Air Quality Report

Air Quality Assessment Report for the Eastern Leases Project

Prepared for

Hansen Bailey on behalf of South32 Pty Ltd

Prepared by

Katestone Environmental Pty Ltd

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Abbreviations, Units and Glossary

Unit	
$\mu g/m^3$	micrograms per cubic metre
°C	degrees Celsius
CO	Carbon monoxide
CO_2	Carbon dioxide
g/s	grams per second
km	kilometre
km/h	kilometres per hour
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
mg	milligram
t	tonnes
Mtpa	Million tonnes per annum
PM	Particulate matter (fine dust)
$PM_{2.5}$ and PM_{10}	Particulate matter less than 2.5 or 10 microns, respectively
TSP	Total suspended particulates
Abbreviation	
Air NEPM	*National Environment Protection (Ambient Air Quality) Measure*
ANFO	Ammonium nitrate/fuel oil (widely used industrial explosive mixture)
BoM	Bureau of Meteorology
EA	Environmental Authority
ELR	Exploration Licence in Retention
GEMCO	Groote Eylandt Mining Company Pty Ltd
HVAS	High volume air sampler
LVAS	Low volume air sampler
ML	Mineral Lease
NSW Approved Methods	*Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DEC, 2005)
Northern EL	Northern Eastern Lease
NPI	National Pollutant Inventory
OEL	Occupational Exposure Level
US EPA	United States Environmental Protection Agency
Southern EL	Southern Eastern Lease
TAPM	The Air Pollution Model

Glossary	
Ambient Air	Ambient air is the outdoor air in which humans and other organisms live and breath
Averaging period	Length of time over which an average of that data is taken. For example; if temperatures are measured once every minute over a day, an hour averaging period is obtained if the sixty measurements for each hour are averaged.
Background levels	Existing concentrations of pollutants in ambient air
CALMET	Meteorological model used in conjunction with CALPUFF. It develops hourly wind and temperature fields on a three dimensional gridded modelling domain (refer Section 4.4)
CALPUFF	A transport and dispersion model that advects 'puffs' of material emitted from modelled sources, simulating dispersion and transformation processes (refer Section 4.4)
Concentration	Concentration is the mass of particulate matter that is suspended per unit volume of air. Suspended particulate matter in ambient air is usually measured in micrograms per cubic metre (µg/m³).
Dispersion modelling	Computer based software package used to mathematically simulate the effect on plume dispersion under varying atmospheric conditions; used to calculate spatial and temporal fields of concentrations due to emissions from various source types. (DEC, 2006)
Dust deposition rate	Deposition is the mass of particulate matter that settles per unit surface area. Deposited particulate matter is usually measured in grams per square metre per month (g/m^2/month) or milligrams per square metre per day (mg/m^2/day).
Dust or particulate matter	Dust or particulate matter are terms used to define solid or liquid particles that may be suspended in the atmosphere. Particulate matter is a generic term that is commonly used interchangeably with other terms such as smoke, soot, haze and dust. The potential affect of particulate matter on the environment, human health and amenity depends on the size of the particles, the concentration of particulate matter in the atmosphere and the rate of deposition.
High volume air sampler	A high volume air sampler is an instrument used to collect sample air to measure the concentration of particles. The difference between a high and a low volume air sampler is the amount of air sampled. High volume air samplers typically draw through $1500m^3$ of air over a 24-hour period, compared to a low volume air sampler that draws in $24m^3$ or less, of air over a 24-hour period.
Low volume air sampler	A low volume air sampler is an instrument used to collect samples of air particles. The difference between a high and low volume air sampler is the amount of air sampled. Low volume air samplers typically draw through $24m^3$ of air or less over a 24-hour period, compared to a high volume air sampler that draws in $1500m^3$ of air over a 24-hour period.
Mixing height	The layer of air through which pollutants are presumed to be mixed, due to convection caused by daytime heating of the earth's surface. The height of this layer of air is measured from the ground to the height of the

	lowest inversion.
Outstation	Small, rural Aboriginal settlement.
Relative humidity	The amount of water vapour present in air (measured as vapour density or pressure) as a percentage of the maximum amount of vapour that the air could hold at the same temperature. Its maximum value is 100%.
Sensible and latent heat fluxes	Sensible heat flux is the rate of heat transferred from the Earth's surface to the atmosphere by conduction. Latent heat flux is the rate of heat transfer from the Earth's surface to the atmosphere that is associated with evaporation of water at the surface and subsequent condensation of water vapour in the troposphere. A change in sensible heat may be "sensed" by a thermometer, the change in latent heat is invisible to a thermometer.
Stability class	Stability is a term applied to the properties of the atmosphere that govern the acceleration of the vertical motion of an air parcel. The acceleration is positive in an unstable atmosphere (turbulence increases), zero when the atmosphere is neutral and negative (deceleration) when the atmosphere is stable (turbulence is suppressed). Atmospheric stability is typically classified under the Pasquill-Gifford scheme, with six main categories designated as A (highly unstable or convective), B (moderately unstable), C (slightly unstable), D (neutral), E (slightly stable) and F (stable).
Wind speed	The rate of movement of wind in distance per unit of time. When measured by an anemometer, this is a short-term average reading of horizontal wind vector magnitude, usually cited for measurement heights of 10 m.
Wind direction	Australian convention is to report wind direction by the direction from which it originates. For example, wind from the east is reported with a wind direction = 90°.

1. INTRODUCTION

1.1 Project description

Katestone Environmental Pty Ltd was commissioned by Hansen Bailey on behalf of BHP Billiton Manganese Australia Pty Ltd to complete an air quality assessment as part of the Environmental Impact Statement (EIS) for the Eastern Leases Project (the project).

The project proponent is the Groote Eylandt Mining Company Pty Ltd (GEMCO), which has two shareholders, namely: South32 Pty Ltd (60%) and Anglo Operations (Australia) Pty Ltd (40%). BHP Billiton Manganese Australia Pty Ltd was previously a shareholder in GEMCO, however its interest is now represented by South32.

The project involves the development of a number of open cut mining areas to the east of the existing GEMCO mine on Groote Eylandt in the Gulf of Carpentaria, approximately 650 km south-east of Darwin (Figure 1). The proposed additional mining areas are located on the Eastern Leases, which are two Exploration Licences in Retention (ELRs). ELR28161 is termed the Northern Eastern Lease (Northern EL) and ELR28162 is termed the Southern Eastern Lease (Southern EL).

The Eastern Leases are located 2 km east of the existing GEMCO mine at the closest point. The township of Angurugu is located approximately 6 km to the north-west of the Eastern Leases, and is the closest residential community (Figure 1). The Eastern Leases are located on Aboriginal land, scheduled under the *Aboriginal Land Rights (Northern Territory) Act 1976*. The land within the Eastern Leases comprises natural bushland, with the Emerald River and a small section of the Amagula River traversing the Northern EL and Southern EL, respectively.

The project involves:

- Developing a number of open cut mining areas (termed "quarries") within the Eastern Leases and mining manganese ore by the same mining methods that are in use at the existing GEMCO mine;
- Constructing limited mine related infrastructure in the Eastern Leases (dams, water fill points, crib hut, truck park up areas and laydown storage areas); and
- Transporting the ore by truck on a new haul road to be constructed between the existing GEMCO mine and the Eastern Leases.

Ore will be processed at the concentrator at the existing GEMCO mine and the concentrate will be transported to market via the existing port (Figure 2). No changes or upgrades to the existing GEMCO mine facilities are required as a result of the project. Ore mined from the Eastern Leases will supplement production from the existing GEMCO mine, but the project will not increase GEMCO's annual production rate of approximately 5 Million tonnes per annum (Mtpa) of product manganese. The EIS does not include any assessment of operations within the existing GEMCO mine, given that these operations are subject to existing environmental approvals, and will not be altered by the project.

The project site for the purposes of the EIS is the Northern and Southern ELs and the new section of haul road linking the Eastern Leases to the existing GEMCO mine. The project site is approximately 4,600 ha.

Mining in the Eastern Leases would take place concurrently with the operation of the existing GEMCO mine. According to current planning, construction in the Northern EL would commence in 2017 (termed Project Year 1) and mining activities would commence in 2018 (Project Year 2). Construction in the Southern EL is scheduled to commence approximately four years later in 2022 (Project Year 6) and mining would then take place in both of the tenements until approximately 2031 (Project Year 15). This equates to a total of 13 years of mining operations (i.e. mining of ore).

1.2 Scope of works

This study summarises the aspects of the project that may result in emissions to the atmosphere, as well as the legislation, policies and guidelines that are relevant to the assessment and management of air emissions in the Northern Territory and Australia. The study was designed to address the requirements of the Terms of Reference (TOR) for the project issued by the Northern Territory Environment Protection Authority (NT EPA).

The key emissions to the atmosphere likely to be generated by the project are dust and greenhouse gases.

Dust emissions will occur as a result of the construction and operation of the project. Elevated levels of dust have the potential to adversely impact the amenity and health of people living nearby. Dispersion modelling has been conducted to estimate ground-level concentrations of dust associated with the project for assessment against amenity and health objectives.

The report also addresses other air pollutants that may potentially be generated by the project (e.g. oxides of nitrogen, carbon monoxide) and explains why these pollutants tend not to be relevant to mining projects. The report also describes the measures that are in place to monitor and manage any potential emissions of manganese in dust.

A greenhouse gas assessment for the project has also been conducted. The greenhouse gas assessment includes a discussion of the relevant legislation, the methodology for the assessment, the estimated greenhouse gas emissions and mitigation strategies that are proposed to be implemented for the project.

2. EMISSIONS TO THE ATMOSPHERE

Particulate matter (i.e. dust) will be the key air emission generated by activities on the project site. Particulate matter is discussed further in Section 2.1, and other potential pollutants are discussed in Section 2.2.

2.1 Particulate matter

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

Dust can affect communities in various ways, depending upon the source and size of particles present. Dust typically emitted as a result of ore mining operations is assessed in terms of total suspended particulates (TSP), dust deposition and particulate matter with an aerodynamic diameter less than 10 micrometres (PM_{10}).

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

Smaller particles such as PM_{10} can also be generated through mining activities. Elevated levels of PM_{10} have the potential to affect human health as these particles can be trapped in the nose, mouth or throat, or be drawn into the lungs.

Very fine particles such as $PM_{2.5}$, are mostly generated through combustion processes and vehicle exhaust rather than through mining activities. Localised burn-offs (non-mine related) are common on Groote Eylandt and are likely to be the main source of $PM_{2.5}$ emissions. The $PM_{2.5}$ emissions anticipated to be generated by the project will be due to the exhaust emissions from the small mining vehicle fleet. These emissions of $PM_{2.5}$ that may be generated by the project are considered negligible and are not expected to be a significant contributing factor to adverse air quality conditions. $PM_{2.5}$ is therefore not considered further in this assessment.

2.2 Other pollutants

Small quantities of other air pollutants such as oxides of nitrogen, carbon monoxide and sulfur dioxide may also be emitted from vehicle traffic within the project site. The emission rates of these air pollutants are extremely low compared to the emission rates of particulate matter from mining activities and these air pollutants are likely to have negligible impacts. Hence, particulate matter is considered the critical air pollutant for this assessment. Compliance with air quality objectives for particulate matter at the nearest sensitive receptors will, as a consequence, demonstrate compliance with air quality standards for nitrogen dioxide, carbon monoxide and sulphur dioxide. Therefore, these air pollutants do not require further assessment.

2.2.1 Manganese

A fraction of the particulate emissions will likely be manganese. GEMCO has a program for occupational health and safety (OH&S) surveillance and monitoring, including monitoring for manganese levels in air, and this OH&S monitoring program will continue for the life of the project.

Based on GEMCO's 50 years of mining on the island, there has been no record of human health effects in the mine workforce or in communities that are located in close proximity to mining operations. This is evidenced by substantial surveillance data gathered for employees and contractors over many years as part of routine health checks of the workforce. Surveillance data is measured against rigorous GEMCO mandated measurement and reporting criteria for health impacts. It is also compared to published occupational exposure standards and the data is used to identify priorities for abatement projects and control design. This data does not indicate any human health issues associated with air quality impacts from mining processes.

In addition to ongoing health surveillance, the GEMCO workforce was also the subject of a comprehensive research project undertaken by the University of Tasmania between 2006 and 2008 (Summers et al, 2011). The research project examined the relationship between occupational exposure to manganese particulate and clinical and subclinical health impacts. This research concluded that exposure to manganese dust or fumes is not associated with impacts to human neuromotor or neuropsychological performance.

As the annual production rate from GEMCO's mining operations will not increase as a result of the project (refer to Section 1), the overall exposure to manganese amongst the workforce or in nearby communities is therefore unlikely to increase beyond current levels, and therefore air borne manganese does not require further assessment.

2.2.2 Odour

Odour is unlikely to be emitted from any mining activity and therefore odour has not been assessed further in this assessment.

2.3 Air Quality Standards and Criteria

The main pollutants emitted by the project will be particulate matter, a component of which will be manganese. The Northern Territory Environment Protection Authority (NT EPA) has not enacted legislation that specifies air quality standards or criteria relevant to the assessment of new projects. This report has therefore nominated assessment criteria and objectives for the project, based on standards used in other Australian states, and the federal government standards relating to air quality.

2.3.1 Ambient Air Quality NEPM

The National Environment Protection Council (NEPC) defines national ambient air quality standards and goals in consultation, and with agreement from all Australian state and territory governments. These were first published in 1998 in the *National Environment Protection (Ambient Air Quality) Measure* (Air NEPM). The NEPM contains, amongst other parameters, standards for 24-hour PM_{10}. Compliance with the Air NEPM standards is determined by ambient air quality monitoring undertaken at locations prescribed by the Air NEPM and that are representative of large urban populations. The goal of the Air NEPM was for the ambient air quality standards to be achieved at these prescribed monitoring stations within ten years of the commencement of the Air NEPM; that is in 2008.

A number of Australian states have adopted the Air NEPM standards as assessment criteria for air quality objectives. Although the NT government has not yet legislated the use of the Air NEPM standards, these standards are widely used in environmental assessments in the NT and throughout Australia. The NEPM standard for PM_{10} has therefore been adopted for this assessment (Section 2.3.3).

2.3.2 NSW Approved Methods

The Air NEPM does not provide assessment criteria for TSP or dust deposition. However, for jurisdictions such as the Northern Territory that do not have criteria for TSP or dust deposition, the criteria as provided in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (NSW DEC 2005) (Approved Methods) have been commonly used for environmental assessments in the NT, and are well accepted by regulators.

The Approved Methods lists the statutory methods and air quality criteria that are to be used to model and assess emissions and impacts of air pollutants from stationary sources.

The Approved Methods criteria for TSP and Dust Deposition have therefore been adopted for this assessment (Section 2.3.3).

2.3.3 Recommended Ambient Air Quality Standards and Criteria

Table 1 presents the air quality standards and criteria selected for use in the air quality assessment for this project. The objective for PM_{10} is based on the Air NEPM standard, and the TSP and dust deposition criteria are based on the NSW Approved Methods.

Table 1 Recommended air quality standards and criteria

Indicator	Averaging period	Air quality standard / criteria	Number of days of exceedance allowed per year
Particles as PM_{10} [1]	24-hour	50 µg/m³	5
Total Suspended Particulates [2]	1-year	90 µg/m³	*Not Applicable*
Deposited Dust (incremental) [2]	1-year	2 g/m²/month	*Not Applicable*

Table note:

[1] Derived from Air NEPM Standard

[2] Derived from the NSW Approved Methods. The incremental guideline has been applied to assess the project in isolation. That is, without the inclusion of existing levels of deposited dust.

3. EXISTING ENVIRONMENT

3.1 Climate and meteorology

The Bureau of Meteorology (BoM) operates a monitoring station at Groote Eylandt Airport (BoM weather station number 014518) (Figure 2). Data have been recorded at this station since 1999 and were used to summarise the climatic conditions for the project site.

Groote Eylandt experiences a tropical climate, which is characterised by hot humid summers during which the majority of rainfall occurs, and dry winters. The prevailing winds in the region are from the east. However, during the active monsoon season (from November to April) north-westerly winds draw in moist air from the ocean, leading to heavy rainfall periods associated with intense storms and cyclones.

In general, it is under hot, dry and windy conditions where dust emissions have the highest potential to adversely impact on air quality away from their point of release. The meteorological parameters that may lead to these conditions are summarised in the following sections.

3.1.1 Temperature

The mean daily maximum and minimum temperatures at the Groote Eylandt Airport BoM monitoring station are presented for each month in Table 2 and in Figure 3. The analysis identifies a seasonal temperature profile typical of the Northern Territory climate, with relatively warm temperatures year-round, and slightly cooler temperatures from June to August.

The highest mean daily maximum temperature at the Groote Eylandt Airport BoM monitoring station was 34.3°C for November. The lowest mean daily minimum temperature was 15.0°C for August.

Table 2 Mean minimum and maximum daily temperatures at Groote Eylandt Airport BoM Station (from 1999 to 2014)

Mean maximum temperature (°C)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
33.3	32.9	32.3	32.3	31.0	28.8	28.7	30.1	32.6	34.2	34.3	34.2	32.1
Mean minimum temperature (°C)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
25.1	24.9	23.7	21.7	19.0	16.5	15.4	15.0	17.9	21.1	23.5	25.0	20.7

3.1.2 Rainfall

The average and highest recorded monthly rainfall recorded at the Groote Eylandt Airport BoM monitoring station is presented in Table 3 and Figure 4. The annual pattern of rainfall illustrates the tropical climate in the region, with 97% of the annual rainfall occurring during November to April. Just 1% percent of the annual rainfall occurs in the winter months of June to August. The highest mean monthly rainfall at the Groote Eylandt Airport BoM monitoring station was 333.1 mm in March. The lowest mean monthly rainfall was 0.9 mm in August.

Table 3 Mean and Maximum Monthly Rainfall, and Mean Rain Days at Groote Eylandt Airport BoM Monitoring Station (1999 to 2014)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Rainfall (mm)	240.9	242.4	333.1	162.1	27.0	5.0	3.6	0.9	2.7	27.7	130.2	185.0	1326.4
Maximum Rainfall (mm)	577.0	507.2	570.0	445.8	76.4	30.2	25.4	4.8	20.2	80.4	245.2	498.2	1819.6
Mean Rain Days (>=1mm)	15.1	14.9	15.5	9.7	3.5	0.8	0.4	0.1	0.6	2.6	7.5	11.3	82.6

3.1.3 Relative humidity

The availability of atmospheric moisture is an important factor that influences the climate by affecting the transfer of heat in the atmosphere through the balance between sensible and latent heat fluxes, and the occurrence of precipitation. Relative humidity is one of several measures used to describe the quantity of moisture in the atmosphere, and is the ratio of the actual amount of moisture in the atmosphere to the maximum amount that could be held, at a given temperature.

Relative humidity has been analysed from long-term averages based on daily measurements collected at 9am and 3pm at the Groote Eylandt Airport BoM monitoring station. The monthly average relative humidity at 9am and 3pm is presented in Table 4 and illustrated in Figure 5. In regard to average daily variations, the analysis indicates that relative humidity was approximately 14% higher at 9am than at 3pm on average during the summer months, and approximately 33% higher at 9am than at 3pm during the winter months. The higher variation in relative humidity at 9am compared to 3pm over the winter months is due to a lack of rainfall at this time of year, therefore any moisture in the morning air typically evaporates as the day progresses resulting in much lower relative humidity by the afternoon.

Table 4 Mean relative humidity at 9am and 3pm at Groote Eylandt Airport BoM Station (1999 to 2010)

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
9am (%)	77	78	79	75	70	69	70	65	61	61	65	71	70
3pm (%)	68	69	70	65	56	57	51	46	49	50	56	62	58

3.1.4 Wind speed and direction

Wind speed and wind direction are important parameters for the transport and dispersion of air pollutants. The BoM monitoring station at Groote Eylandt Airport records wind data every 30 minutes. A summary of measurements of wind speed and direction from the monitoring station are presented in Table 5.

The site is characterised predominantly by moderate winds (2 - 4.99 m/s), with these occurring 45.4% of the time. Strong winds (i.e. >5m/s), which are important for dust generation occur for 11.5% of the year. A high proportion (24.6%) of winds were recorded as calms (i.e. winds of 0 m/s).

The predominant winds experienced at the Groote Eylandt Airport BoM Station are from easterly directions, with 59.6% of winds occurring from the north-east and south-east sectors (Figure 6). Winds from the south to south-west are the most infrequent. Further analysis of the diurnal and seasonal variations in wind speeds and wind direction is presented in Appendix A based on meteorological data generated for the dispersion modelling.

