WEST ANGELAS DUST DISPERSION MODELLING – DEPOSITS A, B, E, F, AWEST, C, D AND G

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 model dust emissions in association with mining deposits A, B, E, F, Awest, C, D and G at West Angelas as they are developed over the years from 2016 to 2032. This assessment is intended to support applications for environmental approvals under Part V of the *Environmental Protection Act 1986*.

Previous assessments of the West Angelas dust impacts are described in:

- Environmental Alliances Pty Ltd (ENVALL), 2007, "Preliminary Air Quality Assessment Report West Angelas Operations", May 2007;
- Environmental Alliances Pty Ltd (ENVALL), 2010, "West Angelas Iron Ore Operation Deposit E Project - Dust Impact Assessment", January 2010;
- Environmental Alliances Pty Ltd (ENVALL), 2013, "Validation of Dust Dispersion Modelling For West Angelas Iron Ore Mining Operations", January 2013;
- Environmental Alliances Pty Ltd (ENVALL), 2013, "Dust Impact Assessment for Development of Deposit B -West Angelas Iron Ore Mining Operations", June 2013.

A report titled "West Angelas Dust Dispersion Modelling – Deposits A, B, E, F, Awest, C, D and G" was prepared in 2015 (ENVALL 2015). This report is a revised version of the afore-mentioned to account for a change in the blast size from 1,200 kg to 4,500 kg[1].

2. LOCATION

The West Angelas mine operation is located in the Eastern Pilbara region of Western Australia approximately 130 kms west of Newman (see Figure 1). The deposits are located within the Mining Lease Number AML70/00248 within the Shire of East Pilbara.

1 References to changes in dust levels throughout this report can be found by searching for "4,500 kg".

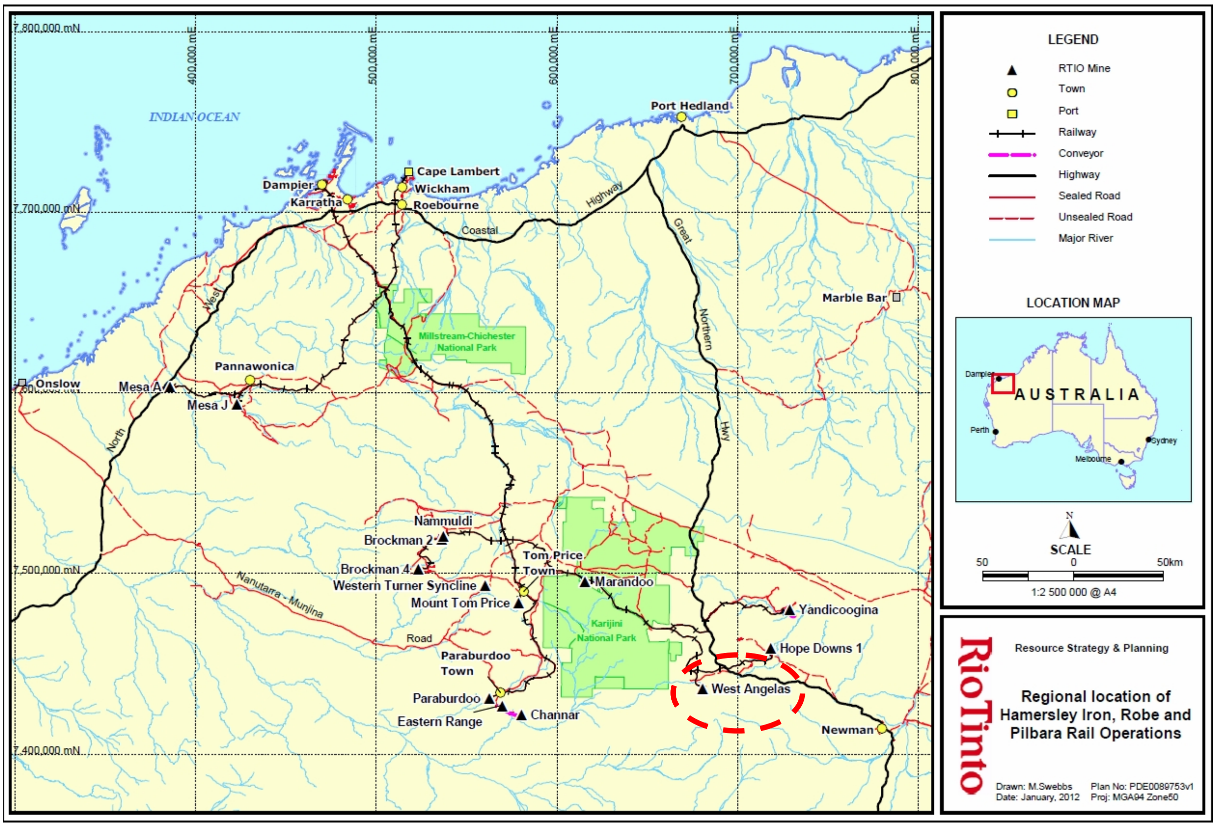

Figure 1 Regional location of West Angelas operation

3. ASSESSMENT CRITERIA

3.1 NATURE OF DUST

Particulates, alternatively referred to as particulate matter (PM), aerosols or fine particles, are tiny particles of solid (a smoke) or liquid (an aerosol) suspended in a gas. They range in size from less than 10 nanometers to more than 100 micrometers (µm) in diameter. "Dust" is a more common name for particulate matter and is generally defined as particles that can remain suspended in the air by turbulence for an appreciable length of time. Dust can consist of crustal material, pollens, sea salts and smoke from combustion products.

Typically, particulate matter 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.

This report addresses TSP, PM10 and dust deposition impacts. PM2.5 is not assessed, as health impacts from crustal sources are considered to be less than from urban sources and therefore no applicable criterion has been adopted by environmental regulators[2].

3.2 DUST CRITERIA

3.2.1 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.

This is illustrated by ambient dust monitoring data from Boodarie (near Port Hedland), considered to be a "background site", in the 2007 State of the Environment Report (Table A.3.1 EPA, 2007). This showed that over 1996 to 2001, there were up to 22 exceedences of the NEPM 24-hour average PM10 standard in some years, and zero exceedences for other years. For the six years of data reported, there was on average 8.5 exceedences of the PM10 standard per year.

The Western Australian Department of Environmental Regulation (DER) and Environmental Protection Authority (EPA) do not have generic dust criteria applicable to remote mining operations. The criteria used here are from other references as an indication of what might be considered acceptable.

3.2.2 Airborne concentrations for human health and amenity

The RTIO E2 Air Quality Standard requires the development of ambient air quality criteria in the absence of specific government regulations. Dust criteria for inland Pilbara mining operations adopted by RTIO are described in "Iron Ore (WA) Cleaner Air Management Plan" (February 2011). RTIO's airborne dust concentration criteria for human health and amenity are shown in Table 1.

[2] Note that the National Environmental Protection Measure for Ambient Air Quality was amended in 2003 to include an "advisory reporting standard" for PM2.5. This is intended to "provide a tool for communicating information to the community on air quality related to PM2.5, and enable the effectiveness of air quality management programs that are designed to manage PM2.5 emissions to be assessed" (NEPC 2003). Consequently, the modelling for this work can provide PM2.5 predictions if subsequently required.

Table 1 RTIO internal dust concentration criteria – inland mining operations

Parameter/ Particle size	Averaging time	Concentration	Frequency	Location	Relevant Sites
PM10	24 hours	70 µg/m^3 [(a)]	Not more than 10 days a year	Nearest sensitive receptor to operations (eg. camp, towns, nearest residence)	Tom Price, Greater Paraburdoo, Marandoo, Brockman 2, Brockman Syncline 4, Nammuldi, West Angelas, Hope Downs, Yandi, Robe Valley mines
	Annual[(b)]	70 µg/m^3	Annual average	Nearest sensitive receptor to operations (eg. camp, towns, nearest residence)	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) From the Port Hedland Air Quality and Noise Management Plan for managing air quality impacts from Port Hedland port operations on nearby residential and commercial areas (see http://www.dsd.wa.gov.au/7899.aspx). The dust criterion is defined as *a maximum allowable level for Port Hedland dust (PM10) of 70 µg/m^3 (micrograms per cubic metre) over 24 hours with not more than 10 exceedances per year.* The criterion was based on the recommendations of a report commissioned by the Department of Health (Lung Institute of Western Australia Inc and Institute of Occupational Medicine 2007). The Western Australian Government has adopted the Plan.

(b) The basis of this is not known, however it is considered to be too high relative to the 24-hour guideline.

Other criteria used for regulatory assessments of dust impacts in populated/urban areas in Western Australia, are:

- For PM10, the National Environmental Protection Measure for Ambient Air Quality ("Air NEPM") Standard of 50 µg/m^3, 24-hour average (NEPC 2003); and
- For TSP, the Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992 and Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992, collectively referred to as the "Kwinana EPP".

These are summarised in Table 2. In the past, the DER has accepted that the PM10 Standard specified in the Air NEPM cannot be met in the inland Pilbara[3].

[3] 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

Table 2 Other Western Australian criteria for airborne dust concentrations in populated areas

Parameter	Value	Units	Averaging time[c]	Frequency	Reference
PM10 concentration	50	$\mu g/m^3$	1 day	Not more than 5 days per year	Air NEPM (NEPC 2003)
TSP concentration	90	$\mu g/m^3$	1 day	"Desirable not to be exceeded" [b]	Kwinana EPP, Area C (residential) [a]

[a] Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992 and Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992.

[b] This has been interpreted as the 5th highest 24-hour average in a year for the purposes of environmental impact assessments of Dampier Port upgrades (EA 2005). This is approximately the 99th percentile and is also consistent with the NEPM PM10 Standard which is referenced to the 5th highest 24-hour average in a year. This means that if the 6th highest predicted PM10 or TSP concentrations exceed the relevant concentration limit, the guideline is predicted to be exceeded.

[c] Averaging times defined as calendar periods.

3.2.3 Dust deposition

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. RTIO's dust deposition criterion is shown in Table 3.

Table 3 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

[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.

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].

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)".

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.

3.2.4 Aerodrome

There is no specific criterion for the operation of the aerodrome and residential criteria are not relevant in this case. Occupational hygiene should be considered in a separate study. Aerodrome Management Services (AMS) is assisting RTIO in aerodrome management.

3.2.5 Fauna habitat

Whilst there is no established criterion for Ghost Bats, the species has a conservation status of Priority 4 as listed by the Department of Parks and Wildlife. In addition, the 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, RTIO have Blast Management Plans in place for Deposits E and B, and further plans will be developed specific to each deposit (i.e. Deposit F), as required. The Management Plans cover aspects such as monitoring, blast prediction and utilisation of sonic fencing for protection against noise and dust from blasting.

[5] O. Pitts pers com from greenfields monitoring data.

3.3 SUMMARY OF GUIDELINES

The dust guidelines considered applicable in remote areas of the Pilbara and used in this report are summarised in Table 4.

Table 4 Guidelines for airborne dust concentrations

Parameter	Averaging time[b]	Value	Frequency	Location	Reference(s)
PM10 concentration	1 day	70 $\mu g/m^3$	Not more than 10 days a year	Nearest sensitive receptor to operations (eg. camp, towns, nearest residence)	PHNDMP (Government of WA 2010) "Iron Ore (WA) Cleaner Air Management Plan" (Rio Tinto 2011)
TSP concentration	1 day	90 $\mu g/m^3$	"Desirable not to exceed" - Not more than 5 days a year		Kwinana EPP, Area C (residential) [a]
Deposited Dust[c]	Annual	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.		Mining lease boundary/nearest sensitive receptor	NSW (2005) "Iron Ore (WA) Cleaner Air Management Plan" (Rio Tinto 2011)

(a) Environmental Protection (Kwinana) (Atmospheric Waste) Policy 1992 and Environmental Protection (Kwinana) (Atmospheric Waste) Regulations 1992.

(b) Averaging times defined as calendar periods.

(c) Deposited dust is determined as the insoluble solids as defined by AS 3580.10.1-2003.

4. BACKGROUND AIRBORNE CONCENTRATIONS ASSUMED FOR MODELLING

In previous Pilbara mining assessments, ENVALL has assumed a "clean" regional background PM10 concentration of 11 $\mu g/m^3$, which was based on the average concentration from ambient monitoring during offshore winds at Dampier where the upwind fetch was undisturbed land.

Background levels can, however, be higher than this if there are other local human activities (e.g. towns, public roads and pastoral) in the region that cause dust emissions. In such cases, background levels are subject to higher variability.

RTIO have previously provided ambient PM10 data for the period July 2011 to June 2012 from an E-Sampler dust monitor, located 500 m east of the on-site Village (data described in detail in ENVALL (2013)).

This report has assumed 18 $\mu g/m^3$ as representative of local background PM10 concentrations. This was determined from the 70th percentile of 24-hour average PM10 concentrations from the monitor. The use of the 70th percentile of measured concentrations as an estimate of background levels for modelling is recommended in the Victoria Government Gazette (2001).

For TSP, ENVIRON (2004) reported a 70th percentile 24-hour average TSP concentrations from monitoring at Port Hedland of 33 $\mu g/m^3$. In that study, the daily background was determined as the minimum from all the Port Hedland monitoring sites for that day.

It is assumed that background levels of TSP in the West Angelas Village should be similar to those in Port Hedland and hence a background level of 33 $\mu g/m^3$ has been used in this study, noting that this is really only applicable to predicted TSP at the Village.

5. SENSITIVE RECEPTOR LOCATIONS

5.1 IMPACTS TO HUMANS

The nearest sensitive receptors to the West Angelas operation, where impacts to humans are relevant, are the mine village and the aerodrome, which are approximately 6 kms west of Deposit B (see Figure 3).

Table 5 Locations of dust-sensitive receptors for impact to humans

Location	GDA94E (Km)	GDA94N (Km)
Mine village (south side)	673.660	7,440.730
Aerodrome	675.441	7441.096
	675.552	7440.985
	674.072	7439.585
	673.969	7439.686
	674.559	7440.248
	674.500	7440.311

5.2 BAT LOCATIONS

Rio Tinto personnel have also provided locations of local ghost bat caves for which dust level predictions are required. The locations of these are shown in Table 6.

Table 6 Locations of bat caves

Location	GDA94E (Km)	GDA94N (Km)
Caves A1 & A2	681.780	7442.620
Caves L2 & L3	682.928	7442.614
Cave AA1	686.953	7434.461

6. MODELLING METHODOLOGY

6.1 DISPERSION MODEL

The United States Environmental Protection Agency's (US EPA's) CALPUFF version 6 model was used to predict dust impacts from the West Angelas operation. This model 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 US EPA Guideline provides for the use of CALPUFF on a case-by-case basis for air quality estimates involving complex meteorological flow conditions, where steady-state straight-line transport assumptions are inappropriate. 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.

An example of the input parameters used for the CALPUFF model is provided in Appendix 6.

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

- meteorological modelling grid resolution used of 1 km with a pollution grid resolution of 500 m used to improve predictions closer to sources[6];
- terrain height data was sourced from the United States Geological Survey (USGS) Shuttle Radar Topography Mission (SRTM) archive (see http://dds.cr.usgs.gov/srtm/version2_1/SRTM3/). These data were obtained from the STS-99 mission of the Space Shuttle Endeavour during February 2000. For Australia, these data are available at a resolution of 3 arc-seconds (referred to as SRTM3) or approximately 90 m with elevated features removed;
- 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 taken into account using plume partial height adjustment scheme; and
- particle settling[7] and deposition taken into account.

[6] It was originally intended to use a 250 m resolution for the pollution grid, however the computational requirements across the domain for the number of sources used became excessive.

[7] Note that this requires the setting of the MTILT=1 option outside the CALPUFF GUI and each particle size to be modelled separately

6.2 METEOROLOGICAL DATA

Surface meteorological data for the modelling period 1/7/2011 to 30/6/2012, was derived from the RTIO West Angelas anemometer, with missing data from the Commonwealth Scientific and Industrial Research Organisation's (CSIRO's) The Air Pollution Model (TAPM) prognostic model (see Appendix 1). An annual wind speed and direction frequency rose from these data is shown in Figure 2 This shows that winds from the north-north-east to east are dominant. The average wind speed of 3.0 m/s is fairly typical of Pilbara inland locations.

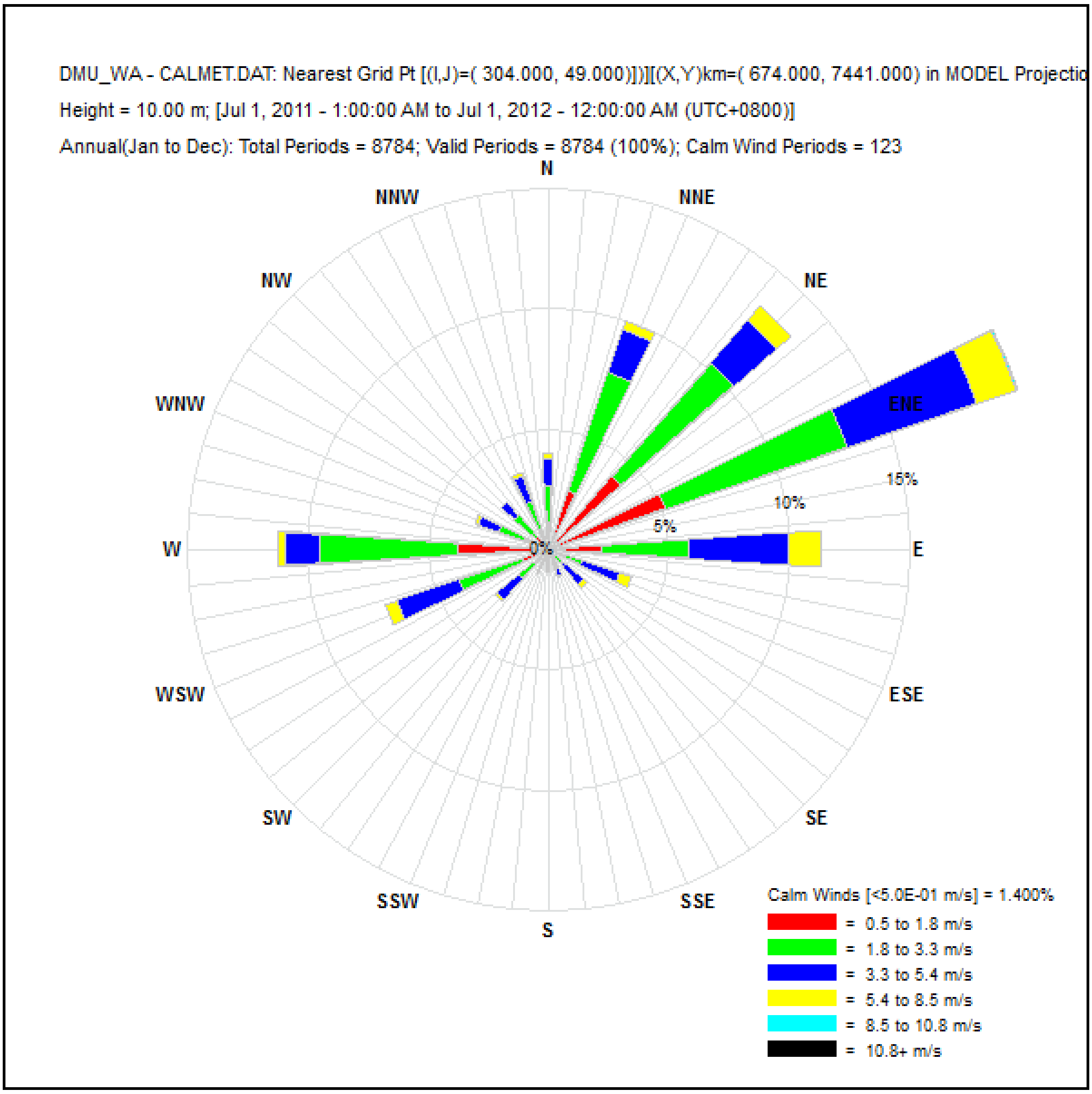

Figure 2 Wind speed and direction frequency matrix and rose for West Angelas 1/7/2011 to 30/6/2012

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.

An upper air profile for CALMET was also generated using TAPM (see Appendix 1).

7. DUST EMISSIONS

Dust emissions estimates were based on PM10 emissions for the 2013-14 year for the existing operation reported by RTIO 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)[8].

Four broad categories of sources were defined for modelling purposes:

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

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

The assumed distribution of PM10 emissions sources from the source groups for the existing operation are summarised in Table 7.

[8] 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”[8].

Table 7 Dust emissions apportionment by source for 2013-14

Source	Dust emissions apportionment by source (%)				
	Total	Pits	Waste dumps	Ore Stockpiles/ Outloading	Process Area
Drilling	1.3	1.3			
Blasting	1.5	1.5			
Excavator	0.9	0.9			
Dozers	13.2	7.8	5.4		
Unloading Haul trucks	1.3	0.8	0.5		
Haul truck wheels in pits/dumps	52.4	22.3	30.1		
Graders	0.1	0.1	0.1		
Wind erosion	6.5	1.2	4.3	0.1	0.9
Primary Crushing	1.6				1.6
Loading Haul trucks	0.4	0.3	0.2		
Transfers/Stackers/Train Load Out/Locos	20.8			20.8	
Total/Sub-totals	**100.0**	**36.1**	**40.5**	**20.9**	**2.5**

7.1 DEVELOPMENT OF WEST ANGELAS

The layout and mining stages of the West Angelas deposits relevant to this study are shown in Figure 3 and Table 8 respectively.

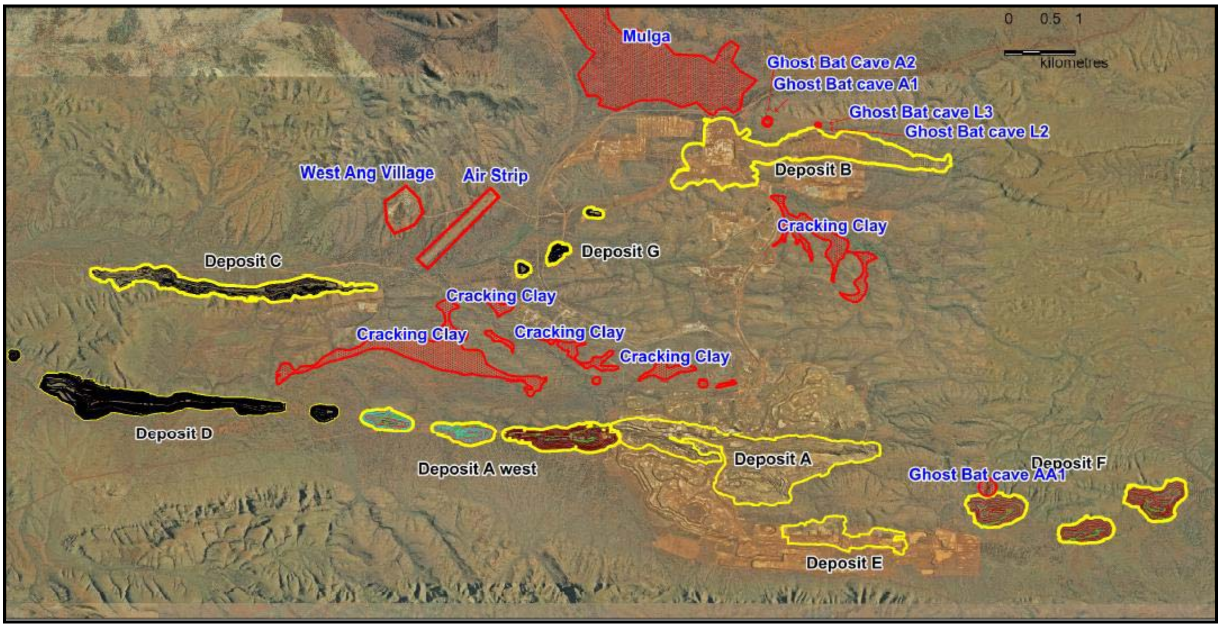

Figure 3 West Angelas current and future deposits

The estimated dust (as PM10) emissions are shown in Table 9. Emissions for hauls roads external to pits and dumps were considered as additional sources. The derivation of these emissions is discussed in Appendix 3, as these are very uncertain and have a large impact on predicted ambient dust levels. The years modelled – 2017, 2019, 2021, 2022, 2023, 2025, 2027 and 2029, were selected to indicate likely worst-case impacts through the project at various different locations closest to the maximum producing pits.

