Wedgerock Pty Ltd

ABN: 15 099 038 123

Karuah South Quarry

Air Quality Impact Assessment

Prepared by

Northstar Air Quality Pty Ltd

December 2018

Specialist Consultant Studies Compendium

Volume 1, Part 1

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Air Quality Impact Assessment

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COMMONLY USED ACRONYMS

AHD	Australian Height Datum
ABS	Australian Bureau of Statistics
AQIA	air quality impact assessment
AQMS	air quality monitoring station
BoM	Bureau of Meteorology
CO	carbon monoxide
CO_2	carbon dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EETM	emission estimation technique manual
EPA	Environmental Protection Authority
ha	hectare
$mg{\cdot}m^{-3}$	milligram per cubic metre of air
$mg{\cdot}Nm^{-3}$	milligram per normalised cubic metre of air
$m{\cdot}s^{-1}$	metres per second
MW	megawatt
$\mu g{\cdot}m^{-3}$	microgram per cubic metre of air
NCAA	National Clean Air Agreement
NEPM	National Environment Protection Measure
NO	nitric oxide
NO_X	oxides of nitrogen
NO_2	nitrogen dioxide
O_3	ozone
OEH	NSW Office of Environment and Heritage
OU	odour unit
PM	particulate matter
PM_{10}	particulate matter with an aerodynamic diameter of 10 µm or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 µm or less
POEO	*Protection of Environment Operations Act*
ppb	parts per billion ($1x\ 10^{-9}$)
pphm	parts per hundred million ($1x\ 10^{-8}$)
ppm	parts per million ($1x\ 10^{-6}$)
SO_X	oxides of sulphur
SO_2	sulphur dioxide
TAPM	The Air Pollution Model
TSP	total suspended particulates
US EPA	United States Environmental Protection Agency
VOC	volatile organic compound

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EXECUTIVE SUMMARY

A detailed air quality impact assessment has been performed to assess the potential impacts of the site establishment and construction, and Stage 1C and Stage 2B operations to be performed as part of the proposed Karuah South Quarry development (the Project).

The air quality impact assessment has been performed in accordance with the NSW Environment Protection Authority *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* document (NSW EPA, 2017), and with due reference to the Secretary's Environmental Assessment Requirements, and NSW Environment Protection Authority requirements associated with State Significant Development 17_8795.

The air quality criteria applicable to the Project have been adopted from Commonwealth and State legislation and guidance.

The impacts of the Project have been considered in the context of the current environment, being impacted by currently approved and operating quarrying operations (Karuah East and Karuah Quarry). The impacts have also been considered in the context of a likely future environment, in which the proposed Karuah Red Quarry may be operational.

A detailed modelling exercise has been performed to characterise the meteorological environment of the area surrounding the Site. A full description of the input data, modelling and validation of the outputs is presented within the report.

A detailed dispersion modelling exercise has been performed to characterise the predicted impacts from the Project at a number of surrounding privately- and site-owned receptors. A similarly detailed modelling exercise has been performed to assess the predicted impacts from all other surrounding quarrying operations at those receptors. A background air quality dataset has been generated and added to those modelled impacts to determine a total, cumulative impact.

Details of the operations of all sites (Karuah, Karuah East and the proposed Karuah Red Quarry) surrounding the Project have been obtained from publicly available information. Emissions inventories characterising the operation of those sites have been prepared and are outlined in full. Also presented is a detailed Best Practice Management dust assessment for the development. Uncontrolled emissions associated with proposed Stage 2B of operations have been quantified, with sources contributing to 95% of all emissions subject to further assessment. All available dust control measures for those sources have been identified and adopted where appropriate. Full justification for the inclusion and exclusion of all measures is provided.

For the purposes of providing 'worst-case' assessment results, with which to compare against the short-term air quality criteria, operations have been assumed to operate at a throughput of 3,000 t per day during operations. This activity rate is significantly greater than the average operational throughput and represents a 3.7 times increase over average Stage 1C and 1.8 times increase over Stage 2B operations. Blasting has also been assumed to occur on each operating hour of the year, where blasting would only likely occur on 18 hours in the year.

These conservative assumptions provide confidence that the impacts of the Project are not likely to be greater than those presented within this assessment.

The dispersion modelling exercise indicates that the Project can operate across all stages of development (Site Establishment and Construction, Stage 1C and Stage 2B) with no exceedances of adopted air quality criteria, save for one minor exceedance of the maximum 24-hour average PM_{10} concentration during Stage 1C operations (at receptor 16 to the west of the Site). This minor exceedance (50.4 $\mu g \cdot m^{-3}$ compared to the criterion of 50 $\mu g \cdot m^{-3}$) has been reviewed in detail, with the contribution from the development being minor on this day. Annual average $PM_{2.5}$ modelling results have also been compared to the criterion for respirable crystalline silica, with impacts in all stages of the development predicted to be minimal.

Dispersion modelling results do indicate that incremental (i.e. Project related) impacts can be not-insignificant at surrounding receptor locations during worst-case meteorological and operating conditions. To ensure that impacts from the Project do not result in exceedances of the air quality criteria at surrounding residential locations, a real-time air quality monitoring program is proposed to be supported by a detailed Air Quality Management Plan.

The air quality monitoring program would be designed to provide information to the Site operator regarding real-time particulate concentrations and provide a framework for reducing Site emissions should data indicate that Site operations are contributing to any increased concentrations. The detail of the monitoring program would be provided following Project approval, but the commitment is provided by the Applicant that the Site would be operated with due consideration of off-site impacts. Operations would be altered should it be required, to ensure that no exceedances of the air quality criteria resulting from those operations are experienced.

A Blast Management Plan would be constructed and implemented as part of Site operations which would outline all the measures to be implemented to ensure that impacts associated with blast dust and fume emissions at all surrounding sensitive receptor locations are minimised.

A greenhouse gas assessment has been performed to examine the potential impacts of the operation of the Project relating to emissions of greenhouse gas. A quantitative assessment of emissions has been performed with emissions compared with total national and NSW greenhouse gas emissions for context.

Emissions associated with the Project are anticipated to represent <0.001 % of Australian and <0.01 % of NSW emissions totals for the year 2016.

Emissions are proposed to be reduced further through the implementation of a maintenance program for all plant and equipment, and the investigation into using B5 fuel where possible.

1. INTRODUCTION

R.W. Corkery & Co. Pty. Ltd (RWC) has engaged Northstar Air Quality Pty Ltd (Northstar) on behalf of Wedgerock Pty Ltd (Wedgerock) to perform an air quality impact assessment (AQIA) and greenhouse gas (GHG) assessment for the proposed construction and operation of the Karuah South Quarry (the Project).

Wedgerock (the Applicant) is proposing to develop and operate the Project that would extract and process hard rock for use in construction and infrastructure projects within the Hunter and Greater Sydney Metropolitan Regions. The Project would be constructed and operated on the southern section of Lot 11, DP1024564, (the Site). The Site is approximately 21 hectares (ha) and is located approximately 40 kilometres (km) north of Newcastle and 4 km northeast of Karuah (refer **Figure 1**).

The Site is located immediately south of the Karuah Quarry and southwest of the Karuah East Quarry, both owned and operated by Hunter Quarries Pty Ltd.

The AQIA presents an assessment of the impacts of the proposed construction and operation of the Project and provides an assessment of the cumulative impacts of the Project and the adjacent Karuah Quarry, Karuah East Quarry and the proposed Karuah Red Quarry.

The GHG assessment provides an assessment of the potential GHG emissions during the construction and operation of the Project.

1.1 ASSESSMENT REQUIREMENTS

The NSW Department of Planning and Environment (DP&E) has provided Secretary's Environmental Assessment Requirements (SEARs) for the Project (application number SSD 17_8795), issue date 2 November 2017. The requirements of the SEARs in relation to air quality are presented in **Table 1**, with the relevant section(s) of this AQIA in which they have been addressed.

Table 1
SEARs (SSD 17_8795) – Air Quality

Issue	Requirement	Relevant Section(s)
Air Quality	A detailed assessment of potential construction and operational impacts, in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*, and with a particular focus on dust emissions including $PM_{2.5}$ and PM_{10}, and having regard to the *Voluntary Land Acquisition and Mitigation Policy.*	Section 6
	An assessment of potential dust and other emissions generated from processing, operational activities and transportation of quarry products	Section 6
	Reasonable and feasible mitigation measures to minimise dust and emissions.	Section 9 **Annexure 2**
	Monitoring and management measures, in particular, real-time air quality monitoring.	Section 9

It is noted that there are no specific requirements relating to the GHG assessment provided within the SEARs, although this has been performed in accordance with standard practice and requirements.

In the preparation of the SEARs, relevant government agencies have been consulted. The NSW Environment Protection Authority (EPA) responded on 20 October 2017 and has provided a detailed list of requirements to be addressed in the preparation of the AQIA. These requirements are listed in full in **Table 2**.

No specific assessment requirements have been provided by the MidCoast Council (Council) for the AQIA or GHG Assessment.

Table 2
NSW EPA requirements for SSD 17_8795 – Air Quality

Page 1 of 3

Issue	Requirement	Addressed
General	The EIS should include an air quality impact assessment (AQIA) in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW, including, as a minimum the following components	This report
Assessment Objective	Demonstrate the proposed project will incorporate and apply best management practice emission controls	Section 9 **Annexure 2**
	Demonstrate that the project will not cause violation of the project adopted air quality impact assessment criteria at any residential dwelling or other sensitive receptor	Section 6
Assessment Criteria	Define applicable assessment criteria for the proposed development referencing the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW, including appendices and updates	Section 3
	Demonstrate the proposal's ability to comply with the relevant regulatory framework, specifically the *Protection of the Environment Operations* (POEO) *Act* (1997) and the POEO (Clean Air) Regulation (2010)	Section 3.2.3
Existing Environment	Provide a detailed description of the existing environment within the assessment domain, including:	Section 4.1
	• geophysical form and land-uses	Section 4.2
	• location of all sensitive receptors	Section 4.2
	• existing air quality	Section 0
	• local and regional prevailing meteorology	Section 4.4 **Annexure 1**
	Justify all data used in the assessment, specifically including analysis of inter-annual trends (preferably five consecutive years of data), availability of monitoring data, and local topographical features	**Annexure 1**
	Meteorological modelling must be verified against monitored data. Verification should involve comparative analysis of wind speed, wind direction and temperature, at a minimum	**Annexure 1**
	A review of all existing, recently approved and planned developments likely to contribute to cumulative air quality impacts must be completed	Section 4.5

Table 2 (Cont'd)
NSW EPA requirements for SSD 17_8795 – Air Quality

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Issue	Requirement	Addressed
Emissions Inventory	Provide a detailed description of the project and identify the key stages with regards to the potential for air emissions and impacts on the surrounding environment	Section 2.1 Section 2.5
	Identify all sources of air emissions, including mechanically generated, combustion and transport related emissions likely to be associated with the proposed development	Section 2.5
	Estimate emissions of TSP, PM_{10}, $PM_{2.5}$, NO_X (tonnes per year), at a minimum, for all identified sources during each key development stage	**Annexure 2**
	The emissions inventory must be explicitly coupled with the project description	**Annexure 2**
	Provide a detailed summary and justification of all parameters adopted within all emission estimation calculations, including site specific measurements, proponent recommended values or published literature	**Annexure 2**
	Document, including quantification and justification, all air quality emission control techniques/practices proposed for implementation during the project. As a minimum, consideration must be given to source control techniques, emission control through mine planning and reactive/predictive management techniques	**Annexure 2**
	Blasting emission estimation should provide specific details on likely activities, including the frequency of blasts, area per blast, amount and type of explosives used and blasting hours	**Annexure 2**
	Demonstrate that the proposed control techniques/practices are consistent with best management practice	**Annexure 2**
Dispersion Modelling and Interpretation of Results	Atmospheric dispersion modelling should be undertaken in accordance with the Approved Methods for the Modelling and Assessment of Air Pollutants in NSW, including appendices and updates	Section 5.1
	Modelling must implement fit for purpose modelling techniques that: • have regard for the most up to date and scientifically accepted dispersion modelling techniques • contextualise all assumptions based on current scientific understanding and available data • include a thorough validation of adopted methods and model performance	Section 5.1 Section 5.1.3
	Use an appropriate atmospheric dispersion model to predict, at a minimum, incremental ground level concentrations/levels of the following: • 24-hour and annual average PM_{10} concentrations • 24-hour and annual average $PM_{2.5}$ concentrations • 1-hour and annual average NO_2 concentrations. NO_2 concentrations should be assessed using a well justified approach for the transformation of NO_X to NO_2.	Section 6 Section 6 Section 6
	Ground level concentrations of pollutants should be presented for surrounding privately-owned properties, site-owned properties and other sensitive receptors (as applicable)	Section 6

Table 2 (Cont'd)
NSW EPA requirements for SSD 17_8795 – Air Quality

Page 3 of 3

Issue	Requirement	Addressed
Dispersion Modelling and Interpretation of Results (Cont'd)	Undertake a cumulative assessment of predicted impacts. The contribution of all identified existing and recently approved development should be accounted for in the cumulative assessment.	Section 6
	Results of dispersion modelling should be presented as follows: • isopleth plots showing the geographic extent of maximum pollutant concentrations (incremental and cumulative)	Section 6
	• tables presenting the maximum predicted pollutant concentrations (increment and cumulative) and the frequency of any predicted exceedances at each surrounding privately-owned properties, mine-owned properties and other sensitive receptors (as applicable)	Section 6
	• time series and frequency distribution plots of pollutant concentrations at each private receptor location at which an exceedance is predicted to occur. Where no exceedances are predicted, the analysis must be performed for the most impacted off site sensitive receptor	Section 6
Air Quality Emission Control Measures	Provide a detailed discussion of all proposed air quality emission control measures, including details of a reactive/predictive management system. The information provided must include: • explicit linkage of proposed emission controls to the site specific best practice determination assessment	Section 9
	• timeframe for implementation of all identified emission controls	Section 9
	• key performance indicators for emission controls	Section 9
	• monitoring methods (location, frequency, duration)	Section 9
	• response mechanisms	Section 9
	• responsibilities for demonstrating and reporting achievement of KPIs	Section 9
	• record keeping and complaints response register	Section 9
	• compliance reporting	Section 9

Further to the above, the SEARs and the EPA outline the documents to be consulted in the preparation of the AQIA. These are reproduced below (in alphabetical order):

- Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA);
- Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (EPA);
- Coal Mine Particulate Matter Control Best Practice – Site specific determination guide (OEH);
- Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia' (OEH);

- POEO (Clean Air) Regulation 2010; and,
- Voluntary Land Acquisition and Mitigation Policy for State Significant Mining, Petroleum and Extractive Industry Developments (DP&E).

The Greenhouse Gas Assessment has been performed with reference to:

- Australian Government Department of the Environment, Australian National Greenhouse Accounts, National Greenhouse Accounts Factors, July 2017 (DoE, 2018);
- The World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) GHG Protocol: A Corporate Accounting and Report Standard (WRI, 2004);
- ISO 14064-1:2006 (Greenhouse Gases – Part 1: Specification with guidance at the organisation level for quantification and reporting of GHG emissions and removal;
- ISO 14064-2:2006 (Greenhouse Gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of GHG emission reductions or removal enhancements); and,
- ISO 14064-3:2006 (Greenhouse Gases – Part 3: Specification with guidance for the validation and verification of GHG assertions) guidelines (internationally accepted best practice).

2. THE PROJECT

2.1 PROJECT BACKGROUND

The Applicant is proposing to develop and operate the Karuah South Quarry (the Project) that would extract and process hard rock for use in construction and infrastructure projects within the Hunter and Greater Sydney Metropolitan Regions. The Project would be constructed and operated on the southern section of Lot 11, DP1024564, (the Site). The Site is approximately 21 ha and is located approximately 40 km north of Newcastle and 4 km northeast of Karuah (refer **Figure 1**).

The Site is located immediately south of the Karuah Quarry and southwest of the Karuah East Quarry, both owned and operated by Hunter Quarries Pty Ltd.

The Project would utilise conventional drill and blast, load and haul and processing methods to produce up to 600,000 tonnes per annum (tpa) of quarry products. These products would principally be used for road pavement products concrete and sealing aggregates, pre-coat products, gabion, armour rock, decorative gravel, crusher fines and select fill. Extraction would be undertaken in a staged manner, i.e. over two stages with each stage comprising three sub-stages. Production during the initial sub-stages of extraction would be lower with production during subsequent sub-stages gradually increasing. An estimated 10 million tonnes (Mt) of fresh rock and 1.25 Mt of weathered rock have been identified within the proposed extraction area.

It is expected that extraction and processing operations would continue for a period of approximately 25 years following Project commencement and would provide fulltime employment for between 14 and 20 persons.

Whilst the principal components of the Project have been defined based upon the occurrence of the underlying hard rock resource and local topographic constraints, both the extraction and processing operations have been designed to optimise the recovery of the hard rock resource whilst satisfying environmental and Site constraints.

Figure 3 displays the following principal components of the Project that would be located on the Site.

- Extraction Area - Stage 1

  The Stage 1 extraction area would cover approximately 4.9 ha with its footprint typically between approximately 30 metres (m) Australian Height Datum (AHD) and 75 m AHD (to a floor with an elevation of 8m AHD).

- Extraction Area - Stage 2

  The Stage 2 extraction area would cover approximately 5.9 ha with its footprint typically between 75 m AHD and 120 m AHD (to a sloping floor from an elevation of 8 m to 12 m AHD).

- Quarry Infrastructure Area

  The quarry infrastructure area would be located on the southern side of the extraction area and would incorporate the product stockpiling area, ancillary components area and mobile processing plant.

- Product Stockpiling Area

  The product stockpiling area would be located on the northern section of the quarry infrastructure area during Stage 1. This area would be expanded to cover northern, southern and western portions of the quarry infrastructure area during Stage 2 (see **Figure 3**).

- Mobile Processing Plant

  The mobile processing plant would incorporate a range of crushers and screens and would be located on the western section of the quarry infrastructure area during Stage 1. During Stage 2, the mobile processing plant would be relocated to the eastern section of the quarry infrastructure area to minimise product haulage distances.

- Internal Roads

  A network of roads to provide access for off-road haul trucks between the extraction and processing area.

- Quarry Access Road

  The inclined, sealed section of road extending from the quarry entrance to the southern side of the quarry infrastructure area.

- Sediment Basins

  Two sediment basins (Western and Southern), each with a with pre-treatment pond, would be constructed to collect sediment laden runoff from the disturbed sections of the Quarry.

- Diversion Drains

  Two clean water diversion (CWD) drains (CWD East and CWD West) would be constructed to direct runoff from undisturbed areas upslope of the extraction area.

Quarry products would be despatched by road using the existing road network with access to the Site via a new entrance to Lot 11 DP 1024564 from Blue Rock Close. The location of the quarry entrance would be close to the existing entrance to the property and would be constructed to accommodate quad-dog trailers and semi-trailers.

The overall footprint of the operation would be kept as small as possible during all stages of operation, with vegetation and soil removed immediately prior to the progressive extension of operations. Progressive rehabilitation would be undertaken as soon as practicable following disturbance.

2.2 ENVIRONMENTAL SETTING

The Site is located approximately 40 km north of Newcastle and 4 km northeast of Karuah. The Site is located immediately south of the Karuah Quarry and southwest of the Karuah East Quarry, both owned and operated by Hunter Quarries Pty Ltd.

The location of the Project is illustrated in **Figure 1**.

Figure 1
Locality Plan

Source: 95802_Section 2_Project Description

2.3 OVERVIEW AND PURPOSE

The purpose of the AQIA is to identify and quantify the potential air quality risks to human health or the natural environment from the proposed construction and operation of the Project and identify potential mitigation measures that may be required, in order to reduce those risks to acceptable levels.

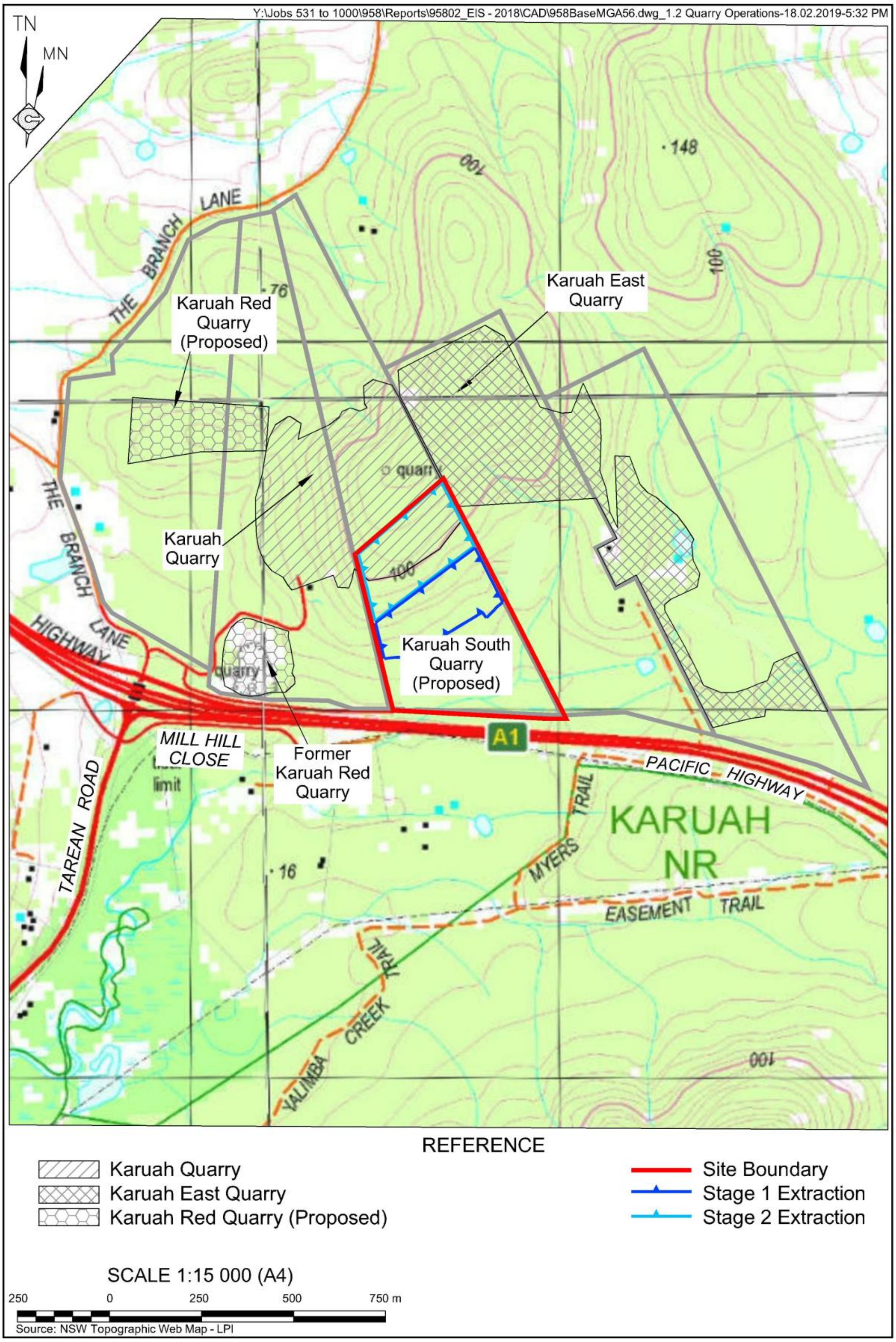
An important consideration for any AQIA is to identify and quantify the discrete impacts from the Project being assessed and place those potential impacts in context of the prevailing conditions at that location. In terms of air quality studies, that requirement includes a consideration of the general background conditions on a regional scale (performed by examination of available sources of air quality monitoring that may reasonably be compared to the Site location) and more localised emissions to air from more proximate activities that need to be considered in aggregation to the anticipated Project impacts. This consideration is typically called a 'cumulative impact assessment' and is a requirement of the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2017).

The geographical scale of the required cumulative impact assessment depends on the nature of the proposed activities at the Site and the likely impact footprint of those emissions. In terms of the Project, the neighbouring Karuah Quarry, Karuah East Quarry and proposed Karuah Red Quarry (see **Figure 1** and **Figure 2**) have the potential to give rise to similar air quality impacts over similar geographical areas, and hence it is considered critical that the AQIA presents a thorough assessment of potential cumulative air quality impacts with those operations, in addition to general regional air quality conditions.

In regard to the above requirement, the aims of this AQIA are to provide an assessment of the potential impacts of the proposed construction and operation of the Project, provide an assessment of the cumulative impacts of the Project and the adjacent Karuah Quarry, Karuah East Quarry and Karuah Red Quarry, and identify how those emissions may be managed in accordance with best practice.

The corresponding aim of the GHG assessment is to provide an assessment of the potential GHG emissions during the construction and operation of the Project and identify how those emissions may be managed in accordance with best practice.

Figure 2
Neighbouring Hard Rock Quarries



Source: 95802_Section 2_Project Description

2.4 SPECIFIC OPERATIONAL DETAILS

The specific operational details may be succinctly presented from Table 2.1 of the Preliminary Environmental Assessment (RWC, 2017), which is (partially) reproduced in **Table 3**.

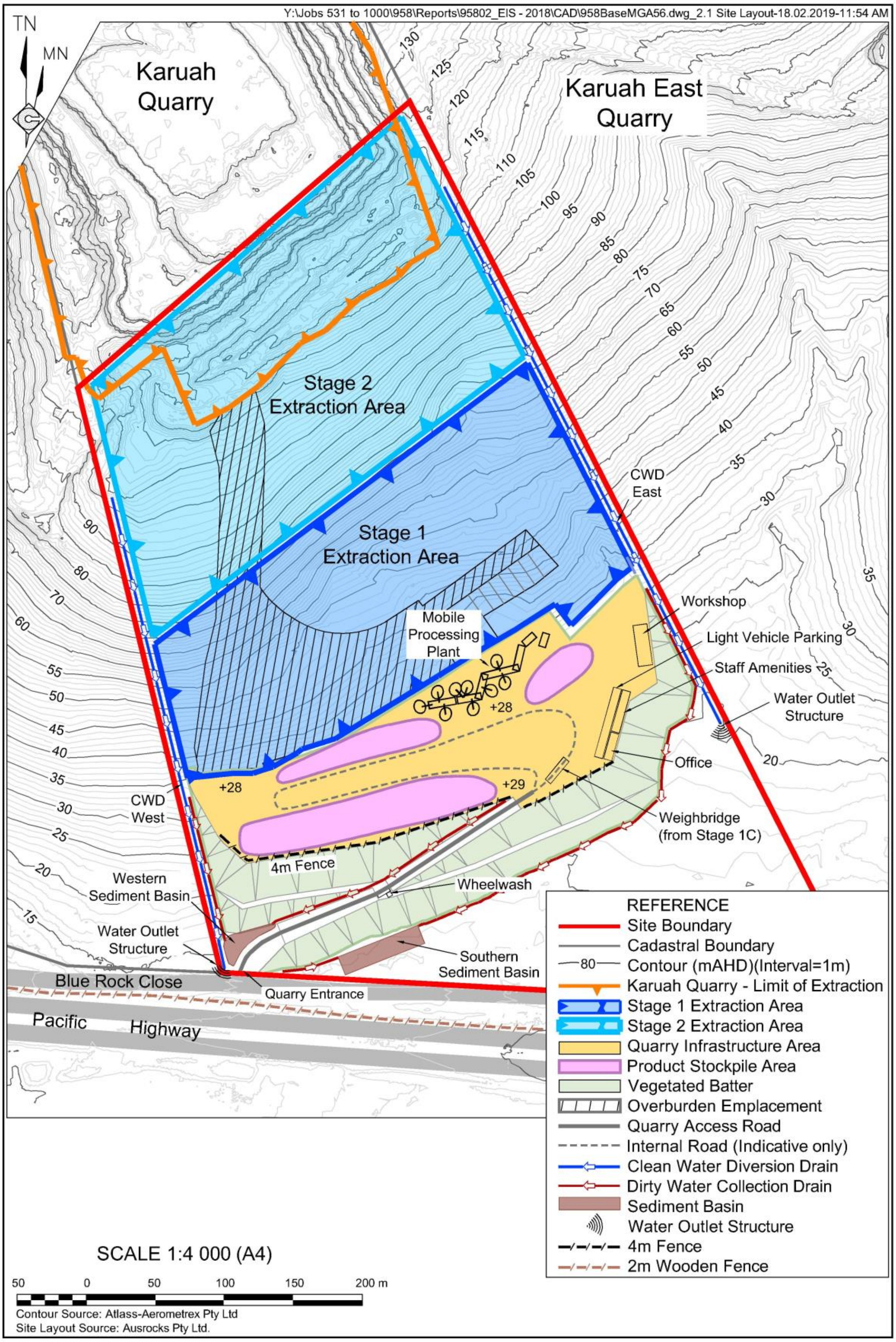
Table 3
Indicative Key Project Components

Project Component	Summary Description
Extraction Method	Drill and blast in a two-stage extraction area covering up to approximately 4.9 ha for Stage 1 and 5.9 ha for Stage 2.
Resource	Igneous rock (rhyodacitic ignimbrite) at least 80 m thick.
Disturbance Area	Disturbance of approximately 21 ha.
Total Recoverable Resource	Approximately 10 million tonnes of fresh rock. Approximately 1.2 million tonnes of weathered rock.
Annual Production	Up to 600,000 tonnes per year of quarry products.
Project Life	Construction stage: approximately 6 months, and Extraction / processing: approximately 5 years for Stage 1 and a further 20 years for Stage 2.
Processing	Crushing and screening.
Waste Management	Minimal waste materials are anticipated to be generated.
Workforce	Construction: 10 persons Operational: approximately 20 persons (Quarry personnel, contractors and transport sub-contractors).
Hours of Operation	Extraction and processing operations 7:00am – 6:00pm Monday to Friday 7:00am – 1:00pm Saturday Blasting 10:00am – 4:00pm Monday to Friday Transport operations 5:00am – 6:00pm Monday to Friday 5:00am – 1:00pm Saturday Maintenance operations 24hrs Monday to Saturday

The Project would utilise drill and blast, load and haul, and processing methods to produce up to 600,000 tpa of quarry product. The recovered materials would be hauled on internal roads to a processing plant, where the materials would be crushed and screened, and then stored at the product stockpiling area. Quarry product would subsequently be despatched by road using the existing road network for delivery to customers.

The indicative site layout is presented in **Figure 3**.

Figure 3
Indicative Project Component Locations



Source: 95802_Section 2_Project Description

2.5 IDENTIFIED POTENTIAL FOR EMISSIONS TO AIR

The construction and operation of the Project is considered likely to generate emissions to air which need to be qualified / quantified and addressed in this AQIA. The identified potential emissions to air are discussed below.

2.5.1 Site Establishment and Construction Stage

This stage of the Project is anticipated to last approximately 6 months, and would involve:

- Vegetation clearance;
- Topsoil and overburden removal;
- Bulk earthworks;
- Development of quarry infrastructure area; and
- Product stockpiling area.

The key emissions to air during the site establishment and construction stage are considered to be:

- Construction dust, arising from site clearance activities, earthworks (including overburden removal and placement), construction, construction traffic and track-out onto the Pacific Highway; and,
- Plant and vehicle engine exhaust emissions.

2.5.2 Operational Stages

The operational stage of the Project is expected to last up to 25 years from the completion of the site establishment and construction stage or until the economic recovery of the resource is completed.

The activities to be conducted during operations would include:

- Blasting and drilling;
- Recovered material handling, transfer and storage;
- Recovered material processing using mobile processing plant;
- Quarry product / storage; and,
- Quarry product loading and despatch to market.

The key emissions to air during the operational stage are considered to include:

- Particulate emissions from the extraction, processing and storage of the material;
- Wheel-generated particulate emissions from the haulage of material on unpaved and paved road surfaces;
- Blasting emissions of particulates and products of combustion; and,
- Plant and vehicle exhaust emissions.

With regard to blasting emissions, the products of combustion are considered to include carbon monoxide (CO) and volatile organic compounds (VOC) generated through the incomplete combustion of fuels in the explosives, and oxides of nitrogen (NO_X) generated through the thermal oxidation of nitrogen (N_2) during the combustion process. Combined, these are typically called 'blast fume'.

Although the overall rate of emission from blasting may be low compared to annualised emissions from the Project, their potential toxicity, rate of release and high concentration during a blasting event means that the AQIA needs to adequately account for those potential impacts and demonstrate that the Project is able to manage potential impacts accordingly.

- Of the components in blast fume, the emission of NO_X is of critical concern due to the toxicity of nitrogen dioxide (NO_2) and nitric oxide (NO). The aggregation of NO_2 and NO is termed as NO_X. [$NO_X = NO + NO_2$]).
- Correspondingly, the principal consideration in this AQIA to blasting emissions is to particulate matter and NO_X (which is assessed as NO_2).

Emissions of greenhouse gases (GHG) would also be generated through the combustion of fuel in mobile plant and equipment during the operation of the Project. Emissions of GHG may also be generated through the off-site transport of product to markets and through employee vehicle use.

3. LEGISLATION, REGULATION AND GUIDANCE

As outlined in Section 2.5, the emissions of most concern during the construction and operation of the Project will be particulate matter and products of combustion from plant and machinery, vehicles and blasting. The following sections outline the Commonwealth and State air quality criteria relevant to those emissions. Also outlined are relevant legislation and guidance related to GHG emissions.

3.1 COMMONWEALTH AIR QUALITY STANDARDS AND REGULATIONS

3.1.1 National Environment Protection (Ambient Air Quality) Measure

The *National Environment Protection (Ambient Air Quality) Measure* (Ambient Air Quality NEPM) was promulgated in July 1998 and established ambient air quality standards for six key pollutants across Australia and provides a standard method for monitoring and reporting on air quality. Air quality standards and performance monitoring goals for the six key air pollutants include:

- Carbon monoxide (CO);
- Lead (Pb);
- Nitrogen dioxide (NO_2);
- Particles (particulate matter with an aerodynamic equivalent diameter of 10 microns (µm) or less (PM_{10});
- Photochemical oxidants, as ozone (O_3); and,
- Sulphur dioxide (SO_2).

The Ambient Air Quality NEPM was varied in July 2003 to include advisory reporting standards for fine particulate matter with an aerodynamic equivalent diameter of 2.5 microns (µm) or less ($PM_{2.5}$) and in February 2016 (NEPC, 2016), introducing varied standards for PM_{10} and $PM_{2.5}$.

The air quality standards and goals as set out in the (revised) Ambient Air Quality NEPM for the pollutants considered within this assessment are presented in **Table 4**.

Table 4
National Environment Protection (Ambient Air Quality) Measure Standards and Goals

Pollutant	Averaging Period	Criterion	Allowable Exceedance per Year
Particulates (as PM_{10})	1 day	50 $\mu g \cdot m^{-3}$	None
	1 year	25 $\mu g \cdot m^{-3}$	None
Particulates (as $PM_{2.5}$)	1 day	25 $\mu g \cdot m^{-3}$	None
	1 year	8 $\mu g \cdot m^{-3}$	None
Nitrogen dioxide (NO_2)	1 hour	0.12 ppm[(a)]	1 day a year
	1 year	0.03 ppm[(a)]	None

Note (a) parts per million (1 x 10^{-6})

3.1.2 National Clean Air Agreement

The National Clean Air Agreement (NCAA) was agreed by Australia's Environment Ministers on 15 December 2015. The NCAA establishes a framework and work plans for the development and implementation of various policies aimed at improving air quality across Australia.

Regarding air quality standards with relevance to this report, the Work Plan 2018-2020 of the NCAA sets an objective to review scientific evidence in relation to annual average PM_{10} standards and to review the Ambient Air Quality NEPM for NO_2.

The Work Plan 2015-2017 sought to strengthen particle reporting standards for PM_{10} and $PM_{2.5}$ which came into effect on 4 February 2016. These standards have been adopted as part of this assessment.

3.2 NSW AIR QUALITY STANDARDS AND REGULATIONS

3.2.1 NSW EPA Approved Methods

State air quality guidelines adopted by the NSW EPA are published in the '*Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*' (the Approved Methods (NSW EPA, 2017)) which has been consulted during the preparation of this assessment report.

The Approved Methods lists the statutory methods that are to be used to model and assess emissions of criteria air pollutants from stationary sources in NSW. Section 7.1 of the Approved Methods clearly outlines the impact assessment criteria for the project (see also Section 1.1 and **Table 1**).

The criteria listed in the Approved Methods are derived from a range of sources (including NHMRC, NEPC, DoE and WHO).

The criteria specified in the Approved Methods are the defining ambient air quality criteria for NSW. The standards adopted to protect members of the community from health impacts in NSW are presented in **Table 5**.

The criteria listed in **Table 5** have been applied within this AQIA.

Table 5
NSW EPA air quality standards and goals

Pollutant	Averaging period	Units	Criterion	Notes
Nitrogen dioxide (NO_2)	1 hour	$\mu g{\cdot}m^{-3}$ (a)(e) pphm(f)	246 12	Numerically equivalent to the AAQ NEPM(b) standards and goals.
	1 year	$\mu g{\cdot}m^{-3}$ pphm	62 3	
Particulates (as PM_{10})	24 hours	$\mu g{\cdot}m^{-3}$	50	
	1 year	$\mu g{\cdot}m^{-3}$	25	
Particulates (as $PM_{2.5}$)	24 hours	$\mu g{\cdot}m^{-3}$	25	
	1 year	$\mu g{\cdot}m^{-3}$	8	
Particulates (as TSP)	1 year	$\mu g{\cdot}m^{-3}$	90	
Particulates (as dust deposition)	1-year(c)	$g{\cdot}m^{-2}{\cdot}month^{-1}$	2	Assessed as insoluble solids as defined by AS 3580.10.1
	1-year(d)	$g{\cdot}m^{-2}{\cdot}month^{-1}$	4	

Notes: (a): micrograms per cubic metre of air (b): National Environment Protection (Ambient Air Quality) Measure
(c): maximum increase in deposited dust level (d): Maximum total deposited dust level
(e) gas volumes are expressed at 25°C (298 K) and at an absolute pressure of 1 atmosphere (101.325 kPa) (f): parts per hundred million ($1x10^{-8}$)

3.2.2 NSW Voluntary Land Acquisition and Mitigation Policy

The NSW Government published the "*Voluntary Land Acquisition and Mitigation Policy for State Significant Mining, Petroleum and Extractive Industry Developments*" (hereafter, the policy) in December 2014 (NSW Government, 2014). The policy is to be applied by consent authorities when assessing and determining applications for mining, petroleum and extractive industry developments that are subject to State Significant Development provisions of the *Environmental Planning and Assessment Act 1979*.

A number of policies and guidelines include Air Quality Assessment criteria to protect the amenity, health and safety of people, including those outlined in Section 3.2.1. They typically require Operators to implement all reasonable and feasible avoidance and/or mitigation measures to minimise the impacts of a development. In some circumstances however, it may not be possible to comply with these assessment criteria even with the implementation of all reasonable and feasible avoidance and/or mitigation measures. This can occur with large resource projects where the resources are fixed, and there is limited scope for avoiding and/or mitigating impacts. However, as outlined within the policy it is important to recognise that:

- Not all exceedances of the relevant assessment criteria equate to unacceptable impacts.
- Consent authorities may decide that it is in the public interest to allow the development to proceed, even though there would be exceedances of the relevant assessment criteria, because of the broader social and economic benefits of the development.
- Some landowners may be prepared to accept higher impacts on their land, subject to entering into suitable negotiated agreements with Operators, which may include the payment of compensation.

Consequently, the assessment process can lead to a range of possible outcomes.

In the application of the policy, the Applicant must demonstrate that all viable alternatives have been considered, and all reasonable and feasible avoidance and mitigation measures have been incorporated into the project design. Should acquisition or mitigation criteria (see **Table 6** and **Table 7**) be exceeded as a result of the project operation then the Applicant should consider a negotiated agreement with the affected landowner or acquisition of the affected land. Full details of the negotiated agreement and acquisition process is provided in the policy (NSW Government, 2014).

In relation to air quality, the policy applies specifically to particulate matter (TSP, PM_{10} and dust deposition). Applicants are required to assess the impacts of the development in accordance with the Approved Methods document (NSW EPA, 2017). Should exceedances of the relevant particulate matter criteria (refer **Table 5**) be predicted, then comparison with the mitigation and acquisition criteria is performed.

3.2.2.1 Voluntary Mitigation

As outlined in the policy, a consent authority should only apply voluntary mitigation rights where, even with the implementation of best practice management, the development contributes to exceedances of the mitigation criteria outlined in **Table 6**:

- At any residence on privately owned land; or
- At any workplace on privately owned land where the consequences of those exceedances in the opinion of the consent authority are unreasonably deleterious to worker health or the carrying out of business at that workplace, including consideration of the following factors:
  - the nature of the workplace;
  - the potential for exposure of workers to elevated levels of particulate matter;
  - the likely period of exposure; and,
  - the health and safety measures already employed in that workplace.

Table 6

Particulate Matter Mitigation Criteria

Pollutant	**Averaging Period**	**Mitigation Criterion**		**Impact Type**
PM_{10}	Annual	25 $\mu g{\cdot}m^{-3}$ (a,c)		Human health
PM_{10}	24-hour	50 $\mu g{\cdot}m^{-3}$ (b)		Human health
Total suspended particulates (TSP)	Annual	90 $\mu g{\cdot}m^{-3}$ (a)		Amenity
Deposited dust	Annual	2 $g{\cdot}m^{-2}{\cdot}month^{-1}$ (b)	4 $g{\cdot}m^{-2}{\cdot}month^{-1}$ (a)	Amenity

(a) Cumulative impact (i.e. increase in concentrations due to the development plus background concentrations due to all other sources)

(b) Incremental impact (i.e. increase in concentrations due to the development alone), with zero allowable exceedances of the criteria over the life of the development).

(c) Annual average PM_{10} criterion stated in the Approved Methods (NSW EPA, 2017) is 25 $\mu g{\cdot}m^{-3}$ and is assumed to supersede the 30 $\mu g{\cdot}m^{-3}$ stated in the policy (taken from the 2005 Approved Methods document).

Mitigation measures should be directed towards reducing the potential human health and amenity impacts of the development and must be directly relevant to the mitigation of those impacts.

3.2.2.2 Voluntary Acquisition

A consent authority should only apply voluntary acquisition rights where, even with the implementation of best practice management, the development is predicted to contribute to exceedances of the acquisition criteria in **Table 7**:

- At any residence on privately owned land; or
- At any workplace on privately owned land where the consequences of those exceedances in the opinion of the consent authority are unreasonably deleterious to worker health or the carrying out of business at that workplace, including consideration of the following factors:
  - the nature of the workplace;
  - the potential for exposure of workers to elevated levels of particulate matter;
  - the likely period of exposure; and
  - the health and safety measures already employed in that workplace.
- On more than 25% of any privately-owned land where there is an existing dwelling or where a dwelling could be built under existing planning controls.

Table 7
Particulate Matter Acquisition Criteria

Pollutant	Averaging Period	Acquisition Criterion		Impact Type
PM_{10}	Annual	25 µg·m^{-3} (a,c)		Human health
PM_{10}	24-hour	50 µg·m^{-3} (b)		Human health
Total suspended particulates (TSP)	Annual	90 µg·m^{-3} (a)		Amenity
Deposited dust	Annual	2 g·m^{-2}·month^{-1} (b)	4 g·m^{-2}·month^{-1} (a)	Amenity

(a) Cumulative impact (i.e. increase in concentrations due to the development plus background concentrations due to all other sources)

(b) Incremental impact (i.e. increase in concentrations due to the development alone), with up to 5 allowable exceedances of the criteria over the life of the development).

(c) Annual average PM_{10} criterion stated in the Approved Methods (NSW EPA, 2017) is 25 µg·m^{-3} and is assumed to supersede the 30 µg·m^{-3} stated in the policy (taken from the 2005 Approved Methods document).

3.2.3 NSW Statutory Frameworks

3.2.3.1 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations* (POEO) *Act* (1997) sets the statutory framework for managing air quality in NSW, including establishing the licensing scheme for major industrial premises and a range of air pollution offences and penalties.

Should the Project gain approval, an Environment Protection Licence (EPL) would be required to be obtained and once issued would contain a range of requirements related to minimisation of emissions from the Site, operations at which would be defined as a scheduled activity under the POEO.

3.2.3.2 Protection of the Environment (Clean Air) Regulation 2010

The Protection of the Environment (Clean Air) Regulation 2010 (POEO (Clean Air) Regulation) sets standards of concentration for emissions to air from both scheduled and non-scheduled activities. For the activities to be performed at the Site, the POEO (Clean Air) Regulation covers emissions from motor vehicles and motor vehicle fuels and also provides general standards of concentration for scheduled premises which are presented in **Table 8** for the pollutants of relevance to this assessment.

Table 8

POEO (Clean Air) Regulation – Standards of Concentration

Air Impurity	Activity	Standard of Concentration (Group 6)
Solid particles (total)	Any activity or plant (except as listed below)	50 $mg \cdot m^{-3}$
	Any crushing, grinding, separating or materials handling activity	20 $mg \cdot m^{-3}$
Nitrogen dioxide (NO_2) or Nitric Oxide (NO) or both, as NO_2 equivalent	Any activity or plant (except boilers, gas turbines and stationary reciprocating internal combustion engines listed below)	350 $mg \cdot m^{-3}$

Further to the requirements in **Table 8**, Part 4 Clause 15 of the POEO (Clean Air) Regulation requires that motor vehicles do not emit excessive air impurities which may be visible for a period of more than 10-seconds when determined in accordance with the relevant standard.

Schedule 8 of the POEO (Clean Air) Regulation indicates that burning of vegetation is prohibited, except with approval in the Great Lakes Council (now MidCoast Council) area.

As part of the construction of the Project and during operation, all vehicles, plant and equipment to be used either at the Site or to transport materials to and from the Site, will be maintained regularly and in accordance with manufacturers' requirements. No burning of materials would be performed as part of the construction or operation of the Project.

3.3 PROJECT SPECIFIC ASSESSMENT CRITERIA

Based upon the foregoing, the criteria presented in **Table 9** are considered to represent the appropriate air quality impact assessment criteria for the Project.

Table 9
Project-Specific Air Quality Assessment Criteria

Pollutant	Averaging period	Units	Criterion	Notes
Nitrogen dioxide (NO_2)	1 hour	$\mu g \cdot m^{-3}$ (a)(e) pphm(f)	246 12	Numerically equivalent to the AAQ NEPM(b) standards and goals.
	1 year	$\mu g \cdot m^{-3}$ pphm	62 3	
Particulates (as PM_{10})	24 hours	$\mu g \cdot m^{-3}$	50	
	1 year	$\mu g \cdot m^{-3}$	25	
Particulates (as $PM_{2.5}$)	24 hours	$\mu g \cdot m^{-3}$	25	
	1 year	$\mu g \cdot m^{-3}$	8	
Particulates (as TSP)	1 year	$\mu g \cdot m^{-3}$	90	
Particulates (as dust deposition)	1-year(c)	$g \cdot m^{-2} \cdot month^{-1}$	2	Assessed as insoluble solids as defined by AS 3580.10.1
	1-year(d)	$g \cdot m^{-2} \cdot month^{-1}$	4	

Notes: (a): micrograms per cubic metre of air (b): National Environment Protection (Ambient Air Quality) Measure
(c): Maximum increase in deposited dust level (d): Maximum total deposited dust level
(e) Gas volumes are expressed at 25°C (298 K) and at an absolute pressure of 1 atmosphere (101.325 kPa)
(f): Parts per hundred million ($1x10^{-8}$)

Although not required to be assessed within the SEARs, it is understood that there may be some community concern with regard to respirable crystalline silica. NSW EPA do not provide air quality criteria for this pollutant, although VIC EPA in their State Environmental Planning Policy (SEPP) Protocol for Environmental Management: Mining and Extractive Industries (PEM) (VIC EPA, 2007) do include a criterion for respirable crystalline silica (as $PM_{2.5}$) as 3 $\mu g \cdot m^{-3}$ (annual average), which has been adopted from the California EPA Office for Environmental Health Hazard Assessment Reference Exposure Levels. This criterion is referenced in this assessment and calculates respirable crystalline silica by adjusting annual average $PM_{2.5}$ modelling results *pro-rata* to account for the determined maximum free silica content of the extracted material (20%). Respirable crystalline silica is generally an occupational health and safety issue rather than an environmental issue when considering quarries of the nature of the Project. Respirable crystalline silica would be considered in the operation of the Site in regard to occupational health through consideration of occupational dust control measures.

3.4 GREENHOUSE GAS LEGISLATION AND GUIDANCE

The Australian Government Clean Energy Regulator administers schemes legislated by the Australian Government for measuring, managing, reducing or offsetting Australia's carbon emissions.

Schemes administered by the Clean Energy Regulator include:

- National Greenhouse and Energy Reporting Scheme, under the *National Greenhouse and Energy Reporting Act* (2007).
- Emissions Reduction Fund, under the *Carbon Credits (Carbon Farming Initiative) Act* (2011).
- Renewable Energy Target, under the *Renewable Energy (Electricity) Act* (2000).
- Australian National Registry of Emissions Units, under the *Australian National Registry of Emissions Units Act* (2011).

3.4.1 National Greenhouse and Energy Reporting Scheme

The National Greenhouse and Energy Reporting (NGER) scheme, established by the *National Greenhouse and Energy Reporting Act* (2007) (NGER Act), is a national framework for reporting and disseminating company information about greenhouse gas emissions, energy production, energy consumption and other information specified under NGER legislation.

The objectives of the NGER scheme are to:

- inform government policy.
- inform the Australian public.
- help meet Australia's international reporting obligations.
- assist Commonwealth, state and territory government programmes and activities.
- avoid duplication of similar reporting requirements in the states and territories.

Further information on the NGER scheme, specifically the definitions of various scopes and types of GHG emissions which have also been adopted for the purposes of this assessment, is provided in Section 5.2.

3.4.2 Relevant NSW Legislation

There is no specific GHG legislation administered within NSW. The NGER scheme (and other identified Commonwealth schemes in Section 3.4.1) is the applicable legislation within NSW.

3.4.3 Guidance

The GHG accounting and reporting principles adopted within this GHG assessment are based on the following financial accounting and reporting standards:

- Australian Government Department of the Environment, Australian National Greenhouse Accounts, National Greenhouse Accounts Factors, July 2017 (DoE, 2018).
- The World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) GHG Protocol: A Corporate Accounting and Report Standard (WRI, 2004).
- ISO 14064-1:2006 (Greenhouse Gases – Part 1: Specification with guidance at the organisation level for quantification and reporting of GHG emissions and removal.
- ISO 14064-2:2006 (Greenhouse Gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of GHG emission reductions or removal enhancements).
- ISO 14064-3:2006 (Greenhouse Gases – Part 3: Specification with guidance for the validation and verification of GHG assertions) guidelines (internationally accepted best practice).

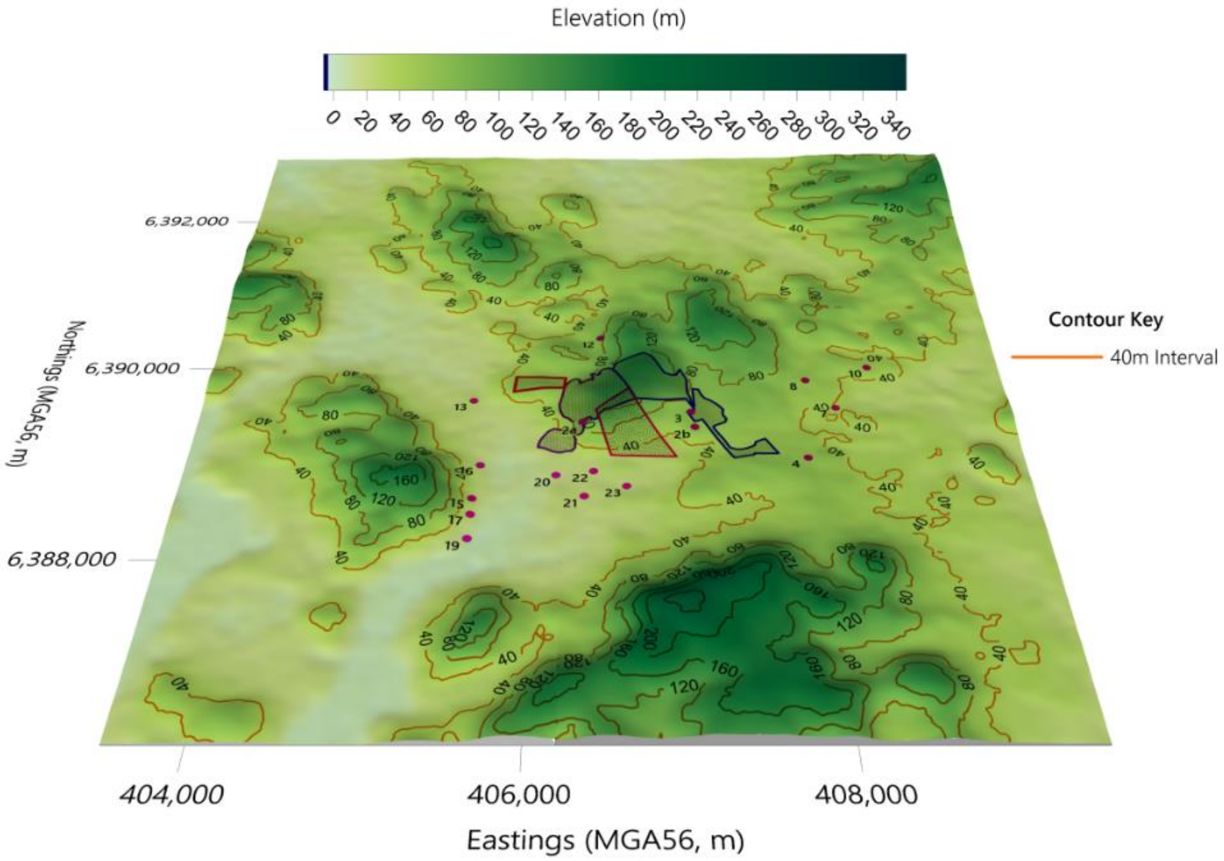
4. EXISTING CONDITIONS

This section provides an overview and description of the existing environment surrounding the Site. The data used to derive the description are also discussed.

4.1 TOPOGRAPHY

The Site is located in an area of low undulating topography, as illustrated in **Figure 4**. The Site, in its current landform, is at approximately 40 m to 100 m Australian Height Datum (AHD), with the land rising to over 240 m AHD to the south.

Figure 4
Topography Surrounding the Site



Source: Northstar Air Quality, derived from NASA SRTM 1-arc second data

Figure 4 above additionally shows the relevant site boundaries and receptor locations (see Section 4.2). These are illustrated in the figure to show how topography varies between the Site and the various sensitive receptor locations used in the AQIA. The topography between the sensitive receptors and the Site can be considered to be complicated, warranting a detailed assessment using appropriate modelling tools (refer Section 5.1).

4.2 EXISTING LAND USE

4.2.1 Sensitive Land Uses

Air quality assessments typically use a desk-top mapping study to identify ’discrete receptor locations’, or ‘sensitive receptors’, which are intended to represent a selection of locations that may be susceptible to changes in air quality. In broad terms, the identification of sensitive receptors refers to places at which humans may be present for a period representative of the averaging period for the pollutant being assessed.

Typically, these locations are identified as residential properties although other sensitive land uses may include schools, medical centres, places of employment, recreational areas or ecologically sensitive locations.

It is important to note that the selection of discrete receptor locations is not intended to represent a fully inclusive selection of all sensitive receptors across the study area. The location selected should be considered to be representative of its location, and may be reasonably assumed to be representative of the immediate environs.

It is further noted that in addition to the identified ‘discrete’ receptor locations, the entire modelling area is gridded with ‘uniform’ receptor locations that are used to plot out the predicted impacts, and as such the non-inclusion of a location sensitive to changes in air quality does not render the AQIA invalid, or otherwise incapable of assessing those potential risks.

In accordance with the requirements of the Approved Methods (NSW EPA, 2017), a number of receptor locations representing surrounding residences have been identified and these receptors adopted for use within this AQIA are presented in **Table 10** and illustrated in **Figure 5**.

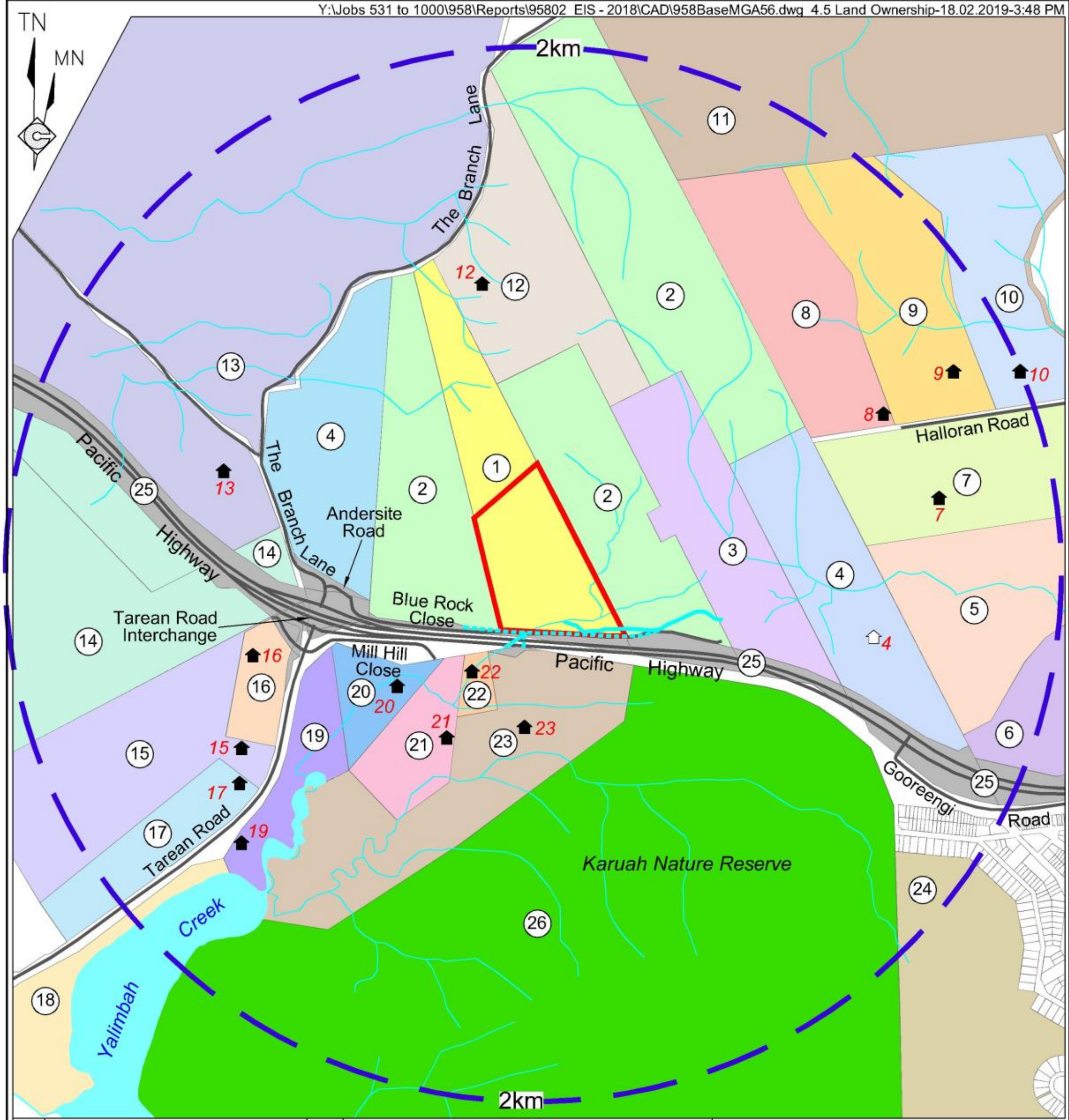
4.2.2 Land Use Zoning

The land surrounding the Site is predominantly zoned as ‘rural landscape’ in the Great Lakes Environment Plan. However, to the south of the Pacific Highway the land is zoned as ‘national parks and nature reserves’.

4.2.3 Land Ownership

Figure 5 also presents the Lot boundaries with the relevant Lot owners. This has been presented to facilitate the assessment of potential air quality impacts in accordance with the “*Voluntary Land Acquisition and Mitigation Policy For State Significant Mining, Petroleum and Extractive Industry Developments*” (see Section 3.2.2).

Figure 5
Land Use – Sensitive Receptor Locations



Ref	Landowner	Ref	Landowner
1	MJ Kiely	14	RN Pickford,RF Pickford, KL Pickford
2	Branch Land Pty Ltd	15	DB Clarke
3	HR Grugeon, BC Grugeon	16	PR Wood
4	Branch Land Pty Ltd	17	WE Cameron, D Taylor
5	J Vallas, M Vallas	18	AF Percy
6	Tea Garden Farms Pty Ltd	19	S Emanuel
7	Bao Lin Pty Ltd	20	GA Norbury
8	WB Hestelow, TA Hestelow	21	WR Plover
9	AW Woodfield, JA Woodfield	22	RJ Trotter
10	J Tonna	23	GB Myers, DL Myers
11	Firstcomp Pty Ltd	24	Walker North Arm Cove Developments Pty Limited
12	G J Mis, S Mis	25	Roads and Traffic Authority of New South Wales
13	Upper Wantagong Station Pty Ltd	26	Minister Administering The National Parks and Wildlife Act

REFERENCE
- Site Boundary
- Sealed Road
- Watercourse/Drainage Line
- Longitudinal Drain and Culvert
- Former Watercourse
- Cadastral Boundary
- Landowner Reference
- Privately-owned Residence
- Resource Company-owned Residence
- 19 Sensitive Receiver Identifier

SCALE 1:25 000 (A4)

250 0 250 500 750 1000 1250 m

Landowner Source: Department of Lands Online Search - February 2019
Cadastral Boundary Source: © NSW Department of Finance and Services
Panorama Avenue Bathurst NSW 2795 www.lpi.nsw.gov.au

Table 10
Sensitive Receptor Locations

Landowner Ref. No.	Property Name	Landowner	Co-ordinates UTM	
			m E	m S
2a	Lot 21 DP1024341	Branch Land Pty Ltd	406,330	6,389,326
2b	Lot 12 DP1024564	Branch Land Pty Ltd	407,150	6,389,280
3	Lot 13 DP1024564	HR Grugeon, BC Grugeon	407,128	6,389,442
4	Lot 14 DP 1024564	HR Grugeon, GA Chevalley, RA Badior	407,944	6,388,955
7	Lot 1 DP 1032636	Bao Lin Pty Ltd	408,204	6,389,511
8	Lot 10 DP 1032636	WB Hestelow, TA Hestelow	408,007	6,389,812
10	Lot 12 DP 1032636	J Tonna	408,492	6,389,968
12	Lot 4 DP838128	G J Mis, S Mis	406,458	6,390,302
13	Lot 50 DP 1036893	Upper Wantagong Station Pty Ltd	405,516	6,389,603
15	Lot 250 DP 1092111	DB Clarke	405,569	6,388,563
16	Lot 22 DP 1024341	PR Wood	405,607	6,388,906
17	Lot 2 DP596780	WE Cameron, D Taylor	405,567	6,388,414
19	Lot 5 DP595881	S Emanuel	405,560	6,388,190
20	Lot 1 DP 785172	GA Norbury	406,147	6,388,807
21	Lot 2 DP 785172	WR Plover	406,349	6,388,593
22	Lot 3 DP 785172	RJ Trotter	406,414	6,388,846
23	Lot 100 DP 785172	GB Myers, DL Myers	406,646	6,388,693

4.3 AIR QUALITY

The air quality experienced at any location will be a result of emissions generated by natural and anthropogenic sources on a variety of scales (local, regional and global). The relative contributions of sources at each of these scales to the air quality at a given location will vary based on a wide number of factors including the type, location, proximity and strength of the emission source(s), prevailing meteorology, land uses and other factors affecting the generation, dispersion and fate of those emissions.

When assessing the potential impact of any particular source of emissions on the air quality at a location, the impact of all other sources of an individual pollutant should also be assessed. This 'background' air quality will vary depending on the pollutants to be assessed and can often be characterised by using representative air quality monitoring data. In some instances, where a number of emission sources are in close proximity to each other and air quality monitoring data is not continuously collected in the area, then an alternative approach must be investigated.

This section and the associated **Annexure 3** outlines the air quality which is currently experienced in the area surrounding the Site. This has been determined through the examination of air quality monitoring data which is collected as part of ongoing operations at Karuah and Karuah East quarries (refer Section 4.5.1 and Section 4.5.2) and derived from measurements obtained by NSW OEH at air quality monitoring stations (AQMS) in the Newcastle area.

An AQIA performed to support the Karuah East Quarry (SLR Consulting Australia Pty Ltd, 2012) utilised air quality monitoring data from the NSW OEH AQMS at Wallsend to characterise the air quality of the local area, without the impacts of the Karuah East Quarry. This approach was not supported by the NSW EPA who considered that the impacts of the Karuah Quarry (and the Kiely's Karuah Quarry which was proposed at that time, now called Karuah South Quarry) would not be appropriately captured by those measurements.

Subsequent to the above a revised AQIA (SLR Consulting Australia Pty Ltd, 2013) adopted the Wallsend measurements as a regional background dataset, to which were added the impacts of the (modelled) Karuah Quarry and Karuah East Quarry (the Kiely's/Karuah South Quarry proposal having been withdrawn at that time).

The approach adopted here is similar, with the impacts of the Karuah, Karuah Red and Karuah East Quarry determined through a dispersion modelling exercise across the two scenarios. The addition of the Wallsend AQMS data as a representation of regional background has been modified slightly. The reason for the modification is that measurements at Wallsend will be influenced by different sources than those which are predominantly experienced in the area surrounding the Site. An examination of PM_{10} data collected at Wallsend and as part of the Karuah East Quarry operations indicates that PM_{10} concentrations in the area surrounding the Site are consistently lower (across the whole percentile distribution) than measurements of PM_{10} at Wallsend.

Sufficient data for $PM_{2.5}$ are not available to allow a similar relationship to be derived, and therefore the unadjusted $PM_{2.5}$ data from Wallsend have been adopted to characterise the regional background $PM_{2.5}$ environment. For clarity, in addition to the assumed background are added impacts of $PM_{2.5}$ resulting from the operation of the Karuah, Karuah Red and Karuah East Quarry which have been derived through dispersion modelling.

A full description of the methods used to derive the background air quality environment surrounding the Site is provided in **Annexure 3**. In summary the approach has resulted in the adoption of the following air quality data which represents a regional component of air quality, to which are added the modelled impacts associated with Karuah, Karuah Red and Karuah East Quarry.

Table 11
Background (Regional) Air Quality Adopted for Assessment

Pollutant	Averaging Period	Value	Data Source
PM_{10}	24-hour	Hourly varying	Adjusted from Wallsend 2012 using the relationship derived in **Annexure 3**, **Figure 3-4** [Site PM_{10}] = 1.2[Wallsend PM_{10}] - 7.6
	Annual	14.9 $\mu g \cdot m^{-3}$	Wallsend 2012 (no adjustment applied)
$PM_{2.5}$	24-hour	Hourly varying	Wallsend 2012 (no adjustment applied)
	Annual	5.1 $\mu g \cdot m^{-3}$	Wallsend 2012 (no adjustment applied)
TSP	Annual	26.3 $\mu g \cdot m^{-3}$	Derived from the relationship in **Annexure 3**, **Figure 3-4** [Site TSP] = 1.5[PM_{10}] + 4.2
Dust Deposition	Monthly	2 $g \cdot m^{-2} \cdot month^{-1}$	Approved Methods
NO_2	1-hour	4.3 pphm 88.1 $\mu g \cdot m^{-3}$	Maximum 1-hour value, Wallsend 2012-2016
	Annual	0.8 pphm 16.4 $\mu g \cdot m^{-3}$	Average value Wallsend 2012-2016

Note: Impacts associated with Karuah, Karuah Red and Karuah East Quarry not included – impacts to be quantitatively assessed (modelled)

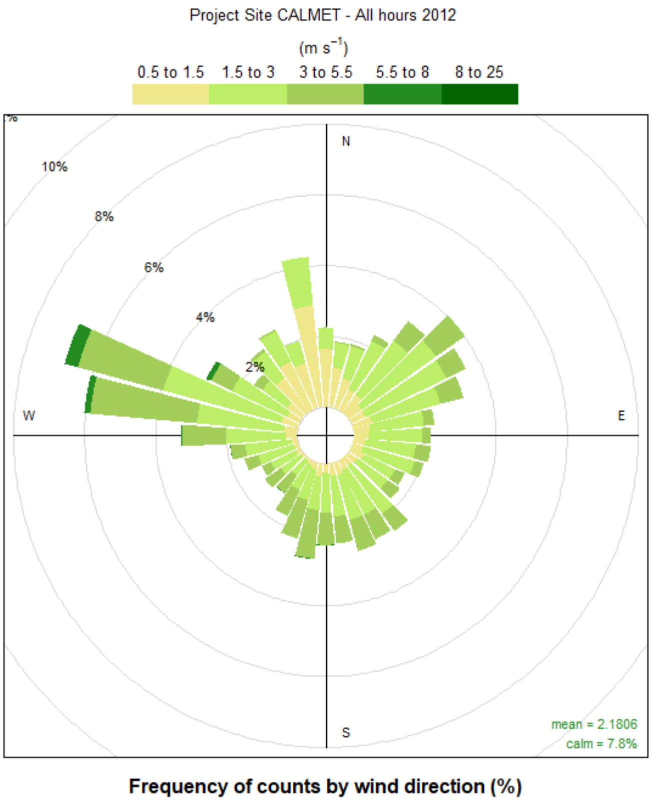
4.4 METEOROLOGY

The meteorology experienced within a given area can govern the generation (in the case of wind dependent emission sources), dispersion, transport and eventual fate of pollutants in the atmosphere. The meteorological conditions surrounding the Site have been characterised using data collected by the Australian Government Bureau of Meteorology (BoM) at a number of surrounding Automatic Weather Stations (AWS) (**Annexure 1**).

To provide a characterisation of the meteorology which would be expected at the Site, a meteorological modelling exercise has been performed. A full description of the modelling exercise, methods and input data used, and a full validation exercise using statistical benchmarks is presented in **Annexure 1**.

A summary of the wind conditions predicted by CALMET at the Site for 2012 is presented in **Figure 6**. These data have been used in the dispersion modelling exercise described in Section 5.1.

Figure 6
CALMET Predicted Wind Conditions – Site, 2012



4.5 POTENTIAL FOR CUMULATIVE IMPACTS

As previously discussed, the Site is located in an area of existing quarrying activity, with two Hunter Quarries Pty Ltd operations located to the north and north-west (Karuah Quarry) and north-east and east (Karuah East Quarry), with a proposed quarry (Karuah Red Quarry) to the west of Karuah Quarry. In addition, the Site is located adjacent to the Pacific Highway, a major transport corridor. A discussion of each of these sources of pollution is presented in the following sections.

No additional significant sources of pollutants have been identified in the area surrounding the Site.

4.5.1 Karuah Quarry

4.5.1.1 Background

Karuah Quarry is located to the immediate north and north west of the Site. Karuah Quarry is located on Lot 21 DP1024341, Lot 11 DP1024564 and part of Lot 12 DP024564 with quarrying activities proceeding on Lot 11 under a licence agreement with Wedgerock and on Lot 21 which is owned by Hunter Quarries Pty Ltd. Refer to **Figure 7** for an overview of the site location of Karuah Quarry.

The Karuah Quarry is approved to produce and despatch up to 500,000 tonnes of hard rock quarry products per year. Annual Environmental Management Reports (AEMRs) prepared by Hunter Quarries between 2002 and 2015 have reported annual production levels of between 122,181 tonnes and 494,117 tonnes of quarry products. During that period, approximately 5.5 million tonnes of quarry products were produced from rock extracted from Lot 11.

Operations at the Karuah Quarry are approved until 3 June 2027, although it is noted that Hunter Quarries has previously documented that the economic life of the Quarry will be exhausted by the end of 2017. In a more recent AEMR, Hunter Quarries has stated that "although the production rate at the site will likely decrease after 2017 "i.e. as production commences in the Karuah East Quarry", Hunter Quarries nominated that beyond 2017 "the Site will still remain operational for campaign-based extraction" and "there is no current date for final closure". The extent of operations within the Karuah Quarry once the Karuah East Quarry becomes operational have been discussed with Hunter Quarries personnel. It is understood that extraction will continue on Lot 11, albeit at a rate less than in the past. It is understood that Hunter Quarries planned future extraction within Lot 11 will involve the removal of the remaining overburden to the approved southern boundary of the extraction area and the removal of hard rock resource set back from the southern boundary in a similar manner to the eastern boundary.

The following overview of activities has been relied upon for the cumulative impact assessment with those activities planned within the Site.

Extraction will proceed in two stages.

- Stage A – will involve the removal of the overburden to the southern boundary and the commencement of hard rock extraction to an elevation of approximately 100 m AHD. It is anticipated Stage A will occur in 2019 – 2020.
- Stage B – will involve the removal of the remaining hard rock on the southern side of the extraction area down to an elevation of approximately 62 m AHD, i.e. the current floor of the existing extraction area. It is assumed that Stage B will occur beyond 2020.
- Annual production could vary between 100,000 tpa to 400,000 tpa.

Figure 7
Karuah Quarry – Overview

Source: 95802_Draft Section 1.5 Extract_20180904

- Mobile equipment likely to be used in each stage is as follows[1].

  Stage A: – Bulldozer (D8K or similar)
  - Articulated Haul Trucks (x 2) (Caterpillar 730C or similar)
  - Excavator (x 1) (PC 300 or similar)
  - Percussion drill (x 1) (Atlas Coco T40 or similar)

  Stage B: – Percussion Drill (x 1) (Atlas Coco T40 or similar)
  - Excavator (x 1) (PC 300 or similar)
  - Articulated Haul Trucks (x 2) (Caterpillar 730C or similar)
- Product truck movements would vary between 120 and 144 movements per day, i.e. 60 loads to 72 loads per day.

The most recent version of the EPL (dated 26 August 2016) restricts the annual processing capacity of the approved ‘crushing, grinding or separating’ and ‘land-based extractive’ (also covering processing and storage) activities to between 100,000 t and 500,000 t per annum.

The most recent Annual Environmental Management Report (AEMR) (Hunter Quarries Pty Ltd, 2015) for Karuah Quarry indicates that a total of 412,779 t of rock product and saleable product were produced between January 16, 2015 and January 15, 2016. Data for the most recent year (January 2016 to January 2017) is not yet available but a forecast of 410,000t is provided within the 2015 AEMR.

A summary of the adopted activity data used in the calculation of particulate emissions from the Karuah Quarry for the purposes of cumulative assessment are presented in **Annexure 2**.

4.5.1.2 Previous Assessments of Air Quality

The AQIA associated with the most recent approval (DA265-10-2004) predicted that the air quality impacts associated with the extension would meet the then NSW Department of Environment and Conservation (DEC) air quality criteria for dust deposition, TSP and PM_{10} at locations 420 m, 540 m, 640 m south of the quarry (generally indicative of residences 20 to 23, refer **Figure 5**) and 1,090 m south-west of the quarry (assumed to represent residence 15, refer **Figure 5**) in both year 1 and year 8 of operation. Maximum cumulative concentrations of particulate matter were predicted to be generally dominated by background (existing) air quality at the locations assessed (NSW DIPNR, 2004).

In 2013, an AQIA associated with Karuah East Quarry (refer Section 4.5.2) provided dispersion modelling predictions of dust deposition, TSP, PM_{10} and $PM_{2.5}$ associated with Karuah Quarry to enable the presentation of a cumulative assessment of air quality associated with both the Karuah and Karuah East Quarries (SLR Consulting Australia Pty Ltd, 2013). The findings of the 2013 AQIA are reproduced in **Table 12** and are presented as incremental values.

