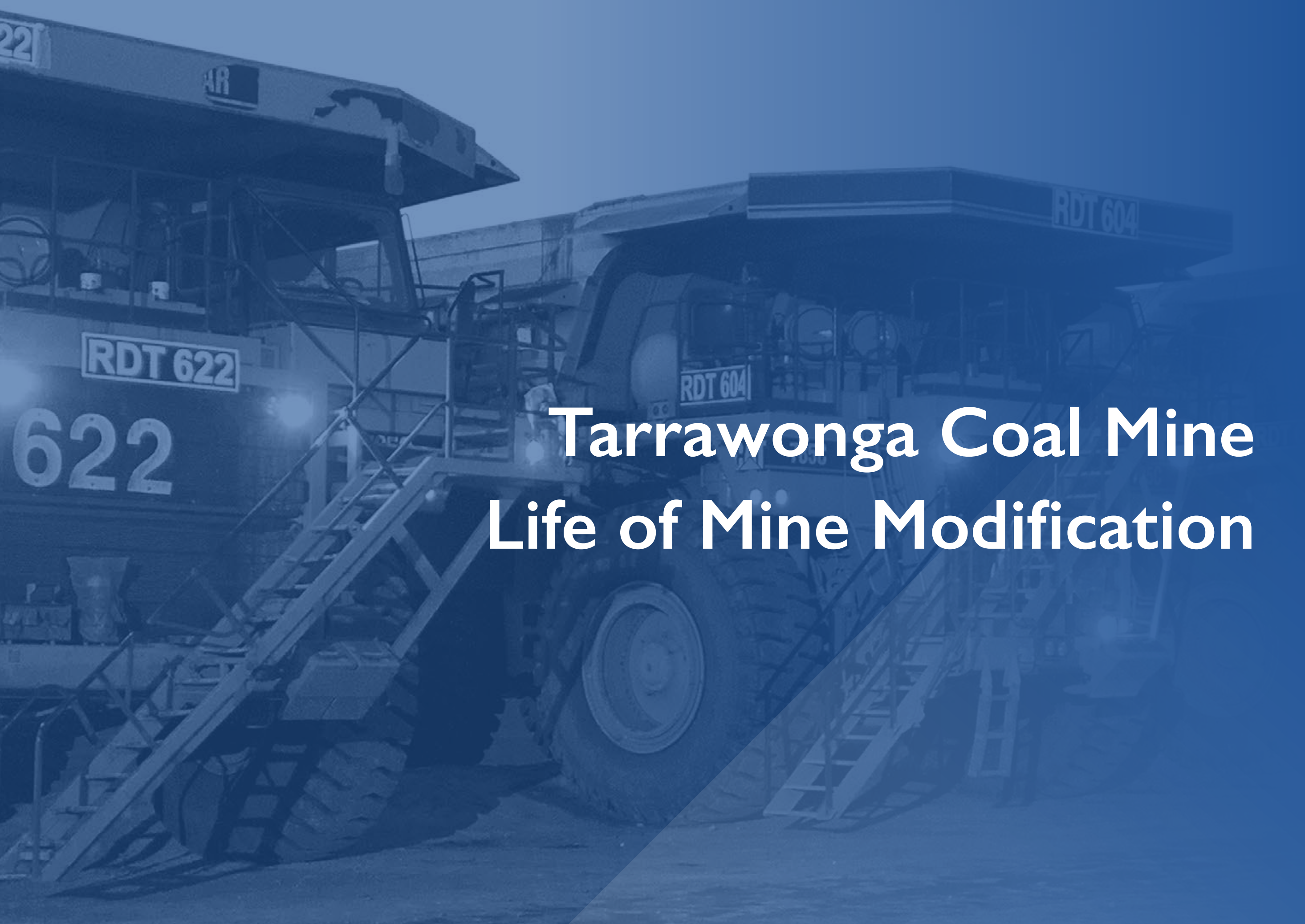

Tarrawonga Coal Mine
Life of Mine Modification

Appendix D

Air Quality and Greenhouse Gas Assessment

WHITEHAVEN COAL

Intended for
Whitehaven Coal Limited

Document type
Report

Date
October 2019

Project No.
318000317

TARRAWONGA COAL MINE LIFE OF MINE MODIFICATION
AIR QUALITY AND GREENHOUSE GAS ASSESSMENT

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AIR QUALITY AND GREENHOUSE GAS ASSESSMENT

Revision	Date	Made by	Checked by	Approved by
Draft v1	23/04/2019	R.Kellaghan	M.Parsons	N.Houldsworth
Draft v2	22/05/2019	R.Kellaghan	M.Parsons	N.Houldsworth
Draft v3	19/06/2019	R.Kellaghan	M.Parsons	N.Houldsworth
Draft v4	27/06/2019	R.Kellaghan	M.Parsons	N.Houldsworth
Final	1/10/2019	R.Kellaghan	M.Parsons	N.Houldsworth

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APPENDICES

1. INTRODUCTION

The Tarrawonga Coal Mine is located approximately 42 kilometres (km) north-northwest of Gunnedah in New South Wales (NSW) (**Figure 1-1**). The Tarrawonga Coal Mine is owned and operated by Tarrawonga Coal Pty Limited (TCPL), a wholly owned subsidiary of Whitehaven Coal Limited (Whitehaven).

The Tarrawonga Coal Mine is an open cut coal mine which has been in operation since 2006. Run-of-mine (ROM) coal is crushed and screened on-site, and the sized ROM coal is loaded onto on-highway trucks for transport via the Approved ROM Coal Transport Route to the Whitehaven coal handling preparation plant (CHPP).

Mining operations at the Tarrawonga Coal Mine are conducted in accordance with Project Approval (PA) 11_0047, as modified.

TCPL proposes a modification of its PA 11_0047. The Tarrawonga Coal Mine Life of Mine Modification (the Modification) would be sought under section 4.55(2) of the NSW *Environmental Planning and Assessment Act, 1979*.

This Air Quality and Greenhouse Gas Assessment forms part of a Modification Report, which has been prepared in support of a Development Application for the Modification.

1.1 Overview of modification

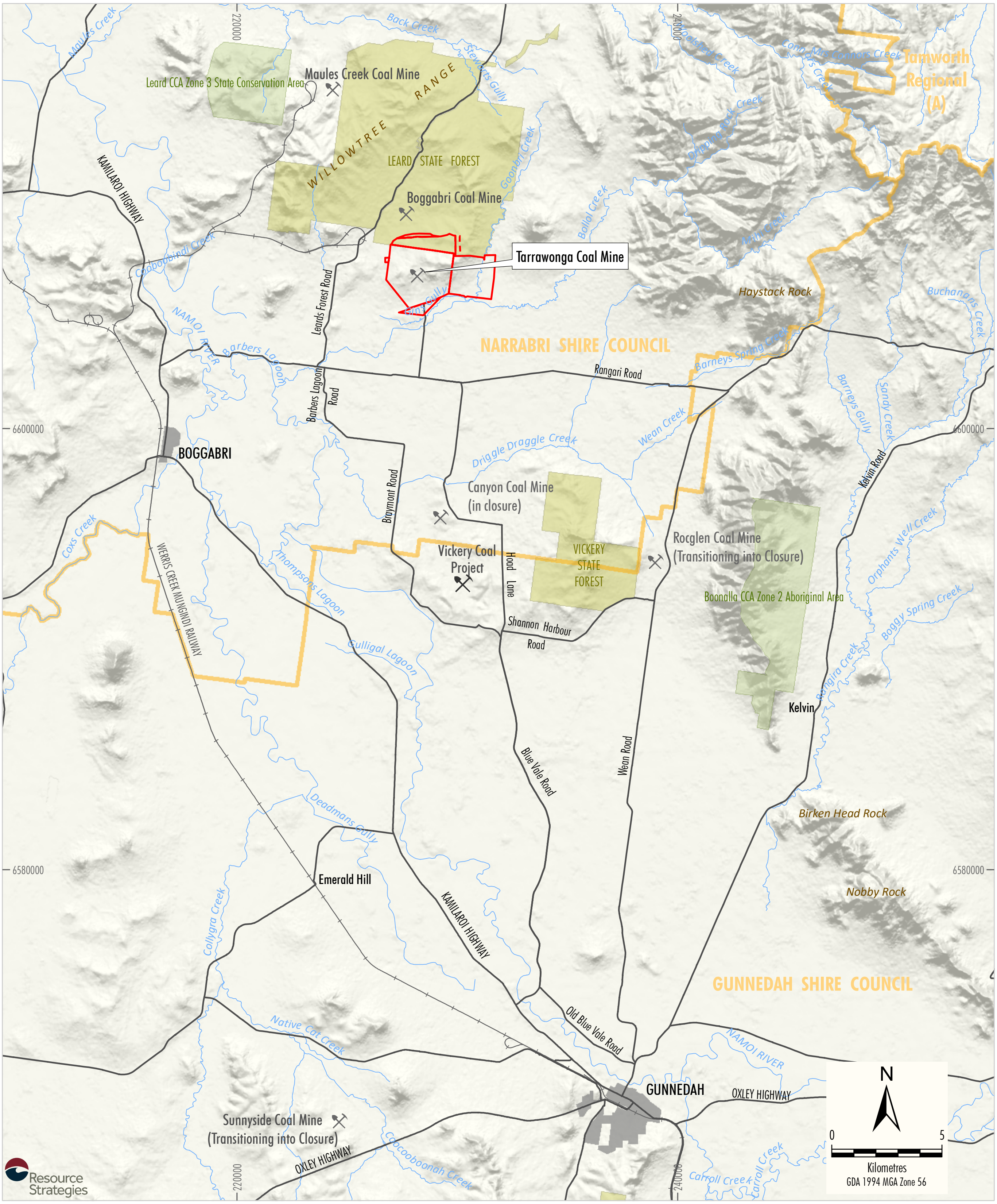
The main activities associated with the Modification include:

- ROM coal production rate increase from 3.0 to 3.5 million tonnes per annum (Mtpa);
- increase in ROM coal transported along the Northern Section of the Approved ROM Coal Transport Route from 3.0 to 3.5 Mtpa;
- reduction of the open cut extent to avoid mining:
  - the Upper Namoi alluvium; and
  - Goonbri Creek.
- revision of the post-mining landform and land use;
- relocation of the ROM coal stockpile and associated infrastructure;
- construction of a new site access road and intersection to allow haulage of ROM coal along a section of Goonbri Road; and
- construction and use of a water transfer pipeline between the Tarrawonga Coal Mine and the proposed Vickery Extension Project (which is the subject of a separate Development Application for State Significant Development 7480).

Figure 1-2 shows the Modification general arrangement.

The Modification would result in no change to the following elements of the Tarrawonga Coal Mine:

- mine life and operating hours;
- mining tenements;
- mining methods;
- employment; and
- domestic coal production.



LEGEND
- Mining Tenement Boundary (ML, CL and AUTH)
- Mining Lease Application Boundary (MLA 1)
- NSW State Forest
- State Conservation Area, Aboriginal Area
- Major Roads
- Railway
- Local Government Boundary

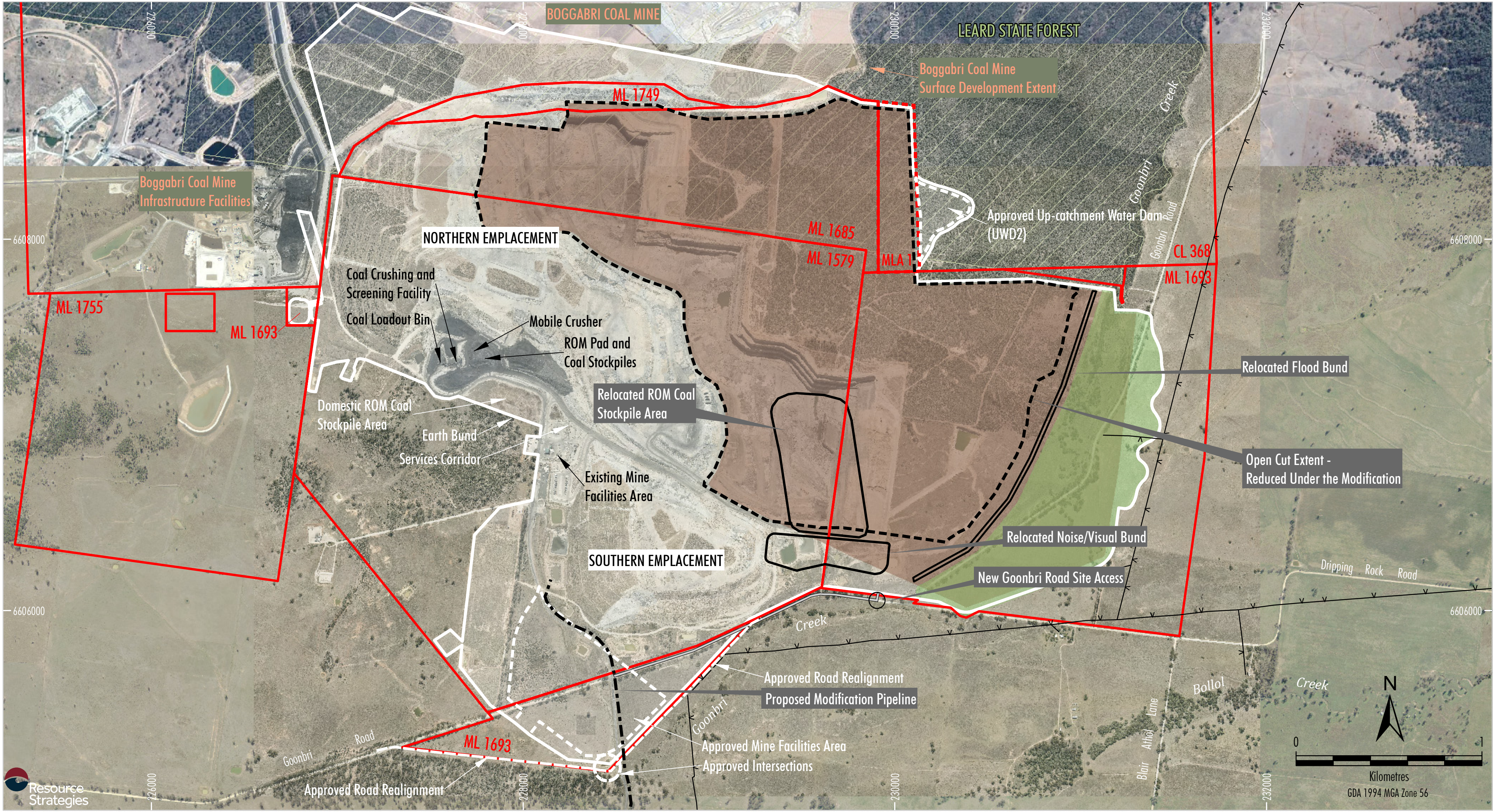
Source: LPMA - Topographic Base (2010); NSW Department of Industry (2018)

WHITEHAVEN COAL

TARRAWONGA COAL MINE

Regional Location

Figure 1-1



LEGEND
- Mining Lease Boundary (ML & CL)
- Mining Lease Application Boundary (MLA 1)
- 11kV Electricity Transmission Line
- 11kV Electricity Transmission Line Realignment
- Leard State Forest
- Approximate Extent of Approved Surface Development
- Approximate Extent of Approved Open Cut
- Modification Open Cut Extent
- Approved Surface Development Area - No Longer Proposed
- Modification ROM Coal Transport Route Along Goonbri Road
- Indicative Location of Modification Pipeline

Source: © State of New South Wales and Department of Planning and Environment (2017); © Department Finance, Services & Innovation (2017); Whitehaven Coal (2018); Orthophoto: Whitehaven Coal (2018); Google (2018)

WHITEHAVEN COAL

TARRAWONGA COAL MINE

Indicative Modification General Arrangement

Figure 1-2

1.2 Production schedule

An indicative production schedule has been provided for the Modification. The projected ROM coal (Mt[1]) and waste rock (Mbcm[2]) is shown in **Table 1-1**. The mine years chosen for assessment are highlighted in bold.

Year 3 is selected to represent peak production for both ROM coal and waste rock. Year 7 represents the eastern extent of mining before production rates decline at the end of the mine life and is selected as a worst-case scenario for the closest receptors located to the east.

Table 1-1: Production schedule for Modification

Modification year[1]	Waste (Mbcm)	Open Cut ROM Coal (Mt)
Year 1	20.1	2.3
Year 2	27.3	2.9
Year 3	**38.2**	**3.5**
Year 4	34.0	3.5
Year 5	37.4	3.5
Year 6	36.1	3.5
Year 7	**34.0**	**3.5**
Year 8	27.1	2.7
Year 9	24.0	2.4
Year 10	23.6	2.1
Year 11	11.1	1.0

1 Assumed Modification commencement date is 1 January 2020.

[1] Mt = Million tonnes.
[2] Mbcm = Million bank cubic metres.

2. ASSESSMENT APPROACH

The air quality and greenhouse gas assessment (AQIA) for the Modification presents a quantitative assessment of potential air quality impacts, with an emphasis on emissions of particulate matter (PM), the key pollutant of concern associated with mining operations.

The AQIA has been prepared in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales ("the Approved Methods") (NSW Environmental Protection Agency [EPA], 2016).

Local air quality impacts from the Modification are assessed using a Level 2 assessment approach, as follows:

- Emissions are estimated for all related activities, using best practice emission estimation techniques.
- Dispersion modelling using a regulatory dispersion model is used to predict ground level concentrations (GLCs) for key pollutants at surrounding sensitive receivers.
- Cumulative impacts are assessed, taking into account the combined effect of existing baseline air quality, other local sources of emissions, reasonably foreseeable future emissions and any indirect or induced effects.
- Estimates of the greenhouse gas (GHG) emissions are presented and benchmarked against GHG accounts for NSW and Australia.

2.1 Assessment criteria

When first regulated, airborne PM was assessed based on concentrations of "total suspended particulate matter" (TSP). In practice, this typically referred to PM smaller than 30-50 micrometres (µm) in diameter. As air sampling technology improved and the importance of particle size and chemical composition become more apparent, ambient air quality standards have been revised to focus on the smaller particle sizes, thought to be most dangerous to human health. Contemporary air quality assessment typically focuses on "fine" and "coarse" inhalable PM, based on health-based ambient air quality standards set for PM_{10} and $PM_{2.5}$[3].

Air quality criteria for PM in Australia are given for particle size metrics including TSP, PM_{10} and $PM_{2.5}$. The 2016 update to the 'Approved Methods', gazetted on 20 January 2017, includes particle assessment criteria that are consistent with revised National Environment Protection (Ambient Air Quality) Measure national reporting standards (National Environment Protection Council [NEPC], 1998; NEPC, 2015).

For the purpose of this report, predicted GLCs are assessed against the NSW EPA's impact assessment criteria presented in **Table 2-1**.

Table 2-1: NSW EPA's impact assessment criteria for PM

PM metric	Averaging period	Concentration (µg/m³)
TSP	Annual	90
PM_{10}	24-hour	50
	Annual	25
$PM_{2.5}$	24-hour	25
	Annual	8

Note: µg/m³ = micrograms per cubic metre.

[3] PM with an aerodynamic diameter of less than 10 µm and 2.5 µm respectively.

The Approved Methods specifies that the impact assessment criteria for 'criteria pollutants[4]' are applied at the nearest existing or likely future off-site sensitive receptor and compared against the 100th percentile (i.e. the highest) dispersion modelling prediction. Both the incremental and cumulative impacts need to be considered (consideration of existing ambient background concentration is required).

The Approved Methods also prescribes nuisance-based goals for dust deposition, which relate to amenity type impacts such as soiling of exposed surfaces. The NSW EPA impact assessment criteria for dust deposition are summarised in **Table 2-2**, illustrating the maximum increase and total dust deposition rates which would be acceptable so that dust nuisance can be avoided.

Table 2-2: Dust deposition criteria

Pollutant	Maximum Increase in Dust Deposition	Maximum Total Dust Deposition Level
Deposited dust (assessed as insoluble solids)	2 g/m^2/month	4 g/m^2/month

Note: g/m^2/month = grams per square metre per month.

2.1.1 Voluntary land acquisition and mitigation policy

The NSW Department of Planning and Environment (DP&E) Voluntary Land Acquisition and Mitigation Policy for State Significant Mining, Petroleum and Extractive Industry Developments (the VLAMP)[5] describes the voluntary mitigation and land acquisition policy to address dust (and noise) impacts, and outlines mitigation and acquisition criteria for PM. Essentially, the VLAMP formalises the acquisition criteria that have previously been outlined in conditions of approval for major mining and extractive industries.

Under the VLAMP, if an applicant cannot comply with the relevant impact assessment criteria, or if the mitigation or acquisition criteria may be exceeded, the applicant should consider a negotiated agreement with the affected landowner or acquire the land. In doing so, the land is then no longer subject to the impact assessment, mitigation or acquisition criteria, although provisions do apply to "use of the acquired land", primarily related to informing and protecting existing or prospective tenants.

Voluntary mitigation rights apply when a development contributes to exceedances of the criteria set out in **Table 2-3** and voluntary acquisition rights apply when a development contributes to exceedances of the criteria set out in **Table 2-4**. The criteria for voluntary mitigation and acquisition are the same, with the exception of the number of allowable days above short-term impact assessment criteria for PM_{10}, which is zero for mitigation and five for acquisition.

Voluntary mitigation rights apply to any residence on privately-owned land or any workplace on privately-owned land where the consequences of the exceedance, in the opinion of the consent authority, are unreasonably deleterious to worker health or the carrying out of business.

Voluntary acquisition rights also apply to any residence or any workplace on privately-owned land but also apply when an exceedance occurs across more than 25% of any privately-owned land where there is an existing dwelling or where a dwelling could be built under existing planning controls.

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[4] 'Criteria pollutants' is used to describe air pollutants that are commonly regulated and typically used as indicators for air quality. In the Approved Methods, the criteria pollutants are TSP, PM_{10}, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), deposited dust, hydrogen fluoride and lead.

[5] https://www.planning.nsw.gov.au/-/media/Files/DPE/Reports/Att-E-Revised-VLAMPaccessible-version.pdf?la=en

Table 2-3: DP&E mitigation criteria

Pollutant	Averaging period	Mitigation Criterion		Impact Type
$PM_{2.5}$	24 hour	25 µg/m³ *		Human Health
	Annual	8 µg/m³ **		Human Health
PM_{10}	24 hour	50 µg/m³ *		Human Health
	Annual	25 µg/m³ **		Human Health
TSP	Annual	90 µg/m³ **		Amenity
Deposited Dust	Annual	2 g/m²/month *	4 g/m²/month **	Amenity

Note: *Incremental increase due to development alone, with zero allowable exceedances over the life of the development. **Cumulative impact due to the development plus background from other sources.

Table 2-4: DP&E acquisition criteria

Pollutant	Averaging period	Acquisition Criterion		Impact Type
$PM_{2.5}$	24 hour	25 µg/m³ *		Human Health
	Annual	8 µg/m³ **		Human Health
PM_{10}	24 hour	50 µg/m³ *		Human Health
	Annual	25 µg/m³ **		Human Health
TSP	Annual	90 µg/m³ **		Amenity
Deposited Dust	Annual	2 g/m²/month *	4 g/m²/month **	Amenity

Note: *Incremental increase due to development alone, with up to 5 allowable exceedances over the life of the development. **Cumulative impact due to the development plus background from other sources.

2.2 Dispersion model selection

Dispersion modelling for this assessment uses the CALMET/CALPUFF modelling system, commonly used in NSW for applications where non-steady state conditions may occur (i.e. in complex terrain) (NSW EPA, 2016). CALMET, the meteorological pre-processor for the dispersion model CALPUFF, calculates fine resolution three-dimensional meteorological data, incorporating mesoscale and local scale effects. CALPUFF then calculates the dispersion of pollutants within this three-dimensional meteorological field.

Where no upper air measurements are available, CALMET can be run using prognostic upper air data (as a three-dimensional '3D.dat' file), generated using The Air Pollution Model (TAPM) and used to derive an 'initial guess' wind field. Surface observations are also included in the modelling to provide real-world observations and improve the accuracy of the wind field (refer **Section 4.1**). This modelling approach is known as the "hybrid" approach (TRC Environmental Corporation, 2011) and is applied for this assessment.

2.3 Cumulative impacts

Cumulative impacts are assessed by combining the contribution from the Modification with the existing ambient air quality environment. The existing ambient air quality environment is determined by modelling the contribution from all existing (approved) local mining operations (excluding the Tarrawonga Coal Mine) and adding a background for all other non-mining sources.

Modelling of existing conditions includes:

- Approved operations at the Boggabri Coal Mine.
- Approved operations at the Maules Creek Coal Mine.
- Proposed extension of the Vickery Coal Mine (the Vickery Extension Project), currently undergoing Independent Planning Commission review.

Background concentrations are derived from a monitoring station that is located away at distance from these existing mining operations but close enough to be representative of the local airshed (refer **Section 4.2**).

Emissions from the Narrabri Underground Mine and Rocglen Coal Mine have been excluded from the cumulative impact assessment on the basis that their contribution to air quality around the Tarrawonga Coal Mine would be negligible. Rocglen Coal Mine will be transitioning to closure in 2019.

