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Vulcan South Air Quality Assessment

Prepared for:

Vitrinite Pty Ltd

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Final

Prepared by:

Katestone Environmental Pty Ltd
ABN 92 097 270 276
Ground Floor, 16 Marie Street | PO Box 2217
Milton, Brisbane, Queensland, 4064, Australia

www.katestone.global
admin@katestone.com.au
Ph +61 7 3369 3699

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Prepared by:	Daniel Gallagher
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Glossary

Term	Definition
µg/m^3	micrograms per cubic metre
µm	microns
°C	degrees Celsius
km	kilometre
km/h	kilometre per hour
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
Nomenclature	**Definition**
PM_{10}	particulate matter with a diameter less than 10 micrometres
$PM_{2.5}$	particulate matter with a diameter less than 2.5 micrometres
TSP	total suspended particles
Abbreviations	**Definition**
Air EPP	*Environmental Protection (Air) Policy 2019*
BoM	Bureau of Meteorology
DES	Department of Environment and Science
EF	Emission Factor
EP Act	*Environmental Protection Act 1994*
ER	Emission Rate
ML	Mine Lease
NPI	National Pollutant Inventory database
OB	Overburden
ROM	Run of Mine
TAPM	The Air Pollution Model
US EPA	United States Environmental Protection Agency
VCM	Vulcan Coal Mine
VS	Vulcan South

EXECUTIVE SUMMARY

Katestone Environmental Pty Ltd (Katestone) was commissioned by Mining and Energy Technical Services Pty Limited (METServe), on behalf of Vitrinite Pty. Ltd., owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite), to complete an air quality assessment of Vulcan South (VS), a proposed small scale open-cut coking coal mine located 30 km south of Moranbah with a mine life of 9 years.

The air quality assessment has investigated the potential for the VS to affect air quality in the region. Year 2 and Year 7 of VS operations have been assessed based on the proposed mining schedule and the proximity of sensitive receptors to critical emission generating activities. The assessment has used meteorological and dispersion models to assess the effect of particulate matter (dust) emissions on concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates in the surrounding region.

Concentrations of air pollutants due to proposed activities associated with the VS in isolation, and with the inclusion of background levels of dust, were determined at sensitive residential receptors and on a cartesian grid covering the region. Predicted ground-level concentrations of air pollutants and dust deposition rates were compared with the relevant air quality objectives and guidelines.

It is significant to note that in past years the ambient concentrations of PM_{10} and $PM_{2.5}$ exceed the Air EPP objectives for 24-hour average and annual average PM_{10}. Dry conditions likely contributed to or exacerbated conditions with 2019 showing the lowest rainfall for the Moranbah region over the period 2012 – 2020; Australia-wide 2019 had the lowest annual rainfall since 1900. The assessment has included these ambient concentrations as background and therefore represents an upper bound of ambient concentrations for Moranbah.

The air quality assessment of the VS found the following:

TSP

- Predicted ground-level concentrations of TSP ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7.

PM_{10}

- Predicted 24-hour average ground-level concentrations of PM_{10} for Year 2 and Year 7 comply with the relevant air quality objective at all sensitive receptors, in isolation and cumulatively, with the application of proposed proactive mitigation measures as discussed in Section 6.2.1; and
- Existing annual average concentrations of PM_{10} are higher than the relevant air quality objective. The contribution from VS to the annual average concentrations PM_{10} at a sensitive receptor is at most 2.8 µg/m³ or 11% of the Air EPP objective.

$PM_{2.5}$

- Predicted 24-hour average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7;
- Predicted annual average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7; and
- The background annual average concentration of $PM_{2.5}$ is 6.4 µg/m³ or 80% the Air EPP objective of 8 µg/m³. The maximum contribution of the VS to annual average $PM_{2.5}$ at the sensitive receptors is at most 0.6 µg/m³ or approximately 2.3% of the Air EPP objective.

Dust Deposition

- Predicted dust deposition rates due to the VS ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7.

1. INTRODUCTION

Vitrinite Pty. Ltd. (Vitrinite) is the proponent of Vulcan South (VS), a small scale open cut coal mine located 45 km south of Moranbah in Queensland's Bowen Basin (Figure 1). The VS Mining Lease (ML) is located immediately to the south of Vitrinite's initial mining project, the Vulcan Coal Mine (VCM), located on ML700060 and immediately west of several established mining operations including BMA's Peak Downs and Saraji mines. The VS mining lease application area abuts the VCM ML700060. The proposed mining activities at VS will be located approximately 7km further south than VCM and will not commence until VCM is complete. .

The VS will operate for 9 years and will extract approximately 13.5 million tonnes (Mt) of Run of Mine (ROM) hard coking coal at a rate of up to 1.95 million tonnes per annum (Mtpa). Truck and shovel mining methods will be employed to develop three open cut pits. Year 1 will involve a high wall mining trial to the immediate north of the VS in addition to the three main pits. This trial will occur across four highwall mining benches with a target of extracting approximately 750 kilotonnes (kt) of hard coking coal. The site will include development of a mine infrastructure area and a modular coal handling and preparation plant (CHPP), rail loop and train load-out facility (TLO). The CHPP will include tailings dewatering technologies to maximise water recycling and to produce a dry tailings waste product for permanent storage within active waste rock dumps. Waste rock material will be dumped in previously excavated active pit areas for progressive rehabilitation.

Katestone Environmental Pty Ltd (Katestone) was commissioned by Mining and Energy Technical Services Pty Limited (METServe), on behalf of Vitrinite, to complete an air quality assessment of the VS to support an environmental authority (EA) application.

This air quality assessment has been carried out in accordance with the Queensland Department of Environment and Science's (DES) requirements. The following scope of works has been completed:

- Describe the VS with a focus on elements pertaining to impacts to air quality;
- Describe regulatory requirements relevant to the VS, including air quality objectives and indicators in the *Environmental Protection (Air) Policy 2019*;
- Describe the environmental values in and surrounding the VS areas including sensitive receptors, site topography and built environment, ambient air quality, and an assessment of meteorology;
- Describe onsite sources of air pollutants and develop an air pollutant emission inventory for two operational years of the mine;
- Conduct dispersion modelling to predict ground-level concentrations of dust associated with the mine, providing all model input data/parameters and assumptions;
- Analyse the incremental and cumulative concentrations of dust against the relevant air quality criteria and objectives for dust deposition and particulates;
- Discuss any requirements for proactive mitigation measures, including the need to cease specific operations, and details of dates, durations, and meteorological conditions relevant to these occasions; and
- Prepare an air quality assessment report for inclusion in the EA application.

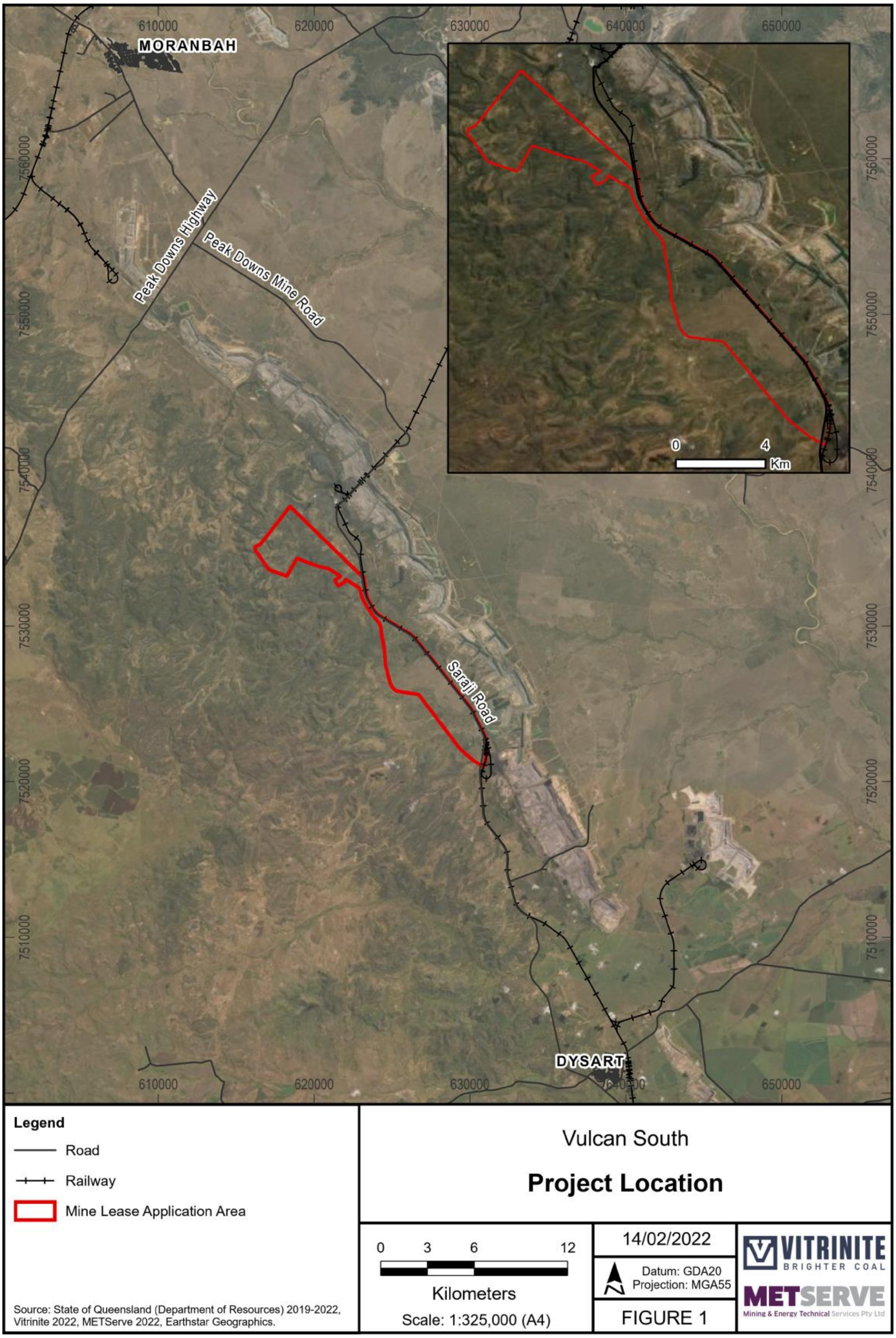

Figure 1 **Vulcan South – Location Plan**

2. OVERVIEW OF THE ASSESSMENT METHODOLOGY

The purpose of this air quality assessment is to address the potential impact to the air environment through consideration of the requirements in the DES's *Application requirements for activities with impacts to air* (DES, 2021). The following sections outline the methodologies adopted in this assessment.

2.1 Assessment scenarios

The VS is a small-scale mining operation, with coal extraction planned for approximately 8 years, followed by completion of rehabilitation activities in Year 9. This air quality assessment has considered two scenarios selected to represent worst-case years based upon volumes of total material extracted, location of activities and location of sensitive receptors. Mine years 2 and 7 have been selected.

Mining information is provided in Table 1 for the eight extraction years. The Year 2 and Year 7 general arrangements are provided in Figure 2 and Figure 3.

Table 1 Project schedule for assessment year

Project Year	Topsoil (t)	Waste Rock (t)	ROM Coal (t)
Year 1	716,977	11,509,214	776,137
Year 2	611,505	41,185,398	1,890,350
Year 3	338,083	40,546,244	1,809,366
Year 4	305,290	40,431,863	1,841,120
Year 5	389,958	40,855,127	1,728,933
Year 6	325,525	41,206,793	1,810,451
Year 7	456,390	40,977,582	1,949,667
Year 8	273,137	25,536,073	1,488,437

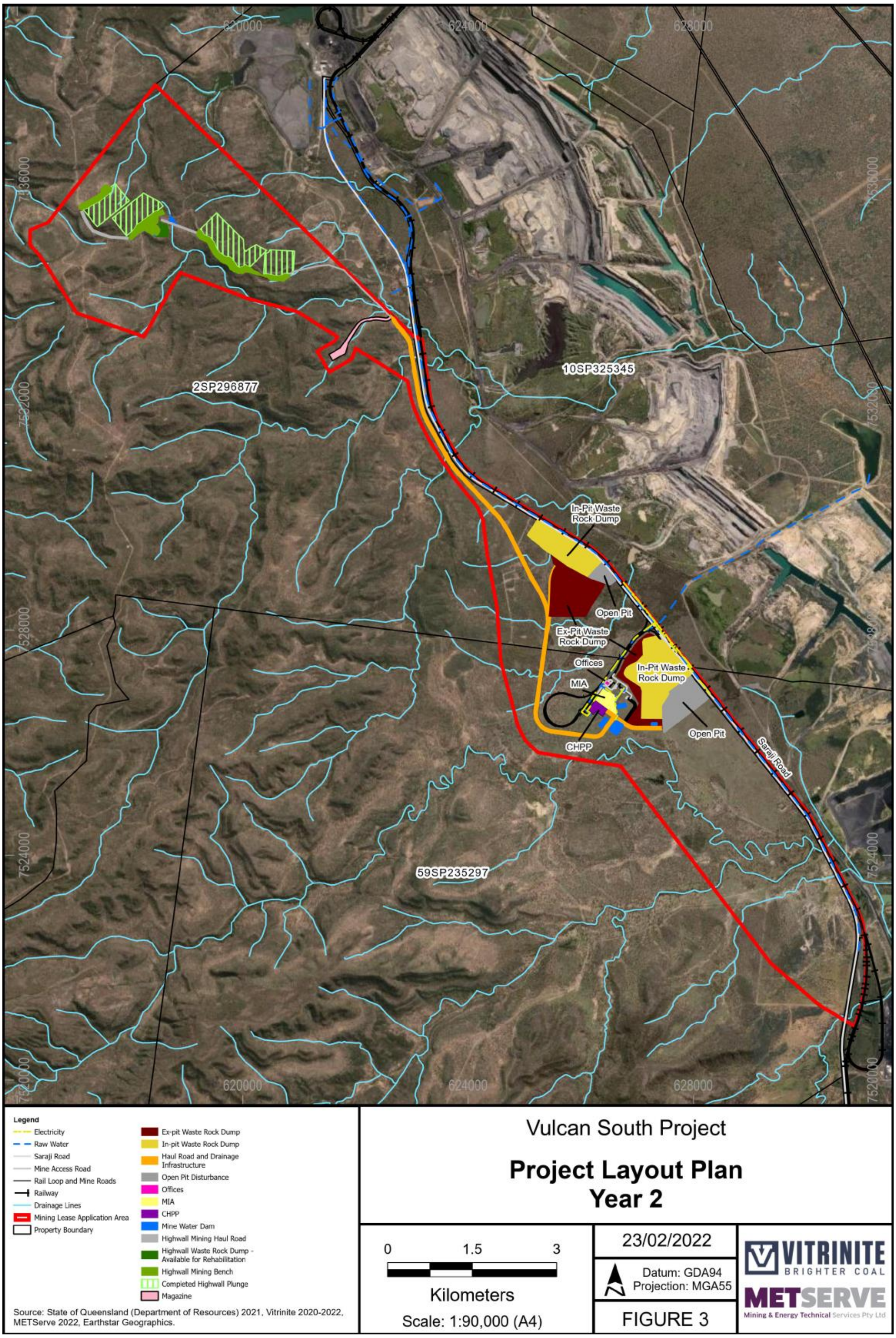

Figure 2 VS Year 2 - Project General Arrangement

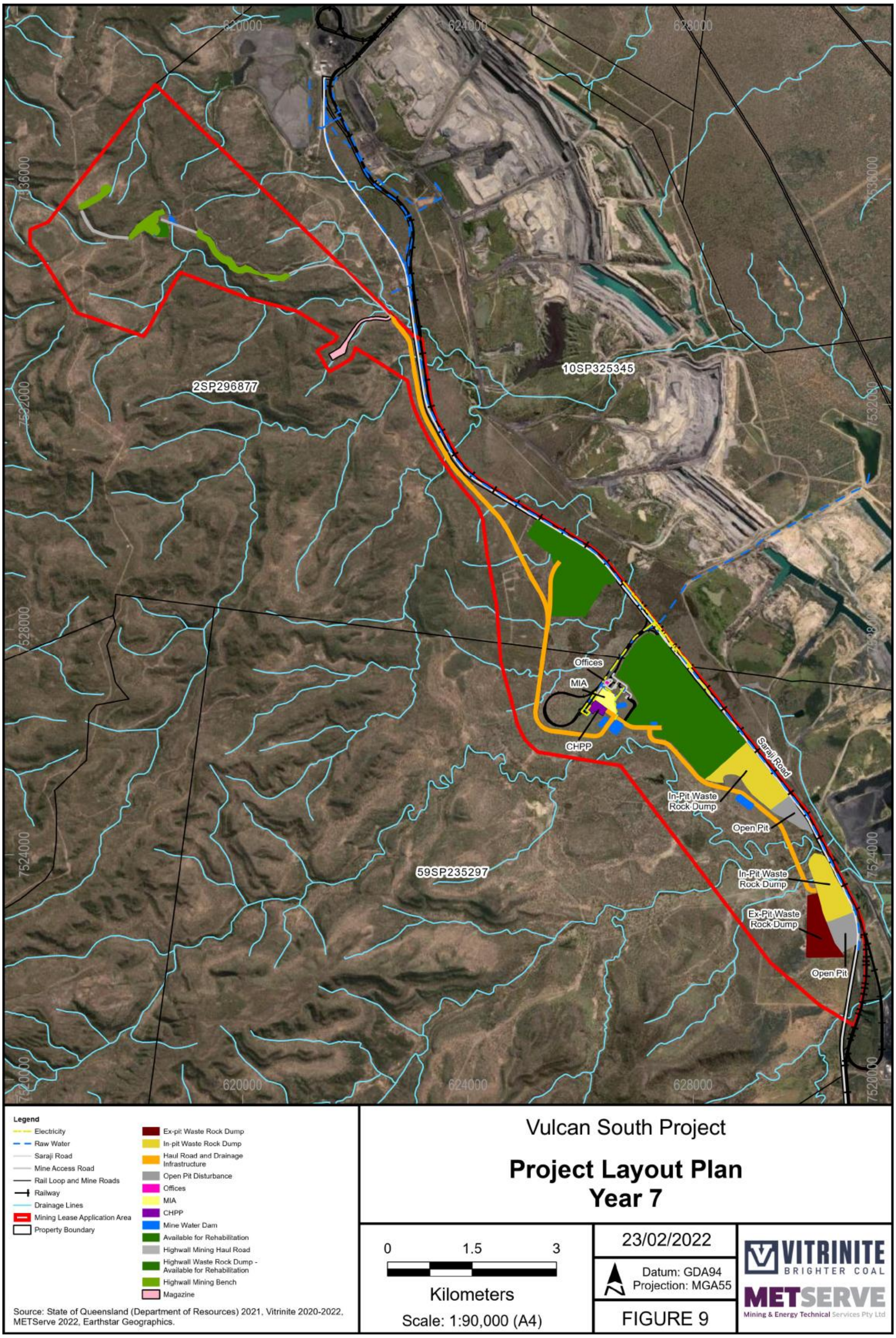

Figure 3 VS Year 7 - Project General Arrangement

2.2 Considerations for assessing air quality

Air pollutants likely to be emitted from the VS have been identified and the current Queensland regulatory requirements pertaining to these air pollutants have been reviewed and relevant objectives presented. Results of the dispersion modelling of air emissions from the VS have been assessed against the applicable air quality objectives.

2.3 Existing environment

The assessment includes an analysis of the existing environment characteristics in the project area that are important for the dispersion of air pollutants from the site, and that may influence the level of air pollutants in the surrounding area. Characteristics include the climate and local meteorology (temperature, wind, humidity and rainfall), any terrain features, the neighbouring land uses and the location of sensitive receptors. The existing air quality in the project area has been quantified through analysis of available ambient air quality monitoring data. Existing sources of similar air pollutants to the air pollutants released by the VS have been identified.

2.4 Emissions

Emissions to the atmosphere associated with the proposed Year 2 and Year 7 VS mining activities have been estimated. The primary air pollutant emitted from mining activities is particulate matter (PM) made up of various sized particles, including: TSP (total suspended particulates), PM_{10} (particulate matter with an aerodynamic diameter less than 10 microns) and $PM_{2.5}$ (particulate matter with an aerodynamic diameter less than 2.5 microns). Other air pollutants anticipated to be generated by the VS, such as combustion emissions related to haul trucks, will be emitted in relatively small quantities and, have therefore, been addressed qualitatively.

2.5 Impact assessment

The potential of the VS to impact air quality has been assessed through a dispersion modelling study and comparison with the air quality assessment criteria.

Source characteristics and dust emission rates from VS activities were incorporated into the CALPUFF dispersion model. CALPUFF is an advanced non-steady-state air quality modelling system. The meteorological data for 2018 generated by the TAPM/CALMET model was used as input for the dispersion model in order to include all weather conditions likely to be experienced in the region during a typical year.

Dust emissions for each scenario have been modelled over a full year assuming 24 hours/day mining activities, except for blasting, which has been modelled between 6 am and 6 pm.

