APPENDIX E –
AIR QUALITY IMPACT ASSESSMENT

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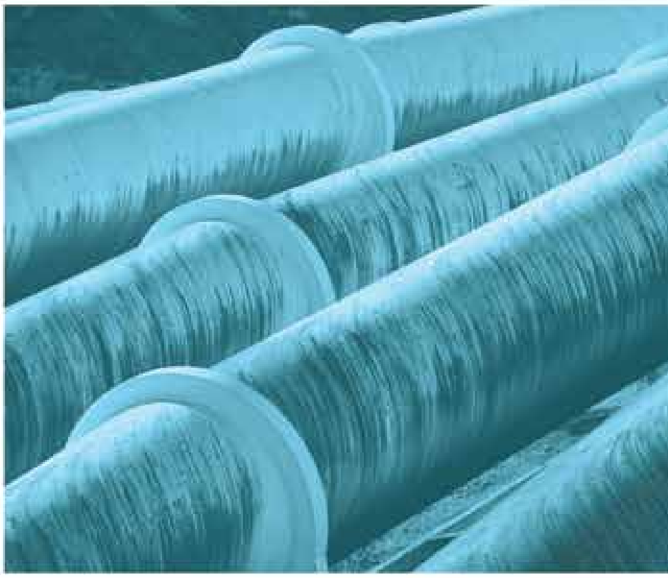
Luddenham Quarry Modification Report
DA 315-7-2003 MOD5

Air Quality Impact Assessment

Prepared for Coombes Property Group & KLF Holdings Pty Ltd
August 2020



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Luddenham Quarry - Modification 5

Air quality impact assessment

Report Number

J190749 RP16

Client

Coombes Property Group & KLF Holdings Pty Ltd

Date

6 August 2020

Version

v3 Final

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Executive Summary

ES1 Overview and assessment approach

Coombes Property Group (CPG) in partnership with KLF Holdings Pty Ltd (KLF) propose to reactivate quarrying operations at Luddenham Quarry, 275 Adams Road, Luddenham, through a modification of existing consent State significant development (SSD) consent DA 317-7-2003 (the proposed modification – MOD5). This air quality impact assessment (AQIA) has been prepared to assess the air quality impacts of the proposed modification on existing sensitive assessment locations in the area. The AQIA has been prepared in general accordance with the guidelines specified by the NSW Environment Protection Authority (EPA) in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2016).

ES2 Existing environment

The nearest sensitive locations to the quarry were identified for the purpose of assessing potential air quality impacts. The closest occupied residence is located adjacent to the lot's northern boundary and about 70 m east of the site access road. The Hubertus Country Club is located immediately west of the site.

Analysis of meteorology for the local area is presented based on data obtained from the Bureau of Meteorology (BoM) automatic weather station (AWS) monitoring site at Badgerys Creek, located approximately 2.4 km south of the site.

To demonstrate compliance with impact assessment criteria, consideration of cumulative impact is required. Cumulative impacts were assessed by taking into account the existing baseline or background air quality, which is described based on monitoring data collected onsite and at the closest publicly available monitoring site. The Western Sydney Airport (WSA) is scheduled to operate from 2026 and its influence on local air quality was also considered in the cumulative assessment.

ES3 Emissions and modelling

A single emissions scenario was modelled, based on the maximum approved extraction rate of 300,000 tonnes per annum. Fugitive dust emissions associated with the operation of the quarry were quantified using the published emission factor equations for each relevant activity.

The air quality impacts of the MOD5 proposal were assessed with atmospheric dispersion modelling, using the regulatory dispersion model AERMOD. Predicted project increment and cumulative ground level concentrations (GLCs) for key pollutants were presented for each assessment location and compared against the NSW Environment Protection Authority's (EPA's) impact assessment criteria.

The modelling indicates that no cumulative exceedances of the impact assessment criteria are predicted to occur at any assessment location for annual average PM_{10} concentrations, annual average $PM_{2.5}$ concentrations, annual average total suspended particulates (TSP) concentrations and annual average dust deposition levels. It is noted that the predicted annual average $PM_{2.5}$ concentration at R3 is equal to impact assessment criterion of 8 $\mu g/m^3$. Similarly, for 24-hour average PM_{10} and $PM_{2.5}$ concentrations, when the predicted project increment is paired with background, there are no additional cumulative exceedances of the impact assessment criterion at any assessment location, although it is noted that that the cumulative 24-hour PM_{10} concentration at R6 is equal to the impact assessment criterion of 50 $\mu g/m^3$.

ES4 Management and monitoring

The potential for short-term impacts will be managed by planning for adverse weather and through reactive and corrective dust controls, which will be formally documented in an air quality management plan. The existing *Air Quality Monitoring Programme* (Golder 2009) will be reviewed and augmented following approval of MOD5.

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1 Introduction

1.1 Background

CFT No 13 Pty Ltd, a member of Coombes Property Group (CPG), has recently acquired the property at 275 Adams Road, Luddenham NSW (Lot 3 in DP 623799, 'the site') within the Liverpool City Council municipality. The site is host to an existing shale/clay quarry.

CPG owns, develops, and manages a national portfolio of office, retail, entertainment, land, and other assets. The company's business model is to retain long-term ownership and control of all its assets. CPG has the following staged vision to the long-term development of the site:

- Stage 1 Quarry Reactivation: **Solving a problem**. CPG intends to responsibly avoid the sterilisation of the remaining natural resource by completing the extraction of shale which is important to the local construction industry as raw material used by brick manufacturers in Western Sydney. Following the completion of approved extraction activities, the void will be prepared for rehabilitation.

- Stage 2 Advanced Resource Recovery Centre and Quarry Rehabilitation: **A smart way to fill the void**: CPG in partnership with KLF Holdings Pty Ltd (KLF) and in collaboration between the circular economy industry and the material science research sector, intends to establish a technology-led approach to resource recovery, management, and reuse of Western Sydney's construction waste, and repurposing those materials that cannot be recovered for use to rehabilitate the void. This will provide a sustainable and economically viable method of rehabilitating the void for development.

- Stage 3 High Value Employment Generating Development: **Transform the land to deliver high value agribusiness jobs**. CPG intends to develop the rehabilitated site into a sustainable and high-tech agribusiness hub supporting food production, processing, freight transport, warehousing, and distribution, whilst continuing to invest in the resource recovery R&D initiatives. This will deliver the vision of a technology-led agribusiness precinct as part of the Aerotropolis that balances its valuable assets including proximity to the future Western Sydney Airport (WSA) and Outer Sydney Orbital.

This report relates to a modification application relating to the delivery of stage 1 as described above.

1.2 Purpose of this report

CPG in partnership with KLF propose to reactivate quarrying operations at the site, through a modification of existing state significant (SSD) consent DA 317-7-2003 (the proposed modification – MOD5). The existing quarry on the site is approved by SSD consent DA 315-7-2003, issued by the NSW Minister for Planning under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). This consent has been modified three times (MODs 1–3). A fourth modification application (MOD 4) was withdrawn. CPG/KLF have no relationship to the previous site owners/operators of the quarry.

This air quality impact assessment (AQIA) has been prepared to assess the air quality impacts of the MOD5 proposal on existing sensitive assessment locations in the area.

1.3 Proposed modification

Luddenham quarry reactivation will require an approved modification (MOD5) to SSD DA 317-7-2003. A detailed description of the proposed modification is provided in Chapter 2 of the Modification Report (EMM 2020) with key components summarised as follows:

- the use of the exiting site access road from Adams Road by quarry vehicles;
- new stockpiling area, weighbridge and other site infrastructure within Lot 3 DP 623799 (a change to the site layout in Appendix 1);
- administrative modification of some conditions of consent to align with current government policy and/or site conditions;
- removal of activities on Lot 1 DP 838361 (adjacent to the eastern boundary of the site); and
- administrative modification of some conditions of consent to align with current government policy and/or site conditions (ie reduced development footprint) including revision of the wording of Schedule 4, Condition 7 relating to air quality monitoring to reflect the smaller development footprint.

The modification does not seek to increase the approved extraction rate, quarry life or approved area or depth of extraction.

A conceptual site layout of the proposed modification is provided in Figure 1.1.

Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

KEY

▭ Study area

▭ Cadastral boundary

Proposed site modifications

🟪 Approved extraction footprint

🟧 Existing noise bunds

🟩 Existing stockpiling area

🟩 Extended stockpiling area

⬛ Internal road

🟨 Site entry infrastructure (incl. offices, amenities, weighbridge)

🟪 Equipment laydown area

Proposed modification

Luddenham Quarry - Modification 5
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Figure 1.1

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2 Assessment approach

2.1 Introduction

This AQIA presents a quantitative assessment of potential air quality impacts, with an emphasis on emissions of particulate matter (PM) – the key pollutant associated with quarry. The AQIA has been prepared in general accordance with the guidelines specified by the NSW Environment Protection Authority (EPA) in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (EPA 2016), hereafter referred "the Approved Methods for Modelling".

The AQIA uses a Level 2 assessment approach, as follows:

- emissions were estimated for all relevant activities, using best practice emission estimation techniques;
- dispersion modelling using a regulatory dispersion model was used to predict ground-level concentrations for key pollutants at surrounding sensitive receptors; and
- cumulative impacts were assessed, taking into account the combined effect of the project with existing baseline air quality.

2.2 Assessment criteria

The NSW EPA's impact assessment criteria for particulate matter, as documented in Section 7 of the Approved Methods for Modelling, are presented in Table 2.1. The assessment criteria for PM_{10} and $PM_{2.5}$ are consistent with the national air quality standards that are defined in the *National Environment Protection (Ambient Air Quality) Measure* (AAQ NEPM) (Department of the Environment 2016).

Total suspended particulates (TSP), which relates to airborne particles less than around 50 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 (NSW EPA 2013). Particles less than 10 µm in diameter, accounted for in this assessment by PM_{10} and $PM_{2.5}$, are a subset of TSP and are fine enough to enter the human respiratory system and can therefore lead to adverse human health impacts. The NSW EPA impact assessment criteria for PM_{10} and $PM_{2.5}$ are therefore used to assess the potential impacts of airborne particulate matter on human health.

The Approved Methods for Modelling classifies TSP, PM_{10}, $PM_{2.5}$ and dust deposition as 'criteria pollutants'. The impact assessment criteria for criteria pollutants are applied at the nearest existing or likely future off-site sensitive receptors[1], and compared against the 100th percentile (ie the highest) dispersion modelling prediction for the relevant averaging. Both the incremental (project only) and cumulative (project + background) impacts need to be presented, with the latter requiring consideration of the existing ambient background concentrations.

For dust deposition, the NSW EPA (2016) specifies criteria for the 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.

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[1] NSW EPA (2016) defines a sensitive receptor as a location where people are likely to work or reside; this may include a dwelling, school, hospital, office or public recreational area.

Table 2.1 Impact assessment criteria for particulate matter

PM metric	Averaging period	Impact 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 meter; g/m^2/month: grams per square metre per month

2.3 Assessment locations

The nearest sensitive locations to the quarry have been identified for the purpose of assessing potential air quality impacts. Details are provided in Table 2.2 and their locations are shown in Figure 2.1. The closest occupied residence (R3) is located adjacent to the lot's northern boundary and about 70 m east of the site access road. The Hubertus Country Club and pistol range is located immediately west of the site.

Table 2.2 Assessment locations

ID	Address	Classification	Easting	Northing
R1	2161–2177 Elizabeth Drive, Luddenham	Residential	288774	6250224
R2	2111–2141 Elizabeth Drive, Luddenham	Residential	289130	6250072
R3	285 Adams Road, Luddenham	Residential	288940	6249722
R4	5 Anton Road, Luddenham	Residential	288347	6249272
R5	185 Adams Road, Luddenham	Residential	288273	6249161
R6	225 Adams Road, Luddenham	Residential	288751	6249563
R7	161 Adams Road, Luddenham	Residential	287916	6249080
R8	2510–2550 Elizabeth Drive, Luddenham	Residential	288334	6250275
C1	Hubertus Club – restaurant including outdoor facilities	Commercial	288680	6249400
AR1	Hubertus Country Club – outdoor firing range	Active recreation	288643	6249324

Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

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Assessment locations

Luddenham Quarry - Modification 5
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Figure 2.1

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3 Overview of local meteorology

3.1 Introduction

Meteorological mechanisms govern the generation, dispersion, transformation and eventual removal of pollutants from the atmosphere. To adequately characterise the dispersion meteorology of a region, information is needed on the prevailing wind regime, ambient temperature, rainfall, relative humidity, mixing depth and atmospheric stability. Analysis of meteorology for the local area is presented based on data obtained from the Bureau of Meteorology (BoM) automatic weather station (AWS) monitoring site at Badgerys Creek, located approximately 2.4 km south of the site.

3.2 Selection of a representative dataset for modelling

In selecting a representative year for modelling, the following criteria were considered:

- data availability – the higher the data capture rate the better and the more complete the modelling period;
- representativeness of the meteorology – this is particularly important for wind conditions, which have a greater influence on dispersion for fugitive dust sources; and
- representativeness of the existing ambient background – the modelling year should also avoid years with significantly lower or higher ambient background concentrations, if these are not representative of longer-term averages.

Six years of hourly data were reviewed for the period 2013 to 2018 and the calendar year 2017 was selected for modelling based on the following observations:

- Figure A.1 shows the % data capture rate by year, with the red bars indicating gaps in the data. The calendar year 2017 has the highest data capture rate of recent years for the majority of parameters;
- annual wind roses for the period 2013 to 2018 are presented in Figure 3.1. The analysis shows consistency in wind direction, average wind speed and percentage occurrence of calm winds (<= 0.5 m/s) for all years; and
- the calendar year 2019 was specifically excluded because the extensive bushfire events in November and December have resulted in elevated levels of PM_{10} and $PM_{2.5}$ which are not representative of a typical year (refer Section 4). In 2019, exceptional events led to poor air quality on 127 days, compared with 50 days in 2018 and 18 days in 2017[2].

3.3 Prevailing winds

Figure 3.1 shows the dominant wind direction for 2017 is from the southwest, with winds from all other directions recorded for a small percentage of time. The annual average wind speed for 2017 is 2.5 m/s and percentage occurrence of calm winds is 7.1%. Seasonal and diurnal variation in winds is show in Figure A.3. During autumn and winter, there is a higher proportion of winds from the southwest, particularly at night. During spring and summer, there is a higher frequency of winds from the north-east. During night-time hours, mean wind speeds are lower than during the day and the percentage occurrence of calm winds is generally higher.

