MESA H DUST DISPERSION MODELLING

Prepared for

RioTinto

Rio Tinto Pty Ltd

by

ENVALL

Environmental Alliances Pty Ltd

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1. INTRODUCTION

ENVALL has been engaged by Rio Tinto Iron Ore (RTIO) to predict dust levels at a number of sensitive receptor locations, arising from the development of the Mesa H iron ore deposit over the years from 2020 to 2035[1].

It is understood that while the assessment may be used to support applications for environmental approvals under Parts IV and V of the *Environmental Protection Act 1986*, its primary purpose is to provide guidance on the general level of impact and the need for site-specific management strategies.

2. LOCATION

The Mesa H deposit is located in the Eastern Pilbara region of Western Australia approximately 15 kms south-west of the Pannawonica township.

3. DEVELOPMENT OF MESA H

The mining stages of the Mesa H deposits are summarised in Table 1 and Figure 1.

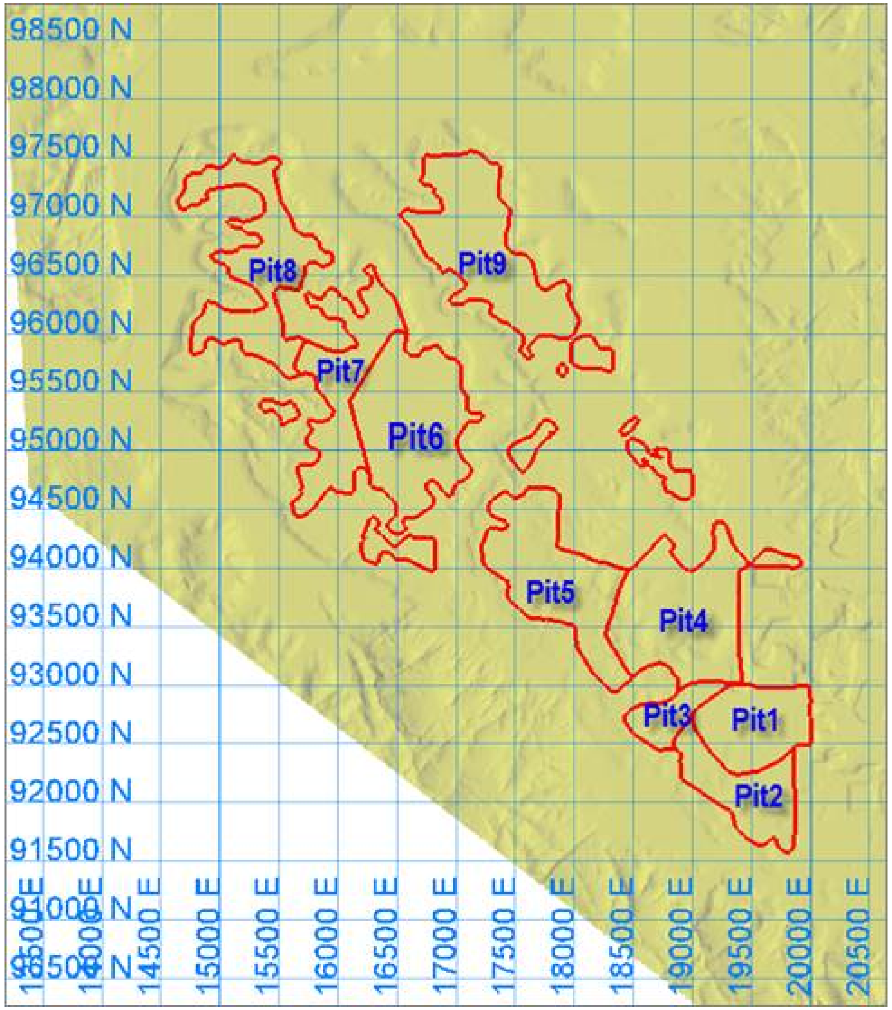
It is noteworthy that the total material moved (TMM), which is the parameter that, broadly speaking, most affects dust levels near the pits, is quite variable from year to year.

[1] Based on RTIO Mine Plan emailed 6/12/2017.

Table 1 Annual pit and total production for Mesa H 2021 to 2035

pit_name	Destination_cru	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Grand Total
mesah_p04	**mesaJ Plant**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.28**	**0.20**	**6.03**	**6.23**	**12.69**	**0.00**	**0.00**	**25.42**
	waste_wt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	1.44	29.89	3.94	3.00	0.00	0.00	38.47
mesah_p04 Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	1.64	35.92	10.17	15.69	0.00	0.00	63.89
mesah_p05	**mesaJ Plant**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**10.42**	**1.68**	**25.14**	**1.79**	**39.03**
	Stockpile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.39	0.79	1.24
	waste_wt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.05	37.81	14.11	0.60	83.57
mesah_p05 Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.53	39.49	39.64	3.18	123.84
mesah_p06	**mesaJ Plant**	**1.69**	**7.77**	**6.07**	**2.52**	**2.68**	**3.74**	**0.26**	**1.25**	**0.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**26.01**
	Stockpile	0.14	1.68	3.13	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.34
West_Dump	waste_wt	4.42	3.70	3.86	10.86	4.21	0.82	0.09	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.14
mesah_p06 Total		6.25	13.14	13.06	13.79	6.89	4.56	0.35	1.41	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	59.49
mesah_p07	**mesaJ Plant**	**0.00**	**0.00**	**0.00**	**0.00**	**1.35**	**0.00**	**6.27**	**3.01**	**1.10**	**0.00**	**4.20**	**3.33**	**0.00**	**2.22**	**0.00**	**3.89**	**25.37**
	Stockpile	0.00	0.00	0.00	0.00	0.41	0.00	1.32	1.73	0.63	0.00	1.28	0.00	0.00	0.00	0.00	0.11	5.48
	waste_wt	0.00	0.00	0.00	0.00	1.85	0.00	2.77	1.78	0.65	0.00	7.94	9.78	0.00	0.32	0.00	0.34	25.42
mesah_p07 Total		0.00	0.00	0.00	0.00	3.61	0.00	10.36	6.52	2.38	0.00	13.42	13.11	0.00	2.54	0.00	4.33	56.27
mesah_p08	**mesaJ Plant**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**7.91**	**1.00**	**6.03**	**2.64**	**1.63**	**1.08**	**1.27**	**0.00**	**0.00**	**0.00**	**0.00**	**21.56**
	Stockpile	0.00	0.00	0.00	0.00	0.00	1.82	0.51	4.44	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.03
	waste_wt	0.00	0.00	0.00	0.00	0.00	2.40	0.36	2.62	10.01	1.14	0.61	0.34	0.00	0.00	0.00	0.00	17.49
mesah_p08 Total		0.00	0.00	0.00	0.00	0.00	12.13	1.87	13.10	13.90	2.78	1.69	1.61	0.00	0.00	0.00	0.00	47.08
mesah_p01	**mesaJ Plant**	**0.00**	**0.00**	**0.00**	**0.04**	**0.00**	**0.00**	**0.00**	**1.06**	**14.14**	**9.52**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**24.77**
	Stockpile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
South_Dump	waste_wt	0.00	0.00	0.00	0.80	0.00	0.00	19.13	4.12	9.36	1.28	0.00	0.00	0.00	0.00	0.00	0.00	34.69
mesah_p01 Total		0.00	0.00	0.00	0.84	0.00	0.00	19.13	5.51	23.51	10.80	0.00	0.00	0.00	0.00	0.00	0.00	59.79
mesah_p02	**mesaJ Plant**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**4.70**	**10.44**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**15.14**
	Stockpile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.03
South_Dump	waste_wt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.87	3.07	0.00	0.00	0.00	0.00	0.00	26.94
mesah_p02 Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.59	13.52	0.00	0.00	0.00	0.00	0.00	42.11
mesah_p03	**mesaJ Plant**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.56**	**2.75**	**6.11**	**0.79**	**0.00**	**0.00**	**0.00**	**10.21**
	Stockpile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.06
	waste_wt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61	17.07	3.10	0.10	0.00	0.00	0.00	21.88
mesah_p03 Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.23	19.81	9.21	0.89	0.00	0.00	0.00	32.15
mesah_p09	**mesaJ Plant**	**0.00**	**0.00**	**3.86**	**6.00**	**13.27**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**23.12**
East_Dump	waste_wt	0.00	0.00	0.98	0.52	3.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.73
mesah_p09 Total		0.00	0.00	4.83	6.52	16.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.85
		6.25	**13.14**	**17.89**	**21.15**	**27.01**	**16.69**	**31.71**	**26.54**	**39.82**	**44.88**	**50.08**	**59.85**	**52.59**	**57.71**	**39.64**	**7.51**	**512.46**
		6.25	**13.14**	**17.89**	**21.15**	**27.01**	**16.69**	**31.71**	**26.54**	**39.82**	**44.88**	**50.08**	**59.85**	**52.59**	**57.71**	**39.64**	**7.51**	**512.46**
Total Ore (t)		1,823,281	9,446,126	13,053,977	8,966,827	17,710,866	13,473,147	9,358,918	17,861,574	19,790,240	16,769,780	19,954,072	16,740,449	17,496,384	16,581,098	25,530,856	6,581,281	231,138,877
Total Waste (t)		4,422,992	3,697,767	4,832,818	12,180,749	9,300,669	3,219,392	22,354,132	8,681,430	20,032,577	28,106,712	30,123,494	43,106,976	35,092,835	41,128,729	14,110,585	931,423	281,323,280
TMM (t)		6,246,273	13,143,893	17,886,795	21,147,577	27,011,535	16,692,539	31,713,050	26,543,004	39,822,817	44,876,492	50,077,566	59,847,425	52,589,218	57,709,827	39,641,441	7,512,704	512,462,157

Ref: As provided by RTIO dated 6/12/2017.



Pit number	Waste located in
Pit 1	Southern waste dump
Pit 2	Southern waste dump
Pit 3	Pit1
Pit 4	Pit 1
Pit 5	Pit 4
Pit 6	Western Waste dump
Pit 7	Pit 9
Pit 8	Pit 6
Pit 9	Eastern waste dump & pit 6

Figure 1 Mesa H pit development and dump usages

Note that the pit boundaries were slightly changed in subsequent information from RTIO from the above figure.

4. SENSITIVE RECEPTORS

The sensitive receptors identified by RTIO for the assessment of dust impacts are shown in Figure 2 and Table 2. Table 2 also shows the environmental value to be assessed for each receptor and the year during which the ore production rates from the nearest pit was highest.

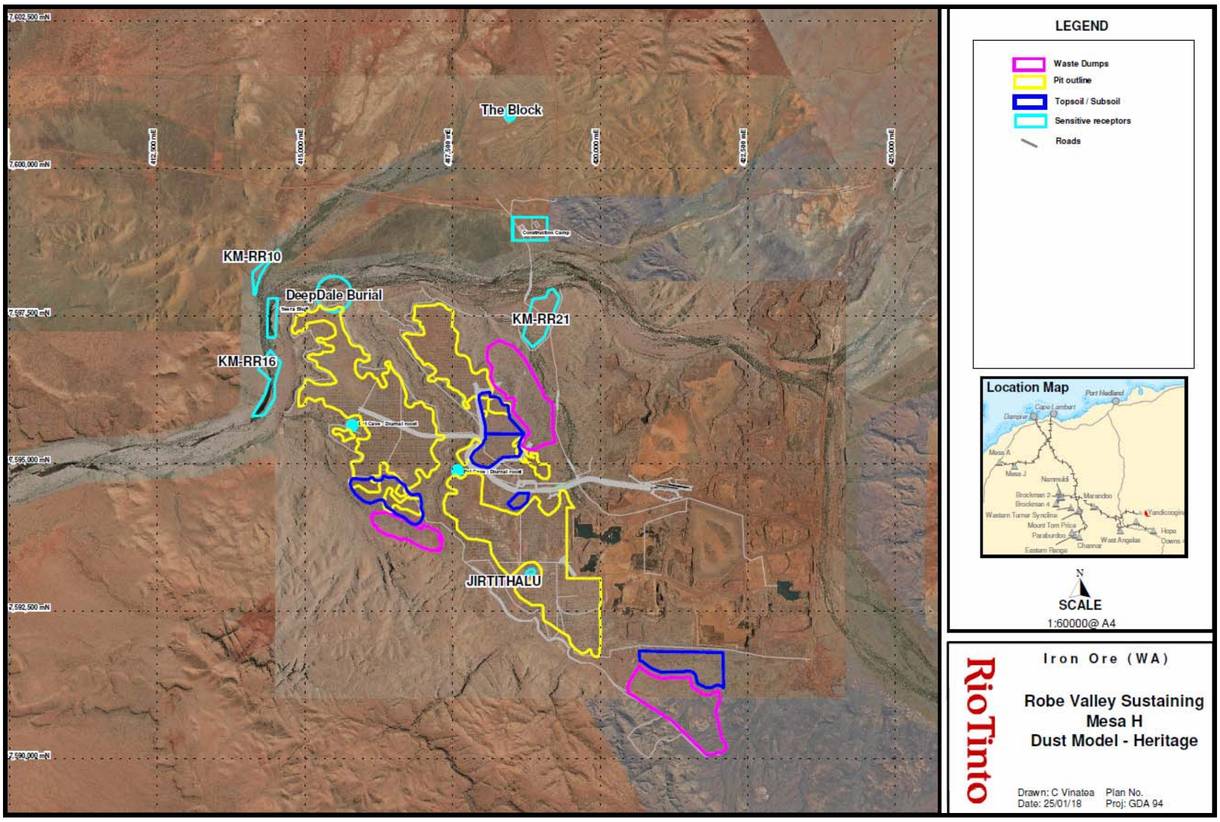


Figure 2 Mesa H location and dust-sensitive receptors

Table 2 Sensitive receptor locations and environmental values to be assessed

ID	Sensitive receptor	Easting (km)	Northing (Km)	Environmental value to be assessed
1	Jirtithalu	418.839	7592.521	Heritage
2	Bat Cave South	417.593	7593.907	Fauna habitat
3	Bat Cave North	415.800	7594.517	Fauna habitat
4	KM-RR16[(b)]	414.490	7594.911	Heritage (Pool area below Yeera Bluff visited regularly by Kuruma Marthudunera and other Pilbara people)
5	Yeera Bluff[(b)]	414.516	7595.814	Heritage (Hill above KM-RR16 visited regularly by Kuruma Marthudunera and other Pilbara people)
6	KM-RR10	414.160	7596.310	Heritage (Law ground not visited regularly, however is driven past to get to Yeera Bluff)
7	Deepdale Burial	415.482	7596.055	Heritage (A burial on the terrace just above the river at the base of the mesa escarpment; not visited regularly)
8	KM-RR21	418.699	7595.737	Heritage (Law Ground visited (or driven past) regularly by Kuruma Marthudunera (people often go down to the river here when they are staying at 'The Block'))
9	Construction Camp	418.534	7597.034	Human Health
10	The Block	418.483	7598.738	Heritage/Human Health (Homestead and associated graves – visited regularly by Kuruma Marthudunera)
11	Pannawonica[(a)]	430.2	760.7	Human Health

(a) ENVALL has undertaken numerous dust assessments of RTIO's Pilbara iron ore mines. These have consistently shown that dust levels are well below ambient criteria more than 3 kms from the nearest part of the mining operation. On this basis, the Pannawonica township, being approximately 15 km away, has not been explicitly included in this study.

(b) KM-RR16 and Yeera Bluff are essentially the same area.

