Talison Lithium Greenbushes Operations

Air Quality Assessment

Final Report
Version 4

Prepared for Talison Lithium Australia Pty Ltd

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Talison Lithium Greenbushes Operations

Final Report

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Executive Summary

Overview of assessment

Talison Lithium Australia Pty Ltd (Talison) own and operate the Greenbushes Operations (GBO) located immediately to the south of the Greenbushes townsite, approximately 250 kilometres (km) south of Perth, Western Australia. In response to market demand Talison is expanding the GBO from the approved beneficiation rate of 7.1 Million tonnes per annum (Mtpa) (Baseline case - mining tonnage at 15.3 Mtpa) up to 12.5 Mtpa. Expansion activities modelled by this study include:

- operation of two new Crushers – Crusher 3 (Cr3) and Crusher 4 (Cr4)
- operation of two new Process Plants – Chemical Grade Plant #3 (CGP3) and Chemical Grade Plant #4 (CGP4)
- operation of three new Ore Sorters – Ore Sorter 2, Ore Sorter 3, Ore Sorter 4
- mining up to 27.3 Mtpa of waste rock and ore
- beneficiation of up to 12.5 Mtpa of ore
- storage of up to 15.6 Mtpa of waste rock in Floyds Waste Rock Landform (WRL).

This air quality assessment report has been prepared to accompany the environmental approvals application by Talison for the Project. The potential impacts of the Project were determined through a dispersion modelling study. The scope of the modelling assessment is summarised below.

Modelled meteorological period	1 January to 31 December 2019
Model selection	WRF/CALMET/CALPUFF model suite
Key Pollutants	Particulate matter (as TSP, PM_{10}, $PM_{2.5}$ and deposition)
Meteorological data	Three-dimensional prognostic meteorological data developed using the Weather Research and Forecasting (WRF) model.
Background Air Quality	Background air quality was based on Talison monitoring data and is assumed to be indicative for the Project location and setting.
Project Emissions	Emission estimation was undertaken with reference to the appropriate equations, or factors, from the *National Pollutant Inventory Emission Estimation Technique Manual for Mining Version 3.1*. Operating parameters used to characterise sources were provided by Talison. The modelling includes fugitive dust emissions (as volume sources) and wind erosion (as area sources).
Receptors of Interest including Sensitive Receptors	Multiple set of receptors are included in the model to align with the various model applications: • Nearest sensitive receptor locations (residents) consistent with DWER guidelines for regulatory assessments • Discrete receptor locations coinciding with GBO ambient monitoring locations.

Model Scenarios	The model scenarios included in the assessment consider the GBO in isolation or other emission sources, as well as cumulatively with the assumed background air quality (based on locally measured data).
	The key scenarios modelled are:
	• 2023 Base Case:
	  ○ GBO mining tonnage at 15.3 Mtpa and processing at 7.1 Mtpa.
	• 2028 Scenario 1:
	  ○ GBO mining tonnage at 27.3 Mtpa and processing at 11.7 Mtpa.

Key findings

The key findings of the assessment are:

- 2023 Base Case Scenario:
  - For PM_{10} the predicted concentration is above the 24-hour criterion at all the Greenbushes township receptors in isolation, with the remaining residential receptors being within the 24-hour criterion.
  - The predicted PM_{10} annual average concentrations (with and without background) are within annual assessment criterion at all the residential receptors.
  - For $PM_{2.5}$ the predicted concentrations at all the residential receptors are below the 24-hour and annual average assessment criterion both with and without the inclusion of background concentration.
  - With TSP the predicted concentrations at all the Greenbushes Township receptors (Town A to Town F) are above the 24-hour average assessment criterion both with and without the inclusion of the background concentration.
  - Deposition rates are predicted to be lower than the maximum increase above background criteria.
- 2028 Scenario 1 (Expansion):
  - The predicted concentration is above the 24-hour criterion at 9 residential receptors in isolation and at 18 receptors with background concentration included.
  - For $PM_{2.5}$ the predicted 24-hour concentrations will be above the assessment criterion both with and without the inclusion of background concentration at Town receptors A and B. The predicted annual average concentrations are below the assessment criterion at all residential receptors both with and without the inclusion of background concentration.
  - The TSP predicted concentration at all the Town receptors and receptor H are predicted to be above the 24-hour average assessment criterion for TSP without the inclusion of background concentration.
  - Deposition rates are predicted to be higher than the maximum increase above background criteria for the Town A and B Greenbushes receptors.

The modelling indicates that the proposed GBO expansion (from 7.1 Mtpa up to 12.5 Mtpa) will result in more frequent occurrences of particulate concentrations are elevated in comparison to the relevant air quality criteria at residential receptors, most notably in the Greenbushes township. However it should be noted that the vegetated screen that is located between the GBO and the Town of Greenbushes (Section 2.3) will assist in alleviating the predicted ground level concentrations.

A conservative approach has been used for this modelling assessment, and the levels of pollutant concentrations are likely to be lower (when measured in the environment) than predicted in this study. It is important to note that, as a risk-based assessment approach is normally applied to the assessment of air quality, a modelled result above the numerical ambient guideline value or assessment criteria is not an indicator of unacceptable impact or loss of environmental value, but is an indication that the potential risk for impact requires further consideration, such as ongoing ambient monitoring.

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1 Introduction

1.1 Background

Talison Lithium Australia Pty Ltd (Talison) own, and operate, the Greenbushes Operations (GBO) which is located immediately to the south of the Greenbushes townsite, approximately 250 kilometres (km) south of Perth, Western Australia (Figure 1-1). Mining is undertaken using traditional methods including drilling, blasting, loading ore and waste (in-pit) for haulage, crushing and processing (through one of several plants). The mining and processing is a continual process occurring for 24 hours a day, 7 days a week.

The GBO produces two categories of lithium concentrate:

- Technical Grade lithium mineral concentrate with low iron content, primarily for feedstock for glass and ceramic industries; and
- Chemical Grade concentrate used to produce batteries and greases.

In response to market demand Talison is expanding the GBO from the approved beneficiation rate of 7.1 Million tonnes per annum (Mtpa) (Baseline case - mining tonnage at 15.3 Mtpa) up to 12.5 Mtpa. Expansion activities modelled by this study include:

- operation of two new Crushers – Crusher 3 (Cr3) and Crusher 4 (Cr4)
- operation of two new Process Plants – Chemical Grade Plant #3 (CGP3) and Chemical Grade Plant #4 (CGP4)
- operation of three new Ore Sorters – Ore Sorter 2, Ore Sorter 3, Ore Sorter 4
- mining up to 27.3 Mtpa of waste rock and ore
- beneficiation of up to 12.5 Mtpa of ore
- storage of up to 15.6 Mtpa of waste rock in Floyds Waste Rock Landform (WRL).

Talison commissioned Environmental Technologies & Analytics (ETA) to undertake a desk-top air quality modelling study of the Project with the aim of determining potential air quality impacts, as documented in this report.

Figure 1-1: Project location and setting.

1.2 Scope of work

The objectives of this assessment include the development of a comprehensive air quality model for both the existing and proposed GBO to determine the potential change in air quality impacts at nearby receptors.

Reference has been made to the following key regulatory policy and guidance:

- Air Quality Modelling Guidance Notes (DoE, 2006)
- Guideline - Air Emissions, draft for external consultation (DWER, 2019)
- Guideline - Dust Emissions, draft for external consultation (DWER, 2021)
- Environmental Factor Guideline – Air Quality (EPA, 2020)
- Environmental Factor Guideline – Social Surrounds (EPA, 2016; EPA, 2023)
- *Environmental Protection Act, 1986, as amended*
- Environmental Protection Act Regulations 1987.

1.3 Structure of report

This report describes the methods and findings of a dispersion modelling assessment of the potential impacts to the air environment arising from the Talison operations. The assessment includes:

- The assessment methodology in Section 2.

- Atmospheric dispersion modelling of the emissions using CALPUFF in Section 3.
- Project emission estimation and inventory in Section 4.
- An evaluation of the potential impact from the Project in Section 5.
- Conclusions of the assessment are presented in Section 6.

The appendices contain supporting information, specifically:

- The analysis to determine the representative meteorological year for modelling.
- The detailed configuration for the Weather, Research & Forecast (WRF) model and CALMET (meteorological pre-processor model).
- Emission parameters and emission rates for each source modelled.

2 Assessment methodology

This section outlines the air quality study and assessment approach. It includes the methodology applied to define the meteorological characteristics of the Project area relevant to the assessment, the emission estimation, the dispersion, and the ambient assessment criteria selected for the purposes of determining the significance of the dispersion model results, and therefore the potential impact.

The simplified study structure is shown in Figure 2-1 and detailed in the following subsections.

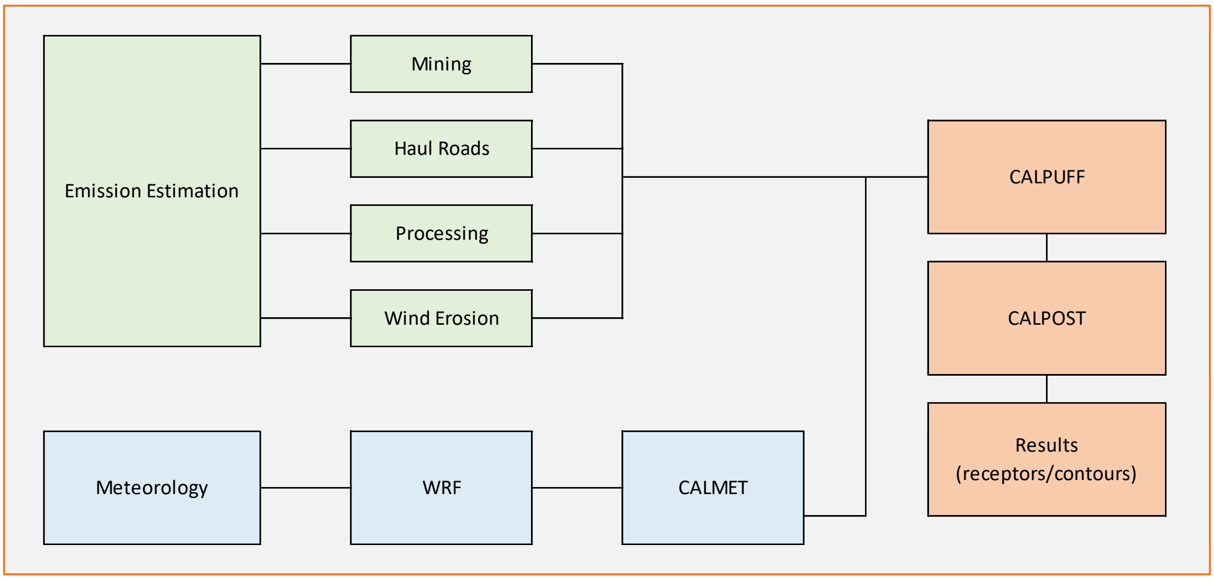

Figure 2-1: Air quality assessment – modelling approach.

2.1 Climate and Meteorology

This section outlines the key climate and meteorological characteristics of the region important for the dispersion, transformation and removal (or deposition) of pollutants from the atmosphere, and therefore ambient air quality.

The Project area is located approximately 10 km north of Bridgetown in the South West region of WA. This region has a Mediterranean climate, characterised by warm, dry summers with cool and wet winter periods. The climate is classified according to the Köppen-Geiger climate classification system as Csa (Temperate, dry and warm summer) (Kottek et al, 2006).

A summary of the long-term meteorological conditions as measured at the Bureau of Meteorology (BoM) Automatic Weather Station (AWS) at Bridgetown (009617) is shown in the following sections. Although this meteorological station is located 10 km from the Project the information is indicative of the broader region, including Greenbushes, and is appropriate for this assessment.

A review of 11 years (2012 to 2022) of historical surface observations obtained from the BoM Bridgetown AWS concluded the 2019 calendar year as being the most representative against longer term climatic averages. The 2019 calendar year was selected for modelling on this basis. The analysis is detailed in Appendix A.

2.1.1 Temperature

Recorded temperature at the BoM Bridgetown AWS clearly shows the Mediterranean style climate with the measured mean monthly maximum temperatures ranging from a high of 30 degrees Celsius (°C) in January to 15.8°C in July. The mean monthly minimum temperatures range from 13.5°C in February down to 4.7°C in July, as shown in Figure 2-2.

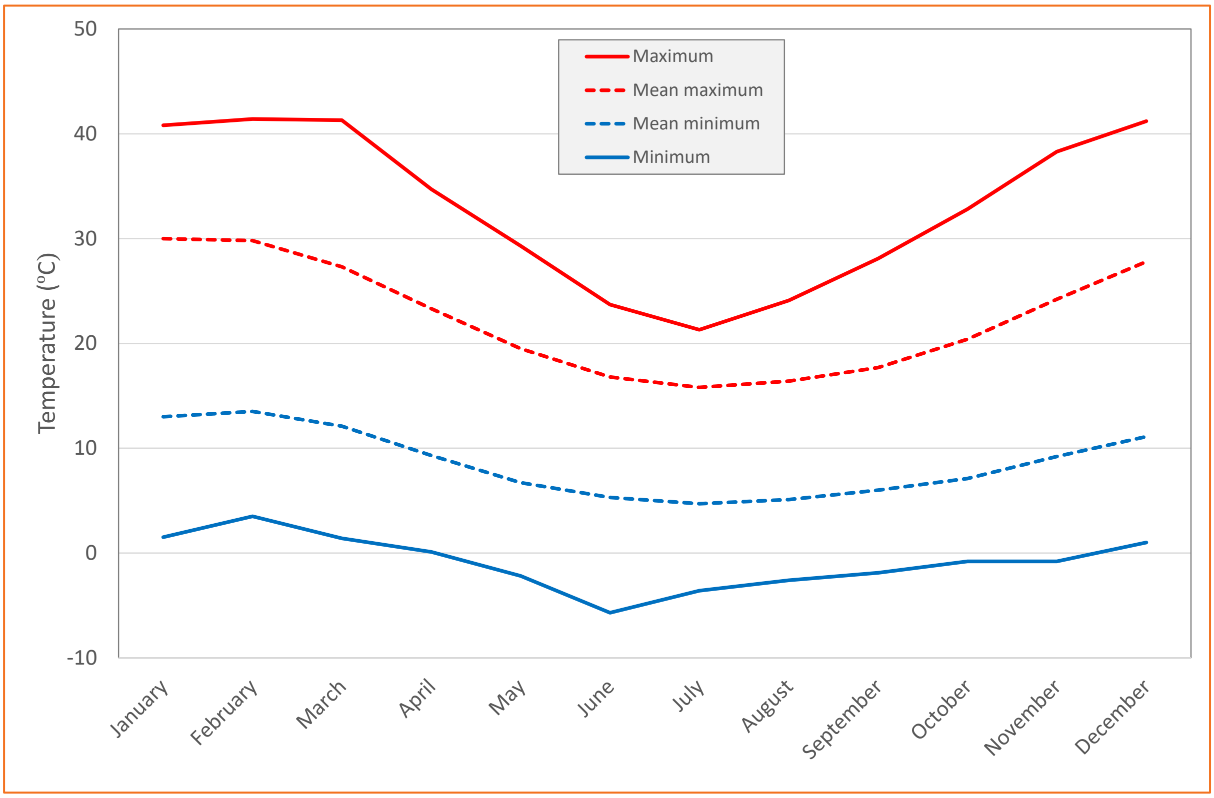

Figure 2-2: Mean Temperature 1998 to 2023 (BoM Bridgetown).

2.1.2 Humidity

As shown in Figure 2-3 the humidity at the BoM Bridgetown AWS is characterised by relatively low humidity during the summer months, increasing during the winter months. Across all months the average 9am relative humidity is higher than the 3pm relative humidity.

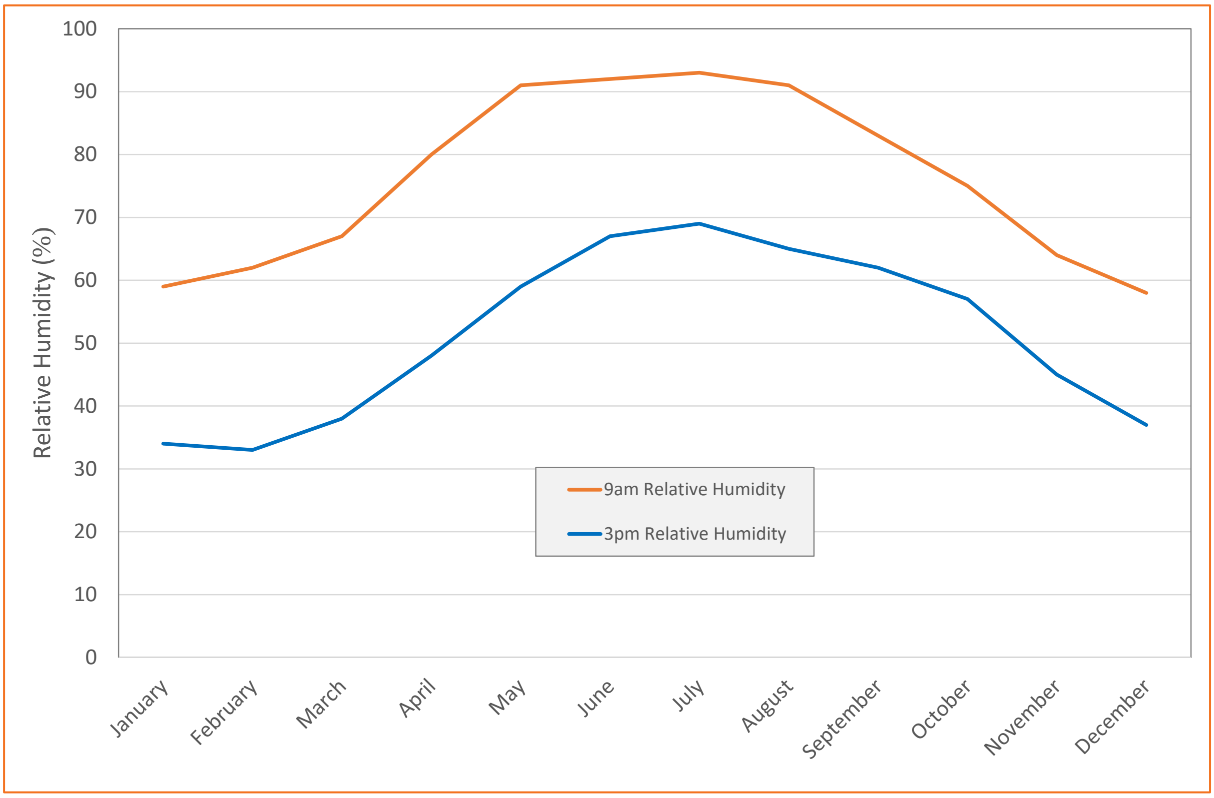

Figure 2-3: Mean Relative Humidity 1998 to 2023 (BoM Bridgetown).

2.1.3 Rainfall

The long-term rainfall data measured at the BoM Bridgetown AWS is presented in Figure 2-4 and this data highlights the Mediterranean climate of the region – relatively dry summers with wet winters. The rainfall patterns in the region are influenced by a range of factors, including ocean currents, atmospheric pressure systems, and local topography. The region experiences distinct seasons with the rainfall varying as follows:

- Summer (December to February): Summers in Bridgetown are generally hot and dry. The region receives the least amount of rainfall during this season, with sporadic and occasional thunderstorms. The average monthly rainfall during summer is relatively low, often below 20 millimetres (mm).
- Autumn (March to May): Autumn in Bridgetown brings mild temperatures and a slight increase in rainfall. The region experiences occasional showers and thunderstorms as the season progresses. Rainfall amounts gradually rise during autumn, with average monthly rainfall ranging between 22 mm and 98 mm.
- Winter (June to August): Winters in Bridgetown are cooler and wetter. This is the peak of the rain season, and the region receives the majority of its annual rainfall during this time. Rainfall intensifies, with regular rain events, drizzles, and occasional storms. Average monthly rainfall during winter ranges from 105 mm to 130 mm.
- Spring (September to November): Spring in Bridgetown brings warmer temperatures and a gradual decrease in rainfall. The region experiences occasional showers and thunderstorms at the beginning of the season, but as spring progresses, rainfall tapers off. Average monthly rainfall during spring ranges between 30 mm and 85 mm.

It's important to note that these descriptions provide a general overview of the seasonal rainfall patterns in Bridgetown. Weather patterns can vary from year to year, and some seasons may experience more or less rainfall than average.

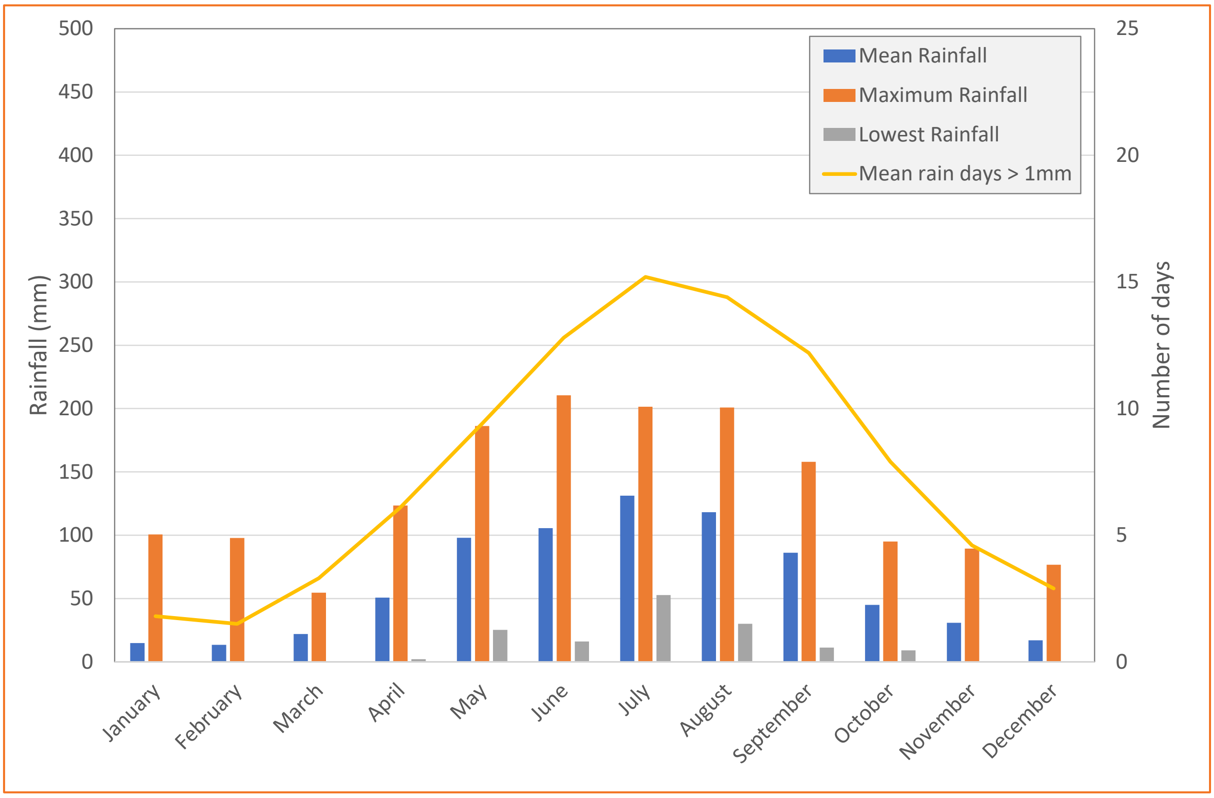

Figure 2-4: Rainfall 1998 to 2023 (BoM Bridgetown).

2.1.4 Wind speed and direction

Within the region there are two meteorological stations with wind speed and direction recorded at 10 m:

- Talison operate a meteorological station within their operational area, to the northwest of the operations. The station was originally located on Tailings Storage Facility 1 (TSF1), however was relocated due to the reclamation of TSF1. Data from 1 January 2017 to 9 December 2021 has been used in this assessment.
- The Bureau of Meteorology (BoM) operates an automatic weather station (AWS) at Bridgetown approximately 10 kilometres (km) to the south of the operations. For this assessment hourly data from the 1 January 2012 to 31 December 2022 was used.

The annual wind roses for these two stations, derived from the available data, is presented in Figure 2-5. From this figure it can be seen that:

- There is a notable difference, in both wind speed and direction, between the two annual wind roses.
- The BoM Bridgetown data shows:
    - Prevailing winds from the south and the north-north-west.
    - A high percentage of winds below 2 m/s with minimal wind speeds above 6 m/s.
    - An overall average wind speed of 1.8 m/s.

- The TSF1 data shows:
    - Prevailing winds from the east to southeast and west to northwest.
    - Minimal winds below 0.5 m/s (low percentage of calm winds).
    - A high proportion of winds above 4 m/s including wind speeds above 8 m/s.
    - An overall average wind speed of 3.9 m/s.

The difference in wind speed and direction between the two AWS may be due to a range of factors including:

- Elevation: The town of Greenbushes is approximately 324 m above sea level (asl) while Bridgetown is approximately 157 m asl – a difference of 167 m.
- Topography: The Bridgetown BoM station is located within a valley to the northwest of the town which may result in channelling of the winds. The TSF1 meteorological station was located upon a tailings storage area, indicating that it was relatively flat, and relatively open area in the immediate vicinity.

Figure 2-5: Annual wind roses from the BOM Bridgetown and ex-TSF on-site meteorological station

Talison operate a series of Osiris nephelometer monitors within the region, including a unit to the south east of the operations 'South Cemetery' and another unit adjacent to the North Cormwall pit 'North Cormwall'. Both of these units are fitted with wind speed/direction sensors mounted approximately 3 m above the ground.

The annual wind roses from these three wind sensors are presented in Figure 2-6. From this figure it is evident that there is a high degree of variability in the wind direction within the vicinity of the operations. These variations may be attributed to a range of factors including elevation, topography (including valleys), land use (including vegetation) as well as the quality of the monitoring data (in turn influenced by the equipment specifications and measurement height above the ground).

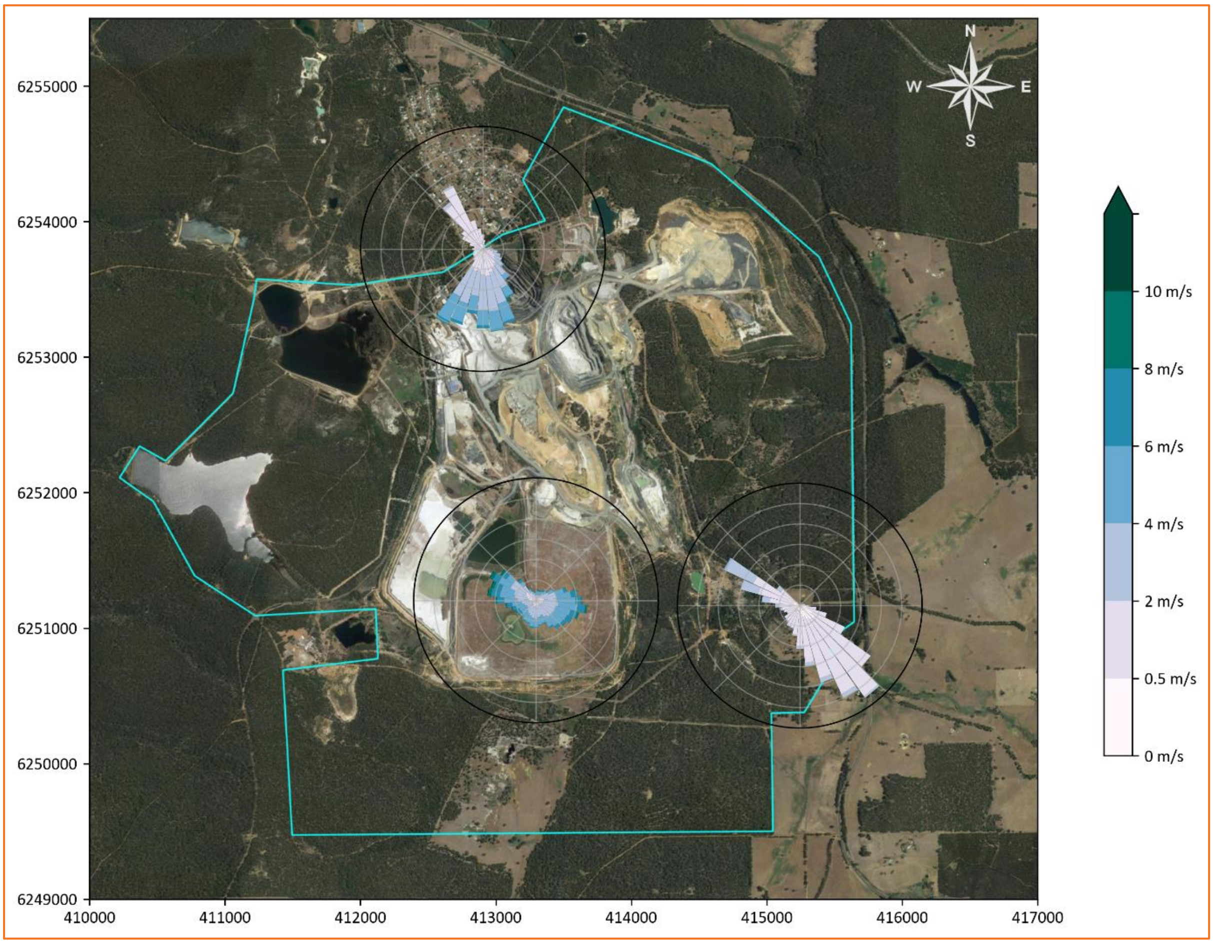

Figure 2-6: Wind roses from TSF1 meteorological station (decommissioned), North Cornwall Pit Osiris monitoring station, and South Cemetery monitoring station.

2.2 Pollutants of Interest

There are a number of potential emissions from the construction of the GBO expansion, and operation, of the Project including:

- Particulate matter from construction activities including:
  - Clearing
  - Removal and storage of topsoil
  - Wind erosion from open areas
  - Vehicle movements
- Particulate matter from mining and processing activities including:

- Scrapers removing topsoil and subsoil,
- Excavators on waste and tailings,
- Bulldozers,
- Wheel generated dust from roads and haul roads,
- Wind erosion from stockpiles and open areas.

Construction related emissions vary both spatially and temporally and tend to be relatively short term (weeks or months) and are not considered in this modelling assessment. These are best addressed through the dust control and management plan. Likewise gaseous emissions are also not considered in this assessment due to the relatively low number of sources and their spatial variability.

Based on the description of the Project and key processes considered, the key pollutants of interest have been determined to be particulate emissions from mining and processing activities and these are summarised in Table 2-1.

Table 2-1: Air pollutants of interest from the Project.

Pollutant to be Assessed		
Particulate Matter	Airborne particles are a broad class of diverse substances that may be solid or liquid (liquid particles are often called aerosols) and are produced by a wide range of natural and human activities. Airborne particles are commonly classified by their size as total suspended particles (TSP), visibility reducing particles (PM_2), and inhalable particles (coarse fraction PM_{10} and fine fraction $PM_{2.5}$). **Project sources are principally from mining, handling of ore/waste, processing and wind generated surface erosion.**	
	PM_{10}	Inhalable particles are grouped into two size categories: those with a diameter of up to 10 µm (PM_{10}) and those with a diameter of up to 2.5 µm ($PM_{2.5}$). Inhalable particles are associated with increases in respiratory illnesses such as asthma, bronchitis and emphysema, with an increase in risk related to their size, chemical composition and concentration. Particles in the PM_{10} size fraction have been strongly associated with increases in the daily prevalence of respiratory symptoms, hospital admissions and mortality.
	$PM_{2.5}$	Particles in the $PM_{2.5}$ size fraction can be inhaled more deeply into the lungs than PM_{10}, and have been associated with health effects similar to those of PM_{10}. There is some evidence to suggest that $PM_{2.5}$ might be more deleterious to health than other size fractions. No lower limit for the onset of adverse health effects has yet been observed.
	TSP	Total suspended particulates (TSP) refers to the total amount of the PM suspended in air, typically up to 50 µm. These larger particles are primarily associated with amenity or visibility issues and are likely to be removed by gravitational settling within a short time of being emitted (i.e. they settle to the ground or other surfaces fairly quickly).
	Deposited Dust	Deposited matter refers to any dust that falls out of suspension in the atmosphere.

2.3 Existing | background air quality

It is a requirement of the Department of Water and Environmental Regulation (DWER) that existing concentrations of each modelled pollutant be accounted for to ensure that potential cumulative impacts are presented (DoE, 2006). For this assessment the potential contribution of existing or background concentrations was referenced to the air quality monitoring undertaken by Talison within the immediate region.

Talison operate two regulatory standard monitors within the region including a High Volume Air Sampler (HVAS) and a Tapered Element Oscillating Microbalance (TEOM). Both are fitted with PM_{10} size selective inlets. The HVAS is located immediately north of the operations, adjacent to Greenbushes. A review of this monitoring location (ETA, 2023) identified a number of constraints associated with monitoring location and that it is not located in accordance with AS/NZS 3580.1.1:2016. The constraints include :

- There is no clear sky angle of 120^o around this monitor.
- There is only 4 metres (m) to the dripline of the nearest tree (requirement is for > 10 m).
- There is a large, vegetated screen immediately to the south of the monitor which would result in the adsorption/absorption of particles which would alter the concentrations recorded at this monitor. Note that this vegetated screen is critical to assisting in reducing potential emissions from the operations impacting receptors within the town of Greenbushes.

Based on the points noted above the use of the HVAS data was excluded from being considered as a suitable representation of existing air quality.

During 2020 the TEOM monitor was located approximately 2 km to the north west of the operations and data from the 7 April 2020 to 31 December 2020 was available for analysis. A review of the TEOM monitoring location by ETA determined that it did not experience the same limitations as the HVAS. The TEOM data was used to determine a representative background concentration.

When determining a suitable background concentration it is appropriate to utilise the 70th percentile of one year's observed concentrations (Victorian Government, 2001) and the available data should still be representative of the region. The nominated constant PM_{10} background concentrations are as follows:

- 13.8 µg/m^3 (24-hour average)
- 13.4 µg/m^3 (annual average)

For $PM_{2.5}$ the nominated constant background concentrations are taken as 15% of the PM_{10} concentrations, in line with the estimated emissions of $PM_{2.5}$ (Section 4.2). The 24-hour TSP background concentration is assumed to be double the PM_{10} concentration. The nominated $PM_{2.5}$ and TSP background concentrations are as follows:

- $PM_{2.5}$:
  - 2.1 µg/m^3 (24-hour average)
  - 2.0 µg/m^3 (annual average)
- TSP
  - 27.6 µg/m^3 (24-hour average)

These concentrations will be utilised in this assessment to represent background concentrations.

2.4 Sensitive receptors and environmental values

This modelling assessment considers the potential air quality impacts on relevant environmental values and sensitive receptors, consistent with EPA (EPA, 2005), and DWER (DWER, 2019), noting that the current DWER guidelines excludes the consideration of on-site project related receptors as sensitive receptors.

A sensitive receptor, as outlined in EPA (2005), is defined as a receptor that is '*potentially sensitive to emissions from industry and infrastructure including residential developments, hospitals…caravan parks, schools, nursing homes…playgrounds and some public buildings*.'.

The definition of environment in the *Environmental Protection Act, 1986* (as amended) (EP Act) includes social surroundings, where "*environment, subject to subsection (2) means living things, their physical, biological and social surroundings, and interactions between all of these (Subsection 3(1)).*" (EPA, 2016). Social surroundings, as outlined in the EPA guidelines (EPA, 2016; EPA 2023) includes Aboriginal heritage and culture, natural and historical heritage, amenity values.

The key receptor locations considered in the modelling are presented in Figure 2-7 relative to the Project. Receptor information is summarised in in Appendix C.