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[2] https://www.environment.nsw.gov.au/topics/air/air-quality-statement

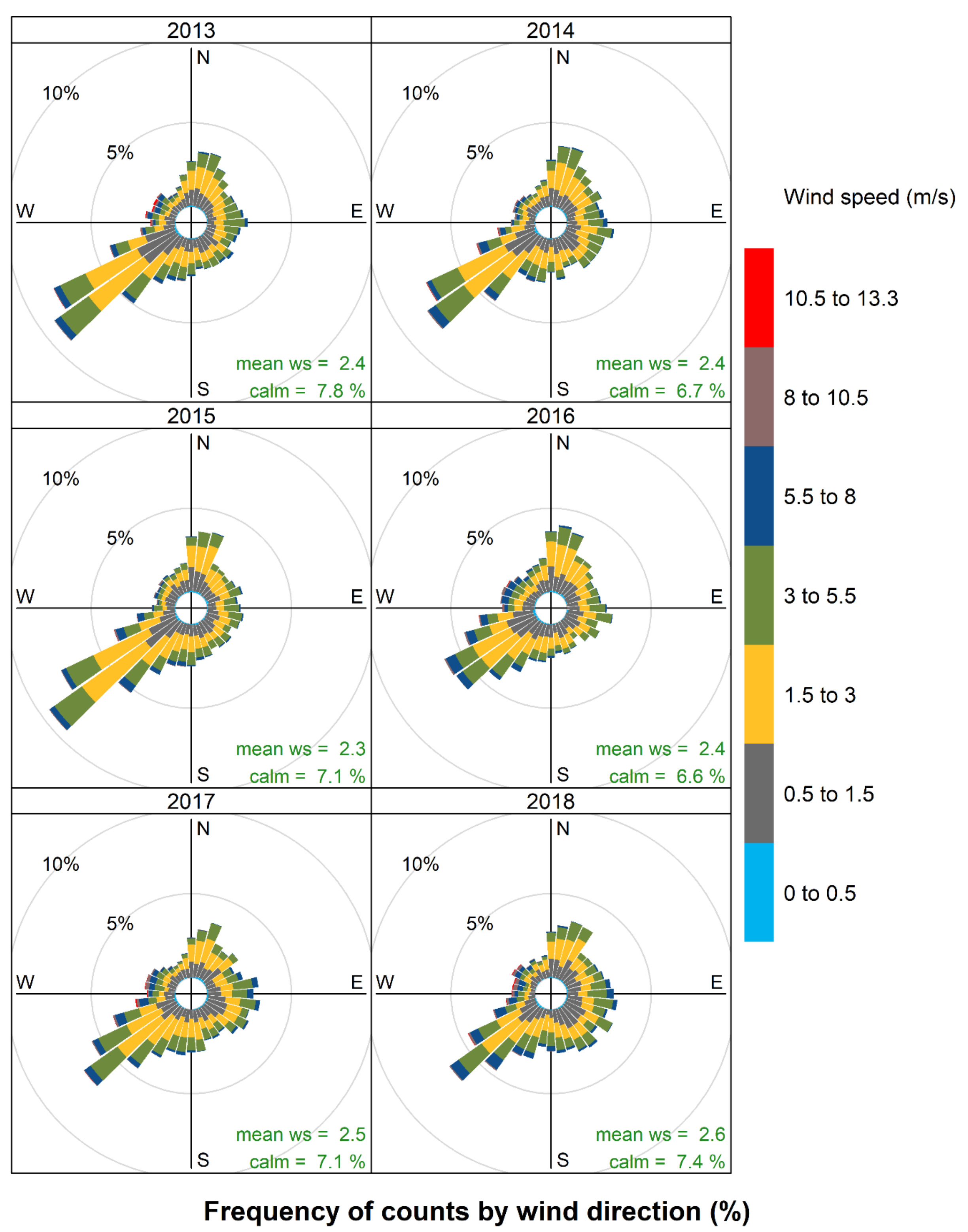

Figure 3.1 Interannual wind roses for Badgerys Creek AWS – 2013 – 2018

3.4 Ambient temperature

The inter-annual variation in temperature for Badgerys Creek is presented as a box and whisker plot in Figure A.4. The inter-annual variation in temperature is presented for a longer 10-year period from 2009–2019. The plot shows that the monthly minimum, maximum, mean and upper and lower quartile temperatures for the modelled year (2017) are consistent and therefore representative when compared with longer-term measurements.

3.5 Rainfall

To provide a conservative (upper bound) estimate of the PM concentrations, wet deposition (removal of particles from the air by rainfall) was excluded from the dispersion modelling simulations undertaken in this report. Furthermore, the emission inventories developed for this study have not applied a natural mitigation factor[3] for rainfall and are therefore more conservative (higher) than if rainfall was incorporated.

3.6 Meteorological modelling

Atmospheric dispersion modelling for this assessment has been completed using the AMS[4]/USEPA[5] regulatory model (AERMOD) (model version v18081). The meteorological inputs for AERMOD were generated using the AERMET meteorological processor using local surface observations and upper air profiles generated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) TAPM meteorological modelling module.

Hourly average meteorological data from the Badgerys Creek AWS were used as observations in the TAPM and AERMET modelling. Further details of the TAPM meteorological modelling and AERMET data processing completed to prepare the inputs for AERMOD are documented in Appendix A.

3.6.1 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 3.2 illustrates the overall diurnal variation of atmospheric stability derived from the Monin-Obukhov length calculated by AERMET based on observations collected at the Badgerys Creek AWS in 2017. The diurnal profile shows that atmospheric instability increases during the daylight hours as the sun generated convective energy increases, whereas stable atmospheric conditions prevail during the night-time. This profile indicates that the potential for effective atmospheric dispersion of emissions would be greatest during day-time hours and lowest during evening through to early morning hours.

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[3] The US EPA AP-42 emission factor documentation for unsealed roads (Chapter 13.2.2) describes a 'natural mitigation' factor, which can be applied for rainfall and other precipitation, based on the assumption that annual emissions are inversely proportional to the number of days with measurable rain, defined as the number of days with greater than 0.25 mm recorded.

[4] AMS: American Meteorological Society

[5] USEPA: United States Environmental Protection Agency

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

Hourly-varying atmospheric boundary layer depths were generated by AERMET, the meteorological processor for the AERMOD dispersion model. The variation in AERMET-calculated boundary layer depth by hour of the day is illustrated in Figure 3.3. Greater boundary layer depths occur during the daytime hours, peaking in the mid to late afternoon.

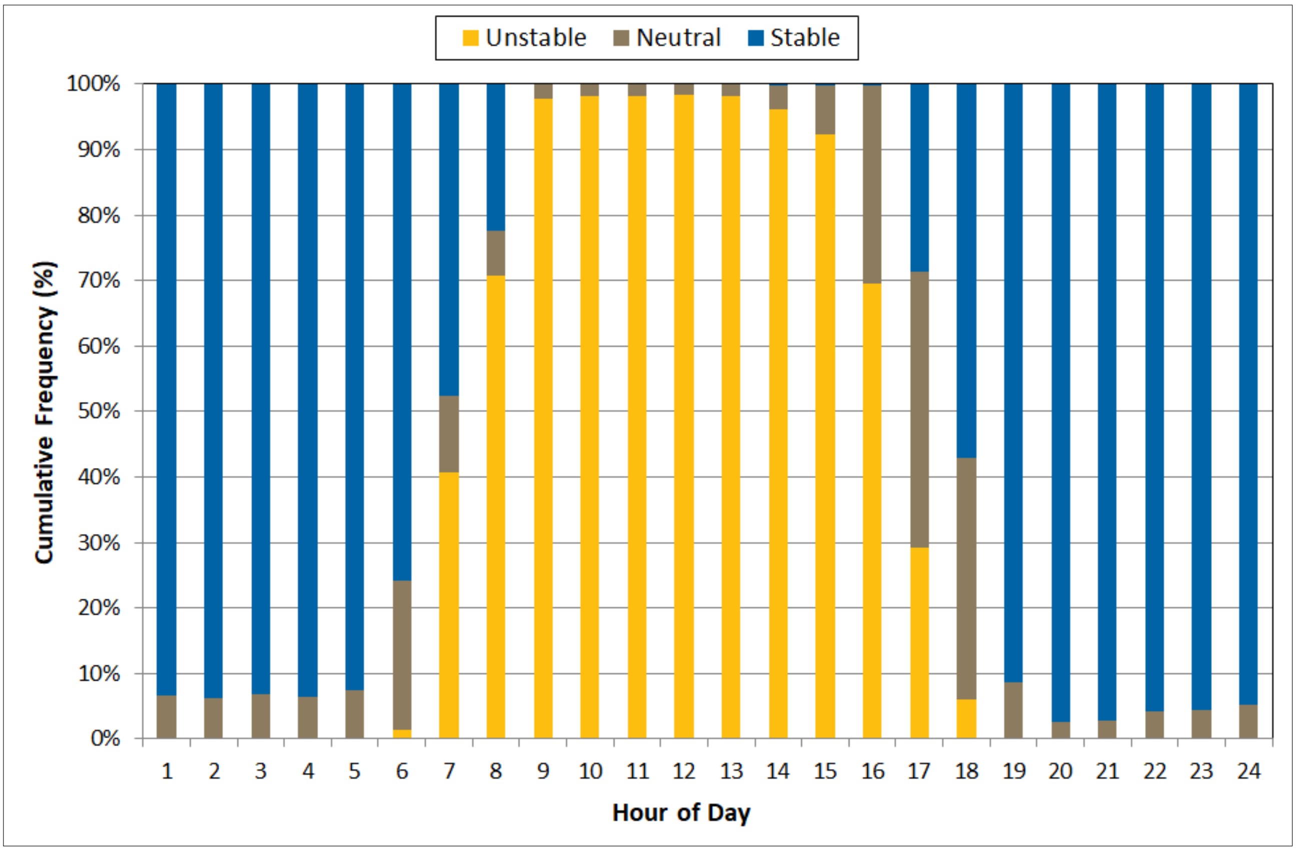

Figure 3.2 Diurnal variations in AERMET-generated atmospheric stability

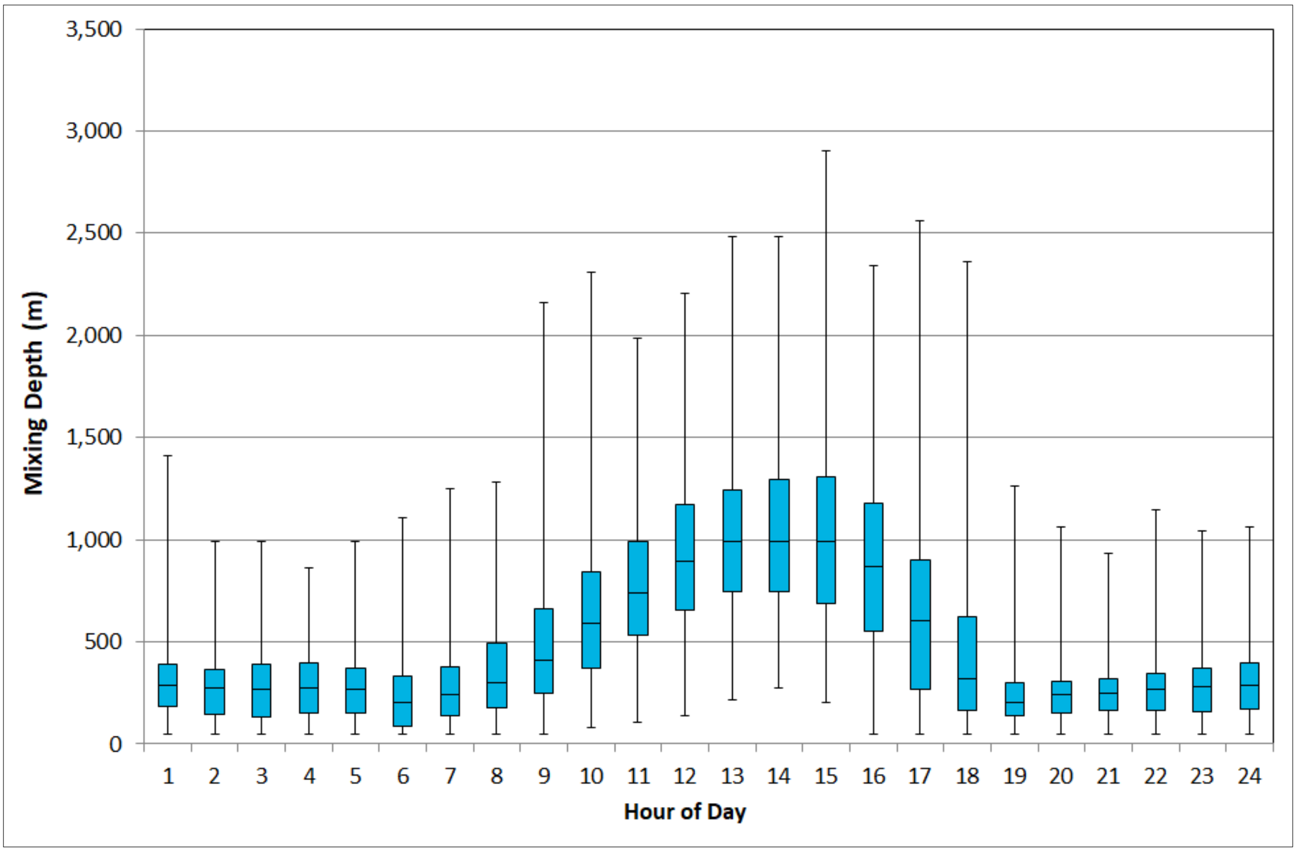

Figure 3.3 Diurnal variation in AERMET generated mixing heights

4 Existing air quality

4.1 Introduction

To demonstrate compliance with impact assessment criteria, consideration of cumulative impact is required to assess how the project will interact with existing and future sources of emissions. Cumulative impacts are assessed by taking into account the existing baseline or background air quality. The local air quality environment is expected to be primarily influenced by traffic, other commercial activity, seasonal emissions from household wood heaters and episodic emissions from bushfires. Baseline or background air quality is described based on monitoring data collected at the closest publicly available monitoring site (the Department of Planning, Industry and Environment (DPIE) monitoring site at Bringelly, located approximately 6 km south-east of the site.

4.2 PM_{10} and $PM_{2.5}$ concentrations

4.2.1 Summary statistics

The relevant summary statistics for PM_{10} and $PM_{2.5}$ for the previous five years are presented in Table 4.1 (monitoring for $PM_{2.5}$ commenced in 2016). In 2019, a significantly higher number of exceedances occurred as a result of the extensive bushfire that occurred in November and December. Exceptional events led to poor air quality on 127 days across NSW, compared with 50 days in 2018 and 18 days in 2017[6]. Therefore, 2019 is not considered a representative year for a discussion on existing air quality.

Excluding 2019, annual mean PM_{10} concentrations range from 15.8 µg/m³ in 2015 to 21.2 µg/m³ in 2018. On average baseline concentrations are 18.5 µg/m³, or 74% of the NSW EPA annual average criterion of 25 µg/m³. Excluding 2019, annual mean $PM_{2.5}$ concentrations range from 7.5 µg/m³ in 2017 to 8.0 µg/m³ in 2018 and on average baseline concentrations are 7.3 µg/m³ or 92% of the NSW EPA annual average criterion.

Exceedances of the 24-hour average reporting standards for PM_{10} occurred in all years, ranging from one day in 2015 to nine days in 2018. Exceedances of the 24-hour average reporting standards for $PM_{2.5}$ occurred in 2017 (twice) and 2018 (four times). Also presented in Table 4.1 is the highest concentration not above the relevant NSW EPA annual average criterion, which is used for cumulative assessment to demonstrate if additional exceedances would occur.

Table 4.1 Summary statistics for particulate matter at Bringelly

Pollutant	Statistic	2015	2016	2017	2018	2019
PM_{10}	Annual mean concentration	15.8	16.9	19.8	21.2	23.6
	Maximum 24-hour average concentration	57.0	61.6	83.7	92.9	134.0
	Number of days that the 24-hour average concentration is above 50 µg/m³	1	3	6	9	24
	Highest 24-hour average concentration not above 50 µg/m³	37.4	40.4	49.5	49.2	49.2
$PM_{2.5}$	Annual mean concentration	-	7.6	7.5	8.0	11.3
	Maximum 24-hour average concentration	-	21.6	52.5	55.6	178.0
	Number of days that the 24-hour average concentration is above 25 µg/m³	-	0	2	4	27
	Highest 24-hour average concentration not above 25 µg/m³	-	14.7	22.1	20.3	24.6

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[6] https://www.environment.nsw.gov.au/topics/air/air-quality-statement

4.2.2 2017 dataset

As described above, the calendar year 2017 is selected for modelling. To provide a continuous dataset for modelling, gaps in the data have been filled as follows:

- for hours where one of PM_{10} or $PM_{2.5}$ concentrations are missing, gaps were filled using a simply linear regression, derived by plotting the relationship between all measurements over the 5-year period; and
- for remaining hours where both the PM_{10} and $PM_{2.5}$ concentrations are missing, gaps were filled using the 70th percentile of the complete data record for each.