2.4 Emissions from the combustion of diesel fuel

The combustion of diesel in mining equipment results in combustion-related emissions, including $PM_{2.5}$, oxides of nitrogen (NO_x), SO_2, CO, carbon dioxide (CO_2) and volatile organic compounds (VOCs). Gaseous combustion emissions from mining equipment would not result in significant off-site concentrations and are unlikely to compromise ambient air quality goals. Therefore, except for PM, combustion emissions have not been quantitatively assessed.

The United States (US) EPA AP-42 emission factors developed for coal mine emission inventories do not separate PM emissions from mechanical processes (i.e. crustal material) and diesel exhaust (combustion) and are therefore assumed to include the diesel component of PM.

However, the emissions controls (i.e. watering) are often only relevant to the crustal fraction of total PM, for example the watering of haul roads does not control the diesel component of the emissions (US EPA, 1998a). Adjustments to the emission inventories have been made to account for this and are discussed further in **Section** 5.

GHG emissions from diesel combustion are considered in **Section** 7.

2.5 Blast fume

Blast fume is the result of a less than optimal chemical reaction of ammonium nitrate explosives during the open cut blasting process, resulting in the release of nitric oxide and NO_2. Fume generation can be the result of water and explosives mixing in the hole (geological and/or meteorological influences), the quality of explosive product supplied, and contamination of the explosive product during loading and/or on bench. Potential adverse impacts from blast fume can be effectively managed through good practice blast management.

Whitehaven has developed a Blast Management Plan for the approved Tarrawonga Coal Mine, which includes blast fume prevention measures developed in accordance with the *Code of Good Practice: Prevention and Management of Blast Generated NO_x Gases in Surface Blasting* (Code of Practice) (Australian Explosives Industry and Safety Group Inc., 2011).

The Blast Management Plan includes monitoring requirements for blast fume, including identification and rating of visual blast fume, as per Appendices 2 and 3 of the Code of Practice. No evidence of blast fume leaving the site boundary has been reported for the previous three Annual Reviews periods and therefore no additional assessment of blast fume is presented in this report. It is noted that PM emissions from blasting are included in the emission inventories presented in **Section** 5.

3. LOCAL SETTING AND RECEPTOR LOCATIONS

The Tarrawonga Coal Mine is part of a mining complex comprising the Boggabri, Tarrawonga and Maules Creek Coal Mines (referred to as the BTM Complex). The approved Vickery Coal Mine and the operational Rocglen Coal Mine are located to the south, although Rocglen Coal Mine is transitioning to closure in 2019. The regional setting is presented in **Figure 3-1**, showing local and regional approved mining operations.

Significant geographic features in the wider area include the Mount Kaputar National Park to the north and the Namoi River to the southwest. The BTM Complex is located within the undulating landforms of Leard State Forest and surrounded by low lying flood plains of Goonbri Creek (a tributary of the Namoi River) to the south.

The local area contains a number of rural-residential properties situated at varying distances from the Modification. The locations of the private and mine-owned receptor locations assessed in this report are shown in **Figure 3-2** (refer to **Appendix 2** for a tabulated list of receptors).

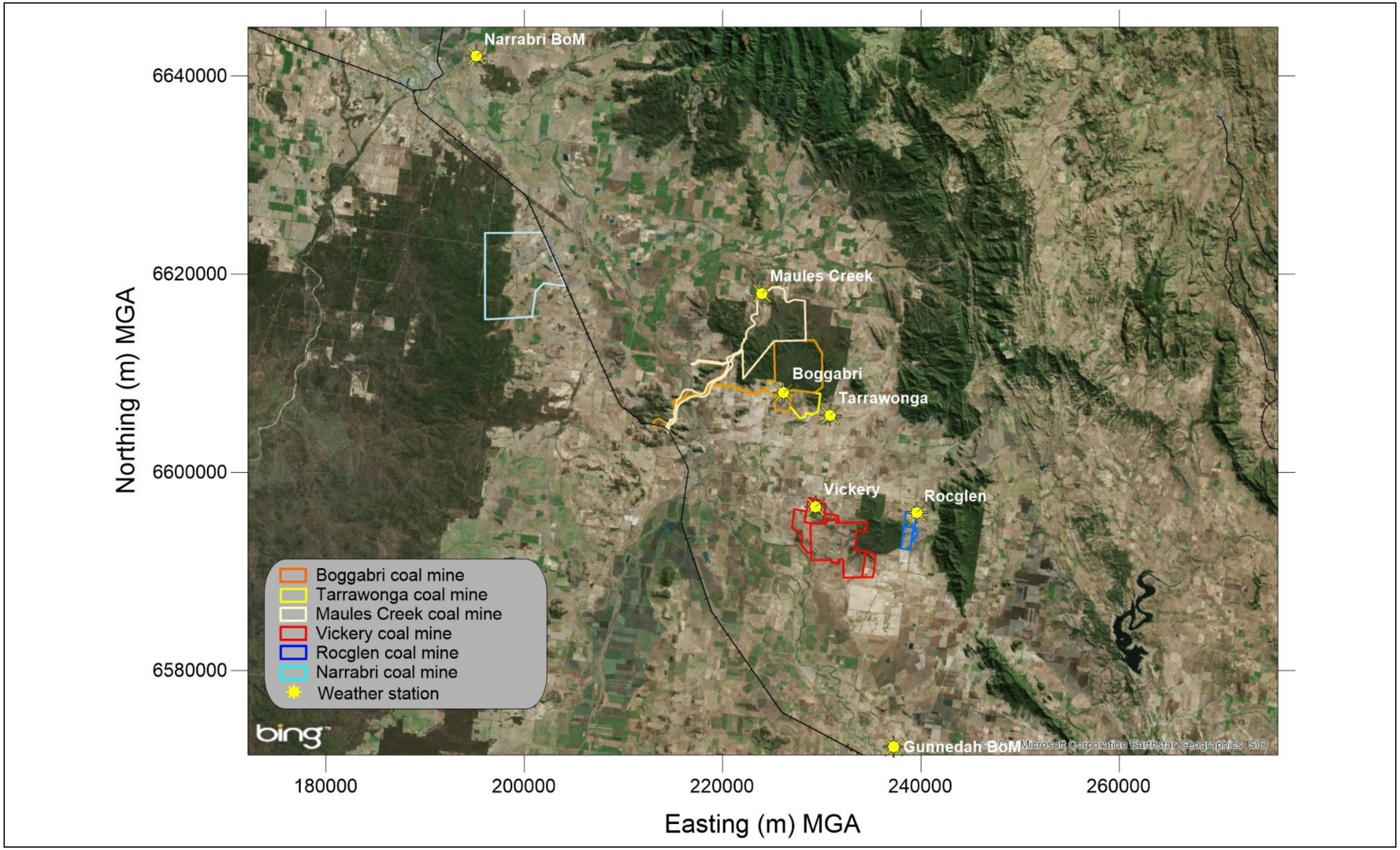


Figure 3-1: Approved mining operations and meteorological monitoring sites for the region

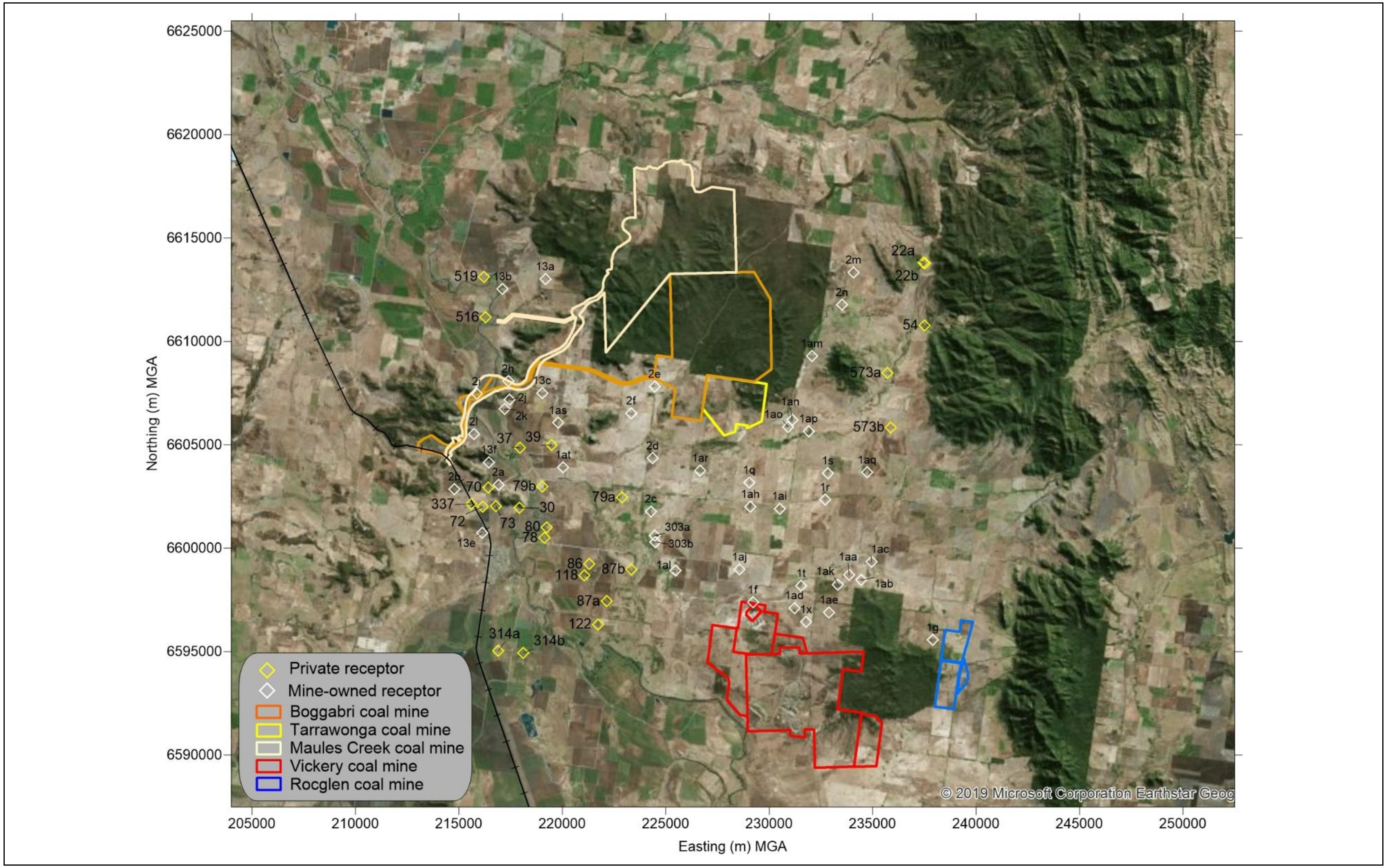


Figure 3-2: Receptor assessment locations

4. EXISTING ENVIRONMENT

4.1 Local and regional meteorology

Analysis of meteorology for the region is primarily based on meteorological monitoring stations operated by the mines within the BTM Complex.

Figure 3-1 shows the location of the BTM Complex and other regional mining operations, and their meteorological monitoring stations. The closest Bureau of Meteorology (BoM) automatic weather stations (AWS) at Gunnedah and Narrabri are also shown.

4.1.1 Overview of prevailing winds

Hourly data for the Tarrawonga Coal Mine AWS were reviewed and the annual wind roses for 2013 to 2018 are presented in **Figure 4-1**. The wind roses display consistency in wind direction, average wind speed and the percentage occurrence of calm winds (<= 0.5 metres per second [m/s]) across each year.

The high degree of consistency in winds across all years indicates that each calendar year would be suitable for modelling. The period of January to December 2017 was selected for modelling, being the most complete calendar year available at the time of modelling (**Appendix 3**).

The winds recorded at the Tarrawonga Coal Mine in 2017 are compared to regional monitoring stations and presented in **Figure 4-2**. Most sites display a general wind direction alignment along a north-west to south-east axis, however there are also some clear differences across each monitoring site, most likely due to local topographical influences within the Leard State Forest and further afield.

Boggabri, Maules Creek and Vickery Coal Mines display a dominant north-west to south-east alignment, with the Maules Creek Coal Mine sheltered from the north and the Boggabri Coal Mine sheltered from the northeast. The Tarrawonga and Vickery Coal Mines also display a northeast component that is missing from other sites. This is most likely from terrain induced channelling or drainage flow. The average winds speed measured across the sites are consistent, as are the percentage occurrence of calm winds (except for Vickery which has significantly less calms).

4.1.2 Ambient temperature

The inter-annual variation in temperature is presented as a box and whisker plot in **Figure 4-4**. The plot shows the monthly minimum, maximum, mean and upper and lower quartile temperatures for the modelled year (2017) are representative when viewed in the context of the most recent five-year period of measurements.

4.1.3 Rainfall

Based on long-term records at Gunnedah, rainfall averages approximately 620 millimetres (mm) per year. Analysis of the on-site data for the five-year period 2013 – 2017 shows that the annual rainfall is comparable to the long-term average, ranging from 524 mm in 2014 to 631 mm in 2016. The annual rainfall for the modelling period 2017 is 585 mm, comparable to the five-year average of 596 mm.

To provide a conservative (upper bound) estimate of the PM concentrations, wet deposition (removal of particles from the air by rainfall) was excluded from the dispersion modelling simulations undertaken in this report. Sensitivity analysis completed for the Upper Hunter Particle Model (Kellaghan et al, 2014) indicates that the inclusion of wet deposition may reduce PM_{10} concentrations by 20% to 50% during a period of rainfall, depending on distance from source to receptor.

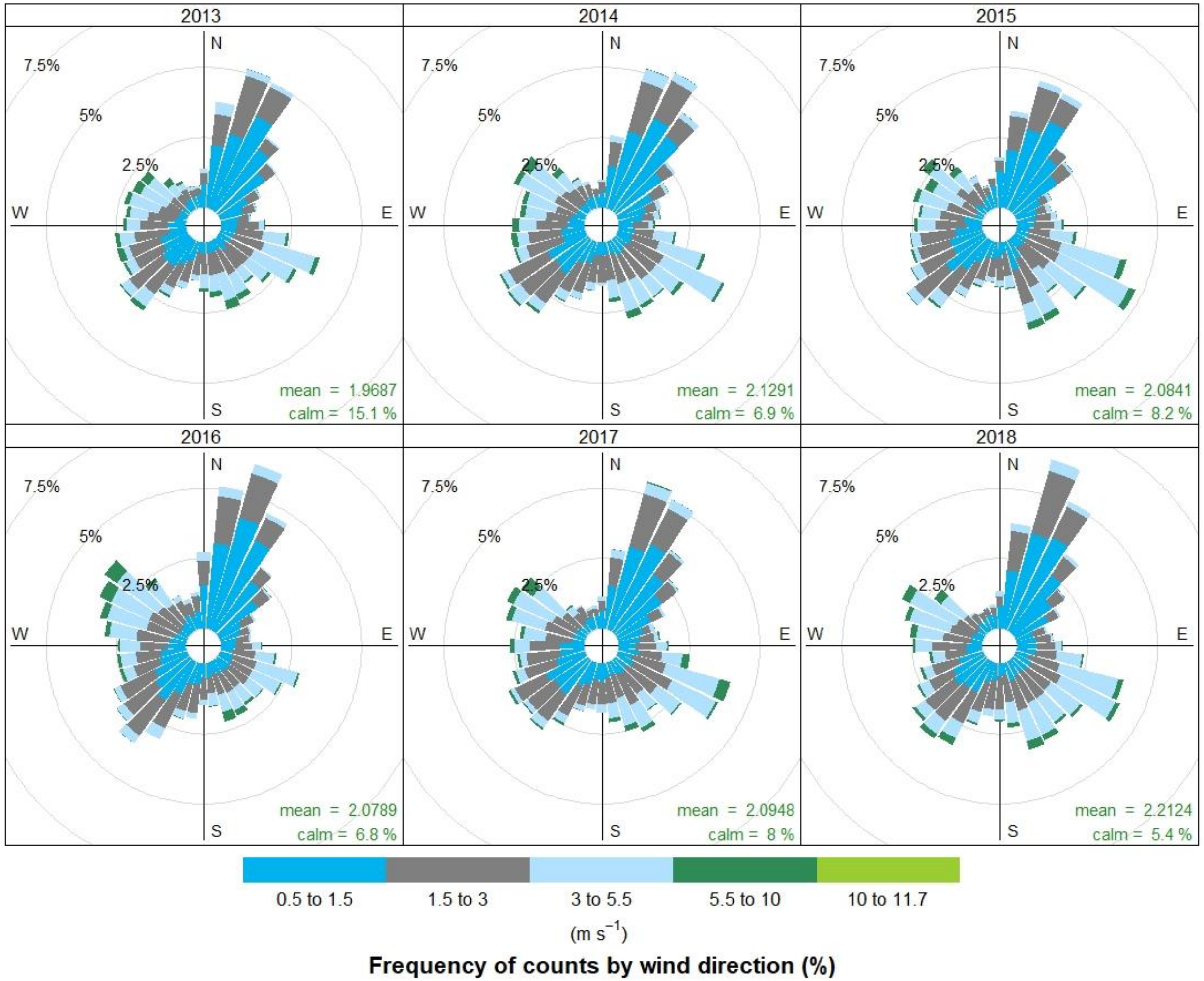


Figure 4-1: Wind roses for the Tarrawonga Coal Mine meteorological monitoring station

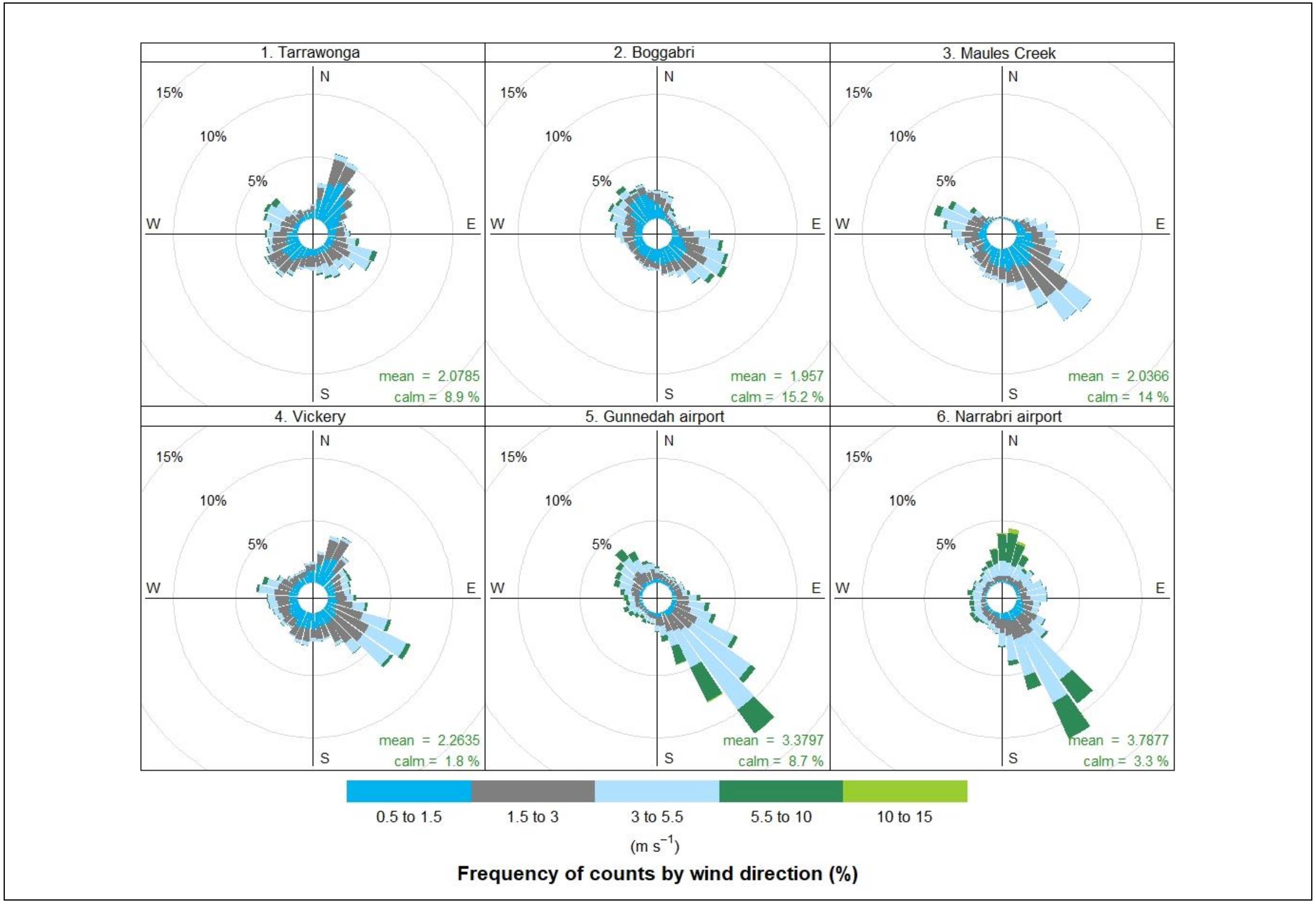


Figure 4-2: 2017 wind roses for regional meteorological monitoring stations

The US EPA (1998a) AP-42 emission factor documentation for unsealed roads (Chapter 13.2.2) describes a 'natural mitigation' factor, which can be applied for rainfall and other precipitation, based on the assumption that annual emissions are inversely proportional to the number of days with measurable rain, defined as the number of days with greater than 0.25 mm recorded. The emissions inventories developed for this study have not applied this natural mitigation factor and are therefore more conservative than if rainfall was incorporated.

4.1.4 Evaluation of CALMET predicted winds

As described above, surface observations are included in the modelling to provide real-world observations and improve the accuracy of the wind field. Measurements at Vickery, Maules Creek and Boggabri Coal Mines are included as local surface observations for modelling. The BoM AWS sites at Gunnedah and Narrabri are primarily included to obtain parameters not measured by the local monitoring sites but required for modelling (i.e. cloud amount and atmospheric pressure).

Due to the proximity of the Boggabri and Tarrawonga Coal Mines monitoring sites to each other (approximately 2 km apart), Tarrawonga Coal Mine is excluded from the modelling and instead used to evaluate the performance of the model (i.e. the ability to adjust the wind field to account for local topographical influences). Excluding one of the Boggabri or Tarrawonga Coal Mines also allows a radius of influence (CALMET setting RMAX) of 10 km to be assigned for each surface station, without overlap or the need for barriers. The relative weighting of the Step 1 wind field and the observation (CALMET setting R1) is assigned a smaller value of 2 km, to reflect the local scale topographical influence seen in the observational data.

The CALMET predicted winds speeds at the Tarrawonga Coal Mine meteorological station are compared with measurements and shown in **Figure 4-4**. The dominant wind direction and mean wind speeds are similar, although the frequency of calm conditions predicted by CALMET is lower than observed.

What the comparison shows is that despite the Step 2 wind field being heavily weighted towards the observations at the Boggabri Coal Mine (out to a distance of 2 km), the final CALMET wind field for the area around the Tarrawonga Coal Mine is adjusted for slope flows and terrain effects. This results in local CALMET winds which better match the Tarrawonga Coal Mine observation than the Boggabri Coal Mine observation, despite observational nudging from Boggabri Coal Mine and not from the Tarrawonga Coal Mine.

It is noted that the model does underestimate the frequency of occurrence of west-southwest winds, with a higher frequency of occurrence from other directions.

4.1.5 Atmospheric boundary layer heights

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of air flow due to the frictional drag of the earth's surface (mechanical mechanisms), or as a result of the heat and moisture exchanges that take place at the surface (convective mixing) (Stull, 1997; Oke, 2003).

During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated subsidence inversion. Elevated inversions may occur for a variety of reasons including anticyclonic subsidence and the passage of frontal systems. Due to radiative flux divergence, nights are typically characterised by weak to no vertical mixing and the predominance of stable conditions. These conditions are normally associated with low wind speeds and, hence, lower dilution potentials.