Table 5 Summary of the distribution of wind speed and wind direction at Groote Eylandt Airport BoM Station (2000 to 2014)

Wind Direction	Distribution of Wind Speeds (% of total winds)			
	Light Winds > 0 – 1.99 m/s	Moderate Winds 2 – 4.99 m/s	Strong Winds > 5 m/s	Total Winds > 0 – 10.0 m/s
N	0.6%	2.6%	0.8%	4.0%
NNE	0.6%	2.0%	0.6%	3.2%
NE	0.9%	2.9%	0.6%	4.5%
ENE	1.5%	4.2%	1.2%	6.8%
E	5.5%	6.8%	3.4%	15.7%
ESE	3.5%	5.8%	1.3%	10.6%
SE	2.3%	5.5%	0.8%	8.6%
SSE	1.1%	2.6%	0.4%	4.1%
S	0.7%	1.3%	0.1%	2.1%
SSW	0.3%	0.7%	0.0%	1.0%
SW	0.2%	0.9%	0.0%	1.1%
WSW	0.2%	1.4%	0.0%	1.6%
W	0.3%	3.2%	0.4%	3.9%
WNW	0.2%	1.9%	0.6%	2.7%
NW	0.2%	1.9%	0.7%	2.9%
NNW	0.2%	1.8%	0.6%	2.6%
All directions (100%)	18.4%	45.4%	11.5%	75.4%
Calms (0 m/s)	24.6%			

3.2 Local terrain and land use

The physiography of most of Groote Eylandt is rugged, with over half of its area including most of the central and eastern sections dominated by deeply dissected plateaux of sandstone hills up to 120m Australian Height Datum (AHD). The sandstone plateaux largely comprise sandstone, which has been deeply incised to create valleys and gorges.

In the west, coastal plains extend up to 15km inland at their widest point near Angurugu. These plains rarely exceed an altitude of 17m AHD and are dominated by Eucalypt, Acacia and Melaleuca woodlands.

The southern and eastern coastal margins of Groote Eylandt are lined by extensive dune fields, which are greater than 10km wide in some areas.

The topography across the project site varies from level to undulating plains, to sandy colluvial footslopes with rugged uplands. Elevations range from approximately 10m AHD to 120m AHD (Figure 7). Several drainage lines traverse the project site, including sections of the Emerald and Amagula Rivers, and their tributaries.

The land within and surrounding the project site comprises natural bushland, that is mainly eucalypt dominated open forest, woodland and shrubland. The most common eucalypts are Darwin Woollybutt and Stringybarks, but a wide variety of other native plants occur. Other vegetation types include forms of swamp forest and rainforest.

No farming or agriculture activities are undertaken within, or in the vicinity of the project site.

GEMCO has been undertaking manganese exploration activities across the Eastern Leases site since 2001.

3.3 Sensitive receptors

There are four sensitive receptors included in the assessment, shown in Figure 2. These receptors are the nearest sensitive residences or recreation areas to the project site. The predicted ground-level concentrations of air quality emissions attributable to the project will be less at locations further than these sensitive receptor locations. Table 6 provides the approximate locations of these receptors.

Table 6 Sensitive receptor locations

ID	Name	Type	Easting	Northing	Distance to Project Site
R1	Angurugu	Township	658061	8453390	6.5 km
R2	Yedikba	Outstation	657336	8443030	2.2 km
R3	Wurrumenbumanja	Outstation	663633	8436591	3.5 km
R4	Leske Pools Swimming Hole	Recreation Area	665871	8437377	2.4 km

The township of Angurugu (receptor R1) is home to approximately 850 residents. The township is located inland from the western coastline of Groote Eylandt, and is adjacent to the Angurugu River. Angurugu is approximately 6.5km to the northwest of the Northern EL. The existing GEMCO mine bounds the township on three sides, with the Groote Eylandt Airport located directly to the north. The closest Angurugu residence to the existing mining operations is located approximately 500m to the northeast of existing activities (product stockpiles).

Yedikba (receptor R2) is an Aboriginal outstation located approximately 2.2km to the west of the Southern EL. It comprises three outstation buildings. Yedikba is not a permanently occupied outstation, and is reported to have varying levels of use, from occasional visitation to sporadic residency. Although Yedikba is located 400m from the mineral lease boundary of the existing GEMCO mine, there are currently no mining activities occurring within the vicinity of this outstation, with the nearest operations at the existing mine taking place over 2km from the outstation buildings. Mining activities within the existing GEMCO mine may, however, extend further to the south and closer to Yedikba in the future.

Wurrumenbumanja (receptor R3) is an Aboriginal outstation located approximately 3.5km to the south of the Southern EL. It comprises four outstation buildings. Wurrumenbumanja is not a permanently occupied outstation, and is reported to have low levels of use, typically limited to occasional visitation. There are no mining activities occurring within the vicinity of this outstation, with the nearest operations at the existing mine taking place over 11km from the outstation buildings.

The Leske Pools Swimming Hole (receptor R4) is a public recreation area used by Groote Eylandt residents and visitors to the island for swimming, camping and fishing activities. It is located approximately 2.4km to the south of the Southern EL. There are no mining activities occurring within the vicinity of this recreation area, with the nearest operations at the existing mine taking place over 11km from this location.

3.4 Ambient air quality

3.4.1 Existing sources

Air quality on Groote Eylandt is likely to be affected by the following:

- Natural dust including pollens, grass seeds, wind blown dust from unvegetated areas, salt spray as well as smoke and ash particulates from bushfires;
- Cultural / ceremonial burning practices;
- Domestic burning of rubbish and leaf litter;
- Operations at the existing GEMCO mine and Milner Bay Port Facility;
- Airport operations near Angurugu;
- Power generation (i.e. diesel fuel power station) at the Rowell Highway and Umbakumba Power Stations; and
- Motor vehicles.

3.4.2 GEMCO's monitoring network

GEMCO currently operates a monitoring network that measures particulate matter as PM_{10}. The monitoring network currently comprises three Low Volume Air Samplers (LVAS) that have been in operation since July 2012. The network previously included two High Volume Air Samplers (HVAS) that were in operation from mid 2001 to mid 2012. Data from the HVAS samplers have been used in preference to the LVAS for this assessment due to there being a greater data capture rate for the HVAS.

Data from 2008 has been used because this year had the highest data capture rate (91 days).

Six E-samplers, measuring PM_{10}, wind direction and wind speed are also currently in operation on the island. However, these monitoring stations only operate during the driest (and consequently dustiest) period of the year to provide higher-resolution data to assist management of site activities. The E-Samplers consequently do not provide air quality over a full year, and the data from the E-samplers has therefore been excluded from this assessment.

The location of the HVAS monitors is presented in Figure 2, and a summary of the monitors is provided in Table 7.

Table 7 Location of HVAS PM_{10} monitors

Monitor Location	Station Start	Station End	Average Data Capture Rate	Easting (m, E)	Northing (m, N)	Distance from Operations at Existing Mine
A1 – Alyangula	7 July 2001	8 May 2012	66%	653393	8468256	9.5km
A2 – Angurugu	28 June 2001	7 June 2012	66%	658235	8454173	1.5km

3.4.3 Particulate matter as PM_{10}

A summary of the 24-hour PM_{10} measurements recorded at Alyangula (A1), and Angurugu (A2) is presented in Table 8. These have been used to determine the most appropriate ambient background concentrations of PM_{10} at the four sensitive receptors for use in the air quality impact assessment.

Table 8 Summary of 24-hour average PM_{10} measured at Alyangula (A1) and Angurugu (A2) (2008)

Parameter	A1: Alyangula HVAS Location	A2: Angurugu HVAS Location
Maximum	113 µg/m^3	111 µg/m^3
70th Percentile^	20 µg/m^3	32 µg/m^3
Average	14 µg/m^3	23 µg/m^3
Sampling cycle	24-hour average (1 in six days)	24-hour average (1 in six days)

^ The NT EPA does not specify a method for determining ambient background concentrations. However, the Victorian EPA specifies within the *State Environment Protection Policy (Air Quality Management)* (EPA Victoria, 2007) the use of a 70th percentile as being an appropriate method for determining ambient background concentrations. This approach has been adopted for this assessment.

3.4.4 Particulate matter as TSP

GEMCO does not currently monitor particulate matter as TSP or dust deposition. Previous assessments by Katestone and standard conversion ratios detailed in the US EPA's Compilation of Air Pollution Emission Factors Volume 1 (AP-42) and in the National Pollutant Inventory (NPI) Handbooks, have found that PM_{10} is usually 50% of the TSP concentration. For non-urban areas a PM_{10}/TSP ratio of 0.5 can be applied to annual average concentrations of PM_{10}.

In relation to dust deposition rate, the Approved Methods allows for a cumulative assessment that includes background or an incremental assessment to be made. The project has been assessed against the incremental criteria.

3.4.5 Summary of Ambient Air Quality

Table 9 provides a summary of the background levels used for this assessment.

Table 9 Background levels assumed in the assessment relevant to each sensitive receptor

Pollutant	Averaging period	Value	Explanation / Comment
PM_{10}	24-hour	32 µg/m^3 (R1 and R2)	Based on an analysis of the 70th percentile data from Angurugu 2008 (Table 8)
		20 µg/m^3 (R3 and R4)	Based on an analysis of the 70th percentile data from Alyangula 2008 (Table 8)
TSP	1-year	64 µg/m^3 (R1 and R2)	For non-urban areas a PM_{10}/TSP ratio of 0.5 can be applied to annual average PM_{10} concentrations
		40 µg/m^3 (R3 and R4)	
Dust deposition	1-year	-	The dust deposition criterion is based on the incremental deposited dust due to the project in isolation, and therefore the addition of a background deposited dust level is not required.

The background levels for PM_{10} and TSP were selected as follows:

- The background levels chosen for Angurugu (R1) are based on particulate data recorded from the Angurugu monitoring station (A2).

- The background levels chosen for Yedikba (R2) are based on particulate data recorded from the Angurugu monitoring station (A2), which is located approximately 1.5km from operations at the existing mine. Although operations at the existing mine are currently located well over 2km from Yedikba, GEMCO has approval to extend the mining operations further to the south within the mineral lease, and therefore operations may be in closer proximity to Yedikba in the future. Utilising the background data from the Angurugu monitoring station (A2) therefore provides a level of conservatism to the assessment, given that Yedikba is remote from the current mining operations.
- The background levels for Wurrumenbumanja (R3) and Leske Pools Swimming Hole (R4) are based on particulate data recorded from the Alyangula monitoring station (A1). This monitoring station is located over 9km from operations at the existing mine, and approximately 1km to the north of the Milner Bay Port Facility. Although this monitoring station would be unlikely to be affected by air emissions from the existing GEMCO mine, it may record particulates from the port. Utilising the data from Alyangula monitoring station (A1) as background data for Wurrumenbumanja (R3) and Leske Pools Swimming Hole (R4), therefore provides a level of conservatism to the assessment, particularly given these receptors are located in relatively pristine environment, over 11km from operations at the existing mine.

4. AIR QUALITY IMPACT ASSESSMENT METHODOLOGY

4.1 Meteorology

The prognostic model TAPM (The Air Pollution Model) (CSIRO, 2006) was used in conjunction with local observations of meteorological data to represent wind flows in the region. The meteorological data obtained from this was then used in the dust and odour dispersion modelling.

Appendix A discusses details of the generation of the site-specific meteorological dataset, including:

1. TAPM model configuration;
2. Evaluation of model performance; and
3. Discussion of meteorological parameters that drive the dispersion model (i.e. wind speed and direction, mixing heights, atmospheric stability).

The model evaluation shows that the data generated by TAPM provides a very good representation of meteorological conditions in the region.

4.2 Scenarios Assessed

Three project scenarios were selected to allow the potential envelope of impacts to be adequately assessed at each sensitive receptor. These are:

1. Project Year 3;
2. Project Year 9; and
3. Project Year 13.

These scenarios all represent worst case years for these receptors, both in terms of the proximity of project activities to the receptors and the quantity of overburden excavated and transported (i.e. main dust source). The scenarios were assessed using a conservative estimate of the maximum daily ore extraction rate. It should be noted that the production rate varies substantially over the life of the project and these scenarios represent the worst case years in terms of quantity of material moved (and hence dust generated). All other years would have reduced dust levels at sensitive receptors, compared to the worst year.

Figure 8 to Figure 10 present the proposed layout of mining operations at the project site in each of the selected years.

4.3 Dust Emission Rates

Emission rates of dust associated with the operation of the project for each scenario were estimated, accounting for proposed emission controls, using emission factors published in authoritative sources including the National Pollutant Inventory (NPI) Handbooks or the USEPA AP42 Emission Estimation Manuals (USEPA, 1998; USEPA, 2006; NPI, 2012). Operating parameters such as throughputs, location of equipment and utilisation rates, were based on information provided by GEMCO, as detailed in Appendix B. Details of the methodology and the emission factors used for estimating dust emissions are provided in Appendix C.

Section 5 provides a comprehensive discussion of the sources of dust that were included in the dust assessment.

All years have been assessed using a conservative estimate of the maximum daily ore extraction rate. In practice this extraction rate is unlikely to be achieved regularly, and therefore the dispersion modelling assessment provides a conservative estimate of potential annual impacts (refer to Section 4.6).

4.4 Dispersion Modelling

The dispersion modelling of emissions from the mine has been undertaken using the CALPUFF dispersion model. The CALPUFF model utilises the three-dimensional wind fields from CALMET to simulate the dispersion of air pollutants to predict ground-level concentrations across a gridded domain. CALPUFF is a non-steady-state Lagrangian Gaussian puff model containing parameterisations for complex terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal, and simple chemical transformation. CALPUFF employs the three dimensional meteorological fields generated from the CALMET model by simulating the effects of time and space varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF contains algorithms that can resolve near-source effects such as building downwash, transitional plume rise, partial plume penetration, sub-grid scale terrain interactions, as well as the long range effects of removal, transformation, vertical wind shear, overwater transport and coastal interactions. Emission sources can be characterised as an arbitrarily-varying point, area, volume and lines or any combination of those sources within the modelling domain.

The model has been adopted by the US EPA in its guideline on air quality models (40 CFR, Part 51, Appendix W) as the preferred model for assessing long range transport of pollutants and on a case-by-case basis for certain near-field applications involving complex meteorological conditions. CALPUFF is accepted for use by the NT EPA and other environmental jurisdictions throughout Australia for modelling of air pollutants emitted from mining.

Details of the CALPUFF model configuration are provided in Appendix A. Dispersion modelling has accounted for a number of mining activities that only occur during the day.

Modelling results have been presented as ground-level concentrations or dust deposition rates at sensitive receptors as well as contours across the modelling domain.

4.5 Limitations of Dispersion Modelling

This study relies on the accuracy of a number of data sets including, but not limited to:

- Meteorological information; and
- Calculation of emission rates from mining activities

It is important to note that numerical models are based on an approximation of governing equations and will inherently be associated with some degree of uncertainty. The more complex the physical model, the greater the number of physical processes that must be included.

There will be physical processes that are not explicitly accounted for in the model and, in general, these approximations tend to lead to an over prediction of air pollutant levels. For example, in the real world when a plume of dust reaches an area of sloping terrain, mass from the plume will be removed through impaction on the surface. However, in a dust model, the dust plume is treated as a gas and the plume will pass over or around the obstacle with no loss of mass. This difference in characterisation can lead to an over prediction of dust levels downwind from the source.

4.6 Conservatism of Modelling Assumptions

A number of assumptions have been made in the modelling that provide for a high degree of conservatism to the assessment. This includes the background levels that have been selected for the assessment (as provided in Table 9) and the operating years that were modelled.

4.6.1 Background Levels

Background dust levels at Angurugu include dust from the existing GEMCO mine, with the assumption that the mine is operating at near peak capacity (refer to Section 3.4.2). As described in Section 1.1, ore mined from the Eastern Leases will supplement production from the existing GEMCO mine, rather than increase production. However, for the purposes of this assessment, dust generated by the Eastern Leases has been added to measured background dust (which represents dust from full production at the existing GEMCO mine). In reality, production from the existing GEMCO mine will scale back to allow for the project, leading to a reduction in dust from the existing GEMCO mine. This scaling back of operations has not been accounted for in the air assessment, and this therefore introduces a high degree of conservatism into the assessment.

4.6.2 Selected Operating Scenarios

The operating years that were selected for modelling are worst case years, both in terms of the intensity of mining activity (i.e. production rate and volume of overburden moved) and the proximity to sensitive receptors. These years were selected to confirm that compliance with air quality criteria could be achieved during worst case operating conditions. Project generated dust levels over the remainder of the project life would be no higher than during these worst case years, and for much of the time would be significantly lower.

5. DUST EMISSIONS FROM THE PROJECT

Dust emissions are likely to be produced during construction and operation of the project. The project will generate dust emissions from the extraction, handling and transportation of material from the project's active quarries, as well as from wind erosion of exposed areas and overburden stockpiles. Details of the construction and operational phases of the project, controls and mitigation measures and an emissions inventory are provided in the following sections.

5.1 Construction Phase Activities

Construction phase activities at the project site include works associated with the construction of infrastructure required for the project. Activities will include:

- Removal of vegetation;
- Excavation and stockpiling of topsoil;
- Earthworks associated with the construction of the haul roads, river crossings, laydown areas and mine water dams; and
- Civil works associated with the installation of drainage works.

5.2 Operation Phase Activities

Operation phase activities at the project site include site clearance works associated with the development of active quarries, and the mining and transportation of the manganese ore. Activities include:

- Removal of vegetation;
- Excavation and stockpiling of topsoil;
- Removal and stockpiling of overburden;
- Drilling and blasting of ore;
- Removal and haulage of ore from the project site to the existing GEMCO mine; and
- Earthworks associated with the maintenance of the haul roads and laydown areas.

5.3 Dust Generating Activities

The project will generate dust emissions, and project activities have the potential to cause elevated levels of dust if not appropriately managed. Key activities undertaken as part of the project that can contribute to dust generation include:

- Transportation of ore from the Eastern Leases to the existing mine;
- Transport of overburden from active quarry areas to designated temporary overburden emplacement areas;
- Removal, relocation and stockpiling of topsoil resources;
- Wind erosion of exposed quarry surfaces and overburden stockpiles;
- Dozer activity on ore and overburden;
- Drilling and blasting of ore;

- Loading and unloading of trucks; and
- Maintenance of the haul roads.

The majority of these activities are associated with the operations phase of the project. The quantity of material moved during the operations phase (i.e., topsoil, overburden and ore) will be significantly higher than in the construction phase. Consequently, the dust generated by construction activities will be minimal in comparison to the dust generated during the operations phase of the project. This assessment therefore focuses on dust generation from the operations phase.

5.4 Dust Controls and Emissions Inventory

The assessment has considered a worst-case scenario for dust emissions, in that ore extraction and processing rates have been assumed to be at their maximum level throughout the mine life. The dust emission rates estimated for the different activities during the three selected project years are summarised in Table 10, Table 11 and Table 12 and are based on factors from the USEPA AP-42 and the NPI.

The key measures to control emissions and minimise the potential impact of the project include Level 2 watering on all haul routes, and progressive rehabilitation practices across the project site. Consequently, the following control factors have been applied in the emissions estimation:

- 75% reduction in wheel generated dust due to Level 2 watering on all haul routes;
- 60% reduction in wind erosion from partly rehabilitated areas; and
- 100% reduction in wind erosion from fully rehabilitated areas (i.e. areas rehabilitated for 4 years or longer).

Further details of the methodology and the emission factors used for estimating dust emissions are provided in Appendix C.

Operating parameters, such as extraction rates, location of equipment and utilisation rates, were based on information provided by GEMCO. These are detailed in Appendix B. Other factors that determine dust emissions are the ore and overburden moisture and silt contents as well as the mitigation measures that may be employed. These key factors have been accounted for in estimating the dust emissions for the project.

The activities that are likely to generate the most dust are haulage of ore and overburden. Emission rates vary between the three scenarios assessed, primarily due to changes in overburden extraction rate and the increases in exposed areas as mining progresses. Emission rates have been calculated based on haul lengths which reflect the dumping of overburden in areas of active spoil near the operating quarries, and the haulage of extracted ore from the operating quarries to the existing mine. As can be seen in the following tables, other mining activities such as rehabilitation operations, excavators loading materials to trucks, and drilling and blasting, are relatively small contributors to the overall dust emissions from the project, and emissions due to these activities are therefore not expected to vary significantly throughout the project's lifetime.

