APPENDIX

L

Air Quality Technical Report

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

ARTC

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Inland Rail North Star to NSW/QLD Border

Appendix L: Air Quality Technical Report

Australian Rail Track Corporation

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Abbreviations

Abbreviation	Explanation
µm	micrometre
AOI	area of influence
AQIA	air quality impact assessment
ARTC	Australian Rail Track Corporation Ltd
ATMS	Advanced Train Management Systems
B2G	NSW/QLD Border to Gowrie Inland Rail project
BoM	Bureau of Meteorology
CALMET	A diagnostic three-dimensional meteorological model, which provides input for the CALPUFF model.
CALPUFF	CALPUFF is an advanced non-steady-state air quality modelling system developed in the US.
CEMP	Construction Environmental Management Plan
CIA	cumulative impact assessment
CO	carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPIE	NSW Department of Planning, Industry and Environment
ENSO	El Niño-Southern Oscillation
EPA	Environment Protection Authority
IARC	International Agency for Research on Cancer
Inland Rail	Melbourne to Brisbane Inland Rail
ISCA	Infrastructure Sustainability Council of Australia
km	kilometres
m	metre
MEI	Multivariate ENSO Index
NO	nitrogen oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
N2SB	North Star to NSW/QLD border Inland Rail project
N2NS	Narrabri to North Star Inland Rail project
NSW	New South Wales
O_3	ozone
OEH	NSW Office of Environment and Heritage (former division of NSW Government, replaced by DPIE)
OEMP	Operational Environmental Management Plan
ONI	Oceanic Niño Index
PAHs	polycyclic aromatic hydrocarbons
PM_{10}	particulate matter less than 10 micrometers
$PM_{2.5}$	particulate matter less than 2.5 micrometers
POEO Act	Protection of the Environment Operations Act 1997
QLD	Queensland
SOI	Southern Oscillation Index
the proponent	Australian Rail Track Corporation Ltd
US EPA	US Environmental Protection Agency
VOCs	volatile organic compounds

Executive summary

Future Freight Joint Venture (FFJV) was engaged by Australian Rail Track Corporation Ltd (ARTC) to prepare an Environmental Impact Statement (EIS) for the North Star to NSW/QLD border section of Inland Rail (the proposal).

The proponent is seeking approval to construct and operate the proposal, which consists of approximately 25 km of upgraded track between North Star and a greenfield deviation around Whalan Creek, and 5 km of new track between Whalan Creek and the NSW/QLD border. The proposal is a key component of the wider Inland Rail network between Melbourne and Brisbane.

Key elements of the air quality impact assessment included:

- Desktop review, including review of other studies in the area, relevant legislation, historical meteorological data, and ambient air quality monitoring data
- Generation of study area specific meteorology
- Qualitative discussion of potential air quality impacts during construction activities
- Air quality dispersion modelling of the operation
- Impact assessment and mitigation.

For the operational phase of the Project, in order to quantify the emissions for diesel locomotives, an emissions inventory was developed. The key pollutants of interest included in the emissions inventory for diesel locomotives oxides of nitrogen (NO_x), particulates less than 10 micrometres (PM_{10}), particulates less than 2.5 micrometres ($PM_{2.5}$) and total suspended particulates (TSP).

A modelling assessment was completed based upon methodologies and guidance presented in Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016) and Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the Approved Methods for Modelling and Assessment in New South Wales (Barclay and Scire 2011). As no Bureau of Meteorology (BoM) monitoring stations were located within the model domain for the proposal site, meteorological data was derived in accordance with the aforementioned guidance from The Air Pollution Model (TAPM) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (CSIRO 2008) was utilised in the assessment. Dispersion modelling of pollutants was then completed utilising CALPUFF, with meteorology refined using CALMET. The predicted air quality concentrations were compared to proposal-specific air quality goals prescribed by Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016).

A survey of sensitive receptors adjacent to the proposal site has been conducted. Dispersion modelling carried out for the proposal concludes that forecast concentrations are predicted to be lower than the proposal goals at all identified sensitive receptor locations.

During the detailed phase of construction planning a Construction Environment Management Plan (CEMP) will be developed. A list of recommended construction mitigation measures to be considered when working in close proximity to sensitive receptors has been provided for incorporation into the CEMP. During the construction phase of the Project dust sources will be variable in magnitude and intensity and the potential risk of impact will vary with the proximity of construction activity to sensitive receptors. The construction mitigation measures included in the CEMP need to address this variability.

1 Introduction

Future Freight Joint Venture (FFJV) was engaged by Australian Rail Track Corporation Ltd (ARTC) to prepare an Environmental Impact Statement (EIS) for the North Star to NSW/QLD border section of Inland Rail (the proposal).

To support the EIS, an air quality impact assessment (AQIA) has been prepared to determine whether construction and operation of the proposal are likely to comply with the relevant ambient air quality standards and goals in NSW. The report outlines the current regulatory system relevant to air quality management, the baseline air quality and meteorological conditions in the area, and the methodology used to carry out an assessment of the air quality. Air quality mitigation measures and strategies are also provided where relevant. This technical report will accompany the air quality chapter presented within the EIS for the proposal.

The proposal is one of 13 projects making up the 1,700 kilometre (km) Inland Rail as presented in Figure 1.1. The proposal is a new rail corridor approximately 30 km in length that connects to the Narrabri to North Star (N2NS) project in the south and the NSW/QLD Border to Gowrie (B2G) project to the north.

Figure 1.1 Inland Rail location map

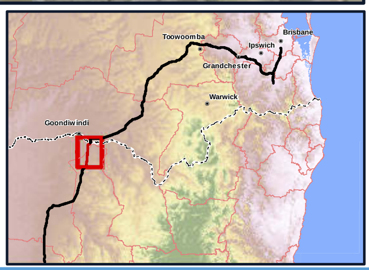
The proposal will involve constructing a new rail line in the existing non-operational rail corridor towards Boggabilla and then across the Macintyre River before joining the existing rail line in Queensland. The study area commences approximately 1.5 km north of North Star and continues to the NSW/QLD Border. Figure 1.2 presents the proposal site.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: <mxd author> Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201906051626_Air_Quality_Assessment\270-EAP-201906051626_Fig1.2_NS2B_Alignment_ARTC_v2.mxd Date: 11/11/2019 11:19

Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border



A4 scale: 1:170,000

0 1 2 3 4 5 km

Future Freight
Integrating Community, Environment and Engineering

Date: 23/10/2019 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

Figure 1.2:
North Star to border section of Inland Rail

1.1 Assessment scope

An AQIA has been prepared to ensure emissions along the rail corridor are understood and any potential impacts on sensitive receptors along the proposal site have been considered.

The scope of the AQIA included the following:

- An assessment of air quality impacts based upon peak train movements for the year 2040
- An analysis of the expected construction and operational activities from an air quality perspective
- Identification of relevant ambient air quality objectives
- Discussion of existing air quality based on available NSW Department of Planning, Industry and Environment (DPIE) data
- Discussion of local meteorology and climate conditions based on available BoM data
- Identification of potential sources of air emissions from surrounding land uses
- A qualitative risk assessment of particulate emissions from construction works
- A quantitative dispersion modelling assessment of operational emissions associated with freight rail movements
- Review of the potential for cumulative air quality impacts
- Recommendation of potential mitigation measures and assessment of the residual impact with the inclusion of the recommended mitigation measures.

The AQIA has been prepared with consideration given to the following guidelines:

- Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA 2016). This document was generally referenced as a source of factors needing to be considered when assessing air quality projects.
- Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the Approved Methods for Modelling and Assessment in New South Wales (Barclay and Scire 2011). This document provides guidance on settings and methodologies for modelling utilising CALPUFF.
- Guidance on the assessment of dust from demolition and construction, United Kingdom (UK) Institute of Air Quality Management (IAQM) (UK IAQM 2014). This document provides a qualitative risk assessment process for the potential impact of dust generated from demolition, earthmoving and construction activities.

1.1.1 Secretary's environmental assessment requirements

This report has been prepared to address the SEARs as shown in Table 1.1.

Table 1.1 Secretary's environmental assessment requirements compliance

Desired performance outcome	**12. Air quality** The project is designed, constructed and operated in a manner that minimises air quality impacts (including nuisance dust and odour) to minimise risks to human health and the environment to the greatest extent practicable.
Current guideline	Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC 2005) Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DEC 2005) Technical Framework - Assessment and Management of Odour from Stationary Sources in NSW (DEC 2006)
SEARs requirement	**EIS Section**
1. The Proponent must undertake an air quality impact assessment (AQIA) for the establishment and operation of the borrow sites and road haulage in accordance with the current guidelines, with a particular focus on dust emissions, including $PM_{2.5}$ and PM_{10}.	Section 6

2. The Proponent must ensure the AQIA also includes the following:	
(a) Demonstrated ability to comply with the relevant regulatory framework specifically the Protection of the Environment Operations Act 1997 and the Protection of the Environment Operations (Clean Air) Regulation (2010); and	Section 6 and 7
(b) A cumulative local and regional air quality impact assessment.	Section 8

1.2 Report structure

The structure of this technical report is as presented in Table 1.2.

Table 1.2 Report structure

Content	Reference
Introduction	Section 1
Proposal description	Section 2
Relevant legislation	Section 3
Existing environment	Section 4
Assessment methodology	Section 5
Construction impact assessment	Section 6
Operation impact assessment	Section 7
Cumulative risk impact assessment	Section 8
Mitigation and management measures	Section 9
Sustainability	Section 10
Conclusion	Section 11
References	Section 12
Meteorological data	Appendix A
Dispersion model details	Appendix B

2 Proposal description

2.1 Overview

The proponent is seeking approval to construct and operate the NS2B section of Inland Rail. The proposal consists of approximately 25 km of upgraded track between North Star and a greenfield deviation around Whalan Creek, and 5 km of new track between Whalan Creek and the NSW/QLD border. The proposal is a key component of the wider Inland Rail network between Melbourne and Brisbane.

The key components to the proposal include:

- Single track dual gauge rail line with one crossing loop to ultimately accommodate trains up 3,600 m long based on business needs, but initially constructed for 1,800 m long train sets
- Bridges to accommodate topography and proposal crossings of waterways and other infrastructure including one major rail crossing the Macintyre River
- The construction of associated rail infrastructure including a maintenance siding and signalling infrastructure to support the Advanced Train Management Systems (ATMS)
- Rail crossings including level crossings, grade separations/road overbridges, occupational/private crossings, fauna crossing structures
- Ancillary works including road and public utility crossings and realignments
- Construction workspace, access roads, and borrow pits.

Subject to approval of the proposal, construction of the proposal is planned to occur between 2021 and 2025. The proposal will be managed and maintained by ARTC; however, train services will be provided by a variety of operators. Trains will be double stacked (up to 6.5 m high) and operate on a 24/7 basis. Train services are not expected to commence until all 13 sections of Inland Rail are complete, which is planned to be in 2025.

The proposal will be trafficked by an estimated 14 trains per day in 2025, increasing to an estimated 21 trains per day in 2040. Annual freight tonnages will increase in parallel, from approximately 12 million tonnes per year in 2025 to 20 million tonnes per year in 2040.

2.2 Construction

It has been assumed that the following activities will occur during the construction of the proposal:

- Site preparation including site clearance, establishment of site compounds and facilities, installation of temporary and permanent fencing, installation of drainage and water management controls, borrow pits and construction of site access including temporary haul roads
- Civil works including bulk earthworks, construction of cuts and embankments, installation of permanent drainage controls, bridge and watercourse crossing construction, and borrow pits
- Track works including the installation of ballast, sleepers and rails
- Rail systems infrastructure and wayside equipment including signals, turnouts and asset monitoring infrastructure
- Commissioning, integration testing and handover process to achieve operational readiness.

A construction workers camp is proposed at the locality of North Star, which is less than 1 km from the closest section of the proposal.

2.3 Operation

The following train and wagon information in Table 2.1, Table 2.2, and Table 2.3 has been used as a basis for the impact assessment.

Table 2.1 Locomotive data

Train description	Locomotives	Maximum wagons length (m)	Maximum train speed (km/hr)
Express freight	NR Class (3)	1750	115
Super freighter	SCT Class (2)	1750	115
Grain, cotton, and livestock	Class 82 and 2300 Class (2, 3)[a.]	1750	80
Coal	PR22L (3)	990	100
Passenger	XPT (2)	120	80

Table note:

a Locomotive configuration dependant on wagon payload

Source: ARTC Phase 2 Interim Operational Modelling Report

Table 2.2 Locomotive specifications

Feature	NR Class	SCT/LDP	Class 82
Manufacturer	UGL/GE	Downer EDI	Downer EDI/EMD
Prime Mover	7FDL16	GTA46C-ACe	12-710G3AJWC
US EPA Emissions Standard	Tier 0	Tier 1	Tier 0
Rated Max Power (kW)	2917	3350	2425

Source: ARTC Phase 2 Interim Operational Modelling Report

Table 2.3 2040 Peak weekly train movements for the proposal

Train type/description	NS2B				End destination – Acacia Ridge	End destination – Bromelton
	# of trains per week	NR Class	SCT Class	Class 82		
MB Express (Bromelton)	14	x	-	-	-	x
MB Express (Acacia Ridge)	14	x	-	-	x	-
GB Superfreighter (Bromelton)	22	-	x	-	-	x
GB Superfreighter (Acacia Ridge)	10	-	x	-	x	-
MB Superfreighter (Bromelton)	40	-	x	-	-	x
MB Superfreighter (Acacia Ridge)	8	-	x	-	x	-
Narrabri – Fishermans Island Export (CONT) (POB)	12	-	-	x	x	-

Source: ARTC Phase 2 Interim Operational Modelling Report

One new crossing loop for the NS2B alignment is proposed. The loop would be constructed as new sections of track parallel to the existing track. They range in length to accommodate the surrounding area and topography and fit the design length of the train (1,800 m). Table 2.4 presents the crossing loop start and end chainage locations. These chainage locations represent the initial planned crossing loops prior to the extension to provide capacity for 3,600 m long trains. Should the location of the crossing loop change significantly, further assessment may be required.

Table 2.4 Crossing loop chainage locations

Crossing loop	Phase	Start chainage (km)	End chainage (km)
Boonal	Initial	22.700	24.900

Source: 30 per cent Feasibility Design Report NS2B

2.4 Proposal air emissions

Pollutants of potential concern to the proposal have been identified through a review of expected activities, applicable National Pollution Inventory (NPI) emission estimation manuals, and EIS literature for similar rail projects.

The primary source of air pollution during the operation of the proposal will be locomotive engine exhaust. The gaseous pollutants contained in the exhaust are produced as a product of diesel combustion and include (oxides of nitrogen (NO_x) including nitrogen dioxide (NO_2), carbon monoxide (CO), fine particulate matter (PM_{10} and $PM_{2.5}$), volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs).

During the construction phase, particulate matter deposited as total suspended particulates (TSP) and airborne concentrations of PM_{10} will be of primary concern. These pollutants have the potential for nuisance impacts if not correctly managed (UK IAQM 2014). In addition to construction dust, odour and VOCs will be emitted from fuel tanks located at laydown areas.

A brief discussion regarding these pollutants and their potential effects on health and the environment follows.

2.4.1 Particulate matter

Airborne particles are commonly differentiated according to size based on their equivalent aerodynamic diameter. TSP refer to airborne particles, generally up to 100 micrometers (µm) in diameter. TSP is primarily associated with aesthetic impacts associated with coarse particles settling on surfaces, which also causes soiling and discolouration. These large particles can, however, cause some irritation of mucosal membranes, which pose a greater risk to health when ingested if they are contaminated. Particles with diameters less than or equal to 10 µm (known as PM_{10}) can be created through crushing and grinding of rocks and soil, and typically comprise soot, dirt, mould and pollen. These particles tend to remain suspended in the air for longer periods than larger particles (minutes or hours) and can penetrate human lungs. Fine particulates (those with diameters less than or equal to 2.5 µm, known as $PM_{2.5}$) are typically generated from vehicle exhaust, bushfires, and some industrial activities and can remain suspended in the air for days or weeks. As these fine particulates can travel further into human lungs than the larger particulates and are often made up of heavy metals and carcinogens, fine particulates are considered to pose a greater risk to health.

Exposure to particulate matter has been linked to a variety of adverse health effects, such as respiratory problems (for example coughing, aggravated asthma, chronic bronchitis), lung damage and non-fatal heart attacks. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from inhalation of the dust.

TSP, PM_{10} and $PM_{2.5}$ have been considered in detail in this assessment.

2.4.2 Nitrogen oxides

Nitrogen dioxide (NO_2) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide (NO). The mixture of these two gases is commonly referred to as NO_x. Nitrogen oxides are a product of combustion processes. In urban areas, motor vehicles and industrial combustion processes are the major sources of ambient nitrogen oxides. Nitrogen dioxide can cause damage to the human respiratory tract, increasing a person's susceptibility to respiratory infections and asthma. Sensitive populations, such as the elderly, children, and people with pre-existing health conditions are most susceptible to the adverse effects of NO_2 exposure. NO_2 can also cause damage to plants, especially in the presence of other pollutants such as ozone and SO_2. Nitrogen oxides are also primary ingredients in the reactions that lead to photochemical smog formation.

NO_2 has been considered in detail in this assessment.

2.4.3 Carbon monoxide

CO is a colourless, odourless gas produced by the incomplete combustion of fuels containing carbon (e.g. oil, gas, coal and wood). Carbon monoxide is absorbed through the lungs of humans, where it reacts to reduce the blood's oxygen-carrying capacity. In urban areas, motor vehicles account for up to 90 per cent of all CO emissions.

Concentrations of CO normally present in the atmosphere are unlikely to cause ill effects and therefore have not been considered in detail in the assessment. Further discussion of anticipated emissions of CO is provided in Section 5.3.1.

2.4.4 Sulphur dioxide

SO_2 is a colourless gas with a sharp, irritating odour. It is formed in combustion processes through burning fossil fuels containing sulfur. SO_2 may be oxidised in the atmosphere to form sulfuric acid, which contributes to acid rain. SO_2 is also an irritant gas that can cause respiratory tract infections. People with pre-existing respiratory conditions such as asthma are most sensitive to SO_2 exposure. The simultaneous presence of airborne particulate matter can compound these effects. SO_2 and its aerosols can also damage vegetation and some materials.

The regulation of low sulphur content fuel in Australia has significantly decreased the generation and concentrations of SO_2 near transport sources. Due to the low likelihood of significant impact, SO_2 has not been considered in detail this assessment. Further discussion of anticipated emissions of SO_2 is provided in Section 5.3.1.

2.4.5 Volatile organic compounds

Organic compounds with a vapour pressure at 20°C exceeding 0.13 kilopascals are referred to as volatile organic compounds (VOCs). VOCs can be a major precursor in the production of photochemical smog, which causes atmospheric haze, eye irritation, and respiratory problems. VOCs are commonly emitted from vehicle exhausts. Three primary VOCs (benzene, toluene and xylenes) are components of petroleum and diesel fuel and are typically the focus for assessments of engine combustion emissions.

Benzene, toluene and xylene have been considered in detail in this assessment.

2.4.5.1 Benzene

Benzene is an airborne substance that is a precursor to photochemical smog. Benzene exposure commonly occurs through inhalation of air containing the substance. It can also enter the body through the skin, although it is poorly absorbed this way. Low levels of benzene exposure result from car exhaust. Benzene is considered to be a toxic health hazard and a carcinogen. It has high acute toxic effects on aquatic life and long-term effects on marine life and agricultural crops. Human exposure to very high levels for even brief periods of time can potentially result in death, while lower level exposure can cause skin and eye irritation, drowsiness, dizziness, headaches and vomiting, damage to the immune system, leukaemia and birth defects.

2.4.5.2 Toluene

Toluene (methylbenzene) is a highly volatile chemical that quickly evaporates to a gas if released as a liquid. Due to relatively fast degradation, toluene emissions are usually confined to the local area in which it is emitted. Human exposure typically occurs through breathing contaminated air, but toluene can also be ingested or absorbed through the skin (in liquid form). Toluene usually leaves the body within twelve hours.

Short-term exposure to high levels of toluene can cause dizziness, sleepiness, unconsciousness and sometimes death. Long-term exposure can cause kidney damage and permanent brain damage that can lead to speech, vision and hearing problems, as well as loss of muscle and memory functions. The substance can cause membrane damage in plant leaves and is moderately toxic to aquatic life with long-term exposure.

2.4.5.3 Xylenes

Xylenes are flammable liquids that are moderately soluble in water. They are quickly degraded by sunlight when released to air, and rapidly evaporate when released to soil or water. They are used as solvents and in petrol and chemical manufacturing.

Xylenes can enter the body through inhalation or skin absorption (liquid form), and can cause irritation of the eyes and nose, stomach problems, memory and concentration problems, nausea and dizziness. High-level exposure can cause death. The substances have high acute and chronic toxicity to aquatic life and can adversely affect crops.

2.4.6 Polycyclic aromatic hydrocarbons

PAHs are a group of over 100 chemicals, which are formed through the incomplete combustion of organic materials, such as petrol. Exposure to these chemicals can cause a range of adverse reactions, including irritation of the eyes, nose and throat and skin. Exposure to very high levels can result in symptoms such as headaches, nausea, damage to the liver and kidneys, and damage to red blood cells. A number of PAHs were declared to be probable or possible carcinogens to humans by the International Agency for Research on Cancer (IARC).

PAHs can attach to dust particles and be transported through the air. The compounds break down over days or weeks through chemical reactions in the atmosphere.

PAHs are moderately or highly acutely toxic to birds and aquatic organisms and moderately/highly chronic toxicity to aquatic life. Some of these compounds are known to cause damage and death to crops. PAHs can bioaccumulate, and are moderately persistent in the environment.

PAHs have been considered in detail in the assessment.

2.4.7 Dioxins

Dioxins form part of a group of chemicals known as persistent organic compounds, which are of concern due to their highly toxic potential. Exposure in the long terms can cause cancer, and impairment of the endocrine, immune, and reproductive systems. Dioxins can bioaccumulate within animals in the environment and tends to accumulate in fat.

Emissions of dioxins will occur as a result of fuel combustion in trains, motor vehicles and mobile plant. An inventory of dioxin emission sources in Australia in 2002 was prepared by the Department of the Environment and Heritage (DEH 2004). The inventory determined that transport was a minor source of dioxins, contributing less than 2 per cent of total emissions.

Based on the rural location of the proposal it is expected that existing background concentrations of dioxins will be low, and therefore a background concentration of zero has been assumed for the assessment. It is considered unlikely that emissions from the proposal have the potential to result in significant impacts or exceedance of the relevant air quality objectives for dioxins.

2.4.8 Trace metals

Heavy metals such as cadmium, lead, and mercury are common air pollutants that are typically emitted from industrial activities and fuel combustion. Exposure to heavy metals can result in a range of health impacts, including kidney and bone damage, developmental and neurobehavioral disorders, elevated blood pressure and potentially even lung cancer.

Very minor emissions of trace metals will occur as a result of fuel combustion in trains, motor vehicles and mobile plant. As such, cumulative concentrations of trace metals at sensitive locations are expected to be well below relevant air quality objectives.

Trace metal species have been considered in detail in the assessment.

2.4.9 Ozone

Ozone is not emitted directly from fuel combustion, but rather is a secondary pollutant formed via chemical reaction of other pollutant species (primarily NO_X and VOCs) in the local atmosphere.

Ozone is a short-term lung irritant, affects lung function and can worsen asthma. Short term exposure to ozone can cause difficulty in breathing, coughing, and throat irritation if exercising outdoors when ozone levels are high.

Assessment of the formation of ozone and other secondary pollutants has not been considered in this assessment.

2.4.10 Odour

Odour emissions can be either a single compound or a mixture of compounds that have the potential to affect environmental amenity and cause nuisance. Potential sources of odour from the proposal include wastewater odour and odour from fuel storage tanks.

Portable toilet facilities will be located along the alignment during construction for workers. A suitably qualified contractor will be engaged for the removal and transport of the sewage to an approved off-site treatment facility. Odour impacts from portable toilet facilities are not expected to be significant and have not been considered further.

Odour emissions from fuel storage tanks are discussed specifically in Section 6.2.

3 Legislation, policies, standards and guidelines

Air quality in NSW is governed through the *Protection of the Environment Operations Act 1997* (NSW) (POEO Act) and its associated regulations. The POEO Act sets the regulatory framework for managing air quality and setting environment protection licences for scheduled development work and scheduled activities (premise-based and not-premise based) to control emissions to air. The POEO Act is supported by the Protection of the Environment Operations (General) Regulation 2009, which provides the administration of the licencing scheme and the economic incentives for reducing pollution.

In addition to the POEO Act and the Protection of the Environment Operation (General) Regulation 2009, there are two additional pieces of air quality related legislation. These legislative instruments are as follows:

- The NSW Protection of the Environment Operations (Clean Air) Regulation 2010 – this legislation contains provisions for the regulation of a variety of areas including motor vehicles and fuels
- National Environment Protection (Ambient Air Quality) Measure – this legislation is federal legislation which sets standards for six major air pollutants in Australia. This legislation is not commonly used to assess the performance of individual projects.

Statutory methods for assessing air quality in NSW are governed by Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016), which lists statutory methods for modelling and assessing air pollutants from non-moving sources such as chimneys and industrial machinery.

Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016) sets out detailed requirements for the assessment of projects in NSW, and in particular outlines the requirements for selection and use of meteorology, receptor selection and location, emissions estimation and the criteria against which the modelled pollutants are compared to assess compliance.

3.1 Air quality objectives for the proposal

The air quality objectives and guidelines values sourced from the guidance document, Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016) are shown in Table 3.1 and have been applied as the proposed air quality objectives for the proposal.

Table 3.1 Proposed air quality objectives

Pollutant	Air quality objective (µg/m^3)	Averaging period	Statistic
1,3-butadiene	40	1 hour	99.9th percentile
Arsenic and compounds	0.09	1 hour	99.9th percentile
Benzene	29	1 hour	99.9th percentile
Cadmium and compounds	0.018	1 hour	99.9th percentile
Chromium and compounds	0.09	1 hour	99.9th percentile
Chromium (III) compounds	9	1 hour	99.9th percentile
CO	30,000	1 hour	Maximum
	10,000	8 hours	Maximum
Dioxins and furans	2.0×10^{-06}	1 hour	99.9th percentile
NO_2	246	1 hour	Maximum
	62	Annual	Maximum
Lead	0.5	Annual	Average
PM_{10}	50	24 hours	Maximum
	25	Annual	Average

Pollutant	Air quality objective (µg/m^3)	Averaging period	Statistic
$PM_{2.5}$	25	24 hours	Maximum
	8	Annual	Average
Polycyclic aromatic hydrocarbon (as benzo[a]pyrene)	0.04	1 hour	99.9th percentile
SO_2	570	1 hour	Maximum
	228	24 hours	Maximum
	57	Annual	Average
TSP	90	Annual	Average
Zinc oxide	90	1 hour	99.9th percentile

Source: NSW EPA 2016

4 Existing environment

4.1 Background air quality

The existing environment has the potential to influence the level of air pollutants adjacent to a particular site. Aspects of the ambient environment relevant to this assessment include:

- Existing air quality due to regional and local sources of air pollution (natural and anthropogenic) that emit similar air pollutants as those being assessed
- Nearby sensitive receptor locations
- Meteorological conditions
- Terrain and land use.

The following sections describe the existing environment of the study area.