Table 8 Summary of West Angelas production 2016 to 2032 (000's tonnes)

Year	2013-14	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Pits																		
Awest		0	0	0	0	0	0	0	0	0	538	4,840	1,959	8,576	11,056	3,211	0	0
DepA		7,485	8,837	4,053	774	0	0	0	0	0	0	0	0	0	0	0	0	0
DepB		22,398	22,228	25,709	19,438	7,997	8,856	2,191	5,003	8,204	1,172	0	0	0	0	0	0	0
DepC		0	0	0	232	10,100	16,173	16,395	12,210	7,044	3,448	618	1,635	0	0	28	0	0
DepD		0	0	0	0	1,018	3,650	11,304	12,596	7,424	9,046	2,417	1,979	1	369	2,256	3,695	950
DepE		4,987	0	0	0	62	168	156	1,590	5,802	5,865	1,576	3,376	2,691	0	3,997	0	0
DepF		38	3,392	4,698	13,799	15,070	5,650	4,443	1,093	243	0	0	0	0	0	0	0	0
DepG		0	0	0	0	0	0	0	1,975	2,564	1,803	418	580	0	0	0	0	0
DepH	36,975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-Totals		34,908	34,456	34,460	34,243	34,247	34,496	34,488	34,467	31,282	21,873	9,871	9,529	11,268	11,425	9,492	3,695	950
Dumps																		
Awest		0	0	0	0	0	0	0	0	32,899	45,836	55,481	45,015	46,223	25,861	3,265	0	0
DepA		26,793	13,163	5,947	137	0	0	0	0	0	0	0	0	0	0	0	0	0
DepB		62,386	61,627	50,522	29,506	35,782	28,844	28,847	34,997	13,038	815	0	0	0	0	0	0	0
DepC		0	0	0	968	28,094	36,577	40,680	19,309	17,468	11,552	877	1,710	0	0	186	0	0
DepD		0	0	0	0	6,982	50,786	60,610	52,716	24,518	17,070	2,302	1,530	7,513	27,969	14,707	7,113	646
DepE		10,486	0	11,454	24,155	23,797	15,099	22,602	31,206	28,822	12,934	4,138	11,504	8,327	0	6,612	0	0
DepF		762	39,156	40,812	42,933	38,077	24,323	13,395	1,641	59	0	0	0	0	0	0	0	0
DepG		0	0	0	0	0	0	0	16,358	5,487	1,187	60	904	0	0	0	0	0
DepH	82,130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-Totals		100,427	113,946	108,735	97,699	132,732	155,628	166,134	156,226	122,290	89,394	62,859	60,663	62,063	53,830	24,771	7,113	646

Note: As provided by RTIO "WA_CDG_OoM_report_03_basecase_MM_25AL_FINAL" spreadsheet date Tuesday 16 June 2015. Beige shaded years are those modelled.

Table 9 Estimates PM10 emissions per year over duration of West Angelas project

Year	PM10 Emissions (kg/year)										
	Operations areas [a]				Haul Roads (outside pits/dumps)[b]						
	Pits[c]	Waste dumps	Ore Stockpiles/ Outloading	Process Area	Deposit Awest	Deposit B	Deposit C	Deposit D	Deposit E	Deposit F	Deposit G
2016	1,146,981	1,667,943	663,260	79,276	0	5,359,856	0	0	1,240,419	65,163	0
2017	1,132,129	1,892,474	654,672	78,249	0	5,750,893	0	0	0	3,520,665	0
2018	1,132,261	1,805,927	654,748	78,258	0	5,656,769	0	0	639,344	3,980,009	0
2019	1,125,131	1,622,635	650,625	77,766	0	3,800,215	65,534	0	1,470,409	5,762,929	0
2020	1,125,262	2,204,481	650,701	77,775	0	2,783,593	2,776,956	427,393	1,860,723	6,023,356	0
2021	1,133,443	2,584,750	655,432	78,340	0	2,630,315	4,066,790	3,293,226	1,269,097	2,918,336	0
2022	1,133,181	2,759,239	655,280	78,322	0	1,608,520	4,232,270	5,170,906	2,025,120	2,139,857	0
2023	1,132,491	2,594,681	654,881	78,274	0	2,894,553	2,790,707	4,952,197	3,141,665	412,715	976,298
2024	1,027,840	2,031,055	594,365	71,041	3,544,312	1,545,629	1,809,996	2,806,345	3,622,568	68,930	482,133
2025	718,686	1,484,701	415,592	49,673	5,077,335	182,811	957,873	2,638,968	2,241,765	0	216,883
2026	324,334	1,043,994	187,551	22,417	7,147,671	0	125,409	576,920	566,963	0	41,214
2027	313,097	1,007,522	181,053	21,640	5,162,309	0	312,106	478,861	1,679,152	0	108,279
2028	370,235	1,030,774	214,094	25,590	6,719,387	0	0	346,152	1,438,200	0	0
2029	375,394	894,036	217,078	25,946	4,916,072	0	0	1,631,590	0	0	0
2030	311,881	411,409	180,350	21,556	906,998	0	13,332	1,247,154	1,566,345	0	0
2031	121,408	118,136	70,206	8,391	0	0	0	1,148,229	0	0	0
2032	31,214	10,729	18,050	2,157	0	0	0	223,710	0	0	0

[a] All emissions scaled by 1.24 based on the results of previous modelling validation exercises for RTIO iron ore mining operations (see Appendix 4).

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 activity, the crusting of erodible areas following rain periods and assuming that waste dumps are progressively rehabilitated.

It was assumed that all equipment would be operating continuously during the operational hours.

[b] Deposit A haul roads considered within pits/dumps.

[c] The increase in blast size to 4,500 kg increases dust emissions from the pits by 21%, however only increases all sources dust emissions by 0.7 to 2.4% depending on the year.

7.2 PARTICLE SIZE DISTRIBUTION

Since dust is subject to gravitation settling and deposition, assumptions need to be made regarding particle sizes. A particle size distribution for modelling dust dispersion was therefore 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 10 (from Air Assessments 2011).

Table 10 Airborne particle size distributions

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

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 3.03 times the PM10 emission rates.

8. MODEL PREDICTIONS

8.1 MODEL UNCERTAINTY

Atmospheric dispersion models represent a simplification of the many complex processes involved in determining ground level concentrations of pollutants. Model uncertainty is composed of model chemistry/physics uncertainties, data uncertainties, and stochastic uncertainties. Models predict 'ensemble mean' concentrations for any specific set of input data (for example, 1-hourly over a year), that is, they predict the mean concentrations that would result from a large set of observations under the specific conditions being modelled. However, for any specific hour with those exact mean hourly conditions, the predicted ground level concentrations will never exactly match the actual pattern of ground level concentrations, due to the effects of random turbulent motions and random fluctuations in other factors such as temperature.

As described in US EPA (2005), from the results of numerous studies of model accuracy:

- models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations; and
- models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ± 10 to 40 percent are found to be typical i.e., certainly well within the often quoted "factor-of-two" accuracy that has long been recognized for models. However, estimates of concentrations that occur at a specific time and location are poorly correlated with actually observed concentrations and are much less reliable.

For this study, a somewhat coarse pollution grid interval of 500 m was used to reduce computational requirements. This means that predictions close to sources will be less reliable within this distance.

8.2 PREDICTED DUST LEVELS FOR EACH YEAR

The predicted dust levels at each discrete receptor are shown in Table 11 to Table 14. Time series plot of predicted dust levels at each discrete receptor are shown in Figure 4 to Figure 8. In these figures, the change resulting from the blast size increase to 4,500 kg is shown above the previous values and labelled with a "-Rev" in the Legend. It should also be noted that the background contributions are relatively large.

From these, in general, the prediction in relation to the criterion for TSP is a little more stringent than for PM10. This could be because the TSP criterion was derived for urban residential areas where the ambient environment has low background dust, whereas the PM10 criterion has been derived for the dustier Pilbara conditions.

Some general observations from the tables and figures are:

- the maximum predicted dust levels at the Village for all parameters are for 2022; and
- the maximum predicted dust levels at the most impacted area of the aerodrome are also at 2022.

The reasons the highest dust levels occur at the Village and aerodrome during 2022 are:

- over the year 2022, the TMM, and therefore dust emissions, peak for Deposit C;
- the peak annual TMM from Deposit C is reasonably high (approximately 57 Mtpa);
- Deposit C is relatively close to the Village and aerodrome (approximately 1 -2 kms to the west-south-west);
- winds from the west-south-west, are reasonably frequent at approximately 7 – 8% of the time. Furthermore, winds from the due west, which would also cause dust from the western end of Deposit C to impact the Village and aerodrome, are even more frequent at approximately 11% of the time; and
- the dimensions of Deposit C are largest along the east-west axis, which means that dust emissions result in a narrow, more concentrated plume for winds near westerly.

In relation to the ghost bat caves:

- the maximum predicted dust levels at the ghost bat caves A1 and A2 are at 2017 after which they decrease;
- the maximum predicted dust levels at the ghost bat caves L2 and L3 are at 2017 after which they decrease; and

- the maximum predicted dust levels at the ghost bat caves AA1 are at 2019 after which they decrease.

The dust impacts at the ghost bat caves are simply coincidental to the year that the highest TMM occurs from the adjacent deposit.

Table 11 Predicted 11th highest 24-hour PM10 concentrations at Village and aerodrome each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion (µg/m^3)	70	70	70	70	70	70	70	70
Background (µg/m^3)	18	18	18	18	18	18	18	18
Predicted from operation (µg/m^3)								
Mine village	49	37	58	67	62	52	33	32
Aerodrome	52	40	53	63	65	54	36	34
	56	41	57	65	69	56	38	36
	39	32	104	117	84	62	43	39
	38	31	96	110	81	59	41	38
	41	32	67	78	68	52	37	34
	40	31	65	76	67	51	36	32
Aerodrome maximum	56	41	104	117	84	62	43	39
Cumulative (operation + background) (µg/m^3)								
Mine village	67	55	76	85	80	70	51	50
Aerodrome maximum	74	59	122	135	102	80	61	57
Percent of criterion (%)								
Mine village	96%	79%	109%	122%	115%	100%	74%	71%

Table 12 Predicted 6th highest 24-hour TSP concentrations at Village and aerodrome each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion (µg/m^3)	90	90	90	90	90	90	90	90
Background (µg/m^3)	33	33	33	33	33	33	33	33
Predicted from operation (µg/m^3)								
Mine village	76	57	90	104	96	78	49	46
Aerodrome	89	67	82	93	102	78	53	51
	96	68	87	97	107	82	56	54
	67	51	174	200	143	99	71	63
	67	49	165	190	138	96	68	60
	70	53	107	125	107	83	59	53
	69	53	103	119	105	82	57	51
Aerodrome maximum	96	68	174	200	143	99	71	63
Cumulative (operation + background) (µg/m^3)								
Mine village	109	90	123	137	129	111	82	79
Aerodrome maximum	129	101	207	233	176	132	104	96
Percent of criterion (%)								
Mine village	122%	100%	136%	152%	144%	123%	91%	87%

Table 13 Predicted annual average dust deposition addition at Village and Aerodrome each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion (g/m^2/month)	4	4	4	4	4	4	4	4
Background (g/m^2/month)	2	2	2	2	2	2	2	2
Predicted from operation (g/m^2/month)								
Mine village	1.0	0.7	2.0	2.3	1.8	0.8	0.5	0.4
Aerodrome	1.7	1.1	1.6	1.8	1.5	0.8	0.4	0.4
	1.2	0.8	3.7	4.2	3.2	1.5	0.8	0.7
	1.4	0.9	2.7	3.0	2.4	1.1	0.6	0.6
Aerodrome maximum	1.7	1.1	3.7	4.2	3.2	1.5	0.8	0.7
Cumulative (operation + background) (g/m^2/month)								
Mine village	3.0	2.7	4.0	4.3	3.8	2.8	2.5	2.4
Aerodrome maximum	3.7	3.1	5.7	6.2	5.2	3.5	2.8	2.7
Percent of criterion (%)								
Mine village	76%	67%	101%	108%	95%	70%	62%	61%

Table 14 Predicted annual average dust deposition addition at ghost bat caves each year

Location	2017	2019	2021	2022	2023	2025	2027	2029
Criterion (g/m^2/month)	4	4	4	4	4	4	4	4
Background (g/m^2/month)	1	1	1	1	1	1	1	1
Predicted from operation (g/m^2/month)								
Caves A1 & A2	7.4	6.0	3.3	1.6	2.7	0.9	0.3	0.3
Caves L2 & L3	9.5	8.1	4.2	1.8	3.3	1.0	0.3	0.3
Cave AA1	2.7	6.1	2.9	2.2	1.3	0.9	0.7	0.1
Cumulative (operation + background) (g/m^2/month)								
Caves A1 & A2	9.4	8.0	5.3	3.6	4.7	2.9	2.3	2.3
Caves L2 & L3	11.5	10.1	6.2	3.8	5.3	3.0	2.3	2.3
Cave AA1	4.7	8.1	4.9	4.2	3.3	2.9	2.7	2.1

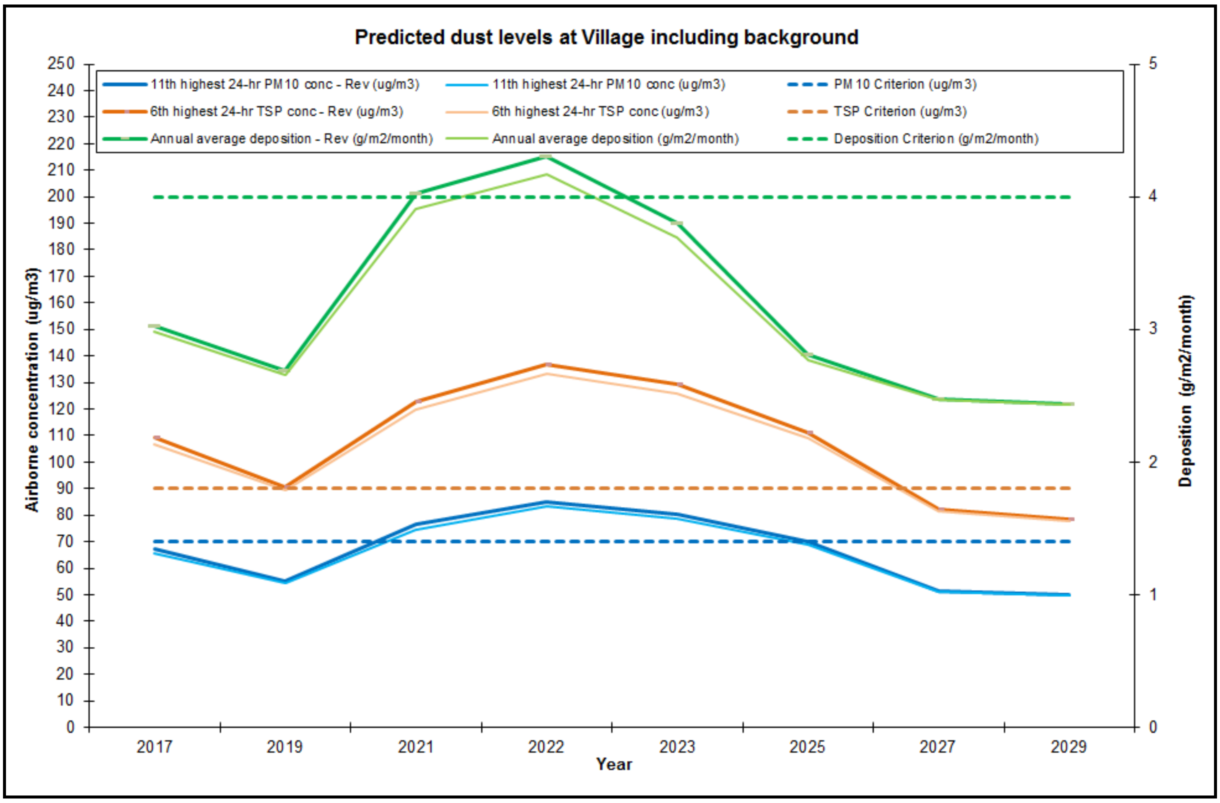

Figure 4 Predicted dust levels at Village including background each year

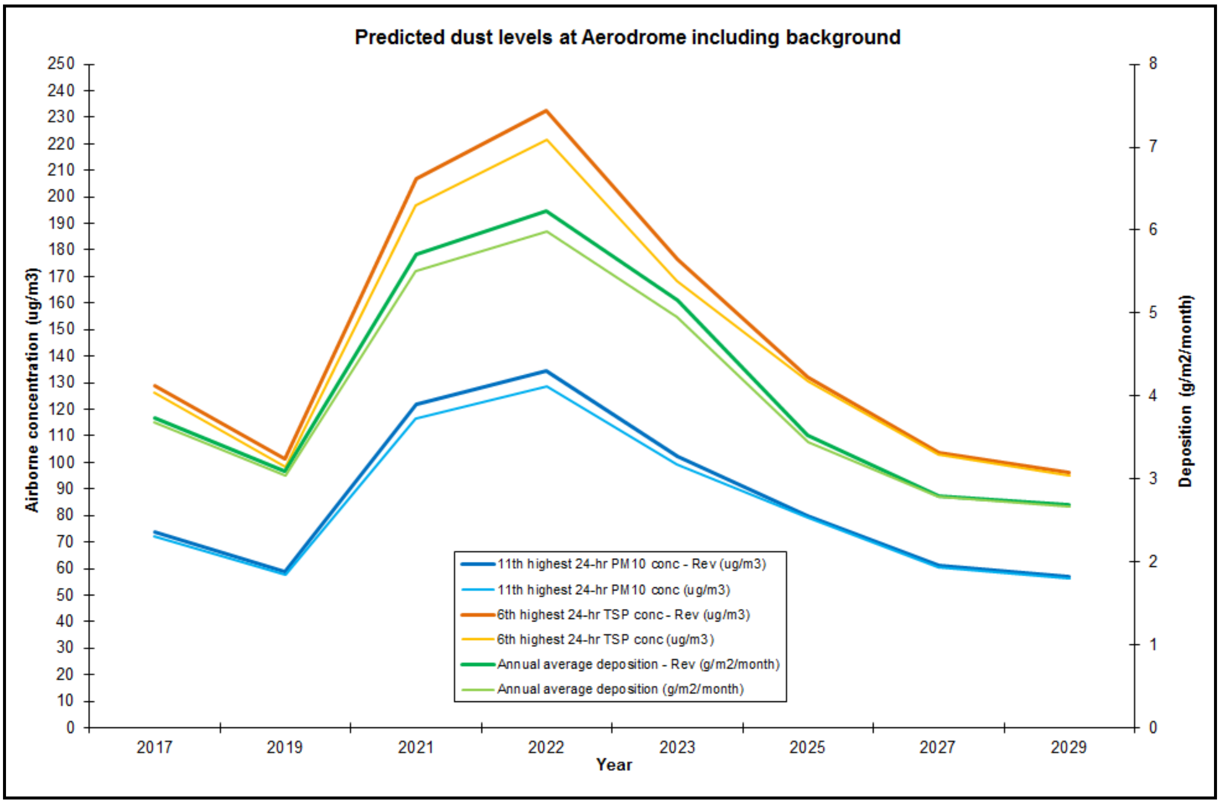

Figure 5 Predicted dust levels at Aerodrome including background each year

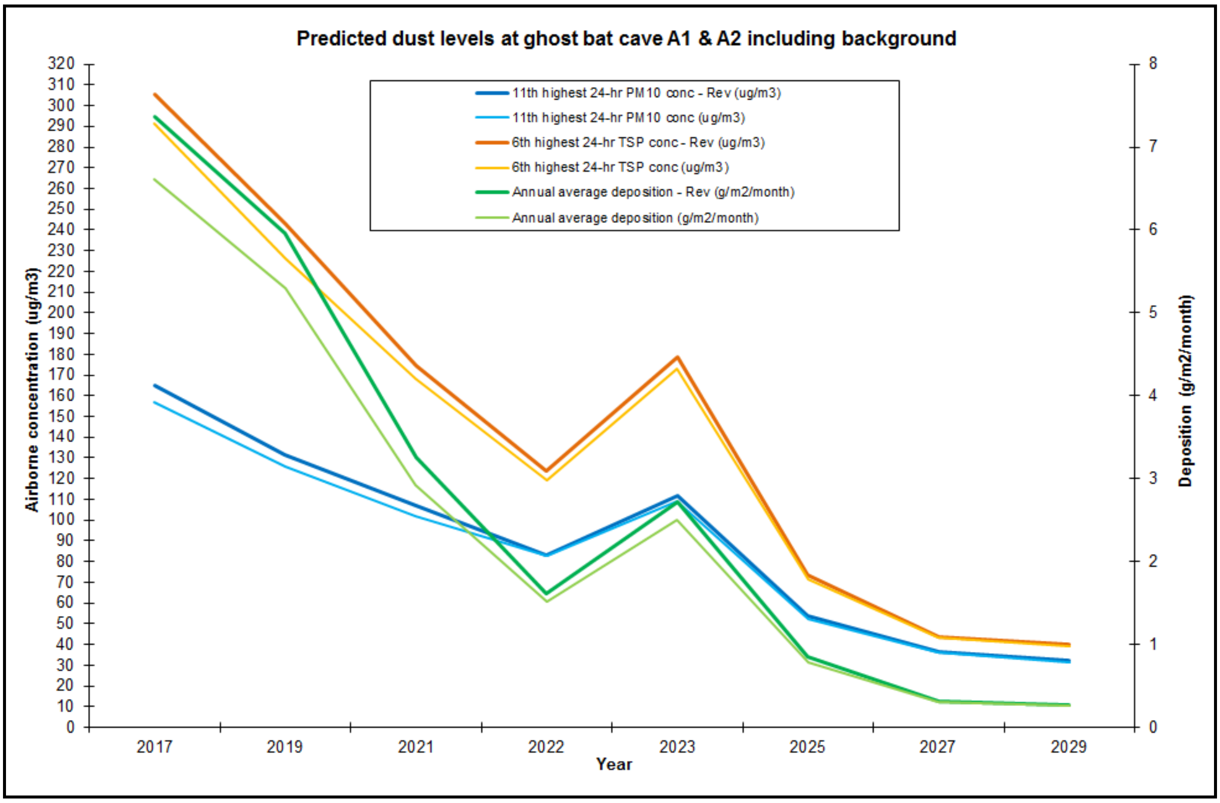

Figure 6 **Predicted dust levels at ghost bat caves A1 & A2 including background each year**

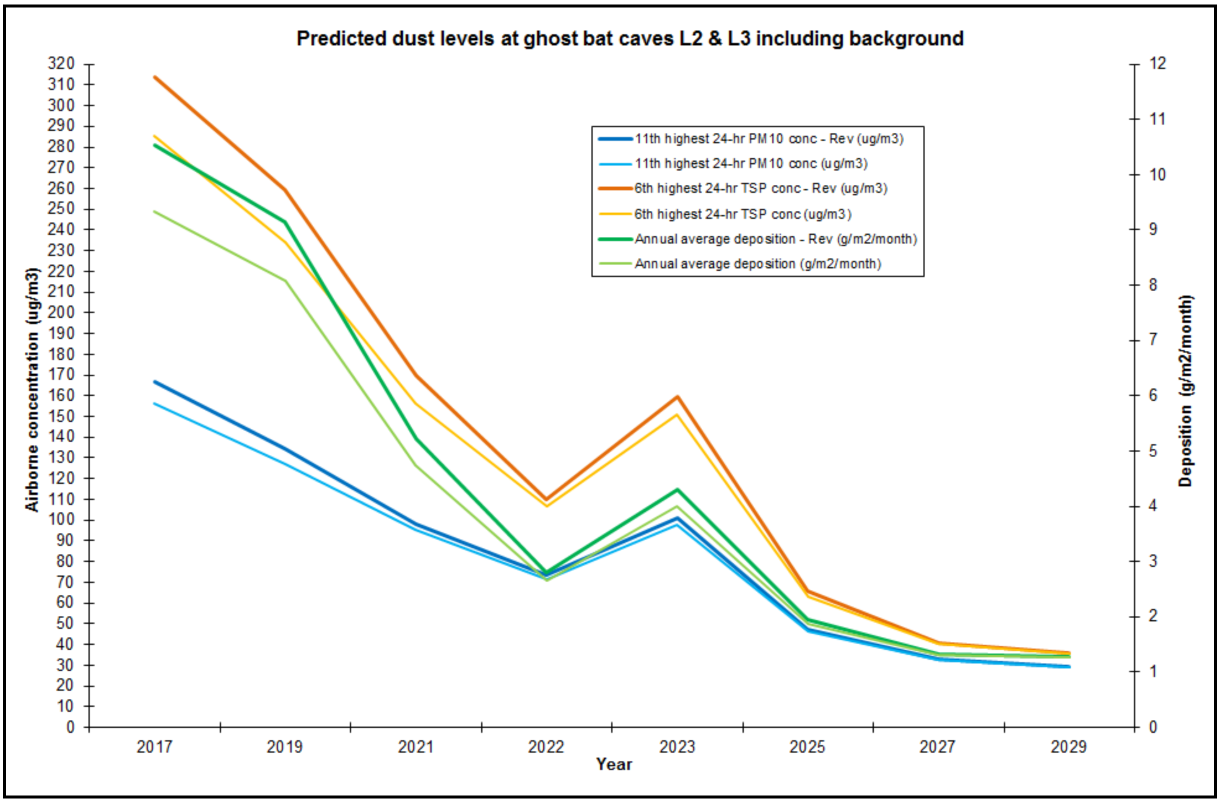

Figure 7 **Predicted dust levels at ghost bat caves L2 & L3 including background each year**

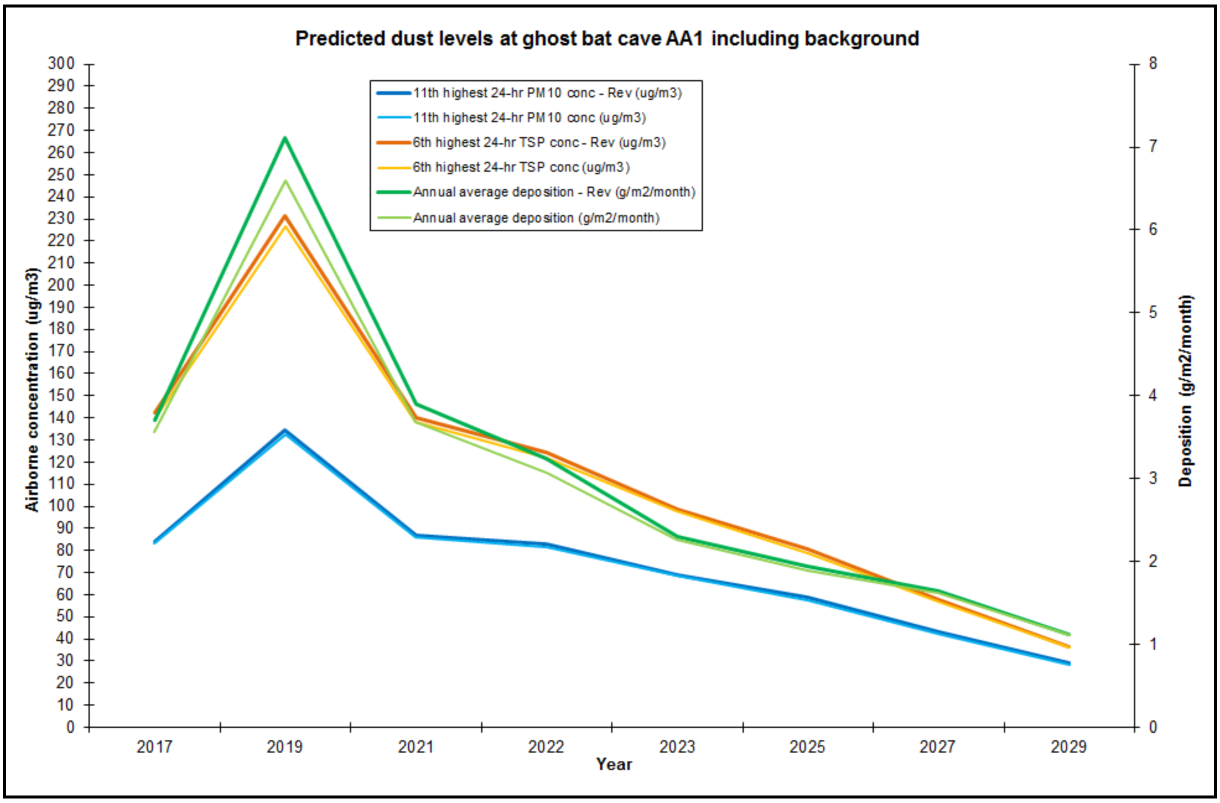

Figure 8 Predicted dust levels at ghost bat cave AA1 including background each year

8.3 CONTOUR PLOTS

Contour plots are a visual representation of the spatial extent of dust levels. Predicted dust level contours for each year are illustrated for each criterion in the following figures. Contours plots are shown for:

- predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations each year in Figure 9 to Figure 16;
- predicted 6th highest 24-hour average TSP concentrations from West Angelas operations each year in Figure 17 to Figure 24; and
- predicted annual average dust deposition from West Angelas operations each year in Figure 25 to Figure 32.