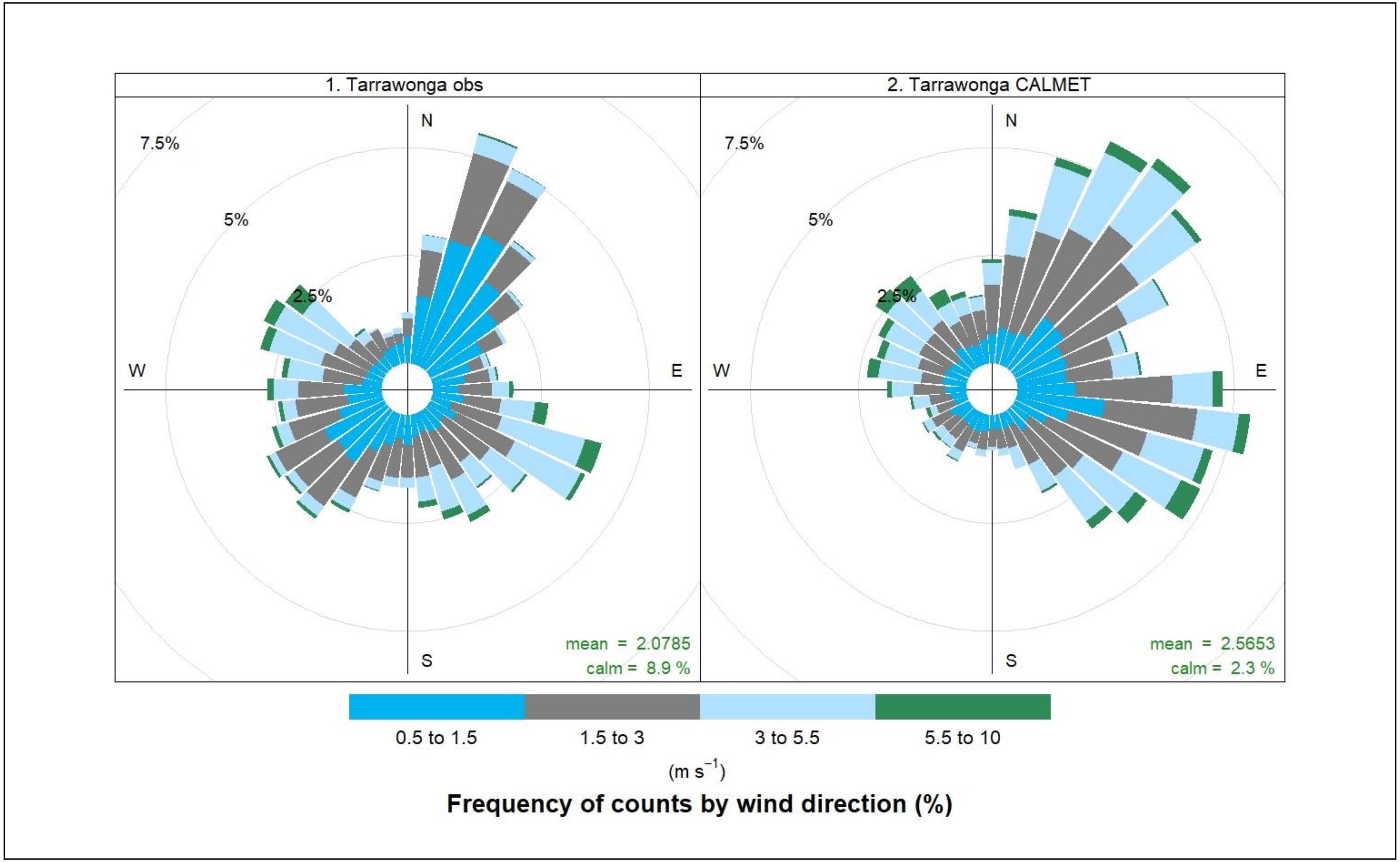


Figure 4-3: Comparison of CALMET winds with observations

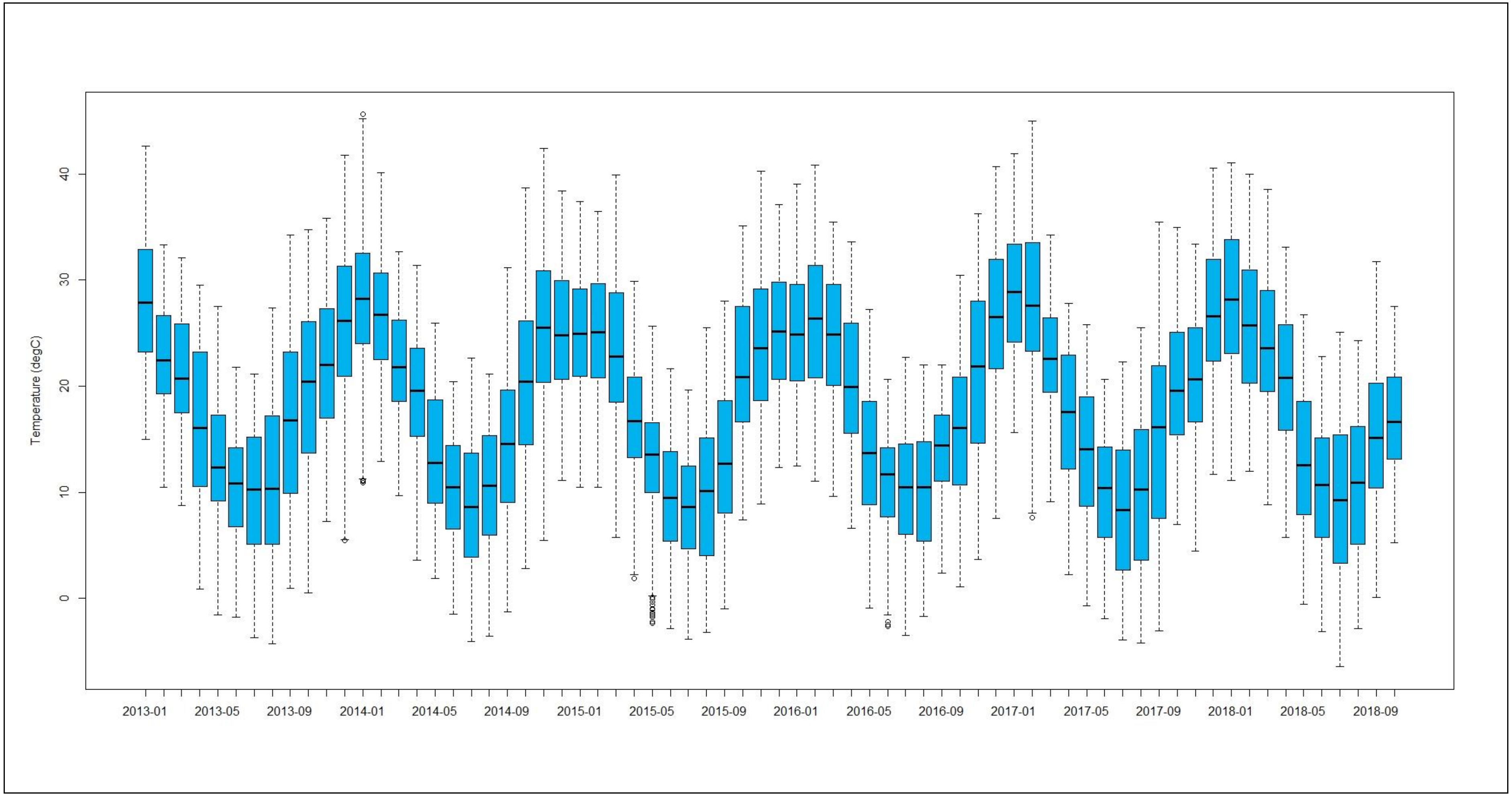
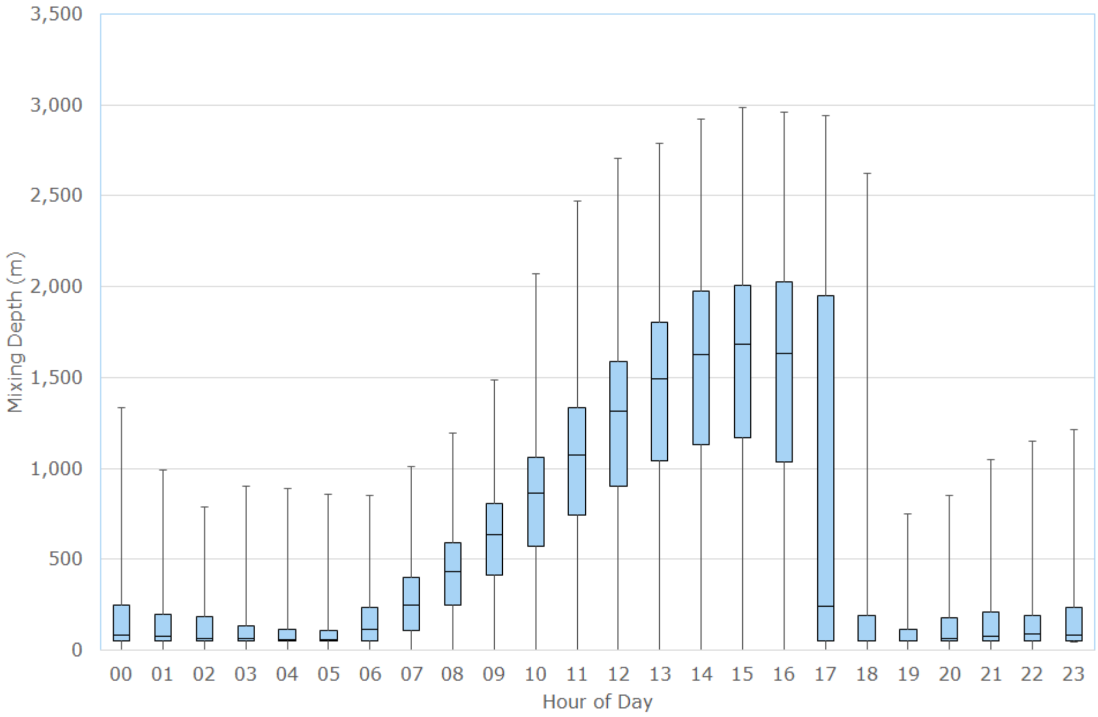


Figure 4-4: Box and whisker plot of temperature 2013 – 2018

CALMET generated mixing heights by hour of the day are shown in **Figure 4-5** (for a single point in the CALMET domain representing the location of the Tarrawonga Coal Mine meteorological station).

As seen in the median and upper and lower quartiles, the highest boundary layer heights are experienced during the day time hours, peaking in the mid- to late afternoon. Higher day-time wind velocities and the onset of incoming solar radiation increases the amount of mechanical and convective turbulence in the atmosphere. As turbulence increases so too does the depth of the boundary layer, generally contributing to higher mixing depths and greater potential for atmospheric dispersion of pollutants.



Lower, middle and upper box markers indicate 25th percentile, median and 75th percentile of mixing height data, respectively, while upper and lower whiskers indicate maximum and minimum values.

Figure 4-5: Diurnal variation in CALMET-generated mixing heights

4.1.6 Atmospheric stability

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

Figure 4-6 illustrates the diurnal variation of atmospheric stability, derived from the Monin-Obukhov length calculated by CALMET (for a single point of the CALMET domain representing the location of the Tarrawonga Coal Mine meteorological station).

The diurnal profile illustrates that atmospheric instability increases during daylight hours as convective energy increases, while stable atmospheric conditions prevail during the night-time. The potential for atmospheric dispersion of emissions is therefore greatest during day time hours and lowest during evening through to early morning hours.

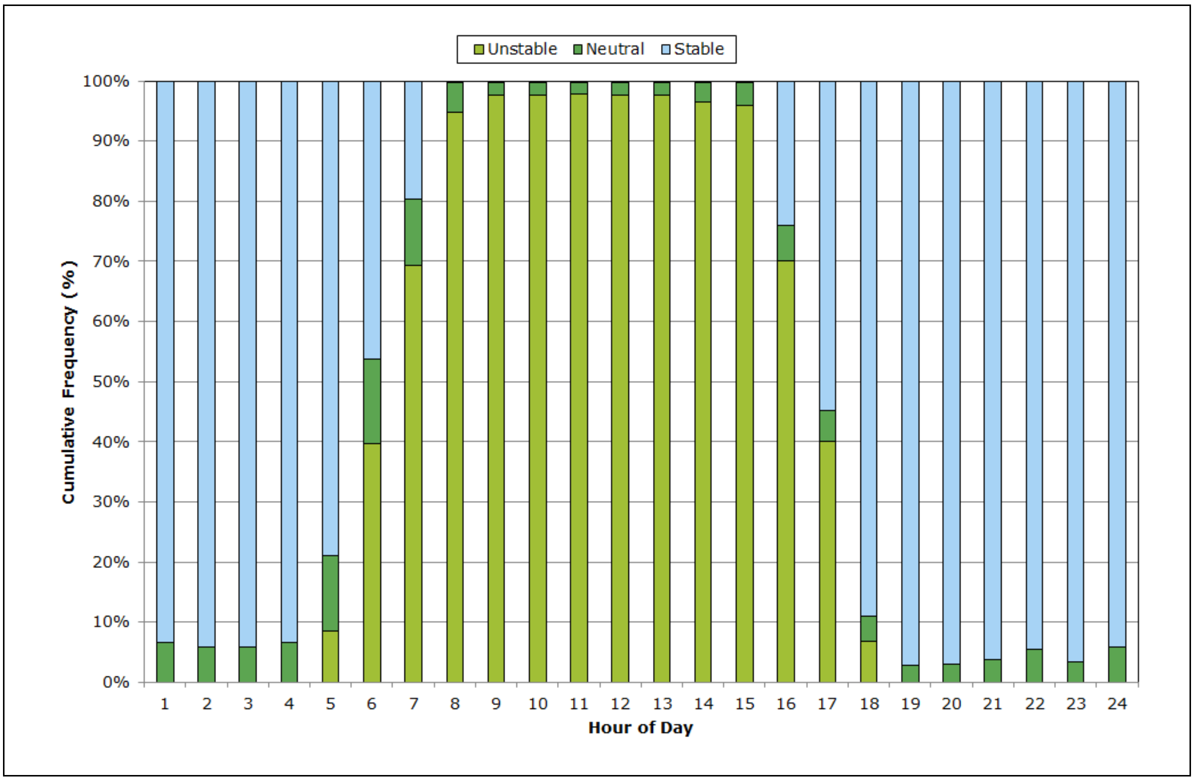


Figure 4-6: Diurnal variations in CALMET-generated atmospheric stability

4.2 Baseline ambient air quality

Cumulative impacts are assessed by combining the contribution from the Modification with the existing ambient air quality environment. Characterising the existing ambient air quality environment is not straightforward. The air quality monitoring sites operated by TCPL are used for either management purposes or to assess compliance for existing operations. Measurements at these sites, therefore, include the contribution from existing mining operations at the Tarrawonga Coal Mine and other local mining operations. These sites are not useful to characterise background, as it is not possible to accurately remove the contribution from existing operations to allow the Modification to be evaluated independently.

Summary statistics for compliance and management monitoring sites in the vicinity of the Tarrawonga Coal Mine are presented in **Table 4-1**. The locations of these sites are shown in **Figure 4-7**.

Excursions above the 24-hour average PM_{10} criterion of 50 µg/m^3 occur across most sites for most years, while the annual average remains below the impact assessment criterion of 25 µg/m^3 across all sites and all years. For the modelled year 2017, there were five days above 50 µg/m^3 at Coomalgah and three days above 50 µg/m^3 at the Flixton tapered element oscillating microbalance (TEOM).

It is noted that excursions above 50 µg/m^3 are often caused by local or regional factors and not necessarily a result of mining activity. For example, the 2017 Annual Review for the Tarrawonga Coal Mine reported that the five exceedances at the Coomalgah High Volume Air Sampler (HVAS) were likely a result of farming activity (harvesting of wheat).

It is also noted that the HVAS sites do not provide continuous measurements[6] and therefore do not always represent a true annual average or accurate indication of the number of exceedance days.

The monitoring sites in **Table 4-1** may be influenced, to varying degrees, by the existing operations at Tarrawonga, Boggabri and Maules Creek Coal Mines. The approach to cumulative assessment is therefore to use background data obtained further afield and to explicitly model the contribution from all existing and proposed local mining operations.

Whitehaven has operated a TEOM-DF[7] at the Wil-Gai property since early 2012, collecting baseline data for the Vickery Coal Mine (location shown on **Figure 4-7**). Monitoring data collected between 2013 and 2017 have been analysed and used to describe baseline concentrations of PM_{10} and $PM_{2.5}$ for use in the cumulative assessment[8].

The Wil-Gai TEOM is located approximately 10 km from existing mining operations at the Tarrawonga Coal Mine and therefore while measurements of PM will include some contribution from existing mining, this is expected to be relatively small.

The Wil-Gai TEOM is therefore considered largely representative of background from other non-mining sources.

[6] HVAS are typically run on a one-day-in-six run cycle

[7] TEOM, used to measure PM. The TEOM-DF refers to a dichotomous model which measures both PM_{10} and $PM_{2.5}$.

[8] In presenting TEOM monitoring data, validation has been performed on the 1-hour data. As a first step, 1-hour average data below negative 10 were removed. A 24-hour average concentration was calculated where the data recovery is greater than 75% for that day (i.e. more than 18 hourly data points).

Table 4-1: Summary statistics for compliance and management monitoring sites in the vicinity of Tarrawonga Coal Mine

Year	Tarrawonga Coal Mine						Boggabri Coal Mine			
	Templemore (HVAS[1])		Coomalgah (HVAS)		Flixton (TEOM)		Merriown (HVAS)		Roma (HVAS)	
	Annual average	Days > 50 µg/m³	Annual average	Days > 50 µg/m³	Annual average	Days > 50 µg/m³	Annual average	Days > 50 µg/m³	Annual average	Days > 50 µg/m³
2013	19.7	1								
2014	27.0	5					13.5	0		
2015	23.4	2			14.7	4	11.4	0	11.4	0
2016	23.3	2	12.3	0	15.7	4	10.4	0	9.9	0
2017			21.8	5[2]	16.3	3	12.0	1	12.5	2

[1] Templemore HVAS replaced by Coomalgah in 2016.

[2] Investigations indicated these exceedances were not mine related.

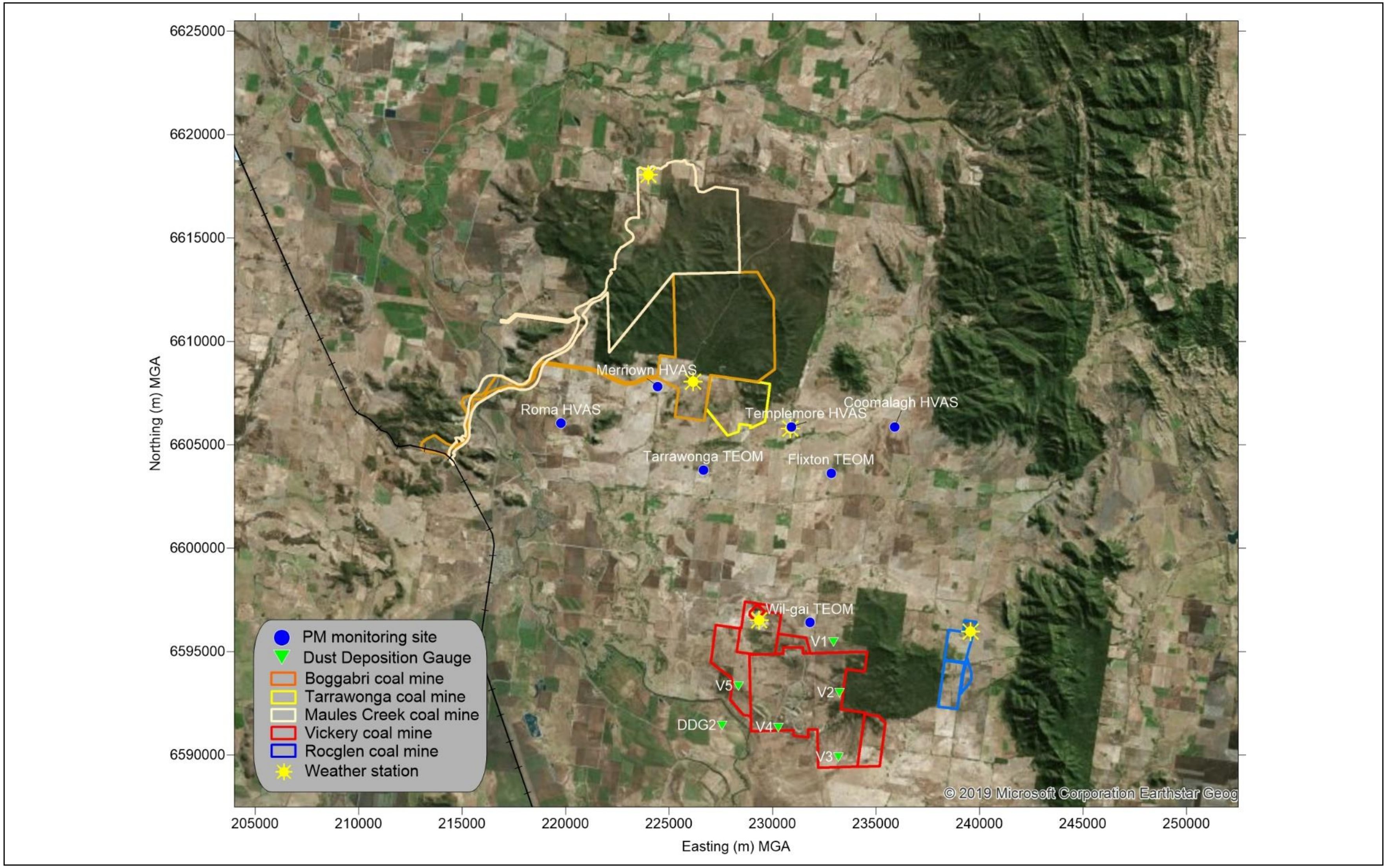


Figure 4-7: Monitoring locations

Annual average PM_{10} and $PM_{2.5}$ concentrations for the Wil-Gai TEOM are presented in **Table 4-2**[9]. The annual average PM_{10} concentration for 2017 is slightly higher than the 5-year average while the annual average $PM_{2.5}$ concentration for 2017 is less than the 5-year average. However, 2017 is largely consistent with other years and adopted as suitable background for cumulative assessment.

Table 4-2: Annual average PM_{10} and $PM_{2.5}$

Pollutant	2013	2014	2015	2016	2017
PM_{10} concentration (µg/m^3)	12.0	13.8	9.6	12.5	12.3
$PM_{2.5}$ concentration (µg/m^3)	5.3	4.6	4.1	5.3	4.0

The 24-hour average PM_{10} and $PM_{2.5}$ concentrations measured at Wil-Gai are presented in **Figure 4-8** and **Figure 4-9**. With the exception of one day in 2014 and one day in September 2017, 24-hour PM_{10} concentrations were below the impact assessment criteria for the period 2013 – 2017. There were no days when the 24-hour $PM_{2.5}$ concentration was above the impact assessment criteria.

The daily varying 24-hour PM_{10} and $PM_{2.5}$ concentrations for 2017 are paired with each daily modelling prediction for cumulative assessment. It is noted that gaps in the background dataset for 2017 were filled to ensure a full year of combined cumulative 24-hour average predictions.

Where either PM_{10} or $PM_{2.5}$ were missing for a day, the gap was filled using a simple linear regression analysis of the available data. Where both PM_{10} or $PM_{2.5}$ were missing, gaps were filled by calculating a random percentile between the upper and lower quartile of the available data. This gap filling may result in a slightly different annual average concentrations than would be obtained from the raw data.