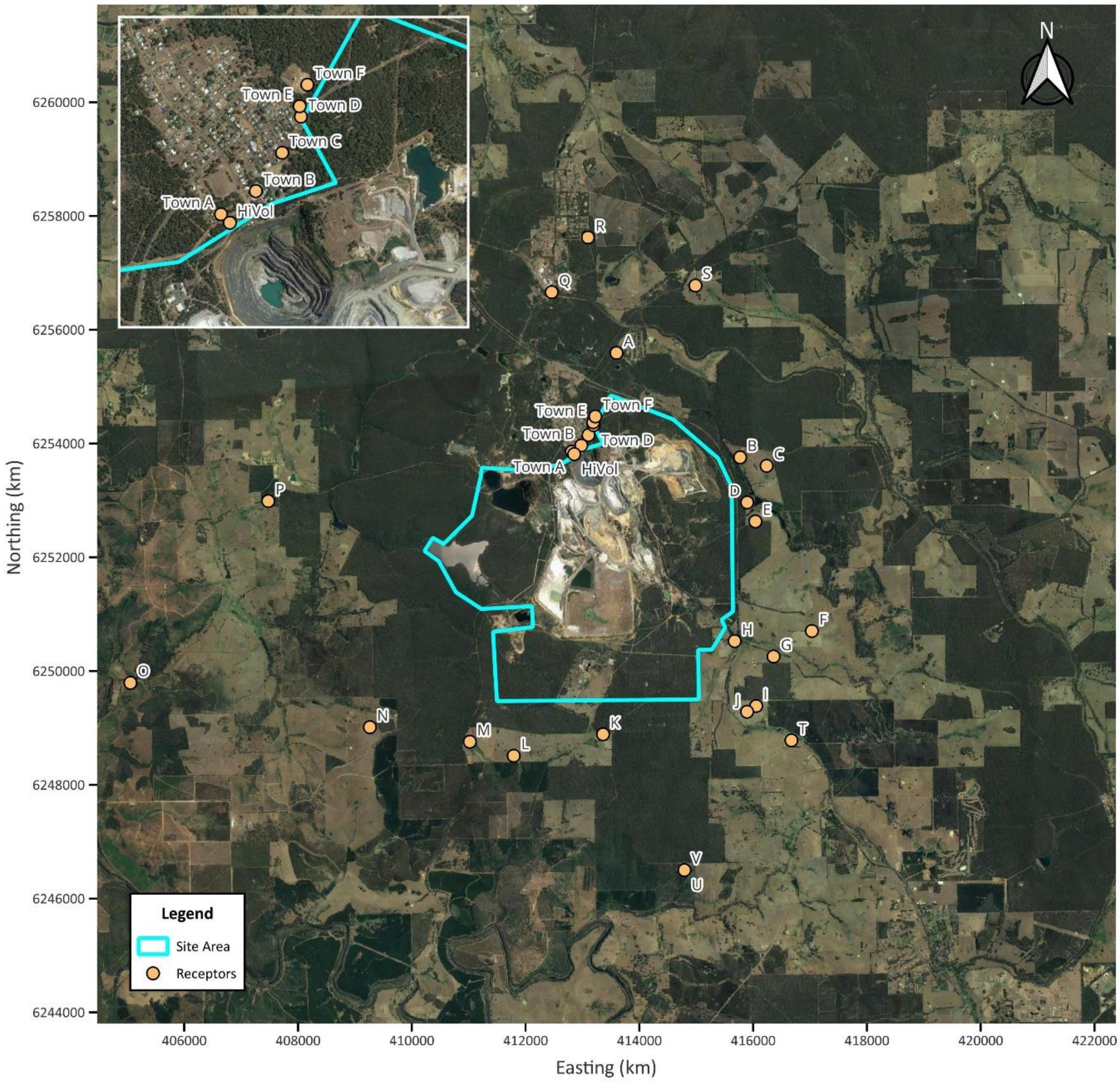

Figure 2-7: Receptor locations (GDA94, Zone 50).

2.5 Impact assessment

Ground-level concentrations of particulates (as Total Suspended Particulates (TSP), PM_{10} and $PM_{2.5}$) and dust deposition, predicted at nominated receptors and the surrounding environment are compared with the relevant air quality assessment criteria as an indication of potential impact. This assessment has considered the potential impact attributable to the GBO, as well as the cumulative (background) impact (i.e. in conjunction with the existing emission sources in the area).

Modelling results, at nominated receptors, are compared to the numerical value of the criteria, and assessed as being either above or below the numerical value (nominated criteria). It is important to note that, as a risk-based assessment approach is normally applied to the assessment of air quality, a modelled result above the numerical value is not an indicator of unacceptable impact, but is an indication that the potential risk for impact requires further consideration.

2.5.1 Human Health Assessment and Amenity Criteria

Modelled ground level concentrations for particulates are compared to ambient air quality assessment criteria to determine the potential changes in impact resulting from the Project.

The assessment criteria adopted for this study (for particulates) are primarily based on the DWER (2019; 2021) guidelines, which also reference the numerical values from the ambient air quality standards specified in the Ambient Air Quality NEPM (NEPC, 2021).

In their current draft form, the DWER (2019) guidelines for TSP, PM_{10} and $PM_{2.5}$ (defined as *criteria pollutants* in the guideline) require the criteria to generally be *"…met at all existing and future offsite sensitive receptors in the modelling domain"*. DWER (2021) draft guideline addresses the settling or deposition of dust. At the time of this assessment both DWER guidelines are draft and subject to post-public consultation finalisation.

2.5.2 Impact on Vegetation Criteria

With respect to vegetation health, research on the effects of dust deposition has been undertaken in Australia by Doley (2006). Doley concluded that "*critical dust loads that result in significant alterations in the most sensitive plant functions vary with the particle size distribution and colour of the dust, from about 1 g/m^2 for carbon black with a median diameter of about 0.15 µm to about 8 g/m^2 for coarse road or limestone dusts with median diameters greater than about 50 µm. The critical loads vary with the plant function, and it is not possible to predict precisely the nature of one plant response from the knowledge of another*". For mineral dust, Farmer (1993) showed that direct physical effects of mineral dusts on vegetation became apparent only at relatively high surface loads (e.g. greater than 7 g/m^2).

For this study, 7 g/m^2/month is used as an indicative criterion for potential effects on vegetation. A modelling result that is higher than the assessment criteria is interpreted as an indication that results may need further consideration for the sensitive receptor, and is not necessarily a predicted impact or loss of environmental value.

2.5.3 Summary of Applied Assessment Criteria

A consolidated summary of the applicable assessment criteria and relevant receptor application is provided in Table 2-2.

Table 2-2: Summary of adopted assessment criteria.

Pollutant	Air quality assessment criteria					Reference
	Concentration [1]	Concentration [2]	Averaging Period	Allowable Exceedances	Environmental value protected	
PM_{10}	50 µg/m^3	46 µg/m^3	24-hour	exception event	Human health and amenity	DWER (2019) consistent with NEPM (NEPC, 2021)
	25 µg/m^3	23 µg/m^3	annual	none		
$PM_{2.5}$	25 µg/m^3	23 µg/m^3	24-hour	exception event		
	8 µg/m^3	8 µg/m^3	annual	none		
TSP	90 µg/m^3	82 µg/m^3	24-hour	none		DWER (2019)
Dust deposition	2 g/m^2/30 days		30-days	Maximum increase above background	Amenity | Nuisance	DWER (2021)
	4 g/m^2/30 days		30-days	Maximum		DWER (2021) referencing NSW EPA (2017)
	7 g/m^2/30 days		30-days	None	Ecological (vegetation/leaf) impact	Doley (2006)

Notes:
1 Concentrations referenced to 0ºC (excluding reference to dust deposition)
2 Concentrations referenced to 25ºC (excluding reference to dust deposition)

3 Modelling

For this assessment there are two potential atmospheric dispersion models than could be used: CALPUFF and AERMOD. A brief overview of each model is provided below.

- CALPUFF: A multi-layer, multi species, non-steady-state puff dispersion model that can simulate the effects of time-varying and space-varying meteorological conditions on pollutant transport, transformation and removal. The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects. CALPUFF is a USEPA regulatory model for long range transport and on a case-by-case basis for near field applications involving complex flows.
- AERMOD: A steady state plume model developed by the American Meteorological Society and the USEPA. It is the USEPA regulatory model for near field applications for both simple and complex terrain.

A key difference between these two models is that CALPUFF is a puff model, while AERMOD is a plume model. CALPUFF, as a non-steady-state puff model, continuously tracks discrete emissions puffs and can model the changes in plume dispersion within time and space more realistically than a plume model. A plume model, such as AERMOD, assumes that within a given time period (nominally hourly) the meteorological conditions are uniform over the entire model domain, with the next time step being modelled for conditions within that hour (previous hourly plume is forgotten).

It is noted that previous air quality assessments for the operations (GHD, 2018: GHD, 2022) utilised the AERMOD dispersion model. Both of the GHD assessments used meteorological parameters from the Talison TSF meteorological station which, as outlined in Section 2.1.4, is not entirely representative of the meteorology in the region.

Based on the variability of the wind speed and direction within the region immediately surrounding the operations (Section 2.1.4) it is apparent that the use of a steady-state model would be inappropriate, and this assessment has been conducted using CALPUFF (Version 6.42, Level: 110325) with meteorological data produced from the WRF prognostic model.

The CALPUFF model has been used to predict ground level concentrations across the model domain. The potential air quality impacts associated with the Project have been considered in isolation of other emission sources, for particulates. The model was configured to predict the ground-level concentrations on a rectangular grid. The model domain was defined with the Southwest corner of the model domain at 404,470 m Easting and 6,253,810 m Northing (UTM Zone 50).

The 2019 calendar year was selected based on the results of the statistical study presented in Appendix A.

Specifics for the modelling configuration are described further in this section.

3.1 Meteorological model (WRF and CALMET)

The meteorology component of a dispersion model is a key element for the effectiveness or representativeness of the dispersion model outputs. Both upper air and surface information are needed for modelling (or assumptions).

3.1.1 WRF model

In order to generate the 3-dimensional meteorology required by CALMET for the region, the Weather Research and Forecast (WRF V4.0) model (http://wrf-model.org/index.php) was utilised. WRF is the next-generation mesoscale numerical weather prediction system. The model was primarily designed to serve both operational forecasting and atmospheric research. WRF features multiple dynamical cores, a 3-dimensional variational data assimilation system and a software architecture allowing for computational parallelism and system extensibility. Further details on WRF configuration and validation are provided in Appendix B.

3.1.2 CALMET

The 3-Dimensional meteorological data generated by WRF was input to CALMET (Version 6.42 Level: 110325) for further processing to the finer resolution used in the dispersion modelling. This procedure will be referred to as the 'WRF-CALMET methodology'. The output from the CALMET meteorological model is then used to drive the pollution dispersion in the CALPUFF model.

CALMET is a three-dimensional meteorological pre-processor that includes a wind field generator containing objective analysis and parameterised treatments of slope flows, terrain effects and terrain blocking effects. The pre-processor produces fields of wind components, air temperature, relative humidity, mixing height and other micro-meteorological variables to produce the three-dimensional, spatially- and temporal-varying meteorological fields that are utilised in the CALPUFF dispersion model.

CALMET requires several datasets to resolve the surface and upper air meteorology occurring for each hour of the year:

- surface observations and upper air observations or gridded prognostic meteorological model data.
- land use and topographical data.

CALMET was run for a 180 x 180 grid domain at a spatial resolution of 100 m. Vertically, the model consisted of 11 levels extending to 3,000 m. The southwest corner coordinates of the domain were Easting of 404,470 m and a Northing of 6,253,810 m.

The 90 m resolution Shuttle Radar Topography Mission (SRTM) dataset was used as input into the CALMET model to indicate terrain heights within the model domain. CALMET also requires geophysical data including gridded fields of land use categories. The CALMET land use is sourced from the 100 m spatial resolution Copernicus Global Land "CGLOPS-1" dataset (Buchhorn et al, 2020), and converted to the 52-category United States Geological Service land use and land cover classification system required by CALMET (Figure 3-1).

The configuration of CALMET is detailed in Appendix C and selected CALMET results are provided in Appendix C.

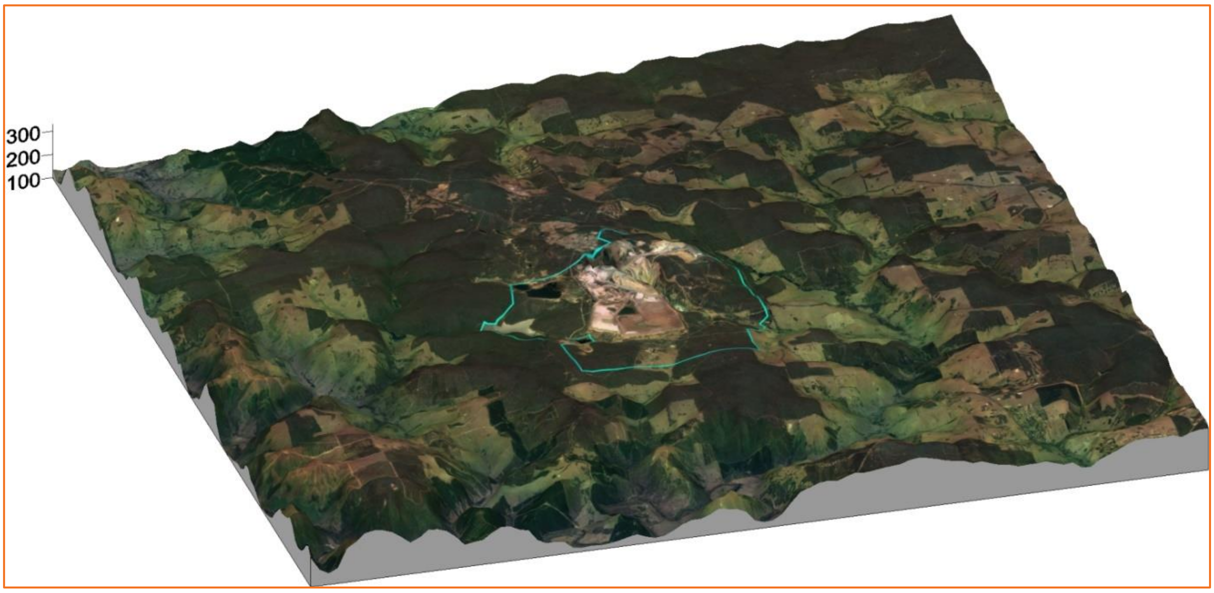

Figure 3-1: Image of terrain elevation used in CALMET (GDA94, Zone 50).

3.2 CALPUFF

CALPUFF is the dispersion module of the CALMET/CALPUFF suite of models. It is a multi-layer, multi species, non-steady-state puff dispersion model that can simulate the effects of time-varying and space-varying meteorological conditions on pollutant transport, transformation and removal. The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer range effects such as pollutant removal, chemical transformation, vertical wind shear and coastal interaction effects. The model employs dispersion equations based on a Gaussian distribution of pollutants across released puffs and considers the complex arrangement of emissions from point, area, volume and line sources (Scire *et al*., 2000).

The CALPUFF model was set to calculate concentrations on a set grid (gridded receptors). The model domain was defined as 18 km in the east–west and 20 km north-south direction at a spacing of 100 m x 100 m.

3.3 Particle sizing | gravitational settling

Since particulate matter is subject to gravitational settling, assumptions need to be made regarding particle sizes. Source specific particle size distribution information is required to define the relative PM_{10} and $PM_{2.5}$ component of total emitted PM and to simulate gravitational settling of particles present in emissions. Project specific particle size distribution information was not available for the emission sources.

A particle size distribution for modelling PM/dust dispersion was therefore estimated using composite data from the USEPA for dust emissions from:

- unpaved roads (USEPA, 2006)
- aggregate handling and storage piles (USEPA, 2006b)
- industrial wind erosion (USEPA, 2006c).

These categories are considered the most appropriate for mining sources and are relevant to the Project sources. The resulting distributions are shown as percentages for each size range in Table 3-1.

Table 3-1: Particle size distribution (%).

Size range (µm)	Representative size (µm)	TSP	PM_{10}	$PM_{2.5}$
<2.5	1.3	6	15	100
2.5 – 5.0	3.5	14	36	-
5.0 – 10.0	7.5	19	48	-
10.0 – 15.0	12.5	14	-	-
15.0 – 30.0	22.5	29	-	-
30.0 – 50.0	37.5	18	-	-

4 Emissions to air estimation

This section outlines the emission estimation process for the GBO. Emission estimates are sourced from this inventory for inclusion in the dispersion model. Emissions from all key sources associated with these operations have been identified according to accepted methods. The emphasis of the emission estimation and modelling is on the potential impact from the operating phase of the Project. The output from the emission estimation process is an hourly variable emission file for the Project.

4.1 Emission Source Inventory

The key emission sources for the operations are associated with:

- Drilling,
- Blasting,
- Loading of ore/waste in-pit,
- Unloading of ore/waste,
- Bulldozers,
- Loading of ore at Run of Mine (RoM) pad,
- Crushing/screening,
- Stacking,
- Wheel generated dust from roads and haul roads,
- Wind erosion from stockpiles and open areas.

A summary of the estimated tonnages for designated equipment at the GBO are presented in Table 4-1.

Table 4-1: Forecast equipment tonnages for proposed GBO operations (tpa).

Source	2023	2028
Ore	6,654,700	11,714,600
Waste	8,884,500	15,639,900
Total	15,530,200	27,354,500

The location of the sources, as modelled, are presented in Figure 4-1 with the emission parameters presented in Appendix F.

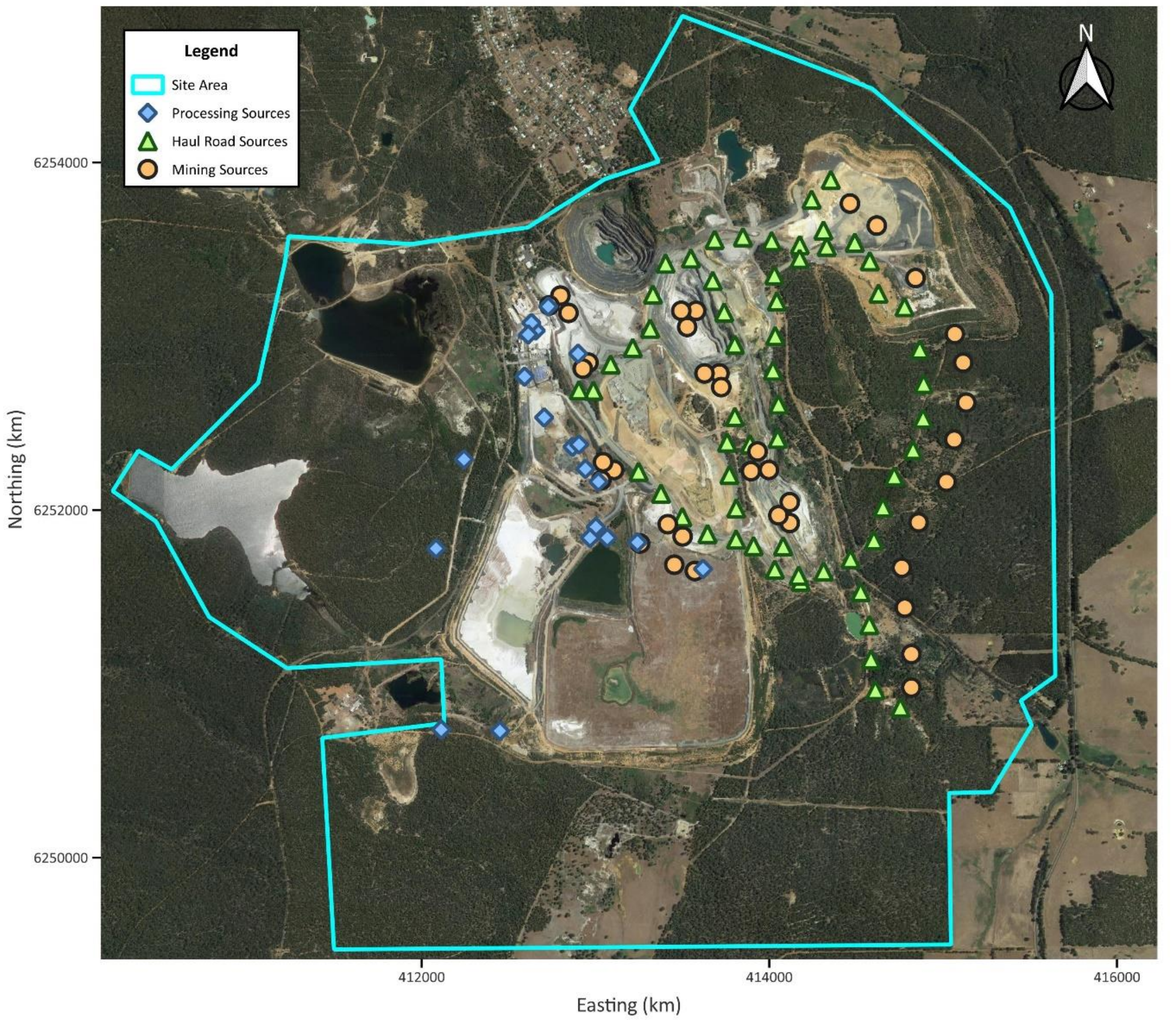

Figure 4-1: Location of modelled air emission sources for the GBO.

4.2 Emission Estimation

The primary reference source for the emissions estimation is based on the National Pollutant Inventory Emission Estimation Technique Manual for Mining Version 3.1, (EETM for mining) published by Environment Australia (EA, 2012).

4.2.1 Drilling

Emissions for drilling have been calculated using the default emissions contained within the EETM for Mining (EA, 2012a). The default values are:

- TSP: 0.59 kg/hole
- PM_{10}: 0.31 kg/hole
- $PM_{2.5}$: 15% of PM_{10} emissions

The statistics of the annual PM_{10} emissions from drilling are contained in Appendix G.

4.2.2 Blasting

Emissions for blasting have been calculated using Equation 19 outlined in Appendix A of the EETM for Mining (EA, 2012a). This is represented by Equation 1:

Equation 1: $$EF_{TSP\ (kg/blast)} = 0.00022 \times A^{1.5}$$

Where A = blast area (m^2)

The emission factor for PM_{10} is taken as 52% of the TSP emission and the $PM_{2.5}$ emissions are taken as 15% of the PM_{10} emissions. The statistics of the annual PM_{10} emissions for blasting are contained in Appendix G.

Within the model blasting was assumed to occur approximately twice per week within each pit area with blasting times at 2pm.

4.2.3 Loading ore/waste

Emissions for loading ore and waste have been calculated using the default value for excavators and front end loaders on overburden from Appendix A (Section 1.1.2) of the EETM for Mining (EA, 2012a) as follows:

- TSP: 0.025 kg/t
- PM_{10}: 0.012 kg/t

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual emissions for loading for PM_{10} are contained in Appendix G.

4.2.4 Unloading ore/waste

Emissions for unloading ore and waste have been calculated using the default values from Appendix A (Section 1.1.5) of the EETM for Mining (EA, 2012a) as follows :

- TSP: 0.012 kg/t
- PM_{10}: 0.0043 kg/t

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual PM_{10} emissions for loading are contained in Appendix G.

4.2.5 Bulldozing

Emissions for the operation of bulldozers on both ore and waste have been determined using Equation 16 and Equation 17 outlined in Appendix A of the EETM for Mining (EA, 2012) and presented below as Equation 2 for TSP and Equation 3 for PM_{10}. The silt and moisture contents used were the defaults listed in the manual (2% moisture, 10% silt).

Equation 2: $$EF_{TSP\ (kg/hr)} = 2.6 \times \frac{s^{1.2}{}_{(\%)}}{M^{1.3}{}_{(\%)}}$$

Equation 3: $$EF_{PM_{10}\ (kg/hr)} = 0.34 \times \frac{s^{1.5}{}_{(\%)}}{M^{1.4}{}_{(\%)}}$$

Where: s = silt content (%)
M = moisture (%)

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual PM_{10} emissions for bulldozing are contained in Appendix G.

4.2.6 Front end loaders

Emissions for the operation of front end loaders used the default emission factor listed in Appendix A of the EETM for Mining (EA, 2012) for overburden. These factors are:

- TSP: 0.025 kg/tonne
- PM_{10}: 0.012 kg/tonne

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual PM_{10} emissions for loading are contained in Appendix G.

4.2.7 Primary Crusher

The emissions for the primary crusher were determined using the default emission factors for high moisture content ores from Table 3 of the EETM for Mining (EA, 2012). These factors are:

- TSP: 0.01 kg/tonne
- PM_{10}: 0.004 kg/tonne

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual emissions for loading for PM_{10} are contained in Appendix G.

4.2.8 Screening

The emissions for screening operations were determined using the default emission factors for high moisture content ores from Table 3 of the EETM for Mining (EA, 2012). These factors are:

- TSP: 0.08 kg/tonne
- PM_{10}: 0.06 kg/tonne

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual emissions for loading for PM_{10} are contained in Appendix G.

4.2.9 Ore Sorters

The emissions for operating the ore sorters were taken as the same as those for screening operations which were determined using the default emission factors for high moisture content ores from Table 3 of the EETM for Mining (EA, 2012). These factors are:

- TSP: 0.08 kg/tonne
- PM_{10}: 0.06 kg/tonne

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual emissions for loading for PM_{10} are contained in Appendix G.

4.2.10 Transfer stations, stacking and reclaiming

The emissions for transfer stations, stacking and reclaiming operations were determined using the default emission factors for high moisture content ores from Table 3 of the EETM for Mining (EA, 2012). These factors are:

- TSP: 0.005 kg/tonne
- PM_{10}: 0.002 kg/tonne

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual emissions for loading for PM_{10} are contained in Appendix G.

4.2.11 Haul Roads

To determine emissions from wheel generated dust along the haul roads the default equation for 'unpaved roads from wheels' was utilised (Equation 4). The weight of the haul trucks was taken as 119 tonnes – being the average of an empty and fully laden CAT777 haul truck and the default silt content of 10% was utilised.

Equation 4:

$$EF_{(kg/VKT)} = \frac{0.4536}{1.6093} \times k \times \left(\frac{s_{(\%)}}{12}\right)^{a} \times \left(\frac{W_{(t)}}{3}\right)^{b}$$

Where: k = constant (TSP = 4.9, PM_{10} = 1.5)
$s_{(\%)}$ = silt content (%)
$W_{(t)}$ = vehicle mass (t)
a = constant (TSP = 0.7, PM_{10} = 0.9)
b = constant (0.45)

The emission factor for $PM_{2.5}$ emissions is taken as 15% of the PM_{10} emissions. The statistics of the annual emissions for loading for PM_{10} are contained in Appendix G.

4.2.12 Wind erosion – Mines and open areas

The default emission factor for wind erosion in the EETM for Mining is a constant emission of 0.2 kg/ha/hr which, while potentially suitable for the calculation of annual emissions, is not suitable for inclusion in atmospheric modelling. This assessment used the modified Shao equation outlined in SKM (2005) which is represented as Equation 5:

Equation 5:

$$PM_{10_{(g/m^2/s)}} = k \times \left\{WS^3 \times \left(1 - \left(WS_O{}^2/WS^2\right)\right)\right\} \qquad WS > WS_O$$

$$PM_{10_{(g/m^2/s)}} = 0 \qquad WS < WS_O$$

Where: WS = wind speed (m/s)
WS_0 = threshold for particulate matter lift off (m/s)
k is a constant

For this assessment the k factor was assigned a value of 8.80×10^{-7}.

The emission factor for TSP is taken as twice that of the PM_{10} emissions while $PM_{2.5}$ emissions are taken as 15% of the PM_{10} emissions.

4.2.13 Emission controls

Emissions controls (for dust abatement) were included in the emissions estimation, and the default control factors outlined in Table 4 in the EETM for Mining (EA, 2012) was applied. These controls are summarised in Table 4-2, along with the percentage reduction applied to each source type.

Table 4-2: Project dust abatement in place (included in model).

Source	Dust abatement description	Emission Reduction
Drilling	In-pit reduction	50% TSP / 5% PM_{10}
Blasting	In-pit reduction	50% TSP / 5% PM_{10}
Loading (ore/waste) in pit	In-pit reduction	50% TSP / 5% PM_{10}
Unloading ore / waste	No reduction	-
Bulldozers	No reduction	-
Loading (ROM pad/product)	Watering	50%
Crushers	Enclosed with extractions (2023) Enclosed with extractions (2028) [1]	80% 90%
Screens	Enclosed with extractions	90%
Ore Sorters	Enclosed with water sprays	85%
Stacking	Telescopic chute with water sprays As above and with wind fence (2028)	75% 82.5%
Haul roads	Watering (level 2), gravel roads	80%
Wind erosion	Watering (pits/waste rock landform) Chemical surfactant (TSF)	50% 80%

Note:
- Indicates no suggested dust control specified.
[1] assumes slightly increased control efficiency for future scenarios to account for increased focus on emission reduction.

Due to the relatively high rainfall of the Project location, especially during the winter months (Section 2.1.3), the hourly rainfall from the on-site meteorological station, for 2019, was incorporated into the emission estimation process. This facilitates the emission estimates to be reduced either within a particular hour to account for wet deposition or, for wind erosion from open areas, to account for the crusting of the surface material.

The reductions for rainfall followed a similar process to that detailed in Air Assessments (2014) in that:

- If the rainfall within an hour was more than 0.2 millimetres (mm) then emissions from all sources were set to zero.
- If the rainfall within a rolling 24-hour period was higher than that time period’s evaporation rate, then only the wind erosion emissions for that 24-hour period were set to zero.

4.3 Emission summary

A summary of the estimated annual emissions (for the modelled year), for each particle size fraction, is shown in Table 4-3. The estimated total emissions for the 2023 Baseline scenario, as presented in Table 4-3, are lower than that reported by Talison to the NPI for the 2021/2022 reporting period (1,000,000 kg/yr), and also lower than those determined in a previous air quality assessment by GHD (2018).

Table 4-3: Estimates of the emissions for the Project (kg/year).

Source	2023 Baseline			2028 Scenario 1		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Crushing	11,573	4,629	694	10,355	4,142	621
Screening	7,410	5,557	834	21,905	16,429	2,464
Stacking	4,499	1,799	270	2,862	1,145	172
Transfer	8,018	3,207	481	14,679	5,872	881
Ore Sorters	-	-	-	65,714	49,286	7,393
Load out	6,322	3,034	455	14,184	6,808	1,021
Drilling	7,351	7,339	1,101	7,351	7,339	1,101
Blasting	9,016	8,908	1,336	9,016	8,908	1,336
Load (pit)	177,068	161,486	24,223	311,703	284,273	42,641
Unload waste	97,201	34,830	5,225	171,018	61,281	9,192
Unload ore	72,760	26,072	3,911	128,107	45,905	6,886
Bulldozers	30,337	6,354	953	45,564	9,543	1,431
Load ore (crusher)	75,792	69,122	10,368	133,445	121,702	18,255
Unload ore (crusher)	50,932	18,251	2,738	89,675	32,134	4,820
Haul Roads	1,650,409	487,136	73,070	1,069,466	315,665	118,374
Wind erosion	161,758	58,099	8,715	142,728	87,135	13,070
TOTAL	2,370,445	895,825	134,374	2,237,772	1,057,566	158,635

A brief review (ETA, 2023) of the emission estimation process in the GHD 2018 report highlighted some potential issues across a range of the emissions including:

- The GHD (2018) report notes that the total TSP emissions for blasting are 300,750 kg/yr. This annual emission rate appeared elevated so using the outlined emission estimation techniques ETA reproduced the emission calculation. The process is as follows:
  - Area per blast = 4,000m^2
  - Number of blasts = 1 per day
  - TSP emission calculation used – $EF_{TSP} = 0.00022 * A^{1.5}$ (where EF_{TSP} = kg/blast and A = area)
  - EF_{TSP} = 55.7 kg/blast
  - Total TSP emissions from blasting = 20,314 kg/year
  - Noting that this annual emission does not include any abatement (pit reduction, watering etc).
  - The TSP emissions, as presented by GHD, are 14.8 times higher than those calculated by ETA using identical information.
- The emissions resulting from haul trucks are extremely low at only 59,580 kg/yr. Such a low emission rate appears to be due to the misapplication of abatement measures where both Level 1 watering and chemical application have been included cumulatively – as opposed to only one (if a chemical product is being applied you cannot also claim Level 1 watering). There also appears to be a reduction for wind breaks within the haul road emissions when such an abatement does not exist at the operations.

5 Predicted Air Quality Impact

This assessment has used the WRF/CALMET/CALPUFF modelling suite to estimate the air quality impacts associated with the Project. The results are presented for the GBO operations. The emissions are modelled for the representative meteorology year 2019 (Section 4.1).

To assess the potential air quality impact, modelled concentrations of particulates (as TSP, PM_{10}, $PM_{2.5}$ and deposition) are compared to the assessment criteria outlined in Table 2-2. The comparison of the modelling results to nominated ambient air quality assessment criteria has been done as an indicator for potential changes in conditions at the nominated receptor locations. It should be noted that the nominated receptors are locations of interest (consistent with EPA guidelines for Part IV assessments) and not all nominated receptors are locations are consistent with the DWER definition of a "sensitive receptor" for a Part V assessment. The assessment criteria applicable to a sensitive receptor has been applied at all receptor locations as a conservative comparison approach.

5.1 2023 – Base Case

The GBO 2023-Base Case is described as:

- GBO mining tonnage at 15.3 Mtpa and processing at 7.1 Mtpa

5.1.1 Particulates as PM_{10}

The statistics of the predicted ground level concentrations of PM_{10} are presented in Table 5-1 for both standalone (project only) and cumulatively (i.e. including background concentrations). The results at the residential receptors (Appendix C) indicate that:

- The predicted concentration are higher than the 24-hour criterion at all the Greenbushes township receptors, for GBO emissions in isolation.
- The remaining residential receptors are within the 24-hour criterion.
- The predicted annual average concentrations (with and without background) are below the PM_{10} annual assessment criterion at all the residential receptors.

The predicted isopleths (contours) for ground level concentrations of particulates (as PM_{10}) are presented as follows:

- Annual average PM_{10} concentrations for the operations in isolation (Figure 5-1), and cumulatively with background concentrations (Figure 5-2).
- Maximum predicted 24-hour PM_{10} concentrations for the operations in isolation (Figure 5-3) and cumulatively with background concentrations (Figure 5-4).

The red contour (when present in a figure) corresponds to the relevant assessment criterion contour.

Table 5-1: 2023 - Predicted PM_{10} concentrations at receptor locations (µg/m³).

Receptor Type	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Residential (Greenbushes Town)	Town A	104	82	72	39	22	15	117	95	86	53	36	29
	Town B	115	81	69	41	20	15	129	95	83	55	34	29
	Town C	77	57	48	24	12	9	91	71	62	38	26	23
	Town D	62	49	45	19	9	7	76	63	59	33	23	21
	Town E	60	46	43	18	8	7	74	60	57	32	22	21
	Town F	58	44	40	17	7	6	72	58	54	31	21	20
Residential	A	34	23	19	9	3	3	48	37	33	22	16	17
	B	31	20	16	9	1	2	45	34	30	22	15	16
	C	27	18	15	7	1	2	41	32	29	21	15	16
	D	27	19	18	9	2	3	41	33	32	23	16	17
	E	36	17	16	9	2	3	50	31	30	23	16	16
	F	24	12	9	5	0	1	38	25	23	18	14	15
	G	17	14	10	4	1	1	31	28	24	18	14	15
	H	27	16	13	6	1	2	41	30	27	19	15	16
	I	19	9	8	3	0	1	32	23	22	17	14	15
	J	19	9	8	3	0	1	33	23	21	17	14	15
	K	45	11	10	3	0	1	59	25	23	17	14	15
	L	17	9	8	2	0	1	31	23	21	16	14	15
	M	13	8	6	2	0	1	27	22	20	16	14	14
	N	15	5	5	2	0	1	28	19	18	15	14	14

Receptor Type	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
	O	7	3	2	1	0	0	21	16	16	15	14	14
	P	11	6	5	2	0	1	25	20	19	16	14	15
	Q	15	13	10	5	1	2	29	27	24	19	15	15
	R	14	10	8	3	1	1	28	24	21	17	14	15
	S	24	10	8	3	1	1	38	24	22	17	15	15
	T	10	7	5	2	0	1	23	21	19	16	14	14
	U	8	4	3	1	0	0	22	18	17	15	14	14
	V	8	4	3	1	0	0	22	18	17	15	14	14
Assessment criteria[1]		**50**					**25**	**50**					**25**

Note:

Shading indicates model result above the assessment criterion.

