APPENDIX 6-4

Yangibana and Auer -

Air quality Assessment

YANGIBANA RARE EARTHS PROJECT

AIR QUALITY ASSESSMENT

DOCUMENT NO. YGB-00-000-HSE-ENV-ASS-0015

CONSULTANT DOCUMENT NUMBER: 0504573

REVISION	DATE	ISSUED FOR	PREPARED BY	REVIEWED BY	APPROVED BY
00	25/03/20	Issued for Use	P. Thorpe	R. Chalmer	D. Roddis

Auer and Yangibana Deposits

Air Quality Assessment

25 March 2020

Project No.: 0504573

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Document details	
Document title	Auer and Yangibana Deposits
Document subtitle	Air Quality Assessment
Project No.	0504573
Date	25 March 2020
Version	1.0
Author	P. Thorpe. R. Chalmer
Client Name	Hastings Technology Metals Limited

Document history

				ERM approval to issue		
Version	Revision	Author	Reviewed by	Name	Date	Comments
Draft	00	P. Thorpe	R. Chalmer	D. Roddis	13.03.2020	Draft to Client
Final	01	P. Thorpe	R. Chalmer	D. Roddis	25.03.2020	Final to Client

Signature Page

25 March 2020

Auer and Yangibana Deposits

Air Quality Assessment

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1. INTRODUCTION

Hastings Technology Metals Limited ('Hastings') is currently developing the Yangibana Rare Earths Project ('Project'). The Project is located 270 km (line of sight) east-northeast of Carnarvon on Gifford Creek Station in the Gascoyne region of Western Australia. The scope of the Project includes mining and processing of rare earths from five deposits i.e. Frasers, Bald Hill and Bald Hill East, Yangibana North and Yangibana West deposits. ERM has completed a number of studies for the Project:

- ERM (previously Pacific Environment) completed an air quality assessment for the mining activities of the Project (Pacific Environment, 2017) and this was submitted as part of the Environmental Approvals process.
- In addition to the air quality assessment, evaluation of radon and thoron concentrations at discrete receptors was also completed to support the radiation assessment (Pacific Environment, 2016)
- A plume study was completed to assess the impact of a number of operating scenarios for the major stack sources at the processing plant (ERM, 2018).
- ERM has completed an Air Quality Management Plan that assessed emissions from the processing plant operations of the Project (ERM, 2019)
- A screening level study of Ammonia emissions from the Hydromet tailings storage facility (TSF) operations was also completed (ERM, 2019). This assessed a worst-case ammonia emissions scenario including an assessment against both ambient and occupational health and safety (OHS) levels.

Two new deposits (Auer pits (x 4) and the Yangibana pit (x1)) are recent additions to the Project's scope and will require additional environmental approvals applications. The ore will be processed at the Project's processing plant to produce a mixed rare-earth concentrate and two tailings streams, which will be stored in the designed and dedicated tailings storage facilities (TSF) on site. The product will be transported via truck to port for overseas export.

For this assessment, ERM was engaged to perform an updated air quality impact assessment for the proposed Auer and Yangibana deposits. This air quality assessment will contribute to the environmental approvals applications for the additional deposits.

1.1 Scope of Work

The focus of this assessment was to assess the contribution of mining activities at Auer and Yangibana deposits to air quality and potential impacts at discrete receptors.

The key outcomes of this assessment are:

- Estimation of particulate (TSP[1], PM_{10}[2], $PM_{2.5}$[3] and dust deposition) and radiation (radon and thoron) emissions relating to the Auer and Yangibana deposits;
- Estimation of cumulative emissions of Auer and Yangibana deposits in addition to that of the overall project (as previously modelled);
- Modelling of impacts using AERMOD;

[1] Total suspended particulates

[2] Particulate matter with an aerodynamic diameter less than 10 µm

[3] Particulate matter with an aerodynamic diameter less than 2.5 µm

- Assessment of the particulate and radiation results at discrete receptors (Accommodation Village, Gifford Creek Station and Edmund Station);
- Cumulative impacts, taking account of the mining schedule, against relevant air quality assessment criteria; and
- Reporting (this document).

2. ASSESSMENT APPROACH

This section outlines the approach applied to the ambient air quality assessment.

2.1 Climate Assessment Methodology

The climate and meteorological characteristics of the region control the dispersion, transformation and removal (or deposition) of pollutants from the atmosphere (i.e. ambient air quality).