[9] Annual averages for 2013 to 2016 taken from the Air Quality Impact Assessment for the Vickery Extension Project https://majorprojects.accelo.com/public/9756e01a2a237f14113f99e59fc006d9/25.%20Appendix%20E_%20Air%20Quality%20and%20Greenhouse%20Gas%20Assessment.pdf

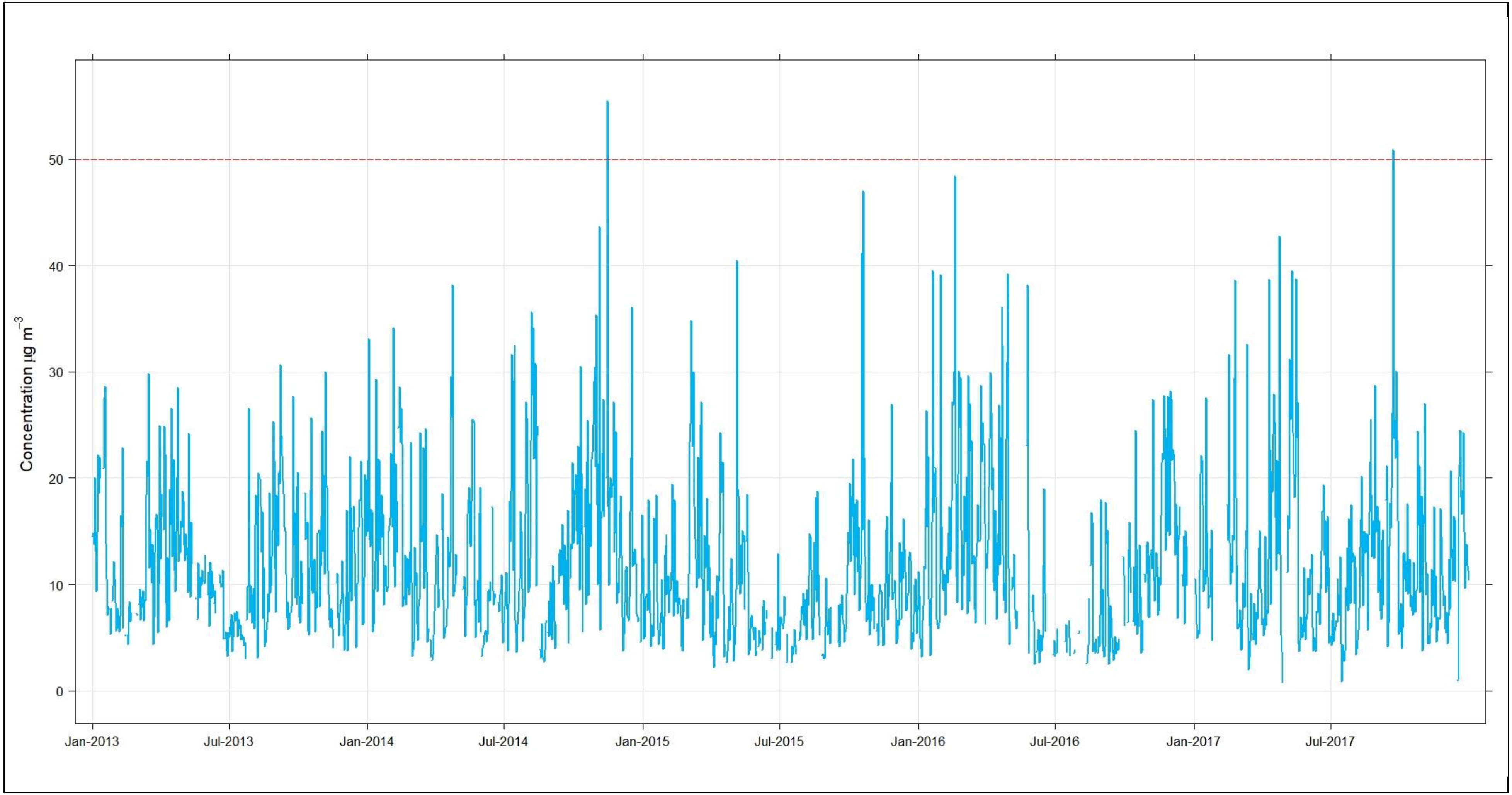


Figure 4-8: 24-hr average PM_{10} concentration - 2013 to 2017

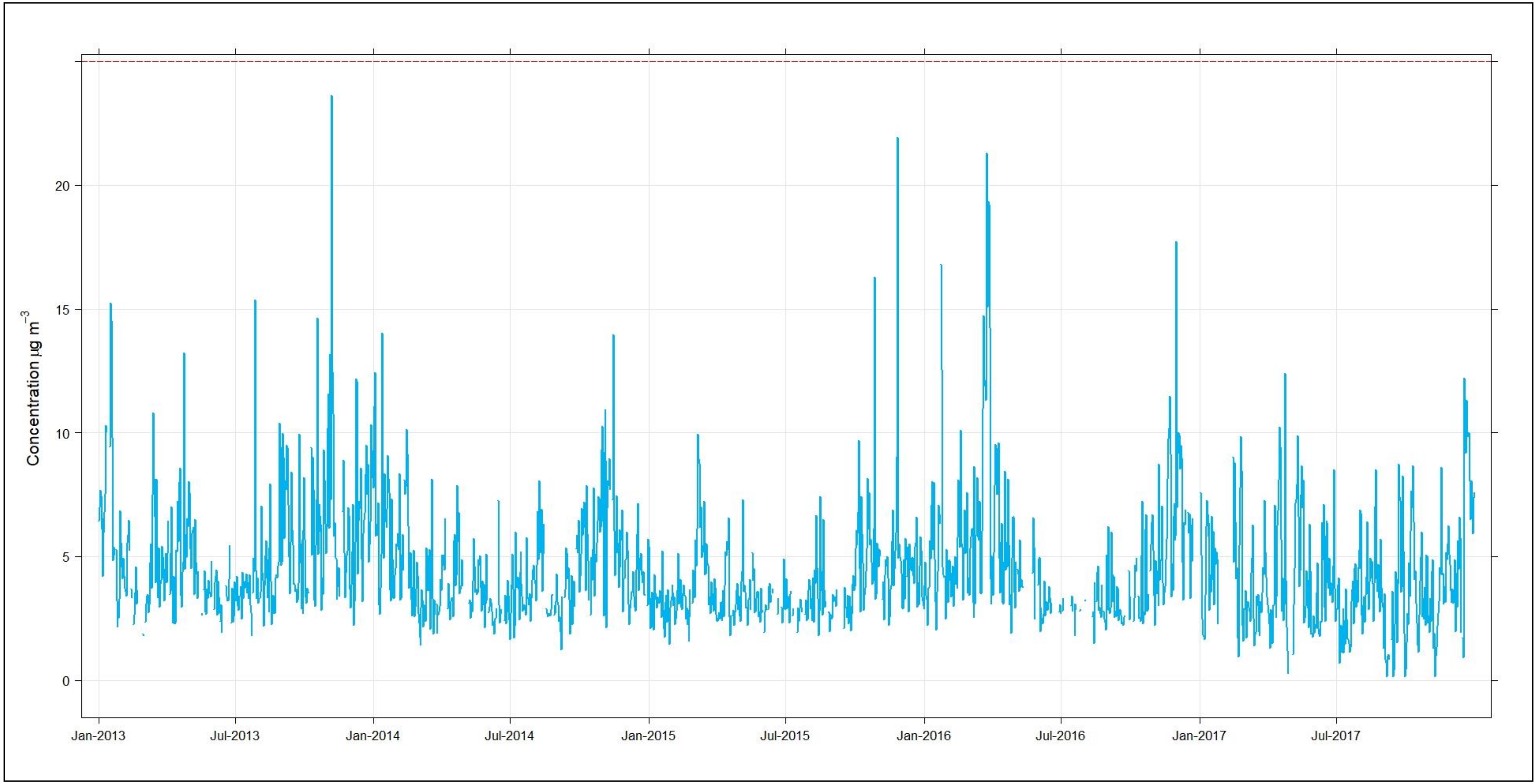


Figure 4-9: 24-hr average $PM_{2.5}$ concentration - 2013 to 2017

4.2.1 TSP concentration

TSP concentrations are not measured in the vicinity of the Modification, however annual average TSP concentrations can be derived based on typical ratios of PM_{10}/TSP. A PM_{10}/TSP ratio of 0.5 has been applied, consistent with the ratio applied for reporting TSP in the Annual Review[10]. This ratio has been applied to the annual average PM_{10} concentrations to derive a representative TSP background concentration ranging from 19 µg/m³ to 27 µg/m³.

4.2.2 Dust deposition

Whitehaven have been collecting dust deposition monitoring data in the vicinity of the Vickery Coal Project since late 2011 (see **Figure 4-7**). Annual average dust deposition levels are presented in **Table 4-3**. The annual average dust deposition levels across the dust deposition gauge (DDG) network range from 1.7 to 3.7 g/m²/month.

The DDG location "V1" is at the northern extent of the Vickery Coal Project mine lease boundary, closest to the receptors assessed for this report and therefore the best representative location for background. It is also the closest DDG site to the Wil-Gai monitoring sites, used to characterise background PM.

The deposition level for 2017 at V1 is significantly lower than previous years, however the long-term average is 2.1 g/m²/month, which is generally consistent with levels recorded in rural areas of NSW.

Table 4-3: Annual average dust deposition (g/m²/month)

Site	2012	2013	2014	2015	2016	2017
DDG1	1.0	0.9	1.8	2.5	2.3	5.1
DDG2	9.7	7.0	17.5	8.2	1.2	1.4
DDG3	1.7	1.7	1.8	1.2	0.8	0.9
V1	1.2	1.2	2.9	2.8	4.0	0.7
V2	0.6	0.8	1.2	1.0	0.6	1.5
V3	3.4	2.5	1.8	8.6	4.0	1.3
V4	1.7	2.1	0.9	4.3	2.1	1.1
V5	0.7	0.9	1.7	1.4	0.8	1.5
Average	**2.5**	**2.1**	**3.7**	**3.7**	**2.0**	**1.7**

4.2.3 Adopted background for cumulative assessment

The following background values are adopted for cumulative assessment:

- 24-hour PM_{10} concentration – daily varying.
- Annual average PM_{10} concentration – 12.3 µg/m³.
- 24-hour $PM_{2.5}$ concentration – daily varying.
- Annual average $PM_{2.5}$ concentration – 4.0 µg/m³.
- Annual average TSP concentration – 25 µg/m³.
- Annual average dust deposition – 2.1 g/m²/month.

[10] http://www.whitehavencoal.com.au/sustainability/environmental-management/tarrawonga-mine/

5. EMISSION INVENTORY

Emissions inventories have been developed for two representative years of mining operations, selected to assess the air quality impacts of worst-case operations, for example where material movement is high and where extraction or wind erosion areas are largest, or where operations are located closest to receivers (refer to **Table 1-1** for the indicative Modification production schedule). The operational scenarios chosen for assessment are:

- Year 3 – representative of peak production, for both ROM coal and waste rock [overburden].
- Year 7 – representative of eastern extent of mine before production tails off.

Consistent with the Approved Methods, emission factors developed by the US EPA[11], have been applied to estimate the amount of dust produced by each activity (soil stripping, waste rock [overburden] removal, coal removal and processing, wind erosion and hauling).

5.1 Summary of estimated emissions

A summary of the controlled emission estimates for PM_{10} and $PM_{2.5}$ are presented in **Table 5-1**. The emissions estimates incorporate controls based on a Best Practice Management (BMP) determination done for the Modification, incorporating existing / proposed controls.

Full details on the emission inventory development, including the assumptions, input data, emission factors and BMP determination, are provided in **Appendix 4**. Annual emission inventories for TSP are also shown in **Appendix 4**.

Annual emissions are split into (where the emission rate is independent of the wind speed), wind-sensitive sources (where there is a relationship between the emission rate and wind speed) and wind erosion sources (where the emission is dependent on the wind speed), and these splits are used to proportion emissions into these categories so that hourly emission files can be developed for modelling and varied according to the local wind speed (described in **Appendix 4**).

Table 5-1: Annual PM_{10} and $PM_{2.5}$ emissions (kg/annum)

Activity	PM_{10}		$PM_{2.5}$	
	Year 3	Year 7	Year 3	Year 7
Vegetation and topsoil stripping				
Dozers stripping	3,196	3,196	1,420	1,420
Excavator loading trucks	70	42	11	6
Hauling	589	248	105	53
Unloading trucks	70	42	11	6
Overburden removal and dumping				
Drilling	1,078	960	62	55
Blasting	26,678	23,764	1,539	1,371
Excavator loading trucks	63,597	56,648	9,630	8,578
Hauling	343,958	253,129	55,372	43,998
Unloading trucks	22,259	19,827	3,371	3,002
Dozers - Pit	18,145	18,145	8,062	8,062
Dozers - Dump	36,290	36,290	16,124	16,124

[11] US EPA AP-42 Compilation of Air Pollutant Emission Factors (US EPA, 1998b; US EPA, 2004; US EPA, 2006).

Activity	PM_{10}		$PM_{2.5}$	
	Year 3	**Year 7**	**Year 3**	**Year 7**
Coal removal				
Dozer ripping	29,626	29,626	2,401	2,401
Ex/FEL loading trucks	33,733	33,733	4,987	4,987
Hauling	21,773	17,040	3,030	2,557
Coal handling and processing				
Unloading to ROM stockpile	294	294	45	45
FEL rehandle at ROM stockpile	29,626	29,626	2,401	2,401
Crushing domestic coal	270	270	11	11
Screening domestic coal	968	968	6	6
Crushing gravel	119	119	5	5
Screening gravel	426	426	2	2
Rehandle gravel	24	24	4	4
Transfer coal to bin	504	504	76	76
Loading trucks	366	366	55	55
Haulage of coal to CHPP (unsealed)	13,607	13,607	1,361	1,361
Haulage of coal to CHPP (sealed)	2,981	2,981	721	721
Haulage to rejects from CHPP to Tarrawonga Coal Mine	N/A	N/A	N/A	N/A
Unloading rejects	8	8	1	1
Wind erosion of exposed ground				
Prestrip	21,038	12,750	3,156	1,913
Active pit	42,798	34,000	6,420	5,100
Active dump	92,055	72,250	13,808	10,838
Active rehabilitation	7,348	6,843	1,102	1,026
Soil stockpiles	744	744	112	112
Stockpile wind erosion and maintenance				
ROM stockpile	118,260	118,260	17,739	17,739
Miscellaneous				
Grading roads	8,692	11,176	747	960
Total (kg/annum)	**941,188**	**797,905**	**153,895**	**134,995**

Note: FEL = Front End Loader
kg/annum = kilograms per annum

5.2 Diesel emissions

As discussed previously, emissions of PM_{10} and $PM_{2.5}$ from diesel combustion in mining equipment are assumed to be included in the total emissions for each relevant source and are not explicitly modelled as a separate emission source. However, adjustments have been made to account for the fact that emission reductions applied to the inventory (i.e. watering) are not relevant to control of diesel exhaust emissions.

The NSW EPA completed a benchmarking study to evaluate a number of options for reducing diesel emissions for all 64 coal mines in NSW (NSW EPA, 2014). Total $PM_{2.5}$ emissions (1,298 tonnes per annum [tpa]) and diesel combustion (936,440 kilolitres [kL]) were reported in NSW EPA (2014) and used to derive a fleet average emission factor of 1.39 kilograms (kg) $PM_{2.5}$/kL diesel.

Diesel consumption for the Modification is estimated based on the reported FY17 diesel consumption[12] and scaled for the projected ROM coal and waste rock production for Year 3 and Year 7. The majority of mine site diesel (97%) is consumed in haul trucks (62%), excavators (19%) and dozers/loaders (15%) (NSW EPA, 2014). The emissions inventory applies no controls for dozers/loaders and excavators, therefore the adjustments for diesel emissions are only needed for haul road controls.

It is assumed, therefore, that 62% of the total site diesel consumption is used for hauling and the total emissions are allocated to coal haul and waste haul pro-rata, based on the total tonnage hauled along each route. The estimated diesel emissions for hauling are subtracted from the uncontrolled haul road emissions to derive the wheel-generated component of emissions for each haul road. The control for watering is then applied to the wheel-generated component only, and the diesel emissions are then added back to derive the final emission estimate from haul trucks.

The estimated emissions of PM_{10} and $PM_{2.5}$ from diesel combustion for the Modification are presented in **Table 5-2**, based on an assumed NSW fleet average emission factor for $PM_{2.5}$[13]. It is noted that emissions from the onsite diesel generators are not included in the assessment.

Table 5-2: Annual PM_{10} and $PM_{2.5}$ emissions from diesel combustion (kg/annum)

	PM_{10}		$PM_{2.5}$	
Year	**Year 3**	**Year 7**	**Year 3**	**Year 7**
Estimated diesel emissions	42,055	40,830	37,611	36,516
% of total emissions	1.0%	8.6%	1.1%	9.8%

5.3 Modelling the contribution from other mines

As previously described, cumulative impacts are assessed using a combination of modelled emissions from other local mining operations and a background derived from monitoring data to account for all other sources. Modelling for other mining operations is based on the emission inventories reported in the respective air quality assessments prepared as part of the Environment Assessment/EIS process.

The derived emissions for other mines are presented in **Table 5-3**. A conservative approach is to use the worst-case emission scenarios for each mine, irrespective of the nominal mining year and whether it corresponds with the Modification scenario year. Further conservatism is added for cumulative assessment through the addition of background data for 2017, which will include

[12] Reported in Whitehaven Coal's National Greenhouse and Energy Reporting (NGER) Energy and Emissions Report for the period 2017 – 2018.

[13] Annual PM_{10} emissions are estimated based on the assumption that $PM_{2.5}$ emissions are 97% of PM_{10} emissions (NSW EPA, 2012)

some contribution from existing operations at Tarrawonga, Boggabri and Maules Creek Coal Mines during 2017.

Table 5-3: Derived emissions for other mines (kg/annum)

Mine	TSP	PM_{10}	$PM_{2.5}$	Basis	Reference
Boggabri Coal Mine	8,395,716	3,282,725	394,599	Based on maximum emissions in Year 21 (nominally 2032).	PAEHolmes (2011)
Maules Creek Coal Mine	7,929,117	3,100,285	372,668	Based on maximum emissions in Year 10 (nominally 2021).	PAEHolmes (2010)
Vickery Extension Project	5,531,688	1,644,234	228,564	Based on maximum emissions in Year 7 (nominally 2025).	Ramboll (2018)
Note: PM_{10} and $PM_{2.5}$ are not reported in the AQIAs for Boggabri and Maules Creek Coal Mines and emissions are therefore estimated based on the particle size fractions used to scale TSP modelling results and reported in the respective AQIA.					

Annual emissions are split into wind-insensitive, wind-sensitive and wind erosion sources, and these splits are used to proportion emissions into these categories so that hourly emission files can be developed for modelling and varied according to the local wind speed (described in **Appendix 4**).

6. DISPERSION MODELLING RESULTS

The predicted Modification-only and cumulative modelling results are presented below at each privately-owned receptor.

Under the VLAMP, non-private (mine-owned or properties under option agreement with Whitehaven) receptors are not necessarily subject to impact assessment, mitigation or acquisition criteria, however provisions do apply for "use of the acquired land", primarily related to protecting existing or prospective tenants. The predicted Modification-only and cumulative modelling results for mine-owned receptors are presented in **Appendix 5**. The modelling results are also presented as contour plots in **Appendix 6**, showing the extent of predicted impacts across private and mine-owned land.

The modelling results incorporate a material level of conservatism through a number of conservative assumptions applied in the model input data and model settings, including:

- The dust emission estimates do not account for natural mitigation due to rainfall.
- The model does not incorporate wet deposition (removal of particles due to rainfall).
- The background adopted for assessment will include some contribution from existing mining operations, therefore there will be some double counting when modelled concentrations are added to background without adjustment.
- For cumulative assessment, modelling for other mines is based on maximum approved or proposed production, and therefore likely to be higher than what would eventuate.

6.1 Annual average PM_{10} and $PM_{2.5}$ concentration

The predicted Modification-only and cumulative annual average PM_{10} and $PM_{2.5}$ concentrations for private receptors are presented in **Table 6-1**. The highest predicted increment in annual average PM_{10} is 2.3 µg/m³ (at receptor 79a). The highest predicted increment in annual average $PM_{2.5}$ is 0.5 µg/m³ (also at receptor 79a).

There are no private receptors where the cumulative annual average PM_{10} concentrations are greater than 25 µg/m³ or where the cumulative annual average $PM_{2.5}$ concentrations are greater than 8 µg/m³.

Table 6-1: Predicted Modification-only and cumulative annual average PM_{10} and $PM_{2.5}$ concentration (µg/m³) at private receptors

ID	Modification-only				Cumulative			
	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
79a	2.3	2.3	0.5	0.5	20.5	20.4	5.1	5.2
72	0.7	0.6	0.1	0.1	15.8	15.7	4.4	4.4
73	0.8	0.6	0.2	0.1	16.4	16.3	4.5	4.5
30	1.0	0.8	0.2	0.2	17.3	17.1	4.7	4.6
80	1.1	0.9	0.2	0.2	18.3	18.1	4.9	4.9
78	1.0	0.9	0.2	0.2	18.0	17.9	4.9	4.8
86	1.4	1.2	0.3	0.3	18.9	18.7	5.0	5.0
87b	1.8	1.7	0.3	0.4	19.7	19.6	5.2	5.2
118	1.3	1.1	0.2	0.2	18.5	18.3	4.9	4.9
87a	1.2	1.2	0.2	0.2	18.1	17.9	4.9	4.9
122	1.0	1.0	0.2	0.2	17.2	17.1	4.8	4.7

ID	Modification-only				Cumulative			
	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
79b	1.1	1.0	0.2	0.2	17.9	17.8	4.8	4.7
70	0.8	0.6	0.1	0.1	16.2	16.1	4.5	4.5
337	0.7	0.5	0.1	0.1	15.7	15.6	4.4	4.4
39	1.4	1.2	0.3	0.3	19.5	19.3	5.0	5.0
37	1.1	0.9	0.2	0.2	17.9	17.8	4.7	4.7
516	0.8	0.8	0.2	0.2	17.3	17.6	4.7	4.7
54	0.3	0.2	0.1	0.1	13.3	13.3	4.0	4.0
519	0.7	0.6	0.1	0.1	17.1	17.4	4.7	4.7
22b	0.2	0.1	0.0	0.0	13.2	13.2	4.0	4.0
22a	0.2	0.1	0.0	0.0	13.2	13.2	4.0	4.0
314a	0.5	0.4	0.1	0.1	14.4	14.3	4.2	4.2
314b	0.6	0.5	0.1	0.1	14.6	14.5	4.2	4.2
573a	0.7	0.7	0.1	0.2	14.3	14.3	4.2	4.2
573b	1.0	1.0	0.2	0.2	14.5	14.5	4.3	4.3

6.2 Maximum 24-hour average PM_{10} concentration

The Year 3 predicted Modification-only and cumulative 24-hour average PM_{10} concentrations for private receptors are presented in **Table 6-2**. The highest predicted incremental 24-hour average PM_{10} for Year 3 is 42.4 µg/m³ (at receptor 573b).

Modelling results for existing mines plus background show that without the contribution from the Tarrawonga Coal Mine (either approved operations or the proposed Modification), exceedances are predicted across all receptors.

The cumulative column in **Table 6-2** represents the addition of the Modification to existing environment (existing mines plus background). With the addition of the Modification, there are 14 receptors where no additional exceedance days are predicted, seven receptors where the Modification results in one additional exceedance day and four receptors where the Modification results in two additional exceedance days. It is also noted that at many of the receptors the maximum predicted 24-hour average concentration does not increase with the addition of the Modification.

The BTM Complex Air Quality Management Strategy (Parsons Brinkerhoff, 2017) is used to proactively monitor and manage cumulative air quality impacts from the BTM Complex. The BTM Complex Air Quality Management Strategy includes an integrated predictive (forecast meteorology and modelling) and reactive (real-time monitoring network) and is specifically designed to prevent short-term exceedances of the impact assessment criteria, such as those predicted in **Table 6-2**. It does this by applying proactive, reactive or corrective measures across the BTM Complex when potential short-term exceedances are predicted or detected.

Table 6-2: Predicted Modification-only and cumulative maximum 24-hour average PM_{10} concentration (µg/m³) at private receptors – Year 3

ID	Modification only	Background and existing mines		Cumulative	
	Concentration (µg/m³)	Concentration (µg/m³)	Days over 50 µg/m³	Concentration (µg/m³)	Additional days over 50 µg/m³
79a	14.1	55.8	6	57.7	2
72	4.1	50.9	1	50.9	0
73	4.8	50.9	1	51.0	1
30	6.0	50.9	1	52.5	1
80	7.0	51.0	1	51.3	1
78	6.7	51.0	1	51.0	1
86	6.7	55.0	2	56.8	0
87b	10.8	51.4	1	52.0	2
118	7.4	52.9	2	54.9	0
87a	9.1	51.2	1	51.2	0
122	9.5	51.1	1	51.2	0
79b	7.0	51.0	1	54.7	2
70	10.2	50.9	1	51.3	1
337	4.8	50.9	1	50.9	0
39	20.8	57.9	2	61.6	1
37	17.4	54.6	2	57.8	1
516	5.0	52.7	4	56.7	0
54	12.8	55.0	1	55.0	0
519	3.5	54.6	2	56.5	0
22b	4.0	53.0	1	53.0	0
22a	4.0	53.0	1	53.0	0
314a	5.0	50.9	1	50.9	0
314b	6.1	50.9	1	50.9	0
573a	18.2	59.6	1	59.7	0
573b	42.4	61.7	1	64.0	2

The Year 7 predicted Modification-only and cumulative 24-hour average PM_{10} concentrations for private receptors are presented in **Table 6-3**. The highest predicted incremental 24-hour average PM_{10} for Year 7 is 39.0 µg/m³ (at receptor 573b).

Modelling results for existing mines plus background show that without the contribution from the Tarrawonga Coal Mine (either approved operations or the proposed Modification), exceedances are predicted across all receptors.

The cumulative column in **Table 6-3** represents the addition of the Modification to existing environment (existing mines plus background). With the addition of the Modification, there are 16 receptors where no additional exceedance days are predicted, six receptors where the Modification results in one additional exceedance day and three receptors where the Modification results in two additional exceedance days.

As discussed above, BTM Complex Air Quality Management Strategy (Parsons Brinkerhoff, 2017) is specifically designed to prevent short-term exceedances of the impact assessment criteria, such as those predicted in **Table 6-3**.

Table 6-3: Predicted Modification-only and cumulative maximum 24-hour average PM_{10} concentration (µg/m³) at private receptors – Year 7

ID	Modification only	Background and existing mines		Cumulative	
	Concentration (µg/m³)	Concentration (µg/m³)	Days over 50 µg/m³	Concentration (µg/m³)	Additional days over 50 µg/m³
79a	15.0	54.1	4	55.4	2
72	3.9	50.9	1	50.9	0
73	4.6	51.0	1	51.0	0
30	5.8	51.0	1	51.1	1
80	6.8	51.0	1	51.0	1
78	6.5	51.0	1	51.0	0
86	6.5	53.0	2	54.3	0
87b	12.1	51.4	1	51.4	2
118	6.1	51.1	2	52.5	0
87a	10.1	51.2	1	51.2	0
122	10.0	51.2	1	51.2	0
79b	6.2	51.0	1	53.4	1
70	8.7	50.9	1	50.9	1
337	4.2	50.9	1	50.9	0
39	18.0	57.7	2	60.7	1
37	15.1	54.1	2	56.7	1
516	5.2	52.7	4	56.8	0
54	11.9	56.2	1	56.2	0
519	4.2	54.2	2	56.2	0
22b	3.4	54.6	1	54.6	0

ID	Modification only	Background and existing mines		Cumulative	
	Concentration (µg/m³)	Concentration (µg/m³)	Days over 50 µg/m³	Concentration (µg/m³)	Additional days over 50 µg/m³
22a	3.5	54.7	1	54.7	0
314a	3.7	50.9	1	50.9	0
314b	4.4	51.0	1	51.0	0
573a	21.3	60.5	1	60.6	0
573b	39.0	61.8	1	64.0	2

6.3 Maximum 24-hour average $PM_{2.5}$ concentration

The predicted cumulative 24-hour average $PM_{2.5}$ concentrations for private receptors are presented in **Table 6-4**. The highest predicted incremental 24-hour average $PM_{2.5}$ for Year 3 is 7.3 µg/m³ and for Year 7 is 6.9 µg/m³ (both at receptor 573b). There are no private receptors where the cumulative 24-hour average $PM_{2.5}$ concentrations are greater than 25 µg/m³.

