Department of Primary Industry & Resources

Rum Jungle 2A - Air Noise & Vibration

Air Quality Impact Assessment

October 2019

Executive summary

This air quality impact assessment addresses relevant concerns outlined in the Environmental Impact Statement Terms of Reference (ToR) and the Project Risk Register for the proposed Rum Jungle Rehabilitation Project. The assessment was completed with a focus on the prediction of the potential for human health impacts at sensitive receptors due to dust emissions from the Project. The following key activities were carried out:

1. A short-term baseline air quality monitoring campaign was carried out during the dry season of 2018. Most significantly, a comparison of measurements from the Project site and from the NT EPA Palmerston Air Quality Monitoring Station (AQMS), suggests sufficient correlation to warrant use of the Palmerston AQMS as a surrogate for long-term, high quality background air quality data.
2. Of the identified residential premises within the investigation area, a sub-set of sensitive receptors were selected on the basis of their proximity to the key operational activities, emission sources and orientation in relation to typical wind patterns.
3. Meteorological modelling was completed with key inputs from the Batchelor Airport Bureau of Meteorology Automatic Weather Station. An emission scenario was developed to represent a worst-case dust emission potential from the Project. Dispersion modelling was completed for a period of three years (2016-2018) to capture the coincident occurrence of worst-case meteorological conditions and worst-case dust generating capacity of the project.
4. The impact assessment, which is considered conservative in nature, has predicted exceedances of nationally recognised ambient air quality objectives at sensitive receptors surrounding the main project site and at satellite sites. Predicted exceedances of air quality objectives were classified as a basis for providing receptor specific mitigation measures, as outlined in the table below.

ID	Closest project area	Direction from project area	Approx. min. distance to works	Nature of exceedance
R1	Mt Fitch	NE	1.7 km	No exceedance
R2	Mt Burton	NW	1.2 km	Moderate exceedance
R3	Mt Burton	SW	0.2 km	Major exceedance
R4	Rum Jungle	NW	1.2 km	Moderate exceedance
R5	Rum Jungle	SW	2.0 km	Minor exceedance
R6	Granular Borrow	WSW	1.5 km	Minor exceedance
R7	Clay Borrow	NW	1.2 km	Moderate exceedance
R8	Clay Borrow	N	0.1 km	Moderate exceedance
R9	Clay Borrow	SE	1.2 km	Moderate exceedance
R10	Granular Borrow	SSE	1.8 km	No exceedance
R11	Granular Borrow	ESE	6.0 km	No exceedance
R12	Rum Jungle	SE	8.0 km	No exceedance

5. A hierarchy of mitigation measures, including operational controls, as well as reactive and compliance-level monitoring options, are provided in Table 5-2. Those measures are expected to reduce the probability of exposure of receptors to air quality impacts and importantly will introduce the operational ability to control or restrict operations with the aim of reducing emissions of particulate matter from the Project site. A summary of recommended receptor specific mitigation measures are outlined in the table below:

Type of mitigation measure	Number of receptors measure is recommended
Relocation of resident during operations	1 (at Mt Burton)
Ceasing operations at relevant project areas during range of wind directions	1 (at Mt Burton), 0 if relocation of resident carried out
Compliance level air quality monitoring	1 (at Mt Burton), 0 if relocation of resident carried out
Reduced rate of operation during specified wind directions	2, 1 if relocation of resident carried out
Reduced rate of operation during poor air quality days	5, 4 if relocation of resident carried out
Real-time, reactive air-quality monitoring	5, 4 if relocation of resident carried out
Dust deposition gauges	8, 7 if relocation of resident carried out

6. The outcomes of each assessment and how they relate to each item of the ToR and Risk Register are summarised in Table 6-1 and Table 6-2 respectively. Where potential environmental impacts of the ToR and risk register were not directly addressed through quantitative assessment, mitigation measures are discussed to allow for estimation of; and protection from, the associated risk.

It is concluded that where recommended mitigation measures are effectively incorporated into the relevant operational Environmental Management Plan, air quality related risks outlined in the ToR and Project Risk Register will be controlled to an acceptable level.

Glossary

Term	Definition
AQIA	Air Quality Impact Assessment
AQMS	Air Quality Monitoring Station
AWS	Automatic weather station
BOM	Bureau of Meteorology
CO	Carbon monoxide
DIIS	Department of Industry, Innovation & Science
DPIR	Department of Primary Industry and Resources
Dust	Particulate matter, more specifically, total insoluble matter
EBFR	East Branch Finniss River
EET	Emission Estimation Technique
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
Existing air quality	The ambient level of atmospheric pollutants not associated with the assessed activity. Sources of pollutants could be natural source such as wind erosion or anthropogenic sources such as burning of fossil fuel.
FRTL	Finniss River Land Trust
GHD	GHD
GLC	Ground level concentration
LDWQOs	Locally derived water quality objectives
NEPM	National Environment Protection (Ambient Air Quality) Measure
NO	Nitrogen oxide
NO_x	Oxides of nitrogen
NO_2	Nitrogen dioxide
NPI	National Pollutant Inventory
NT	Northern Territory
OEH	Office of Environment & Heritage
PM_{10}	Particulate matter with aerodynamic diameter of less than 10 microns
$PM_{2.5}$	Particulate matter with aerodynamic diameter of less than 2.5 microns
Sensitive receptor	Locations more susceptible to the adverse effects of exposure to pollutants such as residences, hospitals, schools and day-care facilities.
SO_2	Sulphur dioxide
TAPM	The Air Pollution Model
TEOM	Tapered Element Oscillating Microbalance
ToR	Terms of Reference

Term	Definition
TSP	Total Suspended Particulates
US EPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
VKT	Vehicle kilometres travelled
WSF	Waste Storage Facility

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1. Introduction

The Northern Territory Government's Department of Primary Industry and Resources (DPIR) is the Proponent for the rehabilitation of the former Rum Jungle mine and associated satellite mines at Mt Burton and Mt Fitch (the Project). The majority of rehabilitation activities will occur at the main Rum Jungle mine (the Site), which is located approximately six kilometres north of Batchelor, in the Northern Territory. DPIR are delivering the Project in partnership with the Commonwealth Government's Department of Industry, Innovation & Science (DIIS).

1.1 Rehabilitation project objectives

The high-level objectives of the Project are two-fold and incorporate environmental remediation and advancement towards resolution of the Finniss River Land Claim:

- Improve the environmental condition of the Site and downstream catchment of the East Branch Finniss River (EBFR), with success measured against the following key outcomes:
  a. Surface water quality conditions within the EBFR progressively improve, such that they lastingly meet locally derived water quality objectives (LDWQOs).
  b. Constructed and rehabilitated landforms are chemically and physically stable.
  c. Self-sustaining vegetation systems are established within the rehabilitated landforms.
  d. Physical environmental conditions support intended final land uses.
- Improve site conditions to support future progress of the Finniss River Land Claim over the Rum Jungle site, inclusive of the following key outcomes:
  a. Restoration of flows to the original course of the EBFR, as far as is possible.
  b. Culturally insensitive landforms are relocated to locations that are deemed to provide a culturally safe separation distance from known Sacred Sites.
  c. Return living systems including endemic species to the remaining landforms.
  d. Preserve Aboriginal cultural heritage artefacts and places.
  e. Isolate sources of pollution including radiological hazards.
  f. Maximise opportunities for Traditional Owners to work on site, to aid reconnection to country.

On 30 August 2016, the Northern Territory Environment Protection Authority (EPA) determined that the Project required assessment under the *Environment Assessment Act 1992,* at the level of an Environmental Impact Statement (EIS). Since then, several rounds of consultation and associated rehabilitation design adjustments have resulted in some updates being made to the EPA Terms of Reference (ToR) for the Project, which provide guidance on matters requiring assessment under the EIS.

To meet the requirements of the ToR (NT EPA, 2019), DPIR engaged GHD (in 2018) to prepare air-quality, noise and vibration impact assessments for the Project.

1.2 Air quality assessment objectives

This Air Quality Impact Assessment (AQIA) considers air quality risks and impacts that may be caused by the Project at surrounding sensitive land use areas.

The EPA's updated ToR requires information from the Proponent with regards to air quality as outlined in Table 1-1.

Table 1-1 Potential air quality impacts requiring assessment

Section	Topic	Information required (relevant to air emissions only)
2.2.1 - Terrestrial flora and fauna	Potential impacts and risks	Quantify and/or discuss any potential for a decline in distribution, abundance or health of identified values due to: • **Dust**, noise, vibration and light • Radionuclide exposure from **dust** emissions, contaminated water resources or other sources of exposure
2.2.7 - Human health	Potential impacts and risks	Quantify and/or discuss the following potential impacts for the Proposal, including post-rehabilitation: • Radiological impacts including: – details of radiation dose potential from Proposal elements to human health including consideration of exposure due to all pathways: radon and its decay products, radioactive particles in **dust**, and alpha and gamma radiation

Potential air quality impacts identified in project risk workshops (documented in the project risk register) are considered more relevant; and more thoroughly identify drivers for assessing potential air quality impacts. The relevant excerpts of the risk register are provided in Table 1-2.

Table 1-2 Potential air quality impacts identified in environmental risk register

Potential event	Environmental Factor	Description of impact
Emissions of dust from exposed surfaces due to wind erosion, excavation and material handling and vehicle movements on haul roads and access tracks	Human health and safety	Transport of dust to sensitive receptors leading to increase of inhalation of ambient particulate matter (TSP, PM_{10}, $PM_{2.5}$).
	Socio-economic	Transport to and deposition of dust at sensitive receptors leading to loss of amenity.
	Historic and cultural heritage	Transport to and deposition of dust at cultural heritage site, sacred sites or artefacts leading to loss of amenity and/or disturbance of the site.
	Biodiversity - Terrestrial Ecosystem	Transport to and deposition of dust in the environment leading to reduction in habitat quality and/or quantity (within and surrounding the project area) leading to a decrease in the diversity and/or abundance of species.
Emissions of radionuclides within dust emissions from exposed surfaces due to wind erosion, excavation and material handling and vehicle movements on haul roads and access tracks	Human health and safety	Transport of dust to sensitive receptors leading to increase of inhalation and ingestion of radionuclides
	Human health and safety	Worker exposure dust leading to increase of inhalation and ingestion of radionuclides
	Biodiversity - Terrestrial Ecosystem	Transport of dust to the environment leading to reduction in habitat quality and/or quantity (within and surrounding the project area) leading to a decrease in the diversity and/or abundance of species.
Emissions of hazardous pollutants due to combustion of fuels from fixed or mobile plant	Human health and safety	Transport of dust to sensitive receptors leading to increase of inhalation of hazardous pollutants (CO, NOx, SOx, volatile organic compounds (VOC))

1.3 Project overview

1.3.1 Project location

The Project is located approximately 105 km (by road) south of Darwin and 6 km north of Batchelor. The legacy mine sites to be rehabilitated lie within the Rum Jungle Uranium field and are located within the following three land parcels:

- Rum Jungle proper – Section 2968 Hundred of Goyder (vacant Crown land recommended for grant by the Aboriginal Land Commissioner Justice Toohey on 22 May 1981)
- Mt Burton – Section 998 Hundred of Goyder (estate in fee simple held privately)
- Mt Fitch – within NT Portion 3283 (Crown Lease Perpetual 862 held by the Northern Territory Land Corporation)

Additional soil materials required by the Project will be sourced from two further sites:

- Cover materials sourced from pre-disturbed land owned by Coomalie Council
- Cover materials sourced from former sand mining areas, located on Finniss River Land Trust (FRLT)

Figure 1-1 shows the location of the site and the overall project layout showing each of the project components listed above.

1.3.2 Key project activities

The following key activities will occur as part of the Project:

- Project establishment, including:
  - Construction of new haul roads
  - Construction of new or upgraded river crossings
  - Establishment of office compound facilities
  - Establishment of laydown areas, maintenance facilities and hard stands
- Abstraction and treatment of acid-mine drainage impacted groundwater within the Rum Jungle mine site, via a purpose built water treatment plant
- In-situ treatment of water within the Main and Intermediate Pits, using reagents as required
- Excavation of the base of the two new Waste Storage Facilities (WSFs) to extract suitable material for construction or rehabilitation purposes elsewhere on site
- Relocation of contaminated waste rock, tailings and soil from across the site into the WSFs
- Sub-aqueous deposition of waste rock and tailings into the Main Pit
- Relocation of contaminated waste rock from Mt. Burton to the Rum Jungle WSFs
- Replacement of waste rock and (uncontaminated) spoil stockpiled at Mt Fitch into the existing open pit at Mt Fitch
- Capping of the WSFs with clay material, growth medium and rock armouring
- Rehabilitation of exposed footprints beneath existing waste rock dumps and contaminated soil areas
- Restoration of the original course of the EBFR through the Main Pit and Intermediate Pit
- Site disestablishment and clean up, including:
  - Removal of all haul roads and river crossings
  - Removal of all project related infrastructure
  - Removal of all project related equipment

Site location and overall project layout

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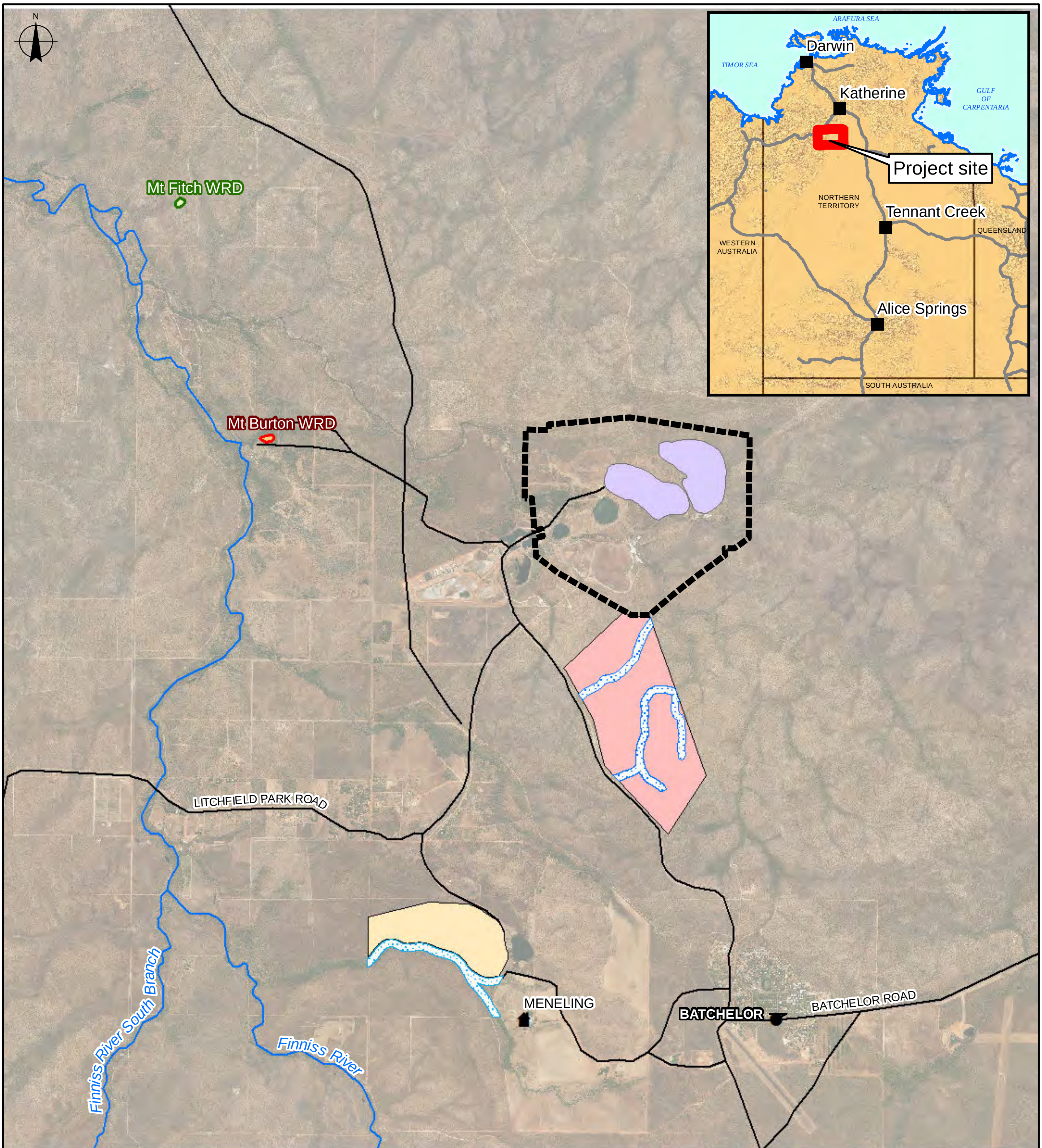
FIGURE 1-1