Table 10 Emission rates for Project Year 3

Activity	Activity Symbol (Refer Figure 8)	Emission Rate (g/s)	
		TSP	PM_{10}
Topsoil and overburden removal		**6.6**	**1.3**
Excavator loading topsoil to truck		*0.0053*	*0.0025*
Topsoil haulage		*0.53*	*0.14*
Truck dumping topsoil		*0.0053*	*0.0025*
Dozers - on overburden		*5.99*	*1.14*

Excavator - loading overburden to truck		*0.06*	*0.03*
Truck dumping overburden		*0.06*	*0.03*
Ore extraction		**1.6**	**0.3**
Drilling		*0.000664*	*0.000349*
Blasting		*0.000251*	*0.000130*
Dozers - on ore		*1.54*	*0.29*
Excavator - loading blasted ore to truck		*0.07*	*0.03*
Haulage		**76.4**	**20.2**
Overburden haulage		*5.74*	*1.52*
Ore haulage (to edge of D Quarry within existing mineral lease)		*70.63*	*18.70*
Rehabilitation		**0.5**	**0.1**
Loading topsoil to truck (for rehabilitation)		*0.00531*	*0.00251*
Topsoil haulage - from dumping area to rehabilitation areas		*0.53*	*0.14*
Truck dumping topsoil (for rehabilitation)		*0.0053*	*0.0025*
Grading		**0.0014**	**0.0005**
Wind erosion		**3.1**	**1.5**
Exposed, unrehabilitated areas (quarries, overburden emplacement)		*3.03*	*1.52*
Rehabilitated areas		*0.05*	*0.02*
Total		**88.2**	**23.6**

Table 11 Emission rates for Project Year 9

Activity	Activity Symbol (Refer Figure 9)	Emission Rate (g/s)	
		TSP	PM_{10}
Topsoil and overburden removal		**6.6**	**1.3**
Excavator loading topsoil to truck		*0.0073*	*0.0035*
Topsoil haulage		*0.52*	*0.14*
Truck dumping topsoil		*0.0073*	*0.0035*
Dozers - on overburden		*5.99*	*1.14*
Excavator - loading overburden to truck		*0.05*	*0.02*
Truck dumping overburden		*0.05*	*0.02*
Ore extraction		**1.6**	**0.3**
Drilling		*0.00106*	*0.00056*
Blasting		*0.00040*	*0.00021*
Dozers - on ore		*1.54*	*0.29*
Excavator - loading blasted ore to truck		*0.07*	*0.03*
Haulage		**77.0**	**20.4**
Overburden haulage		*3.72*	*0.99*
Ore haulage (to edge of D Quarry within existing mineral lease)		*73.25*	*19.39*
Rehabilitation		**0.5**	**0.1**

Loading topsoil to truck (for rehabilitation)		*0.00730*	*0.00345*
Topsoil haulage - from dumping area to rehabilitation areas		*0.52*	*0.14*
Truck dumping topsoil (for rehabilitation)		*0.0073*	*0.0035*
Grading		**0.0014**	**0.0005**
Wind erosion		**7.7**	**3.8**
Exposed, unrehabilitated areas (quarries, overburden emplacement)		*5.43*	*2.71*
Rehabilitated areas		*2.27*	*1.14*
Total		**93.5**	**26.0**

Table 12 Emission rates for Project Year 13

Activity	Activity Symbol (Refer Figure 10)	Emission Rate (g/s)	
		TSP	PM_{10}
Topsoil and overburden removal		**7.3**	**1.5**
Excavator loading topsoil to truck		*0.0088*	*0.0042*
Topsoil haulage		*0.97*	*0.26*
Truck dumping topsoil		*0.0088*	*0.0042*
Dozers - on overburden		*5.99*	*1.14*
Excavator - loading overburden to truck		*0.14*	*0.07*
Truck dumping overburden		*0.14*	*0.07*
Ore extraction		**1.6**	**0.3**
Drilling		*0.001183*	*0.000622*
Blasting		*0.000445*	*0.000231*
Dozers - on ore		*1.54*	*0.29*
Excavator - loading blasted ore to truck		*0.07*	*0.03*
Haulage		**78.0**	**20.7**
Overburden haulage		*15.58*	*4.12*
Ore haulage (to edge of D Quarry within existing mineral lease)		*62.46*	*16.53*
Rehabilitation		**1.0**	**0.3**
Loading topsoil to truck (for rehabilitation)		*0.00885*	*0.00419*
Topsoil haulage - from dumping area to rehabilitation areas		*0.97*	*0.26*
Truck dumping topsoil (for rehabilitation)		*0.0088*	*0.0042*
Grading		**0.0014**	**0.0005**
Wind erosion		**15.1**	**7.6**
Exposed, unrehabilitated areas (quarries, overburden emplacement)		*10.97*	*5.49*
Rehabilitated areas		*4.15*	*2.07*
Total		**103.0**	**30.3**

6. AIR QUALITY IMPACT ASSESSMENT

The CALPUFF dispersion model has been used to quantify the incremental change in dust associated with the project during the three assessed project scenarios. Ground-level dust concentrations and dust deposition rates associated with mining operations in the Eastern Leases have been predicted at the sensitive receptors and are presented in Table 6. Background dust levels have been added to the incremental model predictions in order to obtain an estimate of the potential cumulative impacts of the project with existing natural and anthropogenic sources of dust. Impacts at sensitive receptors have been assessed by comparing the predicted concentrations and dust deposition rates with the relevant air quality objectives.

Ground-level dust concentrations and dust deposition rates were also predicted at a network of evenly-spaced grid points covering the study region. Contour plots indicative of ground-level concentrations or dust deposition rates due to the project operating in isolation are presented in the following sections. Contour plots of the project plus background levels are not presented due to the expected variations in ambient background concentrations at the different sensitive receptors across the model domain.

When considering the results, it is important to note that the 24-hour average dispersion modelling results are based on the maximum concentration of each pollutant predicted at the receptors over the one-year period and thus represent a peak-impact scenario. The contour plots are constructed such that the maximum value is obtained and stored from each point in the modelled domain. As these maximum values may occur at different times at different grid points, these figures do not represent a single snapshot of conditions at any given time.

6.1 PM_{10}

Table 13 provides the predicted 6th highest 24-hour average ground-level concentrations of PM_{10} for each project year scenario for the project in isolation (i.e. without the background) and with background levels applied.

Contours of the predicted 6th highest 24-hour average ground-level concentrations of PM_{10} are presented in Figure 11, Figure 12 and Figure 13 and provide the results of the dispersion model of the project in isolation.

Table 13 Predicted 6th high 24-hour average ground-level concentrations of PM_{10} (µg/m³)

Receptor	Project Year 3		Project Year 9		Project Year 13	
	Project (in isolation)	Project + Background	Project (in isolation)	Project + Background	Project (in isolation)	Project + Background
R1 – Angurugu	12.3	44.3	6.4	38.4	12.0	44.0
R2 – Yedikba	17.3	49.3	17.3	49.3	17.2	49.2
R3 – Wurrumenbumanja	3.0	23.0	7.8	27.8	10.1	30.1
R4 – Leske Pools Swimming Hole	3.0	23.0	9.4	29.4	15.7	35.7
Objective	**50 µg/m³**					

The results show that the predicted concentrations of PM_{10} due to the project ***comply*** with the relevant air quality objective at all sensitive receptors, in all modeled project years. The results show compliance for the project in isolation, and utilising the highly conservative background levels that have been applied to this assessment.

6.2 TSP

Table 14 provides the predicted annual average ground-level TSP concentrations for each project year scenario for the project in isolation (i.e. without the background) and with background levels applied.

Contours of the predicted annual average ground-level TSP concentrations are presented in Figure 14, Figure 15 and Figure 16 and provide the results of the dispersion model of the project in isolation.

Table 14 Predicted annual average ground-level concentrations of TSP (µg/m^3)

Receptor	Project Year 3		Project Year 9		Project Year 13	
	Project (in isolation)	Project + Background	Project (in isolation)	Project + Background	Project (in isolation)	Project + Background
R1 – Angurugu	3.5	67.5	1.6	65.6	3.1	67.1
R2 – Yedikba	7.6	71.6	9.7	73.7	9.1	73.1
R3 – Wurrumenbumanja	0.4	40.4	2.0	42.0	2.7	42.7
R4 – Leske Pools Swimming Hole	0.4	40.4	1.6	41.6	4.7	44.7
Objective	**90 µg/m^3**					

The results show that the predicted concentrations of TSP due to the project ***comply*** with the relevant air quality objective at all sensitive receptors, in all modeled project years. The results show compliance for the project in isolation, and utilising the highly conservative background levels that have been applied to this assessment.

6.3 Dust Deposition

Table 15 provides the predicted annual average dust deposition rate for each project year scenario for the project in isolation (i.e. without the background). Contours showing the results of the dispersion model are presented in Figure 17, Figure 18 and Figure 19.

Table 15 Predicted annual average dust deposition rate (g/m^2/month)

Receptor	Project Year 3	Project Year 9	Project Year 13
	Project (in isolation)	Project (in isolation)	Project (in isolation)
R1 – Angurugu	0.10	0.04	0.09
R2 – Yedikba	0.30	0.30	0.30
R3 – Wurrumenbumanja	0.01	0.04	0.05
R4 – Leske Pools Swimming Hole	0.01	0.04	0.10
Objective	**2.00 g/m^2/month**		

The results show that the predicted concentrations of dust deposition due to the project ***comply*** with the relevant air quality objective at all sensitive receptors, in all modeled project years.

7. DUST MITIGATION AND MONITORING

A number of controls have been included in the project design to limit dust emissions from the project including:

- 75% reduction in wheel generated dust due to Level 2 watering on all haul routes; and
- Progressive rehabilitation of areas that have been mined.

PM_{10} will continue to be monitored on an ongoing basis through GEMCO's existing dust monitoring network. The monitoring network currently comprises three Low Volume Air Samplers (LVAS) and six E-samplers (Figure 2). The E-samplers only operate during the driest (and consequently dustiest) period of the year to provide higher-resolution data so as to assist in the pro-active management of site activities, and trigger the implementation of additional dust mitigation measures if required.

Meteorological data is available from the Groote Eylandt Airport BoM weather station, which is the closest weather station to the project site (Figure 2). This station, which has been in operation since April 1999, utilises a continuous monitor to collect ambient data such as rainfall, temperature, relative humidity, wind speeds and wind direction. Data from this station will continue to provide suitable meteorological data for the Eastern Leases Project.

If monitoring indicates any unexpected exceedances of air quality objectives, an investigation will be conducted by GEMCO, and additional dust controls will be applied.

In addition to maintaining the monitoring program described above, the proponent will continue the operation of its complaints handling procedure. Community complaints which relate to air quality impacts will be responded to in an appropriate and timely manner by GEMCO.

8. GREENHOUSE GAS ASSESSMENT

8.1 Climate change and the greenhouse effect

This greenhouse gas (GHG) assessment considers the potential impact of the project on the global climate system through changes that it may cause to net greenhouse gas emissions.

Energy from fossil fuels underpins the global economy and changing this pattern to reduce emissions and limit climate change is extremely difficult. The need for a global solution to this problem has led to the United Nations Framework Convention on Climate Change (UNFCCC), the associated Kyoto Protocol and the world scientific body, the Intergovernmental Panel on Climate Change (IPCC). In 2010, governments agreed that emissions need to be reduced so that global temperature increases are limited to below two degrees Celsius (UNFCCC, 2012). Australia is an active participant in these global arrangements and this has a strong effect on domestic economic and environmental policy.

The main GHGs that are influenced directly by human activities and that are included in carbon accounting are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and synthetic gases, such as sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). These gases vary in effect and longevity in the atmosphere, but scientists have devised a system named Global Warming Potential to allow them to be described in equivalent terms to CO_2 (the most prevalent greenhouse gas) called carbon dioxide equivalents (CO_2-e). A unit of one tonne of CO_2-e is the basic unit used in carbon accounting. In simple terms an emissions inventory is calculated as the sum of the emission rate of each greenhouse gas multiplied by its associated global warming potential. For example:

$$\text{tonnes } \mathbf{CO_2\text{-}e} = \text{tonnes } \mathbf{CO_2} \times \boxed{\mathbf{1}} + \text{tonnes } \mathbf{CH_4} \times \boxed{\mathbf{21}} + \text{tonnes } \mathbf{N_2O} \times \boxed{\mathbf{310}}$$

Any source or sink of GHG has a nominally equivalent effect no matter where on Earth it occurs. Available evidence including the recent IPCC Fifth Assessment (IPCC, 2013) report suggests that:

1. Global warming is unequivocal and occurring at an unprecedented rate;
2. Increased levels of GHG are directly linked to an increase in global average surface temperatures; and
3. Human activities are largely responsible for recent increases in GHG emissions.

While few, if any, individual projects would make a noticeable change to the Earth's climate, the summation of human activities increasing the concentrations of GHG in the upper atmosphere does. Climate change is an environmental concern at a global level. Governments and the global scientific community have established conventions to account for GHG emissions to enable pollution control among all global jurisdictions. This assessment employs these established conventions so that the relative impact of the proposed project can be properly understood.

8.2 Policy and legislative context

8.2.1 Australian international commitments

As a signatory to the Kyoto Protocol created under the UNFCCC, Australia has a legally binding commitment to reduce national GHG emissions. The Australian Government has a constitutional power to ensure that Australia meets its international commitments to reduce GHG emissions.

The *Clean Energy Act 2011* that established a carbon emissions trading system for Australia has been repealed. This abolished the carbon pricing mechanism effective from 1 July 2014. The government has proposed 'Direct Action' in place of the carbon pricing mechanism in order to reduce carbon emissions to meet Australia's commitments under the second period of the Kyoto Protocol (UNFCCC,2008). Obligations for large GHG emitters under the 'Direct Action' policy are currently unclear. GEMCO will continue to monitor the development and enactment of new legislation in order to ensure it remains up-to-date on its corporate obligations relating to GHG emissions.

8.2.2 National Greenhouse and Energy Reporting (NGER)

The *National Greenhouse and Energy Reporting Act 2007* (*NGER Act*) (DIICCSCRTE, 2013b) established a national framework for corporations to report GHG emissions and energy consumption. The NGER Act 2007 is administered by the Clean Energy Regulator with details of the scheme and allowable calculation methodologies contained in the:

1. *National Greenhouse and Energy Reporting Regulations 2008* (NGER Regulation) (DIICCSCRTE, 2013d); and
2. *National Greenhouse and Energy Reporting Determination 2008* (NGER Determination) (DIICCSCRTE, 2013c).

The NGER Regulation recognises Scope 1 and Scope 2 emissions as follows:

- Scope 1 emissions – in relation to a facility, means the release of GHG into the atmosphere as a direct result of an activity or series of activities (including ancillary activities) that constitute the facility; and
- Scope 2 emissions – in relation to a facility, means the release of GHG into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility.

Registration and reporting is mandatory for corporations that have energy production, energy use or GHG emissions that exceed specified GHG emission thresholds. GHG emission thresholds include Scope 1 and Scope 2 emissions.

8.3 Greenhouse gas emission estimation methodology

GHG emissions associated with the project have been estimated for each year of operations. A summary of estimated emissions, expressed as tonnes per annum of CO_2 equivalent (CO_2-e) is presented. Reporting obligations based on conservative estimates of annual GHG emissions are summarised, along with measures to mitigate GHG emissions through avoidance and minimisation.

The methodologies used to estimate the GHG emissions resulting from the Project are consistent with:

1. NGER Determination 2008;
2. The National Greenhouse Accounts (DIICCSCRTE, 2013a); and
3. The Greenhouse Gas Protocol (WBCSD/WRI, 2005).

In particular, the methodology is generally consistent with a Method 1 approach as detailed in the *NGER Determination*.

Scope 1 emissions result predominantly from diesel combustion for site equipment and vehicles, and for power generation, with a small contribution from the use of explosives. All electricity requirements for the project will be met by diesel generators, and therefore there will be no Scope 2 emissions relevant to the Project.

The emission factors for diesel combustion and explosives used to estimate greenhouse gas emissions are presented in Appendix D.

8.4 Greenhouse gas emissions

GHG emissions for the project and energy consumption are summarised in Table 16. Activity rates used to calculate greenhouse gas emissions are presented in Appendix D, along with a breakdown of energy consumption and greenhouse gas emissions for each project year. The estimated annual GHG emissions range from 7,200 tCO_2-e to 70,600 tCO_2-e (Appendix D).

For comparative purposes the latest annual GHG inventory estimates for Australia and the Northern Territory (excluding emissions from Land Use, Land Use Change and Forestry (LULUCF)) are 542,000,000 tCO_2-e and 14,800,000 tCO_2-e, respectively (Commonwealth of Australia, 2014a and Commonwealth of Australia, 2014b).

Table 16 Summary of GHG Emissions for the Life of the Project

Activity	Total energy consumption (GJ)	Total Scope 1 emissions (tCO2-e)
Diesel Consumption (Equipment/haul trucks)	5,685,317	397,404
Diesel Consumption (Electricity)	2,234,576	155,303
Explosives (ANFO)	-	666
Total	**7,919,892**	**553,373**

8.4.1 NGER obligations

GEMCO currently has NGER reporting obligations associated with the existing mine. GHG emissions and energy use/production associated with the project will need to be accounted for in ongoing annual NGER reporting associated with the existing mine in accordance with the *NGER Act 2007* and supporting legislation.

8.5 Greenhouse gas mitigation strategies

The following initiatives are proposed to help mitigate, reduce, control or manage GHG emissions through energy efficiency:

- Regular assessment, review and evaluation of GHG reduction opportunities;
- Procurement policies that require the selection of energy efficient equipment and vehicles;
- Monitoring and maintenance of equipment in accordance with manufacturer recommendations; and
- Optimisation of diesel consumption through logistics analysis and planning.

GEMCO also conducts regular internal review of reported GHG data, and annual audits of NGER data are conducted by an external party. This data is then used to measure performance against GEMCO policy, objectives and targets. Through this review process, areas of concern are raised and corrective actions and requests for further clarification are issued and implemented.

9. CONCLUSIONS

An air quality and greenhouse assessment was undertaken to assess the potential impacts from the Eastern Leases Project. This assessment was conducted in accordance with recognised techniques for dispersion modelling and emission estimation in order to determine potential impacts to identified sensitive receptors and the surrounding environment.

Dust impacts were assessed using three representative years from the project schedule: Project Years 3, 9 and 13. The assessment of impacts due to operations during these years was conducted based on a dispersion modelling study that incorporates source characteristics, estimated emissions, local meteorology, terrain, land use and the geographical location of sensitive receivers. Emissions from project operations were estimated using emission factors from the USEPA AP-42 and the NPI. The site-specific meteorological dataset was generated by the meteorological model TAPM. The CALPUFF dispersion model was used to estimate ground-level concentrations of PM_{10}, TSP and dust deposition rates at identified sensitive receptors and the surrounding environment.

Key sources of dust emissions from the project include:

- Haulage of ore from the Eastern Leases to the existing operations;
- Haulage of overburden from the active quarries to designated temporary overburden emplacement areas; and
- Wind erosion of exposed areas.

Assessment of the operation of the project shows that:

- Predicted ground-level concentrations of PM_{10}, TSP and dust deposition rates, when considered in conjunction with existing background levels where appropriate, **comply** with the recommended air quality objectives at all sensitive receptors.

The major activity of the project that is associated with the release of greenhouse gases involves the consumption of diesel for haul trucks and other ancillary equipment such as mobile generators. The maximum annual greenhouse gas emission rate due to the project is 70,600 tCO_2-e.

