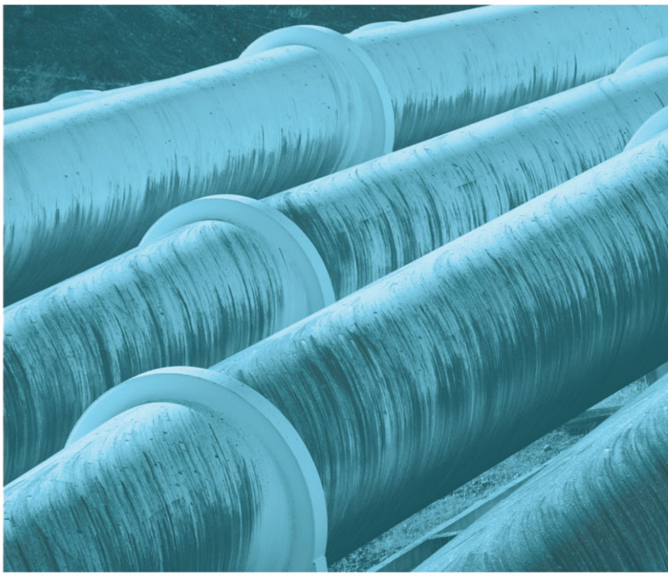
Bombo Quarry Modification

Air quality impact assessment

Prepared for Boral Resources (NSW) Pty Ltd

May 2019



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Bombo Quarry Modification

Air quality impact assessment

Report Number

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Client

Boral Resources (NSW) Pty Ltd

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7 May 2019

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7 May 2019

Executive Summary

Bombo Quarry (the quarry) is a hard rock quarry owned and operated by Boral Resources (NSW) Pty Ltd (Boral), located approximately 1.5 km north of Kiama, in the south-eastern region of NSW. The quarry operates under a development consent (DA 10.1971.97.2) originally granted by Kiama Municipal Council (Council) on 13 September 1971 (DA 10.1971.97.1). Boral also holds a development consent (DA 4/86) to operate a concrete batching plant (CBP) within the quarry, approved by Council on 29 April 1986.

Boral is seeking to modify the current quarry consent to allow for importation of clean fill material (Virgin Excavated Natural Material/Excavated Natural Material) generated by large infrastructure construction projects in the Sydney metropolitan area. EMM Consulting Pty Limited (EMM) has been engaged by Boral to assess the potential air quality impacts associated with the proposed modification.

Existing environment conditions were quantified primarily using the Bureau of Meteorology monitoring station at Kiama (Bombo Headland) and the NSW Office of Environment and Heritage air quality monitoring station at Albion Park South. Local measurements of dust deposition from three Boral-maintained dust deposition gauges were also referenced.

Emissions of total suspended particulates (TSP), particulate matter less than 10 microns in aerodynamic equivalent diameter (PM_{10}) and particulate matter less than 2.5 microns in aerodynamic equivalent diameter ($PM_{2.5}$) associated with the historical approved operations at the quarry were estimated and modelled to establish a reference baseline for impacts to the surrounding environment under existing approvals. Additionally, neighbouring Sydney Trains Bombo Quarry operations were also estimated and modelled for cumulative assessment purposes.

Boral proposes a number of rail-based options for the delivery of material to site, made up of either spoil filled containers or wagons, accessing the quarry site via a rail spur line off the main southern railway line and an onsite unloading facility. Material would also be delivered to site by road. A summary of the potential road and rail delivery options is provided below.

Material transfer option	Description
Container Option 1: transfer to void with conveyors	Each container will be unloaded off the train and stacked ready for unloading between train deliveries. Containers will be unloaded onto a screen to separate out oversized material to stockpile for further processing prior to placement. Suitably sized material will be transferred down into the quarry void via mobile conveyors. Emptied containers will be stacked ready for reloading onto the next available train. Oversized material stockpiles will be periodically crushed using a portable crusher and transferred down into the quarry void via mobile conveyors.
Container Option 2: transfer to void with haul truck	Containers will be unloaded off the train and stacked ready for unloading between train deliveries. Containers will be emptied into haul trucks, which then transfer the material to the void via haul roads. The material is then dumped at the fill face directly from the haul truck. Emptied containers will be stacked ready for reloading onto the next available train.
Container Option 3: containers emptied at the void	Containers will be unloaded off the train and stacked ready for unloading between train deliveries. Containers are transferred to the void using skel trucks (low lying semi-trailer). The containers are then emptied at the fill face directly from the skel truck. Emptied containers will be stacked ready for reloading onto the next available train.
Wagon Option 1: transfer to void with conveyors	Wagons will be emptied into a mobile hopper and transferred onto a screen to separate oversized material to stockpile for further processing prior to placement. Suitably sized material will be transferred down into the quarry void via mobile conveyors. Oversized material stockpiles will be periodically crushed using a portable crusher and transferred down into the quarry void via mobile conveyors.

Material transfer option	Description
Wagon Option 2: transfer to void with haul truck	Wagons will be emptied into a mobile hopper and transferred to temporary stockpiles. Haul trucks will be loaded using front-end loaders and material transferred to the void via haul roads. Oversized material will be separated during the spread and compaction process and pushed to temporary stockpiles to be crushed using a portable crusher ready for placement.

A qualitative review of emission sources associated with these five rail material importation options was undertaken, with the Wagon Option 2 identified as the worst case for air quality impact potential.

Atmospheric dispersion modelling of air pollution emissions for historical and proposed Wagon Option 2 activities at the quarry site was undertaken using the AERMOD dispersion model.

The results of the dispersion modelling conducted indicated that the proposed worst-case material importation activities would not result in any exceedance of applicable cumulative impact assessment criteria at any surrounding receptor location. Further, the comparison of these results with model predictions for historical approved operations at the quarry indicates that the activities proposed as part of the modification are unlikely to result in a significant change at any of the surrounding assessment locations.

Proposed mitigation measures (principally water carts and water sprays) and operational time restrictions were incorporated into the emission calculations and dispersion modelling conducted. On the basis of the low magnitude of predicted impacts, it is considered that the proposed mitigation measures are appropriate for the management of particulate matter emissions and impacts during material importation activities.

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1 Introduction

Bombo Quarry (the quarry) is a hard rock quarry owned and operated by Boral Resources (NSW) Pty Ltd (Boral), located approximately 1.5 km north of Kiama, in the south-eastern region of NSW. The regional and local context of the Bombo Quarry site is illustrated in Figure 1.1 and Figure 1.2 respectively.

Boral operates Bombo Quarry in accordance with a development consent (DA 10.1971.97.2) originally granted by Kiama Municipal Council (Council) under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) (DA 10.1971.97.1). The consent allows for 24 hr quarry production and dispatch of material via both road and rail at unlimited quantities. The site is currently licensed for extraction, processing and storage of up to 500,000 tonnes per annum (tpa) in accordance with environment protection licence (EPL) 313 granted by the NSW Environment Protection Authority (EPA) under the NSW *Protection of the Environment Operations Act 1997* (POEO Act). Boral also has a development consent (DA 4/86) to operate a concrete batching plant (CBP) within the quarry.

Quarry operations were suspended in 2014 due to Boral's operations being strategically focused at its Dunmore Quarry, approximately 5 km north of Bombo. Since that time, the quarry has been inactive but managed in accordance with the consent and EPL conditions.

The site forms part of a broader area incorporating the adjacent Sydney Trains (RailCorp) quarry site, for which Boral and Sydney Trains, in consultation with the Department of Planning and Environment (DPE), Transport for NSW (TfNSW) and Council, have been investigating the potential highest and best future land use options for the rehabilitated quarry sites.

The development consent requires the quarry be rehabilitated at the completion of quarrying activities, including returning overburden and unused product stockpiles into the quarry void. Boral proposes to modify the current consent to facilitate importation of clean fill (Virgin Excavated Natural Material (VENM) or Excavated Natural Material (ENM) from external sources via rail and road to be utilised in rehabilitation of the quarry void. To achieve Boral's rehabilitation objectives for the quarry, an estimated 4.5 million m^3 of supplementary material is required to fill the void.

This air quality impact assessment (AQIA) has been prepared by EMM Consulting Pty Limited (EMM) on behalf of Boral, to assess potential air quality impacts associated with the proposed modification. It has been prepared in general accordance with the guidelines specified by the NSW EPA in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA, 2016), hereafter "the Approved Methods for Modelling". This AQIA supports a Statement of Environmental Effects (SEE) which will accompany an application to modify the development consent.

1.1 Overview of proposed modification

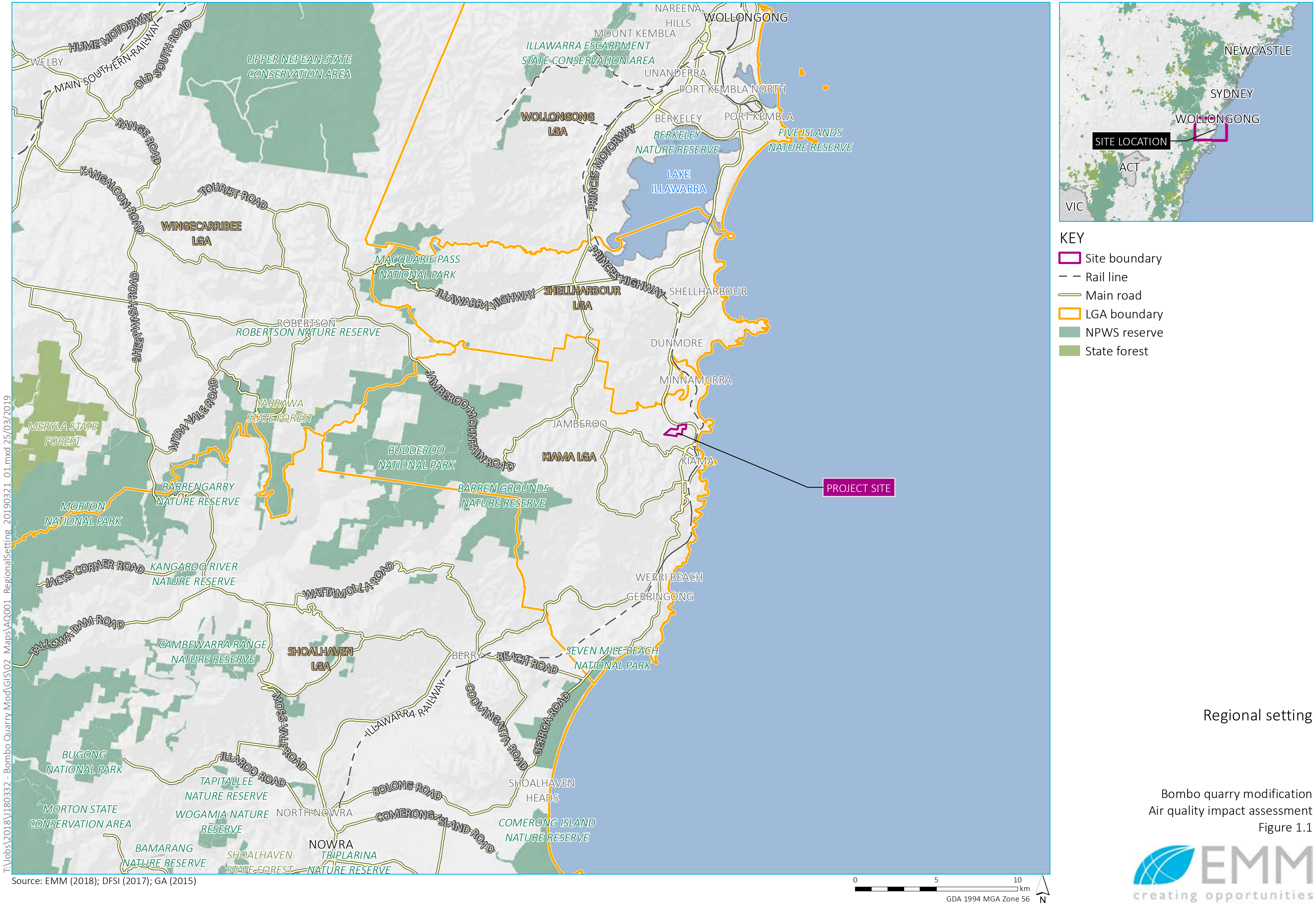
Boral is seeking to modify the consent under Section 4.55(2) within Part 4 of the NSW EP&A Act to:

- update consent details to correctly describe title and applicant details;
- amend approved rehabilitated batter slopes; and
- allow for the importation of fill material to be used for rehabilitation.

The proposed modifications are highlighted in **bold** in Table 1.1. Boral is seeking to adopt flexible consent conditions to allow the final rehabilitated landform and associated batters to be adjusted in response to the availability of suitable fill material during rehabilitation, which will be driven by spoil-generating market conditions.

Table 1.1 Proposed modification

	Existing consent (DA 10.1971.97.1 & DA 10.1971.97.2)	Proposed modification (DA 10.1971.97.3)
Applicant	Boral Basic Industries	**Boral Resources (NSW) Pty Ltd**
Batter slope	1:1	**Batter slope specification to be determined in consultation with a suitably qualified and experienced geotechnical engineer to ensure that the batters are left in a stable and serviceable condition.**
Importation timing	N/A	**5 – 8 years depending on fill availability**
Production/importation volumes	Quarry production: unlimited	**Virgin Excavated Natural Material (VENM) / Excavated Natural Material (ENM) importation: 4.5 million m^3**
Maximum despatch	Despatch of quarry material:	**Receival of VENM/ENM**:
Road (tpa)	Road – unlimited	Road – unlimited
Rail (tpa)	Rail – unlimited	Rail – unlimited
Rail spur & unloading facility	A dedicated rail spur from the main southern railway line allowed the quarry to load quarry product and transport via rail. Portions of the spur line rail track were removed some years ago.	Boral intends to reinstate the rail spur and unloading facility as allowed under the existing consent. No provision for this re-instatement is required as a part of the modification.
Hours of operation		
Extraction and infilling	No consent restrictions Drill and blast operations managed through EPL	Material processing (crushing) of imported material limited to daytime (7am – 6pm) Material receival/stockpiling – unlimited; Infilling/shaping – 7am – 10pm
VENM/ENM importation via rail	VENM/ENM importation via rail: N/A	Unlimited
VENM/ENM importation via road	VENM/ENM importation via road: N/A	Unlimited



Source: EMM (2018); DFSI (2017); GA (2015)

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Regional setting

Bombo quarry modification
Air quality impact assessment
Figure 1.1

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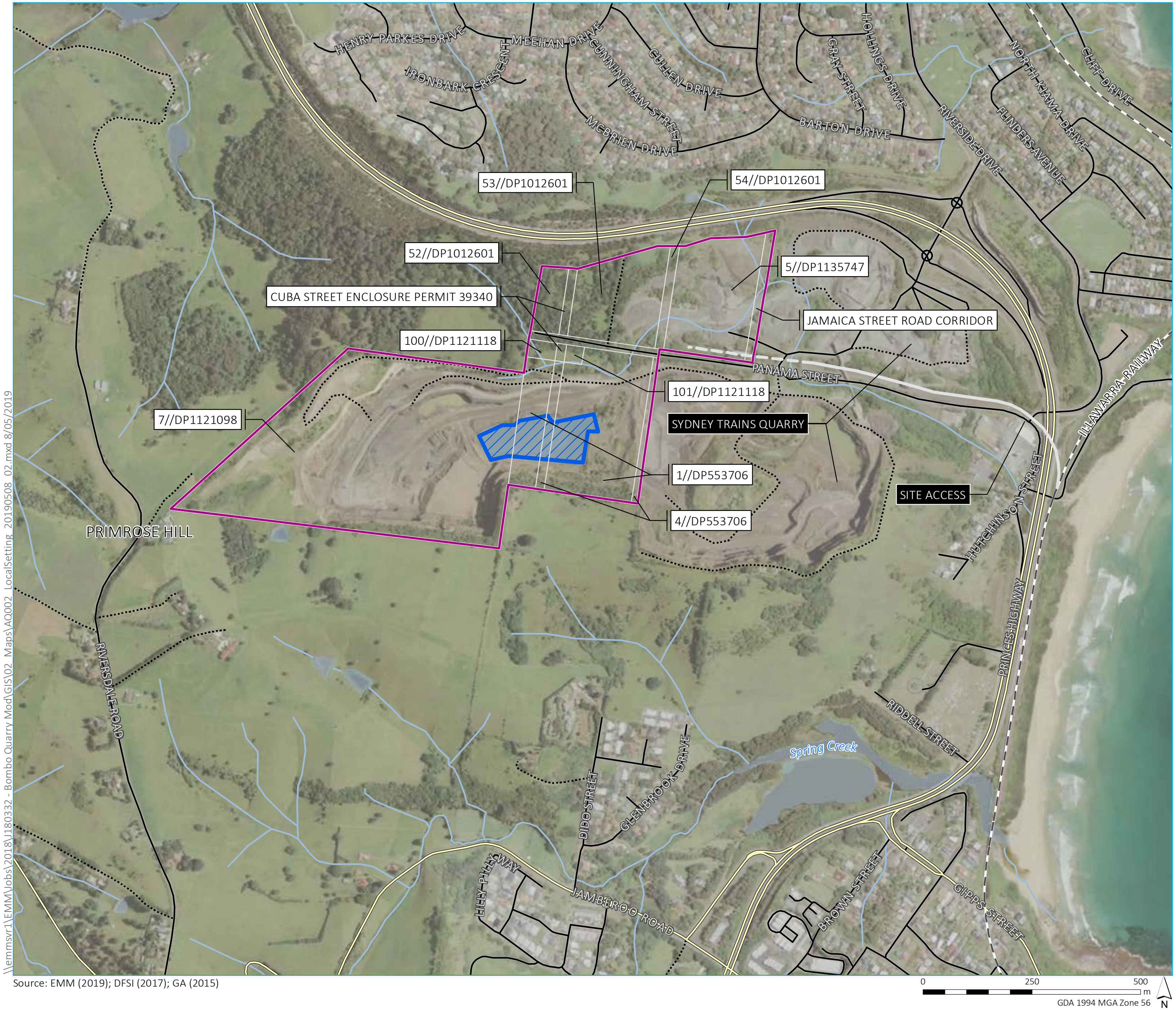
KEY

- Site boundary
- Site cadastre
- Pit sump
- Bombo rail siding (existing)
- Bombo rail siding (to be reinstated)
- Main southern railway line
- Main road
- Local road
- Vehicular track
- Watercourse / drainage line
- Waterbody



Source: EMM (2019); DFSI (2017); GA (2015)

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Local setting

Bombo quarry modification
Air quality impact assessment
Figure 1.2

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2 Site setting and project description

2.1 Site description and historic operations

The quarry is located off Panama Street, and adjacent to the Princes Highway, Bombo. The nearest townships are Kiama Downs to the north of the Princes Highway and Kiama to the south. It is located immediately adjacent to a quarry currently owned and operated by Sydney Trains (refer Figure 1.2).

The quarry is accessed from the western end of Panama Street, Bombo. It has an area of approximately 45 ha and is made up of nine lots, the legal description and size of each are detailed in Table 2.1 and illustrated on Figure 1.2.

Table 2.1 Legal description and size of lot

Lot	Area (ha)	Land owner
Lot 7 DP1121098	24.35	Boral
Lot 1 DP553706	8.447	Boral
Lot 4 DP553706	1.282	Boral
Lot 52 DP1012601	0.8691	Boral
Lot 53 DP1012601	4.05	Boral
Lot 54 DP1012601	0.4817	Boral
Lot 5 DP1135747	5.299	Boral
Lot 100 DP1121118	0.2306	Boral
Lot 101 DP1121118	0.1740	Boral
Cuba Street Enclosure Permit 39340	0.6905	Crown Lands (Enclosure Permit 39340 held by Boral)
Panama Street	n/a	Council
Jamaica Street	n/a	Crown Lands

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The existing quarry consent (as modified) allows for unlimited quarry production and places no limits on dispatch of material via road and rail.

The quarry is currently licensed under EPL 313 to extract, process or store up to 500,000 tpa without limitation on road or rail dispatch. Historic records of operations at the quarry indicate while the approval has unlimited production volumes, peak production approximated the current EPL extraction limit of 500,000 tpa. Similarly, the quarry's consent allowed 24 hours per day operations when required. The quarry operated, on average, 275 days per year.

2.1 Assessment locations

A number of sensitive receptor assessment locations, chosen as representative of the surrounding environment, were selected for prediction of air quality impacts associated with emission sources at the quarry site. Representative assessment locations considered in the AQIA are listed in Table 2.2. All locations are residential and are consistent with those used for the noise impact assessment for the proposed modification.

Table 2.2 Assessment locations

ID	Receptor Type	Address	Easting (m, MGA56s)	Northing (m, MGA56s)
R1	Residential	4 Dundas Street, Bombo	303177	6162955
R2	Residential	28 Darien Avenue, Bombo	303481	6163517
R3	Residential	34 Riverside Drive, Kiama Downs	303356	6163755
R4	Residential	86 Barton Drive, Kiama Downs	303097	6163825
R5	Residential	19 McBrien Drive, Kiama Downs	302620	6163842
R6	Residential	13A Michael Crescent, Kiama Downs	302079	6163805
R7	Residential	Riversdale Road, Jamberoo	301212	6163571
R8	Residential	Riversdale Road, Jamberoo	301381	6162977
R9	Residential	Riversdale Road, Jamberoo	301403	6162811
R10	Residential	Riversdale Road, Jamberoo	301518	6162722
R11	Residential	25 Dido Street, Kiama	302287	6162588
R12	Residential	37 Glenbrook Drive, Kiama	302515	6162562
R13	Residential	Riddell St, Bombo	302973	6162667

Source: EMM (2018); DFSI (2017); GA (2015)

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KEY
- Site boundary
- Pit sump
- Bombo rail siding (existing)
- Bombo rail siding (to be reinstated)
- Main southern railway line
- Main road
- Local road
- Vehicular track
- Watercourse / drainage line
- Waterbody
- Air quality assessment location

Assessment locations

Bombo quarry modification
Air quality impact assessment
Figure 2.1

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2.2 Project description

2.2.1 Importation rate and process

The proposed modification seeks to facilitate importation of VENM/ENM from external sources to be utilised in rehabilitation of the quarry void. It is estimated that 4.5 million m^3 of supplementary material is required to fill the void, which is proposed to be transported to site via road and/or rail on an estimate of five to eight years of importation timing (depending on fill availability).

The proposed road and rail transport options and associated onsite material transfer options are summarised in the following sections.

2.2.2 Transportation via rail

Trains, made up of either spoil filled containers or wagons, will access the site via a rail spur line off the main southern railway line and an onsite unloading facility. A number of material transfer methods may be utilised for both the container and wagon delivery options as summarised in Table 2.3 and Table 2.4.

Table 2.3 Container based spoil delivery and void transfer options

Material transfer option	Description
Option 1: transfer to void with conveyors	Each container will be unloaded off the train and stacked ready for unloading between train deliveries. Containers will be unloaded onto a screen to separate out oversized material to stockpile for further processing prior to placement. Suitably sized material will be transferred down into the quarry void via mobile conveyors. Emptied containers will be stacked ready for reloading onto the next available train. Oversized material stockpiles will be periodically crushed using a portable crusher and transferred down into the quarry void via mobile conveyors.
Option 2: transfer to void with haul truck	Containers will be unloaded off the train and stacked ready for unloading between train deliveries. Containers will be emptied into haul trucks, which then transfer the material to the void via haul roads. The material is then dumped at the fill face directly from the haul truck. Emptied containers will be stacked ready for reloading onto the next available train.
Option 3: containers emptied at the void	Containers will be unloaded off the train and stacked ready for unloading between train deliveries. Containers are transferred to the void using skel trucks (low lying semi-trailer). The containers are then emptied at the fill face directly from the skel truck. Emptied containers will be stacked ready for reloading onto the next available train.

Table 2.4 Wagon based spoil delivery and void transfer options

Material transfer option	Description
Option 1: transfer to void with conveyors	Wagons will be emptied into a mobile hopper and transferred onto a screen to separate oversized material to stockpile for further processing prior to placement. Suitably sized material will be transferred down into the quarry void via mobile conveyors. Oversized material stockpiles will be periodically crushed using a portable crusher and transferred down into the quarry void via mobile conveyors.
Option 2: transfer to void with haul truck	Wagons will be emptied into a mobile hopper and transferred to temporary stockpiles. Haul trucks will be loaded using front-end loaders and material transferred to the void via haul roads. Oversized material will be separated during the spread and compaction process and pushed to temporary stockpiles to be crushed using a portable crusher ready for placement.

For all rail delivery and transfer options, earthmoving equipment will be utilised onsite to spread and compact fill material to meet relevant geotechnical requirements. A water cart will also be used onsite for moisture conditioning and to minimise dust impacts. All earthmoving equipment associated with receival and placement of imported material would operate within the site and not on public roads.