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0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 52

LEGEND

- Towns
- Homesteads
- Roads
- Waterways
- Railway
- Clay Borrow Area Creek Buffer
- Clay Borrow Area
- Granular Material Borrow Area Creek Buffer
- Granular Material Borrow Area
- Mt Burton WRD
- Mt Fitch WRD
- WRD Max Footprint
- Project Site

Issue Date: 26/09/2019

Map ID:

Figure Number: 4322822_003.mxd

Data Source:
GA - Towns, Homesteads, Roads, Waterways, Railway (2015). ESRI - SRTM (2008). NTG - Mine Features (2019). . Created by: cmacgregor

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1.4 Scope and structure of this report

1.4.1 Scope of report

GHD has assessed potential impacts to air quality from operations on the main project site and satellite sites. The assessment has involved the following tasks:

- Initial desktop review using aerial photography to identify receptors sensitive to potential air quality effects.
- Background air quality monitoring at locations selected as being representative of the local air quality environment.
- Development of an air quality emissions inventory for the Project.
- Development of meteorological data files for dispersion modelling using the CALMET model, with inputs from The Air Pollution Model (TAPM) and the Bureau of Meteorology Automatic Weather Station sited at Batchelor Airport.
- Using the meteorological and emission inputs developed above, the CALPUFF dispersion model was run for TSP, PM_{10} and $PM_{2.5}$.
- Comparison of air quality modelling results against the relevant air quality objectives.
- Identification of typical mitigation measures or controls that may be adopted during the Project to manage air quality emissions.

1.4.2 Report structure

- **Chapter 1 – Introduction:** identifies the project and sites assessed
- **Chapter 2 – Project description:** describes details, methods and timing of the proposed construction works, relevant to air quality impact assessment
- **Chapter 3 – Existing environment:** summarises the meteorological conditions and describes the development of the meteorological model files. Describes existing air quality conditions and details the air quality monitoring methodology and results.
- **Chapter 4 – Impact assessment:** presents a summary of the air quality modelling and identifies potential air quality impacts of the proposed works.
- **Chapter 5 – Mitigation of effects:** provides an overview of proposed air quality mitigation measures for the operational phase of the Project
- **Chapter 6 – Conclusion:** summarises potential air quality impacts and principal conclusions of the assessment.
- **Chapter 7 – References:** lists documents used or referenced within this report

1.5 Definitions

The following are terms used within this report:

- 'Project' refers to rehabilitation of the former Rum Jungle Mine site (the Project), including the main project site and the satellite sites
- 'Main project site' refers to Rum Jungle proper – Section 2968 Hundred of Goyder (vacant Crown land recommended for grant by the Aboriginal Land Commissioner Justice Toohey on 22 May 1981)
- 'Satellite sites' refers to the two satellite mines, being Mt Fitch and Mt Burton, and the two borrow sites, being the clay borrow site and the granular borrow site
- 'Mt Fitch' refers to a parcel of land within NT Portion 3283 (Crown Lease Perpetual 862 held by the Northern Territory Land Corporation)
- 'Mt Burton' refers a parcel of land - Section 998 Hundred of Goyder (estate in fee simple held privately)
- 'Clay borrow site' refers to pre-disturbed land owned by Coomalie Council near Rum Jungle Creek South where cover materials will be sourced from
- 'Granular borrow site' refers to former sand mining areas which are located on Finnis River Land Trust (FRLT)
- 'Study area' refers to the area within 13 kilometres of the main project site and includes any identified sensitive receptor within this zone

1.6 Limitations

This report has been prepared by GHD for Department of Primary Industry & Resources and may only be used and relied on by Department of Primary Industry & Resources for the purpose agreed between GHD and the Department of Primary Industry & Resources as set out in section 1.4.1 of this report.

GHD otherwise disclaims responsibility to any person other than Department of Primary Industry & Resources arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Department of Primary Industry & Resources and others who provided information to GHD (including other Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. Project description

2.1 Project layout

The relative layout of the former Rum Jungle mine, satellite mines (Mt Fitch and Mt Burton) and borrow sites (Clay borrow site and Granular borrow site) is provided in Figure 1-1.

2.2 Operational hours

The proposed works are expected to be carried out during the following times:

- Seven days per week, between the hours of 6 am and 6 pm
- No work on public holidays

2.3 Workforce

The workforce plan is intended to maximise employment opportunities for members of Traditional Owner communities and local residents, and to maximise benefits of the Project in Batchelor and the region. The total number of workers is anticipated to range between 40 and 50 people during the first five operational years of the Project.

The proposed 12-hour work days and seven-day per week operation will necessitate rostered working patterns and will therefore utilise interchangeable work crews. Seasonal considerations and material movement limitations will further define working patterns and will require consideration in maintaining stable regional employment levels and patterns.

2.4 Timing and equipment

2.4.1 Timing

The main construction and key earthworks activities of the Project are expected to take approximately five years to complete.

Additional phases of revegetation and landform management, monitoring and maintenance are anticipated to continue for up to another four years; and will facilitate a staggered process of land relinquishment.

2.4.2 Plant and equipment

To provide a basis for air quality impact assessment, the magnitude and duration of construction and earthworks effort has been based on the simplified activity and equipment schedule provided in Table 2-1.

2.5 Primary material movements

2.5.1 Internal haul roads

Spoil excavated from waste rock dumps or contaminated soil areas will be hauled to the new WSFs within the Project boundaries via internal haul roads, with the exception of waste rock material brought into the Rum Jungle mine site from Mt Burton.

2.5.2 Spoil movement from the borrow sites

It is estimated that approximately 1,600,000 m^3 of low permeability material will be brought into the site from the 'Clay borrow site' near Rum Jungle Creek South.

Approximately 1,700,000 m^3 of granular (growth material) cover will be brought into the Site from the 'Granular borrow site', within former sand mining areas immediately south of the Site.

Clay material will be transported to site using Poett Road, Litchfield Park Road, Rum Jungle Road and internal haul roads. Granular material will be transported into the site via internal site haul roads (no use of public roads).

It is anticipated that borrow material transport will involve between 50 and 70 truck movements per day.

2.5.3 Spoil movement from the Mt Burton site

The excavated contaminated waste rock or soil at Mt Burton will be transported to the new WSFs using White road, Lithgow Road, Bevan Road, Litchfield Park Road, Rum Jungle Road and internal haul roads at a rate of approximately 25 truck movements per day.

Table 2-1 Activities, equipment and duration

Operational Activity	Equipment Required
Construct haul roads and other establishment tasks	1 x excavator/shovel 3 x Cat 777 1 x grader 2 x 835 compactors 2 x smooth drum rollers
Progressive WSF foundation preparation	
Excavate contaminated waste rock or soil and haul to new WSFs (within Project boundaries)	1 x excavator/shovel 4 x Cat 777
Place, lime and nominally compact soil and waste rock in new WSFs	1 x D10 dozer with tyne 1 x spreader 2 x 825 compactors 1 x smooth drum roller
Excavate contaminated waste rock or soil and haul to Main Pit for lime amendment and sub-aqueous deposition	1 x excavator/shovel 4 x Cat 777 Conveyor and barge
Excavate contaminated waste rock or soil at Mt Burton and haul to new WSFs	1 x excavator/shovel 4 x 1 B-double road train
Excavate contaminated waste rock or soil at Mt Fitch and replace into Mt Fitch pit	
Haul from cover borrow area to the Project	1 x excavator 2 x B-double road trains
Haul from granular borrow area to the Project	1 x excavator 2 x B-double road trains
Ancillary earthworks support equipment	2 x water trucks 1 x grader 1 x fuel truck 1 x maintenance truck 1 x material movement truck (ITP) 6 x light vehicles
Groundwater and pit-water treatment activities	1 x barge

3. Existing environment

3.1 Project location and sensitive receptors

The Project is located approximately 65 km south-southeast of Darwin, west of the Stuart Highway and lies approximately six kilometres north of the township of Batchelor. The air quality assessment includes assessment of impacts at sensitive receptors selected on the basis of their proximity to the key operational activities, emission sources and typical wind patterns. In order to allow for ease of interpretation of modelling predictions, a sub-set of all sensitive receptors are selected for the assessment.

The sensitive receptors considered in the assessment are listed in Table 3-1 and shown in Figure 3-1. Air quality modelling results are also presented as contour plots to allow for the interpretation of spatial variability of predicted impacts.

Table 3-1 Sub-set of sensitive receptors

ID	Co-ordinates (GDA94 Zone 52)		Closest project area	Direction from project area	Approx. min. distance to works*
	X	Y			
R1	713,047	8,568,582	Mt Fitch	NE	1.7 km
R2	712,281	8,565,172	Mt Burton	NW	1.2 km
R3	713,008	8,564,129	Mt Burton	SW	0.2 km
R4	715,622	8,564,766	Rum Jungle	NW	1.2 km
R5	714,728	8,561,350	Rum Jungle	SW	2.0 km
R6	716,163	8,559,949	Granular Borrow	WSW	1.5 km
R7	714,552	8,558,943	Clay Borrow	NW	1.2 km
R8	715,532	8,558,811	Clay Borrow	N	0.1 km
R9	716,820	8,556,418	Clay Borrow	SE	1.2 km
R10	719,516	8,557,398	Granular Borrow	SSE	1.8 km
R11	724,909	8,557,815	Granular Borrow	ESE	6.0 km
R12	726,954	8,559,831	Rum Jungle	SE	8.0 km
Note: Distance to works is calculated as the nearest distance to project area boundary or haul roads entering or exiting a project area.					

Sensitive receiver locations

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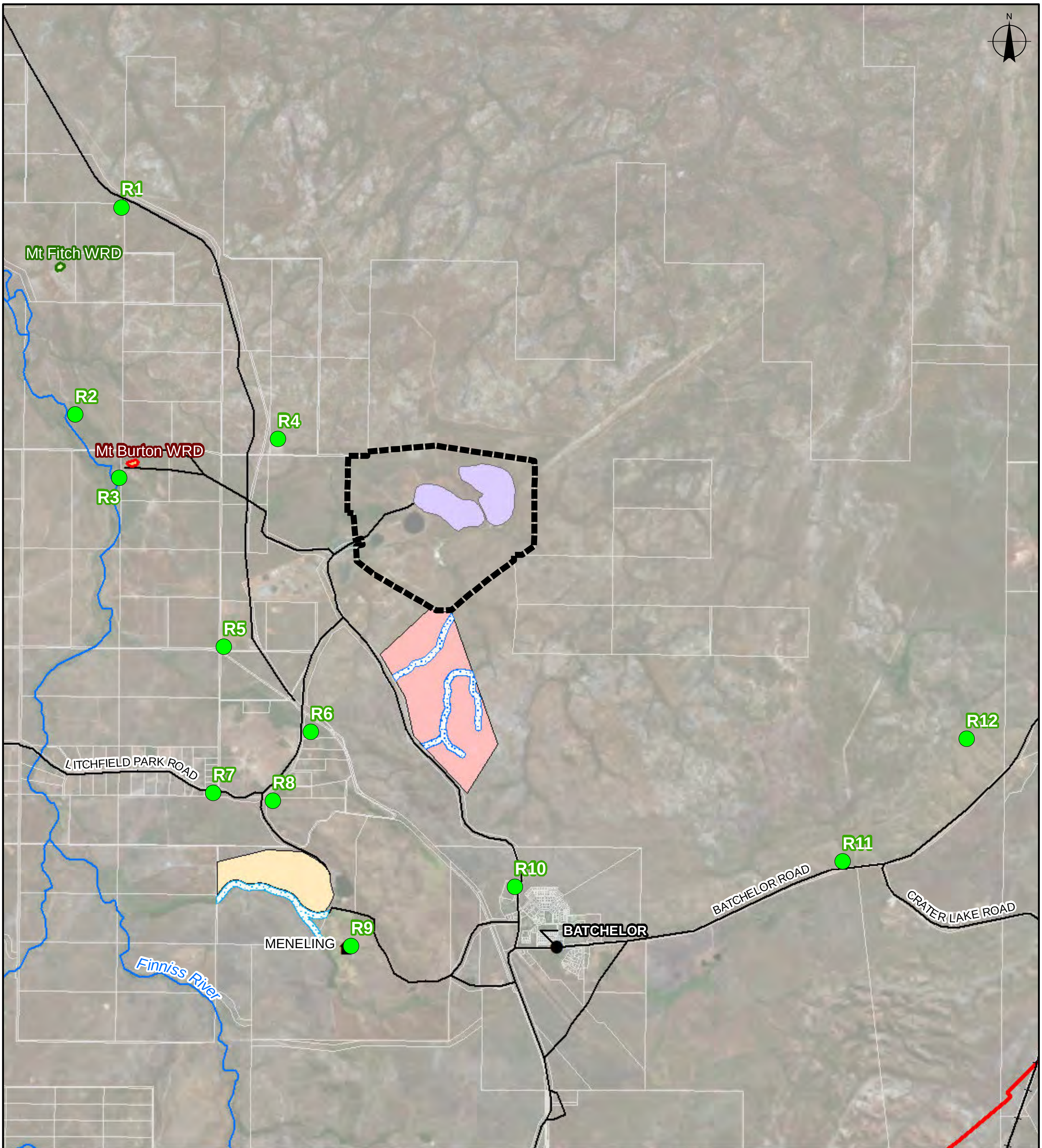
Figure 3-1



Scale 1:90,000 @ A4

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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 52

LEGEND

- Sensitive receiver
- Towns
- Homesteads
- Roads
- Waterways
- Railway
- Clay Borrow Area Creek Buffer
- Clay Borrow Area
- Granular Material Borrow Area Creek Buffer
- Granular Material Borrow Area
- Mt Burton WRD
- Mt Fitch WRD
- WRD Max Footprint
- Study Area
- Project Site
- Cadastre

Issue Date: 10/10/2019

Map ID:

Figure Number: 4322822_016.mxd

Data Source:
GA - Towns, Homesteads, Roads, Waterways, Railway (2015). GHD - Sensitive Receivers (2019). NTG - Cadastre (2007). Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: cmacgregor

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3.2 Meteorology

The Bureau of Meteorology (BOM) operates an Automatic Weather Station (AWS) at Batchelor Airport (Station ID: 014272), located approximately 6.5 km south-southeast of the Rum Jungle site. It has been assumed that the Bureau of Meteorology Automatic Weather Station sited at Batchelor Airport is representative of meteorological conditions (wind, temperature, humidity, rainfall) across the investigation area.