To determine the impact of the VS upon the surrounding environment in a cumulative way, a representative background concentration for relevant air pollutants is required. Background levels of TSP, PM_{10}, $PM_{2.5}$ and dust deposition have been added to the dispersion modelling results of each scenario to provide a cumulative impact.

Where necessary, proactive mitigation measures will be discussed, identifying sources with emissions that require additional control and the duration that the controls are required. Meteorological conditions occurring during these periods of mitigation will also be discussed to aid in identifying conditions which may facilitate increased impacts at sensitive receptors.

The modelling has been used to predict maximum ground-level concentrations and deposition rates of dust across a Cartesian grid of the VS region and at the locations of the identified sensitive receptors.

Technical details of the configuration of the CALPUFF model are discussed in Appendix B.

2.6 Limitations of dispersion modelling

This study relies on the accuracy of several datasets including, but not limited to:

- Third party meteorological information;
- Mine plans and mining activity information; and
- DES ambient air quality monitoring data.

It is important to note that numerical models are based on an approximation of governing equations that represent complex natural processes. These will inherently incorporate some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included. Where uncertainty exists in characterising important properties of the environment or activities associated with the VS, this study has erred on the side of caution and selected conservative inputs. The model outputs are therefore considered to be conservative.

3. CONSIDERATIONS FOR ASSESSING AIR QUALITY

3.1 Pollutants

Particulate matter (i.e. dust) is the key air pollutant anticipated to be generated by activities on the VS site.

3.1.1 Particulate matter

Mining activities can give rise to dust that, in elevated concentrations, has the potential to cause adverse impacts on the amenity and health of people living in the vicinity.

Dust can affect communities in various ways, depending upon the source and size of particles present. Dust typically emitted as a result of mining activities is assessed using the following metrics: TSP (total suspended particulates), dust deposition rate, PM_{10} and $PM_{2.5}$.

Dust from mining activities consists primarily of larger particles generated through the handling of rock and soil, as well as through wind erosion of stockpiles and exposed ground. Larger particles (measured as dust deposition and TSP) are mostly associated with dust nuisance or amenity impacts in residential areas, through settling or deposition of the particles. Elevated dust deposition rates can reduce public amenity, through soiling of clothes, buildings and other surfaces in the area.

Smaller particles such as PM_{10} and $PM_{2.5}$ can also be generated through mining activities. Elevated levels of PM_{10} and $PM_{2.5}$ have the potential to affect human health as these particles can be trapped in the nose, mouth or throat, or be drawn into the lungs. Fine particles (i.e. $PM_{2.5}$) are typically generated through combustion processes.

3.1.2 Other pollutants

Quantities of other air pollutants, such as oxides of nitrogen (NO_x), carbon monoxide (CO) and sulfur dioxide (SO_2), may also be emitted from vehicle traffic and blasting within the VS site. The emission rates of these air pollutants are very low compared to the emission rates of particulate matter from mining activities. Further, the emissions are transient in nature, and therefore, are unlikely to have any negligible effect on air quality outside of the pit and haul road corridor. Hence, particulate matter is considered the critical air pollutant for this assessment.

Odour is unlikely to be emitted from typical mining activities. Spontaneous combustion is a potential source of odour from mining activities but the potential for this is low and, therefore, odour has not been assessed further.

3.2 Legislative framework for air quality

The *Environmental Protection Act 1994* (EP Act) provides for the management of the air environment in Queensland. The EP Act gives DES the power to create Environmental Protection Policies that identify, and aim to protect, environmental values of the atmosphere that are conducive to the health and well-being of humans and biological integrity. *The Environmental Protection (Air) Policy* (Air EPP) was made under the EP Act and gazetted in 1997; the Air EPP was revised and reissued in 2019.

The purpose of the Air EPP is to identify the environmental values of the air environment to be enhanced or protected and to achieve the object of the Act, that is, ecologically sustainable development.

The environmental values to be enhanced or protected under the Air EPP are the qualities of the environment that are conducive to:

- protecting health and biodiversity of ecosystems;
- human health and wellbeing;
- protecting the aesthetics of the environment, including the appearance of building structures and other property; and
- protecting agricultural use of the environment.

The administering authority (DES) must consider the requirements of the Air EPP when it decides an application for an environmental authority, amendment of a licence or approval of a draft environmental management plan. Schedule 1 of the Air EPP specifies air quality indicators and objectives for pollutants that may be present in the air environment.

The air quality objectives that are relevant to the key air pollutants that may be generated from the VS are presented in Table 2.

Also relevant is DES's *Application requirements for activities with impacts to air*, which outlines the information required to be provided to DES as part of the EA application process for environmentally relevant activities and how the information is used. It also outlines how the proposed activity will be assessed in the context of the requirements stipulated in the EP Act. In particular this requires an application to include, if applicable:

- Description of the site and surrounding areas, including topography, prevailing winds and ambient air quality (Section 4);
- Identification and appropriate assessment of any nearby sensitive places (Section 4.2);
- Proposed management and mitigation measures (Section 5 and Section 7); and
- Identification and evaluation of possible impacts on air quality (Section 6).

Table 2 Air quality objectives (Air EPP)

Pollutant	Environmental value	Averaging period	Air quality objective/ guideline
TSP	Health and wellbeing	1-year	90 µg/m³
PM_{10}	Health and wellbeing	24-hour	50 µg/m³
		1-year	25 µg/m³
$PM_{2.5}$	Health and wellbeing	24-hour	25 µg/m³
		1-year	8 µg/m³
Dust deposition	Amenity	1-month	120 mg/m²/day[1]

Note:

[1] The dust deposition guideline is not defined in the Air EPP. DES's Model Mining Conditions (DEHP, 2017a) contains this guideline for dust deposition, which applies to total insoluble solids.

4. EXISTING ENVIRONMENT

4.1 Local terrain and land-use

The VS is located approximately 35 km north of Dysart and 30 km south of Moranbah in central Queensland's Bowen Basin. The VS is located on the lower eastern slopes of the Peak Downs Range.

The terrain rises steeply to the west of the VS, due to the Peak Downs Range, with a maximum elevation of approximately 500 m above sea level. To the east the land is relatively flat and comprised of the plains adjacent to the Isaac River.

The land use within the region is predominantly rural, with the townships of Dysart and Moranbah located to the south and north. State forest, low intensity cattle grazing, and coal mining are the dominant land uses in the VS area.

4.2 Sensitive receptors

Sensitive receptors in proximity to the VS have been identified by METServe, as shown in Table 3 and Figure 4. It is noted that two of the receptors are located within the VS ML (property manager and workers accommodation) and are likely to be removed once VS is approved or when mining occurs in the southern half of the ML (Year 3 onwards). Notwithstanding this, they have been considered as receptors in this assessment (Year 2 only).

There are a number of industrial commercial receptors that are located at nearby operating coal mines to the VS that have not been classed as sensitive receptors. These receptors (Processing plant, rail loadouts and remote crib room areas) are located within nearby operational coal mines and are likely to be exposed to dust from their own onsite operations at levels greater than that produced by VS, and therefore, any potential exposure should be attributable to onsite conditions. As such, only receptors designated as residential have been considered for impacts as part of the assessment.

Table 3 Nearest receptors to the VS

Receptor ID	Type	Description	Easting (km)	Northing (km)	Distance and direction from the VS ML
1	Residential	Property Manager	630.434	7523.439	Within VS ML
2		Workers Accommodation	630.689	7522.987	Within VS ML
3		O'Sullivan Residence	629.573	7519.127	2.3 km S
4	Industrial/Commercial	BMA Peak Downs	621.289	7536.144	0.8 km NE
5		BMA Peak Downs	622.256	7536.261	1.6 km NE
6		BMA Peak Downs	622.156	7536.420	1.6 km NE
7		BMA Peak Downs	621.439	7537.872	2.2 km NE
8		BMA Saraji	631.500	7520.239	1 km S
9	Residential	Luxor Residence	615.449	7508.336	19.5 km SW
10		Cheeseboro Residence	605.305	7519.510	18.4 km W

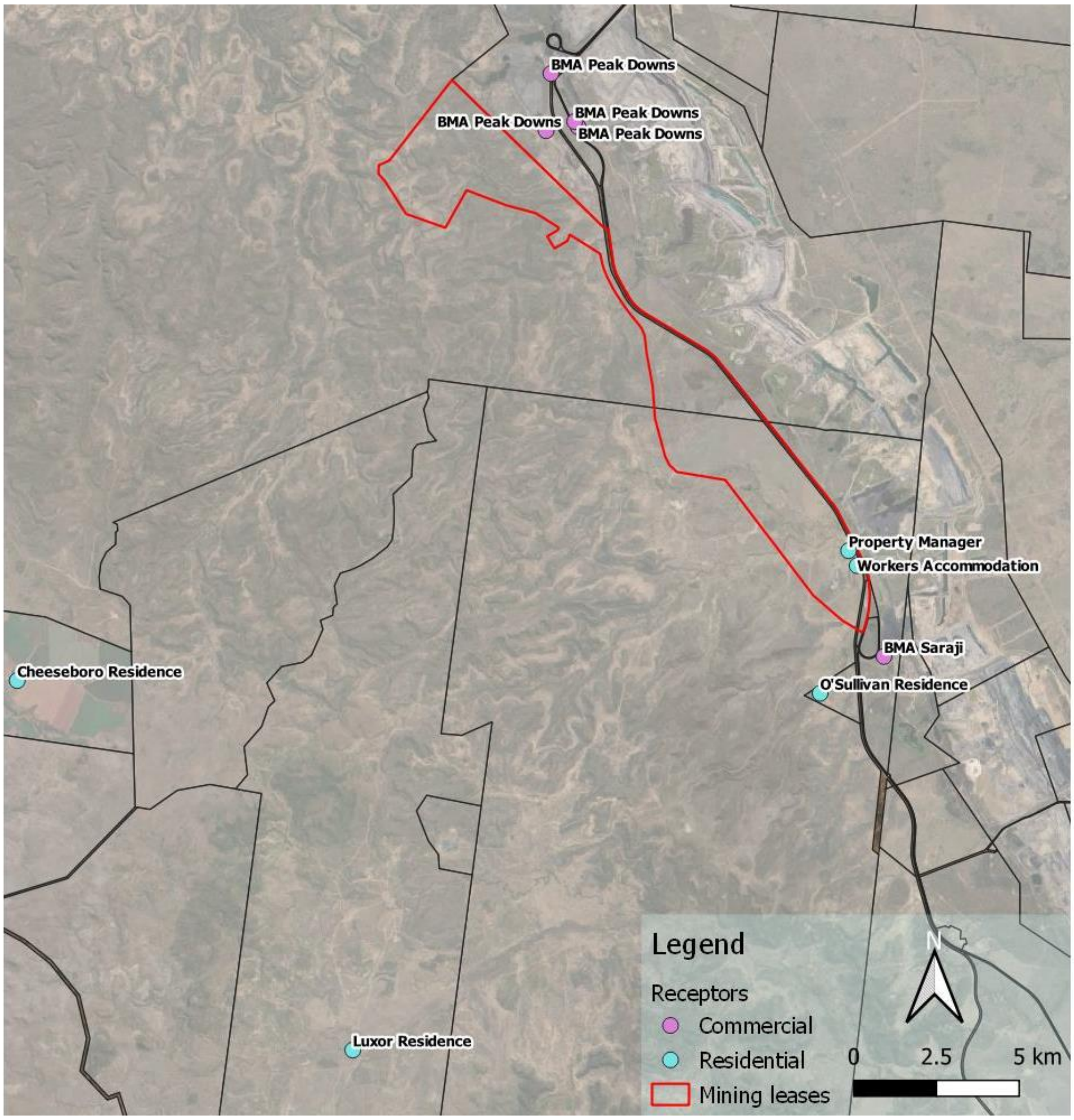

Figure 4 Location of sensitive receptors

4.3 Climate

Central Queensland has a sub-tropical continental climate characterised by high variability in rainfall, temperature and evaporation. The region can experience droughts, floods, heatwaves and frosts. In general, winter days are warm and nights are cool, while summer days are hot and nights are warm. Rainfall is summer dominant with almost half of the average annual rainfall occurring from December to February due to storms and tropical low-pressure systems associated with cyclones.

The Bureau of Meteorology (BoM) weather monitoring station nearest to the VS is located at Moranbah Airport, approximately 35 km northwest. However, this weather station has only been in operation since 2012. Long-term climate data in the VS region, from 1972 to 2012, has been collected from the (now decommissioned) BoM weather monitoring station located at Moranbah Water Treatment Plant. The data is described in the sections below.

4.3.1 Temperature and solar exposure

The mean daily maximum and minimum temperatures by month are presented in Figure 5. The analysis identifies a seasonal temperature profile typical of the sub-tropical Queensland climate, with cooler winter months of June to August and warmer summer months of December to February. The highest mean maximum daily temperature at the Moranbah monitoring station was 33.8 degrees Celsius (°C), recorded during the summer. The lowest mean minimum daily temperature at the monitoring station was 9.9°C, recorded during July.

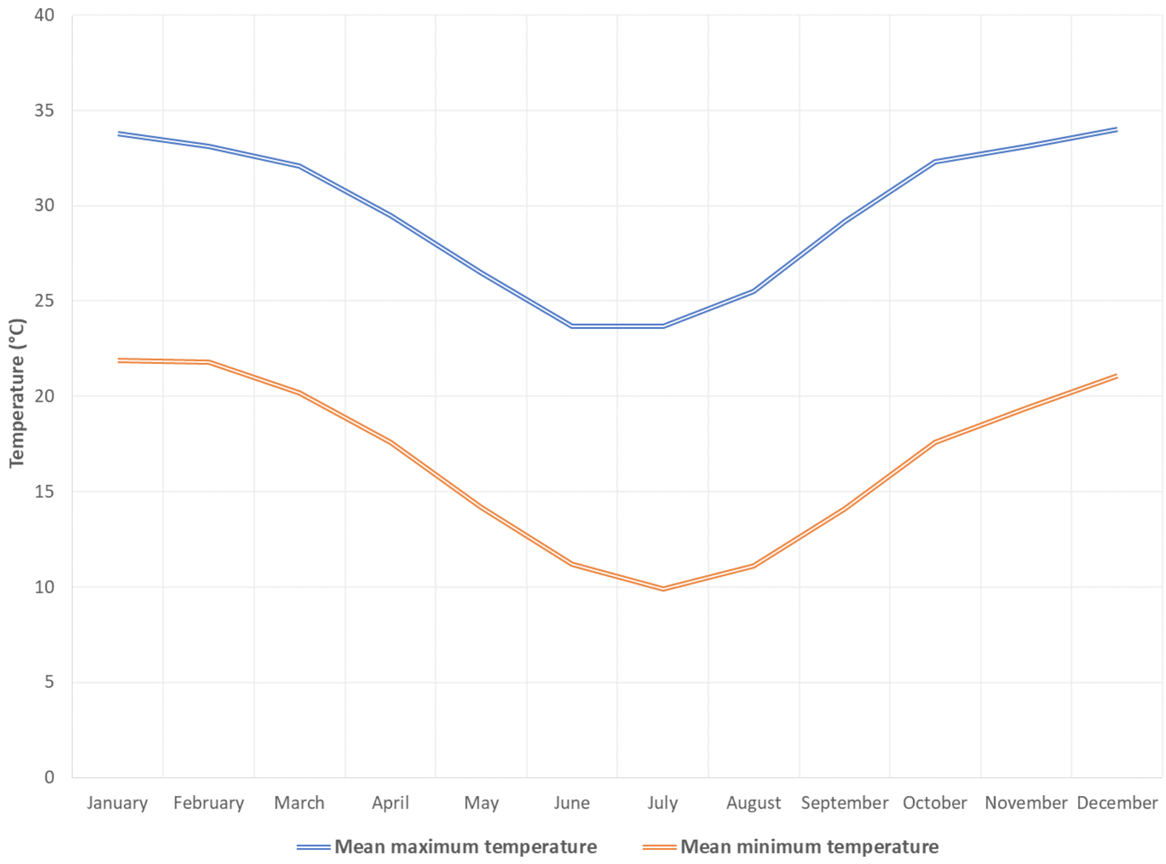

Figure 5 Monthly mean temperature (°C) measured at Moranbah Water Treatment Plant (1986-2012)

The amount of solar radiation received at ground-level is a primary driver for the weather patterns and climatic cycles that influence the Central Queensland region. The average daily solar radiation in megajoules per square metre (MJ/m²) by month is presented in Figure 6. This figure illustrates a clear seasonal pattern whereby summer solar radiation is much greater than during the winter months.

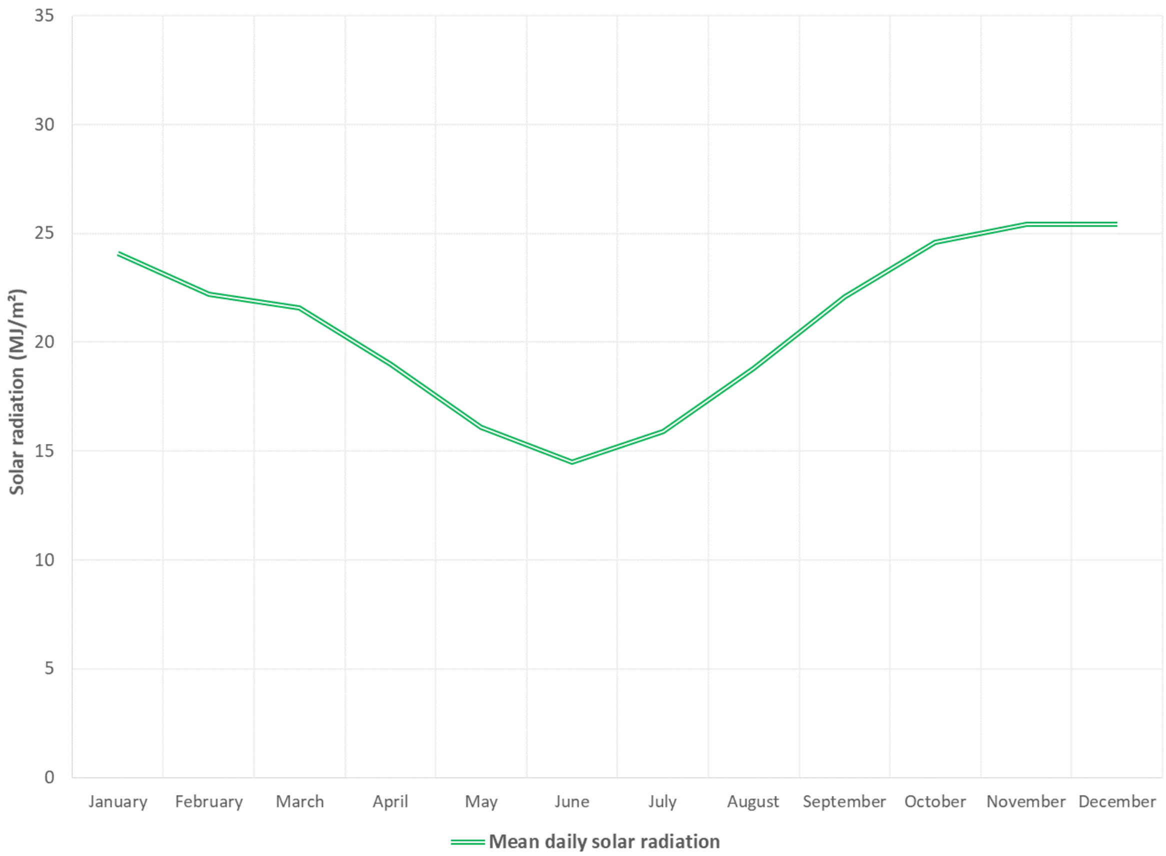

Figure 6 **Mean daily solar radiation (MJ/m²) by month at Moranbah Water Treatment Plant (1986-2012)**

4.3.2 Rainfall

The range of total monthly rainfall (mean and highest) at the Moranbah Water Treatment Plant for 1986-2012 is illustrated in Figure 7. The annual average rainfall is 614 millimetres (mm), with the wettest period occurring during the warmer months from December to February when, on average, 50% of the annual rainfall occurs.