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Figure 1	**GEMCO Eastern Leases Project - Location Plan**	
Location: Groote Eylandt, NT	**Prepared by:** Hansen Bailey	**Date:** February 2015

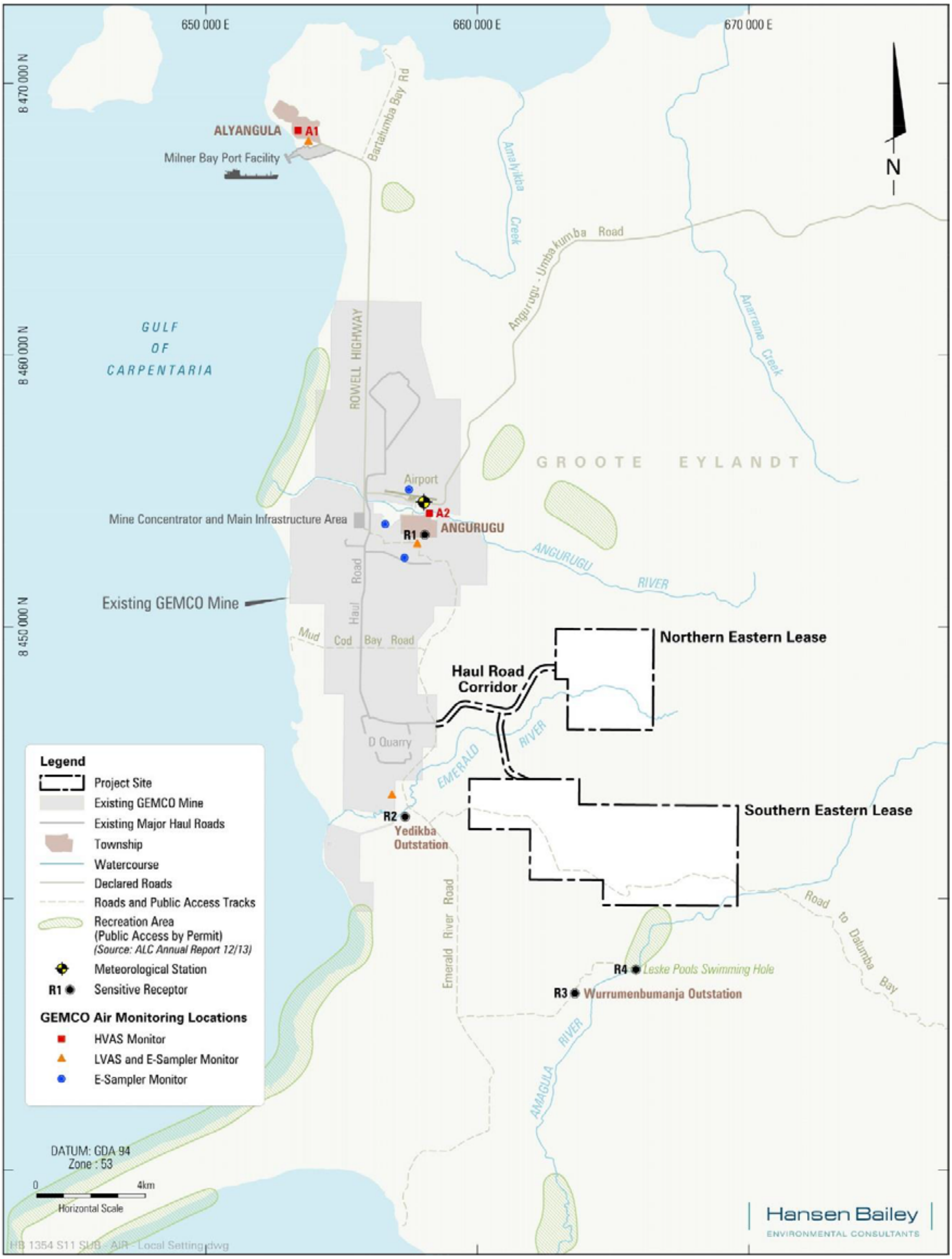

Figure 2	**GEMCO Eastern Leases Project - Local Setting**	
Location: Groote Eylandt, NT	**Prepared by:** Hansen Bailey	**Date:** February 2015

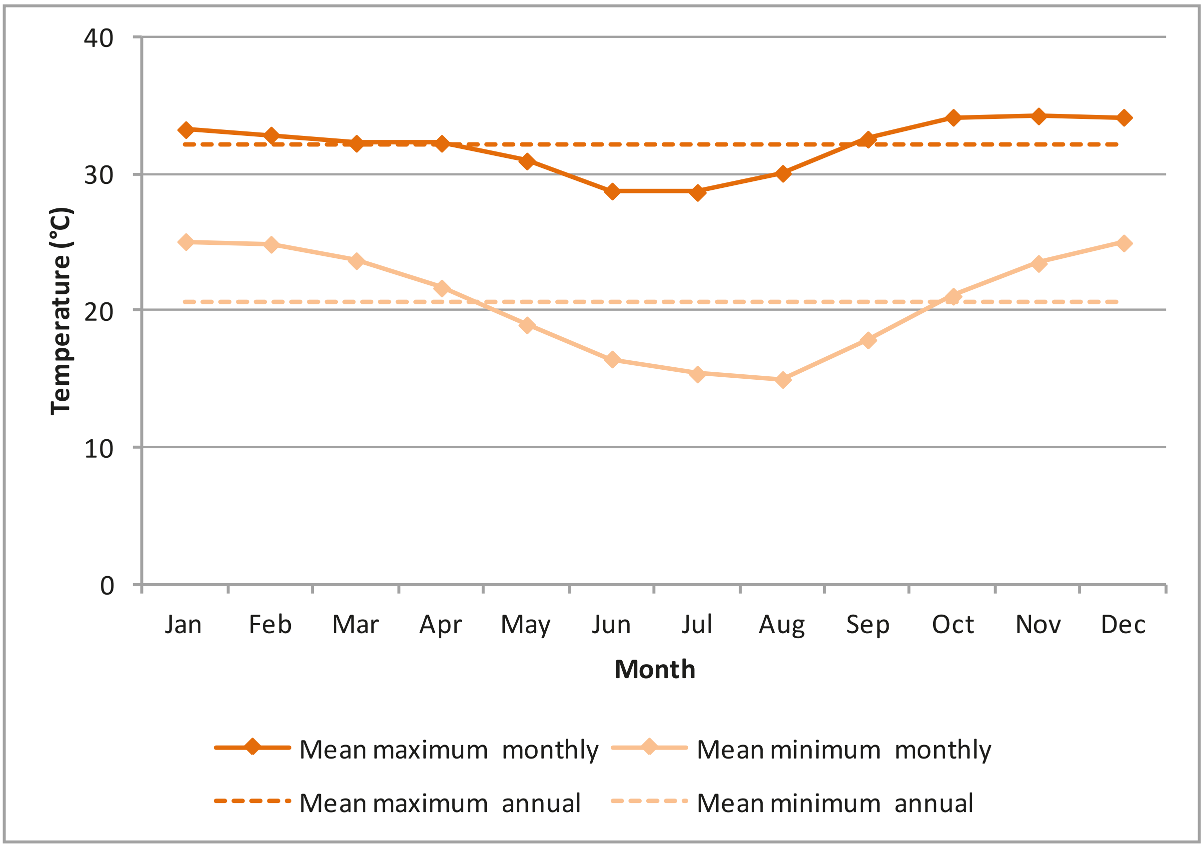

Figure 3	**Mean recorded daily minimum and maximum temperatures at Groote Eylandt Airport BoM Monitoring Station by month**	
Location: Groote Eylandt, NT	**Data source:** BoM	**Units:** Degrees Celsius
Type: Time-series	**Prepared by:** Tania Haigh	**Date:** February 2015

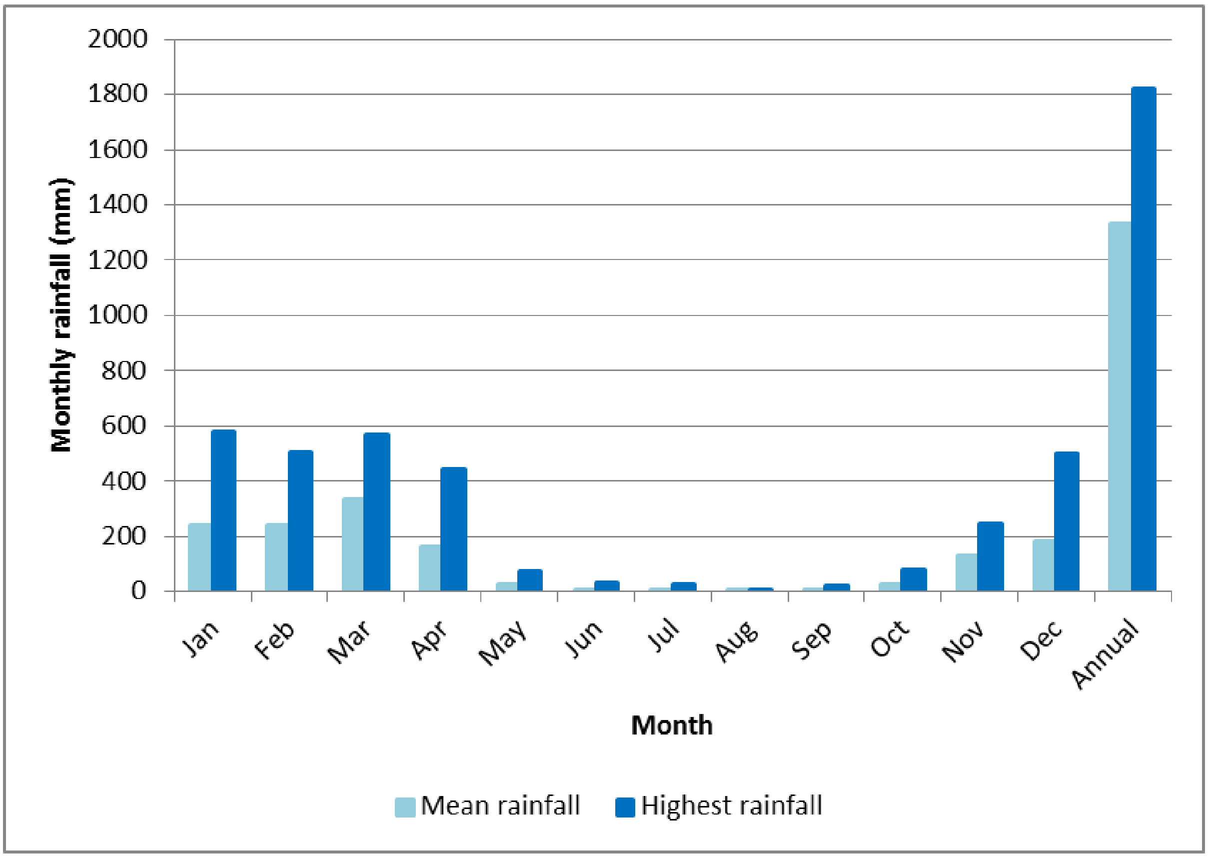

Figure 4 **Mean and highest rainfall recorded at Groote Eylandt Airport BoM Monitoring Station by month**

Location:	**Data source:**	**Units:**
Groote Eylandt, NT	BoM	Millimetres
Type:	**Prepared by:**	**Date:**
Time-series	Tania Haigh	February 2015

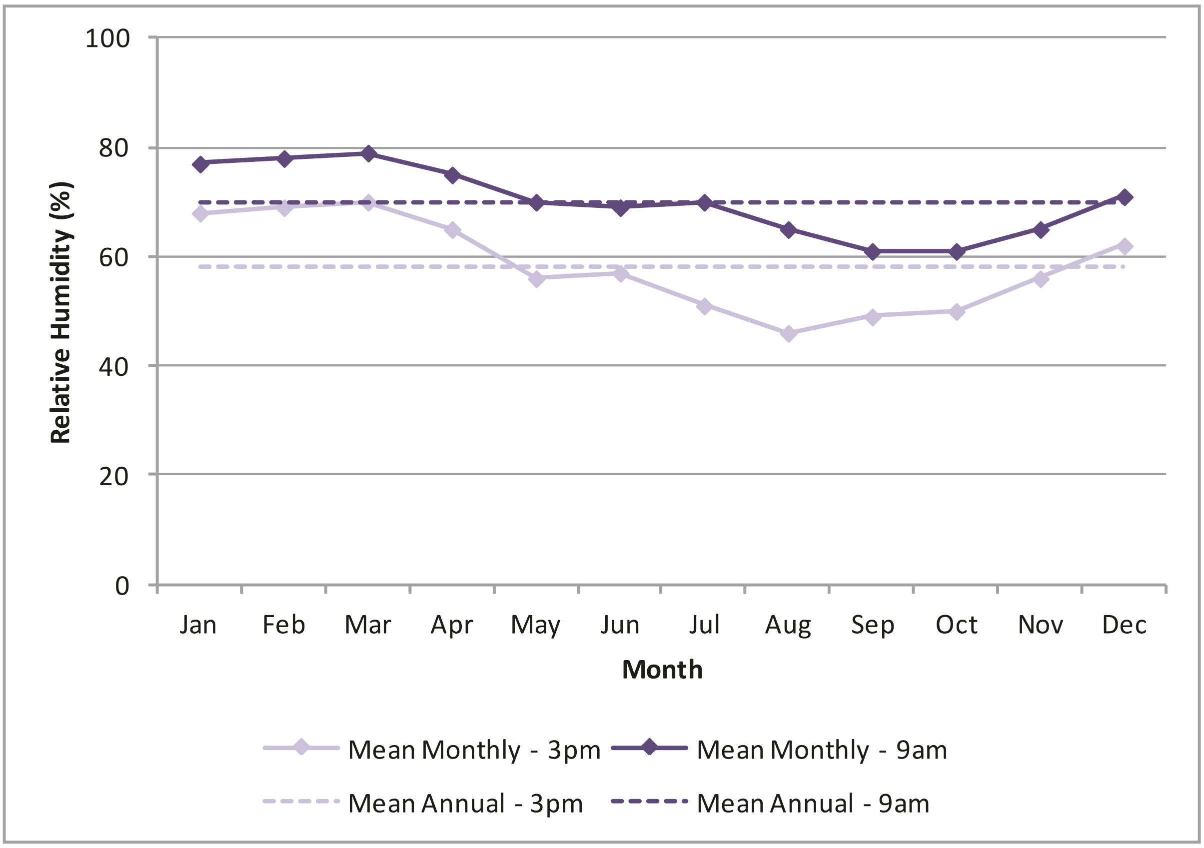

Figure 5	**Mean 9am and 3pm relative humidity recorded at Groote Eylandt Airport BoM Monitoring Station by month**

Location:	**Data source:**	**Units:**
Groote Eylandt, NT	BoM	Percent
Type:	**Prepared by:**	**Date:**
Time-series	Tania Haigh	February 2015

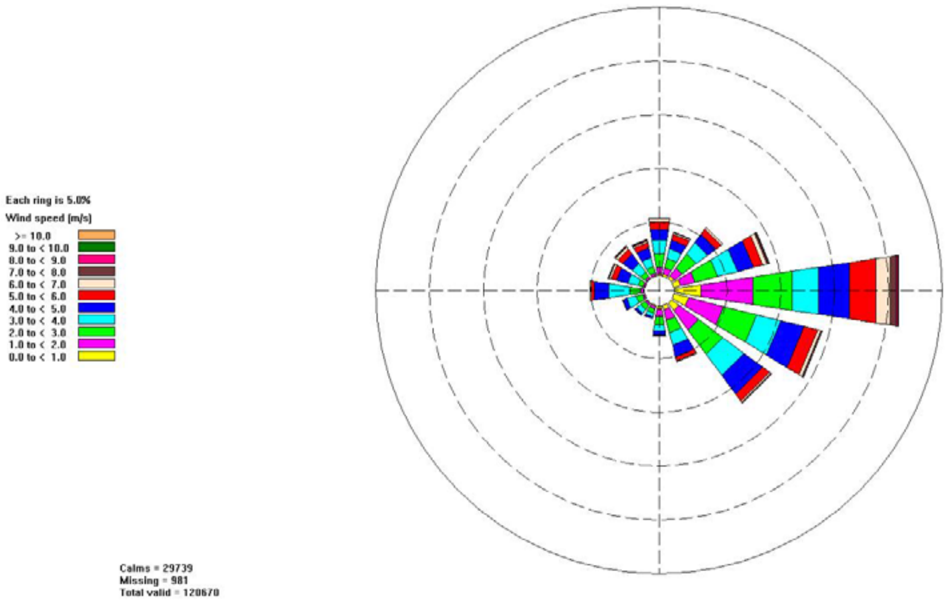

Figure 6 Annual distribution of winds at Groote Eylandt Airport

Location: Groote Eylandt	**Period:** 2000 to 2014	**Data source:** BoM	**Units:** m/s and °
Type: Wind rose		**Prepared by:** Tania Haigh	**Date:** February 2015

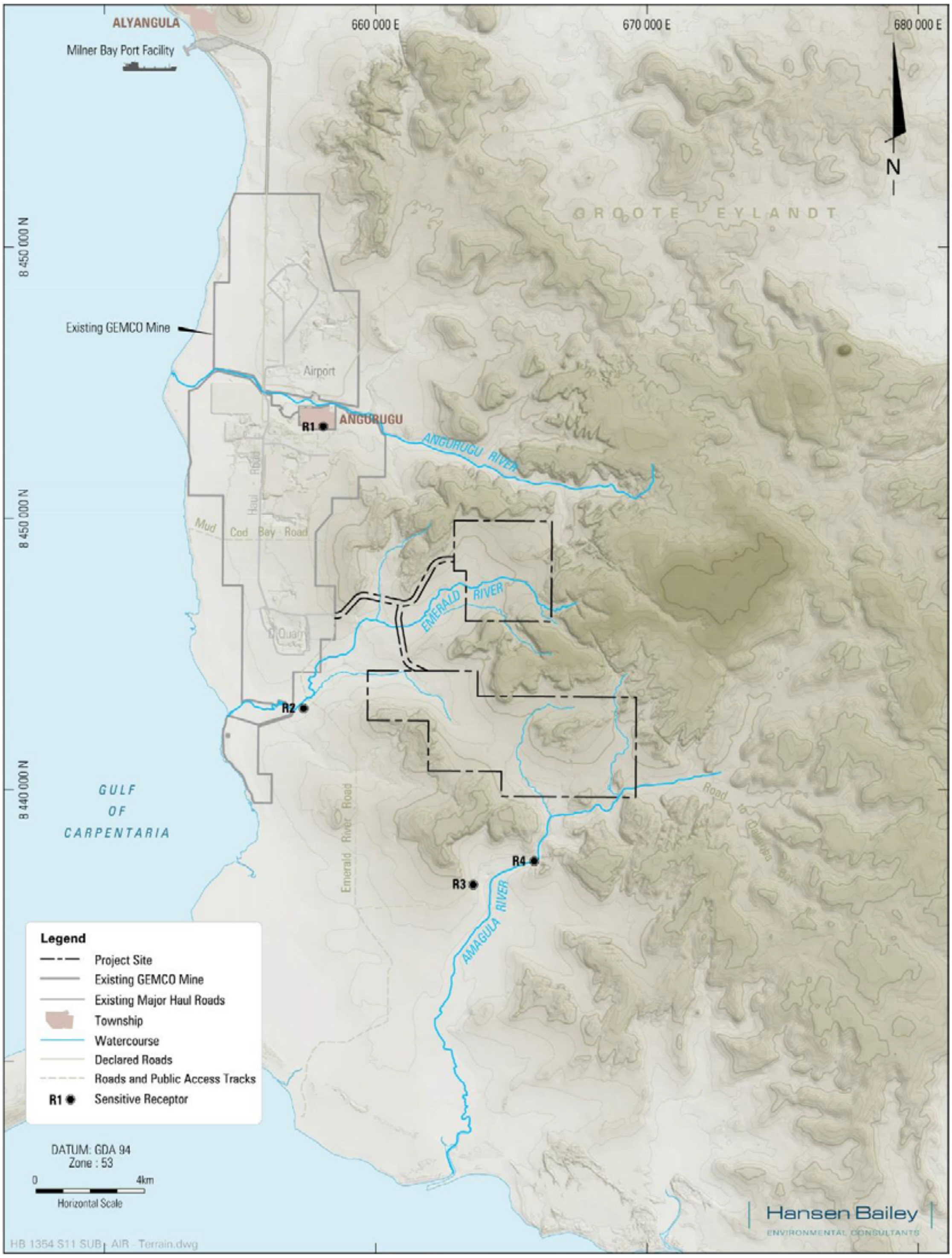

Figure 7 **Terrain surrounding the Eastern Leases Project**

Location:	**Prepared by :**	**Date:**
Groote Eylandt, NT	Hansen Bailey	February 2015

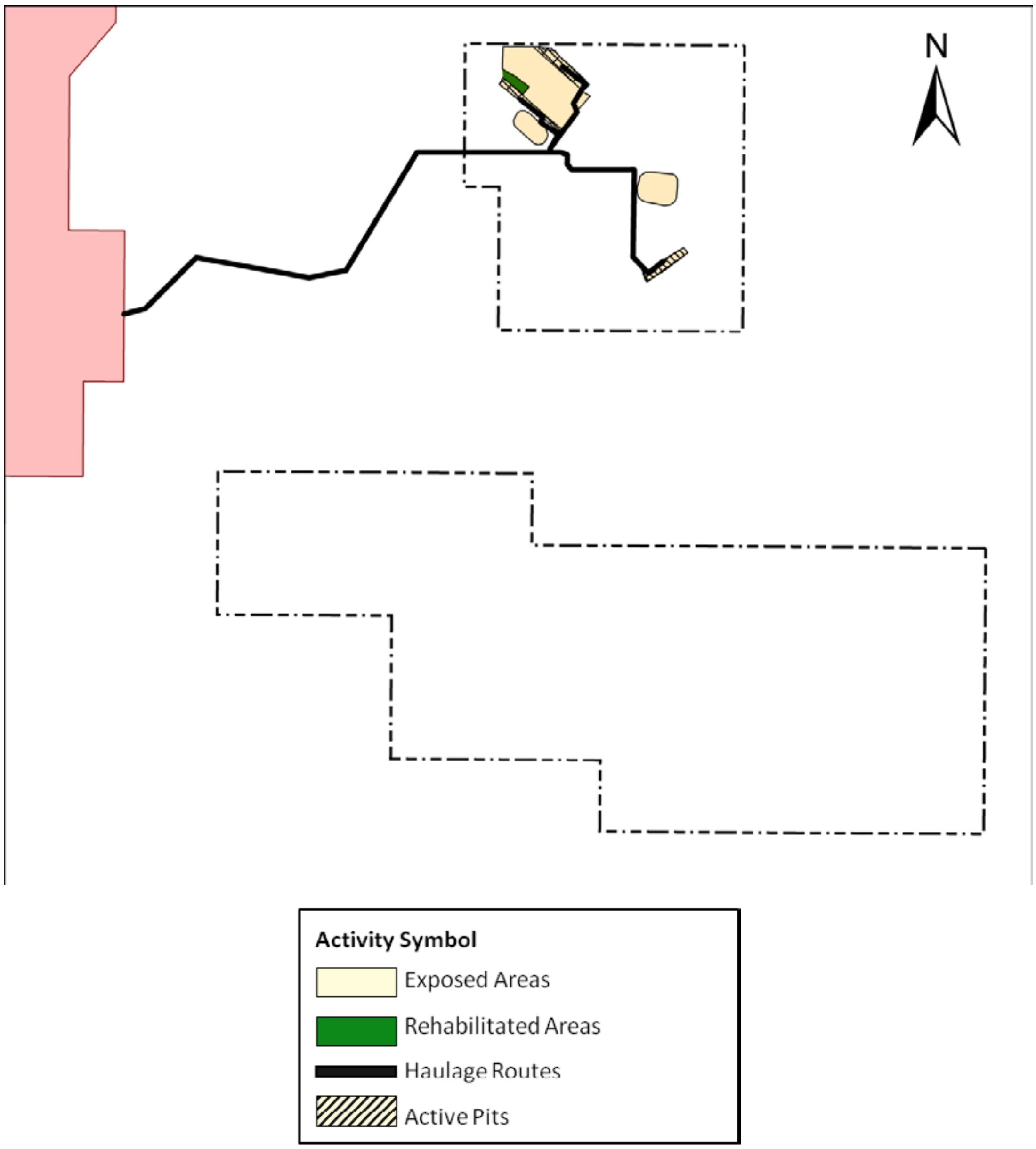

Figure 8 **Layout during Project Year 3**

Location: Project site, Groote Eylandt, NT	**Data source:** GEMCO	
Type: Schematic	**Prepared by:** Tania Haigh	**Date:** February 2015