To allow for assessment of wind patterns and for air dispersion modelling inputs, meteorological modelling has been completed in order to develop a 3D meteorological data set. The CALMET diagnostic meteorological model was used to develop the 3D meteorological grid for subsequent use in dispersion modelling.

CALMET was configured in 'Hybrid' mode, whereby surface observations from the Batchelor Airport BOM AWS were used in conjunction with coarse three-dimensional data developed using the prognostic meteorological model, The Air Pollution Model (TAPM). The model was run for a period of three years, from 1 January 2016 through 31 December 2018.

Model settings were selected with consideration of the New South Wales Office of Environment & Heritage (OEH) (OEH NSW, 2011) guidance documentation and modelling guidelines. The CALMET domain extended 13.5 km in each direction from the Rum Jungle site with a grid resolution of 300 m. Model settings used in TAPM and CALMET are provided in Table 3-2.

Table 3-2 TAPM and CALMET model parameters

Parameter	Value
TAPM	
Modelled Period	01 January 2016 12:00 am – 31 December 2018 11:59 pm
Domain centre	UTM: 52H 718,315 mE, 8563,473 mS Latitude =-12° 59' Longitude = 131° 0.5'
Number of vertical levels	25
Number of Easting Grid Points	31
Number of Northing Grid Points	31
Outer Grid Spacing	30,000 m x 30,000 m
CALMET	
Modelled Period	01 January 2016 12:00 am – 31 December 2018 11:59 pm
Mode	Hybrid (NOOBS = 1)
UTM Zone	52
Domain Origin (South-West Corner)	Easting: 705.000 km Northing: 8550.000 km
Domain Size	90 x 90 at 0.30 km resolution (27.0 km x 27.0 km)
Number of vertical levels	11
Vertical Levels (m)	20, 40, 60, 90, 120, 180, 250, 500, 1000, 2000, 3000

3.2.1 Local Wind Field

The local meteorology largely determines the pattern of off-site air quality impact on receptors. The effect of wind on dispersion patterns can be examined using the wind distributions at the subject site. The winds at a site are most readily displayed by means of wind rose.

Figure 3-2 shows the annual average, dry season (1 May – 30 November) and wet season (1 December – 30 April) wind roses for the years combined modelling period. The following key features are observed:

- The average wind speeds are:
  - – Annual average – 2.6 m/s
  - – Dry season average – 2.6 m/s
  - – Wet season average – 2.5 m/s
- Dry season wind pattern is dominated by south-easterly sector winds.
- Wet season wind pattern has dominant features in south-easterly and north-westerly sectors.
- Light winds (< 2 m/s) make up over half of the wind class distribution and all sectors excluding the south-westerly sector experience significant contributions.
- The observed wind speed distribution indicates that the largest proportion of high wind speeds (> 6 m/s) are from the west.

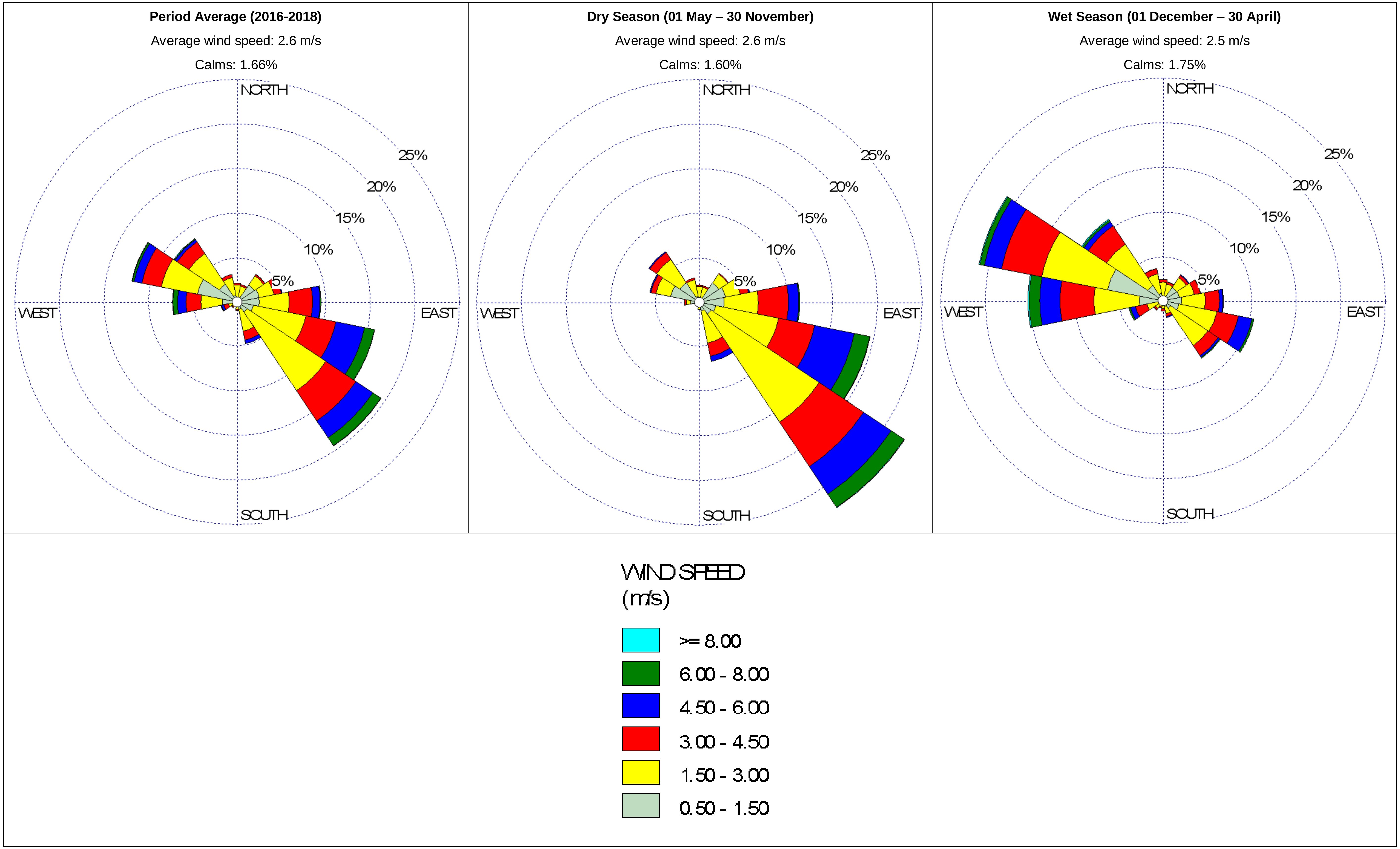

Figure 3-2 Wind roses – extracted from CALMET at Rum Jungle Project Site

3.2.2 Rainfall

It is expected that site operations, activity rates and the moisture content of site surfaces will considerably affect the potential and variability of particulate emissions throughout the year.

These factors will be significantly dependent on rates of rainfall and the 'wet' – 'dry' seasonality experienced in tropical climates of northern Australia. The wet season is typically considered to occur between 1 December and 30 April, despite the relatively frequent occurrence of early rainfall in October and November.

Historical rainfall data from the Batchelor Airport BOM station is presented in Figure 3-3 below, and confirms the magnitude of wet and dry seasons experienced at the Project site.

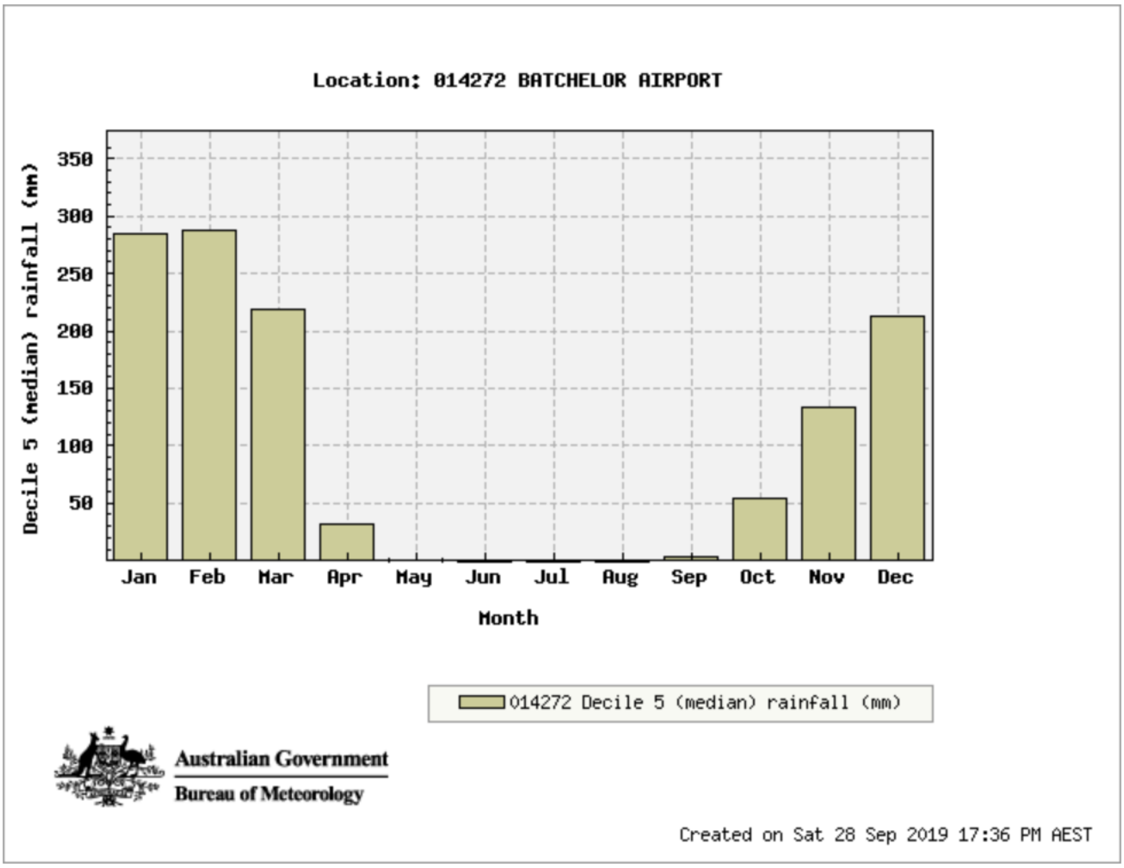

Figure 3-3 Median monthly rainfall at Batchelor Airport BOM[1]

[1] Bureau of Meteorology Climate statistics for Australian locations, Sourced 28/09/2019, http://www.bom.gov.au/jsp/ncc/cdio/cvg/av?p_stn_num=014272&p_prim_element_index=22&p_display_type=statGraph&period_of_avg=ALL&normals_years=allYearOfData&staticPage=

3.3 Baseline air quality

3.3.1 Site specific monitoring

GHD conducted baseline air quality monitoring at six sites surrounding the Project between the dates of 4 June and 5 October 2018. The monitoring period was intentionally implemented over dry season months, with the intention of capturing comparatively 'worst-case' air-quality conditions. The monitoring locations used in the baseline monitoring are shown in Figure 3-4. Air quality monitoring was conducted for the following parameters:

- Dust deposition rates, including analysis of dust samples for:
  - Total insoluble matter
  - Total soluble matter
  - Heavy metals
- Ambient gas concentrations including:
  - Nitrogen Dioxide (NO_2)
  - Sulphur Dioxide (SO_2)
- Ambient particulate concentrations, including:
  - PM_{10}
  - $PM_{2.5}$

A summary of the results of the air quality monitoring conducted is provided below.

Dust deposition

Dust deposition monitoring was undertaken from July 2018 to October 2018, with these dry-season months considered reasonably worst case for baseline dust deposition. Total insoluble material measured during the monitoring period is presented in Table 3-3 below.

Table 3-3 Dust deposition results

Site	Rate of deposition – total insoluble matter (g/m²/month)			
	5 July 2018	7 August 2018	6 September 2018	5 October 2018
1	0.6	0.6	0.7	1.5
3	0.6	0.5	0.3	0.8
4	0.7	0.4	1.0	1.5
5	0.3	0.2	0.1	0.7
6	0.4	0.2	0.4	1.0

It was found that the overall deposited dust levels remained relatively constant across the monitoring period, with an increase seen at all sites in October. The highest measured value (1.5 g/m²/month) was recorded at Site 4 and Site 5 during October.