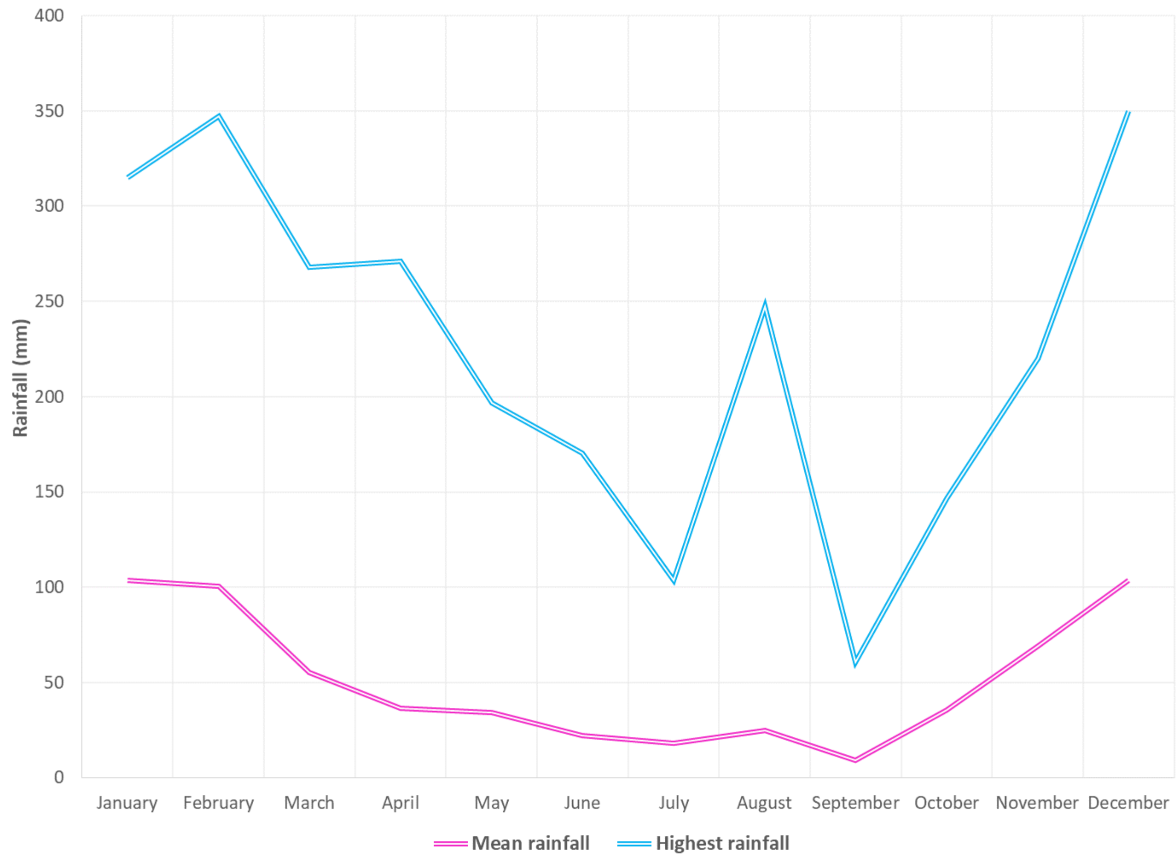

Figure 7 **Range of total monthly rainfall measured at Moranbah Water Treatment Plant (1986-2012)**

4.4 Local Meteorology

The prognostic model TAPM (2008) (developed by the Commonwealth Scientific and Industrial Research Organisation [CSIRO]) and the diagnostic meteorological model CALMET (developed by Earth Tech, Inc.) were used to generate the three-dimensional meteorological dataset at the location of the VS for use in the dispersion model assessment.

The year 2018 was selected as a representative year for meteorological modelling based on analysis of the last five complete years (2014 to 2018) of observations at the BoM Moranbah Airport monitoring station. The year 2018 was selected as representative, as observations of wind speed, wind direction and temperature in 2018 were closest to the average of the 2014 to 2018 period. The three-dimensional wind field for 2018 produced by TAPM/CALMET was then used to create a meteorological file suitable for use with the CALPUFF dispersion model.

The following sections describe the local meteorology of the VS area, focusing on parameters that are important for dispersion of air pollutants, namely wind speed, wind direction, atmospheric stability and boundary layer mixing height.

Details of the TAPM/CALMET model configuration and evaluation are discussed in Appendix B.

4.4.1 Wind speed and wind direction

Wind speed and wind direction influence the rate of dispersion of dust emissions from sources such as wheel generated dust, material transfers, material processing and wind erosion. Wind speed also determines the amount of dust lifted into the air by wind erosion. The 2018 annual, seasonal and diurnal frequencies of winds at the VS site are shown as wind roses in Figure 8, Figure 9 and Figure 10, respectively.

The majority of winds at the site are from the north and south, with the remainder coming primarily from the east to southeast. Seasonally, autumn and winter see winds predominantly from the south, with some south-easterly winds. Wind direction shifts to come predominantly from the north during Spring and Summer, with Summer also observing some winds from the east. Annual average wind speed for the site is 2.53 m/s.

There is a diurnal variation in the wind distribution, with a higher frequency of light winds occurring overnight (6 pm to 6 am) compared to the day. Strong winds from the east and southeast occur during the afternoon (midday to 6 pm). Morning winds (6 am to midday) are mostly from the south and southeast.

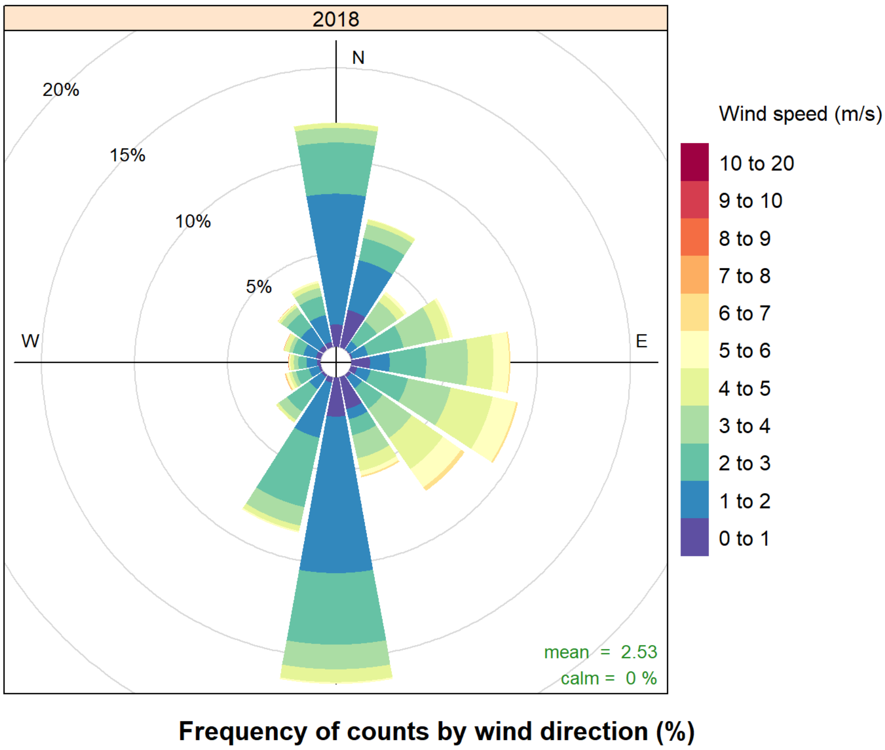

Figure 8 Annual wind rose for the VS site (extracted from CALMET) - 2018

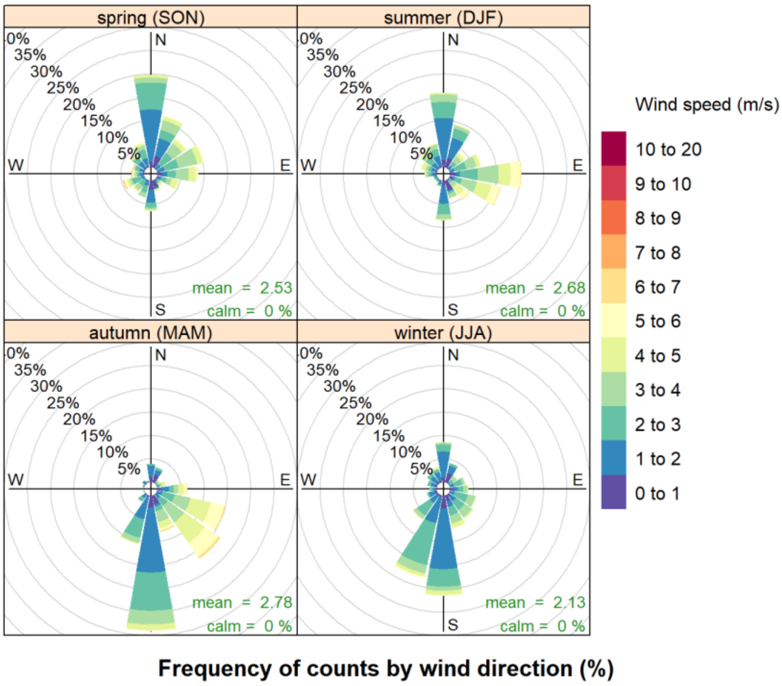

Figure 9 Seasonal wind roses for the VS site (extracted from CALMET) – 2018

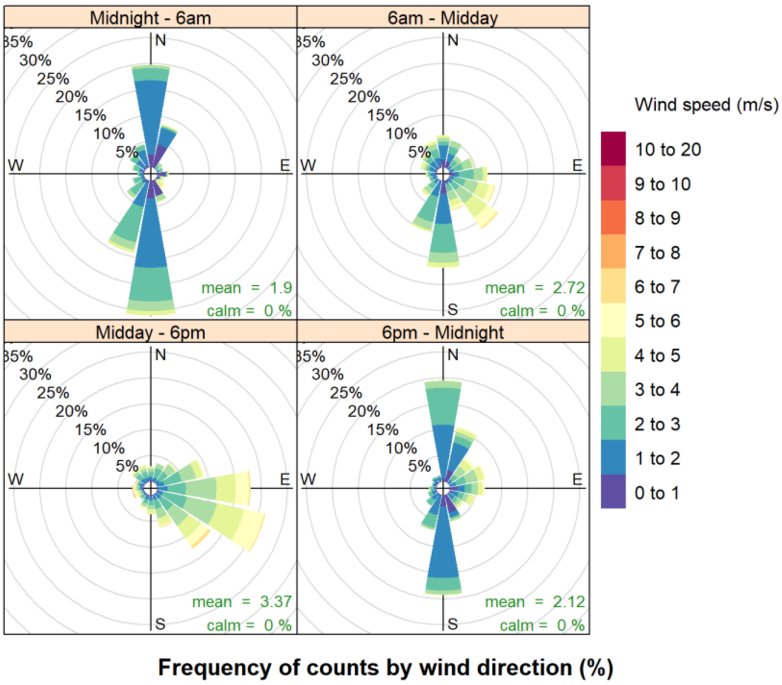

Figure 10 Diurnal wind roses for the VS site (extracted from CALMET) - 2018

4.4.2 Atmospheric stability and mixing height

Atmospheric stability class is a measure of the stability of the atmosphere. Stability classes range from A class to F class. Figure 11 shows the predicted annual frequency of stability classes in the VS area (taken from the meteorological dataset generated by the TAPM/CALMET models).

Class A represents the most unstable conditions and Class F the most stable conditions. Unstable conditions (Classes A to C) are characterised by strong to moderate solar heating of the ground. This induces turbulent mixing in the atmosphere close to the ground. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for the most frequently occurring Class D conditions are dominated by mechanical turbulence, generated as the wind passes over irregularities in the local surface. During light wind and clear sky conditions at night, the atmosphere is generally stable (classes E and F). Strong winds and/or overcast conditions at night lead to Class D conditions.

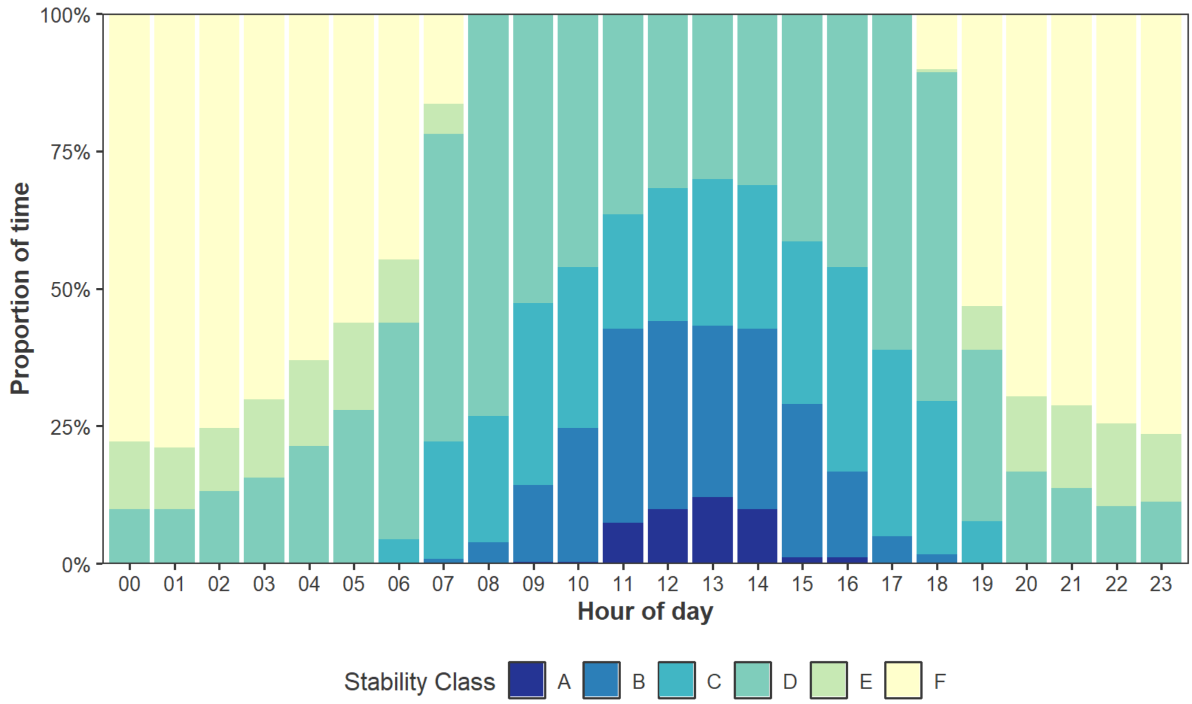

Figure 11 Stability class frequency for the VS site (extracted from CALMET) - 2018

The mixing height defines the height of the mixed atmosphere above the ground (mixed layer), which varies diurnally. Particulate matter, or other pollutants released at or near the ground, will become dispersed within the mixed layer. During stable atmospheric conditions, the mixing height is often quite low and particulate dispersion is limited to within this layer. During the day, solar radiation heats the ground and causes the air above it to warm, resulting in convection and an increase to the mixing height. The growth of the mixing height is dependent on how well the warmer air from the ground can mix with the cooler upper level air and, therefore, depends on meteorological factors such as the intensity of solar radiation and wind speed. During strong wind speeds, the air will be well mixed, resulting in a high mixing height.

Hourly mixing height information in 2018 has been extracted from the CALMET simulation over the VS area and is presented in Figure 12 as a diurnal frequency plot. The data shows that, on average (blue dots), the mixing height develops at approximately 7 am, increases to a peak between 3 pm and 4 pm before descending rapidly until 6 pm.

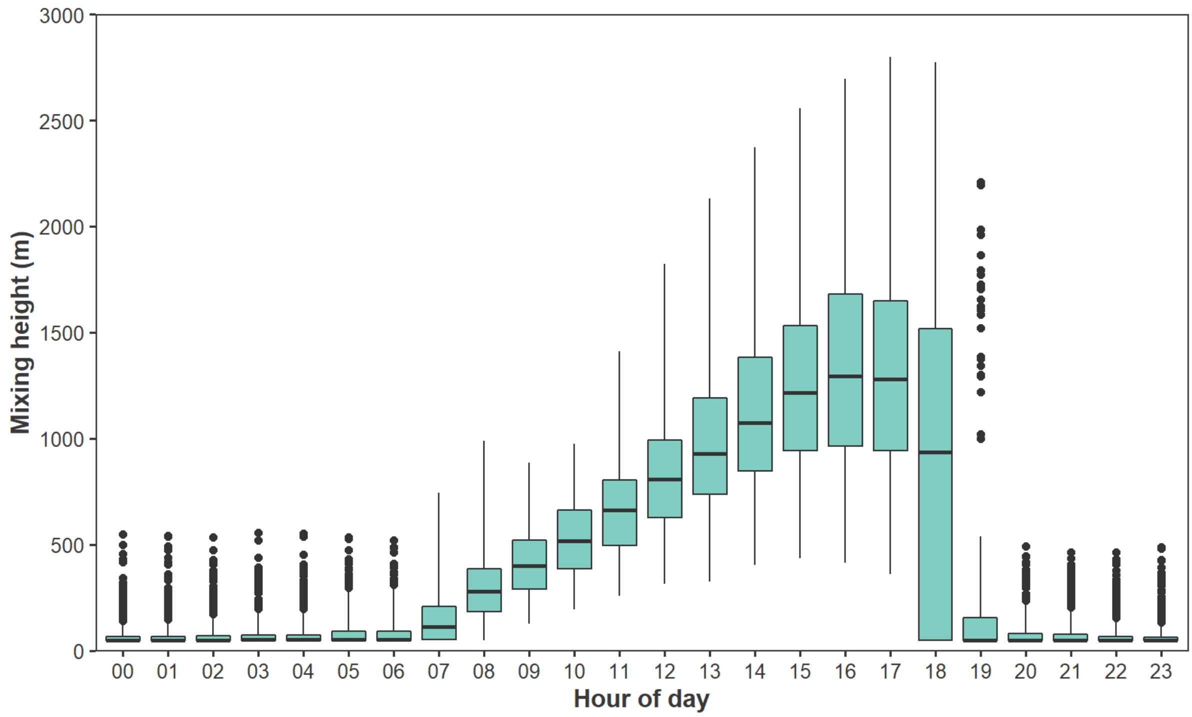

Figure 12 **Diurnal variation in mixing height at the VS site (extracted from CALMET) - 2018**

4.5 Ambient air quality

There are several existing sources in the vicinity of the VS that may generate dust, including a number of existing coal mines (BMA's Caval Ridge, Peak Downs and Saraji mines). Naturally generated dust in the environment may also be generated in the VS region, sources include pollen and grass seeds; dust from the use of dirt roads; agricultural activities and wind erosion of non-vegetated areas.

Existing air quality has been determined from a review of available information on dust emissions and representative ambient air quality monitoring data in the region.

4.5.1 Existing sources of air pollutants

Industries within 35 km of the VS that produce noteworthy dust emissions (PM_{10} and $PM_{2.5}$) have been identified through a review of the National Pollutant Inventory (NPI) database. The dominant contributing industry in the region is coal mining.

Table 4 details the dust emissions (PM_{10} and $PM_{2.5}$) reported to the NPI for 2018/19 (the most recent publicly available dataset) from identified industries in the VS region.

Table 4 Dust emissions reported to NPI for 2019/2020

Facility Name	Main Activities	Distance and Direction from VS CPP	PM_{10} (tonnes/year)	$PM_{2.5}$ (tonnes/year)
Caval Ridge Mine	Coal Mining	18.4 km Northwest	7,588	109
Daunia Mine	Coal Mining	27.5 km Northeast	1,934	69
Lake Vermont	Open cut coal mining	34.9 km Southeast	9,921	663
Peak Downs Mine	Coal Mining	1.6 km North	14,600	191
Poitrel Coal Mine	Coal Mining	26 km Northeast	2,340	76
Saraji Mine	Coal Mining	17.3 km South	8,218	167
South Walker Creek Mine Operations	Coal Mining	4.8 km East	3,458	57

4.5.2 Existing ambient air quality

4.5.2.1 PM_{10} and $PM_{2.5}$

Long-term continuous monitoring data for PM_{10} and $PM_{2.5}$ in the Project area is available from two DES monitoring stations located in the township of Moranbah (approximately 28 km north-northwest). A summary of the two stations is provided below in Table 5.

Table 5 Summary of DES Monitoring locations

Monitoring Station	Monitoring Period	Parameters Monitored
Moranbah East (Utah Drive)	March 2011 - Current	PM_{10}, $PM_{2.5}$[1]
Moranbah West (Cunningham Way)	June 2020 – Current	PM_{10}, $PM_{2.5}$

Table notes:
[1] $PM_{2.5}$ monitoring at Moranbah East started in October 2019

As monitoring at Moranbah West (Cunningham Way) only commenced in June 2020, it has not been considered further. Relevant PM_{10} statistics from data measured from 2011 to 2021 at DES's Moranbah East (Utah Drive) site are presented in Table 6, while $PM_{2.5}$ statistics from data measured from 2019 to 2021 are presented in Table 7. (Queensland Data, 2019).