Table 6-4: Predicted Modification only and cumulative maximum 24-hour average $PM_{2.5}$ concentration (µg/m³) at private receptors

ID	Modification only		Cumulative	
	Year 3	Year 7	Year 3	Year 7
79a	2.6	3.1	14.7	14.7
72	0.8	0.9	14.8	14.6
73	1.0	1.1	15.0	14.9
30	1.2	1.3	15.5	15.3
80	1.3	1.5	16.7	16.6
78	1.3	1.4	16.7	16.6
86	1.3	1.4	14.0	13.9
87b	2.0	2.4	12.9	12.8
118	1.3	1.3	13.9	13.8
87a	1.7	2.0	12.9	12.8
122	1.8	2.0	12.8	12.8
79b	1.2	1.2	15.8	15.6
70	1.8	1.6	14.7	14.5
337	0.9	0.9	14.6	14.4
39	3.6	3.4	15.8	15.5
37	3.1	2.9	15.0	14.7
516	1.0	1.1	14.5	14.6
54	2.3	2.2	12.9	12.8
519	0.7	0.9	14.4	14.4
22b	0.8	0.8	12.5	12.7

ID	Modification only		Cumulative	
	Year 3	Year 7	Year 3	Year 7
22a	0.8	0.8	12.5	12.7
314a	0.9	0.7	14.2	14.0
314b	1.1	0.8	13.9	13.8
573a	3.5	4.3	14.0	13.9
573b	7.3	6.9	13.4	13.4

6.4 TSP concentration and dust deposition

The predicted Modification-only and cumulative annual average TSP concentrations for all private receptors are presented in **Table 6-5**. The cumulative results include a baseline concentration of 25 µg/m³ plus the contribution from the other local mines. There are no receptors where the Modification-only or cumulative annual average TSP concentrations are greater than 90 µg/m³.

The predicted Modification-only and cumulative annual average dust deposition for all private receptors is presented in **Table 6-5**. For all receptors, Modification-only modelling predictions are less than 2 g/m²/month. Cumulative dust deposition is presented based on a baseline of 2.1 g/m²/month plus the contribution from other local mines. There are no receptors where the cumulative annual average dust deposition is greater than 4 g/m²/month.

Table 6-5: Predicted Modification-only and cumulative annual average TSP (µg/m³) and dust deposition (g/m²/month) at private receptors

ID	Modification-only				Cumulative			
	TSP (µg/m³)		Depos (g/m²/m)		TSP (µg/m³)		Depos (g/m²/m)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
79a	4.0	3.4	0.08	0.06	37.5	36.8	2.3	2.3
72	1.2	0.8	0.02	0.01	30.0	29.6	2.2	2.2
73	1.4	0.9	0.03	0.02	30.8	30.3	2.2	2.2
30	1.7	1.1	0.03	0.02	32.1	31.5	2.2	2.2
80	1.9	1.3	0.04	0.02	34.3	33.7	2.4	2.4
78	1.8	1.3	0.03	0.02	33.9	33.3	2.4	2.4
86	2.4	1.8	0.05	0.03	35.6	35.0	2.4	2.4
87b	3.1	2.5	0.06	0.05	37.3	36.7	2.5	2.5
118	2.2	1.6	0.04	0.03	34.8	34.2	2.4	2.4
87a	2.1	1.6	0.04	0.03	34.3	33.8	2.4	2.4
122	1.8	1.3	0.03	0.02	32.8	32.4	2.4	2.3
79b	2.0	1.4	0.04	0.02	33.1	32.6	2.2	2.2
70	1.3	0.9	0.03	0.02	30.5	30.0	2.2	2.2
337	1.2	0.7	0.02	0.01	29.8	29.4	2.2	2.2
39	2.3	1.7	0.04	0.03	35.2	34.7	2.3	2.2
37	1.8	1.3	0.03	0.02	32.8	32.4	2.2	2.2

ID	Modification-only				Cumulative			
	TSP (µg/m³)		Depos (g/m²/m)		TSP (µg/m³)		Depos (g/m²/m)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
516	1.3	1.0	0.04	0.03	31.6	31.3	2.3	2.3
54	0.4	0.3	0.01	0.01	26.3	26.2	2.1	2.1
519	1.0	0.8	0.03	0.02	31.1	30.9	2.3	2.3
22b	0.2	0.2	0.01	0.00	26.1	26.1	2.1	2.1
22a	0.2	0.2	0.01	0.00	26.2	26.1	2.1	2.1
314a	0.8	0.6	0.02	0.01	28.0	27.7	2.2	2.1
314b	1.0	0.7	0.02	0.01	28.3	28.0	2.2	2.1
573a	1.1	1.0	0.03	0.02	27.7	27.6	2.2	2.2
573b	1.5	1.3	0.03	0.03	28.0	27.8	2.2	2.2

6.5 Voluntary land acquisition on vacant land

Voluntary land acquisition criteria also apply if the development contributes to an exceedance on more than 25% of privately-owned land upon which a dwelling could be built under existing planning controls. Analysis of the contour plots presented in **Appendix 6** indicates that Modification-only 24-hour PM_{10} concentrations does exceed the incremental impact criterion of 50 µg/m³ across more than 25% of the property 573 (when considered on a combined contiguous basis).

To assess against voluntary land acquisition criteria for cumulative annual average PM_{10} and TSP, a fixed background value, described in **Section 4.2.3**, is added to the incremental contour plots presented in **Appendix 6** (**Figure A6-2**, **Figure A6-5**, **Figure A6-8**, **Figure A6-11**). Based on this, no additional land would be subject to voluntary land acquisition.

For dust deposition, the Modification-only contribution does not exceed 2 g/m²/month across more than 25% of any private property and the cumulative contribution (when a conservative background of 2.6 g/m²/month is added) does not exceed 4 g/m²/month across more than 25% of any private property.

7. GREENHOUSE GAS ASSESSMENT

7.1 Introduction

The estimation of GHG emissions for the Modification is based on the Australian Government Department of Environment and Energy (DEE) *National Greenhouse Accounts Factors (NGAF) workbook* (DEE, 2018). The methodologies in the NGAF workbook follow a simplified approach, equivalent to the "Method 1" approach outlined in the *National Greenhouse and Energy Reporting (Measurement) Technical Guidelines* (Technical Guidelines) (Department of the Environment [DoE], 2014). The Technical Guidelines are used for the purpose of reporting under the *National Greenhouse and Energy Reporting Act 2007.*

For accounting and reporting purposes, GHG emissions are defined as 'direct' and 'indirect' emissions. Direct emissions (also referred to as Scope 1 emissions) occur within the boundary of an organisation and as a result of that organisation's activities. Indirect emissions are generated as a consequence of an organisation's activities but are physically produced by the activities of another organisation (DEE, 2018). Indirect emissions are further defined as Scope 2 and Scope 3 emissions. Scope 2 emissions occur from the generation of the electricity purchased and consumed by an organisation. Scope 3 emissions occur from all other upstream and downstream activities, for example the downstream use of products and services or the upstream extraction and production of raw materials.

Scope 3 is an optional reporting category (Bhatia et al, 2010) and should not be used to make comparisons between organisations, for example in benchmarking GHG intensity of products or services. Typically, only major sources of Scope 3 emissions are accounted and reported by organisations[14].

7.2 Emissions sources

The GHG emissions sources included in this assessment are listed in **Table 7-1**, representing the most significant sources associated with the Modification. Other minor sources of GHG emissions, such as those generated by employee travel and waste disposal, are anticipated to be negligible in comparison and have not been considered in this assessment. Emissions from the shipping of product coal are not included in this assessment due to the uncertainties in emission estimates, including uncertainty in future export destinations and limited data on emission factors and/or fuel consumption for ocean-going vessels.

Table 7-1: Scope 1, 2 and 3 emission sources

Scope 1	Scope 2	Scope 3
Direct emissions from fuel combustion (diesel) by on-site plant and equipment.	Indirect emissions associated with the consumption of purchased electricity.	Indirect upstream emissions from the extraction, production and transport of diesel fuel.
Fugitive emissions of methane from disturbed coal seams.		Indirect upstream emissions from electricity lost in delivery in the transmission and distribution network.
		Downstream emissions generated from off-site transportation of product coal to Gunnedah by road and to Newcastle by rail.
Emissions from the use of explosives.		Downstream emissions generated from the end use of product coal.

[14] Specific Scope 3 emission factors are provided in the NGAF workbook for the consumption of fossil fuels (relating to extraction and transport) and purchased electricity (relating to transmission and distribution losses), making it straightforward for these sources to be included in a GHG inventory.

7.3 Activity data

Activity data for the emission estimates are presented in **Table 7-2**. The annual diesel consumption, electricity and explosive usage have been estimated based on intensity factors derived as follows:

- Diesel intensity factor (gigajoules [GJ] per tonne ROM) is derived based on the reported FY18 diesel consumption[15] (mining and transport) and ROM coal production[16] for the same period.
- Electricity intensity factor (GJ per tonne ROM) is derived based on the reported FY18 electricity use[15] and ROM coal production for the same period.
- Explosive intensity factor (tonnes per bcm overburden) is derived based on the reported FY18 explosive use[17] and overburden for the same period. Overburden production for the FY18 period is not reported, therefore it is estimated based on a stripping ratio (tonnes ROM coal/bcm [tonnes ROM coal per bank cubic metre]), derived from production statistics reported in the 2017 Annual Review.

An estimate of diesel consumption from product coal transportation by rail is based on a NSW fleet average diesel consumption rate of 4.03 litres per kilotonne.kilometre (L/kilotonne.km) (NSW EPA, 2012). The annual product coal production (kt) and travel distance (350 km) are combined to estimate the gross-tonne-km travelled for loaded trains. For the return trip, an estimate of the gross-tonne-km for empty trains is made based on a wagon weight of 23 tonnes (t), an average of 88 wagons per train and average train capacity of 8,336 t.

Table 7-2: Annual ROM coal production schedule and activity data

Modification Year	ROM coal production (Mt)	Product coal production (Mt)	Diesel consumption (kL) - mining	Diesel consumption (kL) - transport	Explosives usage (t)	Electricity (kWh)
Year 1	2.3	2.1	18,630	73	11,655	1,319,750
Year 2	2.9	2.7	23,491	93	15,848	1,664,033
Year 3	3.5	3.3	28,351	112	22,146	2,008,316
Year 4	3.5	3.3	28,351	112	19,722	2,008,316
Year 5	3.5	3.3	28,351	112	21,688	2,008,316
Year 6	3.5	3.3	28,351	112	20,936	2,008,316
Year 7	3.5	3.3	28,351	112	19,727	2,008,316
Year 8	2.7	2.5	21,924	86	15,714	1,553,049
Year 9	2.4	2.2	19,704	78	13,923	1,395,788
Year 10	2.1	2.0	17,172	68	13,695	1,216,465
Year 11	1.0	0.9	8,432	33	6,423	597,309

Note: kWh = kilowatt-hour

[15] Reported in Whitehaven Coal's NGER Energy and Emissions Report for the period 2017 – 2018.
[16] Reported in Whitehaven Coal's quarterly production statistics.
[17] Reported in Whitehaven Coal's National Pollution Inventory (NPI) Report for 17/18 financial year.

7.4 Emission factors

Emissions are estimated using the methodologies outlined in the NGAF workbook, using fuel energy contents and Scope 1, 2 and 3 emission factors (EF) for coal, diesel and electricity use in NSW.

The EF are taken from the NGAF workbook, with the exception of fugitive methane, which is based on an EF of 0.001 tonnes of carbon dioxide equivalent per tonne (t CO_2-e/t) of ROM coal , based on borehole samples analysed for both the Maules Creek Coal Mine and the Vickery Coal Project (PAEHolmes, 2011 and 2012a).

7.5 Emission estimates

The estimated annual GHG emissions for each source are presented in **Table 7-3**. Annual average Scope 1 emissions represent approximately 0.05% of total GHG emissions for NSW and 0.01% of total GHG emissions for Australia, based on the *National Greenhouse Gas Inventory for 2016*[18]. The Modification's contribution to projected climate change, and the associated environmental impacts, would be in proportion with its contribution to global GHG emissions.

The Modification would result in a reduction of total GHG emissions compared to the approved Tarrawonga Coal Mine due to the reduction in total ROM coal and waste rock quantities over the life of the mine associated with the reduced open pit extent.

7.6 Emissions intensity

The estimated GHG emissions intensity for the Modification is approximately 0.02 t CO_2-e/t ROM (this includes all Scope 1 and 2 emissions). This is comparable to the GHG emissions intensity of other existing local mines, including the Boggabri Coal Mine (0.06 t CO_2-e/t ROM), Rocglen Coal Mine (0.06 t CO_2-e/t ROM) and Maules Creek Coal Mine (0.02 t CO_2-e/t ROM).

[18] http://ageis.climatechange.gov.au/

Table 7-3: Estimated GHG emissions (t CO_2-e)

Modification Year	ROM (Mt)	Scope 1					Scope 2	Scope 3					
		Diesel (mining)	Diesel (transport)	Fugitive methane	Blasting	Total	Electricity	Diesel (mining)	Diesel (transport)	Electricity	Diesel (product transport)	End use of product coal	Total
Year 1	2.3	50,483	211	2,001	1,981	54,676	1,083	2,589	11	133	12,001	5,126,986	5,141,719
Year 2	2.9	63,653	266	2,523	2,694	69,135	1,366	3,264	14	168	15,131	6,464,460	6,483,037
Year 3	3.5	76,822	321	3,045	3,765	83,953	1,648	3,940	16	202	18,818	8,039,493	8,062,469
Year 4	3.5	76,822	321	3,045	3,353	83,541	1,648	3,940	16	202	18,818	8,039,493	8,062,469
Year 5	3.5	76,822	321	3,045	3,687	83,875	1,648	3,940	16	202	18,818	8,039,493	8,062,469
Year 6	3.5	76,822	321	3,045	3,559	83,747	1,648	3,940	16	202	18,818	8,039,493	8,062,469
Year 7	3.5	76,822	321	3,045	3,354	83,541	1,648	3,940	16	202	18,818	8,039,493	8,062,469
Year 8	2.7	59,407	248	2,355	2,671	64,681	1,275	3,047	13	157	14,122	6,033,307	6,050,645
Year 9	2.4	53,392	223	2,116	2,367	58,098	1,146	2,738	11	141	12,692	5,422,377	5,437,960
Year 10	2.1	46,532	194	1,844	2,328	50,899	998	2,386	10	123	11,405	4,872,420	4,886,343
Year 11	1.0	22,848	95	906	1,092	24,941	490	1,172	5	60	5,132	2,192,589	2,198,958

8. MANAGEMENT AND MONITORING

The Tarrawonga Coal Mine operates under an Air Quality and Greenhouse Gas Management Plan[19] developed for approved operations at the site. The dust management measures applied to the emission estimates for the Modification are consistent with the Air Quality Management Plan and are outlined in **Appendix 4**.

Other control measures, while not explicitly applied as reduction factors in the emission calculations, are accounted for in the modelled emissions on the basis of the mine plan, including:

- Direct placement of waste rock and soil where possible, reducing the double handling of material, potential for wind erosion and haulage distances.
- Progressive rehabilitation of disturbed areas.
- Minimising the double handling of material, wherever practicable (i.e. direct movement of ROM coal to the ROM hopper).
- Avoiding disturbance, or temporary rehabilitation of long-term soil stockpiles and waste rock emplacements.

In addition to the preventative measures outlined above, the BTM Complex Air Quality Management Strategy (Parsons Brinkerhoff, 2017) is used to proactively monitor and manage cumulative air quality impacts from the BTM Complex. Proactive, reactive or corrective measures are applied in response to issues identified by an integrated predictive system (forecast meteorology and modelling) and reactive system (real-time monitoring network).

8.1 Monitoring

The air quality monitoring network for the Tarrawonga Coal Mine is described in the most recent Air Quality and Greenhouse Gas Management Plan and consists of a meteorological monitoring station, 13 dust deposition gauges, a HVAS for compliance monitoring and real-time monitors used for air quality management purposes including two TEOMs and E-samplers. Additional monitoring sites are operated by other mining operations as part of the BTM Complex Air Quality Management Strategy (Parsons Brinkerhoff, 2017).

This existing monitoring network is considered suitable for ongoing operations associated with the Modification.

[19] http://www.whitehavencoal.com.au/sustainability/environmental-management/tarrawonga-mine/

9. CONCLUSION

The Modification proposes a reduction in the total ROM coal and waste rock quantities to be mined over the life of mine compared to the approved Tarrawonga Coal Mine.

Air quality impacts from the Modification were assessed using a Level 2 assessment approach in general accordance with the Approved Methods. Emissions inventories have been developed for two representative years of mining operations, selected to assess the air quality impacts of worst-case operations.

Dispersion modelling was used to predict GLCs for key pollutants from the Modification, at surrounding private and mine-owned receptors. Cumulative impacts were assessed, taking into account the combined effect of existing baseline air quality, other local sources of emissions, reasonably foreseeable future emissions and any indirect or induced effects.

The modelling results incorporate a level of conservatism through a number of conservative assumptions applied in the model input data and model settings, including:

- The dust emission estimates do not account for natural mitigation due to rainfall.
- The model does not incorporate wet deposition (removal of particles due to rainfall).
- The background adopted for assessment will include some contribution from existing mining operations, therefore there will be some double counting when modelled concentrations are added to background without adjustment.
- For cumulative assessment, maximum approved production rates are assumed for other mining operations.

Notwithstanding the conservative approach, the predicted Modification-only and cumulative annual average PM_{10}, $PM_{2.5}$ and TSP concentrations and dust deposition levels indicate that no private receptors would experience exceedances of the impact assessment criteria. Similarly, there are no private receptors where the Modification-only 24-hour average PM_{10} concentrations are greater than 50 $\mu g/m^3$ and no private receptors where the Modification-only and cumulative 24-hour average $PM_{2.5}$ concentrations are greater than 25 $\mu g/m^3$.

For the assessment of cumulative 24-hour average PM_{10} concentrations, modelling results are initially presented for existing mines plus background. The results show that without the contribution from the Tarrawonga Coal Mine (either approved operations or the proposed Modification), exceedances are predicted across all receptors from existing mines plus background. Furthermore, for many receptors, the maximum predicted cumulative 24-hour average concentration does not increase with the addition of the Modification.

The cumulative modelling (Modification plus existing mines plus background) shows that there are 14 receptors where no additional exceedances of the 24-hour average PM_{10} impact assessment criterion are predicted. There are seven receptors where the cumulative modelling (Modification plus existing mines plus background) results in one additional exceedance (i.e. days where the 24-hour PM_{10} criteria are exceeded) and four receptors where the cumulative modelling (Modification plus existing mines plus background) results in two additional exceedances. The BTM Complex Air Quality Management Strategy (Parsons Brinkerhoff, 2017) is specifically designed to prevent these short-term exceedances, by applying proactive, reactive or corrective measures across the BTM Complex when potential short-term exceedances are predicted or detected. There are no receivers (i.e. dwellings) or vacant land requiring acquisition or mitigation in accordance with the VLAMP Policy.

Annual average Scope 1 emissions represent approximately 0.05% of total GHG emissions for NSW and 0.01% of total GHG emissions for Australia, based on the National Greenhouse Gas Inventory for 2016. The Modification would result in a reduction of total GHG emissions compared to the approved Tarrawonga Coal Mine due to the reduction in total ROM coal and waste rock quantities over the life of the mine associated with the reduced open pit extent.

10. REFERENCES

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APPENDIX 1
MODEL SETTINGS

Table A1-1: TAPM settings	
Parameter	**Setting**
Model Version	TAPM v.4.0.5
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Number of grid points	25 x 25
Vertical grids / vertical extent	30 / 8000m (~400mb)
Centre of analysis	Lat -30.5, long 150.025 Easting 214817, Northing 6621751
Year of analysis	2017
Terrain and land use	Default TAPM values based on land-use and soils data sets from Geoscience Australia and the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC)
Assimilation sites	Maules Creek Coal Mine, Boggabri Coal Mine, Tarrawonga Coal Mine, Gunnedah BoM, Narrabri BoM

Table A1-2: CALMET settings	
Parameter	**Setting**
Grid domain	90 km x 100 km
Grid resolution	1 km
Number of grid points	90 x 100
Reference grid coordinate	170.000, 6570.000
Vertical grids / vertical extent	10 cell heights / 4,000m
Upper air meteorology	Prognostic 3D.dat extracted from TAPM at 3km grid
Surface observations	Maules Creek Coal Mine, Boggabri Coal Mine, Gunnedah BoM, Narrabri BoM (Tarrawonga Coal Mine used for model evaluation)

Table A1-3: CALMET model options

Flag	Description	Recommended setting	Value used
NOOBS	Meteorological data options	0,1,2	1 - combination of surface and prognostic data
ICLOUD	Cloud Data Options – Gridded Cloud Fields	4	4 -Gridded cloud cover from Prognostic relative humidity at all levels (MM5toGrads algorithm)
IEXTRP	Extrapolate surface wind observations to upper layers	-4	-4 - similarity theory used
IFRADJ	Compute Froude number adjustment effects	1	1 - applied
IKINE	Compute kinematic effects	0	0 - not computed
BIAS (NZ)	Relative weight given to vertically extrapolated surface observations vs. upper air data	NZ * 0	NZ * 0 - layers in lower levels of model will have stronger weighting towards surface, higher levels will have stronger weighting to upper air data
TERRAD	Radius of influence of terrain	No default (typically 5-15km)	5 km
RMAX1 and RMAX2	Maximum radius of influence over land for observations in layer 1 and aloft	No Default	10 km, 20km
R1 and R2	Distance from observations in layer 1 and aloft at which observations and Step 1 wind fields are weighted equally	No Default	R1 - 2 km, R2 – 10 km

Table A1-4: CALPUFF model options

Flag	Description	Value used	Description
MCHEM	Chemical Transformation	0	Not modelled
MDRY	Dry Deposition	1	Yes
MWET	Wet Deposition	0	Not modelled
MTRANS	Transitional plume rise allowed?	1	Yes
MTIP	Stack tip downwash?	1	Yes
MRISE	Method to compute plume rise	1	Briggs plume rise
MSHEAR	Vertical wind Shear	0	Vertical wind shear not modelled
MPARTL	Partial plume penetration of elevated inversion?	1	Yes
MSPLIT	Puff Splitting	0	No puff splitting
MSLUG	Near field modelled as slugs	0	Not used
MDISP	Dispersion Coefficients	2	Based on micrometeorology
MPDF	Probability density function used for dispersion under convective conditions	1	Yes
MROUGH	PG sigma y,z adjusted for z	0	No
MCTADJ	Terrain adjustment method	3	Partial Plume Adjustment
MBDW	Method for building downwash	1	ISC Method

APPENDIX 2
ASSESSMENT LOCATIONS

Table A2-1: Assessment locations

ID	Land Ownership	Location (m MGA, Zone 55)		Elevation (m AHD)
		Easting	Northing	
79a	KENNETH DAVID GILLHAM	222883.4	6602454.9	245
2c	BOGGABRI COAL PTY LIMITED	224284.5	6601780.9	251
303a	WHITEHAVEN COAL MINING LIMITED & BOGGABRI COAL PTY LIMITED	224469.1	6600620.8	248
1al	WHITEHAVEN COAL MINING PTY LIMITED	225481.0	6598912.3	249
1aj	WHITEHAVEN COAL MINING PTY LIMITED	228572.2	6598980.5	256
1q	WHITEHAVEN COAL MINING PTY LIMITED	229044.0	6603177.8	267
1ah	WHITEHAVEN COAL MINING PTY LIMITED	229097.1	6602015.9	266
1ai	WHITEHAVEN COAL MINING PTY LIMITED	230503.8	6601914.2	270
1ad	WHITEHAVEN COAL MINING PTY LIMITED	231215.5	6597109.7	260
1t	WHITEHAVEN COAL MINING PTY LIMITED	231546.6	6598183.5	261
1x	WHITEHAVEN COAL MINING PTY LIMITED	231783.6	6596438.6	269
1r	WHITEHAVEN COAL MINING PTY LIMITED	232693.3	6602343.7	278
1s	WHITEHAVEN COAL MINING PTY LIMITED	232841.2	6603631.2	283
1ae	WHITEHAVEN COAL MINING PTY LIMITED	232894.7	6596895.6	280
1ak	WHITEHAVEN COAL MINING PTY LIMITED	233317.8	6598233.8	304
2a	BOGGABRI COAL PTY LIMITED	216911.1	6603075.5	243
72	RICHARD WALTER KEMP EDWARD JOHN KEMP AS TENANTS IN COMMON IN EQUAL SHARES	216153.1	6602004.0	249
73	LEE WAYNE HUNT MARGARET DIANNE HUNT AS JOINT TENANTS	216800.0	6602035.7	256
30	MARILYN FRANCES HART IN 6/9 SHARE PENELOPE FRANCES RICE IN 1/9 SHARE TIMOTHY THOMPSON HART IN 1/9 SHARE SOPHIE LOUISE HART IN 1/9 SHARE AS TENANTS IN COMMON	217911.2	6601948.4	258
80	A D WATSON HOLDINGS PTY LTD	219252.7	6601018.9	243
303b	WHITEHAVEN COAL MINING LIMITED & BOGGABRI COAL PTY LIMITED	224507.3	6600300.3	247
78	JAMES MICHAEL MCKECHNIE NICOLE MARY MCKECHNIE AS JOINT TENANTS	219125.7	6600495.1	244
86	PETER J WATSON HOLDINGS PTY LTD	221297.4	6599229.8	249
87b	DAVID SINCLAIR RILEY	223342.1	6598974.2	249
118	ANDREW DAVID WATSON	221075.1	6598682.1	251
87a	DAVID SINCLAIR RILEY	222138.8	6597432.0	247
1f	WHITEHAVEN COAL MINING PTY LIMITED	229210.0	6597383.8	272