Baseline monitoring locations

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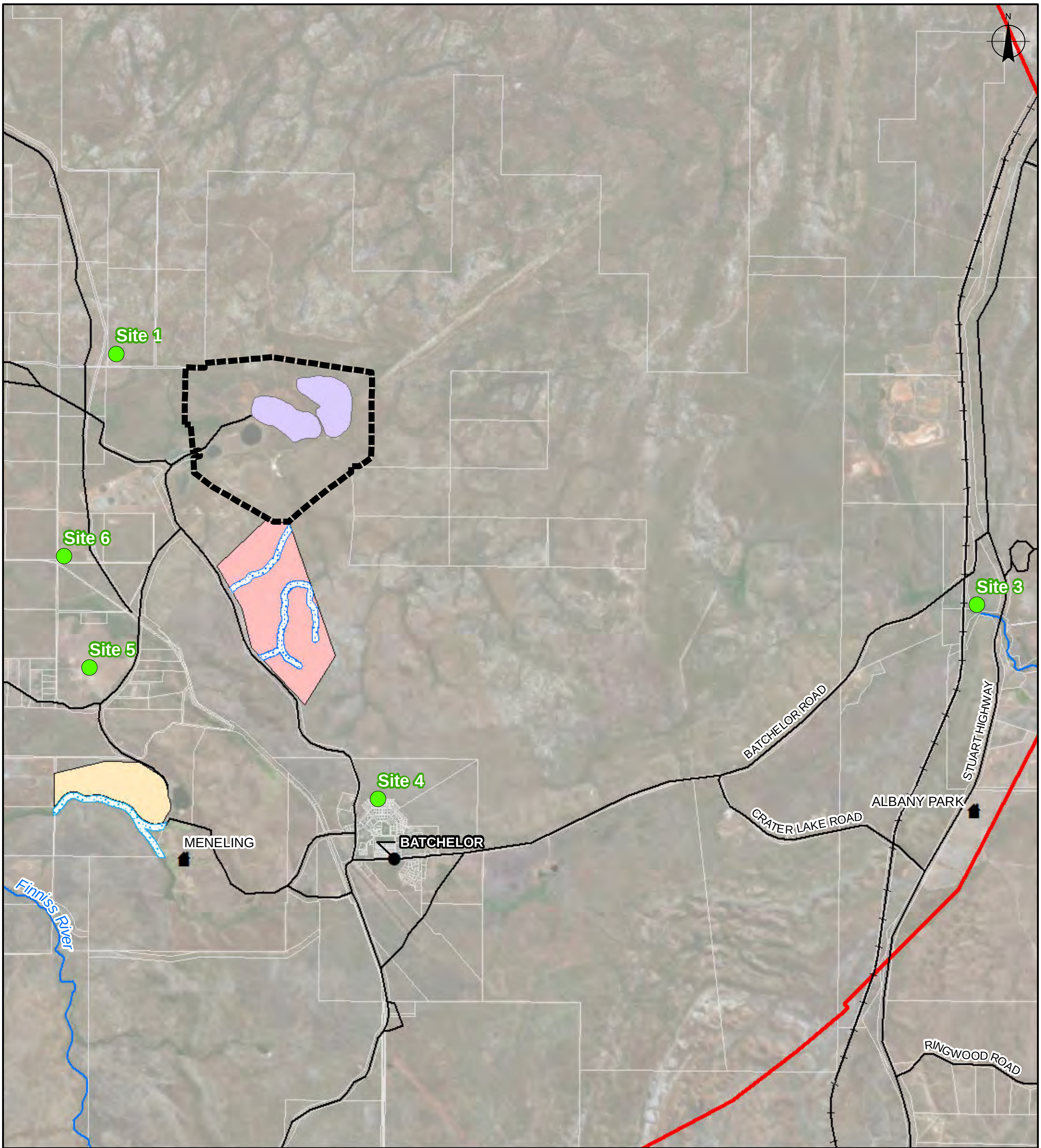
Figure 3-2



Scale 1:90,000 @ A4

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 52

LEGEND

- Monitoring location
- Towns
- Homesteads
- Roads
- Waterways
- Railway
- Clay Borrow Area Creek Buffer
- Clay Borrow Area
- Granular Material Borrow Area Creek Buffer
- Granular Material Borrow Area
- WRD Max Footprint
- Study Area
- Project Site
- Cadastre

Issue Date: 10/10/2019

Map ID:

Figure Number: 4322822_017.mxd

Data Source:
GA - Towns, Homesteads, Roads, Waterways, Railway (2015). GHD - Sensitive Receivers (2019). NTG - Cadastre (2007). Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: cmacgregor

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Screening assessment of ambient gases (NO_2 and SO_2)

A screening assessment was undertaken and involved the deployment of passive diffusion samplers at Site 1 and Site 3. The first period of monitoring occurred from 4 June to 5 July 2018. The second monitoring period occurred from 5 July to 7 August 2018.

Passive diffusion samplers report cumulative ambient gas concentrations detected over the full duration of each monitoring period and therefore do not allow comparison to regional ambient gas concentrations measured in real-time, nor concentration-based criteria. However, replication of this monitoring program during the construction period is expected to allow the detection of any incremental impact caused by site operations. The results of the two baseline monitoring periods are presented in Table 3-4 in Table 3-5 below.

Table 3-4 4 June to 5 July ambient gas results

Pollutant	Site 1 Results (µg/tube)		Site 3 Results (µg/tube)	
	Sample 1	Sample 2	Sample 1	Sample 2
Nitrate as NO2	9.4	12	25	24
Nitrate as NO3	1	1.7	4.7	3.3
Sulphate as SO4	1.1	1.3	15	14

Table 3-5 5 July to 7 August ambient gas results

Pollutant	Site 1 Result (µg/tube)		Site 3 Result (µg/tube)	
	Sample 1	Sample 2	Sample 1	Sample 2
Nitrate as NO2	8.8	7.6	3.1	8.7
Nitrate as NO3	17	5.6	0.8	4
Sulphate as SO4	13	2.9	1.3	4.7

Ambient particulate matter (PM_{10} and $PM_{2.5}$)

A TSI DustTrak DRX Aerosol Monitor 8533 (DustTrak) was deployed at Site 1 between 5 July and 5 October 2018. One of the objectives of this baseline monitoring was to evaluate the degree of correlation between site-specific conditions and air quality records available from the Palmerston Air Quality Monitoring Station (AQMS) operated and maintained by the Department of Environment and Natural Resources (DENR).

The use of Palmerston AQMS station data as a surrogate data source for the project provides advantages in the evaluation of baseline air quality conditions, due to the length of records available from NT-EPA equipment and due to the measurement precision available from AQMS instruments.

For the purpose of comparing the data-sets, $PM_{2.5}$ results from the DustTrak at Rum Jungle Site 1 were compared to $PM_{2.5}$ data generated by a Tapered Element Oscillating Microbalance (TEOM) particulate monitor at the Palmerston AQMS. The comparative results of are shown in Figure 3-5 below, which demonstrates a good degree of correlation between the Palmerston and Rum Jungle $PM_{2.5}$ results. Similar short-term peaks (daily) and long-term (weekly) trends were observed in both datasets. Consequently, it is concluded that use of Palmerston AQMS station data as a surrogate data source for the project is appropriate.

Significantly lesser concentrations of PM_{10} were recorded by the DustTrak at Rum Jungle Site 1 in comparison to those measured at the Palmerston AQMS. Furthermore, the measured PM_{10} concentrations from the DustTrak deployed at Site 1 were marginally higher than the measured $PM_{2.5}$ concentrations from the same instrument. This trend was not observed in data from the Palmerston AQMS nor is it typical of the expected distribution of particle sizes in ambient air. This disparity is interpreted to relate to sampling limitations of the DustTrak and the PM_{10} records were therefore not considered reliable.

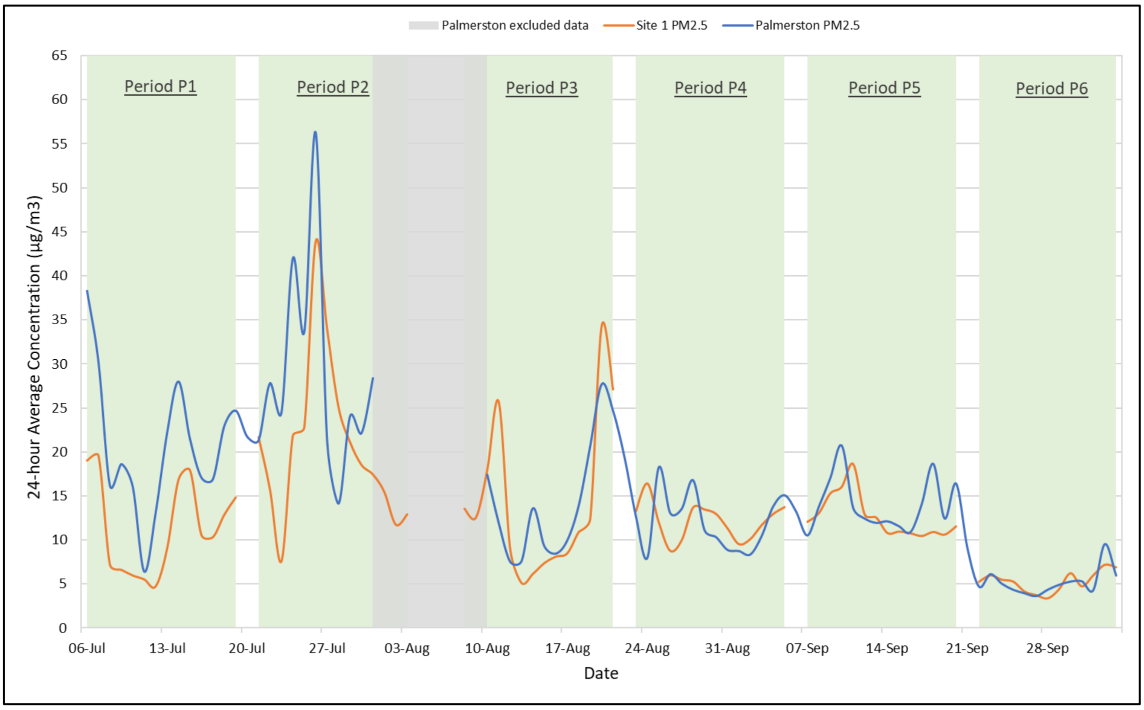

Figure 3-5 Rum Jungle Site 1 and Palmerston $PM_{2.5}$

3.3.2 Identified trends in baseline air quality

Background air quality will need to be considered during the Project construction period. The lack of rainfall during the dry season (1 May – 30 November) typically results in a reduced capacity for natural dust suppression and an increased incidence of fires. This causes worst-case air quality conditions to occur throughout the region during the dry season. As such, a more detailed assessment of particulate trends has been completed to allow consideration of cumulative air quality impacts from both background air quality and the Project.

Table 3-6 and Table 3-7 respectively show average monthly $PM_{2.5}$ and PM_{10} records between 2016 and 2018, using data retrieved from the Palmerston AQMS. The average 70th percentile[2] value during 2016 to 2018 is also shown in Figure 3-6.

From Table 3-6, there were 12 exceedances of the objective for $PM_{2.5}$ (25 µg/m^3) specified in the National Environment Protection (Ambient Air Quality) Measure (NEPM) (National Environment Protection Council, 2015) (AAQ-NEPM). All 12 exceedances occurred during the early to mid-dry season. In particular, July had the highest average number of exceedances (5). It is noted that no exceedances occurred during September to October, indicating the greater likelihood of exceedances at the beginning of the dry season. The average $PM_{2.5}$ concentrations were elevated at all percentile levels during the dry season, when compared to the wet season.

[2] The Protocol for Environmental Management (EPA Victoria, 2007) provides requirements for assessment and management of emissions to the air environment from mining and extractive industries. It provides an alternate method to assess cumulative impacts by using the 70th percentile of background concentrations. This method is considered more appropriate for this project based on the intermittent and changing location of air quality emissions anticipated during the Project.

From Table 3-7 it can be seen that there was an average of five exceedances of the AAQ-NEPM objective for PM_{10} (50 µg/m^3), which also all occurred during the dry season. It is again noted that no exceedances occurred during September to October, which in similarity to the $PM_{2.5}$ dataset, suggests exceedances are more likely to occur earlier in the dry season. The average PM_{10} concentrations were elevated at all percentile levels during the dry season, when compared to the wet season.

The average monthly $PM_{2.5}$ and PM_{10} trends measured at the Palmerston AQMS between 2016 and 2018 indicate that the background air quality environment will need to be considered during the construction and operation of Project. In particular, the increase in baseline $PM_{2.5}$ and PM_{10} levels and the corresponding potential for NEPM exceedances, in combination with dust generating sources from the Project.

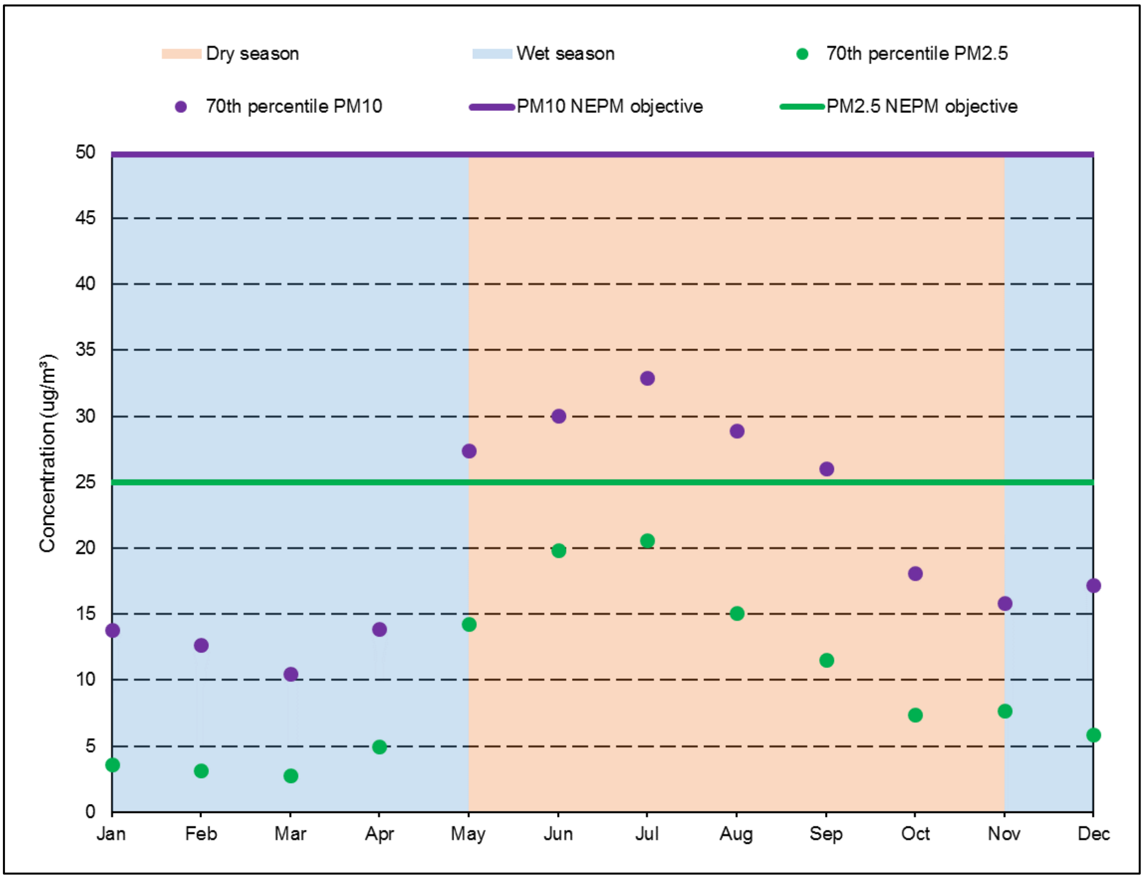

Figure 3-6 Palmerston $PM_{2.5}$ and PM_{10} average 70th percentile value 2016 – 2018

Table 3-6 Palmerston 2016 - 2018 $PM_{2.5}$ average statistics

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average monthly exceedances of NEPM objective (25 µg/m³)	0	0	0	0	3	3	5	1	0	0	0	0
100th percentile	7	5	4	16	34	45	38	32	18	11	11	10
90th percentile	5	4	3	8	21	28	27	22	14	9	9	7
80th percentile	4	4	3	6	17	22	23	19	12	8	9	6
70th percentile	4	3	3	5	14	20	21	15	12	7	8	6
50th percentile	3	3	2	4	11	14	17	12	10	6	6	5

Table 3-7 Palmerston 2016 - 2018 PM_{10} average statistics

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average monthly exceedances of NEPM objective (50 µg/m³)	0	0	0	0	2	1	1	1	0	0	0	0
100th percentile	26	20	16	33	46	59	82	51	40	26	25	26
90th percentile	21	15	13	18	36	39	41	37	30	22	19	21
80th percentile	16	14	12	16	31	33	35	32	27	19	17	19
70th percentile	14	13	10	14	27	30	33	29	26	18	16	17
50th percentile	10	11	9	11	23	24	29	25	22	14	14	14

4. Impact Assessment

4.1 Pollutants of concern

Dust and particulate matter was identified as the primary air emission of concern during the Project. The impact assessment has therefore involved the estimation of emissions and dispersion modelling for the following parameters:

- Total suspended particulates – TSP
- Particulate matter with aerodynamic diameter of less than 10 microns – PM_{10}
- Particulate matter with aerodynamic diameter of less than 2.5 microns – $PM_{2.5}$

4.2 Air quality objectives

Table 4-1 below outlines the criteria adopted in the impact assessment for the pollutants of concern outlined above.