4.1.1 Monitoring data availability

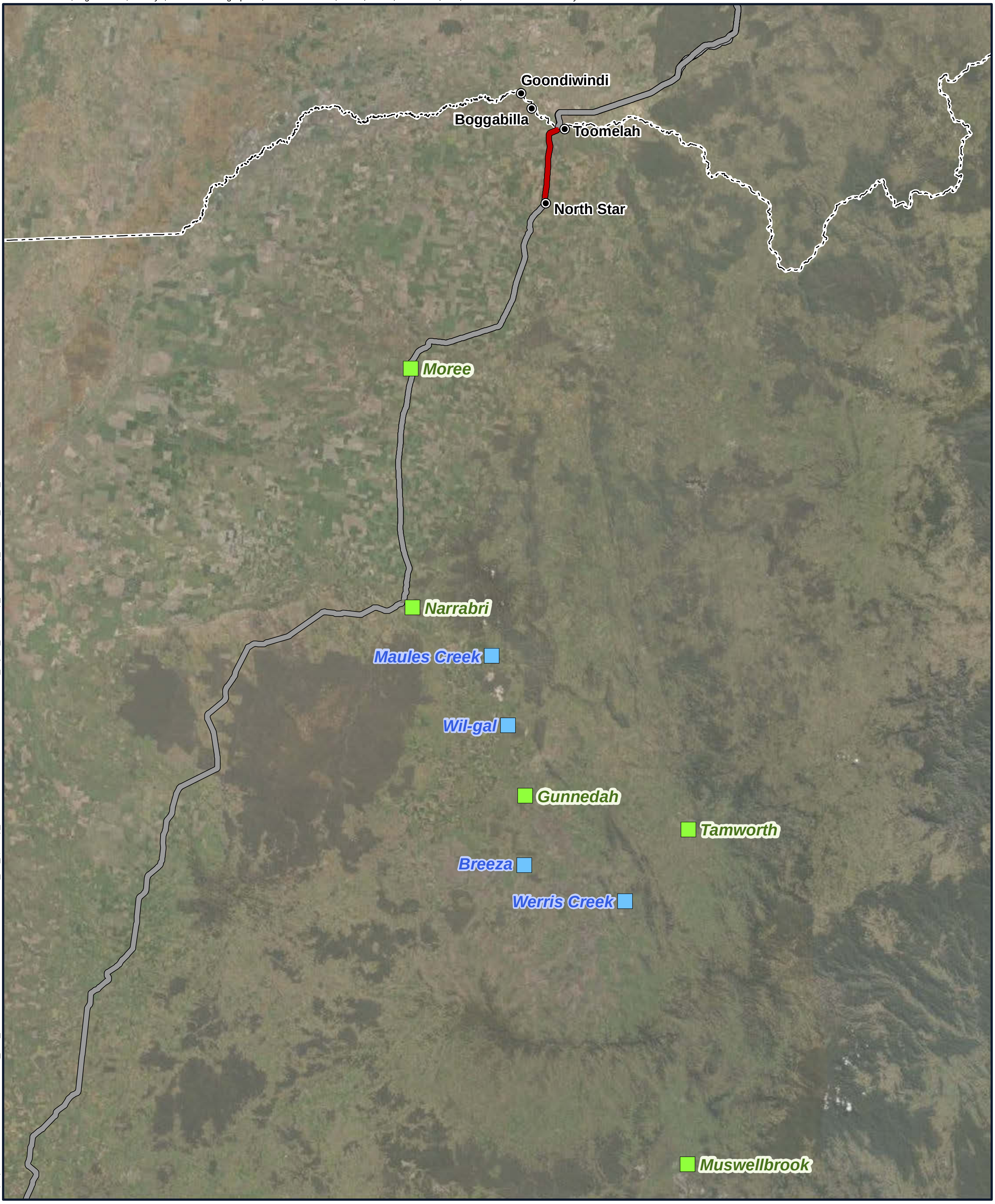
The DPIE (formerly the Office of Environment and Heritage, OEH) monitors air quality at a range of locations throughout the state each year and assesses those concentrations against the impact assessment criteria outlined in Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016). The air quality objectives that are linked to the impact assessment criteria are set at levels that are designed to protect beneficial uses, including human health and wellbeing, visibility, aesthetic enjoyment and local amenity. The goals in the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016) specify the maximum permissible number of exceedances of the objectives per year and guide the formulation of strategies for the management of human activities that may affect the environment.

The ambient data collected by DPIE monitoring stations captures pollutants from both anthropogenic (industry, motor vehicles, domestic sources such as fires, construction) and natural (bushfires, dust storms, pollen, marine particles) sources. A variety of pollutants are present in air monitoring data from each source; the contribution of each source varies depending on the monitoring stations location, sources of pollution in the surrounding environment and meteorological conditions.

The closest DPIE monitoring stations to the proposal site are situated in Gunnedah, Narrabri, and Moree (refer Figure 4.1). However, these stations are limited by the monitoring techniques utilised and the amount of available data. Additionally, not all pollutants are measured at each station with limited monitoring data available from many of the stations (many of which have only recently been commissioned). As such, monitoring data from a variety of stations is required to be utilised for the assessment of air quality for the proposal.

The pollutant species monitored at each DPIE station and the commissioning date for each station is presented in Table 4.1. In addition, two industry operated monitoring stations, located at Maules Creek and Wil-gai have been included for analysis of ambient air quality in the region.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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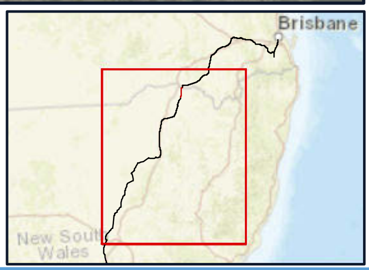
Legend

- Localities
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border

Air Quality monitoring locations

- Industry monitoring location
- OEH monitoring location



A4 scale: 1:2,000,000

0 10 20 30 40 50 km

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Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

Figure 4.1: Air Quality monitoring locations

Table 4.1 Air quality monitoring stations and pollutants monitored

Monitoring station	Station operated by	Commissioned	Pollutant species monitored				Meteorology
			PM_{10}	$PM_{2.5}$	TSP	NO_2	
Gunnedah (SE)[a.]	DPIE	2003	**x**	**x**	**x**	-	-
Gunnedah	DPIE	2017 (December)	**x**	**x**	-	**x**	**x**
Moree [a.]	DPIE	2008	-	-	**x**	-	-
Muswellbrook	DPIE	2010	**x**	**x**	-	**x**	**x**
Tamworth	DPIE	2000	**x**	**x**	-	-	**x**
Maules Creek	Industry	2011	**x**	**x**	-	-	-
Wil-gai	Industry	2012	**x**	**x**	-	-	-
Narrabri	DPIE	2017 (December)	**x**	**x**	-	-	**x**

Table notes:

a Pollutant monitoring completed at these stations utilise "indicative" non-compliance methodologies and are not appropriate for use in this air quality assessment.

"**x**" indicates that the pollutant species is monitored at this station, "-" indicates that the pollutant species is not monitored.

All of the pollutants listed above are emitted from diesel trains and will need to be considered cumulatively with the background pollutant concentrations as required by Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016).

4.1.2 Particulate matter

Given the limited data sets available for the Gunnedah and Narrabri locations, data from monitoring stations located at Tamworth, Maules Creek and Wil-gai has been used to define the background particulate concentrations for the proposal. The monitoring stations at Maules Creek and Wil-gai are operated by local industry, however, the monitoring data has been provided to DPIE (Todoroski Air Sciences 2017a; 2017b; 2017c). The Maules Creek and Wil-gai monitoring locations are located closer to the proposal location than the Tamworth station, but are located near several active open cut coal mines.

4.1.2.1 PM_{10}

PM_{10} data for the Tamworth DPIE monitoring station for the years 2013 to 2018, and Maules Creek and Wil-gai for 2015 to 2017 has been examined for this assessment. Monitoring data for PM_{10} for these stations is presented in Table 4.2 to Table 4.4.

The measured PM_{10} concentrations at each of the stations is plotted in Figure 4.2.

Table 4.2 Tamworth DPIE monitoring location ambient PM10 concentrations for 2013 to 2018

Statistic	PM_{10} concentration ($\mu g/m^3$)					
	2013	2014	2015	2016	2017	2018
Maximum 24 hour concentration	47.5	66.6	52.7	68.9	54.1	145.4
24 hour objective	50					
24 hour exceedance count	0	1	1	1	2	9
Highest 24 hour concentration below objective	47.5	39.2	48.0	37.1	39.6	47.4
Annual average	16.6	15.8	14.1	15.3	15.3	20.3
Annual average objective	25					

Table 4.3 Maules Creek ambient PM_{10} concentrations for July 2015 to May 2017

Statistic	PM_{10} concentration (µg/m³)		
	2015[a.]	2016	2017[a.]
Maximum 24 hour concentration	29.2	62.8	52.5
24 hour objective	50		
24 hour exceedance count	0	1	1
Highest 24 hour concentration below objective	29.2	37.6	34.7
Annual average	16.3	9.0	9.6
Annual average objective	25		

Table note:

a Monitoring data for 2015 and 2017 represent data availability of less than 50 per cent of their representative monitoring years.

Table 4.4 Wil-gai ambient PM_{10} concentrations for July 2015 to May 2017

Statistic	PM_{10} concentration (µg/m³)		
	2015[a.]	2016	2017[a.]
Maximum 24 hour concentration	37.4	49.5	41.8
24 hour objective	50		
24 hour exceedance count	0	0	0
Highest 24 hour concentration below objective	37.4	38.9[b.]	41.8
Annual average	8.0	11.0	14.3
Annual average objective	25		

Table notes:

a Monitoring data for 2015 and 2017 represent data availability of less than 50 per cent of their representative monitoring years.

b Highest recorded PM_{10} concentration for the year of 2016 represents 99 per cent of the compliance objective, the next highest recorded concentration 24 hour average PM_{10} was 38.9 µg/m³.

The Tamworth PM_{10} monitoring data (refer Table 4.2) shows exceedances of the 24 hour average objective (50 µg/m³) for each year between 2014 and 2018, with 2013 representing the only year without an exceedance of the compliance objective. The highest number of exceedances of the 24 hour average objective occurred in 2018, with a total of nine exceedances recorded.

The industry operated station at Maules Creek (refer Table 4.3) recorded one exceedance of the 24 hour average objective in 2016 and one exceedance in 2017. However, monitoring in 2017 was only undertaken for part of the year (until May 2017). The highest measured 24 hour concentration at Maules Creek was 62.8 µg/m³ in 2016. This exceedance was likely attributable to a localised dust event, as it was not observed at the nearby Tamworth monitoring station and wind conditions at the time make it unlikely to be resultant from nearby mining activity (Todoroski Air Sciences 2017c).

The industry operated station at Wil-gai (refer Table 4.4) did not recorded any exceedances of the 24 hour average objective from 2015 to 2017.

Annual PM_{10} average values were below the annual objective of 25 µg/m³ for all years at both the Maules Creek and Wil-gai stations.

In NSW the DPIE reviews air quality data measured by their network of monitoring stations, which includes information on compliance with the objectives and probable causes of any reported exceedances. The OEH Annual Air Quality Statements (OEH 2015; 2016; 2017; 2018) indicated that the exceedances in all years were due to exceptional events, which are defined as events related to bushfires, hazard reduction burns, and dust storms. It is not unusual for exceedances of the PM_{10} objective to occur due to anthropogenic and natural causes.

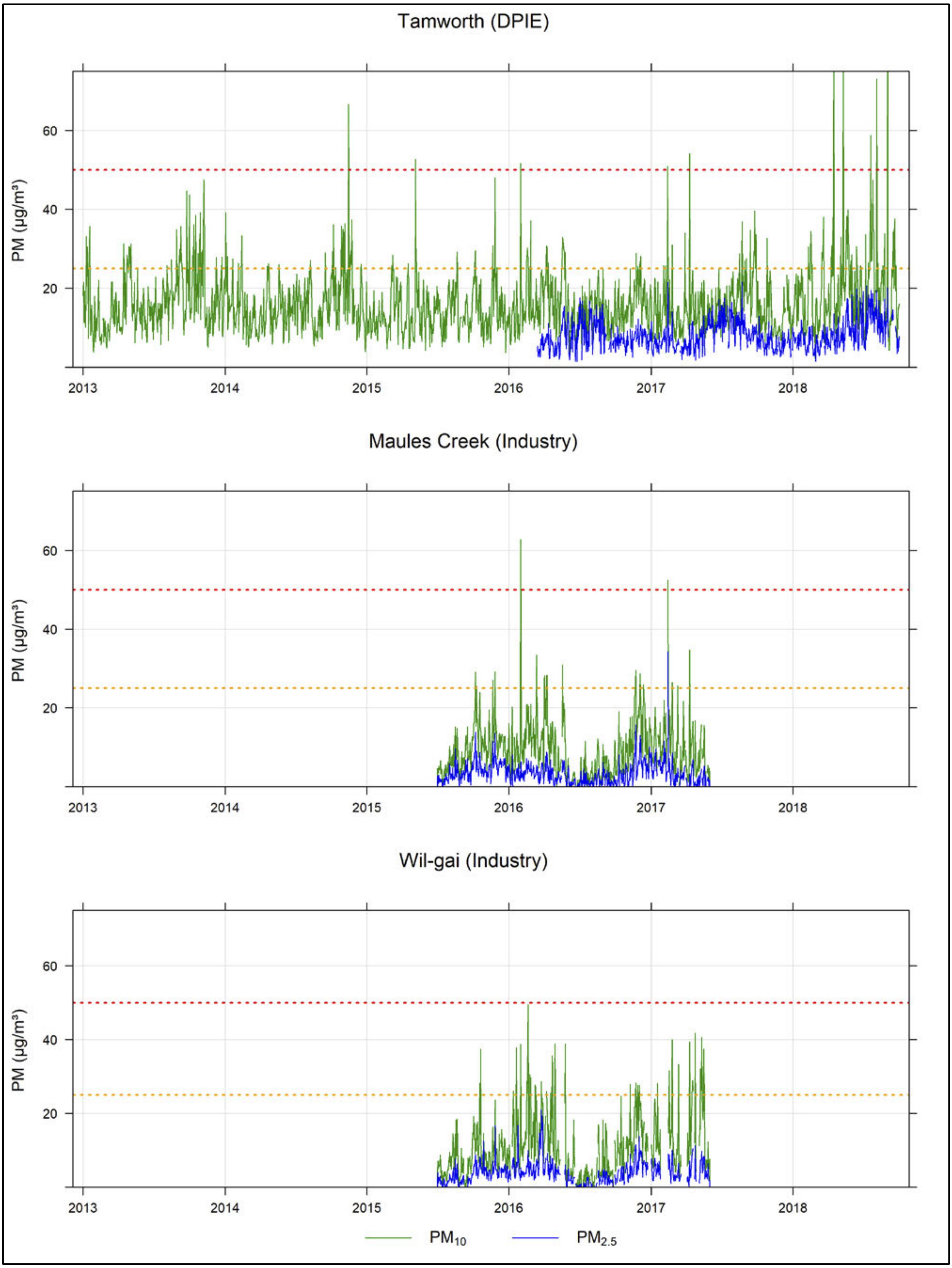


Figure 4.2 **Tamworth DPIE monitoring location ambient PM_{10} and $PM_{2.5}$ concentrations (2013 to 2018)**

The OEH 2018 NSW Annual Air Quality Statement stated the following regarding particle pollution in 2018:

"Particle pollution (PM_{10} and $PM_{2.5}$) increased due to more frequent exceptional events, such as dust storms, bushfires and hazard reduction burning. In 2018, there were 51 days where exceptional events led to poor air quality (compared with 18 days in 2017). In 2018:

- *25 days were affected by dust storms in 2018 (three days in 2017).*
- *26 days were affected by bushfires or hazard reduction burning (15 days in 2017)."*

Based on the increased number of exceptional events in 2018, monitoring data from this year for Tamworth has not been considered for use in the assessment as it is considered an atypical year.

The Maules Creek and Wil-gai monitoring locations are located closer to the proposal location and generally surrounded by similar land-uses. However, several open cut coal mines are located near these monitoring stations. The open cut mines are a source of PM_{10} not present near the proposal and therefore it is considered likely that measured PM_{10} concentrations at Maules Creek and Wil-gai will be higher than those observed in the study area. Therefore, the monitoring data from Tamworth is considered more appropriate for the assessment of PM_{10}.

4.1.2.2 $PM_{2.5}$

$PM_{2.5}$ data for the Tamworth DPIE monitoring station for the years 2016 to 2018, and Maules Creek and Wil-gai for 2015 to 2017 has been examined for this assessment. Monitoring data for $PM_{2.5}$ for these stations is presented in Table 4.5 to Table 4.7.

The measured PM_{10} concentrations at each of the stations is plotted in Figure 4.2.

Table 4.5 Tamworth ambient $PM_{2.5}$ concentrations for 2016 to 2018

Statistic	$PM_{2.5}$ concentration (µg/m^3)		
	2016	2017	2018
Maximum 24 hour concentration	17.6	21.6	24.2
24 hour objective	25		
24 hour exceedance count	0	0	0
Annual average	7.6	7.8	9.2
Annual average objective	8		

Table 4.6 Maules Creek ambient $PM_{2.5}$ concentrations for July 2015 to May 2017

Statistic	$PM_{2.5}$ concentration (µg/m^3)		
	2015[a.]	2016	2017[a.]
Maximum 24 hour concentration	13.9	15.7	34.3
24 hour objective	25		
24 hour exceedance count	0	0	2
Highest concentration below objective	13.9	15.7	11.3
Annual average	4.0	2.9	3.3
Annual average objective	8		

Table note:

a Monitoring data for 2015 and 2017 represent data availability of less than 50 per cent of their representative monitoring years.

Table 4.7 Wil-gai industry monitoring location ambient $PM_{2.5}$ concentrations for July 2015 to May 2017

Statistic	$PM_{2.5}$ concentration (µg/m^3)		
	2015[a.]	2016	2017[a.]
Maximum 24 hour concentration	16.6	21.0	11.3
24 hour objective	25		
24 hour exceedance count	0	0	0
Highest concentration below objective	16.6	21.0	11.3
Annual average	3.2	3.8	4.5
Annual average objective	8		

Table note:

a Monitoring data for 2015 and 2017 represent data availability of less than 50 per cent of their representative monitoring years.

Table 4.5 shows that the measured annual average $PM_{2.5}$ concentration at Tamworth in 2018 (9.2 µg/m^3) exceeded the annual objective (8.0 µg/m^3). As discussed for PM_{10}, 2018 is considered an atypical year due to the increased number of extreme events in this year. The measured annual average concentrations in 2016 (7.6 µg/m^3) and 2017 (7.8 µg/m^3) were below the annual objective, but represented 95 per cent and 98 per cent of the objective respectively.

The Tamworth monitoring data shows no exceedances of the 24 hour objectives for either of the three monitoring years.

Figure 4.2 shows that peak $PM_{2.5}$ concentrations occur in the middle of the year during winter. A likely source of these peak concentrations is from wood smoke coupled with temperature inversions due to local terrain and cooler winter temperatures. This is a common situation observed in reasonably populated regions of inland Australia utilising wood heating and where local terrain and cooler temperatures cause temperature inversions; thus, trapping wood smoke emissions close to the surface (Todd 2015; Todd, et al. 2015). It is expected that these conditions will not be present in the study area due to the flat terrain and lower population density. Therefore these measured $PM_{2.5}$ concentrations are considered to be higher than would be expected in the study area.

Monitoring data from the Maules Creek and Wil-gai monitoring stations (refer Table 4.6 and Table 4.7) demonstrates compliance with annual objective for 2016, which represents the only complete year of monitoring.

The 24 hour average $PM_{2.5}$ objective was exceeded twice in 2017 at the Maules Creek station, but was not exceeded at the Wil-gai station. Todoroski Air Sciences (2017a) attributes the exceedances are the Maules Creek station to bush fire smoke plumes, which were observed from satellite imagery for the region on 12 and 13 February 2017 (the dates the exceedances occurred).

4.1.2.3 TSP

Compliant monitoring of TSP is not undertaken at any of the monitoring stations considered in the assessment. As such, TSP was estimated from the measured annual PM_{10} using a ratio of 2.5, which is based on a PM_{10}:TSP ratio of 0.4 as reported by the Australian Coal Association Research Program (ACARP 1999). This is considered a conservative estimate and is likely an over estimation of the actual TSP present. However, this is a common ratio for dust and is considered appropriate in the absence of recently monitored data.

4.1.3 Nitrogen oxides

Very limited local monitoring data is available for NO_2 in the northern NSW region. The closest monitoring station with available long-term monitoring data is the Muswellbrook DPIE station (approximately 370 km to the south of the proposal site). The closest monitoring station to the proposal site is located at Gunnedah, approximately 220 km to the south of the proposal site, but this station only started monitoring in March 2018. Data has been extracted from these two stations with the results shown in Table 4.8 and Figure 4.3.

Table 4.8 Muswellbrook and Gunnedah DPIE ambient NO_2 concentrations

Statistic	NO_2 concentration ($\mu g/m^3$)						
	Muswellbrook						Gunnedah
	2013	2014	2015	2016	2017	2018	2018
Maximum 1 hour concentration	51.3	73.3	79.0	79.0	84.6	88.4	64.0
1 hour objective	246						
1 hour exceedance count	0	0	0	0	0	0	0
Annual average	15.4	17.9	16.3	16.2	19.0	19.9	10.3
Annual average objective	62						

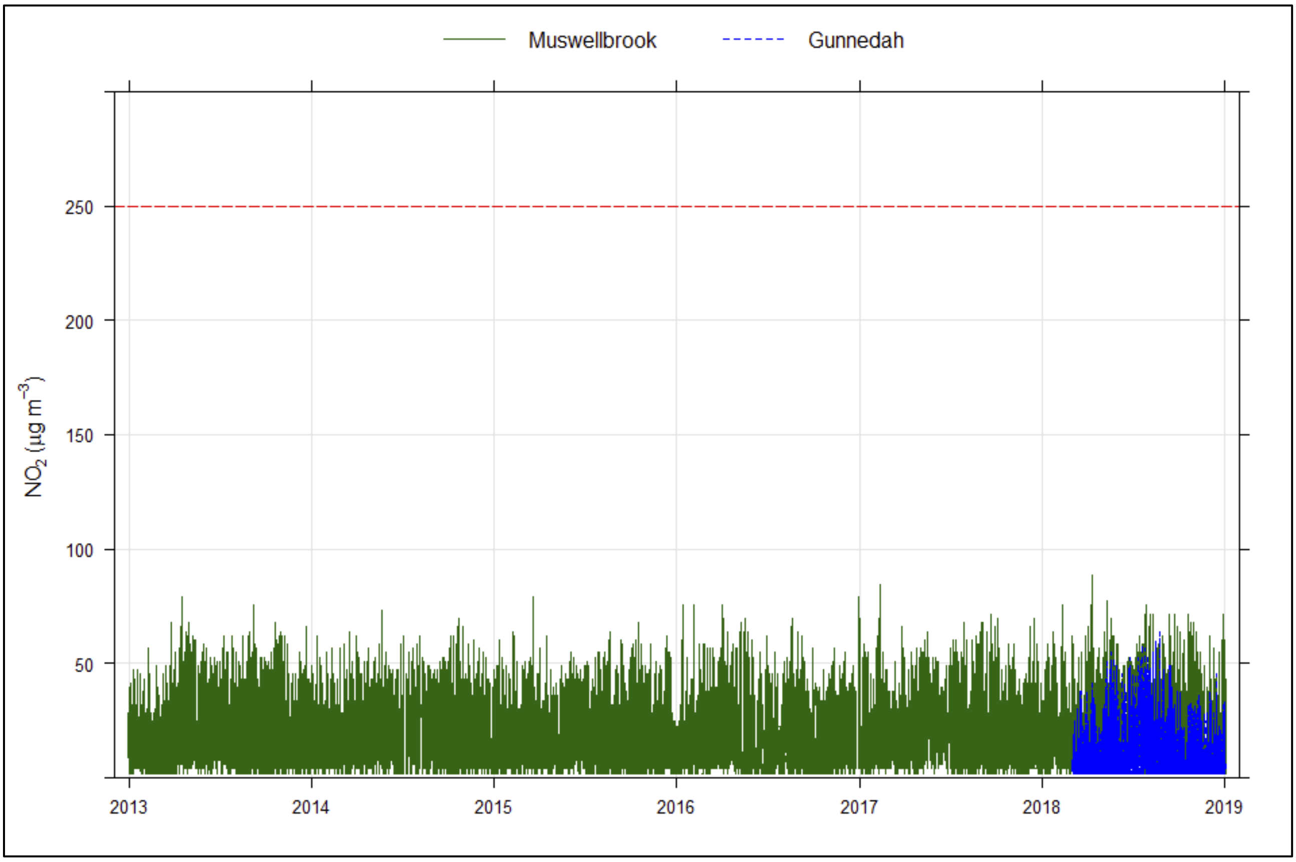


Figure 4.3 Muswellbrook and Gunnedah DPIE monitoring locations ambient NO2 concentrations (2013 to 2018)

The monitoring data shows no exceedances of the 1 hour (246 $\mu g/m^3$) or annual average (62 $\mu g/m^3$) objectives for all monitoring years examined. Available data from the Gunnedah monitoring station is generally consistent with recorded concentrations at the Muswellbrook location.

4.1.4 Volatile organic compounds

Assessment of cumulative VOC species is not required by NSW EPA unless there are significant known emissions of VOC in the area surrounding a proposed activity. Given the lack of VOC sources along the NS2B route, background VOC concentrations have been assumed to be negligible and have not been considered cumulatively.

4.1.5 Metals, dioxins and PAHs

There is no ambient monitoring data for metals, dioxins or PAHs which is available for the assessment. There are no significant sources of these pollutant species along the NS2B route and therefore concentrations have been assumed to be negligible and have not been considered cumulatively.

4.1.6 Summary of existing pollutant concentrations

The background pollutant concentrations adopted for this assessment to determine the cumulative impacts are been presented in Table 4.9.

As discussed in Section 5.2, a contemporaneous Level 2 assessment following the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016) has been undertaken for PM_{10} and NO_2 whereby hourly measured concentrations from Tamworth (PM_{10}) and Muswellbrook (NO_2) monitoring stations for 2013 have been added to the model predicted hourly concentrations. The background concentrations presented in Table 4.9 for PM_{10} and NO_2 are not used specifically but are provided for completeness.

Table 4.9 Adopted background air quality pollutant concentrations

Pollutant	Average period	Units	Adopted concentration	Objective	DPIE monitoring station data
TSP	Annual average	µg/m^3	41.5	90	Calculated from Tamworth PM_{10} (2013)
PM_{10}	24 hour	µg/m^3	47.5[a]	50	Tamworth (2013)
	Annual average	µg/m^3	16.6[a]	25	Tamworth (2013)
$PM_{2.5}$	24 hour	µg/m^3	21.0	25	Wil-gai (2016)
	Annual average	µg/m^3	3.8	8	Wil-gai (2016)
NO_2	1 hour average	µg/m^3	51.3[a]	246	Muswellbrook (2013)
	Annual average	µg/m^3	15.4[a]	62	Muswellbrook (2013)

Table note:

a A contemporaneous Level 2 assessment has been undertaken for PM_{10} and NO_2 as discussed in Section 5.2.

4.2 Climate and meteorology

The BoM operates a monitoring network in Australia with long-term data and statistics available for the majority of stations. The BoM station that best represents the study area is located at Moree, approximately 80 km to the south of the proposal. Selected long-term regional meteorological data were obtained from the Moree AERO BoM monitoring station; a summary is provided in the following sections. Average climate parameters recorded at this station are shown in Appendix A.

From review of the Moree AERO BoM monitoring data, the following key statistics were identified:

- The warmest temperatures occur between November and March, with the warmest average maximum temperatures occurring in January (34.0°C)
- The coldest temperatures are recorded in the winter months, with the lowest average minimum temperature occurring in July (4.5°C)
- The highest average rainfall is recorded in January (81.0 mm), while April is the driest month (23.4 mm)
- Humidity in the area is relatively low, with recorded levels typically between 30 and 70 per cent
- Wind speeds are typically higher at 3.00 pm compared to 9.00 am.

The long-term wind rose diagrams for the Moree monitoring station are shown in Appendix A. The wind roses show the frequency of occurrence of winds by direction and strength. The bar at the top of each wind rose diagram represents winds blowing from the north (i.e. northerly winds). The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds.

Winds recorded at Moree at 9.00 am blow predominantly from the northwest at an average wind speed of 4.8 m/s (17.4 km/h). In the afternoons, recorded 3.00 pm winds blow predominantly from the north and southwest with an average wind speed of 4.6 m/s (16.5 km/h).

4.2.1 El Niño–Southern Oscillation

For Australia, the El Niño-Southern Oscillation (ENSO) has the strongest effect on year to year climate variability in Australia, mostly affecting rainfall and temperature. El Niño incidences represent periods of unusually warm Pacific Ocean conditions along the western coast of South America, which frequently present as high rainfall events in South America and drought conditions for Australia. Conversely, La Niña periods represent cooler ocean surface temperatures along the western coast of South America and increase the likelihood of drought conditions locally and high rainfall periods in Australia.

The Southern Oscillation Index (SOI), Oceanic Niño Index (ONI), and Multivariate ENSO Index (MEI) are measures that can indicate episodes of El Niño and La Niña. Due to differences in methodology each of these aforementioned indices can have slightly differing results. However, utilising the SOI, ONI, and MEI measures for ENSO, agreeance can be seen on which years represent periods of El Niño or La Niña. The three indices show that the year 2013 was relatively neutral and represents a period that would be impacted minimally from climate variability caused by ENSO. Appendix B includes further detail on the analysis of the ENSO measurement indices.