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[1] Equipment size and/or capacity has been assumed for the Hunter Quarries operations in the absence of specific information being provided.

Table 12

Predicted Incremental Particulate Concentrations – Karuah Quarry

ID	Landowner Ref. No.	Deposition Flux $g \cdot m^{-2} \cdot month^{-1}$	Concentration $\mu g \cdot m^{-3}$				
		Dust Deposition	TSP	PM_{10}		$PM_{2.5}$	
		Annual	Annual	24-hr	Annual	24-hr	Annual
A	23	<0.1	0.5	2.4	0.2	0.3	<0.1
B	22	0.1	0.9	2.9	0.4	0.4	0.1
C	20	0.1	0.9	2.5	0.4	0.5	0.1
D	16	0.1	0.9	3.3	0.3	0.7	0.1
E	15	<0.1	0.5	1.8	0.2	0.3	<0.1
G	7	<0.1	0.4	1.9	0.2	0.2	<0.1

Note: Receptor ID "F" in (SLR Consulting Australia Pty Ltd, 2013) determined not to be a residence
Data taken from Table 29 and 32 of (SLR Consulting Australia Pty Ltd, 2013)
Increments do not include the impact of particulates associated with combustion of fuel in plant, machinery and vehicles

From examination of table 1 of (NSW DIPNR, 2004), predictions of maximum 24-hour PM_{10} at locations 420 m south of the Karuah Quarry (likely related to receptors 20, 22 and 23 in **Table 12**) were predicted to be of the order of 13 $\mu g \cdot m^{-3}$ and minimal (<0.9 $\mu g \cdot m^{-3}$) at all other locations in 2004. The maximum 24-hour PM_{10} increments predicted by (SLR Consulting Australia Pty Ltd, 2013) are approximately four times lower than those outlined in (NSW DIPNR, 2004).

The current assessment has revisited these predictions to allow characterisation of the existing air quality of the area, without the impact of the then proposed Karuah South Quarry (then named Kiely's Hard Rock Quarry). These results are outlined in Section 6.

No blast fume assessment was performed for the Karuah Quarry to support Development Consent (DA265-10-2004).

4.5.1.3 Air Quality Control Measures

The conditions associated with DA265-10-2004 (condition 14) requires that all practical measures to minimise and/or prevent the emission of dust from the site are to be implemented.

As outlined within the 2015 AEMR for Karuah Quarry (Hunter Quarries Pty Ltd, 2015), several management measures are adopted to control dust:

- Minimising disturbance of land to only what is required by quarry activities;
- Minimising distance travelled by hauling rock the shortest distance possible;
- Utilising quarry runoff water for dust suppression on roads, stockpiles, production plant and work areas;
- A 13,000 litre (L) water cart is used at the site to assist with firefighting capabilities and dust management. Water is regularly collected from sediment dams and applied on roads throughout the quarry to limit dust generated from vehicle movements;

- Engaging the services of a contract road sweeper to regularly clean roadways around the entrance to the quarry; and,
- Ensuring loads are covered when leaving the site.

Source: (Hunter Quarries Pty Ltd, 2015).

The AQIA performed for Karuah East Quarry (SLR Consulting Australia Pty Ltd, 2013) quantitatively assessed the potential cumulative impacts resulting from the operation of Karuah Quarry and Karuah East Quarry. In that AQIA, emission control measures adopted at Karuah Quarry were taken to be:

- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the grading of unpaved roads (50 % control);
- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the haulage of materials from the pit to the ROM stockpile on unpaved roads (50 % control);
- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the haulage of waste rock from the pit to the overburden emplacement on unpaved roads (50 % control);
- Controls during primary and secondary crushing (watering);
- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the haulage of materials from the processing plant to the product stockpiles on unpaved roads (50 % control);
- Use of paved roads to haul product to Freeway;
- Use of water sprays and wind breaks around the ROM and product stockpiles (combined 65 % control); and,
- Use of water sprays on the overburden emplacement (50 % control).

Source: (SLR Consulting Australia Pty Ltd, 2013).

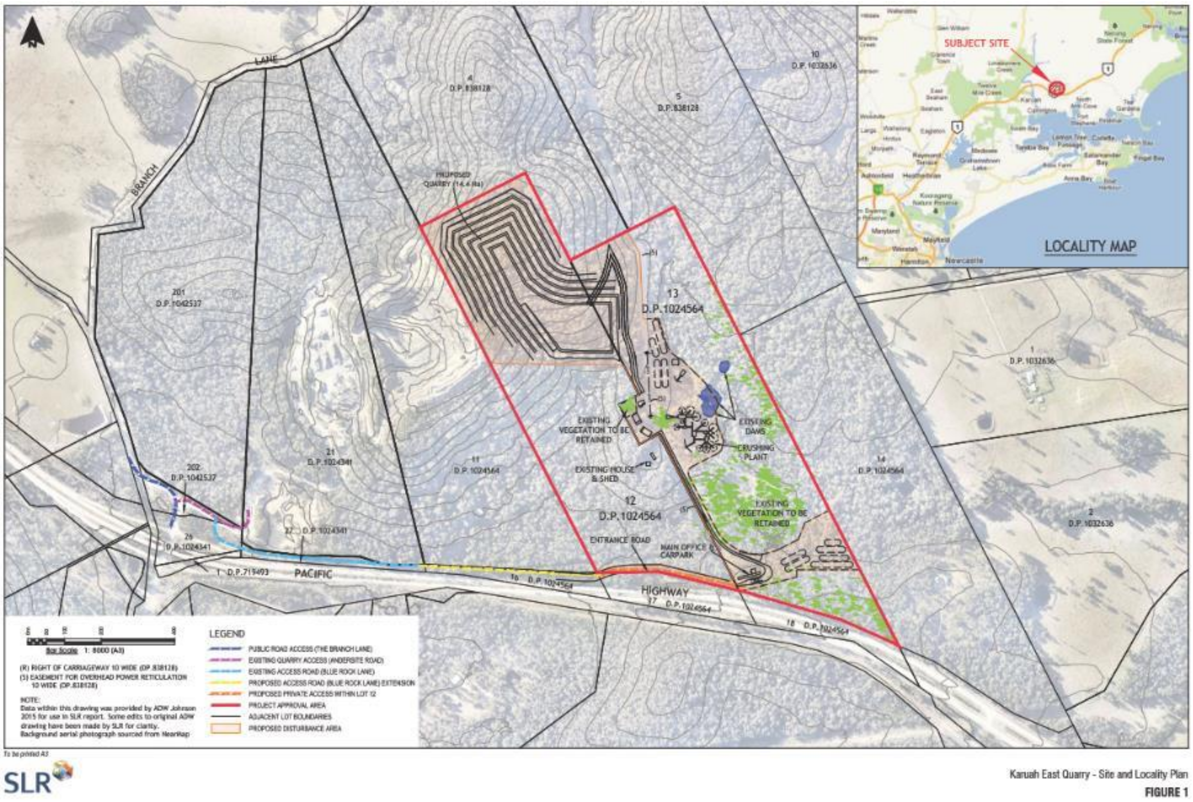
4.5.2 Karuah East Quarry

4.5.2.1 Background

Karuah East Quarry Pty Ltd was granted development by the Planning Assessment Commission on 17 June 2014 to develop and operate the Karuah East Quarry (Project Approval PA 09_0175) and to produce up to 1.5 Mt of hard rock quarry products per year for a period of 20 years. In total, the Quarry will result in the clearing of approximately 28 ha of native vegetation.

Following its construction, the Karuah East Quarry is to be developed in five stages with the extraction area progressively expanding across an area of approximately 14.4 ha (refer **Figure 8**).

Figure 8
Karuah East Quarry - Overview



Source: Karuah East Quarry Project, Air Quality and Greenhouse Gas Management Plan (SLR Consulting Australia Pty Ltd, 2015b)

For the purposes of the cumulative impact assessments for the proposed Karuah South Quarry, reliance has been placed upon the information on the Quarry's Site layout, production stages and operational equipment presented in the EIS for the Quarry (dated 31 January 2013) and the Noise Assessment (dated 2 November 2012). Proposed layouts for the Karuah East Quarry in Stage 1 and 3 indicate that during Stage 1, three operational benches would be present at 135 m AHD, 120 m AHD and 105 m AHD. During Stage 2, the depth of extraction would be greater with operational benches at 120 m AHD, 105 m AHD and 90 m AHD. The key information relied upon for the cumulative assessments are as follows.

- Two operational stages have been selected (Stages 1 and 3).
- Annual production would be 500,000 tpa for Stage 1 and 1.5 Mtpa for Stage 3.
- Mobile equipment likely to be used in each stage is as follows[2].

Stage 1: –Bulldozer (D8K or similar)
- Articulated Haul Trucks (x 2) (Caterpillar 730C or similar)
- Excavator (x 1) (PC 300)

[2] Equipment size and/or capacity has been assumed for the Hunter Quarries operations in the absence of specific information being provided.

- Percussion drill (x 1) (Atlas Copco T40 or similar)
- Front-end loader (x 2) (Komatsu W470-1 or similar)

Stage 3:
- Percussion drill (x 1) (Atlas Coco T40 or similar)
- Excavator (x 1) (PC 300)
- Articulated Haul Trucks (x 3) (Caterpillar 730C or similar)
- Front end loader (x 3) (Komatsu W470-1 or similar)

- Truck movements would vary between 144 and 432 per day, i.e. 72 loads to 216 loads per day.

An application was submitted to the NSW DP&E by Karuah East Quarry Pty Ltd in January 2018 to amend PA 09_0175. The amendment relates to a required expansion to the disturbance footprint which "*will allow for improved operational efficiencies associated with plant infrastructure with the quarry by reducing internal truck movements, allowing for better vehicle manoeuvrability and improving site security*" (ADW Johnson, 2018).

A summary of the adopted activity data used in the calculation of particulate and nitrogen dioxide emissions from the Karuah East Quarry for the purposes of cumulative assessment are presented in **Annexure 2**.

4.5.2.2 Previous Assessments of Air Quality

An AQIA supporting the development of Karuah East Quarry was submitted to the (then) NSW Department of Planning and Infrastructure (DoPI) in November 2011. Following review of that document, NSW DoPI requested that additional information be provided to allow the assessment of the potential cumulative impacts associated with a received development application for the Karuah South Quarry (the Kiely's Quarry), in addition to the operational Karuah Quarry.

A supplementary assessment was completed in May 2012 which indicated that exceedance of air quality criteria was likely when all three quarries were operational. A Best Practice Management (BPM) dust assessment was subsequently performed and after further dispersion modelling, it was concluded that should best practice dust control be implemented at Karuah East Quarry and Karuah South Quarry, the three quarries would not result in exceedance of any particulate matter air quality criteria (SLR Consulting Australia Pty Ltd, 2012). Importantly, the AQIA conducted in 2011 and 2012 assumed that the TSP and PM_{10} data collected by High Volume Air Sampler (HVAS) (on a 1-in-6-day cycle) in the area immediately surrounding the Karuah Quarry would be representative of those quarrying operations. As a continuous dataset is required for use in AQIA, through comparison and analysis, air quality monitoring data from the NSW Office of Environment and Heritage (OEH) air quality monitoring station (AQMS) at Wallsend was selected as being a good representation of air quality at the Karuah East Quarry and was taken forward to represent the air quality of the area and importantly, representative of the environment with the Karuah Quarry being operational. For clarity, impacts associated with the Karuah East Quarry and Karuah South Quarry were determined through dispersion modelling in that assessment.

Following further review by NSW EPA, the AQIA (SLR Consulting Australia Pty Ltd, 2012) was determined to have not been conducted in accordance with the Approved Methods for a number of reasons, including:

- The use of air quality monitoring data from Wallsend not being considered to be representative of air quality at properties located around the Karuah Quarry.
- Meteorological data used in the dispersion modelling exercise was not considered to have been demonstrated to be site-representative and potentially not representative of the longer-term monitoring record.
- The lack of assessment of blast fume emissions.

In July 2013 a further update of the AQIA was submitted (SLR Consulting Australia Pty Ltd, 2013) which sought to address the comments above. The assessment did not include any impacts associated with the Karuah South Quarry and the general response to the submissions indicated that the Karuah South Quarry proposal had been formally withdrawn at that time (12 June 2013, (ADW Johnson, 2013b)).

A summary of the results outlined in the July 2013 AQIA as they relate to the Karuah Quarry operations are presented in Section 4.5.1.2. In relation to the Karuah East Quarry operations, the results of the AQIA are presented in **Table 13** as predicted incremental concentrations.

Table 13
Predicted Incremental Particulate Concentrations – Karuah East Quarry

ID	Landowner Ref. No.	Deposition Flux $g \cdot m^{-2} \cdot month^{-1}$	Concentration $\mu g \cdot m^{-3}$				
		Dust Deposition	TSP	PM_{10}		$PM_{2.5}$	
		Annual	Annual	24-hr	Annual	24-hr	Annual
A	23	0.4	4.9	14.5	1.8	2.2	0.3
B	22	0.7	8.4	16.6	2.7	2.8	0.5
C	20	0.4	5.0	12.8	1.7	2.2	0.3
D	16	0.2	2.5	11.7	1.0	2.2	0.2
E	15	0.1	1.8	8.9	0.7	1.5	0.1
G	7	0.3	3.3	11.5	1.5	1.5	0.2

Note: Receptor ID "F" in (SLR Consulting Australia Pty Ltd, 2013) determined not to be a residence
Data taken from Tables 32, 33, 34, 35, 36 and 37 of (SLR Consulting Australia Pty Ltd, 2013)
Increments do not include the impact of particulates associated with combustion of fuel in plant, machinery and vehicles

The AQIA for the Karuah East Quarry used air quality monitoring data from the NSW OEH Wallsend AQMS to characterise 'regional' background air quality conditions at the site. With the addition of these regional concentrations and the addition of the incremental predictions associated with the Karuah Quarry (refer Section 4.5.1.2) criteria for all pollutants (PM_{10}, $PM_{2.5}$, TSP and dust deposition) were predicted to be achieved at all receptor locations assessed. The maximum cumulative 24-hour PM_{10} concentration (the criteria most likely not to be achieved) was predicted at receptor G (Residence 7) to be 46.5 $\mu g \cdot m^{-3}$ (with an already exceeding background concentration having been removed). For all other pollutants assessed, maximum concentrations were predicted at receptor B (residence 22).

The current assessment has revisited these predictions to allow characterisation of the existing air quality of the area, without the impact of the Karuah South Quarry (then named Kiely's Hard Rock Quarry). These results are outlined in Section 6.

A blast fume assessment was performed for the Karuah East Quarry to support PA 09_0175 (SLR Consulting Australia Pty Ltd, 2013). The results of that assessment are presented in **Table 14** which indicates that no exceedances of the 246 $\mu g \cdot m^{-3}$ criterion were predicted at any receptor assessed. The assessment assumed that 10 t of ANFO explosives would be used in each blasting event, which is considered to be high.

Table 14
Predicted Nitrogen Dioxide Concentrations – Karuah East Quarry

ID	Landowner Ref. No.	Concentration $\mu g \cdot m^{-3}$		
		Background	Increment	Cumulative
		1-hr	1-hr	1-hr
A	23	58	142	174
B	22	58	173	205
C	20	58	136	165
D	16	58	121	150
E	15	58	95	123
G	7	58	73	104

Note: Receptor ID "F" in (SLR Consulting Australia Pty Ltd, 2013) determined not to be a residence
Data taken from Table 46 of (SLR Consulting Australia Pty Ltd, 2013)

No cumulative assessment of blast fume impacts is performed within this current assessment. As discussed in (SLR Consulting Australia Pty Ltd, 2013) in reference to concurrent blasting at Karuah and Karuah East Quarries, it is highly unlikely that this would occur. It is further considered that the three quarries could easily communicate and manage their respective blasting schedules to avoid blasting on the same day.

No air quality assessment has been performed for the proposed MOD1 (amendment relating to a required expansion to the disturbance footprint).

4.5.2.3 Air Quality Control Measures

Section 7.1 of Appendix 6 of Project Approval 09_0175 outlines the Statement of Commitments in relation to air quality. The commitments include:

- Air quality monitoring;
- Sealing of haul roads from the site to the Pacific Highway;
- Watering of any unsealed roads (Level 1 watering at 2 $L \cdot m^{-2} \cdot hour^{-1}$);
- Enclosure of the crusher; and,
- Stockpile watering and installation of wind breaks.

4.5.3 Karuah Red Quarry (Proposed)

4.5.3.1 Background

Hunter Quarries Pty Ltd. Intends to develop Karuah Red Quarry, which is to be located to the north west of the Site and immediate west of the Karuah Quarry. Karuah Red Quarry is located on Lot 21 DP1024341 and Lot 201 DP1042537. Hunter Quarries has pursued for Secretary's Environmental Assessment Requirements (SEARs) for an EIS. Refer to **Figure 9** for an overview of the site location.

The Karuah Red Quarry would involve the extraction of 100,000 tpa of red rhyodacite for processing at the existing Karuah Quarry. It is expected that 2 Mt in resources can be extracted over a project life of up to 20 years. The material is expected to be extracted via the methods of drilling and blasting before being loaded and hauled to the existing Karuah Quarry for processing. Many operational facilities will be utilised from the existing Karuah Quarry, principally the existing internal road network, administration offices, employee amenities and weighbridge. Three full-time personnel are proposed during operational hours alongside additional contract labour. Approximately 24 to 32 truck movements per day are anticipated to transport the material off site.

Hours of operations are planned to be the same as Karuah Quarry, specifically from 7:00am to 6:00pm Monday to Friday and 7am to 1pm on Saturday. Operations would not be carried out on Sunday or Public Holidays.

A summary of the adopted activity data used in the calculation of particulate emissions from the Karuah Red Quarry for the purposes of cumulative assessment are presented in **Annexure 2**.

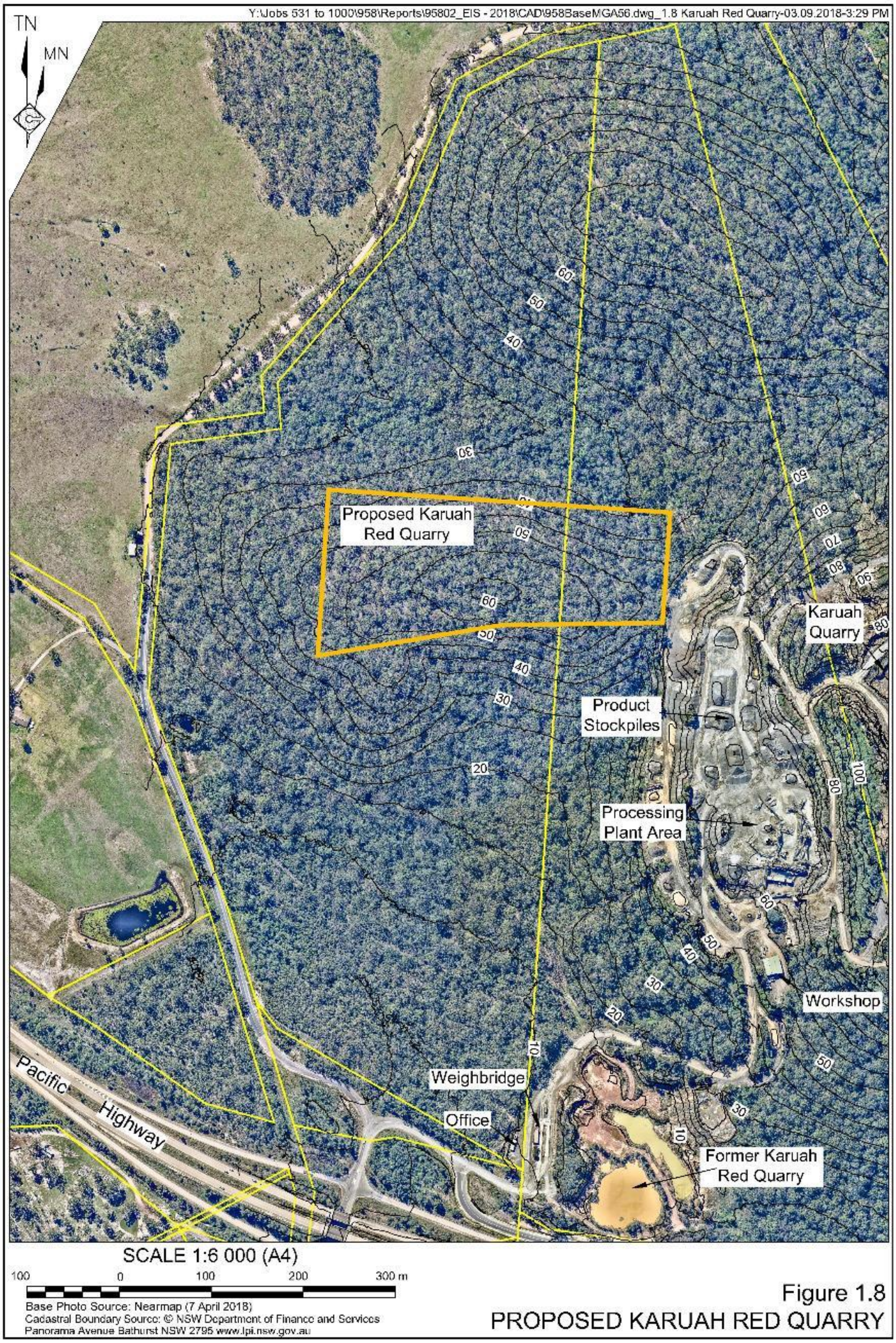
4.5.4 Pacific Highway

The NSW Department of Planning and Environment guidance (DPE, 2008) indicates that air quality should be a design consideration (i.e. may impact upon sensitive receptors/development) "within 20 metres of a freeway or main road (with more than 2,500 vehicles per hour, moderate congestion levels of less than 5 % idle time and average speeds of greater than 40 km/hr)".

Northbound traffic flow, data collected by the NSW Roads and Maritime Services (RMS) in 2010, at a location 1.5 km east of The Bucketts Way (approx. 13 km from the Site) indicated annual average daily traffic (AADT) flows of 6,724 vehicles per day. Assuming that the northbound traffic flows are replicated in the southbound lanes, combined AADT flows on the Pacific Highway, in the vicinity of the Site, may be expected to be less than 14,000 vehicles per day. Assuming that peak hourly flows represent 10% of the AADT flow then the Pacific Highway can be expected to experience combined peak hourly flows of 1,400 vehicles per hour.

All sensitive receptors subject to the air quality assessment for the Project are over 100 m from the Pacific Highway, with the closest receptor (R2) being 107 m from the closets lane of the Pacific Highway. At distances of 100 m from the closest lane, NSW Department of Planning and Environment guidance (DPE, 2008) considers that under adverse conditions (e.g. temperature inversions and light winds), pollutant concentrations can be expected to be 10% of roadside levels with further reductions occurring as the distance from the road increases.

Figure 9
Karuah Red Quarry - Overview



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With regard to the assessment of potential cumulative impacts arising from contributions from the Pacific Highway, specifically relating to NO_2 and particulate matter, it is noted that the background air quality data applied for the assessment of the Project utilises data collected at the HVAS currently operated as part of the Karuah East Quarry operations (5770 Pacific Highway, 120 m to the south of the closest lane of the Pacific Highway) and data collected at the NSW OEH AQMS at Wallsend (refer Annexure 3). The data from NSW OEH AQMS at Wallsend have been subject to adjustment, as described in Annexure 3, to more accurately reflect the background particulate matter conditions at the Site. Subsequently, any influence of the Pacific Highway on NO_2 and particulate matter is considered to be accounted for in the background air quality data.

Therefore, given that the location of the nearest sensitive receptor is over 100 m from the Pacific Highway, and peak hour traffic volumes are likely to be less than 2,500 vehicles per hour, it is not considered that air pollution from the Pacific Highway would adversely affect those sensitive receptors.

4.6 GREENHOUSE GAS

Emissions of GHG are tracked by the Commonwealth of Australia via the Australian National Greenhouse Accounts program. This program, and the reports and data submitted as part of the program, fulfils Australia's international and domestic reporting requirements. Carbon emission totals by State and Territory by year and by sector are reported in the 'State and Territory Greenhouse Gas Inventories' report each year.

These data are used to:

- meet Australia's reporting commitments under the United Nations Framework Convention on Climate Change (UNFCCC);
- track progress against Australia's emission reduction commitments; and,
- inform policy makers and the public.

Data from the 2015 report for Australia (DEE, 2017a) and NSW (DEE, 2017b) have been obtained for the purposes of this GHG assessment. These reports are the most recent available at the time of reporting.

Emissions of GHG from Australia in 2015 across all economic sectors were 538.2 Mt carbon dioxide equivalent (CO_2-e). Emissions from the quarrying industry sector (including metal ore and non-metallic mineral mining and quarrying) accounted for 14.9 Mt CO_2-e, or 2.8 % of total emissions (DEE, 2017a).

State and Territory shares of national emissions (including emissions and removals from land use, land use change and forestry (LULCF) activities) comprised:

- 24.8 % from New South Wales;
- 28.3 % from Queensland;
- 22.3 % from Victoria;
- 16.1 % from Western Australia;
- 5.6 % from South Australia;

- 2.4 % from the Northern Territory
- 0.2 % from Tasmania;
- 0.3 % from the Australian Capital Territory (a partial estimate only, as some sectors are included within NSW); and,
- 0.01 % from External Territories.

GHG emissions in NSW in 2015 were 133.4 Mt CO_2-e with emissions from the mining sector (no information on quarrying available) being 20.5 Mt CO_2-e, or 15.4 % (DEE, 2017b).

5. APPROACH TO ASSESSMENT

5.1 AIR QUALITY ASSESSMENT

The following provides a brief description of the methodology used to assess the potential air quality impacts resulting from the site establishment and construction and operational phases of the Project.

As described in Section 2.5.1, the key emissions to air are anticipated during the site establishment and construction, and operational stages of the Project are:

- Construction dust, arising from site clearance activities, overburden removal and placement activities, earthworks, and construction;
- Particulate emissions from the extraction, processing and storage of the resource;
- Wheel-generated particulate emissions from the haulage of recovered and product materials on unpaved and paved road surfaces;
- Blasting emissions of particulate and products of combustion (principally NO_X); and,
- Plant and vehicle exhaust emissions (particulate matter and NO_X).

The calculation of emissions of particulate matter and NO_X from these processes is discussed in detail in **Annexure 2**. This also includes the selection of Best Practice Management particulate control measures, the assessment of which has been performed in accordance with NSW EPA guidance (NSW EPA, 2011).

Additionally, emissions of particulate matter associated with the surrounding operations at Karuah Quarry, Karuah Red and Karuah East Quarry have been quantified, with reference to the activity rates for those operations outlined in Section 4.5 and in detail in **Annexure 2**.

A quantitative assessment has been performed to assess the impact of these emissions on surrounding sensitive receptor locations as discussed in Section 4.2.

5.1.1 Modelling Approach

A dispersion modelling assessment has been performed using the NSW EPA approved CALPUFF atmospheric dispersion modelling system.

The CALPUFF modelling system includes three main components: CALMET, CALPUFF and CALPOST and a large set of pre-processing programs designed to interface the model to routinely available meteorological and geophysical datasets.

In the simplest terms, CALMET is a meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded domain. Associated two-dimensional fields such as mixing height, surface characteristics, and dispersion properties are also included in the file produced by CALMET (refer to Section 4.4 and **Annexure 1**).

CALPUFF is a transport and dispersion model that advects "puffs" of material emitted from modelled sources (refer **Annexure 2**), simulating dispersion and transformation processes along the way. In doing so, it typically uses the fields generated by CALMET. Temporal and spatial variations in the meteorological fields are explicitly incorporated into the resulting distribution of puffs throughout a simulation period. The primary output files from CALPUFF contain either hourly concentrations or deposition fluxes evaluated at selected receptor locations.

CALPOST is used to process the CALPUFF output files, producing tabulations that summarise the results of the simulation (refer Section 6) (Scire, Strimaitis, & Yamartino, 2000).

In March 2011, NSW OEH published generic guidance and optimal settings associated with the CALPUFF modelling system for inclusion in the Approved Methods (Barclay & Scire, 2011). These guidelines and settings have been considered in the performance of this assessment.

This modelling approach is taken as CALPUFF is able to account for the complicated terrain between the Site and the sensitive receptor locations. The use of CALPUFF is also consistent with the modelling approach taken in the Karuah East Quarry AQIA (SLR Consulting Australia Pty Ltd, 2013).

5.1.2 Modelling Scenarios

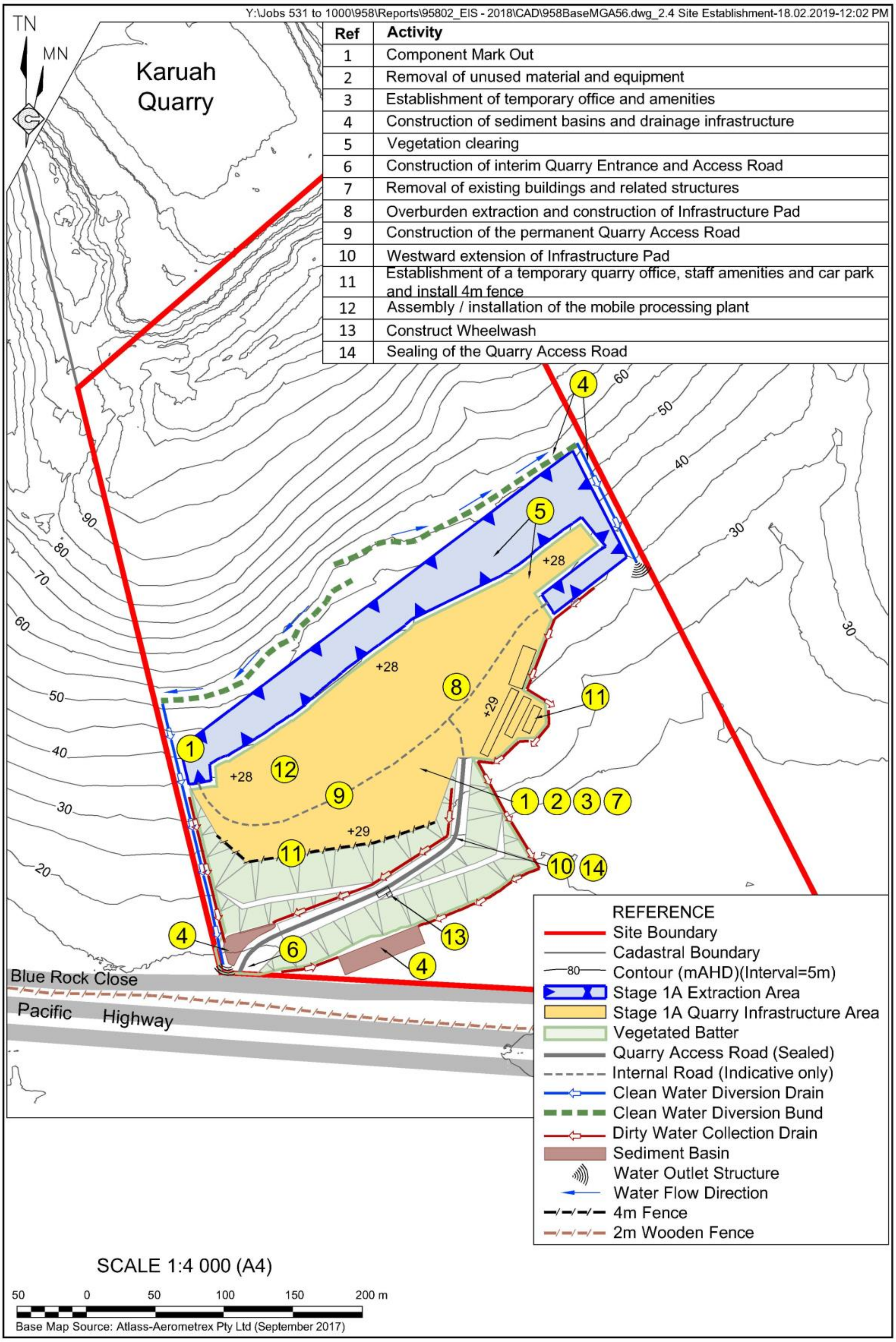
An assessment of the impacts of the operation of activities at the Site has been performed which characterises the likely day-to-day operation of the Site, approximating average and likely maximum operational characteristics which are appropriate to assess against longer term (annual average) and shorter term (24-hour) criteria for particulate matter, and the longer term (annual average) and short term (1-hour) criteria for NO_2.

As required by the SEARs two operational scenarios have been selected for dispersion modelling. In addition, the site establishment and construction phase has also been subject to dispersion modelling. A summary of the three scenarios is provided in **Table 15**, with the extraction/processing rates at each quarry indicated. Full emissions inventories for each modelled operation at each stage of operation are provided in **Annexure 2**.

Table 15
Summary of Modelling Scenarios

Operational Stage at Karuah South Quarry	Karuah Quarry	Karuah East Quarry	Karuah Red Quarry
Site Establishment and Construction **Figure 10**	Stage A 400,000 tpa	Stage 1 500,000 tpa	Not operational
Stage 1C 300,000 tpa Max: 3,000 $t\cdot day^{-1}$ **Figure 11**	Stage A 400,000 tpa	Stage 1 500,000 tpa	Not operational
Stage 2B 600,000 tpa Max: 3,000 $t\cdot day^{-}$ **Figure 12**	No extraction Processing of Karuah Red 100,000 tpa	Stage 3 1.5 Mtpa	Extraction 100,000 tpa

Figure 10
Karuah South Quarry – Site Establishment and Construction



northstar AIR QUALITY

Figure 11
Karuah South Quarry – Stage 1C Operations

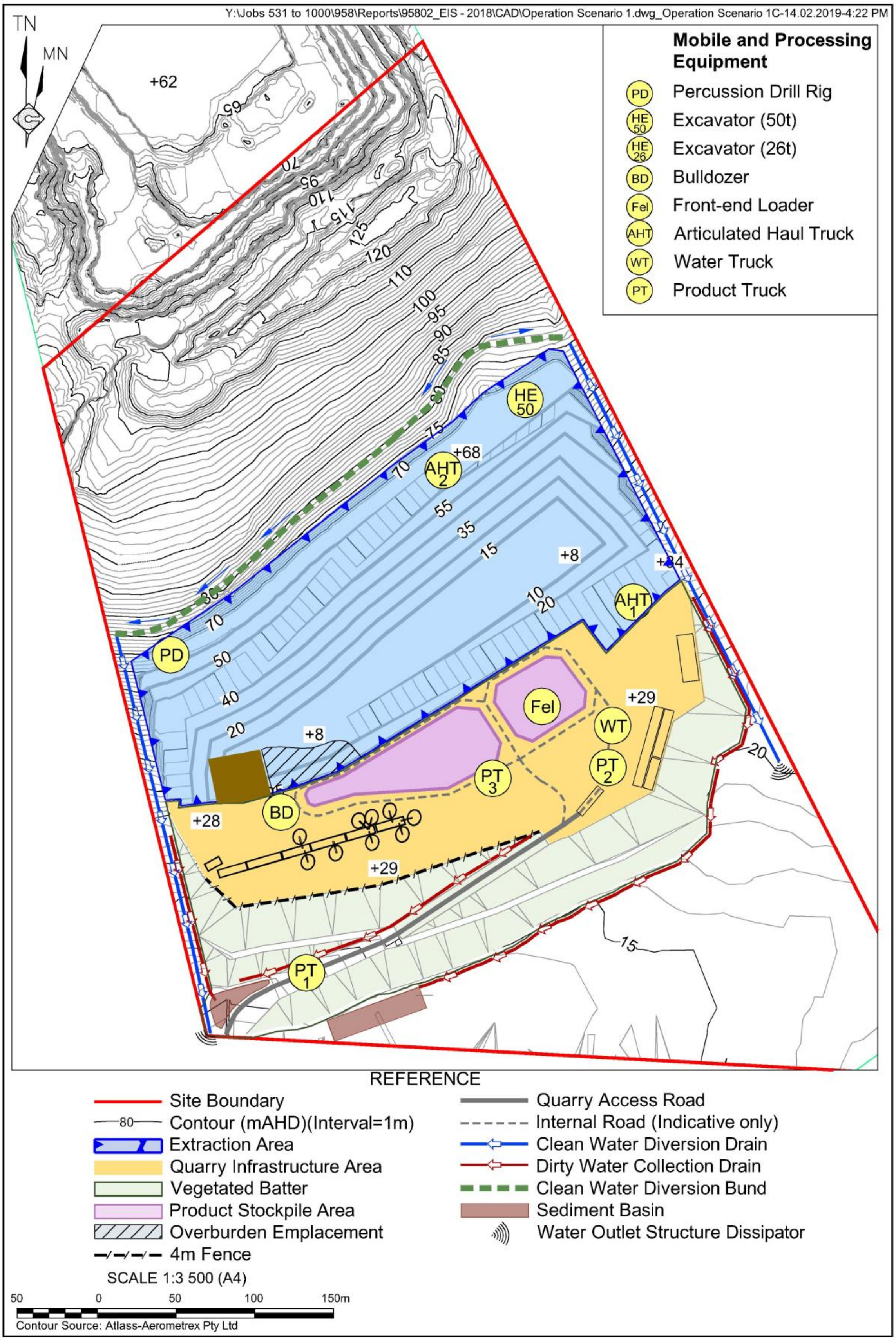
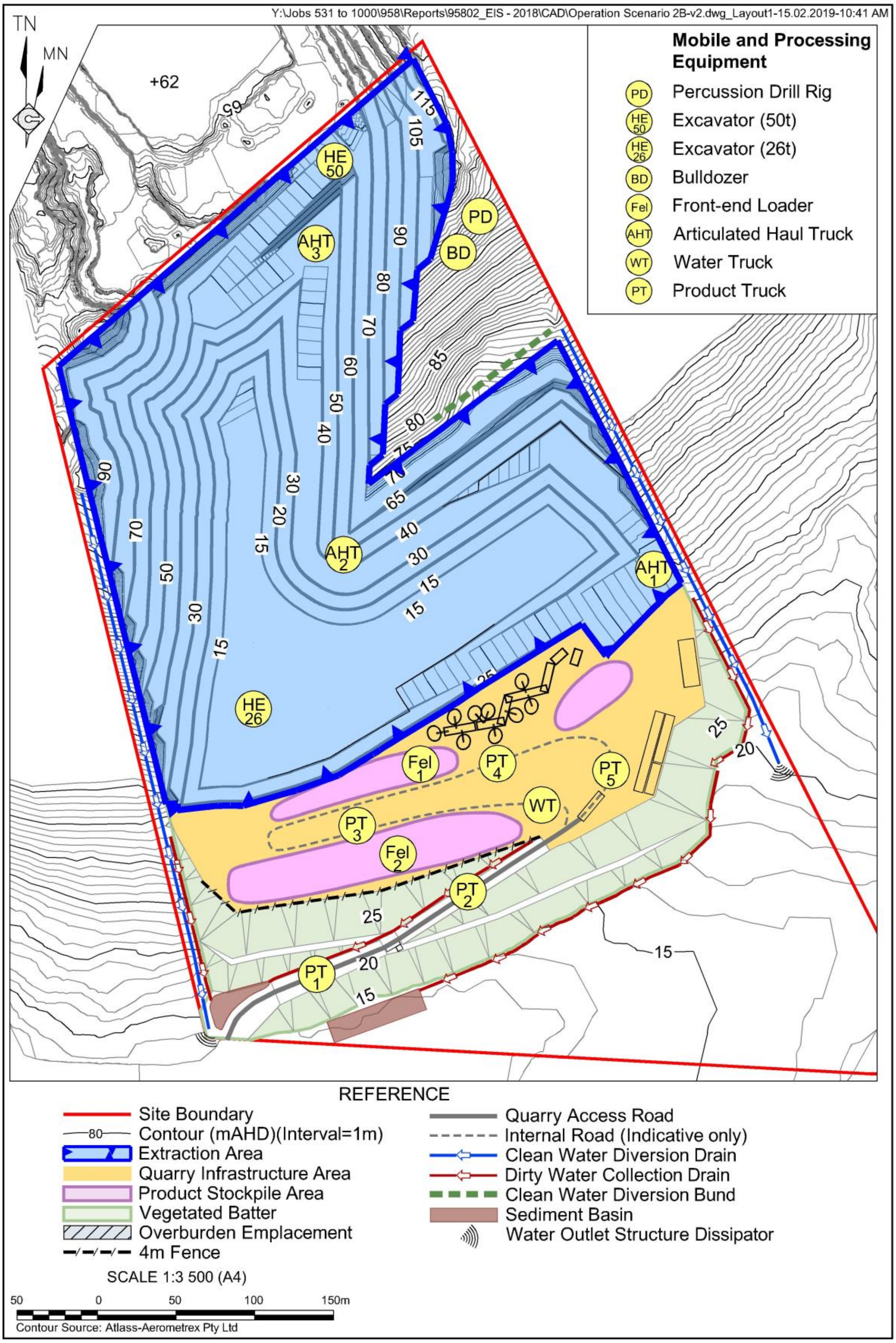


Figure 12
Karuah South Quarry – Stage 2B Operations



The modelling scenarios provide an indication of the air quality impacts of the activities at the Site. Added to these impacts are those resulting from the neighbouring operations identified (refer Section 4.5) and regional background air quality concentrations (refer Section 4.3) which together represent the air quality which may be expected within the area surrounding the Site.

As required within the SEARs, the results of dispersion modelling in Section 6 have been presented to show the contribution from each contributing development in the area, namely Karuah Quarry, Karuah East Quarry, Karuah Red Quarry and the Project.

5.1.3 Model Set Up

The following section outlines the dispersion model set-up and includes details of modelled source characteristics, source locations etcetera to provide full transparency in the modelling performed.

A detailed discussion of the generation and validation of meteorological data used in dispersion modelling is provided in **Annexure 1**. In summary, the CALMET model was ultimately run in 'hybrid' mode, with gridded numerical meteorological data from TAPM supplemented by surface observational data from the BoM meteorological monitoring station at Williamtown RAAF. Although (Barclay & Scire, 2011) recommend that CALMET is run in 'no-obs' (no observations) mode due to its simplicity, the hybrid approach is justified in this instance given the poor model performance in 'no-obs' mode. The values adopted for critical parameters in CALMET are outlined in **Annexure 1**. All values have been adopted taking into account guidance, or are within recommended values outlined in (Barclay & Scire, 2011).

In relation to the CALPUFF modelling performed as part of this AQIA, two of the three sources types have been used. Volume sources have been used to characterise emissions from drilling, blasting, materials handling, haulage routes, and materials processing. Area sources have been used to characterise emissions from sources of wind erosion such as the active pit, overburden emplacement area and product stockpiles. Point sources (i.e. stack emissions) have not been used as there are no such sources proposed at the Site during any stage of development.

Presented in **Table 16** are the source characteristics adopted for each source type across each modelling scenario. The sigma y and sigma z values provide an initial estimation of the horizontal and vertical spread of the modelled plume, respectively.

The locations of all modelled sources during each scenario are presented in **Figure 13** (site establishment and construction), **Figure 14** (Stage 1C), and **Figure 15** (Stage 2B). The numbers in each figure relate to the relevant emissions inventory presented in **Annexure 2**.

Table 16
Source Characteristics – CALPUFF Modelling – All Scenarios

Source	Parameter		
	Height (m AGL)	SigmaY (m)	SigmaZ (m)
Volume: Excavator, Front End Loader, Dozer, Drilling, Truck loading/dumping, crushing, screening	0	5	2
Volume: Transport of materials around Site in haul trucks	2.98	9	2.77
Volume: Transport of materials from Site in road trucks	3.66	9	3.4
Volume: Blasting	20	9.3	9.3
Area: Wind erosion	0	-	0

Figure 13
Modelled Source Locations – Site Establishment and Construction

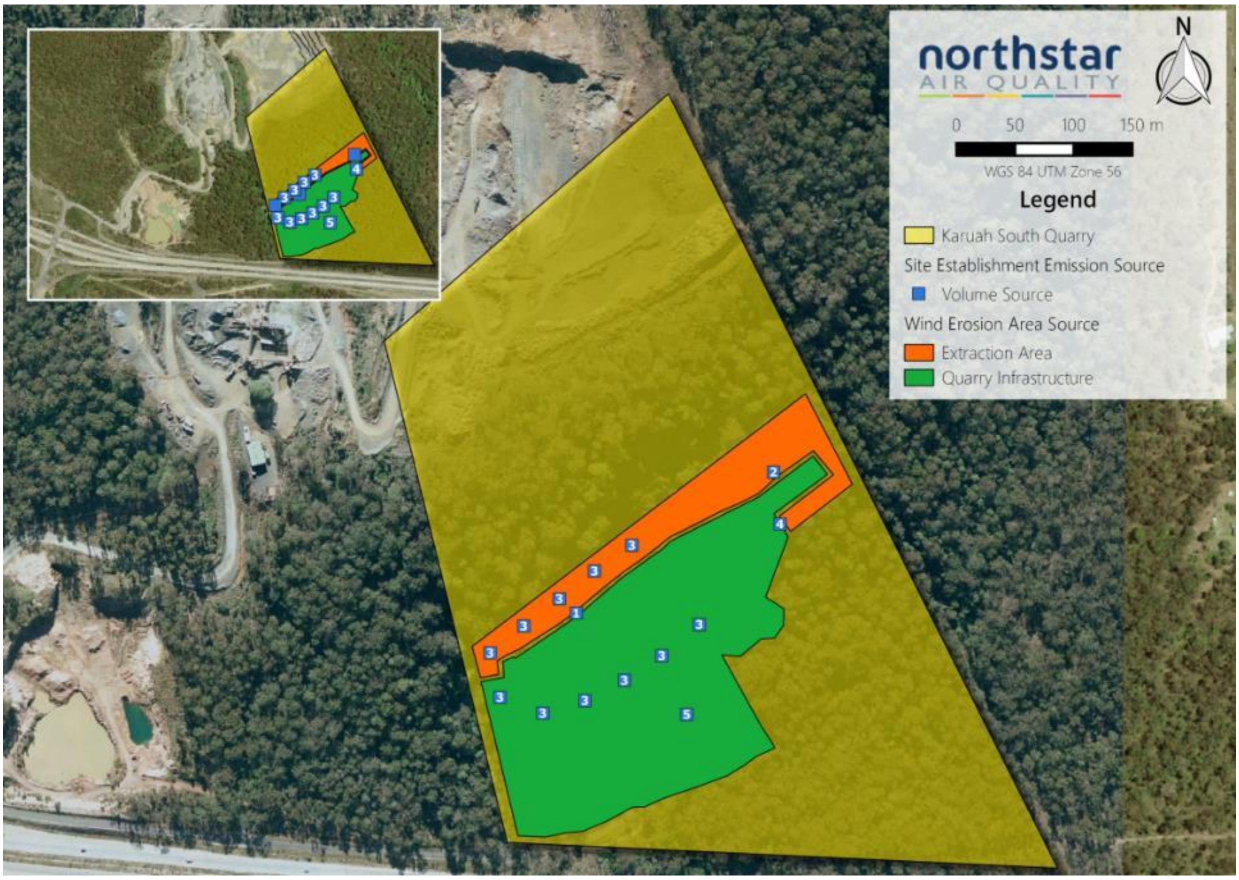


Figure 14
Modelled Source Locations – Stage 1C Operations

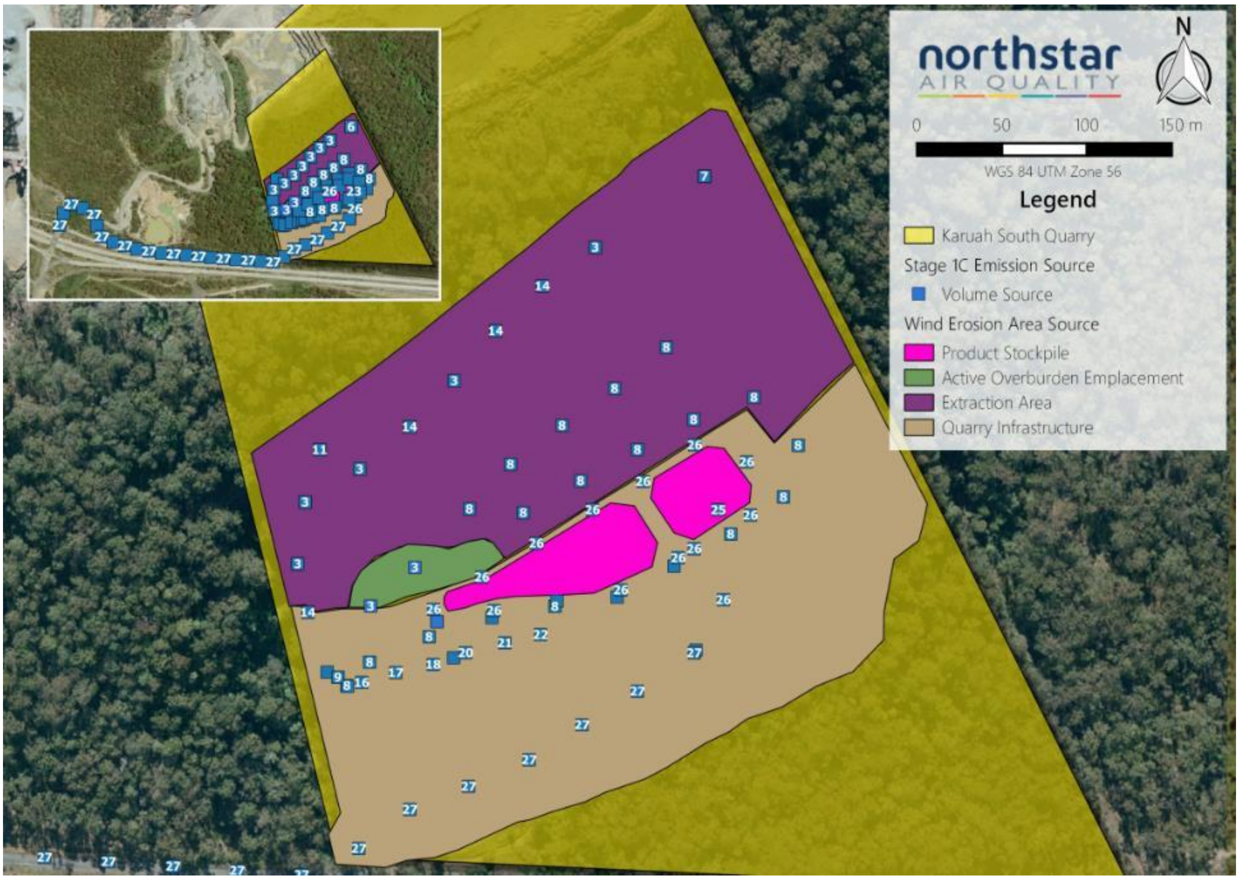
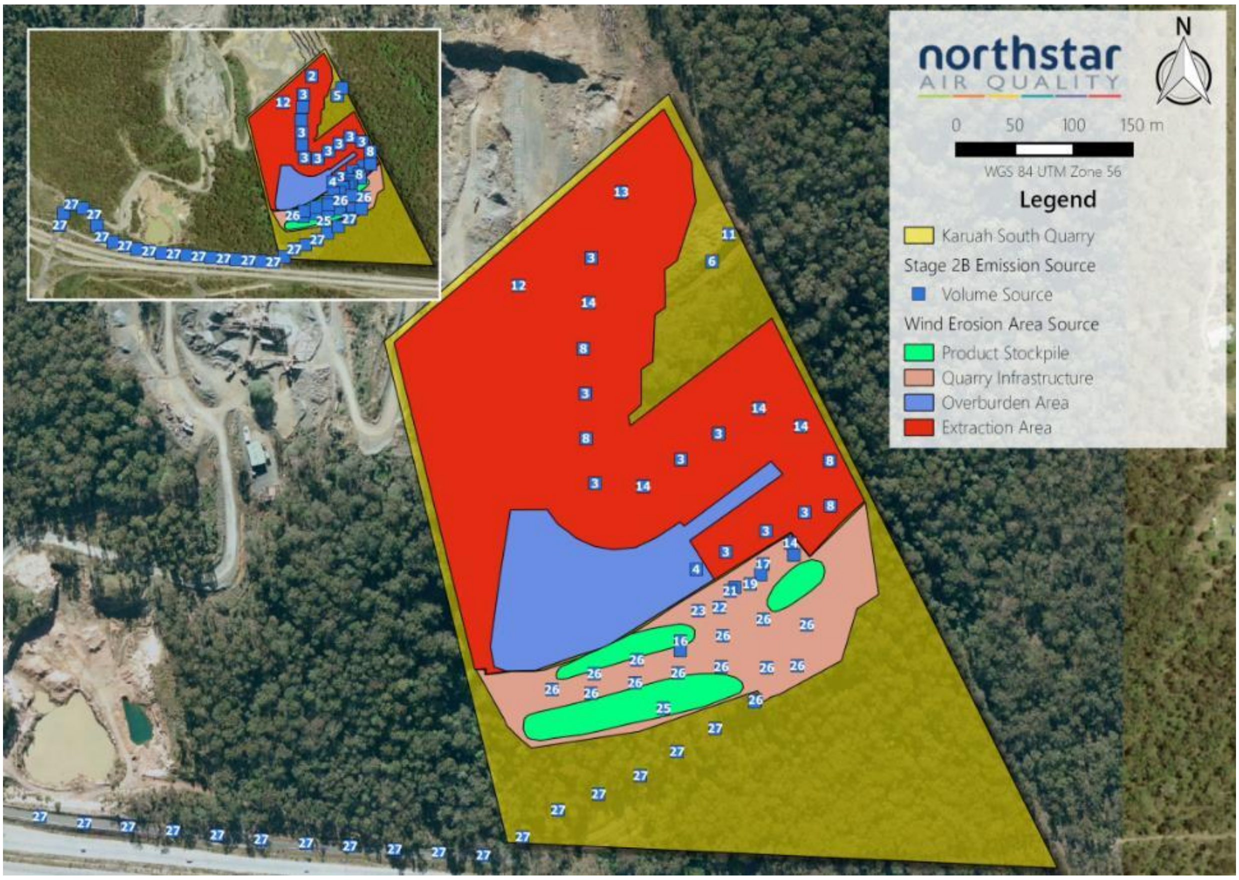


Figure 15
Modelled Source Locations – Stage 2B Operations



Maximum 1-hour average impacts have been assessed and associated with blasting at Karuah South Quarry only. Cumulative assessment with the existing Karuah Quarry and Karuah East Quarry, or the proposed Karuah Red Quarry has not been conducted. This is considered appropriate as it is highly unlikely that blasting will be conducted concurrently at all of the sites. Even if the blasting was conducted within one day, it is likely that there will be minimal cumulative impacts due to large time difference between the blasts. This assumption is consistent with that adopted in (SLR Consulting Australia Pty Ltd, 2013).

5.1.4 NO to NO_2 Conversion

The conversion of NO to NO_2 has been assumed to be 100%, as per Method 1 of the NSW EPA Approved Methods (section 8.1.1 of (NSW EPA, 2017)). This represents a highly conservative assumption.

5.1.5 Presentation of Results - Criteria

As required by the SEARs (**Table 1**), results are presented in Section 6 for surrounding privately-owned properties and site-owned properties. Discussion of the compliance status of the Project is limited to the privately-owned properties however, as site-owned properties are subject to significant quantities of pollution generated by operations performed at the respective sites. Results for site-owned properties are presented in greyed-out portions at the bottom of each table of results in Section 6.

The Voluntary Mitigation and Acquisition air quality criteria outlined in Section 3.2.2 (NSW Government, 2014) state that exceedances of those criteria should be considered:

> *At any workplace on privately owned land where the consequences of those exceedances in the opinion of the consent authority are unreasonably deleterious to worker health or the carrying out of business at that workplace, including consideration of the following factors:*
>
> - *the nature of the workplace;*
> - *the potential for exposure of workers to elevated levels of particulate matter;*
> - *the likely period of exposure; and*
> - *the health and safety measures already employed in that workplace.*

Given that these site-owned properties are associated with identical activity types as those proposed at the Site, it is considered that (and confirmed through dispersion modelling):

1) workers at those locations are already likely to be exposed to elevated levels of particulate matter resulting from the operations at the sites on which they are employed; and
2) health and safety measures appropriate to quarrying operations should already be adopted by those employers.

Therefore, any voluntary mitigation and acquisition criteria are not considered to apply to the surrounding quarry operations and have not been discussed further in this regard.

5.1.6 Presentation of Results - Tables

Section 6 provides the results of the dispersion modelling assessment for the following three stages of the Project development:

- Site Establishment and Construction in Section 6.1;
- Stage 1C in Section 6.2; and,
- Stage 2B in Section 6.2.

As previously discussed in Section 5.1.1, the impacts from the proposed Karuah South Quarry have been predicted using a dispersion modelling approach. Impacts associated with other surrounding quarry activities (namely Karuah East Quarry, Karuah Quarry and the proposed Karuah Red Quarry) have also been predicted using such an approach. To those predictions has been added a background component, which represents sources of particulate matter not modelled (discussed in detail in Section 4.3 and **Annexure 3**).

The cumulative impacts (all sources) outlined in the following sections are presented to allow determination of the impact from each individual operation plus background associated with the relevant averaging period.

For annual averaging periods, the impacts are presented as below, where the values in the red box to the right are summed to total the cumulative impact in the green box to the left.

Receptor	Annual Average Concentration (µg·m^{-3})				
	Cumulative Impact	**KSQ**	**KEQ**	**KQ**	**BG**
23	23.9	0.2	3.2	1.1	19.5

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

For 24-hour averaging periods, two tables are presented, one which provides the maximum predicted cumulative impact, and one which provides the maximum incremental impact from the Karuah South Quarry during each modelled stage.

The tables associated with maximum cumulative 24-hour impacts present the contributions from each quarry or background on the day of maximum cumulative impact at each receptor. It is important to note that the numbers in the red boxes in the sample below may not be the maximum impacts associated with each quarry at each receptor location. The value in the green box to the left below is, however, the maximum total impact predicted to be experienced at each receptor.

Receptor	Maximum 24-hour Concentration (µg·m^{-3})				
	Cumulative Impact	**KSQ**	**KEQ**	**KQ**	**BG**
23	39.9	0.4	0.8	1.2	37.5

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

The second table associated with maximum 24-hour impacts presents the maximum increment predicted resulting from operations at the Karuah South Quarry. Although these values are often greater than those presented in the previous table, they do not sum with impacts from other quarries plus background to total any concentration greater than that shown in the table above.

Receptor	Maximum Incremental 24-hour PM_{10} Concentration (µg·m^{-3}) Karuah South Quarry
23	5.9

5.2 GREENHOUSE GAS ASSESSMENT

The purpose of the GHG assessment is to examine the potential impacts of the operation of the Project relating to emissions of GHG. A quantitative assessment of emissions is performed with direct emissions compared with total national and NSW GHG emissions for context (refer Section 4.6.

The scope of the GHG assessment is to provide a quantitative assessment of GHG emissions arising from the operation of the Project. This report does not provide a definitive quantification of GHG emissions arising from the Project but provides the general context of the likely quantum of emissions.

Opportunities for reduction of GHG emissions are discussed.

5.2.1 Emission Types

The Australian Government Department of the Environment (DoE) document, "National Greenhouse Accounts Factors" Workbook (NGA Factors) (DoE, 2018) defines two types of GHG emissions (see **Table 17**), namely 'direct' and 'indirect'. This assessment considers both direct emissions and indirect emissions resulting from the Project operation.

Table 17
Greenhouse Gas Emission Types

Emission Type	Definition
Direct	Produced from sources within the boundary of an organisation and as a result of that organisation's activities (e.g. consumption of fuel in on-site vehicles)
Indirect	Generated in the wider economy as a consequence of an organisation's activities (particularly from its demand for goods and services), but which are physically produced by the activities of another organisation (e.g. consumption of purchased electricity).

Note: Adapted from NGA Factors Workbook (DoE, 2018)

5.2.2 Emission Scopes

The NGA Factors (DoE, 2018) identifies two 'scopes' of emissions for GHG accounting and reporting purposes as shown in **Table 18**.

Table 18
Greenhouse Gas Emission Scopes

Emission Scope	Definition
Scope 1	Direct (or point-source) emission factors give the kilograms of carbon dioxide equivalent (CO_2-e) emitted per unit of activity at the point of emission release (i.e. fuel use, energy use, manufacturing process activity, mining activity, on-site waste disposal, etc.). These factors are used to calculate Scope 1 emissions.
Scope 2	Indirect emission factors are used to calculate Scope 2 emissions from the generation of the electricity purchased and consumed by an organisation as kilograms of CO_2-e per unit of electricity consumed. Scope 2 emissions are physically produced by the burning of fuels (coal, natural gas, etc.) at the power station.

Note: Adapted from NGA Factors Workbook (DoE, 2018)

A third scope of emissions, Scope 3 Emissions, are also recognised in some GHG assessments. The Greenhouse Gas Protocol (GHG Protocol) (WRI, 2004) defines Scope 3 emissions as "other indirect GHG emissions":

> *"Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of Scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services."*

Electricity is to be consumed at the Site for low voltage applications (e.g. office, weighbridge, lighting and workshop). Quantification of the electricity likely to be consumed is not possible at this time, although compared to emissions associated with fuel combustion in vehicles and processing plant and equipment, they are likely to represent a minor fraction of the total and therefore Scope 2 emissions have not been considered further within this assessment.

Scope 3 emissions related to the transport of materials to and from the Site are considered in this assessment. Emissions of GHG resulting from the extraction and transport of fuels, and the use of fuels in employee transport have also been considered.

5.2.3 Source Identification and Boundary Definition

The geographical boundary set for the GHG assessment covers the Site but also includes the transport of materials from the Site.

All Scope 1 and Scope 3 emissions within the defined boundary have been identified and reported as far as possible (as noted above, electricity [a Scope 2 emission] is not likely to represent a large contribution to total energy consumed as part of the Project).

5.2.4 Emission Source Identification

The GHG emission sources associated with the existing operations and the operation of the Project have been identified through review of the activities as described in Section 2.5.

The activities/operations being performed as part of the Project which have the potential to result in emissions of GHG are presented in **Table 19**. Emissions of GHG resulting from land clearance have not been estimated, given that the Site will be rehabilitated at the end of the extraction period.

Table 19
Greenhouse Gas Emission Sources

Proposal Component	Scope	Emission Source Description
Consumption of diesel fuel in mobile plant and equipment at the Site	1, 3	Emissions from combustion of fuel (scope 1) Emissions associated with extraction and processing of fuel (scope 3)
Consumption of diesel fuel / unleaded fuel for employee transport purposes	3	Emissions associated with the extraction and processing of fuels
Consumption of diesel fuel / unleaded fuel for material transport purposes	3	Emissions associated with the extraction and processing of fuels

5.2.5 Emissions Estimation

Emissions of GHG from each of the sources identified in **Table 19** have been calculated using activity data for each source per annum (e.g. kL diesel fuel) and the relevant emission factor for each source.

The assumptions used in the calculation of activity data for each emissions source are presented below. Emission factors are presented in the following section.

5.2.5.1 Activity Data

Information relating to the quantities of diesel and unleaded fuel to be used on site have been provided for the Project. In the calculation of certain values, assumptions have been made based on the levels of activity at the Site. These data and assumptions are outlined in **Table 20**.

Table 20
Calculated Activity Data

Project Component	Assumptions	Activity	Units
Consumption of diesel fuel in mobile plant and equipment at the Site	Bulldozer – 72 L·hr^{-1} over 3,084 hrs·yr^{-1} Excavator (50 t) - 59 L·hr^{-1} over 3,084 hrs·yr^{-1} Excavator (26 t) - 25 L·hr^{-1} over 3,084 hrs·yr^{-1} Haul truck - 32 L·hr^{-1} over 3,084 hrs·yr^{-1} FEL - 30 L·hr^{-1} over 3,084 hrs·yr^{-1} Bobcat (289D) - 13 L·hr^{-1} over 3,084 hrs·yr^{-1} Drill rig - 30 L·hr^{-1} over 240 hrs·yr^{-1} Water truck - 32 L·hr^{-1} over 1,018 hrs·yr^{-1} Mobile processing plant – 1,464 kWh over 3,084 hrs·yr^{-1} (converted to 421.1 kL·annum^{-1} using energy content of diesel [38.6 Gj·kL], and 1kWh = 3.6 Mj, as per (DoE, 2018))	1,173.3	kL·annum^{-1}
Consumption of diesel fuel / unleaded fuel for employee transport purposes	20 full time equivalent employees at 600,000 tpa extraction rate 100 km as a two-way journey (Assumed employees reside in Newcastle as worst case) 280 days per year 10.6 L per 100km fuel efficiency (ABS, 2017)	0.33	kL·annum^{-1}
Consumption of diesel fuel / unleaded fuel for material transport purposes	120 km transport distance as a one-way journey (potential average maximum) based on distance from Quarry to M2 Pennant Hills Road Junction (180 km) and Quarry to Honeysuckle, Newcastle (60 km) 144 movements per day 56.3 L per 100 km fuel efficiency (ABS, 2017)	2,727.5	kL·annum^{-1}

Note: One-way journey assessed for transportation of materials from site. Trucks are not owned by the Operator and may not return for additional loads.

5.2.6 Emission Factors

Emissions factors used for the assessment of GHG emissions associated with existing operations and the operation of the Project have been sourced from the NGA Factors (DoE, 2018) (refer to **Table 21**).

Table 21
Greenhouse Gas Emission Factors

Emission Scope	Emission Source	Emission Factor	Energy Content Factor
Scope 1	Diesel fuel for mobile plant and equipment	70.2 kg CO_2-e GJ^{-1}	38.6 $GJ \cdot kL^{-1}$
Scope 3	Diesel fuel for mobile plant and equipment	3.6 kg CO_2-e GJ^{-1}	38.6 $GJ \cdot kL^{-1}$
	Unleaded fuel for employee transport	3.6 kg CO_2-e GJ^{-1}	34.2 $GJ \cdot kL^{-1}$
	Diesel fuel for material transport	3.6 kg CO_2-e GJ^{-1}	38.6 $GJ \cdot kL^{-1}$

6. AIR QUALITY IMPACT ASSESSMENT

The following section provides the results of the dispersion modelling exercise described in Section 5.1, with all input data provided in **Annexure 1** and **Annexure 2**. Results are provided as tables which provide the predicted concentrations at a particular point, and as isopleth (contour) plots which provide a visualisation of predicted impacts in the area around the Site, as required by the SEARs (**Table 1**).

The dispersion model predictions include the effects of determined Best Practice Management dust control, the full assessment of which is provided in **Annexure 2**.

It is important to note that dispersion modelling provides an assessment of risk, and includes an inherent uncertainty, no matter how accurate the modelling inputs may be. (Barclay & Scire, 2011) state:

"The sources of uncertainty in model predictions can be significantly reduced by collecting the proper input data, preparing the input files correctly, checking and re-checking for errors, correcting for 'odd' model behaviour, insuring that errors in the measured data are minimised and applying the correct model to suit each application. As well as user 'error' inputs there is some 'inherent uncertainty' in model predictions which occurs in all dispersion models' due to the uncertainty of atmospheric behaviour.

Consider the following general statements on model performance which have been derived from the EPA 2003 and are to be considered in their totality, i.e., altogether.

- *Models are more reliable for estimating longer time averaged concentrations than for estimating short-term concentrations at specific locations*
- *Estimates of concentrations that occur at a specific time and site are poorly correlated with actual observed concentrations (paired in space and time) and are less reliable (mostly due to reducible uncertainty such as error in plume location due to a wind direction error).*
- *Models are reasonably reliable in estimating the highest concentrations occurring sometime, somewhere in an area. Model certainty is expected to be in the range of a factor of 2."*

6.1 SUMMARY OF RESULTS

A summary of the predicted compliance status of the Project based on modelling predictions is provided in **Table 22**. A detailed description of the model results, the comparison with criteria and the compliance status of the Project during each modelled stage is presented in the following sections.

Table 22
Summary of Predicted Compliance with Air Quality Criteria at Residential Receptors

Criteria Source	**Ambient Air Quality Criteria** **NSW EPA, 2017** **AAQ NEPM** (refer Section 3.1.1, Section 3.2.1)			**Voluntary Acquisition and Mitigation Criteria** **NSW Government, 2014** (refer Section 3.2.2)	
Receptor	**Annual average**	**Maximum 24-hour average**	**Maximum 1-hour average**	**Annual average**	**Maximum 24-hour average**
	Particulate matter **NO_2**	**Particulate matter**	**NO_2**	**Particulate matter** **NO_2**	**Particulate matter**
23	☑	☑	☑	☑	☑
22	☑	☑	☑	☑	☑
20	☑	☑	☑	☑	☑
16	☑	☒ 50.4 µg·m^{-3} in Stage 1C (criterion 50 µg·m^{-3})	☑	☑	☑
15	☑	☑	☑	☑	☑
7	☑	☑	☑	☑	☑
12	☑	☑	☑	☑	☑
13	☑	☑	☑	☑	☑
8	☑	☑	☑	☑	☑
10	☑	☑	☑	☑	☑
21	☑	☑	☑	☑	☑
17	☑	☑	☑	☑	☑
19	☑	☑	☑	☑	☑

6.2 SITE ESTABLISHMENT AND CONSTRUCTION STAGE

The results of dispersion modelling for activities to be performed under the site establishment and construction phase of the Project are presented in Section 6.1.1 (annual averages), Section 6.1.2(maximum 24-hour averages) and Section 6.1.3 (maximum 1-hour averages).

6.2.1 Annual Average TSP, PM_{10}, $PM_{2.5}$ and NO_2

In the case of annual average predictions, all criteria (impact assessment and voluntary land acquisition and mitigation criteria) are predicted to be met at surrounding residential locations during the site establishment and construction phase. Contributions from these activities are shown in all cases to result in minimal / negligible impact at all receptor locations.

Presented in **Table 23** are dispersion model predictions of annual average TSP concentrations. The maximum predicted increment resulting from the Site establishment and construction phase is predicted to be 0.2 $\mu g \cdot m^{-3}$, at receptors 22 and 23. This represents less than (<) 1 % of the annual average TSP criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of TSP during the site establishment and construction phase being <31 % of the criterion.

Table 23
Predicted Annual Average TSP Concentrations – Site Establishment

Receptor	Annual Average TSP Concentration ($\mu g \cdot m^{-3}$)				
	Cumulative Impact	KSQ	KEQ	KQ	BG
23	23.9	0.2	3.2	1.1	19.5
22	27.7	0.2	5.5	2.4	19.5
20	26.1	0.2	3.5	2.8	19.5
16	23.8	0.1	1.5	2.8	19.5
15	21.5	0.1	0.9	0.9	19.5
7	21.4	0.0	1.6	0.3	19.5
12	22.2	0.0	1.6	1.1	19.5
13	21.9	0.1	0.9	1.4	19.5
8	21.5	<0.1	1.7	0.3	19.5
10	20.4	<0.1	0.7	0.2	19.5
21	22.6	0.1	1.9	1.0	19.5
17	21.1	0.1	0.8	0.7	19.5
19	20.7	0.1	0.6	0.5	19.5
2a	61.4	0.2	3.3	38.3	19.5
2b	59.7	0.2	38.6	1.3	19.5
4	27.1	0.1	6.7	0.7	19.5
3	36.5	0.1	15.3	1.5	19.5
Criterion	90	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Figure 16 and **Figure 17** present the annual average incremental (Karuah South Quarry, site establishment and construction) and cumulative (all quarries plus background) TSP concentration isopleth plots, respectively.

Figure 16
Predicted Incremental Annual Average TSP Concentrations – Site Establishment

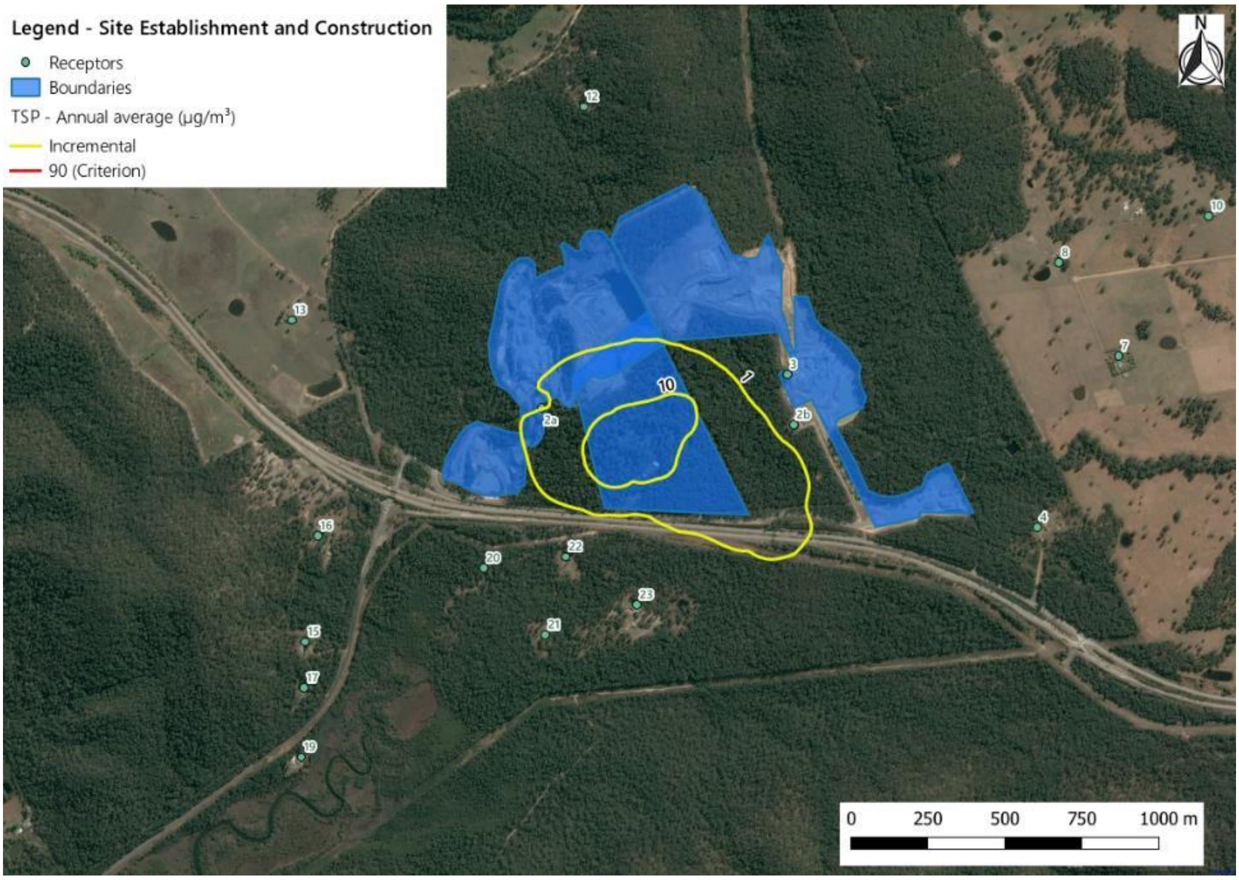
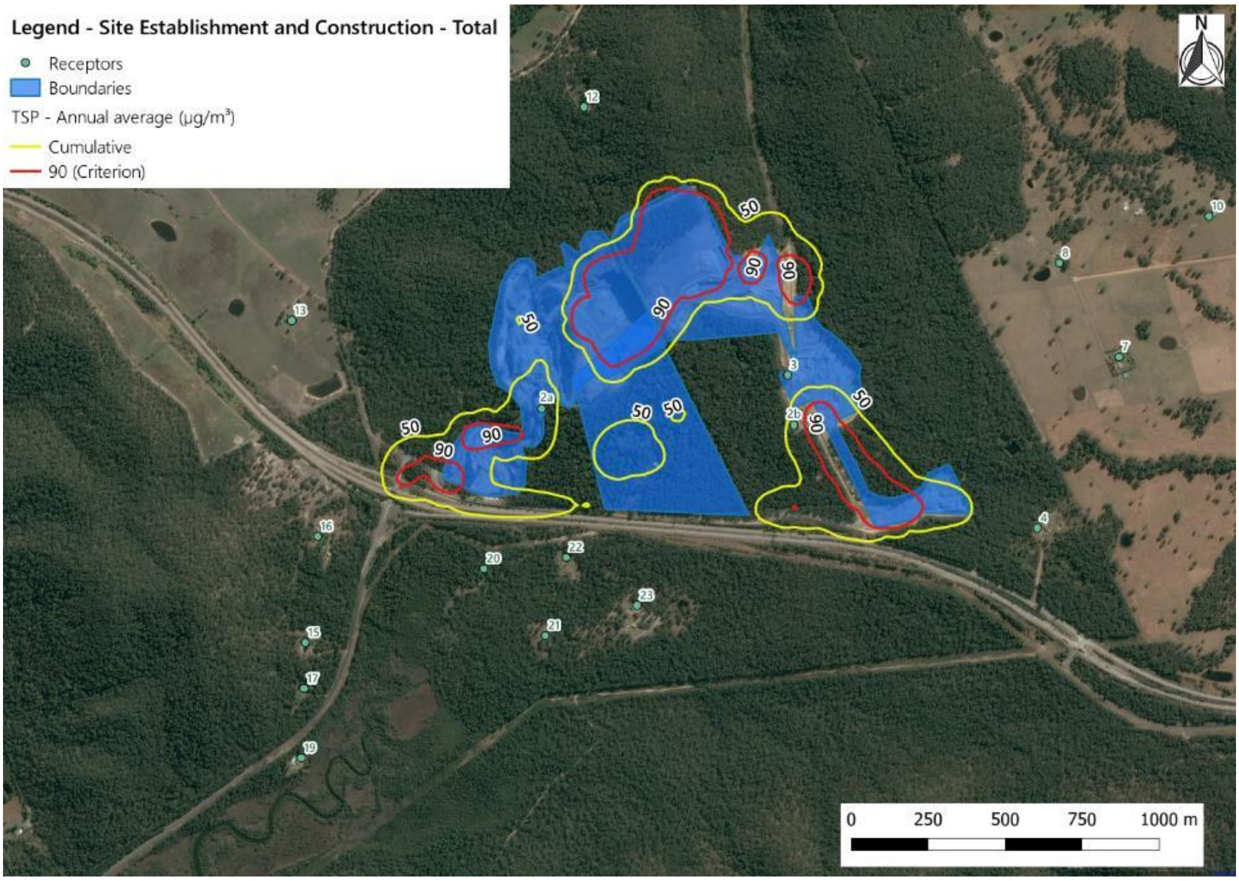


Figure 17
Predicted Cumulative Annual Average TSP Concentrations – Site Establishment



Presented in **Table 24** are dispersion model predictions of annual average PM_{10} concentrations. The maximum predicted increment resulting from the site establishment and construction phase is predicted to be 0.1 µg·m^{-3} which represents <1 % of the annual average PM_{10} criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of PM_{10} during the site establishment and construction phase being <54 % of the criterion.