During peak delivery, there are likely to be up to four trains unloaded per 24-hour period, including up to two trains during the night (10 pm to 7 am). At other times, there are likely to be two trains per day.

2.2.3 Transportation via road

Fill material may be transported to the site via road from either the north or south via Panama Street. Trucks would be unloaded to dedicated onsite material stockpiles for subsequent transfer to the quarry pit, or direct to the pit for spreading and compaction.

The quarry development consent (DA 10.1971.97.2) places no restrictions on quarrying operations including truck movements. Notwithstanding, unlimited transportation of fill material is not being sought as part of the proposed modification. Rather, the proposal for transportation of imported fill material via road would be capped consistent with peak historical traffic volumes from the site; ie on average up to a total of 222 truck movements per day with a maximum of up to 256 truck movements per day.

As stated above, for both the rail and road transportation options, a minor number of light vehicle movements associated with rehabilitation activities would be generated by employees and visitors travelling to and from the site. This is estimated at up to eight light vehicles (16 light vehicle movements) per day.

There will be occasional equipment maintenance or delivery vehicles associated with the quarry rehabilitation activity, however, the frequency and volume of maintenance or delivery vehicles are almost negligible relative to the future rehabilitation related road traffic movements.

2.2.4 Hours of operation

Consistent with historic operations and the current consent, proposed road and rail movements associated with importation of material will be undertaken 24 hours. Material receival (from trains or trucks) and stockpiling will also be undertaken 24 hours.

Material processing (crushing) associated with the imported fill material is proposed to be limited to daytime hours of 7 am - 6 pm; and material infilling/shaping activities are proposed to be limited to the hours of 7 am - 10 pm

3 Assessment approach

As stated in Chapter 1, this AQIA has been conducted in general accordance with the guidelines specified by the EPA in the Approved Methods for Modelling. Consistent with Section 2.1 of the Approved Methods for Modelling, this AQIA is classed as a Level 2 assessment and implements a refined dispersion modelling approach using site-specific/representative input.

The AQIA comprises of the following sections:

- a description of the local setting and surrounds of the quarry;
- relevant pollutants for assessment and applicable impact assessment criteria;
- a description of baseline inputs, specifically:
  - meteorology and climate; and
  - existing air quality environment;
- a detailed air pollution emissions inventory for the proposed modification;
- results of atmospheric dispersion modelling conducted for the proposed modification, including an analysis of project-only and cumulative impacts accounting for baseline air quality; and
- overview of mitigation measures and monitoring requirements for the proposed modification.

4 Pollutants and assessment criteria

4.1 Potential air pollutants

The importation of material to the quarry has the potential to generate emissions of various air pollutants to the ambient atmosphere. Emission sources will comprise a mixture of fugitive (material handling and sorting activities, dozer/compactor activities and wind erosion of exposed surfaces) and mobile combustion sources (mobile equipment fleet, road trucks and locomotive engines). Air pollutants will comprise:

- particulate matter, specifically:
  - total suspended particulate matter (TSP);
  - particulate matter less than 10 microns in aerodynamic diameter (PM_{10}); and
  - particulate matter less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$);
- oxides of nitrogen (NO_x);
- sulphur dioxide (SO_2);
- carbon monoxide (CO); and
- volatile organic compounds (VOCs).

Particulate matter pollutants (TSP, PM_{10} and $PM_{2.5}$) are anticipated to be the primary pollutants with regards to emissions generated by the proposed modification and associated compliance with impact assessment criteria at surrounding receptors. This assessment will therefore focus on the quantification of particulate matter emissions and impacts (fugitive releases and diesel combustion related particulate matter). Emissions and impacts from other pollutants associated with diesel combustion (NO_x, SO_2, CO and VOCs) are expected to be minor and have not been addressed further in this assessment.

Criteria applicable to particulate matter is presented in the following sections. The proposed modification must demonstrate compliance with the impact assessment criteria outlined in the Approved Methods for Modelling (EPA, 2016). The impact assessment criteria are designed to maintain ambient air quality that allows for the adequate protection of human health and well-being.

4.2 Applicable air quality assessment criteria

The EPA's impact assessment criteria for particulate matter pollutants, as documented in Section 7 of the Approved Methods for Modelling, are presented in Table 4.1. The assessment criteria for PM_{10} and $PM_{2.5}$ are consistent with revised National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) national reporting standards (National Environment Protection Council [NEPC], 1998; NEPC, 2015).

TSP, which relates to air borne particles less than 50 micrometres (µm) in diameter, is used as a metric for assessing amenity impacts (reduction in visibility, dust deposition and soiling of buildings and surfaces) rather than health impacts (EPA, 2013). Particles less than 10 µm in diameter, a subset of TSP, are fine enough to enter the human respiratory system and can lead to adverse human health impacts. The assessment criteria for PM_{10} and $PM_{2.5}$ are therefore used to assess the potential impact to human health from particulate matter concentrations.

The Approved Methods for Modelling classifies TSP, PM_{10}, $PM_{2.5}$ and dust deposition as 'criteria pollutants'. Assessment criteria for 'criteria pollutants' are applied at the nearest existing or likely future off-site sensitive receptor and compared against the 100th percentile (ie the highest) dispersion modelling prediction. Both the incremental and cumulative impacts need to be presented, requiring consideration of existing ambient background concentrations for the criteria pollutants assessed.

For dust deposition, the EPA (2016) specifies criteria for project-only increment and cumulative dust deposition levels. Dust deposition impacts are derived from TSP emission rates and particle deposition calculations in the dispersion modelling process.

Table 4.1 Impact assessment criteria for particulate matter

PM metric	Averaging period	Assessment criteria
TSP	Annual	90 µg/m^3
PM_{10}	24-hour	50 µg/m^3
	Annual	25 µg/m^3
$PM_{2.5}$	24-hour	25 µg/m^3
	Annual	8 µg/m^3
Dust deposition	Annual	2 g/m^2/month (project increment only)
		4 g/m^2/month (cumulative)

Notes: µg/m^3: micrograms per cubic metre
g/m^2/month: gram per square metre per month

5 Meteorology and climate

5.1 Monitoring data resources

There are no meteorological measurements conducted at the quarry, nor is there a requirement to do so in the applicable development consent and EPL. In reviewing the meteorological and climate environments of the local area, monitoring data from the following resources has been collated:

- Bureau of Meteorology (BoM) automatic weather station (AWS) locations at Kiama (Bombo Headland), located 1.5 km to the east of the quarry, and Albion Park (Wollongong Airport), located 11 km to the north-north-west of the quarry. One-minute and one-hour average datasets from both stations were accessed and interrogated for the period between 2013 and 2018.

- NSW Office of Environment and Heritage (OEH) air quality station (AQS) at Albion Park South, located 10 km to the north-northwest of the quarry.

- BoM climate station at Kiama Bowling Club, 2.5 km south of the quarry. Data from this location is available for the period between 1897 and 2011.

Data from the BoM Kiama (Bombo Headland) AWS is the primary resource for representing meteorological conditions at the quarry, with measurements of wind speed and direction, temperature and relative humidity adopted for modelling. These data were supplemented with data taken from Wollongong Airport (station level pressure and cloud) and Albion Park South (solar radiation).

For the purpose of this AQIA, the 2017 calendar year was selected as the most recent and representative 12-month period of monitoring data at the commencement of modelling. Details relating to the selection of meteorological year and the representativeness of the dataset are provided in Appendix A.

5.2 Meteorological modelling and processing

Atmospheric dispersion modelling for this assessment has been completed using the AERMOD dispersion model. The meteorological inputs for AERMOD were generated using the AERMET meteorological processor, using local surface observations and upper air profiles generated by the CSIRO TAPM meteorological modelling module.

Further details of the TAPM meteorological modelling and AERMET data processing completed to prepare inputs to AERMOD are documented in Appendix A.

5.3 Prevailing winds

A wind rose showing wind speed and direction data recorded at the Kiama (Bombo Headland) AWS during 2017 is presented in Figure 5.1. Similar to the inter-annual wind roses presented in Appendix A, the 2017 annual recorded wind pattern is dominated by north-east, south-west and westerly airflow. Highest wind speeds recorded are most frequently experienced from the southwest. The average recorded wind speed for 2017 was 4.4 m/s, with a frequency of calm conditions (wind speeds less than 0.5 m/s) in the order of 1.9 % of the time.

Seasonal and diurnal wind roses for the Kiama (Bombo Headland) AWS data recorded between 2013 and 2017 are provided in Appendix A.

Seasonal and diurnal (dividing each 24-hour period into night and day) wind roses for the Kiama (Bombo Headland) AWS meteorological dataset are presented within Appendix A. Pronounced seasonal variation is evident in the data. The north-east component is most defined during the summer months, while the south-west component is dominant during autumn and winter. The westerly component is most frequent during winter. The seasonal average wind speed is greatest during summer, however the incidence of calm conditions is also highest at this time.

There is minimal diurnal variation in the wind data recorded at Kiama (Bombo Headland) AWS. Both periods experience winds from the north-east, south-west and west. The westerly component is more prominent during the night hours. The average wind speed is slightly lower and the incidence of calm conditions slightly higher during the night period.

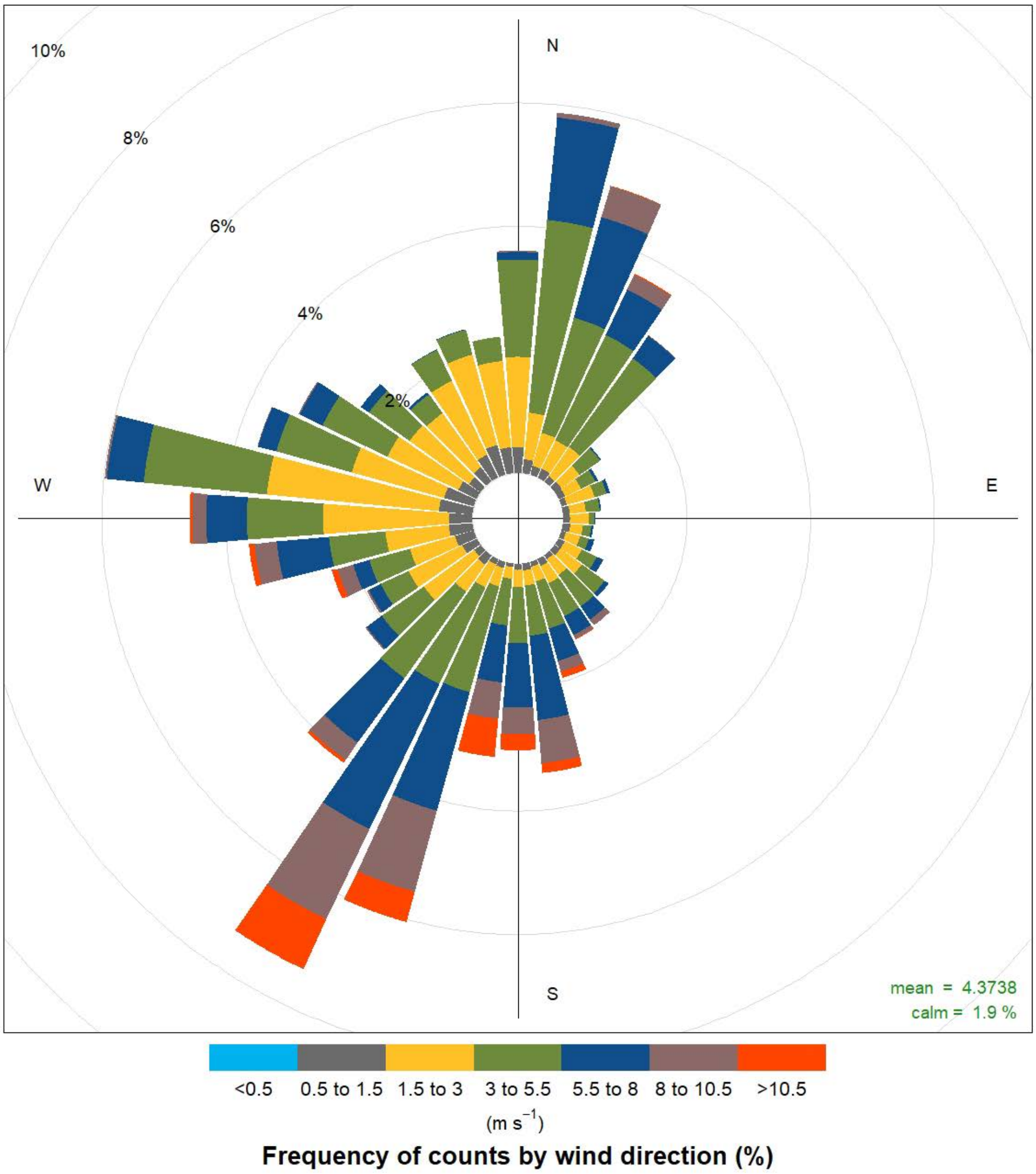

Figure 5.1 Inter-annual comparison of recorded wind speed and direction – Kiama (Bombo Headland) AWS – 2017

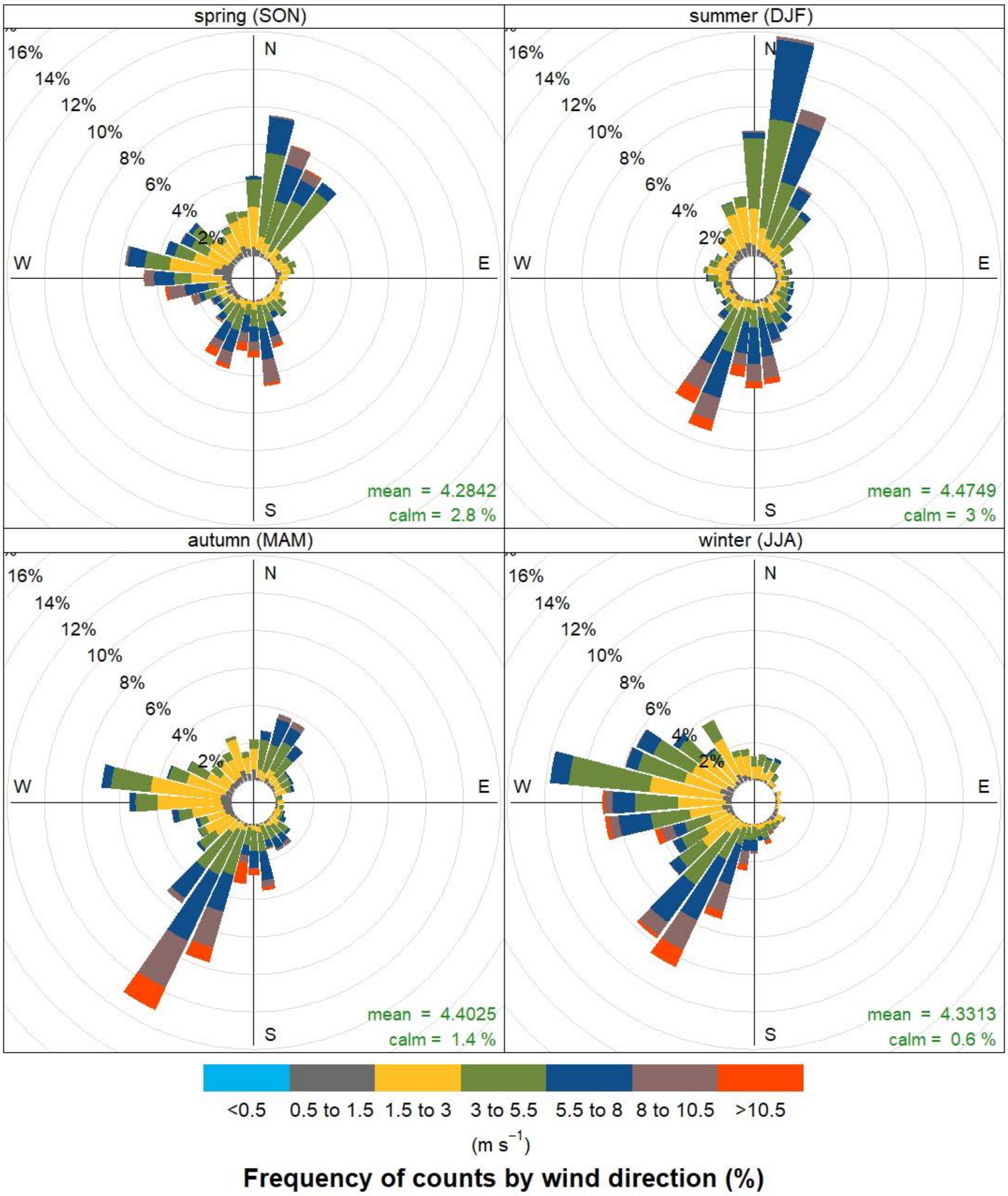

Figure 5.2 Seasonal wind speed and direction – Kiama (Bombo Headland) AWS – 2017

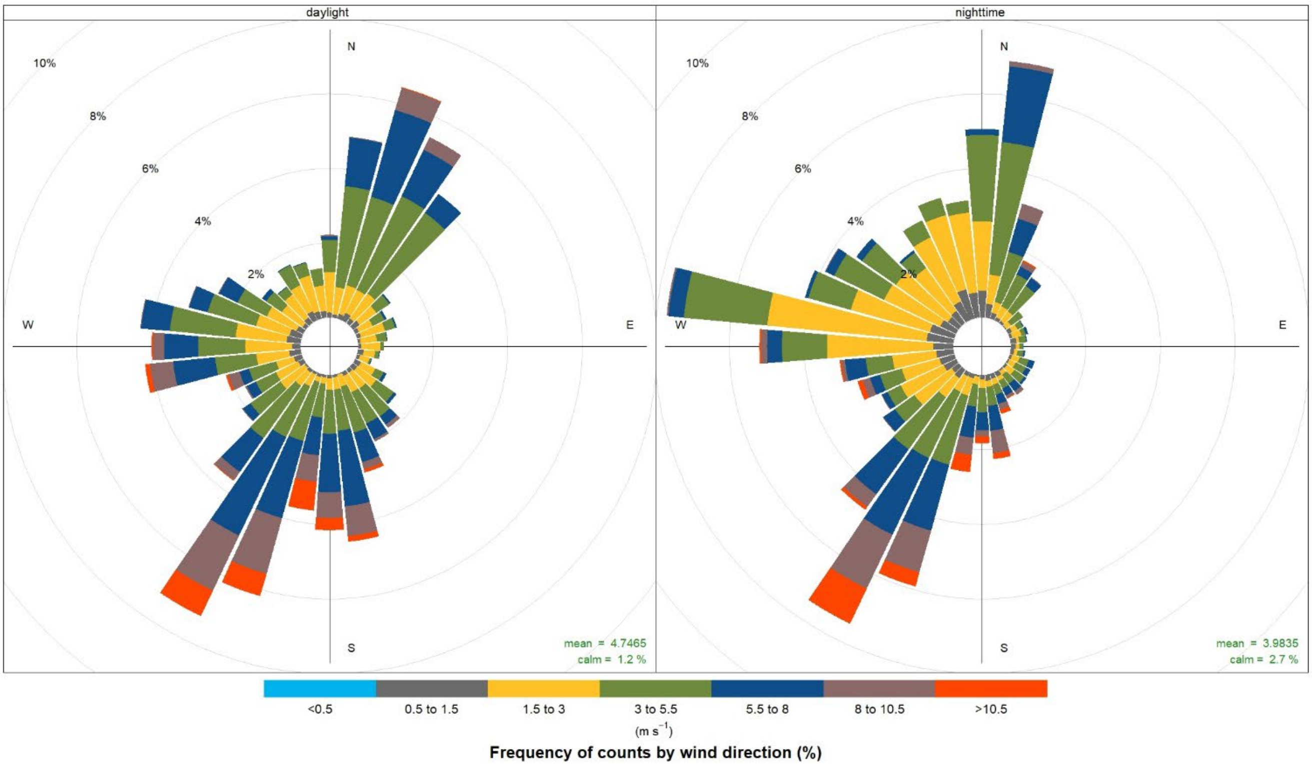

Figure 5.3 Diurnal wind speed and direction – Kiama (Bombo Headland) AWS – 2017

5.4 Atmospheric stability and mixing depth

Atmospheric stability refers to the degree of turbulence or mixing that occurs within the atmosphere and is a controlling factor in the rate of atmospheric dispersion of pollutants.

The Monin-Obukhov length (L) provides a measure of the stability of the surface layer (ie 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 5.4 illustrates the seasonal variation of atmospheric stability derived from the Monin-Obukhov length calculated by AERMET based on the Kiama (Bombo Headland) AWS. The diurnal profile presented illustrates that atmospheric instability increases during daylight hours as convective energy increases, whereas stable atmospheric conditions prevail during the night-time. This profile indicates that the potential for atmospheric dispersion of emissions would be greatest during day time hours and lowest during evening through to early morning hours.

Hourly-varying atmospheric boundary layer depths were generated by AERMET, the meteorological processor for the AERMOD dispersion model. The variation in average boundary layer depth by hour of the day is illustrated in Figure 5.5. It can be seen that greater boundary layer depths 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.

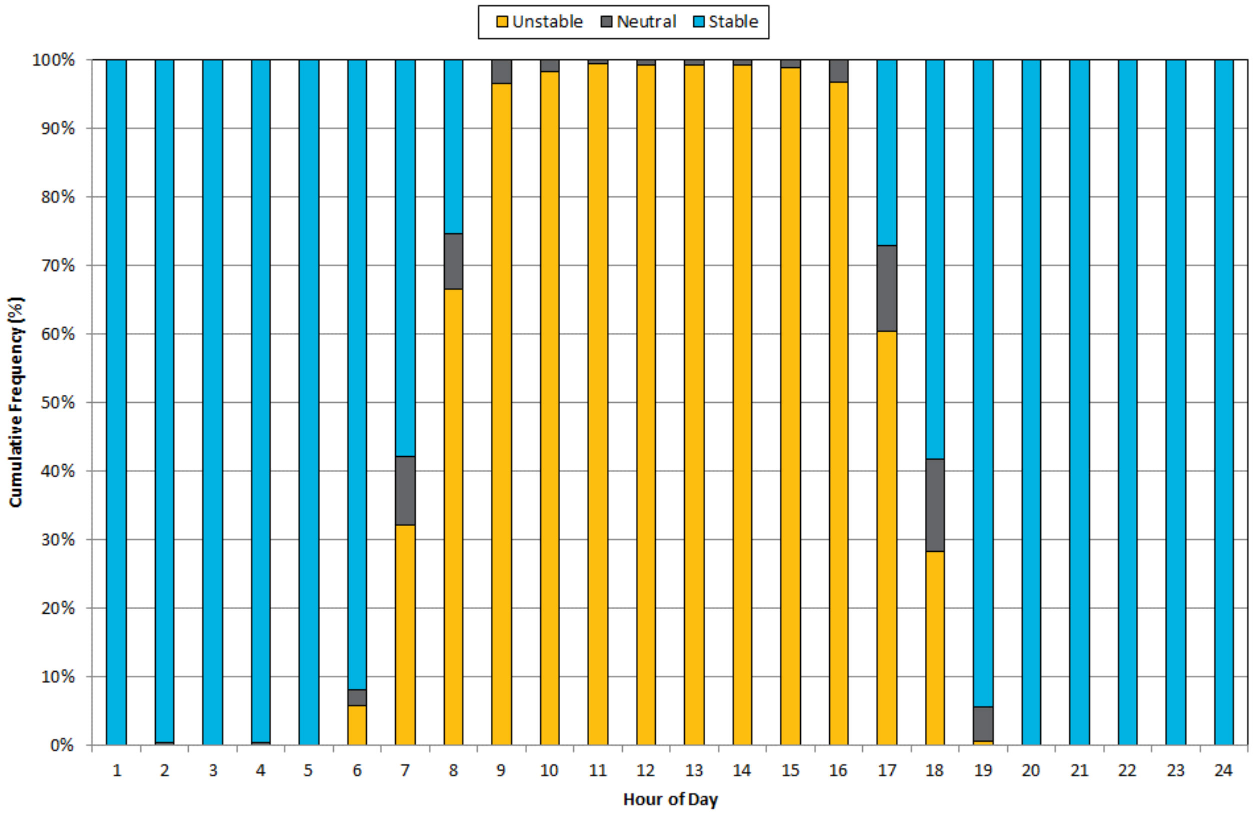

Figure 5.4 **AERMET-calculated diurnal variation in atmospheric stability– Kiama (Bombo Headland) AWS 2017**

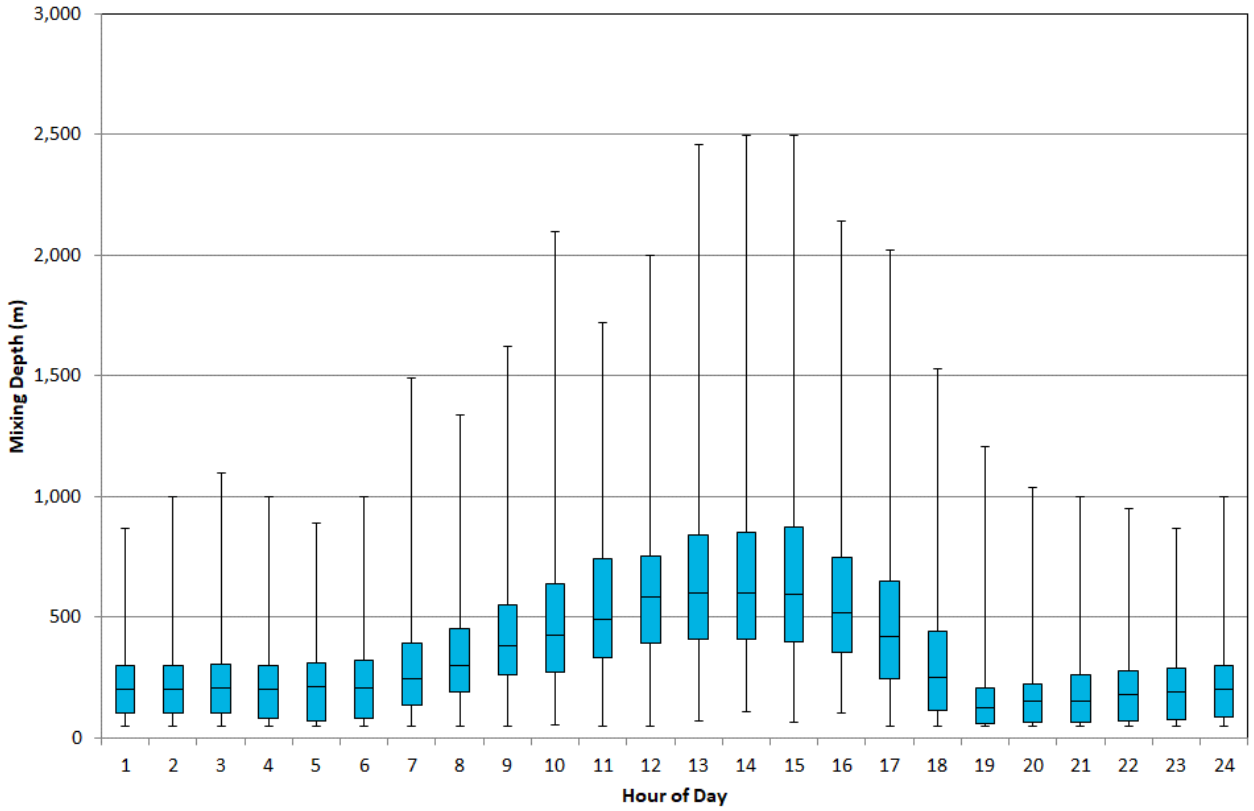

Figure 5.5 AERMET-calculated diurnal variation in atmospheric mixing depth – Kiama (Bombo Headland) AWS 2017

6 Baseline air quality

6.1 Existing sources of emissions

The National Pollutant Inventory (NPI) database identifies seven reporting sources of air pollution emissions in the surrounding 10 km from the quarry, as listed in Table 6.1. Of these NPI reporting sources, only the four listed hard rock quarry operations have the potential to generate emissions of particulate matter.