5. SCOPE OF WORK

The scope of work is:

- to assess ambient dust levels at the sensitive receptors in Table 2 for the project operation;
- to assess ambient dust levels at receptors 1 to 7 in Table 2 (Jirtithalu, Bat Cave South, Bat Cave North, KM-RR16, Yeera Bluff, KM-RR-10, Deep Dale Burial) from pre-operational clearing operations.

6. ASSESSMENT CRITERIA

6.1 NATURE OF DUST

6.1.1 Airborne dust

Dust is the general term used to describe particles of crustal material that can remain suspended in the air by turbulence for an appreciable length of time.

Dust is a component of a wider range of airborne particulate matter (PM). PM may also include smoke from combustion, pollens, sea salts and liquids (aerosols). PM may range in size from less than 10 nanometers to more than 100 micrometers (µm) in diameter.

Typically, PM is characterised by its size, as measured by collection devices specified by regulatory agencies. The particulate size ranges specified in ambient air guidelines are:

- Total suspended particulate (TSP);

- Particulate matter measured with a sampler with 50% cut point at 10 µm (PM10); and
- Particulate matter measured with a sampler with 50% cut point at 2.5 µm (PM2.5).

TSP refers to particulates that can remain suspended in the air or can be measured though a TSP sampler. The particle size is not a fixed physical size, but varies, as the size of particle that can remain suspended in the air is a function of air turbulence. TSP is associated with nuisance impacts such as a reduction in visibility. PM10 is inhalable; PM2.5 is more associated with health impacts. In addition such impacts are dependent on the actual particulate type / content, as some are more likely to have health implications than others.

6.1.2 Dust deposition

Dust deposition refers to the gravitational settling and subsequent deposition of airborne dust onto the ground or a ground surface feature.

Dust deposition is typically measured in accordance with “AS/NZS 3580.10.1:2016 Methods for sampling and analysis of ambient air - Method 10.1: Determination of particulate matter - Deposited matter - Gravimetric method”. This involves setting out a glass jar and funnel on a stand over a month and allowing particle matter to fall in by gravity. A mesh across the jar opening protects against interference from birds and other interferences is possible. Water and chemicals in the bottom of the jar are used to collect the dust and to prevent mould contamination. At the end of the sampling period, the jar with its contents is taken to a laboratory for analysis. After any liquid has evaporated, the remaining insoluble solids are weighed and typically converted to standard units of grams per square metre.

The modelling of dust deposition from industrial source emissions does not take into account secondary wind erosion and (re) deposition influences.

Modelling is also separated into “dry” and “wet” deposition. “Dry” deposition is deposition outside of rainfall periods. “Wet” deposition is the much higher rate of deposition that occurs during rainfall. Since rainfall periods are very infrequent in the inland Pilbara, the overall amount of dust deposited annually from wet deposition is small. Conventionally, only the results from modelling dry deposition are considered for comparison to ambient human-nuisance-based criteria. Surface dust is, however, also washed during rainfall. Hence the amount of deposited dust that is ultimately accumulated onto a surface over the longer term is subject to the complexities that arise from washing, drainage, pooling, chemical reactions etc. The modelling results of dry deposition simply present the accumulated dust-fall from dry deposition; however, after any rainfall, the results would not represent the total amount of dust that resides on a particular surface area.

The particle size distribution used for modelling dust deposition was estimated using composite data from the US EPA size distributions and the National Energy Research, Development and Demonstration Council (NERDDC) (1988) study, as summarised in Table 3 (from Air Assessments 2011).

Table 3 Airborne particle size distributions

<table>
<tr><th>Source/ Aerodynamic particle diameter range (µm)</th><th><2.5</th><th>2.5-5.0</th><th>5.0-10.0</th><th>10-15</th><th>15-30</th><th>30-50</th><th>50-90</th><th>90-150</th></tr>
<tr><td colspan="9">Percentage of PM30</td></tr>
<tr><td>USEPA (2006) wind erosion</td><td>7.5</td><td colspan="2">42.5</td><td>10</td><td>40</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>USEPA (2006) unpaved road</td><td>3.1</td><td colspan="2">27.6</td><td colspan="2">69.4</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td colspan="9">Percentage of TSP</td></tr>
<tr><td>USEPA aggregate handling (Nov 2006)</td><td>5.3</td><td>14.7</td><td>15</td><td>13</td><td>26</td><td colspan="3">26</td></tr>
<tr><td>NERDDC (1988) operations iso-kinetic sampler</td><td>4</td><td>9</td><td>17</td><td>11</td><td>22</td><td>17</td><td>13</td><td>7</td></tr>
<tr><td>Composite fraction of TSP (%)</td><td>5</td><td>12</td><td>16</td><td>12</td><td>25</td><td>15</td><td>10</td><td>5</td></tr>
<tr><td colspan="9">Used in this assessment</td></tr>
<tr><td>Aerodynamic particle diameter range (µm)</td><td><2.5</td><td>2.5-5.0</td><td>5.0-10.0</td><td>10-15</td><td>15-30</td><td>>30</td><td></td><td></td></tr>
<tr><td>Fraction of TSP (%)</td><td>5</td><td>12</td><td>16</td><td>12</td><td>25</td><td>30</td><td></td><td></td></tr>
<tr><td>Assumed aerodynamic particle diameter (µm)</td><td>1.8</td><td>3.8</td><td>7.5</td><td>12</td><td>22</td><td>40</td><td></td><td></td></tr>
</table>

Notes

1) USEPA TSP percentages were estimated from the PM_{30} based on 74% of wind erosion material and 76% of batch drop dust is below PM_{30}.

2) Mass in size fraction as a percentage of PM10 adopted this study TSP/PM10 =3.03; PM2.5/PM10 = 0.16.

The above distribution indicates that the fraction of PM10 in TSP is 0.33. Therefore, the modelled TSP emission rates are 1/0.33 = 3.03 times the PM10 emission rates.

6.2 DUST IN THE PILBARA

The regulatory management of dust from industrial sources in the Pilbara is complicated by the ubiquitous nature of other dust sources which can, for example, take the form of vehicle-generated dust from unpaved roads and wind erosion of unpaved roads, non-vegetated and disturbed areas. The Pilbara environment is also characterised by periodic “dust storms” caused by large scale wind erosion of inland areas that have been denuded of vegetation by recent wildfires or following a prolonged dry period.

The Western Australian Department of Water and Environment Regulation (DWER) and Environmental Protection Authority (EPA) do not have generic dust criteria directly applicable to remote mining operations. The criteria used here are from other references as an indication of what might be considered acceptable. Their selection is based on the nature of the adverse impact to be prevented.

6.3 DUST CRITERIA FOR AIRBORNE CONCENTRATIONS

6.3.1 Human health

The criteria in the National Environment Protection (Ambient Air Quality) Measure ("Air NEPM") are used for the assessment of human-health related impacts in populated areas. In the past, DWER has accepted that the PM10 Standard specified in the Air NEPM cannot be met in the inland Pilbara[2].

The Air NEPM was varied on 3 February 2016. Amongst other things, the previous 24-hour average PM10 goal of 50 µg/m^3, inclusive of up to five "exceptional (dust) events", was modified to a maximum concentration of 50 µg/m^3 exclusive of such "exceptional events". Correspondingly, for reporting compliance against the PM10 (and PM2.5) 1 day average standards, monitoring data that "has been determined as being directly associated with an "exceptional event" is to be excluded. An "exceptional event" is defined as "a fire or dust occurrence that adversely affects air quality at a particular location, and causes an exceedance of 1 day average standards in excess of normal historical fluctuations and background levels, and is directly related to: bushfire; jurisdiction authorised hazard reduction burning; or continental scale windblown dust" (NEPC 2016).

It should be noted that the revised NEPM criteria is likely to be more stringent than the PM10 criteria for inland Pilbara mining operations adopted by RTIO in "Iron Ore (WA) Cleaner Air Management Plan" (February 2011), therefore this has not been referred to in this study.

6.3.2 Heritage (human amenity)

In order to provide some sort of benchmark against which predicted dust levels can be assessed, the "acute" dust as TSP criterion from the Kwinana EPP has been adopted. This is a dust (as TSP) concentration of 1000 µg/m^3 averaged over 15 minutes.

At a concentration of 1000 µg/m^3, dust is generally visible in normal light conditions. This may then create the perception of diminished heritage values and hence this level as a benchmark may be useful on this basis.

6.3.3 Fauna habitat (Ghost Bats)

Whilst there is no established criterion for Ghost Bats (*Macroderma gigas*), the species is listed under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*, and in Schedule 3 of the Western Australian *Wildlife Conservation Act 1950*, as "Vulnerable".

As a precedent, the Rio Tinto West Angelas Operational Environmental Management Plan (Ministerial Statement 970) specifies the requirement to protect Ghost Bat habitat in close proximity to deposits. For this reason, Rio Tinto has Blast Management Plans in place for mining operations. The Management Plans cover aspects such as monitoring, blast prediction and utilisation of sonic fencing for protection against noise and dust from blasting.

It is anticipated that a similar procedure will be adopted in relation to the development of the Mesa H deposits.

In order to provide some sort of benchmark against which predicated dust levels can be assessed, the "acute" dust as TSP criterion from the Kwinana EPP has been adopted.

As described above, at a concentration of 1000 µg/m^3, dust is generally visible. This may possibly create the perception that any Ghost Bats may be affected – irrespective of whether they are or not, and hence this level as a benchmark may be useful on this basis[3].

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[2] See the Environmental Assessment Report in the Mesa A licence - http://portal.environment.wa.gov.au/pls/portal/docs/PAGE/ADMIN_LICENSING/LICENCES/2006/TAB8118754/8388ROBEMESA_3.PDF

6.3.4 Dust deposition for Heritage

Deposited dust is that defined by the sampling method in Australian Standard AS 3580.10.1-2003. Particles that settle from the air are collected in a vessel. The sample is then sieved, filtered and the mass of remaining insoluble solids weighed.

Human amenity

RTIO's dust deposition criterion is shown in Table 4.

Table 4 RTIO internal dust deposition criterion – inland mining operations

Parameter/ Particle size	Averaging time	Concentration	Frequency	Location	Relevant Sites
Deposited Dust	Annual[(a)]	4 g/m^2/month as total maximum from all sources; equivalent to - 2 g/m^2/month as additional maximum from mining operations for 2 g/m^2/month background; or - 3 g/m^2/month as additional maximum from mining operations for 1 g/m^2/month background.	Monthly	Mining lease boundary/nearest sensitive receptor	Tom Price, Greater Paraburdoo, Marandoo, Brockman 2, Brockman Syncline 4, Nammuldi, West Angelas, Hope Downs, Yandi, Robe Valley mines

From RTIO (2011), Table 5.
[(a)] The criterion is an annual average but expressed on a "monthly" basis where the averaging period of a month is classified as a 30-day period.

This criterion is from the New South Wales (NSW) "Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales" (2005). The NSW dust deposition criterion is based on nuisance effects to humans and applies at sensitive human receptors. Table 7.1 of the NSW document clarifies that the criterion is actually one part of a dual-part criteria. The 4 g/m^2/month[4] refers to total deposited dust, while the adjacent specification of 2 g/m^2/month is the additional deposition attributable to the (industrial) source. Consequently, it has therefore also been assumed that background dust deposition around population centres in the Pilbara is 2 g/m^2/month. Away from population centres, the background dust deposition in the Pilbara is considered to be around 1 g/m^2/month[5].

Vegetation

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

[3] Note that this has been changed from TSP-24hr in the scope of work, as it is considered that short-term dust levels may be more relevant

[4] A dust deposition rate of 4g/m^2/month equates to a visible layer of dust on outdoor furniture or on a clean car deposited each month.

[5] O. Pitts *pers com* from green-fields monitoring data.

The Pilbara environment is naturally dusty, hence native vegetation is expected to be reasonably tolerant to dust deposition. Internal studies undertaken for Rio Tinto (Butler 2009) suggest that the potential for adverse dust deposition effects on plants is seasonally related. This is consistent with the results from other studies on the effects of air pollutants on vegetation, which indicate that adverse effects are usually related to the growing season.

The Butler (2009) study failed to identify any significant loss of plant function for exposures of Pilbara species to deposited crustal dust loadings on plant leaves of up to a very high level of 7,500 g/m^2 (Butler 2009). This level should not strictly be compared to dust deposition predictions from modelling. Dust deposition predictions from modelling are effectively from vertical settling only. Plant leaves tend to trap dust irrespective of whether the dust is deposited from vertical settling or impacted horizontally from the wind. Therefore a plant leaf dust loading of 7,500 g/m^2 would correspond to a predicted deposition of somewhat less than this.

For this study, 7 g/m^2/month is used as an indicative criterion for potential effects on vegetation, however the Butler (2009) work shows that this is probably very conservative.

Heritage

Since "heritage" encapsulates human amenity impacts as well as vegetation health, the more conservative criteria of the two has been adopted, which is 3 g/m^2/month of additional deposition.

6.4 SUMMARY OF GUIDELINES

The dust guidelines considered applicable for this study are shown in Table 5.

Table 5 Dust parameters to be assessed for environmental values

Sensitive Receptor Environmental Value	Dust Parameter to be assessed	Guideline
Human Health	PM10-24hr	50 μg/m^3
Heritage	TSP-15min	1000 μg/m^3
	Deposition-annual	4 g/m^2/month as total maximum from all sources; equivalent to - 3 g/m^2/month as additional maximum from mining operations for 1 g/m^2/month background.
Fauna Habitat (Ghost Bats)	TSP-15min	1000 μg/m^3

7. DUST IMPACTS FROM CLEARING PHASES OF THE WESTERN-MOST PITS

7.1 DESCRIPTION OF PROCESS

Topsoil and subsoil clearing is conducted in line with the Iron Ore (WA) Soil Resource Management Work Practice (RTIO-HSE-0011596).

In general, mining area topsoil is cleared to 200 mm and subsoil to 600 mm, and dumped separately. Vegetation grubbing is included in the topsoil clearing.

Dozers are used to push up the soil into piles that can be handled by a Front-End Loader or similar. The orientation of piles is usually into ribs, as determined by the terrain and safe loading practices. The topsoil is the trucked directly to the final topsoil stockpiles.

Clearing is undertaken during both day and night shifts, subject to dust, weather and other safety considerations where work-arounds are implemented. For example, during rainfall periods, higher areas that drain well are cleared.

From advice from RTIO[6], a typical dozer (e.g. D11) can clear approximately 1000 tonnes per hour[7]. For typical ground, the rate of clearing is therefore about 3 Ha per day (24 hours) for topsoil and 1 Ha per day for subsoil. Clearing is slower during the wet season (December to March) and in contour and rocky areas.

The Mine Plan determines the clearing progression for each pit.

The pits are broken into smaller manageable areas. Generally, areas to be accessed first are cleared first. Areas to be mined later in the life of the pit will be cleared of topsoil closer to the planned mining dates. 100% of topsoil and subsoil before waste is stripped.

Prevailing winds and weather conditions are also considered by Supervisors, with the ultimate program based on the safest method/plan of clearing to ensure sensitive receptors are minimally impacted.

Dust generation during clearing therefore arises from:

- dozing;
- loading; and
- wind generation from open/exposed areas.

The short-term dust impact to sensitive receptors is determined by a number of complex factors such as:

- rate of clearing;
- the exact location of the clearing activity in relation to proximity to the relevant sensitive receptor; and
- the prevailing hourly wind and other meteorological conditions affecting dust generation and subsequent dispersion.

It is not possible to be able to determine how these interact in advance. Therefore, it was considered the only practical way to provide guidance on potential mitigation requirements was by modelling the "worst case"[8] dispersion of dust emissions from clearing. This involves using a "screening" meteorological data set containing all possible combinations of wind speeds and stabilities.