The Moranbah East PM_{10} data shows the following:

- The Moranbah monitoring station has recorded 109 days when the 24-hour average concentration of PM_{10} was greater than 50 µg/m³ (Air EPP objective) over the 11 years of monitoring. In particular, 2012, 2018 and 2019 show a large number of PM_{10} concentrations greater than 50 µg/m³;
    - In 2012, there were 36 days when the 24-hour average concentration of PM_{10} was greater than 50 µg/m³. DES's monthly monitoring reports indicate that, for a period of 4 months, housing construction work was occurring within 100 meters of the monitoring station and was the likely cause of the elevated concentrations;

- In 2017, there were 7 days when the 24-hour average concentration of PM_{10} was greater than 50 µg/m³. DES's monthly monitoring reports indicate that bushfires contributed to these elevated concentrations;
- In 2018, there were 19 days when the 24-hour average concentration of PM_{10} was greater than 50 µg/m³. DES's monthly monitoring reports indicate that dust storms and bushfires contributed to these elevated concentrations;
- In 2019, there were 32 days when the 24-hour average concentration of PM_{10} was greater than 50 µg/m³. DES's monthly monitoring reports indicate that a combination of emission sources including dust storms, bushfires, and hazard-reduction burning contributed to these elevated concentrations;
- In 2020, there were 5 days when the 24-hour average concentration of PM_{10} was greater than 50 µg/m³. DES's monthly monitoring reports indicate that a combination of emissions sources including dust storms, smoke from bushfires and local dust sources contributed to these elevated concentrations; and
- Annual average concentrations of PM_{10} at the Moranbah monitoring station were greater than the Air EPP objective of 25 µg/m³ for four of the nine years, 2012, 2017, 2018 and 2019.

The Moranbah East $PM_{2.5}$ data shows the following:

- The Moranbah monitoring station has recorded 5 days when the 24-hour average concentration of $PM_{2.5}$ was greater than 25 µg/m³ (Air EPP objective) over the last 2 years of monitoring.
  - From October onwards in 2019, there was 1 day when the 24-hour average concentration of $PM_{2.5}$ was greater than 25 µg/m³. DES's monthly monitoring reports indicate that a combination of smoke haze from bushfires and local dust sources contributed to this elevated concentration;
  - In 2020, there were 4 days when the 24-hour average concentration of $PM_{2.5}$ was greater than 25 µg/m³. DES's monthly monitoring reports indicate that it is most likely that smoke and dust generated by vehicles on unsealed roads contributed to elevated concentrations on days in May and July. DES has not yet released the monthly bulletins for September, when the other two exceedance days occurred; and
  - Annual average concentrations of $PM_{2.5}$ at the Moranbah East monitoring station were greater than the Air EPP objective of 8 µg/m³ for the three-months of monitoring in 2019.

Of the available monitored concentrations of $PM_{2.5}$ at the Moranbah East monitoring station, only 2020 data is validated and complete. Hence, the 2020 dataset provides the most representative ambient $PM_{2.5}$ concentrations in the vicinity of the Project, and thus were used in the cumulative assessment.

Table 6 **Summary of 24-hour average PM_{10} concentrations measured at Moranbah East (Utah Drive)**

Year	PM_{10} (µg/m³)			
	24-hour average (Maximum)	No. days above 50 µg/m³	24-hour average (70th percentile)	Annual average
2011	67.6	5	23.4	20.3
2012	492.8	36	29.5	27.9
2013	99.9	1	26.5	22.4
2014	49.9	0	24.0	20.4
2015	91.9	4	25.3	21.3
2016	49.5	0	27.2	22.1
2017	68.8	7	29.6	26.1
2018	113.6	19	34.6	30.3
2019	217.8	32	35.5	31.2
2020	89.8	5	23.4	21.1
2021[1,2]	47.3	0	23.6	20.8
Objective	**50**	**-**	**-**	**25**

Table note:

[1] Eleven months of data in 2021 for Utah Drive

[2] Data downloaded from DES portal. Data was unvalidated at time of assessment.

Table 7 **Concentrations of $PM_{2.5}$ at Moranbah East (Utah Drive) monitoring station from 2019 to 2021 inclusive**

Year	$PM_{2.5}$ (µg/m³)			
	24-hour average (Maximum)	No. days above 25 µg/m³	24-hour average (70th percentile)	Annual average
2019[1]	26.1	1	13.6	11.7
2020	53.9	4	6.6	6.4
2021[2,3]	11.3	0	6.3	5.6
Objective	**25**	**-**	**-**	**8**

Table note:

[1] 2019 does not represents a full year of monitoring, it represents a period from October 2019

[2] Eleven months of data in 2021 for Utah Drive

[3] Data downloaded from DES portal. Data was unvalidated at time of assessment.

Analysis of rainfall at the BoM Moranbah Airport meteorological monitoring station for the period 2012 to 2020 indicates that the last three years were driest. Total days of rainfall per annum were close to the 2012 to 2020 average (Figure 13); however, total annual rainfall was well below average for 2018, 2019, and 2020, with 2019 being the lowest compared to other years, reaching 35% below average (Figure 14). Annual total rainfall for all Australia shows 2019 was the driest overall year for the last 120 years (Table 8) with 275.71 mm of rain compared to the 120-year annual average rainfall of 457.21 mm, approximately 40% below average (BoM, 2020). These dry conditions are likely to exacerbate the potential for air-borne dust.

Therefore, the use of monitoring data from any of the last three years is likely to provide a conservative assessment of cumulative impacts.

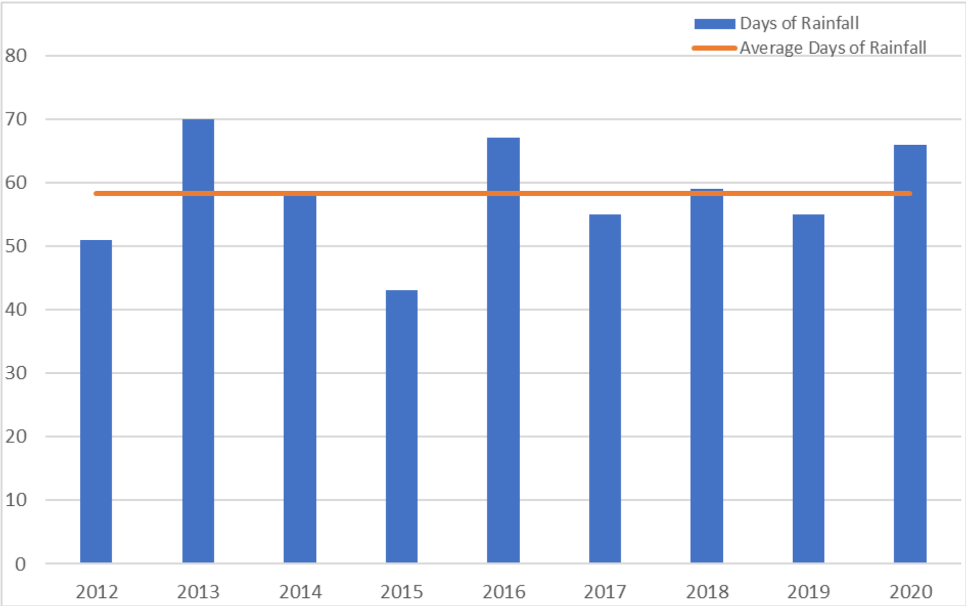

Figure 13 **Total rain days recorded at the Moranbah Airport BoM meteorological station 2012-2020**

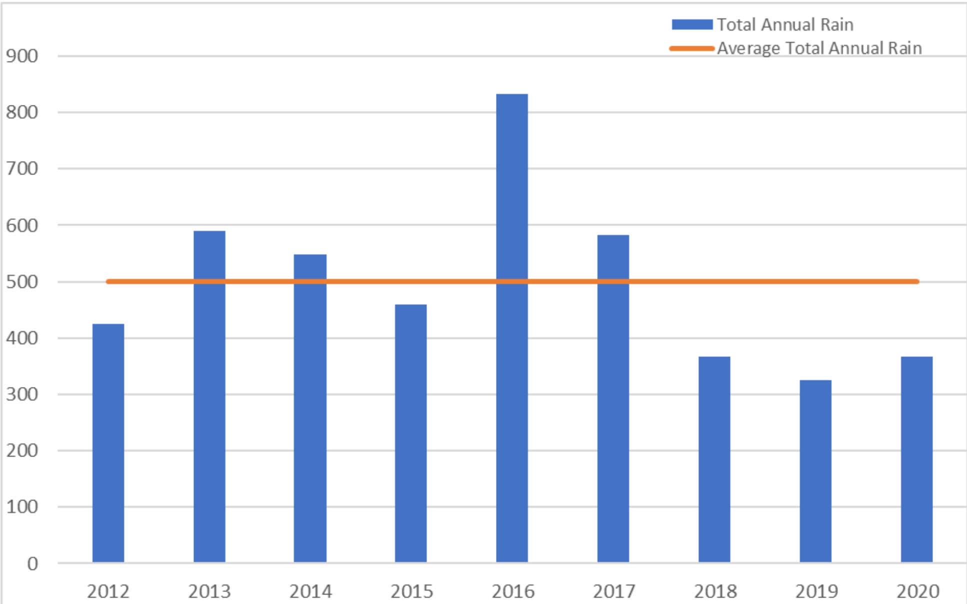

Figure 14 **Total annual rainfall (mm) recorded at the Moranbah Airport BoM meteorological station 2012-2020**

Table 8 Summary of 120 years of annual average rainfall data for Australia (BoM 2020)

Average Rainfall (1900 to 2019)	Min Rainfall (1900 to 2019)	Max Rainfall (1900 to 2019)	2019 Annual Rainfall
457.21	275.71	760.57	275.71

4.5.2.2 TSP

DES does not conduct monitoring for TSP at its Moranbah site. TSP has been calculated from DES Moranbah PM_{10} data, assuming TSP is twice the PM_{10}. This assumption is based on the TSP/PM_{10} ratios found in the NPI manual mining emission factors for fugitive dust that range from 25% to 52%.

4.5.2.3 Dust deposition rate

DES began monitoring dust deposition at its Moranbah stations in 2020. Moranbah East began monitoring in February 2020, while Moranbah West began in July 2020. Validated monthly maximum concentrations for both stations are available until July 2021 currently. Moranbah West data was not considered due to having only 12 months of validated data compared to 18 months at Moranbah East. Rolling annual averages were calculated for data from Moranbah East, with the maximum rolling annual average being 79.4 mg/m^2/day.

4.5.3 Summary of background dust levels

Background levels of TSP, PM_{10}, $PM_{2.5}$ and dust deposition used in this assessment are summarised in Table 9. The background levels have been derived from the publicly available data presented in the previous sections.

Table 9 Ambient background concentrations used to assess cumulative impacts

Pollutant	Averaging Period	Concentration	Comment
TSP	Annual	62.4 µg/m^3	Used annual average PM_{10} of 31.2 and assumed PM_{10} is 50% of TSP
PM_{10}	24-hour	35.5 µg/m^3	Highest 70th percentile value at DES Moranbah East, 2019
	Annual	31.2 µg/m^3	Highest average value at DES Moranbah East, 2019
$PM_{2.5}$	24-hour	6.6 µg/m^3	70th percentile value at DES Moranbah East, 2020
	Annual	6.4 µg/m^3	Average value at DES Moranbah East, 2020
Dust deposition	Annual average	79.4 mg/m^2/day	Rolling average at DES Moranbah East

5. EMISSIONS TO THE ATMOSPHERE

Dust will be emitted over the life of the VS. Dust emissions can occur from the extraction, handling, transportation and processing of material (topsoil, overburden and coal), as well as from wind erosion of exposed areas and material stockpiles.

In addition to dust emissions, emissions of NO_X, SO_X and CO would occur due to blasting activities and the combustion of fuels on site. These emissions are transient, occur within the haul road corridor and open-cut pits and low in magnitude compared to dust emissions and have not been considered further.

Dust mitigation measures proposed by Vitrinite and a dust emissions inventory for the VS are provided in the following sections.

5.1 Overview

The key dust-generating activities over the life of the VS would be:

- Topsoil stripping;
- Drilling and blasting;
- Haulage of overburden and ROM coal;
- Wind erosion of stockpiles, exposed and rehabilitated areas;
- CHPP and rail load out;
- Dozers;
- Material handling; and
- Road grading.

5.2 Emission estimation

To assess potential air quality impacts due to the VS, potential dust emissions from individual mining activities in each scenario were accounted for and have been explicitly modelled. Specific activity information used to calculate dust emission rates associated with individual mining activities were provided or confirmed by METServe.

Dust emission rates were estimated using the base equation:

$$ER = A \times EF \times (1 - CF)$$

where:

ER	emission rate
A	activity / operations data
EF	emission factor
CF	reduction in emissions due to the implementation of control measures.

Emissions of TSP, PM_{10} and $PM_{2.5}$ from mining activities were estimated using recognised and accepted methods of dust emissions estimation. These include approximation of emission rates from NPI emissions estimation technique handbooks and the United States Environmental Protection Agency (US EPA) AP42 emission handbooks (US EPA, 1998; US EPA, 2006a; US EPA, 2006b; NPI, 2012).

The emissions estimation techniques applied in this assessment are based on standard methods that are applied throughout Australia and in the United States. These methods are consistent with those adopted for other air quality assessments conducted for other coal mines in Australia. The size distribution of dust particles was derived from the emission rates estimated for TSP, PM_{10}, and $PM_{2.5}$.

A dust emission inventory for the VS is detailed in Section 5. The activity data and emission factor equations used to estimate dust emissions are detailed in Appendix A.

5.3 Mitigation measures

5.3.1 Standard dust control measures

Dust mitigation and operational controls have been included in the VS design to limit dust emissions from mining activities, including:

- Water application on all major haul routes within the VS domain; and
- Progressive rehabilitation of areas that have been mined.

These dust mitigation measures have been accounted for in the dust emissions inventory. The effectiveness of each control measure is presented in Table 10. An additional control factor of 50% for TSP and 5% for PM_{10} has been applied to all pit activities to account for pit retention (NPI, 2012 – Table 4).

Table 10 Standard dust control measures and relative reduction in emissions

Activity	Control measure	Reduction (%)
Wheel-generated dust and grading	Water application	85
Wind erosion	Rehabilitated areas (initial)	40

5.3.2 Proactive mitigation measures

In order to maintain compliance with the Air EPP (2019) air quality objectives additional proactive mitigation measures may be required. These proactive measures involve ceasing particular operations within the VS site for certain periods when a combination of meteorological conditions and VS operations are likely to result in elevated ground-level concentrations. Details of proactive mitigation steps are provided in Section 6.

5.4 Emission inventory

A summary of the total dust emission rates estimated for Year 2 and Year 7 of the VS are presented in Table 11. A detailed breakdown of the dust inventory for each year is then provided in Table 12.

Emissions have been estimated as described in Appendix A. The inventory includes all VS mining activities up to and including loading of product coal to trains for transport off site.

Table 11 Estimated TSP, PM_{10} and $PM_{2.5}$ emission rates for the VS

Mine Year	Units	TSP	PM_{10}	$PM_{2.5}$
Year 2	kg/annum	2,607,256	1,054,308	157,387
Year 7	kg/annum	2,838,281	1,116,748	172,073

Table 12 VS Year 2 and Year 7 – breakdown of TSP, PM_{10} and $PM_{2.5}$ emission rates (g/s)

Activity	Year 2			Year 7		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Pit activities						
Drilling and blasting	5.66	2.94	0.17	2.83	1.47	0.08
Excavating overburden	33.13	15.90	2.37	32.85	15.77	2.35
Excavating ROM	2.19	0.34	0.16	2.26	0.35	0.16
Dumping activities						
Truck dumping overburden	15.74	5.62	1.04	15.69	5.62	1.12
Truck dumping ROM	2.19	0.34	0.12	2.26	0.35	0.12
Bulldozing overburden	0.77	0.21	0.08	0.69	0.17	0.07
Bulldozing ROM	2.55	0.88	0.06	2.55	0.88	0.06
Bulldozing Rehabilitation areas	0	0	0	0.23	0.06	0.02
Haulage						
ROM coal haulage	2.23	0.56	0.06	3.78	0.94	0.09
Overburden haulage	6.64	1.65	0.17	11.21	2.80	0.28
Grading haul roads	0.99	0.29	0.03	0.99	0.29	0.03
CHPP Processing						
Sizing and crushing	0.91	0.33	0.03	0.94	0.34	0.03
Truck loading and transfers including rail loadout	1.34	0.21	0.10	1.38	0.22	0.10
Wind erosion						
Stockpiles	0.39	0.19	0.03	0.39	0.19	0.03
Exposed areas	7.94	3.97	0.60	5.41	2.70	0.41
Rehabilitated areas	0	0	0	6.53	3.27	0.49
Total (g/s)	**82.68**	**33.43**	**4.99**	**90.0**	**35.4**	**5.46**

6. IMPACT ASSESSMENT RESULTS

This section presents the results of the dispersion modelling assessment of the VS. Modelling results associated with proposed Year 2 and Year 7 activities have been presented as ground-level concentrations or dust deposition rates at the residential sensitive receptors as well as contours across the modelling domain. As previously noted, Receptors 1-3 are considered in Year 2 and only Receptor 3 is considered in Year 7.

Background dust levels have been added to the incremental model predictions in order to obtain an estimate of the potential cumulative impacts of the VS at sensitive receptors. Results have been assessed by comparing the predicted concentrations and dust deposition rates with the relevant air quality objectives.

The contour plots illustrate the spatial dispersion of pollutants over time. They are constructed such that the highest 24-hour average or annual average value is obtained and stored at each point in the modelled domain. As these values may occur at different times at different grid points, the contour plots do not represent a single snapshot of concentrations at any given time, rather a peak impact.

6.1 TSP

The predicted annual average ground-level concentrations of TSP for Year 2 and Year 7 of the VS assessed in isolation and with background levels applied (cumulative assessment) are presented in Table 13.

Contour plots of the predicted annual average ground-level TSP concentrations for Year 2 and Year 7 of the VS are presented in Plate 1 and Plate 2, respectively, and provide the results for the VS in isolation.

The results show that:

- Predicted ground-level concentrations of TSP ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7.

Table 13 Predicted annual average ground-level concentrations of TSP (µg/m³)

Receptor	Label	Year 2		Year 7	
		VS	Cumulative	VS	Cumulative
1	Property Manager	3.0	65.4	*Not applicable to Year 7*	
2	Workers Accommodation	3.0	65.4		
3	O'Sullivan Residence	0.7	63.1	2.2	64.6
9	Luxor Residence	0.2	62.6	0.2	62.6
10	Cheeseboro Residence	0.2	62.6	0.2	62.6
	Background	-	*62.4*	-	*62.4*
Objective		**90 µg/m³**			

6.2 PM_{10}

The predicted maximum 24-hour average and annual average ground-level concentrations of PM_{10} for Year 2 and Year 7 of the VS in isolation and with background levels applied (cumulative assessment) are presented in Table 14 and Table 15, respectively.

Contours of the predicted maximum 24-hour average and annual average ground-level concentrations of PM_{10} for Year 2 and Year 7 of the VS are presented in Plate 3, Plate 4, Plate 5 and Plate 6, respectively and provide the results for the VS in isolation.

The results show that:

- Predicted 24-hour average ground-level concentrations of PM_{10} for Year 2 and Year 7 comply with the air quality objective at all sensitive receptors, in isolation and cumulatively with a combination of standard and proactive mitigation measures. Receptors 1 - 3 comply with the application of additional proactive mitigation measures including:
    - For Year 2:
        - Proactive mitigation measures may be required up to 22 nights per year to maintain compliance at R1 and R2. The modelling indicates that a complete shutdown of mining operations during the night is required. This includes all operations identified in Table 16.
        - Proactive mitigation measures may be required one night of the year to maintain compliance at R3. The modelling indicates that ceasing operation of the Main pit for one night will be sufficient to maintain compliance. The specific activities in this operational location include pre-stripping waste material with excavators, excavating OB, and excavating ROM.
    - For Year 7:
        - Proactive mitigation measures may be required up to 10 nights per year to maintain compliance at R3. On these nights the modelling indicates ceasing operation of the South pit, Main pit and South pit – outpit dump is required as shown in Table 17. The specific activities in these operational locations include pre-stripping waste material with excavators, excavating OB and ROM, and truck dumping and dozing of OB.
- Predicted annual average ground-level concentrations of PM_{10} for Year 2 and Year 7 comply with the air quality objective at all sensitive receptors in isolation.
- The background annual average concentration of PM_{10} is 31.2 µg/m³, which is above the Air EPP objective of 25 µg/m³. The maximum contribution of the VS (Year 2 or Year 7) to annual average $PM_{2.5}$ at the sensitive receptors is at most 2.8 µg/m³ or approximately 11% of the Air EPP objective.

Additional details regarding proactive mitigation measures are discussed in the following section, including when mitigation is required, which sources require reductions in activity, and meteorological conditions conducive to producing exceedances.

Table 14 Predicted ground-level concentrations of PM_{10} (µg/m³) for Year 2

Receptor	Label	Year 2			
		24-hour		Annual	
		VS	Cumulative[D]	VS	Cumulative
1	Property Manager	14.4[A]	49.9[A]	2.8	34.0
2	Workers Accommodation	14.3[B]	49.8[B]	2.8	34.0
3	O'Sullivan Residence	9.3[C]	44.8[C]	0.7	31.9
9	Luxor Residence	2.3	37.8	0.2	31.4
10	Cheeseboro Residence	2.0	37.5	0.1	31.3
	Background	-	*35.5*	-	*31.2*
Objective		**50 µg/m³**		**25 µg/m³**	

Table note:

[A] Predicted concentration accounts for shutting down all night-time activities for 22 nights per year

[B] Predicted concentration accounts for shutting down all night-time pit activities for 22 nights per year.

