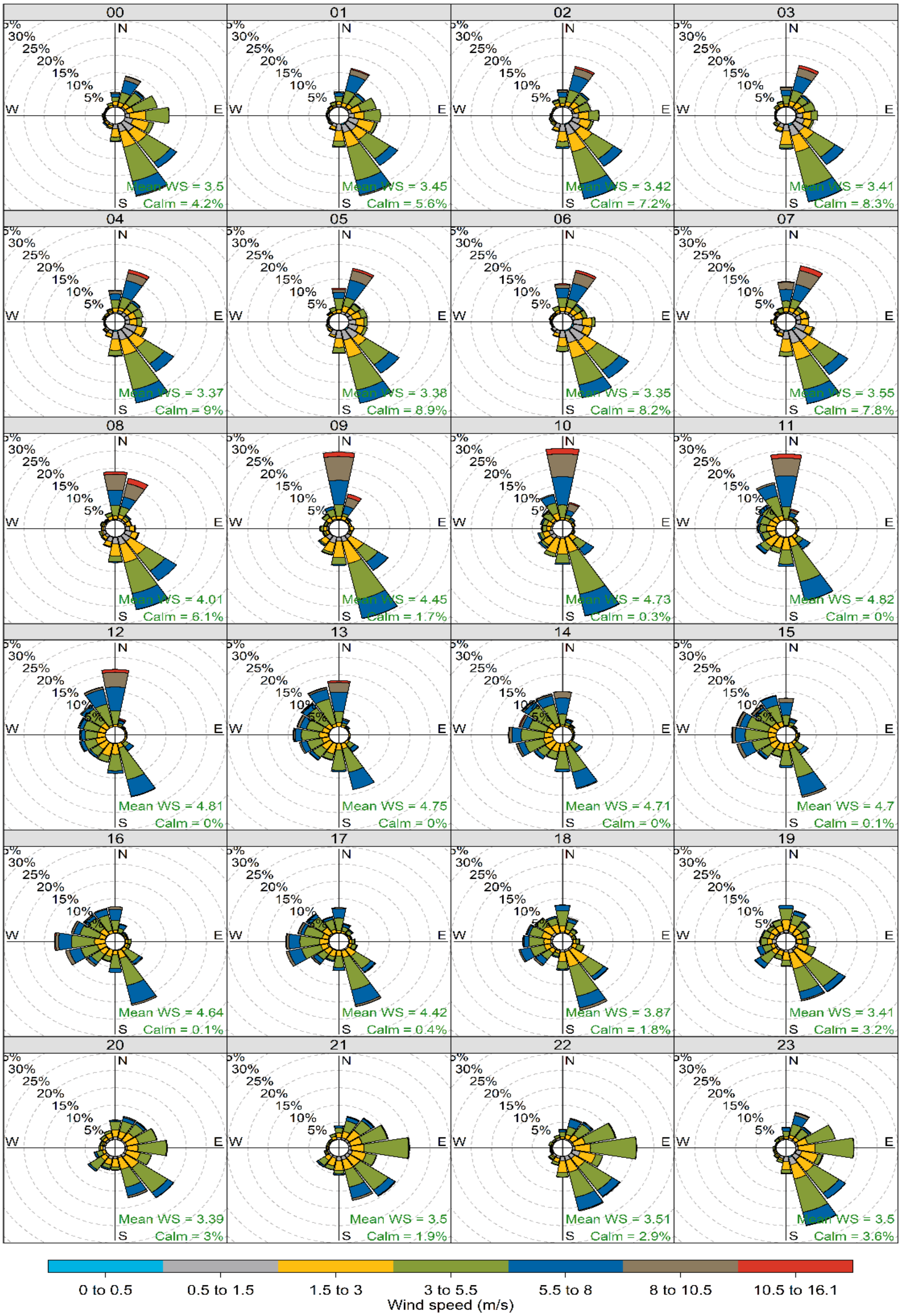


Figure A.13 Wind roses by hour of the day (BoM Narrabri Airport AWS, 2016-2020)

iv Comparison with DPE monitoring station

Meteorological parameters are also measured at DPE's air quality monitoring station in Narrabri. The characteristics of this monitoring station are summarised in Section A.4.1. The DPE station is located very close to the BoM station, being around 350 m to the south, and unsurprisingly the wind patterns at both stations are very similar. For example, the seasonal wind roses for the DPE station in Figure A.14 closely match the patterns seen in the corresponding wind roses for the BoM station (Figure A.12), especially given that the DPE data are for 2018–2020 and the BoM data are for 2016–2020.

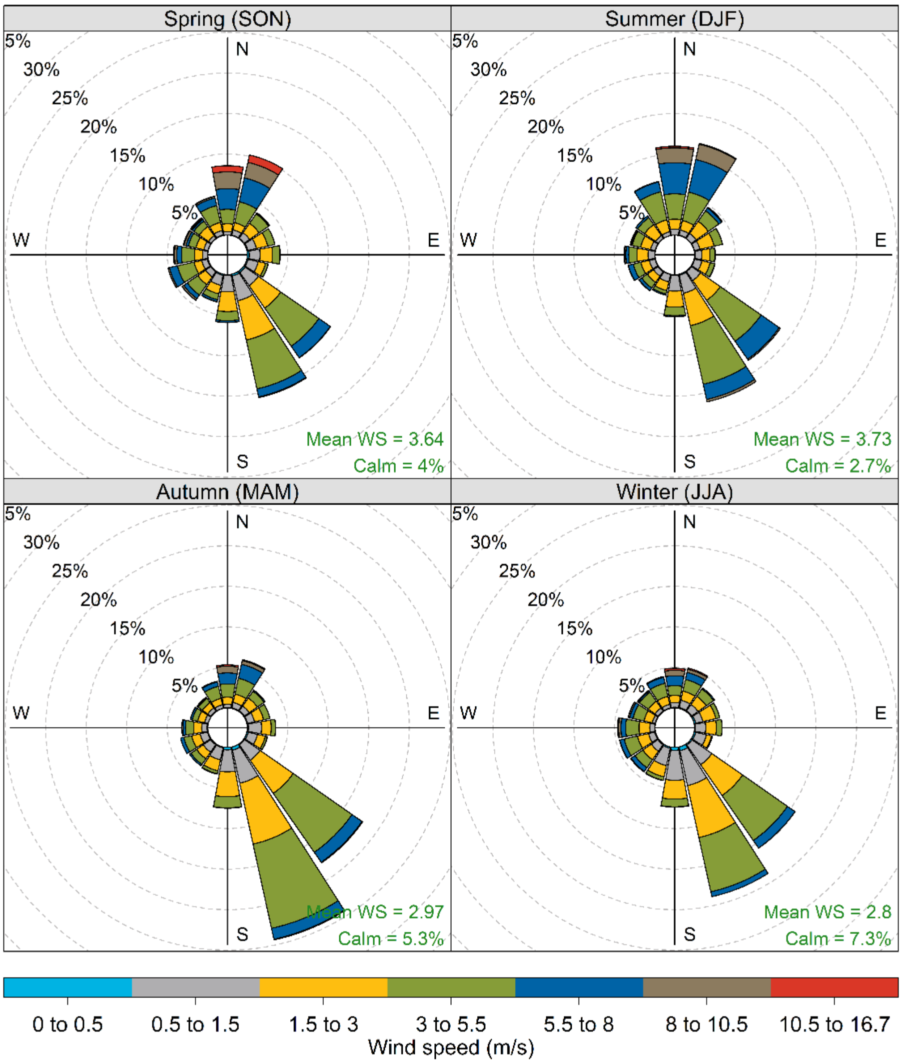


Figure A.14 Seasonal wind roses (DPE Narrabri, 2018-2020)

The main findings of the analysis were as follows:

- There was a high degree of consistency between years in terms of the most important parameters for pollutant dispersion: wind direction, wind speed and the occurrence of calm winds.
- The wind patterns in all four seasons were similar, with winds from the south-east quadrant being the most common. The main seasonal difference was that northerly winds were more common in spring and summer than in autumn and winter.

- The SAP will be located to the west of the Narrabri population. Westerly winds, which would transport emissions from the SAP to towards the population, were relatively infrequent overall. However, westerly winds did occur in the afternoon.
- The highest wind speeds typically occur in the mid-late morning. The average wind speed overnight is around 3.5 m/s, and peaks at 4.8 m/s around mid-day. The proportion of calm winds during the night peaked at around 9%, whereas for most of the day it was close to 0%.

v Selection of representative data

Given the between-year consistency, any of the years between 2016 and 2020 would have been suitable for use in the assessment. The 2020 dataset was the most recent complete calendar year and was considered to be representative of the project area in the long-term.

The data capture rate is excellent for 2020 (greater than 99.6% for key parameters). Consequently, the 2020 calendar year was adopted as the 12-month period for the purpose of meteorological modelling.

A.3.6 Meteorological modelling

i Overview

The atmospheric dispersion modelling used the CALMET/CALPUFF model.

Surface observations from the Narrabri Airport AWS were included in the modelling (referred to as data assimilation) to provide real-world observations and improve the accuracy of the wind field. The distance at which the observation influences the model (radius of influence (ROI)) is determined by the CALMET setting 'RMAX'. The relative importance of the observation in the model (relative weighting of the Step 1 wind field and the observation) is determined by the CALMET setting 'R1'. A relatively large RMAX of 12 km and R1 of 10 km is assigned in the model, selected due to relatively flat terrain for the area and to give equal weight to the observations at Narrabri Airport.

CALMET was used to produce three-dimensional meteorological fields for use in the CALPUFF model. In the absence of upper air measurements, CALMET was run using prognostic upper air data (as a three-dimensional '3D.dat' file), which was used to derive an initial wind field (known as the Step 1 wind field in the CALMET model). The model then incorporated mesoscale and local scale effects, including surface observations, to adjust the wind field. This modelling approach is known as the 'hybrid' approach (TRC 2011) and was adopted for this assessment.

The Commonwealth Scientific and Industry Research Organisation (CSIRO) prognostic meteorological model TAPM was used to generate gridded upper air data for each hour of the model run period, for input into CALMET. TAPM configuration and settings is presented in Table A.4.

The CALMET model settings are presented in Table A.5.

CALMET and CALPUFF model options are presented in Table A.6, selected in accordance with recommendations in the Approved Methods for Modelling and TRC (2011).