Table 24
Predicted Annual Average PM_{10} Concentrations – Site Establishment

Receptor	Annual Average PM_{10} Concentration ($\mu g \cdot m^{-3}$)				
	Cumulative Impact	**KSQ**	**KEQ**	**KQ**	**BG**
23	12.4	0.1	1.4	0.6	10.3
22	13.5	0.1	2.0	1.1	10.3
20	12.9	0.1	1.4	1.2	10.3
16	12.2	0.1	0.7	1.2	10.3
15	11.3	0.1	0.5	0.5	10.3
7	11.5	<0.1	1.0	0.2	10.3
12	12.1	<0.1	1.1	0.7	10.3
13	11.5	<0.1	0.5	0.7	10.3
8	11.6	<0.1	1.1	0.2	10.3
10	10.9	<0.1	0.5	0.2	10.3
21	11.8	0.1	0.9	0.5	10.3
17	11.2	0.1	0.5	0.4	10.3
19	11.0	0.1	0.4	0.3	10.3
2a	**25.7**	0.1	1.7	13.7	10.3
2b	**25.8**	0.1	14.5	0.9	10.3
4	14.8	0.1	3.9	0.5	10.3
3	18.8	0.1	7.4	1.1	10.3
Criterion	25	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Figure 18 and **Figure 19** present the annual average incremental (Karuah South Quarry, site establishment and construction) and cumulative (all quarries plus background) PM_{10} concentration isopleth plots, respectively.

Figure 18
Predicted Incremental Annual Average PM_{10} Concentrations – Site Establishment

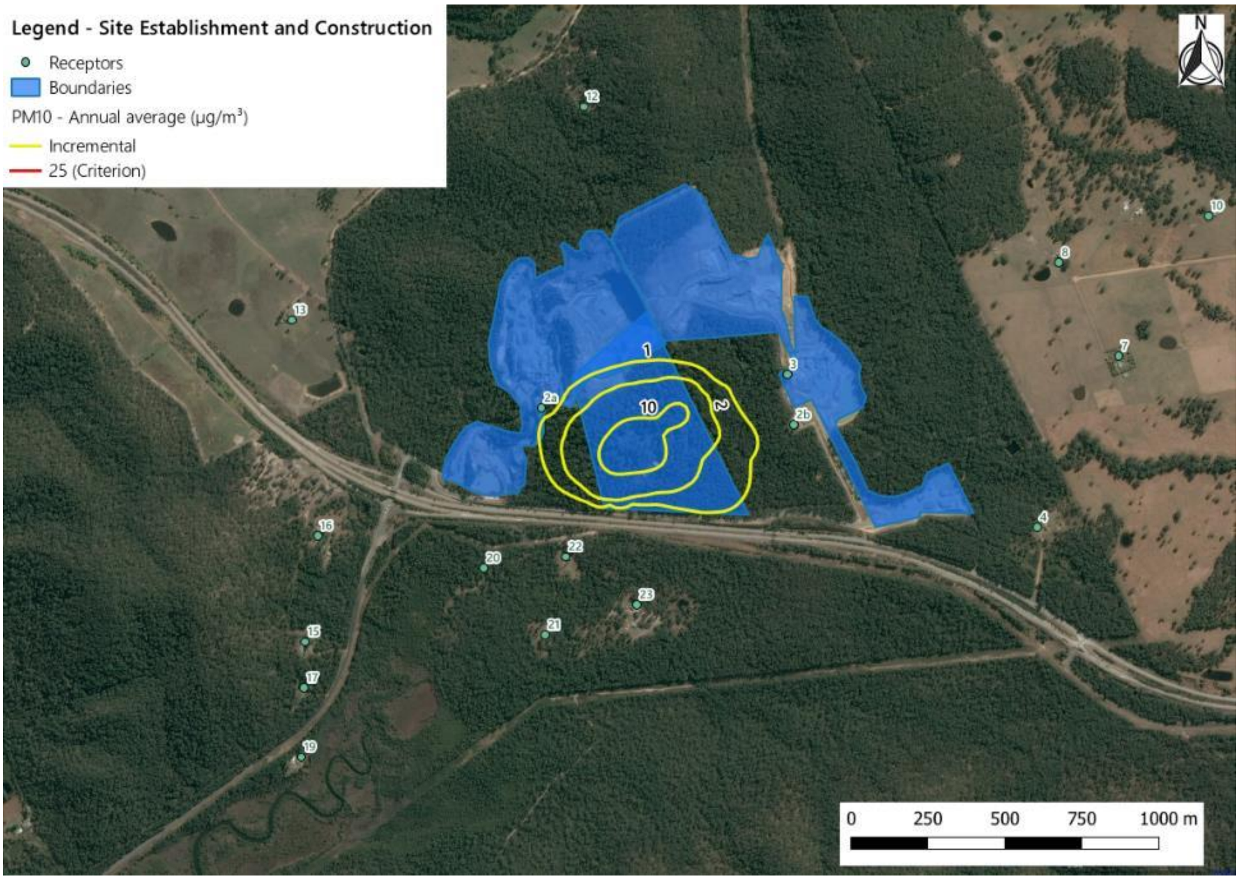
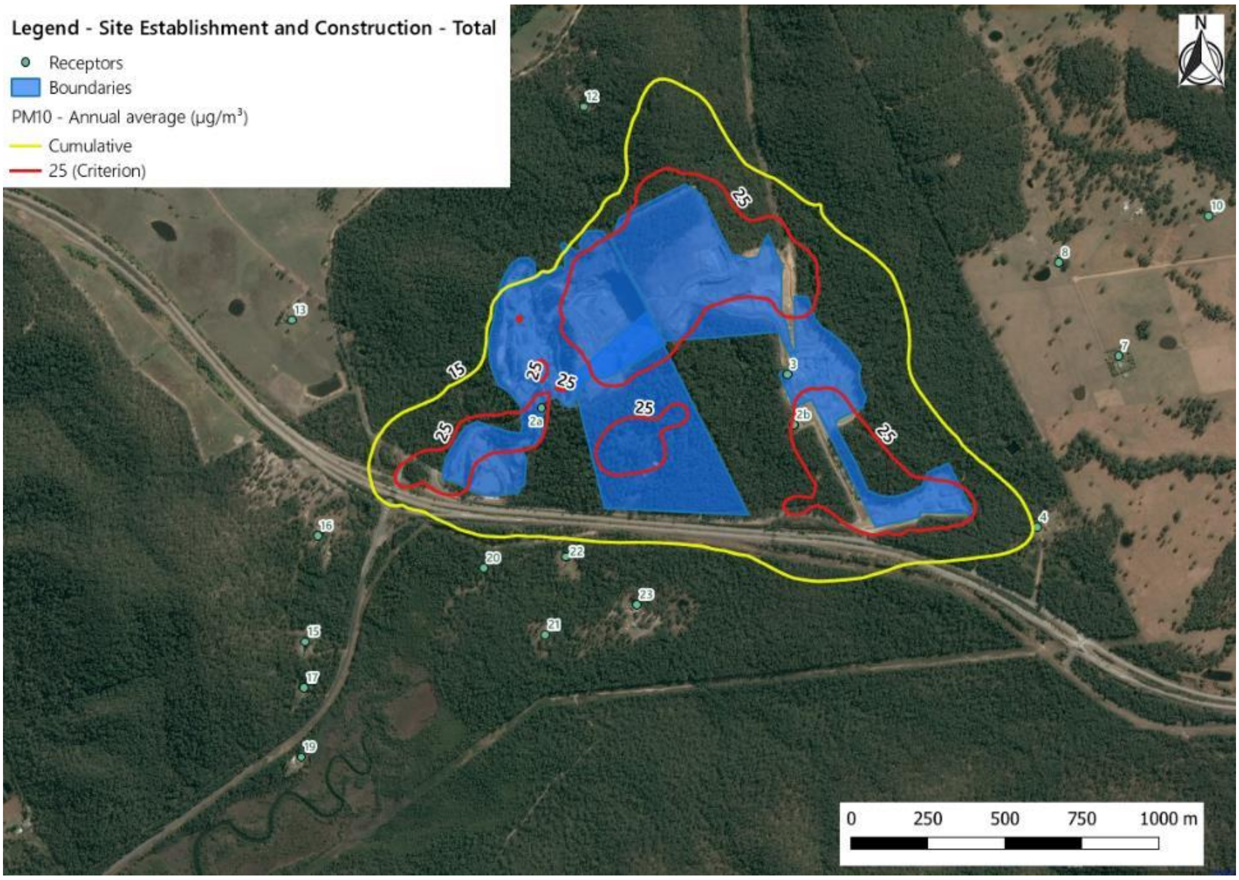


Figure 19
Predicted Cumulative Annual Average PM_{10} Concentrations – Site Establishment



Presented in **Table 25** are dispersion model predictions of annual average $PM_{2.5}$ concentrations. The maximum predicted increment resulting from the site establishment and construction phase is predicted to be <0.1 $\mu g \cdot m^{-3}$ which represents <1 % of the annual average $PM_{2.5}$ criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of $PM_{2.5}$ during the site establishment and construction phase being <71 % of the criterion.

Although not required by the SEARs, and not an applicable criterion in NSW, the VIC EPA SEPP PEM (VIC EPA, 2007) annual average criterion for respirable crystalline silica (as $PM_{2.5}$) of 3 $\mu g \cdot m^{-3}$ has been assessed. The maximum incremental concentration from the Karuah South Quarry site establishment and construction operations (adjusted to account for the free silica content of extracted material [20%]) results in respirable crystalline silica impacts at all residential receptors being <0.1 $\mu g \cdot m^{-3}$. With the impacts of all other quarries (and assuming that the existing background is silica free), the maximum cumulative impact is likely to be <0.2 $\mu g \cdot m^{-3}$ and well below the 3 $\mu g \cdot m^{-3}$ criterion.

Table 25
Predicted Annual Average $PM_{2.5}$ Concentrations – Site Establishment

Receptor	Annual Average $PM_{2.5}$ Concentration (µg·m^{-3})				
	Cumulative Impact	KSQ	KEQ	KQ	BG
23	5.5	<0.1	0.3	0.1	5.1
22	5.7	<0.1	0.4	0.2	5.1
20	5.6	<0.1	0.3	0.2	5.1
16	5.5	<0.1	0.1	0.2	5.1
15	5.3	<0.1	0.1	0.1	5.1
7	5.3	<0.1	0.1	0.0	5.1
12	5.4	<0.1	0.2	0.1	5.1
13	5.3	<0.1	0.1	0.1	5.1
8	5.3	<0.1	0.2	<0.1	5.1
10	5.2	<0.1	0.1	<0.1	5.1
21	5.4	<0.1	0.2	0.1	5.1
17	5.3	<0.1	0.1	0.1	5.1
19	5.2	<0.1	0.1	<0.1	5.1
2a	7.0	<0.1	0.3	1.6	5.1
2b	7.0	<0.1	1.7	0.1	5.1
4	5.8	<0.1	0.6	0.1	5.1
3	6.2	<0.1	1.0	0.2	5.1
Criterion	8	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Figure 20 and **Figure 21** present the annual average incremental (Karuah South Quarry, site establishment and construction) and cumulative (all quarries plus background) $PM_{2.5}$ concentration isopleth plots, respectively.

Figure 20
Predicted Incremental Annual Average $PM_{2.5}$ Concentrations – Site Establishment

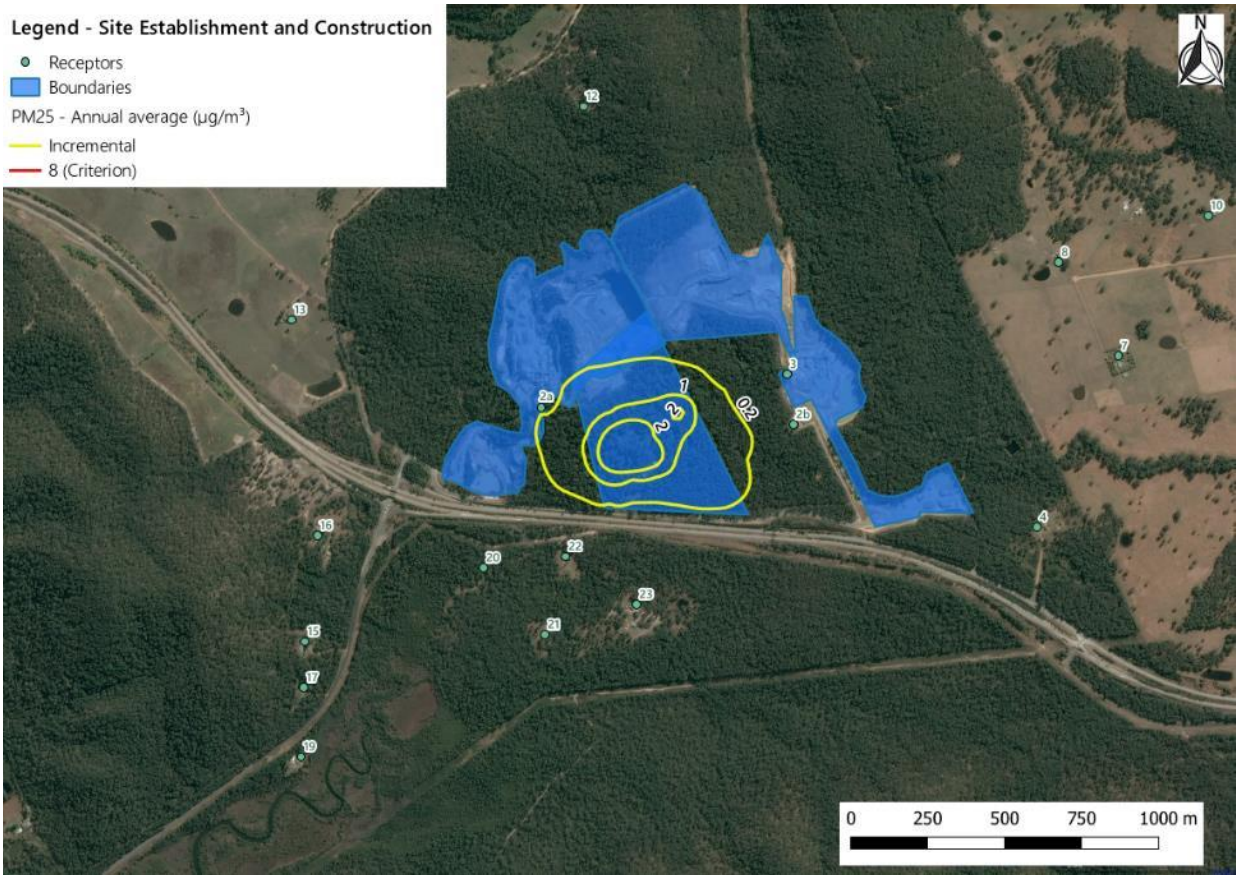
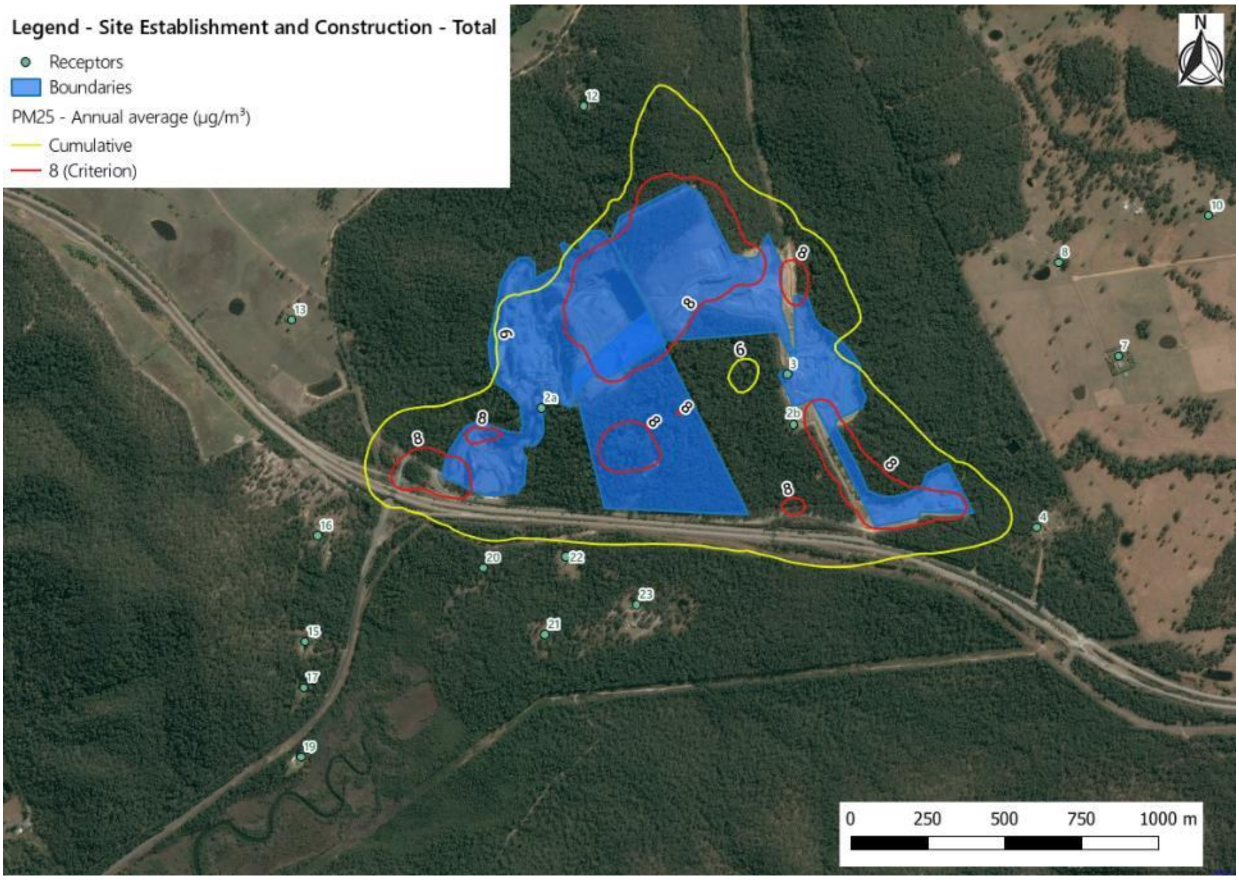


Figure 21
Predicted Cumulative Annual Average $PM_{2.5}$ Concentrations – Site Establishment



Presented in **Table 26** are dispersion model predictions of annual average dust deposition rates. The maximum predicted increment resulting from the site establishment and construction phase is predicted to be <0.1 $g{\cdot}m^{-2}{\cdot}month^{-1}$ which represents <1 % of the incremental annual average dust deposition criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of dust deposition during the site establishment and construction phase being <73 % of the cumulative criterion.

Table 26
Predicted Annual Average Dust Deposition Rates– Site Establishment

Receptor	Annual Average Dust Deposition Rate ($g \cdot m^{-2} \cdot month^{-1}$)				
	Cumulative Impact	**KSQ**	**KEQ**	**KQ**	**BG**
23	2.4	<0.1	0.3	0.1	2.0
22	2.9	<0.1	0.7	0.2	2.0
20	2.6	<0.1	0.4	0.2	2.0
16	2.5	<0.1	0.2	0.3	2.0
15	2.2	<0.1	0.1	0.1	2.0
7	2.1	<0.1	0.1	<0.1	2.0
12	2.2	<0.1	0.1	0.1	2.0
13	2.2	<0.1	0.1	0.1	2.0
8	2.1	<0.1	0.1	<0.1	2.0
10	2.0	<0.1	<0.1	<0.1	2.0
21	2.2	<0.1	0.2	0.1	2.0
17	2.1	<0.1	0.1	<0.1	2.0
19	2.1	<0.1	<0.1	<0.1	2.0
2a	**8.0**	<0.1	0.4	**5.6**	2.0
2b	**6.5**	<0.1	**4.4**	0.1	2.0
4	2.7	<0.1	0.6	0.0	2.0
3	3.8	<0.1	1.7	0.1	2.0
Criterion	4	2	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Figure 22 and **Figure 23** present the annual average incremental (Karuah South Quarry, site establishment and construction) and cumulative (all quarries plus background) dust deposition rate isopleth plots, respectively.

Figure 22
Predicted Incremental Annual Average Dust Deposition Rates – Site Establishment

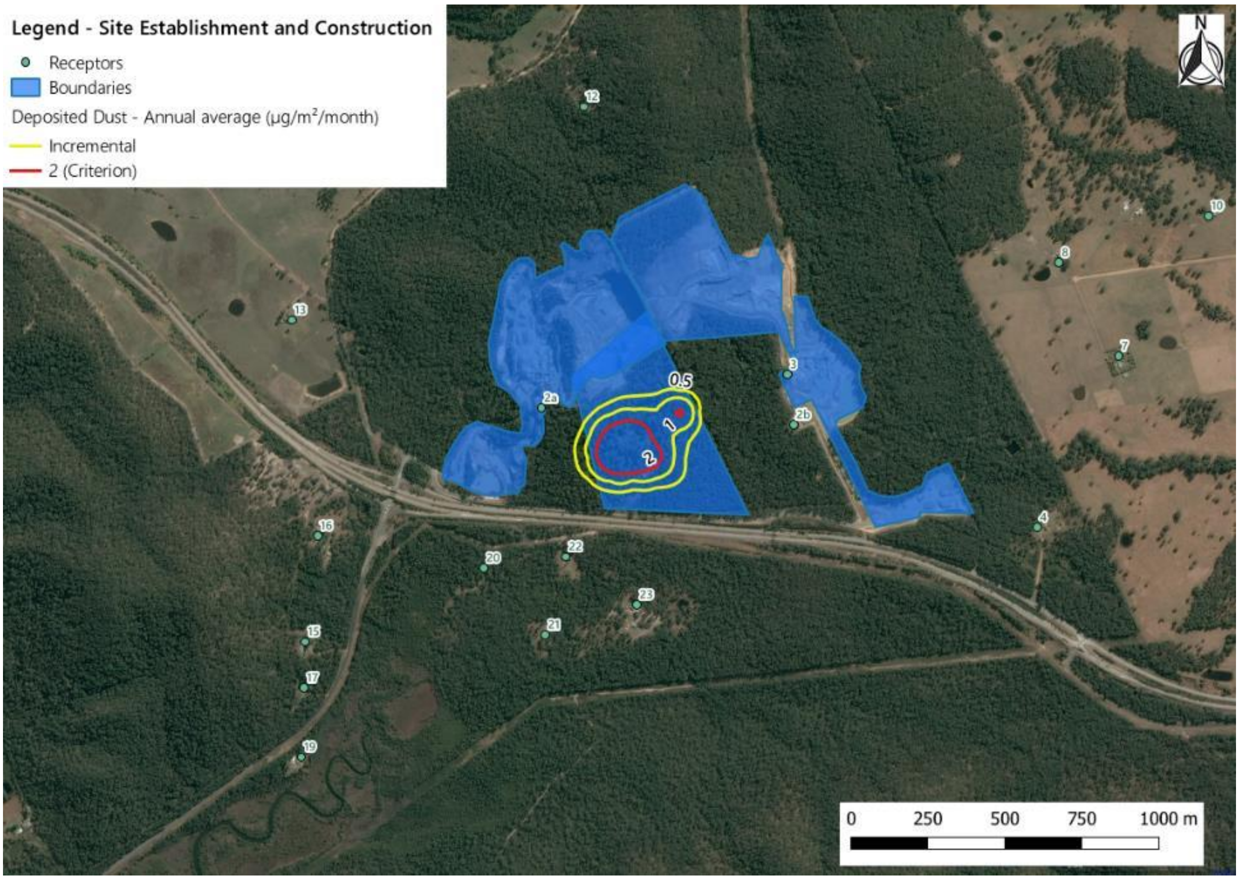
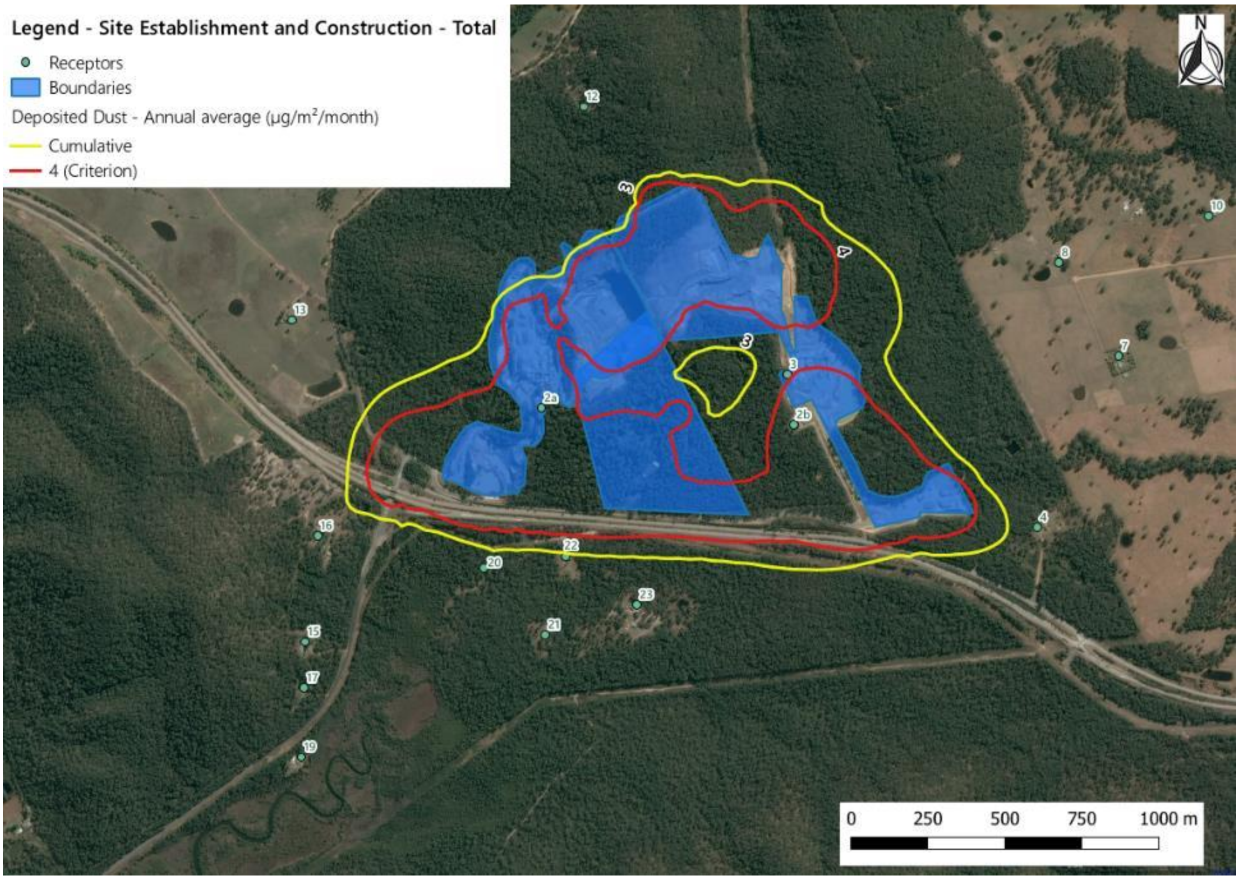


Figure 23
Predicted Cumulative Annual Average Dust Deposition Rates – Site Establishment



Presented in **Table 27** are dispersion model predictions of annual average NO_2 concentrations. The maximum predicted increment resulting from the site establishment and construction phase is predicted to be <0.1 µg·m^{-3} which represents <1 % of the annual average NO_2 criterion.

Given the low predicted impacts associated with the site establishment and construction phase, addition of other quarry increments has not been performed as it is anticipated that these would also provide minimal increments.

The addition of the predicted impact of background air quality results in total cumulative impacts of NO_2 during the site establishment and construction phase being <27 % of the criterion.

Table 27
Predicted Annual Average NO_2 Concentrations – Site Establishment

Receptor	**Annual Average NO_2 Concentration ($\mu g \cdot m^{-3}$)**		
	Cumulative Impact	**KSQ**	**BG**
23	16.5	<0.1	16.4
22	16.5	<0.1	16.4
20	16.5	<0.1	16.4
16	16.5	<0.1	16.4
15	16.5	<0.1	16.4
7	16.5	<0.1	16.4
12	16.5	<0.1	16.4
13	16.5	<0.1	16.4
8	16.5	<0.1	16.4
10	16.5	<0.1	16.4
21	16.5	<0.1	16.4
17	16.5	<0.1	16.4
19	16.5	<0.1	16.4
2a	16.5	<0.1	16.4
2b	16.5	<0.1	16.4
4	16.5	<0.1	16.4
3	16.5	<0.1	16.4
Criterion	62	-	-

Note: KSQ = Karuah South Quarry, BG = background

Given the predicted low incremental impacts, no concentration isopleth plots associated with annual average NO_2 impacts during the site establishment and construction phase are provided.

6.2.2 Maximum 24-hour Average PM_{10} and $PM_{2.5}$

In the case of maximum 24-hour average predictions, all criteria (impact assessment and voluntary land acquisition and mitigation criteria) are predicted to be met at surrounding residential locations during the site establishment and construction phase. Contributions from these activities are shown in all cases to result in minor impacts at all receptor locations.

Presented in **Table 28** are dispersion model predictions of maximum cumulative 24-hour average PM_{10} concentrations. The maximum predicted contribution to the maximum cumulative PM_{10} impact resulting from the site establishment and construction phase activities is predicted to be 0.8 $\mu g \cdot m^{-3}$, at receptor 16. This represents <2 % of the maximum 24-hour average PM_{10} criterion.

Table 28
Predicted Maximum 24-hour Average Cumulative PM_{10} Concentrations – Site Establishment

Receptor	Maximum 24-hour PM_{10} Concentration (µg·m^{-3})				
	Cumulative Impact	**KSQ**	**KEQ**	**KQ**	**BG**
23	39.9	0.4	0.8	1.2	37.5
22	41.3	<0.1	1.7	2.1	37.5
20	38.9	<0.1	0.5	0.9	37.5
16	47.4	0.8	5.2	16.4	24.9
15	37.5	<0.1	<0.1	<0.1	37.5
7	37.6	<0.1	0.1	<0.1	37.5
12	37.5	<0.1	<0.1	<0.1	37.5
13	37.5	<0.1	<0.1	<0.1	37.5
8	37.5	<0.1	<0.1	<0.1	37.5
10	37.5	<0.1	<0.1	<0.1	37.5
21	38.2	<0.1	0.2	0.5	37.5
17	37.5	<0.1	<0.1	<0.1	37.5
19	37.5	<0.1	<0.1	<0.1	37.5
2a	**71.1**	9.9	5.2	46.6	9.4
2b	**105.0**	0.2	93.3	<0.1	11.5
4	41.8	2.7	30.0	5.1	4.0
3	**88.8**	1.0	**76.9**	1.8	9.1
Criterion	50	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background
The maximum cumulative impact is presented, with the contributions from each quarry operation on the day of maximum impact presented. Maximum incremental impacts associated with the Karuah South Quarry are presented in the following table.

On the day of maximum predicted cumulative impact at all modelled receptors, the 24-hour average PM_{10} criterion is predicted to be achieved, with the addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality resulting in total cumulative impacts of PM_{10} during the site establishment and construction phase being <95 % of the criterion.

The maximum predicted incremental 24-hour average PM_{10} concentrations resulting from activities during the site establishment and construction phase are presented in **Table 29**. These predictions indicate that the activities during the site establishment and construction phase could potentially result in incremental impacts up to 5.9µg·m^{-3} at the modelled receptor locations, which represents <12 % of the relevant criterion.

Table 29
Predicted Maximum 24-hour Average Incremental PM_{10} Concentrations – Site Establishment

Receptor	Maximum Incremental 24-hour PM_{10} Concentration ($\mu g \cdot m^{-3}$) Karuah South Quarry
23	5.9
22	5.9
20	5.9
16	3.1
15	2.1
7	0.8
12	1.8
13	2.6
8	1.2
10	0.6
21	2.7
17	2.2
19	1.2
2a	15.1
2b	6.1
4	2.7
3	5.2

Figure 24 and **Figure 25** present the maximum 24-hour average incremental (Karuah South Quarry, Site Establishment and Construction) and cumulative (all quarries plus background) PM_{10} concentration isopleth plots, respectively.

Figure 24
Predicted Incremental Maximum 24-hour Average PM_{10} Concentrations – Site Establishment

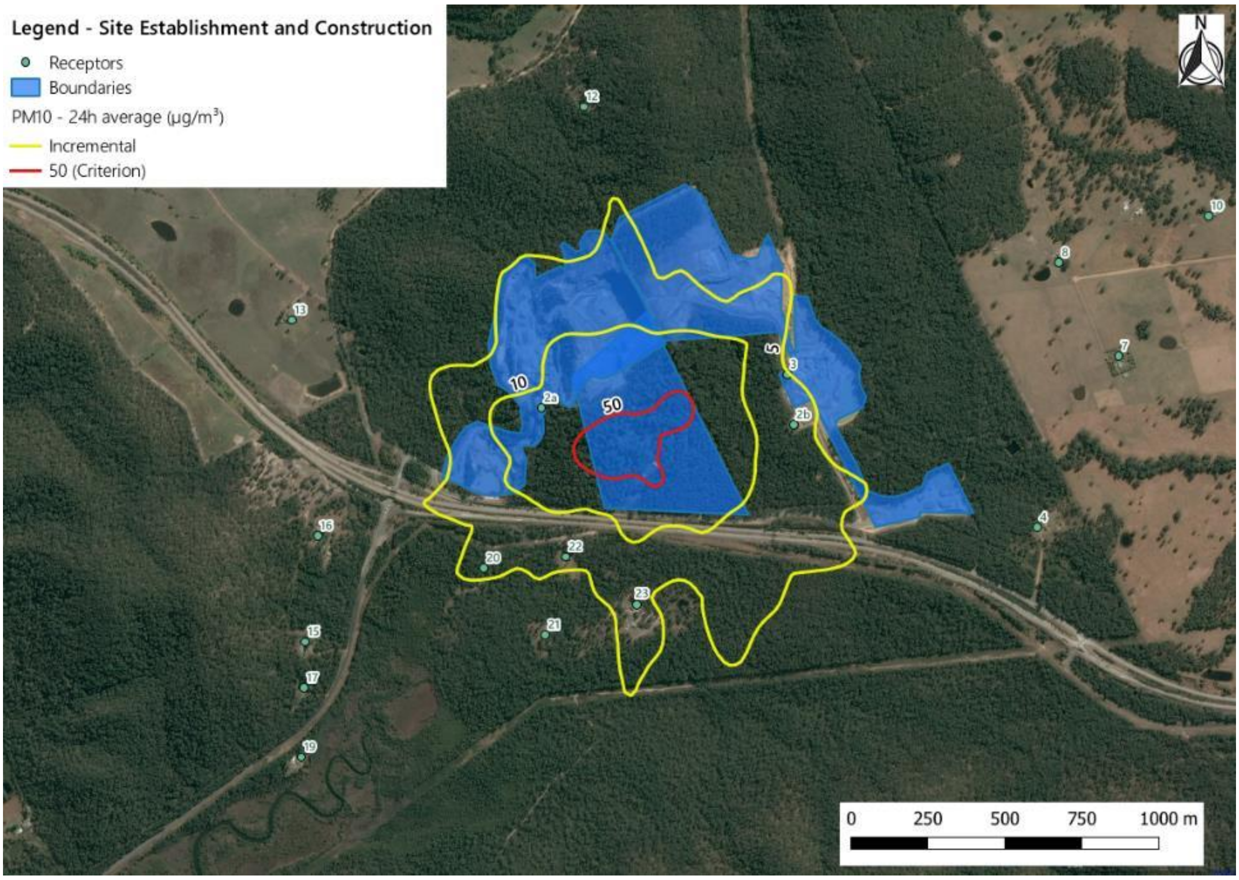
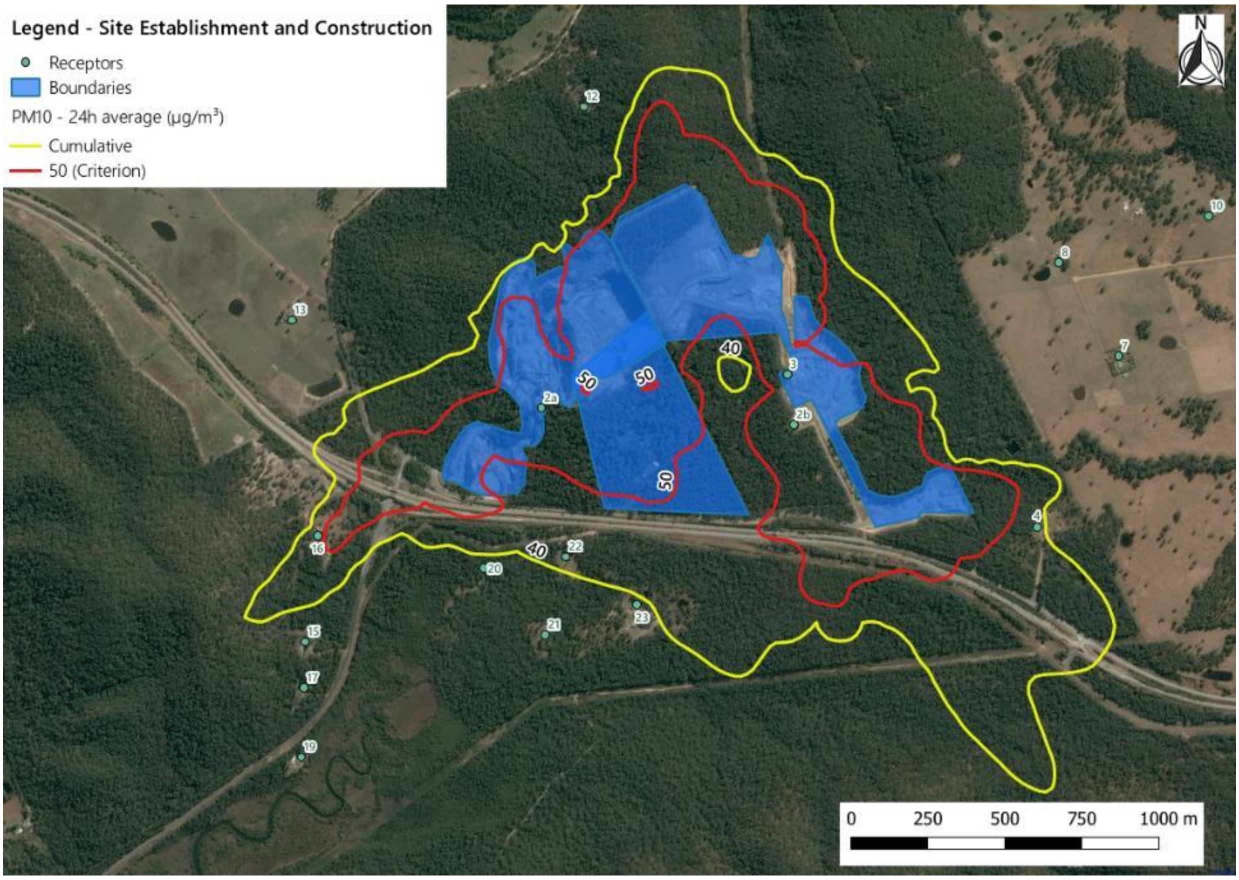


Figure 25
Predicted Cumulative Maximum 24-hour Average PM_{10} Concentrations – Site Establishment



Presented in **Table 30** are dispersion model predictions of maximum cumulative 24-hour average $PM_{2.5}$ concentrations. The maximum predicted contribution to the maximum cumulative $PM_{2.5}$ impact resulting from the site establishment and construction phase activities is predicted to be 0.2 $\mu g \cdot m^{-3}$. This represents <1 % of the maximum 24-hour average $PM_{2.5}$ criterion.

On the day of maximum predicted cumulative impact at all modelled receptors, the 24-hour average $PM_{2.5}$ criterion is predicted to be achieved, with the addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality resulting in total cumulative impacts of $PM_{2.5}$ during the site establishment and construction phase being <69 % of the criterion.

Table 30
Predicted Maximum 24-hour Average Cumulative $PM_{2.5}$ Concentrations – Site Establishment

Receptor	Maximum 24-hour $PM_{2.5}$ Concentration (µg·m^{-3})				
	Cumulative Impact	KSQ	KEQ	KQ	BG
23	16.9	0.2	0.3	0.1	16.2
22	17.3	0.2	0.6	0.3	16.2
20	17.5	0.1	0.5	0.7	16.2
16	16.3	<0.1	<0.1	0.1	16.2
15	16.2	<0.1	<0.1	<0.1	16.2
7	16.2	<0.1	<0.1	<0.1	16.2
12	16.2	<0.1	<0.1	<0.1	16.2
13	16.2	<0.1	<0.1	<0.1	16.2
8	16.2	<0.1	<0.1	<0.1	16.2
10	16.2	<0.1	<0.1	<0.1	16.2
21	16.8	0.2	0.2	0.2	16.2
17	16.2	<0.1	<0.1	<0.1	16.2
19	16.3	<0.1	<0.1	0.1	16.2
2a	18.1	<0.1	0.1	1.8	16.2
2b	18.8	<0.1	9.0	<0.1	9.8
4	16.2	<0.1	<0.1	<0.1	16.2
3	16.8	<0.1	0.6	<0.1	16.2
Criterion	25	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background
The maximum cumulative impact is presented, with the contributions from each quarry operation on the day of maximum impact presented. Maximum incremental impacts associated with the Karuah South Quarry are presented in the following table.

The maximum predicted incremental 24-hour average $PM_{2.5}$ concentrations resulting from activities during the site establishment and construction phase are presented in **Table 31**. These predictions indicate that the activities during the site establishment and construction phase could potentially result in incremental impacts up to 1.4 µg·m^{-3} at the modelled receptor locations, which represents <6 % of the relevant criterion.

Table 31
Predicted Maximum 24-hour Average Incremental $PM_{2.5}$ Concentrations – Site Establishment

Receptor	Maximum Incremental 24-hour $PM_{2.5}$ Concentration ($\mu g \cdot m^{-3}$) Karuah South Quarry
23	1.4
22	1.3
20	1.2
16	0.7
15	0.5
7	0.2
12	0.4
13	0.7
8	0.3
10	0.1
21	0.6
17	0.5
19	0.3
2a	5.1
2b	1.3
4	0.5
3	1.1

Figure 26 and **Figure 27** present the maximum 24-hour average incremental (Karuah South Quarry, Site Establishment and Construction) and cumulative (all quarries plus background) PM_{10} concentration isopleth plots, respectively.

Figure 26

Predicted Incremental Maximum 24-hour Average $PM_{2.5}$ Concentrations – Site Establishment

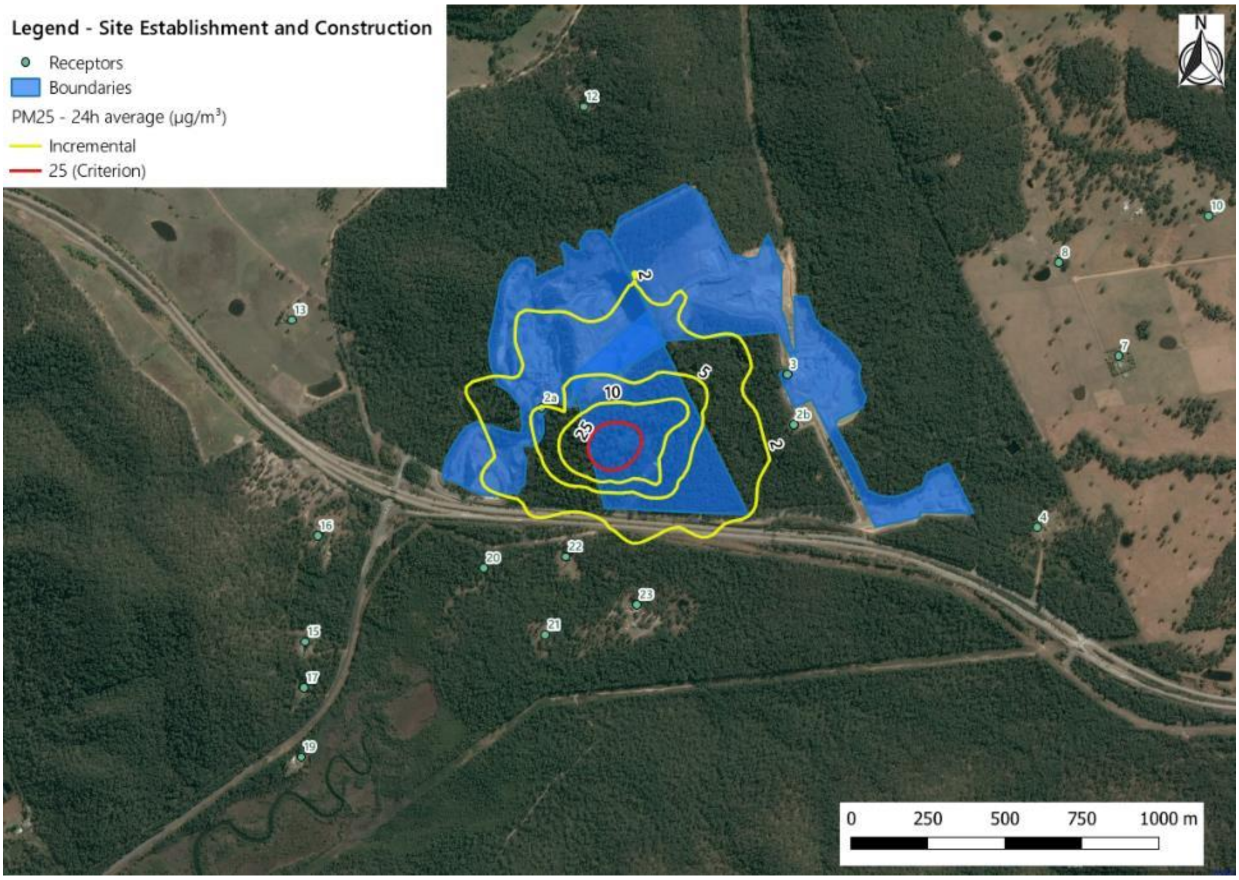
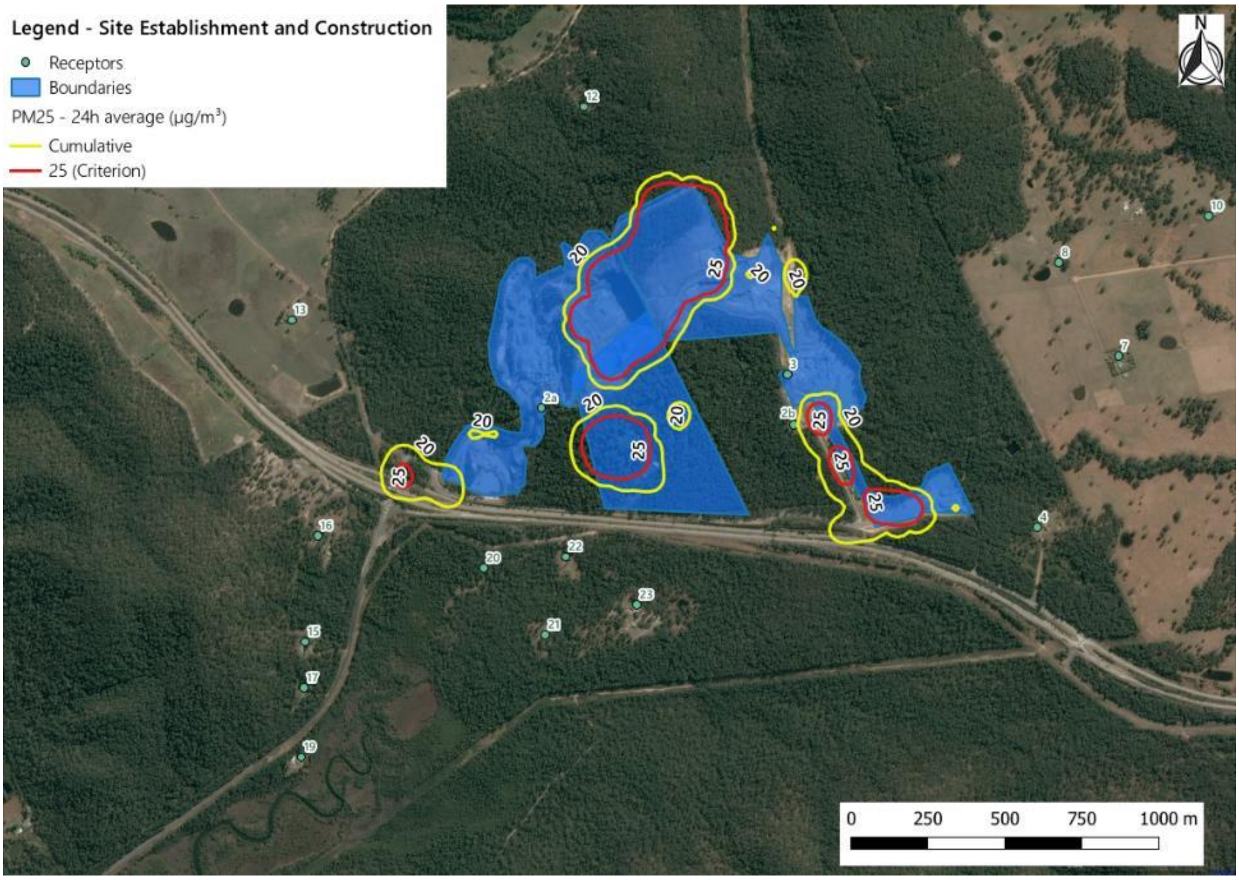


Figure 27
Predicted Cumulative Maximum 24-hour Average $PM_{2.5}$ Concentrations – Site Establishment



6.2.3 Maximum 1-hour Average NO_2

In the case of maximum 1-hour average predictions of NO_2, the impact assessment criterion is predicted to be met at surrounding residential locations during the site establishment and construction phase. Contributions from these activities are shown in all cases to result in insignificant impacts at all receptor locations.

An assumption has been made that impacts from blasting are limited to the operational phase of the development. Should blasting be required to be performed during the site establishment and construction phase, then impacts would be as per those presented for Stage 1C of operations (refer Section 6.2.3).

Given the low predicted impacts associated with the site establishment and construction phase, addition of other quarry increments has not been performed as it is anticipated that these would also provide minimal increments.

Presented in **Table 32** are dispersion model predictions of maximum cumulative 1-hour average NO_2 concentrations. The maximum predicted contribution to the maximum cumulative NO_2 impact resulting from the site establishment and construction phase activities is predicted to be <0.1 µg·m^{-3}, at all receptors. This represents <1 % of the maximum 1-hour average NO_2 criterion. The corresponding cumulative impact of 88.9 µg·m^{-3} represents <36% of the criterion.

Table 32
Predicted Maximum 1-hour Average NO_2 Concentrations – Site Establishment

Receptor	Maximum 1-hour Average NO_2 Concentration (µg·m^{-3})		
	Cumulative Impact	KSQ	BG
23	88.9	<0.1	88.8
22	88.9	<0.1	88.8
20	88.9	<0.1	88.8
16	88.9	<0.1	88.8
15	88.9	<0.1	88.8
7	88.9	<0.1	88.8
12	88.9	<0.1	88.8
13	88.9	<0.1	88.8
8	88.9	<0.1	88.8
10	88.9	<0.1	88.8
21	88.9	<0.1	88.8
17	88.9	<0.1	88.8
19	88.9	<0.1	88.8
2a	88.9	<0.1	88.8
2b	88.9	<0.1	88.8
4	88.9	<0.1	88.8
3	88.9	<0.1	88.8
Criterion	246	-	-

Note: KSQ = Karuah South Quarry, BG = background

6.3 OPERATIONAL STAGES

The results of dispersion modelling for activities proposed to be performed under Stage 1C of Site operations are presented in

- Section 6.2.1 (annual averages);
- Section 6.2.2 (maximum 24-hour averages); and,
- Section 6.2.3 (maximum 1-hour averages).

For Stage 2B, these results are presented in

- Section 6.2.4 (annual averages);
- Section 6.2.5 (maximum 24-hour averages); and,
- Section 6.2.6 (maximum 1-hour averages).

For both Stage 1C and Stage 2B, the maximum 24-hour average model predictions are based on the assumption that 3,000 tonnes of material is being extracted, transported, processed, loaded and transported off site each and every day of the modelled year. This equates to an annual throughput of 1.1 Mtpa which is 3.7 times greater than the proposed annual throughput in Stage 1C and 1.8 times greater than the proposed annual throughout in Stage 2B. Modelling is performed in this way to ensure that the potential worst-case meteorological conditions coincide with the potential maximum daily throughput. Predicted impacts associated with 24-hour averaging periods (PM_{10}, $PM_{2.5}$) at each receptor location can then be confidently stated to represent 'worst-case' impacts.

Similarly, in the case of maximum 1-hour average NO_2 impacts, blasting has been assumed to occur between 10 am and 4 pm on every day of the modelled year. Blasting is proposed to occur once every three to four weeks, although to ensure that the potential worst-case meteorological conditions coincide with the performance of a blasting event. Predicted impacts associated with maximum 1-hour average NO_2 at each receptor location can be confidently stated to represent 'worst-case' impacts.

In the case of annual average concentrations, the operation of Stage 1C and Stage 2B has been assumed to occur at the appropriate annual throughput of the Site.

6.3.1 Stage 1C Annual Average TSP, PM_{10}, $PM_{2.5}$ and NO_2

In the case of annual average predictions, all criteria (impact assessment and voluntary land acquisition and mitigation criteria) are predicted to be met at surrounding residential locations during Stage 1C of operations. Contributions from these activities are shown in all cases to result in minor / minimal impact at all receptor locations.

Presented in **Table 33** are dispersion model predictions of annual average TSP concentrations. The maximum predicted increment resulting from Stage 1C operations is predicted to be 2.5 $\mu g \cdot m^{-3}$, at receptor 22. This represents <3 % of the annual average TSP criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of TSP during Stage 1C operations being <33 % of the criterion.

Table 33
Predicted Annual Average TSP Concentrations – Stage 1C

Receptor	Cumulative Impact	Annual Average TSP Concentration (µg·m^{-3})			
		KSQ	KEQ	KQ	BG
23	25.2	1.4	3.2	1.1	19.5
22	29.7	2.5	5.2	2.5	19.5
20	27.2	1.5	3.5	2.8	19.5
16	24.2	0.5	1.6	2.8	19.5
15	21.7	0.4	1.0	1.0	19.5
7	21.5	0.2	1.6	0.3	19.5
12	22.2	0.3	1.6	0.9	19.5
13	22.1	0.3	0.9	1.4	19.5
8	21.5	0.2	1.7	0.3	19.5
10	20.5	0.1	0.7	0.2	19.5
21	23.0	0.8	1.8	0.9	19.5
17	21.2	0.3	0.8	0.7	19.5
19	20.8	0.2	0.6	0.4	19.5
2a	64.4	5.2	3.3	36.4	19.5
2b	58.6	2.3	35.5	1.2	19.5
4	28.1	0.6	7.4	0.7	19.5
3	37.6	1.5	15.4	1.3	19.5
Criterion	90	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Figure 28 and **Figure 29** present the annual average incremental (Karuah South Quarry, Stage 1C) and cumulative (all quarries plus background) TSP concentration isopleth plots, respectively.

Figure 28
Predicted Incremental Annual Average TSP Concentrations – Stage 1C

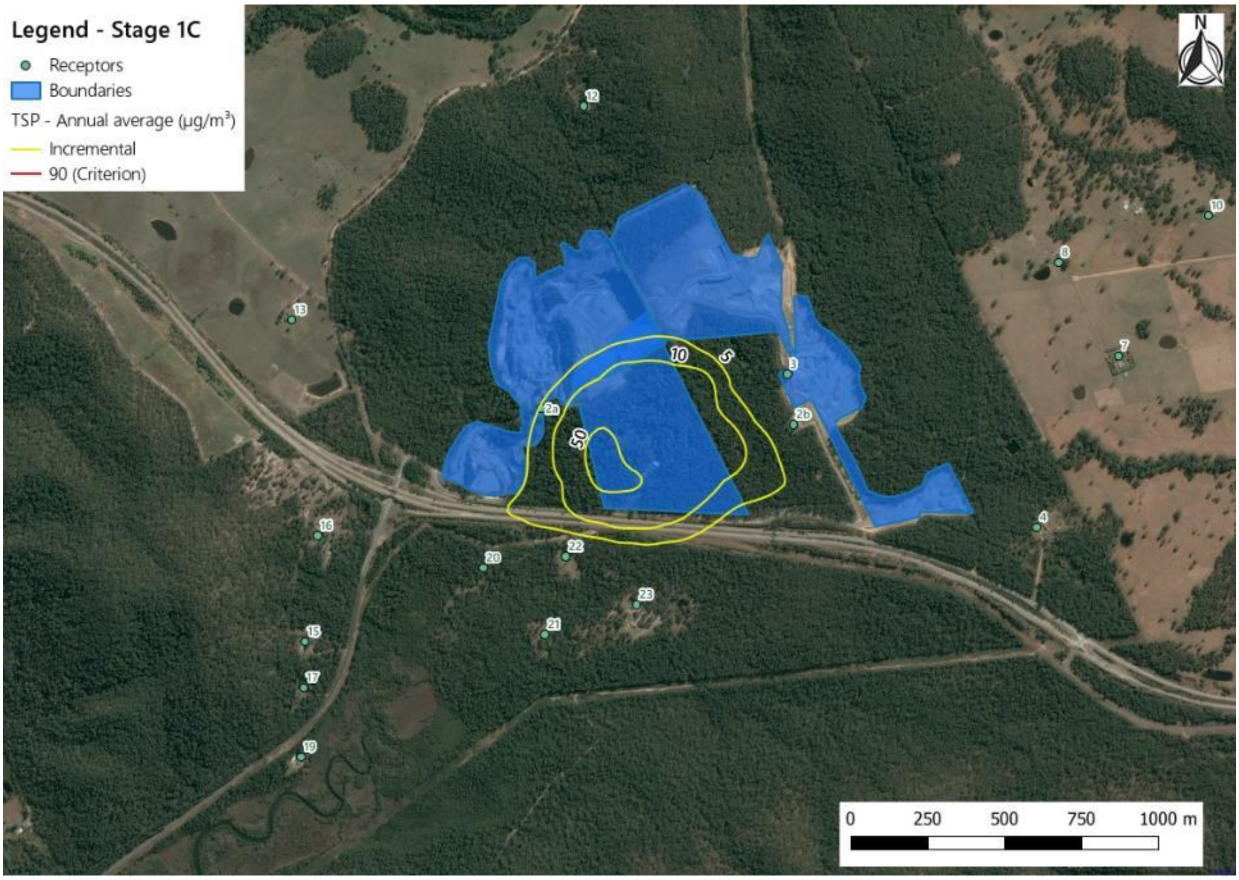
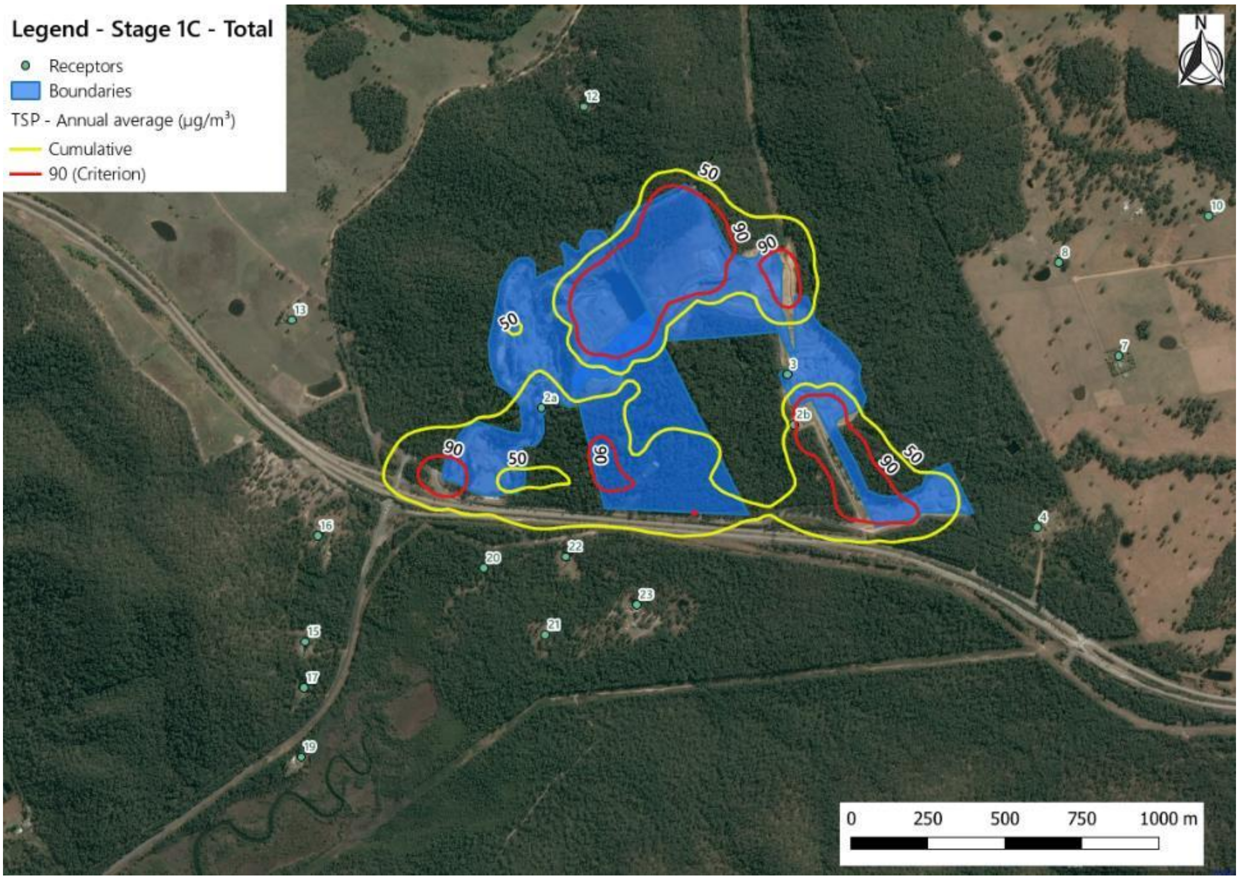


Figure 29
Predicted Cumulative Annual Average TSP Concentrations – Stage 1C



Presented in **Table 34** are dispersion model predictions of annual average PM_{10} concentrations. The maximum predicted increment resulting from the Stage 1C operations is predicted to be 1.5 µg·m^{-3} at receptor 22 which represents <6 % of the annual average PM_{10} criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of PM_{10} during Stage 1C operations being <60 % of the criterion.

Table 34
Predicted Annual Average PM_{10} Concentrations – Stage 1C

Receptor	Cumulative Impact	Annual Average PM_{10} Concentration ($\mu g \cdot m^{-3}$)			
		KSQ	KEQ	KQ	BG
23	13.2	0.9	1.4	0.6	10.3
22	14.8	1.5	2.0	1.1	10.3
20	13.6	0.9	1.3	1.1	10.3
16	12.4	0.3	0.7	1.1	10.3
15	11.5	0.2	0.5	0.5	10.3
7	11.6	0.1	0.9	0.2	10.3
12	12.1	0.2	1.0	0.6	10.3
13	11.6	0.2	0.5	0.7	10.3
8	11.6	0.1	1.0	0.2	10.3
10	11.0	0.1	0.5	0.1	10.3
21	12.1	0.5	0.9	0.4	10.3
17	11.3	0.2	0.5	0.3	10.3
19	11.1	0.2	0.4	0.2	10.3
2a	**28.0**	2.7	1.6	13.4	10.3
2b	**26.1**	1.4	13.6	0.8	10.3
4	15.4	0.4	4.3	0.5	10.3
3	19.5	0.9	7.4	0.9	10.3
Criterion	25	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Figure 30 and **Figure 31** present the annual average incremental (Karuah South Quarry, Stage 1C) and cumulative (all quarries plus background) PM_{10} concentration isopleth plots, respectively.

Figure 30
Predicted Incremental Annual Average PM_{10} Concentrations – Stage 1C

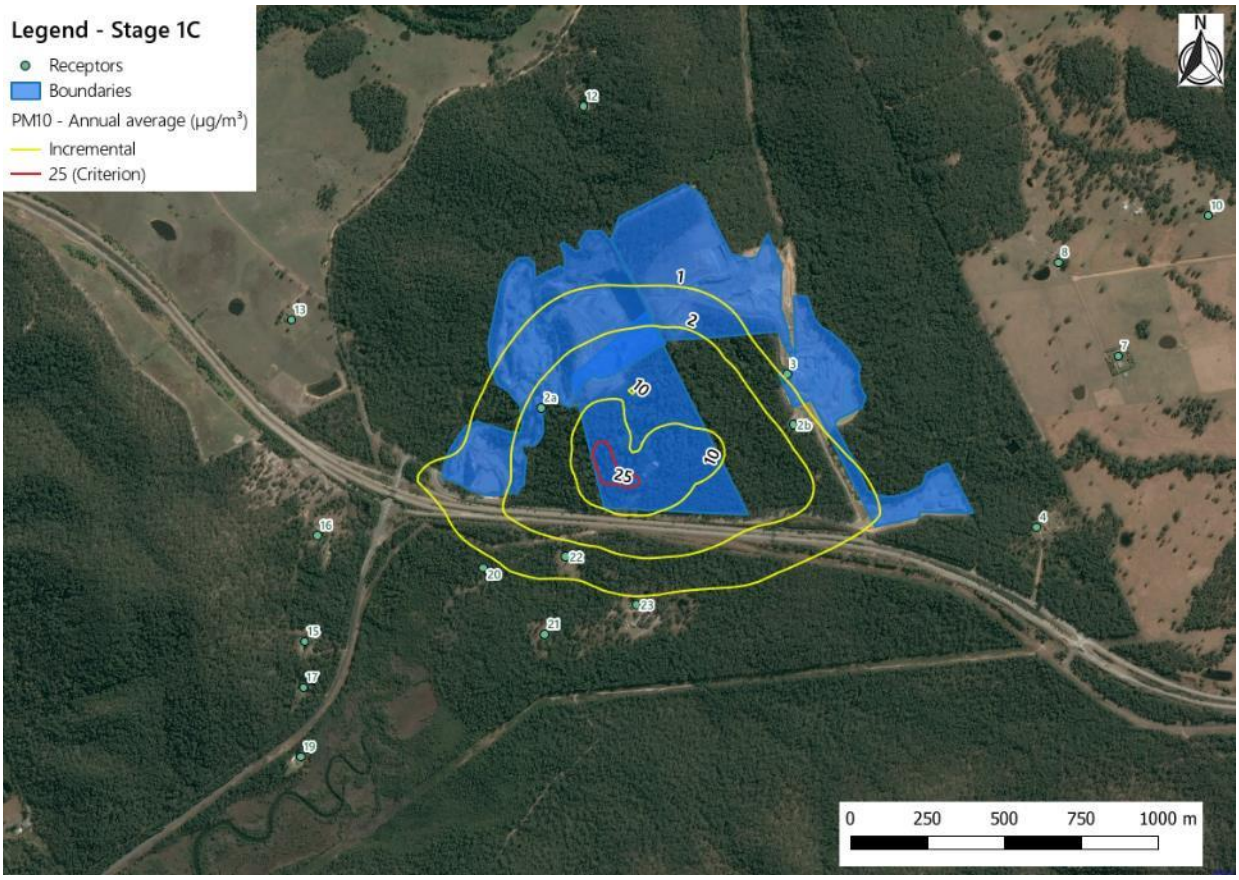
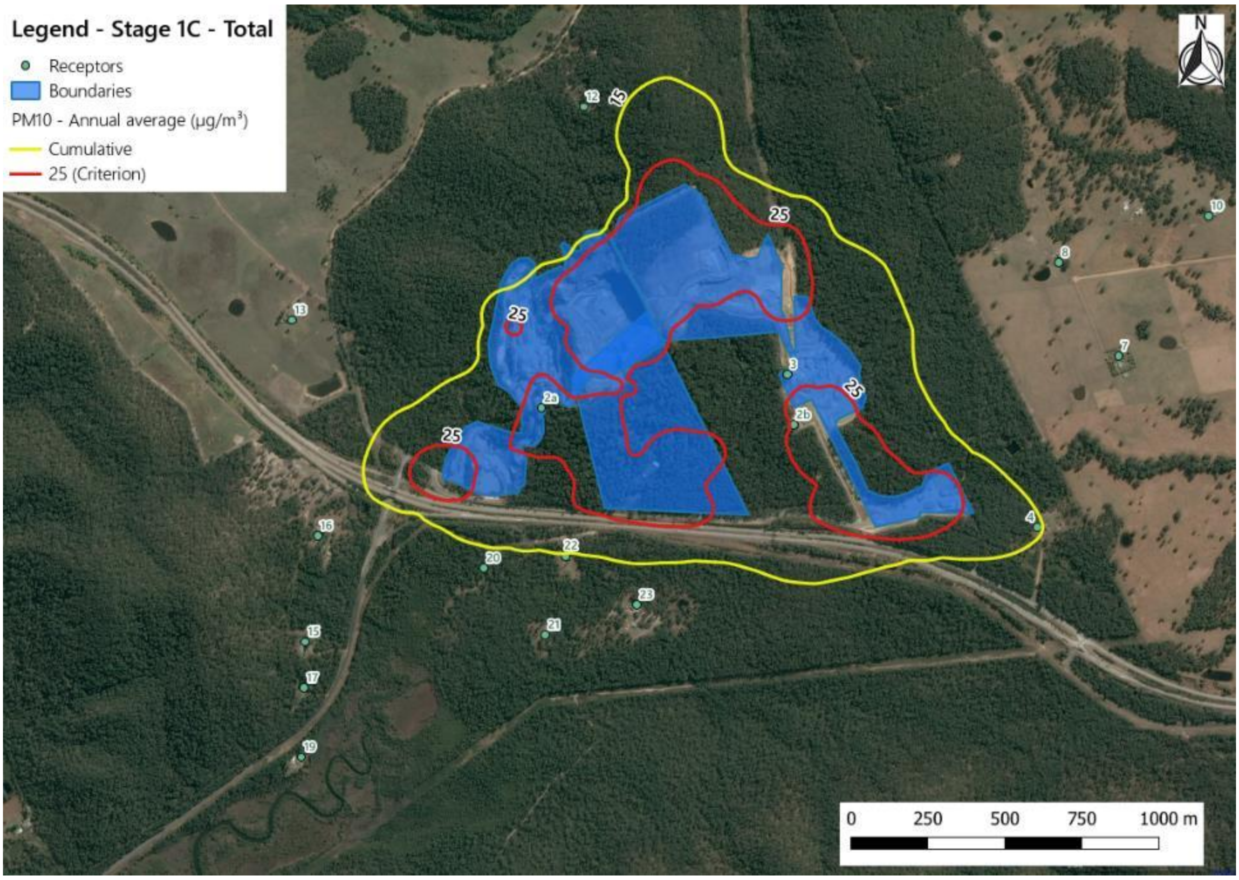


Figure 31
Predicted Cumulative Annual Average PM_{10} Concentrations – Stage 1C



Presented in **Table 35** are dispersion model predictions of annual average $PM_{2.5}$ concentrations. The maximum predicted increment resulting from the Stage 1C operations is predicted to be 0.2 µg·m^{-3} at receptor 22 which represents <3 % of the annual average $PM_{2.5}$ criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of $PM_{2.5}$ during Stage 1C operations being <74 % of the criterion.

Table 35
Predicted Annual Average $PM_{2.5}$ Concentrations – Stage 1C

Receptor	Cumulative Impact	Annual Average $PM_{2.5}$ Concentration ($\mu g{\cdot}m^{-3}$)			
		KSQ	KEQ	KQ	BG
23	5.6	0.1	0.3	0.1	5.1
22	5.9	0.2	0.4	0.2	5.1
20	5.7	0.1	0.3	0.2	5.1
16	5.5	<0.1	0.1	0.2	5.1
15	5.3	<0.1	0.1	0.1	5.1
7	5.3	<0.1	0.1	<0.1	5.1
12	5.4	<0.1	0.2	0.1	5.1
13	5.3	<0.1	0.1	0.1	5.1
8	5.3	<0.1	0.1	<0.1	5.1
10	5.2	<0.1	0.1	<0.1	5.1
21	5.4	0.1	0.2	0.1	5.1
17	5.3	<0.1	0.1	0.1	5.1
19	5.2	<0.1	0.1	<0.1	5.1
2a	7.3	0.4	0.3	1.5	5.1
2b	7.0	0.2	1.6	0.1	5.1
4	5.8	0.1	0.6	0.1	5.1
3	6.3	0.1	0.9	0.1	5.1
Criterion	8	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Although not required by the SEARs, and not an applicable criterion in NSW, the VIC EPA SEPP PEM (VIC EPA, 2007) annual average criterion for respirable crystalline silica (as $PM_{2.5}$) of 3 $\mu g{\cdot}m^{-3}$ has been assessed. The maximum incremental concentration from the Karuah South Quarry Stage 1C operations (adjusted to account for the free silica content of extracted material [20%]) results in respirable crystalline silica impacts at all residential receptors being <0.1 $\mu g{\cdot}m^{-3}$. With the impacts of all other quarries (and assuming that the existing background is silica free), the maximum cumulative impact is likely to be <0.2 $\mu g{\cdot}m^{-3}$ and well below the 3 $\mu g{\cdot}m^{-3}$ criterion.