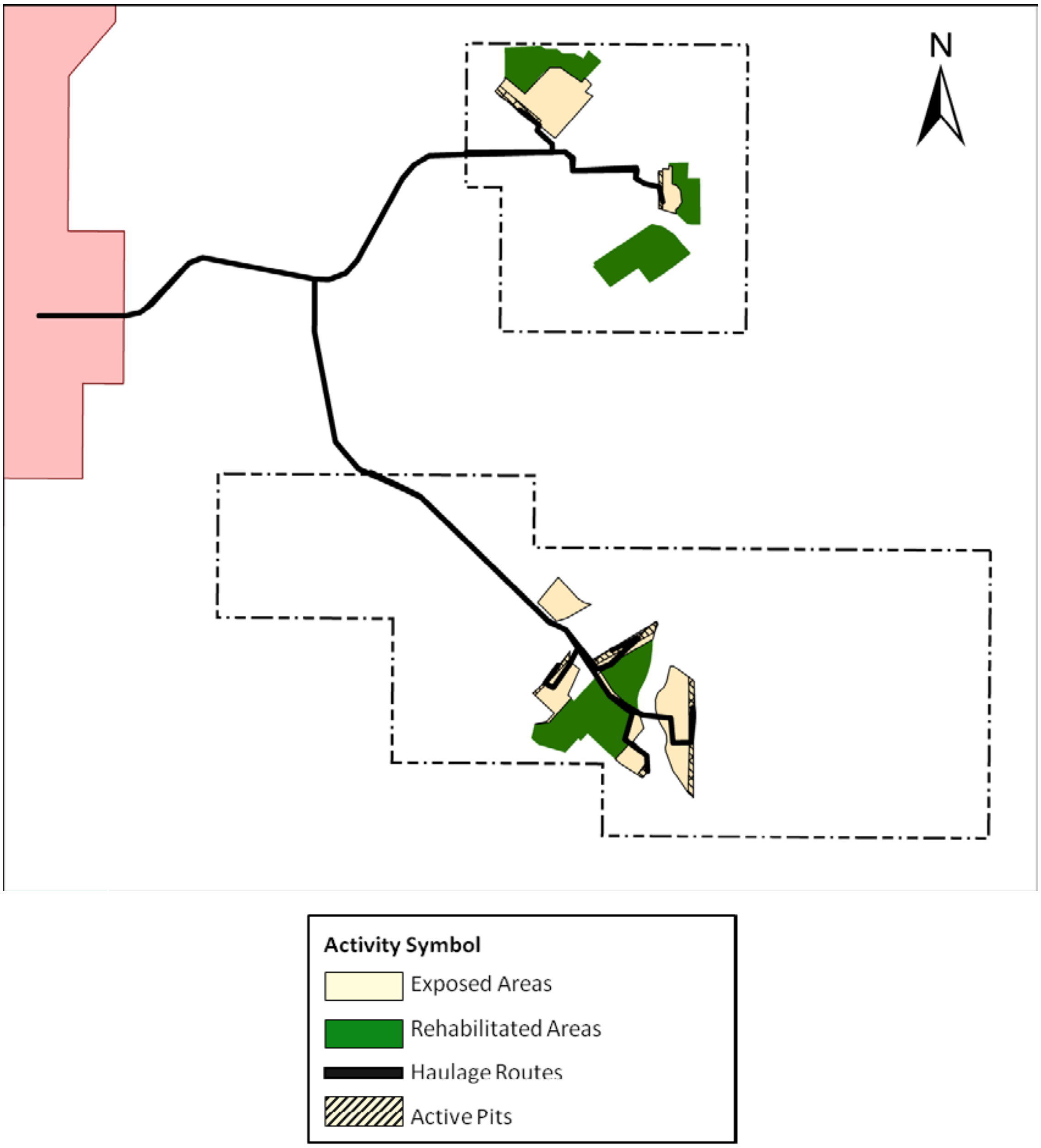

Figure 9	**Layout during Project Year 9**	
Location: Project site, Groote Eylandt, NT	**Data source:** GEMCO	
Type: Schematic	**Prepared by:** Tania Haigh	**Date:** February 2015

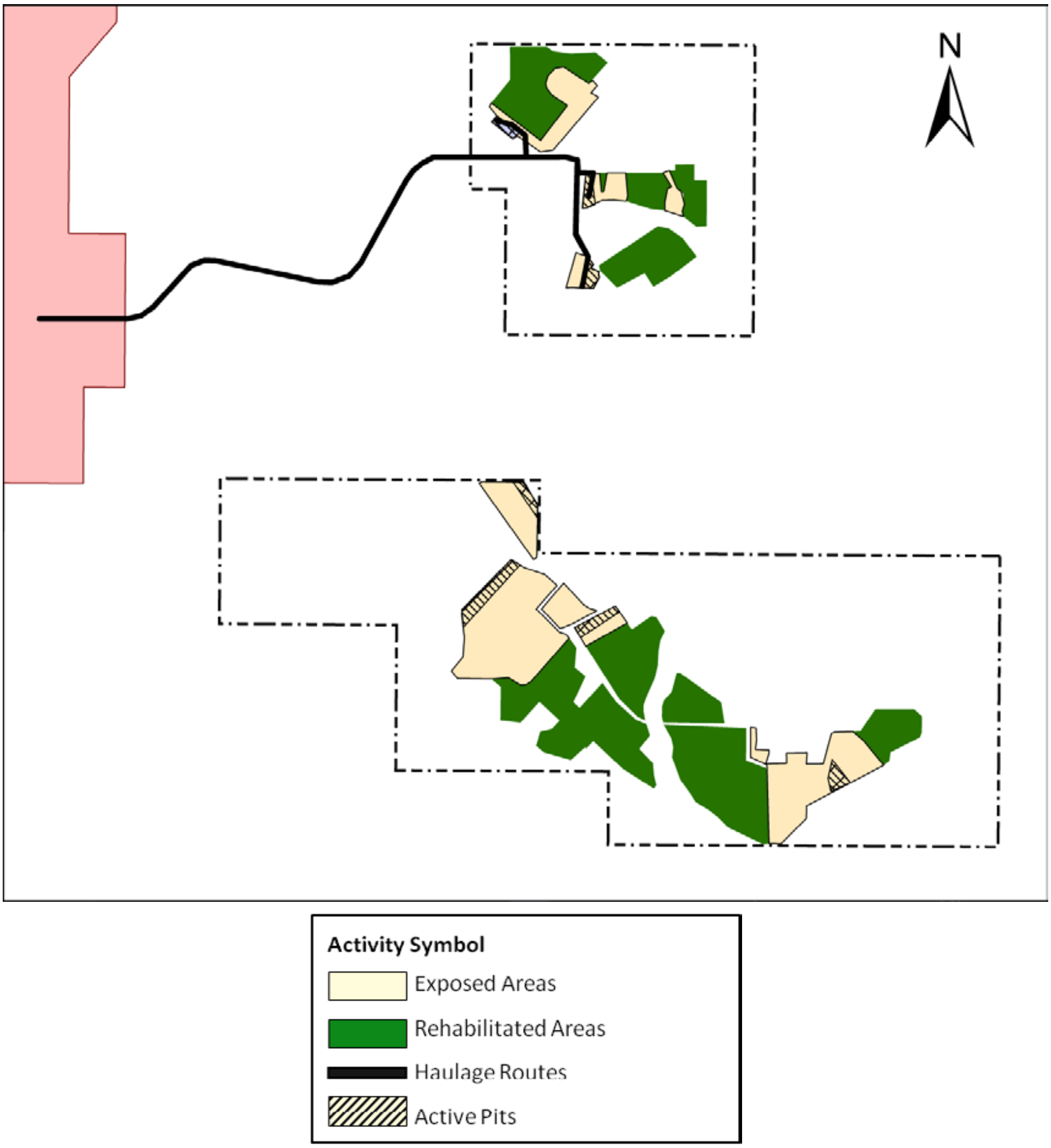

Figure 10 **Layout during Project Year 13**

Location: Project site, Groote Eylandt, NT	**Data source:** GEMCO	
Type: Schematic	**Prepared by:** Tania Haigh	**Date:** September 2014

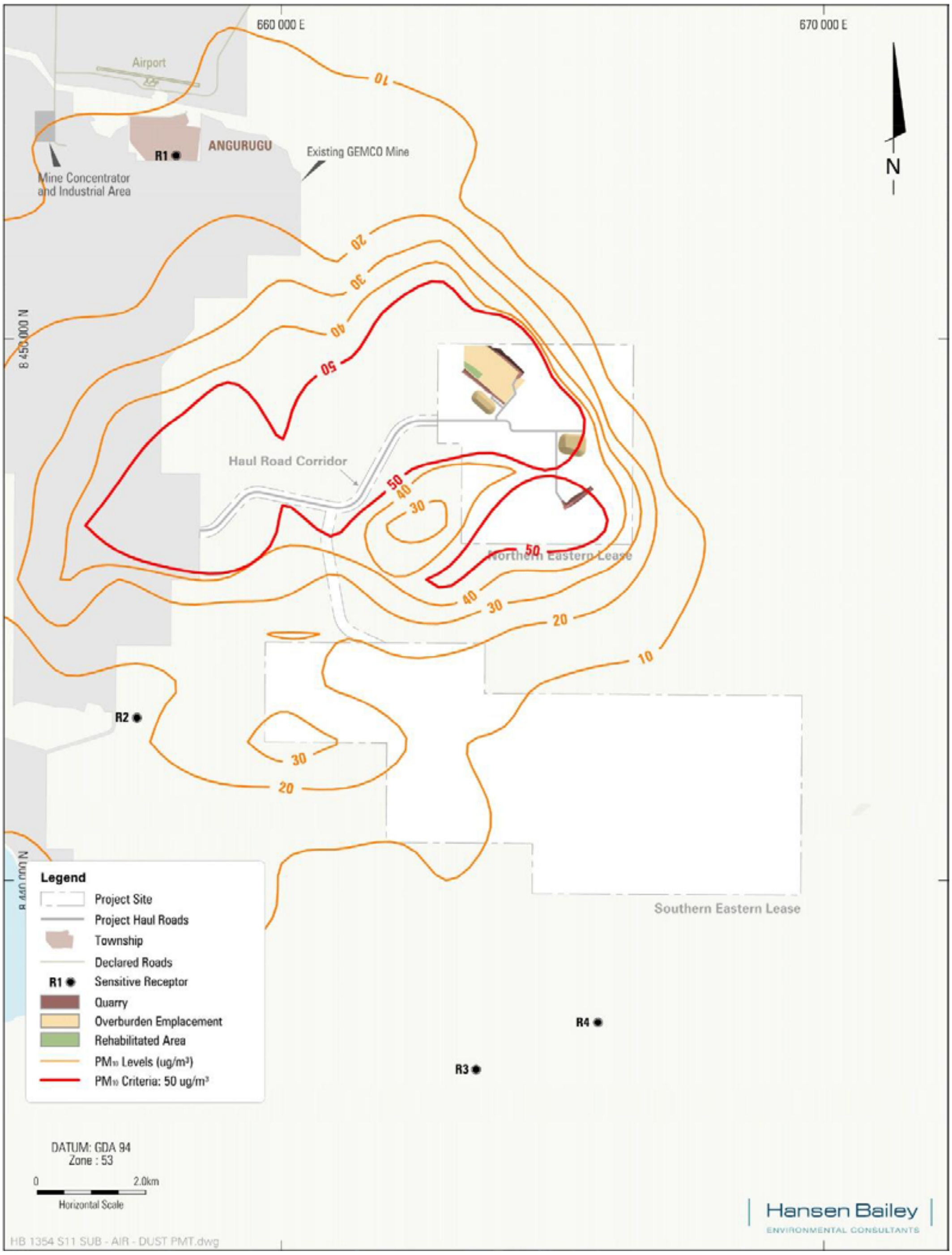

Figure 11 **Project Year 3 Predicted 6th highest 24-hour average ground-level concentrations of PM_{10} due to the project in isolation**

Location:	Averaging period:	Data source:	Units:
Groote Eylandt, NT	24-hour	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Maximum contours	50 µg/m³	Tania Haigh	February 2015

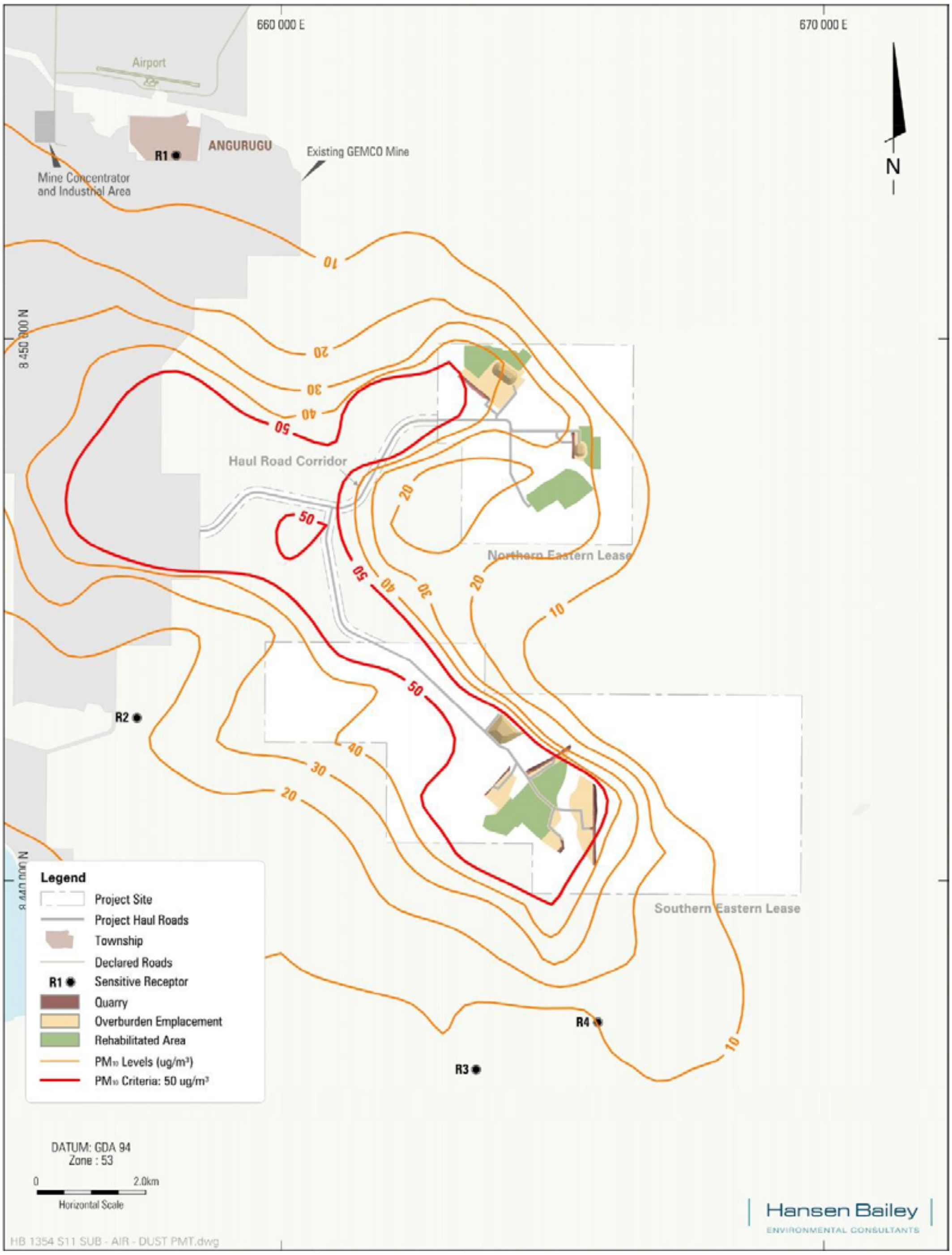

Figure 12 **Project Year 9 Predicted 6th highest 24-hour average ground-level concentrations of PM_{10} due to the project in isolation**

Location:	**Averaging period:**	**Data source:**	**Units:**
Groote Eylandt, NT	24-hour	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Maximum contours	50 µg/m³	Tania Haigh	February 2015

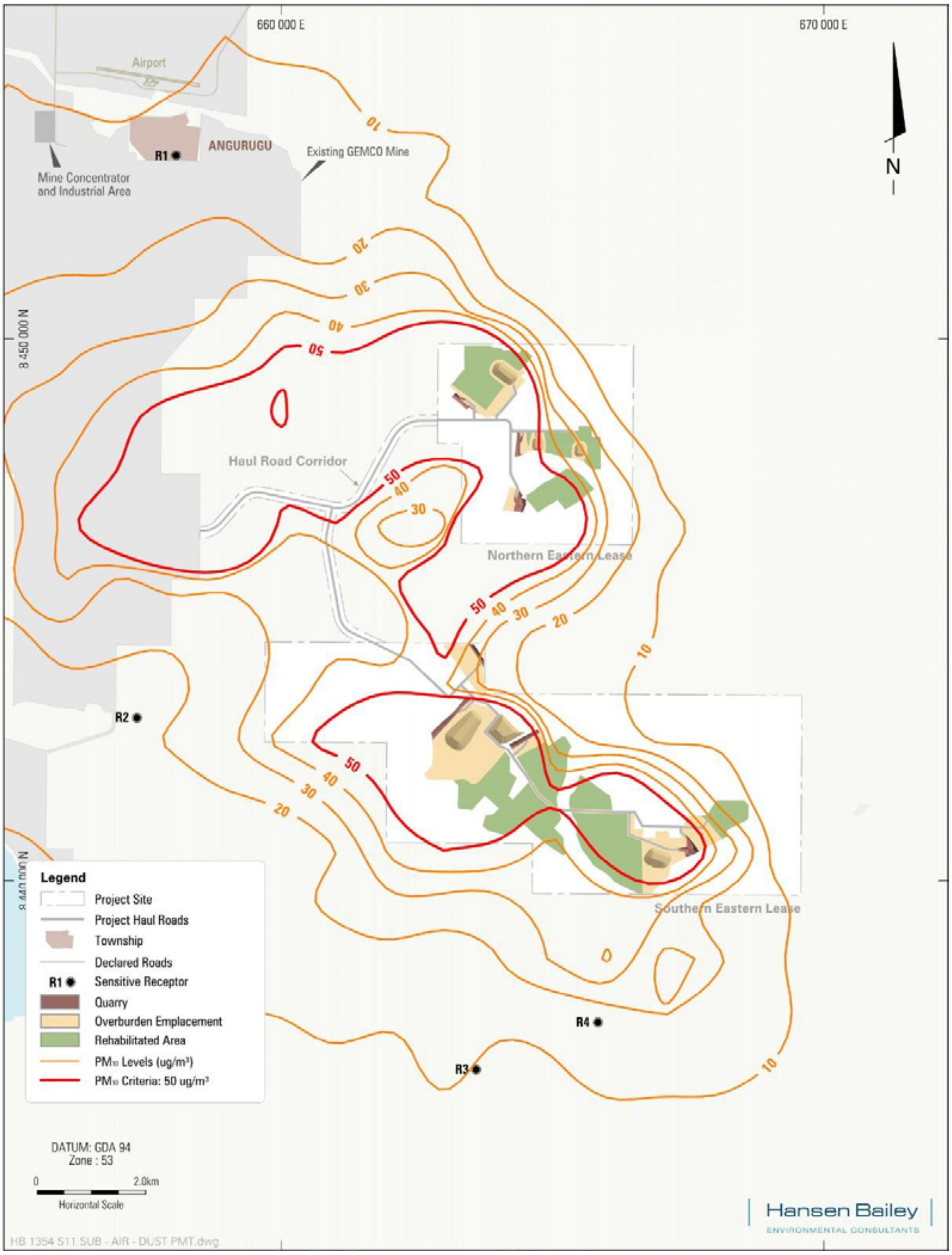

Figure 13 **Project Year 13 Predicted 6th highest 24-hour average ground-level concentrations of PM_{10} due to the project in isolation**