Table A.4 TAPM settings

Parameter	Setting
Model Version	TAPM v.4.0.5
Number of grids (spacing)	3 (30 km, 10 km, 3 km)
Number of grid points	25 x 25
Vertical grids / vertical extent	25 / 8,000 m (~400 mb)
Centre of analysis	Lat -30.3333, long 149.7167 Easting 761026, Northing 6640798
Year of analysis	2020
Terrain and land use	Default TAPM values based on land-use and soils data sets from Geoscience Australia and the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC)
Assimilation sites	Narrabri BoM

Table A.5 CALMET settings

Parameter	Setting
Grid domain	85 km x 85 km
Grid resolution	0.5 km
Number of grid points	170 x 170
Reference grid coordinate	717.500, 6597.500
Vertical grids / vertical extent	10 cell heights / 4,000 m
Upper air meteorology	Prognostic 3D.dat extracted from TAPM at 3 km grid
Surface observations	Narrabri BoM

Table A.6 CALMET model options

Flag	Description	Recommended setting	Value used
NOOBS	Meteorological data options	0,1,2	1 - combination of surface and prognostic data
ICLOUD	Cloud Data Options – Gridded Cloud Fields	4	4 -Gridded cloud cover from Prognostic relative humidity at all levels (MM5toGrads algorithm)
IEXTRP	Extrapolate surface wind observations to upper layers	-4	-4 - similarity theory used
IFRADJ	Compute Froude number adjustment effects	1	1 - applied
IKINE	Compute kinematic effects	0	0 - not computed

Table A.6 CALMET model options

Flag	Description	Recommended setting	Value used
BIAS (NZ)	Relative weight given to vertically extrapolated surface observations vs. upper air data	NZ * 0	-1.0,-0.5, 0, 0, 0, 0, 0, 0, 0, 0
TERRAD	Radius of influence of terrain	No default (typically 5- 15 km)	15 km
RMAX1 and RMAX2	Maximum radius of influence over land for observations in layer 1 and aloft	No Default	12 km, 12 km
R1 and R2	Distance from observations in layer 1 and aloft at which observations and Step 1 wind fields are weighted equally	No Default	R1 – 10 km, R2 – 10 km

ii CALMET predicted winds for the investigation area

Evaluation of model performance is typically assessed by comparing model predictions with observations at sites not included as observations in the modelling. In this case, observations at the Narrabri Airport AWS (BoM) site were included and observations at the Narrabri DPE AQMS were excluded. While this would typically make the Narrabri DPE AQMS a suitable site for model evaluation, it is noted that this site is located very close to the Narrabri Airport AWS and records very similar winds to the Narrabri Airport AWS. Due to the selected ROI applied in the modelling, the model is strongly biased to observations at Narrabri Airport AWS (and thus Narrabri DPE AQMS); therefore, the modelling effectively includes Narrabri DPE AQMS as a de facto observation.

To review model performance, a wind rose is extracted from CALMET at the Narrabri SAP site and compared with the observations at Narrabri Airport (BoM) and the Narrabri DPE AQMS (see Figure A.15). As shown, the wind directions, mean wind speed and frequency of calm winds are reflected well in the modelled outputs at the Narrabri SAP. This is the intended outcome in selecting an ROI that gives equal weight to the observations from Narrabri Airport AWS at the location of the Narrabri SAP.

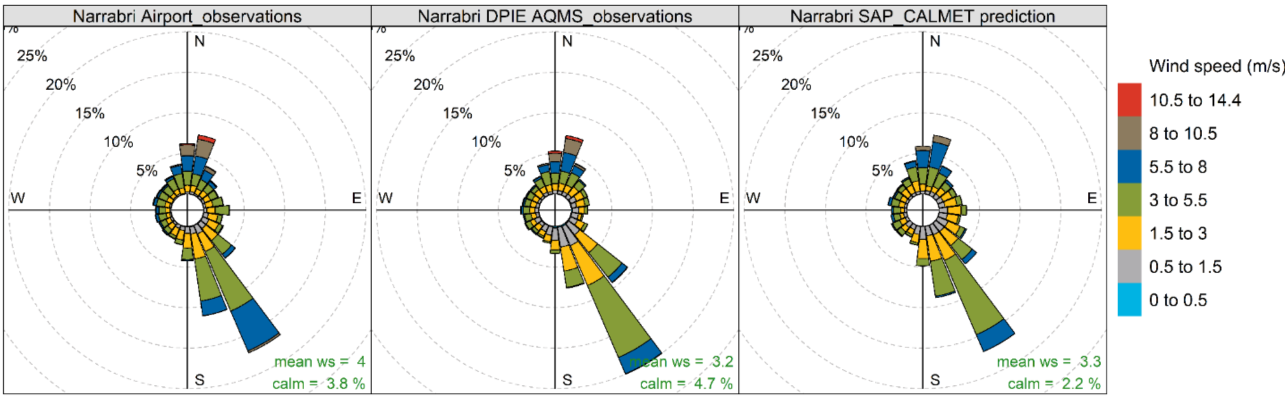


Figure A.15 Wind roses comparing observations with CALMET model predictions for the Narrabri SAP

iii Atmospheric stability and boundary layer heights

Atmospheric stability refers to the degree of turbulence or mixing that occurs within the atmosphere and is a controlling factor in the rate of atmospheric dispersion of pollutants. The Monin-Obukhov length (L) provides a measure of the stability of the surface layer (i.e. the layer above the ground in which vertical variation of heat and momentum flux is negligible; typically, about 10% of the mixing height). Negative L values correspond to unstable atmospheric conditions, while positive L values correspond to stable atmospheric conditions. Very large positive or negative L values correspond to neutral atmospheric conditions.

Figure A.16 illustrates the diurnal variation of atmospheric stability, derived from the Monin-Obukhov length calculated by CALMET at the Narrabri SAP site.

The diurnal profile shows that atmospheric instability increases during the daylight hours as the sun generated convective energy increases, whereas stable atmospheric conditions prevail during the night-time. The diurnal profile indicates that dispersion would be greatest during daytime hours and emissions occurring overnight are likely to result in higher ground level concentrations, relative to daytime hours.

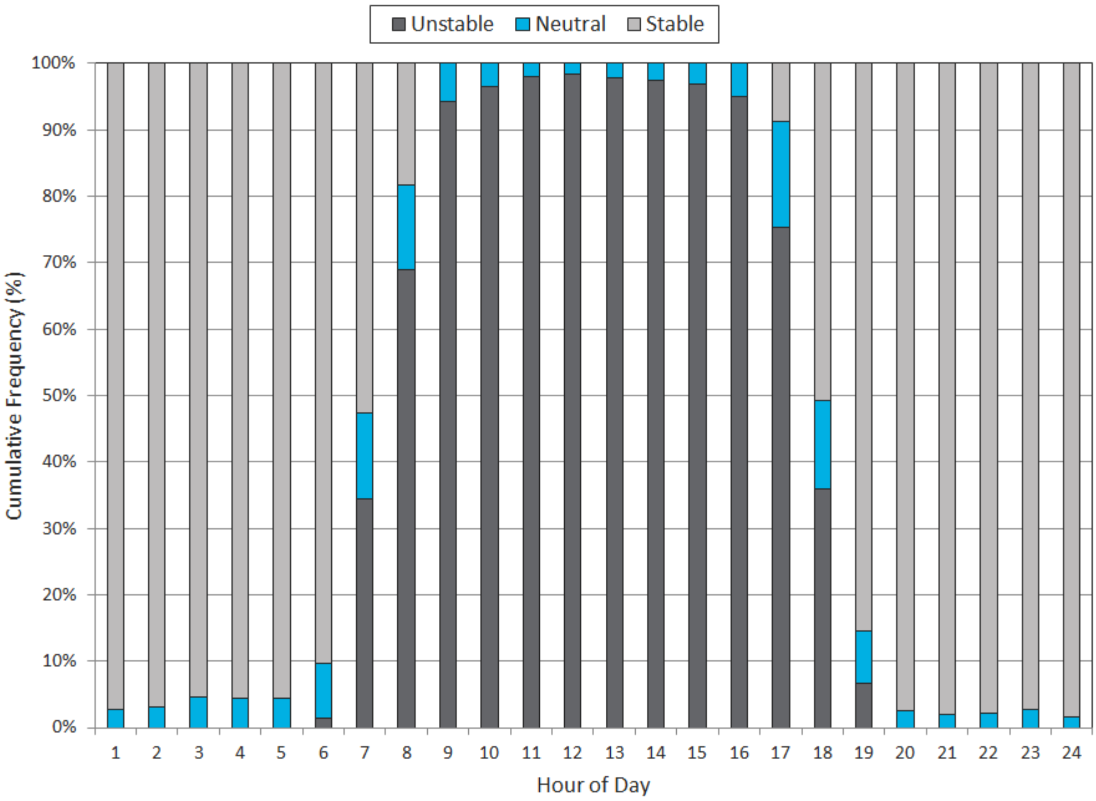
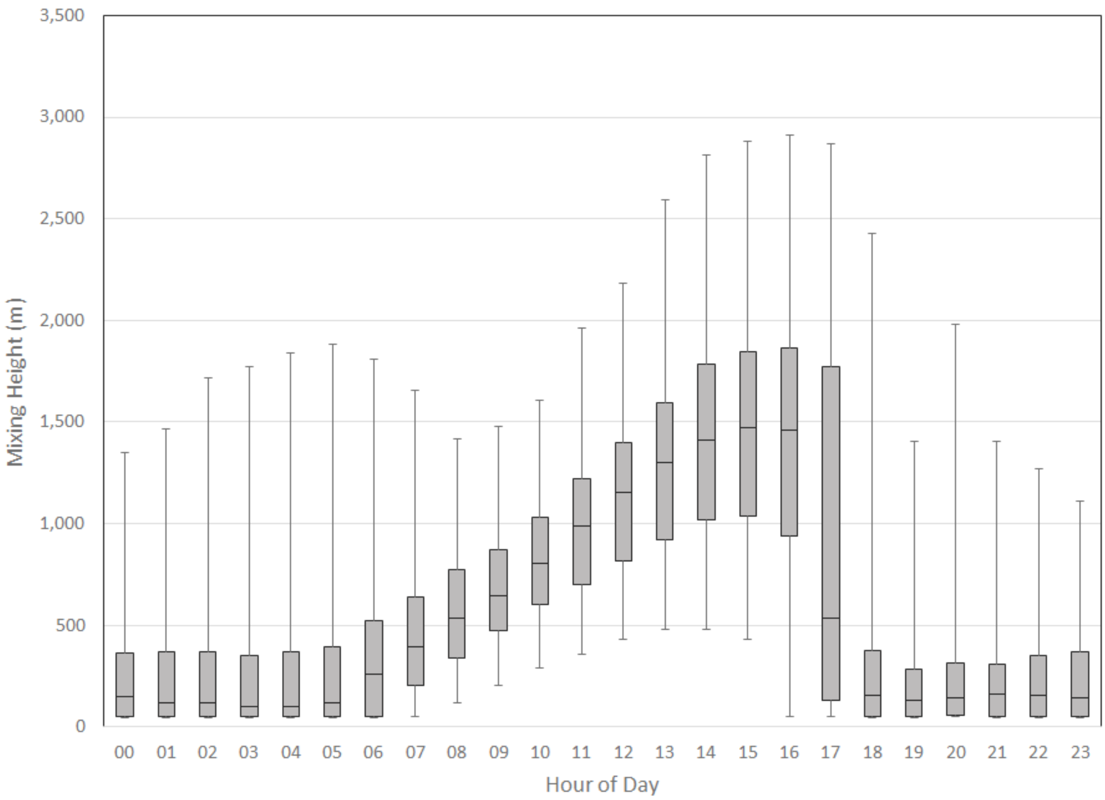


Figure A.16 Diurnal variations in CALMET-generated atmospheric stability

Mixing height refers to the height of the atmosphere above ground level within which the dispersion of air pollution occurs. The mixing height of the atmosphere is influenced by mechanical (associated with wind speed) and thermal (associated with solar radiation) turbulence. Similar to the Monin-Obukhov length analysis above, higher daytime wind speeds and the onset of incoming solar radiation increases the amount of mechanical and convective turbulence in the atmosphere. As turbulence increases, so too does the depth of the boundary layer, generally contributing to higher mixing heights and greater potential for the atmospheric dispersion of pollutants.