Figure 32 and **Figure 33** present the annual average incremental (Karuah South Quarry, Stage 1C) and cumulative (all quarries plus background) $PM_{2.5}$ concentration isopleth plots, respectively.

Figure 32
Predicted Incremental Annual Average $PM_{2.5}$ Concentrations – Stage 1C

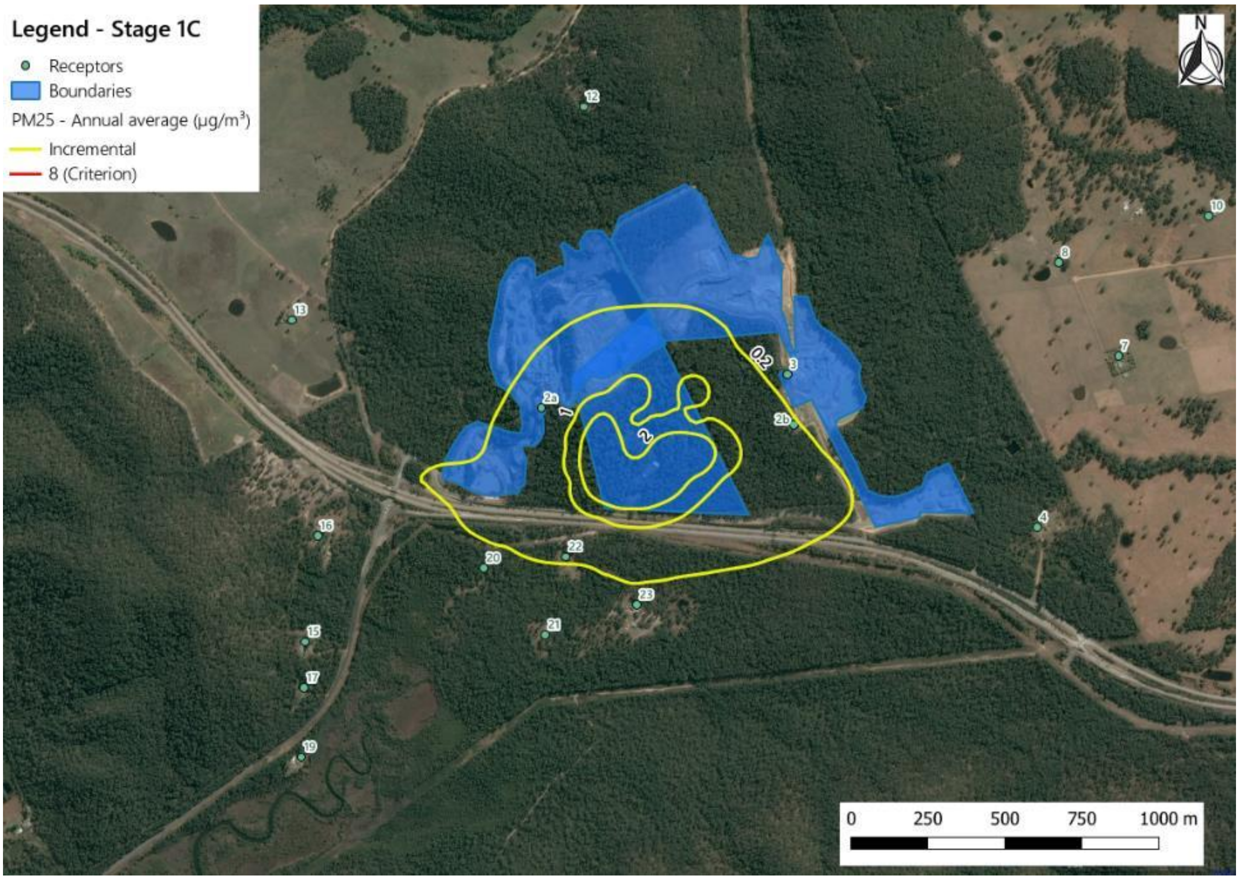
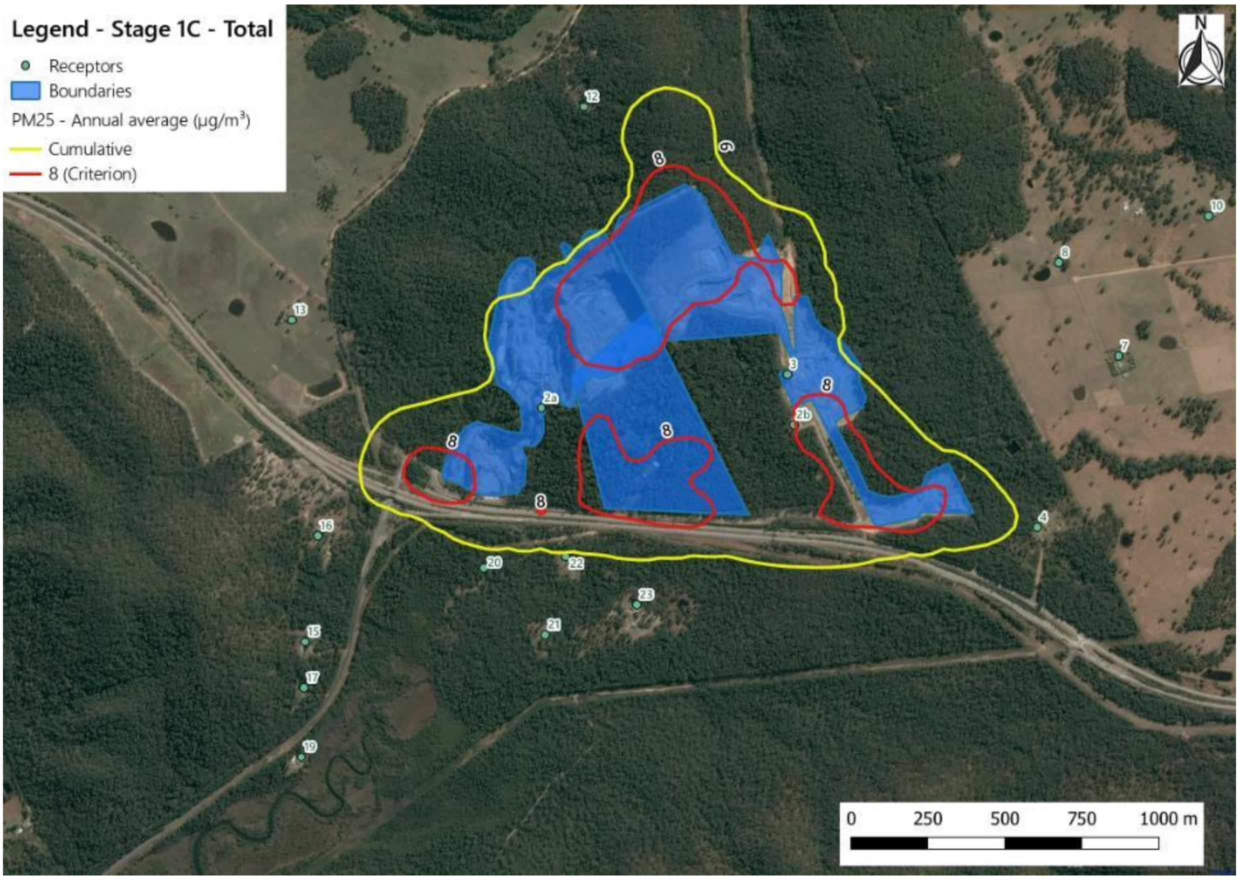


Figure 33
Predicted Cumulative Annual Average $PM_{2.5}$ Concentrations – Stage 1C



Presented in **Table 36** are dispersion model predictions of annual average dust deposition rates. The maximum predicted increment resulting from the Stage 1C operations is predicted to be 0.2 $g \cdot m^{-2} \cdot month^{-1}$ at receptor 22 which represents <9 % of the annual average incremental dust deposition criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of dust deposition during Stage 1C operations being <78 % of the cumulative criterion.

Table 36
Predicted Annual Average Dust Deposition Rates– Stage 1C

Receptor	Cumulative Impact	Annual Average Dust Deposition Rate ($g \cdot m^{-2} \cdot month^{-1}$)			
		KSQ	**KEQ**	**KQ**	**BG**
23	2.5	0.1	0.3	0.1	2.0
22	3.1	0.2	0.7	0.2	2.0
20	2.7	0.1	0.4	0.2	2.0
16	2.5	<0.1	0.2	0.3	2.0
15	2.2	<0.1	0.1	0.1	2.0
7	2.2	<0.1	0.1	<0.1	2.0
12	2.2	<0.1	0.1	0.1	2.0
13	2.2	<0.1	0.1	0.1	2.0
8	2.2	<0.1	0.1	<0.1	2.0
10	2.1	<0.1	<0.1	<0.1	2.0
21	2.3	<0.1	0.2	0.1	2.0
17	2.1	<0.1	0.1	<0.1	2.0
19	2.1	<0.1	<0.1	<0.1	2.0
2a	8.4	0.5	0.4	5.6	2.0
2b	6.7	0.2	4.4	0.1	2.0
4	2.7	<0.1	0.6	<0.1	2.0
3	3.9	0.1	1.7	0.1	2.0
Criterion	4	2	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Figure 34 and **Figure 35** present the annual average incremental (Karuah South Quarry, Stage 1C) and cumulative (all quarries plus background) dust deposition rate isopleth plots, respectively.

Figure 34
Predicted Incremental Annual Average Dust Deposition Rate – Stage 1C

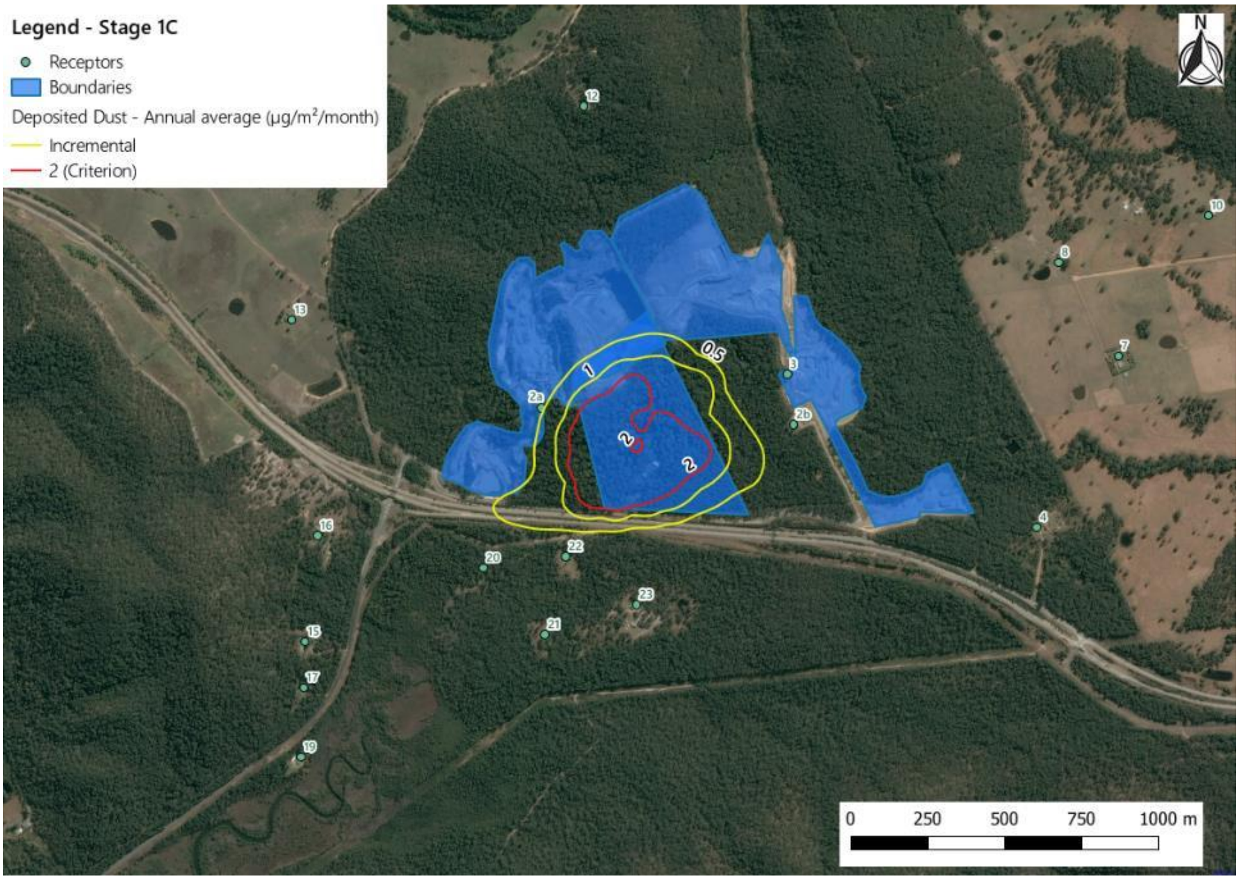
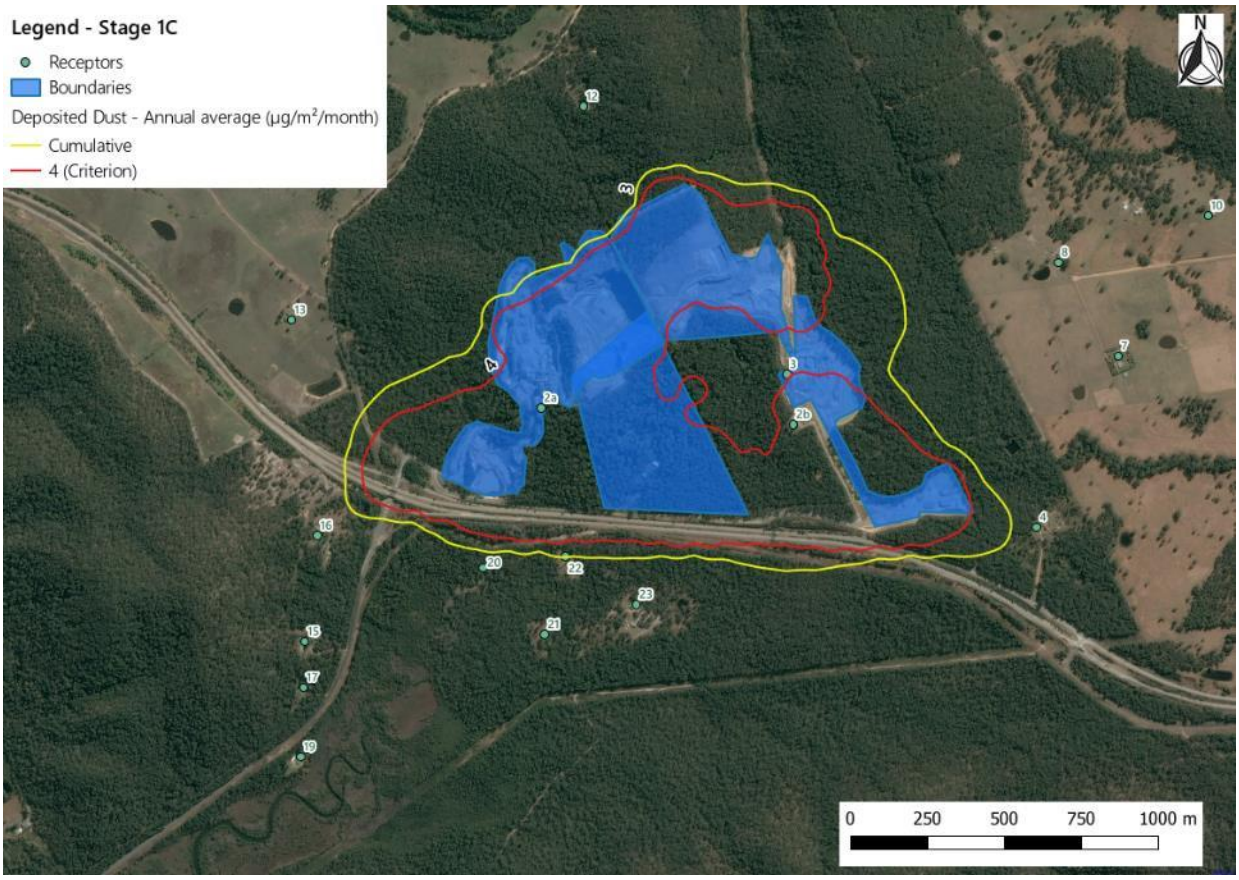


Figure 35
Predicted Cumulative Annual Average Dust Deposition Rate – Stage 1C



Presented in **Table 37** are dispersion model predictions of annual average NO_2 concentrations. The maximum predicted increment resulting from Stage 1C operations is predicted to be <0.1 µg·m^{-3} which represents <1 % of the annual average NO_2 criterion.

The addition of the predicted impact of background air quality results in total cumulative impacts of NO_2 during Stage 1C operations being <27 % of the criterion.

Table 37
Predicted Annual Average NO_2 Concentrations – Stage 1C

Receptor	Cumulative Impact	Annual Average NO_2 Concentration ($\mu g \cdot m^{-3}$)			
		KSQ	KEQ	KQ	BG
23	16.4	<0.1	<0.1	<0.1	16.4
22	16.5	<0.1	<0.1	<0.1	16.4
20	16.4	<0.1	<0.1	<0.1	16.4
16	16.4	<0.1	<0.1	<0.1	16.4
15	16.4	<0.1	<0.1	<0.1	16.4
7	16.5	<0.1	<0.1	<0.1	16.4
12	16.5	<0.1	<0.1	<0.1	16.4
13	16.4	<0.1	<0.1	<0.1	16.4
8	16.5	<0.1	<0.1	<0.1	16.4
10	16.4	<0.1	<0.1	<0.1	16.4
21	16.4	<0.1	<0.1	<0.1	16.4
17	16.4	<0.1	<0.1	<0.1	16.4
19	16.4	<0.1	<0.1	<0.1	16.4
2a	16.6	<0.1	<0.1	<0.1	16.4
2b	16.5	<0.1	<0.1	<0.1	16.4
4	16.4	<0.1	<0.1	<0.1	16.4
3	16.5	<0.1	<0.1	<0.1	16.4
Criterion	62	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background

Given the predicted low incremental impacts, no concentration isopleth plots associated with annual average NO_2 impacts during Stage 1C of operations are provided.

6.3.2 Stage 1C Maximum 24-hour Average PM_{10} and $PM_{2.5}$

In the case of maximum 24-hour average predictions, all criteria (impact assessment and voluntary land acquisition and mitigation criteria) are predicted to be met at surrounding residential locations during Stage 1C operations, with the exception of maximum 24-hour average PM_{10} at receptor 16.

Presented in **Table 38** are dispersion model predictions of maximum cumulative 24-hour average PM_{10} concentrations. The maximum predicted contribution to the maximum cumulative PM_{10} impact resulting from Stage 1C operations is predicted to be 17.5 $\mu g \cdot m^{-3}$, at receptor 23. This represents <35 % of the maximum 24-hour average PM_{10} criterion.

On the day of maximum predicted cumulative impact at all modelled receptors, the 24-hour average PM_{10} criterion is predicted to be achieved at all receptors except receptor 16, with the addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality resulting in total cumulative impacts of PM_{10} during Stage 1C operations being <97 % of the criterion and <102% of the criterion at receptor 16.

Table 38
Predicted Maximum 24-hour Average Cumulative PM_{10} Concentrations – Stage 1C

Receptor	Maximum 24-hour PM_{10} Concentration ($\mu g \cdot m^{-3}$)				
	Cumulative Impact	KSQ	KEQ	KQ	BG
23	48.2	17.5	4.9	0.9	24.8
22	43.7	9.4	4.1	2.1	28.1
20	46.0	15.5	5.6	<0.1	24.9
16	**50.8**	4.7	5.6	15.6	24.9
15	37.6	5.7	4.5	2.5	24.9
7	37.6	<0.1	0.1	<0.1	37.5
12	37.5	0.0	<0.1	<0.1	37.5
13	38.2	1.1	0.8	0.7	35.5
8	37.5	<0.1	<0.1	<0.1	37.5
10	37.5	<0.1	<0.1	<0.1	37.5
21	38.3	3.1	1.0	1.4	32.8
17	37.5	<0.1	<0.1	<0.1	37.5
19	37.5	<0.1	<0.1	<0.1	37.5
2a	**86.8**	28.8	4.7	43.8	9.4
2b	**92.2**	<0.1	**84.3**	<0.1	7.9
4	48.7	9.1	31.3	4.4	4.0
3	**91.9**	1.9	**79.2**	1.6	9.1
Criterion	50	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background
The maximum cumulative impact is presented, with the contributions from each quarry operation on the day of maximum impact presented. Maximum incremental impacts associated with the Karuah South Quarry are presented in the following table.

The predicted minor exceedance at receptor 16 is examined further, as required by the SEARs (refer **Table 1**). Time series of predicted 24-hour average PM_{10} concentrations at receptor 16 are presented in **Figure 36** for impacts resulting from the operation of Stage 1C only. Time series of impacts resulting from Stage 1C operation, plus background, plus the impact of Karuah East and Karuah Quarries are presented in **Figure 37**. A frequency distribution plot of incremental (Karuah South, Karuah East and Karuah Quarries), background and cumulative impacts at receptor 16 is presented in **Figure 38.**

The time series of predicted incremental impact at receptor 16 (**Figure 36**) indicates that concentrations of 24-hour PM_{10} vary between 0 µg·m^{-3} and 10.1 µg·m^{-3}. The average 24-hour PM_{10} concentration over the modelled year is predicted to be 0.6 µg·m^{-3}. Through examination of **Figure 37** which also includes the impact of other quarry operations and the existing background air quality, the impact resulting from the Karuah South Quarry can be seen to be minor.

The frequency distribution plot presented in **Figure 38** for impacts predicted at receptor 16 shows that for the Karuah South Quarry (and all quarries), the majority of impacts over 24-hour averaging periods are predominantly within the 0 µg·m^{-3} to 5 µg·m^{-3} range (97.8 % of predicted impacts [357 / 365] are in this range at receptor 16 resulting from operations during Stage 1C). Impacts from the Karuah Quarry, and more importantly the existing background air quality are shown to more greatly increase the risk of exceedance of the 24-hour average PM_{10} criterion at receptor 16. It is these impacts which are the driver for the predicted exceedance.

Notwithstanding this conclusion, the maximum predicted incremental 24-hour average PM_{10} concentrations resulting from activities during Stage 1C of operations are presented in **Table 39**. These predictions indicate that the activities during Stage 1C could potentially result in incremental impacts up to 23.1 µg·m^{-3} at receptor 22, which represents <47 % of the relevant criterion. It is important to note that the model predictions indicate that even during these periods of elevated 24-hour PM_{10} impacts at all receptors except receptor 16, no exceedance of the maximum 24-hour average PM_{10} criterion are predicted.

To ensure that these short-term elevations in incremental PM_{10} concentrations do not result in exceedances of the criterion at surrounding residential locations, a real-time air quality monitoring program will be implemented. This program, and the air quality management measures which are informed by those monitoring results, is described in detail in Section 8.

Figure 36
24-hour Average PM_{10} Concentrations, Receptor 16, Stage 1C – Karuah South Quarry Only

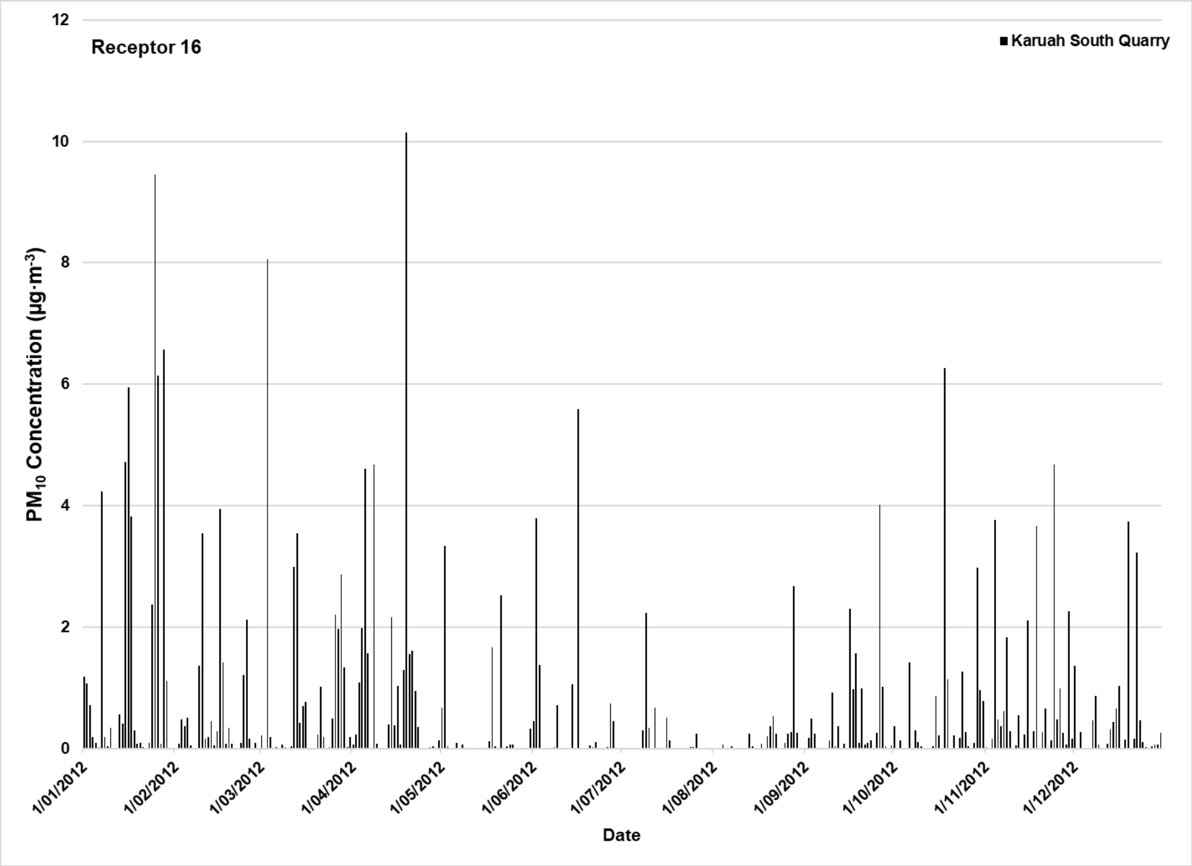


Figure 37
24-hour Average PM_{10} Concentrations, Receptor 16, Stage 1C – All Impacts

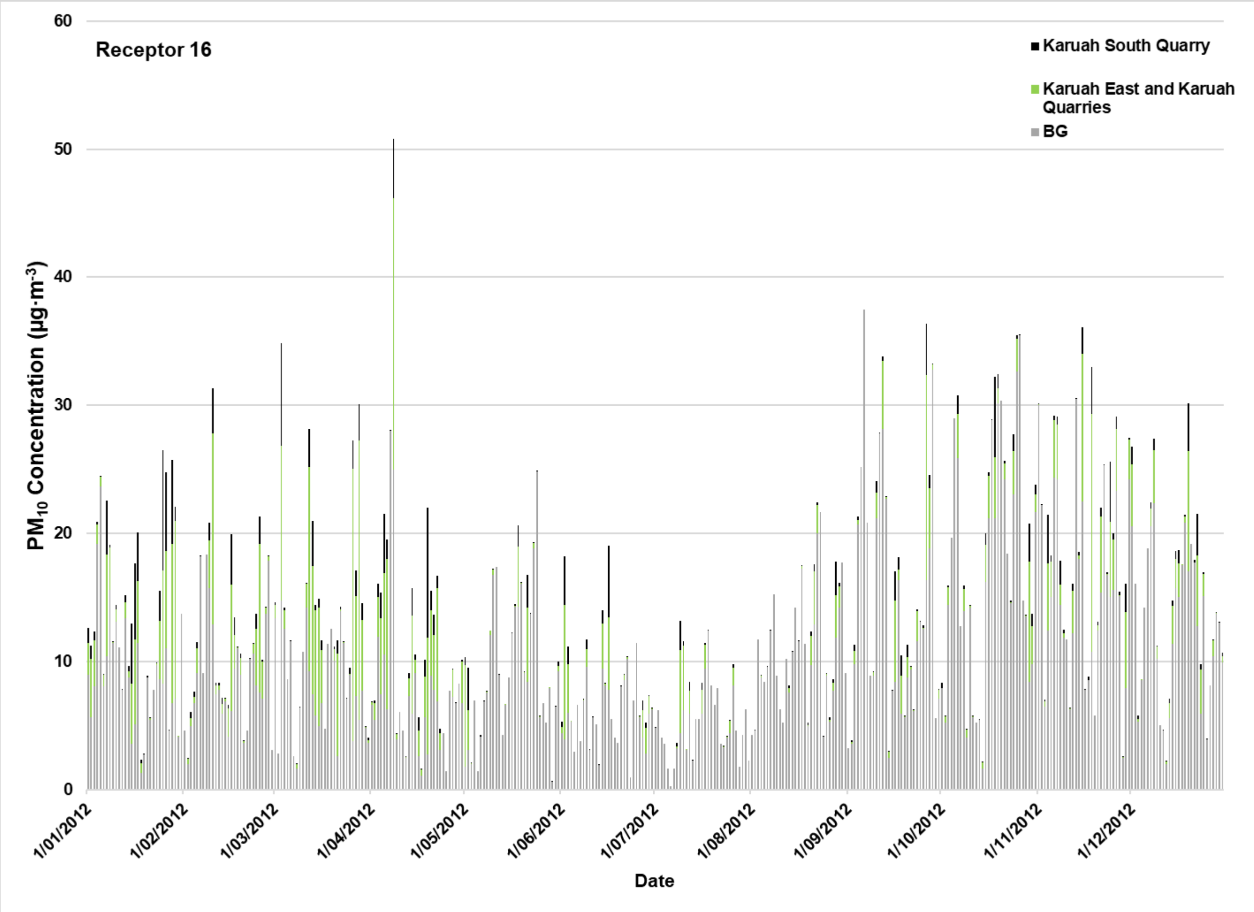
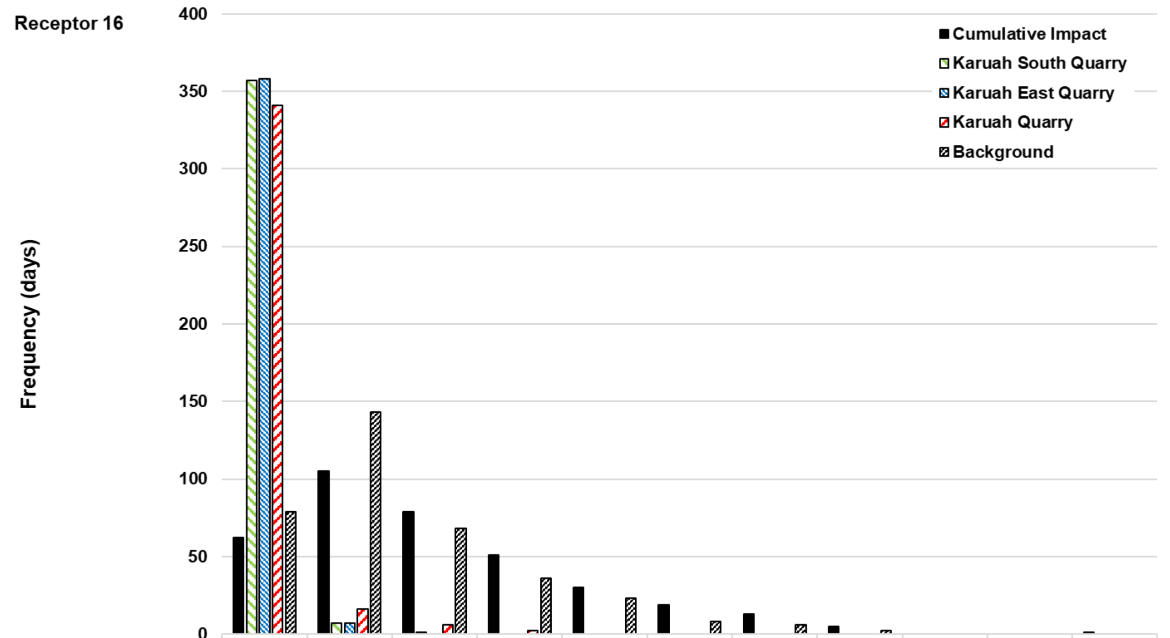


Figure 38
Frequency Distribution of 24-hour Average PM_{10} Concentrations, Receptor 16, Stage 1C – All Impacts



	0 - 5	5.01 - 10	10.01 - 15	15.01 - 20	20.01 - 25	25.01 - 30	30.01 - 35	35.01 - 40	40.01 - 45	45.01 - 50	50.01 - 55
Cumulative Impact	62	105	79	51	30	19	13	5	0	0	1
Karuah South Quarry	357	7	1	0	0	0	0	0	0	0	0
Karuah East Quarry	358	7	0	0	0	0	0	0	0	0	0
Karuah Quarry	341	16	6	2	0	0	0	0	0	0	0
Background	79	143	68	36	23	8	6	2	0	0	0

PM_{10} Concentration ($\mu g \cdot m^{-3}$)

Table 39

Predicted Maximum 24-hour Average Incremental PM_{10} Concentrations – Stage 1C

Receptor	Maximum Incremental 24-hour PM_{10} Concentration ($\mu g \cdot m^{-3}$) Karuah South Quarry
23	17.5
22	23.1
20	20.2
16	10.1
15	7.2
7	3.6
12	6.8
13	7.0
8	3.4
10	2.2
21	9.5
17	6.8
19	3.3
2a	48.8
2b	22.1
4	9.1
3	13.7

Figure 39 and **Figure 40** present the maximum 24-hour average incremental (Karuah South Quarry, Stage 1C) and cumulative (all quarries plus background) PM_{10} concentration isopleth plots, respectively.

Figure 39
Predicted Incremental Maximum 24-hour Average PM_{10} Concentrations – Stage 1C

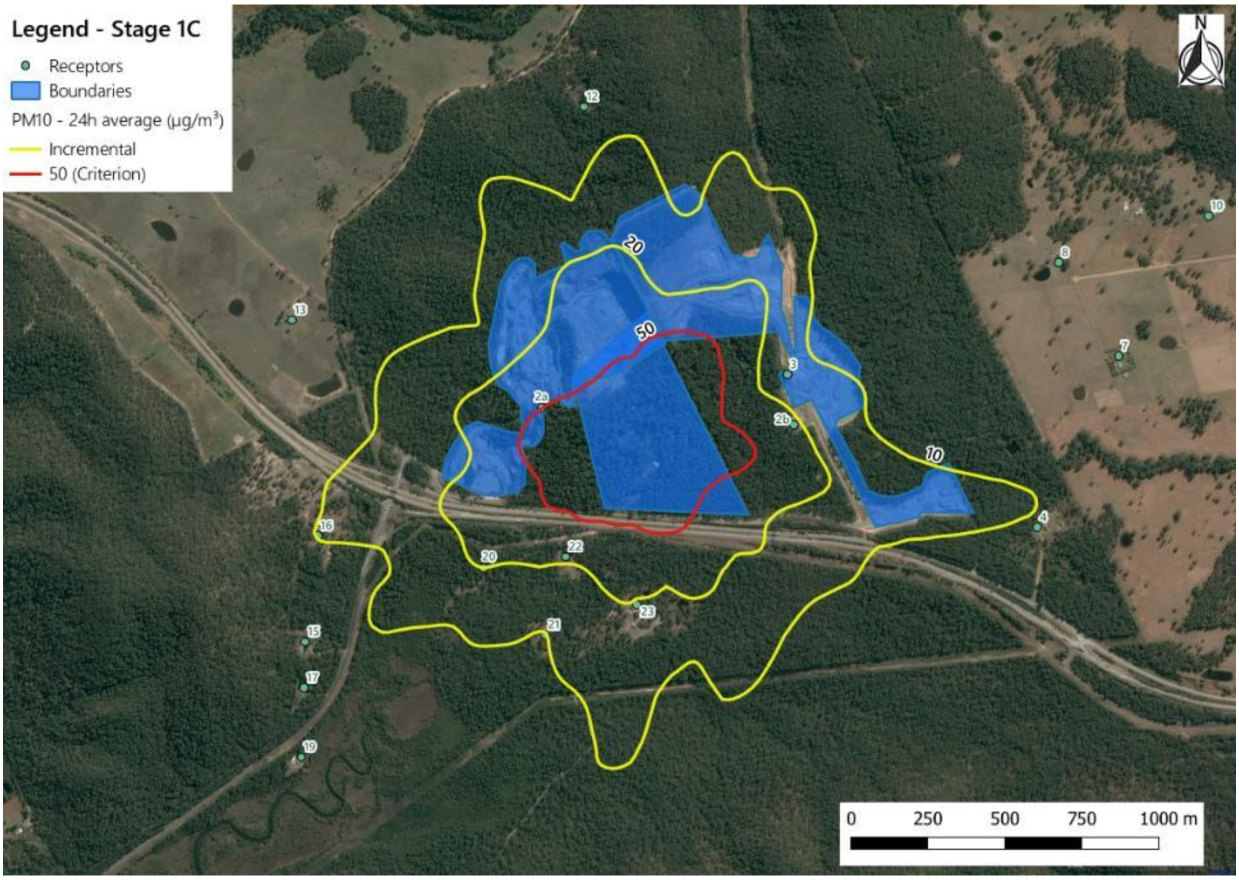
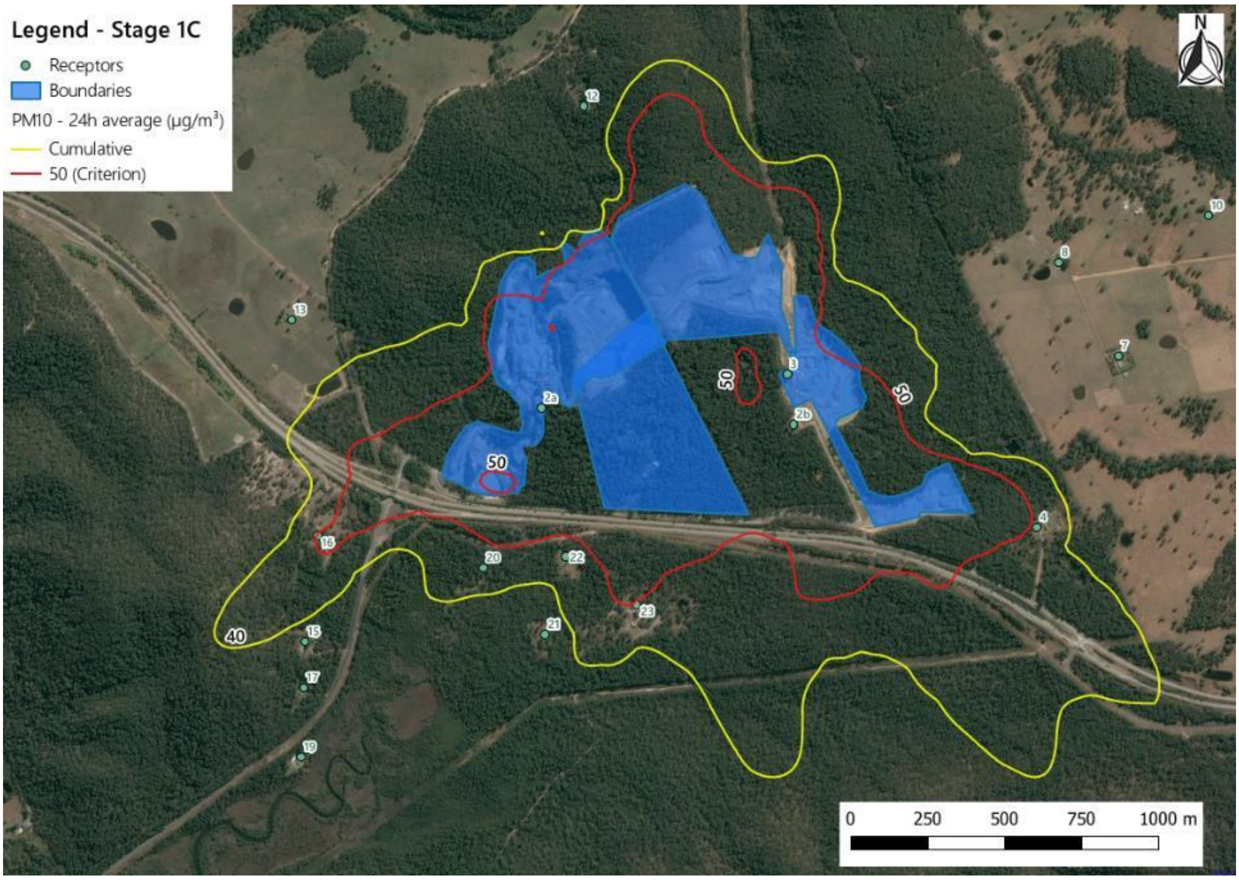


Figure 40
Predicted Cumulative Maximum 24-hour Average PM_{10} Concentrations – Stage 1C



Presented in **Table 40** are dispersion model predictions of maximum cumulative 24-hour average $PM_{2.5}$ concentrations during Stage 1C operations. The maximum predicted contribution to the maximum cumulative $PM_{2.5}$ impact resulting from Stage 1C operations is predicted to be 0.9 µg·m^{-3} at receptor 23. This represents <4 % of the maximum 24-hour average $PM_{2.5}$ criterion.

On the day of maximum predicted cumulative impact at all modelled receptors, the 24-hour average $PM_{2.5}$ criterion is predicted to be achieved, with the addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality resulting in total cumulative impacts of $PM_{2.5}$ during Stage 1C operations being <72 % of the criterion.

Table 40
Predicted Maximum 24-hour Average Cumulative $PM_{2.5}$ Concentrations – Stage 1C

Receptor	Maximum 24-hour $PM_{2.5}$ Concentration (µg·m^{-3})				
	Cumulative Impact	KSQ	KEQ	KQ	BG
23	17.6	0.9	0.4	0.1	16.2
22	17.9	0.8	0.6	0.3	16.2
20	17.7	0.4	0.5	0.7	16.2
16	16.3	<0.1	<0.1	0.1	16.2
15	16.3	<0.1	<0.1	<0.1	16.2
7	16.2	<0.1	<0.1	<0.1	16.2
12	16.2	<0.1	<0.1	<0.1	16.2
13	16.2	<0.1	<0.1	<0.1	16.2
8	16.2	<0.1	<0.1	<0.1	16.2
10	16.2	<0.1	<0.1	<0.1	16.2
21	17.1	0.5	0.2	0.2	16.2
17	16.3	<0.1	<0.1	<0.1	16.2
19	16.3	<0.1	<0.1	0.1	16.2
Criterion	25	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KQ = Karuah Quarry, BG = background
The maximum cumulative impact is presented, with the contributions from each quarry operation on the day of maximum impact presented. Maximum incremental impacts associated with the Karuah South Quarry are presented in the following table.

The maximum predicted incremental 24-hour average $PM_{2.5}$ concentrations resulting from activities during Stage 1C are presented in **Table 41**. These predictions indicate that the activities during Stage 1C operations could potentially result in incremental impacts up to 3.5 µg·m^{-3} at the modelled receptor locations, which represents <14 % of the relevant criterion.

Table 41
Predicted Maximum 24-hour Average Incremental $PM_{2.5}$ Concentrations – Stage 1C

Receptor	Maximum Incremental 24-hour $PM_{2.5}$ Concentration (µg·m^{-3}) Karuah South Quarry
23	2.4
22	3.5
20	2.9
16	1.4
15	1.0
7	0.5
12	0.9
13	1.0
8	0.5
10	0.3
21	1.3
17	1.0
19	0.6

Figure 41 and **Figure 42** present the maximum 24-hour average incremental (Karuah South Quarry, Stage 1C) and cumulative (all quarries plus background) $PM_{2.5}$ concentration isopleth plots, respectively.

Figure 41
Predicted Incremental Maximum 24-hour Average $PM_{2.5}$ Concentrations – Stage 1C

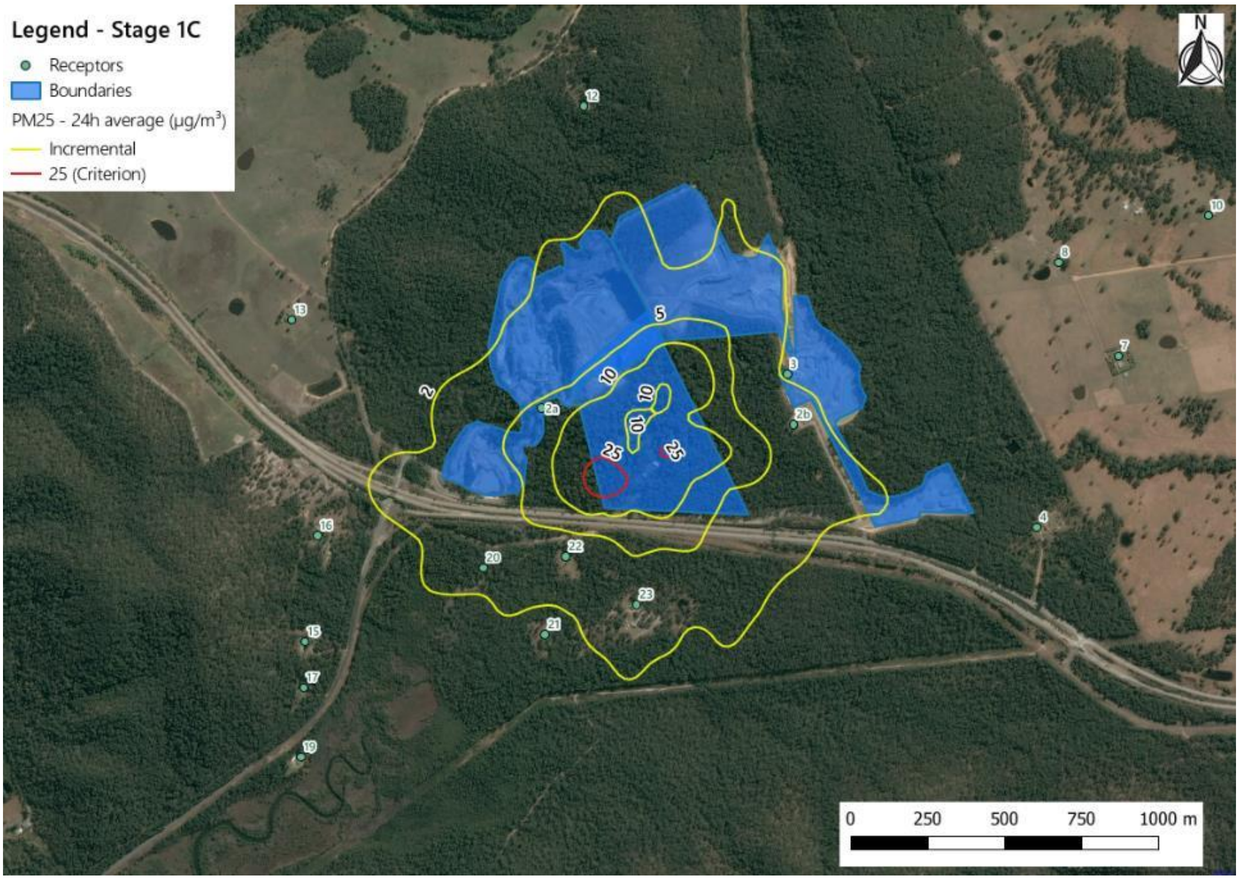
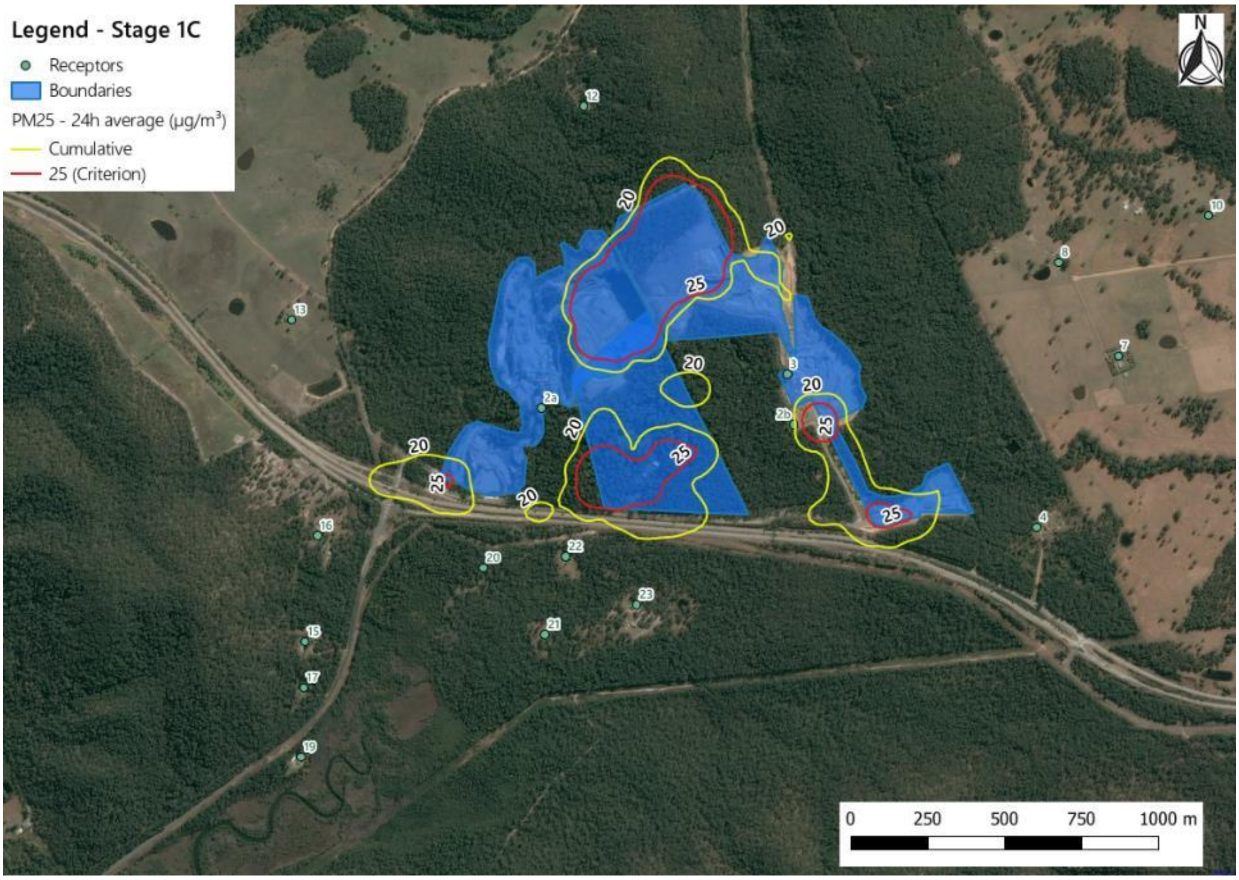


Figure 42
Predicted Cumulative Maximum 24-hour Average $PM_{2.5}$ Concentrations – Stage 1C



6.3.3 Stage 1C Maximum 1-hour Average NO_2

In the case of maximum 1-hour average predictions of NO_2, the impact assessment criterion is predicted to be met at surrounding residential locations during Stage 1C operations. Concentrations of NO_2 have been predicted using 100% conversion of NO to NO_2 method as outlined in **Annexure 2**.

No cumulative impacts (other than the addition of background air quality) have been assessed, as it has been assumed that simultaneous blasting at surrounding sites would not occur.

Presented in **Table 42** are dispersion model predictions of maximum cumulative 1-hour average NO_2 concentrations. The maximum predicted cumulative 1-hour impact resulting from Stage 1C operations is predicted to be 79.5 $\mu g{\cdot}m^{-3}$, at receptor 22. This represents <33 % of the maximum 1-hour average NO_2 criterion.

Table 42
Predicted Maximum 1-hour Average NO_2 Concentrations – Stage 1C

Receptor	Maximum 1-hour Average NO_2 Concentration ($\mu g \cdot m^{-3}$)	
	Cumulative	**KSQ**
23	7.4	77.1
22	9.8	79.5
20	5.0	74.7
16	5.8	75.5
15	4.1	73.8
7	3.2	72.9
12	7.1	76.8
13	2.9	72.6
8	8.2	77.9
10	2.5	72.2
21	5.5	75.2
17	3.4	73.1
19	1.9	71.6
2a	30.1	99.8
2b	15.6	85.3
4	3.6	73.3
3	21.7	91.4
Criterion	246	-

Note: KSQ = Karuah South Quarry, Cumul = cumulative

Figure 43 presents the maximum 1-hour average incremental NO_2 concentration isopleth plot with **Figure 44** presenting the maximum 1-hour average cumulative (increment plus background) NO_2 concentration isopleth plot.

The dispersion model predictions assume that blasting occurs on each operating hour of the year where in reality, blasting would only likely occur on 18 hours in the year. The implementation of a blast management plan would ensure that no blasting would occur when winds are blowing (or likely to blow) in the direction of the nearest sensitive receptors. The predicted concentrations of NO_2 can therefore be considered to be highly conservative. Should the blast management plan be implemented and operated effectively, no exceedances of the short-term NO_2 criterion would be likely at any surrounding receptor location.

Figure 43
Predicted Incremental Maximum 1-hour Average NO_2 Concentrations – Stage 1C

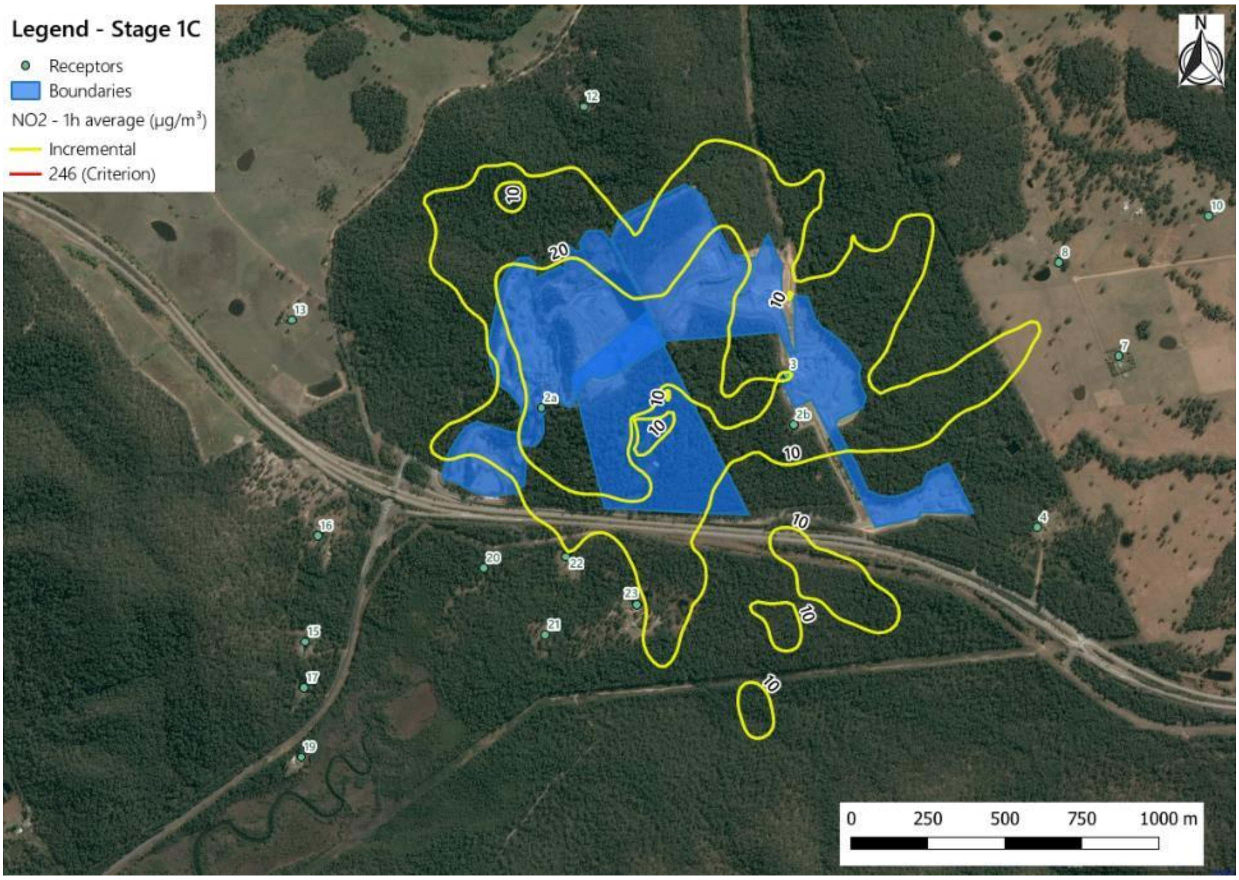
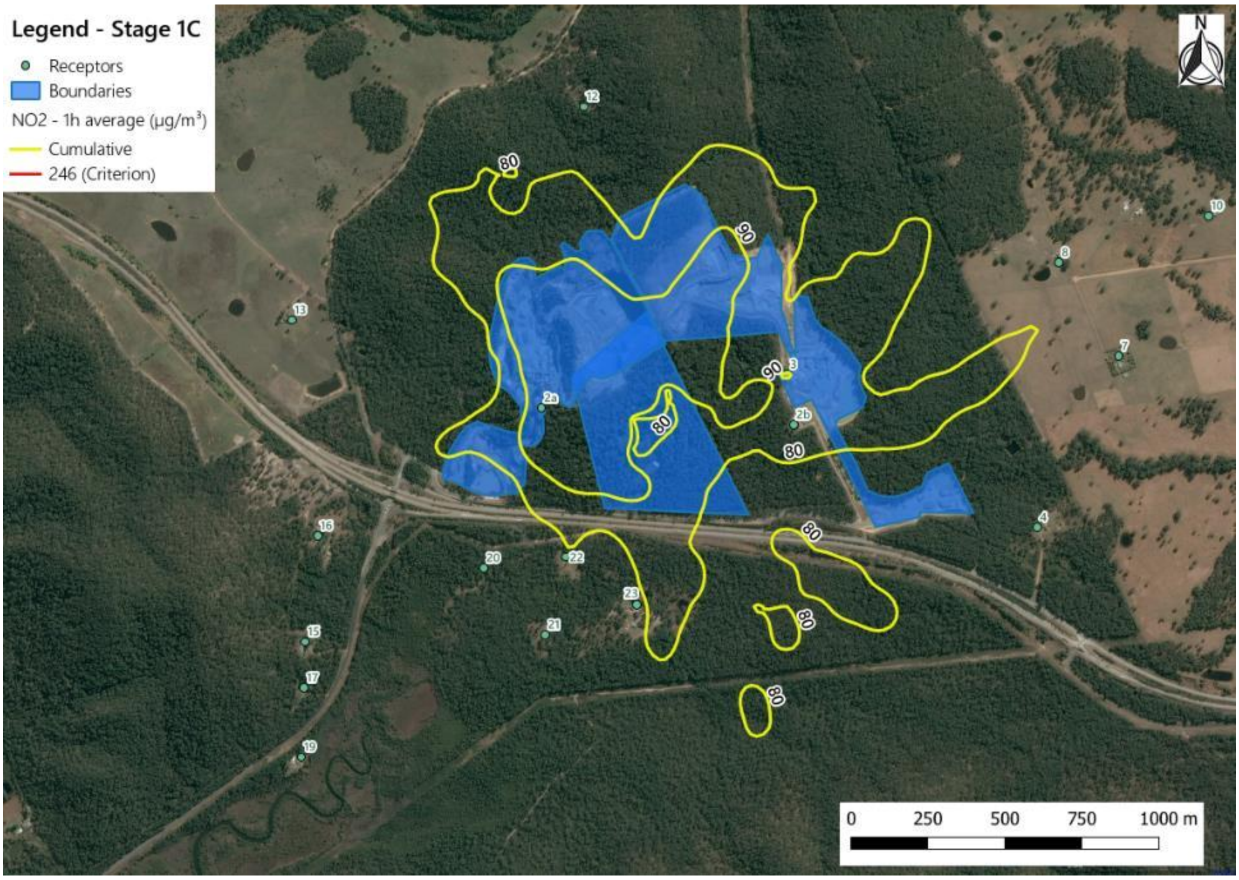


Figure 44
Predicted Cumulative Maximum 1-hour Average NO_2 Concentrations – Stage 1C



6.3.4 Stage 2B Annual Average TSP, PM_{10}, $PM_{2.5}$ and NO_2

In the case of annual average predictions, all criteria (impact assessment and voluntary land acquisition and mitigation criteria) are predicted to be met at surrounding residential locations during Stage 2B of operations. Contributions from these activities are shown in all cases to result in minor / minimal impact at all receptor locations.

Presented in **Table 43** are dispersion model predictions of annual average TSP concentrations. The maximum predicted increment resulting from Stage 2B operations is predicted to be 3.7 $\mu g \cdot m^{-3}$, at receptor 22. This represents <5 % of the annual average TSP criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of TSP during Stage 2B operations being <36 % of the criterion.

Note that impacts associated with the Karuah Red Quarry reflect extraction operations at Karuah Red and processing operations at the existing Karuah Quarry.

Table 43
Predicted Annual Average TSP Concentrations – Stage 2B

Receptor	**Cumulative Impact**	**Annual Average TSP Concentration (µg·m^{-3})**			
		KSQ	**KEQ**	**KRQ**	**BG**
23	26.5	1.7	5.1	0.2	19.5
22	32.1	3.7	8.5	0.5	19.5
20	27.6	2.1	5.5	0.6	19.5
16	23.4	0.9	2.4	0.6	19.5
15	21.8	0.7	1.5	0.2	19.5
7	22.8	0.4	2.9	0.1	19.5
12	23.6	0.9	2.8	0.4	19.5
13	22.1	0.7	1.4	0.5	19.5
8	22.9	0.3	3.1	0.1	19.5
10	21.0	0.2	1.3	0.0	19.5
21	24.2	1.5	3.0	0.2	19.5
17	21.4	0.5	1.2	0.2	19.5
19	20.9	0.4	1.0	0.1	19.5
2a	39.6	11.7	5.4	3.0	19.5
2b	89.7	7.9	62.0	0.3	19.5
4	32.2	1.2	11.4	0.1	19.5
3	52.3	4.5	27.9	0.4	19.5
Criterion	90	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KRQ = Karuah Red Quarry (processing at Karuah Quarry), BG = background

Figure 45 and **Figure 46** present the annual average incremental (Karuah South Quarry, Stage 2B) and cumulative (all quarries plus background) TSP concentration isopleth plots, respectively.

Figure 45
Predicted Incremental Annual Average TSP Concentrations – Stage 2B

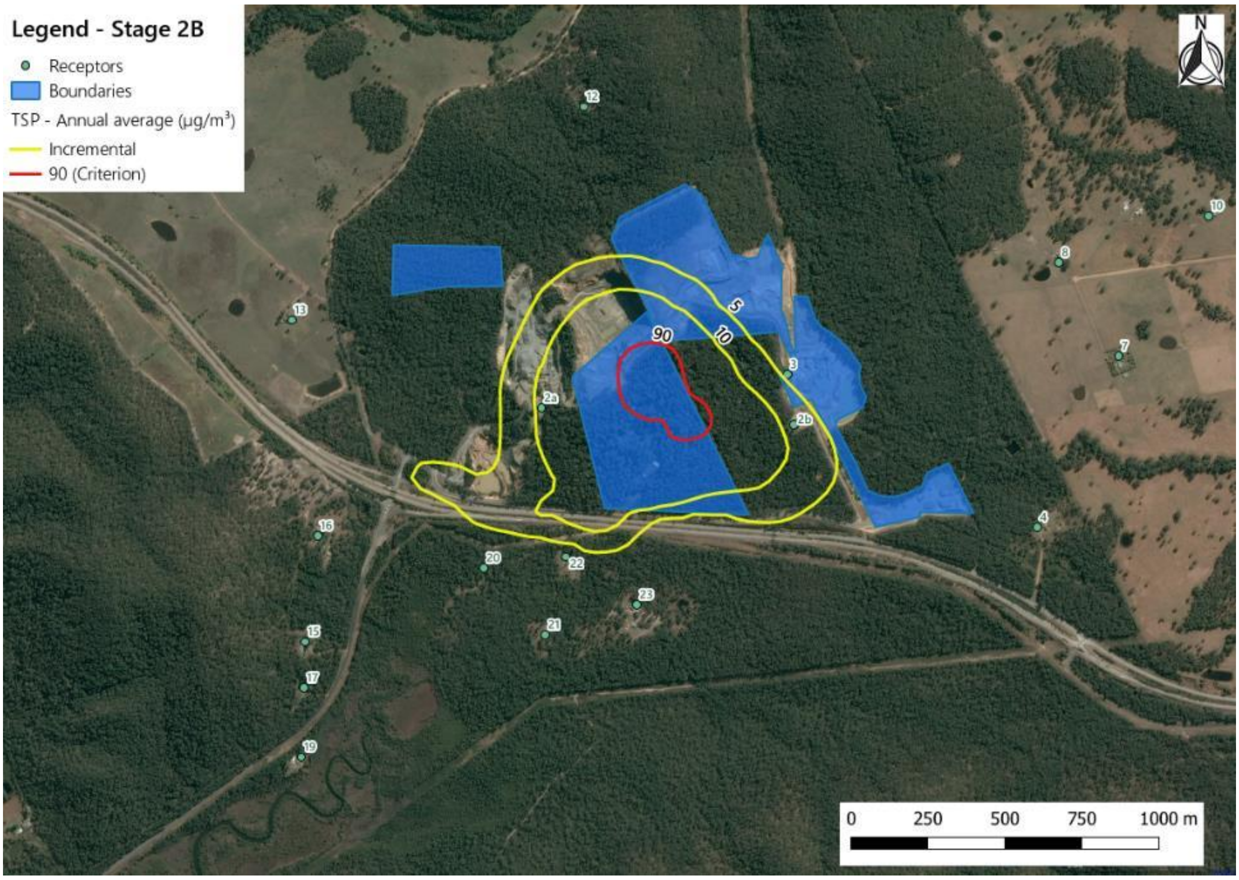
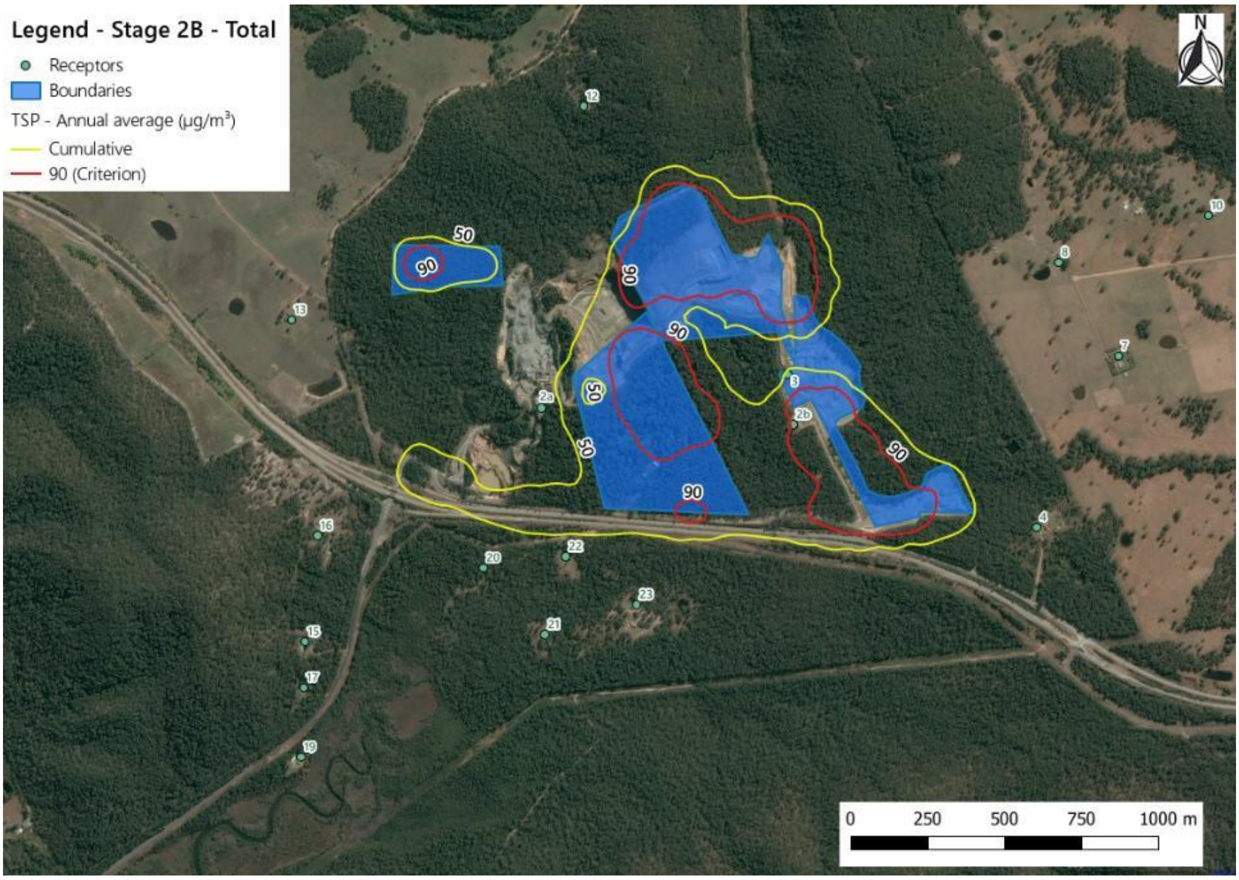


Figure 46
Predicted Cumulative Annual Average TSP Concentrations – Stage 2B



Presented in **Table 44** are dispersion model predictions of annual average PM_{10} concentrations. The maximum predicted increment resulting from the Stage 2B operations is predicted to be 1.8 $\mu g{\cdot}m^{-3}$ at receptor 22 which represents <8 % of the annual average PM_{10} criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of PM_{10} during Stage 2B operations being <62 % of the criterion.

Table 44
Predicted Annual Average PM_{10} Concentrations – Stage 2B

Receptor	Cumulative Impact	Annual Average PM_{10} Concentration ($\mu g \cdot m^{-3}$)			
		KSQ	**KEQ**	**KRQ**	**BG**
23	13.6	0.9	2.3	0.1	10.3
22	15.5	1.8	3.2	0.2	10.3
20	13.6	1.0	2.2	0.2	10.3
16	12.1	0.5	1.1	0.3	10.3
15	11.6	0.4	0.8	0.1	10.3
7	12.3	0.2	1.7	0.1	10.3
12	12.8	0.5	1.8	0.3	10.3
13	11.8	0.4	0.8	0.3	10.3
8	12.3	0.2	1.8	0.1	10.3
10	11.3	0.1	0.8	0.0	10.3
21	12.7	0.8	1.5	0.1	10.3
17	11.4	0.3	0.7	0.1	10.3
19	11.2	0.2	0.6	0.1	10.3
2a	19.8	4.9	2.7	1.9	10.3
2b	**37.9**	3.5	23.9	0.2	10.3
4	17.4	0.7	6.3	0.1	10.3
3	**26.1**	2.3	13.3	0.3	10.3
Criterion	25	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KRQ = Karuah Red Quarry (processing at Karuah Quarry), BG = background

Figure 47 and **Figure 48** present the annual average incremental (Karuah South Quarry, Stage 2B) and cumulative (all quarries plus background) PM_{10} concentration isopleth plots, respectively.