Timeseries plots of the daily 24-hour PM_{10} and $PM_{2.5}$ concentrations for 2017 are presented in Figure 4.1 and Figure 4.2. As presented in Table 4.1 there are six existing exceedances of the daily PM_{10} criterion and two existing exceedances of the daily $PM_{2.5}$ criterion in the 2017 background dataset.

The NSW Air Quality Statement for 2017[7] reported that three of the PM_{10} exceedances where due to exceptional events (bushfires, hazard reduction burns and dust storms) and three of the PM_{10} exceedances where due to non-exceptional events. Both of the $PM_{2.5}$ exceedances were attributed to exceptional events, with the highest occurring during a hazard reduction burn on 14/8/2017. For PM_{10}, the plots also show two additional days when background concentrations are elevated but just below daily PM_{10} criterion, both occurring immediately following an exceedance event. The elevated background concentration on 15/8/2017 (49.5 $\mu g/m^3$), for example, is due to lingering smoke from a hazard reduction burn on the previous day and the elevated background concentration on 23/9/2017 (49.4 $\mu g/m^3$) is due to a regional dust storm event[8].

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[7] https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Air/nsw-air-quality-statement-2017-180044.pdf

[8] https://www.environment.nsw.gov.au/research-and-publications/publications-search/dust-episode-from-22-to-24-september-2017

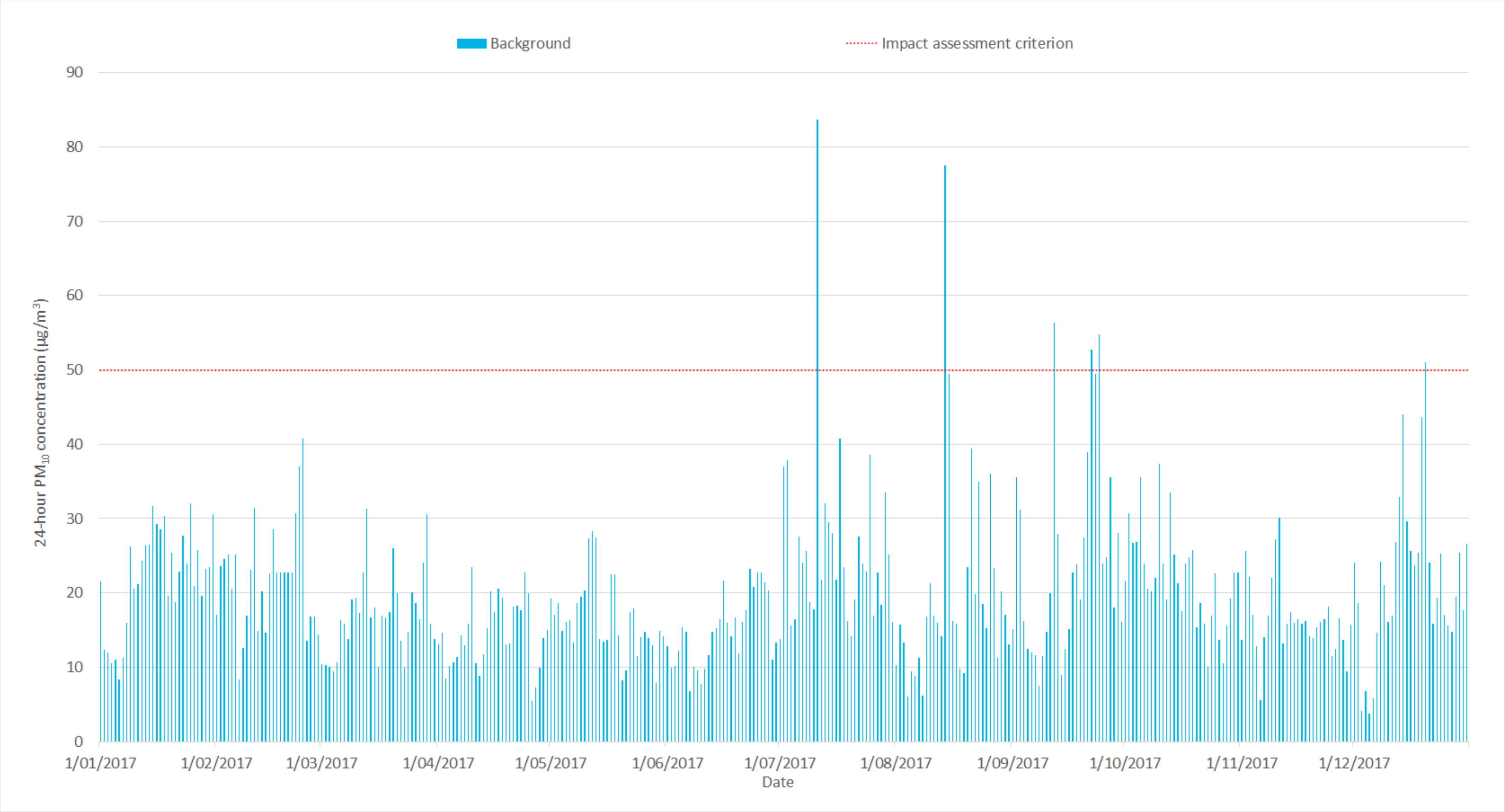

Figure 4.1 Daily varying background 24-hour average PM_{10} concentrations (µg/m³)

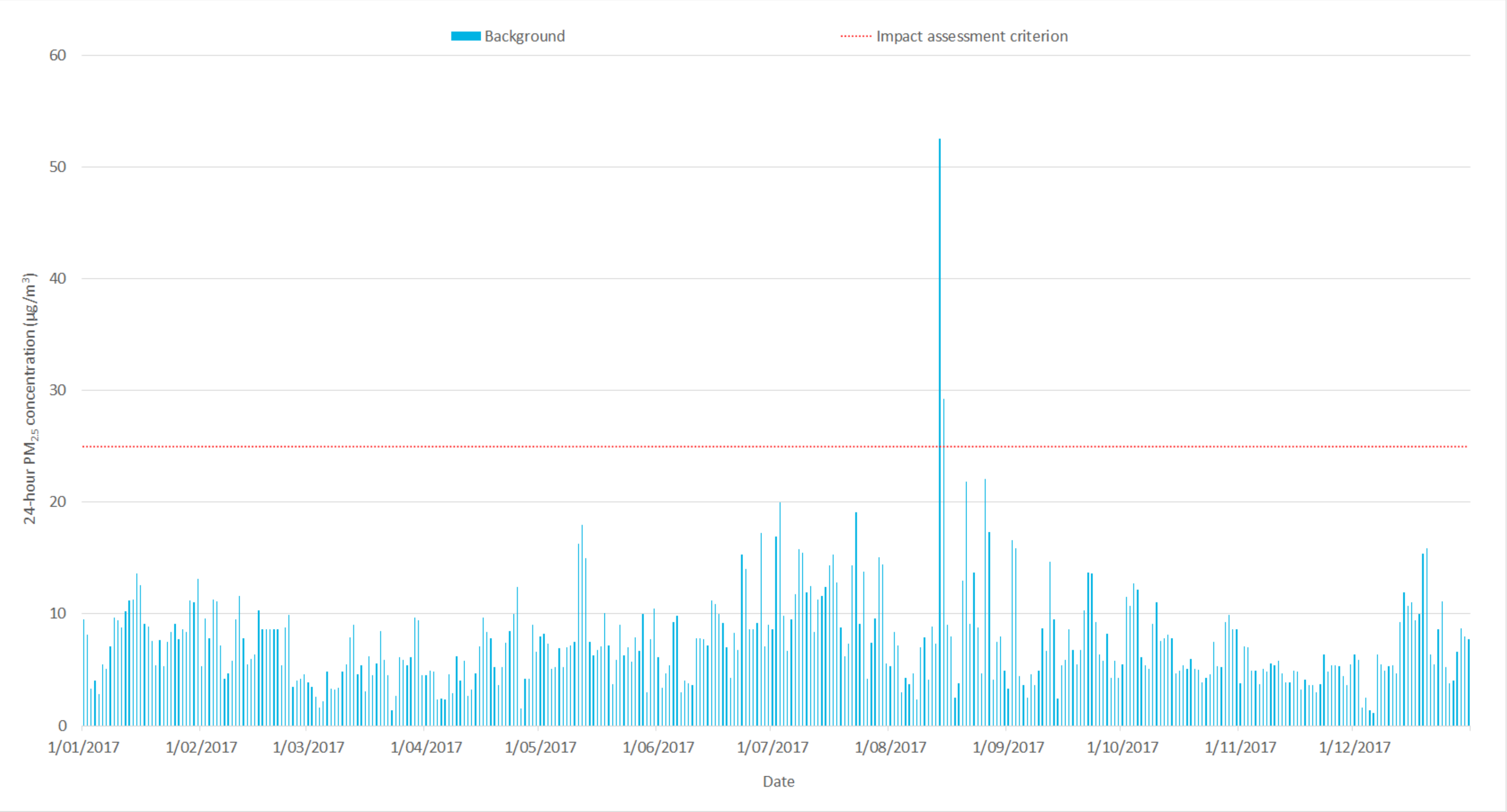

Figure 4.2 Daily varying background 24-hour average $PM_{2.5}$ concentrations (µg/m³)

4.3 TSP concentrations

Total suspend particulate concentrations are not measured at Bringelly, however annual average TSP concentrations can be derived from the PM_{10} data, based on ratios of PM_{10}/TSP which would typically range from 0.4 to 0.5 (ie PM_{10} is typically 40% to 50% of TSP).

4.4 Dust deposition

Dust deposition monitoring was conducted onsite between 2015 to 2018. A summary of the monitoring results is presented in Table 4.2. As shown, a complete year of monthly monitoring results are available for 2016 and 2017 only and the annual average dust deposition for these years range from 0.7 to 3.7 g/m^2/month, with an average across all sites of 1.5 g/m^2/month.

Table 4.2 Summary of dust deposition monitoring results (expressed as insoluble solids)

Year	D1 Adams Rd		D2 East House		D3 Jackson Rd		D4 South Paddock	
	Average (g/m^2/month)	No. of samples	Average (g/m^2/month)	No. of samples	Average (g/m^2/month)	No. of samples	Average (g/m^2/month)	No. of samples
2015	1.5	1	-	-	3.6	2	7.2	2
2016	1.1	12	1.1	12	0.9	12	2.9	12
2017	1.1	12	0.7	12	0.7	11	3.7	12
2018	1.1	4	0.8	4	1.0	4	3.4	4

4.5 Western Sydney Airport

The Western Sydney Airport (WSA), which is currently under construction and scheduled to operate from 2026, will influence local air quality during construction and operation. There are no other quarries, resource recovery centres or other ongoing activities within the vicinity of the site that required consideration as part of the cumulative impact assessment.

An air quality impact assessment prepared for the WSA (PEL 2016) presented modelling predictions for the operation of the airport and included receptor locations at the Hubertus Country Club (receptor C1) and at the corner of Adams Road and Elizabeth Drive. A summary of the WSA air quality modelling predictions for construction and operation is presented in Table 4.3 and Table 4.4.

The operation of the airport was assessed in stages, with Stage 1 scheduled to reach capacity of 10 million passengers per year five years after operations commence (ie in 2030). Stage 2 would not operate for another 40 years. The modelled operation scenario for Stage 1 at full passenger capacity (2030) would not occur concurrently with the approved quarry life to December 2024. The construction scenario is therefore expected to be most relevant to assessment of cumulative impacts for MOD5.

Modelling results indicate that the construction of the WSA will influence local air quality in the vicinity of the site. Relative to construction works, the operation of the WSA would have a relative minor influence on local air quality in the vicinity of the site.

The construction phase of the WSA is included in the cumulative assessment presented in Section 6.

Table 4.3 Modelling predictions for the construction phase of the WSA

		Stage	Hubertus Club	Corner Adams Rd and Elizabeth Drive
PM_{10}	Annual average	WSA bulk earthworks	1.4	1.0
	Maximum 24-hour average		6.9	6.5
$PM_{2.5}$	Annual average		0.3	0.2
	Maximum 24-hour average		2.0	1.8
Dust dep	Annual average		0.3	0.2
PM_{10}	Annual average	Aviation infrastructure	0.4	0.3
	Maximum 24-hour average		3.7	3.6
$PM_{2.5}$	Annual average		0.1	0.1
	Maximum 24-hour average		1.5	2.1
Dust dep	Annual average		0.1	0.1

Table 4.4 Modelling predictions for the Stage 1 operation of the WSA

		Stage	Hubertus Club	Corner Adams Rd and Elizabeth Drive
PM_{10}	Annual average	Stage 1	0.2	0.1
	Maximum 24-hour average		1.8	0.7
$PM_{2.5}$	Annual average		0.2	0.1
	Maximum 24-hour average		1.7	0.7

4.6 Adopted background for cumulative assessment

The following background values were adopted for cumulative assessment:

- 24-hour PM_{10} concentration – daily varying Bringelly data for 2017 with the contribution from the construction phase of WSA included by adding the maximum predicted 24-hour average concentration to every day of the background dataset;

- annual average PM_{10} concentration – 4-year average for 2015-2018[9] of 18.5 µg/m³ plus the predicted contribution from the WSA (1.4 µg/m³);

- 24-hour $PM_{2.5}$ concentration – daily varying Bringelly data for 2017 with the contribution from the construction phase of WSA included by adding the maximum predicted 24-hour average concentration to every day of the background dataset;

- annual average $PM_{2.5}$ concentration – 4-year average for 2015–2018 (filled data) of 7.3 µg/m³ plus the predicted contribution from the WSA (0.3 µg/m³);

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[9] 2019 excluded due to extensive bushfire activity

- annual average TSP concentration of 49.7 µg/m³ is adopted, derived from the PM_{10} dataset and assuming PM_{10} is 40% of TSP; and
- annual average dust deposition level of 1.5 g/m^2/month, derived from the average of the onsite measurements for 2016 and 2017 plus the predicted contribution from the WSA (0.3 g/m^2/month).

5 Emission inventory

Fugitive dust sources associated with the operation of the quarry were quantified using the National Pollution Inventory (NPI) emission estimation techniques and United States Environmental Protection Agency (USEPA) AP-42 emission factor equations. Particulate matter emissions were quantified for various particle size fractions, with the TSP fraction being estimated to provide an indication of dust deposition rates. Coarse particles (PM_{10}) and fine particles ($PM_{2.5}$) were estimated using ratios for the different particle size fractions available within the literature (principally the USEPA AP-42).

5.1 Sources of operational emissions

Sources of atmospheric emissions associated with the quarry are anticipated to include:

- extraction of material within the pit using excavator or scraper;
- dozer pushing material in the pit;
- handling of material (loading to trucks and unloading to stockpiles);
- crushing/screening of material within the approved quarry footprint;
- movement of vehicles across paved and unpaved roads and surfaces within the site;
- rehandle of material to product stockpiles;
- loading of product to truck for dispatch;
- diesel fuel combustion by on-site plant and equipment[10]; and
- wind erosion associated with material stockpiles and exposed ground.