7.2 EMISSIONS

The dust emissions from clearing were estimated using the NPI equations and an average clearing rate of 2 Ha/day and 1000 t/hour from RTIO advice, and are shown in Table 6.

6 Email from RTIO 20/12/2017.

7 Assuming Equivalent Usage factor of ~55%.

8 As per the DWER modelling guidance: https://ia801403.us.archive.org/10/items/AIRQUALITYMODELLINGGUIDANCENOTESMAR2006WEB/AIRQUALITYMODELLINGGUIDANCENOTES_MAR2006WEB.pdf accessed 9/6/2018.

Table 6 Estimation of clearing dust emissions

Activity	Equation reference[(a)]	Emission Factor[(a)] (PM10)	Units	Total Activity value per year		PM10 emissions (g/s)	TSP emissions (g/s)
Excavators/Shovels/ Front-end loaders (on overburden)	NPI (2012) Table 2	0.012	kg/t	8,760,000	t/yr	3.3	10.1
Bulldozer on material other than coal	NPI (2012) Table 2	4.1	kg/hr	8,760	hr/yr	1.1	3.5
Wind erosion	NPI (2012) Table 2	0.2	kg/ha/h	730	ha/yr	<0.1	<0.1
TOTAL						4.5	13.6

[(a)] NPI (2012) assuming default soil moisture and silt values.

Note that based on the estimated clearing rate, the total estimated time to clear any pit is 83 days (see Table 7). Since the dust deposition criterion is based on an annual period, it is not meaningful to assess dust deposition from clearing, as the time period is too short.

Table 7 Estimated time required to clear each pit

Pit	Estimated time required to clear (days)
Pit1	17
Pit2	30
Pit3	12
Pit4	58
Pit5	53
Pit6	56
Pit7	56
Pit8	83
Pit9	60

7.3 BACKGROUND DUST

The emphasis of this study is short-term dust levels, which are in the order of some hundreds of µg/m^3 Background dust levels in the order of 10-20 µg/m^3 are therefore only a small percentage of these and are too small to be considered in view of other modelling uncertainties.

7.4 DISPERSION MODEL

For downwind centre-line predictions, the Ausplume model (EPAV 2000) was used. This is a gaussian model developed by the Environment Protection Authority of Victoria, which can handle particle gravitation settling and deposition.

7.5 PREDICTIONS

Figure 3 shows the predicted maximum (plume centre-line) 15-minute average TSP concentrations downwind from clearing activity for day and night. As described above, these are the highest (i.e.

"worst case") predicted concentrations that may occur for any hour over a year, at each distance downwind of the clearing activity.

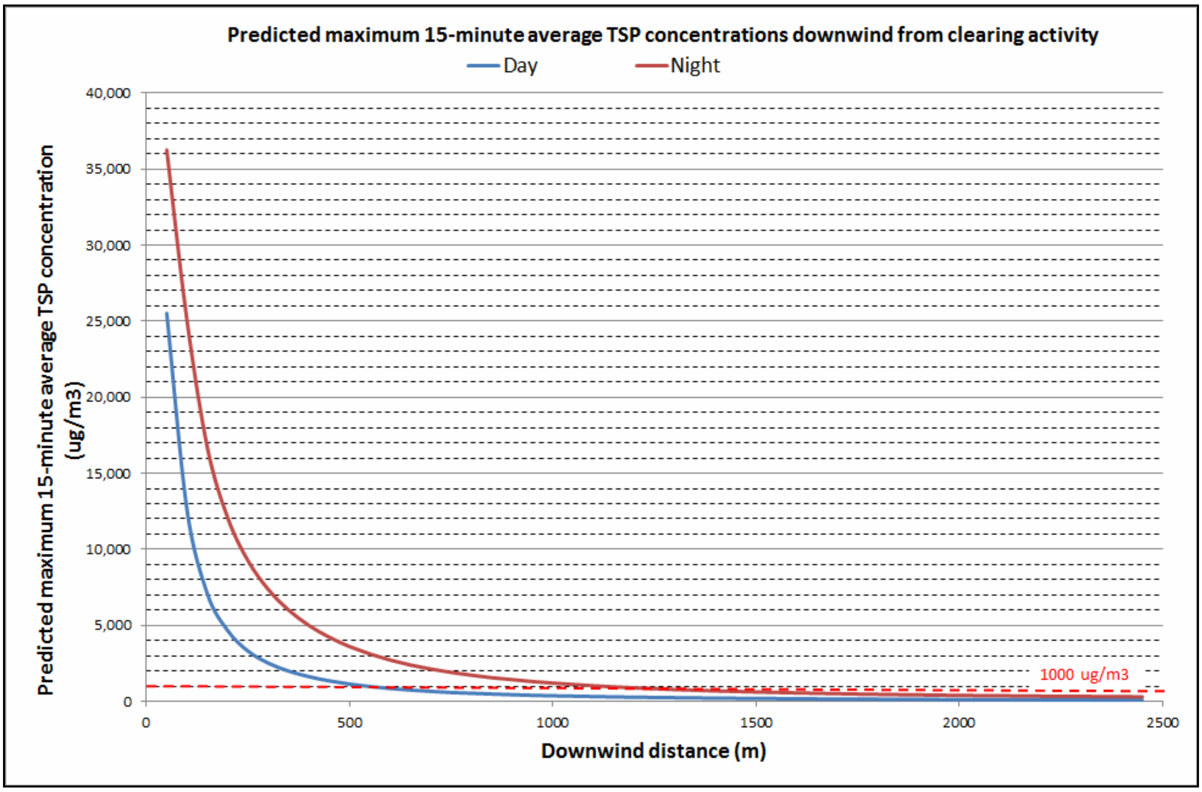


Figure 3 Predicted maximum 15-minute average TSP concentrations downwind from clearing activity

For the assumed criteria of 1000 µg/m^3 (15-minute average), the distance is 550 m and 1410 m for day and night respectively. It is considered that clearing activities during dry conditions within these distances when the wind is from the clearing activity to the sensitive receptor, needs increased dust control management.

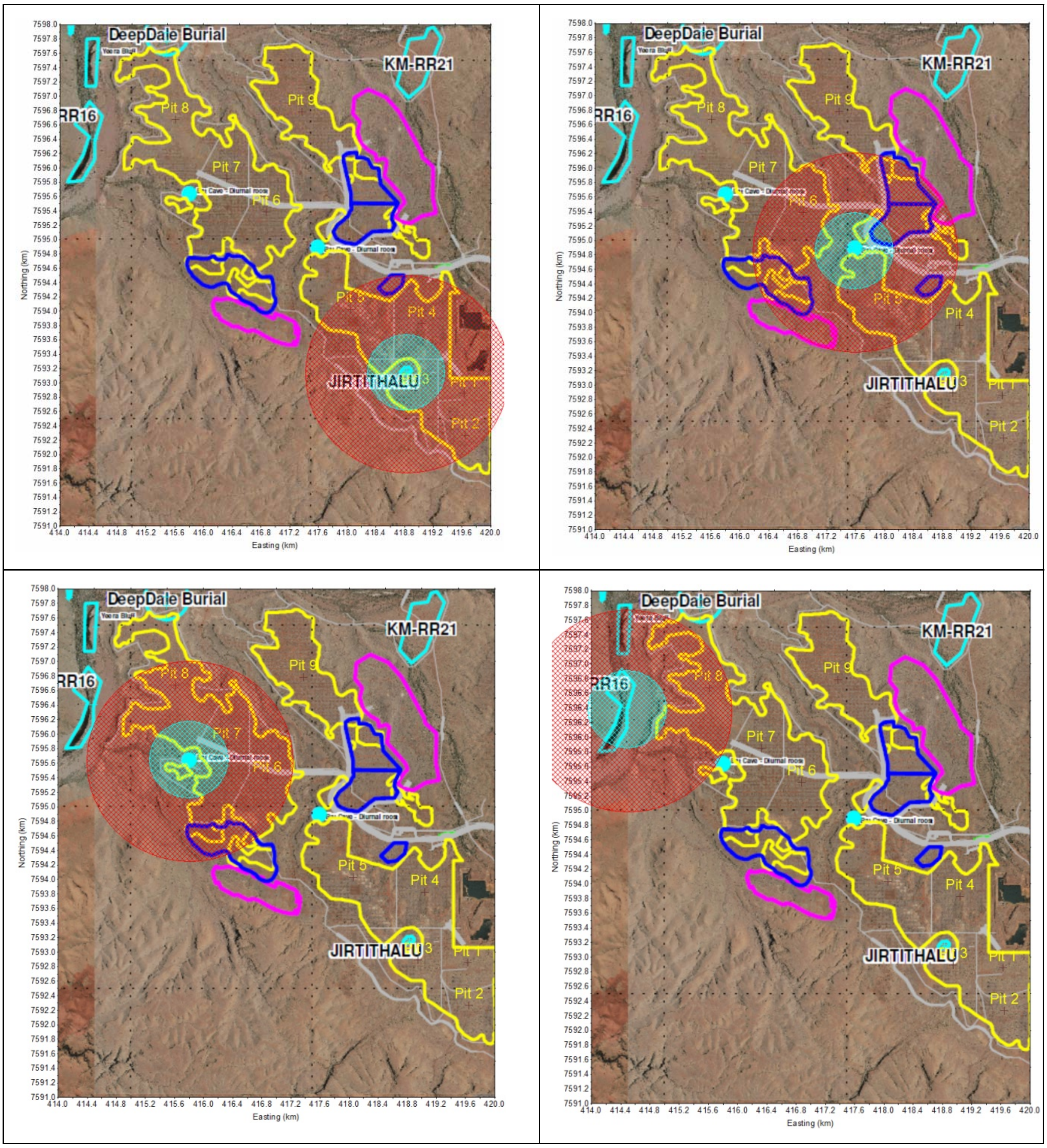
The predicted worst case clearing dust mitigation requirement zones for daytime (blue hatch) and night-time (red hatch) for each sensitive receptor based on the distances above are shown in Figure 4. It needs to be emphasized that these are very much worst case illustrations of where dust mitigation may need to be considered, based on the most adverse meteorological conditions when winds are from the clearing activity to the closest point of the sensitive receptor area to the mining operation, and a criterion based on visibility reduction causing a human nuisance - rather than any known adverse fauna or flora impacts.

Mitigation measures may include increased water control[9] and reduction/cessation of activities when they are located within the day/night distances as above, and winds are from the clearing activity toward the relevant sensitive receptor.

It may be appropriate to verify these modelling predictions (and inherent dust emission estimates) through on-site dust sampling downwind of clearing operations currently being undertaken at a representative mining operation. This may enable the development of a more precise "dust risk

[9] The NPI Mining Handbook (NPI 2012) does not list any dust emission reduction factors for waste control of dozing or truck loading activities, indicating that water controls for these activities may be difficult to implement.

matrix" based on day/night wind speeds and downwind dust concentrations, that would lessen the required occurrence of dust mitigation measures.


DeepDale Burial
KM-RR21
RR16
Pit 8
Pit 9
Pit 7
Pit 6
Pit 5
Pit 4
JIRTITHALU
Pit 1
Pit 2
Northing (km)
Easting (km)

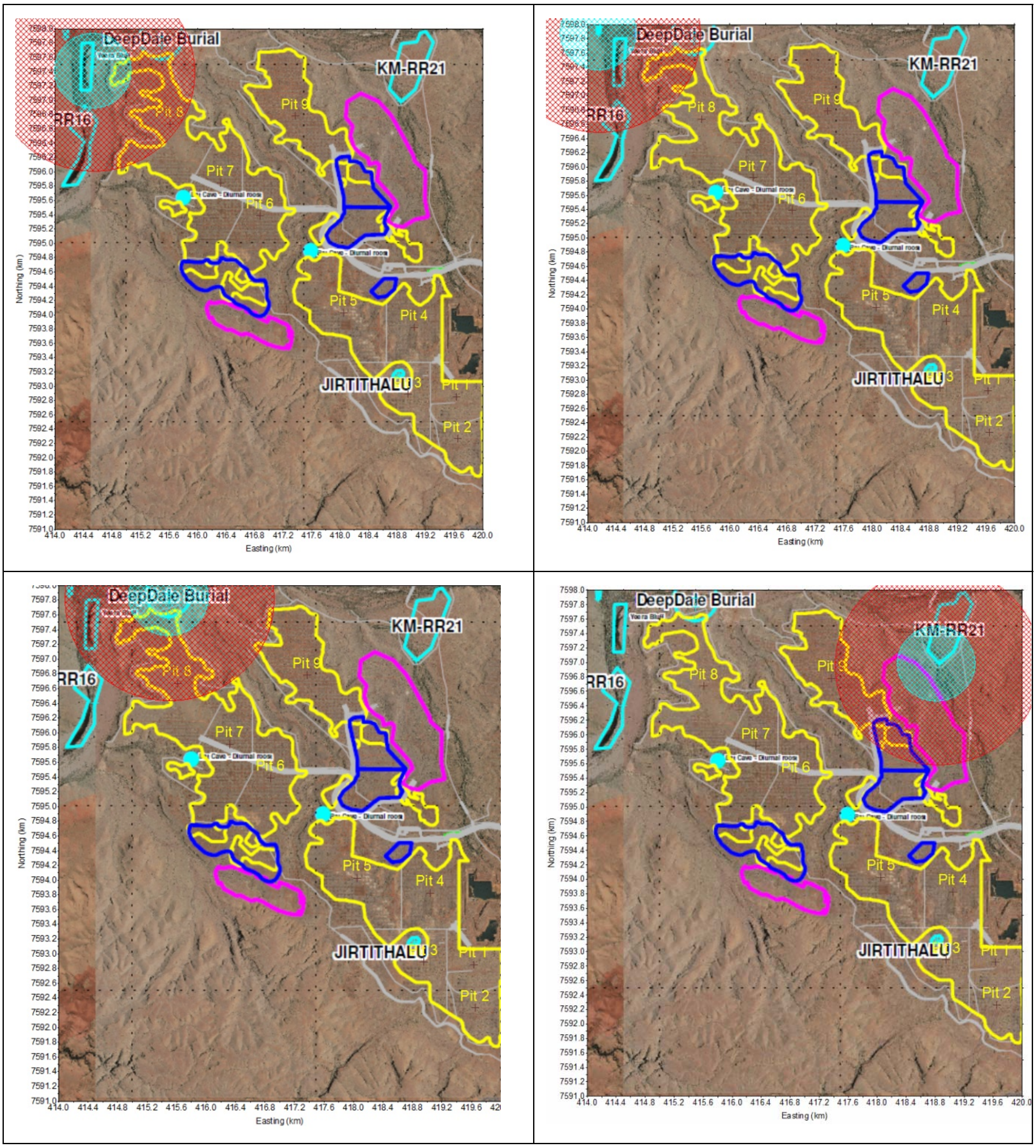


Figure 4 Predicted worst case clearing dust mitigation requirement zones for daytime (blue hatch) and night-time (red hatch) for each sensitive receptor

Top row left to right: 1, Jirtithalu; 2, Bat Cave South

2nd row left to right: 3, Bat Cave North; 4, KM-RR16

3rd row left to right: 5, Yeera Bluff; 6, KM-RR-10

4th row left to right: 7, Deep Dale Burial; 8, KM-RR21

8. DUST IMPACTS FROM MINING OPERATIONS

8.1 DISPERSION MODEL

The United States Environmental Protection Agency's (US EPA's) CALPUFF version 6 model was used to predict dust impacts from the operations phase (2020 to 2035). This is a 3-dimensional model which has been adopted by the US EPA in its "Guideline of Air Quality Models" as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas, and on a case-by-case basis for certain near-field applications involving complex meteorological conditions.