4.3 Terrain and land use

Terrain features and land use can influence meteorological conditions on both a local and regional scale. For the study area, the terrain is primarily flat with elevations that range from 250 to 200 m above sea level. To the southeast (~40 km) of the study area exist some areas of elevated terrain in Dthinna Dthinnawan National Park where elevations reach 400 m above sea level. Land uses in the study area are dominated by agriculture. Along the Macintyre River and associated tributaries are areas of bushland. Several large irrigation dams are also present in the northern section of the study area.

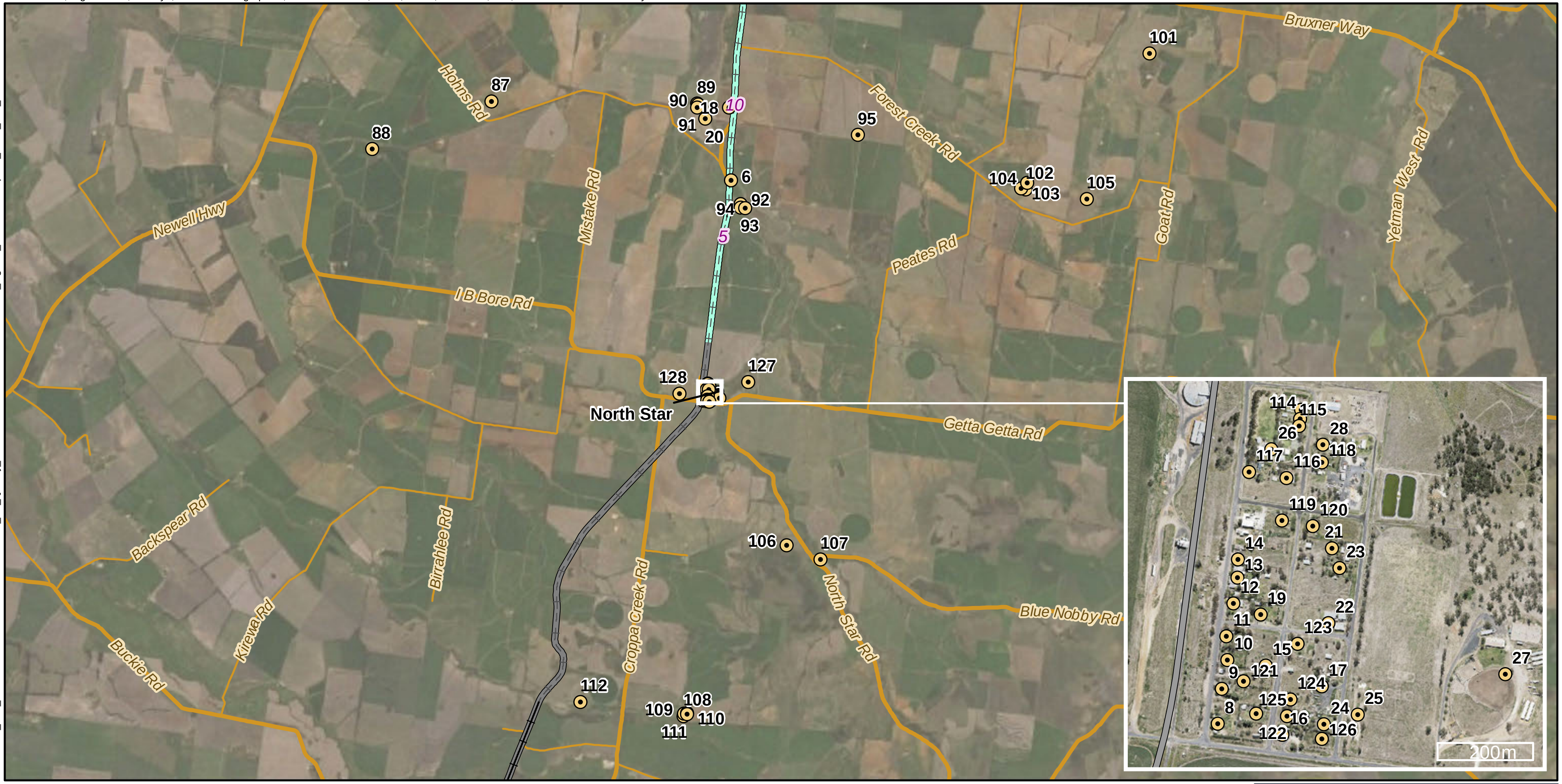
4.4 Sensitive receptors

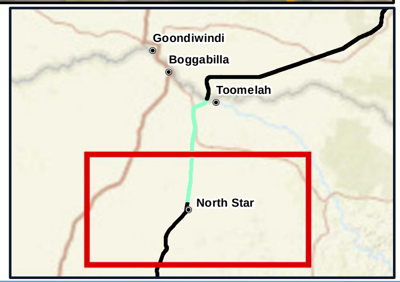
The NSW EPA defines sensitive receptors to be areas where people are likely to either live or work, or engage in recreational activities or may be reasonably expected to do so in the future (EPA 2016). There are a small number of residential receptor locations spread along the length of the proposal site, with several sensitive receptors concentrated within the locality of North Star.

A total of 128 sensitive receptor locations were identified and included in the assessment of operational air quality impacts, with the location of these receptors presented in Figure 4.4. The sensitive receptors were identified via a desktop review and no field verification was undertaken. The 128 sensitive receptor locations included in the assessment of operational impacts were chosen as they represent the receptors with the highest potential to be impacted by the proposal.

The methodology used for the assessment of construction dust impacts considers the total number of sensitive receptors near construction emission sources and the distance to these sources. One construction workers accommodation camp is included in the construction phase of the proposal, with this camp to be located at laydown area CMP000.1 which is located at the southern extent of the proposal site in North Star, to the east of Wilby Street and the north of North Star Road. This accommodation use will be present during the construction phase of the proposal and therefore the construction air quality assessment considered a total of 129 receptors.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community





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Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

A4 scale: 1:225,000

0 2 4 6 8 10 km

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Date: 12/02/2020 Version: 5
Coordinate system: MGA56

North Star to NSW/QLD border
Figure 4.4a:
Sensitive receptor locations

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: RB/GN Date: 12/02/2020 13:23
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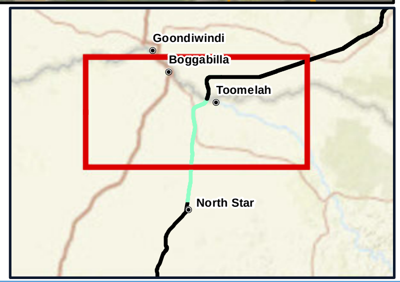
Legend

⊙	Sensitive receptors		North Star to NSW/QLD border alignment
5	Chainage (km)		Adjoining alignments
◉	Localities		Major roads
	Existing rail (operational)		Minor roads
	Existing rail (non-operational)		NSW/QLD border



A4 scale: 1:225,000

0 2 4 6 8 10 km

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Coordinate system: MGA56

North Star to NSW/QLD border
Figure 4.4b: Sensitive receptor locations

5 Assessment methodology

The air quality assessment methodology for the construction and operation of the proposal included the following key elements:

- Desktop review to include the following:
  - Identify potential sources of air emissions for the proposal
  - Identify pollutants of interest for the proposal
  - Identify and review of relevant air quality legislation and regulatory framework
  - Description of the existing environment in the study area, in terms of meteorology and ambient air quality
- Undertake the impact assessment for the construction to estimate potential air quality impacts
- Undertake the impact assessment for the operation to estimate potential air quality impacts
- Review the potential for cumulative air quality impacts
- Recommend potential migration measures where appropriate.

These elements are explained in more detail below.

5.1 Construction air quality assessment

The main pollutant of concern during the construction phase is particulates, predominantly dust as PM_{10}.

In absence of NSW or Australian specific assessment guidance, the assessment methodology used for the construction phase is the 2014 UK IAQM Guidance on the assessment of dust from demolition and construction (UK IAQM 2014). It is noted that NSW EPA provides an Air Quality Guidance Note for Construction Sites (2017), which discusses construction air emission sources, potential impacts and mitigation measures. However, the NSW EPA guidance note does not provide an assessment methodology, and therefore the IAQM assessment methodology has been adopted.

The IAQM process is a four-step risk-based assessment of dust emissions associated with demolition, including land clearing and earth moving, and construction activities. The methodology of the IAQM risk assessment procedure is tailored specifically to the assessment of emissions to air from construction activities and is considered the most appropriate method for the assessment.

The IAQM risk assessment method considers the sensitivity of the study area to air quality impacts based on separation distance and existing air quality, and the potential risk of adverse impacts based on the emissions magnitude of the construction activities. Although written for the UK, the IAQM method is a robust procedure and is suitable for assessment of Australian projects. Where required, the assessment method has been modified to suit local conditions (e.g. assessment against air quality objectives applicable for NSW).

Construction emissions for large linear infrastructure projects are complex due to the number of construction activities, the distribution of sites across a large geographical area, and the transitory nature of many individual construction activities at particular locations. As such, the potential construction air quality impacts associated with the proposal were risk assessed considering the nature of proposed works, plant and equipment, potential emissions sources and relevant air quality objectives.

A breakdown of each step and the associated findings of the dust impact assessment are detailed in Section 6.

In addition to construction dust, odour and VOCs will be emitted from fuel tanks located at laydown areas. Impacts from fuel storage have been assessed qualitatively based on the separation distance to receptors.

In addition to assessment using the IAQM method, construction impacts from crushing and blasting at borrow pits have also been assessed qualitatively considering the Environment Protection Authority Victoria (EPA Victoria) guideline Recommended separation distances for industrial residual air emissions (EPA Victoria 2013), which provides guidance on suitable separation distances between mining and extractive activities and neighbouring sensitive receptors. The EPA Victoria guideline has been used in the absence of NSW specific guidance. The EPA Victoria guideline is commonly applied for air quality assessments in other Australian States and is considered appropriate for the assessment of the proposal.

5.2 Operation air quality assessment

The air dispersion modelling conducted for this assessment was undertaken using the CALPUFF modelling suite with prognostic meteorological data derived from The Air Pollution Model (TAPM). The data available for this assessment and a discussion of the methodologies required to implement CALPUFF are discussed in the following sections.

The assessment method used has followed the levels of assessment prescribed by the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016). The levels of assessment are summarised as follows:

- Level 1: screening-level dispersion modelling technique using worst-case input data
- Level 2: refined dispersion modelling technique using site-specific input data.

The following statement is provided by the EPA to inform the selection of the assessment level:

> *"The impact assessment levels are designed so that the impact estimates from the second level should be more accurate than the first. This means that, for a given facility, the result of a Level 1 impact assessment would be more conservative and less specific than the result of a Level 2 assessment. It is not intended that an assessment should routinely progress through the two levels. If air quality impact is considered to be a significant issue, there is no impediment to immediately conducting a Level 2 assessment. Equally, if a Level 1 assessment conclusively demonstrates that adverse impacts will not occur, there is no need to progress to Level 2."*

The assessment of the operational phase of the proposal has been generally undertaken in accordance with the Level 2 assessment method. The methodology is summarised as follows:

- For the assessment of TSP and $PM_{2.5}$, the maximum measured background concentrations (refer Section 4.1) have been assumed as the background (Level 1 assessment method).
- For the assessment of PM_{10} and NO_2, hourly monitoring data for 2013 (which is contemporaneous with the meteorological data used) has been used, with the dispersion model prediction at each receptor added to the corresponding hours measured background concentration (e.g. the first hourly average dispersion model prediction is added to the first hourly average background concentration) to obtain hourly predictions of total impact (Level 2 assessment method).
- Assessment of VOC species and heavy metals have not been considered cumulatively due to the absence of significant known emission sources in the area surrounding the proposed activity.

The flow diagram in Figure 5.1 shows the general process of programs used and the input data required for the dispersion modelling completed.

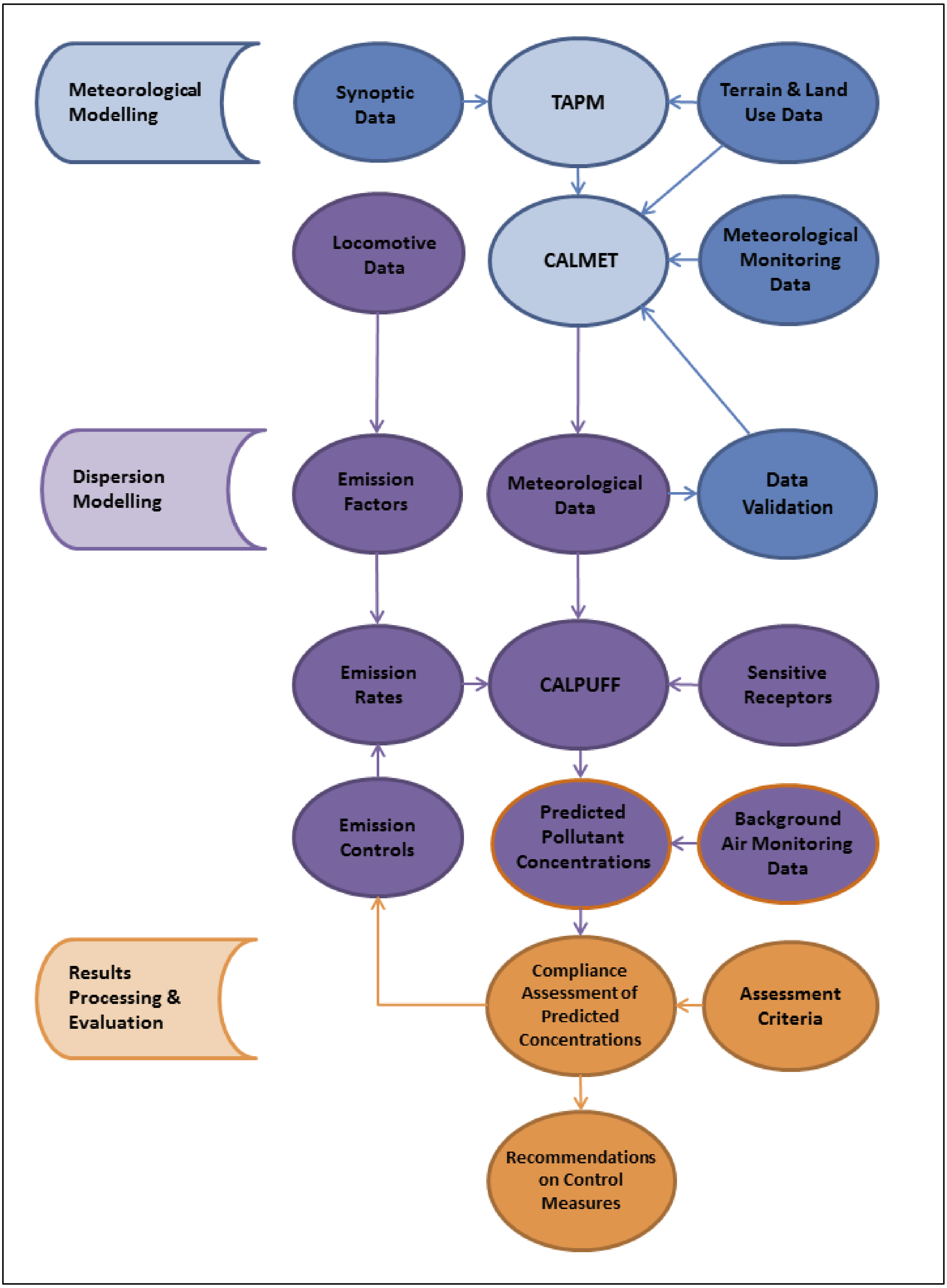


Figure 5.1 Diagrammatic representation of the CALPUFF modelling methodology

5.2.1 Modelling methodology

The selection of the dispersion model for this assessment was undertaken in accordance with the guidelines published in Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA 2016). Details of the modelling inputs and assumptions are provided in the following sections with further details on the dispersion models provided in Appendix B.

5.2.2 TAPM

TAPM is a prognostic meteorological model that incorporates data for terrain, vegetation and soil type, leaf area index, sea-surface temperature, and synoptic-scale meteorological analyses for Australia. TAPM is used to predict meteorological parameters at both ground level and at heights of up to 8,000 m above the surface; these data can be utilised as input into the dispersion model CALPUFF. The TAPM output files require processing through CALTAPM to generate inputs compatible to CALMET, which can then generate the three-dimensional wind fields required by the CALPUFF dispersion model.

The settings used for the TAPM program are provided in Table 5.1.

Table 5.1 The Air Pollution Model settings

Parameter	Setting
TAPM Version	4.0.5
Grid centre coordinates	-28.7749
	150.4083
Date parameters	2013 full calendar year
Number of grid points	nx = 41
	ny = 41
Outer grid spacing	dx1 = 30000 m
	dy1 = 30000 m
Number of grid domains	4
Grid spacing for CALTAPM	Inner most grid (t010a) = 1000m
Number of vertical grid levels	nz = 25
Observation file	Not used

5.2.3 CALMET

CALMET is a meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded modelling domain. Associated two-dimensional fields such as mixing height, surface characteristics and dispersion properties are also included in the file produced by CALMET. CALMET produces a meteorological file that is used within the CALPUFF model to predict the movement of pollution.

The settings in Table 5.2 were specifically selected in order to run CALMET in the 'noobs' mode discussed in Barclay and Scire (2011). Only those parameters that deviate from the program default values or are significant to the AQIA are provided.

Table 5.2 CALMET settings

Parameter	Setting
CALMET version	6.5.0
Grid spacing	0.200 km
Grid size	24 km x 24 km (north and south domains)
# Cells NX	120
# Cells NY	120

Parameter	Setting
Source of land use data	Site-specific creation based on USGS data system
Geo processer used	Used external data in the Geophysical Processer program
Surface and overwater	TAPM prognostic data
Upper air	TAPM prognostic data
Convective mixing height method	Maul-Carson for land and water
Overwater surface flux method	COARSE with no wave parameterisation
Use 3D temperature from	Prognostic data
Surface temperature	Compute internally from 2-D spatially varying
Surface wind vertical extrapolation	Extrapolate using similarity theory and exclude upper air observations from level 1
Wind field guess	Compute internally
Seven critical CALMET parameters	TERRAD = 5

5.2.4 CALPUFF

CALPUFF is a non-steady-state three-dimensional Gaussian puff model developed for the US Environmental Protection Agency (US EPA) and approved by the NSW EPA for use in situations where basic Gaussian plume models are not effective. This can include areas with complex meteorological or topographical conditions, such as areas with a high proportion of calm conditions, coastal areas with re-circulating sea breezes or locations with steep terrain. The CALPUFF model substantially overcomes the basic limitations of the steady-state Gaussian plume models, and as such, was chosen as the most suitable dispersion model for the AQIA. Some examples of applications for which CALPUFF may be suitable include:

- Near-field impacts in complex flow or dispersion situations:
  - Complex terrain
  - Stagnation, inversion, recirculation, and fumigation conditions
  - Overwater transport and coastal conditions
  - Light wind speed and calm wind conditions
- Long range transport
- Visibility assessments and Class I area impact studies
- Criteria pollutant modelling, including application to development applications
- Secondary pollutant formation and particulate matter modelling
- Buoyant area and line sources (e.g. forest fires and aluminium reduction facilities).

As light wind speed and calm wind conditions are expected for the study area, CALPUFF was selected as an appropriate model to complete dispersion modelling for the operation air quality impact assessment. Those parameters that deviate from the program default values or are significant to the AQIA are provided in Table 5.3.

Table 5.3 CALPUFF settings

Parameter	Setting
CALPUFF version	7.2.1
Sampling Grid	6 km x 8 km
Calculation type	Concentration
Chemical transformation method	Not modelled

Parameter	Setting
Dispersion Option	Dispersion coef. Use turbulence computed from micrometeorology
Use PDF method for Sigma-z in the convective BL	On
Puff splitting	No puff splitting
Plume rise method	Briggs
Transitional plume rise	On
Stack tip downwash	On
Partial plume penetration	On
Partial plume penetration (buoyant)	On
Terrain adjustment method	Partial plume path adjustment
Building wake calculation	NA

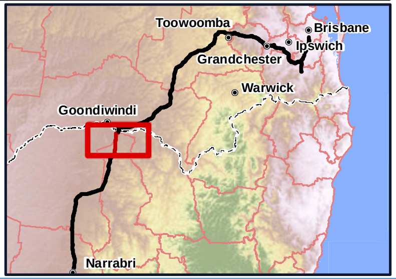
5.2.5 CALPOST

The CALPOST program is used to process the outputs of the CALPUFF program into a format defined by the user. Results can be tabulated for selected options including percentiles, selected days, gridded results or discrete locations, and can be adjusted to account for chemical transformation and background values.

The program default settings were used for the CALPOST program, ensuring that the correct averaging periods, percentiles and receptors were selected to meet the NSW EPA ambient pollutant objectives. CALPOST version 6.292 was used in the assessment.

Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Crossing loops
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border
- CALPUFF model domain



A4 scale: 1:310,000

0 3 6 9 12 15 km

Map by: MF/GN/MEF Date: 19/02/2020 10:23

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North Star to NSW/QLD border

Figure 5.2: Model domains

5.3 Emissions inventory

To quantify the emissions for diesel locomotives, an emissions inventory was developed. The pollutants of interest included in the emissions inventory for diesel locomotives are TSP, PM_{10}, $PM_{2.5}$, NO_x, CO and VOCs. The emissions inventory was based on the engine type, rail traffic quantities and the speed (both in terms of engine emissions).

5.3.1 Diesel locomotive emissions

Emissions factors have been sourced from emissions testing completed on locomotives by the NSW EPA and rated emission standards published by the US EPA (US EPA 2009). Table 5.4 presents the referenced emissions factors on a grams per kilowatt hour basis.

Table 5.4 Locomotive emissions factors

Locomotive	NR Class		SCT/LDP	Class 82
	Cycle weighted	Idling		
Locomotive max power (kW)	2917		3350	2460
Rated emission standard	US EPA – Tier 0		US EPA – Tier 1	US EPA – Tier 0
Total particulates (g/kWhr)	0.8	1.09	0.60	0.8
NO_x (g/kWhr)	12.74	43.7	9.92	12.74
THC (g/kWhr)	1.34	4.66	0.74	1.34
CO (g/kWhr)	6.71	7.63	2.95	6.71
Source	US EPA emissions limits – line haul locomotives	Diesel Locomotive Fuel Efficiency & Emission Testing Report Nov 2016 by ABMARC for NSW EPA (NR121 & 93 Class)	US EPA emissions limits – line haul locomotives	

The NSW EPA testing emissions factors are based on an US EPA emissions testing cycle. The cycle includes periods of locomotive engine idle, dynamic braking, a ramping up of notch settings 1 through 8, and a period of stabilised notch 8. In addition to the referenced cycle weighted emission factors, idle emissions factors have been included for the NR Class locomotives. Idling emissions factors are considerably higher compared to the cycle weighted emissions; however, engine kilowatt-hours for an idling engine are considerably lower than during operation and result in overall lower emissions. As idling emissions factors were not available for the other locomotive type, the NR Class idling emissions factors were utilised for all other locomotive types.

As specific emissions testing results for the other locomotive classes is not available, US EPA emissions standards were utilised in the calculation of emissions rates. The cited emissions standards simply represent a maximum allowable emission rate per kilowatt-hour.

Average hourly power consumption rates were calculated for idling and operating based on the US EPA emissions testing cycle, presented in Table 5.5.

Table 5.5 Locomotive power usage

Power	NR Class	SCT/LDP	Class 82
Idle (kWhr)	6	7	5
Max power (kWhr)	2917	3350	2425
Derived duty cycle (kWhr)	742	852	616

Pollutant diesel combustion emission rates were then calculated utilising the following parameters and assumptions:

- Locomotive type and configuration
- An average of 17 trains per day (ARTC Operational Modelling Report)
- 75 per cent of journey time to include travel time, and the remaining 25 per cent of journey time where the trains are stationary and producing idling emissions (ARTC Operational Modelling Report).

Where emissions factors for specific pollutants of concern were not available, the NPI Emissions Estimation Technique Manual for Railway Yard Operation was utilised (Department of the Environment, Water, Heritage and the Arts 2008). The derived speciation of NPI locomotive emissions factors are presented in Table 5.6.

Table 5.6 NPI locomotive emission factors and speciation

Pollutant	NPI emission factor (kg/kL)	Speciation percentage
Total suspended particulates		
PM_{10}	3.53	97.6 per cent
$PM_{2.5}$	3.39	96 per cent (per cent of PM_{10})
Arsenic and compounds	0.036	1.00 per cent
Cadmium and compounds	0.0034	0.09 per cent
Chromium (III) compounds	0.025	0.69 per cent
Chromium (VI) compounds	0.0109	0.30 per cent
Lead and compounds	0.038	1.05 per cent
Nickel and compounds	0.0034	0.09 per cent
Selenium and compounds	0.0034	0.09 per cent
Zinc and compounds	0.038	1.05 per cent
SO_2	0.0167	0.46 per cent
Total hydrocarbons		
Total VOCs	4.27	100 per cent
Polychlorinated dioxins and furans (TEQ)	8.35×10^{-11}	1.96×10^{-11} per cent
Polycyclic aromatic hydrocarbons (B[a]Peq)	0.0017	0.040 per cent
1,3-Butadiene	0.31	7.3 per cent
Benzene	0.35	8.2 per cent

Table 5.7 presents the maximum travel speeds along the proposal alignment. Class 82 trains speeds were not known at the time of the assessment; however, as they are similar in type and configuration to coal locomotives on the Queensland rail sections and they have been assumed to travel at the same speed.

Table 5.7 Locomotive maximum travel speed

Power	Direction of travel	NR Class	SCT/LDP	Class 82
Maximum line speed (km/hr)	North	115	115	80
	South	115	115	80
Average line speed (km/hr)	North	86	86	60
	South	86	86	60

The derived pollutant locomotive diesel emission rates are presented below in Table 5.8. The locomotive idling emissions rates are also presented, which represent emissions from the proposed crossing loop locations.

Table 5.8 Derived pollutant diesel combustion emission rates

Pollutant	Total NS2B Emissions (g/s)	Total NS2B Idling Emissions (g/s)
NO_x	5.366	0.03556
TSP	0.330	0.00089
PM_{10}	0.322	0.00087
$PM_{2.5}$	0.309	0.00083
CO	2.138	0.00621
Total VOC	0.654	0.00379
SO_2	0.0015	0.0000042

The derived pollutant emission rates for SO_2 are several orders of magnitude less than those calculated for the other pollutants. Historically, regulatory changes had resulted in a reduction in the sulphur content of diesel from 500 ppm to 50 ppm, and then down to 10 ppm in 2009 as specified by the Australian Fuel Standard (Automotive Diesel) Determination 2001. Following the introduction of these low sulphur fuels, emissions of SO_2 in Australia now originate mainly from industries such as coal-fired power generation or smelting of mineral ores. Thus, it is expected that impacts to the surrounding environment from diesel locomotive sulphur emissions to be negligible and have not been considered further in this assessment.

Emission rates of CO were calculated and were found to be less than half of the derived NO_x emissions. The adopted pollutant objective for CO is 10,000 µg/m^3 over an 8-hour period, which when compared to the NO_2 1-hour limit of 250 µg/m^3 is significantly higher, especially so if the CO objective was to be weighted to a 1-hour concentration. Given the large differences between the NO_2 and CO emission rates and objective pollutant concentrations, only a very significant exceedance of NO_2 would also be coupled with an exceedance of the CO objective. Further, background concentrations of CO in NSW are very low with the maximum monitored result at 20 per cent of the NEPM standard, which was recorded in Sydney at the Liverpool DPIE station, in a highly urbanised area (OEH 2019). Therefore, impacts to the nearby surrounding environment from the emissions of CO are expected to be negligible and have not been considered further in this assessment.

5.3.2 Conversion of NO_X to NO_2

Nitrogen oxides are produced in most combustion processes and are formed during the oxidation of nitrogen in fuel and nitrogen in the air. During high-temperature processes, a variety of oxides are formed including NO and NO_2. NO will generally comprise 95 per cent of the volume of NO_X at the point of emission. The remaining NO_X will consist primarily of NO_2. The conversion of NO to NO_2 requires ozone to be present in the air, as ozone is the catalyst for the conversion. Ultimately, however, all NO emitted into the atmosphere is oxidised to NO_2 and then further to other higher oxides of nitrogen.

In this assessment, as a conservative assumption it has been assumed that 100 per cent conversion of NO_x to NO_2 occurs.