Analysis of the hourly wind speed and wind direction, amongst other parameters, was conducted using data derived from the closest relevant Bureau of Meteorology (BoM) station at Paraburdoo Airport (180 km from the project). Analysis of 10-year of historical surface observations from this BoM station identified 2011 as the most representative meteorological year. A comparison of the collected BoM meteorological data and the site weather station was completed in 2017 (ERM, 2017). The comparison showed that the wind rose patterns were very similar, however, higher wind speeds were observed at the site weather station. This adds a level of conservatism to the modelling.

The same meteorological data were used for this assessment as developed and used in the previous air quality assessment (Pacific Environment, 2017; Pacific Environment, 2016; Pacific Environment, 2018). Further discussion of the meteorological modelling is presented in Appendix A.

2.2 Emission Estimation

Emissions were estimated using the same methodology from the previous assessment. Emissions data are further discussed in Section 3 and detailed in Appendix B.

2.3 Dispersion Modelling

For this assessment, air dispersion modelling was conducted using the US EPA approved model AERMOD. The dispersion model was used to predict the ground level concentrations at the selected discrete receptor locations, as further discussed in Section 2.5.

2.4 Model Scenarios

Two scenarios were investigated for this assessment, which included the incremental impacts from the Auer and Yangibana pits and cumulative impacts with the previously assessed mining activities (Pacific Environment, 2017).

2.5 Discrete Receptors

For this assessment, predicted ground level concentrations were assessed at discrete receptors only, as presented in Table 2.1 and Figure 2.1. The location of the new and previously assessed deposits and waste rock facilities are also shown in this figure.

Table 2.1: Discrete receptors location

Receptor	UTM Zone 50 S Easting (m)	UTM Zone 50 S Northing (m)
Accommodation Village	421,700	7,346,593
Gifford Creek homestead	420,600	7,340,300
Edmund homestead	410,370	7,371,700