More specifically to this study, the hilly terrain around the Pilbara mine-sites and the relatively large distances between sources and areas of interest necessitates the use of this type of model for realistic predictions of dispersion and deposition.

The CALPUFF modelling system consists of three main components; CALMET - a diagnostic 3-dimensional meteorological model, CALPUFF - an air quality dispersion model, and CALPOST - a post-processing package.

The following is a summary of key model set-ups:

- meteorological modelling grid resolution of 250 m with a nested pollution grid resolution of 125 m used to improve predictions closer to sources;
- terrain heights were obtained from the Geoscience Australia 1 arc second (approx 30 m resolution) DEM data base (Geoscience Australia 2011). These data were obtained from the STS-99 mission of the Space Shuttle Endeavour during February 2000 and have been processed by Geoscience Australia to remove elevated features such as trees and hydrologically enforced to be consistent with major water courses.
- a land use category of 30 – "Rangeland" was defined for modelling domain. The CALMET defaults were used for this category except for a slightly increased roughness length of 0.25 m;
- terrain effects on dispersion are taken into account using plume partial height adjustment scheme; and
- particle deposition was taken into account.

8.2 METEOROLOGICAL DATA

The nearest location of continuous meteorological measurements suitable for modelling is the Mesa H weather station, which is approximately 10 km from the site.

There are approximately five years of 10-minute average measurements available.

The time period selected was from 1/7/2016 to 30/6/2017, since this corresponds to the NPI emission calculation period used as the basis of the dust emissions estimates for the modelling. The data recovery for this period was 97.3%.

The CSIRO's TAPM model was used to fill in missing data gaps (and to generate the upper air data file required by CALMET).

The key TAPM setups were:

- grid dimensions of 41 x 41 cells with nests at 10000 m, 3000 m and 1000 m;
- local deep soil moisture levels of 0.1 % volume were from the Pilbara Air Quality Study; and
- all other settings were defaults.

The annual wind rose and frequency occurrence matrix is shown in Figure 5. The annual average wind speed at the 10 m measurement height is 2.9 m/s.

The diurnal and seasonal wind roses are shown in Appendix 1.

Winds tend to be from the east to south-east in the morning to afternoon, and west to north-west from the late evening. Spring to summer winds are predominately south-west to west-north-west, while autumn and winter winds are predominantly from the east-north-west to south-south-east.

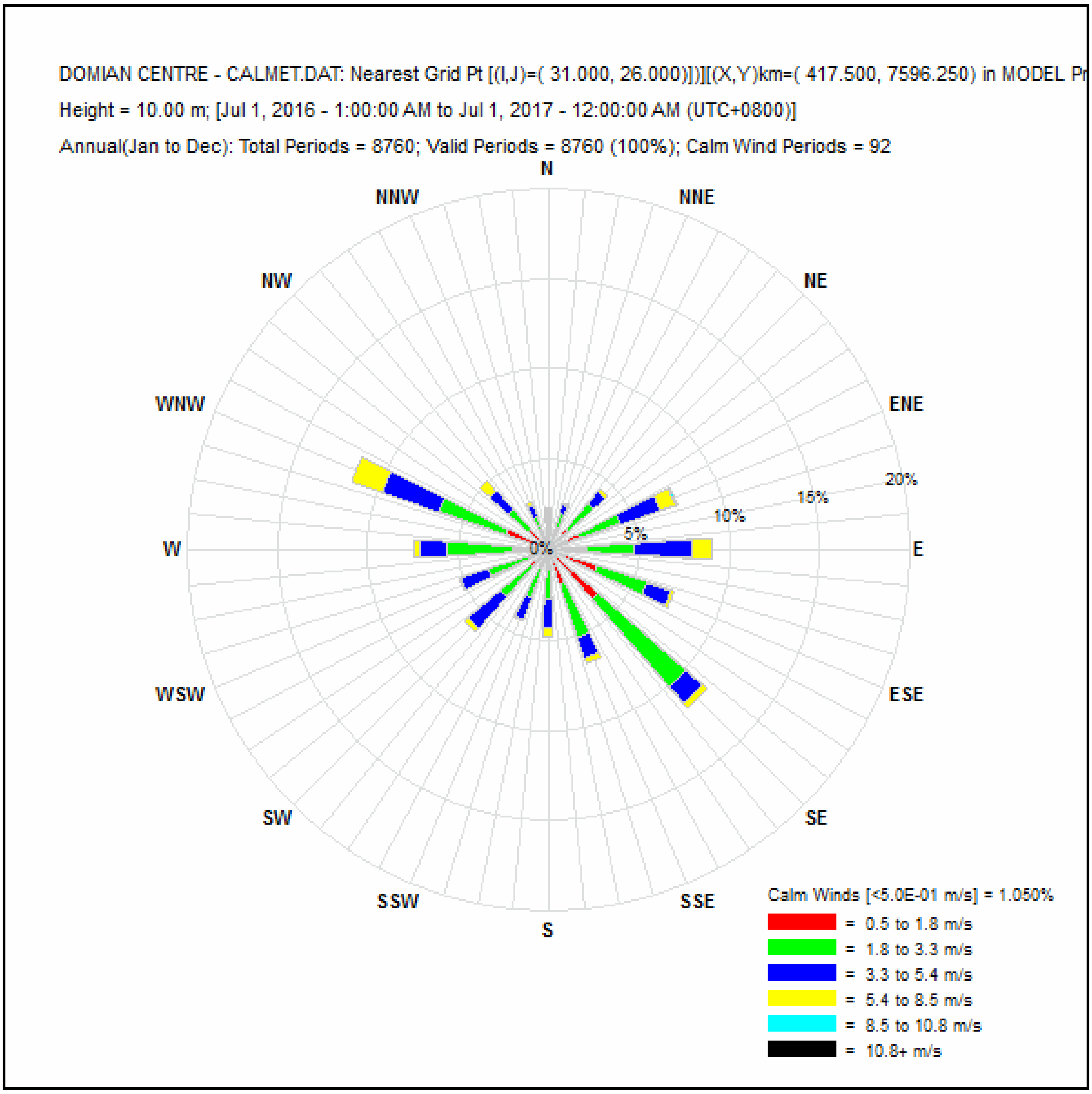


Figure 5 Wind speed and direction frequency rose from Mesa J anemometer 1/7/2016 to 30/6/2017

Seasonal and diurnal roses are shown in Appendix 1. The diurnal regime is for strong east winds from the early morning, becoming lighter during the day and swinging to west to north-west in the late evening.

8.3 DUST EMISSIONS

Dust emissions estimates were based on PM10 emissions for the 2016-17 year for the existing operation reported by Rio Tinto pursuant to the National Pollutant Inventory (NPI) requirements. It is noted that dust emissions from mining operations are difficult to determine accurately using generalised emissions estimation techniques (EETs)[10].

The broad categories of sources defined for modelling purposes were:

- active pits;
- active waste dumps; and
- plant/process areas.

In most cases, the general physical locations of the emissions sources are apparent from the NPI spreadsheets (e.g. wind erosion from pits), however in some cases, assumptions are required for the physical location of the sources (e.g. truck dumping, dozing etc).

The assumed distribution of PM10 emissions sources from the source groups for the existing operation are summarised in Table 8.

[10] As stated on the NPI EET web page "It should be emphasised that the emissions data derived using any EET will have a degree of uncertainty associated with it"[10].

Table 8 Dust emissions by source and basis for 2016-17

Source	Total per source (kg)	Activity (kg)			Wind generated (kg)		
		Pits	Waste dumps	Process Area	Pits	Waste dumps	Process Area
Drilling	5,310	5,310					
Blasting	20,738	20,738					
Excavator	1,727	1,183	544				
Loader	6,404	4,388	2,015				
Dozers	13,161	9,019	4,142				
Loading Haul trucks	7,615	5,218	2,396				
Haul truck wheels	220,509	151,113	69,396				
Service truck wheels	287,830	197,247	90,583				
Light vehicle wheels	22,647	15,520	7,127				
Graders	1,559	1,559					
Ore Stockpile	652						652
Ore Access/Pit	51,011				51,011		
Haul Road/Parkup/Carpark	3,377				2,984	393	
Infrastructure/Plant/Buildings/Comms	3,884						3,884
Roads and Access Tracks	3,290				2,908	383	
Topsoil/Subsoil	940					940	
Waste Dumps/Stockpile	17,196					17,196	
Stackers/Reclaimers	16,032			16,032			
Transfers/Stackers/Train Load Out/Locos	398						398
Sub-totals Basis/Source		411,295	176,204	16,032	56,902	18,911	4,934
Sub-totals Basis		603,531			80,747		
Total	684,278	684,278					

It would be very time consuming to explicitly model dust for each year. Therefore it was generally assumed for defining the scope of work that the dust impacts at each sensitive receptor would be greatest for the year in which the TMM was highest from the nearest pit. An exception to this was for KM-RR21 where the eastern waste dump is closer than any pit, therefore the year for which the waste deposition to this dump was the highest, was selected.

The pits/dump nearest to each sensitive receptor and therefore the year modelled is shown in Table 9. Therefore, the years 2024, 2028, 2030, 2031 and 2032 were modelled.

Table 9 Dust impact assessment on nearby sensitive receptors each year

ID	Sensitive receptor	Environmental value to be assessed	Clearing Phase	Mining Phase		
			Parameters to be assessed		Most affecting Pit/ Dump	Year
1	Jirtithalu	Heritage	TSP-15min, deposition	TSP-15min, deposition	Pit 4	2031
2	Bat Cave South	Fauna habitat		TSP-15min	Pit 5	2032
3	Bat Cave North	Fauna habitat		TSP-15min	Pit 7	2030
4	KM-RR16	Heritage	TSP-15min, deposition	TSP-15min, deposition	Pit 8	2028
5	Yeera Bluff	Heritage	TSP-15min, deposition	TSP-15min, deposition	Pit 8	2028
6	KM-RR-10	Heritage	TSP-15min, deposition	TSP-15min, deposition	Pit 8	2028
7	Deep Dale Burial	Heritage	TSP-15min, deposition	TSP-15min, deposition	Pit 8	2028
8	KM-RR21	Heritage	TSP-15min, deposition	TSP-15min, deposition	East Dump	2024
9	Construction Camp	Human Health	-	PM10-24hr	Pit 9	2024
10	The Block	Heritage/Human Health	-	PM10-24hr, deposition	Pit 9	2024

The emissions in Table 8 were scaled for the relevant pits each modelled year of the Mesa H development with the following assumptions:

- As NPI-based emission estimates are quite uncertain, all emissions were scaled by 1.45 (i.e. upwards), based on the results of previous modelling validation exercises for RTIO iron ore mining operations (see Appendix 2). This should ensure that emissions are not under-stated.
- It was assumed that all equipment would be operating continuously during the operational hours.
- It is assumed that there are no wind-generated dust emissions from operational areas once activity has ceased. This is considered reasonable on the basis that erodible dust from exposed areas is depleted in the absence of continuing disturbances, the crusting of erodible areas following rain periods and assuming that finished waste dumps are rehabilitated.
- Dust emissions from in-pit waste filling were not considered as these are unlikely to be significant outside the final pit, and would necessitate a far more complex approach to the modelling set-up.

8.4 RESULTS

As a general indication of the extent of dust impacts, contours for the highest 15-minute average TSP concentrations for the years modelled are shown in Figure 6 to Figure 3.

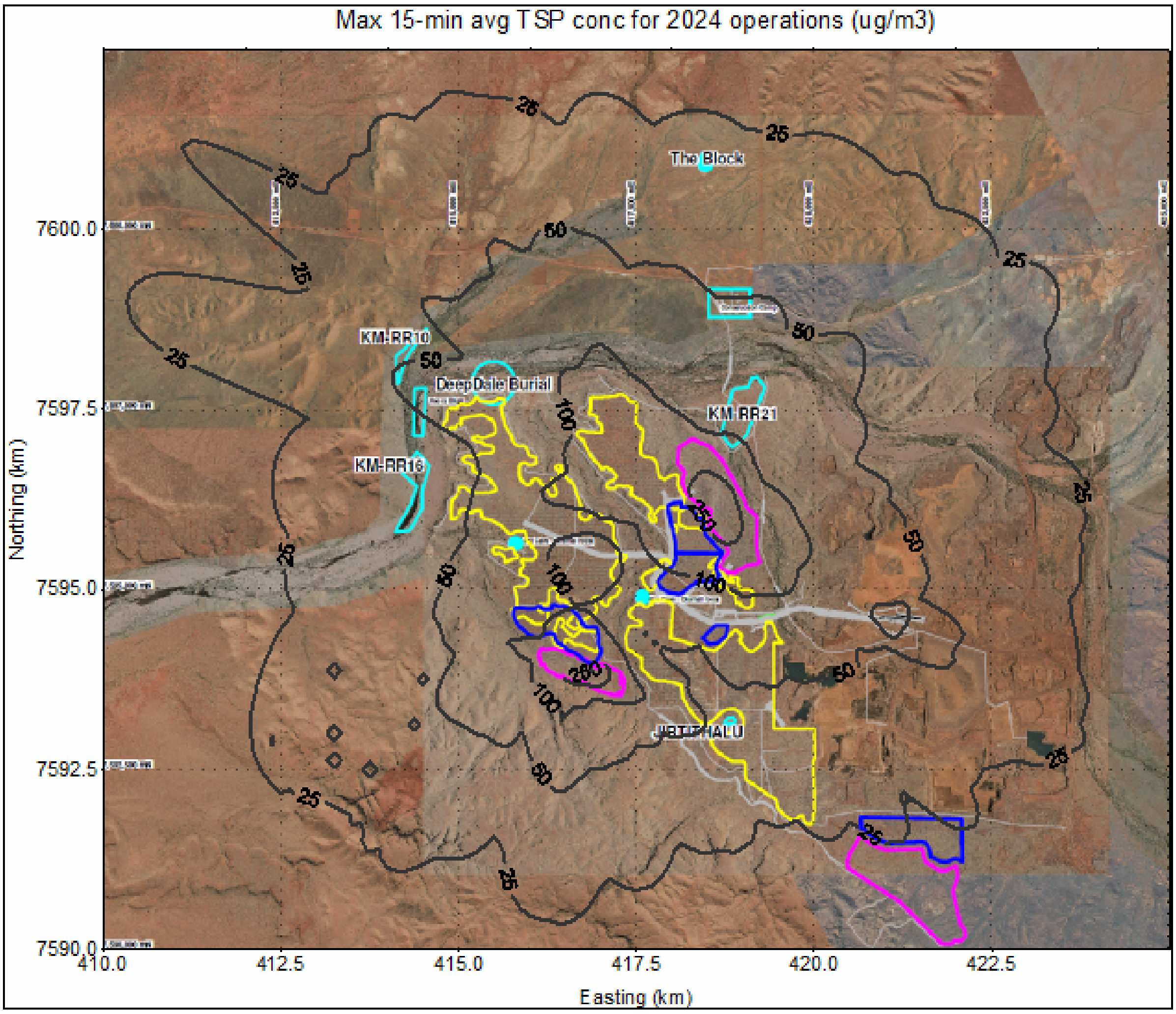


Figure 6 Predicted maximum 15-min average TSP concentrations for 2024 operations

Note: 2024 is the year for which KM-RR21, Construction Camp & The Block are predicted to be most affected.