5.4 Sustainability

The Inland Rail Sustainability Implementation Framework (ARTC 2017), combined with the Environment and Sustainability Policy (ARTC 2018) provide an overarching vision, objectives, targets and direction for the commitments made by the proposal in relation to sustainability. This includes the pursuit of an Infrastructure Sustainability (IS) rating, implementation of a proposal specific Sustainability Management Plan and proposal specific initiatives. Table 5.9 presents the relevant benchmarks and required evidence for levels 1 to 3 for the Infrastructure Sustainability Council of Australia (ISCA) Dis-4 sustainability goals.

Table 5.9 Dis-4 air quality benchmarks and criteria

	Level 1	Level 2	Level 3
Benchmark	▪ Measures to minimise adverse impacts to local air quality during construction and operation have been identified and implemented. ▪ Monitoring of air emissions and/or air quality is undertaken at appropriate intervals and in response to complaints during construction.	▪ The requirements for Level 1 are achieved. ▪ Monitoring and modelling demonstrates no recurring or major exceedances of air emission or air quality goals.	▪ The requirements for Level 2 are achieved. ▪ Monitoring and modelling demonstrates no exceedances of air emission or air quality goals.
Evidence	▪ Design report, as-built drawings, environmental management plan, asset management plan. ▪ Monitoring reports.	▪ The evidence for Level 1.	▪ The evidence for Level 1.

5.5 Cumulative impact risk assessment

As part of the EIS process for the proposal, a cumulative impact assessment (CIA) is to be completed utilising the methodology described in the Inland Rail Programme – Environmental Assessment Procedure.

The CIA for the proposal will be conducted based on the following principles:

- Only consider 'state significant' or 'strategic' projects outside of the Program that are in the public domain as being planned, constructed or operated at the time of Basis of Assessment (ToR, SEARS or other) finalisation.
- The Inland Rail projects immediately adjacent to the project being assessed will be included in the CIA, e.g. in the case of the proposal, the CIA needs to consider the B2G project to the north and the N2NS project to the south.
- Apply the areas of influence (AOI) when considering spatial impacts.
- Current operational projects and commercial or agricultural operations that are in the AOI around the proposal, and considered in the CIA, are all accounted for in the corresponding technical baseline studies (e.g. air, noise, social, economic etc.).
- The CIAs will not be retrospective. That is, they will not take into account impacts from past land use e.g. vegetation clearing. The environment at the time of the Basis of Assessment finalisation is the baseline for cumulative assessment.

The CIA for the proposal should adhere to the following steps:

1. Develop a list of applicable projects and operations for consideration in the CIA. To ensure consistency between projects, this list should be formed from a combination of sources, including a general ARTC database and government approval agency's webpages. The register of assessable projects will be provided to the relevant regulator for endorsement.
2. Develop a figure showing the areas of spatial influence of the proposal being assessed, demonstrating the overlap of potential cumulative impact with projects or operations identified through Step 1. The figure should identify known sensitive receptors to nuisance/health impacts (e.g. noise, air quality, visual etc.) within areas of overlap.
3. Develop a timeline (construction, operation and decommissioning) to show the temporal relationship between the project being assessed and other projects and operations identified through Step 1. This will provide the temporal impact zone of influence.

4. Determine the applicable environmental values for each identified project (the list of environmental values will be the same for each project in the Program. In some cases there will be no impact for certain environmental values).
5. Undertake the CIA to determine the significance of cumulative impacts with respect to beneficial or detrimental effects.
6. Cumulative impacts deemed to be of 'medium' or 'high' significance may warrant additional mitigation measures to be proposed, beyond those already proposed by the relevant technical impact assessments.

5.6 Limitations

The atmosphere is a complex, physical system, and the movement of air in a given location is dependent on a number of different variables, including temperature, topography and land use, as well as larger-scale synoptic processes. Dispersion modelling is a method of simulating the movement of air pollutants in the atmosphere using mathematical equations. The model equations necessarily involve some level of simplification of these very complex processes based on our understanding of the processes involved and their interactions, available input data, and processing time and data storage limitations.

These simplifications come at the expense of accuracy, which particularly affects model predictions during certain meteorological conditions and source emission types. For example, the prediction of pollutant dispersion under low wind speed conditions (typically defined as those wind speeds less than 1 m/s) or for low-level, non-buoyant sources, is problematic for most dispersion models. To accommodate these known deficiencies, the model outputs tend to provide conservative estimates of pollutant concentrations at particular locations.

While the models contain a large number of variables that can be modified to increase the accuracy of the predictions under any given circumstances, the constraints of model use in a commercial setting, as well as the lack of data against which to compare the results in most instances, typically precludes extensive testing of the impacts of modification of these variables. With this in mind, model developers typically specify a range of default values for model variables that are applicable under most modelling circumstances. These default values are recommended for use unless there is sufficient evidence to support their modification.

As a result, the results of dispersion modelling provide an indication of the likely level of pollutants within the modelling domain. While the models, when used appropriately and with high quality input data, can provide very good indications of the scale of pollutant concentrations and the likely locations of the maximum concentrations occurring, their outputs should not be considered to be representative of exact pollutant concentrations at any given location or point in time. As stated above, however, the model predictions are typically conservative, and tend to over predict maximum pollutant concentrations at receiver locations.

This assessment was undertaken with the data available at the time of the assessment. Should changes to the proposal be made, further assessment may be required to determine if the findings of this assessment are still applicable.

6 Construction air quality impact assessment

The following sections provide an assessment of air quality impacts during the construction of the proposal.

6.1 UK IAQM assessment process

In absence of appropriate Australian construction dust guidance, the construction dust impact assessment was based on the methodology described in the UK IAQM document, Guidance on the assessment of dust from demolition and construction. The risk of dust deposition and human health impacts due to particulate matter (PM_{10}) on surrounding areas were determined based on the scale of activities and proximity to sensitive receptors. The IAQM method uses a four-step process to assess dust impacts:

- Step 1: Screening based on distance to nearest sensitive receptors
- Step 2: Assess risk of dust impacts from activities based on:
  - Scale and nature of the works, which determines the potential dust emission magnitude
  - Sensitivity of the area
- Step 3: Determine site-specific mitigation for dust-emitting activities
- Step 4: Reassess risk of dust impacts after mitigation has been considered.

Figure 6.1 presents the locations of the permanent and temporary disturbance areas along the proposal site with the addition of any laydown areas and haul routes.

The IAQM assessment process is described in the following sections.

6.1.1 Step 1 – Screening assessment

An assessment will normally be required where there is a “human receptor” within:

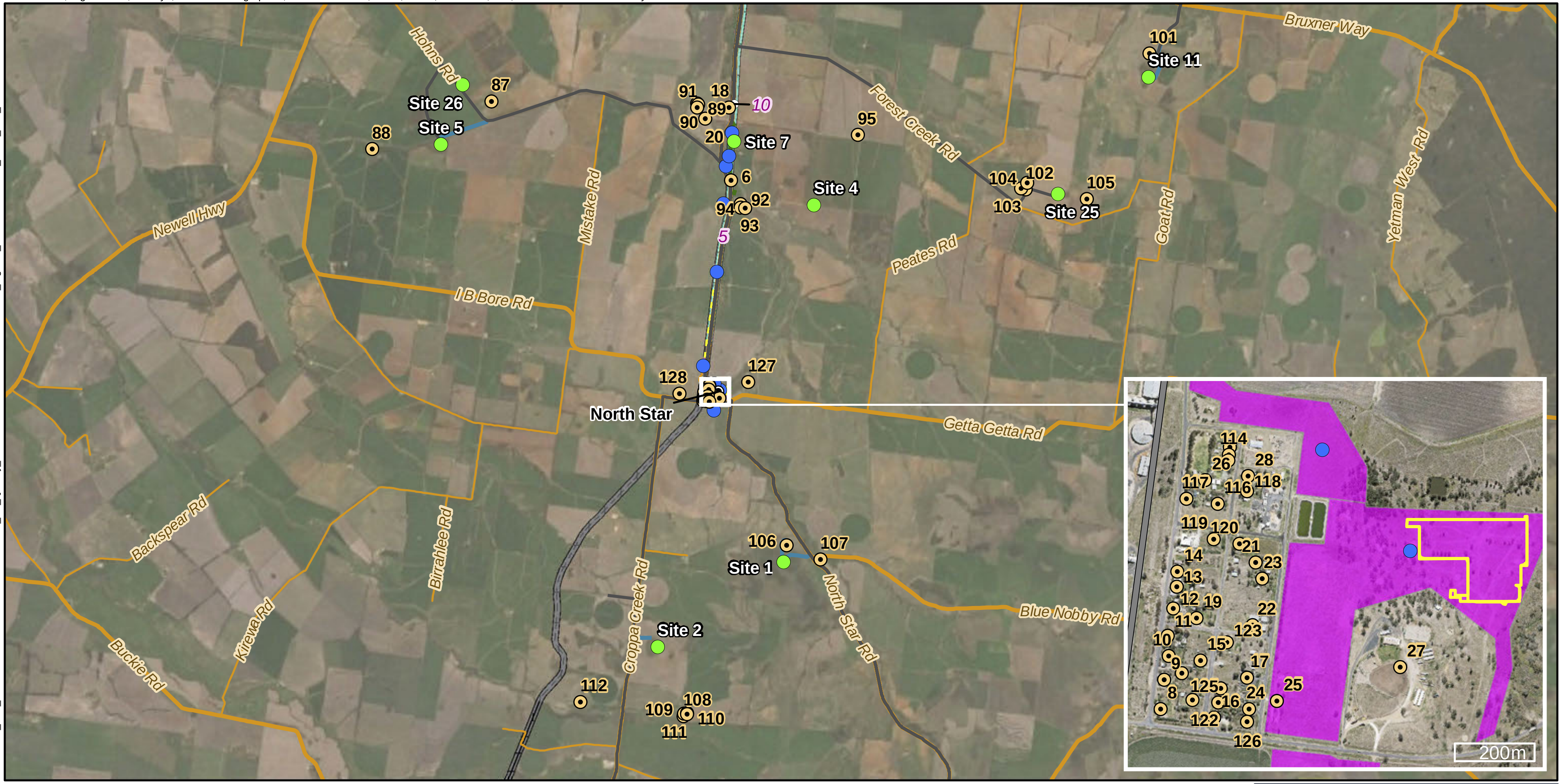
- 350 m from the boundary of a site
- 50 m from the route used by construction vehicles on public roads up to 500 m from a site entrance.

For the purpose of the assessment, the location of human receptors in respect to borrow pits (excavation points for material usage) and laydown areas (locations for the receipt, storage and assembly of equipment and materials for the proposal) has also been determined. It should be noted that not all laydowns areas have the same purpose, materials stored or activities conducted.

One construction workers accommodation camp is included in the proposal, with this camp to be located at laydown area CMP000.1 which is located at the southern extent of the proposal site in North Star, to the east of Wilby Street and the north of North Star Road. The location of the accommodation camp is shown in Figure 6.1a. The accommodation camp has been considered as a sensitive receptor for the purpose of the construction impact assessment.

Within the study area, 129 sensitive receptors (including the accommodation camp) were identified for inclusion in the construction impact assessment. Their respective distances from the construction boundaries and access tracks are presented in Table 6.1.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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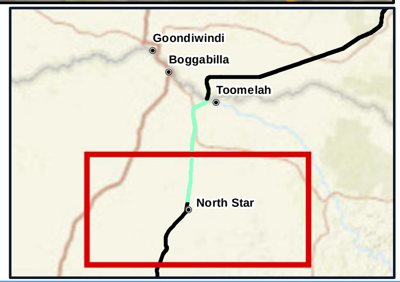
Legend

- Proposed borrow pit locations
- Sensitive receptors
- 5 Chainage (km)
- Localities
- Laydown area delivery point
- Haul roads
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Laydown access track
- Geotechnical access track
- Borrow pit access track
- NSW/QLD border
- Laydown
- NS2B permanent disturbance area
- NS2B temporary disturbance area
- Proposed construction camp



A4 scale: 1:225,000

0 2 4 6 8 10 km

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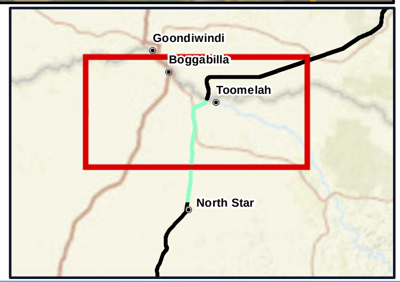
Coordinate system: MGA56

North Star to NSW/QLD border
Figure 6.1a:
Construction disturbance areas

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- Proposed borrow pit locations
- Sensitive receptors
- 5 Chainage (km)
- Localities
- Laydown area delivery point
- Haul roads
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Laydown access track
- Geotechnical access track
- Borrow pit access track
- NSW/QLD border
- Laydown
- NS2B permanent disturbance area
- NS2B temporary disturbance area



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North Star to NSW/QLD border
Figure 6.1b:
Construction disturbance areas

Table 6.1 Summary of sensitive receptors

Distance from (m)	Number of receptors			
	Access tracks	Borrow pits	Laydown areas	Construction corridor
<20	2	0	2	3
21 to 50	9	0	2	3
51 to 100	10	0	7	7
101 to 350	26	1	23	25
>350	82	128	95	91
Total	**129**	**129**	**129**	**129**

6.1.2 Step 2 – Dust risk assessment

Step 2 in the IAQM is a risk assessment tool designed to appraise the potential for dust impacts due to unmitigated dust emissions from a construction project. The key components of the risk assessment are defining the dust emission magnitudes (Step 2A), the surrounding area sensitivity (Step 2B), and then combining these in a risk matrix (Step 2C) to determine an overall risk of dust impacts.

6.1.3 Step 2A – Dust emission magnitude

Dust emission magnitudes are estimated according to the scale of works being undertaken and other considerations such as meteorology, types of material being used, or general demolition methodology. The IAQM guidance provides examples to aid classification, as presented in the following excerpt from IAQM:

> 'The dust emission magnitude is based on the scale of the anticipated works and should be classified as Small, Medium, or Large. The following are examples of how the potential dust emission magnitude for different activities can be defined. Note that, in each case, not all the criteria need to be met, and that other criteria may be used if justified in the assessment:

Demolition: Example definitions for demolition are:

- Large: Total building volume >50,000 m^3, potentially dusty construction material (e.g. concrete), on-site crushing and screening, demolition activities >20 m above ground level.
- Medium: Total building volume 20,000 m^3 to 50,000 m^3, potentially dusty construction material, demolition activities 10 to 20 m above ground level.
- Small: Total building volume <20,000 m^3, construction material with low potential for dust release (e.g. metal cladding or timber), demolition activities <10 m above ground, demolition during wetter months.

Earthworks: Earthworks will primarily involve excavating material, haulage, tipping and stockpiling. This may also involve levelling the site and landscaping. Example definitions for earthworks are:

- Large: Total site area >10,000 m^2, potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size), >10 heavy earth moving vehicles active at any one time, formation of bunds >8 m in height, total material moved >100,000 tonnes.
- Medium: Total site area 2,500 m^2 to10,000 m^2, moderately dusty soil type (e.g. silt), 5 to10 heavy earth moving vehicles active at any one time, formation of bunds 4 m to 8 m in height, total material moved 20,000 tonnes to 100,000 tonnes.
- Small: Total site area <2,000 m^2 – soil type with large grain size, e.g. sand, <5 heavy earth moving vehicles at one time, formation of bunds <4 m in height, total material moved <20,000 tonnes, earthworks during wetter months.

Construction: The key issues when determining the potential dust emission magnitude during the construction phase include the size of the building(s)/infrastructure, method of construction, construction materials, and duration of build. Example definitions for construction are:

- Large: Total building volume >100,000 m^3, on site concrete batching, sandblasting.
- Medium: Total building volume 25,000 m^3 to 100,000 m^3, potentially dusty construction material (e.g. concrete), on site concrete batching.
- Small: Total building volume <25,000 m^3, construction material with low potential for dust release (e.g. metal cladding or timber).

Trackout: Factors which determine the dust emission magnitude are vehicle size, vehicle speed, vehicle numbers, geology and duration. As with all other potential sources, professional judgement must be applied when classifying trackout into one of the dust emission magnitude categories. Example definitions for trackout are:

- Large: >50 truck (>3.5 t) outward movements in any one day, potentially dusty surface material (e.g. high clay content), unpaved road length 50 m to 100 m.
- Medium: 10 to 50 truck (>3.5 t) outward movements in any one day, moderately dusty surface material (e.g. high clay content), unpaved road length 50 m to 100 m.
- Small: <10 truck (>3.5 t) outward movements in any one day, surface material with low potential for dust release, unpaved road length <50 m.'

Potential dust emission magnitudes for the proposal were estimated based on the IAQM examples listed above. Justification and the factors used in determining the magnitudes are presented in Table 6.2. Construction for the proposal is expected to occur Monday to Saturday, with work days no longer than 12 hours. Where required, track possessions may occur continuously (24 hours and 7 days). Due to time constraints, multiple work fronts will be present at any one time along the alignment.

Table 6.2 Construction activities and dust emission magnitude justification

Activity	Potential dust emission magnitude	Justification
Demolition	Small	▪ No major structures requiring removal ▪ Some derelict infrastructure such as rail, sleepers, ballast and structures (culverts and bridges) to be removed. Infrastructure is expected to be mostly of low dust potential steel and wood material. Building volumes currently unknown. ▪ Possible demolition and realignment of existing roads as required - to be confirmed in detailed design phase of the proposal. ▪ Relocation of utilities pending consultation with the providers.
Earthworks	Large	▪ Possibility of multiple work fronts at any one time along the alignment. ▪ Vegetation clearing along the proposed alignment corridor for new access tracks and laydown areas will occur where necessary – no known quantities at this stage however most of the area is grazing pastoral land. ▪ Topsoil along entire alignment (30 km long) will be stripped (approximate depth of 0.3 m) and stockpiled. Wherever possible and appropriate material will be reused within Study area. ▪ 19 laydown areas along the alignment (including bridge construction sites), primarily to act as locations for excavation stockpiling, material storage and handling. ▪ 19 borrow pits (to be confirmed), where material will be excavated from when required. Majority of these pits are pre-existing. Cut and fill volumes to be confirmed. ▪ Crushing may be undertaken at the Site 2 borrow pit. In addition to consideration in the IAQM risk assessment, the potential for impacts from crushing are discussed in Section 6.3. ▪ Blasting is proposed for the excavation of borrow material from borrow pits. In addition to consideration in the IAQM risk assessment, the potential for impacts from blasting are discussed in Section 6.4.

Activity	Potential dust emission magnitude	Justification
		■ Of the 19 laydown areas, it is assumed four will act as major construction compounds. These compounds will have the site office operations, and act as primary material and equipment delivery points. ■ Earthworks material likely to be dusty especially during dry season. Soil types along corridor location to be confirmed.
Construction	Medium	■ Construction period of five years, with the possibility of multiple work fronts at any one time along the alignment. ■ Installation of 30 km of railway utilising steel rail, sleepers, ballast and concrete. Concrete and ballast present high dust risk. ■ Construction of 11 new bridge structures – steel material low dust risk but concrete high dust risk. ■ Temporary site offices and parking facilities likely to be constructed at each construction compound. ■ Construction of fuel storage facilities at each construction compound: two approximately <20,000 L, and two approximately <10,000 L (four total). ■ One laydown area (CMP000.1) will include a construction camp as discussed in Section 6.1.1. ■ Construction of temporary and permanent fencing (total lengths to be determined during detailed design phase).
Trackout	Large	■ Possibility for multiple work fronts at any one time along alignment. ■ High amount of daily vehicle movements expected per work site (both light and heavy vehicles). ■ Movement of ballast from sources (local quarries and borrow pits), and between construction compounds via 18 t dump trucks. ■ After construction, access tracks are expected to only be used for maintenance activities. ■ Total length of unpaved access tracks unknown until design is finalised but is assumed to be >100 m due to the size of the proposal.

6.1.4 Step 2B – Sensitivity of surrounding area

The IAQM methodology classifies the surrounding area sensitivity to dust deposition and human health impacts due to particulate matter effects to be classified as high, medium, or low. The classifications are determined according to matrix tables for both dust deposition and human health impacts, which are reproduced in Table 6.3 and Table 6.4 respectively below. Factors used in the matrix tables to determine the surrounding area sensitivity are described as follows:

- Receptor sensitivity (for individual receptors in the area):
  - High sensitivity – locations where members of the public are likely to be exposed for eight hours or more in a day (e.g. private residences, hospitals, schools, or aged care homes)
  - Medium sensitivity - places of work where exposure is likely to be eight hours or more in a day
  - Low sensitivity – locations where exposure is transient – e.g. one or two hours maximum. For example parks, footpaths, shopping streets, playing fields
- Number of receptors of each sensitivity type in the area
- Distance from source
- Annual mean PM_{10} concentration (only applicable to the human health impact matrix).

Table 6.3 details the IAQM guidance sensitivity levels from dust deposition effects on people and property. As detailed in Section 6.1.1, the total number of receptors identified in the study area is 129. All 129 receptors are classified as high sensitivity – most are private residences, two are schools and one is a construction workers accommodation camp. Of the 129 receptors, 47 are located within 350 m of a construction dust source; 28 are located within 100 m; 15 are located within 50 m; and four are located within 20 m. As such, the study area sensitivity level to dust deposition effects is expected to be 'Medium'.

Table 6.3 Surrounding area sensitivity to dust deposition effects on people and property

Receptor sensitivity	Number of receptors	Distance from the source			
		<20	<50	<100	<350
High	>100	High	High	Medium	Low
	10 to 100	High	Medium	Low	Low
	1 to 10	Medium	Low	Low	Low
Medium	>1	Medium	Low	Low	Low
Low	>1	Low	Low	Low	Low

A modified version of the IAQM guidance for assessing the sensitivity of an area to human health impacts is shown in Table 6.4. For high and medium sensitivity receptors, the IAQM methods takes the existing background concentrations of PM_{10} (as an annual average) experienced in the area of interest (e.g. AQIA study area). As the UK objectives for PM_{10} objectives differ from the ambient air quality objectives adopted for use in this assessment the annual mean concentration categories used in the assessment have been modified from those presented in the IAQM method. This approach is consistent with the IAQM guidance, which notes that in using the tables to define the sensitivity of an area, professional judgement may be used to determine alternative sensitivity categories.

As detailed in Section 4.1, the background annual average PM_{10} concentrations range from 14.1 to 16.6 µg/m^3. Assessing the sensitivity level to human health impacts using the IAQM guidance and Table 6.4 the sensitivity is determined to be 'Low'.

Table 6.4 Surrounding area sensitivity to human health impacts

Receptor sensitivity	Annual mean PM_{10} concentration[a]	Number of receptors	Distance from the source				
			<20	<50	<100	<250	<350
High	> 25 µg/m^3	> 100	High	High	High	Medium	Low
		10 - 100	High	High	Medium	Low	Low
		1 - 10	High	Medium	Low	Low	Low
	21 to 25 µg/m^3	> 100	High	High	Medium	Low	Low
		10 - 100	High	Medium	Low	Low	Low
		1 - 10	High	Medium	Low	Low	Low
	17 to 21 µg/m^3	> 100	High	Medium	Low	Low	Low
		10 - 100	High	Medium	Low	Low	Low
		1 - 10	Medium	Low	Low	Low	Low
	< 17 µg/m^3	> 100	Medium	Low	Low	Low	Low
		10 - 100	Low	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low
Medium	> 25 µg/m^3	> 10	High	Medium	Low	Low	Low
		1 - 10	Medium	Low	Low	Low	Low
	21 to 25 µg/m^3	> 10	Medium	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low

Receptor sensitivity	Annual mean PM_{10} concentration[a]	Number of receptors	Distance from the source				
			<20	<50	<100	<250	<350
	17 to 21 µg/m^3	> 10	Low	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low
	< 17 µg/m^3	> 10	Low	Low	Low	Low	Low
		1 - 10	Low	Low	Low	Low	Low
Low	Any	>1	Low	Low	Low	Low	Low

Table note:

a The PM_{10} concentration categories have been modified from the IAQM guidance to adjust for Australian PM_{10} objectives.

6.1.5 Step 2C – Unmitigated risks of impacts

The dust emission magnitudes for each activity as determined in Step 2A were combined with the sensitivity of the area (in Table 6.3 and Table 6.4) to determine the risk of construction dust air quality impacts with no mitigation applied. The risk of impacts for each activity is assessed according to the IAQM risk matrix provided in Table 6.5. The 'without mitigation' dust risk impacts for each activity are summaries in Table 6.6.

Table 6.5 IAQM risk matrix

Activity	Surrounding area sensitivity	Dust emission magnitude		
		Large	Medium	Small
Demolition	High	High risk	Medium risk	Medium risk
	Medium	High risk	Medium risk	Low risk
	Low	Medium risk	Low risk	Negligible
Earthworks	High	High risk	Medium risk	Low risk
	Medium	Medium risk	Medium risk	Low risk
	Low	Low risk	Low risk	Negligible
Construction	High	High risk	Medium risk	Low risk
	Medium	Medium risk	Medium risk	Low risk
	Low	Low risk	Low risk	Negligible
Trackout	High	High risk	Medium risk	Low risk
	Medium	Medium risk	Low risk	Negligible
	Low	Low risk	Low risk	Negligible

Table 6.6 Without mitigation dust risk impacts for NS2B construction activities

Potential Impact	Risk			
	Demolition	Earthworks	Construction	Trackout
Scale of Activity (IAQM Table 4)	**Small**	**Large**	**Medium**	**Large**
Dust Deposition	Low	Medium	Medium	Medium
Human Health	Negligible	Low	Low	Low

The result of the qualitative air quality risk assessment shows that the unmitigated air emissions from the construction of the proposal poses a 'Low' risk of human health impacts but a 'Medium' risk of dust deposition.

6.1.6 Step 3 – Management strategies

The outcome of Step 2C is used to determine the level of management that is required to ensure that dust impacts on surrounding sensitive receptors are maintained at an acceptable level. A high or medium-level risk rating means that suitable management measures must be implemented.

A Construction Environmental Management Plan (CEMP) will be developed to mitigate and manage potential impacts during the construction. The implementation of approved site-specific and in-principle management measures, as listed in Section 9 should result in minimal risk of dust impacts on surrounding receptors.

6.1.7 Step 4 – Reassessment

The final step of the IAQM methodology is to determine whether there are significant residual impacts, post mitigation, arising from a proposed development. The guidance states:

> 'For almost all construction activity, the aim should be to prevent significant effects on receptors through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be "not significant".'

It is anticipated that the proposal will not constitute an atypical case and that with implementation of the proposed mitigation measures described in Section 9, the residual effect (impacts) will be "not significant" in regard to dust deposition and human health impacts.

6.2 Tank fuel storage

Fuel tank storage locations are proposed at four locations along the proposal site during the construction of the proposal. Table 6.7 presents the proposed construction areas that will include diesel fuel storage areas, volumes proposed, and distances to the closest identified sensitive receptors.

Table 6.7 Fuel tank storage locations

Construction area ID	Location	Fuel storage proposed	Distance to closest sensitive receptor
NS2B-LDN007.4	North Star Rd	10,000 L	450 m
NS2B-LDN020.0	North Star Rd	2 x 10,000 L	1100 m
NS2B-LDN029.8	Tucka Tucka Rd	10,000 L	850 m
NS2B-LDN035.6	Kildonan Rd	2x 10,000 L	4500 m

The closest diesel storage tank proposed will be greater than 450 m from the nearest sensitive receptor and have a capacity of less than 10,000 litres. The additionally proposed storage locations will be greater than 850 m from the closest sensitive receptor. It is anticipated that for the proposed fuel storage volumes and associated separations distances pollutant emissions and impacts to nearby sensitive receptors will be negligible, and as such, have not been considered further in this assessment.

6.3 Crushing plant

Onsite crushing may be required the at the Site 2 borrow pit, which is the southernmost borrow pit in the study area. The need for crushing will be confirmed and is dependent on the nature of the material excavated from the borrow pit.

If crushing is required, crushing plant will be located within the Site 2 borrow pit boundary. The exact model of crushing plant proposed is not known at this time. Crushing would generate dust emissions and these emissions have the potential to impact sensitive receptors.

The EPA Victoria guideline Recommended separation distances for industrial residual air emissions (EPA Victoria 2013) provides guidance on suitable separation distances between mining and extractive activities and neighbouring sensitive receptors, including for crushing. Table 6.8 presents the recommended separation distances for crushing associated with different mining and extractive activities.