ID	Land Ownership	Location (m MGA, Zone 55)		Elevation (m AHD)
		Easting	Northing	
122	NANDEWAR PTY LIMITED	221722.0	6596320.7	249
1g	WHITEHAVEN COAL MINING PTY LIMITED	237902.4	6595556.6	302
79b	KENNETH DAVID GILLHAM	219041.0	6602977.5	242
70	DENNIS WILLIAM KEYS ANNE MARIE KEYS AS JOINT TENANTS	216407.0	6602931.6	245
1aa	WHITEHAVEN COAL MINING PTY LIMITED	233860.8	6598698.8	286
1ab	WHITEHAVEN COAL MINING PTY LIMITED	234446.8	6598460.8	291
1ac	WHITEHAVEN COAL MINING PTY LIMITED	234948.4	6599351.9	271
13f	ESTATE: PERPETUAL LEASE ASTON COAL 2 PTY LTD IDEMITSU BOGGABRI COAL PTY LIMITED AS TENANTS IN COMMON IN EQUAL SHARES	216450.0	6604160.0	256
2b	BOGGABRI COAL PTY LIMITED	214795.0	6602850.0	270
337	PAUL JAMES BELL	215595.0	6602145.0	255
13e	ASTON COAL 2 PTY LTD	216140.0	6600745.0	255
2k	BOGGABRI COAL PTY LIMITED	217213.7	6606728.4	239
2j	BOGGABRI COAL PTY LIMITED	217461.7	6607174.9	241
1as	WHITEHAVEN COAL MINING PTY LIMITED	219798.2	6606061.2	246
2l	BOGGABRI COAL PTY LIMITED	215720.8	6605518.6	243
39	DAVID VICTOR GILLHAM	219480.9	6604997.1	243
1at	WHITEHAVEN COAL MINING PTY LIMITED	220037.6	6603915.5	240
37	RICHARD JOHN BROWNING ELAINE JOY BROWNING AS TENANTS IN COMMON IN EQUAL SHARES	217952.4	6604864.4	261
2i	BOGGABRI COAL PTY LIMITED	215853.6	6607463.8	237
516	PETER JOHN WATSON GEORGIA PARKIN AS JOINT TENANTS	216292.8	6611163.3	318
13c	ASTON COAL 2 PTY LIMITED & BOGGABRI COAL PTY LIMITED & ICRA MC PTY LIMITED & J-POWER AUSTRALIA PTY LIMITED	219019.5	6607512.2	345
2f	BOGGABRI COAL PTY LIMITED	223331.1	6606527.2	304
1ar	WHITEHAVEN COAL MINING PTY LIMITED	226671.6	6603754.2	259
2e	BOGGABRI COAL PTY LIMITED	224463.5	6607818.8	236
2h	BOGGABRI COAL PTY LIMITED	217385.6	6608067.8	425
13b		217106.0	6612530.4	287
2d	BOGGABRI COAL PTY LIMITED	224370.0	6604350.9	249
1ap	WHITEHAVEN COAL MINING PTY LIMITED	231906.5	6605660.7	247
2n	BOGGABRI COAL PTY LIMITED	233520.5	6611771.0	318

ID	Land Ownership	Location (m MGA, Zone 55)		Elevation (m AHD)
		Easting	Northing	
54	PETER ANDREW DEVINE	237514.1	6610780.8	345
1am	WHITEHAVEN COAL MINING PTY LIMITED	232069.4	6609299.3	304
2m	BOGGABRI COAL PTY LIMITED	234081.0	6613345.4	326
1ao	WHITEHAVEN COAL MINING PTY LIMITED	230898.7	6605873.6	298
13a	ESTATE: PERPETUAL LEASE MICHAEL JOHN NOTT MAREE LOUISE NOTT AS JOINT TENANTS	219177.7	6613017.2	341
519	RIVERWAY BOGGABRI PTY LTD	216220.2	6613128.3	277
22b	CHRISTOPHER DONALD BALDWIN CAROLYN ANNE BALDWIN AS JOINT TENANTS	237526.0	6613782.5	259
22a	CHRISTOPHER DONALD BALDWIN CAROLYN ANNE BALDWIN AS JOINT TENANTS	237463.5	6613803.7	236
1aq	WHITEHAVEN COAL MINING PTY LIMITED	234735.7	6603666.9	425
314a	GLOBAL AG PROPERTIES AUSTRALIA PTY LTD	216884.7	6595028.5	424
314b	GLOBAL AG PROPERTIES AUSTRALIA PTY LTD	218109.5	6594937.2	287
1an	WHITEHAVEN COAL MINING PTY LIMITED	231116.2	6606204.7	287
573a	MHPF BELLEVUE LAND PTY LTD	235725.6	6608475.0	249
573b	MHPF BELLEVUE LAND PTY LTD	235880.4	6605843.1	247

Note: m AHD = metres Australian Height Datum; MGA = Map Grid of Australia

APPENDIX 3
WIND ROSES

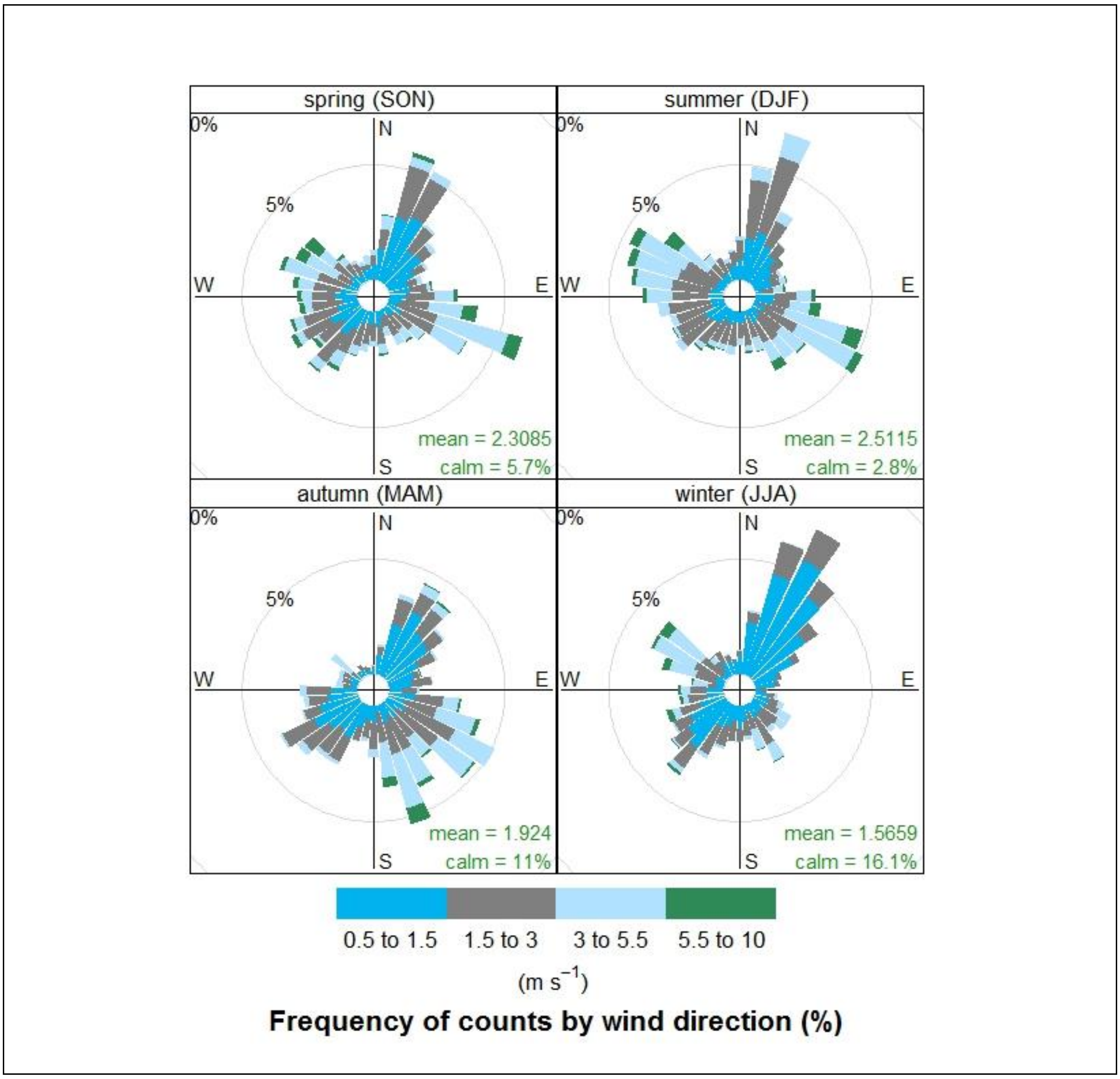

Figure A3-1: Tarrawonga Coal Mine seasonal wind roses for 2017

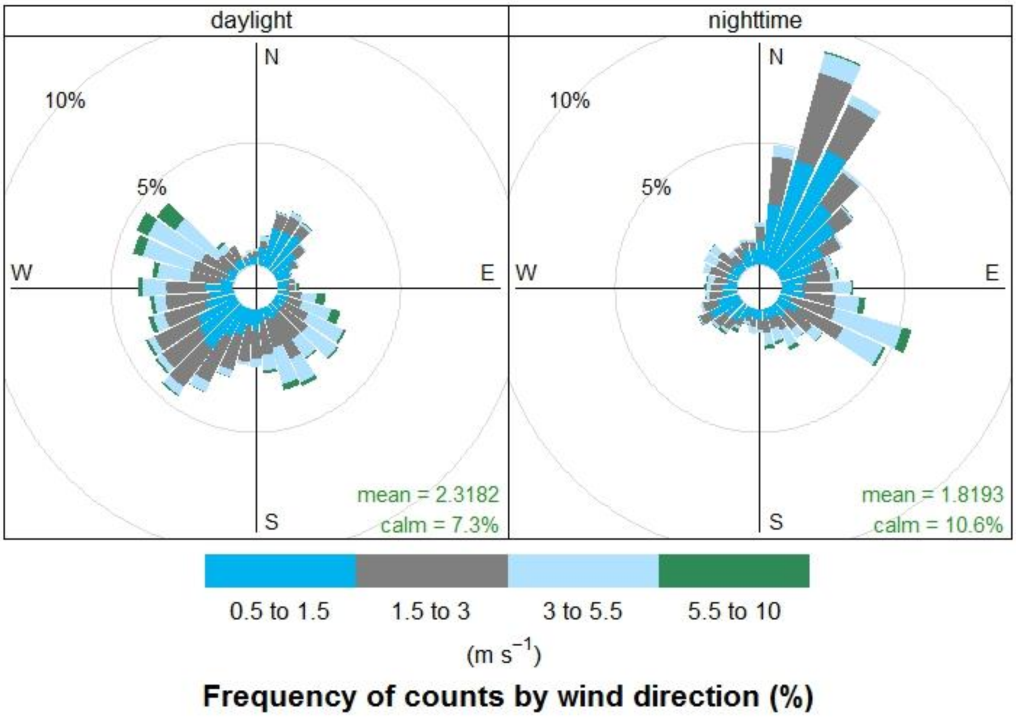

Figure A3-2: Tarrawonga Coal Mine diurnal wind roses for 2017

APPENDIX 4
EMISSIONS INVENTORY DEVELOPMENT

Overview

Dust emissions were estimated using US EPA AP-42 emission factors and predictive equations taken from the following chapters:

- Chapter 11.9 Western Surface Coal Mining.
- Chapter 13.2.2 Unpaved Roads.
- Chapter 13.2.4 Aggregate Handling and Storage Piles.
- Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing.
- Chapter 13.2.5 Industrial Wind Erosion.

The material properties listed in **Table A4-1** are used as input to the various emission factor equations listed in **Table A4-2** to derive site-specific uncontrolled emission factors for each source. The selection of the material property inputs (described in **Table A4-1**) aims to strike a balance between being conservative and using site-specific values where available, appropriate and robust.

Table A4-1: Material properties

Properties	Value	Source of information
Silt content of unpaved roads	4%	Average of all measurements for controlled and uncontrolled haul roads at the Tarrawonga Coal Mine, measured as part of Australian Coal Association Research Project C22027 (Roddis et al., 2015). Previous modelling used a default EF, therefore no silt content was reported.
Silt content of overburden	10%	Value used in previous modelling (PAEHolmes, 2012b), selected as the more conservative value than site-specific measurements (4.4% average).
Silt content of ROM coal	4.1%	Average of all measurements for ROM coal at the Tarrawonga Coal Mine, measured as part of ACARP project C22027 (Roddis et al., 2015). Previous modelling used a value of 10%, however this is not based on any measurements.
Moisture content of overburden	2.5%	Value used in previous modelling (PAEHolmes, 2012b), selected as the more conservative value than site-specific measurements (5% average).
Moisture content of ROM coal	5.5%	Average of all measurements for ROM coal at the Tarrawonga Coal Mine, measured as part of ACARP project C22027 (Roddis et al., 2015) and value used in previous modelling (PAEHolmes, 2012b).

Emissions were quantified for each particle size fraction, with the TSP size fraction also used to predict dust deposition rates. Fine particles (PM_{10} and $PM_{2.5}$) were estimated using the fraction-specific equations or ratios for the different particle size fractions available within the literature (shown in **Table A4-2**).

Table A4-2: Equations and emission factors

Inventory activity	Units	TSP emission factor/equation	PM_{10} emission factor/equation	$PM_{2.5}$ emission factor/equation	EF source
Material handling (loading trucks OB, unloading trucks [coal and OB], rehandle, conveyor transfer, loading trains)	kg/t	$0.74 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.35 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	$0.053 \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\right)$	AP42 13.2.4
Material handling (loading trucks with coal)	kg/t	$\frac{0.58}{M^{1.2}}$	$\frac{0.75 * 0.0596}{M^{0.9}}$	0.019 x TSP	AP42 11.9
Dozers on coal	kg/hr	$35.6 \times \frac{s^{1.2}}{M^{1.3}}$	$6.33 \times \frac{s^{1.5}}{M^{1.4}}$	0.022 x TSP	AP42 11.9
Dozers on OB	kg/hr	$2.6 \times \frac{s^{1.2}}{M^{1.3}}$	$0.3375 \times \frac{s^{1.5}}{M^{1.4}}$	0.105 x TSP	AP42 11.9
Wind erosion from exposed ground	kg/ha/yr	0.85×1000	0.5 * TSP	0.075 * TSP	AP42 11.9 & 13.2.5
Wind erosion and maintenance of stockpiles and ROM stockpiles	kg/ha/hr	1.8 * u	0.5 * TSP	0.075 * TSP	AP42 11.9 & 13.2.5
Hauling on unsealed roads (including diesel exhaust)	kg/VKT	$\left(\frac{0.4536}{1.6093}\right) \times 4.9 * \left(\frac{s}{12}\right)^{0.7} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$\left(\frac{0.4536}{1.6093}\right) \times 1.5 * \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	$\left(\frac{0.4536}{1.6093}\right) \times 0.15 * \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$	AP42 13.2.2
Grading roads	kg/VKT	$0.0034 \times S^{2.5}$	$0.00336 \times S^{2.0}$	$0.0001054 \times S^{2.5}$	AP42 11.9
Crushing coal (controlled)	kg/t	0.0006	0.00027	0.00005	AP42 11.19.2
Screening coal (controlled)	kg/t	0.0011	0.00037	0.00003	AP42 11.19.2
Soil stripping	kg/t	0.029	TSP x 0.5	TSP x 0.105	AP42 11.9

Note: OB = Overburden; VKT = vehicle kilometre travelled; U/u = wind speed (m/s); M = moisture content (%); s = silt content (%); W = vehicle weight (t); S = speed (km/hr); ha = hectares; kg/t = kilograms per tonne; kg/VKT = kilograms per vehicle kilometre travelled; kg/ha/yr = kilograms per hectare per year; kg/ha/hr = kilograms per hectare per hour; kg/hr = kilograms per hour.

BMP determination

In June 2011 the NSW EPA published the best practice document 'NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining' (Katestone, 2011). Following on from the Benchmarking Study, the EPA developed a series of pollution reduction programmes (PRPs) for coal mines, - referred to as the "Dust Stop" PRPs and issued guidelines for Best Management Practice (BMP) determinations for operating coal mines. Each operating coal mine in NSW had to identify the top four mining activities that contribute to the emissions of TSP, PM_{10} and $PM_{2.5}$. For each of the top four activities, a BMP determination was required, taking into account the practicability of implementation, costs, regulatory requirements, environmental impacts, safety implications and compatibility with operations.

An overview of the BMP determination for the Modification and the emission reductions applied, is presented in **Table A4-3**. Control measures are applied to the most significant emissions sources for the Modification, consistent with best practice emissions controls (Katestone, 2011). Other control measures, while not explicitly applied as a reduction factor, are accounted for in the emission inventory on the basis of the mine plan, including:

- Direct placement of overburden where possible, reducing the double handling of material, potential for wind erosion and haulage distances.
- Site-wide vehicle speed limits.
- Progressive rehabilitation of disturbed areas.
- Minimising the double handling of material, wherever practicable (i.e. direct dump to ROM hopper).
- Avoiding disturbance, or temporary rehabilitation of long-term soil stockpiles and waste rock emplacements.
- Proactive, reactive or corrective measures where watering is not sufficient (for example, as determined through monitoring and/or visual inspection), certain activities may be ceased or relocated to more sheltered areas.

Whitehaven reserves the right to achieve BMP through alternative methods so as to allow for technological advances and economic comparative analysis of options.

Table A4-3: BMP determination and emission controls

Activity	BMP	Applied ?	Control %	Comment
Hauling	Speed reduction	Yes	N/A	Speed restrictions would apply, however controls are not applied in the emission inventory.
	Surface improvements	No	N/A	Haul roads will be actively maintained and watered, however specific surface improvements outlined in Katestone (2011) are not proposed for the Modification.
	Surface treatments	Yes	90%	90% control is assumed for watering, with no additional surface treatments planned. ACARP project C20023 (Cox & Laing, 2014) demonstrated that watering alone can achieve 85% to 95% control efficiency for unsealed roads. Tarrawonga Coal Mine, operated by Whitehaven, was one of the sites included in the study and recorded an average control efficiency of 91%.
	Use of larger trucks	Yes	N/A	Use of larger trucks for waste hauling (assists to reduce wheel-generated emissions).
	Conveyors	No	N/A	Use of conveyors to move ROM coal from the open cut to the CHPP is not proposed for the Modification.
Wind erosion on exposed areas	Minimise pre-strip	Yes	N/A	Incorporated into mine planning, however controls are not applied in the emission inventory.
	Surface stabilisation	Yes	65% - 95%	Controls are applied in the emissions inventory for active rehabilitation areas and soil stockpiles (65%). Controls are based on ACARP project C22027 (Roddis et al., 2015).
	Wind speed reduction	Yes	N/A	Achieved through emplacement within the footprint of the open cut void where possible and vegetative cover for rehabilitation areas.
OB handling	Avoidance	Yes	N/A	Achieved through emplacement within the footprint of the open cut void where possible.
	Minimising drop heights	Yes	N/A	Would apply for the Modification and implemented through driver training, however controls are not applied in the emissions inventory.
	Water application	No	N/A	Water application across the large areas of waste rock emplacement is not proposed for the Modification.
	Modify activities in windy conditions	Yes	N/A	Would apply for the Modification and implemented through the Air Quality Management Plan and BTM Complex Air Quality Management Strategy, however controls are not applied in the emission inventory.
	Minimise dozer	Yes	N/A	Operational efficiency implemented through mine planning and operator training.

Activity	BMP	Applied ?	Control %	Comment
	travel movements			
	Keep dozer travel routes moist	No	N/A	Not proposed for the Modification.
Coal handling	Avoidance	Yes	N/A	Achieved through bypassing the ROM pad where possible and direct dump to hopper.
	Minimising drop heights	Yes	30%	Would apply for the Modification and implemented through driver training.
	Enclosure of dump hopper	Yes	40%	Controls applied for wind shielding
	Water application	Yes	50%	Watering controls applied for transfer or coal to bin.
	Dust extraction	No	N/A	Not proposed for the Modification.
Coal Stockpiles	Water sprays	Yes	50%	Water sprays on coal stockpiles.
Coal processing	Wet suppression	Yes	50%	Controls applied for watering
	Wind shielding	Yes	N/A	Relocated ROM stockpile would consider shielding for crusher, however controls not applied for the emission inventory.

Hourly varying emissions

Emission sources can be categorised as wind-insensitive sources (where the emission rate is independent of the wind speed), wind-sensitive sources (where there is a relationship between the emission rate and wind speed) and wind erosion sources (where the emission is dependent on the wind speed).

Hourly emissions files for modelling are developed from the annual emissions as follows:

- The annual emissions for wind-insensitive sources are evenly apportioned for each hour of the year (no adjustment applied).
- Hourly varying emissions for wind erosion sources are derived using equation 1, adjusted according to the cube of the hourly average wind speed and normalised so that the total emission over all hours in the year adds up to the estimated annual total emission.
- The emissions for wind-sensitive sources are converted to hourly emissions in a similar manner, however the wind speed adjustment is made based on equation 2.