Figure A.17 presents the hourly-varying atmospheric boundary layer depths generated by CALMET at the Narrabri SAP site. Similar to the diurnal profile for stability, Figure A.17 indicates that dispersion would be greatest during daytime hours.



Box and whisker plot showing upper and lower quartile range (boxes) and minimum and maximum (whiskers). The mean is shown by the line in the centre of the box.

Figure A.17 Diurnal variation in CALMET-generated mixing heights

A.4 Air quality

A.4.1 Monitoring stations

DPE operates a network of monitoring stations across the state. The closest DPE monitoring station to the SAP is at Narrabri, around 8 km to the north-east. Other DPE monitoring sites in the region are located at Gunnedah (90 km to the south-east) and Tamworth (145 km to the south-east). PM_{10} and $PM_{2.5}$ are measured at all three stations, whereas gases (NO, NO_2, NO_X and O_3) are only measured at Gunnedah.

The three DPE monitoring stations considered in the study are summarised in Table A.7. The monitoring stations are all at background locations. A long-term record of monitoring (since 2000) is available for the Tamworth station, whereas the other stations have been operational for the last 3–4 years. PM_{10} and $PM_{2.5}$ are measured at all three stations, whereas gases (NO, NO_2, NO_X and O_3) are only measured at Gunnedah. Meteorological parameters are also measured at all three stations.

The availability of the data for PM_{10} and $PM_{2.5}$ is summarised in Table A.8. Where a given station was operational for a full year, the data availability was very high (86% to 99%). At Gunnedah, the availability of NO_X/NO_2 data was 78% in 2018, and 95% in 2019 and 2020. Only years with complete data (>75%) were included in the analysis.

Table A.7 Air quality monitoring stations

Station	Location	Distance from SAP boundary (km)	Elevation (m, AHD)	Monitoring period	Parameters measured
Gunnedah	Kitchener Park Lat: -30.98178° Long: 150.26069°	90	272	December 2017 to present (PM) March 2018 to present (gases)	PM_{10}, $PM_{2.5}$, NO, NO_2, NO_X, O_3
					Wind speed, wind direction, sigma theta, temperature, relative humidity, rainfall
Narrabri	Airport Road Lat: -30.31842° Long: 149.82932°	8.5	239	December 2017 to present	PM_{10}, $PM_{2.5}$
					Wind speed, wind direction, sigma theta, temperature, relative humidity
Tamworth	Hyman Park Lat: -31.10990° Long: 150.91451°	145	405	October 2000 to present	PM_{10}, $PM_{2.5}$
					Wind speed, wind direction, sigma theta, temperature, relative humidity

Table A.8 Data availability – PM_{10} and $PM_{2.5}$

Pollutant	Year	Gunnedah	Narrabri	Tamworth
PM_{10} (%)	2016	-	-	99%
	2017	7%	6%	99%
	2018	98%	99%	99%
	2019	92%	98%	99%
	2020	95%	98%	99%
$PM_{2.5}$ (%)	2016	-	-	72%
	2017	7%	6%	90%
	2018	98%	98%	86%
	2019	95%	98%	91%
	2020	99%	98%	98%

A.4.2 Analysis

The measurements from the three DPE stations were analysed for the five-year period between 2016 and 2020. The objectives of the analysis were to select a representative station and year for the air quality assessment, and to develop time series of background concentrations of pollutants.

i PM$_{10}$

The annual mean PM$_{10}$ concentrations at the DPE monitoring stations are given in Table A.9. Concentrations were typically highest at Tamworth and lowest at Narrabri. The measurements at all sites in late 2019 were strongly influenced by the extensive 'Black Summer' bushfires. Although the bushfires continued into January 2020, the annual mean concentrations for 2020 were less affected. For example, the PM$_{10}$ concentration at Tamworth in 2020 (16.8 µg/m^3) was reasonably representative of the historical measurements at the site; over the decade between 2006 and 2015[9], the concentrations at Tamworth ranged from 12.0 to 16.7 µg/m^3. The NSW impact assessment criterion for annual mean PM$_{10}$ (25 µg/m^3) was only exceeded at Tamworth in 2019.

Table A.9 Annual mean PM$_{10}$ concentration

Year	PM$_{10}$ (µg/m^3)		
	Gunnedah	Narrabri	Tamworth
2016	-	-	15.3
2017	-	-	15.3
2018	18.9	14.3	20.1
2019	24.8	23.2	33.7
2020	13.9	12.4	16.8
Impact assessment criterion	**25**	**25**	**25**

The effects of the bushfires during 2019 are clear in the time series of 24-hour PM$_{10}$ concentrations at the DPE monitoring sites (Figure A.18). Summary statistics for PM$_{10}$, including exceedances of the 24-hour criterion of 50 µg/m^3, are provided in Table A.10. The patterns in concentration were similar at all three sites. Although the criterion for 24-hour PM$_{10}$ was occasionally exceeded before 2019, it was exceeded on multiple days between August 2019 and February 2020. Between 22 October 2019 and 24 December 2019, between 33% (Narrabri) and 65% (Tamworth) of all days had an exceedance of the criterion.

Figure A.19 shows mean PM$_{10}$ concentrations by hour of the day, day of the week and month of the year. The plots are based on the available data for each monitoring station between 2016 and 2020, although the measurements for the bushfire-affected period between October 2019 and January 2020 were excluded as they were not typical.

The Gunnedah and Tamworth stations are located in urban areas, and the diurnal PM$_{10}$ profiles reflect patterns of activity. The morning and evening peaks suggest impacts from road traffic and domestic heating. Meteorological conditions are also important. Cold nights and clear skies can also create temperature inversions which trap pollution near the ground. During the night, the wind speed tends to be lower than during the day because of reduced convection. Between 5:00 am and 6:00 am, an increase in emissions from traffic is combined with low wind speeds at the end of the night-time period, leading to relatively high concentrations. The Narrabri monitoring station is located away from the population, around 4 km to the east of the town of Narrabri and – as noted in Appendix A – the proportion of westerly winds is quite low. As a consequence, the peaks in PM$_{10}$ are less pronounced than at the other sites.

9 Excluding 2009, when PM$_{10}$ concentrations across NSW were severely affected by the dust storm in September of that year.

There was little variation in average concentrations by day of the week, but there was some seasonal variation. PM_{10} concentrations tend to be elevated during in summer as a result of several factors, including lower rainfall leading to dry conditions, stronger winds generating dust, bush fires and dust storms. At Gunnedah and Tamworth there was also a winter-time peak due to wood burning.

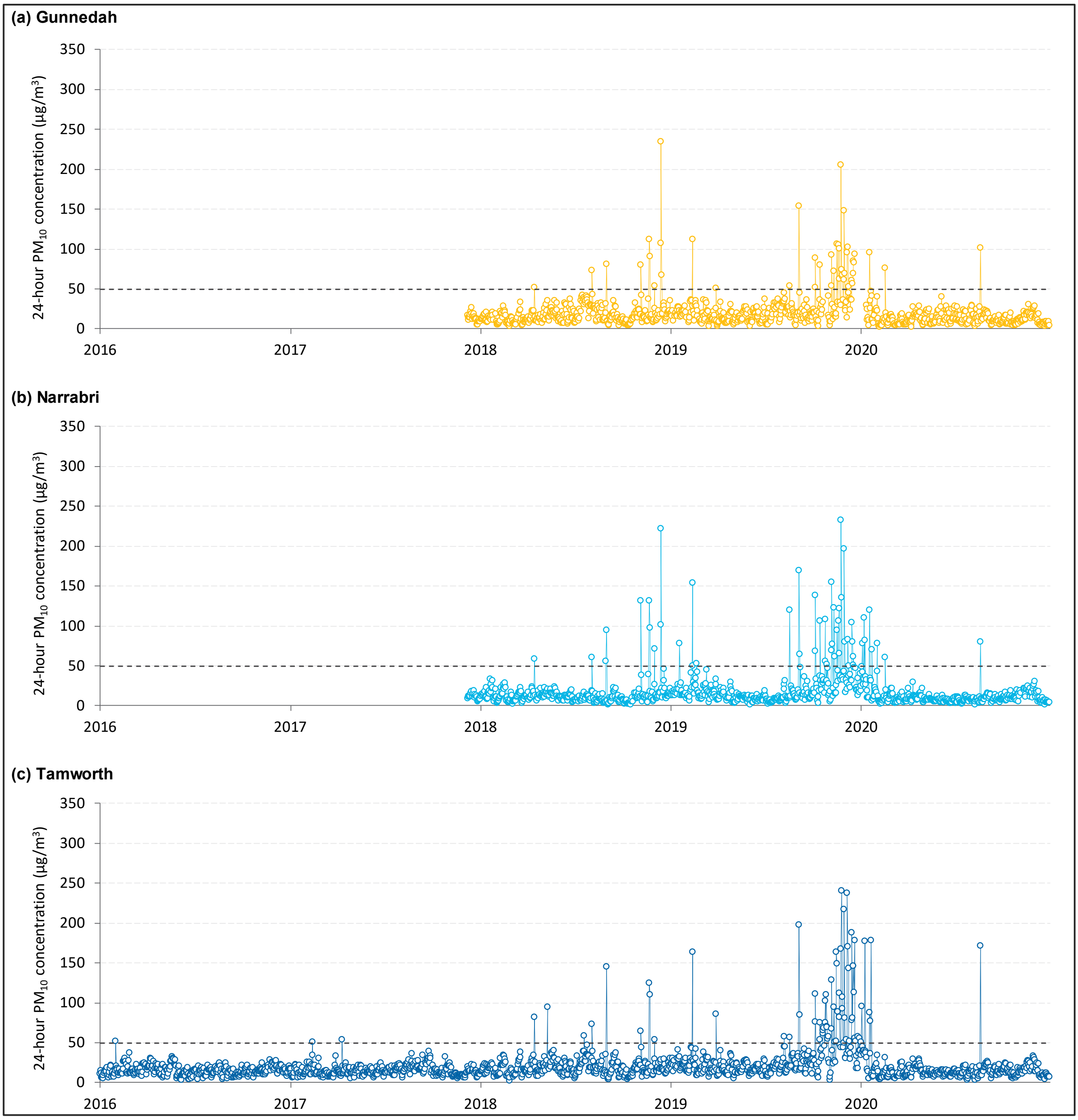


Figure A.18 Time series - 24-hour mean PM_{10} concentration

Table A.10 Summary statistics for 24-hour PM_{10} concentration

Year	Gunnedah	Narrabri	Tamworth
98th percentile (µg/m³)			
2016	-	-	30.0
2017	-	-	33.4
2018	65.6	60.4	57.7
2019	101.2	122.5	167.2
2020	35.5	58.8	49.9
Maximum (µg/m³)			
2016	-	-	51.7
2017	-	-	54.1
2018	234.9	221.7	145.4
2019	205.2	232.6	240.2
2020	101.2	119.6	178.0
Impact assessment criterion	**50**	**50**	**50**
Number of exceedances per year (days)			
2016	-	-	1
2017	-	-	2
2018	10	10	9
2019	30	31	52
2020	3	8	8