Table 6.8 Separation distances for crushing associated with mining and extractive industries

Mining or extractive operation	Type of activity	Recommended separation distance (m)
Open cut coal mine	Harvesting, crushing, screening, stockpiling and conveying of coal	1000
Mine for other minerals	Crushing, screening, stockpiling and conveying of other minerals	250
Quarry	Quarrying, crushing, screening, stockpiling and conveying of rock	250 (without blasting) 500 (with blasting or with respirable crystalline silica)

The nearest sensitive receptor to the boundary of the Site 2 borrow pit is located approximately 2.4 km to the south-east, which is greater than the recommended separation distances presented in Table 6.8. Based on the separation distance to sensitive receptors it is expected that crushing at the Site 2 borrow pit will have minimal impact on air quality at sensitive receptors in the study area.

6.4 Blasting

Blasting is proposed for the excavation of borrow material from borrow pits. Blasting will generate dust which has the potential to impact sensitive receptors.

The ARTC Guideline for Blasting in Proximity to ARTC Infrastructure (ARTC, Guidelines for Blasting in Proximity to ARTC Infrastructure n.d.) outlines the procedure proposed to ensure that blasting operations do not have detrimental effect on ARTC assets or operations or impact the safety of people or property. The Guideline states that ARTC will assess risks from blasting in two stages as required:

- Stage 1: ARTC will undertake an initial appraisal and provide ‘in principle’ approval to blast in proximity to ARTC infrastructure.
- Stage 2: Detailed assessment and approval.

The EPA Victoria guideline Recommended separation distances for industrial residual air emissions (EPA Victoria 2013) includes a recommended separation distance of 500 m for quarries which undertake blasting (refer Table 6.8). Of the 129 receptors considered in the construction dust assessment, three receptors are located within 500 m of a borrow pit as described below:

- Receptor 18: Located 307 m to the north-west of the Site 7 borrow pit
- Receptor 100: Located 408 m to the west of the Site 9 borrow pit
- Receptor 106: Located 486 m to the north of the Site 1 borrow pit.

Based on the EPA Victoria guideline, dust emissions from blasting at the Site 7, Site 9 and Site 1 borrow pits may impact sensitive receptors.

In accordance with the ARTC Approved Mitigation Measures (ARTC, Inland Rail Programme Environmental Management Plan 2018), to minimise the risk of impact to sensitive receptors it is recommended that blasting is not undertaken at the Site 7, Site 9 and Site 1 borrow pits if the prevailing wind conditions are likely to transport dust emissions toward the nearest sensitive receptors. For example, for receptor 18 and the Site 7 borrow pit, blasting should not be undertaken if the prevailing wind direction is a south-easterly wind (blowing towards the north-west), as this wind would transport dust towards receptor 18.

In accordance with the ARTC Guideline for Blasting in Proximity to ARTC Infrastructure it is recommended that the risk assessments undertaken for blasting at borrow pits include consideration of the potential impact to air quality at sensitive receptors.

7 Operational air quality impact assessment

The results of the dispersion modelling for the operation of the proposal are shown in Table 7.1. The tabulated results show the highest predicted cumulative concentrations at the worst affected modelled sensitive receptor.
The concentrations shown in Table 7.1 are the 100th percentile (maximum predicted concentration) for all pollutants with the exception of VOCs and heavy metals, which are hourly predictions and are required to be assessed as the 99.9th percentile (ninth highest hourly prediction of the modelled 8,760 hours in the year) of all predicted concentrations in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (NSW EPA 2016).

Assessment for NO_2 and PM_{10} has been completed as a cumulative contemporaneous assessment within the dispersion model, adding hourly background data to hourly model predictions. As such, only cumulative predicted concentrations have been presented for these pollutants.

Table 7.1 Highest predicted ground level concentrations at sensitive receptors

Pollutant	Average period	Source only predicted concentration (µg/m³)	Cumulative concentration (µg/m³)	EPA objectives (µg/m³)
TSP	Annual average	0.5	42.0	90
PM_{10}	24 hour maximum	-	48.1[a]	50
	Annual average	-	17.0[a]	25
$PM_{2.5}$	24 hour maximum	2.5	23.5	25
	Annual average	0.4	4.2	8
NO_2	1 hour maximum	-	168[a]	246
	Annual average	-	28.2[a]	62
Arsenic and compounds	1 hour, 99.9th percentile	0.08	-[b]	0.09
Cadmium and compounds	1 hour, 99.9th percentile	0.007	-[b]	0.018
Chromium III and compounds	1 hour, 99.9th percentile	0.05	-[b]	9
Chromium VI and compounds	1 hour, 99.9th percentile	0.023	-[b]	0.09
Lead and compounds	Annual	0.0050	-[b]	0.5
Zinc and compounds	1 hour, 99.9th percentile	0.08	-[b]	90
Dioxins and furans	1 hour, 99.9th percentile	2.94×10^{-10}	-[b]	2.00×10^{-06}
Polycyclic aromatic hydrocarbon (as benzo[a]pyrene)	1 hour, 99.9th percentile	0.006	-[b]	0.4
1,3-butadiene	1 hour, 99.9th percentile	1.1	-[b]	40
Benzene	1 hour, 99.9th percentile	1.2	-[b]	29

Table notes:

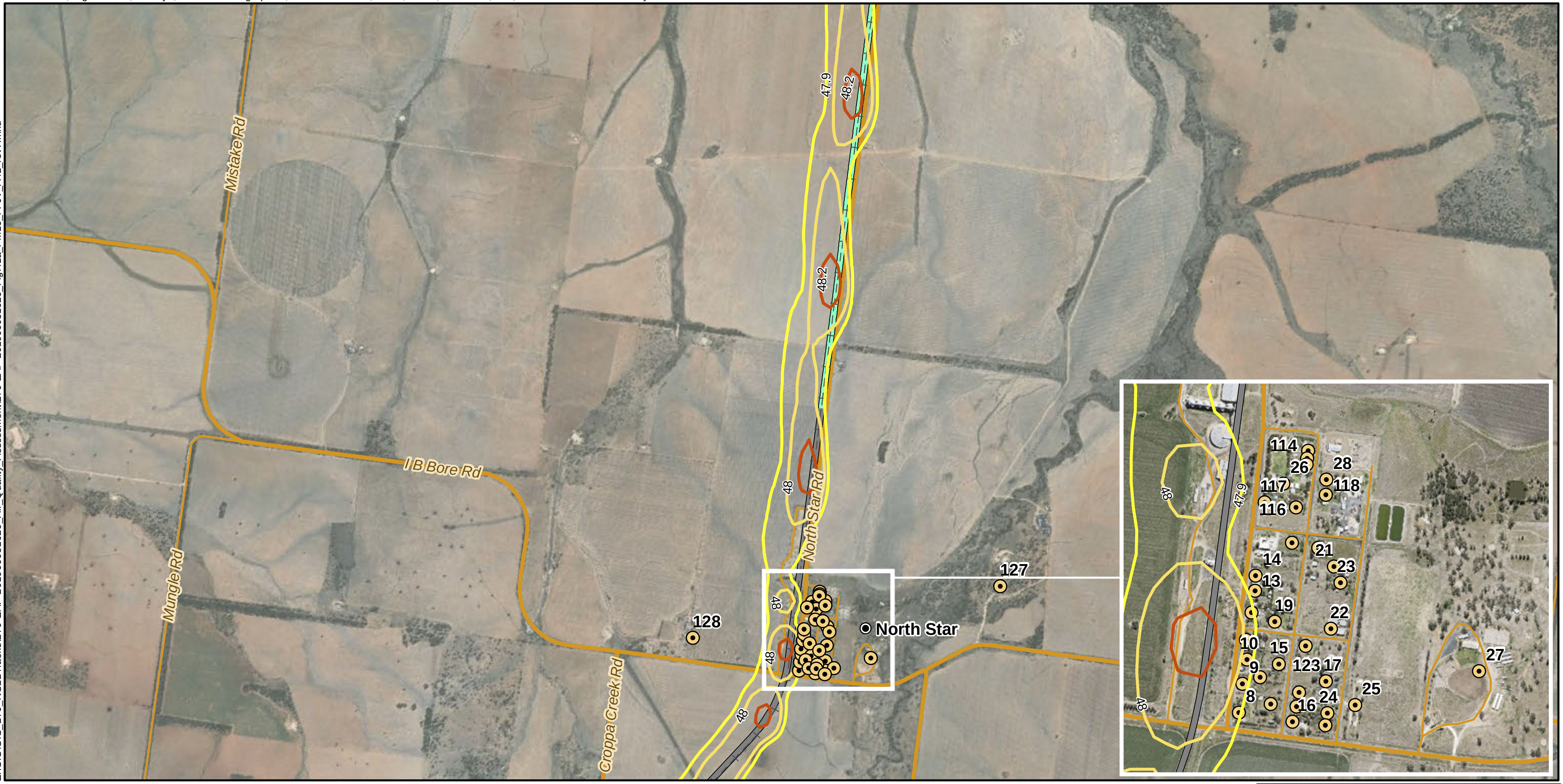
a Assessment has been completed as a cumulative contemporaneous assessment within the dispersion model, adding hourly background data to hourly model predictions. As such, only cumulative predicted concentrations are presented.

b There are no significant sources of these pollutant species along the NS2B route and therefore concentrations have been assumed to be negligible and have not been considered cumulatively.

Cumulative concentration contours have been prepared for predicted concentrations for PM_{10} (maximum 24 hour average), $PM_{2.5}$ (annual average concentration) and NO_2 (maximum 1 hour average) and are presented in Figure 7.1 to Figure 7.3.

As the concentration contours are cumulative the concentrations plotted can be compared against the relevant air quality objectives for each pollutant. All pollutants are compliant with the relevant objectives.

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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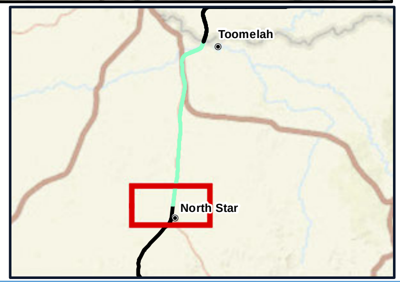


Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative PM_{10} maximum 24 hour ground level concentration (µg/m³)

- 47.9
- 48
- 48.2
- 48.4

A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

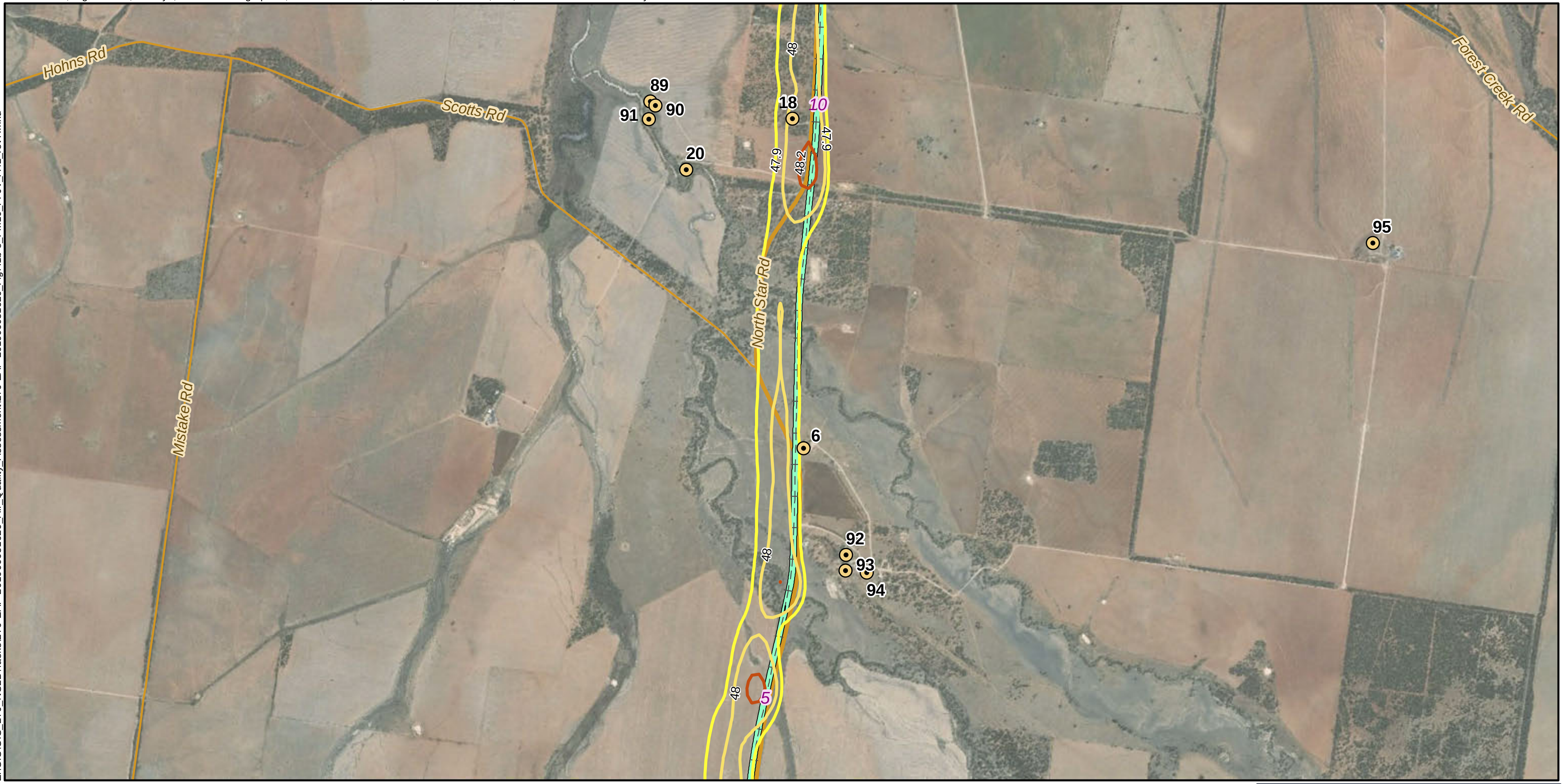
Future Freight
Integrating Community, Environment and Engineering

Date: 17/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.1a: Predicted cumulative PM_{10} maximum 24 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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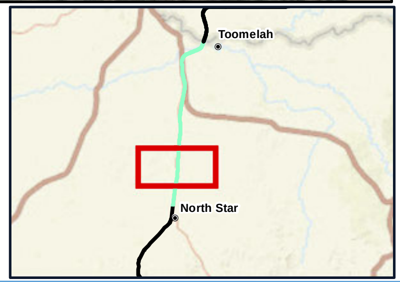
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative PM_{10} maximum 24 hour ground level concentration (µg/m³)

- 47.9
- 48
- 48.2
- 48.4



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

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Integrating Community, Environment and Engineering

Date: 17/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.1b: Predicted cumulative PM_{10} maximum 24 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: CW/DMcP/GN/MEF Date: 17/02/2020 14:01
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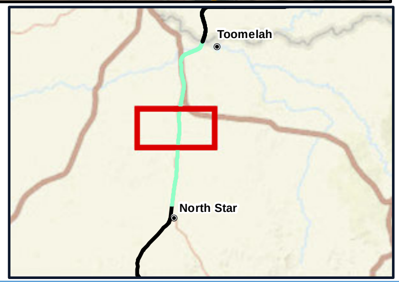
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative PM_{10} maximum 24 hour ground level concentration (µg/m³)

- 47.9
- 48
- 48.2
- 48.4



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

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Date: 17/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.1c: Predicted cumulative PM_{10} maximum 24 hour average ground level concentration

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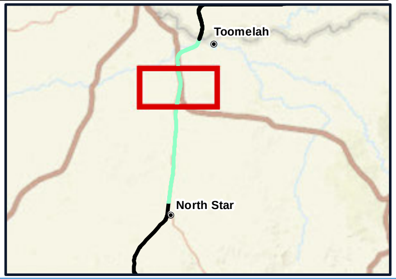
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Crossing loops
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative PM_{10} maximum 24 hour ground level concentration (µg/m³)

- 47.9
- 48
- 48.2
- 48.4



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

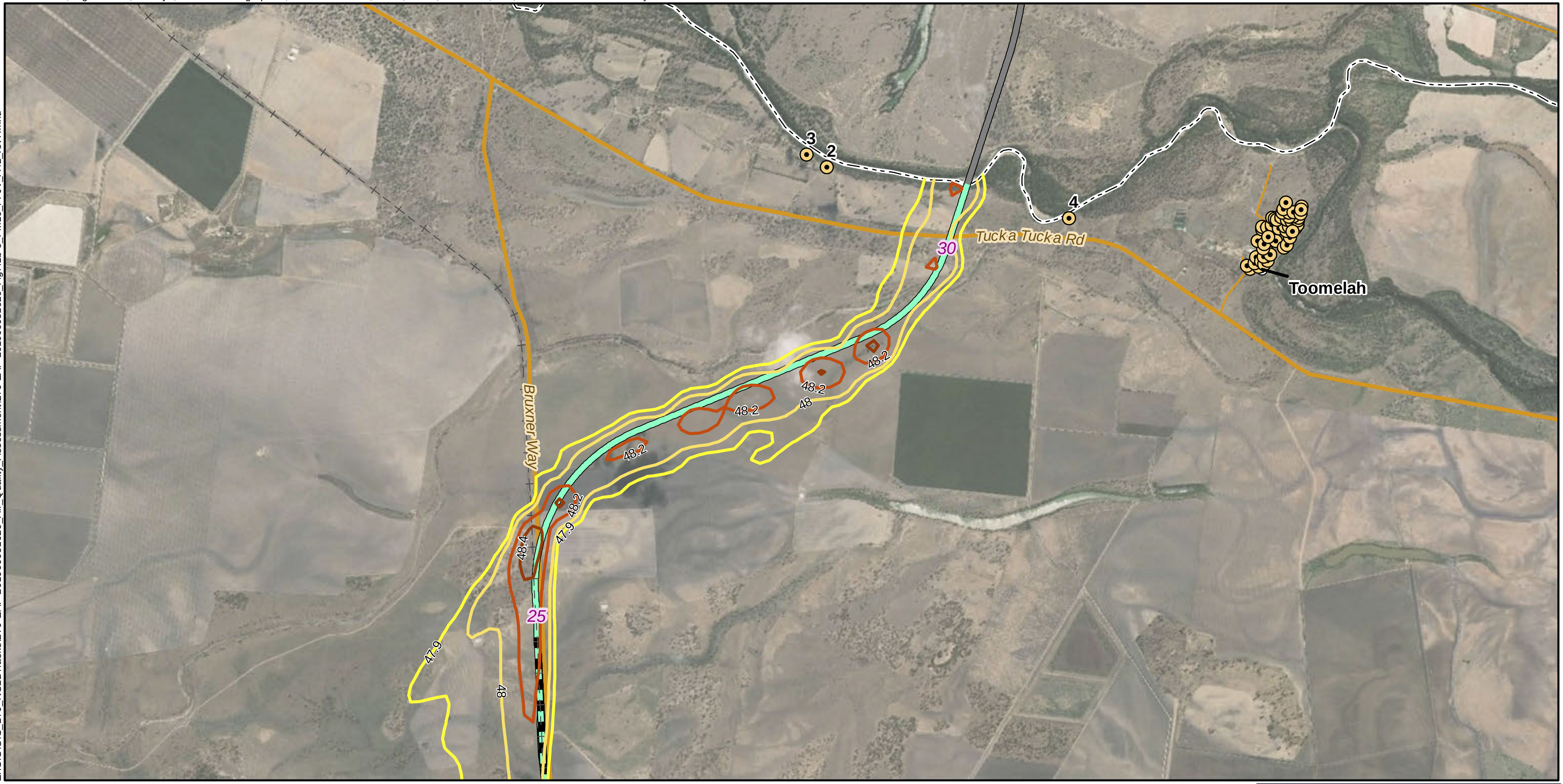
Future Freight
Integrating Community, Environment and Engineering

Date: 17/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.1d: Predicted cumulative PM_{10} maximum 24 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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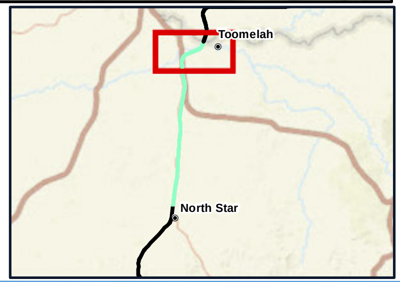
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Crossing loops
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative PM_{10} maximum 24 hour ground level concentration (µg/m³)

- 47.9
- 48
- 48.2
- 48.4



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

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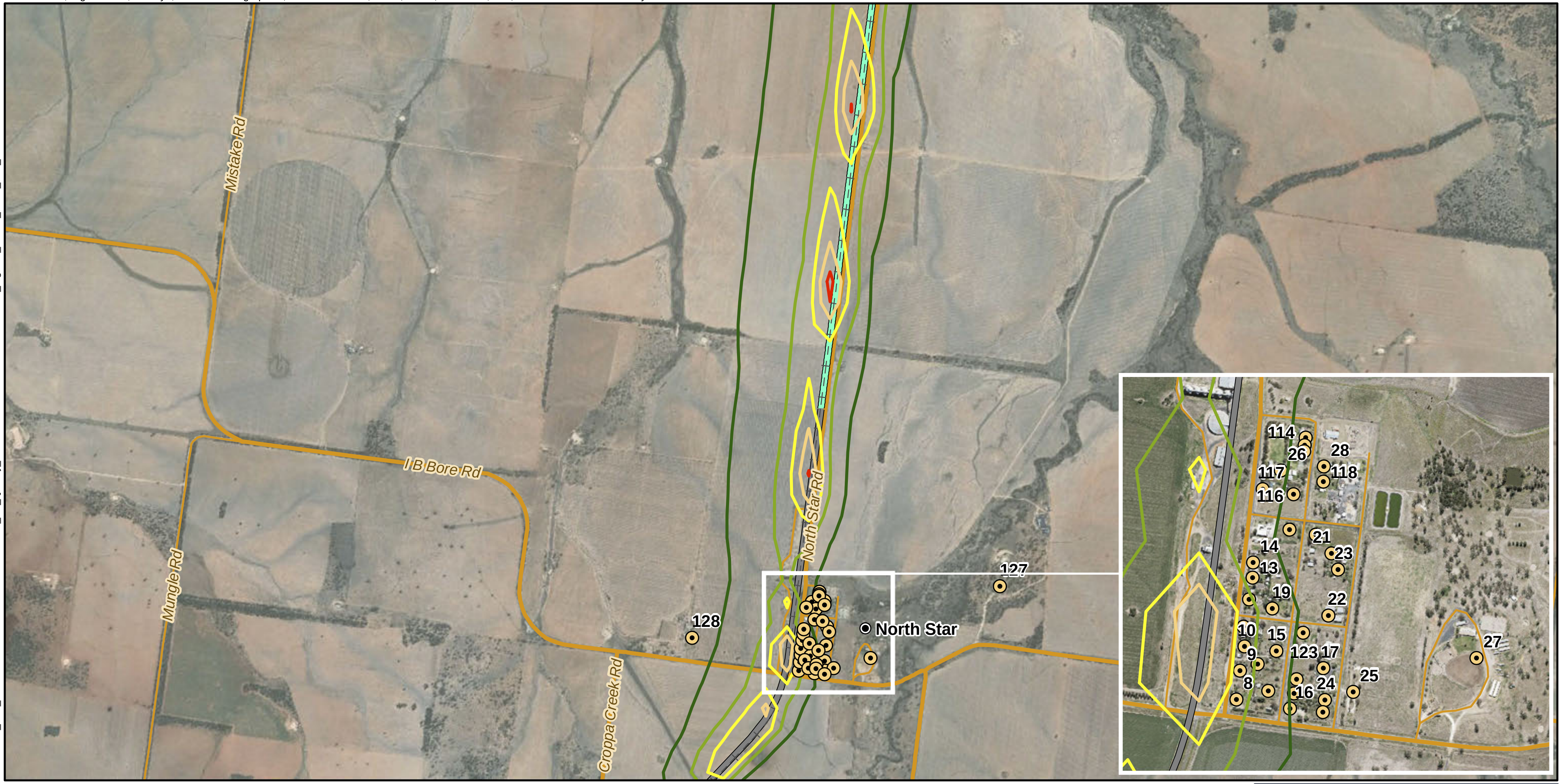
Date: 17/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.1e: Predicted cumulative PM_{10} maximum 24 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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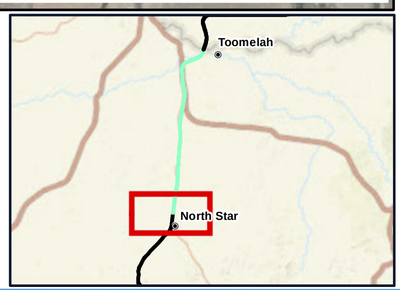
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative $PM_{2.5}$ annual average ground level concentration (µg/m³)

- 3.9
- 4
- 4.1
- 4.2
- 4.3



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

Date: 18/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.2a: Predicted cumulative $PM_{2.5}$ annual average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: CW/DMcP/GN/MEF Date: 18/02/2020 16:30
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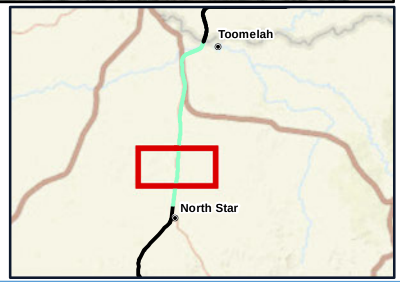
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative $PM_{2.5}$ annual average ground level concentration (µg/m³)

- 3.9
- 4
- 4.1
- 4.2
- 4.3



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

Date: 18/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.2b: Predicted cumulative $PM_{2.5}$ annual average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: CW/DMcP/GN/MEF Date: 18/02/2020 16:30
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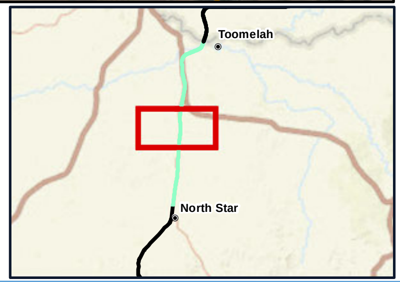
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative $PM_{2.5}$ annual average ground level concentration (µg/m³)

- 3.9
- 4
- 4.1
- 4.2
- 4.3



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

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Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.2c: Predicted cumulative $PM_{2.5}$ annual average ground level concentration

Map by: CW/DMcP/GN/MEF Date: 18/02/2020 16:30
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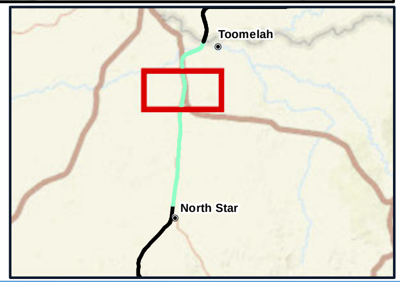
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Crossing loops
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative $PM_{2.5}$ annual average ground level concentration (µg/m³)