[1] AGV (DWER, 2019) specified at 25ºC.

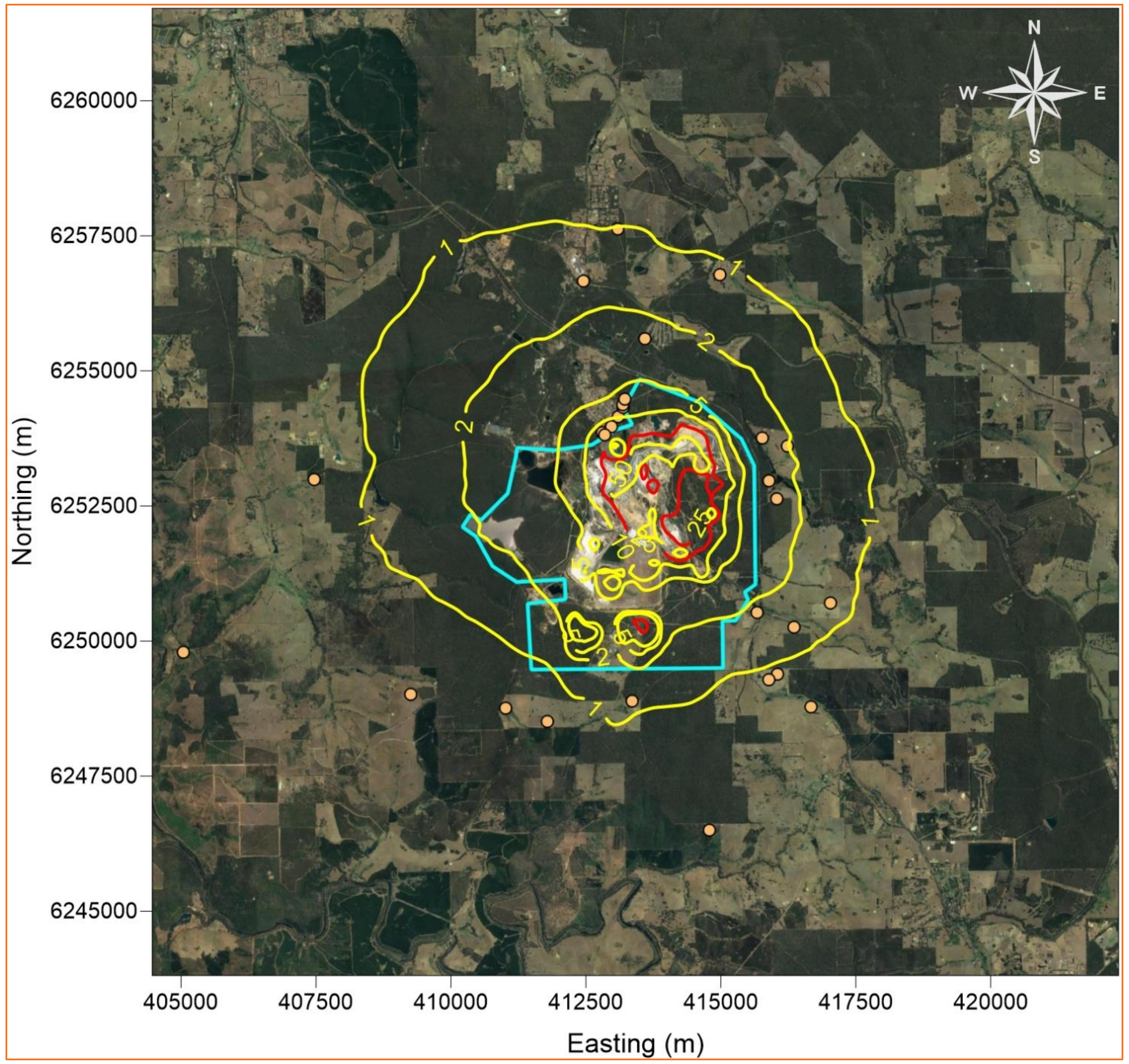

Figure 5-1: 2023 – Annual average PM_{10} concentration – Project only.[1]

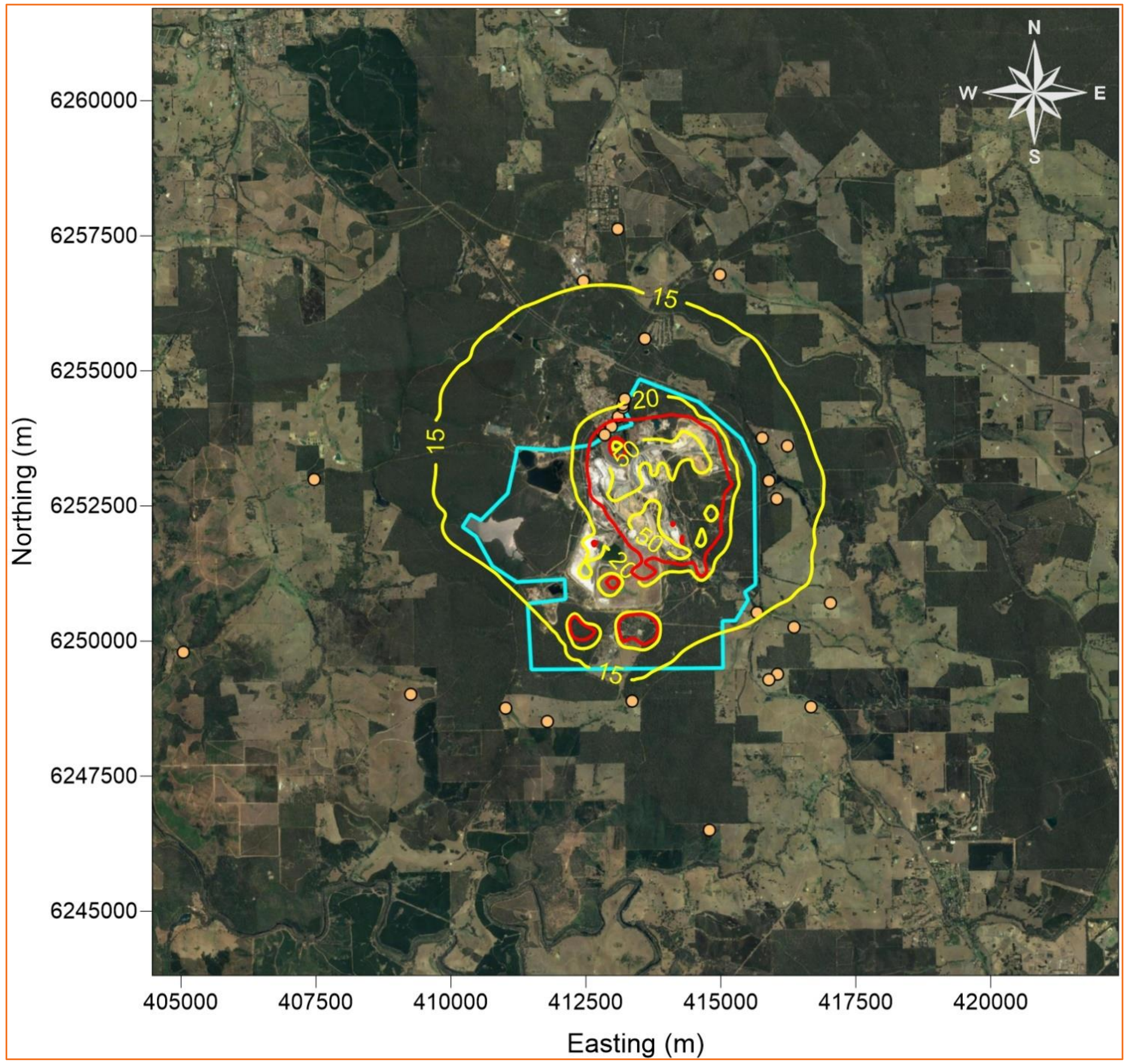

Figure 5-2: 2023 - Annual average PM_{10} concentration – Project with background included.[2]

[1] Red contour corresponds to the relevant assessment criterion contour.

[2] Red contour corresponds to the relevant assessment criterion contour.

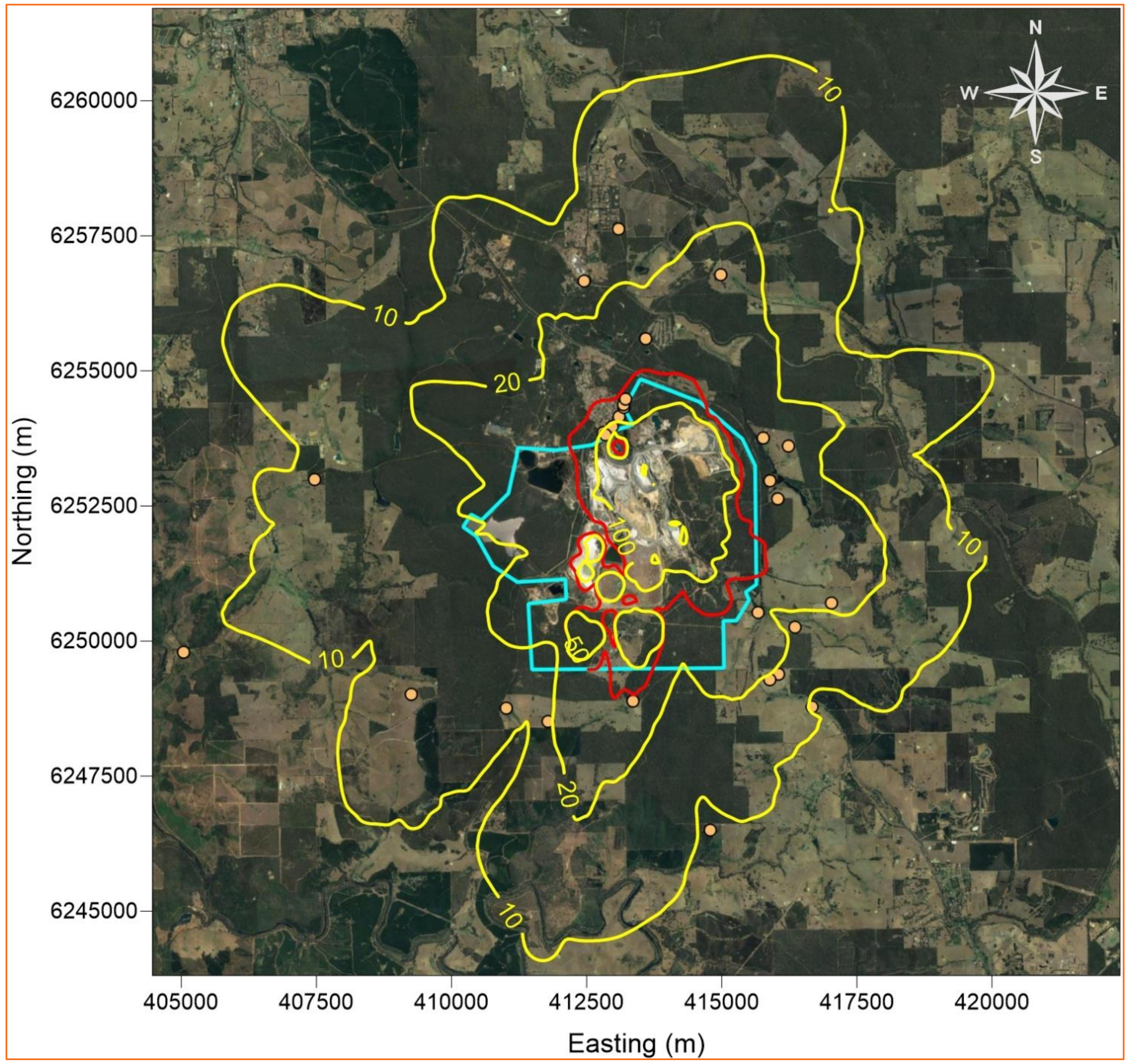

Figure 5-3: 2023 - Maximum 24-hour PM_{10} concentration – Project only.[3]

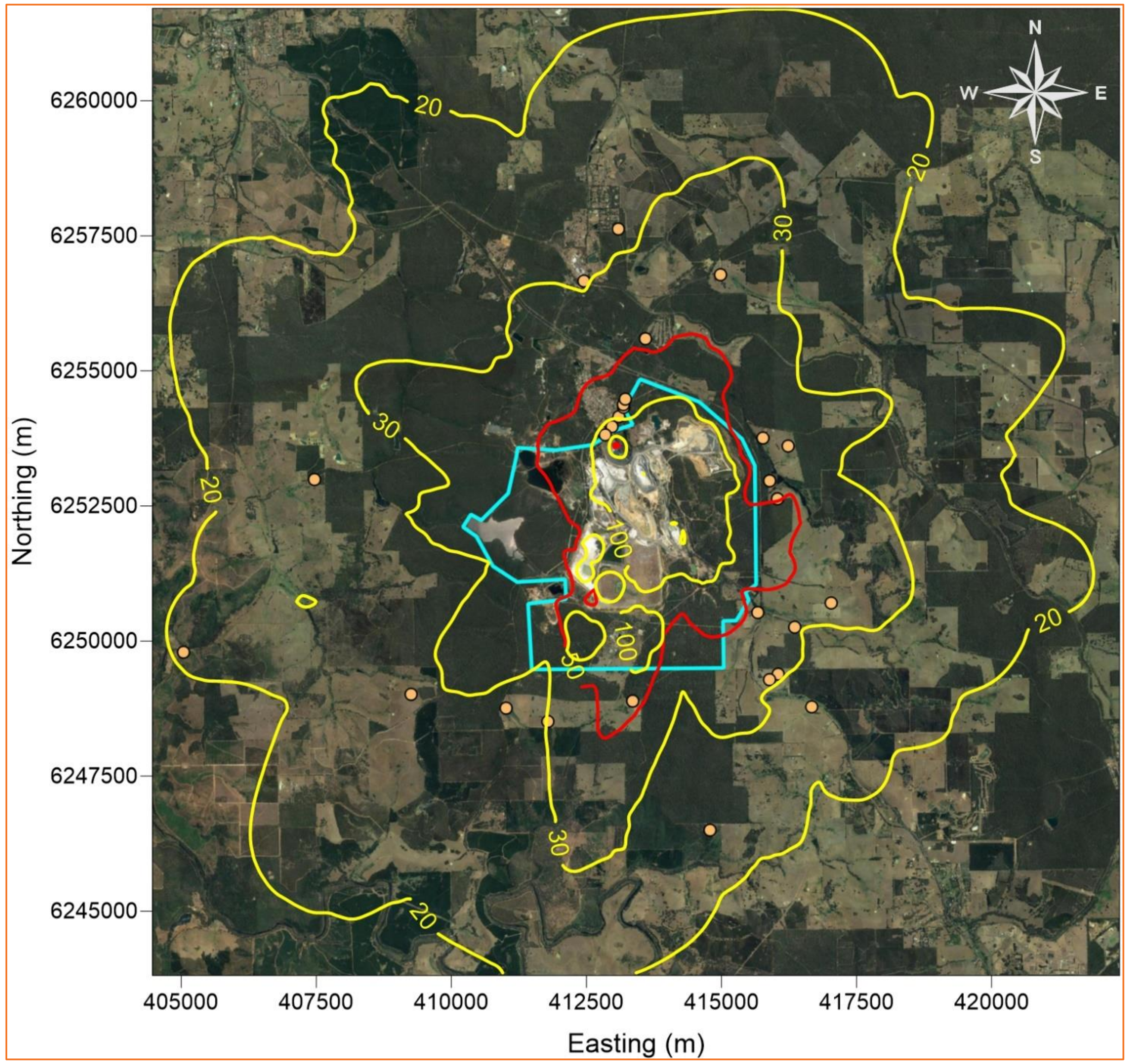

Figure 5-4: 2023 - Maximum 24-hour PM_{10} concentration – Project with background included.[4]

[3] Red contour corresponds to the relevant assessment criterion contour.

[4] Red contour corresponds to the relevant assessment criterion contour.

5.1.2 Particulates as $PM_{2.5}$

The statistics of the predicted ground level concentrations of $PM_{2.5}$, at all nominated receptors, are presented in Table 5-2 for both standalone impacts (Project only) and cumulatively (including background concentrations). The results at the nominated receptors for assessing impact indicate that:

- The predicted concentration at all the residential receptors is below the 24-hour average assessment criterion for $PM_{2.5}$ both with and without the inclusion of background concentration.
- The predicted annual average concentration from the mine (with and without background) is below the $PM_{2.5}$ annual assessment criterion at all the residential receptors.

The predicted isopleths (contours) for ground level concentrations of particulates (as $PM_{2.5}$) are presented as follows:

- Annual average $PM_{2.5}$ concentrations for the operations in isolation (Figure 5-5) and cumulatively with background concentrations (Figure 5-6).
- Maximum predicted 24-hour $PM_{2.5}$ concentrations for the operations in isolation (Figure 5-7) and cumulatively with background concentrations (Figure 5-8).

Table 5-2: 2023 - Predicted $PM_{2.5}$ concentrations at receptors ($\mu g/m^3$).

Receptor Type	Receptor	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Residential (Greenbushes Town)	Town A	16	12	11	6	3	2	18	14	13	8	5	4
	Town B	17	12	10	6	3	2	19	14	12	8	5	4
	Town C	12	9	7	4	2	1	14	11	9	6	4	3
	Town D	9	7	7	3	1	1	11	9	9	5	3	3
	Town E	9	7	6	3	1	1	11	9	9	5	3	3
	Town F	9	7	6	3	1	1	11	9	8	5	3	3
Residential	A	5	3	3	1	0	0	7	6	5	3	2	3
	B	5	3	2	1	0	0	7	5	5	3	2	2
	C	4	3	2	1	0	0	6	5	4	3	2	2
	D	4	3	3	1	0	0	6	5	5	3	2	3
	E	5	3	2	1	0	0	7	5	5	3	2	2
	F	4	2	1	1	0	0	6	4	3	3	2	2
	G	3	2	2	1	0	0	5	4	4	3	2	2
	H	4	2	2	1	0	0	6	5	4	3	2	2
	I	3	1	1	0	0	0	5	4	3	3	2	2
	J	3	1	1	0	0	0	5	4	3	3	2	2
	K	7	2	1	0	0	0	9	4	4	3	2	2
	L	3	1	1	0	0	0	5	3	3	2	2	2
	M	2	1	1	0	0	0	4	3	3	2	2	2
	N	2	1	1	0	0	0	4	3	3	2	2	2

Receptor Type	Receptor	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
	O	1	0	0	0	0	0	3	2	2	2	2	2
	P	2	1	1	0	0	0	4	3	3	2	2	2
	Q	2	2	2	1	0	0	4	4	4	3	2	2
	R	2	2	1	0	0	0	4	4	3	3	2	2
	S	4	2	1	1	0	0	6	4	3	3	2	2
	T	1	1	1	0	0	0	4	3	3	2	2	2
	U	1	1	1	0	0	0	3	3	3	2	2	2
	V	1	1	1	0	0	0	3	3	3	2	2	2
Assessment criteria						**23**	**7**					**23**	**7**

Note:

Shading indicates model result above the assessment criterion.

[1] AGV (DWER, 2019) specified at 25ºC.

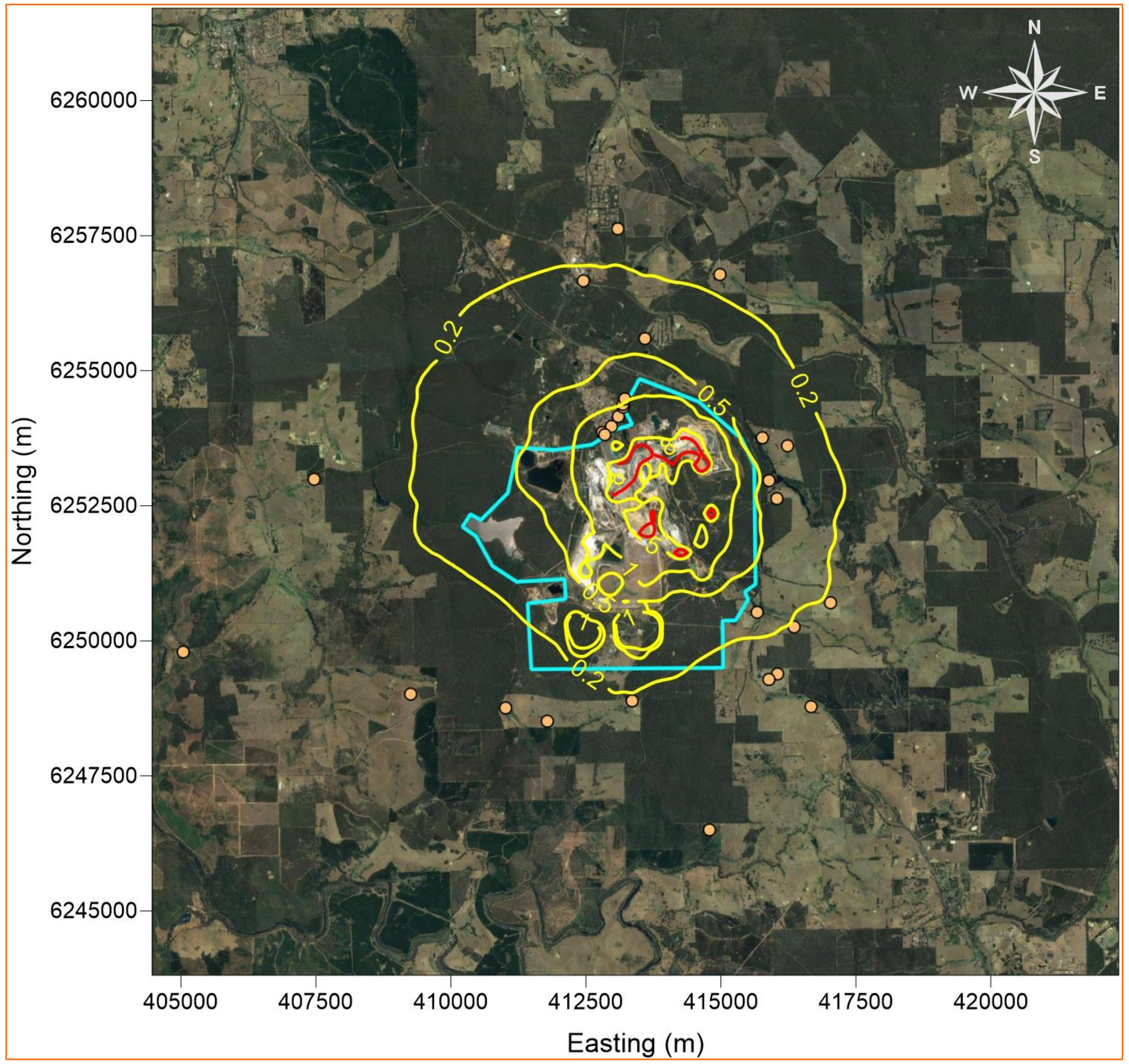

Figure 5-5: 2023 - Annual average PM$_{2.5}$ concentration – Project only.

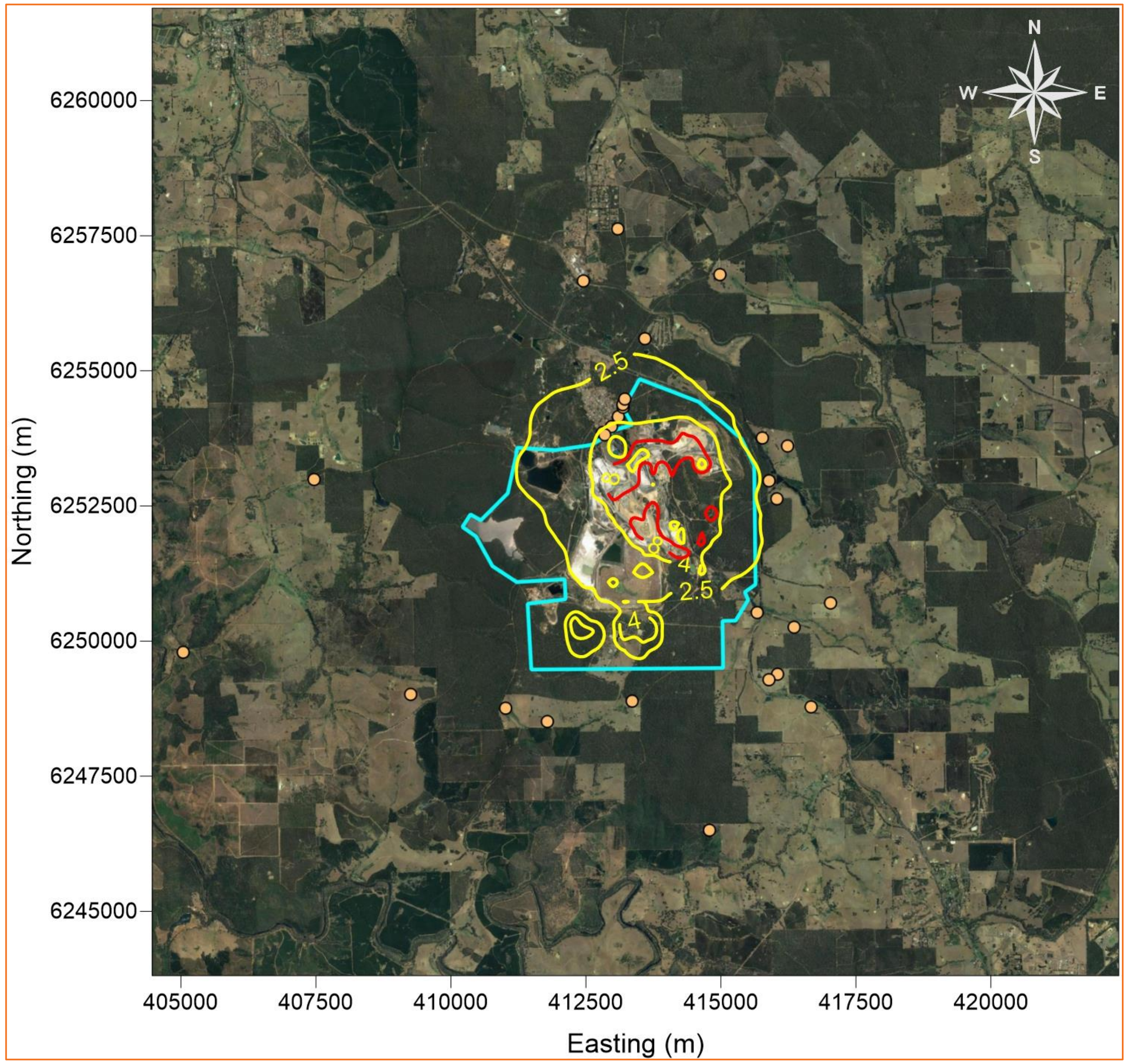

Figure 5-6: 2023 - Annual average PM$_{2.5}$ concentration – Project with background included.[5]

[5] Red contour corresponds to the relevant assessment criterion contour.

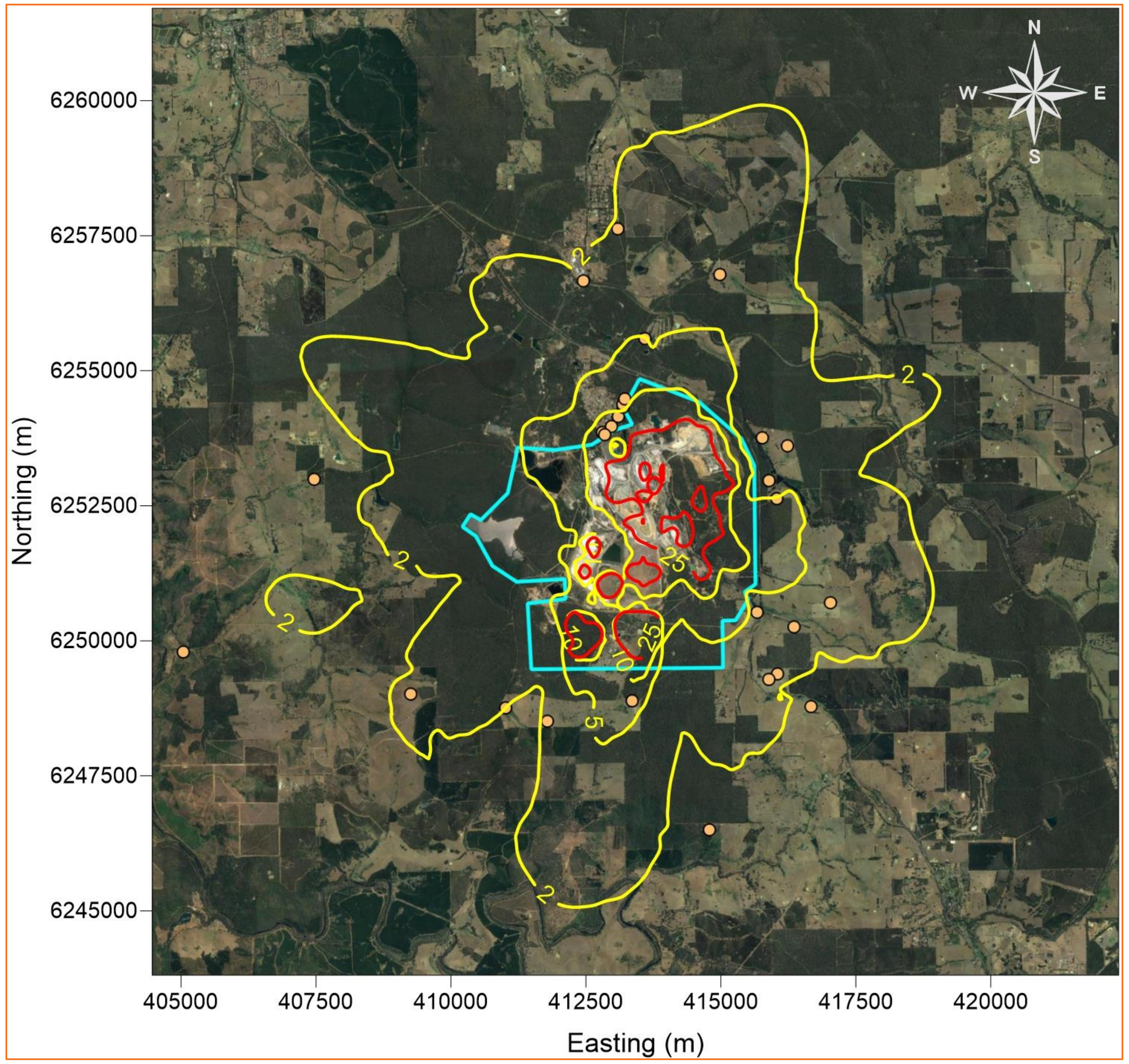

Figure 5-7: 2023 - Maximum 24-hour PM2.5 concentration – Project only.

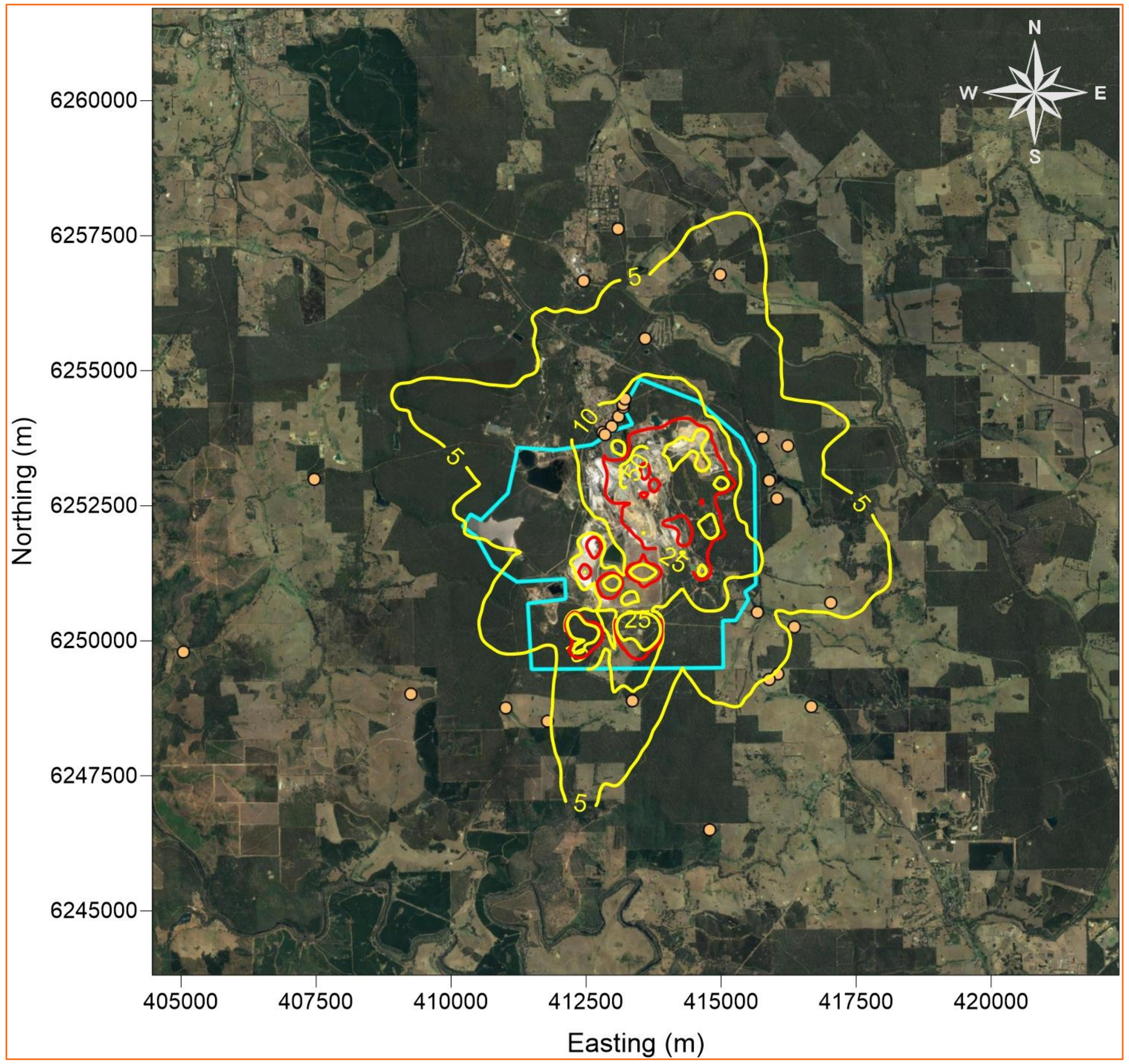

Figure 5-8: 2023 - Maximum 24-hour PM2.5 concentration – Project with background included.[6]

[6] Red contour corresponds to the relevant assessment criterion contour.