[C] Predicted concentration accounts for shutting down Main pit night-time activities for 1 night per year.

[D] It is important to note although different receptors require different levels of proactive mitigation, the most stringent requirement will need to be applied to achieve compliance across all receptors. Furthermore, each receptor may require mitigation on different nights and therefore the total number of nights of mitigation may be more than noted above for any individual receptor.

Table 15 Predicted ground-level concentrations of PM_{10} (µg/m³) for Year 7

Receptor	Label	Year 7			
		24-hour		Annual	
		VS	Cumulative[B]	VS	Cumulative
1	Property Manager	*Not applicable to Year 7*			
2	Workers Accommodation				
3	O'Sullivan Residence	13.3[A]	48.9[A]	2.0	33.5
9	Luxor Residence	2.5	38.0	0.2	31.4
10	Cheeseboro Residence	2.7	38.2	0.1	31.3
	Background	-	*35.5*	-	*31.2*
Objective		**50 µg/m³**		**25 µg/m³**	

Table note:

[A] Predicted concentration accounts for shutting down all night-time pit activities and South Pit – outpit dumping for 10 nights per year.

[B] It is important to note although different receptors require different levels of proactive mitigation, the most stringent requirement will need to be applied to achieve compliance across all receptors. Furthermore, each receptor may require mitigation on different nights and therefore the total number of nights of mitigation may be more than noted above for any individual receptor.

6.2.1 Proactive mitigation measures for PM_{10}

Proactive mitigation measures may be necessary to achieve compliance with the Air EPP air quality objective for 24-hour ground-level PM_{10} at sensitive receptors 1 to 3. Contributions to predicted ground-level concentrations of PM_{10} from all operations occurring within VS including standard and proactive mitigation and the level of operation reduction for each source are provided in Table 16 and Table 17 for Year 2 and Year 7, respectively. Table 18 presents the dates when ground-level PM_{10} exceedances have been predicted and, therefore, require proactive mitigation to achieve compliance.

It can be seen from the source contribution tables that existing ambient background is the primary source of 24-hour average PM_{10}, contributing between 32% to 68% to the cumulative ground-level concentrations depending upon receptor and year of operation. Besides ambient background, for each year and receptor, pit operations (Main pit, North pit, South pit) are the primary contributors to predicted ground-level PM_{10}. In each case these active areas are those nearest to the O'Sullivan residence (sensitive receptor 3) which may explain their greater contributions. Activities occurring within these pit areas include pre-stripping waste material with excavators, excavating OB, and excavating ROM. It is significant to note for Year 2 operations that the proactive mitigation measure of 22 nights complete mine shutdown is a result of the proximity of onsite sensitive receptors R1 and R2 which are owned by VS. It is, therefore, possible for VS to review the suitability of these sites as necessary to reduce impacts.

Regarding the influence of meteorological conditions on dispersion of dust, wind speed and atmospheric stability are two of the most important factors. Low wind speeds (less than 2m/s) and stable nighttime conditions result in poorly mixed air which can lead to higher concentrations of pollutants.

Therefore, proactive mitigation measures for reducing ground-level concentrations of PM_{10} have focused on ceasing operations during evening hours (7 pm – 6 am) to minimise buildup of dust in the more stable nighttime conditions.

Prevailing wind direction is also important for predicting impacts at sensitive receptors. As the nearest sensitive receptors are all located to the east and south of VS operations it is expected that winds from the directions of southwest – north/northwest may correspond with increased impacts at sensitive receptors. Indeed, analysis of dominant wind directions on occasions when proactive mitigation is required indicates winds are blowing between approximately 200º – 320º (SW-NW) making the sensitive receptors downwind of VS operations.

Although the described meteorological conditions are expected to facilitate increases in particulate concentrations, they do not provide an indication of where particulates are coming from. It will often be the case that background ambient concentrations of particulates is the major contributor to levels experienced at sensitive receptors, while contributions from VS only constitute a very minor part (as shown in Table 16 and Table 17).

Table 16 Year 2 - Operation and Ambient Background contributions to predicted ground-level concentrations of PM_{10} at each receptor (maximum exceedance day) with standard mitigation and after proactive mitigation steps, and percent reduction required

VS activities	Percent contribution of each source and percent reduction								
	Receptor 1			Receptor 2			Receptor 3		
	Standard mitigation	Proactive mitigation	% Rdtn[1]	Standard mitigation	Proactive mitigation	% Rdtn[1]	Standard mitigation	Proactive mitigation	% Rdtn[1]
CHPP	2.3%	0.3%	100%	3.4%	0.1%	100%	0.8%	0.9%	0%
Main pit	45.5%	20.3%	100%	40.4%	19.8%	100%	20.6%	7.8%	100%
Main pit - Drilling/Blasting	0.5%	0.0%	100%	0.1%	0.0%	100%	0.1%	0.1%	0%
Main pit - inpit OB dump	6.2%	2.6%	100%	5.0%	1.1%	100%	3.5%	4.1%	0%
Main pit - outpit dump	2.1%	0.8%	100%	1.0%	0.3%	100%	0.8%	0.9%	0%
Main pit - OB haul (inpit dump)	2.3%	1.0%	100%	2.5%	1.1%	100%	1.5%	1.8%	0%
Main pit - OB haul outpit dump	1.0%	0.4%	100%	0.4%	0.1%	100%	0.3%	0.4%	0%
Main pit - ROM haul	0.7%	0.3%	100%	0.5%	0.1%	100%	0.3%	0.4%	0%
North pit	2.0%	0.8%	100%	4.8%	2.9%	100%	2.2%	2.6%	0%
North pit - Drilling/Blasting	0.2%	0.4%	100%	0.1%	0.0%	100%	0.01%	0.0%	0%
North pit - inpit OB dump	1.0%	0.3%	100%	1.7%	0.9%	100%	0.6%	1.7%	0%
North pit - outpit dump	2.7%	1.2%	100%	1.8%	0.7%	100%	0.4%	0.5%	0%
North pit - OB haul (inpit dump)	0.3%	0.1%	100%	0.6%	0.3%	100%	0.3%	0.3%	0%
North pit - OB haul outpit dump	0.4%	0.2%	100%	0.4%	0.2%	100%	0.2%	0.2%	0%
North pit - ROM haul	0.5%	0.2%	100%	0.6%	0.1%	100%	0.1%	0.1%	0%
Wind Erosion	0.0%	0.0%	0%	0.0%	0.0%	0%	0.0%	0.0%	0%
Amb Background	32.2%	71%	NA	36.7%	71.3%	NA	68.2%	79.2%	NA

Table Notes:
[1] Percent operations must be reduced by to achieve compliance. These apply to nights identified in Table 14.

Table 17 Year 7 - Operation and Ambient Background contributions to predicted ground-level concentrations of PM_{10} at each receptor (maximum exceedance day) with standard mitigation and after proactive mitigation steps, and percent reduction required

VS activities	Percent contribution of each source and percent reduction				
	Receptor 1	Receptor 2	Receptor 3		
			Standard mitigation	Proactive mitigation	% Rdtn[1]
CHPP	Not applicable to Year 7	Not applicable to Year 7	0.0%	0.5%	0%
Main pit			11.3%	8.0%	100%
Main pit - Drilling Blasting			0.02%	0.0%	0%
Main pit - inpit OB dump			0.8%	1.1%	0%
Main pit - OB haul (inpit dump)			1.5%	2.0%	0%
Main pit - ROM haul			0.2%	0.3%	0%
South pit			21.2%	4.9%	100%
South pit - Drilling Blasting			0.1%	0.1%	0%
South pit - inpit dump			3.3%	4.4%	0%
South pit - outpit dump			3.5%	0.7%	100%
South pit - OB haul (inpit dump)			2.0%	2.6%	0%
South pit - OB haul (outpit dump)			1.7%	2.3%	0%
South pit - ROM haul			0.7%	1.0%	0%
Main pit - Rehab			0.0%	0.0%	0%
North pit - Rehab			0.0%	0.0%	0%
Highwall Rehab			0.0%	0.0%	0%
WE			0.0%	0.0%	0%
Amb Background			53.7%	72.5%	NA

Table Notes:
[1] Percent operations must be reduced by to achieve compliance. These apply to nights identified in Table 15.

Table 18 Dates of predicted ground-level PM_{10} exceedances requiring proactive mitigation

	Receptor and Model Year			
	R1 - Yr2	R2 - Yr2	R3 - Yr2	R3 - Yr11
Dates Requiring Proactive Mitigation	1/01/2018	1/01/2018	25/07/2018	20/01/2018
	13/01/2018	13/01/2018	-	15/02/2018
	1/02/2018	1/02/2018		24/02/2018
	10/02/2018	10/02/2018		3/03/2018
	13/02/2018	13/02/2018		27/07/2018
	19/02/2018	19/02/2018		31/08/2018
	26/02/2018	26/02/2018		15/09/2018
	2/03/2018	2/03/2018		19/09/2018
	10/05/2018	10/05/2018		4/10/2018
	12/06/2018	12/06/2018		7/11/2018
	13/06/2018	13/06/2018		2/12/2018
	16/07/2018	16/07/2018		-
	29/07/2018	29/07/2018		
	16/08/2018	16/08/2018		
	8/09/2018	23/08/2018		
	16/09/2018	8/09/2018		
	4/10/2018	16/09/2018		
	5/10/2018	4/10/2018		
	11/10/2018	5/10/2018		
	26/10/2018	11/10/2018		
	28/10/2018	26/10/2018		
	27/11/2018	28/10/2018		

6.3 $PM_{2.5}$

The predicted maximum 24-hour average and annual average ground-level concentrations of $PM_{2.5}$ for Year 2 and Year 7 of the VS in isolation and with background levels applied (cumulative assessment) are presented in Table 19 and Table 20.

Contours of the predicted maximum 24-hour average and annual average ground-level concentrations of $PM_{2.5}$ for Year 2 and Year 7 of the VS are presented in Plate 7, Plate 8, Plate 9 and Plate 10, respectively and for the VS in isolation.

The results show that:

- Predicted 24-hour average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7;
- Predicted annual average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7; and
- The background annual average concentration of $PM_{2.5}$ is 6.4 µg/m³ or 80% the Air EPP objective of 8 µg/m³. The maximum contribution of the VS to annual average $PM_{2.5}$ at the sensitive receptors is at most 0.6 µg/m³ or approximately 2.3% of the Air EPP objective.

Table 19 Predicted maximum 24-hour average and annual average ground-level concentrations of $PM_{2.5}$ (µg/m³) for Year 2

Receptor	Label	Year 2			
		24-hour		Annual	
		VS	Cumulative	VS	Cumulative
1	Property Manager	15.9	22.5	0.6	7.0
2	Workers Accommodation	13.5	20.1	0.6	7.0
3	O’Sullivan Residence	5.4	12.0	0.2	6.6
9	Luxor Residence	0.7	7.3	0.05	6.4
10	Cheeseboro Residence	0.5	7.1	0.04	6.4
	Background	-	*6.6*	-	*6.4*
Objective		**25 µg/m³**		**8 µg/m³**	

Table 20 Predicted maximum 24-hour average and annual average ground-level concentrations of $PM_{2.5}$ (µg/m³) for Year 7

Receptor	Label	Year 7			
		24-hour		Annual	
		VS	Cumulative	VS	Cumulative
1	Property Manager	*Not applicable to Year 7*			
2	Workers Accommodation				
3	O'Sullivan Residence	9.0	15.6	0.5	6.9
9	Luxor Residence	0.7	7.3	0.05	6.5
10	Cheeseboro Residence	0.6	7.2	0.03	6.4
	Background	-	*6.6*	-	*6.4*
Objective		**25 µg/m³**		**8 µg/m³**	

6.4 Dust Deposition

The predicted maximum monthly dust deposition rates for Year 2 and Year 7 of the VS in isolation and with background levels applied (cumulative assessment) are presented in Table 21.

Contours of the predicted maximum monthly dust deposition rate for Year 2 and Year 7 of the VS are presented in Plate 11 and Plate 12 for the VS in isolation.

The results show that:

- Predicted dust deposition rates due to the VS ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7.

Table 21 Predicted maximum monthly dust deposition rates (mg/m²/day)

Receptor	Label	Year 2		Year 7	
		VS	Cumulative	VS	Cumulative
1	Property Manager	3.6	83.0	*Not applicable to Year 7*	
2	Workers Accommodation	3.3	82.7		
3	O'Sullivan Residence	0.7	80.1	2.2	81.6
9	Luxor Residence	0.2	79.6	0.4	79.8
10	Cheeseboro Residence	0.2	79.6	0.5	79.9
	Background	-	*79.4*		*79.4*
Objective		**120 µg/m³**			

7. MONITORING AND MITIGATION

Dust management and mitigation measures will be implemented at the VS in an Air Quality Management Plan (AQMP) to ensure that dust levels are minimised as far as practicable. As discussed in Section 5.3, everyday dust management measures will include application of water to truck haul routes and progressive rehabilitation of the site.

8. CONCLUSIONS

The air quality assessment has investigated the potential for the VS to affect air quality in the region. Year 2 and Year 7 of VS operations have been assessed based on the proposed mining schedule and the proximity of sensitive receptors to critical emission generating activities. The assessment has used meteorological and dispersion models to assess the effect of particulate matter (dust) emissions on concentrations of TSP, PM_{10}, $PM_{2.5}$ and dust deposition rates in the surrounding region.

Concentrations of air pollutants due to proposed activities associated with the VS in isolation, and with the inclusion of background levels of dust, were determined at sensitive residential receptors and on a cartesian grid covering the region. Predicted ground-level concentrations of air pollutants and dust deposition rates were compared with the relevant air quality objectives and guidelines.

It is significant to note that in past years the ambient concentrations of PM_{10} and $PM_{2.5}$ exceed the Air EPP objectives for 24-hour average and annual average PM_{10}. Dry conditions likely contributed to or exacerbated conditions with 2019 showing the lowest rainfall for the Moranbah region over the period 2012 – 2020; Australia-wide 2019 had the lowest annual rainfall since 1900. The assessment has included these ambient concentrations as background and therefore represents an upper bound of ambient concentrations for Moranbah.

The air quality assessment of the VS found the following:

TSP

- Predicted ground-level concentrations of TSP ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7.

PM_{10}

- Predicted 24-hour average ground-level concentrations of PM_{10} for Year 2 and Year 7 comply with the relevant air quality objective at all sensitive receptors, in isolation and cumulatively, with the application of proposed proactive mitigation measures as discussed in Section 6.2.1; and

- Existing annual average concentrations of PM_{10} are higher than the relevant air quality objective. The contribution from VS to the annual average concentrations PM_{10} at a sensitive receptor is at most 2.8 µg/m³ or 11% of the Air EPP objective.

$PM_{2.5}$

- Predicted 24-hour average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7;

- Predicted annual average ground-level concentrations of $PM_{2.5}$ ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7; and

- The background annual average concentration of $PM_{2.5}$ is 6.4 µg/m³ or 80% the Air EPP objective of 8 µg/m³. The maximum contribution of the VS to annual average $PM_{2.5}$ at the sensitive receptors is at most 0.6 µg/m³ or approximately 2.3% of the Air EPP objective.

Dust Deposition

Predicted dust deposition rates due to the VS ***comply*** with the relevant air quality objective at all residential receptors, in isolation and cumulatively for Year 2 and Year 7.

Furthermore, dust management and mitigation measures are proposed to be implemented at the VS to ensure that dust levels are minimised. A proactive dust management system will be implemented to avoid the potential for elevated cumulative air quality impacts at nearby sensitive receptors.

9. REFERENCES

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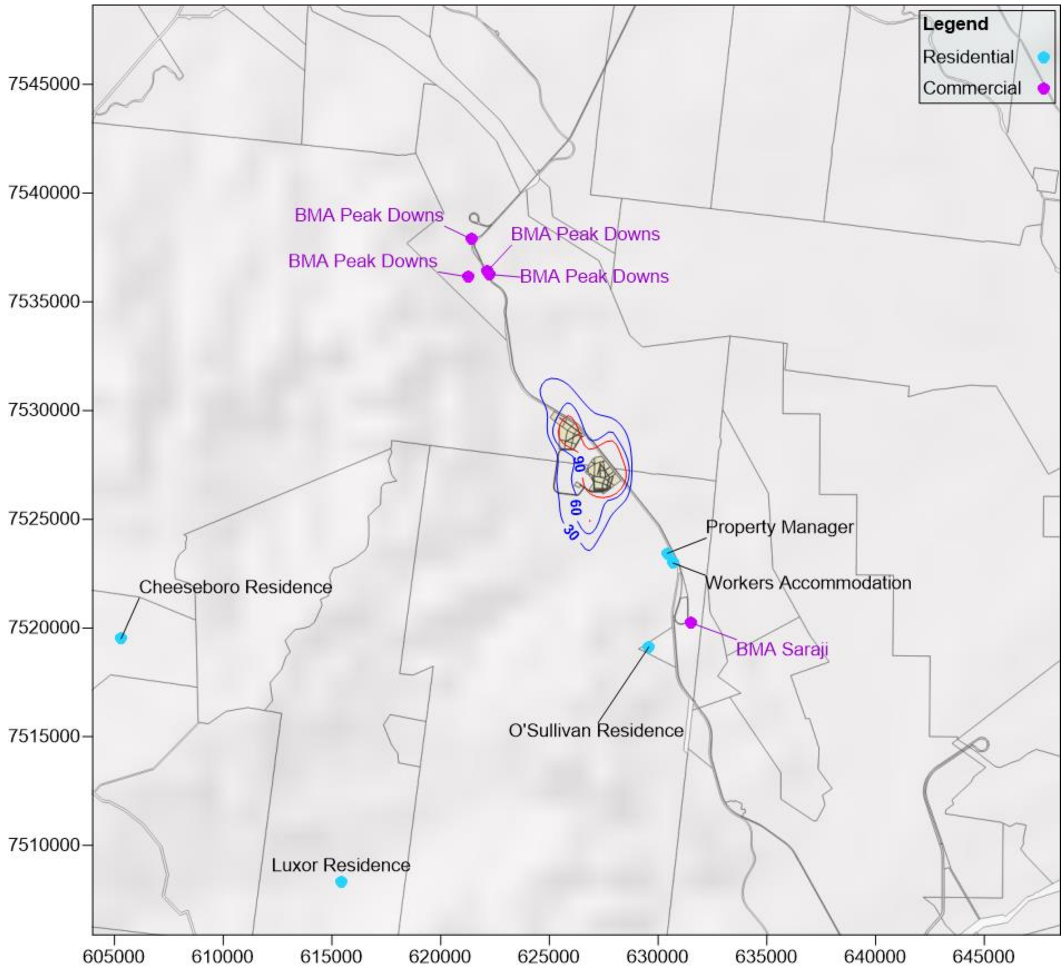

Plate 1 **Predicted annual average ground-level concentrations of TSP for the VS Year 2 in isolation using standard mitigation measures**

Location: Vulcan South, Moranbah, QLD	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Average contours	**Objective:** 90 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

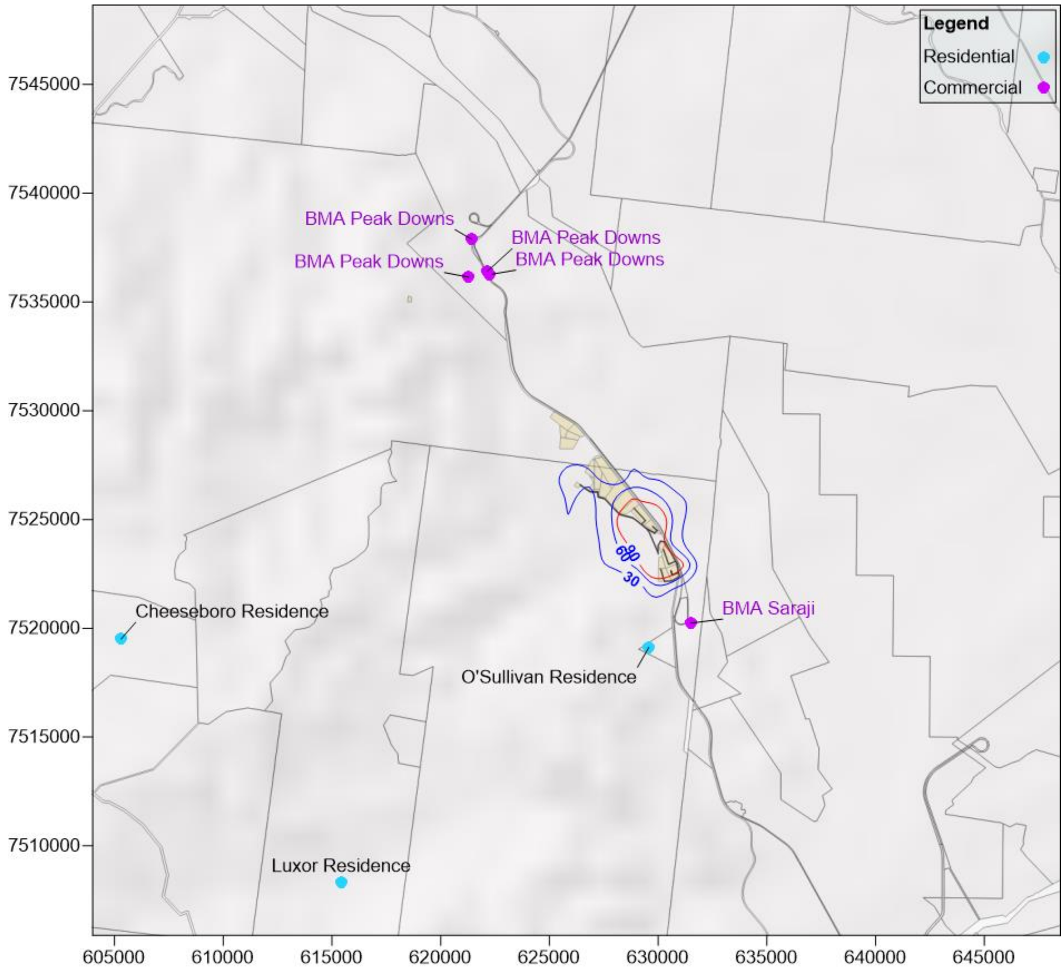

Plate 2	**Predicted annual average ground-level concentrations of TSP for the VS Year 7 in isolation using standard mitigation measures**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan South, Moranbah, QLD	Annual	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	90 µg/m³ (red)	Daniel Gallagher	November 2020