- 3.9
- 4
- 4.1
- 4.2
- 4.3



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

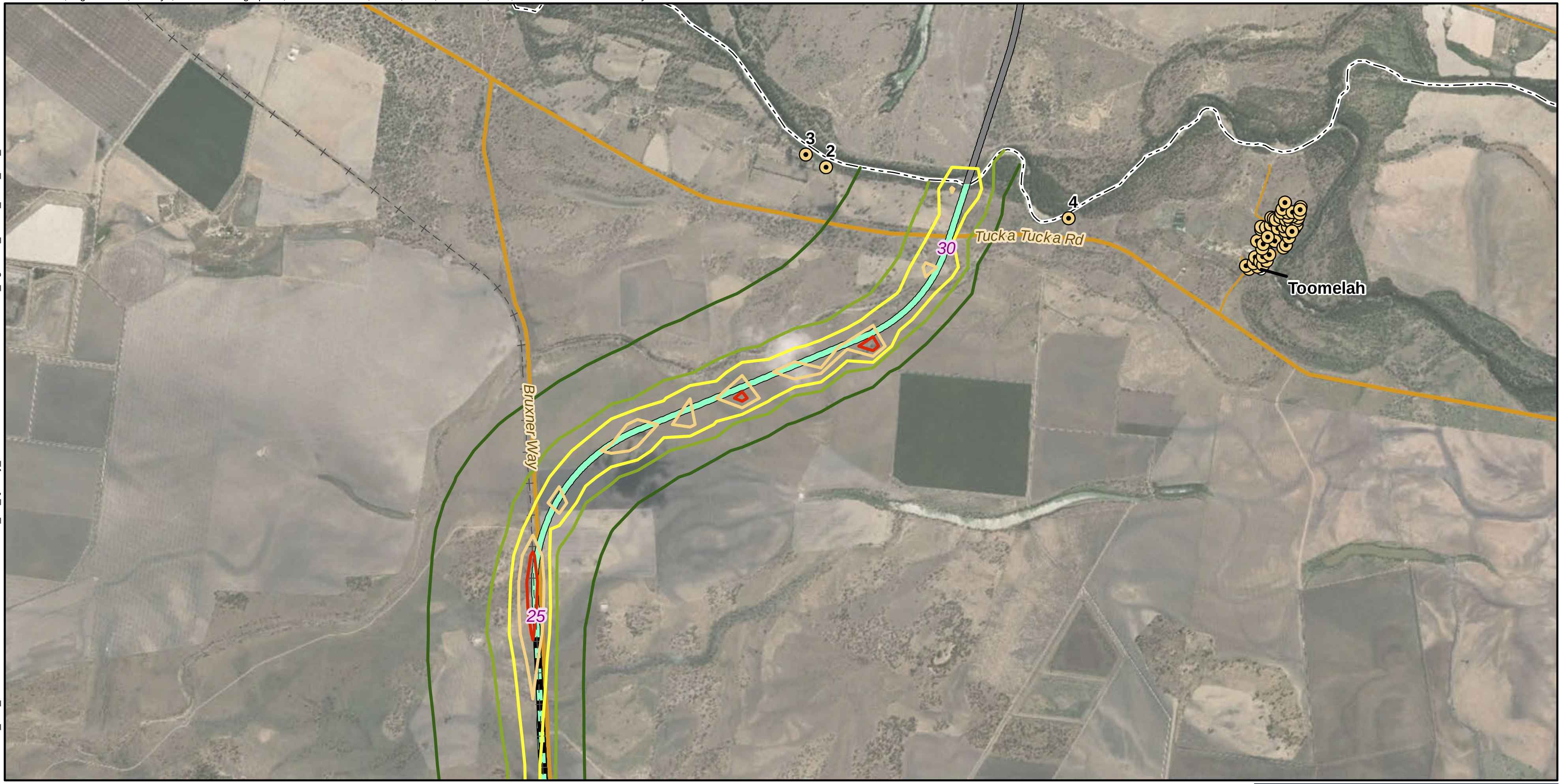
Future Freight
Integrating Community, Environment and Engineering

Date: 18/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.2d: Predicted cumulative $PM_{2.5}$ annual average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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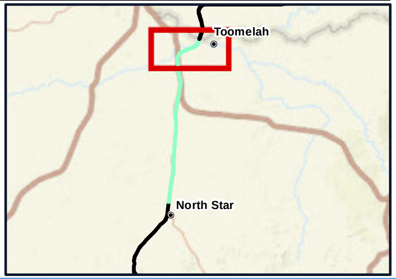
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Crossing loops
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative $PM_{2.5}$ annual average ground level concentration (µg/m³)

- 3.9
- 4
- 4.1
- 4.2
- 4.3



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

Date: 18/02/2020 Version: 7

Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.2e: Predicted cumulative $PM_{2.5}$ annual average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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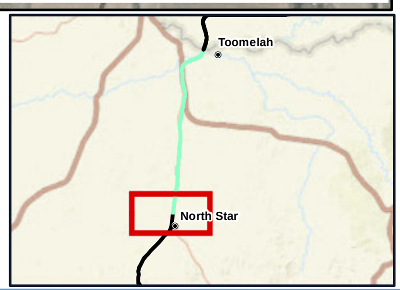

Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative NO_2 maximum 1 hour ground level concentration (µg/m³)

- 100
- 150
- 200
- 246 (NO_2 1 hour maximum criterion)
- 300

A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

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Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.3a: Predicted cumulative NO_2 maximum 1 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map by: CW/DMcP/GN/MEF Date: 18/02/2020 16:42
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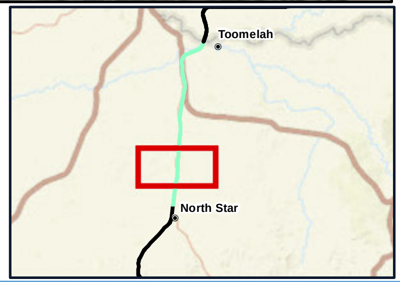
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative NO_2 maximum 1 hour ground level concentration (µg/m³)

- 100
- 150
- 200
- 246 (NO_2 1 hour maximum criterion)
- 300



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

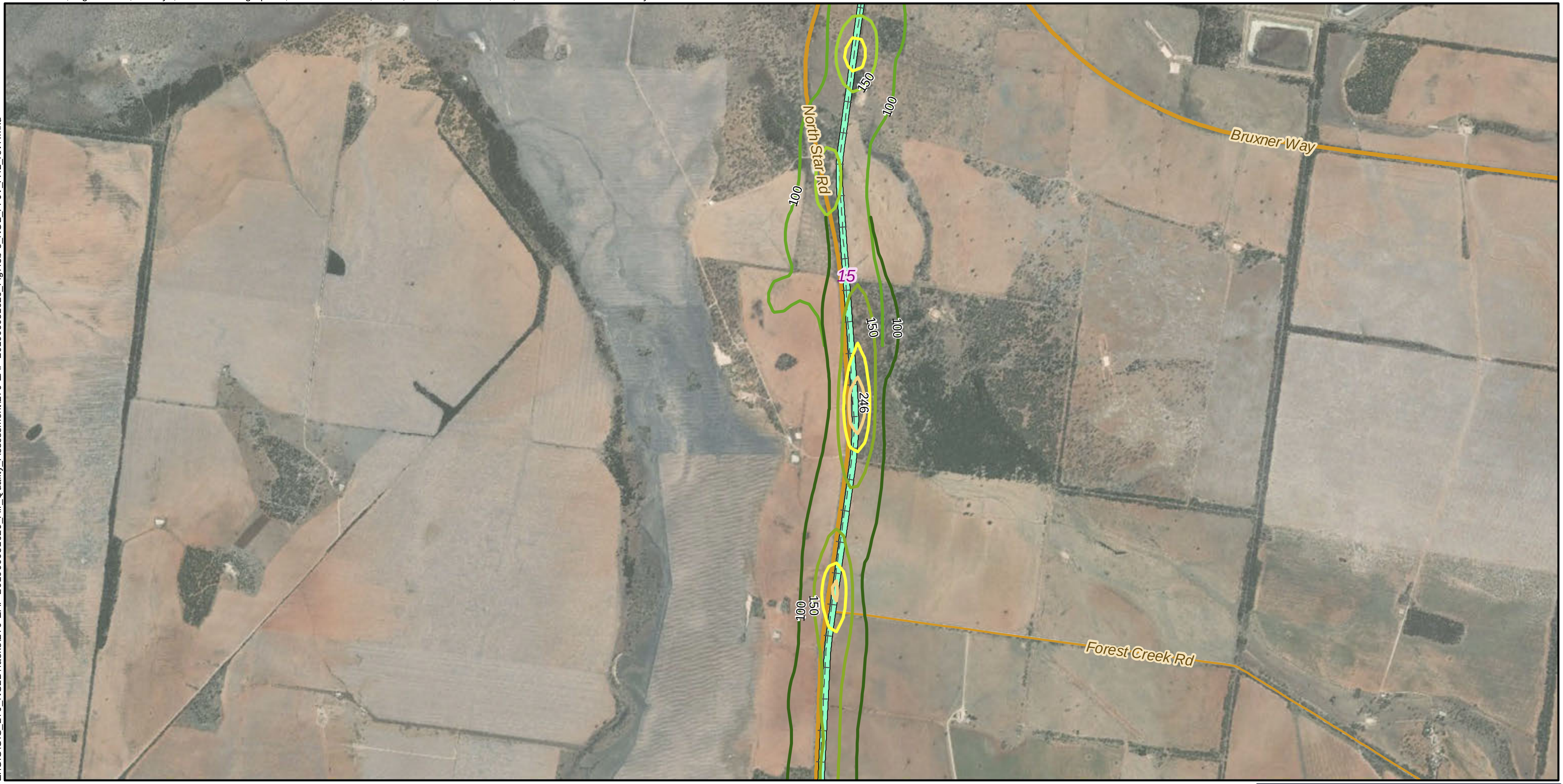
Future Freight
Integrating Community, Environment and Engineering

Date: 18/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.3b: Predicted cumulative NO_2 maximum 1 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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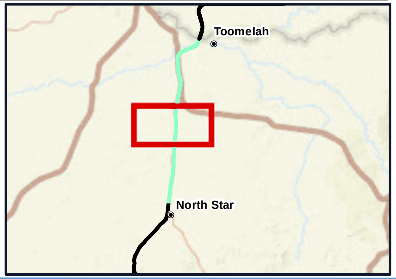
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative NO_2 maximum 1 hour ground level concentration (µg/m³)

- 100
- 150
- 200
- 246 (NO_2 1 hour maximum criterion)
- 300



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

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Integrating Community, Environment and Engineering

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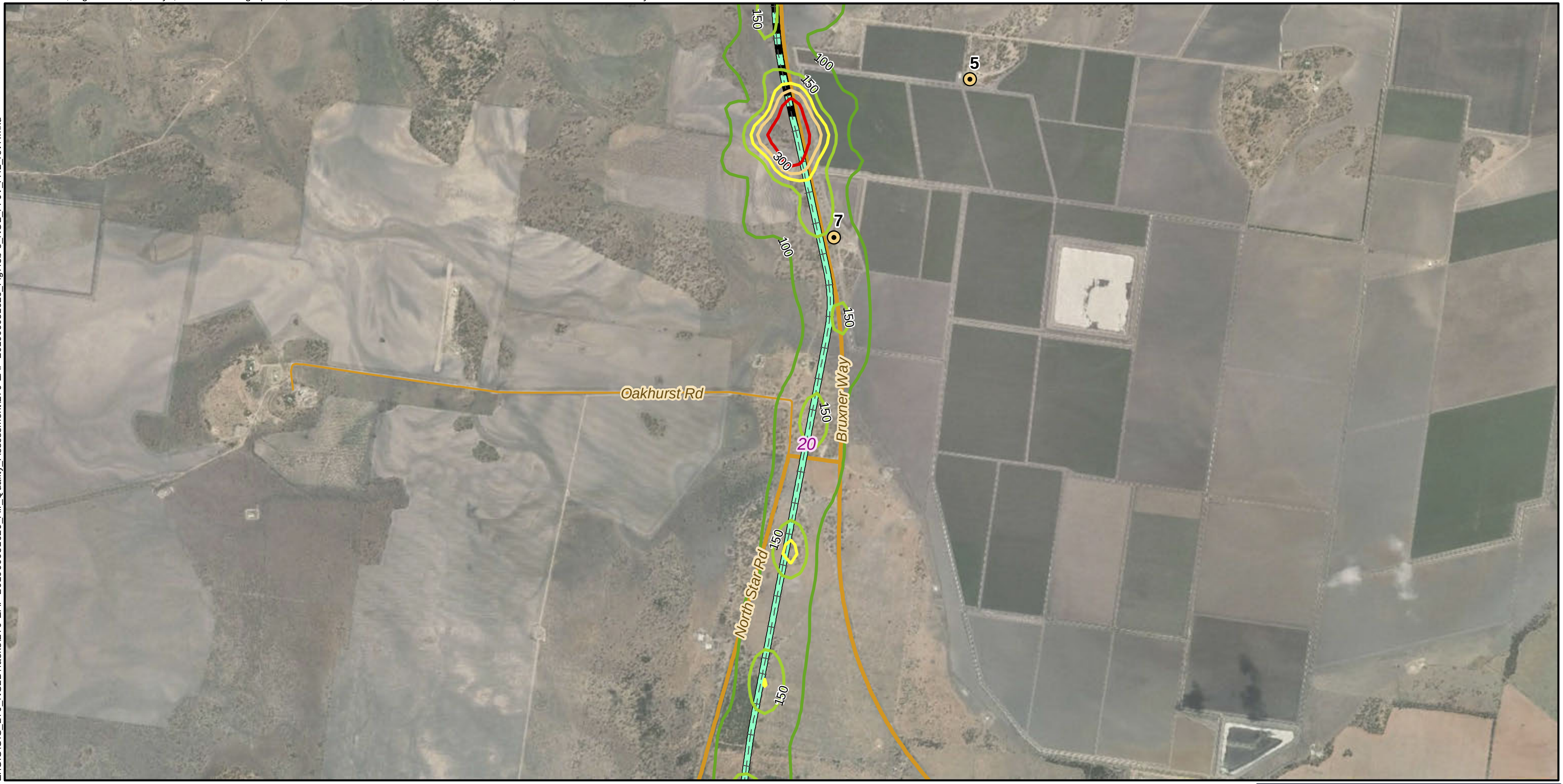
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.3c: Predicted cumulative NO_2 maximum 1 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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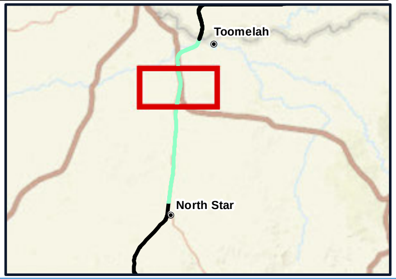
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Crossing loops
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative NO_2 maximum 1 hour ground level concentration (µg/m³)

- 100
- 150
- 200
- 246 (NO_2 1 hour maximum criterion)
- 300



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

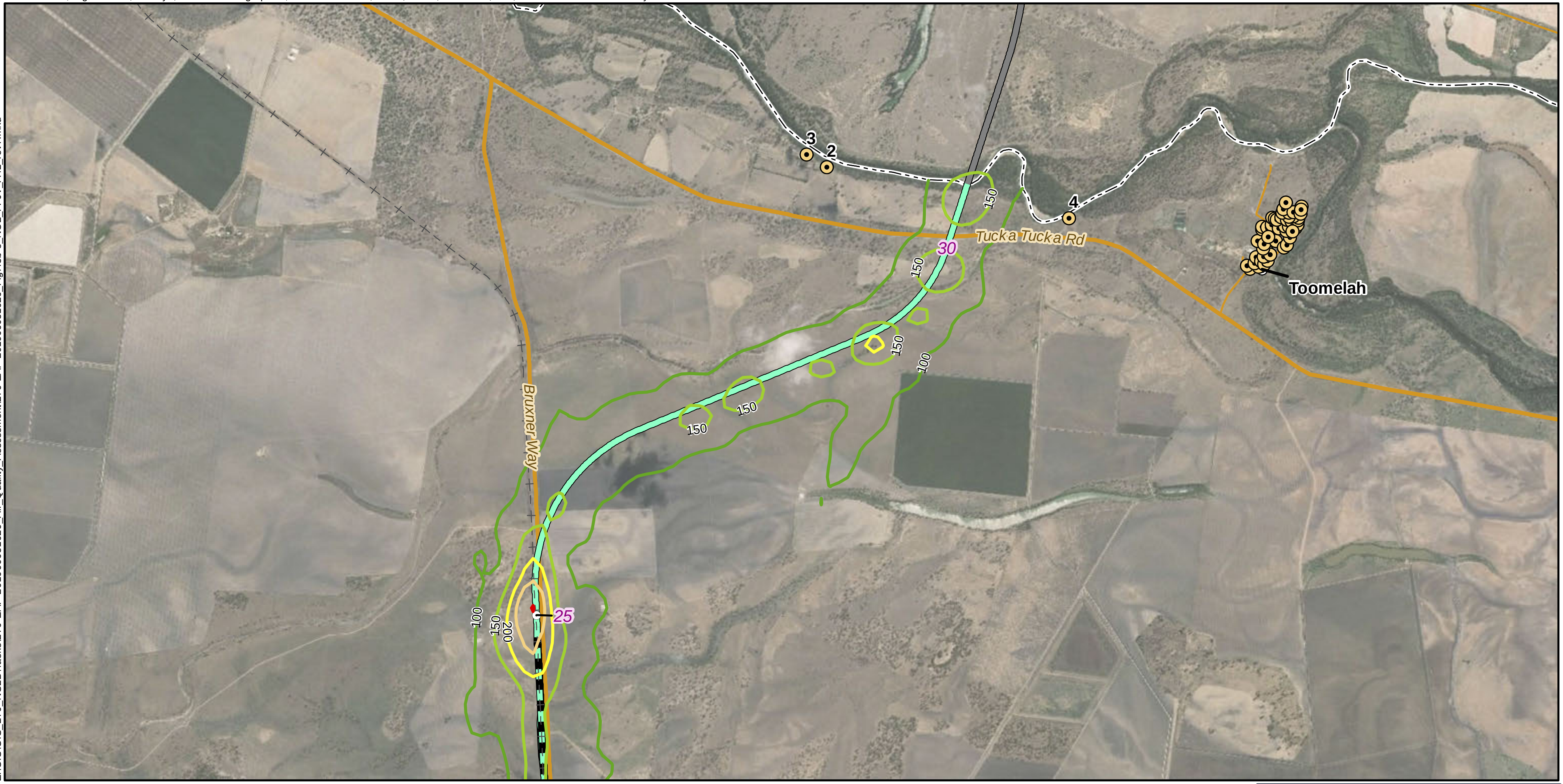
Future Freight
Integrating Community, Environment and Engineering

Date: 18/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.3d: Predicted cumulative NO_2 maximum 1 hour average ground level concentration

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Map by: CW/DMcP/GN/MEF Date: 18/02/2020 16:42
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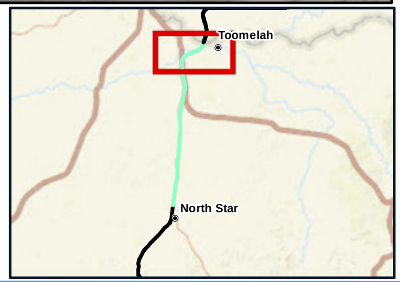
Legend

- Sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Crossing loops
- Adjoining alignments
- Major roads
- Minor roads
- NSW/QLD border

Predicted cumulative NO_2 maximum 1 hour ground level concentration (µg/m³)

- 100
- 150
- 200
- 246 (NO_2 1 hour maximum criterion)
- 300



A4 scale: 1:50,000

0 0.5 1 1.5 2 2.5 km

Future Freight
Integrating Community, Environment and Engineering

Date: 18/02/2020 Version: 7
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 7.3e: Predicted cumulative NO_2 maximum 1 hour average ground level concentration

8 Cumulative impact risk assessment

The following CIA for the environmental value of air has been completed in accordance with the approach and framework detailed in the ARTC Environmental Assessment Procedure described in Section 5.5.

The area of influence (AOI) for cumulative air quality impacts has been derived from the aforementioned assessments in this report: the qualitative impact assessment for the construction, and the quantitative impact assessment for the operation of the proposal. This AOI includes 128 existing sensitive receptor locations, described in Section 4.4 and displayed in Figure 4.4, and one proposed construction workers accommodation camp (refer Figure 6.1). It is at these receptor locations that air quality objectives per pollutant (detailed in Section 3.1) must be met. All receptors are within 2.5 km of the proposal site.

The environment in which the proposal will be constructed and operated is likely to have a number of existing regional and local sources of air pollution (natural and anthropogenic) that emit similar air pollutants as those being assessed. As such, background estimations of the relevant pollutants in the study area were made and used in the assessments of construction and operation (refer Section 4.1.6). However, these background estimations could not consider other projects that, at the time of this assessment, were being planned or constructed in the region. It is these projects that are further investigated in this CIA.

Table 8.1 details the projects determined 'State Significant' or 'Strategic' which require further discussion with respect to the potential for cumulative air quality impacts.

Both ARTC projects (B2G and N2NS) have been explicitly included in the operational air quality assessment, as they will have the same trains as the proposal. While there is potential for the construction of N2NS, the proposal and B2G to overlap, dust impacts are likely to be localised to the site locations and managed by ARTC approved mitigation measures via the relevant CEMP.

All non-ARTC projects detailed are unlikely to emit pollutants in their operation (i.e. not mining, or heavy industry in nature), so road traffic emission increases and dust during construction are likely to be the only potential air quality concerns. However, as the projects proposed locations are more than 50 km away, these potential impacts are expected to be low and outside of the air environment (or AOI) of the proposal.

Despite their temporary lifetime, establishment and operation of the borrow pits and associated road haulage may occur concurrently with the projects listed in Table 8.1. Operation of the borrow pits has the potential to impact sensitive receptors near to the pits and haul routes as discussed in Sections 6.3 and 6.4. However, as the identified 'State Significant' and 'Strategic' project locations are more than 50 km away, the risk of significant cumulative air quality impacts as a result of the operation of borrow pits is negligible.

The cumulative impact of the operation of the borrow pits and other proposal-related construction activity has been considered in the construction dust assessment (refer Section 6.1).

Table 8.1 Projects identified as 'Significant' or 'Strategic' nearby to NS2B

Project and Proponent	Location	Description	EIS status	Relationship to Inland Rail	Potential for cumulative impacts to air quality
B2G – Inland Rail (ARTC)	New South Wales/Queensland and B2G	Comprised of approximately 146km of new dual gauge track and 78km of upgraded track from the NSW/QLD border, near Yelarbon, to Gowrie Junction, north west of Toowoomba in Queensland.	Project feasibility.	Potential overlap on construction commencement for B2G and finalisation of NS2B. B2G and NS2B will operate concurrently.	This project is not anticipated to present a risk of cumulative impacts during construction due to the separation distance of active construction areas associated with this project and the mitigation measures which will be implemented. Cumulative impacts during operation have been assessed.
Narrabri to North Star – Inland Rail (ARTC)	Narrabri (NSW) to the village of North Star in NSW	An upgrade to approximately 188km of track within the existing rail corridor and construction of approximately 1.6km of new rail corridor.	Project assessment (late 2017 – late 2018).	Potential overlap of finalisation of N2NS and commencement of NS2B. NS2B and N2NS will operate concurrently.	This project is not anticipated to present a risk of cumulative impacts during construction due to the separation distance of active construction areas associated with this project and the mitigation measures which will be implemented. Cumulative impacts during operation have been assessed.
Moree Solar Farm	10km south of Moree, off the Newell Highway in Northern NSW	Construction of a 56MWac/70.1MWdc single axis tracking solar PV facility. Construction works currently involve the installation of the framing system which consists of the BladePiles and the NexTracker tracking systems, the JA Solar photovoltaic modules, the DC and AC wiring of the electrical equipment, the 22/66kV on-site substation and the 66kV transmission line.	Project was approved by the NSW Major Projects Office on 17/07/2011.	Potential increase of traffic on the Newell Highway. Construction of Moree Solar Farm is scheduled around the peak visitation to Moree in autumn.	Additional traffic on the Newell Highway is not considered to present a risk for cumulative air quality impacts.
Newell Highway Moree Town Centre Bypass	Moree	Construction of a 4.4 km two-lane bypass of the Moree town centre.	Approved by the NSW Minister for Planning on 20 July 2004. Latest modification 8 approved 7 July 2010.	Potential increase of traffic on the Newell Highway.	Additional traffic on the Newell Highway is not considered to present a risk for cumulative air quality impacts.
Hunter Gas Pipeline	Wallumbilla to Newcastle	420 km high pressure gas transmission pipeline from the Wallumbilla Gas Hub in South Central Queensland to the existing Sydney-Newcastle pipeline at Hexham in New South Wales.	Project determined under Part 3A – now transitioned to State Significant Infrastructure (SSI) pathway.	If construction occurs at the same time there is potential for increase in traffic using similar routes and demand for construction resources and personnel.	Cumulative construction traffic is not considered to present a significant risk for cumulative air quality impacts.

Project and Proponent	Location	Description	EIS status	Relationship to Inland Rail	Potential for cumulative impacts to air quality
White Rock Wind Farm	20 km south-west of Glen Innes, 40 km east of Inverell NSW	Stage 2 of White Rock Wind Farm upgrades will consist of up to 48 turbines, producing up to 202 MW of clean renewable electricity.	Approved by the NSW Minister for Planning on 10 July 2012.	Approximately 150 km from the NS2B alignment. Potential increase in road traffic on the Gwydir Highway and the Newell Highway.	Significant distance from NS2B. Additional traffic is not considered to present a risk for cumulative air quality impacts.

9 Mitigation

This section outlines the initial mitigation measures included in the proposal design and identifies proposed mitigation measures to manage predicted environmental impacts in the preconstruction, and construction and operational phases of the proposal.

9.1 Initial mitigation – design measures

The initial mitigation measures presented in Table 9.1 have been incorporated into the proposal design. These design measures have been identified through collaborative development of the design and consideration of environmental constraints and issues, including proximity to sensitive receptors. These design measures are relevant to both construction and operational phases of the proposal.

Table 9.1 Initial mitigation in design

Aspect	Initial mitigation
Emissions from refuelling activities during construction	The planning, siting and assessment of potential fuel storage locations has taken into consideration the location of sensitive receptors.
Fugitive dust emissions (windborne erosion) during construction and operation	The disturbance footprint defined in proposal design has aimed to minimise clearing extents to that required to construct and operate the works. Railway batters and other exposed surfaces have been designed to enable stabilisation to reduce fugitive dust emissions.
Emissions from idling locomotives	The planning and siting of the crossing loop between chainage 22.7 km to chainage 24.9 km has considered the location of sensitive receptors.

9.2 Operational management measures

Dust and air quality management measures will be incorporated into the frameworks that will apply to third party freight train operators as part of network access agreements. The access agreements established will require train operators to prepare suitably detailed environmental management plans for their operations to detail how the operator will manage all risks. These plans will include clear performance requirements and traceable corrective measures and be subject to verification and auditing by the operator.

Prior to accessing the Inland Rail network, ARTC will ensure any and all operator(s):

- Develop and implement their plan in a manner that is consistent with ARTC's Environmental Management Plan(s)
- Comply with all relevant conditions of approval, licences, permits, consent or other requirement of any authority, body or organisation having jurisdiction in connection with the Inland Rail network.

At all times while accessing the Inland Rail network, any and all operators will be required to:

- Perform activities in a satisfactory manner consistent with the principles of best practice management
- Undertake activities on the Inland Rail network in a proper and efficient manner to minimise emissions
- Seek opportunities to improve the management of air quality and reduce fugitive emissions through the adoption of suitable procedures.

Maintenance activities with the potential to generate dust or air quality impacts will be managed in accordance with the measures prescribed in ARTC's Operational Environmental Management Plan (OEMP).

9.3 Proposed mitigation measures

In order to manage risks during construction a number of mitigation measures have been proposed for implementation in future phases of delivery of the proposal, as presented in Table 9.2. These proposed mitigation measures have been identified to address specific issues and opportunities, address legislative requirements, accepted government plans, policy and practice.

In the pre-construction and construction phases of the proposal, dust sources will be variable and transitory in nature and the potential for impacts will vary with proximity to sensitive receptors.

Table 9.2 identifies the relevant proposal phase, the aspect to be managed, and the proposed mitigation measure, which is then factored into the assessment of residual significance in Table 9.3.

9.4 Impact assessment

Chapter 10: Assessment methodology, presents the qualitative (significance) and quantitative (compliance) assessment methods adopted for this impact assessment. Potential air quality impacts during construction have been assessed in accordance with the qualitative impact assessment methodology. A quantitative (compliance) assessment has been undertaken for potential operational impacts, as predicted concentrations at sensitive receptors have been assessed against legislative and other nominated air quality objectives. The results of the quantitative assessment of potential operational impacts are detailed in Section 7.

Potential impacts to sensitive receptors due to construction of the proposal have been assessed in Table 9.3. These impacts have been assessed following the IAQM risk assessment methodology as discussed in Section 6.

The initial significance assessment is undertaken on the assumption that the design measures factored into the reference design phase (refer Table 9.1) have been implemented. The residual significance level of the potential impacts is reassessed taking into consideration the implementation of the proposed additional mitigation measures listed in Table 9.2.

The IAQM construction dust assessment guidance states:

> 'For almost all construction activity, the aim should be to prevent significant effects on sensitive receptors through the use of suitable and effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be "not significant".'

Table 9.3 shows that the residual significance with the proposed mitigation measures is low or negligible. Consistent with the IAQM statement, it is expected that with implementation of the proposed mitigation measures the impacts to air quality with respect to dust deposition and human health will not be significant. This table has been structured to maintain consistency with the IAQM methodology which is activity based and as such earthworks are assessed across both the pre-construction and construction phase.