5.1.3 Total Suspended Particulates

The statistics of the predicted ground level concentrations of TSP at all the nominated receptors are presented in Table 5-3 as standalone impacts (Project only) and cumulatively (including background concentrations). The results at these selected receptors indicate that:

- The predicted concentration at all the Greenbushes Township receptors is above the 24-hour average assessment criterion for TSP both with and without the inclusion of background concentration.
- The predicted maximum 24-hour TSP concentration at the remaining residential receptors are within the 24-hour average assessment criterion for TSP.
- Modelled results higher than the assessment criteria should not be interpreted as a predicted impact or loss of environmental value but as an indication that results may need further consideration for the receptor location.

The maximum predicted 24-hour ground level concentrations of TSP concentrations for the mining operations are presented in Figure 5-9 (standalone) and cumulatively with background concentrations in Figure 5-10.

Table 5-3: 2023 - Predicted TSP concentrations at receptors (µg/m³).

Receptor Type	Receptor	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Residential (Greenbushes Town)	Town A	265	207	184	106	59	40	278	221	198	120	73	54
	Town B	281	205	174	111	53	40	295	219	188	124	67	53
	Town C	174	117	108	61	29	22	187	131	122	75	43	36
	Town D	124	103	98	46	20	17	138	116	112	60	34	30
	Town E	116	96	92	44	19	15	130	110	106	58	33	29
	Town F	104	95	83	40	17	14	118	108	97	54	30	28
Residential	A	62	43	40	17	5	6	76	57	54	31	19	19
	B	67	40	37	19	3	6	81	54	51	33	17	19
	C	56	36	30	17	2	4	70	49	44	30	16	18
	D	64	45	42	21	6	6	77	58	56	35	20	20
	E	73	41	37	19	6	6	86	55	51	33	19	20
	F	43	22	19	9	1	2	56	35	33	22	15	16
	G	37	27	20	8	1	3	51	41	34	22	15	16
	H	61	37	28	12	2	4	75	51	42	26	16	17
	I	39	19	12	6	1	2	53	33	26	19	15	16
	J	39	18	14	5	0	2	53	32	27	19	14	15
	K	66	19	16	6	0	2	80	33	30	20	14	16
	L	26	14	14	5	0	1	40	28	27	18	14	15
	M	21	13	11	4	0	1	35	27	25	18	14	15
	N	23	10	8	3	0	1	37	24	22	17	14	15

Receptor Type	Receptor	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
	O	9	4	3	1	0	0	23	18	17	15	14	14
	P	16	11	9	4	1	1	29	24	23	18	15	15
	Q	29	24	19	10	2	3	43	37	33	23	16	17
	R	25	16	13	6	1	2	38	29	27	20	15	16
	S	41	19	15	7	2	2	55	33	29	21	15	16
	T	19	14	9	4	0	1	33	28	23	17	14	15
	U	14	7	5	2	0	1	28	20	19	16	14	14
	V	14	7	5	2	0	1	28	20	19	16	14	14
Assessment Criteria		**90**					-	**90**					-

Note:

Shading indicates model result above the assessment criterion.

[1] AGV (DWER, 2019) specified at 25ºC.

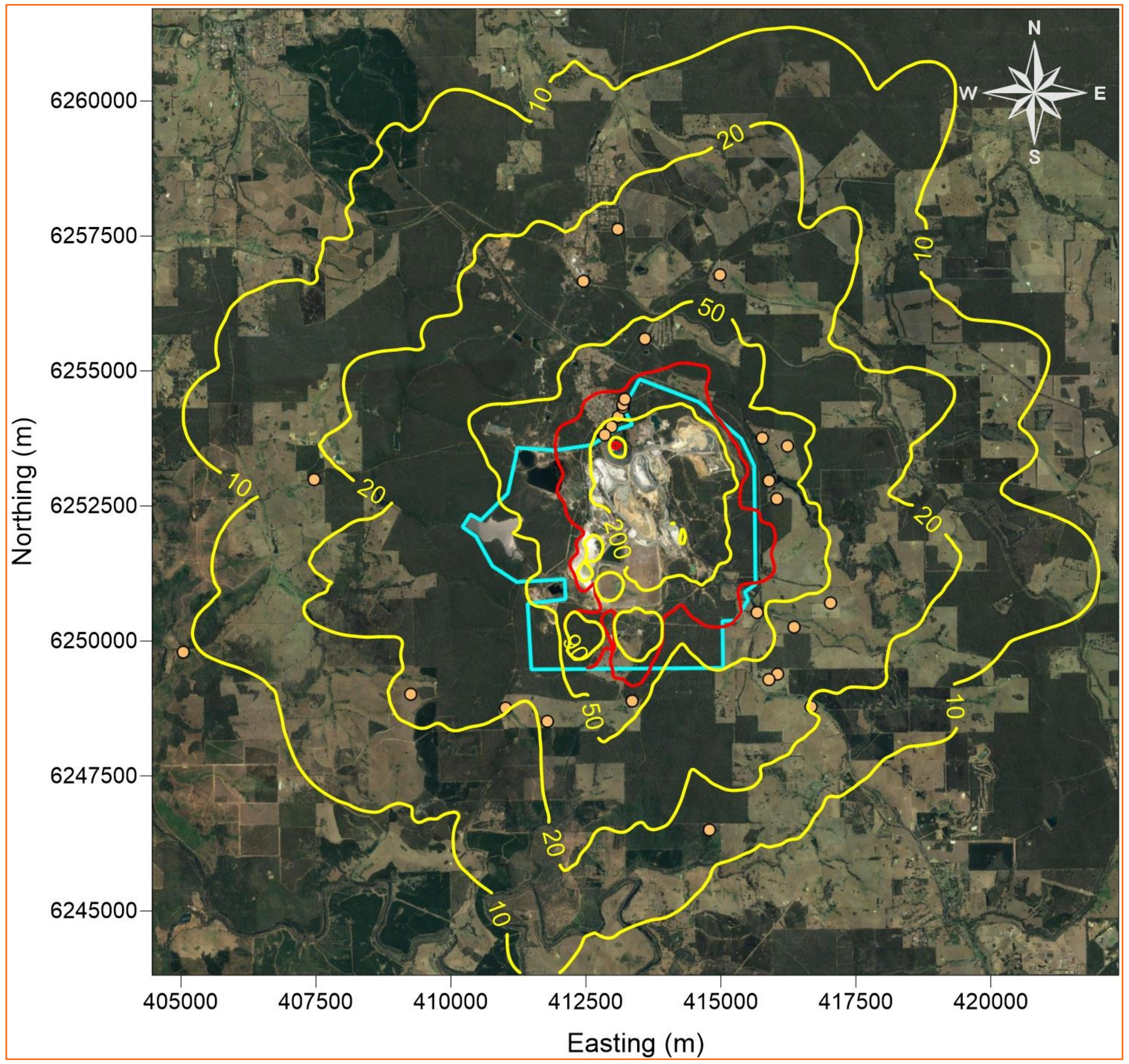

Figure 5-9: 2023 - Maximum 24-hour TSP concentration – Project only.[7]

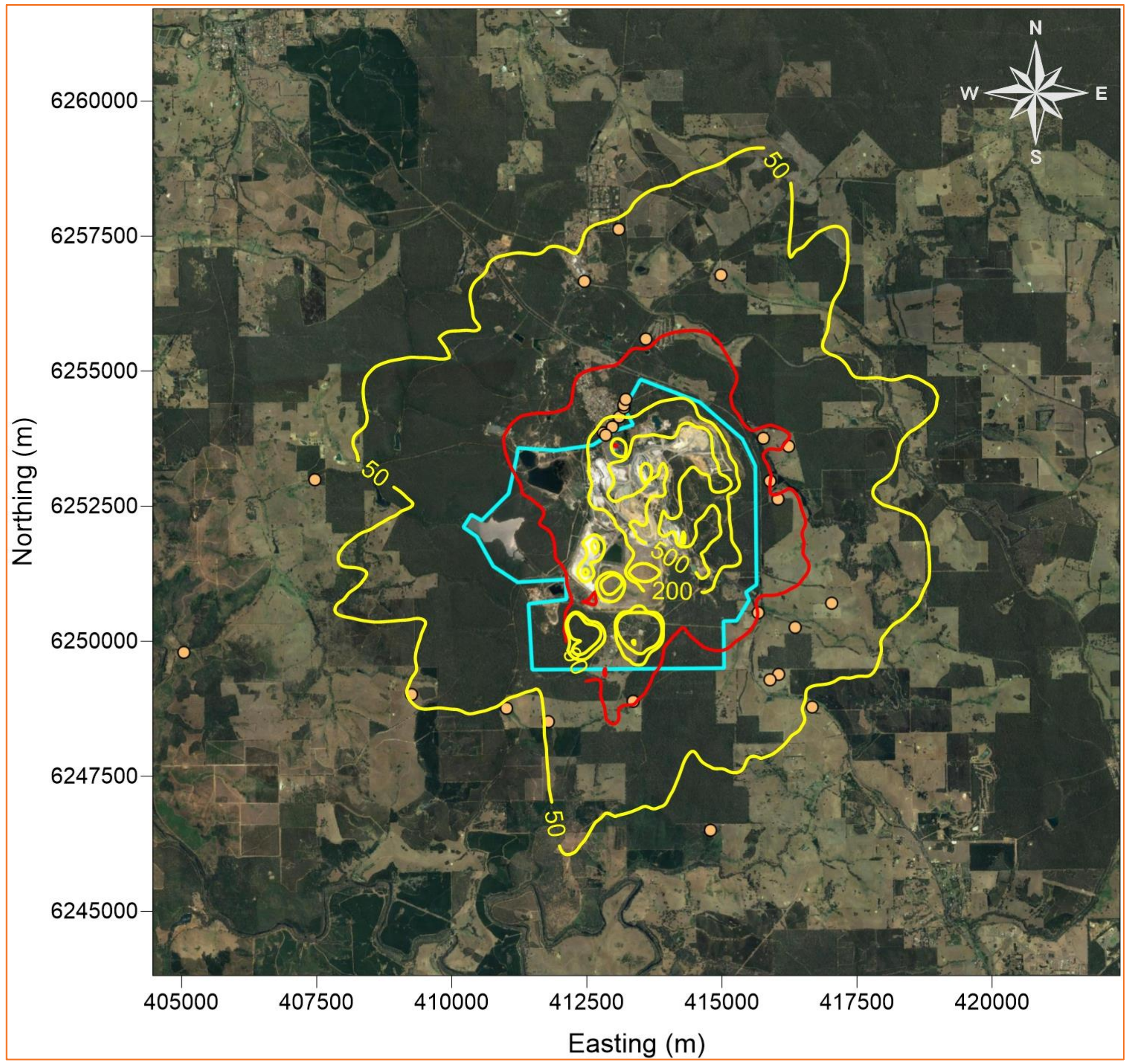

Figure 5-10: 2023 - Maximum 24-hour TSP concentration – Project with background included.[8]

[7] Red contour corresponds to the relevant assessment criterion contour.

[8] Red contour corresponds to the relevant assessment criterion contour.

5.1.4 Dust deposition

The modelling predicts that the deposition rates will not exceed the maximum increase above background criteria of 2 g/m^2/month at all identified sensitive receptors (Table 5-4).

Table 5-4: 2023 - Predicted dust deposition at receptors – in isolation (g/m^2/month).

Receptor ID	Receptor Name	Maximum	Receptor ID	Receptor Name	Maximum
1	Town A	1.97	15	I	0.11
2	Town B	1.98	16	J	0.10
3	Town C	1.70	17	K	0.28
4	Town D	1.35	18	L	0.12
5	Town E	1.28	19	M	0.07
6	Town F	1.13	20	N	0.04
7	A	0.38	21	O	0.02
8	B	0.36	22	P	0.07
9	C	0.21	23	Q	0.22
10	D	0.47	24	R	0.12
11	E	0.42	25	S	0.13
12	F	0.09	26	T	0.08
13	G	0.15	27	U	0.05
14	H	0.27	28	V	0.05
Assessment Criteria		**2 g/m^2/month**	**Assessment Criteria**		**7 g/m^2/month**

Note:
Shading indicates result above the assessment criterion.

The predicted monthly dust deposition (based on annual average predicted flux rates) is presented in Figure 5-11. The contour plot shows that the monthly deposition criterion is limited to the site envelope.

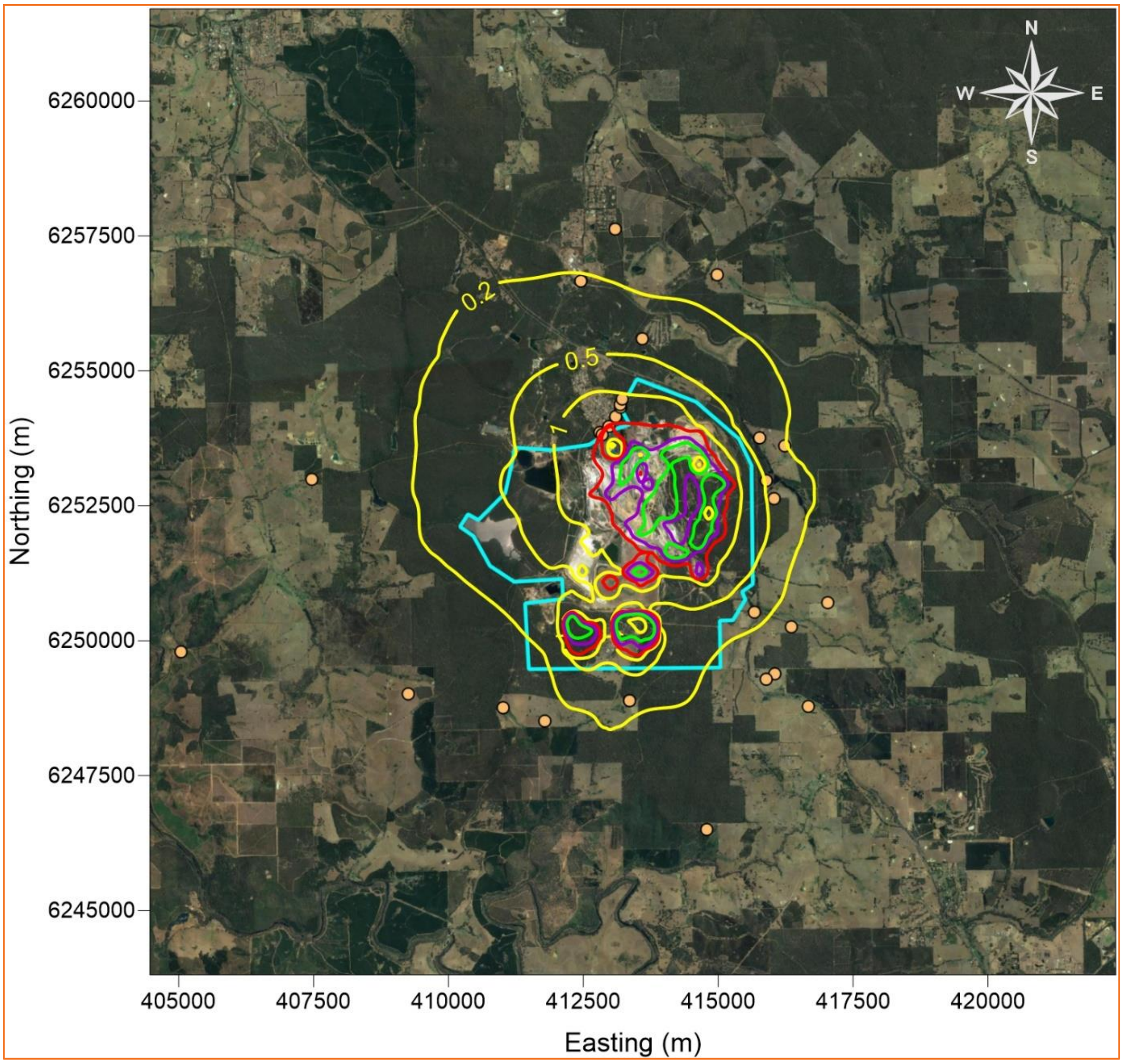

Figure 5-11: 2023 - Total predicted monthly dust deposition (g/m²/month) – Project only. [9]

[9] Red contour corresponds to the 2 g/m²/month assessment criterion contour, purple contour corresponds to the 4 g/m²/month assessment criterion contour, and green contour corresponds to the 7 g/m²/month assessment criterion contour.

5.2 2028 – Scenario 1

The GBO 2023-Base Case is described as:

- GBO mining tonnage at 15.3 Mtpa and processing at 7.1 Mtpa, and includes the following expansion activities –
  - operation of two new Crushers – Crusher 3 (Cr3) and Crusher 4 (Cr4)
  - operation of two new Process Plants – Chemical Grade Plant #3 (CGP3) and Chemical Grade Plant #4 (CGP4)
  - operation of three new Ore Sorters – Ore Sorter 2, Ore Sorter 3, Ore Sorter 4
  - mining up to 27.3 Mtpa of waste rock and ore
  - beneficiation of up to 12.5 Mtpa of ore
  - storage of up to 15.6 Mtpa of waste rock in Floyds Waste Rock Landform (WRL).

5.2.1 Particulates as PM_{10}

The statistics of the predicted ground level concentrations of PM_{10} are presented in Table 5-5 for both standalone (project only) and cumulatively (i.e. including background concentrations). The results at the residential receptors (Appendix C) indicate that:

- The predicted concentrations are higher than the 24-hour criterion at –
  - 9 residential receptors in isolation
  - 18 receptors with background concentration included.
- The predicted annual average concentrations are higher than the PM_{10} assessment criterion at Town receptor A with the facility in isolation and at 3 of the town receptors when background concentrations are included.

The predicted isopleths (contours) for ground level concentrations of particulates (as PM_{10}) are presented as follows:

- Annual average PM_{10} concentrations for the operations in isolation (Figure 5-12) cumulatively with background concentrations (Figure 5-13).
- Maximum predicted 24-hour PM_{10} concentrations for the operations in isolation (Figure 5-14) and cumulatively with background concentrations (Figure 5-15).

The red contour (when present in a figure) corresponds to the relevant assessment criterion contour.

Table 5-5: 2028 Scenario 1- Predicted PM_{10} concentrations at receptor locations (µg/m³).

Receptor	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Residential (Greenbushes Town)	Town A	206	133	122	72	35	27.6	220	147	136	86	49	41.4
	Town B	207	123	117	67	30	24.9	221	137	131	80	44	38.7
	Town C	131	95	75	41	18	14.5	145	109	88	54	32	28.3
	Town D	89	78	58	27	12	10.4	103	92	72	40	25	24.2
	Town E	86	74	54	25	11	9.7	99	88	68	39	24	23.5
	Town F	81	70	47	23	9	8.7	95	84	61	36	23	22.5
Residential	A	55	31	27	12	4	4	69	45	41	25	18	17.8
	B	42	32	27	14	3	4.2	56	46	41	28	17	18.0
	C	41	29	24	12	3	3.5	54	43	37	26	17	17.3
	D	48	38	31	17	5	5.4	62	51	45	31	19	19.2
	E	46	36	33	17	5	5.2	60	50	46	31	19	19.0
	F	54	20	19	9	2	2.7	67	34	33	23	16	16.5
	G	41	31	21	10	2	3	55	45	35	24	16	16.8
	H	66	41	30	13	4	4.2	79	54	44	27	17	18.0
	I	40	19	17	6	1	1.9	54	33	31	20	15	15.7
	J	40	20	17	6	1	1.9	53	34	30	20	15	15.7
	K	49	21	17	7	0.6	2.1	63	35	31	20	14	15.9
	L	27	17	16	5	0.2	1.5	40	31	30	18	14	15.3
	M	30	18	13	4	0.4	1.4	44	31	27	18	14	15.2
	N	28	11	10	4	0.2	1.1	42	25	24	17	14	14.9

Receptor	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
	O	13	5	4	2	0.2	0.5	27	19	18	15	14	14.3
	P	21	12	10	4	1	1.4	34	26	24	18	15	15.8
	Q	27	20	16	7	2	2.4	41	34	29	21	16	17.5
	R	26	17	12	5	1	1.6	40	31	26	19	15	16.3
	S	40	17	13	5	1	1.7	54	31	27	19	15	16.5
	T	22	13	11	4	0.7	1.3	36	27	25	18	15	15.7
	U	19	10	6	2	0.2	0.7	32	24	20	16	14	14.9
	V	19	10	6	2	0.2	0.7	32	24	20	16	14	14.9
Assessment Criteria[1]		**46**					**23**	**46**					**23**

Note:

Shading indicates model result above the assessment criterion.

[1] AGV (DWER, 2019) specified at 25ºC.

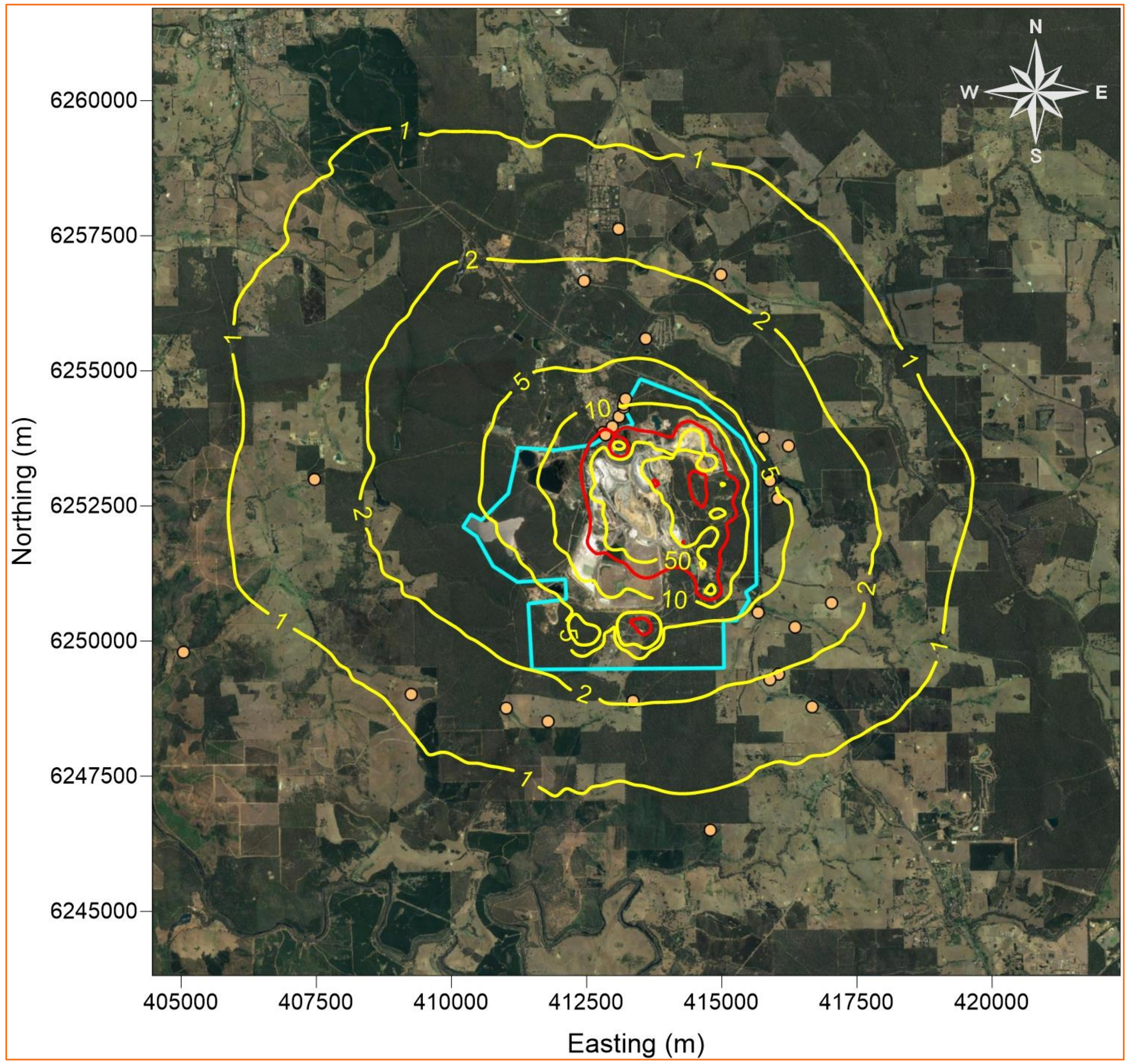

Figure 5-12: 2028 – Annual average PM$_{10}$ concentration – Project only.[10]

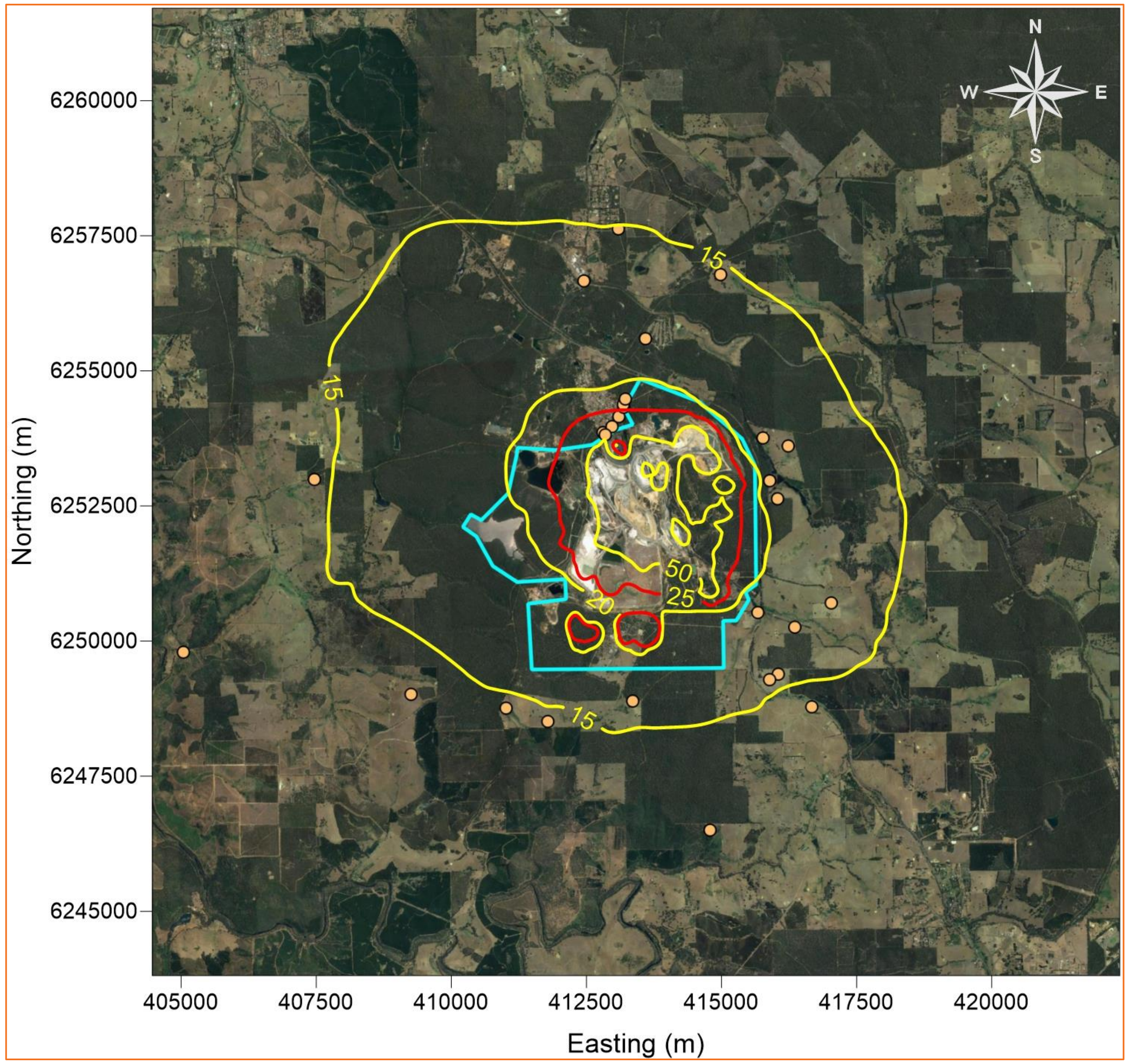

Figure 5-13: 2028 - Annual average PM$_{10}$ concentration – Project with background included.[11]

[10] Red contour corresponds to the relevant assessment criterion contour.

[11] Red contour corresponds to the relevant assessment criterion contour.

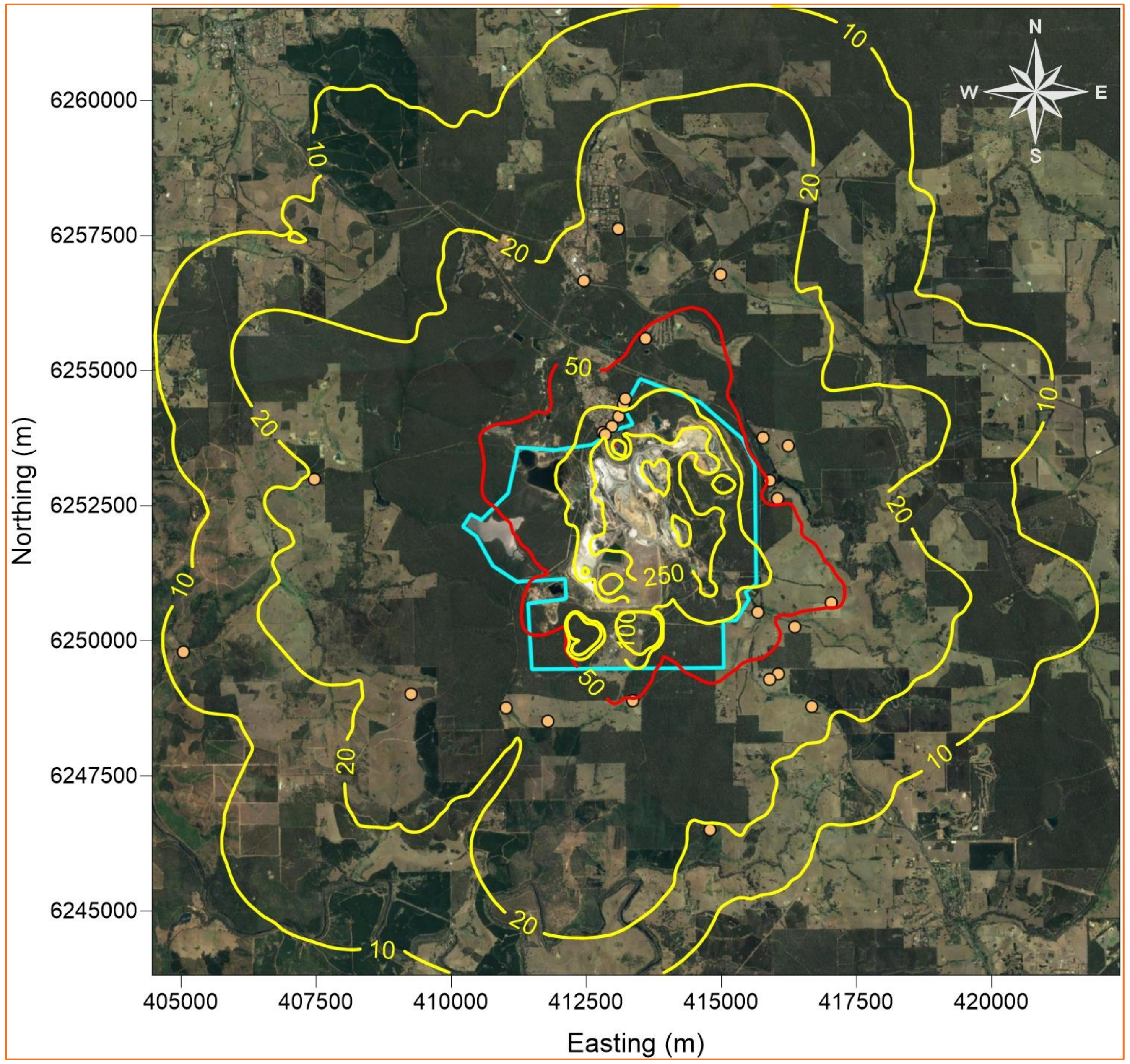

Figure 5-14: 2028 – Maximum 24-hour PM_{10} concentration – Project only.[12]

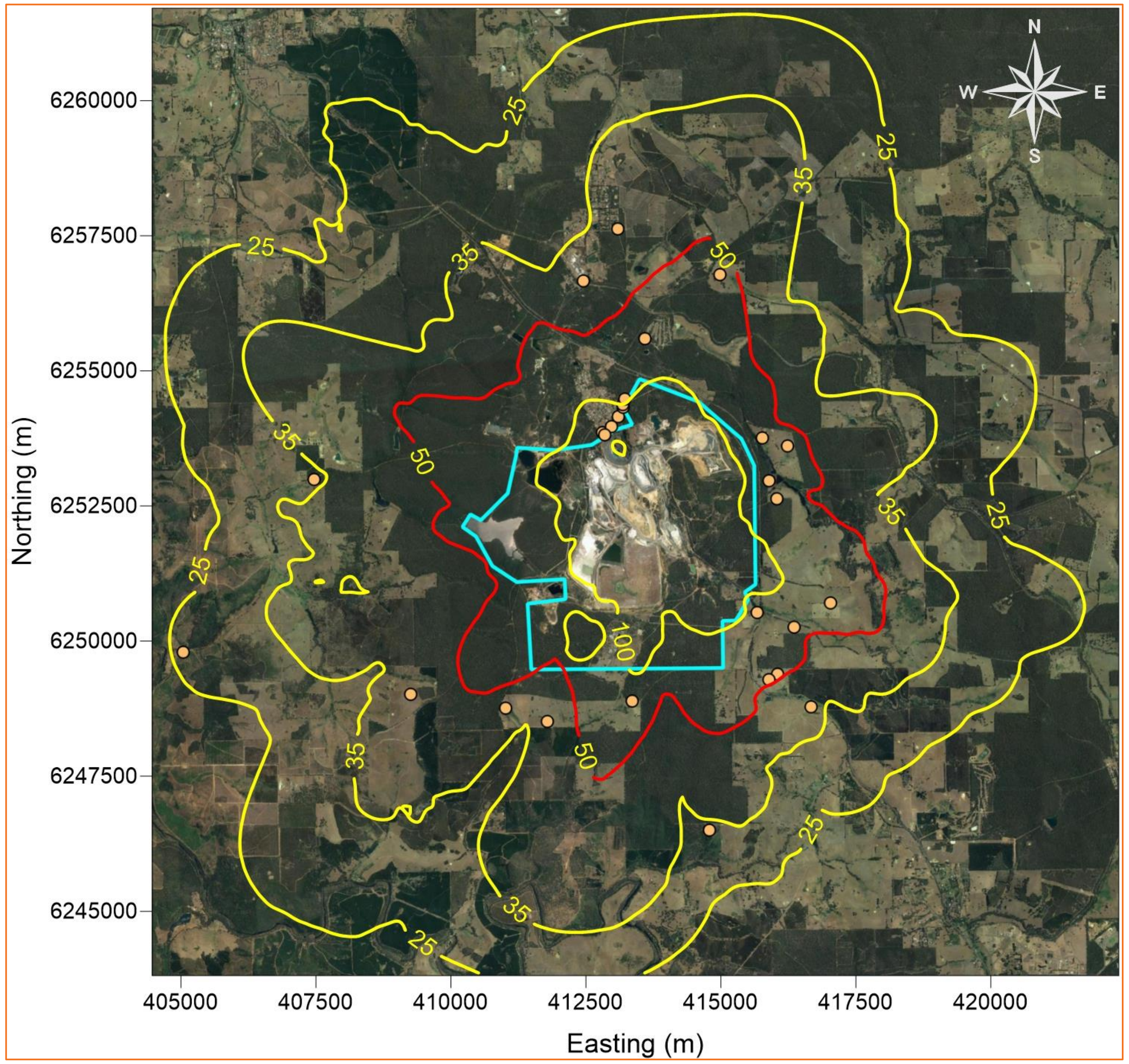

Figure 5-15: 2028 - Maximum 24-hour PM_{10} concentration – Project with background included.[13]

[12] Red contour corresponds to the relevant assessment criterion contour.