Table 6.1 NPI reporting emission sources within 10 km of quarry site

Reporting emission source name	Operator	Location of source	Description of activities
Albion Park Main Line Valve	Jemena Eastern Gas Pipeline Pty Ltd	Albion Park	Main line valve - gas supply pipeline
Albion Park Quarry	Holcim (Australia) Pty Ltd	Albion Park	Hard rock extraction
Bombo Sewage Treatment Plant	Sydney Water Corporation	Bombo	Secondary biological sewage treatment plant
Sydney Trains Bombo Quarry	Rail Corporation New South Wales	Bombo	Hard rock extraction
Boral Dunmore Quarry	Boral	Dunmore	Hard rock extraction
Shellharbour Sewage Treatment System	Sydney Water Corporation	Shellharbour	Secondary biological sewage treatment plant
Bass Point Quarry	Hanson Construction Materials Pty Ltd	Shellharbour	Hard rock extraction

In addition to NPI reporting facilities listed in Table 6.1, a review of the EPA EPL register for operations in the surrounding 10 km area identified the Dunmore Sand and Soil Sand Quarry, the Cleary Bros (Bombo) Albion Park Quarry and several small waste depot/material recycling facilities.

With the exception of the adjacent Sydney Trains Bombo Quarry, the identified NPI and EPL operations are unlikely to directly influence baseline air quality at the residences surrounding the quarry, with any indirect contribution accounted for in the air quality monitoring data collated for the area (Section 6.2). For cumulative impact assessment purposes, emissions from the Sydney Trains Bombo Quarry have been estimated and modelled (see Section 6.3 for further detail).

Other sources that contribute to particulate matter concentrations in the vicinity of the quarry include:

- dust entrainment and tyre and break wear due to vehicle movements along public roads;
- petrol and diesel emission from vehicle movements along public roads;
- regional industrial emission sources to the north in the Port Kembla area;
- agricultural practices;
- wind generated dust from exposed areas within the surrounding region;
- seasonal emissions from household wood burning fires; and
- sea salts contained in sea breezes.

More remote sources which contribute episodically to suspended particulates in the region include dust storms and bushfires.

6.2 Background air quality environment

6.2.1 PM_{10}

A time series of recorded 24-hour average PM_{10} concentrations at the Albion Park South AQS is presented in Figure 6.1. Recorded 24-hour average PM_{10} concentrations fluctuate throughout the presented period, with higher concentrations recorded between September and May. Concentrations at the Albion Park South AQS are typically below the EPA assessment criterion of 50 µg/m³. Two exceedances were recorded in October 2013 which coincided with the extensive bushfires that occurred across NSW.

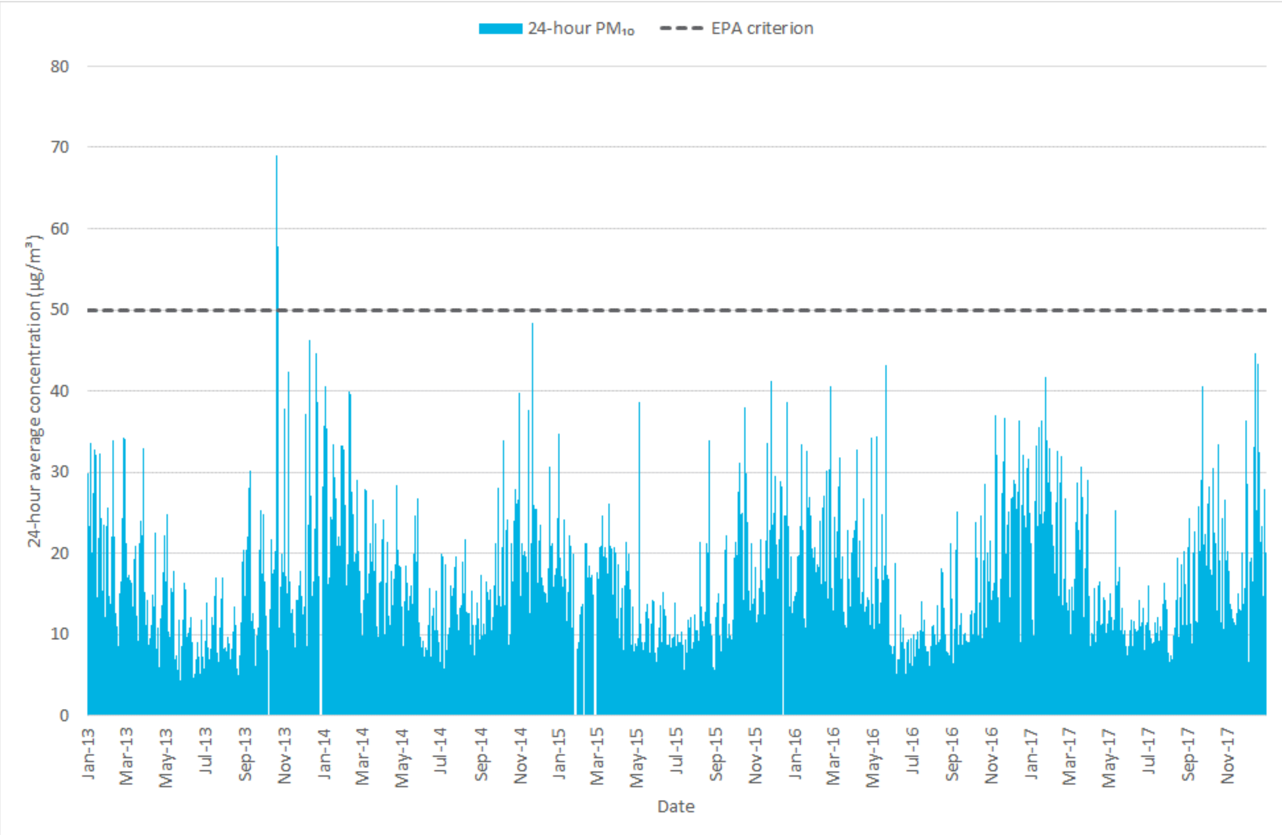

Figure 6.1 Time series of 24-hour average PM_{10} concentrations – OEH Albion Park South AQS – 2013 to 2017

Key statistics for the five years of analysed data from the Albion Park South AQS are presented in Table 6.2. Excluding the maximum concentration and exceedance days for 2013, attributed to extensive bushfire activity as previously noted, the presented statistics are comparable across the five years of monitoring data. Additionally, the frequency of recorded PM_{10} concentrations at the Albion Park South AQS by year for the period 2013 to 2017 is illustrated in Figure 6.2. The distribution of recorded concentrations is comparable across all five years of presented data and it is therefore considered that all years provide a representative dataset for baseline purposes.

Table 6.2 Statistics for PM_{10} concentrations – OEH Albion Park South AQS – 2013 to 2017

Year	Maximum	95th percentile	90th percentile	75th percentile	Median	Average	Days > 50 µg/m³
	24-hour average PM_{10} concentration (µg/m³)						
2013	69.0	32.3	24.9	17.5	12.3	14.2	2
2014	48.3	29.6	25.9	19.9	15.1	16.1	0
2015	41.2	26.0	22.1	17.3	12.2	13.3	0
2016	43.1	30.3	25.6	19.4	12.8	14.7	0
2017	44.6	30.2	25.9	19.1	12.9	15.3	0

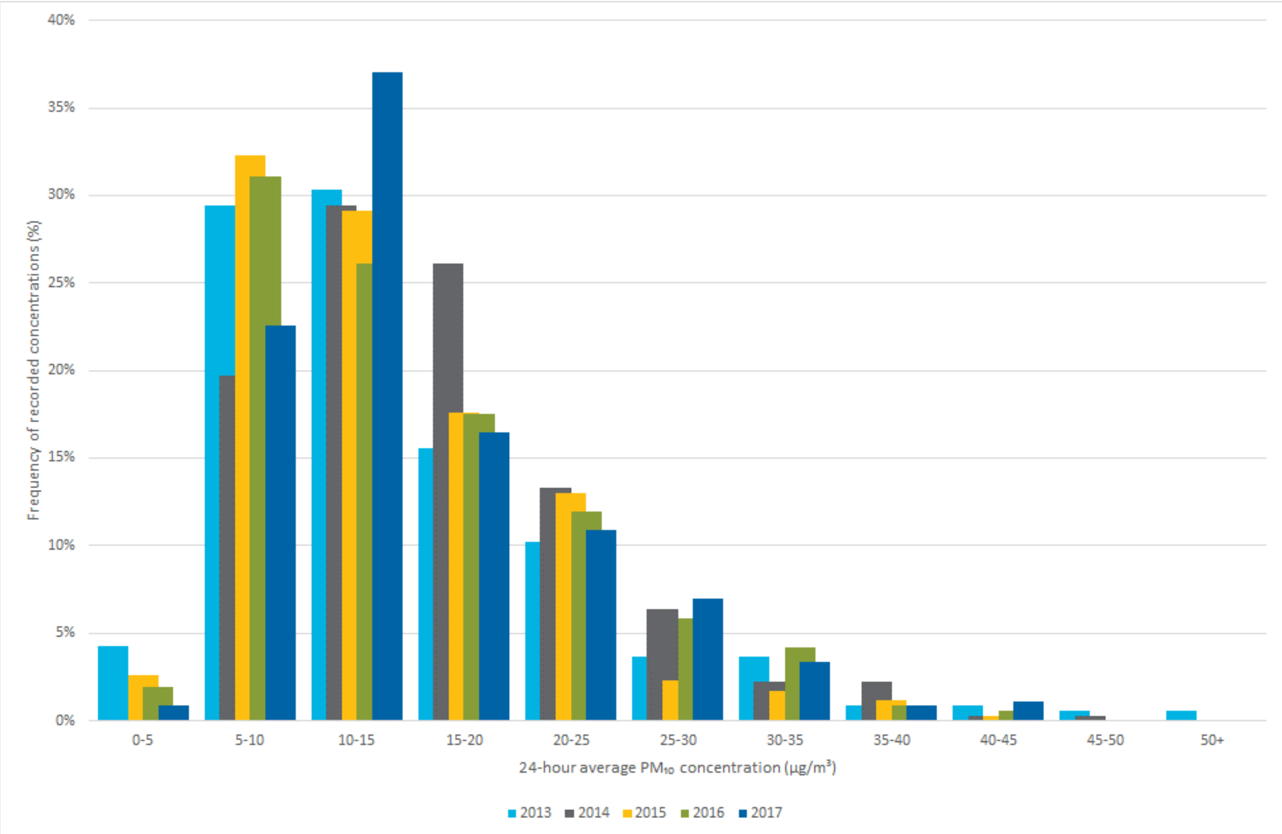

Figure 6.2 Frequency distribution of PM_{10} monitoring data – OEH Albion Park South AQS – 2013 to 2017

The relationship between recorded 1-hour average PM_{10} concentrations, wind speed and direction at the Albion Park South AQS is illustrated in Figure 6.3. This plot is a bivariate pollution rose, with average recorded PM_{10} concentration represented by the changing colour scale relative to the wind direction (angular axis) and wind speed (radial axis). Figure 6.3 highlights that higher PM_{10} concentrations are experienced when winds are strong and from the south-east and north-east. Based on the distribution in Figure 6.3 and the location of the Albion Park South AQS, the likely contributing sources to recorded PM_{10} concentrations are sea spray (both south-east and north-east components), neighbouring quarrying operations (south-east component) and urban emission (domestic heating, motor vehicles).

Consistent with the 2017 calendar year meteorological dataset adopted for the modelling period, the 2017 calendar year PM_{10} dataset from the Albion Park South AQS has been adopted to represent baseline conditions.

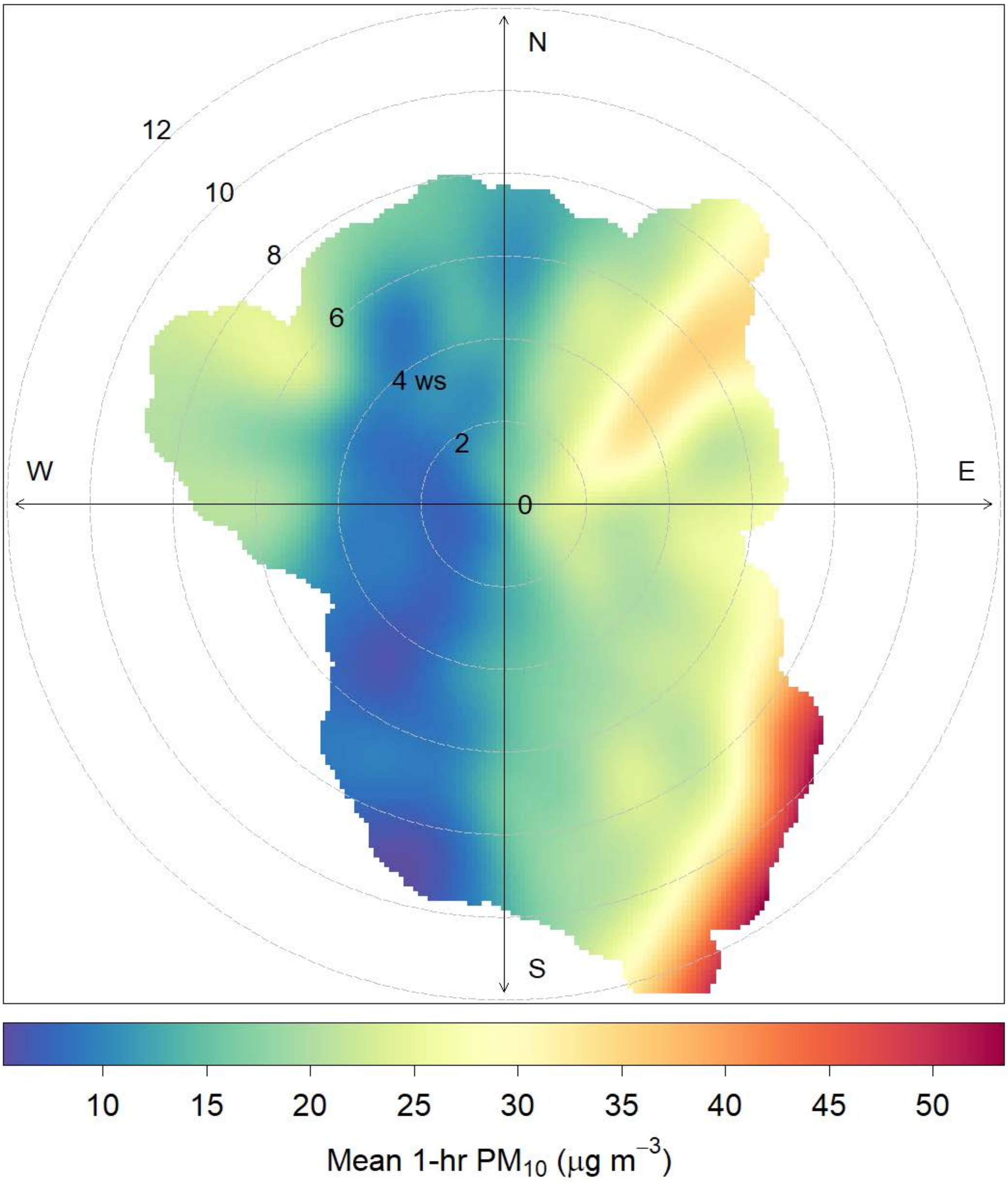

Figure 6.3 Bivariate pollution rose – 1-hour average PM_{10} concentrations (µg/m³) by wind speed (ms^{-1}) and direction (deg) – OEH Albion Park South AQS – 2013 to 2017

6.2.2 $PM_{2.5}$

The Albion Park South AQS commenced measurement of $PM_{2.5}$ concentrations in March 2015. To complete the five-year period of data analysis, hourly $PM_{2.5}$ concentrations for 2013 and 2014 from the NSW OEH Wollongong AQS, located 26 km north of the quarry, were also reviewed. A time series of recorded 24-hour average $PM_{2.5}$

concentrations at the Wollongong (2013 and 2014) and Albion Park South (2015 to 2017) AQS locations is presented in Figure 6.4. Like the PM_{10} concentrations, the recorded 24-hour average $PM_{2.5}$ concentrations fluctuate throughout the presented period. Recorded $PM_{2.5}$ concentrations were generally below the EPA assessment criterion of 25 µg/m³. Five exceedances were recorded in October and November 2013 which coincided with the extensive bushfires that occurred across NSW at that time. Two exceedances were also recorded in May 2016, which were classed as exceptional events attributed to hazard reduction burns (OEH, 2017).

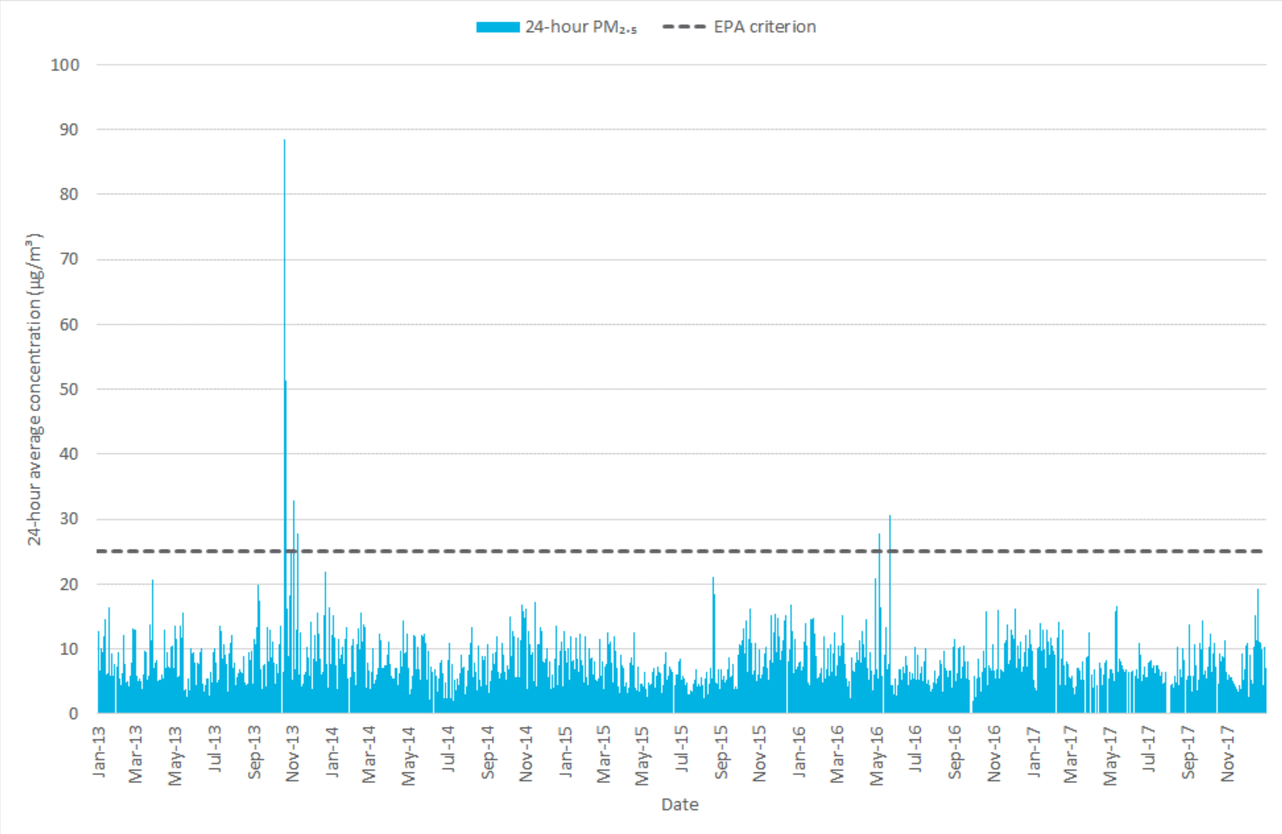

Figure 6.4 Time series of 24-hour average $PM_{2.5}$ concentrations – OEH Albion Park South and Wollongong AQS – 2013 to 2017

Note: Monitoring of $PM_{2.5}$ at the Albion Park South AQS commenced in March 2015. $PM_{2.5}$ data from Wollongong AQS presented for 2013 and 2014.

Key statistics for the five years of analysed $PM_{2.5}$ monitoring data from the Wollongong and Albion Park South AQS locations are presented in Table 6.3. While 2013 demonstrates higher concentrations across presented statistics due to the greater influence of bushfire/hazard reduction burns, the four other years of monitoring data are comparable. The comparable nature of 2014 to 2017 is also reflected in the frequency histogram of recorded $PM_{2.5}$ (Figure 6.5). From the five-year period analysed, it is considered that the years 2014 through to 2017 provide the most appropriate representation of background $PM_{2.5}$ concentrations for the region.

Consistent with the 2017 calendar year meteorological dataset adopted for the modelling period, the 2017 calendar year $PM_{2.5}$ dataset from the Albion Park South AQS has been adopted to represent background conditions.

Table 6.3 Statistics for $PM_{2.5}$ concentrations – OEH Wollongong and Albion Park South AQS – 2013 to 2017

Year	Maximum	95th percentile	90th percentile	75th percentile	Median	Average	Days > 25 µg/m³
	24-hour average $PM_{2.5}$ concentration (µg/m³)						
2013	88.4	15.1	12.7	8.9	6.2	7.3	5
2014	17.3	12.8	11.5	8.9	6.1	6.5	0
2015	21.1	12.5	10.8	7.7	5.3	6.0	0
2016	30.7	12.8	10.9	8.3	6.0	6.4	2
2017	19.3	11.2	10.3	7.4	5.6	6.4	0

Note: Monitoring of $PM_{2.5}$ at the Albion Park South AQS commenced in March 2015. $PM_{2.5}$ data from Wollongong AQS presented for 2013 and 2014.