5.2 Emissions scenario

To assess the potential impacts from the proposed modification, a single emissions scenario was modelled, based the maximum approved extraction rate of 300,000 tonnes per annum (tpa). The following general assumptions were made in deriving the emission inventory:

- annual extraction and transport of 300,000 tpa, comprising approximately 20% clay and 80% shale;
- extraction of material from pit using a scraper and/or dozer;
- processing (crushing/screening) of 240,000 tpa shale per annum (ie 80% of 300,000);
- internal transfer of material via 45 tonne haul trucks;
- external transport of product via 32 tonne road trucks;

---

[10] Emissions of other pollutants (including oxides of nitrogen, carbon monoxide and sulphur dioxide) associated with diesel fuel combustion are likely to be minor relative to particulate matter emissions and were not included in this assessment.

- hours of operation are 7.00 am to 6.00 pm, 5 days a week with equipment (dozer/scraper/grader) operating at 70% utilisation; and
- wind erosion was assumed to occur from approximately half the area of the pit and the entire stockpile area.

5.3 Emission reduction factors

The following dust mitigation measures have been incorporated into the emission inventory based on emission reduction factors reported in the literature[11], as follows:

- water cart to operate on the internal unsealed haulage routes (75% control factor for trucks and 50% for grading roads);
- sealing of the access road between Adams Road and the weighbridge (emission estimated using the paved road emission factor equation);
- minimising drop heights when unloading from trucks (30% control factor applied);
- watering applied to the crushing plant (50% control factor applied); and
- sheltering factor applied for wind erosion within the established pit (30% control applied for wind breaks).

5.4 Particulate matter emissions

A summary of calculated annual emissions by source type is presented in Table 5.1. The most significant source of emissions is associated with the haulage of extract material and product (includes grading of haulage routes). Material handling and wind erosion are next biggest contributors for the coarser particle fraction (TSP and PM_{10}) while the significance of diesel combustion emissions increases with decreasing particle size (diesel combustion is the next largest source of $PM_{2.5}$ after haulage).

The relative significance of key source types by particle size is illustrated in Figure 5.1. Further details regarding emission estimation factors and assumptions are provided in Appendix B.

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[11] Katestone (2011)

Table 5.1 Calculated annual TSP, PM_{10} and $PM_{2.5}$ emissions

Emissions source	Calculated annual emissions (kg/year) by source		
	TSP	PM_{10}	$PM_{2.5}$
Material extraction			
Scraper or excavator ripping clay	9.3	4.4	0.7
Scraper or excavator ripping shale	97.9	46.3	7.0
Dozer in pit	5,463	1,157	0.0
Excavator loading clay to haul trucks	9.3	4.4	0.7
Excavator loading shale to haul trucks	97.9	46.3	7.0
Hauling clay to stockpiling area	1,323	339.9	34.0
Hauling shale to processing area	5,291	1,360	136.0
Processing and dispatch			
Unloading clay	6.5	3.1	0.5
Unloading shale	68.5	32.4	4.9
Rehandle shale to processing circuit	68.5	32.4	4.9
Crushing	1,500	144.0	26.7
Screening	516.0	516.0	3.0
Rehandle shale to stockpile	68.5	32.4	4.9
FEL at processing area	68.5	32.4	4.9
Loading clay to trucks	6.5	3.1	0.5
Loading shale to trucks	68.5	32.4	4.9
Haul product off-site – unsealed	8,409	2,161	216.1
Haul product off-site – sealed	3,179	610.1	147.6
Wind erosion			
Active pit	2,027	1,014	152.0
Stockpile area	1,434	716.8	107.5
Miscellaneous			
Grader (road maintenance)	4,481	1,565	138.9
Onsite diesel consumption	474.0	474.0	434.5
Total (kg/yr)	**34,666**	**10,327**	**1,437**

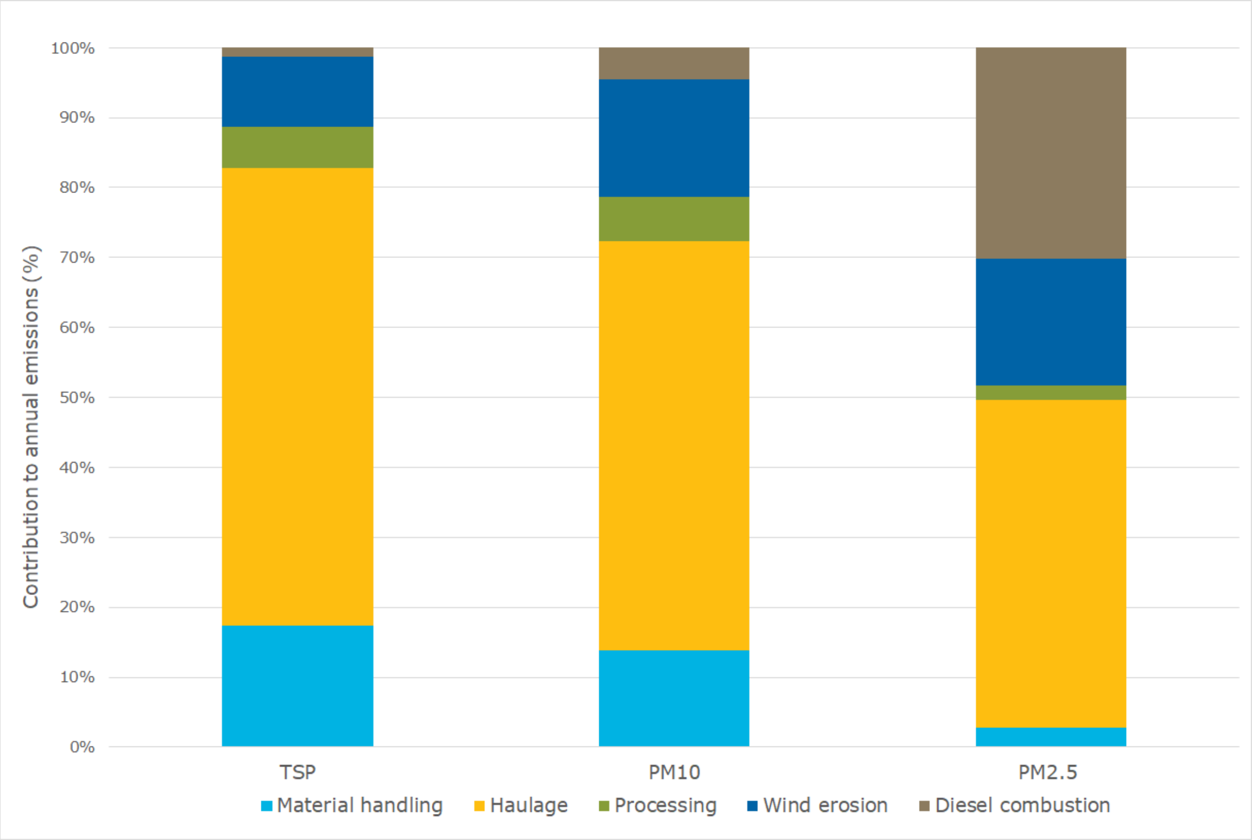

Figure 5.1 Relative contribution of emission sources to total annual emissions

6 Modelling results

6.1 Dispersion model selection

The atmospheric dispersion modelling completed for this assessment used the AERMOD dispersion model (version v18081). 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. Specific activities and emission sources (listed in Table 5.1) were represented by line-volume, volume and area sources located according to the layout of the project. The modelled source locations are shown in Figure B.1.

The predicted project increment and cumulative ground level concentrations (GLCs) are tabulated for each assessment location. Gridded ground level concentrations (GLCs) were also predicted over a 4 km by 4 km domain with a 100 m resolution) and used to generate concentration isopleth plots (Appendix C).

6.2 Annual average PM_{10} and $PM_{2.5}$

The predicted project increment and cumulative annual average PM_{10} and $PM_{2.5}$ concentrations are presented in Table 6.1.

The highest predicted project increment for annual average PM_{10} is 1.8 µg/m³ at assessment location R3. The next highest predicted project increment (1.4 µg/m³) occurs at the Hubertus Country Club (C1/AR1). Cumulative annual average results are based on the project increment plus assumed background concentrations described in Section 4, which includes the contribution from the construction phase of WSA.

When the predicted project increment is combined with background, there are no cumulative exceedances of the impact assessment criterion for annual average PM_{10} at any assessment location.

The highest predicted project increment for annual average $PM_{2.5}$ is 0.4 µg/m³ also at assessment location R3. The next highest predicted project increment (0.3 µg/m³) occurs at the Hubertus Country Club (C1/AR1). Cumulative annual average results are based on the project increment plus assumed background concentrations described in Section 4, which includes the contribution from the construction phase of WSA.

When the predicted project increment is combined with background, there are no cumulative exceedances of the impact assessment criterion for annual average $PM_{2.5}$ at any assessment location, although it is noted that the predicted annual average $PM_{2.5}$ concentration at R3 is equal to impact assessment criterion of 8 µg/m³.

Table 6.1 Predicted incremental and cumulative annual average PM_{10} and $PM_{2.5}$ concentrations

Receptor	**PM_{10} (µg/m³)**		**$PM_{2.5}$ (µg/m³)**	
	Increment	**Cumulative**	**Increment**	**Cumulative**
Goal	**25 µg/m³**		**8 µg/m³**	
R1	0.1	19.6	<0.1	7.5
R2	0.2	19.7	0.1	7.6
R3	1.8	21.7	0.4	8.0
R4	0.3	20.2	0.1	7.7
R5	0.2	20.1	0.1	7.7
R6	1.3	21.2	0.3	7.9
R7	0.1	20.0	<0.1	7.6
R8	0.1	19.6	<0.1	7.5
C1	1.4	21.3	0.3	7.9
AR1	1.2	21.1	0.3	7.9

6.3 24-hour average PM_{10} and $PM_{2.5}$

The predicted project increment and cumulative 24-hour average PM_{10} and $PM_{2.5}$ concentrations are presented in Table 6.2. The highest predicted project increment for 24-hour average PM_{10} is 10.2 µg/m³, at assessment location R3. The next highest predicted project increment (8.6 µg/m³) occurs at the Hubertus Country Club (C1/AR1). The highest predicted project increment for 24-hour average $PM_{2.5}$ is 1.9 µg/m³, at assessment location R3. The next highest predicted project increment (1.6 µg/m³) occurs at the Hubertus Country Club (C1/AR1).

Cumulative daily-varying 24-hour average results at each receptor are based on the project-only predicted increment combined with the corresponding background concentrations described in Section 4. The background concentrations comprise of the 2017 Bringelly monitoring dataset combined with the maximum predicted 24-hour average concentration from the construction phase of WSA, added to every day of the background dataset. This approach is considered conservative for the assessment of cumulative impacts.

The Approved Methods for Modelling requires that "no additional exceedances" of the criterion occur as a result of a project. As described in in Section 4, there are six existing exceedances of the daily PM_{10} criterion in the 2017 background dataset. With the additional contribution from the construction phase of WSA, there are another four exceedances of the daily PM_{10} criterion. Therefore, the 11th highest cumulative concentrations are presented for 24-hour average PM_{10}. There are two existing exceedances of the daily $PM_{2.5}$ criterion in the 2017 background dataset. Therefore, the third highest cumulative concentrations are presented for 24-hour average $PM_{2.5}$.

For the purpose of this assessment, an exceedance is predicted if the 11th highest cumulative 24-hour average PM_{10} concentration and the third highest $PM_{2.5}$ concentration are above the applicable criterion.

When the predicted project increment is paired with background, there are no additional cumulative exceedances of the impact assessment criterion at any assessment location, although it is noted that that the cumulative 24-hour PM_{10} concentration at R6 is equal to the impact assessment criterion of 50 µg/m³.

Table 6.2 Predicted incremental and cumulative 24-hour average PM_{10} and $PM_{2.5}$ concentrations

Receptor	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
	Increment	Cumulative with WSA (11th highest)	Increment	Cumulative
Goal	**50 µg/m³**		**25 µg/m³**	
R1	1.0	47.6	0.2	24.1
R2	2.2	47.7	0.5	24.0
R3	10.2	49.9	1.9	24.5
R4	3.2	48.3	0.7	24.1
R5	2.6	48.2	0.7	24.1
R6	5.5	50.0	1.4	24.4
R7	1.4	47.9	0.4	24.1
R8	1.2	47.5	0.3	23.9
C1	8.0	49.8	1.6	24.3
AR1	8.6	49.6	1.6	24.2

6.4 Annual average TSP and dust deposition

The predicted project increment and cumulative annual average TSP concentrations and dust deposition levels are presented in Table 6.3.

The highest predicted project increment for annual average TSP is 6.1 µg/m³, at assessment location R3. When combined with background, there are no cumulative exceedances of the impact assessment criterion at any assessment location.

The highest predicted project increment for annual average dust deposition (0.7 g/m²/month at R3) is below the incremental impact assessment criterion of 2 g/m²/month. When combined with background, there are no cumulative exceedances of the cumulative impact assessment criterion of 4 g/m²/month.

Table 6.3 Predicted incremental and cumulative annual average TSP concentrations and dust deposition levels

Receptor	TSP (µg/m³)		Dust deposition (g/m²/month)	
	Increment	Cumulative	Increment	Cumulative
Goal	**90 µg/m³**		**2 g/m²/month**	**4 g/m²/month**
R1	0.4	50.1	<0.1	1.8
R2	0.7	50.4	0.1	1.9
R3	6.1	55.8	0.7	2.5
R4	0.9	50.6	0.1	1.9
R5	0.7	50.4	0.1	1.9
R6	3.8	53.5	0.4	2.2
R7	0.3	50.0	<0.1	1.8
R8	0.2	49.9	<0.1	1.8
C1	4.1	53.8	0.5	2.3
AR1	3.4	53.1	0.4	2.2

7 Dust management and monitoring

7.1 Mitigation and management

The proposed dust controls for the site were incorporated into the emission inventory developed for this assessment, as follows:

- a water cart will operate on the internal unsealed haulage routes as required;
- the access road between Adams road and the weighbridge will be sealed;
- drop heights will be minimised when loading trucks;
- watering will be applied to the crushing plant as required to minimise dust emissions.

Other control measures not explicitly applied as a reduction factor in the emission inventory include:

- double handling of material will be avoided where possible;
- site-wide vehicle speed limits will be applied (potentially different on sealed and unsealed roads);
- disturbance of stabilised ground cover will be avoided where possible;
- meteorological forecasts will be used to predict when the risk of dust emissions are high (due to adverse wind conditions) and preparatory measures will be implemented, that may include:
  - watering surfaces so they are moist prior to hot and windy conditions;
  - planning additional water spraying during the day;
  - ceasing some activities or reducing activity levels; and
  - re-scheduling product dispatch.

These dust controls will be formally documented in the air quality management plan, prepared following approval for the reactivation of the quarry.

7.2 Monitoring

An *Air Quality Monitoring Programme* was developed in 2009 for the operation of the quarry (Golder 2009) and this will be reviewed and augmented following approval for the reactivation of the quarry. As described in Section 4.4, the monitoring programme currently consists of four dust deposition gauges. The existing four locations will be reviewed based on the revised quarry plan and based on the outcomes of this assessment.

In addition, daily visual inspections of activities would be undertaken to monitor the effectiveness of dust controls and allow for reactive and corrective measures to be implemented.

The inspections will focus on the following key issues:

- inspect the sealed access road for high silt loading and clean surface using water cart/street sweeper if required;
- inspect and report on excessive dust being generated at source (wheel generated dust, excavators, FEL, wind erosion);
- inspect and report on water cart activity and effectiveness; and
- inspect and report on dust leaving the site.