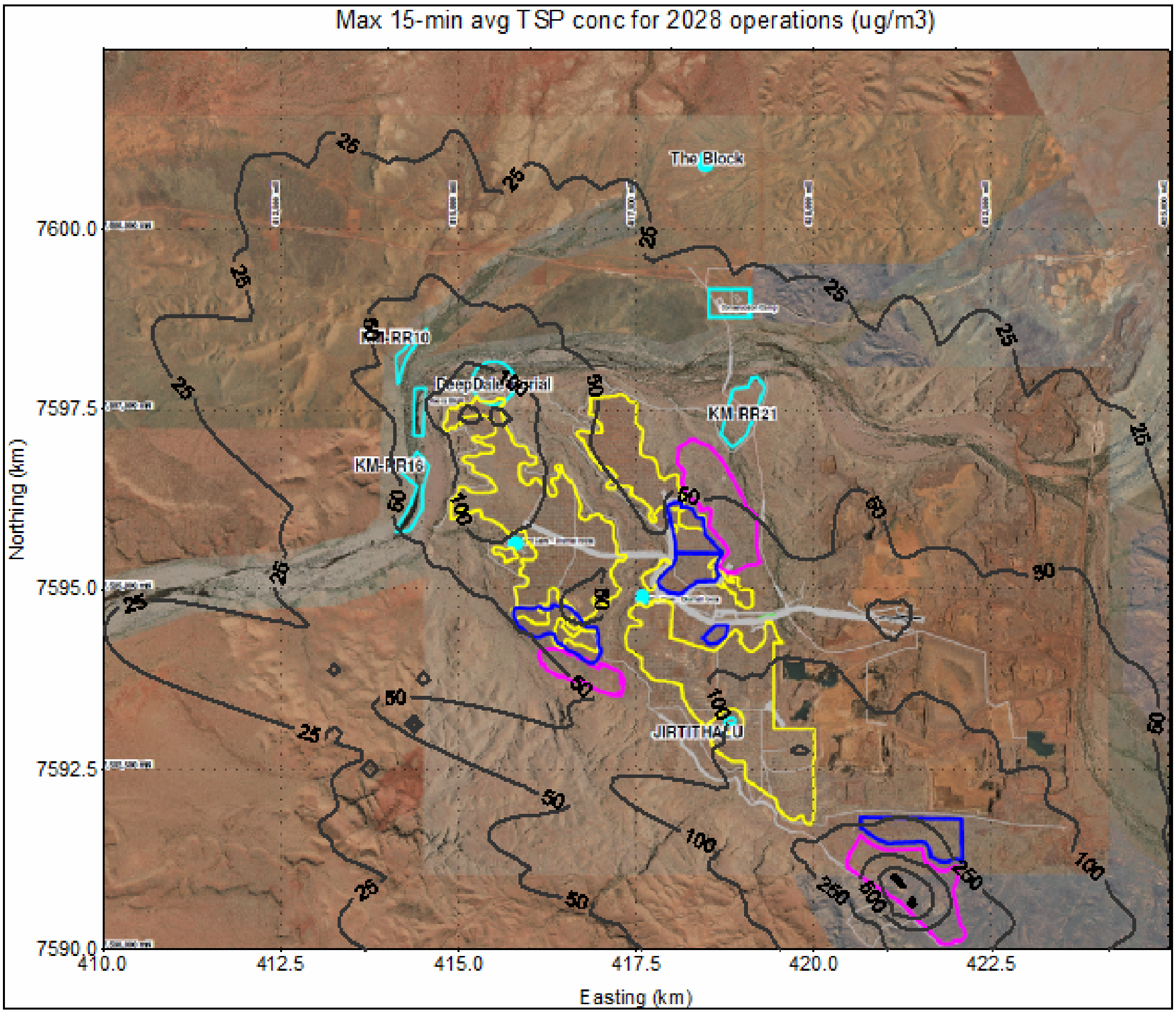


Figure 7 Predicted maximum 15-min average TSP concentrations for 2028 operations

Note: 2028 is the year for which Deep Dale Burial, Yeera Bluff & KM-RR10 are predicted to be most affected.

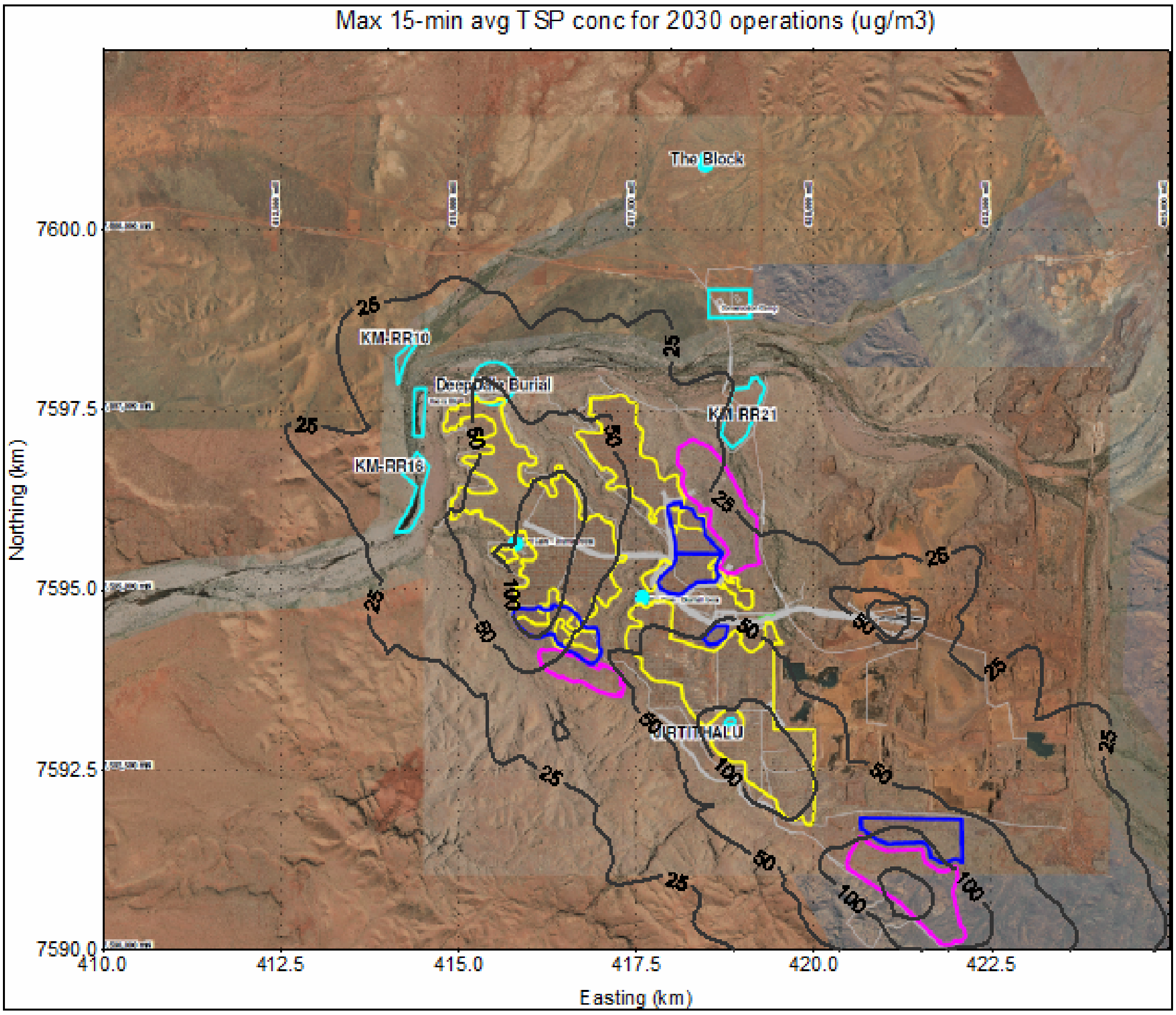


Figure 8 Predicted maximum 15-min average TSP concentrations for 2030 operations

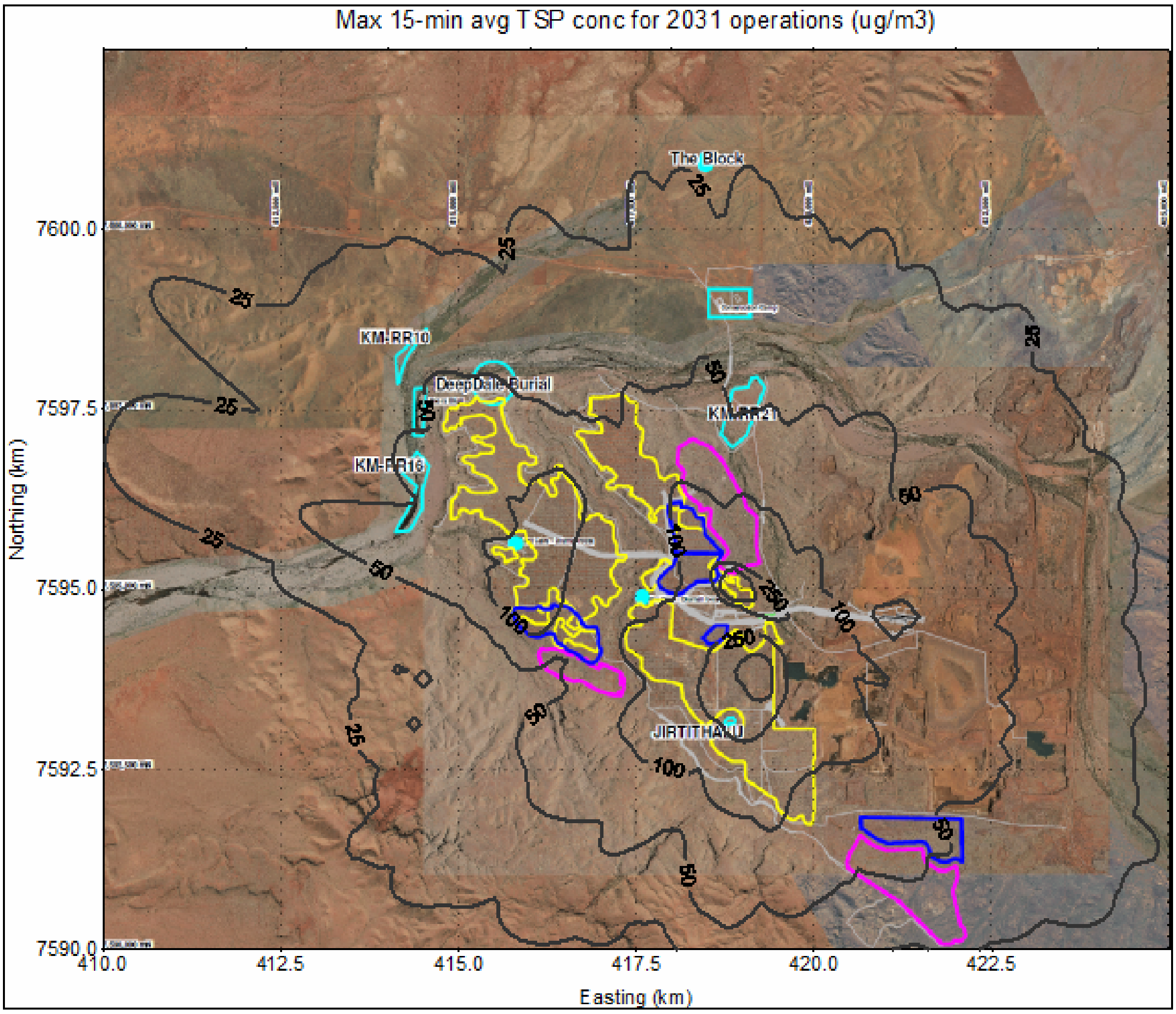


Figure 9 Predicted maximum 15-min average TSP concentrations for 2031 operations

Note: 2031 is the year for which Jirtithalu is predicted to be most affected.

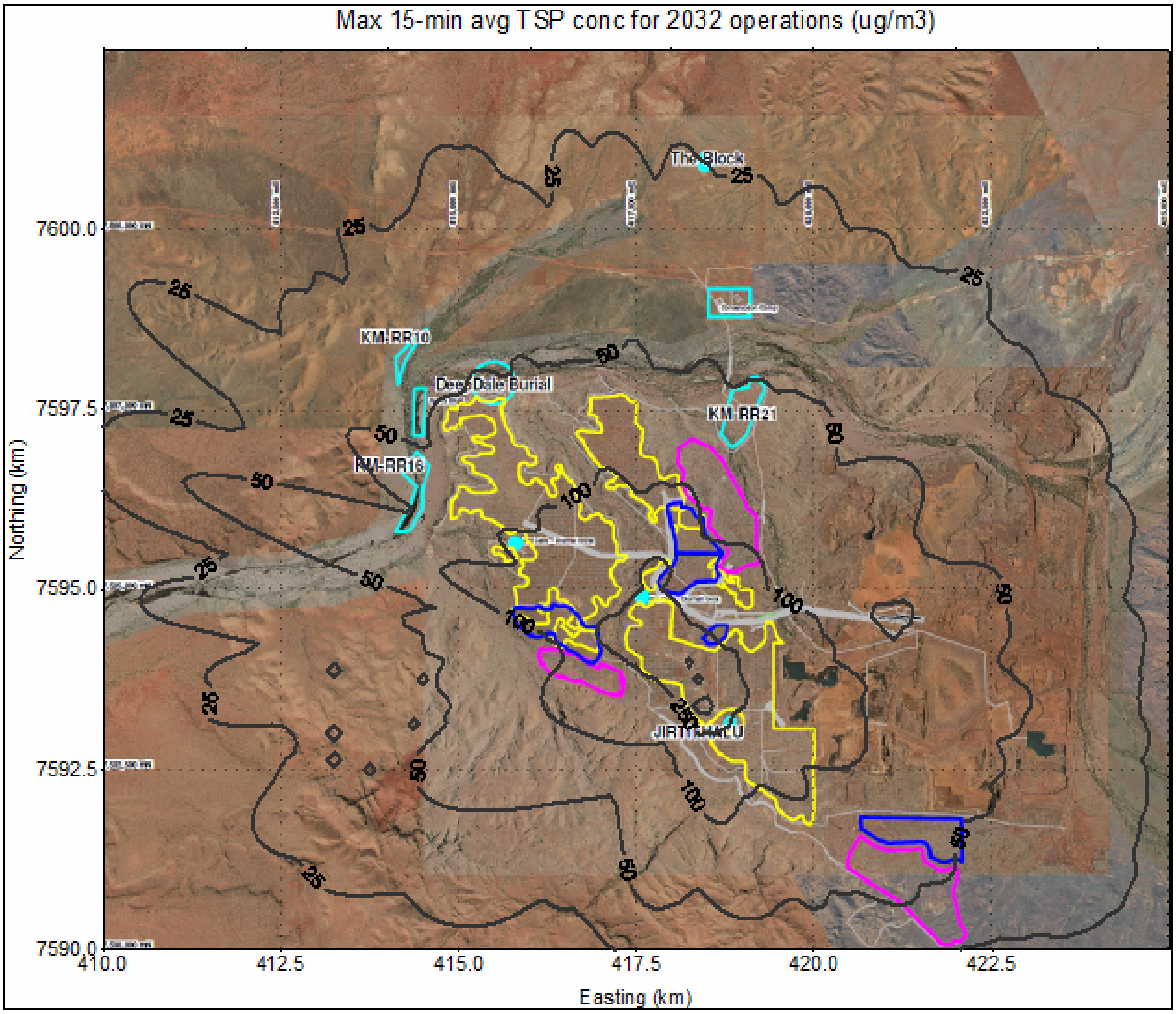


Figure 10 Predicted maximum 15-min average TSP concentrations for 2032 operations

Note: 2032 is the year for which Bat Cave South, Bat Cave North & KM-RR16 are predicted to be most affected.

A summary of predicted maximum 15-minute average TSP at sensitive receptors is shown in Table 10.