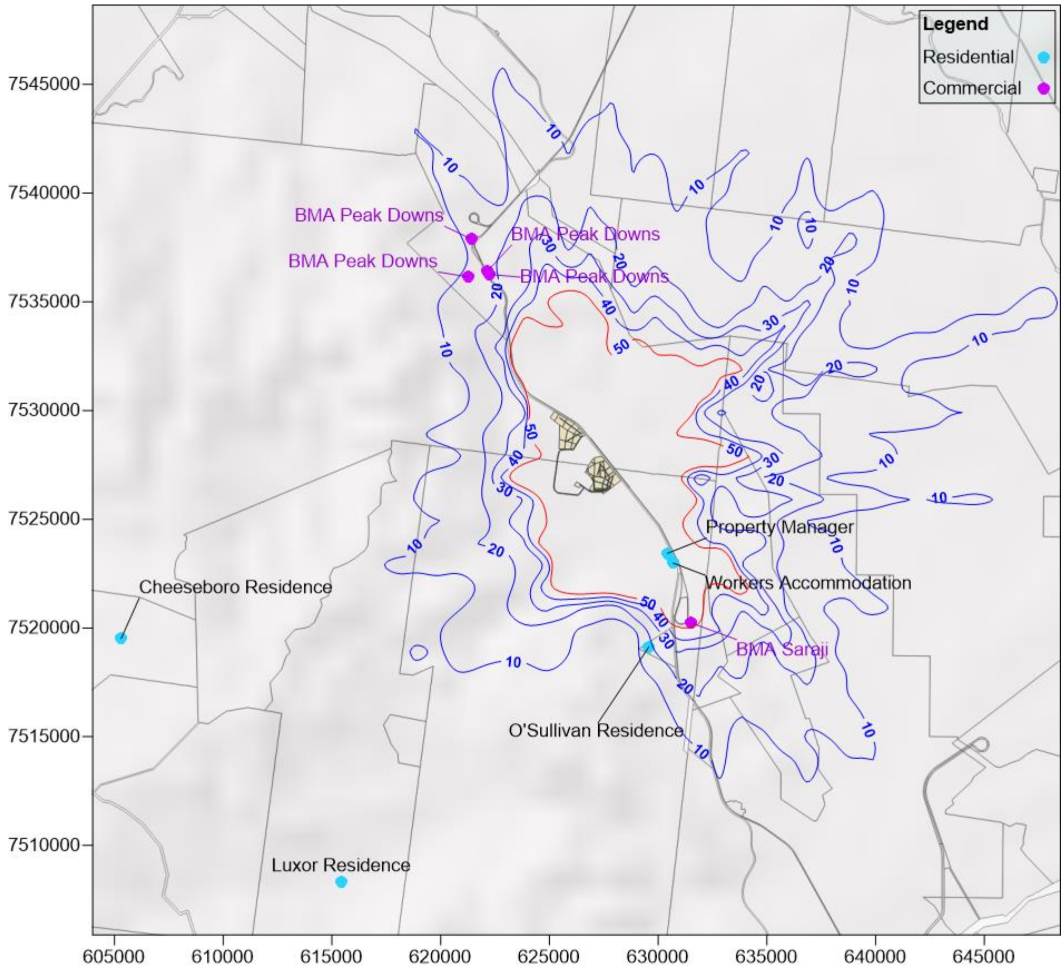

Plate 3	**Predicted maximum 24-hour average ground-level concentrations of PM_{10} for the VS Year 2 in isolation using standard mitigation measures**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan Mine South, Moranbah, QLD	24-hour maximum	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Maximum contours	50 µg/m³ (red)	Daniel Gallagher	November 2020

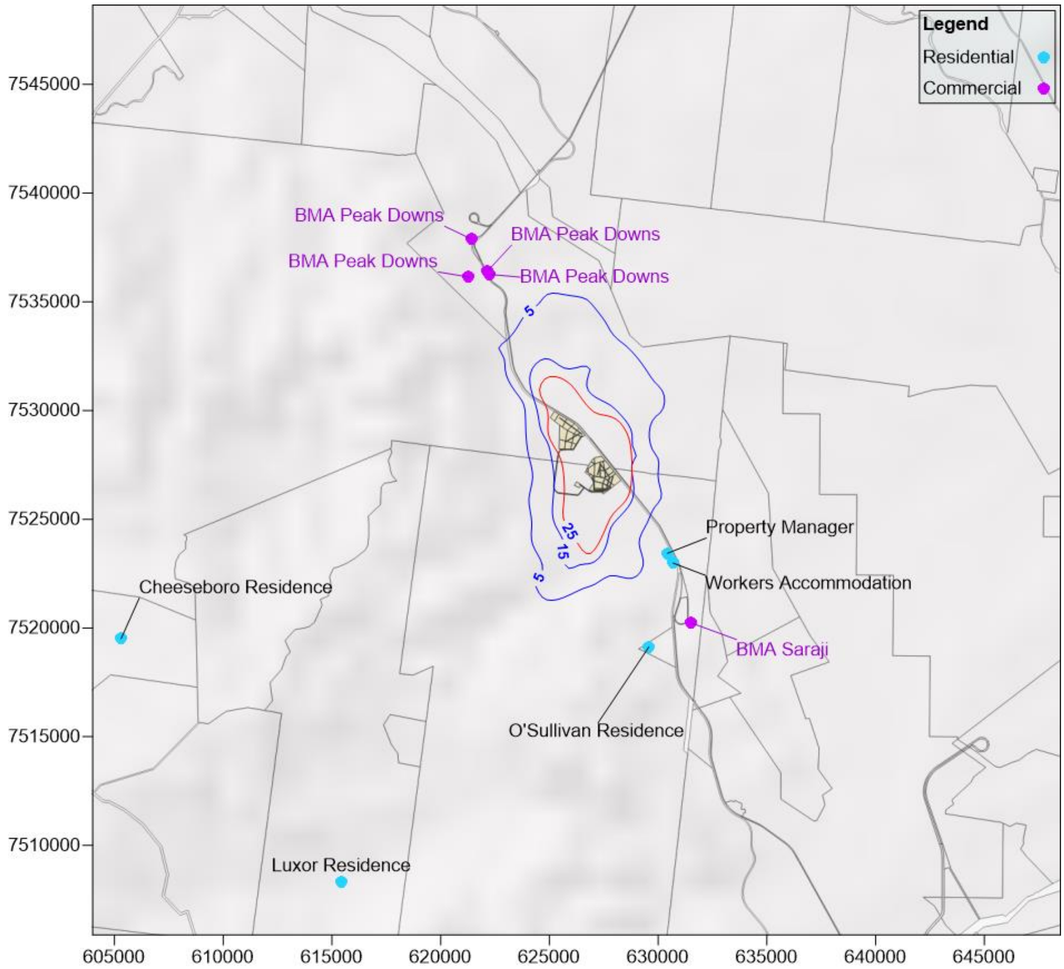

Plate 4	**Predicted annual average ground-level concentrations of PM_{10} for the VS Year 2 in isolation using standard mitigation measures**		
Location: Vulcan South, Moranbah, QLD	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Average contours	**Objective:** 25 µg/m³	**Prepared by:** Daniel Gallagher	**Date:** November 2020

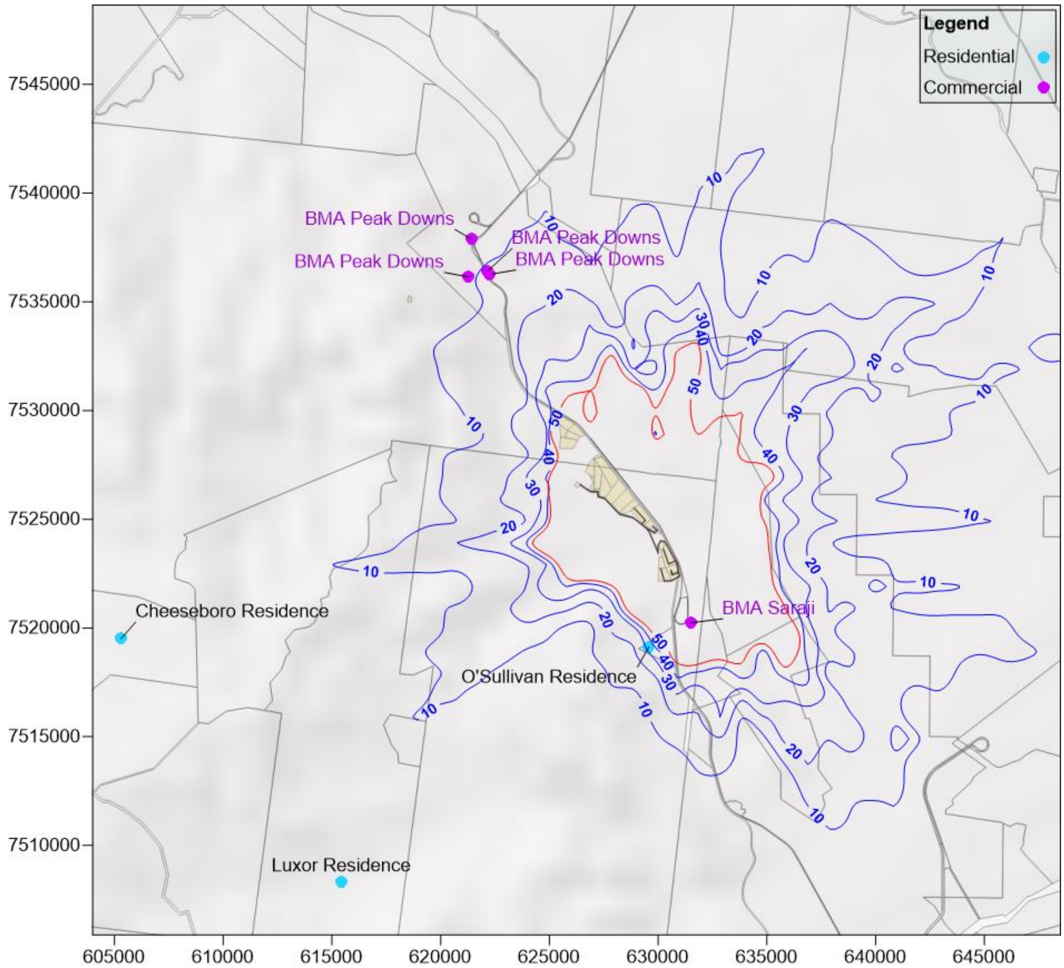

Plate 5	Predicted maximum 24-hour average ground-level concentrations of PM_{10} for the VS Year 7 in isolation using standard mitigation measures		
Location: Vulcan South, Moranbah, QLD	**Averaging period:** 24-hour maximum	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours	**Objective:** 50 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

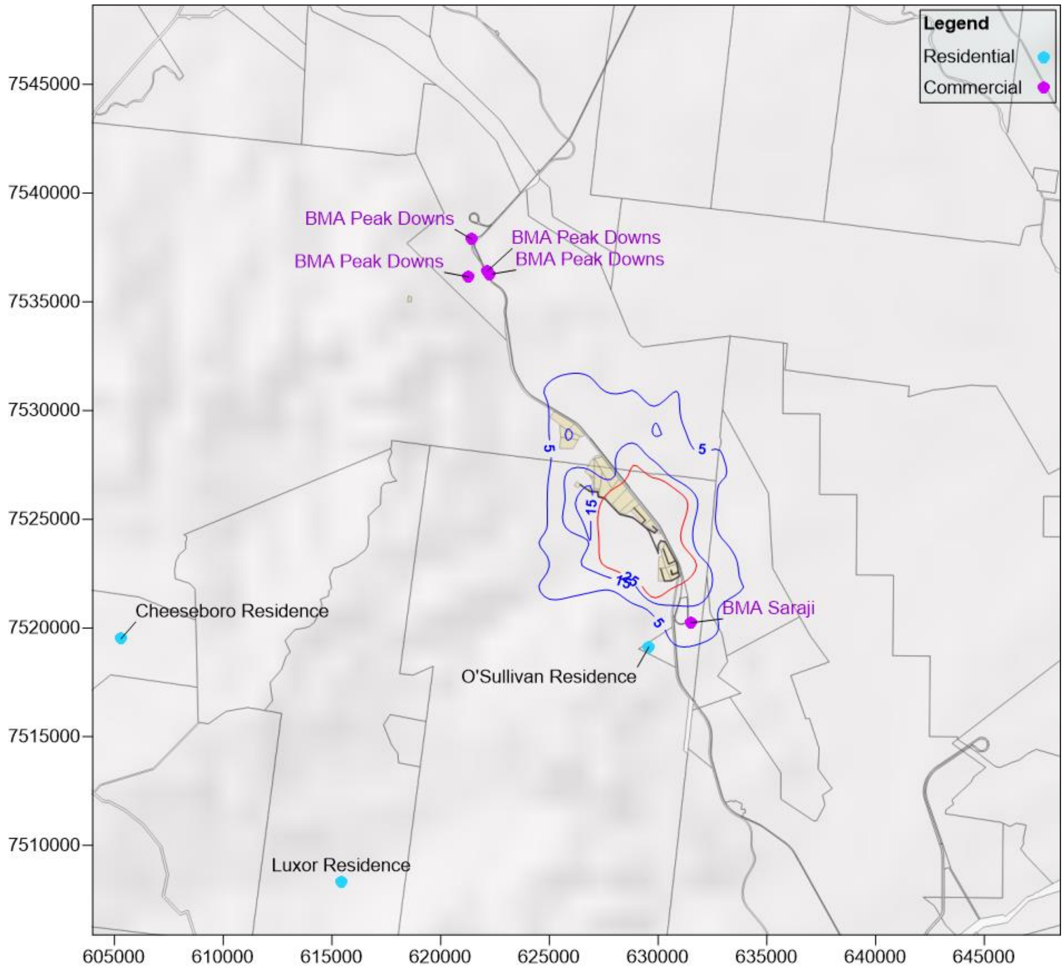

Plate 6	Predicted annual average ground-level concentrations of PM_{10} for the VS Year 7 in isolation using standard mitigation measures

Location: Vulcan South, Moranbah, QLD	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Average contours	**Objective:** 25 µg/m³	**Prepared by:** Daniel Gallagher	**Date:** November 2020

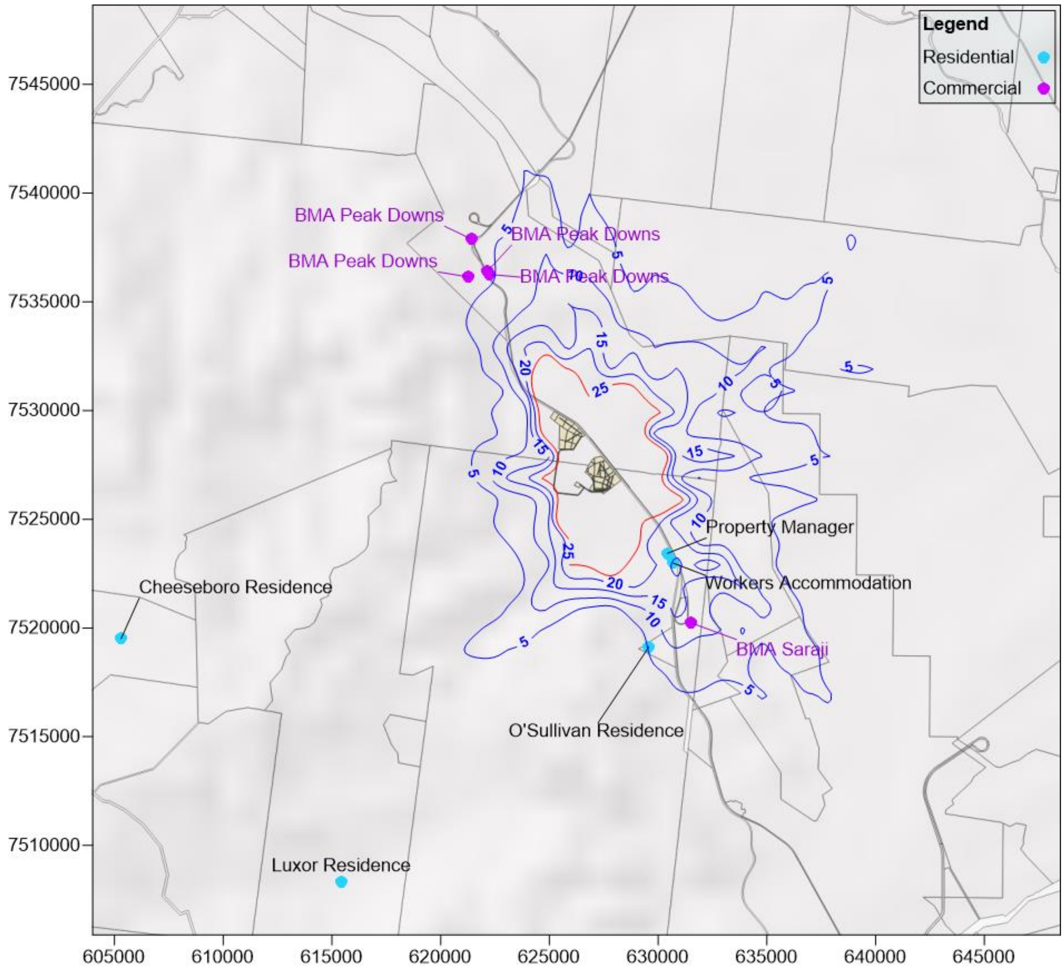

Plate 7	**Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ for the VS Year 2 in isolation using standard mitigation measures**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan South, Moranbah, QLD	24-hour maximum	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Maximum contours	25 µg/m³ (red)	Daniel Gallagher	November 2020

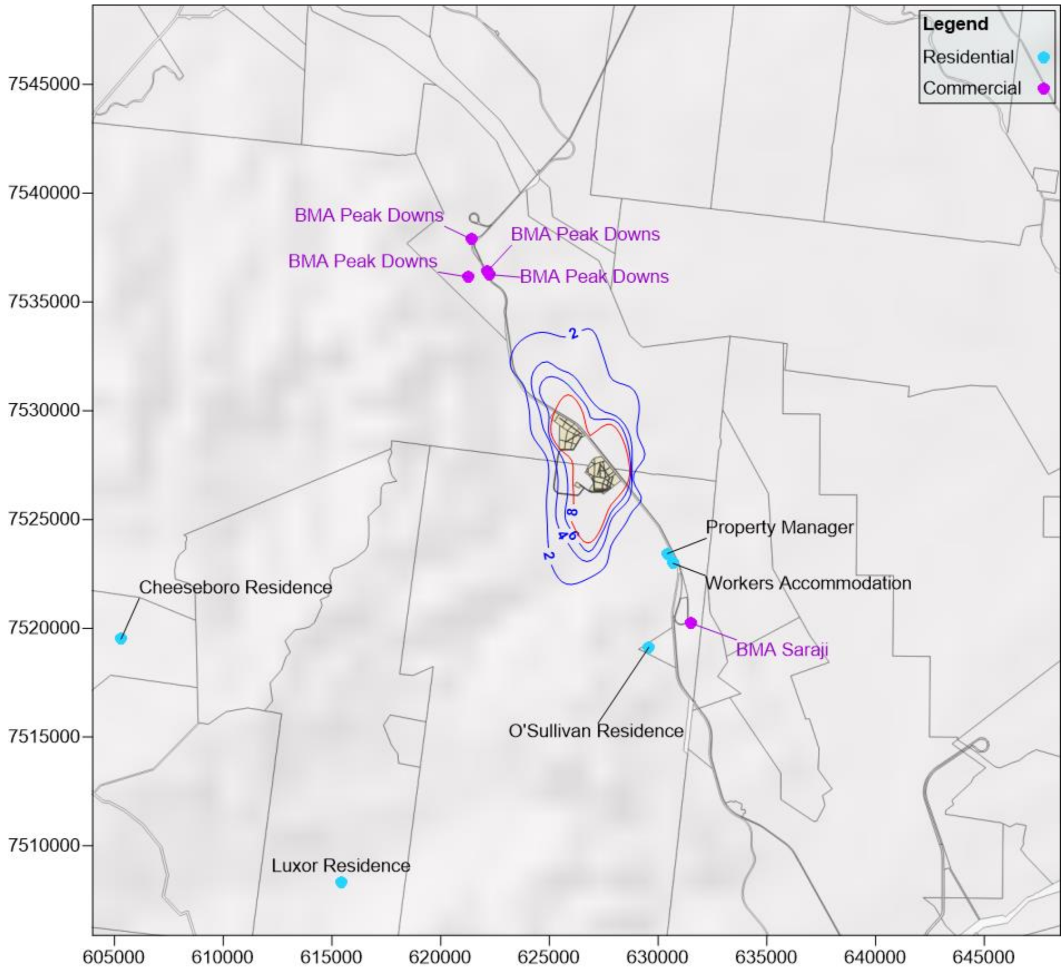

Plate 8	**Predicted annual average ground-level concentrations of $PM_{2.5}$ for the VS Year 2 in isolation using standard mitigation measures**