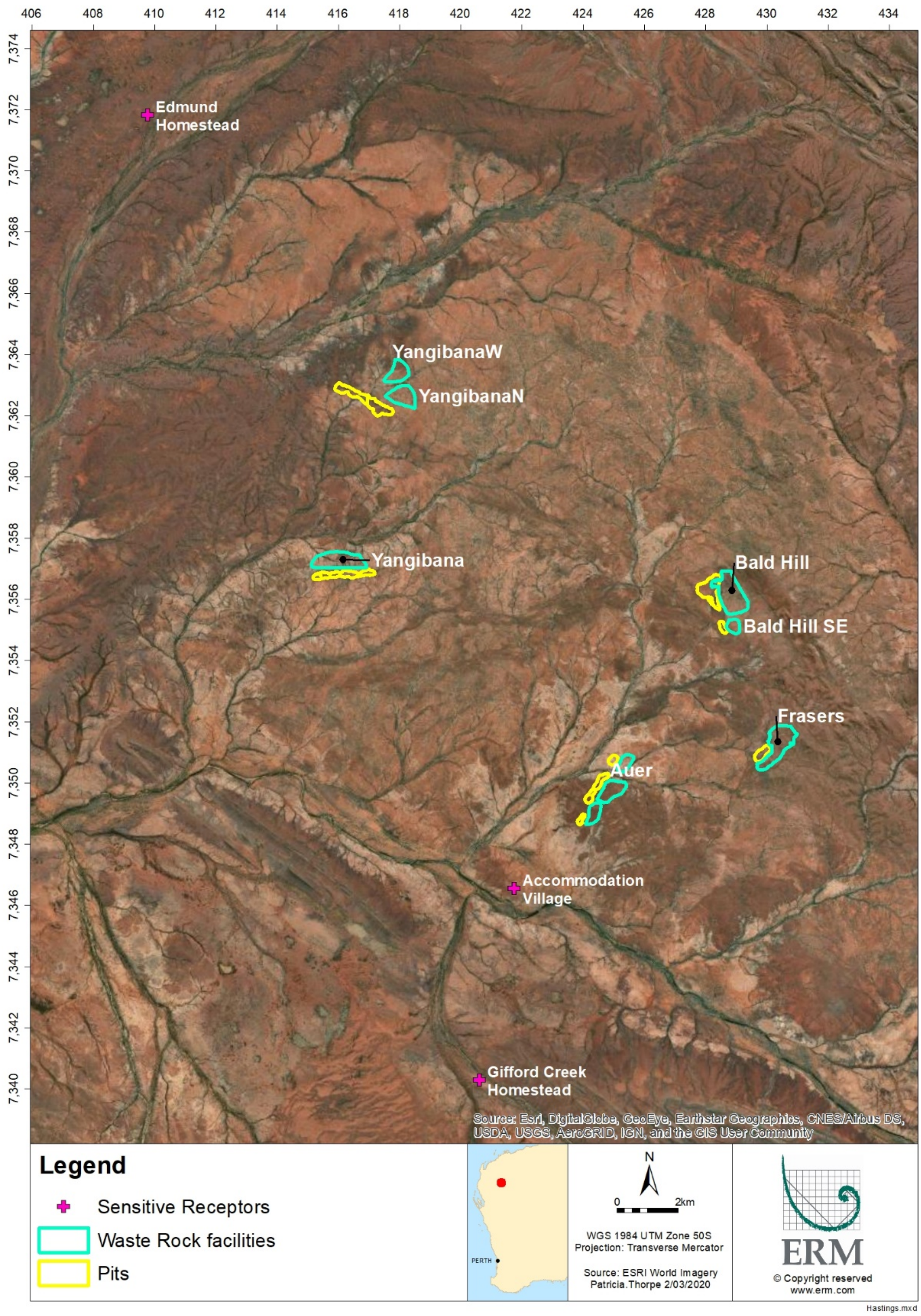

Figure 2.1: Discrete receptors and deposit locations

2.6 Assessment Criteria

Predicted ground level concentrations were compared against the air quality assessment criteria, as summarised in Table 2.2. The assessment criteria from the previous assessment were adopted for this assessment (Pacific Environment, 2017).

Assessment criteria selected for the study were based on:

- Local guidelines, criteria or standards adopted by the Western Australian Department of Water and Environment Regulation (DWER) or Environmental Protection Authority (EPA);
- National standards adopted by the WA State Government; and
- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.

In October 2019, DWER released a draft guideline that ensures that adequate information is provided to assess activities that generate air emissions, as regulated under the *Environmental Protection Act 1986* (EP Act).

The concentrations presented in Table 2.2 have been adjusted to a standard temperature of 25ºC as the dispersion model (AERMOD) uses this parameter (as opposed to 0ºC, which is used in Australia).

Table 2.2: Air quality assessment criteria adopted

Pollutant	Averaging Period	Guideline Value (µg/m³) at 0˚C	Guideline Value (µg/m³) at 25˚C	Source
TSP	24 hour	90	82	Draft Guideline (DWER, 2019)
PM_{10}	24 hour	50	46	Draft Guideline (DWER, 2019)
	Annual average	25	23	Draft Guideline (DWER, 2019)
$PM_{2.5}$	24 hour	25	23	Draft Guideline (DWER, 2019)
	Annual average	8	7	Draft Guideline (DWER, 2019)

As there is no formal dust deposition criterion available in Western Australia and given the remoteness of the region and lack of information on background dust deposition levels, predicted dust deposition levels were assessed against the NSW DEC (DEC, 2005) incremental criteria as presented in Table 2.3. It is noted that the criterion was set to address nuisance dust and not as an indicator for assessing impact on vegetation.

Table 2.3: Deposition assessment criteria

Pollutant	Averaging Period	Value (g/m²/month)	Source
Dust Deposition	Annual average	2	(DEC, 2005)

2.7 Background Concentration

The background concentrations, presented in Table 2.4, adopted in the previous air quality assessment are applied to this assessment (Pacific Environment, 2017).

Table 2.4: Background concentrations

Background	Value	Unit	Averaging Period
TSP	35	µg/m^3	24-hour
PM_{10}	19	µg/m^3	24-hour
$PM_{2.5}$	2.9	µg/m^3	24-hour

2.8 Model Uncertainty

Atmospheric dispersion models represent a simplification of the many complex processes involved in determining ground level concentrations of substances.

Model uncertainty comprises of model chemistry/physics uncertainties, input data uncertainties, and stochastic uncertainties. In addition, there is inherent uncertainty in the behaviour of the random turbulence. The generic sources of uncertainty in dispersion models and their potential effects on this assessment are summarised in Table 2.5.