The contour figures for PM10 and TSP include the additional of background levels to enable a direct comparison with the criteria, which include background levels. The contour figures for dust deposition do not include background levels because the derivation of the criterion is actually based on the additional deposition attributable to the operation.

It is notable that dust deposition decreases with distance from the source more rapidly than airborne dust concentrations.

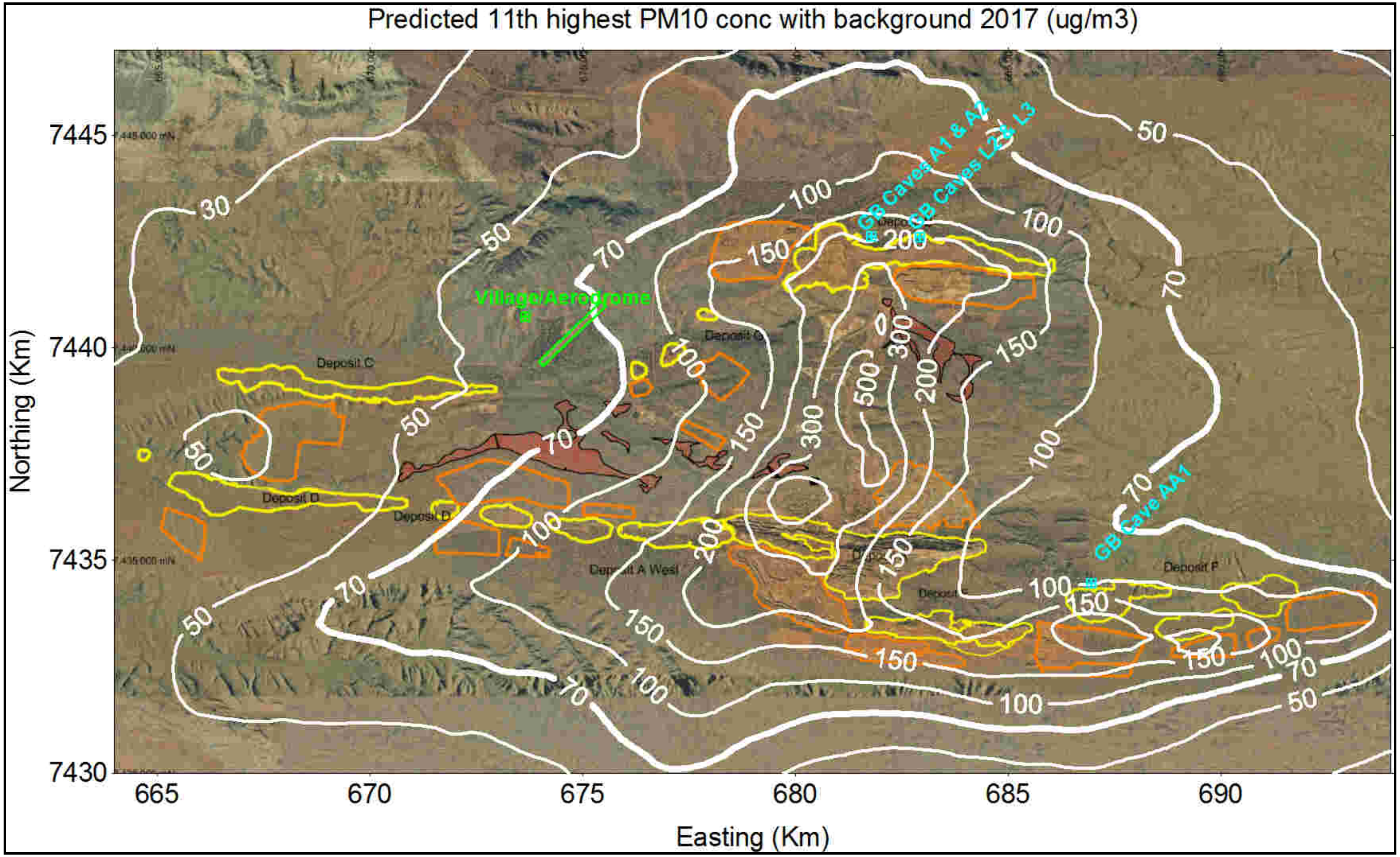

Figure 9 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2017

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

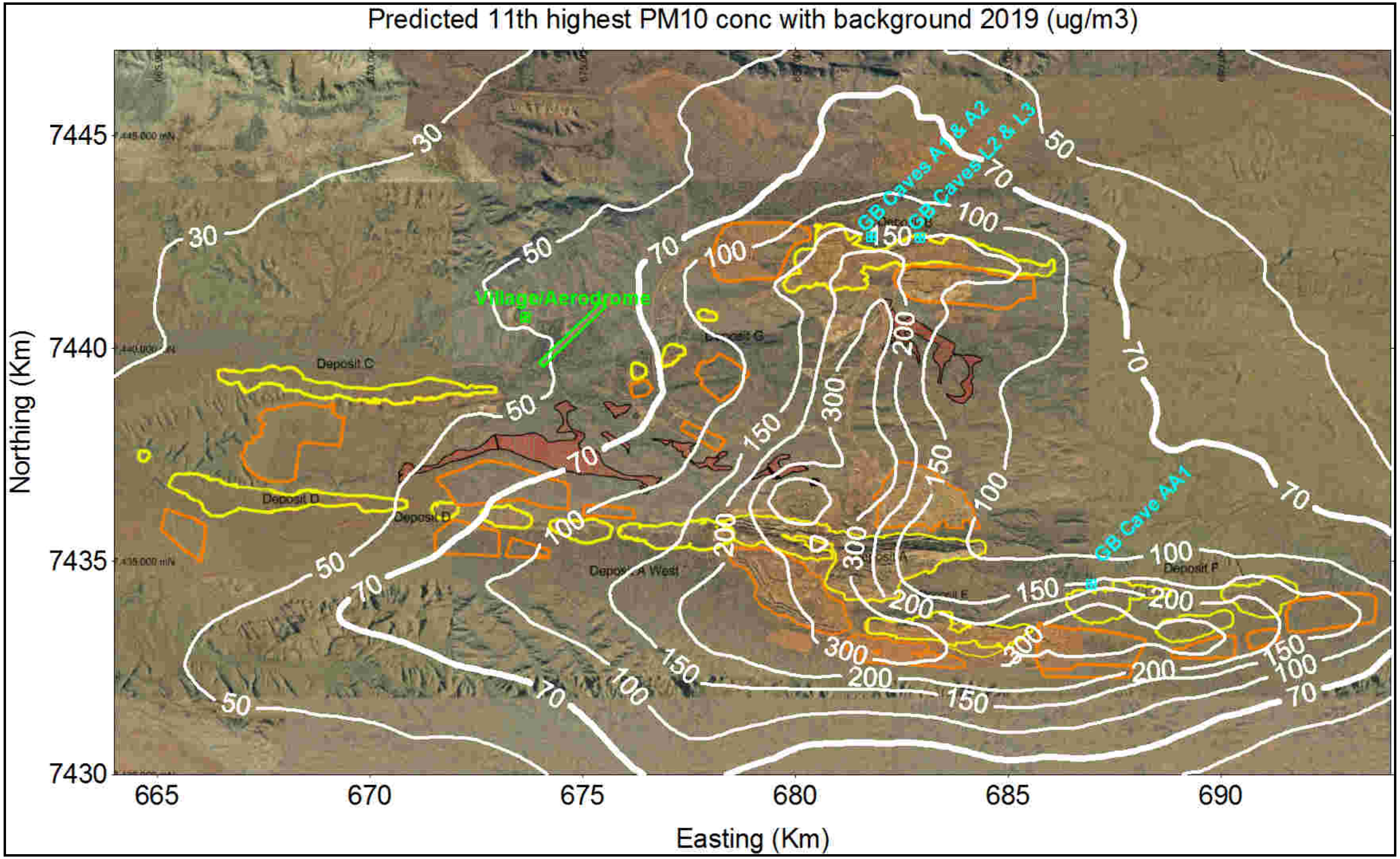

Figure 10 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2019

Notes: 1) Criterion is 70 µg/m³. An allowance of 18 µg/m³ has been added to the model predictions to account for background.

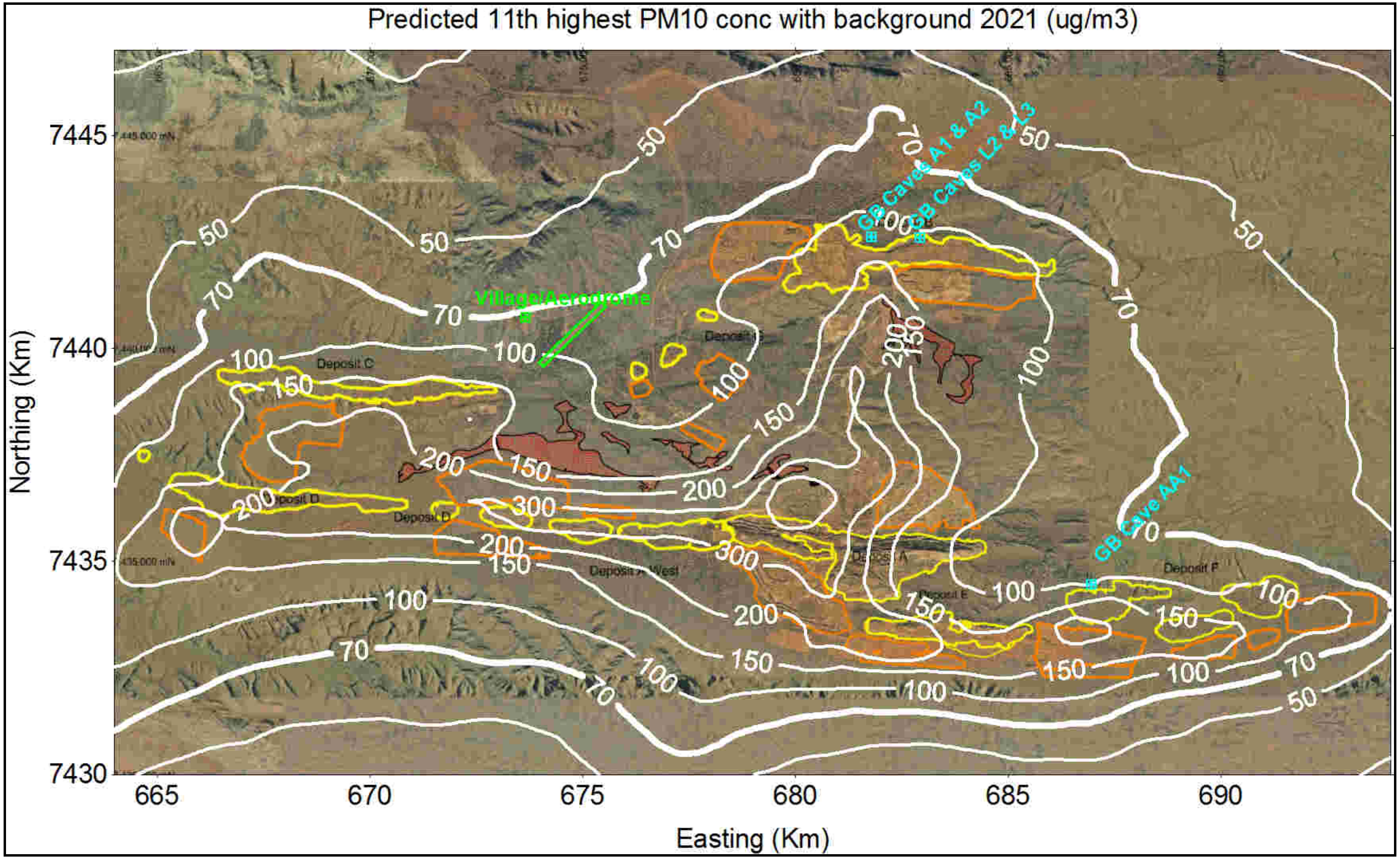

Figure 11 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2021

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

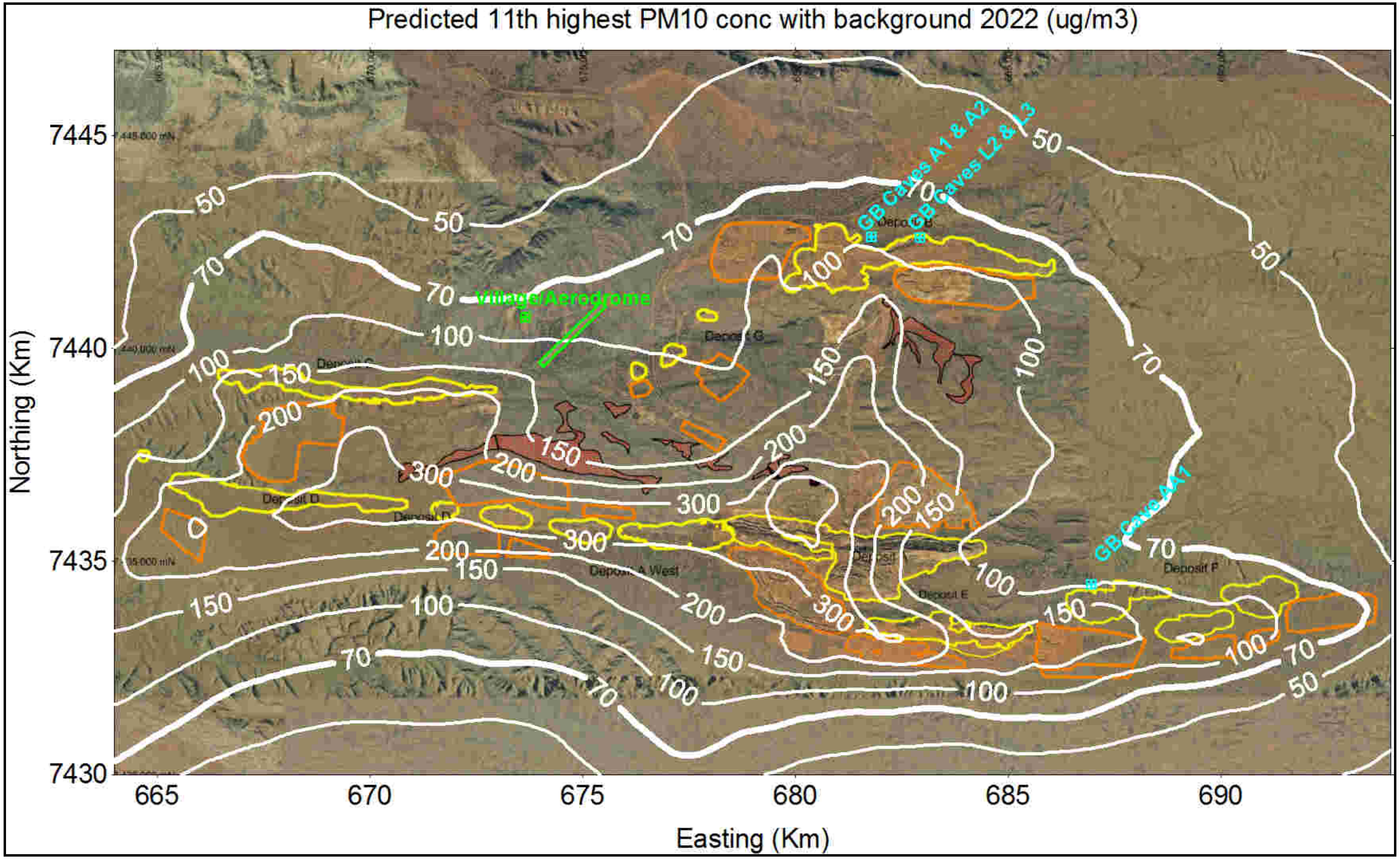

Figure 12 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2022

Notes: 1) Criterion is 70 µg/m³. An allowance of 18 µg/m³ has been added to the model predictions to account for background.