8 Conclusion

The air quality impacts of the MOD5 proposal were assessed with atmospheric dispersion modelling, using the regulatory dispersion model AERMOD. Predicted project increment and cumulative ground level concentrations (GLCs) for key pollutants were presented for each assessment location and compared against the NSW EPA's impact assessment criteria.

The modelling indicates that there are no cumulative exceedances of the impact assessment criteria at any assessment location for annual average PM_{10} concentrations, annual average $PM_{2.5}$ concentrations, annual average TSP concentrations and annual average dust deposition levels. It is noted that the predicted annual average $PM_{2.5}$ concentration at R3 is equal to impact assessment criterion of 8 µg/m³.

Similarly, for 24-hour average PM_{10} and $PM_{2.5}$ concentrations, when the predicted project increment is paired with background, there are no additional cumulative exceedances of the impact assessment criterion at any assessment location, although it is noted that that the cumulative 24-hour PM_{10} concentration at R6 is equal to the impact assessment criterion of 50 µg/m³.

The potential for short-term impacts will be managed by planning for adverse weather and through reactive and corrective dust controls, which will be formally documented in an air quality management plan.

9 References

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USEPA 1987, *Update of fugitive dust emission factors in AP-42 Section 11.2*, EPA Contract No. 68-02-3891, Midwest Research Institute, Kansas City, MO, July 1987.

USEPA 1998a, *Emission Factor Documentation for AP-42. Section 13.2.2. Unpaved Roads*. Final Report for U.S. United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Factor and Inventory Group. MRI Project No. 4864. September 1998.

USEPA 1998b, AP-42 Emission Factor Database*, Chapter 11.9 Western Surface Coal Mining*, United States Environmental Protection Agency, 1998.

USEPA 2004, *User's Guide for the AMS/EPA Regulatory Model - AERMOD.*

USEPA 2006, AP-42 Emission Factor Database, *Chapter 13.2.5 Industrial Wind Erosion*, United States Environmental Protection Agency, November 2006.


Appendix !

Analysis of meteorology




A.1 Summary plot

Note: stlp = station level pressure and slp = sea level pressure. SigT = standard deviation of wind direction (sigma theta)

Figure A.1 Summary plot showing data availability for Badgerys Creek AWS – 2013–2018

A.2 Wind roses

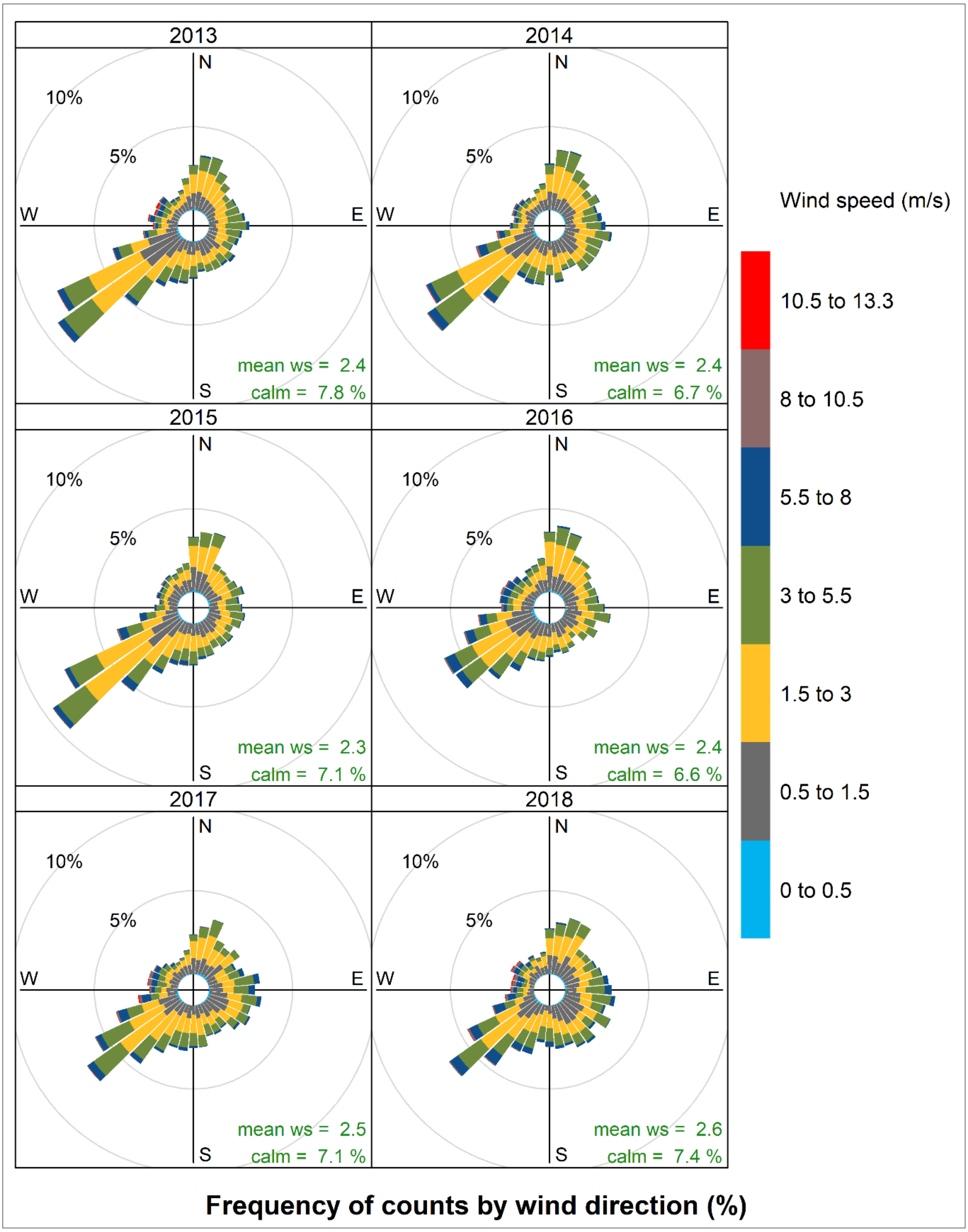


Figure A.2 Interannual wind roses for Badgerys Creek AWS – 2013–2018

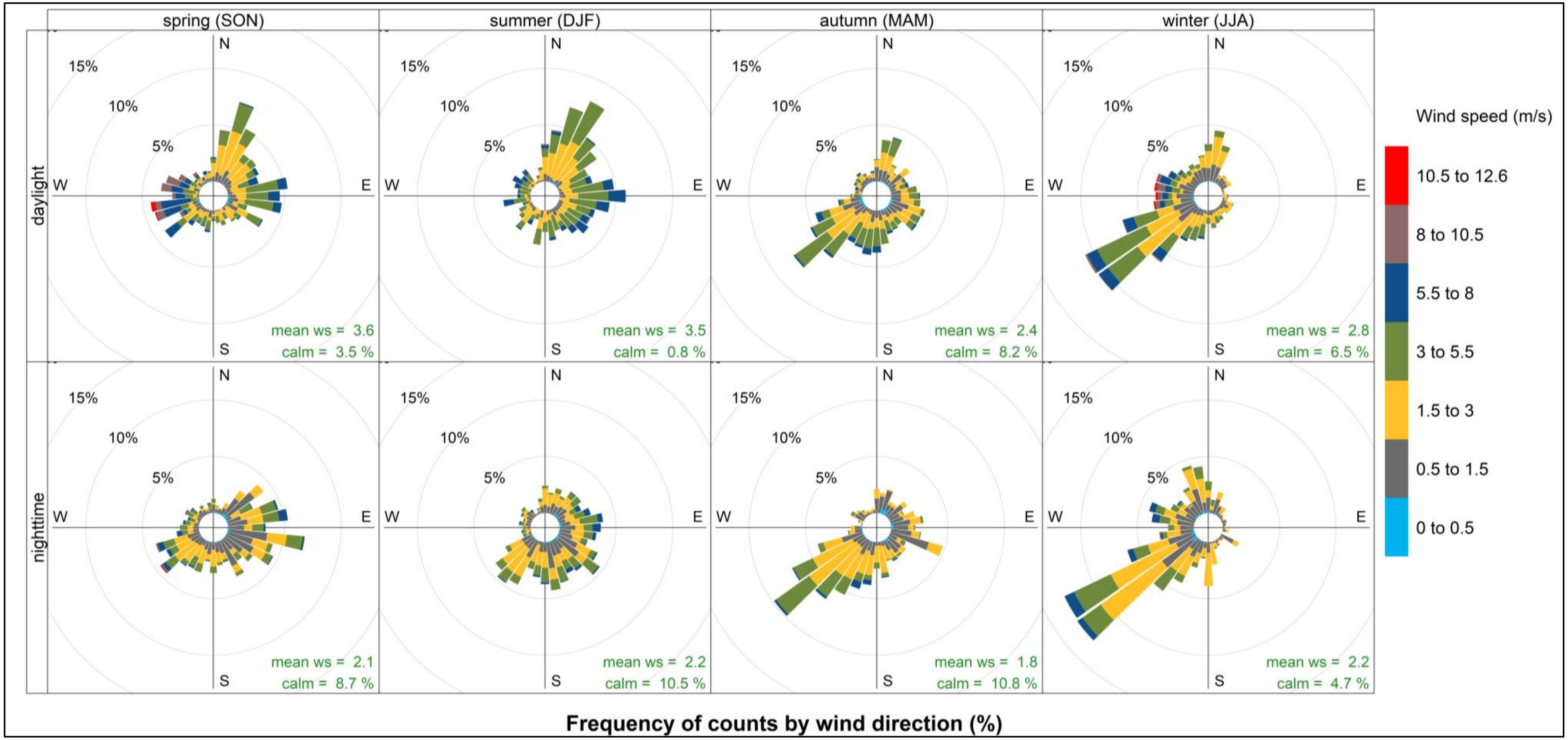


Figure A.3 Seasonal wind roses for Badgerys Creek AWS – 2017

A.3 Ambient temperature

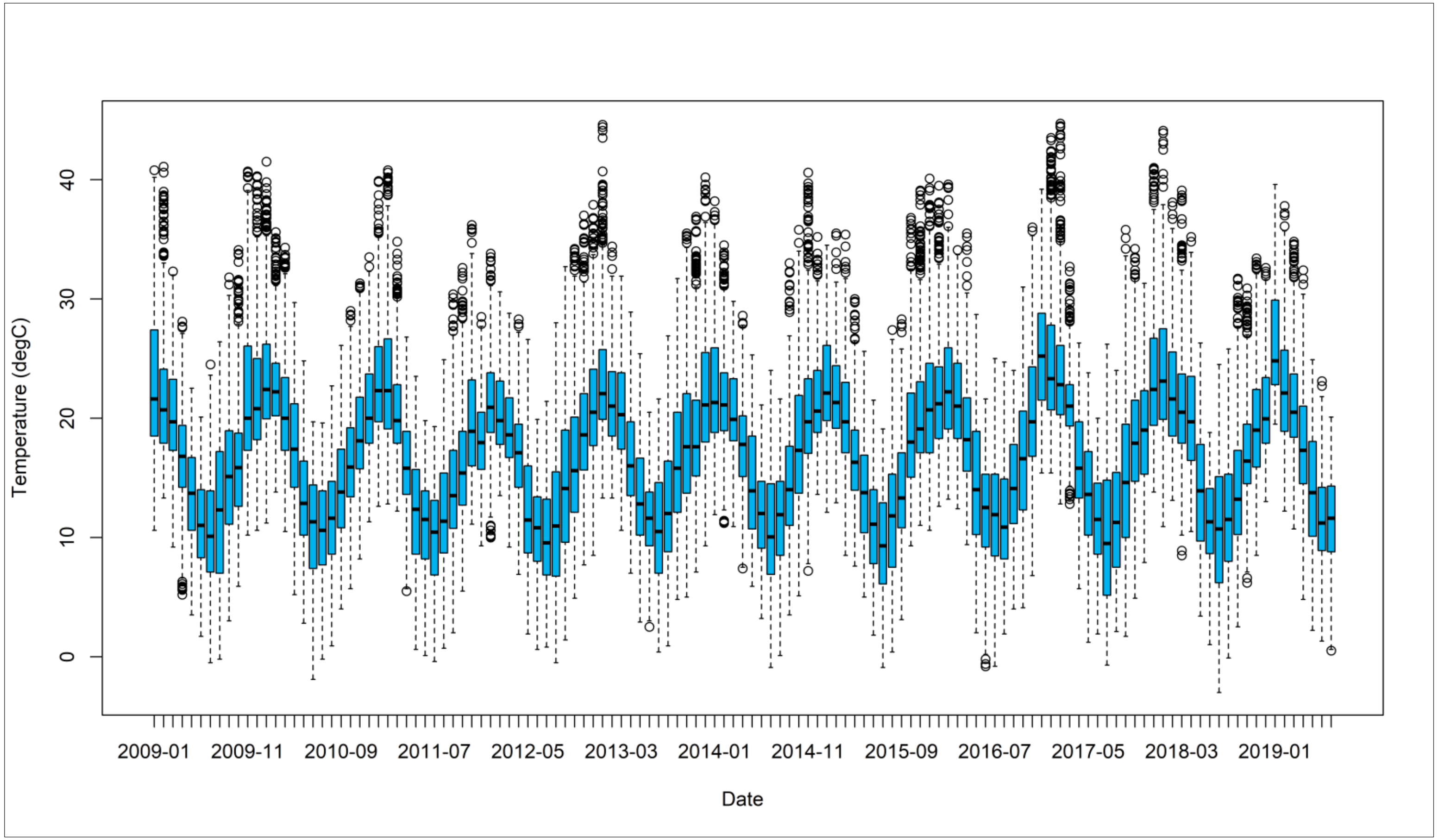


Figure A.4 Interannual variation in monthly temperature for Badgerys Creek AWS – 2009–2019

A.4 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 that are 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 for Modelling as follows:

- TAPM version 4.0.5;
- Grid domains with cell resolutions of 30 km, 10 km, 3 km and 1 km. 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.5 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.