Table 4-1 Impact assessment adopted air quality objectives

Pollutant	Averaging Period	Type	Concentration (µg/m³)	Source
TSP	Annual	Maximum	90	NSW [3]
PM10	24-hour	Maximum	50	NEPM [4]
	Annual	Average	25	NEPM
PM2.5	24-hour	Maximum	25	NEPM
	Annual	Average	8	NEPM

4.3 Emissions inventory

A single worst-case air emission scenario has been considered in this impact assessment, developed to target maximum potential day-to-day material handing effort and vehicle movements. This scenario assumes material handling, vehicle movements and subsequently air emissions are occurring simultaneously at the main project site and all satellite sites 12 hours per day, seven days per week, for a three-year model period. Not all activities at the main project site have been included in the assessment, under the assumption that not all activities would not occur simultaneously with the more significant operational activities, such as the relocation of materials from existing Waste Rock Dumps (WRD) to the new Waste Storage Facility (WSF).

Where detailed construction information was incomplete, assumptions have been made that lead to an increasingly conservative estimation of air quality impact at the nearest sensitive receptors. Moreover, where any information was not provided, information has been sourced from previous Northern Territory mining development projects in which GHD has been involved and where that information satisfies the above assumptions.

[3] NSW Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales, 2016

[4] National Environment Protection (Ambient Air Quality) Measure, 2015

Importantly, the model scenario assumes that materials from all satellite sites will be transported to and deposited at the main project site simultaneously and for the full duration of the modelled period. In reality, it is expected that operations at satellite sites will occur on an intermittent basis or will occur for only a small fraction of the modelled period (months rather than years). This inherently increases the conservatism of the modelled dust generating capacity of the Project.

Emission sources are included for key activities within the following project areas:

- Rum Jungle main project site
- Mt Burton
- Mt Fitch
- Clay borrow site
- Granular borrow site

An inventory of modelled emission sources within each Project Area is presented in Table 4-2.

Table 4-2 Source inventory

Source Description	Source ID
Rum Jungle	
Excavators on WRD	RJ_1a
Loading waste rock to trucks	RJ_1b
Dump waste rock at WSF	RJ_2a
Dump granular material at WSF	RJ_2b
Dump clay at WSF	RJ_2c
Dump Mt Burton waste rock at WSF	RJ_2d
Dump lime at WSF	RJ_2e
Mixing lime at WSF	RJ_2f
Grader at WSF	RJ_2g
Compactor at WSF	RJ_2h
Haul Mt Burton waste rock in to site (from paved road to WSF)	RJ_3a
Haul lime in to site (from paved road to WSF)	RJ_3b
Haul Clay in to site (from paved road to WSF)	RJ_3c
Haul granular material in to site (from paved road to WSF)	RJ_3d
Haul waste rock from WRF to WSF (internal)	RJ_4
Wind erosion (WRD)	RJ_5
Wind erosion (South-west WSF)	RJ_6
Mt Burton	
Excavators at Mt Burton WRD	MB_1a
Loading Mt Burton waste rock to trucks	MB_1b
Haul Mt Burton waste rock (from Mt Burton to paved road)	MB_2
Wind erosion (Mt Burton WRD)	MB_3

Source Description	Source ID
Mt Fitch	
Excavator at Mt Fitch WRD	MF_1a
Dumping Mt Fitch waste rock to pit	MF_1b
Wind Erosion (Mt Fitch WRD)	MF_2
Clay borrow Site	
Excavator on clay borrow	CB_1a
Load clay to trucks	CB_1b
Haul clay (from clay borrow site to paved roads)	CB_2
Wind erosion (1/4 clay borrow site area)	CB_3
Granular borrow Site	
Excavator on granular borrow	GB_1a
Load granular material to trucks	GB_1b
Haul granular material (from granular borrow site to paved road)	GB_2
Wind erosion (1/4 granular borrow site area)	GB_3

4.4 Emission estimation

The general equation used to estimate TSP and PM_{10} emissions from mining activities is described mathematically as:

$$E_i = A \times EF_i \times \left(\frac{100 - CE}{100}\right)$$

Where:

E_i = Emission rate of pollutant *i* (kg per activity)

A = Activity data (units dependent on emission factors)

EF_i = Uncontrolled emissions factor for pollutant *i* (kg per activity)

CE = Control efficiency (%)

Where possible, the activity data and control efficiencies used in the modelling to estimate emissions from the sources described in Table 4-2 were based on the Project Description and other project activity information provided by DPIR. Emission factors used to estimate emissions of TSP and PM_{10} have been sourced from the publically available National Pollutant Inventory (NPI) Emissions Estimation Technique (EET) Manual for Mining, Version 3.1 (Australian Government, 2012) and the NPI EET Manual for Mining and Processing of Non-Metallic Minerals, Version 2 (Australian Government, 2014). Where possible, EET's were selected for overburden sources or sources from a 'material other than coal'. To allow for the estimation of emissions of $PM_{2.5}$ from each source, it is assumed that the fraction of PM_{10} which is also $PM_{2.5}$ is 25%.

Default emission factors are used for all emission sources. A description of the sources of the emissions is provided in the following sections.

It is noted that particulate emissions from mobile plant (e.g. excavators, haul trucks, light vehicles) are insignificant compared to dust emissions from mining and excavation operations, so these have not been modelled. Similarly, gaseous emissions from mobile plant are very low risk (e.g. truck exhaust compared to mega-watt scale power generation), and these have also not been modelled.

4.4.1 Activity data

The key activity data required for emission estimation are the following:

- Hourly material handling rates for each material type
- Kilometres travelled on each haul route per hour
- Exposed areas for wind erosion

Activity data (including material handling and excavation rates, exposed areas, vehicle specifications) have been selected in consideration of data provided by the DPIR and the rehabilitation design consultant (SLR Consulting). Where a range of values are applicable, the most conservative (worst-case) value has been selected. Where no data were available, default values were used.

A summary of estimated material handling effort for all material streams presented in Table 4-3.

A summary of estimated haul truck distances travelled is presented in Table 4-4.

Table 4-3 Material handling rates

Estimated daily effort (m^3/day)	Assumed density (t/m^3)	Estimated daily effort (t/day)	Shift length (hours)	Hourly effort (t/hour)
Rum Jungle waste rock				
5000	1.8	9000	12	750
Mt Burton waste rock				
750	1.8	1350	12	112.5
Mt Fitch waste rock				
750	1.8	1350	12	112.5
Clay				
600	1.8	1080	12	90
Granular material				
600	1.8	1080	12	90
Lime				
750	1.8	1350	12	112.5

Table 4-4 Haul truck distances travelled[5]

Hourly tonnage moved (t/hour)	Truck capacity (t)	Estimated trips per hour	Total haul length (km)	Total distance travelled (km/hour)
Haul waste rock from WRD to WSF (internal)				
750	90	8	4	33
Haul Mt Burton waste rock in to site (from paved road to WSF)				
375	33	12	6	69
Haul lime in to site (from paved road to WSF)				
113	33	3	6	21
Haul clay in to site (from paved road to WSF)				
90	33	3	6	17
Haul granular material in to site (from paved road to WSF)				
90	33	3	6	17
Haul Mt Burton waste rock (from Mt Burton to paved road)				
375	33	12	4	46
Haul clay (from clay borrow site to paved roads)				
90	33	3	4	11
Haul granular material (from granular borrow site to paved road)				
90	33	3	6	17

4.4.2 Emission factors, activity data and emission rates

Emission factors, activity data and modelled emission rates are detailed in Appendix A.

[5] Emissions of particulates due to haulage on sealed roads have not been included.

4.4.3 Modelled dust control measures

The modelled scenario considers basic dust control measures whereby active dust emission control factors are applied in the form of haul road watering and naturally moist topsoil only. Additional dust emission control measures would include misting/water sprays at excavation areas and around material handling activities.

A summary of 'control-factors' applied in the emissions modelling are provided in Table 4-5 and are further discussed below.

Table 4-5 Summary of applied controls - enhanced controls

Control type	Control factor (% reduction)	Applicable to which emission sources types	Source ID's
Level 2 watering	TSP – 75% PM_{10} – 75%	Haul roads	All haul road sources
Topsoil naturally moist	TSP – 50% PM_{10} – 50%	All sources	All sources during wet season

Haul road watering

It is assumed that water trucks will be able to apply level 2 watering to achieve enhanced controls. Level 2 watering, as described in the NPI EET Manual for Mining (Australian Government, 2012) is a watering rate of greater than 2 litre/m^2/hr. A level 2 watering rate can achieve dust emission reduction of 75 percent.

Despite the extensive lengths of planned haul routes, the use of the ambitious Level 2 watering control factor in the modelling is justified on the basis that additional primer-sealants may be applied to haul routes closest to dust-sensitive receptors.

Topsoil naturally moist

It is assumed that particulate emissions from all activities will be greatly reduced during the wet season due to high rainfall rates and subsequently, high moisture levels across all material surfaces. The rate at which emissions will be controlled will depend on source type. Naturally moist topsoil, as described in the NPI EET Manual for Mining (Australian Government, 2012), is estimated to provide a 50% reduction in particulate emissions from all sources.

4.5 Dispersion modelling

4.5.1 Model set up

The air quality dispersion modelling was conducted using the US EPA regulatory Gaussian puff model CALPUFF Version 5. Details of model configuration are outlined below:

- Model: CALPUFF Version 5.8.
- The years 2016, 2017 and 2018 were modelled.
- A Cartesian receptor grid was modelled with a 150 m nested grid resolution.
- 12 residences were identified as discrete receptors, as presented in Table 3-1 and located as shown in Figure 3-1. These receptors were selected on the basis of proximity and orientation to nearest operational areas. In some instances a single receptor represents a group of residences (i.e. Rum Jungle Township and Batchelor).
- Modelling was completed for a 1-hour time step.

- Air quality impacts have been estimated using variable emission rates for each source. The following emission variation schemes were used:
  - For all material handling, excavation and haul road emissions:
    - Zero emissions between 6 pm to 6 am when operations are not occurring.
    - Emissions are reduced by 40% during the wet season (December-May) to account for reduced activity rates.
  - For all sources, emission rates are further reduced by 50% during the wet season (December-May) to account for increased surface soil moisture.
  - No consideration of expected operational durations at each project area were included in the model (discussed further in Section 4.6.1).
- Meteorology data was sourced from CALMET as per Section 3.2.
- All CALPUFF settings were consistent with the model default values.
- All sources were modelled as volume sources. Source locations are shown in Figure 4-1, noting the following:
  - Material handling emission sources are located within the footprint of each emission area as identified through review of spatial data provided by DPIR. For each activity area, emissions from all material handling activities are modelled as a single volume.
  - Haul paths and segment lengths are mapped based on available aerial imagery. Haul paths are included for unsealed roads only and are mapped on the basis of existing roads/access tracks only. Any proposed access tracks that would reduce the length of haul routes have not been considered.
  - Additional locations are selected that allow for a reasonably conservative estimate of ground level concentrations (GLC) at the nearest sensitive receptor.
- Post processing of the model results was completed as follows:
  - For comparison against annual criterion, annual averages were calculated for each model year, with the maximum of these values presented at each receptor.
  - For comparing against 24-hour criterion, daily averages were calculated for all 1096 model days, with the maximum of these values presented at each receptor.

Modelled source locations

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Figure 4-1

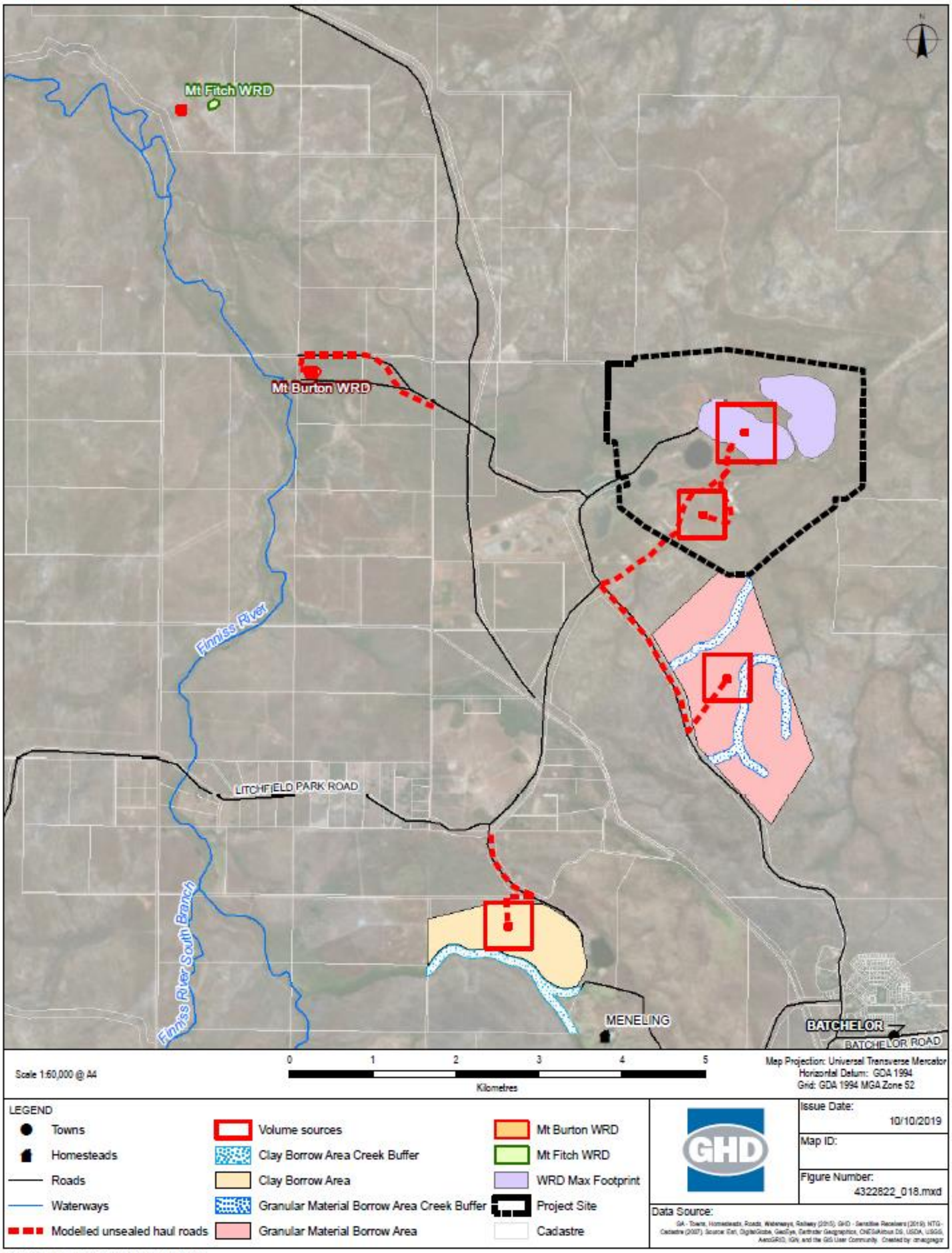

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Figure 4-1 Modelled source locations

4.5.2 Project related (incremental) impact

The predicted ground level dust concentrations generated by the Project (i.e. excluding background pollutant concentrations) are presented as contour plots for each pollutant in the following figures:

- Figure 4-2 – Ground level TSP concentrations are presented as the maximum annual average concentration. The objective of 90 µg/m³ is shown as a yellow contour line. No exceedances of the objective are shown at any sensitive receptor location.
- Figure 4-3 – Ground level PM_{10} concentrations are presented as:
  - The maximum annual average concentration. The objective of 25 µg/m³ is shown as a yellow contour line. No exceedances of the objective are shown at any sensitive receptor location.
  - The maximum 24-hour average concentration. The objective of 50 µg/m³ is shown as a purple contour line. Exceedances of the objective were reported by the model at sensitive receptors R3 (Mt Burton) and R8 (Clay Borrow).
- Figure 4-4 – Ground level $PM_{2.5}$ concentrations are presented as:
  - The maximum annual average concentration. The objective of 8 µg/m³ is shown as a yellow contour line. No exceedances of the objective are shown at any sensitive receptor location.
  - The maximum 24-hour average concentration. The objective of 25 µg/m³ is shown as a purple contour line. Exceedances of the objective were reported by the model at sensitive receptor R3 (Mt Burton) only.