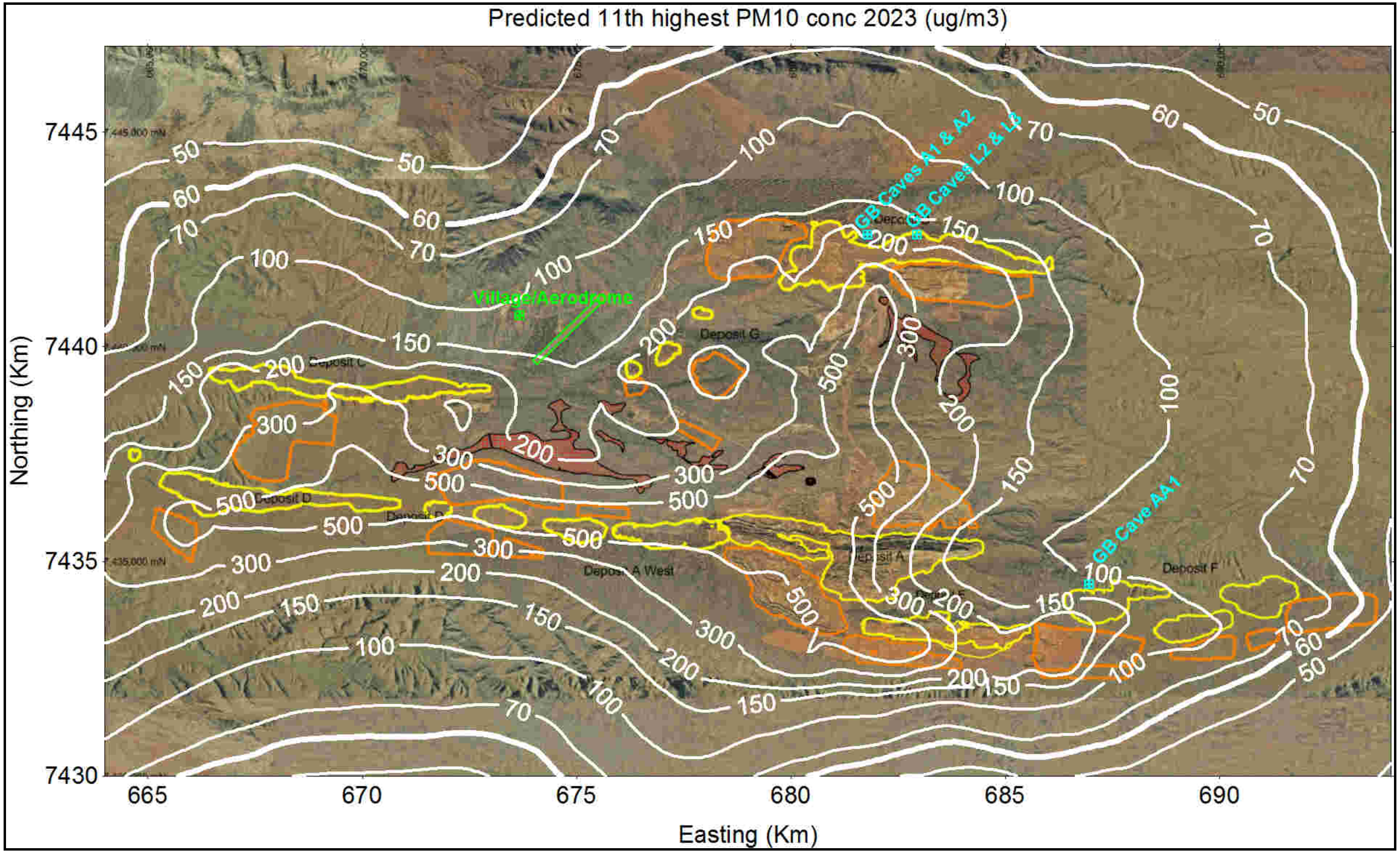

Figure 13 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2023

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

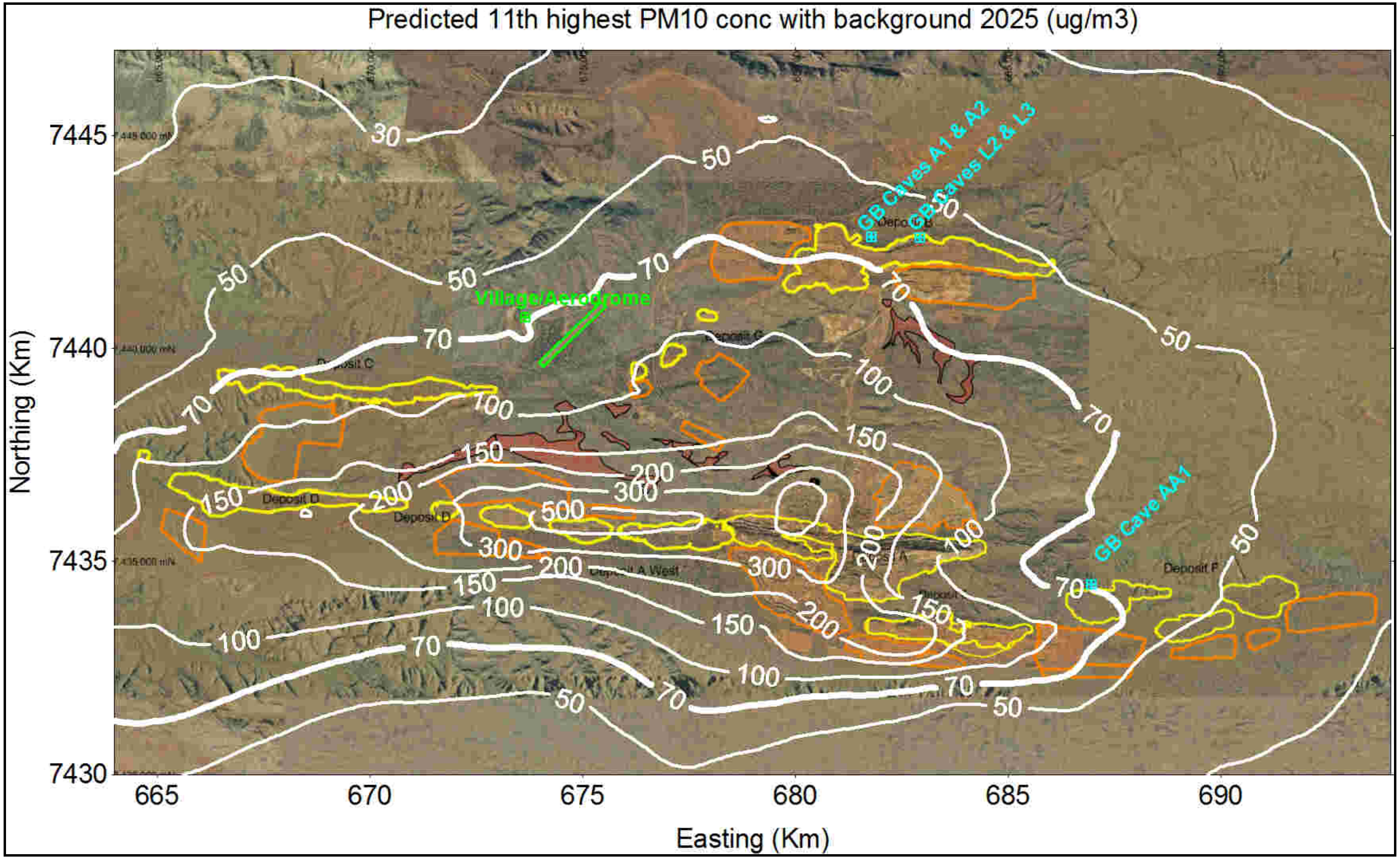

Figure 14 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2025

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

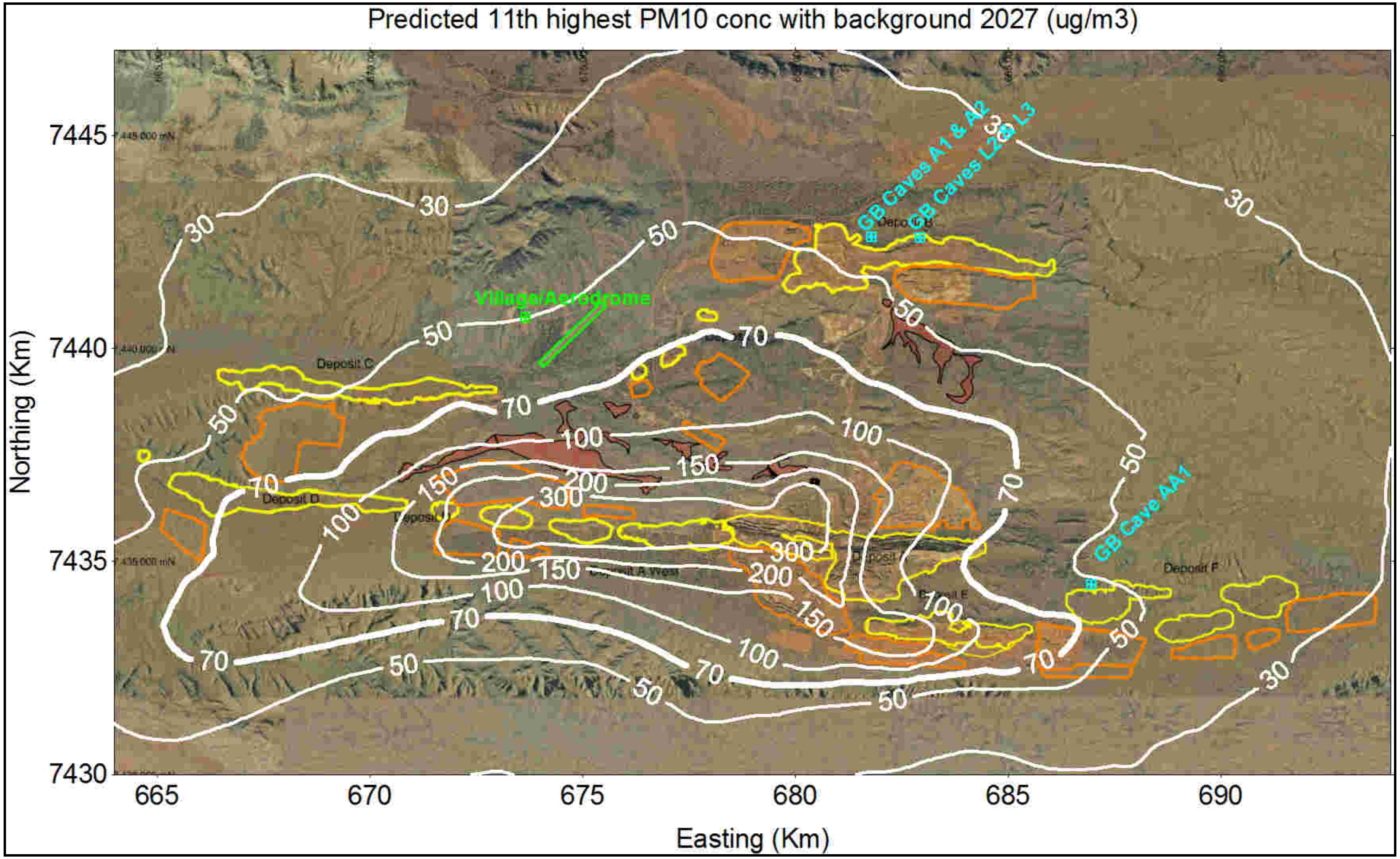

Figure 15 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2027

Notes: 1) Criterion is 70 µg/m^3. An allowance of 18 µg/m^3 has been added to the model predictions to account for background.

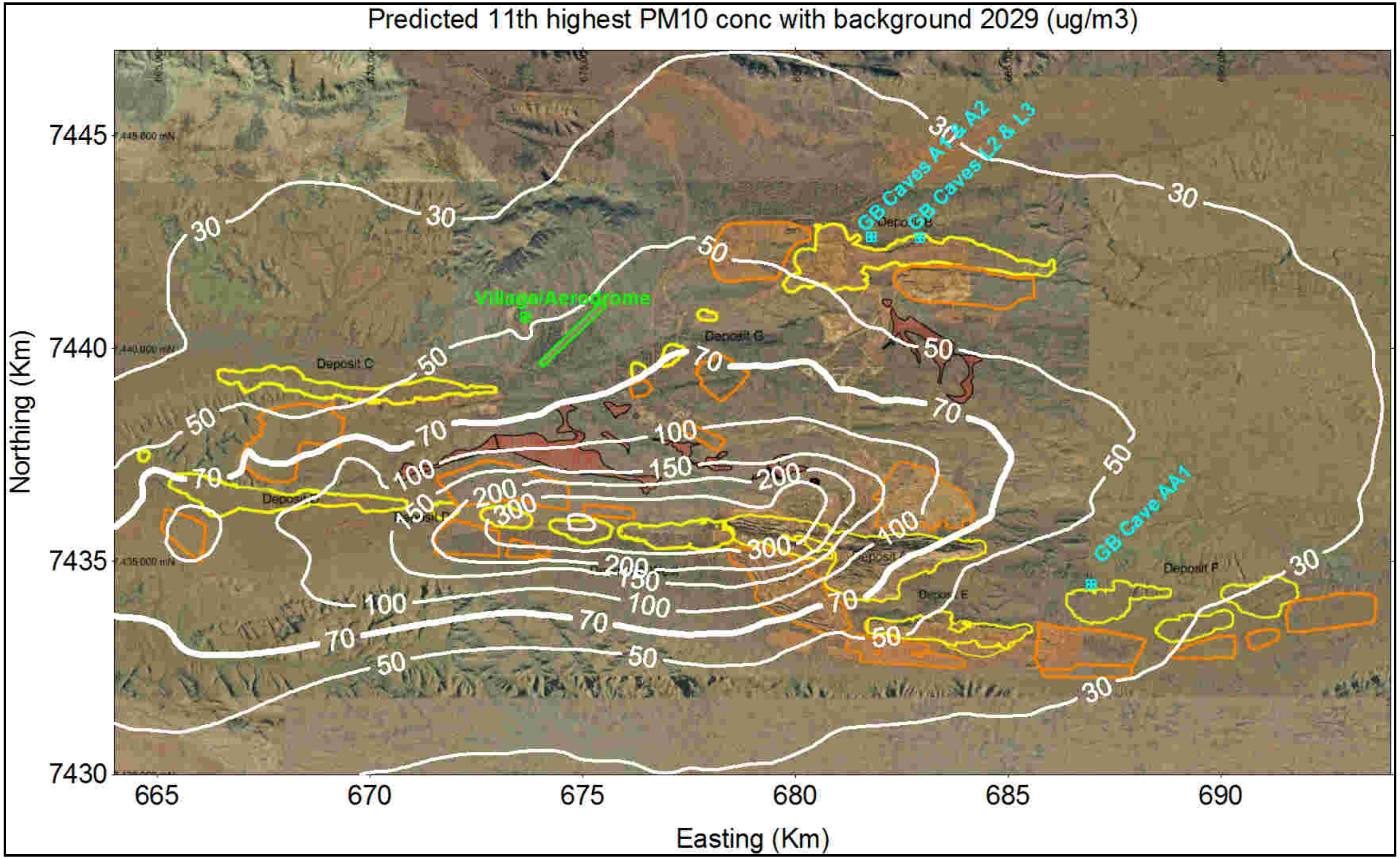

Figure 16 Predicted 11th highest 24-hour average PM10 concentrations from West Angelas operations with background at 2029

Notes: 1) Criterion is 70 µg/m³. An allowance of 18 µg/m³ has been added to the model predictions to account for background.

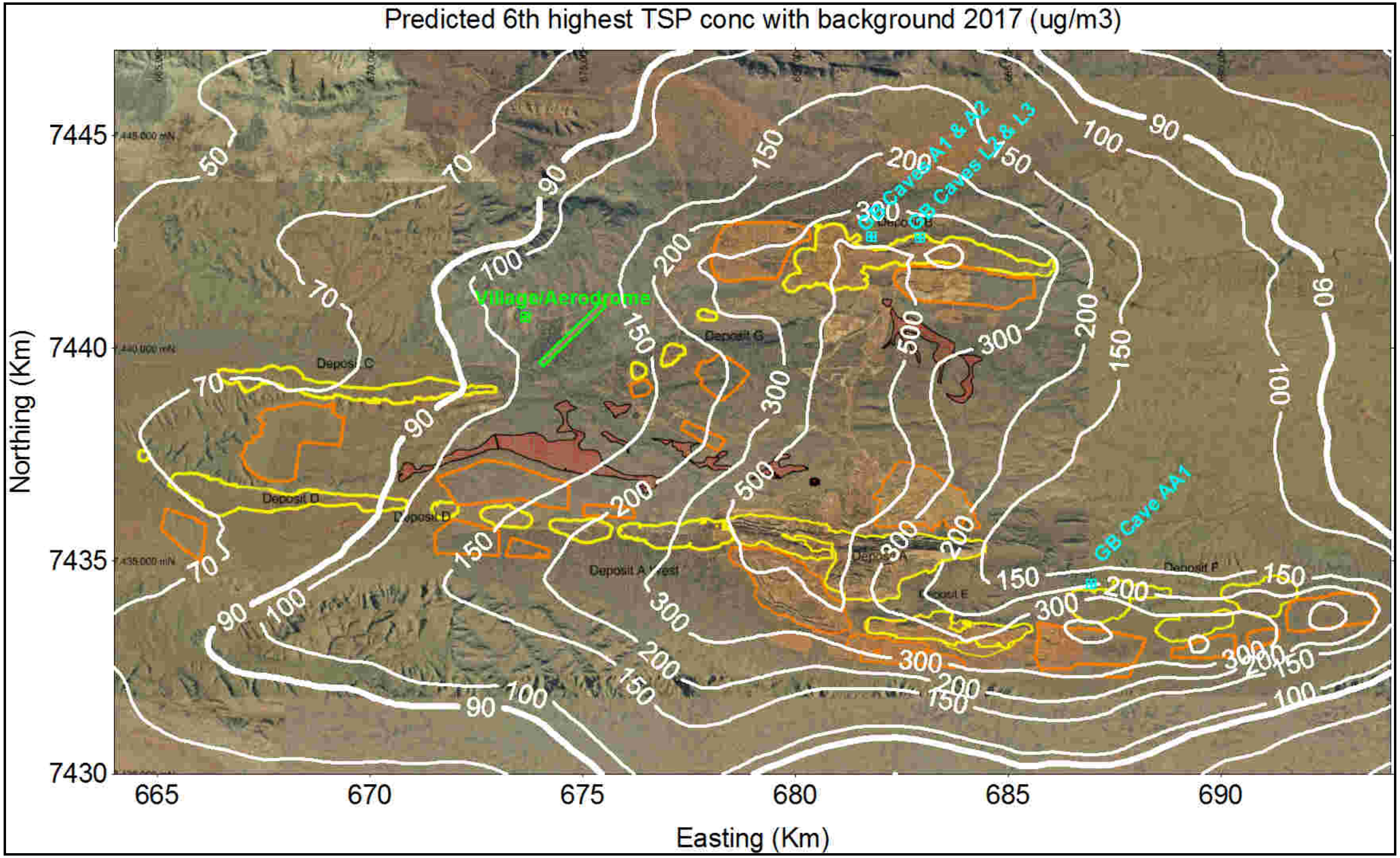

Figure 17 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2017

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

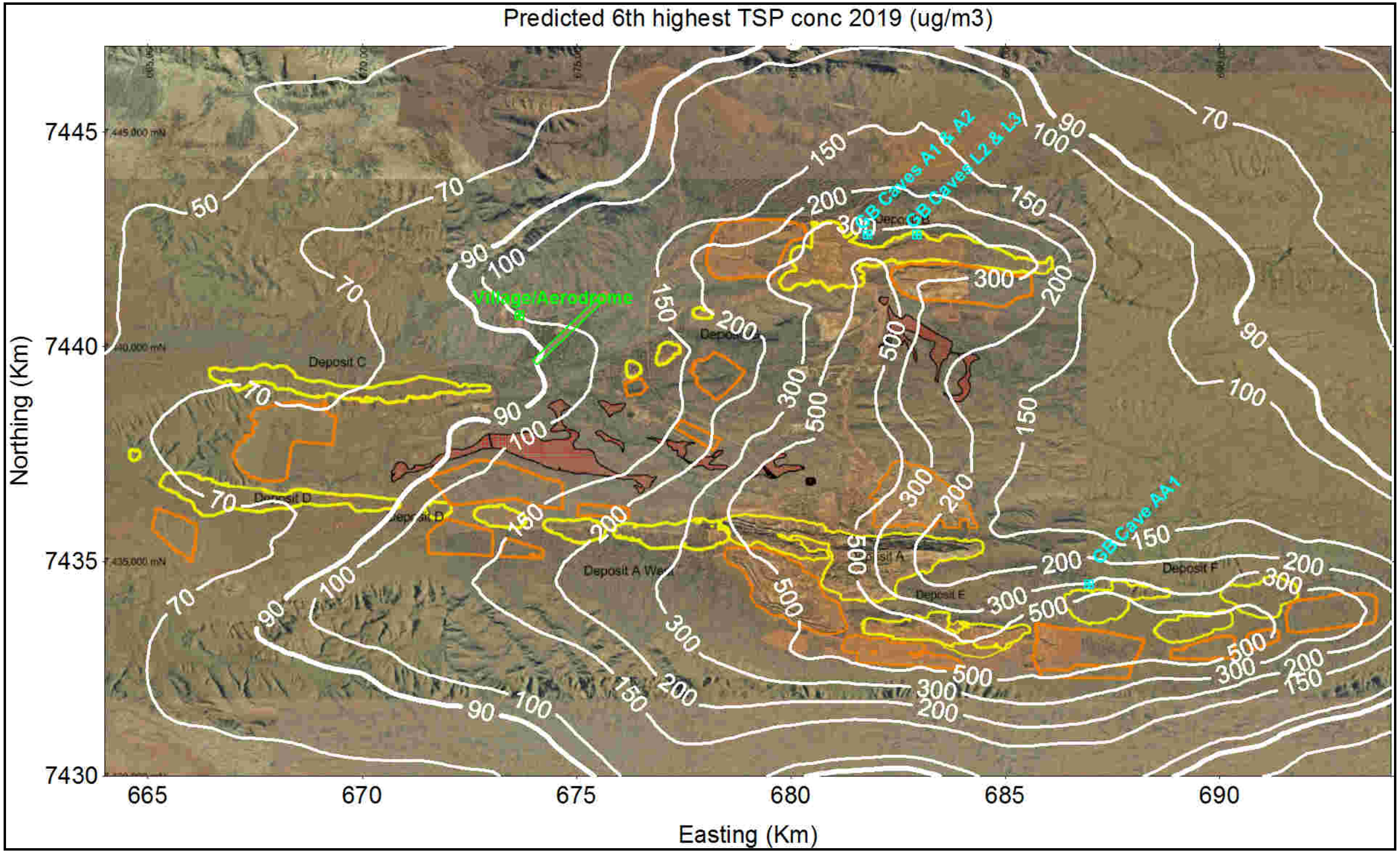

Figure 18 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2019

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

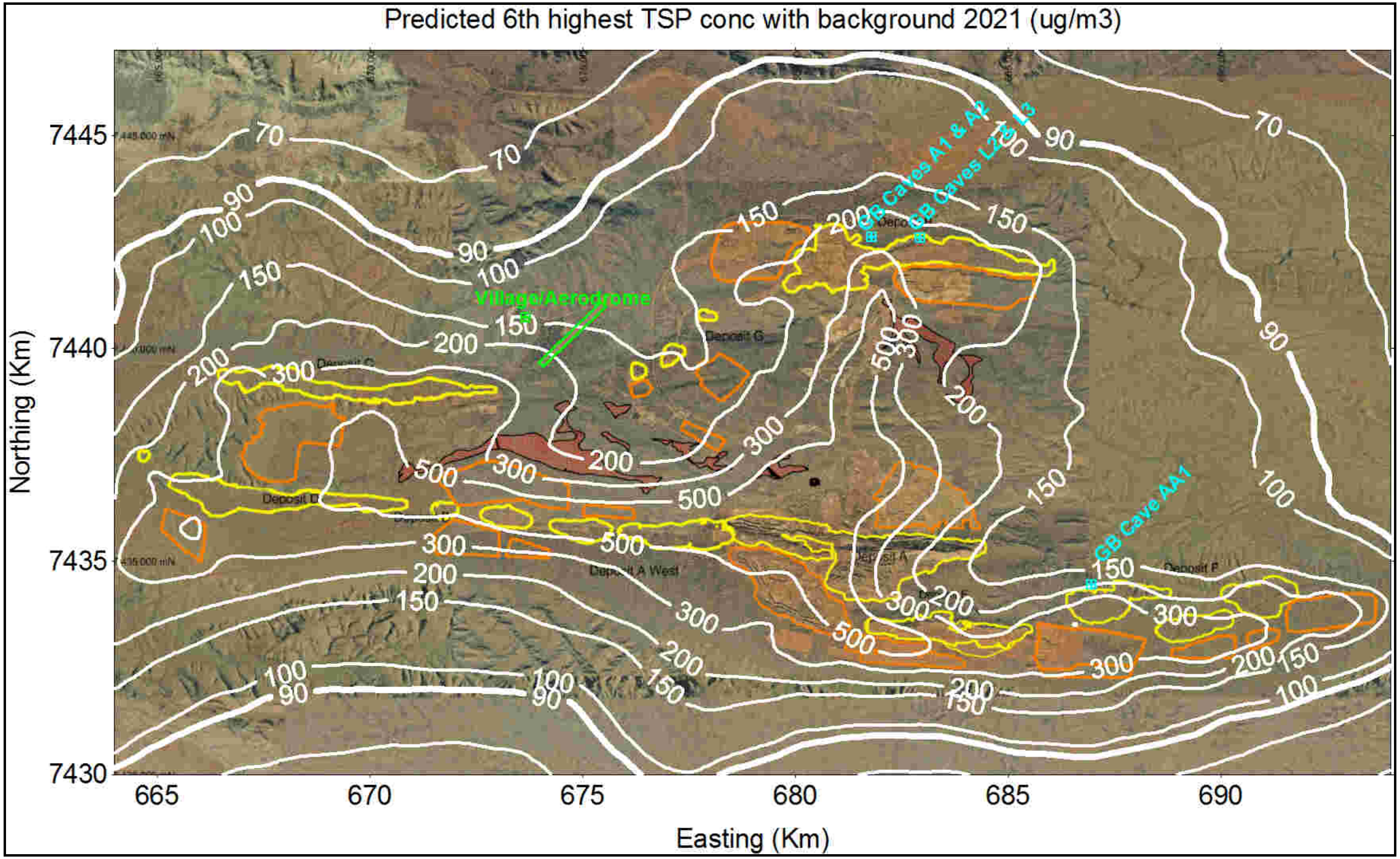

Figure 19 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2021

Notes: 1) Criterion is 90 µg/m³. An allowance of 33 µg/m³ has been added to the model predictions to account for background.