Figure 47
Predicted Incremental Annual Average PM_{10} Concentrations – Stage 2B

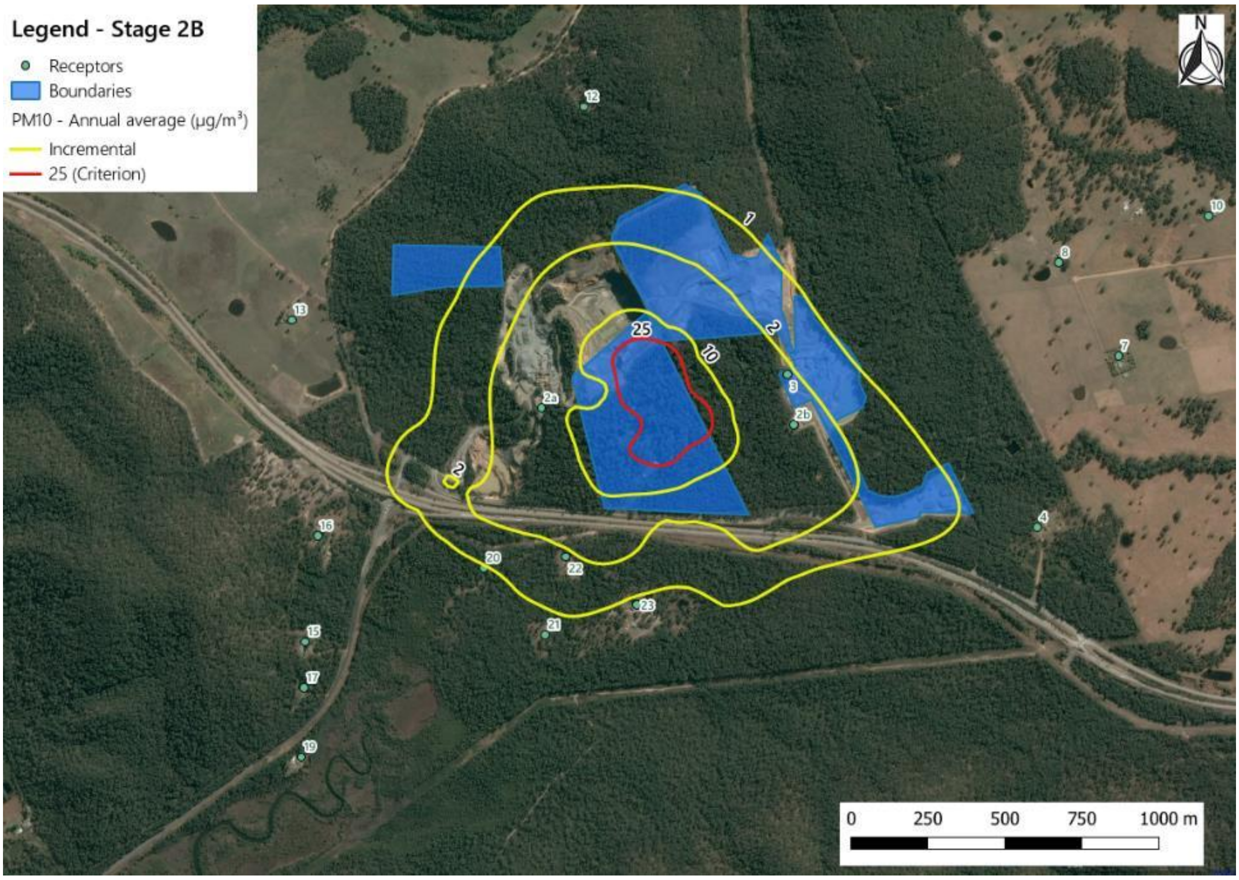
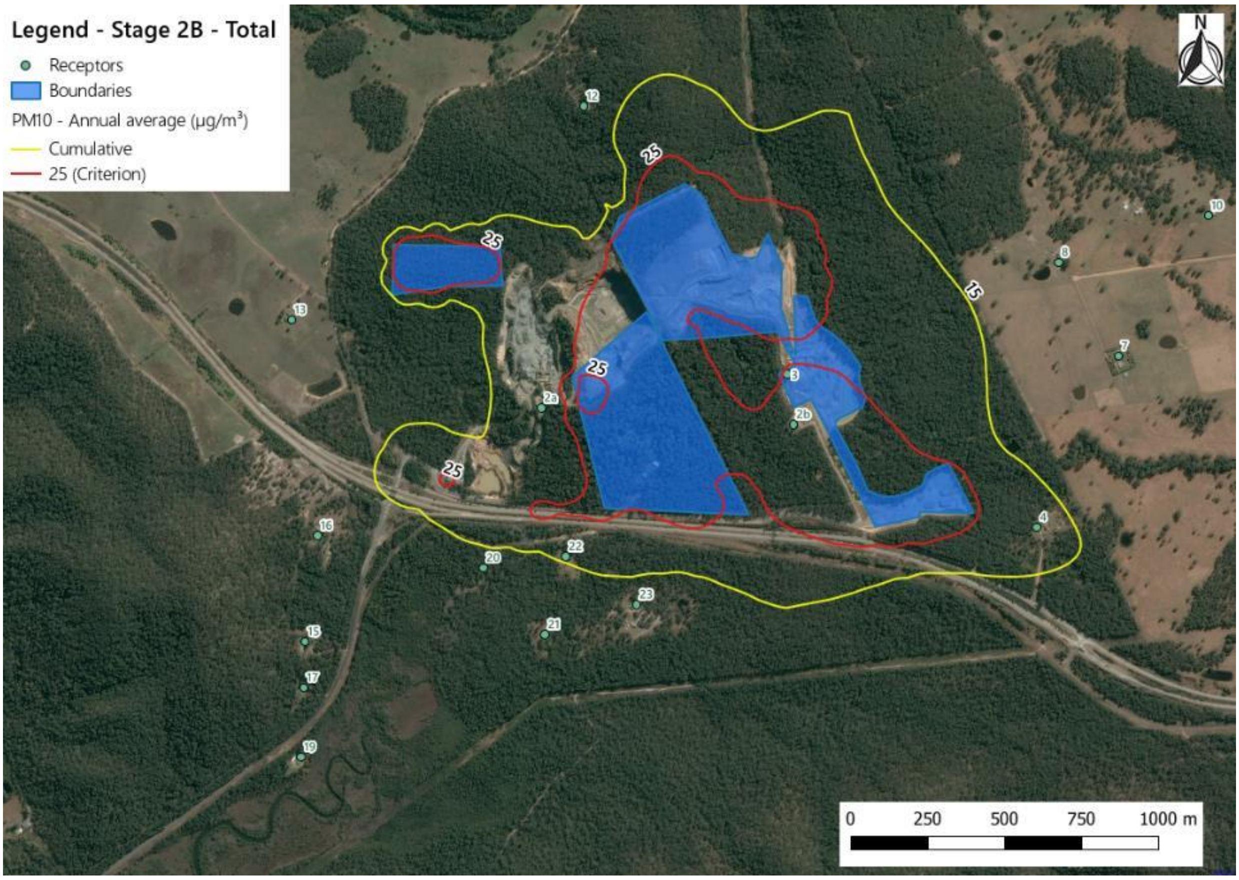


Figure 48
Predicted Cumulative Annual Average PM_{10} Concentrations – Stage 2B



Presented in **Table 45** are dispersion model predictions of annual average $PM_{2.5}$ concentrations. The maximum predicted increment resulting from the Stage 2B operations is predicted to be 0.3 µg·m^{-3} at receptor 22 which represents <4 % of the annual average $PM_{2.5}$ criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of $PM_{2.5}$ during Stage 2B operations being <77 % of the criterion.

Table 45
Predicted Annual Average $PM_{2.5}$ Concentrations – Stage 2B

Receptor	Cumulative Impact	Annual Average $PM_{2.5}$ Concentration (µg·m^{-3})			
		KSQ	KEQ	KRQ	BG
23	5.7	0.1	0.4	0.0	5.1
22	6.1	0.3	0.7	0.0	5.1
20	5.7	0.2	0.4	0.1	5.1
16	5.4	0.1	0.2	0.1	5.1
15	5.3	0.1	0.1	0.0	5.1
7	5.4	0.0	0.2	0.0	5.1
12	5.5	0.1	0.3	0.0	5.1
13	5.3	0.1	0.1	0.1	5.1
8	5.4	0.0	0.2	0.0	5.1
10	5.2	0.0	0.1	0.0	5.1
21	5.5	0.1	0.3	0.0	5.1
17	5.3	0.0	0.1	0.0	5.1
19	5.2	0.0	0.1	0.0	5.1
2a	6.5	0.7	0.5	0.3	5.1
2b	**8.4**	0.5	2.8	0.0	5.1
4	6.1	0.1	0.9	0.0	5.1
3	7.1	0.3	1.7	0.0	5.1
Criterion	8	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KRQ = Karuah Red Quarry (processing at Karuah Quarry), BG = background

Although not required by the SEARs, and not an applicable criterion in NSW, the VIC EPA SEPP PEM (VIC EPA, 2007) annual average criterion for respirable crystalline silica (as $PM_{2.5}$) of 3 µg·m^{-3} has been assessed. The maximum incremental concentration from the Karuah South Quarry Stage 2B operations (adjusted to account for the free silica content of extracted material [20%]) results in respirable crystalline silica impacts at all residential receptors being <0.1 µg·m^{-3}. With the impacts of all other quarries (and assuming that the existing background is silica free), the maximum cumulative impact is likely to be <0.2 µg·m^{-3} and well below the 3 µg·m^{-3} criterion.

Figure 49 and **Figure 50** present the annual average incremental (Karuah South Quarry, Stage 2B) and cumulative (all quarries plus background) $PM_{2.5}$ concentration isopleth plots, respectively.

Figure 49
Predicted Incremental Annual Average $PM_{2.5}$ Concentrations – Stage 2B

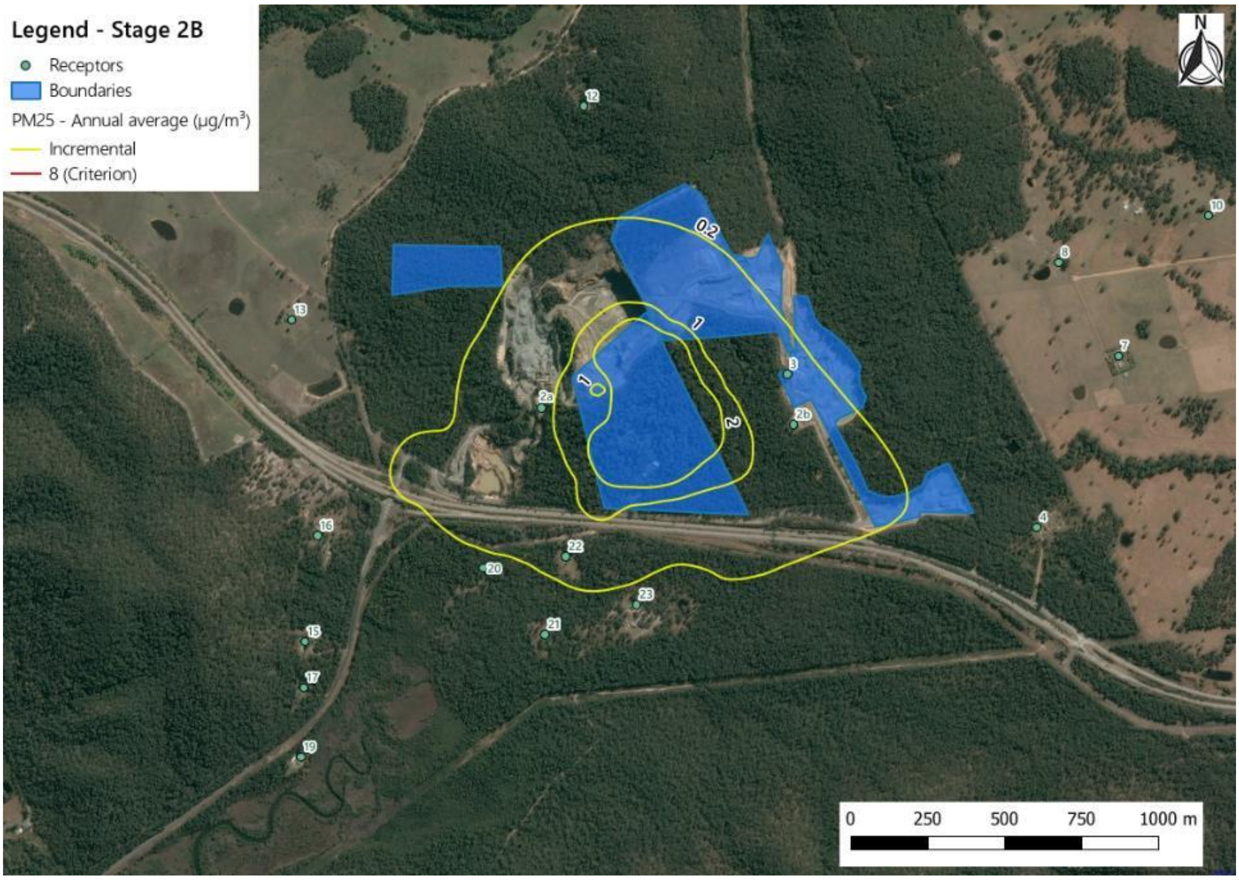
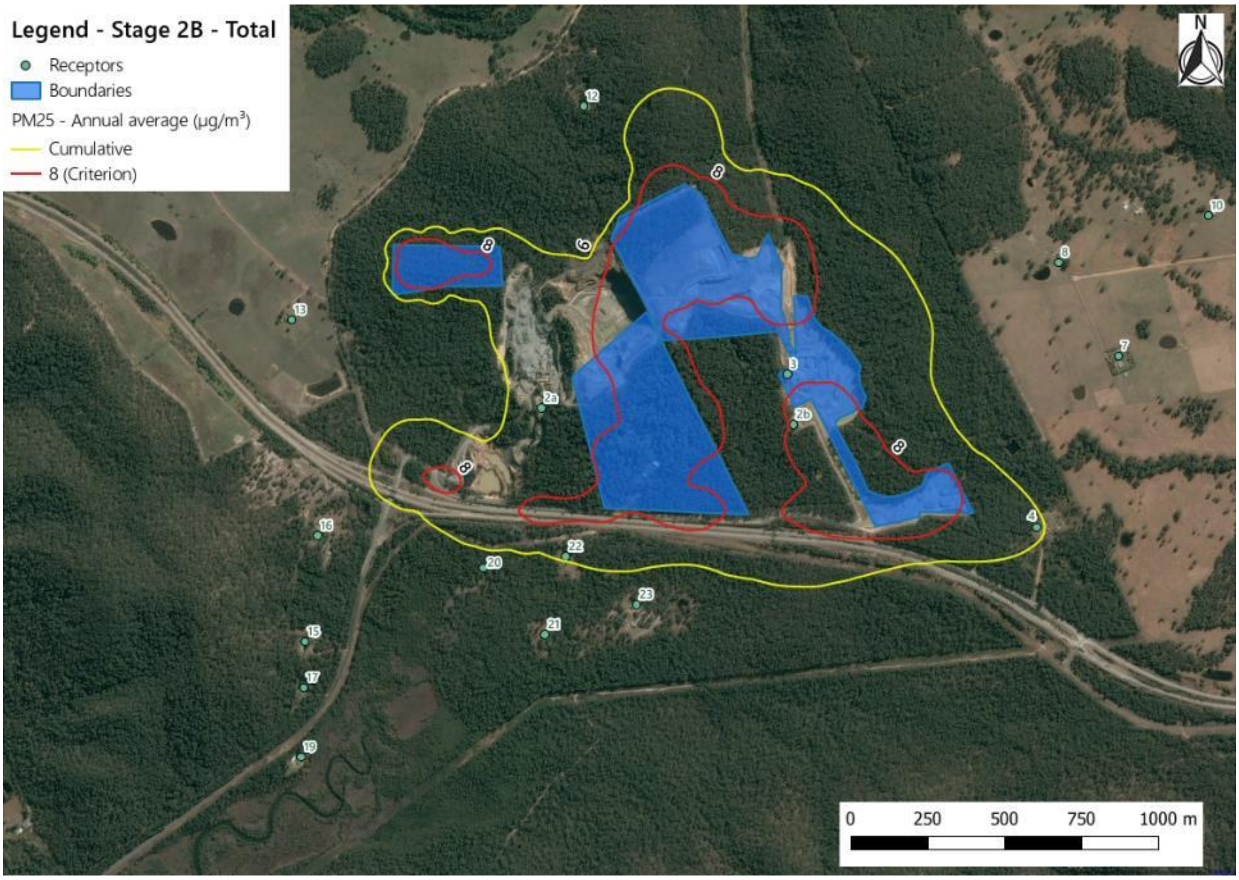


Figure 50
Predicted Cumulative Annual Average $PM_{2.5}$ Concentrations – Stage 2B



Presented in **Table 46** are dispersion model predictions of annual average dust deposition rates. The maximum predicted increment resulting from the Stage 2B operations is predicted to be 0.3 $g{\cdot}m^{-2}{\cdot}month^{-1}$ at receptor 22 which represents <16 % of the annual average incremental dust deposition criterion.

The addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality results in total cumulative impacts of dust deposition during Stage 2B operations being <84 % of the cumulative criterion.

Table 46
Predicted Annual Average Dust Deposition Rates– Stage 2B

Receptor	Cumulative Impact	Annual Average Dust Deposition Rate ($g \cdot m^{-2} \cdot month^{-1}$)			
		KSQ	KEQ	KRQ	BG
23	2.6	0.1	0.5	<0.1	2.0
22	3.4	0.3	1.0	<0.1	2.0
20	2.8	0.2	0.6	<0.1	2.0
16	2.4	0.1	0.3	0.1	2.0
15	2.2	0.1	0.1	<0.1	2.0
7	2.3	<0.1	0.3	<0.1	2.0
12	2.3	0.1	0.2	<0.1	2.0
13	2.2	0.1	0.1	<0.1	2.0
8	2.3	<0.1	0.3	<0.1	2.0
10	2.1	<0.1	0.1	<0.1	2.0
21	2.4	0.1	0.3	<0.1	2.0
17	2.2	0.1	0.1	<0.1	2.0
19	2.1	<0.1	0.1	<0.1	2.0
Criterion	4	2	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KRQ = Karuah Red Quarry (processing at Karuah Quarry), BG = background

Figure 51 and **Figure 52** present the annual average incremental (Karuah South Quarry, Stage 2B) and cumulative (all quarries plus background) dust deposition rate isopleth plots, respectively.

Figure 51
Predicted Incremental Annual Average Dust Deposition Rate – Stage 2B

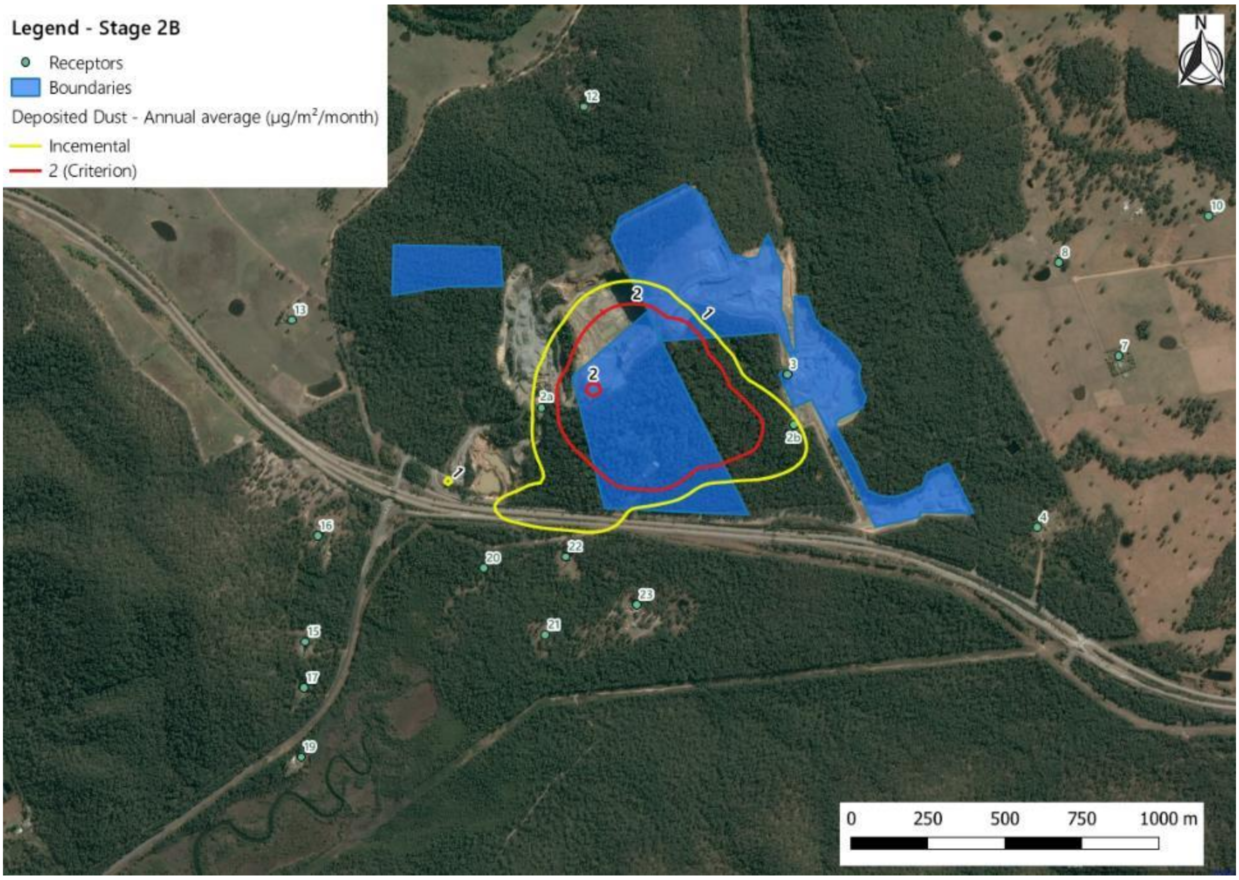
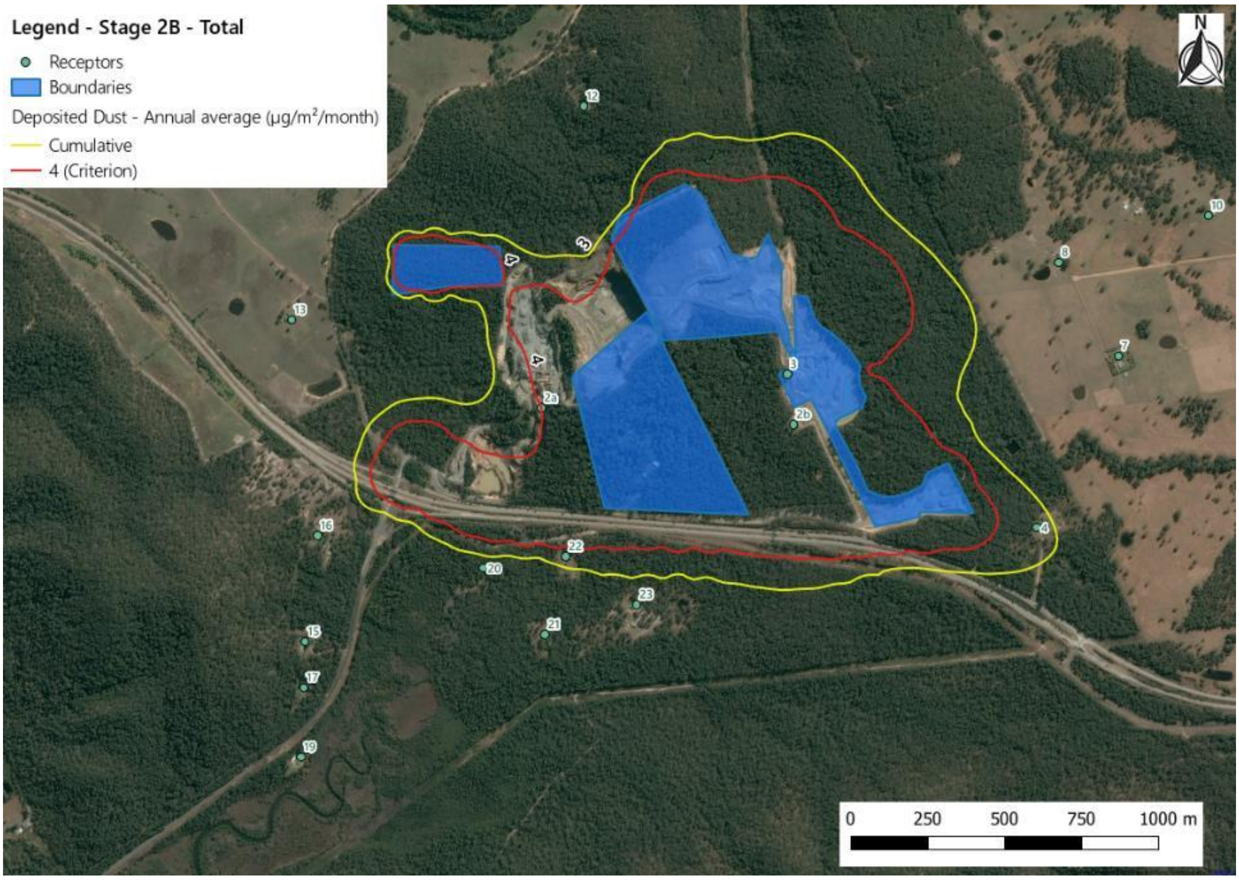


Figure 52
Predicted Cumulative Annual Average Dust Deposition Rate – Stage 2B



Presented in **Table 47** are dispersion model predictions of annual average NO_2 concentrations. The maximum predicted increment resulting from Stage 2B operations is predicted to be <0.1 µg·m^{-3} which represents <1 % of the annual average NO_2 criterion.

The addition of the predicted impact of background air quality results in total cumulative impacts of NO_2 during Stage 1C operations being <27 % of the criterion.

Table 47
Predicted Annual Average NO_2 Concentrations – Stage 2B

Receptor	Cumulative Impact	Annual Average NO_2 Concentration (µg·m^{-3})			
		KSQ	KEQ	KRQ	BG
23	16.4	<0.1	<0.1	<0.1	16.4
22	16.5	<0.1	<0.1	<0.1	16.4
20	16.4	<0.1	<0.1	<0.1	16.4
16	16.5	<0.1	<0.1	<0.1	16.4
15	16.4	<0.1	<0.1	<0.1	16.4
7	16.5	<0.1	<0.1	<0.1	16.4
12	16.5	<0.1	<0.1	0.1	16.4
13	16.5	<0.1	<0.1	0.1	16.4
8	16.5	<0.1	<0.1	<0.1	16.4
10	16.4	<0.1	<0.1	<0.1	16.4
21	16.4	<0.1	<0.1	<0.1	16.4
17	16.4	<0.1	<0.1	<0.1	16.4
19	16.4	<0.1	<0.1	<0.1	16.4
2a	16.7	<0.1	<0.1	<0.1	16.4
2b	16.5	<0.1	<0.1	<0.1	16.4
4	16.4	<0.1	<0.1	<0.1	16.4
3	16.6	<0.1	<0.1	<0.1	16.4
Criterion	62	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KRQ = Karuah Red Quarry, BG = background

Given the predicted low incremental impacts, no concentration isopleth plots associated with annual average NO_2 impacts during Stage 2B of operations are provided.

6.3.5 Stage 2B Maximum 24-hour Average PM_{10} and $PM_{2.5}$

In the case of maximum 24-hour average predictions, all criteria (impact assessment and voluntary land acquisition and mitigation criteria) are predicted to be met at surrounding residential locations during Stage 2B operations.

Presented in **Table 48** are dispersion model predictions of maximum cumulative 24-hour average PM_{10} concentrations. The maximum predicted contribution to the maximum cumulative PM_{10} impact resulting from Stage 2B operations is predicted to be 13.0 µg·m^{-3} at receptor 23. This represents <26 % of the maximum 24-hour average PM_{10} criterion.

On the day of maximum predicted cumulative impact at all modelled receptors, the 24-hour average PM_{10} criterion is predicted to be achieved at all receptors even with the addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality. Total cumulative impacts of PM_{10} during Stage 2B operations being <97 % of the criterion.

Table 48
Predicted Maximum 24-hour Average Cumulative PM_{10} Concentrations – Stage 2B

Receptor	Maximum 24-hour PM_{10} Concentration (µg·m^{-3})				
	Cumulative Impact	KSQ	KEQ	KRQ	BG
23	46.2	13.0	8.3	0.1	24.8
22	44.2	4.8	14.5	<0.1	24.9
20	48.3	12.5	10.7	0.1	24.9
16	42.4	6.1	8.8	2.6	24.9
15	40.7	7.5	8.0	0.3	24.9
7	37.7	<0.1	0.2	<0.1	37.5
12	37.6	6.1	7.4	0.4	23.6
13	39.4	2.3	1.4	0.2	35.5
8	37.5	<0.1	<0.1	<0.1	37.5
10	37.5	<0.1	<0.1	<0.1	37.5
21	39.4	5.0	1.4	0.2	32.8
17	38.1	6.5	6.6	0.1	24.9
19	37.5	<0.1	<0.1	<0.1	37.5
2a	**75.2**	44.4	15.0	0.1	15.7
2b	**154.9**	<0.1	**147.0**	<0.1	7.9
4	**63.4**	9.2	49.8	0.5	4.0
3	**153.0**	4.0	**139.6**	0.4	9.1
Criterion	50	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KRQ = Karuah Red Quarry (processing at Karuah Quarry), BG = background
The maximum cumulative impact is presented, with the contributions from each quarry operation on the day of maximum impact presented. Maximum incremental impacts associated with the Karuah South Quarry are presented in the following table.

The maximum predicted incremental 24-hour average PM_{10} concentrations resulting from activities during Stage 2B of operations are presented in **Table 49**. These predictions indicate that the activities during Stage 2B could potentially result in incremental impacts up to 21.6 µg·m^{-3} at receptor 22, which represents <44 % of the relevant criterion. It is important to note that the model predictions indicate that even during these periods of elevated 24-hour PM_{10} impacts no exceedance of the maximum 24-hour average PM_{10} criterion are predicted at any residential receptor.

To ensure that these short-term elevations in incremental PM_{10} concentrations do not result in exceedances of the criterion at surrounding residential locations, a real-time air quality monitoring program will be implemented. This program, and the air quality management measures which are informed by those monitoring results, is described in detail in Section 8.

Table 49
Predicted Maximum 24-hour Average Incremental PM_{10} Concentrations – Stage 2B

Receptor	Maximum Incremental 24-hour PM_{10} Concentration ($\mu g \cdot m^{-3}$) Karuah South Quarry
23	16.2
22	21.6
20	15.9
16	8.6
15	7.7
7	5.5
12	9.4
13	8.4
8	4.5
10	3.3
21	12.7
17	6.5
19	3.4
2a	48.7
2b	37.8
4	9.2
3	25.1

Figure 53 and **Figure 54** present the maximum 24-hour average incremental (Karuah South Quarry, Stage 2B) and cumulative (all quarries plus background) PM_{10} concentration isopleth plots, respectively.

Figure 53
Predicted Incremental Maximum 24-hour Average PM_{10} Concentrations – Stage 2B

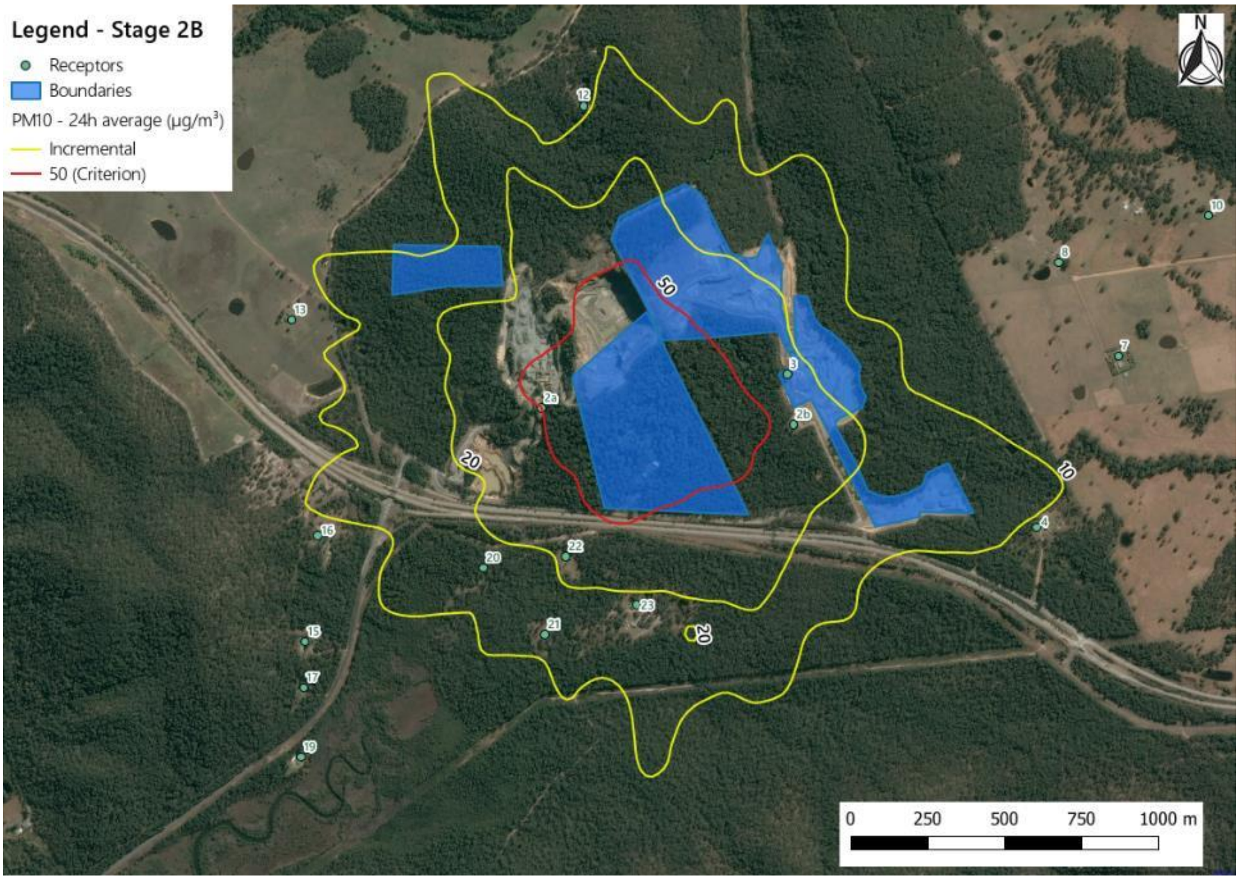
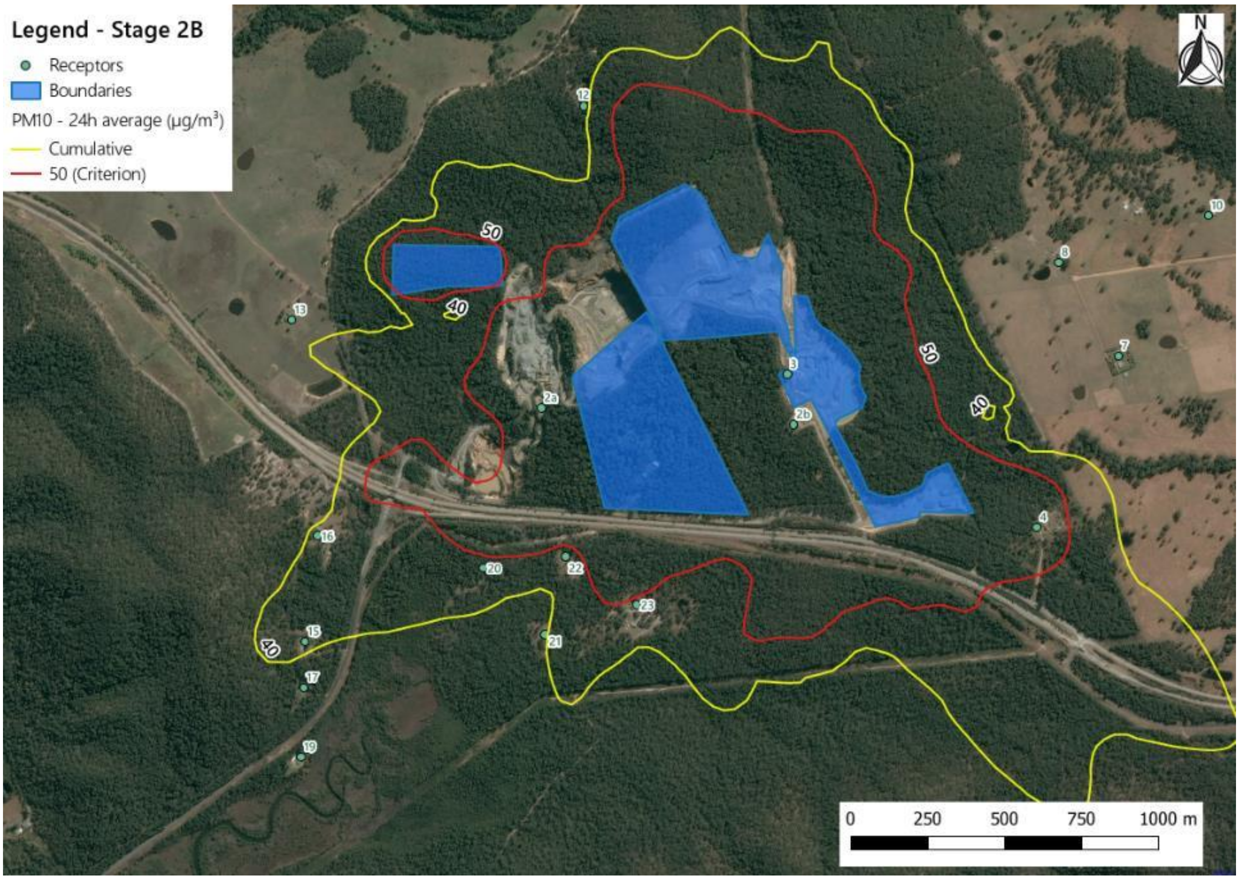


Figure 54
Predicted Cumulative Maximum 24-hour Average PM_{10} Concentrations – Stage 2B



Presented in **Table 50** are dispersion model predictions of maximum cumulative 24-hour average $PM_{2.5}$ concentrations during Stage 2B operations. The maximum predicted contribution to the maximum cumulative $PM_{2.5}$ impact resulting from Stage 2B operations is predicted to be 0.9 $\mu g \cdot m^{-3}$ at receptor 23. This represents <4 % of the maximum 24-hour average $PM_{2.5}$ criterion.

On the day of maximum predicted cumulative impact at all modelled receptors, the 24-hour average $PM_{2.5}$ criterion is predicted to be achieved, with the addition of the predicted impact of all other quarries (operational as outlined in Section 5.1.2) and background air quality resulting in total cumulative impacts of $PM_{2.5}$ during Stage 2B operations being <72 % of the criterion.

Table 50
Predicted Maximum 24-hour Average Cumulative $PM_{2.5}$ Concentrations – Stage 2B

Receptor	Maximum 24-hour $PM_{2.5}$ Concentration ($\mu g \cdot m^{-3}$)				
	Cumulative Impact	**KSQ**	**KEQ**	**KRQ**	**BG**
23	17.2	0.5	0.5	<0.1	16.2
22	18.0	0.9	0.8	<0.1	16.2
20	17.3	0.3	0.7	0.1	16.2
16	16.3	<0.1	<0.1	0.1	16.2
15	16.3	<0.1	<0.1	0.1	16.2
7	16.2	<0.1	<0.1	<0.1	16.2
12	16.2	<0.1	<0.1	<0.1	16.2
13	16.2	<0.1	<0.1	<0.1	16.2
8	16.2	<0.1	<0.1	<0.1	16.2
10	16.2	<0.1	<0.1	<0.1	16.2
21	17.3	0.8	0.3	<0.1	16.2
17	16.3	<0.1	<0.1	0.1	16.2
19	16.3	<0.1	<0.1	0.1	16.2
2a	17.1	0.2	0.1	0.6	16.2
2b	24.9	<0.1	15.1	<0.1	9.8
4	16.2	<0.1	<0.1	<0.1	16.2
3	22.0	0.6	14.7	0.1	6.6
Criterion	25	-	-	-	-

Note: KSQ = Karuah South Quarry, KEQ = Karuah East Quarry, KRQ = Karuah Red Quarry (processing at Karuah Quarry), BG = background
The maximum cumulative impact is presented, with the contributions from each quarry operation on the day of maximum impact presented. Maximum incremental impacts associated with the Karuah South Quarry are presented in the following table.

The maximum predicted incremental 24-hour average $PM_{2.5}$ concentrations resulting from activities during Stage 2B are presented in **Table 51**. These predictions indicate that the activities during Stage 2B operations could potentially result in incremental impacts up to 3.0 $\mu g \cdot m^{-3}$ at the modelled receptor locations, which represents <12 % of the relevant criterion.

Table 51
Predicted Maximum 24-hour Average Incremental $PM_{2.5}$ Concentrations – Stage 2B

Receptor	Maximum Incremental 24-hour $PM_{2.5}$ Concentration ($\mu g \cdot m^{-3}$) Karuah South Quarry
23	2.2
22	3.0
20	2.3
16	1.3
15	1.1
7	0.7
12	1.2
13	1.0
8	0.6
10	0.4
21	1.8
17	0.9
19	0.5
2a	5.5
2b	4.4
4	1.2
3	2.9

Figure 55 and **Figure 56** present the maximum 24-hour average incremental (Karuah South Quarry, Stage 2B) and cumulative (all quarries plus background) $PM_{2.5}$ concentration isopleth plots, respectively.

Figure 55
Predicted Incremental Maximum 24-hour Average $PM_{2.5}$ Concentrations – Stage 2B

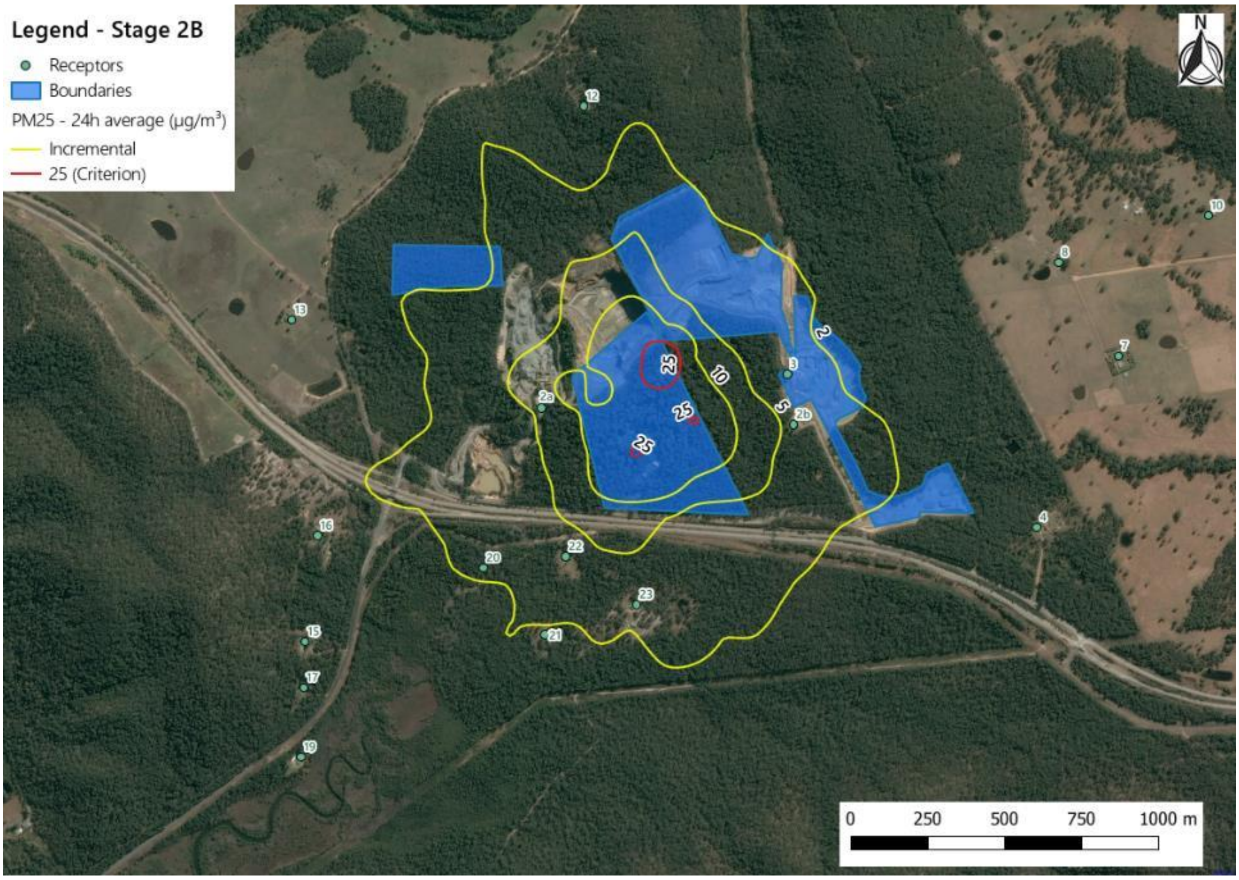
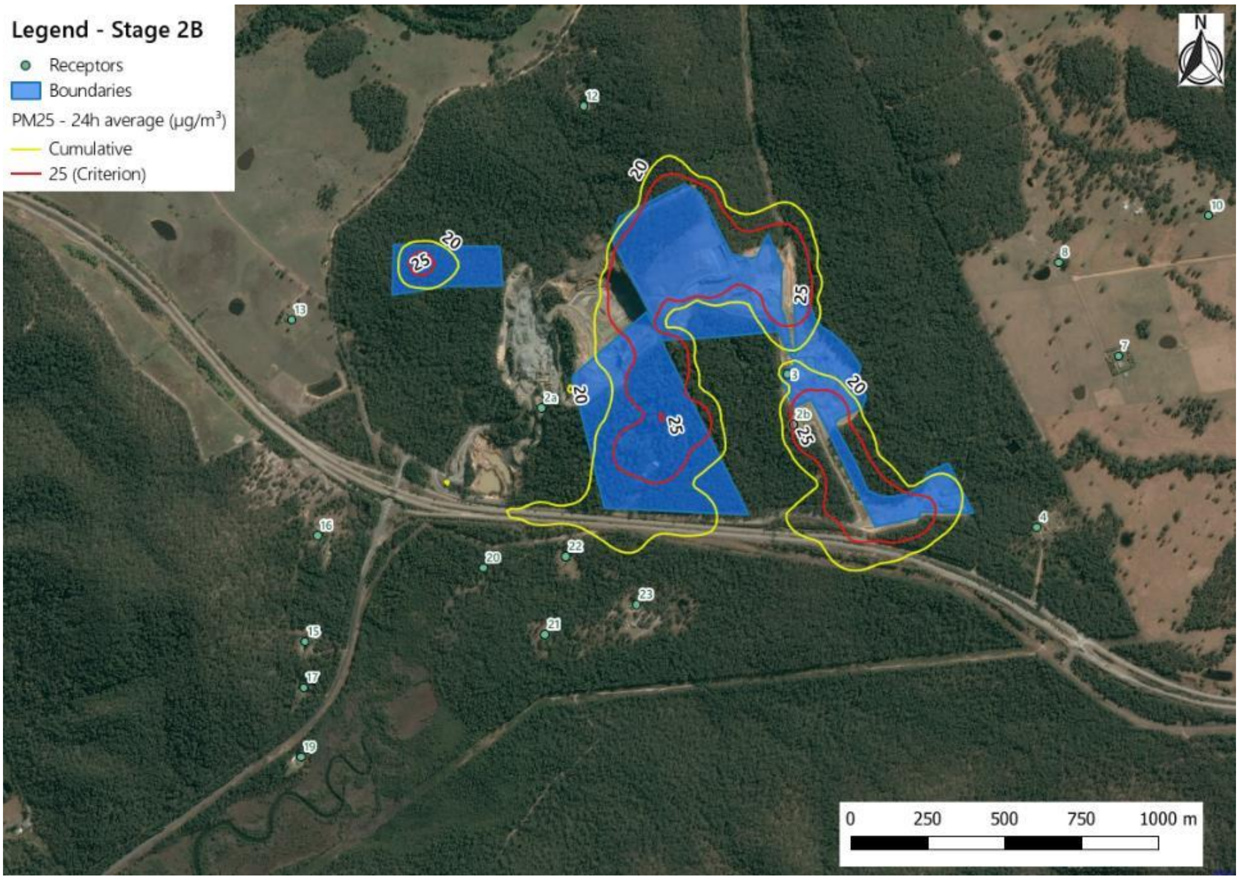


Figure 56
Predicted Cumulative Maximum 24-hour Average $PM_{2.5}$ Concentrations – Stage 2B



6.3.6 Stage 2B Maximum 1-hour Average NO_2

In the case of maximum 1-hour average predictions of NO_2, the impact assessment criterion is predicted to be met at surrounding residential locations during Stage 1C operations. Concentrations of NO_2 have been predicted using 100% conversion of NO to NO_2 method as outlined in **Annexure 2**.

No cumulative impacts (other than the addition of background air quality) have been assessed, as it has been assumed that simultaneous blasting at surrounding sites would not occur.

Presented in **Table 52** are dispersion model predictions of maximum cumulative 1-hour average NO_2 concentrations. The maximum predicted cumulative 1-hour impact resulting from Stage 2B operations is predicted to be 82.2 $\mu g \cdot m^{-3}$, at receptor 12. This represents <34 % of the maximum 1-hour average NO_2 criterion.

Table 52
Predicted Maximum 1-hour Average NO_2 Concentrations – Stage 2B

Receptor	Maximum 1-hour Average NO_2 Concentration (µg·m^{-3})	
	Cumulative	**KSQ**
23	8.7	78.4
22	9.6	79.3
20	4.8	74.5
16	3.6	73.3
15	2.9	72.6
7	4.3	74.0
12	12.5	82.2
13	5.6	75.3
8	4.1	73.8
10	2.3	72.0
21	7.6	77.3
17	3.2	72.9
19	3.8	73.5
2a	49.3	119.0
2b	17.0	86.7
4	4.3	74.0
3	20.9	90.6
Criterion	246	-

Note: KSQ = Karuah South Quarry, Cumul = cumulative

Figure 57 presents the maximum 1-hour average incremental NO_2 concentration isopleth plot with **Figure 58** presenting the maximum 1-hour average cumulative (increment plus background) NO_2 concentration isopleth plot.

The dispersion model predictions assume that blasting occurs on each operating hour of the year where in reality, blasting would only likely occur on 18 hours in the year. The implementation of a blast management plan would ensure that no blasting would occur when winds are blowing (or likely to blow) in the direction of the nearest sensitive receptors. The predicted concentrations of NO_2 can therefore be considered to be highly conservative. Should the blast management plan be implemented and operated effectively, no exceedances of the short-term NO_2 criterion would be likely at any surrounding receptor location.

Figure 57
Predicted Incremental Maximum 1-hour Average NO_2 Concentrations – Stage 2B

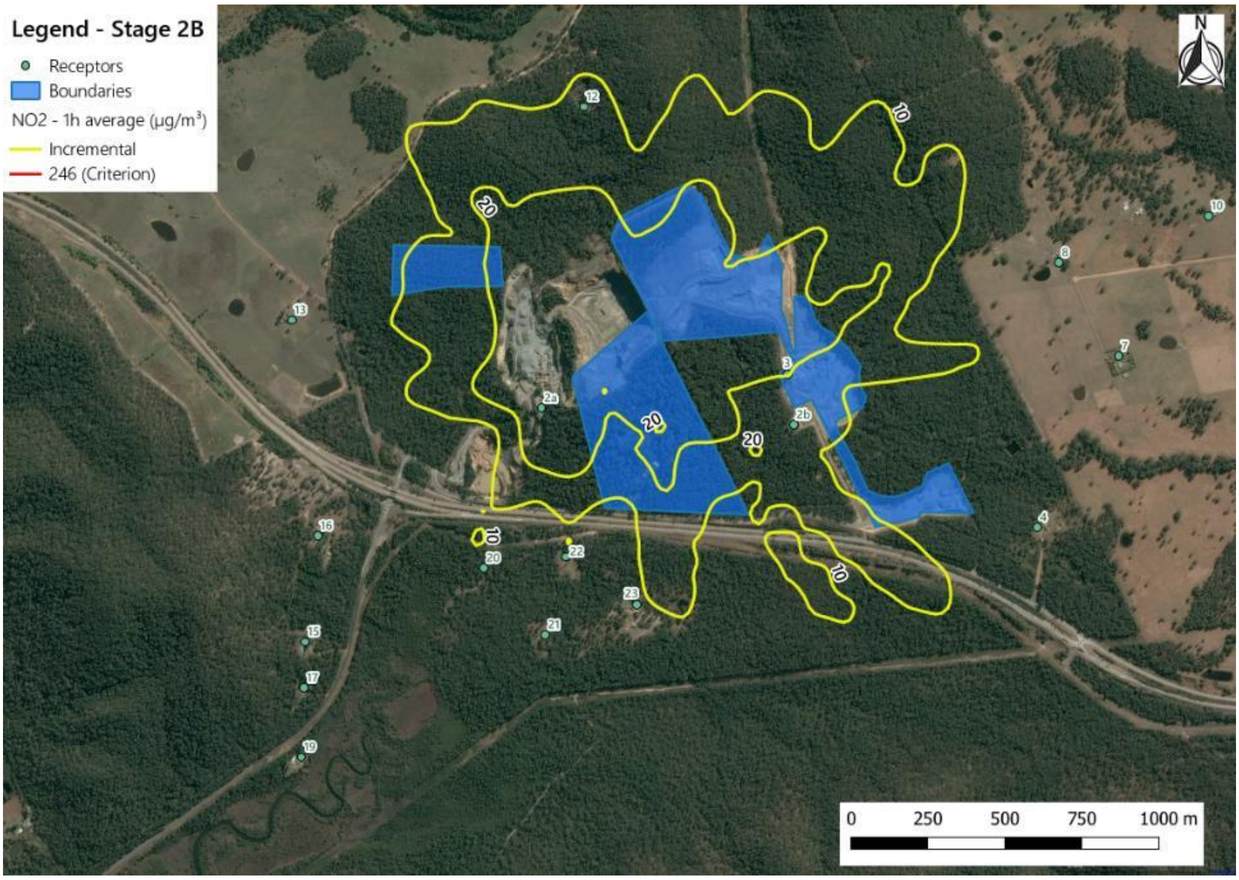
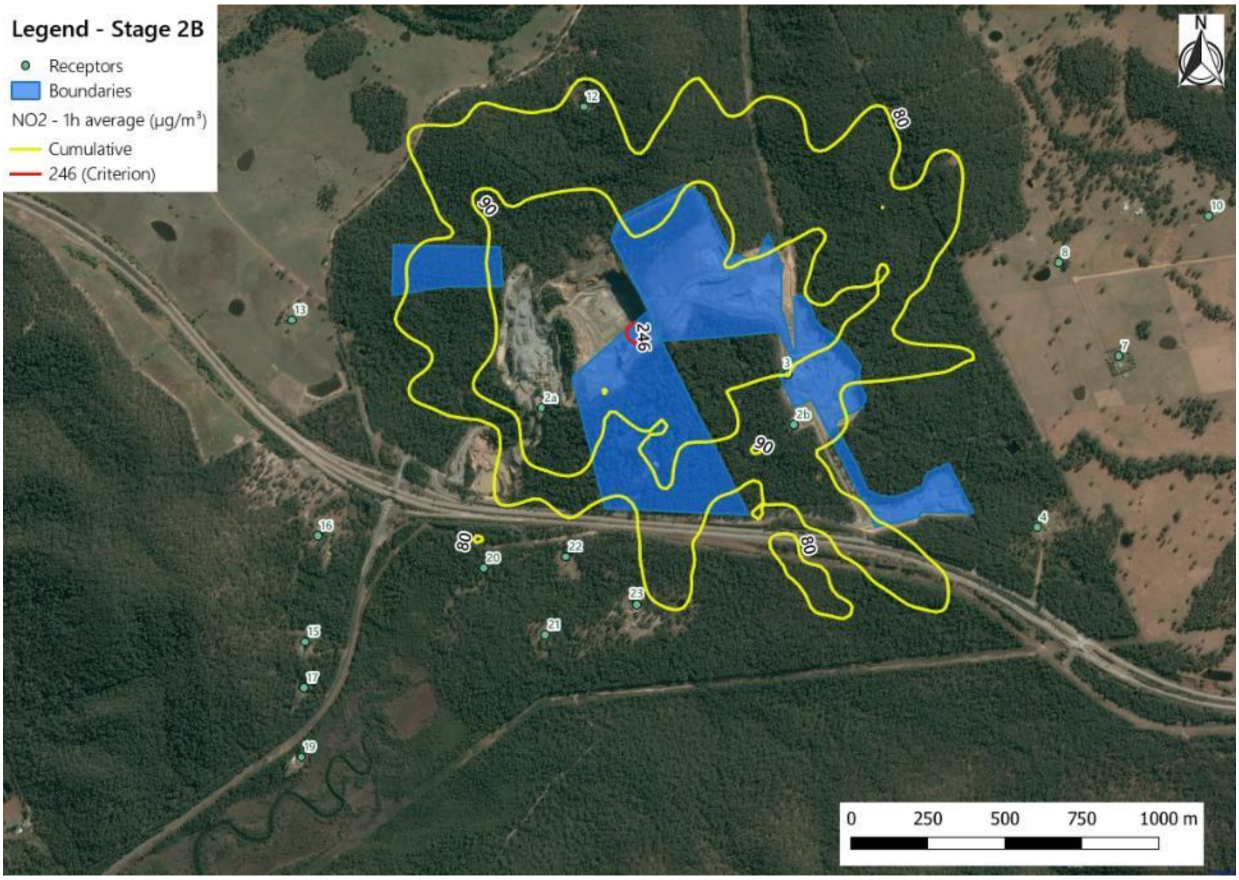


Figure 58
Predicted Cumulative Maximum 1-hour Average NO_2 Concentrations – Stage 2B



6.4 VOLUNTARY LAND ACQUISITION POLICY

The previous sections of this report confirm that the relevant criteria associated with the NSW Voluntary Mitigation Policy are achieved at all surrounding residences. The minor exceedance of the cumulative 24-hour PM_{10} criterion is not applicable to the Voluntary Mitigation Policy as that policy relates to incremental 24-hour PM_{10} impacts rather than cumulative impacts.

The previous sections also confirm that the Voluntary Acquisition criteria are also achieved at all surrounding sensitive receptor locations. However, the Voluntary Acquisition criteria are also to be applied across privately owned land (rather than just residences). Specifically, voluntary acquisition rights may be applied by the consent authority "*where the development is predicted to result in exceedances of the relevant criteria on more than 25% of any privately-owned land where there is an existing dwelling or where a dwelling could be built under existing planning controls.*"

Outlined in **Table 53** are the results of the assessment of the land area of each private landholder over which an exceedance of the relevant criterion is experienced. For example, for landholder reference 12, the annual average PM_{10} air quality criterion is exceeded across 8% of the land area which is under the 25% criterion and thus does not trigger the land acquisition criterion.

The Voluntary Acquisition criteria are not exceeded across any private landholding in the area.

Table 53
Assessment of Voluntary Land Acquisition Criteria

Landowner Ref. No.	Property Name	Landowner	PM_{10}		TSP	Deposited dust	
			Annual	24-hour	Annual	Annual	Annual
			Cumul.	Incr.	Cumul.	Incr.	Cumul.
12	Lot 4 DP838128	G J Mis, S Mis	8%	-	2%	-	8%
16	Lot 22 DP 1024341	PR Wood	-	-	-	-	-
20	Lot 1 DP 785172	GA Norbury	-	-	-	-	1%
21	Lot 2 DP 785172	WR Plover	-	-	-	-	2%
22	Lot 3 DP 785172	RJ Trotter	-	-	-	-	16%
23	Lot 100 DP 785172	GB Myers, DL Myers	-	-	-	-	4%
		Criterion	25 µg·m^{-3}	50 µg·m^{-3}	90 µg·m^{-3}	2 g.m^{-2}.month^{-1}	4 g.m^{-2}.month^{-1}

7. GREENHOUSE GAS ASSESSMENT

7.1 CALCULATION OF GHG EMISSIONS

Based on the activity data and emissions factors outlined in Section 5.2, **Table 54** presents the calculated Scope 1 and 3 GHG emissions associated with Stage 2 of the development (i.e. maximum extraction rates). Note that no Scope 2 emissions have been calculated given that electricity is anticipated to be a minor energy source at the Site.

Table 54
Greenhouse Gas Emissions

Emission Scope	Emission Source	Emission Factor	Energy Content Factor	Activity Rate	Emissions (t CO2-e·yr^{-1})
Scope 1	Diesel fuel for mobile plant and equipment	70.2 kg CO_2-e GJ^{-1}	38.6 GJ·kL^{-1}	1,173.3 kL·$annum^{-1}$	3,179.2
			Total Scope 1		**3,179.2**
Scope 2	Electricity consumption	0.82 kg CO_2-e kWh^{-1}	-	Negligible	0.0
			Total Scope 2		**0.0**
Scope 3	Diesel fuel for mobile plant and equipment	3.6 kg CO_2-e GJ^{-1}	38.6 GJ·kL^{-1}	1,173.3 kL·$annum^{-1}$	163.0
	Unleaded fuel for employee transport	3.6 kg CO_2-e GJ^{-1}	34.2 GJ·kL^{-1}	0.33 kL·$annum^{-1}$	0.04
	Diesel fuel for material transport	3.6 kg CO_2-e GJ^{-1}	38.6 GJ·kL^{-1}	2,727.5 kL·$annum^{-1}$	379.0
			Total Scope 3		**542.1**

7.2 COMPARISON WITH NATIONAL TOTALS

A comparison of the calculated GHG emissions associated with the Project and NSW, Australia, and mining industry total emissions in 2016 is presented in **Table 55**.

Table 55
Greenhouse Gas Emissions in Context

Emission Scope	Proposal total (t CO2-e·yr^{-1})	Emissions (Mt CO_2-e·yr^{-1})			
		Australia (2016) (excluding LULUCF) 549.2 Mt	NSW (2016) 131.6Mt	Australian Mining Sector (2016) 82.3Mt	NSW Mining Sector (2016) 20.7Mt
Scope 1	3,179.2	0.0006%	0.0024%	0.0039%	0.0154%

Note: LULUCF = Land Use Land Use Change and Forestry

These data indicate that the operation of the Project at maximum capacity would contribute up to 0.003% of NSW total GHG emissions and up to 0.0006% of Australian total GHG emissions in 2016.

7.3 MANAGEMENT OF GHG EMISSIONS

The above assessment indicates that GHG emissions resulting from the operation of the Project are anticipated to be small, although emissions could be further reduced through the application of a number of measures:

- All vehicles/plant and machinery should be turned off when not in use and regularly serviced to ensure efficient operation, including the optimisation of tyre pressures;
- Truck routes and loading capacity should be designed to reduce the distance and effort required by the vehicles;
- Maintenance of roads in good condition to avoid meandering of vehicles;
- Reducing gradients around site where feasible;
- Where possible, B5 fuel should be used in plant and equipment.

8. AIR QUALITY MONITORING AND MANAGEMENT

A detailed Best Practice Management (BPM) dust control assessment has been performed (**Annexure 2**) which considers all of the possible dust control measures which could be employed on all significant sources of particulate matter. Following a detailed assessment of the practicability of implementing each of the particulate control measures at the Site with due consideration given to:

- implementation costs;
- regulatory requirements;
- environmental impacts;
- safety implications; and,
- compatibility with future developments,

a number of measures were taken forward and adopted within the dispersion modelling assessment and would be employed as part of the ongoing Project operation. **Table 56** outlines the particulate control measures adopted.

Table 56
Summary of Adopted Particulate Control Measures

Control Measure	Emission Control Efficiency Adopted
Haul Roads Paving around processing plant	97 % reduction in TSP emissions, 98 % reduction in PM_{10} emissions, 94 % reduction in $PM_{2.5}$ emissions Use of a recycled crushed concrete and crushed used asphalt in accordance with the NSW EPA's *Specification for Supply of Recycled Material for Pavements, Earthworks and Drainage 2010*. Calculated through comparison of unpaved roads (US EPA, 2006a) and paved roads (US EPA, 2011) emission factors
Haul Roads Watering	72 % to 90 % as described in **Annexure 2** for hourly application of water (US EPA, 1987)
Material Processing Water sprays	77.7 % (US EPA, 2004)
Material Processing Screening	91.6 % (US EPA, 2004)
Wind Erosion of Exposed Areas Minimise pre-strip	100 % per m^2 avoided (Katestone, 2011)
Wind Erosion of Exposed Areas Watering	50 % (DSEWPC, 2012)
Wind Erosion of Exposed Areas Fencing, bunding or shelterbelts	30 % (DSEWPC, 2012)
Drilling Water Sprays	70 % (DSEWPC, 2012)

Although not captured within the BPM assessment methodology as the emissions totals were below the threshold values, additional emission control measures will be adopted as part of the Project operation. These measures, and their associated particulate emission reduction efficiencies are presented below:

- All activities
  - Pit retention – 50 % for TSP, 5 % for PM_{10} and $PM_{2.5}$
- Blasting
  - Delay blasting during unfavourable conditions – no quantifiable reductions but would be experienced in practice

A dispersion modelling exercise has explicitly included these control measures, with emissions inventories for each stage of Project development presented in **Annexure 2**.

The results of dispersion modelling presented in Section 6 indicate that activities during all stages of Project development (Site Establishment and Construction, Stage 1C and Stage 2B) compliance with the adopted air quality criteria is generally achieved. Only one predicted exceedance of the maximum 24-hour average PM_{10} criterion is predicted, at receptor 16 during Stage 1C operations (see Section 6.3.2).

Predicted incremental concentrations of 24-hour PM_{10} and $PM_{2.5}$ are predicted to be not-insignificant at a number of residential receptor locations, most notably those to the south of the Project (receptors 20, 22 and 23).

To ensure that the Project is operated in compliance with the air quality criteria at surrounding residential receptor locations, a real-time air quality monitoring program is proposed. The air quality monitoring program would form part of a broader Air Quality Management Plan (AQMP) for the Project which would be required to be performed in consultation with NSW EPA, and approved by DP&E. The AQMP would include a description of all of the particulate control measures to be adopted as part of the Project operation and how these would be implemented, managed, and audited.

The specific detail of the monitoring program (monitoring method, monitoring locations etcetera) will be determined at a later date and in full consultation with relevant parties. The following does provide the recommended an over-arching methodology for the performance of any air quality monitoring program to be implemented at the Site.

8.1 AIR QUALITY MONITORING PROGRAM

8.1.1 General Requirements of the Air Quality Monitoring Program

The monitoring program would be designed to ensure that air quality is measured at representative locations in the vicinity of the Site operations. Data from the monitoring program would be used to determine the impact of the Site operations on the surrounding air environment and private properties in the vicinity of the Site, and the compliance status of those operations in relation to any Consent conditions for the development.

The proposed Air Quality Monitoring Program would:

- be capable of evaluating the performance of the Site operations;
- include risk-based monitoring to demonstrate compliance with the criteria in Section 3;
- include ongoing real-time particulate monitoring;
- include a Trigger Action Response Plan (TARP) which describes the actions to be taken when specific trigger levels are exceeded;
- adequately supports the air quality management system (which includes the controls adopted to mitigate emissions to air); and
- evaluates and reports on the adequacy of the air quality management system.

From experience in providing AQMPs for other developments in NSW, it is acknowledged that NSW EPA consider that the management responses to any trigger values are generally of more concern / importance that the actual values themselves. Additionally, the trigger values themselves evolve over time following implementation of a real-time particulate monitoring system, based on site observations and analysis of data. A regular review process of the air quality monitoring program is likely to occur frequently, particularly within the first three to six months of operation.

An appropriate number of monitoring locations would be required to provide adequate coverage. Based on the results of the dispersion modelling assessment, locations of sensitive receptors most impacted are to the east and south of the Site. A suitable number of monitoring locations would be required to ensure that the impacts at these more critical locations can be determined, whilst also allowing determination of whether activities being performed at the Site are the cause of any observed elevated concentrations. The number of monitoring locations may be reviewed at a later date if it reasonably demonstrated that the monitoring program and AQMP could be operated with alternative configurations.

The monitoring locations would conform to the requirements of AS 3580.1.1:2007 *Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment*, subject to local site constraints with any deviations from the standard noted in the siting documentation.

8.1.2 Proposed Monitoring Method

Based upon the results presented in the preceding AQIA, it is noted that the particulate fraction most likely to be exceeded is the 24-hour PM_{10} criterion of 50 $\mu g \cdot m^{-3}$. Given this identified risk, it is considered appropriate for the recommended monitoring program to include measures to manage the risk associated with PM_{10}.

The monitoring method is not proposed at this time, although would be required to allow simultaneous measurement of (at least) PM_{10}, includes alarms, and the ability to remotely monitor and log concentrations.

8.1.3 Proposed Monitoring Locations

The aim of the proposed air quality monitoring network is to avoid exceedances of air quality criteria at nearby sensitive receptors and provide a mechanism for proactive and reactive air quality management. A real-time monitoring programme, combined with a Trigger Action Response Plan (TARP), will provide a proactive approach to minimising particulate matter offsite. Further details of the monitoring triggers, TARP, and appropriate averaging periods are described in Section 8.2, and these measures would be regularly reviewed and updated if required during system implementation.

The placement of monitoring equipment would be influenced by the site conditions, nearby sources of emissions (namely the surrounding quarry operations) and safety / logistical limitations of the Site although appropriate placement would be determined prior to commencement of any Site operations. To ensure that the monitors are not overly impacted by Site related dust at high concentrations close to operations, placement at maximum distance from those activities would be required to evaluate off-site impacts which may require consultation with surrounding land owners.

A meteorological monitoring station should also be installed for the duration of the Project so that measured concentrations can be associated with wind directions, and alarms on monitoring equipment set to take into account the directions under which impacts at sensitive receptor locations may be more likely (i.e. under westerly and northerly flows). Triggering of alarms and implementation of additional dust management should be avoided when impacts are not likely at these receptors.

The monitoring locations will be compliant with the requirements of Australian Standard (AS) 3580.1.1:2016 *Methods for sampling and analysis of ambient air, Part 1.1: Guide to siting air monitoring equipment*, including requirements for height above ground, clear sky angle of 120°, unrestricted airflow, 20 m from trees, minimum distance from road traffic etc, as far as possible.

The meteorological station would be required to be installed and situated in compliance with AS 3580.14-2011 *Method for sampling and analysis of ambient air - Meteorological monitoring for ambient air quality monitoring applications*.

It would be considered optimal if one of the monitors was able to be co-located with the meteorological monitoring station.

8.2 AIR QUALITY MONITORING PROGRAM – TRIGGER ACTION RESPONSE PLAN

A Trigger Action Response Plan (TARP) is proposed to be developed as part of the AQMP. The TARP describes the actions to be taken when specific trigger levels are exceeded.

The description of the TARP has been divided into two sections. Firstly, a description of how the trigger levels would be determined is described in Section 8.2.1 and secondly, the actions which would be taken in response to the trigger levels is provided within Section 8.2.3. These measures (as a minimum) would include those determined through the performance of the BPM assessment provided within this report, the effects of which have been subject to detailed air quality modelling.

8.2.1 Determination of Trigger Levels for the TARP

The trigger levels for the TARP would require consideration of the location of the monitors. Trigger levels would be lower at greater distances from the Site operations. The trigger levels for the TARP would need to be aligned with the relevant 24-hour PM_{10} air quality criterion (e.g. 50 $\mu g \cdot m^{-3}$) (and duly adjusted to allow a 1-hour PM_{10} trigger value to be calculated). Should the value be triggered too often, then a review of the trigger value would be performed, taking into account the concentrations not to be exceeded at the monitoring locations, to allow compliance with the criteria at the nearest sensitive receptors to be achieved.

Should measured concentrations indicate that an exceedance of the 24-hour PM_{10} criterion is likely (or indeed, any concentration determined to be required to be achieved), and that modification of activities at the Site would assist in reducing the likelihood of that exceedance (or value), then a system can be implemented to ensure that those modifications occur to achieve the preferred environmental outcome.

8.2.2 Operation of the TARP

Several issues arise in the operation of a responsive system such as this, which include:

- Are concentrations measured at the monitoring locations representative of the impacts likely to be measured off-site?
- What is the relationship between short-term (e.g. 1 hour) PM_{10} concentrations and 24-hour PM_{10} concentrations in different wind directions?
- How is the hierarchy of particulate control (e.g. reducing/modifying/ceasing operations) to be determined?
- How is success of the system to be determined?

The following provides responses to those issues, in relation to the current proposed monitoring plan. It is noted that the composite elements of the TARP are necessarily described in broad detail given the stage of the Project development.

Are concentrations measured at the monitoring locations representative of the impacts likely to be measured off-site?

Given that the air quality monitors may be located within, or close to the site boundary, the concentrations of PM_{10} measured are likely to be higher than those experienced at surrounding receptor locations, assuming that the major source of particulate matter is the activities being performed at the Site. A conservative approach might be adopted which assumes that the concentrations measured within or near to the Site boundary are the same as those measured off-site. However, dispersion modelling results presented in Section 6 indicate that this would be an unrealistic assumption. Alternatively, a monitoring campaign can be conducted to determine the relationship between on and off-site PM_{10} measurements, should a suitable and secure location be able to be identified.

What is the relationship between short-term (e.g. 1-hour) PM_{10} concentration and 24-hour PM_{10} concentration in different wind directions?

The proposed monitoring network would be designed to enable and facilitate pro-active and reactive modification of site activities to ensure that air quality criteria are not exceeded at surrounding receptor locations. Given that the relevant criterion for PM_{10} relates to a 24-hour averaging period, modification must be performed on a shorter timeframe to ensure that the 24-hour criterion is achieved / managed. A relationship between the 1-hour and 24-hour PM_{10} concentrations would be derived once the real-time monitoring program is operational.

Clearly, the relationship will differ according to the locations of activities being performed (both at the Site and surrounding sites) and the direction and strength of the wind. Monitoring data should be examined over a period of time to assess the appropriate 1-hour / 24-hour relationships in various wind directions and if possible, associate these relationships with activities and locations of activities being performed. Based on meteorological monitoring data, the contribution from the operations in certain wind directions can be performed and an assessment of whether modification of activities would be beneficial can be provided depending on the risk of off-site exceedances.

In conditions when the background particulate environment is significantly affected by external sources (such as dust storms or bushfire), then modification of activities may not result in any meaningful reductions in off-site impacts associated with the Site operations.

For the purposes of further discussion within this assessment, an interim 1-hour trigger level of 100 $\mu g \cdot m^{-3}$ is initially assumed. To allow an appropriate management response / action associated with increasing risk of off-site particulate impacts, a 'traffic light' system is proposed which is outlined in **Table 57**. This would be revised in response to the measured concentration values following monitoring program implementation.

Table 57
Proposed Trigger Levels under the TARP

Action level	1-hour average PM_{10} concentration (µg·m-3)
None	<100 $\mu g \cdot m^{-3}$
A	≥100 $\mu g \cdot m^{-3}$ <150 $\mu g \cdot m^{-3}$
B	≥150 $\mu g \cdot m^{-3}$ <250 $\mu g \cdot m^{-3}$
C	

A balance must be found at the early stage of network design and development so that exceedances do not occur, whilst also not unreasonably and unnecessarily restricting construction activities.

It is noted that the relationships between 1-hour and rolling 24-hour average PM_{10} concentrations are suggested for the purposes of further discussion at this stage. Usual practice is to determine compliance or otherwise with a 24-hour standard based on the daily average (00:00hrs to 23:59hrs). However, the presence of short-term peaks, especially towards the end of the day can often provide insufficient time to modify activities to ensure that standards are not exceeded, especially during those days when the background (i.e. non-Site related) concentrations are approaching, but not exceeding the criterion. This distinction is important and would be noted in any reporting of compliance against the air quality criteria.

How is the hierarchy of particulate control (e.g. reducing/modifying/ceasing operations) to be determined in different wind directions?

When the 1-hour average PM_{10} concentration exceeds the relevant trigger level, then additional management measures should be introduced. A range of management measures would be constantly and consistently implemented as part of the Site operations, as identified through the performance of the BPM assessment (**Annexure 2**).

Any adopted additional management measures will be identified through cross referencing of the activities being performed at the time when the trigger level was exceeded and the hierarchy of controls which should be implemented for that/those activities. The hierarchy of controls is included in Section 8.2.3. For clarity, any measured 1-hour PM_{10} concentration above (nominally) 100 $\mu g \cdot m^{-3}$ would not necessarily result in management measures being required. An assessment of whether any modification would result in offsite reductions in PM_{10} concentrations would need to be performed initially, taking into account upwind /downwind concentrations.

How is success of the system to be determined?

The success of the system would be determined through

- the successful calibration of the real-time monitoring stations
- Real-time monitoring data indicates compliance with the criteria in Section 3
- Absence of any complaints related to air quality that can be directly attributed to the Site operations

8.2.3 Responses to Trigger Levels in the TARP

Should the trigger levels outlined in **Table 57** be reached, then a hierarchy of management and mitigation options would be initiated. The measures proposed to be continually implemented are outlined in **Table 56** (and **Annexure 2**).

The site manager will maintain a log of activities being performed on the Site. The log would be required to include the activity being performed and the general location of the activity. These variables would allow a management response to be initiated, and would provide options on how to deal with the triggering of any level.

The hierarchy of response would be (each level including continual monitoring of particulate concentrations):

- Action Level A: Identify activities being performed and whether any additional emission controls can be applied to those activities (i.e. additional watering of roads and stockpiles, moving and/or restricting movement and handling of materials);
- Action Level B: Apply the controls identified during Action Level A.
- Action Level C: Depending on the activities being performed, progressively decrease the rate of activity or cease the operations.

Table 58 indicates the management response for each trigger level.

Table 58
TARP Hierarchy of Management Responses

Action level	1-hour average PM_{10} concentration ($\mu g \cdot m^{-3}$) Example Only	Summary of management response
None	$<100\ \mu g \cdot m^{-3}$	Continue operations with normal management measures in place. Monitor particulate concentrations for any increases.
A	$\geq 100\ \mu g \cdot m^{-3}$ $<150\ \mu g \cdot m^{-3}$	Monitor operations and prepare to implement additional controls according to the management hierarchy for those operations. Monitor the response in particulate concentrations.
B	$\geq 150\ \mu g \cdot m^{-3}$ $<250\ \mu g \cdot m^{-3}$	Implement additional controls according to the management hierarchy for current operations. Monitor the response in particulate concentrations.
C	$\geq 250\ \mu g \cdot m^{-3}$	Progressively cease higher risk operations until particulate concentrations $<250\ \mu g \cdot m^{-3}$

The above discussion seeks to act as a guide only and provides the broad principles around which the proposed AQMP would be constructed. It serves to provide a commitment by the Applicant to operate the Site with due consideration of off-site impacts, and alteration of those operations should it be required, to ensure that no exceedances of the air quality criteria resulting from those operations are experienced.