Trackout has also been assessed across both the pre-construction and construction phases. Trackout is the transport of dust and dirt from the construction/demolition site onto the public road network, where it may be deposited and then re-suspended by vehicles using the network. In the case of the proposal, this also includes vehicle travel on unsealed roads.

Given the uncertainty associated with timeframe for decommissioning, this phase has not been considered in this impact assessment.

Table 9.2 Air quality mitigation measures

Delivery phase	Aspect	Proposed mitigation measures
Detailed design	Dust generation (windborne erosion) from construction or operation	Incorporate treatments in earthworks and landscape design of railway batters and other exposed surfaces. Define and design temporary access tracks to minimise dust generation, e.g. appropriate surface treatments for the predicted construction traffic movements, installation of rumble grids, concrete pads or other physical measures to reduce trackout. Define proposed stockpiles locations with consideration of proximity to sensitive receptors.
	Emissions from refuelling activities during construction	Review and refine the location of proposed fuel tank storage locations, particularly where the separation distance to a sensitive receptor is less than 50 m.
Construction	Dust generation from earthworks, clearing and grubbing, construction activities and exposed areas within the construction disturbance footprint	Limit clearing to that required to construct and operate the proposal Where practical, stage clearing and grubbing and construction activities to limit the size of exposed areas. Implement controls to prevent or minimise dust generation during activities involving excavation or disturbance of soils or vegetation, or handling ballast (e.g. use water sprays or water carts for dust suppression as required). Stabilise disturbed areas and exposed surfaces as soon as practical. Long-term stockpiles should be avoided wherever possible. However, where necessary, long-term stockpiles should be established in locations with suitable separation from sensitive receptors and not in the path of prevailing winds (which would transport dust towards sensitive receptors). Stabilise and protect long-term stockpiles from erosive processes whilst not in use. Provide timely, meaningful responses to air quality or dust complaints. This may include investigations, corrective actions, monitoring or notification to relevant authorities. Establish and communicate the protocol for notifying relevant stakeholders when potentially dust generating activities are planned to be carried out, with contact details for queries or complaints. Visually monitor dust generation (visible plumes) throughout construction. In addition, undertake visual inspection at the boundary of the disturbance footprint in areas in proximity to sensitive receptors to inform when corrective actions are required.
	Dust generation and deposition as a result of adverse weather conditions	Avoid ground-disturbing activities during windy conditions. When this is not practical, implement additional management measures, such as enhanced watering of access roads and works areas to minimise the potential increase in dust generation. Implement additional dust suppression controls prior to the onset of adverse weather, including covering of stockpiles and additional watering of access roads.
	Emissions from refuelling activities	Refuelling activities to be located and operated in accordance with a risk assessment to minimise odour and air quality issues at a sensitive place.
	Emissions from combustion engines (construction vehicles and generators)	Maintain and operate construction plant, vehicles and machinery in accordance with manufacturer's recommendations. Turn off idling plant, equipment and vehicles when not in use.
	Use of non-potable water for dust suppression	Water used in dust suppression must be of suitable quality and not result in environmental or human health risks, or impact rehabilitation outcomes. Water additives used to improve dust suppression effectiveness (e.g. the addition of soil binders to water for dust suppression on roads or hand stand areas) are to be risk assessed prior to adoption.

Delivery phase	Aspect	Proposed mitigation measures
	Dust generated by traffic on access tracks	Where sensitive receptors are located within 350 metres of construction works, or visible dust is generated from vehicles using unsealed access roads, road watering or other appropriate controls are to be implemented. Adjust access road watering or treatments as required to prevent visible dust generation or impacts to sensitive receptors.
	Dust emissions from vehicles transporting materials to and from site	Cover vehicles transporting potentially dust and/or spillage generating material to and from the construction site immediately after loading (prior to traversing public roads). Visually inspect vehicles entering/exiting the site and implement additional controls if corrective actions are required.

Table 9.3 Initial and residual significance assessment for potential air quality impacts associated with construction

Activity	Aspect[1]	Potential impact	Receptor sensitivity	Initial significance[2]		Residual significance[3]	
				Emission magnitude	Significance	Emission magnitude	Significance
Demolition	All dust generating sources associated with demolition	Dust deposition	Medium	Small	Low	Small	Low
		Human health	Low	Small	Negligible	Small	Negligible
Earthworks associated with pre-construction and construction phase	All dust generating sources associated with pre-construction and construction phase earthworks	Dust deposition	Medium	Large	Medium	Small	Low
		Human health	Low	Large	Low	Small	Negligible
Construction	All dust generating sources associated with the construction phase	Dust deposition	Medium	Medium	Medium	Small	Low
		Human health	Low	Medium	Low	Small	Negligible
Trackout associated with pre-construction and construction phase.	All dust generating sources associated with pre-construction and construction phase traffic	Dust deposition	Medium	Large	Medium	Medium	Low
		Human health	Low	Large	Low	Medium	Low

Table notes:

1 Refer to Table 9.2 for reference to the proposed additional mitigation measures relevant to each aspect.
2 Includes implementation of initial mitigation specified in Table 9.1.
3 Assessment of residual risk with the implementation of the mitigation measures in Table 9.2.

10 Sustainability

The following key points have been found from the air quality impact assessment from the operation and construction of the proposal.

- Modelling of the operation of the proposal demonstrates that it is likely that the proposal will be compliant with the adopted air quality objectives.
- From the construction dust impact assessment, recommendations have been included for dust control measures to be included in a CEMP, as per Section 9.3.

This demonstrates partial compliance with Dis-4 air quality benchmarks for Levels 1 through 3. However, in order to fully comply with Level 1 or higher benchmarks the following steps would also be required:

- Monitoring of air quality at appropriate intervals during construction and operation of the proposal, which could include the following:
  - Dust deposition monitoring during the construction of the proposal and in response to nuisance complaints
  - Ambient air quality monitoring for the following pollutants – particulates (i.e. PM_{10} and $PM_{2.5}$) and oxides of nitrogen (NO_x) utilising methodologies outlined in appropriate Australia Standards.

11 Conclusions

An air quality impact assessment has been conducted to examine the proposal to ensure emissions along the proposal site are understood and any potential impacts on receptors along the rail corridor are mitigated. Based on the assessment, the following conclusions in relation to potential air quality impacts can be made:

- A CEMP will be required for the construction of the proposal to manage potential impacts from dust emission.
- Atmospheric dispersion modelling undertaken as part of the assessment predicts air quality pollutants to be below the air quality objectives at all the nearest sensitive receptors.

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APPENDIX

L

Air Quality
Technical Report

Appendix A Meteorological Data

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

Appendix A
Meteorological data

El Niño-Southern Oscillation

For Australia, the El Niño-Southern Oscillation (ENSO) has the strongest effect on year to year climate variability in Australia, mostly affecting rainfall and temperature. El Niño incidences represent periods of unusually warm Pacific Ocean conditions along the western coast of South America, which frequently presents as high rainfall events in South America and drought conditions for Australia. Conversely, La Niña periods represent cooler ocean surface temperatures along the western coast of South America and increase the likelihood of drought conditions locally and high rainfall periods in Australia.

The Southern Oscillation Index (SOI), Oceanic Niño Index (ONI), and Multivariate ENSO Index (MEI) are measures that indicate episodes of El Niño and La Niña. Due to differences in methodology, each of these aforementioned indices can have slightly differing results. In order to provide a robust investigation of ENSO periods, monthly results from each of these measures have been analysed.

The SOI is defined as the standardized differences in barometric readings from Darwin, Australia and Tahiti. Sustained negative SOI values of below -7 often present as El Niño episodes, and positive SOI values above 7 are associated with La Niña. Figure A1 presents the monthly SOI values for the period of 2008 to 2017. Several episodes of El Niño and La Niña have been documented by BoM for this period.

These include the following:

- El Nino periods in 2015 – 2016 and 2009 – 2010
- La Nina periods in 2010 – 2012 and 2008 – 2009.

From review of the monthly SOI, three years have been identified as being relatively neutral. These include 2013, 2014, and 2017, which were measured to have 7, 5, and 8 months of the year to be neutral in terms of the SOI, respectively.

The ONI is the primary indicator utilised by the National Oceanic and Atmospheric Administration (NOAA) in the USA to monitor the strength of ENSO. ONI is based upon the averages in sea surface temperature anomalies in an area of the east-central equatorial Pacific Ocean, which is called the Niño-3.4 region. The index consists of a monthly 3-monthly running mean in order to better isolate variability closely related to the ENSO phenomenon. Threshold values of +/- 0.5 ^{o}C indicate periods of higher likelihood for El Niño and La Niña.

For the period of 2008 to 2017 the following El Niño and La Niña periods have been identified by NCEP utilising the ONI index.

- 2007 – 2008 Strong La Niña
- 2008 – 2009 Weak La Niña
- 2009 – 2010 Moderate El Niño
- 2010 – 2011 Strong La Niña
- 2011 – 2012 Moderate La Niña
- 2014 – 2015 Weak El Niño
- 2015 – 2016 Very Strong El Niño
- 2016 – 2017 Weak La Niña
- 2017 – 2018 Weak La Niña

The period of 2012 to 2013 and 2013 to 2014 represent the only years that have been neutral in terms of ENSO utilising the ONI measure for the years 2008 to 2017.

The Multivariate ENSO Index (MEI) utilises six main observed variables of the tropical Pacific. These six variables are: sea-level pressure, zonal and meridional components of surface wind, sea surface temperature, and total cloudiness fraction of the sky. Negative values of the MEI represent the cold ENSO phase, La Niña, while positive MEI values represent the warm ENSO phase (El Niño). From review of the MEI monthly values, significant periods of La Niña are observed for 2008, 2010-2011, and El Niño for 2009 and 2014 to 2016. Weaker periods of El Niño in 2012 and the first half of 2017 were recorded. Neutral conditions were observed for 2013 utilising the MEI measure.

Utilising the SEI, ONI, and MEI measures for ENSO, agreeance can be seen on which years represent periods of El Niño or La Niña. The three indices show that the year 2013 was relatively neutral in terms of ENSO. Therefore, the year 2013 represents an ideal candidate for selection of meteorological period that is relatively unaffected by variances in weather due to ENSO.

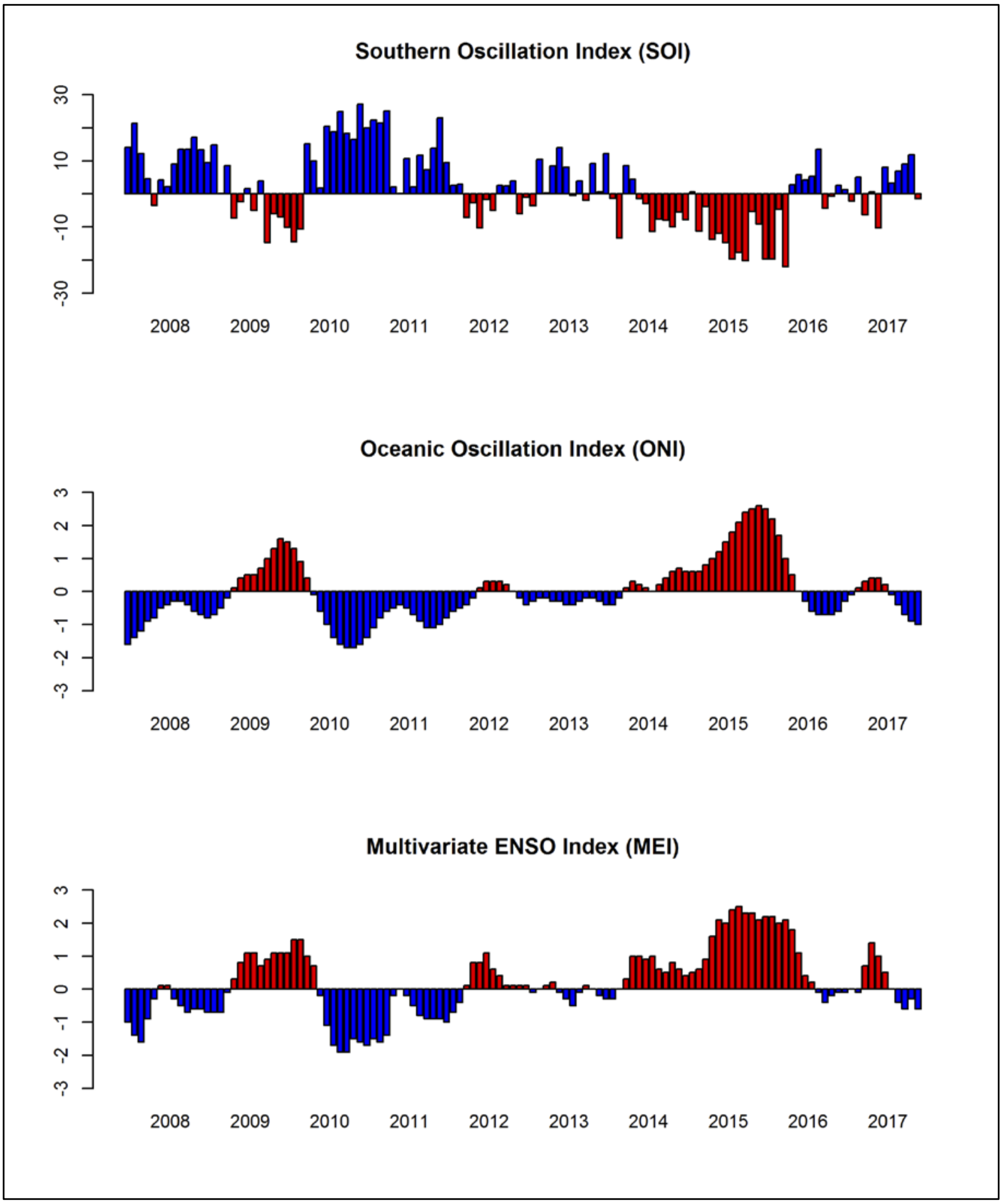

Figure A1 **Comparison of Monthly SOI, ONI, and MEI for 2008 to 2017 (red indicating higher likelihood of El Niño conditions, and blue indicating higher likelihood of La Niña conditions)**

Moree Meteorological Data

Table A1, Figure A2, and Figure A3 contain a summary of the meteorological data for the Bureau of Meteorology (BoM) Moree AERO monitoring station.

Historical meteorological data including average temperatures; rainfall; relative humidity; wind speed and wind roses showing the average monthly wind conditions at 9.00 am and 3.00 pm were obtained from the BOM website (http://www.bom.gov.au/climate/averages/tables/cw_053115.shtml; accessed 4 September 2018).

The warmest temperatures occur in summer, with the average maximum temperature recorded in January (34.0 °C). July is the coldest month with an average minimum temperature of 4.5 °C. Rainfall is highest in January (mean rainfall of 81.0 mm) and lowest in April (mean rainfall of 23.4 mm). Annual average rainfall is 583.0 mm. Both morning and afternoon mean wind speed is relatively consistent throughout the year ranging from 12.9 to 21.0 km/h (3.6 to 5.8 m/s) with wind roses showing the following patterns:

- January to March - morning winds are predominantly from the northeast with very low calm conditions (1 per cent). Afternoon winds become variable with very low (<1 per cent) calm conditions.
- April to June - morning winds are predominantly from the east with low calm conditions (2 to 4 per cent). Afternoon winds change to a southwest with very low (<1 per cent) calm conditions.
- July to September - morning winds are predominantly from the northeast with low calm conditions of 1 to 5 per cent. Afternoon winds change to a southwest with low (<1 to 2 per cent) calm conditions.
- October to December – both morning winds are predominantly from the north and northeast with very low (1 per cent) calm conditions. Afternoon winds show an increase in winds from the southwest with very low calm conditions (<1 per cent).

Table A1 Meteorological data at Moree AERO BoM Station (1995 to 2017)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Mean maximum temperature (°C)	34.0	33.2	31.1	27.3	22.6	18.9	18.1	20.4	24.5	28.1	30.8	32.7	26.8
Mean minimum temperature (°C)	20.2	19.7	17.3	12.8	8.2	6.0	4.5	5.2	8.9	12.7	16.4	18.5	12.5
Rainfall													
Mean rainfall (mm)	81.0	69.4	53.6	23.4	27.9	39.7	36.3	25.4	35.1	46.3	75.4	68.4	583.0
Decile 5 (median) rainfall (mm)	76.0	63.4	54.2	17.4	23.6	30.8	18.2	15.0	23.9	47.6	54.2	61.2	534.2
Mean number of days of rain ≥ 1 mm	5.8	5.3	4.4	2.5	3.0	4.1	4.0	2.9	4.1	5.2	6.0	6.5	53.8
9.00 am conditions													
Mean 9.00 am temperature (°C)	24.7	24.0	21.8	20.1	15.1	11.5	10.3	12.8	17.4	20.7	22.1	24.1	18.7
Mean 9.00 am relative humidity (per cent)	58	62	62	55	64	75	73	62	56	50	54	55	60
Mean 9.00 am wind speed (km/h)	20.8	19.3	17.7	16.3	13.7	12.9	13.3	15.8	17.7	19.7	20.6	21.0	17.4
Mean 9.00 am calms (per cent)	<1	1	1	2	4	4	5	3	1	1	<1	1	2
3.00 pm conditions													
Mean 3.00 pm temperature (°C)	31.9	31.1	29.5	26.1	21.5	18.0	17.2	19.5	23.4	26.6	28.5	30.8	25.3
Mean 3.00 pm relative humidity (per cent)	35	37	34	31	38	46	43	35	32	30	32	32	35
Mean 3.00 pm wind speed (km/h)	15.5	15.7	15.3	15.6	15.6	16.2	16.8	17.8	17.0	17.3	18.0	17.3	16.5
Mean 3.00 pm calms (per cent)	<1	<1	<1	<1	<1	<1	2	<1	1	<1	<1	<1	<1

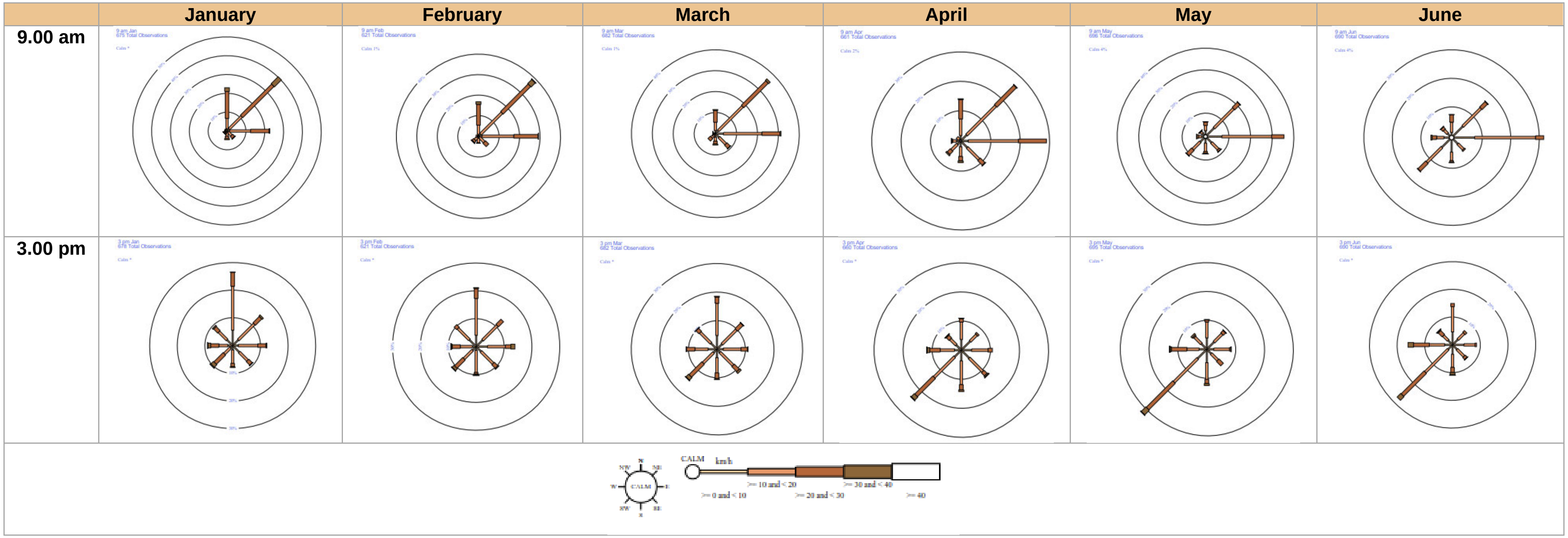

Figure A2 January to June 9.00 am and 3.00 pm wind roses – Moree AERO BoM Station (1995 to 2017)

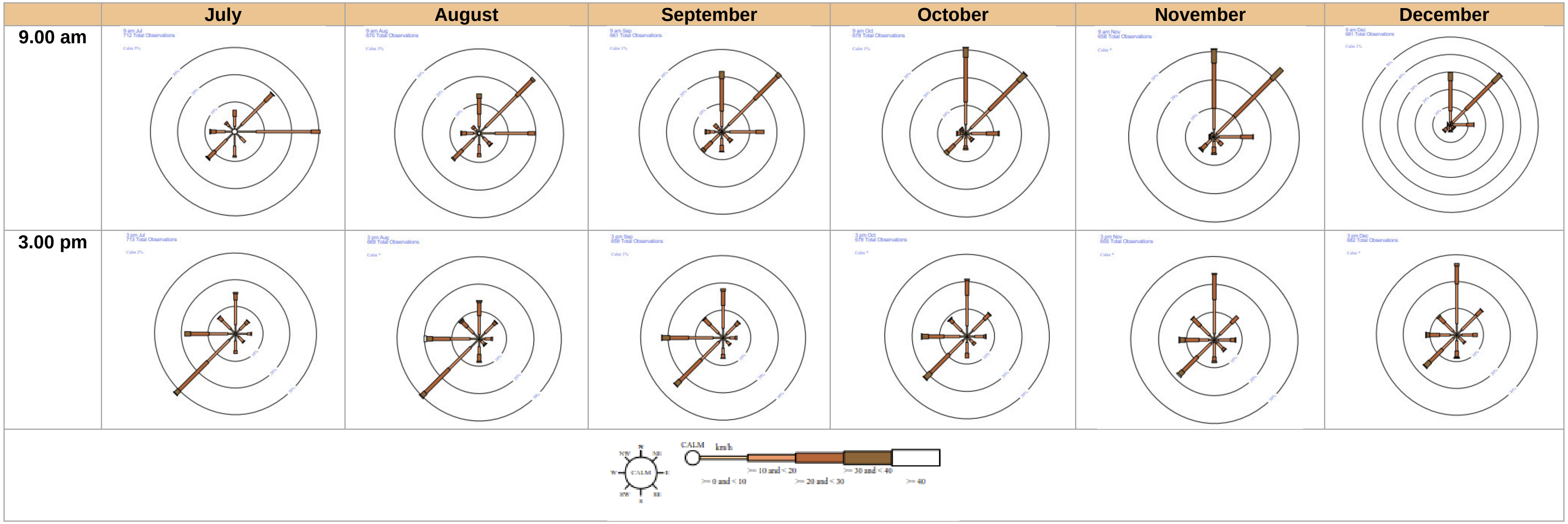

Figure A3 July to December 9.00 am and 3.00 pm wind roses – Moree AERO BoM Station (1995 to 2017)

Prognostic meteorological data

As no site specific meteorological monitoring data was available at the time of the assessment, meteorological data was generated utilising the meteorological models TAPM and CALMET. Due to the significant separation distance (~80 km) between the Moree AERO BoM station and the Study area direct comparisons cannot be made within the model domain to validate the meteorological dataset. However, due to the flat terrain and similar land use in the area it is expected that meteorological conditions in the Study area would be relatively similar to those at the Moree AERO BoM station. As such, some comparisons can be made to determine representativeness of the utilised dataset to the Study area.

Figure A4 to Figure A7 show the 9.00 am and 3.00 pm wind roses for the generated data for 2013 for both the northern and southern CALPUFF model domains.

From review of the generated meteorological data and monthly wind roses the following key features were identified. Both morning and afternoon mean wind speed is relatively consistent throughout the year ranging from 2.2 to 4.7 m/s with wind roses showing the following patterns:

- January to March - morning winds are predominantly from the northeast and east with very low calm conditions (<1 per cent). Afternoon winds are predominantly from the east with very low (<1 per cent) calm conditions.
- April to June - morning winds are predominantly from the east with low calm conditions (3 to 6 per cent). Afternoon winds change to a southwest with very low (<1 per cent to 6 per cent) calm conditions.
- July to September - morning winds are predominantly from the northeast with low calm conditions of 3 to 6 per cent. Afternoon winds change to a southwest with low (<1 to 2 per cent) calm conditions.
- October to December – both morning winds are predominantly from the north and northeast with very low (1 per cent) calm conditions. Afternoon winds show an increase in winds from the southwest with very low calm conditions (<1 per cent).