[13] Red contour corresponds to the relevant assessment criterion contour.

5.2.2 Particulates as $PM_{2.5}$

The statistics of the predicted ground level concentrations of $PM_{2.5}$, at all nominated receptors, are presented in Table 5-6 for both standalone impacts (Project only) and cumulatively (including background concentrations). The results at the nominated receptors for assessing impact indicate that:

- The predicted concentrations at Town A and B are predicted to be higher than the 24-hour average assessment criterion for $PM_{2.5}$ both with and without the inclusion of background concentration.
- The predicted annual average concentrations (with and without background) are below the $PM_{2.5}$ annual assessment criterion at the residential receptors.

The predicted isopleths (contours) for ground level concentrations of particulates (as $PM_{2.5}$) are presented as follows:

- Annual average $PM_{2.5}$ concentrations for the operations in isolation (Figure 5-16) and cumulatively with background concentrations (Figure 5-17).
- Maximum predicted 24-hour $PM_{2.5}$ concentrations for the operations in isolation (Figure 5-18) and cumulatively with background concentrations (Figure 5-19).

Table 5-6: 2028 Scenario 1 - Predicted $PM_{2.5}$ concentrations at receptors (µg/m³).

Receptor Type	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Residential (Greenbushes Town)	Town A	31	20	18	11	5	4	33	22	20	13	7	6.2
	Town B	31	18	18	10	5	4	33	21	20	12	7	5.8
	Town C	20	14	11	6	3	2	22	16	13	8	5	4.3
	Town D	13	12	9	4	2	2	15	14	11	6	4	3.7
	Town E	13	11	8	4	2	1	15	13	10	6	4	3.6
	Town F	12	10	7	3	1	1	14	13	9	6	3	3.4
Residential	A	8	5	4	2	1	1	10	7	6	4	3	2.7
	B	6	5	4	2	0	1	8	7	6	4	3	2.7
	C	6	4	4	2	0	1	8	6	6	4	3	2.6
	D	7	6	5	3	1	1	9	8	7	5	3	2.9
	E	7	5	5	3	1	1	9	8	7	5	3	2.9
	F	8	3	3	1	0	0	10	5	5	4	2	2.5
	G	6	5	3	1	0	0	8	7	5	4	2	2.5
	H	10	6	5	2	1	1	12	8	7	4	3	2.7
	I	6	3	3	1	0	0	8	5	5	3	2	2.4
	J	6	3	2	1	0	0	8	5	5	3	2	2.4
	K	7	3	3	1	0	0	9	5	5	3	2	2.4
	L	4	3	2	1	0	0	6	5	5	3	2	2.3
	M	4	3	2	1	0	0	7	5	4	3	2	2.3
	N	4	2	2	1	0	0	6	4	4	3	2	2.3

Receptor Type	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
	O	2	1	1	0	0	0	4	3	3	2	2	2.2
	P	3	2	2	1	0	0	5	4	4	3	2	2.3
	Q	4	3	2	1	0	0	6	5	4	3	2	2.5
	R	4	3	2	1	0	0	6	5	4	3	2	2.3
	S	6	3	2	1	0	0	8	5	4	3	2	2.4
	T	3	2	2	1	0	0	5	4	4	3	2	2.3
	U	3	1	1	0	0	0	5	4	3	2	2	2.2
	V	3	1	1	0	0	0	5	4	3	2	2	2.2
Assessment Criteria [1]		**23**					**7**	**23**					**7**

Note:

Shading indicates model result above the assessment criterion.

[1] AGV (DWER, 2019) specified at 25ºC.

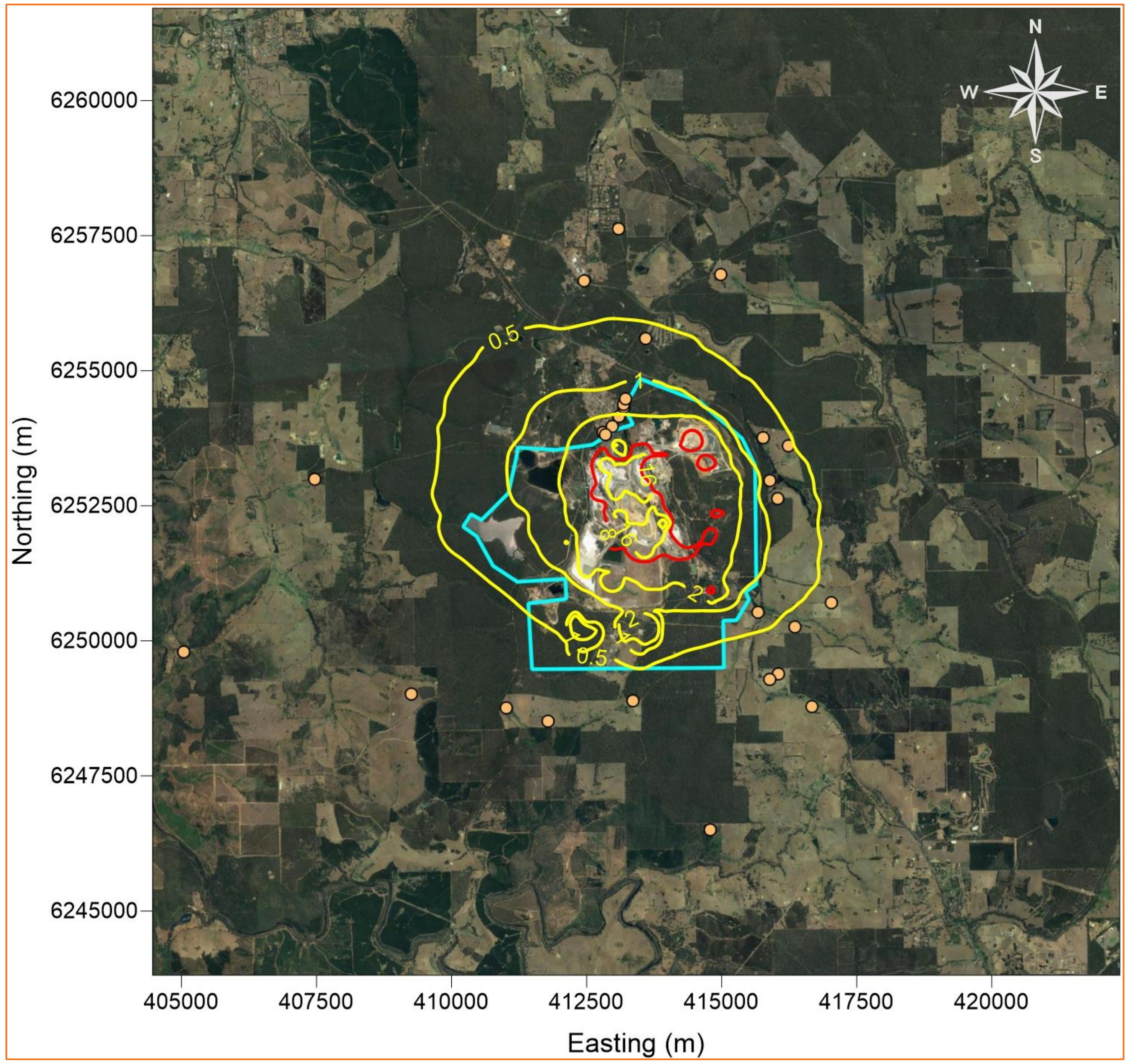

Figure 5-16: 2028 – Annual average $PM_{2.5}$ concentration – Project only.[14]

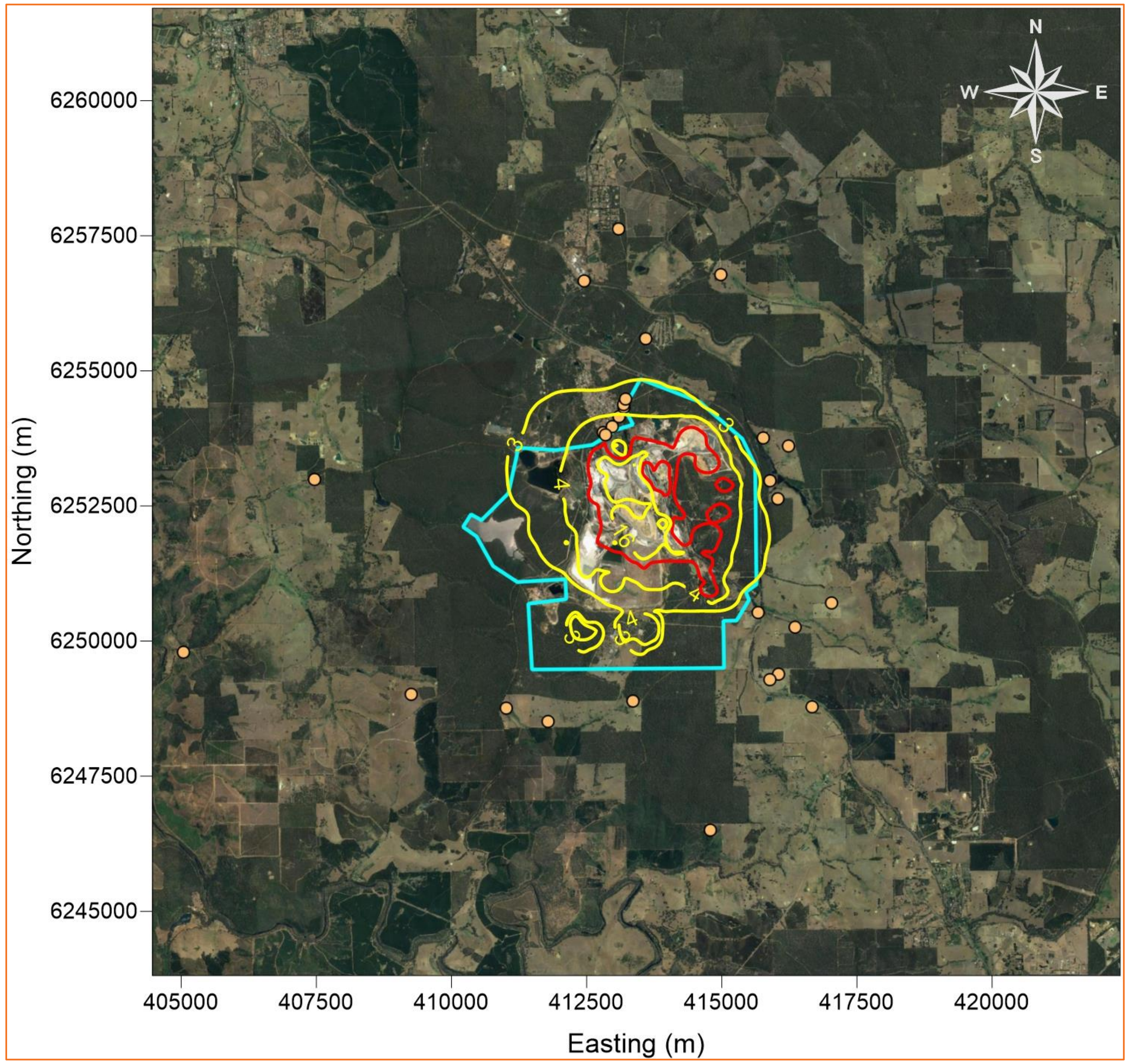

Figure 5-17: 2028 - Annual average $PM_{2.5}$ concentration – Project with background included.[15]

[14] Red contour corresponds to the relevant assessment criterion contour.

[15] Red contour corresponds to the relevant assessment criterion contour.

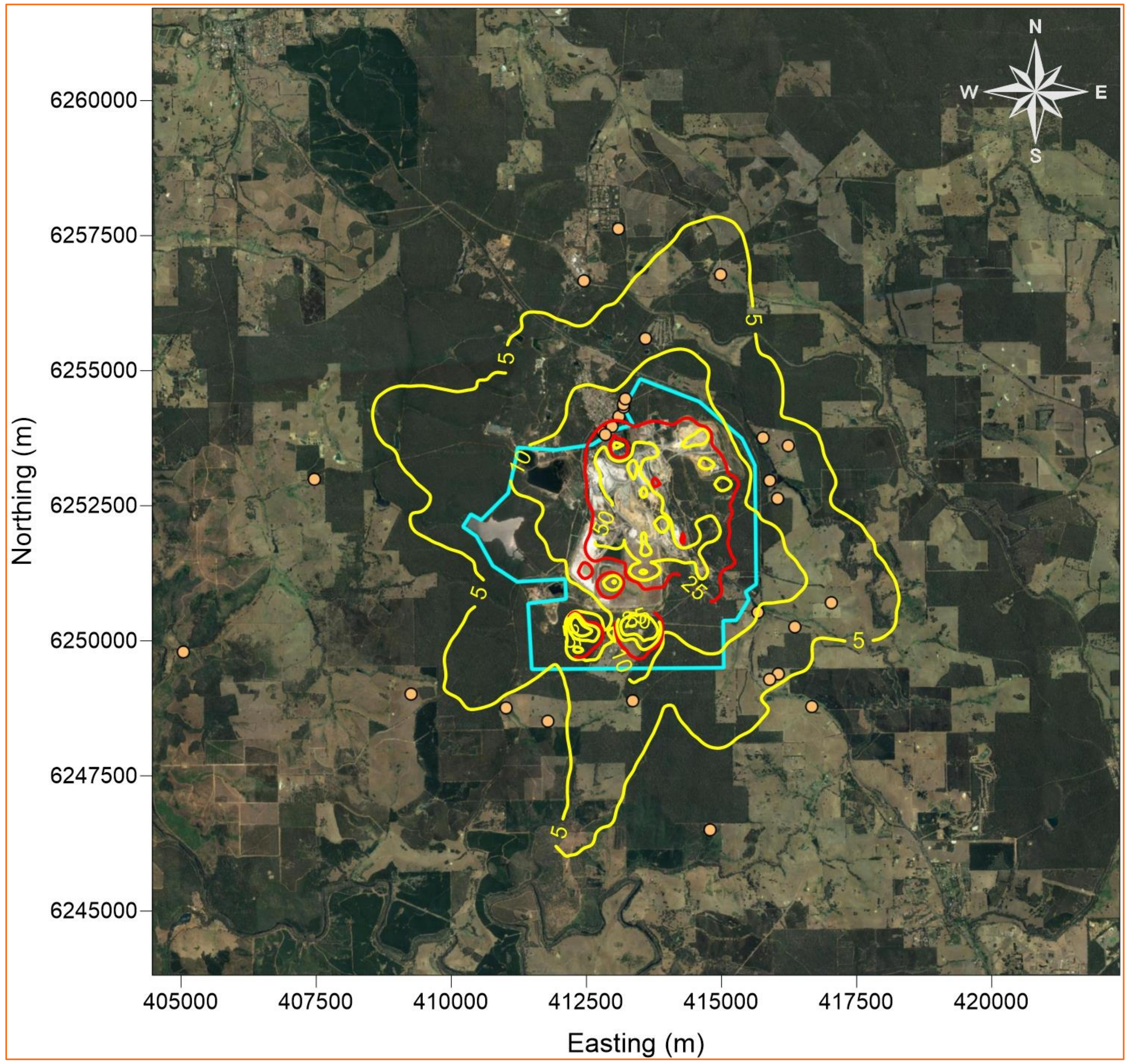

Figure 5-18: 2028 – Maximum 24-hour $PM_{2.5}$ concentration – Project only.[16]

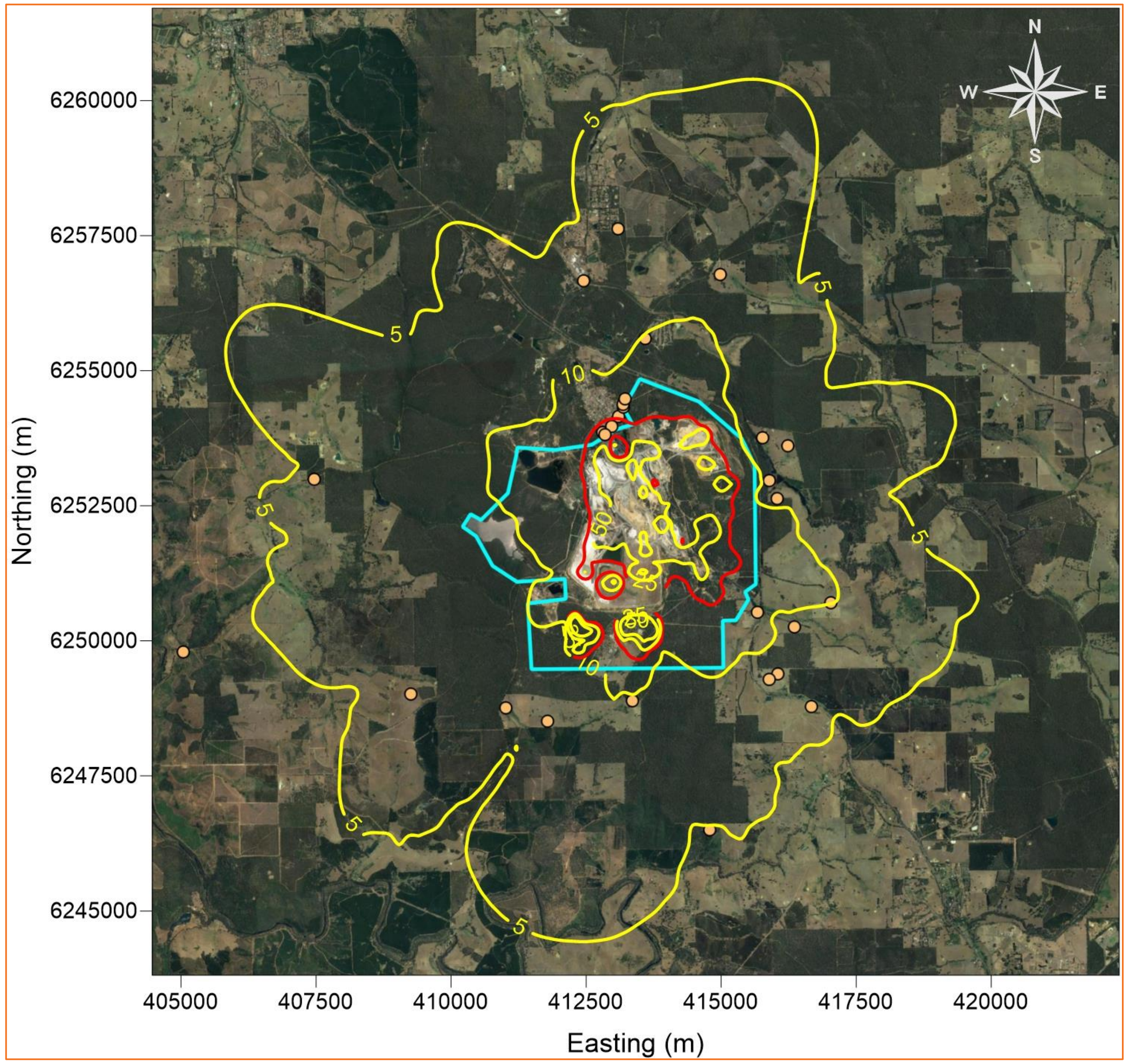

Figure 5-19: 2028 – Maximum 24-hour $PM_{2.5}$ concentration – Project with background included.[17]

[16] Red contour corresponds to the relevant assessment criterion contour.

[17] Red contour corresponds to the relevant assessment criterion contour.

5.2.3 Total Suspended Particulates

The statistics of the predicted ground level concentrations of TSP at all the nominated receptors are presented in Table 5-7 as standalone impacts (Project only) and cumulatively (including background concentrations). The results at these selected receptors indicate that:

- The predicted concentration at all Town and Receptor H are predicted to be higher than the 24-hour average assessment criterion for TSP without the inclusion of background concentration.
- Modelled results higher than the assessment criteria should be interpreted as an indication that results may need further consideration for the sensitive receptor, and is not necessarily a predicted impact or loss of environmental value.

The maximum predicted 24-hour ground level concentrations of TSP concentrations for the mining operations are presented in Figure 5-20. (standalone) and cumulatively with background concentrations in Figure 5-21.

Table 5-7: 2028 Scenario 1 - Predicted TSP concentrations at receptors (µg/m^3).

Receptor Type	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
Residential (Greenbushes Town)	Town A	276	191	174	103	57	41.4	304	219	202	130	84	69.0
	Town B	284	188	169	100	51	38.3	312	216	196	128	79	65.9
	Town C	176	123	106	59	27	21.8	203	151	134	87	54	49.4
	Town D	118	102	84	42	18	15.6	146	129	112	69	46	43.2
	Town E	110	96	78	38	17	14.5	138	123	106	66	45	42.1
	Town F	98	90	68	33	15	12.9	126	117	96	61	43	40.5
Residential	A	65	39	37	17	5	5.6	92	67	64	44	33	33.2
	B	62	46	37	22	5	6.4	89	73	64	49	33	34.0
	C	55	35	31	18	4	5.1	83	62	59	45	32	32.7
	D	73	51	46	27	8	8.2	100	79	74	54	36	35.8
	E	68	52	44	25	8	7.7	95	80	72	53	36	35.3
	F	66	29	24	11	2	3.6	93	57	52	39	30	31.2
	G	56	40	26	13	3	4.0	84	68	54	41	30	31.6
	H	97	56	46	19	5	6.0	124	84	73	46	33	33.6
	I	56	27	20	8	1	2.5	83	54	48	35	29	30.1
	J	55	28	17	8	1	2.4	82	55	45	35	29	30.0
	K	67	24	20	8	1	2.7	94	52	48	36	29	30.3
	L	26	20	18	6	0	1.7	54	48	45	33	28	29.3
	M	30	19	15	5	1	1.7	58	46	43	33	28	29.3

Receptor Type	Receptor ID	Standalone						Cumulative					
		Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average	Maximum	6th Highest	10th Highest	90th Percentile	70th Percentile	Average
	N	28	12	10	4	0	1.3	56	40	38	32	28	28.9
	O	10	5	4	2	0	0.5	38	32	32	29	28	28.1
	P	22	12	11	6	1	1.6	50	40	38	33	29	29.2
	Q	30	25	19	9	3	3.0	58	52	47	37	31	30.6
	R	26	16	15	6	2	2.0	54	44	42	34	29	29.6
	S	42	20	15	7	2	2.2	70	47	43	35	29	29.8
	T	29	16	13	5	1	1.6	57	44	40	32	28	29.2
	U	17	8	7	2	0	0.8	45	36	35	30	28	28.4
	V	17	8	7	2	0	0.8	45	36	35	30	28	28.4
Assessment Criteria		**82**						**82**					

Note:

Shading indicates model result above the assessment criterion.

[1] AGV (DWER, 2019) specified at 25ºC.

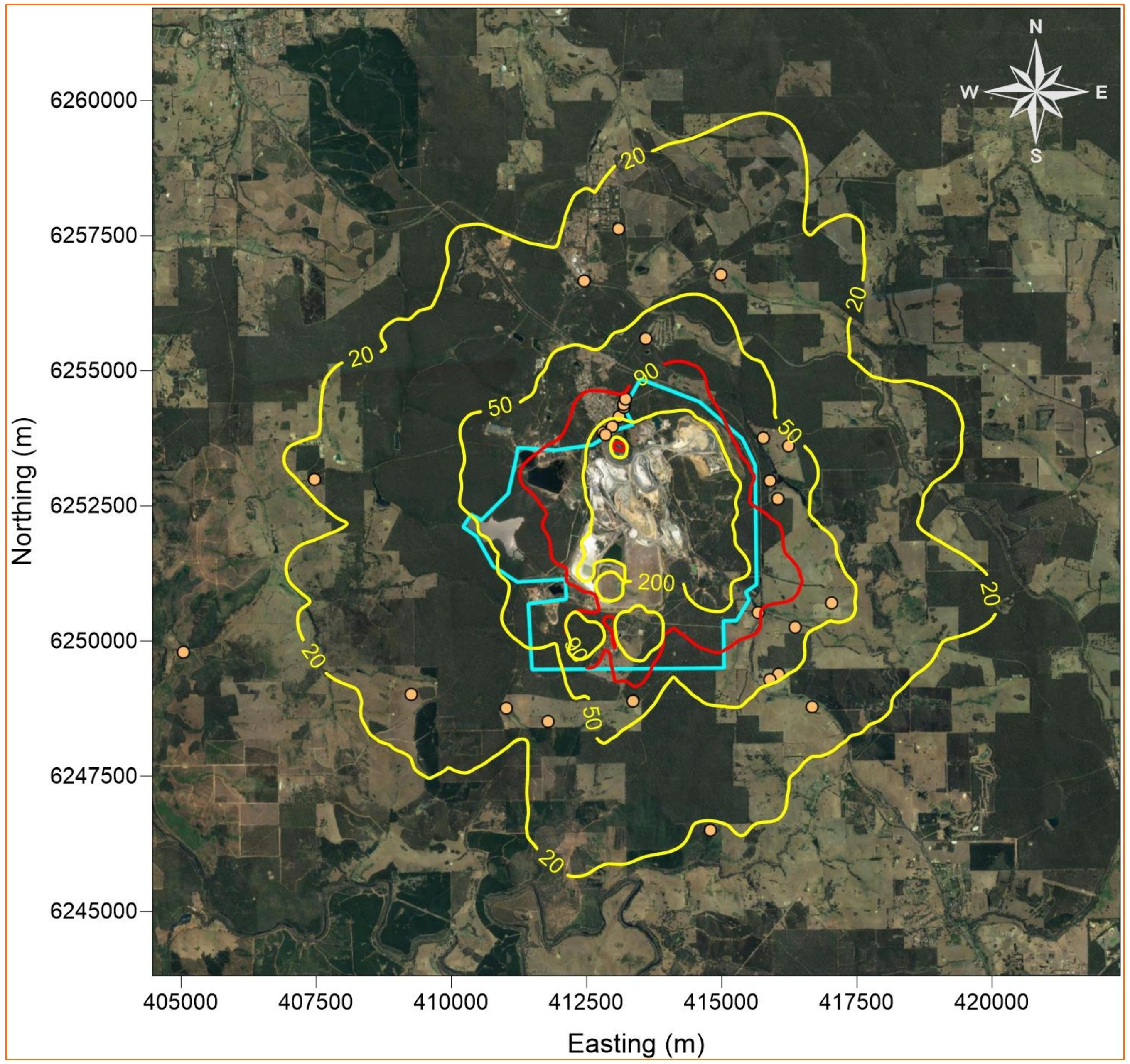

Figure 5-20: 2028 – Maximum 24-hour TSP concentration – Project only.[18]

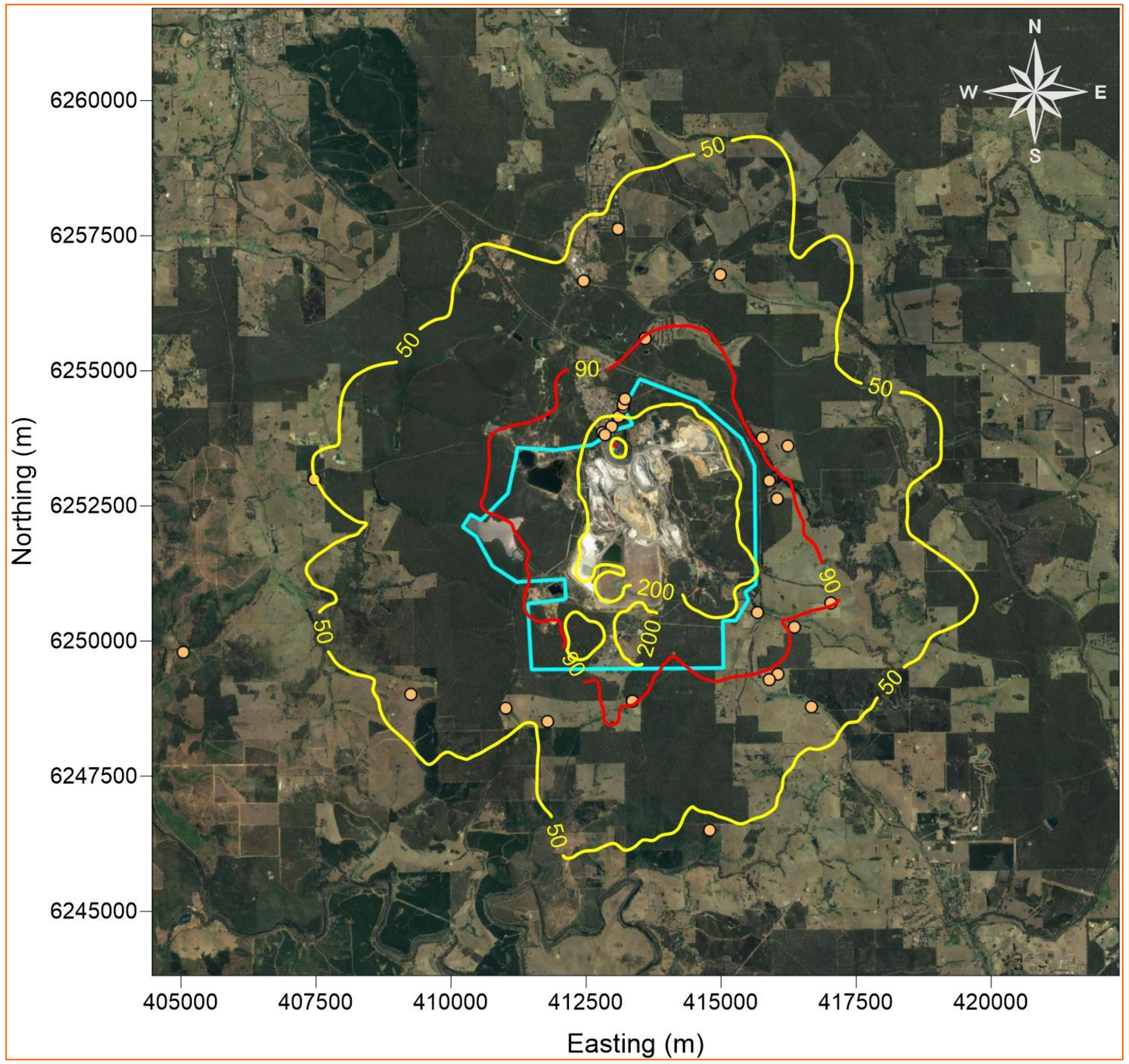

Figure 5-21: 2028 – Maximum 24-hour TSP concentration – Project with background included.[19]

[18] Red contour corresponds to the relevant assessment criterion contour.

[19] Red contour corresponds to the relevant assessment criterion contour.

5.2.4 Dust deposition

The modelling predicts that the deposition rates will just exceed the maximum increase above background criteria of 2 g/m^2/month two of the identified Greenbushes township receptors (Table 5-8).

Table 5-8: 2028 Scenario 1 - Predicted dust deposition at receptors – in isolation (g/m^2/month).

Receptor Type	Receptor ID	Maximum	Receptor Type	Receptor ID	Maximum
Residential (Greenbushes Town)	Town A	2.1	Residential	I	0.1
	Town B	2		J	0.1
	Town C	1.7		K	0.3
	Town D	1.3		L	0.1
	Town E	1.3		M	0.1
	Town F	1.1		N	0
Residential	A	0.4		O	0
	B	0.4		P	0.1
	C	0.3		Q	0.2
	D	0.6		R	0.1
	E	0.5		S	0.1
	F	0.1		T	0.1
	G	0.2		U	0
	H	0.4		V	0
Assessment Criteria		**2 g/m^2/month**	**Assessment Criteria**		**2 g/m^2/month**

Note:
Shading indicates result above the assessment criterion.

The predicted monthly dust deposition (based on annual average predicted flux rates) is presented in Figure 5-22. The contour plot shows that monthly deposition is largely limited to within the site boundary although it does extend across parts of Greenbushes township to the north.

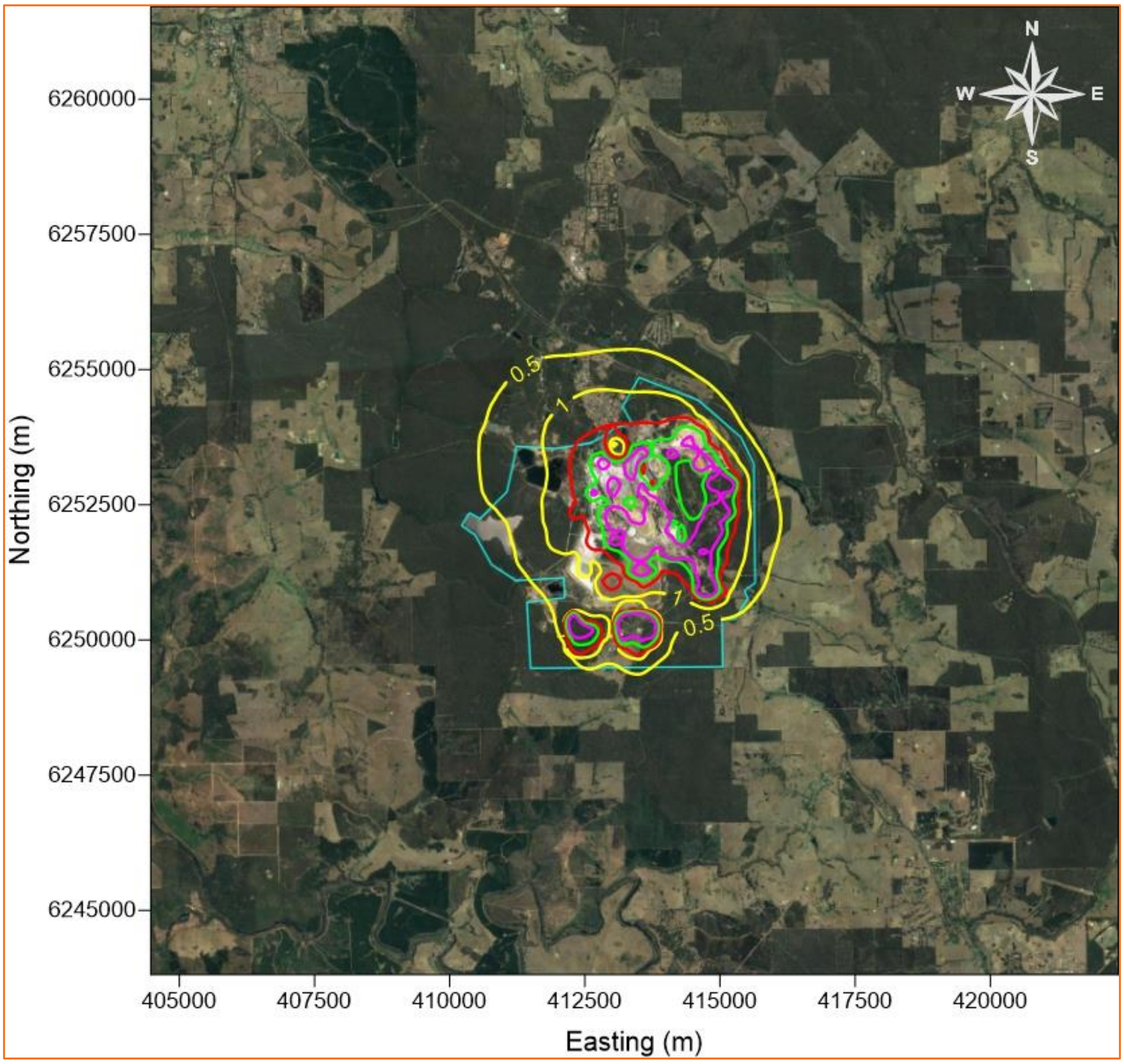

Figure 5-22: 2028 - Total predicted monthly dust deposition (g/m²/month) – Project only. [20]

[20] Red contour corresponds to the 2g/m²/month assessment criterion contour, and Purple contour corresponds to the 4g/m²/month assessment criterion contour.