8.3 AIR QUALITY MANAGEMENT PLAN

The monitoring program proposed in Section 8.1, and the Trigger Action Response Plan outlined in Section 8.2 would for part of the broader Air Quality Management Plan (AQMP) for the Project.

The following provides a discussion of the management procedures which would underpin the AQMP. Given the stage of the Project development, the finer detail regarding the operation of this plan would be provided following Project approval. Once again however, the following seeks to provide clarification that the Operator would operate the Project to ensure that no exceedances of air quality criteria are experienced at surrounding residential receptor locations due to the operations at the Site.

8.3.1 Proactive Response Procedure

The Quarry Manager will perform visual checks on a daily basis as described to ensure that operations are relocated, modified and/or halted as required to ensure adverse air quality impacts are not realised at off-site sensitive receptor locations. The Environmental Officer will assess monitoring data and meteorological data on a monthly basis to verify the successful implementation of this plan. The air quality monitoring equipment will be re-calibrated on a basis in accordance with manufacturer recommendations.

8.3.2 Non-Compliance Response Procedure

In the event that the real-time monitoring indicates the potential exceedance of any of the following criteria at any monitoring site:

- • Incremental 24-hr PM_{10} concentration of 50 $\mu g \cdot m^{-3}$ when determined in accordance with the method described above (to be refined);

The following actions will be taken:

- The event will be investigated to determine possible emission sources including investigation into the prevailing wind conditions experienced at the time of the possible exceedance to identify the possible source of the particulate matter;
- Where the source is identified as the Karuah South Quarry, additional controls will be implemented, or operational activities altered until a favourable outcome can be achieved;
- The Environmental Officer shall notify the Secretary and EPA as soon as reasonably practicable, after becoming aware of any potential exceedance of the relevant air quality criteria (taking into account relevant averaging periods for the relevant air quality criteria); and,
- Within 7 days of becoming aware of the exceedance, the Operator will provide the Secretary and any relevant agencies with a detailed report of the exceedance.

The detailed report will include the following:

- the cause, time and duration of the event potential exceedance;
- the concentration of PM_{10} measured at each monitoring point for the duration of the potential exceedance;
- the name, address and business hours telephone number of the Quarry Manager and Environmental Officer of the Karuah South Quarry;
- the name, address and business hours telephone number of other key personnel that were on the site during the potential exceedance;
- action taken by the licensee in relation to the event, including any follow-up contact with any complainants;
- details of any measure taken or proposed to be taken to prevent or mitigate against a recurrence of such an event; and,
- any other relevant matters.

The detailed report will also suggest reasonable additional monitoring that is to be undertaken to assess compliance against any relevant Development Consent. The requirements for any reasonable additional monitoring of particulate matter will be assessed to be commensurate with the risk of the potential exceedance.

8.3.3 Complaints Handling Procedure

The Operator would operate a telephone complaints line during its operating hours with the number publicly notified via the Quarry website.

For any complaint received relating to air quality impacts from the quarry, the following measures will be taken:

- Environmental Officer to review monitoring results from all stations within one business day of receiving the complaint;
- Where all monitoring stations show 24-hour PM_{10} concentrations remained below 50 $\mu g \cdot m^{-3}$ for the period 24 hours either side of the complaint, no further action will be taken;
- Where 24-hour PM_{10} concentrations exceeded 50 $\mu g \cdot m^{-3}$ in the period of the complaint, however data collected by the on-site meteorological station indicates that the site was not a significant contributor to the measurements, no further action will be taken;
- Where 24-hour PM_{10} concentrations exceeded 50 $\mu g \cdot m^{-3}$ in the period of the complaint, and data collected by the AWS indicates that the site could potentially have been a contributor to the measurements:
  - Additional monitoring would be performed at the location of the complainant. Details of this monitoring are to be determined.

The Operator will keep a record of any complaint made to the Site or any employee or any agent of the quarry in relation to air quality from the Site. A Complaint Register will be maintained on the company website and will be produced to any authorised officer of the EPA if requested. Records of individual complaints will include:

- Date and time of complaint.
- Method by which the complaint was made.
- Personal details of the complainant (if provided).
- Nature of the complaint.
- The details of an initial response to the complaint.
- Action taken by the Operator and any follow up actions.
- If no action was taken, the reason why no action was taken.
- Weather conditions corresponding to the time of the complaint will also be noted in the logbook for assessment purposes.

8.3.4 Maintenance and Servicing Requirements

The real-time air quality monitoring units will require regular servicing to meet manufacturer requirements. This will involve some downtime of the system. It is anticipated that this process will be undertaken sequentially, or with replacement monitors used for the duration of maintenance.

8.4 BLAST MANAGEMENT PLAN

The results of the dispersion modelling exercise indicate that the tonnages of ANFO explosives used within each blast performed may be required to be limited to ensure short-term off-site impacts associated with NO_2 are not experienced at nearby sensitive receptors. The dispersion modelling study is necessarily conservative and assumes that during each blast, winds act to transport those emissions towards the location of each sensitive receptor. The results presented in Section 6 are therefore highly conservative.

Prior to the commencement of the Project, a Blast Management Plan would be prepared, which would outline all the measures to be implemented to ensure that impacts associated with dust and fume emissions at all surrounding sensitive receptor locations are minimised.

This would be achieved by the following:

- Fine material collected during drilling will not be used for blast stemming;
- All blast holes would be adequately stemmed with aggregate;
- Blasts would be limited to one event per day;
- Blasting to only occur between the hours 10.00 am and 4.00 pm, Monday to Friday; and,
- In excessive wind events (i.e. prolonged visual dust observed in a particular area), temporary halting of blasting activities and resuming when weather conditions have improved following appropriate assessment of weather conditions.

A professional contractor would be hired to survey the blast area, create a Blasting Plan and to conduct the blast. Blasting would only occur following appropriate assessment of weather conditions by the Environment Coordinator (or equivalent role) and the professional and suitably qualified Drill and Blast Superintendent to ensure that wind speed and direction (as measured by the on-site meteorological monitoring station) will not result in the transport of excess fume (or dust) emissions from the site in the direction of the sensitive receptor locations. This measure will be effective in controlling off-site impacts due to fumes released during blasting operations.

Additionally, the design for each blast will aim to maximise the blast efficiency and minimise the emission of fumes (as well as dust and odour) in order to ensure compliance with site specific blasting criteria.

9. CONCLUSIONS

9.1 AIR QUALITY

A detailed air quality impact assessment (AQIA) has been performed to assess the potential impacts of the site establishment and construction, and Stage 1C and Stage 2B operations to be performed as part of the proposed Karuah South Quarry development (the Project).

The AQIA has been performed in accordance with the NSW Environment Protection Authority (EPA) *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* document (NSW EPA, 2017), and with due reference to the Secretary's Environmental Assessment Requirements (SEARs), and NSW EPA requirements associated with State Significant Development (SSD 17_8795).

The air quality criteria applicable to the Project have been adopted from Commonwealth and State legislation and guidance and are presented in Section 3.

The impacts of the Project have been considered in the context of the current environment, being impacted by currently approved and operating quarrying operations (Karuah East and Karuah Quarry). The impacts have also been considered in the context of a likely future environment, in which the proposed Karuah Red Quarry may be operational.

A detailed modelling exercise has been performed to characterise the meteorological environment of the area surrounding the Site. A full description of the input data, modelling and validation of the outputs is presented in **Annexure 1**.

A detailed dispersion modelling exercise has been performed to characterise the predicted impacts from the Project at a number of surrounding privately- and site-owned receptors. A similarly detailed modelling exercise has been performed to assess the predicted impacts from all other surrounding quarrying operations at those receptors. A background air quality dataset has been generated and added to those modelled impacts to determine a total, cumulative impact.

Details of the operations of all sites (Karuah, Karuah East and the proposed Karuah Red Quarry) surrounding the Site have been obtained from publicly available information. Emissions inventories characterising the operation of those sites have been prepared and are outlined in full in **Annexure 2**. Also presented in **Annexure 2** is a detailed Best Practice Management dust assessment for the Site. Uncontrolled emissions associated with proposed Stage 2B of operations have been quantified, with sources contributing to 95% of all emissions subject to further assessment (NSW EPA, 2011). All available dust control measures for those sources have been identified and adopted where appropriate. Full justification for the inclusion and exclusion of all measures is provided in **Annexure 2**.

For the purposes of providing 'worst-case' assessment results, with which to compare against the short-term air quality criteria, operations at the Site have been assumed to operate at a throughput of 3,000 t per day during operations. This activity rate is significantly greater than the average operational throughput and represents a 3.7 times increase over average Stage 1C and 1.8 times increase over Stage 2B operations. Blasting has also been assumed to occur on each operating hour of the year, where blasting would only likely occur on 18 hours in the year.

These conservative assumptions provide confidence that the impacts of the Project are not likely to be greater than those presented within this assessment.

The dispersion modelling exercise indicates that the Project can operate across all stages of development (Site Establishment and Construction, Stage 1C and Stage 2B) with no exceedances of adopted air quality criteria, save for one minor exceedance of the maximum 24-hour average PM_{10} concentration during Stage 1C operations (at receptor 16 to the west of the Site). This minor exceedance (50.4 $\mu g \cdot m^{-3}$ compared to the criterion of 50 $\mu g \cdot m^{-3}$) has been reviewed in detail in Section 6, with the contribution from the Site being minor on this day. Annual average $PM_{2.5}$ modelling results have also been compared to the criterion for respirable crystalline silica, with impacts in all stages of the Project predicted to be minimal.

Dispersion modelling results do indicate that incremental (i.e. Project related) impacts can be not-insignificant at surrounding receptor locations during worst-case meteorological and operating conditions. To ensure that impacts from the Project do not result in exceedances of the air quality criteria at surrounding residential locations, a real-time air quality monitoring program is proposed to be supported by a detailed Air Quality Management Plan.

The air quality monitoring program would be designed to provide information to the Site operator regarding real-time particulate concentrations and provide a framework for reducing Site emissions should data indicate that Site operations are contributing to any increased concentrations. The detail of the monitoring program would be provided following Project approval, but the commitment is provided by the Applicant that the Site would be operated with due consideration of off-site impacts. Operations would be altered should it be required, to ensure that no exceedances of the air quality criteria resulting from those operations are experienced.

A Blast Management Plan would be constructed and implemented as part of Site operations which would outline all the measures to be implemented to ensure that impacts associated with blast dust and fume emissions at all surrounding sensitive receptor locations are minimised.

9.2 GREENHOUSE GAS

A greenhouse gas (GHG) assessment has been performed to examine the potential impacts of the operation of the Project relating to emissions of GHG. A quantitative assessment of emissions has been performed with emissions compared with total national and NSW GHG emissions for context.

Emissions associated with the Project are anticipated to represent <0.001 % of Australian and <0.01 % of NSW emissions totals for the year 2016.

Emissions are proposed to be reduced further through the implementation of a maintenance program for all plant and equipment, and the investigation into using B5 fuel where possible.

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Annexures

(Total No. of pages including blank pages = 107)

Annexure 1 Meteorology

Annexure 2 Emissions

Annexure 3 Background Air Quality

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Annexure 1

Meteorology

(Total No. of pages including blank pages = 24)

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Observed Meteorology and Selection of Representative Year

As discussed in Section 4.4 a meteorological modelling exercise has been performed to characterise the meteorology of the Site in the absence of site-specific measurements. The meteorological modelling has been based on measurements taken at a number of surrounding automatic weather stations (AWS) operated by the Bureau of Meteorology (BoM).

A summary of the relevant monitoring sites is provided in **Table 1-1** and also displayed in **Figure 1-1** (AQMS sites referenced in **Annexure 3**).

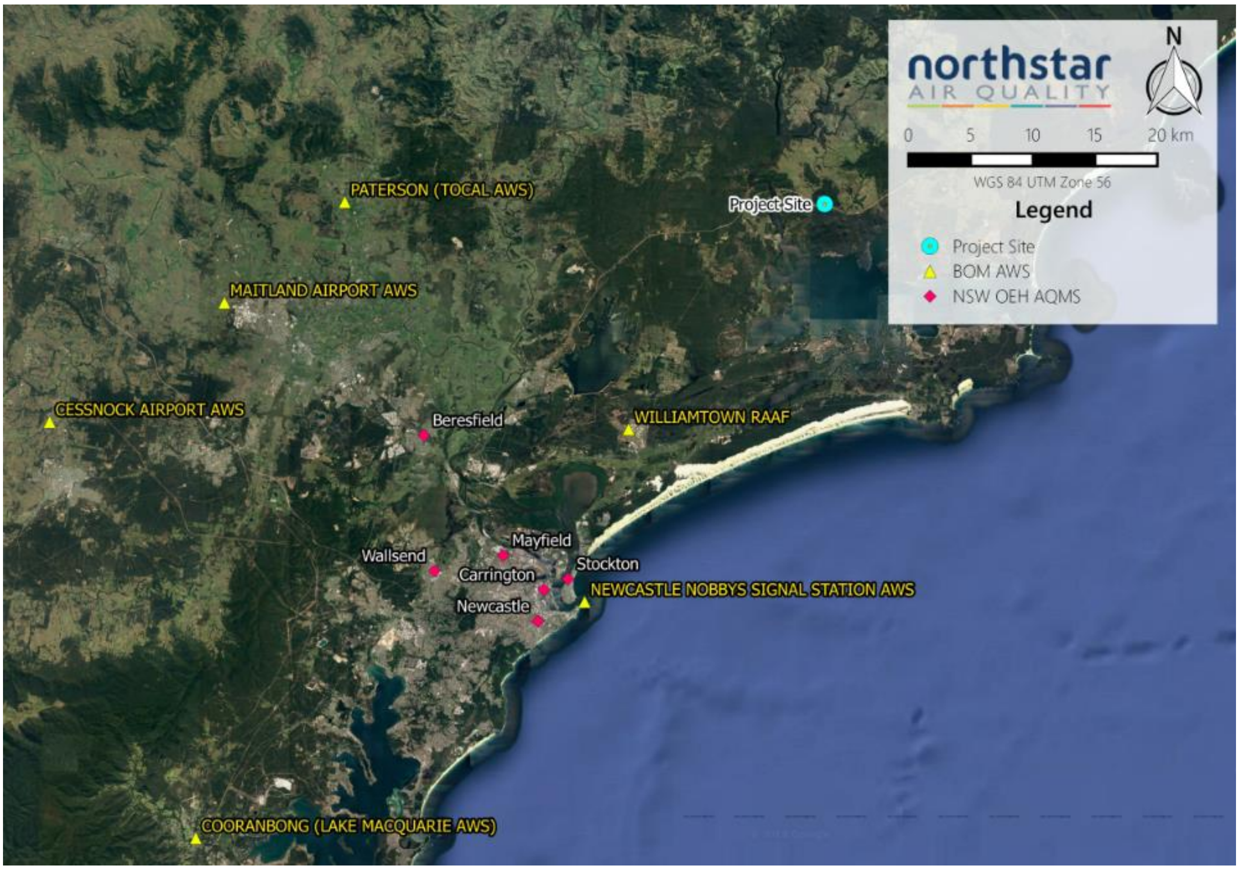
It is noted that a number of other technical studies supporting the Project have adopted meteorological data from the BoM AWS at Nelson Bay (station ID #061054). However, these data are collected at 9.00 am and 3.00 pm and do not provide sufficient data for use within this AQIA.

Table 1-1
Details of Meteorological Monitoring Surrounding the Site

Site Name	**Approximate Location (Latitude, Longitude)**		**Approximate Distance to Site**
	˚S	**˚E**	**km**
Newcastle Nobbys Signal Station AWS – Station # 061055	32.92	151.80	37.0
Williamtown RAAF – Station # 061078	32.79	151.84	23.7
Paterson Tocal AWS – Station # 061250	32.63	151.59	38.6
Maitland Airport AWS – Station # 061428	32.70	151.49	48.9
Cessnock Airport AWS – Station # 061260	32.79	151.34	64.7
Cooranbong (Lake Macquarie) AWS – Station # 064017	33.09	151.46	71.5

Figure 1-1

Meteorological Monitoring Surrounding the Site



Note: NSW OEH AQMS stations are referenced in **Annexure 3** and do not form a part of this Annexure but have been provided for location context.

Given their proximity to the Site, meteorological conditions at Newcastle Nobbys Signal Station AWS, Williamtown RAAF and Paterson Tocal AWS have been examined to determine a 'typical' or representative dataset for use in dispersion modelling. Annual wind roses for the most recent years of data (2008 to 2017 for Newcastle Nobbys AWS and Williamtown RAAF, and 2011 to 2017 for Paterson Tocal AWS) are presented in **Figure 1-2**, **Figure 1-3** and **Figure 1-4**.

Paterson Tocal was brought on-line in 2011, hence the restricted record of meteorological data available, compared to Newcastle Nobbys AWS and Williamtown RAAF AWS.

Figure 1-2

Annual Wind Roses 2008 to 2017, Newcastle Nobbys Signal Station AWS

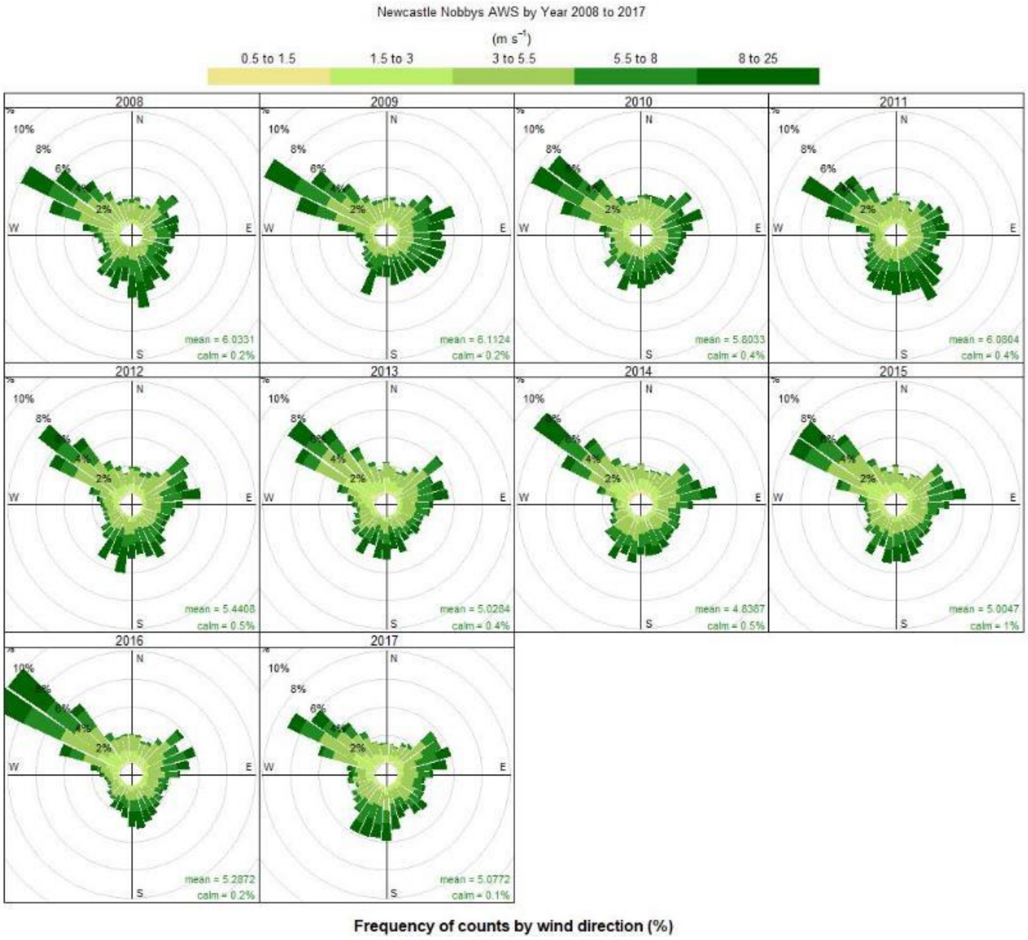


Figure 1-3

Annual Wind Roses 2008 to 2017, Williamtown RAAF AWS

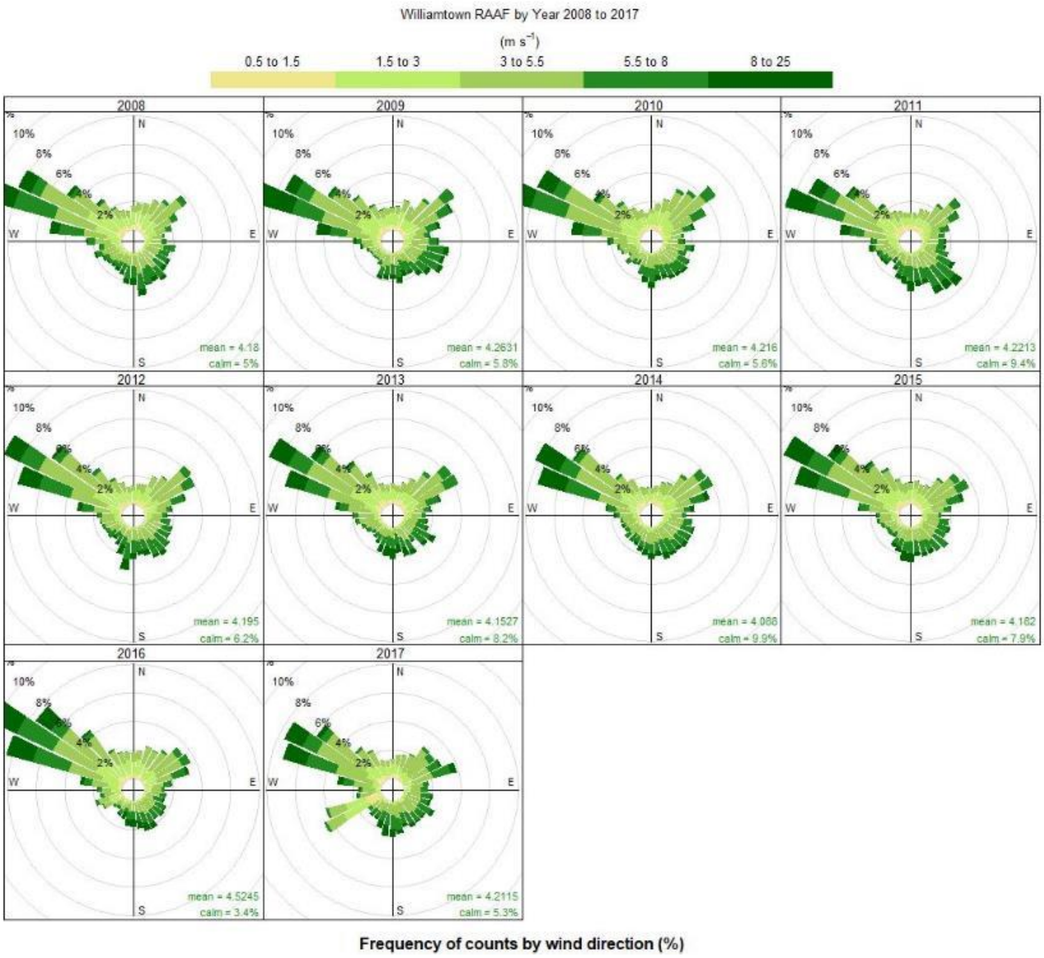
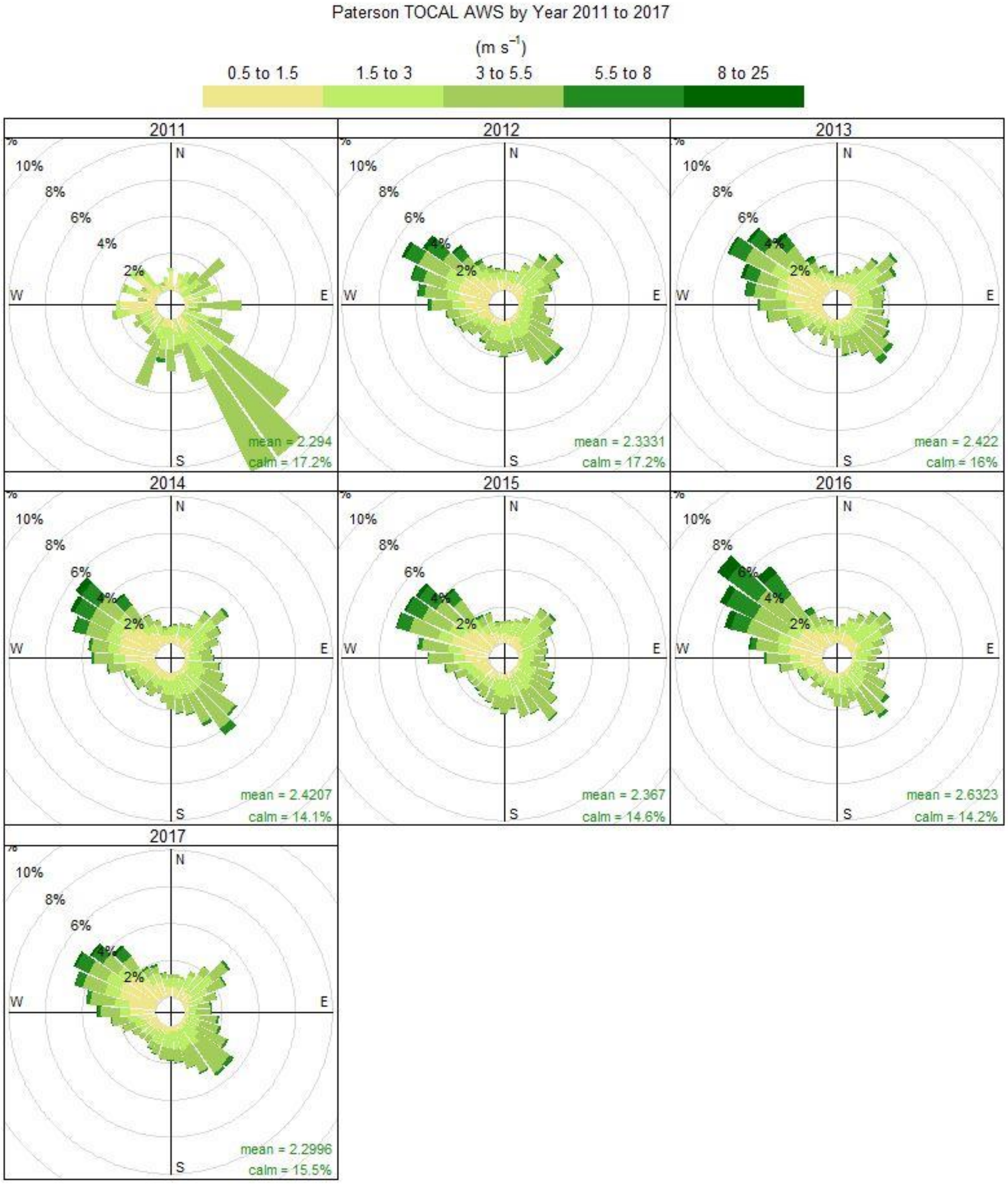


Figure 1-4

Annual Wind Roses 2011 to 2017, Paterson Tocal AWS



The wind roses indicate that from 2008 to 2017, winds at Newcastle Nobbys Signal Station AWS and Williamtown RAAF show similar spatial distribution patterns. However, Paterson Tocal AWS does not reflect these trends, apart from the prevailing north-westerlies. This distinction is most likely due to the inland location of Paterson Tocal AWS compared to the more coastal location of both Newcastle Nobbys Signal Station AWS and Williamtown RAAF AWS.

Data from Paterson Tocal AWS is presented for context. Given the size of the grids used in TAPM/CALMET modelling, data from Paterson Tocal AWS was not able to be used in model validation and data collected at Paterson Tocal AWS is not discussed further.

The majority of wind speeds experienced at Newcastle Nobbys Signal Station AWS and Williamtown RAAF AWS between 2008 and 2017 are generally in the range of 1.5 metres per second (m·s^{-1}) to ≥8 m·s^{-1}, with the highest wind speeds occurring from a north-westerly direction. Winds of this speed are somewhat frequent occurring during 18 % of the observed hours during the 10 years of data examined at Newcastle Nobbys Signal Station AWS and 9 % at Williamtown RAAF AWS.

Calm wind conditions (defined as <0.5 m·s^{-1}) are infrequent at Newcastle Nobbys Signal Station AWS and Williamtown RAAF AWS, occurring for 0.3 % and 6.6 % of hours across the 10 years examined, respectively.

Examination of the wind speed distribution at both the Newcastle Nobbys Signal Station AWS and Williamtown RAAF AWS are presented in **Figure 1-5** and **Figure 1-6**, respectively. The review of 10 years of data indicates that the year 2012 shows a distribution closest to the average conditions. This is important, especially for wind speed as a higher/lower frequency of calm wind conditions may over/under estimate the importance of wind erosion, or other wind dependent emissions sources.

Figure 1-5

Annual Wind Speed Distribution – Newcastle Nobbys Signal Station AWS

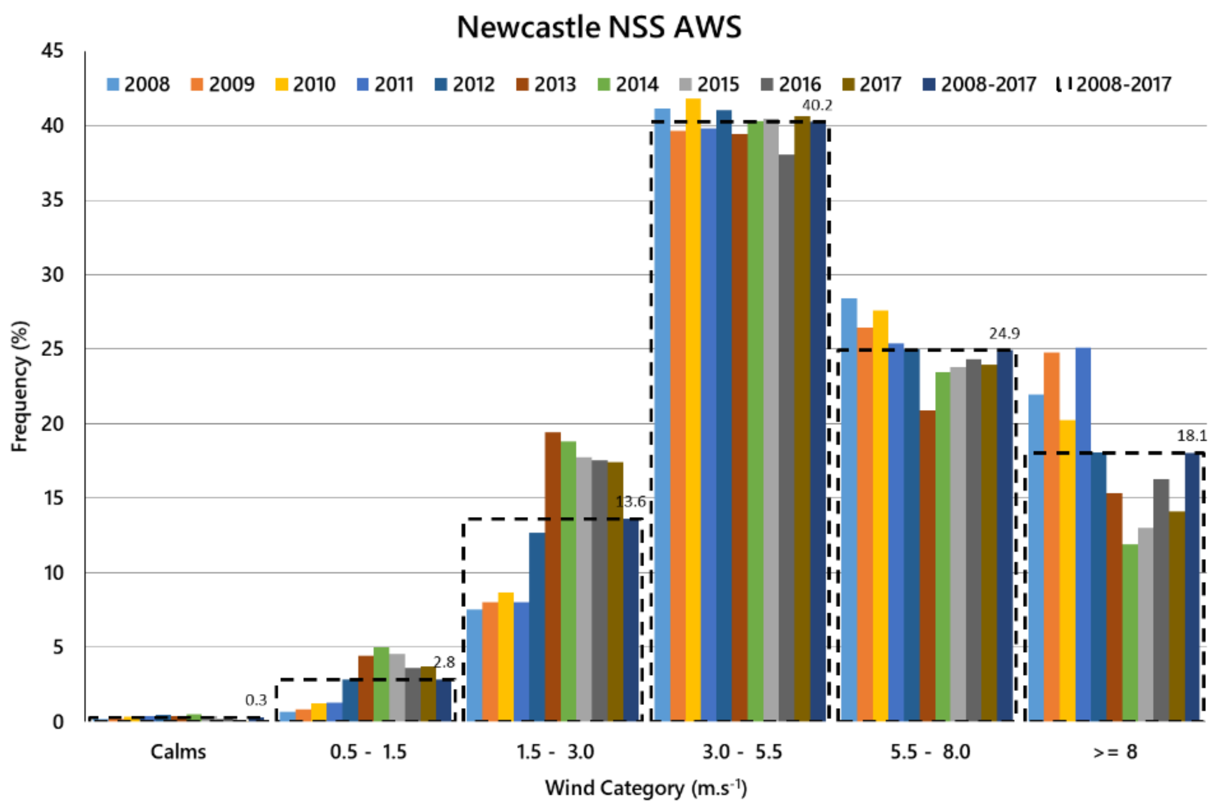
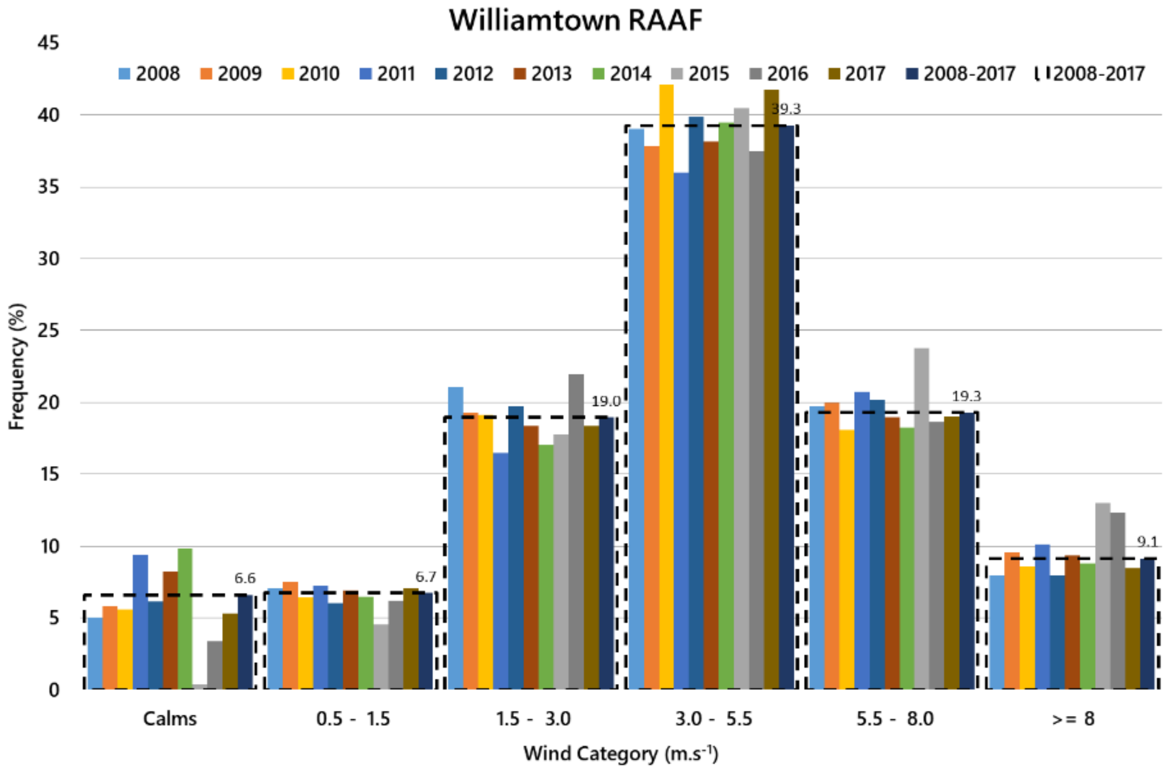


Figure 1-6

Annual Wind Speed Distribution – Williamtown RAAF



Given the distribution in wind speed and wind direction across the 10 years of data reviewed, it is concluded that the year 2012 adequately represents the general or average trend at the AWS examined and may be considered to provide a suitably representative dataset for use in dispersion modelling.

Figure 1-7 and **Figure 1-8** present the long-term (2008 to 2017) wind roses for Newcastle Nobbys Signal Station AWS and Williamtown RAAF AWS against data for the year 2012. The data are shown to compare well.

Figure 1-7

Annual Wind Rose 2008 - 2017, and 2012 – Newcastle Nobbys AWS

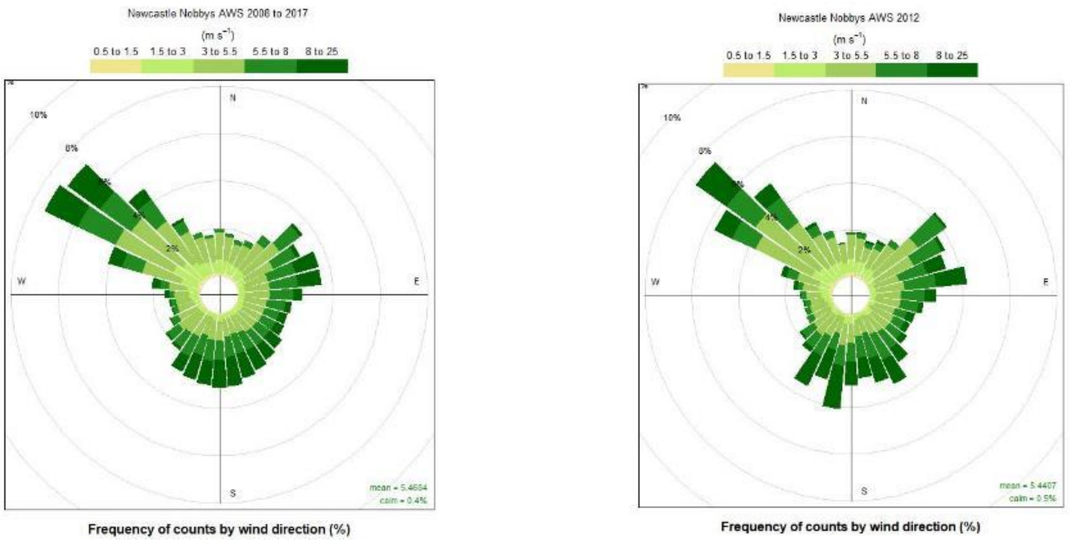
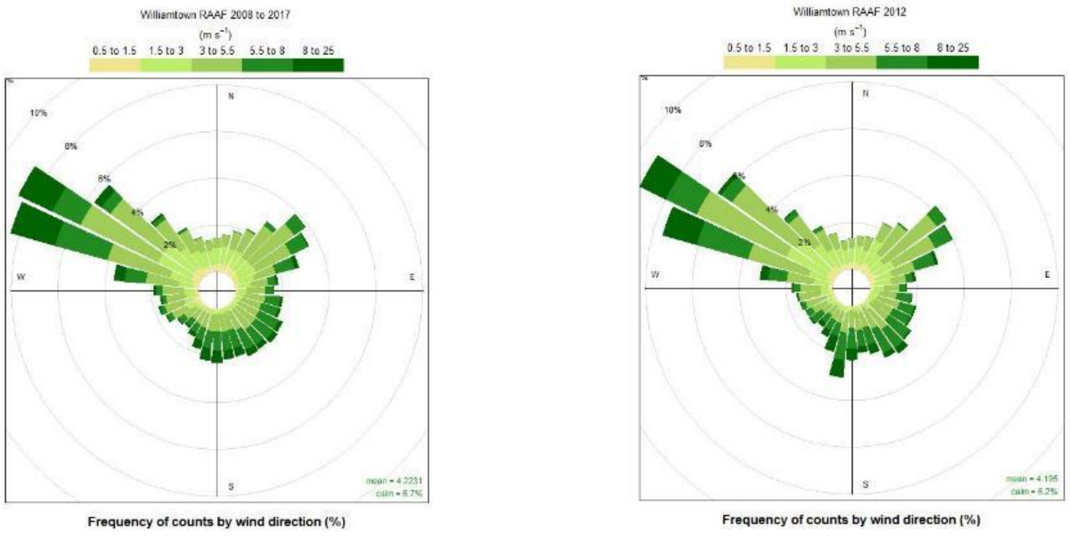


Figure 1-8

Annual Wind Rose 2008 - 2017, and 2012 – Williamtown RAAF AWS



Meteorological Modelling

The BoM data discussed in the preceding section adequately covers the issues of data quality assurance; however, it is limited by its location compared to the Site. To address these uncertainties, a multi-phased assessment of meteorological data has been performed.

In absence of any measured onsite meteorological data available for this assessment, site representative meteorological data for this Project was generated using the TAPM meteorological model in a format suitable for use in in the CALPUFF dispersion model (refer Section 4.4).

Meteorological modelling using The Air Pollution Model (TAPM, v 4.0.5) has been performed to predict the meteorological parameters required as input for CALMET (the meteorological pre-processor for CALPUFF). TAPM, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is a prognostic model which may be used to predict three-dimensional meteorological data and air pollution concentrations.

TAPM predicts wind speed and direction, temperature, pressure, water vapour, cloud, rain water and turbulence. The program allows the user to generate synthetic observations by referencing databases (covering terrain, vegetation and soil type, sea surface temperature and synoptic scale meteorological analyses) which are subsequently used in the model input to generate site-specific hourly meteorological observations at user-defined levels within the atmosphere.

Initially, TAPM was run in '*no-obs*' mode, meaning that no observational data were used to 'nudge' model predictions. Outputs of that model run were reviewed and analysis of observed versus modelled parameters of temperature, wind speed and wind direction at both Newcastle Nobbys Signal Station AWS and Williamtown RAAF AWS were performed using visual (wind roses) and statistical measures (discussed in more detail later). As a result of that analysis, certain statistical, referenced benchmarks were not met and a further TAPM run was performed, this time using observational data from Williamtown RAAF AWS to 'nudge' model predictions towards the observed values. A further round of visual and statistical analysis of model data against observations at Newcastle Nobbys Signal Station AWS were performed to ensure that the TAPM model was performing appropriately.

TAPM data were formatted using the CALTAPM software and used as input to the CALMET meteorological pre-processor. CALMET is a meteorological model that develops wind and temperature fields on a three-dimensional gridded modelling domain. Associated two-dimensional fields such as mixing height, surface characteristics, and dispersion properties are also included in the file produced by CALMET. The interpolated wind field is then modified within the model to account for the influences of topography, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field and thus the final wind field reflects the influences of local topography and current land uses.

The modelled meteorology presented within this Annexure relate to the existing environment and have been applied to the site establishment and construction phase. Minor changes to the pit configuration have been made to approximate topography in Stage 1C and Stage 2B of operations.

The parameters used in TAPM and CALMET modelling are presented in **Table 1-2**.

Table 1-2
Meteorological Parameters used for this Assessment

TAPM v 4.0.5	
Modelling period	1 January 2012 to 31 December 2012
Centre of analysis	395,400 mE, 6,374,950 mN (UTM Coordinates)
Number of grid points	52 × 52 × 25
Number of grids (spacing)	4 (22 km, 9 km, 3 km, 1 km)
Terrain	AUSLIG 9 second DEM
Data assimilation	Williamtown RAAF AWS
CALMET	
Modelling period	1 January 2012 to 31 December 2012
Centre of analysis	406,180 mE 6,389,854 mN (UTM Coordinates)
Number of grid points	100 x 100 x 10
Number of grids (spacing)	11 (0m, 20m, 40m, 80m, 160m, 320m, 640m, 1200m, 2000m, 3000m, 4000m)
Data assimilation	Williamtown RAAF AWS
Other variables required to be reported to the NSW EPA	Terrad = 1 km[a], IEXTRP = 1[b], RMin2 = 4[c], MCLOUD = 4[d]

Note [a] - Set to 1 km radius of influence of terrain features. (Barclay & Scire, 2011, p. 51; Earth Tech, Inc., 2000)

[b] - Set to 1 to not extrapolate any of the surface data. (Barclay & Scire, 2011, p. 51; Earth Tech, Inc., 2000)

[c] - Set to 4 km, so that surface stations within 4km of an upper air station will not be subject to vertical extrapolation within any of the IEXTRP. (Barclay & Scire, 2011, p. 55; Earth Tech, Inc., 2000)

[d] - Set to 4, so that the numerical weather predictions (NWP) model used (4) computes the gridded cloud cover from prognostic relative humidity at all levels. (Barclay & Scire, 2011, p. 54; British Columbia Ministry of Environment, 2015)

Following output of data from CALMET, a third and final round of visual and statistical evaluation was performed. The results of this final evaluation are presented below. These data have been adopted within the assessment.

Meteorological Data Validation

As required within the SEARs, validation/verification of meteorological modelling against monitored data is required to be performed. The SEARs require that the analysis of wind speed, wind direction and temperature are presented.

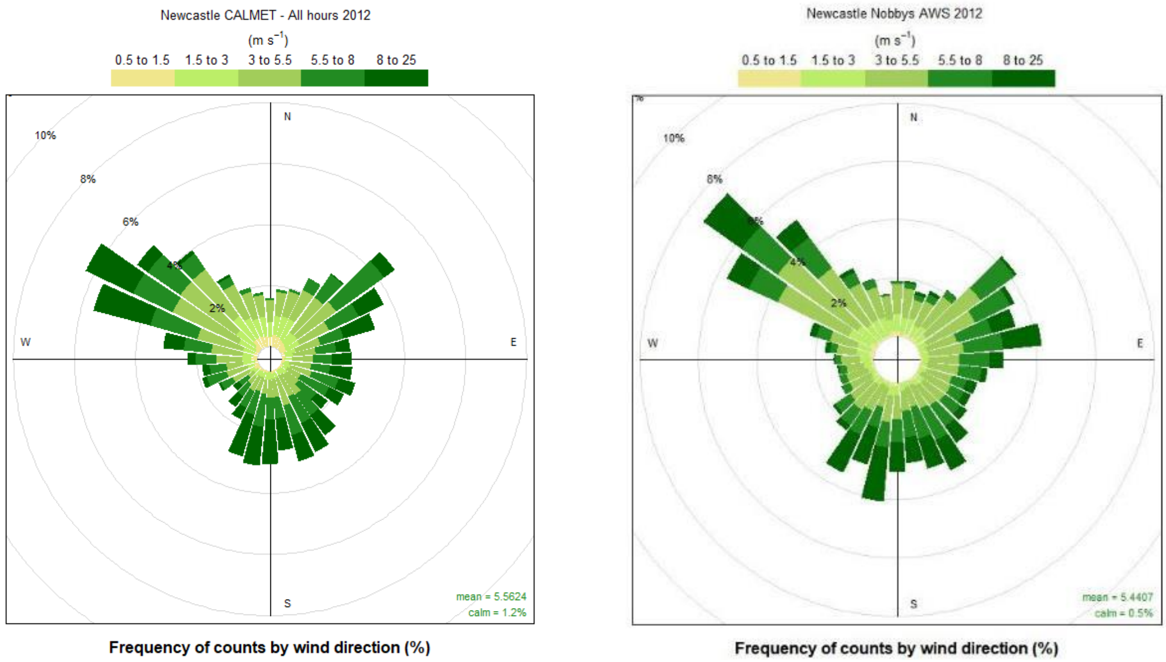
Visual Analysis

A comparison of the modelled (TAPM/CALMET) meteorological data, extracted at the Newcastle Nobbys Signal Station AWS and observations at that AWS are presented in **Figure 1-9**. These data generally compare well which provides confidence that the meteorological conditions modelled as part of this assessment are appropriate.

Figure 1-9

Modelled and Observed Meteorological Data – Newcastle Nobbys Signal Station AWS, 2012

Modelled data | **Observations**



A visual comparison of wind speed, wind direction and temperature data (modelled versus observed) at Newcastle Nobbys Signal Station AWS is presented in **Figure 1-10, Figure 1-11, Figure 1-12**.

The modelled output is considered to be highly similar to the observed data, providing reassurance that the models have performed as expected.

Figure 1-10

Time Variation Plot of CALMET Modelled and Observed Wind Speed – Newcastle Nobbys Signal Station AWS, 2012

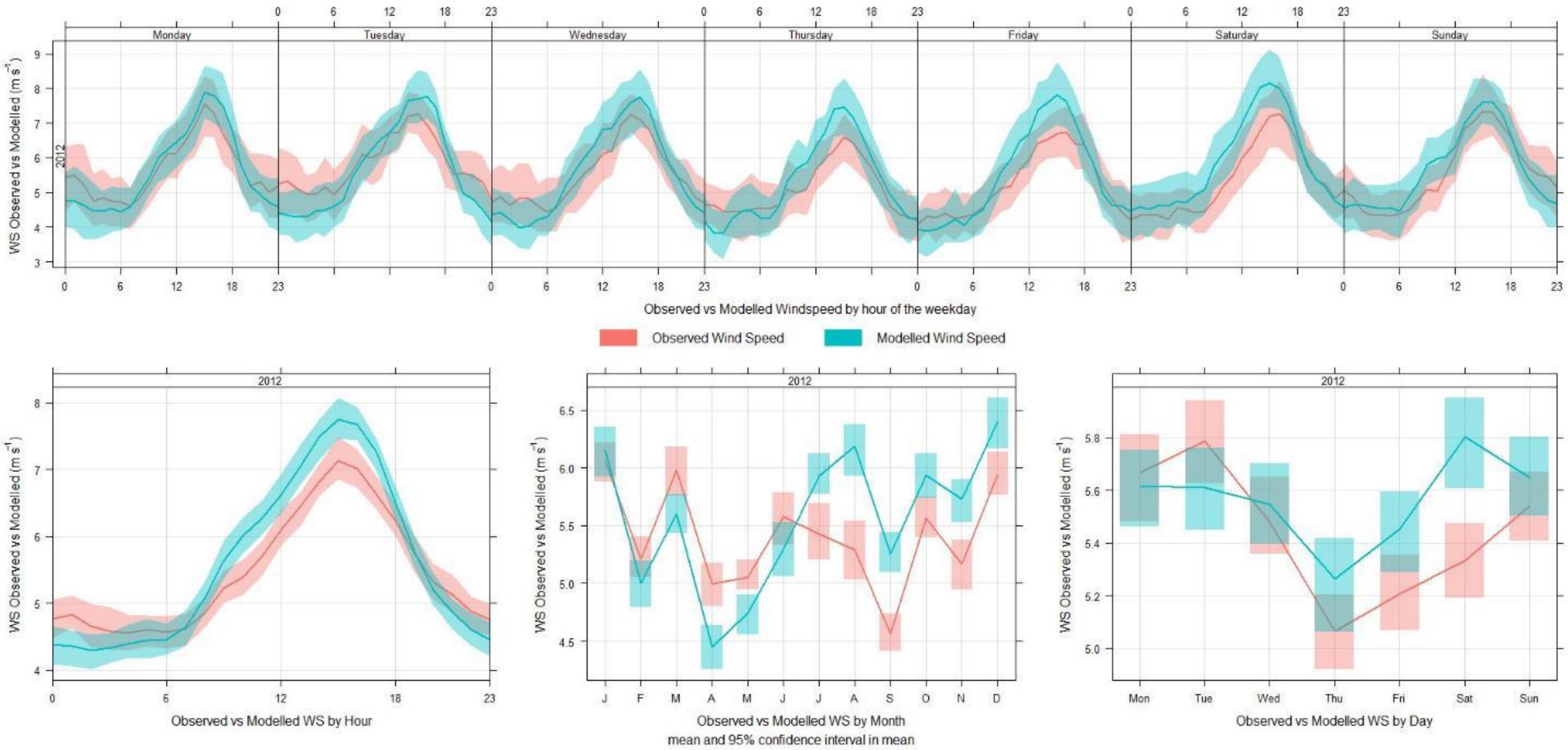


Figure 1-11

Time Variation Plot of CALMET Modelled and Observed Wind Direction – Newcastle Nobbys Signal Station AWS, 2012

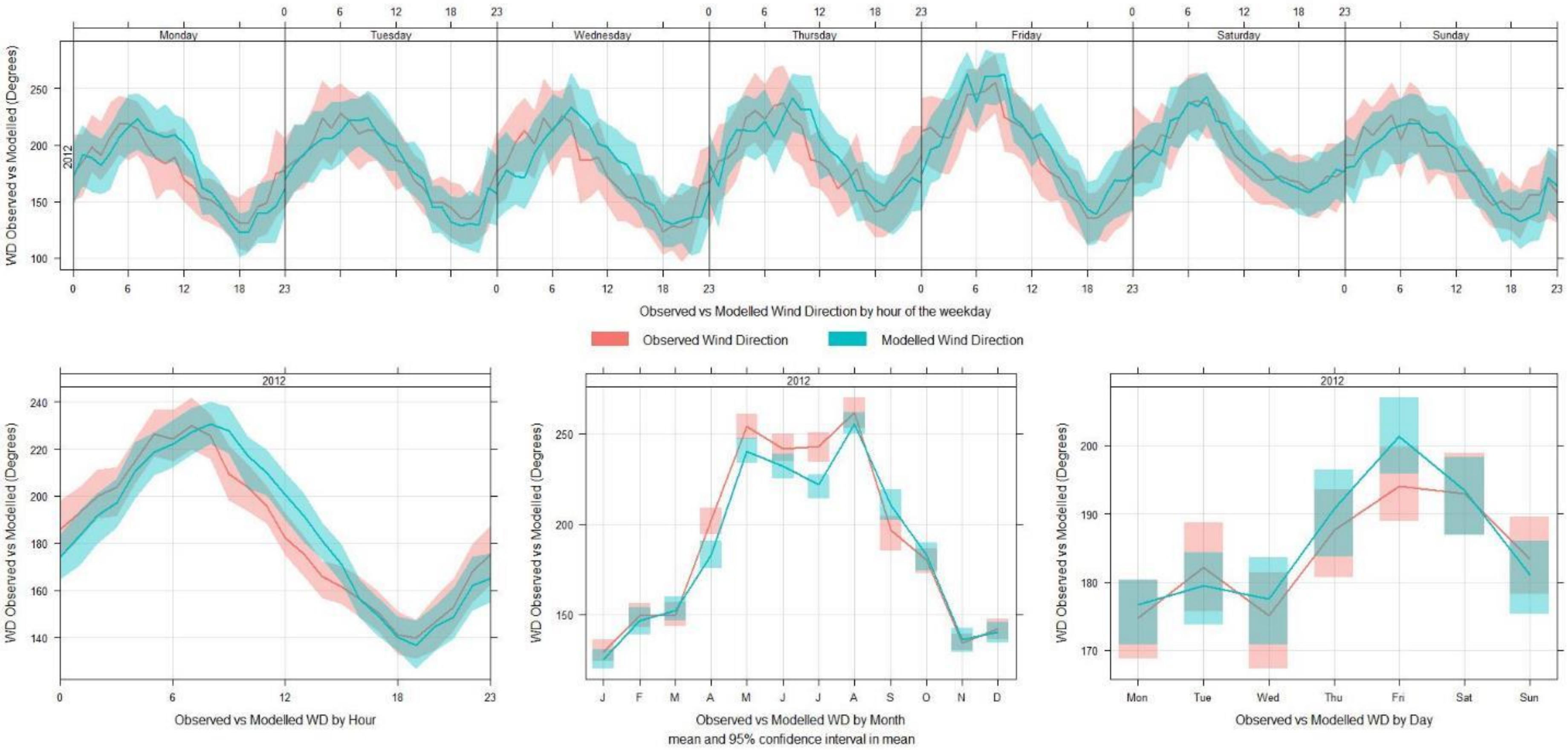
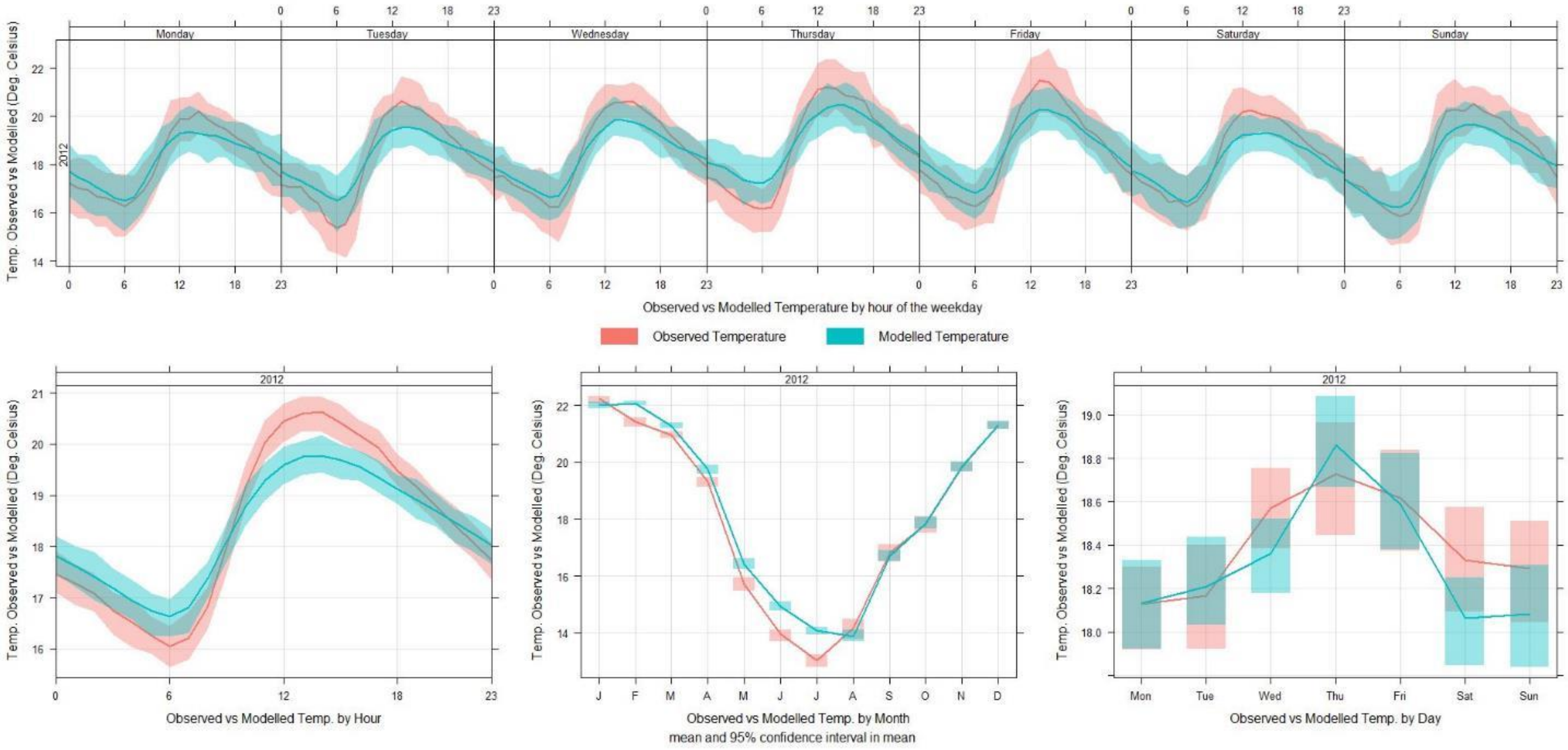


Figure 1-12

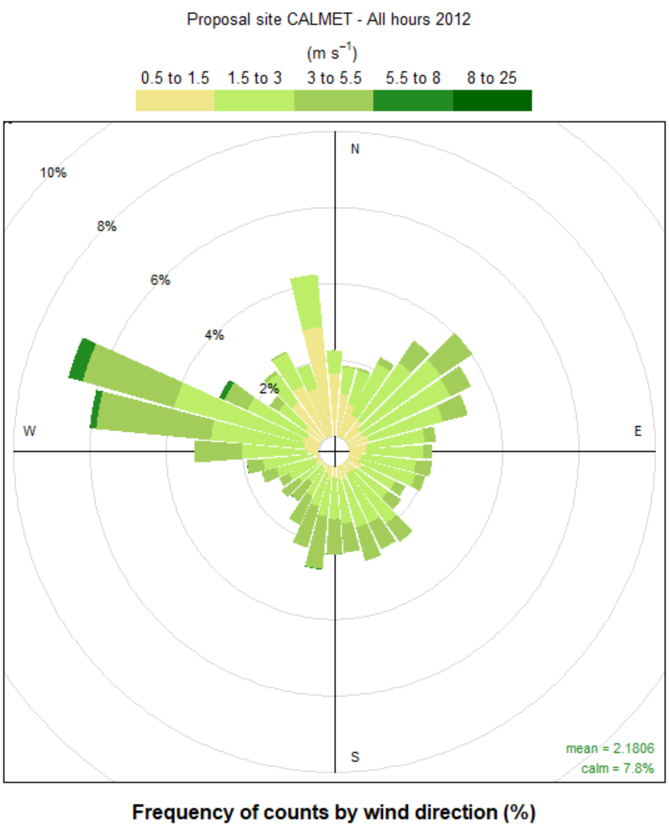
Time Variation Plot of CALMET Modelled and Observed Temperature – Newcastle Nobbys Signal Station AWS, 2012



In addition to the data presented above, and as generally required by the NSW EPA, the following provides a summary of additional variables output as part of the meteorological modelling exercise. Given the nature of the pollutant emission sources at the Site, detailed discussion of the humidity, evaporation, cloud cover, katabatic air drainage and air recirculation potential of the Site has not been provided. Details of the CALMET predicted wind conditions at the Site during 2012 are presented in **Figure 1-13**.

Figure 1-13

Modelled Meteorological Data – Site, 2012

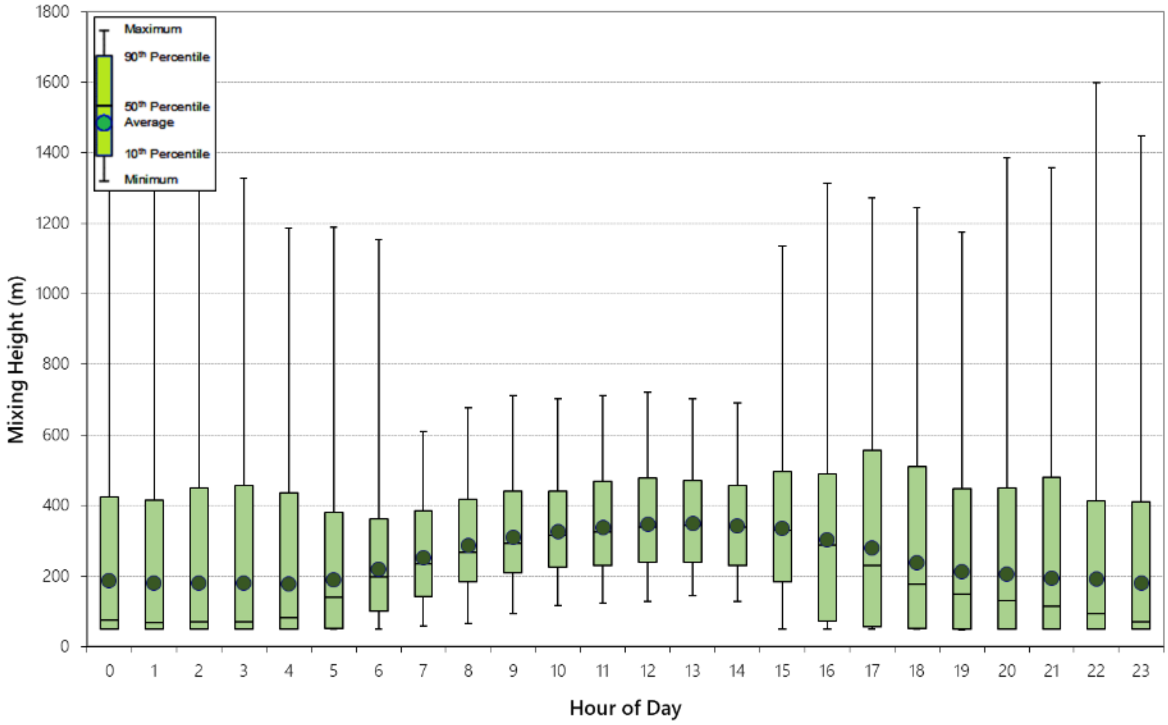


Diurnal variations in maximum and average mixing heights predicted by CALMET at the Site during 2012 are illustrated in **Figure 1-14**.

As expected, an increase in mixing height during the morning is apparent, arising due to the onset of vertical mixing following sunrise. Maximum mixing heights occur in the late afternoon, due to the dissipation of ground-based temperature inversions and growth of the convective mixing layer.

Figure 1-14

Predicted Mixing Height – Site, 2012



Statistical Analysis

A number of statistical measures have been calculated to allow comparison of observed and modelled meteorological data. These statistical outputs have been compared with general guidelines for model performance suggested by (Emery, Tai, & Yarwood, 2001) and refined in (Office of Air Quality Planning and Standards, 2002) and (US National Parks Service, 2010), which are presented **Table 1-3**.

The statistical measures are described as follows where:

n = number of observations

M_i = modelled value

O_i = observed value

$\bar{M}$ = mean of modelled values

$\bar{O}$ = mean of observed values

Mean Bias (MB) is the degree of correspondence between the mean prediction and the mean observation, with lower numbers indicative of better performance. Values less than 0 indicate under-prediction. The Mean Gross Error (MGE), is the Mean Bias applied over a longer period of time.

$$MB \,\&\, MGE = \frac{1}{n}\sum_{i=1}^{n}|M_i - O_i|$$

Root Mean Square Error (RMSE) is a good overall measure of model performance. The weighting of (prediction-observation) by its square tends to inflate RMSE, particularly when extreme values are present. With respect to a good model the root mean square error should approach zero.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(M_i - O_i)^2}$$

Index of Agreement (IOA) is a relative measure of the degree of which predictions are error free. The denominator accounts for the model's deviation from the mean of the observations as well as to the observations deviation from their mean. It does not provide information regarding systematic and unsystematic errors. The index of agreement approaches 1 when model performance is best.

$$IOA = 1 - \frac{\sum_{i=1}^{n}(M_i - O_i)^2}{\sum_{i=1}^{n}(|M_i - \bar{O}| + |O_i - \bar{O}|)^2}$$

Table 1-3
Statistical Measures used for this Study

Statistical Measure	WS	WDIR	T	WS	WDIR	T
Mean Bias	D	D	D	≤ ± 0.5 m/s	≤ ± 10°	≤ ± 0.5 K
Mean Gross Error	M / A	M / A	M / A	≤ 2 m/s	≤ ± 30°	≤ 2 K
Root Mean Square Error	D / M / A	-	-	≤ 2 m/s	-	-
Index of Agreement	D / M / A	-	D / M / A	≥ 0.6	-	≥ 0.8
D = daily, M = monthly, A = annual, WS = wind speed, WDIR = wind direction, T = Temperature						

A summary of model performance on a monthly and annual basis is presented in **Table 1-4**. Values outside of the benchmarks are shown as italicised bold text. Modelled data generally performs well against observations on these averaging periods.

Table 1-4
Comparison of Monthly and Annual Statistical Benchmarks

Statistical Measure	Bm	J	F	M	A	M	Ju	J	A	S	O	N	D	An
MGE (T) K	≤ 2	0.3	0.6	0.3	0.5	0.7	1.0	0.8	0.1	0.2	0.0	0.0	0.0	0.3
MGE (WS) $m \cdot s^{-1}$	≤ 2	0.1	0.2	0.4	0.6	0.3	0.4	0.7	1.0	0.4	0.4	0.6	0.4	0.1
MGE (WDIR) °	≤ 30	4.4	2.7	3.6	19.7	15.0	5.5	21.9	1.5	2.5	3.5	2.0	1.7	5.1
RMSE (WS) $m \cdot s^{-1}$	≤ 2	1.8	1.7	1.5	1.5	1.4	1.5	1.2	1.3	1.3	1.6	1.9	***2.1***	1.6
IOA (T)	≥ 0.8	0.8	***0.7***	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9	0.9	0.8	1.0
IOA (WS)	≥ 0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Note: Bm = Benchmark, MGE = Mean Gross Error, RMSE = Root Mean Square Error, IOA = Index of Agreement
Daily benchmarks presented in **Figure 1-14**, **Figure 1-15** and **Figure 1-16** (Mean Bias, RMSE, IOA)

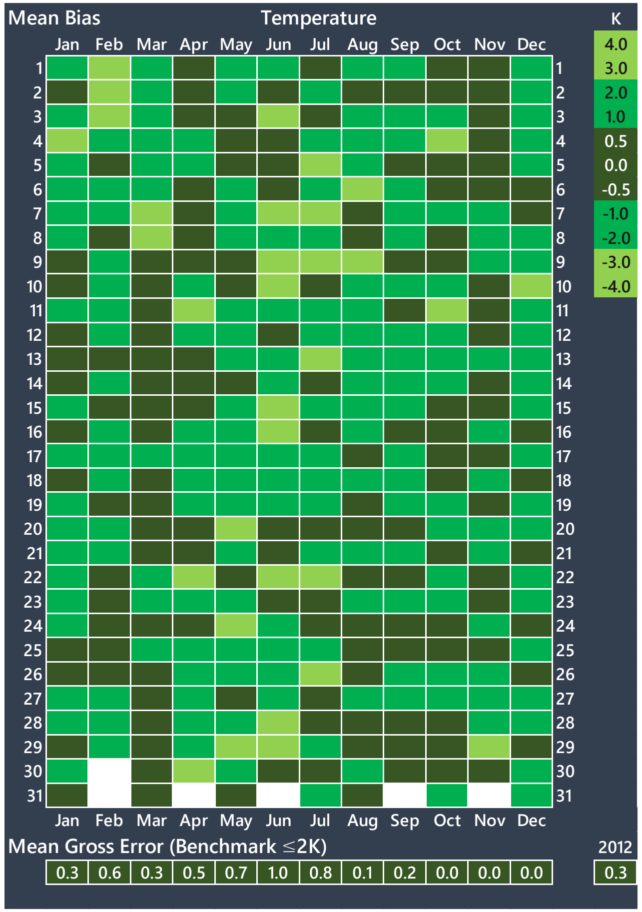
The outputs of the statistical analysis have been visualised in **Figure 1-15**, **Figure 1-16** and **Figure 1-17**. Dark green colouring indicates values which meet the benchmarks in **Table 1-3**. Progressively lighter colours indicate values which are outside of the benchmark. Care should be taken when interpreting these charts to ensure that the correct benchmark is applied; especially for Mean Bias / Mean Gross Error; the benchmarks vary between daily and monthly/annual time periods.

When viewing the results of both the visual and statistical analysis of modelled meteorological data together, the model is generally shown to perform well. It is noted that models provide a calculation of the meteorology at a point in space and time. Although best efforts are made to provide accurate input data and use the most appropriate models and variables applied within those models, perfect model performance on every day of the year cannot be expected.

Figure 1-15

Model Performance – Temperature

Mean Bias – Daily
Mean Gross Error – Monthly and Annual



Index of Agreement – Daily, Monthly and Annual

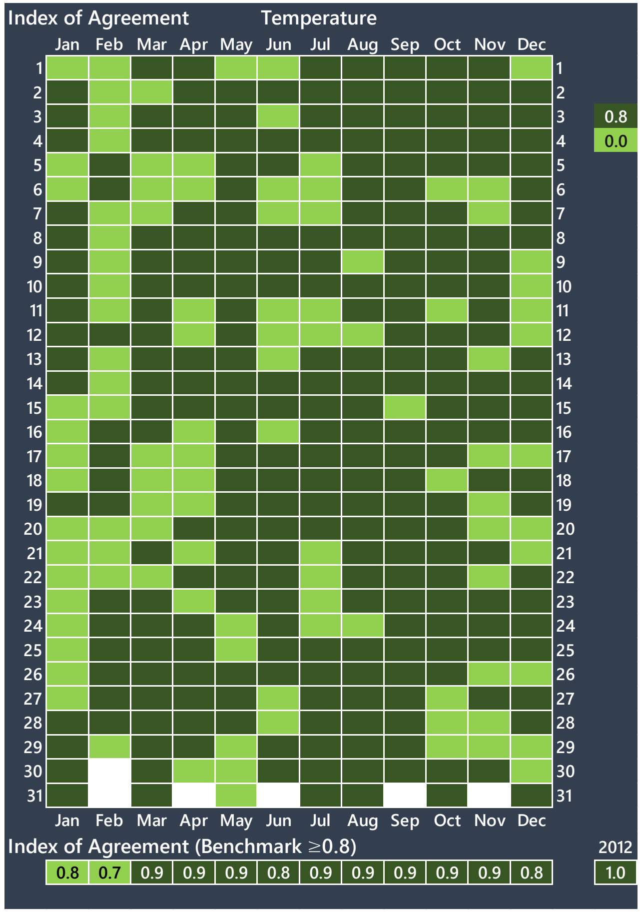


Figure 1-16

Model Performance – Wind Speed

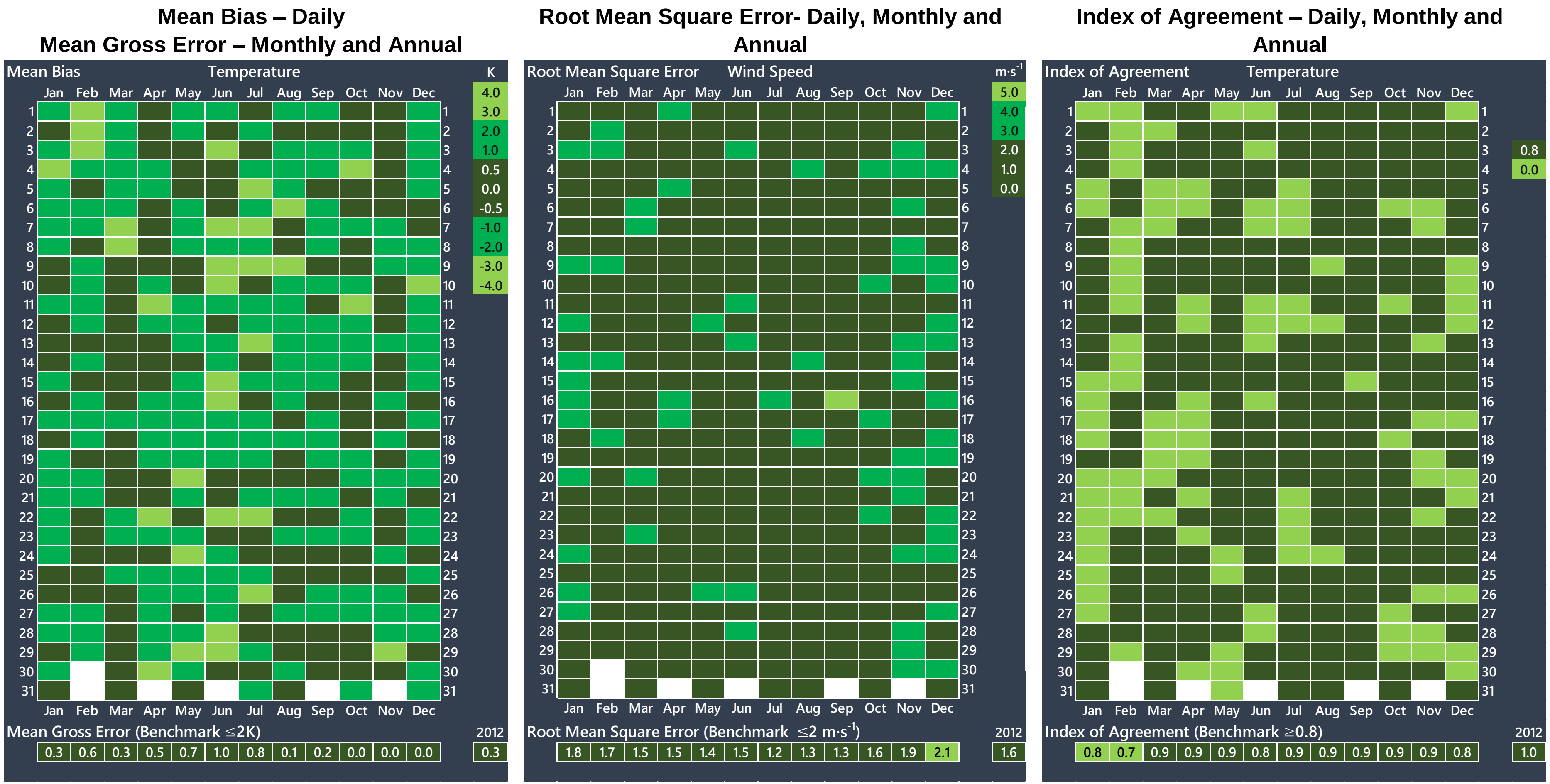
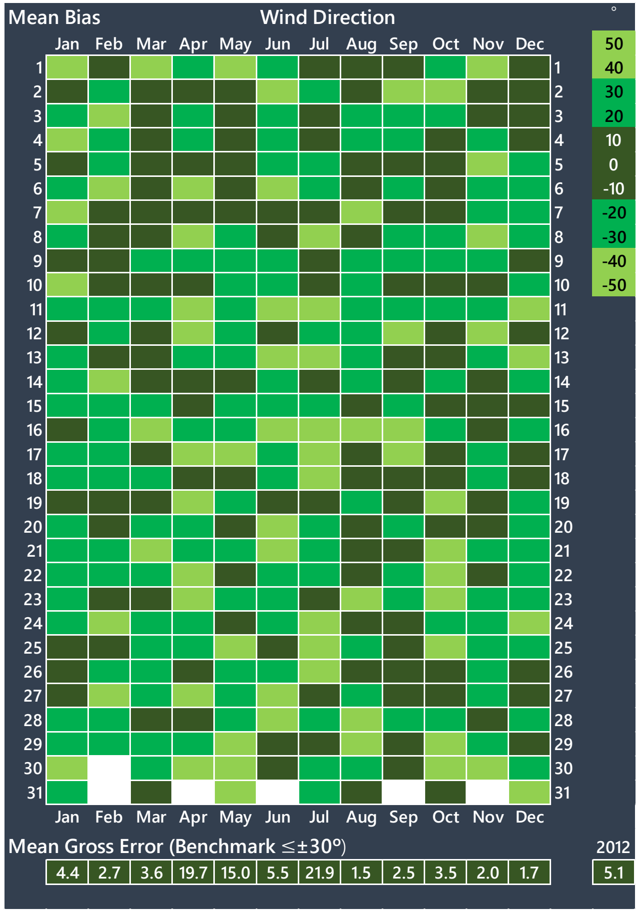


Figure 1-17

Model Performance – Wind Direction

Mean Bias – Daily
Mean Gross Error – Monthly and Annual



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Annexure 2

Emissions

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EMISSIONS ESTIMATION – UNCONTROLLED EMISSION FACTORS

As outlined in Section 2.5, a number of operations to be performed as part of the Project operation have the potential to result in emissions of particulate matter and combustion gases. A detailed outline of the emission estimation techniques adopted to derive total emissions from the sources identified in Section 2.5 are presented below.