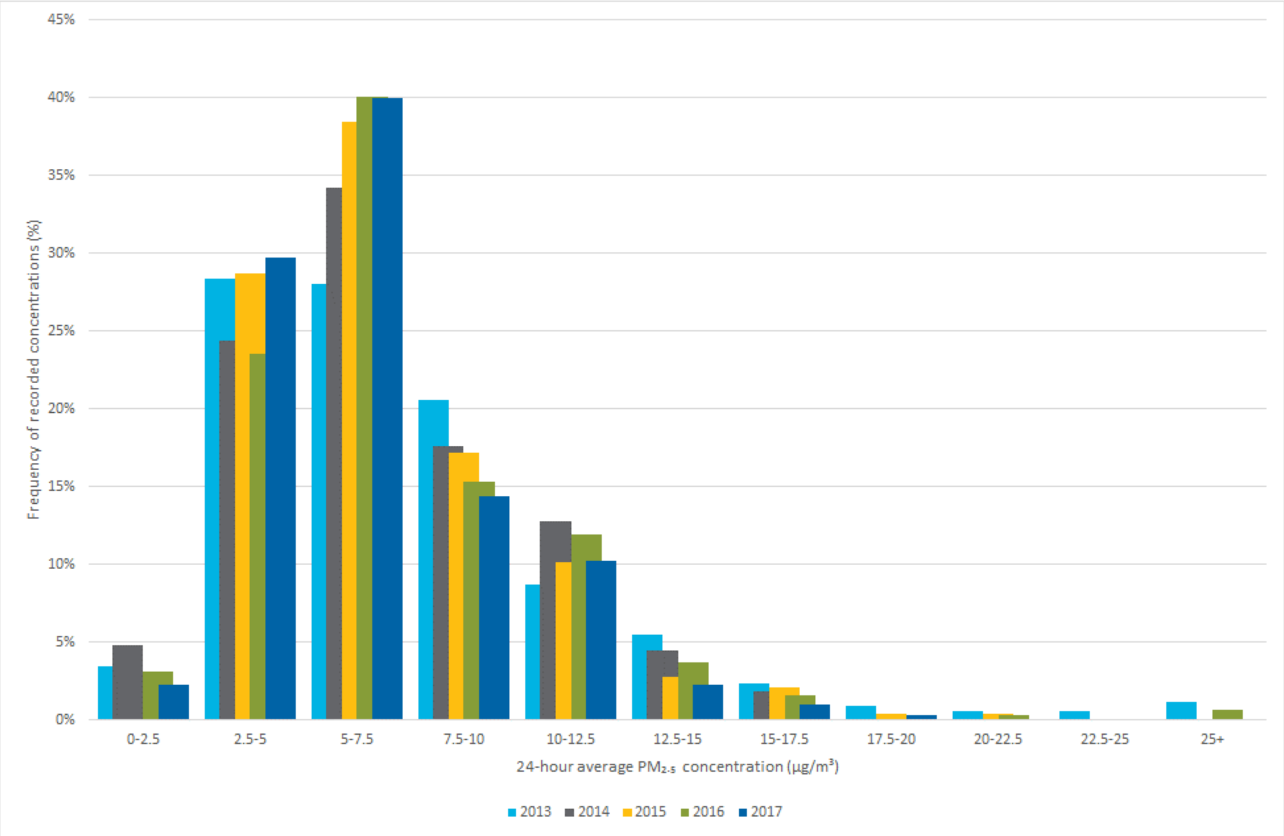

Figure 6.5 Frequency distribution of $PM_{2.5}$ monitoring data – OEH Wollongong and Albion Park South AQS – 2013 to 2017

Note: Monitoring of $PM_{2.5}$ at the Albion Park South AQS commenced in March 2015. $PM_{2.5}$ data from Wollongong AQS presented for 2013 and 2014.

The relationship between recorded 1-hour average $PM_{2.5}$ concentrations, wind speed and direction at the Wollongong and Albion Park South AQS locations is illustrated in Figure 6.6. Like the relationship for recorded PM_{10} concentrations (Figure 6.3), recorded $PM_{2.5}$ concentrations are higher when winds are from the south-east and north-east. Differing from the plot for PM_{10} concentrations, elevated $PM_{2.5}$ concentrations are also evident for lighter wind speeds and for periods where winds are from the north-west. This difference is considered reflective of local urban area combustion emission sources, such as domestic heating and motor vehicle emissions, which have a higher proportion of fine particulate matter.

6.2.3 TSP

There are no measurements of TSP at the quarry. The typical ratio between annual average PM_{10} and TSP concentrations is between 0.4 and 0.5. In the absence of locally sourced TSP monitoring data, a ratio of 0.4 has been applied to the annual average PM_{10} concentration for 2017 from the Albion Park South AQS (see Section 6.2.1), returning a TSP background concentration of 38.3 µg/m³.

6.2.4 Dust deposition

Boral have three dust deposition gauges installed in the vicinity of the quarry currently recording dust deposition levels:

- Site 3 – Seabreeze Apartments - Glenbrook Street, Kiama (offsite to the south of quarry boundary);
- Site 4 - Honey Farm - end Riverdale Drive (offsite to northwest of quarry boundary); and
- Site 7 - John Holland North Kiama Bypass (onsite to west of CBP and stockpiling area).

Boral provided records of dust deposition rates recorded at three locations in the vicinity of the quarry. Dust deposition results for the previous five years were processed, with the results presented in Table 6.4.

Table 6.4 Annual dust deposition results – Boral monitoring locations at quarry

Monitoring year	Annual average dust deposition levels (g/m²/month)		
	Site 3	Site 4	Site 7
2013-2014	-	-	2.5
2014-2015	2.4	2.9	2.5
2015-2016	2.4	1.8	3.4
2016-2017	2.0	2.3	2.5
2017-2018	2.2	2.5	2.4
Criterion	**4**		

Note: annual deposition rates presented for the 12-month period between July and June of the following year

For all years of monitoring, the applicable impact assessment criterion was not exceeded at any monitoring location. The highest annual average dust deposition level recorded for the 2017-2018 period was 2.5 g/m²/month at Site 4. This value will be adopted as background for this assessment.

It should be noted that Boral's Bombo quarry was not operational at this time, but monitoring was undertaken as part of the EPL requirements.

6.2.5 Adopted background summary

The baseline air quality conditions for the quarry area, based on the analysis presented in the preceding sections, are summarised in Table 6.5.

Table 6.5 Adopted background air quality conditions

Pollutant	Averaging period	Value	Unit
TSP	Annual	38.3	µg/m³
PM_{10}	24-hour	Daily varying	
	Annual	15.3	
$PM_{2.5}$	24-hour	Daily varying	
	Annual	6.4	
Dust deposition	Month	2.5	g/m²/month

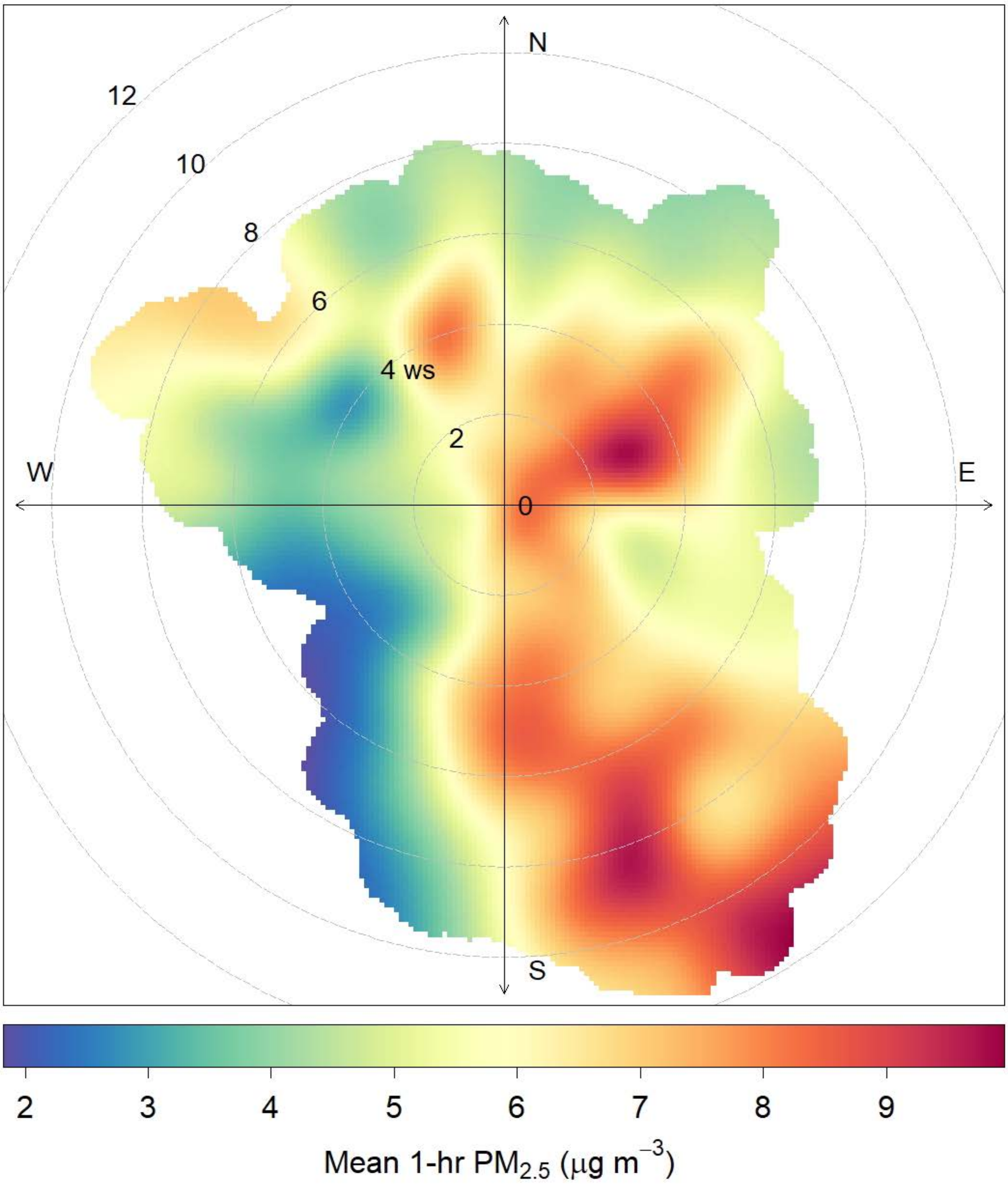

Figure 6.6 Bivariate pollution rose – 1-hour average $PM_{2.5}$ concentrations (µg/m³) by wind speed (ms^{-1}) and direction (deg) – OEH Albion Park South AQS – 2013 to 2017

Note: Monitoring of $PM_{2.5}$ at the Albion Park South AQS commenced in March 2015. $PM_{2.5}$ data from Wollongong AQS presented for 2013 and 2014.

6.3 Existing and neighbouring operations

Due to the distance of the Albion Park AQS from the quarry and the neighbouring Sydney Trains Bombo Quarry, it is unlikely that the impacts from these operations are appropriately accounted for in the adopted Albion Park South AQS monitoring datasets. For the purpose of cumulative impact analysis at sensitive receptors surrounding the quarry, it is considered necessary to quantify potential emissions and associated impacts from the Sydney Trains Bombo Quarry.

Due to a lack of detail relating to the Sydney Trains Bombo Quarry in the public domain, a range of assumptions have been made in order to quantify emissions from approved operations at that site. According to the EPL for the Sydney Trains Bombo Quarry (EPL 79), the site is approved to extract, process or store up to 2 Mtpa of material. To conservatively estimate impacts from the Sydney Trains Bombo Quarry, emissions are estimated based on a maximum approved throughput of 2 Mtpa, even though the actual production volumes for the Sydney Trains quarry is expected to be much less than this. Full details of the emissions inventory prepared for the Sydney Trains Bombo Quarry are listed in Appendix B.

In order to understand the magnitude of historical impacts from approved operations at the site and the Sydney Trains Bombo Quarry, emission estimation and dispersion modelling has been conducted for the following sources:

- quarry operations at the maximum approved extraction and processing rate of 500,000 tpa;
- Boral CPB operations at the approved maximum daily traffic rate of 46 movements per day; and
- Sydney Trains Bombo Quarry operations at the maximum approved extraction and processing rate of 2,000,000 tpa.

In the absence of operational specifics for any of these approved operations, particulate matter emissions inventory calculations were completed using several assumptions based on EMM's experience with the assessment of quarry and CBP operations. These assumptions are listed in Appendix B.

A summary of calculated annual particulate matter emissions for the three existing operations at maximum licenced production rates is presented in Table 6.6.

Table 6.6 Calculated annual emission totals – existing licenced operations

Approved operation	Annual emissions (kg/annum)		
	TSP	PM_{10}	$PM_{2.5}$
Boral Bombo Quarry	46,764.3	18,439.9	3,212.5
Boral CBP	7,296.6	2,022.3	235.5
Sydney Trains Bombo Quarry	92,556.2	36,536.1	7,879.4

Dispersion modelling was conducted for the three approved operations based on the quantified maximum production rates for each site. The cumulative impacts at each of the sensitive receptor assessment locations surrounding the quarry site are presented in Table 6.7 have been assessed in the following way:

- for 24-hour average concentrations, the predicted 24-hour average model predictions for PM_{10} and $PM_{2.5}$ from each operation, for each day of the modelling period, has been combined with the corresponding background 24-hour average PM_{10} and $PM_{2.5}$ concentration from the NSW OEH Albion Park South 2017 monitoring dataset, as presented in Section 6.2; and
- for annual average concentrations and deposition rates, the predicted annual average concentrations and deposition rates have been paired with the corresponding background annual average levels listed in Table 6.5.

Predicted cumulative TSP, PM_{10} and $PM_{2.5}$ concentrations and dust deposition levels associated with the three existing operations are summarised in Table 6.7. These predicted cumulative concentrations are considered a baseline for approved operations, and used for comparison with modelling results for proposed worst case material importation activities at the quarry (Section 8).

Table 6.7 Cumulative (existing approved operations + background) concentration and deposition results

Receptor ID	Predicted cumulative concentration (µg/m³) or deposition rate (g/m²/month)					
	TSP	PM_{10}		$PM_{2.5}$		Dust deposition
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	Annual
Criterion	90	50	25	25	8	4
R1	41.2	45.1	16.2	19.4	6.5	2.6
R2	42.6	44.7	16.6	19.4	6.6	2.8
R3	42.3	44.7	16.5	19.4	6.6	2.7
R4	49.8	44.9	18.3	19.5	6.9	3.2
R5	45.5	44.7	18.6	19.5	6.9	2.9
R6	39.8	44.6	16.2	19.3	6.5	2.5
R7	38.1	44.6	15.4	19.3	6.4	2.4
R8	38.2	44.6	15.4	19.3	6.4	2.4
R9	38.2	44.6	15.4	19.3	6.4	2.4
R10	38.3	44.6	15.5	19.3	6.4	2.4
R11	40.9	46.1	16.3	19.6	6.6	2.6
R12	42.3	48.9	16.6	20.1	6.6	2.7
R13	41.2	47.0	16.2	19.6	6.5	2.6

7 Emissions inventory

Fugitive dust sources associated with the proposed importation and emplacement of material at the quarry were quantified through the application of NPI emission estimation techniques and United States Environmental Protection Agency (US-EPA) AP-42 emission factor equations. Particulate matter emissions were quantified for the three size fractions identified in Section 4.1, with the TSP fraction also used to provide an indication of dust deposition rates. Coarse particles (PM_{10}) and fine particle ($PM_{2.5}$) were estimated using ratios for the different particle size fractions available within the literature (principally the US-EPA AP-42).

7.1 Material delivery options and selected emission scenario

As discussed in Section 2.2.1, Boral is investigating several options for the delivery of material to the quarry. Each of the material delivery options was reviewed for particulate matter emission generation potential on a qualitative basis. It was determined that the material delivery option with the greatest potential for particulate matter emission generation was Wagon Option 2 (as per Table 2.4). This option involves the delivery of material to site by bottom-dump wagons, transfer to an initial storage stockpile, loading to off-road haul truck by front end loader (FEL) and haulage to the pit for campaign crushing as required and emplacement.

Consequently, the Wagon Option 2 material delivery option was selected for the quantification of worst-case potential impacts from the proposed rail delivery of material to the quarry.

To assess the potential impacts associated with the proposed material delivery at the quarry, two emissions scenarios have been developed:

- average day, assuming delivery at a rate of 9,000 tpd; and
- peak day, assuming delivery at a rate of 12,000 tpd.

For both the average day and peak day scenarios, it is also assumed that a proportion of the total incoming material is delivered to site by road trucks. Transport via road would be capped consistent with peak historical traffic volumes from the site; ie on average up to a total of 222 truck movements per day.

The average day scenario is used to predict compliance with annual average criteria, while the peak day scenario is used to predict compliance with 24-hour average criteria. Modelling assumptions made in this assessment are listed within Appendix B.

7.2 Sources of operational emissions

Sources of atmospheric emissions associated with the material importation scenario include:

- locomotive combustion emissions;
- unloading from bottom-dump rail wagons;
- conveying and stockpiling of unloaded material;
- loading to off-road haul trucks for transportation of material to pit;
- unloading, handling and crushing of material within the pit;
- material emplacement within the pit using a dozer and two compactors;

- direct delivery of material to the pit via road truck;
- diesel fuel combustion by on-site plant and equipment; and
- wind erosion associated with material stockpiles and exposed surfaces.

Emissions of non-particulate matter pollutants (including NO_x, CO and SO_2) associated with diesel fuel combustion are likely to be minor in nature relative to particulate matter emissions. Such emissions were not included in this assessment.

7.3 Emission reduction factors

The following emission reduction factors were applied to select emission sources associated with the material importation activities at the quarry:

- 30% for wind breaks (NPI, 2012) to account for the bottom dump unloading of material from incoming rail wagons;
- 86% reduction for unpaved road traffic emissions for the combined use of water sprays (75%, NPI 2012) and travel speeds below 40 km/hr (US-EPA, 2011);
- 70% reduction for enclosure (NPI, 2012) for activities occurring within the processing shed; and
- 50% reduction for water sprays (NPI, 2012) for material storage stockpiles at the rail unloading area and inside the pit, material crushing in the pit and dozer/compactor operations in the pit.

While not quantifiable through an emission reduction factor, the following operational management controls were also integrated into the emissions assessment:

- all activities, excluding train unloading, initial material stockpiling after wagon unloading and road truck deliveries of material to the quarry site, will be limited to the hours of 7 am and 10 pm; and
- road truck deliveries will operate up to a maximum of 65% of capacity between the hours of 10 pm and 7 am.

7.4 Particulate matter emissions

A summary of annual site emissions, based on the average day scenario, by source type is presented in Table 7.1 and illustrated in Figure 7.1. Particulate matter control measures, as documented in Section 7.3 are accounted for in these emission totals.

For proposed material delivery operations, the most significant source of emissions are associated with the movement of vehicles across unpaved road surfaces. Dozer and compactor operations in the pit are also a notable contributor to annual emissions, principally for larger particle size emissions. The significance of diesel combustion emissions (mobile equipment, trucks and locomotives) increases with decreasing particle size. Further details regarding emission estimation factors and assumptions are provided in Appendix B.

Table 7.1 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions – average day rate

Emissions source	**Calculated annual emissions (kg/annum) by source**		
	TSP	**PM_{10}**	**$PM_{2.5}$**
Road delivery to site - paved	1,461.6	280.6	67.9
Road delivery to site - unpaved	10,441.1	2,877.8	287.8
Road delivery site to pit - unpaved	7,457.9	2,055.5	205.6
Train wagon unloading	421.1	199.2	30.2
Initial material stockpile loading	601.6	284.5	43.1
Material to haul truck by FEL	601.6	284.5	43.1
Haulage to pit - unpaved	22,304.5	6,147.6	614.8
Haul truck unloading in pit	753.9	356.6	54.0
Loading to mobile crusher	152.3	72.0	10.9
Mobile crusher in pit	675.0	300.0	55.0
Handling of crushed material in pit	152.3	72.0	10.9
Dozer/compactor activities in pit	15,904.0	3,455.9	362.9
Wind erosion - pit	4,710.7	2,355.4	353.3
Wind erosion - stockpiling area	2,097.2	1,048.6	157.3
Diesel combustion - onsite plant	1,198.0	1,198.0	1,100.5
Diesel combustion - locomotives	634.4	634.4	615.4
Total	**69,567.2**	**21,622.6**	**4,012.4**

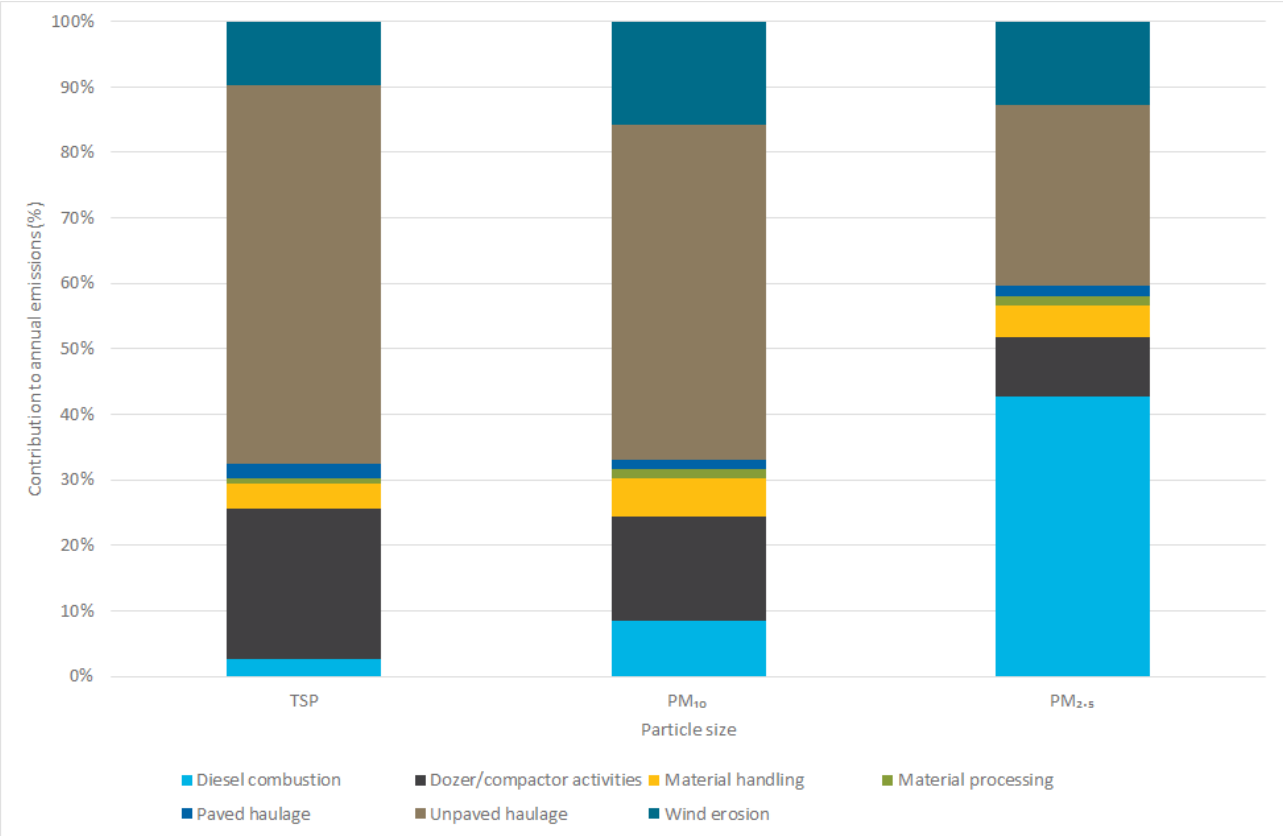

Figure 7.1 Contribution to annual emissions by emissions source type and particle size

8 Air dispersion modelling

8.1 Dispersion model selection and configuration

The atmospheric dispersion modelling completed within this assessment used the AMS/US-EPA regulatory model (AERMOD) (US-EPA, 2004). AERMOD is designed to handle a variety of pollutant source types, including surface and buoyant elevated sources, in a wide variety of settings such as rural and urban as well as flat and complex terrain.

In addition to the 13 individual receptor locations (documented in Section 2.1), particulate matter concentrations were predicted over a 5.5 km by 5.5 km domain featuring nested grids (a 1.5 km domain with 100 m resolution, a 4.5 km domain with 200 m resolution and a 5.5 km domain with 500 m resolution).

Simulations were undertaken for the 12 month period of 2017 using the AERMET-generated file based largely on the BoM Kiama (Bombo Headland) AWS meteorological monitoring dataset as input (see Chapter 5 for description of input meteorology).