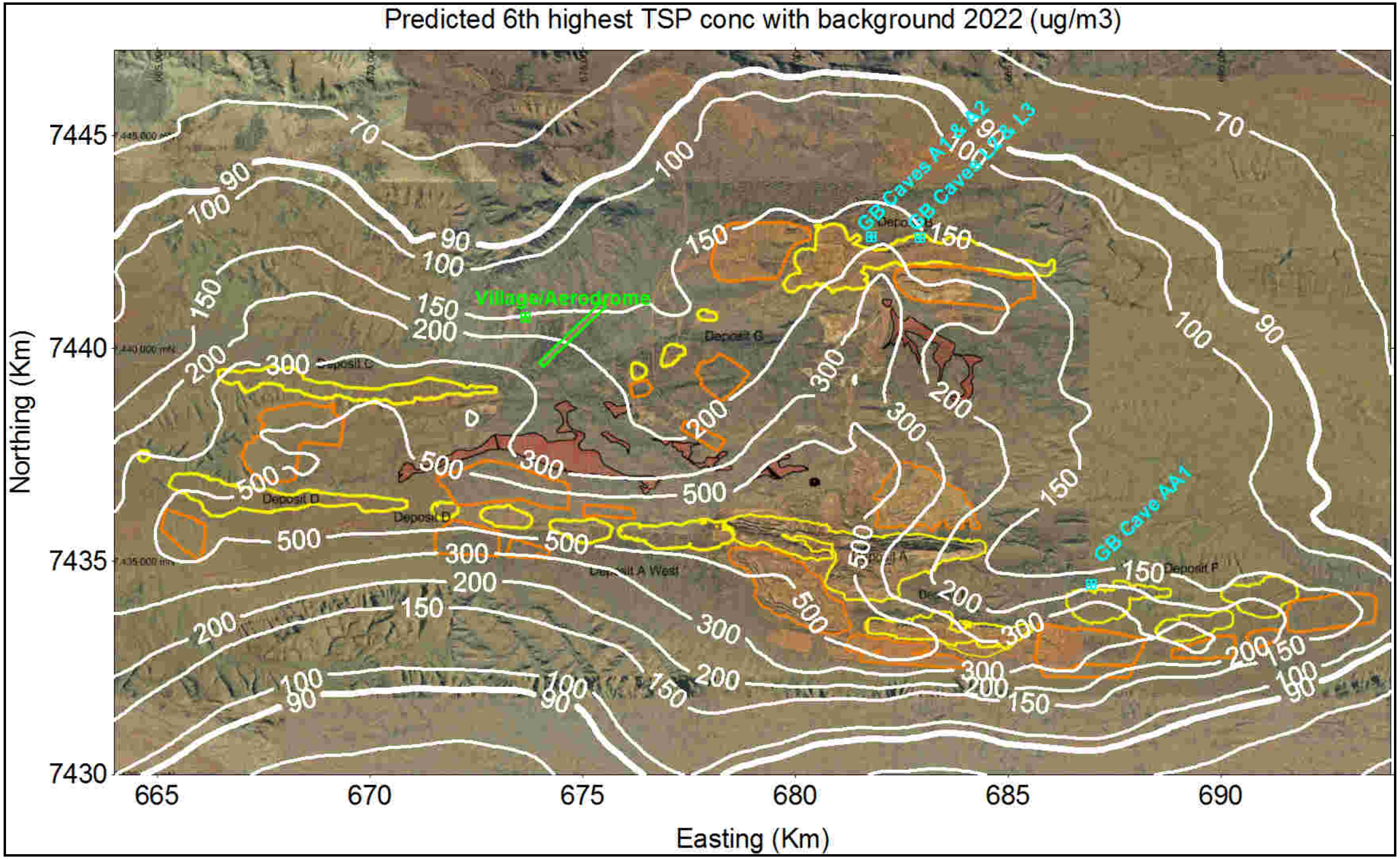

Figure 20 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2022

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

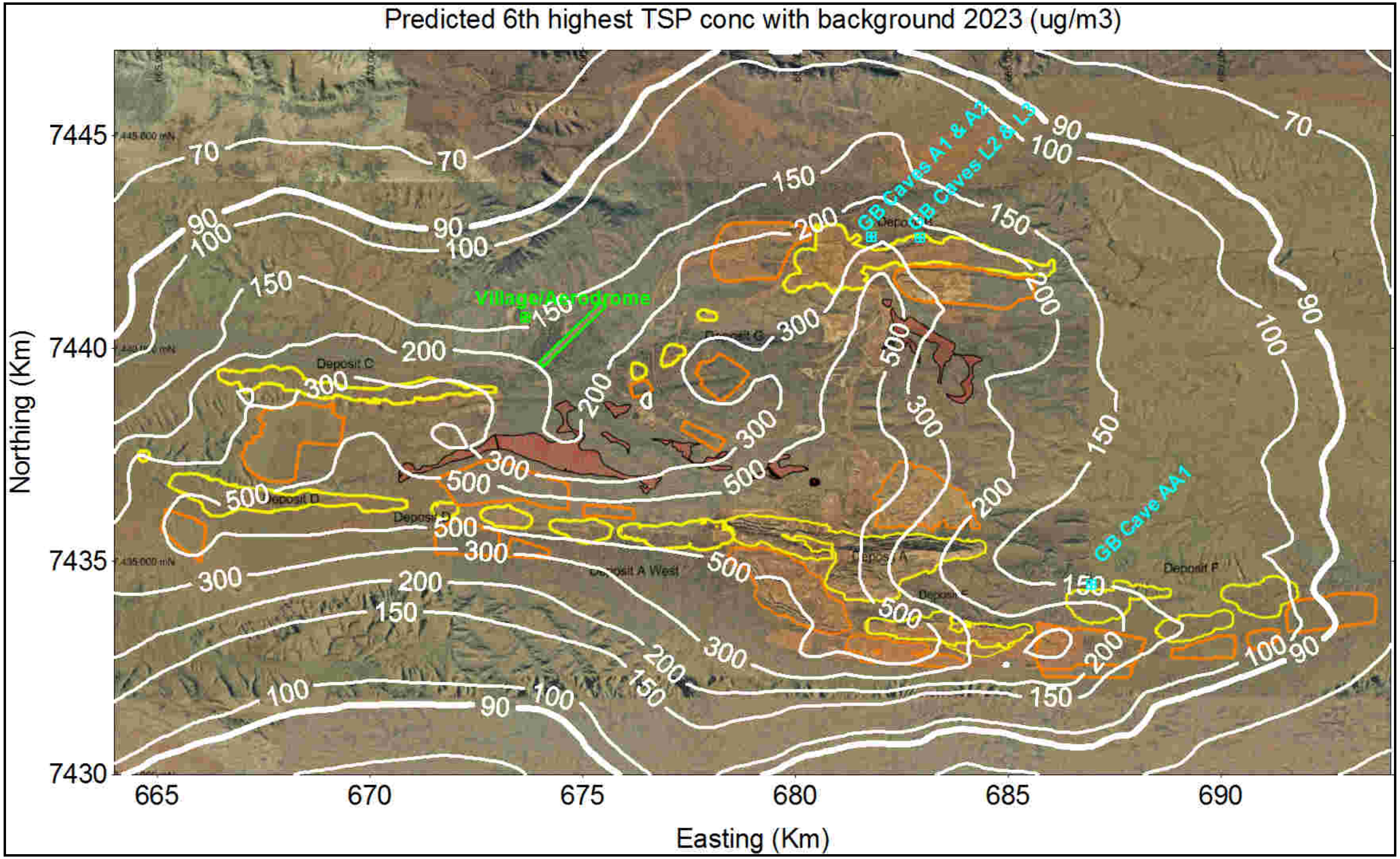

Figure 21 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2023

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

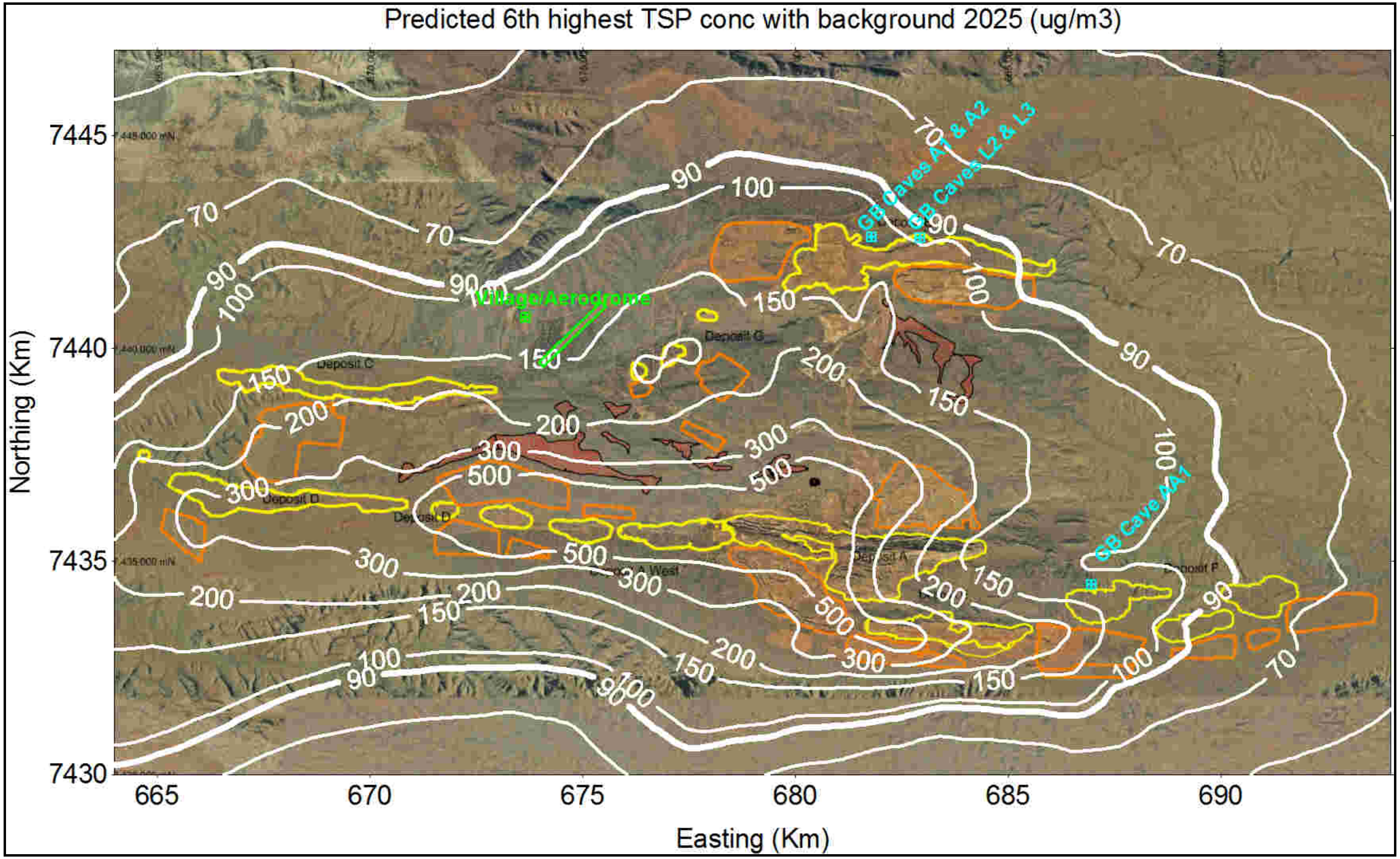

Figure 22 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2025

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

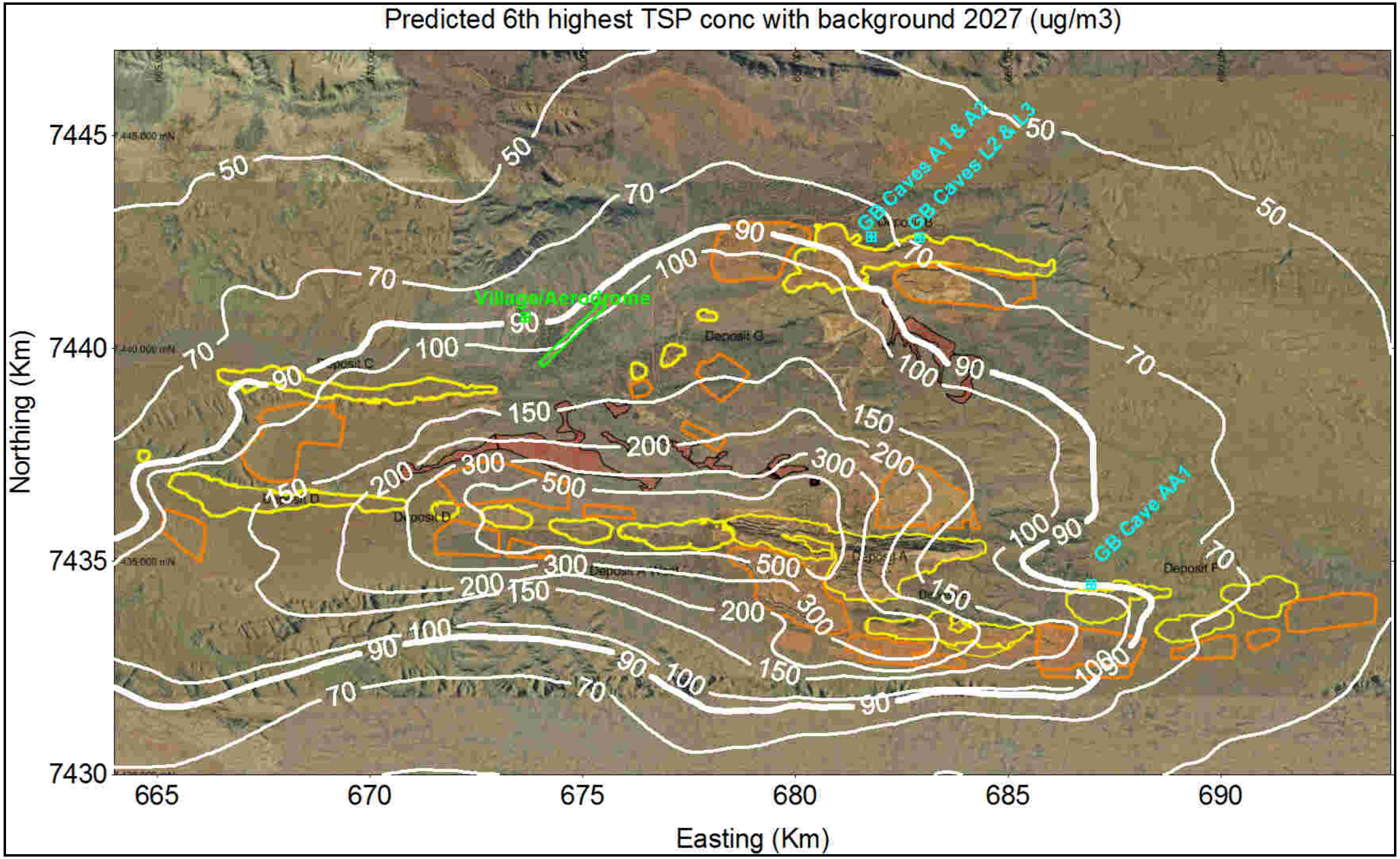

Figure 23 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2027

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

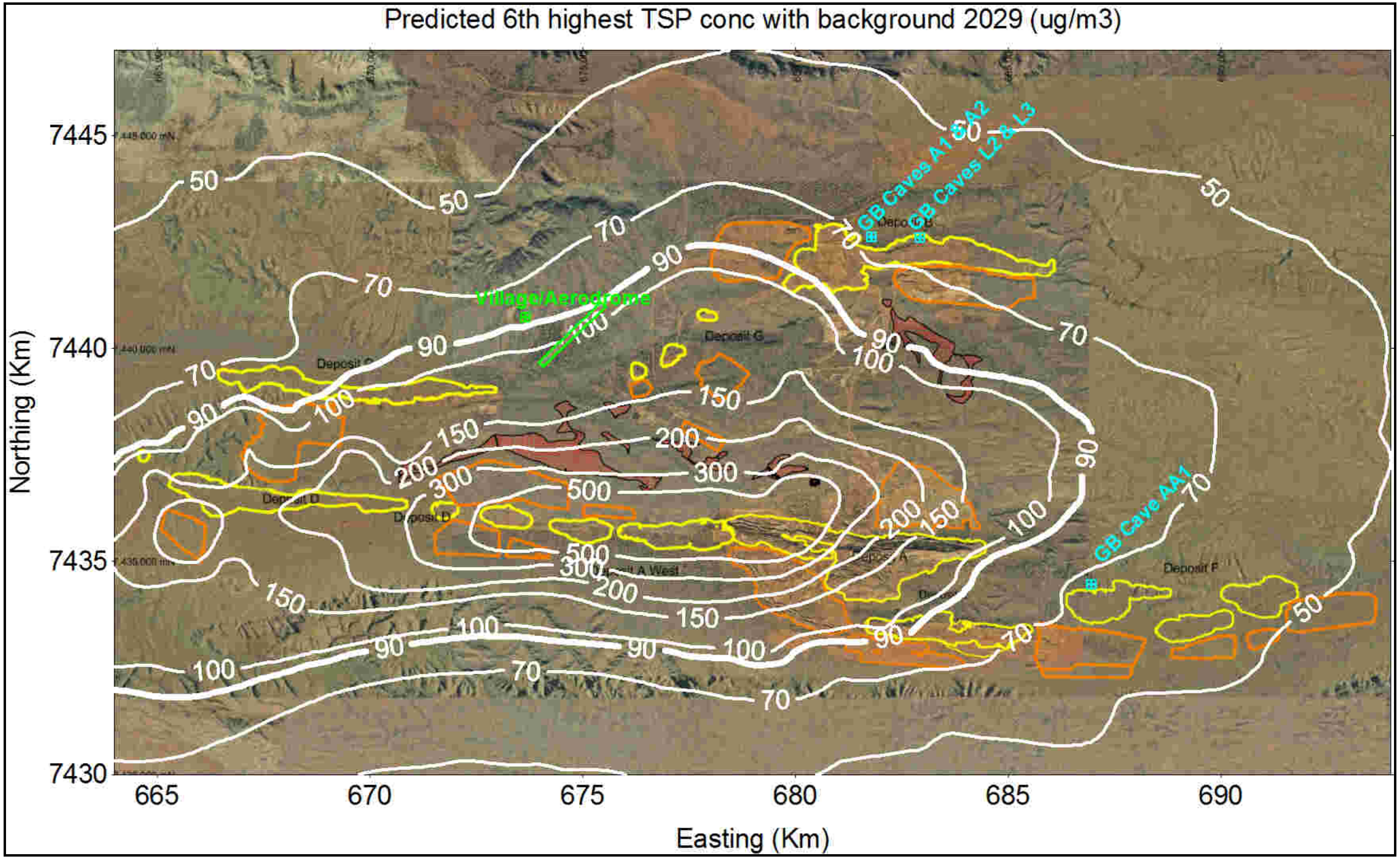

Figure 24 Predicted 6th highest 24-hour average TSP concentrations from West Angelas operations with background at 2029

Notes: 1) Criterion is 90 µg/m^3. An allowance of 33 µg/m^3 has been added to the model predictions to account for background.

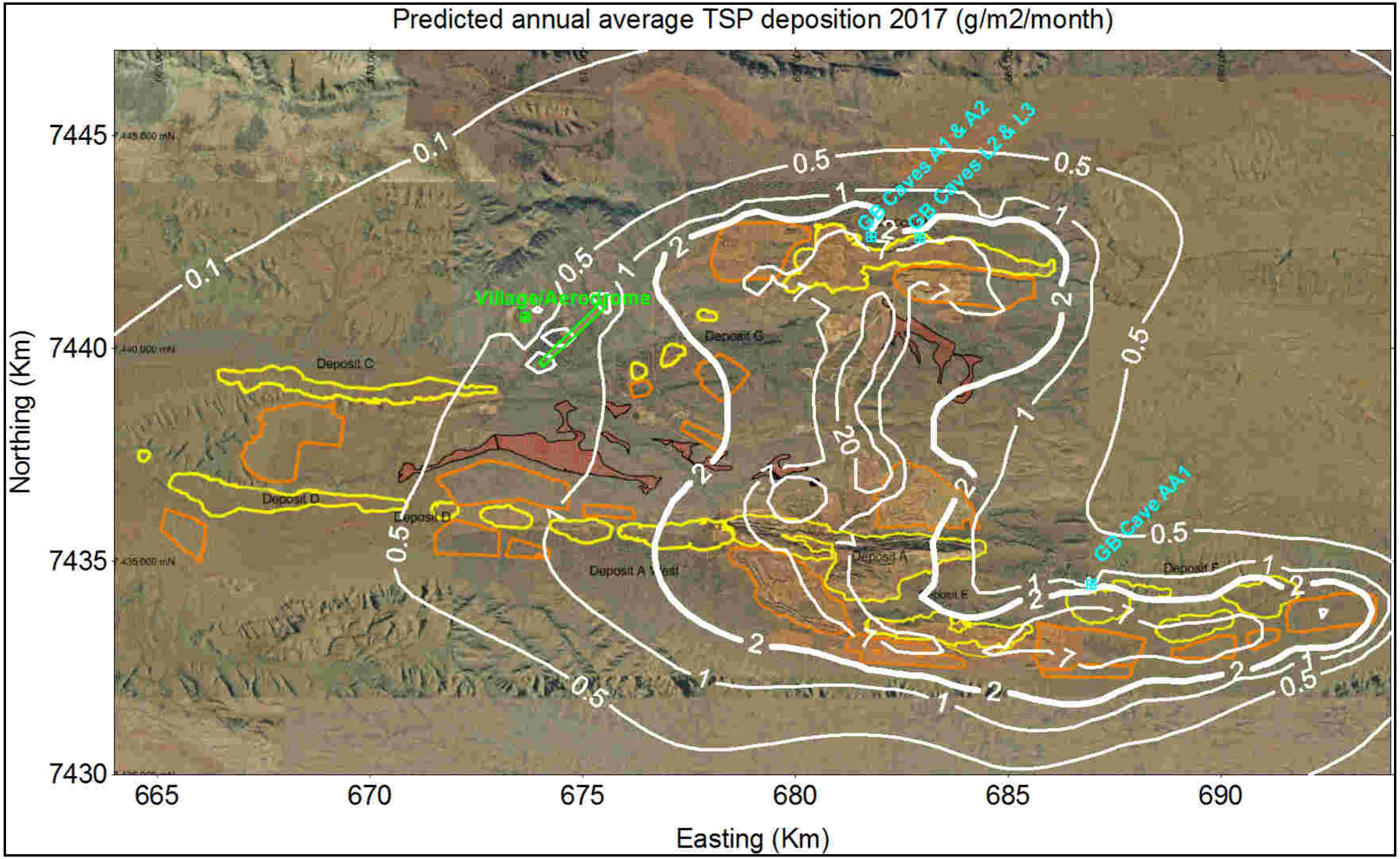

Figure 25 Predicted annual average dust deposition from West Angelas operations at 2017

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

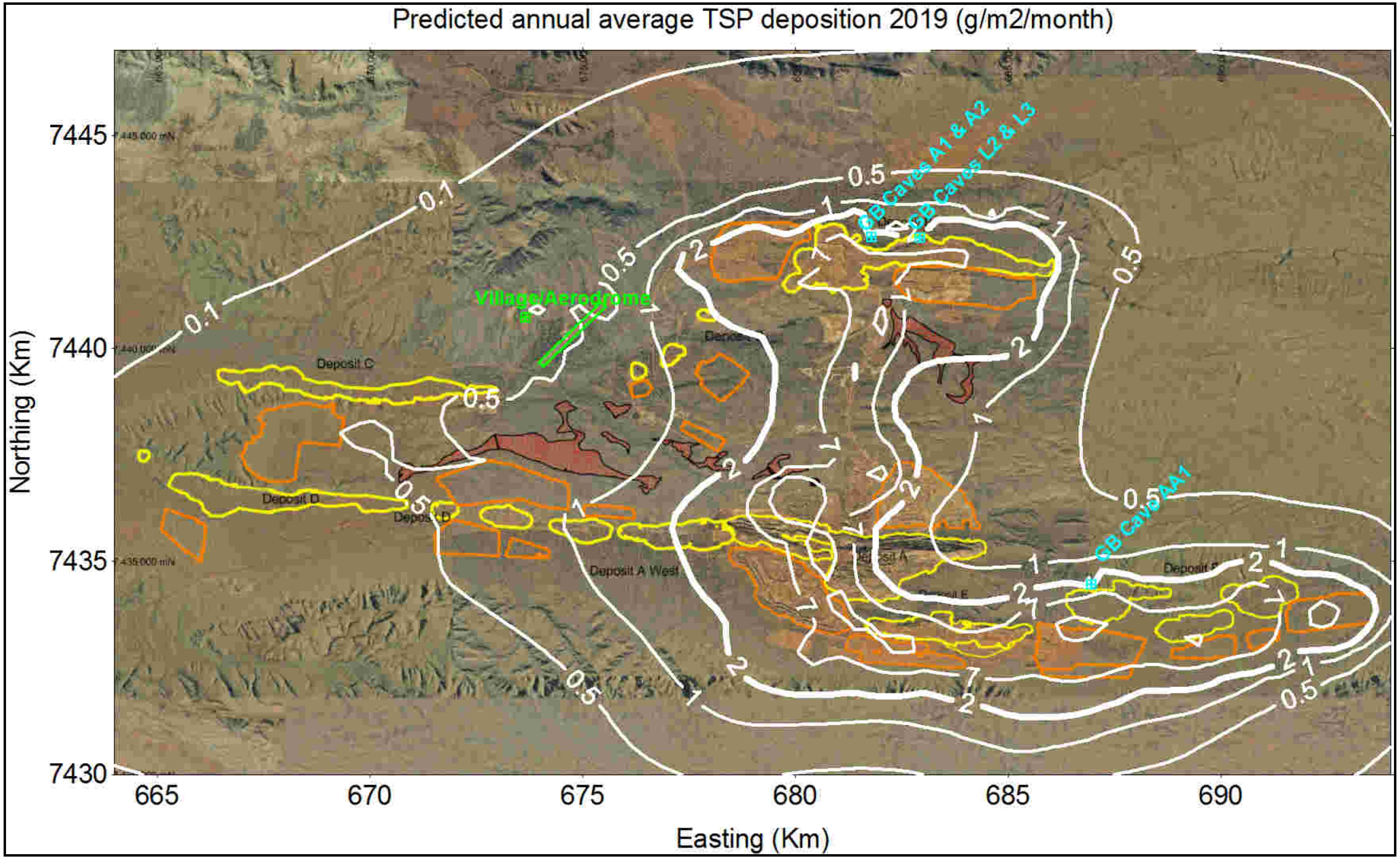

Figure 26 Predicted annual average dust deposition from West Angelas operations at 2019

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

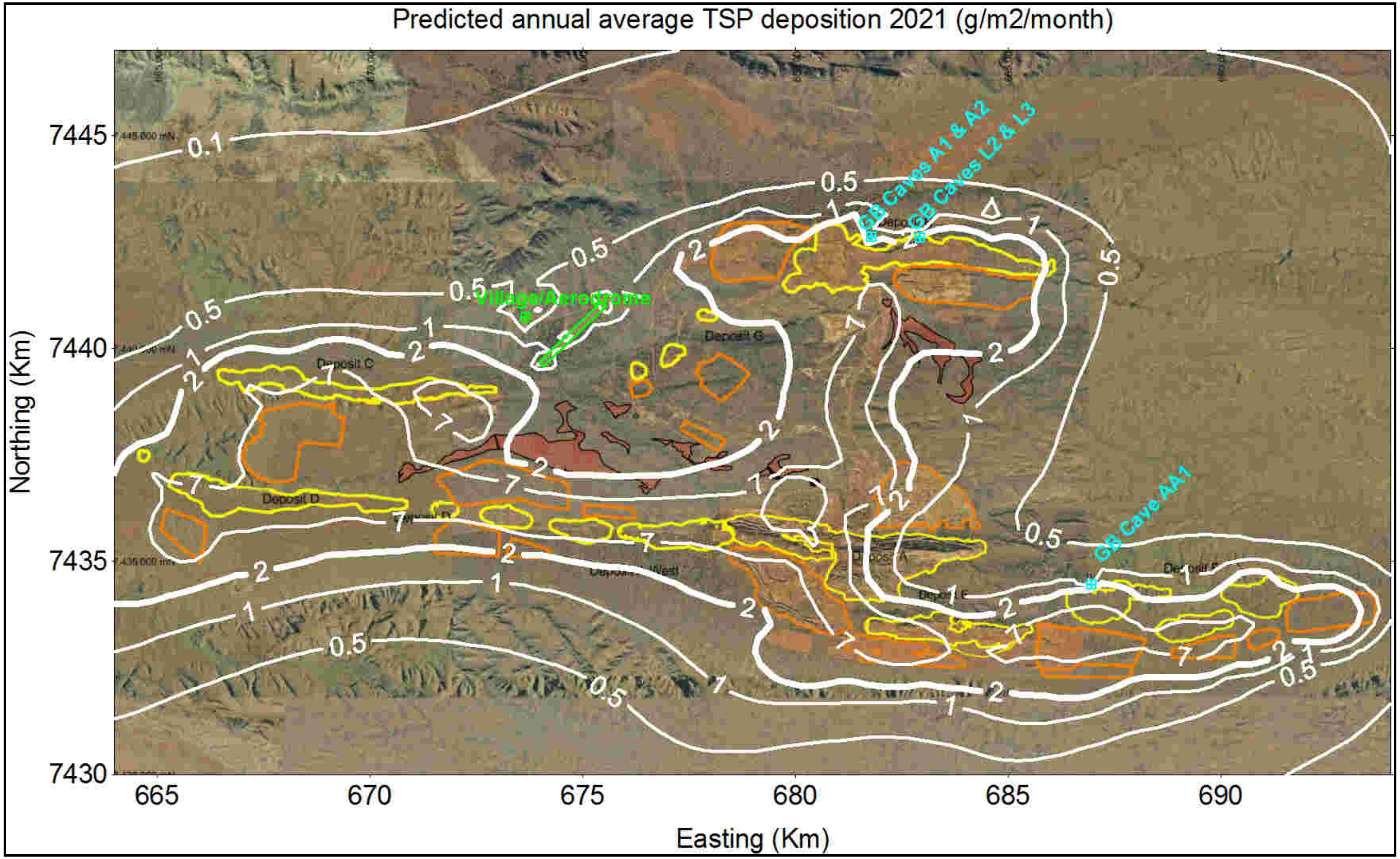

Figure 27 Predicted annual average dust deposition from West Angelas operations at 2021