Location:	**Averaging period:**	**Data source:**	**Units:**
Vulcan South, Moranbah, QLD	Annual	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	8 µg/m³ (red)	Daniel Gallagher	November 2020

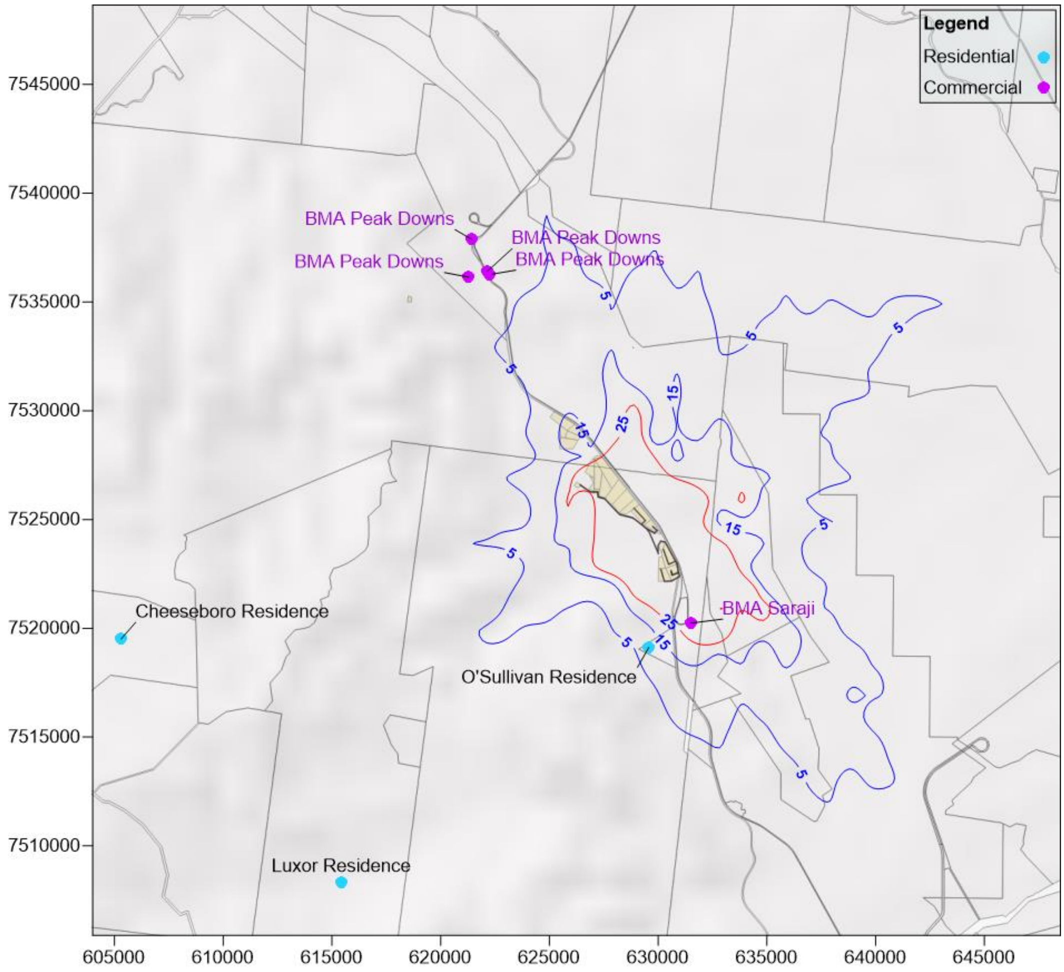

Plate 9	**Predicted maximum 24-hour average ground-level concentrations of $PM_{2.5}$ for the VS Year 7 in isolation using standard mitigation measures**		
Location: Vulcan South, Moranbah, QLD	**Averaging period:** 24-hour maximum	**Data source:** CALPUFF	**Units:** µg/m³
Type: Maximum contours	**Objective:** 25 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

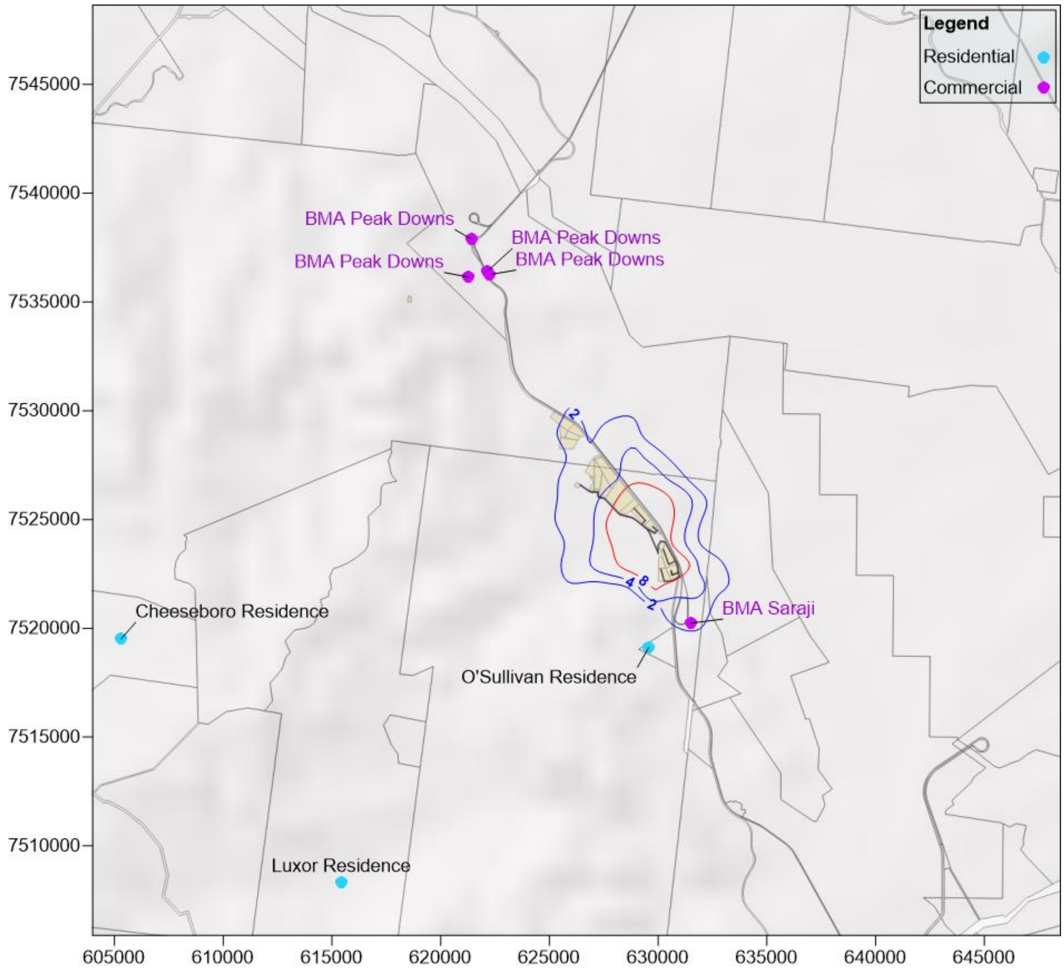

Plate 10	**Predicted annual average ground-level concentrations of $PM_{2.5}$ for the VS Year 7 in isolation using standard mitigation measures**		
Location: Vulcan South, Moranbah, QLD	**Averaging period:** Annual	**Data source:** CALPUFF	**Units:** µg/m³
Type: Average contours	**Objective:** 8 µg/m³ (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

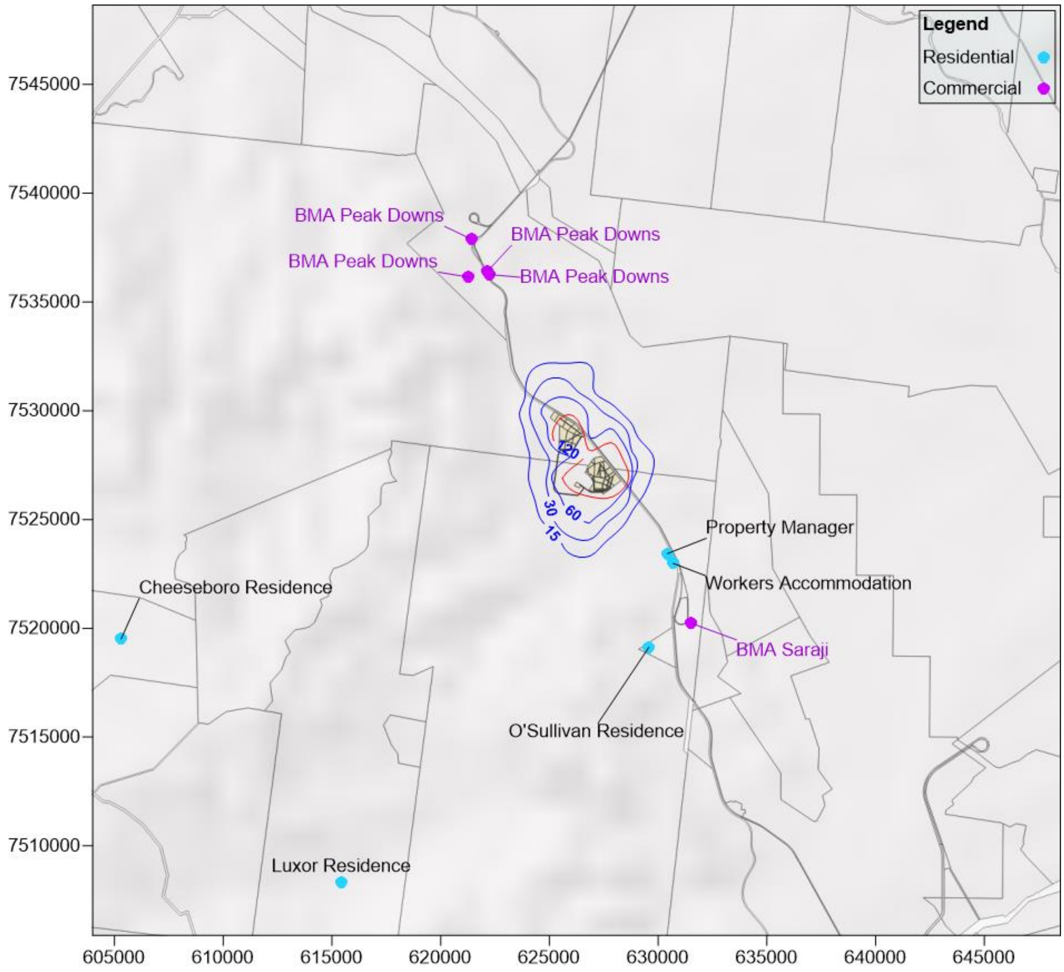

Plate 11	**Predicted maximum monthly dust deposition rate for the VS Year 2 in isolation using standard mitigation measures**		
Location: Vulcan South, Moranbah, QLD	**Averaging period:** Monthly	**Data source:** CALPUFF	**Units:** mg/m²/day
Type: Maximum contours	**Guideline:** 120 mg/m²/day (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

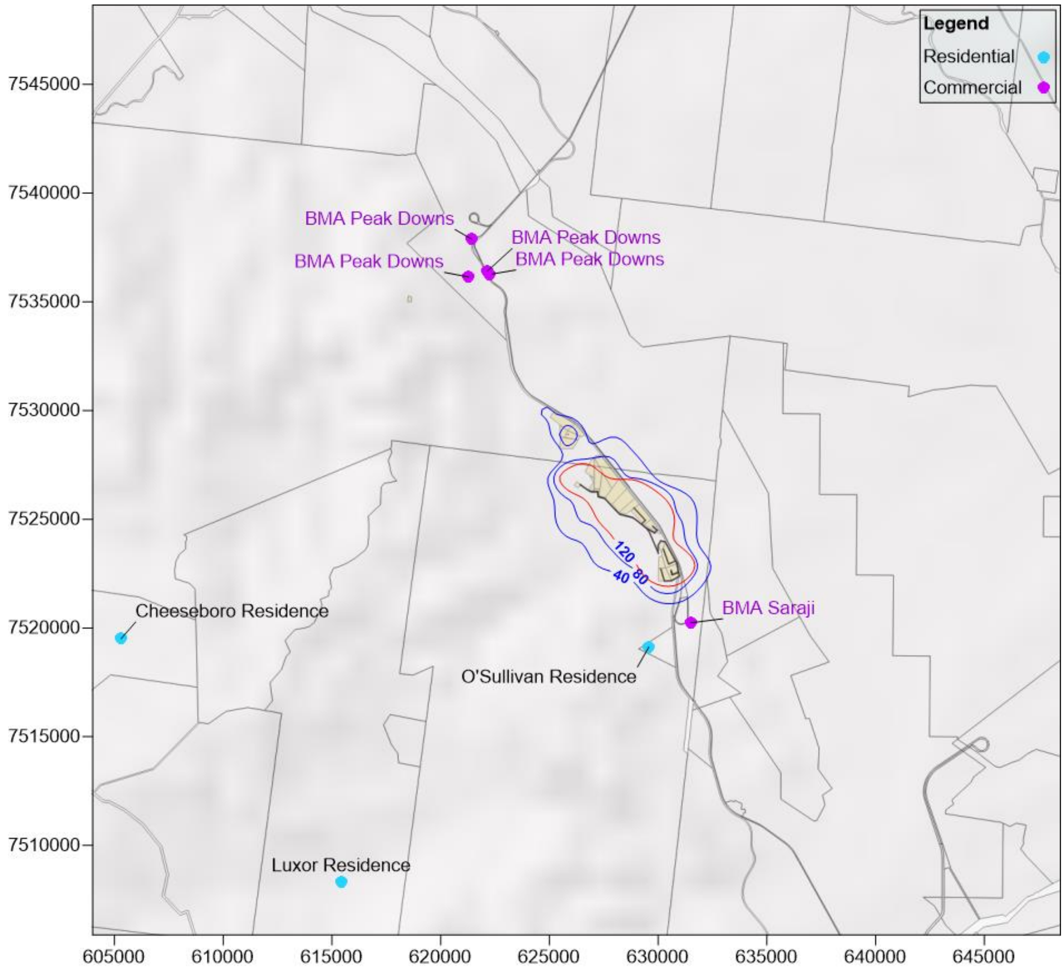

Plate 12	**Predicted maximum monthly dust deposition rate for the VS Year 7 in isolation using standard mitigation measures**		
Location: Vulcan South, Moranbah, QLD	**Averaging period:** Monthly	**Data source:** CALPUFF	**Units:** mg/m²/day
Type: Maximum contours	**Guideline:** 120 mg/m²/day (red)	**Prepared by:** Daniel Gallagher	**Date:** November 2020

APPENDIX A DETAILED DUST EMISSIONS INVENTORY DATA

A1 ACTIVITY DATA

The activity data presented in Table A1 are based on the following information:

- Information provided by METServe and Vitrinite, including site layouts, operational details, mining methods, throughput and fleet specifications; and
- Typical emissions characteristics documented in the National Pollutant Inventory (NPI) Handbooks and US EPA Compilation of Air Pollutant Emission Factors (AP-42).

Overburden and ROM extraction volumes, drilling activity, and dozer and grader utilisation have been determined based on the relative spatial extent of the active mining areas indicated in the supplied site plans. Where suitable values were not available, conservative assumptions have been used.

Table A1 Mine operations and activities data

Activity	Units	VS Year 2	VS Year 7	Information Source
Hours of operation (except blasting and Pits 7 and 8)	hours/day days/year	24	24	METServe – Copy of Noise data - VS Assessment Data Requirements.xlsx
Blasting hours	hours/day	8	8	
Overburden				
Moisture content	%	8	8	AP-42 Chapter 11.9-3, default value
Silt content	%	7	7	AP-42 Chapter 11.9-3, default value
Coal (ROM and product)				
Moisture content	%	10	10	AP-42 Chapter 11.9-3, default value
Silt content	%	9	9	AP-42 Chapter 11.9-3, default value
Road surface silt content	%	4.3	4.3	AP-42 Chapter 13.2.2, mean value for pit haul
Overburden				
Total overburden	tpa	41,185,398	40,977,582	METServe - Final Project Description_VS_June 2020 (MET00281835-010).pdf
Coal				
ROM coal total	Mtpa	1,890,350	1,949,667	METServe - Final Project Description_VS_June 2020 (MET00281835-010).pdf
Product coal total	Mtpa	1,134,210	1,169,800	
Maximum number of blasts per year	blasts/year	104	104	METServe – Copy of Noise data - VS Assessment Data Requirements.xlsx
Horizontal area of blast	m^2	20,000	20,000	
Number of holes drilled per blast	holes/blast	400	400	
Total holes drilled per year	holes/year	41,600	41,600	Calculated assuming maximum of 24 blasting days per year (METServe)
Exposed and active areas				
Total active pit area	ha	55.1	47.7	
Total overburden dump area (in-pit)	ha	147.8	114.7	

Activity	Units	VS Year 2	VS Year 7	Information Source
Total overburden dump area (ex-pit)	ha	93.7	38.3	Measured from site layouts provided by METServe – V1011_VCM Stage 2_StagePlans.pdf
Total rehabilitation area	ha	0	402.2	
Total ROM coal stockpile area	ha	4.8	4.8	
Haulage				
Total waste haulage	VKT/year	279,236	471,926	Calculated using site layouts provided by METServe
Total ROM coal haulage	VKT/year	150,140	254,272	
Total grader travel	VKT/year	138,852	138,852	
Waste trucks (Cat 789)				
Empty weight	tonnes	143.3	143.3	Manufacturer specification
Maximum payload	tonnes	181	181	Manufacturer specification
Average weight	tonnes	233.8	233.8	Calculated
Waste trucks (Cat 793)				
Empty weight	tonnes	183.8	183.8	Manufacturer specification
Maximum payload	tonnes	200	200	Manufacturer specification
Average weight	tonnes	191.9	191.9	Calculated
ROM coal trucks (Cat 777)				
Empty weight	tonnes	75.3	75.3	Manufacturer specification
Maximum payload	tonnes	89.4	89.4	Manufacturer specification
Average weight	tonnes	120.0	120.0	Calculated
Bulldozers				
Hours of operation per year	hr.op/year/vehicle	4060	4060	METServe – Copy of Noise data - VS Assessment Data Requirements.xlsx
Number	#	5	5	
Graders				
Number in operation	#	3	3	METServe – Copy of Noise data - VS Assessment Data Requirements.xlsx
Average speed	km/h	11.4	11.4	

Activity	Units	VS Year 2	VS Year 7	Information Source
Mean wind speed	m/s	2.53	2.53	CALMET modelling
Proportion of winds faster than 5.4 m/s	%	2.8	2.8	CALMET modelling
Coal stockpile height	m	15	15	Assumed (typical value)

A2 CALCULATION OF EMISSION FACTORS

A2.1 Drilling

Emission factors for drilling were calculated according to AP-42 Chapter 11.9. The default TSP emission factor of 0.59 kg/hole was used, with PM_{10} and $PM_{2.5}$ fractions of 52.5% (0.31 kg/hole) and 3% (0.02 kg/hole), respectively, according to AP-42 Chapter 11.9.

A2.2 Blasting

Emission factors for blasting were calculated according to AP-42 Chapter 11.9. The TSP emission factor is given by:

$$\mathrm{EF_{TSP}} = 0.00022\,A^{1.5}$$

where:

$\mathrm{EF_{TSP}}$	=	TSP emission factor (kg/blast)
A	=	horizontal blast area (m²)

PM_{10} and $PM_{2.5}$ emission factors were calculated using fractions of 52.5% and 3%, respectively, according to AP-42 Chapter 11.9.