Table 2.5: Summary of main sources of modelling uncertainty

Source	Effects
Oversimplification of physics in model code (varies with type of model)	A variety of effects that can lead to both under-prediction and over-prediction. Errors are greater in Gaussian plume models, which do not include the effects of non-steady-state meteorology (i.e., spatially- and temporally-varying meteorology).
Errors in emissions data	Ground-level concentrations are proportional to emission rate. Plume rise is affected by source dimensions, temperature and exit velocity.
Errors in wind data	Wind direction affects direction of plume travel. Wind speed affects plume rise and dilution of plume, resulting in potential errors in distance of plume impact from source, and magnitude of impact.
Errors in stability estimates	Gaussian plume models use estimates of stability class, and 3-D models use explicit vertical profiles of temperature and wind (which are used directly or indirectly to estimate stability class for Gaussian models). In either case, errors in these parameters can cause either under prediction or over prediction of ground-level concentrations.
Errors in temperature	Usually the effects are small, but temperature affects plume buoyancy, with potential errors in distance of plume impact from source, and magnitude of impact.
Inherent uncertainty	Models predict ‘ensemble mean’ concentrations for any specific set of input data (say on a 1-hour basis), i.e., they predict the mean concentrations that would result from a large set of observations under the specific conditions being modelled. However, for any specific hour with those exact mean hourly conditions, the predicted ground-level concentrations will never exactly match the actual pattern of ground-level concentrations, due to the effects of random turbulent motions and random fluctuations in other factors such as temperature.

3. EMISSIONS ESTIMATION

The emissions estimation for the proposed pits adopted the same approach applied for the previous air quality assessment (Pacific Environment, 2017). The estimated emissions are further discussed in Appendix B.

The monthly ore and waste production for the Auer and Yangibana pits were provided by Hastings (2019). For a conservative assessment, the highest production year from each pit was assumed for this assessment, which corresponded to the 9th year of production for both pits. The annual tonnages of ore and waste from each pit are summarised in Table 3.1.

Table 3.1: Mining production assumed for the assessment

Activity	Total Value (kt)
Tonnage of Ore – Auer Pit	986
Tonnage of waste – Auer Pit	20,110
Tonnage of Ore – Yangibana Pit	875
Tonnage of waste – Yangibana Pit	18,057

Source: (Hastings, 2019)

3.1 Particulate Emissions

The key emission sources for the operating phase of the deposits are considered to be associated with the mining operations below:

- Blasting;
- Drilling;
- Material loading and unloading into and from trucks;
- Wheel generated dust from haul roads;
- Bulldozers on ore and waste;
- Conveyors;
- Primary crushing; and
- Wind erosion from stockpiles and open areas.

Emissions from the sources listed above are estimated based on data provided by Hastings (2019). The annual estimated emissions are summarised in Table 3.2. Also included within the table are the estimated emissions from the previous assessment. Emission estimation of construction activities are excluded from the assessment.

The methodology to estimate particulate emission described in Pacific Environment (2017) was applied for this assessment. This methodology uses the emission estimation techniques sourced from the National Pollution Inventory (NPI) literature.

Table 3.2: Summary of emissions estimation for Yangibana and Auer pits

	TSP Emissions (kg/year)	PM_{10} Emissions (kg/year)	$PM_{2.5}$ Emissions (kg/year)
Wheel generated dust	892,336	263,383	58,998
Drilling	59	59	13
Blasting	84	83	19
Loading of Ore	27,253	15,635	11,451
Loading of Waste Rock	39,725	36,229	8,115
Unloading of Ore	10,798	3,869	2,291
Unloading of Waste	38,136	13,665	3,061
Bulldozing	97,734	23,793	5,330
Primary Crushing	4,268	1,707	1,707
Conveyor	4,268	1,707	1,707
Wind erosion Waste Rock Stockpile	1,565	547	123
Total – Auer and Yangibana deposits	*1,116,226*	*360,679*	*92,814*
Total – Previous Assessment [a]	*2,154,623*	*795,826*	*178,215*
Total – Cumulative assessment	**3,270,849**	**1,156,505**	**271,029**

[a] *excluding Power generation and Carbon Regeneration kiln*

3.2 Radiation

Radiation modelling for this assessment adopts the previously provided emission rates for radon and thoron. Emissions were modelled as radon (^{222}Rn) and thoron (^{220}Tn) from the sources summarised in Table 3.3. As per the previous study, the sources have been modelled as area sources. The summary of emissions applied to each substance and the representative areas of the proposed pits are presented in Table 3.4.

Table 3.3: Radiation emissions

Source	Radon (MBq[a]/s)	Thoron (MBq[a]/s)	Reference
Mining	0.13	8	(Pacific Environment, 2016)

[a] *Becquerel refers to the amount of ionizing radiation released when an element spontaneously emits energy as a result of the radioactive decay (or disintegration) in a given time period (NRC, 2019).*

Table 3.4: Radiation emission summary Auer and Yangibana deposits

Source	Emission Rate Radon (Bq/s)	Emission Rate Thoron (Bq/s)	Area (m^2)	Radon Emission Rate ($Bq/m^2/s$)	Thoron Emission Rate ($Bq/m^2/s$)
Auer deposit	43,333	2,666,667	183,400	0.24	14.54
Yangibana deposit	43,333	2,666,667	194,321	0.22	13.72

4. RESULTS

4.1 Particulate Results

The maximum ground level concentration particulate results are presented as Auer and Yangibana results alone and cumulative impacts with previous assessments (Pacific Environment, 2017; Pacific Environment, 2016). Background concentrations were also included for this assessment.