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

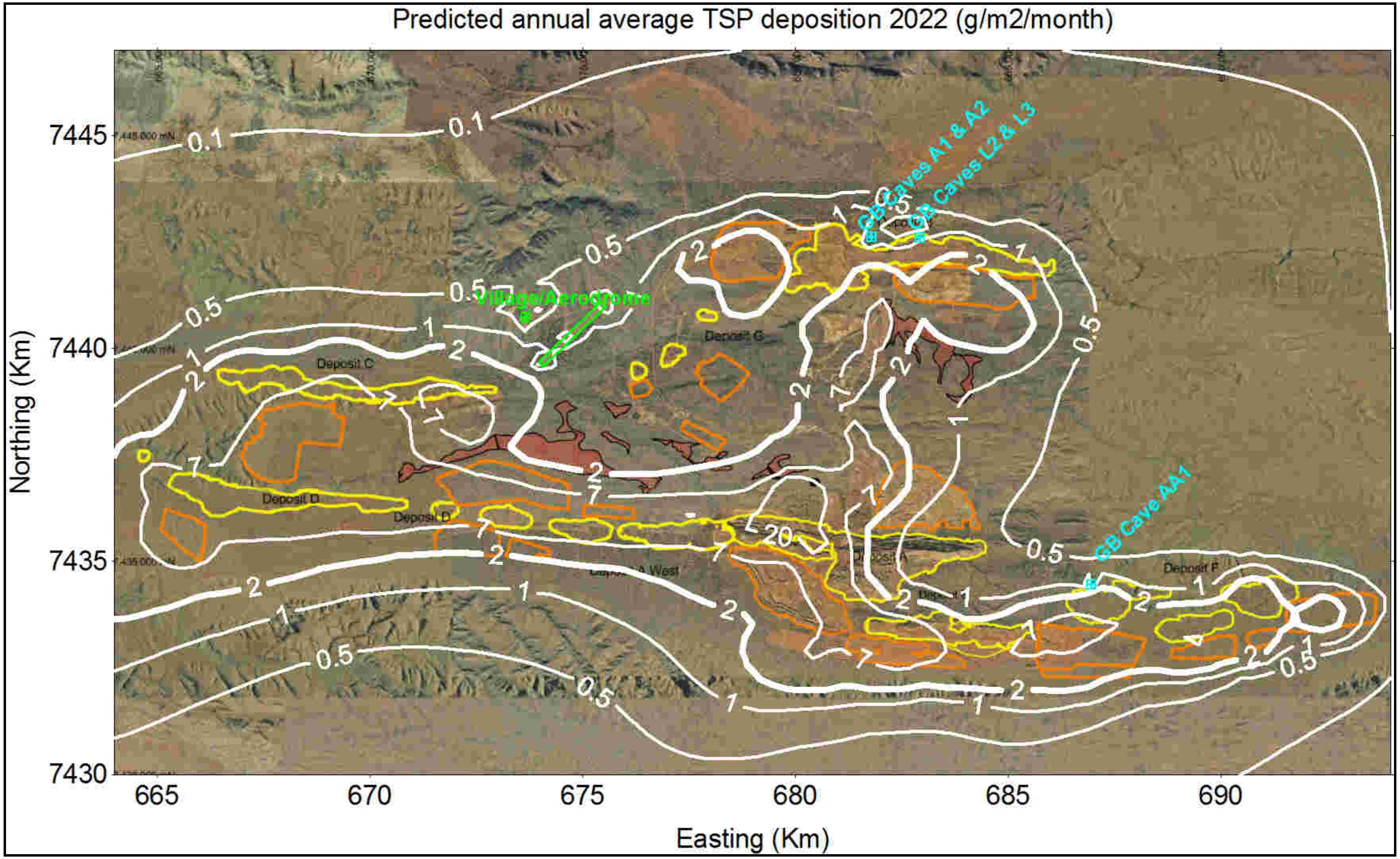

Figure 28 Predicted annual average dust deposition from West Angelas operations at 2022

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

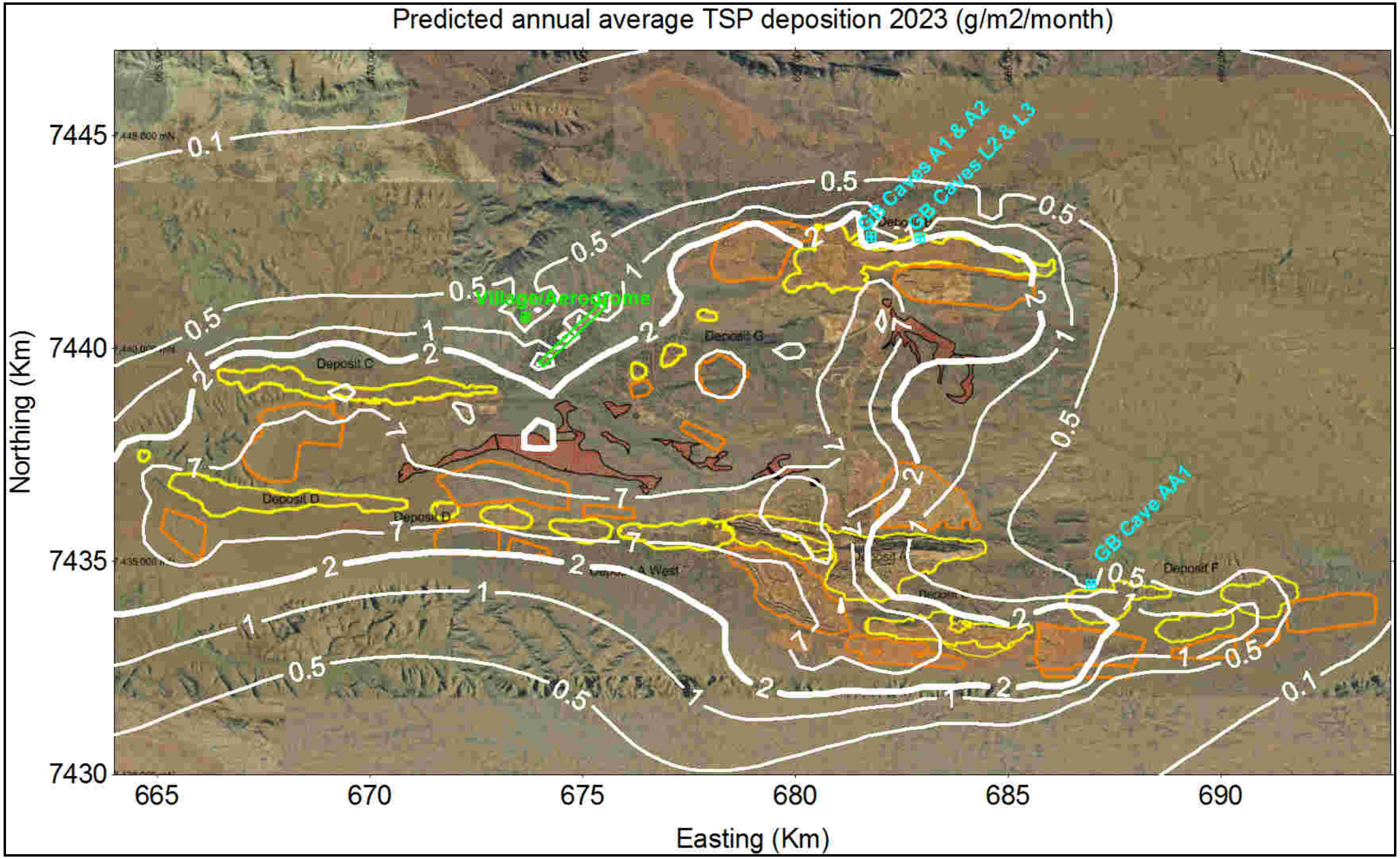

Figure 29 Predicted annual average dust deposition from West Angelas operations at 2023

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

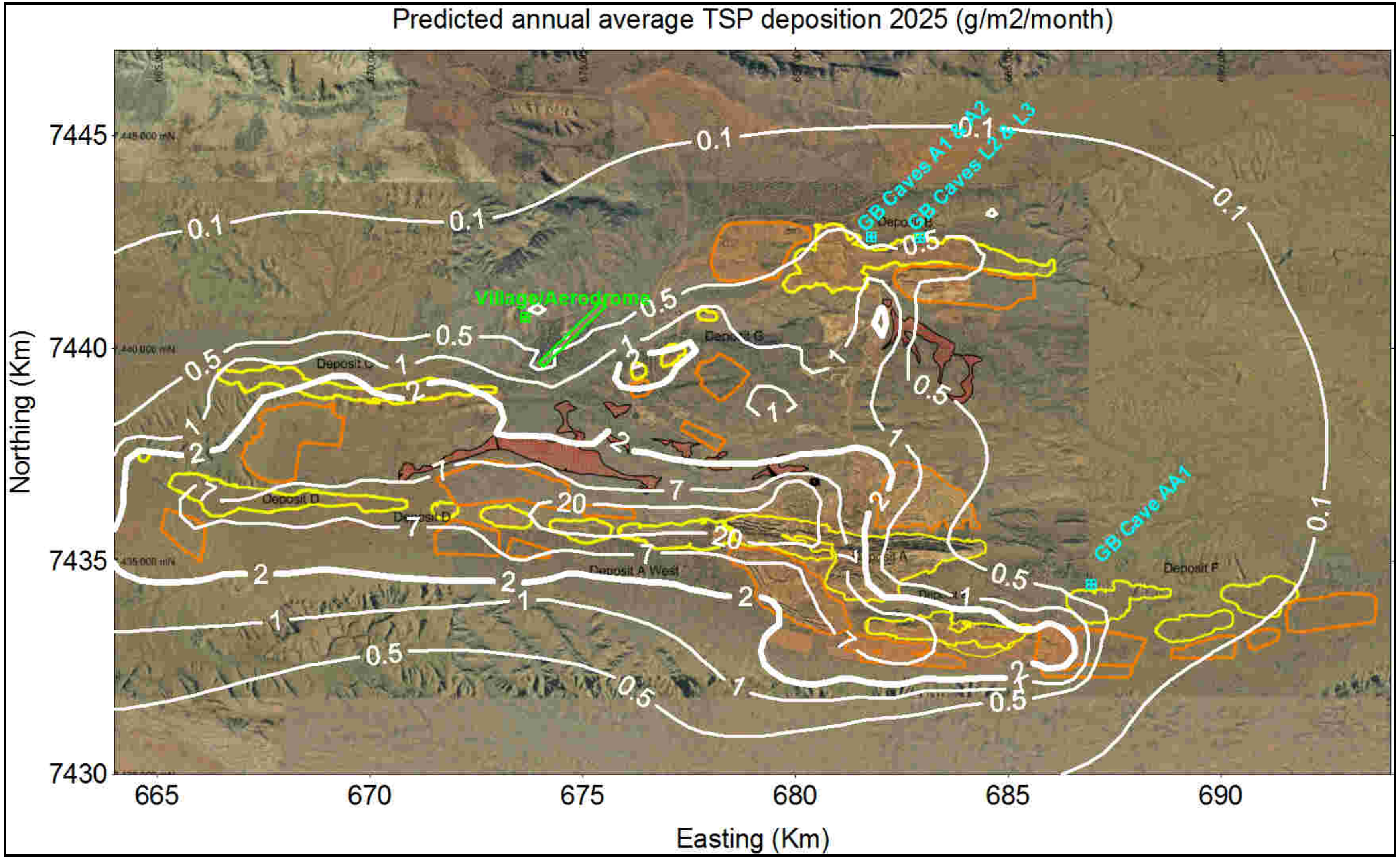

Figure 30 Predicted annual average dust deposition from West Angelas operations at 2025

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

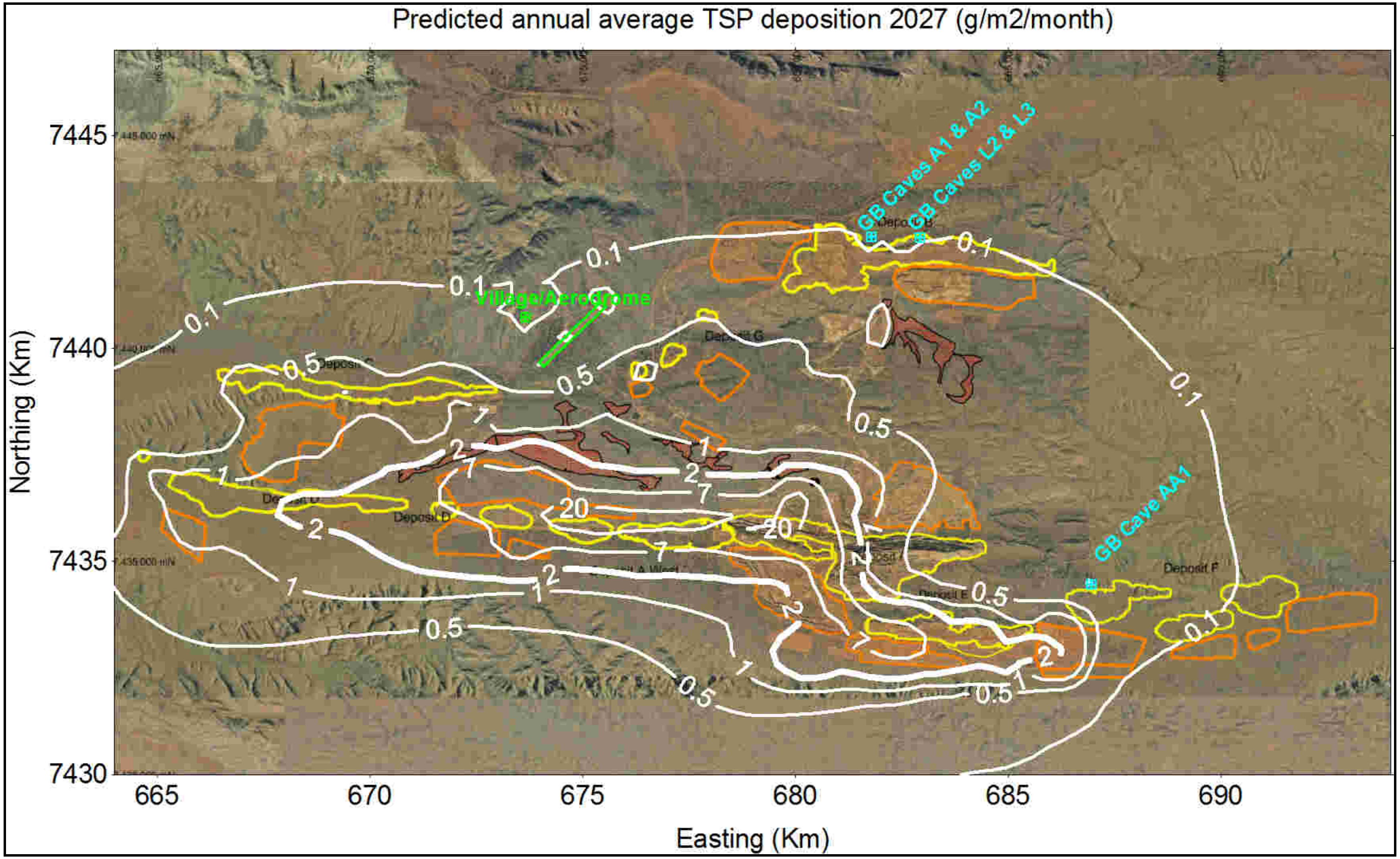

Figure 31 Predicted annual average dust deposition from West Angelas operations at 2027

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

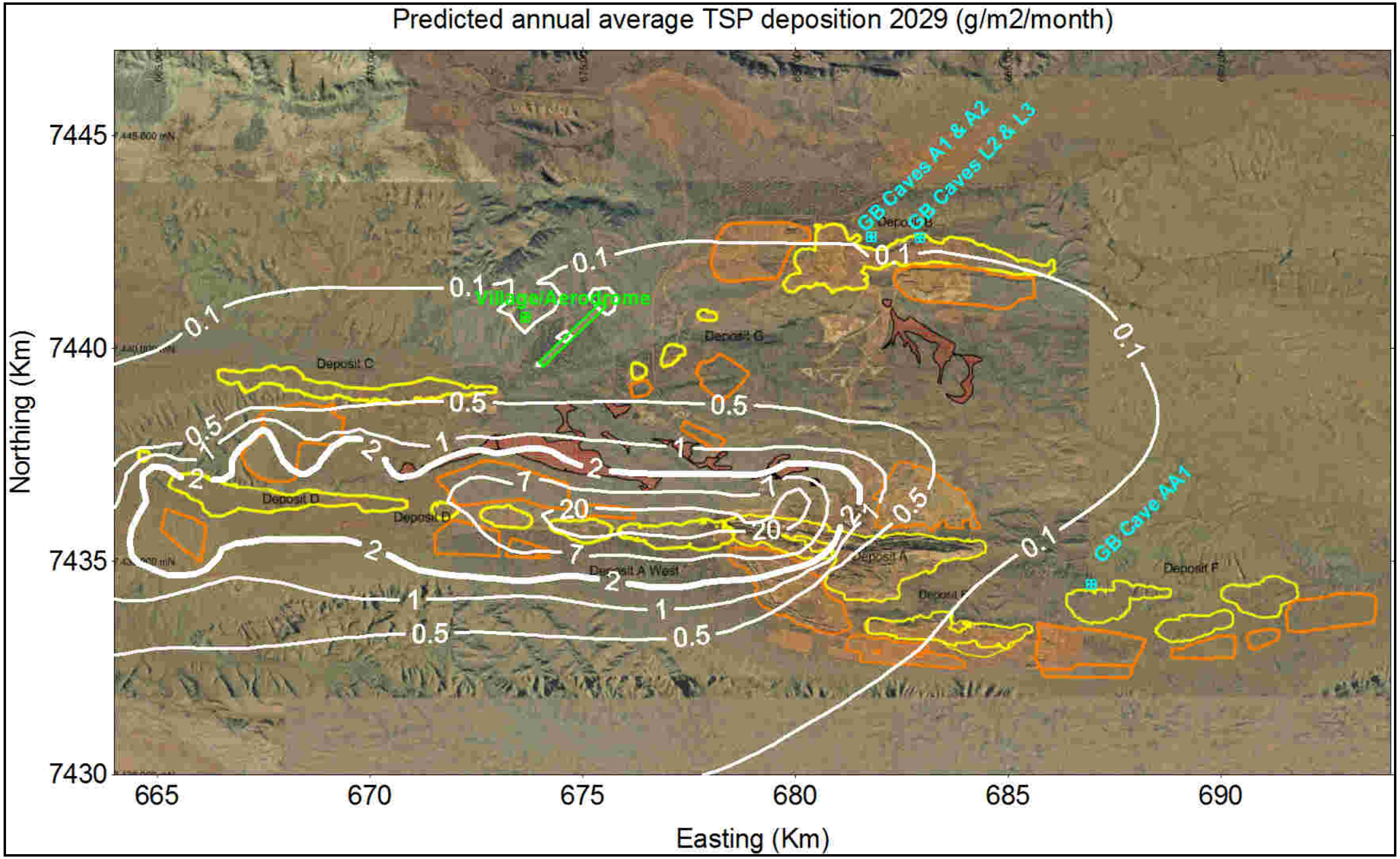

Figure 32 Predicted annual average dust deposition from West Angelas operations at 2029

Notes: 1) Criteria of 2 g/m^2/month (Village/Aerodrome) additional, shown in bold.

9. SUMMARY AND RECOMMENDATIONS

This report describes a dust dispersion modelling study of predicted dust impacts arising from the West Angelas Deposits A, B, E, F, Awest, C, D and G from 2017 to 2031. 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 nearest populated area in the region is the existing West Angelas village, which is approximately 1.4 kms from Deposit C and 2.4 kms from Deposit G. Another dust-sensitive facility is the aerodrome, which is approximately 1.3 kms from Deposit G.

The US EPA's CALPUFF Version 6 dispersion model was used to predict ambient concentrations around the operation arising from dust emissions. Aspects included in the modelling included terrain effects on dispersion and deposition of dust particles. Meteorological data for the modelling was derived primarily from on-site measurements.

Dust emissions estimates were based on those reported through the NPI. These estimates carry uncertainties, with dust emissions from haul roads being particularly uncertain, as these depend on the level of control applied in practice.

Based on the above approach:

- the maximum predicted dust levels for all parameters at the Village are at 2022; and
- the maximum predicted dust levels at the most impacted area of the aerodrome are also at 2022.

The reasons the highest dust levels occur at the Village and aerodrome during 2022 are:

- over the year 2022, the TMM, and therefore dust emissions, peak for Deposit C;
- the peak annual TMM from Deposit C is reasonably high (approximately 57 Mtpa);
- Deposit C is relatively close to the Village and aerodrome (approximately 1 -2 kms to the west-south-west);
- winds from the west-south-west, are reasonably frequent at approximately 7 – 8% of the time. Furthermore, winds from the due west, which would also cause dust from the western end of Deposit C to impact the Village and aerodrome, are even more frequent at approximately 11% of the time; and
- the dimensions of Deposit C are largest along the east-west axis, which means that dust emissions result in a narrow, more concentrated plume for winds near westerly.

It is therefore recommended that a dust monitor be installed between the Village and south-west end of the aerodrome during, or prior to, 2019. The installation of a monitor would invoke the application of the on-site IEMS Procedure – "Methodology and Instructions for Estimating Site Contributions to E-Sampler Dust Levels" for purposes of managing potential impacts at the Village. This Procedure describes the methodology used on-site to estimate individual site percentage contributions to 24-hour PM10 levels, as measured from dust monitoring units (E-Samplers) located at, or near, sensitive receptors nearest to a mining operation. An investigation is undertaken into the causes of any exceedence of the internal 24 hour PM10 criteria of 70 $\mu g/m^3$. This then provides a platform for continuously identifying and rectifying the causes of circumstances that lead to excessive dust levels so that the criterion concentration of 70 $\mu g/m^3$ can be limited to less than 11 times per year, as stipulated by the RTIO Cleaner Air Management Plan. The modelling has included conservative estimates for dust control from hauls roads, hence it is anticipated that improving dust control from the Deposit C hauls roads will be the most effective measure to reduce dust levels at the Village and aerodrome if required. Aerodrome Management Services (AMS) is assisting RTIO in aerodrome operations in relation to potential dust impacts.

In relation to the ghost bat caves:

- the maximum predicted dust levels at the ghost bat caves A1 and A2 are at 2017 after which they decrease;
- the maximum predicted dust levels at the ghost bat caves L2 and L3 are at 2017 after which they decrease; and
- the maximum predicted dust levels at the ghost bat caves AA1 are at 2019 after which they decrease.

The dust impacts at the ghost bat caves are simply coincidental to the year that the highest TMM occurs from the adjacent deposit.

The 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, RTIO have Blast Management Plans in place for Deposits E and B, and further plans will be developed specific to each deposit (i.e. Deposit F) as required. The Management Plans cover aspects such as monitoring, blast prediction and utilisation of sonic fencing for protection against noise and dust from blasting. As Deposit B and Deposit E fauna and heritage sites are currently being adequately managed under existing regulatory requirements, it is anticipated that Deposit F fauna habitat will follow the same management principles.

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11. GLOSSARY

Abbreviation	Definition
µg/m^3	micrograms per cubic metre of air.
µm	microns or micrometers.
BoM	Bureau of Meteorology.
CALPUFF	CALifornian PUFF model
DEC	Department of Environment and Conservation
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 dated 26 June 1998.
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 Brief description of TAPM model

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research. Briefly, TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components, eliminating the need to have site-specific meteorological observations. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

TAPM incorporates the following databases for input to its computations:

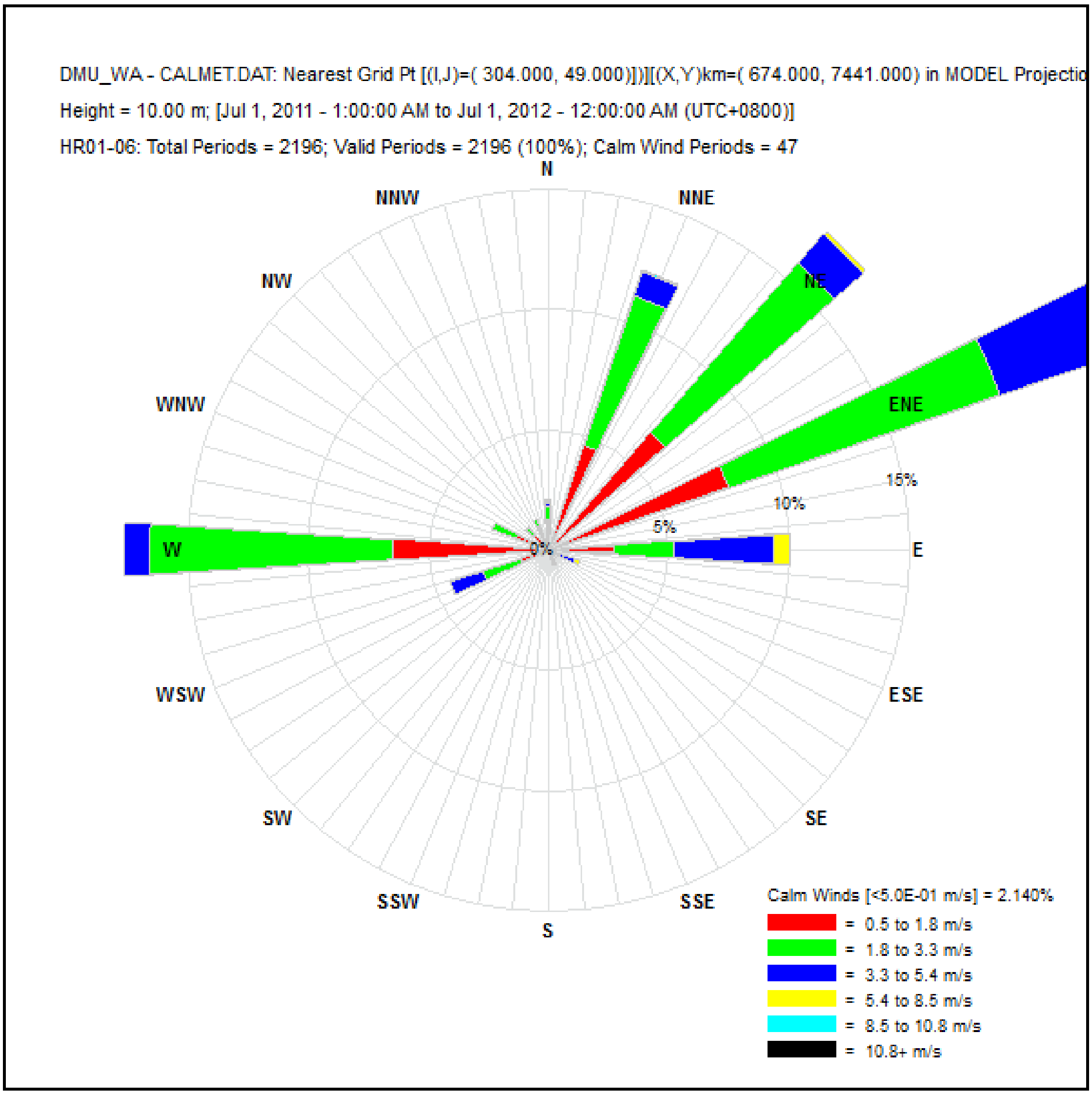
- Gridded database of terrain heights on a longitude/latitude grid of 30 second grid spacing, (approximately 1 km). This default dataset was supplemented by finer resolution data at 90m spacing for this study.
- Australian vegetation and soil type data at 3 minute grid spacing, (approximately 5 km).
- Rand's global long term monthly mean sea-surface temperatures on a longitude/latitude grid at 1 degree grid spacing, (approximately 100 km).
- Six-hourly synoptic scale analyses on a longitude/latitude grid at 0.75-degree grid spacing, (approximately 75 km), derived from the LAPS analysis data from the Bureau of Meteorology.
- Prognostically derived surface and upper air meteorological data (from TAPM) are increasingly being used in dispersion modelling where no observational meteorological data exists or where the network is sparse. This method of coupling derived meteorological with observational data has been used in modelling the dispersion of pollutants for this study.