The contour plots show the predicted impact from the Project only and do not include any contribution to ground level concentrations caused by background pollutant load events (such as those demonstrated in baseline data-sets, including regional bush-fire events). Whilst this method generates a simplistic understanding of the spatial variation in predicted pollutant levels due to the Project, it does not allow for a true comparison against the adopted criteria.

Cumulative (Project and background) ground level concentrations are assessed for each receptor in Section 4.5.3.

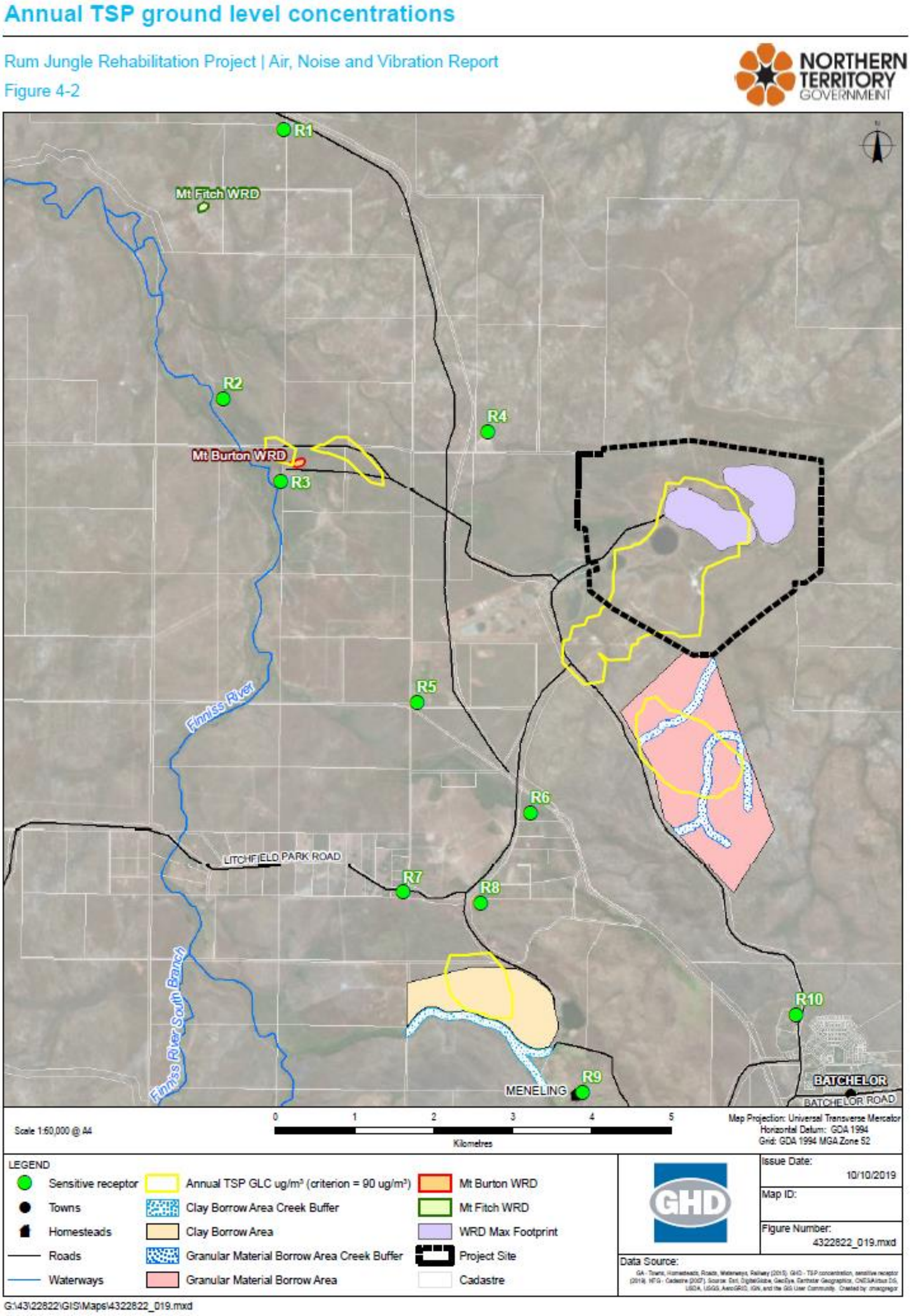

Figure 4-2 Annual TSP ground level concentrations

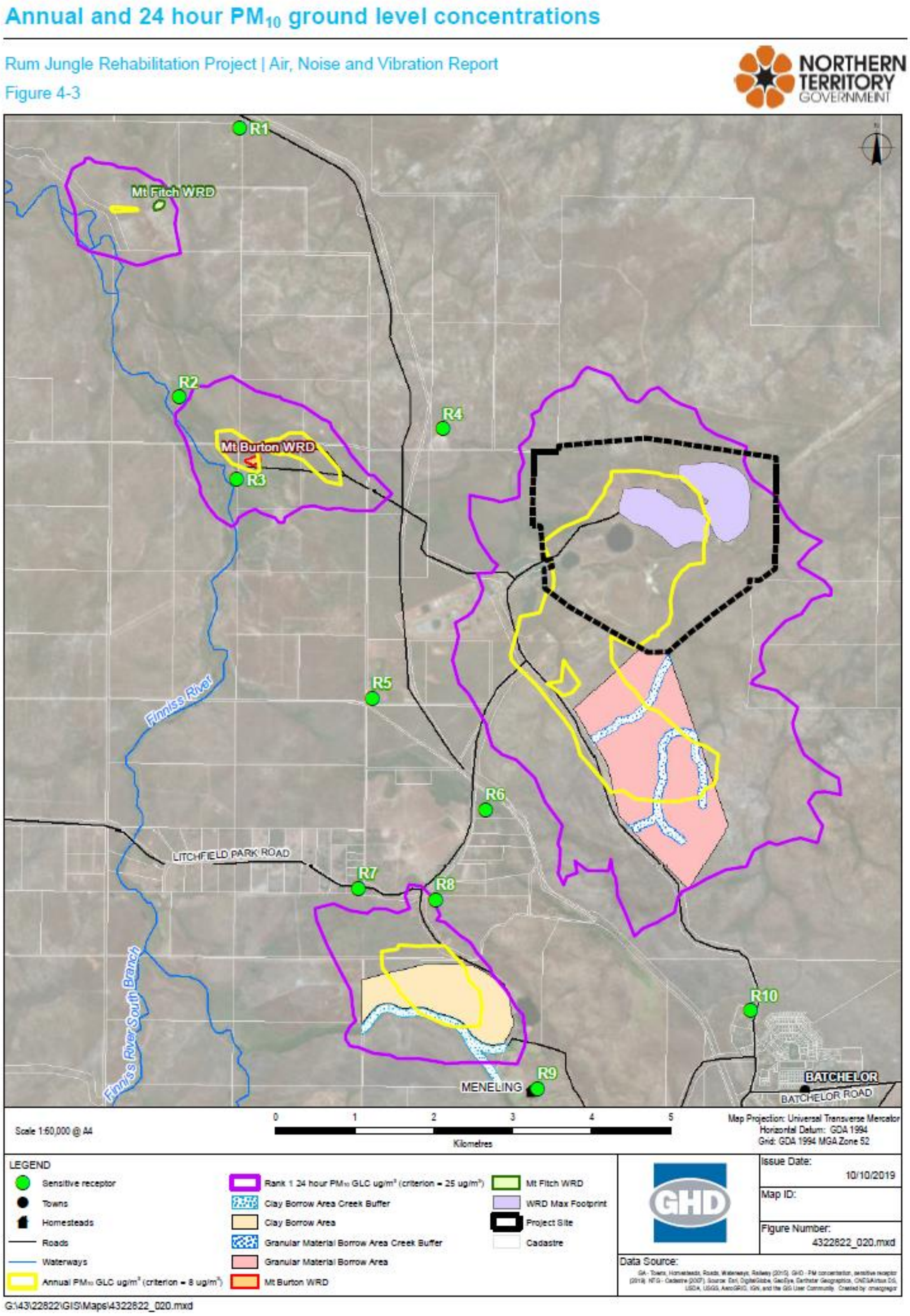

Figure 4-3 Annual and 24 hour PM10 ground level concentrations

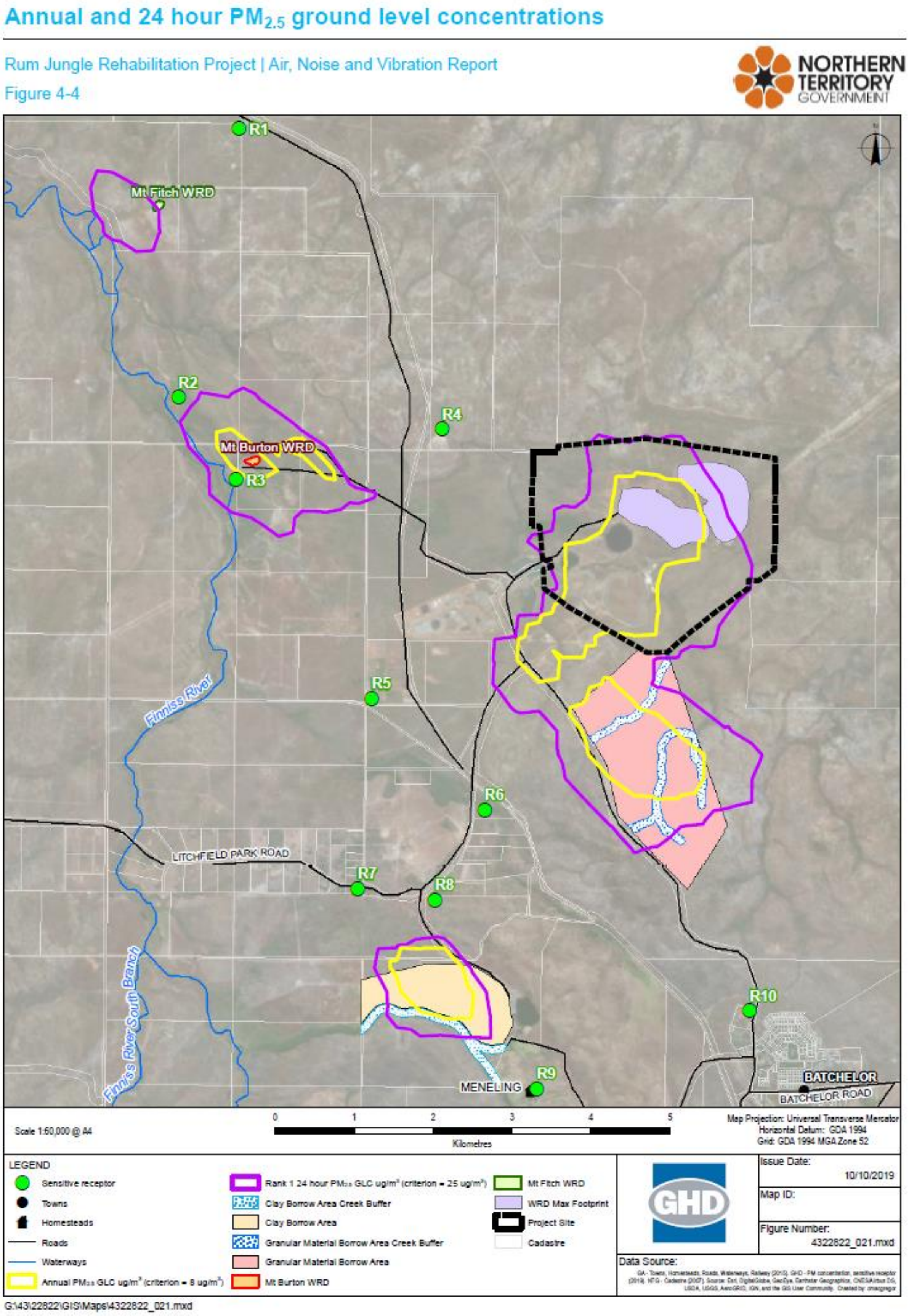

Figure 4-4 Annual and 24 hour PM2.5 ground level concentrations

4.5.3 Estimated cumulative impact

The cumulative impact (i.e. from the Project and background levels of pollutants) is predicted as described below:

- Cumulative impact is calculated for pollutants 24-hour PM_{10} and $PM_{2.5}$ which through assessment of the initial Project related contour plots have the highest predicted incremental impacts.
- Background air quality data are sourced from the Palmerston AQMS, as described in Section 3.3.2. The 70th percentile[6] 24-hour average concentration have been selected, as shown in Figure 3-6, and are used as the background values for each month of the year.
- The monthly background values are summed with the maximum 24-hour prediction of the incremental (Project only) impact for each month.

This method and results are shown in Table 4-6 and Table 4-7 for PM_{10} and $PM_{2.5}$, respectively. Where the cumulative result is greater than the respective objectives (i.e. 24-hour PM_{10} criterion of 50 µg/m³ and 24-hour $PM_{2.5}$ criterion of 25 µg/m³) these results are highlighted in blue.

[6] The Protocol for Environmental Management (EPA Victoria, 2007) provides the requirements for assessment and management of emissions to the air environment from mining and extractive industries. It provides an alternate method fpr assessing cumulative impacts by using the 70th percentile of background concentrations. This method is considered appropriate based on the anticipated intermittent and changing location of air quality emissions during the Project.