Location:	**Averaging period:**	**Data source:**	**Units:**
Groote Eylandt, NT	24-hour	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Maximum contours	50 µg/m³	Tania Haigh	February 2015

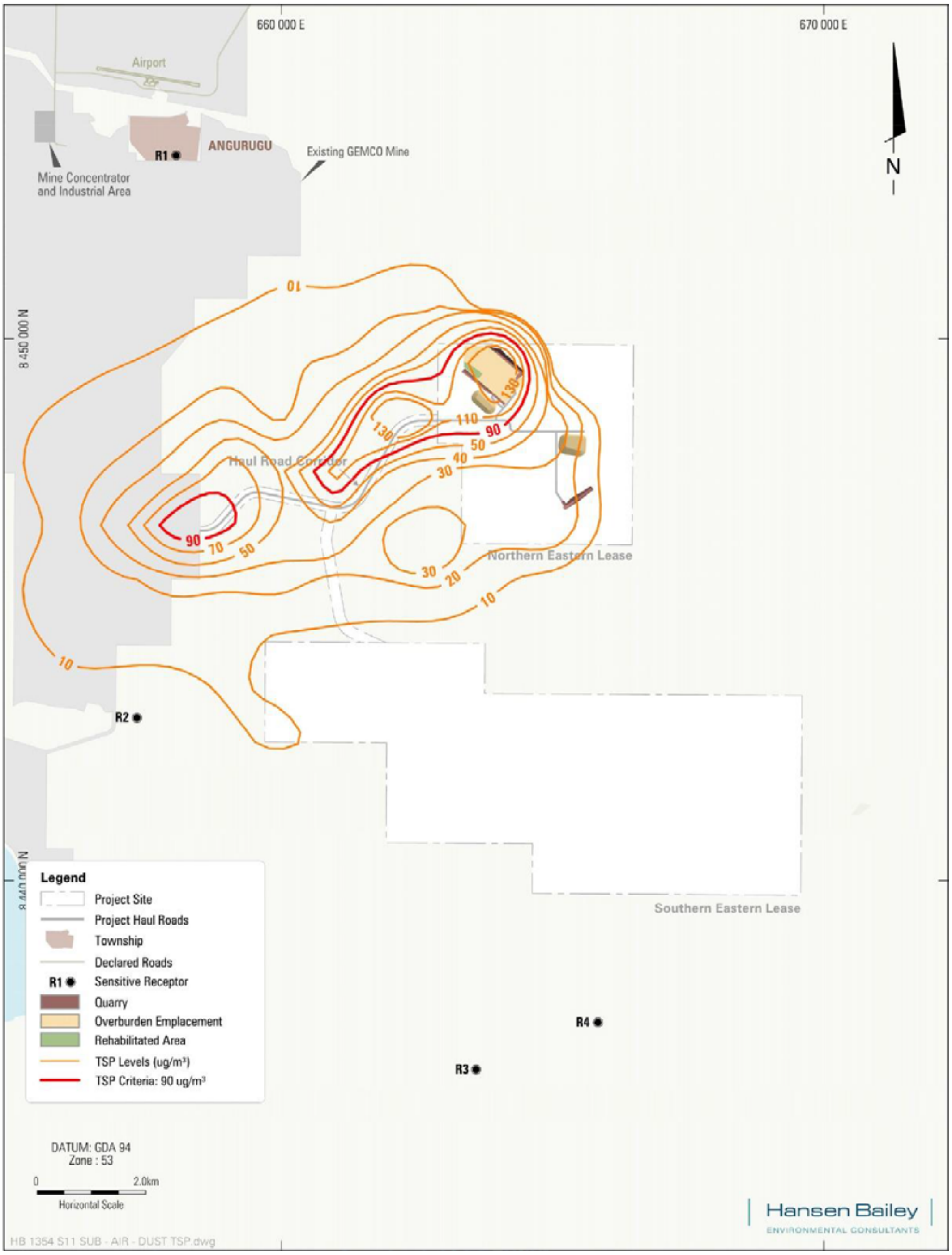

Figure 14 **Project Year 3 Predicted annual average ground-level concentrations of TSP due to the project in isolation**

Location:	**Averaging period:**	**Data source:**	**Units:**
Groote Eylandt, NT	1-year	CALPUFF	µg/m³
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	90 µg/m³	Tania Haigh	February 2015

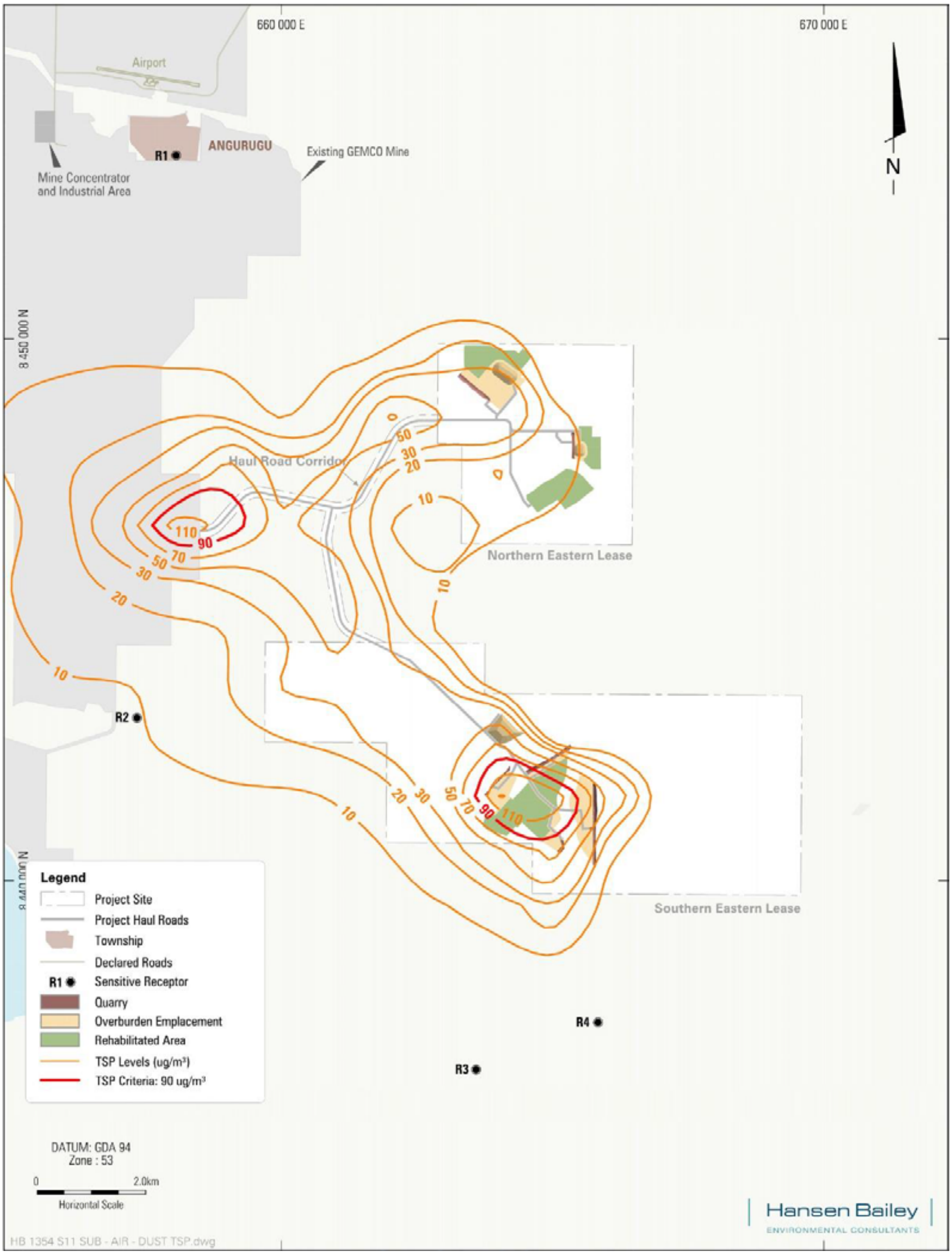

Figure 15 **Project Year 9 Predicted annual average ground-level concentrations of TSP due to the project in isolation**

Location: Groote Eylandt, NT	**Averaging period:** 1-year	**Data source:** CALPUFF	**Units:** µg/m^3
Type: Average contours	**Objective:** 90 µg/m^3	**Prepared by:** Tania Haigh	**Date:** February 2015

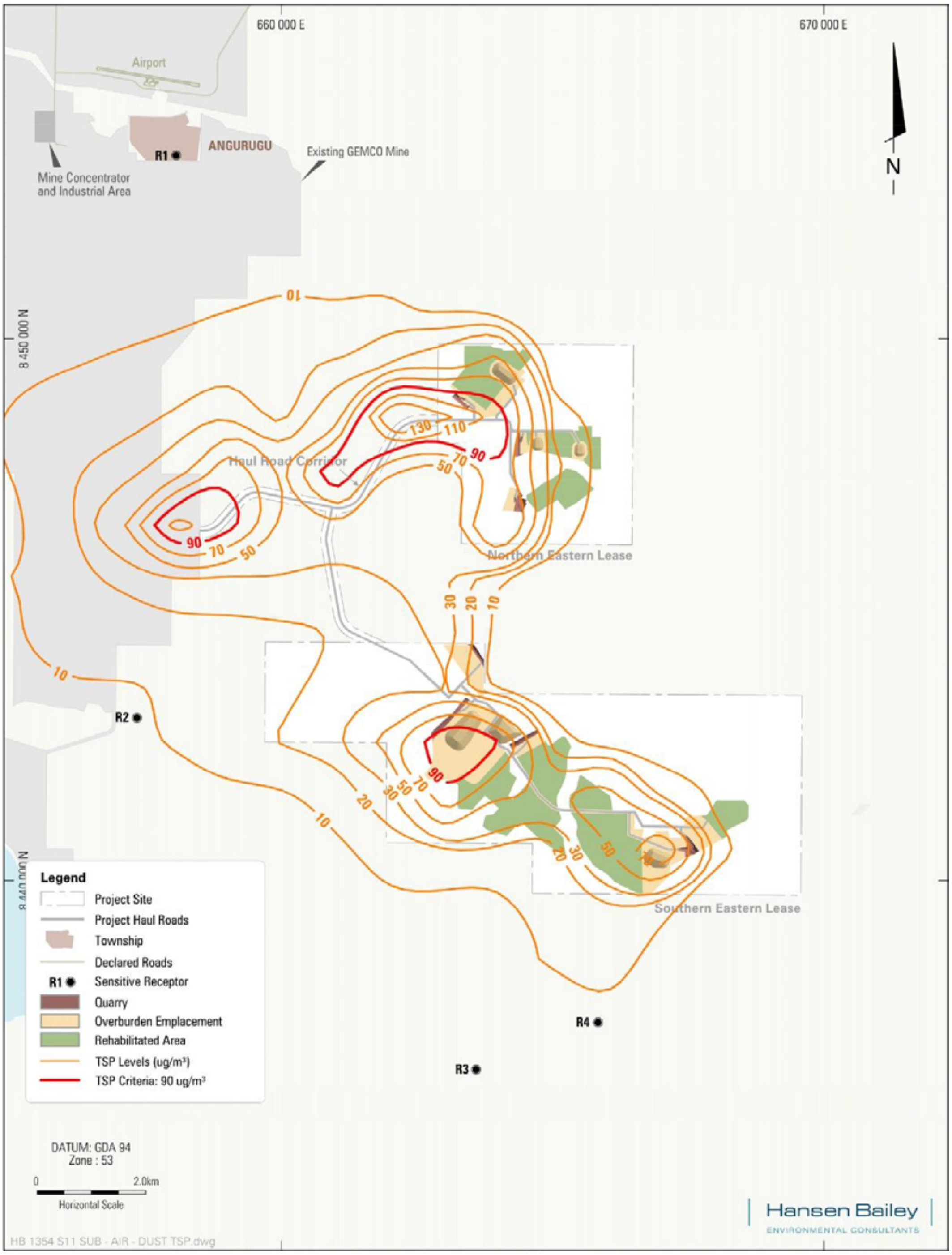

Figure 16 **Project Year 13 - Predicted annual average ground-level concentrations of TSP due to the project in isolation**

Location:	**Averaging period:**	**Data source:**	**Units:**
Groote Eylandt, NT	1-year	CALPUFF	µg/m^3
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	90 µg/m^3	Tania Haigh	February 2015

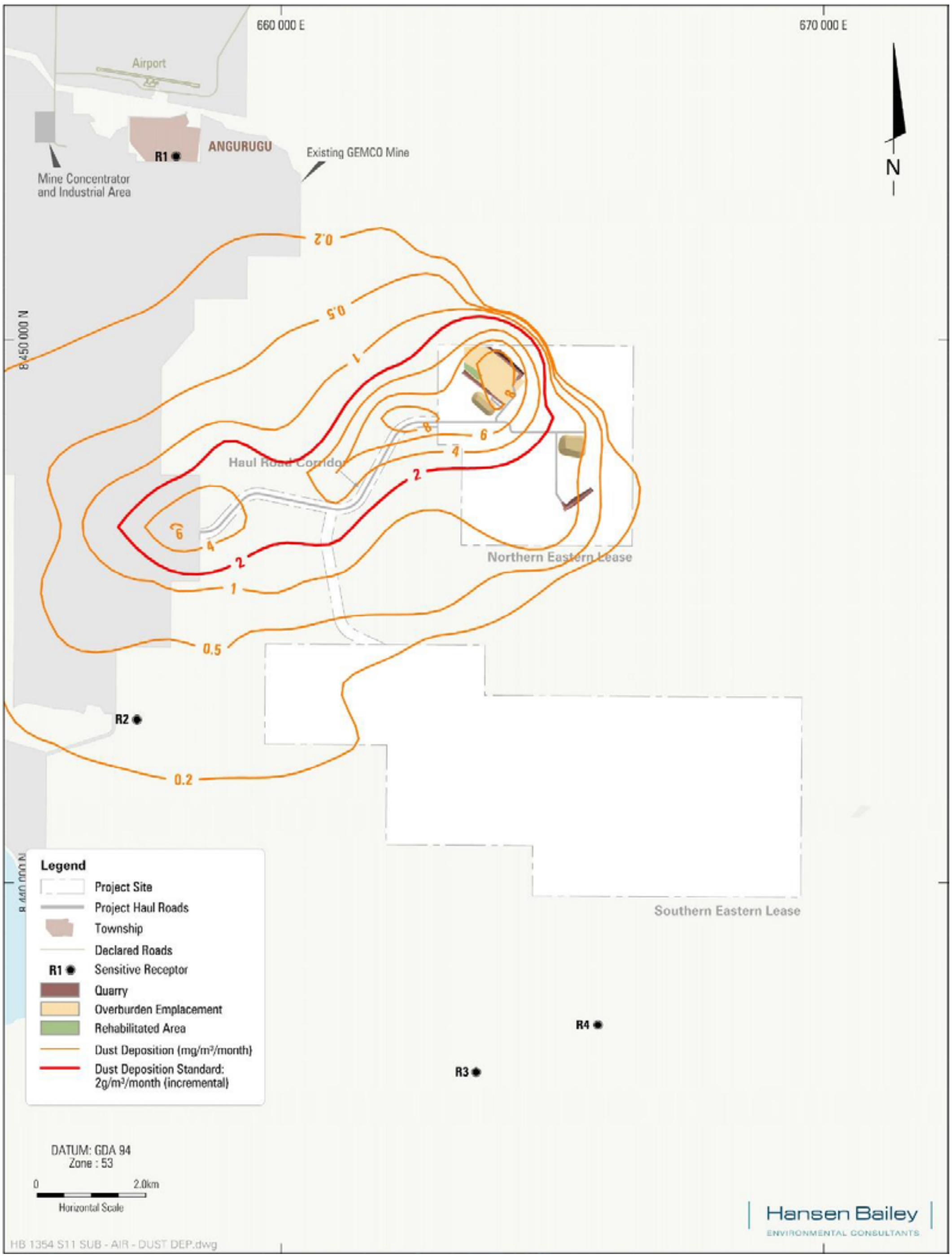

Figure 17 **Project Year 3 Predicted annual average dust deposition rate due to the project in isolation**

Location: Groote Eylandt, NT	**Averaging period:** 1-year	**Data source:** CALPUFF	**Units:** g/m²/month
Type: Average contours	**Objective:** 2 g/m²/month	**Prepared by:** Tania Haigh	**Date:** February 2015

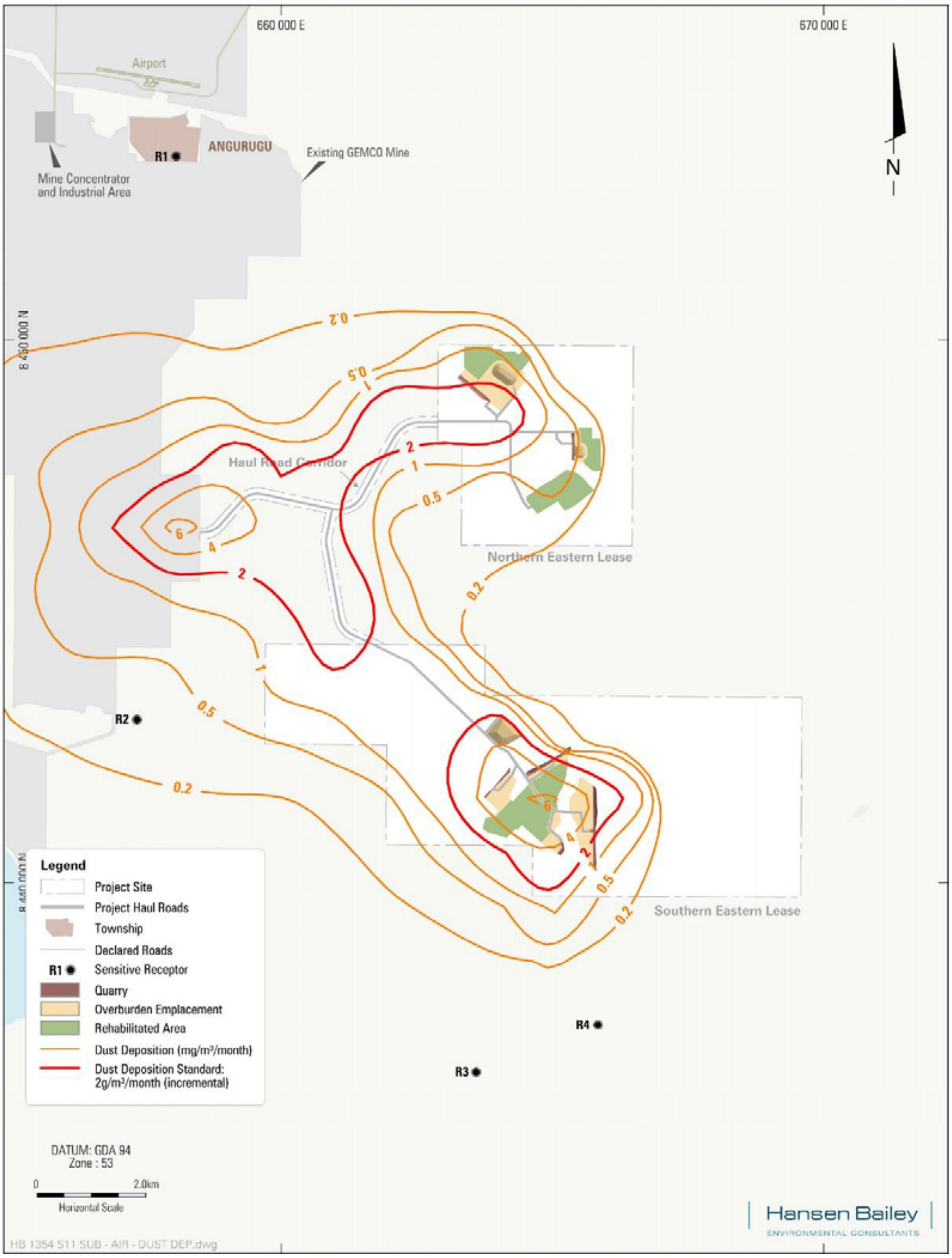

Figure 18 **Project Year 9 Predicted annual average dust deposition rate due to the project in isolation**