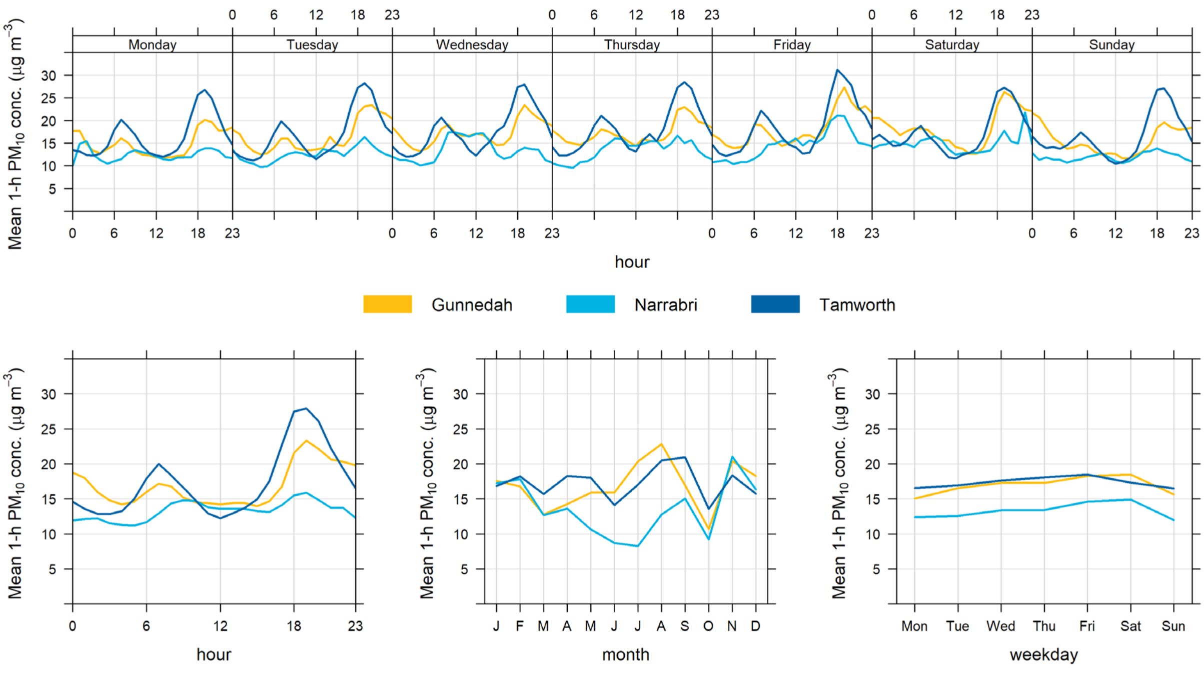


Figure A.19 Time variation in 1-hour mean PM_{10} concentration

ii $PM_{2.5}$

The annual mean $PM_{2.5}$ concentrations are given in Table A.9. As with PM_{10}, the measurements at all sites in 2019 were strongly influenced by the extensive bush fires. The NSW impact assessment criterion for annual mean $PM_{2.5}$ (8 µg/m^3) was exceeded at Gunnedah in 2018 and 2019, and at Tamworth in 2018 and 2019. The AQQ NEPM also contains a goal for annual mean $PM_{2.5}$ of 7 µg/m^3 from 2025. The sites that achieved the goal were Narrabri in 2018 and 2020, and Tamworth in 2020.

Table A.11 Annual mean $PM_{2.5}$ concentration

Year	$PM_{2.5}$ (µg/m^3)		
	Gunnedah	Narrabri	Tamworth
2016	-	-	-
2017	-	-	7.8
2018	9.0	4.9	8.3
2019	11.2	7.8	14.4
2020	7.7	5.5	6.8
Impact assessment criterion	**8**	**8**	**8**

The time series of 24-hour $PM_{2.5}$ concentrations are shown in Figure A.20. Summary statistics for PM_{10}, including numbers of exceedances of the NSW 24-hour impact assessment criterion of 25 µg/m^3, are provided in Table A.12.

The time series of concentration followed a similar pattern to that for PM_{10}. Prior to 2019, at Gunnedah and Narrabri the impact assessment criterion was occasionally exceeded, whereas at Tamworth it was not exceeded. During late 2019 and early 2020, the $PM_{2.5}$ concentrations at all stations were strongly influenced by bushfires. The AQQ NEPM also contains a goal for 24-hour $PM_{2.5}$ of 20 µg/m³ from 2025. During 2020 the NEPM goal was exceeded around 2-3 times more frequently than the impact assessment criterion.

Figure A.21 shows the time variation in $PM_{2.5}$ concentration. The plots are based on the available data for each monitoring station between 2017 and 2020. As with PM_{10}, the bushfire-affected period was excluded.

For Gunnedah and Tamworth, the time-of-day profiles were quite different from those for PM_{10}, with clear overnight peak in concentration and relatively low daytime concentrations. $PM_{2.5}$ concentrations were also markedly higher in winter than in summer. This points strongly to domestic wood combustion for heating as the source of $PM_{2.5}$. Again, the Narrabri monitoring station is located further from the population, and the average $PM_{2.5}$ profile was very flat compared with the other sites.

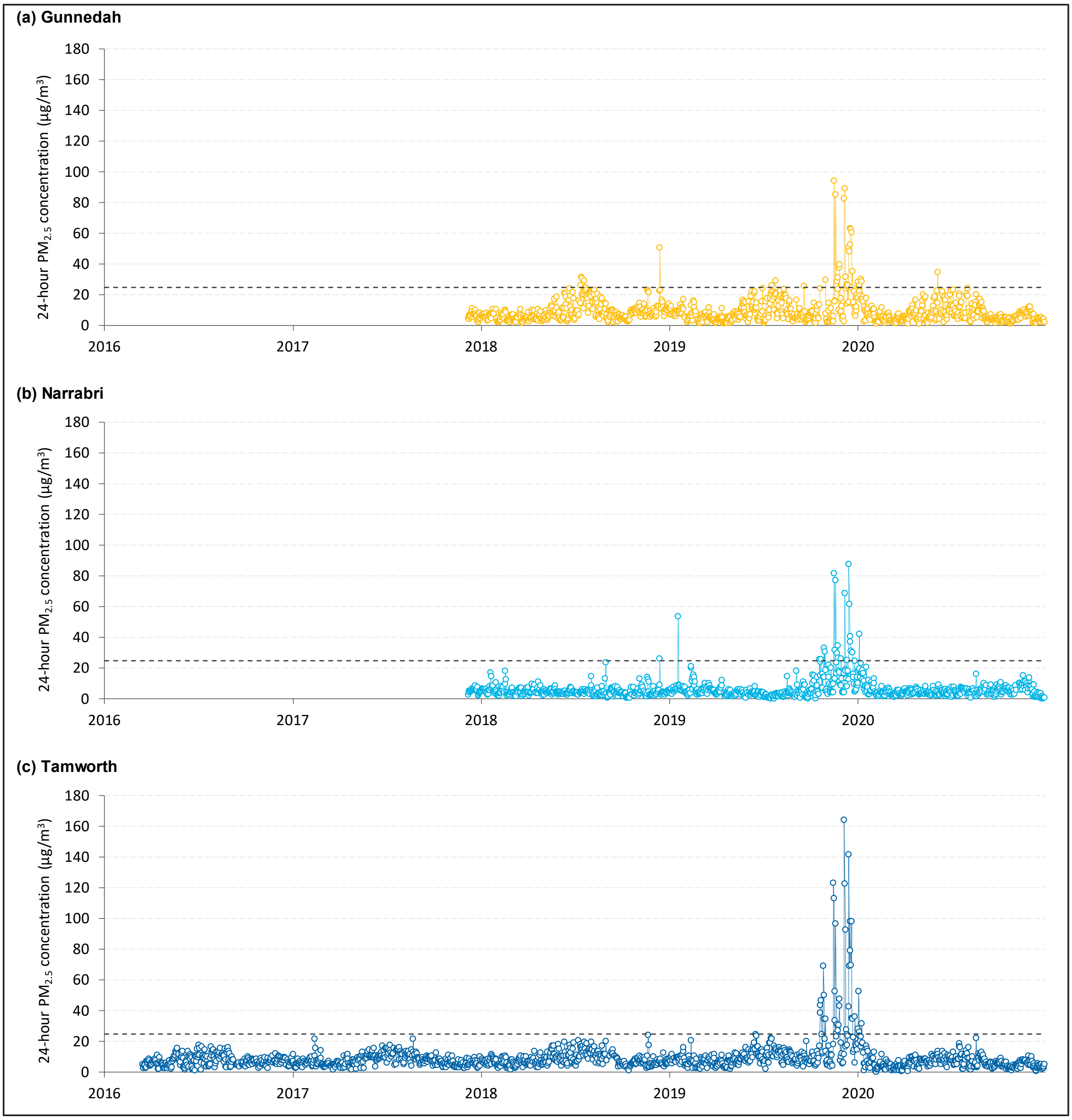


Figure A.20 Time series - 24-hour mean $PM_{2.5}$ concentration

Table A.12 Summary statistics for 24-hour $PM_{2.5}$ concentration

Year	Gunnedah	Narrabri	Tamworth
98th percentile (µg/m³)			
2016	-	-	-
2017	-	-	15.7
2018	23.4	13.4	18.9
2019	53.7	36.9	96.2
2020	23.3	16.7	20.2
Maximum (µg/m³)			
2016	-	-	-
2017	-	-	21.6
2018	50.7	26.3	24.2
2019	94.1	87.7	164.2
2020	34.7	42.4	52.6
Impact assessment criterion	**25**	**25**	**25**
Number of exceedances per year (days)			
2016	-	-	-
2017	-	-	0
2018	5	1	0
2019	24	20	32
2020	6	1	4

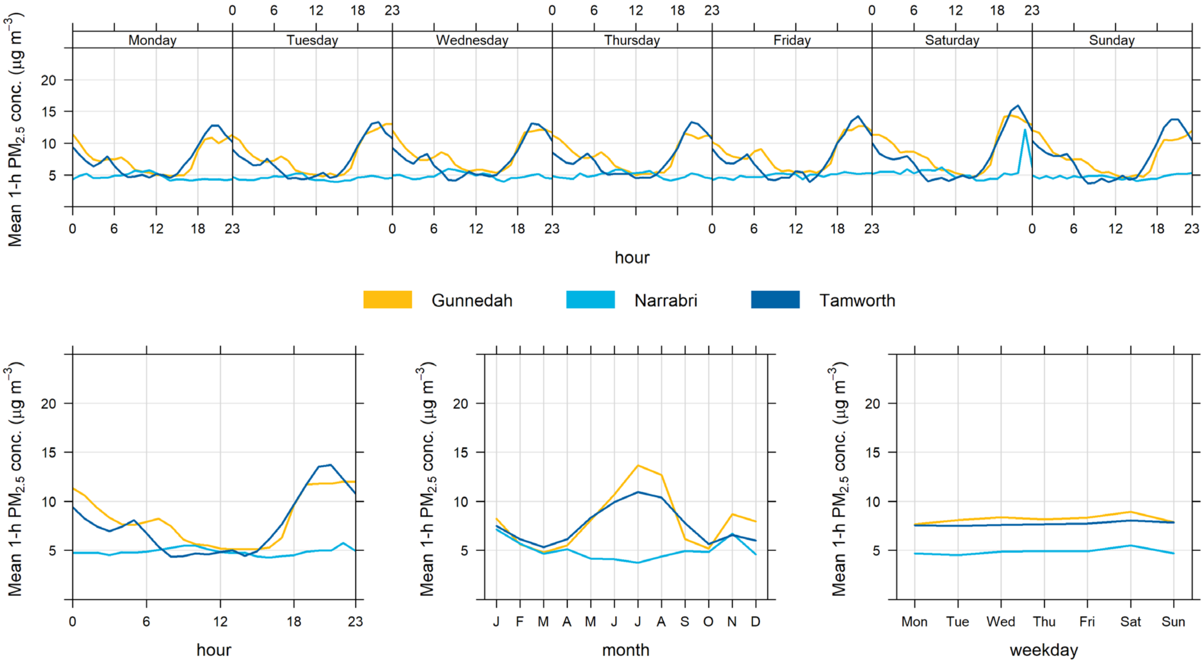


Figure A.21 Time variation in 1-hour mean $PM_{2.5}$ concentration

iii NO_X and NO_2

NO_X and NO_2 concentrations were only measured at Gunnedah, and from March 2018 onwards. The annual mean concentrations are given in Table A.13. NO_2 concentrations in all years were well below the NSW impact assessment criterion of 62 µg/m^3 and the national air quality standard in the AAQ NEPM of 31 µg/m^3. There are no air quality criteria for NO_X in NSW, and these values are largely of interest in relation to the characterisation of NO_2.