6 Conclusions

In response to market demand Talison is expanding the GBO from a beneficiation rate of 12.5 Mtpa up to 9.1 Mtpa. This expansion includes increasing mining of spodumene and the development of:

- Two new Crushers – Crusher 3 (Cr3) and Crusher 4 (Cr4)
- Two new Process Plants – Chemical Grade Plant #3 (CGP3) and Chemical Grade Plant #4 (CGP4)
- Three new Ore Sorters – Ore Sorter 2, Ore Sorter 3, Ore Sorter 4
- Mining up to 27.3 Mtpa of waste rock and ore
- Beneficiation of up to 12.5 Mtpa of ore
- Storage of up to 15.6 Mtpa of waste rock in Floyds Waste Rock Landform (WRL).

This modelling assessment determined the potential air quality impacts of particulates (as TSP, PM_{10}, $PM_{2.5}$ and deposition) using the CALMET/CAPUFF modelling suite for determining predicted ground level concentrations for the existing facility (Base scenario) and for the 2028 expansion (Scenario 1). Modelling assessed the project in isolation, as well as cumulatively with background air quality. The 3-dimensional meteorological fields required by CALMET were generated using the WRF prognostic meteorological model. Fine resolution terrain elevation (SRTM) data with 90 m resolution was used in conjunction with CGLOPS-1 land-use data to characterise the geophysical environment.

Emissions were estimated using methodologies outlined in the NPI EET for Mining manual (EA, 2012) and input into the CALPUFF dispersion model as volume sources to simulate mining and haulage emissions, and area sources to simulate wind-blown dust emissions.

Modelled ground level concentrations for the key pollutants as particulates (as TSP, PM_{10}, $PM_{2.5}$ and dust deposition) have been compared to ambient air quality assessment criteria, derived from the draft DWER Air Emissions Guideline (DWER, 2019) and the draft Dust Emissions Guideline (DWER, 2021) to determine the potential impacts to environmental values. Receptor types considered in the assessment include residences (where the protection of human health, well-being and amenity is considered), and environmental receptors (primarily flora).

6.1 Modelling results – comparison to air quality assessment criteria

For the assessment of potential impacts on human health and amenity, and nuisance the model predicts that:

- For PM_{10}:
  - Base Case:
    - The predicted concentration is higher than the 24-hour criterion at all the Greenbushes township receptors in isolation.
    - The remaining residential receptors are within the 24-hour criterion.
    - The predicted annual average concentrations (with and without background) are within annual assessment criterion at all the residential receptors.
  - Scenario 1:
    - The predicted concentration is higher than the 24-hour criterion at –
      - 9 residential receptors in isolation
      - 18 receptors with background concentration included.
    - The predicted annual average concentration is higher than the assessment criterion at Town receptor A with GBO in isolation and at 3 town receptors when background concentration is included.

- For $PM_{2.5}$:
  - Base Case:
    - The predicted concentration at all the residential receptors is below the 24-hour average assessment criterion both with and without the inclusion of background concentration.
    - The predicted annual average concentration (with and without background) is below the annual assessment criterion at all the residential receptors.
  - Scenario 1:
    - The predicted concentrations at Town A and Town B are higher than the 24-hour average assessment criterion both with and without the inclusion of background concentration.
    - The predicted annual average concentrations are below the assessment criterion at the residential receptors both with and without the inclusion of background concentration.
- For TSP:
  - Base Case:
    - The predicted concentration at all the Greenbushes Township receptors (Town A to Town F) are higher than the 24-hour average assessment criterion for TSP both with and without the inclusion of background concentration.
  - Scenario 1:
    - The predicted concentration at all Township receptors and receptor H are predicted to be higher than the 24-hour average assessment criterion for TSP without the inclusion of background concentration.
- For monthly deposition:
  - Deposition rates will not exceed the maximum increase above background criteria for the Base scenario.
  - Deposition rates are however predicted to be higher than the maximum increase above background criteria for both the Town A and Town B receptors.

The modelling indicates that the proposed GBO expansion (from 7.1 Mtpa up to 9.5 Mtpa) will result in more frequent occurrence of particulate concentrations that are elevated in comparison to the relevant air quality assessment criteria at residential receptors, most notably in the Greenbushes township. However it should be noted that the vegetated screen that is located between the GBO and the Town of Greenbushes (Section 2.3) will assist in alleviating the predicted ground level concentrations.

A conservative approach has been used for this modelling assessment, and the levels of pollutant concentrations are likely to be lower (when measured in the environment) than predicted in this study. It is important to note that, as a risk-based assessment approach is normally applied to the assessment of air quality, a modelled result above the numerical ambient guideline value or assessment criteria is not an indicator of unacceptable impact or loss of environmental value, but is an indication that the potential risk for impact requires further consideration, such as ongoing ambient monitoring.

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8 Acronyms and Glossary

Acronym	Description
AFWA	Air Force Weather Agency
BoM	Bureau of Meteorology
BWh	Koppen-Geiger classification - hot desert climate, with no distinct rainy season
C	Degrees Celsius (temperature)
Csb	Temperate, dry and warm summer
DSD	Department of State Development
DWER	Department of Water and Environmental Regulation
EA	Environment Australia
EE	Emissions estimation
EET	Emissions Estimation Technique
EETM	Emissions Estimation Technique Manual
EF	Emission factor
ETA	Environmental Technologies & Analytics Pty Ltd
FAA	Federal Aviation Administration
FSL	Forecast Systems Laboratory
GDA94	Geocentric Datum of Australia 1994
g/m^2/month	Grams per square metre per month
g/s	Grams per second
h/yr	Hours per year
kg	Kilogram
kg/ha/yr	Kilograms per hectare per year
kg/t	Kilogram per tonne
kg/yr	Kilograms per year
kPa	KiloPascals
km	Kilometre
km/h	Kilometres per hour
LSM	Land Surface Model
m	Metre

Acronym	Description
m^2	Metres squared
m/s	Metres per second
mm	Millimetre
MOST	Monin-Obukhov Similarity Theory
Mt	Million tonnes
Mtpa	Million tonnes per annum
NCAR	National Center for Environmental Prediction
NCEP	National Center for Environmental Prediction
NEPC	National Environment Protection Council
NEPM	National Environmental Protection Measure
NOAA	National Oceanic and Atmospheric Administration
NPI	National Pollutant Inventory
NSW	New South Wales, Australia
PBL	Planetary Boundary Layer
PM	Particulate matter, small particles and liquid droplets that can remain suspended in air.
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 µm or less.
PM_{10}	Particulate matter with an aerodynamic diameter of 10 µm or less.
ROM	Run of mine
SEA	Strategic Environmental Assessment
SRTM	Shuttle Radar Topography Mission
t	Tonnes
t/h	Tonnes per hour
tpa	Tonnes per annum
tph	Tonnes per hour

Acronym	Description
TS	Transfer station
TSP	Total suspended particulates
µg/m^3	Micro grams (one millionth of a gram) per cubic metre
µm	Micrometre
USEPA	United States Environment Protection Agency

Acronym	Description
USGS	United State Geological Services
WA	Western Australia, Australia
WHO	World Health Organisation
WRF	Weather Research & Forecast Model
>	Greater than value
<	Less than value

9 Appendices

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Appendix A – Selection of Representative Meteorological Year for Modelling

This Appendix summarises the analysis undertaken to determine a representative modelling year, based on the review of long term measured data from the nearest BoM climate station at Bridgetown (2012 to 2022 inclusive).

A.1: Selection of Representative Meteorological Year for Modelling

For this assessment, air dispersion modelling has been conducted using the CALMET/CALPUFF suite of models with meteorological data produced from the WRF prognostic model. The CALMET meteorological model has been used to develop the required meteorological inputs, and the CALPUFF model has been used to predict the concentrations at ground-level across the model domain and at nominated discrete sensitive receptor locations. Meteorological measurements representative of the region has been used to verify and refine the meteorological inputs for the modelling.

Generally, a minimum of one year of meteorological data is acceptable for dispersion modelling in Australia. The data must, however, adequately represent worst-case meteorological conditions and the data should be assessed in terms of representativeness against climatic averages. In other words, the meteorology for selected years must be deemed representative of the "normal" range of conditions in the area.

To determine the year of meteorological data to use for the dispersion modelling, 11-years of historical hourly [21] surface observations from the nearest BoM station at Bridgetown (2012 to 2022 inclusive) were reviewed. The Chi^2 Goodness of Fit test was used to statistically identify the representative modelling year based on recorded meteorological parameters including wind speed, wind direction, temperature, and rainfall.

The statistical analysis shows that 2019 can be considered largely representative of longer-term average conditions. The meteorological variables affecting dispersion, namely wind speed, temperature and direction compare favourably to the long-term average conditions.

The results of the statistical analysis performed to support selection of the representative year is described in the following sub-sections.

Chi^2 Goodness of Fit test

The Chi^2 goodness of fit test was used to statistically identify the representative modelling year based on recorded meteorological parameters including wind speed, wind direction and temperature. The Chi^2 goodness of fit test is a non-parametric hypothesis test used to determine whether a variable is likely to come from a specified distribution or not. It is often used to evaluate whether sample data (in this case, an individual year) is representative of the full population (e.g. multiple years).

The null hypothesis is that there is no significant difference between hourly values in an individual year and the hourly averages for long term average values. If values fall within the vertical lines (at 5% confidence interval, two tailed), then accept the null hypothesis (Appendix Figure 1).

[21] Calculated from 1-minute data.

Wind Direction

The Chi^2 test results for wind direction for 2012 to 2022 at BoM Bridgetown are compared in Appendix Figure 2. From this figure it is apparent that the wind direction frequency distribution during 2016, 2017, 2018 and 2019 were not significantly different to the long-term wind direction frequency distribution.

Wind Speed

The basic statistics for average wind speed for the 8-year period and individual years are shown in Appendix Table 1. Overall, there is minimal difference between the chosen years though the average and standard deviations during 2021 are closest to long term averages. The frequency of stronger (>20 km/h and lighter (<5 km/h) winds during most years are generally within 1% of long-term average values.

Appendix Table 1: Annual wind speed statistics for Bridgetown (2012-2022).

Year	Mean	Standard Deviation	% <5 hm/h	% >20 km/h
11-yr average	6.3	5.4	44.1	0.8
2012	6.2	5.6	46.7	1.2
2013	6.6	5.6	42.3	1.3
2014	6.4	5.4	43.5	0.9
2015	6.2	5.3	45.4	0.0
2016	6.6	5.4	42.2	1.0
2017	6.3	5.2	43.3	0.9
2018	6.3	5.3	43.7	0.7
2019	6.0	5.3	45.8	0.8
2020	6.5	5.6	43.2	1.1
2021	6.3	5.4	44.6	0.6
2022	6.4	5.2	43.8	0.4

The Chi^2 test results for wind speed are presented in Appendix Figure 3. This figure indicates that 2014 to 2016 and 2019 to 2021 were representative of 11-year average conditions at the 5% confidence interval.

Temperature

The basic statistics for average temperature for the 11-year period and individual years are shown in Appendix Table 2. The average temperature for the years 2012 to 2022 are all within 0.5°C of the 1-year average.

Appendix Table 2: Annual temperature statistics for Busselton Aerodrome (2014-2021).

Year	Mean	Standard Deviation	% <5°C	% >35°C
11-yr average	15.0	6.7	5.6	0.5
2012	15.1	7.1	7.1	0.9
2013	15.4	6.6	4.5	0.4
2014	15.3	6.4	4.3	0.3
2015	15.3	7.1	6.8	0.0
2016	14.5	6.9	6.8	0.5
2017	14.6	6.6	5.9	0.4
2018	14.7	6.6	6.6	0.1
2019	15.0	7.1	6.9	0.8
2020	15.2	6.5	4.2	0.3
2021	14.8	6.6	4.6	0.5
2022	15.0	6.7	4.4	0.8

The Chi^{2}test results for temperature are presented in Appendix Figure 4. From this figure it is apparent that the hourly temperature frequency distributions during 2012 to 2022 were not significantly different to the long-term frequency distribution.

Rainfall

The annual rainfall at Busselton, available for the extended period 1993-2022, is displayed in Appendix Figure 5, noting that there is incomplete data for 2008, 2009 and 2012. There is some variation in rainfall between each year which is to be expected for the region. Post 2010, the years 2015 and 2019 have annual rainfall that just fall outside the 10th and 90th percentile [22] long-term (30 year) rainfall totals.

Conclusions

It is important to note that it is highly unusual for multiple climatological parameters to all fall within "representative" levels. With that in mind, the following conclusions can be made for the period reviewed:

- All years are representative of longer-term (11 year) temperature average frequency distribution at the 99% significance level.
- 2014, 2015, 2016, 2019,2020 and 2021 are representative of longer-term wind speed average frequency distribution at the 99% significance level.

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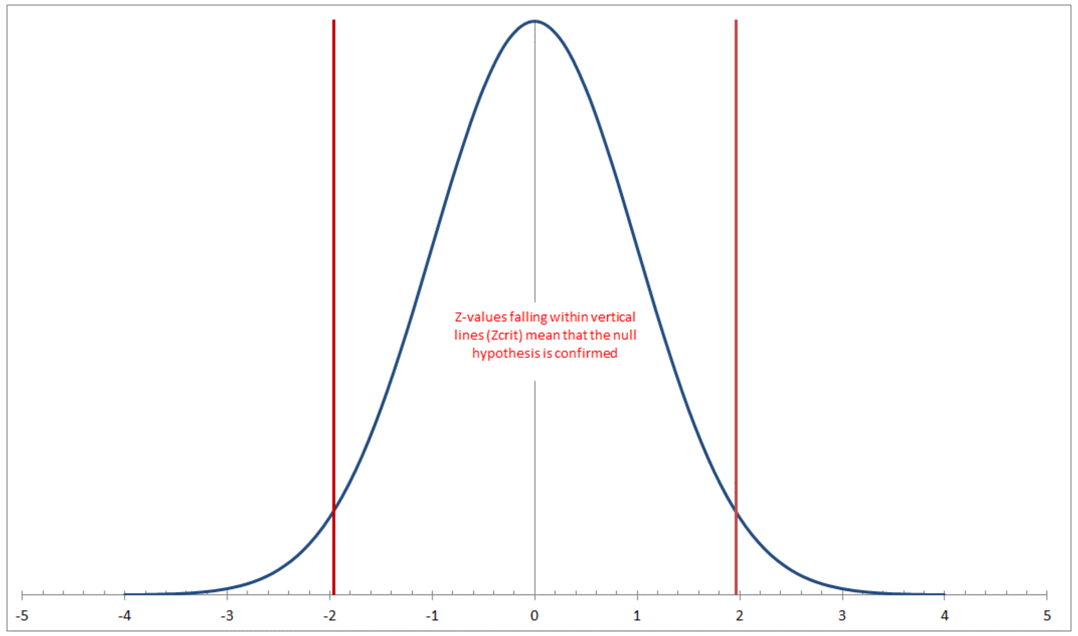
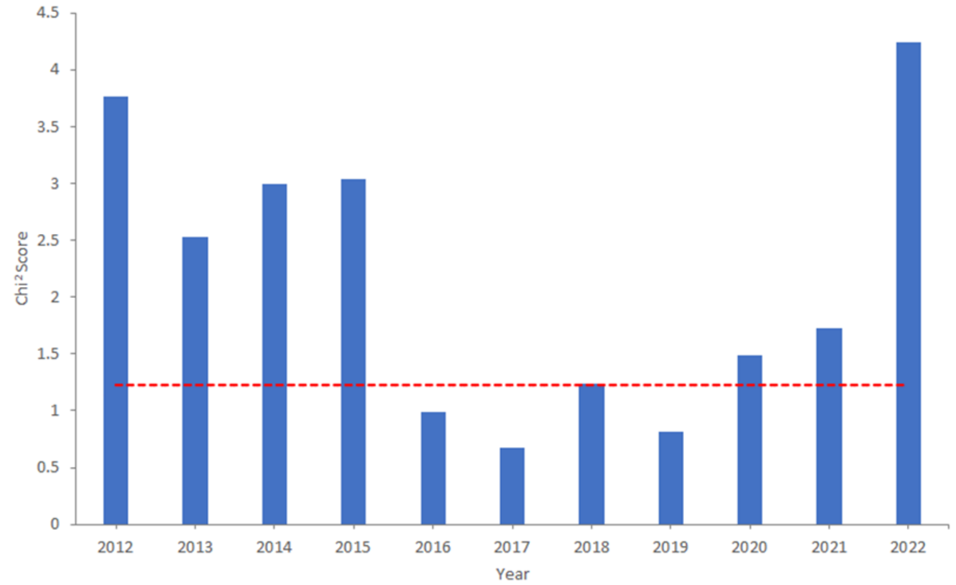
[22] The 10th and 90th percentile values are classed as well below and well above average according to the Bureau of Meteorology

- For wind direction, frequency distributions during 2016, 2017, 2018 and 2019 are representative of longer-term direction frequency distributions at the 99% significance level.
- For annual rainfall at Greenbushes, all years (post 2010) except 2010, 2015 and 2019 fall within the longer-term 10th and 90th percentile values.

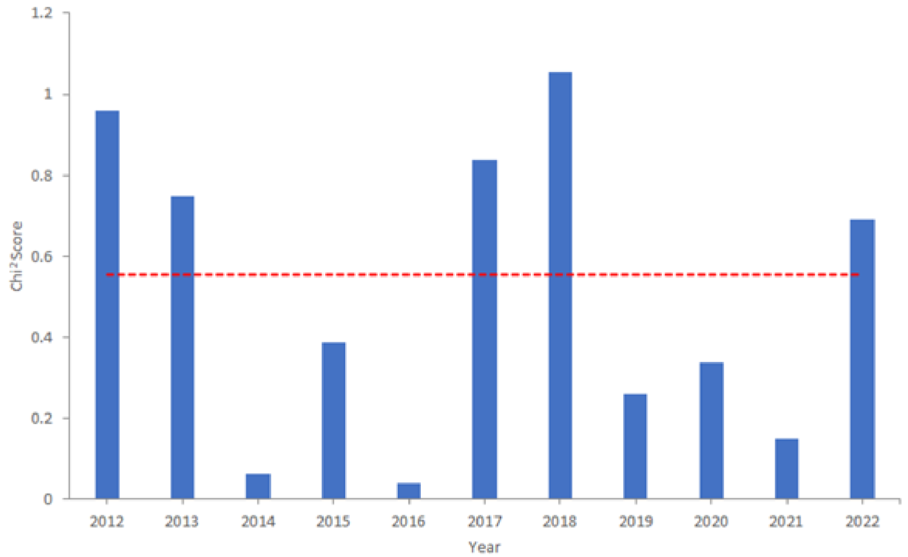
Based on the above analysis, only 2016 is representative of longer-term conditions for all parameters examined. While 2019 is representative for temperature, wind speed and wind direction, it was a statistically anomalously dry year. It was however decided to use the more recent 2019 as the modelling year as the meteorological variables affecting dispersion, namely wind speed, wind direction, temperature, compare favourably to the long-term average conditions. The slightly drier conditions will produce marginally more conservative dust emissions.



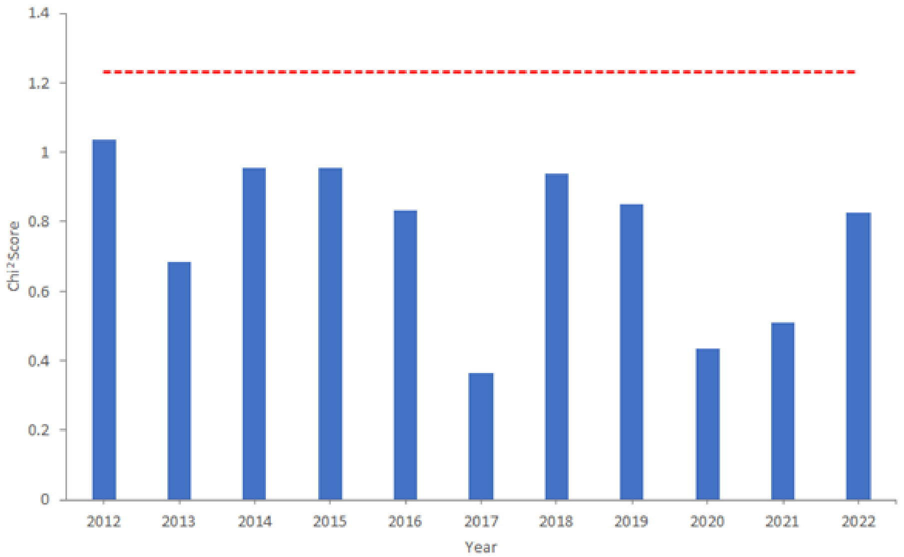
Appendix Figure 1: Null Hypothesis for Chi² test.



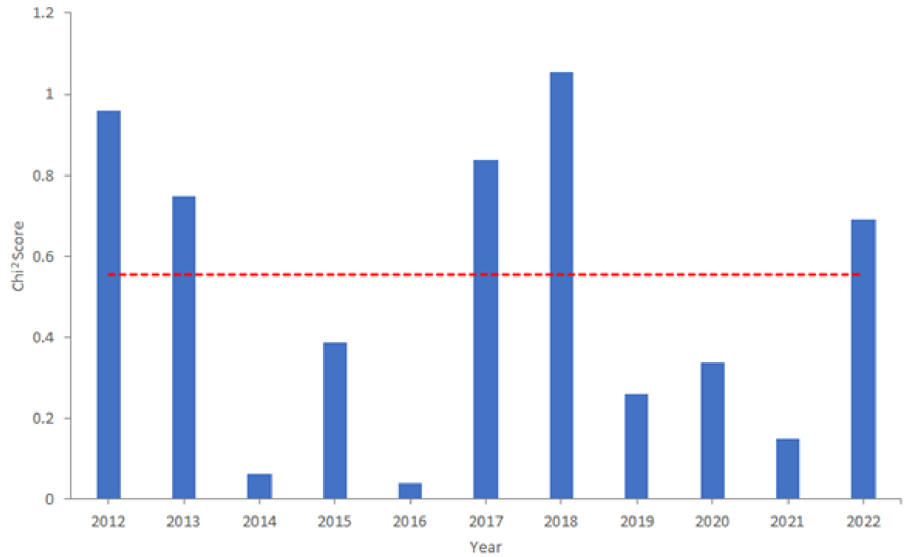
Appendix Figure 2: Chi² test result for wind direction at Bridgetown (2012-2022).



Appendix Figure 3: Chi² test result for wind speed at Bridgetown (2012-2022).



Appendix Figure 4: Chi² test result for temperature at Bridgetown (2012-2022).



Appendix Figure 5: Chi² test result for wind speed at Bridgetown (2012-2022).

Appendix B – Weather Research and Forecast (WRF) Model Configuration and Validation

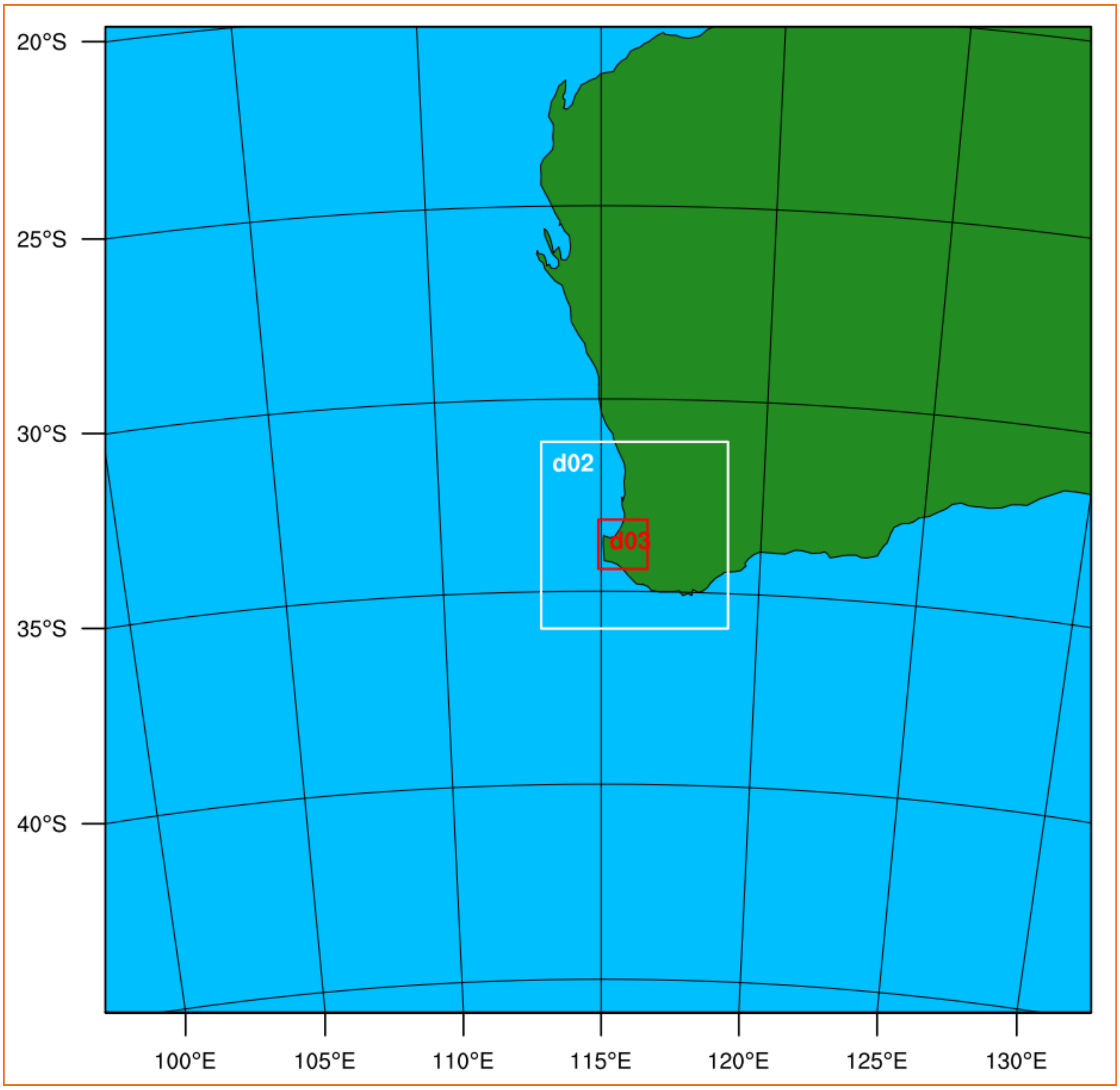
WRF was developed (and continues to be developed) in the United States by a collaborative partnership including the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (the National Center for Environmental Prediction (NCEP), the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, the Federal Aviation Administration (FAA) and others.

WRF is a fully compressible, Eulerian, non-hydrostatic meso-scale numerical model developed by the National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration (NOAA) in the United States. WRF is suitable for a broad spectrum of applications across scales ranging from metres to thousands of kilometres. The model utilises global reanalysis[23] data to produce fine-scale 3-dimensional meteorological fields that considers local terrain and land-use effects.

WRF was run with a three-nest structure (30 km, 7.5 km, and 1.9 km horizontal grid space resolution) centred on 33.86319°S and 116.0635°E. This is shown in Appendix Figure 6. The model vertical resolution consists of 50 hybrid-eta levels[24].

Physics options in WRF are to represent atmospheric radiation, surface, and boundary layer as well as cloud and precipitation processes. WRF can be run with a variety of model physics options which can lead to varying results and hence it is crucial for the most appropriate model setup for a particular purpose over a given region/domain. The physics options selected for the modelling are based on the results of a sensitivity study undertaken over southwestern Western Australia, where simulations of 14 combinations of land surface model, longwave radiation scheme, shortwave radiation scheme, cumulus scheme, planetary boundary layer scheme, surface layer scheme and microphysics schemes were compared to observations (Kala et. al., 2015). The combination of physics options found to produce the most accurate results, were used in this study, and are summarised in Appendix Table 3.

[23] Global modelling using observed climate data for temperature, wind speed, and pressure. The observations are analysed; interpolated onto a system of grids and the model initialised with this data.
[24] Terrain-following close to the earth's surface and pressure levels higher in the atmosphere.



Appendix Figure 6: Three nest structure, WRF model.

Appendix Table 3: WRF Physics Options Selected for Model.

	Domain 1	Domain 2	Domain 3	Explanatory Notes
mp_physics	4	4	4	WRF Single–moment 5–class Scheme
ra_lw_physics	1	1	1	Rapid radiative transfer model scheme
ra_sw_physics	1	1	1	Dudhia scheme for cloud and clear sky absorption and scattering
Radt	10	10	10	Time step for radiation schemes
sf_sfclay_physics	1	1	1	MM5 based on MOST
sf_surface_physics	2	2	2	Noah land surface model with 6 soil layers
bl_pbl_physics	1	1	1	Non-local K-scheme with entrainment layer
bldt	0	0	0	Boundary layer time step (0=every time step)
cu_physics	1	1	0	Kain-Fritch scheme using mass flux approach for domain 1 only.
cudt	5	5	5	Cumulus physics time step (minutes)

Six-hourly global final analysis[25] synoptic data (from http://nomads.ncdc.noaa.gov/data/gfsanl/) was used to initialise the model and provide boundary conditions.

Land-use and terrain data was sourced from the United State Geological Services (USGS) database. Inspection of the land-use indicates an acceptable resolution and category for the model area with shrub land being the dominant vegetation type.

The selection of an appropriate Land Surface Model (LSM) is critically important to provide the boundary conditions at the land-atmosphere interface because:

- The Planetary Boundary Layer (PBL) schemes are sensitive to surface fluxes.
- The cloud/cumulus schemes are sensitive to the PBL structures.
- There is a need to capture mesoscale circulations forced by surface variability in albedo, soil moisture/temperature and land use.

The Noah Land-Surface Model was selected in this case to account for the sub-grid-scale fluxes. This sophisticated scheme provides 4 quantities to the parent atmospheric model (WRF), namely:

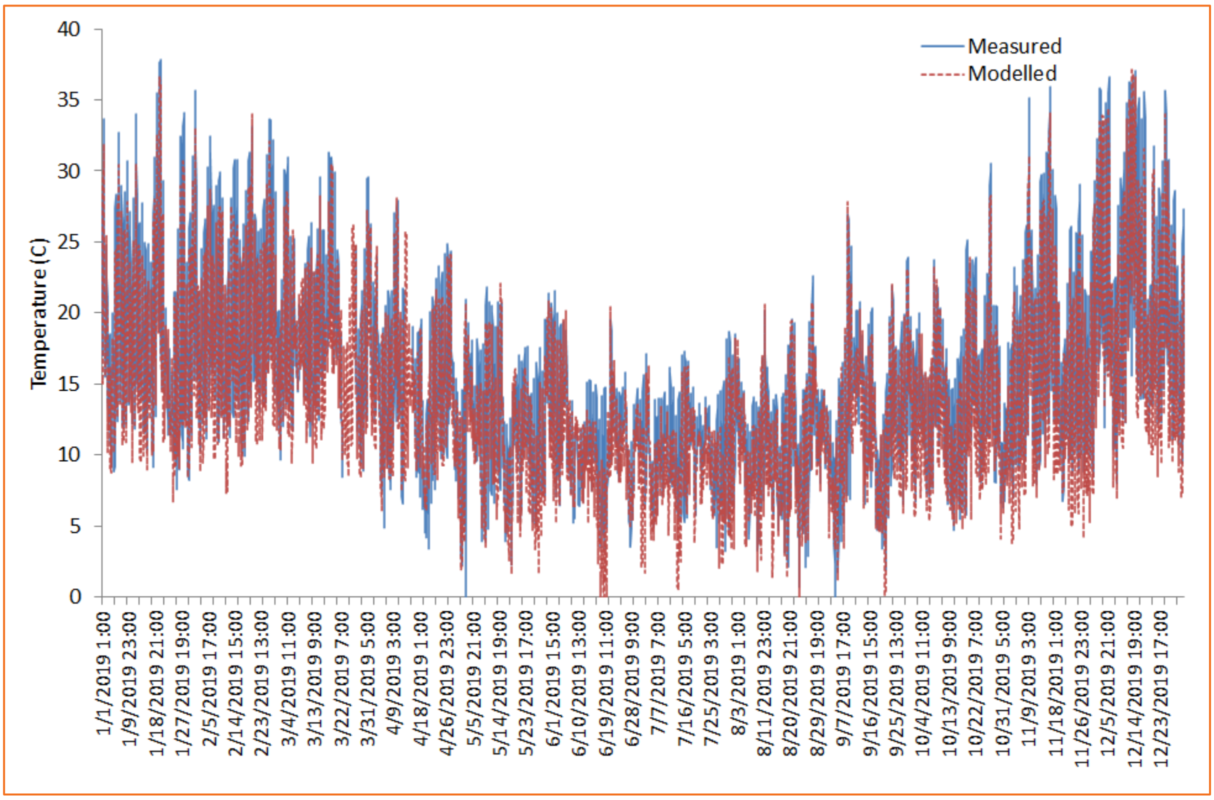
- surface sensible heat flux
- surface latent heat flux
- upward longwave radiation, and
- upward (reflected) shortwave radiation.

[25] Final analysis data is global modelled data that has been retrospectively corrected using surface, upper air and satellite measurements.

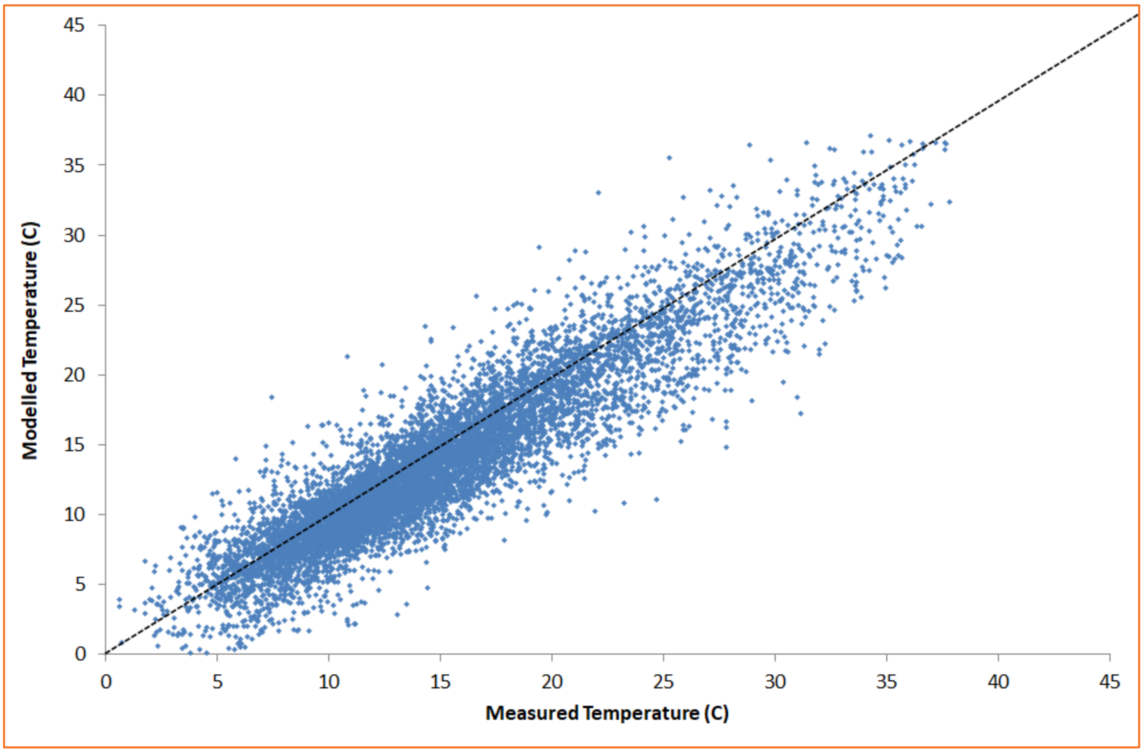
Model Validation

The accuracy of the meteorology generated by WRF was assessed by comparing model output against corresponding measurement data at the Talison weather station located at 413499 m East and 6251894m N. At an initial level of validation, the model output is visually compared against measured temperature, wind speed and wind direction.