Equation 1 (Skidmore, 1998)

$$E_i = E_{annual} \times \frac{U_i^3}{\sum_{i=1}^{N} U_i^3}$$

Equation 2 (US EPA, 1987)

$$E_i = E_{annual} \times \frac{\left(\frac{U_i}{2.2}\right)^{1.3}}{\sum_{i=1}^{N} \left(\frac{U}{2.2}\right)^{1.3}}$$

Where: $E_i = emissions\ for\ hour\ i$

$E_{annual} = annual\ emissions$

$U_i = wind\ speed\ for\ each\ hour\ i$

$N = number\ of\ hours\ of\ wind\ speed$

APPENDIX 5
MODELLING RESULTS FOR NON-PRIVATE RECEPTORS

Table 5-1: Predicted Modification-only and cumulative annual average PM_{10} and $PM_{2.5}$ concentration concentrations (µg/m³) at mine-owned receptors

ID	Modification-only				Cumulative			
	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
2c	3.1	3.1	0.6	0.6	22.0	21.9	5.5	5.5
303a	2.6	2.6	0.5	0.5	20.7	20.7	5.3	5.3
1al	2.1	2.1	0.4	0.4	19.9	19.9	5.2	5.3
1aj	2.2	2.2	0.4	0.4	19.4	19.5	5.2	5.2
1q	6.5	7.1	1.2	1.4	23.0	23.6	5.7	5.9
1ah	5.4	5.7	0.9	1.1	21.1	21.4	5.3	5.4
1ai	3.0	3.2	0.6	0.6	18.2	18.4	4.9	5.0
1ad	1.1	1.1	0.2	0.2	18.2	18.1	5.0	5.0
1t	0.8	0.8	0.2	0.2	20.2	20.1	5.4	5.4
1x	5.8	6.2	1.1	1.2	21.5	21.9	5.5	5.6
1r	2.8	2.9	0.5	0.6	17.7	17.8	4.8	4.9
1s	0.8	0.7	0.2	0.2	17.3	17.2	4.8	4.8
1ae	1.0	0.9	0.2	0.2	16.7	16.6	4.7	4.7
1ak	0.6	0.6	0.1	0.1	15.2	15.2	4.4	4.4
2a	0.8	0.7	0.2	0.2	16.5	16.4	4.5	4.5
303b	2.5	2.5	0.5	0.5	20.4	20.4	5.3	5.3
1f	2.2	2.1	0.4	0.4	22.9	22.8	5.8	5.8
1g	0.3	0.3	0.1	0.1	14.0	13.9	4.2	4.2
1aa	0.4	0.3	0.1	0.1	14.8	14.8	4.3	4.3
1ab	1.3	1.4	0.3	0.3	15.2	15.3	4.4	4.4
1ac	0.8	0.8	0.2	0.2	15.5	15.5	4.2	4.2
13f	0.9	0.7	0.2	0.2	17.0	16.9	4.6	4.6
2b	0.6	0.5	0.1	0.1	15.8	15.7	4.4	4.4
13e	0.7	0.5	0.1	0.1	15.6	15.5	4.4	4.4
2k	1.0	0.9	0.2	0.2	17.7	17.7	4.7	4.7
2j	1.1	1.0	0.2	0.2	18.1	18.1	4.8	4.8
2l	0.8	0.6	0.1	0.1	16.6	16.5	4.5	4.5
2i	0.8	0.7	0.2	0.2	16.8	16.8	4.6	4.6
13c	1.5	1.4	0.3	0.3	19.8	19.8	5.0	5.1
2f	3.5	3.5	0.7	0.8	28.8	28.7	6.4	6.4
1ar	8.3	8.5	1.5	1.7	27.8	28.0	6.4	6.6

ID	Modification-only				Cumulative			
	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
1as	1.5	1.4	0.3	0.3	20.0	19.9	5.1	5.1
1at	1.4	1.3	0.3	0.3	19.3	19.1	5.0	4.9
2e	5.1	4.9	1.0	1.0	39.8	39.4	7.9	7.9
2h	1.2	1.1	0.2	0.2	18.4	18.4	4.8	4.8
13b	0.8	0.7	0.2	0.2	17.6	17.9	4.7	4.8
2d	3.7	3.8	0.7	0.8	25.1	25.0	5.8	5.9
1ap	1.9	2.2	0.4	0.5	17.7	18.1	4.8	4.9
2n	0.9	0.9	0.2	0.2	16.3	16.2	4.3	4.3
1am	2.3	2.3	0.4	0.5	16.9	17.0	4.7	4.7
2m	0.9	0.8	0.2	0.2	15.9	15.8	4.3	4.3
1ao	12.5	13.8	2.2	2.7	29.4	30.7	6.8	7.2
13a	0.9	0.8	0.2	0.2	20.7	21.2	5.2	5.3
1aq	1.3	1.4	0.3	0.3	15.2	15.3	4.4	4.4
1an	1.0	1.0	0.2	0.2	20.3	20.2	5.4	5.4

Table A5-2: Predicted Modification-only and cumulative maximum 24-hour average PM_{10} concentration (µg/m³) at mine-owned receptors – Year 3

ID	Modification only	Background and existing mines		Cumulative	
	Concentration (µg/m³)	Concentration (µg/m³)	Days over	Concentration (µg/m³)	Additional days over
2c	15.2	56.6	5	61.4	2
303a	13.8	53.0	3	57.5	0
1al	16.0	53.9	2	55.7	2
1aj	17.4	60.0	2	60.8	4
1q	62.7	87.3	7	101.7	22
1ah	41.9	77.9	5	83.7	13
1ai	40.0	85.7	5	96.3	12
1ad	16.6	69.5	1	78.7	4
1t	12.5	66.6	1	74.4	4
1x	93.7	91.3	4	132.4	24
1r	52.9	86.3	3	102.0	9
1s	10.9	70.4	1	81.3	2

ID	Modification only	Background and existing mines		Cumulative	
	Concentration ($\mu g/m^3$)	Concentration ($\mu g/m^3$)	Days over	Concentration ($\mu g/m^3$)	Additional days over
1ae	16.5	77.1	3	93.5	0
1ak	13.2	60.9	1	60.9	0
2a	11.3	50.9	1	52.1	1
303b	14.5	52.9	2	56.4	1
1f	15.2	62.2	2	64.4	6
1g	4.7	62.4	1	65.7	0
1aa	9.1	57.2	2	57.2	0
1ab	23.0	70.3	1	75.0	0
1ac	13.5	70.2	1	78.8	0
13f	13.8	51.2	2	54.4	0
2b	9.9	50.9	1	50.9	1
13e	4.6	50.9	1	50.9	0
2k	10.0	56.2	3	58.1	0
2j	8.6	57.2	3	58.9	0
2l	8.2	52.4	2	54.6	0
2i	7.2	54.3	2	55.8	1
13c	9.8	59.5	3	61.3	0
2f	20.7	105.7	19	105.7	11
1ar	45.3	83.6	14	85.8	26
1as	13.7	61.1	3	63.8	0
1at	19.7	53.0	2	58.3	1
2e	29.4	172.0	81	172.0	27
2h	8.3	57.1	3	58.6	0
13b	4.2	55.3	2	57.6	0
2d	20.1	92.8	14	95.7	1
1ap	30.8	69.7	3	71.8	7
2n	14.6	75.1	1	89.7	2
1am	35.1	85.3	3	112.7	5
2m	12.1	73.7	1	85.7	2
1ao	146.7	107.7	6	203.2	53
13a	5.9	59.6	6	61.3	0
1aq	23.0	70.3	1	75.0	0

ID	Modification only	Background and existing mines		Cumulative	
	Concentration (µg/m³)	Concentration (µg/m³)	Days over	Concentration (µg/m³)	Additional days over
1an	13.6	65.8	1	72.7	2

Table A5-3: Predicted Modification-only and cumulative maximum 24-hour average PM_{10} concentration (µg/m³) at mine-owned receptors – Year 7

ID	Modification only	Background and existing mines		Cumulative	
	Concentration (µg/m³)	Concentration (µg/m³)	Days over	Concentration (µg/m³)	Additional days over
2c	16.1	55.9	5	59.9	1
303a	14.7	52.5	2	55.8	1
1al	14.8	53.4	2	55.2	2
1aj	21.7	60.0	2	60.7	5
1q	76.0	87.3	7	111.4	26
1ah	54.3	77.9	5	90.3	15
1ai	44.5	85.4	5	95.7	13
1ad	16.6	69.3	1	78.0	4
1t	11.9	66.4	1	73.3	2
1x	98.0	90.5	4	145.3	26
1r	53.2	85.6	3	104.6	9
1s	10.7	69.9	1	79.7	2
1ae	14.4	76.2	3	90.6	0
1ak	18.0	63.1	1	63.1	0
2a	9.6	51.0	1	51.0	1
303b	15.7	52.4	2	55.4	1
1f	17.3	62.1	1	63.9	6
1g	4.0	61.8	1	64.9	0
1aa	9.2	60.7	2	60.7	0
1ab	24.7	69.7	1	74.1	1
1ac	14.0	69.6	1	78.9	2
13f	11.2	51.0	2	53.0	0
2b	8.4	50.9	1	50.9	0

ID	Modification only	Background and existing mines		Cumulative	
	Concentration (µg/m³)	Concentration (µg/m³)	Days over	Concentration (µg/m³)	Additional days over
13e	4.4	50.9	1	50.9	0
2k	5.5	55.0	3	56.7	0
2j	6.5	55.9	3	57.5	0
2l	5.8	51.4	2	53.1	0
2i	4.8	53.5	2	54.7	1
13c	8.2	58.4	3	60.2	0
2f	21.8	101.3	18	101.3	12
1ar	48.0	83.0	14	84.4	30
1as	11.4	60.7	2	63.2	1
1at	16.7	52.9	2	57.1	1
2e	32.4	169.0	79	169.0	33
2h	7.0	55.9	3	57.3	0
13b	5.4	55.1	3	57.5	0
2d	21.0	92.4	12	94.0	2
1ap	37.2	69.4	2	77.0	8
2n	14.3	74.4	1	88.7	2
1am	34.9	84.6	3	118.1	4
2m	11.8	72.9	1	84.7	2
1ao	140.3	107.1	6	247.4	52
13a	5.8	59.4	5	61.0	1
1aq	24.7	69.7	1	74.1	1
1an	13.1	65.6	1	71.9	2

Table A5-4: Predicted Modification-only and cumulative maximum 24-hour average $PM_{2.5}$ concentration (µg/m³) at mine-owned receptors

ID	Modification only		Cumulative	
	Year 3	Year 7	Year 3	Year 7
2c	2.9	3.4	13.1	13.0
303a	2.7	3.1	13.0	12.9
1al	2.8	3.0	12.6	12.5
1aj	3.3	4.5	14.2	14.5
1q	11.3	14.8	20.1	22.6

ID	Modification only		Cumulative	
	Year 3	Year 7	Year 3	Year 7
1ah	7.6	10.7	18.5	19.7
1ai	7.1	9.2	18.3	19.9
1ad	3.1	3.3	13.3	13.4
1t	2.3	2.4	12.6	12.7
1x	18.4	19.3	24.9	27.5
1r	9.9	10.8	18.1	19.0
1s	2.1	2.2	13.8	13.7
1ae	3.2	3.1	15.8	15.6
1ak	2.6	3.4	15.1	14.7
2a	2.0	1.8	14.8	14.7
303b	2.6	3.0	12.9	12.8
1f	2.8	3.5	14.1	14.3
1g	1.1	1.0	12.4	12.4
1aa	1.8	1.8	14.5	14.6
1ab	4.6	5.6	15.1	15.6
1ac	2.4	2.7	13.3	13.5
13f	2.5	2.2	14.7	14.5
2b	1.8	1.6	14.4	14.3
13e	0.9	1.0	15.0	14.8
2k	1.7	1.0	14.8	14.9
2j	1.5	1.2	14.9	15.0
2l	1.5	1.2	14.5	14.6
2i	1.3	1.0	14.3	14.6
13c	1.8	1.7	15.3	15.1
2f	3.7	4.7	18.3	18.0
1ar	8.1	9.2	16.0	16.6
1as	2.3	2.1	15.7	15.3
1at	3.4	3.1	16.3	16.0
2e	5.5	6.3	26.0	25.5
2h	1.5	1.3	14.8	15.1
13b	0.9	1.2	14.6	14.6
2d	3.8	4.1	17.9	17.5
1ap	5.7	7.3	16.7	17.6

ID	Modification only		Cumulative	
	Year 3	**Year 7**	**Year 3**	**Year 7**
2n	2.8	3.0	15.2	15.3
1am	6.3	6.7	18.9	20.4
2m	2.3	2.5	14.5	14.5
1ao	25.5	27.6	36.3	42.4
13a	1.2	1.3	15.1	15.0
1aq	4.6	5.6	15.1	15.6
1an	2.5	2.6	12.8	13.0

Table A5-5: Predicted Modification-only and cumulative TSP (µg/m³) and dust deposition (g/m²/month) at mine-owned receptors

ID	Modification-only				Cumulative			
	TSP (µg/m³)		Depos (g/m²/m)		TSP (µg/m³)		Depos (g/m²/m)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
2c	5.4	4.6	0.11	0.10	40.2	39.5	2.5	2.4
303a	4.5	3.9	0.09	0.08	38.5	37.9	2.5	2.4
1al	3.6	3.1	0.07	0.06	38.1	37.6	2.6	2.6
1aj	4.0	3.7	0.08	0.08	37.6	37.3	2.5	2.5
1q	11.8	11.9	0.23	0.25	42.3	42.4	2.4	2.5
1ah	12.3	12.1	0.32	0.33	41.8	41.6	2.5	2.5
1ai	5.3	5.3	0.10	0.10	34.1	34.0	2.3	2.3
1ad	1.8	1.5	0.03	0.02	35.5	35.3	2.5	2.5
1t	1.4	1.1	0.02	0.02	40.4	40.1	2.7	2.7
1x	9.8	10.2	0.23	0.26	39.3	39.6	2.4	2.5
1r	4.3	4.2	0.09	0.08	32.7	32.5	2.3	2.3
1s	1.3	1.0	0.02	0.01	34.4	34.1	2.5	2.4
1ae	1.7	1.2	0.03	0.02	32.7	32.2	2.3	2.3
1ak	0.9	0.8	0.02	0.02	28.8	28.7	2.2	2.2
2a	1.4	1.0	0.03	0.02	30.9	30.5	2.2	2.2
303b	4.3	3.7	0.09	0.07	38.1	37.6	2.5	2.5
1f	5.0	4.6	0.12	0.11	47.0	46.6	2.9	2.9
1g	0.5	0.4	0.02	0.01	28.0	27.8	2.2	2.2
1aa	0.6	0.5	0.01	0.01	28.1	28.0	2.2	2.2
1ab	2.0	1.8	0.04	0.03	29.0	28.8	2.2	2.2
1ac	1.3	1.1	0.03	0.02	30.2	29.9	2.3	2.2
13f	1.5	1.0	0.03	0.02	31.5	31.0	2.2	2.2
2b	1.1	0.7	0.03	0.02	29.8	29.3	2.2	2.2
13e	1.2	0.8	0.02	0.01	29.7	29.3	2.2	2.2
2k	1.6	1.2	0.03	0.02	32.5	32.1	2.2	2.2
2j	1.8	1.3	0.04	0.03	33.0	32.6	2.2	2.2
2l	1.3	0.9	0.03	0.02	30.9	30.4	2.2	2.2
2i	1.4	1.0	0.04	0.02	31.1	30.7	2.2	2.2
13c	2.3	2.0	0.04	0.03	35.4	35.0	2.3	2.3
2f	5.5	5.1	0.09	0.09	49.9	49.4	2.5	2.5
1ar	14.7	13.9	0.28	0.28	49.8	49.0	2.5	2.5

ID	Modification-only				Cumulative			
	TSP (µg/m³)		Depos (g/m²/m)		TSP (µg/m³)		Depos (g/m²/m)	
	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7	Year 3	Year 7
1as	2.4	1.9	0.04	0.03	35.9	35.4	2.3	2.3
1at	2.4	1.8	0.04	0.03	35.2	34.6	2.3	2.2
2e	8.2	7.2	0.15	0.13	68.3	67.3	2.9	2.9
2h	1.9	1.5	0.04	0.03	33.3	32.9	2.3	2.2
13b	1.1	0.9	0.03	0.02	31.8	31.6	2.3	2.3
2d	6.3	5.6	0.10	0.09	44.7	44.1	2.4	2.4
1ap	2.9	3.3	0.08	0.08	32.4	32.8	2.3	2.3
2n	1.6	1.2	0.03	0.02	31.7	31.3	2.3	2.3
1am	3.6	3.3	0.07	0.06	31.6	31.3	2.2	2.2
2m	1.4	1.0	0.03	0.02	31.0	30.6	2.3	2.3
1ao	25.0	27.2	0.68	0.81	56.1	58.3	2.9	3.1
13a	1.3	1.0	0.04	0.03	35.6	35.3	2.4	2.4
1aq	2.0	1.8	0.04	0.03	29.0	28.8	2.2	2.2
1an	1.6	1.3	0.03	0.02	40.7	40.4	2.7	2.7

APPENDIX 6
CONTOUR PLOTS

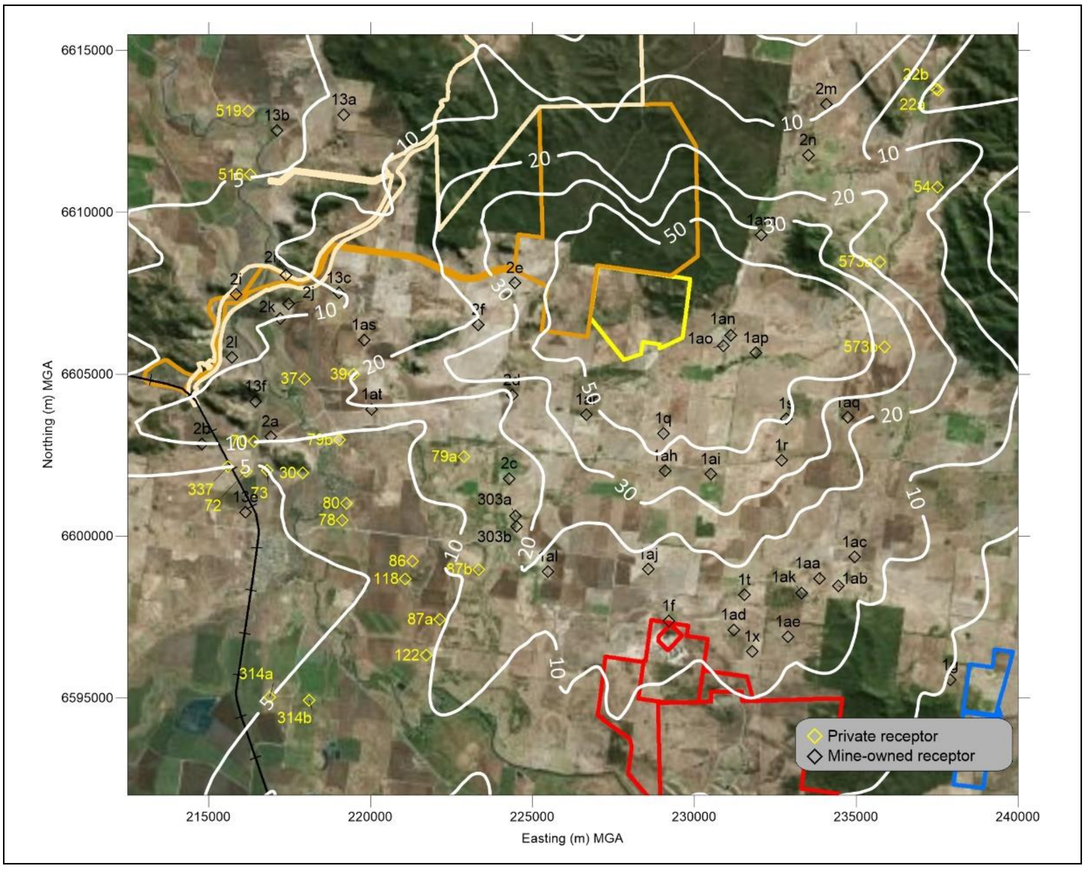

Figure A6-1: Modification-only 24-hour average PM_{10} concentration ($\mu g/m^3$) contours – Year 3

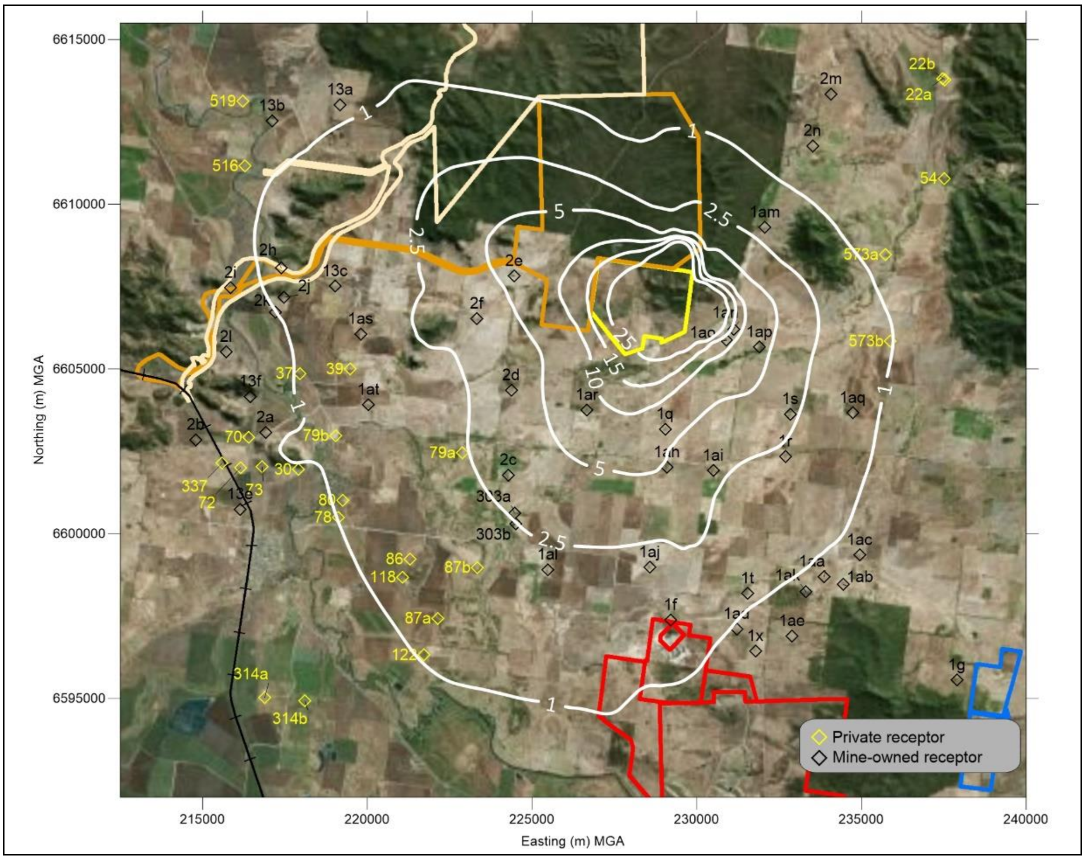

Figure A6-2: Modification-only annual average PM_{10} concentration ($\mu g/m^3$) contours – Year 3

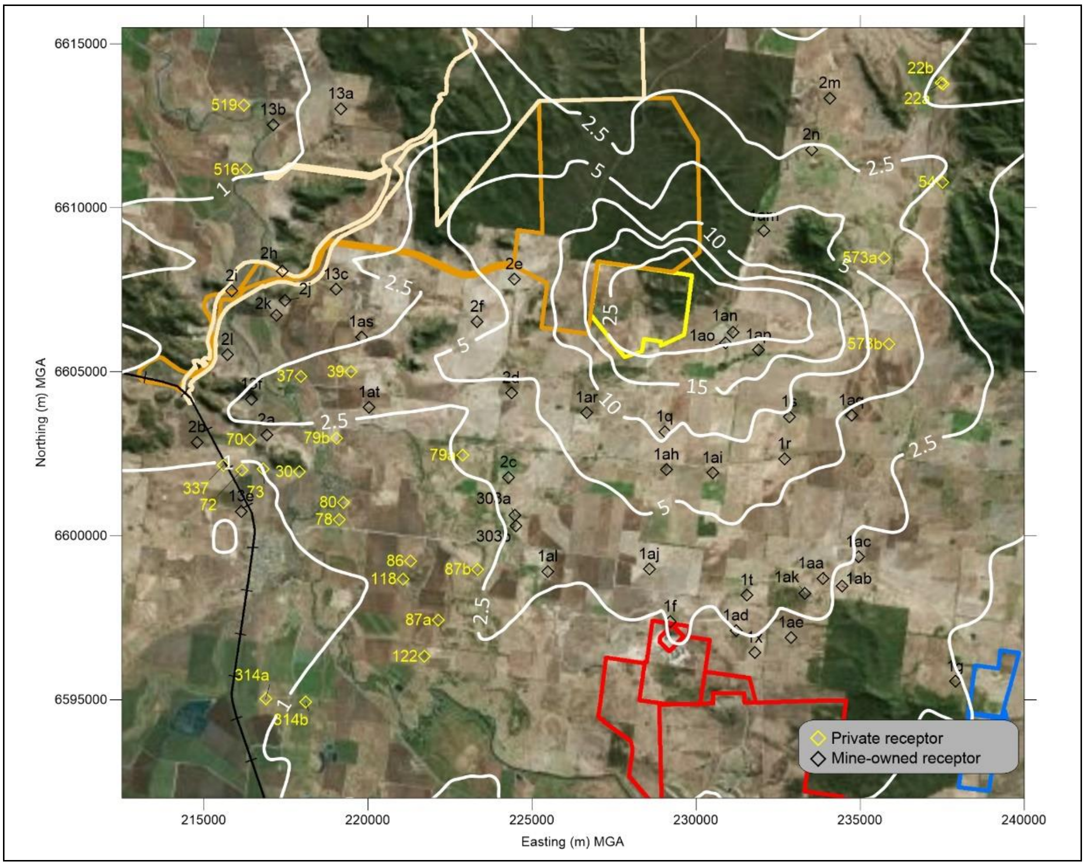

Figure A6-3: Modification-only 24-hour average $PM_{2.5}$ concentration ($\mu g/m^3$) contours – Year 3

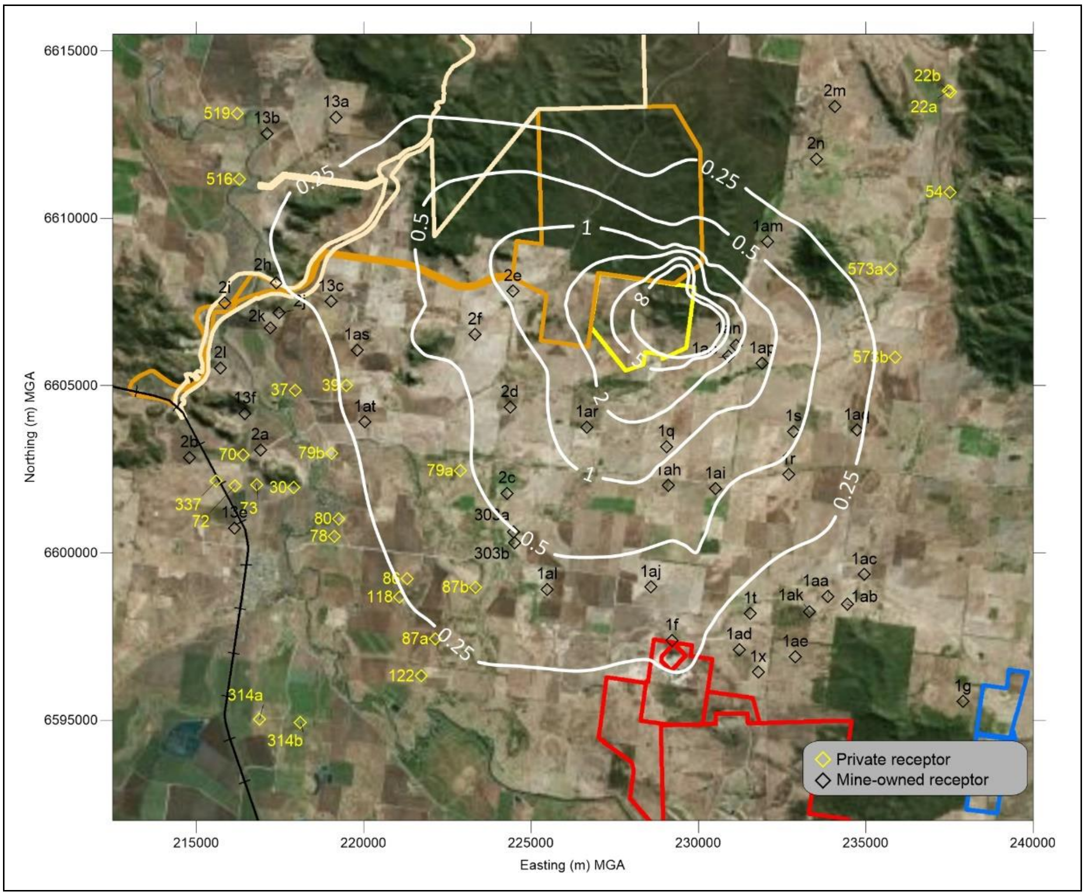

Figure A6-4: Modification-only annual average $PM_{2.5}$ concentration ($\mu g/m^3$) contours – Year 3