Table A.13 Annual mean NO_X and NO_2 concentrations at Gunnedah

Year	NO_X (µg/m^3)	NO_2 (µg/m^3)
2018	14.4	10.3
2019	14.4	10.3
2020	10.3	6.2
NSW impact assessment criterion	**Not applicable**	**62**

The time series of 1-hour mean NO_X and NO_2 concentrations at Gunnedah are shown in Figure A.22. The bushfires of 2019/2020 had little effect on the measurements. Summary statistics for 1-hour NO_X and NO_2 are provided in Table A.10. For NO_2 there were no exceedances of the 1-hour criterion of 246 µg/m^3 in any year. Indeed, the maximum concentration during the entire three-year period (74 µg/m^3) was well below the impact assessment criterion. There were also no exceedances of the national air quality standard in the AAQ NEPM of 164 µg/m^3.

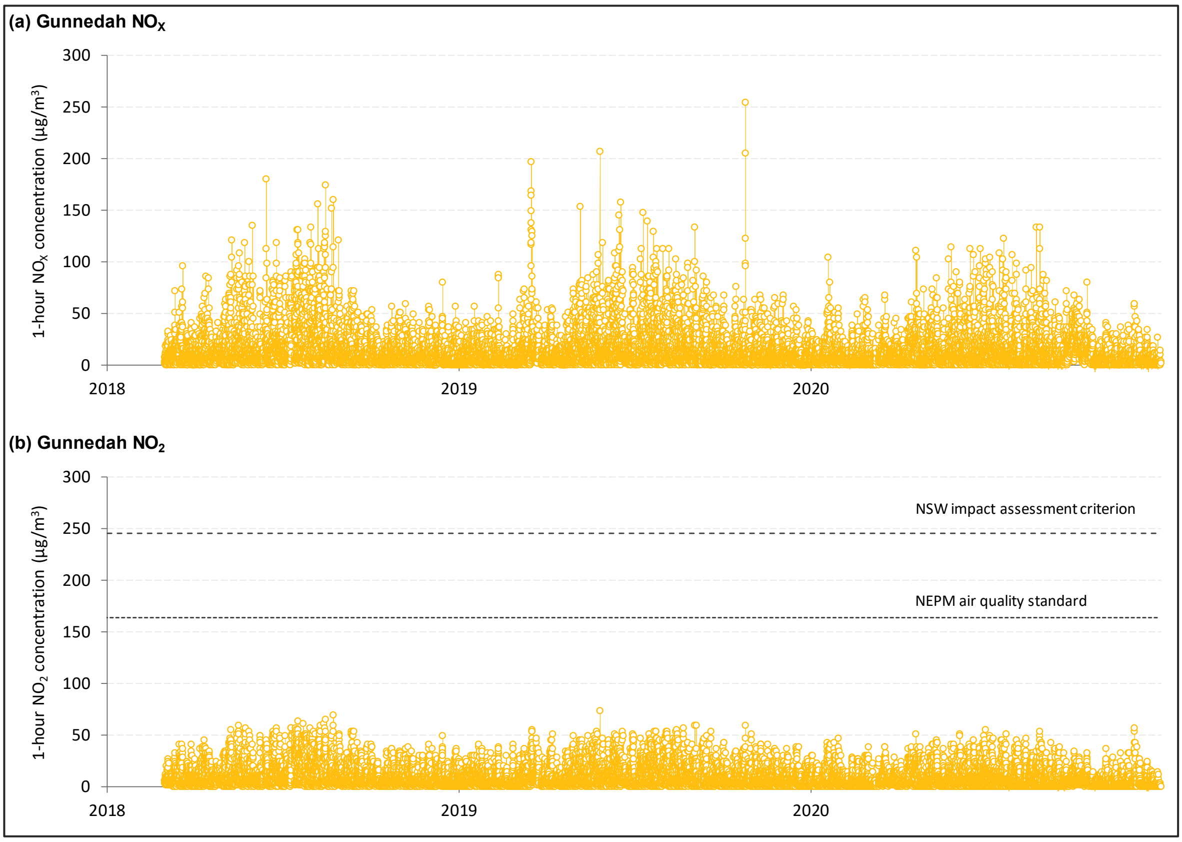


Figure A.22 Time series - 1-hour mean NO_X and NO_2 concentrations

Table A.14 Summary statistics for 1-hour NO_X and NO_2 concentrations

Year	NO_X	NO_2
98th percentile (µg/m³)		
2018	71.8	43.1
2019	67.7	41.0
2020	53.4	32.8
Maximum (µg/m³)		
2018	180.6	69.8
2019	254.5	73.9
2020	133.4	57.5
Impact assessment criterion	**Not applicable**	**246**
Number of exceedances per year (hours)		
2018	Not applicable	0
2019	Not applicable	0
2020	Not applicable	0

Figure A.23 shows the time variation in NO_X and NO_2 concentrations.

On weekdays, concentration increased from 3:00 am to a narrow peak at around 6:00 am. Concentrations were lowest during the early afternoon, and there was a smaller and slightly broader peak in the evening. Concentrations were very low around 10:00 am. On Saturdays and Sundays, there were also morning and evening peaks, but they were lower than on weekdays.

There was a strong seasonal variation in concentrations, with values being markedly higher in winter than in summer. This is commonly observed for NO_X and NO_2 (and other pollutants) and is due to a combination of winter-time factors, such as an increase in combustion for heating purposes (elevated emissions from road vehicles may also be a contributing factor). In addition, cold nights and clear skies can create temperature inversions in the atmosphere which reduce the effectiveness of dispersion and trap pollution near the ground. These temperature inversions are more frequent and persistent in winter. Another contributing factor may be the reaction of NO_2 with the hydroxyl radical (OH) acting as a sink for NO_X; concentrations of OH are highest in the summer.

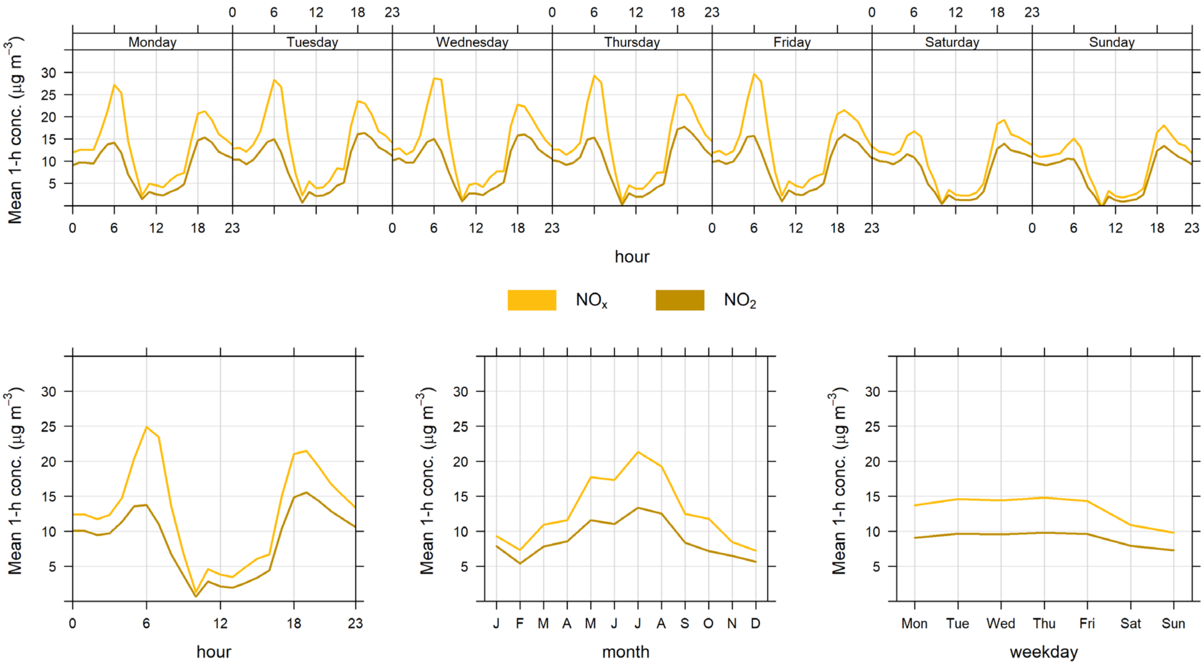


Figure A.23 Time variation in 1-hour mean NO_X and NO_2 concentration

iv Summary

The main findings of the analysis are summarised by pollutant below:

- PM_{10}
  - Concentrations were typically highest at Tamworth and lowest at Narrabri.
  - The measurements at all sites in late 2019 were strongly influenced by the extensive 'Black Summer' bush fires. Although the bushfires continued into January 2020, the annual mean concentrations for 2020 were less affected.
  - The NSW impact assessment criterion for annual mean PM_{10} (25 µg/m^3) was only exceeded at Tamworth in 2019.

- Although the criterion for 24-hour PM_{10} (50 µg/m^3) occasionally exceeded before 2019, it was exceeded on multiple days between August 2019 and February 2020.

- The Gunnedah and Tamworth stations are in urban areas, and the diurnal PM_{10} profiles suggest impacts from road traffic and domestic heating. The Narrabri monitoring station is located around 4 km to the east of the town of Narrabri and the proportion of westerly winds is low. As a consequence, the peaks in PM_{10} were less pronounced than at the other sites.

- PM_{10} concentrations tend to be elevated during in summer as a result of several factors, including lower rainfall leading to dry conditions, stronger winds generating dust, bush fires and dust storms. At Gunnedah and Tamworth there was a winter-time peak in PM_{10} due to wood burning.

• $PM_{2.5}$

- The NSW impact assessment criterion for annual mean $PM_{2.5}$ (8 µg/m^3) was exceeded at Gunnedah in 2018 and 2019, and at Tamworth in 2018 and 2019.

- Prior to 2019, at Gunnedah and Narrabri the impact assessment criterion for 24-hour $PM_{2.5}$ (25 µg/m^3) was occasionally exceeded, whereas at Tamworth it was not exceeded. During late 2019 and early 2020, the $PM_{2.5}$ concentrations at all stations were strongly influenced by bushfires, with multiple exceedances of the criterion.