Table 10 Summary of predicted maximum 15-min average TSP at sensitive receptors

ID	Receptor	2024	2028	2030	2031	2032	Max. for any year	Max. as % of criterion	Year of max.	Nearest pit(s)
		Predicted maximum 15-min average TSP concentration. Criterion =1000 (μg/m^3)								
1	Jirtithalu	42	105	119	311	245	311	31%	2031	Pit 3 & 4
2	Bat Cave South	62	60	39	88	330	330	33%	2032	Pit 5
3	Bat Cave North	83	88	93	105	109	109	11%	2032	Pit 7
4	KM-RR16	40	61	36	55	71	71	7%	2032	Pit 8
5	Yeera Bluff	54	97	37	49	48	97	10%	2028	Pit 8
6	KM-RR-10	51	70	33	43	39	70	7%	2028	Pit 8
7	Deep Dale Burial	68	222	73	74	58	222	22%	2028	Pit 8
8	KM-RR21	107	38	23	63	61	107	11%	2024	North-east dump
9	Construction Camp	53	26	16	34	41	53	5%	2024	Pit 9
10	The Block	33	17	12	22	25	33	3%	2024	Pit 9

Note: Grey shaded cells shows maximum concentration for years modelled.

The maximum predicted TSP concentrations are at Bat Cave South and Jirtithalu, however these are still only 33% and 31% of the criterion respectively. In summary, the predictions at all the sensitive receptors are below the criterion.

8.5 INTERPRETATION OF RESULTS

Models are better at predicting long term averages (e.g. 24-hour, annual averages) or for short term averages, lower percentile (e.g. below 99.9 percentile of 1-hourly averages), at locations relatively distant from sources (e.g. greater than several hundreds of metres). For this study, the model predictions are for maximum, very short terms averages (e.g. 15 minutes) at locations close to sources.

The dust emissions based on NPI equations add to uncertainties, although by adjusting these based on validation studies using similar methodologies (see Appendix 2), these uncertainties should be reduced for 24-hour and longer average predictions.

The meteorological data appears to be of good quality, is representative of the site, and hence there is confidence in this aspect.

All things considered, it needs to be recognised that these modelling predictions have more than the usual uncertainties.

Nevertheless, assuming that the criteria are appropriate, and given that the dust predictions are comfortably below criteria, this should be interpreted as adverse impacts being generally unlikely, subject to the following qualifications:

Highest risk scenarios

For the mining scenarios where the maximum predicted dust levels are within a factor of 5 of the criteria – as shown below, it is considered that there should be additional measures taken to ensure no adverse impacts. These may include the installation of dust monitoring at the receptor and the implementation of dust control measures if dust levels approach excessive levels, or simply during the suspension of mining during dry conditions when winds are towards the sensitive receptor.

	ID	Receptor	Pit	Year
•	1	Jirtithalu	Pit 4	2031
•	2	Bat Cave South	Pit 5	2032
•	7	Deep Dale Burial	Pit 8	2028

Dust from blasting

Although the predicted concentrations include concentrations from blasting emissions, a substantial difficulty in determining adverse impacts (i.e. in additional to normal emission and other uncertainties) is that the dust exposure from a blast plume "close" to the blast location (e.g. up to 500 m away) lasts for only a very short time period – less than 2-3 minutes for typical wind speeds. Therefore even the shortest averaging period dust criteria of 1000 $\mu g/m^3$ averaged over 15 minutes would, for example, still be met for a 1-minute concentration of 15 times the criterion, 2-minute concentration of 7.5 times the criterion etc. Such associated peak concentrations of say 7,500 to 15,000 $\mu g/m^3$ may well however, actually cause adverse impacts. It is therefore considered that blasting should be avoided when the winds are from the blast site to the sensitive receptors for the pits and years shown in Table 9.

It is understood that Rio Tinto has Blast Management Plans in place for mining operations. The Management Plans cover aspects such as monitoring, blast prediction and utilisation of sonic fencing for protection against noise and dust from blasting. It is considered that these could be adapted and used for the bat caves near the Mesa H development for the pits and years as below.

	ID	Receptor	Pit	Year
•	2	Bat Cave South	Pit 5	2032
•	3	Bat Cave North	Pit 7	2030

"Arterial" haul road

While dust emissions from haul roads immediately associated with pits and dumps have been included in the modelling, dust emissions from the location of the major haul road have not been specifically included. The close proximity of this to the Bat Cave South imply that this site should be directly monitored for dust levels as there are too many uncertainties attempting to predict levels by modelling in the context of this study[11].

8.6 DUST DEPOSITION

Contours of the predicted dust deposition for the modelled years are shown in Appendix 4.

The predicted depositions at the sensitive receptors are all not more than 33% of the criterion of 3 g/m^2/month (Jirtithula for 2031). Since dust deposition is a long term prediction and hence should be more accurate than short term concentration predictions described above, assuming the criteria is appropriate, deposition is not considered to be a constraint to mining operations.

[11] For a 15-minute average criterion, the timing of passes from haul trucks would need to be known, which cannot be predicted.

9. SUMMARY AND RECOMMENDATIONS

This report describes a dust dispersion modelling study of predicted dust impacts at nominated sensitive receptors arising from the proposed development of the Mesa H deposit over 2021 to 2032.

The sensitive receptors considered are:

ID	Sensitive receptor	Environmental value to be assessed
1	Jirtithalu	Heritage
2	Bat Cave South	Fauna habitat
3	Bat Cave North	Fauna habitat
4	KM-RR16	Heritage
5	Yeera Bluff	Heritage
6	KM-RR-10	Heritage
7	Deep Dale Burial	Heritage
8	KM-RR21	Heritage
9	Construction Camp	Human Health
10	The Block	Heritage/Human Health
11	Pannawonica	Human Health[12]

The assessment has been based on the early designs of the mine, therefore the results and recommendations should be interpreted in the context that design, layout and management strategies will be subject to change and refinement.

The Ausplume and CALPUFF dispersion models were used to predict ambient concentrations arising from dust emissions during the clearing and operational phases of the project respectively. Aspects included in the modelling deposition of dust particles and for the operational phase, terrain effects on dispersion and meteorological data derived from on-site measurements.

Dust emissions estimates were based on those reported through the NPI. These estimates have considerable uncertainties, being especially dependent on the level of control applied in practice.

Based on the modelled approach-

Dust deposition

Predicted dust depositions for both clearing and operations are much lower relevant to their associated criteria than (15-minute average) dust concentrations, hence it is dust concentrations that are the constraint.

For clearing activities

It is considered that clearing activities during dry conditions - up to 550 m for day and 1410 m for night while the wind is from the clearing to the sensitive receptor - needs increased dust control management. The areas for which management may be required, which are based on worst case meteorological conditions, are shown in Figure 4. Mitigation measures may include reduction/cessation of activities.

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12 ENVALL has undertaken numerous dust assessments of RTIO's Pilbara iron ore mines. These have consistently shown that dust levels are well below ambient criteria more than 3 kms from the nearest part of the mining operation. On this basis, the Pannawonica township, being approximately 15 km away, has not been explicitly included in this study.

For mining operations

The dust predictions for typical operating circumstances were comfortably below criteria indicating that adverse impacts are generally unlikely, subject to the following qualifications:

Highest risk scenarios

For the mining scenarios where the maximum predicted dust levels are within a factor of 5 of the criteria – as shown below, it is considered that there should be additional measures taken to ensure no adverse impacts. These may include the installation of dust monitoring at the receptor and the implementation of dust control measures if dust levels approach excessive levels, or simply during the suspension of mining during dry conditions when winds are towards the sensitive receptor.

ID	Receptor	Pit	Year
1	Jirtithalu	Pit 4	2031
2	Bat Cave South	Pit 5	2032
7	Deep Dale Burial	Pit 8	2028

Dust from blasting

It is considered that Blast Management Plans in the form used for West Angelas be developed for the bat caves near the Mesa H development, for the pits and years as below.

ID	Receptor	Pit	Year
2	Bat Cave South	Pit 5	2032
3	Bat Cave North	Pit 7	2030

"Arterial" haul road and Bat Cave South

The close proximity of the main haul road to the Bat Cave South imply that this site should be directly monitored for dust levels, as there are too many uncertainties attempting to predict levels by modelling.

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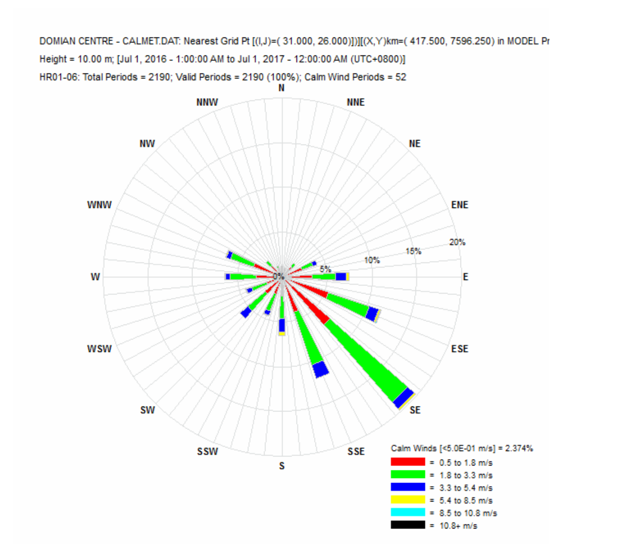
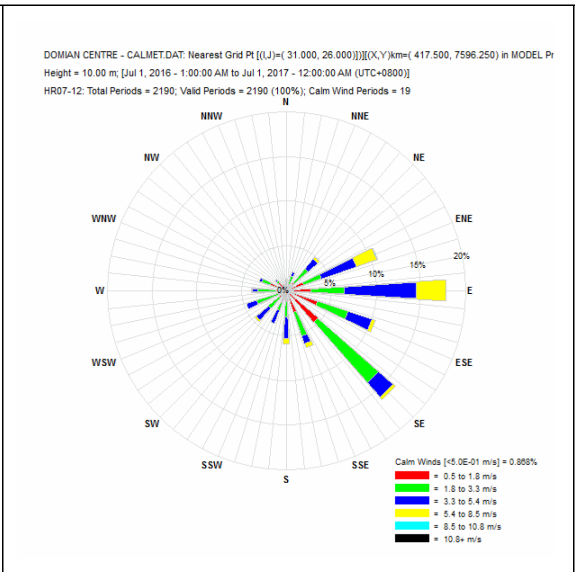
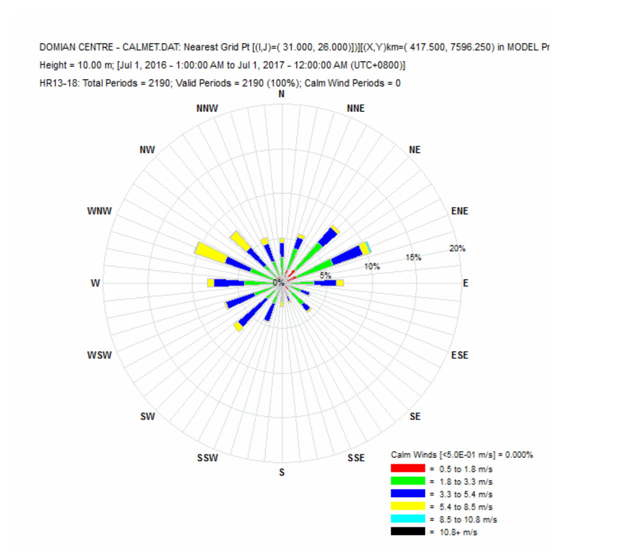
11. GLOSSARY

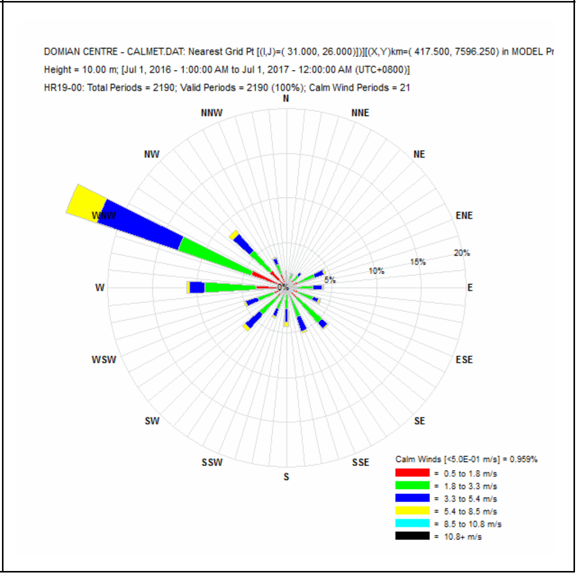
Abbreviation	Definition
$\mu g/m^3$	micrograms per cubic metre of air.
µm	microns or micrometers.
BoM	Bureau of Meteorology.
CALPUFF	CALifornian PUFF model
DWER	Department of Water and Environment Regulation
g/m^2/month	grams per square metre per month.
g/s	grams per second.
hr	hour.
Kg	kilograms.
Km	kilometres.
m	metres.
m/s	metres per second.
m^3/s	cubic metres per second.
Mtpa	Mega tonnes per annum.
NEPM	National Environment Protection Measure for Ambient Air Quality.
NPI	National Pollutant Inventory.
percentile	The division of a distribution into 100 groups having equal frequencies.
PM10	Airborne particles with an equivalent aerodynamic diameter of less than 10 µm.
PM2.5	Airborne particles with an equivalent aerodynamic diameter of less than 2.5 µm.
TAPM	The Air Pollution Model
TMM	Total Materials Moved.
TSP	Total Suspended Particulates.