As required by the SEARs a detailed summary and justification of all parameters adopted within the emissions estimation calculations is provided.

Emission factors are presented below as uncontrolled emission rates. The requirement for the application of emissions reductions measures has been determined through the performance of a Best Practice Management (BPM) assessment, which has been guided by the NSW EPA Particulate Matter Control, Best Practice Guideline (NSW EPA, 2011).

Following the BPM assessment, the required emissions reductions have been applied to the calculated uncontrolled emissions to determine an annual controlled emission from the Site.

As required by the SEARs, a summary of particulate matter (TSP, PM_{10} and $PM_{2.5}$) and NO_X emissions resulting from the Project operation is outlined, for each key development stage.

Particulate Matter

Emission factors published by the US EPA in the Compilation of Air Pollutant Emission Factors (AP-42) have been adopted to allow estimation of particulate matter emissions (TSP, PM_{10} and $PM_{2.5}$) from Project operation. Several AP-42 sections have been consulted in the preparation of this assessment including:

- 11.9 Western Surface Coal Mining
- 11.19.2 Crushed Stone Processing and Pulverised Mineral Processing
- 13.2.2 Unpaved Roads
- 13.2.1 Paved Roads
- 13.2.4 Aggregate Handling and Storage Piles

Drilling and blasting

Emissions of particulate matter resulting from drilling and blasting have been estimated using the emission factor presented in Section 11.9 of AP-42 (Western Surface Coal Mining) (US EPA, 1998).

The emission factor in Table 11.9-2 has been adopted for blasting:

$$TSP\ (kg \cdot blast^{-1}) = 0.00022(A)^{1.5}$$

where:

A is the horizontal area (m^2) with blasting depth ≤ 21 m.

PM_{10} and $PM_{2.5}$ emission factors are derived using the scaling factors outlined in Table 11.9.2 of (US EPA, 1998), which are 0.52 for PM_{10} and 0.03 for $PM_{2.5}$ (applied to the TSP emission factor).

The emission factor in Table 11.9-4 has been adopted for drilling:

$$TSP\ (kg \cdot hole^{-1}) = 0.59$$

PM_{10} and $PM_{2.5}$ emission factors have been derived using the same scaling factors as for blasting as outlined above in the absence of drilling specific factors.

The maximum blasting area (m^2) in each of the modelled operational stages has been taken to be 1,600 m^2. Blasting would occur once every three to four weeks and for the purposes of this assessment, blasting has been assumed to occur once every three weeks (or a maximum of 18 blasts per year).

Loading and unloading, managing stockpiles

Emissions of particulate matter resulting from the loading of materials to trucks, and the unloading of materials at the raw feed, crusher hopper, overburden emplacement area and stockpiles, and the management of stockpiles at the processing plant have been estimated using the emission factor presented in Section 13.2.4 of AP-42 (Aggregate Handling and Storage Piles) (US EPA, 2006b).

The emission factor on page 13.2.4-4 has been adopted for the operations outlined above:

$$E\ (kg \cdot tonne^{-1}) = k(0.0016)\ \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

where:

E = emission factor

k = particle size multiplier (dimensionless)

U = mean wind speed ($m \cdot s^{-1}$)

M = material moisture content (%)

The particle size multiplier for TSP, PM_{10} and $PM_{2.5}$ are provided in (US EPA, 2006b) as 0.74, 0.35 and 0.2, respectively.

The value adopted for U (mean wind speed) has been calculated from the output of the modelled meteorological file which is discussed in detail in **Annexure 1**. This value has been calculated to be 2.1 $m \cdot s^{-1}$.

The value adopted for M (material moisture content) has been assumed to be 2 % for all materials handled at the Site. A review of several AQIA was performed which indicates that a range of values between 2 % and 5 % moisture content for materials handled at hard rock or aggregate quarries have been previously adopted:

- 2 % for soil as per page 17 of (GHD, 2016)
- 4 % for hard rock as per page 24 of (GHD, 2009)
- 3 % for rock and 5% for overburden as per page 25 of (Heggies, 2008)
- 2 % for aggregate as per page B-4 of (Pacific Environment Limited, 2017)
- 5 % for hard rock and 4% for product as per page 3-38 of (BMT WBM Pty Ltd, 2011)

In the case of the AQIA reviewed, no source data for those moisture content values are provided. For the purposes of this assessment, a value of 2 % has been adopted for all materials to be handled as part of Project operations. This is the lowest value of those reviewed and is conservative.

Processing

Emissions of particulate matter resulting from the processing of materials (primary, secondary and tertiary crushing and screening) have been estimated using the emission factors presented in Section 11.19.2 of AP-42 (Crushed Stone Processing and Pulverised Mineral Processing) (US EPA, 2004).

The emission factors within Table 11.19.2-1 have been adopted for the operations outlined above. No emission factors associated with primary or secondary crushing are available within AP-42 although emission factors for tertiary crushers can be used as an upper limit for primary or secondary crushing (US EPA, 2004).

For uncontrolled tertiary crushing (and uncontrolled primary and secondary crushing):

$$\text{TSP}\ (kg \cdot tonne^{-1}) = 0.0027$$

$$\text{PM}_{10}\ (kg \cdot tonne^{-1}) = 0.0012$$

$$\text{PM}_{2.5}\ (kg \cdot tonne^{-1}) = 0.00012$$

$PM_{2.5}$ emission factors are not available in AP42 although have been taken to be 10% of PM_{10} as per aggregate handling sources (MRI, 2006).

For uncontrolled screening:

$$\text{TSP}\ (kg \cdot tonne^{-1}) = 0.0125$$

$$\text{PM}_{10}\ (kg \cdot tonne^{-1}) = 0.0043$$

$$\text{PM}_{2.5}\ (kg \cdot tonne^{-1}) = 0.00043$$

$PM_{2.5}$ emission factors are not available in AP42 although taken to be 10% of PM_{10} as per aggregate handling sources (MRI, 2006).

Transportation

Emissions of particulate matter resulting from the movement of materials on unpaved and paved roads have been estimated using the emission factors presented in Section 13.2.2 (Unpaved Roads) and 13.2.1 (Paved Roads) of AP-42, respectively (US EPA, 2006a), (US EPA, 2011).

The emission factor on page 13.2.2-4 of (US EPA, 2006a) has been adopted for the operations of vehicles on unpaved roads:

$$E\ (kg \cdot VKT^{-1}) = 0.2819\ \times k(s/12)^{a}(W\ \times\ 0.907185/3)^{b}$$

where:

E = emission factor (kg per vehicle kilometre travelled) multiplied by 0.2819 to convert from lb per vehicle mile travelled

k = particle size multiplier (dimensionless)

s = surface material silt content (%)

W = mean vehicle weight (tons) multiplied by 0.907185 to convert to metric tonnes

The particle size multipliers for TSP, PM_{10} and $PM_{2.5}$ (k) are provided in (US EPA, 2006a) as 4.9, 1.5 and 0.15, respectively. The silt content of unpaved haul roads at the Site has been taken to be 8.3 % which equates to a haul road to/from pit at a stone quarrying and processing facility (Table 13.2.2-1 of (US EPA, 2006a)). This is considered to most appropriately reflect the proposed operations.

The mean weight of vehicles has been calculated based on the use of '40 t' dump trucks, such as the CAT 730C (or similar) which has a payload of 28 t, tare weight of 24 t and a loaded weight of 52.0 t (ritchiespecs.com). The average vehicle weight has therefore been calculated to be 38 t (metric).

The emission factor on page 13.2.1-4 of (US EPA, 2011) has been adopted for the operations of vehicles on paved roads:

$$E\ (kg \cdot VKT^{-1}) = k(sL)^{0.91}(W\ \times\ 0.907185)^{1.02}$$

where:

E = emission factor (kg per vehicle kilometre travelled)

k = particle size multiplier (dimensionless)

sL = road surface silt loading ($g \cdot m^{-2}$)

W = average weight (tons) of vehicles travelling the road multiplied by 0.907185 to convert to metric tonnes

The particle size multipliers for TSP, PM_{10} and $PM_{2.5}$ (k) are provided in (US EPA, 2011) as 3.23, 0.62 and 0.15, respectively.

The road surface silt loading of the paved haul road between the Pacific Highway and Site has been taken to be 1 $g \cdot m^{-2}$. This value is considered to represent a potential worst-case. (US EPA, 2011) provides discussion regarding limited access roadways with the recommendation that a silt loading value of 0.015 $g \cdot m^{-2}$ be adopted. The value of 1 $g \cdot m^{-2}$ is therefore considered to be highly conservative.

The mean weight of vehicles has been calculated based on the use of 30 t to 35 t capacity B-Double vehicles (average 32.5 t), which would have a payload of 32.5 t, tare weight of 13.5 t and a loaded weight of 45.5 t. The average vehicle weight has therefore been calculated to be 29.5 t (metric).

Wind Erosion

Emissions of particulate matter resulting from the wind erosion of materials from the open pit, stockpiles, overburden emplacement and topsoil stockpiles have been estimated using the emission factor presented in Section 11.9 of AP-42 (Western Surface Coal Mining) (US EPA, 1998).

The emission factor in Table 11.9-4 of (US EPA, 1998) has been adopted for the action of wind erosion:

$$\text{TSP}\ (tonne \cdot ha^{-1} \cdot yr^{-1}) = 0.85$$

$$\text{PM}_{10}\ (tonne \cdot ha^{-1} \cdot yr^{-1}) = 0.425$$

$$\text{PM}_{2.5}\ (tonne \cdot ha^{-1} \cdot yr^{-1}) = 0.06375$$

To determine PM_{10} and $PM_{2.5}$ emissions, the particle size multipliers in Section 13.2.5 (Industrial Wind Erosion) of AP-42 have been applied to TSP emissions, specifically 0.5 for PM_{10} and 0.075 for $PM_{2.5}$ (US EPA, 2006c).

Diesel Engine Particulate Matter

In addition to the emissions of process related particulate matter outlined above, recent studies have shown that emissions of fine particulate matter resulting from diesel combustion can significantly contribute to the fine particulate matter emissions profile of a site. To appropriately quantify these emissions, information contained within the NSW EPA report "*Reducing Emissions from Non-road Diesel Engines*" (NSW EPA, 2014) has been reviewed. It has been assumed that all emissions from diesel combustion are fine particulate (i.e. $PM_{2.5}$) emissions. The assumptions adopted within the assessment, including the emission factors is presented in **Table 2-1**. The full emissions inventory is presented below.

Table 2-1
Diesel Particulate Matter – Assumptions and Emission Factors

Equipment	kW Rating	Operating Hours[1]	Load Factor[2]	$PM_{2.5}$ Emission Factor ($g \cdot kWh^{-1}$)[3]
Percussion Drill Rig (Atlas Copco T40 or similar)	168	3,084	0.59	0.2
Hydraulic Excavator 50t (Caterpillar 349F or similar)"	322	3,084	0.59	0.2
Hydraulic Excavator 26t (Caterpillar 325F or similar)"	132	3,084	0.59	0.2
Bulldozer (Caterpillar D9T Dozer)	346	3,084	0.59	0.2
Front-end Loader (Caterpillar 980K or similar)	264	3,084	0.59	0.2
Mobile jaw crusher (MC125Z or similar)	350	3,084	0.59	0.2
Mobile cone crusher (MCO13 or similar)	430	3,084	0.59	0.2
Mobile screening plant (MS15Z or similar)	76	3,084	0.59	0.2
Mobile cone crusher (MCO13S or similar)	507	3,084	0.59	0.2
Mobile screening plant (MS20D or similar)	101	3,084	0.59	0.2

Equipment	$VKT \cdot yr^{-1}$			$PM_{2.5}$ Emission Factor ($g \cdot VKT^{-1}$)[4]
	Const.	Stage 1C	Stage 2B	
Articulated Haul Truck (CAT 730C or similar)	5,464	9,909	33,003	0.584
Product truck	0	25,292	50,215	

Notes: 1: Extraction and processing: 11 hrs per day Monday to Friday, 6 hrs on Saturday. Transport operations: 13 hrs per day Monday to Friday, 8 hrs on Saturday
2: From Table D1 of (NSW EPA, 2014)
3: From Table 5 of (NSW EPA, 2014)
4: 1996 Australian Design Rule (ADR) 70/00 in (NSW EPA, 2013)

The numbers of plant and vehicles required for each modelled stage of the Project are presented below in **Table 2-2**.

Table 2-2
Anticipated Plant and Vehicle Numbers

Equipment	Number		
	Construction and Site Establishment	Stage 1C	Stage 2B
Percussion Drill Rig (Atlas Copco T40 or similar)	0	1	1
Hydraulic Excavator 50t (Caterpillar 349F or similar)"	1	1	1
Hydraulic Excavator 26t (Caterpillar 325F or similar)"	1	0	1
Bulldozer (Caterpillar D9T Dozer)	1	1	1
Front-end Loader (Caterpillar 980K or similar)	1	1	2
Mobile jaw crusher (MC125Z or similar)	0	1	1
Mobile cone crusher (MCO13 or similar)	0	1	1
Mobile screening plant (MS15Z or similar)	0	1	1
Mobile cone crusher (MCO13S or similar)	0	1	1
Mobile screening plant (MS20D or similar)	0	1	1
Articulated Haul Truck (CAT 730C or similar)	2	2	3
Product truck	0	3	5

Combustion Gases

Diesel Engine Combustion Gases

Non-road diesel engine and equipment exhaust consists of hundreds of gas-phase, semi-volatile and particle-phase organic compounds that are produced through fossil fuel combustion. Oxides of nitrogen (NOx) and volatile organic compound (VOC) emissions released from engine/equipment exhausts are of interest individually and due to their being precursors of photochemical smog including ozone (ENVIRON, 2010).

A report on the performance of non-road diesel engines in Australia (ENVIRON, 2010) indicates that approximately 70% of non-road diesel engines in Australia in 2008 were compliant with US EPA Tier 2 / EU Stage II emission standards.

Tier 2 emission standards for NO_X (plus non-methane hydrocarbons [NMHC]) are presented below. Tier 2 emission standards for NO_X alone are not prescribed.

$$NO_X\ (g \cdot kWh^{-1})(75\ \leq kWh\ < 225) = 6.6$$

$$NO_X\ (g \cdot kWh^{-1})(225\ \leq kWh\ \geq 560) = 6.4$$

Blast Fume

Under ideal blasting conditions, blasting explosives containing ammonium nitrate/fuel oil (ANFO) react to form carbon dioxide, water and nitrogen. However, small changes in stoichiometry in either the bulk material, moisture in blast holes, mineral matter etc.) can result in a non-ideal explosive reaction and lead to the formation of carbon monoxide (CO) and nitric oxide (NO). In the presence of oxygen (O_2) and ozone (O_3), the nitric oxide (NO) may be oxidised to form nitrogen dioxide (NO_2) which may impact on downwind receptor locations.

The conditions under which blasting occurs can generally be well managed through the implementation of a blast management plan which would include measures including (but not limited to):

- Limiting the time of blasting to hours with generally better dispersion conditions;
- Using explosive suppliers with an externally accredited quality system; and
- Performance of visual checks at discharge point.

In some conditions however, emissions of NO_X may be experienced as a visible orange/red fume.

A study performed by (Attalla, Day, Lange, Lilley, & Morgan, 2008) measured varying emission rates of NO_X from 27 blast events of between 0 and 5.3 kg·tonne explosive^{-1}. The National Pollutant Inventory (NPI) Emissions Estimation Technique Manual (EETM) for Explosives Detonation and Firing Ranges (DEE, 2016) provides an emission rate of NO_X for on-site mixed ANFO as 8 kg·tonne explosive^{-1}, 3.8 kg·tonne explosive^{-1} for branded <152 mm (small bore), and 1.4 kg·tonne explosive^{-1} for branded >152mm (large bore).

The AQIA for the Karuah East Quarry (SLR Consulting Australia Pty Ltd, 2013) assumed an emission rate of NO_X of 5.3 kg·tonne explosive^{-1} in line with the maximum value measured by (Attalla, Day, Lange, Lilley, & Morgan, 2008).

The drill hole bore diameter at the Site would be <102 mm and therefore an emissions rate of 3.8 kg·tonne explosive^{-1} has been adopted (associated with small bore holes <152 mm).

Assessment of NO_2 concentrations has been performed using Method 1, 100% conversion of NO to NO_2 as outlined in section 8.1.1 of the Approved Methods (NSW EPA, 2017). This is a highly conservative assumption.

The Project description indicates that for each blast, between 60 kg and 80 kg of explosives (MIC) would be required.

No cumulative impacts of short-term NO_2 concentrations are predicted for short term impacts given that it is unlikely that neighbouring sites would perform blasting within the same hour. It is considered to be a simple task to ensure that this does not occur.

Cumulative impacts associated with annual averages have been predicted, with each blast at Karuah Quarry, Karuah East Quarry and Karuah Red Quarry assumed to require 10 t of explosive per blast as outlined in (SLR Consulting Australia Pty Ltd, 2013). These tonnages of explosives seem high when compared to the Project, but have been adopted in the absence of any other input.

ACTIVITY DATA

Karuah South Quarry

Site Establishment and Construction, Stage 1C and Stage 2B

Activity data for each modelled phase of the construction and operations to be performed as part of the Karuah South Quarry are presented in **Table 2-3** overleaf. Notes on the assumptions adopted in the calculation of those data are outlined below.

Note A: Quantity also reflects loading to trucks by excavator and unloading at final location
Note B: Quantity also reflects ripping by bulldozer, loading to trucks by excavator and unloading at processing plant
Note C: Not all weathered rock processed and sold. Some use for on-site rehabilitation or used for on-site earthworks or sold as low-grade fill.
Note D: Annual blast m^2 calculated by assuming one blast every 3 weeks, multiplied by the area per blast (52/3*1,600 [assumed 40,000 t blasts])
Note E: Annual drill holes calculated by assuming one blast every 3 weeks
Note F: 24-hour drill holes assumed to be related to 2 days of drilling for a 1,600 m^2 blast (173 holes)
Note G: Annual quantities calculated from information provided in Table 2.1 on page 2-9 of the Project Description divided by years associated with each stage. Stage 1C assumed to be 2 years in duration (Year 4 to Year 5 [Section 2.5.2.3]) and Stage 2B assumed to be 7 years in duration (Year 9 to Year 15 [Section 2.5.3.3]). Values increased pro rata to 300,000 tpa and 600,000 tpa to reflect maximum sought extraction rate.
Note H: Calculated through review of Figure 2.12 (Processing Flow Chart) on Page 2-28 of the Project Description. Numbers based on Note G. Numbers have been altered to reflect 300 ktpa and 600 ktpa extraction / processing rates.
Note J: Numbers based on operating capacities quoted in Section 2.5.9 of the Project Description and scaled per crusher/screen through review of Figure 2.12 (Processing Flow Chart) on Page 2-28 of the Project Description
Note K: Material transported during the 'worst-case' 24-hour period is limited by the availability of haul trucks. The rate of movement is assumed to be driven by the processing rate through the processing plant (3,000 t per day). The overburden transport during that worst-case day is therefore taken to be negligible (i.e. 0) as haul trucks would be at capacity transporting rock to the processing plant. The distribution of fresh/weathered rock being transported has been calculated based on the availability of that material in each stage and has been calculated on the basis of values provided in Table 2.1 (Stage 1C – 83 % Fresh Rock, 17 % Weathered Rock. Stage 2B – 91 % Fresh Rock, 9 % Weathered Rock).
Note L: Topsoil stripping quantities assumed to be negligible (i.e. 0) due to the nature of the site
Note M: All overburden for Stage 1A assumed to be relocated during the Site Establishment and Construction stage
Note N: Assumed 2 x 28 tonne capacity haul trucks operating at 4 trips per truck per hour, over 11 hours

The controls applied to each source have been applied as outlined within the following section regarding the assessment of Best Management Practice.

The calculated controlled annual and maximum 24-hour particulate emissions resulting from the application of the identified controls is also included within that section.

Table 2-3
Karuah South Quarry – Adopted Activity Data

Parameter	**Units**	**Site Establishment and Construction**		**Stage 1C**		**Stage 2B**	
Period	-	6 months	24-hour	1 year	24-hour	1 year	24-hour
Topsoil stripping[A]	tonnes	0[L]	0[L]	0[L]	0[L]	0[L]	0[L]
Overburden removal[A]	tonnes	197,000[M]	2,464[N]	37,000[G]	0[K]	37,000[G]	0[K]
Overburden transport route	kilometres	0.39	0.39	0.37	-	0.72	-
Weathered rock removal[B,C]	tonnes			50,424[G]	504[K]	56,184[G]	504[K]
Weathered rock transport route	kilometres			0.71	0.71	0.72	0.72
Drilling	holes			2,999[E]	-[F]	2,999[E]	-[F]
	diameter (mm)			102	-	102	-
Blasting	m^2			27,733[D]	-	27,733[D]	-
Fresh rock removal[A]	tonnes			249,576[G]	2,496[K]	543,816[G]	2,496[K]
Fresh rock transport route	kilometres			0.36	0.36	0.73	0.73
Primary crushing (Jaw)	tonnes			300,000[H]	3,000[J]	600,000[H]	3,000[J]
Secondary crushing (Cone)	tonnes			272,000[H]	2,720[J]	544,000[H]	2,720[J]
Double deck screen	tonnes			272,000[H]	2,720[J]	544,000[H]	2,720[J]
Tertiary crushing (Cone)	tonnes			148,667[H]	1,486[J]	297,333[H]	1,486[J]
Quaternary crushing (Impactor)	tonnes			150,000[H]	1,500[J]	300,000[H]	1,500[J]
Triple deck screening (1)	tonnes			150,000[H]	1,500[J]	300,000[H]	1,500[J]
Triple deck screening (2)	tonnes			84,667[H]	847[J]	169,333[H]	847[J]
Product transported off site	tonnes			300,000[H]	3,000[J]	600,000[H]	3,000[J]
Product transport route (paved on site)	kilometres			0.54	0.54	0.52	0.52
Product transport route (paved)	kilometres			1.1	1.1	1.1	1.1
Extraction area	hectares	1.3	1.3	4.9	4.9	7.4	7.4
Quarry infrastructure area	hectares	4.6	4.6	5.0	5.0	2.2	2.2
Product stockpiles	hectares			0.6	0.6	0.8	0.8
Active overburden area	hectares			0.2	0.2	1.2	1.2
Inactive overburden area	hectares					0.8	0.8

Karuah East Quarry

Stage 1 and Stage 3

Activity data for each modelled phase of the operations to be performed as part of the Karuah East Quarry are presented in **Table 2-4** overleaf. These data have been taken from those reported within the AQIA performed for the Karuah East EIS (SLR Consulting Australia Pty Ltd, 2013).

The controls applied to each source are as outlined within Section 4.5.2.3 as taken from (SLR Consulting Australia Pty Ltd, 2013):

- Sealing of haul roads from the site to the Pacific Highway;
- Watering of any unsealed roads (Level 1 watering at 2 $L \cdot m^{-2} \cdot hour^{-1}$);
- Enclosure of the crusher; and,
- Stockpile watering and installation of wind breaks.

It is noted that the controlled annual PM_{10} emissions calculated/replicated for the Stage 3 emissions scenario within this AQIA are within 0.3 % of those reported in (SLR Consulting Australia Pty Ltd, 2013).

Notes on the assumptions adopted in the calculation of those emissions are outlined below.

Note A: Activity data in SLR (2013) is provided for the 1.5 Mtpa scenario (Stage 3) only. These data have been adjusted *pro-rata* to enable a 500,000 tpa scenario to be modelled (i.e. divided by 3)
Note B: Activity data in SLR (2013) indicates annual data (and emissions) only. It is assumed that the worst-case 24-hour activities are based on annual / 365 with the exception of blasting which has been calculated by (27,733 / 24 blasts per year), and wind erosion areas which have been assumed to remain constant
Note C: Quantity also reflects loading to trucks by excavator and unloading at final location
Note D: Also includes grading of roads

Based on the above, the calculated controlled emissions associated with Stage 1 and Stage 3 of the Karuah East Quarry operation are presented in **Table 2-5** and **Table 2-6** overleaf.

Table 2-4
Karuah East Quarry – Adopted Activity Data

Parameter	**Units**	**Stage 1[A]**	**Stage 3**
Period	-	1 year[B]	1 year
Maximum production rate	tonnes	500,000	1,500,000
Waste rock removal[C]	tonnes	12,500	37,500
Waste rock transport route[D]	Vehicle kilometres	375	1,125
Blasting	number	24	24
	m^2	27,733	27,733
Drilling	holes	240	240
Rock removal[C]	tonnes	500,000[G]	1,500,000
Rock transport route[D]	Vehicle kilometres	16,666	50,000
Jaw crusher in pit	tonnes	500,000	1,500,000
Primary crushing	tonnes	500,000	1,500,000
Secondary crushing	tonnes	500,000	1,500,000
Haulage from crusher to product stockpiles[C,D]	Vehicle kilometres	31,666	95,000
Product transported off site	tonnes	500,000[H]	1,500,000
Product transport route	Vehicle kilometres	56,667	170,000
Open pit wind erosion	hectares	12.6	12.6
Overburden emplacement wind erosion	hectares	1.1	1.1
ROM stockpile wind erosion	hectares	0.2	0.21
Product stockpile wind erosion	hectares	0.9	0.99

Table 2-5
Karuah East Quarry – Stage 1 Annual Controlled Emissions

Description	TSP ($kg{\cdot}yr^{-1}$)	PM_{10} ($kg{\cdot}yr^{-1}$)	$PM_{2.5}$ ($kg{\cdot}yr^{-1}$)
Blasting	27.4	14.3	0.8
Drilling of blast holes	141.6	73.6	4.2
Grading of unpaved roads	618.2	216.0	19.2
Wind erosion of open pit	44,275.9	22,138.0	3,320.7
Jaw crusher in pit	1,350.0	600.0	108.0
Loading rock to trucks	557.3	263.6	39.9
Hauling - pit to ROM stockpile	23,763.3	6,374.5	637.4
Loading ROM stockpile	557.3	263.6	39.9
Loading crusher	557.3	263.6	39.9
Primary crushing	26.5	11.8	2.1
Secondary crushing	301.1	133.8	24.1
Loading of crushed product to trucks	557.3	263.6	39.9
Hauling - crusher to product stockpiles	45,150.3	12,111.5	1,211.2
Loading product stockpiles	557.3	263.6	39.9
Loading product trucks	557.3	263.6	39.9
Hauling - product stockpiles to freeway	29,306.4	5,625.4	1,361.0
Wind erosion - ROM stockpile	257.5	128.8	19.3
Wind erosion - product stockpile	1,215.5	607.7	91.2
Excavator on waste rock	13.9	6.6	1.0
Hauling - pit to OB emplacement	534.7	143.4	14.3
Trucks dumping waste rock	13.9	6.6	1.0
Wind erosion - OB emplacement	1,960.1	980.0	147.0
Total	**152,300.0**	**50,753.4**	**7,202.0**

Table 2-6
Karuah East Quarry – Stage 3 Annual Controlled Emissions

Description	**TSP ($kg \cdot yr^{-1}$)**	**PM_{10} ($kg \cdot yr^{-1}$)**	**$PM_{2.5}$ ($kg \cdot yr^{-1}$)**
Blasting	27.4	14.3	0.8
Drilling of blast holes	141.6	73.6	4.2
Grading of unpaved roads	1,854.7	648.0	57.5
Wind erosion of open pit	44,275.9	22,138.0	3,320.7
Jaw crusher in pit	4,050.0	1,800.0	324.0
Loading rock to trucks	1,671.8	790.7	119.7
Hauling - pit to ROM stockpile	71,290.0	19,123.4	1,912.3
Loading ROM stockpile	1,671.8	790.7	119.7
Loading crusher	1,671.8	790.7	119.7
Primary crushing	79.5	35.3	6.4
Secondary crushing	903.2	401.4	72.3
Loading of crushed product to trucks	1,671.8	790.7	119.7
Hauling - crusher to product stockpiles	135,451.0	36,334.5	3,633.5
Loading product stockpiles	1,671.8	790.7	119.7
Loading product trucks	1,671.8	790.7	119.7
Hauling - product stockpiles to freeway	87,919.2	16,876.1	4,082.9
Wind erosion - ROM stockpile	257.5	128.8	19.3
Wind erosion - product stockpile	1,215.5	607.7	91.2
Excavator on waste rock	41.8	19.8	3.0
Hauling - pit to OB emplacement	1,604.0	430.3	43.0
Trucks dumping waste rock	41.8	19.8	3.0
Wind erosion - OB emplacement	1,960.1	980.0	147.0
Total	**361,143.9**	**104,375.3**	**14,439.5**

Karuah Quarry

Stage A

Activity data for each modelled phase of the operations to be performed as part of the Karuah Quarry are presented in **Table 2-7** overleaf. These data have been taken from those reported within the AQIA performed for the Karuah East EIS (SLR Consulting Australia Pty Ltd, 2013) to maintain consistency between the input data adopted for the assessment of potential cumulative impact. The data reported in (SLR Consulting Australia Pty Ltd, 2013) were associated with an extraction rate of 500,000 tpa. The scenario presented within this AQIA reflects a 400,000 tpa extraction rate and therefore the activity data have been scaled accordingly.

The controls applied to each source are as outlined within Section 4.5.1.3 as taken from (SLR Consulting Australia Pty Ltd, 2013):

- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the grading of unpaved roads (50 % control);
- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the haulage of materials from the pit to the ROM stockpile on unpaved roads (50 % control);
- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the haulage of waste rock from the pit to the overburden emplacement on unpaved roads (50 % control);
- Controls during primary and secondary crushing (watering);
- Level 1 watering (2 $L \cdot m^{-2} \cdot hr^{-1}$) during the haulage of materials from the processing plant to the product stockpiles on unpaved roads (50 % control);
- Use of paved roads to haul product to Freeway;
- Use of water sprays and wind breaks around the ROM and product stockpiles (combined 65 % control); and,
- Use of water sprays on the overburden emplacement (50 % control).

Notes on the assumptions adopted in the calculation of those data are outlined below.

A further scenario reflecting no extraction at Karuah Quarry, and the processing of material extracted at the Karuah Red Quarry with processing of that material at the Karuah Quarry has been considered and is discussed in the following section regarding the Karuah Red Quarry.

Note A: Activity data in SLR (2013) is provided for the 0.5 Mtpa scenario only. These data have been adjusted *pro-rata* to enable a 400,000 tpa scenario to be modelled
Note B: Activity data in SLR (2013) indicates annual data (and emissions) only. It is assumed that the worst-case 24-hour activities are based on annual / 365 with the exception of blasting which has been calculated by (27,733 / 24 blasts per year), and wind erosion areas which have been assumed to remain constant
Note C: Quantity also reflects loading to trucks by excavator and unloading at final location
Note D: Also includes grading of roads

Based on the above, the calculated controlled emissions associated with Stage A of the Karuah Quarry operation are presented in **Table 2-7** overleaf.

Table 2-7
Karuah Quarry – Adopted Activity Data

Parameter	Units	Stage A[A]
Period	-	1 year[B]
Maximum production rate	tonnes	400,000
Waste rock removal[C]	tonnes	10,000
Waste rock transport route[D]	Vehicle kilometres	300
Blasting	number	24
	m^2	27,733
Drilling	holes	240
Rock removal[C]	tonnes	400,000[G]
Rock transport route[D]	Vehicle kilometres	13,333
Jaw crusher in pit	tonnes	400,000
Primary crushing	tonnes	400,000
Secondary crushing	tonnes	400,000
Haulage from crusher to product stockpiles[C,D]	Vehicle kilometres	1,866
Product transported off site	tonnes	400,000
Product transport route	Vehicle kilometres	25,344
Open pit wind erosion	hectares	5.8
Overburden emplacement wind erosion	hectares	1.5
ROM stockpile wind erosion	hectares	0.2
Product stockpile wind erosion	hectares	0.3

Table 2-8
Karuah Quarry – Stage A Annual Controlled Emissions

Parameter	**TSP ($kg \cdot yr^{-1}$)**	**PM_{10} ($kg \cdot yr^{-1}$)**	**$PM_{2.5}$ ($kg \cdot yr^{-1}$)**
Blasting	27.4	14.3	0.8
Drilling of blast holes	141.6	73.6	4.2
Grading of unpaved roads	796.4	278.3	24.7
Wind erosion of open pit	20,378.9	10,189.4	1,528.4
Jaw crusher in pit	1,080.0	480.0	86.4
Loading rock to trucks	445.8	210.9	31.9
Hauling - pit to ROM stockpile	19,011.1	5,099.7	510.0
Loading ROM stockpile	445.8	210.9	31.9
Loading crusher	445.8	210.9	31.9
Primary crushing	21.2	9.4	1.7
Secondary crushing	240.8	107.0	19.3
Loading of crushed product to trucks	445.8	210.9	31.9
Hauling - crusher to product stockpiles	2,661.1	713.8	71.4
Loading product stockpiles	445.8	210.9	31.9
Loading product trucks	445.8	210.9	31.9
Hauling - product stockpiles to freeway	13,101.8	2,514.9	608.4
Wind erosion - ROM stockpile	246.0	123.0	18.4
Wind erosion - product stockpile	368.9	184.5	27.7
Excavator on waste rock	11.1	5.3	0.8
Hauling - pit to OB emplacement	427.7	114.7	11.5
Trucks dumping waste rock	11.1	5.3	0.8
Wind erosion - OB emplacement	2,635.2	1,317.6	197.6
Total	**63,835.3**	**22,495.9**	**3,303.7**

Karuah Red Quarry

As discussed in Section 4.5.3, Hunter Quarries intends to develop the Karuah Red Quarry. Specific information relating to the operation of that quarry is not available at the current time, although a range of assumptions have been made and are documented below.

Extraction

Activity data for the modelled phase of the operations to be performed as part of the Karuah Red Quarry are presented in **Table 2-9** overleaf.

The controls applied to each source are assumed to be the same as those applied as part of the Karuah Quarry operation as outlined within Section 4.5.1.3 as taken from (SLR Consulting Australia Pty Ltd, 2013):

- Level 1 watering (2 $L{\cdot}m^{-2}{\cdot}hr^{-1}$) during the grading of unpaved roads (50 % control);
- Level 1 watering (2 $L{\cdot}m^{-2}{\cdot}hr^{-1}$) during the haulage of materials from the pit to the ROM stockpile on unpaved roads (50 % control);
- Level 1 watering (2 $L{\cdot}m^{-2}{\cdot}hr^{-1}$) during the haulage of waste rock from the pit to the overburden emplacement on unpaved roads (50 % control);
- Controls during primary and secondary crushing (watering);
- Level 1 watering (2 $L{\cdot}m^{-2}{\cdot}hr^{-1}$) during the haulage of materials from the processing plant to the product stockpiles on unpaved roads (50 % control);
- Use of paved roads to haul product to Freeway;
- Use of water sprays and wind breaks around the ROM and product stockpiles (combined 65 % control); and,
- Use of water sprays on the overburden emplacement (50 % control).

Notes on the assumptions adopted in the calculation of those data are outlined below.

The scenario reflects not only the extraction of material from the Karuah Red Quarry, but transportation to, and processing at the Karuah Quarry. Transportation of product to market has been assumed to occur as per the operations at Karuah Quarry outlined in the section above.

Note A: Activity data associated with crushing/screening/loading and transportation offsite in SLR (2013) have been provided for a 0.5 Mtpa scenario only. These data have been adjusted *pro-rata* to enable a 100,000 tpa scenario to be modelled
Note B: Activity data in SLR (2013) indicates annual data (and emissions) only. It is assumed that the worst-case 24-hour activities are based on annual / 365
Note C: Quantity also reflects loading to trucks by excavator and unloading at final location
Note D: Also includes grading of roads

Based on the above, the calculated controlled emissions associated with the extraction stage of the Karuah Red Quarry operation are presented in **Table 2-10** overleaf.

Table 2-9
Karuah Red Quarry – Adopted Activity Data

Parameter	Units	Extraction[A]
Period	-	1 year
Maximum production rate	tonnes	100,000
Waste rock removal[C]	tonnes	10,000
Waste rock transport route[D]	Vehicle kilometres	75
Blasting	number	24
	m^2	27,733
Drilling	holes	240
Rock removal[C]	tonnes	100,000[G]
Rock transport route[D]	Vehicle kilometres	3,333
Jaw crusher in pit	tonnes	100,000
Primary crushing at Karuah Quarry	tonnes	100,000
Secondary crushing at Karuah Quarry	tonnes	100,000
Haulage from crusher to product stockpiles[C,D]	Vehicle kilometres	467
Product transported off site from Karuah Quarry	tonnes	100,000
Product transport route	Vehicle kilometres	6,333
Open pit wind erosion	hectares	0.7
Overburden emplacement wind erosion	hectares	0.4
ROM stockpile wind erosion	hectares	0.2
Product stockpile wind erosion	hectares	0.3

Table 2-10
Karuah Red Quarry – Extraction Stage Annual Controlled Emissions

Parameter	TSP ($kg{\cdot}yr^{-1}$)	PM_{10} ($kg{\cdot}yr^{-1}$)	$PM_{2.5}$ ($kg{\cdot}yr^{-1}$)
Blasting	27.4	14.3	0.8
Drilling of blast holes	141.6	73.6	4.2
Grading of unpaved roads	199.1	69.6	6.2
Wind erosion of open pit	2,459.5	1,229.8	184.5
Jaw crusher in pit	270.0	120.0	21.6
Loading rock to trucks	111.5	52.7	8.0
Hauling - pit to ROM stockpile at Karuah Quarry	4,752.8	1,274.9	127.5
Loading ROM stockpile at Karuah Quarry	111.5	52.7	8.0
Loading crusher at Karuah Quarry	111.5	52.7	8.0
Primary crushing at Karuah Quarry	5.3	2.4	0.4
Secondary crushing at Karuah Quarry	60.2	26.8	4.8
Loading of crushed product to trucks at Karuah Quarry	111.5	52.7	8.0
Hauling - crusher to product stockpiles at Karuah Quarry	665.3	178.5	17.8
Loading product stockpiles at Karuah Quarry	111.5	52.7	8.0
Loading product trucks at Karuah Quarry	111.5	52.7	8.0
Hauling - product stockpiles to freeway at Karuah Quarry	3,275.5	628.7	152.1
Wind erosion - ROM stockpile at Karuah Quarry	246.0	123.0	18.4
Wind erosion - product stockpile at Karuah Quarry	368.9	184.5	27.7
Excavator on waste rock	2.8	1.3	0.2
Hauling - pit to OB emplacement	106.9	28.7	2.9
Trucks dumping waste rock	11.1	5.3	0.8
Wind erosion - OB emplacement	667.6	333.8	50.1
Total	**13,928.7**	**4,611.2**	**667.9**

BEST PRACTICE MANAGEMENT DUST CONTROL

Approach

A site-specific Best Practice Management (BPM) assessment has been performed for the operations at the proposed Karuah South Quarry in accordance with the methodology outlined in (NSW EPA, 2011).

The BPM assessment has been performed to allow the identification of control measures which might be implemented as part of the Project operation whilst taking into consideration:

- regulatory requirements;
- environmental impacts;
- safety implications; and,
- compatibility with proposed future development.

NSW EPA guidance relating to best practice dust assessments for the coal mining industry (there are no guidelines specific to the quarrying industry) indicated that either the top four sources, or sources representing 95% of total annual site emissions should be examined for application of further controls.

Assessment of Major Sources

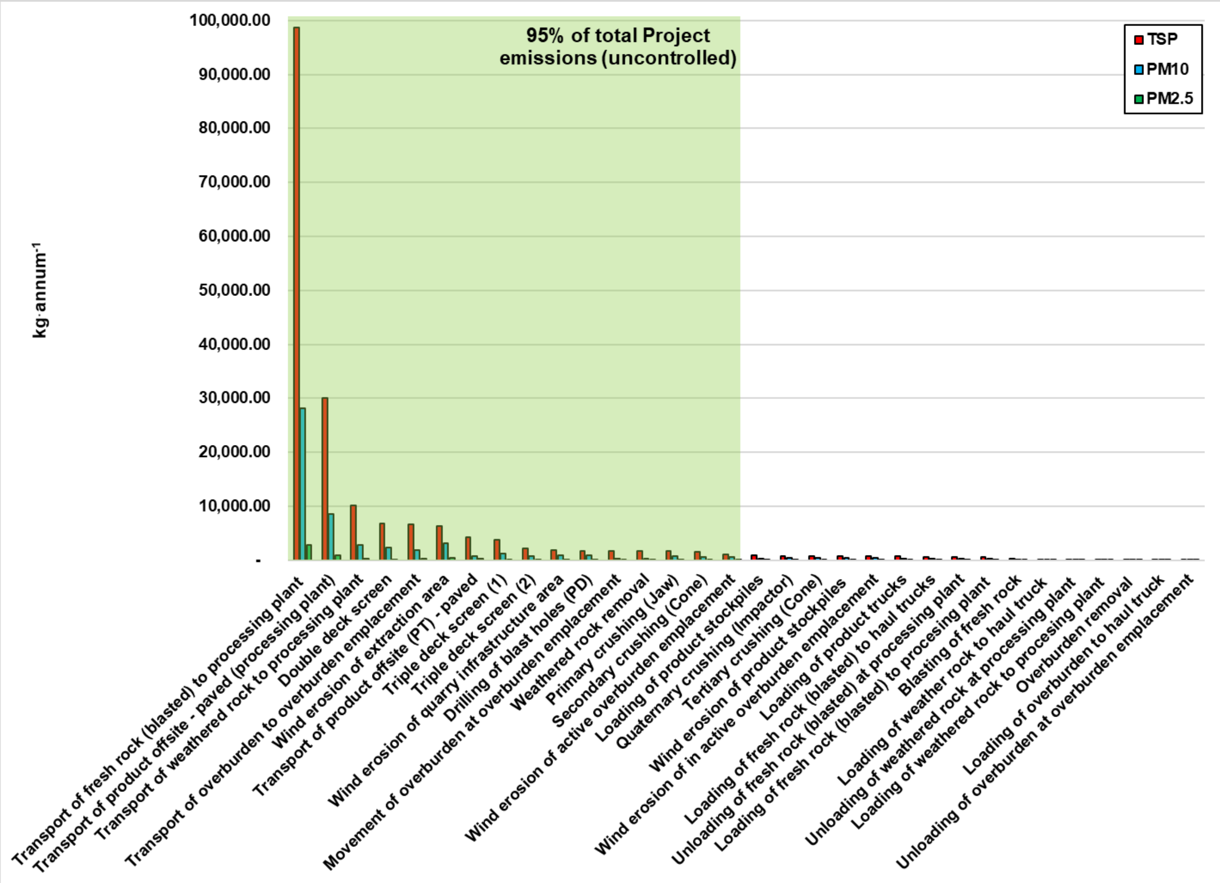
Uncontrolled emissions of particulate matter for Stage 2B of Project development have been calculated adopting the emission factors outlined in the preceding section given that this stage of operation is associated with the maximum extraction rate and highest quantity of particulate emissions. The results indicate that the top emission sources in this stage of operation, covering 95% of total site emissions (of TSP) comprise of (and rank):

- Movement of vehicles on unpaved site roads
  - Transport of fresh rock to processing plant (1)
  - Transport of product offsite on unpaved haul road section (2)
  - Transport of weathered rock to processing plant (3)
  - Transport of overburden to overburden emplacement (5)
- Movement of vehicles on paved roads
  - Transport of product offsite (8)
- Material processing
  - Screening Double deck screen (4, 9, 10)
  - Primary Crushing (Jaw) (15)
  - Secondary Crushing (Cone) (16)
- Wind erosion
  - Wind erosion of extraction area (6)
  - Wind erosion of quarry infrastructure area (11)

- Drilling of blast holes (12)
- Movement of overburden at overburden emplacement (13)
- Weathered rock removal (14)

The uncontrolled emissions calculated for Stage 2B of the Project are presented in **Figure 2-1**.

Figure 2-1
Uncontrolled Particulate Emissions – Stage 2B



The following section provides a review of the options available to control particulate emissions associated with the sources which make up the top 95% of those emissions.

Assessment of Control Measures

Unpaved Haul Roads

Options for the control of dust emissions from unpaved haul roads fall into the following three categories:

- Vehicle restrictions that limit the speed, weight or number of vehicles on the road;
- Surface improvement by measures such as (a) paving or (b) adding gravel or slag to a dirt road; and,
- Surface treatment such as watering or treatment with chemical dust suppressants.

The applicability of the above control methods varies significantly due to the costs of installing and operating the various options, the timing of the implementation of the controls (for example at planning stage or applied retrospectively when the quarry is operating) and the scale of the quarrying operation.

For example, vehicle restrictions that are considered at the quarry planning stage might be relatively easy to apply, such as the replacement of a large number of small haul trucks with a smaller fleet of larger trucks, or other considerations such as upward facing vehicle exhausts to minimise the resuspension of loose materials. Vehicle speed restrictions may offer an effective control, but may pose a logistical or economic constraint if it restricts the transport of materials in the quarry and may be difficult to manage and enforce.

Clearly, replacement of haul trucks with automated material handling systems, such as conveyors may offer a significant opportunity to reduce particulate emissions, if feasible.

The improvement of the road structure using non-sealed surfaces (such as gravelled surfaces) or substrata design (such as design to limit water penetration, pooling, camber and corners) are easier to implement during the planning stages as they may require site layout considerations, such as the location of plant and processes to be altered. The use of non-sealed surfaces may require much greater frequency of maintenance, particularly during adverse weather conditions or heavily trafficked periods. Surface improvements may not be cost-effective with heavy haul vehicles that require high-grade engineered road structures to carry the load without road disintegration.

Surface watering is a commonly applied control option, however the availability of water supplies may represent a constraint to its use, particularly during peak demand periods, such as high winds during prolonged dry periods. The use of chemical suppressants or surface binding agents offer enhanced dust control efficiency and may also reduce the volume of water required, or a reduction in the time required between watering and in some instances, watering after the application of chemical suppressants may reduce the efficacy of the overall dust control. Generally, chemical additives and suppressants offer an improved efficiency than water but not in all situations (e.g. temporary roads).

A summary of the potential control measures for minimising particulate emissions from haul roads, and their effectiveness, is provided in **Table 2-11** (Katestone, 2011).

Table 2-11
Best Practice Control Measures – Haul Roads

Control Type	**Control Measures**	**Effectiveness (%)**
Vehicle speed restrictions	Reduction from 75 $km \cdot hr^{-1}$ to 50 $km \cdot hr^{-1}$	40-75
	Reduction from 65 $km \cdot hr^{-1}$ to 30 $km \cdot hr^{-1}$	50-85
Surface improvements	Pave the surface	>90
	Low silt aggregate	30
	Oil and double chip surface	80
Surface treatments	Watering level 1 (2 $L \cdot m^{-2} \cdot hr^{-1}$)	50
	Watering level 2 (>2 $L \cdot m^{-2} \cdot hr^{-1}$)	75
	Hygroscopic salts[1]	Ave. 45 over 14 days 82 within 2 weeks
	Polymer and tar/bitumen emulsions	70 over 58 days

Note 1: Use of hygroscopic salts can also act to extend the required time between watering by 33% to 50% (USDHHS, 2012)
Source: (Katestone, 2011), Table 66, (DSEWPC, 2012)

In relation to unpaved haul road watering, an alternative approach (US EPA, 1987) takes into account site specific factors including the daytime evaporation rate, traffic volumes, time between application and application intensity.

The Control Efficiency (CE) is given by:

$$CE = 100 - \left(\frac{0.8 \times P \times D \times T}{I}\right)$$

where:

P = potential average daytime evaporation rate ($mm \cdot hr^{-1}$)

D = average hourly daytime traffic data ($veh \cdot hr^{-1}$)

T = time between applications (hours)

I = application intensity ($L \cdot m^{-2}$)

Evaporation data was obtained from Williamtown RAAF AWS. The calculated control efficiencies afforded by an hourly application of water during each stage of construction and operation is presented below in **Table 2-12**.

The minimum control efficiency during each modelled scenario is highlighted in **Table 2-12** with this minimum value being adopted across all seasons in the interests of conservatism. As expected, the lowest control efficiency is calculated during summer months.

A variable control efficiency for watering of unpaved haul roads has been applied to each modelled scenario, with a 72 % control efficiency being adopted as part of Stage 2B, which is the subject of the Best Practice Management assessment presented here.

Table 2-12
Calculation of Watering Control Efficiency – Haul Roads

Scenario		Annual	Winter	Spring	Summer	Autumn
Construction and site establishment	P (mm·hr^{-1})	0.39	0.24	0.46	0.56	0.31
	D (veh·hr^{-1})	9.1	9.1	9.1	9.1	9.1
	T (hours)	1	1	1	1	1
	I (L·m^{-2})	0.41	0.41	0.41	0.41	0.41
	CE (%)	93.0	95.7	91.8	90.0	94.4
Stage 1C	P (mm·hr^{-1})	0.39	0.24	0.46	0.56	0.31
	D (veh·hr^{-1})	13.8	13.8	13.8	13.8	13.8
	T (hours)	1	1	1	1	1
	I (L·m^{-2})	0.19	0.19	0.19	0.19	0.19
	CE (%)	77.4	86.2	73.6	67.8	81.9
Stage 2B	P (mm·hr^{-1})	0.39	0.24	0.46	0.56	0.31
	D (veh·hr^{-1})	26.7	26.7	26.7	26.7	26.7
	T (hours)	1	1	1	1	1
	I (L·m^{-2})	0.43	0.43	0.43	0.43	0.43
	CE (%)	80.6	88.2	77.3	72.3	84.5

An alternative source of evaporation data has been adopted in the surface water assessment (refer to Part 5 of the Specialist Consultant Studies Compendium). In preparing the site water balance for that assessment, SILO Data Drill synthetic evaporation data were examined to establish the annual average daily evaporation rate (0.34 mm·hr^{-1}) and the average daily summer evaporation rate (0.48 mm·hr^{-1}). Both of these values are lower than those adopted above, and result in higher control efficiencies in all stages of Site development assessed. Using the SILO data, control efficiencies in the construction and site establishment phase would increase to 91.4%, in Stage 1C to 72.3% and in Stage 2B to 76.2%.

The control efficiencies as outlined in **Table 2-12** have been adopted in the performance of this assessment and can be viewed as providing a conservative representation of haul road watering control efficiency.

Paved Haul Roads

Emissions reductions measures which can be applied to paved road surfaces are not considered in (Katestone, 2011). This is unsurprising as the paving of road surfaces can be viewed as the maximum level of control for haulage roads. Management of those road surfaces can ensure that the silt loading is minimised, although no quantifiable control factors are available for those control measures in (US EPA, 2011).

Material Processing

No emission reduction factors for material processing operations are provided in (Katestone, 2011). Emission reduction factors are outlined in both the NPI EETM for Mining (DSEWPC,

2012) and AP-42 (US EPA, 2004). These control factors are outlined in **Table 2-13**. Two control factors are available for the application of water sprays. The control factor of 50% quoted within (DSEWPC, 2012) is not shown in **Table 2-13** as the values from AP-42 are more applicable given that they are derived through calculation of controlled versus uncontrolled emission factors, and are associated with the AP-42 emission factor for crushing and screening which has been adopted for this assessment.

Table 2-13
Best Practice Control Measures – Material Processing

Control Type	Control Measures	Effectiveness (%)
Crushing	Application of water sprays	77.7
	Windbreaks	30
	Hooding with cyclones	65
	Hooding with scrubbers	75
	Hooding with fabric filters	83
	Enclosed or underground	100
Screening	Application of water sprays	91.6
	Windbreaks	30
	Hooding with cyclones	65
	Hooding with scrubbers	75
	Hooding with fabric filters	83
	Enclosed or underground	100

Source: (US EPA, 2004), (DSEWPC, 2012)

Wind Erosion of Exposed Areas

Best practice measures to control emissions of particulate matter from exposed areas include:

- Minimise pre-strip to a maximum of one block ahead
- Maximise rehabilitation works
- If exposed area is a potential source of particulate matter emissions and is likely to be exposed for more than 3-months, revegetation should take place
- Strategic use of watering, suppressants and hydraulic mulch seeding to minimise emissions of particulate matter depending on circumstances
- Pave areas where practical e.g. around offices, carparks, maintenance and storage areas

Emission reduction factors are outlined in (Katestone, 2011) and are outlined in **Table 2-14**.

Table 2-14
Best Practice Control Measures – Wind Erosion (Exposed Areas)

Control Type	Control Measures	Effectiveness (%)
Avoidance	Minimise pre-strip. EMP should specify a benchmark for optimal performance and report annually against benchmark	100 per m^2 of pre-strip avoided
Surface stabilisation	Watering	50
	Chemical suppressants	70 – 84
	Paving and cleaning	>95
	Apply gravel to stabilise disturbed open areas	84
	Rehabilitation. EMP should specify a rehabilitation goal and report annually against benchmark	99
Wind speed reduction	Fencing, bunding, shelterbelts or in-pit dump. Height should be greater than the height of the erodible surface	30 70-80
	Vegetative ground cover	70

Source: (Katestone, 2011), Table 71, (DSEWPC, 2012)

Drilling

Best practice measures to control emissions of particulate matter during drilling include:

- Wet suppression through watering; and/or,
- Dry collection through fabric filters or cyclones

Emission reduction factors are outlined in (Katestone, 2011) and (DSEWPC, 2012) and are outlined in **Table 2-15**.

Table 2-15
Best Practice Control Measures – Drilling

Control Type	Control Measures	Effectiveness (%)
Watering	Water sprays	50 (DSEWPC, 2012) 3-96 (Katestone, 2011) 70 (Katestone, 2011)
Dry Collection	Fabric filter Cyclone	99 (Katestone, 2011) 80-90 (Katestone, 2011)

Source: (Katestone, 2011), Table 82, (DSEWPC, 2012)

Assessment of Control Measures

The practicability of implementing each of the particulate control options identified above is assessed with due consideration given to:

- implementation costs;
- regulatory requirements;
- environmental impacts;
- safety implications; and,
- compatibility with future developments.

Each measure is provided a risk rating (**low**, **medium** or **high**) which identifies the broad level of constraint(s) which may result in the implementation of the measure not being practical at the Site. Where any of the measures of practicability are rated as high, these measures are not taken forward for an assessment of cost implication and feasibility.

Evaluation Findings

Table 2-16 provides a summary of the feasibility of control measures for unpaved haul roads. **Table 2-17** provides a summary of the feasibility of control measures for material processing operations, specifically crushing and screening. **Table 2-18** provides a summary of the feasibility of control measures for wind erosion of exposed areas and **Table 2-19** provides a summary of the feasibility of control measures for drilling activities.

Evaluation Findings – Summary

A summary of the emission control measures to be adopted following performance of the BPM assessment are outlined in **Table 2-16**.

Although not captured within the BPM assessment methodology as the emissions totals were below the threshold values, additional emission control measures will be adopted as part of the Project operation. These measures, and their associated particulate emission reduction efficiencies are presented below:

- All activities
  - Pit retention – 50 % for TSP, 5 % for PM_{10} and $PM_{2.5}$
- Blasting
  - Delay blasting during unfavourable conditions – no quantifiable reductions but would be experienced in practice

Table 2-16
Summary of Adopted Particulate Control Measures

Control Measure	Emission Control Efficiency Adopted
Haul Roads Paving around processing plant	97 % reduction in TSP emissions, 98 % reduction in PM_{10} emissions, 94 % reduction in $PM_{2.5}$ emissions Use of a recycled crushed concrete and crushed used asphalt in accordance with the NSW EPA's *Specification for Supply of Recycled Material for Pavements, Earthworks and Drainage 2010*. Calculated through comparison of unpaved roads (US EPA, 2006a) and paved roads (US EPA, 2011) emission factors
Haul Roads Watering	72 % to 90 % as described above for hourly application of water (US EPA, 1987)
Material Processing Water sprays	77.7 % (US EPA, 2004)
Material Processing Screening	91.6 % (US EPA, 2004)
Wind Erosion of Exposed Areas Minimise pre-strip	100 % per m^2 avoided (Katestone, 2011)
Wind Erosion of Exposed Areas Watering	50 % (DSEWPC, 2012)
Wind Erosion of Exposed Areas Fencing, bunding or shelterbelts	30 % (DSEWPC, 2012)
Drilling Water Sprays	70 % (DSEWPC, 2012)

Table 2-17
Practicability of Implementing Control Measures on Unpaved Haul Roads

Control Measure – Haul Roads	Regulatory Requirements RISK	Environmental Impacts RISK	Safety Implications RISK	Compatibility with Future Developments RISK	Conclusion of Evaluation
Pave the surface	RISK = LOW Follow industry practice for the safe design of roads	RISK = MEDIUM Recycled materials can be used to form road base and surface. The road surface would be required to be re-laid from Stage 1 to Stage 2	RISK = LOW Safety would likely be improved following paving as risk of accidents would be reduced. Speed restrictions would need to be closely monitored	RISK = MEDIUM The road surface would be required to be re-laid from Stage 1 to Stage 2	☑ Adopted for road around the processing plant Not suitable for haulage routes from pit
Low silt aggregate	RISK = LOW Follow industry practice for the safe design of roads	RISK = MEDIUM As part of quarry rehabilitation, removal of the road will generate significant quantities of waste materials requiring disposal or re-use.	RISK = MEDIUM Safety may be compromised following application of gravelling as risk of accidents may be increased as risk of skidding increases. Speed restrictions would need to be closely monitored to ensure this is not an issue.	RISK = MEDIUM The road surface would be required to be continually re-laid (for haul routes from pit) and not required for road around processing plant	☒ Not considered further in this assessment Application of water to haul routes considered to be appropriate to control emissions Road around processing plant to be paved
Oil and double chip surface	RISK = LOW Ensure all chemicals are registered on-site with relevant MSDS at Stores	RISK = HIGH Very little information or data is available to support this control option, and as such it is not considered likely to represent best practice.	RISK = MEDIUM Ensure road surface provides adequate traction for haul trucks to prevent skidding/slipping.	RISK = MEDIUM The road surface would be required to be continually re-laid (for haul routes from pit) and not required for road around processing plant	☒ Not considered further in this assessment Application of water to haul routes considered to be appropriate to control emissions Road around processing plant to be paved

Control Measure – Haul Roads	**Regulatory Requirements RISK**	**Environmental Impacts RISK**	**Safety Implications RISK**	**Compatibility with Future Developments RISK**	**Conclusion of Evaluation**
Watering	RISK = LOW Ensure that run off is appropriately captured, filtered and discharged or recycled to on-site dams	RISK = LOW Ensure that run off is appropriately captured, filtered and discharged or recycled to on-site dams	RISK = MEDIUM Ensure road surface provides adequate traction for haul trucks to prevent skidding/slipping.	RISK = LOW Compatible	☑ Adopted
Hygroscopic salts	RISK = LOW Ensure all chemicals are registered on-site with relevant MSDS at Stores	RISK = LOW Ensure that application rate is appropriate to avoid run off into watercourses. Ensure application is performed during appropriate meteorological conditions to avoid wash/blow off onto non-haul road areas. Based on the MSDS, a spill management program should be formulated.	RISK = MEDIUM Ensure road surface provides adequate traction for haul trucks to prevent skidding/slipping. Ensure suitable storage and handling procedures are implemented to prevent harmful exposure to any chemicals in the suppressant product	RISK = LOW Compatible	☒ Not considered further in this assessment Application of water to haul routes considered to be appropriate to control emissions Road around processing plant to be paved
Polymer and tar/bitumen emulsions	RISK = LOW Ensure all chemicals are registered on-site with relevant MSDS at Stores	RISK = LOW Ensure that application rate is appropriate to avoid run off into watercourses. Ensure application is performed during appropriate meteorological conditions to avoid wash/blow off onto non-haul road areas. Based on the MSDS, a spill management program should be formulated.	RISK = MEDIUM Ensure road surface provides adequate traction for haul trucks to prevent skidding/slipping. Ensure suitable storage and handling procedures are implemented to prevent harmful exposure to any chemicals in the suppressant product	RISK = MEDIUM The road surface would be required to be continually re-laid (for haul routes from pit) and not required for road around processing plant	☒ Not considered further in this assessment Application of water to haul routes considered to be appropriate to control emissions Road around processing plant to be paved

Table 2-18
Practicability of Implementing Control Measures for Material Processing Operations

Control Measure – Crushing / Screening	Regulatory Requirements RISK	Environmental Impacts RISK	Safety Implications RISK	Compatibility with Future Developments RISK	Conclusion of Evaluation
Water sprays	RISK = LOW Follow industry practice for the safe design of roads	RISK = LOW Ensure that any run off is appropriately captured, filtered and discharged or recycled to on-site dams	RISK = MEDIUM Ensure mists and sprays do not hinder mobile equipment operator vision	RISK = LOW Compatible	☑ Adopted
Windbreaks	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = MEDIUM Space limitations in processing area would make the use of wind breaks generally impractical The use of a noise wall to the south of the processing plant (Stage 1C) and stockpiles (Stage 2B) does provide reduction in emissions for a small area	☑ Adopted for small area close to the proposed noise wall (refer Noise Impact Assessment)
Hooding with cyclones or fabric filters	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible.	RISK = HIGH Volumes of air required to be drawn would be excessive	☒ Not considered further in this assessment
Enclosure	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = HIGH Continual movement of processing plant would render this measure impractical	☒ Not considered further in this assessment

Table 2-19

Practicability of Implementing Control Measures for Wind Erosion of Exposed Areas

Control Measure – Wind Erosion	**Regulatory Requirements RISK**	**Environmental Impacts RISK**	**Safety Implications RISK**	**Compatibility with Future Developments RISK**	**Conclusion of Evaluation**
Minimise pre-strip	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	☑ Adopted
Watering	RISK = LOW Compatible	RISK = LOW Ensure that any run off is appropriately captured, filtered and discharged or recycled to on-site dams	RISK = MEDIUM Ensure mists and sprays do not hinder mobile equipment operator vision	RISK = LOW Compatible	☑ Adopted
Chemical suppressants	RISK = LOW Ensure all chemicals are registered on-site with relevant MSDS at Stores	RISK = LOW Ensure that application rate is appropriate to avoid run off into watercourses. Ensure application is performed during appropriate meteorological conditions to avoid wash/blow off onto non-haul road areas. Based on the MSDS, a spill management program should be formulated.	RISK = MEDIUM Ensure suitable storage and handling procedures are implemented to prevent harmful exposure to any chemicals in the suppressant product	RISK = LOW Compatible	☒ Not considered further in this assessment Application of water considered to be appropriate to control emissions
Paving and cleaning	RISK = LOW Compatible	RISK = HIGH As part of quarry development and rehabilitation, removal of the road will generate significant quantities of waste materials requiring disposal.	RISK = LOW Safety would likely be improved following paving as risk of accidents would be reduced. Speed restrictions would need to be closely monitored	RISK = HIGH Routes, especially those to/from the pit would need to be regularly changed, creating large volumes of waste and at high cost	☒ Not considered further in this assessment

Control Measure – Wind Erosion	**Regulatory Requirements RISK**	**Environmental Impacts RISK**	**Safety Implications RISK**	**Compatibility with Future Developments RISK**	**Conclusion of Evaluation**
Gravel application	RISK = LOW Follow industry practice for the safe design of roads	RISK = MEDIUM As part of quarry rehabilitation, removal of the road will generate significant quantities of waste materials requiring disposal or re-use.	RISK = MEDIUM Safety may be compromised following application of gravelling as risk of accidents may be increased as risk of skidding increases. Speed restrictions would need to be closely monitored to ensure this is not an issue.	RISK = HIGH Routes, especially those to/from the pit would need to be regularly changed.	☒ Not considered further in this assessment
Rehabilitation	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = HIGH Rehabilitation of exposed areas such as the open pit will be performed as per the Rehabilitation Management Plan at the end of the total extraction period.	☒ Not considered further in this assessment
Fencing, bunding or shelterbelts	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = HIGH Continual movement of areas subject to wind erosion would render this measure impractical	☒ Not considered further in this assessment
Vegetative ground cover	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = HIGH Rehabilitation of exposed areas such as the open pit will be performed as per the Rehabilitation Management Plan at the end of the total extraction period.	☒ Not considered further in this assessment

Table 2-20
Practicability of Implementing Control Measures for Drilling

Control Measure – Drilling	Regulatory Requirements RISK	Environmental Impacts RISK	Safety Implications RISK	Compatibility with Future Developments RISK	Conclusion of Evaluation
Water Sprays	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	☑ Adopted
Dry Collection	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	RISK = LOW Compatible	☒ Both measures not required, dry collection not considered further in this assessment

EMISSIONS ESTIMATION – CONTROLLED PARTICULATE EMISSION RATES

Based on the application of the particulate emission control measures identified above, **Figure 2-2** provides a summary of the anticipated controlled emissions resulting from the operation of Stage 2B of the Project.

Table 2-21 outlines the total annual uncontrolled and controlled particulate emissions anticipated during Stage 2 B of the Project and provides a site wide control efficiency resulting from the implementation of the adopted controls. Particulate emissions would be controlled by between 75% and 85%.

Figure 2-2
Controlled Particulate Emissions – Stage 2B

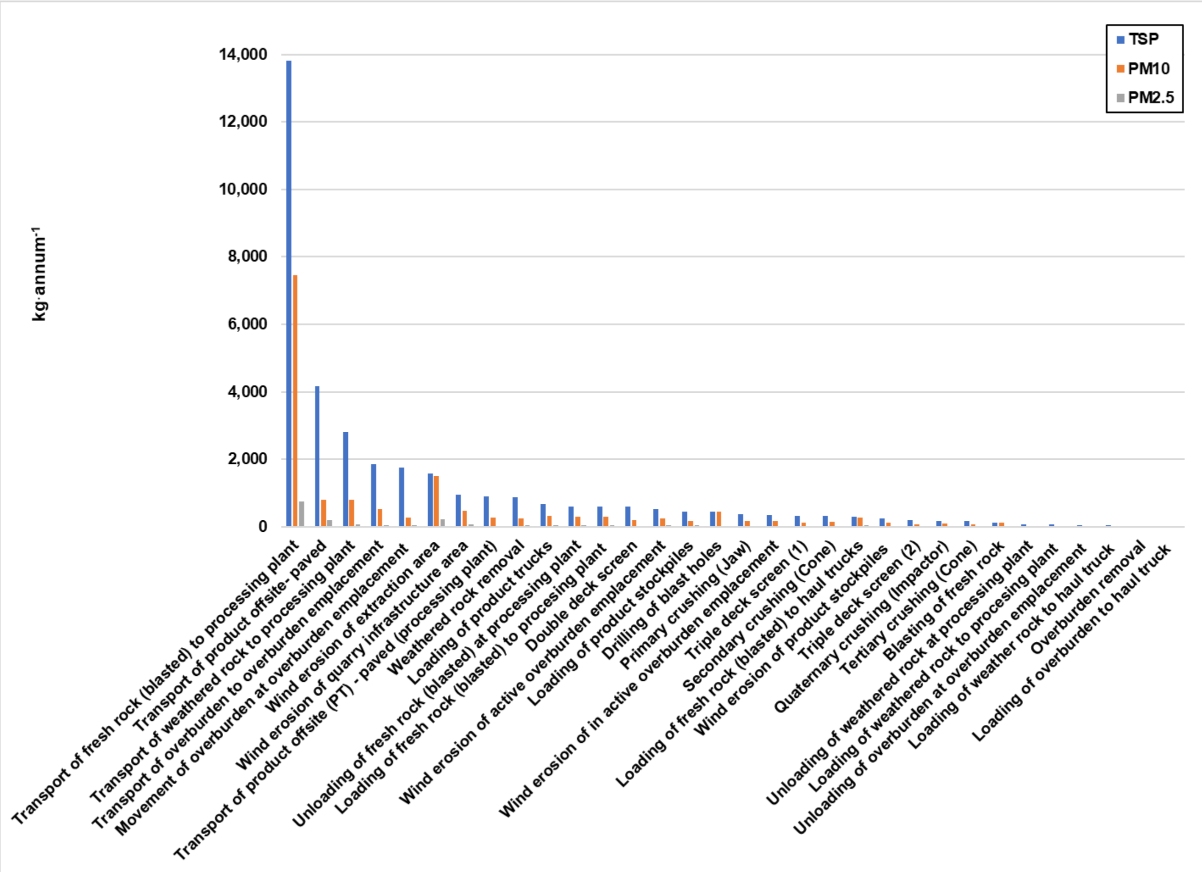


Table 2-21
Summary of Particulate Control Measure Efficiency – Stage 2B

Emissions	TSP	PM_{10}	$PM_{2.5}$
Uncontrolled (kg·annum^{-1})	233,688	68,905	7,872
Controlled (kg·annum^{-1})	35,413	15,759	1,940
Control efficiency (total) (%)	84.8	77.1	75.4

The detailed emissions inventories for each stage of the Project are presented below

Table 2-22
Emissions Inventory -Annual – Site Establishment and Construction

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate (kg·period^{-1})		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Overburden removal	AP-42 - Bulldozing (Overburden) - Table 11.9-2	2.43	0.36	0.25	kg·hr^{-1}	1,452.0	hr	Watering (50)	3,522.4	525.2	369.9
Loading of overburden to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	197,000.0	t		219.6	103.8	15.7
Transport of overburden to pad	AP-42 Unpaved roads – Section 13.2.2	3.50	0.99	0.10	kg·VKT^{-1}	5,463.9	VKT	Watering (90)	19,110.5	5,434.3	543.4
Unloading of overburden at pad	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	197,000.0	t		219.6	103.8	15.7
Movement of overburden and pad construction	NPI - Excavators/shovels/front-end loaders (on overburden) - Section 1.1.2	0.0011	0.0005	0.0001	kg·t^{-1}	197,000.0	t		219.6	103.8	15.6
Wind erosion of extraction area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	kg·ha^{-1}·yr^{-1}	1.3	ha	Watering (50)	1,105.0	552.5	82.9
Wind erosion of quarry infrastructure area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	kg·ha^{-1}·yr^{-1}	4.6	ha	Watering (50)	3,910.0	1,955.0	293.3

Table 2-23
Emissions Inventory -Maximum 24-hour – Site Establishment and Construction

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate ($kg \cdot period^{-1}$)**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Overburden removal	AP-42 - Bulldozing (Overburden) - Table 11.9-2	2.43	0.36	0.25	$kg \cdot hr^{-1}$	11	hr	Watering (50)	13.3	2.0	1.4
Loading of overburden to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	2464	t		2.7	1.3	0.2
Transport of overburden to pad	AP-42 Unpaved roads – Section 13.2.2	3.50	0.99	0.10	$kg \cdot VKT^{-1}$	68.3	VKT	Watering (90)	23.9	6.8	0.7
Unloading of overburden at pad	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	2464	t		2.7	1.3	0.2
Movement of overburden and pad construction	NPI - Excavators/shovels/front-end loaders (on overburden) - Section 1.1.2	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	2464	t		2.7	1.3	0.2
Wind erosion of extraction area	AP-42 - Wind erosion of exposed areas - annual - Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	1.3	ha	Watering (50)	1.5	0.8	0.1
Wind erosion of quarry infrastructure area	AP-42 - Wind erosion of exposed areas - annual - Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	4.6	ha	Watering (50)	5.4	2.7	0.4

Table 2-24
Emissions Inventory -Annual – Stage 1C

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate ($kg \cdot period^{-1}$)		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Overburden removal	NPI - Excavators/shovels/front-end loaders (on overburden) - Section 1.1.2	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	37,000.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	20.6	18.5	2.8
Loading of overburden to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	37,000.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	20.6	18.5	2.8
Transport of overburden to overburden emplacement	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	$kg \cdot VKT^{-1}$	973.6	VKT		1,089.7	309.9	31.0
Unloading of overburden at overburden emplacement	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.000527137	0.00008	$kg \cdot t^{-1}$	37,000.0	t		41.2	19.5	3.0
Movement of overburden at overburden emplacement	NPI - Bulldozer on material other than coal - Table 2	2.426	0.364	0.055	$kg \cdot hr^{-1}$	726.0	hr		1,761.2	264.6	39.7
Weathered rock removal	NPI - Bulldozer on material other than coal - Table 2	2.426	0.364	0.055	$kg \cdot hr^{-1}$	726.0	hr	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	880.6	251.3	37.7
Loading of weather rock to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	50,424.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	28.1	25.3	3.8
Transport of weathered rock to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.49	0.99	0.099	$kg \cdot VKT^{-1}$	2,546.1	VKT	Watering (68)	2,849.6	810.3	81.0

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate ($kg \cdot period^{-1}$)**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Unloading of weathered rock at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	50,424.0	t		56.2	26.6	4.0
Loading of weathered rock to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	50,424.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5) Watering (50)	56.2	26.6	4.0
Drilling of blast holes	NPI - Drilling - Section 1.1.8	0.59	0.31	0.01770	$kg \cdot hole^{-1}$	2,999.0	holes	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	442.4	441.6	25.2
Blasting of fresh rock	NPI - Blasting - Section 1.1.9	14.08	7.296	0.43776	$kg \cdot blast^{-1}$	17.3	blasts	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	122.0	120.1	7.2
Loading of fresh rock (blasted) to haul trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	249,576.0	t		139.1	125.0	18.9
Transport of fresh rock (blasted) to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	$kg \cdot VKT^{-1}$	6,389.6	VKT		3,575.7	1,931.9	193.2
Unloading of fresh rock (blasted) at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	249,576.0	t		278.2	131.6	19.9
Loading of fresh rock (blasted) to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	249,576.0	t		278.2	131.6	19.9
Primary crushing (Jaw)	AP-42 - Primary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg \cdot t^{-1}$	300,000.0	tonnes	Controlled (77.7) Noise wall wind break (30)	126.4	56.2	10.1

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate (kg·period⁻¹)		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Secondary crushing (Cone)	AP-42 - Secondary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg{\cdot}t^{-1}$	272,000.0	tonnes	Controlled (77.7) Noise wall wind break (30)	114.6	51.0	9.2
Double deck screen	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	$kg{\cdot}t^{-1}$	272,000.0	tonnes	Controlled (91.2) Noise wall wind break (30)	209.4	72.0	5.0
Tertiary crushing (Cone)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg{\cdot}t^{-1}$	148,667.0	tonnes	Controlled (77.7) Noise wall wind break (30)	62.7	27.8	5.0
Quaternary crushing (Impactor)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg{\cdot}t^{-1}$	150,000.0	tonnes	Controlled (77.7) Noise wall wind break (30)	63.2	28.1	5.1
Triple deck screen (1)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	$kg{\cdot}t^{-1}$	150,000.0	tonnes	Controlled (91.2) Noise wall wind break (30)	115.5	39.7	2.8
Triple deck screen (2)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	$kg{\cdot}t^{-1}$	84,667.0	tonnes	Controlled (91.2) Noise wall wind break (30)	65.2	22.4	1.6
Loading of product stockpiles	AP-42 - Conveyor transfer point - Table 11.19.2.1	0.0015	0.00055	0.00015	$kg{\cdot}t^{-1}$	300,000.0	tonnes	Watering (50)	225.0	82.5	23.1
Loading of product trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg{\cdot}t^{-1}$	300,000.0	t		334.4	158.1	23.9

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate ($kg \cdot period^{-1}$)**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Transport of product offsite - rolled asphalt (paved)	AP-42 Paved roads – Section 13.2.1	0.103	0.0198	0.0047	$kg \cdot VKT^{-1}$	4,984.6	VKT	Watering (30) Speed reduction (50)	179.4	34.4	8.3
Transport of product offsite paved	AP-42 Paved roads – Section 13.2.1	0.103	0.0198	0.0047	$kg \cdot VKT^{-1}$	20,307.7	VKT		2,088.4	400.9	97.0
Wind erosion of active overburden emplacement	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.2	ha	Watering (50)	85.0	42.5	6.4
Wind erosion of extraction area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	4.9	ha	Watering (50) Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	1,041.3	989.2	148.4
Wind erosion of product stockpiles	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.6	ha	Watering (50)	255.0	127.5	19.1
Wind erosion of quarry infrastructure area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	5.0	ha	Watering (50)	2,125.0	1,062.5	159.4

Note: Required noise wall acts to reduce emissions from the processing plant during this Stage.