- For Gunnedah and Tamworth, the time-of-day profiles were quite different from those for PM_{10}, with clear overnight peak in concentration and relatively low daytime concentrations. $PM_{2.5}$ concentrations were also markedly higher in winter than in summer, pointing strongly to domestic wood combustion for heating as the source of $PM_{2.5}$. Again, the Narrabri monitoring station is located further from the population, and the average $PM_{2.5}$ profile was very flat compared with the other sites.

• NO_X and NO_2 (Gunnedah only)

- The availability of NO_X/NO_2 data was 78% in 2018, and 95% in 2019 and 2020.

- Annual mean NO_2 concentrations were well below the NSW impact assessment criterion of 62 µg/m^3, and there were no exceedances of the 1-hour criterion of 246 µg/m^3.

- On weekdays, concentrations peaked at around 6:00 am and 6:00 pm. On Saturdays and Sundays there were also morning and evening peaks, but they were lower than on weekdays.

- There was a strong seasonal variation in concentrations, with values being markedly higher in winter than in summer.

A.4.3 Selection of representative data

The DPE Narrabri station was selected as the most appropriate and representative source of background concentrations for PM_{10} and $PM_{2.5}$. The main advantages of the Narrabri station were:

• its proximity to the project – it was much closer than the alternatives

• its environment – it was located in a similar type of location to the project and was a similar distance from the population of Narrabri.

The Gunnedah and Tamworth stations are located in urban areas, and the diurnal PM_{10} profiles reflect patterns of activity. These are less representative of the project area than the Narrabri station.

For NO_X and NO_2, background concentrations were taken from the only available source: DPE's Gunnedah station.

For consistency with the meteorological data, as well as being a logical outcome of the analysis of air quality, 2020 was selected as the representative year for the background concentrations. For example, the PM data for 2019 were considered to be unsuitable due to unusually high concentrations resulting from the bushfires. The only other year with complete data at Narrabri was 2018. The analysis of the long-term dataset for Tamworth suggested that 2020 was more representative of historical levels of PM_{10} than 2018, which was influenced by intensifying drought conditions across Eastern Australia. Maximum 24-hour concentrations were also especially high in 2018 and 2019, and with more exceedances than in previous years. For NO_X and NO_2, the concentrations at Gunnedah in 2020 were lower than those in 2018 and 2019. However, no long-term record was available to assess representativeness.

A.4.4 Background concentrations

For PM_{10} and $PM_{2.5}$, background concentrations in 2020 were taken from the DPE monitoring station at Narrabri. For NO_X and NO_2, background concentrations were taken from DPE's Gunnedah station.

The data availability for PM_{10} and $PM_{2.5}$ in 2020 at the Narrabri monitoring station was 98%. At the Gunnedah station, the availability of NO_X and NO_2 data was 94%. Gap-filling techniques were used to complete the 2020 background concentration profiles. For 24-hour PM_{10} and $PM_{2.5}$ concentrations at Narrabri, there were two gaps in the data: a two-day period in April and a five-day period in November. These were filled using the ratio of the concentrations at Gunnedah and Tamworth to those at Narrabri, based on the periods before and after the gaps (three days before and three days after). For 1-hour NO_X and NO_2 concentrations at Gunnedah, one-hour gaps were filled by interpolation, and larger gaps were filled using the data for the corresponding hours on the previous day. Any resulting negative values in the background profiles were set to zero.

Summary statistics for the 2020 background concentrations, based on the complete profiles, are provided in Table A.15. The short-term values were not used in the assessment and are included for completeness.

As noted previously, but both annual mean and maximum 1-hour NO_2 concentrations were well below the respective impact assessment criteria (62 $\mu g/m^3$ and 246 $\mu g/m^3$). The background concentrations for PM_{10} and $PM_{2.5}$ were a more material concern in relation to the assessment, especially the 24-hour concentrations. The maximum 24-hour concentrations of both PM_{10} and $PM_{2.5}$ were above the corresponding criteria (50 $\mu g/m^3$ and 25 $\mu g/m^3$).

There were eight exceedance days for PM_{10}, and one exceedance day for $PM_{2.5}$. Most of the exceedances were associated with the bushfires in January. The ninth highest 24-hour PM_{10} concentration, and the highest value below the criterion, was 48.7 $\mu g/m^3$. The second highest 24-hour $PM_{2.5}$ concentration, and the highest value below the criterion, was 23.1 $\mu g/m^3$.

Figure A.24 shows the ranked 24-hour PM_{10} and $PM_{2.5}$ concentrations in 2020. This provides further illustration that the majority of values are below the criteria.

Table A.15 Summary statistics for background concentrations (2020)

Pollutant	Averaging period	Statistic	Units	Value
NO_X	Annual	Mean	µg/m^3	11.0
	1-hour	Maximum	µg/m^3	133.4
NO_2	Annual	Mean	µg/m^3	7.0
	1-hour	Maximum	µg/m^3	57.5
PM_{10}	Annual	Mean	µg/m^3	12.4
	24-hour	Maximum	µg/m^3	119.6
		99th percentile	µg/m^3	78.9
		95th percentile	µg/m^3	30.0
		Days over 50 µg/m^3	-	8
		Highest value <50 µg/m^3	µg/m^3	48.7
$PM_{2.5}$	Annual	Mean	µg/m^3	5.5
	24-hour	Maximum	µg/m^3	42.4
		99th percentile	µg/m^3	19.0
		95th percentile	µg/m^3	11.3
		Days over 25 µg/m^3	-	1
		Highest value <25 µg/m^3	µg/m^3	23.1

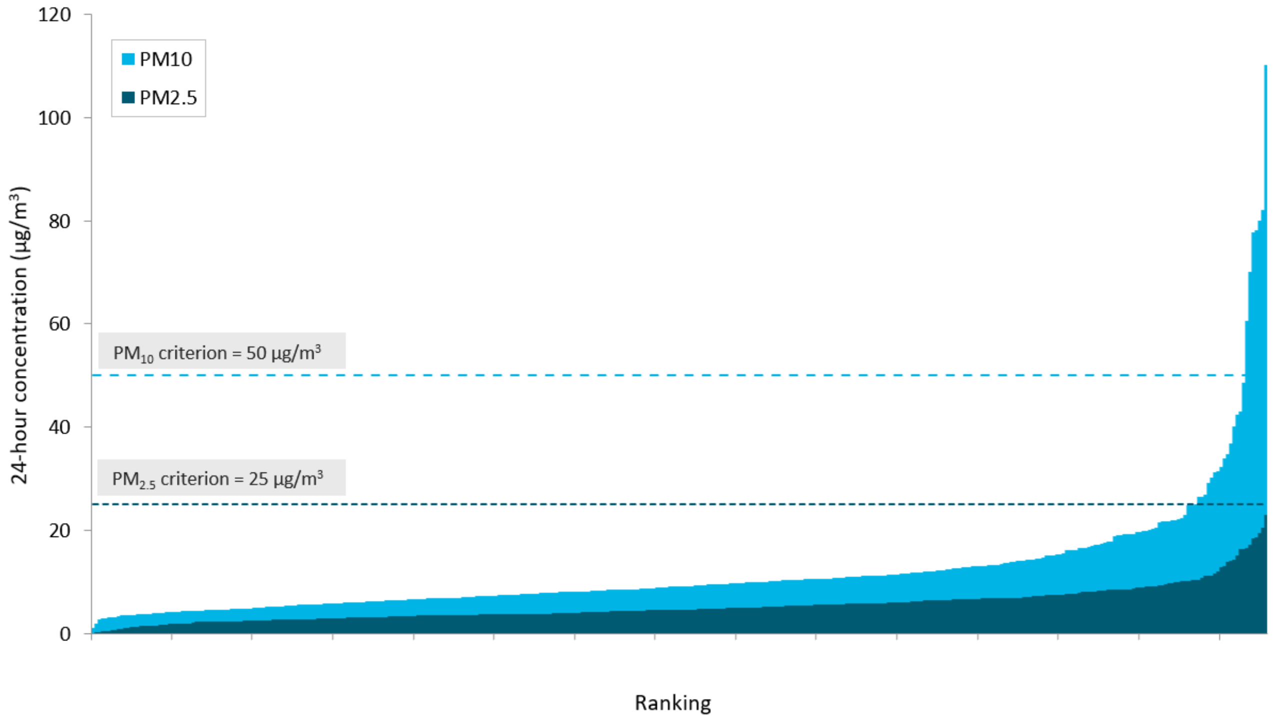


Figure A.24 Ranked 24-hour PM_{10} and $PM_{2.5}$ concentrations in 2020

A.5 Odour

The existing odour environment in the vicinity of the SAP is expected to be primarily influenced by the existing Narrabri Landfill, located within the proposed SAP boundary. The document 'Environmental Guidelines - Solid waste landfills' (NSW EPA 2016) notes that – in the case of large[10] putrescible waste landfills – buffers of at least 1,000 metres should be provided where practicable to residential zones, schools and hospitals to protect the amenity of these land uses from odour, noise and other impacts. The current filling rate is approximately 18,000 m^3 per annum and the licenced limit is 30,000 m^3 per annum (GHD 2020). Assuming a bulk density of 300 kg/m^3, both the current and licenced filling rate are significantly lower than what is defined by EPA as a large landfill, and a significantly reduced buffer distance is therefore likely to be applicable for future development within the SAP.

A Statement of Environment Effects (SEE) was prepared for a recent modification to the consent, to allow for the ongoing operation of the landfill by increasing the capacity (GHD 2020). The SEE found that odour was not a significant issue for the site, for existing sensitive receptors in the vicinity of the site.

[10] More than 50,000 tonnes of putrescible waste per year.