4.1.1 TSP Results

TSP ground level concentration results have been compared to the Draft WA DWER 24-hour average criteria of 82 µg/m³ (Section 2.6). Statistics for the predicted concentrations of TSP at receptors are presented in Table 4.1. The model results indicate the following:

- The TSP maximum 24-hour average predicted concentrations for both scenarios are expected to occur at the Accommodation Village.
- The TSP maximum 24-hour concentration results do not indicate exceedance of the assessment criterion of 82 µg/m³ for all scenarios assessed.

Table 4.1: Predicted 24-hour TSP concentration results

	Accommodation Village (µg/m³)			Gifford Creek Homestead (µg/m³)			Edmund Homestead (µg/m³)		
Assessment Criteria: 82 µg/m³ - 24 hour average									
	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background
Maximum	4.8	5.7	41	1.0	1.5	36	0.7	3.3	38
99th Percentile	3.0	3.9	39	0.6	1.1	36	0.5	2.0	37
95th Percentile	1.9	2.5	37	0.4	0.8	36	0.3	1.2	36
90th Percentile	1.4	2.0	37	0.3	0.6	36	0.2	1.0	36
70th Percentile	0.7	1.0	36	0.2	0.4	35	0.1	0.6	36

4.1.2 PM_{10} Results

As detailed in Section 2.6, predicted ground level concentrations of PM_{10} are assessed against Draft WA DWER (2019) 24-hour average criteria of 46 µg/m³ (Table 4.2) and annual average of 23 µg/m³ (Table 4.3). The model results indicated the following:

- The PM_{10} maximum 24-hour concentration for the incremental impacts of Auer and Yangibana deposits do not indicate exceedance of the criterion.
- The PM_{10} maximum 24-hour concentrations are not predicted to exceed the 24-hour assessment criterion of 46 µg/m³ for all scenarios assessed.
- The predicted PM_{10} annual average concentrations do not exceed the criterion for all scenarios assessed.

Table 4.2: Predicted 24-hour PM_{10} concentration results

	Accommodation Village (µg/m³)			Gifford Creek homestead (µg/m³)			Edmund homestead (µg/m³)		
Assessment Criteria: 46 µg/m³ - 24-hour average									
	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background
Maximum	2.5	3.2	22	0.5	0.9	20	0.3	2.0	21
99th Percentile	1.4	2.4	21	0.3	0.6	20	0.2	1.2	20
95th Percentile	0.9	1.3	20	0.2	0.4	19	0.2	0.7	20
90th Percentile	0.6	1.1	20	0.2	0.4	19	0.1	0.6	20
70th Percentile	0.3	0.5	20	0.1	0.2	19	0.1	0.4	19

Table 4.3: Predicted annual average PM_{10} concentration results

	Accommodation Village (µg/m³)			Gifford Creek homestead (µg/m³)			Edmund homestead (µg/m³)		
Assessment Criteria: 23 µg/m³ - Annual average									
	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background
Annual Average	0.3	0.5	19	0.1	0.2	19	0.1	0.3	19

4.1.3 $PM_{2.5}$ Results

Modelled $PM_{2.5}$ concentrations were compared to the Draft WA DWER 24-hour average criteria of 23 µg/m³ (Section 2.6) and annual average of 7 µg/m³ (Table 4.5). The model results indicated the following:

- Excluding background, $PM_{2.5}$ maximum concentrations are predicted to be significantly below the assessment criteria 24-hour average (23 µg/m³) for all scenarios assessed (Table 4.4).
- $PM_{2.5}$ annual average predicted concentrations were expected to be significantly below the criterion (7 µg/m³) for all three receptors for all scenarios assessed (Table 4.5).