Table 4-6 Predicted cumulative PM_{10} impact at sensitive receptor location

Receptor ID	Monthly, maximum 24-hour average PM_{10} concentration (µg/m³)												Maximum (µg/m³)	Number of months where objective (50 µg/m³) is exceeded
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec		
Background Value (see Table 3-7)	14	13	10	14	27	30	33	29	26	18	16	17	70th percentile (µg/m³)	
1	24	14	13	19	34	40	43	37	33	25	21	18	43	0
2	54	24	22	26	48	68	73	68	51	43	31	23	73	5
3	83	70	71	35	56	77	175	62	26	237	282	83	282	10
4	22	20	20	28	47	55	63	56	52	41	34	21	63	4
5	21	25	19	22	44	49	48	46	45	34	32	23	49	0
6	24	34	32	27	44	48	53	45	53	40	44	31	53	2
7	19	23	17	30	62	74	70	64	44	39	34	22	74	4
8	23	21	21	22	51	41	59	60	52	47	45	27	60	4
9	31	26	30	22	46	55	66	55	55	45	49	33	66	4
10	25	17	21	19	32	40	39	46	40	32	35	30	46	0
11	19	17	14	16	30	33	39	39	31	25	23	21	39	0
12	16	16	14	15	29	31	35	35	29	21	21	20	35	0

Table 4-7 Predicted cumulative $PM_{2.5}$ impact at sensitive receptor location

Receptor ID	Monthly, maximum 24-hour average $PM_{2.5}$ concentration (µg/m³)												Maximum (µg/m³)	Number of months where objective (25 µg/m³) is exceeded
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec		
Background Value (see Table 3-6)	4	3	3	5	14	20	21	15	12	7	8	6	70th percentile (µg/m³)	
1	6	4	3	6	16	22	23	17	13	9	9	6	23	0
2	22	7	6	10	22	36	39	27	25	18	12	7	39	3
3	26	19	21	33	49	48	75	73	75	62	115	26	115	10
4	6	5	5	8	19	26	28	22	18	13	12	7	28	2
5	5	6	5	7	18	26	24	19	16	11	12	7	26	1
6	6	9	8	8	18	25	26	19	18	13	15	9	26	1
7	5	6	4	9	23	30	30	24	16	12	12	7	30	2
8	6	5	5	7	20	22	27	23	18	14	15	8	27	1
9	8	6	8	7	19	26	29	21	19	14	16	10	29	2
10	6	4	5	6	15	23	22	19	15	11	12	9	23	0
11	5	4	4	5	15	21	22	18	13	9	10	7	22	0
12	4	4	4	5	15	20	21	17	12	8	9	7	21	0

4.6 Discussion of predicted impacts

4.6.1 Conservatism in the assessment

The results of the air quality modelling provide an understanding of which sensitive receptors are most likely to be most affected by an increase in ambient particulate matter concentrations cause by the Project. The modelled emissions scenarios also provide information regarding the spatial variability in predicted air quality impacts from the Project. The assessment of predicted cumulative (Project plus background) concentrations, indicates that exceedances of the PM_{10} and $PM_{2.5}$ objectives may result at a number of receptor locations.

Control measures to alleviate air quality impacts at each receptor are suggested in Section 5. However, it is noted that the modelled impact assessment incorporates conservatism via the adoption of several assumptions and model settings; and that in reality, anticipated air quality impacts may be of a significantly lesser magnitude than are modelled in this impact assessment. The following factors have contributed to the modelled conservatism:

- The model scenario makes the assumption that for all working hours, operations are occurring at each satellite site, with materials from all satellite sites (excluding Mt Fitch) being deposited at the Rum Jungle site concurrently.
- The model configuration does not consider the specific duration of operations at each of the satellite sites. For example, although earthworks at Mt Burton are expected to be completed within a two month timeframe, the modelled scenario assumes operations at Mt Burton will occur for the 1,096 days modelled. This methodology is necessary to ensure that worst-case meteorological conditions are captured to be coincident with the Mt Burton works. However, the monthly maximum 24-hr average concentrations predicted by the model can be evaluated against AAC-NEPM objectives for PM_{10} (50 $\mu g/m^3$) and $PM_{2.5}$ (25 $\mu g/m^3$), irrespective of the modelled works timing or duration.
- Default emission factors have been sourced from the National Pollutant Inventory Manual for Mining. The Manual allows for some site specific variation to emission factors, which has not been utilised in this assessment. Where accurate, site specific data is available for particular material types, less conservative emission factors can be used. In particular, the particle size distribution of the waste rock in the existing WRDs includes a well-graded mixture of soil particles up to cobble and boulder dimensions. Although such materials will exhibit lesser particulate emission rates, the addition and spreading of agricultural lime (as a neutralising soil amendment) may produce greater than average dust impacts. Emission estimation factors for these types of material are not provided in the NPI EET manuals and default model parameters have therefore been used.

4.6.2 Identification of most affected receptors

Of the 12 sensitive receptors considered in the estimate of cumulative PM_{10} and $PM_{2.5}$ impacts, exceedances of one or more of the objectives were predicted at eight locations. Based on the results presented in Table 4-6, the exceedances at each receptor can be further classified as follows:

- **No exceedance**
- **Minor exceedance** – the maximum cumulative PM_{10} and/or $PM_{2.5}$ concentration exceeds the objective by less than 10 µg/m³ for all months where an exceedance is recorded.
- **Moderate exceedance** – the maximum cumulative PM_{10} and/or $PM_{2.5}$ concentration exceeds the objective by more than 10 µg/m³ for more than one month.
- **Major exceedance** – the maximum cumulative PM_{10} and/or $PM_{2.5}$ concentration is significantly elevated above the objective for most months.

The application of this classification system to each receptor is summarised in Table 4-8 and can be used to provide a framework for the types and quantity of monitoring or mitigation measures recommended to protect against impacts at each receptor.

Table 4-8 Nature of exceedances at sensitive receptors

ID	Closest project area	Direction from project area	Approx. min. distance to works	Nature of exceedance
R1	Mt Fitch	NE	1.7 km	No exceedance
R2	Mt Burton	NW	1.2 km	Moderate exceedance
R3	Mt Burton	SW	0.2 km	Major exceedance
R4	Rum Jungle	NW	1.2 km	Moderate exceedance
R5	Rum Jungle	SW	2.0 km	Minor exceedance
R6	Granular Borrow	WSW	1.5 km	Minor exceedance
R7	Clay Borrow	NW	1.2 km	Moderate exceedance
R8	Clay Borrow	N	0.1 km	Moderate exceedance
R9	Clay Borrow	SE	1.2 km	Moderate exceedance
R10	Granular Borrow	SSE	1.8 km	No exceedance
R11	Granular Borrow	ESE	6.0 km	No exceedance
R12	Rum Jungle	SE	8.0 km	No exceedance

5. Mitigation of predicted effects

Recommended mitigation measures are ranked by effectiveness in a tiered system, with Tier 1 recommendations encompassing a series of highly-effective measures, through Tier 3 recommendations, which provide a lower hierarchy of control. Each type of mitigation measure is outlined in Table 5-1 below.

Table 5-1 Recommended mitigation

Control tier	Control Type	Description of mitigation measure
Tier 1	Elimination of risk	Relocation of residents during operations.
Tier 2	Operational restrictions	Cease all operations for specified range of meteorological conditions.
		Reduction in rate of operations based on a specified range of meteorological conditions.
		Cease or reduce the rate of operations on days with poor background air quality.
		Real-time air quality monitoring to allow for reactive management of elevated particulate levels.
Tier 3	Enhanced controls	Elevated levels of water sprays on haul roads, during excavation and material handling. Use of chemical suppressants where higher efficiencies are required.
	Compliance/trend analysis	Lag-indicator air quality monitoring, such as dust deposition gauges and high-volume air samplers. These would allow assessment of compliance and post-event corrective actions in response to non-compliances.
Applied to all community members as appropriate	Community engagement	Engage with the community to gather data on operations, provide a platform for community to lodge complaints, respond in a timely fashion to complaints, and offer services such as roof/car/water tank cleaning to alleviate community concerns.

Table 5-2 (following page) outlines recommendations for operational air quality mitigation measures during the Project.

The recommendations have been developed and targeted to specific receptors, however it is expected that adoption of operational mitigation measures are likely to provide benefits to the wider air-shed environment. Whilst the mitigation measures have been developed based on predicted exceedances of relevant human health criteria, it is expected that the application of these mitigation measures will provide significant protection to environmental values other than human health and safety. These environmental values include; protection from radiation, socio-economic effects, biodiversity – terrestrial ecosystem and historic and cultural heritage.

Targeted recommendations are not provided for receptors where the predicted cumulative PM_{10} and/or $PM_{2.5}$ impact is in compliance with the relevant AAQ-NEPM objective.

Table 5-2 Recommended mitigation measures by receptor

Mitigation Tier			Comment
Tier 1	Tier 2	Tier 3	
Receptor 2 – Approximately 1.2 km northwest of Mt Burton operations			
Not recommended	A combination of: • reduced rates of operation during wind directions between east-southeast and southeast • further reduction/cessation of operations during poor air quality days[1] • real-time air quality monitoring system[2] to enable the application of controls	Elevated controls including enhanced watering rates on haul road and water sprays during material handling activities Dust deposition gauge to monitor effect and compliance	Whilst there is significant separation to the Mt Burton site, this receptor will be downwind of a concentrated material handling effort during operations in the dry season. For protection of human health at this receptor, a real-time air quality monitoring system is recommended.
Receptor 3 – Approximately 200 m southwest of Mt Burton operations			
Relocation of residents during operations.	Cease all operations at Mt Burton site, including hauling, for wind directions between north and east. OR: A combination of: • reduced rates of operation during wind directions between north and east • further reduction/cessation of operations during poor air quality days[1] • real-time air quality monitoring system[2] to enable the application of controls	Elevated controls including enhanced watering rates on haul road and water sprays during material handling activities Dust deposition gauge to monitor effect and compliance	Where residents are relocated from the property during operations at Mt Burton, it is not expected that additional mitigation measures will be required. However, cleaning of roof/car/water tanks prior to the resident returning to the premises is recommended.
Receptor 4 – Approximately 1.2 km northwest of Rum Jungle operations			
Not recommended	Reduced rates of operation during poor air quality days[1] and operation of a real-time air quality monitoring system[2]	Dust deposition gauge to monitor effect and compliance	Whilst there is significant separation to the Rum Jungle site, this receptor will be downwind of an extensive material handling effort during operations in the dry season. This receptor may be impacted for the majority of the Project duration and as such it is less feasible to apply an operational restriction based on wind directions. Operation of a real-time air quality monitoring system will allow application of operational restrictions only when truly required.
Receptor 5 – Approximately 2.0 km southwest of Rum Jungle operations			
Not recommended	Not recommended	Dust deposition gauge to monitor effect and compliance	Predicted exceedances are minor and infrequent. Dust deposition gauges to be operated at the receptor location to allow for trends in pollutant loads to be examined.
Receptor 6 – Approximately 1.5 km west-southwest of operations at the Granular Borrow Area			
Not recommended	Not recommended	Dust deposition gauge to monitor effect and compliance	Predicted exceedances are minor and infrequent. Dust deposition gauges to be operated at the receptor location to allow for trends in pollutant loads to be examined.

1. A poor air quality day as defined on the Northern Territory Environment Protection Authority air monitoring network (http://ntepa.webhop.net/NTEPA/Default.ltr.aspx). On days where air quality is very poor or severe, it is recommended that major material handling and hauling operations are ceased.
2. Real-time air quality monitoring should be installed at the receptor location and will have telemetered alarms to alert operators when and where a trigger level is exceeded.
3. Equipment types could include high-volume air sampler or real-time monitoring equipment with relevant compliance with Australian Standards. Feasibility of equipment type will be dependent on a number of factors including, duration of works, level of concern demonstrated by resident, access to mains power for siting.

Mitigation Tier			Comment
Tier 1	Tier 2	Tier 3	
Receptor 7 – Approximately 1.2 km northwest of operations at the Clay Borrow Area			
Not recommended	Reduced rates of operation during poor air quality days[1] and operation of a real-time air quality monitoring system[2]	Elevated controls including enhanced watering rates on haul road as well as limiting vehicle speeds Dust deposition gauge to monitor effect and compliance	Predicted impacts at this receptor are expected to be representative of impacts at a number of receptors within the Rum Jungle Township. Whilst there is significant separation from operational areas, the receptor will be downwind of the operations and haul routes during the dry season. Real-time air quality monitoring is recommended to allow for the protection of human health at this receptor and others within the Rum Jungle Township.
Receptor 8 – Approximately 100 m east of the haul access track to the Clay Borrow Area			
Not recommended	Reduced rates of operation during poor air quality days[1] and operation of a real-time air quality monitoring system[2]	Elevated controls including enhanced watering rates on haul road as well as limiting vehicle speeds on haul road Dust deposition gauge to monitor effect and compliance	Impacts at this receptor are likely to be driven by emissions from vehicle traffic on the access track. Due to the extended length of operations at this site, sealing the access track should be considered and would provide beneficial outcomes for multiple receptors in the Rum Jungle Township.
Receptor 9 – Approximately 1.2 km southeast of operations at the Clay Borrow Area			
Not recommended	Reduced rates of operation during poor air quality days[1]	Dust deposition gauge to monitor effect and compliance	Predicted exceedances are minor and infrequent. Dust deposition gauges to be operated at the receptor location to allow for trends in pollutant loads to be examined.

1. A poor air quality day as defined on the Northern Territory Environment Protection Authority air monitoring network (http://ntepa.webhop.net/NTEPA/Default.ltr.aspx). On days where air quality is very poor or severe, it is recommended that major material handling and hauling operations are ceased.
2. Real-time air quality monitoring should be installed at the receptor location and will have telemetered alarms to alert operators when and where a trigger level is exceeded.
3. Equipment types could include high-volume air sampler or real-time monitoring equipment with relevant compliance with Australian Standards. Feasibility of equipment type will be dependent on a number of factors including, duration of works, level of concern demonstrated by resident, access to mains power for siting.

6. Conclusions

This air quality impact assessment is considered to address relevant items outlined in the ToR and the Project Risk Register. The assessment was completed with a focus on prediction of human health impacts at sensitive receptors due to dust emissions from the Project.

The impact assessment, which is conservative in nature, has predicted exceedances of ambient air quality objectives at sensitive receptors surrounding the main project site and at satellite sites. A hierarchy of mitigation measures, including operational controls, as well as reactive and compliance-level monitoring options, are provided in Table 5-2. Those measures are expected to reduce the probability of exposure of receptors to air quality impacts and importantly control/restrict operations with the aim of reducing emissions of particulate matter from the Project site.

The outcomes of each assessment and how they relate to each item of the ToR and Risk Register are summarised in Table 6-1 and Table 6-2 respectively.

Where potential environmental impacts of the ToR and risk register were not addressed through quantitative assessment, mitigation measures are discussed to allow for estimation of the associated risk.