Appendix B
Assessment locations

creating opportunities

Table B.1 Assessment locations

Assessment location code	Easting	Northing	Type	Inside or outside SAP
InSAP_R1	759385	6640547	Residential	Inside SAP
InSAP_R2	759753	6640313	Residential	Inside SAP
InSAP_R3	760030	6640296	Residential	Inside SAP
InSAP_R4	760071	6640397	Residential	Inside SAP
InSAP_R5	760239	6640212	Residential	Inside SAP
InSAP_R6	760364	6640204	Residential	Inside SAP
InSAP_R7	760732	6640305	Residential	Inside SAP
InSAP_R8	760958	6640388	Residential	Inside SAP
InSAP_R9	761912	6639819	Residential	Inside SAP
InSAP_R10	761653	6640246	Residential	Inside SAP
InSAP_R11	761527	6640438	Residential	Inside SAP
InSAP_R12	761209	6640556	Residential	Inside SAP
InSAP_R12a	759087	6640353	Residential	Inside SAP
InSAP_R13	758956	6640349	Residential	Inside SAP
InSAP_R14	758726	6640293	Residential	Inside SAP
InSAP_R15	758470	6642776	Residential	Inside SAP
InSAP_R16	757506	6639962	Residential	Inside SAP
InSAP_R17	757134	6640067	Residential	Inside SAP
InSAP_R18	756272	6643194	Residential	Inside SAP
InSAP_R19	755169	6643435	Residential	Inside SAP
InSAP_CI_1	762640	6641074	Commercial/Industrial	Inside SAP
InSAP_CI_2	762489	6640756	Commercial/Industrial	Inside SAP
InSAP_CI_3	761896	6641211	Commercial/Industrial (Landfill)	Inside SAP
RR_1	759344	6639585	Rural Residential	Outside SAP
RR_2	759971	6639744	Rural Residential	Outside SAP
RR_3	760339	6639936	Rural Residential	Outside SAP
RR_4	760406	6639920	Rural Residential	Outside SAP
RR_5	763284	6638765	Rural Residential	Outside SAP
RR_6	763544	6639133	Rural Residential	Outside SAP
RR_7	763686	6639409	Rural Residential	Outside SAP
RR_8	763410	6639468	Rural Residential	Outside SAP
RR_9	763502	6639727	Rural Residential	Outside SAP

Table B.1 Assessment locations

Assessment location code	Easting	Northing	Type	Inside or outside SAP
RR_10	763396	6639787	Rural Residential	Outside SAP
RR_11	761615	6639024	Rural Residential	Outside SAP
RR_12	761607	6637317	Rural Residential	Outside SAP
RR_13	761230	6637000	Rural Residential	Outside SAP
RR_14	763972	6641202	Rural Residential	Outside SAP
ED_1	764879	6640912	Kogil Street Preschool	Outside SAP
ED_2	765599	6639734	Narrabri West Public School	Outside SAP
REC_1	764906	6640355	Playground	Outside SAP
RR_15	759739	6637605	Rural Residential	Outside SAP
RR_16	763790	6639766	Rural Residential	Outside SAP
RR_17	759825	6642984	Rural Residential	Outside SAP
RR_18	761079	6643399	Rural Residential	Outside SAP
RR_19	761815	6642188	Rural Residential	Outside SAP
RR_20	761812	6641992	Rural Residential	Outside SAP
RR_21	763124	6641707	Rural Residential	Outside SAP
RR_22	763439	6641499	Rural Residential	Outside SAP
RR_23	763688	6641509	Rural Residential	Outside SAP
RR_24	764354	6641276	Rural Residential	Outside SAP
RR_25	764356	6639407	Rural Residential	Outside SAP
RR_26	764343	6639214	Rural Residential	Outside SAP
RR_27	764194	6639157	Rural Residential	Outside SAP
RR_28	763794	6639121	Rural Residential	Outside SAP
RR_29	763745	6639045	Rural Residential	Outside SAP
RR_30	765095	6639027	Rural Residential	Outside SAP
RR_31	764616	6638864	Rural Residential	Outside SAP
RR_32	763952	6638492	Rural Residential	Outside SAP
RR_33	763830	6638451	Rural Residential	Outside SAP
RR_34	763498	6638745	Rural Residential	Outside SAP
RR_35	763752	6638317	Rural Residential	Outside SAP
RR_36	763401	6638599	Rural Residential	Outside SAP
RR_37	763176	6638300	Rural Residential	Outside SAP
RR_38	762881	6636995	Rural Residential	Outside SAP

Table B.1 Assessment locations

Assessment location code	Easting	Northing	Type	Inside or outside SAP
RR_39	763158	6636984	Rural Residential	Outside SAP
RR_40	763271	6636886	Rural Residential	Outside SAP
RR_41	763096	6636699	Rural Residential	Outside SAP
RR_42	763328	6636633	Rural Residential	Outside SAP
RR_43	762841	6636641	Rural Residential	Outside SAP
RR_44	762749	6636508	Rural Residential	Outside SAP
RR_45	759006	6639697	Rural Residential	Outside SAP
RR_46	758231	6639707	Rural Residential	Outside SAP
RR_47	758083	6643576	Rural Residential	Outside SAP
RR_48	763715	6636858	Rural Residential	Outside SAP
RR_49	763464	6636448	Rural Residential	Outside SAP
RR_50	763366	6634625	Rural Residential	Outside SAP
RR_51	758141	6637266	Rural Residential	Outside SAP
RR_52	763866	6636540	Rural Residential	Outside SAP
RR_53	764138	6636221	Rural Residential	Outside SAP
RR_54	763382	6636282	Rural Residential	Outside SAP
RR_55	756324	6639176	Rural Residential	Outside SAP
RR_56	764845	6641787	Rural Residential	Outside SAP
RR_57	764495	6643028	Rural Residential	Outside SAP
RR_58	763737	6643582	Rural Residential	Outside SAP
RR_59	765305	6641712	Rural Residential	Outside SAP
RR_60	765233	6642025	Rural Residential	Outside SAP
RR_61	754432	6639349	Rural Residential	Outside SAP
RR_62	754292	6638300	Rural Residential	Outside SAP
RR_63	754229	6638015	Rural Residential	Outside SAP
RR_64	753741	6637654	Rural Residential	Outside SAP
RR_65	753009	6645575	Rural Residential	Outside SAP
RR_66	752978	6645718	Rural Residential	Outside SAP
RR_67	765075	6640092	Rural Residential	Outside SAP
SR_1	764269	6640955	Suburban Residential	Outside SAP
SR_2	764325	6640890	Suburban Residential	Outside SAP
SR_3	763984	6640563	Suburban Residential	Outside SAP

Table B.1 Assessment locations

Assessment location code	Easting	Northing	Type	Inside or outside SAP
SR_4	764014	6640549	Suburban Residential	Outside SAP
SR_5	764045	6640534	Suburban Residential	Outside SAP
SR_6	763899	6640319	Suburban Residential	Outside SAP
SR_7	765214	6641264	Suburban Residential	Outside SAP
CI_1	765115	6640061	Commercial/Industrial	Outside SAP
CI_2	764554	6640412	Commercial/Industrial	Outside SAP
CI_3	763535	6641441	Commercial/Industrial	Outside SAP
CI_4	764257	6641243	Commercial/Industrial	Outside SAP
CI_5	764273	6641206	Commercial/Industrial	Outside SAP
CI_6	764779	6639658	Commercial/Industrial	Outside SAP
CI_7	762893	6637937	Commercial/Industrial	Outside SAP
CI_8	763022	6636437	Commercial/Industrial	Outside SAP
CI_9	754513	6640747	Commercial/Industrial	Outside SAP
CI_10	764528	6640423	Commercial/Industrial	Outside SAP
CI_11	764582	6640399	Commercial/Industrial	Outside SAP
CI_12	764607	6640367	Commercial/Industrial	Outside SAP
CI_13	763412	6641522	Commercial/Industrial	Outside SAP
CI_14	763308	6641684	Commercial/Industrial	Outside SAP
CI_15	757301	6637906	Commercial/Industrial - Wilga Park PS	Outside SAP
CI_16	760900	6639844	Commercial/Industrial	Outside SAP
CI_17	761410	6639652	Commercial/Industrial	Outside SAP
CI_18	762523	6638330	Commercial/Industrial	Outside SAP
CI_19	763644	6640363	Commercial/Industrial	Outside SAP
CI_20	763878	6641041	Commercial/Industrial	Outside SAP
CI_21	764029	6641175	Commercial/Industrial	Outside SAP
CI_22	763912	6641233	Commercial/Industrial	Outside SAP
CI_23	763686	6641166	Commercial/Industrial	Outside SAP
CI_24	763600	6641221	Commercial/Industrial	Outside SAP
CI_25	763480	6641242	Commercial/Industrial	Outside SAP
CI_26	764121	6640723	Commercial/Industrial (Cargill)	Outside SAP

Appendix C
Characterisation of emission sources

EMM
creating opportunities

C.1 Existing facilities (in or near SAP)

C.1.1 NSC waste management facility

The EPL for the landfill (EPL 12193, dated 11 May 2021) does not contain any requirements with respect to ambient air quality or odour.

In the atmospheric dispersion modelling for the Narrabri SAP, the landfill was considered as part of the circular economy land use (stage 1 of SAP).

C.1.2 Australian Recycled Plastics

Australian Recycled Plastics is a manufacturing plant which is the first of its kind in Australia that can process kerbside collected recyclable plastic materials to produce polyethylene terephthalate (PET) flake and high-density polyethylene (HDPE) flake simultaneously. The processing facility is housed in a single, large shed. The process generally consists of raw material delivery via road, processing and washing of the raw material and, finally, packing and delivery of the final product via road. There are no significant chemical or combustion processes at the facility. It was, therefore, considered unlikely that the facility would feature significant emission sources, and it was excluded from the modelling for the SAP.

C.1.3 AGT Narrabri

AGT Foods Australia operates a pulse crop production facility on Williams Drive in Narrabri, near the eastern boundary of the SAP.

In the absence of any site-specific data for the facility, in the modelling it was treated in the same way as grain processing (see Section C.3.1).

C.1.4 Cargill Processing Limited

Cargill Processing Limited operates an oilseed processing facility at Baranbar Street, Narrabri, which is near the north-eastern corner of the SAP. Emissions data for the facility were taken from the National Pollutant Inventory (NPI) in 2016/2017[11].

The emission source characteristics for the SAP modelling are given in Table C.1.

Table C.1 Emissions data – Cargill Processing Ltd

Parameter	Stack
Stack height (m)	14.7
Stack diameter (m)	0.98
Stack temp (°C)	153.4
Exit velocity (m/s)	19.0
NO_X emission rate (g/s)	1.142
PM_{10} emission rate (g/s)	0.276
$PM_{2.5}$ emission rate (g/s)	0.092

11 http://www.npi.gov.au/npidata/action/load/emission-by-individual-facility-result/criteria/state/NSW/year/2017/jurisdiction-facility/378

C.2 New land uses in the Structure Plan for the SAP (Stage 1)

C.2.1 Transport and logistics

Stage 1 of the Narrabri SAP will involve the construction of a freight and logistics terminal with access to Inland Rail, as well as an industrial park with all of the enabling infrastructure required to support business operations. This 'transport and logistics' land use of the SAP will include a 1,800 m rail siding with slip road infrastructure to facilitate rail loading and storage capability. The main operational impacts of the land use will relate to diesel combustion in freight trains, heavy vehicles and equipment.

In the atmospheric dispersion modelling, the transport and logistics land use was treated as a line-volume source. The proxy facility was taken to be Stage 1 of the Moorebank Intermodal Terminal, which was assumed to be broadly representative of typical activities at intermodal terminals.

The data for the proxy facility were taken from the AQIA by ENVIRON (2015) and Ramboll (2016), which included movements of trucks, locomotives, container handling equipment, warehousing and heating/cooling. This facility covered a total area of around 89 ha. The emissions rates (in g/s) for all activities at the proxy facility were divided by the area of the proxy facility to give an emission rate in g/s/m^2. These emission rates were then multiplied by the area of the land use for transport and logistics in the Narrabri SAP (106.2 ha) to give emission rates for the SAP.

The emission source characteristics for the SAP modelling are given in Table C.2.

Table C.2 Emissions data – transport and logistics

Parameter	NO_X	PM_{10}	$PM_{2.5}$
Emission rate for proxy facility (g/s)[a]	1.8	0.08	0.07
Emission rate for proxy facility (g/s/m^2)	2.02×10^{-6}	8.65×10^{-8}	8.26×10^{-8}
Emission rate for SAP (g/s)	2.15	0.0919	0.088

(a) Emission rate for all activities at proxy facility

C.2.2 Agriculture and food processing

In the atmospheric dispersion modelling, two facilities were allocated to the 'agriculture and food processing' land use of the Narrabri SAP:

- a grain processing facility
- a cotton gin.