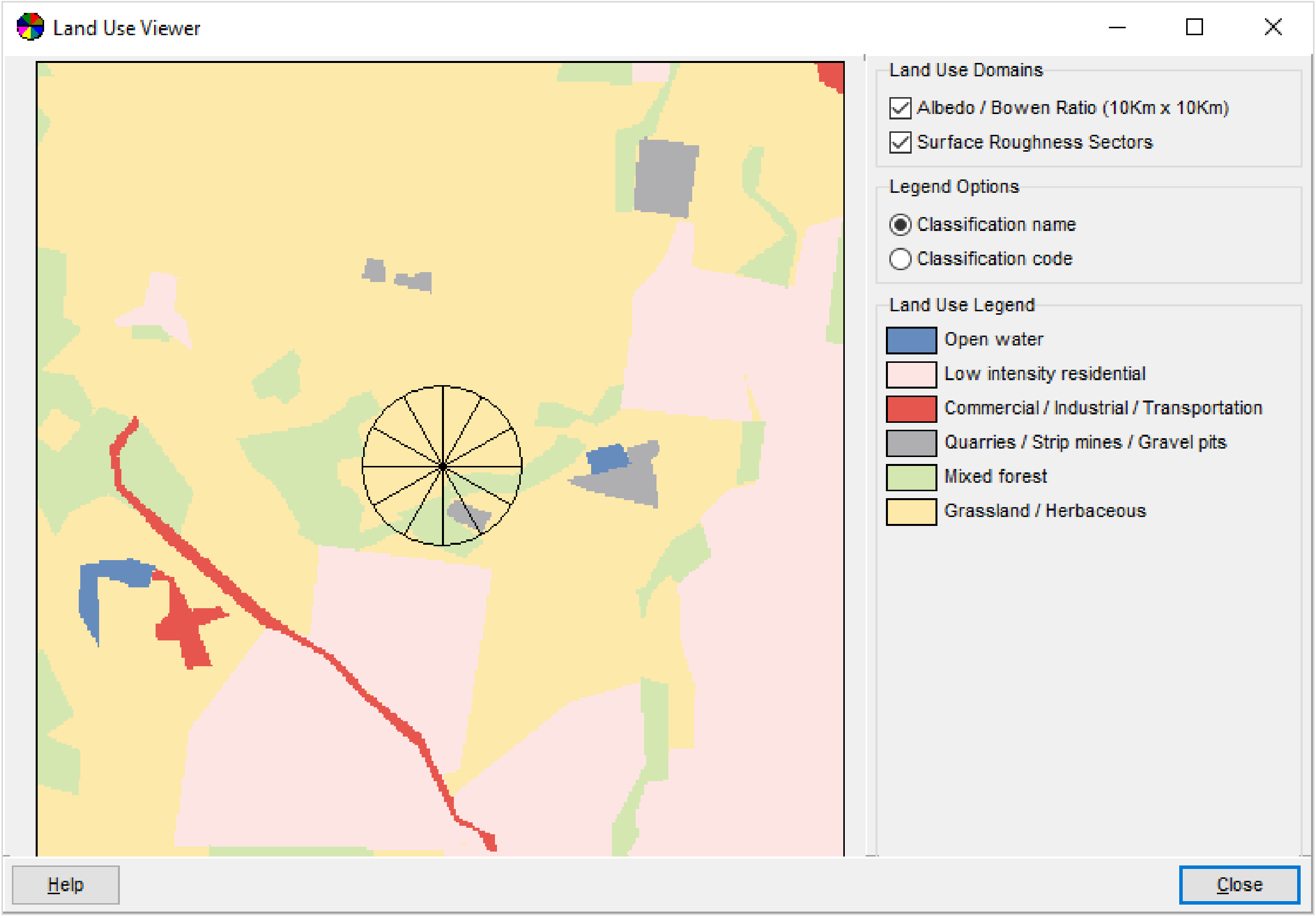
A.5.1 Surface characteristics

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 USEPA (2013), the surface roughness length is related to the height of obstacles to the wind flow (eg vegetation, built environment) 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 10 km by 10 km area surrounding the project was mapped (see Figure A.5). Using the AERSURFACE tool and following the associated guidance of USEPA (2013), surface roughness was determined for 12 (30 degree) sectors grouped by similar land use types within a 1 km radius around the on-site meteorological station, while the Bowen ratio and albedo were determined for the total area. Monthly-varying values for surface roughness, Bowen ratio and albedo were allocated to each sector based on the values prescribed by USEPA (2013).



Land Use Domains
☑ Albedo / Bowen Ratio (10Km x 10Km)
☑ Surface Roughness Sectors

Legend Options
● Classification name
○ Classification code

Land Use Legend
- 🟦 Open water
- ▨ Low intensity residential
- 🟥 Commercial / Industrial / Transportation
- ▨ Quarries / Strip mines / Gravel pits
- 🟩 Mixed forest
- 🟨 Grassland / Herbaceous

Figure A.5 **Land use map for AERSURFACE processing**

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

A.5.2 Meteorological inputs

Monitoring data from the Badgerys Creek AWS were combined with TAPM meteorological modelling outputs for input to AERMET. The following parameters were input as on-site data to AERMET:

- wind speed and direction – Badgerys Creek AWS;
- temperature (heights of 2 m and 10 m) – Badgerys Creek AWS;
- relative humidity – Badgerys Creek AWS;
- station level pressure – Badgerys Creek AWS;
- solar insolation – Bringelly DPIE station; and
- mixing depth – TAPM at on-site station.

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

A.5.3 Upper air profile

Due to the absence of necessary local upper air meteorological measurements, the hourly profile file generated by TAPM at the on-site meteorological station 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 (10 m) temperature observations from the Badgerys Creek AWS.

Appendix B

Emissions inventory

B.1 Particulate matter emissions inventory

Particulate matter emissions from the site were quantified through the application of accepted published emission estimation factors, collated from a combination of United States Environmental Protection Agency (USEPA) AP-42 *Air Pollutant Emission Factors* and NPI emission estimation manuals, including the following:

- *NPI Emission Estimation Technique Manual for Mining* (NPI 2012);
- AP-42 Chapter 11.9 – Western Surface Coal Mining (USEPA 1998);
- AP-42 Chapter 11.19.2 – Crushed Stone Processing and Pulverized Mineral Processing (USEPA 2004);
- AP-42 Chapter 13.2.1 – Paved Roads (USEPA 2011); and
- AP-42 Chapter 13.2.4 – Aggregate Handling and Storage Piles (USEPA 2006).

Particulate releases were quantified for TSP, PM_{10} and $PM_{2.5}$ are shown in Table B.1.

B.2 Diesel combustion emissions

Diesel combustion emissions were calculated based on an estimated annual diesel consumption of 395 kL/annum (7,900 litres per week for 50 weeks) and NPI emissions factors for combustion engines (very HGV)[12].

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[12] http://www.npi.gov.au/system/files/resources/afa15a7a-2554-c0d4-7d0e-d466b2fb5ead/files/combustion-engines.pdf

Table B.1 TSP emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1		Variable 2		Variable 3		Variable 4		Variable 5		Control %	Control
Material extraction																	
Excavator ripping topsoil/overburden	0.0	0	t/y	0.0015	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator ripping clay	9.3	60,000	t/y	0.0002	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator ripping shale	97.9	240,000	t/y	0.0004	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3								
Dozer in pit	5,463	1,820	h/y	3.0	kg/h	7.5	moisture content in %	10	silt content in %								
Excavator loading topsoil/overburden to haul trucks	0.0	0	t/y	0.0015	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator loading clay to haul trucks	9.3	60,000	t/y	0.0002	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator loading shale to haul trucks	97.9	240,000	t/y	0.0004	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3								
Hauling overburden to stockpile area	0.0	0	t/y	0.0882	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	2.8	kg/VKT	5.0	% silt content	75	Watering
Hauling clay to stockpiling area	1,323	60,000	t/y	0.0882	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	2.8	kg/VKT	5.0	% silt content	75	Watering
Hauling shale to processing area	5,291	240,000	t/y	0.0882	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	2.8	kg/VKT	5.0	% silt content	75	Watering
Processing and dispatch																	
Unloading topsoil/overburden	0.0	0	t/y	0.0015	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Unloading clay	6.5	60,000	t/y	0.0002	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)

Table B.1 TSP emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1		Variable 2		Variable 3		Variable 4		Variable 5		Control %	Control
Unloading shale	68.5	240,000	t/y	0.0004	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Rehandle shale to processing circuit	68.5	240,000	t/y	0.0004	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Crushing	1,500	240,000	t/y	0.0125	kg/t											50	Watering
Screening	516.0	240,000	t/y	0.0043	kg/t											50	Watering
Rehandle shale to stockpile	68.5	240,000	t/y	0.0004	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
FEL at processing area	68.5	240,000	t/y	0.0004	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Loading clay to trucks	6.5	60,000	t/y	0.0002	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Loading shale to trucks	68.5	240,000	t/y	0.0004	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Haul product off-site – unsealed	8,409	300,000	t/y	0.1121	kg/t	32	t/load	36	Ave trip vehicle gross mass (t)	1.5	km/return trip	2.4	kg/VKT	5.0	% silt content	75	Watering
Haul product off-site – sealed	3,179	300,000	t/y	0.0106	kg/t	32	t/load	36	Ave trip vehicle gross mass (t)	0.4	km/return trip	0.8	kg/VKT	8.2	road surface silt loading (g/m2)		
Wind erosion																	
Active pit	2,027	3.4	ha	850	kg/ha/yr											30	wind breaks
Stockpile area	1,434	1.7	ha	850	kg/ha/yr												
Miscellaneous																	
Grader (road maintenance)	4,481	14,560	km/y	0.615	kg/km	8	speed of graders in km/h	1,820	grader hours							50	Watering grader routes

Table B.1 TSP emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Control %	Control
Onsite diesel consumption	474.0	395	kL/yr	1.2	kg/kL							
Total (kg/yr)	**34,666**											

Table B.2 PM$_{10}$ emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1		Variable 2		Variable 3		Variable 4		Variable 5		Control %	Control
Material extraction																	
Excavator ripping topsoil/overburden	0.0	0	t/y	0.0007	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator ripping clay	4.4	60,000	t/y	0.0001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator ripping shale	46.3	240,000	t/y	0.0002	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3								
Dozer in pit	1,157	1,820	h/y	0.6356	kg/h	7.5	moisture content in %	10	silt content in %								
Excavator loading topsoil/overburden to haul trucks	0.0	0	t/y	0.0007	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator loading clay to haul trucks	4.4	60,000	t/y	0.0001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator loading shale to haul trucks	46.3	240,000	t/y	0.0002	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3								
Hauling overburden to stockpile area	0.0	0	t/y	0.0227	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	0.7	kg/VKT	5	% silt content	75	Watering
Hauling clay to stockpiling area	339.9	60,000	t/y	0.0227	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	0.7	kg/VKT	5	% silt content	75	Watering
Hauling shale to processing area	1,360	240,000	t/y	0.0227	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	0.7	kg/VKT	5	% silt content	75	Watering
Processing and dispatch																	
Unloading topsoil/overburden	0.0	0	t/y	0.0007	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)

Table B.2 PM$_{10}$ emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1		Variable 2		Variable 3		Variable 4		Variable 5		Control %	Control
Unloading clay	3.1	60,000	t/y	0.0001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Unloading shale	32.4	240,000	t/y	0.0002	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Rehandle shale to processing circuit	32.4	240,000	t/y	0.0002	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Crushing	144.0	240,000	t/y	0.0012	kg/t											50	Watering
Screening	516.0	240,000	t/y	0.0043	kg/t											50	Watering
Rehandle shale to stockpile	32.4	240,000	t/y	0.0002	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
FEL at processing area	32.4	240,000	t/y	0.0002	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Loading clay to trucks	3.1	60,000	t/y	0.0001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Loading shale to trucks	32.4	240,000	t/y	0.0002	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Haul product off-site – unsealed	2,161	300,000	t/y	0.0288	kg/t	32	t/load	36	Ave trip vehicle gross mass (t)	1.5	km/return trip	0.6	kg/VKT	5	% silt content	75	Watering
Haul product off-site – sealed	610.1	300,000	t/y	0.0020	kg/t	32	t/load	36	Ave trip vehicle gross mass (t)	0.4	km/return trip	0.2	kg/VKT	8.2	road surface silt loading (g/m2)		
Wind erosion																	
Active pit	1,014	3.4	ha	425	kg/ha/yr											30	wind breaks
Stockpile area	716.8	2	ha	425	kg/ha/yr											0	0

Table B.2 PM$_{10}$ emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Control %	Control
Miscellaneous												
Grader (road maintenance)	1,565	14,560	km/y	0.215	kg/km	8 speed of graders in km/h	1,820 grader hours				50	Watering grader routes
Onsite diesel consumption	474.0	395	kL/yr	1.2	kg/kL							
Total (kg/yr)	**10,327**											

Table B.3 PM$_{2.5}$ emissions inventory

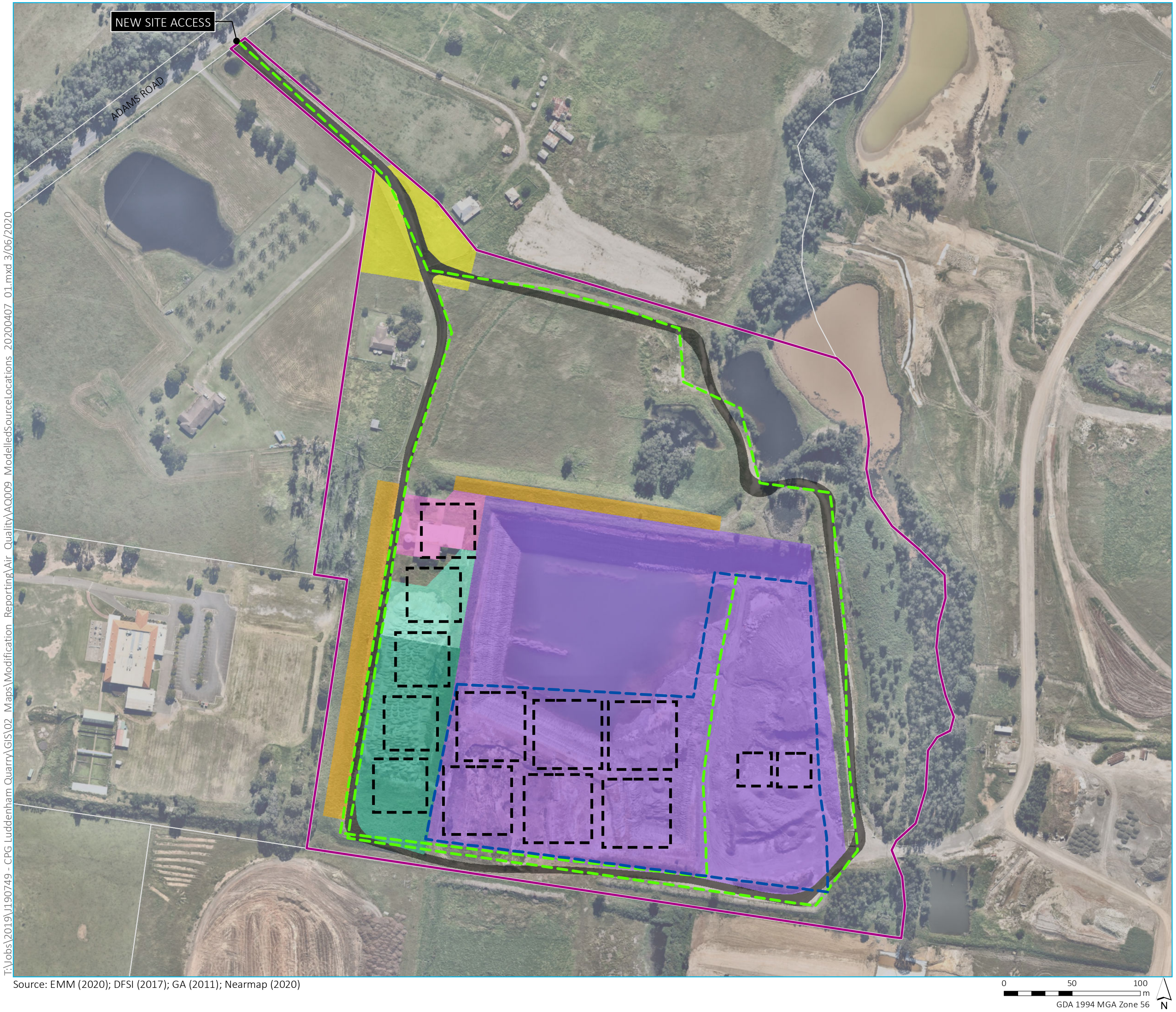
Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1		Variable 2		Variable 3		Variable 4		Variable 5		Control %	Control
Material extraction																	
Excavator ripping topsoil/overburden	0.0	0	t/y	0.00011	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator ripping clay	0.7	60,000	t/y	0.00001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator ripping shale	7.0	240,000	t/y	0.00003	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3								
Dozer in pit	0.0	1,820	h/y		kg/h	7.5	moisture content in %	10	silt content in %								
Excavator loading topsoil/overburden to haul trucks	0.0	0	t/y	0.00011	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator loading clay to haul trucks	0.7	60,000	t/y	0.00001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3								
Excavator loading shale to haul trucks	7.0	240,000	t/y	0.00003	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3								
Hauling overburden to stockpile area	0.0	0	t/y	0.0023	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	0.07	kg/VKT	5	% silt content	75	Watering
Hauling clay to stockpiling area	34.0	60,000	t/y	0.0023	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	0.07	kg/VKT	5	% silt content	75	Watering
Hauling shale to processing area	136.0	240,000	t/y	0.0023	kg/t	45	t/load	53	Ave trip vehicle gross mass (t)	1.4	km/return trip	0.07	kg/VKT	5	% silt content	75	Watering
Processing and dispatch																	
Unloading topsoil/overburden	0.0	0	t/y	0.00011	kg/t	2	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Unloading clay	0.5	60,000	t/y	0.00001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)