Table 4.4: Predicted 24-hour $PM_{2.5}$ concentration results

	Accommodation Village (µg/m³)			Gifford Creek homestead (µg/m³)			Edmund homestead (µg/m³)		
Assessment Criteria: 23 (µg/m³) - 24-hour average									
	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background
Maximum	0.6	0.7	3.6	0.18	0.3	3.1	0.08	0.5	3.3
99th Percentile	0.4	0.5	3.4	0.10	0.2	3.0	0.06	0.3	3.2
95th Percentile	0.2	0.3	3.2	0.05	0.1	3.0	0.05	0.2	3.0
90th Percentile	0.2	0.3	3.1	0.04	0.1	2.9	0.03	0.1	3.0
70th Percentile	0.08	0.1	3.0	0.02	0.05	2.9	0.02	0.1	2.9

Table 4.5: Predicted annual average $PM_{2.5}$ concentration results

	Accommodation Village (µg/m³)			Gifford Creek homestead (µg/m³)			Edmund homestead (µg/m³)		
Assessment Criteria: 7 (µg/m³) - Annual average									
	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background	Auer and Yangibana deposits	Cumulative	Cumulative with background
Annual Average	0.08	0.1	3.0	0.02	0.04	2.9	0.01	0.1	2.9

4.2 Dust Deposition Results

The predicted dust deposition results for the discrete receptors are presented in Table 4.6. The model results indicate the following:

- The deposition results of Auer and Yangibana pits indicated that the activities performed at site are not predicted to exceed the assessment criteria of 2 g/m²/month at any of the discrete receptors included in the assessment.
- Dust deposition for the cumulative scenario is predicted to be significantly below the assessment criteria at all three receptor locations.

Table 4.6: Predicted annual average dust deposition results

	Annual Average Dust Deposition (g/m²/month)		
Scenario	**Accommodation Village**	**Gifford Creek homestead**	**Edmund homestead**
Assessment criteria: 2 (g/m²/month)			
Auer and Yangibana deposits	0.00085	0.00018	0.00014
Cumulative	0.0012	0.00034	0.00065

4.3 Radiation Results

The predicted annual average concentrations of radon and thoron at the discrete receptors are presented in Table 4.7 for both scenarios assessed. The results show the highest radiation concentrations for both radon and thoron are predicted to occur at the Accommodation Village, which is expected as it is located closest to the Project., As observed in the previous radiation assessment, this assessment also predicts that no thoron will be detected at Edmund homestead (Pacific Environment, 2016).

Table 4.7: Predicted annual average radiation concentration results

	Accommodation Village (Bq/m^3)		Gifford Creek homestead (Bq/m^3)		Edmund homestead (Bq/m^3)	
	Auer and Yangibana deposits	Cumulative	Auer and Yangibana deposits	Cumulative	Auer and Yangibana deposits	Cumulative
Radon (Bq/m^3)	1.8×10^{-3}	4.8×10^{-3}	3.9×10^{-4}	1.5×10^{-3}	5.7×10^{-4}	2.8×10^{-3}
Thoron (Bq/m^3)	3.3×10^{-6}	3.3×10^{-6}	6.8×10^{-10}	7.0×10^{-10}	-	-

5. CONCLUSIONS

The purpose of this assessment was to understand the incremental and cumulative predicted impacts of the proposed Auer and Yangibana deposits at the discrete receptors (Accommodation Village, Gifford Creek homestead and Edmund homestead). The model is considered conservative as the highest production capacity for each deposit was assumed.

The results of this assessment showed that:

- The predicted particulate concentration and dust deposition results showed that the associated assessment criteria of each pollutant is not expected to be exceeded for any receptors considering both incremental and cumulative scenarios.
- The maximum 24-hour (TSP, PM_{10} and $PM_{2.5}$) and annual average (PM_{10} and $PM_{2.5}$) cumulative scenario concentrations (including background) were predicted to be well below the DWER criteria at all three receptors.
- Deposition results were predicted to be below the assessment criteria for both incremental and cumulative scenarios.
- Radiation is predicted to have the highest level at the Accommodation Village for both Radon and Thoron, excluding background.
- No thoron levels are predicted at Edmund Homestead, due to the extremely short half-life of thoron.

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APPENDIX A METEOROLOGICAL MODELLING

METEOROLOGICAL MODELLING TOOLS

This assessment used a suite of modelling tools to estimate air quality impacts. TAPM and AERMET were used to generate three-dimensional meteorological fields for a representative year, 2011. AERMOD was used for dispersion modelling. Below is a short description of these models and their set-up for this study.

TAPM

The Air Pollution Model (TAPM) was used to generate the meteorological data needed for AERMET, the meteorological pre-processor for AERMOD.