Emissions were modelled for peak day (12,000 tpd) operational emissions to predict 24-hour average concentrations and average day (9,000 tpd) operational emissions for annual average concentrations and deposition rates. The methodology and results of the emissions inventory developed for this study are presented in Chapter 7 and Appendix B.

8.2 Incremental (site-only) results

Predicted incremental TSP, PM_{10}, $PM_{2.5}$ concentrations and dust deposition rates from proposed Wagon Option 2 material delivery activities are presented in Table 8.1 for each of the selected receptor locations. As discussed, the 24-hour average predictions are based on the peak day scenario (12,000 tpd delivery) while annual average predictions are based on average day scenario (9,000 tpd delivery).

The predicted concentrations and deposition rates for all pollutants and averaging periods are below the applicable EPA assessment criterion at all neighbouring receptors.

With the exception of dust deposition, the assessment criteria listed are applicable to cumulative concentrations. Analysis of cumulative impact compliance is presented in Section 8.3.

Isopleth plots, illustrating spatial variations in site-related incremental TSP, PM_{10} and $PM_{2.5}$ concentrations and dust deposition rates are provided in Appendix C. Isopleth plots of the maximum 24-hour average concentrations presented in Appendix C do not represent the dispersion pattern on any individual day, but rather illustrate the maximum daily concentration that was predicted to occur at each model calculation point given the range of meteorological conditions occurring over the 2017 modelling period.

Table 8.1 Incremental (Wagon Option 2 material delivery activities only) concentration and deposition results

Receptor ID	Predicted incremental concentration (µg/m³) or deposition rate (g/m²/month)					
	TSP	PM_{10}		$PM_{2.5}$		Dust deposition
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	Annual
Criterion	90	50	25	25	8	2
R1	2.4	4.0	0.7	0.7	0.1	0.1
R2	1.7	3.8	0.6	0.8	0.1	0.1
R3	1.4	3.5	0.5	1.1	0.1	0.1
R4	1.8	7.0	0.6	1.4	0.2	0.1
R5	3.4	8.0	1.3	1.3	0.2	0.2
R6	2.2	4.6	0.7	0.8	0.1	0.1
R7	0.3	2.4	0.1	0.4	<0.1	<0.1
R8	0.4	7.7	0.1	1.2	<0.1	<0.1
R9	0.3	6.3	0.1	1.0	<0.1	<0.1
R10	0.7	5.3	0.2	0.9	<0.1	<0.1
R11	1.4	3.7	0.4	0.6	0.1	0.1
R12	1.4	3.4	0.5	0.6	0.1	0.1
R13	1.4	2.5	0.5	0.9	0.1	0.1

8.3 Cumulative (site + neighbouring sources + background) results

Cumulative impacts at each of the sensitive receptor assessment locations surrounding the quarry have been assessed in the following way:

- For 24-hour average concentrations, the predicted 24-hour average model predictions for PM_{10} and $PM_{2.5}$ from the Wagon Option 2 activities for each day of the modelling period has been combined with the corresponding model predicted concentrations for approved Boral CBP and Sydney Trains Bombo Quarry and the corresponding background 24-hour average PM_{10} and $PM_{2.5}$ concentration from the NSW OEH Albion Park South 2017 monitoring dataset.

- For annual average concentrations, the predicted annual average concentrations have been paired with the corresponding annual average concentrations for Boral CBP (model predicted), Sydney Trains Bombo Quarry (model predicted) and background annual average concentration (Table 6.5).

Predicted cumulative TSP, PM_{10} and $PM_{2.5}$ concentrations and dust deposition rates associated with the Wagon Option 2 activities are presented in Table 8.2 for each of the selected receptor locations.

Table 8.2 Cumulative (Wagon Option 2 material delivery + Boral CBP + Sydney Trains Bombo Quarry + background) concentration and deposition results

Receptor ID	Predicted cumulative concentration (µg/m³) or deposition rate (g/m²/month)					
	TSP	PM_{10}		$PM_{2.5}$		Dust deposition
	Annual	24-hour maximum	Annual	24-hour maximum	Annual	Annual
Criterion	90	50	25	25	8	4
R1	42.4	46.6	16.5	19.5	6.6	2.8
R2	42.5	44.7	16.5	19.5	6.6	2.9
R3	42.5	44.7	16.5	19.4	6.6	2.8
R4	49.3	44.7	18.1	19.5	6.9	3.3
R5	45.3	44.7	17.7	19.5	6.8	3.0
R6	40.8	44.7	16.2	19.3	6.5	2.7
R7	38.3	44.6	15.4	19.3	6.4	2.5
R8	38.5	44.6	15.5	19.3	6.4	2.5
R9	38.4	44.6	15.5	19.3	6.4	2.5
R10	38.8	44.6	15.6	19.3	6.4	2.6
R11	41.3	47.8	16.3	19.9	6.6	2.8
R12	42.3	49.1	16.6	20.2	6.7	2.8
R13	41.3	47.4	16.2	19.7	6.6	2.7

The predicted cumulative concentrations for all pollutants and averaging periods presented in Table 8.2are below the applicable EPA assessment criterion at all representative receptor locations for both peak day (12,000 tpd) and average day (9,000 tpd) material importation operations at the quarry.

To provide further analysis on cumulative concentrations and the significance of predicted concentration from proposed material delivery activities relative to ambient background concentrations, the following figures are presented:

- Figure 8.1 - daily-varying cumulative 24-hour average PM_{10} concentrations at the residential receptor with highest site-only contribution (receptor 5);
- Figure 8.2 - daily-varying cumulative 24-hour average PM_{10} concentrations at the residential receptor with highest cumulative concentration (receptor 12);
- Figure 8.3 - cumulative annual average PM_{10} concentrations at all receptor locations;
- Figure 8.4 - daily-varying cumulative 24-hour average $PM_{2.5}$ concentrations at the residential receptor with highest site-only contribution (receptor 4);
- Figure 8.5 - daily-varying cumulative 24-hour average $PM_{2.5}$ concentrations at the residential receptor with highest cumulative concentration (receptor 12); and
- Figure 8.6 - cumulative annual average $PM_{2.5}$ concentrations at all receptor locations.

All of the figures demonstrate that the ambient background levels, adopted from the Albion Park South air quality monitoring station, dominate total cumulative concentrations across the modelling period.

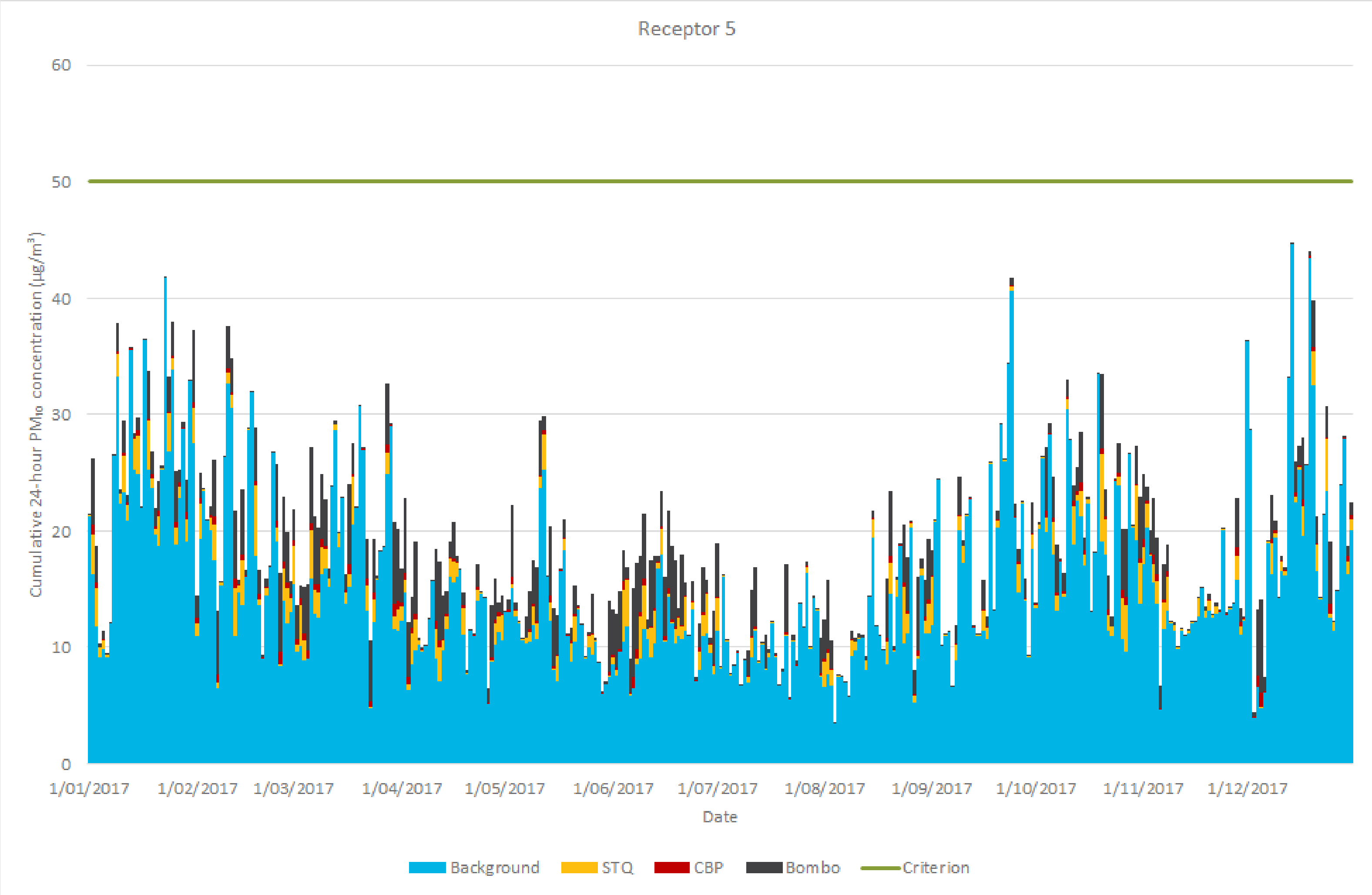

Figure 8.1 Daily-varying (24-hour average) cumulative PM_{10} concentrations at receptor 5 – Wagon Option 2 activities

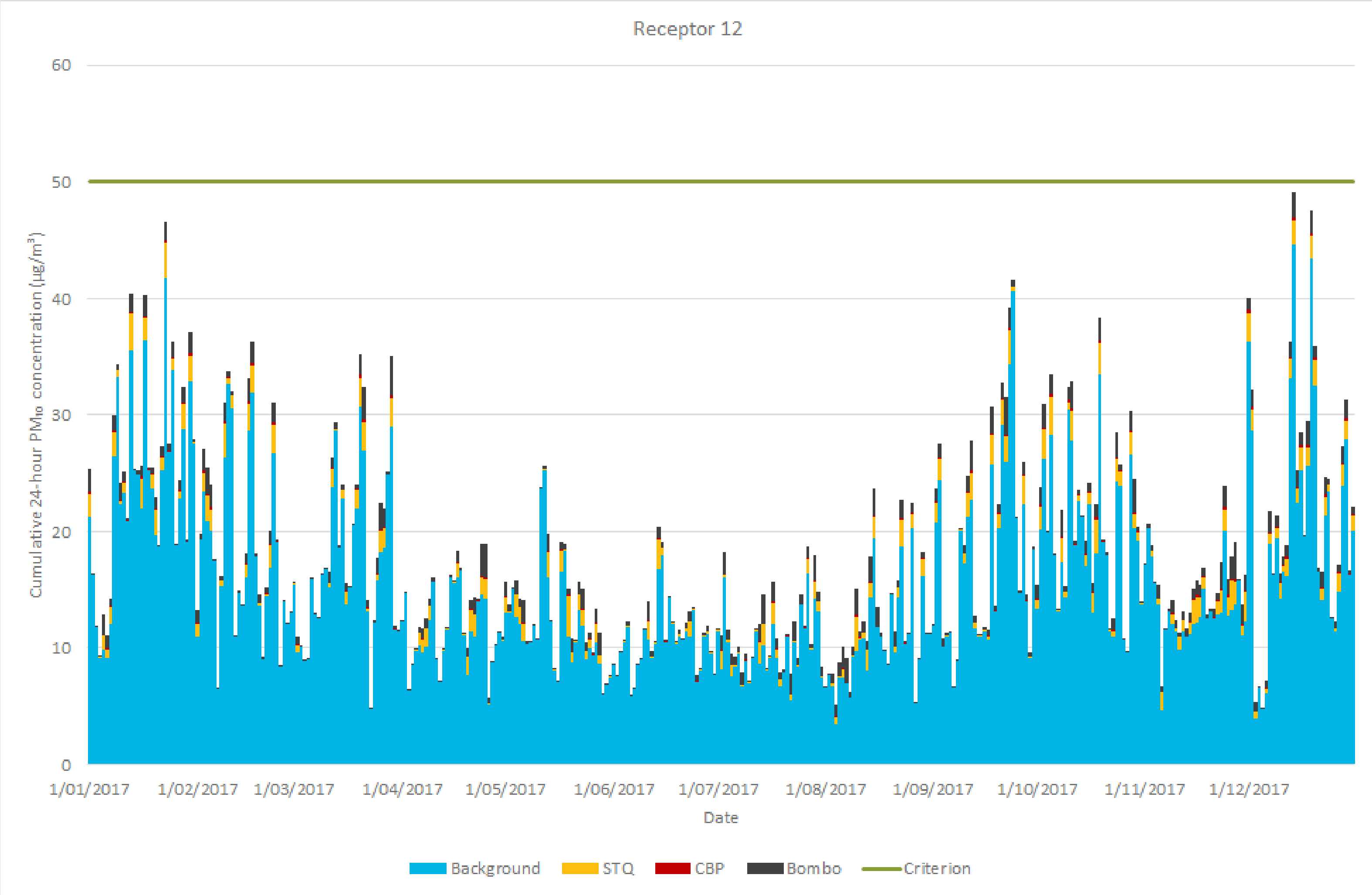

Figure 8.2 **Daily-varying (24-hour average) cumulative PM_{10} concentrations at receptor 12 – Wagon Option 2 activities**

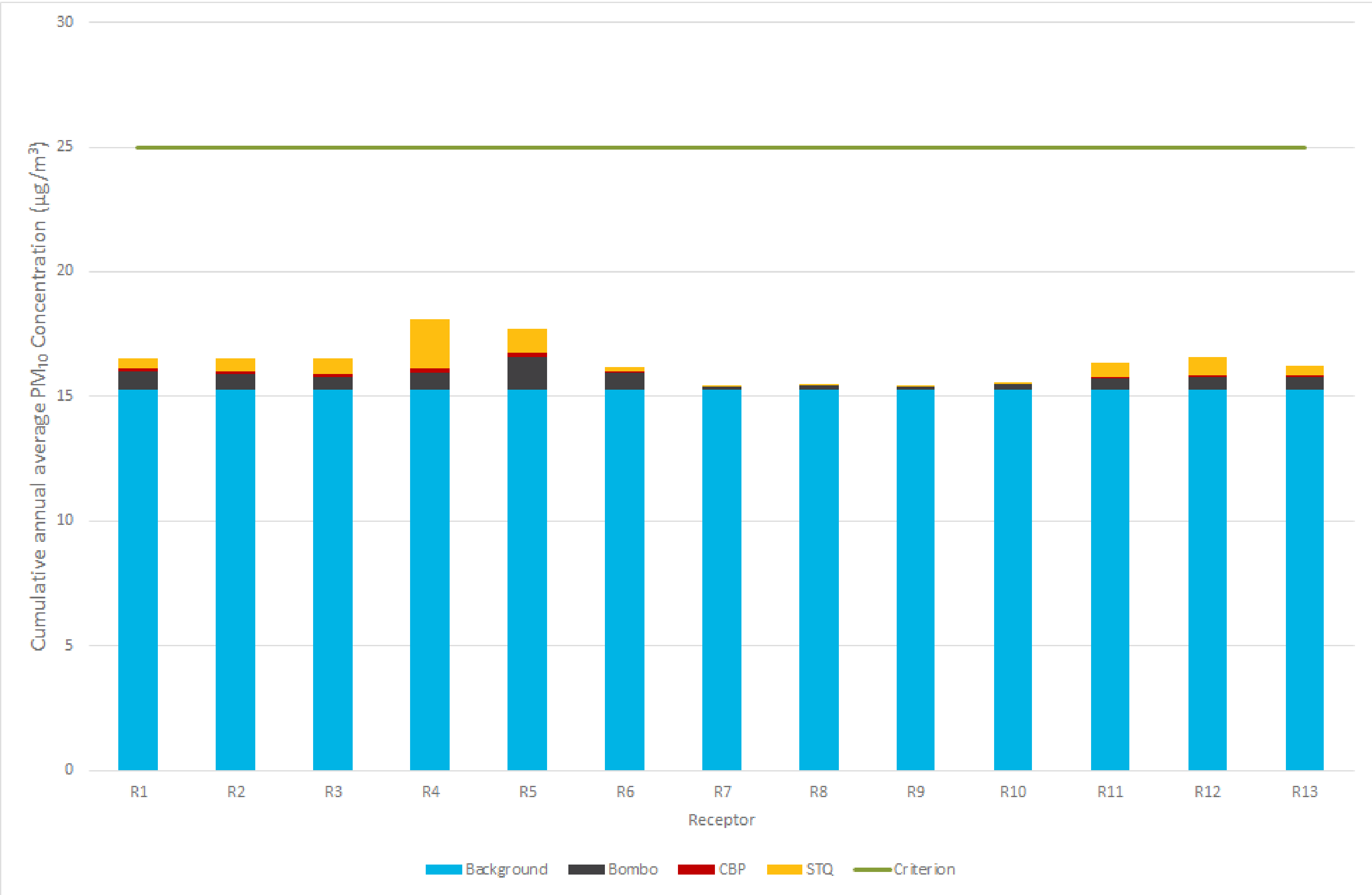

Figure 8.3 **Cumulative annual average PM_{10} concentrations by receptor location – Wagon Option 2 activities**

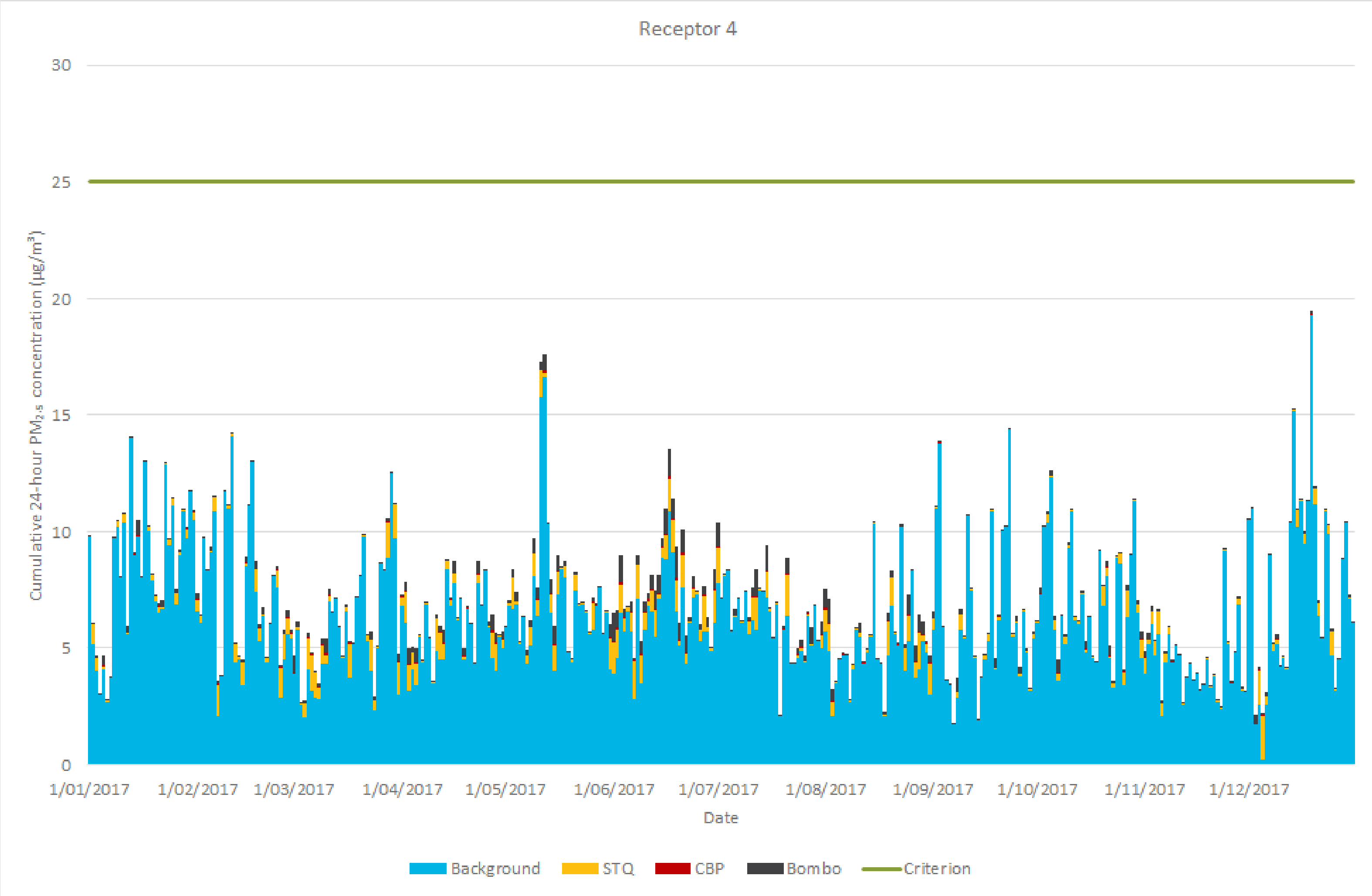

Figure 8.4 Daily-varying (24-hour average) cumulative $PM_{2.5}$ concentrations at receptor 4 – Wagon Option 2 activities

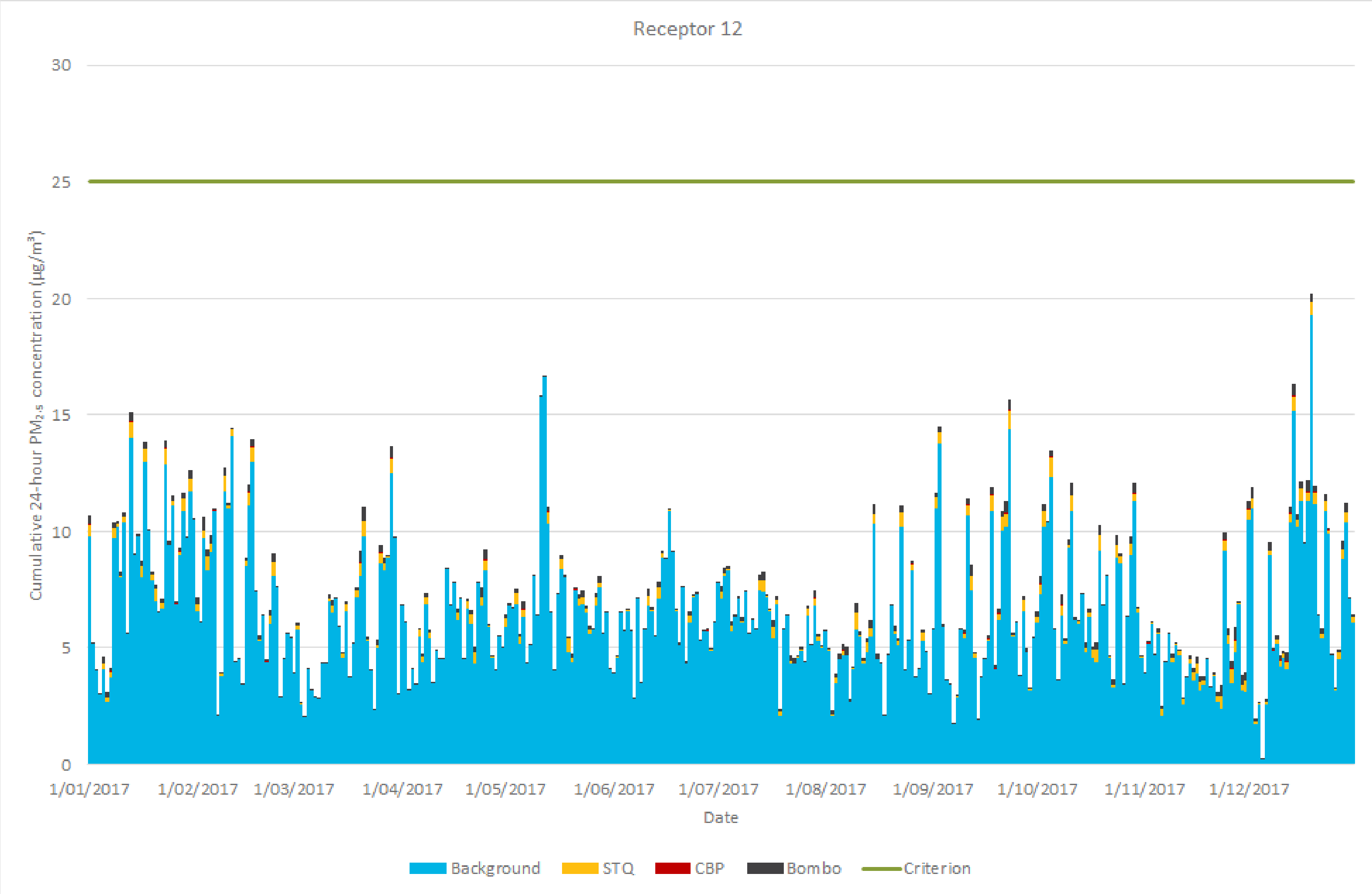

Figure 8.5 **Daily-varying (24-hour average) cumulative $PM_{2.5}$ concentrations at receptor 12 – Wagon Option 2 activities**