The hourly temperature comparison between modelled and measured is shown in Appendix Figure 7. The model reflects the daily and seasonal trends, as well as maxima generally well. However, maximum temperatures are slightly overpredicted. This is not surprising given that the temperature measurement height is 6 m while the modelled height is 10 m. The scatterplot in Appendix Figure 8 shows good correspondence between modelled and measured values, although model underprediction at higher temperatures is evident.

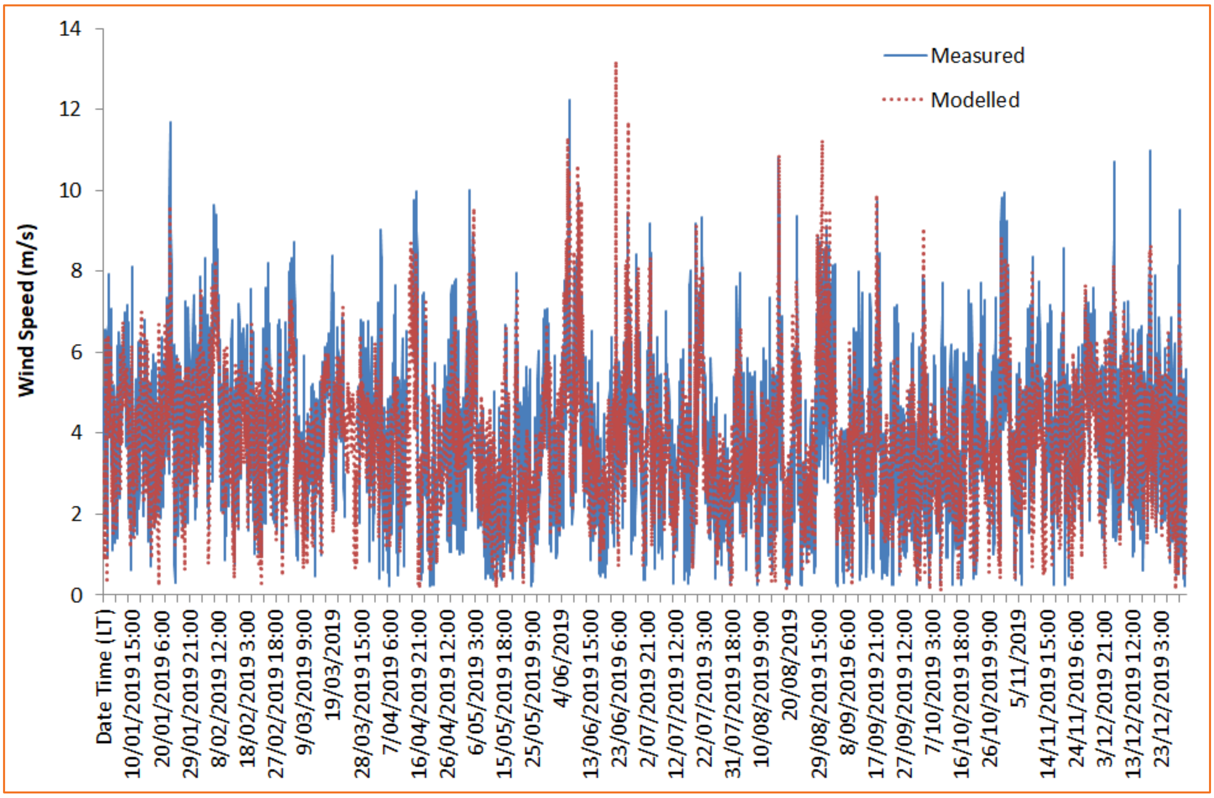


Appendix Figure 7: Time series of modelled at measured temperature at the onsite met station.

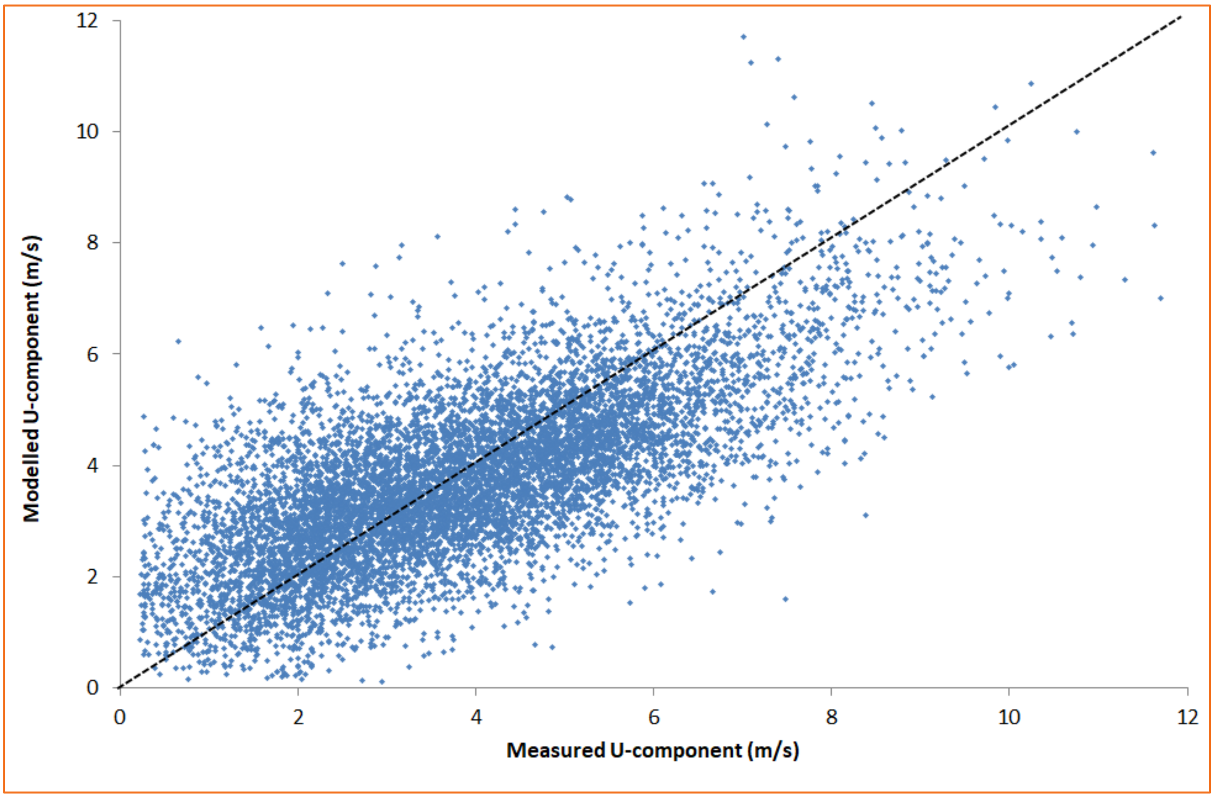


Appendix Figure 8: Scatterplot of modelled and measured temperature at the onsite met station

The time series of predicted and measured 10 m wind speed is shown in Appendix Figure 9. The model predictions reflect observational trends and predicts both lower and higher winds well. The scatterplot of wind speed shows that the model tends to underpredict higher wind speed on occasions (Appendix Figure 10).

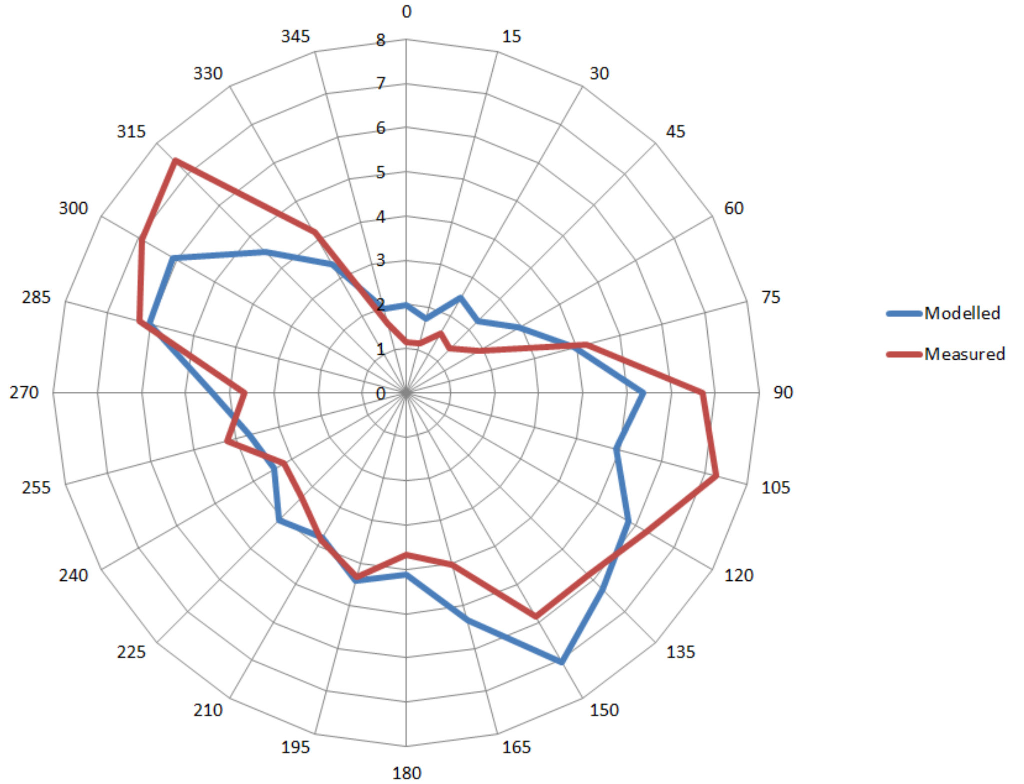


Appendix Figure 9: Time series of modelled at measured wind speed at the onsite met station.



Appendix Figure 10: Scatterplot of modelled and measured wind speed at the onsite met station.

The annual wind direction radar plots (Appendix Figure 11) show that while the model predicts the general wind directions well, the model slightly underpredicts the frequency of north-westerly and east-south-easterly flow.



Appendix Figure 11: Measured (left) and modelled (right) annual wind roses at the onsite met station.

More objective methods to evaluate model performance are assessed using statistical tests that have been specifically developed for this purpose. These tests used are discussed in detail below.

Model Bias

The model bias (MB) is the mean error and is given by:

$$MB = \frac{1}{n}\sum_{i=1}^{n}(O_i - P_i)$$

Where:

n	=	the number of pairs of observed data
O_i	=	the observed value for the i-th hour
P_i	=	the predicted value for the i-th hour

The ideal value for the bias is zero.

Gross Error

The gross error (GE) is the mean of absolute error and is given by:

$$GE = \frac{1}{n}\sum_{i=1}^{n} | O_i - P_i |$$

where:

n	=	the number of pairs of observed data
O_i	=	the observed value for the i-th hour
P_i	=	the predicted value for the i-th hour

The ideal value for gross error is zero. GE is greater than MB, representing the expected error for each hourly observation.

Root Mean Square Error (RMSE)

The Root Mean Square Error is given by:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - P_i)^2}$$

where:

N	=	the number of pairs of data
O_i	=	the observed (measured) value for the i-th hour
P_i	=	the predicted (modelled) value for the i-th hour

While the ideal RMSE value is 0, large errors in a small section of the data may produce a large RMSE even though errors may be small elsewhere.

Index of Agreement

The index of agreement (IOA) is the measure of how well the model estimates departure from the observed mean.

$$IOA = 1 - \left[\frac{N(RMSE)^2}{\sum_{i=1}^{n} \left\{ \left| P_i - \bar{O} \right| + \left| O_i - \bar{O} \right| \right\}^2} \right]$$

where:

n	=	the number of pairs of observed data
O_i	=	the observed value for the i-th hour
$\bar{O}_i$	=	the mean observed value

The index of agreement has a theoretical range of 0 to 1. The ideal value for IOA is 1.

A set of benchmarks were set for mesoscale model evaluation by Emery *et al.* (2001) and Teschke *et al.* (2001). The purpose of these benchmarks is not necessarily to give a passing or failing grade but to put the results into a proper context (Emery, et al., 2001).

Verification of WRF performance has been conducted by comparing hourly predictions at the onsite weather station against corresponding measurements between January 2019 and December 2019. Temperature, wind speed and wind direction compared (Appendix Table 4).

Appendix Table 4: Results of statistical validation test at the onsite met station

Variable	Performance Criteria	Benchmark Range	Statistic	
			Score	Benchmark
Wind Speed	RMSE	<±2 m/s	1.32	Within
	BIAS	<± 0.5 m/s	0.08	Within
	IOA	>0.6	0.83	Within
Wind Direction	Gross error	<30 °	26.04	Within
	BIAS	<10 °	5.50	Within
Temp	Gross error	<±2 K	2.0	Within
	BIAS	<± 0.5 K	1.24	Outside
	IOA	>0.8	0.95	Within

Based on the results shown in the table, it can be concluded that:

- The model predicts surface temperature with a moderate to high degree of skill. underprediction at higher temperatures has been identified (most likely due to incompatible modelled and measured heights). Two of the three benchmark criteria are met with the Bias values falling just outside the benchmark criterion.
- The model predicts wind speed with a high degree of skill. All three benchmarks are met.
- The model predicts wind direction with a high degree of accuracy. Both benchmark criteria are met.

The meteorological model performance can therefore be considered acceptable when compared to measurement data.

Appendix C – Sensitive Receptors

Appendix Table 4:Model Receptor Description.

Receptor ID	Easting	Northing	Receptor Name	Receptor Type	Assessment Criteria	Pollutant Impact Assessed			
						PM_{10}	$PM_{2.5}$	TSP	Dust deposition
1	412813	6253855	Town A	Residential (Greenbushes Town)	Human health | amenity | nuisance	✓	✓	✓	✓
2	412980	6253966	Town B			✓	✓	✓	✓
3	413106	6254150	Town C			✓	✓	✓	✓
4	413196	6254323	Town D			✓	✓	✓	✓
5	413190	6254373	Town E			✓	✓	✓	✓
6	413227	6254476	Town F			✓	✓	✓	✓
7	413599	6255592	A	Residential		✓	✓	✓	✓
8	415772	6253756	B			✓	✓	✓	✓
9	416238	6253607	C			✓	✓	✓	✓
10	415896	6252964	D			✓	✓	✓	✓
11	416041	6252630	E			✓	✓	✓	✓
12	417034	6250703	F			✓	✓	✓	✓
13	416360	6250255	G			✓	✓	✓	✓
14	415676	6250526	H			✓	✓	✓	✓
15	416054	6249386	I			✓	✓	✓	✓
16	415894	6249284	J			✓	✓	✓	✓
17	413363	6248888	K			✓	✓	✓	✓
18	411793	6248510	L			✓	✓	✓	✓
19	411021	6248757	M			✓	✓	✓	✓
20	409264	6249013	N			✓	✓	✓	✓
21	405054	6249792	O			✓	✓	✓	✓
22	407477	6252988	P			✓	✓	✓	✓
23	412460	6256660	Q			✓	✓	✓	✓
24	413097	6257623	R			✓	✓	✓	✓
25	414987	6256777	S			✓	✓	✓	✓
26	416674	6248781	T			✓	✓	✓	✓
27	414793	6246500	U			✓	✓	✓	✓
28	414793	6246500	V			✓	✓	✓	✓
29	412855.2	6253814	Dust monitor			✓	✓	✓	✓

Appendix D – CALMET Configuration

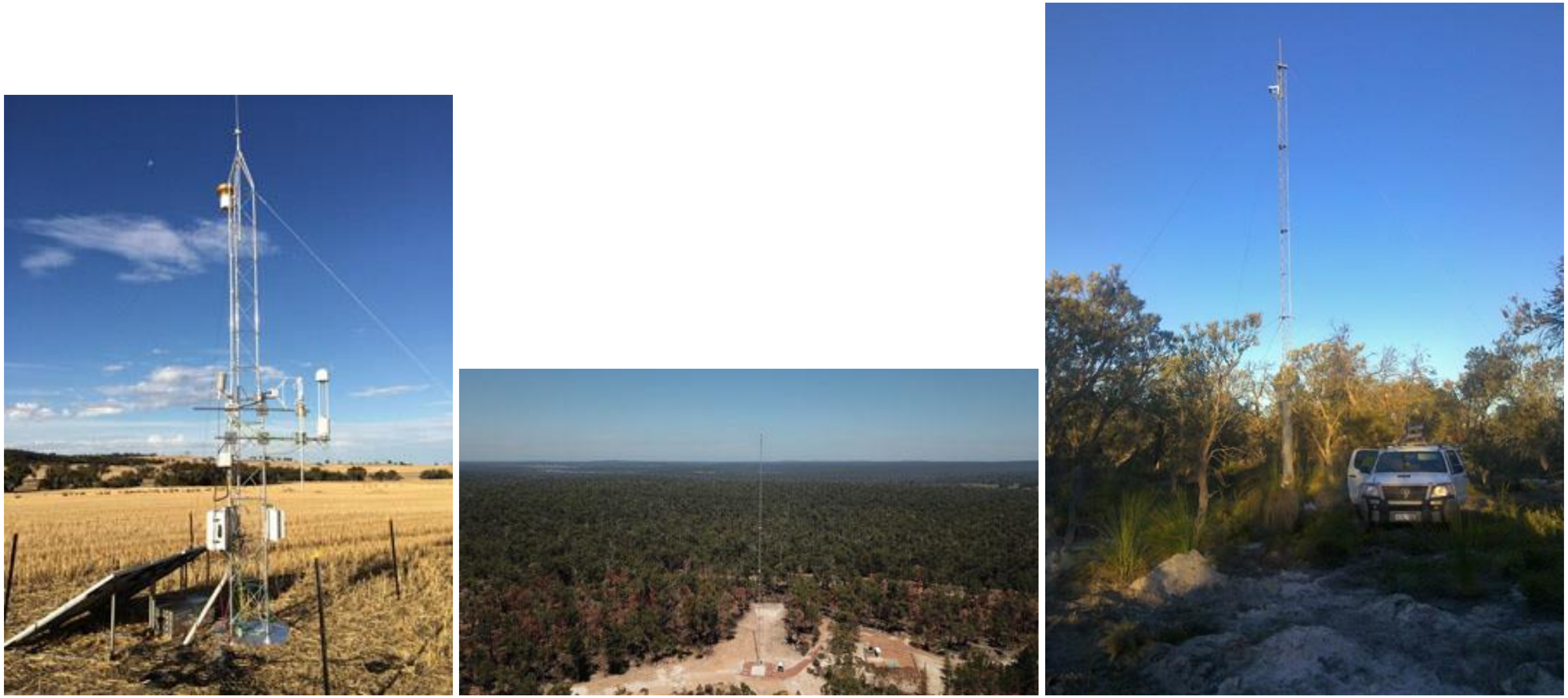
Selected CALMET model switches and settings used in the modelling are summarised in Appendix Table 5. These specifically show settings that deviate from the model default values.

Appendix Table 5: Selected CALMET Settings and switches.

Code	Setting	Explanatory Notes
NOOBS	2	Use MM4/MM5/3D.DAT for surface, overwater, and upper air data
ICLOUD	4	Gridded cloud cover from Prognostic Rel. Humidity
IWFCOD	1	Diagnostic wind module
IFRADJ	1	Froude number adjustment
ISLOPE	1	Compute slope flow effects
IEXTRP	1	No surface wind observation extrapolation to upper layers
IPROG	14	Use gridded prognostic wind field model output fields as input to the diagnostic wind field model as initial guess field
RMAX1	0.01	Maximum radius of influence over land in the surface layer
RMAX2	0.01	Maximum radius of influence over land aloft
TERRAD	3	Radius of influence of terrain features
R1	0.01	Relative weighting of the first guess field and observations in the SURFACE layer
R2	0.01	Relative weighting of the first guess field and observations in the layers ALOFT

The geophysical data used in CALMET is critical for simulating deflection, blocking, and channelling of the air flow. In addition, other parameters such as roughness length, albedo and Bowen ratio are important for the simulation of turbulence, and heat fluxes (used to determine the growth of the mixing height, *inter alia*).

The default United States Geological Service (USGS) geophysical parameters used in CALMET are based on North American vegetation types and is most likely unrepresentative of Australian vegetation types. It was therefore decided to calculate these parameters, where possible, for the local vegetation specifically, based on Ozflux flux tower measurement data at Ridgefield for cropland (Beringer, 2016), Collie for local forest (Beringer, 2018) and Gingin for shrubland/ Banksia woodland (Silberstein, 2015) (Appendix Figure 12). Measurements at these sites include wind speed, direction, friction velocity, heat fluxes (sensible and latent) as well as incoming and outgoing radiation.



Appendix Figure 12: Flux towers at Ridgefield (left), Collie (centre) and Gingin (right).

Roughness length is a critical parameter in dispersion modelling as it affects nocturnal mixing heights as well as dispersion rate of the plume through dispersion coefficients. The following relationship was used to calculate roughness length[26] (z_o) from friction velocity (u_*), wind speed (u) and anemometer height (z) at the three locations:

$$z_0 = (z - D)^{\frac{-kU(z)}{u*}}$$

The local seasonal roughness lengths thus determined are shown in Appendix Table 6. The reduction in roughness length during autumn and winter reflects the wheat cropland sowing period (bare soil) from April to June in WA. Z_0 remains relatively constant for shrub and forest due to evergreen nature of the vegetation.

The calculated values for cropland approximate the USGS values, while the calculated values for Australian forests are significantly lower than the default USGS value and more in line with values cited in Peel *et al* (2005) for south-western Western Australia.

Seasonal Bowen ratios[27] for 2019 were obtained from 30-minute average latent and sensible heat flux measurements for local cropland, forest and shrub land cover types (Siberstein, 2015; Beringer, 2016, 2018), and were calculated as follows:

$$\beta = \frac{Q_h}{Q_e}$$

Where Q_H and Q_e are sensible and latent heat fluxes, respectively.

The local seasonal Bowen ratios thus determined are shown in Appendix Table 6. The calculated values for cropland approximate the average USGS value, while the calculated values for Australian forests and shrubland are significantly higher than the corresponding default USGS value. These values reflect the low evapotranspiration rates seen for native Australian vegetation species. Reduction in Bowen ratio is seen during winter in response to increased rainfall during that season.

Local seasonal albedo[28] were calculated from the ratio of outgoing shortwave (i.e., reflected) radiation to incoming radiation and are shown in Appendix Table 6. The calculated values for cropland approximate the average USGS value, while the calculated values for Australian forests are slightly higher than the default USGS value. These values, which are consistent with the value cited in Peel *et al* (2005) for south-western Western Australia, confirms the higher reflectance of eucalyptus species compared to North American tree species.

Geophysical parameters for the remaining land-use categories were sourced from Hagermann (2002) and Peel *et al* (2005).

Seasonal geophysical (geo.dat) files were utilised in the modelling to reflect the changing geophysical parameters between the wet and dry seasons.

[26] Roughness length is related to the roughness characteristics of the terrain.
[27] Bowen ratio is important in determining the degree of convective turbulence.
[28] The albedo is the degree to which a surface will reflect incoming shortwave solar radiation and is used in the model to determine the radiation balance.

Appendix Table 6: Calculated seasonal roughness length (zo), albedo (α) and Bowen ratio (β)

	zo	α	β
Dry cropland			
Summer	0.21	0.23	0.99
Autumn	0.12	0.22	0.85
Winter	0.07	0.20	0.89
Spring	0.29	0.22	0.70
Forest			
Summer	0.68	0.14	2.09
Autumn	0.68	0.14	1.17
Winter	0.68	0.13	0.14
Spring	0.68	0.13	0.79
Shrubland			
Summer	0.32	0.14	2.40
Autumn	0.31	0.13	1.43
Winter	0.32	0.13	0.49
Spring	0.30	0.13	1.54

Appendix E– CALMET Output

This section summarises the model's performance in predicting the meteorological conditions compared to the measured data for the project area.

Wind Direction and Speed

Selected meteorological variable were extracted from the gridded CALMET output for a point corresponding to the project site (412,830 m Easting and 6,251,640 m Northing). The general features of the 10 m winds illustrated in the annual and seasonal wind rose diagrams for the 12-month period from January 2019 – December 2019[29] are shown in Appendix Figure 13.

The wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points – N, NNE, NE, etc. The bar at the top of each wind rose diagram represents winds blowing from the north (i.e. northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds.

The major features of the wind rose are as follows:

- Annual wind direction is predominantly from the southeast with secondary maxima from the northwest.
- During summer, the predominant wind direction is southeasterly due to the ridging effect of the South Indian Ocean anticyclone.
- Autumn is characterised by winds from the southeast, northeast and slightly increased frequency of north-westerly winds.
- During the winter months, winds are predominantly from the west and northwest in response to the northward shift of the westerly wind belt during that season.
- Spring winds are from the northwest with increased frequency of southeasterly winds.
- Average wind speeds are 3.7 m/s with strongest hourly wind speed of 13.4 m/s.
- Light winds (< 1 m/s) occur for 2.5% (216 hours) of the year.
- Stronger winds (> 6 m/s) occur for 7 % (619 hours) of the year.

The time-date [30] diagrams for wind direction and wind speed are shown in Appendix Figure 14. The diagrams depict wind direction (as arrows) and speed (as contours) by hour of the day on the x-axis and day of the year on the y-axis. The figures show that winds are generally from the east in the summer and from the west and northwest in the winter. Wind speeds show a cyclical pattern, with lighter winds occurring on average every 16 days. Wind speeds do not show any clear diurnal pattern.

The spatial variation of wind direction, as modelled by WRF-CALMET, is shown in Appendix Figure 14. Terrain influence on the prevailing airflow is evident, with channelling effects along the valleys.

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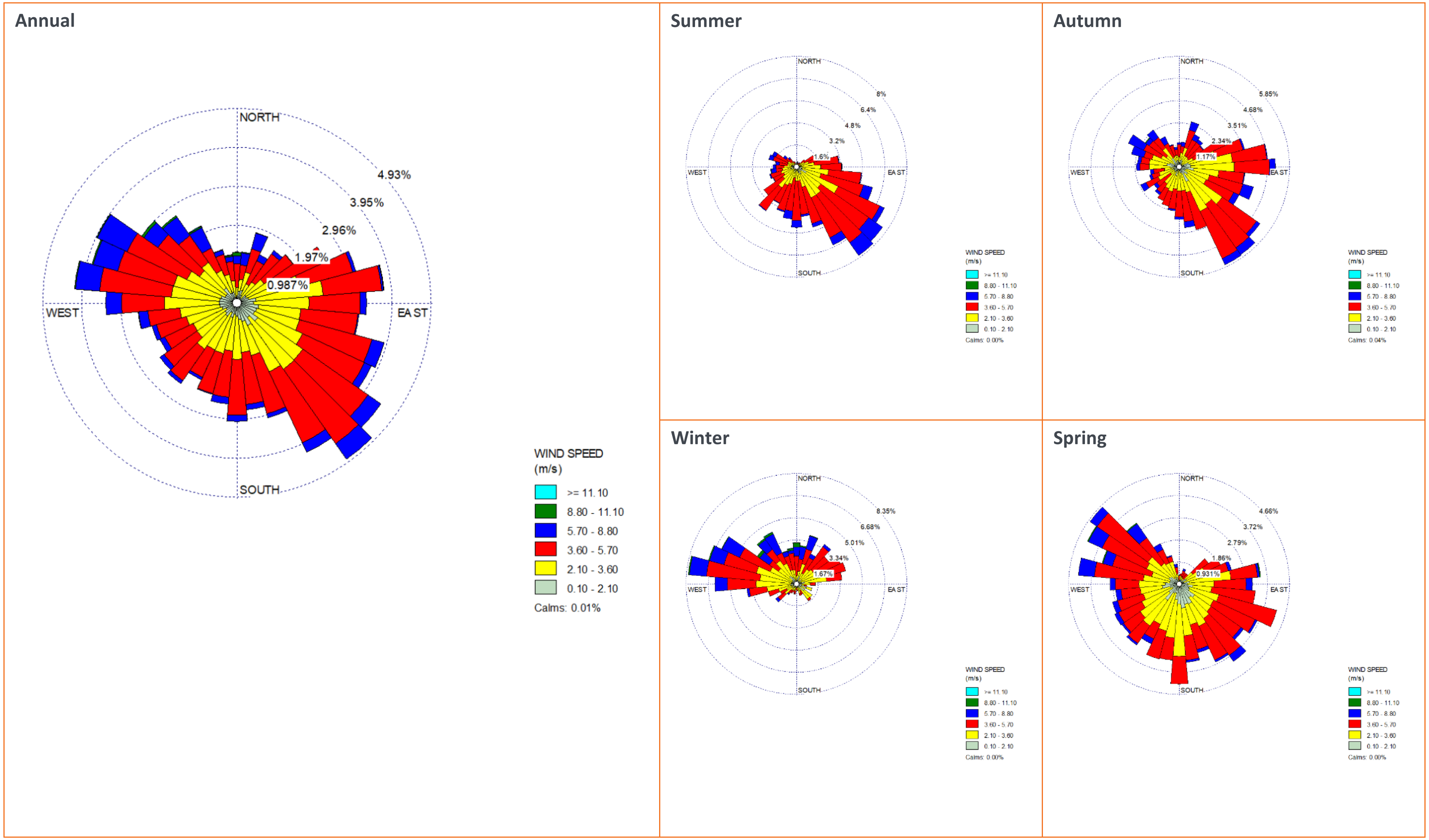
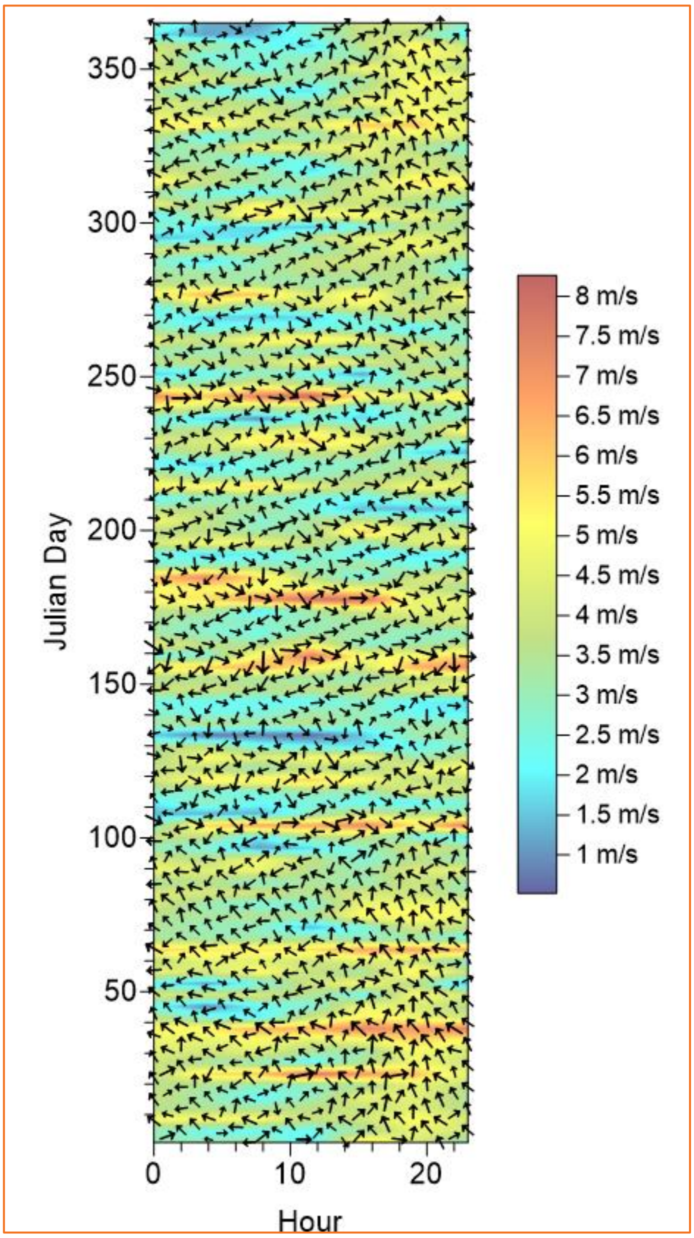
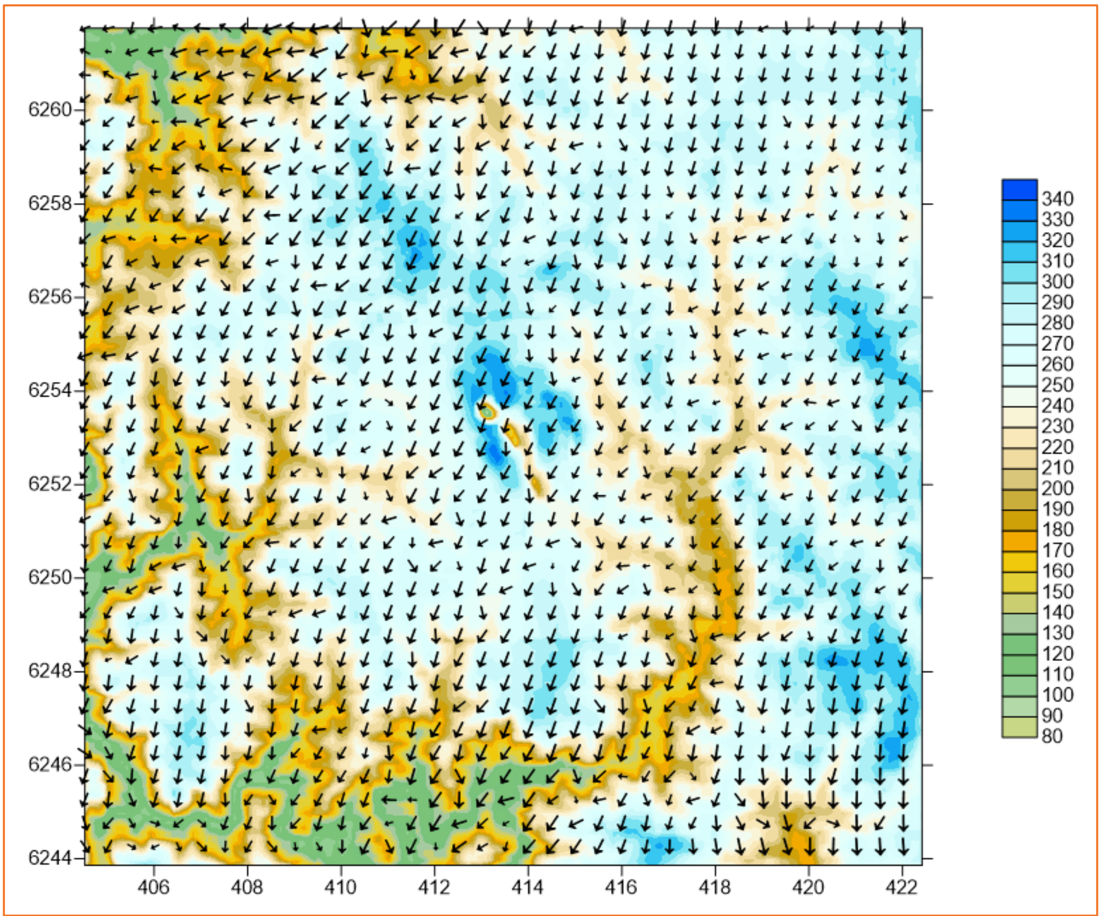
[29] The selected representative meteorological year (as determined in Appendix A).
[30] These diagrams are useful for displaying large amounts of data in a meaningful and understandable form.