The TAPM setups for this study were:

- grid domain of 130 x 76 cells nested at 30 km, 10 km and 3 km;
- initial soil moistures were set at 0.05 kg/kg for all months except for January-February (highest rainfall months) where 0.10 kg/kg was used – these choices were based on dispersion modelling in the Pilbara coast (Physick and Blockley 2001) where 0.05 kg/kg was used for all months.

All other settings were defaults including no incorporation of any surface wind observations.

Appendix 2 Wind roses – diurnal and seasonal



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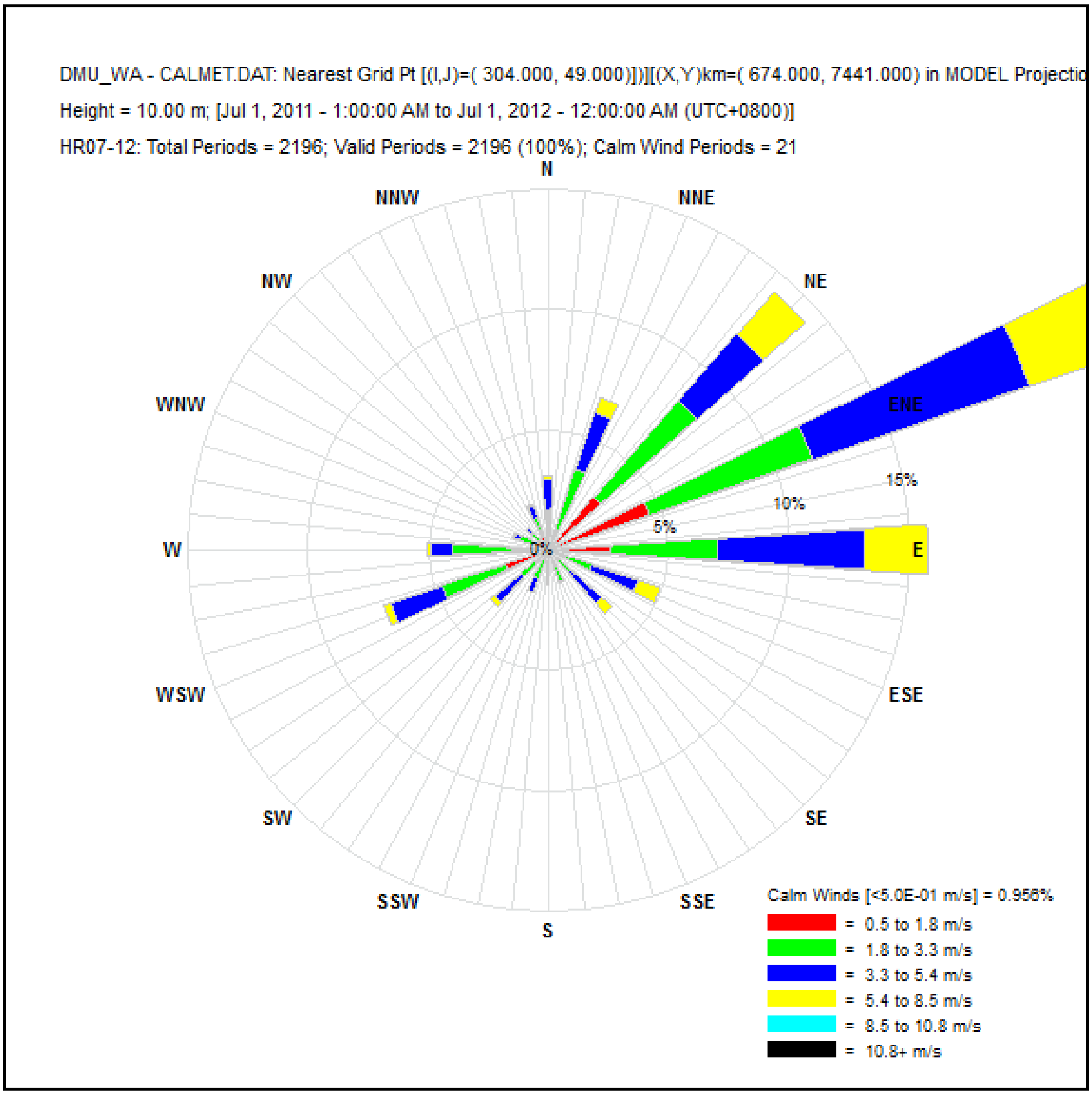
HR01-06: Total Periods = 2196; Valid Periods = 2196 (100%); Calm Wind Periods = 47
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.140%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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NNE
NE
ENE
E
ESE
SE
SSE
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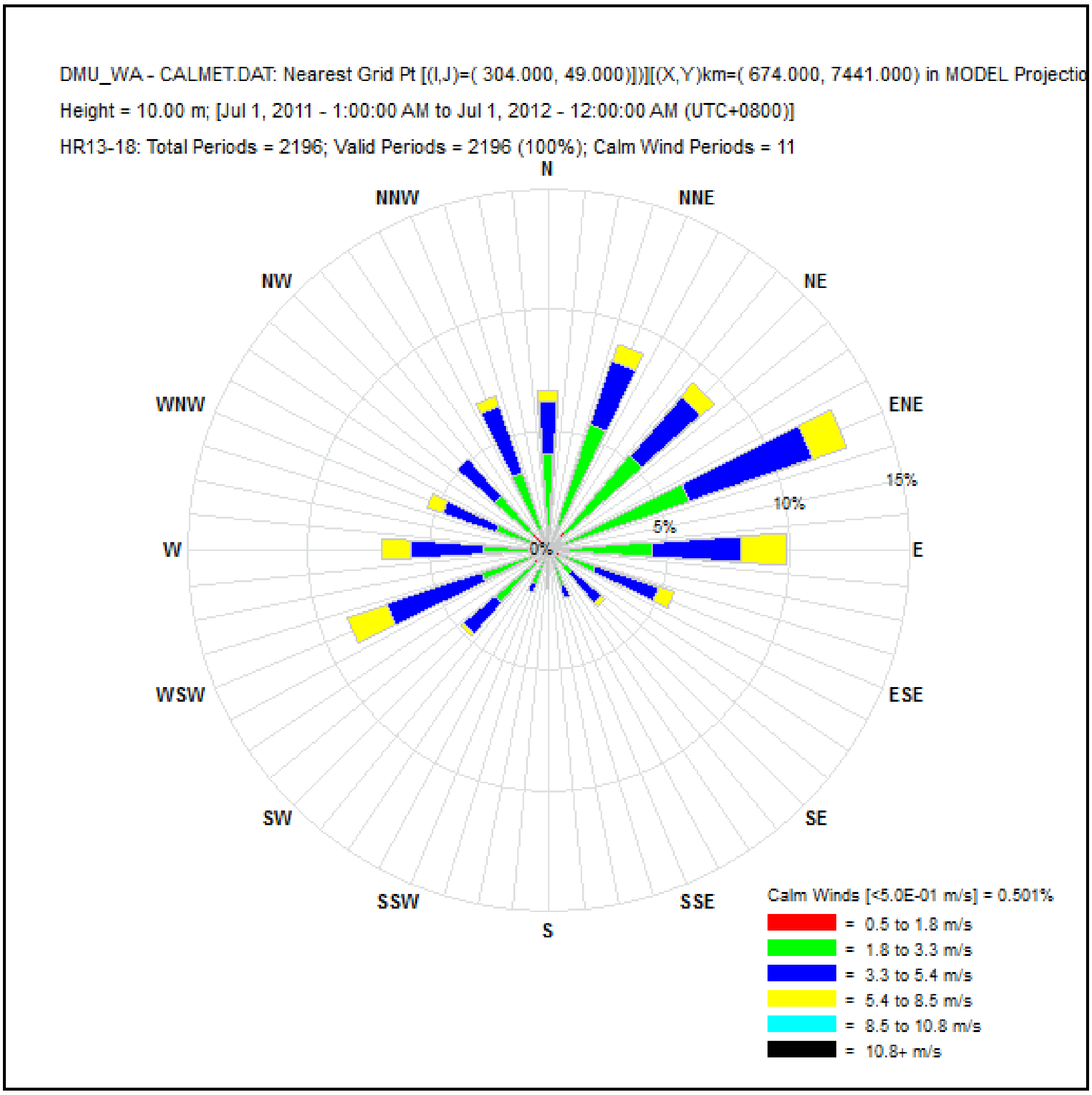
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 0.956%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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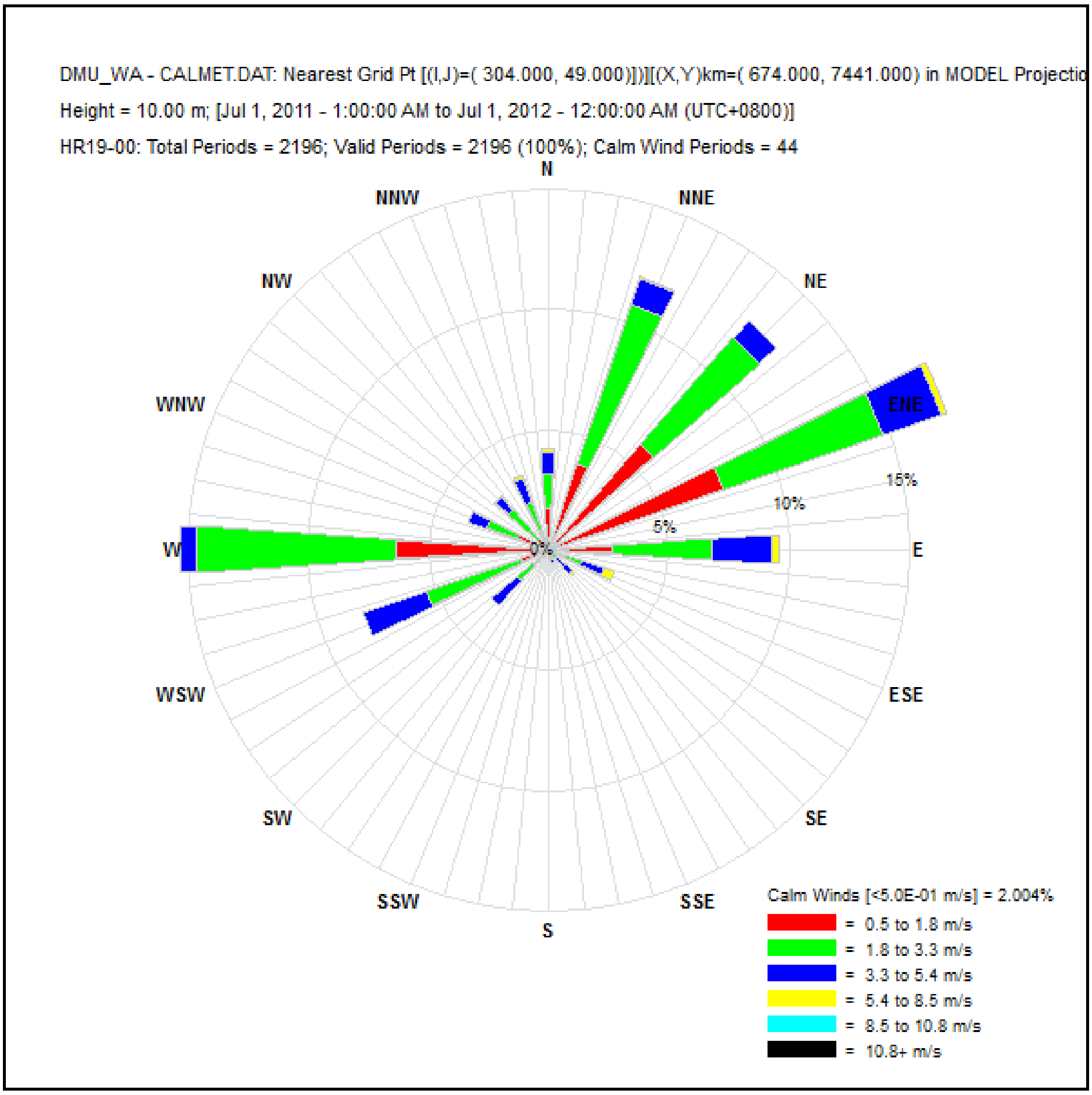
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 0.501%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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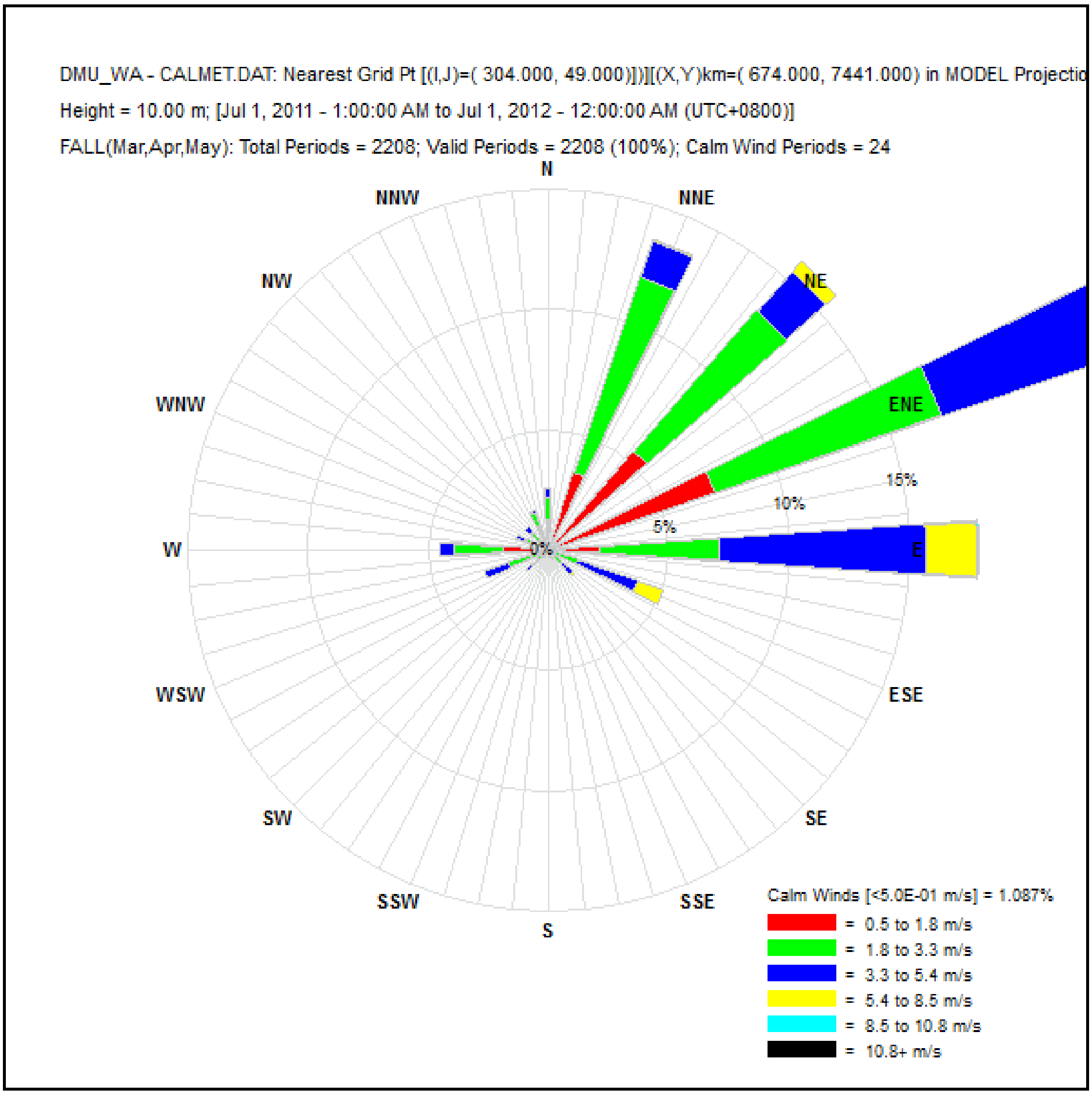
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.004%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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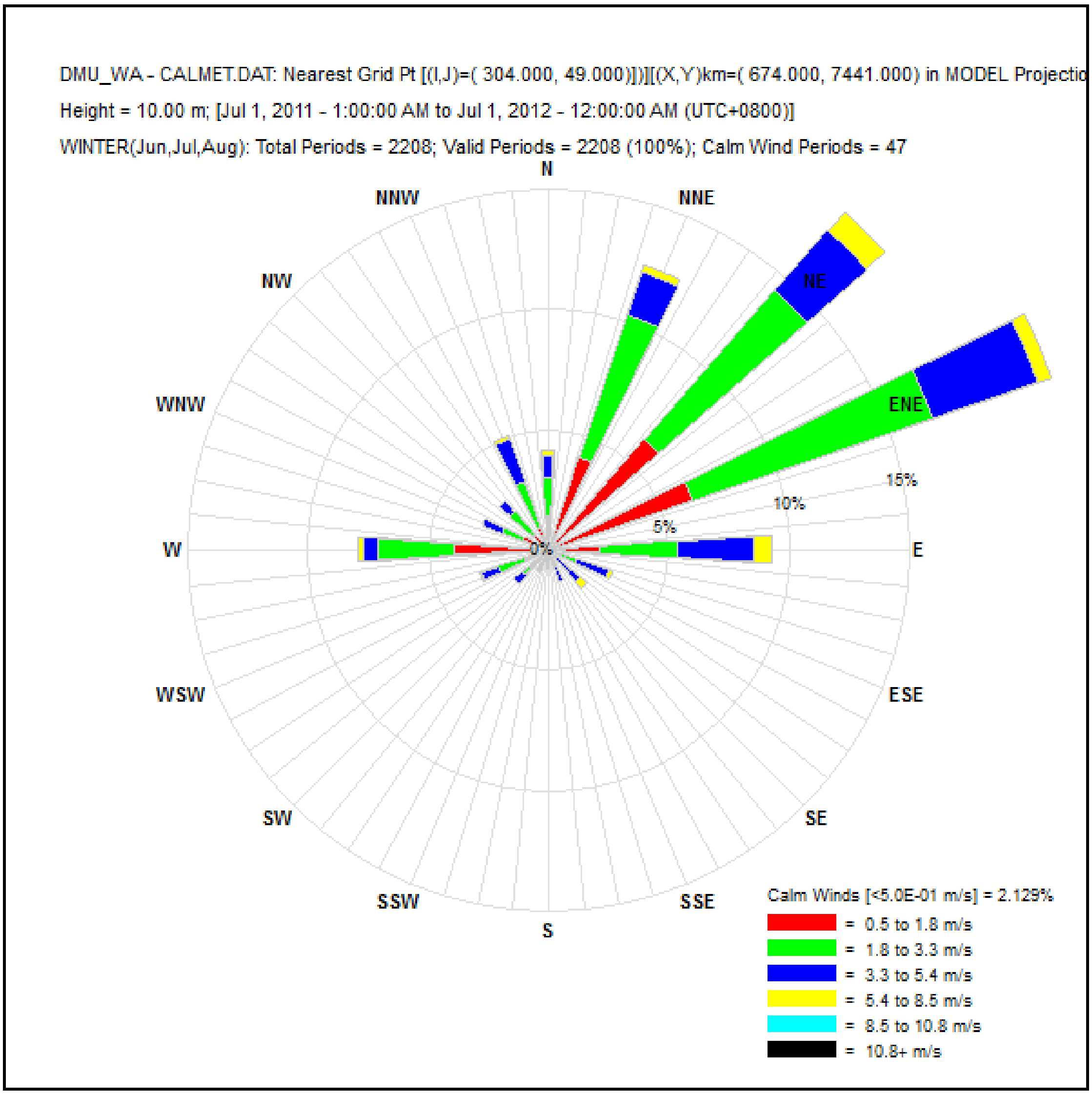
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 1.087%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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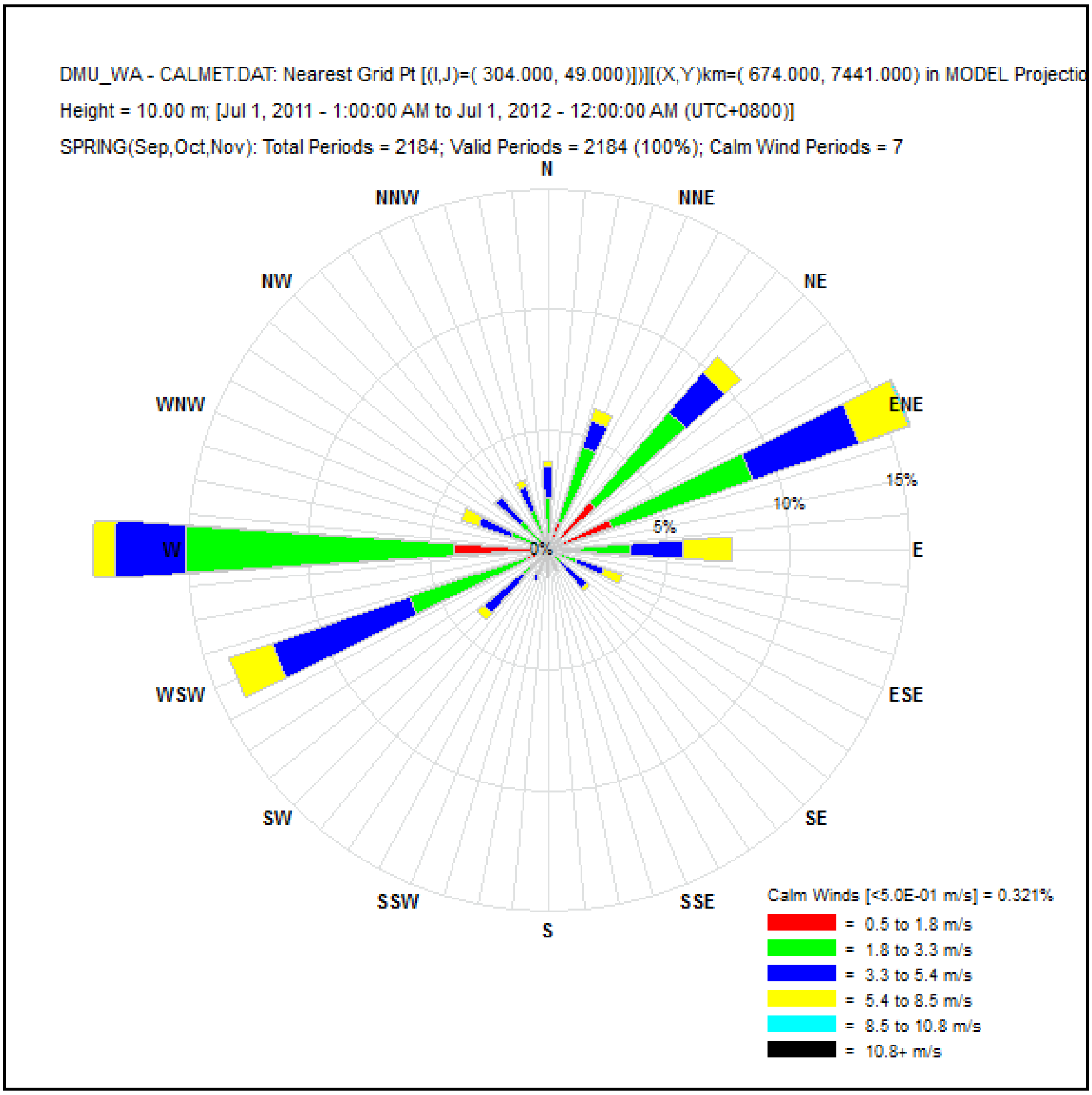
WINTER(Jun,Jul,Aug): Total Periods = 2208; Valid Periods = 2208 (100%); Calm Wind Periods = 47
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.129%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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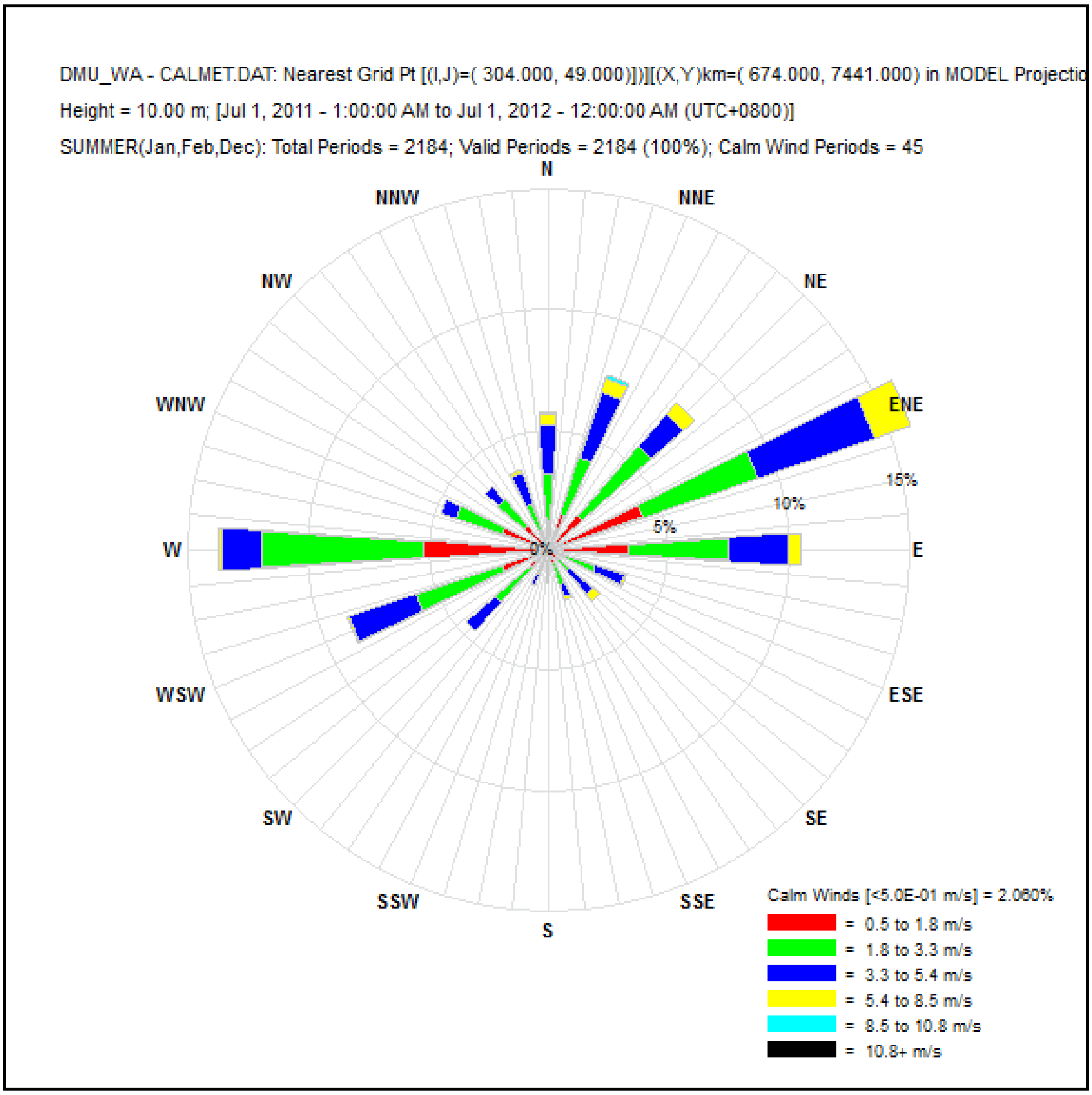
SPRING(Sep,Oct,Nov): Total Periods = 2184; Valid Periods = 2184 (100%); Calm Wind Periods = 7
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 0.321%
= 0.5 to 1.8 m/s
= 1.8 to 3.3 m/s
= 3.3 to 5.4 m/s
= 5.4 to 8.5 m/s
= 8.5 to 10.8 m/s
= 10.8+ m/s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N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
0%
5%
10%
15%
Calm Winds [<5.0E-01 m/s] = 2.060%
= 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 3 Dust emissions from haul roads