A2.3 Bulldozing on overburden

Emission factors for dozers operating on overburden were calculated according to NPI Mining. The TSP and PM_{10} emission factors are given by:

$$\mathrm{EF_{TSP}} = \frac{2.6\,s^{1.2}}{M^{1.3}}$$

$$\mathrm{EF_{PM10}} = \frac{0.34\,s^{1.5}}{M^{1.4}}$$

where:

$\mathrm{EF_{TSP}}$	=	TSP emission factor (kg/ hr)
$\mathrm{EF_{PM10}}$	=	PM_{10} emission factor (kg//hr)
s	=	overburden silt content (%)
M	=	overburden moisture content (%)

The $PM_{2.5}$ emission factor was calculated from TSP using a fraction of 10.5% according to AP-42 Chapter 11.9.

A2.4 Bulldozing on coal

Emission factors for dozers operating on overburden were calculated according to NPI Mining. The TSP and PM_{10} emission factors are given by:

$$\mathrm{EF_{TSP}} = \frac{35.6\,s^{1.2}}{M^{1.4}}$$

$$\mathrm{EF_{PM10}} = \frac{6.33\,s^{1.5}}{M^{1.4}}$$

where:

$\mathrm{EF_{TSP}}$	=	TSP emission factor (kg/ hr)

EF_{PM10}	=	PM_{10} emission factor (kg//hr)
s	=	coal silt content (%)
M	=	coal moisture content (%)

The $PM_{2.5}$ emission factor was calculated from TSP using a fraction of 2.2% according to AP-42 Chapter 11.9.

A2.5 Material transfers and handling

Materials handling and transfers include truck loading, dumping, conveyor transfers and train load-out. These emission factors were calculated according to AP-42 Chapter 13.2.4 using the following equation:

$$\mathrm{EF} = k(0.0016)\left(\frac{U}{2.2}\right)^{1.3}\left(\frac{M}{2}\right)^{-1.4}$$

where:

EF	=	emission factor (kg/Mg)
k	=	particle size multiplier
U	=	mean wind speed (m/s)
M	=	material moisture content (%)

The particle size multiplier k varies with aerodynamic particle size range as follows:

$k = 0.74$	Particle size < 30 µm (TSP)
$k = 0.35$	Particle size < 10 µm (PM_{10})
$k = 0.053$	Particle size < 2.5 µm ($PM_{2.5}$)

A2.6 Grading

Emission factors for grading were calculated according to AP-42 Chapter 11.9. The TSP and PM_{10} emission factors are given by:

$$\mathrm{EF}_{\mathrm{TSP}} = 0.0034\, S^{2.5}$$

$$\mathrm{EF}_{\mathrm{PM10}} = 0.0034\, S^{2}$$

where:

EF_{TSP}	=	TSP emission factor (kg/VKT)
EF_{PM10}	=	PM_{10} emission factor (kg/VKT)
S	=	grader average speed (km/h)

The $PM_{2.5}$ emission factor was calculated from TSP using a fraction of 3.1% according to AP-42 Chapter 11.9.

A2.7 Wind erosion from active stockpiles

Emission factors for wind erosion of active stockpiles were calculated on an hourly basis using the emission factor for active storage piles from AP-42 Chapter 11.9. The TSP emission factor is given by:

$$\mathrm{EF}_{\mathrm{TSP}} = 1.8u$$

Where:

EF_{TSP}	=	TSP emission factor (kg/ha/hr)
u	=	hourly-average wind speed (m/s)

PM_{10} and $PM_{2.5}$ emission factors were calculated using fractions of 50% and 7.5%, respectively, according to AP-42 Chapter 11.9.

A2.8 Wind erosion from exposed areas

Emission factors for wind erosion of exposed areas were calculated on an hourly basis using the emission factor for exposed areas from AP-42 Chapter 11.9 and adapted to include a threshold for dust lift-off.

The default TSP emission factor of 0.85 Mg/ha/yr was used, with the annual emissions apportioned into hourly emissions according to the square of the hourly wind speed compared with the threshold of $(5.4\ \mathrm{m/s})^2$. This reflects the tendency for stronger winds to generate more dust lift-off (if above the threshold for lift-off) and yields worse emissions during hours of strong winds.

PM_{10} and $PM_{2.5}$ emission factors were calculated using fractions of 50% and 7.5%, respectively, according to AP-42 Chapter 11.9.

A2.9 Wheel-generated dust

Emission factors for wheel-generated dust on unpaved roads were calculated according to AP-42 Chapter 13.2.2 via the following equation:

$$\mathrm{EF} = k(281.9)\left(\frac{s}{12}\right)^a\left(\frac{W}{3}\right)^b$$

where

EF	=	emission factor (g/VKT)
k	=	particle size multiplier
s	=	surface material silt content (%)
W	=	mean vehicle weight (tons)
a, b	=	empirical constants

A factor of 1.10231 was used to convert the vehicle weights in Table A1 to imperial tons. The particle size multiplier and empirical constants vary with aerodynamic particle size range as defined in Table A2.

Table A2 Constants used in calculating emissions from wheel-generated dust

Constant	TSP (assumed from PM_{30})	PM_{10}	$PM_{2.5}$
k	4.9	1.5	0.15
a	0.7	0.9	0.9
b	0.45	0.45	0.45

A2.10 Crushing

Emission factors for the crushing of coal were calculated according to AP-42 Chapter 11.19.2. The default TSP and PM_{10} emission factors were used, equal to 0.0027 kg/tonne and 0.0012 kg/tonne of coal crushed, respectively. The $PM_{2.5}$ emission factor was calculated from TSP using a ratio of 8.33% according to AP-42 Chapter 11.19.2.

A2.11 Screening

Emission factors for the screening of coal were calculated according to AP-42 Chapter 11.19.2. The default TSP and PM_{10} emission factors were used, equal to 0.0125 kg/tonne and 0.0043 kg/tonne of coal screened, respectively. The $PM_{2.5}$ emission factor was calculated from TSP using a ratio of 2.27% according to AP-42 Chapter 11.19.2.

APPENDIX B METEOROLOGICAL AND DISPERSION MODELLING METHODOLOGY

B1 METEOROLOGY

The meteorological modelling methodology for the VS included the following steps:

- Selection of a representative year;
- TAPM modelling; and
- CALMET modelling.

The following sections describe each step of the meteorological modelling conducted for the VS.

B1.1 Selection of representative year

A representative year is required to be selected at the beginning of the meteorological modelling process. Using a representative year in the air quality assessment ensures that the conditions experienced at the VS site are reflected in the model.

Selection of a representative year has been done through statistical analysis of historical meteorological observations at BoM Moranbah Airport weather station. Meteorological observations from the past five years at Moranbah Airport were analysed in order to assess the inter-annual variability.

The annual frequency distributions of wind direction, wind speed and temperature for the period 2014 to 2018 were analysed and compared to the average distribution for the same five-year period. The analysis indicated that there was not a significant amount of variation in the distributions of wind direction, wind speed or temperature as illustrated graphically in Figure B1 to Figure B3, with the exception of Year 2016. Based on the analysis, the year 2018 was selected as the year for modelling as this year presented as the most recent year and also close to the 5-year average.

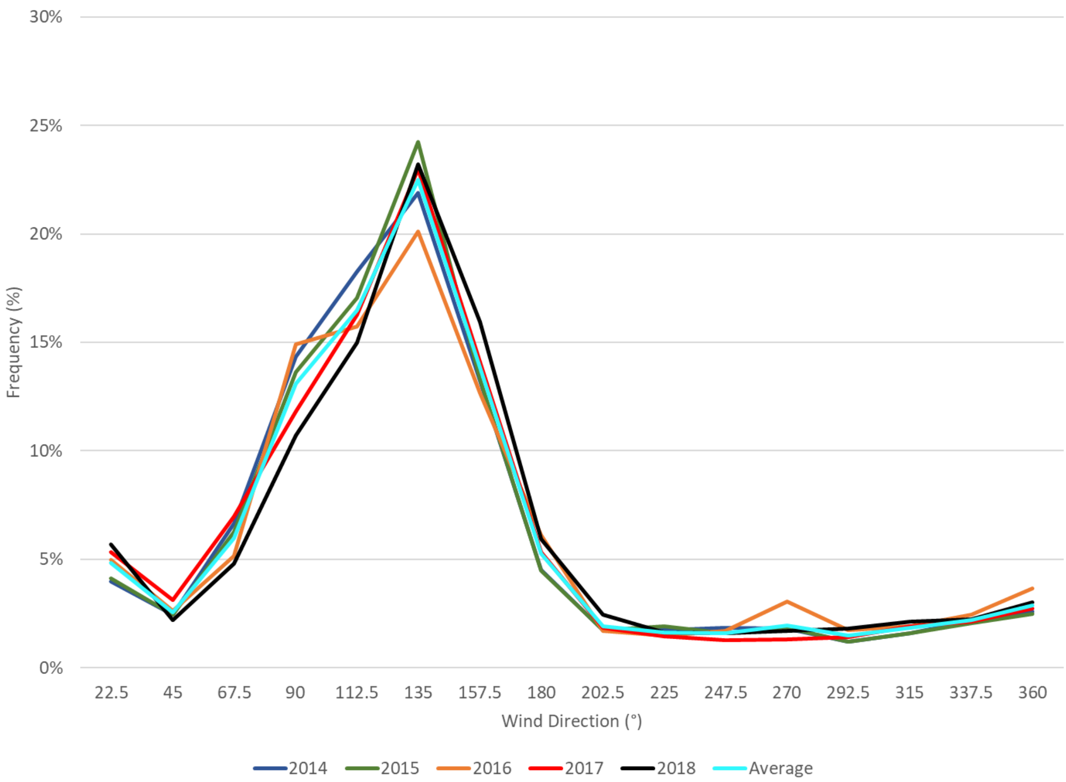

Figure B1 Annual Wind Direction Frequency Distribution at Moranbah Airport

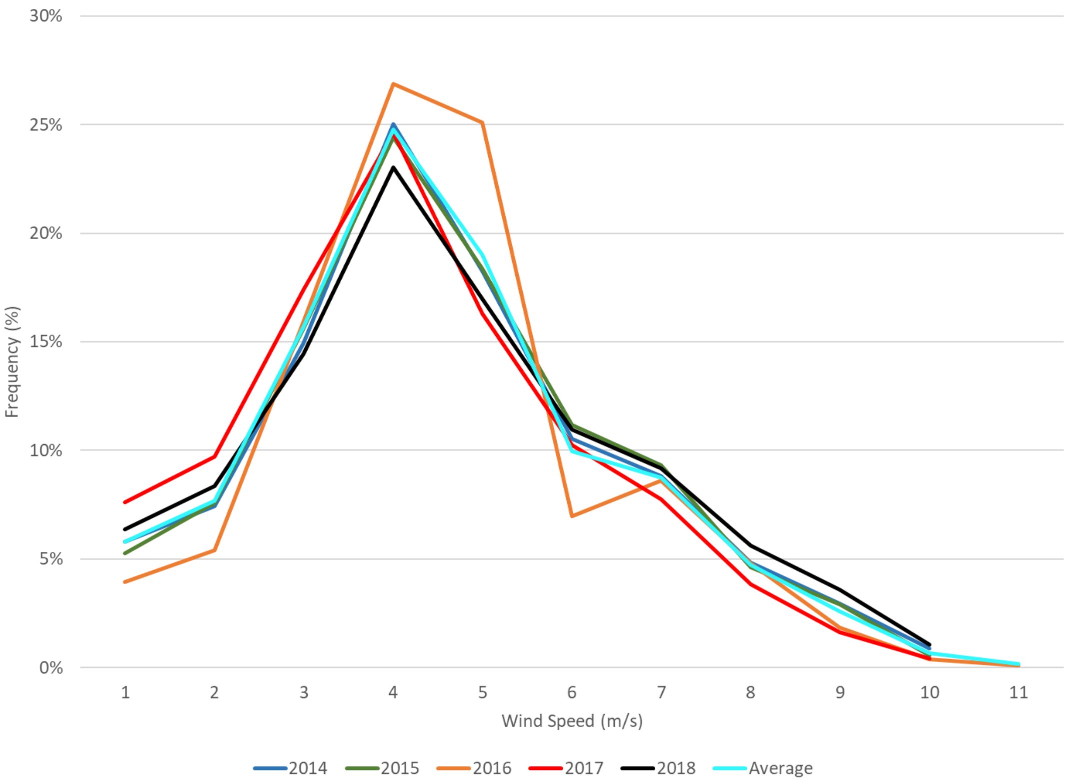

Figure B2 Annual Wind Speed Frequency Distribution at Moranbah Airport

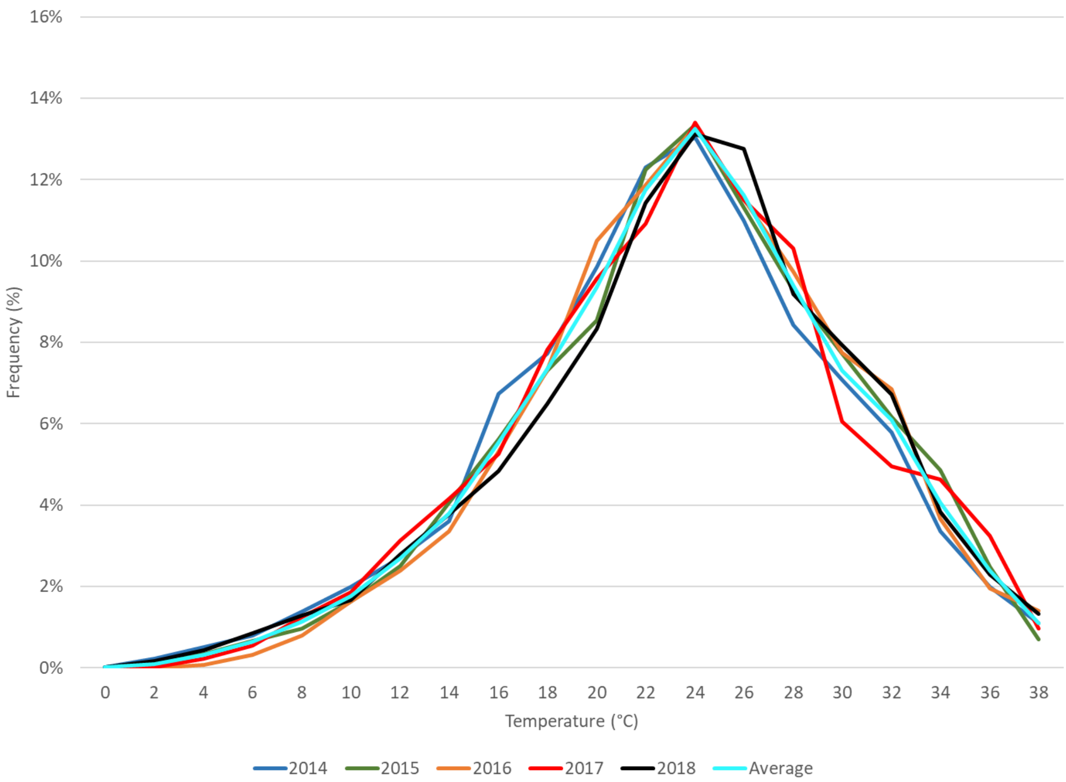

Figure B3 **Annual Temperature Frequency Distribution at Moranbah Airport**

B1.2 TAPM meteorology

The meteorological model, TAPM has been validated by the CSIRO, Katestone and others for many locations in Australia, in south-east Asia and in North America (CSIRO, 2008). Katestone has used the TAPM model throughout Australia as well as in parts of America, Bangladesh, New Caledonia and Vietnam. This model has performed well for simulating regional winds patterns. TAPM has proven to be a useful model for simulating meteorology in locations where monitoring data is unavailable.

TAPM is a prognostic meteorological model which predicts the flows important to regional and local scale meteorology, such as sea breezes and terrain-induced flows from the larger-scale meteorology provided by the synoptic analyses. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 km to 200 km) and at a local scale (down to a few hundred metres (m)). TAPM includes parameterisations for cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM requires synoptic meteorological information for the region. This information is generated by a global model similar to the large-scale models used to forecast the weather. The data were supplied on a grid resolution of approximately 75 km, and at elevations of 100 m to 5 km above the ground. TAPM uses this synoptic information, along with specific details of the location such as surrounding terrain, land-use, soil moisture content and soil type to simulate the meteorology of a region as well as at a specific location.

Landcover data for TAPM are sourced from the US Geological Survey, Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC) at 30-second (approximately 1 km) grid spacing.

TAPM was configured as follows:

- Modelling period for one year from 1 January to 31 December 2018;
- 30 x 30 grid point domain with an outer grid of 30 km and nesting grids of 10 km, 3 km and 1 km;
- 25 vertical levels;
- Grid centred near the VS (latitude –22° 21.0’, longitude 148° 14.5’);
- Geoscience Australia 9 second DEM terrain data;
- Land cover data based on TAPM’s default land-use database and edited to match recent land-use imagery;
- Default options selected for advanced meteorological inputs; and
- No data assimilation.

B1.3 CALMET meteorological modelling

CALMET is an advanced non-steady-state diagnostic 3D meteorological model with micro-meteorological modules for overwater and overland boundary layers. The model is the meteorological pre-processor for the CALPUFF modelling system. CALMET can read hourly meteorological data as data assimilation from multiple sites within the modelling domain; it can also be initialised with the gridded three-dimensional prognostic output from other meteorological models such as TAPM. This can improve dispersion model output, particularly over complex terrain as the near surface meteorological conditions are calculated for each grid point.

CALMET (version 6.5) was used to simulate meteorological conditions in the region. The CALMET simulation was initialised with the gridded TAPM 3D wind field data from the 3 km grid. CALMET treats the prognostic model output as the initial guess field for the CALMET diagnostic model wind fields. The initial guess field is then adjusted for the kinematic effects of terrain, slope flows, blocking effects and 3D divergence minimisation.

Key features of CALMET used to generate the wind fields are as follows:

- Domain area of 81 by 81 grid points at 1 km spacing;
- Twelve vertical levels set at 20 m, 60 m, 100 m, 150 m, 200 m, 250 m, 350 m, 500 m, 800 m, 1600 m, 2600 m and 4600 m;
- 365 days (1 January to 31 December 2018);
- No observations mode, with prognostic wind fields generated by TAPM input as MM5/3D.dat at surface and upper air for “initial guess” field;
- Gridded cloud cover from prognostic relative humidity at all levels;
- No extrapolation of surface winds observations;
- All other wind field options set as default;
- Terrain radius of influence set at 20 kilometres;
- Mixing height parameters all set as default;
- 3D Relative humidity and temperature from prognostic data; and
- No data assimilation.

All other options and factors were set to default.

B2 DISPERSION MODELLING

CALPUFF simulates the dispersion of air pollutants to predict ground-level concentration and deposition rates across a network of receptors spaced at regular intervals, and at identified discrete locations. CALPUFF is a non-steady-state Lagrangian Gaussian puff model. CALPUFF employs the 3D meteorological fields generated from the CALMET model by simulating the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal.

CALPUFF takes into account the geophysical features of the study area that affects dispersion of pollutants and ground-level concentrations of those pollutants in identified regions of interest. CALPUFF contains algorithms that can resolve near-source effects such as building downwash, transitional plume rise, partial plume penetration, sub-grid scale terrain interactions, as well as the long-range effects of removal, transformation, vertical wind shear, overwater transport and coastal interactions. Emission sources can be characterised as arbitrarily-varying point, area, volume and lines or any combination of those sources within the modelling domain.

Key features of CALPUFF v7.2.1 used to simulate dispersion in the VS assessment include:

- Domain area of 81 km by 81 km equivalent to the domain defined in CALMET;
- 365 days modelled (1 January to 31 December 2018);
- Gridded 3D hourly-varying meteorological conditions generated by CALMET;
- Partial plume path adjustment and transitional plume rise modelled;
- No chemical transformation or wet removal modelled;
- PDF used for dispersion under convective conditions; and
- Dispersion coefficients calculated internally from sigma v and sigma w using micrometeorological variables.

All other options set to default.

B2.1 Source configuration

Characteristics for modelled sources are summarised in Table B1.

Emissions from all source types (haul roads, extraction and material handling, wind erosion and processing area) were modelled as area sources. Wind erosion was modelled as an hourly-varying emission source. Emissions from blasting were modelled to reflect daytime operations only from 6 am to 6 pm.

An additional control factor of 50% for TSP and 5% for PM_{10} has been applied to in-pit activities (drilling and blasting and material extraction/handling) to account for pit retention.

Table B1 Characteristics of modelled area sources

Source Type	Effective height	Initial vertical dispersion coefficient (σ_z)
	m	m
Haul roads	10	2.5
Pit activities (drilling and blasting)	8	2
All extraction and material handling activities	10	2.5
Wind erosion of exposed and rehabilitated areas	1	0.25
Processing area	10	2.5