Table B.3 PM$_{2.5}$ emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1		Variable 2		Variable 3		Variable 4		Variable 5		Control %	Control
Unloading shale	4.9	240,000	t/y	0.00003	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Rehandle shale to processing circuit	4.9	240,000	t/y	0.00003	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Crushing	26.7	240,000	t/y	0.00022	kg/t											50	Watering
Screening	3.0	240,000	t/y	0.00003	kg/t											50	Watering
Rehandle shale to stockpile	4.9	240,000	t/y	0.00003	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
FEL at processing area	4.9	240,000	t/y	0.00003	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Loading clay to trucks	0.5	60,000	t/y	0.00001	kg/t	10	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Loading shale to trucks	4.9	240,000	t/y	0.00003	kg/t	5	moisture content in %	1.2	(wind speed/2.2)^1.3							30	Minimise drop ht (10m to 5m)
Haul product off-site – unsealed	216.1	300,000	t/y	0.0029	kg/t	32	t/load	36	Ave trip vehicle gross mass (t)	1.5	km/return trip	0.06	kg/VKT	5	% silt content	75	Watering
Haul product off-site – sealed	147.6	300,000	t/y	0.0005	kg/t	32	t/load	36	Ave trip vehicle gross mass (t)	0.4	km/return trip	0.04	kg/VKT	8.2	road surface silt loading (g/m2)		0
Wind erosion																	
Active pit	152.0	3	ha	64	kg/ha/yr											30	wind breaks
Stockpile area	107.5	2	ha	64	kg/ha/yr												
Miscellaneous																	
Grader (road maintenance)	138.9	14,560	km/y	0.0191	kg/km	8	speed of graders in km/h	1,820	grader hours							50	Watering grader routes

Table B.3 PM$_{2.5}$ emissions inventory

Activity	Emission estimate (kg/year)	Intensity	Units	Emission Factor	Units	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Control %	Control
Onsite diesel consumption	434.5	395	kL/yr	1.1	kg/kL							
Total (kg/yr)	**1,437**											



Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

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KEY

- ▭ Study area
- ▭ Cadastral boundary
- ⬚ Material extraction, handling, processing and stockpiling
- - - Open pit wind erosion
- - - Haulage route

Proposed site modifications

- ■ Approved extraction footprint
- ■ Existing noise bunds
- ■ Existing stockpiling area
- ■ Extended stockpiling area
- ■ Internal road
- ■ Site entry infrastructure (incl. offices, amenities, weighbridge)
- ■ Workshop and equipment laydown area

Modelled source locations

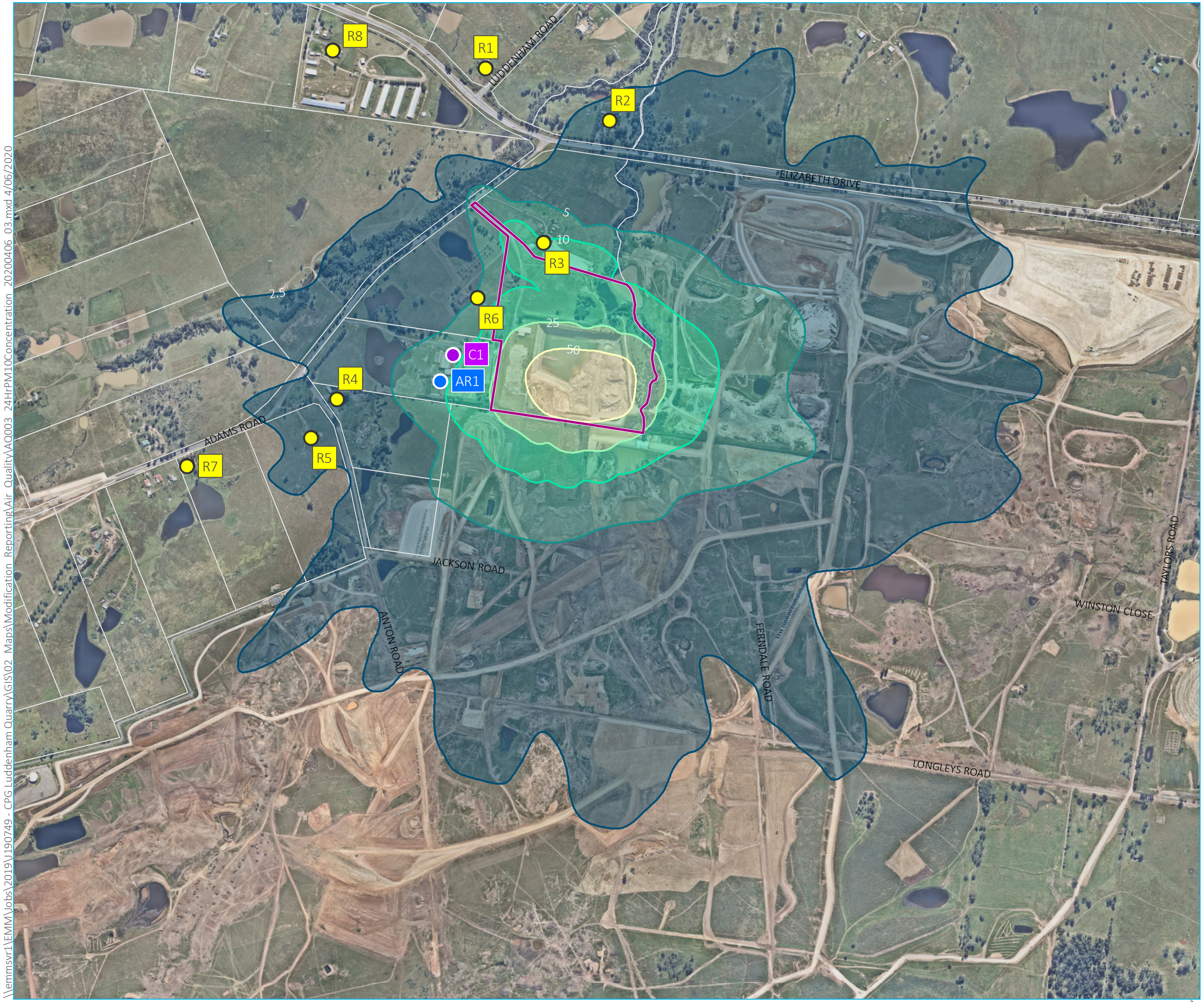
Luddenham Quarry - Modification 5
Modification Report
Figure 6.2

EMM
creating opportunities


Appendix C

Contour plots



Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

0 250 500
m
GDA 1994 MGA Zone 56
N

KEY

▭ Study area

▭ Cadastral boundary

Assessment location

● Active recreation

● Commercial

● Residential

24hr PM_{10} concentration ($\mu g/m^3$)

▨ 2.5 -5 $\mu g/m^3$

▨ 5 -10 $\mu g/m^3$

▨ 10 -25 $\mu g/m^3$

▨ 25 -50 $\mu g/m^3$

▨ over 50 $\mu g/m^3$

Predicted incremental 24-hour average PM_{10} concentration ($\mu g/m^3$)

Luddenham Quarry - Modification 5
Air Quality Impact Assessment
Figure C.1

EMM
creating opportunities

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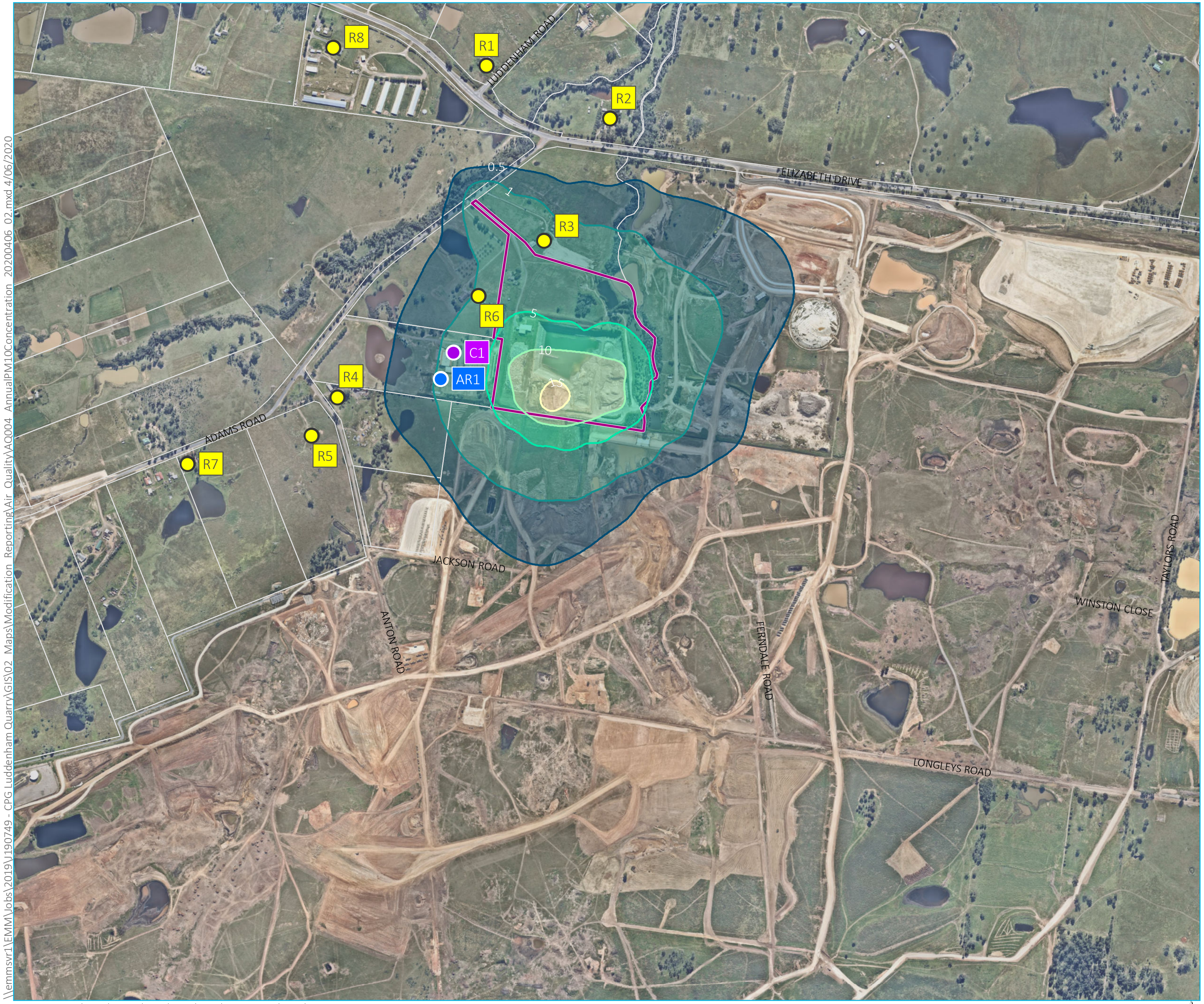


KEY

▭ Study area

▭ Cadastral boundary

Assessment location

● Active recreation

● Commercial

● Residential

Annual PM_{10} concentration (µg/m^3)

▨ 0.5 - 1 µg/m^3

▨ 1 - 5 µg/m^3

▨ 5 - 10 µg/m^3

▨ 10 - 15 µg/m^3

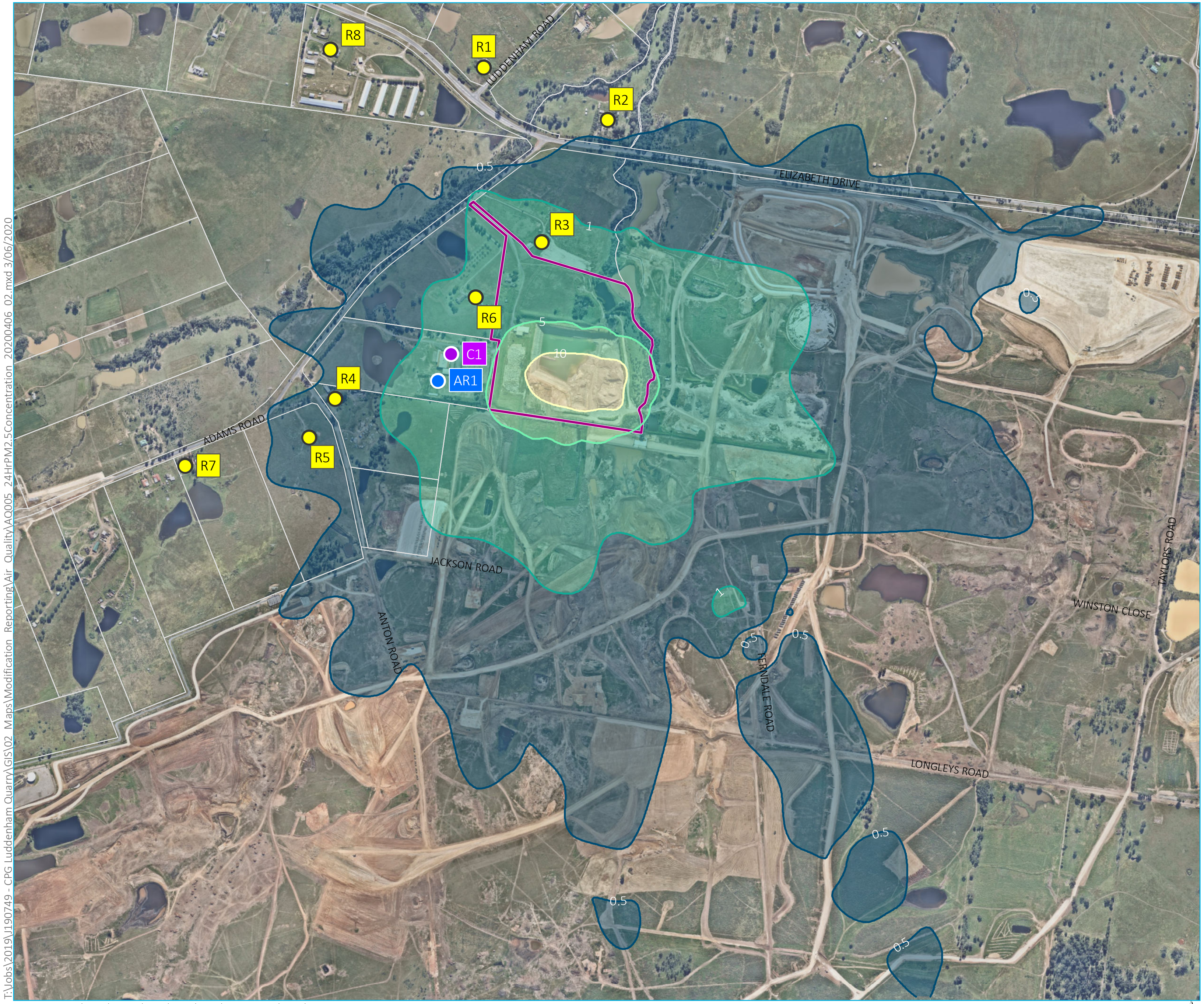
▨ 15 µg/m^3

Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

0 250 500
m
GDA 1994 MGA Zone 56
N

Predicted incremental annual average PM_{10} concentration (µg/m^3)