Location:	**Averaging period:**	**Data source:**	**Units:**
Groote Eylandt, NT	1-year	CALPUFF	g/m²/month
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	2 g/m²/month	Tania Haigh	February 2015

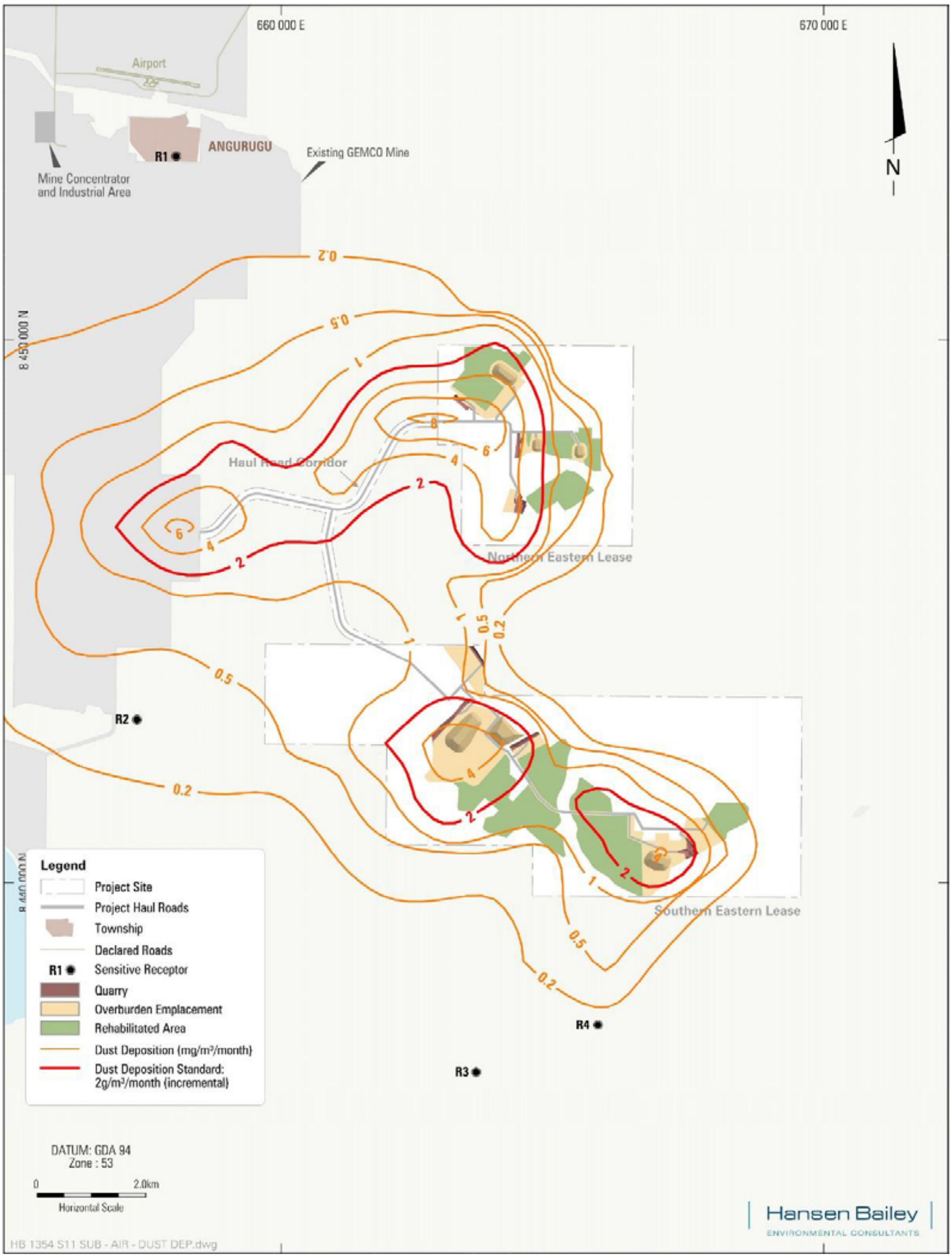

Figure 19 **Project Year 13 - Predicted annual average dust deposition rate due to the project in isolation**

Location:	**Averaging period:**	**Data source:**	**Units:**
Groote Eylandt, NT	1-year	CALPUFF	$g/m^2/month$
Type:	**Objective:**	**Prepared by:**	**Date:**
Average contours	$2\ g/m^2/month$	Tania Haigh	February 2015

APPENDIX A METEOROLOGICAL AND DISPERSION MODELLING METHODOLOGY

A1 Meteorological modelling

For the purposes of dispersion modelling a 3-dimensional meteorological database was required. The coupled TAPM/CALMET modelling system was used in order to generate a 3-dimensional database that is representative of the project site and Groote Eylandt. The data collected by the BoM at Groote Eylandt Airport weather station was incorporated into the modelling system through data assimilation to ensure that the meteorological modelling was representative of actual conditions.

The meteorological modelling methodology is consistent with industry standards and conforms to regulatory guidance documents. In particular, modelling was conducted in accordance with:

- The user's manuals for each model
- The *Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into The Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia* prepared for the NSW Office of Environment and Heritage – in the absence of specific guidelines by the NT EPA
- NSW Office of Environment and Heritage's (OEH) *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*

The meteorological conditions modelled were representative of the year 2013, as the Groote Eylandt Airport BoM station had 100% data capture in 2013 for all parameters.

Figure A1 shows the extent of the modelling domain, which was sized based on the following factors:

- Terrain influences;
- Location of sensitive receptors; and
- Guidance contained in the TAPM user guide.

The domain was made as large as possible to incorporate the sensitive receptors and existing mining operations.

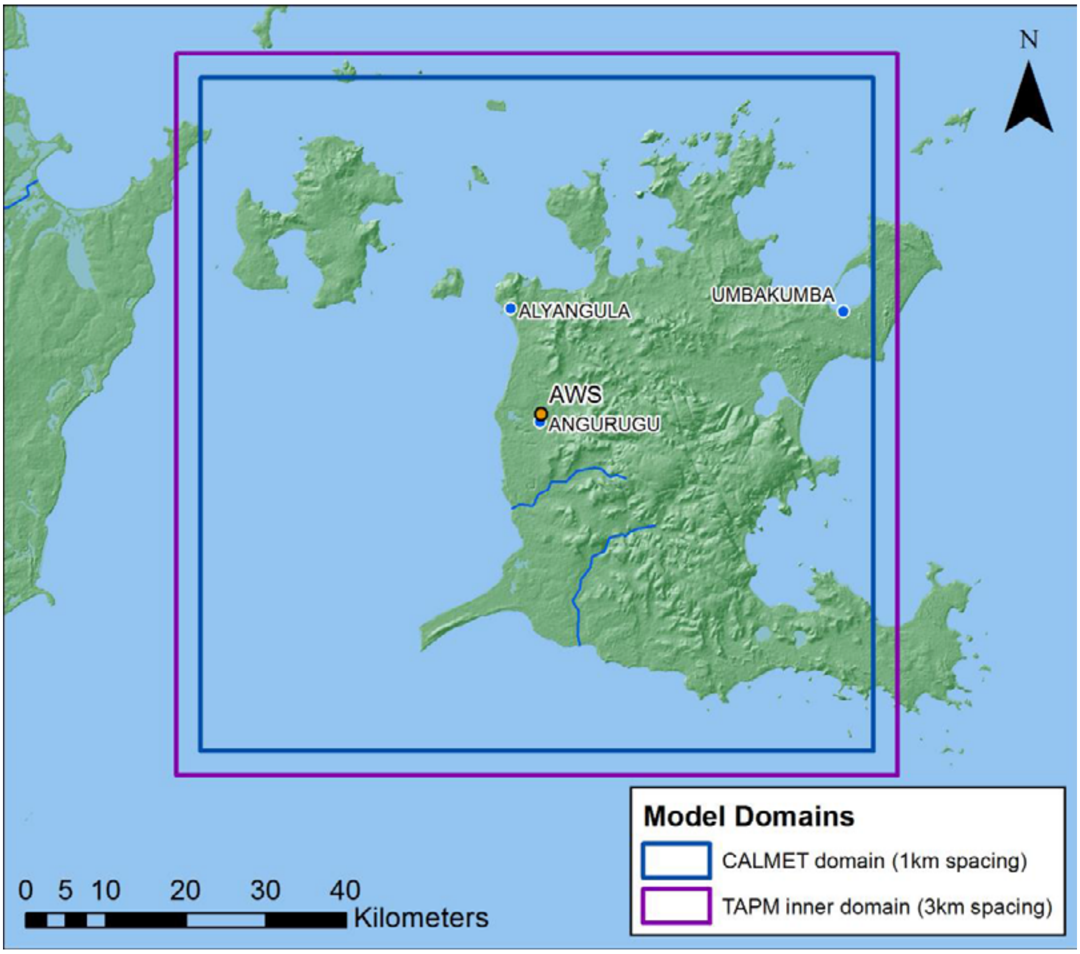

Figure A1 Modelling domains

A1.1 TAPM meteorological simulations

TAPM was configured as follows:

- Mother domain of 30 km with 2 nested daughter grids of 10 km and 3 km
- 30 x 30 grid points for all modelling domains resulting in a 90 x 90 km domain at 3 km resolution
- 25 vertical levels; from the surface up to an altitude of 8000 metres above ground level
- AUSLIG 9 second DEM terrain data
- The TAPM defaults for sea surface temperature and land use
- Default options selected for advanced meteorological inputs
- Year modelled; 1 January 2013 to 31 December 2013
- The BoM monitoring station at Groote Eylandt Airport was assimilated into the model

The TAPM configuration is consistent with the guidance documents detailed in section A1.

A1.2 CALMET meteorological simulations

Key features of the CALMET configuration used to generate the 3D-wind fields are as follows:

- Domain area of 84 by 84 grid points at 1 km spacing
- Twelve vertical levels set at 20 m, 60 m, 100 m, 150 m, 200 m, 250 m, 350 m, 500 m, 800 m, 1600 m, 2600 m and 4600 m
- 365 days (1 January 2013 to 31 December 2013)
- Prognostic wind fields generated by TAPM input as MM5/3D.dat at surface and upper air for "initial guess" field
- A distance for the influence of terrain of 10 km
- Terrain data for 90m resolution using Shuttle Radar Topography Data (SRTM3)

The CALMET configuration is consistent with the guidance documents detailed in section A1.

A1.3 Validation of model performance

An evaluation of the performance of the meteorological model is presented in the following section. The evaluation compares the observational meteorological data from the Groote Eylandt Airport BoM monitoring station with output from CALMET, which was run using a dataset generated by TAPM with data assimilation. The observational data were assimilated into TAPM to improve the model performance particularly in relation to the frequencies of calms and low wind speeds and the generated dataset was then used as input into CALMET.

Table A1 presents statistical comparisons of TAPM/CALMET output (wind speed and temperature) to meteorological data recorded at the Groote Eylandt Airport BoM monitoring station. Figure A2 shows probability density functions that graphically compare statistical distributions of meteorological parameters between the TAPM/CALMET output and observational data. The TAPM/CALMET output was extracted from the closest inner grid point to the location of the automatic weather station.

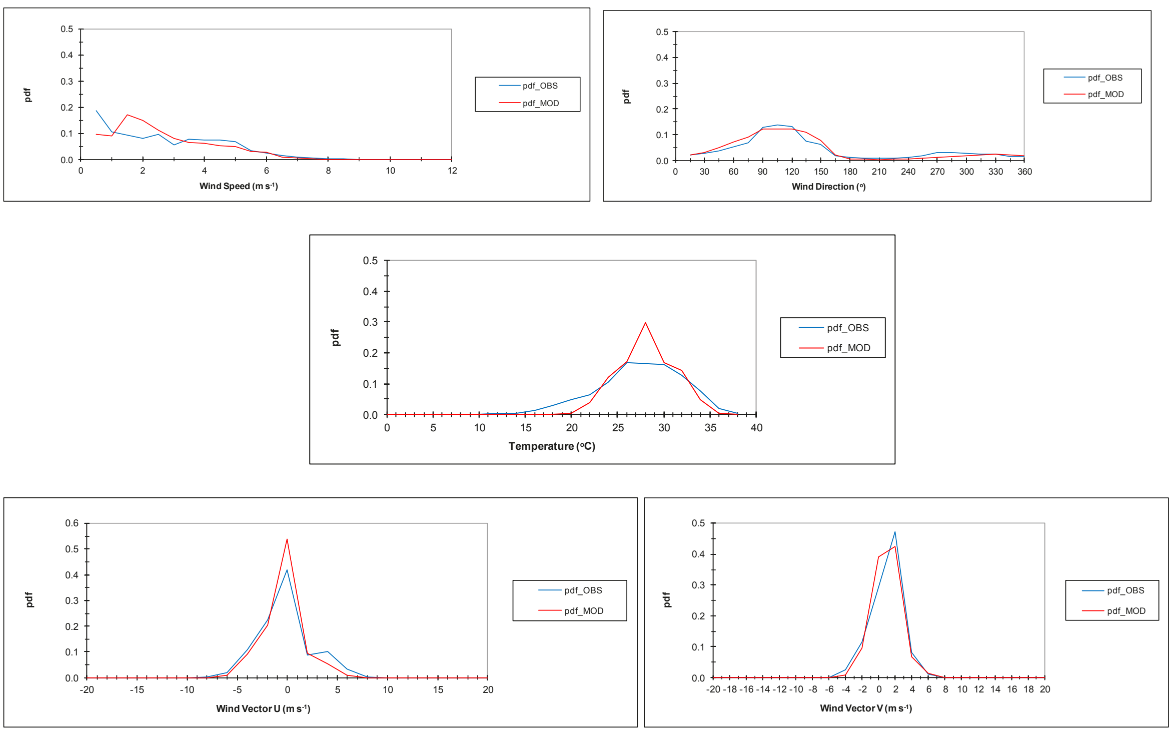

Figure A2 Probability density functions (pdfs) comparing observational on site data (blue) with TAPM/CALMET

The following statistical measures of model accuracy are presented in the tables.

The **mean bias**, which is the mean model prediction minus the mean observed value. Values of the mean bias close to zero show good prediction accuracy.

The **root mean square error (RMSE)**, which is the standard deviation of the differences between predicted values and observed values. The RMSE is non-negative and values of the RMSE close to zero show good prediction accuracy.

The RMSE is given by:

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

where:

N is the number of observations;

P_i are the hourly model predictions; and

O_i are the hourly observations

The **index of agreement (IOA)**, which takes a value between 0 and 1, with 1 indicating perfect agreement between predictions and observations. The IOA is calculated following a method described in Willmott (1982), using the equation:

$$\text{IOA} = 1 - \frac{\sum_{i=1}^{N}(P_i - O_i)^2}{\sum_{i=1}^{N}(|P_i - O_{mean}| + |O_i - O_{mean}|)^2}$$

where:

N is the number of observations;

P_i are the hourly model predictions;

O_i are the hourly observations; and

O_{mean} is the observed observation mean.

Table A1 shows that the majority of the statistics are within the benchmarks for good performance of a meteorological model and therefore the results of the model are representative of the area. The exception to this is the temperature bias, which was found to be only marginally outside the benchmark range. This is not a significant issue because the emission rates and dispersion of those emissions from the Eastern Leases Project are strongly dependent on the wind distribution, which the model predicted well. The ambient temperature is not a significant factor for modelling dust from mining activities, where the plume is not buoyant.

Table A1 **A comparison of the observed meteorological data with the first-level CALMET output**

Statistic	"Good" value	Wind speed			Temperature		
		Benchmark	Observational data	CALMET	Benchmark	Observational data	CALMET
Mean	-	-	2.4	2.2	-	26.4	26.9
Standard deviation	-	-	1.9	1.4	-	4.6	3.1
Minimum	-	-	0	0	-	9.6	18.7
Maximum	-	-	11.1	7.8	-	37.5	36.1
Bias	0	<±0.5 m/s	-0.19		≤±0.5 °C	0.55	
Root mean square error (RMSE)	Close to 0	<2 m/s	0.97		-	2.63	
Index of agreement	Close to 1	>0.6	0.91		≥0.8	0.88	

A1.4 Site-specific meteorology

This section presents an analysis of the site-specific meteorological data generated by the coupled TAPM/CALMET modelling system. The meteorological data cover the twelve month period from 1 January 2013 to 31 December 2013. The meteorological data presented in this section is from the Groote Eylandt Airport BoM monitoring station, which is representative of the proposed location of the Eastern Leases Project.

A1.4.1 Wind speed and direction

The annual, diurnal and seasonal distributions of winds at the project site are presented as wind roses in Figure A3, Figure A4 and Figure A5, respectively.

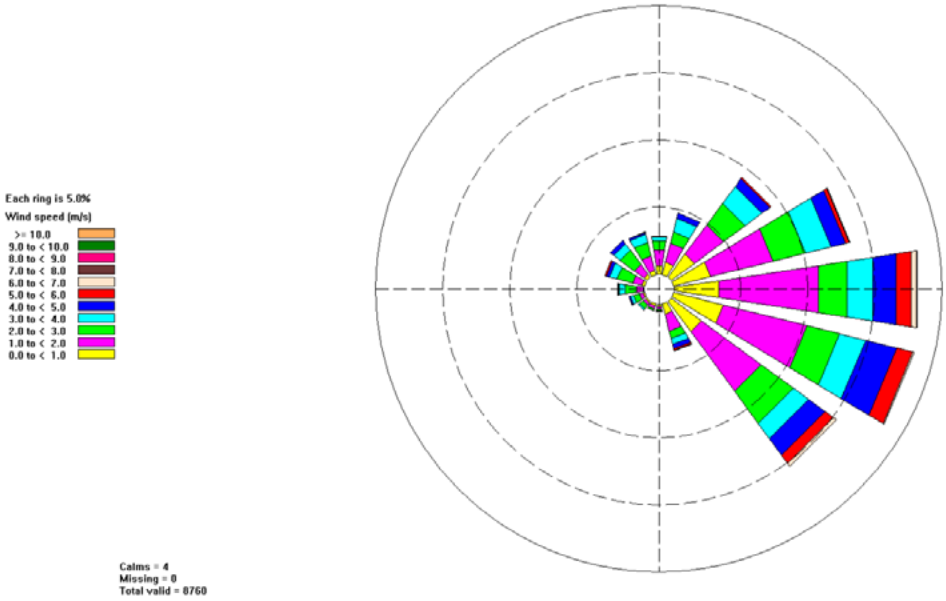

Figure A3 Predicted annual wind rose at the project site

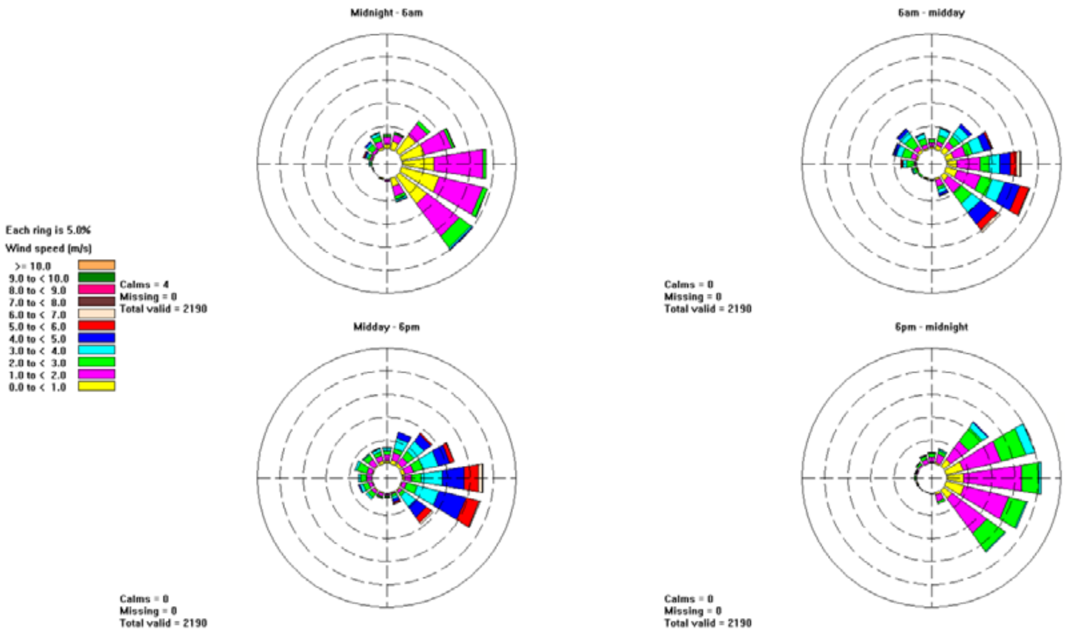

Figure A4 Predicted diurnal distribution of winds at the project site

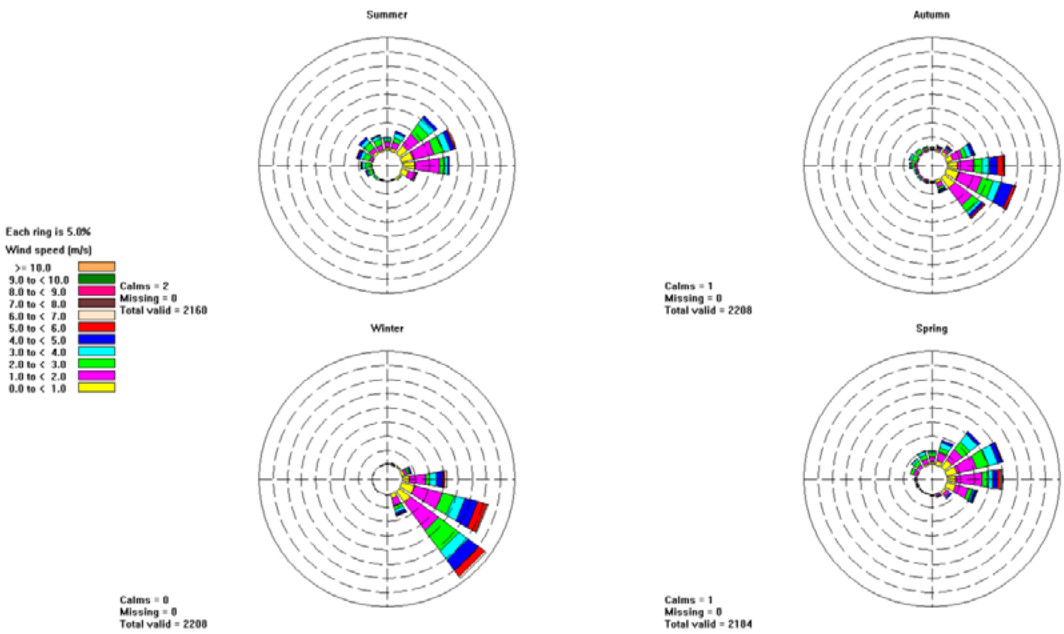

Figure A5 Predicted seasonal distribution of winds at the project site

The annual wind rose (Figure A3) shows the predominant wind directions are from the easterly quadrants, with the strong winds tending to occur from the southeast to east. The diurnal distribution of winds (Figure A4) illustrates that overnight winds are typically lighter than wind speeds during the day. Between midnight and midday, south-easterlies are dominant, whereas during the afternoon winds are predominantly from the east (east-north-easterly to east-south-easterly). Winds are most frequently from the northeast between 6pm and midnight.