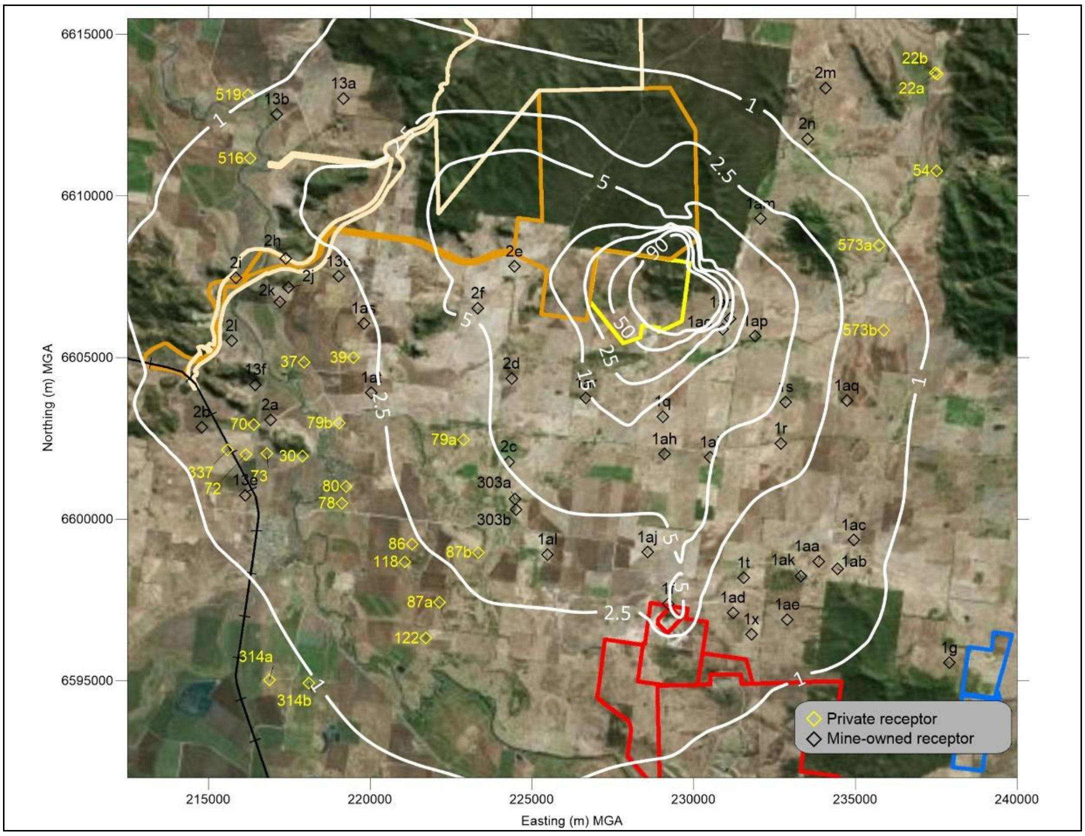

Figure A6-5: Modification-only annual average TSP concentration (µg/m³) contours – Year 3

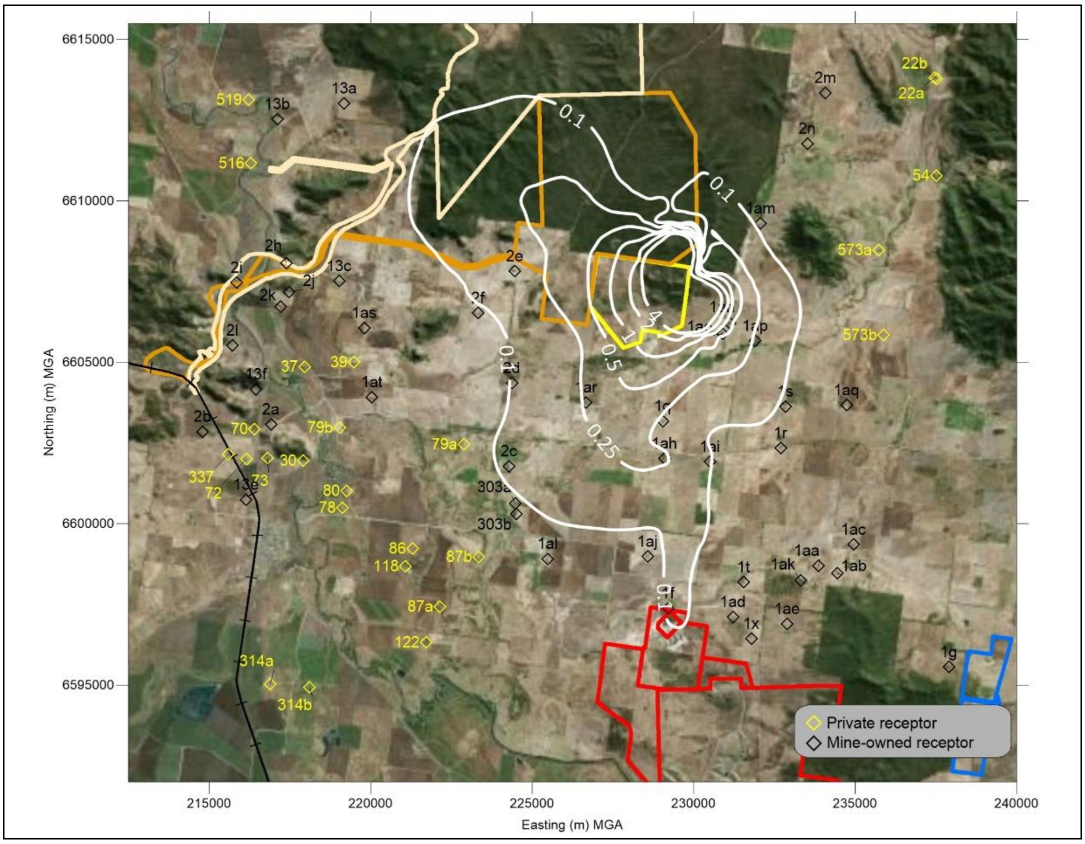

Figure A6-6: Modification-only annual average dust deposition (g/m²/month) contours – Year 3

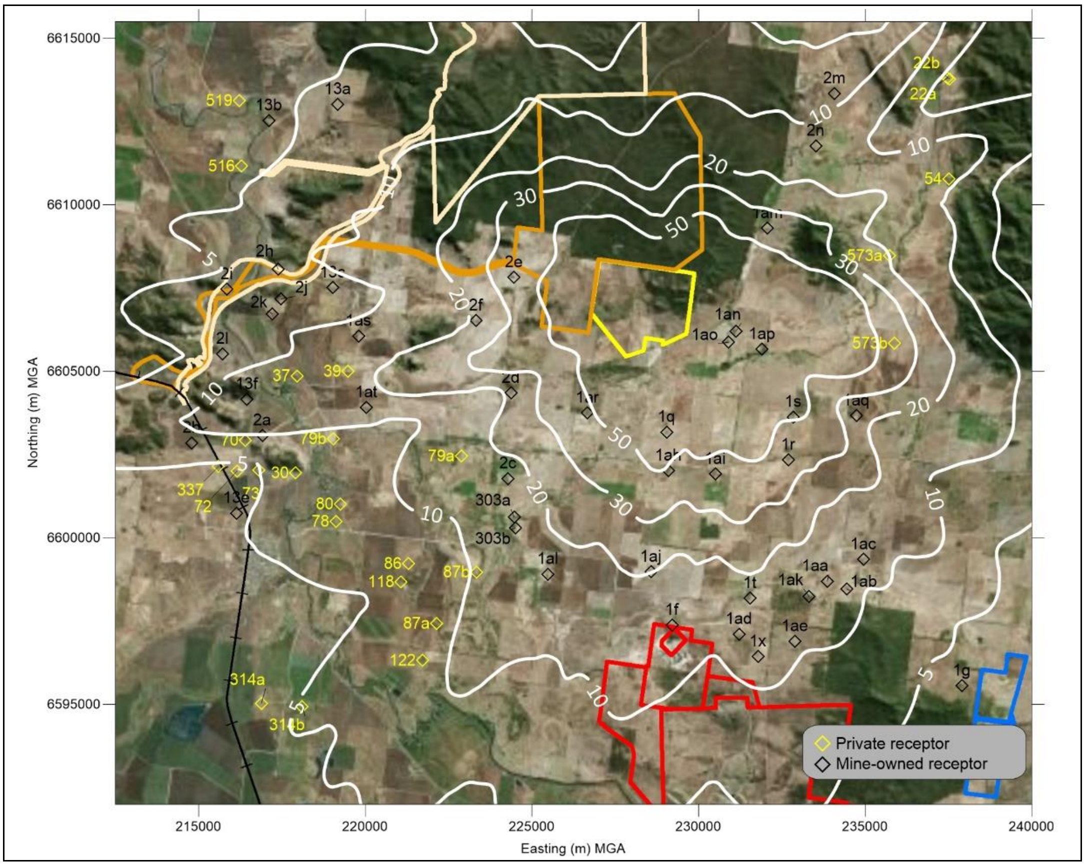

Figure A6-7: Modification-only 24-hour average PM_{10} concentration ($\mu g/m^3$) contours – Year 7

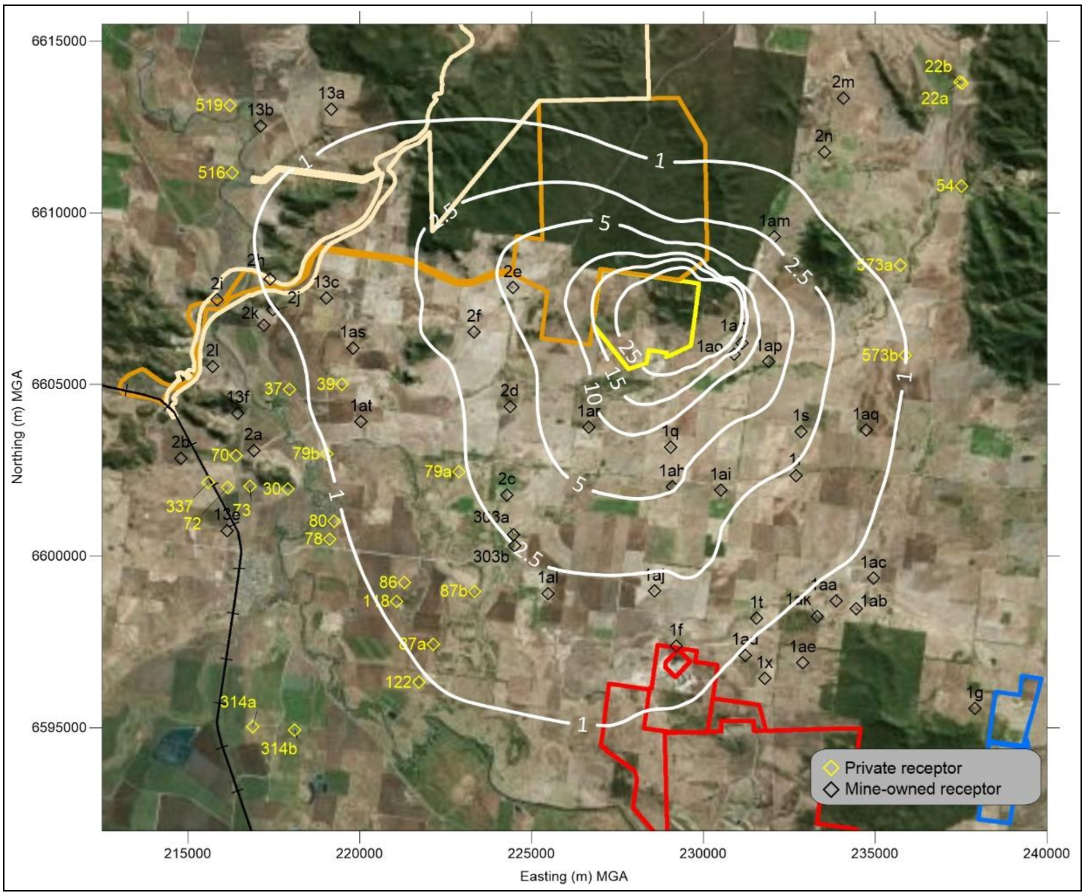

Figure A6-8: Modification-only annual average PM_{10} concentration ($\mu g/m^3$) contours – Year 7

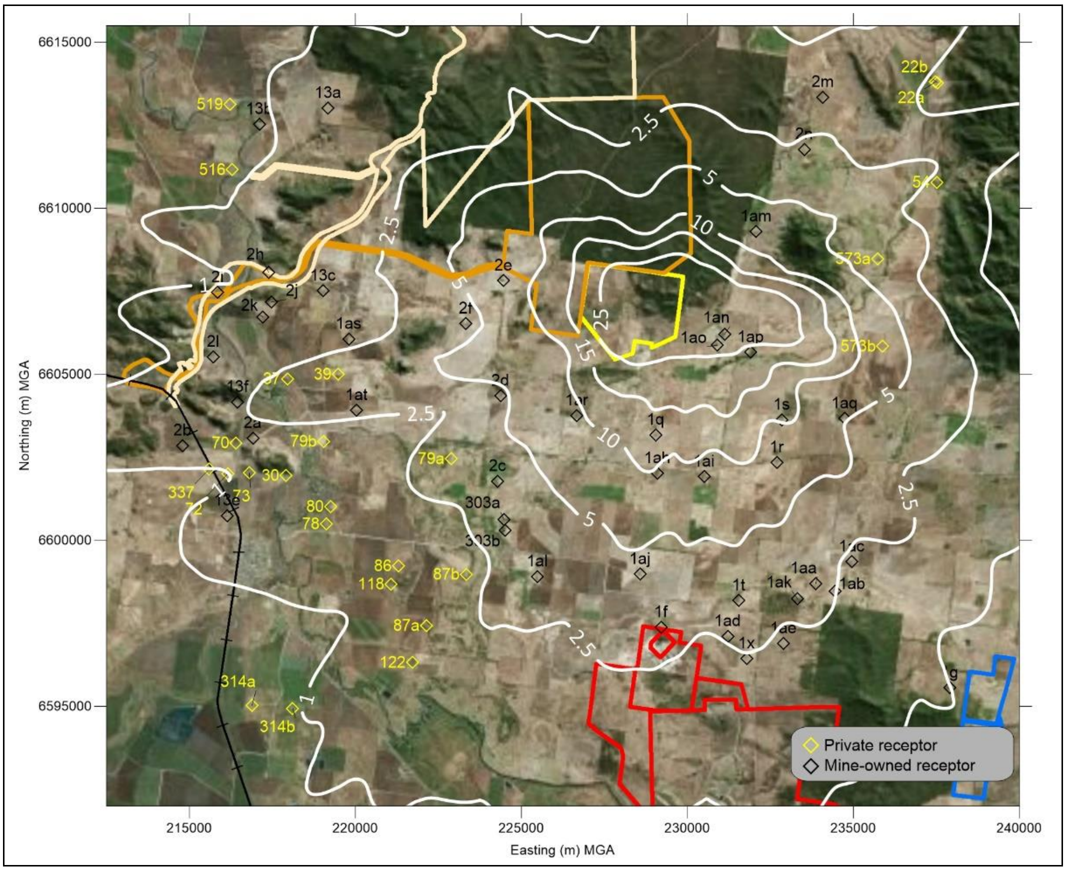

Figure A6-9: Modification-only 24-hour average $PM_{2.5}$ concentration ($\mu g/m^3$) contours – Year 7

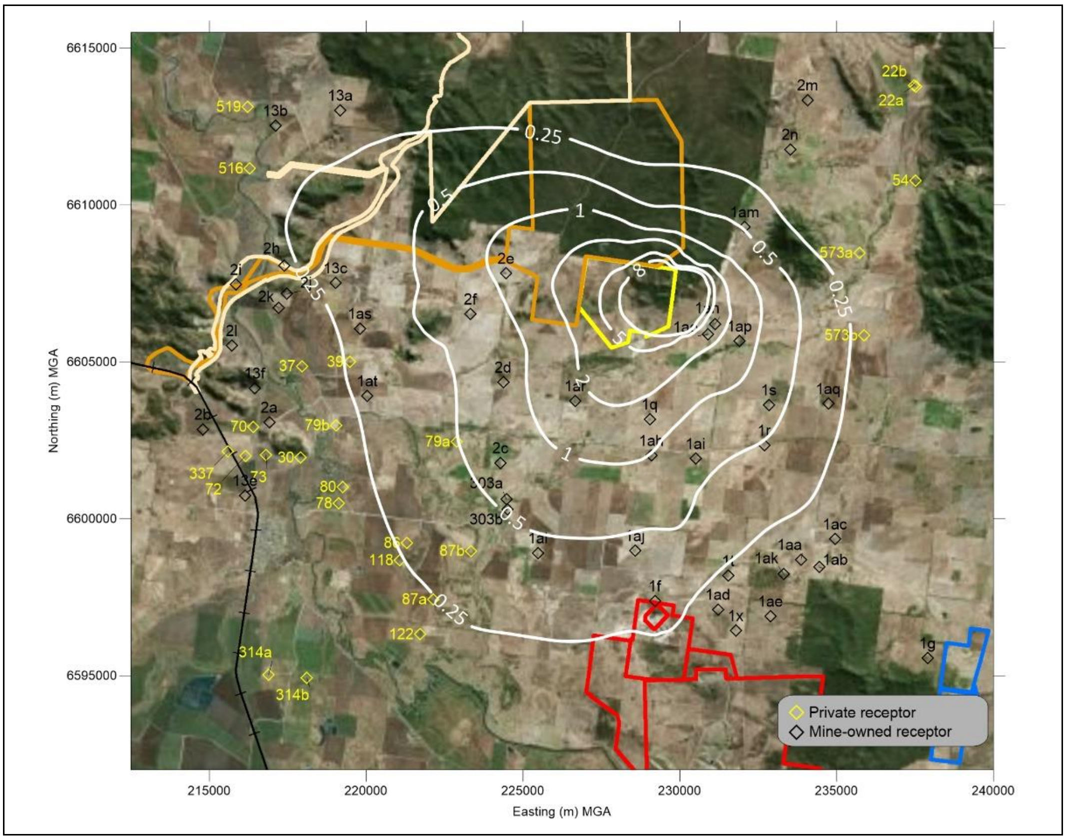

Figure A6-10: Modification-only annual average $PM_{2.5}$ concentration ($\mu g/m^3$) contours – Year 7

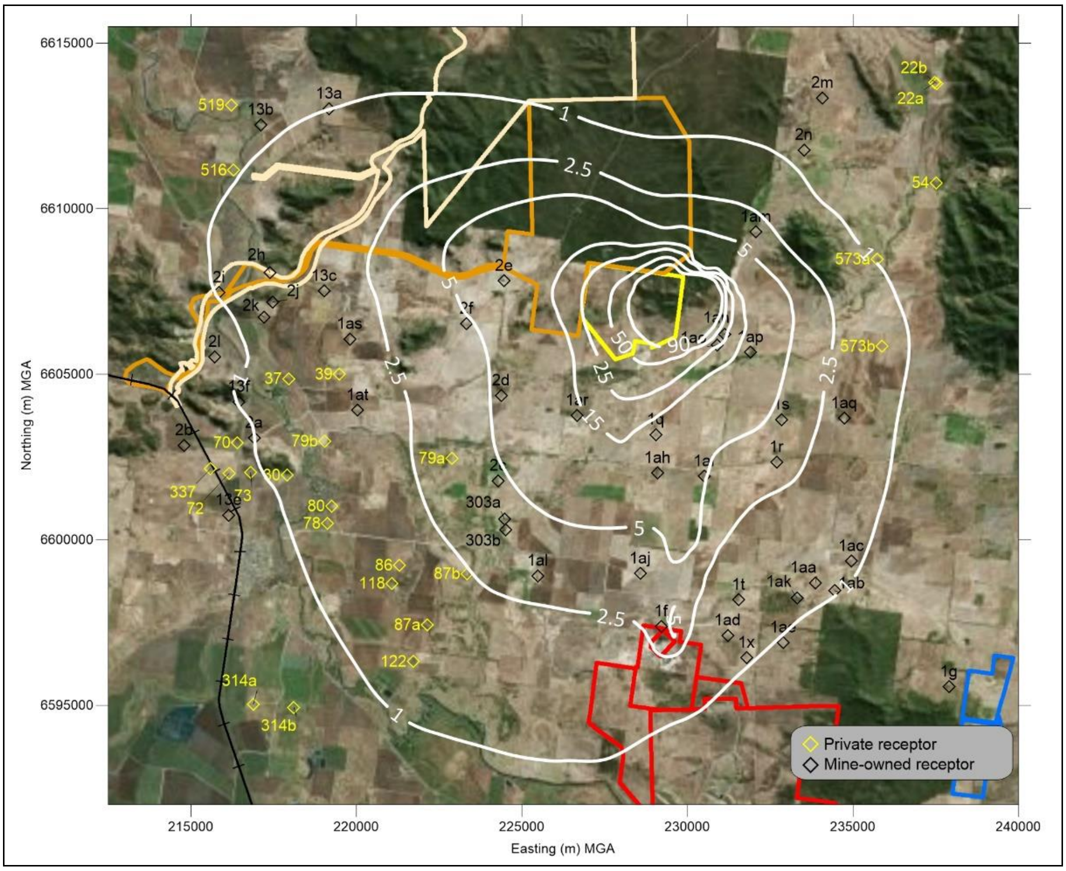

Figure A6-11: Modification-only annual average TSP concentration (µg/m³) contours – Year 7

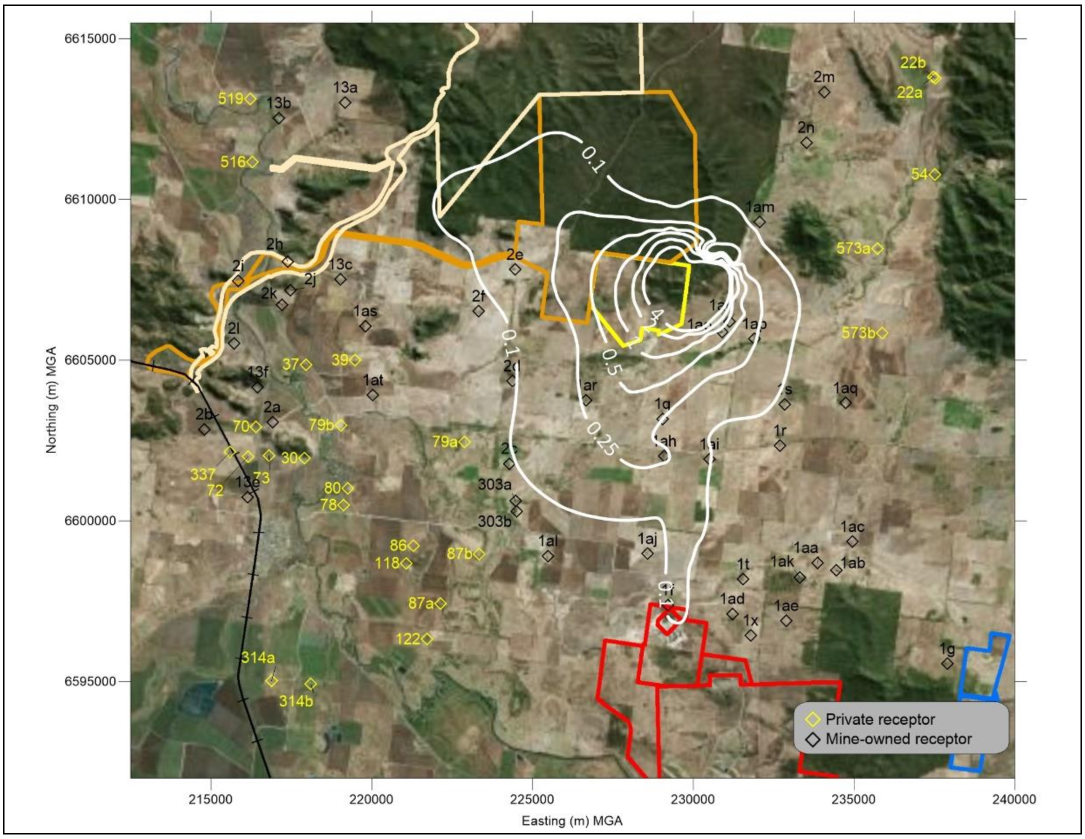

Figure A6-12: Modification-only annual average dust deposition (g/m²/month) contours – Year 7