A major uncertainty in the dust modelling results in this study is the dust emissions from the haul roads outside the pits, as reasonable variations in the assumptions used can lead to very high (order of magnitude) changes in the calculated emissions. The issues are discussed below.

NPI Mining Handbook

The NPI Mining Handbook (2012) uses the AP-42 Chapter 13.2.2 (Nov 2006) equation for wheel generated dust as below:

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

Where:

k_{TSP}	= 4.9 for total suspended particles
$k_{PM_{10}}$	= 1.5 for PM_{10}
$s_{(\%)}$	= silt content of material (%)
$W_{(t)}$	= vehicle mass (t)
a_{TSP}	= 0.7 (empirical constant)
$a_{PM_{10}}$	= 0.9 (empirical constant)
b	= 0.45 (empirical constant)

The NPI Handbook then gives a default uncontrolled emissions factor EF PM10 of 1.25 (kg/VKT) based on W(t) = 48 tonnes; s(%) = 10 . This is often used as the basis for estimating dust emissions from haul trucks modelling despite the underlying parameterisations being inconsistent – most obviously, vehicle mass. In the version before this (up to 2011), a different equation was used which resulted in the default emission rate of 0.96 kg/VKT.

It is noteworthy that the above equation:

- does not include a vehicle speed parameter – which is well known to be proportional to dust emissions; and
- does not take into account rainfall periods, which would obviously reduce dust emissions to negligible during rainfall and substantially after rainfall up to the time the road surface has dried out.

Reduction in emissions from controls

For control, the NPI provides three levels of control of:

- 50% for level 1 watering (up to 2 litres/m2/hr);
- 75% for level 2 watering (> 2 litres/m2/hr); and

- 100% for sealed or salt-encrusted roads[9].

The two levels of watering controls were based on calculations undertaken for typical Hunter Valley haul road usage in the 1990s and evaporation using the equation of Cowherd et al (1988) where:

$$C = 100 - (0.8\ P\ d\ t)/ I$$

Where

- C = average control efficiency percent (%);
- P = potential average daytime evaporation rate mm/hr based on a maximum extreme hourly evaporation rate of 2 mm/hr for a hot windy day;
- d = average hourly traffic rate of 30 truck passes per hour;
- I = application intensity of 1 and 2 L/m2/hr; and
- t = time between applications of 1 hour.

Therefore, the default recommended values are just two discrete points on a continuum. With higher water application rates, higher controls could occur.

Since this earlier work, the USEPA have revised their formulation based the control on the ratio of the controlled moisture content to the uncontrolled moisture content (see Figure 33).

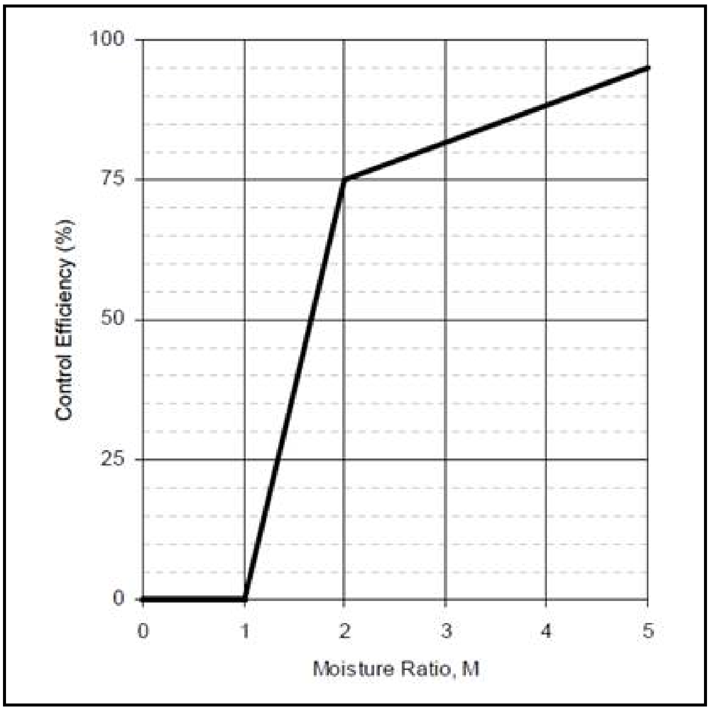

Figure 33 Watering control effectiveness for unpaved travel services from AP42 13.2.2

[9] The control sealed or salt-encrusted road of 100% is considered incorrect (added only to this 2012 version by the editors) as paved roads do emit airborne particulate as illustrated by the USEPA providing a paved road emissions factor.

By increasing the surface moisture content of the road by two, a 75% control is achieved. After this the increase in control decreases with a 95% control achieved by increasing the moisture 5 times. The uncontrolled moisture content depends on the surface and may vary from typically 0.5 to 3%.

Note the WRAPAIR emission factor handbook recommends the following applicable factors (Countess, 2006);

- limiting maximum speed on unpaved roads to 25 miles per hour achieved 44% reduction;
- implementing watering twice a day for industrial unpaved road achieved 55% reduction; and
- paving unpaved roads and unpaved parking areas achieved 99% reduction.

Monitoring of haul truck dust at Dampier port operations (2004)

This control efficiency agrees with monitoring results by Environmental Alliances (2007). The PM10 emissions from haul trucks during bulking at Dampier port used for dust modelling are shown in Table 15.

Table 15 Haul truck emissions factors

Surface condition	Control (%)	PM10 emissions factors for 125 t haul truck (kg/VKT)
very wet	90	0.15 [(a)]
wet	75	0.40
medium	50	0.80
very dry	0	3.5

[(a)] Wind speed during monitoring 4.8 m/s at 10m; Haul truck speed 25 km/hr. The actual measured emission factor was 0.085 kg/VKT on a road surface wet enough immediately after watering to cause the haul truck to slide around corners and being frequently watered. This was assumed to represent 95% control. Note that the measurements also include dust emissions from the vehicle itself, which is correlated with vehicle speed.

Reference:

Environmental Alliances, 2007, "Dust Dispersion Modelling for Pilbara Iron Dampier Port Expansion to 145 Mtpa (Phase B) – Development of Dust Emissions Estimates", Version 7b (J5104), Prepared for Sinclair Knight Merz, May 2007. Source data in Environmental Alliances, 2004, "Hamersley Iron – Dampier Port Operations – Compliance with Dust Management Conditions in Ministerial Statement of Approval for 95 Mtpa Expansion", (J4048), August 2004.

These emissions factors were developed from a combination of direct monitoring for the "very wet conditions" plus the monitoring of other vehicles of varying masses and road wetness conditions, then using the AP-42 equations of the time to adjust for mass, speed and road wetness in an effort to produce a consistent dust emissions factors for such parameterisations. The emissions factors ultimately used were considered reasonable of the basis of good results from modelling verification studies using ambient PM10 monitoring.

Emissions factor used for this study

For this study, the following assumptions were used:

- average haul truck mass: 355 t;
- default NPI silt (10%) and moisture (2%) values;

- dust control from road watering: 75% (from road watering of 2 $l/m^2/hr$);
- average speed outside pit areas: 50 km/hr;
- activity ratio (i.e. fraction of total operating time travelling at above speed): 0.2.

The resulting PM10 emissions factor is 0.76 kg/VKT.

Appendix 4 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 34. 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 34 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.

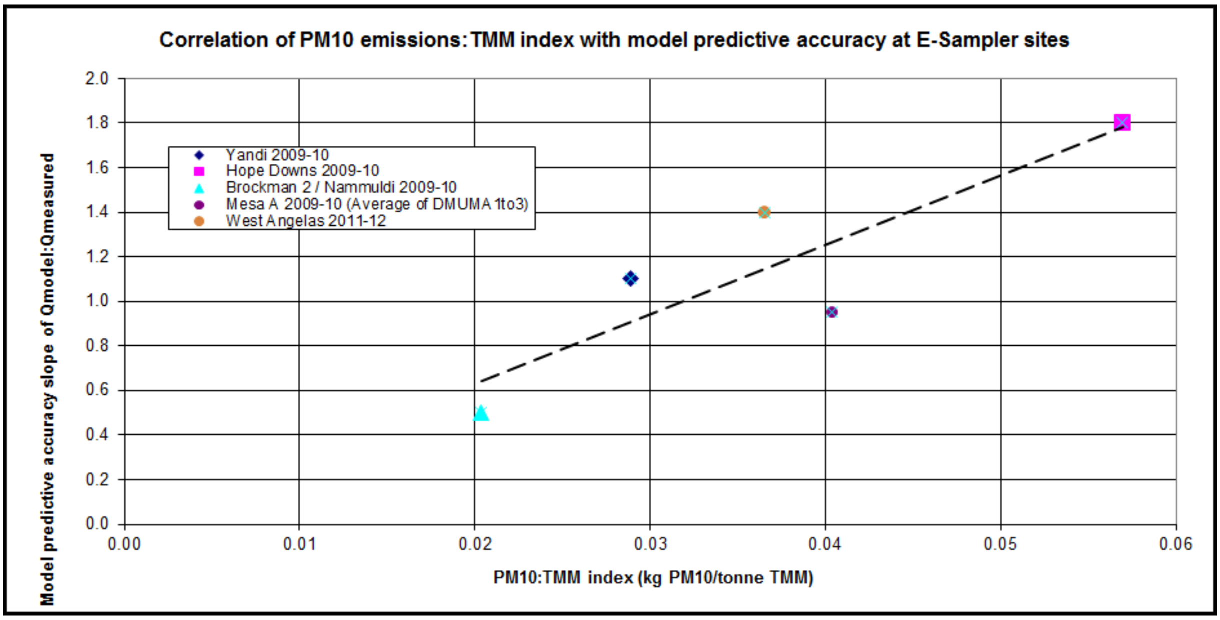

Figure 34 Relationship between emissions and modelling predictive accuracy for previous RTIO minesite validation studies

The PM10:TMM index for the West Angelas 2013-14 operation was 0.028 kg/tonne. It is therefore considered that there is a risk of under-predicting dust levels. Hence the NPI-calculated emissions were increased by 1.25 (i.e. 0.035/0.028).

Appendix 5 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:

For R > 0

$$SW_{1\text{-hour}} = SW_{1\text{-hour,previous}} + R - (1.5 \times Evap) \quad \text{for } R > 1.5Evap \qquad \textbf{Equation 3}$$

$$SW_{1\text{-hour}} = SW_{1\text{-hour,previous}} + Evap + (R - Evap)/1.5 \quad \text{for } Evap < R \leq 1.5Evap \qquad \textbf{Equation 4}$$

$$SW_{1\text{-hour}} = SW_{1\text{-hour,previous}} + R - Evap \quad \text{for } R \leq Evap \qquad \textbf{Equation 5}$$

For R = 0

$SW_{1\text{-hour}} = SW_{1\text{-hour,previous}} – Evap$ **Equation 6**

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 SW1-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 6 CALPUFF model set-up parameters

Note: File is for source ID: M:\L5103\Cal\Tilt2017\Puf\AREPM75.INP (PM7.5 fraction for 2017 model run).

```
CALPUFF.INP     2.0             File version record
L5103 West Angelas - 1 Km Grid
File is: AREPM75.INP  Source is M:\...\PM75\AREWA000.SRC

---------------- Run title (3 lines) ------------------------------------------

                    CALPUFF MODEL CONTROL FILE
! PUFLST =M:\L5103\CAL\TILT2017\PUF\AREPM75.LST  !
! CONDAT =M:\L5103\CAL\TILT2017\PUF\AREPM75.CON     !
! DFDAT  =M:\L5103\CAL\TILT2017\PUF\AREPM75.DRY     !
! ARDAT  =M:\L5103\CAL\TILT2017\EMIS\PM75\AREWA000.SRC  !
! AUXEXT =AUX     !
! LCFILES = F !
! NMETDOM =   1   !
! NMETDAT =   6   !
! NPTDAT =   0   !
! NARDAT =   0   !
! NVOLDAT =   0   !
!END!
! METDAT1 = M:\L5103\CAL\MET\PILB1107.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1109.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1111.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1201.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1203.MET     !
! METDAT1 = M:\L5103\CAL\MET\PILB1205.MET     !
! METRUN =   0  !
! IBYR  =  2011  !
! IBMO  =  7  !
! IBDY  =  1  !
! IBHR  =  0  !
! IBMIN =  0  !
! IBSEC =  0  !
! IEYR  =  2012  !
! IEMO  =  6  !
! IEDY  =  30  !
! IEHR  =  0  !
! IEMIN =  0  !
! IESEC =  0  !
! ABTZ= UTC+0800 !
! NSECDT =  3600  !
! NSPEC =  1   !
! NSE =  0   !
! ITEST =  2   !
! MRESTART =  0   !
! NRESPD =  0   !
! METFM =  1   !
! MPRFFM =  1   !
! AVET = 60. !
! PGTIME = 10. !
! IOUTU =  1   !
! IOVERS =  2   !
!END!
! MGAUSS =  1   !
! MCTADJ =  3   !
! MCTSG =  0   !
! MSLUG =  0   !
! MTRANS =  1   !
! MTIP =  1  !
! MRISE =  1  !
! MBDW =   1  !
! MSHEAR =  1  !
! MSPLIT =  0  !
! MCHEM =  0   !
! MAQCHEM =  0   !
! MLWC =  1   !
! MWET =  1   !
! MDRY =  1   !
! MTILT =  1   !
! MDISP =  2   !
```

```
! MTURBVW =  3  !
! MDISP2 =  3  !
! MTAULY =  0  !
! MTAUADV =  0  !
! MCTURB =  1  !
! MROUGH =  0  !
! MPARTL =  1  !
! MPARTLBA =  0  !
! MTINV =  0  !
! MPDF =  0  !
! MSGTIBL = 0  !
! MBCON = 0  !
! MSOURCE = 0  !
! MFOG =  0   !
! MREG =  0   !
!END!
! CSPEC =       PM75_2 !
!       PM75_2  =         1,                 0,             2,                   0   !
!END!
! PMAP = UTM  !
! FEAST  = 0.000  !
! FNORTH = 0.000  !
! IUTMZN =  50   !
! UTMHEM = S  !
! RLAT0 = -20.6N  !
! RLON0 = -116.67W  !
! XLAT1 = -30N  !
! XLAT2 = -60N  !
! DATUM = WGS-84  !
! NX =  389   !
! NY =  227   !
! NZ =  6   !
! DGRIDKM = 1.0 !
! ZFACE = .0, 20.0, 80.0, 200.0, 380.0, 680.0, 1200.0 !
! XORIGKM = 370.5 !
! YORIGKM = 7392.5 !
! IBCOMP =  292   !
! JBCOMP =  38   !
! IECOMP =  324   !
! JECOMP =  55   !
! LSAMP = T !
! IBSAMP =  292   !
! JBSAMP =  38   !
! IESAMP =  324   !
! JESAMP =  55   !
! MESHDN =  2  !
!END!
!  ICON =  1   !
!  IDRY =  1   !
!  IWET =  0   !
!  IT2D =  0   !
!  IRHO =  0   !
!  IVIS =  0   !
! LCOMPRS = T !
!  IQAPLOT =  1   !
! IMFLX =  0  !
! IMBAL =  0  !
! INRISE =  0  !
! ICPRT =  1   !
! IDPRT =  1   !
! IWPRT =  0   !
! ICFRQ =  12   !
! IDFRQ =  12   !
! IWFRQ =  1   !
! IPRTU =  3   !
! IMESG =  2   !
!       PM75_2 =     1,           1,           1,           1,           0,           0,
0   !
! LDEBUG = F !
! IPFDEB =  1  !
! NPFDEB =  1  !
! NN1 =  1   !
! NN2 =  10  !
!END!
! NHILL =  0   !
! NCTREC =  0   !
```

```
! MHILL =  2   !
! XHILL2M = 1.0 !
! ZHILL2M = 1.0 !
! XCTDMKM = 0 !
! YCTDMKM = 0 !
! END !
!END!
!       PM75_2 =           7.5,                      .0   !
!END!
!  RCUTR = 30.0 !
!    RGR = 10.0 !
! REACTR = 8.0 !
!   NINT =  9  !
!   IVEG =  1   !
!END!
!       PM75_2 =         1.0E-04,             3.0E-05 !
!END!
! MOZ =  0   !
!  BCKO3 = 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
!
! MNH3 =  0   !
! MAVGNH3 =  1   !
!  BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
!
! RNITE1 = .2 !
! RNITE2 = 2.0 !
! RNITE3 = 2.0 !
! MH2O2 =  1   !
!  BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
!  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
!  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
!  VCNX   = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
!
! NDECAY =  0   !
!END!
! SYTDEP = 5.5E02 !
! MHFTSZ =  0   !
! JSUP =  5   !
! CONK1 = .01 !
! CONK2 = .1 !
! TBD = .5 !
! IURB1 =  10  !
! IURB2 =  19  !
! ILANDUIN =  70  !
! Z0IN = .05 !
! XLAIIN = .05 !
! ELEVIN = .0 !
! XLATIN = -20.67 !
! XLONIN = -116.72 !
! ANEMHT = 10.0 !
! ISIGMAV =  1  !
! IMIXCTDM =  0  !
! XMXLEN = 1.0 !
! XSAMLEN = 1.0 !
! MXNEW =  99   !
! MXSAM =  99   !
! NCOUNT =  2   !
! SYMIN = 1.0  !
! SZMIN = 1.0  !
! SZCAP_M = 5.0E06 !
! SVMIN = 0.400, 0.400, 0.400, 0.400, 0.400, 0.400, 0.370, 0.370, 0.370, 0.370, 0.370, 0.370!
! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016, 0.200, 0.120, 0.080, 0.060, 0.030, 0.016!
! CDIV = .0, .0 !
! NLUTIBL =  4  !
! WSCALM = .5 !
! XMAXZI = 3000.0 !
! XMINZI = 50.0 !
! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !
! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !
! PTG0 = 0.020,   0.035 !
!  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !
! SL2PF = 10.0 !
! NSPLIT =  3  !
!  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !
! ZISPLIT = 100.0 !
! ROLDMAX = 0.25 !
```

```
! NSPLITH =  5  !
! SYSPLITH = 1.0 !
! SHSPLITH = 2.0 !
! CNSPLITH = 1.0E-07 !
! EPSSLUG = 1.0E-04 !
! EPSAREA = 1.0E-06 !
! DSRISE = 1.0 !
! HTMINBC = 500.0 !
! RSAMPBC = 10.0 !
! MDEPBC =  1  !
!END!
!  NPT1 =  0  !
!  IPTU =   1  !
!  NSPT1 =  0  !
!  NPT2 =  0  !
!END!
!  NAR1 =  0   !
!  IARU =   1  !
!  NSAR1 =  0  !
!  NAR2 =  69   !
!END!
!  NLN2 =  0   !
! NLINES =  0  !
!  ILNU =   1  !
!  NSLN1 =  0  !
! MXNSEG =  7  !
! NLRISE =  6  !
! XL = .0 !
! HBL = .0 !
! WBL = .0 !
! WML = .0 !
! DXL = .0 !
! FPRIMEL = .0 !
!END!
!  NVL1 =  0   !
!  IVLU =   1  !
!  NSVL1 =  0  !
!  NVL2 =   0   !
!END!
!  NREC =  25   !
!END!
! X =   674.31604, 7441.08447,     725.000,       2.000!
! X =  673.660034, 7440.73047,     728.000,       2.000!
! X =     681.792,   7442.618,     740.000,       2.000!
! X =      681.78,    7442.62,     740.000,       2.000!
! X =     681.784,   7442.669,     740.000,       2.000!
! X =     681.792,   7442.618,     740.000,       2.000!
! X =      681.78,    7442.62,     740.000,       2.000!
! X =     682.876,   7442.598,     743.000,       2.000!
! X =     682.928,   7442.614,     743.000,       2.000!
! X =      681.78,    7442.62,     740.000,       2.000!
! X =     682.876,   7442.598,     743.000,       2.000!
! X =     684.534,   7443.153,     779.000,       2.000!
! X =     682.379,   7442.595,     743.000,       2.000!
! X =     682.899,   7442.582,     743.000,       2.000!
! X =     686.953,   7434.461,     810.000,       2.000!
! X =    675.4408,   7441.096,     715.000,       2.000!
! X =    675.5523,   7440.985,     715.000,       2.000!
! X =    674.0715,   7439.585,     701.000,       2.000!
! X =    673.9687,   7439.686,     700.000,       2.000!
! X =    674.5593,   7440.248,     701.000,       2.000!
! X =    674.5002,   7440.311,     701.000,       2.000!
! X =    673.6537,   7441.381,     728.000,       2.000!
! X =    673.9534,   7440.913,     728.000,       2.000!
! X =    673.6843,   7440.418,     700.000,       2.000!
! X =    673.1397,   7440.795,     728.000,       2.000!
```