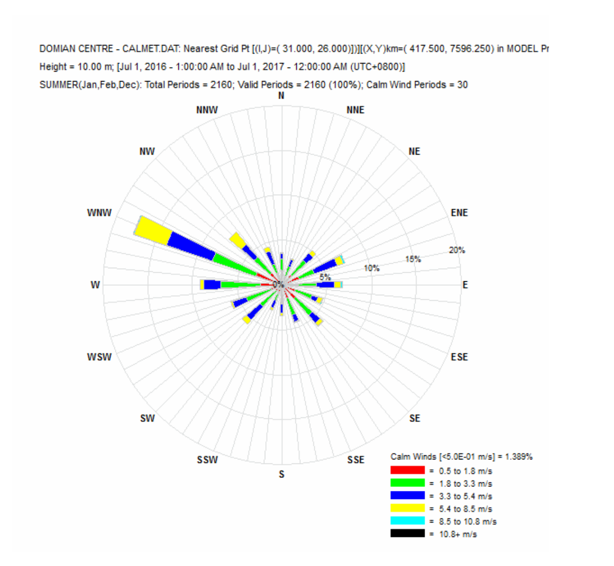
Appendix 1 Wind roses – Diurnal and Seasonal

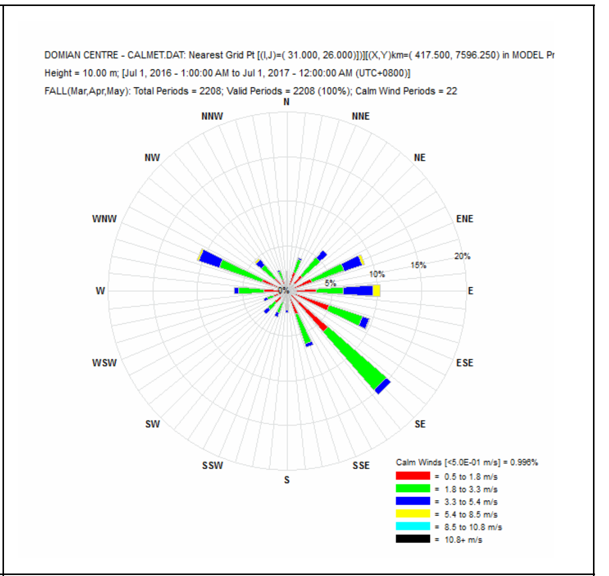









DOMIAN CENTRE - CALMET.DAT: Nearest Grid Pt [(I,J)=(31.000, 26.000)])][(X,Y)km=(417.500, 7596.250) in MODEL Pr
Height = 10.00 m; [Jul 1, 2016 - 1:00:00 AM to Jul 1, 2017 - 12:00:00 AM (UTC+0800)]
SUMMER(Jan,Feb,Dec): Total Periods = 2160; Valid Periods = 2160 (100%); Calm Wind Periods = 30
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
20%
Calm Winds [<5.0E-01 m/s] = 1.389%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s


DOMIAN CENTRE - CALMET.DAT: Nearest Grid Pt [(I,J)=(31.000, 26.000)])][(X,Y)km=(417.500, 7596.250) in MODEL Pr
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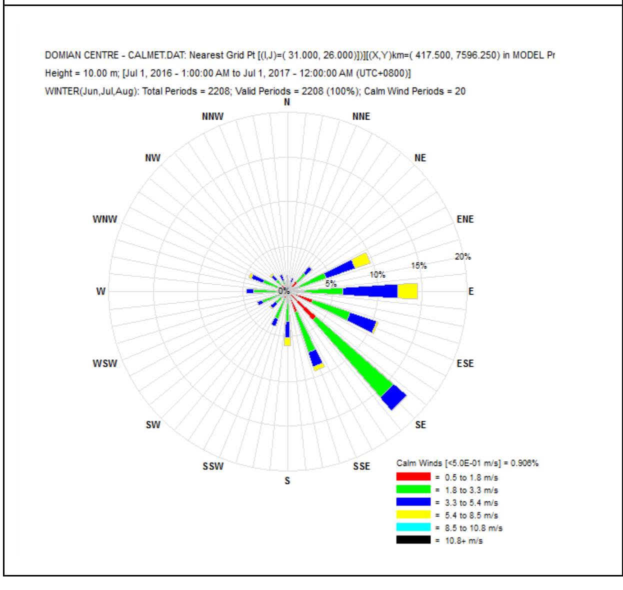
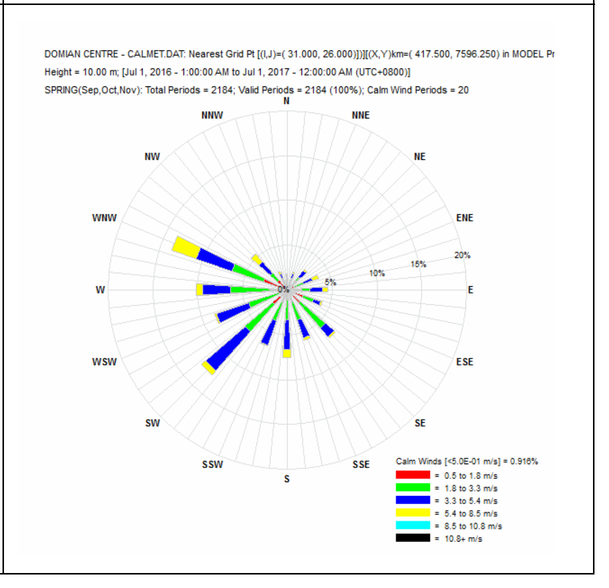
FALL(Mar,Apr,May): Total Periods = 2208; Valid Periods = 2208 (100%); Calm Wind Periods = 22
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
20%
Calm Winds [<5.0E-01 m/s] = 0.996%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s


DOMIAN CENTRE - CALMET.DAT: Nearest Grid Pt [(I,J)=(31.000, 26.000)])][(X,Y)km=(417.500, 7596.250) in MODEL Pr
Height = 10.00 m; [Jul 1, 2016 - 1:00:00 AM to Jul 1, 2017 - 12:00:00 AM (UTC+0800)]
WINTER(Jun,Jul,Aug): Total Periods = 2208; Valid Periods = 2208 (100%); Calm Wind Periods = 20
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
20%
Calm Winds [<5.0E-01 m/s] = 0.906%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s


DOMIAN CENTRE - CALMET.DAT: Nearest Grid Pt [(I,J)=(31.000, 26.000)])][(X,Y)km=(417.500, 7596.250) in MODEL Pr
Height = 10.00 m; [Jul 1, 2016 - 1:00:00 AM to Jul 1, 2017 - 12:00:00 AM (UTC+0800)]
SPRING(Sep,Oct,Nov): Total Periods = 2184; Valid Periods = 2184 (100%); Calm Wind Periods = 20
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
20%
Calm Winds [<5.0E-01 m/s] = 0.916%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s

Appendix 2 Previous modelling validation studies

A summary of the modelling validation performance (using Calpuff) for the Yandi, Hope Downs, Brockman 2/Nammuldi and Mesa A operations undertaken previously by ENVALL is shown in Figure 11. Emissions for these operations were derived from NPI reports. This shows the modelling predictive PM10 accuracy at E-Sampler monitors (i.e. where y=1 is perfect correspondence between predicted and measured concentrations), against an index defined as the ratio of the annual NPI PM10 emission to annual TMM. This form of this index is based on the expectation that emissions from the same general type of operation – iron ore mines, should be reasonably correlated with the volume of materials handling (i.e. ore plus waste volumes). This is because most of the dust impacts from mining operations arise from activity sources and assumes that exposed areas subject to wind erosion are progressively stabilised and hence not vastly dissimilar in proportion to production between operations.

Figure 11 shows that a PM10:TMM index of about 0.032 – 0.035 kg PM10 emitted/tonne TMM has been associated with good modelling validation results.

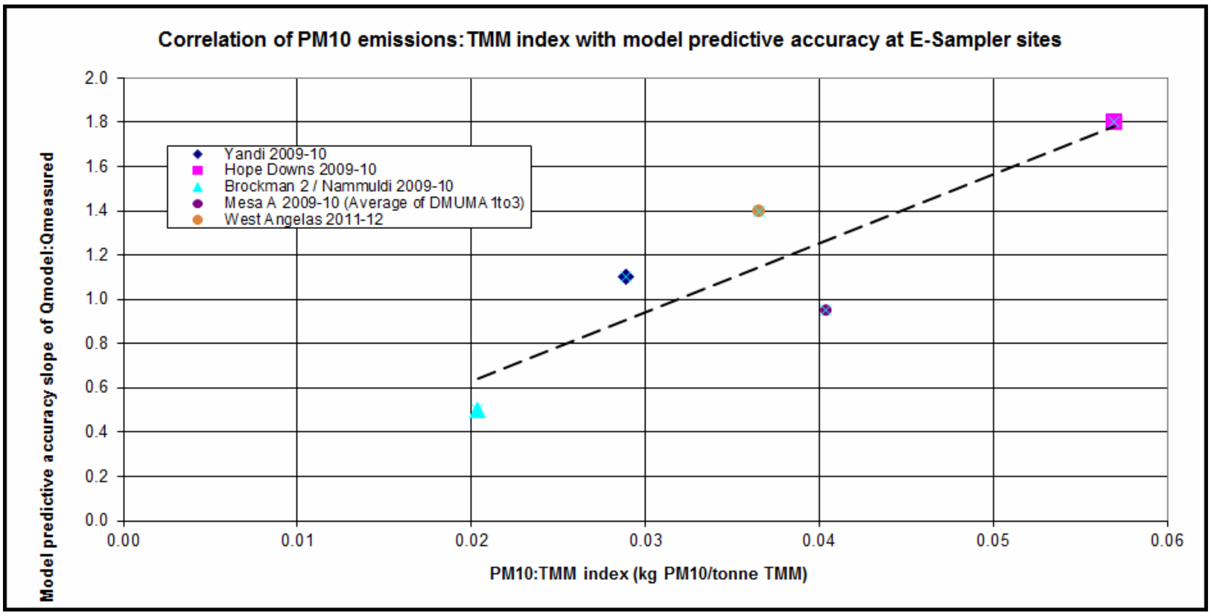


Figure 11 Relationship between emissions and modelling predictive accuracy for previous RTIO mine-site validation studies

The PM10:TMM index for the Mesa H 2016-17 operation was 0.024 kg/tonne. It is therefore considered that there is a risk of under-predicting dust levels. Hence the NPI-calculated emissions were increased by 1.45 (i.e. 0.035/0.024).

Appendix 3 Wind-generated dust

The NPI dust estimates are annual aggregates. It would be unrealistic to model wind generated dust as constant dust emission rate, therefore time-varying emissions were estimated based on prevailing meteorology.

Dust lift-off from open areas is wind-speed and rainfall dependent.

Dust emissions as a function of wind speed were estimated as follows:

$$Q_{PM10,a} = K_{s,a} U_{10}^{3} \left(1 - \frac{U_t^{2}}{U_{10}^{2}} \right) \quad (U_{10} > U_t) \qquad \textbf{Equation 1}$$

$$Q_{PM10} = Q_{PM10,a} x A \qquad \textbf{Equation 2}$$

where-

$Q_{PM10,a}$ = PM10 unit area emission rate (g/s/m^2).

$K_{s,a}$ = Site specific empirical constant (g.s^2/m^5).

U_{10} = Local wind speed measured at 10 m (m/s).

U_t = Wind speed threshold for lift off of the material expressed in terms of wind speed measured at 10 m (m/s), assumed to be 5.4 m/s.

Q_{PM10} = PM10 emission rate (g/s).

A = Source surface area (m^2).

The onset of sufficient rainfall dampens surface materials and prevents dust emissions.

The NPI emission equation for wind generated dust from uses a daily total rainfall of 0.25 mm to reflect loss of dust potential from rainfall. This is a very coarse approximation of the effect of rainfall in reducing dust potential. For example, a 1-hour rainfall event of exactly 0.25 mm has the same dust mitigating effect as a much larger 1-hourly rainfall, which is clearly unrealistic.

For the modelling performed in this report, a scheme that approximates that used in RWEQ (Fryrear et al, 1998) was used that defines a soil wetness (SW) factor. The hourly soil wetness was defined by:

$SW_{1\text{-hour}}$ = R – (1.5 x Evap) **Equation 3**

Where-

$SW_{1\text{-hour}}$ = the soil wetness for a given hour.

$SW_{1\text{-hour,previous}}$ = the soil wetness for the preceding hour.

R = the rainfall for that hour.

Evap = the evaporation rate for that hour - determined from the monthly daily average evaporation rate divided by 24.

The use of the factor of 1.5 times the evaporation allows for infiltration and runoff once the hourly rainfall has exceeded the evaporation rate.

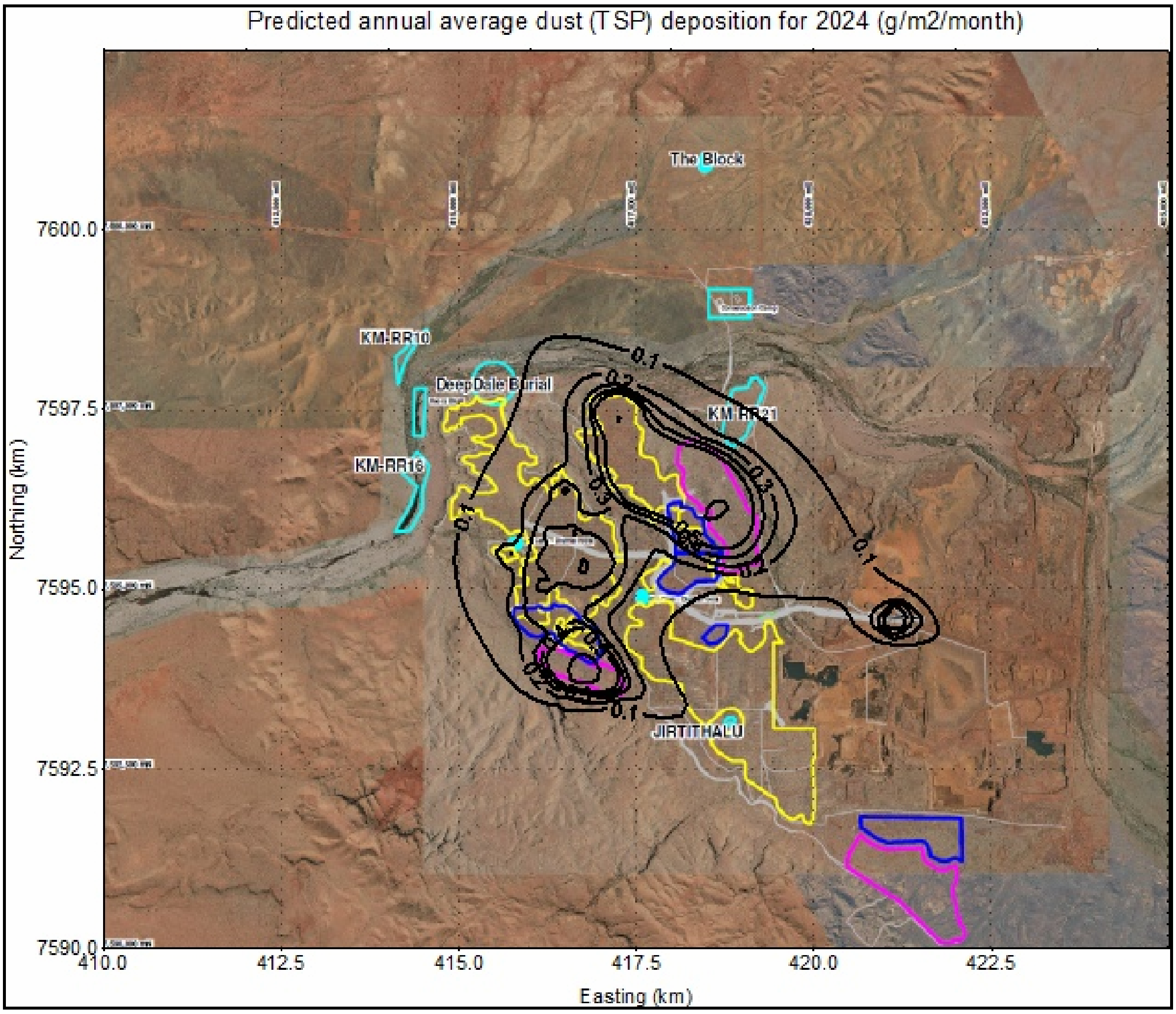
Where $SW_{1\text{-hour}}$ exceeded 0.25 mm, no dust emission was assumed for that hour.