TAPM, is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research (Hurley, 2008a; Hurley, 2008b; Hurley, 2008c). TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components, eliminating the need to have site-specific meteorological observations. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

All surface and upper air meteorological data were generated using TAPM (v4.0.4). TAPM was run for a full year (2011) with four nested domains (30 km, 10 km, 3 km and 1 km) centred at 23.96S and 116.030E. The output from TAPM was extracted to create an onsite met file and an upper air file in FSL format for input into AERMET.

AERMET

To drive AERMET, meteorological data were required to be prepared in certain formats. Two meteorological data files are required; surface met file and upper air file. In the absence of surface and upper air meteorological data in the model domain, extracted data from TAPM were used as input for AERMET.

The following parameters were extracted from TAPM for input as surface file into AERMET:

- Net radiation
- Cloud cover
- Ceiling height
- Mixing height.

The upper air file for AERMET provides information on the vertical structure of the atmosphere and requires a minimum two soundings per day; around sunrise and sunset. These data were also extracted from TAPM and formatted into a FSL file. In applying the AERMET meteorological processor to prepare the meteorological data for the AERMOD model appropriate values for three surface characteristics needed to be determined:

- Surface roughness length
- Albedo
- Bowen ratio.

The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer.

The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux. Average land use characteristics were derived from TAPM and are based on USGS Land Use Category Number 51. These land use parameters were input into AERMET across all sectors (Table 6.1).

Table 6.1: Land-use characteristic inputs for AERMET

Surface roughness length (m)	Albedo	Bowen Ratio
0.15	0.25	3

Data for AERMOD was generated using Lakes Environment's AERMET View v9.1.0 software (US EPA AERMET executable AERMET_15181.exe). The main AERMET options and assumptions used are listed below:

- Threshold wind speed of 0.5m/s was used.
- Adjust surface friction velocity (ADJ_U*) option was used for low winds.
- Adjust horizontal meander using LOWWIND2 was used for low winds.

A plot of the wind roses generated based on AERMET output meteorological data is presented in Figure C.1. Quality assurance was undertaken on the AERMET output meteorological data and is thoroughly discussed in the previous assessment (Pacific Environment, 2017)

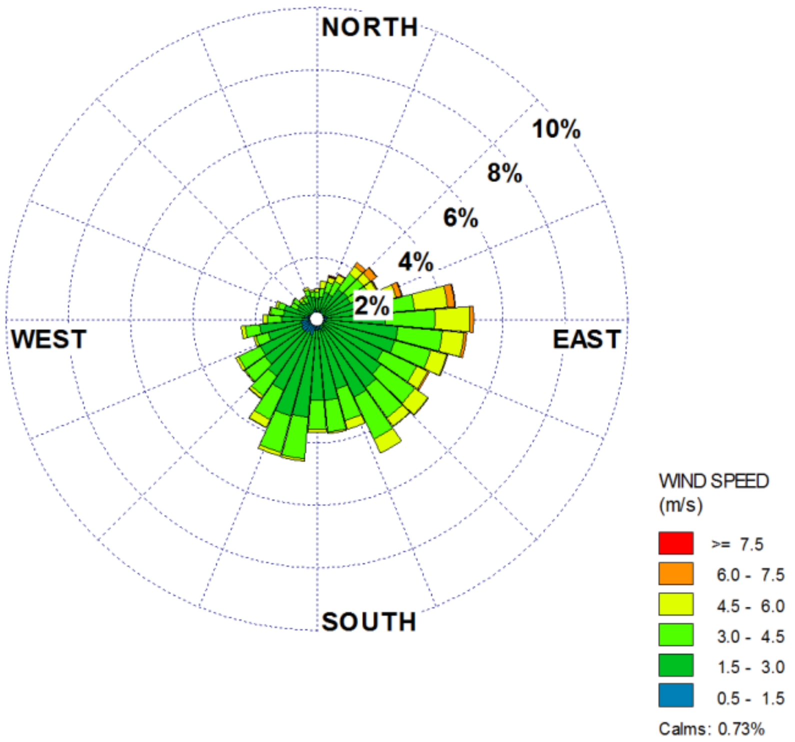

Figure 6.1: Annual wind rose generated by AERMET (2011)

APPENDIX B EMISSIONS FROM AUER AND YANGIBANA PITS

EMISSION ESTIMATION

Details on the emissions estimation for the identified sources in this assessment are provided below.

Emissions were estimated using the equations detailed in Table 8.2, for the sources detailed above in Section 3.1.