Table 6-1 ToR required information relevant to air quality and outcomes

Section	Topic	Information required (relevant to air emissions only)	Outcome from assessment
2.2.1 - Terrestrial flora and fauna	Potential impacts and risks	Quantify and/or discuss any potential for a decline in distribution, abundance or health of identified values due to: • **Dust**, noise, vibration and light • Radionuclide exposure from **dust** emissions, contaminated water resources or other sources of exposure	Quantification of impacts and risk to Terrestrial flora and fauna are not included in the air quality impact assessment. However, the following general recommendations are provided, which can be applied within an operational environmental management plan: • Dust deposition gauges (or gravimetric air quality monitoring equipment) can be installed at areas identified as being ecologically sensitive to airborne deposition of particulates and their constituents. Temporal and spatial analysis of deposition rates as well as composition of dusts can be used to inform ecological assessments. • Meteorological analysis / patterns of air pollutant dispersion can be utilised as a tool in ecological impact assessment where a receptor is identified as being sensitive to air pollution.
2.2.7 - Human health	Potential impacts and risks	Quantify and/or discuss the following potential impacts for the Proposal, including post-rehabilitation: • Radiological impacts including: – details of radiation dose potential from Proposal elements to human health including consideration of exposure due to all pathways: radon and its decay products, radioactive particles in **dust**, and alpha and gamma radiation	The completed air quality impact assessment focusses on the prediction of human health impacts at sensitive receptors due to dust emissions from the Project. Mitigation measures - including operational controls - are provided in Table 5-2 which both reduce the probability of exposure of receptors and effective operational controls and restrictions that will reduce particulate emissions from the operation. Quantification of radiological impacts and risks to Human health due to are not included in the air quality impact assessment. However, the following general recommendations are provided, which can be applied within an operational environmental management plan: • During the movement of known radiological materials, enhanced dust control measures can be applied such as water sprays during excavation/dumping of materials, water sprays on stockpiles, wind breaks, chemical suppressants. • Daily risk forecasts and operational restrictions during movements of known radiological materials may be applied. Analysis of meteorological conditions (elevated wind speeds, wind directions) can be used to reduce risk of pollutants being transferred to the receptors. • Dose monitoring for workers as recommended by radiological experts. • Ambient monitoring at receptor locations as recommended by radiological experts.

Table 6-2 Potential air quality impacts identified in environmental risk register

Potential event	Environmental Factor	Description of impact	Outcome from assessment
Emissions of dust from exposed surfaces due to wind erosion, excavation, material handling and vehicle movements on haul roads and access tracks	Human health and safety	Transport of dust to sensitive receptors leading to increase of inhalation of ambient particulate matter (TSP, PM_{10}, $PM_{2.5}$).	The air quality impact assessment predicted (in worst-case scenarios) exceedances of relevant air quality objectives for the protection of human health. These exceedances were predicted at a number of receptor locations distributed across the Project. Exceedances were predicted as a result of emissions from all satellite project areas with exception of Mt Fitch. Receptor specific mitigation measures are provided in Table 5-2 which recommend measures ranging from highly effective measures (such as relocation of residents during operations) through to basic measures, such as operation of dust deposition gauges at receptor locations. Through appropriate incorporation of the recommendations within an air quality/environmental management plan, it is expected that unacceptable human health and safety impacts on the surrounding community will be avoided.
	Socio-economic	Transport to and deposition of dust at sensitive receptors leading to loss of amenity.	Estimation of dust deposition rates and subsequent quantification of socio-economic risk was not included in the air quality impact assessment. However, the recommendations outlined in Table 5-2 will act to reduce the probability of exposure of receptors and importantly control/restrict operations with the aim of reducing emissions of particulates from the operation. Community engagement measures are outlined in Table 5-1 which can play an important role in alleviation of community concerns and dissatisfaction after events of loss of amenity. Further they can provide valuable information to the operator, allowing process specific changes to occur, reducing future impacts. Through appropriate incorporation of the recommendations within an air quality/environmental management plan, it is expected that unacceptable socio-economic impacts on the surrounding community will be avoided.
	Historic and cultural heritage	Transport to and deposition of dust at cultural heritage site, sacred sites or artefacts leading to loss of amenity and/or disturbance of the site.	Quantification of risk to historic and cultural heritage was not included in the air quality impact assessment. However, the recommendations outlined in Table 5-2 will act to reduce the probability of exposure of receptors and importantly control/restrict operations with the aim of reducing emissions of particulates from the operation. Through appropriate incorporation of the recommendations within an air quality/environmental management plan, it is expected that impacts to cultural and heritage sites will be avoided.
	Biodiversity - Terrestrial Ecosystem	Transport to and deposition of dust in the environment leading to reduction in habitat quality and/or quantity (within and surrounding the project area) leading to a decrease in the diversity and/or abundance of species.	Quantification of impacts and risk to Terrestrial flora and fauna are not included in the air quality impact assessment. However, the following general recommendations are provided, which can be applied within an environmental management plan: • Dust deposition gauges (or gravimetric air quality monitoring equipment) can be installed at areas identified as being ecologically sensitive to airborne deposition of particulates and their constituents. Temporal and spatial analysis of deposition rates as well as the composition of dusts can be used to inform ecological assessments. • Meteorological analysis / patterns of air pollutant dispersion can be used in ecological impact assessments where a receptor is identified as being sensitive to air pollution. • Through appropriate incorporation of the recommendations within an air quality/environmental management plan, it is expected that unacceptable impacts on surrounding terrestrial ecosystems may be avoided.
Emissions of radionuclides within dust emissions from exposed surfaces due to wind erosion, excavation and material handling and vehicle movements on haul roads and access tracks	Human health and safety	Transport of dust to sensitive receptors leading to increase of inhalation and ingestion of radionuclides	Quantification of risk to human health and safety or biodiversity – terrestrial ecosystem due emissions of radiological materials was not included in the air quality impact assessment. However, the following general recommendations are provided, which can be applied within an operational environmental management plan: • During movement of known radiological materials, enhanced dust control measures can be applied such as water sprays during excavation/dumping of materials, water sprays on stockpiles, wind breaks, chemical suppressants. • Daily risk forecast and operational restrictions during movements of known radiological materials. Analysis of meteorological conditions (elevated wind speeds, wind directions) can be utilised to reduce risk of pollutants being transferred to the nearest receptors. • Dose monitoring for workers as recommended by radiological experts. • Ambient monitoring at receptor locations as recommended by radiological experts. • Dust deposition monitoring and subsequent testing for radionuclides at ecologically sensitive locations as recommended by radiological experts.
	Human health and safety	Worker exposure dust leading to increase of inhalation and ingestion of radionuclides	
	Biodiversity - Terrestrial Ecosystem	Transport of dust to the environment leading to reduction in habitat quality and/or quantity (within and surrounding the project area) leading to a decrease in the diversity and/or abundance of species.	
Emissions of hazardous pollutants due to combustion of fuels from mobile plant	Human health and safety	Transport of dust to sensitive receptors leading to increase of inhalation of hazardous pollutants (CO, NOx, SOx, volatile organic compounds (VOC))	Quantification of risk to human health due emissions of hazardous pollutants from the combustion of fuels was not included in the air quality impact assessment. However, the following general recommendations are provided, which can be applied within an operational environmental management plan: • Supply of electricity for the facility from mains connections or solar panels will alleviate the requirement for onsite fuel consumption and emissions from site generators. Where on-site generators are used for temporary or permanent power supply, an air quality impact assessment may be completed. • Sampling for constituents using passive samplers (as described in section 3.3.1) can be carried out, compared to the background results presented in 3.3.1 and analysed for any temporal and spatial variation in pollutant loads.

7. References

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Appendices

Appendix A – Emission factors, activity data and emission rates

A summary of the emission factors used for in the modelling is provided in Table A 1.

A summary of source specific activity data used is provided in Table A 2.

A summary of emission rates is provided in Table A 3.

Table A 1 Summary of uncontrolled emissions factors

Activity type	Required Information	Emission Factor[7]		Units	Applicable to Source ID
		TSP	PM_{10}		
Excavators/shovels/front-end loaders	Tonnes of material handled	0.025	0.012	kg/t/hour	RJ_1a, RJ_2f, MB_1a, MF_1a, CB_1a, GB_1a
Trucks dumping	Tonnes of material handled	0.012	0.0043	kg/t/hour	RJ_1b, RJ_2a, RJ_2b, RJ_2c, RJ_2d, RJ_2e, RJ_2f, MB_1a, MB_1b, MF_1a, MF_1b, CB_1a, CB_1b, GB_1a, GB_1b
Bulldozers	Operational hours	17	4.1	kg/hour	RJ_2h
Graders	Total kilometres travelled	0.19	0.085	kg/km/hour	RJ_2g
Unpaved haul roads (internal roads)[8]	Total kilometres travelled	4.6	1.4	kg/km/hour	RJ_4
Unpaved haul roads (external haul routes)[9]	Total kilometres travelled	3.2	0.95	kg/km/hour	RJ_3a, RJ_3b, RJ_3c, RJ_3d, RJ_4, MB_2, CB_2, GB_2
Wind erosion	Exposed area	0.4	0.2	kg/ha/hour	RJ_5, RJ_6, MB_3, MF_2, CB_3, GB_3

[7] All emission factors sourced from National Pollutant Inventory (NPI) Emissions Estimation Technique (EET) Manual for Mining, Version 3.1, Table 2.

[8] CAT777D Off-highway truck assumed for internal haulage, Gross Weight = 163.36 t, Nominal Payload Capacity = 90.4 t

[9] B-Double trucks assumed for haulage between sites, Assumed Gross Weight = 42.5 t, Assumed Payload Capacity = 32.5 t

Table A 2 Source activity data

Source description	Source ID	Activity data[10]	Unit	Comment
Rum Jungle				
Excavators on WRD	RJ_1a	750	t/hour	As per Table 4-3
Loading waste rock to trucks	RJ_1b	750	t/hour	
Dump waste rock at WSF	RJ_2a	750	t/hour	
Dump granular material at WSF	RJ_2b	90	t/hour	
Dump clay at WSF	RJ_2c	90	t/hour	
Dump Mt Burton waste rock at WSF	RJ_2d	375	t/hour	
Dump lime at WSF	RJ_2e	112.5	t/hour	
Mixing lime at WSF	RJ_2f	112.5	t/hour	
Grader at WSF	RJ_2g	5	km/hour	Assumed 5 k/h travel speed
Compactor at WSF	RJ_2h	1	hour/hour	-
Haul Mt Burton waste rock in to site (from paved road to WSF)	RJ_3a	69	km/hour	As per Table 4-4
Haul lime in to site (from paved road to WSF)	RJ_3b	21	km/hour	
Haul Clay in to site (from paved road to WSF)	RJ_3c	17	km/hour	
Haul granular material in to site (from paved road to WSF)	RJ_3d	17	km/hour	
Haul waste rock from WRD to WSF (internal)	RJ_4	33	km/hour	
Wind erosion (WRD)	RJ_5	32	ha/hour	Approximate area based on WRD footprint
Wind erosion (South-west WSF)	RJ_6	51	ha/hour	Approximate area based on WSF footprint

[10] Material handling rates shown are maximum, dry season rates.

Source description	Source ID	Activity data[10]	Unit	Comment
Mt Burton				
Excavators at Mt Burton WRD	MB_1a	375	t/hour	As per Table 4-3
Loading Mt Burton waste rock to trucks	MB_1b	375	t/hour	
Haul Mt Burton waste rock (from Mt Burton to paved road)	MB_2	46	km/hour	As per Table 4-4
Wind erosion (Mt Burton WRD)	MB_3	1.3	ha/hour	Approximate area based on WRD footprint
Mt Fitch				
Excavator at Mt Fitch WRD	MF_1a	375	t/hour	As per Table 4-3
Dumping Mt Fitch waste rock to pit	MF_1b	375	t/hour	
Wind Erosion (Mt Fitch WRD)	MF_2	0.7	ha/hour	Approximate area based on WRD footprint
Clay borrow site				
Excavator on clay borrow	CB_1a	90	t/hour	As per Table 4-3
Load clay to trucks	CB_1b	90	t/hour	
Haul clay (from clay borrow site to paved roads)	CB_2	11	km/hour	As per Table 4-4
Wind erosion (1/4 clay borrow site area)	CB_3	32	ha/hour	Assumed as ¼ of total footprint
Granular borrow site				
Excavator on granular borrow	GB_1a	90	t/hour	As per Table 4-3
Load granular material to trucks	GB_1b	90	t/hour	
Haul granular material (from granular borrow site to paved road)	GB_2	17	km/hour	As per Table 4-4
Wind erosion (1/4 granular borrow site area)	GB_3	66	ha/hour	Assumed as ¼ of total footprint

Table A 3 Source emission rates

Source description	Source ID	Modelled emission rate (g/s)		
		TSP	PM_{10}	$PM_{2.5}$
Rum Jungle				
Excavators on WRD	RJ_1a	5.2	2.5	0.63
Loading waste rock to trucks	RJ_1b	2.5	0.90	0.22
Dump waste rock at WSF	RJ_2a	2.5	0.90	0.22
Dump granular material at WSF	RJ_2b	0.30	0.11	0.027
Dump clay at WSF	RJ_2c	0.30	0.11	0.027
Dump Mt Burton waste rock at WSF	RJ_2d	1.3	0.45	0.11
Dump lime at WSF	RJ_2e	0.38	0.13	0.034
Mixing lime at WSF	RJ_2f	0.78	0.38	0.094
Grader at WSF	RJ_2g	0.26	0.12	0.030
Compactor at WSF	RJ_2h	4.7	1.1	0.28
Haul Mt Burton waste rock in to site (from paved road to WSF)	RJ_3a	20	6.0	1.5
Haul lime in to site (from paved road to WSF)	RJ_3b	6.1	1.8	0.45
Haul Clay in to site (from paved road to WSF)	RJ_3c	4.9	1.4	0.36
Haul granular material in to site (from paved road to WSF)	RJ_3d	4.9	1.4	0.36
Haul waste rock from WRD to WSF (internal)	RJ_4	9.7	2.9	0.72
Wind erosion (WRD)	RJ_5	3.5	1.8	0.44
Wind erosion (South-west WSF)	RJ_6	5.7	2.8	0.71

Source description	Source ID	Modelled emission rate (g/s)		
		TSP	PM_{10}	$PM_{2.5}$
Mt Burton				
Excavators at Mt Burton WRD	MB_1a	2.6	1.3	0.31
Loading Mt Burton waste rock to trucks	MB_1b	1.3	0.45	0.11
Haul Mt Burton waste rock (from Mt Burton to paved road)	MB_2	14	4.0	1.0
Wind erosion (Mt Burton WRD)	MB_3	0.14	0.072	0.018

Source description	Source ID	Modelled emission rate (g/s)		
		TSP	PM_{10}	$PM_{2.5}$
Mt Fitch				
Excavator at Mt Fitch WRD	MF_1a	2.6	1.3	0.31
Dumping Mt Fitch waste rock to pit	MF_1b	1.3	0.45	0.11
Wind Erosion (Mt Fitch WRD)	MF_2	0.08	0.039	0.010
Clay borrow site				
Excavator on clay borrow	CB_1a	0.63	0.30	0.075
Load clay to trucks	CB_1b	0.30	0.11	0.027
Haul clay (from clay borrow site to paved roads)	CB_2	3.3	1.0	0.24
Wind erosion (1/4 clay borrow site area)	CB_3	3.5	1.8	0.44
Granular borrow site				
Excavator on granular borrow	GB_1a	0.63	0.30	0.075
Load granular material to trucks	GB_1b	0.30	0.11	0.027
Haul granular material (from granular borrow site to paved road)	GB_2	4.9	1.4	0.36
Wind erosion (1/4 granular borrow site area)	GB_3	7.4	3.7	0.92

GHD

Level 15, 133 Castlereagh Street
Sydney NSW 2000
T: (02) 9239 7100 F: (02) 9475 0725 E: sydmail@ghd.com

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Revision	Author	Reviewer		Approved for Issue		
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0	D Craggs	Evan Smith		C Sylianteng		28/10/19

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