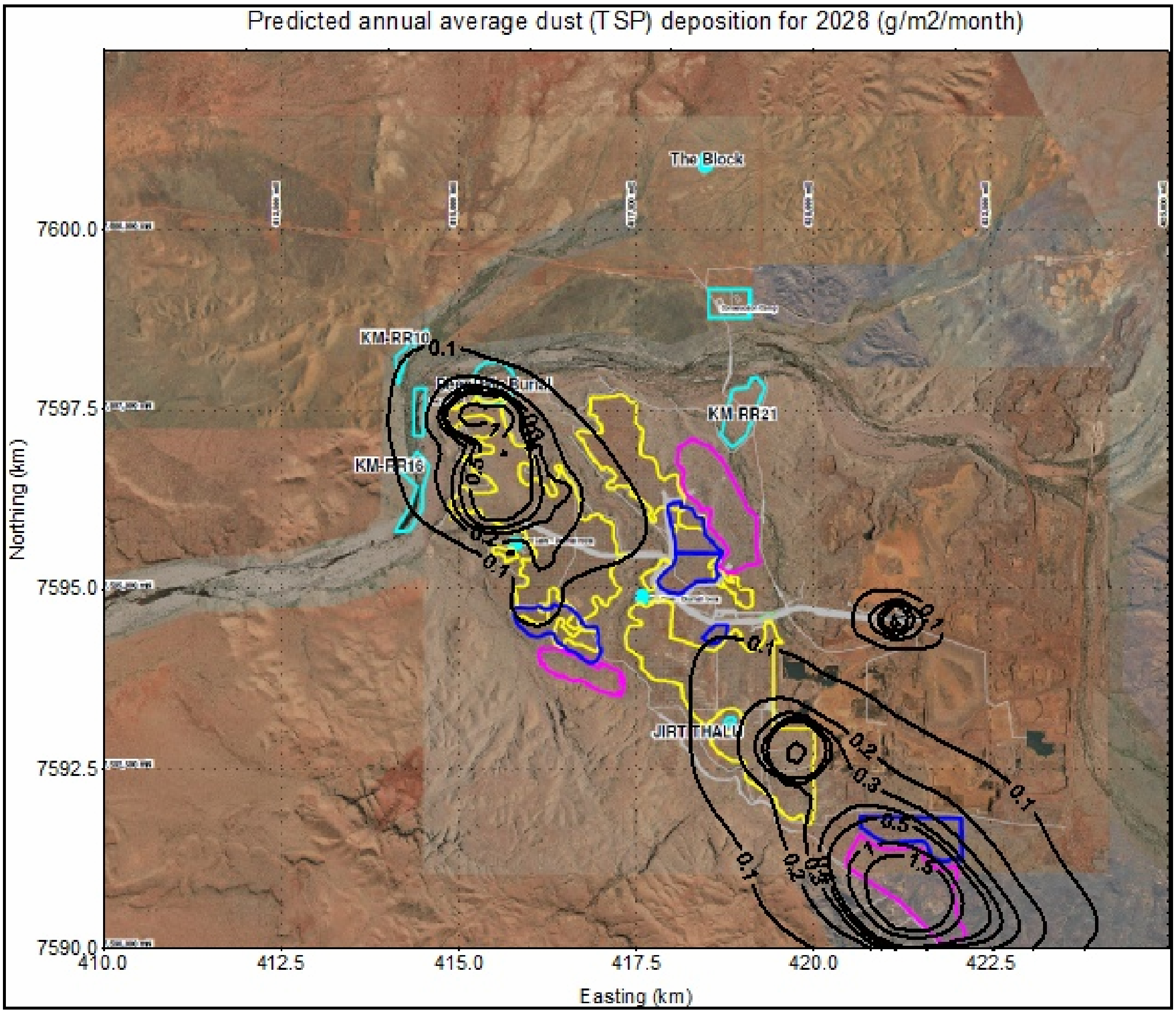
The net effect of this scheme was a more realistic time-varying profile of dust emission potential around periods of rainfall, while retaining consistency with the NPI approach.

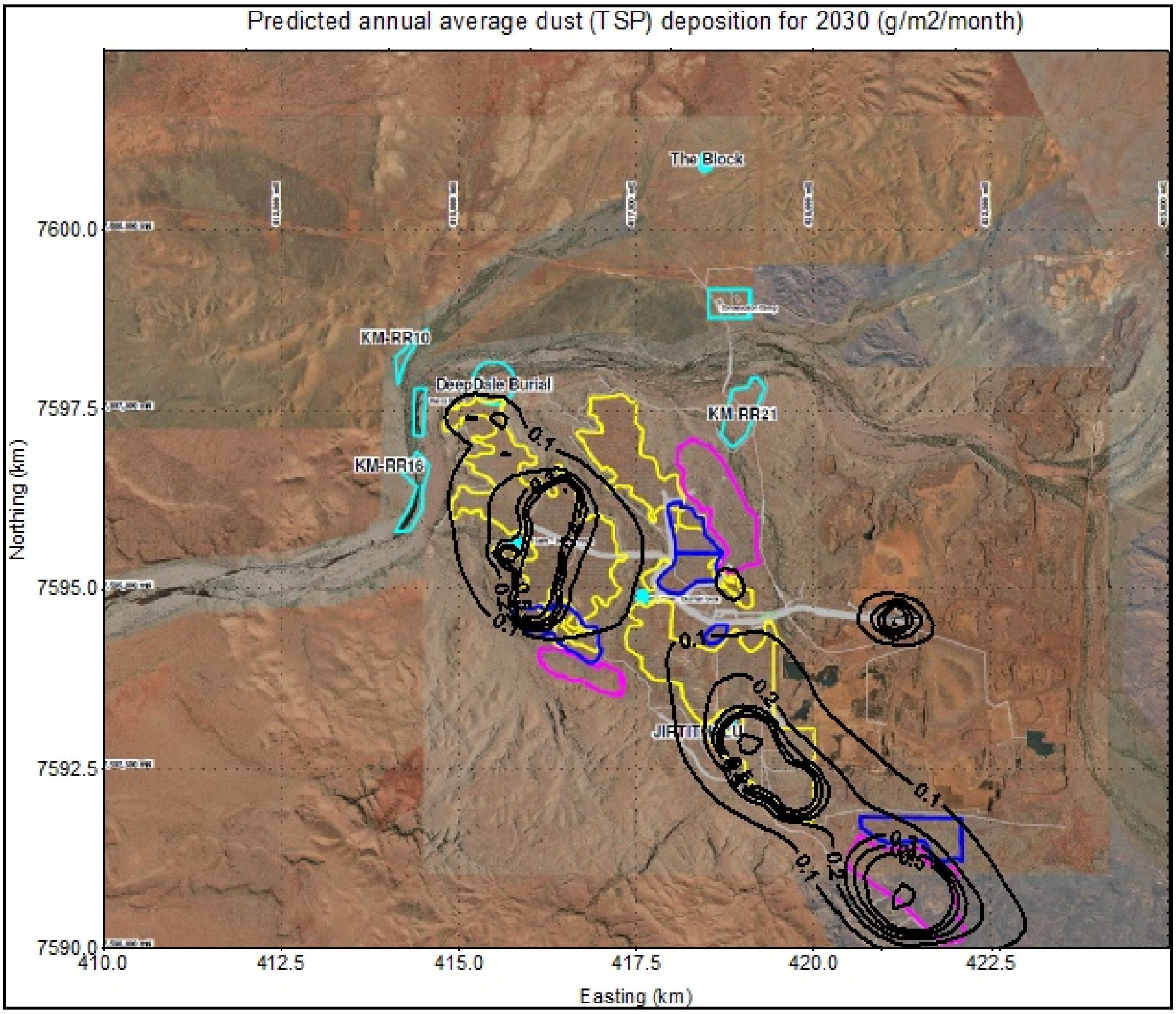
It is noted that the NPI method is still an approximation, since actual dust emission potential depends largely on the complex process underlying whether crusts are formed. If a crust is formed (which depends on the soil properties and the amount of rain), the surface will remain non-erodable until it is disturbed. Therefore, the actual erosion potential is dependent on quite a few parameters such as the rainfall, crusting ability of the material and disturbance frequency of the area.

It should also be noted that the NPI methodology does not take into account the effect of rainfall in reducing emissions from activity-based sources (eg dust from vehicles wheels). This is unrealistic but this study has maintained consistency with the NPI approach in the calculation of 1-hourly dust emissions from activity sources by simply assuming there is no rainfall effect.

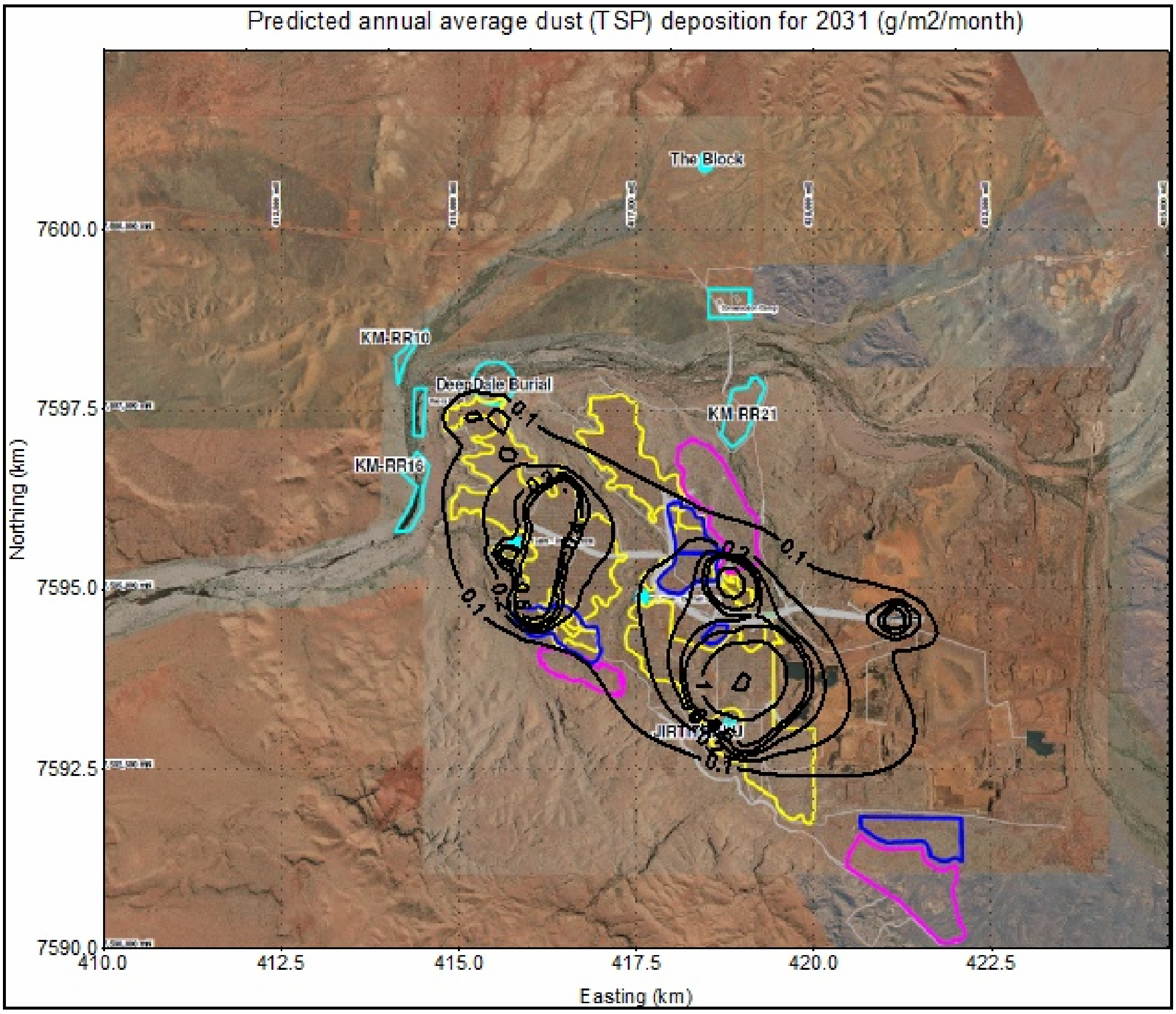
Appendix 4 Contours of predicted dust deposition for years modelled



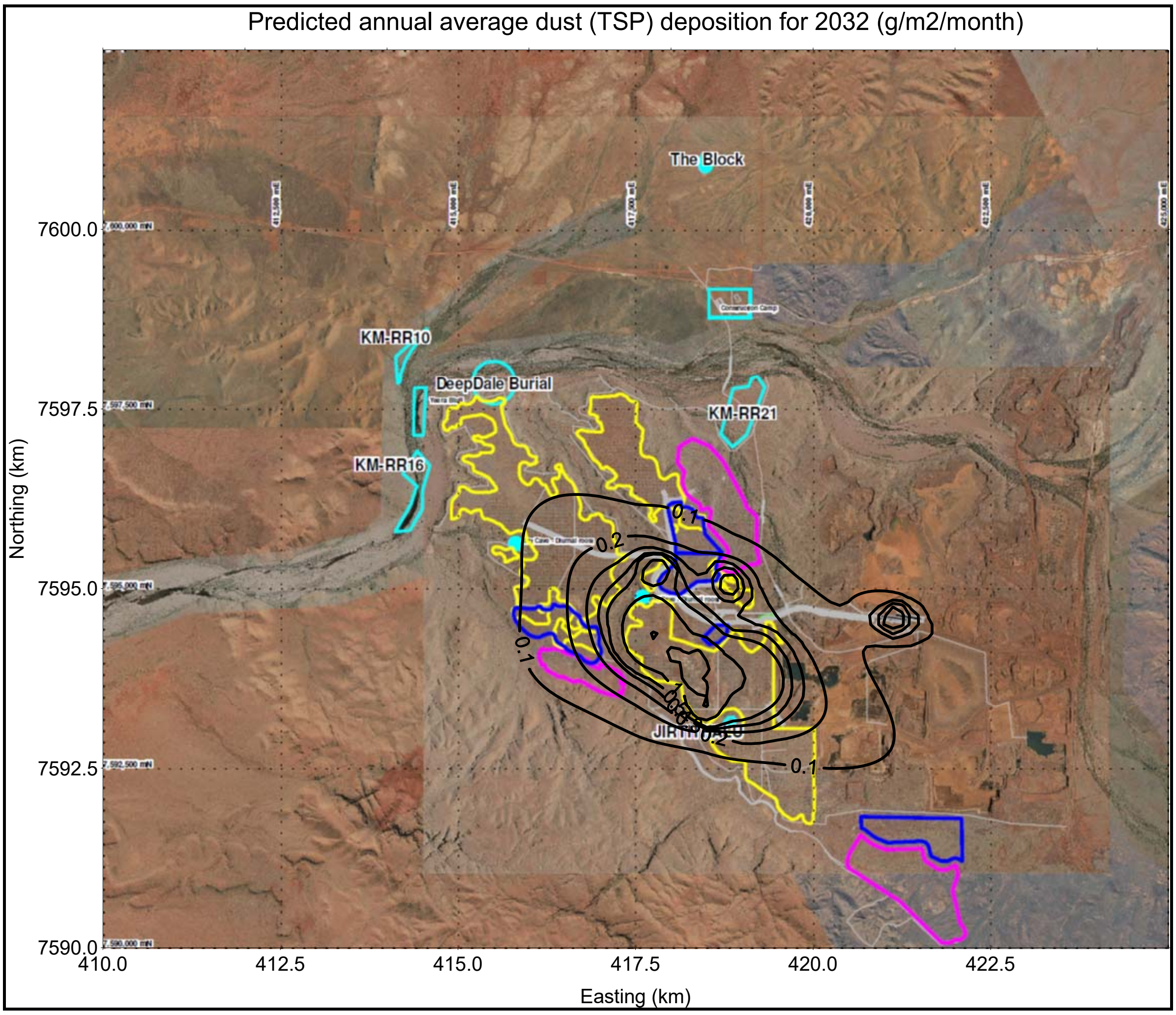

Predicted annual average dust (TSP) deposition for 2028 (g/m2/month)
Northing (km)
Easting (km)
7600.0
7597.5
7595.0
7592.5
7590.0
410.0
412.5
415.0
417.5
420.0
422.5
The Block
KM-RR10
KM-RR16
KM-RR21
JIRTTHALU
0.1
0.2
0.3
0.5
1.5



Note maximum at any discrete receptor is 0.5 g/m^2/month at Jirtithula.



Note maximum at any discrete receptor is 1.0 g/m^2/month at Jirtithula.



Note maximum at any discrete receptor is 0.5 g/m^2/month at Jirtithula and Bat Cave South.