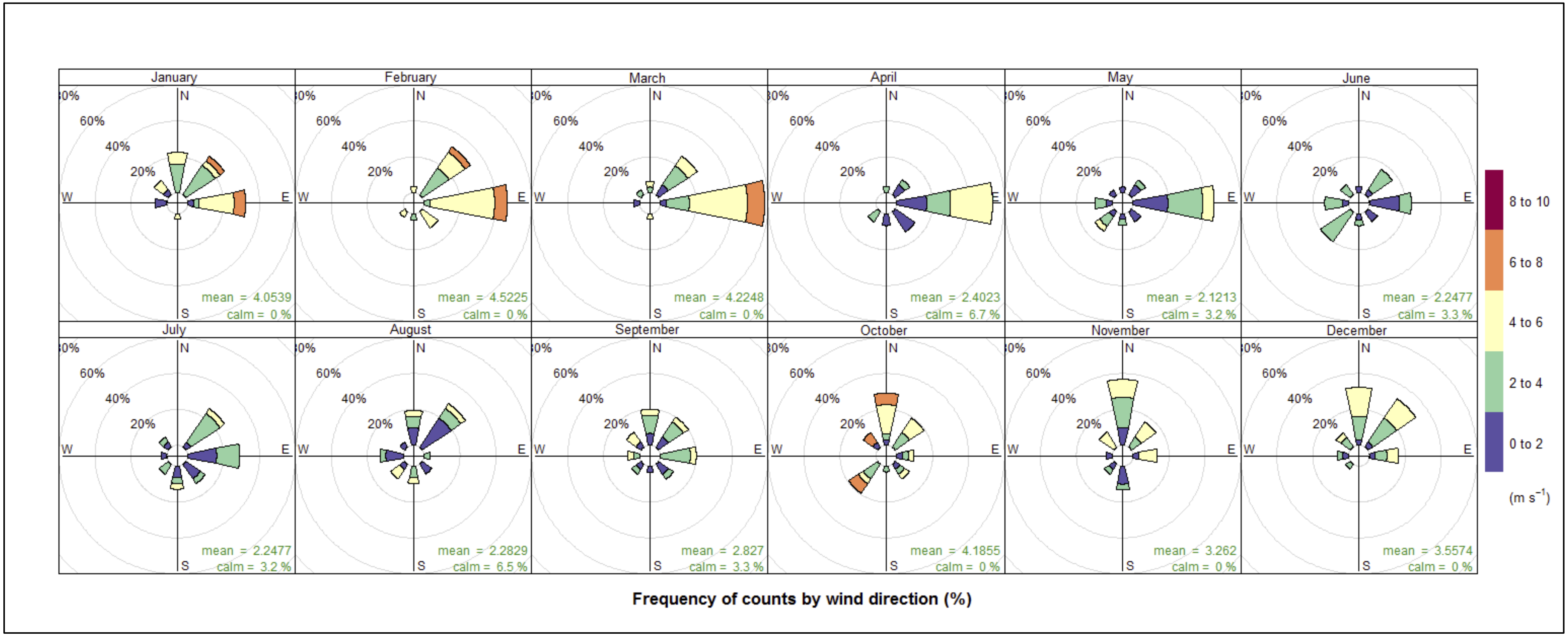

Figure A4 Monthly 9.00 am wind roses – Northern model domain CALMET (2013)

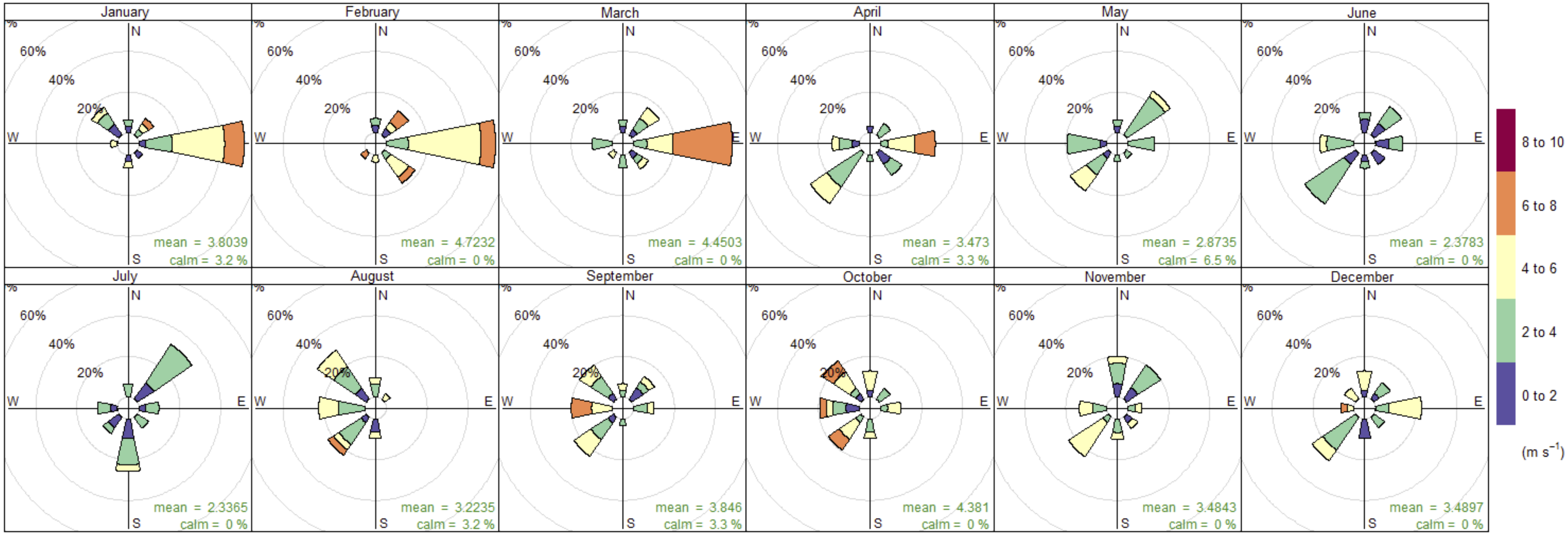

Figure A5 Monthly 3.00 pm wind roses – Northern model domain CALMET (2013)

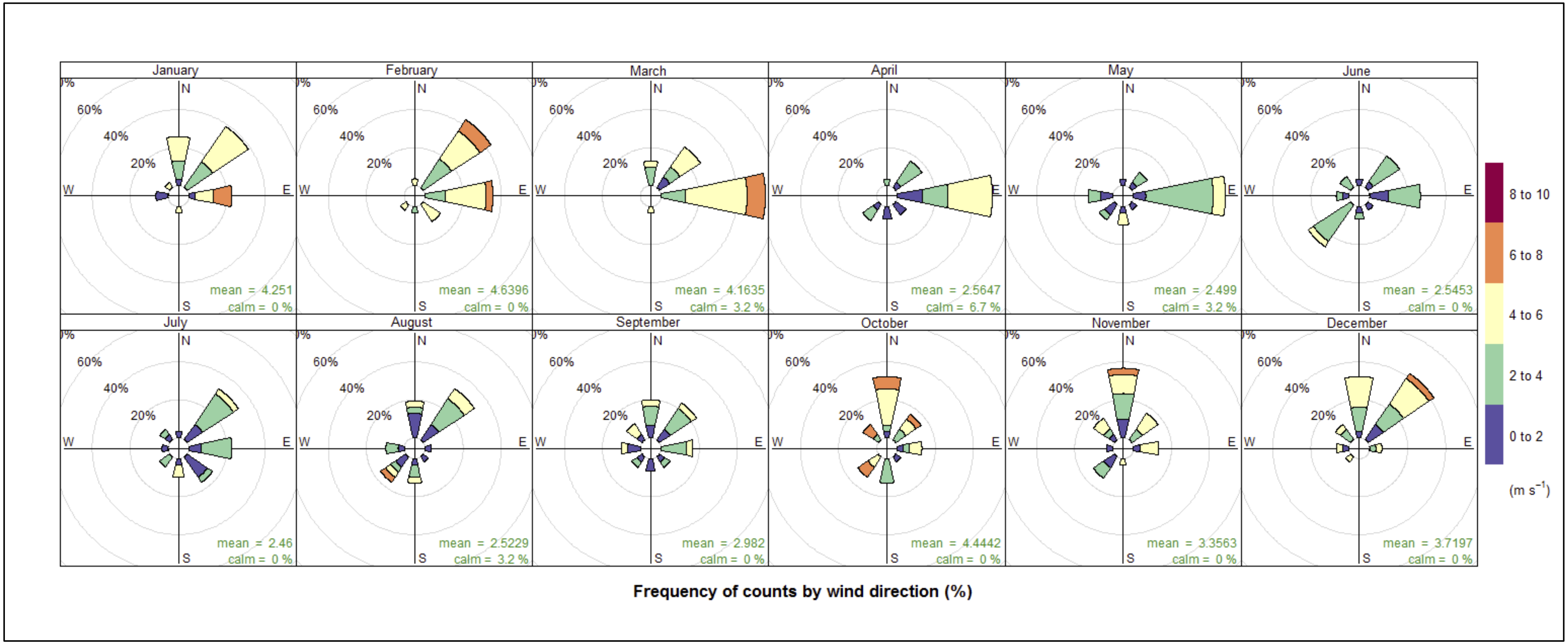

Figure A6 Monthly 9.00 am wind roses – Southern model domain CALMET (2013)

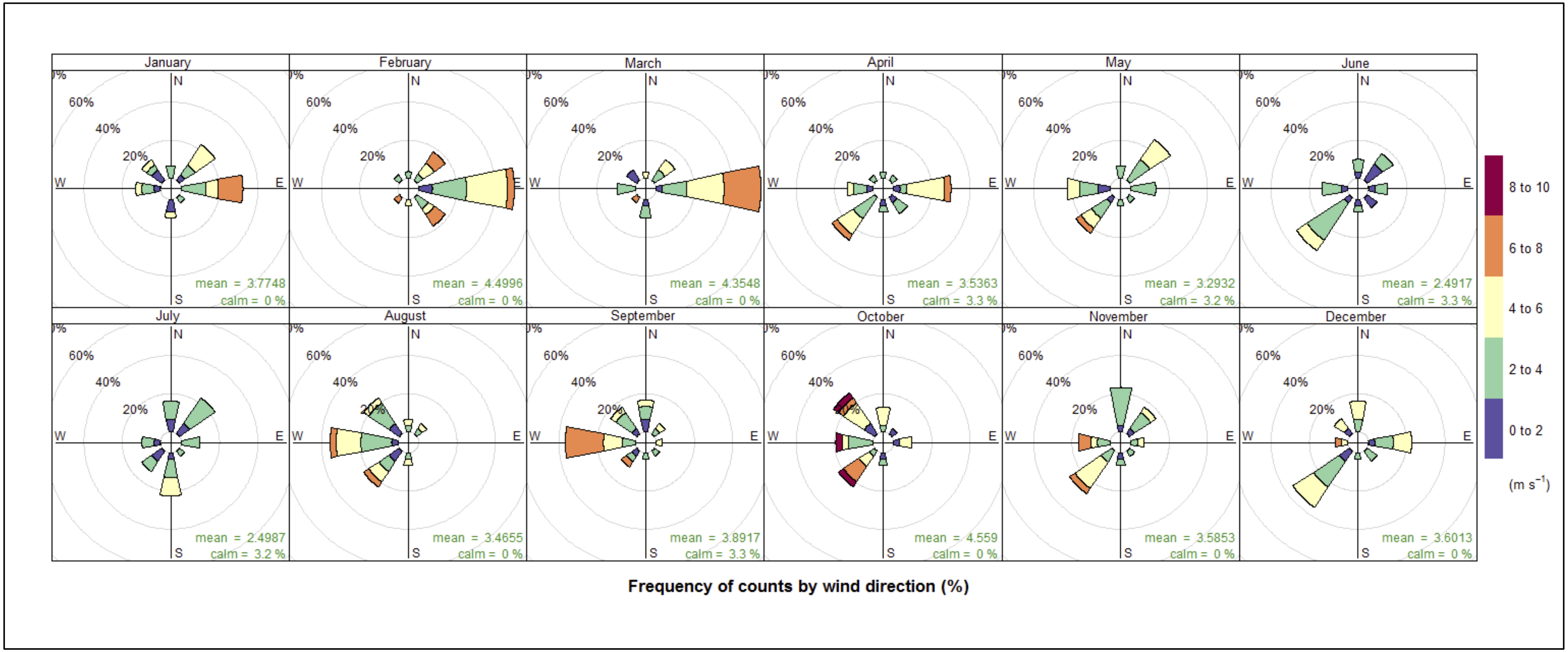

Figure A7 Monthly 3.00 pm wind roses – Southern model domain CALMET (2013)

Atmospheric stability

Atmospheric stability is a measure of the convective properties of a parcel of air. Stable conditions occur when convective processes are low, while unstable conditions are associated with stronger convective processes, which are associated with potentially rapid changes in temperature. Stable atmospheres occur when a parcel of air is cooler than the surrounding environment, so the parcel of air (and any pollution within it) sinks. Conversely, unstable atmospheres occur when a parcel of air is warmer than the surrounding environment, making the parcel of air buoyant and, subsequently, leading to the parcel of air rising.

Stability class data extracted from the CALMET files at locations representing the northern and southern CALPUFF modelling domains. The following tables indicate stability classes designated as A to F, which correspond to the Pasquill-Gifford stability class designations. Classes A, B and C represent unstable conditions, with class A representing very unstable conditions and C representing slightly unstable conditions. Class D stability corresponds to neutral conditions, which are typical during overcast days and nights. Classes E and F correspond to slightly stable and stable conditions respectively, which occur at night.

The stability class data were analysed for time of day as shown in the following tables. As expected, the stability classes indicate stable conditions during the night hours and neutral and unstable conditions during the day. Wind speeds were found to be highest for the class D stability and lowest wind speeds associated with classes A and B. Stability class F made up the greatest proportion if stability classes, which occurred during night time periods. It is expected that this is an over representation of stability class F, with actual night time stability would present a greater proportion of class E. The over prediction of highly stable conditions at night time is a known issue with prognostic data generated by the TAPM model utilised in this assessment. In terms of dispersion modelling impacts, it is likely to worsen dispersion conditions for periods of stability class F and result in over prediction of pollutant concentrations. As such, results from dispersion modelling are expected to be conservative due to the input prognostic meteorology.

Table A2 Hourly stability class frequency for CALMET generated for Northern modelling domain (2013)

Hour	Stability class frequency counts					
	A	B	C	D	E	F
1	0	0	0	13	70	281
2	0	0	0	11	56	298
3	0	0	0	6	54	305
4	0	0	0	5	48	312
5	0	0	0	6	41	318
6	0	0	24	87	17	237
7	0	15	124	117	9	100
8	0	39	220	106	0	0
9	3	137	196	29	0	0
10	6	162	170	27	0	0
11	51	188	111	15	0	0
12	64	206	88	7	0	0
13	63	201	93	8	0	0
14	49	173	117	26	0	0
15	5	132	180	48	0	0
16	4	98	179	84	0	0
17	0	24	160	181	0	0
18	0	7	69	180	16	93
19	0	0	10	99	49	207
20	0	0	0	38	74	253

Hour	Stability class frequency counts					
	A	B	C	D	E	F
21	0	0	0	33	87	245
22	0	0	0	20	104	241
23	0	0	0	17	102	246
24	0	0	0	17	96	251
Proportion	3 per cent	16 per cent	20 per cent	13 per cent	9 per cent	39 per cent
Average wind speed (m/s)	**1.4**	**2.4**	**3.6**	**4.4**	**4.0**	**2.0**

Table A3 Hourly stability class frequency for CALMET generated for Southern modelling domain (2013)

Hour	Stability class frequency counts					
	A	B	C	D	E	F
1	0	0	0	13	79	272
2	0	0	0	11	64	290
3	0	0	0	9	58	298
4	0	0	0	6	50	309
5	0	0	0	6	45	314
6	0	0	22	90	23	230
7	0	14	116	126	8	101
8	0	32	225	108	0	0
9	4	124	201	36	0	0
10	6	145	176	38	0	0
11	48	174	123	20	0	0
12	62	196	99	8	0	0
13	59	190	104	12	0	0
14	43	166	121	35	0	0
15	5	136	157	67	0	0
16	4	96	178	87	0	0
17	0	25	161	179	0	0
18	0	9	75	169	17	95
19	0	0	10	104	37	214
20	0	0	0	41	64	260
21	0	0	0	38	74	253
22	0	0	0	30	89	246
23	0	0	0	20	97	248
24	0	0	0	18	98	248
Proportion	3 per cent	15 per cent	20 per cent	15 per cent	9 per cent	39 per cent
Average wind speed (m/s)	**1.4**	**2.5**	**3.7**	**4.5**	**4.0**	**2.0**

Mixing height

Mixing height is estimated within CALMET for stable and convective conditions (respectively), with a minimum mixing height of 50 m. The following figures present mixing height statistics by hour of day across the meteorological dataset, as generated by CALMET in the northern and southern modelling domains. These results are consistent with general atmospheric processes that show increased vertical mixing with the progression of the day, as well as

Flower mixing heights during night time. In addition, peak mixing heights are consistent with typical ranges.

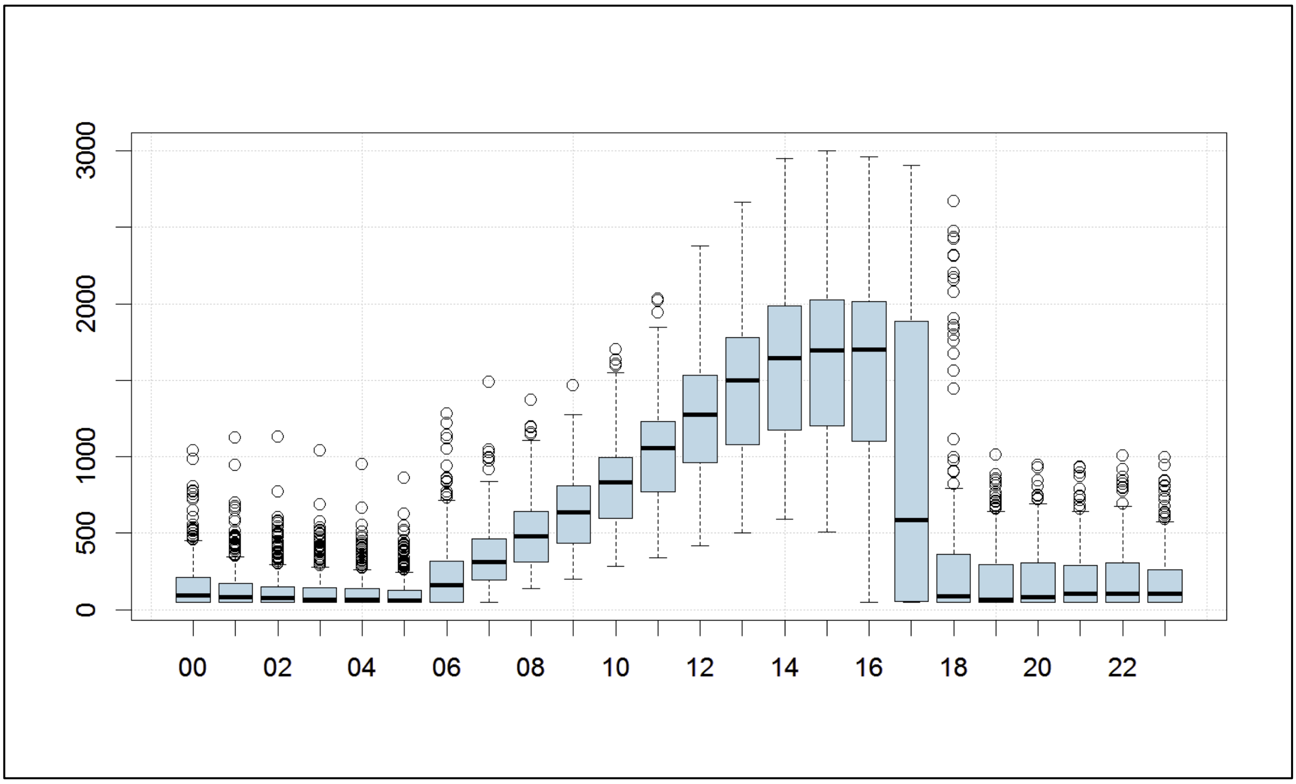

Figure A8 **Mixing height statistics by hour of day for Northern CALPUFF modelling domain (2013)**

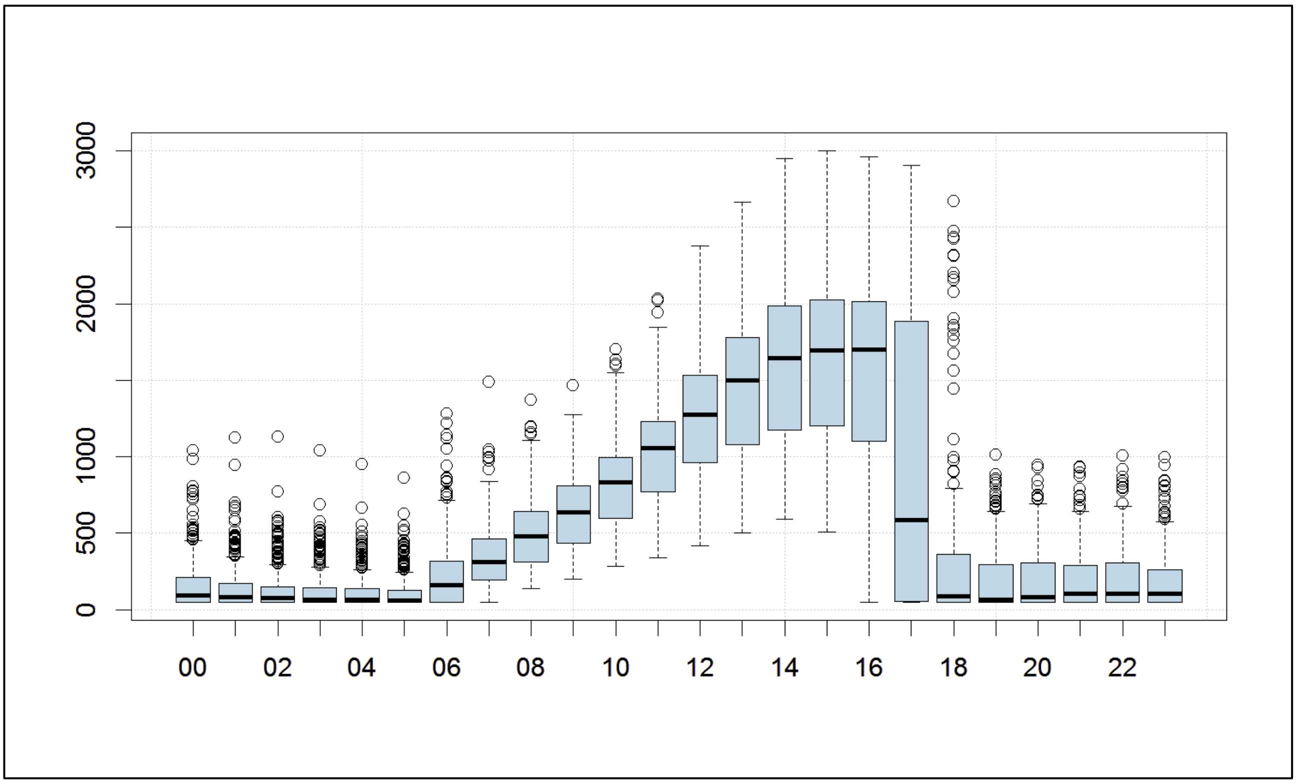

Figure A9 Mixing height statistics by hour of day for Southern CALPUFF modelling domain (2013)

APPENDIX

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Air Quality Technical Report

Appendix B Dispersion Model Details

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

ARTC

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Appendix B
Dispersion model details

Dispersion modelling uses mathematical equations to characterise atmospheric processes, which disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, dispersion models can be used to predict concentrations at selected downwind receiver locations. Air quality models are used to determine compliance with air quality standards. Two well-known and internationally used US EPA guideline models were used in this assessment - CALPUFF and CALROADS. Details of both these models can be found on the US EPA SCRAM (Support Centre for Regulatory Atmospheric Modeling) Bulletin board. The models are addressed in Appendix A of the US EPA's Guideline on Air Quality Models (also published as Appendix W.pdf) of 40 CFR Part 51.

Dispersion models

Two dispersion models are recommended for regulatory assessments in Australia and New Zealand, which are CALPUFF and AERMOD. AERMOD has recently replaced AUSPLUME as the guideline model for all near-field, steady state modelling applications in Victoria. CALPUFF is recommended for use for all modelling applications where the steady state assumption does not apply; this includes complex terrain and coastal environments. A major difference between AERMOD and CALPUFF is in the models' treatment of meteorology. AERMOD is a 2-dimensional model where the effects of one single surface station and one single upper air station are assumed to be spatially uniform across the entire modelling region in its meteorological processor. In contrast, CALMET (CALPUFF's meteorological module) is a 3-dimensional model and is able to use the output of numerical prognostic meteorological models as well as multiple observation sites to assist in the development of three-dimensional wind fields.

Overview of the CALPUFF suite of models

The CALPUFF modelling system provides a non-steady state modelling approach, which evaluates the effects of spatial changes in the meteorological and surface characteristics. It offers the ability to treat stagnation, multiple-hour pollutant build-up, recirculation and causality effects, which are beyond the capabilities of steady-state models. The CALPUFF modelling system was adopted by the U.S. EPA as a guideline model for long range transport applications and, on a case-by-case basis, for near-field applications involving complex flows (Federal Register, April 15 2003, pp 18,440-18,482). CALPUFF is also recommended by both the Federal Land Managers Air Quality Workgroup (FLAG 2000, 2008) and the Interagency Workgroup on Air Quality Modelling (IWAQM 1998). It was adopted for world-wide use by the United Nations International Atomic Energy Agency (IAEA). CALPUFF is widely used in many countries (over 100 countries) throughout the world, and has been incorporated as a regulatory model in several countries.

The CALPUFF modelling system includes three main components - CALMET, CALPUFF and CALPOST - and a large set of pre-processing programs designed to interface the model to standard, routinely-available meteorological and geophysical datasets. In simple terms, CALMET is a meteorological model, which develops hourly wind and temperature fields on a three-dimensional gridded modelling domain. CALPUFF is a transport and dispersion model, which advects 'puffs' of material emitted from modelled source, simulating dispersion and transformation processes along the way. In doing so, it uses the fields generated by CALMET. The primary output files from CALPUFF contain either hourly concentrations or hourly deposition fluxes evaluated at selected receiver locations. CALPOST is used to process these files, producing summaries of the results of the simulation.

CALMET overview

CALMET is a diagnostic meteorological model, which produces three-dimensional wind fields based on parameterised treatments of terrain effects such as slope flows and terrain blocking effects. Meteorological observations are used to determine the wind field in areas of the domain within which the observations are representative. Fine scale terrain effects are determined by the diagnostic wind module in CALMET.

The CALMET meteorological model consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers (Scire et al. 2000a). When using large domains, the user has the option to adjust input winds to a Lambert Conformal Projection coordinate system to account for the Earth's curvature. The diagnostic wind field module uses a two-step approach to the computation of the wind fields (Douglas and Kessler 1988). In the first step, an initial-guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects to produce a Step 1 wind field. The second step consists of an objective analysis procedure to introduce observational data into the Step 1 wind field in order to produce a final wind field. An option is provided to allow gridded prognostic wind fields to be used by CALMET, which may better represent regional flows and certain aspects of sea breeze circulations and slope/valley circulations. The prognostic data (as a 3D.DAT file) can be introduced into CALMET in three different ways:

- As a replacement for the initial guess wind field
- As a replacement for the Step 1 field
- As observations in the objective analysis procedure

The techniques used in the CALMET model are briefly described below.

Step 1 wind field

Kinematic effects on terrain: CALMET uses the approach of Liu and Yocke (1980) to evaluate kinematic terrain effects. The domain-scale winds are used to compute a terrain-forced vertical velocity, subject to an exponential stability-dependent decay function. The kinematic effects of terrain on the horizontal wind components are evaluated by applying a divergence-minimisation scheme to the initial guess wind field. The divergence minimisation scheme is applied iteratively until the three-dimensional divergence is less than a threshold value.

Slope flows. Slope flows are computed based on the shooting flow parameterisation of Mahrt (1982). Shooting flows are buoyancy-driven flows, balanced by advection of weaker momentum, surface drag and entrainment at the top of the slope flow layer. The slope flow is parameterised in terms of the terrain slope, distance to the crest and local sensible heat flux. The thickness of the slope flow layer varies with the elevation drop from the crest.

Blocking effects. The thermodynamic blocking effects of terrain on the wind flow are parameterised in terms of the local Froude number (Allwine and Whiteman 1985). If the Froude number at a particular grid point is less than a critical value and the wind has an uphill component, the wind direction is adjusted to be tangential to the terrain.

Step 2 wind field

The wind field resulting from the adjustments of the initial guess wind described above is the Step 1 wind field. The second step of the procedure involves the introduction of observational data into the Step 1 wind field through an objective analysis procedure. An inverse-distance squared interpolation scheme is used, which weighs observational data heavily in the vicinity of the observational station, while the Step 1 wind field dominates the interpolated wind field in regions with no observational data. The resulting wind field is subject to smoothing, an optional adjustment of vertical velocities based on the O'Brien (1970) method, and divergence minimisation to produce final Step 2 wind fields.

Overview of CALPUFF

CALPUFF is a non-steady-state puff dispersion model. It accounts for spatial changes in the meteorological fields, variability in surface conditions such as (elevation, surface roughness, vegetation type, etc.), chemical transformation, wet removal due to rain and snow, dry deposition and terrain influences on plume interaction with the surface. CALPUFF can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF contains algorithms for near-source effects, such as building downwash, transitional plume rise, partial plume penetration, sub-grid scale terrain interactions, as well as longer range effects, such as pollutant removal (wet scavenging and dry deposition), chemical transformation, vertical wind shear, overwater transport and coastal interaction effects. It can accommodate arbitrarily-varying point source and gridded area source emissions. The major features of CALPUFF model are detailed below (after Scire et al. 2002).

Major features of the CALPUFF model

- Source types
  - Point sources (constant or variable emissions)
  - Line Sources (constant or variable emissions)
  - Area Sources (constant or variable emissions)
  - Volume sources (constant or variable emissions)
- Non-steady-state emissions and meteorological conditions
  - Gridded 3D fields of meteorological variables
  - Spatially variable 3D fields of mixing height, friction velocity, convective velocity scale, Monin-Obukhov length, precipitation rate
  - Vertically and horizontally-varying turbulence and dispersion rates
  - Time-dependent source and emissions data
- Efficient sampling functions
  - Integrated puff formulation
  - Elongated puff (slug) formulation
- Dispersion coefficient options
  - Direct measures of sigma v and sigma w
  - Estimated values of sigma v and sigma w based on similarity theory
  - PG dispersion coefficients (rural areas)
  - McElroy Pooler dispersion coefficients (urban areas)
  - CTDM dispersion coefficients (neutral/stable)
- Vertical wind shear
  - Puff Splitting
  - Differential advection and dispersion
- Plume Rise
  - Partial penetration
  - Buoyant and momentum rise
  - Stack tip downwash effects
  - Vertical wind shear

  - Building downwash effects
- Building downwash
  - Huber-Snyder method
  - PRIME downwash
  - Schulman Scire method
- Dry deposition
  - Gases and particulate matter
  - Three options
    - Full treatment of space and time variations of deposition with a resistance model
    - User-specified diurnal cycles for each pollutant
    - No dry deposition
- Overwater and coastal interaction effects
  - Overwater boundary layer parameters
  - Abrupt change in meteorological conditions, plume dispersion at coastal boundary
  - Plume fumigation
  - Option to introduce sub grid scale TIBLs into coastal grid cells
- Chemical transformation options
  - Pseudo-first-order chemical mechanism for SO_2, SO_4, NO_x HNO_3 and NO_3 (MESOPUFF II method)
  - User specified diurnal cycles of transformation rates
  - No chemical conversion
  - Wet Removal
  - Scavenging coefficient approach
  - Removal rate a function of precipitation intensity and precipitation type