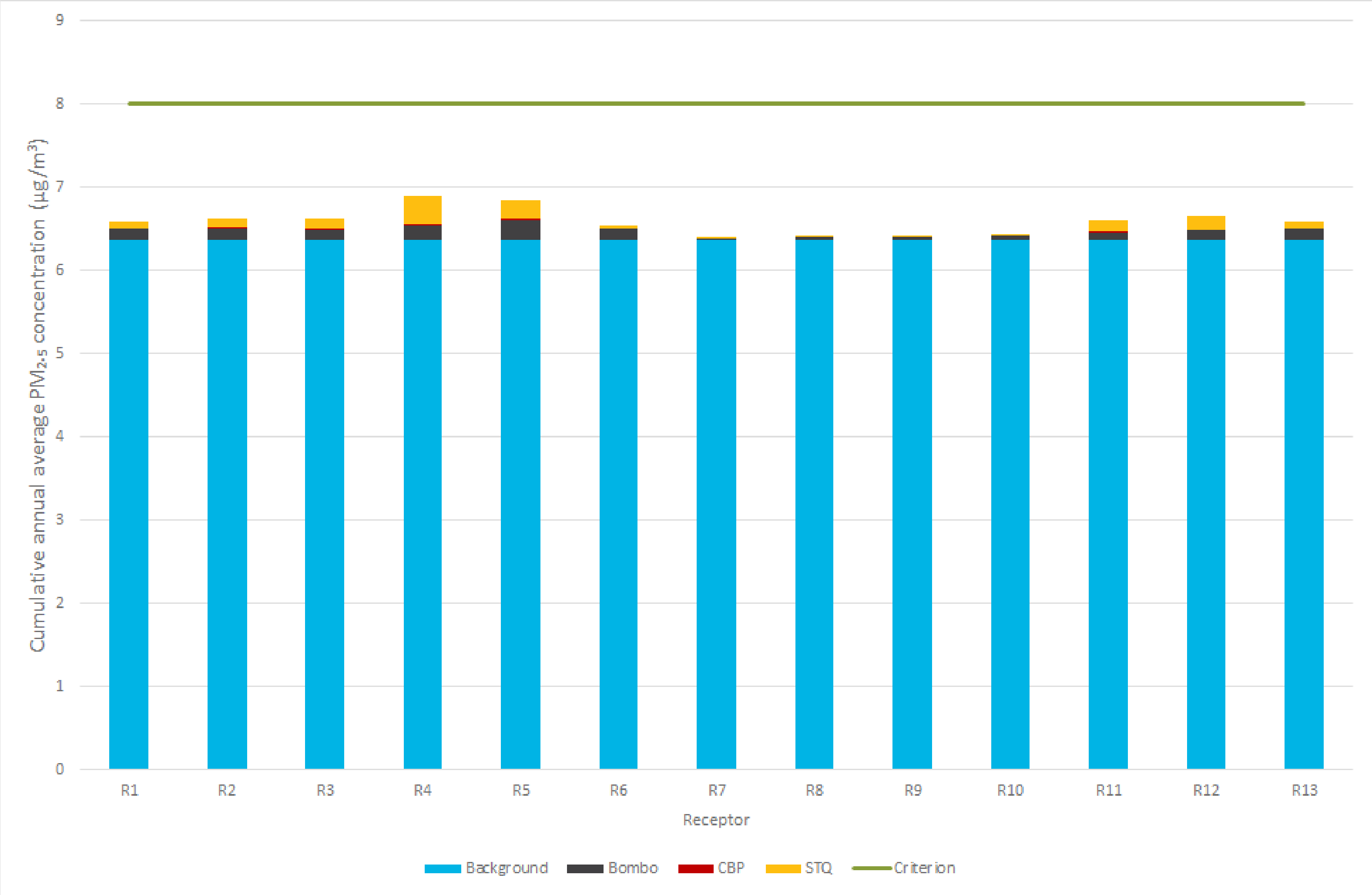

Figure 8.6 Cumulative annual average $PM_{2.5}$ concentrations by receptor location – Wagon Option 2 activities

8.4 Predicted change from existing maximum approved operations

In order to understand the significance of proposed material delivery activities and associated impacts, a comparison between the corresponding cumulative modelling results for approved maximum production rate activities at the quarry (Table 6.7) and the Wagon Option 2 (Table 8.2) was conducted. The relative change in predicted cumulative results between the two site configurations is presented in Figure 8.7. The following points are noted:

- cumulative concentrations under the Wagon Option 2 activities will decrease or remain similar to cumulative concentrations from existing approved operations at the quarry at the residential receptors to the north of the quarry site (receptor 3, 4 and 5);
- cumulative concentrations under the Wagon Option 2 activities will increase at the receptors to the south-east and south of the quarry (receptor 1, 11, 12 and 13;
- the predicted change at all receptors, increase or decrease, is less than 5% and is therefore considered minor; and
- the results of the modelling indicate that the proposed worst case material delivery emissions return air quality impacts that are comparable to existing consented operations

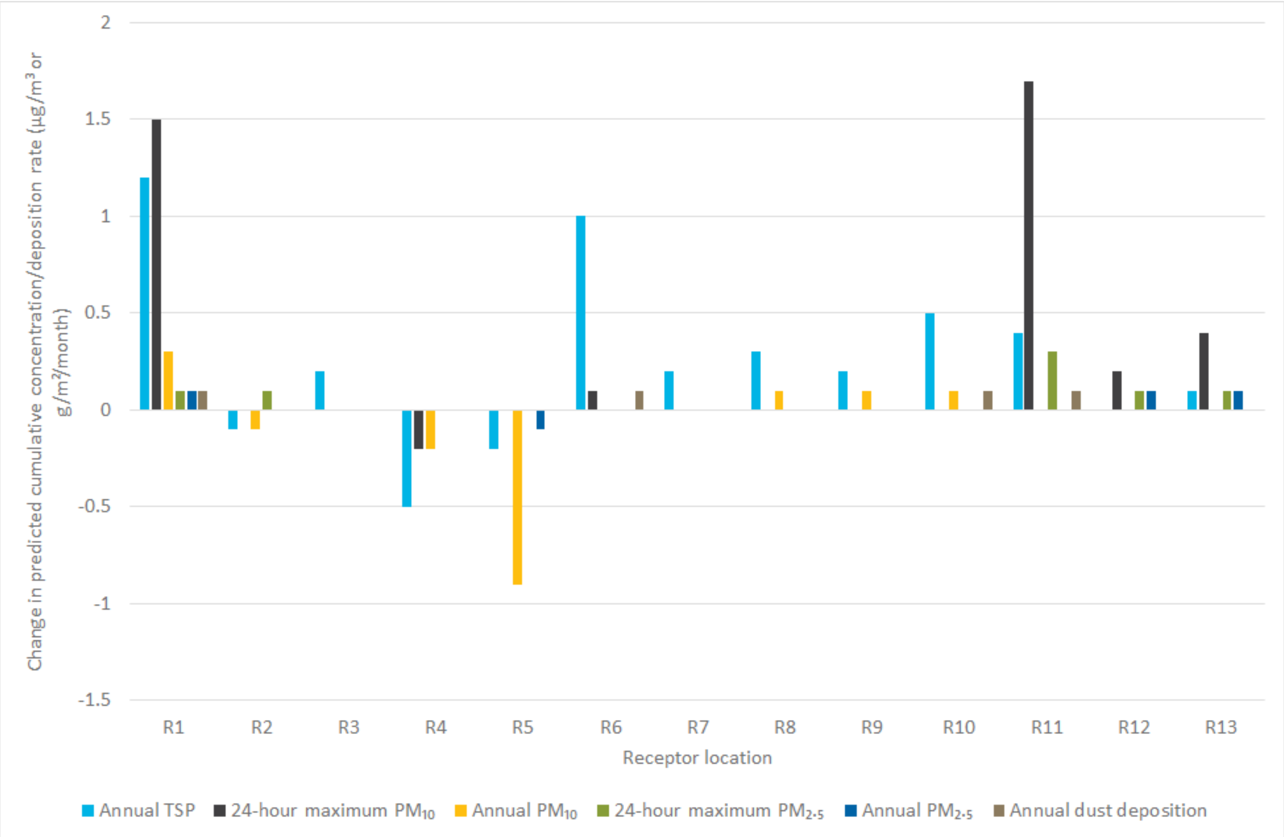

Figure 8.7 Change in predicted cumulative concentrations and deposition rates at surrounding receptors – Wagon Option 2 activities versus approved quarry activities

9 Mitigation and monitoring

9.1 Mitigation measures

As discussed in Section 7.3, particulate matter emissions during the proposed material importation operations will be controlled primarily through the use of water carts and sprays to unpaved roads, material stockpiling and emplacement areas and crusher operations.

Mitigation of impacts will also be achieved through time of day restrictions for material emplacement operations within the pit. By restricting the majority of emplacement operations to between the hours of 7 am and 10 pm, the hours of the day that typically have poorer pollution dispersion potential (ie late night and early morning hours) will be avoided as much as practicable.

The results of the modelling presented within this AQIA indicate that the proposed mitigation measures and operational restrictions are effective for the purpose of minimising air quality impacts to the surrounding environment.

9.2 Air quality monitoring

As discussed in Section 6.2.4, Boral maintain a network of three dust deposition gauges at the quarry. These three locations would be continued throughout the life of the material importation project. Results of dust deposition monitoring would be reported on the Boral website, consistent with current reporting requirements for the quarry.

10 Conclusions

EMM was engaged by Boral to undertake an AQIA for the proposed importation and emplacement of material at the quarry.

Emissions of TSP, PM_{10} and $PM_{2.5}$ associated with the historical approved operations at the quarry were estimated and modelled to establish a reference baseline for impacts to the surrounding environment under existing approvals. Additionally, the neighbouring Sydney Trains Bombo Quarry operations were also estimated and modelled for cumulative assessment purposes.

A qualitative review of emission sources associated with assorted material rail importation options was undertaken, with the Wagon Option 2 identified as the worst case for air quality impact potential.

All atmospheric dispersion modelling predictions of air pollution emissions for historical and proposed activities was undertaken using the AERMOD dispersion model.

The results of the dispersion modelling conducted indicated that the proposed worst-case material importation activities would not result in any exceedance of applicable cumulative impact assessment criteria at any surrounding receptor location. Further, the comparison of these results with model predictions for historical approved operations at the quarry indicates that the activities proposed as part of the modification are unlikely to result in a significant change at any of the surrounding assessment locations.

Proposed mitigation measures (principally water carts and water sprays) and operational time restrictions were incorporated into the emission calculations and dispersion modelling conducted. On the basis of the low magnitude of predicted impacts, it is considered that the proposed mitigation measures are appropriate for the management of particulate matter emissions and impacts during material importation activities.

References

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US-EPA 1998a, AP-42 Chapter 11.9 - Western Surface Coal Mining

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US-EPA, 2004, AP-42 Chapter 11.19.2 – Crushed Stone Processing and Pulverized Mineral Processing

US-EPA, 2006a, AP-42 Chapter 11.12 – Concrete Batching

US-EPA 2006b, AP-42 Chapter 13.2.4 – Aggregate Handling and Storage Piles

US-EPA 2009, Emission Factors for Locomotives

US-EPA 2011, AP-42 Chapter 13.2.1 – Paved Roads

US-EPA 2013, AERSURFACE User's Guide

Abbreviations

AHD	Australian height datum
Approved Methods for Modelling	*Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*
AQS	Air quality station
AWS	Automatic weather station
BoM	Bureau of Meteorology
CO	Carbon monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPE	Department of Planning and Environment
ENM	Excavated Natural Material
EPA	Environment Protection Authority
NOx	Oxides of nitrogen
OEH	Office of Environment and Heritage
PM_{10}	Particulate matter less than 10 microns in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in aerodynamic diameter
SO_2	Sulphur dioxide
TAPM	The Air Pollution Model
TfNSW	Transport for NSW
TSP	Total suspended particulates
US-EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
VENM	Virgin Excavated Natural Material

Appendix A

Meteorological modelling and processing

A.1 Meteorological monitoring datasets

As discussed in Section 5.1, meteorological datasets were collated from the following monitoring stations:

- BoM Kiama (Bombo Headland) AWS, located 1.5km to the east of the quarry;
- BoM Wollongong Airport AWS, located 11km to the north-north-west of the quarry; and
- OEH Albion Park South AQS, located 10km to the north-north-west of the quarry.

Due to the proximity of the BoM Kiama (Bombo Headland) AWS to the quarry, this monitoring station has been adopted as the primary source of meteorological data for the assessment. Data from this station was collected for the period between January 2013 and December 2017. Data availability and analysis of inter-annual trends for this five-year period is presented in the following sections.

A.1.1 Data availability

A summary of data availability for the BoM Kiama (Bombo Headland) AWS 2013 to 2017 dataset is provided in Figure A.1. The following points are noted:

- data completeness is close to 100% for all parameters for all years between 2013 and 2017 (98.5% for 2013 and 98.7% for 2014). Consequently, all years of monitoring data analysed meet the minimum 90% data completeness requirements specified with Section 4.1 of the Approved Methods for Modelling (EPA, 2016); and
- the 2017 calendar year is the most recent and complete period of monitoring data from the BoM Kiama (Bombo Headland) AWS.

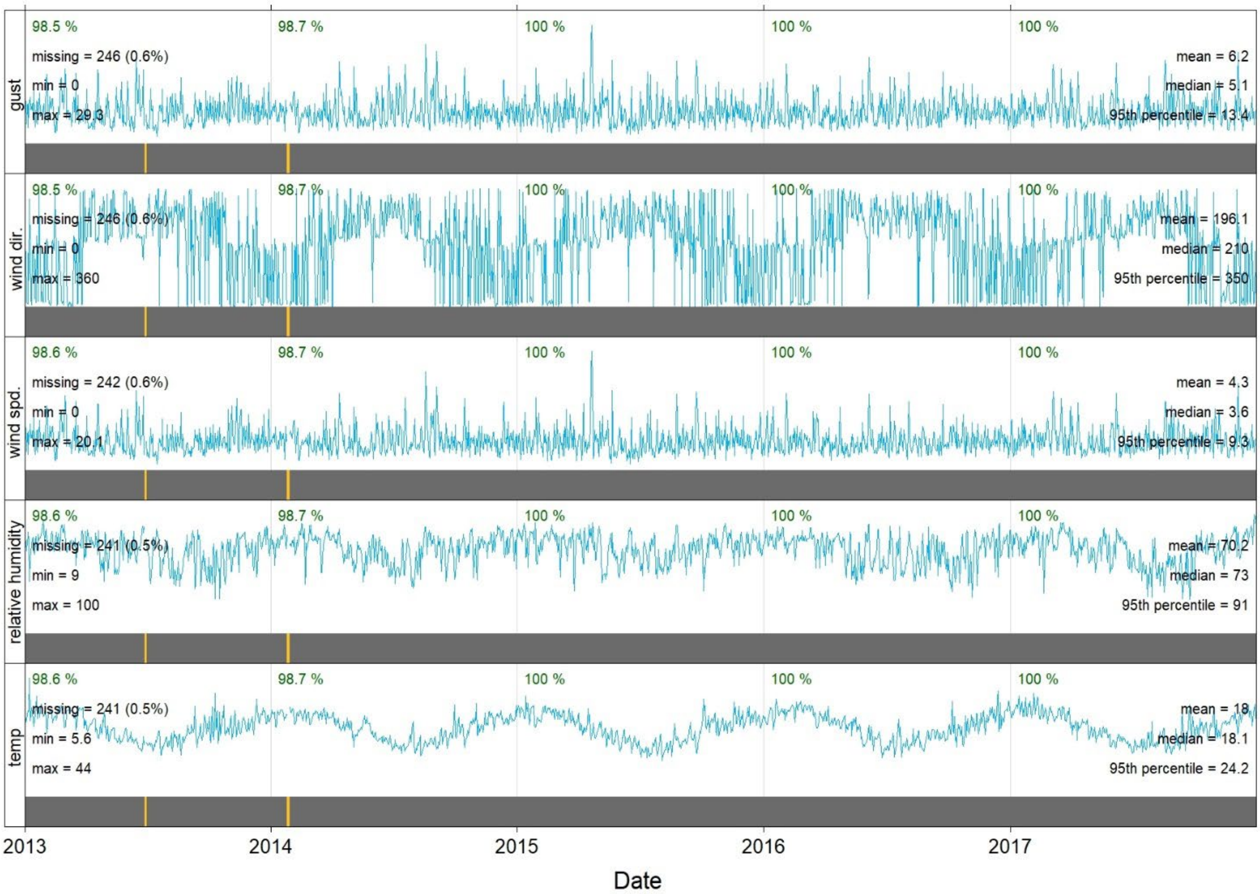


Figure A.1 **Five-year data completeness analysis plot – BoM Kiama (Bombo Headland) AWS**

A.1.2 Selection of a representative year

While 2017 is the most recent and complete year of monitoring data from the BoM Kiama (Bombo Headland) AWS, in order to determine the most representative year of data, an analysis of inter-annual trends has been conducted. Inter-annual wind roses are presented in Figure A.2, while the diurnal distribution of wind speed (Figure A.3), wind direction (Figure A.4), temperature (Figure A.5) and relative humidity (Figure A.6) recorded between 2013 and 2017 are also analysed. All figures demonstrate that the 2017 dataset is representative of the Kiama (Bombo Headland) AWS location based on the previous five years of data.

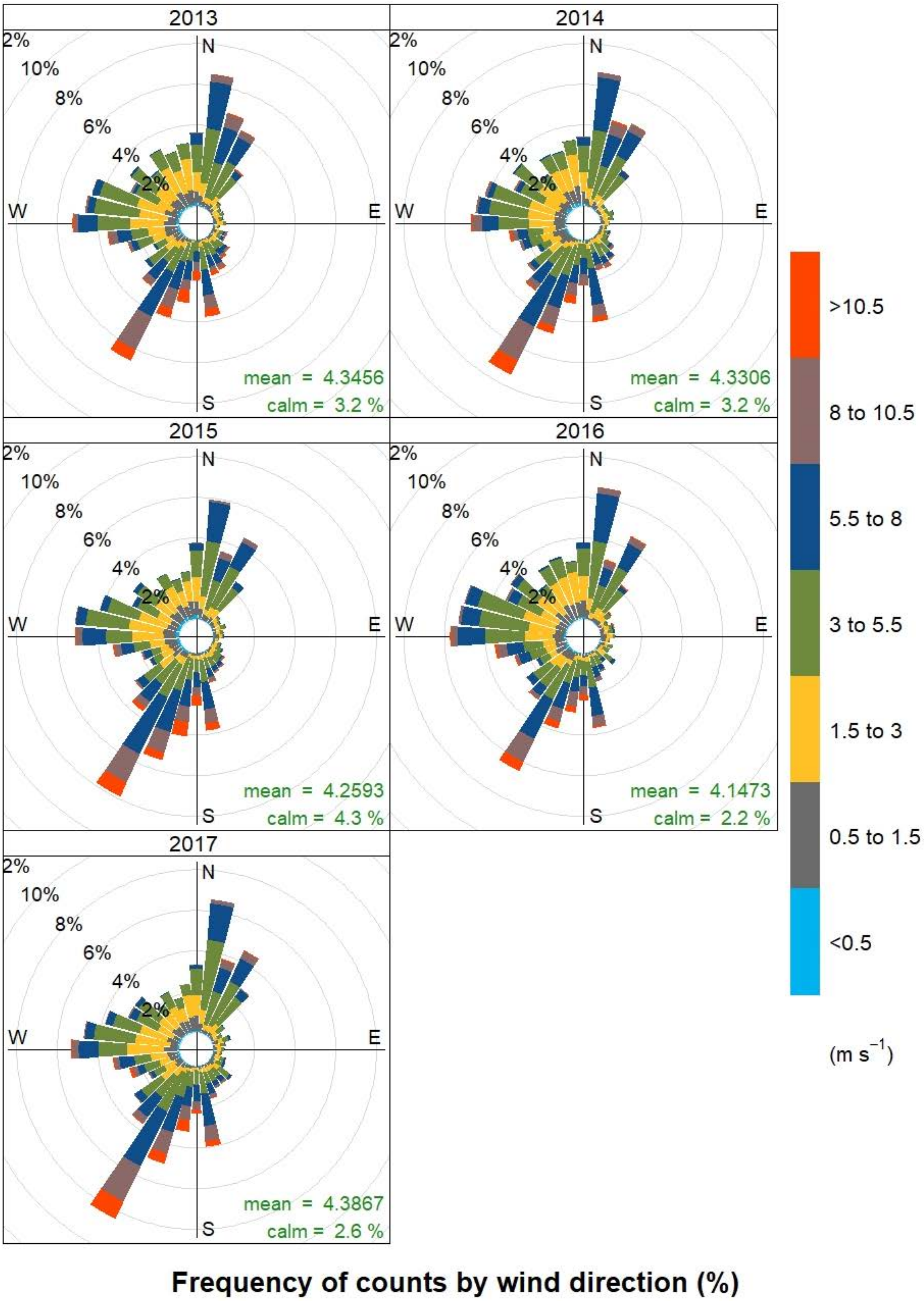


Figure A.2 Inter-annual wind roses – BoM Kiama (Bombo Headland) AWS – 2013 to 2017

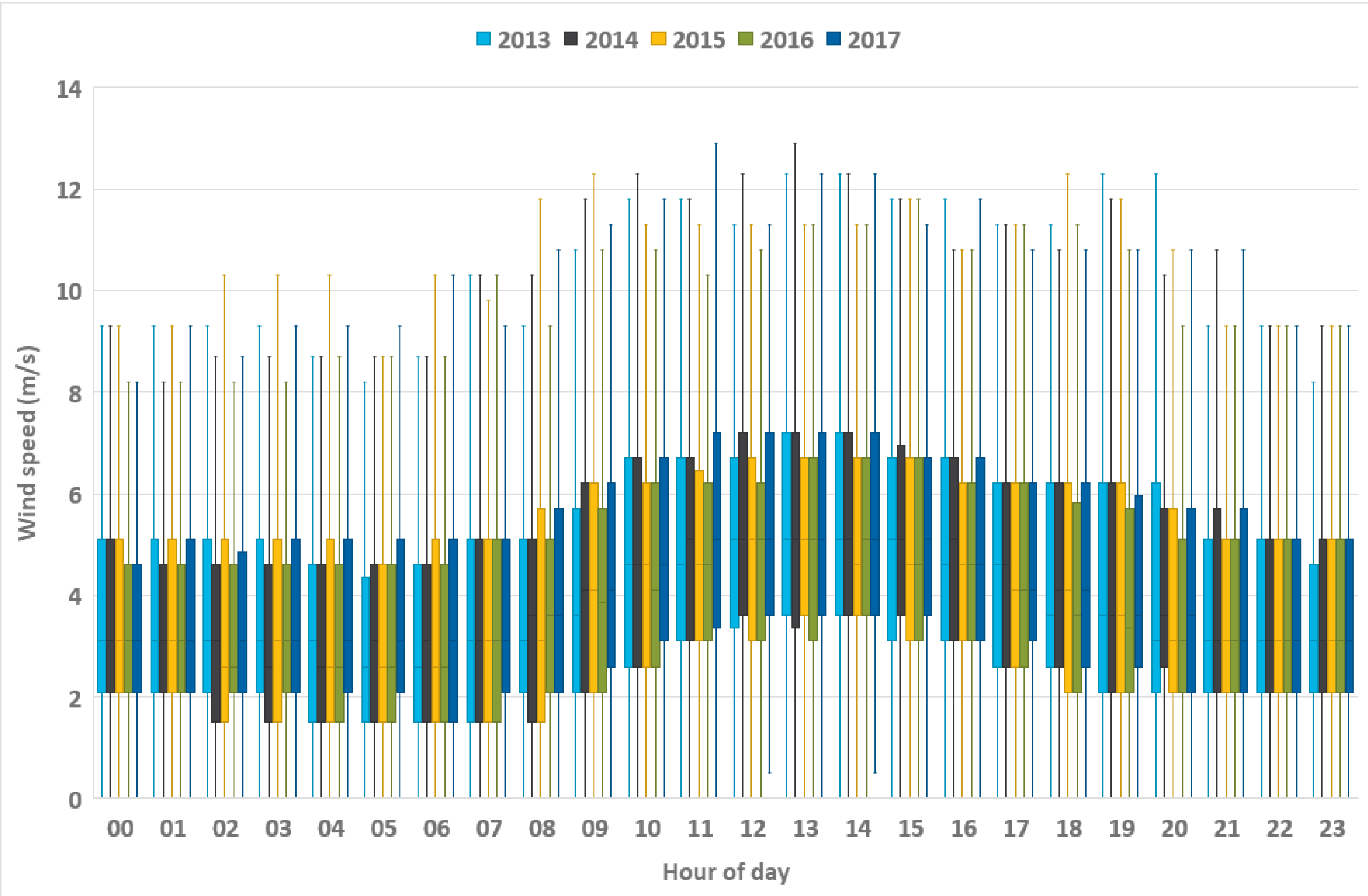


Figure A.3 **Inter-annual variability in diurnal wind speed – BoM Kiama (Bombo Headland) AWS – 2013 to 2017**