Luddenham Quarry - Modification 5
Air Quality Impact Assessment
Figure C.2



Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

0 250 500 m
GDA 1994 MGA Zone 56
N

KEY

▭ Study area

▭ Cadastral boundary

Assessment location

● Active recreation

● Commercial

● Residential

24-hour $PM_{2.5}$ concentration (µg/m^3)

▇ 0.5 - 1 µg/m^3

▇ 1 - 5 µg/m^3

▇ 5 - 10 µg/m^3

▇ over 10 µg/m^3

Predicted incremental
24-hour average $PM_{2.5}$
concentration (µg/m^3)

Luddenham Quarry - Modification 5
Air Quality Impact Assessment
Figure C.3

EMM
creating opportunities

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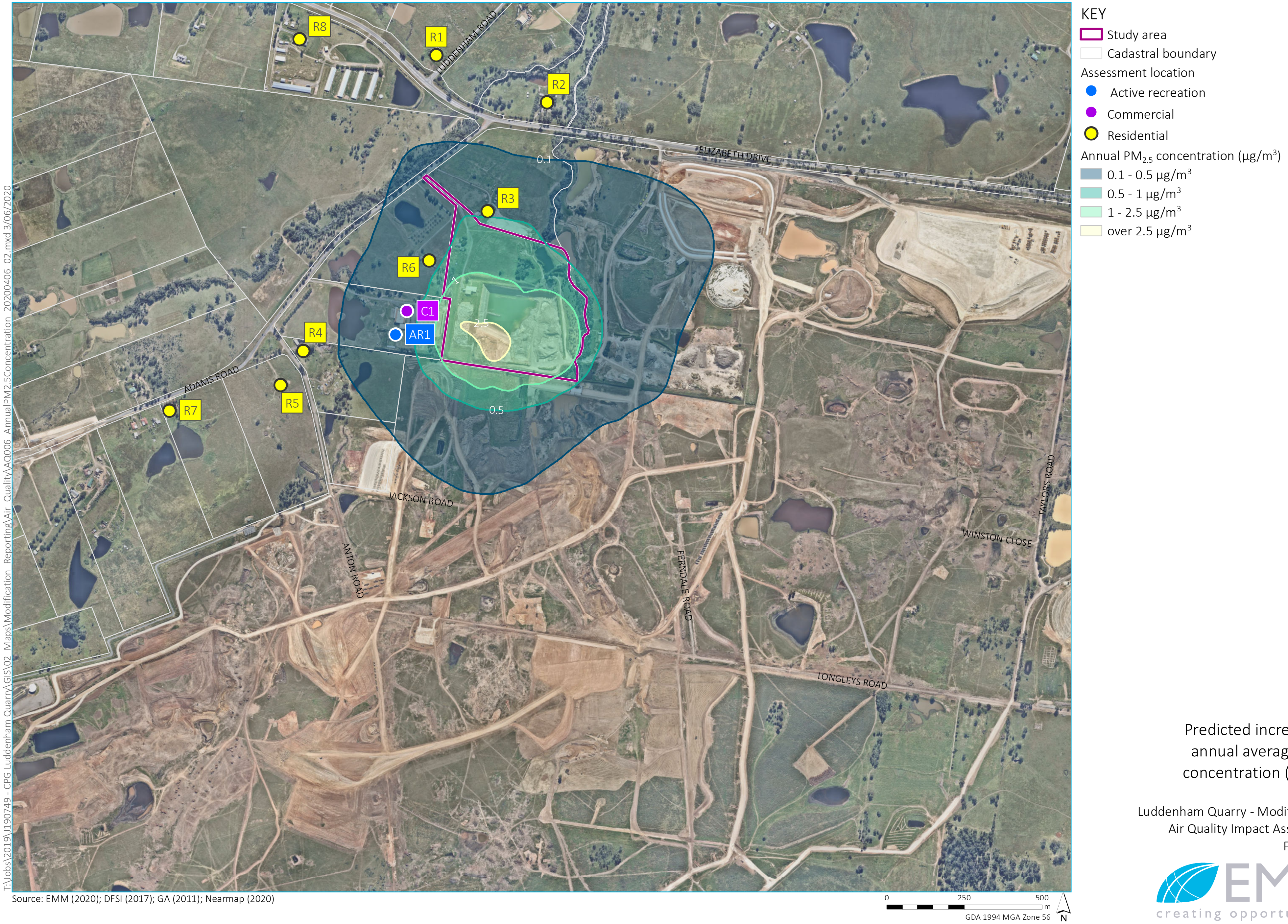

Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

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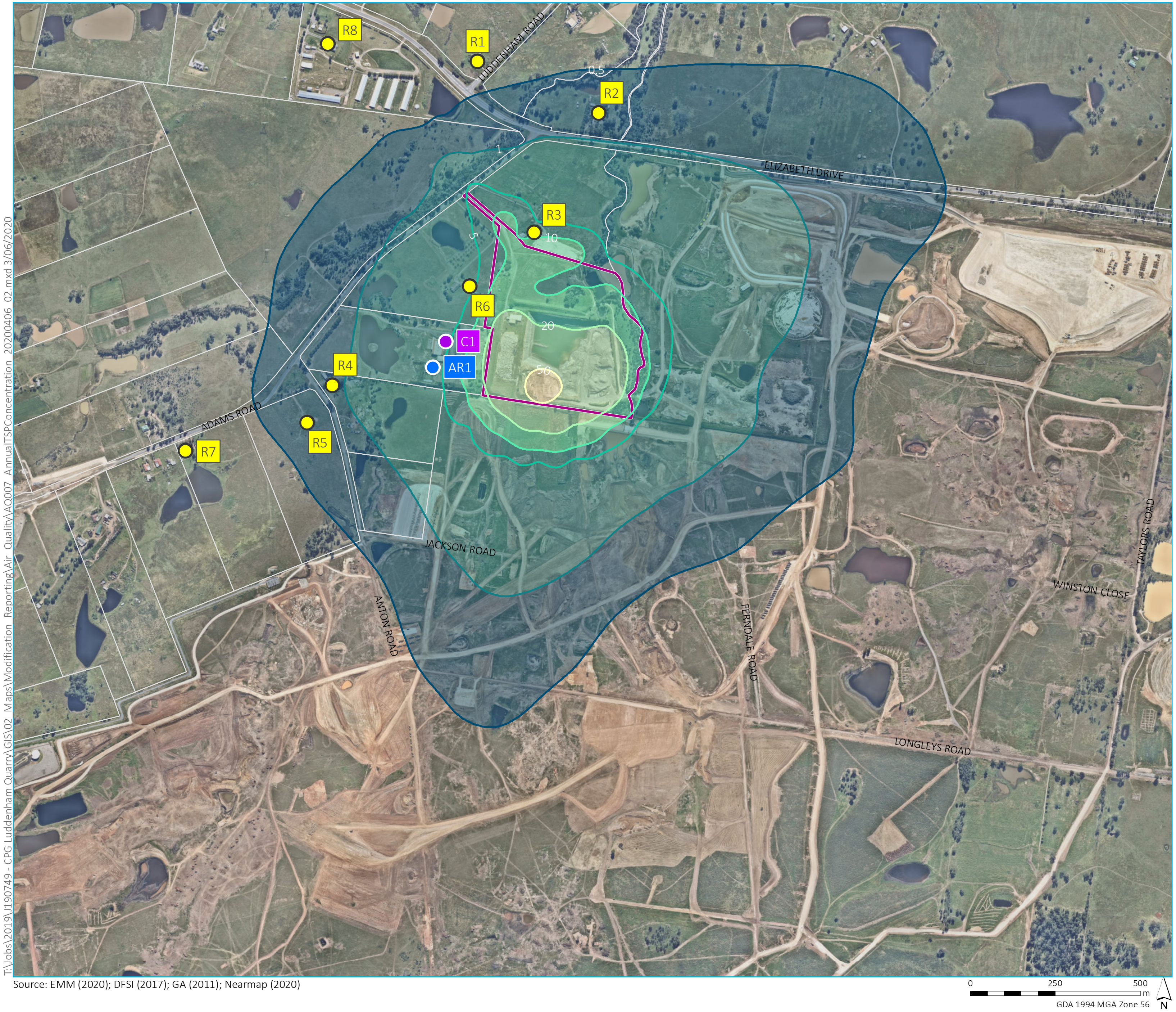
Predicted incremental
annual average $PM_{2.5}$
concentration ($\mu g/m^3$)

Luddenham Quarry - Modification 5
Air Quality Impact Assessment
Figure C.4

EMM
creating opportunities



Source: EMM (2020); DFSI (2017); GA (2011); Nearmap (2020)

KEY
▭ Study area
▭ Cadastral boundary
Assessment location
● Active recreation
● Commercial
○ Residential
Annual TSP concentration (µg/m^3)
▨ 0.5 - 1 µg/m^3
▨ 1 - 5 µg/m^3
▨ 5 - 10 µg/m^3
▨ 10 - 20 µg/m^3
▨ 20 - 50 µg/m^3
▨ over 50 µg/m^3

Predicted incremental
annual average TSP
concentration (µg/m^3)

Luddenham Quarry - Modification 5
Air Quality Impact Assessment
Figure C.5

EMM
creating opportunities

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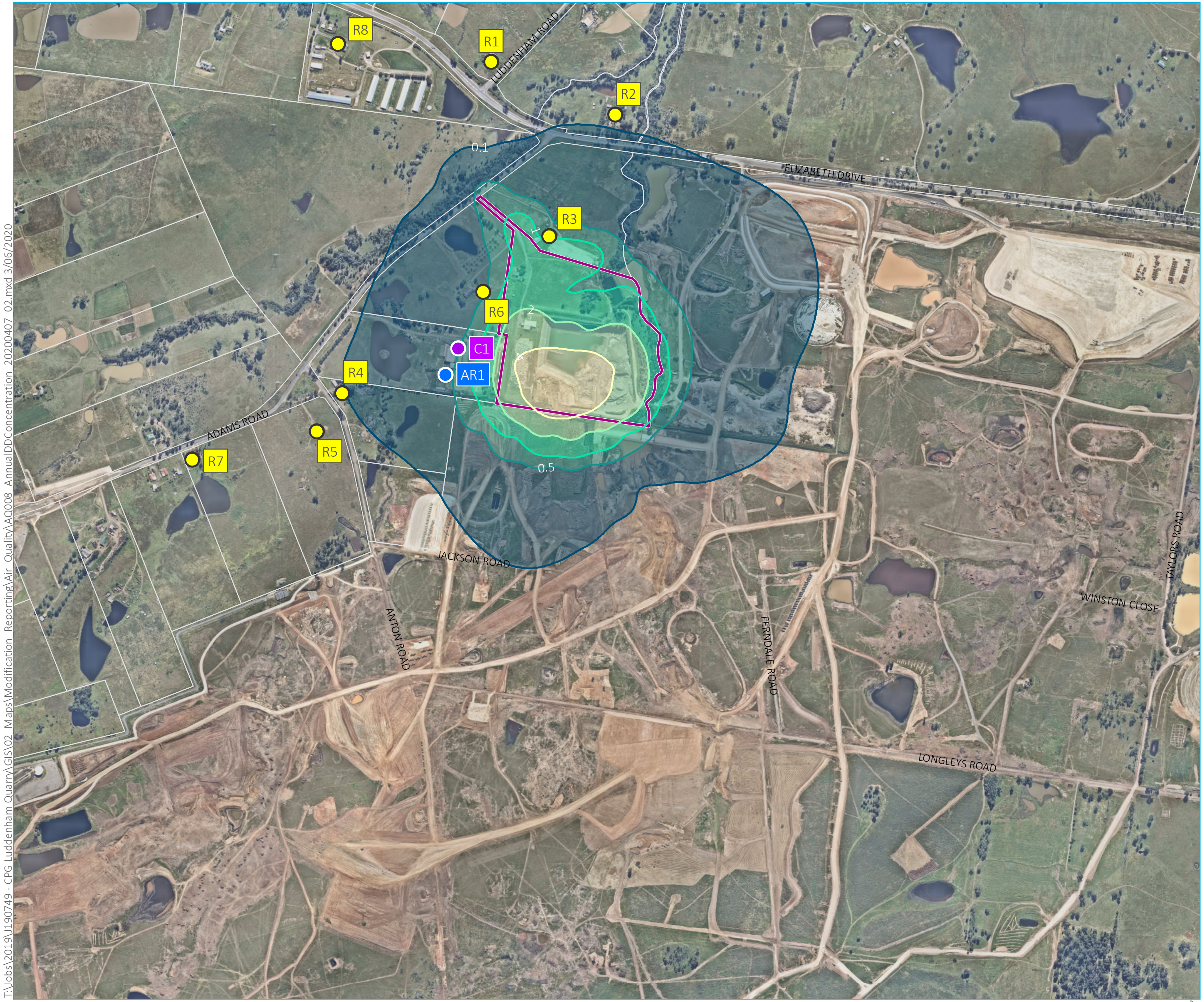

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KEY

- ▭ Study area
- ▭ Cadastral boundary

Assessment location

- ● Active recreation
- ● Commercial
- ● Residential

Annual dust deposition (g/m^2/month)

- ■ 0.1 - 0.5 g/m^2/month
- ■ 0.5 - 1 g/m^2/month
- ■ 1 - 2 g/m^2/month
- ■ 2 - 4 g/m^2/month
- ■ over 4 g/m^2/month

Predicted incremental annual average dust deposition concentration (g/m^2/month)

Luddenham Quarry - Modification 5
Air Quality Impact Assessment
Figure C.6

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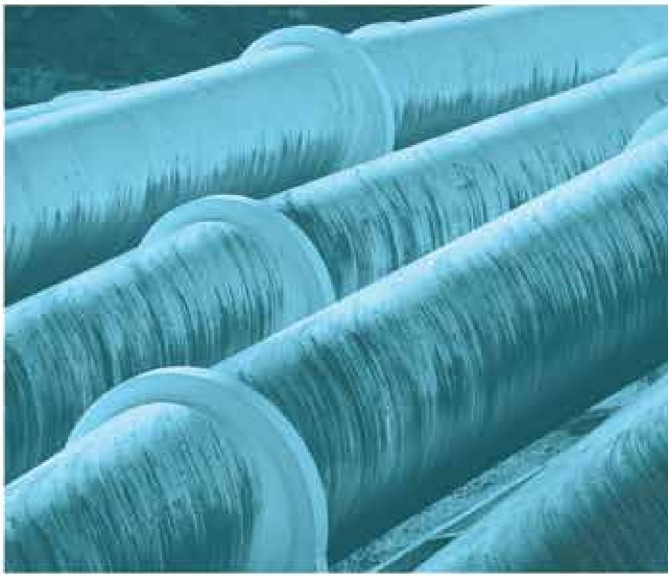

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