Table 2-25
Emissions Inventory – Maximum 24-hour – Stage 1C

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate ($kg \cdot period^{-1}$)**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Overburden removal	NPI - Excavators/shovels/front-end loaders (on overburden) - Section 1.1.2	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	0.0	t		0.0	0.0	0.0
Loading of overburden to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	0.0	t		0.0	0.0	0.0
Transport of overburden to overburden emplacement	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	$kg \cdot VKT^{-1}$	0.0	VKT		0.0	0.0	0.0
Unloading of overburden at overburden emplacement	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	0.0	t		0.0	0.0	0.0
Movement of overburden at overburden emplacement	NPI - Bulldozer on material other than coal - Table 2	2.426	0.364	0.055	$kg \cdot hr^{-1}$	726.0	hr		0.0	0.0	0.0
Weathered rock removal	NPI - Bulldozer on material other than coal - Table 2	2.426	0.364	0.055	$kg \cdot hr^{-1}$	726.0	hr	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	13.3	3.8	0.6
Loading of weather rock to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	50,424.0	t	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	0.3	0.3	0.0
Transport of weathered rock to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.49	0.99	0.099	$kg \cdot VKT^{-1}$	2,546.1	VKT	Watering (68)	28.5	8.1	0.8

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate (kg·period^{-1})		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Unloading of weathered rock at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	50,424.0	t		0.6	0.3	0.0
Loading of weathered rock to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	50,424.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5) Watering (50)	0.6	0.3	0.0
Drilling of blast holes	NPI - Drilling - Section 1.1.8	0.59	0.31	0.01770	kg·hole^{-1}	0	holes	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	0.0	0.0	0.0
Blasting of fresh rock	NPI - Blasting - Section 1.1.9	14.08	7.296	0.43776	kg·blast^{-1}	0	blasts	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	0.0	0.0	0.0
Loading of fresh rock (blasted) to haul trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	249,576.0	t		1.4	1.2	0.2
Transport of fresh rock (blasted) to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	kg·VKT^{-1}	6,389.6	VKT		35.8	19.3	1.9
Unloading of fresh rock (blasted) at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	249,576.0	t		2.8	1.3	0.2
Loading of fresh rock (blasted) to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	249,576.0	t		2.8	1.3	0.2
Primary crushing (Jaw)	AP-42 - Primary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	300,000.0	tonnes	Controlled (77.7) Noise wall wind break (30)	1.3	0.6	0.1

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate (kg·period^{-1})		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Secondary crushing (Cone)	AP-42 - Secondary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	272,000.0	tonnes	Controlled (77.7) Noise wall wind break (30)	1.1	0.5	0.1
Double deck screen	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	kg·t^{-1}	272,000.0	tonnes	Controlled (91.2) Noise wall wind break (30)	2.1	0.7	0.1
Tertiary crushing (Cone)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	148,667.0	tonnes	Controlled (77.7) Noise wall wind break (30)	0.6	0.3	0.1
Quaternary crushing (Impactor)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	150,000.0	tonnes	Controlled (77.7) Noise wall wind break (30)	0.6	0.3	0.1
Triple deck screen (1)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	kg·t^{-1}	150,000.0	tonnes	Controlled (91.2) Noise wall wind break (30)	0.7	0.2	0.0
Triple deck screen (2)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	kg·t^{-1}	84,667.0	tonnes	Controlled (91.2) Noise wall wind break (30)	2.3	0.8	0.1
Loading of product stockpiles	AP-42 - Conveyor transfer point - Table 11.19.2.1	0.0015	0.00055	0.00015	kg·t^{-1}	300,000.0	tonnes	Watering (50)	2.3	0.8	0.2
Loading of product trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	300,000.0	t		3.3	1.6	0.2

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate ($kg \cdot period^{-1}$)**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Transport of product offsite - rolled asphalt (paved)	AP-42 Paved roads – Section 13.2.1	0.103	0.0198	0.0047	$kg \cdot VKT^{-1}$	4,984.6	VKT	Watering (30) Speed reduction (50)	1.8	0.3	0.1
Transport of product offsite paved	AP-42 Paved roads – Section 13.2.1	0.103	0.0198	0.0047	$kg \cdot VKT^{-1}$	20,307.7	VKT		20.9	4.0	1.0
Wind erosion of active overburden emplacement	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.2	ha	Watering (50)	0.2	0.1	0.0
Wind erosion of extraction area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	4.9	ha	Watering (50) Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	2.9	2.7	0.4
Wind erosion of product stockpiles	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.6	ha	Watering (50)	0.7	0.3	0.1
Wind erosion of quarry infrastructure area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	5.0	ha	Watering (50)	5.8	2.9	0.4

Note: On a day where 3,000 tonnes of product material is to be extracted from the pit, transported to the processing plant, processed, loaded to vehicles and despatched, the availability of excavators and haul trucks to remove, load and transport overburden would be limited. Therefore, these activities are assumed not to occur on these days of maximum production. Additionally, the performance of a blast would severely limit the ability to load, haul and process the maximum 3,000 tonnes and therefore no blasting is assumed to occur on these days of maximum production.

Required noise wall acts to reduce emissions from the processing plant during this Stage.

Table 2-26
Emissions Inventory -Annual – Stage 2B

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate (kg·period^{-1})		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Overburden removal	NPI - Excavators/shovels/front-end loaders (on overburden) - Section 1.1.2	0.0011	0.0005	0.0001	kg·t^{-1}	37,000.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	20.6	18.5	2.8
Loading of overburden to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	37,000.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	20.6	18.5	2.8
Transport of overburden to overburden emplacement	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	kg·VKT^{-1}	1,894.5	VKT	Watering (72)	1,855.4	527.6	52.8
Unloading of overburden at overburden emplacement	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	37,000.0	t		41.2	19.5	3.0
Movement of overburden at overburden emplacement	NPI - Bulldozer on material other than coal - Table 2	2.426	0.364	0.054	kg·hr^{-1}	726.0	hr		1,761.2	264.6	39.7
Weathered rock removal	NPI - Bulldozer on material other than coal - Table 2	2.425885 778	0.364402977	0.05466	kg·hr^{-1}	726.0	hr	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	880.6	251.3	37.7
Loading of weather rock to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	56,184.0	t	Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	31.3	28.1	4.3
Transport of weathered rock to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	kg·VKT^{-1}	2,876.8	VKT	Watering (72)	2,817.4	801.2	80.1

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate ($kg \cdot period^{-1}$)**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Unloading of weathered rock at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	56,184.0	t		62.6	29.6	4.5
Loading of weathered rock to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	56,184.0	t		62.6	29.6	4.5
Drilling of blast holes	NPI - Drilling - Section 1.1.8	0.59	0.31	0.01770	$kg \cdot hole^{-1}$	2,999.0	holes	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5) Watering (50)	442.4	441.6	25.2
Blasting of fresh rock	NPI - Blasting - Section 1.1.9	14.08	7.296	0.43776	$kg \cdot blast^{-1}$	17.3	blasts	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	122.0	120.1	7.2
Loading of fresh rock (blasted) to haul trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	543,816.0	t	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	303.0	272.3	41.2
Transport of fresh rock (blasted) to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	$kg \cdot VKT^{-1}$	28,232.3	VKT	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5) Watering (72)	13,824.3	7,469.2	746.9
Unloading of fresh rock (blasted) at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	543,816.0	t		606.1	286.7	43.4
Loading of fresh rock (blasted) to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg \cdot t^{-1}$	543,816.0	t		606.1	286.7	43.4
Primary crushing (Jaw)	AP-42 - Primary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg \cdot t^{-1}$	600,000.0	tonnes	Controlled (77.7)	361.3	160.6	28.9
Secondary crushing (Cone)	AP-42 - Secondary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg \cdot t^{-1}$	544,000.0	tonnes	Controlled (77.7)	327.5	145.6	26.2

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate ($kg·period^{-1}$)		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Double deck screen	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	$kg·t^{-1}$	544,000.0	tonnes	Controlled (91.2)	598.4	205.8	14.4
Tertiary crushing (Cone)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg·t^{-1}$	297,333.0	tonnes	Controlled (77.7)	179.0	79.6	14.3
Quaternary crushing (Impactor)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	$kg·t^{-1}$	300,000.0	tonnes	Controlled (77.7)	180.6	80.3	14.5
Triple deck screen (1)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	$kg·t^{-1}$	300,000.0	tonnes	Controlled (91.2)	330.0	113.5	7.9
Triple deck screen (2)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	$kg·t^{-1}$	169,333.0	tonnes	Controlled (91.2)	186.3	64.1	4.5
Loading of product stockpiles	AP-42 - Conveyor transfer point - Table 11.19.2.1	0.0015	0.00055	0.00015	$kg·t^{-1}$	600,000.0	tonnes	Watering (50)	450.0	165.0	46.2
Loading of product trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	$kg·t^{-1}$	600,000.0	t		668.7	316.3	47.9
Transport of product offsite - rolled asphalt (paved)	AP-42 Paved roads – Section 13.2.1	0.103	0.0198	0.0047	$kg·VKT^{-1}$	9,600.0	VKT	Watering (30) Speed reduction (50)	345.5	66.3	16.0
Transport of product offsite paved	AP-42 Paved roads – Section 13.2.1	0.103	0.0198	0.0047	$kg·VKT^{-1}$	40,615.4	VKT		4,176.9	801.8	194.0
Wind erosion of extraction area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg·ha^{-1}·yr^{-1}$	7.4	ha	Watering (50) Pit retention (TSP – 50, PM_{10} , $PM_{2.5}$ -5)	1,572.5	1,493.9	224.1
Wind erosion of quarry infrastructure area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg·ha^{-1}·yr^{-1}$	2.2	ha	Watering (50)	935.0	467.5	70.1

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate ($kg \cdot period^{-1}$)		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Wind erosion of product stockpiles	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.8	ha	Watering (50) Noise wall wind break (30)	238.0	119.0	17.9
Wind erosion of active overburden emplacement	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	1.2	ha	Watering (50)	510.0	255.0	38.3
Wind erosion of in active overburden emplacement	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.8	ha	Watering (50)	340.0	170.0	25.5

Note: Required noise wall acts to reduce emissions from the processing plant stockpiles during this Stage. Emissions from the processing plant are not mitigated due to the movement of these activities to the east of the Site.

Table 2-27
Emissions Inventory -Maximum 24-hour – Stage 2B

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate (kg·period^{-1})		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Overburden removal	NPI - Excavators/shovels/front-end loaders (on overburden) - Section 1.1.2	0.0011	0.0005	0.0001	kg·t^{-1}	0.0	t	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	0.0	0.0	0.0
Loading of overburden to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	0.0	t	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	0.0	0.0	0.0
Transport of overburden to overburden emplacement	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	kg·VKT^{-1}	0.0	VKT	Watering (72)	0.0	0.0	0.0
Unloading of overburden at overburden emplacement	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	0.0	t		0.0	0.0	0.0
Movement of overburden at overburden emplacement	NPI - Bulldozer on material other than coal - Table 2	2.425	0.364	0.054	kg·hr^{-1}	0.0	hr		0.0	0.0	0.0
Weathered rock removal	NPI - Bulldozer on material other than coal - Table 2	2.425	0.364	0.054	kg·hr^{-1}	11.0	hr	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	13.3	3.8	0.6
Loading of weather rock to haul truck	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	504.0	t	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	0.3	0.3	0.0
Transport of weathered rock to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	kg·VKT^{-1}	25.8	VKT	Watering (72)	25.3	7.2	0.7

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate (kg·period^{-1})**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Unloading of weathered rock at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	504.0	t		0.6	0.3	0.0
Loading of weathered rock to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	504.0	t		0.6	0.3	0.0
Drilling of blast holes	NPI - Drilling - Section 1.1.8	0.59	0.31	0.01770	kg·hole^{-1}	0.0	holes	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5) Watering (50)	0.0	0.0	0.0
Blasting of fresh rock	NPI - Blasting - Section 1.1.9	14.08	7.296	0.43776	kg·blast^{-1}	0.0	blasts	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	0.0	0.0	0.0
Loading of fresh rock (blasted) to haul trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	2,496.0	t	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	1.4	1.2	0.2
Transport of fresh rock (blasted) to processing plant	AP-42 Unpaved roads – Section 13.2.2	3.498	0.995	0.099	kg·VKT^{-1}	129.6	VKT	Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5) Watering (72)	63.5	34.3	3.4
Unloading of fresh rock (blasted) at processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	2,496.0	t		2.8	1.3	0.2
Loading of fresh rock (blasted) to processing plant	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	2,496.0	t		2.8	1.3	0.2
Primary crushing (Jaw)	AP-42 - Primary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	3,000.0	tonnes	Controlled (77.7)	1.8	0.8	0.1
Secondary crushing (Cone)	AP-42 - Secondary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	2,720.3	tonnes	Controlled (77.7)	1.6	0.7	0.1

Description	Emission Factor				Units	Activity Rate	Units	Emission Controls (efficiency %)	Emission Rate (kg·period^{-1})		
	Source	TSP	PM_{10}	$PM_{2.5}$					TSP	PM_{10}	$PM_{2.5}$
Double deck screen	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	kg·t^{-1}	2,720.3	tonnes	Controlled (91.2)	3.0	1.0	0.1
Tertiary crushing (Cone)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	1,486.5	tonnes	Controlled (77.7)	0.9	0.4	0.1
Quaternary crushing (Impactor)	AP-42 - Tertiary crushing - Table 11.19.2.1	0.0027	0.0012	0.00022	kg·t^{-1}	1,500.0	tonnes	Controlled (77.7)	0.9	0.4	0.1
Triple deck screen (1)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	kg·t^{-1}	1,500.0	tonnes	Controlled (91.2)	1.7	0.6	0.0
Triple deck screen (2)	AP-42 - Screening – Table 11.19.2.1	0.0125	0.0043	0.00030	kg·t^{-1}	846.8	tonnes	Controlled (91.2)	0.9	0.3	0.0
Loading of product stockpiles	AP-42 - Conveyor transfer point - Table 11.19.2.1	0.0015	0.00055	0.00015	kg·t^{-1}	3,000.0	tonnes	Watering (50)	2.3	0.8	0.2
Loading of product trucks	AP-42 - Batch drop – Section 13.2.4.3	0.0011	0.0005	0.0001	kg·t^{-1}	3,000.0	t		3.3	1.6	0.2
Transport of product offsite - rolled asphalt (paved)	AP-42 Paved roads – Section 13.2.1	0.103	0.0197	0.0047	kg·VKT^{-1}	48.0	VKT	Watering (30) Speed reduction (50)	1.7	0.3	0.1
Transport of product offsite paved	AP-42 Paved roads – Section 13.2.1	0.103	0.0197	0.0047	kg·VKT^{-1}	203.1	VKT		20.9	4.0	1.0
Wind erosion of extraction area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	kg·ha^{-1}·yr^{-1}	7.4	ha	Watering (50) Pit retention (TSP – 50, PM_{10}, $PM_{2.5}$ -5)	4.3	4.1	0.6
Wind erosion of quarry infrastructure area	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	kg·ha^{-1}·yr^{-1}	2.2	ha	Watering (50)	2.6	1.3	0.2

Description	**Emission Factor**				**Units**	**Activity Rate**	**Units**	**Emission Controls (efficiency %)**	**Emission Rate (kg·period-1)**		
	Source	**TSP**	**PM_{10}**	**$PM_{2.5}$**					**TSP**	**PM_{10}**	**$PM_{2.5}$**
Wind erosion of product stockpiles	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.8	ha	Watering (50) Noise wall wind break (30)	0.7	0.3	0.0
Wind erosion of active overburden emplacement	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	1.2	ha	Watering (50)	1.4	0.7	0.1
Wind erosion of in active overburden emplacement	AP-42 - Wind erosion of exposed areas - annual – Table 11.9-4	850.0	425.0	63.8	$kg \cdot ha^{-1} \cdot yr^{-1}$	0.8	ha	Watering (50)	0.9	0.5	0.1

Note: On a day where 3,000 tonnes of product material is to be extracted from the pit, transported to the processing plant, processed, loaded to vehicles and despatched, the availability of excavators and haul trucks to remove, load and transport overburden would be limited. Therefore, these activities are assumed not to occur on these days of maximum production. Additionally, the performance of a blast would severely limit the ability to load, haul and process the maximum 3,000 tonnes and therefore no blasting is assumed to occur on these days of maximum production.

Required noise wall acts to reduce emissions from the processing plant stockpiles during this Stage. Emissions from the processing plant are not mitigated due to the movement of these activities to the east of the Site.

EMISSIONS ESTIMATION – EMISSIONS FROM VEHICLES AND PLANT

OXIDES OF NITROGEN EMISSION RATES

Based on the activity data outlined in **Table 2-1** and **Table 2-2** and emission factors outlined above, **Table 2-22** presents the calculate NO_X emission associated with plant and vehicles for each modelled stage of the Project.

Emissions from each source have been modelled as a volume source, with characteristics as indicated in Section 5.1.3.

Table 2-22
Diesel NOx –Emission Rates

Equipment	**kW Rating**	**Operating Hours[1]**	**Load Factor[2]**	**kg NOx·yr^{-1}**		
				Const.	**Stage 1C**	**Stage 2B**
Percussion Drill Rig (Atlas Copco T40 or similar)	168	3,084	0.59	0	2,017.5	2,017.5
Hydraulic Excavator 50t (Caterpillar 349F or similar)"	322	3,084	0.59	3,749.7	3,749.7	3,749.7
Hydraulic Excavator 26t (Caterpillar 325F or similar)"	132	3,084	0.59	1,585.2	0	1,585.2
Bulldozer (Caterpillar D9T Dozer)	346	3,084	0.59	4,029.2	4,029.2	4,029.2
Front-end Loader (Caterpillar 980K or similar)	264	3,084	0.59	3,074.3	3,074.3	6,148.7
Mobile jaw crusher (MC125Z or similar)	350	3,084	0.59	0	4,075.8	4,075.8
Mobile cone crusher (MCO13 or similar)	430	3,084	0.59	0	5,007.4	5,007.4
Mobile screening plant (MS15Z or similar)	76	3,084	0.59	0	912.7	912.7
Mobile cone crusher (MCO13S or similar)	507	3,084	0.59	0	5,904.1	5,904.1
Mobile screening plant (MS20D or similar)	101	3,084	0.59	0	1,212.9	1,212.9
Articulated Haul Truck (CAT 730C or similar)	276	3,084	1	10,895.2	10,895.2	16,342.7
Product truck	372	3,084	1	0	22,027.2	36,711.9
			Total	**23,333.7**	**62,906.1**	**87,698**

FINE PARTICULATE MATTER EMISSION RATES

Based on the activity data outlined in **Table 2-1** and **Table 2-2** and emission factors outlined above, **Table 2-23** presents the calculate $PM_{2.5}$ emission associated with plant and vehicles for each modelled stage of the Project.

Emissions from each source have been modelled as a volume source, with characteristics as indicated in Section 5.1.3.

Table 2-23
Diesel Particulate Matter –Emission Rates

Equipment	kW Rating	Operating Hours[1]	Load Factor[2]	kg $PM_{2.5}\cdot yr^{-1}$		
				Const.	Stage 1C	Stage 2B
Percussion Drill Rig (Atlas Copco T40 or similar)	168	3,084	0.59	0.0	0.4	0.4
Hydraulic Excavator 50t (Caterpillar 349F or similar)"	322	3,084	0.59	0.4	0.4	0.4
Hydraulic Excavator 26t (Caterpillar 325F or similar)"	132	3,084	0.59	0.4	0.0	0.4
Bulldozer (Caterpillar D9T Dozer)	346	3,084	0.59	0.4	0.4	0.4
Front-end Loader (Caterpillar 980K or similar)	264	3,084	0.59	0.4	0.4	0.7
Mobile jaw crusher (MC125Z or similar)	350	3,084	0.59	0.0	0.4	0.4
Mobile cone crusher (MCO13 or similar)	430	3,084	0.59	0.0	0.4	0.4
Mobile screening plant (MS15Z or similar)	76	3,084	0.59	0.0	0.4	0.4
Mobile cone crusher (MCO13S or similar)	507	3,084	0.59	0.0	0.4	0.4
Mobile screening plant (MS20D or similar)	101	3,084	0.59	0.0	0.4	0.4
Articulated Haul Truck (CAT 730C or similar)	276	3,084	1	3.2	5.8	19.3
Product truck	372	3,084	1	0.0	14.8	29.3
			Total	**4.6**	**23.8**	**52.6**

Annexure 3

Background Air Quality

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BACKGROUND AIR QUALITY

This Annexure presents a summary of background air quality data used in this assessment.

The following sections in this Annexure sequentially provide details relating to:

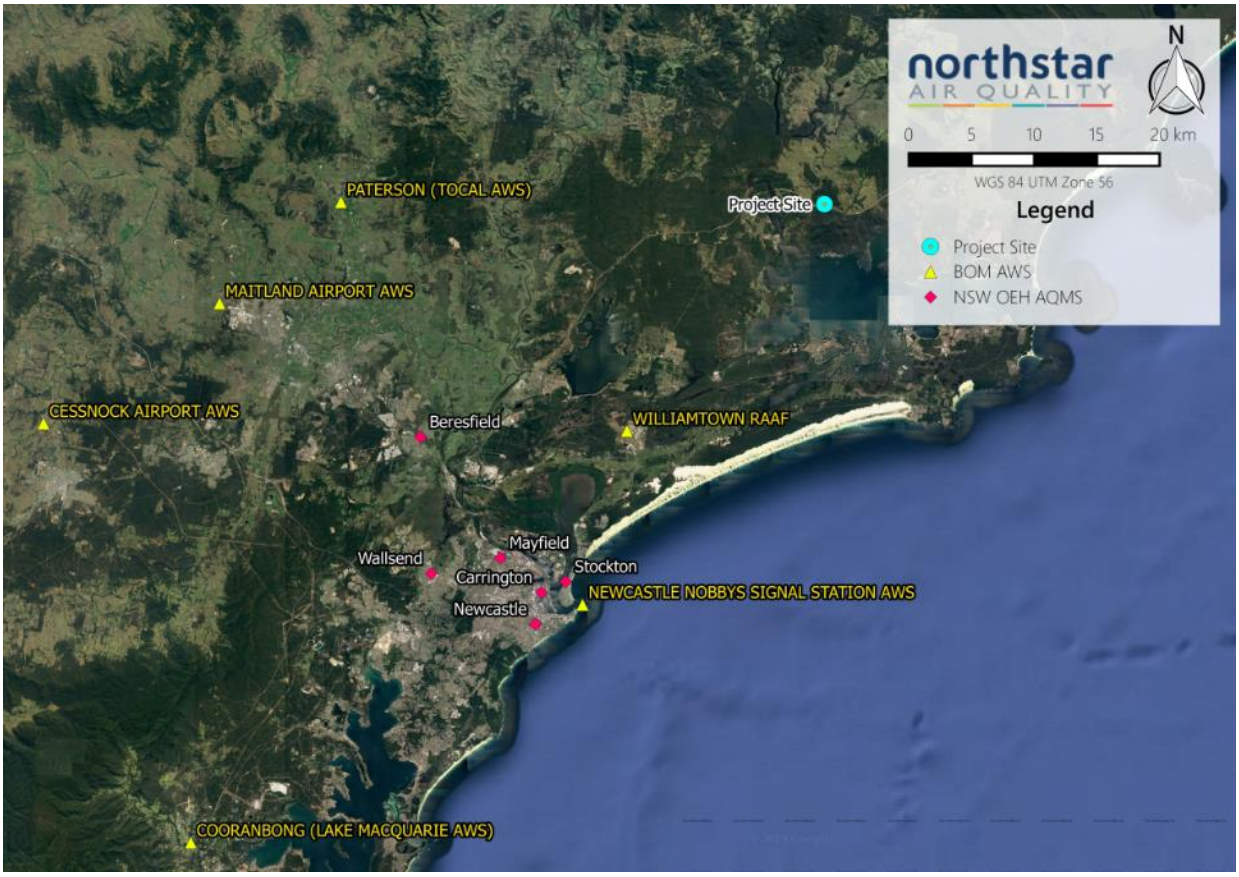
- Sources of data – including a description, methods and periods of measurement;
- Summary statistics – including a range of statistics relating to the measurements performed;
- Discussion of the data – including variability and relevance to the Site; and,
- Summary of the data adopted within the assessment.

SOURCES OF DATA

The sources of air quality monitoring data presented in this Annexure relate to measurements taken at the following locations:

- Karuah Quarry, performed by Hunter Quarries Pty Ltd;
- Karuah East Quarry, performed by Hunter Quarries Pty Ltd;
- Wallsend Air Quality Monitoring Station (AQMS), performed by NSW OEH;
- Newcastle Air Quality Monitoring Station (AQMS), performed by NSW OEH; and,
- Beresfield Air Quality Monitoring Station (AQMS), performed by NSW OEH.

Figure 3-1
Air Quality Monitoring Stations



Note: BOM AWS stations are referenced in **Annexure 1** and do not form a part of this Annexure but have been provided for location context.

Table 3-1
Sources of Air Quality Monitoring Data

Source	Monitoring Performed (Relevant to the Project)					
	NO_X / NO_2	O_3	TSP	PM_{10}	$PM_{2.5}$	Dust Dep
Karuah Quarry	✗	✗	✓	✓	✗	✓
Karuah East Quarry	✗	✗	✓	✓	✗	✓
Wallsend AQMS	✓	✓	✗	✓	✓	✗
Newcastle AQMS	✓	✓	✗	✓	✓	✗
Beresfield AQMS	✓	✓	✗	✓	✓	✗

Karuah Quarry

Karuah Quarry is located to the immediate north and north west of the Site.

Historically, Hunter Quarries Pty Ltd has performed air quality monitoring at locations to the south of Karuah Quarry. TSP monitoring by High Volume Air Sampler (HVAS) was performed at one location between March 2007 and December 2008 and PM_{10} monitoring was performed at the same location between October 2006 and December 2008.

Both TSP and PM_{10} monitoring were performed on a 1-in-6-day cycle, in accordance with the requirements of the relevant Australian Standards. Whilst useful to demonstrate compliance, the non-continuous nature of the measurements means that the data is of reduced value in establishing background conditions in support of a detailed AQIA.

Monitoring for both pollutants was ceased at the request of Hunter Quarries Pty Ltd due to the absence of exceedances in the monitoring records (SLR Consulting Australia Pty Ltd, 2013). TSP and PM_{10} monitoring is to be recommenced at approximately the same location as part of Karuah East Quarry operations (refer Section 4.5.2).

Dust deposition monitoring using dust deposition gauges (DDG) is currently performed at four locations as part of the Karuah Quarry operations:

- DDG 1 (at residence 20);
- DDG 2 (at residence 22);
- DDG 3 (within DP 1024341); and,
- DDG 4 (at residence 8).

DDG 1 to 3 were installed in October 2006 with DDG 4 operational since January 2012.

DDG 1 to 3 are located to the south of Karuah Quarry, with DDG4 located to the east of Karuah East Quarry.

Two further DDG are located at the front gate to Lot 11 (DDG5) and at receptor A (residence 23 in Section 4.2) as part of Karuah East Quarry operations (SLR Consulting Australia Pty Ltd, 2015b) (refer Section 4.5.2).

The following provides a succinct summary of the value of the Karuah Quarry air quality monitoring data in this assessment:

- Advantageous aspects
  - local source of dust deposition, TSP and PM_{10} measurements
- Disadvantageous aspects
  - provides no real-time PM_{10} and $PM_{2.5}$ data that is required for contemporaneous air quality assessment
  - provides no NO_X nor O_3 data that is required for the blast fume assessment

Karuah East Quarry

Section 7.1 of Appendix 6 of Project Approval 09_0175 outlines a Statement of Commitments in relation to air quality. The commitments include air quality monitoring.

In addition to the monitoring data performed by Hunter Quarries Pty Ltd outlined above for Karuah Quarry, air quality monitoring for TSP and PM_{10} has been re-instated near to receptor A (residence 23 in Section 4.2). These data are measured on a 1-in-6 day cycle in accordance with the requirements of the relevant Australian Standards.

The following provides a succinct summary of the value of the Karuah East Quarry air quality monitoring data in this assessment:

- Advantageous aspects
  - local source of TSP and PM_{10} measurements
- Disadvantageous aspects
  - provides no real-time PM_{10} and $PM_{2.5}$ data that is required for the contemporaneous air quality assessment
  - Provides no NO_X nor O_3 data that is required for the blast fume assessment

OEH Monitoring in the Lower Hunter Air Quality Monitoring Network

The NSW OEH operates a state-wide air quality monitoring network, including a number of air quality monitoring stations (AQMS) in the Lower Hunter. The Lower Hunter Air Quality Monitoring Network includes AQMS located at Wallsend, Newcastle and Beresfield.

The Wallsend AQMS and Newcastle AQMS were both commissioned in 1992, and the Beresfield AQMS was commissioned in 1993. All three AQMS measure a range of pollutants including PM_{10} and $PM_{2.5}$ by Tapered Element Oscillating Microbalance (TEOM), NO_X and O_3 which are of relevance to this assessment.

None of the three OEH AQMS are proximate to the Site:

- Wallsend AQMS is approximately 43 km to the south-west;
- Newcastle AQMS is located approximately 40 km to the south-south-west; and,
- Beresfield AQMS is located approximately 37 km to the west-south-west

The measurements at Newcastle are considered to be most atypical of the three AQMS, and have been discounted from use in the assessment.

In addition to not being immediately proximate to the site, all three AQMS are located within the Newcastle metropolitan area and are influenced by a different mix of sources than would contribute to the results of monitoring performed near to Karuah Quarry and Karuah East Quarry. Such sources would include medium to high density network road traffic, local solid-fuel heating and surrounding industrial uses.

However, the three OEH AQMS measure PM_{10} and $PM_{2.5}$ using a ‘real-time’ TEOM which provides a useful source of data for this assessment, and measure NO_X and O_3 which are important parameters in the assessment of blast fume.

The following provides a succinct summary of the value of the NSW OEH air quality monitoring data in this assessment:

- Advantageous aspects
  - provides real-time PM_{10} and $PM_{2.5}$ data that is required for contemporaneous air quality assessment
  - provides real-time NO_X or O_3 data that is required for the blast fume assessment

- Disadvantageous aspects
  - does not provide local data
  - measurements may be skewed due to the differing sources of air pollution, compared to that expected at the Site
  - provides no NO_X nor O_3 data that is required for contemporaneous air quality assessment

SUMMARY STATISTICS

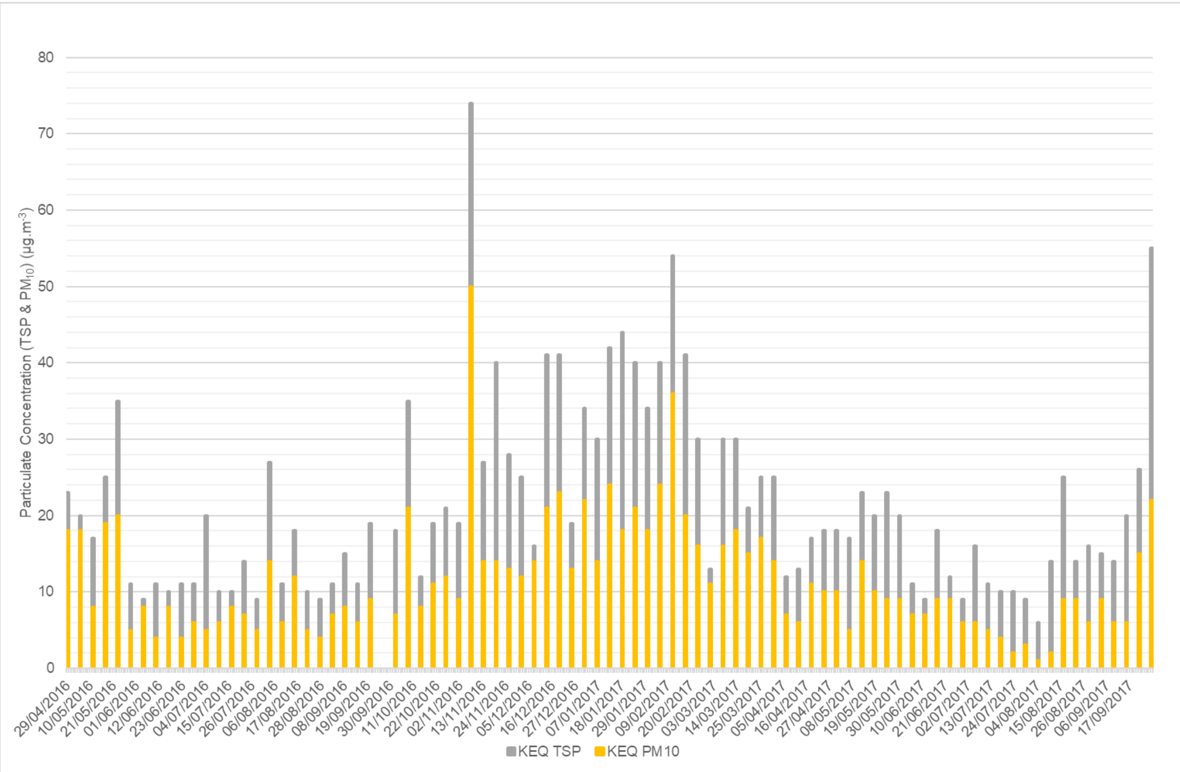
Provided below is a summary of the various sources of monitoring data.

Particulates

Rather than present a summary of historical data (which is of limited value to represent current conditions), the assessment has examined the measurements of PM_{10} and TSP taken near to Karuah East Quarry (KEQ in **Table 3-1** and **Figure 3-2**) with those from the Lower Hunter Air Quality Monitoring Network (namely Wallsend and Beresfield) over the period from 29 April 2016 to 27 September 2017 (the data publicly available for the Karuah East Quarry).

For reference, the time series of PM_{10} and TSP measurements at Karuah East Quarry over this period is presented in **Figure 3-2**.

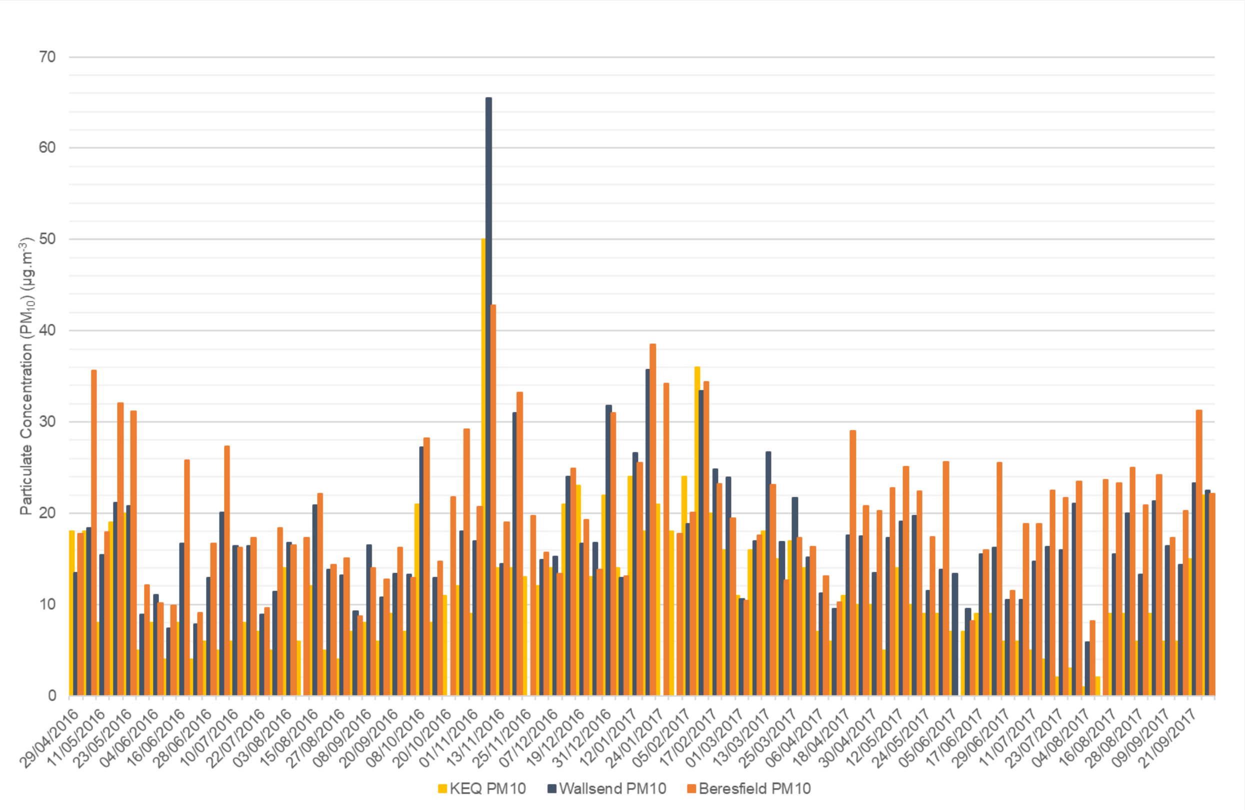
Figure 3-2
Measured PM_{10} and TSP at Karuah East Quarry



Source: (Hunter Quarries Pty Ltd, 2017a), (Hunter Quarries Pty Ltd, 2017b)

Against the PM_{10} measurements presented above in **Figure 3-2**, the corresponding (contemporaneous) 24-hour average measurements at Beresfield and Wallsend are presented in **Figure 3-3**.

Figure 3-3
Contemporaneous Measured PM_{10} Karuah East Quarry, Wallsend and Beresfield



Source: (Hunter Quarries Pty Ltd, 2017a), (Hunter Quarries Pty Ltd, 2017b), http://www.environment.nsw.gov.au/

A summary of the key descriptive statistics and distribution of the measured contemporaneous PM_{10} data is presented in **Table 3-2**.

Table 3-2
Summary of Measured Air Quality Monitoring Data – PM_{10}

Location	**Beresfield**	**Wallsend**	**KEQ**
Pollutant	**PM_{10}**	**PM_{10}**	**PM_{10}**
Period	**24-hour**	**24-hour**	**24-hour**
Units	**$\mu g \cdot m^{-3}$**	**$\mu g \cdot m^{-3}$**	**$\mu g \cdot m^{-3}$**
Mean	20.2	17.4	11.6
Standard Deviation	7.4	8.1	7.7
Skew	*0.7*	*3.0*	*2.0*
Kurtosis	*0.3*	*15.4*	*6.9*
Minimum	8.2	5.9	1.0
1st percentile	8.2	7.1	1.9
2nd percentile	8.5	7.6	2.0
3rd percentile	8.9	8.2	2.6
4th percentile	9.3	8.9	3.4
5th percentile	9.7	8.9	4.0
10th percentile	10.8	10.4	5.0
25th percentile	15.1	13.3	6.0
50th percentile	19.3	16.4	9.0
75th percentile	24.2	20.0	15.0
90th percentile	31.1	25.0	21.0
95th percentile	34.0	31.0	22.8
96th percentile	34.3	31.7	23.6
97th percentile	35.0	32.8	24.0
98th percentile	36.5	34.4	27.6
99th percentile	39.2	42.0	38.1
100th percentile	42.8	65.5	50.0
Count	85.0	80.0	86.0
Capture	98.8 %	93.0 %	100.0 %

Note: All data is presented as measured values expressed as $\mu g \cdot m^{-3}$, with the exception of skew and kurtosis which are dimensionless, count which is expressed as a value and capture which is expressed as a percentage.

Skew is a dimensionless value representing how the data population relates to a normal distribution. A positive skew represents data more weighted by values larger than the median, and a negative skew represents data weighted by values less than the median.

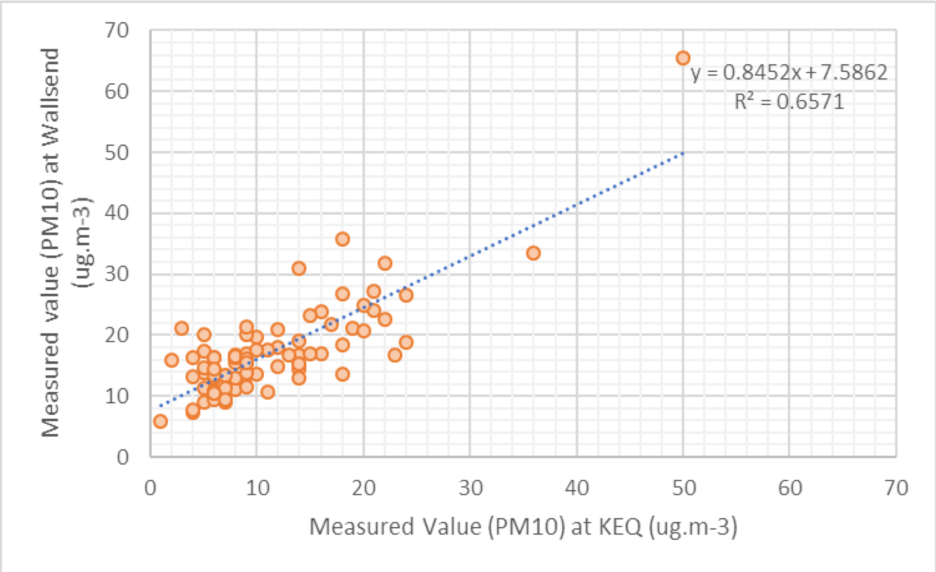
Kurtosis is a dimensionless value representing the 'peakedness' of the data, as relates to a normal distribution. A positive kurtosis represents more peaked data (i.e. Representing high value outliers) and a negative kurtosis representing a mire flattened distribution.

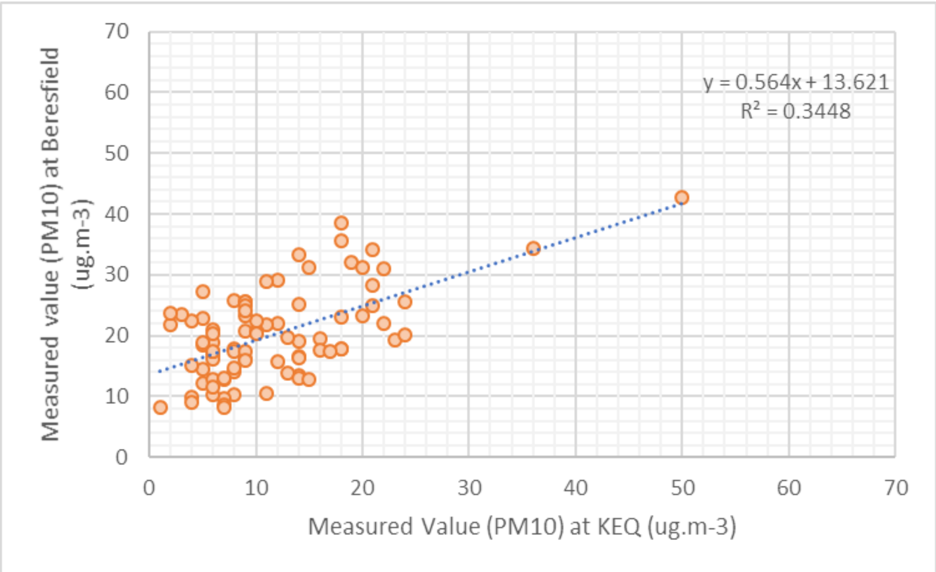
The rate of capture presented above at Karuah East Quarry is presented as 100 %, which merely represents the total measured values over the period against which the OEH data has been filtered, rather than a statement of compliance.

This has been performed to examine the relationship between PM_{10} and TSP values measured at site against longer-term data measured by the OEH in the Lower Hunter Air Quality Monitoring Network. The relationships between these measurements is illustrated in **Figure 3-4**.

A summary of the measured PM_{10} data at Wallsend during 2012 is presented in **Figure 3-5**. No exceedances of the annual average or 24-hr PM_{10} criteria were experienced at Wallsend in 2012.

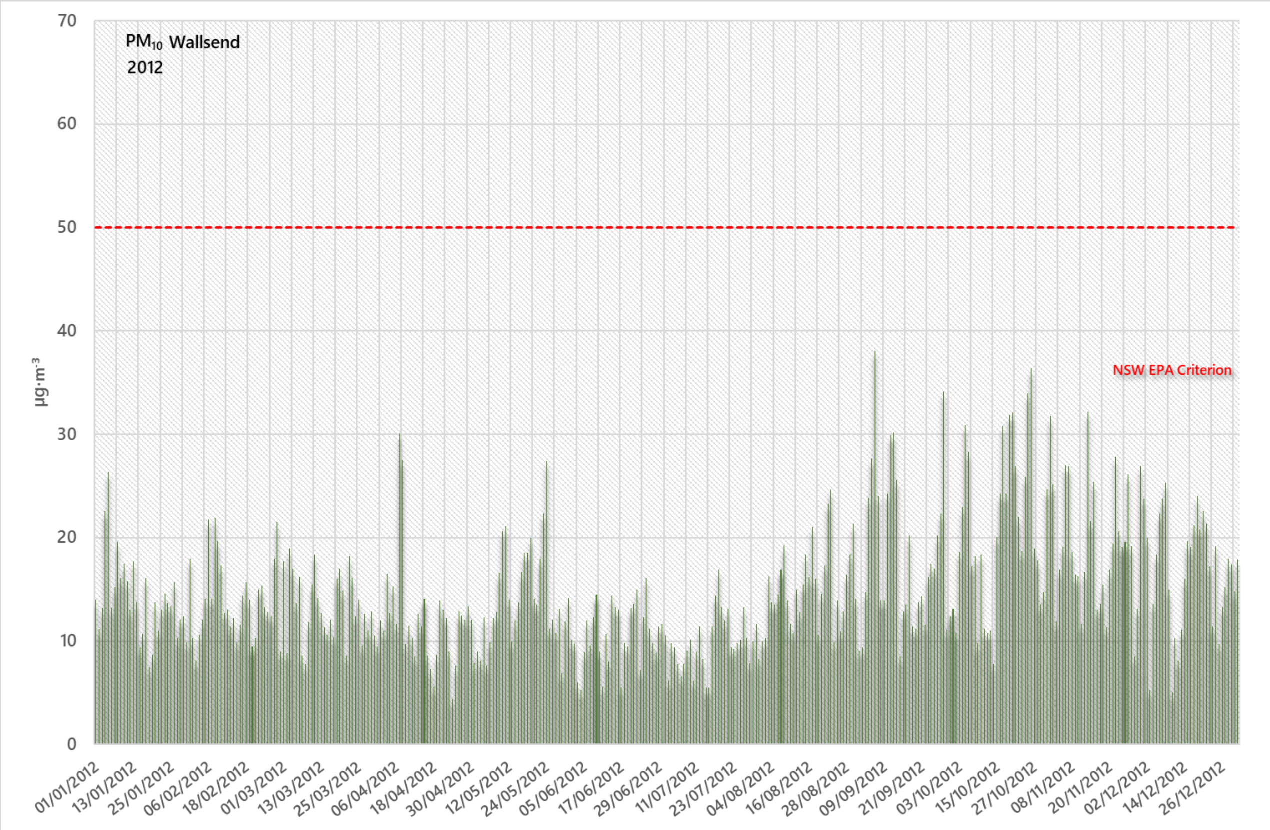
Figure 3-4
Relationship between Measured PM_{10} at Karuah East Quarry, Wallsend and Beresfield





The *X-Y* scatter plots above indicate that a much more significant statistical relationship between the measurements at Karuah East Quarry and Wallsend than with Beresfield. The R-squared value (R^2) of 0.6571 shows a reasonably reliable relationship, given the aforementioned identified difference between source contributions at the two locations.

Figure 3-5
Measured PM_{10} Wallsend, 2012



The distribution of measured values (as percentiles of each distribution) between that measured at Karuah East Quarry and Wallsend and Beresfield is presented in **Figure 3-6**.

Figure 3-6
Relationship of Distribution of Measured PM_{10} at Karuah East Quarry, Wallsend and Beresfield

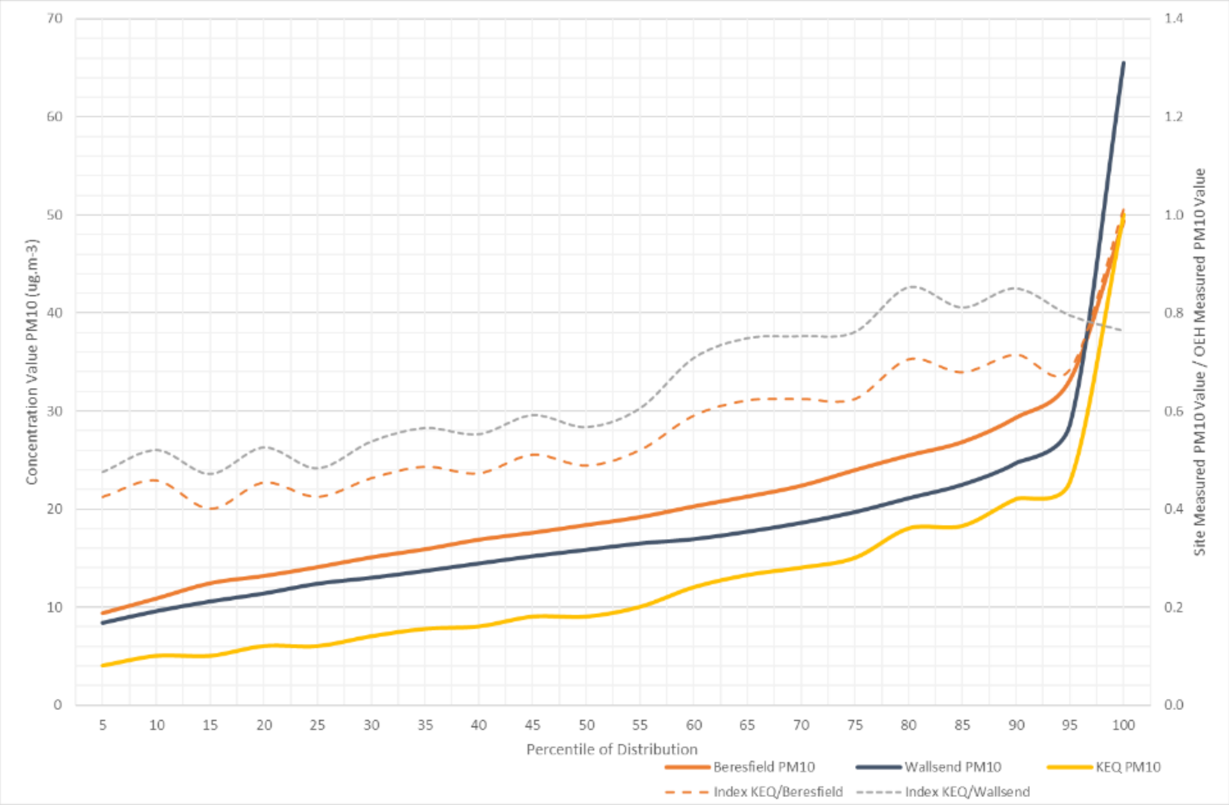


Figure 3-6 shows the percentile distribution of the measured values, and an index of each relationship (shown as the dashed line) respectively for Wallsend and Beresfield.

Figure 3-6 presents a much clearer relationship between the distribution of measurements at Karuah East Quarry to Wallsend, which is further illustrated by the flatter index line.

Based on the above, it is considered reasonable to use the established statistical relationship between PM_{10} measurements at Karuah East Quarry (see **Figure 3-4**) to the longer-term data measured at Wallsend to derive an equivalence background dataset for the Site for the assessment year (2012).

$PM_{2.5}$ measurements are not collected as part of the Karuah Quarry or Karuah East Quarry operations. A relationship as derived for PM_{10} cannot therefore be determined. In the absence of these data, the continuous monitoring data collected at the NSW OEH Wallsend AQMS have been adopted as a representation of regional background concentrations. This approach is conservative, as the $PM_{2.5}$ environment surrounding the Wallsend AQMS would be anticipated to demonstrate a higher concentration due to the impact of localised sources. For clarity, the impact of the contribution of $PM_{2.5}$ emissions from the existing quarrying operations surrounding the Site has been determined through dispersion modelling.

A summary of the $PM_{2.5}$ data collected at Wallsend in 2012 is presented in **Figure 3-7**, with a statistical summary presented in **Table 3-3**. No exceedances of the annual average or 24-hr $PM_{2.5}$ criteria were experienced at Wallsend in 2012.

Figure 3-7
Measured $PM_{2.5}$ Wallsend, 2012

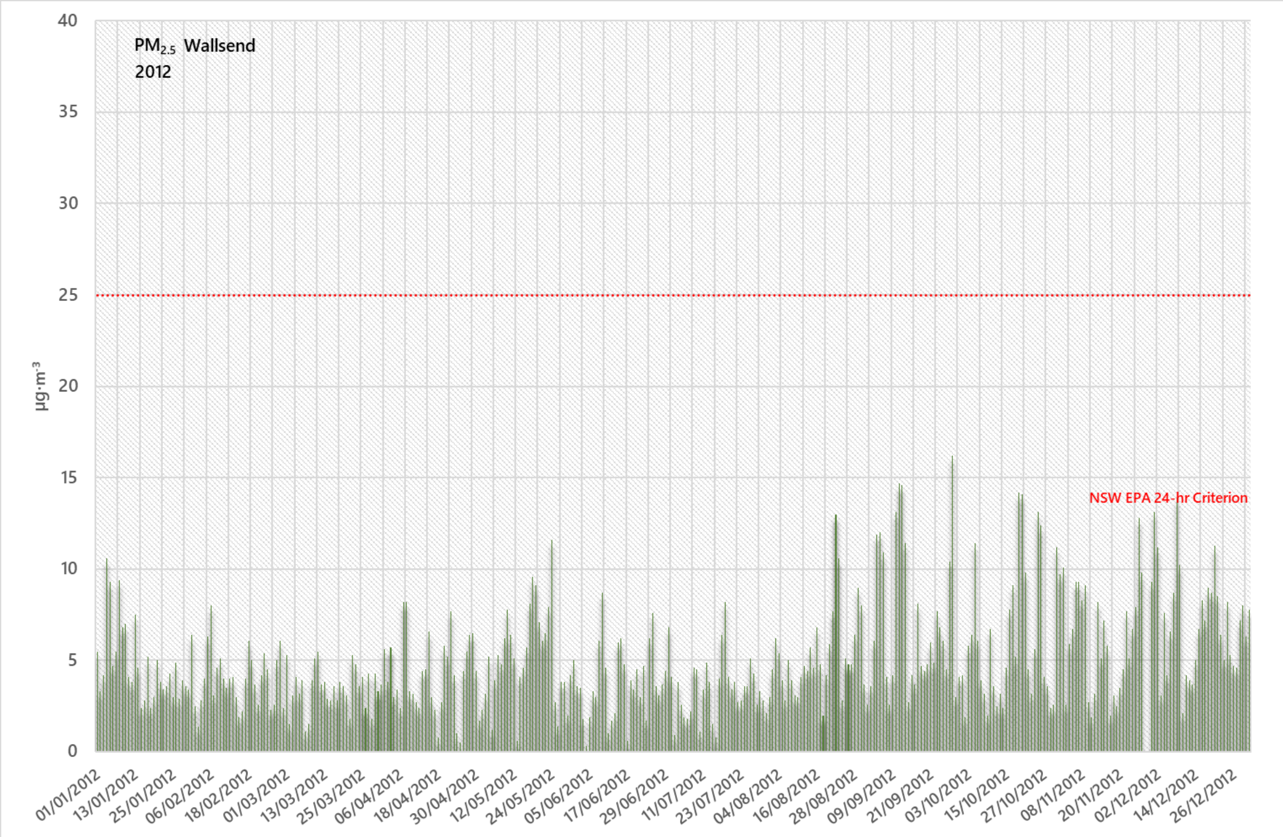


Table 3-3
Summary of Measured Air Quality Monitoring Data – $PM_{2.5}$

Location	**Wallsend**
Pollutant	**PM2.5**
Period	**24-hour**
Units	**$\mu g \cdot m^{-3}$**
Mean	5.1
Standard Deviation	2.9
Skew	*1.2*
Kurtosis	*1.5*
Minimum	0.3
1st percentile	0.7
2nd percentile	1.0
3rd percentile	1.2
5th percentile	1.7
10th percentile	2.2
25th percentile	3.1
50th percentile	4.4
75th percentile	6.4
90th percentile	9.1
95th percentile	11.2
97th percentile	12.4
98th percentile	13.1
99th percentile	14.1
100th percentile	16.2
Count	364
Capture	99.5%

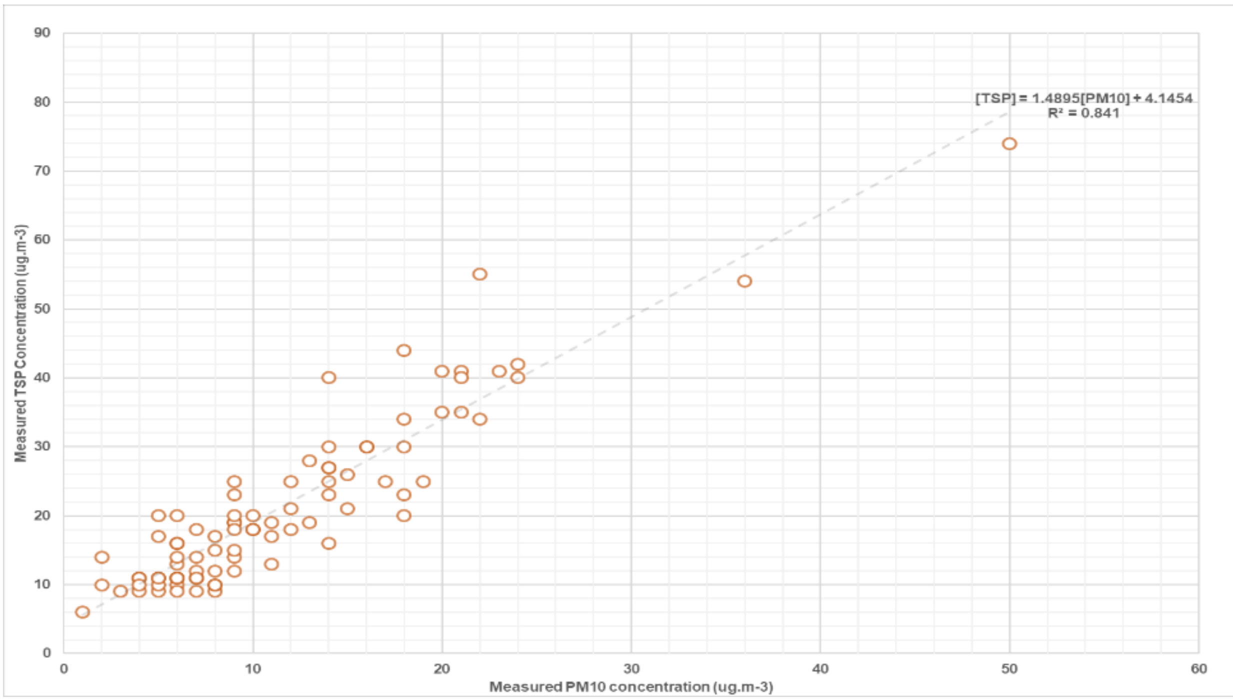
Note: All data is presented as measured values expressed as $\mu g \cdot m^{-3}$, with the exception of skew and kurtosis which are dimensionless, count which is expressed as a value and capture which is expressed as a percentage.

Skew is a dimensionless value representing how the data population relates to a normal distribution. A positive skew represents data more weighted by values larger than the median, and a negative skew represents data weighted by values less than the median.

Kurtosis is a dimensionless value representing the ‘peakedness’ of the data, as relates to a normal distribution. A positive kurtosis represents more peaked data (i.e. Representing high value outliers) and a negative kurtosis representing a mire flattened distribution.

In regard to TSP, the summary of site-specific measurements of PM_{10} and TSP are presented in **Figure 3-8** below.

Figure 3-8
Relationship between Measured PM_{10} and TSP at Karuah East Quarry



The statistical relationship between PM_{10} (see above) and TSP will be derived using the given relationship.

In relation to dust deposition the most recent full year of measurements (2016) indicate that annual average dust deposition was between 0.6 $g{\cdot}m^{-2}{\cdot}month^{-1}$ (DDG5) and 2.1 $g{\cdot}m^{-2}{\cdot}month^{-1}$ (DDG1). It would be anticipated that these values would increase once Karuah East Quarry begins full operations. The incremental impact criterion of 2 $g{\cdot}m^{-2}{\cdot}month^{-1}$ as outlined within the Approved Methods has been adopted which effectively provides a background deposition level of 2 $g{\cdot}m^{-2}{\cdot}month^{-1}$ (the total allowable deposition being 4 $g{\cdot}m^{-2}{\cdot}month^{-1}$).

Gaseous Pollutants

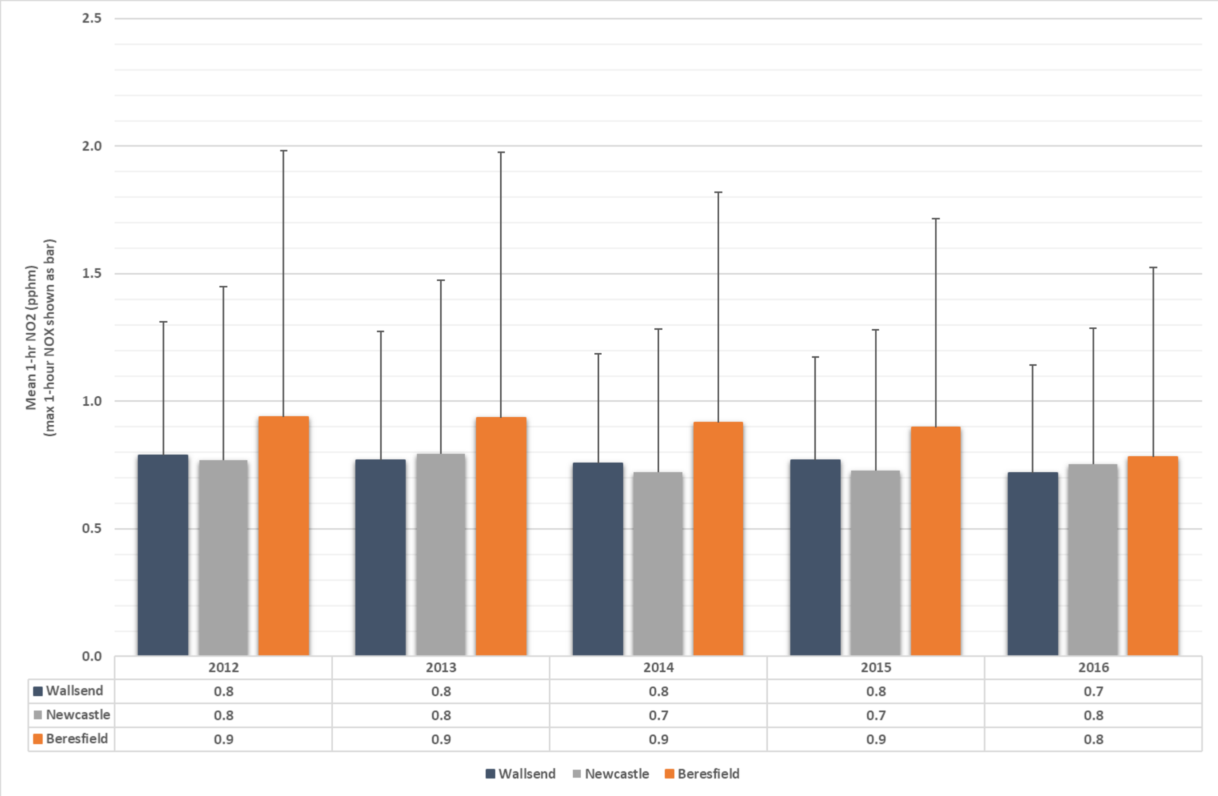
Measurements of NO_X (NO and NO_2) are performed at the NSW OEH AQMS at Wallsend, Beresfield and Newcastle. The data over the period 2012 to 2016 has been reviewed. For clarity, this data is summarised in **Table 3-4**.

Table 3-4
Summary of Measured Air Quality Monitoring Data – NO_X

Location	**Wallsend**			**Beresfield**			**Newcastle**		
Pollutant	**NO_2**	**NO**	**NO_X**	**NO_2**	**NO**	**NO_X**	**NO_2**	**NO**	**NO_X**
Period	**1-hour**	**1-hour**	**1-hour**	**1-hour**	**1-hour**	**1-hour**	**1-hour**	**1-hour**	**1-hour**
Units	**pphm**	**pphm**	**pphm**	**pphm**	**pphm**	**pphm**	**pphm**	**pphm**	**pphm**
Average	0.8	0.5	1.2	0.9	0.9	1.8	0.8	0.6	1.4
StDev	0.5	1.1	1.5	0.7	1.6	2.1	0.7	1.6	2.1
Skew	1.1	3.9	2.7	0.8	3.1	2.3	1.1	4.2	3.0
Kurtosis	1.2	19.3	10.0	0.2	12.6	6.8	0.7	22.5	12.1
Minimum	-0.1	-0.2	-0.1	-0.3	-0.2	-0.3	-0.2	-0.2	-0.2
1	0.1	-0.1	0.0	0.0	-0.1	0.0	0.0	-0.1	-0.1
2	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
3	0.1	-0.1	0.1	0.1	0.0	0.1	0.0	-0.1	-0.1
4	0.1	-0.1	0.1	0.1	0.0	0.1	0.0	-0.1	-0.1
5	0.1	-0.1	0.1	0.1	0.0	0.1	0.0	-0.1	0.0
10	0.2	-0.1	0.2	0.1	0.0	0.2	0.1	-0.1	0.0
25	0.3	0.0	0.3	0.3	0.1	0.4	0.2	0.0	0.2
50	0.6	0.0	0.7	0.8	0.2	1.1	0.5	0.0	0.6
75	1.1	0.3	1.5	1.3	0.9	2.4	1.2	0.4	1.6
90	1.5	1.5	3.0	1.8	2.9	4.5	1.9	1.9	3.8
95	1.8	2.8	4.3	2.2	4.4	6.1	2.2	3.8	5.8
96	1.9	3.2	4.7	2.2	4.9	6.6	2.3	4.4	6.4
97	2.1	3.7	5.2	2.3	5.5	7.3	2.5	5.1	7.1
98	2.2	4.4	5.9	2.5	6.4	8.2	2.6	6.1	8.2
99	2.4	5.6	7.0	2.7	7.9	9.8	2.8	7.9	10.0
100	4.3	13.9	15.4	4.9	17.8	20.2	4.6	21.3	23.8
Capture	93%	93%	93%	93%	93%	93%	93%	93%	93%

The inter-year variability is low, as illustrated in **Figure 3-8**.

Figure 3-8
Inter-year Variability in Measured NO_X at Wallsend, Newcastle and Beresfeld



SUMMARY OF THE DATA USED IN THE ASSESSMENT

Provided in **Table 3-5** is a summary of the data adopted.

Table 3-5
Summary of Measured Air Quality Monitoring Data – NO_X

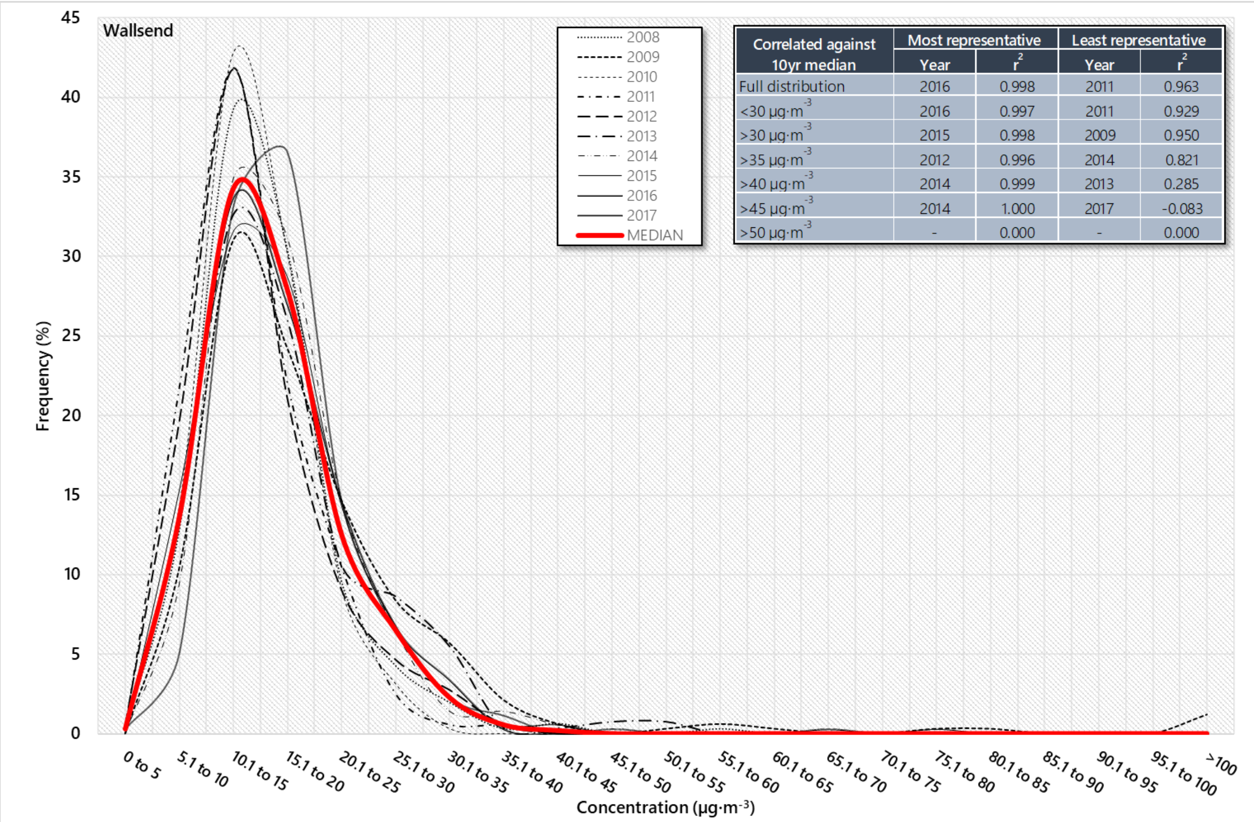
Pollutant	Averaging Period	Value	Data Source
PM_{10}	24-hour	Hourly varying	Adjusted from Wallsend 2012 using the relationship derived in **Figure 3-4** [Site PM_{10}] = 1.183[Wallsend PM_{10}] - 7.5862
	Annual	14.9 $\mu g \cdot m^{-3}$	Wallsend 2012 (no adjustment applied)
$PM_{2.5}$	24-hour	Hourly varying	Wallsend 2012 (no adjustment applied)
	Annual	5.1 $\mu g \cdot m^{-3}$	Wallsend 2012 (no adjustment applied)
TSP	Annual	26.3 $\mu g \cdot m^{-3}$	Derived from the relationship in **Figure 3-4** [Site TSP] = 1.4895[PM10] + 4.1454
Dust Deposition	Monthly	2 $g \cdot m^{-2} \cdot month^{-1}$	Approved Methods
NO_2	1-hour	4.3 pphm	Maximum 1-hour value, Wallsend 2012-2016
	Annual	0.8 pphm	Average value Wallsend 2012-2016

The relationships derived to determine the regional background TSP, PM_{10} and $PM_{2.5}$ concentrations are acknowledged as being specific to the period April 2016 to September 2017. However, these relationships have been derived over the period of a full year of measurements, include all seasons and given the data publicly available are considered to provide a good representation of the regional air quality environment. In the absence of any additional data, these relationships have been applied to the year 2012.

Particulate matter concentrations vary from year to year and can often be impacted by natural climatic variability, which in turn can impact upon the incidence of bushfires, or dust storm events. Measures of natural climatic variability (such as El Nino or La Nina climate cycles) show a correlation with the number of particulate matter events in eastern Australia with El Nino cycles (drier than usual conditions) being related to a higher number of exceedances of the 24-hour PM_{10} criterion, with La Nina (wetter than usual conditions) related to a lower number of those exceedances when compared to the 10-year median.

A statistical analysis of the long term 24-hour average PM_{10} dataset collected at Wallsend AQMS between 2008 and 2017 is presented in **Figure 3-9**.

Figure 3-9
Inter-year Variability in Measured PM_{10} at Wallsend



Correlated against 10yr median	Most representative		Least representative	
	Year	r^2	Year	r^2
Full distribution	2016	0.998	2011	0.963
<30 µg·m^{-3}	2016	0.997	2011	0.929
>30 µg·m^{-3}	2015	0.998	2009	0.950
>35 µg·m^{-3}	2012	0.996	2014	0.821
>40 µg·m^{-3}	2014	0.999	2013	0.285
>45 µg·m^{-3}	2014	1.000	2017	-0.083
>50 µg·m^{-3}	-	0.000	-	0.000

In summary, data collected at Wallsend AQMS in 2016 shows the best correlation with the longer-term record when considering the full data distribution. However, when examining concentrations of particulate matter over 35 µg·m^{-3} (which are of greater importance in assessing the potential impacts of the Project operation against the relevant criteria than lower concentrations), data collected during the years 2012 and 2014 compares best with the long-term median trend. The years 2012 and 2014 were strong El Nino years (drier than usual conditions).

The long-term analysis of meteorological conditions (refer Section 4.4 and **Annexure 1**) indicates that the year 2012 was most representative of the 10-year record examined, especially when taking into account wind speed frequencies, which are important in the transportation of pollutants from source to receptor. Although the appropriate selection of both a representative background air quality and meteorological year are important, the concomitance of those two years may not always occur.

For the purposes of this assessment, representative meteorology during the year 2012 has been selected as priority, with air quality monitoring data for 2012 selected to enable a contemporaneous assessment to be presented, with data selected as discussed in detail above.

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