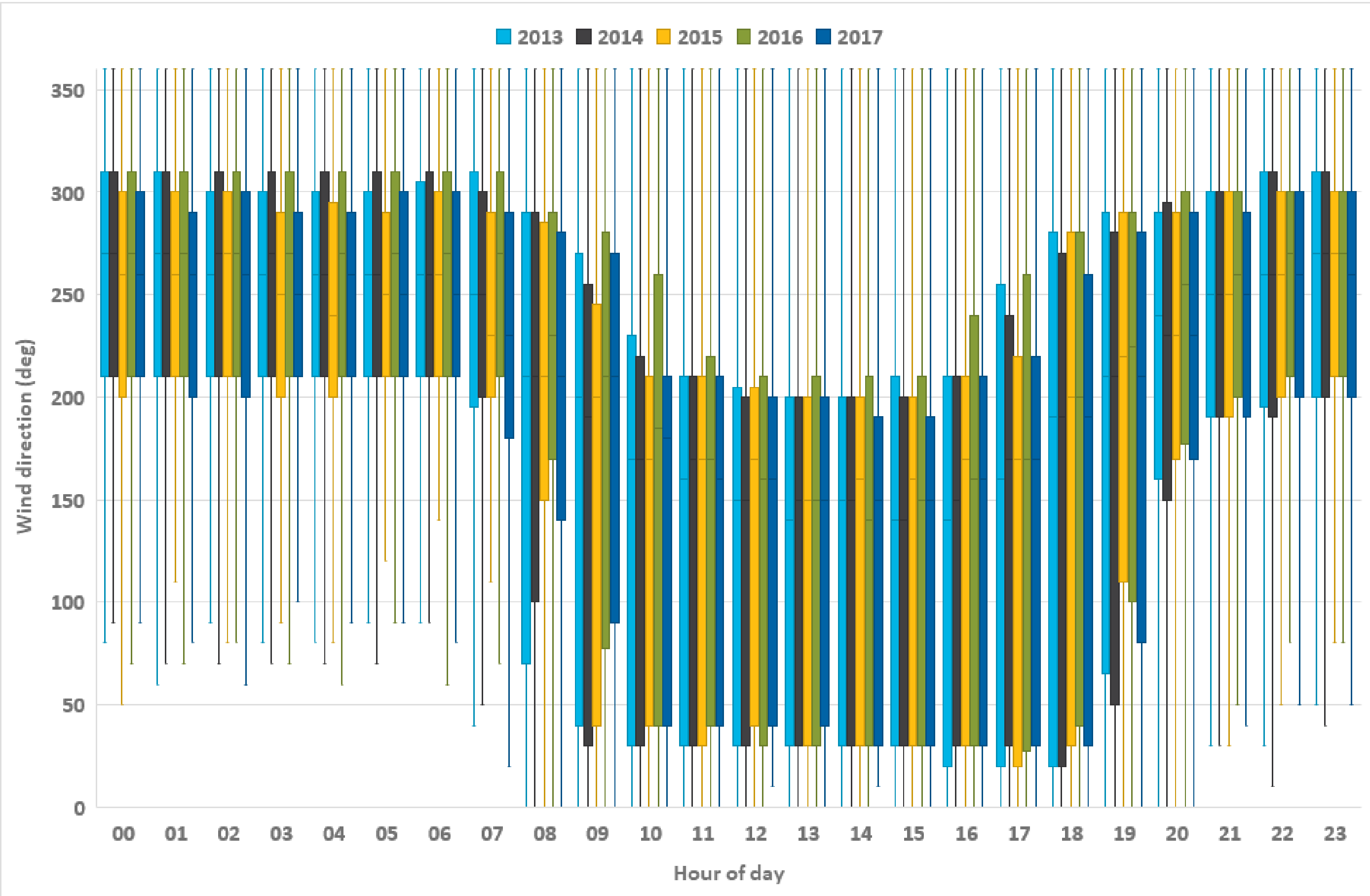


Figure A.4 Inter-annual variability in diurnal wind direction – BoM Kiama (Bombo Headland) AWS – 2013 to 2017

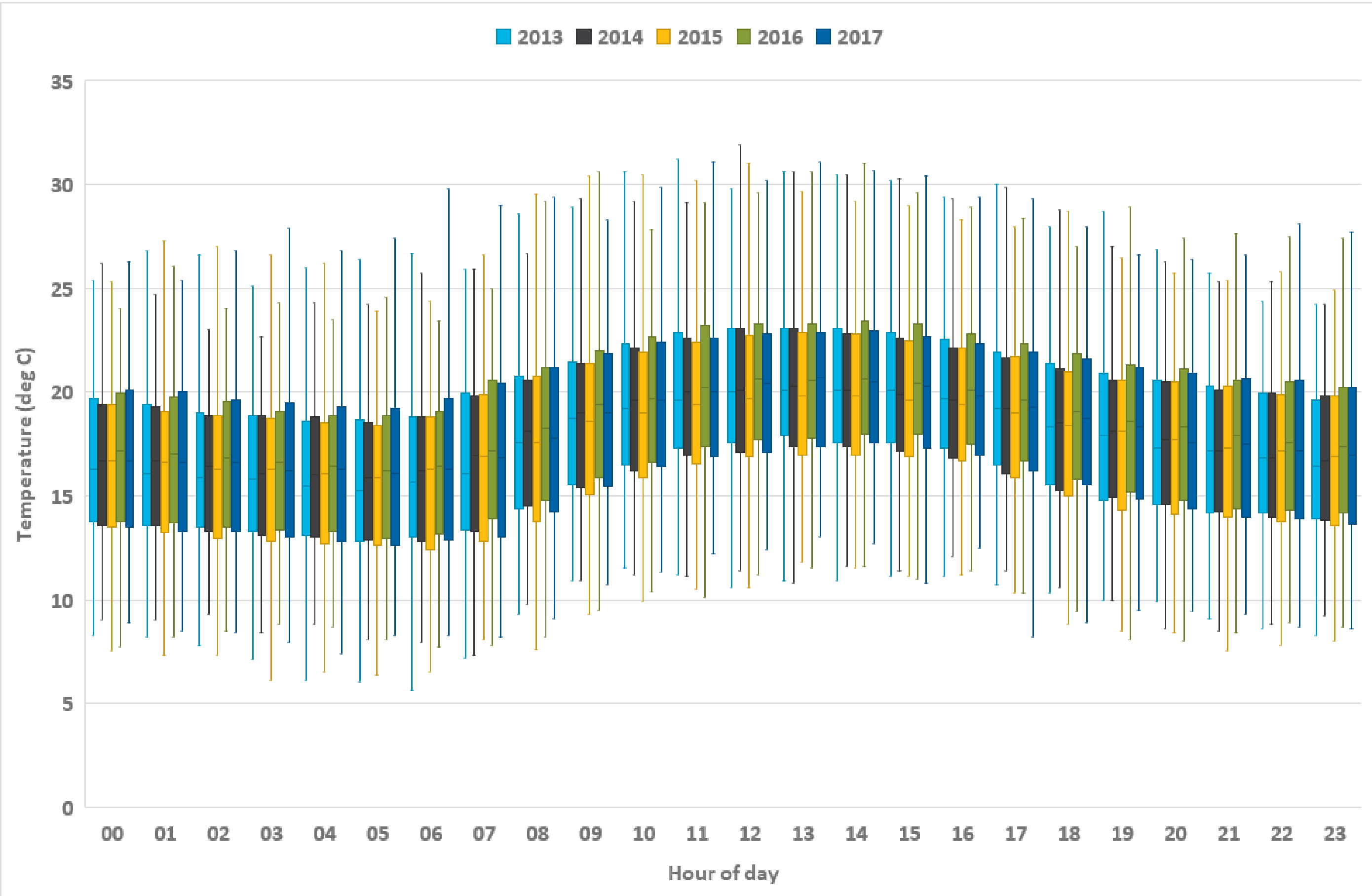


Figure A.5 **Inter-annual variability in diurnal air temperature – BoM Kiama (Bombo Headland) AWS – 2013 to 2017**

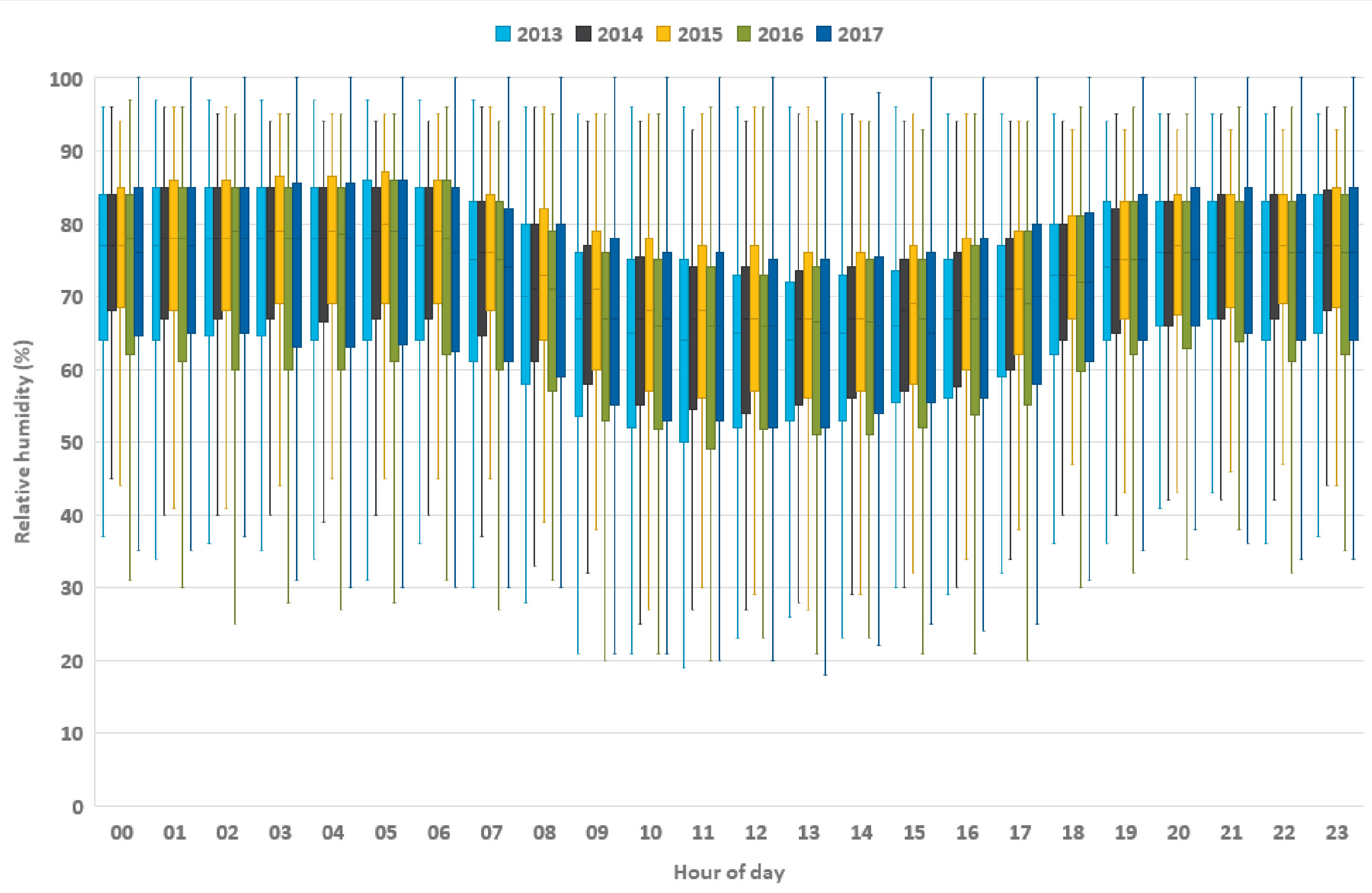


Figure A.6 Inter-annual variability in diurnal relative humidity – BoM Kiama (Bombo Headland) AWS – 2013 to 2017

A.2 TAPM modelling

To supplement the meteorological monitoring datasets adopted for this assessment, the Commonwealth Scientific and Industry Research Organisation (CSIRO) prognostic meteorological model The Air Pollution Model (TAPM) was used to generate required parameters not routinely measured, specifically mixing height and vertical wind/temperature profile.

TAPM was configured and run in accordance with the Section 4.5 of the Approved Methods as follows:

- TAPM version 4.0.5;
- inclusion of high resolution (90 m) regional topography (improvement over default 250 m resolution data);
- grid domains with cell resolutions of 30 km, 10 km, 3 km, 1 km and 0.3km. Each grid domain features 25 x 25 horizontal grid points and 25 vertical levels;
- TAPM default databases for land use, synoptic analyses and sea surface temperature; and
- TAPM defaults for advanced meteorological inputs.

A.3 AERMET Meteorological Processing

The meteorological inputs for AERMOD were generated using the AERMET meteorological processor. The following sections provide an overview of meteorological processing completed for this assessment.

A.3.1 Surface characteristics

Prior to processing meteorological data, the surface characteristics of the area surrounding the adopted monitoring station require parameterisation. The following surface parameters are required by AERMET:

- surface roughness length;
- albedo; and
- Bowen ratio.

As detailed by US-EPA (2013), the surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer. The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux.

The land cover of the 10km by 10km area surrounding the BoM Kiama (Bombo Headland) AWS was mapped (see Figure A.7). Using the AERSURFACE tool and following the associated guidance of US-EPA (2013), surface roughness was determined for twelve (30 degree) sectors grouped by similar land use types within a 1km radius around the BoM Kiama (Bombo Headland) AWS, while Bowen ratio and albedo were determined for the total 10 km by 10 km area. Monthly-varying values for surface roughness, Bowen ratio and albedo were allocated to each sector based on the values prescribed by US-EPA (2013). The following profiles were applied to individual months:

- Midsummer – January, February, March, December;
- Autumn – April, May;
- Late autumn / winter without snow – June, July, August; and
- Transitional spring – September, October, November.

The surface moisture characteristics for the 2017 calendar year was determined by comparing to the previous 30-year rainfall records for Kiama (BoM Kiama Bowling Club and Kiama [Brighton St]). Annual rainfall for 2017 was 1,127 mm, which places the year with the middle 40th-percentile for the previous 30 years, therefore an average surface moisture classification was allocated.

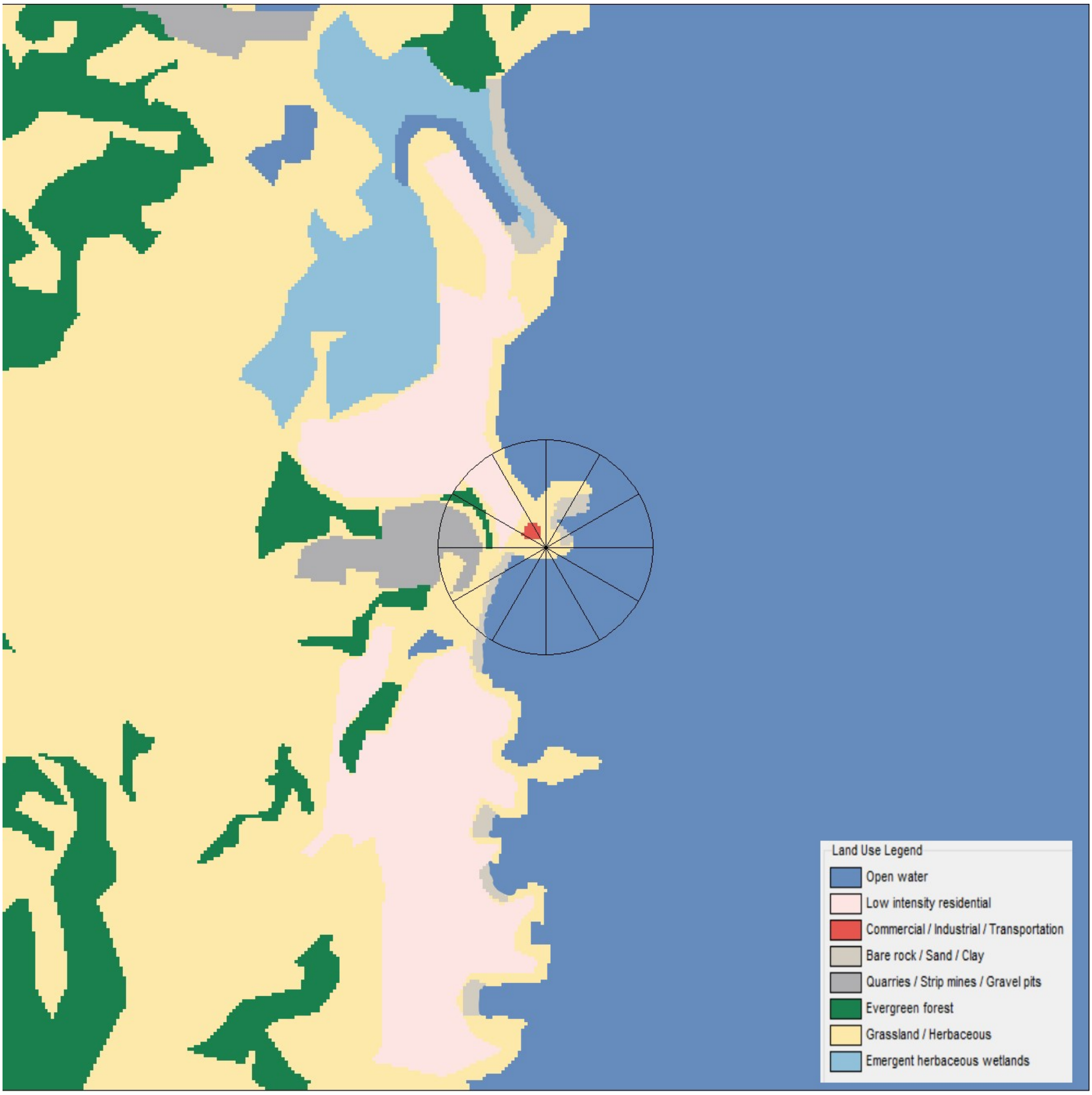


Figure A.7 Land use map for AERSURFACE processing – BoM Kiama (Bombo Headland) AWS

Note: Marked in figure are the 1km radius for surface roughness (12 sectors defined) and 10km x 10km for albedo/bowen ratio (total image shown)

Table A.1 Monthly surface roughness length values by sector

Month	Surface roughness length (m) by sector (degrees)											
	0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-0
Jan	0.017	0.006	0.002	0.004	0.002	0.002	0.001	0.007	0.079	0.198	0.339	0.017
Feb	0.017	0.006	0.002	0.004	0.002	0.002	0.001	0.007	0.079	0.198	0.339	0.017
Mar	0.017	0.006	0.002	0.004	0.002	0.002	0.001	0.007	0.079	0.198	0.339	0.017
Apr	0.017	0.006	0.002	0.004	0.002	0.002	0.001	0.007	0.079	0.198	0.339	0.017
May	0.017	0.006	0.002	0.004	0.002	0.002	0.001	0.007	0.079	0.198	0.339	0.017
Jun	0.006	0.004	0.002	0.002	0.001	0.001	0.001	0.003	0.02	0.056	0.169	0.005
Jul	0.006	0.004	0.002	0.002	0.001	0.001	0.001	0.003	0.02	0.056	0.169	0.005
Aug	0.006	0.004	0.002	0.002	0.001	0.001	0.001	0.003	0.02	0.056	0.169	0.005
Sep	0.012	0.005	0.002	0.003	0.002	0.002	0.001	0.006	0.052	0.137	0.288	0.012
Oct	0.012	0.005	0.002	0.003	0.002	0.002	0.001	0.006	0.052	0.137	0.288	0.012
Nov	0.012	0.005	0.002	0.003	0.002	0.002	0.001	0.006	0.052	0.137	0.288	0.012
Dec	0.017	0.006	0.002	0.004	0.002	0.002	0.001	0.007	0.079	0.198	0.339	0.017

Table A.2 Monthly Bowen ratio and albedo values (all sectors)

Month	Monthly value (all sectors)	
	Bowen ratio	Albedo
January	0.23	0.13
February	0.23	0.13
March	0.23	0.13
April	0.27	0.13
May	0.27	0.13
June	0.27	0.14
July	0.27	0.14
August	0.27	0.14
September	0.21	0.13
October	0.21	0.13
November	0.21	0.13
December	0.23	0.13

A.3.2 Meteorological inputs

Monitoring data from the BoM Kiama (Bombo Headland) and Wollongong Airport AWS and NSW OEH Albion Park South AQS were combined with TAPM meteorological modelling outputs for input to AERMET. The following parameters were input as onsite data to AERMET:

- wind speed and direction - Kiama (Bombo Headland);
- sigma-theta (standard deviation of wind direction) - Kiama (Bombo Headland);
- temperature - Kiama (Bombo Headland);
- relative humidity - Kiama (Bombo Headland);
- station level pressure - Wollongong Airport;
- cloud cover - Wollongong Airport;
- solar insolation - Albion Park South;
- mixing depth – TAPM at Kiama (Bombo Headland) location; and
- temperature difference (based on 50 m above ground temperature) – TAPM at Kiama (Bombo Headland) location.

The period of meteorological data input to AERMET was 1 January 2017 to 31 December 2017.

A.3.3 Upper air profile

Due to the absence of necessary local upper air meteorological measurements, the hourly profile file generated by TAPM at the BoM Kiama (Bombo Headland) AWS location was adopted. Using the temperature difference between levels, the TAPM-generated vertical temperature profile for each hour was adjusted relative to the hourly surface temperature observations from the Kiama (Bombo Headland) AWS.

Appendix B

Emissions inventory background

B.1 Particulate matter emissions inventory

The emissions inventory developed for the historical Bombo Quarry, Boral Concrete Batching Plant, Sydney Trains Quarry and proposed Wagon Option 2 material delivery activities are documented in Table B.2, Table B.3, Table B.4, Table B.5 and Table B.6 respectively.

Operational assumptions for each emission source are documented in these tables.

B.2 Diesel combustion emissions

Diesel combustion emissions were calculated

- due to a lack of details relating to quarry fleet, an assumed historical diesel consumption rate of 300,000 L for Boral Quarry and 1,200,000 L for Sydney Trains. The NPI (2008) emission factors for miscellaneous industrial vehicles was applied;
- equipment fleet emissions for Wagon Option 2 were based on the proposed equipment fleet specifications and US-EPA Tier 2 emission factors (as presented in Table B.1); and
- emission from road trucks were quantified through calculated annual VKT and the EPA PM Emission Factor for road trucks (EPA, 2012), based on the specifications of 1996 ADR70/00.

Table B.1 Diesel equipment fleet emission – Wagon Option 2

Equipment type	Make/Model	Number	Power	Operating hours	Load factor	Emission factor (g/kWh)	Energy (kWh)	Annual emission (kg/annum)		
								TSP emissions	PM_{10} emissions	$PM_{2.5}$ emissions
Dozer	CAT D6	1	161	4,125	0.5	0.2	664,125	66.4	66.4	60.9
Compactor	CAT825	2	324	4,125	0.5	0.2	2,673,000	267.3	267.3	245.0
Haul truck	CAT745	2	381	4,125	0.5	0.2	3,143,250	314.3	314.3	288.1
Haul truck	Komatsu HD465	1	533	4,125	0.5	0.2	2,198,625	219.9	219.9	201.5
FEL	CAT972	1	205	4,125	0.5	0.2	845,625	84.6	84.6	77.5
Crusher	SANDVIK QJ341+	1	265	4,125	0.5	0.2	1,093,125	109.3	109.3	100.2
Excavator	CAT336	1	226	4,125	0.5	0.2	932,250	93.2	93.2	85.5

Emissions from locomotive emission associated with the dispatch of product to market (historical Sydney Trains Quarry) and future material importation to the quarry site were estimated. The following assumptions were made in estimating emissions from locomotives:

- each train is serviced by two TT class locomotives. The engine power rating of this model is 4,450 hp;
- locomotive engines are assumed to be in notch 1 when idling. Idling time is four hours per train for Sydney Trains and 3 hours per train for the quarry site material delivery trains;

- the following train numbers per day were assumed; two per day for Sydney Trains, four per day for average day material delivery operations and six per day for peak day material delivery operations;
- based on Table 5-2 of US-EPA (1998), the power output of for notch 1 is 4.5% of gross power rating respectively;
- locomotive emissions were estimated based on US-EPA uncontrolled emission factors (US-EPA, 2009); and
- the US-EPA emission factor for locomotive engines is for PM_{10}. 97% of PM_{10} is assumed to be made up of much smaller $PM_{2.5}$ particles (US-EPA, 2009).