Table 6.1: Mining – emission equations

Eq.No	Emission Source	Equations	Reference
1	Blasting	$EF_{PM10} = 0.000114 \times A^{1.5}$ Where EF_{PM10} is emission factor for PM_{10} (kg/blast) A is area per blast in m^2	NPI EET Manual for Mining v3.1, Table 2, p15 [a]
2	Wheel generated dust from unpaved roads	$EF_{PM10} = 0.282 \times 1.5 \times (s/12)^{0.9} \times (W/3)^{0.45}$ Where EF_{PM10} is emission factor for PM_{10} (kg/VKT) s is silt content of haul road % W is average weight of vehicles in tonne	Pitts and Hibberd 2009; Pitts, R.O. and Hibberd, M. 2009. Workshop Report. ModSIG Workshop, Sydney 7th November 2008. Air Quality And Climate Change. Volume 43, No. 3, August 2009, page 14
3	Bulldozer	$EF_{PM10} = 0.34 \times (s)^{1.5}/M^{1.4}$ Where, EF_{PM10} is emission factor for PM_{10} (kg/hour) s is silt content % M is moisture content of material in %	NPI EET Manual for Mining v3.1, Section 1.1.5 [a]
4	Drilling	0.31 kg/hole	NPI EET Manual for Mining v3.1, Table 2, p15 [a]
5	Loading of trucks with ore/waste	0.012 kg/tonne	NPI EET Manual for Mining v3.1, Appendix A 1.1.2 [a]
6	Unloading of trucks with ore/waste	0.0043 kg/tonne	NPI EET Manual for Mining v3.1, Appendix A 1.1.6 [a]
7	Conveying	0.002 kg/tonne	NPI EET Manual for Mining v3.1, Table 3, p20; High Moisture Ore [a]
8	Primary Crushing	0.004 kg/tonne	NPI EET Manual for Mining v3.1, Table 3, p20; Primary Crusher; High Moisture Ore [a]

[a] *(NPI, 2012)*

Operations

The mining production used to estimate the particulate emissions from ore and waste in the Yangibiana and Auer deposits was the maximum ore and waste produced in mining data provided by Hastings, which pointed out to be the 9th year of production of the two pits (Table 6.3). The estimation based on maximum yearly amount of material produced allows for the calculations of worst case scenario of emissions. Mining emissions data for Auer and Yangibana pits are presented below in Table 6.3 to Table 6.5.

Table 6.2: Maximum mining production

Activity	Total Value	Unit
Tonnage of Ore – Yangibiana	199,000	tonnes/year
Tonnage of Ore – Auer	231,000	tonnes/year
Tonnage of waste – Yangibiana	3,401,000	tonnes/year
Tonnage of waste – Auer	5,261,000	tonnes/year
(Hastings, 2019)		

Table 6.3: Mining – data for operational phase

Activity	Value	Unit
No of holes drilled – Yangibiana	25,103	holes
No of holes drilled – Auer	38,296	holes
No. of blast per year - Yangibiana	25	holes
No. of blast per year - Auer	38	holes
Number of haul truck trips per year - waste - Yangibana	75,578	Trips/ year
Number of haul truck trips per year - ore Yangibana	4,422	Trips/ year
Number of haul truck trips per year - waste Auer	116,911	Trips/ year
Number of haul truck trips per year - ore Auer	5,133	Trips/ year

Table 6.4: Wheel generated dust emissions data

	YA to processing facility	YA to Waste dump	AU to processing facility	AU to Waste Dump	Water truck for YA and AU
VKT / yr (km)	53,297	75,578	26,308	116,911	13,999
TSP					
Emissions Unpaved Road (kg/VKT)	6.3	6.3	6.3	6.3	6.0
Emissions Unpaved Road (kg/yr); No control	333,155	472,434	164,452	730,807	83,503
Emissions Unpaved Road (kg/yr); watering	166,577	236,217	82,226	365,403	41,751
Emissions Unpaved Road (kg/hr); 85% operating hours	22.4	31.7	11.0	49.1	5.6
Emissions Unpaved Road (g/s)	6.2	8.8	3.1	13.6	1.6
PM_{10}					
Emissions Unpaved Road (kg/VKT)	1.85	1.85	1.85	1.85	1.76
Emissions Unpaved Road (kg/yr); No control	98,334	139,444	48,540	215,706	24,647
Emissions Unpaved Road (kg/yr); watering	49,167	69,722	24,270	107,853	12,323
Emissions Unpaved Road (kg/hr); 85% operating hours	6.6	9.4	3.3	14.5	1.7
Emissions Unpaved Road (g/s)	1.8	2.6	0.9	4.0	0.5

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