Appendix Figure 13: Annual and seasonal wind roses generated from WRF/CALMET for Greenbushes.



Appendix Figure 14: Date-time plot of wind direction (arrows) and wind speed (contours) generated from WRF/CALMET.



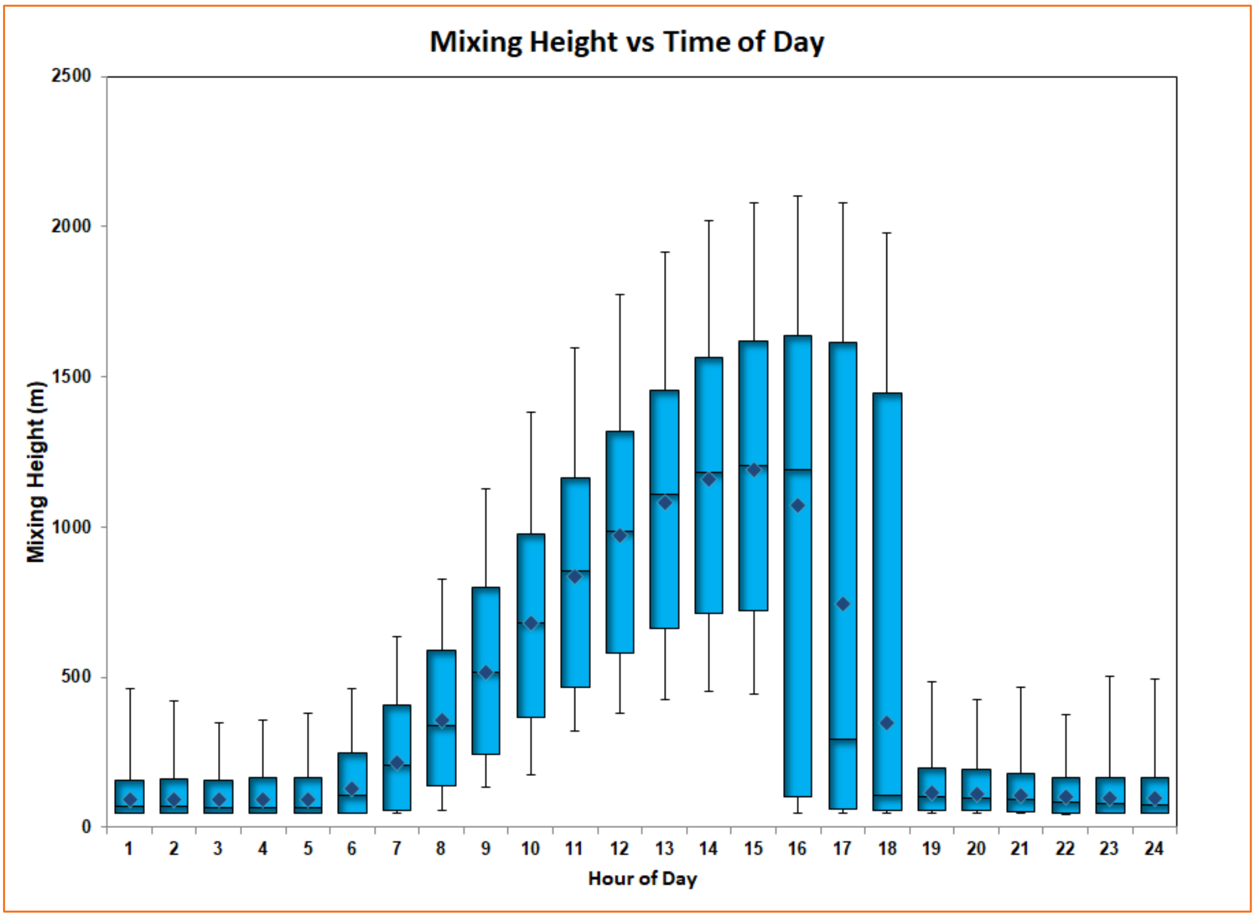
Appendix Figure 15: Snapshot of surface wind vectors

Mixing Height

Mixing height is the depth of the atmospheric surface layer beneath an elevated temperature inversion. It is an important parameter within air pollution meteorology. Vertical diffusion or mixing of a plume is limited by the mixing height, as the air above this layer tends to be stable, with restricted vertical motion.

A series of internal algorithms within CALMET is used to calculate mixing heights for the subject site where it is assumed that mixing height is formed through mechanical means (wind speed) at night and through a mixture of mechanical and convective means (wind speed and solar radiation) during the day (Scire et al. 2011). During the night and early morning when the convective mixed layer is absent or small, the full depth of the planetary boundary layer (PBL) may be controlled by mechanical turbulence. During the day, the height of the PBL during convective conditions is then taken as the maximum of the estimated (or measured if available) convective boundary layer height and the estimated (or measured if available) mechanical mixing height. It is calculated from the early morning potential temperature sounding (prior to sunrise), and the time varying surface heat flux to calculate the time evolution of the convective boundary layer.

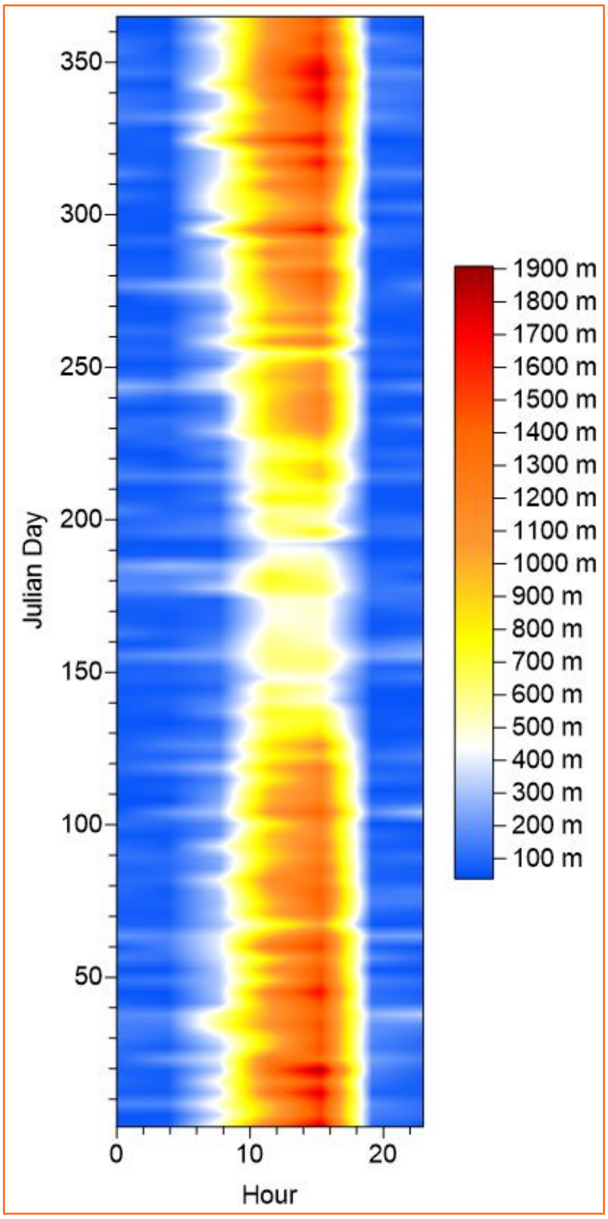
The hourly variation of mixing height at the facility is summarised in Appendix Figure 16[31] with the diurnal cycle evident. At night, mixing height is normally low and after sunrise it typically increases to between 700 m and 1,500 m in response to convective mixing generated by solar heating of the Earth's surface. A rapid reduction in mixing height commences around sunset when convective mixing ceases and a mechanical mixing regime is re-established.



Appendix Figure 16: Simulated annual statistics of hourly mixing heights, Greenbushes.

The date-time plot of mixing height shows that, as expected, mixing heights are greatest during the summer months when solar radiation and resulting convection is greatest (Appendix Figure 17).

[31] The blue bars depict the 10th and 90th percentile values while the diamond shape show the average conditions. The whiskers indicate minimum and maximum values of the data, and the line within the blue bar indicates the median.



Appendix Figure 17: Date-time plot of mixing height generated from WRF/CALMET.

Stability

An important aspect of pollutant dispersion is the level of turbulence in the lowest 1 km or so of the atmosphere, known as the planetary boundary layer (PBL). Turbulence controls how effectively a plume is diffused into the surrounding air and hence diluted. It acts by increasing the cross-sectional area of the plume due to random motions. With stronger turbulence, the rate of plume diffusion increases. Weak turbulence limits diffusion and contributes to high plume concentrations downwind of a source.

Turbulence is generated by both thermal and mechanical effects to varying degrees. Thermally driven turbulence occurs when the surface is being heated, in turn transferring heat to the air above by convection. Mechanical turbulence is caused by the frictional effects of wind moving over the earth's surface and depends on the roughness of the surface as well as the flow characteristics.

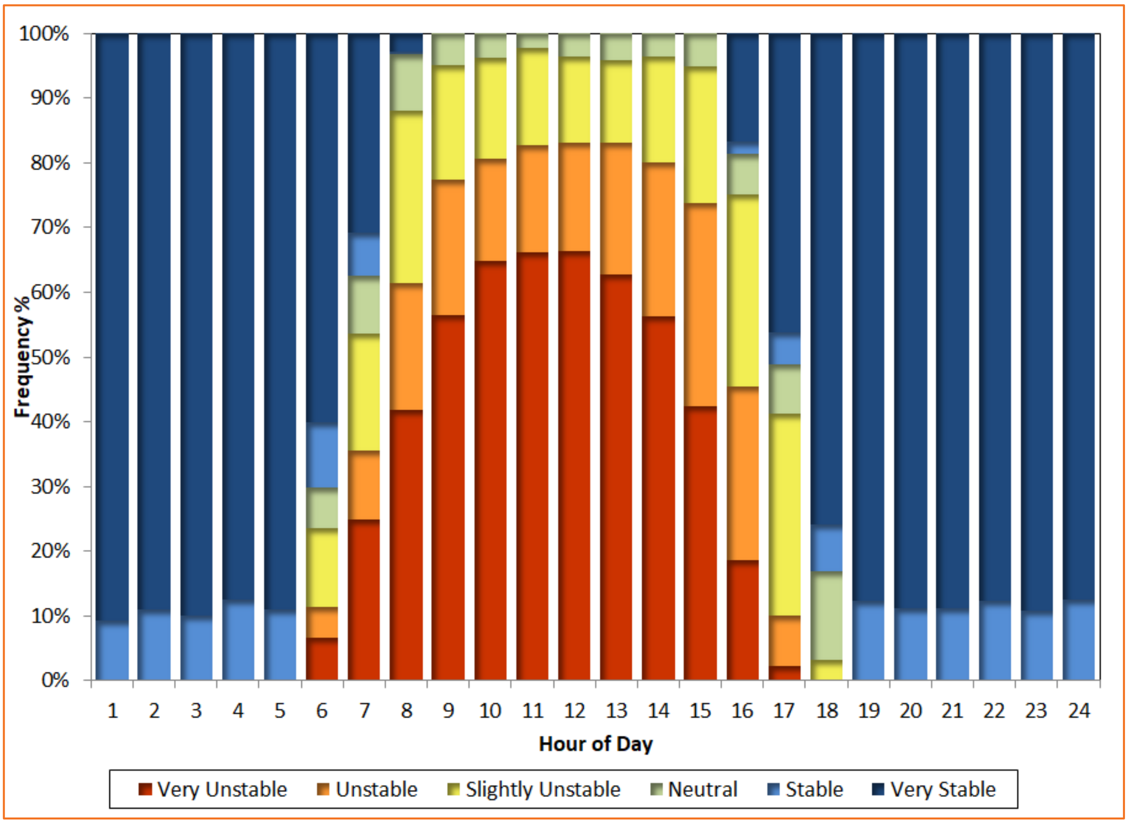
Turbulence in the boundary layer is influenced by the vertical temperature gradient, which is one of several indicators of stability. Plume models use indicators of atmospheric stability in conjunction with other meteorological data to estimate the dispersion conditions in the atmosphere.

Stability can be described across a spectrum ranging from highly unstable through neutral to highly stable. A highly unstable boundary layer is characterised by strong surface heating and relatively light winds, leading to intense convective turbulence and enhanced plume diffusion. At the other extreme, very stable conditions are often associated with strong temperature inversions and light winds, which commonly occur under clear skies at night and in the early morning. Under these conditions, plumes can remain relatively undiluted for considerable distances downwind. Neutral conditions are linked to windy and/or cloudy weather, and short periods around sunset and sunrise, when surface rates of heating or cooling are very low.

The stability of the atmosphere plays a significant role In determining the dispersion of a plume and it is important to have it correctly represented in the dispersion model. CALPUFF uses the Monin-Obukhov Similarity Theory (MOST) to characterise turbulence and other processes in the PBL. One of the measures of the PBL is the Monin-Obukhov length (L), which approximates the height at which turbulence is generated equally by thermal and mechanical effects (Seinfeld and Pandis 2006). It is a measure of the relative importance of mechanical and thermal forcing on atmospheric turbulence.

Because values of L diverge to + and–- infinity as stability approaches neutral from the stable and unstable sides, respectively, it is often more convenient to use the inverse of L (i.e. 1/L) when describing stability.

The hourly averaged 1/L computed from all data in the CALMET surface file is presented in Appendix Figure 18. This plot indicates that the PBL is stable to very stable overnight becoming very unstable (reaching maximum instability between 10:00 am and 2:00 pm) as radiation from the sun heats the surface layer of the atmosphere and drives convection.

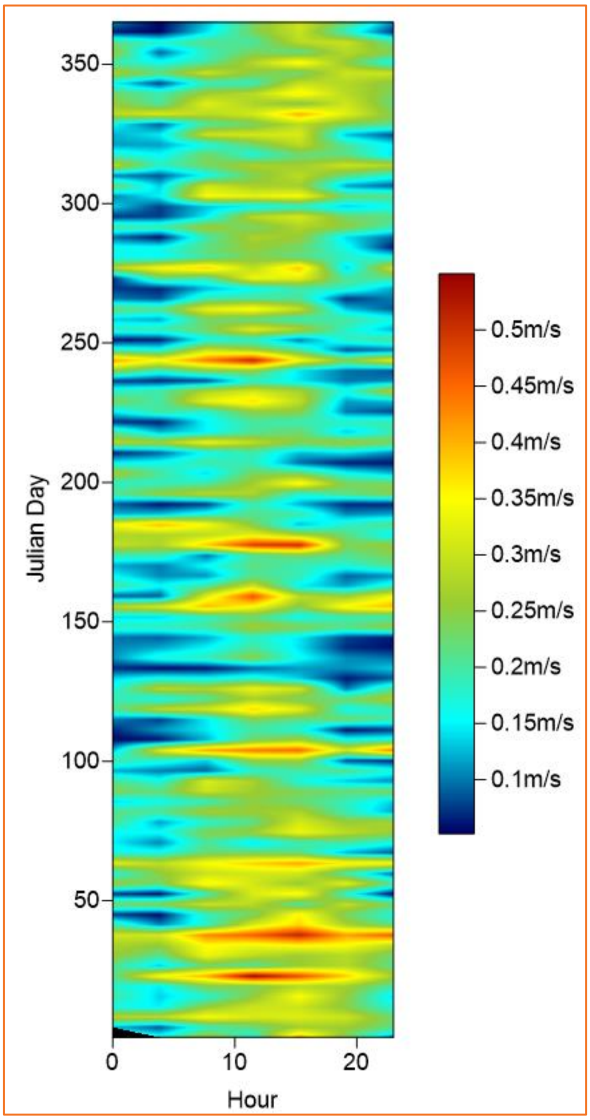


Appendix Figure 18: Simulated annual statistics of hourly stability, Greenbushes

Friction Velocity

An important quantity in wind erosion studies is threshold friction velocity u_{*t}, which describes the capacity of the surface to resist wind erosion. u_{*t} is the minimum friction velocity (u_*) required for the initiation of mobilization of sand particles from the ground into the atmosphere. Friction velocity is affected by a range of factors, such as wind speed, vegetation cover, and other roughness elements.

The time-day diagram of CALMET-generated friction velocity shows that the highest friction velocity (and therefore dust lift-off potential) mainly occurs during the day (Appendix Figure 19).



Appendix Figure 19: Hour-Date-time plot of friction velocity generated from WRF/CALMET.

Appendix F – Emission Parameters

A summary of the volume sources (statistical characteristics for emission rates) input into the model are shown in:

- Appendix Table 5 for mining sources
- Appendix Table 6 for haul road sources
- Appendix Table 7 for processing sources
- Appendix Table 8 for wind erosion sources

Appendix Table 5: Emission parameters for operational mining sources.

Source Id	Easting	Northing	Effective Height	Sigma Y	Sigma Z
Drill1	413579	6253147	1.5	62.5	0.70
Drill2	413713	6252787	1.5	62.5	0.70
Drill3	413933	6252337	1.5	62.5	0.70
Drill4	414118	6251926	1.5	62.5	0.70
Blast1	413528	6253054	20	15.81	9.30
Blast2	413723	6252708	20	15.81	9.30
Blast3	413998	6252231	20	15.81	9.30
Blast4	414053	6251970	20	15.81	9.30
Load1	413494	6253147	5	62.5	2.33
Load2	413627	6252787	5	62.5	2.33
Load3	413895	6252224	5	62.5	2.33
Load4	414118	6252046	5	62.5	2.33
UnW1	414464	6253764	2	125	0.93
UnW2	414841	6253336	2	125	0.93
UnW3	415116	6252849	2	125	0.93
UnW4	415064	6252406	2	125	0.93
UnW4	414859	6251929	2	125	0.93
UnW6	414780	6251439	2	125	0.93
UnW7	414817	6250979	2	125	0.93
Bull1	414618	6253637	2	125	0.93
Bull2	415068	6253013	2	125	0.93
Bull3	415133	6252619	2	125	0.93
Bull4	415020	6252163	2	125	0.93
Bull5	414763	6251669	2	125	0.93
Bull6	414817	6251171	2	125	0.93
UnO1	412799	6253234	2	125	0.93
UnO2	412960	6252849	2	125	0.93
UnO3	413107	6252231	2	125	0.93
UnO4	413502	6251849	2	125	0.93
UnO5	413454	6251686	2	125	0.93
LO1	412845	6253135	5	125	0.93
LO2	412927	6252814	5	125	0.93
LO3	413044	6252276	5	125	0.93

Source Id	Easting	Northing	Effective Height	Sigma Y	Sigma Z
LO4	413416	6251919	5	125	0.93
LO5	413572	6251650	5	125	0.93
UnCr1	412735	6253178	2	5	0.93
UnCr2	413034	6252172	2	5	0.93
UnCr3	413256	6251808	2	5	0.93

Appendix Table 6: Emission parameters for haul road sources.

Source Id	Easting	Northing	Effective Height	Sigma Y	Sigma Z
HR1	413685	6253556	4.4	16.7	4.1
HR2	413848	6253571	4.4	16.7	4.1
HR3	414014	6253548	4.4	16.7	4.1
HR4	414175	6253526	4.4	16.7	4.1
HR5	414312	6253610	4.4	16.7	4.1
HR6	414243	6253787	4.4	16.7	4.1
HR7	414354	6253901	4.4	16.7	4.1
HR8	414181	6251588	4.4	16.7	4.1
HR9	414032	6251658	4.4	16.7	4.1
HR10	413910	6251794	4.4	16.7	4.1
HR11	414526	6251529	4.4	16.7	4.1
HR12	414576	6251339	4.4	16.7	4.1
HR13	414585	6251142	4.4	16.7	4.1
HR14	414611	6250966	4.4	16.7	4.1
HR15	414754	6250865	4.4	16.7	4.1
HR16	414080	6251792	4.4	16.7	4.1
HR17	414169	6251623	4.4	16.7	4.1
HR18	414313	6251647	4.4	16.7	4.1
HR19	414467	6251719	4.4	16.7	4.1
HR20	414602	6251827	4.4	16.7	4.1
HR21	414654	6252016	4.4	16.7	4.1
HR22	414719	6252196	4.4	16.7	4.1
HR23	414827	6252347	4.4	16.7	4.1
HR24	414885	6252529	4.4	16.7	4.1
HR25	414888	6252728	4.4	16.7	4.1
HR26	414866	6252925	4.4	16.7	4.1
HR27	414049	6252411	4.4	16.7	4.1
HR28	414053	6252609	4.4	16.7	4.1
HR29	414021	6252803	4.4	16.7	4.1
HR30	414034	6253002	4.4	16.7	4.1
HR31	414043	6253201	4.4	16.7	4.1
HR32	414029	6253352	4.4	16.7	4.1
HR33	414175	6253447	4.4	16.7	4.1
HR34	414331	6253517	4.4	16.7	4.1
HR35	414492	6253539	4.4	16.7	4.1
HR36	414579	6253433	4.4	16.7	4.1

Source Id	Easting	Northing	Effective Height	Sigma Y	Sigma Z
HR37	414628	6253246	4.4	16.7	4.1
HR38	414778	6253170	4.4	16.7	4.1
HR39	413889	6252380	4.4	16.7	4.1
HR40	413802	6252537	4.4	16.7	4.1
HR41	413757	6252390	4.4	16.7	4.1
HR42	413771	6252203	4.4	16.7	4.1
HR43	413810	6252010	4.4	16.7	4.1
HR44	413809	6251831	4.4	16.7	4.1
HR45	413645	6251863	4.4	16.7	4.1
HR46	413500	6251960	4.4	16.7	4.1
HR47	413377	6252095	4.4	16.7	4.1
HR48	413248	6252221	4.4	16.7	4.1
HR49	413801	6252952	4.4	16.7	4.1
HR50	413741	6253138	4.4	16.7	4.1
HR51	413675	6253320	4.4	16.7	4.1
HR52	413549	6253449	4.4	16.7	4.1
HR53	413404	6253419	4.4	16.7	4.1
HR54	413331	6253241	4.4	16.7	4.1
HR55	413315	6253045	4.4	16.7	4.1
HR56	413215	6252934	4.4	16.7	4.1
HR57	413087	6252838	4.4	16.7	4.1
HR58	412988	6252688	4.4	16.7	4.1
HR59	412905	6252690	4.4	16.7	4.1

Appendix Table 7: Emission parameters for processing sources.

Source Id	Easting	Northing	Effective Height	Sigma Y	Sigma Z
Crush1	412729	6253172	6	5	2.8
Crush2	412900	6252900	4	5	1.9
Stack 1	412656	6253033	8	15	3.7
TS1	412632	6253077	3	2	1.4
TS2	412613	6253010	3	2	1.4
LoadOut1	412592	6252769	3	37.5	1.4
Crush3	413018	6252163	6	5	2.8
Screen1	412942	6252237	5	6.25	2.3
Stack2	412868	6252364	8	15	3.7
TS3	412906	6252378	3	2	1.4
Load2	412705	6252533	3	37.5	1.4
Crush4	413242	6251814	6	5	2.8
Screen2	413068	6251840	5	6.25	2.3
Stack3	413002	6251903	8	15	3.7
TS4	412244	6252292	3	2	1.4
Load3	412083	6251779	3	37.5	1.4
OreSort1	412969	6251840	4	5	1.9
OreSort2	413619	6251662	4	5	1.9

Source Id	Easting	Northing	Effective Height	Sigma Y	Sigma Z
TRP_Unload	412450	6250730	3	3	1.4
TRP_Load	412113	6250737	3	37.5	1.4

Appendix Table 8: Wind Erosion model parameters.

Source Id	Easting1	Easting2	Easting3	Easting4	Northing1	Northing2	Northing3	Northing4
WE1	413551	413711	413711	413551	6253024	6253024	6252864	6252864
WE2	413784	413944	413944	413784	6252503	6252503	6252343	6252343
WE3	414042	414202	414202	414042	6252050	6252050	6251890	6251890
WE4	414469	414749	414749	414469	6253897	6253897	6253617	6253617
WE5	414839	415119	415119	414839	6253012	6253012	6252732	6252732
WE6	414722	415002	415002	414722	6252264	6252264	6251984	6251984
WE7	414613	414893	414893	414613	6251462	6251462	6251182	6251182
WE8	412836	412986	412986	412836	6253208	6253208	6253058	6253058
WE9	412928	413078	413078	412928	6252872	6252872	6252722	6252722
WE10	413050	413150	413150	413050	6252301	6252301	6252201	6252201
WE11	413488	413638	413638	413488	6252038	6252038	6251888	6251888
WE12	413446	413596	413596	413446	6251764	6251764	6251614	6251614
WE13	413395	413695	413695	413395	6251410	6251410	6251110	6251110
WE14	412860	413160	413160	412860	6251187	6251187	6250887	6250887
WE15	413174	413724	413724	413174	6250444	6250444	6249894	6249894
WE16	412245	412795	412795	412245	6250451	6250451	6249901	6249901
WE17	412632	412682	412682	412632	6253050	6253050	6253000	6253000
WE18	412674	412734	412734	412674	6252996	6252996	6252936	6252936
WE19	412853	412903	412903	412853	6252431	6252431	6252381	6252381
WE20	412974	413024	413024	412974	6251923	6251923	6251873	6251873
WE21	412569	412619	412619	412569	6252788	6252788	6252738	6252738
WE22	412669	412719	412719	412669	6252535	6252535	6252485	6252485
WE23	412548	412748	412748	412548	6251884	6251884	6251684	6251684
WE24	412350	412550	412550	412350	6251431	6251431	6251231	6251231

Appendix G – Emission Rates

A summary of the PM_{10} emission rates for the base case (2023), used as input into the model is shown in:

- Appendix Table 9 for operational mining sources.
- Appendix Table 10 for haul road sources.
- Appendix Table 11 for processing sources
- Appendix Table 12 for wind erosion sources.

Appendix Table 9: PM_{10} emission rates for operational mining sources.

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
Drill1	0.08	0.08	0.08	0.08	0.08	0.06
Drill2	0.08	0.08	0.08	0.08	0.08	0.06
Drill3	0.08	0.08	0.08	0.08	0.08	0.06
Drill4	0.08	0.08	0.08	0.08	0.08	0.06
Blast1	7.64	0.00	0.00	0.00	0.00	0.07
Blast2	7.64	0.00	0.00	0.00	0.00	0.07
Blast3	7.64	0.00	0.00	0.00	0.00	0.07
Blast4	7.64	0.00	0.00	0.00	0.00	0.07
Load1	1.65	1.65	1.65	1.65	1.65	1.27
Load2	1.65	1.65	1.65	1.65	1.65	1.29
Load3	1.65	1.65	1.65	1.65	1.65	1.28
Load4	1.65	1.65	1.65	1.65	1.65	1.28
UnW1	0.29	0.29	0.29	0.29	0.29	0.22
UnW2	0.29	0.29	0.29	0.29	0.29	0.22
UnW3	0.29	0.29	0.29	0.29	0.29	0.22
UnW4	0.29	0.29	0.29	0.29	0.29	0.22
UnW4	0.29	0.29	0.29	0.29	0.29	0.22
UnW6	0.00	0.00	0.00	0.00	0.00	0.00
UnW7	0.00	0.00	0.00	0.00	0.00	0.00
Bull1	0.14	0.14	0.14	0.14	0.14	0.05
Bull2	0.14	0.14	0.14	0.14	0.14	0.05
Bull3	0.14	0.14	0.14	0.14	0.14	0.05
Bull4	0.14	0.14	0.14	0.14	0.14	0.05
Bull5	0.00	0.00	0.00	0.00	0.00	0.00
Bull6	0.00	0.00	0.00	0.00	0.00	0.00
UnO1	0.36	0.36	0.36	0.36	0.36	0.28
UnO2	0.36	0.36	0.36	0.36	0.36	0.28
UnO3	0.36	0.36	0.36	0.36	0.36	0.28
UnO4	0.00	0.00	0.00	0.00	0.00	0.00
UnO5	0.00	0.00	0.00	0.00	0.00	0.00
LO1	0.94	0.94	0.94	0.94	0.94	0.73
LO2	0.94	0.94	0.94	0.94	0.94	0.73
LO3	0.94	0.94	0.94	0.94	0.94	0.73
LO4	0.00	0.00	0.00	0.00	0.00	0.00

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
LO5	0.00	0.00	0.00	0.00	0.00	0.00
UnCr1	0.25	0.25	0.25	0.25	0.25	0.19
UnCr2	0.50	0.50	0.50	0.50	0.50	0.39
UnCr3	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table 10: PM_{10} emission rates for haul road sources.

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
HR1	0.26	0.26	0.26	0.26	0.26	0.18
HR2	0.26	0.26	0.26	0.26	0.26	0.18
HR3	0.26	0.26	0.26	0.26	0.26	0.18
HR4	0.26	0.26	0.26	0.26	0.26	0.18
HR5	0.26	0.26	0.26	0.26	0.26	0.18
HR6	0.26	0.26	0.26	0.26	0.26	0.18
HR7	0.26	0.26	0.26	0.26	0.26	0.18
HR8	0.31	0.31	0.31	0.31	0.31	0.22
HR9	0.31	0.31	0.31	0.31	0.31	0.22
HR10	0.31	0.31	0.31	0.31	0.31	0.22
HR11	0.00	0.00	0.00	0.00	0.00	0.00
HR12	0.00	0.00	0.00	0.00	0.00	0.00
HR13	0.00	0.00	0.00	0.00	0.00	0.00
HR14	0.00	0.00	0.00	0.00	0.00	0.00
HR15	0.00	0.00	0.00	0.00	0.00	0.00
HR16	0.52	0.52	0.52	0.52	0.52	0.35
HR17	0.52	0.52	0.52	0.52	0.52	0.35
HR18	0.52	0.52	0.52	0.52	0.52	0.35
HR19	0.52	0.52	0.52	0.52	0.52	0.35
HR20	0.52	0.52	0.52	0.52	0.52	0.35
HR21	0.52	0.52	0.52	0.52	0.52	0.35
HR22	0.26	0.26	0.26	0.26	0.26	0.18
HR23	0.26	0.26	0.26	0.26	0.26	0.18
HR24	0.26	0.26	0.26	0.26	0.26	0.18
HR25	0.26	0.26	0.26	0.26	0.26	0.18
HR26	0.26	0.26	0.26	0.26	0.26	0.18
HR27	0.52	0.52	0.52	0.52	0.52	0.36
HR28	0.52	0.52	0.52	0.52	0.52	0.36
HR29	0.52	0.52	0.52	0.52	0.52	0.36
HR30	0.52	0.52	0.52	0.52	0.52	0.36
HR31	0.52	0.52	0.52	0.52	0.52	0.36
HR32	0.52	0.52	0.52	0.52	0.52	0.36
HR33	0.52	0.52	0.52	0.52	0.52	0.36
HR34	0.52	0.52	0.52	0.52	0.52	0.36
HR35	0.52	0.52	0.52	0.52	0.52	0.36

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
HR36	0.52	0.52	0.52	0.52	0.52	0.36
HR37	0.52	0.52	0.52	0.52	0.52	0.36
HR38	0.52	0.52	0.52	0.52	0.52	0.36
HR39	0.31	0.31	0.31	0.31	0.31	0.22
HR40	0.31	0.31	0.31	0.31	0.31	0.22
HR41	0.31	0.31	0.31	0.31	0.31	0.22
HR42	0.31	0.31	0.31	0.31	0.31	0.22
HR43	0.31	0.31	0.31	0.31	0.31	0.22
HR44	0.33	0.33	0.33	0.33	0.33	0.22
HR45	0.33	0.33	0.33	0.33	0.33	0.22
HR46	0.33	0.33	0.33	0.33	0.33	0.22
HR47	0.33	0.33	0.33	0.33	0.33	0.22
HR48	0.33	0.33	0.33	0.33	0.33	0.22
HR49	0.57	0.57	0.57	0.57	0.57	0.40
HR50	0.57	0.57	0.57	0.57	0.57	0.40
HR51	0.57	0.57	0.57	0.57	0.57	0.40
HR52	0.57	0.57	0.57	0.57	0.57	0.40
HR53	0.65	0.65	0.65	0.65	0.65	0.44
HR54	0.65	0.65	0.65	0.65	0.65	0.44
HR55	0.65	0.65	0.65	0.65	0.65	0.44
HR56	0.65	0.65	0.65	0.65	0.65	0.44
HR57	0.33	0.33	0.33	0.33	0.33	0.22
HR58	0.33	0.33	0.33	0.33	0.33	0.22
HR59	0.33	0.33	0.33	0.33	0.33	0.22

Appendix Table 11: PM_{10} emission rates for processing sources.

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
Crush1	0.07	0.07	0.07	0.07	0.07	0.04
Crush2	0.08	0.08	0.08	0.08	0.08	0.06
CPG1-2 Stk	0.04	0.04	0.04	0.04	0.04	0.03
TS1	0.05	0.05	0.05	0.05	0.05	0.03
TS2	0.05	0.05	0.05	0.05	0.05	0.03
LoadOut1	0.13	0.13	0.13	0.13	0.13	0.10
Crush3	0.08	0.08	0.08	0.08	0.08	0.05
Screen1	0.32	0.32	0.32	0.32	0.32	0.18
Stack2	0.05	0.05	0.05	0.05	0.05	0.03
TS3	0.06	0.06	0.06	0.06	0.06	0.04
Load2	0.00	0.00	0.00	0.00	0.00	0.00
Crush4	0.00	0.00	0.00	0.00	0.00	0.00
Screen2	0.00	0.00	0.00	0.00	0.00	0.00
Stack3	0.00	0.00	0.00	0.00	0.00	0.00
TS4	0.00	0.00	0.00	0.00	0.00	0.00

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
Load3	0.00	0.00	0.00	0.00	0.00	0.00
OreSort1	0.95	0.95	0.95	0.95	0.95	0.53
OreSort2	0.00	0.00	0.00	0.00	0.00	0.00
TRP_Unload	0.18	0.18	0.18	0.18	0.18	0.12
TRP_Load	0.03	0.03	0.03	0.03	0.03	0.03

Appendix Table 8: PM_{10} emission rates for wind erosion.

Source Id	Maximum (g/s)	99th Percentile (g/s)	95th Percentile (g/s)	90th Percentile (g/s)	70th Percentile (g/s)	Average (g/s)
WE1	14.28	2.00	0.25	0.00	0.00	0.07
WE2	14.28	2.00	0.25	0.00	0.00	0.07
WE3	14.28	2.00	0.25	0.00	0.00	0.07
WE4	43.73	6.14	0.76	0.00	0.00	0.22
WE5	43.73	6.14	0.76	0.00	0.00	0.22
WE6	43.73	6.14	0.76	0.00	0.00	0.22
WE7	0.00	0.00	0.00	0.00	0.00	0.00
WE8	12.55	1.76	0.22	0.00	0.00	0.06
WE9	12.55	1.76	0.22	0.00	0.00	0.06
WE10	5.58	0.78	0.10	0.00	0.00	0.03
WE11	12.55	1.76	0.22	0.00	0.00	0.06
WE12	0.00	0.00	0.00	0.00	0.00	0.00
WE13	50.20	7.05	0.87	0.00	0.00	0.25
WE14	50.20	7.05	0.87	0.00	0.00	0.25
WE15	0.00	0.00	0.00	0.00	0.00	0.00
WE16	0.00	0.00	0.00	0.00	0.00	0.00
WE17	1.39	0.20	0.02	0.00	0.00	0.01
WE18	2.01	0.28	0.03	0.00	0.00	0.01
WE19	1.39	0.20	0.02	0.00	0.00	0.01
WE20	0.00	0.00	0.00	0.00	0.00	0.00
WE21	1.39	0.20	0.02	0.00	0.00	0.01
WE22	1.39	0.20	0.02	0.00	0.00	0.01
WE23	22.31	3.13	0.39	0.00	0.00	0.11
WE24	22.31	3.13	0.39	0.00	0.00	0.11

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