Details of the assumptions for these are provided below.

i Grain processing facility

In the modelling, grain processing was characterised using point sources. The proxy facility was taken to be the Selby Wheat Processing Facility in the UK (Hydrock 2019). This was the only grain processing facility with an AQIA found in an online search. The only emission sources at the proxy facility were point sources (stacks), and emission rates for NO_X and PM_{10} were provided for multiple individual stacks. For the Narrabri SAP, average stack parameters were selected for the two pollutants ('stack 1' for NO_X and 'stack 2 for PM_{10}). Emissions from emergency generators were excluded from this calculation exercise.

For stack 2, a $PM_{2.5}$ emission rate was also derived from the PM_{10} emission rate using a ratio[12] based on the USEPA's AP-42 generalised particle size distribution for 'Category 7 - Grain Processing'[13].

The emission source characteristics for the SAP modelling are given in Table C.3.

Odour impacts were not assessed by Hydrock (2019) (there were no odour complaints).

Table C.3 Emissions data – agriculture and food processing (grain processing facility)

Parameter	Stack 1 (average NO_X stack)	Stack 2 (average PM_{10} stack)
Stack height (m)	29.7	18.4
Stack diameter (m)	1.8	0.5
Stack temp (°C)	105.0	77.8
Exit velocity (m/s)	16.2	10.4
NO_X emission rate (g/s)	3.56	-
PM_{10} emission rate (g/s)	-	0.87
$PM_{2.5}$ emission rate (g/s)	-	0.33

ii Cotton gin

The cotton gin was characterised using a combination of a point source (stack) and a line-volume source (hauling), and the proxy facility was taken to be Carrathool Cotton Gin (PEL 2014). This was the only cotton gin with an AQIA found in an online search.

The AQIA contained data for multiple processes and stacks, from which a single representative stack was identified for the SAP modelling. Total emission rates for PM_{10} and $PM_{2.5}$ were determined for the SAP. The emission rates for all hauling activities in the AQIA were summated for use in the SAP.

The emission source characteristics for the SAP modelling are given in Table C.4.

Table C.4 Emissions data – agriculture and food processing (cotton gin)

Parameter	Point source (stack)	Line-volume source (hauling)
Stack height (m)	10.0	-
Stack diameter (m)	2.0	-
Stack temp (°C)	15.0	-
Exit velocity (m/s)	10.0	-
PM_{10} emission rate (g/s)	1.346	0.530
$PM_{2.5}$ emission rate (g/s)	0.091	0.053

12 $PM_{2.5}$ = 38% of PM_{10} (based on ratios to TSP).

13 https://www.epa.gov/sites/default/files/2020-11/documents/appb-2.pdf

C.2.3 Manufacturing

It was considered unlikely that the 'manufacturing' land use would feature significant emission sources, and it was therefore excluded from the modelling for the SAP.

C.2.4 Interim hazardous uses

It was considered unlikely that the 'interim hazardous uses' land use would feature significant emission sources, and it was therefore excluded from the modelling for the SAP.

C.2.5 Circular economy (landfill)

The 'circular economy' land use was characterised as the existing NSC landfill plus a proposed landfill[14].

The proposed landfill was modelled using line-volume sources for dust and odour. The proxy facility was taken to be Melbourne Regional Landfill (PEL 2016)[15]. In the AQIA, PEL modelled odour and TSP. For all sources, the 'worst case' scenario from the AQIA was selected.

For odour, the emission flux from PEL (2016) was converted to an odour emission rate for the Narrabri SAP based on the assumed area for the circular economy land use. The modelled activities included the active landfill face (assumed area of 1,000 m^2), intermediate covered cells (assumed areas for daily cap 1,000 m^2 and established cover 100,000 m^2) and leachate ponds (assumed area of 500 m^2). It was assumed that future cells would have some controls. In line with PEL (2016), it was conservatively assumed that the odour emissions from the intermediate established covered cells would be reduced by 50%, allowing for landfill gas capture, while some of the area would not have effective capture. It was also assumed that active tipping emissions would only occur between 6:00 am and 6:00 pm.

For PM_{10}, the emission rates from PEL (2016) for all dust sources were summated. These sources included excavators, trucks, wind erosion, haul roads and combustion. The emission rate for $PM_{2.5}$ was assumed to be 10% of that for PM_{10}, based on the USEPA's AP-42[16].

The emission source characteristics for the SAP modelling are given in Table C.5.

Table C.5 Emissions data – circular economy and existing landfill

Parameter	Odour sources (landfill existing and future)	All dust sources
Odour emission rate (ou.m^3/s)	11,480	-
PM_{10} emission rate (g/s)	-	0.532
$PM_{2.5}$ emission rate (g/s)	-	0.0532

14 Circular economy uses could also include recycling. If the use is recycling rather than landfill, then the air quality and odour impacts should be lower than those presented in this report.

15 The Melbourne landfill receives 780,000 t/year of municipal solid waste.

16 https://www3.epa.gov/ttnchie1/conference/ei15/session14/cowherd.pdf

C.2.6 Waste management and recycling

The 'waste management and recycling' land use of the Narrabri SAP was treated as a volume source.

The proxy facility was assumed to be the Girraween Resource Recovery Facility, the data for which were taken from the AQIA by EMM (2019). The emissions rates for PM_{10} and $PM_{2.5}$ (in g/s) for all activities at the proxy facility were applied to the Narrabri SAP. The activities included delivery, loading and unloading of waste, screening and transfer. EMM (2019) also modelled odour for green waste at Girraween. However, this was excluded from the Narrabri SAP modelling as the SAP description does not include green waste.

The emission source characteristics for the SAP modelling are given in Table C.6.

Table C.6 Emissions data – waste management and recycling

Parameter	All dust sources
PM_{10} emission rate (g/s)	0.034
$PM_{2.5}$ emission rate (g/s)	0.011

C.3 New land uses in the Structure Plan for the SAP (Stage 2)

C.3.1 Grain production

Emission sources in the 'grain production' land use in Stage 2 of the Narrabri SAP were characterised using the same assumptions as those used for grain processing in Stage 1.

C.3.2 Fertiliser and chemicals

It was assumed that this land use would incorporate several different facilities, as outlined below.

i Ammonium nitrate plant

Perdaman has a Memorandum of Understanding (MoU) with NSC to develop an ammonia-based derivative manufacturing plant within SAP. The manufacturing plant will use low-emissions technology and be capable of supplying product to domestic and international markets.

Emissions from ammonium nitrate production typically include particulate matter (mainly as ammonium nitrate itself), ammonia and nitric acid. Emission rates are dependent on specific plant operating characteristics. The ammonium nitrate plant in the SAP was characterised using a combination of a point source (stack) and a line-volume source (hauling), and the proxy facility was taken to be the ammonium nitrate plant at Kooragang Island (URS 2012). The AQIA contained data for multiple stacks, from which total annualised emission rates for NO_X and PM_{10} were extracted and adopted for the Narrabri SAP. A $PM_{2.5}$ emission rate was also derived from the PM_{10} emission rate using a ratio[17] based on the USEPA's AP-42 generalised particle size distribution for 'Category 9 - Condensation, Hydration, Absorption, Prilling, and Distillation'[18]. For all hauling activities in the AQIA, the NO_X and PM_{10} emission rates were summated.

The emission source characteristics for the SAP modelling are given in Table C.7.

[17] $PM_{2.5}$ = 83% of PM_{10} (based on ratios to TSP).

[18] https://www.epa.gov/sites/default/files/2020-11/documents/appb-2.pdf

Table C.7 Emissions data – ammonium nitrate plant

Parameter	Point source (stack)	Line-volume source (all)
Stack height (m)	43.7	-
Stack diameter (m)	1.6	-
Stack temp (°C)	236.0	-
Exit velocity (m/s)	19.1	-
NO_X emission rate (g/s)	2.638	0.012
PM_{10} emission rate (g/s)	0.369	0.243
$PM_{2.5}$ emission rate (g/s)	0.306	0.024

It was assumed that the ammonium nitrate plant would be located at the northern end of the corresponding land use zone (fertiliser and chemicals) of the SAP.

ii Sodium bicarbonate plant

In the absence of a proxy facility, emission intensity factors for sodium carbonate production from the USEPA AP-42 (Pacific Environmental Services 1993) were adopted. Emissions associated with a plant fitted with an electrostatic precipitator were adopted. In the absence of stack emission parameters, equivalent parameters from the ammonia nitrate plant assumptions were adopted.

Table C.8 Emissions data – sodium bicarbonate plant

Parameter	Point source (stack)
Stack height (m)	43.7
Stack diameter (m)	1.6
Stack temp (°C)	236.0
Exit velocity (m/s)	19.1
NO_X emission rate (g/s)	3.60
PM_{10} emission rate (g/s)	13.27
$PM_{2.5}$ emission rate (g/s)	11.00

iii Methanol plant

In the modelling, methanol production was characterised using a point source, and the proxy facility was taken to be a methanol complex on the Burrup Peninsula (WA EPA 2002). A 'normal operation' scenario from the corresponding AQIA was used, rather than a worst-case scenario that represented start-up and emergency conditions.

WA EPA provided data for multiple individual stacks. For the Narrabri SAP, the (dominant) flue gas stack was taken to represent stack parameters but using the total NO_X emission rate across all stacks.

The emission source characteristics for the SAP modelling are given in Table C.9.

Table C.9 Emissions data – methanol plant

Parameter	Flue gas stack
Stack height (m)	35
Stack diameter (m)	3.7
Stack temp (°C)	160
Exit velocity (m/s)	20
NO_X emission rate (g/s)	28.048

C.3.3 Solar power

It was considered unlikely that the solar power land use would feature significant emission sources, and it was therefore excluded from the modelling for the SAP.

C.3.4 Bioproducts

In the modelling, the bioproducts land use of the Narrabri SAP was allocated to biodiesel production, with odour being characterised using point and area sources. The proxy facility was the Wagga Wagga Biodiesel Plant, with data being taken from the odour impact assessment by The Odour Unit (2008). The activities included in the odour impact assessment were oil seed crushing, meal blending, solvent extraction (all point sources) and a storage dam (area source). For the Narrabri SAP a single, representative stack was used to characterise the point sources in the odour impact assessment, with the emission rates being summated.

The emission source characteristics for the SAP modelling are given in Table C.10.

Table C.10 Emissions data – bioproducts (biodiesel)

Parameter	Point source (stack)	Area source (storage dam)
Stack height (m)	20.3	-
Stack diameter (m)	3.7	-
Stack temp (°C)	38.3	-
Exit velocity (m/s)	15	-
Odour emission rate (ou.m3/s)	150,000	-
Odour emission rate (ou.m^3/m^2/s)	-	0.119

C.3.5 Energy (gas power generation)

The proxy facility for gas power generation was the Newcastle Power Station (ERM 2019), which was comparable in capacity (250 MW) to the working assumption for the SAP.

In the SAP, the power station was modelled as single stack which combined the emission rates from the ERM study. The emission source characteristics for the SAP modelling are given in Table C.11.

Table C.11 Emissions data – energy (gas power generation)

Parameter	Point source (stack)
Stack height (m)	20.0
Stack diameter (m)	5.6
Stack temp (°C)	679
Exit velocity (m/s)	60
NO_X emission rate (g/s)	33.2
PM_{10} emission rate (g/s)	4.184
$PM_{2.5}$ emission rate (g/s)	4.184

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