There is quite a distinct variation in the seasonal frequency of wind direction (Figure A5). During spring and summer winds are predominantly north-easterly, whereas winter and autumn winds are characterised by south-easterlies. The strongest winds are expected to occur during autumn and winter. Northwesterlies are more frequent during the warmer seasons of the year, as would be expected given the topical location of the project and the influence of the monsoon.

In terms of the proposed mine, the frequency of wind speeds and the distribution of wind direction are key factors in the dispersion of pollutants. Activities at the Eastern Leases Project leading to dust emissions will include:

- Excavation and mining of quarries
- Haulage
- Crushing and screening
- Wind erosion of stockpiles and exposed areas

Strong winds, particularly wind speeds that are greater than 5 m/s, enhance dust generation from mining activities. Activities that involve dropping materials, cleared areas and stockpiles will emit higher levels of dust during stronger winds. The strongest winds at the site are expected to occur predominantly during autumn and winter, and during the daytime (6am - 6pm). Rainfall will act to suppress dust emissions from all activities. Consequently, during the wet season dust emissions will generally be suppressed.

The sensitive receptors identified for the project may be downwind of dust generating activities, particularly during the autumn and winter months. Dust management and control at these times should be focused to minimise emissions.

A1.4.2 Mixing height

The mixing height refers to the height above ground within which particulates or other pollutants released at or near ground can mix with ambient air. During stable atmospheric conditions, the mixing height is often quite low and particulate dispersion is limited to within this layer. During the day, solar radiation heats the air at the ground level and causes the mixing height to rise. The air above the mixing height during the day is generally cooler. The growth of the mixing height is dependent on how well the air can mix with the cooler upper level air and therefore depends on meteorological factors such as the intensity of solar radiation and wind speed. During strong wind speed conditions the air will be well mixed, resulting in a high mixing height.

Mixing height information has been extracted from the CALMET simulation at the Project site and is presented in Figure A6. The data shows that the mixing height develops around 7am, increases to a peak around 3 pm before descending rapidly after 4pm.

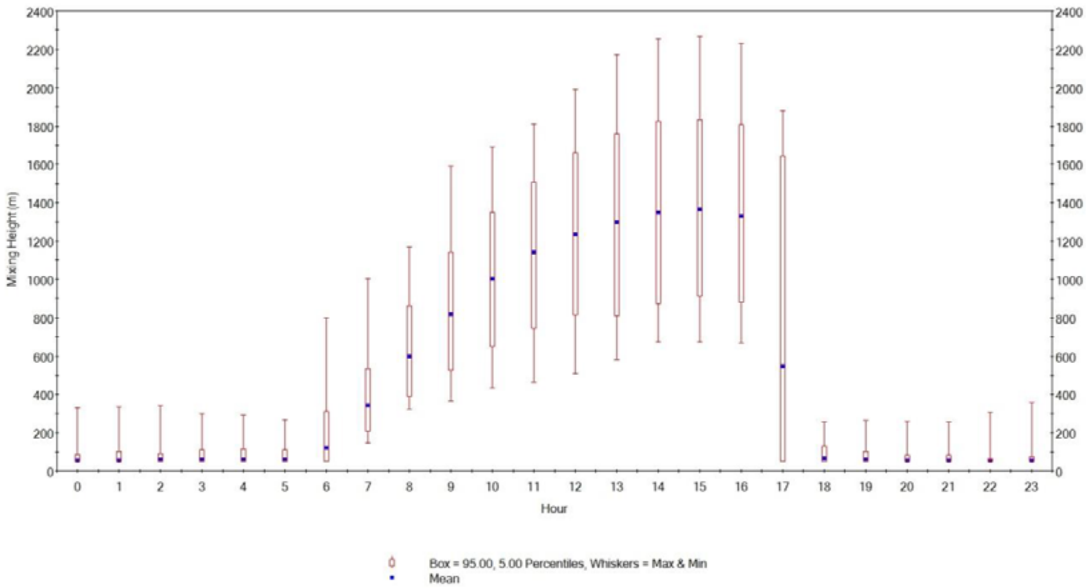

Figure A6 Predicted mixing height at the project site

A1.4.3 Atmospheric stability

Stability classification is a measure of the stability of the atmosphere and can be determined from wind measurements and other atmospheric measurements. The stability classes range from A Class, which represents very unstable atmospheric conditions that may typically occur on a sunny day, to F Class stability which represents very stable atmospheric conditions that typically occur during light wind conditions at night. Unstable conditions (Classes A to C) are characterised by strong solar heating of the ground that induces turbulent mixing in the atmosphere close to the ground. This turbulent mixing is the main driver of dispersion during unstable conditions. Dispersion processes for Class D conditions are dominated by mechanical turbulence generated as the wind passes over irregularities in the local surface. During the night, the atmospheric conditions are generally stable (often Classes E and F).

Table A2 shows the percentage of stability classes at the Project site for the January to December 2013 period. The most frequently occurring stability class at the Eastern Leases Project site is class F, characterised by low wind speeds and low cloud cover.

Table A2 Frequency of occurrence (%) of surface atmospheric stability at the Project site under the Pasquil-Gifford stability classification scheme

Pasquil-Gifford stability class	Classification	Frequency (%)
A	Extremely unstable	3%
B	Unstable	16%
C	Slightly unstable	19%
D	Neutral	13%
E	Slightly stable	4%
F	Stable	45%

A1.5 CALPUFF dispersion modelling

CALPUFF (version 6.42) was used to simulate the dispersion characteristics and concentrations of pollutants generated by the proposed activities. Hourly varying meteorological conditions used to drive the dispersion model were generated by CALMET as described in the previous section.

The dispersion model has been used to predict pollutant concentrations on a gridded receptor network corresponding to the modelling domain and at discrete points corresponding to the locations of sensitive receptors.

Key features of CALPUFF used to simulate dispersion:

- Domain area of 84 x 84 grids at 1 km spacing, equivalent to the domain defined in CALMET;
- 365 days modelled (1 January 2013 to 31 December 2013);
- No chemical transformation or wet removal;
- Dispersion coefficients internally calculated from sigma v and sigma w using micrometeorological variables;
- Dry depletion on for dust sources;
- Minimum wind speed for non-calm conditions set to 0.2 m/s; and
- All other options set to default.

Topsoil removal, haulage and dumping, as well as blasting will not occur overnight and so were modelled as occurring 12 hours/day only. All other activities were modelled using a constant emission rate for all hours of the day and night.

APPENDIX B ACTIVITY DATA

B1 ACTIVITY DATA

Table B1 List of activity data and assumptions used in estimation of dust emission rates

Parameter	Units	Value		
		Project Year 13	Project Year 9	Project Year 3
Operating hours				
Blasting, topsoil removal, haulage, dumping, rehabilitation works	hours/day	12	12	12
	days/year	365	365	365
All other activities	hours/day	24	24	24
	days/year	365	365	365
Throughput				
Topsoil	tpa	635,370	524,041	380,964
Overburden - total	tpa	20,350,370	7,455,790	8,298,396
Maximum ore extraction and transportation rate	t/day	24,000	24,000	24,000
Equipment				
Haul truck capacity (Cat 777)	t	95	95	95
Haul truck empty weight	t	65	65	65
Dozers extracting overburden	Number	12	12	12
	Hours/yr (total)	105120	105120	105120
Dozers on ore	Number	3	3	3
	Hours/yr (total)	26280	26280	26280
Grader (Cat 16M)	Number	1	1	1
Grader average speed	Km/h	8	8	8
Grader operating hours	Hours/year	8760	8760	8760
Grader distance travelled annually	VKT/yr	70080	70080	70080
Drilling and Blasting				
Number of holes drilled	holes/year	63250	56500	35500
Number of blasts	blasts/year	126	113	71
Spacing between holes	m	4	4	4
Number of rows	number	25	25	25
Holes per row	number	10	10	10
Area loaded per day	m²	4000	4000	4000
Maximum area blasted per day (based on 3 days of loading being blasted at once)	m²	12000	12000	12000
Haul Roads				
Northern EL ore haul	m	9640	9618	10900

Parameter	Units	Value		
		Project Year 13	**Project Year 9**	**Project Year 3**
Northern EL overburden haul	m	770	380	935
Southern EL ore haul	m	15100	12990	0
Southern EL overburden haul	m	1300	970	0
Exposed Areas				
Total exposed, unrehabbed areas (active quarry, overburden dumping and emplacement areas)	ha	407.14	201.33	112.45
Partly rehabilitated areas – 60% control	ha	384.89	210.60	4.23
Fully rehabilitated areas - 100% control	ha	210.60	4.23	0.00
Meteorological parameters				
Mean wind speed	m/s	2.64	2.64	2.64

APPENDIX C METHODOLOGY FOR CALCULATING DUST EMISSIONS FROM INDIVIDUAL SOURCES

C1 Drilling

Dust emitted during drilling was estimated based on the emission factor defined in the NPI. The TSP emission factor is 0.59 kg/hole. The ratio of PM_{10} to TSP emissions used were those defined for blasting in the NPI (52%).

C2 Blasting

The emission rate for blasting has been calculated using the following equation (NPI, 2012):

$EF_{TSP} = 0.00022 \times A^{1.5}$

where:

EF_{TSP}: TSP blasting emission factor (kg/blast)

A: Area blasted (m²)

Blasting was assumed to occur during daylight hours and was modelled between 6 am and 6 pm. Of TSP emissions, 52% are estimated to be PM_{10}. The particulate matter distribution is based on size particle distribution for blasting as defined in the AP42.

C3 Transfer points

Transfer points are locations where material is transferred from one location to another. Emissions are dependent on the amount of materials transferred (kg/tonne of material).

Emission rates for transfer points were calculated using the following equation (NPI, 2001):

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

where:

k: 0.74 for particles less than 30 µm

0.35 for particles less than 10 µm

U: Mean wind speed in m/s

M: Material moisture content, 6.9% adopted in this study based on the mean value defined in AP42

Emissions from the loading of topsoil, overburden and ore to trucks, and the dumping of those materials from trucks were estimated using the transfer point emission factor.

C4 Bulldozing

Bulldozers will be used to excavate overburden as well as to clean up the ore after blasting. Emissions from dozing are dependent on hours of operation (kg/hr).

The TSP and PM_{10} emission factors for bulldozing were calculated using the equation for materials other than coal, as defined in the NPI and AP42 (NPI, 2012):

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

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

where

s: Silt content, 6.2% adopted in this study based on the mean value defined in AP42

M: Moisture content, 6.9% adopted in this study based on the mean value defined in AP42

The silt and moisture contents detailed in Table C1 were used in the emissions estimation.

Table C1 Material characteristics used in the emissions estimation

Parameter		Value	Source
Ore	Moisture content	7.0 %	Provided by GEMCO (lower end of the provided range was selected as a conservative approach)
	Silt content	6.2 %	Mean value for overburden defined in AP42
Overburden	Moisture content	7.9 %	Mean value for overburden defined in AP42
	Silt content	6.9 %	Mean value defined in AP42

No control factors have been applied for dozer activity.

C5 Wind erosion

Emissions from wind erosion of the active quarry, overburden emplacement, and other unused but exposed areas are dependent on the size of the exposed area (Mg/ha/yr). The emission rate is based on the equation defined in the AP42 for estimating emissions of wind exposed areas and is 0.85 Mg/ha/yr for TSP.

Of TSP emissions, 50% are estimated to be PM_{10}. The particulate matter distribution is based on size particle distribution for wind erosion as defined in the AP42 and the NPI.

The Eastern Leases area will be progressively rehabilitated. To account for this, emissions from areas expected to be fully or partly rehabilitated were reduced using the control factors of 100% and 60% respectively, as defined in the NPI for Mining.

C6 Haulage on unpaved roads

Wheel-generated dust was estimated using the emission factor defined in AP42 for haulage of materials through unpaved roads. The emission factor for wheel-generated dust on haul roads is dependent on the size of the truck and the silt content of the road. In equation form, the emission factors (g/VKT) for dust are defined using the following equations:

$$EF_{TSP} = 281.9 \times 4.9 \times \left(\frac{s}{12}\right)^{0.7} \times \left(\frac{W}{3}\right)^{0.45}$$

$$EF_{PM10} = 281.9 \times 1.5 \times \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W}{3}\right)^{0.45}$$

where:

s: Silt content of the road, 5.8% adopted in this study based on the mean value defined in AP42 for the haul to/from quarry for taconite mining and processing

W: mean vehicle weight in tons

The total emissions are dependent on the total distance travelled by the truck, which is based on truck capacity and the length of the haul road to be travelled. Level 2 watering is assumed to be applied, which would result in a reduction of 75% of emissions.

C7 Grading

Maintenance of haul roads would be achieved with the use of a grader. Emissions of TSP and PM_{10} during grading were estimated using the equation defined in AP42:

$$EF_{TSP} = 0.0034 \times (S)^{2.5}$$

$$EF_{PM10} = 0.0034 \times (S)^{2}$$

APPENDIX D GREENHOUSE GAS

D1 EMISSION FACTORS

D1.1 Diesel combustion

GHG emissions relating to diesel combustion have been calculated based on a Method 1 approach as detailed in *NGER Determination Division 2.4.2 Method 1 – emissions of carbon dioxide, methane and nitrous oxide from liquid fuels other than petroleum based oils or greases)*, based on the following equation.

$$E_{ij} = \frac{Q_i \times EC_i \times EF_{ijoxec}}{1000}$$

where:

E_{ij}	emissions of gas type (***j***) being CO_2, CH_4 or N_2O released from the combustion of fuel type (***i***) measured in tonnes CO_2-e (tCO_2-e).
Q_i	quantity of fuel type (i) measured in kilolitres
EC_i	energy content factor for fuel type (i)
EF_{ijoxec}	emission factor for each gas type (j) measured in $kgCO_2$-e/GJ of fuel type (i)

D1.2 Explosives related emissions

GHG emissions resulting from the combustion of fuel oil as a component of the explosive ANFO have been estimated using a methodology consistent with a Method 1 approach, based on the following equation.

$$E_{ij} = \frac{Q_i \times EF_{ij}}{1000}$$

where:

E_{ij}	emissions of gas type (***j***) being CO_2, CH_4 or N_2O released from the combustion of fuel type (***i***) measured in tonnes CO_2-e (tCO_2-e).
Q_i	quantity of explosive type (i) measured in tonnes
EF_{ijoxec}	emission factor for each gas type (j) measured in tCO_2-e/t explosive for each explosive type (i)

D1.3 Emission factor summary

GHG emission sources for the project will be diesel usage for site equipment, vehicles and power generation; and fuel oil combustion due to the use of ANFO based explosives. Emission factors (EF) and energy content factors used for this assessment are summarised in Table 17.

Table D1 GHG emission source summary for the project

Emission source description	Energy content	Units	EF CO_2	EF CH_4	EF N_2O	EF CO_2-e	Units
Diesel	38.6	GJ/kL	69.2	0.1	0.2	69.5	kgCO_2-e/GJ
Explosives (ANFO)[1]	-	-	-	-	-	0.17	tCO_2-e/ t explosive

Table notes:
[1] Source: NGA Factors Workbook (January 2008)

D2 EMISSION RATES

Table D2 GHG emission source summary for the project

Year	Diesel (equipment/ haul trucks)	Diesel (electricity)	Explosives
	kL	kL	t ANFO
Project Year 1	3,530	-	122
Project Year 2	8,715	-	267
Project Year 3	8,964	1,858	246
Project Year 4	6,462	3,984	145
Project Year 5	5,151	3,744	164
Project Year 6	8,640	2,186	284
Project Year 7	9,675	2,460	291
Project Year 8	12,433	4,204	425
Project Year 9	15,049	4,373	517
Project Year 10	8,181	6,168	224
Project Year 11	12,377	7,581	365
Project Year 12	17,885	3,269	476
Project Year 13	19,158	5,311	395
Project Year 14	8,387	7,016	-
Project Year 15	2,681	5,738	-
TOTALS	**147,288**	**57,891**	**3,921**

Table D3 Annual Scope 1 GHG emissions for the Project

Production Year	Diesel (equipment/ haul trucks)	Diesel (electricity)	Explosives	TOTAL
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
Project Year 1	9,524	-	21	9,545
Project Year 2	23,514	4,984	45	28,543
Project Year 3	24,186	10,687	42	34,915
Project Year 4	17,435	10,043	25	27,503
Project Year 5	13,898	5,863	28	19,789
Project Year 6	23,312	6,599	48	29,959
Project Year 7	26,105	11,277	50	37,431
Project Year 8	33,546	11,733	72	45,351
Project Year 9	40,604	16,546	88	57,239
Project Year 10	22,073	20,338	38	42,449
Project Year 11	33,395	8,771	62	42,228
Project Year 12	48,256	14,247	81	62,585
Project Year 13	51,691	18,821	67	70,579
Project Year 14	22,629	15,394	-	38,023
Project Year 15	7,234	-	-	7,234
TOTALS	**397,404**	**155,303**	**666**	**553,373**

Table D4 Annual Energy Consumption and Production for the Project

Production Year	Diesel (equipment/ haul trucks)	Diesel (electricity)	Total Consumed
	GJ	GJ	GJ
Project Year 1	136,258	0	136,258
Project Year 2	336,399	71,710	408,109
Project Year 3	346,010	153,767	499,777
Project Year 4	249,433	144,508	393,941
Project Year 5	198,829	84,364	283,193
Project Year 6	333,504	94,949	428,453
Project Year 7	373,455	162,257	535,712
Project Year 8	479,914	168,816	648,730
Project Year 9	580,891	238,077	818,968
Project Year 10	315,787	292,631	608,417
Project Year 11	477,752	126,199	603,951
Project Year 12	690,361	204,999	895,360
Project Year 13	739,499	270,806	1,010,305
Project Year 14	323,738	221,494	545,232
Project Year 15	103,487	0	103,487
TOTALS*	**5,685,317**	**2,234,576**	**7,919,892**

Table note:
* In some cases totals may not equal the appropriate total number due to rounding.