Table B.2 Emissions inventory – historical operations Boral Quarry site

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Drilling	AP-42 11.9 - Drilling factor	Holes per year	1,890	Holes/blast	105							0.59	0.31	0.0465	kg/hole			1.12	0.59	0.09
Blasting	AP-42 11.9 - Blasting Equation	Blasts per year	18	Area/blast (m²)	1,050							7.485	3.892	0.584	kg/blast			0.13	0.07	0.01
Blasted rock to trucks	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000	Average wind speed (m/s)	4.381357389	Moisture content (%)	2					0.003	0.001	0.000	kg/tonne			1.45	0.69	0.10
Haul truck to crusher	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	14,912	Road silt content (%)	8.3	Haul distance (km)	0.85	Loads per year	8,771.93	Ave Truck Weight (t)	71.5	4.645	1.321	0.132	kg/VKT	Watering + speed limit <40km/h	0.86	9.70	2.76	0.28
Unloading to crusher	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000	Average wind speed (m/s)	4.381357389	Moisture content (%)	2					0.003	0.001	0.000	kg/tonne			1.45	0.69	0.10
Material crushing	USEPA AP-42 11.19.2 - Tertiary Crushing Factor	Tonnes per year	1,500,000	Stages of Crushing	3							0.0027	0.0012	0.00022	kg/tonne	Watering and cladding	0.85	0.61	0.27	0.05
Material screening	USEPA AP-42 11.19.2 - Screening Factor	Tonnes per year	1,500,000	Stages of Screening	3							0.0125	0.0043	0.00003	kg/tonne	Watering and cladding	0.85	2.81	0.97	0.01

Table B.2 Emissions inventory – historical operations Boral Quarry site

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Stockpile loading	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000	Average wind speed (m/s)	4.381357389	Moisture content (%)	2					0.003	0.001	0.000	kg/tonne			1.45	0.69	0.10
Loading to train wagons	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	0	Average wind speed (m/s)	4.381357389	Moisture content (%)	2					0.003	0.001	0.000	kg/tonne			0.00	0.00	0.00
Loading to product trucks	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000	Average wind speed (m/s)	4.381357389	Moisture content (%)	2					0.003	0.001	0.000	kg/tonne			1.45	0.69	0.10
Product truck dispatch - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	25,025	Road silt content (%)	7.1	Haul distance (km)	0.7	Loads per year	17,875.00	Ave Truck Weight (t)	34	2.980	0.821	0.082	kg/VKT	Watering + speed limit <40km/h	0.86	10.44	2.88	0.29
Product truck dispatch - paved	AP-42 13.2.1 - Paved Road Equation	VKT per year	17,875	Road silt loading (g/m²)	0.6	Haul distance (km)	0.5	Loads per year	17,875.00	Ave Truck Weight (t)	34	0.082	0.016	0.004	kg/VKT			1.46	0.28	0.07
Wind erosion - pit	AP-42 11.9 - Wind erosion of exposed areas factor	Area (ha)	11									850	425	63.75	kg/ha/year			9.42	4.71	0.71
Wind erosion - processing area	AP-42 11.9 - Wind erosion of exposed areas factor	Area (ha)	5									850	425	63.75	kg/ha/year			4.19	2.10	0.31

Table B.3 Emissions inventory – historical operations Boral Concrete Batching Plant

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Aggregate Transfer	AP-42 11.12 Concrete Batching - Aggregate transfer	Tonnes per year	42,780.0									0.0035	0.0017	0.0003	kg/tonne	watering	0.5	0.07	0.04	0.01
Sand transfer	AP-42 11.12 Concrete Batching - Sand transfer	Tonnes per year	33,120.0									0.0011	0.0005	0.0001	kg/tonne	watering	0.5	0.02	0.01	0.00
Cement unloading	AP-42 11.12 Concrete Batching - Cement unloading to elevated storage silo (pneumatic)	Tonnes per year	15,318.0									0.0045	0.0024	0.0004	kg/tonne			0.07	0.04	0.01
Weigh hopper loading	AP-42 11.12 Concrete Batching - Weigh hopper loading	Tonnes per year	48,438.0									0.0	0.0	0.0	kg/tonne			0.13	0.06	0.01
Truck loading (truck mix)	AP-42 11.12 Concrete Batching - Truck loading (truck mix)	Tonnes per year	15,318.0									0.04900	0.01310	0.00198	kg/tonne			0.75	0.20	0.03
CBP dispatch - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	17,710.0	Road silt content (%)	7.1	Haul distance (km)	0.7	Loads per year	14.0152968	Ave Truck Weight (t)	19	2.29359	0.63216	0.06322	kg/VKT	Watering + speed limit <40km/h	0.86	5.69	1.57	0.16

Table B.4 Emissions inventory – maximum approved operations Sydney Trains Quarry site

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Drilling	AP-42 11.9 - Drilling factor	Holes per year	7,400.0	Holes/blast	200.0							0.5900	0.3100	0.0465	kg/hole			4.37	2.29	0.34
Blasting	AP-42 11.9 - Blasting Equation	Blasts per year	37.0	Area/blast (m^2)	2,000.0							19.6774	10.2322	1.5348	kg/blast			0.73	0.38	0.06
Blasted rock to trucks	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	2,000,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	2					0.0029	0.0014	0.0002	kg/tonne			5.80	2.74	0.42
Haul truck to crusher	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	42,105.3	Road silt content (%)	8.3	Haul distance (km)	0.6	Loads per year	35087.7193	Ave Truck Weight (t)	71.5	4.6	1.3	0.1	kg/VKT	Watering + speed limit <40km/h	0.86	27.38	7.79	0.78
Unloading to crusher	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	2,000,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	2					0.00290	0.00137	0.00021	kg/tonne	Watering and cladding	0.85	0.87	0.41	0.06
Material crushing	USEPA AP-42 11.19.2 - Tertiary Crushing Factor	Tonnes per year	6,000,000.0	Stages of Crushing	3.0							0.00270	0.00120	0.00022	kg/tonne	Watering and cladding	0.85	2.43	1.08	0.20
Material screening	USEPA AP-42 11.19.2 - Screening Factor	Tonnes per year	6,000,000.0	Stages of Screening	3.0							0.01250	0.00430	0.00003	kg/tonne	Watering and cladding	0.85	11.25	3.87	0.03

Table B.4 Emissions inventory – maximum approved operations Sydney Trains Quarry site

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Stockpile loading	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	2,000,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	2					0.00290	0.00137	0.00021	kg/tonne	Water sprays	0.5	2.90	1.37	0.21
Loading to train wagons	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	800,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	2					0.00290	0.00137	0.00021	kg/tonne	Watering and cladding	0.85	0.35	0.16	0.02
Loading to product trucks	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	1,200,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	2					0.00290	0.00137	0.00021	kg/tonne			3.48	1.65	0.25
Product truck dispatch - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	42,857.1	Road silt content (%)	7.1	Haul distance (km)	1	Loads per year	42857.14286	Ave Truck Weight (t)	34	3.0	0.8	0.1	kg/VKT	Watering + speed limit <40km/h	0.86	17.88	4.93	0.49
Wind erosion - pit	AP-42 11.9 - Wind erosion of exposed areas factor	Area (ha)	8.9									850.0	425.0	63.8	kg/ha/year			7.53	3.76	0.56
Wind erosion - processing area	AP-42 11.9 - Wind erosion of exposed areas factor	Area (ha)	7.0									850.0	425.0	63.8	kg/ha/year	Water sprays	0.5	2.99	1.50	0.22

Table B.5 Emissions inventory – Wagon Option 2 material emplacement operations – peak day calculations

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Road delivery to site - paved	AP-42 13.2.1 - Paved Road Equation	VKT per year	17,875.0	Road silt loading (g/m²)	0.6	Haul distance (km)	0.5	Loads per year	17875	Ave Truck Weight (t)	34	0.0818	0.0157	0.0038	kg/VKT			1.46	0.28	0.07
Road delivery to site - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	25,025.0	Road silt content (%)	7.1	Haul distance (km)	0.7	Loads per year	17875	Ave Truck Weight (t)	34	2.9802	0.8214	0.0821	kg/VKT	Watering + speed limit <40km/h	0.86	10.44	2.88	0.29
Road delivery site to pit - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	28,600.0	Road silt content (%)	7.1	Haul distance (km)	0.8	Loads per year	17875	Ave Truck Weight (t)	34	2.9802	0.8214	0.0821	kg/VKT	Watering + speed limit <40km/h	0.86	11.93	3.29	0.33
Train wagon unloading	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	2,800,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne	Wind breaks	0.3	0.60	0.28	0.04
Initial material stockpile loading	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	2,800,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.85	0.40	0.06
Material to haul truck by FEL	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	2,800,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.85	0.40	0.06
Haulage to pit - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	92,371.1	Road silt content (%)	7.1	Haul distance (km)	0.8	Loads per year	57731.95876	Ave Truck Weight (t)	62.25	3.9124	1.0783	0.1078	kg/VKT	Watering + speed limit <40km/h	0.86	50.59	13.94	1.39

Table B.5 Emissions inventory – Wagon Option 2 material emplacement operations – peak day calculations

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Haul truck unloading in pit	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	3,300,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			1.01	0.48	0.07
Loading to mobile crusher	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.15	0.07	0.01
Mobile crusher in pit	USEPA AP-42 11.19.2 - Tertiary Crushing Factor	Tonnes per year	500,000.0	Stages of Crushing	1.0							0.0027	0.0012	0.0002	kg/tonne	Watering	0.5	0.68	0.30	0.06
Handling of crushed material in pit	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.15	0.07	0.01
Dozer/compactor activities in pit	AP-42 11.9 - Bulldozer on Material Other Than Coal	Hours per year	12,375.0	Number of units	3.0	Hours per day	15	Moisture content (%)	10	Silt content (%)	12	2.5703	0.5585	0.0586	kg/hour	Watering	0.5	15.90	3.46	0.36
Wind erosion - pit	AP-42 11.9 - Wind erosion of exposed areas factor	Area (ha)	11.1									850.0000	425.0000	63.7500	kg/ha/year	Watering	0.5	4.71	2.36	0.35

Table B.6 Emissions inventory – Wagon Option 2 material emplacement operations – average day calculations

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Road delivery to site - paved	AP-42 13.2.1 - Paved Road Equation	VKT per year	17,875.0	Road silt loading (g/m^2)	0.6	Haul distance (km)	0.5	Loads per year	17875	Ave Truck Weight (t)	34	0.0818	0.0157	0.0038	kg/VKT			1.46	0.28	0.07
Road delivery to site - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	25,025.0	Road silt content (%)	7.1	Haul distance (km)	0.7	Loads per year	17875	Ave Truck Weight (t)	34	2.9802	0.8214	0.0821	kg/VKT	Watering + speed limit <40km/h	0.86	10.44	2.88	0.29
Road delivery site to pit - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	17,875.0	Road silt content (%)	7.1	Haul distance (km)	0.5	Loads per year	17875	Ave Truck Weight (t)	34	2.9802	0.8214	0.0821	kg/VKT	Watering + speed limit <40km/h	0.86	7.46	2.06	0.21
Train wagon unloading	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	1,975,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne	Wind breaks	0.3	0.42	0.20	0.03
Initial material stockpile loading	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	1,975,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.60	0.28	0.04
Material to haul truck by FEL	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	1,975,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.60	0.28	0.04

Table B.6 Emissions inventory – Wagon Option 2 material emplacement operations – average day calculations

Source Name	Emission factor source	Activity Rate	Unit	Parameter 1	Value	Parameter 2	Value	Parameter 3	Value	Parameter 4	Value	TSP EF	PM_{10} EF	$PM_{2.5}$ EF	EF Unit	Emission Controls	Reduction factor	TSP (tpa)	PM_{10} (tpa)	$PM_{2.5}$ (tpa)
Haulage to pit - unpaved	AP-42 13.2.2 - Unpaved Road Equation	VKT per year	40,721.6	Road silt content (%)	7.1	Haul distance (km)	0.5	Loads per year	40721.64948	Ave Truck Weight (t)	62.25	3.9124	1.0783	0.1078	kg/VKT	Watering + speed limit <40km/h	0.86	22.30	6.15	0.61
Haul truck unloading in pit	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	2,475,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.75	0.36	0.05
Loading to mobile crusher	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.15	0.07	0.01
Mobile crusher in pit	USEPA AP-42 11.19.2 - Tertiary Crushing Factor	Tonnes per year	500,000.0	Stages of Crushing	1.0							0.0027	0.0012	0.0002	kg/tonne	Watering	0.5	0.68	0.30	0.06
Handling of crushed material in pit	AP-42 13.2.4 - Materials Handling Equation / NPI Mining Equation 10	Tonnes per year	500,000.0	Average wind speed (m/s)	4.4	Moisture content (%)	10					0.0003	0.0001	0.0000	kg/tonne			0.15	0.07	0.01
Dozer/compactor activities in pit	AP-42 11.9 - Bulldozer on Material Other Than Coal	Hours per year	12,375.0	Number of units	3.0	Hours per day	15	Moisture content (%)	10	Silt content (%)	12	2.5703	0.5585	0.0586	kg/hour	Watering	0.5	15.90	3.46	0.36
Wind erosion - pit	AP-42 11.9 - Wind erosion of exposed areas factor	Area (ha)	11.1									850.0000	425.0000	63.7500	kg/ha/year	Watering	0.5	4.71	2.36	0.35

Appendix C

Incremental (site-only) isopleth plots

Source: EMM (2018); DFSI (2017); GA (2015)

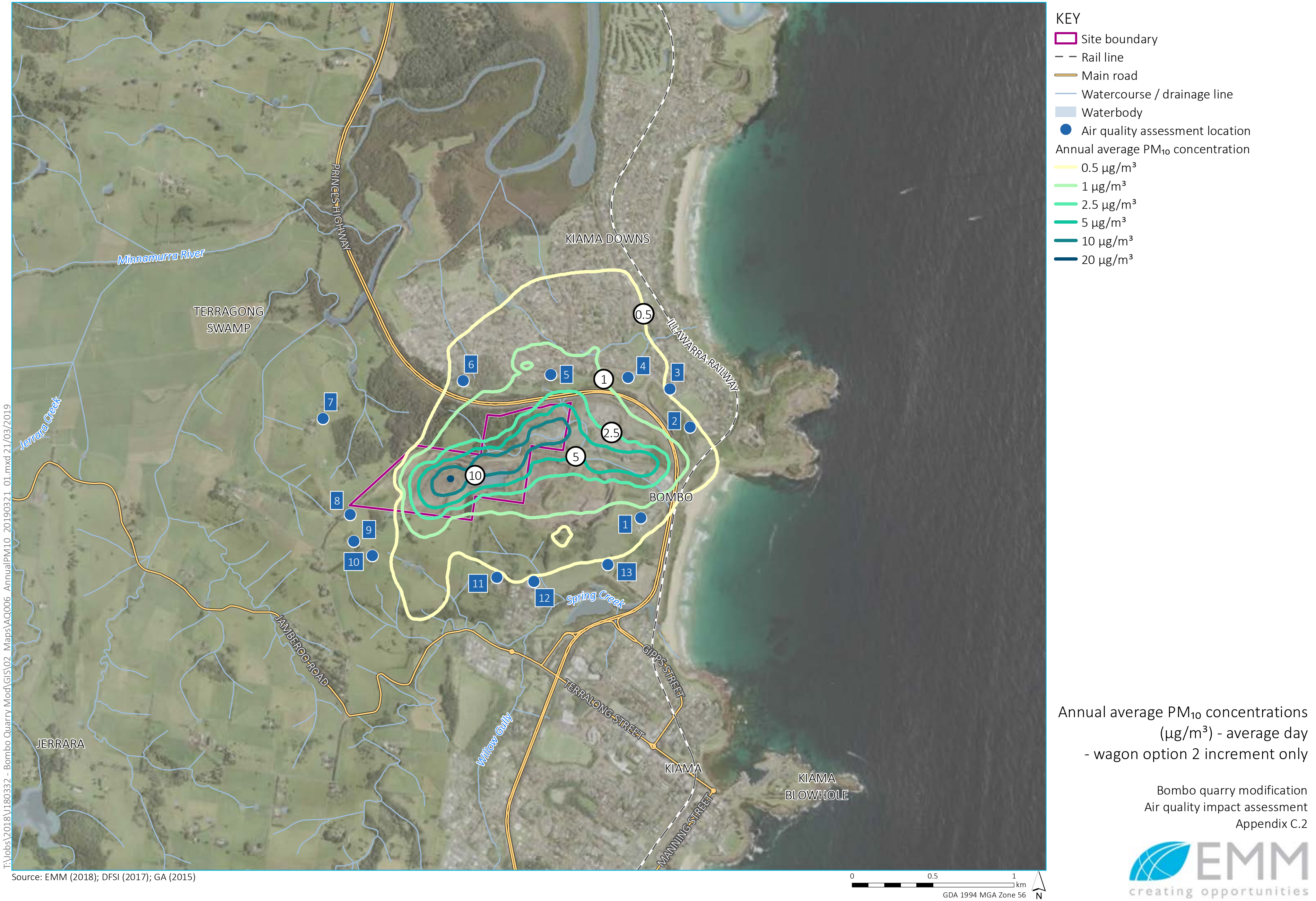
KEY
- Site boundary
- Rail line
- Main road
- Watercourse / drainage line
- Waterbody
- Air quality assessment location

Maximum 24-hour average PM_{10} concentration
- 2.5 µg/m³
- 5 µg/m³
- 10 µg/m³
- 25 µg/m³
- 50 µg/m³

Maximum 24-hour average PM_{10} concentrations (µg/m³) - peak day - wagon option 2 increment only

Bombo quarry modification
Air quality impact assessment
Appendix C.1

EMM creating opportunities



Source: EMM (2018); DFSI (2017); GA (2015)

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Annual average PM_{10} concentrations ($\mu g/m^3$) - average day - wagon option 2 increment only

Bombo quarry modification
Air quality impact assessment
Appendix C.2

EMM
creating opportunities

KEY
Site boundary
Rail line
Main road
Watercourse / drainage line
Waterbody
Air quality assessment location
Maximum 24-hour average $PM_{2.5}$ concentration
0.5 µg/m³
1 µg/m³
2.5 µg/m³
5 µg/m³
10 µg/m³

Source: EMM (2018); DFSI (2017); GA (2015)

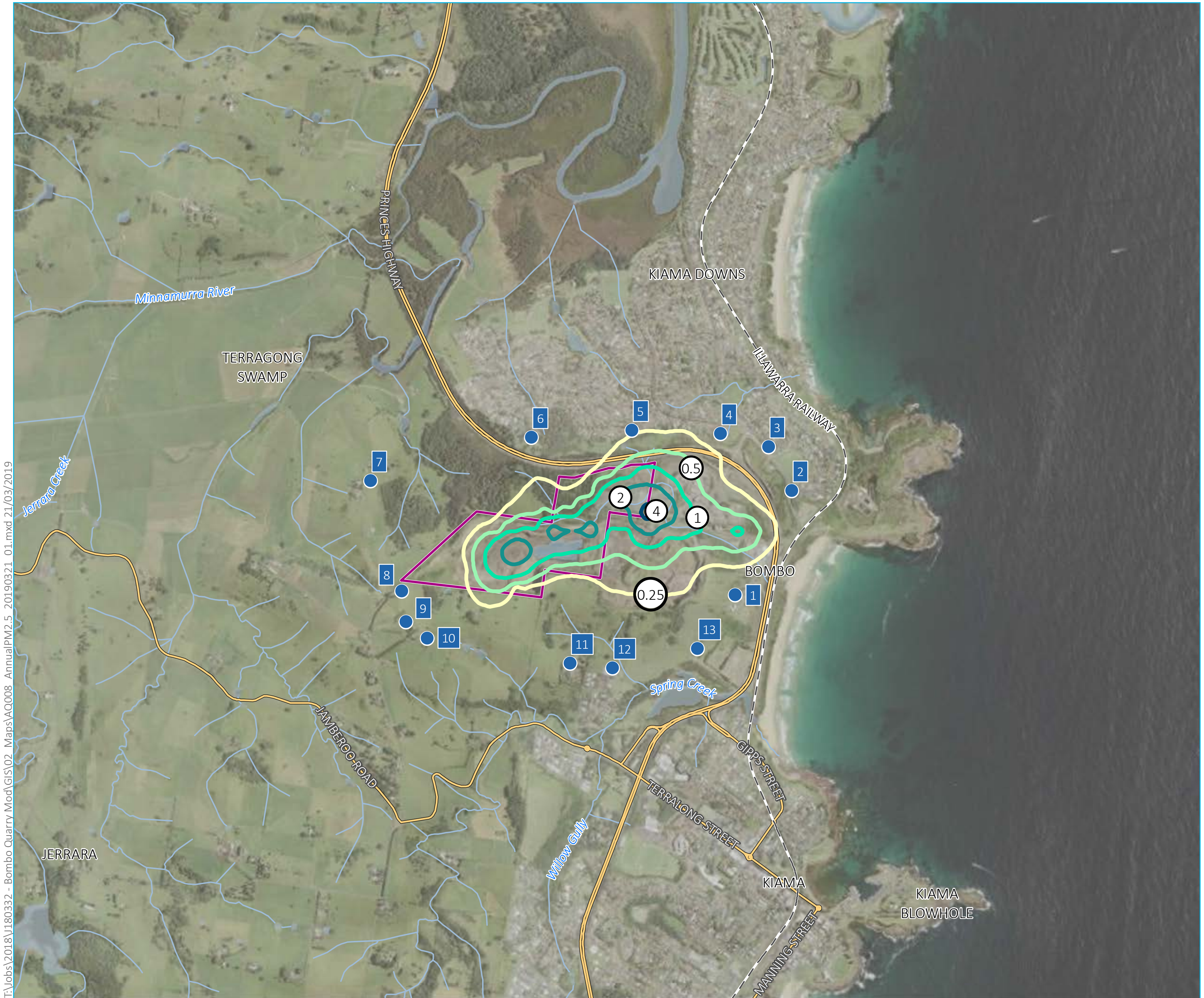
0 0.5 1 km
GDA 1994 MGA Zone 56

T:\Jobs\2018\J180332 - Bombo Quarry Mod\GIS\02_Maps\AQ007_24hrPM2.5Peak_20190321_01.mxd 21/03/2019

Maximum 24-hour average $PM_{2.5}$ concentrations (µg/m³) - peak day - wagon option 2 increment only

Bombo quarry modification
Air quality impact assessment
Appendix C.3

EMM
creating opportunities



Source: EMM (2018); DFSI (2017); GA (2015)

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Annual average $PM_{2.5}$ concentrations (µg/m³)
- average day
- wagon option 2 increment only

Bombo quarry modification
Air quality impact assessment
Appendix C.4

EMM
creating opportunities

T:\Jobs\2018\J180332 - Bombo Quarry Mod\GIS\02_Maps\AQ009_AnnualTSP_20190321_01.mxd 21/03/2019

Source: EMM (2018); DFSI (2017); GA (2015)

KEY
- Site boundary
- Rail line
- Main road
- Watercourse / drainage line
- Waterbody
- Air quality assessment location

Annual average TSP concentration
- 1 µg/m³
- 2.5 µg/m³
- 5 µg/m³
- 15 µg/m³
- 30 µg/m³

Annual average TSP concentrations (µg/m³) - average day - wagon option 2 increment only

Bombo quarry modification
Air quality impact assessment
Appendix C.5

EMM creating opportunities

Source: EMM (2018); DFSI (2017); GA (2015)

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KEY
- Site boundary
- Rail line
- Main road
- Watercourse / drainage line
- Waterbody
- Air quality assessment location

Annual average dust deposition levels
- 0.1 g/m²/month
- 0.25 g/m²/month
- 0.5 g/m²/month
- 1 g/m²/month
- 2 g/m²/month

Annual average dust deposition levels (g/m²/month)
- average day
- wagon option 2 increment only

Bombo quarry modification
Air quality impact assessment
Appendix C.6

EMM creating opportunities